REVIEW OF PARTICLE PHYSICS*

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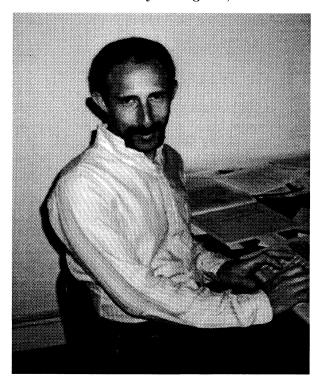
Abstract

This biennial review summarizes much of Particle Physics. Using data from previous editions, plus 1900 new measurements from 700 papers, we list, evaluate, and average measured properties of gauge bosons, leptons, quarks, mesons, and baryons. We also summarize searches for hypothetical particles such as Higgs bosons, heavy neutrinos, and supersymmetric particles. All the particle properties and search limits are listed in Summary Tables. We also give numerous tables, figures, formulae, and reviews of topics such as the Standard Model, particle detectors, probability, and statistics. A booklet is available containing the Summary Tables and abbreviated versions of some of the other sections of this full *Review*.

Special thanks are due to our administrative assistant at LBNL, Gail Harper, for her careful proofreading of the text, layout, and graphics in this *Review*.

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[†]In memoriam: Gary S. Wagman, 1954–1995

Gary Wagman, Programmer for the Particle Data Group from 1985 to 1995, died of AIDS on Friday, April 21, 1995. Gary, a respected member of the gay community, was a native of Houston, Texas, and graduated from the University of Houston in Computer Science.

Gary made many contributions to the Particle Data Group, and thus to the entire international high-energy physics community. He did much of the intricate design and all of the advanced programming that brought the *Review of Particle Physics* from its primitive state in 1984 to the beautiful and valuable document it is today, in both its printed and electronic forms. He was recognized a few months before his death with a Lawrence Berkeley Laboratory Outstanding Performance Award for these achievements. Gary's work was characterized by his constant striving for perfection, by his deep concern for accuracy, and by his understanding of our scientific mission.

In addition to his work as a programmer, Gary loved to travel. He was intrigued by exotic and magical places, visiting the pyramids in Egypt and the Taj Mahal in India. Europe was another favorite destination where he enjoyed speaking French. Gary traveled to Israel several times, once spending six months on a kibbutz picking grapefruit. An avid hiker and camper, he also explored many parts the United States.

Gary's meticulous nature led him to excel at woodworking, and he spent several years remodeling his house in San Francisco. A member of the Dahlia Society, he further enhanced his home and garden through his love of flowers. He was also a connoisseur of fine food, eating, and baking, delighting the PDG with many wonderful birthday cakes.

Always interested in spirituality and mysticism, Gary had recently begun studying Sufism. This spiritual practice was so meaningful to him that, in December 1995, he insisted on participating in a Sufi turning exhibition even though he was very ill.

In October 1995, a memorial service was held for Gary at the Pinnacles National Monument in California, one of his favorite spiritual places.

Gary was our friend and colleague for ten years, and all of us who had the privilege of knowing him miss him greatly.

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INTRODUCTION

1. Overview

The Review of Particle Physics and the abbreviated version, the Particle Physics Booklet, are reviews of the field of Particle Physics. This complete Review includes a compilation/evaluation of data on particle properties, called the "Particle Listings." These Listings include 1900 new measurements from 700 papers, in addition to the 14,000 measurements from 4000 papers that first appeared in previous editions.

Both books include Summary Tables with our best values and limits for particle properties such as masses, widths or lifetimes, and branching fractions, as well as an extensive summary of searches for hypothetical particles. In addition, we give a long section of "Reviews, Tables, and Plots" on a wide variety of theoretical and experimental topics, a quick reference for the practicing particle physicist.

The Review and the Booklet are published in evennumbered years. This edition is an updating through December 1995 (and, in some areas, well into 1996). As described in the section "Using Particle Physics Databases" following this introduction, the content of this Review is available on the World-Wide Web, and is updated between printed editions (http://pdg.lbl.gov/).

The Summary Tables give our best values of the properties of the particles we consider to be well established, a summary of search limits for hypothetical particles, and a summary of experimental tests of conservation laws.

The Particle Listings contain all the data used to get the values given in the Summary Tables. Other measurements considered recent enough or important enough to mention, but which for one reason or another are not used to get the best values, appear separately just beneath the data we do use for the Summary Tables. The Particle Listings also give information on unconfirmed particles and on particle searches, as well as short "reviews" on subjects of particular interest or controversy.

The Particle Listings were once an archive of all published data on particle properties. This is no longer possible because of the large quantity of data. We refer interested readers to earlier editions for data now considered to be obsolete.

We organize the particles into six categories:

Gauge and Higgs bosons

Leptons

Quarks

Mesons

Baryons

Searches for monopoles,

supersymmetry, compositeness, etc.

The last category only includes searches for particles that do not belong to the previous groups; searches for heavy charged leptons and massive neutrinos, by contrast, are with the leptons.

In Sec. 2 of this Introduction, we list the main areas of responsibility of the authors, and also list our large number of consultants, without whom we would not have been able to produce this *Review*. In Sec. 3, we mention briefly the naming scheme for hadrons. In Sec. 4, we discuss our procedures for choosing among measurements of particle

properties and for obtaining best values of the properties from the measurements.

The accuracy and usefulness of this *Review* depend in large part on interaction between its users and the authors. We appreciate comments, criticisms, and suggestions for improvements of any kind. Please send them to the appropriate author, according to the list of responsibilities in Sec. 2 below, or to the LBNL addresses below.

To order a copy of the *Review* or the *Particle Physics Booklet* from North and South America, Australia, and the Far East, write to

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The Particle Data Group benefits greatly from the assistance of some 700 physicists who are asked to verify every piece of data entered into this *Review*. Of special value is the advice of the PDG Advisory Committee which meets annually and thoroughly reviews all aspects of our operation. The members of the 1995 committee were:

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3. Naming scheme for hadrons

We introduced in the 1986 edition [2] a new naming scheme for the hadrons. Changes from older terminology affected mainly the heavier mesons made of u, d, and s quarks. Otherwise, the only important change to known hadrons was that the F^{\pm} became the D_s^{\pm} . None of the lightest pseudoscalar or vector mesons changed names, nor did the $c\bar{c}$ or $b\bar{b}$ mesons (we do, however, now use χ_c for the $c\bar{c}$ χ states), nor did any of the established baryons. The Summary Tables give both the new and old names whenever a change has occurred.

The scheme is described in "Naming Scheme for Hadrons" (p. 76) of this *Review*.

We give here our conventions on type-setting style. Particle symbols are italic (or slanted) characters: e^- , p, Λ , π^0 , K_L , D_s^+ , b. Charge is indicated by a superscript: B^- , Δ^{++} . Charge is not normally indicated for p, n, or the quarks, and is optional for neutral isosinglets: η or η^0 . Antiparticles and particles are distinguished by charge for charged leptons and mesons: τ^+ , K^- . Otherwise, distinct antiparticles are indicated by a bar (overline): $\overline{\nu}_\mu$, \overline{t} , \overline{p} , \overline{K}^0 , and $\overline{\Sigma}^+$ (the antiparticle of the Σ^-).

4. Procedures

4.1. Selection and treatment of data: The Particle Listings contain all relevant data known to us that are published in journals. With very few exceptions, we do not include results from preprints or conference reports. Nor do we include data that are of historical importance only (the Listings are not an archival record). We search every volume of 20 journals through our cutoff date for relevant data. We also include later published papers that are sent to us by the authors (or others).

In the Particle Listings, we clearly separate measurements that are used to calculate or estimate values given in the Summary Tables from measurements that are not used. We give explanatory comments in many such cases. Among the reasons a measurement might be excluded are the following:

- It is superseded by or included in later results.
- No error is given.
- It involves assumptions we question.
- It has a poor signal-to-noise ratio, low statistical significance, or is otherwise of poorer quality than other data available.

- It is clearly inconsistent with other results that appear to be more reliable. Usually we then state the criterion, which sometimes is quite subjective, for selecting "more reliable" data for averaging. See Sec. 4.
- It is not independent of other results.
- It is not the best limit (see below).
- It is quoted from a preprint or a conference report.

In some cases, *none* of the measurements is entirely reliable and no average is calculated. For example, the masses of many of the baryon resonances, obtained from partial-wave analyses, are quoted as estimated ranges thought to probably include the true values, rather than as averages with errors. This is discussed in the Baryon Particle Listings.

For upper limits, we normally quote in the Summary Tables the strongest limit. We do not average or combine upper limits except in a very few cases where they may be re-expressed as measured numbers with Gaussian errors.

As is customary, we assume that particle and antiparticle share the same spin, mass, and mean life. The Tests of Conservation Laws table, following the Summary Tables, lists tests of CPT as well as other conservation laws.

We use the following indicators in the Particle Listings to tell how we get values from the tabulated measurements:

- OUR AVERAGE—From a weighted average of selected data.
- OUR FIT—From a constrained or overdetermined multiparameter fit of selected data.
- OUR EVALUATION—Not from a direct measurement, but evaluated from measurements of related quantities.
- OUR ESTIMATE—Based on the observed range of the data. Not from a formal statistical procedure.
- OUR LIMIT—For special cases where the limit is evaluated by us from measured ratios or other data. Not from a direct measurement.

An experimentalist who sees indications of a particle will of course want to know what has been seen in that region in the past. Hence we include in the Particle Listings all reported states that, in our opinion, have sufficient statistical merit and that have not been disproved by more reliable data. However, we promote to the Summary Tables only those states that we feel are well established. This judgment is, of course, somewhat subjective and no precise criteria can be given. For more detailed discussions, see the minireviews in the Particle Listings.

- **4.2.** Averages and fits: We divide this discussion on obtaining averages and errors into three sections:
- (1) treatment of errors; (2) unconstrained averaging;
- (3) constrained fits.

4.2.1. Treatment of errors: In what follows, the "error" δx means that the range $x \pm \delta x$ is intended to be a 68.3% confidence interval about the central value x. We treat this error as if it were Gaussian. Thus when the error is Gaussian, δx is the usual one standard deviation (1σ) . Many experimenters now give statistical and systematic errors separately, in which case we usually quote both errors, with the statistical error first. For averages and fits, we then add the the two errors in quadrature and use this combined error for δx .

When experimenters quote asymmetric errors $(\delta x)^+$ and $(\delta x)^-$ for a measurement x, the error that we use for that measurement in making an average or a fit with other measurements is a continuous function of these three quantities. When the resultant average or fit \overline{x} is less than $x-(\delta x)^-$, we use $(\delta x)^-$; when it is greater than $x+(\delta x)^+$, we use $(\delta x)^+$. In between, the error we use is a linear function of x. Since the errors we use are functions of the result, we iterate to get the final result. Asymmetric output errors are determined from the input errors assuming a linear relation between the input and output quantities.

In fitting or averaging, we usually do not include correlations between different measurements, but we try to select data in such a way as to reduce correlations. Correlated errors are, however, treated explicitly when there are a number of results of the form $A_i \pm \sigma_i \pm \Delta$ that have identical systematic errors Δ . In this case, one can first average the $A_i \pm \sigma_i$ and then combine the resulting statistical error with Δ . One obtains, however, the same result by averaging $A_i \pm (\sigma_i^2 + \Delta_i^2)^{1/2}$, where $\Delta_i = \sigma_i \Delta [\sum (1/\sigma_j^2)]^{1/2}$. This procedure has the advantage that, with the modified systematic errors Δ_i , each measurement may be treated as independent and averaged in the usual way with other data. Therefore, when appropriate, we adopt this procedure. We tabulate Δ and invoke an automated procedure that computes Δ_i before averaging and we include a note saying that there are common systematic errors.

Another common case of correlated errors occurs when experimenters measure two quantities and then quote the two and their difference, e.g., m_1 , m_2 , and $\Delta = m_2 - m_1$. We cannot enter all of m_1 , m_2 and Δ into a constrained fit because they are not independent. In some cases, it is a good approximation to ignore the quantity with the largest error and put the other two into the fit. However, in some cases correlations are such that the errors on m_1 , m_2 and Δ are comparable and none of the three values can be ignored. In this case, we put all three values into the fit and invoke an automated procedure to increase the errors prior to fitting such that the three quantities can be treated as independent measurements in the constrained fit. We include a note saying that this has been done.

4.2.2. Unconstrained averaging: To average data, we use a standard weighted least-squares procedure and in some cases, discussed below, increase the errors with a "scale factor." We begin by assuming that measurements of a given quantity are uncorrelated, and calculate a weighted average and error as

$$\overline{x} \pm \delta \overline{x} = \frac{\sum_{i} w_i \ x_i}{\sum_{i} w_i} \pm \left(\sum_{i} w_i\right)^{-1/2} , \qquad (1)$$

where

$$w_i = 1/(\delta x_i)^2 .$$

Here x_i and δx_i are the value and error reported by the ith experiment, and the sums run over the N experiments. We then calculate $\chi^2 = \sum w_i(\overline{x} - x_i)^2$ and compare it with N-1, which is the expectation value of χ^2 if the measurements are from a Gaussian distribution.

If $\chi^2/(N-1)$ is less than or equal to 1, and there are no known problems with the data, we accept the results.

If $\chi^2/(N-1)$ is very large, we may choose not to use the average at all. Alternatively, we may quote the calculated average, but then make an educated guess of the error, a conservative estimate designed to take into account known problems with the data.

Finally, if $\chi^2/(N-1)$ is greater than 1, but not greatly so, we still average the data, but then also do the following:

(a) We increase our quoted error, $\delta\overline{x}$ in Eq. (1), by a scale factor S defined as

$$S = \left[\chi^2/(N-1)\right]^{1/2} \ . \tag{2}$$

Our reasoning is as follows. The large value of the χ^2 is likely to be due to underestimation of errors in at least one of the experiments. Not knowing which of the errors are underestimated, we assume they are all underestimated by the same factor S. If we scale up all the input errors by this factor, the χ^2 becomes N-1, and of course the output error $\delta \overline{x}$ scales up by the same factor. See Ref. 3.

When combining data with widely varying errors, we modify this procedure slightly. We evaluate S using only the experiments with smaller errors. Our cutoff or ceiling on δx_i is arbitrarily chosen to be

$$\delta_0 = 3N^{1/2} \, \delta \overline{x} \, ,$$

where $\delta \overline{x}$ is the unscaled error of the mean of all the experiments. Our reasoning is that although the low-precision experiments have little influence on the values \overline{x} and $\delta \overline{x}$, they can make significant contributions to the χ^2 , and the contribution of the high-precision experiments thus tends to be obscured. Note that if each experiment has the same error δx_i , then $\delta \overline{x}$ is $\delta x_i/N^{1/2}$, so each δx_i is well below the cutoff. (More often, however, we simply exclude measurements with relatively large errors from averages and fits: new, precise data chase out old, imprecise data.)

Our scaling procedure has the property that if there are two values with comparable errors separated by much more than their stated errors (with or without a number of other values of lower accuracy), the scaled-up error $\delta \overline{x}$ is approximately half the interval between the two discrepant values.

We emphasize that our scaling procedure for *errors* in no way affects central values. And if you wish to recover the unscaled error $\delta \overline{x}$, simply divide the quoted error by S.

(b) If the number M of experiments with an error smaller than δ_0 is at least three, and if $\chi^2/(M-1)$ is greater than 1.25, we show in the Particle Listings an ideogram of the data. Fig. 1 is an example. Sometimes one or two data points lie apart from the main body; other times the data split into two or more groups. We extract no numbers from these ideograms; they are simply visual aids, which the reader may use as he or she sees fit.

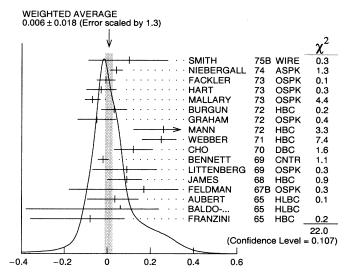


Figure 1: A typical ideogram. The arrow at the top shows the position of the weighted average, while the width of the shaded pattern shows the error in the average after scaling by the factor S. The column on the right gives the χ^2 contribution of each of the experiments. Note that the next-to-last experiment, denoted by the incomplete error flag (\bot) , is not used in the calculation of S (see the text).

Each measurement in an ideogram is represented by a Gaussian with a central value x_i , error δx_i , and area proportional to $1/\delta x_i$. The choice of $1/\delta x_i$ for the area is somewhat arbitrary. With this choice, the center of gravity of the ideogram corresponds to an average that uses weights $1/\delta x_i$ rather than the $(1/\delta x_i)^2$ actually used in the averages. This may be appropriate when some of the experiments have seriously underestimated systematic errors. However, since for this choice of area the height of the Gaussian for each measurement is proportional to $(1/\delta x_i)^2$, the peak position of the ideogram will often favor the high-precision measurements at least as much as does the least-squares average. See our 1986 edition [2] for a detailed discussion of the use of ideograms.

4.2.3. Constrained fits: Except for trivial cases, all branching ratios and rate measurements are analyzed by making a simultaneous least-squares fit to all the data and extracting the partial decay fractions P_i , the partial widths Γ_i , the full width Γ (or mean life), and the associated error matrix.

Assume, for example, that a state has m partial decay fractions P_i , where $\sum P_i = 1$. These have been measured in N_r different ratios R_r , where, e.g., $R_1 = P_1/P_2$, $R_2 = P_1/P_3$, etc. [We can handle any ratio R of the form $\sum \alpha_i P_i/\sum \beta_i P_i$, where α_i and β_i are constants, usually 1 or 0. The forms $R = P_i P_j$ and $R = (P_i P_j)^{1/2}$ are also allowed.] Further assume that each ratio R has been measured by N_k experiments (we designate each experiment with a subscript k, e.g., R_{1k}). We then find the best values of the fractions P_i by minimizing the χ^2 as a function of the m-1 independent parameters:

$$\chi^2 = \sum_{r=1}^{N_r} \sum_{k=1}^{N_k} \left(\frac{R_{rk} - R_r}{\delta R_{rk}} \right)^2 , \qquad (3)$$

where the R_{rk} are the measured values and R_r are the fitted values of the branching ratios.

In addition to the fitted values \overline{P}_i , we calculate an error matrix $\langle \delta \overline{P}_i \ \delta \overline{P}_j \rangle$. We tabulate the diagonal elements of $\delta \overline{P}_i = \langle \delta \overline{P}_i \ \delta \overline{P}_i \rangle^{1/2}$ (except that some errors are scaled as discussed below). In the Particle Listings, we give the complete correlation matrix; we also calculate the fitted value of each ratio, for comparison with the input data, and list it above the relevant input, along with a simple unconstrained average of the same input.

Three comments on the example above:

- (1) There was no connection assumed between measurements of the full width and the branching ratios. But often we also have information on partial widths Γ_i as well as the total width Γ . In this case we must introduce Γ as a parameter in the fit, along with the P_i , and we give correlation matrices for the widths in the Particle Listings.
- (2) We do not allow for correlations between input data. We do try to pick those ratios and widths that are as independent and as close to the original data as possible. When one experiment measures all the branching fractions and constrains their sum to be one, we leave one of them (usually the least well-determined one) out of the fit to make the set of input data more nearly independent.
- (3) We calculate scale factors for both the R_r and P_i when the measurements for any R give a larger-than-expected contribution to the χ^2 . According to Eq. (3), the double sum for χ^2 is first summed over experiments k=1 to N_k , leaving a single sum over ratios $\chi^2 = \sum \chi_r^2$. One is tempted to define a scale factor for the ratio r as $S_r^2 = \chi_r^2/\langle \chi_r^2 \rangle$. However, since $\langle \chi_r^2 \rangle$ is not a fixed quantity (it is somewhere between N_k and N_{k-1}), we do not know how to evaluate this expression. Instead we define

$$S_r^2 = \frac{1}{N_k} \sum_{k=1}^{N_k} \frac{\left(R_{rk} - \overline{R}_r\right)^2}{(\delta R_{rk})^2 - (\delta \overline{R}_r)^2} , \qquad (4)$$

where $\delta \overline{R}_r$ is the fitted error for ratio r. With this definition the expected value of S_r^2 is one.

The fit is redone using errors for the branching ratios that are scaled by the larger of S_r and unity, from which new

and often larger errors $\delta \overline{P}'_i$ are obtained. The scale factors we finally list in such cases are defined by $S_i = \delta \overline{P}'_i/\delta \overline{P}_i$. However, in line with our policy of not letting S affect the central values, we give the values of \overline{P}_i obtained from the original (unscaled) fit.

There is one special case in which the errors that are obtained by the preceding procedure may be changed. When a fitted branching ratio (or rate) \overline{P}_i turns out to be less than three standard deviations $(\delta \overline{P}'_i)$ from zero, a new smaller error $(\delta \overline{P}''_i)^-$ is calculated on the low side by requiring the area under the Gaussian between $\overline{P}_i - (\delta \overline{P}''_i)^-$ and \overline{P}_i to be 68.3% of the area between zero and \overline{P}_i . A similar correction is made for branching fractions that are within three standard deviations of one. This keeps the quoted errors from overlapping the boundary of the physical region.

4.3. Discussion: The problem of averaging data containing discrepant values is nicely discussed by Taylor in Ref. 4. He considers a number of algorithms that attempt to incorporate inconsistent data into a meaningful average. However, it is difficult to develop a procedure that handles simultaneously in a reasonable way two basic types of situations: (a) data that lie apart from the main body of the data are incorrect (contain unreported errors); and (b) the opposite—it is the main body of data that is incorrect. Unfortunately, as Taylor shows, case (b) is not infrequent. He concludes that the choice of procedure is less significant than the initial choice of data to include or exclude.

We place much emphasis on this choice of data. Often we solicit the help of outside experts (consultants). Sometimes, however, it is simply impossible to determine which of a set of discrepant measurements are correct. Our scale-factor technique is an attempt to address this ignorance by increasing the error. In effect, we are saying that present experiments do not allow a precise determination of this quantity because of unresolvable discrepancies, and one must await further measurements. The reader is warned of this situation by the size of the scale factor, and if he or she desires can go back to the literature (via the Particle Listings) and redo the average with a different choice of data.

Our situation is less severe than most of the cases Taylor considers, such as estimates of the fundamental constants like h, etc. Most of the errors in his case are dominated by systematic effects. For our data, statistical errors are often at least as large as systematic errors, and statistical errors are usually easier to estimate. A notable exception occurs in partial-wave analyses, where different techniques applied to the same data yield different results. In this case, as stated earlier, we often do not make an average but just quote a range of values.

A brief history of early Particle Data Group averages is given in Ref. 3. Figure 0.2 shows some histories of our values of a few particle properties. Sometimes large changes occur. These usually reflect the introduction of significant new data or the discarding of older data. Older data are discarded in favor of newer data when it is felt that the newer data have smaller systematic errors, or have more checks on systematic errors, or have made corrections unknown at the time of the older experiments, or simply have much smaller errors. Sometimes, the scale factor becomes large near the time at which a large jump takes place, reflecting the uncertainty introduced by the new and inconsistent data.

By and large, however, a full scan of our history plots shows a dull progression toward greater precision at central values quite consistent with the first data points shown.

We conclude that the reliability of the combination of experimental data and our averaging procedures is usually good, but it is important to be aware that fluctuations outside of the quoted errors can and do occur.

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We thank all those who have assisted in the many phases of preparing this *Review*. We particularly thank the many who have responded to our requests for verification of data entered in the Listings, and those who have made suggestions or pointed out errors. The CERN group wishes to thank Andrew Hicks for his technical help.

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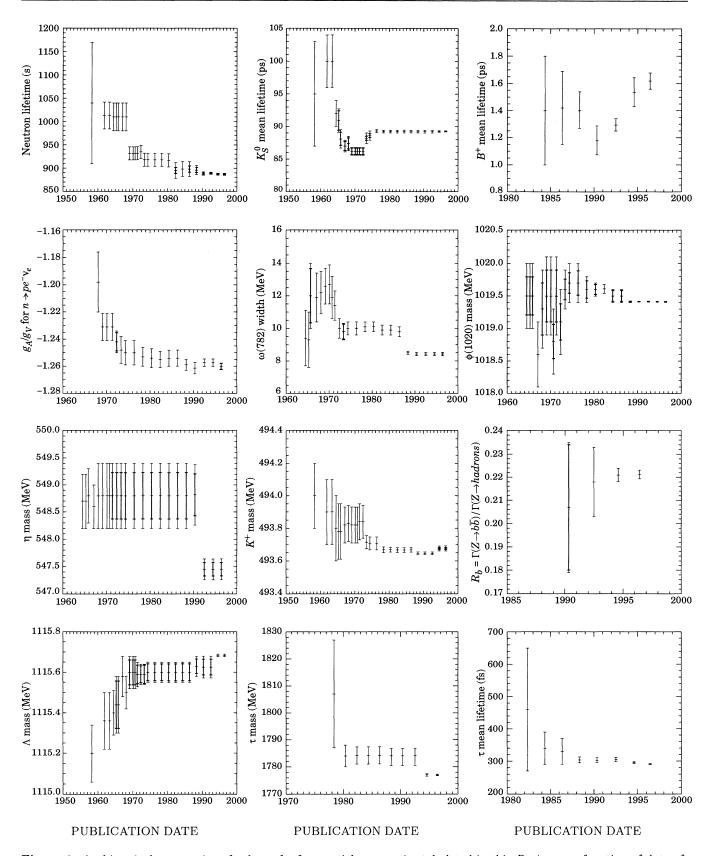


Figure 2: An historical perspective of values of a few particle properties tabulated in this *Review* as a function of date of publication of the *Review*. A full error bar indicates the quoted error; a thick-lined portion indicates the same but without the "scale factor."

Revised by P. Kreitz, May 1996

The purpose of this list is to organize a broad set of online catalogs, databases, directories, World-Wide Web (WWW) pages, etc., that are of value to the particle physics physics community. While a substantial amount of particle physics physics information is computer accessible through the Internet's World-Wide Web, most listings do not provide descriptions of a resource's scope and content so that searchers know which source to use for a specific information need. This compilation lists the main information sources with brief annotations and basic Internet WWW addresses (URL's). Because this list must be fixed in print, it is important to consult the updated version of this compilation which includes newly added resources and hypertext links to more complete information at:

http://www.slac.stanford.edu/library/pdg/hepinfo.html

In this edition, a resource is excluded if it provides information primarily of interest to one institution. In some cases, multiple databases covering much the same material have been included with the assumption that users will make subsequent choices based on Internet speeds, search system interfaces, or differences in scope, presentation, and coverage. Databases and resources focusing primarily on accelerator physics have been excluded in deference to the excellent compilation at the World Wide Web Virtual Library of Accelerator Physics:

http://beam.slac.stanford.edu/www/library/w3/alab.htmlx

Please send suggestions, additions, changes, ideas for category groupings, exclusions, etc., via the WWW form linked to the URL above, or by e-mail to pkreitz@slac.stanford.edu.

1. Particles & Properties Data:

• REVIEW OF PARTICLE PHYSICS (RPP): A comprehensive review of the field of Particle Physics produced by the Particle Data Group (PDG). Includes a compilation/evaluation of data on particle properties, summary tables with best values and limits for particle properties, extensive summaries of searches for hypothetical particles, and a long section of reviews, tables, and plots on a wide variety of theoretical and experimental topics of interest to particle and astrophysicists. The linked table of contents provides access to particle listings, reviews, summary tables, errata, indices, etc. The current printed version is Physical Review D54, xxx (1996). Maintained at:

http://pdg.lbl.gov/

• PARTICLE PHYSICS BOOKLET: An extract from the most recent edition of the full Review of Particle Physics. Contains images in an easy-to-read print useful for classroom studies:

http://pdg.lbl.gov/rpp/booklet/contents.html

• PARTICLE PROPERTIES Database: Durham/RAL provides a simple index to the PDG particle properties information contained in the Review of Particle Physics. Maintained at:

http://durpdg.dur.ac.uk/HEPDATA/PART

• PARTICLE PHYSICS INTERACTIVE DATABASE: A searchable database containing information from the Review of Particle Physics. Updated around summer of every year. Available by telnet as follows:

Telnet: //pdg_public@muse.lbl.gov/ (User name PDG_PUBLIC, no password).

• COMPUTER-READABLE FILES: Currently available from the PDG: tables of masses, widths, and PDG Monte Carlo particle numbers and cross section data, including hadronic total and elastic cross sections vs laboratory momenta and total center-of-mass energy. Overview page at:

http://pdg.lbl.gov/computer_read.html

 PARTICLE PHYSICS DATA SYSTEM: Maintained by the COM-PAS group at IHEP, this system, currently under construction, provides an online version of the Guide to Experimental Elementary Particle Physics Literature (1895–1995). Permits searching by author, title, accelerator, detector, reaction, particle, etc. For research from 1950 to the present, it will provide online searching of compilations of integrated cross sections data and numerical data on observables in reactions. Also provides a chronology of key events in particle physics:

http://muse.lbl.gov:8001/ppds.html

• REACTION DATA: A part of the HEPDATA databases at Durham/RAL, this database is a collaboration of Durham and the COMPAS Group for the PDG. Contains numerical values of cross sections, structure, functions, polarizations, etc.:

http://durpdg.dur.ac.uk/HEPDATA/REAC

• PHYSICS AROUND THE WORLD: DATA AND TABLES: Includes links to periodic tables of elements, laws and constants, scales of measurement, particle and nuclear data, equations, and (peripheral) "more data and tables:"

http://www.physics.mcgill.ca:8081/ physics-services/physics_tables.html

2. Collaborations & Experiments:

• EXPERIMENTS Database: Contains more than 1,800 experiments in elementary particle physics. Search and browse by author; title; experiment number or prefix; institution; date approved, started or completed; accelerator or detector; polarization, reaction, final state or particle; or by papers produced. Maintained at SLAC for the LBNL Particle Data Group. Supplies the information for "Current Experiments in Particle Physics (LBL-91)." Updated every second year (next: Summer 1996):

 $\verb|http://www-spires.slac.stanford.edu/find/experiments|$

• EXPERIMENTS ONLINE: Home Pages of HEP Experiments: A list from SLAC of accelerator and non-accelerator experiments with an active link to each home page. Accelerator experiments are organized by institution, machine, and experiment name:

 $\verb|http://www-spires.slac.stanford.edu/find/explist.html|$

• HIGH ENERGY PHYSICS EXPERIMENTS: A HEPNET page providing links to HEP collaborations around the world. List arranged alphabetically by collaboration name:

http://www.hep.net/experiments/collabs.html

3. Conferences:

CONFERENCES: Contains conferences, schools, and meetings of
interest to high-energy physicists. Searchable database produced
jointly by the SLAC and DESY libraries of over 5,000 listings
covering 1973 to 1999+. Search or browse by title, acronym, date,
location. Includes links to the conference home page, information
about published proceedings, links to submitted papers from the
SPIRES-HEP database, and links to the electronic versions of the
papers if available:

http://www-spires.slac.stanford.edu/ spires/form/confspif.html

• CONFERENCES, WORKSHOPS, AND SUMMER SCHOOLS: By The Internet Pilot to Physics. Several hundred listings, including those for regional meetings of national societies and meetings of ancillary groups such as physics teachers. Provides a WWW form for adding a conference, and automatically uploads new entries to the EPS EurophysNet meeting list.

http://www.tp.umu.se/TIPTOP/FORUM/CONF/

• CONFNEWS: Provides listings of current and future conferences divided by subfield or by region. Also provides links to WWW conference pages and an e-mail interface (robot@physics.umd.edu with CONFMENU in the subject line):

http://www.physics.umd.edu/robot/confer/confmenu.html

• EUROPHYSICS Meetings List: Meta-level list of other conference lists with active links to the URL of the organization's meeting calendar, the conference database, etc. Useful for searching by organization, providing access to meetings and conferences that are of interest, but not central to high-energy physics. Maintained by the European Physical Society but international in scope. Organized alphabetically by the name of the resource or organization:

http://epswww.epfl.ch/conf/urls.html

• HEP EVENTS: A list maintained by CERN of upcoming conferences, schools, workshops, seminars, and symposia of interest to high-energy physics organized by type of meeting, e.g. school, workshop:

http://www.cern.ch/Physics/Conferences

• PHYSICS CONFERENCE ANNOUNCEMENTS by Thread: Lists current year's conference announcements with links to WWW pages. Posting is voluntary, which is perhaps why this resource lacks the breadth of other databases covering conferences:

http://xxx.lanl.gov/Announce/Conference/

4. Current Notices & Announcement Services:

• CONFERENCES, WORKSHOPS, AND SUMMER SCHOOLS: By The Internet Pilot to Physics. Provides a Web form for adding a conference and automatically uploads new entries to the EPS EurophysNet meeting list.

http://www.tp.umu.se/TIPTOP/FORUM/CONF/

- CONFNEWS & WEBNEWS: Provides a system for broadcasting a conference or job opening to "a large number of physicists worldwide." For further information, e-mail: kim@umdhep.umd.edu
- E-PRINT ARCHIVES: The LANL-based E-Print Archives provides daily notices of what new high-energy physics preprints have been submitted to the archives as full text electronic documents. Use the WWW-accessible listings:

http://xxx.lanl.gov/

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(under "Description of e-Mail Commands") to receive the automatic e-mail notices. Covers over two dozen subfields of high-energy physics, and provides active links to abstracts and full text versions of the preprints.

Note: Use the library pages below to find information on recently received books and proceedings. Use the online table of contents listings below to find journal table of contents. Conference announcements can also be sent via e-mail to most of the conference database providers listed above who often supply their e-mail address at the bottom of their Web page.

5. Directories:

5.1. Directories - Organizations:

• DIRECTORY OF RESEARCH INSTITUTES in High Energy Physics: Maintained by CERN and organized into three alphabetical lists by country, town, and institutional name. Provides addresses, and, where available, the following: phone and fax numbers; e-mail addresses; active URL links; and information about the institution's physics program:

http://preprints.cern.ch/institutes/welcome.html

 HEP INSTITUTIONS ONLINE: Active links to the home pages of more than 200 HEP-related institutions with WWW servers. Maintained by SLAC and organized by country, and then alphabetically by institution:

http://www-spires.slac.stanford.edu/find/instlink.html

 INSTITUTIONS: Database of over 5,000 high-energy physics Institutes, Laboratories, and University departments in which some research on elementary particle physics is performed. Covers six continents and almost one hundred countries, and is searchable by name, acronym, location, *etc.* Provides address, phone and fax numbers, and e-mail and URL addresses where available. Has pointers to the recent HEP papers from an institution. Maintained by SLAC:

http://www-spires.slac.stanford.edu/ spires/form/instspif.html

PHYSICS: High-Energy Physics and Nuclear Physics Labs: This
list of WWW home pages is usefully arranged into accelerator
labs by country, research groups at universitites, and national
and international institutes. The theoretical physics section is
thin. Part of a larger effort maintained by Physics Around the
World/TIPTOP to organize physics-related institutions by field of
research:

http://www.physics.mcgill.ca:8081/ physics-services/physics_hep_labs.html

5.2. Directories - People:

 HEPNAMES: Searchable database of 25,500 e-mail addresses of people related to high-energy physics. Access by individual name, and, in the near future, by institution or place.

http://www-spires.slac.stanford.edu/find/hepnames

This site is mirrored at Durham under a different name (EMAIL-ID) and with a search interface written and maintained by Durham:

http://durpdg.dur.ac.uk/HEPDATA/ID

• HEP VIRTUAL PHONEBOOK: A list of links to phonebooks and directories of high-energy physics sites around the world. Maintained by HEPNET:

http://www.hep.net/sites/directories.html

${\bf 5.3.} \quad {\bf Directories-Publishers:}$

 PHYSICS AROUND THE WORLD: A page of active links to institutions, societies, or companies involved in supplying physicsrelated information. Organized into sections, the most useful of which are: Preprint Archives, Journals, Magazines, Newsletters, Publishers, and Books:

http://www.physics.mcgill.ca:8081/ physics-services/physics_publ2.html

6. E-Prints/Pre-Prints, Papers & Reports:

• ALICE: The CERN Library's database which contains citations to more than 190,000 monographs, series, preprints and official committee documents held by the Library or the Archives:

http://wwwas.cern.ch/ASinfo/AS-SI/alice/ALICE.html

Also provides links to CERN's full text preprint server:

http://preprints.cern.ch/.

• HEP DATABASE (SLAC/SPIRES): Contains over 300,000 bibliographic summaries for particle physics papers (e-prints, journal articles, preprints, reports, theses, etc.). Covers 1974 to the present and is updated daily with links to electronic texts (e.g. from LANL, CERN, KEK, and other HEP servers). Searchable by all authors and authors' affiliations, title, topic, report number, citation, e-print archive number, date, etc: A joint project of the SLAC and DESY libraries with the collaboration of many other institutions including APS, Fermilab, and Kyoto.

http://www-spires.slac.stanford.edu/find/hep

 KISS: KEK preprint database, contains bibliographic records of preprints and technical reports held in the KEK library with links to the full text images of over 90,000 items in their collection:

http://keklib.kek.jp/KISS.v2/kiss_prepri.html

• LANL E-PRINT ARCHIVES: An automated electronic repository of physics preprints, primarily in the subfields of high-energy physics, but also in other physics fields such as chemical, nuclear, condensed matter, etc. Began with a core set of subfield archives in 1991. Provides access to the full text of the electronic versions of these preprints, and permits searching by author, title, key word in abstract, and by limiting by subfield archive or by date. Papers are sent electronically to the archives by the author:

http://xxx.lanl.gov

• DOCUMENTS: (IHEP-COMPAS/PDG) A database providing the source information for the print publication "A Guide to Experimental Elementary Particle Physics Literature" (LBL-90). Provides bibliographic summaries of experimental papers which report new experimental data and theoretical papers which extract new information from experiments. Excludes instrumentation and papers mainly of interest only to nuclear physicists. Coverage is from 1895 to the present:

http://muse.lbl.gov:8001/ppds.html

7. Particle Physics Libraries & Scholarly Societies:

• American Astronomical Society:

http://www.aas.org/AAS-homepage.html

• American Institute of Physics:

http://aip.org/

• American Physical Society:

http://aps.org/

• Argonne National Lab Library:

http://www.ipd.anl.gov/aim/alec/

• Brookhaven National Lab Library:

http://www.bnl.gov/RESLIB/reslib.html

 $\bullet\,$ European Laboratory for Particle Physics (CERN) Library:

http://wwwas.cern.ch/ASinfo/AS-SI/library_home.html

• Institute of Physics:

http://www.iop.org/

• Deutsches Elektronen-Synchrotron (DESY) Library:

http://www.desy.de/library/homepage.html

• European Physical Society: EurophysNet

http://www.nikhef.nl/www/pub/eps/eps.html

• Fermilab Library:

http://fnalpubs.fnal.gov/library/welcome.html

• Institute of Physics:

http://www.iop.org/

 $\bullet\,$ National Laboratory for High Energy Physics (KEK) Library:

http://garnet.kek.jp/libhome.html

• Los Alamos National Laboratory Library:

http://lib-www.lanl.gov/

• Stanford Linear Accelerator Center Library:

http://www.slac.stanford.edu/FIND/spires.html

8. Particle Physics Journals & Reviews:

8.1. ONLINE JOURNALS: (Note: some of these may limit access to subscribers; check with your institution's library.)

• American Journal of Physics

 $http://www.amherst.edu/\sim ajp/$

• Applied Physics Letters Online

http://www.aip.org/epub/aplointro.html

• Astrophysical Journal and Letters

http://www.aas.org/ApJ/

• Classical and Quantum Gravity

http://www.ioppublishing.com/EJ/Unreg/bin/main

• Computers in Physics

http://www.aip.org/cip/ciphome.html

• European Journal of Physics

http://www.ioppublishing.com/EJ/Unreg/bin/main

• Journal of Physics A

http://www.ioppublishing.com/EJ/Unreg/bin/main

• Journal of Physics G

http://www.ioppublishing.com/EJ/Unreg/bin/main

• Nuclear Physics A

http://www.nucphys.nl/www/pub/nucphys/npe.html

• Nuclear Physics B

http://www.nucphys.nl/www/pub/nucphys/npe.html

• Nuclear Physics B (Proceedings Supplements)

http://www.nucphys.nl/www/pub/nucphys/npe.html

• Physical Review D (Advanced papers accepted by PRD)

http://publish.aps.org/PRDO/prdhm.html

• Physical Review Letters

http://publish.aps.org/PRL/prlinfo.html

• Physics Express Letters (PEL)

http://www.iop.org/EJ/Unreg/bin/pelmain

• Physics Today

http://www.aip.org/pt/phystoday.html

• Physics - Uspekhi

http://ufn.ioc.ac.ru/ufn.html

• Reviews of Modern Physics

http://www.phys.washington.edu/~rmp/

• Science

http://science-mag.aaas.org/science/

8.2. ONLINE REVIEW PUBLICATIONS:

 Net Advance of Physics: A free electronic journal/encyclopaedia of review articles and lecture notes in physics and allied sciences from around the Internet. Presently consists mainly of links to other sites, but welcomes contributions of original review articles:

http://web.mit.edu/afs/athena.mit.edu/ user/r/e/redingtn/www/netadv/welcome.html

• Physics Reports:

http://www.elsevier.nl/cas/estoc/ contents/SAK/03701573.html

• Reviews of Modern Physics

http://www.phys.washington.edu/~rmp/

• The Virtual Review (Brown U.): An informal journal which collects active hotlists of preprints which the editors find interesting, arranged by topic. Some editors' contributions include review and comment, some provide only listings with connections to the full text versions:

http://www.het.brown.edu/physics/review/index.html

8.3. ONLINE TABLES OF CONTENTS:

• American Journal of Physics

http://www.amherst.edu/~ajp/toc/toc.html

• Astroparticle Physics

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http://www.elsevier.nl/cas/estoc/ contents/SAK/09276505.html

• Classical and Quantum Gravity

http://www.ioppublishing.com/EJ/Unreg/bin/main

• European Journal of Physics

http://www.ioppublishing.com/EJ/Unreg/bin/main

• Journal of Physics A

http://www.ioppublishing.com/EJ/Unreg/bin/main

• Journal of Physics G

http://www.ioppublishing.com/EJ/Unreg/bin/main

• Nuclear Instruments and Methods in Physics Research, Section B http://www.elsevier.nl/cas/estoc/ contents/SAK/0168583X.html

• Nuclear Physics A

http://www.elsevier.nl:80/cas/estoc/ contents/SAK/03759474.html

• Nuclear Physics B

http://www.elsevier.nl:80/cas/estoc/ contents/SAK/05503213.html

• Nuclear Physics B (Proceedings Supplements)

http://www.elsevier.nl:80/cas/estoc/ contents/SAK/09205632.html

• Physica A

http://www.elsevier.nl/cas/estoc/ contents/SAK/03784371.html

• Physica B

http://www.elsevier.nl/cas/estoc/ contents/SAK/09214526.html

• Physica C

http://www.elsevier.nl/cas/estoc/ contents/SAK/09214534.html

• Physica D

http://www.elsevier.nl/cas/estoc/ contents/SAK/01672789.html

• Physical Review D

http://publish.aps.org/PRTOC/hometoc.html#prd

• Physical Review Letters

http://publish.aps.org/PRTOC/hometoc.html#prl

 $\bullet\,$ Physics Letters B

http://www.elsevier.nl/cas/estoc/

contents/SAK/03702693.html

• Physics Reports

http://www.elsevier.nl/cas/estoc/ contents/SAK/03701573.html

• Physics Today

http://www.aip.org/pt/contmenu.html

Progress in Particle and Nuclear Physics
 http://www.elsevier.nl/cas/estoc/contents/SAK/01466410.html

• Reviews of Modern Physics

http://www.phys.washington.edu/~rmp/contents.html

Science

http://science-mag.aaas.org/science/home/browse.shtml

9. Particle Physics Education Sites:

• Brookhaven National Laboratory:

http://sun20.ccd.bnl.gov/~scied/

• CEBAF:

http://www.cebaf.gov/services/pced/pcedhome.html

• Contemporary Physics Education Project (CPEP):

http://pdg.lbl.gov/cpep.html

• Center for Particle Astrophysics in Berkeley:

http://physics7.berkeley.edu/home.html

• Fermilab:

http://www-ed.fnal.gov/

• Stanford Linear Accelerator Center:

http://www.slac.stanford.edu/
winters/pub/www/education/education.html

10. Software Directories:

• CERNLIB: CERN program library:

http://wwwcn.cern.ch/pl/index.html

• FREEHEP: A collection of software and information about software useful in high-energy physics. Searching either by title, subject, date acquired, or date updated, or by browsing alphabetical list of all packages:

http://www-spires.slac.stanford.edu/find/fhmain.html

• FERMITOOLS: Software repository of Fermilab-developed software packages of value to the HEP community. Permits searching for packages by title or subject, by browsing FTP site, and by recent acquisitions:

http://www.fnal.gov/fermitools/ http://www.hep.net/software.html

• HEPIC: Software used in HEP research:

MATHEMATICAL & OTHER SOFTWARE: A comprehensive list maintained by Physics Around the World/TIPTOP of software packages, libraries, companies, archives, languages and computing-related journals. Organized by scope: e.g. "Software, Free & Commercial;" "Field-Specific Programs/Programming" (see Astronomy & Astrophysics, HEPNP, Graphics & Visualization); "Program Archives by Platform and Language." Also provides links to other Web compendia of software repositories and directories:

http://www.physics.mcgill.ca:8081/ physics-services/physics_software.html

SUMMARY TABLES OF PARTICLE PHYSICS

Gauge an	α.	\mathbf{n}_{1}	gg	5 1	30	SOI	15		٠	٠	٠	٠	•	•	٠	•	•	٠	•	٠	٠	19
Leptons																	•					21
																						24
Mesons				١.										•				•				25
Baryons								•	•		٠.	•		•								48
Searches*																				٠.	٠,	58
Tests	0	f c	on	se	rva	ati	on	la	ws	3	•	•	٠	•	•	٠	•	٠	•	•	•	59
	Μe	esc	n	Q۱	uic	k l	Re	fei	ren	ıce	r	'ab	le					•				46
]	Ba	ry	on	Q	ui	ck	R	efe	ere	nc	e '	Га	ble	?	٠.				٠.			47

^{*} There are also search limits in the Summary Tables for the Gauge and Higgs Bosons, the Leptons, the Quarks, and the Mesons.

SUMMARY TABLES OF PARTICLE PROPERTIES

July 1996

Particle Data Group

R.M. Barnett, C.D. Carone, D.E. Groom, T.G. Trippe, C.G. Wohl, B. Armstrong*, P.S. Gee*, G.S. Wagman*†, F. James, M. Mangano, K. Mönig, L. Montanet, J.L. Feng, H. Murayama, J.J. Hernández, A. Manohar, M. Aguilar-Benitez, C. Caso, R.L. Crawford, M. Roos, N.A. Törnqvist, K.G. Hayes, K. Hagiwara, K. Nakamura, M. Tanabashi, K. Olive, K. Honscheid, P.R. Burchat, R.E. Shrock, S. Eidelman, R.H. Schindler, A. Gurtu, K. Hikasa, G. Conforto, R.L. Workman, C. Grab, and C. Amsler

*Technical Associate

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(Approximate closing date for data: January 1, 1996)

GAUGE AND HIGGS BOSONS



$$I(J^{PC}) = 0.1(1^{--})$$

Mass $m<6\times10^{-16}$ eV, CL =99.7% Charge $q<5\times10^{-30}$ e Mean life au= Stable



$$I(J^P) = 0(1^-)$$

Mass m = 0 [a] SU(3) color octet



$$J = 1$$

Charge $= \pm 1~e$ Mass $m = 80.33 \pm 0.15~{\rm GeV}$ $m_Z - m_W = 10.85 \pm 0.15~{\rm GeV}$ $m_{W^+} - m_{W^-} = -0.2 \pm 0.6~{\rm GeV}$ Full width $\Gamma = 2.07 \pm 0.06~{\rm GeV}$

 \mathcal{W}^- modes are charge conjugates of the modes below.

W+ DECAY MODES	F	raction (I	Γ _i /Γ)	Confidence level	<i>p</i> (MeV/ <i>c</i>)
$\ell^+ \nu$	[b]	(10.8±0	0.4) %		40110
$e^+ \nu$		(10.8 ± 0)	0.4) %		40110
$\mu^+ \nu$		(10.4 ± 0)	0.6) %		40110
$\tau^+ \nu$		(10.9 ± 1)	1.0) %		40110
hadrons		(67.9 ± 1)	1.5) %		
$\pi^+\gamma$		< 5	× 10 ⁻	95%	40110



J = 1

 $\begin{array}{l} {\rm Charge} = 0 \\ {\rm Mass} \; m = 91.187 \, \pm \, 0.007 \; {\rm GeV} \, ^{[c]} \\ {\rm Full} \; {\rm width} \; \Gamma = 2.490 \, \pm \, 0.007 \; {\rm GeV} \\ {\rm } \Gamma(\ell^+\ell^-) = 83.83 \, \pm \, 0.27 \; {\rm MeV} \, ^{[d]} \\ {\rm } \Gamma({\rm invisible}) = 498.3 \, \pm \, 4.2 \; {\rm MeV} \, ^{[d]} \\ {\rm } \Gamma({\rm hadrons}) = 1740.7 \, \pm \, 5.9 \; {\rm MeV} \\ {\rm } \Gamma(\mu^+\mu^-)/\Gamma(e^+e^-) = 1.000 \, \pm \, 0.005 \\ {\rm } \Gamma(\tau^+\tau^-)/\Gamma(e^+e^-) = 0.998 \, \pm \, 0.005 \, ^{[e]} \end{array}$

Average charged multiplicity

 $\langle N_{charged} \rangle = 20.99 \pm 0.14$

Couplings to leptons

 $g_A^{\ell} = -0.0376 \pm 0.0012$ $g_A^{\ell} = -0.5008 \pm 0.0008$ $g^{\nu_e} = 0.53 \pm 0.09$ $g^{\nu_{\mu}} = 0.502 \pm 0.017$

Asymmetry parameters [f]

 $A_e = 0.156 \pm 0.008$ (S = 1.2) $A_\tau = 0.145 \pm 0.009$ $A_c = 0.59 \pm 0.19$ $A_b = 0.89 \pm 0.11$

Charge asymmetry (%) at Z pole

harge asymmetry (%) a
$$A_{FB}^{(0\ell)} = 1.59 \pm 0.18$$

$$A_{FB}^{(0s)} = 13 \pm 4$$

$$A_{FB}^{(0c)} = 7.22 \pm 0.67$$

$$A_{FB}^{(0b)} = 9.92 \pm 0.35$$

Z DECAY MODES		Fraction (Γ_i/Γ)	Confiden	ce level	р (MeV/c)
e+ e-		(3.366±0.008	3) %		45600
$\mu^+\mu^-$		(3.367±0.013	3) %		45600
$\tau^+\tau^-$		(3.360±0.015	5) %		45600
$\ell^+\ell^-$		[b] (3.366±0.006	5) %		45600
invisible		(20.01 ± 0.16)) %		-
hadrons		(69.90 ±0.15) %		-
$(u\overline{u}+c\overline{c})/2$		(9.6 ± 1.3)) %		-
$(d\overline{d} + s\overline{s} + b\overline{b})/3$		(16.9 ± 0.9)) %		_
c̄c		(11.0 ± 0.7)) %		-
$b\overline{b}$		(15.46 ± 0.14)) %		-
$\pi^0 \gamma$		< 5.2	\times 10 ⁻⁵	95%	45600
$\eta \gamma$		< 5.1	$\times 10^{-5}$	95%	45600
$\omega \gamma$		< 6.5	× 10 ⁻⁴	95%	45600
$\eta'(958)\gamma$		< 4.2	× 10 ⁻⁵	95%	45600
$\gamma \gamma$		< 5.2	× 10 ⁵	95%	45600
$\gamma \gamma \gamma$		< 1.0	× 10 ⁻⁵	95%	45600
$\pi^{\pm}W^{\mp}$		[g] < 7	× 10 ⁻⁵	95%	10300
$\rho^{\pm}W^{\mp}$		[g] < 8.3	$\times 10^{-5}$	95%	10300
$J/\psi(1S)X$		(3.80 ±0.27	$) \times 10^{-3}$		_
$\psi(2\dot{S})\dot{X}$		(1.60 ±0.33	$) \times 10^{-3}$		_
$\chi_{c1}(1P)X$		(6.0 ±1.9	$) \times 10^{-3}$		_
rx		(1.0 ±0.5	$) \times 10^{-4}$		_
(D^0/\overline{D}^0) X		(20.7 ±2.0) %		_
D [±] X		(12.2 ±1.7) %		-
D*(2010) ± X		[g] (11.4 ±1.3) %		_
$B_s^0 X$		seen	•		_
anomalous γ + hadrons		[h] < 3.2	$\times 10^{-3}$	95%	
$e^+e^-\gamma$		[h] < 5.2	× 10 ⁻⁴	95%	45600
$\mu^{+}\mu^{-}\gamma$		[h] < 5.6	× 10 ⁻⁴	95%	45600
$\tau^+\tau^-\gamma$		[h] < 7.3	$\times 10^{-4}$	95%	45600
$\ell^+\ell^-\gamma\gamma$		[i] < 6.8	× 10 ⁻⁶	95%	45600
$q \overline{q} \gamma \gamma$		[i] < 5.5	× 10 ⁻⁶	95%	
$\nu \overline{\nu} \gamma \gamma$		[/] < 3.1	× 10 ⁻⁶	95%	45600
$e^{\pm}\mu^{\mp}$	LF	[g] < 1.7	\times 10 ⁻⁶	95%	45600
$e^{\pm} \tau^{\mp}$	LF	[g] < 9.8	× 10 ⁻⁶	95%	45600
$\mu^{\pm}\tau^{\mp}$	LF	[g] < 1.7	× 10 ⁻⁵	95%	45600
•		(0)		0	

Gauge & Higgs Boson Summary Table

Higgs Bosons — H^0 and H^\pm , Searches for H^0 Mass m > 58.4 GeV, CL = 95% H^0_1 in Supersymmetric Models ($m_{H^0_1} < m_{H^0_2}$) [J] Mass m > 44 GeV, CL = 95% A^0 Pseudoscalar Higgs Boson in Supersymmetric Models [J] Mass m > 24.3 GeV, CL = 95% $\tan \beta > 1$, $m_t < 200$ GeV H^\pm Mass m > 43.5 GeV, CL = 95%

See the Particle Listings for a Note giving details of Higgs Bosons.

Heavy Bosons Other Than Higgs Bosons, Searches for

Additional W Bosons

```
W_R — right-handed W Mass m>406 GeV, CL = 90% (assuming light right-handed neutrino) W' with standard couplings decaying to e\nu, \mu\nu Mass m>652 GeV, CL = 95%
```

Additional Z Bosons

```
\boldsymbol{Z}_{\text{SM}}^{\prime} with standard couplings
  Mass m > 505 GeV, CL = 95%
                                            (pp direct search)
   Mass m > 779 GeV, CL = 95%
                                            (electroweak fit)
Z_{LR} of SU(2)_L \times SU(2)_R \times U(1)
   (with g_L = g_R)
   Mass m > 445 GeV, CL = 95%
                                            (p\overline{p} \text{ direct search})
   Mass m > 389 GeV, CL = 95%
                                            (electroweak fit)
Z_{\chi} of SO(10) \rightarrow SU(5)\timesU(1)\chi
   (coupling constant derived from G.U.T.)
   Mass m > 425 GeV, CL = 95\%
                                            (p\overline{p} \text{ direct search})
   Mass m > 321 GeV, CL = 95%
                                            (electroweak fit)
Z_{\psi} of E_6 \rightarrow SO(10) \times U(1)_{\psi}
   (coupling constant derived from G.U.T.)
                                           (p\overline{p} \text{ direct search})
   Mass m > 415 GeV, CL = 95%
   Mass m > 160 GeV, CL = 95\%
Z_{\eta} of E_6 \rightarrow SU(3)\times SU(2)\times U(1)\times U(1)_{\eta}
   (coupling constant derived from G.U.T.);
   charges are Q_{\eta}=\sqrt{3/8}Q\chi-\sqrt{5/8}Q_{\psi})
   Mass m > 440 GeV, CL = 95% (p\overline{p} direct search)
   Mass m > 182 GeV, CL = 95\% (electroweak fit)
```

Scalar Leptoquarks

```
Mass m>116 GeV, CL = 95% (1st generation, pair prod.) Mass m>230 GeV, CL = 95% (1st gener., single prod.) Mass m>97 GeV, CL = 95% (2nd gener., pair prod.) Mass m>73 GeV, CL = 95% (2nd gener., single prod.) Mass m>45 GeV, CL = 95% (3rd gener., pair prod.) (The second, fourth, and fifth limits above are for charge -1/3, weak isoscalar.)
```

Axions (A⁰) and Other Very Light Bosons, Searches for

The standard Peccei-Quinn axion is ruled out. Variants with reduced couplings or much smaller masses are constrained by various data. The Particle Listings in the full *Review* contain a Note discussing axion searches.

The best limit for the half-life of neutrinoless double beta decay with Majoron emission is $> 7.2 \times 10^{24}$ years (CL = 90%).

NOTES

In this Summary Table:

When a quantity has "(S = ...)" to its right, the error on the quantity has been enlarged by the "scale factor" S, defined as S = $\sqrt{\chi^2/(N-1)}$, where N is the number of measurements used in calculating the quantity. We do this when S > 1, which often indicates that the measurements are inconsistent. When S > 1.25, we also show in the Particle Listings an ideogram of the measurements. For more about S, see the Introduction.

A decay momentum p is given for each decay mode. For a 2-body decay, p is the momentum of each decay product in the rest frame of the decaying particle. For a 3-or-more-body decay, p is the largest momentum any of the products can have in this frame.

- [a] Theoretical value. A mass as large as a few MeV may not be precluded.
- [b] ℓ indicates each type of lepton (e, μ , and τ), not sum over them.
- [c] The Z-boson mass listed here corresponds to a Breit-Wigner resonance parameter. It lies approximately 34 MeV above the real part of the position of the pole (in the energy-squared plane) in the Z-boson propagator.
- [d] This partial width takes into account Z decays into $\nu\overline{\nu}$ and any other possible undetected modes.
- [e] This ratio has not been corrected for the au mass.
- [f] Here $A \equiv 2g_V g_A/(g_V^2+g_A^2)$.
- [g] The value is for the sum of the charge states of particle/antiparticle states indicated.
- [h] See the ${\it Z}$ Particle Listings for the γ energy range used in this measurement.
- [i] For $m_{\gamma\gamma}=$ (60 \pm 5) GeV.
- [j] The limits assume no invisible decays.

LEPTONS

е

$J=\frac{1}{2}$

Mass $m=0.51099907\pm0.00000015$ MeV $^{[a]}=(5.48579903\pm0.00000013)\times10^{-4}$ u $(m_{e^+}-m_{e^-})/m<4\times10^{-8},$ CL =90% $|q_{e^+}+q_{e^-}|/e<4\times10^{-8}$ Magnetic moment $\mu=1.001159652193\pm0.000000000010$ μ_B $(g_{e^+}-g_{e^-})$ / $g_{average}=(-0.5\pm2.1)\times10^{-12}$ Electric dipole moment $d=(-0.3\pm0.8)\times10^{-26}$ e cm Mean life $\tau>4.3\times10^{23}$ yr, CL =68% $^{[b]}$

μ

$J = \frac{1}{2}$

Mass $m=105.658389\pm0.000034$ MeV $^{[c]}$ = 0.113428913 ±0.000000017 u Mean life $\tau=(2.19703\pm0.00004)\times10^{-6}$ s $\tau_{\mu^+}/\tau_{\mu^-}=1.00002\pm0.00008$ $c\tau=658.654$ m Magnetic moment $\mu=1.001165923\pm0.000000008$ $e\hbar/2m_{\mu}$ ($g_{\mu^+}-g_{\mu^-})$ / $g_{\rm average}=(-2.6\pm1.6)\times10^{-8}$ Electric dipole moment $d=(3.7\pm3.4)\times10^{-19}$ e cm

Decay parameters [d]

 $\begin{array}{l} \rho = 0.7518 \pm 0.0026 \\ \eta = -0.007 \pm 0.013 \\ \delta = 0.749 \pm 0.004 \\ \xi P_{\mu} = 1.003 \pm 0.008 \\ \xi^{\prime} = 1.003 \pm 0.008 \\ \xi^{\prime} = 1.00 \pm 0.04 \\ \xi^{\prime\prime} = 0.7 \pm 0.4 \\ \alpha/A = (0 \pm 4) \times 10^{-3} \\ \alpha^{\prime}/A = (0 \pm 4) \times 10^{-3} \\ \beta/A = (4 \pm 6) \times 10^{-3} \\ \beta^{\prime}/A = (2 \pm 6) \times 10^{-3} \\ \overline{\eta} = 0.02 \pm 0.08 \end{array}$

 μ^+ modes are charge conjugates of the modes below.

μ^- DECAY MODES		Fraction ($\Gamma_i/\Gamma)$	Confidence level	<i>p</i> (MeV/ <i>c</i>)
$e^- \overline{\nu}_e \nu_\mu$		≈ 100%			53
$e^-\overline{ u}_e u_\mu\gamma$		[f] (1.4±0	.4) %		53
$e^- \overline{ u}_e u_\mu e^+ e^-$		[g] (3.4 ± 0)	$.4) \times 10^{-5}$		53
Lep	ton Family n	umber (<i>LF</i>)	violating r	nodes	
$e^- \nu_e \overline{\nu}_\mu$	LF	[h] < 1.2	%	90%	53
$e^-\gamma$	LF	< 4.9	$\times 10^{-13}$		53
$e^{-}e^{+}e^{-}$	LF	< 1.0	$\times 10^{-13}$	90%	53
$e^- 2\gamma$	LF	< 7.2	× 10 ⁻¹	90%	53



$$J = \frac{1}{2}$$

Mass $m=1777.00^{+0.30}_{-0.27}~{\rm MeV}$ Mean life $\tau=(291.0\pm1.5)\times10^{-15}~{\rm s}$ $c\tau=87.2~{\rm \mu m}$

Electric dipole moment $d < 5 \times 10^{-17}~e\,\mathrm{cm}$, $\mathrm{CL} = 95\%$

Weak dipole moment

$${\rm Re}(d_{\tau}^w) < 7.8 \times 10^{-18}~{\rm e\,cm,\,CL} = 95\% \\ {\rm Im}(d_{\tau}^w) < 4.5 \times 10^{-17}~{\rm e\,cm,\,CL} = 95\% \\$$

Decay parameters

See the au Particle Listings for a note concerning au-decay parameters.

 $\begin{array}{l} \rho^{\tau}(e \text{ or } \mu) = 0.742 \pm 0.027 \\ \rho^{\tau}(e) = 0.736 \pm 0.028 \\ \rho^{\tau}(\mu) = 0.74 \pm 0.04 \\ \xi^{\tau}(e \text{ or } \mu) = 1.03 \pm 0.12 \\ \xi^{\tau}(e) \text{ PARAMETER} = 1.03 \pm 0.25 \\ \xi^{\tau}(\mu) \text{ PARAMETER} = 1.23 \pm 0.24 \\ \eta^{\tau}(e \text{ or } \mu) \text{ PARAMETER} = -0.01 \pm 0.14 \\ \eta^{\tau}(\mu) \text{ PARAMETER} = -0.24 \pm 0.29 \\ (\delta\xi)^{\tau}(e \text{ or } \mu) \text{ PARAMETER} = 0.76 \pm 0.11 \\ (\delta\xi)^{\tau}(e) \text{ PARAMETER} = 1.11 \pm 0.18 \\ (\delta\xi)^{\tau}(\mu) \text{ PARAMETER} = 0.71 \pm 0.15 \\ \xi^{\tau}(\pi) = 0.99 \pm 0.06 \\ \xi^{\tau}(\rho) = 1.04 \pm 0.07 \\ \xi^{\tau}(a_1) = 1.01 \pm 0.04 \\ \xi^{\tau}(\text{all hadronic modes}) = 1.011 \pm 0.027 \end{array}$

 τ^+ modes are charge conjugates of the modes below. " h^\pm " stands for π^\pm or K^\pm . " ℓ " stands for e or μ . "Neutral" means neutral hadron whose decay products include γ 's and/or π^0 's.

τ ⁻ DECAY MODES		Fraction (Γ _/	·/୮)	Scale factor/ Confidence level	
Modes with		e charged	particle	•	
particle ≥ 0 neutrals $\geq 0K_0^0 \nu_{ au}$. 011	(84.96±			_
("1-prong")		(0	, ,,		
particle ≥ 0 neutrals $\geq 0K^0\nu_{\tau}$		(85.53±	0.14) %	S=1.3	-
$\mu^- \overline{ u}_\mu u_ au$	[i]	$(17.35 \pm$	0.10) %		885
$\mu^- \stackrel{'}{\overline{ u}}_\mu u_ au \gamma$		(2.3 ±	1.0)×	10-3	-
$(E_{\gamma} > 37 \text{ MeV})$					
$e^-\overline{ u}_e u_ au$	[i]	(17.83 \pm	0.08) %		888
$h^- \geq 0$ neutrals $\geq 0 K_L^0 u_ au$		$(49.78 \pm$	0.17) %	S=1.2	-
$h^- \geq 0 K_L^0 \; u_{ au}$		(12.51 \pm	0.13) %	S=1.1	-
$h^- u_ au$		(12.03 \pm	0.14) %	S=1.1	
$\pi^- u_{m{ au}}$	[/]				883
$K^- \nu_{ au}$	[i]	(7.1 ±			820
$h^- \geq 1 \pi^0 u_ au$		$(36.97 \pm$			-
$h^-\pi^0 u_{\tau}$		(25.76±		S=1.1	_
$\pi^{-}\pi^{0}\nu_{\tau}$	[i]			S=1.1	878
$\pi^{-}\pi^{0}$ non- $\rho(770)\nu_{\tau}$		(3.0 ±			878
$egin{aligned} \mathcal{K}^-\pi^0 u_{ au}\ h^- &> 2\pi^0 u_{ au} \end{aligned}$	[/]				814
$h \geq 2\pi^{\circ} u_{ au}$ $h^{-} 2\pi^{0} u_{ au}$		(10.95± (9.50±		S=1.1	
$h^{-}2\pi^{0}\nu_{\tau}$ (ex. K^{0})		(9.35±		S=1.1 S=1.1	_
$\pi^{-}2\pi^{0}\nu_{\tau}(ex.K^{0})$	[/]		,	S=1.1	862
$K^{-}2\pi^{0}\nu_{\tau}(ex.K^{0})$	[/]				796
$h^- > 3\pi^0 \nu_{\tau}$	[1]	(1.46 ±		S=1.1	7 70
$h = 3\pi^0 \nu_{\tau}$		(1.48±	,	3=1.1	
$\pi^{-}3\pi^{0}\nu_{\tau}$ (ex. K^{0})	[/]	•	,		836
$K^{-}3\pi^{0}\nu_{\tau}(\text{ex}.K^{0})$	[/]			10-4	766
$h^-4\pi^0\nu_{\tau}$ (ex. K^0)	, 1-1	(1.8 ±			-
$h^- 4\pi^0 \nu$ (ex. $K^0 n$)	[/]				_
$h^- 4\pi^0 \nu_{ au} (ex. K^0, \eta)$ $K^- \geq 1 \; (\pi^0 \; or \; K^0) \; u_{ au}$	[1]	(9.4 ±			_
		•			
$h^-\overline{K}^0 > 0$ neutrals $>$	des	with <i>K</i> 0's		S=1.3	_
$0K_L^0 u_ au$		(1.541	0.10) /6	3-1.3	
$h^{-}\overline{K}^{0}\nu_{-}$		(9.2 ±	0.8) ×	10 ⁻³ S=1.3	_
$\pi^- \overline{K}^{0} \nu_{\tau}$	[/]	(7.7 ±			812
$\pi^-\overline{K}{}^0$.,	< 1.7		10 ⁻³ CL=95%	812
$(\text{non-}K^*(892)^-)\nu_{\tau}$					
$\kappa^- \kappa^0 \nu_{\tau}$	[<i>i</i>]	(1.55±	0.28) ×	10-3	737
$\mathit{h}^-\overline{K}{}^0\pi^0 u_{ au}$		(5.5 \pm	0.5)×	10-3	_
$\pi^-\overline{K}{}^0\pi^0 u_ au$	[i]	(4.1 \pm			794
$\mathcal{K}^-\mathcal{K}^0\pi^0 u_ au$	[i]				685
$h^{-} K_{5}^{0} K_{5}^{0} \nu_{\tau}$		(2.5 \pm			
$\pi^- K^0 \overline{K^0} \nu_{\tau}$	[i]				682
$K^-K^0 \ge 0$ neutrals ν_τ		(2.9 ±		10-3	_
$K^- \geq 0\pi^0 \geq 0K^0 \nu_{\tau}$		(1.65±			_
K^0 (particles) $^ u_ au$ K^0 h^+ $h^ h^ \geq 0$ neut. $ u_ au$		(1.58± < 1.7		S=1.2 10 ⁻³ CL=95%	_
κ κ κ κ κ κ κ		<u> 1.1</u>	×	10 - CL≔95%	_

Lepton Summary Table

	three charged particles		
$h^- h^- h^+ \geq 0$ neut. ν_{τ} ("3-prong")	(14.91 ± 0.14) %	S=1.3	_
$h^-h^-h^+ \geq 0$ neutrals ν_{τ} (ex. $K_S^0 \rightarrow \pi^+\pi^-$)	(14.36± 0.14) %	S=1.3	_
$\pi^-\pi^+\pi^- \geq 0$ neutrals ν_{τ}	(14.09± 0.31) %		
$h^-h^-h^+ u_{ au}^-$	(9.80 ± 0.10) %	S=1.1	-
$h^- h^- h^+ \nu_{\tau} (ex.K^0)$	(9.48 ± 0.10) %	S=1.1	-
$h^- h^- h^+ u_{ au} (\mathrm{ex}.K^0, \omega)$	[i] (9.44± 0.10) %	S=1.1	-
$h^-h^-h^+ \geq 1$ neutrals $ u_{ au}$	$(5.08 \pm 0.11)\%$	S=1.2	-
$h^-h^-h^+ \geq 1$ neutrals $ u_{ au}$ (ex. $ K_S^0 o \pi^+\pi^- $)	(4.88± 0.11) %	S=1.2	_
$h^- h^- h^+ \pi^0 \nu_{\tau}$	(4.44 ± 0.09) %	S=1.1	-
$h^- h^- h^+ \pi^0 \nu_{\tau} (ex. K^0)$	(4.25 ± 0.09) %	S=1.1	-
$h^{-}h^{-}h^{+}\pi^{0}\nu_{\tau}(\text{ex. }K^{0},\omega)$	[i] (2.55± 0.09) %		_
$h^{-}(\rho\pi)^{0}\nu_{\tau}$	(2.84± 0.34) % < 2.0 %	CL=95%	_
$(a_1(1260)h)^- u_{ au}\ h^- ho\pi^0 u_{ au}$	(1.33 ± 0.20) %		_
$h^-\rho^+h^-\nu_{ au}$	$(4.4 \pm 2.2) \times 10^{-3}$		_
$h^-\rho^-h^+ u_ au$	(1.15 ± 0.23) %		_
$h^- h^- h^+ 2 \pi^0 u_{ au}$	$(5.2 \pm 0.5) \times 10^{-3}$	•	_
$h^- h^- h^+ 2\pi^0 \nu_{ au} (\text{ex}.K^0)$	$(5.1 \pm 0.5) \times 10^{-3}$		-
$h^- h^- h^+ 2\pi^0 \nu_{\tau} (\text{ex.} K^0, \omega, \eta)$		•	-
$h^- h^- h^+ \geq 3\pi^0 \nu_\tau$	[i] $(1.1 \pm 0.6) \times 10^{-3}$		-
$\mathcal{K}^-h^+h^-\geq 0$ neutrals $ u_ au$	$< 6 \times 10^{-3}$	CL=90%	-
$\mathcal{K}^-\pi^+\pi^-\geq 0$ neut. $ u_{ au}$	$(3.9 \ ^{+} \ ^{1.9} _{-}) \times 10^{-3}$	S=1.5	-
$\mathcal{K}^-\pi^+\mathcal{K}^- \geq$ 0 neut. $ u_{ au}$	< 9 × 10 ⁻⁴	CL=95%	_
$K^-K^+\pi^- \geq 0$ neut. $ u_{ au}$	$(1.5 \ ^{+}_{-} \ 0.9 \) \times 10^{-3}$		
$K^-K^+\pi^- u_ au$	$(2.2 + 1.8 \times 10^{-3}) \times 10^{-3}$	68	5
$\phi \pi^- u_ au$	< 3.5 × 10 ⁻⁴	CL=90% 58	5
$K^-K^+K^- \geq 0$ neut.	< 2.1 × 10 ⁻³		-
$\pi^- {\stackrel{.}{K}}^{\!$	$< 2.5 \times 10^{-3}$	CL=95%	-
$e^-e^-e^+\overline{ u}_e u_ au$	$(2.8 \pm 1.5) \times 10^{-5}$	88	8
$\mu^-e^-e^+\overline{ u}_\mu u_ au$	$< 3.6 \times 10^{-5}$	CL=90% 88	5
Modes with	five charged particles		
26-26+ > 0 noutrals			
$3h^-2h^+\geq 0$ neutrals $ u_ au$	$(9.7 \pm 0.7) \times 10^{-4}$		_
$(ex. K_S^0 \rightarrow \pi^-\pi^+)$ ("5-prong")	$(9.7 \pm 0.7) \times 10^{-4}$		-
(ex. $K_S^0 \rightarrow \pi^- \pi^+$) ("5-prong") $3h^- 2h^+ \nu_{\tau}$ (ex. K^0)	[i] (7.5 \pm 0.7) \times 10 ⁻⁴		_
(ex. $K_S^0 \to \pi^- \pi^+$) ("5-prong") $3h^- 2h^+ \nu_{\tau} (ex.K^0)$ $3h^- 2h^+ \pi^0 \nu_{\tau} (ex.K^0)$	[i] $(7.5 \pm 0.7) \times 10^{-4}$ [i] $(2.2 \pm 0.5) \times 10^{-4}$		_
(ex. $K_S^0 \rightarrow \pi^- \pi^+$) ("5-prong") $3h^- 2h^+ \nu_{\tau}$ (ex. K^0)	[i] (7.5 \pm 0.7) \times 10 ⁻⁴		-
$\begin{array}{l} (\text{ex. } K_{\text{S}}^{0} \rightarrow \pi^{-}\pi^{+}) \\ \text{("5-prong")} \\ 3h^{-}2h^{+}\nu_{\tau}(\text{ex.}K^{0}) \\ 3h^{-}2h^{+}\pi^{0}\nu_{\tau}(\text{ex.}K^{0}) \\ 3h^{-}2h^{+}2\pi^{0}\nu_{\tau} \end{array}$ $\qquad \qquad \qquad$	[i] (7.5 ± 0.7) × 10^{-4} [i] (2.2 ± 0.5) × 10^{-4} < 1.1 × 10^{-4}	CL=90%	
$ \begin{array}{l} (\text{ex. } K_S^0 \to \pi^- \pi^+) \\ (\text{``5-prong''}) \\ 3h^- 2h^+ \nu_\tau (\text{ex.} K^0) \\ 3h^- 2h^+ \pi^0 \nu_\tau (\text{ex.} K^0) \\ 3h^- 2h^+ 2\pi^0 \nu_\tau \end{array} $	[i] (7.5 \pm 0.7) × 10 ⁻⁴ [i] (2.2 \pm 0.5) × 10 ⁻⁴ < 1.1 × 10 ⁻⁴ is other allowed modes (3.3 \pm 0.7) × 10 ⁻³		-
$\begin{array}{l} (\text{ex. } K_{S}^{0} \rightarrow \pi^{-}\pi^{+}) \\ \text{("5-prong")} \\ 3h^{-}2h^{+}\nu_{\tau}(\text{ex.}K^{0}) \\ 3h^{-}2h^{+}\pi^{0}\nu_{\tau}(\text{ex.}K^{0}) \\ 3h^{-}2h^{+}2\pi^{0}\nu_{\tau} \\ \\ \hline \text{Miscellaneou} \\ (5\pi)^{-}\nu_{\tau} \\ 4h^{-}3h^{+} \geq 0 \text{ neutrals } \nu_{\tau} \\ \text{("7-prong")} \end{array}$	[i] (7.5 \pm 0.7)×10 ⁻⁴ [i] (2.2 \pm 0.5)×10 ⁻⁴ < 1.1 ×10 ⁻⁴ is other allowed modes (3.3 \pm 0.7)×10 ⁻³ < 1.9 ×10 ⁻⁴		
$\begin{array}{l} (\text{ex. } K_{S}^{0} \rightarrow \pi^{-}\pi^{+}) \\ (\text{"5-prong"}) \\ 3h^{-}2h^{+}\nu_{\tau}(\text{ex.}K^{0}) \\ 3h^{-}2h^{+}\pi^{0}\nu_{\tau}(\text{ex.}K^{0}) \\ 3h^{-}2h^{+}2\pi^{0}\nu_{\tau} \\ \\ \hline \qquad \qquad$	[i] $(7.5 \pm 0.7) \times 10^{-4}$ [i] $(2.2 \pm 0.5) \times 10^{-4}$ $< 1.1 \times 10^{-4}$ is other allowed modes $(3.3 \pm 0.7) \times 10^{-3}$ $< 1.9 \times 10^{-4}$		
$\begin{array}{l} (\text{ex. } K_S^0 \to \pi^-\pi^+) \\ (\text{"5-prong"}) \\ 3h^-2h^+\nu_\tau(\text{ex.}K^0) \\ 3h^-2h^+\pi^0\nu_\tau(\text{ex.}K^0) \\ 3h^-2h^+2\pi^0\nu_\tau \\ \\ & \qquad \qquad$	[i] $(7.5 \pm 0.7) \times 10^{-4}$ [i] $(2.2 \pm 0.5) \times 10^{-4}$ $< 1.1 \times 10^{-4}$ is other allowed modes $(3.3 \pm 0.7) \times 10^{-3}$ $< 1.9 \times 10^{-4}$ $(1.94 \pm 0.31)\%$ $(1.33 \pm 0.13)\%$	CL=90%	
$\begin{array}{l} (\text{ex. } K_S^0 \to \pi^- \pi^+) \\ (\text{``5-prong''}) \\ 3h^- 2h^+ \nu_\tau (\text{ex.} K^0) \\ 3h^- 2h^+ \pi^0 \nu_\tau (\text{ex.} K^0) \\ 3h^- 2h^+ 2\pi^0 \nu_\tau \\ & \text{Miscellaneou} \\ (5\pi)^- \nu_\tau \\ 4h^- 3h^+ \geq 0 \text{ neutrals } \nu_\tau \\ (\text{``7-prong''}) \\ K^* (892)^- \geq 0 (h^0 \neq K_S^0) \nu_\tau \\ K^* (892)^- \geq 0 \text{ neutrals } \nu_\tau \\ K^* (892)^- \nu_\tau \\ \end{array}$	[i] (7.5 \pm 0.7) × 10 ⁻⁴ [i] (2.2 \pm 0.5) × 10 ⁻⁴ < 1.1 × 10 ⁻⁴ is other allowed modes (3.3 \pm 0.7) × 10 ⁻³ < 1.9 × 10 ⁻⁴ (1.94 \pm 0.31) % (1.33 \pm 0.13) % (1.28 \pm 0.08) %		
(ex. $K_S^0 \to \pi^- \pi^+$) ("5-prong") $3h^- 2h^+ \nu_{\tau}$ (ex. K^0) $3h^- 2h^+ \pi^0 \nu_{\tau}$ (ex. K^0) $3h^- 2h^+ 2\pi^0 \nu_{\tau}$ Miscellaneous $(5\pi)^- \nu_{\tau}$ $4h^- 3h^+ \ge 0$ neutrals ν_{τ} ("7-prong") $K^*(892)^- \ge 0 (h^0 \ne K_S^0) \nu_{\tau}$ $K^*(892)^- \nu_{\tau}$ $K^*(892)^0 K^- \ge 0$ neutrals ν_{τ} $K^*(892)^0 K^- \ge 0$ neutrals ν_{τ} $K^*(892)^0 K^- \ge 0$	[i] $(7.5 \pm 0.7) \times 10^{-4}$ [i] $(2.2 \pm 0.5) \times 10^{-4}$ $< 1.1 \times 10^{-4}$ Is other allowed modes $(3.3 \pm 0.7) \times 10^{-3}$ $< 1.9 \times 10^{-4}$ $(1.94 \pm 0.31)\%$ $(1.28 \pm 0.08)\%$ $(3.2 \pm 1.4) \times 10^{-3}$	CL=90%	-
(ex. $K_S^0 \to \pi^- \pi^+$) ("5-prong") $3h^- 2h^+ \nu_{\tau}$ (ex. K^0) $3h^- 2h^+ \pi^0 \nu_{\tau}$ (ex. K^0) $3h^- 2h^+ 2\pi^0 \nu_{\tau}$ Miscellaneous $(5\pi)^- \nu_{\tau}$ $4h^- 3h^+ \ge 0$ neutrals ν_{τ} ("7-prong") $K^*(892)^- \ge 0 (h^0 \ne K_S^0) \nu_{\tau}$ $K^*(892)^- \nu_{\tau}$ $K^*(892)^0 K^- \ge 0$ neutrals ν_{τ} $K^*(892)^0 K^- \ge 0$ neutrals ν_{τ} $K^*(892)^0 K^- \ge 0$	[i] $(7.5 \pm 0.7) \times 10^{-4}$ [i] $(2.2 \pm 0.5) \times 10^{-4}$ $< 1.1 \times 10^{-4}$ Is other allowed modes $(3.3 \pm 0.7) \times 10^{-3}$ $< 1.9 \times 10^{-4}$ $(1.94 \pm 0.31)\%$ $(1.33 \pm 0.13)\%$ $(1.28 \pm 0.08)\%$ $(3.2 \pm 1.4) \times 10^{-3}$ $(2.0 \pm 0.6) \times 10^{-3}$	CL=90%	-
$\begin{array}{l} (\text{ex. } K_S^0 \to \pi^- \pi^+) \\ (\text{"5-prong"}) \\ 3h^- 2h^+ \nu_{\tau}(\text{ex.} K^0) \\ 3h^- 2h^+ \pi^0 \nu_{\tau}(\text{ex.} K^0) \\ 3h^- 2h^+ 2\pi^0 \nu_{\tau} \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ $	[i] $(7.5 \pm 0.7) \times 10^{-4}$ [i] $(2.2 \pm 0.5) \times 10^{-4}$ $< 1.1 \times 10^{-4}$ s other allowed modes $(3.3 \pm 0.7) \times 10^{-3}$ $< 1.9 \times 10^{-4}$ $(1.94 \pm 0.31)\%$ $(1.33 \pm 0.13)\%$ $(1.28 \pm 0.08)\%$ $(3.2 \pm 1.4) \times 10^{-3}$ $(2.0 \pm 0.6) \times 10^{-3}$ $(3.8 \pm 1.7) \times 10^{-3}$	CL=90%	- 9 -
(ex. $K_S^0 \to \pi^- \pi^+$) ("5-prong") $3h^- 2h^+ \nu_{\tau}$ (ex. K^0) $3h^- 2h^+ \pi^0 \nu_{\tau}$ (ex. K^0) $3h^- 2h^+ 2\pi^0 \nu_{\tau}$ Miscellaneous $(5\pi)^- \nu_{\tau}$ $4h^- 3h^+ \ge 0$ neutrals ν_{τ} ("7-prong") $K^*(892)^- \ge 0 (h^0 \ne K_S^0) \nu_{\tau}$ $K^*(892)^- \nu_{\tau}$ $K^*(892)^0 K^- \ge 0$ neutrals ν_{τ} $K^*(892)^0 K^- \ge 0$ neutrals ν_{τ} $K^*(892)^0 K^- \ge 0$	[i] $(7.5 \pm 0.7) \times 10^{-4}$ [i] $(2.2 \pm 0.5) \times 10^{-4}$ $< 1.1 \times 10^{-4}$ Is other allowed modes $(3.3 \pm 0.7) \times 10^{-3}$ $< 1.9 \times 10^{-4}$ $(1.94 \pm 0.31)\%$ $(1.33 \pm 0.13)\%$ $(1.28 \pm 0.08)\%$ $(3.2 \pm 1.4) \times 10^{-3}$ $(2.0 \pm 0.6) \times 10^{-3}$	CL=90%	- 9 - 3
$\begin{array}{l} (\text{ex. } K_S^0 \to \pi^-\pi^+) \\ (\text{"5-prong"}) \\ 3h^-2h^+\nu_{\tau}(\text{ex.}K^0) \\ 3h^-2h^+\pi^0\nu_{\tau}(\text{ex.}K^0) \\ 3h^-2h^+2\pi^0\nu_{\tau} \\ & \\ \\ \text{Miscellaneou} \\ (5\pi)^-\nu_{\tau} \\ 4h^-3h^+ \geq 0 \text{ neutrals } \nu_{\tau} \\ (\text{"7-prong"}) \\ K^*(892)^- \geq 0(h^0 \neq K_S^0)\nu_{\tau} \\ K^*(892)^- \geq 0 \text{ neutrals } \nu_{\tau} \\ K^*(892)^-\nu_{\tau} \\ K^*(892)^0K^- \geq 0 \text{ neutrals } \nu_{\tau} \\ \overline{K}^*(892)^0K^-\nu_{\tau} \\ \overline{K}^*(892)^0\pi^- \geq 0 \text{ neutrals } \nu_{\tau} \\ \overline{K}^*(892)^0\pi^-\nu_{\tau} \end{array}$	[i] (7.5 \pm 0.7)×10 ⁻⁴ [i] (2.2 \pm 0.5)×10 ⁻⁴ < 1.1 ×10 ⁻⁴ is other allowed modes (3.3 \pm 0.7)×10 ⁻³ < 1.9 ×10 ⁻⁴ (1.94 \pm 0.31) % (1.33 \pm 0.13) % (1.28 \pm 0.08) % (3.2 \pm 1.4)×10 ⁻³ (2.0 \pm 0.6)×10 ⁻³ (3.8 \pm 1.7)×10 ⁻³ (2.5 \pm 1.1)×10 ⁻³	CL=90%	- :9 - :3
$\begin{array}{l} (\text{ex. } K_S^0 \to \pi^- \pi^+) \\ (\text{"5-prong"}) \\ 3h^- 2h^+ \nu_\tau (\text{ex.} K^0) \\ 3h^- 2h^+ \nu_\tau (\text{ex.} K^0) \\ 3h^- 2h^+ 2\pi^0 \nu_\tau (\text{ex.} K^0) \\ 3h^- 2h^+ 2\pi^0 \nu_\tau \\ \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & $	[i] $(7.5 \pm 0.7) \times 10^{-4}$ [i] $(2.2 \pm 0.5) \times 10^{-4}$ $< 1.1 \times 10^{-4}$ is other allowed modes $(3.3 \pm 0.7) \times 10^{-3}$ $< 1.9 \times 10^{-4}$ $(1.94 \pm 0.31)\%$ $(1.33 \pm 0.13)\%$ $(1.28 \pm 0.08)\%$ $(3.2 \pm 1.4) \times 10^{-3}$ $(2.0 \pm 0.6) \times 10^{-3}$ $(3.8 \pm 1.7) \times 10^{-3}$ $(2.5 \pm 1.1) \times 10^{-3}$ $(4 \pm 4) \times 10^{-3}$	CL=90% 66 53 65 43	- - - - 3 - 5
$\begin{array}{l} (\text{ex. } K_S^0 \to \pi^- \pi^+) \\ \text{("5-prong")} \\ 3h^- 2h^+ \nu_{\tau}(\text{ex.} K^0) \\ 3h^- 2h^+ \pi^0 \nu_{\tau}(\text{ex.} K^0) \\ 3h^- 2h^+ 2\pi^0 \nu_{\tau} \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ $	$ \begin{bmatrix} [i] & (7.5 \pm 0.7) \times 10^{-4} \\ [i] & (2.2 \pm 0.5) \times 10^{-4} \\ < 1.1 & \times 10^{-4} \\ \end{bmatrix} $ is other allowed modes $ \begin{bmatrix} 3.3 \pm 0.7 \times 10^{-3} \\ < 1.9 & \times 10^{-4} \end{bmatrix} $ $ \begin{bmatrix} 1.94 \pm 0.31 \times 10^{-3} \\ (1.28 \pm 0.08) \times 10^{-3} \\ (2.0 \pm 0.6) \times 10^{-3} \\ (3.8 \pm 1.7) \times 10^{-3} \\ (2.5 \pm 1.1) \times 10^{-3} \\ (4 \pm 4) \times 10^{-3} \\ < 3 & \times 10^{-3} \\ < 1.4 & \times 10^{-4} \\ \end{bmatrix} $	CL=90% 66 53 65 43 33 CL=95% 31 CL=95% 79	- 19 - 13 15 7
$\begin{array}{l} (\text{ex. } K_S^0 \to \pi^- \pi^+) \\ \text{("5-prong")} \\ 3h^- 2h^+ \nu_\tau (\text{ex.} K^0) \\ 3h^- 2h^+ \nu_\tau (\text{ex.} K^0) \\ 3h^- 2h^+ 2\pi^0 \nu_\tau (\text{ex.} K^0) \\ 3h^- 2h^+ 2\pi^0 \nu_\tau (\text{ex.} K^0) \\ 3h^- 2h^+ 2\pi^0 \nu_\tau \\ \\ & \text{Miscellaneou} \\ (5\pi)^- \nu_\tau \\ 4h^- 3h^+ \geq 0 \text{ neutrals } \nu_\tau \\ \text{("7-prong")} \\ K^*(892)^- \geq 0 (h^0 \neq K_S^0) \nu_\tau \\ K^*(892)^- \nu_\tau \\ K^*(892)^- \nu_\tau \\ K^*(892)^- \nu_\tau \\ K^*(892)^0 K^- \geq 0 \text{ neutrals } \nu_\tau \\ K^*(892)^0 K^- \nu_\tau \\ \hline K^*(892)^0 \pi^- \geq 0 \text{ neutrals } \nu_\tau \\ K^*(892)^0 \pi^- \nu_\tau \\ K_1(1270)^- \nu_\tau \\ K_1(1400)^- \nu_\tau \\ K_2^*(1430)^- \nu_\tau \\ \eta \pi^- \nu_\tau \end{array}$	$ \begin{bmatrix} [i] & (7.5 \pm 0.7) \times 10^{-4} \\ [i] & (2.2 \pm 0.5) \times 10^{-4} \\ < 1.1 & \times 10^{-4} \\ \end{bmatrix} $ is other allowed modes $ \begin{bmatrix} 3.3 \pm 0.7 \times 10^{-3} \\ < 1.9 & \times 10^{-4} \end{bmatrix} $ is other allowed modes $ \begin{bmatrix} 1.94 \pm 0.31 \end{bmatrix} \% $ $ \begin{bmatrix} 1.94 \pm 0.31 \end{bmatrix} \% $ $ \begin{bmatrix} 1.28 \pm 0.08 \end{bmatrix} \% $ $ \begin{bmatrix} 3.2 \pm 1.4 \times 10^{-3} \\ (2.0 \pm 0.6) \times 10^{-3} \\ (3.8 \pm 1.7) \times 10^{-3} \\ (2.5 \pm 1.1) \times 10^{-3} \\ (4 \pm 4 \times 10^{-3} \\ (8 \pm 4 \times 10^{-3} \\ < 3 & \times 10^{-3} \\ < 1.4 & \times 10^{-4} \\ \end{bmatrix} $ $ \begin{bmatrix} 1.71 \pm 0.28 \times 10^{-4} \\ \end{bmatrix} $	CL=90% 66 53 65 43 31 CL=95% 79	- 19 - 13 15 7 18
$\begin{array}{l} (\text{ex. } K_S^0 \to \pi^- \pi^+) \\ (\text{``5-prong''}) \\ 3h^- 2h^+ \nu_\tau (\text{ex.} K^0) \\ 3h^- 2h^+ \pi^0 \nu_\tau (\text{ex.} K^0) \\ 3h^- 2h^+ 2\pi^0 \nu_\tau \\ \\ & \\ & \\ \\ & \\ & \\ \\ &$	[i] $(7.5 \pm 0.7) \times 10^{-4}$ [i] $(2.2 \pm 0.5) \times 10^{-4}$ $< 1.1 \times 10^{-4}$ IS other allowed modes $(3.3 \pm 0.7) \times 10^{-3}$ $< 1.9 \times 10^{-4}$ (1.94± 0.31) % (1.28± 0.08) % (3.2 ± 1.4) × 10 ⁻³ (2.0 ± 0.6) × 10 ⁻³ (3.8 ± 1.7) × 10 ⁻³ (2.5 ± 1.1) × 10 ⁻³ (4 ± 4) × 10 ⁻³ (8 ± 4) × 10 ⁻³ (8 ± 4) × 10 ⁻³ (1.4 × 10 ⁻⁴ (1.71± 0.28) × 10 ⁻³ (1.71± 0.28) × 10 ⁻³	CL=90% 66 53 65 43 33 CL=95% 77 CL=95% 74	- 9 - 3 3 5 7 8 6
$\begin{array}{l} (\text{ex. } K_S^0 \to \pi^-\pi^+) \\ \text{("5-prong")} \\ 3h^-2h^+\nu_1(\text{ex.}K^0) \\ 3h^-2h^+\pi^0\nu_\tau(\text{ex.}K^0) \\ 3h^-2h^+2\pi^0\nu_\tau \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ $	[i] (7.5 ± 0.7) × 10^{-4} [i] (2.2 ± 0.5) × 10^{-4} < 1.1 × 10^{-4} Is other allowed modes (3.3 ± 0.7) × 10^{-3} < 1.9 × 10^{-4} (1.94 ± 0.31) % (1.33 ± 0.13) % (1.28 ± 0.08) % (3.2 ± 1.4) × 10^{-3} (2.0 ± 0.6) × 10^{-3} (3.8 ± 1.7) × 10^{-3} (2.5 ± 1.1) × 10^{-3} (4 ± 4) × 10^{-3} (8 ± 4) × 10^{-3} < 1.4 × 10^{-3} < 1.4 × 10^{-4} [i] (1.71 ± 0.28) × 10^{-3} < 4.3 × 10^{-4} (2.6 ± 0.7) × 10^{-4}	CL=90% 66 53 65 43 33 CL=95% 31 CL=95% 79 CL=95% 74	- 3 - 3 - 3 - 5 - 7 - 8 - 8 - 6 - 9
$\begin{array}{l} (\text{ex. } K_S^0 \to \pi^-\pi^+) \\ \text{("5-prong")} \\ 3h^-2h^+\nu_1(\text{ex.}K^0) \\ 3h^-2h^+\pi^0\nu_\tau(\text{ex.}K^0) \\ 3h^-2h^+2\pi^0\nu_\tau \\ & \text{Miscellaneou} \\ (5\pi)^-\nu_\tau \\ 4h^-3h^+ \geq 0 \text{ neutrals } \nu_\tau \\ \text{("7-prong")} \\ K^*(892)^- \geq 0 (h^0 \neq K_S^0)\nu_\tau \\ K^*(892)^- \geq 0 \text{ neutrals } \nu_\tau \\ K^*(892)^- \geq 0 \text{ neutrals } \nu_\tau \\ K^*(892)^- \nabla = 0 \text{ neutrals } \nu_\tau \\ K^*(892)^0 K^- \geq 0 \text{ neutrals } \nu_\tau \\ K^*(892)^0 K^- \geq 0 \text{ neutrals } \nu_\tau \\ \overline{K}^*(892)^0 \pi^- \geq 0 \text{ neutrals } \nu_\tau \\ \overline{K}^*(892)^0 \pi^- \nabla = 0 \\ \overline{K}^*(892)^0 \pi^- \nabla =$	$ \begin{bmatrix} i] & (7.5 \pm 0.7) \times 10^{-4} \\ [i] & (2.2 \pm 0.5) \times 10^{-4} \\ < 1.1 & \times 10^{-4} \\ \end{bmatrix} $ is other allowed modes $ (3.3 \pm 0.7) \times 10^{-3} \\ < 1.9 & \times 10^{-4} \\ \end{bmatrix} $ $ (1.94 \pm 0.31) \% \\ (1.33 \pm 0.13) \% \\ (1.28 \pm 0.08) \% \\ (3.2 \pm 1.4) \times 10^{-3} \\ (2.0 \pm 0.6) \times 10^{-3} \\ (3.8 \pm 1.7) \times 10^{-3} \\ (2.5 \pm 1.1) \times 10^{-3} \\ (4 \pm 4) \times 10^{-3} \\ < 8 \pm 4) \times 10^{-3} \\ < 1.4 & \times 10^{-4} \\ \end{bmatrix} $ $ (1.71 \pm 0.28) \times 10^{-3} \\ < 4.3 & \times 10^{-4} \\ (2.6 \pm 0.7) \times 10^{-4} \\ < 3 & \times 10^{-3} \\ \end{aligned} $	CL=90% 66 53 65 43 33 CL=95% 79 77 CL=95% 74 CL=95% 74	- 9 - 3 - 3 - 3 - 5 - 7 - 8 - 8 - 6 - 9 -
$\begin{array}{l} (\text{ex. } K_S^0 \to \pi^- \pi^+) \\ \text{("5-prong")} \\ 3h^- 2h^+ \nu_{\tau}(\text{ex.} K^0) \\ 3h^- 2h^+ \pi^0 \nu_{\tau}(\text{ex.} K^0) \\ 3h^- 2h^+ 2\pi^0 \nu_{\tau} \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ $	$ \begin{bmatrix} [i] & (7.5 \pm 0.7) \times 10^{-4} \\ [i] & (2.2 \pm 0.5) \times 10^{-4} \\ < 1.1 & \times 10^{-4} \\ \end{bmatrix} $ so ther allowed modes $ \begin{bmatrix} 3.3 \pm 0.7 \times 10^{-3} \\ < 1.9 & \times 10^{-4} \end{bmatrix} $ $ \begin{bmatrix} 1.94 \pm 0.31 \times 10^{-3} \\ (1.33 \pm 0.13) \times 10^{-3} \\ (1.28 \pm 0.08) \times 10^{-3} \\ (2.0 \pm 0.6) \times 10^{-3} \\ (3.8 \pm 1.7) \times 10^{-3} \\ (2.5 \pm 1.1) \times 10^{-3} \\ (4 \pm 4) \times 10^{-3} \\ < 8 \pm 4 \times 10^{-3} \\ < 1.4 & \times 10^{-4} \\ \end{bmatrix} $ $ \begin{bmatrix} [i] & (1.71 \pm 0.28) \times 10^{-3} \\ < 4.3 & \times 10^{-4} \\ < 2.6 \pm 0.7 \times 10^{-3} \\ < 1.1 & \times 10^{-3} \\ < 1.1 & \times 10^{-4} \\ \end{bmatrix} $	CL=90% 66 53 65 43 33 CL=95% 31 CL=95% 79 77 CL=95% 74 CL=95% 63	- 3 3 5 7 8 8 6 9 - 7
$\begin{array}{l} (\text{ex. } K_S^0 \to \pi^-\pi^+) \\ \text{("5-prong")} \\ 3h^-2h^+\nu_1(\text{ex.}K^0) \\ 3h^-2h^+\pi^0\nu_\tau(\text{ex.}K^0) \\ 3h^-2h^+2\pi^0\nu_\tau \\ & \text{Miscellaneou} \\ (5\pi)^-\nu_\tau \\ 4h^-3h^+ \geq 0 \text{ neutrals } \nu_\tau \\ \text{("7-prong")} \\ K^*(892)^- \geq 0 (h^0 \neq K_S^0)\nu_\tau \\ K^*(892)^- \geq 0 \text{ neutrals } \nu_\tau \\ K^*(892)^- \geq 0 \text{ neutrals } \nu_\tau \\ K^*(892)^- \nabla = 0 \text{ neutrals } \nu_\tau \\ K^*(892)^0 K^- \geq 0 \text{ neutrals } \nu_\tau \\ K^*(892)^0 K^- \geq 0 \text{ neutrals } \nu_\tau \\ \overline{K}^*(892)^0 \pi^- \geq 0 \text{ neutrals } \nu_\tau \\ \overline{K}^*(892)^0 \pi^- \nabla = 0 \\ \overline{K}^*(892)^0 \pi^- \nabla =$	$ \begin{bmatrix} i] & (7.5 \pm 0.7) \times 10^{-4} \\ [i] & (2.2 \pm 0.5) \times 10^{-4} \\ < 1.1 & \times 10^{-4} \\ \end{bmatrix} $ is other allowed modes $ (3.3 \pm 0.7) \times 10^{-3} \\ < 1.9 & \times 10^{-4} \\ \end{bmatrix} $ $ (1.94 \pm 0.31) \% \\ (1.33 \pm 0.13) \% \\ (1.28 \pm 0.08) \% \\ (3.2 \pm 1.4) \times 10^{-3} \\ (2.0 \pm 0.6) \times 10^{-3} \\ (3.8 \pm 1.7) \times 10^{-3} \\ (2.5 \pm 1.1) \times 10^{-3} \\ (4 \pm 4) \times 10^{-3} \\ < 8 \pm 4) \times 10^{-3} \\ < 1.4 & \times 10^{-4} \\ \end{bmatrix} $ $ (1.71 \pm 0.28) \times 10^{-3} \\ < 4.3 & \times 10^{-4} \\ (2.6 \pm 0.7) \times 10^{-4} \\ < 3 & \times 10^{-3} \\ \end{aligned} $	CL=90% 66 53 65 43 33 CL=95% 79 77 CL=95% 74 72 CL=90% CL=95% 63	- 3 3 5 7 8 8 6 9 - 7
$\begin{array}{l} (\text{ex. } K_S^0 \to \pi^- \pi^+) \\ \text{("5-prong")} \\ 3h^- 2h^+ \pi^0 \nu_\tau (\text{ex.} K^0) \\ 3h^- 2h^+ \pi^0 \nu_\tau (\text{ex.} K^0) \\ 3h^- 2h^+ 2\pi^0 \nu_\tau \\ & \text{Miscellaneou} \\ (5\pi)^- \nu_\tau \\ 4h^- 3h^+ \geq 0 \text{ neutrals } \nu_\tau \\ \text{("7-prong")} \\ K^*(892)^- \geq 0 \text{ (h}^0 \neq K_S^0) \nu_\tau \\ K^*(892)^- \geq 0 \text{ neutrals } \nu_\tau \\ K^*(892)^- \nu_\tau \\ K^*(892)^0 K^- \geq 0 \text{ neutrals } \nu_\tau \\ \overline{K}^*(892)^0 K^- \nu_\tau \\ \overline{K}^*(892)^0 \pi^- \nu_\tau \\ K_1(1270)^- \nu_\tau \\ K_1(1400)^- \nu_\tau \\ K_2^*(1430)^- \nu_\tau \\ \eta \pi^- \pi^0 \nu_\tau \\ \eta \pi^- \pi^0 \nu_\tau \\ \eta \pi^+ \pi^- \pi^- \geq 0 \text{ neutrals } \nu_\tau \\ \eta \eta \pi^- \pi^0 \nu_\tau \\ h^- \omega \geq 0 \text{ neutrals } \nu_\tau \\ h^- \omega \nu_\tau \\ h^- \omega \nu_\tau \end{array}$	$ \begin{bmatrix} [i] & (7.5 \pm 0.7) \times 10^{-4} \\ [i] & (2.2 \pm 0.5) \times 10^{-4} \\ < 1.1 & \times 10^{-4} \\ \end{bmatrix} $ is other allowed modes $ (3.3 \pm 0.7) \times 10^{-3} \\ < 1.9 & \times 10^{-4} \\ \end{bmatrix} $ is other allowed modes $ (3.3 \pm 0.7) \times 10^{-3} \\ < 1.9 & \times 10^{-4} \\ \end{bmatrix} $ $ (1.94 \pm 0.31) \% \\ (1.33 \pm 0.13) \% \\ (1.28 \pm 0.08) \% \\ (3.2 \pm 1.4) \times 10^{-3} \\ (2.0 \pm 0.6) \times 10^{-3} \\ (3.8 \pm 1.7) \times 10^{-3} \\ (2.5 \pm 1.1) \times 10^{-3} \\ (4 \pm 4) \times 10^{-3} \\ < 8 \pm 4) \times 10^{-3} \\ < 1.4 & \times 10^{-4} \\ (2.6 \pm 0.7) \times 10^{-4} \\ < 3 & \times 10^{-3} \\ < 1.1 & \times 10^{-4} \\ < 2.0 & \times 10^{-4} \\ < 2.0 & \times 10^{-4} \\ (2.32 \pm 0.11) \% \\ [i] & (1.91 \pm 0.09) \% $	CL=90% 66 53 65 43 33 CL=95% 31 CL=95% 79 77 CL=95% 74 CL=95% 63	- 3 3 5 7 8 8 6 9 - 7
$\begin{array}{l} (\text{ex. } K_S^0 \to \pi^- \pi^+) \\ \text{("5-prong")} \\ 3h^- 2h^+ \nu_\tau (\text{ex.} K^0) \\ 3h^- 2h^+ \nu_\tau (\text{ex.} K^0) \\ 3h^- 2h^+ 2\pi^0 \nu_\tau (\text{ex.} K^0) \\ 3h^- 2h^+ 2\pi^0 \nu_\tau (\text{ex.} K^0) \\ 3h^- 2h^+ 2\pi^0 \nu_\tau (\text{ex.} K^0) \\ \hline \\ & \text{Miscellaneou} \\ (5\pi)^- \nu_\tau \\ 4h^- 3h^+ \ge 0 \text{ neutrals } \nu_\tau \\ ("7-prong") \\ K^*(892)^- \ge 0 \text{ neutrals } \nu_\tau \\ K^*(892)^- \ge 0 \text{ neutrals } \nu_\tau \\ K^*(892)^- \nu_\tau \\ K^*(892)^0 K^- \ge 0 \text{ neutrals } \nu_\tau \\ K^*(892)^0 \pi^- \ge 0 \text{ neutrals } \nu_\tau \\ \overline{K}^*(892)^0 \pi^- \nu_\tau \\ K_1(1270)^- \nu_\tau \\ K_1(1400)^- \nu_\tau \\ K_2^*(1430)^- \nu_\tau \\ \eta\pi^- \pi^0 \nu_\tau \\ \eta\pi^- \pi^0 \nu_\tau \\ \eta\pi^+ \pi^- \pi^- \ge 0 \text{ neutrals } \nu_\tau \\ \eta\eta\pi^- \pi^0 \nu_\tau \\ \eta\eta\pi^- \pi^0 \nu_\tau \\ \eta\eta\pi^- \pi^0 \nu_\tau \\ h^- \omega \ge 0 \text{ neutrals } \nu_\tau \\ \end{array}$	$ \begin{bmatrix} [i] & (7.5 \pm 0.7) \times 10^{-4} \\ [i] & (2.2 \pm 0.5) \times 10^{-4} \\ < 1.1 & \times 10^{-4} \\ \end{bmatrix} $ is other allowed modes $ (3.3 \pm 0.7) \times 10^{-3} \\ < 1.9 & \times 10^{-4} \\ \end{bmatrix} $ is other allowed modes $ (3.3 \pm 0.7) \times 10^{-3} \\ < 1.9 & \times 10^{-4} \\ \end{bmatrix} $ $ (1.94 \pm 0.31) \% \\ (1.33 \pm 0.13) \% \\ (1.28 \pm 0.08) \% \\ (3.2 \pm 1.4) \times 10^{-3} \\ (2.0 \pm 0.6) \times 10^{-3} \\ (3.8 \pm 1.7) \times 10^{-3} \\ (3.8 \pm 1.7) \times 10^{-3} \\ (4 \pm 4) \times 10^{-3} \\ < 5 \pm 1.1) \times 10^{-3} \\ < 8 \pm 4) \times 10^{-3} \\ < 1.4 & \times 10^{-4} \\ (1.71 \pm 0.28) \times 10^{-3} \\ < 4.3 & \times 10^{-4} \\ < 2.6 \pm 0.7) \times 10^{-4} \\ < 3 & \times 10^{-3} \\ < 1.1 & \times 10^{-4} \\ < 2.0 & \times 10^{-4} \\ < 2.0 & \times 10^{-4} \\ (2.32 \pm 0.11) \% $	CL=90% 66 53 65 43 33 CL=95% 31 CL=95% 79 77 CL=95% 74 CL=95% 63	- 3 3 5 7 8 8 6 9 - 7

Lepton Family number (LF), Lepton number (L), or Baryon number (B) violating modes (in the modes below, ℓ means a sum over e and μ modes)

L means lepton number violation (e.g. $\tau^- \to e^+\pi^-\pi^-$). Following common usage, LF means lepton family violation and not lepton number violation (e.g. $\tau^- \to e^-\pi^+\pi^-$).

violation (e.g. 1 →	е и и	٦٠				
$e^-\gamma$	LF	<	1.1	$\times 10^{-4}$	CL=90%	888
$\mu^- \gamma$	LF	<	4.2	\times 10 ⁻⁶	CL=90%	885
$e^-\pi^0$	LF	<	1.4	$\times 10^{-4}$	CL=90%	883
$\mu^-\pi^0$	LF	<	4.4	\times 10 ⁻⁵	CL=90%	880
e^-K^0	LF	<	1.3	$\times 10^{-3}$	CL=90%	819
$\mu^- \mathcal{K}^0$	LF	<	1.0	$\times 10^{-3}$	CL=90%	815
$e^- \eta$	LF	<	6.3	$\times 10^{-5}$	CL=90%	804
$\mu^-\eta_{_2}$	LF	<	7.3	\times 10 ⁻⁵	CL=90%	800
$e^-\rho^0$	LF	<	4.2	× 10 ⁻⁶	CL=90%	722
$\mu^- \rho^0$	LF	<	5.7	$\times 10^{-6}$	CL=90%	718
e ⁻ K*(892) ⁰	LF	<	6.3	\times 10 ⁻⁶	CL=90%	663
$\mu^- K^* (892)^0$	LF	<	9.4	$\times 10^{-6}$	CL=90%	657
$\pi^- \gamma$	L	<	2.8	$\times 10^{-4}$	CL=90%	883
$\pi^-\pi^0$	L	<	3.7	\times 10 ⁻⁴	CL=90%	878
e-e+e-	LF	<	3.3	$\times 10^{-6}$	CL=90%	888
$e^-\mu^+\mu^-$	LF	<	3.6	$\times 10^{-6}$	CL=90%	882
$e^{+}\mu^{-}\mu^{-}$	LF	<	3.5	$\times 10^{-6}$	CL=90%	882
$\mu^{-}e^{+}e^{-}$	LF	<	3.4	$\times 10^{-6}$	CL=90%	885
$\mu^{+}e^{-}e^{-}$	L	<	3.4	\times 10 ⁻⁶	CL=90%	885
$\mu^{-}\mu^{+}\mu^{-}$	LF	<	1.9	$\times 10^{-6}$	CL=90%	873
$e^{-}\pi^{+}\pi^{-}$	LF	<	4.4	$\times 10^{-6}$	CL=90%	877
$e^{+}\pi^{-}\pi^{-}$	L	<	4.4	$\times 10^{-6}$	CL=90%	877
$\mu^- \pi^+ \pi^-$	LF	<	7.4	$\times 10^{-6}$	CL=90%	866
$\mu^{+}\pi^{-}\pi^{-}$	L	<	6.9	$\times 10^{-6}$	CL=90%	866
e-π+K-	LF	<	7.7	$\times 10^{-6}$	CL=90%	813
$e^{-}\pi^{-}K^{+}$	LF	<	4.6	$\times 10^{-6}$	CL=90%	813
$e^{+}\pi^{-}K^{-}$	L	<	4.5	\times 10 ⁻⁶	CL=90%	813
$\mu^-\pi^+K^-$	LF	<	8.7	\times 10 ⁻⁶	CL=90%	800
$\mu^{-}\pi^{-}K^{+}$	LF	<	1.5	\times 10 ⁻⁵	CL=90%	800
$\mu^{+}\pi^{-}K^{-}$	L	<	2.0	$\times 10^{-5}$	CL=90%	800
$\overline{p}\gamma$	L,B	<	2.9	$\times 10^{-4}$	CL=90%	641
$\overline{p}\pi^0$	L,B	<	6.6	$\times 10^{-4}$	CL=90%	632
$\overline{p}\eta$	L,B	<	1.30	$\times 10^{-3}$	CL=90%	475
$e^{-}\overline{K}^{*}(892)^{0}$	LF	<	1.1	\times 10 ⁻⁵	CL=90%	663
$\mu = \overline{K}^*(892)^0$	LF	<	8.7	\times 10 ⁻⁶	CL=90%	657
e light boson	LF	<	2.7	× 10 ⁻³	CL=95%	_
μ^- light boson	LF	<	5	× 10 ⁻³	CL=95%	_
E B. 1. BOSOII		`	-	10	52-7570	

Heavy Charged Lepton Searches

 L^\pm – charged lepton Mass m>42.7 GeV, CL =95% $m_{\nu}\approx0$ L^\pm – stable charged heavy lepton Mass m>42.8 GeV, CL =95%

Neutrinos

See the Particle Listings for a Note giving details of neutrinos, masses, mixing, and the status of experimental searches.



$$J=\frac{1}{2}$$

Mass m: Unexplained effects have resulted in significantly negative m^2 in the new, precise tritium beta decay experiments. It is felt that a real neutrino mass as large as 10-15 eV would cause observable spectral distortions even in the presence of the end-point count excesses.

Mean life/mass, $\tau/m_{\nu_e}>300$ s/eV, CL =90% Magnetic moment $\mu<1.8\times10^{-10}~\mu_B$, CL =90%



$$J = \frac{1}{8}$$

Mass m<0.17 MeV, CL = 90% Mean life/mass, $\tau/m_{\nu_{\mu}}>15.4$ s/eV, CL = 90% Magnetic moment $\mu<7.4\times10^{-10}~\mu_{B}$, CL = 90% $u_{ au}$

$$J=\frac{1}{2}$$

Mass m < 24 MeV, CL = 95% Magnetic moment $\mu < 5.4 \times 10^{-7}~\mu_{B}$, CL = 90%

Number of Light Neutrino Types

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(including \nu_e,~\nu_\mu,~{\rm and}~\nu_\tau)

Number N=2.991\pm0.016 (Standard Model fits to LEP data)

Number N=3.09\pm0.13 (Direct measurement of invisible Z
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Massive Neutrinos and Lepton Mixing, Searches for

For excited leptons, see Compositeness Limits below.

See the Particle Listings for a Note giving details of neutrinos, masses, mixing, and the status of experimental searches.

No direct, uncontested evidence for massive neutrinos or lepton mixing has been obtained. Sample limits are:

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Mass m > 45.0, CL = 95% (Dirac)
Mass m > 39.5, CL = 95% (Majorana)
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u oscillation: $u_{\mu} \rightarrow u_{e} (\theta = \text{mixing angle})$

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Mass m>19.6 GeV, CL = 95% (all |U_{\ell j}|^2) (Dirac) Mass m>45.7 GeV or m<25, CL = 95% (|U_{\ell j}|^2>10^{-13} (Dirac)
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ν oscillation: $\overline{\nu}_e \not \rightarrow \overline{\nu}_e$

$$\Delta(m^2) < 0.0075 \text{ eV}^2, \text{ CL} = 90\% \quad (\text{if } \sin^2 2\theta = 1) \\ \sin^2 2\theta < 0.02, \text{ CL} = 90\% \quad (\text{if } \Delta(m^2) \text{ is large})$$

ν oscillation: $\nu_{\mu} \rightarrow \nu_{e}$ ($\theta = \text{mixing angle}$)

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\begin{array}{lll} \Delta(m^2) &< 0.09 \; \text{eV}^2, \; \text{CL} = 90\% & (\text{if } \sin^2\!2\theta = 1) \\ \sin^2\!2\theta &< 2.5 \times 10^{-3}, \; \text{CL} = 90\% & (\text{if } \Delta(m^2) \; \text{is large}) \end{array}
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NOTES

In this Summary Table:

When a quantity has "(S = ...)" to its right, the error on the quantity has been enlarged by the "scale factor" S, defined as S = $\sqrt{\chi^2/(N-1)}$, where N is the number of measurements used in calculating the quantity. We do this when S > 1, which often indicates that the measurements are inconsistent. When S > 1.25, we also show in the Particle Listings an ideogram of the measurements. For more about S, see the Introduction.

A decay momentum p is given for each decay mode. For a 2-body decay, p is the momentum of each decay product in the rest frame of the decaying particle. For a 3-or-more-body decay, p is the largest momentum any of the products can have in this frame.

- [a] The ucertainty in the electron mass in unified atomic mass units (u) is ten times smaller than that given by the 1986 CODATA adjustment, quoted in the Table of Physical Contants (Section 1). The conversion to MeV via the factor 931.49432(28) MeV/u is more uncertain because of the electron charge uncertainty. Our value in MeV differs slightly from the 1986 CODATA result.
- [b] This is the best "electron disappearance" limit. The best limit for the mode $e^-\to~\nu\gamma$ is $>2.35\times10^{25}$ yr (CL=68%).
- [c] The muon mass is most precisely known in u (unified atomic mass units). The conversion factor to MeV via the factor 931.49432(28) MeV/u is more uncertain because of the electron charge uncertainty.
- [d] See the "Note on Muon Decay Parameters" in the μ Particle Listings for definitions and details.
- [e] P_μ is the longitudinal polarization of the muon from pion decay. In standard V-A theory, $P_\mu=1$ and $\rho=\delta=3/4$.
- [f] This only includes events with the γ energy > 10 MeV. Since the $e^-\overline{\nu}_e\,\nu_\mu$ and $e^-\overline{\nu}_e\,\nu_\mu\gamma$ modes cannot be clearly separated, we regard the latter mode as a subset of the former.
- [g] See the μ Particle Listings for the energy limits used in this measurement.
- [h] A test of additive vs. multiplicative lepton family number conservation.
- [i] Basis mode for the τ .

Quark Summary Table

QUARKS

The u-, d-, and s-quark masses are estimates of so-called "current-quark masses," in a mass-independent subtraction scheme such as $\overline{\rm MS}$ at a scale $\mu\approx 1$ GeV. The c- and b-quark masses are estimated from charmonium, bottomonium, D, and B masses. They are the "running" masses in the $\overline{\rm MS}$ scheme. These can be different from the heavy quark masses obtained in potential models.

$$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$$

Mass m = 2 to 8 MeV [a] $m_u/m_d = 0.25$ to 0.70

Charge = $\frac{2}{3} e I_Z = +\frac{1}{2}$

$$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$$

Mass m = 5 to 15 MeV ^[a] $m_s/m_d = 17$ to 25

Charge $=-\frac{1}{3}$ e $I_Z=-\frac{1}{2}$

$$I(J^P) = 0(\frac{1}{2}^+)$$

Mass m=100 to 300 MeV $^{[a]}$ Charge $=-\frac{1}{3}$ e Strangeness =-1 $(m_s-(m_u+m_d)/2)/(m_d-m_u)=34$ to 51

C

$$I(J^P)=0(\tfrac{1}{2}^+)$$

Mass m=1.0 to 1.6 GeV

 $Charge = \frac{2}{3} e \quad Charm = +1$

b

$$I(J^P)=0(\tfrac{1}{2}^+)$$

t

$$I(J^P)=0(\tfrac{1}{2}^+)$$

 $\mathsf{Top} = +1$

Charge =
$$\frac{2}{3} e$$

Mass $m=180\pm12$ GeV (direct observation of top events) Mass $m=179\pm8^{+17}_{-20}$ GeV (Standard Model electroweak fit)

b' (4th Generation) Quark, Searches for

Mass m > 85 GeV, CL = 95% ($p\bar{p}$, charged current decays) Mass m > 46.0 GeV, CL = 95% (e^+e^- , all decays)

Free Quark Searches

All searches since 1977 have had negative results.

NOTES

[a] The ratios m_u/m_d and m_s/m_d are extracted from pion and kaon masses using chiral symmetry. The estimates of u and d masses are not without controversy and remain under active investigation. Within the literature there are even suggestions that the u quark could be essentially massless. The s-quark mass is estimated from SU(3) splittings in hadron masses.

LIGHT UNFLAVORED MESONS (S=C=B=0)

For I=1 $(\pi,\,b,\,\rho,\,a)$: $u\overline{d},\,(u\overline{u}-d\overline{d})/\sqrt{2},\,d\overline{u};$ for I=0 $(\eta,\,\eta',\,h,\,h',\,\omega,\,\phi,\,f,\,f')$: $c_1(u\overline{u}+d\overline{d})+c_2(s\overline{s})$



$$I^G(J^P)=\mathbf{1}^-(0^-)$$

Mass $m = 139.56995 \pm 0.00035 \text{ MeV}$ Mean life $\tau = (2.6033 \pm 0.0005) \times 10^{-8}$ s (S = 1.2) $c\tau = 7.8045 \text{ m}$

$\pi^{\pm} ightarrow \ell^{\pm} \nu \gamma$ form factors $^{[a]}$

 $F_V = 0.017 \pm 0.008$ $F_A = 0.0116 \pm 0.0016$ (S = 1.3) $R = 0.059^{\,+\,0.009}_{\,-\,0.008}$

 π^- modes are charge conjugates of the modes below.

π^+ DECAY MODES	Fraction $(\Gamma_{\hat{I}}/\Gamma)$			Confidence level	(MeV/c)
$\frac{\mu^+ u_\mu}{\mu^+ u_\mu\gamma}$	[b]	(99.9877	0±0.000	04) %	30
$\mu^{\dot+} u_{\mu}\gamma$	[c]	(1.24	±0.25	$) \times 10^{-4}$	30
$e^+ \nu_e$	[<i>b</i>]	(1.230	±0.004	$) \times 10^{-4}$	70
$e^+ u_e\gamma$	[c]	(1.61	± 0.23	$) \times 10^{-7}$	70
$e^+ \nu_e \pi^0$		(1.025	± 0.034) × 10 ⁻⁸	4
$e^{+} \nu_{e} e^{+} e^{-}$		(3.2	± 0.5) × 10 ⁻⁹	70
$e^+ \nu_e \nu \overline{\nu}$		< 5		× 10 ⁻⁶ 90%	70

Lepton Family number (LF) or Lepton number (L) violating modes

$\mu^+ \overline{\nu}_e$	L	[d] <	1.5	$\times 10^{-3} 90\%$	30
$\mu^+ \nu_e$	LF	[d] <	8.0	$\times 10^{-3} 90\%$	30
$\mu^{-} e^{+} e^{+} \nu$	LF	<	1.6	× 10 ⁻⁶ 90%	30



$$I^{G}(J^{PC}) = 1^{-}(0^{-+})$$

Mass $m = 134.9764 \pm 0.0006$ MeV $m_{\pi^{\pm}} - m_{\pi^{0}} = 4.5936 \pm 0.0005 \text{ MeV}$ Mean life $\tau = (8.4 \pm 0.6) \times 10^{-17}$ s (S = 3.0) $c\tau = 25.1 \text{ nm}$

π^0 DECAY MODES	Fraction (Γ_i/Γ)		le factor/ lence level	<i>p</i> (MeV/ <i>c</i>)
2γ	(98.798±0.032	2) %	S=1.1	67
$e^+e^-\gamma$	(1.198±0.032	2) %	S=1.1	67
γ positronium	(1.82 ±0.29	$) \times 10^{-9}$		67
$e^{+}e^{+}e^{-}e^{-}$	(3.14 ±0.30	$) \times 10^{-5}$		67
e^+e^-	(7.5 ±2.0	$) \times 10^{-8}$		67
4γ	< 2	$\times 10^{-8}$	CL=90%	67
$ u \overline{ u}$	[e] < 8.3	\times 10 ⁻⁷	CL=90%	67
$\nu_e \overline{\nu}_e$	< 1.7	$\times 10^{-6}$	CL=90%	67
$ u_{\mu}\overline{\nu}_{\mu}$	< 3.1	$\times 10^{-6}$	CL=90%	67
$ u_{ au} \overline{ u}_{ au}$	< 2.1	\times 10 ⁻⁶	CL=90%	67

Charge conjugation (C) or Lepton Family number (LF) violating modes < 3.1 × 10⁻⁸ CL=90% × 10⁻⁸ CL=90% $\mu^{+}e^{-} + e^{-}\mu^{+}$ 26



$$I^{G}(J^{PC}) = 0^{+}(0^{-}+)$$

 $\label{eq:mass_m} \begin{aligned} \text{Mass } m = 547.45 \pm 0.19 \text{ MeV} \quad \text{(S} = 1.6) \\ \text{Full width } \Gamma = 1.18 \pm 0.11 \text{ keV} \quad \text{(f)} \quad \text{(S} = 1.8) \end{aligned}$

C-nonconserving decay parameters [g]

 $\pi^+\pi^-\pi^0$ Left-right asymmetry = (0.09 \pm 0.17) \times 10⁻² $\pi^+\pi^-\pi^0$ Sextant asymmetry = $(0.18 \pm 0.16) \times 10^{-2}$ $\pi^{+}\pi^{-}\pi^{0}$ Quadrant asymmetry = $(-0.17 \pm 0.17) \times 10^{-2}$ $\pi^+\pi^-\gamma$ Left-right asymmetry = $(0.9 \pm 0.4) \times 10^{-2}$ $\pi^{+}\pi^{-}\gamma$ β (*D*-wave) = 0.05 ± 0.06 (S = 1.5)

η DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	(MeV/c)
neutral modes	(71.4 ±0.6)%	S=1.3	_
2γ	[f] $(39.25\pm0.31)\%$	S=1.3	274
$3\pi^{0}$	$(32.1 \pm 0.4)\%$	S=1.2	180
π^0 2 γ	$(7.1 \pm 1.4) \times 1$	10-4	258
other neutral modes	< 2.8 %	CL=90%	_

charged modes	(28.6 ±0.6) %	S=1.3	-
$\pi^+\pi^-\pi^0$	$(23.2 \pm 0.5)\%$	S=1.3	175
$\pi^+\pi^-\gamma$	(4.78±0.12) %	S=1.2	236
$e^+e^-\gamma$	$(4.9 \pm 1.1) \times 10^{-3}$		274
$\mu^+\mu^-\gamma$	$(3.1 \pm 0.4) \times 10^{-4}$		253
e^+e^-	$< 3 \times 10^{-4}$	CL=90%	274
$\mu^+\mu^-$	$(5.8 \pm 0.8) \times 10^{-6}$		253
$\pi^+\pi^-e^+e^-$	$(1.3 \begin{array}{c} +1.2 \\ -0.8 \end{array}) \times 10^{-3}$		236
$\pi^+\pi^-2\gamma$	$< 2.1 \times 10^{-3}$		236
$\pi^+\pi^-\pi^0\gamma$	$< 6 \times 10^{-4}$	CL=90%	175
$\pi^0 \mu^+ \mu^- \gamma$	$< 3 \times 10^{-6}$	CL=90%	211

Charge conjugation (C), Parity (P), or Charge conjugation × Parity (CP) violating modes

$\pi^+\pi^-$	P,CP	<	1.5	×	10-3		236
3γ	c	<	5	×	10^{-4}	CL=95%	274
$\pi^0 e^+ e^-$	c	[h] <	4	×	$_{10}^{-5}$	CL=90%	258
$\pi^{0} \mu^{+} \mu^{-}$	c	[h] <	5	×	₁₀ -6	CL=90%	211

$$f_0$$
(400–1200) [f] or σ

$$I^{G}(J^{PC}) = 0^{+}(0^{+})$$

The interpretation of this entry as a particle is controversial. See the "Note on scalar mesons" in the Particle Listings under the $f_0(1370)$. Mass m = (400-1200) MeVFull width $\Gamma = (600-1000) \text{ MeV}$

f₀(400-1200) DECAY MODES Fraction (Γ_i/Γ) p (MeV/c) dominant $\pi\pi$ seen

ρ(770) [/]

 $\gamma \gamma$

$$I^{G}(J^{PC}) = 1^{+}(1^{-})$$

Mass $m = 768.5 \pm 0.6 \text{ MeV}$ (S = 1.2) Full width Γ = 150.7 \pm 1.2 MeV $\Gamma_{ee} = 6.77 \pm 0.32 \text{ keV}$

ρ(770) DECAY MODES	Fraction (Γ_i/Γ)		ale factor/ dence level	
ππ	~ 100	%		358
	$ ho(770)^{\pm}$ decays			
$\pi^{\pm}\gamma$	(4.5 ± 0.5)	$\times 10^{-4}$	S=2.2	372
$\begin{array}{l} \pi^{\pm} \gamma \\ \pi^{\pm} \eta \\ \pi^{\pm} \pi^{+} \pi^{-} \pi^{0} \end{array}$	< 6	$\times 10^{-3}$	CL=84%	146
$\pi^{\pm}\pi^{+}\pi^{-}\pi^{0}$	< 2.0	× 10 ⁻³	CL=84%	249
	$\rho(770)^0$ decays			
$\pi^+\pi^-\gamma$	(9.9 ±1.6)	$\times 10^{-3}$		358
$\pi^+\pi^-\gamma$ $\pi^0\gamma$	(7.9 ±2.0)	$\times 10^{-4}$		372
$\eta \gamma$	(3.8 ±0.7)	$\times 10^{-4}$		189
$\eta \gamma_{\mu^+\mu^-}$	[k] (4.60 ± 0.28)	$\times 10^{-5}$		369
e+ e-	$[k]$ (4.48 \pm 0.22)	$\times 10^{-5}$		384
$\pi^{+}\pi^{-}\pi^{0}$	< 1.2	$\times 10^{-4}$	CL=90%	319
$\pi^{+}\pi^{-}\pi^{+}\pi^{-}$	< 2	$\times 10^{-4}$	CL=90%	246
$\pi^{+}\pi^{-}\pi^{0}\pi^{0}$	< 4	× 10 ⁻⁵	CL=90%	252

ω (782)

$$I^{G}(J^{PC}) = 0^{-}(1^{-})$$

Mass $m = 781.94 \pm 0.12$ MeV (S = 1.5) Full width $\Gamma=8.43\,\pm\,0.10$ MeV $\Gamma_{ee} = 0.60 \pm 0.02 \; keV$

ω (782) DECAY MODES	Fraction (Γ_i/Γ) Confidence I	<i>p</i> evel (MeV/ <i>c</i>)
$\frac{1}{\pi^{+}\pi^{-}\pi^{0}}$	(88.8 ±0.7)%	327
$\pi^0 \gamma$	$(8.5 \pm 0.5)\%$	379
$\pi^+\pi^-$	(2.21 ± 0.30) %	365
neutrals (excluding $\pi^0\gamma$)	$(5.3 \begin{array}{c} +8.7 \\ -3.5 \end{array}) \times 10^{-3}$	-
$\eta \gamma$	$(8.3 \pm 2.1) \times 10^{-4}$	199
$^{\eta \gamma}_{\pi^0 e^+ e^-}$	$(5.9 \pm 1.9) \times 10^{-4}$	379
$\pi^{0} \mu^{+} \mu^{-}$	$(9.6 \pm 2.3) \times 10^{-5}$	349

			5			
e^+e^-		(7.15±0	$(.19) \times 10^{-5}$		391	
$\pi^{+}\pi^{-}\pi^{0}\pi^{0}$		< 2	%	90%	261	
$\pi^+\pi^-\gamma$		< 3.6	\times 10 ⁻³	95%	365	
$\pi^{+}\pi^{-}\pi^{+}\pi^{-}$		< 1	\times 10 ⁻³	90%	256	
$\pi^0 \pi^0 \gamma$		(7.2 \pm 2	.5) × 10 ⁻⁵		367	
$\mu^+\mu^-$		< 1.8	\times 10 ⁻⁴	90%	376	
3γ		< 2	× 10 ⁻⁴	90%	391	
Charge conjugation (C)						
$\eta \pi^0$ $3\pi^0$	С	< 1	× 10 ⁻³	90%	162	
$3\pi^0$	С	< 3	× 10 ⁻⁴	90%	329	

 $\eta'(958)$

$$I^{G}(J^{PC}) = 0^{+}(0^{-+})$$

Mass $m = 957.77 \pm 0.14 \; {\sf MeV}$

Full width $\Gamma=0.201\pm0.016$ MeV $\,$ (S = 1.3)

		` .		_
η'(958) DECAY MODES	Fraction $(\Gamma_i/$		icale factor/ fidence level	p (MeV/c)
$\pi^+\pi^-\eta$	(43.7 ±1.5	,	S=1.1	232
$\rho_{\perp}^{0}\gamma_{\perp}$	(30.2 ±1.3	3)%	S=1.1	169
$\pi^0 \pi^0 \eta$	(20.8 ± 1.3)) %	S=1.2	239
$\omega \gamma$	(3.02 ± 0.3)	30) %		160
$\gamma\gamma$	$(2.12 \pm 0.1$.3) %	S=1.2	479
$3\pi^0$	(1.55 ± 0.2)	$(6) \times 10^{-3}$		430
$\mu^+\mu^-\gamma$	(1.04 ± 0.2)	$(6) \times 10^{-4}$		467
$\pi^{+}\pi^{-}\pi^{0}$	< 5	%	CL=90%	427
$\pi^{0} \rho^{0}$	< 4	%	CL=90%	118
$\pi^+\pi^-$	< 2	%	CL=90%	458
$\pi^{0} e^{+} e^{-}$	< 1.3	%	CL=90%	469
$\eta e^+ e^-$	< 1.1	%	CL=90%	322
$\pi^{+}\pi^{+}\pi^{-}\pi^{-}$	< 1	%	CL=90%	372
$\pi^+\pi^+\pi^-\pi^-$ neutrals	< 1	%	CL=95%	-
$\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0}$	< 1	%	CL=90%	298
6π	< 1	%	CL=90%	189
$\pi^{+}\pi^{-}e^{+}e^{-}$	< 6	$\times 10^{-3}$	CL=90%	458
$\pi^{0} \pi^{0}$	< 9	\times 10 ⁻⁴	CL=90%	459
$\pi^0 \gamma \gamma$	< 8	$\times 10^{-4}$	CL=90%	469
$4\pi^0$	< 5	$\times 10^{-4}$	CL=90%	379
3γ	< 1.0	\times 10 ⁻⁴	CL=90%	479
$\mu + \mu - \pi^0$	< 6.0	\times 10 ⁻⁵		445
$\mu^+\mu^-\eta$	< 1.5	\times 10 ⁻⁵	CL=90%	274
e+ e-	< 2.1	$\times 10^{-7}$	CL=90%	479

f₀(980) [/]

$$I^{G}(J^{PC}) = 0^{+}(0^{+})$$

Mass $m=980\pm10~{\rm MeV}$ Full width $\Gamma=40~{\rm to}~100~{\rm MeV}$

f ₀ (980) DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	(MeV/c)
$\pi\pi$	(78.1 ±2.4) %		470
$\kappa \overline{\kappa}$	$(21.9 \pm 2.4)\%$		-
$\gamma \gamma$	$(1.19\pm0.33) \times$	10-5	490
$e^{+}e^{-}$	< 3 ×	10 ⁻⁷ 90%	490

a₀(980) [i]

$$I^{G}(J^{PC}) = 1^{-}(0^{+})$$

Mass $m=983.5\pm0.9~{\rm MeV}$ Full width $\Gamma=50~{\rm to}~100~{\rm MeV}$

a ₀ (980) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$\eta \pi$	dominant	321
KΚ	seen	_
$\gamma \gamma$	seen	492

 $\phi(1020)$

$$I^{G}(J^{PC}) = 0^{-}(1^{-})$$

Mass $m=1019.413\pm0.008$ MeV Full width $\Gamma=4.43\pm0.05$ MeV $\Gamma_{ee}=1.37\pm0.05$ keV

ϕ (1020) DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	
K+ K-	(49.1 ±0.6)%	S=1.2	127
$K_L^0 K_S^0$	(34.1 \pm 0.5) %	S=1.1	110
$\rho\pi$	(12.9 ±0.7)%		181

$\pi^{+}\pi^{-}\pi^{0}$	(2.7 ±0.9	∍)%	S=1.1	462
$\eta \gamma$	(1.26±0.0	06) %	S=1.1	363
$\pi^0 \gamma$	(1.31±0.1	$13) \times 10^{-3}$		501
e^+e^-	(3.00±0.0	$(10^{-4}) \times 10^{-4}$	S=1.1	510
$\mu^+\mu^-$	(2.48±0.3	$(34) \times 10^{-4}$		499
ηe^+e^-	$(1.3 \begin{array}{c} +0.8 \\ -0.6 \end{array})$	$\frac{3}{5}$) × 10 ⁻⁴		363
$\pi^+\pi^-$	(8 +5	$) \times 10^{-5}$	S=1.5	490
$\omega \gamma$	< 5	%	CL=84%	210
$ ho\gamma$	< 2	%	CL=84%	219
$\pi^+\pi^-\gamma$	< 7	\times 10 ⁻³	CL=90%	490
$\pi^0\pi^0\gamma$	< 1	\times 10 ⁻³	CL=90%	492
$\pi^{+}\pi^{-}\pi^{+}\pi^{-}$	< 8.7	\times 10 ⁻⁴	CL=90%	410
$\eta'(958)\gamma$	< 4.1	× 10 ⁻⁴	CL=90%	60
$\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0}$	< 1.5	\times 10 ⁻⁴	CL=95%	341
$\pi^0e^+e^-$	< 1.2	\times 10 ⁻⁴	CL=90%	501
$a_0(980)\gamma$	< 5	\times 10 ⁻³	CL=90%	36

h₁(1170)

$$I^{G}(J^{PC}) = 0^{-}(1^{+})$$

Mass $m=1170\pm 20$ MeV Full width $\Gamma=360\pm 40$ MeV

h ₁ (1170) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
ρπ	seen	310

 $b_1(1235)$

$$I^{G}(J^{PC}) = 1^{+}(1^{+})$$

Mass $m=1231\pm 10$ MeV ^[I] Full width $\Gamma=142\pm 8$ MeV (S = 1.1)

b1(1235) DECAY MODES	Fraction	(Γ_i/Γ)	Confidence level	(MeV/c)
$\omega \pi$ [D/S amplitude ratio = 0.	domii 26 + 0 041	nant		348
$\pi^{\pm}\gamma$		=0.4) × 10	₀ -3	608
$\eta \rho$	seen			_
$\pi^{+}\pi^{+}\pi^{-}\pi^{0}$	< 50	%	84%	536
$(K\overline{K})^{\pm}\pi^{0}$	< 8	%	90%	248
$K_S^0 K_I^0 \pi^{\pm}$	< 6	%	90%	238
$K_S^0 K_L^0 \pi^{\pm}$ $K_S^0 K_S^0 \pi^{\pm}$	< 2	%	90%	238
$\pi \phi$	< 1.5	%	84%	146

a₁(1260) [m]

$$I^{G}(J^{PC}) = 1^{-}(1^{+})$$

Mass $m=1230\pm40$ MeV ^[/] Full width $\Gamma\sim400$ MeV

a ₁ (1260) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)	
$\rho\pi$	dominant	356	
$\pi \gamma$	seen	607	
$K\overline{K}^*(892)$	possibly seen	_	

f₂(1270)

$$I^{G}(J^{PC}) = 0^{+}(2^{+})$$

Mass $m=1275\pm 5$ MeV ^[/] Full width $\Gamma=185\pm 20$ MeV ^[/]

f ₂ (1270) DECAY MODES	Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
ππ	(84.7 +2.6) %	S=1.3	622
$\pi^{+}\pi^{-}2\pi^{0}$	$(7.2 \begin{array}{c} +1.4 \\ -2.9 \end{array})\%$	S=1.3	562
κ κ	(4.6 ±0.5)%	S=2.8	403
$2\pi^{+}2\pi^{-}$	(2.8 ± 0.4) %	S=1.2	559
$\eta\eta$	(4.5 ± 1.0) $ imes$	10 ⁻³ S=2.4	327
$4\pi^{0}$	(3.0 \pm 1.0) \times	10-3	564
$\gamma\gamma$	$(1.32^{+0.18}_{-0.16}) \times$	10-5	637
$\eta \pi \pi$	< 8 ×	10 ⁻³ CL=95%	475
$K^0 K^- \pi^+ + \text{c.c.}$		10 ⁻³ CL=95%	293
e ⁺ e ⁻	< 9 ×	10 ⁻⁹ CL=90%	637

f₁(1285)

$$I^{G}(J^{PC}) = 0^{+}(1^{++})$$

Mass $m=1282.2\pm0.7$ MeV ^[/] (S = 1.7) Full width $\Gamma=24.8\pm1.3$ MeV ^[/] (S = 1.3)

f ₁ (1285) DECAY MODES	Fraction (Γ_i/Γ)	Scale factor/ Confidence level	<i>р</i> (MeV/ <i>c</i>)
4π	(29 ± 6)%		563
$\pi^0\pi^0\pi^+\pi^-$	(15 + 9) %	S=1.1	-
$2\pi^{+}2\pi^{-}$	$(15 \pm 6)\%$		563
$ ho^0 \pi^+ \pi^-$	dominates $2\pi^+$ $2\pi^-$		340
$4\pi^0$	< 7 × 10	-4 CL=90%	568
$\eta \pi \pi$	$(54 \pm 15)\%$		479
$a_0(980)\pi$ [ignoring $a_0(980) \rightarrow \mathcal{K}\overline{\mathcal{K}}$]	(44 ± 7)%	S=1.1	234
$\eta \pi \pi$ [excluding $a_0(980)\pi$]	$(10 + \frac{7}{6})\%$	S=1.1	
$K\overline{K}\pi$	(9.7± 1.6) %	S=1.2	308
K K̄*(892)	not seen		_
$\gamma \rho^0$	(6.6 ± 1.3) %	S=1.5	410
$\phi \gamma$	$(8.0 \pm 3.1) \times 10^{-3}$	-4	236

 $\eta(1295)$

$$I^{G}(J^{PC}) = 0^{+}(0^{-})$$

Mass $m=1295\pm 4~{\rm MeV}$ Full width $\Gamma=53\pm 6~{\rm MeV}$

η(1295) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$\eta \pi^+ \pi^-$	seen	488
$a_0(980)\pi$	seen	245

 $\pi(1300)$

$$I^{G}(J^{PC}) = 1^{-}(0^{-}+)$$

Mass $m = 1300 \pm 100 \text{ MeV}$ [/] Full width $\Gamma = 200 \text{ to } 600 \text{ MeV}$

π(1300) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c	
$ ho\pi$	seen	406	
$\pi(\pi\pi)_{S}$ -wave	seen	612	

a₂(1320)

$$I^{G}(J^{PC}) = 1^{-}(2^{+})$$

Mass $m=1318.1\pm0.7$ MeV (S = 1.2) Full width $\Gamma=107\pm5$ MeV $^{[I]}$ ($\mathcal{K}^{\pm}\mathcal{K}^{0}_{S}$ and $\eta\pi$ modes)

a ₂ (1320) DECAY MODES	Fraction (Γ_i/Γ)	Scale factor/ Confidence level	<i>p</i> (MeV/c)
$\rho\pi$	(70.1 ± 2.7) %	S=1.2	419
$\eta \pi$	(14.5 ± 1.2) %		535
$\omega \pi \pi$	(10.6 ± 3.2) %	S=1.3	362
$\kappa \overline{\kappa}$	(4.9±0.8) %		437
$\eta'(958)\pi$	$(5.7 \pm 1.1) \times$	10-3	287
$\pi^{\pm}\gamma$	(2.8±0.6) ×	10-3	652
$\gamma \gamma$	$(9.7 \pm 1.0) \times$	10-6	659
$\pi^{+}\pi^{-}\pi^{-}$	< 8 %	CL=90%	621
e^+e^-	< 2.3 ×	10 ⁻⁷ CL=90%	659

 $f_0(1370)^{[i]}$ was $f_0(1300)$

$$I^{G}(J^{PC}) = 0^{+}(0^{+})$$

Mass m = 1200 to 1500 MeV Full width $\Gamma = 300$ to 500 MeV

In two-particle decay modes the $\pi\pi$ decay is dominant. We include here the resonance observed in 4π under the same entry as the one decaying to 2 pseudoscalars. See also the minireview under non- $q\bar{q}$ candidates.

f ₀ (1370) DECAY MODES	Fraction (Γ_i/Γ)	ρ (MeV/c)
ππ	seen	_
4π	seen	
$2\pi^{+}2\pi^{-}$	seen	_
$\pi^{+}\pi^{-}2\pi^{0}$	seen	-

$\eta\eta$	seen	-
KK	seen	_
$\gamma \dot{\gamma}$	seen	-
e^+e^-	not seen	-

f₁(1420) [n]

$$I^{G}(J^{PC}) = 0^{+}(1^{++})$$

Mass $m=1426.8\pm2.3~{\rm MeV}~{\rm (S=1.3)}$ Full width $\Gamma=53\pm5~{\rm MeV}$

f ₁ (1420) DECAY MODES	Fraction $(\Gamma_{\hat{I}}/\Gamma)$	p (MeV/c)
KKπ	dominant	439
$\eta \pi \pi$	possibly seen	571

ω(1420) ^[o]

$$I^{G}(J^{PC}) = 0^{-}(1^{-})$$

Mass $m=1419\pm31~{
m MeV}$ Full width $\Gamma=174\pm60~{
m MeV}$

ω(1420) DECAY MODES	Fraction (Γ_i/Γ)	ρ (MeV/c)
$\rho\pi$	dominant	488

η(1440) [ρ]

$$I^{G}(J^{PC}) = 0^{+}(0^{-}+)$$

Mass m= 1415 \pm 10 MeV $^{[I]}$ Full width $\Gamma=$ 60 \pm 20 MeV $^{[I]}$

η(1440) DECAY MODES	Fraction (Γ_i/Γ)	ρ (MeV/c)
$\overline{K}\pi$	seen	429
$\eta \pi \pi$	seen	564
$a_0(980)\pi$	seen	347
4π	seen	637

ρ(1450) ^[q]

$$I^{G}(J^{PC}) = 1^{+}(1^{-})$$

Mass $m=1465\pm25$ MeV $^{[I]}$ Full width $\Gamma=310\pm60$ MeV $^{[I]}$

ρ(1450) DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	<i>p</i> (MeV/ <i>c</i>)
$\pi\pi$	seen		719
4π e^+e^-	seen		665
e ⁺ e ⁻	seen		732
$\eta \rho$	<4 %		317
$\omega \pi$	<2.0 %	95%	512
$\phi\pi$	<1 %		358
$\kappa \overline{\kappa}$	$< 1.6 \times 10^{-3}$	95%	541

 $f_0(1500)^{[r]}$ was $f_0(1525)$ and $f_0(1590)$

$$I^{G}(J^{PC}) = 0^{+}(0^{+})$$

Mass $m=1503\pm11~{\rm MeV}$ Full width $\Gamma=120\pm19~{\rm MeV}$

f ₀ (1500) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$\eta \eta'(958)$	seen	_
$\eta \eta$	seen	515
$4\pi^0$	seen	690
$\pi^{0}\pi^{0}$	seen	739
$2\pi^{+}2\pi^{-}$	seen	686

f₁(1510)

$$I^{G}(J^{PC}) = 0^{+}(1^{+})$$

Mass $m=1512\pm 4$ MeV Full width $\Gamma=35\pm 15$ MeV

f ₁ (1510) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$\overline{K}\overline{K}^*(892)$ + c.c.	seen	292

 $f_2'(1525)$

 $I^{G}(J^{PC}) = 0^{+}(2^{+})$

Mass $m=1525\pm 5$ MeV ^[I] Full width $\Gamma=76\pm 10$ MeV ^[I]

f'_2(1525) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
KK	(88.8 ±3.1) %	581
$\eta \eta$	$(10.3 \pm 3.1)\%$	531
$\pi \pi$	$(8.2 \pm 1.5) \times 10^{-3}$	750
$\gamma\gamma$	$(1.32\pm0.21)\times10^{-6}$	763

ω(1600) [s]

$$I^{G}(J^{PC}) = 0^{-}(1^{-})$$

Mass $m=1649\pm24$ MeV (S = 2.3) Full width $\Gamma=220\pm35$ MeV (S = 1.6)

ω(1600) DECAY MODES	Fraction $(\Gamma_{\hat{I}}/\Gamma)$	ρ (MeV/c)
$ ho\pi$	seen	637
$\omega \pi \pi$	seen	601
$e^{+}e^{-}$	seen	824

 ω_3 (1670)

$$I^{G}(J^{PC}) = 0^{-}(3^{-})$$

Mass $m=1667\pm 4$ MeV Full width $\Gamma=168\pm 10$ MeV $^{[I]}$

ω ₃ (1670) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$ ho \pi$	seen	647
$\omega \pi \pi$	seen	614
$b_1(1235)\pi$	possibly seen	359

 π_2 (1670)

$$I^{G}(J^{PC}) = 1^{-}(2^{-})$$

Mass $m=1670\pm20$ MeV $^{[I]}$ Full width $\Gamma=258\pm18$ MeV $^{[I]}$ (S =1.7) $\Gamma_{ee}=1.35\pm0.26$ keV

π_2 (1670) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
3π	(95.8±1.4) %	_
$f_2(1270)\pi$	(56.2±3.2) %	325
$\rho\pi$	(31 ±4)%	649
$f_0(1370)\pi$	(8.7±3.4) %	-
$K\overline{K}^*(892) + \text{c.c.}$	(4.2±1.4) %	453
$\gamma\gamma$	$(5.2\pm1.1)\times10^{-6}$	835

 ϕ (1680)

$$I^{G}(J^{PC}) = 0^{-}(1^{-})$$

Mass $m=1680\pm 20$ MeV ^[/] Full width $\Gamma=150\pm 50$ MeV ^[/]

φ(1680) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$\overline{KK^*}$ (892)+ c.c.	dominant	463
Κ <u>s</u> Kπ KK	seen	620
$\kappa \overline{\kappa}$	seen	681
e^+e^-	seen	840
$\omega \pi \pi$	not seen	622

 $\rho_3(1690)$

$$I^{G}(J^{PC}) = 1^{+}(3^{-})$$

 J^P from the 2π and $K\overline{K}$ modes. Mass $m=1691\pm 5$ MeV $^{[I]}$ Full width $\Gamma=160\pm 10$ MeV $^{[I]}$ (S = 1.5)

$ ho_3$ (1690) DECAY MODES	Fraction (Γ_i/Γ)	Scale factor (MeV/c
4π	(71.1 ± 1.9) %	78
$\pi^{\pm}\pi^{+}\pi^{-}\pi^{0}$	(67 ±22)%	78
$\pi\pi$	$(23.6 \pm 1.3)\%$	83
$\omega \pi$	(16 ± 6)%	65
$K\overline{K}\pi$	(3.8 ± 1.2) %	62
$\kappa \overline{\kappa}$	(1.58± 0.26) %	1.2 68
$\eta \pi^+ \pi^-$	seen	72

 $\rho(1700)^{[q]}$

$$I^{G}(J^{PC}) = 1^{+}(1^{-})$$

Mass $m=1700\pm20$ MeV $^{[I]}$ $(\eta\rho^0$ and $\pi^+\pi^-$ modes) Full width $\Gamma=235\pm50$ MeV $^{[I]}$ $(\eta\rho^0$ and $\pi^+\pi^-$ modes)

ρ(1700) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)	
$\rho \pi \pi$	dominant	640	
$ ho^{0}\pi^{+}\pi^{-}\ ho^{\pm}\pi^{\mp}\pi^{0}$	large	640	
$ ho^{\pm}\pi^{\mp}\pi^{0}$	large	642	
$2(\pi^{+}\pi^{-})$	large	792	
$\pi^+\pi^-$	seen	838	
$K\overline{K}^*(892) + \text{c.c.}$	seen	479	
ηho	seen	533	
$K\overline{K}$	seen	692	
e ⁺ e ⁻	seen	850	

 f_J (1710) $^{[t]}$

$$I^{G}(J^{PC}) = 0^{+}(\text{even}^{+})$$

Mass $m=1697\pm4$ MeV (S =1.4) Full width $\Gamma=175\pm9$ MeV (S =1.7)

f _J (1710) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)	
KΚ	seen	690	
$\eta\eta$	seen	648	
$\pi\pi$	seen	837	

 $\phi_3(1850)$

$$I^{G}(J^{PC}) = 0^{-}(3^{-})$$

Mass $m = 1854 \pm 7 \text{ MeV}$ Full width $\Gamma = 87^{+28}_{-23} \text{ MeV}$ (S = 1.2)

ϕ_3 (1850) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)	
$\overline{\kappa}\overline{\kappa}$	seen	785	
$K\overline{K}^*(892) + \text{c.c.}$	seen	602	

f₂(2010)

$$I^{G}(J^{PC}) = 0^{+}(2^{+})$$

Seen by one group only. Mass $m=2011^{+60}_{-80}~{\rm MeV}$ Full width $\Gamma=202\pm60~{\rm MeV}$

f ₂ (2010) DECAY MODES	Fraction (Γ_i/Γ)	ρ (MeV/c)
$\phi \phi$	seen	_

f₄(2050)

$$I^{G}(J^{PC}) = 0^{+}(4^{+})$$

Mass $m=2044\pm11$ MeV (S = 1.4) Full width $\Gamma=208\pm13$ MeV (S = 1.2)

f4(2050) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)	
ωω	(26 ±6)%	658	
$\pi\pi$	(17.0 ± 1.5) %	1012	
$K\overline{K}$	$(6.8^{+3.4}_{-1.8}) \times 10^{-3}$	895	
$\eta \eta$	$(2.1\pm0.8)\times10^{-3}$	863	
$\eta \eta$ $4\pi^0$	< 1.2 %	977	

f₂(2300)

$$I^{G}(J^{PC}) = 0^{+}(2^{+})$$

Mass $m=2297\pm28$ MeV Full width $\Gamma=149\pm40$ MeV

f ₂ (2300) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$\phi \phi$	seen	529

f₂(2340)

$$I^{G}(J^{PC}) = 0^{+}(2^{+})$$

Mass $m=2339\pm60$ MeV Full width $\Gamma = 319^{+80}_{-70}$ MeV

f ₂ (2340) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)	
$\phi \phi$	seen	573	

STRANGE MESONS $(S = \pm 1, C = B = 0)$

 $K^+ = u\overline{s}$, $K^0 = d\overline{s}$, $\overline{K}^0 = \overline{d}s$, $K^- = \overline{u}s$, similarly for K^* 's

Κ±

$$I(J^P) = \frac{1}{2}(0^-)$$

Mass
$$m=493.677\pm0.016$$
 MeV $^{[u]}$ (S = 2.8) Mean life $\tau=(1.2386\pm0.0024)\times10^{-8}$ s (S = 2.0) $c\tau=3.713$ m

Slope parameter g [v]

(See Particle Listings for quadratic coefficients)

K^{\pm} decay form factors $^{[a,w]}$

$$K_{e3}^+$$
 $\lambda_+ = 0.0286 \pm 0.0022$

$$K_{\mu 3}^{+}$$
 $\lambda_{+} = 0.033 \pm 0.008$ (S = 1.6)

$$K_{\mu 3}^{+}$$
 $\lambda_0 = 0.004 \pm 0.007$ (S = 1.6)

$$K_{\mu 3}^{+}$$
 $|f_{S}/f_{+}| = 0.084 \pm 0.023$ (S = 1.2)

$$K_{e3}^{+} |f_T/f_+| = 0.38 \pm 0.11 \quad (S = 1.1)$$

$$K_{\mu 3}^{+} |f_{T}/f_{+}| = 0.02 \pm 0.12$$

$$K^{+} \rightarrow e^{+} \nu_{e} \gamma \quad |F_{A} + F_{V}| = 0.148 \pm 0.010$$
 $K^{+} \rightarrow \mu^{+} \nu_{\mu} \gamma \quad |F_{A} + F_{V}| < 0.23, \text{ CL} = 90\%$
 $K^{+} \rightarrow e^{+} \nu_{e} \gamma \quad |F_{A} - F_{V}| < 0.49$
 $K^{+} \rightarrow \mu^{+} \nu_{\mu} \gamma \quad |F_{A} - F_{V}| = -2.2 \text{ to } 0.3$

$$K^+ \rightarrow e^+ \nu_0 \gamma |F_A - F_V| < 0.49$$

$$K^+ \to \mu^+ \nu_{\mu} \gamma |F_A - F_V| = -2.2 \text{ to } 0.3$$

 ${\it K}^-$ modes are charge conjugates of the modes below.

		Scale factor/	p
K+ DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	(MeV/c)
$\mu^+ u_{\mu}$	(63.51 ± 0.18)	% S=1.3	236
$e^+ u_e$	(1.55 ± 0.07)	× 10 ⁻⁵	247
$\pi^{+}\pi^{0}$	(21.16 ± 0.14)	% S=1.1	205
$\pi^{+}\pi^{+}\pi^{-}$	(5.59±0.05)	% S=1.8	125
$\pi^{+}\pi^{0}\pi^{0}$	(1.73 ± 0.04)	% S=1.2	133
$\pi^0 \mu^+ u_\mu$	(3.18±0.08)	% S=1.5	215
Called $K_{\mu 3}^+$.			
$\pi^0 e^+ \nu_e$	(4.82±0.06)	% S=1.3	228
Called K_{e3}^+ .			
$\pi^{0} \pi^{0} e^{+} \nu_{e}$	(2.1 ± 0.4)	× 10 ⁻⁵	206
$\pi^{+}\pi^{-}e^{+}\nu_{e}$	(3.91±0.17)	× 10 ⁻⁵	203
$\pi^{+}\pi^{-}\mu^{+}\nu_{\mu}$	(1.4 ± 0.9)	× 10 ⁻⁵	151
$\pi^0 \pi^0 \pi^0 e^+ \nu_e$	< 3.5	× 10 ⁻⁶ CL=90%	135
$\pi^+ \gamma \gamma$	[x] < 1	$\times 10^{-6}$ CL=90%	227
π^+ 3 γ	[x] < 1.0	× 10 ⁻⁴ CL=90%	227
$\mu^+ \nu_\mu \nu \overline{\nu}$	< 6.0	$\times 10^{-6}$ CL=90%	236
$e^+ \nu_e \nu \overline{\nu}$	< 6	$\times 10^{-5}$ CL=90%	247
$\mu^+ u_\mue^+e^-$	(1.06 ± 0.32)	\times 10 ⁻⁶	236
$e^+ u_e e^+ e^-$	$(2.1 \begin{array}{c} +2.1 \\ -1.1 \end{array})$	× 10 ⁻⁷	247
$\mu^+ \nu_\mu \mu^+ \mu^-$	< 4.1	\times 10 ⁻⁷ CL=90%	185
$\mu^+ \nu_\mu \gamma$	[x,y] (5.50 ± 0.28)	× 10 ⁻³	236
$\pi^+\pi^0\gamma$	[x,y] (2.75 ± 0.15)		205
$\pi^+\pi^0\gamma(DE)$	[x,z] (1.8 ±0.4)		205
$\pi^+\pi^+\pi^-\gamma$	[x,y] (1.04 ± 0.31)	× 10 ⁻⁴	125
$\pi^+\pi^0\pi^0\gamma$	$[x,y]$ (7.5 $^{+5.5}_{-3.0}$)	× 10 ⁻⁶	133
$\pi^0 \mu^+ \nu_\mu \gamma$	[x,y] < 6.1	\times 10 ⁻⁵ CL=90%	215
$\pi^0 e^+ \nu_e \gamma$	[x,y] (2.62 ± 0.20)	× 10 ⁻⁴	228
$\pi^0 e^+ \nu_e \gamma$ (SD)		\times 10 ⁻⁵ CL=90%	228
$\pi^{0} \pi^{0} e^{+} \nu_{e} \gamma$	< 5	× 10 ⁻⁶ CL=90%	206

Lepton Family number (LF), Lepton number (L), $\Delta S = \Delta Q$ (SQ) violating modes, or $\Delta S = 1$ weak neutral current (S1) modes

$\pi^+\pi^+e^-\overline{\nu}_e$	5Q	< 1.2	× 10 ⁻⁸	CL=90%	203
$\pi^+\pi^+\mu^-\overline{\nu}_{\mu}$	5Q	< 3.0	$\times 10^{-6}$	CL=95%	151
$\pi^+e^+e^-$	S1	(2.74±0.23	$3) \times 10^{-7}$		227
$\pi^+\mu^+\mu^-$	S 1	< 2.3	$\times 10^{-7}$	CL=90%	172
$\pi^+ u \overline{ u}$	S 1	< 2.4	$\times 10^{-9}$	CL=90%	227
$\mu^- u e^+ e^+$	LF	< 2.0	$\times 10^{-8}$	CL=90%	236
$\mu^+ \nu_e$	LF	[d] < 4	\times 10 ⁻³	CL=90%	236
$\pi^+\mu^+e^-$	LF	< 2.1	$\times 10^{-10}$	CL=90%	214
$\pi^+\mu^-e^+$	LF	< 7	× 10 ⁻⁹	CL=90%	214
$\pi^- \mu^+ e^+$	L	< 7	$\times 10^{-9}$	CL=90%	214
$\pi^- e^+ e^+$	L	< 1.0	$\times 10^{-8}$	CL=90%	227
$\pi^- \mu^+ \mu^+$	L	< 1.5	\times 10 ⁻⁴	CL=90%	172
$\mu^+ \overline{\nu}_e$	L	[d] < 3.3	\times 10 ⁻³	CL=90%	236
$\pi^0 e^+ \overline{\nu}_e$	L.	[d] < 3	\times 10 ⁻³	CL=90%	228

K⁰

$$I(J^P) = \frac{1}{2}(0^-)$$

50% K_S, 50% K_L

Mass
$$m = 497.672 \pm 0.031 \text{ MeV}$$

$$m_{K^0} - m_{K^{\pm}} = 3.995 \pm 0.034 \text{ MeV} \quad (S = 1.1)$$

$$|m_{K^0} - m_{\overline{K}^0}| / m_{\text{average}} < 9 \times 10^{-19} \text{ [bb]}$$

 K_S^0

$$I(J^P) = \frac{1}{2}(0^-)$$

Mean life
$$au = (0.8927 \pm 0.0009) \times 10^{-10} \text{ s}$$

 $c au = 2.6762 \text{ cm}$

CP-violation parameters [cc]

$$Im(\eta_{+-0}) = -0.015 \pm 0.030$$

 $Im(\eta_{000})^2 < 0.1$, CL = 90%

K _S DECAY MODES		Fraction (Γ_{i}	′Г) Со	Scale factor/ nfidence level	
${\pi^+\pi^-}$		(68.61±0.	28) %	S=1.2	206
$\pi^{0} \pi^{0}$		$(31.39 \pm 0.$	28) %	S=1.2	209
$\pi^+\pi^-\gamma$	[y,dd]	(1.78±0.	05) × 10 ⁻³	3	206
$\gamma\gamma$		(2.4 \pm 0.	9)×10 ^{−6}	5	249
$\pi^+\pi^-\pi^0$		$(3.9 \begin{array}{c} +5. \\ -1. \end{array}$	$\frac{5}{9}$) × 10 ⁻⁷	7	133
$3\pi^{0}$		< 3.7	× 10 ⁻⁵	CL=90%	139
$\pi^{\pm} e^{\mp} u$	[ee]	(6.70±0.	$07) \times 10^{-4}$	S=1.3	229
$\pi^{\pm}\mu^{\mp} u$	[ee]	(4.69±0.	$06) \times 10^{-4}$	S=1.2	216
$\Delta S = 1$	weak neuti	ral current ((<i>51</i>) mod	es	
$\mu^{+} \mu^{-}$ $e^{+} e^{-}$	S 1	< 3.2	\times 10 ⁻⁷	CL=90%	225
e+e-	5 1	< 2.8	× 10 ⁻⁶	CL=90%	249

< 1.1

 $\pi^{0}e^{+}e^{-}$

$$I(J^P) = \frac{1}{2}(0^-)$$

CL=90%

× 10⁻⁶

231

$$\begin{split} m_{K_L} - m_{K_S} &= (0.5304 \pm 0.0014) \times 10^{10} \ \hbar \ \text{s}^{-1} \\ &= (3.491 \pm 0.009) \times 10^{-12} \ \text{MeV} \\ \text{Mean life } \tau &= (5.17 \pm 0.04) \times 10^{-8} \ \text{s} \quad (S = 1.1) \end{split}$$

$c\tau = 15.51 \text{ m}$ Slope parameter g [v]

(See Particle Listings for quadratic coefficients)

$$K_L^0 \rightarrow \pi^+\pi^-\pi^0 = 0.670 \pm 0.014 \quad (S = 1.6)$$

K_L decay form factors [w]

$$K_{e3}^{0}$$
 $\lambda_{+} = 0.0300 \pm 0.0016$ (S = 1.2)

$$K_{\mu3}^{0}$$
 $\lambda_{+} = 0.034 \pm 0.005$ (S = 2.3)

$$K_{\mu 3}^{0}$$
 $\lambda_{0} = 0.025 \pm 0.006$ (S = 2.3)

$$K_{e3}^{0} \quad \left| f_{S}/f_{+} \right| < 0.04, \text{ CL} = 68\%$$

$$K_{e3}^{0} |f_{T}/f_{+}| < 0.23$$
, CL = 68%

$$K_{u3}^{0} |f_T/f_+| = 0.12 \pm 0.12$$

$$K_L \to e^+ e^- \gamma$$
: $\alpha_{K^*} = -0.28 \pm 0.08$

$\it CP$ -violation parameters [cc]

$$\begin{split} \delta &= (0.327 \pm 0.012)\% \\ \left| \eta_{00} \right| &= (2.275 \pm 0.019) \times 10^{-3} \quad (5 = 1.1) \\ \left| \eta_{+-} \right| &= (2.285 \pm 0.019) \times 10^{-3} \\ \left| \eta_{00} / \eta_{+-} \right| &= 0.9956 \pm 0.0023 \,^{[ff]} \quad (S = 1.8) \\ \epsilon' / \epsilon &= (1.5 \pm 0.8) \times 10^{-3} \,^{[ff]} \quad (S = 1.8) \\ \phi_{+-} &= (43.7 \pm 0.6)^{\circ} \\ \phi_{00} &= (43.5 \pm 1.0)^{\circ} \\ \phi_{00} &= \phi_{+-} &= (-0.2 \pm 0.8)^{\circ} \\ j \, \text{for } K_{L}^{0} \rightarrow \pi^{+} \pi^{-} \pi^{0} = 0.0011 \pm 0.0008 \\ \left| \eta_{+-\gamma} \right| &= (2.35 \pm 0.07) \times 10^{-3} \end{split}$$

$\phi_{+-\gamma}=$ (44 \pm 4)° $|\epsilon_{+-\gamma}^{'}|/\epsilon$ < 0.3, CL = 90%

$$\begin{split} \Delta \textit{S} &= -\Delta \textit{Q} \text{ in } \textit{K}_{23}^0 \text{ decay} \\ &\text{Re } \textit{x} = 0.006 \pm 0.018 \quad \text{(S} = 1.3) \\ &\text{Im } \textit{x} = -0.003 \pm 0.026 \quad \text{(S} = 1.2) \end{split}$$

CPT-violation parameters

Re Δ = 0.018 \pm 0.020 Im Δ = 0.02 \pm 0.04

Scale factor/ KO DECAY MODES Fraction (Γ_i/Γ) Confidence level (MeV/c) $3\pi^0$ (21.12 +0.27) % S=1.1 139 $\pi^+\,\pi^-\,\pi^0$ $(12.56 \pm 0.20)\%$ S=1.7 133 $\pi^{\pm} \mu^{\mp} \nu$ [gg] (27.17 \pm 0.25)% S=1.1 216 Called K_{u3}^0 . $\begin{array}{cc} \pi^{\pm}\,e^{\mp}\,\nu_{e} & , \\ \text{Called } \mathcal{K}^{0}_{e3}. \end{array}$ [gg] (38.78 \pm 0.27)% S=1.1 229 ($5.92~\pm0.15$) $\times\,10^{-4}$ × 10⁻⁷ CL=90% $3\gamma \atop \pi^{0} 2\gamma \atop \pi^{0} \pi^{\pm} e^{\mp} \nu$ [hh] (1.70 ± 0.28) $\times\,10^{-6}$ 231 [gg] (5.18 ± 0.29) $\times 10^{-5}$ 207 $(\pi \mu atom) \nu$ (1.06 ± 0.11) $\times 10^{-7}$ $\pi^{\pm} e^{\mp} \nu_e \gamma$ [y,gg,hh] (1.3 ±0.8)% 229 $\pi^+\pi^-\gamma$ $\pi^0\pi^0\gamma$ [y,hh] (4.61 ± 0.14) $\times 10^{-5}$ 206 \times 10 $^{-6}$ < 5.6

Charge conjugation \times Parity (*CP*, *CPV*) or Lepton Family number (*LF*) violating modes, or $\Delta S = 1$ weak neutral current (*S1*) modes

$\pi^{+}\pi^{-}$	CPV	(2.06	57±0.035	$) \times 10^{-3}$	S=1.1	206
π ⁰ π ⁰	CPV			$) \times 10^{-4}$		209
$\mu^+\mu^-$	S1	(7.2	± 0.5) × 10 ⁻⁹	S=1.4	225
$\mu^+\mu^-\gamma$	S1	(3.23	3 ±0.30	$) \times 10^{-7}$		225
$e^+ e^-$	S1	< 4.1		$\times 10^{-13}$	LCL=90%	249
$e^+e^-\gamma$	S1	(9.1	± 0.5	$) \times 10^{-6}$		249
$e^+e^-\gamma\gamma$	S1 [hh]	(6.5	±1.2	$) \times 10^{-7}$		249
$\pi^{+} \pi^{-} e^{+} e^{-}$	51	< 2.5		$\times 10^{-6}$	CL=90%	206
$\mu^{+}\mu^{-}e^{+}e^{-}$	S1	< 4.9		$\times 10^{-6}$	CL=90%	225
$e^{+} e^{-} e^{+} e^{-}$	S1 [ii]	(4.1	± 0.8	$) \times 10^{-8}$	S=1.2	249
$\pi^{0} \mu^{+} \mu^{-}$	CP,S1 [jj]	< 5.1		$\times 10^{-9}$	CL=90%	177
$\pi^{0} e^{+} e^{-}$	CP,S1 [jj]	< 4.3		$\times 10^{-9}$	CL=90%	231
$\pi^0 \nu \overline{\nu}$	CP,S1[kk]	< 5.8		$\times 10^{-5}$	CL=90%	231
$e^{\pm}\mu^{\mp}$	LF [gg]	< 3.3		$\times 10^{-11}$	LCL=90%	238

K*(892)

$$I(J^P) = \frac{1}{2}(1^-)$$

 $K^*(892)^\pm$ mass $m=891.59\pm0.24$ MeV (S = 1.1) $K^*(892)^0$ mass $m=896.10\pm0.28$ MeV (S = 1.4) $K^*(892)^\pm$ full width Γ = 49.8 ± 0.8 MeV $K^*(892)^\pm$ full width Γ = 50.5 ± 0.6 MeV (S = 1.1)

K*(892) DECAY MODES	Fraction $(\Gamma_{\hat{I}}/\Gamma)$ Cor	p fidence level (MeV/ c)
Κπ	~ 100 %	291
$\kappa^0\gamma$	$(2.30\pm0.20)\times10^{-1}$	3 310
$K^{\pm}\gamma$	$(1.01\pm0.09)\times10^{-1}$	3 309
$K \pi \pi$	< 7 × 10 ⁻	4 95% 224

K₁(1270)

$$I(J^P) = \frac{1}{2}(1^+)$$

Mass $m=1273\pm7$ MeV ^[I] Full width $\Gamma=90\pm20$ MeV ^[I]

K ₁ (1270) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
Κρ	(42 ±6)%	76
$K_0^*(1430)\pi$	(28 ±4)%	-
$K^*(892)\pi$	(16 ±5)%	301
$K\omega$	(11.0±2.0) %	_
$K f_0(1370)$	(3.0 ± 2.0) %	-

K₁(1400)

$$I(J^P) = \tfrac{1}{2}(1^+)$$

Mass $m=1402\pm7$ MeV Full width $\Gamma=174\pm13$ MeV (S = 1.6)

K1(1400) DECAY MODES	Fraction $(\Gamma_{\hat{I}}/\Gamma)$	p (MeV/c)
K*(892)π	(94 ±6)%	401
$K\rho$	(3.0±3.0) %	298
$K f_0(1370)$	(2.0 ± 2.0) %	
$K\omega$	(1.0±1.0) %	285

K*(1410)

$$I(J^P) = \frac{1}{2}(1^-)$$

Mass $m=1412\pm12$ MeV (S = 1.1) Full width $\Gamma=227\pm22$ MeV (S = 1.1)

K*(1410) DECAY MODES	Fraction (I	Γ _į /Γ)	Confidence level	<i>р</i> (MeV/ <i>c</i>)
K*(892)π	> 40	%	95%	408
Kπ	(6.6±1	L.3) %		611
$K \rho$	< 7	%	95%	309

K*(1430) [//]

$$I(J^P) = \frac{1}{2}(0^+)$$

Mass $m=1429\pm 6~{
m MeV}$ Full width $\Gamma=287\pm 23~{
m MeV}$

K*(1430) DECAY MODES	Fraction $(\Gamma_{\hat{I}}/\Gamma)$	p (MeV/c)
Κπ	(93±10) %	621

K*(1430)

$$I(J^P) = \frac{1}{2}(2^+)$$

 $K_2^*(1430)^\pm$ mass $m=1425.4\pm1.3~{\rm MeV}~(S=1.1)$ $K_2^*(1430)^0$ mass $m=1432.4\pm1.3~{\rm MeV}$ $K_2^*(1430)^\pm$ full width $\Gamma=98.4\pm2.3~{\rm MeV}$ $K_2^*(1430)^0$ full width $\Gamma=109\pm5~{\rm MeV}~(S=1.9)$

K2*(1430) DECAY MODES	Fraction (Γ_j/Γ)	Scale factor/ Confidence level	p (MeV/c)
Κπ	(49.7±1.2) %		622
$K^*(892)\pi$	(25.2 ± 1.7) %		423
$K^*(892) \pi \pi$	(13.0 ± 2.3) %		375
Κρ	(8.8 ± 0.8) %	S=1.2	331
$K \omega$	(2.9±0.8) %		319
$K^+\gamma$	$(2.4 \pm 0.5) \times 10$	₎ -3	627
$K\eta$	$(1.4^{+2.8}_{-0.9}) \times 10$	o-3 S=1.1	492
$K \omega \pi$	< 7.2 × 10	-4 CL=95%	110
$K^0\gamma$	< 9 × 10	0 ⁻⁴ CL=90%	631

K*(1680)

$$I(J^P) = \frac{1}{2}(1^-)$$

Mass $m=1714\pm 20$ MeV (S = 1.1) Full width $\Gamma=323\pm 110$ MeV (S = 4.2)

K*(1680) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
Kπ	(38.7±2.5) %	779
$K \rho$	$(31.4^{+4.7}_{-2.1})\%$	571
$K^*(892)\pi$	$(29.9^{+2.2}_{-4.7})$ %	615

K₂(1770) [mm]

$$I(J^P) = \frac{1}{2}(2^-)$$

Mass $m=1773\pm 8$ MeV Full width $\Gamma=186\pm 14$ MeV

K2(1770) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
Κππ		_
$K_2^*(1430)\pi$	dominant	287
$K^{*}(892)\pi$	seen	653
K f ₂ (1270)	seen	_
$K\phi$	seen	441
$K\omega$	seen	608

$K_3^*(1780)$

$$I(J^P) = \frac{1}{2}(3^-)$$

Mass $m=1770\pm10$ MeV (S = 1.7) Full width $\Gamma=164\pm17$ MeV (S = 1.1)

K*(1780) DECAY MODES	Fraction (Γ_i/Γ)	Scale factor/ Confidence level	<i>p</i> (MeV/ <i>c</i>)
K_{ρ}	(45 ±4)%	S=1.4	612
$K^*(892)\pi$	(27.3 ± 3.2) %	S=1.5	651
$K\pi$	$(19.3 \pm 1.0) \%$		810
$K\eta$	(8.0 ± 1.5) %	S=1.4	715
$K_2^*(1430)\pi$	< 21 %	CL=95%	284

K₂(1820) [nn]

$$I(J^P) = \frac{1}{2}(2^-)$$

Mass $m=1816\pm13~{\rm MeV}$ Full width $\Gamma=276\pm35~{\rm MeV}$

K2(1820) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$K\phi$	possibly seen	481
$K_2^*(1430)\pi$	seen	325
$K^*(892)\pi$	seen	680
$K f_2(1270)$	seen	186
$K\omega$	seen	638

K*(2045)

$$I(J^P) = \frac{1}{2}(4^+)$$

Mass $m=2045\pm 9$ MeV (S = 1.1) Full width $\Gamma=198\pm 30$ MeV

K*(2045) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
Κπ	(9.9±1.2) %	958
$K^*(892)\pi\pi$	(9 ±5)%	800
$K^*(892)\pi\pi\pi$	(7 ±5)%	764
$\rho K \pi$	(5.7±3.2) %	742
$\omega K \pi$	(5.0 ± 3.0) %	736
$\phi K \pi$	(2.8 ± 1.4) %	591
$\phi K^*(892)$	(1.4 ± 0.7) %	363

CHARMED MESONS

 $(C=\pm 1)$

 $D^+ = c\overline{d}, D^0 = c\overline{u}, \overline{D}^0 = \overline{c}u, D^- = \overline{c}d,$ similarly for D^* 's

D±

$$I(J^P) = \frac{1}{2}(0^-)$$

Mass
$$m=1869.3\pm0.5~{
m MeV}~{
m (S}=1.1)$$
 Mean life $\tau=(1.057\pm0.015)\times10^{-12}~{
m s}$ $c au=317~{
m \mu m}$

CP-violation decay-rate asymmetries

$$A_{CP}(K^+K^-\pi^{\pm}) = -0.03 \pm 0.07$$

 $A_{CP}(K^{\pm}K^{*0}) = -0.12 \pm 0.13$
 $A_{CP}(\phi\pi^{\pm}) = 0.07 \pm 0.09$

$D^+ ightarrow \overline{K}^*(892)^0 \ell^+ \nu_\ell$ form factors

$$r_2 = 0.73 \pm 0.15$$

 $r_V = 1.90 \pm 0.25$
 $\Gamma_L/\Gamma_T = 1.23 \pm 0.13$
 $\Gamma_+/\Gamma_- = 0.16 \pm 0.04$

 $\ensuremath{D^{-}}$ modes are charge conjugates of the modes below.

D+ DECAY MODES	Fraction (Γ_i/Γ)	Scale factor/ Confidence level	р (MeV/c)
		Comidence level	(1016 0/10)
e ⁺ anything	lusive modes (17.2 ±1.9) %		_
K ⁻ anything	(24.2 ±2.8) %		_
$\frac{K}{K^0}$ anything + K^0 anything	(59 ±7)%		_
K ⁺ anything	$(5.8 \pm 1.4)\%$		_
* , 3	oo] < 13 %		_
	d semileptonic mod		
$\mu^+ u_\mu$		10 ⁻⁴ CL=90%	932
	[pp] (6.7 ±0.8)%		868
$\overline{K}^0 e^+ \nu_e$	(6.6 ±0.9) %		868
$\overline{K}^0 \mu^+ \nu_{\mu}$	(7.0 + 3.0)%		865
·			865
$K^-\pi^+e^+\nu_e$	$(4.2 \begin{array}{c} +0.9 \\ -0.7 \end{array})\%$	•	863
$\overline{K}^*(892)^0 e^+ \nu_e imes B(\overline{K}^{*0} o K^- \pi^+)$	(3.2 ±0.33) %		720
$K^-\pi^+e^+\nu_e$ nonresonant	< 7 ×	10 ⁻³ CL=90%	863
$K^-\pi^+\mu^+\nu_{\mu}$	(3.2 ±0.4) %		851
$\overline{K}^*(892)^0 \mu^+ \nu_\mu$	(3.0 ±0.4) %		715
$\times \ B(\overline{K}^{*0} \to K^-\pi^+)$	(5.5 ±5) /6		
$K^-\pi^+\mu^+ u_\mu$ nonresonant	(2.7 ±1.1)×	10-3	851
$(\overline{K}^*(892)\pi)^0 e^+ \nu_e$	< 1.2 %		714
$(\overline{K}\pi\pi)^0 e^+ \nu_e \text{ non-} \overline{K}^* (892)$		10 ⁻³ CL=90%	846
$K^-\pi^+\pi^0\mu^+\nu_{\mu}$		10 ⁻³ CL=90%	825
0.41	qq] (5.7 ±2.2)×		930
0 2 %	44) (311 ±212) ×	10	750
Fractions of some of the follow appeared above as submodes or			
T7+ ()0 ol		rticle modes.	720
$K^*(892)^0 e^+ \nu_e$	pp] (4.8 \pm 0.4) %		720 720
$\frac{K}{K}$ *(892) ⁰ $\mu^+ \nu_{\mu}$	(4.8 ±0.5) % (4.5 ±0.6) %	S=1.1	
$\rho^0 e^+ \nu_e$,	10 ⁻³ CL=90%	715
			776
$ ho^0 \mu^+ u_{\mu}$	($2.0 \begin{array}{c} +1.5 \\ -1.3 \end{array}$) $ imes$	10-3	772
$\phi e^+ \nu_e$	< 2.09 %	CL=90%	657
$\phi \mu^+ \nu_{\mu}$	< 3.72 %	CL=90%	651
$\eta'(958)\mu^+\nu_{\mu}$	< 9 ×	10 ⁻³ CL=90%	684
Hadronic mod	des with a \overline{K} or \overline{K}	⟨K	
$\overline{K}^0\pi^+$	(2.74 ± 0.29) %		862
	[rr] (9.1 ±0.6) %		845
$\overline{K}^*(892)^0\pi^+$	$(1.28\pm0.13)\%$		712
$\times B(\overline{K}^{*0} \rightarrow K^{-}\pi^{+})$			
$\overline{K}_{0}^{*}(1430)^{0}\pi^{+}$	(2.3 \pm 0.3) %		368
$\times B(\overline{K}_0^*(1430)^0 \to K^-\pi^+)$			
$\overline{K}^*(1680)^0 \pi^+$	(3.7 ± 0.8) \times	10-3	65
$\times B(\overline{K}^*(1680)^0 \to K^-\pi^+)$			
$K^-\pi^+\pi^+$ nonresonant	(8.6 ±0.9) %		845

$\overline{K}^0\pi^+\pi^0$	[rr] (9.7 ±3.0) %	S=1.1	845	$\pi^{+}\pi^{+}\pi^{-}\pi^{0}$	(, , +1.5	. 0/		
$\overline{K}^0 \rho^+$	(6.6 ±2.5) %		680		$(1.9 \begin{array}{c} +1.5 \\ -1.2 \end{array})$			882
$\overline{K}^*(892)^0 \pi^+$	$(6.4 \pm 0.6) \times 10^{-3}$		712	$\eta\pi^+ imes B(\eta o\pi^+\pi^-\pi^0) \ \omega\pi^+ imes B(\omega o\pi^+\pi^-\pi^0)$	(1.8 ±0.6			848
$\times B(\overline{K}^{*0} \to \overline{K}^0\pi^0)$					< 6	× 10 ⁻³	CL=90%	764
$\overline{K}^0\pi^+\pi^0$ nonresonant	(1.3 \pm 1.1) %		845	$\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}$	$(1.0 \begin{array}{c} +0.8 \\ -0.7 \end{array}$	$) \times 10^{-3}$		845
$\frac{\mathcal{K}^-\pi^+\pi^+\pi^0}{\overline{\mathcal{K}}^*(892)^0} \rho^+$ total	[rr] $(6.4 \pm 1.1)\%$		816	$\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0}$	$(2.9 + 2.9 \\ -2.0$	$) \times 10^{-3}$		799
$\times B(\overline{K}^{*0} \rightarrow K^-\pi^+)$	(1.4 \pm 0.9) %		423		` -2.0	,		
$\overline{K}_1(1400)^0 \pi^+ \times B(\overline{K}_1(1400)^0 \to K^- \pi$	(2.2 ±0.6) %		390	Fractions of some of the fo appeared above as submode				
$K^- \rho^+ \pi^+ \text{total}$	(3.1 ±1.1) %		616	$\eta \pi^+$	(7.5 ±2.5	$) \times 10^{-3}$		848
$K^-\rho^+\pi^+$ 3-body	(1.1 ±0.4) %		616	$ ho^0\pi^+$	< 1.4	\times 10 ⁻³	CL=90%	769
$\overline{K}^*(892)^0\pi^+\pi^0$ total	$(4.5 \pm 0.9)\%$		687	$\omega \pi^+_{\perp}$	< 7	× 10 ⁻³	CL=90%	764
\times B($\overline{K}^{*0} \rightarrow K^-\pi^+$)				$\eta \rho^+$	< 1.2	%	CL=90%	658
$\overline{K}^*(892)^0 \pi^+ \pi^0$ 3-body	(2.8 \pm 0.9) %		687	$\eta'(958)\pi^+ \\ \eta'(958)\rho^+$	< 9 < 1.5	× 10 ⁻³	CL=90% CL=90%	680 355
\times B($\overline{K}^{*0} \rightarrow K^-\pi^+$) $K^*(892)^-\pi^+\pi^+$ 3-body	$(7 \pm 3) \times 10^{-3}$		600	, , ,,			CL=9076	333
$\times B(K^{*-} \to K^{-}\pi^{0})$	(/ ±3) x 10 -		688	$K^+\overline{K}^0$	modes with a K			
$K^-\pi^+\pi^+\pi^0$ nonresonant	[ss] (1.2 \pm 0.6) %		816	$K^+K^-\pi^+$	(7.2 ±1.2			792
$\overline{K}{}^0\pi^+\pi^+\pi^-$	[rr] (7.0 \pm 1.0) %		814	$\phi \pi^+ \times B(\phi \to K^+ K^-)$	[rr] (8.9 ± 0.8 (3.0 ± 0.3			744 647
$\overline{K}{}^0 a_1(1260)^+$	(4.0 ±0.9) %		328	$K^{+}\overline{K}^{*}(892)^{0}$	(2.8 ±0.4			610
$\times B(a_1(1260)^+ \to \pi^+\pi^+$				\times B $(\overline{K}^{*0'} \rightarrow K^- \pi^+)$	•	,		
$\overline{K}_1(1400)^0 \pi^+ \times B(\overline{K}_1(1400)^0 \to \overline{K}^0 \pi^-$	(2.2 ±0.6) %		390	$K^+K^-\pi^+$ nonresonant	(4.6 ±0.9	$) \times 10^{-3}$		744
$K^*(892)^- \pi^+ \pi^+ 3$ -body	(1.4 ±0.6) %		688	$K^0\overline{K}^0\pi^+$				741
\times B($K^{*-} \rightarrow \overline{K}^0 \pi^-$)	(1.1 ±0.0) //		000	$K^*(892)^+\overline{K}^0$	(2.0 ±0.9) %		611
$\overline{K}^0 \rho^0 \pi^+$ total	(4.2 ± 0.9) %		614	$ \begin{array}{c} \times B(K^{*+} \rightarrow K^0 \pi^+) \\ K^+ K^- \pi^+ \pi^0 \end{array} $				682
$\overline{K}^0 \rho^0 \pi^+$ 3-body	$(5 \pm 5) \times 10^{-3}$		614	$\phi \pi^+ \pi^0 \times B(\phi \to K^+ K^-)$	(1.1 ±0.5) %		619
$\overline{\mathcal{K}}{}^0\pi^+\pi^+\pi^-$ nonresonant $\mathcal{K}^-\pi^+\pi^+\pi^+\pi^-$	$(8 \pm 4) \times 10^{-3}$		814	$\phi \rho^+ \times B(\phi \to K^+ K^-)$	< 7	$\times 10^{-3}$	CL=90%	268
$\frac{\pi}{K}*(892)^0\pi^+\pi^+\pi^-$	$(8.2 \pm 1.4) \times 10^{-3}$ $(6.8 \pm 1.8) \times 10^{-3}$		772 642	$K^+K^-\pi^+\pi^0$ non- ϕ	$(1.5 \begin{array}{c} +0.7 \\ -0.6 \end{array})$) %		682
$\times B(\overline{K}^{*0} \rightarrow K^-\pi^+)$	(0.0 ±1.0) × 10		042	$K^+\overline{K}{}^0\pi^+\pi^-$	< 2	%	CL=90%	678
$\overline{K}^*(892)^0 \rho^0 \pi^+$	$(5.1 \pm 2.2) \times 10^{-3}$		242	$\kappa^0 \kappa^- \pi^+ \pi^+$	(1.0 ±0.6			678
$ \begin{array}{c} \times B(\overline{K}^{*0} \to K^{-}\pi^{+}) \\ \overline{K}^{*}(892)^{0} \rho^{0} \pi^{+} \\ \times B(\overline{K}^{*0} \to K^{-}\pi^{+}) \end{array} $,			$K^*(892)^+\overline{K}^*(892)^0$	(1.2 ±0.5			273
$K^-\pi^+\pi^+\pi^0\pi^0$	$(2.2 \begin{array}{c} +5.0 \\ -0.9 \end{array})\%$		775	$\times B^2(K^* \to K\pi^+)$				
$\overline{K}{}^{0}\pi^{+}\pi^{+}\pi^{-}\pi^{0}$	(5.4 + 3.0) %			$K^0K^-\stackrel{\frown}{\pi^+}\pi^+$ non- $K^*\stackrel{\longleftarrow}{+}\stackrel{K^*0}{K^+}K^ \pi^+\pi^+\pi^-$	< 7.9	× 10 ⁻³	CL=90%	678
$\overline{K}^{0}\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}$			773	$\phi \pi^+ \pi^+ \pi^-$	< 1	× 10 ⁻³	CL=90%	600 565
$K^{-}\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{0}$	$(8 \pm 7) \times 10^{-4}$ $(2.0 \pm 1.8) \times 10^{-3}$		714 718	$\times B(\phi \rightarrow K^+K^-)$	` '	× 10	CL=3076	303
$\frac{\kappa}{\kappa^0}\frac{\kappa}{\kappa^0}\frac{\kappa}{\kappa^+}$	(1.8 ±0.8) %		545	$K^+K^-\pi^+\pi^+\pi^-$ nonresonan	t < 3	%	CL=90%	600
	ollowing modes with resonances h			Fractions of the following mabove as submodes of partic			y appeared	
$\overline{K}{}^0 \rho^+$	es of particular charged-particle m	odes.	100	$\phi\pi^+$				647
Ν - ρ '						1 × 10 3		619
\overline{K}^0 2. (1260)+	(6.6 ±2.5) %		680	$\phi \pi^+ \pi^0$	•) × 10 ⁻³		
$\overline{K}^0 a_1(1260)^+$ $\overline{K}^0 a_2(1320)^+$	$(8.1 \pm 1.7)\%$	CL=90%	328	$\phi = 0$ $\phi \pi + \pi^0$ $\phi \rho^+$	(2.3 ±1.0 < 1.5	•	CL=90%	268
$\frac{\overline{K}^0}{K} a_1 (1260)^+$ $\frac{\overline{K}^0}{K} a_2 (1320)^+$ $\frac{\overline{K}^*}{K} (892)^0 \pi^+$		CL=90%		$\phi \pi^{+} \pi^{0} \ \phi \rho^{+} \ \phi \pi^{+} \pi^{+} \pi^{-}$	(2.3 ±1.0 < 1.5 < 2) % % × 10 ⁻³	CL=90% CL=90%	
$rac{\overline{K}^0 a_2(1320)^+}{\overline{K}^*(892)^0 \pi^+} \ rac{\overline{K}^*(892)^0 ho^+}{ ext{total}}$	$(8.1 \pm 1.7)\%$ $< 3 \times 10^{-3}$	CL=90%	328 199	$\phi \pi^{+} \pi^{0} \phi \rho^{+} \phi \pi^{+} \pi^{+} \pi^{-} \mathcal{K}^{+} \overline{\mathcal{K}}^{*} (892)^{0}$	(2.3 ± 1.0) < 1.5 < 2 (4.2 ± 0.5)) % % × 10 ⁻³) × 10 ⁻³		268 565 610
$rac{\overline{K}^0 a_2(1320)^+}{\overline{K}^*(892)^0 \pi^+} \ rac{\overline{K}^*(892)^0 ho^+}{\overline{K}^*(892)^0 ho^+} ext{ total} \ rac{\overline{K}^*(892)^0 ho^+}{ ho^+} ext{ S-wave}$	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	CL=90%	328 199 712	$\phi \pi^{+} \pi^{0} \phi \rho^{+} \phi \pi^{+} \pi^{+} \pi^{-} K^{+} \overline{K}^{*} (892)^{0} K^{*} (892)^{+} \overline{K}^{0}$	(2.3 ±1.0 < 1.5 < 2 (4.2 ±0.5 (3.0 ±1.4) % % × 10 ⁻³) × 10 ⁻³		268 565 610 611
$\overline{K}^0 a_2(1320)^+$ $\overline{K}^*(892)^0 \pi^+$ $\overline{K}^*(892)^0 \rho^+$ total $\overline{K}^*(892)^0 \rho^+$ 5-wave $\overline{K}^*(892)^0 \rho^+ P$ -wave	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	CL=90% CL=90%	328 199 712 423 423 423	$\phi \pi^{+} \pi^{0} \phi \rho^{+} \phi \pi^{+} \pi^{+} \pi^{-} \mathcal{K}^{+} \overline{\mathcal{K}}^{*} (892)^{0}$	(2.3 ± 1.0) < 1.5 < 2 (4.2 ± 0.5)) % % × 10 ⁻³) × 10 ⁻³		268 565 610
$\overline{K}^0 a_2(1320)^+$ $\overline{K}^*(892)^0 \pi^+$ $\overline{K}^*(892)^0 \rho^+$ total $\overline{K}^*(892)^0 \rho^+$ 5-wave $\overline{K}^*(892)^0 \rho^+$ P-wave $\overline{K}^*(892)^0 \rho^+$ D-wave	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	CL=90%	328 199 712 423 423 423 423	$\phi \pi^+ \pi^0$ $\phi \rho^+$ $\phi \pi^+ \pi^- \pi^ K^+ \overline{K}^* (892)^0$ $K^* (892)^+ \overline{K}^0$ $K^* (892)^+ \overline{C}^0$ Doubly Cabib	(2.3 ±1.0 < 1.5 < 2 (4.2 ±0.5 (3.0 ±1.4 (2.6 ±1.1	% % × 10 ⁻³) × 10 ⁻³) %) %	CL=90%	268 565 610 611
$\overline{K}^0 a_2(1320)^+$ $\overline{K}^*(892)^0 \pi^+$ $\overline{K}^*(892)^0 \rho^+$ total $\overline{K}^*(892)^0 \rho^+$ S-wave $\overline{K}^*(892)^0 \rho^+$ P-wave $\overline{K}^*(892)^0 \rho^+$ D-wave longitu-	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$		328 199 712 423 423 423	$\phi \pi^+ \pi^0 \ \phi \rho^+ \ \phi \pi^+ \pi^- \ K^+ \overline{K}^* (892)^0 \ K^* (892)^+ \overline{K}^0 \ K^* (892)^+ \overline{L}^* (892)^0$	(2.3 ±1.0 < 1.5 < 2 (4.2 ±0.5 (3.0 ±1.4 (2.6 ±1.1 bo suppressed (Dieutral current (Ci	% % × 10 ⁻³) × 10 ⁻³) %) % C) modes, of	CL=90% or	268 565 610 611
$\overline{K}^0 a_2(1320)^+$ $\overline{K}^*(892)^0 \pi^+$ $\overline{K}^*(892)^0 \rho^+$ total $\overline{K}^*(892)^0 \rho^+$ 5-wave $\overline{K}^*(892)^0 \rho^+$ P-wave $\overline{K}^*(892)^0 \rho^+$ D-wave longitudinal $\overline{K}_1(1270)^0 \pi^+$	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	CL=90%	328 199 712 423 423 423 423	$\phi \pi^{+} \pi^{0}$ $\phi \rho^{+}$ $\phi \pi^{+} \pi^{+} \pi^{-}$ $K^{+} \overline{K}^{*} (892)^{0}$ $K^{*} (892)^{+} \overline{K}^{0}$ $K^{*} (892)^{+} \overline{K}^{0}$ Doubly Cabib $\Delta C = 1$ weak π Lepton Family number (L	(2.3 ±1.0 < 1.5 < 2 (4.2 ±0.5 (3.0 ±1.4 (2.6 ±1.1 bo suppressed (<i>D</i>) eutral current (<i>C</i>)	% % × 10 ⁻³) × 10 ⁻³) %) % C) modes, ober (L) viola	CL=90% or	268 565 610 611 273
$\overline{K}^0 a_2(1320)^+$ $\overline{K}^*(892)^0 \pi^+$ $\overline{K}^*(892)^0 \rho^+$ total $\overline{K}^*(892)^0 \rho^+$ 5-wave $\overline{K}^*(892)^0 \rho^+$ P-wave $\overline{K}^*(892)^0 \rho^+$ D-wave longitudinal $\overline{K}_1(1270)^0 \pi^+$ $\overline{K}_1(1400)^0 \pi^+$	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	CL=90% CL=90% CL=90%	328 199 712 423 423 423 423 423	$\begin{array}{c} \phi\pi^{+}\pi^{0} \\ \phi\rho^{+} \\ \phi\pi^{+}\pi^{-} \\ K^{+}\overline{K}^{*}(892)^{0} \\ K^{*}(892)^{+}\overline{K}^{0} \\ K^{*}(892)^{+}\overline{K}^{*}(892)^{0} \\ \end{array}$	(2.3 ±1.0 < 1.5 < 2 (4.2 ±0.5 (3.0 ±1.4 (2.6 ±1.1) bo suppressed (Dieutral current (CEF) or Lepton numi (6.5 ±2.6	% % × 10 ⁻³) × 10 ⁻³) %) % C) modes, ober (L) viola) × 10 ⁻⁴	CL=90% or ating modes	268 565 610 611 273
$\overline{K}^0 a_2(1320)^+$ $\overline{K}^* (892)^0 \pi^+$ $\overline{K}^* (892)^0 \rho^+$ total $\overline{K}^* (892)^0 \rho^+$ S-wave $\overline{K}^* (892)^0 \rho^+$ P-wave $\overline{K}^* (892)^0 \rho^+$ D-wave $\overline{K}^* (892)^0 \rho^+$ D-wave longitudinal $\overline{K}_1 (1270)^0 \pi^+$ $\overline{K}_1 (1400)^0 \pi^+$ $\overline{K}^* (1410)^0 \pi^+$	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	CL=90% CL=90%	328 199 712 423 423 423 423 423 423 423 487 390 382	$\begin{array}{cccc} \phi \pi^{+} \pi^{0} & & & \\ \phi \rho^{+} & & & \\ \phi \pi^{+} \pi^{+} \pi^{-} & & \\ K^{+} K^{*} (892)^{0} & & & \\ K^{*} (892)^{+} \overline{K}^{0} & & \\ K^{*} (892)^{+} \overline{K}^{*} (892)^{0} & & \\ & & $	(2.3 ±1.0 < 1.5 < 2 (4.2 ±0.5 (3.0 ±1.4 (2.6 ±1.1 bo suppressed (Dieutral current (Ci F) or Lepton numi (6.5 ±2.6 < 6) % % × 10 ⁻³) × 10 ⁻³) %) % C) modes, or ber (L) violation) × 10 ⁻⁴ × 10 ⁻⁴	or ating modes CL=90%	268 565 610 611 273 845 681
$\overline{K}^0 a_2(1320)^+$ $\overline{K}^* (892)^0 \pi^+$ $\overline{K}^* (892)^0 \rho^+$ total $\overline{K}^* (892)^0 \rho^+$ S-wave $\overline{K}^* (892)^0 \rho^+$ P-wave $\overline{K}^* (892)^0 \rho^+$ D-wave longitudinal $\overline{K}_1 (1270)^0 \pi^+$ $\overline{K}^* (1410)^0 \pi^+$ $\overline{K}^* (1410)^0 \pi^+$ $\overline{K}^* (1430)^0 \pi^+$	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	CL=90% CL=90% CL=90%	328 199 712 423 423 423 423 423 423 487 390 382 368	$\begin{array}{c} \phi\pi^{+}\pi^{0} \\ \phi\rho^{+} \\ \phi\pi^{+}\pi^{-} \\ K^{+}\overline{K}^{*}(892)^{0} \\ K^{*}(892)^{+}\overline{K}^{0} \\ K^{*}(892)^{+}\overline{K}^{*}(892)^{0} \\ \end{array}$	(2.3 ±1.0 < 1.5 < 2 (4.2 ±0.5 (3.0 ±1.4 (2.6 ±1.1) bo suppressed (Dieutral current (CEF) or Lepton numi (6.5 ±2.6) % % × 10 ⁻³) × 10 ⁻³) %) %) % C) modes, ober (L) viola × 10 ⁻⁴ × 10 ⁻⁴ × 10 ⁻⁴	CL=90% or ating modes	268 565 610 611 273
$\begin{array}{l} \overline{K^0} a_2(1320)^+ \\ \overline{K^*}(892)^0 \pi^+ \\ \overline{K^*}(892)^0 \rho^+ \text{total} \\ \overline{K^*}(892)^0 \rho^+ \text{5-wave} \\ \overline{K^*}(892)^0 \rho^+ \text{P-wave} \\ \overline{K^*}(892)^0 \rho^+ \text{D-wave} \\ \overline{K^*}(892)^0 \rho^+ \text{D-wave} \text{In al } \\ \overline{K_1}(1270)^0 \pi^+ \\ \overline{K_1}(1400)^0 \pi^+ \\ \overline{K^*}(1410)^0 \pi^+ \\ \overline{K^*}(1430)^0 \pi^+ \\ \overline{K^*}(1630)^0 \pi^+ \\ \overline{K^*}(1680)^0 \pi^+ \\ \end{array}$	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	CL=90% CL=90% CL=90%	328 199 712 423 423 423 423 423 423 487 390 382 368 65	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	(2.3 ±1.0 < 1.5 < 2 (4.2 ±0.5 (3.0 ±1.4 (2.6 ±1.1) bo suppressed (Dieutral current (Ciental current) (6.5 ±2.6 < 6 < 1.9) % % × 10 ⁻³) × 10 ⁻³) %) %) % C) modes, of the control of	or ating modes CL=90% CL=90%	268 565 610 611 273 845 681 712
$\begin{array}{l} \overline{K^0} a_2(1320)^+ \\ \overline{K^+}(892)^0 \pi^+ \\ \overline{K^+}(892)^0 \rho^+ \text{total} \\ \overline{K^+}(892)^0 \rho^+ \text{total} \\ \overline{K^+}(892)^0 \rho^+ \text{P-wave} \\ \overline{K^+}(892)^0 \rho^+ \text{D-wave} \\ \overline{K^+}(892)^0 \rho^+ \text{D-wave longitudinal} \\ \overline{K_1}(1270)^0 \pi^+ \\ \overline{K_1}(1400)^0 \pi^+ \\ \overline{K^+}(1410)^0 \pi^+ \\ \overline{K^+}(1410)^0 \pi^+ \\ \overline{K^+}(1680)^0 \pi^+ \\ \overline{K^+}(892)^0 \pi^+ \pi^0 \text{total} \\ \end{array}$	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	CL=90% CL=90% CL=90%	328 199 712 423 423 423 423 423 423 423 487 390 382 368 65 687	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	(2.3 ±1.0 < 1.5 < 2 (4.2 ±0.5 (3.0 ±1.4 (2.6 ±1.1 bo suppressed (Dieutral current (Cirr) or Lepton numi (6.5 ±2.6 < 6 < 1.9 < 1.5) % % × 10 ⁻³) × 10 ⁻³) %) %) %) %) modes, of the control	CL=90% or ating modes CL=90% CL=90% CL=90% CL=90% CL=90%	268 565 610 611 273 845 681 712 550
$\overline{K}^0 a_2(1320)^+$ $\overline{K}^*(892)^0 \pi^+$ $\overline{K}^*(892)^0 \rho^+$ total $\overline{K}^*(892)^0 \rho^+$ 5-wave $\overline{K}^*(892)^0 \rho^+$ D-wave $\overline{K}^*(892)^0 \rho^+$ D-wave longitudinal $\overline{K}_1(1270)^0 \pi^+$ $\overline{K}_1(1400)^0 \pi^+$ $\overline{K}^*(1430)^0 \pi^+$ $\overline{K}^*(1680)^0 \pi^+$ $\overline{K}^*(1680)^0 \pi^+$ $\overline{K}^*(892)^0 \pi^+ \pi^0$ total $\overline{K}^*(892)^0 \pi^+ \pi^0$ 3-body	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	CL=90% CL=90% CL=90%	328 199 712 423 423 423 423 423 423 423 487 390 382 368 65 687 687	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	(2.3 ±1.0 < 1.5 < 2 (4.2 ±0.5 (3.0 ±1.4 (2.6 ±1.1 bo suppressed (Dieutral current (CE) eutral current (CE) or Lepton numl (6.5 ±2.6 < 6 < 1.9 < 1.5 < 1.3 < 6.6 < 1.8) % % × 10 ⁻³) × 10 ⁻³) % C) modes, 1) modes, ober (L) viola × 10 ⁻⁴ × 10 ⁻⁴ × 10 ⁻⁴ × 10 ⁻⁴ × 10 ⁻⁵ × 10 ⁻⁵	CL=90% or ating modes CL=90% CL=90% CL=90% CL=90% CL=90% CL=90%	268 565 610 611 273 845 681 712 550 527 929 917
$\overline{K}^0 a_2(1320)^+$ $\overline{K}^*(892)^0 \pi^+$ $\overline{K}^*(892)^0 \rho^+$ total $\overline{K}^*(892)^0 \rho^+$ 5-wave $\overline{K}^*(892)^0 \rho^+$ D-wave $\overline{K}^*(892)^0 \rho^+$ D-wave longitudinal $\overline{K}_1(1270)^0 \pi^+$ $\overline{K}_1(1400)^0 \pi^+$ $\overline{K}^*(1480)^0 \pi^+$ $\overline{K}^*(1680)^0 \pi^+$ $\overline{K}^*(1680)^0 \pi^+$ $\overline{K}^*(892)^0 \pi^+ \pi^0$ total $\overline{K}^*(892)^0 \pi^+ \pi^0$ 3-body $\overline{K}^*(892)^0 \pi^+ \pi^+$ 3-body	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	CL=90% CL=90% CL=90%	328 199 712 423 423 423 423 423 423 487 390 382 368 65 687 687	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	(2.3 ±1.0 < 1.5 < 2 (4.2 ±0.5 (3.0 ±1.4 (2.6 ±1.1 bo suppressed (Dieutral current (Cirr) or Lepton numl (6.5 ±2.6 < 6 < 1.9 < 1.5 < 1.3 < 6.6 < 1.8 < 5.6) % % × 10 ⁻³) × 10 ⁻³) % C) modes, ober (L) viola × 10 ⁻⁴ × 10 ⁻⁴ × 10 ⁻⁴ × 10 ⁻⁴ × 10 ⁻⁵ × 10 ⁻⁵ × 10 ⁻⁵	CL=90% or ating modes CL=90% CL=90% CL=90% CL=90% CL=90% CL=90% CL=90%	268 565 610 611 273 845 681 712 550 527 929 917 759
$\overline{K}^0 a_2(1320)^+$ $\overline{K}^*(892)^0 \pi^+$ $\overline{K}^*(892)^0 \rho^+$ total $\overline{K}^*(892)^0 \rho^+$ 5-wave $\overline{K}^*(892)^0 \rho^+$ D-wave $\overline{K}^*(892)^0 \rho^+$ D-wave longitudinal $\overline{K}_1(1270)^0 \pi^+$ $\overline{K}_1(1400)^0 \pi^+$ $\overline{K}^*(1410)^0 \pi^+$ $\overline{K}^*(1680)^0 \pi^+$ $\overline{K}^*(1680)^0 \pi^+$ $\overline{K}^*(892)^0 \pi^+ \pi^0$ total $\overline{K}^*(892)^0 \pi^+ \pi^0$ 3-body	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	CL=90% CL=90% CL=90%	328 199 712 423 423 423 423 423 423 423 487 390 382 368 65 687 687	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	(2.3 ±1.0 < 1.5 < 2 (4.2 ±0.5 (3.0 ±1.4 (2.6 ±1.1 bo suppressed (Diseutral current (Ciseutral current (Ciseutra	% % \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	CL=90% or ating modes CL=90% CL=90% CL=90% CL=90% CL=90% CL=90% CL=90% CL=90%	268 565 610 611 273 845 681 712 550 527 929 917 759 869
$\begin{array}{l} \overline{K^0} a_2(1320)^+ \\ \overline{K^+}(892)^0 \pi^+ \\ \overline{K^+}(892)^0 \rho^+ \text{total} \\ \overline{K^+}(892)^0 \rho^+ \text{total} \\ \overline{K^+}(892)^0 \rho^+ \text{D-wave} \\ \overline{K^+}(892)^0 \rho^+ \text{D-wave} \\ \overline{K^+}(892)^0 \rho^+ \text{D-wave longitudinal} \\ \overline{K_1}(1270)^0 \pi^+ \\ \overline{K_1}(1400)^0 \pi^+ \\ \overline{K^+}(1410)^0 \pi^+ \\ \overline{K^+}(1430)^0 \pi^+ \\ \overline{K^+}(892)^0 \pi^+ \pi^0 \text{total} \\ \overline{K^+}(892)^0 \pi^+ \pi^0 \text{total} \\ \overline{K^+}(892)^0 \pi^+ \pi^0 \text{s-body} \\ \overline{K^-} \rho^+ \pi^+ \text{total} \\ \overline{K^-} \rho^+ \pi^+ \text{total} \\ \overline{K^-} \rho^0 \pi^+ \text{total} \end{array}$	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	CL=90% CL=90% CL=90%	328 199 712 423 423 423 423 423 423 487 390 382 368 65 687 687 688 616	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	(2.3 ±1.0 < 1.5 < 2 (4.2 ±0.5 (3.0 ±1.4 (2.6 ±1.1) bo suppressed (Dieutral current (CiF) or Lepton numl (6.5 ±2.6 < 6 < 1.9 < 1.5 < 1.3 < 6.6 < 1.8 < 5.6 [tt] < 4.8 [tt] < 3.2) % % × 10 ⁻³) × 10 ⁻³) %) %) %) % C) modes, of the control of the contro	CL=90% ating modes CL=90% CL=90% CL=90% CL=90% CL=90% CL=90% CL=90% CL=90% CL=90%	268 565 610 611 273 845 681 712 550 527 929 917 759 869 856
$\begin{array}{l} \overline{K^0} a_2(1320)^+ \\ \overline{K^+}(892)^0 \pi^+ \\ \overline{K^+}(892)^0 \rho^+ \text{total} \\ \overline{K^+}(892)^0 \rho^+ \text{total} \\ \overline{K^+}(892)^0 \rho^+ \text{D-wave} \\ \overline{K^+}(892)^0 \rho^+ \text{D-wave} \\ \overline{K^+}(892)^0 \rho^+ \text{D-wave longitudinal} \\ \overline{K_1}(1270)^0 \pi^+ \\ \overline{K_1}(1400)^0 \pi^+ \\ \overline{K^+}(1410)^0 \pi^+ \\ \overline{K^+}(1680)^0 \pi^+ \\ \overline{K^+}(1680)^0 \pi^+ \\ \overline{K^+}(892)^0 \pi^+ \pi^0 \text{total} \\ \overline{K^+}(892)^0 \pi^+ \pi^0 \text{s-body} \\ \overline{K^-}(92)^0 \pi^+ \pi^+ \text{3-body} \\ \overline{K^-}\rho^+ \pi^+ \text{total} \\ \overline{K^-}\rho^0 \pi^+ \text{total} \\ \overline{K^0} \rho^0 \pi^+ \text{3-body} \\ \end{array}$	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	CL=90% CL=90% CL=90% CL=90%	328 199 712 423 423 423 423 423 423 487 390 382 368 65 687 687 688 616 616 614 614	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	(2.3 ±1.0 < 1.5 < 2 (4.2 ±0.5 (3.0 ±1.4 (2.6 ±1.1 bo suppressed (Diseutral current (Ciseutral current (Ciseutra	% % \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	CL=90% or ating modes CL=90% CL=90% CL=90% CL=90% CL=90% CL=90% CL=90% CL=90%	268 565 610 611 273 845 681 712 550 527 929 917 759 869
$\overline{K^0}$ $a_2(1320)^+$ $\overline{K^+}$ $(892)^0$ π^+ $\overline{K^+}$ $(892)^0$ ρ^+ botal $\overline{K^+}$ $(892)^0$ ρ^+ botal $\overline{K^+}$ $(892)^0$ ρ^+ P-wave $\overline{K^+}$ $(892)^0$ ρ^+ D-wave $\overline{K^+}$ $(892)^0$ ρ^+ D-wave longitudinal $\overline{K_1}$ $(1270)^0$ π^+ $\overline{K_1}$ $(1400)^0$ π^+ $\overline{K^+}$ $(1410)^0$ π^+ $\overline{K^+}$ $(1480)^0$ π^+ $\overline{K^+}$ $(1680)^0$ π^+ $\overline{K^+}$ $(1680)^0$ π^+ $\overline{K^+}$ $(892)^0$ π^+ π^0 botal $\overline{K^+}$ $(892)^0$ π^+ π^0 s-body $\overline{K^-}$ ρ^+ π^+ total $\overline{K^-}$ ρ^+ π^+ s-body $\overline{K^0}$ ρ^0 π^+ total $\overline{K^0}$ ρ^0 π^+ s-body $\overline{K^0}$ ρ^0 π^0 π^0	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	CL=90% CL=90% CL=90% CL=90%	328 199 712 423 423 423 423 423 423 487 390 382 368 65 687 687 688 616 616 614 614 461	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	(2.3 ±1.0 < 1.5 < 2 (4.2 ±0.5 (3.0 ±1.4 (2.6 ±1.1 bo suppressed (Dieutral current (Ciff) or Lepton numl (6.5 ±2.6 < 6 < 1.9 < 1.5 < 1.3 < 6.6 < 1.8 < 5.6 [tt] < 4.8 [tt] < 3.2 [gg] < 3.8	% % \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	CL=90% or ating modes CL=90% CL=90% CL=90% CL=90% CL=90% CL=90% CL=90% CL=90% CL=90%	268 565 610 611 273 845 681 712 550 527 929 917 759 869 856 926
$\begin{array}{l} \overline{K}^0 a_2(1320)^+ \\ \overline{K}^*(892)^0 \pi^+ \\ \overline{K}^*(892)^0 \rho^+ \text{ total} \\ \overline{K}^*(892)^0 \rho^+ \text{ 5-wave} \\ \overline{K}^*(892)^0 \rho^+ P\text{-wave} \\ \overline{K}^*(892)^0 \rho^+ D\text{-wave longitudinal} \\ \overline{K}_1(1270)^0 \pi^+ \\ \overline{K}_1(1400)^0 \pi^+ \\ \overline{K}^*(1410)^0 \pi^+ \\ \overline{K}^*(1410)^0 \pi^+ \\ \overline{K}^*(1430)^0 \pi^+ \\ \overline{K}^*(1680)^0 \pi^+ \\ \overline{K}^*(892)^0 \pi^+ \pi^0 \text{ total} \\ \overline{K}^*(892)^0 \pi^+ \pi^0 \text{ 3-body} \\ \overline{K}^*(892)^0 \pi^+ \pi^0 \text{ 3-body} \\ \overline{K}^0 \rho^0 \pi^+ \text{ total} \\ \overline{K}^0 \rho^0 \pi^+ \text{ 3-body} \\ \overline{K}^0 \rho^0 \pi^+ \text{ 3-body} \\ \overline{K}^0 \rho^0 \pi^+ 3 \text{ -body} $	$ \begin{array}{c cccc} (\ 8.1\ \pm 1.7\)\ \% \\ < 3 & \times 10^{-3} \\ (\ 1.92\pm 0.19)\ \% \\ (\ 2.1\ \pm 1.4\)\ \% \\ (\ 2.1\ \pm 1.6\)\ \% \\ < 1 & \times 10^{-3} \\ (\ 10\ \pm 7\)\ \times 10^{-3} \\ < 7 & \times 10^{-3} \\ < 7 & \times 10^{-3} \\ (\ 5.0\ \pm 1.3\)\ \% \\ < 7 & \times 10^{-3} \\ (\ 5.0\ \pm 1.3\)\ \% \\ < 7 & \times 10^{-3} \\ (\ 5.0\ \pm 1.3\)\ \% \\ (\ 1.45\pm 0.31)\ \% \\ (\ 1.45\pm 0.31)\ \% \\ (\ 6.7\ \pm 1.4\)\ \% \\ (\ 2.1\ \pm 0.9\)\ \% \\ (\ 2.1\ \pm 0.9\)\ \% \\ (\ 3.1\ \pm 1.1\)\ \% \\ (\ 1.1\ \pm 0.4\)\ \% \\ (\ 4.2\ \pm 0.9\)\ \% \\ (\ 5.5\ 5) \times 10^{-3} \\ < 5 & \times 10^{-3} \\ (\ 1.02\pm 0.27)\ \% \end{array} $	CL=90% CL=90% CL=90% CL=90%	328 199 712 423 423 423 423 423 423 487 390 382 368 65 687 688 616 616 616 614 461 642	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	(2.3 ±1.0 < 1.5 < 2 (4.2 ±0.5 (3.0 ±1.4 (2.6 ±1.1 bo suppressed (Director) or Lepton numl (6.5 ±2.6 < 6 < 1.9 < 1.5 < 1.3 < 6.6 < 1.8 < 5.6 [tt] < 4.8 [tt] < 3.2 [gg] < 3.8 < 3.3 < 3.3 < 3.4	% % \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	CL=90% or ating modes CL=90%	268 565 610 611 273 845 681 712 550 527 929 917 759 869 856 926 926 866
$\overline{K}^0 a_2(1320)^+$ $\overline{K}^*(892)^0 \pi^+$ $\overline{K}^*(892)^0 \rho^+$ total $\overline{K}^*(892)^0 \rho^+$ 5-wave $\overline{K}^*(892)^0 \rho^+$ D-wave $\overline{K}^*(892)^0 \rho^+$ D-wave longitudinal $\overline{K}_1(1270)^0 \pi^+$ $\overline{K}_1(1400)^0 \pi^+$ $\overline{K}^*(1430)^0 \pi^+$ $\overline{K}^*(1680)^0 \pi^+$ $\overline{K}^*(1680)^0 \pi^+$ $\overline{K}^*(892)^0 \pi^+ \pi^0$ total $\overline{K}^*(892)^0 \pi^+ \pi^0$ s-body $\overline{K}^*(892)^0 \pi^+ \pi^0$ total $\overline{K}^*(892)^0 \pi^+ \pi^0$ total $\overline{K}^*(892)^0 \pi^+ \pi^0$ total $\overline{K}^*(892)^0 \pi^+ \pi^0$ total $\overline{K}^*(892)^0 \pi^+ \pi^0$ total $\overline{K}^0 \rho^0 \pi^+$ 5-body $\overline{K}^0 f_0(980) \pi^+$	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	CL=90% CL=90% CL=90% CL=90%	328 199 712 423 423 423 423 423 423 487 390 382 368 65 687 687 688 616 616 614 614 461	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	(2.3 ±1.0 < 1.5 < 2 (4.2 ±0.5 (3.0 ±1.4 (2.6 ±1.1) bo suppressed (Dieutral current (CiF) or Lepton numl (6.5 ±2.6 < 6 < 1.9 < 1.5 < 1.3 < 6.6 < 1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.8 (1.8 < 5.6 (1.8 < 5.8 (1.8 < 5.6 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (1.8 < 5.8 (% % \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	CL=90% pr ating modes CL=90%	268 565 610 611 273 845 681 712 550 527 759 869 866 926 926 866 866
$\begin{array}{l} \overline{K^0} a_2(1320)^+ \\ \overline{K^*}(892)^0 \pi^+ \\ \overline{K^*}(892)^0 \rho^+ \text{total} \\ \overline{K^*}(892)^0 \rho^+ \text{total} \\ \overline{K^*}(892)^0 \rho^+ \text{P-wave} \\ \overline{K^*}(892)^0 \rho^+ \text{D-wave} \\ \overline{K^*}(892)^0 \rho^+ \text{D-wave} \text{Indian} \\ \overline{K_1}(1270)^0 \pi^+ \\ \overline{K_1}(1400)^0 \pi^+ \\ \overline{K^*}(1410)^0 \pi^+ \\ \overline{K^*}(1430)^0 \pi^+ \\ \overline{K^*}(892)^0 \pi^+ \pi^0 \text{total} \\ \overline{K^*}(892)^0 \pi^+ \pi^0 \text{3-body} \\ \overline{K^*}(892)^0 \pi^+ \pi^0 \text{3-body} \\ \overline{K^0} \rho^0 \pi^+ \text{total} \\ \overline{K^0} \rho^0 \pi^+ \text{total} \\ \overline{K^0} \rho^0 \pi^+ \text{sody} \\ \overline{K^0} \rho^0 \pi^+ \text{total} \\ \overline{K^0} \rho^0 \pi^+ \text{sody} \\ \overline{K^0} \rho^0 \pi^+ \text{total} $	$ \begin{array}{c cccc} (\ 8.1\ \pm 1.7\)\ \% \\ < 3 & \times 10^{-3} \\ (\ 1.92\pm 0.19)\ \% \\ (\ 2.1\ \pm 1.4\)\ \% \\ [ss] & (\ 1.7\ \pm 1.6\)\ \% \\ < 1 & \times 10^{-3} \\ (\ 10\ \pm 7\)\ \times 10^{-3} \\ < 7 & \times 10^{-3} \\ < 7 & \times 10^{-3} \\ (\ 5.0\ \pm 1.3\)\ \% \\ < 7 & \times 10^{-3} \\ (\ 5.0\ \pm 1.3\)\ \% \\ < 7 & \times 10^{-3} \\ (\ 5.0\ \pm 1.3\)\ \% \\ (\ 1.45\pm 0.31)\ \% \\ (\ 6.7\ \pm 1.4\)\ \% \\ (\ 1.45\pm 0.31)\ \% \\ (\ 6.7\ \pm 1.4\)\ \% \\ (\ 2.1\ \pm 0.9\)\ \% \\ (\ 3.1\ \pm 1.1\)\ \% \\ (\ 1.1\ \pm 0.4\)\ \% \\ (\ 4.2\ \pm 0.9\)\ \% \\ (\ 5.5\ 5\)\ \times 10^{-3} \\ < 5 & \times 10^{-3} \\ (\ 1.02\pm 0.27)\ \% \\ (\ 7.7\ \pm 3.3\)\ \times 10^{-3} \\ \end{array} $ Pionic modes	CL=90% CL=90% CL=90% CL=90%	328 199 712 423 423 423 423 423 423 487 390 382 368 65 687 688 616 616 614 614 614 614 614 642 242	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	(2.3 ±1.0 < 1.5 < 2 (4.2 ±0.5 (3.0 ±1.4 (2.6 ±1.1) bo suppressed (Dieutral current (CiF) or Lepton numl (6.5 ±2.6 < 6 < 1.9 < 1.5 < 1.3 < 6.6 < 1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (3.2 (1.8)) (3.2 (1.8)) (3.2 (1.8)) (3.3 < 3.3 < 3.3 < 3.3 < 3.4 < 3.4 < 4.8	% % 10 ⁻³) % % × 10 ⁻³) % 10 ⁻³) % 0 % C) modes, ober (L) viola × 10 ⁻⁴ × 10 ⁻⁴ × 10 ⁻⁴ × 10 ⁻⁵ × 10 ⁻⁵ × 10 ⁻⁵ × 10 ⁻³ × 10	CL=90% or ating modes CL=90%	268 565 610 611 273 845 681 712 929 917 759 926 926 926 926 866 866 929
$\begin{array}{l} \overline{K^0} a_2(1320)^+ \\ \overline{K^+}(892)^0 \pi^+ \\ \overline{K^+}(892)^0 \rho^+ \text{total} \\ \overline{K^+}(892)^0 \rho^+ \text{total} \\ \overline{K^+}(892)^0 \rho^+ \text{D-wave} \\ \overline{K^+}(892)^0 \rho^+ \text{D-wave} \\ \overline{K^+}(892)^0 \rho^+ \text{D-wave} \text{Indial} \\ \overline{K_1}(1270)^0 \pi^+ \\ \overline{K_1}(1400)^0 \pi^+ \\ \overline{K^+}(1410)^0 \pi^+ \\ \overline{K^+}(1430)^0 \pi^+ \\ \overline{K^+}(892)^0 \pi^+ \pi^0 \text{total} \\ \overline{K^+}(892)^0 \pi^+ \pi^0 \text{s-body} \\ \overline{K^+}(892)^0 \pi^+ \pi^0 \text{s-body} \\ \overline{K^-}(892)^0 \pi^+ \pi^0 \text{s-body} \\ \overline{K^-} \rho^+ \pi^+ \text{total} \\ \overline{K^0} \rho^0 \pi^+ \text{total} \\ \overline{K^0} \rho^0 \pi^+ \text{total} \\ \overline{K^0} \rho^0 \pi^+ \text{s-body} \\ \overline{K^0} \rho^0 \pi^+ \text{s-body} \\ \overline{K^0} \Gamma_0(980) \pi^+ \\ \overline{K^+}(892)^0 \rho^0 \pi^+ \pi^- \\ \overline{K^+}(892)^0 \rho^0 \pi^+ \\ \overline{K^+}(892)^0 \rho^0 \pi^+ \\ \end{array}$	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	CL=90% CL=90% CL=90% CL=90%	328 199 712 423 423 423 423 423 423 487 390 382 368 65 687 687 688 616 616 614 461 461 461 42 242	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	(2.3 ±1.0 < 1.5 < 2 (4.2 ±0.5 (3.0 ±1.4 (2.6 ±1.1) to suppressed (Dieutral current (Ci=) or Lepton numl (6.5 ±2.6 < 6 (1.9 < 1.5 < 1.3 < 6.6 < 1.8 < 5.6 (tt) < 4.8 (tt) < 3.2 (gg) < 3.8 (3.3 < 3.4 < 3.4 < 3.4 < 4.8 < 2.2	% % \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	CL=90% pr ating modes CL=90%	268 565 610 611 273 845 681 712 550 527 759 869 866 926 926 866 866
$\begin{array}{l} \overline{K^0} a_2(1320)^+ \\ \overline{K^*}(892)^0 \pi^+ \\ \overline{K^*}(892)^0 \rho^+ \text{ total} \\ \overline{K^*}(892)^0 \rho^+ \text{ 5-wave} \\ \overline{K^*}(892)^0 \rho^+ \text{ P-wave} \\ \overline{K^*}(892)^0 \rho^+ \text{ D-wave} \\ \overline{K^*}(892)^0 \rho^+ \text{ D-wave} \\ \overline{K^*}(1270)^0 \pi^+ \\ \overline{K_1}(1400)^0 \pi^+ \\ \overline{K^*}(1410)^0 \pi^+ \\ \overline{K^*}(1410)^0 \pi^+ \\ \overline{K^*}(1480)^0 \pi^+ \\ \overline{K^*}(892)^0 \pi^+ \pi^0 \text{ total} \\ \overline{K^*}(892)^0 \pi^+ \pi^0 \text{ 3-body} \\ \overline{K^*}(892)^0 \pi^+ \pi^0 \text{ 3-body} \\ \overline{K^0} \rho^0 \pi^+ \pi^+ \pi^- \\ \overline{K^*}(892)^0 \rho^0 \pi^+ \end{array}$	$ \begin{array}{c cccc} (~8.1~\pm 1.7~)~\% \\ < ~3 & \times 10^{-3} \\ (~1.92\pm 0.19)~\% \\ (~2.1~\pm 1.4~)~\% \\ (~2.1~\pm 1.6~)~\% \\ < ~1 & \times 10^{-3} \\ (~10~\pm 7~)~\times 10^{-3} \\ < ~7 & \times 10^{-3} \\ (~5.0~\pm 1.3~)~\% \\ < ~7 & \times 10^{-3} \\ (~5.0~\pm 1.3~)~\% \\ < ~7 & \times 10^{-3} \\ (~5.0~\pm 1.3~)~\% \\ (~1.45\pm 0.31)~\% \\ (~6.7~\pm 1.4~)~\% \\ (~1.45\pm 0.31)~\% \\ (~6.7~\pm 1.4~)~\% \\ (~2.1~\pm 0.9~)~\% \\ (~3.1~\pm 1.1~)~\% \\ (~1.1~\pm 0.4~)~\% \\ (~4.2~\pm 0.9~)~\% \\ (~5~\pm 5~)~\times 10^{-3} \\ < ~5 & \times 10^{-3} \\ (~1.02\pm 0.27)~\% \\ (~7.7~\pm 3.3~)~\times 10^{-3} \\ \end{array} $	CL=90% CL=90% CL=90% CL=90%	328 199 712 423 423 423 423 423 423 487 390 382 368 65 687 688 616 616 614 614 614 614 614 642 242	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	(2.3 ±1.0 < 1.5 < 2 (4.2 ±0.5 (3.0 ±1.4 (2.6 ±1.1) bo suppressed (Dieutral current (CiF) or Lepton numl (6.5 ±2.6 < 6 < 1.9 < 1.5 < 1.3 < 6.6 < 1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (3.2 (1.8)) (3.2 (1.8)) (3.2 (1.8)) (3.3 < 3.3 < 3.3 < 3.3 < 3.4 < 3.4 < 4.8	% % \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	CL=90% or ating modes CL=90%	268 565 610 611 273 845 681 712 550 929 917 759 869 926 926 926 866 929 917
$\overline{K^0}$ $a_2(1320)^+$ $\overline{K^*}(892)^0$ π^+ $\overline{K^*}(892)^0$ ρ^+ total $\overline{K^*}(892)^0$ ρ^+ 5-wave $\overline{K^*}(892)^0$ ρ^+ D-wave $\overline{K^*}(892)^0$ ρ^+ D-wave longitudinal $\overline{K_1}(1270)^0$ π^+ $\overline{K_1}(1400)^0$ π^+ $\overline{K^*}(1410)^0$ π^+ $\overline{K^*}(1680)^0$ π^+ $\overline{K^*}(1680)^0$ π^+ $\overline{K^*}(1680)^0$ π^+ $\overline{K^*}(1892)^0$ π^+ π^0 3-body $K^*(892)^0$ π^+ π^0 3-body $K^ \rho^+$ π^+ total $K^ \rho^+$ π^+ 5-body $K^ \rho^0$ π^+ and $K^ \rho^0$ π^+ π^0 π^0 π^+ π^0	$ \begin{array}{c cccc} (\ 8.1\ \pm 1.7\)\ \% \\ < 3 & \times 10^{-3} \\ (\ 1.92\pm 0.19)\ \% \\ (\ 2.1\ \pm 1.4\)\ \% \\ [ss] & (\ 1.7\ \pm 1.6\)\ \% \\ < 1 & \times 10^{-3} \\ (\ 10\ \pm 7\)\ \times 10^{-3} \\ < 7 & \times 10^{-3} \\ (\ 5.0\ \pm 1.3\)\ \% \\ < 7 & \times 10^{-3} \\ (\ 5.0\ \pm 1.3\)\ \% \\ < 7 & \times 10^{-3} \\ (\ 5.0\ \pm 1.3\)\ \% \\ < 7 & \times 10^{-3} \\ (\ 3.7\ \pm 0.4\)\ \% \\ (\ 1.45\pm 0.31)\ \% \\ (\ 6.7\ \pm 1.4\)\ \% \\ (\ 4.2\ \pm 1.4\)\ \% \\ (\ 4.2\ \pm 1.4\)\ \% \\ (\ 2.1\ \pm 0.9\)\ \% \\ (\ 3.1\ \pm 1.1\)\ \% \\ (\ 1.1\ \pm 0.4\)\ \% \\ (\ 4.2\ \pm 0.9\)\ \% \\ (\ 5.\ \pm 5\)\ \times 10^{-3} \\ < 5 & \times 10^{-3} \\ (\ 1.02\pm 0.27)\ \% \\ (\ 7.7\ \pm 3.3\)\ \times 10^{-3} \\ \end{array} $ $\begin{array}{c} \textbf{Pionic modes} \\ (\ 2.5\ \pm 0.7\)\ \times 10^{-3} \\ (\ 3.2\ \pm 0.6\)\ \times 10^{-3} \\ \end{array}$	CL=90% CL=90% CL=90% CL=90% CL=90%	328 199 712 423 423 423 423 423 423 487 390 382 368 65 687 688 616 614 614 461 461 461 462 242	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	(2.3 ±1.0 < 1.5 < 2 (4.2 ±0.5 (3.0 ±1.4 (2.6 ±1.1) bo suppressed (Dieutral current (CiF) or Lepton numl (6.5 ±2.6 < 6 < 1.9 < 1.5 < 1.3 < 6.6 < 1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (5.6 (5.6 (5.8)))))))))))))))))))) % % × 10 ⁻³) × 10 ⁻³) % C) modes, 0 ber (L) viola × 10 ⁻⁴ × 10 ⁻⁴ × 10 ⁻⁴ × 10 ⁻⁵ × 10 ⁻⁵ × 10 ⁻⁵ × 10 ⁻³	CL=90% pr ating modes CL=90%	268 565 610 611 273 845 681 712 929 917 759 886 926 926 926 929 917 926 759 866
$\begin{array}{l} \overline{K^0} a_2(1320)^+ \\ \overline{K^*}(892)^0 \pi^+ \\ \overline{K^*}(892)^0 \rho^+ \text{total} \\ \overline{K^*}(892)^0 \rho^+ \text{total} \\ \overline{K^*}(892)^0 \rho^+ \text{D-wave} \\ \overline{K^*}(892)^0 \rho^+ \text{D-wave} \\ \overline{K^*}(892)^0 \rho^+ \text{D-wave longitudinal} \\ \overline{K_1}(1270)^0 \pi^+ \\ \overline{K_1}(1400)^0 \pi^+ \\ \overline{K^*}(1410)^0 \pi^+ \\ \overline{K^*}(1680)^0 \pi^+ \\ \overline{K^*}(1680)^0 \pi^+ \\ \overline{K^*}(1892)^0 \pi^+ \pi^0 \text{3-body} \\ \overline{K^*}(892)^0 \pi^+ \pi^0 \text{3-body} \\ \overline{K^*}(892)^0 \pi^+ \pi^1 \text{3-body} \\ \overline{K^*}(992)^0 \pi^+ \pi^1 \text{3-body} \\ \overline{K^0} \rho^0 \pi^+ \pi^+ \pi^- \\ \overline{K^0} (980) \pi^+ \\ \overline{K^0} (980) \pi^+ \\ \overline{K^0} (990) $	$ \begin{array}{c cccc} (~8.1~\pm 1.7~)~\% \\ < & 3 & \times 10^{-3} \\ (~1.92\pm 0.19)~\% \\ (~2.1~\pm 1.4~)~\% \\ [ss] & (~1.7~\pm 1.6~)~\% \\ < & 1 & \times 10^{-3} \\ (~10~\pm 7~) \times 10^{-3} \\ < & 7 & \times 10^{-3} \\ \end{array} \\ < & 7 & \times 10^{-3} \\ (~5.0~\pm 1.3~)~\% \\ < & 7 & \times 10^{-3} \\ (~5.0~\pm 1.3~)~\% \\ < & 7 & \times 10^{-3} \\ (~5.0~\pm 1.3~)~\% \\ < & 7 & \times 10^{-3} \\ (~5.0~\pm 1.4~)~\% \\ (~1.45\pm 0.31)~\% \\ (~6.7~\pm 1.4~)~\% \\ (~4.2~\pm 1.4~)~\% \\ (~4.2~\pm 1.4~)~\% \\ (~4.2~\pm 1.4~)~\% \\ (~4.2~\pm 0.9~)~\% \\ (~3.1~\pm 1.1~)~\% \\ (~4.2~\pm 0.9~)~\% \\ (~5~\pm 5~) \times 10^{-3} \\ < & 5 & \times 10^{-3} \\ (~1.02\pm 0.27)~\% \\ (~7.7~\pm 3.3~) \times 10^{-3} \\ \end{array} $ $\begin{array}{c} \textbf{Pionic modes} \\ (~2.5~\pm 0.7~) \times 10^{-3} \\ (~3.2~\pm 0.6~) \times 10^{-3} \\ < & 1.4 & \times 10^{-8} \\ \end{array}$	CL=90% CL=90% CL=90% CL=90% CL=90%	328 199 712 423 423 423 423 423 423 487 390 382 368 65 687 687 688 616 614 614 461 642 242	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	(2.3 ±1.0 < 1.5 < 2 (4.2 ±0.5 (3.0 ±1.4 (2.6 ±1.1) bo suppressed (Dieutral current (CiF) or Lepton numl (6.5 ±2.6 < 6 < 1.9 < 1.5 < 1.3 < 6.6 < 1.8 < 5.6 (tt) < 4.8 (tt) < 3.2 (gg) < 3.8 < 3.3 < 3.3 < 3.4 < 3.4 < 4.8 < 2.2 < 3.7 < 5.6 < 9.1 < 5.6 < 9.1 < 3.2) % % × 10 ⁻³) × 10 ⁻³) % × 10 ⁻³) % C) modes, ober (L) viola 1) modes, ober (L) viola 1) × 10 ⁻⁴ × 10 ⁻⁴ × 10 ⁻⁴ × 10 ⁻⁵ × 10 ⁻⁵ × 10 ⁻⁵ × 10 ⁻³ × 10 ⁻⁴	CL=90% or ating modes CL=90%	268 565 610 611 273 845 681 712 5507 929 917 759 869 926 926 926 926 927 929 917 926 928 929 917 929 940 950 950 950 950 950 950 950 950 950 95
$\begin{array}{l} \overline{K^0} a_2(1320)^+ \\ \overline{K^*}(892)^0 \pi^+ \\ \overline{K^*}(892)^0 \rho^+ \text{total} \\ \overline{K^*}(892)^0 \rho^+ \text{total} \\ \overline{K^*}(892)^0 \rho^+ \text{D-wave} \\ \overline{K^*}(892)^0 \rho^+ \text{D-wave} \\ \overline{K^*}(892)^0 \rho^+ \text{D-wave longitudinal} \\ \overline{K_1}(1270)^0 \pi^+ \\ \overline{K_1}(1400)^0 \pi^+ \\ \overline{K^*}(1410)^0 \pi^+ \\ \overline{K^*}(1680)^0 \pi^+ \\ \overline{K^*}(1680)^0 \pi^+ \\ \overline{K^*}(892)^0 \pi^+ \pi^0 \text{3-body} \\ \overline{K^*}(892)^0 \pi^+ \pi^0 \text{3-body} \\ \overline{K^*}(892)^0 \pi^+ \pi^0 \text{3-body} \\ \overline{K^*}(992)^0 \pi^+ \pi^0 \text{3-body} \\ \overline{K^0} \rho^0 \pi^+ \text{3-body} \\ \overline{K^0} f_0(980) \pi^+ \\ \overline{K^*}(892)^0 \rho^0 \pi^+ \\ \overline{K^*}(892)^0 \rho^0 \pi^+ \\ \end{array}$	$ \begin{array}{c cccc} (~8.1~\pm 1.7~)~\% \\ < & 3 & \times 10^{-3} \\ (~1.92\pm 0.19)~\% \\ (~2.1~\pm 1.4~)~\% \\ [ss] & (~1.7~\pm 1.6~)~\% \\ < & 1 & \times 10^{-3} \\ (~10~\pm 7~) \times 10^{-3} \\ < & 7 & \times 10^{-3} \\ \end{array} \\ < & 7 & \times 10^{-3} \\ (~5.0~\pm 1.3~)~\% \\ < & 7 & \times 10^{-3} \\ (~5.0~\pm 1.3~)~\% \\ < & 7 & \times 10^{-3} \\ (~5.0~\pm 1.3~)~\% \\ < & 7 & \times 10^{-3} \\ (~5.0~\pm 1.4~)~\% \\ (~1.45\pm 0.31)~\% \\ (~6.7~\pm 1.4~)~\% \\ (~4.2~\pm 1.4~)~\% \\ (~4.2~\pm 1.4~)~\% \\ (~4.2~\pm 1.4~)~\% \\ (~4.2~\pm 0.9~)~\% \\ (~3.1~\pm 1.1~)~\% \\ (~4.2~\pm 0.9~)~\% \\ (~5~\pm 5~) \times 10^{-3} \\ < & 5 & \times 10^{-3} \\ (~1.02\pm 0.27)~\% \\ (~7.7~\pm 3.3~) \times 10^{-3} \\ \end{array} $ $\begin{array}{c} \textbf{Pionic modes} \\ (~2.5~\pm 0.7~) \times 10^{-3} \\ (~3.2~\pm 0.6~) \times 10^{-3} \\ < & 1.4 & \times 10^{-8} \\ \end{array}$	CL=90% CL=90% CL=90% CL=90% CL=90%	328 199 712 423 423 423 423 423 423 487 390 382 368 65 687 687 688 616 614 614 461 642 242	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	(2.3 ±1.0 < 1.5 < 2 (4.2 ±0.5 (3.0 ±1.4 (2.6 ±1.1) bo suppressed (Dieutral current (CiF) or Lepton numl (6.5 ±2.6 < 6 < 1.9 < 1.5 < 1.3 < 6.6 < 1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (1.8 < 5.6 (5.6 (5.6 (5.8)))))))))))))))))))) % % × 10 ⁻³) × 10 ⁻³) % C) modes, 0 ber (L) viola × 10 ⁻⁴ × 10 ⁻⁴ × 10 ⁻⁴ × 10 ⁻⁵ × 10 ⁻⁵ × 10 ⁻⁵ × 10 ⁻³	CL=90% pr ating modes CL=90%	268 565 610 611 273 845 681 712 929 917 759 886 926 926 926 929 917 926 759 866

					MESON	Sullilli	ary ro	able
				$K^-\pi^+\pi^+\pi^-$	[] / 7.5			
D^0	$I(J^P) = \frac{1}{2}(0^-)$			$K^-\pi^+\rho^0$ total		±0.4)%	S=1.1	812
	1.05 May (6. 1.1)			$\kappa = \pi^+ \rho^- \text{total}$ $\kappa^- \pi^+ \rho^0 3\text{-body}$		±0.4)%		612
	$\pm 0.5 \text{ MeV} (S = 1.1)$	z [mi]		$\frac{\kappa}{K}$ *(892) ⁰ ρ ⁰		± 2.1) $\times 10^{-3}$		612
	$21 \times 10^{10} \ h \ s^{-1}$, CL = 90%	/ ₀ [aa]		$\times B(\overline{K^{*0}} \to K^{-}\pi^{+})$	(9.8	$\pm 2.2 \times 10^{-3}$		418
$m_{D^{\pm}}^{1} - m_{D^{0}}^{2} = 4$				$K^-a_1(1260)^+$	(3 6	±0.6)%		227
Mean life $ au=$ (0.	$415 \pm 0.004) imes 10^{-12} ext{ s}$			$\times B(a_1(1260)^+ \rightarrow \pi$	++ \ (3.0	±0.6) %		327
$c au = 124.4~\mu$				$\overline{K}^*(892)^0 \pi^+ \pi^- \text{total}$		104)0/		600
$ \Gamma_{00} - \Gamma_{00} /\Gamma_{00}$	< 0.17, CL $= 90%$ [uu]			$\times B(\overline{K}^{*0} \to K^{-}\pi^{+})$	(1.5	±0.4)%		683
	+ - (-t- - 70))			$\overline{K}^*(892)^0 \pi^+ \pi^- 3$ -body	(0.5			
$\frac{\Gamma(K - \pi + \text{or } K - \pi)}{\Gamma(K - \pi + \text{or } K - \pi)}$	$\frac{+\pi^{-}(\text{via}\overline{D}^{0}))}{+\pi^{+}\pi^{-})}$ < 0.0037, CL =	= 90%		$\times B(\overline{K}^{*0} \to K^-\pi^+)$	(9.5	$\pm 2.1) \times 10^{-3}$		683
	$\Gamma(\mu^{+}X) < 0.0056$, CL = 90			\times B($K^{+0} \rightarrow K \pi^{+}$) $K_1(1270)^{-}\pi^{+}$				
, , , , , , , , , , , , , , , , ,	. ,	J /0		1 /		± 1.0) $\times 10^{-3}$		483
CP-violation decay-ra	te asymmetries			$\times B(K_1(1270)^- \to K^-)$		= /		
$A_{CP}(K^+K^-) = 0$	0.06 ± 0.05			$\frac{K^-\pi^+\pi^+\pi^-}{K^0\pi^+\pi^-\pi^0}$ nonresonant		5±0.25) %		812
$A_{CP}(K_S^0\phi) = -0$	0.03 ± 0.09			$\overline{K}^0 \eta \times B(\eta \to \pi^+ \pi^- \pi^0)$	[rr] (10.0			812
$A_{CP}(K_S^{0}\pi^{0}) = -$	0.018 ± 0.030			$\overline{K}^0\omega \times B(\omega \to \pi^+\pi^-\pi^0)$	(1.6	± 0.3) $\times 10^{-3}$		772
						±0.4)%		670
$\overline{D}{}^{0}$ modes are charge con	jugates of the modes below.			$egin{array}{ccc} {\cal K}^*(892)^- ho^+ \ imes {\cal B}({\cal K}^{*-} ightarrow \ \overline{\cal K}^0\pi^-) \end{array}$	(4.0	±1.6)%		422
	:	Scale factor/	p	$\overline{K}^*(892)^0 \rho^0$	(
D ⁰ DECAY MODES	Fraction (Γ_i/Γ) Cor	fidence level	(MeV/c)	$\times B(\overline{K}^{*0} \to \overline{K}^0 \pi^0)$	(4.9	$\pm 1.1) \times 10^{-3}$		418
				$K_1(1270)^-\pi^+$	[44] (5.1	114 \10=3		400
4	Inclusive modes			$\begin{array}{c} K_1(1270) & \pi \\ \times \ B(K_1(1270)^- \to \ \overline{K}{}^0\pi \end{array}$	[ss] (5.1 0\	± 1.4) × 10 ⁻³		483
e ⁺ anything	(7.7 ±1.2) %	S=1.1	_	$\overline{K}^*(892)^0 \pi^+ \pi^- 3$ -body				
μ^+ anything	[vv] (6.8 ±1.0)%			$\times B(\overline{K}^{*0} \rightarrow \overline{K}^{0}\pi^{0})$	(4.7	$\pm 1.1) \times 10^{-3}$		683
K ⁻ anything	(53 ±4)%	S=1.3	-	$\overline{K}^0\pi^+\pi^-\pi^0$ nonresonant				
\overline{K}^0 anything $+ K^0$ anything	(42 ± 5) %		_	$\kappa^-\pi^+\pi^-\pi^-$ nonresonant $\kappa^-\pi^+\pi^0\pi^0$		±2.1) %		812
\mathcal{K}^+ anything	$(3.4 \begin{array}{c} +0.6 \\ -0.4 \end{array})\%$		_	$K - \pi + \pi^{0} \pi^{0}$ $K - \pi + \pi + \pi^{-} \pi^{0}$		±5)%		815
η anything	[00] < 13 %	CL=90%	_	$K = \frac{\pi}{K} \pi^{+} \pi^{-} \pi^{0}$	•	±0.4)%		771
,, anything	[00] < 13	CL_3070		$\times B(\overline{K}^{*0} \to K^{-}\pi^{+})$	(1.2	\pm 0.6)%		641
9	Semileptonic modes							
$\mathcal{K}^-\ell^+ u_\ell$	[pp] (3.48 ± 0.16) %	S=1.1	867	$\overline{\mathcal{K}}^*(892)^0 \eta \times B(\overline{\mathcal{K}}^{*0} \to \mathcal{K}^- \pi^+)$	(3.0	$\pm 0.8) \times 10^{-3}$		580
$\mathcal{K}^-e^{\overset{.}{+}} u_e$	(3.64 ± 0.20) %	S=1.1	867	$\times B(K^{*0} \rightarrow K \pi^{+})$				
$\mathcal{K}^-\mu^+ u_\mu$	(3.23±0.19) %		863	$\times B(\eta \to \pi^+\pi^-\pi^0)$. 0\			
$K^{-}\pi^{0}e^{+}\nu_{e}$	$(1.6^{+1.3}_{-0.5})\%$		861	$K^-\pi^+\omega \times B(\omega \to \pi^+\pi^-)$, ,	±0.5)%		605
· ·	•.•		001	$\overline{K}^*(892)^0\omega$	(7	± 3) × 10 ⁻³		406
$\overline{\mathcal{K}}{}^0\pi^-e^+ u_e$	$(2.8 \begin{array}{c} +1.7 \\ -0.9 \end{array})\%$		860	$\times B(\overline{K}^{*0} \to K^-\pi^+)$				
$\overline{K}^*(892)^- e^+ \nu$	(1.34±0.22) %		719	$\frac{\times B(\omega \to \pi^+\pi^-\pi^0)}{\overline{K}^0\pi^+\pi^+\pi^-\pi^-}$				
$\overline{\mathcal{K}}^*(892)^-e^+ u_e imes \mathbb{K}^0\pi^-)$	(1.5410.22) //		117		,	± 1.6) × 10 ⁻³		768
$K^-\pi^+\pi^-\mu^+\nu_\mu$	$< 1.2 \times 10^{-3}$	CL=90%	821	$\overline{K}{}^{0}\pi^{+}\pi^{-}\pi^{0}\pi^{0}(\pi^{0})$	(10.6	+7.3 -3.0) %		771
$(\overline{K}^*(892)\pi)^-\mu^+\nu_{\mu}$	< 1.4 × 10 ⁻³	CL=90%	693	$\overline{\mathcal{K}}{}^0\mathcal{K}^+\mathcal{K}^-$	(9.3	± 1.0) $\times 10^{-3}$		544
, , , , , ,		CL = 90 /6	093	$\overline{K}^0 \phi \times B(\phi \rightarrow K^+ K^-)$		± 0.5) $\times 10^{-3}$		520
$\pi^- e^+ u_e$	$(3.8 \begin{array}{c} +1.2 \\ -1.0 \end{array}) \times 10^{-3}$		927	$\overline{K}^0 K^+ K^- \text{non-}\phi$		± 0.8) $\times 10^{-3}$		544
				$K_S^0 K_S^0 K_S^0$		± 2.3) $\times 10^{-4}$		538
A fraction of the following	resonance mode has already appear	ared above as		$\kappa^+\kappa^-\kappa^-\pi^+$		± 0.5) $\times 10^{-4}$		434
a submode of a charged-p	article mode.			$K^+K^-\overline{K}^0\pi^0$				
$K^*(892)^- e^+ \nu_e$	(2.01 ± 0.33) %		719	$\kappa \cdot \kappa \cdot \kappa^* \pi^*$	(7.2	$^{+4.8}_{-3.5}$) \times 10 ⁻³		435
Lladvania	modes with a \overline{K} or $\overline{K}K\overline{K}$							
$K^-\pi^+$	(3.83±0.12) %		861	Fractions of many of the				
$\frac{\kappa}{K^0}$ π^0	(2.11±0.21) %	S=1.1	860	appeared above as submod for which there are only up				
$\frac{\kappa}{K^0}$ π^+ π^-	[rr] (5.4 ±0.4) %	S=1.1	842	below.)	per minits and A	(692) p submodes	only appear	
$\overline{K}^0 \rho^0$	(1.20±0.17) %	J-1.2	676	$\overline{\mathcal{K}}{}^0\eta$	(70	±1.0) $\times10^{-3}$		772
$\overline{K}^0 f_0(980)$	$(3.0 \pm 0.8) \times 10^{-3}$		549	$\frac{\kappa}{\kappa}$ $_{\rho}^{\eta}$ 0		±1.0) × 10 ° ° ° ° ° ° ° ° ° ° ° ° ° ° ° ° ° °		676
$\times B(f_0 \rightarrow \pi^+\pi^-)$	(2 20.0) 10		,	$\kappa^{\rho}_{\kappa^{-}\rho^{+}}$		±1.0) %	S=1.2	678
$\overline{K}^0 f_2(1270)$	$(2.3 \pm 0.9) \times 10^{-3}$		263	$\frac{\kappa}{\kappa}$ 0 ω	•	±0.4)%	3-1.2	670
$\times B(f_2 \rightarrow \pi^+\pi^-)$, J. , J.			$\frac{\kappa}{\kappa^0} \frac{\omega}{\eta'}$ (958)		±0.4) % 0±0.26) %		565
$\overline{K}^0 f_0(1370)$	(4.3 ± 1.3) $\times 10^{-3}$		_	$\frac{K}{K^0} f_0(980)$,	± 1.6) × 10^{-3}		549
$\times B(f_0 \rightarrow \pi^+\pi^-)$	(, ,			$\frac{\kappa}{\kappa^0} \phi$		± 1.0) × 10^{-3}		520
$K^*(892)^-\pi^+$	$(3.3 \pm 0.3)\%$		711	$K^{-}a_{1}(1260)^{+}$	•	±1.1) %		327
$\times B(K^{*-} \to \overline{K}{}^0\pi^-)$	(0.0 ±0.0) /0			$\frac{K}{K^0} a_1(1260)^0$	< 1.9	±1.1) % %	CL=90%	322
$K_0^*(1430)^-\pi^+$	$(6.4 \pm 1.6) \times 10^{-3}$		364	$\frac{K}{K^0} f_2(1270)$		± 1.5) $\times 10^{-3}$	CL=90%	263
\times B($K_0^*(1430)^- \rightarrow \overline{K}^0$				$\frac{K^0}{K^0} f_0(1370)$		± 2.1) × 10 ⁻³		203
$\frac{1}{K^0}\pi^+\pi^-$ nonresonant			040	$K^{-}a_{2}(1320)^{+}$	< 2	× 10 ⁻³	CL=90%	197
$K^-\pi^+\pi^0$	(1.46±0.24) %	C1 2	842	$K^*(892)^-\pi^+$				
$\kappa \pi \pi^{-} \pi^{-}$ $\kappa^{-} \rho^{+}$	[rr] $(13.9 \pm 0.9)\%$	S=1.3	844	$\frac{K}{K}$ *(892) ⁰ π ⁰		±0.4)%	S=1.2	711
$K^*(892)^-\pi^+$	(10.8 ±1.0) %		678	$\frac{K}{K}$ *(892) ⁰ $\pi^+ \pi^-$ total	•	±0.4)%		709
$\times B(K^{*-} \rightarrow K^-\pi^0)$	(1.7 ±0.2)%		711	$\frac{K^{*}(892)^{\circ}\pi^{+}\pi^{-}\text{total}}{K^{*}(892)^{0}\pi^{+}\pi^{-}3\text{-body}}$		±0.5)%		683
$\frac{\times B(K^{*} \rightarrow K \pi^{0})}{\overline{K}^{*}(892)^{0}\pi^{0}}$	(21 102) 9/		700	$K^-\pi^+\rho^0$ total		2±0.32) %		683
$\times B(\overline{K}^{*0} \rightarrow K^{-}\pi^{+})$	$(2.1 \pm 0.3)\%$		709	$K^-\pi^+\rho^0$ 3-body		± 0.4) % ± 2.1) $\times 10^{-3}$		612
$K^-\pi^+\pi^0$ nonresonant	(60 105)		044	$\frac{K}{K}*(892)^{0} \rho^{0}$				612
$K = \pi^+ \pi^0$ nonresonant $K^0 \pi^0 \pi^0$	$(6.9 \pm 2.5) \times 10^{-3}$		844	$K^*(892)^0 \rho^0$ transverse		7±0.33) %		418
$\overline{K}^{\circ}\pi^{\circ}\pi^{\circ}$ $\overline{K}^{*}(892)^{0}\pi^{0}$	(10 100) 0/		843			±0.5)%		418
$\times B(\overline{K}^{*0} \rightarrow \overline{K}^{0}\pi^{0})$	$(1.0 \pm 0.2)\%$		709	$\overline{K}^*(892)^0 \rho^0 S$ -wave $\overline{K}^*(892)^0 \rho^0 S$ -wave long.		±0.6)%	CI 000/	418
$K^0\pi^0\pi^0$ nonresonant	(70 100)		040	$K^*(892)^0 \rho^0 S$ -wave long. $K^*(892)^0 \rho^0 P$ -wave	< 3	$^{\times 10^{-3}}_{\times 10^{-3}}$	CL=90%	418
A A Homesonant	$(7.8 \pm 2.0) \times 10^{-3}$		843	$\overline{K}^*(892)^0 \rho^0 D$ -wave	< 3		CL=90%	418
				N (032) p D-wave	(1.9	±0.6)%		418

$K^*(892)^- \rho^+$		
	(6.0 ± 2.4) %	422
$\dot{K}^*(892)^- \rho^+$ longitudinal	(2.9 ±1.2) %	422
$K^*(892)^- ho^+$ longitudinal $K^*(892)^- ho^+$ transverse	(3.2 ±1.8) %	422
$K^*(892)^{-}\rho^{+}P$ -wave	< 1.5 % CL=9	
$K^-\pi^+ f_0(980)$	< 1.1 % CL=9	
$\overline{K}^*(892)^0 f_0(980)$	< 7 × 10 ⁻³ CL=9	
$K_1(1270)^- \pi^+$	[ss] (1.06±0.29) %	483
$K_1(1270)^{-\pi}$		
$\frac{K_1(1400)}{K_1(1400)^0} \pi^0$	< 1.2 % CL=9	
	< 3.7 % CL=9	
$K^*(1410)^-\pi^+$	< 1.2 % CL=9	
$K_0^*(1430)^-\pi^+$	(1.04±0.26) %	364
$K_2^*(1430)^-\pi^+$	$< 8 \times 10^{-3} \text{ CL} = 9$	0% 367
$\overline{K}_{2}^{*}(1430)^{0}\pi^{0}$	$< 4 \times 10^{-3} \text{ CL}=9$	0% 363
$\overline{K}^*(892)^0 \pi^+ \pi^- \pi^0$	$(1.8 \pm 0.9)\%$	641
$\vec{K}^*(892)^0 \eta$	(1.9 ±0.5) %	580
$K^-\pi^+\omega$	(3.0 ±0.6) %	605
$\overline{K}^*(892)^0 \omega$	(1.1 ±0.4) %	406
$K^-\pi^+\eta'(958)$	$(7.0 \pm 1.8) \times 10^{-3}$	479
$\overline{\mathcal{K}}^*(892)^0 \eta'(958)$	$< 1.1 \times 10^{-3} \text{ CL}=9$	0% 99
	Pionic modes	
$\pi^+\pi^-$	$(1.52\pm0.11)\times10^{-3}$	922
$\pi^{0}\pi^{0}$	$(8.4 \pm 2.2) \times 10^{-4}$	922
$\pi^{+}\pi^{-}\pi^{0}$		2.7 907
$\pi^{+}\pi^{+}\pi^{-}\pi^{-}$	$(7.4 \pm 0.6) \times 10^{-3}$	879
$\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0}$	(1.9 ±0.4)%	844
$\pi^{+}\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{-}\pi^{-}$	$(4.0 \pm 3.0) \times 10^{-4}$	795
A A A A A A	(4.0 13.0) × 10	133
Hadronic	modes with a $K\overline{K}$ pair	
K ⁺ K ⁻	$(4.33\pm0.27)\times10^{-3}$	791
$K^0\overline{K}^0$	$(1.3 \pm 0.4) \times 10^{-3}$	788
$K^{0}K^{-}\pi^{+}$		1.1 739
K*(892)0 K0		
$\overline{K}^*(892)^0 K^0$	$(6.4 \pm 1.0) \times 10^{-3}$ S= $< 1.1 \times 10^{-3}$ CL=9	
$\stackrel{\cdot}{\times} B(\stackrel{\leftarrow}{K}^{*0} \rightarrow K^-\pi^+)$	$< 1.1 \times 10^{-3} \text{ CL}=9$	0% 605
$\overset{\checkmark}{\mathcal{K}}$ B($\overset{\checkmark}{\mathcal{K}}^{*0} \rightarrow \mathcal{K}^{-}\pi^{+}$) \mathcal{K}^{*} (892) $^{+}\mathcal{K}^{-}$	$(6.4 \pm 1.0) \times 10^{-3}$ S= $< 1.1 \times 10^{-3}$ CL=9 $(2.3 \pm 0.5) \times 10^{-3}$	
$ \overset{\cdot}{K} \overset{\cdot}{(K^{*0 \to K^{-}\pi^{+})}} \\ K^{*}(892)^{+} \overset{\cdot}{K^{-}} \\ \times B(K^{*+} \to K^{0}\pi^{+}) $	$< 1.1 \times 10^{-3} CL=9$ $(2.3 \pm 0.5) \times 10^{-3}$	0% 605 610
$ \begin{array}{ccc} \times & B(\overline{K}^{*0} \to K^{-}\pi^{+}) \\ K^{*}(892)^{+}K^{-} \\ \times & B(K^{*+} \to K^{0}\pi^{+}) \\ K^{0}K^{-}\pi^{+} \text{nonresonant} \end{array} $	< 1.1 $\times 10^{-3}$ CL=9 (2.3 ±0.5)×10 ⁻³ (2.3 ±2.3)×10 ⁻³	0% 605 610 739
$\begin{array}{l} \stackrel{\times}{\times} B(\overline{K}^{*0} \to K^{-}\pi^{+}) \\ K^{*}(892)^{+}K^{-} \\ \times B(K^{*+} \to K^{0}\pi^{+}) \\ K^{0}K^{-}\pi^{+} \text{nonresonant} \\ \overline{K}^{0}K^{+}\pi^{-} \end{array}$	< 1.1 $\times 10^{-3}$ CL=9 (2.3 ±0.5)×10 ⁻³ (2.3 ±2.3)×10 ⁻³ (4.9 ±1.0)×10 ⁻³	0% 605 610 739 739
$\begin{array}{c} \times \ B(\overline{K}^{*0} \to K^{-}\pi^{+}) \\ K^{*}(892)^{+}K^{-} \\ \times \ B(K^{*+} \to K^{0}\pi^{+}) \\ K^{0}K^{-}\pi^{+} \text{ nonresonant} \\ \overline{K}^{0}K^{+}\pi^{-} \\ K^{*}(892)^{0}\overline{K}^{0} \end{array}$	< 1.1 $\times 10^{-3}$ CL=9 (2.3 ±0.5)×10 ⁻³ (2.3 ±2.3)×10 ⁻³	0% 605 610 739 739
$ \stackrel{\times}{K} B(\overline{K}^{*0} \to K^{-}\pi^{+}) $ $ K^{*}(892)^{+}K^{-} $ $ \stackrel{\times}{K} B(K^{*+} \to K^{0}\pi^{+}) $ $ \stackrel{K^{0}}{K^{-}\pi^{+}} \text{ nonresonant} $ $ \stackrel{K^{0}}{K^{0}} K^{+}\pi^{-} $ $ K^{*}(892)^{0} \overline{K}^{0} $ $ \stackrel{\times}{K} B(K^{*0} \to K^{+}\pi^{-}) $	< 1.1 $\times 10^{-3}$ CL=9 (2.3 ±0.5)×10 ⁻³ (2.3 ±2.3)×10 ⁻³ (4.9 ±1.0)×10 ⁻³ < 5 $\times 10^{-4}$ CL=9	0% 605 610 739 739 0% 605
$\begin{array}{c} \stackrel{\times}{\times} B(\overline{K}^{*0} \to K^-\pi^+) \\ K^*(892)^+K^- \\ \times B(K^{*+} \to K^0\pi^+) \\ K^0K^-\pi^+ \text{ nonresonant} \\ \overline{K}^0K^+\pi^- \\ K^*(892)^0\overline{K}^0 \\ \times B(K^{*0} \to K^+\pi^-) \\ K^*(892)^-K^+ \end{array}$	< 1.1 $\times 10^{-3}$ CL=9 (2.3 ±0.5)×10 ⁻³ (2.3 ±2.3)×10 ⁻³ (4.9 ±1.0)×10 ⁻³	0% 605 610 739 739
$ \stackrel{\times}{K} B(\overline{K}^{*0} \to K^{-}\pi^{+}) $ $ K^{*}(892)^{+}K^{-} $ $ \stackrel{\times}{K} B(K^{*+} \to K^{0}\pi^{+}) $ $ \stackrel{K^{0}}{K^{-}\pi^{+}} \text{ nonresonant} $ $ \stackrel{K^{0}}{K^{0}} K^{+}\pi^{-} $ $ K^{*}(892)^{0} \overline{K}^{0} $ $ \stackrel{\times}{K} B(K^{*0} \to K^{+}\pi^{-}) $	< 1.1 $\times 10^{-3}$ CL=9 (2.3 ±0.5)×10 ⁻³ (2.3 ±2.3)×10 ⁻³ (4.9 ±1.0)×10 ⁻³ < 5 $\times 10^{-4}$ CL=9	0% 605 610 739 739 0% 605
$\begin{array}{c} \stackrel{\times}{\times} B(\overline{K}^{*0} \to K^-\pi^+) \\ K^*(892)^+K^- \\ \times B(K^{*+} \to K^0\pi^+) \\ K^0K^-\pi^+ \text{nonresonant} \\ \overline{K}^0K^+\pi^- \\ K^*(892)^0\overline{K}^0 \\ \times B(K^{*0} \to K^+\pi^-) \\ K^*(892)^-K^+ \\ \times B(K^{*-} \to \overline{K}^0\pi^-) \end{array}$	<pre>< 1.1</pre>	0% 605 610 739 739 605 610
$\begin{array}{c} \stackrel{\times}{\times} B(\overline{K}^{*0} \to K^-\pi^+) \\ K^*(892)^+K^- \\ \times B(K^{*+} \to K^0\pi^+) \\ K^0K^-\pi^+ \text{ nonresonant} \\ \overline{K}^0K^+\pi^- \\ K^*(892)^0\overline{K}^0 \\ \times B(K^{*0} \to K^+\pi^-) \\ K^*(892)^-K^+ \\ \times B(K^{*-} \to \overline{K}^0\pi^-) \\ \overline{K}^0K^+\pi^- \text{ nonresonant} \end{array}$	<pre>< 1.1</pre>	0% 605 610 739 739 0% 605 610 739
$\begin{array}{l} \times \ B(\overline{K}^{*0} \to K^{-}\pi^{+}) \\ K^{*}(892)^{+}K^{-} \\ \times \ B(K^{*+} \to K^{0}\pi^{+}) \\ K^{0}K^{-}\pi^{+} \text{nonresonant} \\ \overline{K}^{0}K^{+}\pi^{-} \\ K^{*}(892)^{0}\overline{K}^{0} \\ \times \ B(K^{*0} \to K^{+}\pi^{-}) \\ K^{*}(892)^{-}K^{+} \\ \times \ B(K^{*-} \to \overline{K}^{0}\pi^{-}) \\ \overline{K}^{0}K^{+}\pi^{-} \text{nonresonant} \\ K^{+}K^{-}\pi^{+}\pi^{-} \end{array}$	<pre>< 1.1</pre>	0% 605 610 739 739 605 610 739 676
$\begin{array}{l} \stackrel{\times}{\times} B(\overline{K}^{*0} \rightarrow K^{-}\pi^{+}) \\ K^{*}(892)^{+}K^{-} \\ \times B(K^{*+} \rightarrow K^{0}\pi^{+}) \\ K^{0}K^{-}\pi^{+} \text{nonresonant} \\ \overline{K}^{0}K^{+}\pi^{-} \\ K^{*}(892)^{0}\overline{K}^{0} \\ \times B(K^{*0} \rightarrow K^{+}\pi^{-}) \\ K^{*}(892)^{-}K^{+} \\ \times B(K^{*-} \rightarrow \overline{K}^{0}\pi^{-}) \\ \overline{K}^{0}K^{+}\pi^{-} \text{nonresonant} \\ K^{+}K^{-}\pi^{+}\pi^{-} \\ \phi\pi^{+}\pi^{-} \times B(\phi \rightarrow K^{+}K^{-}) \end{array}$	<pre>< 1.1</pre>	0% 605 610 739 739 0% 605 610 739 676 614
$\begin{array}{l} \stackrel{\times}{\times} B(\overline{K}^{*0} \to K^-\pi^+) \\ K^*(892)^+K^- \\ \times B(K^{*+} \to K^0\pi^+) \\ K^0K^-\pi^+ \text{ nonresonant} \\ \overline{K}^0K^+\pi^- \\ K^*(892)^0\overline{K}^0 \\ \times B(K^{*0} \to K^+\pi^-) \\ K^*(892)^-K^+ \\ \times B(K^{*-} \to \overline{K}^0\pi^-) \\ \overline{K}^0K^+\pi^- \text{ nonresonant} \\ K^+K^-\pi^+\pi^- \\ \phi\pi^+\pi^- \times B(\phi \to K^+K^-) \\ \phi\rho^0 \times B(\phi \to K^+K^-) \end{array}$	<pre>< 1.1</pre>	0% 605 610 739 739 605 610 739 676 614 260
$\begin{array}{l} \stackrel{\times}{\times} B(\overline{K}^{*0} \to K^-\pi^+) \\ K^*(892)^+K^- \\ & \times B(K^{*+} \to K^0\pi^+) \\ K^0K^-\pi^+ \text{ nonresonant} \\ \overline{K}^0K^+\pi^- \\ K^*(892)^0\overline{K}^0 \\ & \times B(K^{*0} \to K^+\pi^-) \\ K^*(892)^-K^+ \\ & \times B(K^{*-} \to \overline{K}^0\pi^-) \\ \overline{K}^0K^+\pi^- \text{ nonresonant} \\ K^+K^-\pi^+\pi^- \\ \phi\pi^+\pi^- \times B(\phi \to K^+K^-) \\ \phi\rho^0 \times B(\phi \to K^+K^-) \\ K^+K^-\rho^0 \text{ 3-body} \end{array}$	<pre>< 1.1</pre>	0% 605 610 739 739 605 610 739 676 614 260 309
$\begin{array}{l} \stackrel{\times}{\times} B(\overline{K}^{*0} \to K^-\pi^+) \\ K^*(892)^+K^- \\ \times B(K^{*+} \to K^0\pi^+) \\ K^0K^-\pi^+ \text{nonresonant} \\ \overline{K}^0K^+\pi^- \\ K^*(892)^0\overline{K}^0 \\ \times B(K^{*0} \to K^+\pi^-) \\ K^*(892)^-K^+ \\ \times B(K^{*-} \to \overline{K}^0\pi^-) \\ \overline{K}^0K^+\pi^- \text{nonresonant} \\ K^+K^-\pi^+\pi^- \\ \phi\pi^+\pi^- \times B(\phi \to K^+K^-) \\ K^+K^-\rho^0 \text{3-body} \\ K^*(892)^0K^-\pi^+ \end{array}$	<pre>< 1.1</pre>	0% 605 610 739 739 605 610 739 676 614 260
$\begin{array}{l} \times \ B(\overline{K}^{*0} \to K^{-}\pi^{+}) \\ K^{*}(892)^{+}K^{-} \\ \times \ B(K^{*+} \to K^{0}\pi^{+}) \\ K^{0}K^{-}\pi^{+} \text{nonresonant} \\ \overline{K}^{0}K^{+}\pi^{-} \\ K^{*}(892)^{0}\overline{K}^{0} \\ \times \ B(K^{*0} \to K^{+}\pi^{-}) \\ K^{*}(892)^{-}K^{+} \\ \times \ B(K^{*-} \to \overline{K}^{0}\pi^{-}) \\ \overline{K}^{0}K^{+}\pi^{-} \text{nonresonant} \\ K^{+}K^{-}\pi^{+}\pi^{-} \\ \phi \pi^{+}\pi^{-} \times B(\phi \to K^{+}K^{-}) \\ K^{+}K^{-}\rho^{0} \times B(\phi \to K^{+}K^{-}) \\ K^{*}(892)^{0}K^{-}\pi^{+} \\ \times B(K^{*0} \to K^{+}\pi^{-}) \end{array}$	<pre>< 1.1</pre>	0% 605 610 739 739 605 610 739 676 614 260 309
$\begin{array}{l} \times \ B(\overline{K}^{*0} \to K^-\pi^+) \\ K^*(892)^+K^- \\ \times \ B(K^{*+} \to K^0\pi^+) \\ K^0K^-\pi^+ \text{nonresonant} \\ \overline{K}^0K^+\pi^- \\ K^*(892)^0\overline{K}^0 \\ \times \ B(K^{*0} \to K^+\pi^-) \\ K^*(892)^-K^+ \\ \times \ B(K^{*-} \to \overline{K}^0\pi^-) \\ \overline{K}^0K^+\pi^- \text{nonresonant} \\ K^+K^-\pi^+\pi^- \\ \phi\pi^+\pi^- \times \ B(\phi \to K^+K^-) \\ \phi\rho^0 \times \ B(\phi \to K^+K^-) \\ K^+K^-\rho^0 \text{ 3-body} \\ K^*(892)^0K^-\pi^+ \\ \times \ B(K^{*0} \to K^+\pi^-) \\ \overline{K}^*(892)^0K^+\pi^- \end{array}$	<pre>< 1.1</pre>	0% 605 610 739 739 605 610 739 676 614 260 309
$\begin{array}{l} \times \ B(\overline{K}^{*0} \to K^-\pi^+) \\ K^*(892)^+K^- \\ \times \ B(K^{*+} \to K^0\pi^+) \\ K^0K^-\pi^+ \text{ nonresonant} \\ \overline{K}^0K^+\pi^- \\ K^*(892)^0\overline{K}^0 \\ \times \ B(K^{*0} \to K^+\pi^-) \\ K^*(892)^-K^+ \\ \times \ B(K^{*-} \to \overline{K}^0\pi^-) \\ \overline{K}^0K^+\pi^- \text{ nonresonant} \\ K^+K^-\pi^+\pi^- \\ \phi\pi^+\pi^- \times \ B(\phi \to K^+K^-) \\ \phi\rho^0 \times \ B(\phi \to K^+K^-) \\ K^+K^-\rho^0 \text{ 3-body} \\ K^*(892)^0K^-\pi^+ \\ \times \ B(K^{*0} \to K^+\pi^-) \\ \overline{K}^*(892)^0K^+\pi^- \\ \times \ B(K^{*0} \to K^-\pi^+) \end{array}$	<pre>< 1.1</pre>	0% 605 610 739 739 0% 605 610 739 676 614 260 309 528
$\begin{array}{l} \times \ B(\overline{K}^{*0} \to K^-\pi^+) \\ K^*(892)^+K^- \\ \times \ B(K^{*+} \to K^0\pi^+) \\ K^0K^-\pi^+ \text{ nonresonant} \\ \overline{K}^0K^+\pi^- \\ K^*(892)^0\overline{K}^0 \\ \times \ B(K^{*0} \to K^+\pi^-) \\ K^*(892)^-K^+ \\ \times \ B(K^{*-} \to \overline{K}^0\pi^-) \\ \overline{K}^0K^+\pi^- \text{ nonresonant} \\ K^+K^-\pi^+\pi^- \\ \phi\pi^+\pi^- \times \ B(\phi \to K^+K^-) \\ \phi\rho^0 \times \ B(\phi \to K^+K^-) \\ K^+K^-\rho^0 \text{ 3-body} \\ K^*(892)^0K^-\pi^+ \\ \times \ B(K^{*0} \to K^+\pi^-) \\ \overline{K}^*(892)^0K^+\pi^- \\ \times \ B(\overline{K}^{*0} \to K^-\pi^+) \\ K^*(892)^0\overline{K}^*(892)^0 \end{array}$	<pre>< 1.1</pre>	0% 605 610 739 739 0% 605 610 739 676 614 260 309 528
$\begin{array}{l} \times \ B(\overline{K}^{*0} \to K^-\pi^+) \\ K^*(892)^+K^- \\ \times \ B(K^{*+} \to K^0\pi^+) \\ K^0K^-\pi^+ \text{ nonresonant} \\ \overline{K}^0K^+\pi^- \\ K^*(892)^0\overline{K}^0 \\ \times \ B(K^{*0} \to K^+\pi^-) \\ K^*(892)^-K^+ \\ \times \ B(K^{*-} \to \overline{K}^0\pi^-) \\ \overline{K}^0K^+\pi^- \text{ nonresonant} \\ K^+K^-\pi^+\pi^- \\ \phi\pi^+\pi^- \times \ B(\phi \to K^+K^-) \\ \phi\rho^0 \times \ B(\phi \to K^+K^-) \\ K^+K^-\rho^0 \text{ 3-body} \\ K^*(892)^0K^-\pi^+ \\ \times \ B(K^{*0} \to K^+\pi^-) \\ \overline{K}^*(892)^0K^+\pi^- \\ \times \ B(\overline{K}^{*0} \to K^-\pi^+) \\ K^*(892)^0\overline{K}^*(892)^0 \end{array}$	<pre>< 1.1</pre>	0% 605 610 739 739 605 610 739 676 614 260 309 528
$\begin{array}{c} \times \ B(\overline{K}^{*0} \to K^-\pi^+) \\ K^*(892)^+K^- \\ \times \ B(K^{*+} \to K^0\pi^+) \\ K^0K^-\pi^+ \text{ nonresonant} \\ \overline{K}^0K^+\pi^- \\ K^*(892)^0\overline{K}^0 \\ \times \ B(K^{*0} \to K^+\pi^-) \\ K^*(892)^-K^+ \\ \times \ B(K^{*-} \to \overline{K}^0\pi^-) \\ \overline{K}^0K^+\pi^- \text{ nonresonant} \\ K^+K^-\pi^+\pi^- \\ \phi\pi^+\pi^- \times \ B(\phi \to K^+K^-) \\ \phi\rho^0 \times \ B(\phi \to K^+K^-) \\ K^+K^-\rho^0 \text{ 3-body} \\ K^*(892)^0K^-\pi^+ \\ \times \ B(K^{*0} \to K^+\pi^-) \\ \overline{K}^*(892)^0K^+\pi^- \\ \times \ B(\overline{K}^{*0} \to K^-\pi^+) \\ K^*(892)^0\overline{K}^*(892)^0 \\ \times \ B^2(K^{*0} \to K^+\pi^-) \\ \end{array}$	<pre>< 1.1</pre>	0% 605 610 739 739 605 610 739 676 614 260 309 528
$\begin{array}{l} \times \ B(\overline{K}^{*0} \to K^{-}\pi^{+}) \\ K^{*}(892)^{+}K^{-} \\ \times \ B(K^{*+} \to K^{0}\pi^{+}) \\ K^{0}K^{-}\pi^{+} \text{nonresonant} \\ \overline{K}^{0}K^{+}\pi^{-} \\ K^{*}(892)^{0}\overline{K}^{0} \\ \times \ B(K^{*0} \to K^{+}\pi^{-}) \\ K^{*}(892)^{-}K^{+} \\ \times \ B(K^{*-} \to \overline{K}^{0}\pi^{-}) \\ \overline{K}^{0}K^{+}\pi^{-} \text{nonresonant} \\ K^{+}K^{-}\pi^{+}\pi^{-} \\ \phi \rho^{0} \times \ B(\phi \to K^{+}K^{-}) \\ K^{+}K^{-}\rho^{0} \times \ B(\phi \to K^{+}K^{-}) \\ K^{+}(892)^{0}K^{-}\pi^{+} \\ \times \ B(K^{*0} \to K^{+}\pi^{-}) \\ \overline{K}^{*}(892)^{0}K^{+}\pi^{-} \\ \times \ B(\overline{K}^{*0} \to K^{-}\pi^{+}) \\ K^{*}(892)^{0}\overline{K}^{*}(892)^{0} \\ \times \ B^{2}(K^{*0} \to K^{+}\pi^{-}) \\ K^{+}K^{-}\pi^{+}\pi^{-} \text{non-}\phi \end{array}$	<pre>< 1.1</pre>	0% 605 610 739 739 0% 605 610 739 676 614 260 309 528 528 257 676
$\begin{array}{l} \times \ B(\overline{K}^{*0} \to K^{-}\pi^{+}) \\ K^{*}(892)^{+}K^{-} \\ \times \ B(K^{*+} \to K^{0}\pi^{+}) \\ K^{0}K^{-}\pi^{+} \text{nonresonant} \\ \overline{K^{0}}K^{+}\pi^{-} \\ K^{*}(892)^{0}\overline{K^{0}} \\ \times \ B(K^{*0} \to K^{+}\pi^{-}) \\ K^{*}(892)^{-}K^{+} \\ \times \ B(K^{*-} \to \overline{K^{0}}\pi^{-}) \\ \overline{K^{0}}K^{+}\pi^{-} \text{nonresonant} \\ K^{+}K^{-}\pi^{+}\pi^{-} \\ \phi\pi^{+}\pi^{-} \times B(\phi \to K^{+}K^{-}) \\ \phi\rho^{0} \times B(\phi \to K^{+}K^{-}) \\ K^{+}K^{-}\rho^{0} \text{3-body} \\ K^{*}(892)^{0}K^{-}\pi^{+} \\ \times B(K^{*0} \to K^{+}\pi^{-}) \\ \overline{K^{*}}(892)^{0}K^{+}\pi^{-} \\ \times B(\overline{K^{*0}} \to K^{-}\pi^{+}) \\ K^{*}(892)^{0}\overline{K^{*}}(892)^{0} \\ \times B^{2}(K^{*0} \to K^{+}\pi^{-}) \\ K^{*}(892)^{0}\overline{K^{*}}(892)^{0} \\ \times B^{2}(K^{*0} \to K^{+}\pi^{-}) \\ K^{+}K^{-}\pi^{+}\pi^{-} \text{nonresonant} \end{array}$	<pre>< 1.1</pre>	0% 605 610 739 739 0% 605 610 739 676 614 260 309 528 528 257 676 676 676
$\begin{array}{l} \times \ B(\overline{K}^{*0} \to K^-\pi^+) \\ K^*(892)^+K^- \\ \times \ B(K^{*+} \to K^0\pi^+) \\ K^0K^-\pi^+ \text{nonresonant} \\ \overline{K}^0K^+\pi^- \\ K^*(892)^0\overline{K}^0 \\ \times \ B(K^{*0} \to K^+\pi^-) \\ K^*(892)^-K^+ \\ \times \ B(K^{*-} \to \overline{K}^0\pi^-) \\ \overline{K}^0K^+\pi^- \text{nonresonant} \\ K^+K^-\pi^+\pi^- \\ \phi\pi^+\pi^- \times B(\phi \to K^+K^-) \\ \phi\rho^0 \times B(\phi \to K^+K^-) \\ K^+K^-\rho^0 \text{ 3-body} \\ K^*(892)^0K^-\pi^+ \\ \times B(K^{*0} \to K^+\pi^-) \\ \overline{K}^*(892)^0K^-\pi^+ \\ \times B(K^{*0} \to K^-\pi^+) \\ K^*(892)^0\overline{K}^*(892)^0 \\ \times B^2(K^{*0} \to K^-\pi^+) \\ K^*(892)^0\overline{K}^*(892)^0 \\ \times B^2(K^{*0} \to K^+\pi^-) \\ K^+K^-\pi^+\pi^- \text{non-}\phi \\ K^+K^-\pi^+\pi^- \text{non-}\phi \\ K^+K^-\pi^+\pi^- \text{non-}\phi \\ K^0\overline{K}^0\pi^+\pi^- \end{array}$	<pre>< 1.1</pre>	0% 605 610 739 739 605 610 739 676 614 260 309 528 528 257 676 676 676 676
$\begin{array}{l} \times \ B(\overline{K}^{*0} \to K^{-}\pi^{+}) \\ K^{*}(892)^{+}K^{-} \\ \times \ B(K^{*+} \to K^{0}\pi^{+}) \\ K^{0}K^{-}\pi^{+} \text{nonresonant} \\ \overline{K^{0}}K^{+}\pi^{-} \\ K^{*}(892)^{0}\overline{K^{0}} \\ \times \ B(K^{*0} \to K^{+}\pi^{-}) \\ K^{*}(892)^{-}K^{+} \\ \times \ B(K^{*-} \to \overline{K^{0}}\pi^{-}) \\ \overline{K^{0}}K^{+}\pi^{-} \text{nonresonant} \\ K^{+}K^{-}\pi^{+}\pi^{-} \\ \phi\pi^{+}\pi^{-} \times B(\phi \to K^{+}K^{-}) \\ \phi\rho^{0} \times B(\phi \to K^{+}K^{-}) \\ K^{+}K^{-}\rho^{0} \text{3-body} \\ K^{*}(892)^{0}K^{-}\pi^{+} \\ \times B(K^{*0} \to K^{+}\pi^{-}) \\ \overline{K^{*}}(892)^{0}K^{+}\pi^{-} \\ \times B(\overline{K^{*0}} \to K^{-}\pi^{+}) \\ K^{*}(892)^{0}\overline{K^{*}}(892)^{0} \\ \times B^{2}(K^{*0} \to K^{+}\pi^{-}) \\ K^{*}(892)^{0}\overline{K^{*}}(892)^{0} \\ \times B^{2}(K^{*0} \to K^{+}\pi^{-}) \\ K^{+}K^{-}\pi^{+}\pi^{-} \text{nonresonant} \end{array}$	<pre>< 1.1</pre>	0% 605 610 739 739 0% 605 610 739 676 614 260 309 528 528 257 676 676 676

Fractions of most of the following modes with resonances have already

		,		
$\overline{K}^*(892)^0 K^0$	< 1.6	$\times 10^{-3}$	CL=90%	605
$K^*(892)^+K^-$	(3.5 ±0.	$8) \times 10^{-3}$		610
$K^*(892)^0 \overline{K}^0$	< 8	\times 10 ⁻⁴	CL=90%	605
$K^*(892)^-K^+$	(1.8 ± 1 .	$0) \times 10^{-3}$		610
$\phi \pi^0$	< 1.4	\times 10 ⁻³	CL=90%	644
$\phi\eta$	< 2.8	$\times 10^{-3}$	CL=90%	489
$\phi \omega$	< 2.1	\times 10 ⁻³	CL=90%	239
$\phi \pi^+ \pi^-$	$(1.07 \pm 0.$	$(29) \times 10^{-3}$		614
$\phi \rho^0$	(1.07 ± 0.00)	$(29) \times 10^{-3}$		260
$\phi\pi^+\pi^-$ 3-body	< 5	\times 10 ⁻⁴	CL=90%	614
$K^*(892)^0 K^- \pi^+$	(3.2 ± 1	$3) \times 10^{-3}$		528
$\overline{K}^*(892)^0 K^+ \pi^-$	$(1.7 \pm 1.$	$(2) \times 10^{-3}$		528
$K^*(892)^0\overline{K}^*(892)^0$	$(1.4 \pm 0.$	$(5) \times 10^{-3}$		257

Doubly Cabibbo suppressed (DC) modes, $\Delta C = 2$ forbidden via mixing (C2M) modes, $\Delta C = 1$ weak neutral current (C1) modes, or Lepton Family number (LF) violating modes

$K^+\pi^-$	DC	(2.9	± 1.4) $\times 10^{-4}$		861
$K^+\pi^-$ (via $\overline{D}{}^0$)	C2M	<		× 10 ⁻⁴	CL=90%	861
$K^{+}\pi^{-}\pi^{+}\pi^{-}$	DC	<	1.4	$\times 10^{-3}$	CL=90%	812
$K^+\pi^-\pi^+\pi^-$ (via $\overline{D}{}^0$)	C2M	<	4	× 10 ⁻⁴	CL=90%	812
μ^- anything (via $\overline{D}{}^0$)	C2M	<	4	× 10 ⁻⁴	CL=90%	_
e^+e^-	C1	<	1.3	$\times 10^{-5}$	CL=90%	932
$\mu^{+}\mu^{-}$	C1	<	7.6	\times 10 ⁻⁶	CL=90%	926
$\pi^0 e^+ e^-$	C1	<	4.5	\times 10 ⁻⁵	CL=90%	927
$\pi^{0} \mu^{+} \mu^{-}$	C1	<	1.8	$\times 10^{-4}$	CL=90%	915
$\eta e^+ e^-$	C1	<	1.1	× 10 ⁻⁴	CL=90%	852
$\eta \mu^+ \mu^-$	C1	<	5.3	$\times 10^{-4}$	CL=90%	838
$ ho^0 e^+ e^-$	C1	<	1.0	× 10 ⁻⁴	CL=90%	773
$\rho^0 \mu^+ \mu^-$	C1	<	2.3	$\times 10^{-4}$	CL=90%	756
ωe^+e^-	C1	<	1.8	$\times 10^{-4}$	CL=90%	768
$\omega \mu^+ \mu^-$	C1	<	8.3	$\times 10^{-4}$	CL=90%	751
φe ⁺ e ⁻	C1	<	5.2	\times 10 ⁻⁵	CL=90%	654
$\phi \mu^+ \mu^-$	C1	<	4.1	× 10 ⁻⁴	CL=90%	631
$\overline{K}^0 e^+ e^-$		[tt] <	1.1	\times 10 ⁻⁴	CL=90%	866
$\overline{K}{}^0\mu^+\mu^-$		[tt]	2.6	\times 10 ⁻⁴	CL=90%	852
$\overline{K}^*(892)^0 e^+ e^-$		[tt] <	1.4	$\times 10^{-4}$	CL=90%	717
$\overline{K}^*(892)^0 \mu^+ \mu^-$		[tt] <	1.18	× 10 ⁻³	CL=90%	698
$\pi^{+}\pi^{-}\pi^{0}\mu^{+}\mu^{-}$	C1	<	8.1	× 10 ⁻⁴	CL=90%	863
$\mu^{\pm} e^{\mp}$	LF	[gg] <	1.9	× 10 ⁻⁵	CL=90%	929
$\pi^0e^\pm\mu^\mp$	LF	[gg] <	8.6	× 10 ⁻⁵	CL=90%	924
$\eta e^{\pm} \mu^{\mp}$	LF	[gg] <	1.0	× 10 ⁻⁴	CL=90%	848
$ ho^0e^\pm\mu^\mp$	LF	[gg] <	4.9	$\times 10^{-5}$	CL=90%	769
$\omegae^\pm\mu^\mp$	LF	[gg] <	1.2	× 10 ⁻⁴	CL=90%	764
$\phie^{\pm}\mu^{\mp}$	LF	[gg] <	3.4	\times 10 ⁻⁵	CL=90%	648
$\overline{\mathcal{K}}^0 e^\pm \mu^\mp$	LF	[gg] <	1.0	× 10 ⁻⁴	CL=90%	862
\overline{K}^* (892) ⁰ $e^{\pm}\mu^{\mp}$	LF	[gg] <	10	× 10 ⁻⁴	CL=90%	712

$D^*(2007)^0$

$$I(J^P) = \frac{1}{2}(1^-)$$

I, J, P need confirmation.

Mass $m = 2006.7 \pm 0.5 \text{ MeV}$ (S = 1.1) $m_{D^{*0}}-m_{D^0}=142.12\pm0.07~{\rm MeV}$ Full width $\Gamma<2.1~{\rm MeV}$, CL =90%

 $\overline{D}^*(2007)^0$ modes are charge conjugates of modes below.

D*(2007)0 DECAY MODES	Fraction (Γ_i/Γ)	ρ (MeV/c)
$D^0 \pi^0$	(61.9±2.9) %	43
$D^0 \gamma$	(38.1 ± 2.9) %	137

$D^*(2010)^{\pm}$

$$I(J^P) = \frac{1}{2}(1^-)$$
 $I \setminus P$ need confirmation

 $\begin{array}{c|c} \textbf{D)}^{\pm} & I(J^P) = \frac{1}{2}(1^-) \\ I, J, P \text{ need confirmation.} \\ \text{Mass } m = 2010.0 \pm 0.5 \text{ MeV} \quad (S = 1.1) \\ \end{array}$ $m_{D^*(2010)^+} - m_{D^+} = 140.64 \pm 0.09 \; {\rm MeV}$ $m_{D^*(2010)^+} - m_{D^0} = 145.42 \pm 0.05 \; {\rm MeV}$ Full width $\Gamma < 0.131 \; {\rm MeV}, \; {\rm CL} = 90\%$

 $D^*(2010)^-$ modes are charge conjugates of the modes below.

D*(2010) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)	
$D^{0}\pi^{+}$	(68.3±1.4) %	39	
$D^+\pi^0$	(30.6 ± 2.5) %	38	
$D^+\gamma$	$(1.1^{+2.1}_{-0.7})\%$	136	

$D_1(2420)^0$

$$I(J^P) = \frac{1}{2}(1^+)$$
 I, J, P need confirmation.

Mass $m = 2422.2 \pm 1.8 \text{ MeV}$ (S = 1.2) Full width $\Gamma=18.9^{+4.6}_{-3.5}~\text{MeV}$

 $\overline{\mathcal{D}}_1(2420)^0$ modes are charge conjugates of modes below.

D ₁ (2420) ⁰ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)	
$D^*(2010)^+\pi^-$	seen	355	
$D^+\pi^-$	not seen	474	

$D_2^*(2460)^0$

$I(J^P) = \frac{1}{2}(2^+)$

= 2⁺ assignment strongly favored (ALBRECHT 89B). Mass $m = 2458.9 \pm 2.0 \text{ MeV}$ (S = 1.2) Full width $\Gamma=23\pm5~\text{MeV}$

 $\overline{\mathcal{D}}_2^*(2460)^0$ modes are charge conjugates of modes below.

D*(2460)0 DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$D^+\pi^-$	seen	503
$D^*(2010)^+\pi^-$	seen	387

$D_2^*(2460)^{\pm}$

$$I(J^P) = \frac{1}{2}(2^+)$$

 $\overline{J^P} = 2^+$ assignment strongly favored (ALBRECHT 89B). Mass $m = 2459 \pm 4 \text{ MeV}$ (S = 1.7) $\begin{array}{ll} m_{D_2^*(2460)^\pm} - m_{D_2^*(2460)^0} = 0.9 \pm 3.3 \; {\rm MeV} \quad ({\rm S}=1.1) \\ {\rm Full \; width \; } \Gamma = 25 {+8 \atop -7} \; {\rm MeV} \end{array}$

 $D_2^*(2460)^-$ modes are charge conjugates of modes below.

$D_2^*(2460)^{\pm}$ DECAY MODES	Fraction (Γ_j/Γ)	p (MeV/c)
$D^0\pi^+$	seen	508
$D^{*0} \pi^+$	seen	390

CHARMED, STRANGE MESONS $(C=S=\pm 1)$

 $D_s^+ = c\overline{s}$, $D_s^- = \overline{c}s$, similarly for D_s^* 's



$$I(J^P) = 0(0^-)$$

Mass $m=1968.5\pm0.6$ MeV (S = 1.1) $m_{D_{c}^{\pm}} - m_{D^{\pm}} = 99.2 \pm 0.5 \text{ MeV} \quad (S = 1.1)$ Mean life $au = (0.467 \pm 0.017) imes 10^{-12} ext{ s}$ c au = 140 $\mu \mathrm{m}$

D_s^+ form factors

 $r_2 = 1.6 \pm 0.4$ $r_{\rm v} = 1.5 \pm 0.5$ $\Gamma_{\text{L}}/\Gamma_{\text{T}} = 0.72\,\pm\,0.18$

Branching fractions for modes with a resonance in the final state include all the decay modes of the resonance. $D_{\rm S}^-$ modes are charge conjugates of the modes below.

			-
D DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	(MeV/c)

Inclusive modes					
K^- anything	(13	$+14 \\ -12$) %		-
$\overline{K}{}^0$ anything $+$ K^0 anything	(39	±28) %		_
\mathcal{K}^+ anything	(20	$^{+18}_{-14}$) %		_
non- $K\overline{K}$ anything	(64	±17) %		_
e^+ anything	< 20		%	90%	-

Leptonic and semileptonic modes

$\mu^+ u_{\mu}$		$(9 \pm 4) \times 10^{-3}$	981
$\phi \ell^+ u_\ell$	[xx]	(1.9 ± 0.5) %	-
$\eta \ell^+ \nu_\ell + \eta'(958) \ell^+ \nu_\ell$		(3.3 ± 1.0) %	-
$\eta \ell^+ u_\ell$		(2.5 ± 0.7) %	-
$n'(958) \ell^{+} \nu_{\ell}$		$(8.7 \pm 3.4) \times 10^{-3}$	_

Hadronic modes with a $K\overline{K}$ pair (including from a ϕ) $(3.6 \pm 1.1)\%$

 $K^{+}\overline{K}^{0}$

$K^+\overline{K}^0$	(3.6 ± 1.1) %		850
$K^+K^-\pi^+$	[rr,yy] (4.6 ± 1.2) %		805
$\phi\pi^+$	(3.6 ± 0.9) %		712
K ⁺ K̄*(892) ⁰	(3.4 ± 0.9) %		682
$f_0(980)\pi^+$	$(1.1 \pm 0.4)\%$		732
$K + \overline{K}_0^* (1430)^0$	$(7 \pm 4) \times 10^{-3}$		186
$f_I(1710)\pi^+ \to K^+K^-\pi^+$	[zz] $(1.5 \pm 2.0) \times 10^{-3}$		204
$K^+K^-\pi^+$ nonresonant	$(9 \pm 4) \times 10^{-3}$		805
$K^0\overline{K}{}^0\pi^+$			802
$K^*(892)^+ \overline{K}{}^0$	(4.3± 1.4) %		683
$K^+K^-\pi^+\pi^0$			748
$\phi \pi^+ \pi^0$	(9 ± 5)%		687
$\phi \rho^+$	(6.7± 2.3) %		407
$\phi\pi^+\pi^0$ 3-body	< 2.6 %	90%	687
$K^+K^-\pi^+\pi^0$ non- ϕ	< 9 %	90%	748
$K^+\overline{K}{}^0\pi^+\pi^-$	< 2.8 %	90%	744
$\kappa^{0} \kappa^{-} \pi^{+} \pi^{+}$	(4.3 ± 1.5) %		744
$K^*(892)^+\overline{K}^*(892)^0$	(5.8 ± 2.5) %		412
$K^0K^-\pi^+\pi^+$ non- $K^{*+}\overline{K}^{*0}$	< 2.9 %	90%	744
$K^{+}K^{-}\pi^{+}\pi^{+}\pi^{-}$			673
$\phi \pi^+ \pi^+ \pi^-$	(1.8 ± 0.6) %		640
$\mathcal{K}^+\mathcal{K}^-\pi^+\pi^+\pi^-$ non- ϕ	$(3.0^{+}_{-2.0}) \times 10^{-3}$		673

Other hadronic modes (0, 1, or 3 K's)

Other hadronic modes (0, 1, or 3 % s)					
$\pi^{+}\pi^{+}\pi^{-}$	(1.4 ± 0.4) %		959		
$\rho^{0} \pi^{+}$	$< 2.9 \times 10^{-3}$	90%	827		
$f_0(980)\pi^+$	(1.2 ± 0.5) %		732		
$\pi^+\pi^+\pi^-$ nonresonant	(1.0 ± 0.4) %		959		
$\pi^{+}\pi^{+}\pi^{-}\pi^{0}$	< 12 %	90%	935		
$\eta\pi^+$	(2.0 ± 0.6) %		902		
$\omega \pi^+$	< 1.8 %	90%	822		
$\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}$	$(3.0^{+}_{-}3.0^{+})\times10^{-3}$		899		
$\pi^{+} \pi^{+} \pi^{-} \pi^{0} \pi^{0}$			902		
$\eta \rho^+$	(10.3 ± 3.2) %		727		
$\eta \pi^+ \pi^0$ 3-body	< 3.0 %	90%	886		
$\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0}$	(4.9 ± 3.2) %		856		
$\eta'(958)\pi^+$	(4.9 ± 1.8) %		743		
$\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0}\pi^{0}$			803		
$\eta'(958) \rho^+$	$(12 \pm 4)\%$		470		
$\eta'(958) \pi^+ \pi^0$ 3-body	< 3.1 %	90%	720		
$K^0\pi^+$	< 8 × 10 ⁻³	90%	916		
$K^{+}\pi^{+}\pi^{-}$	(1.0 ± 0.4) %		900		
$\mathcal{K}^+ ho^0$	$< 2.9 \times 10^{-3}$	90%	747		
$K^*(892)^0 \pi^+$	$(6.5\pm\ 2.8)\times10^{-3}$		773		
K+K+K-	$< 6 \times 10^{-4}$	90%	628		
φK ⁺	< 5 × 10 ⁻⁴	90%	607		

$\Delta C = 1$ weak neutral current (C1) modes, or Lepton number (L) violating modes

	$\pi^{+} \mu^{+} \mu^{-}$	[aaa	0] < 4.3	\times 10 ⁻⁴	90%	968	
	$K^+\mu^+\mu^-$	C1	< 5.9	\times 10 ⁻⁴	90%	909	
	$K^*(892)^+ \mu^+ \mu^-$	C1	< 1.4	\times 10 ⁻³	90%	765	
	$\pi^- \mu^+ \mu^+$	L	< 4.3	\times 10 ⁻⁴	90%	968	
	$K^- \mu^+ \mu^+$	L	< 5.9	\times 10 ⁻⁴	90%	909	
	$K^*(892)^- \mu^+ \mu^+$	L	< 1.4	\times 10 ⁻³	90%	765	



$$I(J^P) = ?(??)$$

Mass $m=2112.4\pm0.7~{\rm MeV}~{\rm (S}=1.1)$ $m_{D_s^{\pm\pm}}-m_{D_s^{\pm}}=143.8\pm0.4~{\rm MeV}$ Full width $\Gamma<1.9~{\rm MeV},~{\rm CL}=90\%$

 D_{S}^{*-} modes are charge conjugates of the modes below.

D*+ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$D_s^+ \gamma$	seen	139
$D_s^+ \pi^0$	seen	48



$$I(J^P) = 0(1^+)$$

I, J, P need confirmation.

Mass m= 2535.35 \pm 0.34 MeV Full width Γ < 2.3 MeV, CL = 90%

 $D_{s1}(2536)^{-}$ modes are charge conjugates of the modes below.

D _{S1} (2536)+ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$D^*(2010)^+ K^0$	seen	150
$D^*(2007)^0 K^+$	seen	169
D^+K^0	not seen	382
$D^0 K^+$	not seen	392
$D_s^{*+}\gamma$	possibly seen	389

$D_{sJ}(2573)^\pm$

$$I(J^P) = ?(??)$$

 J^P is natural, width and decay modes consistent with 2^{+2} . Mass $m=2573.5\pm1.7$ MeV Full width $\Gamma=15^{+5}_{-4}$ MeV

 $D_{sJ}({\it 2573})^-$ modes are charge conjugates of the modes below.

D_{sJ} (2573) $^+$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
D ⁰ K ⁺	seen	436
D*(2007) ⁰ K ⁺	seen	245

BOTTOM MESONS

$$(B=\pm 1)$$

 $B^+=u\overline{b},\, B^0=d\overline{b},\, \overline{B}{}^0=\overline{d}\,b,\, B^-=\overline{u}\,b,\,$ similarly for B^* 's

B-particle organization

Many measurements of B decays involve admixtures of B hadrons. Previously we arbitrarily included such admixtures in the B^\pm section, but because of their importance we have created two new sections: " B^\pm/B^0 Admixture" for $\Upsilon(4S)$ results and " $B^\pm/B^0/B_S^0/B_S^0$ —baryon Admixture" for results at higher energies. Most inclusive decay branching fractions are found in the Admixture sections. $B^0-\overline{B}^0$ mixing data are found in the B^0 section, while $B_S^0-\overline{B}^0$ mixing data and $B-\overline{B}$ mixing data for a B^0/B_S^0 admixture are found in the B_S^0 section. CP-violation data are found in the B^0 section. B^0 -baryons are found near the end of the Baryon section.

The organization of the ${\it B}$ sections is now as follows, where bullets indicate particle sections and brackets indicate reviews.

[Production and Decay of b-flavored Hadrons]

[Semileptonic Decays of B Mesons]

• B±

mass

mean life

branching fractions

 \bullet B^0

mass

mean life

branching fractions

polarization in B^0 decay

 B^0 - $\overline{B}{}^0$ mixing

 $[B^0 \overline{B}^0$ Mixing and *CP* Violation in *B* Decay]

 ${\it CP}$ violation

ullet B^\pm B^0 Admixtures

branching fractions

 \bullet $B^{\pm}/B^{0}/B_{s}^{0}/b$ -baryon Admixtures

mean life

production fractions

branching fractions

B*

mass

• B_s⁰

mass

mean life

branching fractions

polarization in B_s^0 decay

 $B_s^0 - \overline{B}_s^0$ mixing

 $B-\overline{B}$ mixing (admixture of B^0 , B_s^0)

At end of Baryon Listings:

• Ab

mass

mean life

branching fractions

$$I(J^P) = \frac{1}{2}(0^-)$$

I, J, P need confirmation. Quantum numbers shown are quark-model predictions.

Mass
$$m_{B^\pm}=5278.9\pm1.8~{\rm MeV}$$
 Mean life $\tau_{B^\pm}=(1.62\pm0.06)\times10^{-12}~{\rm s}$ $c au=462~{\rm \mu m}$

 B^- modes are charge conjugates of the modes below. Modes which do not identify the charge state of the B are listed in the B^\pm/B^0 ADMIXTURE

The branching fractions listed below assume 50% $B^0\,\overline B{}^0$ and 50% $B^+\,B^$ production at the $\varUpsilon(4S)$. We have attempted to bring older measurements up to date by rescaling their assumed $\varUpsilon(4S)$ production ratio to 50:50 and their assumed $D,\,D_{\mathcal{S}},\,D^*$, and ψ branching ratios to current values whenever this would affect our averages and best limits significantly.

Indentation is used to indicate a subchannel of a previous reaction. All resonant subchannels have been corrected for resonance branching fractions to the final state so the sum of the subchannel branching fractions can exceed that of the final state.

B⁺ DECAY MODES

Scale factor/ Fraction (Γ_i/Γ) Confidence level (MeV/c)

Semilept	tonic and leptonic	modes		
$\ell^+ u_\ell$ anything	[qq] (10.1 ±2.	3)%		-
$\overline{D}{}^0 \ell^+ u_\ell$	[qq] (1.6 ±0.	7)%		_
\overline{D}^* (2007) $^0\ell^+ u_\ell$	[qq] (5.3 ±0.	8)%		-
$\pi^0 e^+ \nu_e$	< 2.2	\times 10 ⁻³	CL=90%	2638
$\omega \ell^+ \nu_\ell$	[qq] < 2.1	$\times 10^{-4}$	CL=90%	_
$ ho^0\ell^+ u_\ell$	[qq] < 2.1	\times 10 ⁻⁴	CL=90%	-
$e^+ u_e$	< 1.5	\times 10 ⁻⁵	CL=90%	2639
$\mu^+ u_{\mu}$	< 2.1	\times 10 ⁻⁵	CL=90%	2638
$ au^+ u_ au$	< 1.8	× 10 ⁻³	CL=90%	2340
D,	D*, or D _s mode	5		
$\overline{D}{}^0\pi^+$	(5.3 ±0.	$5) \times 10^{-3}$		2308
$\overline{D}{}^0 \rho^+$	(1.34±0.	18) %		2238
$\overline{D}{}^{0}\pi^{+}\pi^{+}\pi^{-}$	(1.1 ±0.4	4)%		2289
$\overline{D}{}^0\pi^+\pi^+\pi^-$ nonresonant	(5 ±4	$) \times 10^{-3}$		2289
$\overline{D}{}^0\pi^+\rho^0$	(4.2 ±3.0	$0) \times 10^{-3}$		2209
$\overline{D}{}^0 a_1(1260)^+$	(5 ±4	$) \times 10^{-3}$		2123
$D^*(2010) = \pi^+ \pi^+$	(21 +04	: \ 10-3		2247

$D^0 \rho^+$	$(1.34 \pm 0.$	18) %		2238
$\overline{D}{}^{0}\pi^{+}\pi^{+}\pi^{-}$	(1.1 ±0.			2289
$\overline{D}{}^0\pi^+\pi^+\pi^-$ nonresonant	(5 ±4	$) \times 10^{-3}$		2289
$\overline{D}{}^0\pi^+\rho^0$	(4.2 ±3.	$0) \times 10^{-3}$		2209
$\overline{D}{}^{0}a_{1}(1260)^{+}$	(5 \pm 4	$) \times 10^{-3}$		2123
$D^*(2010)^-\pi^+\pi^+$	(2.1 ±0.	6) $\times 10^{-3}$		2247
$D^-\pi^+\pi^+$	< 1.4	\times 10 ⁻³	CL=90%	2299
$\overline{D}^*(2007)^0\pi^+$	(5.2 ±0.	$8) \times 10^{-3}$		2256
$\overline{D}^*(2007)^0 \rho^+$	(1.55±0.			2183
$\overline{D}^*(2007)^0\pi^+\pi^+\pi^-$	(9.4 ±2.	6) $\times 10^{-3}$		2236
$\overline{D}^*(2007)^0 a_1(1260)^+$	$(1.9 \pm 0.$			2062
$D^*(2010)^-\pi^+\pi^+\pi^0$	$(1.5 \pm 0.$	7)%		2235
$D^*(2010)^-\pi^+\pi^+\pi^+\pi^-$	< 1	%	CL=90%	2217
$\overline{D}_{1}^{*}(2420)^{0}\pi^{+}$	$(1.5 \pm 0.$	6) $\times 10^{-3}$	S=1.3	2081
$\overline{D}_{1}^{*}(2420)^{0} ho^{+}$	< 1.4	\times 10 ⁻³	CL=90%	1997
$\overline{D}_{2}^{*}(2460)^{0}\pi^{+}$	< 1.3	$\times 10^{-3}$	CL=90%	2064
$\overline{D}_{2}^{*}(2460)^{0} ho^{+}$	< 4.7	\times 10 ⁻³	CL=90%	1979
$\overline{D}{}^0 D_s^+$	(1.7 ±0.	6)%		1815
$\overline{D}{}^0D_s^{*+}$	(1.2 ±1.	0)%		1734
$\overline{D}^*(2007)^0 D_s^+$	(10 ±7	$) \times 10^{-3}$		1737
$\overline{D}^*(2007)^0 D_s^{*+}$	(2.3 ±1.			1650
$D_s^+\pi^0$	< 2.0	× 10 ⁻⁴	CL=90%	2270
$D_{s}^{*+}\pi^{0}$	< 3.3	× 10 ⁻⁴	CL=90%	2214
$D_s^{\sharp} \eta$	< 5	× 10 ⁻⁴	CL=90%	2235
$D_{s}^{*+}\eta$	< 8	× 10 ⁻⁴	CL=90%	2177
$D_s^+ \rho^0$	< 4	× 10 ⁻⁴	CL=90%	2198
$D_s^+ \rho^0$ $D_s^{++} \rho^0$ $D_s^+ \omega$ $D_s^{++} \omega$		× 10 × 10 -4		
D_s^+ ρ	, ,		CL=90%	2139
D 5 W	< 5	× 10 ⁻⁴	CL=90%	2195
$D_s^+ \omega$	< 7	× 10 ⁻⁴	CL=90%	2136
$D_s^+ a_1 (1260)^0$	< 2.2	× 10 ⁻³	CL=90%	2079
$D_s^{*+} a_1(1260)^0$	< 1.6	\times 10 ⁻³	CL=90%	2014
$D_s^+\phi$	< 3.2	$\times 10^{-4}$	CL=90%	2141
$D_s^{*+}\phi$	< 4	× 10 ⁻⁴	CL=90%	2079
$D_s^+ \overline{K}^0$	< 1.1	$\times 10^{-3}$	CL=90%	2241
$D_{s}^{*+}\overline{K}^{0}$	< 1.1	$\times 10^{-3}$	CL=90%	2184
$D_s^+ \overline{K}^* (892)^0$	< 5	$\times 10^{-4}$	CL=90%	2171
• • •				

$D_s^{*+}\overline{K}^*(892)^0$	< 4	× 10 ⁻⁴	CL=90%	2110
$D^{-}\pi^{+}K^{+}$	< 8	× 10 ⁻⁴	CL=90%	2222
$D_s^{*-}\pi^+K^+$	< 1.2	$\times 10^{-3}$	CL=90%	2164
$D_s^- \pi^+ K^*(892)^+$	< 6	$\times 10^{-3}$	CL=90%	2137
$D_s^{*-}\pi^+K^*(892)^+$	< 8	$\times 10^{-3}$	CL=90%	2075
	Tharmonium modes			
$J/\psi(1S)K^+$	Charmonium modes (1.01 ± 0.1			1683
$J/\psi(1S)K^{+}\pi^{+}\pi^{-}$	(1.4 ±0.6			1612
$J/\psi(15)K^*(892)^+$	(1.7 ±0.5			1571
$J/\psi(1S)\pi^-$	(4.4 \pm 2.4			1727
$\psi(2S)K^+$	(6.9 ± 3.1		S=1.3	1284
$\psi(2S)K^*(892)^+ \ \psi(2S)K^*(892)^+\pi^+\pi^-$	< 3.0	× 10 ⁻³	CL=90%	1115
$\chi_{c1}(1P)K^+$	(1.9 ±1.2 (1.0 ±0.4			909 1411
$\chi_{c1}(1P)K^*(892)^+$	< 2.1	× 10 ⁻³	CL=90%	1265
7(11) · (032)		× 10	CL 30 /0	1203
$\mathcal{K}^0\pi^+$	K or K* modes	5		
$K^+\pi^0$	< 4.8 < 1.4	$\times 10^{-5} \times 10^{-5}$	CL=90% CL=90%	2614 2615
$K^*(892)^0\pi^+$	< 4.1	× 10 -5	CL=90% CL=90%	2561
$K^*(892)^+\pi^0$	< 9.9	× 10 × 10 – 5	CL=90%	2562
$K^{+}\pi^{-}\pi^{+}$ (no charm)	< 1.9	× 10 ⁻⁴	CL=90%	2609
$K_1(1400)^0\pi^+$	< 2.6	\times 10 ⁻³	CL=90%	2451
$K_2^*(1430)^0\pi^+$	< 6.8	× 10 ⁻⁴	CL=90%	2443
$\mathcal{K}^{+}\rho^{0}$ $\mathcal{K}^{0}\rho^{+}$	< 1.9	× 10 ⁻⁵	CL=90%	2559
K ⁰ ρ ⁺	< 4.8	× 10 ⁻⁵	CL=90%	2559
$K^*(892)^+\pi^+\pi^- \ K^*(892)^+ ho^0$	< 1.1	$\times 10^{-3} \times 10^{-4}$	CL=90%	2556
$K_1(1400)^+ \rho^0$	< 9.0 < 7.8	× 10 × 10 × 10 × 10 × 10 × 10 × 10 × 10	CL=90% CL=90%	2505 2389
$K_2^*(1430)^+ \rho^0$	< 1.5	× 10 ⁻³	CL=90%	2382
K+ K-K+	< 3.1	× 10 ⁻⁴	CL=90%	2522
$K^+\phi$	< 1.2	\times 10 ⁻⁵	CL=90%	2516
K*(892) ⁺ K ⁺ K ⁻	< 1.6	\times 10 ⁻³	CL=90%	2466
$K^*(892)^+ \phi$	< 7.0	× 10 ⁻⁵	CL=90%	2460
$K_1(1400)^+ \phi$	< 1.1	× 10 ⁻³	CL=90%	2339
$K_2^*(1430)^+ \phi$	< 3.4	× 10 ⁻³	CL=90%	2332
$K^{+}f_{0}(980)$ $K^{*}(892)^{+}\gamma$	< 8 (5.7 ±3.3	× 10 ⁻⁵	CL=90%	2524 2564
$K_1(1270)^+ \gamma$	< 7.3	× 10 ⁻³	CL=90%	2486
$K_1(1400)^+ \gamma$	< 2.2	× 10 ⁻³	CL=90%	2453
$K_{2}^{*}(1430)^{+}\gamma$	< 1.4	\times 10 ⁻³	CL=90%	2447
$K^{\overline{*}}(1680)^+ \gamma$	< 1.9	\times 10 ⁻³	CL=90%	2361
$K_3^*(1780)^+\gamma$	< 5.5	\times 10 ⁻³	CL=90%	2343
$K_4^*(2045)^+\gamma$	< 9.9	\times 10 ⁻³	CL=90%	2243
Light u	inflavored meson m	odes		
$\pi^+\pi^0$	< 1.7	\times 10 ⁻⁵	CL=90%	2636
$\pi^{+}\pi^{+}\pi^{-}$	< 1.9	× 10 ⁻⁴	CL=90%	2630
$\rho^0 \pi^+$	< 4.3	× 10 ⁻⁵	CL=90%	2582
$\pi^+ f_0(980)$	< 1.4	× 10 ⁻⁴	CL=90%	2547
$\frac{\pi^+ f_2(1270)}{\pi^+ \pi^0 \pi^0}$	< 2.4 < 8.9	$\times 10^{-4} \times 10^{-4}$	CL=90% CL=90%	2483 2631
$\rho^+\pi^0$	< 7.7	× 10 × 10 ⁻⁵	CL=90%	2582
$\pi^{+}\pi^{-}\pi^{+}\pi^{0}$	< 4.0	× 10 ⁻³	CL=90%	2621
$\rho^+ \rho^0$	< 1.0	\times 10 ⁻³	CL=90%	2525
$a_1(1260)^+\pi^0$	< 1.7	\times 10 ⁻³	CL=90%	2494
$a_1(1260)^0 \pi^+$	< 9.0	× 10 ⁻⁴	CL=90%	2494
$\omega \pi^+ \\ \eta \pi^+$	< 4.0	× 10 ⁻⁴	CL=90%	2580
$\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{-}$	< 7.0 < 8.6	$\times 10^{-4} \times 10^{-4}$	CL=90% CL=90%	2609
$\rho^0 a_1(1260)^+$	< 8.6 < 6.2	× 10 · · · × 10 · ·	CL=90% CL=90%	2608 2434
$\rho^0 a_2(1320)^+$	< 7.2	× 10 ⁻⁴	CL=90%	2411
$\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0}$	< 6.3	× 10 ⁻³	CL=90%	2592
$a_1(1260)^+ a_1(1260)^0$	< 1.3	%	CL=90%	2335
	Baryon modes			
$p\overline{p}\pi^+$	< 1.6	\times 10 ⁻⁴	CL=90%	2439
$p\overline{p}\pi^+\pi^+\pi^-$	< 5.2	\times 10 ⁻⁴	CL=90%	2369
$p\overline{\Lambda}$	< 6	\times 10 ⁻⁵	CL=90%	2430
$\frac{\rho \overline{\Lambda} \pi^+ \pi^-}{\overline{\Lambda} 0}$	< 2.0	× 10 ⁻⁴	CL=90%	2367
$\frac{\overline{\Delta}^0}{\overline{\Delta}^0} p$ $\Delta^{++} \overline{p}$	< 3.8	$\times 10^{-4} \times 10^{-4}$	CL=90% CL=90%	2402
Δ μ	< 1.5	× 10 ,	CL=90%	2402

Lepton Family number	r (<i>LF</i>) or Lepton number (<i>L</i>) vic	lating modes or	D*(2460)+		3 (1 000)	
$\Delta B = 1$	weak neutral current (B1) mod	les	$\overline{D}_2^*(2460)^- ho^+ \ D^-D_s^+$	$< 4.9 \times 10^{-3}$ $(7 \pm 4) \times 10^{-3}$		979 812
$\pi^{+}e^{+}e^{-}$	$B1 < 3.9 \times 10^{-3}$		$D^*(2010)^-D_{\epsilon}^+$	(1.2 ±0.6) %		735
$\pi^{+}\mu^{+}\mu^{-}$	B1 < 9.1 × 10 ⁻³		$D^{-}D_{s}^{*+}$	(2.0 ±1.5) %		731
$K^{+}\mu^{+}\mu^{-}$ $K^{*}(892)^{+}e^{+}e^{-}$	B1 < 1.7 × 10 ⁻⁴ B1 < 6.9 × 10 ⁻⁴		$D^*(2010)^- D_s^{*+}$	(1.9 ±1.2) %	16	649
$K^*(892)^+ \mu^+ \mu^-$	B1 < 1.2 × 10 ⁻¹		$D_s^+\pi^-$	< 2.8 × 10 ⁻⁴	CL=90% 22	270
$\pi^{+}e^{+}\mu^{-}$	LF < 6.4 × 10 ⁻³		$D_{s}^{*+}\pi^{-}$	< 5 × 10 ⁻⁴	CL=90% 22	214
$\pi^+e^-\mu^+$	LF < 6.4 \times 10 ⁻³	B CL=90% 2637	$D_s^+ \rho^-$	< 7 × 10 ⁻⁴	CL=90% 21	198
$K^+e^+\mu^-$	LF < 6.4 \times 10 ⁻³		$D_s^{*+} ho^-$	< 8 × 10 ⁻⁴	CL=90% 21	139
$K^{+}e^{-}\mu^{+}$	LF < 6.4 × 10 ⁻³		$D_s^+ a_1(1260)^-$	$< 2.6 \times 10^{-3}$	3 CL=90% 20	079
$\pi^- e^+ e^+ \\ \pi^- \mu^+ \mu^+$	L < 3.9 × 10 ⁻⁵ L < 9.1 × 10 ⁻⁵		$D_s^{*+} a_1(1260)^-$	$< 2.2 \times 10^{-3}$	B CL=90% 20	014
$\pi^{-}e^{+}\mu^{+}$	L < 6.4 × 10 ⁻³		$D_s^-K^+$	< 2.4 × 10 ⁻⁴		242
$K^-e^+e^+$	$L < 3.9 \times 10^{-3}$	CL=90% 2616	D*- K+	< 1.7 × 10 ⁻²		185
$K^-\mu^+\mu^+$	L < 9.1 \times 10 ⁻²		$D_s^- K^*(892)^+$	< 9.9 × 10 ⁻⁴		172
$K^-e^+\mu^+$	L < 6.4 \times 10 ⁻³	CL=90% 2615	$D_s^{*-}K^*(892)^+ D_s^{-}\pi^+K^0$	< 1.1 × 10 ⁻³		112
			$D_s^* \pi^+ K^0$ $D_s^{*-} \pi^+ K^0$	$< 5 \times 10^{-3}$ $< 3.1 \times 10^{-3}$		221
B^0	$I(J^P) = \frac{1}{2}(0^-)$		$D_s^- \pi^+ K^* (892)^0$	< 3.1 × 10 ⁻³ < 4 × 10 ⁻³		164 136
			$D_s^{*-}\pi^+K^*(892)^0$	< 2.0 × 10 ⁻³		074
I, J, P need confirma	tion. Quantum numbers shown	are quark-model	$\overline{D}^{\circ}_{\pi^{0}}$	< 4.8 × 10 ⁻⁴		308
predictions.			$\frac{D^0}{D^0}$ ρ^0	< 5.5 × 10 ⁻⁴		238
	5279.2 ± 1.8 MeV		$\overline{D}{}^0\eta$	< 6.8 × 10 ⁻⁴	CL=90% 22	274
$m_{B^0} - m_{B^\pm}$	$= 0.35 \pm 0.29 \text{ MeV} (S = 1.1)$		$\overline{D}^0 \eta'$	< 8.6 × 10 ⁻⁴		198
	$= (1.56 \pm 0.06) \times 10^{-12} \text{ s}$		$\overline{D}^0 \omega$	< 6.3 × 10 ⁻⁴		235
$c\tau = 468$ $\tau_{B^+}/\tau_{B^0} = 1$	•	and inferred)	$\overline{D}^*(2007)^0\pi^0 \ \overline{D}^*(2007)^0 ho^0$	< 9.7 × 10 ⁻⁴ < 1.17 × 10 ⁻³		256 183
${{\tau_{B^+}}/{\tau_{B^0}}} = 1$ ${{\tau_{B^+}}/{\tau_{B^0}}} = 1$			$\frac{D}{D}^*(2007)^0 \eta$	< 6.9 × 10 ⁻⁴		220
$\tau_{B^+}/\tau_{B^0} = 0$ $\tau_{B^+}/\tau_{B^0} = 0$		•	$\frac{D}{D}$ *(2007) ⁰ η'	< 2.7 × 10 ⁻³		141
			$\overline{D}^*(2007)^0 \omega$	< 2.1 × 10 ⁻³	GL=90% 21	180
B^0 - \overline{B}^0 mixing par				Charmonium modes		
$\chi_d = 0.175 \pm$	0.016	1012 +1	$J/\psi(1S)K^0$	$(7.5 \pm 2.1) \times 10^{-4}$	16	683
$\Delta m_{B^0} = m_{B^0}$	$_{B_{L}^{0}}-m_{B_{L}^{0}}=(0.474\pm0.031)\times 1$	10-2 h S 2	$J/\psi(1S)K^+\pi^-$	$(1.1 \pm 0.6) \times 10^{-3}$		652
$x_d = \Delta m_{B^0}/1$	$T_{B^0} = 0.73 \pm 0.05$		$J/\psi(1S) K^*(892)^0$	$(1.58\pm0.27)\times10^{-3}$		570
CP violation paras	meters		$J/\psi(1\dot{S})\pi^0 \ \psi(2\dot{S}) K^0$	< 6.9 × 10 ⁻³ < 8 × 10 ⁻⁴		728 283
$\left {{\mathop{\sf Re}} (\epsilon_{B^0})} \right \; < \;$	0.045		$\psi(2S)K^+\pi^-$	< 1 × 10 ⁻³		238
RO modes are charge	conjugates of the modes below. Rea	ctions indicate	$\psi(2S)K^*(892)^0$	$(1.4 \pm 0.9) \times 10^{-3}$		113
the weak decay verte	x and do not include mixing. Modes	which do not	$\chi_{c1}(1P)K^0$	$< 2.7 \times 10^{-3}$		411
	ate of the B are listed in the B^\pm/B^0	ADMIXTURE	$\chi_{c1}(1P)K^*(892)^0$	$< 2.1 \times 10^{-3}$	S CL=90% 12	263
section.				K or K* modes		
	ns listed below assume 50% $B^0\overline{B}{}^0$ an 45). We have attempted to bring older		$K^+\pi^-$	$< 1.7 \times 10^{-5}$		615
	ing their assumed $\Upsilon(4S)$ production		$K^0\pi^0$	< 4.0 × 10 ⁻¹		614
	, $D_{\rm S}$, D^{*} , and ψ branching ratios to		$egin{array}{c} \mathcal{K}^+ \mathcal{K}^- \ \mathcal{K}^+ ho^- \end{array}$	< 4 × 10 ⁻⁶ < 3.5 × 10 ⁻⁵		593 559
	affect our averages and best limits sig	•	$\kappa^0 \rho^0$	< 3.9 × 10 ⁻⁵		559
	o indicate a subchannel of a previous have been corrected for resonance b		$K^0 f_0(980)$	< 3.6 × 10 ⁻⁴		523
	te so the sum of the subchannel bran-		$K^*(892)^+\pi^-$	$< 7.2 \times 10^{-5}$		562
can exceed that of th	e final state.		$K^*(892)^0 \pi^0$	< 2.8 × 10 ⁻¹		562
BO DECAY MODES	Fraction (F /F) Co	Scale factor/ p	$rac{{ m m K_2^*(1430)^+\pi^-}}{{ m m K^0m K^+m K^-}}$	$< 2.6 \times 10^{-3}$ $< 1.3 \times 10^{-3}$		445
B DECAT MODES	Fraction (Γ_i/Γ) Co	nfidence level (MeV/c)	$\kappa^0 \phi$	< 1.3 × 10 ⁻³ < 8.8 × 10 ⁻⁵		522 516
	nileptonic and leptonic modes		$\kappa^-\pi^+\pi^+\pi^-$	$[bbb]$ < 2.1 \times 10 ⁻⁴		600
$\ell^+ \nu_\ell$ anything	[qq] $(10.3 \pm 1.0)\%$	-	$K^*(892)^0 \pi^+ \pi^-$	< 1.4 × 10 ⁻³	CL=90% 25	556
$D^-\ell^+ u_\ell \ D^*(2010)^-\ell^+ u_\ell$	[qq] $(1.9 \pm 0.5)\%$. -	$K^*(892)^0 \rho^0$	< 4.6 × 10 ⁻⁴		504
$\rho^-\ell^+\nu_\ell$	$[qq]$ (4.56±0.27) % $[qq]$ < 4.1 \times 10 ⁻⁴		$K^*(892)^0 f_0(980)$	< 1.7 × 10 ⁻⁴		467
P ~ *E		CE=7070	$rac{\mathcal{K}_1(1400)^+\pi^-}{\mathcal{K}^-a_1(1260)^+}$	$< 1.1 \times 10^{-3}$ $[bbb] < 3.9 \times 10^{-4}$		451 471
D- +	D , D^* , or D_s modes	,	$K^*(892)^0 K^+ K^-$			466
$D^{-}\pi^{+}$	$(3.0 \pm 0.4) \times 10^{-3}$		$\hat{K}^*(892)^0 \phi$	< 4.3 × 10 ⁻¹		459
$rac{D^- ho^+}{D^0}\pi^+\pi^-$	$(7.8 \pm 1.4) \times 10^{-3}$ $< 1.6 \times 10^{-3}$		$K_1(1400)^0 \rho^0$	< 3.0 × 10 ⁻³	CL=90% 23	389
$D^*(2010)^-\pi^+$	$(2.6 \pm 0.4) \times 10^{-3}$		$K_1(1400)^0 \phi$	< 5.0 × 10 ⁻³		339
$D^- \pi^+ \pi^+ \pi^-$	$(8.0 \pm 2.5) \times 10^{-3}$		$K_2^*(1430)^0 \rho^0$	< 1.1 × 10 ⁻³		380
$(D^-\pi^+\pi^+\pi^-)$ nonres			$K_{2}^{*}(1430)^{0} \phi \ K^{*}(892)^{0} \gamma$	$< 1.4 \times 10^{-3}$ $(4.0 \pm 1.9) \times 10^{-5}$		330 564
$D^-\pi^+\rho^0$	$(1.1 \pm 1.0) \times 10^{-3}$		$K^{1}(892)^{0}\gamma$ $K_{1}(1270)^{0}\gamma$	$(4.0 \pm 1.9) \times 10^{-3}$		564 486
$D^- a_1(1260)^+ \ D^*(2010)^- \pi^+ \pi^0$	$(6.0 \pm 3.3) \times 10^{-3}$ $(1.5 \pm 0.5) \%$	2121 2247	$K_1(1270)^{\gamma}$ $K_1(1400)^0 \gamma$	< 4.3 × 10 ⁻³		453
$D^*(2010)^{-} \rho^{+}$	$(7.3 \pm 0.5) \times 10^{-3}$		$K_2^*(1430)^0 \gamma$	< 4.0 × 10 ⁻⁴		445
$D^*(2010)^{-}\pi^{+}\pi^{+}\pi^{-}$	$(7.6 \pm 1.7) \times 10^{-3}$		$K^*(1680)^0 \gamma$	< 2.0 × 10 ⁻³		361
$(D^*(2010)^-\pi^+\pi^+\pi^-)$) non- $(0.0 \pm 2.5) \times 10^{-3}$	2235	$K_3^*(1780)^0 \gamma$	< 1.0 %		343
$D^*(2010)^-\pi^+ ho^0$	(5.7 ±3.1) × 10 ⁻³	2151	$K_4^*(2045)^0 \gamma$	< 4.3 × 10 ⁻³		244
$D^*(2010)^{-1}a_1(1260)^{-1}$		2061	$\phi \phi$	< 3.9 × 10 ⁻⁵	CL=90% 24	435
$D^*(2010)^-\pi^+\pi^+\pi^-\pi^0$	$(3.4 \pm 1.8)\%$	2218				
$\overline{D}_{2}^{*}(2460)^{-}\pi^{+}$	< 2.2 × 10 ⁻³	B CL=90% 2064				

	Light unf	lavored	meson	modes		
$\pi^+\pi^-$	_	<	2.0	\times 10 ⁻⁵	CL=90%	2636
$\pi^{0} \pi^{0}$		<	9.1	\times 10 ⁻⁶	CL=90%	2636
$\eta \pi^0$		<	2.5	× 10 ⁻⁴	CL=90%	2609
$\eta \eta$		<	4.1	× 10 ⁻⁴	CL=90%	2582
$\pi^{+}\pi^{-}\pi^{0}$		<	7.2	\times 10 ⁻⁴	CL=90%	2631
$ ho^0 \pi^0$		<	2.4	\times 10 ⁻⁵	CL=90%	2582
$\rho^{\mp}\pi^{\pm}$		[gg] <	8.8	\times 10 ⁻⁵	CL=90%	2582
$\pi^{+}\pi^{-}\pi^{+}\pi^{-}$		<	2.8	$\times 10^{-4}$	CL=90%	2621
$ ho^0 ho^0$		<	2.8	\times 10 ⁻⁴	CL=90%	2525
$a_1(1260)^{\mp}\pi^{\pm}$		[gg] <	4.9	\times 10 ⁻⁴	CL=90%	2494
$a_2(1320)^{\mp}\pi^{\pm}$		[gg] <	3.0	\times 10 ⁻⁴	CL=90%	2473
$\pi^{+} \pi^{-} \pi^{0} \pi^{0}$		<	3.1	\times 10 ⁻³	CL=90%	2622
$ ho^+ ho^-$		<	2.2	\times 10 ⁻³	CL=90%	2525
$a_1(1260)^0 \pi^0$		<	1.1	\times 10 ⁻³	CL=90%	2494
$\omega \pi^0$		<	4.6	× 10 ⁻⁴	CL=90%	2580
$\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0}$		<	9.0	\times 10 ⁻³	CL=90%	2609
$a_1(1260)^+ ho^-$		<	3.4	\times 10 ⁻³	CL=90%	2434
$egin{array}{c} a_1(1260)^+ ho^- \ a_1(1260)^0 ho^0 \end{array}$		<	2.4	\times 10 ⁻³	CL=90%	2434
$\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{-}$		<	3.0	\times 10 ⁻³	CL=90%	2592
$a_1(1260)^+ a_1(1260)^-$	-	<	2.8	\times 10 ⁻³	CL=90%	2336
$\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{-}\pi^{0}$		<	1.1	%	CL=90%	2572
	E	Baryon m	odes			
$\rho \overline{p}$		<	3.4	\times 10 ⁻⁵	CL=90%	2467
$p\overline{p}\pi^+\pi^-$		<	2.5	\times 10 ⁻⁴	CL=90%	2406
$p \overline{\Lambda} \pi^-$		<	1.8	$\times 10^{-4}$	CL=90%	2401
$\Delta^0 \overline{\Delta}{}^0$		<	1.5	× 10 ⁻³	CL=90%	2334
$\Delta^{++}\Delta^{}$		<	1.1	× 10 ⁻⁴	CL=90%	2334
$\frac{\overline{\Sigma}_{c}^{}}{\overline{\Sigma}_{c}^{}}\Delta^{++}$		<	1.2	× 10 ⁻³	CL=90%	1839
	Family nu	mber (/	F) viol	lating modes,	or	
				(B1) modes	O.	
$\gamma \gamma$	B1	<	3.9	$\times 10^{-5}$	CL=90%	2640
e+ e-	B1	<	5.9	$\times 10^{-6}$	CL=90%	2640
$\mu^{+}\mu^{-}$	B1	<	5.9	$\times 10^{-6}$	CL=90%	2637
$K^0e^+e^-$	B1	<	3.0	× 10 ⁻⁴	CL=90%	2616
$K^0 \mu^+ \mu^-$	B1	<	3.6	× 10 ⁻⁴	CL=90%	2612
$K^*(892)^0 e^+ e^-$	В1	<	2.9	× 10 ⁻⁴	CL=90%	2564
$K^*(892)^0 \mu^+ \mu^-$	B1	<	2.3	× 10 ⁻⁵	CL=90%	2559
$e^{\pm}\mu^{\mp}$	LF	[gg] <	5.9	× 10 ⁻⁶	CL=90%	2639
$e^{\pm} \dot{\tau}^{\mp}$	LF	[gg] <	5.3	× 10 ⁻⁴	CL=90%	2341
$\mu^{\pm} \tau^{\mp}$	LF	[gg] <	8.3	× 10 ⁻⁴	CL=90%	2339

B^{\pm}/B^0 ADMIXTURE

The branching fraction measurements are for an admixture of B mesons at the $\Upsilon(4S)$. The values quoted assume that $\mathsf{B}(\varUpsilon(4S)\to B\overline{B})=100\%$.

the $\Upsilon(4s)$. The values quoted assume that $B(\Upsilon(4s) \to BB) = 100\%$. For inclusive branching fractions, e.g., $B \to D^\pm$ anything, the treatment of multiple D's in the final state must be defined. One possibility would be to count the number of events with one-or-more D's and divide by the total number of B's. Another possibility would be to count the total number of D's and divide by the total number of B's, which is the definition of average multiplicity. The two definitions are identical when only one of the specified particles is allowed in the final state. Even though the "one-or-more" definition seems sensible, for practical reasons inclusive branching fractions are almost always measured using the multiplicity definition. For heavy final state particles, authors call their results inclusive branching fractions while for light particles some authors call their results multiplicities. In the B sections, we list all results as inclusive branching fractions, adopting a multiplicity definition. This means that inclusive branching fractions can exceed 100% and that inclusive partial widths can exceed total widths, just as inclusive cross sections can exceed total cross sections.

 $\overline{\cal B}$ modes are charge conjugates of the modes below. Reactions indicate the weak decay vertex and do not include mixing.

B DECAY MODES	Fraction (Γ_i/Γ)	Scale fa Confidence	ector/ p level (MeV/c)
Semileptor	nic and leptonic mo	des	
	[ccc] (10.4 ±0.4)		i=1.3 -
$\overline{ ho}e^+ u_e$ anything	< 1.6		=90% -
$\mu^+ u_\mu$ anything	[ccc] (10.3 ±0.5)	%	-
	,ccc] (10.43±0.24)	%	_
$D^-\ell^+ u_\ell$ anything	[qq] (2.7 ±0.8)	%	-
$\overline{D}{}^0 \ell^+ u_\ell$ anything	[qq] (7.0 ±1.4)	%	_
$\overline{D}^{**}\ell^+\nu_{\ell}$ [qq,	ddd] (2.7 ± 0.7)	%	-
$\overline{D}(1)(2420)^0\ell^+ u_\ell$ anything	seen		-
\overline{D} (2)*(2460) 0 ℓ^+ $ u_\ell$ any-	not seen		-
$D^{*-}\pi^+\ell^+ u_\ell$ anything	(1.00±0.34)	%	-
$D_s^-\ell^+\nu_\ell$ anything	[qq] < 9	\times 10 ⁻³ CL=	=90% -
$D_s^-\ell^+ u_\ellK^+$ anything	[qq] < 6	\times 10 ⁻³ CL=	=90% -
$D_s^-\ell^+\nu_\ell K^0$ anything	[qq] < 9	$\times 10^{-3}$ CL=	=90% -
$K^+\ell^+\nu_\ell$ anything	[qq] (6.0 ±0.5)		_
$K^-\ell^+\nu_\ell$ anything		× 10 ⁻³	_
$K^0/\overline{K}^0\ell^+ u_\ell$ anything	[qq] (4.4 ±0.5)		-
	D^* , or D_s modes		
D± anything	(24.2 ± 3.3)		-
D^0/\overline{D}^0 anything	(58 ±5)		5=1.1 -
$D_{\downarrow}^{*}(2010)^{\pm}$ anything	(23.1 ± 3.3)	% S	5=1.1 -
D_s^{\pm} anything	$[gg]$ (8.6 ± 1.6)	%	-
D_s^*D , D_s^*D , $D_s^*D^*$, or $D_s^*D^*$	[gg] (4.9 ± 1.1)	%	_
$D^*(2010)\gamma$	< 1.1	× 10 ⁻³ CL=	=90% -
$D_s^+\pi^-$, $D_s^{*+}\pi^-$, $D_s^+\rho^-$,	[gg] < 5	\times 10 ⁻⁴ CL=	=90% -
$D_s^{*+} \rho^-$, $D_s^+ \pi^0$, $D_s^{*+} \pi^0$,			
$D_s^+ \eta$, $D_s^{*+} \eta$, $D_s^+ \rho^0$,			
$D_s^{*+} ho^0$, $D_s^+ \omega$, $D_s^{*+} \omega$			
	rmonium modes		
$J/\psi(1S)$ anything	(1.14 ± 0.06)		-
$J/\psi(1\mathcal{S})$ (direct) anything	(8.0 ± 0.8)		-
$\psi(2S)$ anything	(3.5 ± 0.5)	× 10 ⁻³	-
$\chi_{c1}(1P)$ anything	(4.2 ± 0.7)		-
$\chi_{c1}(1P)$ (direct) anything	(3.7 ± 0.7)		-
$\chi_{c2}(1P)$ anything		_	=90%
$\eta_c(1S)$ anything	< 9	× 10 ⁻³ CL=	=90%
K	or K* modes		
\mathcal{K}^\pm anything	[gg] (78.9 ±2.5)		-
K ⁺ anything		%	_
K ⁻ anything		%	_
K^0/\overline{K}^0 anything		%	_
$K^*(892)^{\pm}$ anything		%	_
$K^*(892)^0 / \overline{K}^*(892)^0$ anything	$[gg]$ (14.6 \pm 2.6)		_
$K_1(1400)\gamma$	< 4.1		=90% -
$K_2^*(1430)\gamma$	< 8.3		=90% -
$K_2(1770)\gamma$	< 1.2		=90% -
$K_3^*(1780)\gamma$	< 3.0		=90% -
$K_4^*(2045)\gamma$	< 1.0		=90%
$\overline{b} \rightarrow \overline{s} \gamma$	(2.3 ± 0.7)	× 10 ⁻⁴	-
Light unf	lavored meson mod	es	
π^{\pm} anything [gg	r,eee] (359 ±7)	%	_
$ ho^0$ anything		%	-
ω anything	< 81	% CL=	=90% -
ϕ anything	(3.5 ± 0.7)	% S	5=1.8 -
F	Baryon modes		
charmed-baryon anything	(6.4 ± 1.1)	%	_
$\overline{\Sigma}_c^-$ anything	(4.8 ±2.5)		_
T anything			=90%
$\overline{\Sigma_{c}^{0}}$ anything $\overline{\Sigma_{c}^{0}}$ anything	< 1.1 (5.2 ±2.5)		- 30 /0
EO M/M	,		
$\overline{\Sigma}_{c}^{0} N(N = p \text{ or } n)$	< 1.7		=90% -
p/panything	[gg] (8.0 ± 0.4)		-
p/\overline{p} (direct) anything	[gg] (5.5 ±0.5)		-
A/Āanything	[gg] (4.0 ±0.5)		_
$\Xi^-/\overline{\Xi}^+$ anything	[gg] (2.7 ±0.6)		
baryons anything	(6.8 ±0.6)		_
ppanything	(2.47±0.23)		_
$\sqrt{p}/\Lambda p$ anything	[gg] (2.5 ± 0.4)		
$\Lambda \overline{\Lambda}$ anything	< 5	× 10 ⁻³ CL=	=90%

e^+e^- anything B1 < 2.4

 $\Delta B = 1$ weak neutral current (B1) modes × 10⁻³ CL=90% ×10⁻³ CL=90% $\mu^+\mu^-$ anything B1 < 2.4

$B^{\pm}/B^{0}/B_{s}^{0}/b$ -baryon ADMIXTURE

These measurements are for an admixture of bottom particles at high energy (LEP, Tevatron, SppS).

Mean life
$$au=(1.549\pm0.020)\times10^{-12}$$
 s Mean life $au=(1.72\pm0.10)\times10^{-12}$ s Charged b -hadron admixture

Mean life
$$au = (1.58 \pm 0.14) imes 10^{-12}$$
 s Neutral b -hadron admixture

$$\tau_{\rm charged\ b-hadron}/\tau_{\rm neutral\ b-hadron}=1.09\pm0.13$$

The branching fraction measurements are for an admixture of B mesons and baryons at energies above the $\Upsilon(4S)$. Only the highest energy results (LEP, Tevatron, $Sp\overline{p}S$) are used in the branching fraction averages. The production fractions give our best current estimate of the admixture at

For inclusive branching fractions, e.g., $B\to D^\pm$ anything, the treatment of multiple D's in the final state must be defined. One possibility would be to count the number of events with one-or-more D's and divide by the total number of B's. Another possibility would be to count the total number of D's and divide by the total number of B's, which is the definition of average multiplicity. The two definitions are identical when only one of the specified particles is allowed in the final state. Even though the "one-or-more" definition seems sensible, for practical reasons inclusive branching fractions are almost always measured using the multiplicity definition. For heavy final state particles, authors call their results inclusive branching fractions while for light particles some authors call their results multiplicities. In the B sections, we list all results as inclusive branching fractions, adopting a multiplicity definition. This means that inclusive branching fractions can exceed 100% and that inclusive partial widths can exceed total widths, just as inclusive cross sections can exceed total cross sections

The modes below are listed for a \overline{b} initial state. b modes are their charge conjugates. Reactions indicate the weak decay vertex and do not include

T DECAY MODES

Fraction (Γ_i/Γ)

Confidence level (MeV/c)

PRODUCTION FRACTIONS

The production fractions for weakly decaying b-hadrons at the Z have been calculated from the best values of mean lives, mixing parameters, and branching fractions in this edition by O. Hayes (CERN) and M. Jimack (U. Birmingham) as described in the note "Production and Decay of b-Flavored Hadrons" in the B^\pm Particle Listings. Values assume

$$\begin{array}{ll} \mathsf{B}(\overline{b}\to B^+) = \mathsf{B}(\overline{b}\to B^0) \\ \mathsf{B}(\overline{b}\to B^+) + \mathsf{B}(\overline{b}\to B^0) + \mathsf{B}(\overline{b}\to B^0_s) + \mathsf{B}(b\to \Lambda_b) = 100 \, \%. \end{array}$$

The notation for production fractions varies in the literature (f_{B^0} , $f(b \rightarrow$ $\overline{\mathcal{B}}^0$), Br $(b \to \overline{\mathcal{B}}^0)$). We use our own branching fraction notation here, B $(\overline{b} \to \mathcal{B}^0)$.

$\overline{b} \rightarrow$	B^+	(37.8 ± 2.2) %	_
$\overline{b} \rightarrow$	B^0	$(37.8 \pm 2.2)\%$	-
$\overline{b} \to $	B_s^0	$(11.2 + 1.8 \atop - 1.9)\%$	_
$b \rightarrow$	Λ_b	(13.2 ± 4.1) %	-

DECAY MODES

Semileptonic and leptonic modes

Semileptonic a	ina leptonic modes	
$\overline{b} \rightarrow e^+ \nu_e$ anything [ccc	(11.1 ± 1.0) %	-
$\overline{b} ightarrow \ \mu^+ u_{\mu}$ anything [ccc	(10.7 ± 0.7) %	-
$\overline{b} \rightarrow \ell^+ \nu_\ell$ anything [qq,ccc	(11.13± 0.29) %	-
	(2.01 ± 0.29) %	-
	(6.6 ± 0.6) %	-
$\overline{b} \rightarrow D^{*-} \ell^+ \nu_{\ell}$ anything [qq	(2.76 ± 0.29) %	-
$\overline{b} ightarrow \overline{D}_j^0 \ell^+ u_\ell$ anything [qq,fff	seen	-
$\overline{b} ightarrow D_i^- \ell^+ u_\ell$ anything [qq,fff		-
$\overline{b} ightarrow \overline{D}_2^*(2460)^0 \ell^+ u_\ell$ any-	seen	-
thing		
$\overline{b} \rightarrow D_2^*(2460)^- \ell^+ \nu_\ell$ any-	seen	-
thing		
$\overline{b} \rightarrow \tau^+ \nu_{ au}$ anything	$(2.7 \pm 0.4)\%$	-
$\overline{b} ightarrow \overline{b} ightarrow \overline{c} ightarrow \ell^- \overline{ u}_\ell$ anything [qq] (7.9 ± 0.8)%	-

_	Charmonium modes			
$\overline{b} ightarrow \ J/\psi(1S)$ anything	(1.16± 0.10) %	-		
$\overline{b} ightarrow \psi(2S)$ anything	$(4.8 \pm 2.4) \times 10^{-3}$	-		
$\overline{b} \rightarrow \chi_{c1}(1P)$ anything	$(1.8 \pm 0.5)\%$	-		
_	K or K* modes			
$\overline{b} ightarrow \overline{s} \gamma$	$< 1.2 \times 10^{-3} 90\%$	_		
$\overline{b} ightarrow \ {\it K}^{\pm}$ anything	(88 ±19)%	-		
$\overline{b} ightarrow \ \mathcal{K}_{\mathcal{S}}^{0}$ anything	$(29.0 \pm 2.9)\%$	-		
	Baryon modes			
$\overline{b} \rightarrow p/\overline{p}$ anything	(14 ± 6)%	-		
$\overline{b} \rightarrow \Lambda/\overline{\Lambda}$ anything	$(5.9 \pm 1.1)\%$			
	Other modes			
$\overline{b} ightarrow ext{charged anything}$	[eee] (584 \pm 40)%	-		
$\Delta B = 1$ weak neutral current (B1) modes				
$\overline{b} \rightarrow \mu^+ \mu^-$ anything	$B1 < 5.0 \times 10^{-5} 90\%$	_		
$\overline{b} ightarrow \overline{ u}$ anything	$B1 < 3.9 \times 10^{-4}$	-		

В*

$$I(J^P) = \frac{1}{2}(1^-)$$

p (MeV/c)

I, J, P need confirmation. Quantum numbers shown are quark-model

Mass
$$m_{B^*} = 5324.8 \pm 1.8 \; {\rm MeV}$$
 $m_{B^*} - m_B = 45.7 \pm 0.4 \; {\rm MeV}$

B* DECAY MODES Fraction (Γ_i/Γ)

 $B\gamma$ dominant

BOTTOM, STRANGE MESONS $(B = \pm 1, S = \mp 1)$

 $B_s^0 = s\overline{b}$, $\overline{B}_s^0 = \overline{s}b$, similarly for B_s^* 's

 B_s^0

$$I(J^P) = 0(0^-)$$

I, J, P need confirmation. Quantum numbers shown are quark-model

Mass
$$m_{B_s^0} = 5369.3 \pm 2.0 \text{ MeV}$$

Mean life $\tau = (1.61^{+0.10}_{-0.09}) \times 10^{-12} \text{ s}$
 $c\tau = 483 \ \mu\text{m}$

$B_s^0 - \overline{B}_s^0$ mixing parameters

$$\begin{array}{l} \chi_s > 0.49, \; \mathrm{CL} = 95\% \\ \chi_B \; \mathrm{at \; high \; energy} = f_d \chi_d + f_s \chi_s = 0.126 \, \pm \, 0.008 \\ \Delta m_{B_s^0} = m_{B_{sH}^0} - m_{B_{sL}^0} > 5.9 \times 10^{12} \; \hbar \; \mathrm{s}^{-1}, \; \mathrm{CL} = 95\% \\ \chi_s = \Delta m_{B_s^0} / \Gamma_{B_s^0} > 9.5, \; \mathrm{CL} = 95\% \end{array}$$

These branching fractions all scale with B($\overline{b} \rightarrow B_s^0$), the LEP B_s^0 production fraction. The first four were evaluated using $B(\overline{b} \rightarrow B_s^0) =$ (11.2 + 1.8)% and the rest assume B($\bar{b} \to B_s^0$) = 12%.

The branching fraction B($B_s^0 \to D_s^- \ell^+ \nu_\ell$ anything) is not a pure measurement since the measured product branching fraction $B(\overline{b} \rightarrow B_s^0) \times$ $B(B_0^0 \to D_0^- \ell^+ \nu_\ell$ anything) was used to determine $B(\overline{b} \to B_0^0)$, as described in the note on "Production and Decay of b-Flavored Hadrons."

B _s DECAY MODES		Fraction ($\Gamma_{I/I}$	/ ୮)	Confidence level	<i>p</i> (MeV/ <i>c</i>)
D_ anything		(87 ±31	1)%		
$D_s^- \ell^+ \nu_\ell$ anything	[gg	g] (7.6 ± 2	2.4) %		-
$D_s^-\pi^+$		< 12	%		2321
$J/\psi(1S)\phi$		< 6	× 10	-3	1590
$\psi(2S)\phi \\ \pi^0\pi^0$		seen			1122
		< 2.1	× 10	-4 90%	2861
$\eta \pi^0$		< 1.0	× 10	-3 90%	2655
$\eta \eta$		< 1.5	× 10	-3 90%	2628
$\pi^+ K^-$		< 2.6	× 10	-4 90%	2660
K ⁺ K ⁻		< 1.4	× 10	-4 90%	2639
$\Delta B = 1$	weak ne	utral current	(<i>B1</i>) m	odes	
$\gamma \gamma$	B1	< 1.48	× 10	-4 90%	2685

η_c	(1	5)

$$I^{G}(J^{PC}) = 0^{+}(0^{-}+)$$

Mass $m = 2979.8 \pm 2.1 \; {\rm MeV} \quad ({\rm S} = 2.1)$ Full width $\Gamma = 13.2^{+3.8}_{-3.2} \; {\rm MeV}$

$\eta_{\mathcal{C}}(1S)$ DECAY MODES	Fraction (Γ_i/Γ_i)	г) с	onfidence level	<i>p</i> (MeV/ <i>c</i>)
Decays in	volving hadronic res	sonance	S	
$\eta'(958) \pi \pi$	(4.1 ±1.7)	%		1319
$\rho \rho$	(2.6 ±0.9)	.%		1275
$K^*(892)^0 K^- \pi^+ + \text{c.c.}$	(2.0 ± 0.7)	%		1273
K*(892) \overline{K}*(892)	(8.5 ± 3.1)	$\times 10^{-3}$		1193
$\phi \phi$	(7.1 ± 2.8)	$\times 10^{-3}$		1086
$a_0(980)\pi$	< 2	%	90%	1323
$a_2(1320)\pi$	< 2	%	90%	1193
$\overline{K^*}$ (892) \overline{K} + c.c.	< 1.28	%	90%	1307
$f_2(\hat{1}270)\eta$	< 1.1	%	90%	1142
ωω	< 3.1	\times 10 ⁻³	90%	1268
Dec	ays into stable hadr	ons		
$K\overline{K}\pi$	(5.5 ± 1.7)	%		1378
$\eta \pi \pi$	(4.9 ± 1.8)	%		1425
$\pi^{+}\pi^{-}K^{+}K^{-}$	$(2.0 \begin{array}{c} +0.7 \\ -0.6 \end{array})$	%		1342
2(K ⁺ K ⁻)	(2.1 ±1.2)	%		1053
$2(\pi^{+}\pi^{-})$	(1.2 ±0.4)			1457
$\rho \overleftarrow{\overline{\rho}}$	(1.2 ±0.4)	$\times 10^{-3}$		1157
$K\overline{K}n$	< 3.1	%	90%	1262
$\pi^+\pi^-p\overline{p}$	< 1.2	%	90%	1023
$\Lambda \overline{\Lambda}$	< 2	\times 10 ⁻³	90%	987
	Radiative decays			
γγ	(3.0 ±1.2)	$\times 10^{-4}$		1489

$J/\psi(1S)$

 $J/\psi(1S)$ DECAY MODES

$$I^{G}(J^{PC}) = 0^{-}(1^{-})$$

Mass $m = 3096.88 \pm 0.04 \text{ MeV}$ Full width $\Gamma=87\pm5~\text{keV}$ $\Gamma_{e\,e}=5.26\pm0.37~{
m keV}~{
m (Assuming}~\Gamma_{e\,e}=\Gamma_{\mu\,\mu}{
m)}$ Scale factor/ p
Confidence level (MeV/c)

Fraction (Γ_i/Γ)

hadrons		$(87.7 \pm 0.5)\%$		-
virtual $\gamma ightarrow $ hadrons		$(17.0 \pm 2.0)\%$		-
$e^{+}e^{-}$		(6.02 ± 0.19) %		1548
$\mu^+\mu^-$		(6.01 ± 0.19) %		1545
Decays invo	lving I	hadronic resonances		
$\rho\pi$		$(1.28 \pm 0.10)\%$		1449
$\rho^0 \pi^0$		$(4.2 \pm 0.5) \times 10^{-3}$		1449
$a_2(1320)\rho$		(1.09±0.22) %		1125
$\omega \pi^+ \pi^+ \pi^- \pi^-$		$(8.5 \pm 3.4) \times 10^{-3}$		1392
$\omega \pi^+ \pi^-$		$(7.2 \pm 1.0) \times 10^{-3}$		1435
$K^*(892)^0 \overline{K}_2^*(1430)^0 + \text{c.c.}$		$(6.7 \pm 2.6) \times 10^{-3}$		1005
$\omega K^*(892)\overline{K} + \text{c.c.}$		(5.3 ± 2.0) $\times 10^{-3}$		1098
$\omega f_2(1270)$		$(4.3 \pm 0.6) \times 10^{-3}$		1143
$K^{+}K^{*}(892)^{-} + \text{c.c.}$		$(5.0 \pm 0.4) \times 10^{-3}$		1373
$K^{0}\overline{K}^{*}(892)^{0} + \text{c.c.}$		$(4.2 \pm 0.4) \times 10^{-3}$		1371
$\omega \pi^0 \pi^0$		$(3.4 \pm 0.8) \times 10^{-3}$		1436
$b_1(1235)^{\pm}\pi^{\mp}$	[gg]	$(3.0 \pm 0.5) \times 10^{-3}$		1299
$\omega K^{\pm} K_{S}^{0} \pi^{\mp}$	[gg]	$(3.0 \pm 0.7) \times 10^{-3}$		1210
$b_1(1235)^0 \pi^0$		$(2.3 \pm 0.6) \times 10^{-3}$		1299
$\phi \hat{K}^*(892) \overline{K} + \text{c.c.}$		$(2.04\pm0.28)\times10^{-3}$		969
$\omega K \overrightarrow{K}$		$(1.9 \pm 0.4) \times 10^{-3}$		1268
$\omega f_J(1710) \rightarrow \omega K \overline{K}$		$(4.8 \pm 1.1) \times 10^{-4}$		878
$\phi 2(\pi^{+}\pi^{-})$		$(1.60\pm0.32)\times10^{-3}$		1318
$\Delta(1232)^{++}\overline{p}\pi^{-}$		$(1.6 \pm 0.5) \times 10^{-3}$		1030
$\omega \eta$		$(1.58\pm0.16)\times10^{-3}$		1394
$\phi K \overline{K}$		$(1.48\pm0.22)\times10^{-3}$		1179
$\phi f_J(1710) \rightarrow \phi K \overline{K}$		$(3.6 \pm 0.6) \times 10^{-4}$		875
$p \overline{p} \omega$		$(1.30\pm0.25)\times10^{-3}$	S=1.3	769
$\Delta(1232)^{++}\overline{\Delta}(1232)^{}$		$(1.10\pm0.29)\times10^{-3}$		938
$\Sigma(1385)^{-}\overline{\Sigma}(1385)^{+}$ (or c.c.)	[gg]	$(1.03\pm0.13)\times10^{-3}$		692
$p\overline{p}\eta'(958)$		$(9 \pm 4) \times 10^{-4}$	S=1.7	596
$\phi f_2'(1525)$		$(8 \pm 4) \times 10^{-4}$	S=2.7	871

. + =					
$\phi \pi^+ \pi^-$	(8.0	±1.2) $\times10^{-4}$		1365
$\phi K^{\pm} K_S^0 \pi^{\mp}$	[gg] (7.2	± 0.9) $\times 10^{-4}$		1114
$\omega f_1(1420)$	(6.8	$\pm 2.4) \times 10^{-4}$		1062
$\phi \eta$	(6.5	± 0.7) $\times 10^{-4}$		1320
-(1520)- - +		(- 0	115)10-4		
$\Xi(1530)^{-}\overline{\Xi}^{+}$	(5.9	± 1.5) $\times 10^{-4}$		597
$pK^{-}\overline{\Sigma}(1385)^{0}$	(5.1	$\pm 3.2) \times 10^{-4}$		645
					1447
$\omega \pi^0$	(± 0.6) × 10 ⁻⁴	S=1.4	1447
$\phi \eta'(958)$	(3.3	± 0.4) $\times 10^{-4}$		1192
				C10	
$\phi f_0(980)$			± 0.9) × 10 ⁻⁴	S=1.9	1182
$\Xi(1530)^0\overline{\Xi}^0$	(3.2	± 1.4) $\times 10^{-4}$		608
$\Sigma(1385)^{-}\overline{\Sigma}^{+}$ (or c.c.)			$\pm 0.5) \times 10^{-4}$		857
2(1363) 2 (01 (.(.)					
$\phi f_1(1285)$	(2.6	± 0.5) $\times 10^{-4}$	S=1.1	1032
	i	1 03	$3 \pm 0.23) \times 10^{-4}$		1398
$\rho\eta$					
$\omega \eta'$ (958)	((1.67	$(\pm 0.25) \times 10^{-4}$		1279
$\omega f_0(980)$,	1 4	± 0.5) × 10^{-4}		1271
$\rho \eta'(958)$	(1.05	$5\pm0.18)\times10^{-4}$		1283
$p \overline{p} \phi$	(4.5	± 1.5) $\times 10^{-5}$		527
		•		C1 000/	
$a_2(1320)^{\pm} \pi^{\mp}$	[gg] <	4.3	× 10 ⁻³	CL=90%	1263
$K\overline{K}_{2}^{*}(1430) + \text{c.c.}$	<	4.0	× 10 ⁻³	CL=90%	1159
$K_2^*(1430)^0 \overline{K}_2^*(1430)^0$	<	2.9	× 10 ⁻³	CL=90%	588
$K^*(892)^0 \overline{K}^*(892)^0$	<-	5	× 10 ⁻⁴	CL=90%	1263
$\phi f_2(1270)$	<	3.7	× 10 ⁻⁴	CL=90%	1036
· ·	<	3.1	× 10 ⁻⁴	CL=90%	779
$p\overline{p}\rho$					
$\phi \eta(1440) \rightarrow \phi \eta \pi \pi$	<	2.5	$\times 10^{-4}$	CL=90%	946
$\omega f_2^{\prime}(1525)$	<	2.2	× 10 ⁻⁴	CL=90%	1003
$\Sigma(1385)^{0}\overline{\Lambda}$	<	2	× 10 ⁻⁴	CL=90%	911
$\Delta(1232)^{+}\overline{p}$	<	1	× 10 ⁻⁴	CL=90%	1100
$\Sigma^{0}\overline{\Lambda}$	<	9	$\times 10^{-5}$	CL=90%	1032
$\phi \pi^0$	<	6.8	× 10 ⁻⁶	CL=90%	1377
Ψπ	_	0.0	× 10	CL= 30 /0	13.7
	Decays into st	abla	hadrone		
	Decays into st	able	nadrons		
$2(\pi^{+}\pi^{-})\pi^{0}$		(3.37	7±0.26) %		1496
$3(\pi^{+}\pi^{-})\pi^{0}$			±0.6)%		1433
$3(\pi^-\pi^-)\pi^-$					
$\pi^+\pi^-\pi^0$	1	(1.50	0 ± 0.20) %		1533
$\pi^{+}\pi^{-}\pi^{0}K^{+}K^{-}$		(1 20	±0.30) %		1368
# # # K K		•			
$4(\pi^+\pi^-)\pi^0$	1	9.0	$\pm 3.0 \times 10^{-3}$		1345
$\pi^{+}\pi^{-}K^{+}K^{-}$		72	$\pm 2.3) \times 10^{-3}$		1407
		(1.2	12.3 / 10		
$K\overline{K}\pi$	((6.1	± 1.0) $\times 10^{-3}$		1440
$p\overline{p}\pi^+\pi^-$					4407
	1		± 0.5) $\times 10^{-3}$	S=1.3	1107
$2(\pi^{+}\pi^{-})$			± 0.5) × 10 3 ± 1.0) × 10 ⁻³	S=1.3	1517
$2(\pi^{+}\pi^{-})$	((4.0	± 1.0) $\times 10^{-3}$	5=1.3	1517
$2(\pi^+\pi^-)$ $3(\pi^+\pi^-)$!	(4.0 (4.0	± 1.0) $\times 10^{-3}$ ± 2.0) $\times 10^{-3}$	5=1.3	1517 1466
$2(\pi^+\pi^-)$ $3(\pi^+\pi^-)$!	(4.0	± 1.0) $\times 10^{-3}$	5=1.3	1517
$2(\pi^{+}\pi^{-})$ $3(\pi^{+}\pi^{-})$ $n\overline{n}\pi^{+}\pi^{-}$!	(4.0 (4.0 (4	± 1.0) $\times 10^{-3}$ ± 2.0) $\times 10^{-3}$ ± 4) $\times 10^{-3}$	5=1.3	1517 1466 1106
$ \begin{array}{l} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\overline{n}\pi^{+}\pi^{-} \\ \Sigma\overline{\Sigma} \end{array} $	1	(4.0 (4.0 (4 (3.8	± 1.0) $\times 10^{-3}$ ± 2.0) $\times 10^{-3}$ ± 4) $\times 10^{-3}$ ± 0.5) $\times 10^{-3}$	5=1.3	1517 1466 1106 992
$ 2(\pi^{+}\pi^{-}) 3(\pi^{+}\pi^{-}) n \overline{n} \pi^{+} \pi^{-} \Sigma \overline{\Sigma} 2(\pi^{+}\pi^{-}) K^{+} K^{-} $	1	(4.0 (4.0 (4 (3.8	± 1.0) $\times 10^{-3}$ ± 2.0) $\times 10^{-3}$ ± 4) $\times 10^{-3}$	5=1.3	1517 1466 1106
$ 2(\pi^{+}\pi^{-}) 3(\pi^{+}\pi^{-}) n \overline{n} \pi^{+} \pi^{-} \Sigma \overline{\Sigma} 2(\pi^{+}\pi^{-}) K^{+} K^{-} $		(4.0 (4.0 (4 (3.8 (3.1	± 1.0) × 10^{-3} ± 2.0) × 10^{-3} ± 4) × 10^{-3} ± 0.5) × 10^{-3} ± 1.3) × 10^{-3}		1517 1466 1106 992 1320
$\begin{array}{c} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\overline{n}\pi^{+}\pi^{-} \\ \overline{\Sigma} \\ \overline{\Sigma} \\ 2(\pi^{+}\pi^{-}) K^{+}K^{-} \\ p\overline{p}\pi^{+}\pi^{-}\pi^{0} \end{array}$	[hhh]	(4.0 (4.0 (4 (3.8 (3.1 (2.3	± 1.0) $\times 10^{-3}$ ± 2.0) $\times 10^{-3}$ ± 4) $\times 10^{-3}$ ± 0.5) $\times 10^{-3}$ ± 1.3) $\times 10^{-3}$ ± 0.9) $\times 10^{-3}$	S=1.3	1517 1466 1106 992 1320 1033
$ 2(\pi^{+}\pi^{-}) 3(\pi^{+}\pi^{-}) n \overline{n} \pi^{+} \pi^{-} \Sigma \overline{\Sigma} 2(\pi^{+}\pi^{-}) K^{+} K^{-} $	[hhh]	(4.0 (4.0 (4 (3.8 (3.1 (2.3 (2.14	± 1.0) $\times 10^{-3}$ ± 2.0) $\times 10^{-3}$ ± 4) $\times 10^{-3}$ ± 0.5) $\times 10^{-3}$ ± 1.3) $\times 10^{-3}$ ± 0.9) $\times 10^{-3}$		1517 1466 1106 992 1320
$\begin{array}{l} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\bar{n}\pi^{+}\pi^{-} \\ \Sigma \overline{\Sigma} \\ 2(\pi^{+}\pi^{-}) K^{+}K^{-} \\ p\bar{p}\pi^{+}\pi^{-}\pi^{0} \\ p\bar{p} \end{array}$	[hhh]	(4.0 (4.0 (4 (3.8 (3.1 (2.3 (2.14	± 1.0) $\times 10^{-3}$ ± 2.0) $\times 10^{-3}$ ± 4) $\times 10^{-3}$ ± 0.5) $\times 10^{-3}$ ± 1.3) $\times 10^{-3}$ ± 0.9) $\times 10^{-3}$		1517 1466 1106 992 1320 1033
$\begin{array}{l} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\overline{n}\pi^{+}\pi^{-} \\ \Sigma \overline{\Sigma} \\ 2(\pi^{+}\pi^{-}) K^{+}K^{-} \\ p\overline{p}\pi^{+}\pi^{-}\pi^{0} \\ p\overline{p} \\ p\overline{p}\eta \end{array}$	[hhh]	(4.0 (4.0 (4 (3.8 (3.1 (2.3 (2.14 (2.09	± 1.0) × 10^{-3} ± 2.0) × 10^{-3} ± 4) × 10^{-3} ± 0.5) × 10^{-3} ± 1.3) × 10^{-3} ± 0.9) × 10^{-3} ± 0.10) × 10^{-3} ± 0.18) × 10^{-3}		1517 1466 1106 992 1320 1033 1232 948
$\begin{array}{l} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\overline{n}\pi^{+}\pi^{-} \\ \Sigma \overline{\Sigma} \\ 2(\pi^{+}\pi^{-})K^{+}K^{-} \\ p\overline{p}\pi^{+}\pi^{-}\pi^{0} \\ p\overline{p}\eta \\ p\overline{n}\pi^{-} \end{array}$	[hhh]	(4.0 (4.0 (4 (3.8 (3.1 (2.3 (2.14 (2.09 (2.00	± 1.0) × 10^{-3} ± 2.0) × 10^{-3} ± 4) × 10^{-3} ± 0.5) × 10^{-3} ± 1.3) × 10^{-3} ± 0.9) × 10^{-3} ± 0.10) × 10^{-3} 0 ± 0.10) × 10^{-3}		1517 1466 1106 992 1320 1033 1232 948 1174
$\begin{array}{l} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\overline{n}\pi^{+}\pi^{-} \\ \Sigma \overline{\Sigma} \\ 2(\pi^{+}\pi^{-}) K^{+}K^{-} \\ p\overline{p}\pi^{+}\pi^{-}\pi^{0} \\ p\overline{p} \\ p\overline{p}\eta \end{array}$	[hhh]	(4.0 (4.0 (4 (3.8 (3.1 (2.3 (2.14 (2.09 (2.00	± 1.0) × 10^{-3} ± 2.0) × 10^{-3} ± 4) × 10^{-3} ± 0.5) × 10^{-3} ± 1.3) × 10^{-3} ± 0.9) × 10^{-3} ± 0.10) × 10^{-3} 0 ± 0.10) × 10^{-3}		1517 1466 1106 992 1320 1033 1232 948
$\begin{array}{c} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\overline{n}\pi^{+}\pi^{-} \\ \overline{\Sigma} \\ \overline{\Sigma} \\ 2(\pi^{+}\pi^{-})K^{+}K^{-} \\ p\overline{p}\pi^{+}\pi^{-}\pi^{0} \\ p\overline{p} \\ p\overline{p}\overline{n}\pi^{-} \\ n\overline{n} \end{array}$	[hhh]	(4.0 (4.0 (4 (3.8 (3.1 (2.3 (2.1 ² (2.00 (1.9	± 1.0) × 10^{-3} ± 2.0) × 10^{-3} ± 4) × 10^{-3} ± 0.5) × 10^{-3} ± 1.3) × 10^{-3} ± 0.9) × 10^{-3} ± 0.10) × 10^{-3} ± 0.10) × 10^{-3} ± 0.5) × 10^{-3}	S=1.9	1517 1466 1106 992 1320 1033 1232 948 1174 1231
$\begin{array}{c} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\bar{n}\pi^{+}\pi^{-} \\ \Sigma \overline{\Sigma} \\ 2(\pi^{+}\pi^{-}) K^{+}K^{-} \\ p\bar{p}\pi^{+}\pi^{-}\pi^{0} \\ p\bar{p}\eta \\ p\bar{n}\pi^{-} \\ n\bar{n} \\ \Xi \overline{\Xi} \end{array}$	[hhh]	(4.0 (4.0 (4 (3.8 (3.1 (2.3 (2.1 ² (2.09 (1.9 (1.8	± 1.0) × 10 ⁻³ ± 2.0) × 10 ⁻³ ± 4) × 10 ⁻³ ± 0.5) × 10 ⁻³ ± 0.5) × 10 ⁻³ ± 0.9) × 10 ⁻³ ± 0.9) × 10 ⁻³ ± 0.10) × 10 ⁻³ ± 0.10) × 10 ⁻³ ± 0.10) × 10 ⁻³ ± 0.5) × 10 ⁻³ ± 0.4) × 10 ⁻³ ± 0.4) × 10 ⁻³	S=1.9 S=1.8	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818
$\begin{array}{c} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\bar{n}\pi^{+}\pi^{-} \\ \Sigma\bar{\Sigma} \\ 2(\pi^{+}\pi^{-})K^{+}K^{-} \\ p\bar{p}\pi^{+}\pi^{-}\pi^{0} \\ p\bar{p} \\ p\bar{p}\bar{n}\eta \\ p\bar{n}\pi^{-} \\ n\bar{n} \\ \bar{\Xi} \\ \bar{\Delta}\bar{\Delta} \end{array}$	[hhh]	(4.0 (4.0 (4 (3.8 (3.1 (2.3 (2.14 (2.09 (1.9 (1.8 (1.3)	±1.0) × 10 ⁻³ ±2.0) × 10 ⁻³ ±4) × 10 ⁻³ ±0.5) × 10 ⁻³ ±1.3) × 10 ⁻³ ±0.9) × 10 ⁻³ ±0.10) × 10 ⁻³ 9±0.18) × 10 ⁻³ 0±0.10) × 10 ⁻³ ±0.5) × 10 ⁻³ ±0.4) × 10 ⁻³ ±0.4) × 10 ⁻³	S=1.9	1517 1466 1106 992 1320 1033 1232 948 1174 1231
$\begin{array}{c} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\bar{n}\pi^{+}\pi^{-} \\ \Sigma\bar{\Sigma} \\ 2(\pi^{+}\pi^{-})K^{+}K^{-} \\ p\bar{p}\pi^{+}\pi^{-}\pi^{0} \\ p\bar{p} \\ p\bar{p}\bar{n}\eta \\ p\bar{n}\pi^{-} \\ n\bar{n} \\ \bar{\Xi} \\ \bar{\Delta}\bar{\Delta} \end{array}$	[hhh]	(4.0 (4.0 (4 (3.8 (3.1 (2.3 (2.14 (2.09 (1.9 (1.8 (1.3)	±1.0) × 10 ⁻³ ±2.0) × 10 ⁻³ ±4) × 10 ⁻³ ±0.5) × 10 ⁻³ ±1.3) × 10 ⁻³ ±0.9) × 10 ⁻³ ±0.10) × 10 ⁻³ 9±0.18) × 10 ⁻³ 0±0.10) × 10 ⁻³ ±0.5) × 10 ⁻³ ±0.4) × 10 ⁻³ ±0.4) × 10 ⁻³	S=1.9 S=1.8	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074
$\begin{array}{c} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\overline{n}\pi^{+}\pi^{-} \\ \Sigma \overline{\Sigma} \\ 2(\pi^{+}\pi^{-})K^{+}K^{-} \\ p\overline{p}\pi^{+}\pi^{-}\pi^{0} \\ p\overline{p} \\ p\overline{p} \\ p\overline{p}\pi^{-} \\ n\overline{n} \\ \Xi \overline{\Sigma} \\ n\overline{p}\pi^{0} \end{array}$	[hhh]	(4.0 (4.0 (4.0 (4.0 (3.8 (3.1 (2.3 (2.0 (2.0 (1.9 (1.3 (1.3 (1.0 (1.0	± 1.0) × 10^{-3} ± 2.0) × 10^{-3} ± 4) × 10^{-3} ± 0.5) × 10^{-3} ± 1.3) × 10^{-3} ± 1.3) × 10^{-3} ± 0.9) × 10^{-3} ± 0.10) × 10^{-3} ± 0.5) × 10^{-3} ± 0.4) × 10^{-3} ± 0.4) × 10^{-3} ± 0.4) × 10^{-3} ± 0.9) × 10^{-3} ± 0.9) × 10^{-3}	S=1.9 S=1.8	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176
$\begin{array}{l} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\overline{n}\pi^{+}\pi^{-} \\ \Sigma\overline{\Sigma} \\ 2(\pi^{+}\pi^{-})K^{+}K^{-} \\ p\overline{p}\pi^{+}\pi^{-}\pi^{0} \\ p\overline{p} \\ p\overline{p}\overline{n} \\ p\overline{n}\pi^{-} \\ n\overline{n} \\ \Xi\overline{\Xi} \\ \lambda\overline{\lambda} \\ p\overline{p}\pi^{0} \\ \lambda\overline{\Sigma}^{-}\pi^{+} \text{ (or c.c.)} \end{array}$	[hhh]	(4.0 (4.0 (4.0 (3.8 (3.1 (2.3 (2.14 (2.00 (1.9 (1.8 (1.3! (1.00 (1	± 1.0) × 10^{-3} ± 2.0) × 10^{-3} ± 4) × 10^{-3} ± 0.5) × 10^{-3} ± 0.5) × 10^{-3} ± 1.3) × 10^{-3} ± 1.0) × 10^{-3} ± 0.10) × 10^{-3} ± 0.5) × 10^{-3} ± 0.4) × 10^{-3} ± 0.4) × 10^{-3} 5 ± 0.14) × 10^{-3} 5 ± 0.12) × 10^{-3} 5 ± 0.12) × 10^{-3}	S=1.9 S=1.8	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945
$\begin{array}{l} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\overline{n}\pi^{+}\pi^{-} \\ \Sigma\overline{\Sigma} \\ 2(\pi^{+}\pi^{-})K^{+}K^{-} \\ p\overline{p}\pi^{+}\pi^{-}\pi^{0} \\ p\overline{p} \\ p\overline{p}\overline{n} \\ p\overline{n}\pi^{-} \\ n\overline{n} \\ \Xi\overline{\Xi} \\ \lambda\overline{\lambda} \\ p\overline{p}\pi^{0} \\ \lambda\overline{\Sigma}^{-}\pi^{+} \text{ (or c.c.)} \end{array}$	[hhh]	(4.0 (4.0 (4.0 (3.8 (3.1 (2.3 (2.14 (2.00 (1.9 (1.8 (1.3! (1.00 (1	± 1.0) × 10^{-3} ± 2.0) × 10^{-3} ± 4) × 10^{-3} ± 0.5) × 10^{-3} ± 0.5) × 10^{-3} ± 1.3) × 10^{-3} ± 1.0) × 10^{-3} ± 0.10) × 10^{-3} ± 0.5) × 10^{-3} ± 0.4) × 10^{-3} ± 0.4) × 10^{-3} 5 ± 0.14) × 10^{-3} 5 ± 0.12) × 10^{-3} 5 ± 0.12) × 10^{-3}	S=1.9 S=1.8	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176
$\begin{array}{l} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\overline{n}\pi^{+}\pi^{-} \\ \Sigma\overline{\Sigma} \\ 2(\pi^{+}\pi^{-})K^{+}K^{-} \\ p\overline{p}\pi^{+}\pi^{-}\pi^{0} \\ p\overline{p} \\ p\overline{p}\overline{n}\pi^{-} \\ n\overline{n} \\ \Xi\overline{\Xi} \\ \lambda\overline{\lambda} \\ p\overline{p}\pi^{0} \\ \lambda\overline{\Sigma}^{-}\pi^{+} \text{ (or c.c.)} \\ pK^{-}\overline{\lambda} \end{array}$	[hhh]	(4.0 (4.0 (4.0 (3.8 (3.1 (2.3 (2.14 (2.09 (1.9 (1.3! (1.09 (1.09 (8.9	± 1.0) × 10 ⁻³ ± 2.0) × 10 ⁻³ ± 4) × 10 ⁻³ ± 4) × 10 ⁻³ ± 0.5) × 10 ⁻³ ± 1.3) × 10 ⁻³ ± 0.9) × 10 ⁻³ 3 ± 0.10) × 10 ⁻³ 3 ± 0.10) × 10 ⁻³ 3 ± 0.15) × 10 ⁻³ 3 ± 0.4) × 10 ⁻⁴	S=1.9 S=1.8	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945 876
$\begin{array}{l} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\bar{n}\pi^{+}\pi^{-} \\ \Sigma \overline{\Sigma} \\ 2(\pi^{+}\pi^{-}) K^{+}K^{-} \\ p\bar{p}\pi^{+}\pi^{-}\pi^{0} \\ p\bar{p} \\ p\bar{p}\eta \\ p\bar{n}\pi^{-} \\ n\bar{n} \\ \equiv \overline{\Xi} \\ \Lambda \overline{\Lambda} \\ p\bar{p}\pi^{0} \\ \Lambda \overline{\Sigma}^{-}\pi^{+} \text{ (or c.c.)} \\ pK^{-}\overline{\Lambda} \\ 2(K^{+}K^{-}) \end{array}$	[hhh]	(4.0 (4.0	#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4) × 10 ⁻³ #0.5) × 10 ⁻³ #1.3) × 10 ⁻³ #1.3) × 10 ⁻³ #1.6) × 10 ⁻⁴	S=1.9 S=1.8	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945 876
$\begin{array}{l} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\overline{n}\pi^{+}\pi^{-} \\ \Sigma\overline{\Sigma} \\ 2(\pi^{+}\pi^{-})K^{+}K^{-} \\ p\overline{p}\pi^{+}\pi^{-}\pi^{0} \\ p\overline{p} \\ p\overline{p}\overline{n}\pi^{-} \\ n\overline{n} \\ \Xi\overline{\Xi} \\ \lambda\overline{\lambda} \\ p\overline{p}\pi^{0} \\ \lambda\overline{\Sigma}^{-}\pi^{+} \text{ (or c.c.)} \\ pK^{-}\overline{\lambda} \end{array}$	[hhh]	(4.0 (4.0	#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4) × 10 ⁻³ #0.5) × 10 ⁻³ #1.3) × 10 ⁻³ #1.3) × 10 ⁻³ #1.6) × 10 ⁻⁴	S=1.9 S=1.8	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945 876
$\begin{array}{l} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\overline{n}\pi^{+}\pi^{-} \\ \Sigma\overline{\Sigma} \\ \overline{\Sigma} \\ 2(\pi^{+}\pi^{-})K^{+}K^{-} \\ p\overline{p}\pi^{+}\pi^{-}\pi^{0} \\ p\overline{p} \\ p\overline{p}\eta \\ p\overline{n}\pi^{-} \\ n\overline{n} \\ \overline{\Xi} \\ \overline{\Lambda}\overline{\Lambda} \\ p\overline{p}\pi^{0} \\ \Lambda\overline{\Sigma}^{-}\pi^{+} \text{ (or c.c.)} \\ pK^{-}\overline{\Lambda} \\ 2(K^{+}K^{-}) \\ pK^{-}\overline{\Sigma}^{0} \end{array}$	[hhh] [gg]	(4.0 (4.0	#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4.0) × 10 ⁻³ #4.1) × 10 ⁻³ #0.5) × 10 ⁻³ #1.3) × 10 ⁻³ #1.0) × 10 ⁻³ #2.1) × 10 ⁻³ #2.2) × 10 ⁻³ #2.3) × 10 ⁻⁴ #2.3) × 10 ⁻⁴ #2.8) × 10 ⁻⁴	S=1.9 S=1.8	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945 876 1131
$\begin{array}{l} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\bar{n}\pi^{+}\pi^{-} \\ \Sigma \overline{\Sigma} \\ \\ 2(\pi^{+}\pi^{-}) K^{+}K^{-} \\ p\bar{p}\pi^{+}\pi^{-}\pi^{0} \\ p\bar{p} \\ p\bar{p}\eta \\ p\bar{n}\pi^{-} \\ n\bar{n} \\ \equiv \overline{\Xi} \\ \lambda \overline{\lambda} \\ p\bar{p}\pi^{0} \\ \lambda \overline{\Sigma}^{-}\pi^{+} \text{ (or c.c.)} \\ pK^{-}\overline{\lambda} \\ 2(K^{+}K^{-}) \\ pK^{-}\overline{\Sigma}^{0} \\ K^{+}K^{-} \end{array}$	[hhh]	(4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0	#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4) × 10 ⁻³ #1.3) × 10 ⁻³ #1.3) × 10 ⁻³ #2.0.10) × 10 ⁻³ #2.0.18) × 10 ⁻³ #2.0.10) × 10 ⁻³ #2.0.10) × 10 ⁻³ #2.0.10) × 10 ⁻³ #2.0.14) × 10 ⁻³ #2.0.20) × 10 ⁻³ #2.0.20) × 10 ⁻³ #2.0.30) × 10 ⁻⁴ #3.0) × 10 ⁻⁴ #3.0) × 10 ⁻⁴ #2.0.31) × 10 ⁻⁴	S=1.9 S=1.8	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945 876 1131 820
$\begin{array}{l} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\overline{n}\pi^{+}\pi^{-} \\ \Sigma\overline{\Sigma} \\ \overline{\Sigma} \\ 2(\pi^{+}\pi^{-})K^{+}K^{-} \\ p\overline{p}\pi^{+}\pi^{-}\pi^{0} \\ p\overline{p} \\ p\overline{p}\eta \\ p\overline{n}\pi^{-} \\ n\overline{n} \\ \overline{\Xi} \\ \overline{\Lambda}\overline{\Lambda} \\ p\overline{p}\pi^{0} \\ \Lambda\overline{\Sigma}^{-}\pi^{+} \text{ (or c.c.)} \\ pK^{-}\overline{\Lambda} \\ 2(K^{+}K^{-}) \\ pK^{-}\overline{\Sigma}^{0} \end{array}$	[hhh]	(4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0	#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4) × 10 ⁻³ #1.3) × 10 ⁻³ #1.3) × 10 ⁻³ #2.0.10) × 10 ⁻³ #2.0.18) × 10 ⁻³ #2.0.10) × 10 ⁻³ #2.0.10) × 10 ⁻³ #2.0.10) × 10 ⁻³ #2.0.14) × 10 ⁻³ #2.0.20) × 10 ⁻³ #2.0.20) × 10 ⁻³ #2.0.30) × 10 ⁻⁴ #3.0) × 10 ⁻⁴ #3.0) × 10 ⁻⁴ #2.0.31) × 10 ⁻⁴	S=1.9 S=1.8	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945 876 1131
$\begin{array}{l} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\overline{n}\pi^{+}\pi^{-} \\ \Sigma\overline{\Sigma} \\ 2(\pi^{+}\pi^{-})K^{+}K^{-} \\ p\overline{p}\pi^{+}\pi^{-}\pi^{0} \\ p\overline{p} \\ p\overline{p}\eta \\ p\overline{p}\pi^{-} \\ n\overline{n} \\ \equiv \overline{\Xi} \\ \lambda\overline{\lambda} \\ p\overline{p}\pi^{0} \\ \lambda\overline{\Sigma}^{-}\pi^{+} \text{ (or c.c.)} \\ pK^{-}\overline{\lambda} \\ 2(K^{+}K^{-}) \\ pK^{-}\overline{\Sigma}^{0} \\ K^{+}K^{-} \\ \lambda\overline{\lambda}\pi^{0} \end{array}$	[hhh]	(4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0	#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4) × 10 ⁻³ #0.5) × 10 ⁻³ #1.3) × 10 ⁻³ #1.3) × 10 ⁻³ #1.0) × 10 ⁻³ #2.0 10) × 10 ⁻⁴ #2.0 10 #2.0 10 #2	S=1.9 S=1.8	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945 876 1131 820 1468 998
$\begin{array}{l} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ \overline{n}\overline{n}\pi^{+}\pi^{-} \\ \overline{\Sigma}\overline{\Sigma} \\ \overline{\Sigma} \\ \overline{\Sigma} \\ \overline{\nu} \\ \overline{p} \\ \overline{n} \\ \pi^{-} \\ \overline{\Xi} \\ \overline{\Xi} \\ \Lambda \overline{\Lambda} \\ \overline{p} \\ \overline{p} \\ \pi^{0} \\ \overline{\Sigma}^{-} \\ \pi^{+} \\ (\text{or c.c.}) \\ p \\ K^{-} \\ \overline{\Lambda} \\ 2(K^{+}K^{-}) \\ p \\ K^{-} \\ \overline{\Sigma}^{0} \\ K^{+} \\ K^{-} \\ \Lambda \overline{\Lambda} \\ \pi^{0} \\ \pi^{+} \\ \pi^{-} \end{array}$	[hhh]	(4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0	#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4) × 10 ⁻³ #4) × 10 ⁻³ #5.5) × 10 ⁻³ #5.5) × 10 ⁻³ #5.9) × 10 ⁻³ #5.9) × 10 ⁻³ #5.0) × 10 ⁻⁴ #5.0) × 10 ⁻⁴ #5.0) × 10 ⁻⁴ #5.1) × 10 ⁻⁴ #5.7) × 10 ⁻⁴ #5.7) × 10 ⁻⁴ #5.7) × 10 ⁻⁴	S=1.9 S=1.8	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 876 1131 820 1468 998 1542
$\begin{array}{l} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ \overline{n}\overline{n}\pi^{+}\pi^{-} \\ \overline{\Sigma}\overline{\Sigma} \\ \overline{\Sigma} \\ \overline{\Sigma} \\ \overline{\nu} \\ \overline{p} \\ \overline{n} \\ \pi^{-} \\ \overline{\Xi} \\ \overline{\Xi} \\ \Lambda \overline{\Lambda} \\ \overline{p} \\ \overline{p} \\ \pi^{0} \\ \overline{\Sigma}^{-} \\ \pi^{+} \\ (\text{or c.c.}) \\ p \\ K^{-} \\ \overline{\Lambda} \\ 2(K^{+}K^{-}) \\ p \\ K^{-} \\ \overline{\Sigma}^{0} \\ K^{+} \\ K^{-} \\ \Lambda \overline{\Lambda} \\ \pi^{0} \\ \pi^{+} \\ \pi^{-} \end{array}$	[hhh]	(4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0	#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4) × 10 ⁻³ #0.5) × 10 ⁻³ #1.3) × 10 ⁻³ #1.3) × 10 ⁻³ #1.0) × 10 ⁻³ #2.0 10) × 10 ⁻⁴ #2.0 10 #2.0 10 #2	S=1.9 S=1.8	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945 876 1131 820 1468 998
$\begin{array}{c} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\bar{n}\pi^{+}\pi^{-} \\ \Sigma \overline{\Sigma} \\ 2(\pi^{+}\pi^{-}) K^{+}K^{-} \\ p\bar{p}\pi^{+}\pi^{-}\pi^{0} \\ p\bar{p} \\ p\bar{p}\eta \\ p\bar{n}\pi^{-} \\ n\bar{n} \\ \equiv \overline{\Xi} \\ \Lambda\bar{\Lambda} \\ p\bar{p}\pi^{0} \\ \Lambda\Sigma^{-}\pi^{+} \text{ (or c.c.)} \\ pK^{-}\bar{\Lambda} \\ 2(K^{+}K^{-}) \\ pK^{-}\overline{\Sigma^{0}} \\ K^{+}K^{-} \\ \Lambda\bar{\Lambda}\pi^{0} \\ \pi^{+}\pi^{-} \\ K^{0}_{S}K^{0}_{L} \end{array}$	[hhh]	(4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0	#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4) × 10 ⁻³ #4.0) × 10 ⁻³ #0.5) × 10 ⁻³ #1.3) × 10 ⁻³ #1.3) × 10 ⁻³ #1.6) × 10 ⁻⁴ #1.6) × 10 ⁻⁴ #1.6) × 10 ⁻⁴ #1.7) × 10 ⁻⁴	S=1.9 S=1.8 S=1.2	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945 876 1131 820 1468 998 1542 1466
$\begin{array}{l} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\overline{n}\pi^{+}\pi^{-} \\ \Sigma\overline{\Sigma} \\ 2(\pi^{+}\pi^{-})K^{+}K^{-} \\ p\overline{p}\pi^{+}\pi^{-}\pi^{0} \\ p\overline{p} \\ p\overline{p}\eta \\ p\overline{n}\pi^{-} \\ n\overline{n} \\ \equiv \overline{\Xi} \\ \Lambda\overline{\Lambda} \\ p\overline{p}\pi^{0} \\ \Lambda\Sigma^{-}\pi^{+} \text{ (or c.c.)} \\ pK^{-}\overline{\Lambda} \\ 2(K^{+}K^{-}) \\ pK^{-}\overline{\Sigma}^{0} \\ K^{+}K^{-} \\ \Lambda\overline{\Lambda}\pi^{0} \\ \pi^{+}\pi^{-} \\ K^{0}SK^{0} \\ \Lambda^{0}\Sigma^{+} + \text{c.c.} \end{array}$	[<i>phh</i>]	(4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0	#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4) × 10 ⁻³ #4) × 10 ⁻³ #5.5) × 10 ⁻³ #5.13) × 10 ⁻³ #5.9) × 10 ⁻³ #5.10) × 10 ⁻⁴	S=1.9 S=1.8 S=1.2	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945 876 1131 820 1468 998 1542 1466 1032
$\begin{array}{l} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\overline{n}\pi^{+}\pi^{-} \\ \Sigma\overline{\Sigma} \\ 2(\pi^{+}\pi^{-})K^{+}K^{-} \\ p\overline{p}\pi^{+}\pi^{-}\pi^{0} \\ p\overline{p} \\ p\overline{p}\eta \\ p\overline{n}\pi^{-} \\ n\overline{n} \\ \equiv \overline{\Xi} \\ \Lambda\overline{\Lambda} \\ p\overline{p}\pi^{0} \\ \Lambda\Sigma^{-}\pi^{+} \text{ (or c.c.)} \\ pK^{-}\overline{\Lambda} \\ 2(K^{+}K^{-}) \\ pK^{-}\overline{\Sigma}^{0} \\ K^{+}K^{-} \\ \Lambda\overline{\Lambda}\pi^{0} \\ \pi^{+}\pi^{-} \\ K^{0}SK^{0} \\ \Lambda^{0}\Sigma^{+} + \text{c.c.} \end{array}$	[hhh]	(4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0	#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4) × 10 ⁻³ #4.0) × 10 ⁻³ #0.5) × 10 ⁻³ #1.3) × 10 ⁻³ #1.3) × 10 ⁻³ #1.6) × 10 ⁻⁴ #1.6) × 10 ⁻⁴ #1.6) × 10 ⁻⁴ #1.7) × 10 ⁻⁴	S=1.9 S=1.8 S=1.2	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945 876 1131 820 1468 998 1542 1466
$\begin{array}{c} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\bar{n}\pi^{+}\pi^{-} \\ \Sigma \overline{\Sigma} \\ 2(\pi^{+}\pi^{-}) K^{+}K^{-} \\ p\bar{p}\pi^{+}\pi^{-}\pi^{0} \\ p\bar{p} \\ p\bar{p}\eta \\ p\bar{n}\pi^{-} \\ n\bar{n} \\ \equiv \overline{\Xi} \\ \Lambda\bar{\Lambda} \\ p\bar{p}\pi^{0} \\ \Lambda\Sigma^{-}\pi^{+} \text{ (or c.c.)} \\ pK^{-}\bar{\Lambda} \\ 2(K^{+}K^{-}) \\ pK^{-}\overline{\Sigma^{0}} \\ K^{+}K^{-} \\ \Lambda\bar{\Lambda}\pi^{0} \\ \pi^{+}\pi^{-} \\ K^{0}_{S}K^{0}_{L} \end{array}$	[gg]	(4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0	#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4) × 10 ⁻³ #4) × 10 ⁻³ #4.1) × 10 ⁻³ #0.5) × 10 ⁻³ #1.3) × 10 ⁻³ #1.6) × 10 ⁻³ #2.1) × 10 ⁻³ #2.2) × 10 ⁻³ #2.3) × 10 ⁻³ #2.4) × 10 ⁻³ #2.5) × 10 ⁻³ #2.6) × 10 ⁻³ #2.6) × 10 ⁻⁴ #2.7) × 10 ⁻⁴ #2.8) × 10 ⁻⁴ #2.8) × 10 ⁻⁴ #2.9) × 10 ⁻⁴ #2.9) × 10 ⁻⁴ #2.1) × 10 ⁻⁴	S=1.9 S=1.8 S=1.2	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945 876 1131 820 1468 998 1542 1466 1032
$\begin{array}{l} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\overline{n}\pi^{+}\pi^{-} \\ \Sigma\overline{\Sigma} \\ 2(\pi^{+}\pi^{-})K^{+}K^{-} \\ p\overline{p}\pi^{+}\pi^{-}\pi^{0} \\ p\overline{p} \\ p\overline{p}\eta \\ p\overline{n}\pi^{-} \\ n\overline{n} \\ \equiv \overline{\Xi} \\ \Lambda\overline{\Lambda} \\ p\overline{p}\pi^{0} \\ \Lambda\Sigma^{-}\pi^{+} \text{ (or c.c.)} \\ pK^{-}\overline{\Lambda} \\ 2(K^{+}K^{-}) \\ pK^{-}\overline{\Sigma}^{0} \\ K^{+}K^{-} \\ \Lambda\overline{\Lambda}\pi^{0} \\ \pi^{+}\pi^{-} \\ K^{0}SK^{0} \\ \Lambda^{0}\Sigma^{+} + \text{c.c.} \end{array}$	[<i>phh</i>]	(4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0	#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4) × 10 ⁻³ #4) × 10 ⁻³ #4.1) × 10 ⁻³ #0.5) × 10 ⁻³ #1.3) × 10 ⁻³ #1.6) × 10 ⁻³ #2.1) × 10 ⁻³ #2.2) × 10 ⁻³ #2.3) × 10 ⁻³ #2.4) × 10 ⁻³ #2.5) × 10 ⁻³ #2.6) × 10 ⁻³ #2.6) × 10 ⁻⁴ #2.7) × 10 ⁻⁴ #2.8) × 10 ⁻⁴ #2.8) × 10 ⁻⁴ #2.9) × 10 ⁻⁴ #2.9) × 10 ⁻⁴ #2.1) × 10 ⁻⁴	S=1.9 S=1.8 S=1.2	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945 876 1131 820 1468 998 1542 1466 1032
$\begin{array}{l} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\bar{n}\pi^{+}\pi^{-} \\ \Sigma\overline{\Sigma} \\ 2(\pi^{+}\pi^{-})K^{+}K^{-} \\ p\bar{p}\pi^{+}\pi^{-}\pi^{0} \\ p\bar{p} \\ p\bar{p}\eta \\ p\bar{n}\pi^{-} \\ n\bar{n} \\ \equiv \overline{\Xi} \\ \Lambda\overline{\Lambda} \\ p\bar{p}\pi^{0} \\ \Lambda\Sigma^{-}\pi^{+} \text{ (or c.c.)} \\ pK^{-}\overline{\Lambda} \\ 2(K^{+}K^{-}) \\ pK^{-}\overline{\Sigma}^{0} \\ K^{+}K^{-} \\ \Lambda\bar{\Lambda}\pi^{0} \\ \pi^{+}\pi^{-} \\ K^{0}_{S}K^{0}_{S} \\ \Lambda^{0}_{S}K^{0}_{S} \end{array}$	[gg]	(4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0	#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4) × 10 ⁻³ #4) × 10 ⁻³ #4.0) × 10 ⁻³ #0.5) × 10 ⁻³ #1.3) × 10 ⁻³ #1.6) × 10 ⁻³ #2.1) × 10 ⁻⁴ #2.2) × 10 ⁻⁴ #2.3) × 10 ⁻⁴ #3.4) × 10 ⁻⁴ #3.5) × 10 ⁻⁴ #3.6) × 10 ⁻⁴ #3.7) × 10 ⁻⁴ #3.7) × 10 ⁻⁴ #3.8) × 10 ⁻⁴ #3.9) × 10 ⁻⁴ ** ** ** ** ** ** ** ** ** ** ** ** **	S=1.9 S=1.8 S=1.2	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945 876 1131 820 1468 998 1542 1466
$\begin{array}{l} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\overline{n}\pi^{+}\pi^{-} \\ \Sigma\overline{\Sigma} \\ \overline{\Sigma} \\ 2(\pi^{+}\pi^{-})K^{+}K^{-} \\ p\overline{p}\pi^{+}\pi^{-}\pi^{0} \\ p\overline{p}\eta \\ p\overline{n}\pi^{-} \\ n\overline{n} \\ \equiv \overline{\Xi} \\ \lambda\overline{\Lambda} \\ p\overline{p}\pi^{0} \\ \Lambda\overline{\Sigma}^{-}\pi^{+} \text{ (or c.c.)} \\ pK^{-}\overline{\Lambda} \\ 2(K^{+}K^{-}) \\ pK^{-}\overline{\Sigma}^{0} \\ K^{+}K^{-} \\ \lambda\overline{\Lambda}\pi^{0} \\ \pi^{+}\pi^{-} \\ K^{0}_{S}K^{0}_{S} \\ \gamma\eta_{c}(1S) \end{array}$	[gg]	(4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0	#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4) × 10 ⁻³ #4) × 10 ⁻³ #5.1) × 10 ⁻³ #5.2) × 10 ⁻³ #5.3) × 10 ⁻⁴ #5.3) × 10 ⁻⁴ #5.3) × 10 ⁻⁴ #7.5) × 10 ⁻⁴ #7	S=1.9 S=1.8 S=1.2 CL=90% CL=90%	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945 876 1131 820 1468 998 1542 1466
$\begin{array}{l} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\overline{n}\pi^{+}\pi^{-} \\ \Sigma\overline{\Sigma} \\ \overline{\Sigma} \\ 2(\pi^{+}\pi^{-})K^{+}K^{-} \\ p\overline{p}\pi^{+}\pi^{-}\pi^{0} \\ p\overline{p}\eta \\ p\overline{n}\pi^{-} \\ n\overline{n} \\ \equiv \overline{\Xi} \\ \lambda\overline{\Lambda} \\ p\overline{p}\pi^{0} \\ \Lambda\overline{\Sigma}^{-}\pi^{+} \text{ (or c.c.)} \\ pK^{-}\overline{\Lambda} \\ 2(K^{+}K^{-}) \\ pK^{-}\overline{\Sigma}^{0} \\ K^{+}K^{-} \\ \lambda\overline{\Lambda}\pi^{0} \\ \pi^{+}\pi^{-} \\ K^{0}_{S}K^{0}_{S} \\ \gamma\eta_{c}(1S) \end{array}$	[gg]	(4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0	#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4) × 10 ⁻³ #4) × 10 ⁻³ #5.1) × 10 ⁻³ #5.2) × 10 ⁻³ #5.3) × 10 ⁻⁴ #5.3) × 10 ⁻⁴ #5.3) × 10 ⁻⁴ #7.5) × 10 ⁻⁴ #7	S=1.9 S=1.8 S=1.2 CL=90% CL=90%	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945 876 1131 820 1468 998 1542 1466
$\begin{array}{l} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\bar{n}\pi^{+}\pi^{-} \\ \Sigma \overline{\Sigma} \\ \\ 2(\pi^{+}\pi^{-}) K^{+}K^{-} \\ p\bar{p}\pi^{+}\pi^{-}\pi^{0} \\ p\bar{p} \\ p\bar{p} \\ n\bar{n} \\ -n\bar{n} \\ \equiv \overline{\Xi} \\ A\overline{A} \\ p\bar{p}\pi^{0} \\ A\Sigma^{-}\pi^{+} \text{ (or c.c.)} \\ pK^{-}\overline{A} \\ 2(K^{+}K^{-}) \\ pK^{-}\overline{\Sigma^{0}} \\ K^{+}K^{-} \\ A\bar{\Lambda}\pi^{0} \\ \pi^{+}\pi^{-} \\ K^{0}_{S}K^{0}_{S} \\ \gamma^{0}_{C}(1S) \\ \gamma^{\pi^{+}}\pi^{-}2\pi^{0} \end{array}$	[hhh] [gg]	(4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0	#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4) × 10 ⁻³ #3.1) × 10 ⁻⁴	S=1.9 S=1.8 S=1.2 CL=90% CL=90%	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945 876 1131 820 1468 998 1542 1466 1032 1466
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	[gg]	(4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0	#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4) × 10 ⁻³ #4) × 10 ⁻³ #4.0) × 10 ⁻³ #5.5) × 10 ⁻³ #5.13) × 10 ⁻³ #5.14) × 10 ⁻³ #5.10) × 10 ⁻⁴ #5.10) × 10 ⁻³ #5.10) × 10 ⁻³	S=1.9 S=1.8 S=1.2 CL=90% CL=90%	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 876 1131 820 1468 998 1542 1466 1032 1466
$\begin{array}{l} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\bar{n}\pi^{+}\pi^{-} \\ \Sigma \overline{\Sigma} \\ \\ 2(\pi^{+}\pi^{-}) K^{+}K^{-} \\ p\bar{p}\pi^{+}\pi^{-}\pi^{0} \\ p\bar{p} \\ p\bar{p} \\ n\bar{n} \\ -n\bar{n} \\ \equiv \overline{\Xi} \\ A\overline{A} \\ p\bar{p}\pi^{0} \\ A\Sigma^{-}\pi^{+} \text{ (or c.c.)} \\ pK^{-}\overline{A} \\ 2(K^{+}K^{-}) \\ pK^{-}\overline{\Sigma^{0}} \\ K^{+}K^{-} \\ A\bar{\Lambda}\pi^{0} \\ \pi^{+}\pi^{-} \\ K^{0}_{S}K^{0}_{S} \\ \gamma^{0}_{C}(1S) \\ \gamma^{\pi^{+}}\pi^{-}2\pi^{0} \end{array}$	[gg] < < Radiative	(4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0	#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4) × 10 ⁻³ #4) × 10 ⁻³ #4.0) × 10 ⁻³ #0.5) × 10 ⁻³ #1.0) × 10 ⁻³ #1.0) × 10 ⁻³ #2.0) × 10 ⁻⁴	S=1.9 S=1.8 S=1.2 CL=90% CL=90%	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945 876 1131 820 1468 998 1542 1466 1032 1466
$\begin{array}{c} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\bar{n}\pi^{+}\pi^{-} \\ \Sigma \overline{\Sigma} \\ \hline{\Sigma} \\ 2(\pi^{+}\pi^{-}) K^{+}K^{-} \\ p\bar{p}\pi^{+}\pi^{-}\pi^{0} \\ p\bar{p} \\ p\bar{p}\eta \\ p\bar{n}\pi^{-} \\ n\bar{n} \\ \equiv \overline{\Xi} \\ \Lambda\bar{\Lambda} \\ p\bar{p}\pi^{0} \\ \Lambda\bar{\Sigma}^{-}\pi^{+} \text{ (or c.c.)} \\ pK^{-}\bar{\Lambda} \\ 2(K^{+}K^{-}) \\ pK^{-}\bar{\Sigma}^{0} \\ K^{+}K^{-} \\ \Lambda\bar{\Lambda}\pi^{0} \\ \pi^{+}\pi^{-} \\ K^{0}_{S}K^{0}_{S} \\ \Lambda^{0} \\ \gamma^{0}\pi^{+}\pi^{-} 2\pi^{0} \\ \gamma^{0}\pi^{0}\pi^{0} \\ \gamma^{0}\pi^{1440} \rightarrow \gamma^{0}K^{K}\pi^{0} \end{array}$	[gg] < < Radiative	(4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0	#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4) × 10 ⁻³ #4) × 10 ⁻³ #4.0) × 10 ⁻³ #0.5) × 10 ⁻³ #1.0) × 10 ⁻³ #1.0) × 10 ⁻³ #2.0) × 10 ⁻⁴	S=1.9 S=1.8 S=1.2 CL=90% CL=90%	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945 876 1131 820 1468 998 1542 1466 1032 1466
$\begin{array}{l} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\bar{n}\pi^{+}\pi^{-} \\ \Sigma \overline{\Sigma} \\ \\ 2(\pi^{+}\pi^{-}) K^{+}K^{-} \\ p\bar{p}\pi^{+}\pi^{-}\pi^{0} \\ p\bar{p} \\ p\bar{p}\eta \\ p\bar{n}\pi^{-} \\ n\bar{n} \\ \equiv \overline{\Xi} \\ \Lambda\bar{\Lambda} \\ p\bar{p}\pi^{0} \\ \Lambda\bar{\Sigma}^{-}\pi^{+} \text{ (or c.c.)} \\ pK^{-}\bar{\Lambda} \\ 2(K^{+}K^{-}) \\ pK^{-}\overline{\Sigma}^{0} \\ K^{+}K^{-} \\ \Lambda\bar{\Lambda}\pi^{0} \\ \pi^{+}\pi^{-} \\ K^{0}_{S}K^{0}_{S} \\ \Lambda\bar{\Sigma}^{+}\text{ c.c.} \\ K^{0}_{S}K^{0}_{S} \\ \gamma\eta_{c}(1S) \\ \gamma\pi^{+}\pi^{-}2\pi^{0} \\ \gamma\eta\pi\pi \\ \gamma\eta(1440) \rightarrow \gamma\gamma\rho^{0} \end{array}$	[gg] - ((4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0	#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4) × 10 ⁻³ #4) × 10 ⁻³ #4.0) × 10 ⁻³ #0.5) × 10 ⁻³ #1.0) × 10 ⁻³ #1.0) × 10 ⁻³ #2.0) × 10 ⁻⁴ #2	S=1.9 S=1.8 S=1.2 CL=90% CL=90%	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945 876 1131 820 1468 998 1542 1466 1032 1466
$\begin{array}{c} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\bar{n}\pi^{+}\pi^{-} \\ \Sigma \overline{\Sigma} \\ \hline{\Sigma} \\ 2(\pi^{+}\pi^{-}) K^{+}K^{-} \\ p\bar{p}\pi^{+}\pi^{-}\pi^{0} \\ p\bar{p} \\ p\bar{p}\eta \\ p\bar{n}\pi^{-} \\ n\bar{n} \\ \equiv \overline{\Xi} \\ \Lambda\bar{\Lambda} \\ p\bar{p}\pi^{0} \\ \Lambda\bar{\Sigma}^{-}\pi^{+} \text{ (or c.c.)} \\ pK^{-}\bar{\Lambda} \\ 2(K^{+}K^{-}) \\ pK^{-}\bar{\Sigma}^{0} \\ K^{+}K^{-} \\ \Lambda\bar{\Lambda}\pi^{0} \\ \pi^{+}\pi^{-} \\ K^{0}_{S}K^{0}_{S} \\ \Lambda^{0} \\ \gamma^{0}\pi^{+}\pi^{-} 2\pi^{0} \\ \gamma^{0}\pi^{0}\pi^{0} \\ \gamma^{0}\pi^{1440} \rightarrow \gamma^{0}K^{K}\pi^{0} \end{array}$	[p]	(4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0	#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4) × 10 ⁻³ #3.0) × 10 ⁻³ #1.3) × 10 ⁻³ #1.0) × 10 ⁻⁴ #1.1) × 10 ⁻⁴ #1.1) × 10 ⁻⁴ #1.2) × 10 ⁻⁴ #1.3) × 10 ⁻⁴ #1.4) × 10 ⁻⁵ #1.8) × 10 ⁻⁴	S=1.9 S=1.8 S=1.2 CL=90% CL=90%	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945 876 1131 820 1468 998 1542 1466 1032 1466
$\begin{array}{c} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\bar{n}\pi^{+}\pi^{-} \\ \Sigma \overline{\Sigma} \\ 2(\pi^{+}\pi^{-}) K^{+}K^{-} \\ p\bar{p}\pi^{+}\pi^{-}\pi^{0} \\ p\bar{p} \\ p\bar{p} \\ p\bar{p} \\ n\bar{n}^{-} \\ n\bar{n} \\ \equiv \overline{\Xi} \\ \Lambda\bar{\Lambda} \\ p\bar{p}\pi^{0} \\ \Lambda\bar{\Sigma}^{-}\pi^{+} \text{ (or c.c.)} \\ pK^{-}\bar{\Lambda} \\ 2(K^{+}K^{-}) \\ pK^{-}\bar{\Sigma}^{0} \\ K^{+}K^{-} \\ \Lambda\bar{\Lambda}\pi^{0} \\ \pi^{+}\pi^{-} \\ K^{0}_{S}K^{0}_{L} \\ \Lambda\bar{\Sigma}^{+}\text{ + c.c.} \\ K^{0}_{S}K^{0}_{S} \\ \\ \gamma\eta_{c}(1S) \\ \gamma\pi^{+}\pi^{-}2\pi^{0} \\ \gamma\eta(1440) \rightarrow \gamma \kappa K \pi \\ \gamma \eta(1440) \rightarrow \gamma \gamma \rho^{0} \\ \gamma \rho \rho \end{array}$	[p]	(4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0	#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4) × 10 ⁻³ #3.0) × 10 ⁻³ #1.3) × 10 ⁻³ #1.0) × 10 ⁻⁴ #1.1) × 10 ⁻⁴ #1.1) × 10 ⁻⁴ #1.2) × 10 ⁻⁴ #1.3) × 10 ⁻⁴ #1.4) × 10 ⁻⁵ #1.8) × 10 ⁻⁴	S=1.9 S=1.8 S=1.2 CL=90% CL=90%	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945 876 6 1131 820 1468 998 1542 1466 1032 1466 1518 1487 1223 1223 1223
$\begin{array}{c} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\overline{n}\pi^{+}\pi^{-} \\ \Sigma \overline{\Sigma} \\ 2(\pi^{+}\pi^{-})K^{+}K^{-} \\ p\overline{p}\pi^{+}\pi^{-}\pi^{0} \\ p\overline{p} \\ p\overline{p}\eta \\ p\overline{p}\pi^{-} \\ n\overline{n} \\ \equiv \overline{\Xi} \\ \lambda\overline{\lambda} \\ p\overline{p}\pi^{0} \\ \lambda\overline{\Sigma}^{-}\pi^{+} \text{ (or c.c.)} \\ pK^{-}\overline{\lambda} \\ 2(K^{+}K^{-}) \\ pK^{-}\overline{\Sigma}^{0} \\ K^{+}K^{-} \\ \lambda\overline{\lambda}\pi^{0} \\ \pi^{+}\pi^{-} \\ K^{0}S^{K}C \\ \lambda\Sigma^{+}\text{ c.c.} \\ K^{0}S^{K}S \\ \end{array}$ $\begin{array}{c} \gamma\eta_{c}(1S) \\ \gamma\pi^{+}\pi^{-}2\pi^{0} \\ \gamma\eta\pi\pi \\ \gamma\eta(1440) \rightarrow \gamma \kappa \overline{\kappa} \\ \gamma \gamma \rho \rho \\ \gamma \gamma' (958) \end{array}$	[βg]	(4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0	#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4) × 10 ⁻³ #4.1) × 10 ⁻³ #1.3) × 10 ⁻³ #1.4) × 10 ⁻³ #1.5) × 10 ⁻³ #1.5) × 10 ⁻³ #1.6) × 10 ⁻³ #1.6) × 10 ⁻⁴ #1.6) × 10 ⁻⁴ #1.7) × 10 ⁻⁴ #1.7) × 10 ⁻⁴ #1.8) × 10 ⁻⁴ #1.9) × 10 ⁻⁴ #1.9) × 10 ⁻⁴ #1.9) × 10 ⁻⁴ #1.0) × 10 ⁻³	S=1.9 S=1.8 S=1.2 CL=90% CL=90%	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945 876 1131 820 1468 1998 1542 1466 1032 1466 1518 1487 1223 1223 1223 1223 1223 1223 1223 122
$\begin{array}{c} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ \overline{n}\overline{n}\pi^{+}\pi^{-} \\ \Sigma \overline{\Sigma} \\ 2(\pi^{+}\pi^{-})K^{+}K^{-} \\ \overline{\rho}\overline{\rho}\pi^{+}\pi^{-}\pi^{0} \\ \overline{\rho}\overline{\rho} \\ \overline{\rho}\overline{\rho} \\ \overline{\rho}\overline{\rho}\pi^{-} \\ \overline{n}\overline{n} \\ \overline{\Xi} \overline{\Xi} \\ \lambda\overline{\lambda} \\ \overline{\rho}\overline{\rho}\pi^{0} \\ \lambda\overline{\Sigma}^{-}\pi^{+} \text{ (or c.c.)} \\ \rho K^{-}\overline{\lambda} \\ 2(K^{+}K^{-}) \\ \rho K^{-}\overline{\Sigma}^{0} \\ K^{+}K^{-} \\ \lambda\overline{\lambda}\pi^{0} \\ \pi^{+}\pi^{-} \\ K^{0}_{S}K^{0}_{S} \\ \overline{\gamma}\eta^{c}(1S) \\ \gamma \eta^{\pi}\pi \\ \gamma \eta(1440) \rightarrow \gamma K^{\overline{K}}\pi \\ \gamma \eta(1440) \rightarrow \gamma \gamma \rho^{0} \\ \gamma \rho^{\rho} \\ \gamma \eta^{\prime}(958) \\ \gamma 2\pi^{+}2\pi^{-} \end{array}$	[gg]	(4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0	#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4) × 10 ⁻³ #4.0) × 10 ⁻³ #0.5) × 10 ⁻³ #1.3) × 10 ⁻³ #1.3) × 10 ⁻³ #2.0.9) × 10 ⁻³ #2.0.10) × 10 ⁻³ #2.0.10) × 10 ⁻³ #2.0.10) × 10 ⁻³ #2.0.14) × 10 ⁻³ #2.0.14) × 10 ⁻³ #2.0.14) × 10 ⁻³ #2.0.15) × 10 ⁻⁴ #2.0.15) × 10 ⁻³ #2.0.16) × 10 ⁻³ #2.0.16) × 10 ⁻³ #2.0.17) × 10 ⁻³ #2.0.17) × 10 ⁻³ #2.0.18) × 10 ⁻³ #2.0.19) × 10 ⁻³	S=1.9 S=1.8 S=1.2 CL=90% CL=90% S=1.9	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945 876 1131 820 1466 1032 1466 1032 1466 1518 1487 1223 1223 1231 1440 1517
$\begin{array}{c} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ \overline{n}\overline{n}\pi^{+}\pi^{-} \\ \Sigma \overline{\Sigma} \\ 2(\pi^{+}\pi^{-})K^{+}K^{-} \\ \overline{\rho}\overline{\rho}\pi^{+}\pi^{-}\pi^{0} \\ \overline{\rho}\overline{\rho} \\ \overline{\rho}\overline{\rho} \\ \overline{\rho}\overline{\rho}\pi^{-} \\ \overline{n}\overline{n} \\ \overline{\Xi} \overline{\Xi} \\ \lambda\overline{\lambda} \\ \overline{\rho}\overline{\rho}\pi^{0} \\ \lambda\overline{\Sigma}^{-}\pi^{+} \text{ (or c.c.)} \\ \rho K^{-}\overline{\lambda} \\ 2(K^{+}K^{-}) \\ \rho K^{-}\overline{\Sigma}^{0} \\ K^{+}K^{-} \\ \lambda\overline{\lambda}\pi^{0} \\ \pi^{+}\pi^{-} \\ K^{0}_{S}K^{0}_{S} \\ \overline{\gamma}\eta^{c}(1S) \\ \gamma \eta^{\pi}\pi \\ \gamma \eta(1440) \rightarrow \gamma K^{\overline{K}}\pi \\ \gamma \eta(1440) \rightarrow \gamma \gamma \rho^{0} \\ \gamma \rho^{\rho} \\ \gamma \eta^{\prime}(958) \\ \gamma 2\pi^{+}2\pi^{-} \end{array}$	[gg]	(4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0	#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4) × 10 ⁻³ #4.0) × 10 ⁻³ #0.5) × 10 ⁻³ #1.3) × 10 ⁻³ #1.3) × 10 ⁻³ #2.0.9) × 10 ⁻³ #2.0.10) × 10 ⁻³ #2.0.10) × 10 ⁻³ #2.0.10) × 10 ⁻³ #2.0.14) × 10 ⁻³ #2.0.14) × 10 ⁻³ #2.0.14) × 10 ⁻³ #2.0.15) × 10 ⁻⁴ #2.0.15) × 10 ⁻³ #2.0.16) × 10 ⁻³ #2.0.16) × 10 ⁻³ #2.0.17) × 10 ⁻³ #2.0.17) × 10 ⁻³ #2.0.18) × 10 ⁻³ #2.0.19) × 10 ⁻³	S=1.9 S=1.8 S=1.2 CL=90% CL=90% S=1.9	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945 876 1131 820 1468 1998 1542 1466 1032 1466
$\begin{array}{c} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ \overline{n}\overline{n}\pi^{+}\pi^{-} \\ \Sigma \overline{\Sigma} \\ \Sigma \overline{\Sigma} \\ 2(\pi^{+}\pi^{-})K^{+}K^{-} \\ p\overline{p}\pi^{+}\pi^{-}\pi^{0} \\ p\overline{p} \\ p\overline{p}\overline{n} \\ p\overline{p}\pi^{-} \\ n\overline{n} \\ \overline{\Xi} \overline{\Xi} \\ \lambda\overline{\lambda} \\ p\overline{p}\pi^{0} \\ \lambda\overline{\Sigma}^{-}\pi^{+} \text{ (or c.c.)} \\ pK^{-}\overline{\lambda} \\ 2(K^{+}K^{-}) \\ pK^{-}\overline{\Sigma}^{0} \\ K^{+}K^{-} \\ \lambda\overline{\lambda}\pi^{0} \\ \pi^{+}\pi^{-} \\ K^{0}_{S}K^{0}_{S} \\ \lambda\Sigma^{+}_{C.c.} \\ K^{0}_{S}K^{0}_{S} \\ \gamma^{0}\pi^{+}\pi^{-}2\pi^{0} \\ \gamma^{0}\pi^{+}\pi^{-}2\pi^{0} \\ \gamma^{0}\pi^{+}\pi^{-}2\pi^{0} \\ \gamma^{0}\eta(1440) \rightarrow \gamma \kappa \overline{K}\pi \\ \gamma^{0}\eta(1440) \rightarrow \gamma \gamma \rho^{0} \\ \gamma^{0}\gamma^{0}(958) \\ \gamma^{2}\pi^{+}2\pi^{-} \\ \gamma^{1}(4050) \end{array}$	[gg] < < Radiative	(4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0	#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4) × 10 ⁻³ #4.0) × 10 ⁻³ #0.5) × 10 ⁻³ #1.3) × 10 ⁻³ #2.10) × 10 ⁻⁴ #2.10) × 10 ⁻³	S=1.9 S=1.8 S=1.2 CL=90% CL=90% S=1.9	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945 876 1131 820 1468 1988 1542 1466 1032 1466 1518 1487 1223 1223 1243 143 1400 1517 874
$\begin{array}{c} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\overline{n}\pi^{+}\pi^{-} \\ \Sigma \overline{\Sigma} \\ 2(\pi^{+}\pi^{-})K^{+}K^{-} \\ p\overline{p}\pi^{+}\pi^{-}\pi^{0} \\ p\overline{p} \\ p\overline{p}n \\ p\overline{p}\pi^{-} \\ n\overline{n} \\ \equiv \overline{\Xi} \\ \lambda\overline{\lambda} \\ p\overline{p}\pi^{0} \\ \lambda\overline{\Sigma}^{-}\pi^{+} \text{ (or c.c.)} \\ pK^{-}\overline{\lambda} \\ 2(K^{+}K^{-}) \\ pK^{-}\overline{\Sigma}^{0} \\ K^{+}K^{-} \\ \lambda\overline{\lambda}\pi^{0} \\ \pi^{+}\pi^{-} \\ K^{0}_{S}K^{0}_{L} \\ \lambda\overline{\Sigma}^{+}\text{ c.c.} \\ K^{0}_{S}K^{0}_{S} \\ \gamma\eta_{\pi}^{-} \\ \gamma\eta(1440) \rightarrow \gamma K\overline{K}\pi \\ \gamma\eta(1440) \rightarrow \gamma \gamma \rho^{0} \\ \gamma \gamma \rho \\ \gamma \gamma \rho \\ \gamma \gamma f_{4}(2050) \\ \gamma \omega \\ \omega \end{array}$	[gg]	(4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0	#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4) × 10 ⁻³ #4) × 10 ⁻³ #4.0) × 10 ⁻³ #0.5) × 10 ⁻³ #1.3) × 10 ⁻³ #1.6) × 10 ⁻³ #2.1) × 10 ⁻⁴ #2.2) × 10 ⁻⁴ #2.3) × 10 ⁻⁴ #2.4) × 10 ⁻⁴ #2.7) × 10 ⁻⁴ #2.7) × 10 ⁻⁴ #2.7) × 10 ⁻⁴ #2.1) × 10 ⁻⁴ #2.1) × 10 ⁻⁴ #2.2) × 10 ⁻⁴ #2.3) × 10 ⁻³ #2.5) × 10 ⁻³ #2.7) × 10 ⁻³ #2.7) × 10 ⁻³ #2.7) × 10 ⁻³ #2.8) × 10 ⁻³ #2.9) × 10 ⁻³	S=1.9 S=1.8 S=1.2 CL=90% CL=90% S=1.9	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945 876 1131 820 1466 1032 1466 1032 1466 1518 1487 1223 1223 1231 1440 1517
$\begin{array}{c} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\overline{n}\pi^{+}\pi^{-} \\ \Sigma \overline{\Sigma} \\ 2(\pi^{+}\pi^{-})K^{+}K^{-} \\ p\overline{p}\pi^{+}\pi^{-}\pi^{0} \\ p\overline{p} \\ p\overline{p}n \\ p\overline{p}\pi^{-} \\ n\overline{n} \\ \equiv \overline{\Xi} \\ \lambda\overline{\lambda} \\ p\overline{p}\pi^{0} \\ \lambda\overline{\Sigma}^{-}\pi^{+} \text{ (or c.c.)} \\ pK^{-}\overline{\lambda} \\ 2(K^{+}K^{-}) \\ pK^{-}\overline{\Sigma}^{0} \\ K^{+}K^{-} \\ \lambda\overline{\lambda}\pi^{0} \\ \pi^{+}\pi^{-} \\ K^{0}_{S}K^{0}_{L} \\ \lambda\overline{\Sigma}^{+}\text{ c.c.} \\ K^{0}_{S}K^{0}_{S} \\ \gamma\eta_{\pi}^{-} \\ \gamma\eta(1440) \rightarrow \gamma K\overline{K}\pi \\ \gamma\eta(1440) \rightarrow \gamma \gamma \rho^{0} \\ \gamma \gamma \rho \\ \gamma \gamma \rho \\ \gamma \gamma f_{4}(2050) \\ \gamma \omega \\ \omega \end{array}$	[gg]	(4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0	#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4) × 10 ⁻³ #4) × 10 ⁻³ #4.0) × 10 ⁻³ #0.5) × 10 ⁻³ #1.3) × 10 ⁻³ #1.6) × 10 ⁻³ #2.1) × 10 ⁻⁴ #2.2) × 10 ⁻⁴ #2.3) × 10 ⁻⁴ #2.4) × 10 ⁻⁴ #2.7) × 10 ⁻⁴ #2.7) × 10 ⁻⁴ #2.7) × 10 ⁻⁴ #2.1) × 10 ⁻⁴ #2.1) × 10 ⁻⁴ #2.2) × 10 ⁻⁴ #2.3) × 10 ⁻³ #2.5) × 10 ⁻³ #2.7) × 10 ⁻³ #2.7) × 10 ⁻³ #2.7) × 10 ⁻³ #2.8) × 10 ⁻³ #2.9) × 10 ⁻³	S=1.9 S=1.8 S=1.2 CL=90% CL=90% S=1.9	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945 876 1131 820 1468 998 1542 1466 1032 1466 11518 1487 1223 1223 1343 1490 1517 874 1337
$\begin{array}{c} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\overline{n}\pi^{+}\pi^{-} \\ \Sigma \overline{\Sigma} \\ 2(\pi^{+}\pi^{-})K^{+}K^{-} \\ p\overline{p}\pi^{+}\pi^{-}\pi^{0} \\ p\overline{p} \\ p\overline{p}\pi^{0} \\ n\overline{n} \\ \overline{\Xi} \\ \lambda\overline{\lambda} \\ p\overline{p}\pi^{0} \\ \lambda\overline{\Sigma}^{-}\pi^{+} \text{ (or c.c.)} \\ pK^{-}\overline{\lambda} \\ 2(K^{+}K^{-}) \\ pK^{-}\overline{\Sigma}^{0} \\ K^{+}K^{-} \\ \lambda\overline{\lambda}\pi^{0} \\ \pi^{+}\pi^{-} \\ K^{0}_{S}K^{0}_{S} \\ \lambda\overline{\Sigma}^{+}\text{ c.c.} \\ K^{0}_{S}K^{0}_{S} \\ \gamma\eta(1440) \rightarrow \gamma K^{0}K^{\pi} \\ \gamma\eta(1440) \rightarrow \gamma \gamma \rho^{0} \\ \gamma\eta'(958) \\ \gamma2\pi^{+}2\pi^{-} \\ \gamma f_{4}(2050) \\ \gamma\omega\omega \\ \gamma\eta(1440) \rightarrow \gamma \rho^{0}\rho^{0} \end{array}$	[gg]	(4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0	#1.0) × 10 ⁻³ #2.0) × 10 ⁻⁴ × 10 ⁻⁴ × 10 ⁻⁴ × 10 ⁻⁶ #2.0) × 10 ⁻⁴ × 10 ⁻⁶ #2.0) × 10 ⁻⁴ × 10 ⁻⁶ #2.0) × 10 ⁻³ #	S=1.9 S=1.8 S=1.2 CL=90% CL=90% S=1.9	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945 876 1131 820 1468 998 1542 1466 1518 1487 1223 1233 1243 1490 1517 874 1274 1274 1274 1274 1274 1274 1274 12
$\begin{array}{c} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ n\overline{n}\pi^{+}\pi^{-} \\ \Sigma \overline{\Sigma} \\ 2(\pi^{+}\pi^{-})K^{+}K^{-} \\ p\overline{p}\pi^{+}\pi^{-}\pi^{0} \\ p\overline{p} \\ p\overline{p}n \\ p\overline{p}\pi^{-} \\ n\overline{n} \\ \equiv \overline{\Xi} \\ \lambda\overline{\lambda} \\ p\overline{p}\pi^{0} \\ \lambda\overline{\Sigma}^{-}\pi^{+} \text{ (or c.c.)} \\ pK^{-}\overline{\lambda} \\ 2(K^{+}K^{-}) \\ pK^{-}\overline{\Sigma}^{0} \\ K^{+}K^{-} \\ \lambda\overline{\lambda}\pi^{0} \\ \pi^{+}\pi^{-} \\ K^{0}_{S}K^{0}_{L} \\ \lambda\overline{\Sigma}^{+}\text{ c.c.} \\ K^{0}_{S}K^{0}_{S} \\ \gamma\eta_{\pi}^{-} \\ \gamma\eta(1440) \rightarrow \gamma K\overline{K}\pi \\ \gamma\eta(1440) \rightarrow \gamma \gamma \rho^{0} \\ \gamma \gamma \rho \\ \gamma \gamma \rho \\ \gamma \gamma f_{4}(2050) \\ \gamma \omega \\ \omega \end{array}$	[gg]	(4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0	#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4) × 10 ⁻³ #4.1) × 10 ⁻³ #5.5) × 10 ⁻³ #5.1) × 10 ⁻³ #5.2) × 10 ⁻³ #5.3) × 10 ⁻³ #5.4) × 10 ⁻³ #5.5) × 10 ⁻³ #5.6) × 10 ⁻⁴ #5.8) × 10 ⁻⁴ #5.8) × 10 ⁻⁴ #5.1) × 10 ⁻³ #5.2) × 10 ⁻³ #5.3) × 10 ⁻³ #5.3) × 10 ⁻³ #5.5) × 10 ⁻³ #5.6) × 10 ⁻³ #5.7) × 10 ⁻³ #5.8) × 10 ⁻³ #5.9) × 10 ⁻³	S=1.9 S=1.8 S=1.2 CL=90% CL=90% S=1.9	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945 876 1131 820 1468 998 1542 1466 1032 1466 11518 1487 1223 1223 1343 1490 1517 874 1337
$\begin{array}{c} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ \overline{n}\overline{n}\pi^{+}\pi^{-} \\ \Sigma \overline{\Sigma} \\ 2(\pi^{+}\pi^{-})K^{+}K^{-} \\ p\overline{p}\pi^{+}\pi^{-}\pi^{0} \\ p\overline{p} \\ p\overline{p}\eta \\ p\overline{p}\pi^{-} \\ \lambda \overline{\Sigma}^{-}\pi^{+} \text{ (or c.c.)} \\ pK^{-}\overline{\lambda} \\ 2(K^{+}K^{-}) \\ pK^{-}\overline{\Sigma}^{0} \\ K^{+}K^{-} \\ \lambda \overline{\lambda}\pi^{0} \\ \pi^{+}\pi^{-} \\ K^{0}S^{K}C \\ \lambda \overline{\Sigma}^{+}\text{ c.c.} \\ K^{0}S^{K}S \\ \end{array}$ $\begin{array}{c} \gamma\eta_{c}(1S) \\ \gamma\pi^{+}\pi^{-}2\pi^{0} \\ \gamma\eta\pi\pi \\ \gamma\eta(1440) \rightarrow \gamma \kappa \overline{K}\pi \\ \gamma \eta(1440) \rightarrow \gamma \gamma \rho^{0} \\ \gamma \rho \rho \\ \gamma \eta'(958) \\ \gamma 2\pi^{+}2\pi^{-} \\ \gamma f_{4}(2050) \\ \gamma \omega \\ \gamma \eta'(1440) \rightarrow \gamma \rho^{0} \rho^{0} \\ \gamma \eta'(1440) \rightarrow \gamma \gamma \gamma \rho^{0} \\ \gamma \eta'(1440) \rightarrow \gamma \gamma \gamma$	[gg]	(4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0 (4.0	#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4) × 10 ⁻³ #4.1) × 10 ⁻³ #5.5) × 10 ⁻³ #5.1) × 10 ⁻³ #5.2) × 10 ⁻³ #5.3) × 10 ⁻³ #5.4) × 10 ⁻³ #5.5) × 10 ⁻³ #5.6) × 10 ⁻⁴ #5.8) × 10 ⁻⁴ #5.8) × 10 ⁻⁴ #5.1) × 10 ⁻³ #5.2) × 10 ⁻³ #5.3) × 10 ⁻³ #5.3) × 10 ⁻³ #5.5) × 10 ⁻³ #5.6) × 10 ⁻³ #5.7) × 10 ⁻³ #5.8) × 10 ⁻³ #5.9) × 10 ⁻³	S=1.9 S=1.8 S=1.2 CL=90% CL=90% S=1.9	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945 876 1131 820 1468 998 1542 1466 1518 1487 1223 1233 1243 1490 1517 874 1274 1274 1274 1274 1274 1274 1274 12
$\begin{array}{c} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ \overline{n}\overline{n}\pi^{+}\pi^{-} \\ \Sigma \overline{\Sigma} \\ 2(\pi^{+}\pi^{-})K^{+}K^{-} \\ \overline{\rho}\overline{\rho}\pi^{+}\pi^{-}\pi^{0} \\ \overline{\rho}\overline{\rho} \\ \overline{\rho}\overline{\rho}\pi^{0} \\ \Lambda \overline{\Sigma}^{-}\pi^{+} \\ (\text{or c.c.}) \\ \overline{\rho}K^{-}\overline{\Lambda} \\ 2(K^{+}K^{-}) \\ \overline{\rho}K^{-}\overline{\Lambda} \\ 2(K^{+}K^{-}) \\ \overline{\rho}K^{-}\overline{\lambda} \\ \Lambda \overline{\Lambda}\pi^{0} \\ \pi^{+}\pi^{-} \\ K^{0}_{S}K^{0}_{S} \\ \Lambda \overline{\Lambda}\pi^{0} \\ \pi^{+}\pi^{-} \\ K^{0}_{S}K^{0}_{S} \\ \gamma\eta_{c}(1S) \\ \gamma\eta\pi\pi \\ \gamma\eta(1440) \rightarrow \gamma K\overline{K}\pi \\ \gamma\eta(1440) \rightarrow \gamma \gamma\rho^{0} \\ \gamma\rho\rho \\ \gamma\eta'(958) \\ \gamma2\pi^{+}2\pi^{-} \\ \gamma f_{4}(2050) \\ \gamma\omega\omega \\ \gamma\eta(1440) \rightarrow \gamma\rho^{0}\rho^{0} \\ \gamma f_{2}(1270) \\ \gamma f_{J}(1710) \rightarrow \gamma K\overline{K} \end{array}$	[gg]	(4.0 (4.0 (#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4) × 10 ⁻³ #4.1) × 10 ⁻³ #1.3) × 10 ⁻³ #1.3) × 10 ⁻³ #1.3) × 10 ⁻³ #1.4) × 10 ⁻³ #1.5) × 10 ⁻³ #1.6) × 10 ⁻³ #1.6) × 10 ⁻³ #1.6) × 10 ⁻⁴ #1.7) × 10 ⁻⁴ #1.8) × 10 ⁻⁴ #1.9) × 10 ⁻³ #1.8) × 10 ⁻⁴ #1.9) × 10 ⁻³	S=1.9 S=1.8 S=1.2 CL=90% CL=90% S=1.9 S=1.3	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 945 876 1131 820 1466 1032 1466 1032 1466 1518 1487 1223 1233 1343 1400 1517 874 1337 1223 1286 1075
$\begin{array}{c} 2(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ 3(\pi^{+}\pi^{-}) \\ \overline{n}\overline{n}\pi^{+}\pi^{-} \\ \Sigma \overline{\Sigma} \\ 2(\pi^{+}\pi^{-})K^{+}K^{-} \\ p\overline{p}\pi^{+}\pi^{-}\pi^{0} \\ p\overline{p} \\ p\overline{p}\eta \\ p\overline{p}\pi^{-} \\ \lambda \overline{\Sigma}^{-}\pi^{+} \text{ (or c.c.)} \\ pK^{-}\overline{\lambda} \\ 2(K^{+}K^{-}) \\ pK^{-}\overline{\Sigma}^{0} \\ K^{+}K^{-} \\ \lambda \overline{\lambda}\pi^{0} \\ \pi^{+}\pi^{-} \\ K^{0}S^{K}C \\ \lambda \overline{\Sigma}^{+}\text{ c.c.} \\ K^{0}S^{K}S \\ \end{array}$ $\begin{array}{c} \gamma\eta_{c}(1S) \\ \gamma\pi^{+}\pi^{-}2\pi^{0} \\ \gamma\eta\pi\pi \\ \gamma\eta(1440) \rightarrow \gamma \kappa \overline{K}\pi \\ \gamma \eta(1440) \rightarrow \gamma \gamma \rho^{0} \\ \gamma \rho \rho \\ \gamma \eta'(958) \\ \gamma 2\pi^{+}2\pi^{-} \\ \gamma f_{4}(2050) \\ \gamma \omega \\ \gamma \eta'(1440) \rightarrow \gamma \rho^{0} \rho^{0} \\ \gamma \eta'(1440) \rightarrow \gamma \gamma \gamma \rho^{0} \\ \gamma \eta'(1440) \rightarrow \gamma \gamma \gamma$	[gg]	(4.0 (4.0 (#1.0) × 10 ⁻³ #2.0) × 10 ⁻³ #2.0) × 10 ⁻³ #4) × 10 ⁻³ #4.1) × 10 ⁻³ #5.5) × 10 ⁻³ #5.1) × 10 ⁻³ #5.2) × 10 ⁻³ #5.3) × 10 ⁻³ #5.4) × 10 ⁻³ #5.5) × 10 ⁻³ #5.6) × 10 ⁻⁴ #5.8) × 10 ⁻⁴ #5.8) × 10 ⁻⁴ #5.1) × 10 ⁻³ #5.2) × 10 ⁻³ #5.3) × 10 ⁻³ #5.3) × 10 ⁻³ #5.5) × 10 ⁻³ #5.6) × 10 ⁻³ #5.7) × 10 ⁻³ #5.8) × 10 ⁻³ #5.9) × 10 ⁻³	S=1.9 S=1.8 S=1.2 CL=90% CL=90% S=1.9 S=1.3	1517 1466 1106 992 1320 1033 1232 948 1174 1231 818 1074 1176 876 1131 820 1468 1542 1466 1032 1466 1518 1487 1223 1223 1343 1400 1517 874 137 1223 1223

$\gamma f_1(1420) \rightarrow \gamma K \overline{K} \pi$	$(8.3 \pm 1.5) \times 10^{-4}$		1220
$\gamma f_1(1285)$	$(6.5 \pm 1.0) \times 10^{-4}$		1283
$\gamma f_2^{\prime}(1525)$	$(6.3 \pm 1.0) \times 10^{-4}$		1173
$\gamma \phi \phi$	$(4.0 \pm 1.2) \times 10^{-4}$	S=2.1	1166
$\gamma p \overline{p}$	$(3.8 \pm 1.0) \times 10^{-4}$		1232
$\gamma \eta$ (2225)	$(2.9 \pm 0.6) \times 10^{-4}$		834
$\gamma \eta(1760) \rightarrow \gamma \rho^0 \rho^0$	$(1.3 \pm 0.9) \times 10^{-4}$		1048
$\gamma \pi^0$	$(3.9 \pm 1.3) \times 10^{-5}$		1546
$\gamma p \overline{p} \pi^+ \pi^-$	$< 7.9 \times 10^{-4}$	CL=90%	1107
$\gamma\gamma$	$< 5 \times 10^{-4}$	CL=90%	1548
$\gamma \Lambda \overline{\Lambda}$	$< 1.3 \times 10^{-4}$	CL=90%	1074
3γ	$< 5.5 \times 10^{-5}$	CL=90%	1548
$\gamma f_0(1370)$	$(3.4 \pm 0.7) \times 10^{-4}$		-
$\gamma f_0(1500)$	$(8.2 \pm 1.5) \times 10^{-4}$		1184

 $\chi_{c0}(1P)$

$$I^{G}(J^{PC}) = 0^{+}(0^{+})$$

Mass $m = 3415.1 \pm 1.0 \text{ MeV}$ Full width $\Gamma=14\,\pm\,5~\text{MeV}$

X _{CO} (1P) DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	(MeV/c)
	Hadronic decays		
$2(\pi^{+}\pi^{-})$	(3.7 ± 0.7) %		1679
$\pi^+\pi^-K^+K^-$	(3.0 ± 0.7) %		1580
$ ho^0 \pi^+ \pi^-$	(1.6 ± 0.5) %		1608
$3(\pi^{+}\pi^{-})$	(1.5 ± 0.5) %		1633
$K^{+}\overline{K}^{*}(892)^{0}\pi^{-}+\text{ c.c.}$	(1.2 ± 0.4) %		1522
$\pi^+\pi^-$	$(7.5\pm2.1)\times10^{-3}$		1702
K^+K^-	$(7.1\pm2.4)\times10^{-3}$		1635
$\pi^+\pi^-\rho\overline{\rho}$	$(5.0\pm2.0)\times10^{-3}$		1320
$\pi^{0}\pi^{0}$	$(3.1\pm0.6)\times10^{-3}$		1702
$\eta \eta$	$(2.5\pm1.1)\times10^{-3}$	1	1617
$\rho \overline{p}$	< 9.0 × 10 ⁻²	90%	1427
	Radiative decays		
$\gamma J/\psi(1S)$	$(6.6 \pm 1.8) \times 10^{-3}$	1	303
$\gamma \gamma$	$(4.0\pm2.3)\times10^{-4}$	ı	1708

 $\chi_{c1}(1P)$

$$I^{G}(J^{PC}) = 0^{+}(1^{+})$$

Mass $m = 3510.53 \pm 0.12 \text{ MeV}$ Full width $\Gamma=0.88\pm0.14~\text{MeV}$

x _{c1} (1P) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
	Hadronic decays	
$3(\pi^{+}\pi^{-})$	(2.2 ± 0.8) %	1683
$2(\pi^{+}\pi^{-})$	(1.6 ± 0.5) %	1727
$\pi^{+}\pi^{-}K^{+}K^{-}$	$(9 \pm 4) \times 10^{-3}$	1632
$\rho^0 \pi^+ \pi^-$	$(3.9\pm3.5)\times10^{-3}$	1659
$K^{+}\overline{K}^{*}(892)^{0}\pi^{-}+\text{ c.c.}$	$(3.2\pm2.1)\times10^{-3}$	1576
$\pi^+\pi^-p\overline{p}$	$(1.4\pm0.9)\times10^{-3}$	1381
ρ p	$(8.6\pm1.2)\times10^{-5}$	1483
$\pi^{+}\pi^{-} + K^{+}K^{-}$	$< 2.1 \times 10^{-3}$	-
	Radiative decays	
$\gamma J/\psi(1S)$	(27.3±1.6) %	389

 $\chi_{c2}(1P)$

$$I^{G}(J^{PC}) = 0^{+}(2^{+})$$

Mass $m = 3556.17 \pm 0.13 \text{ MeV}$ Full width $\Gamma = 2.00\,\pm\,0.18$ MeV

x _{c2} (1P) DECAY MODES	Fraction (Γ_j/Γ)	Confidence level	(MeV/c)
	Hadronic decays		
$2(\pi^{+}\pi^{-})$	(2.2 ±0.5) %		1751
$\pi^{+}\pi^{-}K^{+}K^{-}$	(1.9 ±0.5) %		1656
$3(\pi^+\pi^-)$ $\rho^0\pi^+\pi^-$	$(1.2 \pm 0.8)\%$		1707
	(7 ±4)×	₁₀ -3	1683
$K^{+}\overline{K}^{*}(892)^{0}\pi^{-}+\text{c.c.}$	(4.8 \pm 2.8) $ imes$ 1	10-3	1601
$\pi^+\pi^-\rho\overline{\rho}$	(3.3 ±1.3)×	₁₀ -3	1410
$\pi^+\pi^-$	$(1.9 \pm 1.0) \times 1$	₁₀ -3	1773
K ⁺ K ⁻	(1.5 ± 1.1) \times 3	₁₀ -3	1708
$p\overline{p}$	(10.0 \pm 1.0) \times 3	₁₀ -5	1510
$\pi^0\pi^0$	$(1.10 \pm 0.28) \times 1$	₁₀ -3	1773
$\eta \eta$	(8 ±5)×	10-4	1692
$J/\psi(1S)\pi^{+}\pi^{-}\pi^{0}$	< 1.5 %	90%	185

Radiative decays				
$\gamma J/\psi(1S)$	$(13.5 \pm 1.1)\%$	430		
$\gamma \gamma$	$(1.6 \pm 0.5) \times 10^{-4}$	1778		

 $\psi(2S)$

 $3(\pi^+\pi^-)\pi^0$ $2(\pi^+\pi^-)\pi^0$

$$I^{G}(J^{PC}) = 0^{-}(1^{-})$$

Scale factor/ p

Mass $m = 3686.00 \pm 0.09 \; \mathrm{MeV}$

Full width $\Gamma=277\pm31$ keV (S = 1.1) $\Gamma_{e\,e} =$ 2.14 \pm 0.21 keV (Assuming $\Gamma_{e\,e} = \Gamma_{\mu\,\mu}$)

ψ(25) DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	(MeV/c)
hadrons	(98.10±0.30) %		
virtual $\gamma ightarrow hadrons$	$(2.9 \pm 0.4)\%$		_
e^+e^-	(8.8 ± 1.3) \times 1	_{.0} -3	1843
$\mu^+\mu^-$	(7.7 ± 1.7) \times 1	0-3	1840

Decays into $J/\psi(1S)$ and anything

	, , , , , , , , , , , , , , , , , , , ,		
$J/\psi(1S)$ anything	(57 ±4)%		_
$J/\psi(1S)$ neutrals	(23.2 \pm 2.6) %		-
$J/\psi(1S)\pi^+\pi^-$	$(32.4 \pm 2.6)\%$		477
$J/\psi(1S)\pi^{0}\pi^{0}$	$(18.4 \pm 2.7)\%$		481
$J/\psi(1S)\eta$	(2.7 ±0.4) %	S=1.7	200
$J/\psi(1S)\pi^0$	$(9.7 \pm 2.1) \times 10^{-4}$		527

Hadronic decays $(3.5 \pm 1.6) \times 10^{-3}$

(3.1 ± 0.7) $\times 10^{-3}$

$\pi^{+}\pi^{-}K^{+}K^{-}$	(1.6 ± 0.4)	$) \times 10^{-3}$		1726
$\pi^+\pi^-\rho\overline{\rho}$	(8.0 ± 2.0	$) \times 10^{-4}$		1491
$K^{+}\overline{K}^{*}(892)^{0}\pi^{-}+\text{c.c.}$	(6.7 ± 2.5	$) \times 10^{-4}$		1673
$2(\pi^{+}\pi^{-})$	(4.5 ± 1.0	$) \times 10^{-4}$		1817
$\rho^{0} \pi^{+} \pi^{-}$	(4.2 ± 1.5)	$) \times 10^{-4}$		1751
$\overline{p} p$	(1.9 ± 0.5)	$) \times 10^{-4}$		1586
$3(\pi^{+}\pi^{-})$	(1.5 ±1.0	$) \times 10^{-4}$		1774
$\overline{p} p \pi^0$	(1.4 ± 0.5)	$) \times 10^{-4}$		1543
K ⁺ K ⁻	(1.0 ±0.7	$) \times 10^{-4}$		1776
$\pi^{+}\pi^{-}\pi^{0}$	(9 ±5) × 10 ⁻⁵		1830
$\pi^+\pi^-$	(8 ±5	$) \times 10^{-5}$		1838
$\Lambda \overline{\Lambda}$	< 4	$\times 10^{-4}$	CL=90%	1467
<u>=-=</u> +	< 2	$\times 10^{-4}$	CL=90%	1285
$ ho\pi$	< 8.3	$\times 10^{-5}$	CL=90%	1760
$K^+K^-\pi^0$	< 2.96	\times 10 ⁻⁵	CL=90%	1754
$K^{+}\overline{K}^{*}(892)^{-}+\text{c.c.}$	< 5.4	\times 10 ⁻⁵	CL=90%	1698

Radiative decays				
$\gamma \chi_{c0}(1P)$	(9.3 ±0.8) %		261
$\gamma \chi_{c1}(1P)$	(8.7 ±0.8) %		171
$\gamma \chi_{c2}(1P)$	(7.8 ±0.8) %		127
$\gamma \eta_{\varsigma}(1S)$	(2.8 ± 0.6) × 10 ⁻³		639
$\gamma \pi^0$	< 5.4	\times 10 ⁻³	CL=95%	1841
$\gamma \eta'(958)$	< 1.1	$\times 10^{-3}$	CL=90%	1719
γγ	< 1.6	× 10 ⁻⁴	CL=90%	1843
$\gamma \eta(1440) \rightarrow \gamma K \overline{K} \pi$	< 1.2	× 10 ⁻⁴	CL=90%	1569

 $\psi(3770)$

$$I^{G}(J^{PC}) = ?^{?}(1^{-})$$

Mass $m = 3769.9 \pm 2.5 \text{ MeV}$ (S = 1.8) Full width $\Gamma=23.6\pm2.7$ MeV (S=1.1) $\Gamma_{ee}=0.26\pm0.04$ keV (S=1.2)

ψ(3770) DECAY MODES	Fraction (Γ_i/Γ)	Scale factor	(MeV/c)
DD	dominant		242
e+ e-	$(1.12\pm0.17)\times10^{-5}$	1.2	1885

 ψ (4040) [iii]

$$I^{G}(J^{PC}) = ?^{?}(1^{-})$$

Mass $m=4040\pm 10$ MeV Full width $\Gamma=52\,\pm\,10$ MeV $\Gamma_{ee}\,=\,0.75\,\pm\,0.15\,\,\text{keV}$

ψ (4040) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
e+e-	$(1.4\pm0.4)\times10^{-5}$	2020
$D^0 \overline{D}{}^0$	seen	777
$D^*(2007)^0 \overline{D}{}^0 + \text{c.c.}$	seen -	578
$D^*(2007)^0 \overline{D}^*(2007)^0$	seen	232

ψ(4160) ^[iii]

$$I^{G}(J^{PC}) = ?^{?}(1^{-})$$

Mass $m=4159\pm20$ MeV Full width $\Gamma=78\pm20$ MeV $\Gamma_{ee}=0.77\pm0.23$ keV

ψ(4160) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
e^+e^-	$(10\pm4) \times 10^{-6}$	2079

 ψ (4415) $^{[iii]}$

$$I^{G}(J^{PC}) = ?^{?}(1^{-})$$

Mass $m=4415\pm 6$ MeV Full width $\Gamma=43\pm 15$ MeV (S = 1.8) $\Gamma_{ee}=0.47\pm 0.10$ keV

ψ(4415) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
hadrons	dominant	_
e^+e^-	$(1.1\pm0.4)\times10^{-5}$	2207

$b\overline{b}$ MESONS

T(15)

$$I^{G}(J^{PC}) = 0^{-}(1^{-})$$

Scale factor/

Mass $m = 9460.37 \pm 0.21$ MeV (S = 2.7) Full width $\Gamma = 52.5 \pm 1.8$ keV $\Gamma_{ee} = 1.32 \pm 0.05$ keV

au(1S) DECAY MODES	Fraction	(Γ_j/Γ)	Scale factor/ Confidence level	<i>p</i> (MeV/ <i>c</i>)
$\tau^+\tau^-$	(2.67	+0.14 -0.16) %		4384
e+e-		±0.17) %		4730
$\mu^+\mu^-$		±0.07) %	S=1.1	4729
•	onic deca	,		
$J/\psi(1S)$ anything		±0.4)×10 ⁻	-3	4223
$\rho\pi$	< 2	× 10 ⁻⁴		4698
$\pi^+\pi^-$	< 5	× 10		4728
K+K-	< 5	× 10		4728
$p\overline{p}$	< 5	× 10	-4 CL=90%	4636
PP	()	× 10	CL = 90 /6	4030
	tive deca	ays		
$\gamma 2h^+2h^-$	(7.0	±1.5) × 10	-4	4720
$\gamma 3h^+3h^-$	(5.4 :	±2.0) × 10 ⁻	-4	4703
γ 4 h^+ 4 h^-	(7.4	±3.5) × 10 ⁻	-4	4679
$\gamma \pi^+ \pi^- K^+ K^-$	(2.9	±0.9) × 10	-4	4686
$\gamma 2\pi^+ 2\pi^-$	(2.5	$\pm 0.9 \) \times 10^{-}$	-4	4720
$\gamma 3\pi^+ 3\pi^-$	(2.5	±1.2) × 10 ⁻	-4	4703
$\gamma 2\pi^+ 2\pi^- K^+ K^-$		$\pm 1.2 \) \times 10^{-}$		4658
$\gamma \pi^+ \pi^- p \overline{p}$	(1.5 :	± 0.6) $\times 10^{-}$		4604
$\gamma 2\pi^+ 2\pi^- p \overline{p}$		±6)×10 ⁻		4563
$\gamma 2K^+2K^-$	(2.0	± 2.0) \times 10		4601
$\gamma \eta'$ (958)	< 1.3	× 10 ⁻	-3 CL=90%	4682
$\gamma \eta$	< 3.5	× 10	-4 CL=90%	4714
$\gamma f_2'(1525)$	< 1.4	× 10 ⁻	·4 CL=90%	4607
$\gamma f_2(1270)$	< 1.3	× 10	-4 CL=90%	4644
$\gamma \eta(1440)$	< 8.2	× 10 ⁻	-5 CL=90%	4624
$\gamma f_J(1710) \rightarrow \gamma K \overline{K}$	< 2.6	× 10	4 CL=90%	4576
$\gamma f_0(2200) \rightarrow \gamma K^+ K^-$	< 2	× 10	·4 CL=90%	4475
$\gamma f_J(2220) \rightarrow \gamma K^+ K^-$	< 1.5	× 10 ⁻	·5 CL=90%	4469
$\gamma \eta(2225) \rightarrow \gamma \phi \phi$	< 3	× 10 -	3 CL=90%	4469
γX	< 3	× 10	·5 CL=90%	-
X = pseudoscalar with m < 7.2	? GeV)		_	
$\gamma X \overline{X}$	< 1	× 10	CL=90%	-
$X\overline{X} = \text{vectors with } m < 3.1 \text{ Ge}$	eV)			

χ_{b0}(1P) ^{[[jj]}

$$I^G(J^{PC}) = 0^+(0^{++})$$

J needs confirmation.

Mass $m=9859.8\pm1.3~\mathrm{MeV}$

X _{b0} (1P) DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	<i>p</i> (MeV/ <i>c</i>)
γ Υ(15)	<6 %	90%	391

χ_{b1}(1P) ^{[[j]}

$$J^G(J^{PC}) = 0^+(1^{++})$$

J needs confirmation.

Mass $m=9891.9\pm0.7~{
m MeV}$

X _{b1} (1P) DECAY MODES	Fraction (Γ_j/Γ)	p (MeV/c)
γ Υ (1 S)	(35±8) %	422

χ_{b2}(1P) [iii]

$$I^G(J^{PC}) = 0^+(2^{++})$$

J needs confirmation.

Mass $m = 9913.2 \pm 0.6 \text{ MeV}$

X _{b2} (1P) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
γ Υ(15)	(22±4) %	443

T(25)

$$I^{G}(J^{PC}) = 0^{-}(1^{-})$$

Mass $m=10.02330\pm0.00031$ GeV Full width $\Gamma=44\pm7$ keV $\Gamma_{ee}=0.52\pm0.03$ keV

T(25) DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	(MeV/c)
$\Upsilon(1S)\pi^+\pi^-$	(18.5 ±0.8) %		475
$\Upsilon(1S)\pi^0\pi^0$	(8.8 ± 1.1) %		480
$\tau^+\tau^-$	(1.7 \pm 1.6) %		4686
$\mu^+\mu^-$	(1.31±0.21) %		5011
e^+e^-	seen		5012
$\Upsilon(1S)\pi^0$	< 8 ×	10^{-3} 90%	531
$\Upsilon(1S)\eta$		10^{-3} 90%	127
$J/\psi(1S)$ anything	< 6 ×	10 ⁻³ 90%	4533
	Radiative decays		
$\gamma \chi_{b1}(1P)$	(6.7 ±0.9)%		131
$\gamma \chi_{b2}(1P)$	(6.6 \pm 0.9) %		110
$\gamma \chi_{b0}(1P)$	(4.3 ± 1.0)%		162
$\gamma f_J(1710)$	< 5.9 ×	10 ⁻⁴ 90%	4866
$\gamma f_2'(1525)$	< 5.3 ×	10 ⁻⁴ 90%	4896
$\gamma f_2(1270)$	< 2.41 ×	10-4 90%	4931

χ_{ь0}(2Р) ^[∭]

$$I^G(J^{PC}) = 0^+(0^{++})$$

J needs confirmation.

Mass $m = 10.2321 \pm 0.0006$ GeV

X _{b0} (2P) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$\gamma \Upsilon(2S)$	(4.6±2.1) %	210
$\gamma \ \varUpsilon(1S)$	$(9 \pm 6) \times 10^{-3}$	746

х_ы(2Р) ^[∭]

$$I^G(J^{PC}) = 0^+(1^{++})$$

J needs confirmation.

Mass $m=10.2552\pm0.0005~{\rm GeV}$ $m\chi_{b1(2P)}-m\chi_{b0(2P)}=23.5\pm1.0~{\rm MeV}$

X _{b1} (2P) DECAY MODES	Fraction (Γ_i/Γ)	Scale factor	<i>p</i> (MeV/ <i>c</i>)
$\gamma \Upsilon(2S)$	(21 ±4)%	1.5	229
$\sim \Upsilon(15)$	(85+13)%	1.3	764

χ_{b2}(2P) ^[jjj]

$$I^G(J^{PC}) = 0^+(2^{++})$$

J needs confirmation.

Mass $m=10.2685\pm0.0004~{\rm GeV}$ $m\chi_{b2(2P)}-m\chi_{b1(2P)}=13.5\pm0.6~{\rm MeV}$

X _{b2} (2P) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$\gamma \Upsilon(2S)$	(16.2±2.4) %	242
$\gamma \Upsilon(1S)$	$(7.1 \pm 1.0)\%$	776

T(35)

$$I^{G}(J^{PC}) = 0^{-}(1^{-})$$

Mass $m=10.3553\pm0.0005~{\rm GeV}$ Full width $\Gamma=26.3\pm3.5~{\rm keV}$

T(3S) DECAY MODES	Fraction (Γ_i/Γ)	Scale factor	<i>p</i> (MeV/ <i>c</i>)
$\Upsilon(2S)$ anything	(10.6 ±0.8)%		296
$\Upsilon(2S)\pi^+\pi^-$	(2.8 ±0.6) %	2.2	177
$\Upsilon(25)\pi^0\pi^0$	(2.00 ± 0.32) %		190
$\Upsilon(2S)_{\gamma\gamma}$	(5.0 ±0.7) %		327
$\Upsilon(1S)\pi^{+}\pi^{-}$	(4.48 ± 0.21) %		814
$\Upsilon(1S)\pi^0\pi^0$	(2.06±0.28) %		816
$\mu^{+}\mu^{-}$	$(1.81\pm0.17)\%$		5177
e^+e^-	seen		5177
	Radiative decays		
$\gamma \chi_{b2}(2P)$	$(11.4 \pm 0.8)\%$	1.3	87
$\gamma \chi_{b1}(2P)$	(11.3 ±0.6)%		100
$\gamma \chi_{b0}(2P)$	(5.4 \pm 0.6) %	1.1	123

Υ(4*S*) or *T*(10580)

$$I^{G}(J^{PC}) = ?^{?}(1^{-})$$

Mass $m=10.5800\pm0.0035$ GeV Full width $\Gamma=21\pm4$ MeV (S = 2.3) $\Gamma_{ee}=0.248\pm0.031$ keV (S = 1.3)

T(4S) DECAY MODES	Fraction (Γ	_i /୮)	Confidence level	<i>p</i> (MeV/ <i>c</i>)
	dominar	nt		
e^+e^-	(2.8±0.7	') × 10 ⁻⁵	5	5290
J/ψ (3097) anything	(2.2±0.7	') × 10 ⁻³	3	-
D^{*+} anything $+$ c.c.	< 7.4	%	90%	5099
ϕ anything	< 2.3	$\times 10^{-3}$	90%	5240
$\varUpsilon(1S)$ anything	< 4	$\times 10^{-3}$	90%	1053
non- $B\overline{B}$	< 4	%	95%	_

7(10860)

$$I^{G}(J^{PC}) = ??(1 - -)$$

Mass $m = 10.865 \pm 0.008$ GeV (S = 1.1) Full width $\Gamma = 110 \pm 13$ MeV $\Gamma_{ee} = 0.31 \pm 0.07$ keV (S = 1.3)

au(10860) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
e+ e-	$(2.8\pm0.7)\times10^{-6}$	5432

$\Upsilon(11020)$

$$I^{G}(J^{PC}) = ?^{?}(1^{-})$$

Mass $m=11.019\pm0.008$ GeV Full width $\Gamma=79\pm16$ MeV $\Gamma_{ee}=0.130\pm0.030$ keV

T(11020) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
e+ e-	$(1.6\pm0.5)\times10^{-6}$	5509

NOTES

In this Summary Table:

When a quantity has "(S = ...)" to its right, the error on the quantity has been enlarged by the "scale factor" S, defined as S = $\sqrt{\chi^2/(N-1)}$, where N is the number of measurements used in calculating the quantity. We do this when S > 1, which often indicates that the measurements are inconsistent. When S > 1.25, we also show in the Particle Listings an ideogram of the measurements. For more about S, see the Introduction.

A decay momentum p is given for each decay mode. For a 2-body decay, p is the momentum of each decay product in the rest frame of the decaying particle. For a 3-or-more-body decay, p is the largest momentum any of the products can have in this frame.

- [a] See the "Note on $\pi^\pm \to \ell^\pm \nu \gamma$ and $K^\pm \to \ell^\pm \nu \gamma$ Form Factors" in the π^\pm Particle Listings for definitions and details.
- [b] Measurements of $\Gamma(e^+\nu_e)/\Gamma(\mu^+\nu_\mu)$ always include decays with γ 's, and measurements of $\Gamma(e^+\nu_e\gamma)$ and $\Gamma(\mu^+\nu_\mu\gamma)$ never include low-energy γ 's. Therefore, since no clean separation is possible, we consider the modes with γ 's to be subreactions of the modes without them, and let $[\Gamma(e^+\nu_e)+\Gamma(\mu^+\nu_\mu)]/\Gamma_{\text{total}}=100\%$.
- [c] See the π^\pm Particle Listings for the energy limits used in this measurement; low-energy γ 's are not included.
- [d] Derived from an analysis of neutrino-oscillation experiments.
- [e] Astrophysical and cosmological arguments give limits of order 10^{-13} ; see the π^0 Particle Listings.
- [f] See the "Note on the Decay Width $\Gamma(\eta\to\gamma\gamma)$ " in our 1994 edition, Phys. Rev. **D50**, 1 August 1994, Part I, p. 1451.
- [g] See the "Note on η Decay Parameters" in the η Particle Listings.
- [h] C parity forbids this to occur as a single-photon process.
- [i] See the "Note on scalar mesons" in the $f_0(1370)$ Particle Listings.
- [j] See the "Note on $\rho(770)$ " in the $\rho(770)$ Particle Listings.
- [k] The e^+e^- branching fraction is from $e^+e^- \to \pi^+\pi^-$ experiments only. The $\omega \, \rho$ interference is then due to $\omega \, \rho$ mixing only, and is expected to be small. If $e \, \mu$ universality holds, $\Gamma(\rho^0 \to \mu^+\mu^-) = \Gamma(\rho^0 \to e^+e^-) \times 0.99785$.
- [/] This is only an educated guess; the error given is larger than the error on the average of the published values. See the Particle Listings for details.
- [m] See the "Note on $a_1(1260)$ " in the $a_1(1260)$ Particle Listings.
- [n] See the "Note on the $f_1(1420)$ " in the $f_1(1420)$ Particle Listings.
- [o] See also the $\omega(1600)$ Particle Listings.
- [p] See the "Note on the $\eta(1440)$ " in the $\eta(1440)$ Particle Listings.
- [q] See the "Note on the $\rho({\rm 1450})$ and the $\rho({\rm 1700})$ " in the $\rho({\rm 1700})$ Particle Listings.
- [r] See the "Note on ${\rm non-}q\,\overline{q}$ mesons" in the Particle Listings (see the index for the page number).
- [s] See also the $\omega(1420)$ Particle Listings.
- [t] See the "Note on $f_J(1710)$ " in the $f_J(1710)$ Particle Listings.
- [u] See the note in the K^{\pm} Particle Listings.
- [v] The definition of the slope parameter g of the $K \to 3\pi$ Dalitz plot is as follows (see also "Note on Dalitz Plot Parameters for $K \to 3\pi$ Decays" in the K^\pm Particle Listings):

$$|M|^2 = 1 + g(s_3 - s_0)/m_{\pi^+}^2 + \cdots$$

- [w] For more details and definitions of parameters see the Particle Listings.
- [x] See the K^{\pm} Particle Listings for the energy limits used in this measurement
- [y] Most of this radiative mode, the low-momentum γ part, is also included in the parent mode listed without γ 's.
- [z] Direct-emission branching fraction.
- [aa] Structure-dependent part.
- [bb] Derived from measured values of ϕ_{+-} , ϕ_{00} , $|\eta|$, $\tau_{K_5^0}$, and $|m_{K_L^0} m_{K_5^0}|$, as described in the introduction to "Tests of Conservation Laws."

[cc] The CP-violation parameters are defined as follows (see also "Note on CP Violation in $K_S \rightarrow 3\pi$ " and "Note on CP Violation in K_L^0 Decay" in the Particle Listings):

$$\eta_{+-} = |\eta_{+-}| e^{i\phi_{+-}} = \frac{A(K_L^0 \to \pi^+ \pi^-)}{A(K_S^0 \to \pi^+ \pi^-)} = \epsilon + \epsilon'$$

$$\eta_{00} = |\eta_{00}| \mathrm{e}^{i\phi_{00}} = rac{A(K_L^0 o \pi^0 \pi^0)}{A(K_S^0 o \pi^0 \pi^0)} = \epsilon - 2\epsilon'$$

$$\delta = \frac{\Gamma(K_L^0 \to \pi^- \ell^+ \nu) - \Gamma(K_L^0 \to \pi^+ \ell^- \nu)}{\Gamma(K_L^0 \to \pi^- \ell^+ \nu) + \Gamma(K_L^0 \to \pi^+ \ell^- \nu)},$$

$${\rm Im}(\eta_{+-0})^2 = \frac{\Gamma(K_S^0 \to \ \pi^+\pi^-\pi^0)^{CP \ {\rm viol.}}}{\Gamma(K_L^0 \to \ \pi^+\pi^-\pi^0)} \ ,$$

$${\rm Im}(\eta_{000})^2 = \frac{\Gamma(K_S^0 \to ~\pi^0 \pi^0 \pi^0)}{\Gamma(K_L^0 \to ~\pi^0 \pi^0 \pi^0)}$$

where for the last two relations *CPT* is assumed valid, *i.e.*, ${\rm Re}(\eta_{+-0})\simeq$ 0 and ${\rm Re}(\eta_{000})\simeq~$ 0.

- [dd] See the K_S^0 Particle Listings for the energy limits used in this measurement.
- [ee] Calculated from K_L^0 semileptonic rates and the K_S^0 lifetime assuming $\Delta S = \Delta Q$.
- [ff] ϵ'/ϵ is derived from $\left|\eta_{00}/\eta_{+-}\right|$ measurements using theoretical input on phases.
- [gg] The value is for the sum of the charge states of particle/antiparticle states indicated.
- [hh] See the K_L^0 Particle Listings for the energy limits used in this measurement.
- $[ii] \ m_{e^+e^-} > 470 \ {
 m MeV}.$
- [jj] Allowed by higher-order electroweak interactions.
- [kk] Violates CP in leading order. Test of direct CP violation since the indirect CP-violating and CP-conserving contributions are expected to be suppressed.
- [//] See the "Note on $f_0(1370)$ " in the $f_0(1370)$ Particle Listings and in the 1994 edition.
- [mm] See the note in the L(1770) Particle Listings in Reviews of Modern Physics **56** No. 2 Pt. II (1984), p. S200. See also the "Note on $K_2(1770)$ and the $K_2(1820)$ " in the $K_2(1770)$ Particle Listings.
- [nn] See the "Note on $K_2(1770)$ and the $K_2(1820)$ " in the $K_2(1770)$ Particle Listings.
- [oo] This is a weighted average of D^\pm (44%) and D^0 (56%) branching fractions. See " D^+ and $D^0 \to (\eta \, \text{anything}) / (\text{total } D^+ \, \text{and } D^0)$ " under " D^+ Branching Ratios" in the Particle Listings.

- [pp] This value averages the e^+ and μ^+ branching fractions, after making a small phase-space adjustment to the μ^+ fraction to be able to use it as an e^+ fraction; hence our ℓ^+ is really an e^+ .
- [qq] ℓ indicates e or μ mode, not sum over modes.
- [rr] The branching fractions for this mode may differ from the sum of the submodes that contribute to it, due to interference effects. See the relevant papers in the Particle Listings.
- [ss] The two experiments determining this ratio are in serious disagreement. See the Particle Listings.
- [tt] This mode is not a useful test for a ΔC=1 weak neutral current because both quarks must change flavor in this decay.
- [uu] The D_1^0 - D_2^0 limits are inferred from the D^0 - \overline{D}^0 mixing ratio $\Gamma(K^+\pi^-$ or $K^+\pi^-\pi^+\pi^-$ via \overline{D}^0) / $\Gamma(K^-\pi^+$ or $K^-\pi^+\pi^+\pi^-$).
- [vv] This value is calculated from the ratio $\Gamma(K^-\mu^+\nu_\mu)/\Gamma(\mu^+$ anything) in the D^0 Particle Listings.
- [ww] The experiments on the division of this charge mode amongst its submodes disagree, and the submode branching fractions here add up to considerably more than the charged-mode fraction.
- [xx] For now, we average together measurements of the $\phi\,e^+\nu_e$ and $\phi\,\mu^+\nu_\mu$ branching fractions. This is the average, not the sum.
- [yy] This branching fraction is calculated from appropriate fractions of the next three branching fractions.
- [zz] This value includes only K^+K^- decays of the $f_J(1710)$, because branching fractions of this resonance are not known.
- [aaa] This mode is not a useful test for a ΔC =1 weak neutral current because both quarks must change flavor in this decay.
- $[bbb]\ B^0$ and B^0_s contributions not separated. Limit is on weighted average of the two decay rates.
- [ccc] These values are model dependent. See 'Note on Semileptonic Decays' in the \mathcal{B}^+ Particle Listings.
- [ddd] D^{**} stands for the sum of the $D(1\ ^1P_1),\ D(1\ ^3P_0),\ D(1\ ^3P_1),\ D(1\ ^3P_2),\ D(2\ ^1S_0),$ and $D(2\ ^1S_1)$ resonances.
- [eee] Inclusive branching fractions have a multiplicity definition and can be greater than 100%.
- [fff] D_j represents an unresolved mixture of pseudoscalar and tensor D^{**} (P-wave) states.
- [ggg] Not a pure measurement. See note at head of B_s^0 Decay Modes.
- [hhh] Includes $p\overline{p}\pi^+\pi^-\gamma$ and excludes $p\overline{p}\eta$, $p\overline{p}\omega$, $p\overline{p}\eta'$.
- [iii] J^{PC} known by production in e^+e^- via single photon annihilation. I^G is not known; interpretation of this state as a single resonance is unclear because of the expectation of substantial threshold effects in this energy region
- [jjj] Spectroscopic labeling for these states is theoretical, pending experimental information.

See also the table of suggested $q\overline{q}$ quark-model assignments in the Quark Model section.

- Indicates particles that appear in the preceding Meson Summary Table. We do not regard
 the other entries as being established.
- \dagger Indicates that the value of J given is preferred, but needs confirmation.

	LIGHT UN			STRA		воттом,	STRANGE
	(S = C =	=B=0)	C . DC.	$(S=\pm 1, C)$		$(B=\pm 1,$	
	$I^{G}(J^{PC})$		$I^G(J^{PC})$		$I(J^P)$		$I^{G}(J^{PC})$
• π [±]	1-(0-)	$f_2(1640)$	0+(2++)	• K±	1/2(0-)	• B _s ⁰	0(0-)
• π ⁰	1-(0-+)	• $\omega_3(1670)$	0-(3)	• K ⁰	1/2(0-)	B_s^*	?(??)
• η	0+(0-+)	• $\pi_2(1670)$	1-(2-+)	• K _S ⁰	$1/2(0^{-})$	$B_{sJ}^*(5850)$?(? [?])
• f ₀ (400–1200)	0+(0++)	 φ(1680) 	0-(1)	• K ⁰ _L	$1/2(0^{-})$		
• ρ(770)	1+(1)	• ρ ₃ (1690)	1+(3)	• K*(892)	1/2(1-)		0+(0-+)
• ω(782)	0-(1)	• ρ(1700)	1+(1)	• $K_1(1270)$	1/2(1+)	$\bullet \ \eta_c(1S)$ $\bullet \ J/\psi(1S)$	0-(1)
• η'(958)	$0^{+}(0^{-}+)$	• $f_J(1710)$	0 ⁺ (even ⁺ + +)	• K ₁ (1400)	1/2(1+)	$\bullet \chi_{c0}(1P)$	$0^{+}(0^{+}+)$
• f ₀ (980)	$0^+(0^{++})$ $1^-(0^{++})$	X(1740)	0 ⁺ (even ⁺ +)	·	1/2(1-)	$\bullet \chi_{c0}(1P)$ $\bullet \chi_{c1}(1P)$	$0^{+}(1^{+}+)$
• a ₀ (980)	$0^{-}(1^{-})$	$\eta(1760)$	$0^+(0^{-+})$ $1^-(0^{-+})$	• K ₀ *(1430)	1/2(0+)	$h_c(1P)$??(???)
• $\phi(1020)$ • $h_1(1170)$	$0^{-(1+-)}$	$\pi(1800) \ X(1775)$	1 - (? - +)	• K ₂ (1430)	1/2(2+)	$\bullet \chi_{c2}(1P)$	0+(2++)
$\bullet h_1(1170)$ $\bullet b_1(1235)$	$1^{+}(1^{+}-)$	$f_2(1810)$	$0^{+}(2^{+}+)$	K(1460)	1/2(0-)	$\eta_c(2S)$??(??+)
• $a_1(1260)$	1-(1++)	• $\phi_3(1850)$	0-(3)	$K_2(1580)$	$1/2(2^{-})$	• ψ(2S)	0-(1)
• $f_2(1270)$	$0^{+}(2^{+}+)$	$\eta_2(1870)$	$0^{+}(2^{-}+)$	$K_1(1650)$	$1/2(1^+)$	• ψ(3770)	$?^{(1)'}$
• $f_1(1285)$	$0^{+}(1^{+}+)$	X(1910)	$0^{+(??+)}$	• K*(1680) • K ₂ (1770)	$1/2(1^{-})$	$\bullet \psi (4040)$??(1)
• η(1295)	0+(0-+)	$f_2(1950)$	0+(2++)	$\bullet K_2(1770)$ $\bullet K_3^*(1780)$	1/2(2) 1/2(3)	$\bullet \psi(4160)$	$?^{?}(1)$
π(1300)	$1^{-(0-+)}$	X(2000)	1-(??+)	$\bullet K_3(1780)$ $\bullet K_2(1820)$	$1/2(3^{-})$ $1/2(2^{-})$	• $\psi(4415)$	$?^{?}(1)$
• a ₂ (1320)	1-(2++)	• f ₂ (2010)	$0^{+}(2^{+})$	$K_2(1820)$ $K(1830)$	$1/2(2^{-})$ $1/2(0^{-})$		-
• $f_0(1370)$	0+(0++)	$a_4(2040)$	1-(4++)	$K_0^*(1950)$	$1/2(0^+)$	Ь	
$h_1(1380)$?-(1+?)	• $f_4(2050)$	0+(4++)	$K_0^*(1980)$	$1/2(0^{+})$	 • ↑(15) 	0-(1)
$\hat{ ho}(1405)$	$1^{-}(1^{-+})$	$\pi_2(2100)$	1-(2-+)	• K ₄ (2045)	$1/2(4^+)$	• $\chi_{b0}(1P)$	0+(0++)
• f ₁ (1420)	$0^+(1^{++})$	$f_2(2150)$	$0^{+}(2^{+})$	$K_2(2250)$	$1/2(2^{-})$	$\bullet \chi_{b1}(1P)$	0+(1++)
 ω(1420) 	0-(1)	ho(2150)	1+(1)	$K_3(2320)$	$1/2(3^+)$	• $\chi_{b2}(1P)$	0+(2++)
f ₂ (1430)	$0^+(2^{++})$	$f_0(2200)$	0+(0++)	K ₅ (2380)	1/2(5-)	• \(\gamma(25) \)	0-(1)
 η(1440) 	0+(0-+)	f」(2220)	$0^+(2^{++})$ or	$K_4(2500)$	1/2(4-)	• $\chi_{b0}(2P)$	0+(0++)
$a_0(1450)$	$1^{-}(0^{+}+)$		4 + +)	K(3100)	??(???)	$\bullet \chi_{b1}(2P)$	$0^+(1^{++})$ $0^+(2^{++})$
• ρ(1450)	1+(1)	$\eta(2225)$	0+(0-+)			• $\chi_{b2}(2P)$	$0^{-}(1^{-})$
• $f_0(1500)$	$0^{+}(0^{+}+)$	$\rho_3(2250)$	$1^{+}(3^{-})$	CHAR			$?^{(1)}$
• f ₁ (1510)	$0^{+}(1^{+})$	• f ₂ (2300)	$0^{+}(2^{+}+)$ $0^{+}(4^{+}+)$	(C =		• \(\gamma(43) \)	??(1)
• f' ₂ (1525)	$0^{+}(2^{+}+)$	$f_4(2300)$	$0^{+}(2^{+})$	• D±	1/2(0-)	• $\Upsilon(11020)$	$\frac{1}{?}(1)$
$f_2(1565)$	$0^+(2^{++})$ $0^-(1^{})$	• $f_2(2340)$ $\rho_5(2350)$	$1^{+}(5^{-})$	• D ⁰	1/2(0-)		` '
• ω(1600)	$2^{+}(2^{+}+)$	$a_6(2450)$	1-(6++)	• D*(2007) ⁰	1/2(1-)	NON- <i>q</i> q CA	NDIDATES
X(1600)	2 (2 * *)	$f_6(2510)$	$0^{+}(6++)$	• $D^*(2010)^{\pm}$	$1/2(1^{-})$	Non- $q\overline{q}$ Candi	dates
		X(3250)	??(???)	• $D_1(2420)^0$	1/2(1 ⁺) 1/2(? [?])		
			` ′	$D_1(2420)^{\pm}$ • $D_2^*(2460)^0$	$1/2(?^{+})$ $1/2(2^{+})$		
			T UNFLAVORED	$D_2(2460)$ • $D_2^*(2460)^+$	$1/2(2^+)$ $1/2(2^+)$		
			=B=0)				
		N√(1100–3€		CHARMED, (<i>c</i> = <i>s</i>			
		X(1900–360	0)	• D _s [±]	0(0-)		
				• D _s *±	?(? [?])		
				• $D_{s1}(2536)^{\pm}$	0(1+)		
				• $D_{sJ}(2573)^{\pm}$?(??)		
				ВОТ			
				(B =			
				• B [±]	1/2(0-)		
				• B ⁰ • B*	1/2(0-)		
				1	1/2(1) ?(? [?])		
				B _J (5732)	:(:)		

This short table gives the name, the quantum numbers (where known), and the status of baryons in the Review. Only the baryons with 3-or 4-star status are included in the main Baryon Summary Table. Due to insufficient data or uncertain interpretation, the other entries in the short table are not established as baryons. The names with masses are of baryons that decay strongly. See our 1986 edition (Physics Letters 170B) for listings of evidence for Z baryons (KN resonances).

			1									T		
p	P_{11}	****	Δ (1232)	P_{33}	****	Λ	P_{01}	****	Σ^+	P_{11}	****	Ξ0	P_{11}	****
n	P_{11}	****	Δ (1600)	P_{33}	***	Λ(1405)	S_{01}	****	Σ^0	P_{11}	****	Ξ-	P_{11}	****
N(1440)	P_{11}	****	Δ (1620)	S_{31}	****	Λ(1520)	D_{03}	****	Σ^-	P_{11}	****	$\Xi(1530)$	P_{13}	****
N(1520)	D_{13}	****	Δ (1700)	D_{33}	****	Λ(1600)	P_{01}	***	$\Sigma(1385)$	P_{13}	****	<i>Ξ</i> (1620)		*
N(1535)	S_{11}	****	Δ (1750)	P_{31}	*	Λ(1670)	S_{01}	****	$\Sigma(1480)$		*	<i>Ξ</i> (1690)		***
N(1650)	S_{11}	****	Δ (1900)	S_{31}	***	Λ(1690)	D_{03}	****	$\Sigma(1560)$		**	$\Xi(1820)$	D_{13}	***
N(1675)	D_{15}	****	Δ (1905)	F_{35}	****	<i>∧</i> (1800)	S_{01}	***	$\Sigma(1580)$	D_{13}	**	<i>Ξ</i> (1950)		***
N(1680)	F_{15}	****	Δ (1910)	P_{31}	****	Λ(1810)	P_{01}	***	$\Sigma(1620)$	S_{11}	**	<i>Ξ</i> (2030)		***
N(1700)	D_{13}	***	Δ (1920)	P_{33}	***	Λ(1820)	F_{05}	****	$\Sigma(1660)$	P_{11}	***	$\Xi(2120)$		*
N(1710)	P_{11}	***	$\Delta(1930)$	D_{35}	***	Λ(1830)	D_{05}	****	$\Sigma(1670)$	D_{13}	****	<i>Ξ</i> (2250)		**
N(1720)	P_{13}	****	$\Delta(1940)$	D_{33}	*	Λ(1890)	P_{03}	****	$\Sigma(1690)$		**	<i>Ξ</i> (2370)		**
N(1900)	P_{13}	**	$\Delta(1950)$	F_{37}	****	Λ(2000)		*	Σ (1750)	S_{11}	***	<i>Ξ</i> (2500)		*
N(1990)	F_{17}	**	$\Delta(2000)$	F ₃₅	**	A(2020)	F_{07}	*	Σ (1770)	P_{11}	*			
N(2000)	F_{15}	**	Δ (2150)	S ₃₁	*	Λ(2100)	G_{07}	****	Σ (1775)	D_{15}	****	Ω^-		****
N(2080)	D_{13}	**	$\Delta(2200)$	G_{37}	*	Λ(2110)	F_{05}	***	$\Sigma(1840)$	P_{13}	*	$\Omega(2250)^-$		***
N(2090)	S_{11}	*	△(2300)	H ₃₉	**	A(2325)	D_{03}	*	$\Sigma(1880)$	P_{11}	**	$\Omega(2380)^-$		**
N(2100)	P_{11}	*	$\Delta(2350)$	D_{35}	*	A(2350)	H_{09}	***	$\Sigma(1915)$	F_{15}	****	$\Omega(2470)^-$		**
N(2190)	G_{17}	****	$\Delta(2390)$	F ₃₇	*	Λ(2585)		**	$\Sigma(1940)$	D_{13}	***			
N(2200)	D_{15}	**	△(2400)	G ₃₉	**	l ' '			Σ (2000)	S_{11}	*	Λ_c^+		****
N(2220)	H_{19}	****	$\Delta(2420)$	$H_{3,11}$	****				Σ (2030)	F_{17}	****	$\Lambda_c(2593)^+$		***
N(2250)	G_{19}	****	$\Delta(2750)$	I _{3,13}	**				Σ (2070)	F_{15}	*	$\Lambda_c(2625)^+$		***
N(2600)	$I_{1,11}$	***	Δ (2950)	$K_{3,15}$	**				Σ (2080)	P_{13}	**	Σ_c (2455)		****
N(2700)	$K_{1,13}$	**	(,	- 5,15					Σ (2100)	G_{17}	*	$\Sigma_c(2530)$		*
` ´	-,								Σ (2250)		***	=+ = c		***
									Σ (2455)		**	$= \frac{0}{c}$		***
									$\Sigma(2620)$		**	$\Xi_c(2645)$		***
									Σ(3000)		*	Ω_c^0		***
									Σ(3170)		*	·		
									` ′			Λ_b^0		***
												Ξ_b^0, Ξ_b^-		*
									l					

^{****} Existence is certain, and properties are at least fairly well explored.

^{***} Existence ranges from very likely to certain, but further confirmation is desirable and/or quantum numbers, branching fractions, etc. are not well determined.

^{**} Evidence of existence is only fair.

^{*} Evidence of existence is poor.

N BARYONS (S=0, I=1/2)

 $p, N^+ = uud;$ $n, N^0 = udd$

p

$$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$$

Mass $m = 938.27231 \pm 0.00028$ MeV $^{[a]}$ $=\,1.007276470\,\pm\,0.000000012\;u$ $\left|\frac{q_{\overline{p}}}{m_{\overline{p}}}\right|/\left(\frac{q_{p}}{m_{p}}\right) = 1.0000000015 \pm 0.0000000011$ $\left|q_p + q_{\overline{p}}\right|/e \ < \ 2\times 10^{-5}$ $|q_p + q_e|/e < 1.0 \times 10^{-21} [b]$ Magnetic moment $\mu=$ 2.79284739 \pm 0.00000006 μ_N Electric dipole moment $d = (-4 \pm 6) \times 10^{-23}$ ecm Electric polarizability $\overline{\alpha} = (12.1 \pm 0.9) \times 10^{-4} \text{ fm}^3$ $\begin{array}{l} \mbox{Magnetic polarizability } \overline{\beta} = (2.1 \pm 0.9) \times 10^{-4} \ \mbox{fm}^{3} \\ \mbox{Mean life } \tau > 1.6 \times 10^{25} \mbox{ years} \ \ \mbox{(independent of mode)} \\ = > 10^{31} - 5 \times 10^{32} \mbox{ years} \ \mbox{$^{[c]}$} \ \ \mbox{(mode dependent)} \end{array}$

Below, for N decays, p and n distinguish proton and neutron partial lifetimes. See also the "Note on Nucleon Decay" in our 1994 edition (Phys. Rev. **D50**, 1673) for a short review.

The "partial mean life" limits tabulated here are the limits on $\tau/\mathrm{B}_{\mathrm{J}}$, where au is the total mean life and B_i is the branching fraction for the mode in

p DECAY MODES	Partial mean life (10 ³⁰ years)	Confidence level	p (Me)//c)
p DECAT MODES	(10 years)	Confidence level	(IVIE V/C)
	pton + meson		
$N \rightarrow e^+\pi$	> 130 (n), > 550 (459
$N \rightarrow \mu^+ \pi$	> 100 (n), > 270 (453
$N \rightarrow \nu \pi$	> 100 (n), > 25 (p	•	459
$p \rightarrow e^+_{\perp} \eta$	> 140	90%	309
$p \rightarrow \mu^+ \eta$	> 69	90%	296
$n \rightarrow \nu \eta$	> 54	90%	310
$N \rightarrow e^+ \rho$	> 58 (n), > 75 (p)	90%	153
$N \rightarrow \mu^+ \rho$	> 23 (n), > 110 (p	•	119
$N \rightarrow \nu \rho$ $p \rightarrow e^+ \omega$	> 19 (n), > 27 (p)	90% 90%	153 142
$p \rightarrow e \cdot \omega$ $p \rightarrow \mu^+ \omega$	> 45 > 57	90%	104
$ \begin{array}{ccc} \rho \to & \mu \cdot \omega \\ n \to & \nu \omega \end{array} $	> 57 > 43	90%	144
$N \rightarrow \nu \omega$ $N \rightarrow e^+ K$	> 43 > 1.3 (n), > 150 (μ		337
$p \rightarrow e^+ K_c^0$	> 76	90%	337
$p \rightarrow e^+ K_I^0$	> 44	90%	337
$N \rightarrow \mu^+ K$			326
$p \rightarrow \mu^+ K_S^0$	> 1.1 (n), > 120 (µ > 64	90%	326
$p \rightarrow \mu^+ K_I^0$ $p \rightarrow \mu^+ K_I^0$		90%	326
$p \rightarrow \mu \cdot \kappa_{\bar{L}}$ $N \rightarrow \nu K$	> 44		
$p \rightarrow e^+ K^* (892)^0$	> 86 (n), > 100 (p	*	339
$N \rightarrow \nu K^*(892)$	> 52	90% 90%	45 45
,	> 22 (n), > 20 (p)	90%	45
	oton + mesons		
$p \rightarrow e^+ \pi^+ \pi^-$	> 21	90%	448
$p \rightarrow e^+ \pi^0 \pi^0$	> 38	90%	449
$n \rightarrow e^+ \pi^- \pi^0$	> 32	90%	449
$\rho \rightarrow \mu^+ \pi^+ \pi^-$	> 17	90%	425
$p \rightarrow \mu^+ \pi^0 \pi^0$	> 33	90%	427
$n \rightarrow \mu^+ \pi^- \pi^0$	> 33	90%	427
$n \rightarrow e^+ K^0 \pi^-$	> 18	90%	319
Lept	on + meson		
$n \rightarrow e^- \pi^+$	> 65	90%	459
$n \rightarrow \mu^- \pi^+$	> 49	90%	453
$n \rightarrow e^- \rho^+$	> 62	90%	154
$n \rightarrow \mu^- \rho^+$	> 7	90%	120
$n \rightarrow e^- K^+$	> 32	90%	340
$n \rightarrow \mu^- K^+$	> 57	90%	330
Lepto	on + mesons		
$p \rightarrow e^- \pi^+ \pi^+$	> 30	90%	448
$n \rightarrow e^- \pi^+ \pi^0$	> 29	90%	449
$p \rightarrow \mu^- \pi^+ \pi^+$	> 17	90%	425
$n \rightarrow \mu^- \pi^+ \pi^0$	> 34	90%	427
$p \rightarrow e^- \pi^+ K^+$	> 20	90%	320
$p \rightarrow \mu^- \pi^+ K^+$	> 5	90%	279

	Antilepton + photon(s)		
$ ho ightarrow e^+ \gamma$	> 460	90%	469
$\rho \rightarrow \mu^+ \gamma$	> 380	90%	463
$n \rightarrow \nu \gamma$	> 24	90%	470
$ ho ightarrow e^+ \gamma \gamma$	> 100	90%	469
	Three leptons		
$ ho ightarrow e^+ e^+ e^-$	> 510	90%	469
$ ho ightarrow e^+ \mu^+ \mu^-$	> 81	90%	457
$\rho \rightarrow e^+ \nu \nu$	> 11	90%	469
$n \rightarrow e^+e^-\nu$	> 74	90%	470
$n \rightarrow \mu^+ e^- \nu$	> 47	90%	464
$n \rightarrow \mu^+ \mu^- \nu$	> 42	90%	458
$ ho ightarrow \mu^+ e^+ e^-$	> 91	90%	464
$\rho \rightarrow \mu^+ \mu^+ \mu^-$	> 190	90%	439
$\rho \rightarrow \mu^+ \nu \nu$	> 21	90%	463
$ ho ightarrow e^- \mu^+ \mu^+$	> 6	90%	457
$n \rightarrow 3\nu$	> 0.0005	90%	470
	Inclusive modes		
$N ightarrow e^+$ anything	> 0.6 (n, p)	90%	-
$N ightarrow \mu^+$ anything	> 12 (n, p)	90%	-
$N ightarrow \ e^+ \pi^0$ anything	> 0.6 (n, p)	90%	-
	$\Delta B = 2$ dinucleon modes		

The following are lifetime limits per iron nucleus. $pp \rightarrow \pi^+\pi^+$ 90% > 0.7 $pn \rightarrow \pi^+\pi^0$ 90% > 2 $nn \rightarrow \pi^+\pi^-$ > 0.7 90% $nn \rightarrow \pi^0 \pi^0$ > 3.4 90% $pp \rightarrow e^+e^+$ > 5.8 90% $pp \rightarrow e^+ \mu^+$ > 3.6 90% $pp \rightarrow \mu^+ \mu^+$ > 1.7 90% $pn \rightarrow e^{+\frac{r}{\overline{\nu}}}$ > 2.8 90% $pn \rightarrow \mu^+ \overline{\nu}$ 90% > 1.6 $nn \rightarrow \nu_e \overline{\nu}_e$ > 0.000012 90% $nn \rightarrow \nu_{\mu} \overline{\nu}_{\mu}$ > 0.000006 90%

P DECAY MODES

p DECAY MODES	Partial mean life (years)	Confidence level	р (MeV/ <i>c</i>)
$\overline{p} \rightarrow e^- \gamma$	> 1848	95%	469
$\overline{p} \rightarrow e^{-}\pi^{0}$	> 554	95%	459
$\overline{p} \rightarrow e^- \eta$	> 171	95%	309
$\overline{p} \rightarrow e^- K_S^0$	> 29	95%	337
$\overline{p} ightarrow e^- K_S^0$ $\overline{p} ightarrow e^- K_L^0$	> 9	95%	337

 \overline{n}

 $I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$

Mass $m = 939.56563 \pm 0.00028$ MeV $^{[a]}$ $= 1.008664904 \pm 0.000000014$ u $m_{\it n}-m_{\it p}=$ 1.293318 \pm 0.000009 MeV $= 0.001388434 \,\pm\, 0.000000009 \; u$

Mean life $au=887.0\pm2.0$ s (S = 1.3)

 $c\tau = 2.659 \times 10^8 \text{ km}$

Magnetic moment $\mu = -1.9130428 \pm 0.0000005 \ \mu_N$ Electric dipole moment $d < 1.1 \times 10^{-25}$ e cm, CL = 95%

Electric polarizability $\alpha = (0.98^{+0.19}_{-0.23}) \times 10^{-3} \text{ fm}^3 \quad (S = 1.1)$

Charge $q = (-0.4 \pm 1.1) \times 10^{-21} e$

Mean $n\overline{n}$ -oscillation time > 1.2×10^8 s, CL = 90% [d] (bound n) $> 0.86 \times 10^8 \text{ s, CL} = 90\%$ (free n)

Decay parameters [e]

 $g_A/g_V = -1.2601 \pm 0.0025$ (S = 1.1) $pe^-\overline{\nu}_e$ $A = -0.1139 \pm 0.0011$ (S = 1.3) $B = 0.990 \pm 0.008$ $a=-0.102\,\pm\,0.005$ $\phi_{AV} = (180.07 \pm 0.18)^{\circ} \, ^{[f]}$ $D = (-0.5 \pm 1.4) \times 10^{-3}$

n DECAY MODES	Fraction (Γ_{I}/Γ)	Confidence level	(MeV/c)
p e −	100 %		1.19
CI	harge conservation (Q) violating n	node	
$p\nu_e\overline{\nu}_e$	$Q < 9 \times 10^{-24}$	90%	1.29

N(1440) P₁₁

 $I(J^P)=\tfrac{1}{2}(\tfrac{1}{2}^+)$

Mass m=1430 to 1470 (\approx 1440) MeV Full width $\Gamma=250$ to 450 (\approx 350) MeV $\rho_{\rm beam}=0.61~{\rm GeV}/c$ $4\pi \chi^2=31.0~{\rm mb}$

N(1440) DECAY MODES	Fraction (Γ_i/Γ)	ρ (MeV/c)
Νπ	60-70 %	397
$N\pi\pi$	30-40 %	342
$\Delta\pi$	20-30 %	143
$N \rho$	<8 %	†
$N(\pi\pi)_{S-\text{wave}}^{I=0}$	5-10 %	-
$p\gamma$	0.035-0.048 %	414
$p\gamma$, helicity=1/2	0.035-0.048 %	414
$n\gamma$	0.009-0.032 %	413
$n\gamma$, helicity=1/2	0.009-0.032 %	413

N(1520) D₁₃

 $I(J^P)=\tfrac{1}{2}(\tfrac{3}{2}^-)$

Mass m=1515 to 1530 (\approx 1520) MeV Full width $\Gamma=110$ to 135 (\approx 120) MeV $p_{\rm beam}=0.74~{\rm GeV}/c$ $4\pi \chi^2=23.5~{\rm mb}$

N(1520) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
Nπ	50-60 %	456
$N\pi\pi$	40-50 %	410
$\Delta\pi$	15-25 %	228
$N \rho$	15-25 %	t
$N(\pi\pi)_{S-\text{wave}}^{I=0}$	<8 %	-
$p\gamma$	0.46-0.56 %	470
$p\gamma$, helicity=1/2	0.001-0.034 %	470
$\rho\gamma$, helicity=3/2	0.44-0.53 %	470
$n\gamma$	0.30-0.53 %	470
$n\gamma$, helicity=1/2	0.04-0.10 %	470
$n\gamma$, helicity=3/2	0.25-0.45 %	470

N(1535) S₁₁

$$I(J^P)=\tfrac{1}{2}(\tfrac{1}{2}^-)$$

Mass m=1520 to 1555 (\approx 1535) MeV Full width $\Gamma=100$ to 250 (\approx 150) MeV $p_{\rm beam}=0.76~{\rm GeV}/c$ $4\pi {\it X}^2=22.5~{\rm mb}$

Fraction (Γ_i/Γ)	p (MeV/c)
35-55 %	467
30-55 %	182
1-10 %	422
<1 %	242
<4 %	†
<3 %	
<7 %	†
0.08-0.27 %	481
0.08-0.27 %	481
0.004-0.29 %	480
0.004-0.29 %	480
	35-55 % 30-55 % 1-10 % <1 % <4 % <3 % <7 % 0.08-0.27 % 0.08-0.27 % 0.004-0.29 %

N(1650) S₁₁

$$I(J^P)=\tfrac{1}{2}(\tfrac{1}{2}^-)$$

Mass m=1640 to 1680 (≈ 1650) MeV Full width $\Gamma=145$ to 190 (≈ 150) MeV $p_{\rm beam}=0.96~{\rm GeV}/c$ $4\pi \chi^2=16.4~{\rm mb}$

N(1650) DECAY MODES	Fraction (Γ_i/Γ)	$p \; (MeV/c)$
Nπ	55-90 %	547
$N\eta$	3-10 %	346
ΛK	3-11 %	161
Νππ	10-20 %	511
$\Delta\pi$	1-7 %	344
$N\rho$	4-12 %	t

$N(\pi\pi)_{S-\text{wave}}^{I=0}$	<4 %	_
$N(1440)\pi$	<5 %	147
$p\gamma$	0.04-0.18 %	558
$p\gamma$, helicity=1/2	0.04-0.18 %	558
$n\gamma$	0.003-0.17 %	557
$n\gamma$, helicity=1/2	0.003-0.17 %	557

N(1675) D₁₅

$$I(J^P)=\tfrac{1}{2}(\tfrac{5}{2}^-)$$

Mass m=1670 to 1685 (\approx 1675) MeV Full width Γ = 140 to 180 (\approx 150) MeV $p_{\rm beam}=1.01~{\rm GeV}/c$ $4\pi x^2=15.4~{\rm mb}$

N(1675) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
Nπ	40-50 %	563
ΛK	<1 %	209
$N\pi\pi$	50-60 %	529
$\Delta\pi$	50-60 %	364
$N \rho$	< 1-3 %	t
$p\gamma$	0.004-0.023 %	575
$p\gamma$, helicity=1/2	0.0-0.015 %	575
$p\gamma$, helicity=3/2	0.0-0.011 %	575
$n\gamma$	0.02-0.12 %	574
$n\gamma$, helicity=1/2	0.006-0.046 %	574
$n\gamma$, helicity=3/2	0.01-0.08 %	574

N(1680) F₁₅

$$I(J^P) = \frac{1}{2}(\frac{5}{2}^+)$$

Mass m=1675 to 1690 (\approx 1680) MeV Full width Γ = 120 to 140 (\approx 130) MeV $p_{\rm beam}=1.01~{\rm GeV}/c$ $4\pi {\it X}^2=15.2~{\rm mb}$

N(1680) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
Nπ	60-70 %	567
$N\pi\pi$	30-40 %	532
$\Delta\pi$	5-15 %	369
$N\rho$	3-15 %	†
$N(\pi\pi)_{S-\text{wave}}^{I=0}$	5-20 %	_
$p\gamma$	0.21-0.32 %	578
$p\gamma$, helicity=1/2	0.001-0.011 %	578
$p\gamma$, helicity=3/2	0.20-0.32 %	578
$n\gamma$	0.021-0.046 %	577
$n\gamma$, helicity=1/2	0.004-0.029 %	577
$n\gamma$, helicity=3/2	0.01-0.024 %	577

N(1700) D₁₃

$$I(J^P) = \frac{1}{2}(\frac{3}{2}^-)$$

Mass m=1650 to 1750 (\approx 1700) MeV Full width $\Gamma=50$ to 150 (\approx 100) MeV $p_{\rm beam}=1.05~{\rm GeV}/c$ $4\pi {\it X}^2=14.5~{\rm mb}$

N(1700) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
Nπ	5–15 %	580
ΛK	<3 %	250
$N\pi\pi$	85-95 %	547
$N\rho$	<35 %	†
$p\gamma$	0.01-0.05 %	591
$p\gamma$, helicity=1/2	0.0-0.024 %	591
$p\gamma$, helicity=3/2	0.002-0.026 %	591
$n\gamma$	0.01-0.13 %	590
$n\gamma$, helicity=1/2	0.0-0.09 %	590
$n\gamma$, helicity=3/2	0.01-0.05 %	590

N(1710) P₁₁

 $I(J^P)=\tfrac{1}{2}(\tfrac{1}{2}^+)$

Mass m=1680 to 1740 (\approx 1710) MeV Full width $\Gamma=50$ to 250 (\approx 100) MeV $p_{\rm beam}=1.07~{\rm GeV}/c$ $4\pi {\it X}^2=14.2~{\rm mb}$

N(1710) DECAY MODES	Fraction (Γ_j/Γ)	p (MeV/c)
Nπ	10-20 %	587
ΛK	5-25 %	264
$N\pi\pi$	40-90 %	554
$\Delta\pi$	15-40 %	393
$N\rho$	5-25 %	48
$N(\pi\pi)_{S-\text{wave}}^{I=0}$	10-40 %	-
$p\gamma$	0.002-0.05%	598
$p\gamma$, helicity=1/2	0.002-0.05%	598
$n\gamma$	0.0-0.02%	597
$n\gamma$, helicity=1/2	0.0-0.02%	597

N(1720) P₁₃

 $I(J^P) = \frac{1}{2}(\frac{3}{2}^+)$

Mass m=1650 to 1750 (\approx 1720) MeV Full width $\Gamma=100$ to 200 (\approx 150) MeV $p_{\mathrm{beam}}=1.09~\mathrm{GeV}/c$ $4\pi\lambda^2=13.9~\mathrm{mb}$

N(1720) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
Nπ	10-20 %	594
ΛK	1-15 %	278
$N\pi\pi$	>70 %	561
$N\rho$	70-85 %	104
$p\gamma$	0.003-0.10 %	604
$p\gamma$, helicity=1/2	0.003-0.08 %	604
$p\gamma$, helicity=3/2	0.001-0.03 %	604
$n\gamma$	0.002-0.39 %	603
$n\gamma$, helicity=1/2	0.0-0.002 %	603
$n\gamma$, helicity=3/2	0.001-0.39 %	603

N(2190) G₁₇

 $I(J^P) = \frac{1}{2}(\frac{7}{2})$

Mass m=2100 to 2200 (\approx 2190) MeV Full width $\Gamma=350$ to 550 (\approx 450) MeV $p_{\rm beam}=2.07~{\rm GeV}/c$ $4\pi {\it X}^2=6.21~{\rm mb}$

N(2190) DECAY MODES	Fraction (Γ_i/Γ)	ρ (MeV/c)
$N\pi$	10-20 %	888

$N(2220) H_{19}$

 $I(J^P) = \frac{1}{2}(\frac{9}{2}^+)$

Mass m=2180 to 2310 (\approx 2220) MeV Full width $\Gamma=320$ to 550 (\approx 400) MeV $p_{\rm beam}=2.14~{\rm GeV}/c$ $4\pi \chi^2=5.97~{\rm mb}$

N(2220) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
Nπ	10-20 %	905

$N(2250) G_{19}$

 $I(J^P)=\tfrac{1}{2}(\tfrac{9}{2}^-)$

Mass m=2170 to 2310 (\approx 2250) MeV Full width Γ = 290 to 470 (\approx 400) MeV $p_{\rm beam}=2.21~{\rm GeV}/c$ $4\pi {\it X}^2=5.74~{\rm mb}$

N(2250) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
Nπ	5-15 %	923

N(2600) I_{1,11}

 $I(J^P) = \frac{1}{2}(\frac{11}{2}^-)$

Mass m=2550 to 2750 (\approx 2600) MeV Full width Γ = 500 to 800 (\approx 650) MeV $p_{\rm beam}=3.12~{\rm GeV}/c$ $4\pi x^2=3.86~{\rm mb}$

N(2600) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
Ņπ	5-10 %	1126

\triangle BARYONS (S=0, I=3/2)

 $\Delta^{++} = uuu$, $\Delta^{+} = uud$, $\Delta^{0} = udd$, $\Delta^{-} = ddd$

Δ (1232) P_{33}

 $I(J^P) = \frac{3}{2}(\frac{3}{2}^+)$

Mass m=1230 to 1234 (\approx 1232) MeV Full width $\Gamma=115$ to 125 (\approx 120) MeV $p_{\rm beam}=0.30~{\rm GeV}/c$ $4\pi \chi^2=94.8~{\rm mb}$

△(1232) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
Nπ	>99 %	227
$N\gamma$	0.54-0.61 %	259
$N\gamma$, helicity=1/2	0.12-0.14 %	259
$N\gamma$, helicity=3/2	0.41-0.47 %	259

$\Delta(1600) P_{33}$

 $I(J^P) = \frac{3}{2}(\frac{3}{2}^+)$

Mass m=1550 to 1700 (\approx 1600) MeV Full width $\Gamma=250$ to 450 (\approx 350) MeV $p_{\rm beam}=0.87~{\rm GeV}/c$ $4\pi \chi^2=18.6~{\rm mb}$

△(1600) DECAY MODES	Fraction (Γ_j/Γ)	p (MeV/c)
Nπ	10-25 %	512
$N\pi\pi$	75-90 %	473
$\Delta\pi$	40-70 %	301
$N\rho$	<25 %	†
$N(1440)\pi$	10-35 %	74
$N\gamma$	0.001-0.02 %	525
$N\gamma$, helicity=1/2	0.0-0.02 %	525
$N\gamma$, helicity=3/2	0.001-0.005 %	525

△(1620) S₃₁

 $I(J^P) = \frac{3}{2}(\frac{1}{2}^-)$

Mass m=1615 to 1675 (≈ 1620) MeV Full width $\Gamma=120$ to 180 (≈ 150) MeV $p_{\mathrm{beam}}=0.91~\mathrm{GeV}/c$ $4\pi \chi^2=17.7~\mathrm{mb}$

△(1620) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
Nπ	20-30 %	526
Νππ	70-80 %	488
$\Delta\pi$	30-60 %	318
$N \rho$	7-25 %	†
$N\gamma$	0.004-0.044 %	538
$N\gamma$, helicity=1/2	0.004-0.044 %	538

$\Delta(1700) D_{33}$

 $I(J^P) = \frac{3}{2}(\frac{3}{2}^-)$

Mass m=1670 to 1770 (\approx 1700) MeV Full width $\Gamma=200$ to 400 (\approx 300) MeV $p_{\rm beam}=1.05~{\rm GeV}/c$ $4\pi x^2=14.5~{\rm mb}$

△(1700) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
Nπ	10-20 %	580
$N\pi\pi$	80-90 %	547
$\Delta \pi$	30-60 %	385
$N \rho$	30-55 %	†
$N\gamma$	0.12-0.26 %	591
$N\gamma$, helicity=1/2	0.08-0.16 %	591
$N\gamma$, helicity=3/2	0.025-0.12 %	591

△(1900) S₃₁

 $I(J^P) = \frac{3}{2}(\frac{1}{2}^-)$

Mass m=1850 to 1950 (\approx 1900) MeV Full width $\Gamma=140$ to 240 (\approx 200) MeV $p_{\mathrm{beam}}=1.44~\mathrm{GeV}/c$ $4\pi\chi^2=9.71~\mathrm{mb}$

△(1900) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
Nπ	10-30 %	710

Δ (1905) F_{35}

 $I(J^P) = \frac{3}{2}(\frac{5}{2}^+)$

Mass m=1870 to 1920 (\approx 1905) MeV Full width $\Gamma=280$ to 440 (\approx 350) MeV $p_{\rm beam}=1.45~{\rm GeV}/c$ $4\pi {\it X}^2=9.62~{\rm mb}$

△(1905) DECAY MODES	Fraction (Γ_j/Γ)	p (MeV/c)
Nπ	5-15 %	713
Νππ	85-95 %	687
$\Delta \pi$	<25 %	542
$N\rho$	>60 %	421
$N\gamma$	0.01-0.03 %	721
$N\gamma$, helicity=1/2	0.0-0.1 %	721
$N\gamma$, helicity=3/2	0.004-0.03 %	721

Δ(1910) P₃₁

 $I(J^P) = \frac{3}{2}(\frac{1}{2}^+)$

Mass m= 1870 to 1920 (\approx 1910) MeV Full width $\Gamma=$ 190 to 270 (\approx 250) MeV $\rho_{\mathrm{beam}}=1.46~\mathrm{GeV}/c$ $4\pi \overline{\chi}^2=9.54~\mathrm{mb}$

△(1910) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
Nπ	15-30 %	716
$N\gamma$	0.0-0.2 %	725
$N\gamma$, helicity=1/2	0.0-0.2 %	725

∆(1920) P₃₃

 $I(J^P) = \frac{3}{2}(\frac{3}{2}^+)$

Mass m=1900 to 1970 (\approx 1920) MeV Full width $\Gamma=150$ to 300 (\approx 200) MeV $\rho_{\rm beam}=1.48~{\rm GeV}/c$ $4\pi\lambda^2=9.37~{\rm mb}$

△(1920) DECAY MODES	Fraction (Γ_i/Γ)	<i>р</i> (MeV/ <i>c</i>)
Nπ	5-20 %	722

Δ(1930) D₃₅

 $I(J^P) = \frac{3}{2}(\frac{5}{2}^-)$

Mass m=1920 to 1970 (\approx 1930) MeV Full width $\Gamma=250$ to 450 (\approx 350) MeV $p_{\mathrm{beam}}=1.50~\mathrm{GeV/}c$ $4\pi\lambda^2=9.21~\mathrm{mb}$

△(1930) DECAY MODES	Fraction (Γ_i/Γ)	ρ (MeV/c)
Νπ	10-20 %	729
$N\gamma$	0.0-0.02 %	737
$N\gamma$, helicity=1/2	0.0-0.01 %	737
$N\gamma$, helicity=3/2	0.0-0.01 %	737

Δ(1950) F₃₇

 $I(J^P) = \frac{3}{2}(\frac{7}{2}^+)$

Mass m=1940 to 1960 (≈ 1950) MeV Full width $\Gamma=290$ to 350 (≈ 300) MeV $p_{\mathrm{beam}}=1.54~\mathrm{GeV}/c$ $4\pi\lambda^2=8.91~\mathrm{mb}$

△(1950) DECAY MODES	Fraction (Γ _/ /Γ)	p (MeV/c)
Nπ	35-40 %	741
$N \pi \pi$		716
$\Delta\pi$	20-30 %	574
$N\rho$	<10 %	469
$N\gamma$	0.08-0.13 %	749
$N\gamma$, helicity=1/2	0.03-0.055 %	749
$N\gamma$, helicity=3/2	0.05-0.075 %	749

△(2420) H_{3,11}

 $I(J^P) = \frac{3}{2}(\frac{11}{2}^+)$

Mass m=2300 to 2500 (\approx 2420) MeV Full width $\Gamma=300$ to 500 (\approx 400) MeV $p_{\mathrm{beam}}=2.64~\mathrm{GeV}/c$ $4\pi \chi^2=4.68~\mathrm{mb}$

Δ(2420) DECAY MODES	Fraction $(\Gamma_{\hat{I}}/\Gamma)$	p (MeV/c)
Nπ	5-15 %	1023

Λ BARYONS (S = -1, I = 0)

1

$$I(J^P) = 0(\frac{1}{2}^+)$$

Mass $m=1115.684\pm0.006$ MeV Mean life $\tau=(2.632\pm0.020)\times10^{-10}$ s (S = 1.6)

Magnetic moment $\mu=-0.613\pm0.004~\mu_N$ Electric dipole moment $d<1.5\times10^{-16}~e\,{\rm cm}$, CL = 95%

Decay parameters

 $\begin{array}{lll} \rho\pi^{-} & \alpha_{-} = 0.642 \pm 0.013 \\ \text{"} & \phi_{-} = (-6.5 \pm 3.5)^{\circ} \\ \text{"} & \gamma_{-} = 0.76 \ ^{[g]} \\ \text{"} & \Delta_{-} = (8 \pm 4)^{\circ} \ ^{[g]} \\ n\pi^{0} & \alpha_{0} = +0.65 \pm 0.05 \\ \rho e^{-}\overline{\nu}_{e} & g_{A}/g_{V} = -0.718 \pm 0.015 \ ^{[e]} \end{array}$

A DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
$p\pi^-$	(63.9 ±0.5) %	101
$n\pi^0$	$(35.8 \pm 0.5)\%$	104
$n\gamma$	$(1.75\pm0.15)\times10^{-3}$	162
$\rho\pi^-\gamma$	[h] (8.4 ± 1.4) $\times 10^{-4}$	101
$\rho e^- \overline{\nu}_e$	$(8.32\pm0.14)\times10^{-4}$	163
$p\mu^-\overline{ u}_{\mu}$	$(1.57\pm0.35)\times10^{-4}$	131

Λ(1405) S₀₁

 $I(J^P)=0(\tfrac{1}{2}^-)$

Mass $m=1407\pm 4$ MeV Full width $\Gamma=50.0\pm 2.0$ MeV Below \overline{K} N threshold

A(1405) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
Σπ	100 %	152

$\Lambda(1520) D_{03}$

 $I(J^P) = O(\frac{3}{2})$

Mass $m=1519.5\pm 1.0$ MeV $^{[i]}$ Full width $\Gamma=15.6\pm 1.0$ MeV $^{[i]}$ $p_{\mathrm{beam}}=0.39$ GeV/c $4\pi \chi^2=82.8$ mb

A(1520) DECAY MODES	Fraction (Γ_i/Γ)	ρ (MeV/c)
NK	45 ± 1%	244
$\Sigma \pi$	42 ± 1%	267
$\Lambda \pi \pi$	10 ± 1%	252
$\sum \pi \pi$	$0.9 \pm 0.1\%$	152
$\Lambda\gamma$	$0.8\pm0.2\%$	351

Λ(1600) P₀₁

 $I(J^P) = O(\frac{1}{2}^+)$

Mass m=1560 to 1700 (\approx 1600) MeV Full width $\Gamma=50$ to 250 (\approx 150) MeV $p_{\mathrm{beam}}=0.58~\mathrm{GeV}/c$ $4\pi x^2=41.6~\mathrm{mb}$

A(1600) DECAY MODES	Fraction (Γ_I/Γ)	ρ (MeV/c)
NK	15-30 %	343
$\Sigma \pi$	10-60 %	336

Λ(1670) S₀₁

 $I(J^P) = 0(\frac{1}{2}^-)$

Mass m=1660 to 1680 (≈ 1670) MeV Full width $\Gamma=25$ to 50 (≈ 35) MeV $p_{\rm beam}=0.74~{\rm GeV}/c$ $4\pi x^2=28.5~{\rm mb}$

A(1670) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
NK	15-25 %	414
$\Sigma \pi$	2060 %	393
$\Lambda\eta$	15-35 %	64

Λ(1690) D₀₃

$$I(J^P) = 0(\frac{3}{2}^-)$$

Mass m=1685 to $1695~(\approx 1690)$ MeV Full width $\Gamma=50$ to $70~(\approx 60)$ MeV $p_{\rm beam}=0.78~{\rm GeV}/c$ $4\pi\lambda^2=26.1~{\rm mb}$

A(1690) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
NK	20-30 %	433
$\Sigma \pi$	20-40 %	409
$\Lambda \pi \pi$	~ 25 %	415
$\Sigma \pi \pi$	~ 20 %	350

Λ(1800) S₀₁

$$I(J^P) = 0(\frac{1}{2}^-)$$

Mass m=1720 to 1850 (\approx 1800) MeV Full width $\Gamma=200$ to 400 (\approx 300) MeV $p_{\rm beam}=1.01~{\rm GeV}/c$ $4\pi \chi^2=17.5~{\rm mb}$

A(1800) DECAY MODES	Fraction (Γ_j/Γ)	p (MeV/c)
NK	25-40 %	528
$\Sigma \pi$	seen	493
$\Sigma(1385)\pi$	seen	345
N K* (892)	seen	†

Λ(1810) P₀₁

$$I(J^P) = 0(\frac{1}{2}^+)$$

Mass m=1750 to 1850 (\approx 1810) MeV Full width $\Gamma=50$ to 250 (\approx 150) MeV $\rho_{\rm beam}=1.04~{\rm GeV}/c \qquad 4\pi \chi^2=17.0~{\rm mb}$

A(1810) DECAY MODES	Fraction (Γ_j/Γ)	p (MeV/c)
NK	20-50 %	537
$\Sigma \pi$	10-40 %	501
$\Sigma(1385)\pi$ $N\overline{K}^*(892)$	seen	356
$N\overline{K}^*(892)$	30-60 %	†

Λ(1820) F₀₅

$$I(J^P) = O(\frac{5}{2}^+)$$

Mass m= 1815 to 1825 (\approx 1820) MeV Full width $\Gamma=$ 70 to 90 (\approx 80) MeV $p_{\rm beam}=1.06~{\rm GeV}/c \qquad 4\pi {\it X}^2=16.5~{\rm mb}$

A(1820) DECAY MODES	Fraction (Γ_j/Γ)	p (MeV/c)
NK	55-65 %	545
$\Sigma \pi$	8-14 %	508
$\Sigma(1385)\pi$	5-10 %	362

Λ(1830) D₀₅

$$I(J^P)=0(\tfrac{5}{2}^-)$$

Mass m=1810 to 1830 (≈ 1830) MeV Full width $\Gamma=60$ to 110 (≈ 95) MeV $p_{\rm beam}=1.08~{\rm GeV}/c$ $4\pi {\rm X}^2=16.0~{\rm mb}$

A(1830) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
NK	3-10 %	553
$\Sigma \pi$	35-75 %	515
$\Sigma(1385)\pi$	>15 %	371

Λ(1890) P₀₃

$$I(J^P) = O(\frac{3}{2}^+)$$

Mass m=1850 to 1910 (≈ 1890) MeV Full width $\Gamma=60$ to 200 (≈ 100) MeV $p_{\rm beam}=1.21~{\rm GeV}/c$ $4\pi\lambda^2=13.6~{\rm mb}$

A(1890) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
NK	20-35 %	599
$\Sigma \pi$	3-10 %	559
$\Sigma(1385)\pi$ $N\overline{K}^*(892)$	seen	420
N K*(892)	seen	233

Λ(2100) G₀₇

$$I(J^P) = 0(\frac{7}{2}^-)$$

Mass m=2090 to 2110 (\approx 2100) MeV Full width $\Gamma=100$ to 250 (\approx 200) MeV $p_{\mathrm{beam}}=1.68~\mathrm{GeV}/c$ $4\pi \chi^2=8.68~\mathrm{mb}$

A(2100) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
NK	25-35 %	751
$\Sigma \pi$	\sim 5 %	704
$\Lambda\eta$	<3 %	617
ΞK	<3 %	483
$\Lambda \omega$	<8 %	443
N K̄*(892)	10-20 %	514

Λ(2110) F₀₅

$$I(J^P) = O(\frac{5}{5}^+)$$

Mass m=2090 to 2140 (\approx 2110) MeV Full width $\Gamma=150$ to 250 (\approx 200) MeV $p_{\rm beam}=1.70~{\rm GeV}/c$ $4\pi \chi^2=8.53~{\rm mb}$

A(2110) DECAY MODES	Fraction (Γ_i/Γ)	ρ (MeV/ c)
NK	5-25 %	757
$\Sigma \pi$	10-40 %	711
$\Lambda \omega$	seen	455
$\Sigma(1385)\pi$	seen	589
$\Sigma(1385)\pi$ N $K^*(892)$	10-60 %	524

Λ(2350) H₀₉

$$I(J^P) = 0(\frac{9}{2}^+)$$

Mass m= 2340 to 2370 (\approx 2350) MeV Full width $\Gamma=$ 100 to 250 (\approx 150) MeV $p_{\rm beam}=$ 2.29 GeV/c $4\pi\lambda^2=$ 5.85 mb

A(2350) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
NK	~ 12 %	915
$\Sigma \pi$	~ 10 %	867

Σ BARYONS (S=-1, I=1)

 $\Sigma^+ = uus$, $\Sigma^0 = uds$, $\Sigma^- = dds$



$$I(J^P) = 1(\frac{1}{2}^+)$$

Mass $m=1189.37\pm0.07~{\rm MeV}~{\rm (S}=2.2)$ Mean life $\tau=(0.799\pm0.004)\times10^{-10}~{\rm s}$ $c\tau=2.396~{\rm cm}$

Magnetic moment $\mu=$ 2.458 \pm 0.010 μ_N (S = 2.1) $\Gamma(\Sigma^+ \rightarrow n \ell^+ \nu)/\Gamma(\Sigma^- \rightarrow n \ell^- \overline{\nu})$ < 0.043

Decay parameters

$$\begin{array}{lll} \rho\pi^0 & \alpha_0 = -0.980 ^{+0.017}_{-0.015} \\ \text{"} & \phi_0 = (36 \pm 34)^\circ \\ \text{"} & \gamma_0 = 0.16 \, [\text{g}] \\ \text{"} & \Delta_0 = (187 \pm 6)^\circ \, [\text{g}] \\ n\pi^+ & \alpha_+ = 0.068 \pm 0.013 \\ \text{"} & \phi_+ = (167 \pm 20)^\circ \, (\text{S} = 1.1) \\ \text{"} & \gamma_+ = -0.97 \, [\text{g}] \\ \text{"} & \Delta_+ = (-73^{+133}_{-110})^\circ \, [\text{g}] \\ \rho\gamma & \alpha_\gamma = -0.76 \pm 0.08 \end{array}$$

Σ^+ DECAY MODES		Fraction (F	_[/Γ)	Confidence level	<i>p</i> (MeV/ <i>c</i>)
$p\pi^0$		(51.57±	0.30) %		189
$n\pi^+$		(48.31±	0.30) %		185
$p\gamma$		(1.23±	$0.05) \times 10$	₎ –3	225
$n\pi^+\gamma$	[h]	(4.5 ±	0.5) × 10) ⁻⁴	185
$\Lambda e^+ u_e$		(2.0 ±	0.5) × 10	₎ –5	71
	$= \Delta Q (SQ)$ 1 weak neuti				
$ne^+\nu_e$	5Q	< 5	× 10	₀ -6 90%	224
$n\mu^+ u_\mu$	SQ	< 3.0	× 10	o ⁻⁵ 90%	202
pe+e-	S 1	< 7	× 10)-6	225



$$I(J^P)=1(\tfrac{1}{2}^+)$$

 J^P not measured; assumed to be the same as for the Σ^+ and Σ^- . Mass $m=1192.55\pm0.08$ MeV (S = 1.2) $m_{\Sigma^-}-m_{\Sigma^0}=4.88\pm0.08$ MeV (S = 1.2) $m_{\Sigma^0}-m_{\Lambda}=76.87\pm0.08$ MeV (S = 1.2) Mean life $\tau=(7.4\pm0.7)\times10^{-20}$ s $c\tau=2.22\times10^{-11}$ m

Transition magnetic moment $\left|\mu_{arSigma\Lambda}
ight|=$ 1.61 \pm 0.08 $\mu_{\emph{N}}$

Σ ⁰ DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	<i>р</i> (MeV/ <i>c</i>)
$\Lambda\gamma$	100 %		74
$\Lambda \gamma \gamma$	< 3 %	90%	74
Λe ⁺ e ⁻	[<i>j</i>] 5×10^{-3}		74



$$I(J^P)=1(\tfrac{1}{2}^+)$$

Mass
$$m=1197.436\pm0.033$$
 MeV (S = 1.2) $m_{\varSigma^-}-m_{\varSigma^+}=8.07\pm0.08$ MeV (S = 1.9) $m_{\varSigma^-}-m_{\Lambda}=81.752\pm0.034$ MeV (S = 1.2) Mean life $\tau=(1.479\pm0.011)\times10^{-10}$ s (S = 1.3) $c\tau=4.434$ cm Magnetic moment $\mu=-1.160\pm0.025$ μ_N (S = 1.7)

Decay parameters

$$\begin{array}{lll} n\pi^- & \alpha_- = -0.068 \pm 0.008 \\ " & \phi_- = (10 \pm 15)^\circ \\ " & \gamma_- = 0.98 \ [g] \\ " & \Delta_- = (249 + \frac{12}{120})^\circ \ [g] \\ " & E_2(0)/f_1(0) = 0.97 \pm 0.14 \\ " & D = 0.11 \pm 0.10 \\ \Lambda e^- \overline{\nu}_e & g_{M}/g_A = 0.01 \pm 0.10 \ [e] \\ " & g_{WM}/g_A = 2.4 \pm 1.7 \ [e] \end{array} \right. (S = 1.5)$$

Σ- DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$n\pi^-$	(99.848±0.005) %	193
$n\pi^-\gamma$	[h] (4.6 ± 0.6) $\times 10^{-4}$	193
ne− $\overline{ u}_e$	$(1.017\pm0.034)\times10^{-3}$	230
$n\mu^-\overline{ u}_{\mu}$	$(4.5 \pm 0.4) \times 10^{-4}$	210
$\Lambda e^{-\overline{\nu}_e}$	$(5.73 \pm 0.27) \times 10^{-5}$	79

$\Sigma(1385) P_{13}$

$$I(J^P) = 1(\frac{3}{2}^+)$$

 $\begin{array}{lll} \Sigma(1385)^{+} \text{mass } m = 1382.8 \pm 0.4 \text{ MeV} & (\text{S} = 2.0) \\ \Sigma(1385)^{0} \text{ mass } m = 1383.7 \pm 1.0 \text{ MeV} & (\text{S} = 1.4) \\ \Sigma(1385)^{-} \text{mass } m = 1387.2 \pm 0.5 \text{ MeV} & (\text{S} = 2.2) \\ \Sigma(1385)^{+} \text{full width } \Gamma = 35.8 \pm 0.8 \text{ MeV} \\ \Sigma(1385)^{0} \text{ full width } \Gamma = 36 \pm 5 \text{ MeV} \\ \Sigma(1385)^{-} \text{ full width } \Gamma = 39.4 \pm 2.1 \text{ MeV} & (\text{S} = 1.7) \\ \text{Below } \overline{K} N \text{ threshold} \end{array}$

Σ(1385) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
Λπ	88±2 %	208
$\Sigma \pi$	12±2 %	127

$\Sigma(1660) P_{11}$

$$I(J^P) = 1(\frac{1}{2}^+)$$

Mass m=1630 to 1690 (\approx 1660) MeV Full width Γ = 40 to 200 (\approx 100) MeV $p_{\rm beam}=0.72~{\rm GeV}/c$ $4\pi\lambda^2=29.9~{\rm mb}$

Σ(1660) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
NK	10-30 %	405
$\Lambda\pi$	seen	439
$\Sigma \pi$	seen	385

$\Sigma(1670) D_{13}$

$$I(J^P) = 1(\frac{3}{2}^-)$$

Mass m = 1665 to 1685 (≈ 1670) MeV Full width Γ = 40 to 80 (≈ 60) MeV $\rho_{\rm beam} = 0.74~{\rm GeV}/c$ $4\pi x^2 = 28.5~{\rm mb}$

Σ(1670) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
NK	7–13 %	414
$\Lambda\pi$	5-15 %	447
$\Sigma \pi$	30-60 %	393

Σ (1750) S_{11}

$$I(J^P)=1(\tfrac{1}{2}^-)$$

Mass m=1730 to 1800 (\approx 1750) MeV Full width $\Gamma=60$ to 160 (\approx 90) MeV $\rho_{\rm beam}=0.91~{\rm GeV}/c$ $4\pi {\it X}^2=20.7~{\rm mb}$

Σ(1750) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
NK	10-40 %	486
$\Lambda\pi$	seen	507
$\Sigma \pi$	<8 %	455
$\Sigma \eta$	15-55 %	81

Σ (1775) D_{15}

$$I(J^P) = 1(\frac{5}{2}^-)$$

Mass m=1770 to 1780 (\approx 1775) MeV Full width $\Gamma=105$ to 135 (\approx 120) MeV $p_{\rm beam}=0.96~{\rm GeV}/c$ $4\pi \chi^2=19.0~{\rm mb}$

Σ(1775) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
NK	37-43%	508
$\Lambda\pi$	14-20%	525
$\Sigma \pi$	2-5%	474
$\Sigma(1385)\pi$	8-12%	324
$\Lambda(1520)\pi$	17-23%	198

Σ (1915) F_{15}

$$I(J^P) = 1(\frac{5}{2}^+)$$

Mass m=1900 to 1935 (\approx 1915) MeV Full width $\Gamma=80$ to 160 (\approx 120) MeV $p_{\rm beam}=1.26~{\rm GeV}/c$ $4\pi \chi^2=12.8~{\rm mb}$

Σ(1915) DECAY MODES	Fraction (Γ_i/Γ)	ρ (MeV/c)
NK	5–15 %	618
$\Lambda \pi$	seen	622
$\Sigma \pi$	seen	577
$\Sigma(1385)\pi$	<5 %	440

Σ (1940) D_{13}

$$I(J^P) = 1(\frac{3}{2}^-)$$

Mass m=1900 to 1950 (\approx 1940) MeV Full width $\Gamma=150$ to 300 (\approx 220) MeV $p_{\mathrm{beam}}=1.32~\mathrm{GeV}/c$ $4\pi\lambda^2=12.1~\mathrm{mb}$

Σ(1940) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
NK	<20 %	637
$\Lambda\pi$	seen	639
$\Sigma \pi$	seen	594
$\Sigma(1385)\pi$	seen	460
$\Lambda(1520)\pi$	seen	354
$\Delta(1232)\overline{K}$	seen	410
N K* (892)	seen	320

Σ (2030) F_{17}

$$I(J^P) = 1(\frac{7}{2}^+)$$

Mass m=2025 to 2040 (\approx 2030) MeV Full width $\Gamma=150$ to 200 (\approx 180) MeV $p_{\mathrm{beam}}=1.52~\mathrm{GeV}/c$ $4\pi \chi^2=9.93~\mathrm{mb}$

Σ(2030) DECAY MODES	Fraction (Γ_j/Γ)	p (MeV/c)
NK	17-23 %	702
$\Lambda\pi$	17-23 %	700
$\Sigma \pi$	5-10 %	657
ΞK	<2 %	412
$\Sigma(1385)\pi$	5-15 %	529
$\Lambda(1520)\pi$	10-20 %	430
$\Delta(1232)\overline{K}$	10-20 %	498
N K* (892)	<5 %	438

Σ(2250)

$$I(J^P) = 1(??)$$

Mass m=2210 to 2280 (≈ 2250) MeV Full width $\Gamma=60$ to 150 (≈ 100) MeV $\rho_{\rm beam}=2.04~{\rm GeV}/c$ $4\pi x^2=6.76~{\rm mb}$

Σ(2250) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
NK	<10 %	851
$\Lambda\pi$	seen	842
$\Sigma \pi$	seen	803

$$\Xi$$
 BARYONS
($S=-2$, $I=1/2$)
 $\Xi^0 = uss$, $\Xi^- = dss$

Ξ°

$$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$$

P is not yet measured; + is the quark model prediction.

Mass
$$m=1314.9\pm0.6$$
 MeV $m_{\Xi^-}-m_{\Xi^0}=6.4\pm0.6$ MeV Mean life $\tau=(2.90\pm0.09)\times10^{-10}$ s $c au=8.71$ cm

Magnetic moment $\mu = -1.250 \pm 0.014~\mu_{N}$

Decay parameters

≡ ⁰ DECAY MODES		Fraction (Γ_i	/Γ) Confide	nce level	(MeV/c)
$\Lambda \pi^0$		(99.54±0	.05) %		135
$\Lambda\gamma$		(1.06±0	$.16) \times 10^{-3}$		184
$\Sigma^{\dot{0}} \gamma$		(3.5 ±0	$.4) \times 10^{-3}$		117
$\Sigma^+ e^- \overline{\nu}_e$		< 1.1	$\times 10^{-3}$	90%	120
$\Sigma^+ \mu^- \overline{ u}_{\mu}$		< 1.1	× 10 ⁻³	90%	64
$\Delta S = \Delta Q$ (SQ) violating modes or $\Delta S = 2$ forbidden (S2) modes					
$\Sigma^- e^+ \nu_e$	5Q	< 9	× 10 ⁻⁴	90%	112
$\Sigma^- \mu^+ \nu_{\mu}$	SQ	< 9	\times 10 ⁻⁴	90%	49
$p\pi^-$	52	< 4	\times 10 ⁻⁵	90%	299
$\rho e^- \overline{\nu}_e$	52	< 1.3	$\times 10^{-3}$		323
$p\mu^-\overline{\nu}_{\mu}$	<i>S2</i>	< 1.3	$\times 10^{-3}$		309



$$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$$

P is not yet measured; + is the quark model prediction.

Mass
$$m=1321.32\pm0.13$$
 MeV Mean life $au=(1.639\pm0.015)\times10^{-10}$ s $c au=4.91$ cm Magnetic moment $\mu=-0.6507\pm0.0025~\mu_N$

Decay parameters

$$\begin{array}{lll} \Lambda \pi^- & \alpha = -0.456 \pm 0.014 & (\mathrm{S} = 1.8) \\ \text{"} & \phi = (4 \pm 4)^\circ \\ \text{"} & \gamma = 0.89 \, [\mathrm{g}] \\ \text{"} & \Delta = (188 \pm 8)^\circ \, [\mathrm{g}] \\ \Lambda e^- \overline{\nu}_e & g_A/g_V = -0.25 \pm 0.05 \, [e] \end{array}$$

=- DECAY MODES		Fraction (Γ_i /	Γ) Confidenc	e level	<i>р</i> (MeV/c)
Λπ-		(99.887±0	.035) %		139
$\Sigma^-\gamma$		(1.27 ±0	$.23) \times 10^{-4}$		118
$\Lambda e^- \overline{\nu}_e$			$.31) \times 10^{-4}$		190
$\Lambda\mu^-\overline{ u}_\mu$		$(3.5 \begin{array}{c} +3 \\ -2 \end{array})$	$^{.5}_{.2}$) × 10 ⁻⁴		163
$\Sigma^0 e^- \overline{\nu}_e$		(8.7 ±1	$.7) \times 10^{-5}$		122
$\Sigma^0 \mu^- \overline{\nu}_{\mu}$		< 8	\times 10 ⁻⁴	90%	70
$\equiv^0 e^- \overline{\nu}_e$		< 2.3	× 10 ⁻³	90%	6
	$\Delta S = 2$ forbi	dden (<i>52</i>) r	nodes		
$n\pi^-$	52	< 1.9	\times 10 ⁻⁵	90%	303
ne ⁻ ⊽ _e	52	< 3.2	\times 10 ⁻³	90%	327
$n\mu^-\overline{\nu}_{\mu}$	52	< 1.5	%	90%	314
$p\pi^-\pi^-$	52	< 4	× 10 ⁻⁴	90%	223
$p\pi^-e^-\overline{\nu}_e$	52	< 4	× 10 ⁻⁴	90%	304
$p\pi^-\mu^-\overline{ u}_\mu$	52	< 4	\times 10 ⁻⁴	90%	250
$p\mu^-\mu^-$	L	< 4	\times 10 ⁻⁴	90%	272

Ξ (1530) P_{13}

$$I(J^P) = \frac{1}{2}(\frac{3}{2}^+)$$

 Ξ (1530)⁰ mass $m=1531.80\pm0.32$ MeV (S = 1.3) Ξ (1530)⁻ mass $m=1535.0\pm0.6$ MeV Ξ (1530)⁰ full width $\Gamma=9.1\pm0.5$ MeV Ξ (1530)⁻ full width $\Gamma=9.9_{-1.9}^{+1.7}$ MeV

≡(1530) DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	р (MeV/c)
$\Xi \pi$	100 %		152
Ξγ	<4 %	90%	200

=(1690)

$$I(J^P) = \frac{1}{2}(??)$$

Mass $m=1690\pm 10$ MeV $^{[i]}$ Full width $\Gamma~<~50$ MeV

≡(1690) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$\Lambda \overline{K}$	seen	240
$\Sigma \overline{K}$	seen	51
$\equiv^-\pi^+\pi^-$	possibly seen	214

Ξ(1820) D₁₃

$$I(J^P) = \frac{1}{2}(\frac{3}{2}^-)$$

Mass $m=1823\pm 5$ MeV $^{[i]}$ Full width $\Gamma=24^{+15}_{-10}$ MeV $^{[i]}$

≡(1820) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
ΛK	large	400
$\Sigma \overline{K}$	small	320
$\Xi \pi$	small	413
$\Xi(1530)\pi$	small	234

Ξ(1950)

$$I(J^P) = \frac{1}{2}(?^?)$$

Mass $m=1950\pm15$ MeV $^{[i]}$ Full width $\Gamma=60\pm20$ MeV $^{[i]}$

£(1950) DECAY MODES	Fraction (Γ_i/Γ)	ρ (MeV/c)
$\Lambda \overline{K}$	seen	522
$\Sigma \overline{K}$	possibly seen	460
$\equiv \pi$	seen	518

Ξ(2030)

$$I(J^P) = \frac{1}{2} (\geq \frac{5}{2})$$

Mass $m = 2025 \pm 5 \text{ MeV}^{[i]}$ Full width $\Gamma = 20^{+15}_{-5} \text{ MeV}^{[i]}$

€(2030) DECAY MODES	Fraction (Γ_j/Γ)	p (MeV/c)
$\Lambda \overline{K}$	~ 20 %	589
$\Sigma \overline{K}$	\sim 80 %	533
$\Xi \pi$	small	573
$\Xi(1530)\pi$	small	421
$\Lambda \overline{K} \pi$	small	501
$\Sigma \overline{K} \pi$	small	430

Ω BARYONS (S=-3, l=0)

$$\Omega^-=sss$$

Ω-

$$I(J^P) = O(\frac{3}{2}^+)$$

 $J^{\mbox{\it P}}$ is not yet measured; $\frac{3}{2}^+$ is the quark model prediction.

Mass $m = 1672.45 \pm 0.29 \; \text{MeV}$

Mean life $\tau = (0.822\,\pm\,0.012)\times10^{-10}$ s

 $c\tau = 2.46 \text{ cm}$

Magnetic moment $\mu = -2.02 \pm 0.05~\mu_{ extbf{N}}$

Decay parameters

$$\Lambda K^{-}$$
 $\alpha = -0.026 \pm 0.026$
 $\Xi^{0} \pi^{-}$
 $\alpha = 0.09 \pm 0.14$
 $\Xi^{-} \pi^{0}$
 $\alpha = 0.05 \pm 0.21$

Ω^- DECAY MODES	Fra	action (Γ_i/Γ)	Confidence level	<i>p</i> (MeV/ <i>c</i>)
AK-	((67.8±0.7) %		211
$\equiv^0 \pi^-$	((23.6±0.7) %		294
$=-\pi^0$	((8.6±0.4)%		290
$\Xi^-\pi^+\pi^-$	($(4.3 + 3.4) \times 10$	-4	190
Ξ (1530) $^{0}\pi^{-}$	($(6.4^{+5.1}_{-2.0}) \times 10$	-4	17
$\Xi^0 e^- \overline{\nu}_e$	((5.6±2.8) × 10	-3	319
$\Xi^-\gamma$	<	4.6 × 10	-4 90%	314
	$\Delta S = 2$ forbidde	en (<i>52</i>) modes	3	
$\Lambda\pi^-$	52 <	1.9 × 10	-4 90%	449

$\Omega(2250)^{-}$

$$I(J^P) = 0(??)$$

Mass $m=2252\pm 9$ MeV Full width $\Gamma=55\pm 18$ MeV

Ω(2250) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
Ξ-π+K-	seen	531
Ξ(1530) ⁰ K [−]	seen	437

CHARMED BARYONS (C=+1)

$$\begin{array}{lll} \Lambda_c^+ = u\,d\,c, & \Sigma_c^{++} = u\,u\,c, & \Sigma_c^+ = u\,d\,c, & \Sigma_c^0 = d\,d\,c, \\ \Xi_c^+ = u\,s\,c, & \Xi_c^0 = d\,s\,c, & \Omega_c^0 = s\,s\,c \end{array}$$

 Λ_c^+

 Λ_c^+ DECAY MODES

$$I(J^P) = 0(\tfrac{1}{2}^+)$$

Scale factor/

Confidence level (MeV/c)

J not confirmed; $\frac{1}{2}$ is the quark model prediction.

Mass $m = 2284.9 \pm 0.6 \; \text{MeV}$

Mean life $au = (0.206 \pm 0.012) \times 10^{-12}$ s $c au = 61.8~\mu\mathrm{m}$

Decay asymmetry parameters

$$\Lambda \pi^{+}$$
 $\alpha = -0.98 \pm 0.19$
 $\Sigma^{+} \pi^{0}$ $\alpha = -0.45 \pm 0.32$
 $\Lambda \ell^{+} \nu_{\ell}$ $\alpha = -0.82^{+0.11}_{-0.07}$

Hadronic modes with a p and one \overline{K}			
$ ho \overline{K}{}^0$	(:	2.2 ± 0.4) %	872
pK-π+	(-	4.4 ± 0.6) %	822
$p\overline{K}^*(892)^0$	[k] (1.6 ± 0.4) %	681
$\Delta(1232)^{++}K^{-}$	($7 \pm 4) \times 10^{-3}$	709
$\Lambda(1520)\pi^+$	[k] ($4.0 \begin{array}{c} + & 2.0 \\ - & 1.7 \end{array}) \times 10^{-3}$	626
$ hoK^-\pi^+$ nonresonant	(2.5 + 0.5) %	822
$ ho \overline{K}{}^0 \eta$	(1.10 ± 0.29) %	567

Fraction (Γ_i/Γ)

$p\overline{K}^0\pi^+\pi^-$		(2.1 ± 0.8) %		753
$pK^-\pi^+\pi^0$		seen	2	758
$pK^*(892)^-\pi^+$	[k]		-3	579
$p(K^-\pi^+)_{\text{nonresonant}}\pi$.0	(3.2 ± 0.7) %		758
$\Delta(1232)\overline{K}^*(892)$		seen		416
$0K^{-}\pi^{+}\pi^{+}\pi^{-}$		$(10 \pm 7) \times 10^{-2}$		670
$pK^{-}\pi^{+}\pi^{0}\pi^{0}$		(7.0 ± 3.5) × 10		676
$\rho K^- \pi^+ \pi^0 \pi^0 \pi^0$		(4.4 ± 2.8) × 10		573
Hadronic $_{o\pi^{+}\pi^{-}}$	modes with	a p and zero or two		926
	[k]	$(3.0 \pm 1.6) \times 10^{-6}$ $(2.4 \pm 1.6) \times 10^{-6}$		621
$p f_0(980)$ $p \pi^+ \pi^+ \pi^- \pi^-$	[*]	$(2.4 \pm 1.6) \times 10$ $(1.6 \pm 1.0) \times 10^{-1}$		851
pK+K-		$(2.0 \pm 0.6) \times 10^{-1}$		615
$p\phi$	[k]	$(2.0 \pm 0.8) \times 10^{-1}$		589
• •		es with a hyperon		
$\Lambda \pi^+$	aarome moa	(7.9 ± 1.8) × 10	-3	863
$1\pi^{+}\pi^{0}$		(3.2 ± 0.9)%		843
Λho^0		< 4 %	CL=95%	638
$1\pi^{+}\pi^{+}\pi^{-}$		$(2.9 \pm 0.6)\%$		806
$\Lambda \pi^+ \eta$		(1.5 \pm 0.4) %		690
$\Sigma(1385)^+\eta$	[k]	(7.5 ± 2.4) \times 10	-3	569
1 K ⁺ \overline{K}^0		(5.3 \pm 1.4) \times 10	-3	441
$\Sigma^0 \pi^+$		(8.8 ± 2.0) \times 10^{-2}	-3	824
$\Sigma^{+}\pi^{0}$		(8.8 ± 2.2) \times 10^{-2}		826
$\Sigma^+ \eta$		(4.8 ± 1.7) \times 10	-3	712
$\Sigma^{+}\pi^{+}\pi^{-}$		(3.0 \pm 0.6) %		803
$\Sigma^+ ho^0$		< 1.2 %	CL=95%	578
$\Sigma^-\pi^+\pi^+$		(1.6 \pm 0.6) %		798
$\Sigma^{0}\pi^{+}\pi^{0}$		(1.6 \pm 0.6) %		802
$\Sigma^{0} \pi^{+} \pi^{+} \pi^{-}$		(9.2 \pm 3.4) \times 10	-3	762
$\Sigma^{+} \pi^{+} \pi^{-} \pi^{0}$				766
$\Sigma^+\omega$	[k]			568
$\Sigma^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}$		$(2.6 + 3.5 \times 10^{-1}) \times 10^{-1}$	-3	707
$\Sigma^+ K^+ K^-$		(3.1 ± 0.8) × 10		346
$\Sigma^+ \phi$	[k]	(3.0 ± 1.3) × 10		292
$\Sigma^+ K^+ \pi^-$. ,	$(5.7 + 5.3) \times 10^{-1}$		668
=0 K+		(3.4 ± 0.9) \times 10^{-1}	- o	652
$= K^{+}\pi^{+}$		(4.3 ± 1.1) × 10	-ა _3	564
$\Xi(1530)^0 K^+$	[k]	$(2.3 \pm 0.7) \times 10^{-3}$	-3	471
$1\ell^+ u_\ell$	-	conic modes		
	[/]	$(2.3 \pm 0.5)\%$		_
e+ anything		(4.5 ± 1.7) %		_
e ⁺ anything		(1.8 ± 0.9) %		_
1e ⁺ anything		(1.6 ± 0.6) %		-
$1\mu^+$ anything		(1.5 \pm 0.9) %		_
anything	Inclusi	ve modes (50 ±16)%		_
p anything (no Λ)		(12 ±19)%		_
n anything		(12 ±19) % (50 ±16) %		_
				_
n anything (no Λ) Λanything			S=1.4	_
Σ^\pm anything	[m]	,	3=1.4	_
			s or	
$\Delta C = 1$ weak neutral current (C1) modes, or Lepton number (L) violating modes				
$2u^{+}u^{-}$	C1	< 3.4 × 10	-4 CL=90%	936
$\Sigma^-\mu^+\mu^+$	L	< 7.0 × 10	-4 CL=90%	811

$\Lambda_c(2593)^+$

$$I(J^P) = 0(\frac{1}{2}^-)$$

The spin-parity follows from the fact that $\Sigma_c(2455)\pi$ decays, with little available phase space, dominate.

Mass
$$m=2593.6\pm 1.0$$
 MeV (S = 1.2)
$$m-m_{\Lambda_c^+}=308.6\pm 0.8$$
 MeV (S = 1.3) Full width $\Gamma=3.9^{+2.4}_{-1.6}$ MeV

 $\Lambda_c^+\,\pi\,\pi$ and $\Sigma_c(2455)\pi$ — the latter just barely — are the only strong decays allowed to an excited Λ_c^+ having this mass; and the $\Lambda_c^+\,\pi^+\,\pi^-$ mode seems to be largely via $\Sigma_c^{\,++}\,\pi^-$ or $\Sigma_c^{\,0}\,\pi^+$.

Λ _C (2593) ⁺ DECAY MODES	Fraction (Γ_j/Γ)	p (MeV/c)
$\Lambda_c^+ \pi^+ \pi^-$	seen	124
$\Sigma_c (2455)^{++} \pi^- \Sigma_c (2455)^0 \pi^+$	large	17
Σ_c (2455) 0 π^+	large	23
$\Lambda_c^{+}\pi^{+}\pi^{-}$ 3-body	small	124
$\Lambda_c^+ \pi^0$ $\Lambda_c^+ \gamma$	not seen	261
$\Lambda_c^+ \gamma$	not seen	290

$\Lambda_c(2625)^+$

$$I(J^P) = 0(??)$$

 J^P is expected to be $3/2^-$. Mass $m=2626.4\pm0.9~{\rm MeV}~{\rm (S=1.3)}$ $m-m_{\Lambda_c^+}=341.5\pm0.8~{\rm MeV}~{\rm (S=1.9)}$

Full width Γ < 1.9 MeV, CL = 90%

 Λ_c^+ π_{π} and $\Sigma(2455)\pi$ are the only strong decays allowed to an excited Λ_c^+ having this mass.

A _C (2625)+ DECAY MODES	Fraction (Γ_i/Γ)	ρ (MeV/c)
$\Lambda_{C}^{+}\pi^{+}\pi^{-}$	seen	184
Σ_c (2455) ⁺⁺ π^- Σ_c (2455) ⁰ π^+	small	100
	small	101
$\Lambda_c^+ \pi^+ \pi^-$ 3-body	large	184
$\Lambda_c^+ \pi^0$	not seen	293
$\Lambda_c^+ \gamma$	not seen	319

$\Sigma_c(2455)$

$$I(J^P) = 1(\frac{1}{2}^+)$$

 J^P not confirmed; $\frac{1}{2}$ is the quark model prediction.

$$\begin{split} & \Sigma_c(2455)^{++} \text{mass } m = 2452.9 \pm 0.6 \text{ MeV} \\ & \Sigma_c(2455)^{+} \text{ mass } m = 2453.5 \pm 0.9 \text{ MeV} \\ & \Sigma_c(2455)^{0} \text{ mass } m = 2452.1 \pm 0.7 \text{ MeV} \\ & m_{\Sigma_c^{++}} - m_{\Lambda_c^{+}} = 167.95 \pm 0.25 \text{ MeV} \\ & m_{\Sigma_c^{+}} - m_{\Lambda_c^{+}} = 168.5 \pm 0.7 \text{ MeV} \quad \text{(S} = 1.1) \\ & m_{\Sigma_c^{-}} - m_{\Lambda_c^{+}} = 167.2 \pm 0.4 \text{ MeV} \quad \text{(S} = 1.1) \\ & m_{\Sigma_c^{+}} - m_{\Sigma_c^{0}} = 0.79 \pm 0.33 \text{ MeV} \quad \text{(S} = 1.2) \\ & m_{\Sigma_c^{+}} - m_{\Sigma_c^{0}} = 1.4 \pm 0.6 \text{ MeV} \end{split}$$

 $\Lambda_{c}^{+}\pi$ is the only strong decay allowed to a Σ_{c} having this mass.

Σ_{c} (2455) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$\Lambda_c^+\pi$	≈ 100 %	90



$$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$$

 $I(J^P)$ not confirmed; $\frac{1}{2}(\frac{1}{2}^+)$ is the quark model prediction.

Mass
$$m = 2465.6 \pm 1.4$$
 MeV
Mean life $\tau = (0.35^{+0.07}_{-0.04}) \times 10^{-12}$ s $c\tau = 106~\mu\mathrm{m}$

Ξ_c^+ DECAY MODES Fraction (Γ_i/Γ) ρ (1)	∕leV/c)
$\Lambda K^- \pi^+ \pi^+$ seen	784
$\Lambda \overline{K}^*(892)^0 \pi^+$ not seen	601
$\Sigma(1385)^+K^-\pi^+$ not seen	676
$\Sigma^{+}\dot{\mathcal{K}}^{-}\pi^{+}$ seen	808
$\Sigma^+\overline{K}^*(892)^0$ seen	653
$\Sigma^0 K^- \pi^+ \pi^+$ seen	733
$\equiv^0 \pi^+$ seen	875
$\Xi^-\pi^+\pi^+$ seen	850
$\Xi(1530)^0\pi^+$ not seen	748
$\equiv^0 \pi^+ \pi^0$ seen	854
$\equiv^0 \pi^+ \pi^+ \pi^-$ seen	817
$\equiv^0 e^+ u_e$ seen	882

=0

$I(J^P)=\tfrac{1}{2}(\tfrac{1}{2}^+)$

 $I(J^P)$ not confirmed; $\frac{1}{2}(\frac{1}{2}^+)$ is the quark model prediction.

Mass
$$m=2470.3\pm1.8$$
 MeV (S = 1.3) $m_{\Xi_c^0}-m_{\Xi_c^+}=4.7\pm2.1$ MeV (S = 1.2) Mean life $\tau=(0.098^{+0.023}_{-0.015})\times10^{-12}$ s $c\tau=29~\mu\mathrm{m}$

\equiv_c^0 DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$\Lambda \overline{K}^0$	seen	864
$\equiv -\pi^+$	seen	875
$\Xi^{-}\pi^{+}\pi^{+}\pi^{-}$	seen	816
pK [−] K̄*(892) ⁰	seen	406
Ω^-K^+	seen	522
$\Xi^- e^+ \nu_e$	seen	882
$\Xi^-\ell^+$ anything	seen	-

$\Xi_c(2645)$

$$I(J^P) = ?(??)$$

Mass
$$m=2643.8\pm1.8$$
 MeV $m_{\Xi_c(2645)^0}-m_{\Xi_c^+}=178.2\pm1.1$ MeV Full width $\Gamma<5.5$ MeV, CL $=90\%$

 $\Xi_C\pi$ is the only strong decay allowed to a Ξ_C resonance having this mass.

≡ _C (2645) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$\equiv_c^+ \pi^-$	seen	107



$$I(J^P) = 0(\frac{1}{2}^+)$$

 $I(J^P)$ not confirmed; $O(rac{1}{2}^+)$ is the quark model prediction.

Mass
$$m=2704\pm 4$$
 MeV (S = 1.8)
Mean life $\tau=(0.064\pm 0.020)\times 10^{-12}$ s $c\tau=19~\mu{\rm m}$

Ω_c^0 DECAY MODES	Fraction (Γ_i/Γ)	ρ (MeV/c)
$\Sigma^+ K^- K^- \pi^+$	seen	697
$\Xi^{-}K^{-}\pi^{+}\pi^{+}$	seen	838
$\Omega^-\pi^+$	seen	827
$\Omega^-\pi^-\pi^+\pi^+$	seen	759

BOTTOM (BEAUTY) BARYONS (B=-1)

$$\Lambda_b^0 = u \, d \, b, \, \Xi_b^0 = u \, s \, b, \, \Xi_b^- = d \, s \, b$$



$$I(J^P) = 0(\frac{1}{2}^+)$$

$$I(J^P)$$
 not yet measured; $0(\frac{1}{2}^+)$ is the quark model prediction. Mass $m=5641\pm50$ MeV Mean life $\tau=(1.14\pm0.08)\times10^{-12}$ s $c\tau=342~\mu{\rm m}$

These branching fractions are actually an average over weakly decaying b-b-b-a-y-o-s weighted by their production rates in Z decay (or high-energy $p\overline{p}$), branching ratios, and detection efficiencies. They scale with the LEP Λ_b production fraction $B(b\to\Lambda_b)$ and are evaluated for our value $B(b\to\Lambda_b)=(13.2\pm4.1)\%.$

The branching fractions $\mathrm{B}(\Lambda_b^0\to\Lambda\ell^-\overline{\nu}_\ell$ anything) and $\mathrm{B}(\Lambda_b^0\to\Lambda_c^+\ell^-\overline{\nu}_\ell$ anything) are not pure measurements because the underlying measured products of these with $\mathrm{B}(b\to\Lambda_b)$ were used to determine $\mathrm{B}(b\to\Lambda_b)$, as described in the note "Production and Decay of b-Flavored Hadrons."

AD DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$J/\psi(1S)\Lambda$	(1.4 ± 0.9) %	1756
$pD^0\pi^-$	seen	2383
$\Lambda_{c}^{+} \pi^{+} \pi^{-} \pi^{-}$	seen	2336
$p\mu^-\overline{\nu}$ anything	(3.7 ± 1.7) %	-
$\Lambda \ell^- \overline{\nu}_\ell$ anything	[n] (2.5 ± 0.5) %	
$\Lambda_c^+ \ell^- \overline{\nu}_\ell$ anything	[n] (10.0 ± 3.0) %	
$\Lambda/\overline{\Lambda}$ anything	$(17 \begin{array}{cc} +11 \\ -8 \end{array}) \%$	_

NOTES

This Summary Table only includes established baryons. The Particle Listings include evidence for other baryons. The masses, widths, and branching fractions for the resonances in this Table are Breit-Wigner parameters. The Particle Listings also give, where available, pole parameters. See, in particular, the *Note on N and \(\Delta \) Resonances.*

For most of the resonances, the parameters come from various partial-wave analyses of more or less the same sets of data, and it is not appropriate to treat the results of the analyses as independent or to average them together. Furthermore, the systematic errors on the results are not well understood. Thus, we usually only give ranges for the parameters. We then also give a best guess for the mass (as part of the name of the resonance) and for the width. The Note on N and Δ Resonances and the Note on Λ and Σ Resonances in the Particle Listings review the partial-wave analyses.

When a quantity has "(S = ...)" to its right, the error on the quantity has been enlarged by the "scale factor" S, defined as S = $\sqrt{\chi^2/(N-1)}$, where N is the number of measurements used in calculating the quantity. We do this when S > 1, which often indicates that the measurements are inconsistent. When S > 1.25, we also show in the Particle Listings an ideogram of the measurements. For more about S, see the Introduction.

A decay momentum p is given for each decay mode. For a 2-body decay, p is the momentum of each decay product in the rest frame of the decaying particle. For a 3-or-more-body decay, p is the largest momentum any of the products can have in this frame. For any resonance, the *nominal* mass is used in calculating p. A dagger ("†") in this column indicates that the mode is forbidden when the nominal masses of resonances are used, but is in fact allowed due to the nonzero widths of the resonances.

- [a] The masses of the p and n are most precisely known in u (unified atomic mass units). The conversion factor to MeV, 1 u = 931.49432 \pm 0.00028 MeV, is less well known than are the masses in u.
- [b] The limit is from neutrality-of-matter experiments; it assumes $q_n=q_p+q_e$. See also the charge of the neutron.
- [c] The first limit is geochemical and independent of decay mode. The second entry, a range of limits, assumes the dominant decay modes are among those investigated. For antiprotons the best limit, inferred from the observation of cosmic ray \bar{p} 's is $\tau_{\bar{p}} > 10^7$ yr, the cosmic-ray storage time, but this limit depends on a number of assumptions. The best direct observation of stored antiprotons gives $\tau_{\bar{p}}/B(\bar{p} \to e^-\gamma) > 1848$ yr.
- [d] There is some controversy about whether nuclear physics and model dependence complicate the analysis for bound neutrons (from which the best limit comes). The second limit here is from reactor experiments with free neutrons.
- [e] The parameters g_A , g_V , and g_{WM} for semileptonic modes are defined by $\overline{B}_f[\gamma_\lambda(g_V+g_A\gamma_5)+i(g_{WM}/m_{B_i})\;\sigma_{\lambda\nu}\;q^\nu]B_i$, and ϕ_{AV} is defined by $g_A/g_V=|g_A/g_V|e^{i\phi_{AV}}$. See the "Note on Baryon Decay Parameters" in the neutron Particle Listings.
- [f] Time-reversal invariance requires this to be 0° or 180° .
- [g] The decay parameters γ and Δ are calculated from α and ϕ using

$$\gamma = \sqrt{1-lpha^2} \cos \phi$$
 , $an \Delta = -rac{1}{lpha} \, \sqrt{1-lpha^2} \sin \phi$.

See the "Note on Baryon Decay Parameters" in the neutron Particle Listings

- [h] See the Particle Listings for the pion momentum range used in this measurement.
- [i] The error given here is only an educated guess. It is larger than the error on the weighted average of the published values.
- [i] A theoretical value using QED.
- $[\emph{k}]$ This branching fraction includes all the decay modes of the final-state resonance.
- [I] ℓ indicates e or μ mode, not sum over modes.
- [m] The value is for the sum of the charge states of particle/antiparticle states indicated
- [n] Not a pure measurement. See note at head of Λ_b^0 Decay Modes.

MONOPOLES, SUPERSYMMETRY, COMPOSITENESS, etc., SEARCHES FOR

Magnetic Monopole Searches

Isolated candidate events have not been confirmed. Most experiments obtain negative results.

Supersymmetric Particle Searches

Limits are based on the Minimal Supersymmetric Standard Model. Assumptions include: 1) $\widetilde{\chi}_1^0$ (or $\widetilde{\gamma}$) is lightest supersymmetric particle; 2) R-parity is conserved; 3) $m_{\widetilde{I}_L} = m_{\widetilde{I}_R}$, and all scalar quarks (except \widetilde{t}_L and \widetilde{t}_R) are degenerate in mass.

See the Particle Listings for a Note giving details of supersymmetry.

```
\begin{array}{l} \widetilde{\chi}_{i}^{0} - \text{neutralinos (mixtures of } \widetilde{\gamma}, \ \widetilde{Z}^{0}, \text{ and } \widetilde{H}_{1}^{0}) \\ \text{Mass } m_{\widetilde{\gamma}} > 15 \text{ GeV, CL} = 90\% \qquad \qquad [\text{if } m_{\widetilde{f}} = 100 \text{ GeV} \\ \qquad \qquad \qquad \qquad \qquad (\text{from cosmology})] \\ \text{Mass } m_{\widetilde{\chi}_{1}^{0}} > 23 \text{ GeV, CL} = 95\% \qquad [\tan\beta > 3] \\ \text{Mass } m_{\widetilde{\chi}_{2}^{0}} > 52 \text{ GeV, CL} = 95\% \qquad [\tan\beta > 3] \\ \text{Mass } m_{\widetilde{\chi}_{3}^{0}} > 84 \text{ GeV, CL} = 95\% \qquad [\tan\beta > 3] \\ \text{Mass } m_{\widetilde{\chi}_{4}^{0}} > 127 \text{ GeV, CL} = 95\% \qquad [\tan\beta > 3] \\ \end{array}
```

$$\begin{array}{lll} \widetilde{\chi}_{j}^{\pm} & - \text{charginos (mixtures of } \widetilde{W}^{\pm} \text{ and } \widetilde{H}_{j}^{\pm}) \\ & \text{Mass } m_{\widetilde{\chi}_{1}^{\pm}} > \text{ 45 GeV, CL} = 95\% & [\text{all } m_{\widetilde{\chi}_{0}^{0}}] \\ & \text{Mass } m_{\widetilde{\chi}_{2}^{\pm}} > \text{ 99 GeV, CL} = 95\% & [\text{GUT relations assumed}] \end{array}$$

 $\widetilde{\nu}$ — scalar neutrino (sneutrino)

Mass m > 37.1 GeV, CL = 95% [one flavor] Mass m > 41.8 GeV, CL = 95% [three degenerate flavors]

 \tilde{e} — scalar electron (selectron)

$$\begin{array}{lll} \text{Mass } m > \ 65 \text{ GeV, CL} = 95\% & & [\text{if } m_{\widetilde{\gamma}} = 0] \\ \text{Mass } m > \ 50 \text{ GeV, CL} = 95\% & & [\text{if } m_{\widetilde{\gamma}} < 5 \text{ GeV}] \\ \text{Mass } m > \ 45 \text{ GeV, CL} = 95\% & & [\text{if } m_{\widetilde{\chi}_1^0} < 41 \text{ GeV}] \end{array}$$

 $\widetilde{\mu}$ — scalar muon (smuon)

Mass
$$m>$$
 45 GeV, CL $=$ 95% [if $m_{\widetilde{\chi}^0_1}<$ 41 GeV]

 $\widetilde{ au}$ — scalar tau (stau)

Mass
$$m>$$
 45 GeV, CL $=$ 95% [if $m_{\widetilde{\chi}_1^0}<$ 38 GeV]

 \tilde{q} — scalar quark (squark)

These limits include the effects of cascade decays, evaluated assuming a fixed value of the parameters μ and $\tan\beta$. The limits are weakly sensitive to these parameters over much of parameter space. Limits assume GUT relations between gaugino masses and the gauge coupling; in particular that for $|\mu|$ not small, $m_{\widetilde{\chi}^0_1} \approx m_{\widetilde{g}}/6$.

$$\begin{array}{ll} \text{Mass } m > \ 176 \ \text{GeV, CL} = 95\% & [\text{any } m_{\widetilde{g}} < 300 \ \text{GeV,} \\ \mu = -250 \ \text{GeV, } \tan\beta = 2] \\ \text{Mass } m > \ 224 \ \text{GeV, CL} = 95\% & [m_{\widetilde{g}} \leq m_{\widetilde{d}}, \\ \mu = -400 \ \text{GeV, } \tan\beta = 4] \end{array}$$

 \widetilde{g} — gluino

There is some controversy about a low-mass window (1 $\lesssim m_{\widetilde{g}} \lesssim$ 4 GeV). Several experiments cast doubt on the existence of this window.

These limits include the effects of cascade decays, evaluated assuming a fixed value of the parameters μ and $\tan\beta$. The limits are weakly sensitive to these parameters over much of parameter space. Limits assume GUT relations between gaugino masses and the gauge coupling; in particular that for $|\mu|$ not small, $m_{\widetilde{\chi}_1^0} \approx m_{\widetilde{g}}/6$.

$$\begin{array}{ll} \text{Mass } m > \ 154 \ \text{GeV}, \ \text{CL} = 95\% & [m_{\widetilde{g}} \leq m_{\widetilde{q}}, \ \mu = -400 \ \text{GeV}, \\ \tan\beta = 4] \\ \text{Mass } m > \ 212 \ \text{GeV}, \ \text{CL} = 95\% & [m_{\widetilde{g}} \geq m_{\widetilde{q}}, \ \mu = -250 \ \text{GeV}, \\ \tan\beta = 2] \end{array}$$

Quark and Lepton Compositeness, Searches for

Scale Limits A for Contact Interactions (the lowest dimensional interactions with four fermions)

If the Lagrangian has the form

$$\pm \frac{g^2}{2\Lambda^2} \overline{\psi}_L \gamma_\mu \psi_L \overline{\psi}_L \gamma^\mu \psi_L$$

(with $g^2/4\pi$ set equal to 1), then we define $\Lambda \equiv \Lambda_{LL}^{\pm}$. For the full definitions and for other forms, see the Note in the Listings on Searches for Quark and Lepton Compositeness in the full *Review* and the original literature.

$$\begin{array}{lll} \Lambda_{LL}^+(e\,e\,e\,e) &> 1.6 \; {\rm TeV}, \; {\rm CL} = 95\% \\ \Lambda_{LL}^-(e\,e\,e\,e) &> 3.6 \; {\rm TeV}, \; {\rm CL} = 95\% \\ \Lambda_{LL}^+(e\,e\,\mu\,\mu) &> 2.6 \; {\rm TeV}, \; {\rm CL} = 95\% \\ \Lambda_{LL}^-(e\,e\,\mu\,\mu) &> 1.9 \; {\rm TeV}, \; {\rm CL} = 95\% \\ \Lambda_{LL}^+(e\,e\,\tau\,\tau) &> 1.9 \; {\rm TeV}, \; {\rm CL} = 95\% \\ \Lambda_{LL}^-(e\,e\,\tau\,\tau) &> 2.9 \; {\rm TeV}, \; {\rm CL} = 95\% \\ \Lambda_{LL}^+(e\,e\,\tau\,\tau) &> 2.9 \; {\rm TeV}, \; {\rm CL} = 95\% \\ \Lambda_{LL}^+(\ell\,\ell\ell\ell) &> 3.5 \; {\rm TeV}, \; {\rm CL} = 95\% \\ \Lambda_{LL}^+(\ell\ell\ell\ell) &> 2.8 \; {\rm TeV}, \; {\rm CL} = 95\% \\ \Lambda_{LL}^+(\ell\ell\ell\ell) &> 2.3 \; {\rm TeV}, \; {\rm CL} = 95\% \\ \Lambda_{LL}^+(e\,e\,q\,q) &> 2.2 \; {\rm TeV}, \; {\rm CL} = 95\% \\ \Lambda_{LL}^+(\mu\mu\,q\,q) &> 1.4 \; {\rm TeV}, \; {\rm CL} = 95\% \\ \Lambda_{LL}^+(\mu\mu\,q\,q) &> 1.6 \; {\rm TeV}, \; {\rm CL} = 95\% \\ \Lambda_{LR}^+(\nu_\mu\nu_e\mu\,e) &> 3.1 \; {\rm TeV}, \; {\rm CL} = 90\% \\ \Lambda_{LL}^+(q\,q\,q\,q) &> 1.4 \; {\rm TeV}, \; {\rm CL} = 95\% \\ \Lambda_{LL}^+(q\,q\,q\,q) &> 1.4 \; {\rm TeV}, \; {\rm CL} = 95\% \\ \end{array}$$

Recent CDF measurements of the inclusive jet cross section in $p\overline{p}$ collisions could be interpreted as tentative evidence for a four-quark contact interaction with Λ_{LL}^{\pm} ($q\,q\,q\,q\rangle\sim1.6$ TeV. However, CDF notes that uncertainty in the parton distribution functions, higher-order QCD corrections, and detector calibration may possibly account for the effect.

Excited Leptons

The limits from $\ell^{*+}\ell^{*-}$ do not depend on λ (where λ is the $\ell\ell^*$ transition coupling). The λ -dependent limits assume chiral coupling, except for the third limit for e^* which is for nonchiral coupling. For chiral coupling, this limit corresponds to $\lambda_\gamma = \sqrt{2}$.

 $e^{*\pm}$ — excited electron

```
\begin{array}{lll} \mbox{Mass } m > & 46.1 \mbox{ GeV, CL} = 95\% & (\mbox{from } e^{*+}e^{*-}) \\ \mbox{Mass } m > & 91 \mbox{ GeV, CL} = 95\% & (\mbox{if } \lambda_Z > 1) \\ \mbox{Mass } m > & 146 \mbox{ GeV, CL} = 95\% & (\mbox{if } \lambda_{\gamma} = 1) \end{array}
```

 $\mu^{*\pm}$ — excited muon

Mass
$$m > 46.1$$
 GeV, CL = 95% (from $\mu^{*+}\mu^{*-}$)
Mass $m > 91$ GeV, CL = 95% (if $\lambda_Z > 1$)

 $\tau^{*\pm}$ — excited tau

Mass
$$m>$$
 46.0 GeV, CL = 95% (from $\tau^{*+}\tau^{*-}$)
Mass $m>$ 90 GeV, CL = 95% (if $\lambda_Z>0.18$)

 $\nu^* - \text{excited neutrino}$

$$\begin{array}{lll} \text{Mass } m > \ \, \text{47 GeV, CL} = 95\% & \text{(from } \nu^* \overline{\nu}^*) \\ \text{Mass } m > \ \, \text{91 GeV, CL} = 95\% & \text{(if } \lambda_Z \ > \ 1) \end{array}$$

 q^* — excited quark

Color Sextet and Octet Particles

Color Sextet Quarks (q_6)

Mass
$$m > 84$$
 GeV, $CL = 95\%$ (Stable q_6)

Color Octet Charged Leptons (ℓ_8)

Mass
$$m > 86$$
 GeV, $CL = 95\%$ (Stable ℓ_8)

Color Octet Neutrinos (ν_8)

Mass
$$m>~110$$
 GeV, CL = 90% ($\nu_8 \rightarrow ~\nu\,g$)

TESTS OF CONSERVATION LAWS

Revised by L. Wolfenstein and T.G. Trippe, June 1996.

In keeping with the current interest in tests of conservation laws, we collect together a Table of experimental limits on all weak and electromagnetic decays, mass differences, and moments, and on a few reactions, whose observation would violate conservation laws. The Table is given only in the full Review of Particle Physics, not in the Particle Physics Booklet. For the benefit of Booklet readers, we include the best limits from the Table in the following text. The Table is in two parts: "Discrete Space-Time Symmetries," i.e., C, P, T, CP, and CPT; and "Number Conservation Laws," i.e., lepton, baryon, hadronic flavor, and charge conservation. The references for these data can be found in the the Particle Listings in the Review. A discussion of these tests follows.

CPT INVARIANCE

General principles of relativistic field theory require invariance under the combined transformation CPT. The simplest tests of CPT invariance are the equality of the masses and lifetimes of a particle and its antiparticle. The best test comes from the limit on the mass difference between K^0 and \overline{K}^0 . Any such difference contributes to the CP-violating parameter ϵ . Assuming CPT invariance, ϕ_{ϵ} , the phase of ϵ should be very close to 44°. (See the "Note on CP Violation in K^0_L Decay" in the Particle Listings.) In contrast, if the entire source of CP violation in K^0_L decays were a $K^0-\overline{K}^0$ mass difference, ϕ_{ϵ} would be $44^\circ+90^\circ$. It is possible to deduce that [1]

$$m_{\overline{K}^0} - m_{K^0} \approx \frac{2(m_{K^0_L} - m_{K^0_S}) \left| \eta \right| \left(\frac{2}{3} \phi_{+-} + \frac{1}{3} \phi_{00} - \phi_\epsilon \right)}{\sin \phi_\epsilon} \; . \label{eq:mk0}$$

Using our best values of the CP-violation parameters, we get $|(m_{\overline{K}^0} - m_{K^0})/m_{K^0}| \leq 9 \times 10^{-19}$ (CL = 90%). Limits can also be placed on specific CPT-violating decay amplitudes. Given the small value of $(1-|\eta_{00}/\eta_{+-}|)$, the value of $\phi_{00}-\phi_{+-}$ provides a measure of CPT violation in $K_L^0 \to 2\pi$ decay. Results from CERN [1] and Fermilab [2] indicate no CPT-violating effect.

CP AND T INVARIANCE

Given CPT invariance, CP violation and T violation are equivalent. So far the only evidence for CP or T violation comes from the measurements of η_{+-} , η_{00} , and the semileptonic decay charge asymmetry for $K_L,\ e.g.,\ |\eta_{+-}|=|A(K_L^0 o\pi^+\pi^-)/A(K_S^0$ $\to \pi^+\pi^-)|=(2.285\pm 0.019) imes 10^{-3} ext{ and } [\Gamma(K_L^0 \to \pi^-e^+
u)]$ $\Gamma(K_L^0 \to \pi^+ e^- \overline{\nu})]/[\text{sum}] = (0.333 \pm 0.014)\%$. Other searches for \overline{CP} or T violation divide into (a) those that involve weak interactions or parity violation, and (b) those that involve processes otherwise allowed by the strong or electromagnetic interactions. In class (a) the most sensitive are probably the searches for an electric dipole moment of the neutron, measured to be $< 1.1 \times 10^{-25}$ e cm (95% CL), and the electron $(-0.3 \pm 0.8) \times 10^{-26}$ e cm. A nonzero value requires both P and T violation. Class (b) includes the search for C violation in η decay, believed to be an electromagnetic process, e.g., as measured by $\Gamma(\eta \to \mu^+ \mu^- \pi^0)/\Gamma(\eta \to \text{all}) < 5 \times 10^{-6}$, and searches for T violation in a number of nuclear and electromagnetic reactions.

CONSERVATION OF LEPTON NUMBERS

Present experimental evidence and the standard electroweak theory are consistent with the absolute conservation of three separate lepton numbers: electron number L_e , muon number L_{μ} , and tau number L_{τ} . Searches for violations are of the following types:

- a) $\Delta L=2$ for one type of lepton. The best limit comes from the search for neutrinoless double beta decay $(Z,A) \rightarrow (Z+2,A)+e^-+e^-$. The best laboratory limit is $t_{1/2}>5.6\times 10^{24}$ yr (CL=90%) for ⁷⁶Ge.
- b) Conversion of one lepton type to another. For purely leptonic processes, the best limits are on $\mu \to e \gamma$ and $\mu \to 3e$, measured as $\Gamma(\mu \to e \gamma)/\Gamma(\mu \to \text{all}) < 5 \times 10^{-11}$ and $\Gamma(\mu \to 3e)/\Gamma(\mu \to \text{all}) < 1.0 \times 10^{-12}$. For semileptonic processes, the best limit comes from the coherent conversion process in a muonic atom, $\mu^- + (Z,A) \to e^- + (Z,A)$, measured as $\Gamma(\mu^-\text{Ti} \to e^-\text{Ti})/\Gamma(\mu^-\text{Ti} \to \text{all}) < 4 \times 10^{-12}$. Of special interest is the case in which the hadronic flavor also changes, as in $K_L \to e\mu$ and $K^+ \to \pi^+e^-\mu^+$, measured as $\Gamma(K_L \to e\mu)/\Gamma(K_L \to \text{all}) < 3.3 \times 10^{-11}$ and $\Gamma(K^+ \to \pi^+e^-\mu^+)/\Gamma(K^+ \to \text{all}) < 2.1 \times 10^{-10}$. Limits on the conversion of τ into e or μ are found in τ decay and are much less stringent than those for $\mu \to e$ conversion, e.g., $\Gamma(\tau \to \mu\gamma)/\Gamma(\tau \to \text{all}) < 4.2 \times 10^{-6}$ and $\Gamma(\tau \to e\gamma)/\Gamma(\tau \to \text{all}) < 1.1 \times 10^{-4}$.
- c) Conversion of one type of lepton into another type of antilepton. The case most studied is $\mu^- + (Z,A) \rightarrow e^+ + (Z-2,A)$, the strongest limit being $\Gamma(\mu^- {\rm Ti} \rightarrow e^+ {\rm Ca})/\Gamma(\mu^- {\rm Ti} \rightarrow {\rm all}) < 9 \times 10^{-11}$.
- d) Relation to neutrino mass. If neutrinos have mass, then it is expected even in the standard electroweak theory that the lepton numbers are not separately conserved, as a consequence of lepton mixing analogous to Cabibbo quark mixing. However, in this case lepton-number-violating processes such as $\mu \to e\gamma$ are expected to have extremely small probability. For small neutrino masses, the lepton-number violation would be observed first in neutrino oscillations, which have been the subject of extensive experimental searches. For example, searches for $\overline{\nu}_e$ disappearance, which we label as $\overline{\nu}_e \not \to \overline{\nu}_e$, give measured limits $\Delta(m^2) < 0.0075 \text{ eV}^2 \text{ for } \sin^2(2\theta) = 1, \text{ and } \sin^2(2\theta) < 0.02 \text{ for }$ large $\Delta(m^2)$, where θ is the neutrino mixing angle. Searches for $\nu_{\mu} \rightarrow \nu_{e} \text{ limit } \sin^{2}(2\theta) < 0.0025 \text{ for large } \Delta(m^{2}).$ For larger neutrino masses (>> 1 keV), lepton-number violation is searched for by looking for anomalous decays such as $\pi \to e\nu_x$, where ν_x is a massive neutrino. If the $\Delta L=2$ type of violation occurs, it is expected that neutrinos will have a nonzero mass of the Majorana type.

CONSERVATION OF HADRONIC FLAVORS

In strong and electromagnetic interactions, hadronic flavor is conserved, i.e. the conversion of a quark of one flavor (d,u,s,c,b,t) into a quark of another flavor is forbidden. In the Standard Model, the weak interactions violate these conservation laws in a manner described by the Cabibbo-Kobayashi-Maskawa mixing (see the section "Cabibbo-Kobayashi-Maskawa Mixing Matrix"). The way in which these conservation laws are violated is tested as follows:

- a) $\Delta S = \Delta Q$ rule. In the semileptonic decay of strange particles, the strangeness change equals the change in charge of the hadrons. Tests come from limits on decay rates such as $\Gamma(\Sigma^+ \to n e^+ \nu)/\Gamma(\Sigma^+ \to \text{all}) < 5 \times 10^{-6}$, and from a detailed analysis of $K_L \to \pi e \nu$, which yields the parameter x, measured to be $(\text{Re}\,x,\,\text{Im}\,x) = (0.006 \pm 0.018,\,-0.003 \pm 0.026)$. Corresponding rules are $\Delta C = \Delta Q$ and $\Delta B = \Delta Q$.
- b) Change of flavor by two units. In the Standard Model this occurs only in second-order weak interactions. The classic example is $\Delta S=2$ via $K^0-\overline{K}^0$ mixing, which is directly measured by $m(K_S)-m(K_L)=(3.491\pm0.009)\times10^{-12}$ MeV. There

Tests of Conservation Laws

is now evidence for $B^0-\overline{B}^0$ mixing $(\Delta B=2),$ with the corresponding mass difference between the eigenstates $(m_{B^0_{\rm H}}-m_{B^0_{\rm L}})=(0.73\pm0.05)\Gamma_{B^0}=(3.12\pm0.21)\times10^{-10}$ MeV, and for $B^0_s-\overline{B}^0_s$ mixing, with $(m_{B^0_{sH}}-m_{B^0_{sL}})>9.5\Gamma_{B^0_s}$ or $>4\times10^{-9}$ MeV. No evidence exists for $D^0-\overline{D}^0$ mixing, which is expected to be much smaller in the Standard Model.

c) Flavor-changing neutral currents. In the Standard Model the neutral-current interactions do not change flavor. The low rate $\Gamma(K_L \to \mu^+ \mu^-)/\Gamma(K_L \to {\rm all}) = (7.2 \pm 0.5) \times 10^{-9}~{\rm puts}$ limits on such interactions; the nonzero value for this rate is attributed to a combination of the weak and electromagnetic interactions. The best test should come from a limit on $K^+ \to \pi^+ \nu \overline{\nu}$. which occurs in the Standard Model only as a second-order weak process with a branching fraction of $(1 \text{ to } 8) \times 10^{-10}$. The current limit is $\Gamma(K^+ \to \pi^+ \nu \overline{\nu})/\Gamma(K^+ \to \text{all}) < 2.4 \times 10^{-9}$. Limits for charm-changing or bottom-changing neutral currents are much less stringent: $\Gamma(D^0 \to \mu^+ \mu^-)/\Gamma(D^0 \to \text{all}) < 8 \times 10^{-6}$ and $\Gamma(B^0 \to \mu^+ \mu^-)/\Gamma(B^0 \to \text{all}) < 5.9 \times 10^{-6}$. One cannot isolate flavor-changing neutral current (FCNC) effects in non leptonic decays. For example, the FCNC transition $s \to d + (\overline{u} + u)$ is equivalent to the charged-current transition $s \to u + (\overline{u} + d)$. Tests for FCNC are therefore limited to hadron decays into lepton pairs. Such decays are expected only in second-order in the electroweak coupling in the Standard Model.

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TESTS OF DISCRETE SPACE-TIME SYMMETRIES

CHARGE CONJUGATION (C) INVARIANCE

$\Gamma(\pi^0 \to 3\gamma)/\Gamma_{\text{total}}$		$< 3.1 \times 10^{-8}$, CL = 90%
η C-nonconserving decay parameters		
$\pi^+\pi^-\pi^0$ left-right asymmetry		$(0.09 \pm 0.17) \times 10^{-2}$
parameter		
$\pi^+\pi^-\pi^0$ sextant asymmetry		$(0.18 \pm 0.16) \times 10^{-2}$
parameter		_
$\pi^+\pi^-\pi^0$ quadrant asymmetry		$(-0.17 \pm 0.17) \times 10^{-2}$
parameter		
$\pi^+\pi^-\gamma$ left-right asymmetry		$(0.9 \pm 0.4) \times 10^{-2}$
parameter		
$\pi^+\pi^-\gamma$ parameter eta (<i>D</i> -wave)		$0.05 \pm 0.06 (S = 1.5)$
$\Gamma(\eta \rightarrow 3\gamma)/\Gamma_{\text{total}}$		$<5 \times 10^{-4}$, CL = 95%
$\Gamma(\eta \rightarrow \pi^0 e^+ e^-)/\Gamma_{\text{total}}$		$<$ 4 \times 10 $^{-5}$, CL $=$ 90%
$\Gamma(\eta \rightarrow \pi^0 \mu^+ \mu^-)/\Gamma_{\text{total}}$	[a]	$<5 \times 10^{-6}$, CL = 90%
$\Gamma(\omega(782) ightarrow \eta \pi^0)/\Gamma_{ ext{total}}$		$<1 \times 10^{-3}$, CL = 90%
$\Gamma(\omega(782) \rightarrow 3\pi^0)/\Gamma_{\text{total}}$		$<3 \times 10^{-4}$, CL = 90%

PARITY (P) INVARIANCE

e electric dipole moment	$(-0.3 \pm 0.8) \times 10^{-26} \text{ ecm}$
μ electric dipole moment	$(3.7 \pm 3.4) \times 10^{-19}$ ecm
au electric dipole moment	$< 5 \times 10^{-17} \ e \text{cm, CL} = 95\%$
$\Gamma(\eta \rightarrow \pi^+\pi^-)/\Gamma_{\text{total}}$	$<1.5 \times 10^{-3}$
p electric dipole moment	$(-4 \pm 6) \times 10^{-23} e cm$
n electric dipole moment	$<1.1 \times 10^{-25} \text{ ecm, CL} = 95\%$
Λ electric dipole moment	$< 1.5 \times 10^{-16} \ ecm, CL = 95\%$

TIME REVERSAL (T) INVARIANCE

Limits on e, μ , τ , p, n, and Λ electric dipole moments under Parity above are also tests of Time Reversal Invariance.

```
\mu decay parameters
       transverse e^+ polarization normal to
              plane of \mu spin, e^+ momentum
                                                                       (0 \pm 4) \times 10^{-3}
                                                                       (2\pm6)\times10^{-3}
	au electric dipole moment
                                                                       <5 \times 10^{-17} \text{ ecm, CL} = 95\%
\operatorname{Im}(\xi) in K_{\mu3}^{\pm} decay (from transverse \mu pol.)
                                                                       -0.017 \pm 0.025
{\rm Im}(\xi) in K_{\mu 3}^{0} decay (from transverse \mu pol.)
                                                                       -0.007 \pm 0.026
n \rightarrow p \, e^- \, \nu \, \, {\rm decay} \, {\rm parameters}
                                                                 [b] (180.07 \pm 0.18)^{\circ}
       \phi_{AV}, phase of g_A relative to g_V
                                                                       (-0.5\,\pm\,1.4)\times10^{-3}
       triple correlation coefficient D
triple correlation coefficient D for \Sigma^- \rightarrow
                                                                       0.11\,\pm\,0.10
```

CP INVARIANCE

$Re(d_{\tau}^{W})$		$< 7.8 \times 10^{-18} \text{ ecm, CL} = 95\%$
$\Gamma(\eta \to \pi^+\pi^-)/\Gamma_{\text{total}}$		$<1.5 \times 10^{-3}$
$K^{\pm} \rightarrow \pi^{\pm}\pi^{+}\pi^{-}$ rate difference/average		(0.07 ± 0.12)%
$K^{\pm} \rightarrow \pi^{\pm} \pi^{0} \pi^{0}$ rate difference/average		$(0.0 \pm 0.6)\%$
$\kappa^{\pm} \rightarrow \pi^{\pm} \pi^{0} \gamma$ rate difference/average		(0.9 ± 3.3)%
$(g_{\tau^+} - g_{\tau^-}) / (g_{\tau^+} + g_{\tau^-})$ for $K^{\pm} \rightarrow \pi^{\pm} \pi^{+} \pi^{-}$		$(-0.7 \pm 0.5)\%$
CP-violation parameters in K_S^0 decay		
$Im(\eta_{+-0}) = Im(A(K_S^0 \to \pi^+\pi^-\pi^0),$		-0.015 ± 0.030
CP -violating) / $A(K_L^0 \rightarrow$		
$\pi^{+}\pi^{-}\pi^{0}))$		
$\operatorname{Im}(\eta_{000})^2 = \Gamma(K_{5}^0 \to 3\pi^0) /$		<0.1, CL = 90%
$\Gamma(\mathcal{K}_{L}^{0} \rightarrow 3\pi^{\bar{0}})$		
charge asymmetry j for $K_L^0 ightarrow \pi^+\pi^-\pi^0$		0.0011 ± 0.0008
$ \epsilon'_{+-\gamma} /\epsilon$		<0.3, CL = 90%
$\Gamma(\kappa_L^0 \rightarrow \pi^0 \mu^+ \mu^-)/\Gamma_{\text{total}}$	[c]	$<$ 5.1 \times 10 ⁻⁹ , CL $=$ 90%
$\Gamma(K_L^0 o \pi^0 e^+ e^-)/\Gamma_{ ext{total}}$	[c]	$<4.3 \times 10^{-9}$, CL = 90%
$\Gamma(K_I^{0} \rightarrow \pi^0 \nu \overline{\nu})/\Gamma_{\text{total}}$	[d]	$<$ 5.8 \times 10 ⁻⁵ , CL $=$ 90%
$A_{CP}(K^+K^-\pi^\pm)$ in $D^\pm \to K^+K^-\pi^\pm$		-0.03 ± 0.07
$A_{CP}(K^{\pm}K^{*0})$ in $D^+ \rightarrow K^+\overline{K}^{*0}$ and		-0.12 ± 0.13
$D^- \rightarrow K^- K^{*0}$		
$A_{CP}(\phi\pi^{\pm})$ in $D^{\pm} \rightarrow \phi\pi^{\pm}$		0.07 ± 0.09
$A_{CP}(K^+K^-)$ in D^0 , $\overline{D}{}^0 \to K^+K^-$		0.06 ± 0.05
$A_{CP}(K_S^0\phi)$ in D^0 , $\overline{D}{}^0 o K_S^0\phi$		-0.03 ± 0.09
$A_{CP}({\mathcal K}^0_{\mathcal S}\pi^0)$ in D^0 , $\overline D{}^0 o {\mathcal K}^0_{\mathcal S}\pi^0$		-0.018 ± 0.030
$ \text{Re}(\epsilon_{R^0}) $		<0.045
$\left[\alpha_{-}(\Lambda) + \alpha_{+}(\overline{\Lambda})\right] / \left[\alpha_{-}(\Lambda) - \alpha_{+}(\overline{\Lambda})\right]$		-0.03 ± 0.06
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1		

CP VIOLATION OBSERVED

```
\kappa_I^0 branching ratios
charge asymmetry in K^0_{\ell 3} decays
         \delta(\mu) = [\Gamma(\pi^- \mu^+ \nu_\mu)
                                                                                         (0.304 \pm 0.025)\%
                  -\Gamma(\pi^+\mu^-\overline{\nu}_{\mu})]/\text{sum}
        \delta(e) = \frac{\Gamma(\pi^- e^+ \nu_e)}{-\Gamma(\pi^+ e^- \overline{\nu}_e)]/\text{sum}}
                                                                                         (0.333 \pm 0.014)\%
parameters for \mathcal{K}_L^0 \to 2\pi decay
        |\eta_{00}| = |A(K_L^0 \to 2\pi^0)|
                                                                                         (2.275 \pm 0.019) \times 10^{-3} (S = 1.1)
                 A(K_S^0 \rightarrow 2\pi^0)
         |\eta_{+-}| = |A(K_L^0 \to \pi^+\pi^-) / A(K_S^0 \to \pi^+\pi^-)|
                                                                                         (2.285 \pm 0.019) \times 10^{-3}
         \epsilon'/\epsilon \approx \operatorname{Re}(\epsilon'/\epsilon) = (1-|\eta_{00}/\eta_{+-}|)/3
                                                                                 [e] (1.5 \pm 0.8) \times 10^{-3} (S = 1.8)
         \phi_{+-} , phase of \eta_{+-}
                                                                                         (43.7\pm0.6)^{\circ}
         \phi_{00}, phase of \eta_{00}
                                                                                         (43.5 ± 1.0)°
parameters for K_I^0 \to \pi^+\pi^-\gamma decay
         |\eta_{+-\gamma}| = |A(K_I^0 \rightarrow \pi^+\pi^-\gamma, CP)|
                                                                                         (2.35 \pm 0.07) \times 10^{-3}
                   violating)/\tilde{A}(K_S^0 \rightarrow \pi^+\pi^-\gamma)
          \phi_{+-\gamma} = \text{phase of } \eta_{+-\gamma}
                                                                                         (44 \pm 4)^{\circ}
\Gamma(\kappa_I^0 \rightarrow \pi^+\pi^-)/\Gamma_{\text{total}}
                                                                                        (2.067 \pm 0.035) \times 10^{-3} (S = 1.1)
\Gamma(\kappa_I^0 \to \pi^0 \pi^0)/\Gamma_{\text{total}}
                                                                                         (9.36 \pm 0.20) \times 10^{-4}
```

$(m_{W^+} - m_{W^-}) / m_{\text{average}}$	-0.002 ± 0.007
$(m_{e^+} - m_{e^-}) / m_{\text{average}}$	$<4 \times 10^{-8}$, CL = 90%
$ q_{e^{+}} + q_{e^{-}} /e$	$<4 \times 10^{-8}$
$(g_{e^+} - g_{e^-}) / g_{average}$	$(-0.5 \pm 2.1) \times 10^{-12}$
$(au_{\mu^+} - au_{\mu^-}) / au_{average}$	$(2 \pm 8) \times 10^{-5}$
$(g_{\mu^+} - g_{\mu^-}) / g_{average}$	$(-2.6 \pm 1.6) \times 10^{-8}$
$(m_{\pi^+} - m_{\pi^-}) / m_{\text{average}}$	$(2 \pm 5) \times 10^{-4}$
$(au_{\pi^+} - au_{\pi^-}) / au_{average}$	$(6 \pm 7) \times 10^{-4}$
$(m_{K^+} - m_{K^-}) / m_{\text{average}}$	$(-0.6 \pm 1.8) \times 10^{-4}$
$(\tau_{K^+} - \tau_{K^-}) / \tau_{\text{average}}$	$(0.11 \pm 0.09)\% (S = 1.2)$
${m \kappa}^{\pm} ightarrow \mu^{\pm} u_{\mu}$ rate difference/average	$(-0.5 \pm 0.4)\%$
$\mathcal{K}^{\pm} ightarrow \pi^{\pm} \pi^{0}$ rate difference/average	[f] $(0.8 \pm 1.2)\%$
$ m_{K^0} - m_{\overline{K^0}} / m_{\text{average}}$	$[g] < 9 \times 10^{-19}$
phase difference ϕ_{00} $ \phi_{+-}$	$(-0.2 \pm 0.8)^{\circ}$
<i>CPT</i> -violation parameters in κ^0 decay	
real part of Δ	0.018 ± 0.020
imaginary part of Δ	0.02 ± 0.04
$(\frac{q_{\overline{p}}}{m_{\overline{p}}} -\frac{q_p}{m_p})/ \frac{q}{m} _{\text{average}}$	$(1.5 \pm 1.1) \times 10^{-9}$
$ q_p + q_{\overline{p}} /e$	$<2 \times 10^{-5}$
$(\mu_{m p} - \mu_{\overline{m p}}) \ / \ \mu_{\sf average} $	$(-2.6 \pm 2.9) \times 10^{-3}$
$(m_n - m_{\overline{n}}) / m_{\text{average}}$	$(9 \pm 5) \times 10^{-5}$
	-

 $(m_{\Lambda} - m_{\overline{\Lambda}}) / m_{\Lambda}$

 $(\tau_{\Lambda} - \tau_{\overline{\Lambda}}) / \tau_{\text{average}}$

 $(\mu_{\Sigma^+} - |\mu_{\overline{\Sigma}^-}|) / |\mu|_{\text{average}}$

 $(m_{\Xi^-} - m_{\overline{\Xi}^+}) / m_{\text{average}}$

 $(au_{\Xi^-} - au_{\Xi^+}) / au_{average}$

 $(m_{\Omega^-} - m_{\overline{\Omega}^+}) / m_{\text{average}}$

CPT INVARIANCE

TESTS OF NUMBER CONSERVATION LAWS

 $(-1.0 \pm 0.9) \times 10^{-5}$

 $(1.1 \pm 2.7) \times 10^{-4}$

 0.04 ± 0.09

 0.02 ± 0.18

 $(0 \pm 5) \times 10^{-4}$

 0.014 ± 0.015

LEPTON FAMILY NUMBER

Lepton family number conservation means separate conservation of each of $L_{\rm E},\,L_{\mu},\,L_{\tau}.$

```
\Gamma(Z \rightarrow e^{\pm} \mu^{\mp})/\Gamma_{\text{total}}
                                                                                        [h] <1.7 \times 10^{-6}, CL = 95%
 \Gamma(Z \rightarrow e^{\pm} \tau^{\mp})/\Gamma_{\mathsf{total}}
                                                                                        [h] <9.8 \times 10^{-6}, CL = 95%
 \Gamma(Z \to \mu^{\pm} \tau^{\mp})/\Gamma_{\text{total}}
                                                                                        [h] <1.7 \times 10^{-5}, CL = 95%
limit on \mu^- \rightarrow e^- conversion \sigma(\mu^- {}^{32}{\rm S} \rightarrow e^- {}^{32}{\rm S}) / \sigma(\mu^- {}^{32}{\rm S} \rightarrow \nu_\mu {}^{32}{\rm P}^*)
                                                                                                < 7 \times 10^{-11}, CL = 90%
           \sigma(\mu^- \text{Ti} \rightarrow e^- \text{Ti}) /
                                                                                                <4.3 \times 10<sup>-12</sup>, CL = 90%
                  \sigma(\mu^- \text{Ti} \rightarrow \text{capture})
          \sigma(\mu^- Pb \rightarrow e^- Pb) /
                                                                                                <4.6 \times 10^{-11}, CL = 90%
                  \sigma(\mu^- \text{Pb} \to \text{capture})
                                                                                                <0.13, CL = 90%
 limit on muonium → antimuonium
          conversion R_g = G_C / G_F
 \Gamma(\mu^- \rightarrow e^- \nu_e \overline{\nu}_{\mu})/\Gamma_{\text{total}}
                                                                                         [i] <1.2 × 10<sup>-2</sup>, CL = 90%
 \Gamma(\mu^- \rightarrow e^- \gamma)/\Gamma_{\text{total}}
                                                                                               <4.9 \times 10<sup>-11</sup>, CL = 90%
 \Gamma(\mu^- \rightarrow e^- e^+ e^-)/\Gamma_{\text{total}}
                                                                                                <1.0 \times 10^{-12}, CL = 90%
 \Gamma(\mu^- \rightarrow e^- 2\gamma)/\Gamma_{\text{total}}
                                                                                                < 7.2 \times 10^{-11}, CL = 90%
 \Gamma(\tau^- \rightarrow e^- \gamma)/\Gamma_{\text{total}}
                                                                                                <1.1 \times 10^{-4}, CL = 90%
 \Gamma(\tau^- \rightarrow \mu^- \gamma)/\Gamma_{\text{total}}
                                                                                                <4.2 \times 10^{-6}, CL = 90%
 \Gamma(\tau^- \rightarrow e^- \pi^0)/\Gamma_{\text{total}}
                                                                                               <1.4 \times 10^{-4}, CL = 90%
 \Gamma(\tau^- \rightarrow \mu^- \pi^0)/\Gamma_{\text{total}}
                                                                                               <4.4 \times 10^{-5}, CL = 90%
 \Gamma(\tau^- \rightarrow e^- \kappa^0)/\Gamma_{\text{total}}
                                                                                               <1.3 \times 10^{-3}, CL = 90%
                                                                                               <1.0 \times 10^{-3}, CL = 90%
 \Gamma(\tau^- \rightarrow \mu^- K^0)/\Gamma_{\text{total}}
 \Gamma(\tau^- \rightarrow e^- \eta)/\Gamma_{\text{total}}
                                                                                               <6.3 \times 10^{-5}, CL = 90%
 \Gamma(\tau^- \rightarrow \mu^- \eta)/\Gamma_{\text{total}}
                                                                                               < 7.3 \times 10^{-5}, CL = 90%
 \Gamma(\tau^- \rightarrow e^- \rho^0)/\Gamma_{\text{total}}
                                                                                               <4.2 \times 10^{-6}, CL = 90%
\Gamma(\tau^{-} \rightarrow \mu^{-}\rho^{0})/\Gamma_{\text{total}}
\Gamma(\tau^{-} \rightarrow e^{-}K^{*}(892)^{0})/\Gamma_{\text{total}}
                                                                                               <5.7 \times 10^{-6}, CL = 90%
                                                                                               <6.3 \times 10^{-6}, CL = 90%
 \Gamma(\tau^- \rightarrow \mu^- K^*(892)^0)/\Gamma_{\text{total}}
                                                                                              <9.4 \times 10^{-6}, CL = 90%
                                                                                               < 3.3 \times 10^{-6}, CL = 90%
 \Gamma(\tau^- \rightarrow e^- e^+ e^-)/\Gamma_{\text{total}}
 \Gamma(\tau^- \rightarrow e^- \mu^+ \mu^-)/\Gamma_{\text{total}}
                                                                                                <3.6 \times 10^{-6}, CL = 90%
```

Limits are given at the 90% confidence level, while errors are given as ± 1 standard deviation.

$\Gamma(\tau^- \rightarrow e^+ \mu^- \mu^-)/\Gamma_{\text{total}}$		$<3.5 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to \mu^- e^+ e^-)/\Gamma_{\text{total}}$		$<3.4 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to \mu^- \mu^+ \mu^-)/\Gamma_{\text{total}}$		$<1.9 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to e^- \pi^+ \pi^-)/\Gamma_{\text{total}}$		$<4.4 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to \mu^- \pi^+ \pi^-)/\Gamma_{\text{total}}$		$< 7.4 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to e^- \pi^+ K^-)/\Gamma_{\text{total}}$		$< 7.7 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to e^- \pi^- K^+)/\Gamma_{\text{total}}$		$<4.6 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to \mu^- \pi^+ K^-)/\Gamma_{\text{total}}$		$< 8.7 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \rightarrow \mu^- \pi^- K^+)/\Gamma_{\text{total}}$		$< 1.5 \times 10^{-5}$, CL = 90%
$\Gamma(\tau^- \rightarrow e^- \overline{K}^*(892)^0)/\Gamma_{\text{total}}$		$<1.1 \times 10^{-5}$, CL = 90%
$\Gamma(\tau^- \rightarrow \mu^- \overline{K}^*(892)^0)/\Gamma_{\text{total}}$		$< 8.7 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \rightarrow e^- \text{ light boson})/\Gamma_{\text{total}}$		$<2.7 \times 10^{-3}$, CL = 95%
$\Gamma(\tau^- \rightarrow \mu^- \text{ light boson})/\Gamma_{\text{total}}$		$<5 \times 10^{-3}$, CL = 95%
u oscillations. (For other lepton mixing effects in	n part	icle decays, see the Particle Listings.)
$\overline{\nu}_e \rightarrow \overline{\nu}_e$		
$\Delta(m^2)$ for $\sin^2(2\theta) = 1$ $\sin^2(2\theta)$ for "Large" $\Delta(m^2)$		$< 0.0075 \text{ eV}^2, \text{ CL} = 90\%$
		<0.02, CL = 90%
$ u_{ m e} ightarrow u_{ m au} \ \Delta(m^2) ext{ for sin}^2(2 heta) = 1$		$< 9 \text{ eV}^2, CL = 90\%$
$\Delta(m')$ for sin' $(2b) = 1$ $\sin^2(2\theta)$ for "Large" $\Delta(m^2)$		<0.25, CL = 90%
$\overline{\nu}_e ightharpoonup \overline{\nu}_{\tau}$		(0.23, CL = 90%
$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$		<0.7, CL = 90%
$\nu_{\mu} ightarrow \nu_{e}$		30.7
$\Delta(m^2)$ for $\sin^2(2\theta) = 1$		$<0.09 \text{ eV}^2$, CL = 90%
$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$		$<2.5 \times 10^{-3}$, CL = 90%
$\overline{\nu}_{\mu} \rightarrow \overline{\nu}_{e}$		
$\Delta(m^2)$ for $\sin^2(2\theta)=1$		$<0.14 \text{ eV}^2$, CL = 90%
$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$		<0.004, CL = 95%
$\nu_{\mu}(\overline{\nu}_{\mu}) \rightarrow \nu_{e}(\overline{\nu}_{e})$		
$\Delta(m^2)$ for $\sin^2(2\theta)=1$		$< 0.075 \text{ eV}^2, CL = 90\%$
$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$		$< 3 \times 10^{-3}$, CL = 90%
$\nu_{\mu} \rightarrow \nu_{\tau}$		
$\Delta(m^2)$ for $\sin^2(2\theta)=1$		$<0.9 \text{ eV}^2$, CL = 90%
$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$		< 0.004, CL $= 90%$
$\overline{v}_{\mu} \rightarrow \overline{v}_{ au}$		
$\Delta(m^2)$ for $\sin^2(2 heta)=1$		$<$ 2.2 eV 2 , CL = 90%
$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$		$<4.4 \times 10^{-2}$, CL = 90%
$\nu_{\mu}(\overline{\nu}_{\mu}) \rightarrow \nu_{\tau}(\overline{\nu}_{\tau})$		
$\Delta(m^2)$ for $\sin^2(2 heta)=1$		$<$ 1.5 eV 2 , CL $=$ 90%
$\sin^2(2 heta)$ for "Large" $\Delta(m^2)$		$< 8 \times 10^{-3}$, CL = 90%
$\nu_e \not\rightarrow \nu_e$		
$\Delta(m^2) \text{ for } \sin^2(2\theta) = 1$		$<0.17 \text{ eV}^2, \text{ CL} = 90\%$
$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$		$<7 \times 10^{-2}$, CL = 90%
$\nu_{\mu} ightarrow \nu_{\mu}$		2
$\Delta(m^2) \text{ for } \sin^2(2\theta) = 1$		$<0.23 \text{ or } > 1500 \text{ eV}^2$
$\sin^2(2\theta)$ for $\Delta(m^2) = 100 \text{eV}^2$	IJ	<0.02, CL = 90%
$\overline{\nu}_{\mu} \neq \overline{\nu}_{\mu}$		
$\Delta(m^2)$ for $\sin^2(2 heta)=1$ $\sin^2(2 heta)$ for 190 eV $^2<\Delta(m^2)<$	11.1	<7 or >1200 eV ²
$\sin^{-}(2\theta)$ for 190 eV ⁻ $< \Delta(m^{-}) < 320 \text{ eV}^{2}$	[K]	<0.02, CL = 90%
$\Gamma(\pi^+ \to \mu^+ \nu_e)/\Gamma_{\text{total}}$	[/]	$< 8.0 \times 10^{-3}$, CL = 90%
$\Gamma(\pi^+ \to \mu^- e^+ e^+ \nu)/\Gamma_{\text{total}}$		$<1.6 \times 10^{-6}$, CL = 90%
$\Gamma(\pi^0 \rightarrow \mu^+ e^- + e^- \mu^+)/\Gamma_{\text{total}}$		$< 1.72 \times 10^{-8}$, CL $= 90\%$
$\Gamma(K^+ \rightarrow \mu^- \nu e^+ e^+)/\Gamma_{\text{total}}$		$< 2.0 \times 10^{-8}$, CL = 90%
$\Gamma(K^+ \rightarrow \mu^+ \nu_e)/\Gamma_{\text{total}}$	[/]	$< 4 \times 10^{-3}$, CL = 90%
$\Gamma(K^+ \rightarrow \pi^+ \mu^+ e^-)/\Gamma_{\text{total}}$		$< 2.1 \times 10^{-10}$, CL = 90%
$\Gamma(K^+ \rightarrow \pi^+ \mu^- e^+)/\Gamma_{\text{total}}$		$< 7 \times 10^{-9}$, CL = 90%
$\Gamma(K_I^0 \rightarrow e^{\pm} \mu^{\mp})/\Gamma_{\text{total}}$	[<i>h</i>]	$< 3.3 \times 10^{-11}$, CL = 90%
$\Gamma(D^+ \to \pi^+ e^{\pm} \mu^{\mp})/\Gamma_{\text{total}}$	[<i>h</i>]	$< 3.8 \times 10^{-3}$, CL = 90%
$\Gamma(D^+ \rightarrow \pi^+ e^+ \mu^-)/\Gamma_{\text{total}}$		$< 3.3 \times 10^{-3}$, CL = 90%
$\Gamma(D^+ \rightarrow \pi^+ e^- \mu^+)/\Gamma_{\text{total}}$		$< 3.3 \times 10^{-3}$, CL = 90%
$\Gamma(D^+ \rightarrow K^+ e^+ \mu^-)/\Gamma_{\text{total}}$		$< 3.4 \times 10^{-3}$, CL = 90%
$\Gamma(D^+ \rightarrow K^+ e^- \mu^+)/\Gamma_{\text{total}}$		$< 3.4 \times 10^{-3}$, CL = 90%
$\Gamma(D^0 \rightarrow \mu^{\pm} e^{\mp})/\Gamma_{\text{total}}$	[h]	$<1.9 \times 10^{-5}$, CL = 90%
$\Gamma(D^0 \to \pi^0 e^{\pm} \mu^{\mp})/\Gamma_{\text{total}}$	[<i>h</i>]	$< 8.6 \times 10^{-5}$, CL = 90%
$\Gamma(D^0 \to \eta e^{\pm} \mu^{\mp})/\Gamma_{\text{total}}$	[<i>h</i>]	$<1.0 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \to \rho^0 e^{\pm} \mu^{\mp}) / \Gamma_{\text{total}}$	[<i>h</i>]	$<4.9 \times 10^{-5}$, CL = 90%
$\Gamma(D^0 \to \omega e^{\pm} \mu^{\mp})/\Gamma_{\text{total}}$	[<i>h</i>]	$<1.2 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \to \phi e^{\pm} \mu^{\mp})/\Gamma_{\text{total}}$	[<i>h</i>]	$<3.4 \times 10^{-5}$, CL = 90%
$\Gamma(D^0 \to \overline{K}^0 e^{\pm} \mu^{\mp})/\Gamma_{\text{total}}$		$<1.0 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \to \overline{K}^*(892)^0 e^{\pm} \mu^{\mp})/\Gamma_{\text{total}}$	[h]	$<1.0 \times 10^{-4}$, CL = 90%
$\Gamma(B^+ \to \pi^+ e^+ \mu^-)/\Gamma_{\text{total}}$		$<6.4 \times 10^{-3}$, CL = 90%
$\Gamma(B^+ \to \pi^+ e^- \mu^+)/\Gamma_{\text{total}}$		$<6.4 \times 10^{-3}$, CL = 90%

Tests of Conservation Laws

$<$ 6.4 \times 10 ⁻³ , CL $=$ 90%
$<6.4 \times 10^{-3}$, CL = 90%
[h] $< 5.9 \times 10^{-6}$, CL = 90%
[h] $< 5.3 \times 10^{-4}$, CL = 90%
[h] <8.3 × 10 ⁻⁴ , CL = 90%

TOTAL LEPTON NUMBER

Violation of total lepton number conservation also implies violation of lepton family number conservation.

limit on $\mu^- ightarrow e^+$ conversion		
$\sigma(\mu^{-32}S \rightarrow e^{+32}Si^*)$ /		$<9 \times 10^{-10}$, CL = 90%
$\sigma(\mu^{-32}S \rightarrow \nu_{\mu}^{32}P^*)$		C9 × 10 , CE = 90%
$\sigma(\mu^{-127}I \rightarrow e^{+127}Sb^*) /$		$< 3 \times 10^{-10}$, CL = 90%
$\frac{\sigma(\mu^{-127}I \rightarrow e^{+125}B^{+})}{\sigma(\mu^{-127}I \rightarrow anything)}$		<3 × 10 25, CL ≡ 90%
$\sigma(\mu^- \text{Ti} \rightarrow \text{anything})$ $\sigma(\mu^- \text{Ti} \rightarrow e^+ \text{Ca}) /$		$< 8.9 \times 10^{-11}$, CL = 90%
$\sigma(\mu^- \text{ Ti} \rightarrow e^+ \text{ Ca}) / \sigma(\mu^- \text{ Ti} \rightarrow \text{ capture})$		<8.9 x 10, CL ≡ 90%
$\Gamma(\tau^- \to \pi^- \gamma)/\Gamma_{\text{total}}$		$< 2.8 \times 10^{-4}$, CL = 90%
$\Gamma(\tau^- \to \pi^- \pi^0)/\Gamma_{\text{total}}$		$<3.7 \times 10^{-4}$, CL = 90%
$\tau (\tau \to \pi \pi^*)/\tau \text{total}$		$<3.4 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to \mu^+ e^- e^-)/\Gamma_{\text{total}}$		$< 3.4 \times 10^{-4}$, CL = 90% $< 4.4 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to e^+ \pi^- \pi^-)/\Gamma_{\text{total}}$		
$\Gamma(\tau^- o \mu^+ \pi^- \pi^-)/\Gamma_{\text{total}}$		$<6.9 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \rightarrow e^+ \pi^- K^-)/\Gamma_{total}$		$<4.5 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to \mu^+ \pi^- K^-)/\Gamma_{\text{total}}$		$<2.0 \times 10^{-5}$, CL = 90%
$\Gamma(\tau^- \to \overline{p}\gamma)/\Gamma_{total}$		$<2.9 \times 10^{-4}$, CL = 90%
$\Gamma(\tau^- \to \overline{p}\pi^0)/\Gamma_{\text{total}}$		$<6.6 \times 10^{-4}$, CL = 90%
$\Gamma(\tau^- \to \overline{p}\eta)/\Gamma_{total}$		$<1.30 \times 10^{-3}$, CL = 90%
$\nu_e \rightarrow (\overline{\nu}_e)_L$		_
$lpha\Delta(m^2)$ for $\sin^2(2 heta)=1$		$< 0.14 \text{ eV}^2$, CL = 90%
$\alpha^2 \sin^2(2\theta)$ for "Large" $\Delta(m^2)$		<0.032, CL = 90%
$\nu_{\mu} \rightarrow (\overline{\nu}_e)_L$		
$lpha\Delta(m^2)$ for $\sin^2(2 heta)=1$		$<\!$ 0.16 eV $^{\!2}$, CL $=$ 90%
$lpha^2 \sin^2(2 heta)$ for "Large" $\Delta(m^2)$		<0.001, CL = 90%
$\Gamma(\pi^+ \to \mu^+ \overline{\nu}_e)/\Gamma_{\text{total}}$	[/]	
$\Gamma(K^+ \rightarrow \pi^- \mu^+ e^+)/\Gamma_{\text{total}}$		$< 7 \times 10^{-9}$, CL = 90%
$\Gamma(K^+ \rightarrow \pi^- e^+ e^+)/\Gamma_{\text{total}}$		$<$ 1.0 $ imes$ 10 $^{-8}$, CL $=$ 90%
$\Gamma(K^+ \rightarrow \pi^- \mu^+ \mu^+)/\Gamma_{\text{total}}$		$< 1.5 \times 10^{-4}$, CL $= 90\%$
$\Gamma(K^+ \rightarrow \mu^+ \overline{\nu}_e) / \Gamma_{\text{total}}$	[/]	$< 3.3 \times 10^{-3}$, CL = 90%
$\Gamma(K^+ \to \pi^0 e^+ \overline{\nu}_e)/\Gamma_{\text{total}}$	[/]	$< 3 \times 10^{-3}$, CL = 90%
$\Gamma(D^+ \to \pi^- e^+ e^+)/\Gamma_{\text{total}}$	٠.	$<4.8 \times 10^{-3}$, CL = 90%
$\Gamma(D^+ \to \pi^- \mu^+ \mu^+)/\Gamma_{\text{total}}$		$< 2.2 \times 10^{-4}$, CL = 90%
$\Gamma(D^+ \rightarrow \pi^- e^+ \mu^+)/\Gamma_{\text{total}}$		$<3.7 \times 10^{-3}$, CL = 90%
$\Gamma(D^+ \to \rho^- \mu^+ \mu^+)/\Gamma_{\text{total}}$		$<5.6 \times 10^{-4}$, CL = 90%
$\Gamma(D^+ \to K^- e^+ e^+)/\Gamma_{\text{total}}$		$<9.1 \times 10^{-3}$, CL = 90%
$\Gamma(D^+ \to K^- \mu^+ \mu^+)/\Gamma_{\text{total}}$		$<3.2 \times 10^{-4}$, CL = 90%
$\Gamma(D^+ \to K^- \mu^+ \mu^-)/\Gamma_{\text{total}}$		$<4.0 \times 10^{-3}$, CL = 90%
$\Gamma(D^+ \to K^- e^+ \mu^+)/\Gamma \text{total}$		$< 8.5 \times 10^{-4}$, CL = 90%
$\Gamma(D^+ \rightarrow K^*(892)^- \mu^+ \mu^+)/\Gamma_{\text{total}}$		$< 4.3 \times 10^{-4}$, CL = 90%
$\Gamma(D_s^+ \to \pi^- \mu^+ \mu^+)/\Gamma_{\text{total}}$		
$\Gamma(D_s^+ \to K^- \mu^+ \mu^+)/\Gamma_{\text{total}}$		$<5.9 \times 10^{-4}$, CL = 90%
$\Gamma(D_s^+ \to K^*(892)^- \mu^+ \mu^+)/\Gamma_{\text{total}}$		$<1.4 \times 10^{-3}$, CL = 90%
$\Gamma(B^+ \to \pi^- e^+ e^+)/\Gamma_{\text{total}}$		$< 3.9 \times 10^{-3}$, CL $= 90\%$
$\Gamma(B^+ \rightarrow \pi^- \mu^+ \mu^+)/\Gamma_{\text{total}}$		$<9.1 \times 10^{-3}$, CL = 90%
$\Gamma(B^+ \rightarrow \pi^- e^+ \mu^+)/\Gamma_{\text{total}}$		$<$ 6.4 $ imes$ 10 $^{-3}$, CL $=$ 90%
$\Gamma(B^+ \rightarrow K^- e^+ e^+)/\Gamma_{\text{total}}$		$< 3.9 \times 10^{-3}$, CL $= 90\%$
$\Gamma(B^+ \rightarrow K^- \mu^+ \mu^+)/\Gamma_{total}$		$<$ 9.1 $ imes$ 10 $^{-3}$, CL $=$ 90%
$\Gamma(B^+ \to K^- e^+ \mu^+)/\Gamma_{\text{total}}$		$< 6.4 \times 10^{-3}$, CL = 90%
$\Gamma(\Xi^- \to \rho \mu^- \mu^-)/\Gamma_{\text{total}}$		$<4 \times 10^{-4}$, CL = 90%
$\Gamma(\Lambda_c^+ \to \Sigma^- \mu^+ \mu^+)/\Gamma_{\text{total}}$		$< 7.0 \times 10^{-4}$, CL = 90%
C " I TOTAL		

BARYON NUMBER

$\Gamma(\tau^- \to \overline{p}\gamma)/\Gamma_{\text{total}}$	$< 2.9 \times 10^{-4}, CL = 90\%$
$\Gamma(au^- ightarrow \overline{p}\pi^0)/\Gamma_{ ext{total}}$	$<6.6 \times 10^{-4}$, CL = 90%
$\Gamma(\tau^- o \overline{p}\eta)/\Gamma_{\text{total}}$	$<1.30 \times 10^{-3}$, CL = 90%
p mean life	$>1.6 \times 10^{25}$ years

A few examples of proton or bound neutron decay follow. For limits on many other nucleon decay channels, see the Barvon Summary Table.

decay channels, see the baryon summary Table.	1
$\tau(N \rightarrow e^+\pi)$	$> 130 (n), > 550 (p) \times 10^{30}$ years,
	CL = 90%
$\tau(N \to \mu^+ \pi)$	$> 100 (n), > 270 (p) \times 10^{30}$ years,
	CL = 90%
$\tau(N \rightarrow e^+ K)$	$> 1.3 (n), > 150 (p) \times 10^{30}$ years,
	CL = 90%
$\tau(N \rightarrow \mu^+ K)$	$> 1.1 (n), > 120 (p) \times 10^{30}$ years,
, , ,	CL = 90%
(bound n	52 - 7070
(bound n	
mean time for $n\overline{n}$ transition in vacuum	$[m] > 1.2 \times 10^8 \text{ s, CL} = 90\%$

(free n

 $>\!0.86\times10^{8}$ s, CL =90%limit on $n\overline{n}$ oscillations

ELECTRIC CHARGE (Q)

$\Delta S = \Delta Q$ RULE

Allowed in second-order weak interactions.

$\Gamma(K^+ \rightarrow \pi^+ \pi^+ e^- \overline{\nu}_e) / \Gamma_{\text{total}}$	$< 1.2 \times 10^{-8}$, CL $= 90\%$
$\Gamma(K^+ o \pi^+ \pi^+ \mu^- \overline{\nu}_{\mu})/\Gamma_{\text{total}}$	$< 3.0 \times 10^{-6}$, CL = 95%
$x = A(\overline{K}^0 \rightarrow \pi^- \ell^+ \nu)/A(K^0 \rightarrow \pi^- \ell^+ \nu) = A(\Delta^0)$	$\Delta S = -\Delta Q)/A(\Delta S = \Delta Q)$
real part of x	$0.006 \pm 0.018 (S = 1.3)$
imaginary part of x	-0.003 ± 0.026 (S = 1.2)
$\Gamma(\Sigma^+ \to n\ell^+\nu)/\Gamma(\Sigma^- \to n\ell^-\overline{\nu})$	< 0.043
$\Gamma(\Sigma^+ \rightarrow ne^+\nu_e)/\Gamma_{\text{total}}$	$<$ 5 \times 10 ⁻⁶ , CL = 90%
$\Gamma(\Sigma^+ o n\mu^+ u_\mu)/\Gamma_{ ext{total}}$	$< 3.0 \times 10^{-5}$, CL = 90%
$\Gamma(\Xi^0 \rightarrow \Sigma^- e^+ \nu_e)/\Gamma_{\text{total}}$	$< 9 \times 10^{-4}$, CL = 90%
$\Gamma(\Xi^0 \to \Sigma^- \mu^+ \nu_\mu)/\Gamma_{\text{total}}$	$<9 \times 10^{-4}$, CL = 90%

$\Delta S = 2$ FORBIDDEN

Allowed in second-order weak interactions.

$\Gamma(\Xi^0 \to p\pi^-)/\Gamma_{\text{total}}$	$< 4 \times 10^{-5}$, CL = 90%
$\Gamma(\Xi^0 \rightarrow \rho e^- \overline{\nu}_e)/\Gamma_{\text{total}}$	$< 1.3 \times 10^{-3}$
$\Gamma(\Xi^0 \to \rho \mu^- \overline{\nu}_{\mu})/\Gamma_{\text{total}}$	$<1.3 \times 10^{-3}$
$\Gamma(\Xi^- \rightarrow n\pi^-)/\Gamma_{\text{total}}$	$<1.9 \times 10^{-5}$, CL = 90%
$\Gamma(\Xi^- \rightarrow ne^- \overline{\nu}_e)/\Gamma_{\text{total}}$	$< 3.2 \times 10^{-3}, CL = 90\%$
$\Gamma(\Xi^- o n\mu^-\overline{ u}_\mu)/\Gamma_{total}$	$<1.5 \times 10^{-2}$, CL = 90%
$\Gamma(\Xi^- \to p\pi^-\pi^-)/\Gamma_{\text{total}}$	$<4 \times 10^{-4}$, CL = 90%
$\Gamma(\Xi^- o p\pi^- e^- \overline{\nu}_e)/\Gamma_{\text{total}}$	$<4 \times 10^{-4}$, CL = 90%
$\Gamma(\Xi^- o ho \pi^- \mu^- \overline{ u}_\mu)/\Gamma_{total}$	$< 4 \times 10^{-4}$, CL = 90%
$\Gamma(\Omega^- \to \Lambda \pi^-)/\Gamma_{\text{total}}$	$<1.9 \times 10^{-4}$, CL = 90%

$\Delta S = 2 \text{ VIA MIXING}$

Allowed in second-order weak interactions, e.g. mixing.

$$m_{K_L^0} - m_{K_S^0}$$
 $(0.5304 \pm 0.0014) \times 10^{10} \ \hbar \ s^{-1}$ $m_{K_L^0} - m_{K_S^0}$ $(3.491 \pm 0.009) \times 10^{-12} \ \text{MeV}$

$\Delta C = 2 \text{ VIA MIXING}$

Allowed in second-order weak interactions, e.g. mixing.

$ m_{D_1^0} - m_{D_2^0} $	[0] $<21 \times 10^{10} \ h \ s^{-1}$, CL $=90\%$
$\Gamma(K^+\pi^-(via^-\overline{D}{}^0))/\Gamma(K^-\pi^+)$	<0.005, CL $=$ 90%
$\Gamma(K^+\pi^-\pi^+\pi^-(ext{vla}\ \overline{D}{}^0))/$	<0.005, CL = 90%
$\Gamma(K^-\pi^+\pi^+\pi^-)$	
$\Gamma(\mu^-$ anything (via $\overline{D}{}^0))/\Gamma(\mu^+$ anything)	<0.0056, CL = 90%
$\Gamma(D^0 ightarrow K^+ \pi^- (\text{via } \overline{D}{}^0)) / \Gamma_{ ext{total}}$	$<1.9 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \to K^+\pi^-\pi^+\pi^- \text{(via } \overline{D}{}^0))/\Gamma_{ ext{total}}$	$<4 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 o\mu^-$ anything (via $\overline{D}{}^0))/\Gamma_{ ext{total}}$	$<4 \times 10^{-4}$, CL = 90%

$\Delta B = 2 \text{ VIA MIXING}$

Allowed in second-order weak interactions, e.g. mixing.

χ_d	0.175 ± 0.016
$\Delta m_{B^0} = m_{B_H^0} - m_{B_L^0}$	$(0.474 \pm 0.031) \times 10^{12} \ h \ s^{-1}$
$x_d = \Delta m_{B^0} / \Gamma_{B^0}$	0.73 ± 0.05
x_s	>0.49, CL = 95%
$\Delta m_{B_s^0} = m_{B_{sH}^0} - m_{B_{sL}^0}$	$>5.9 \times 10^{12} \ h \ s^{-1}$, CL = 95%
$x_S = \Delta m_{R^0} / \Gamma_{R^0}$	>9.5, CL = 95%

$\Delta S = 1$ WEAK NEUTRAL CURRENT FORBIDDEN

Allowed by higher-order electroweak interactions.

$(2.74 \pm 0.23) \times 10^{-7}$
$< 2.3 \times 10^{-7}$, CL = 90%
$< 2.4 \times 10^{-9}$, CL = 90%
$< 3.2 \times 10^{-7}$, CL = 90%
$<$ 2.8 \times 10 ⁻⁶ , CL $=$ 90%
$< 1.1 \times 10^{-6}$, CL = 90%
$(7.2 \pm 0.5) \times 10^{-9} \text{ (S} = 1.4)$
$(3.23 \pm 0.30) \times 10^{-7}$
$<$ 4.1 $ imes$ 10 $^{-11}$, CL $=$ 90%
$(9.1 \pm 0.5) \times 10^{-6}$
[ρ] $(6.5 \pm 1.2) \times 10^{-7}$
$< 2.5 \times 10^{-6}$, CL = 90%
$<$ 4.9 \times 10 ⁻⁶ , CL $=$ 90%
[q] $(4.1 \pm 0.8) \times 10^{-8} (S = 1.2)$
$<$ 5.1 $ imes$ 10 $^{-9}$, CL $=$ 90%
$<$ 4.3 $ imes$ 10 $^{-9}$, CL $=$ 90%
$<$ 5.8 $ imes$ 10 $^{-5}$, CL $=$ 90%
$< 7 \times 10^{-6}$

$\Delta C = 1$ WEAK NEUTRAL CURRENT FORBIDDEN

Allowed by higher-order electroweak interactions.

	_
$\Gamma(D^+ \rightarrow \pi^+ e^+ e^-)/\Gamma_{\text{total}}$	$<$ 6.6 \times 10 $^{-5}$, CL $=$ 90%
$\Gamma(D^+ \rightarrow \pi^+ \mu^+ \mu^-)/\Gamma_{\text{total}}$	$< 1.8 \times 10^{-5}$, CL $= 90\%$
$\Gamma(D^+ \rightarrow \rho^+ \mu^+ \mu^-)/\Gamma_{\text{total}}$	$<$ 5.6 \times 10 ⁻⁴ , CL = 90%
$\Gamma(D^0 \rightarrow e^+e^-)/\Gamma_{\text{total}}$	$< 1.3 \times 10^{-5}$, CL = 90%
$\Gamma(D^0 \to \mu^+ \mu^-)/\Gamma_{\text{total}}$	$< 7.6 \times 10^{-6}$, CL = 90%
$\Gamma(D^0 \to \pi^0 e^+ e^-)/\Gamma_{\text{total}}$	$<$ 4.5 \times 10 ⁻⁵ , CL = 90%
$\Gamma(D^0 \to \pi^0 \mu^+ \mu^-)/\Gamma_{\text{total}}$	$< 1.8 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \to \eta e^+ e^-)/\Gamma_{\text{total}}$	$<1.1 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \to \eta \mu^+ \mu^-)/\Gamma_{\text{total}}$	$<$ 5.3 \times 10 ⁻⁴ , CL $=$ 90%
$\Gamma(D^0 \to \rho^0 e^+ e^-)/\Gamma_{\text{total}}$	$<1.0 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \to \rho^0 \mu^+ \mu^-)/\Gamma_{\text{total}}$	$< 2.3 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \to \omega e^+ e^-)/\Gamma_{\text{total}}$	$< 1.8 \times 10^{-4}$, CL $= 90\%$
$\Gamma(D^0 \to \omega \mu^+ \mu^-)/\Gamma_{\text{total}}$	$< 8.3 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \to \phi e^+ e^-)/\Gamma_{\text{total}}$	$<$ 5.2 \times 10 ⁻⁵ , CL $=$ 90%
$\Gamma(D^0 \to \phi \mu^+ \mu^-)/\Gamma_{\text{total}}$	$<$ 4.1 \times 10 ⁻⁴ , CL = 90%
$\Gamma(D^0 \rightarrow \pi^+\pi^-\pi^0\mu^+\mu^-)/\Gamma_{\text{total}}$	$< 8.1 \times 10^{-4}$, CL = 90%
$\Gamma(D_s^+ \to K^+ \mu^+ \mu^-)/\Gamma_{\text{total}}$	$<$ 5.9 $ imes$ 10 $^{-4}$, CL $=$ 90%
$\Gamma(D_s^+ \to K^*(892)^+ \mu^+ \mu^-)/\Gamma_{\text{total}}$	$<\!1.4\times10^{-3}\text{, CL}=90\%$
$\Gamma(\Lambda_c^+ \to \rho \mu^+ \mu^-)/\Gamma_{\text{total}}$	$< 3.4 \times 10^{-4}$, CL = 90%

Limits are given at the 90% confidence level, while errors are given as ± 1 standard deviation.

$\Delta B = 1$ WEAK NEUTRAL CURRENT FORBIDDEN

Allowed by higher-order electroweak interactions.

NOTES

In this Summary Table:

When a quantity has "(S = ...)" to its right, the error on the quantity has been enlarged by the "scale factor" S, defined as $S = \sqrt{\chi^2/(N-1)}$, where N is the number of measurements used in calculating the quantity. We do this when S > 1, which often indicates that the measurements are inconsistent. When S > 1.25, we also show in the Particle Listings an ideogram of the measurements. For more about S, see the Introduction.

- [a] C parity forbids this to occur as a single-photon process.
- [b] Time-reversal invariance requires this to be 0° or 180°.
- [c] Allowed by higher-order electroweak interactions.
- [d] Violates CP in leading order. Test of direct CP violation since the indirect CP-violating and CP-conserving contributions are expected to be suppressed.
- $[e]\,\epsilon'/\epsilon$ is derived from $\left|\eta_{00}/\eta_{+-}\right|$ measurements using theoretical input on phases.
- [f] Neglecting photon channels. See, e.g., A. Pais and S.B. Treiman, Phys. Rev. D12, 2744 (1975).
- [g] Derived from measured values of ϕ_{+-} , ϕ_{00} , $|\eta|$, $\tau_{K^0_S}$, and $|m_{K^0_L} m_{K^0_C}|$, as described in the introduction to "Tests of Conservation Laws."
- [h] The value is for the sum of the charge states of particle/antiparticle states indicated
- [i] A test of additive vs. multiplicative lepton family number conservation.
- $[j] \Delta(m^2) = 100 \text{ eV}^2.$
- [k] 190 eV² $< \Delta(m^2) < 320 \text{ eV}^2$.
- [/] Derived from an analysis of neutrino-oscillation experiments.
- [m] There is some controversy about whether nuclear physics and model dependence complicate the analysis for bound neutrons (from which the best limit comes). The second limit here is from reactor experiments with free neutrons.
- [n] This is the best "electron disappearance" limit. The best limit for the mode $e^-\to\nu\gamma$ is $>2.35\times10^{25}$ yr (CL=68%).
- [o] The D_1^0 - D_2^0 limits are inferred from the D^0 - \overline{D}^0 mixing ratio [$\Gamma(K^+\pi^-$ or $K^+\pi^-\pi^+\pi^-$ via \overline{D}^0)] / $\Gamma(K^-\pi^+$ or $K^-\pi^+\pi^+\pi^-$).
- [p] See the \mathcal{K}^0_L Particle Listings for the energy limits used in this measurement.
- $[q] m_{e^+e^-} > 470 \text{ MeV}.$

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Kinematics, Cross-Section Formulae, and Plots

35. Cross-section formulae for specific processes

 $36.\ {\rm Plots}$ of cross sections and related

34. Kinematics (rev.)

quantities (rev.)

1. PHYSICAL CONSTANTS

Table 1.1. Reviewed 1995 by B.N. Taylor, NIST. Based mainly on the "1986 Adjustment of the Fundamental Physical Constants" by E.R. Cohen and B.N. Taylor, Rev. Mod. Phys. 59, 1121 (1987). The last group of constants (beginning with the Fermi coupling constant) comes from the Particle Data Group. The figures in parentheses after the values give the 1-standard-deviation uncertainties in the last digits; the corresponding uncertainties in parts per million (ppm) are given in the last column. This set of constants (aside from the last group) is recommended for international use by CODATA (the Committee on Data for Science and Technology).

Since the 1986 adjustment, new experiments have yielded improved values for a number of constants, including the Rydberg constant R_{∞} , the Planck constant h, the fine-structure constant α , and the molar gas constant R, and hence also for constants directly derived from these, such as the Boltzmann constant k and Stefan-Boltzmann constant σ . The new results and their impact on the 1986 recommended values are discussed extensively in "Recommended Values of the Fundamental Physical Constants: A Status Report," B.N. Taylor and E.R. Cohen, J. Res. Natl. Inst. Stand. Technol. 95, 497 (1990); see also E.R. Cohen and B.N. Taylor, "The Fundamental Physical Constants," Phys. Today, August 1995 Part 2, BG9. In general, the new results give uncertainties for the affected constants that are 5 to 7 times smaller than the 1986 uncertainties, but the changes in the values themselves are smaller than twice the 1986 uncertainties. Because the output values of a least-squares adjustment are correlated, the new results cannot readily be incorporated with the 1986 values. Until the next complete adjustment of the constants, the 1986 CODATA set, given (in part) below, remains the set of choice.

Quantity	Symbol, equation	Value U1	ncert. (ppm)
speed of light in vacuum	c	299 792 458 m s ⁻¹	exact*
Planck constant	h	$6.626\ 075\ 5(40) \times 10^{-34}\ \text{J s}$	0.60
Planck constant, reduced	$h \equiv h/2\pi$	$1.054\ 572\ 66(63) \times 10^{-34}\ \mathrm{J}\ \mathrm{s}$	0.60
		$= 6.582 \ 122 \ 0(20) \times 10^{-22} \ \text{MeV s}$	0.30
electron charge magnitude	e	$1.602\ 177\ 33(49) \times 10^{-19}\ C = 4.803\ 206\ 8(15) \times 10^{-10}\ esu$	0.30, 0.30
conversion constant	ħc	197.327 053(59) MeV fm	0.30
conversion constant	$(\hbar c)^2$	$0.389\ 379\ 66(23)\ { m GeV^2\ mbarn}$	0.59
electron mass	m_e	$0.510~999~06(15)~{\rm MeV}/c^2 = 9.109~389~7(54) \times 10^{-31}~{\rm kg}$	0.30, 0.59
proton mass	m_p	$938.272\ 31(28)\ \mathrm{MeV}/c^2 = 1.672\ 623\ 1(10) \times 10^{-27}\ \mathrm{kg}$	0.30, 0.59
		= 1.007 276 470(12) u = 1836.152 701(37) m_e	0.012, 0.020
deuteron mass	m_d	$1875.613 \ 39(57) \ \mathrm{MeV}/c^2$	0.30
unified atomic mass unit (u)	$(\text{mass}\ ^{12}\text{C}\ \text{atom})/12 = (1\ \text{g})/(N_A\ \text{mol})$	931.494 32(28) MeV/ $c^2 = 1.660 540 2(10) \times 10^{-27} \text{ kg}$	0.30, 0.59
permittivity of free space	ϵ_0) 1/2	$8.854\ 187\ 817\ \dots \times 10^{-12}\ \mathrm{F\ m^{-1}}$	exact
permeability of free space	$\frac{\epsilon_0}{\mu_0} \left. \right\} \epsilon_0 \mu_0 = 1/c^2$	$4\pi \times 10^{-7} \text{ N A}^{-2} = 12.566 \ 370 \ 614 \dots \times 10^{-7} \text{ N A}^{-2}$	exact
fine-structure constant	$\alpha = e^2/4\pi\epsilon_0 \hbar c$	1/137.035 989 5(61) [†]	0.045
classical electron radius	$r_e = e^2/4\pi\epsilon_0 m_e c^2$	$2.817\ 940\ 92(38) \times 10^{-15}\ \mathrm{m}$	0.13
electron Compton wavelength	$\lambda_e = \hbar/m_e c = r_e \alpha^{-1}$	$3.861\ 593\ 23(35) \times 10^{-13}\ \mathrm{m}$	0.089
Bohr radius $(m_{\text{nucleus}} = \infty)$	$a_{\infty} = 4\pi\epsilon_0 h^2 / m_e e^2 = r_e \alpha^{-2}$	$0.529\ 177\ 249(24) \times 10^{-10}\ \mathrm{m}$	0.045
wavelength of 1 eV/ c particle	hc/e	$1.239\ 842\ 44(37)\times10^{-6}\ \mathrm{m}$	0.30
Rydberg energy	$hcR_{\infty} = m_e e^4 / 2(4\pi\epsilon_0)^2 h^2 = m_e c^2 \alpha^2 / 2$	13.605 698 1(40) eV	0.30
Thomson cross section	$\sigma_T = 8\pi r_e^2/3$	0.665 246 16(18) barn	0.27
Bohr magneton	$\mu_B = eh/2m_e$	$5.788~382~63(52)\times10^{-11}~{ m MeV}~{ m T}^{-1}$	0.089
nuclear magneton	$\mu_N = eh/2m_p$	$3.152\ 451\ 66(28) \times 10^{-14}\ \mathrm{MeV}\ \mathrm{T}^{-1}$	0.089
electron cyclotron freq./field	$\omega_{\mathrm{cycl}}^e/B = e/m_e$	$1.758~819~62(53) \times 10^{11}~{\rm rad~s^{-1}~T^{-1}}$	0.30
proton cyclotron freq./field	$\omega_{ m cycl}^p/B=e/m_p$	$9.578~830~9(29)\times10^7~{\rm rad~s^{-1}~T^{-1}}$	0.30
gravitational constant	G_N	$6.672\ 59(85)\times10^{-11}\ \mathrm{m^3\ kg^{-1}\ s^{-2}}$	128
		= $6.707 \ 11(86) \times 10^{-39} \ hc \ (\text{GeV}/c^2)^{-2}$	128
standard grav. accel., sea level	g	$9.806~65~{\rm m~s^{-2}}$	exact
Avogadro constant	N_A	$6.022\ 136\ 7(36) \times 10^{23}\ \mathrm{mol}^{-1}$	0.59
Boltzmann constant	k	$1.380~658(12) \times 10^{-23}~\mathrm{J~K^{-1}}$	8.5
		$= 8.617 \ 385(73) \times 10^{-5} \ eV \ K^{-1}$	8.4
molar volume, ideal gas at STP	$N_A k(273.15 \text{ K})/(101 325 \text{ Pa})$	$22.414\ 10(19) \times 10^{-3}\ m^3\ mol^{-1}$	8.4
Wien displacement law constant		$2.897 \ 756(24) \times 10^{-3} \text{ m K}$	8.4
Stefan-Boltzmann constant	$\sigma = \pi^2 k^4 / 60 h^3 c^2$	$5.670\ 51(19) \times 10^{-8}\ \mathrm{W\ m^{-2}\ K^{-4}}$	34
Fermi coupling constant [‡]	$G_F/(\hbar c)^3$	$1.166~39(2)\times10^{-5}~{\rm GeV^{-2}}$	20
weak mixing angle	$\sin^2\widehat{\theta}(M_Z)$ $(\overline{\text{MS}})$	0.2315(4)	2200
W^{\pm} boson mass	m_W	$80.33(15) \text{ GeV}/c^2$	1900
Z^0 boson mass	m_Z	91.187(7) GeV/c^2	77
strong coupling constant	$lpha_s(m_Z)$	0.118(3)	25000
$\pi = 3.141\ 592\ 6$		$28\ 459\ 045\ 235 \hspace{1.5cm} \gamma = 0.577\ 215\ 664\ 901\ 532\ 861$	
1 in $\equiv 0.0254 \text{ m}$ 1 G		1.602 177 33(49) × 10^{-19} J kT at 300 K = [38.681 4	$9(33)]^{-1} \text{ eV}$
	$\equiv 10^{-5} \text{ N}$ 1 eV/ $c^2 =$	1.782 662 $70(54) \times 10^{-36} \text{ kg}$ 0 °C \equiv 273.15 K	*
$1 \text{ barn} \equiv 10^{-28} \text{ m}^2$ 1 erg	$\equiv 10^{-7} \text{ J}$ 2.997 924 $58 \times 10^9 \text{ csu} =$	1 C 1 atmosphere $\equiv 760 \text{ torr} \equiv 101 325 1$	Pa

^{*} The meter is the length of the path traveled by light in vacuum during a time interval of 1/299 792 458 of a second.

 $^{^\}dagger$ At $Q^2=0.$ At $Q^2\approx m_W^2$ the value is approximately 1/128.

[‡] See discussion in Sec. 10 "Standard Model of electroweak interactions."

2. ASTROPHYSICAL CONSTANTS

Table 2.1. Written and revised with the help of K.R. Lang, K.A. Olive, J. Primack, S. Rudaz, E.M. Standish, Jr., and M.S. Turner. The figures in parentheses after some values give the 1-standard deviation uncertainties in the last digit(s). While every effort has been made to obtain the most accurate current values of the listed quantities, the table does not represent a critical review or adjustment of the constants, and is not intended as a primary reference.

Quantity	Symbol, equation	Value	Reference
speed of light	c	299 792 458 m s ⁻¹	defined [1]
Newtonian gravitational constant	G_N	$6.67259(85) \times 10^{-11} \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-2}$	[2]
astronomical unit	AU	$1.4959787066(2)\times 10^{11}\mathrm{m}$	[3,4]
tropical year (equinox to equinox) (1994)	yr	31 556 925.2 s	[3]
sidereal year (fixed star to fixed star) (1994)		31 558 149.8 s	[3]
mean sidereal day		23 ^h 56 ^m 04 ^s 090 53	[3]
Jansky	Jy	$10^{-26} \text{ W m}^{-2} \text{ Hz}^{-1}$	
Planck mass	$\sqrt{\hbar c/G_N}$	$1.221047(79) \times 10^{19} \text{ GeV}/c^2$	uses [2]
		$= 2.17671(14) \times 10^{-8} \mathrm{kg}$	
parsec (1 AU/1 arc sec)	pc	$3.0856775807(4) \times 10^{16} \text{ m} = 3.262\text{ly}$	[5]
light year (deprecated unit)	ly	$0.3066 \text{ pc} = 0.9461 \times 10^{16} \text{ m}$	
Schwarzschild radius of the Sun	$2G_N M_{\odot}/c^2$	2.953 250 08 km	[6]
solar mass	M_{\odot}	$1.98892(25) \times 10^{30} \text{ kg}$	[7]
solar luminosity	L_{\odot}	$3.846 \times 10^{26} \text{ W}$	[8]
solar equatorial radius	R_{\odot}	$6.96 \times 10^8 \text{ m}$	[3]
Earth equatorial radius	R_{\oplus}	$6.378140\times10^6\mathrm{m}$	[3]
Earth mass	M_{\oplus}	$5.97370(76) \times 10^{24} \text{ kg}$	[9]
luminosity conversion	L	$3.02 \times 10^{28} \times 10^{-0.4} \ M_b \ \mathrm{W}$	[10]
		$(M_b = absolute bolometric magnitude$	
		= bolometric magnitude at 10 pc)	
flux conversion	${\mathscr F}$	$2.52 \times 10^{-8} \times 10^{-0.4} \ m_b \ \mathrm{W \ m^{-2}}$	from above
		$(m_b = \text{apparent bolometric magnitude})$	
v_{\odot} around center of Galaxy	Θο	220(20) km s ⁻¹	[11]
solar distance from galactic center	R_{\circ}	8.0(5) kpc	[12]
Hubble constant [†]	H_0	$100 \ h_0 \ {\rm km \ s^{-1} \ Mpc^{-1}}$	
	-	$= h_0 \times (9.77813 \text{ Gyr})^{-1}$	[13]
normalized Hubble constant [†]	h_0	$0.5 < h_0 < 0.85$	[14,15,16]
	$c = 3H_0^2/8\pi G_N$	$2.77536627 imes 10^{11}h_0^2M_{\odot}{ m Mpc}^{-3}$. , , ,
,,	J 14	= $1.87882(24) \times 10^{-29} h_0^2 \text{ g cm}^{-3}$	
3 3 3 3 3 4		= 1.053 94(13) × 10 ⁻⁵ h_0^2 GeV cm ⁻³ 3-12 ×10 ⁻²⁴ g cm ⁻³ \approx 2-7 GeV/ c^2 cm ⁻³	(4 m 1
local disk density	$ ho_{ m disk}$		[17]
local halo density	ρ halo	$2-13 \times 10^{-25} \text{ g cm}^{-3} \approx 0.1-0.7 \text{ GeV}/c^2 \text{ cm}^{-3}$	[18]
density parameter of the universe [†]	$\Omega_0 \equiv \rho_0/\rho_c$	$0.1 < \Omega_0 < 2$	[19]
scaled cosmological constant [†]	$\lambda_0 = \Lambda c^2 / 3H_0^2$	$-1 < \lambda_0 < 2$	[20,21]
scale factor for cosmological constant [†]	$c^2/3H_0^2$	$2.853 \times 10^{51} h_0^{-2} \text{ m}^2$	
age of the universe [†]	t_0	15(5) Gyr	[10]
	$\Omega_0 h_0^2$	$\leq 2.4 \text{ for } t_0 \geq 10 \text{ Gyr}$	[10]
		$\leq 1 \text{ for } t_0 \geq 10 \text{ Gyr}, h_0 > 0.4$	[10]
cosmic background radiation (CBR) temperature [†]	T_0	$2.726 \pm 0.005 \text{ K}$	[22,23]
solar velocity with respect to CBR		$369.5 \pm 3.0 \text{ km s}^{-1}$	[23,24]
energy density of CBR	$ ho_{\gamma}$	$4.6477 \times 10^{-34} (T/2.726)^4 \mathrm{g \ cm^{-3}}$	[10,23]
		$= 0.26071 (T/2.726)^4 \text{ eV cm}^{-3}$	
number density of CBR photons	$n_{oldsymbol{\gamma}}$	$410.89 (T/2.726)^3 \mathrm{cm}^{-3}$	[10,23]
entropy density/Boltzmann constant	s/k	$2892.4\ (T/2.726)^3\ \mathrm{cm}^{-3}$	[10]

 $^{^{\}dagger}$ Subscript 0 indicates present-day values.

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- The Astronomical Almanac for the year 1994, U.S. Government Printing Office, Washington, and Her Majesty's Stationary Office, London (1993). Where possible, the values as adjusted for the fitting of the ephemerides to all the observational data are used.
- 4. JPL Planetary Ephemerides, E. Myles Standish, Jr., private communication (1989).
- 5. 1 AU divided by $\pi/648000$; quoted error is from the JPL Planetary Ephemerides value of the AU [4].
- 6. Heliocentric gravitational constant from Ref. 3 times $2/c^2$. The given 9-place accuracy appears to be consistent with uncertainties in actually defining the earth's orbital parameters.
- 7. Obtained from the heliocentric gravitational constant [3] and G_N [2]. The error is the 128 ppm standard deviation quoted for G_N .
- It is surprisingly difficult to find a definitive value for this important constant. In all cases, the solar luminosity is calculated as $4\pi \times (1 \text{ AU})^2$ times the solar constant (or total solar irradiance, TSI). The luminosity given is reduced from TSI = 1367.51 ± 0.01 W m⁻², obtained from SMM/ACRIMI spacecraft measurements during the interval 2/80-6/89 [25]. While the time constant for energy production by the sun is very long, radiation from the surface might be modulated or otherwise modified by sunspots; this has apparently not been taken into account. Accordingly, we quote 4-place accuracy. We do not know the actual error, but suppose it might be 5 or 10 in the last place. Sackmann et al. [26] use $TSI = 1370 \pm 2 \text{ W m}^{-2}$, but conclude that the solar luminosity $(L_{\odot} = 3.853 \times 10^{26} \text{ J s}^{-1})$ has an uncertainty of 1.5%. Their value is based on three 1977-83 papers, and they comment that the error is based on scatter among the reported values, which is substantially in excess of that expected from the individual quoted errors. The conclusion of the 1971 review by Thekaekara and Drummond [27] $(1353 \pm 1\% \text{ W m}^{-2})$ is often quoted [28], and a luminosity based on this value was tabulated in the last two editions of this Review. The conversion to luminosity is not given in the Thekaekara and Drummond paper, and we cannot exactly reproduce the solar luminosity given in Ref. 28. Finally, a value based on the 1954 spectral curve due to Johnson [29] (1395 \pm 1% W m⁻², or $L_{\odot} = 3.92 \times 10^{26} \text{ J s}^{-1}$) has been used widely, and may be the basis for higher value of the solar luminosity and corresponding lower value of the solar absolute bolometric magnitude (4.72) still common in the literature [10].
- 9. Obtained from the geocentric gravitational constant [3] and G_N [2]. The error is the 128 ppm standard deviation quoted for G_N .
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- 11. F.J. Kerr and D. Lynden-Bell, Mon. Not. R. Astr. Soc. **221**, 1023–1038 (1985). "On the basis of this review these $[R_{\circ} = 8.5 \pm 1.1 \text{ kpc}]$ and $\Theta_{\circ} = 220 \pm 20 \text{ km s}^{-1}]$ were adopted by resolution of IAU Commission 33 on 1985 November 21 at Delhi".

- 12. M.J. Reid, Annu. Rev. Astron. Astrophys. 31, 345–372 (1993). Note that Θ_o from the 1985 IAU Commission 33 recommendations is adopted in this review, although the new value for R_o is smaller.
- 13. Conversion using length of tropical year.
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- 5. Kolb and Turner [10] give the more conservative limits $0.4 < h_0 < 1$. For other conclusions, see the recent reviews by Jacoby et al. [30], who say "Using the weighted or unweighted Virgo distances to bootstrap to the Coma cluster, we find the Hubble constant to be either 80 ± 11 or 73 ± 11 km s⁻¹ Mpc⁻¹, respectively," and Huchra [31], who concludes that "Values are still clustered about two numbers, but these numbers are now 50 and 85. A preponderance of the newest local estimates favors the higher value of 85 km s⁻¹ Mpc⁻¹...".
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 The value 0.3 GeV/c² has been taken as "standard" in several papers setting limits on WIMP mass limits, e.g. in M. Mori et al., Phys. Lett. B289, 463 (1992).
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3. INTERNATIONAL SYSTEM OF UNITS (SI)

See "The International System of Units (SI)," NIST Special Publication 330, B.N. Taylor, ed. (USGPO, Washington, DC, 1991); and "Guide for the Use of the International System of Units (SI)," NIST Special Publication 811, 1995 edition, B.N. Taylor (USGPO, Washington, DC, 1995).

	T	
Physical	Name	g , ,
quantity	of unit	Symbol
В	$ase\ units$	
length	meter	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd
Derived units	s with special name	es
plane angle	radian	rad
solid angle	steradian	sr
frequency	hertz	$_{\mathrm{Hz}}$
energy	joule	J
force	newton	N
pressure	pascal	Pa
power	watt	w
electric charge	coulomb	C
electric potential	volt	V
electric resistance	ohm	Ω
electric conductance	siemens	S
electric capacitance	farad	F
magnetic flux	weber	Wb
inductance	henry	Н
magnetic flux density	tesla	T
luminous flux	lumen	lm
illuminance	lux	lx
celsius temperature	degree celsius	°C
activity (of a radioactive source)*	becquerel	Bq
absorbed dose (of ionizing radiation)*	gray	Gy
dose equivalent*	sievert	Sv

	*See our section	25, on	"Radioactivity and	radiation	protection," p. 150.
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SI	prefixe	s
10^{24}	yotta	(Y)
10^{21}	zetta	(Z)
10^{18}	exa	(E)
10^{15}	peta	(P)
10^{12}	tera	(T)
10^{9}	giga	(G)
10^{6}	mega	(M)
10^{3}	kilo	(k)
10^{2}	hecto	(h)
10	deca	(da)
10^{-1}	deci	(d)
10^{-2}	centi	(c)
10^{-3}	milli	(m)
10^{-6}	micro	(μ)
10^{-9}	nano	(n)
10^{-12}	pico	(p)
10^{-15}	femto	(f)
10^{-18}	atto	(a)
10^{-21}	zepto	(z)
10^{-24}	yocto	(y)

4. PERIODIC TABLE OF THE ELEMENTS

longest-lived isotope of that element—no stable isotope exists. For elements 110–112, the atomic numbers of known isotopes are given. However, although Th, Pa, and U have no stable isotopes, they do have characteristic terrestrial compositions, and meaningful weighted masses can be given. Adapted from "Atomic Weights of the Elements 1993," Pure and Applied Chemistry 66, 2423 (1994), and G. Audi and A.H. Wapstra, "The 1993 Mass Evaluation," Nucl. Phys. A565, 1 (1993). The names given below for elements 104 to 109 have been adopted by the American Chemical Society. The nomenclature committee of the International Union of Pure and Applied Chemistry in 1994 recommended different names for elements 104 to 108, but in the subsequent uproar has postponed a final decision until 1997. Table 4.1. Revised 1995. The atomic number (top left) is the number of protons in the nucleus. The atomic mass (bottom) is weighted by isotopic abundances in the Earth's surface. Atomic masses are relative to the mass of the carbon-12 isotope, defined to be exactly 12 unified atomic mass units (u). Errors range from 1 to 9 in the last digit quoted. Relative isotopic abundances often vary considerably, both in natural and commercial samples. A number in parentheses is the mass of the

I A																18 VIIIA
																2 He
Hydrogen 2											13	14	15	16	17	Helium
⋖	ſ										IIIA	ΙΛΑ	۸	۸IA	VIA	4.002602
3 Li 4 Be	e e	ţ		į	(5 B	O 9	N 2	B 6 C 7 N 8 O 9 F 10	9 F	10 Ne
Lithium Beryllium	u	YEK.	IODIC	TABI	E OF	HEF	PERIODIC TABLE OF THE ELEMENTS				Boron	Carbon	Nitrogen	Boron Carbon Nitrogen Oxygen Fluorine	Fluorine	Neon
6.941 9.012182	~										10.811	12.011	14.00674	10.811 12.011 14.00674 15.9994 18.9984032	18.9984032	20.1797
11 Na 12 Mg	ρ0										13 AI	14 Si	15 P	Al 14 Si 15 P 16 S 17 Cl 18	17 CI	18 Ar
Sodium Magnesium			ഹ	9	2 9	œ	6	10	11	12	Aluminum Silicon	Silicon	Phosph.	Sulfur	Chlorine	Argon
22.989768 24.3050	IIIB	IVB	IVB VB	VIB	VIIB	L		Γ	8	EB	26.981539	28.0855	26.981539 28.0855 30.973762 32.066	32.066	35.4527	39.948
19 K 20 Ca 21 Sc 22 Ti 23 V 24	a 21 Sc	22 Ti	23 V		25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	Cr 25 Mn 26 Fe 27 Co 28 Ni 29 Cu 30 Zn 31 Ga 32 Ge 33 As 34 Se 35 Br 36 Kr	35 Br	36 Kr
Potassium Calcium Scandium Titanium Vanadium Chromium Manganese Iron	Scandium	Titanium	Vanadium	Chromium	Manganese	Iron	Cobalt	Cobalt Nickel Copper	Copper	Zinc	Gallium	German.	Arsenic	Zinc Gallium German. Arsenic Selenium Bromine	Bromine	Krypton
39.0983 40.078 44.955910 47.867 50.9415 51.9961 54.93805 55.845 58.93320 58.6934 63.546 65.39 69.723 72.61 74.92159 78.96	44.955910	47.867	50.9415	51.9961	54.93805	55.845	58.93320	58.6934	63.546	62.39	69.723	72.61	74.92159	78.96	79.904	83.80
37 Rb 38 Sr 39 Y 40 Zr 41 Nb 42	ir 39 Y	40 Zr	41 Nb		43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	Mo 43 Tc 44 Ru 45 Rh 46 Pd 47 Ag 48 Cd 49 In 50 Sn 51 Sb 52 Te 53	53	54 Xe
Rubidium Strontium Yttrium Zirconium Niobium Molybd. Technet. Ruthen. Rhodium Palladium Silver Cadmium Indium	n Yttrium	Zirconium	Niobium	Molybd.	Technet.	Ruthen.	Rhodium	Palladium	Silver	Cadmium	Indium	Tin	Antimony	Tin Antimony Tellurium Iodine	Iodine	Xenon
85.4678 87.62 88.90585 91.224 92.90638	88.90585	91.224	92.90638	95.94	(97.907215)	101.07	102.90550	106.42	107.8682	112.411	114.818	118.710	121.760	95.94 (97.907215) 101.07 102.90550 106.42 107.8682 112.411 114.818 118.710 121.760 127.60 126.90447	126.90447	131.29
55 Cs 56 Ba 57–71 72 Hf 73 Ta 74	a 57–71	72 Hf	73 Ta	74 W	75 Re	20 97	77 lr	78 Pt	79 Au	80 Hg	81 TI	82 Pb	83 Bi	W 75 Re 76 Os 77 Ir 78 Pt 79 Au 80 Hg 81 T1 82 Pb 83 Bi 84 Po 85	85 At	At 86 Rn
Cesium Barium Lantha- Hafnium Tantalum Tungsten Rhenium Osmium Iridium Platinum Gold Mercury Thallium Lead Bismuth Polonium Astatine	Lantha-	Hafnium	Tantalum	Tungsten	Rhenium	Osmium	Iridium	Platinum	Gold	Mercury	Thallium	Lead	Bismuth	Polonium	Astatine	Radon
132.90543 137.327	nides	178.49	180.9479	183.84	186.207	190.23	192.217	nides 178.49 180.9479 183.84 186.207 190.23 192.217 195.08 196.96654 200.59	196.96654		204.3833	207.2	208.98037	207.2 208.98037 (208.982415)(209.987131)(222.017570)	(209.987131)	(222.017570
87 Fr 88 Ra 89-103 104 Rf 105 Ha 106 Sg 107 Ns 108 Hs 109 Mt 110	a 89–103	104 Rf	105 Ha	106 Sg	107 Ns	108 Hs	109 Mt		111	112						
Francium Radium Actinides Rutherford Hahnium Seaborg. Nielsbohr. Hassium Meitner.	Actinides	Rutherford	Hahnium	Seaborg.	Nielsbohr.	Hassium	Meitner.									
(223.019731) (226.025402)	(2)	(261.1089)	(262.1144)	(263.1186)	(262.1231)	(265.1306)	(266.1378)	(261.1089) (262.1144) (263.1186) (262.1231) (265.1306) (266.1378) (269, 273) (272)		(277)	44.					

5/ La	28 28	59 P	5/ La 58 Ce 59 Pr 60 Nd		62 Sm	63 Eu	64 Gd	65 lb	66 Uy	67 Ho	68 Er	m_ 69	70 Yb	71 Lu	
Lanthan.	Lanthan. Cerium Praseodym. Neodym	Praseodyn	n. Neodym.	Prometh.	Samarium	Europium	Gadolin.	Terbium	Dyspros.	Holmium	Erbium	Thulium	Ytterbium	Lutetium	Prometh. Samarium Europium Gadolin. Terbium Dyspros. Holmium Erbium Thulium Ytterbium Lutetium Lanthanide
138.9055	140.115	140.9076	138.9055 140.115 140.90765 144.24	(144.912745) 150.36 151.965 157.25 158.92534 162.50 164.93032 167.26 168.93421 173.04 174.967	150.36	151.965	157.25	158.92534	162.50	164.93032	167.26	168.93421	173.04	174.967	series
89 Ac	90 Th	91 P ₂	89 Ac 90 Th 91 Pa 92 U		94 Pu	95 Am	96 Cm	97 Bk	98 Cf	93 Np 94 Pu 95 Am 96 Cm 97 Bk 98 Cf 99 Es 100 Fm 101 Md 102 No 103 Lr 1	100 Fm	101 Md	102 No	103 Lr	Actinide
Actinium	Thorium	Protactin	Actinium Thorium Protactin. Uranium	Neptumium Plutonium Americ. Curium Berkelium Californ. Einstein. Fermium Mendelev. Nobelium Lawrenc.	Plutonium	Americ.	Curium	Berkelium	Californ.	Einstein.	Fermium	Mendelev.	Nobelium	Lawrenc.	series
(227.027747)	232.0381	231.03588	227.027747) 232.0381 231.03588 238.0289	(237.048166)(244.064197)(243.061372)(247.070346)(247.070298)(251.079579) (252.08297) (252.08297) (257.095096)(258.098427) (259.1011) (262.1098)	(244.064197)	(243.061372)	(247.070346)	(247.070298)	(251.079579)	(252.08297)	(257.095096)	(258.098427)	(259.1011)	(262.1098)	

5. ELECTRONIC STRUCTURE OF THE ELEMENTS

Table 5.1. Reviewed 1995 by W.C. Martin, NIST. The electronic configurations and ionization energies here are taken from "Atomic Spectroscopy," W.C. Martin and W.L. Wiese, in *Atomic, Molecular, and Optical Physics Reference Book*, G.W.F. Drake, ed., Amer. Inst. Phys., 1995. The electron configuration for, say, iron indicates an argon electronic core (see argon) plus six 3d electrons and two 4s electrons. The ionization energy is the least energy necessary to remove to infinity one electron from an atom of the element.

٠	Elen	nent	Electron configuration $(3d^5 = \text{five } 3d \text{ electron})$			Ground state ${}^{2S+1}L_J$	Ionization energy (eV)
1	Н	Hydrogen	1s			$^{2}S_{1/2}$	
2	н Не	Helium	$\frac{1s}{1s^2}$			$^{1}S_{0}$	$13.5984 \\ 24.5874$
3	Li	Lithium	(He) 2s			$^{2}S_{1/2}$	5.3917
4	Be	Beryllium	$(\text{He}) 2s^2$			$^{\scriptscriptstyle 1}S_0$	9.3227
5	В	Boron	(He) $2s^2 - 2p$			${}^{2}P_{1/2}$	8.2980
6	C	Carbon	(He) $2s^2 2p^2$ (He) $2s^2 2p^3$			${}^{3}P_{0}^{1/2}$	11.2603
7	N	Nitrogen	(He) $2s^2 2p^3$ (He) $2s^2 2p^4$			$^{4}S_{3/2}^{}_{^{3}P_{2}}$	14.5341
- 8 9	O F	Oxygen Fluorine	(He) $2s^2 - 2p^3$ (He) $2s^2 - 2p^5$			${}^{\circ}P_2$	13.6181
			(He) $2s^2 2p^6$			${}^{2}P_{3/2}$	17.4228
10	Ne	Neon				$\frac{{}^{1}S_{0}}{2}$	21.5646
11	Na	Sodium	(Nc)3s			${}^{2}S_{1/2}$	5.1391
12	Mg	Magnesium	$(Ne) 3s^2$			$^{\scriptscriptstyle 1}S_0$	7.6462
13	Al	Aluminum	(Ne) $3s^2 - 3p$			${}^{2}P_{1/2}$	5.9858
14	Si	Silicon	(Ne) $3s^2 3p^2$			${}^{3}P_{0}$	8.1517
15	P	Phosphorus	(Ne) $3s^2 - 3p^3$			$^{4}S_{3/2}$	10.4867
16	S	Sulfur	(Ne) $3s^2 3p^4$			${}^{3}P_{2}$	10.3600
17	C1	Chlorine	$(\text{Ne}) 3s^2 3p^5$			${}^{2}P_{3/2}$	12.9676
18	Ar	Argon	(Ne) $3s^2 3p^6$			${}^{1}S_{0}$	15.7596
19	K	Potassium	(Ar) 4s			$^{2}S_{1/2}$	4.3407
20	Ca	Calcium	(Ar) $4s^2$			${}^{1}S_{0}$	6.1132
21	Sc	Scandium	$(Ar) 3d 4s^2$	\mathbf{T}		$^{2}D_{3/2}$	6.5615
22	Ti	Titanium	$(Ar) 3d^2 4s^2$	r	e	3F_2	6.8281
23	V	Vanadium	$(Ar) 3d^3 4s^2$	\mathbf{a}	l	${}^{4}F_{3/2}$	6.7463
24	Cr	Chromium	$(\mathrm{Ar})3d^54s$	n	e	$^{\prime}S_{3}$	6.7665
25	Mn	Manganese	$(Ar) 3d^5 4s^2$	s i	\mathbf{m}	$^{6}S_{5/2}$	7.4340
26	Fe	Iron	(Ar) $3d^6 4s^2$	t	e	$^{5}D_{4}$	7.9024
27	$_{\rm Co}$	Cobalt	(Ar) $3d^7 4s^2$	i	n	$^{4}F_{9/2}$	7.8810
28	Ni	Nickel	(Ar) $3d^8 4s^2$	o	t	$^3F_{\prime}$	7.6398
29	Cu	Copper	$({ m Ar})3d^{10}4s$	n	S	${}^{2}S_{1/2}$	7.7264
30	Zn	Zinc	$(Ar) 3d^{10} 4s^2$			$^{1}S_{0}$	9.3942
31	$_{\mathrm{Ga}}$	$\operatorname{Gallium}$	$(Ar) 3d^{10} 4s^2 4p$			$^{2}P_{1/2}$	5.9993
32	Ge	Germanium	(Ar) $3d^{10}4s^2 4p^2$			${}^{3}P_{0}^{1/2}$	7.8994
33	As	Arsenic	$(Ar) 3d^{10} 4s^2 4p^3$			${}^4S_{3/2}$	9.7886
34	Se	Selenium	(Ar) $3d^{10}4s^2 4p^4$			${}^{3}P_{2}$	9.7524
35	Br	Bromine	$(Ar) 3d^{10} 4s^2 4p^5$			${}^{2}P_{3/2}$	11.8138
36	Kr	Krypton	(Ar) $3d^{10}4s^2 4p^6$			$\frac{{}^{1}S_{0}}{{}^{2}S_{0}}$	13.9996
37	Rb	Rubidium	(Kr) 5s			$^{2}S_{1/2}$	4.1771
38	Sr 	Strontium	(Kr) $5s^2$			$^{1}S_{0}$	5.6949
39	Y	Yttrium	$(\mathrm{Kr})4d$ $5s^2$	T		$^{2}D_{3/2}$	6.2171
40	Zr	Zirconium	$({ m Kr})4d^25s^2$	r	e	3F_2	6.6339
41	Nb	Niobium	$(\mathrm{Kr})4d^45s$	\mathbf{a}	1	$^{6}D_{1/2}$	6.7589
42	Mo	Molybdenum	$({\rm Kr}) 4d^5 5s$	n	e	7S_3	7.0924
43	Tc	Technetium	$(Kr) 4d^5 5s^2$	s i	m	$^{6}S_{5/2}$	7.28
44	Ru	Ruthenium	$({\rm Kr})4d^75s$	t	e	${}^{5}F_{5}$	7.3605
45	Rh	Rhodium	$({\rm Kr}) 4d^8 5s$	i	n	$^{4}F_{9/2}$	7.4589
46	Pd	Palladium	$(Kr) 4d^{10}$	o	t s	${}^{1}S_{0}$	8.3369
47	Ag	Silver	$(Kr) 4d^{10} 5s$	n	5	$^{2}S_{1/2}$	7.5763
48	Cd	Cadmium	$({ m Kr})4d^{10}5s^2$			$^{1}S_{0}$	8.9938

49	In	Indium	$({ m Kr})4d^{10}5s^25p$		$^{2}P_{1/2}$	5.7864
50	Sn	Tin	$(Kr) 4d^{10} 5s^2 5p^2$		${}^{3}P_{0}^{1/2}$	7.3439
51	Sb	Antimony	$(Kr) 4d^{10} 5s^2 5p^3$		${}^4S_{3/2}$	8.6084
52	Te	Tellurium	$(Kr) 4d^{10} 5s^2 5p^4$		${}^{3}P_{2}^{-3/2}$	9.0096
53	I	Iodine	$(Kr) 4d^{10} 5s^2 5p^5$		${}^{2}P_{3/2}$	10.4513
54	Xe	Xenon	$(Kr) 4d^{10} 5s^2 5p^6$		${}^{1}S_{0}^{3/2}$	12.1298
55	Cs	Cesium	(Xe) 6s		${}^{2}S_{1/2}$	3.8939
56	$_{ m Ba}$	Barium	(Xe) $6s^2$		${}^{1}S_{0}^{1/2}$	5.2117
 57	La	- $ -$	(Xe) $5d 6s^2$		$^{2}D_{3/2}$	5.5770
58	Ce	Cerium	$(Xe) 4f 5d 6s^2$		1G_4	5.5387
59	$\frac{\mathrm{Ce}}{\mathrm{Pr}}$	Praseodymium	$(Xe)4f^3$ $6s^2$	L	$^{4}I_{9/2}$	5.3367 5.464
	Nd	·	$(Xe)4f$ $6s^2$	a	${}^{19/2}_{5}I_{4}$	
$\frac{60}{61}$	Pm	Neodymium Promethium	$(Xe)4f^5$ $6s^2$	a	${}^{6}H_{5/2}$	5.5250 5.58
	Sm		$(Xe)4f$ 0s $(Xe)4f^6$ 6s ²	n	${}^{7}F_{0}^{F_{5/2}}$	
$\frac{62}{63}$	Eu	Samarium	$(Xe)4f^{7} = 6s^{2}$ $(Xe)4f^{7} = 6s^{2}$	t	8 C	5.6436 5.6704
		Europium	$(Xe)4f^7 \ 5d \ 6s^2$	h	${}^8S_{7/2} \ {}^9D_2$	
64	$\frac{\mathrm{Gd}}{\mathrm{Tb}}$	Gadolinium	$(Xe)4f^{9}$ $6s^{2}$	\mathbf{a}	$^{\circ}D_{2}$	6.1501
65		Terbium	$(Xe)4f^{10}$ $6s^{2}$ $(Xe)4f^{10}$ $6s^{2}$	n	$^{6}H_{15/2}$	5.8638
66	Dy	Dysprosium	$\begin{array}{ccc} ({ m Xe}) 4f^{10} & 6s^2 \ ({ m Xe}) 4f^{11} & 6s^2 \end{array}$	i	${}^{5}I_{8}$	5.9389
67	Но	Holmium		$^{\mathrm{d}}$	$^{4}I_{15/2}$	6.0215
68	Er	Erbium	$\begin{array}{ccc} ({ m Xe})4f^{12} & 6s^2 \ ({ m Xe})4f^{13} & 6s^2 \end{array}$	е	${}^{3}H_{6}$	6.1077
69	Tm	Thulium	$(Xe)4f^{13}$ $6s^2$	S	${}^{2}F_{7/2}$	6.1843
70	Yb	Ytterbium	$(Xe)4f^{14}$ $6s^2$		${}^{1}S_{0}^{'}$	6.2542
71	Lu	Lutetium	$(Xe)4f^{14}5d 6s^2$		$^{2}D_{3/2}$	5.4259
72	$_{ m Hf}$	Hafnium	$(Xe)4f^{14}5d^2 6s^2$	T	$^{3}F_{2}$	6.8251
73	Ta	Tantalum	$(Xe)4f^{14}5d^3 6s^2$	r e	$^{4}F_{3/2}$	7.5496
74	W	Tungsten	$(Xe)4f^{14}5d^4 6s^2$	a l	$^{5}D_{0}$	7.8640
75	Re	Rhenium	$(Xe)4f^{14}5d^5 6s^2$	n e	$^{6}S_{5/2}$	7.8335
76	Os	Osmium	$(Xe)4f^{14}5d^6 6s^2$	s m	$^{5}D_{4}^{^{0/2}}$	8.28
77	Ir	Iridium	$(Xe)4f^{14}5d^7 6s^2$	i e	$^{4}F_{9/2}$	9.02
78	Pt	Platinum	$(Xe)4f^{14}5d^9 6s$	t n	$^{3}D_{3}^{^{3/2}}$	8.9587
79	Au	Gold	$(Xe)4f^{14}5d^{10}6s$	i t	$2S_{1/2}$	9.2255
80	$_{\mathrm{Hg}}$	Mercury	$(\text{Xe})4f^{14}5d^{10}6s^2$	o n	${}^{1}S_{0}^{1/2}$	10.4375
81	Tl	Thallium	$(Xe)4f^{14}5d^{10}6s^2$ 6p		${}^{2}P_{1/2}$	6.1082
82	Pb	Lead	(Xe) $4f^{14}5d^{10}6s^2$ $6p^2$		${}^{3}P_{0}^{1/2}$	7.4167
83	Bi	Bismuth	$(\text{Xe})4f^{14}5d^{10}6s^2 6p^3$		${}^4S_{3/2}$	7.2856
84	Po	Polonium	(Xe) $4f^{14}5d^{10}6s^2 6p^4$		${}^{3}P_{2}$	8.4167
85	At	Astatine	$(Xe)4f^{14}5d^{10}6s^2 6p^5$		${}^{2}P_{3/2}$	0.4107
86	Rn	Radon	$(\text{Xe})4f^{14}5d^{10}6s^2 6p^6$		${}^{1}S_{0}^{3/2}$	10.7485
87	Fr	Francium	(Rn) 7s		$^{2}S_{1/2}$	4.0727
88	Ra	Radium	(Rn) $7s^2$		1S_0	5.2784
89	Ac	Actinium	(Rn) $6d 7s^2$		$^{2}D_{3/2}$	5.17
90	Th	Thorium	(Rn) $6d^2 7s^2$		$^{3}F_{2}$	6.3067
91	Pa	Protactinium	$(Rn)5f^2 \ 6d \ 7s^2$	A	$^{4}K_{11/2}$	5.89
92	U	Uranium	$(Rn)5f^3 6d 7s^2$	c	$^{5}L_{6}$	6.1941
93	Np	Neptunium	$(Rn)5f^4 6d 7s^2$	t	$^{6}L_{11/2}$	6.2657
94	Pu	Plutonium	$(Rn)5f^6$ $7s^2$	i	$^{7}F_{0}$	6.0262
95	Am	Americium	$(Rn)5f^7$ $7s^2$	n	$^{8}S_{7/2}$	5.9738
96	Cm	Curium	$(Rn)5f^7 6d 7s^2$	i J	$^{9}D_{2}$	6.02
97	Bk	Berkelium	$(Rn)5f^9$ $7s^2$	d	$^{6}H_{15/2}$	6.23
98	Cf	Californium	$(Rn)5f^{10}$ $7s^2$	c s	$^{5}I_{8}$	6.30
99	$_{\mathrm{Es}}$	Einsteinium	$(Rn)5f^{11}$ $7s^2$	3	$^{4}I_{15/2}$	6.42
100	Fm	Fermium	$(Rn)5f^{12}$ $7s^2$		$^{3}H_{6}$	6.50
101	Md	Mendelevium	$(\text{Rn})5f^{13}$ $7s^2$		${}^{2}F_{7/2}$	6.58
102	No	Nobelium	$(\text{Rn})5f^{14}$ $7s^2$		${}^{1}S_{0}^{7/2}$	6.65
103	$_{ m Lr}$	Lawrencium	$(\text{Rn})5f^{14}$ $7s^2$ $7p$?		${}^{2}P_{1/2}$?	
104	Rf	Rutherfordium	$(\text{Rn})5f^{14}6d^2 \ 7s^2$?		$^{3}F_{2}$?	6.0?
			(/-)		- 4.	

6. ATOMIC AND NUCLEAR PROPERTIES OF MATERIALS

Table 6.1. Table revised May 1996. Gases are evaluated at 20°C and 1 atm (in parentheses) or at STP [square brackets]. Densities and refractive indices without parentheses or brackets are for solids or liquids, or are for cryogenic liquids at the indicated boiling point (BP) at 1 atm. Refractive indices are evaluated at the sodium D line.

Material	Z	A	$egin{array}{c} ext{Nuclear}^a \ ext{total} \ ext{cross} \ ext{section} \end{array}$	Nuclear ^b inelastic cross section		Nuclear c interaction length λ_I	$\left. \frac{dE/dx _{\min}^{ d}}{\left\{ \frac{\text{MeV}}{\text{g/cm}^2} \right\}} \right.$		tion length e X_0 A^2 {cm}	$\{g/cm^2\}$	Refractive index n $(n-1)\times 10^6$ for gas)
			σ_T {barn}	σ_I {barn}	${\rm g/cm^2}$					3 /	ioi gas)
H ₂ gas	1	1.01	0.0387	0.033	43.3	50.8	(4.103)	63.05	(752300)	(0.0838)[0.0899]	[139.2]
H ₂ (BP 20.39		1.01	0.0387	0.033	43.3	50.8	$\frac{(4.100)}{4.045}f$	63.05	890	0.0708	1.112
D_2 (BP 23.65	,	2.01	0.073	0.061	45.7	54.7	(2.052)	125.98	754	0.169[0.179]	
He (BP 4.224	,	4.00	0.133	0.102	49.9	65.1	(1.937)	94.32	756	0.1248[0.1786]	
Li	3	6.94	0.211	0.157	54.6	73.4	1.639	82.76	155	0.534	
Be	4	9.01	0.268	0.199	55.8	75.2	1.594	65.19	35.3	1.848	
C	6	12.01	0.331	0.231	60.2	86.3	1.745	42.70	18.8	$2.265 ^{g}$	
N ₂ (BP 77.36		14.01	0.379	0.265	61.4	87.8	(1.825)	37.99	47.1	0.8073[1.250]	1.205 [298]
O_2 (BP 90.18	,	16.00	0.420	0.292	63.2	91.0	(1.801)	34.24	30.0	1.141[1.428]	1.22 [296]
Ne (BP 27.09		20.18	0.507	0.347	66.1	96.6	(1.724)	28.94	24.0	1.206[0.9003]	
Al	13	26.98	0.634	0.421	70.6	106.4	1.615	24.01	8.9	2.70	
Si	14	28.09	0.660	0.440	70.6	106.0	1.664	21.82	9.36	2.33	-
Ar (BP 87.28	K) 18	39.95	0.868	0.566	76.4	117.2	(1.519)	19.55	14.0	1.393[1.782]	1.233 [283]
Ti	22	47.88	0.995	0.637	79.9	124.9	1.476	16.17	3.56	4.54	
Fe	26	55.85	1.120	0.703	82.8	131.9	1.451	13.84	1.76	7.87	
Cu	29	63.55	1.232	0.782	85.6	134.9	1.403	12.86	1.43	8.96	
Ge	32	72.59	1.365	0.858	88.3	140.5	1.371	12.25	2.30	5.323	
Sn	50	118.69	1.967	1.21	100.2	163	1.264	8.82	1.21	7.31	
Xe (BP 165.0	K) 54	131.29	2.120	1.29	102.8	169	(1.255)	8.48	2.40	3.52[5.858]	[701]
W	74	183.85	2.767	1.65	110.3	185	1.145	6.76	0.35	19.3	
Pt	78	195.08	2.861	1.708	113.3	189.7	1.129	6.54	0.305	21.45	
Pb	82	207.19	2.960	1.77	116.2	194	1.123	6.37	0.56	11.35	manana.
U	92	238.03	3.378	1.98	117.0	199	1.082	6.00	≈ 0.32	≈ 18.95	
Air, (20°C, 1 a	tm.). [9	STP1			62.0	90.0	(1.815)	36.66	[30420]	(1.205)[1.2931]	(273) [293]
H_2O	,, [-	1			60.1	84.9	1.991	36.08	36.1	1.00	1.33
CO_2					62.4	90.5	(1.819)	36.2	[18310]	[1.977]	[410]
Shielding concr	ete h				67.4	99.9	1.711	26.7	10.7	2.5	
Borosilicate gla		$rex)^i$			66.2	97.6	1.695	28.3	12.7	2.23	1.474
SiO ₂ (fused qu)			67.0	99.2	1.70^{j}	27.05	12.3	$2.20^{\ k}$	1.458
Methane (CH ₄		11 7 K)			54.7	74.0	(2.417)	46.5	[64850]	0.4241[0.717]	[444]
Ethane (C_2H_6)	, ,	,			55.73	74.0 75.71	(2.304)		[34035]	0.4241[0.717] 0.509(1.356)	
Propane (C_3H_6)							(2.304) (2.262)	45.66	[34033]	(1.879)	(1.036)
Isobutane (CH	* . *		P 261 42 K)		56.3	77.4	(2.232) (2.239)	45.2	[16930]	[2.67]	[1900]
Octane, liquid							2.123	40.2	[10330]	0.703	[1900]
Paraffin wax (C			1		-	-	2.087	-		0.93	
	3113(01	12/11 0113,	(10) 10 20)								
Nylon, type 6	(T	`			MARKET		1.974		Name and Associated Association (Associated Associated	1.14	
Polycarbonate	`	/) (C II O)		CO 0	05.77	1.886	20.05	90.7	1.200	
Polyethylene to	-	, -			60.2	85.7	1.848	39.95	28.7	1.39	
Polyethylene (r			$CH_2)$		56.9	78.8	2.076	44.8	≈ 47.9	0.92-0.95	_
Polyimide film Polymethylmet			o Plovidled)		59.2	83.6	1.820	40.55	≈34.4	$1.420 \\ 1.16 - 1.20$	~1.40
			$CO_2CH_3)$		39.2	63.0	1.929	40.55	≈34.4	1.10~1.20	≈ 1.49
Polystyrene, sc				-CH ₂)	58.4	82.0	1.936	43.8	42.4	1.032	1.581
Polytetrafluoro				-/			1.671	40.0	42.4	2.20	1.001
Polyvinyltolule							1.956			1.032	
				0					2.05		1.56
Barium fluoride		-/	(Goo Oct.)		92.1	146 156	1.303	9.91	2.05	4.89	1.56
Bismuth germa Cesium iodide	,	ogo) (Di	4G03O12)		97.4	$156 \\ 167$	$1.251 \\ 1.243$	$7.98 \\ 8.38$	$\frac{1.12}{1.85}$	$7.1 \\ 4.53$	$\frac{2.15}{1.80}$
Cesium iodide Lithium fluorid		١			62.00	88.24	1.614	39.25	1.65	$\frac{4.53}{2.632}$	1.392
Sodium fluorid	, ,				66.78	97.57	1.614	$\frac{39.23}{29.87}$	11.68	2.558	1.332 1.336
Sodium iodide		,			94.8	152	1.305	9.49	$\frac{11.08}{2.59}$	3.67	1.775
	· ,										
Silica Aerogel ⁿ					65.5	95.7	1.83	29.85	≈150	0.1-0.3	$1.0 + 0.25 \rho$
NEMA G10 pla	ate"				62.6	90.2	1.87	33.0	19.4	1.7	

Material	Dielectric	Young's	Coeff. of	Specific	Electrical	Thermal
	constant $(\kappa = \epsilon/\epsilon_0)$	modulus	thermal	heat	resistivity	conductivity
	() is $(\kappa-1)\times10^6$	$[10^6 \text{ psi}]$	expansion	[cal/g-°C]	$[\mu\Omega \text{cm}(@^{\circ}\text{C})]$	[cal/cm-°C-sec]
	for gas	[- 1 -]	$[10^{-6} \mathrm{cm/cm}\text{-}^{\circ}\mathrm{C}]$, , ,	U (//	. , ,
$_{ m H_2}$	(253.9)					
He	(64)	********	name of the second seco			
Li	-		56	0.86	8.55(0°)	0.17
Be	_	37	12.4	0.436	$5.885(0^{\circ})$	0.38
C		0.7	0.6-4.3	0.165	1375(0°)	0.057
N_2	(548.5)					-
O_2	(495)		with a second of the second of			ALCO COMPANIES
Ne	(127)		Minimistry	Wildiams		-
Al	MARINE AND	10	23.9	0.215	$2.65(20^{\circ})$	0.53
Si	11.9	16	2.8 – 7.3	0.162		0.20
Ar	(517)			Morrows	_	
Ti	Miles .	16.8	8.5	0.126	50(0°)	amorane
Fe		28.5	11.7	0.11	9.71(20°)	0.18
Cu		16	16.5	0.092	1.67(20°)	0.94
Ge	16.0		5.75	0.073		0.14
Sn	Administration	6	20	0.052	$11.5(20^{\circ})$	0.16
Xe	-	-	manus.			
W		50	4.4	0.032	$5.5(20^{\circ})$	0.48
Pt		21	8.9	0.032	$9.83(0^{\circ})$	0.17
Pb		2.6	29.3	0.038	$20.65(20^{\circ})$	0.083
U			36.1	0.028	29(20°)	0.064

 σ_T , σ_I , λ_T , and λ_I are energy dependent. Values quoted apply to high energy range given in footnote a or b, where energy dependence is weak

- a. $\sigma_{\rm total}$ at 80–240 GeV for neutrons ($\approx \sigma$ for protons) from Murthy et al., Nucl. Phys. **B92**, 269 (1975). This scales approximately as $A^{0.77}$.
- b. $\sigma_{\text{inelastic}} = \sigma_{\text{total}} \sigma_{\text{elastic}} \sigma_{\text{quasielastic}}$; for neutrons at 60–375 GeV from Roberts et al., Nucl. Phys. **B159**, 56 (1979). For protons and other particles, see Carroll et al., Phys. Lett. **80B**, 319 (1979); note that $\sigma_I(p) \approx \sigma_I(n)$. σ_I scales approximately as $A^{0.71}$.
- c. Mean free path between collisions (λ_I) or inelastic interactions (λ_I) , calculated from $\lambda = A/(N \times \sigma)$, where N is Avogadro's number.
- d. For minimum-ionizing heavy particles (calculated for pions; results are very slightly different for other particles). Minimum dE/dx calculated in 1994, using density effect correction coefficients from R. M. Sternheimer, M. J. Berger, and S. M. Seltzer, Atomic Data and Nuclear Data Tables 30, 261–271 (1984). For electrons and positrons see S.M. Seltzer and M.J. Berger, Int. J. Appl. Radiat. 35, 665–676 (1984). Ionization energy loss is discussed in Sec. 22.
- e. From Y.S. Tsai, Rev. Mod. Phys. 46, 815 (1974); X₀ data for all elements up to uranium are given. Corrections for molecular binding applied for H₂ and D₂.
- f. Density effect constants evaluated for $\rho = 0.0600 \text{ g/cm}^3$ (H₂ bubble chamber?).
- g. For pure graphite; industrial graphite density may vary 2.1-2.3 g/cm³.
- h. Standard shielding blocks, typical composition O_2 52%, Si 32.5%, Ca 6%, Na 1.5%, Fe 2%, Al 4%, plus reinforcing iron bars. The attenuation length, $\ell=115\pm5$ g/cm², is also valid for earth (typical $\rho=2.15$), from CERN-LRL-RHEL Shielding exp., UCRL-17841 (1968).
- i. Main components: $80\% \text{ SiO}_2 + 12\% \text{ B}_2\text{O}_3 + 5\% \text{ Na}_2\text{O}$.
- j. Calculated using Sternheimer's density effect parameterization for $\rho = 2.32$ g cm⁻³. Actual value may be slightly lower.
- k. For typical fused quartz. The specific gravity of crystalline quartz is 2.64.
- ℓ. Solid ethane density at −60°C; gaseous refractive index at 0°C, 546 mm pressure.
- m. $n(SiO_2) + 2n(H_2O)$ used in Čerenkov counters, $\rho = \text{density in g/cm}^3$. From M. Cantin et al., Nucl. Instr. and Meth. 118, 177 (1974).
- n. G10-plate, typical 60% SiO₂ and 40% epoxy.

7. ELECTROMAGNETIC RELATIONS

Quantity	Gaussian CGS	SI
Conversion factors:		
Charge:	$2.997\ 924\ 58 \times 10^9\ \mathrm{esu}$	= 1 C = 1 A s
Potential:	(1/299.792 458) statvolt (ergs/esu)	$= 1 \text{ V} = 1 \text{ J C}^{-1}$
Magnetic field:	$10^4 \text{ gauss} = 10^4 \text{ dyne/esu}$	$= 1 \text{ T} = 1 \text{ N A}^{-1} \text{m}^{-1}$
Lorentz force:	$\mathbf{F} = q\left(\mathbf{E} + \frac{\mathbf{v}}{c} \times \mathbf{B}\right)$	$\mathbf{F} = q\left(\mathbf{E} + \mathbf{v} \times \mathbf{B}\right)$
Maxwell equations:	$\nabla \cdot \mathbf{D} = 4\pi \rho$	$\nabla \cdot \mathbf{D} = \rho$
	$\nabla \times \mathbf{H} - \frac{1}{c} \frac{\partial \mathbf{D}}{\partial t} = \frac{4\pi}{c} \mathbf{J}$	$\nabla \times \mathbf{H} - \frac{\partial \mathbf{D}}{\partial t} = \mathbf{J}$
	$\nabla \cdot \mathbf{B} = 0$	$\nabla \cdot \mathbf{B} = 0$
	$\nabla \times \mathbf{E} + \frac{1}{c} \frac{\partial \mathbf{B}}{\partial t} = 0$	$\nabla \times \mathbf{E} + \frac{\partial \mathbf{B}}{\partial t} = 0$
Constitutive relations:	$\mathbf{D} = \mathbf{E} + 4\pi \mathbf{P}, \mathbf{H} = \mathbf{B} - 4\pi \mathbf{M}$	$\mathbf{D} = \epsilon_0 \mathbf{E} + \mathbf{P}, \mathbf{H} = \mathbf{B}/\mu_0 - \mathbf{M}$
Linear media:	$\mathbf{D} = \epsilon \mathbf{E}, \mathbf{H} = \mathbf{B}/\mu$	$\mathbf{D} = \epsilon \mathbf{E}, \mathbf{H} = \mathbf{B}/\mu$
Permitivity of free space:	1	$\epsilon_0 = 8.854 \ 187 \dots \times 10^{-12} \ \mathrm{F \ m^{-1}}$
Permeability of free space:	1	$\mu_0 = 4\pi \times 10^{-7} \text{ N A}^{-2}$
Fields from potentials:	$\mathbf{E} = -\nabla V - \frac{1}{c} \frac{\partial \mathbf{A}}{\partial t}$	$\mathbf{E} = -\nabla V - \frac{\partial \mathbf{A}}{\partial t}$
	$\mathbf{B} = \mathbf{\nabla} \times \mathbf{A}$	$\mathbf{B} = \mathbf{\nabla} \times \mathbf{A}$
Static potentials: (coulomb gauge)	$V = \sum_{\text{charges}} \frac{q_i}{r_i} = \int \frac{\rho(\mathbf{r}')}{ \mathbf{r} - \mathbf{r}' } d^3x'$	$V = \frac{1}{4\pi\epsilon_0} \sum_{\text{charges}} \frac{q_i}{r_i} = \frac{1}{4\pi\epsilon_0} \int \frac{\rho(\mathbf{r}')}{ \mathbf{r} - \mathbf{r}' } d^3x'$
	$\mathbf{A} = \frac{1}{c} \sum_{\text{currents}} \frac{\mathbf{I}_i}{r_i} = \frac{1}{c} \int \frac{\mathbf{J}(\mathbf{r}')}{ \mathbf{r} - \mathbf{r}' } d^3 x'$	$\mathbf{A} = \frac{\mu_0}{4\pi} \sum_{\text{currents}} \frac{\mathbf{I}_i}{r_i} = \frac{\mu_0}{4\pi} \int \frac{\mathbf{J}(\mathbf{r}')}{ \mathbf{r} - \mathbf{r}' } d^3x'$
Relativistic transformations:	$\mathbf{E}_{\parallel}' = \mathbf{E}_{\parallel}$	$\mathbf{E}_{\parallel}' = \mathbf{E}_{\parallel}$
(v is the velocity of the primed frame as seen	$\mathbf{E}'_{\perp} = \gamma(\mathbf{E}_{\perp} + \frac{1}{c}\mathbf{v} \times \mathbf{B})$	$\mathbf{E}'_{\perp} = \gamma (\mathbf{E}_{\perp} + \mathbf{v} \times \mathbf{B})$
in the unprimed frame)	$\mathbf{B}_{\parallel}' = \mathbf{B}_{\parallel}$	$\mathbf{B}'_{\parallel} = \mathbf{B}_{\parallel}$
	$\mathbf{B}'_{\perp} = \gamma(\mathbf{B}_{\perp} - \frac{1}{c}\mathbf{v} \times \mathbf{E})$	$\mathbf{B}'_{\perp} = \gamma (\mathbf{B}_{\perp} - \frac{1}{c^2} \mathbf{v} \times \mathbf{E})$
$\frac{1}{4\pi\epsilon_0} = c^2 \times 10^{-7} \text{ N A}^{-2} = 8.9$	$87.55 \times 10^9 \text{ m F}^{-1}$; $\frac{\mu_0}{4\pi} = 10^{-7} \text{ N A}$	$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}} = 2.99792458 \times 10^8 \text{ m s}^{-1}$

7.1. Impedances (SI units)

 ρ = resistivity at room temperature in $10^{-8} \Omega$ m:

For alternating currents, instantaneous current I, voltage V, angular frequency $\omega\colon$

$$V = V_0 e^{j\omega t} = ZI . (7.1)$$

Impedance of self-inductance L: $Z = j\omega L$.

Impedance of capacitance C: $Z = 1/j\omega C$.

Impedance of free space: $Z = \sqrt{\mu_0/\epsilon_0} = 376.7 \ \Omega$.

High-frequency surface impedance of a good conductor:

$$Z = \frac{(1+j) \rho}{\delta}$$
, where $\delta = \text{skin depth}$; (7.2)

$$\delta = \sqrt{\frac{\rho}{\pi \nu \mu}} \approx \frac{6.6 \text{ cm}}{\sqrt{\nu (\text{Hz})}} \text{ for Cu}.$$
 (7.3)

7.2. Capacitance \widehat{C} and inductance \widehat{L} per unit length (SI units) [negligible skin depth]

Flat rectangular plates of width w, separated by $d \ll w$ with linear medium (ϵ,μ) between:

$$\widehat{C} = \epsilon \frac{w}{d}; \qquad \widehat{L} = \mu \frac{d}{w};$$
 (7.4)

$$\epsilon/\epsilon_0 = 2$$
 to 6 for plastics; 4 to 8 for porcelain, glasses; (7.5)

$$\mu/\mu_0 \simeq 1 \ . \tag{7.6}$$

Coaxial cable of inner radius r_1 , outer radius r_2 :

$$\widehat{C} = \frac{2\pi \epsilon}{\ln (r_2/r_1)} \; ; \quad \widehat{L} = \frac{\mu}{2\pi} \ln (r_2/r_1) \; .$$
 (7.7)

Transmission lines (no loss):

Impedance:
$$Z = \sqrt{\hat{L}/\hat{C}}$$
. (7.8)

Velocity:
$$v = 1/\sqrt{\hat{L} \hat{C}} = 1/\sqrt{\mu \epsilon}$$
. (7.9)

7.3. Synchrotron radiation (CGS units)

For a particle of charge e, velocity $v=\beta c$, and energy $E=\gamma mc^2$, traveling in a circular orbit of radius R, the classical energy loss per revolution δE is

$$\delta E = \frac{4\pi}{3} \, \frac{e^2}{R} \, \beta^3 \, \gamma^4 \, . \tag{7.10}$$

For high-energy electrons or positrons ($\beta \approx 1$), this becomes

$$\delta E \text{ (in MeV)} \approx 0.0885 \ [E(\text{in GeV})]^4 / R(\text{in m}) \ .$$
 (7.11)

For $\gamma\gg 1$, the energy radiated per revolution into the photon energy interval $d(\hbar\omega)$ is

$$dI = \frac{8\pi}{9} \alpha \gamma F(\omega/\omega_c) d(h\omega) , \qquad (7.12)$$

where $\alpha = e^2/\hbar c$ is the fine-structure constant and

$$\omega_c = \frac{3\gamma^3 c}{2R} \tag{7.13}$$

is the critical frequency. The normalized function F(y) is

$$F(y) = \frac{9}{8\pi} \sqrt{3} \ y \ \int_y^\infty \ K_{5/3} \left(x \right) \ dx \ , \tag{7.14}$$

where $K_{5/3}\left(x\right)$ is a modified Bessel function of the third kind. For electrons or positrons,

$$\hbar\omega_c \,(\mathrm{in\ keV}) \approx 2.22 \,[E(\mathrm{in\ GeV})]^3/R(\mathrm{in\ m}) \,.$$
 (7.15)

Fig. 7.1 shows F(y) over the important range of y.

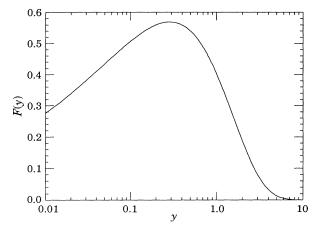


Figure 7.1: The normalized synchrotron radiation spectrum F(y).

For $\gamma \gg 1$ and $\omega \ll \omega_c$,

$$\frac{dI}{d(\hbar\omega)} \approx 3.3\alpha \, (\omega R/c)^{1/3} \quad , \tag{7.16}$$

whereas for

 $\gamma \gg 1$ and $\omega \gtrsim 3\omega_c$,

$$\frac{dI}{d(h\omega)} \approx \sqrt{\frac{3\pi}{2}} \, \alpha \, \gamma \left(\frac{\omega}{\omega_c}\right)^{1/2} e^{-\omega/\omega_c} \left[1 + \frac{55}{72} \frac{\omega_c}{\omega} + \ldots\right] \quad . \tag{7.17}$$

The radiation is confined to angles $\lesssim 1/\gamma$ relative to the instantaneous direction of motion. The mean number of photons emitted per revolution is

$$N_{\gamma} = \frac{5\pi}{\sqrt{3}} \alpha \gamma \,\,, \tag{7.18}$$

and the mean energy per photon is

$$\langle h\omega \rangle = \frac{8}{15\sqrt{3}} h\omega_c \ . \tag{7.19}$$

When $\langle \hbar \omega \rangle \gtrsim O(E)$, quantum corrections are important.

See J.D. Jackson, Classical Electrodynamics, $2^{\rm nd}$ edition (John Wiley & Sons, New York, 1975) for more formulae and details. In his book, Jackson uses a definition of ω_c that is twice as large as the customary one given above.

8. NAMING SCHEME FOR HADRONS

8.1. Introduction

We introduced in the 1986 edition [1] a new naming scheme for the hadrons. Changes from older terminology affected mainly the heavier mesons made of the light $(u,\,d,\,{\rm and}\,s)$ quarks. Old and new names were listed alongside until 1994. Names also change from edition to edition because some characteristic like mass or spin changes. The Summary Tables give both the new and old names whenever a change occurred.

8.2. "Neutral-flavor" mesons (S=C=B=T=0)

Table 8.1 shows the names for mesons having the strangeness and all heavy-flavor quantum numbers equal to zero. The scheme is designed for all ordinary non-exotic mesons, but it will work for many exotic types too, if needed.

Table 8.1: Symbols for mesons with the strangeness and all heavy-flavor quantum numbers equal to zero.

	$J^{PC} =$	$\begin{cases} 0^{-+} \\ 2^{-+} \\ \vdots \end{cases}$	1 ⁺⁻ 3 ⁺⁻ :	1 2 :	0 ⁺⁺ 1 ⁺⁺ :
$q\overline{q}$ content	$^{2S+1}L_J =$	$^1(L \mathrm{even})_J$	$^1(L \operatorname{odd})_J$	$^3(L {\rm even})_J$	$^3(L \text{ odd})_J$
$\overline{u\overline{d},u\overline{u}-d\overline{d},}$		π	b	ρ	\overline{a}
$\frac{d\overline{d} + u\overline{u}}{\text{and/or } s\overline{s}}$	$ \} (I=0)$	η,η'	h,h'	ω,ϕ	f,f'
$c\overline{c}$		η_c	h_c	ψ^{\dagger}	χ_c
$b\overline{b}$		η_b	h_b	Υ	χ_b
$t\bar{t}$		η_t	h_t	θ	χ_t

[†]The J/ψ remains the J/ψ .

First, we assign names to those states with quantum numbers compatible with being $q\overline{q}$ states. The rows of the Table give the possible $q\overline{q}$ content. The columns give the possible parity/charge-conjugation states,

$$PC = -+, +-, --, \text{ and } ++;$$

these combinations correspond one-to-one with the angular-momentum state $^{2S+1}L_J$ of the $q\overline{q}$ system being

$$^{1}(L \text{ even})_{J}$$
, $^{1}(L \text{ odd})_{J}$, $^{3}(L \text{ even})_{J}$, or $^{3}(L \text{ odd})_{J}$.

Here $S,\ L,$ and J are the spin, orbital, and total angular momenta of the $q\overline{q}$ system. The quantum numbers are related by

$$P = (-1)^{L+1}$$
, $C = (-1)^{L+S}$, and G parity $= (-1)^{L+S+I}$,

where of course the C quantum number is only relevant to neutral mesons.

The entries in the Table give the meson names. The spin J is added as a subscript except for pseudoscalar and vector mesons, and the mass is added in parentheses for mesons that decay strongly. However, for the lightest meson resonances, we omit the mass.

Measurements of the mass, quark content (where relevant), and quantum numbers $I,\ J,\ P,$ and C (or G) of a meson thus fix its symbol. Conversely, these properties may be inferred unambiguously from the symbol.

If the main symbol cannot be assigned because the quantum numbers are unknown, X is used. Sometimes it is not known whether a meson is mainly the isospin-0 mix of $u\overline{u}$ and $d\overline{d}$ or is mainly $s\overline{s}$. A prime (or pair ω , ϕ) may be used to distinguish two such mixing states.

We follow custom and use spectroscopic names such as $\Upsilon(1S)$ as the primary name for most of those ψ , Υ , and χ states whose spectroscopic identity is known. We use the form $\Upsilon(9460)$ as an alternative, and as the primary name when the spectroscopic identity is not known.

Names are assigned for $t\overline{t}$ mesons, although the top quark is evidently so heavy that it is expected to decay too rapidly for bound states to form.

Gluonium states or other mesons that are not $q\overline{q}$ states are, if the quantum numbers are *not* exotic, to be named just as are the $q\overline{q}$ mesons. Such states will probably be difficult to distinguish from $q\overline{q}$ states and will likely mix with them, and we make no attempt to distinguish those "mostly gluonium" from those "mostly $q\overline{q}$."

An "exotic" meson with J^{PC} quantum numbers that a $q\overline{q}$ system cannot have, namely $J^{PC}=0^{--},0^{+-},1^{-+},2^{+-},3^{-+},\cdots$, would use the same symbol as does an ordinary meson with all the same quantum numbers as the exotic meson except for the C parity. But then the J subscript may still distinguish it; for example, an isospin-0 1⁻⁺ meson could be denoted ω_1 .

8.3. Mesons with nonzero S, C, B, and/or T

Since the strangeness or a heavy flavor of these mesons is nonzero, none of them are eigenstates of charge conjugation, and in each of them one of the quarks is heavier than the other. The rules are:

1. The main symbol is an upper-case italic letter indicating the heavier quark as follows:

$$s \to \overline{K}$$
 $c \to D$ $b \to \overline{B}$ $t \to T$.

We use the convention that the flavor and the charge of a quark have the same sign. Thus the strangeness of the s quark is negative, the charm of the c quark is positive, and the bottom of the b quark is negative. In addition, I_3 of the u and d quarks are positive and negative, respectively. The effect of this convention is as follows: Any flavor carried by a charged meson has the same sign as its charge. Thus the K^+ , D^+ , and B^+ have positive strangeness, charm, and bottom, respectively, and all have positive I_3 . The D_s^+ has positive charm and strangeness. Furthermore, the $\Delta({\rm flavor}) = \Delta Q$ rule, best known for the kaons, applies to every flavor.

- 2. If the lighter quark is not a u or a d quark, its identity is given by a subscript. The D_s^+ is an example.
- 3. If the spin-parity is in the "normal" series, $J^P=0^+,1^-,2^+,\cdots$, a superscript "*" is added.
- The spin is added as a subscript except for pseudoscalar or vector mesons.

8.4. Baryons

The symbols N, Δ , A, Σ , Ξ , and Ω used for more than 30 years for the baryons made of light quarks (u, d, and s quarks) tell the isospin and quark content, and the same information is conveyed by the symbols used for the baryons containing one or more heavy quarks (c, b, and t quarks). The rules are:

- 1. Baryons with three u and/or d quarks are N's (isospin 1/2) or Δ 's (isospin 3/2).
- 2. Baryons with $two\ u$ and/or d quarks are A's (isospin 0) or Σ 's (isospin 1). If the third quark is a $c,\ b,$ or t quark, its identity is given by a subscript.
- Baryons with one u or d quark are \(\mathcal{Z}\)'s (isospin 1/2). One or two subscripts are used if one or both of the remaining quarks are heavy: thus \(\mathcal{Z}_c\), \(\mathcal{Z}_{cc}\), \(\mathcal{Z}_b\), etc.
- Baryons with no u or d quarks are Ω's (isospin 0), and subscripts indicate any heavy-quark content.

In short, the number of u plus d quarks together with the isospin determine the main symbol, and subscripts indicate any content of heavy quarks. A Σ always has isospin 1, an Ω always has isospin 0,

Reference:

 Particle Data Group: M. Aguilar-Benitez et al., Phys. Lett. 170B (1986).

9. QUANTUM CHROMODYNAMICS

9.1. The QCD Lagrangian

Prepared August 1995 by I. Hinchliffe.

Quantum Chromodynamics (QCD), the gauge field theory which describes the strong interactions of colored quarks and gluons, is one of the components of the $SU(3)\times SU(2)\times U(1)$ Standard Model. A quark of specific flavor (such as a charm quark) comes in 3 colors; gluons come in eight colors; hadrons are color-singlet combinations of quarks, anti-quarks, and gluons. The Lagrangian describing the interactions of quarks and gluons is (up to gauge-fixing terms)

$$L_{\text{QCD}} = -\frac{1}{4} F_{\mu\nu}^{(a)} F^{(a)\mu\nu} + i \sum_{q} \overline{\psi}_{q}^{i} \gamma^{\mu} (D_{\mu})_{ij} \psi_{q}^{j} - \sum_{q} m_{q} \overline{\psi}_{q}^{i} \psi_{qi} , \qquad (9.1)$$

$$F_{\mu\nu}^{(a)} = \partial_{\mu} A_{\nu}^{a} - \partial_{\nu} A_{\mu}^{a} + g_{s} f_{abc} A_{\mu}^{b} A_{\nu}^{c} , \qquad (9.2)$$

$$(D_{\mu})_{ij} = \delta_{ij} \ \partial_{\mu} - ig_s \sum_{s} \frac{\lambda_{i,j}^a}{2} A_{\mu}^a \ ,$$
 (9.3)

where g_s is the QCD coupling constant, and the f_{abc} are the structure constants of the SU(3) algebra (the λ matrices and values for f_{abc} can be found in "SU(3) Isoscalar Factors and Representation Matrices," Sec. 32 of this Review). The $\psi_q^i(x)$ are the 4-component Dirac spinors associated with each quark field of (3) color i and flavor q, and the $A_\mu^a(x)$ are the (8) Yang-Mills (gluon) fields. A complete list of the Feynman rules which derive from this Lagrangian, together with some useful color-algebra identities, can be found in Ref. 1.

The principle of "asymptotic freedom" (see below) determines that the renormalized QCD coupling is small only at high energies, and it is only in this domain that high-precision tests—similar to those in QED—can be performed using perturbation theory. Nonetheless, there has been in recent years much progress in understanding and quantifying the predictions of QCD in the nonperturbative domain, for example, in soft hadronic processes and on the lattice [2]. This short review will concentrate on QCD at short distances (large momentum transfers), where perturbation theory is the standard tool. It will discuss the processes that are used to determine the coupling constant of QCD. Other recent reviews of the coupling constant measurements may be consulted for a different perspective [3].

9.2. The QCD coupling and renormalization scheme

The renormalization scale dependence of the effective QCD coupling $\alpha_s=g_s^2/4\pi$ is controlled by the β -function:

$$\mu \frac{\partial \alpha_s}{\partial \mu} = -\frac{\beta_0}{2\pi} \alpha_s^2 - \frac{\beta_1}{4\pi^2} \alpha_s^3 - \frac{\beta_2}{64\pi^3} \alpha_s^4 - \cdots, \qquad (9.4a)$$

$$\beta_1 = 51 - \frac{19}{3} n_f \,, \tag{9.4c}$$

$$\beta_2 = 2857 - \frac{5033}{9}n_f + \frac{325}{27}n_f^2 ; \qquad (9.4d)$$

where n_f is the number of quarks with mass less than the energy scale μ . In solving this differential equation for α_s , a constant of integration is introduced. This constant is the one fundamental constant of QCD that must be determined from experiment. The most sensible choice for this constant is the value of α_s at a fixed-reference scale μ_0 , but it is more conventional to introduce the dimensional parameter Λ , since this provides a parametrization of the μ dependence of α_s . The definition of Λ is arbitrary. One way to define it (adopted here) is to write a solution of Eq. (9.4) as an expansion in inverse powers of $\ln (\mu^2)$:

$$\alpha_s(\mu) = \frac{4\pi}{\beta_0 \ln(\mu^2/\Lambda^2)} \left[1 - \frac{2\beta_1}{\beta_0^2} \frac{\ln\left[\ln(\mu^2/\Lambda^2)\right]}{\ln(\mu^2/\Lambda^2)} + \frac{4\beta_1^2}{\beta_0^4 \ln^2(\mu^2/\Lambda^2)} \right] \times \left(\left(\ln\left[\ln(\mu^2/\Lambda^2)\right] - \frac{1}{2} \right)^2 + \frac{\beta_2\beta_0}{8\beta_1^2} - \frac{5}{4} \right) \right].$$
(9.5a)

The last term in this expansion is

$$\mathcal{O}\left(\frac{\ln^2\left[\ln\left(\mu^2/\Lambda^2\right)\right]}{\ln^3\left(\mu^2/\Lambda^2\right)}\right) , \tag{9.5b}$$

and is usually neglected in the definition of Λ . We choose to include it even though its effect on $\alpha_s(\mu)$ is smaller than the experimental errors. For a fixed value of $\alpha_s(M_Z)$, the inclusion of this term shifts the value of Λ by ~ 15 MeV. This solution illustrates the asymptotic freedom property: $\alpha_s \to 0$ as $\mu \to \infty$. Alternative definitions of Λ are possible. We adopt this as the standard. Values given by experiments using other definitions are adjusted as needed to meet our definition.

Consider a "typical" QCD cross section which, when calculated perturbatively, starts at $\mathcal{O}(\alpha_s)$:

$$\sigma = A_1 \alpha_s + A_2 \alpha_s^2 + \cdots (9.6)$$

The coefficients A_1 , A_2 come from calculating the appropriate Feynman diagrams. In performing such calculations, various divergences arise, and these must be regulated in a consistent way. This requires a particular renormalization scheme (RS). The most commonly used one is the modified minimal subtraction $(\overline{\text{MS}})$ scheme [4]. This involves continuing momentum integrals from 4 to 4–2 ϵ dimensions, and then subtracting off the resulting $1/\epsilon$ poles and also $(\ln 4\pi - \gamma_E)$, which is another artifact of continuing the dimension. (Here γ_E is the Euler-Mascheroni constant.) To preserve the dimensionless nature of the coupling, a mass scale μ must also be introduced: $g \to \mu^\epsilon g$. The finite coefficients A_i thus obtained depend implicitly on the renormalization convention used and explicitly on the scale μ .

The first two coefficients (β_0, β_1) in Eq. (9.4) are independent of the choice of RS's. In contrast, the coefficients of terms proportional to α_s^n for n>3 are RS-dependent. The form given above for β_2 is in the $\overline{\rm MS}$ scheme. It has become conventional to use the $\overline{\rm MS}$ scheme for calculating QCD cross sections beyond leading order.

The fundamental theorem of RS dependence is straightforward. Physical quantities, in particular the cross section, calculated to all orders in perturbation theory, do not depend on the RS. It follows that a truncated series does exhibit RS dependence. In practice, QCD cross sections are known to leading order (LO), or to next-to-leading order (NLO), or in a few cases, to next-to-next-to-leading order (NNLO); and it is only the latter two cases, which have reduced RS dependence, that are useful for precision tests. At NLO the RS dependence is completely given by one condition which can be taken to be the value of the renormalization scale μ . At NNLO this is not sufficient, and μ is no longer equivalent to a choice of scheme; both must now be specified. One, therefore, has to address the question of what is the "best" choice for μ . There is no definite answer to this question—higher-order corrections do not "fix" the scale, rather they render the theoretical predictions less sensitive to its variation.

One could imagine that choosing a scale μ characteristic of the typical energy scale (E) in the process would be most appropriate. In general, a poor choice of scale generates terms of order $\ln{(E/\mu)}$ in the A_i 's. Various methods have been proposed including choosing: the scale for which the next-to-leading-order correction vanishes ("Fastest Apparent Convergence [5]"); the scale for which the next-to-leading-order prediction is stationary [6], (i.e.), the value of μ where $d\sigma/d\mu=0$); or the scale dictated by the effective charge scheme [7] or by the BLM scheme [8]. By comparing the values of α_s that different reasonable schemes give, an estimate of theoretical errors can be obtained.

An important corollary is that if the higher-order corrections are naturally small, then the additional uncertainties introduced by the μ dependence are likely to be less than the experimental measurement errors. There are some processes, however, for which the choice of scheme can influence the extracted value of $\Lambda_{\overline{\rm MS}}$. There is no resolution to this problem other than to try to calculate even more terms in the perturbation series. It is important to note that, since the perturbation series is an asymptotic expansion, there is a limit to the precision with which any theoretical quantity can be

calculated. In some processes, the highest-order perturbative terms may be comparable in size to nonperturbative corrections (sometimes called higher-twist or renormalon effects, for a discussion see [9]); an estimate of these terms and their uncertainties is required if a value of α_s is to be extracted.

In the cases where the higher-order corrections to a process are known and are large, some caution should be exercised when quoting the value of α_s . In what follows, we will attempt to indicate the size of the theoretical uncertainties on the extracted value of α_s . There are two simple ways to determine this error. First, we can estimate it by comparing the value of $\alpha_s(\mu)$ obtained by fitting data using the QCD formula to highest known order in α_s , and then comparing it with the value obtained using the next-to-highest-order formula (μ is chosen as the typical energy scale in the process). The corresponding A's are then obtained by evolving $\alpha_s(\mu)$ to $\mu = m_Z$ using Eq. (9.4) to the same order in α_s as the fit, and then converting to $\Lambda^{(4)}$ using Eq. (9.7). Alternatively, we can vary the value of μ over a reasonable range, extracting a value of Λ for each choice of μ . This method is of its nature imprecise, since "reasonable" involves a subjective judgment. In either case, if the perturbation series is well behaved, the resulting error on Λ will be small.

In the above discussion we have ignored quark-mass effects, i.e., we have assumed an idealized situation where quarks of mass greater than μ are neglected completely. In this picture, the β -function coefficients change by discrete amounts as flavor thresholds are crossed when integrating the differential equation for α_s . It follows that, for a relationship such as Eq. (9.5) to remain valid for all values of μ , Λ must also change as flavor thresholds are crossed. This leads to the concept of a different Λ for each range of μ corresponding to an effective number of massless quarks: $\Lambda \to \Lambda^{(n_f)}$. There is some arbitrariness in how this relationship is set up. As an idealized case, consider QCD with $n_f - 1$ massless quarks and one quark of mass M. Now imagine an experiment at energy scale μ ; for example, this could be $e^+e^- \to hadrons$ at center-of-mass energy μ . If $\mu \gg M$, the mass M is negligible and the process is well described by QCD with n_f massless flavors and its parameter $\Lambda^{(n_f)}$ up to terms of order M^2/μ^2 . Conversely if $\mu \ll M$, the heavy quark plays no role and the process is well described by QCD with n_f-1 massless flavors and its parameter $\Lambda^{(n_f-1)}$ up to terms of order μ^2/M^2 . If $\mu \sim M$, the effects of the quark mass are process-dependent and cannot be absorbed into the

A mass scale μ' is chosen where the relationship between $\Lambda^{(n_f-1)}$ and $\Lambda^{(n_f)}$ will be fixed. μ' should be of order M and the relationship should not depend on it. A prescription has been given [10] which has this property. We use this procedure choosing $\mu' = M_Q$, where M_Q is the mass of the value of the running quark mass defined in the $\overline{\text{MS}}$ scheme (see the note on "Quark Masses" in the Particle Listings for more details), i.e., where $M_{\overline{\text{MS}}}(M_Q) = M_Q$. Then [10]

$$\begin{split} \beta_0^{n_f-1} \ln \left(\frac{\Lambda^{(n_f)}}{\Lambda^{(n_f-1)}} \right)^2 &= (\beta_0^{n_f} - \beta_0^{n_f-1}) \cdot \ln \left(\frac{M_Q}{\Lambda^{(n_f)}} \right)^2 \\ &+ 2 \left(\frac{\beta_1^{n_f}}{\beta_0^{n_f}} - \frac{\beta_1^{n_f-1}}{\beta_0^{n_f-1}} \right) \cdot \ln \left[\ln \left(\frac{M_Q}{\Lambda^{(n_f)}} \right)^2 \right] \\ &- \frac{2\beta_1^{n_f-1}}{\beta_0^{n_f-1}} \cdot \ln \left(\frac{\beta_0^{n_f}}{\beta_0^{n_f-1}} \right) \cdot \ln \left[\ln \left(\frac{M_Q}{\Lambda^{(n_f)}} \right)^2 \right] \\ &+ \frac{4 \frac{\beta_1^{n_f}}{(\beta_0^{n_f})^2} \left(\frac{\beta_1^{n_f}}{\beta_0^{n_f}} - \frac{\beta_1^{n_f-1}}{\beta_0^{n_f-1}} \right) \cdot \ln \left[\ln \left(\frac{M_Q}{\Lambda^{(n_f)}} \right)^2 \right]}{\ln \left(\frac{M_Q}{\Lambda^{(n_f)}} \right)^2} \\ &+ \frac{\frac{1}{\beta_0^{n_f}} \left[\left(\frac{2\beta_1^{n_f}}{\beta_0^{n_f}} \right)^2 - \left(\frac{2\beta_1^{n_f-1}}{\beta_0^{n_f-1}} \right)^2 - \frac{2\beta_2^{n_f}}{\beta_0^{n_f}} + \frac{2\beta_2^{n_f-1}}{\beta_0^{n_f-1}} - \frac{14}{9} \right]}{\ln \left(\frac{M_Q}{\Lambda^{(n_f)}} \right)^2} \;. \end{split}$$

This result is valid to order α_s^3 (or alternatively to terms of order $1/\ln^2[(M_Q/\Lambda^{(n_f)})^2]$).

An alternative matching procedure can be used [11]. This procedure requires the equality $\alpha_s(\mu)^{(n_f)} = \alpha_s(\mu)^{(n_f-1)}$ for $\mu = M_Q$. This matching is somewhat arbitrary; a different relation between $\Lambda^{(n_f)}$ and $\Lambda^{(n_f-1)}$ would result if $\mu = M_Q/2$ were used. In practice, the differences between these procedures are very small. $\Lambda^{(5)} = 200$ MeV corresponds to $\Lambda^{(4)} = 289$ MeV in the scheme of Ref. 11 and $\Lambda^{(4)} = 280$ MeV in the scheme adopted above. Note that the differences between $\Lambda^{(5)}$ and $\Lambda^{(4)}$ are numerically very significant.

Data from deep-inelastic scattering are in a range of energy where the bottom quark is not readily excited, and hence, these experiments quote $\Lambda_{\overline{\rm MS}}^{(4)}$. Most data from PEP, PETRA, TRISTAN, LEP, and SLC quote a value of $\Lambda_{\overline{\rm MS}}^{(5)}$ since these data are in an energy range where the bottom quark is light compared to the available energy. We have converted it to $\Lambda_{\overline{\rm MS}}^{(4)}$ as required. A few measurements, including the lattice gauge theory values from the ψ system and from τ decay are at sufficiently low energy that $\Lambda_{\overline{\rm MS}}^{(3)}$ is appropriate.

We turn now to a discussion of renormalization-scheme dependence in QCD. Although necessarily rather technical, this discussion is vital to understanding how α_s (or Λ) values can be measured and compared. See the review by Duke and Roberts [12] for further details

In order to compare the values of α_s from various experiments, they must be evolved using the renormalization group to a common scale. For convenience, this is taken to be the mass of the Z boson. This evolution uses third-order perturbation theory and can introduce additional errors particularly if extrapolation from very small scales is used. The variation in the charm and bottom quark masses $(m_b=4.3\pm0.2$ and $m_c=1.3\pm0.3$ are used) can also introduce errors. These result in a fixed value of $\alpha_s(2~{\rm GeV})$, giving an uncertainty in $\alpha_s(M_Z)=\pm0.001$ if only perturbative evolution is used. There could be additional errors from nonperturbative effects that enter at low energy. All values are in the $\overline{\rm MS}$ scheme unless otherwise noted.

9.3. QCD in deep-inelastic scattering

The original and still one of the most powerful quantitative tests of perturbative QCD is the breaking of Bjorken scaling in deep-inelastic lepton-hadron scattering. In the leading-logarithm approximation, the measured structure functions $F_i(x,Q^2)$ are related to the quark distribution functions $q_i(x,Q^2)$ according to the naive parton model, by the formulae in "Cross-section Formulae for Specific Processes," Sec. 35 of this *Review*. (In that section, q_i is denoted by the notation f_q). In describing the way in which scaling is broken in QCD, it is convenient to define nonsinglet and singlet quark distributions:

$$F^{NS} = q_i - q_j$$
 $F^S = \sum_i (q_i + \overline{q}_i)$ (9.8)

The nonsinglet structure functions have nonzero values of flavor quantum numbers such as isospin or baryon number. The variation with Q^2 of these is described by the so-called DGLAP equations [13,14]:

$$Q^2 \; \frac{\partial F^{NS}}{\partial Q^2} = \frac{\alpha_s(|Q|)}{2\pi} P^{qq} * F^{NS} \eqno(9.9a)$$

$$Q^2 \frac{\partial}{\partial Q^2} \begin{pmatrix} F^S \\ G \end{pmatrix} = \frac{\alpha_s(|Q|)}{2\pi} \begin{pmatrix} P^{qq} & 2n_f P^{qg} \\ P^{gq} & P^{gg} \end{pmatrix} * \begin{pmatrix} F^S \\ G \end{pmatrix}$$
(9.9b)

where * denotes a convolution integral:

$$f * g = \int_{x}^{1} \frac{dy}{y} f(y) g\left(\frac{x}{y}\right) . \tag{9.10}$$

The leading-order Altarelli-Parisi [14] splitting functions are

$$P^{qq} = \frac{4}{3} \left[\frac{1+x^2}{(1-x)_+} \right] + 2\delta(1-x) , \qquad (9.11a)$$

$$P^{qg} = \frac{1}{2} \left[x^2 + (1 - x)^2 \right] , \qquad (9.11b)$$

$$P^{gq} = \frac{4}{3} \left[\frac{1 + (1 - x)^2}{x} \right] , \qquad (9.11c)$$

$$P^{gg} = 6 \left[\frac{1-x}{x} + x(1-x) + \frac{x}{(1-x)_{+}} + \frac{11}{12} \delta(1-x) \right] - \frac{n_f}{3} \delta(1-x) . \tag{9.11d}$$

Here the gluon distribution $G(x,Q^2)$ has been introduced and $1/(1-x)_+$ means

$$\int_0^1 dx \frac{f(x)}{(1-x)_+} = \int_0^1 dx \, \frac{f(x) - f(1)}{(1-x)} \,. \tag{9.12}$$

The precision of contemporary experimental data demands that higher-order corrections also be included [15]. The above results are for massless quarks. Algorithms exist for the inclusion of nonzero quark masses [16]. At low Q^2 values, there are also important "higher-twist" (HT) contributions of the form:

$$F_i(x, Q^2) = F_i^{(LT)}(x, Q^2) + \frac{F_i^{(HT)}(x, Q^2)}{Q^2} + \cdots$$
 (9.13)

Leading twist (LT) indicates a term whose behavior is predicted by perturbative QCD. These corrections are numerically important only for $Q^2 < \mathcal{O}(10\,\mathrm{GeV}^2)$ except for x very close to 1.

A detailed review of the current status of the experimental data can be found, for example, in Refs. [17–20], and only a brief summary will be presented here. We shall only include determinations of Λ from the recently published results; the earlier editions of this *Review* should be consulted for the earlier data. In any event, the recent results will dominate the average since their errors are smaller. Data have now appeared from HERA at much smaller values of x than the previous data. They provide valuable information about the shape of the antiquark and gluon distribution functions at $x \sim 10^{-3}$ [21].

From Eq. (9.9), it is clear that a nonsinglet structure function offers in principle the most precise test of the theory, since the Q^2 evolution is independent of the unmeasured gluon distribution. The CCFR collaboration fit to the Gross-Llewellyn Smith sum rule [22] is known to order α_s^3 [23]

$$\begin{split} &\int_0^1 dx (F_3^{\overline{\nu}p}(x,Q^2) + F_3^{\nu p}(x,Q^2)) = \\ &3 \left[(1 - \frac{\alpha_s}{\pi} (1 + 3.58 \frac{\alpha_s}{\pi} + 19.0 (\frac{\alpha_s}{\pi})^2) - \Delta HT \right] , \end{split} \tag{9.14}$$

where the higher-twist contribution $\Delta HT = (0.09 \pm 0.045)/Q^2$ [23,24]. Using the CCFR data [25], this gives α_s (1.76 GeV) = 0.26 \pm 0.035 (expt.) \pm 0.03 (theory). The error from higher-twist terms dominates the theoretical error, the higher-twist term being approximately 50% larger than the α_s^3 term.

A measurement of Λ has been made using F_3 in neutrino scattering [27]. The result is $\Lambda_{\overline{\rm MS}}^{(4)}=179\pm36\pm41$ MeV. The errors are statistical and systematic but do not include (theoretical) errors arising from the choice of μ^2 . Measurements involving singlet-dominated structure functions, such as F_2 , result in correlated measurements of $\Lambda_{\overline{\rm MS}}^{(4)}$ and the gluon distribution. By utilizing high-statistics data at large x (> 0.25) and large Q^2 , where F_2 behaves like an nonsinglet and F_3 at smaller x, a nonsinglet fit can be performed with better statistical precision, and hence, the error on the measured value of $\Lambda_{\overline{\rm MS}}^{(4)}$ is much reduced. CCFR gives $\Lambda_{\overline{\rm MS}}^{(4)}=210\pm28\pm41$ MeV [27] from $F_2(\nu N)$ and $F_3(\nu N)$. There is an additional uncertainty of ±59 MeV from the choice of scale. The NMC collaboration [28] gives $\alpha_s(7~{\rm GeV}^2)=0.264\pm0.018({\rm stat.})\pm0.070({\rm syst.})\pm0.013(~{\rm higher-twist})$. The systematic error is larger than the CCFR result, partially because the data are at smaller values of x and the gluon distribution is

more important. A reanalysis [29] of EMC data [30] gives $\Lambda_{\overline{\rm MS}}^{(4)}=211\pm80\pm80~{\rm MeV}$ from $F_2(\nu N)$. Finally a combined analysis [31] of SLAC [32] and BCDMS [33] data gives $\Lambda_{\overline{\rm MS}}^{(4)}=263\pm42\pm55~{\rm MeV}$. Here the systematic error is an estimate of the uncertainty due to the choice of Q^2 used in the argument of α_s , and in the scale at which the structure functions (factorization scale) used in the QCD calculation are evaluated.

The results from Refs. [27–29] and [31] can be combined to give $\alpha_s(M_Z)=0.112\pm0.002\pm0.004$, or equivalently $\Lambda_{\overline{\rm MS}}^{(4)}=234\pm26\pm50$ MeV. Here the first error is a combination of statistical and systematic errors, and the second error is due to the scale uncertainty. This result is an average of the results weighted by their statistical and systematic errors. The scale error which is common to all is then reapplied to the average.

The spin-dependent structure functions can also be used to determine α_s . Here the values of $Q^2 \sim 2.5 \; \mathrm{GeV}^2$ are small and higher-twist corrections are again important. The values extracted are consistent with the average quote below [26].

At very small values of x and large Q^2 , the x-dependence of the structure functions is predicted by perturbative QCD [34]. Here terms to all orders in $\alpha_s \ln(1/x)$ are summed. The data from HERA [21] on $F_2^{ep}(x,Q^2)$ have been fitted to the this form [35], including the NLO terms which are required to fix the Q^2 scale. The data are dominated by $4 \text{ GeV}^2 < Q^2 < 100 \text{ GeV}^2$. The fit gives $\alpha_s(M_Z) = 0.120 \pm 0.005 \text{ (expt.)} \pm 0.009 \text{ (theory)}$. The dominant part of the theoretical error is from the scale dependence. The fit neglects from this source cannot be estimated and are not included in the quoted error. This result is not averaged with the other ones from scaling violations, since the values there are derived from the Q^2 dependence alone, and this possible source of error is not present.

Typically, Λ is extracted from the data by parametrizing the parton densities in a simple analytic way at some Q_0^2 , evolving to higher Q^2 using the next-to-leading-order evolution equations, and fitting globally to the measured structure functions to obtain $\Lambda_{\overline{\rm MS}}^{(4)}$. Thus, an important by-product of such studies is the extraction of parton densities at a fixed-reference value of Q_0^2 . These can then be evolved in Q^2 and used as input for phenomenological studies in hadron-hadron collisions (see below). To avoid having to evolve from the starting Q_0^2 value each time, a parton density is required; it is useful to have available a simple analytic approximation to the densities valid over a range of x and Q^2 values. A package is available from the CERN computer library that includes an exhaustive set of fits [36]. Some of these fits are obsolete. In using a parameterization to predict event rates, a next-to-leading order fit must be used if the process being calculated is known to next-to-leading order in QCD perturbation theory. In such a case, there is an additional scheme dependence; this scheme dependence is reflected in the $\mathcal{O}(\alpha_s)$ corrections that appear in the relations between the structure functions and the quark distribution functions. There are two common schemes: a deep-inelastic scheme where there are no order α_s corrections in the formula for $F_2(x,Q^2)$ and the minimal subtraction scheme. It is important when these next-to-leading order fits are used in other processes (see below), that the same scheme is used in the calculation of the partonic rates.

9.4. QCD in decays of the τ lepton

The semi-leptonic branching ratio of the tau $(\tau \to \nu_{\tau} + hadrons, R_{\tau})$ is an inclusive quantity. It is related to the contribution of hadrons to the imaginary part of the W self energy $(\Pi(s))$. However, it is more inclusive than R since it involves an integral

$$R_{ au} \sim \int_{0}^{m_{ au}^2} rac{ds}{m_{ au}^2} (1 - rac{s}{m_{ au}^2})^2 \ {
m Im} \left(\Pi(s)
ight) \ .$$

Since the scale involved is low, one must take into account nonperturbative (higher-twist) contributions which are suppressed by powers of the τ mass.

$$R_{\tau} = 3.058 \left[1 + \frac{\alpha_s(m_{\tau})}{\pi} + 5.2 \left(\frac{\alpha_s(m_{\tau})}{\pi} \right)^2 + 26.4 \left(\frac{\alpha_s(m_{\tau})}{\pi} \right)^3 + \right.$$

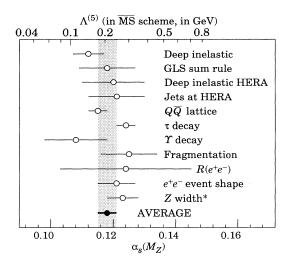


Figure 9.1: Summary of the values of $\alpha_s(M_Z)$ and $\Lambda^{(5)}$ from various processes ordered from top to bottom by increasing energy scale of the measurements. The values shown indicate the process and the measured value of α_s extrapolated up to $\mu = M_Z$. The error shown is the *total* error including theoretical uncertainties. The value denoted by '*' is not used in the average (see text).

$$a\frac{m^2}{m_{\tau}^2} + b\frac{m\psi\overline{\psi}}{m_{\tau}^4} + c\frac{\psi\overline{\psi}\psi\overline{\psi}}{m_{\tau}^6} + \cdots \right]. \tag{9.15}$$

Here a,b, and c are dimensionless constants and m is a light quark mass. The term of order $1/m_{\tau}^2$ is a kinematical effect due to the light quark masses and is consequently very small. The nonperturbative terms are estimated using sum rules [37]. In total, they are estimated to be -0.007 ± 0.004 [38]. This estimate relies on there being no term of order Λ^2/m_{τ}^2 (note that $\frac{\alpha_s(m_{\tau})}{\pi} \sim (\frac{0.5~\text{GeV}}{m_{\tau}})^2$). The a,b, and c can be determined from the data [39] by fitting to moments of the $\Pi(s)$. The values so extracted [40,41] are consistent with the theoretical estimates. If the nonperturbative terms are omitted from the fit, the extracted value of $\alpha_s(m_{\tau})$ decreases by ~ 0.02 .

For $\alpha_s(m_\tau) = 0.37$ the perturbative series for R_τ is $R_\tau \sim$ 3.058(1 + 0.118 + 0.072 + 0.043). The size (estimated error) of the nonperturbative term is 20% (7%) of the size of the order α_s^3 term. The perturbation series in not very well convergent; if the order α_s^3 term is omitted, the extracted value of $\alpha_s(m_\tau)$ increases by 0.05. R_τ , can be extracted from the semi-leptonic branching ratio from the relation $R_{\tau} = 1/(B(\tau \to e\nu\overline{\nu}) - 1.97256$; where $B(\tau \to e\nu\overline{\nu})$ is measured directly or extracted from the lifetime, the muon mass and the muon lifetime assuming universality of lepton couplings. Using the average lifetime of 291.3 \pm 1.6 fs [42] and a τ mass of 1.776.96 \pm 0.30 [43] gives $R_{ au}=3.633\pm0.031$. Assuming e/μ universality, the data give B($\tau \to e\nu\overline{\nu}$) = 0.1780 ± 0.0006 [44]. Averaging these yields $\alpha_s(m_\tau) = 0.370 \pm 0.008$ using the experimental error alone. This result is consistent with measurements reported recently by other collaborations [45,46]. The value of $\alpha_s(m_\tau) = 0.306 \pm 0.017$ quoted by CLEO [41] uses the measured moments and the average value $B(\tau \to e\nu\overline{\nu}) = 0.1810 \pm 0.0012$ from the 1992 edition of this review. We assign a theoretical error equal to 1/2 of the contribution from the order α^3 term and all of the nonperturbative contributions. This then gives $\alpha_s(m_ au) = 0.370 \pm 0.033$ for the final result. Note that the theoretical errors are dominant. The small theoretical errors have been criticized [47].

9.5. QCD in high-energy hadron collisions

There are many ways in which perturbative QCD can be tested in high-energy hadron colliders. The quantitative tests are only useful if the process in question has been calculated beyond leading order in QCD perturbation theory. The production of hadrons with large transverse momentum in hadron-hadron collisions provides a direct probe of the scattering of quarks and gluons: $qq \rightarrow qq, qg \rightarrow qg,$ $gg \to gg$, etc. The present generation of $p\overline{p}$ colliders provide centerof-mass energies which are sufficiently high that these processes can be unambiguously identified in two-jet production at large transverse momentum. Recent higher-order QCD calculations of the jet rates [48] and shapes are in impressive agreement with data [49]. As an example, Fig. 36.7 in this Review shows the inclusive jet cross section at zero pseudorapidity as a function of the jet transverse momentum for $p\overline{p}$ collisions. The QCD prediction combines the parton distributions with the leading-order $2 \rightarrow 2$ parton scattering amplitudes. Data are also available on the angular distribution of jets; these are also in agreement with QCD expectations [50,51].

QCD corrections to Drell-Yan type cross sections (i.e., the production in hadron collisions by quark-antiquark annihilation of lepton pairs of invariant mass Q from virtual photons, or of real W or Z bosons), are known [52]. These $\mathcal{O}(\alpha_s)$ QCD corrections are sizable at small values of Q.

It is interesting to note that the corresponding correction to W and Z production, as measured in $p\overline{p}$ collisions at $\sqrt{s}=0.63$ TeV and $\sqrt{s}=1.8$ TeV, has essentially the same theoretical form and is of order 30%.

The production of W and Z bosons and photons at large transverse momentum can also be used to determine α_s . The leading-order QCD subprocesses are $q\overline{q} \to \gamma g$ and $qg \to \gamma q$. If the parton distributions are taken from other processes and a value of $\Lambda_{\overline{\rm MS}}^{(4)}$ assumed, then an absolute prediction is obtained. Conversely, the data can be used to extract information on quark and gluon distributions and on the value of $\Lambda_{\overline{MS}}^{(4)}$. The next-to-leading-order QCD corrections are known [53,54] (for photons), and for W/Z production [55], and so a precision test is possible in principle. Data exist from the CDF and DØ collaborations [56,57]. The UA2 collaboration [58] has extracted a value of $\alpha_s(M_W) = 0.123 \pm 0.018 ({\rm stat.}) \pm 0.017 ({\rm syst.})$ from the measured ratio $R_W = \frac{\sigma(W+1jet)}{\sigma(W+0jet)}$. The result depends on the algorithm used to define a jet, and the dominant systematic errors due to fragmentation and corrections for underlying events (the former causes jet energy to be lost, the latter causes it to be increased) are connected to the algorithm. The scale at which $\alpha_s(M)$ is to be evaluated is not clear. A change from $\mu = M_W$ to $\mu = M_W/2$ causes a shift of 0.01 in the extracted α_s . The quoted error should be increased to take this into account. There is dependence on the

increased) are connected to the algorithm. The scale at which $\alpha_s(M)$ is to be evaluated is not clear. A change from $\mu=M_W$ to $\mu=M_W/2$ causes a shift of 0.01 in the extracted α_s . The quoted error should be increased to take this into account. There is dependence on the parton distribution functions, and hence, α_s appears explicitly in the formula for R_W , and implicitly in the distribution functions. The DØ collaboration has performed an analysis similar to UA2. They are unable to obtain a fit where the two values of α_s are consistent with one another, and do not quote a value of α_s [59]. The values from this process are no longer used in determining the overall average value of α_s .

9.6. QCD in heavy-quarkonium decay

Under the assumption that the hadronic and leptonic decay widths of heavy $Q\overline{Q}$ resonances can be factorized into a nonperturbative part—dependent on the confining potential—and a calculable perturbative part, the ratios of partial decay widths allow measurements of α_s at the heavy-quark mass scale. The most precise data come from the decay widths of the 1^{--} $J/\psi(1S)$ and \varUpsilon resonances. The total decay width of the \varUpsilon is predicted by perturbative QCD [60]

$$R_{\Upsilon} = \frac{\Gamma(\Upsilon \to \text{hadrons})}{\Gamma(\Upsilon \to \mu^{+}\mu^{-})}$$

$$= \frac{10(\pi^2 - 9)\alpha_s^3(M)}{9\pi\alpha_{\text{em}}^2} \times \left[1 + \frac{\alpha_s}{\pi} \left(-19.4 + \frac{3\beta_0}{2} \left(1.162 + \ln\left(\frac{2M}{M_\Upsilon}\right) \right) \right) \right]. \quad (9.16)$$

Data are available for the \varUpsilon , \varUpsilon' , \varUpsilon'' and ψ . The result is very sensitive to α_s and the data are sufficiently precise $(R_\mu(\varUpsilon)=32.5\pm0.9)$ [61] that the theoretical errors will dominate. There are theoretical corrections to this simple formula due to the relativistic nature of the $Q\overline{Q}$ system; $v^2/c^2\sim0.1$ for the \varUpsilon . They are more severe for the ψ . There are also nonperturbative corrections of the form $\Lambda^2/m_{\varUpsilon}^2$; again these are more severe for the ψ . A fit to \varUpsilon , \varUpsilon' , and \varUpsilon'' [62] gives $\alpha_s(M_Z)=0.108\pm0.001$ (expt.). The results from each state separately and also from the ψ are consistent with each other. There is an uncertainty of order ±0.005 from the choice of scale; the error from v^2/c^2 corrections is a little larger. $\alpha_s(M_Z)=0.108\pm0.010$ is a fair representation of the total error including the possibility of nonperturbative corrections.

9.7. Perturbative QCD in e^+e^- collisions

The total cross section for $e^+e^- \to \text{hadrons}$ is obtained (at low values of \sqrt{s}) by multiplying the muon-pair cross section by the factor $R=3\Sigma_q e_q^2$. The higher-order QCD corrections to this quantity have been calculated, and the results can be expressed in terms of the factor:

$$R = R^{(0)} \left[1 + \frac{\alpha_s}{\pi} + C_2 \left(\frac{\alpha_s}{\pi} \right)^2 + C_3 \left(\frac{\alpha_s}{\pi} \right)^3 + \cdots \right] , \qquad (9.17)$$

where $C_2 = 1.411$ and $C_3 = -12.8$ [63].

 $R^{(0)}$ can be obtained from the formula for $d\sigma/d\Omega$ for $e^+e^- \to f\overline{f}$ by integrating over Ω . The formula is given in Sec. 35.2 of this *Review*. This result is only correct in the zero-quark-mass limit. The $\mathcal{O}(\alpha_s)$ corrections are also known for massive quarks [64]. The principal advantage of determining α_s from R in e^+e^- annihilation is that there is no dependence on fragmentation models, jet algorithms, *etc*.

A comparison of the theoretical prediction of Eq. (9.17) (corrected for the *b*-quark mass), with all the available data at values of \sqrt{s} between 20 and 65 GeV, gives [65] $\alpha_s(35 \text{ GeV}) = 0.146 \pm 0.030$. The size of the order α_s^3 term is of order 40% of that of the order α_s^2 and 3% of the order α_s . If the order α_s^3 term is not included, a fit to the data yields α_s (34 GeV) = 0.142 ± 0.03, indicating that the theoretical uncertainty is smaller than the experimental error.

Measurements of the ratio of hadronic to leptonic width of the Z at LEP and SLC, Γ_h/Γ_μ probe the same quantity as R. Using the average of $\Gamma_h/\Gamma_\mu = 20.788 \pm 0.032$ gives $\alpha_s(M_Z) = 0.123 \pm 0.004 \pm 0.002$ [66]. There are theoretical errors arising from the values of the top-quark and Higgs masses which enter due to electroweak corrections to the Z width and from the choice of scale.

While this method has small theoretical uncertainties from QCD itself, it relies sensitively on the electroweak couplings of the Z to quarks [67]. The experimental results on $\Gamma(Z \to b\overline{b})$ and $\Gamma(Z \to c\overline{c})$ are not in agreement with the Standard Model [68]. If these widths are taken from experiment (rather than from the Standard Model), the extracted vale of $\alpha_s(M_Z)$ is 0.183. If the Standard Model is used for $\Gamma(Z \to c\overline{c})$, $\alpha_s(M_Z) = 0.104$ results. In view of these problems, the value from Γ_h/Γ_μ is not included in the final average.

An alternative method of determining α_s in e^+e^- annihilation is from measuring quantities that are sensitive to the relative rates of two-, three-, and four-jet events. A recent review should be consulted for more details [69] of the issues mentioned briefly here. In addition to simply counting jets, there are many possible choices of such "shape variables": thrust [70], energy-energy correlations [71], planar triple-energy correlations [72], average jet mass, etc. All of these are infrared safe, which means they can be reliably calculated in perturbation theory. The starting point for all these quantities is the multijet cross section. For example, at order α_s , for the process $e^+e^- \to qqg$:

$$\frac{1}{\sigma} \frac{d^2 \sigma}{dx_1 dx_2} = \frac{2\alpha_s}{3\pi} \frac{x_1^2 + x_2^2}{(1 - x_1)(1 - x_2)} , \qquad (9.18)$$

where

$$x_i = \frac{2E_i}{\sqrt{s}} \tag{9.19}$$

are the center-of-mass energy fractions of the final-state (massless) quarks. A distribution in a "three-jet" variable, such as those listed above, is obtained by integrating this differential cross section over an appropriate phase space region for a fixed value of the variable. The order α_s^2 corrections to this process have been computed, as well as the 4-jet final states such as $e^+e^- \to qqgg$ [73].

There are many methods used by the e^+e^- experimental groups to determine α_s from the event topology. The jet-counting algorithm, originally introduced by the JADE collaboration [74], has been used by the LEP groups. Here, particles of momenta p_i and p_j are combined into a pseudo-particle of momentum $p_i + p_j$ if the invariant mass of the pair is less than $y_0\sqrt{s}$. The process is then iterated until no more pairs of particles or pseudo-particles remain. The remaining number is then defined to be the number of jets in the event, and can be compared to the QCD prediction. The Durham algorithm is slightly different: in computing the mass of a pair of partons, it uses $M^2 = 2\min(E_1^2, E_2^2)(1 - \cos\theta_{ij})$ for partons of energies E_i and E_j separated by angle θ_{ij} [75].

There are theoretical ambiguities in the way this process is carried out. Quarks and gluons are massless, whereas the observed hadrons are not, so that the massive jets that result from this scheme (the so-called E-0 scheme) cannot be compared directly to the massless jets of perturbative QCD. Different recombination schemes have been tried, for example combining 3-momenta and then rescaling the energy of the cluster so that it remains massless (p scheme). These schemes result in the same data giving a slightly different values [76,77] of α_s . These differences can be used to determine a systematic error. In addition, since what is observed are hadrons rather than quarks and gluons, a model is needed to describe the evolution of a partonic final state into one involving hadrons, so that detector corrections can be applied. The QCDmatrix elements are combined with a parton-fragmentation model. This model can then be used to correct the data for a direct comparison with the parton calculation. The different hadronization models that are used [78-81] model the dynamics that are controlled by nonperturbative QCD effects which we cannot vet calculate. The fragmentation parameters of these Monte Carlos are tuned to get agreement with the observed data. The differences between these models contribute to the systematic errors. The systematic errors from recombination schemes and fragmentation effects dominate over the statistical and other errors of the LEP/SLD experiments.

The scale M at which $\alpha_s(M)$ is to be evaluated is not clear. The invariant mass of a typical jet (or $\sqrt{sy_0}$) is probably a more appropriate choice than the e^+e^- center-of-mass energy. If the value is allowed to float in the fit to the data, the data tend to prefer values of order $\sqrt{s}/10$ [82]; the exact value depends on the variable that is fitted. The dominant uncertainties arise from the choice of M and from the freedom in the fragmentation Monte Carlos.

The perturbative QCD formulae can break down in special kinematical configurations. For example, the thrust distribution contains terms of the type $\alpha_s \ln^2(1-T)$. The higher orders in the perturbation expansion contain terms of order $\alpha_s^n \ln^m(1-T)$. For $T\sim 1$ (the region populated by 2-jet events), the perturbation expansion is unreliable. The terms with $n\leq m$ can be summed to all orders in α_s [83]. If the jet recombination methods are used higher-order terms involve $\alpha_s^n \ln^m y_0$), these too can be resummed [84]. The resummed results give better agreement with the data at large values of T. Some caution should be exercised in using these resummed results because of the possibility of overcounting; the showering Monte Carlos that are used for the fragmentation corrections also generate some of these leading-log corrections. Different schemes for combining the order α_s^2 and the resummations are available [85]. These different schemes result in shifts in α_s of order ± 0.002 [86].

An average of the recent results from SLD [86], OPAL [87], L3 [88], ALEPH [89], and DELPHI [90], using the combined α_s^2 and resummation fitting to a large set of shape variables, gives $\alpha_s(M_Z) = 0.122 \pm 0.007$. The errors in the values of $\alpha_s(M_Z)$ from

these shape variables are totally dominated by the theoretical uncertainties associated with the choice of scale, and the effects of hadronization Monte Carlos on the different quantities fitted.

Similar studies on event shapes have been undertaken at TRISTAN, at PEP/PETRA, and at CLEO. A combined result from various shape parameters by the TOPAZ collaboration gives α_s (58 GeV) = 0.125 \pm 0.009, using the fixed order QCD result, and α_s (58 GeV) = 0.132 \pm 0.008 (corresponding to $\alpha_s(M_Z)=0.123\pm0.007$), using the same method as in the SLD and LEP average [91].

The measurements of event shapes at PEP/PETRA are summarized in earlier editions of this note. The results are consistent with those from Z decay, but have larger errors. We use α_s (34 GeV) = 0.14 \pm 0.02 [92]. A recent analysis by the TPC group [93] gives α_s (29 GeV) = 0.160 \pm 0.012, using the same method as TOPAZ. This value corresponds to $\alpha_s(M_Z)=0.131\pm0.010$

The CLEO collaboration fits to the order α_s^2 results for the two jet fraction at $\sqrt{s}=10.53$ GeV, and obtains $\alpha_s(10.93)=0.164\pm0.004$ (expt.) ±0.014 (theory) [94]. The dominant systematic error arises from the choice of scale (μ) , and is determined from the range of α_s that results from fit with $\mu=10.53$ GeV, and a fit where μ is allowed to vary to get the lowest χ^2 . The latter results in $\mu=1.2$ GeV. Since the quoted result corresponds to $\alpha_s(1.2)=0.35$, it is by no means clear that the perturbative QCD expression is reliable and the resulting error should, therefore, be treated with caution. A fit to many different variables as is done in the LEP/SLC analyses would give added confidence to the quoted error.

Since the errors in the event shape measurements are dominantly systematic, and are common to the experiments, the results from PEP/PETRA, TRISTAN, LEP, SLC, and CLEO are combined to give $\alpha_s(M_Z)=0.122\pm0.007$. This result is used in forming the final average value of α_s .

The total cross section $e^+e^- \to b\bar{b} + X$ near threshold can be used to determine α_s [95]. The result quoted is $\alpha_s(M_Z) = 0.109 \pm 0.001$. The relevant process is only calculated to leading order and the BLM scheme [8] is used. This results in $\alpha_s(0.632\ m_b)$. If $\alpha_s(m_b)$ is used, the resulting $\alpha_s(M_Z)$ shifts to ~ 0.117 . This result is not used in the average.

9.8. Scaling violations in fragmentation functions

Measurements of the fragmentation function $d_i(z, E)$, being the probability that a hadron of type i be produced with energy zE in e^+e^- collisions at $\sqrt{s}=2E$, can be used to determine α_s . As in the case of scaling violations in structure functions, QCD predicts only the E dependence. Hence, measurements at different energies are needed to extract a value of α_s . Because the QCD evolution mixes the fragmentation functions for each quark flavor with the gluon fragmentation function, it is necessary to determine each of these before α_s can be extracted. The ALEPH collaboration has used data from energies ranging from $\sqrt{s}=22~{\rm GeV}$ to $\sqrt{s}=91$ GeV. A flavor tag is used to discriminate between different quark species, and the longitudinal and transverse cross sections are used to extract the gluon fragmentation function [96]. The result obtained is $\alpha_s(M_Z) = 0.126 \pm 0.007$ (expt.) ± 0.006 (theory) [97]. The theory error is due mainly to the choice of scale. The OPAL collaboration [98] has also extracted the separate fragmentation functions. DELPHI [99] has also performed a similar analysis using data from other experiments at lower energy with the result $\alpha_s(M_Z) = 0.122 \pm 0.012 \pm 0.006$ (theory). An earlier analysis by this collaboration [100], is consistent with this result, but used fixed order QCD. The older result is not used in the average, which is determined to be $\alpha_s(M_Z) = 0.125 \pm 0.006 \pm 0.006$ (theory)

9.9. Jet rates in ep collisions

At lowest order in α_s , the ep scattering process produces a final state of (1+1) jets, one from the proton fragment and the other from the quark knocked out by the process $e+quark \rightarrow e+quark$. At next order in α_s , a gluon can be radiated, and hence a (2+1) jet final state produced. By comparing the rates for these (1+1) and (1+2) jet processes, a value of α_s can be obtained. A NLO QCD calculation is available [101]. The basic methodology is similar to that used in the

jet counting experiments in e^+e^- annihilation discussed above. Unlike those measurements, the ones in ep scattering are not at a fixed value of Q^2 . In addition to the systematic errors associated with the jet definitions, there are additional ones since the structure functions enter into the rate calculations. Results from H1 [102] and ZEUS [103] can be combined to give $\alpha_s(M_Z)=0.121\pm0.004$ (stat.) ±0.008 (syst.). The contributions to the systematic errors from experimental effects (mainly the hadronic energy scale) are comparable to the theoretical ones arising from scale choice, structure functions, and jet definitions. These errors are common to the two measurements; therefore, we have not reduced the systematic error after forming the average.

9.10. Lattice QCD

Lattice gauge theory calculations can be used to calculate the energy levels of a $Q\overline{Q}$ system and then extract α_s . The masses of the $Q\overline{Q}$ states depend only on the quark mass and on α_s . A limitation is that calculations cannot be performed for three light quark flavors. Results are available for zero (quenched approximation) and two light flavors, which allow extrapolation to three. The coupling constant so extracted is in a lattice renormalization scheme, and must be converted to the MS scheme for comparison with other results. Using the mass differences of Υ and Υ' and Υ and χ_b , Davies et al. [104] extract a value of $\alpha_s(M_Z) = 0.115 \pm 0.002$. The result is consistent with an earlier result by the same group based on quenched approximation ($\alpha_s(M_Z) = 0.112 \pm 0.004$) [105]. The error is dominated by the conversion between the coupling constants, which is performed at next-to-leading order in perturbation theory. It is estimated by making an assumption about the size of the NNLO term in this conversion. If it is estimated as one-half of the NLO term, then the resulting value is $\alpha_s(M_Z) = 0.115 \pm 0.003$.

A similar result with larger errors is reported by [106], where results are consistent with $\alpha_s(M_Z)=0.111\pm0.006$. This result confirms that obtained in quenched approximation by [107]. A calculation [108] using the strength of the force between two heavy quarks computed in the quenched approximation obtains a value of $\alpha_s(5~{\rm GeV})$ that is consistent with these results.

The result with a more conservative error $\alpha_s(M_Z)=0.115\pm0.003$ will be used in the average, although a recent reviewer quotes an error of ±0.007 [109].

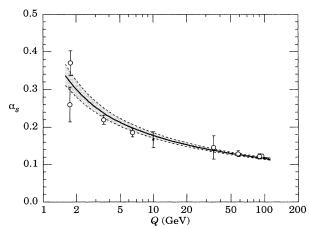


Figure 9.2: Summary of the values of $\alpha_s(Q)$ at the values of Q where they are measured. The lines show the central values and the $\pm 1\sigma$ limits of our average. The figure clearly shows the decrease in $\alpha_s(Q)$ with increasing Q.

9.11. Conclusions

The need for brevity has meant that many other important topics in QCD phenomenology have had to be omitted from this review. One should mention in particular the study of exclusive processes (form factors, elastic scattering, ...), the behavior of quarks and gluons in nuclei, the spin properties of the theory, the interface of soft and hard QCD as manifest, for example, by minijet production and hard diffractive processes, and QCD effects in hadron spectroscopy.

In this short review, we have focused on those high-energy processes which currently offer the most quantitative tests of perturbative QCD. Figure 9.1 shows the values of $\alpha_s(M_Z)$ deduced from the various experiments. Figure 9.2 shows the values and the values of Q where they are measured. This figure clearly shows the experimental evidence for the variation of $\alpha_s(Q)$ with Q.

An average of the values in Fig. 9.1 (except the one from the width of the Z) gives $\alpha_s(M_z) = 0.118$, with a total χ^2 of 9.1 for ten fitted points, showing good consistency among the data. The error on the average, assuming that all of the errors in the contributing results are uncorrelated, is ± 0.0017 , and is surely an underestimate. All the values are dominated by systematic, usually theoretical, errors. The two results with the smallest errors (± 0.003) are the ones from τ decay and lattice gauge theory. If these errors are increased to ± 0.006 , the average is unchanged. There has been discussion of systematic differences in the data. The measurements which are dominated by low-energy (deep-inelastic scattering (not including HERA), τ decay, Υ width, lattice) average to $\alpha_s(M_z) = 0.118$ ($\chi^2 = 8.3$ for 5 points). Results from space-like momentum transfers (all ep results) average to $\alpha_s(M_z) = 0.114 \pm 0.004$, which might indicate some lack of theoretical understanding in comparing the data. Since, in most cases, the dominant error is systematic (mainly theoretical), a more conservative estimate of the final error is obtained by using the smallest of the individual errors on the experimental results, i.e., ± 0.003 . Our average value is then $\alpha_s(M_z) = 0.118 \pm 0.003$, which corresponds to $\Lambda^{(5)} = 209^{+39}_{-33} \text{ MeV}.$

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10. STANDARD MODEL OF ELECTROWEAK INTERACTIONS

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The standard electroweak model is based on the gauge group [1] $\mathrm{SU}(2) \times \mathrm{U}(1)$, with gauge bosons W^i_μ , i=1,2,3, and B_μ for the $\mathrm{SU}(2)$ and $\mathrm{U}(1)$ factors, respectively, and the corresponding gauge coupling constants g and g'. The left-handed fermion fields $\psi_i = \begin{pmatrix} \nu_i \\ \ell_i^- \end{pmatrix}$ and $\begin{pmatrix} u_i \\ d_i^\prime \end{pmatrix}$ of the i^{th} fermion family transform as doublets under $\mathrm{SU}(2)$, where $d_i' \equiv \sum_j V_{ij} \ d_j$, and V is the Cabibbo-Kobayashi-Maskawa mixing matrix. (Constraints on V are discussed in the section on the Cabibbo-Kobayashi-Maskawa mixing matrix.) The right-handed fields are $\mathrm{SU}(2)$ singlets. In the minimal model there are three fermion families and a single complex Higgs doublet $\phi \equiv \begin{pmatrix} \phi^+ \\ \phi^0 \end{pmatrix}$.

After spontaneous symmetry breaking the Lagrangian is

$$\mathcal{L}_{F} = \sum_{i} \overline{\psi}_{i} \left(i \not \partial - m_{i} - \frac{g m_{i} H}{2 M_{W}} \right) \psi_{i}$$

$$- \frac{g}{2\sqrt{2}} \sum_{i} \overline{\psi}_{i} \gamma^{\mu} (1 - \gamma^{5}) (T^{+} W_{\mu}^{+} + T^{-} W_{\mu}^{-}) \psi_{i}$$

$$- e \sum_{i} q_{i} \overline{\psi}_{i} \gamma^{\mu} \psi_{i} A_{\mu}$$

$$- \frac{g}{2 \cos \theta_{W}} \sum_{i} \overline{\psi}_{i} \gamma^{\mu} (g_{V}^{i} - g_{A}^{i} \gamma^{5}) \psi_{i} Z_{\mu} . \tag{10.1}$$

 $\theta_W \equiv \tan^{-1}(g'/g)$ is the weak angle; $e=g\sin\theta_W$ is the positron electric charge; and $A\equiv B\cos\theta_W+W^3\sin\theta_W$ is the (massless) photon field. $W^\pm\equiv (W^1\mp iW^2)/\sqrt{2}$ and $Z\equiv -B\sin\theta_W+W^3\cos\theta_W$ are the massive charged and neutral weak boson fields, respectively. T^+ and T^- are the weak isospin raising and lowering operators. The vector and axial couplings are

$$g_V^i \equiv t_{3L}(i) - 2q_i \sin^2 \theta_W \tag{10.2}$$

$$g_A^i \equiv t_{3L}(i) , \qquad (10.3)$$

where $t_{3L}(i)$ is the weak isospin of fermion i (+1/2 for u_i and ν_i ; -1/2 for d_i and e_i) and q_i is the charge of ψ_i in units of e.

The second term in \mathscr{L}_F represents the charged-current weak interaction [2]. For example, the coupling of a W to an electron and a neutrino is

$$-\frac{e}{2\sqrt{2}\sin\theta_W} \left[W_{\mu}^{-} \ \overline{e} \ \gamma^{\mu} (1 - \gamma^5) \nu + W_{\mu}^{+} \ \overline{\nu} \ \gamma^{\mu} \ (1 - \gamma^5) e \right] \ . \tag{10.4}$$

For momenta small compared to M_W , this term gives rise to the effective four-fermion interaction with the Fermi constant given (at tree level, *i.e.*, lowest order in perturbation theory) by $G_F/\sqrt{2}=g^2/8M_W^2$. CP violation is incorporated in the Standard Model by a single observable phase in V_{ij} . The third term in \mathcal{L}_F describes electromagnetic interactions (QED), and the last is the weak neutral-current interaction.

In Eq. (10.1), m_i is the mass of the i^{th} fermion ψ_i . For the quarks these are the current masses. For the light quarks, as described in the Particle Listings, $m_u \approx 2\text{--}8$ MeV, $m_d \approx 5\text{--}15$ MeV, and $m_s \approx 100\text{--}300$ MeV (these are running masses evaluated at 1 GeV). For the heavier quarks, the "pole" masses are $m_c \approx 1.2\text{--}1.9$ GeV and $m_b \approx 4.5\text{--}4.9$ GeV. The average of the recent CDF [4] and DØ [5] values for m_t is 180 ± 12 GeV. See "The Note on Quark Masses" in the Particle Listings for more information.

H is the physical neutral Higgs scalar which is the only remaining part of ϕ after spontaneous symmetry breaking. The Yukawa coupling of H to ψ_i , which is flavor diagonal in the minimal model, is $gm_i/2M_W$. The H mass is not predicted by the model. Experimental limits are given in the Higgs section. In nonminimal models there are additional charged and neutral scalar Higgs particles [6].

10.1. Renormalization and radiative corrections

The Standard Model has three parameters (not counting M_H and the fermion masses and mixings). A particularly useful set is:

- (a) The fine structure constant α = 1/137.036, determined from the quantum Hall effect. In most electroweak-renormalization schemes, it is convenient to define a running α dependent on the energy scale of the process, with α⁻¹ ~ 137 appropriate at low energy. At energies of order M_Z, α⁻¹ ~ 128. For example, in the modified minimal subtraction (MS) scheme, one has α̂(M_Z)⁻¹ = 127.90 ± 0.09 [7], while the conventional (on-shell) QED renormalization yields [8] α(M_Z)⁻¹ = 128.90 ± 0.09, which differs by finite constants from α̂(M_Z)⁻¹. The uncertainty, due to the low-energy hadronic contribution to vacuum polarization, is the dominant theoretical uncertainty in the interpretation of precision data. The values include recent reevaluations [8-12] of this effect, which, following a correction to [11], are now in reasonable agreement. Further improvement will require improved measurements of the cross section for e⁺e⁻ → hadrons at low energy.
- (b) The Fermi constant, $G_F = 1.16639(2) \times 10^{-5} \text{ GeV}^{-2}$, determined from the muon lifetime formula [13]:

$$\tau_{\mu}^{-1} = \frac{G_F^2 m_{\mu}^5}{192\pi^3} F\left(\frac{m_e^2}{m_{\mu}^2}\right) \left(1 + \frac{3}{5} \frac{m_{\mu}^2}{M_W^2}\right) \times \left[1 + \frac{\alpha(m_{\mu})}{2\pi} \left(\frac{25}{4} - \pi^2\right)\right] , \qquad (10.5a)$$

where

$$F(x) = 1 - 8x + 8x^3 - x^4 - 12x^2 \ln x \tag{10.5b}$$

and

$$\alpha(m_{\mu})^{-1} = \alpha^{-1} - \frac{2}{3\pi} \ln\left(\frac{m_{\mu}}{m_{c}}\right) + \frac{1}{6\pi} \approx 136$$
. (10.5c)

The uncertainty in G_F from the input quantities is 1.1×10^{-10} GeV⁻². The quoted uncertainty of 2×10^{-10} is dominated by second order radiative corrections, estimated from the magnitude of the known $\alpha^2 \ln(m_\mu/m_e)$ term to be $\sim 1.8 \times 10^{-10}$ (alternately, one can view Eq. (10.5) as the exact definition of G_F ; then the theoretical uncertainty appears instead in the formulae for quantities derived from G_F).

(c) $\sin^2 \theta_W$, determined from the Z mass and other Z-pole observables, the W mass, and neutral-current processes [14]. The value of $\sin^2 \theta_W$ depends on the renormalization prescription. There are a number of popular schemes [16–21] leading to $\sin^2 \theta_W$ values which differ by small factors which depend on m_t and M_H . The notation for these schemes is shown in Table 10.1. Discussion of the schemes follows the table.

Table 10.1: Notations used to indicate the various schemes discussed in the text. Each definition of $\sin\theta_W$ leads to values that differ by small factors depending on m_t and M_H .

Scheme	Notation				
On-shell	$s_W = \sin \theta_W$				
NOV	$s_{M_Z} = \sin \theta_W$				
$\overline{\text{MS}}$	$\hat{s}_Z = \sin \theta_W$				
$\overline{ ext{MS}}$ ND	$\hat{s}_{ND} = \sin \theta_W$				
Effective angle	$\overline{s}_f = \sin \theta_W$				

(i) The on-shell scheme promotes the tree-level formula $\sin^2\theta_W=1-M_W^2/M_Z^2$ to a definition of the renormalized $\sin^2\theta_W$ to all orders in perturbation theory, i.e., $\sin^2\theta_W\to s_W^2\equiv 1-M_W^2/M_Z^2$. This scheme is simple conceptually. However, M_W is known much less precisely than M_Z and in practice one extracts s_W^2 from M_Z alone using

$$M_W = \frac{A_0}{s_W (1 - \Delta r)^{1/2}} \tag{10.6a}$$

$$M_Z = \frac{M_W}{c_W} \,, \tag{10.6b}$$

where $s_W \equiv \sin \theta_W$, $c_W \equiv \cos \theta_W$, $A_0 = (\pi \alpha/\sqrt{2}G_F)^{1/2} = 37.2802$ GeV, and Δr includes the radiative corrections relating α , $\alpha(M_Z)$, G_F , M_W , and M_Z . One finds $\Delta r \sim \Delta r_0 - \rho_t/\tan^2\theta_W$, where $\Delta r_0 \approx 1 - \alpha/\alpha(M_Z) \approx 0.06$ is due to the running of α and $\rho_t = 3G_F m_t^2/8\sqrt{2}\pi^2 \approx 0.0100$ $(m_t/180~{\rm GeV})^2$ represents the dominant (quadratic) m_t dependence. There are additional contributions to Δr from bosonic loops, including those which depend logarithmically on the Higgs mass M_H . One has $\Delta r = 0.0376 \pm 0.0025 \pm 0.0007$ for $(m_t, M_H) = (180 \pm 7, 300)$, where the second uncertainty is from $\alpha(M_Z)$. Thus the value of s_W^2 extracted from M_Z includes a large uncertainty (~ 0.0008) from the currently allowed range of m_t .

(ii) A more precisely determined quantity $s_{M_Z}^2$ can be obtained from M_Z by removing the (m_t, M_H) dependent term from Δr [17], i.e.,

$$s_{M_Z}^2 c_{M_Z}^2 \equiv \frac{\pi \alpha(M_Z)}{\sqrt{2} G_F M_Z^2}$$
 (10.7)

This yields $s_{MZ}^2=0.2311\pm0.0002$, with most of the uncertainty from α rather than M_Z . Scheme (ii) is equivalent to using M_Z rather than $\sin^2\theta_W$ as the third fundamental parameter. However, it recognizes that s_{MZ}^2 is still a useful derived quantity. The small uncertainty in s_{MZ}^2 compared to other schemes is because the m_t dependence has been removed by definition. However, the m_t uncertainty reemerges when other quantities $(e.g., M_W)$ or other Z-pole observables) are predicted in terms of M_Z .

Both s_W^2 and $s_{M_Z}^2$ depend not only on the gauge couplings but also on the spontaneous-symmetry breaking, and both definitions are awkward in the presence of any extension of the Standard Model which perturbs the value of M_Z (or M_W). Other definitions are motivated by the tree-level coupling constant definition $\theta_W = \tan^{-1}(g'/g)$.

(iii) In particular, the modified minimal subtraction $(\overline{\text{MS}})$ scheme introduces the quantity $\sin^2 \widehat{\theta}_W(\mu) \equiv \widehat{g}^{\prime 2}(\mu) / [\widehat{g}^{2}(\mu) +$ $\widehat{g}^{\prime 2}(\mu)$, where the couplings \widehat{g} and \widehat{g}' are defined by modified minimal subtraction and the scale μ is conveniently chosen to be M_Z for electroweak processes. The value of $\widehat{s}_Z^2 = \sin^2 \widehat{\theta}_W(M_Z)$ extracted from M_Z is less sensitive than s_W^2 to m_t (by a factor of $\tan^2\theta_W$), and is less sensitive to most types of new physics than s_W^2 or $s_{M_Z}^2$. It is also very useful for comparing with the predictions of grand unification. There are actually several variant definitions of $\sin^2 \widehat{\theta}_W(M_Z)$, differing according to whether or how finite $\alpha \ln(m_t/M_Z)$ terms are decoupled (subtracted from the couplings). One cannot entirely decouple the $\alpha \ln(m_t/M_Z)$ terms from all electroweak quantities because $m_t \gg m_b$ breaks SU(2) symmetry. The scheme that will be adopted here decouples the $\alpha \ln(m_t/M_Z)$ terms from the $\gamma - Z$ mixing [7,18], essentially eliminating any $\ln(m_t/M_Z)$ dependence in the formulae for asymmetries at the Z pole when written in terms of \hat{s}_{Z}^{2} . The various definitions are related by

$$\hat{s}_{Z}^{2} = c(m_{t}, M_{H}) s_{W}^{2} = \overline{c}(m_{t}, M_{H}) s_{M_{Z}}^{2},$$
 (10.8)

where $c=1.035\pm0.003$ for $m_t=180\pm7$ GeV and $M_H=300$ GeV. Similarly $\overline{c}=1.002\pm0.001$. The quadratic m_t dependence is given by $c\sim1+\rho_t/\tan^2\theta_W$. The expressions for M_W and M_Z in the $\overline{\rm MS}$ scheme are

$$M_W = \frac{A_0}{\hat{s}_Z (1 - \Delta \hat{r}_W)^{1/2}} \tag{10.9a}$$

$$M_Z = \frac{M_W}{\hat{\rho}^{1/2} \hat{c}_Z} \ . \tag{10.9b}$$

One predicts $\Delta \hat{r}_W = 0.0705 \pm 0.0001 \pm 0.0007$ for $m_t = 180 \pm 7$ GeV and $M_H = 300$ GeV. $\Delta \hat{r}_W$ has no quadratic m_t dependence, because shifts in M_W are absorbed into the observed G_F , so that $\Delta \hat{r}_W$ is dominated by $\Delta r_0 = 1 - \alpha/\alpha(M_Z)$. Similarly, $\hat{\rho} \sim 1 + \rho_t$. Including bosonic loops, $\hat{\rho} = 0.0103 \pm 0.0008$ for $m_t = 180 \pm 7$ GeV.

(iv) A variant $\overline{\rm MS}$ quantity $\widehat{s}_{\rm ND}^2$ (used in the 1992 edition of this Review) does not decouple the $\alpha \ln(m_t/M_Z)$ terms [19]. It is related to \widehat{s}_Z^2 by

$$\widehat{s}_Z^2 = \widehat{s}_{ND}^2 / \left(1 + \frac{\widehat{\alpha}}{\pi} d \right) \tag{10.10a}$$

$$d = \frac{1}{3} \left(\frac{1}{\widehat{s}^2} - \frac{8}{3} \right) \left[\left(1 + \frac{\widehat{\alpha}_s}{\pi} \right) \ln \frac{m_t}{M_Z} - \frac{15\widehat{\alpha}_s}{\pi} \right] , \quad (10.10b)$$

where $\widehat{\alpha}_s$ is the QCD coupling at M_Z . Thus, $\widehat{s}_Z^2 - \widehat{s}_{\rm ND}^2 \sim -0.0002$ for $(m_t, M_H) = (180, 300)$ GeV.

(v) Yet another definition, the effective angle [20,21] \overline{s}_f^2 for Z coupling to fermion f, is described below.

Experiments are now at such a level of precision that complete $\mathcal{O}(\alpha)$ radiative corrections must be applied. For neutral-current and Z-pole processes, these corrections are conveniently divided into two classes:

- 1. QED diagrams involving the emission of real photons or the exchange of virtual photons in loops, but not including vacuum polarization diagrams. These graphs yield finite and gauge-invariant contributions to observable processes. However, they are dependent on energies, experimental cuts, etc., and must be calculated individually for each experiment.
- 2. Electroweak corrections, including $\gamma\gamma$, γZ , ZZ, and WW vacuum polarization diagrams, as well as vertex corrections, box graphs, etc., involving virtual W's and Z's. Many of these corrections are absorbed into the renormalized Fermi constant defined in Eq. (10.5). Others modify the tree-level expressions for Z-pole observables and neutral-current amplitudes in several ways [14]. One-loop corrections are included for all processes. In addition, certain two-loop corrections are also important. In particular, two-loop corrections involving the top-quark [22] modify ρ_t in $\hat{\rho}$, Δr , and elsewhere by

$$\rho_t \to \rho_t [1 + R(M_H/m_t)\rho_t/3] ,$$
(10.11)

where -3.8 > R > -11.8 is strongly dependent on M_H/m_t : R = -3.8 for M_H at its lower direct limit and R = -7.8 for $M_H = 1.7m_t \approx 300$ GeV. -11.8 is in absolute lower bound for R which is assumed for large M_H . Mixed QCD-electroweak loops of order $\alpha \alpha_s m_t^2$ [23] and $\alpha \alpha_s^2 m_t^2$ [24] multiply ρ_t by 1-2 $\alpha_s(0.3m_t)(\pi^2+3)/9\pi \sim 0.88$, where the three-loop result is included through the use of a lower scale for α_s . These mixed corrections increase the predicted value of m_t by 6%. Analogous electroweak and mixed two-loop terms are also known for the $Z \to b\bar{b}$ vertex [22,25].

10.2. Cross section and asymmetry formulas

It is convenient to write the four-fermion interactions relevant to ν -hadron, νe , and parity-violating e-hadron neutral-current processes in a form that is valid in an arbitrary gauge theory (assuming massless left-handed neutrinos). One has

$$-\mathcal{L}^{\nu \text{Hadron}} = \frac{G_F}{\sqrt{2}} \, \overline{\nu} \, \gamma^{\mu} \, (1 - \gamma^5) \nu$$

$$\times \sum_{i} \left[\epsilon_L(i) \, \overline{q}_i \, \gamma_{\mu} (1 - \gamma^5) q_i + \epsilon_R(i) \, \overline{q}_i \, \gamma_{\mu} (1 + \gamma^5) q_i \right] , \quad (10.12)$$

$$-\mathcal{L}^{\nu e} = \frac{G_F}{\sqrt{2}} \, \overline{\nu}_{\mu} \, \gamma^{\mu} (1 - \gamma^5) \nu_{\mu} \, \overline{e} \, \gamma_{\mu} (g_V^{\nu e} - g_A^{\nu e} \gamma^5) e \quad (10.13)$$

(for $\nu_e e$ or $\overline{\nu}_e e$, the charged-current contribution must be included), and

$$-\mathscr{L}^{e \text{Hadron}} = -\frac{G_F}{\sqrt{2}}$$

$$\times \sum_{i} \left[C_{1i} \ \overline{e} \ \gamma_{\mu} \ \gamma^5 \ e \ \overline{q}_i \ \gamma^{\mu} \ q_i + C_{2i} \ \overline{e} \ \gamma_{\mu} \ e \ \overline{q}_i \ \gamma^{\mu} \ \gamma^5 \ q_i \right] (10.14)$$

(One must add the parity-conserving QED contribution.)

The Standard Model expressions for $\epsilon_{L,R}(i)$, $g_{V,A}^{\nu e}$, and C_{ij} are given in Table 10.2. Note that $g_{V,A}^{\nu e}$ and the other quantities are coefficients of effective four-fermi operators, which differ from the quantities defined in Eq. (10.2) and Eq. (10.3) in the radiative corrections and in the presence of possible physics beyond the Standard Model.

A precise determination of the on-shell s_W^2 , which depends only very weakly on m_t and M_H , is obtained from deep inelastic neutrino scattering from (approximately) isoscalar targets [26]. The ratio $R_{\nu} \equiv \sigma_{\nu N}^{NC}/\sigma_{\nu N}^{CC}$ of neutral- to charged-current cross sections has been measured to 1% accuracy by the CDHS [27] and CHARM [28] collaborations [29,30] at CERN, and the CCFR collaboration at Fermilab [31] has obtained an even more precise result, so it is important to obtain theoretical expressions for R_{ν} and $R_{\overline{\nu}} \equiv \sigma_{\overline{\nu}N}^{NC}/\sigma_{\overline{\nu}N}^{CC}$ (as functions of $\sin^2\theta_W$) to comparable accuracy. Fortunately, most of the uncertainties from the strong interactions and neutrino spectra cancel in the ratio.

A simple zero th -order approximation is

$$R_{\nu} = g_L^2 + g_R^2 r \tag{10.15a}$$

$$R_{\overline{\nu}} = g_L^2 + \frac{g_R^2}{r} \,,$$
 (10.15b)

where

$$g_L^2 \equiv \epsilon_L (u)^2 + \epsilon_L (d)^2 \approx \frac{1}{2} - \sin^2 \theta_W + \frac{5}{9} \sin^4 \theta_W$$
 (10.16a)

$$g_R^2 \equiv \epsilon_R (u)^2 + \epsilon_R (d)^2 \approx \frac{5}{9} \sin^4 \theta_W , \qquad (10.16b)$$

and $r \equiv \sigma^{CC}_{\overline{\nu}N}/\sigma^{CC}_{\nu N}$ is the ratio of $\overline{\nu}$ and ν charged-current cross sections, which can be measured directly. [In the simple parton model, ignoring hadron energy cuts, $r \approx (\frac{1}{3} + \epsilon)/(1 + \frac{1}{3}\epsilon)$, where $\epsilon \sim 0.125$ is the ratio of the fraction of the nucleon's momentum carried by antiquarks to that carried by quarks.] In practice, Eq. (10.15) must be corrected for quark mixing, the s and c seas, c-quark threshold effects, nonisoscalar target effects, W-Z propagator differences, and radiative corrections (which lower the extracted value of $\sin^2 \theta_W$ by ~ 0.009). Details of the neutrino spectra, experimental cuts, x and Q^2 dependence of structure functions, and longitudinal structure functions enter only at the level of these corrections and therefore lead to very small uncertainties. The largest theoretical uncertainty is associated with the c threshold, which mainly affects σ^{CC} . Using the slow rescaling prescription [14]—the central value of $\sin^2 \theta_W$ varies as 0.013 $[m_c(\text{GeV})-1.3]$, where m_c is the effective mass. For $m_c = 1.31 \pm 0.24$ GeV (determined from ν -induced dimuon production [31]) this contributes ± 0.003 to the total theoretical

Table 10.2: Standard Model expressions for the neutral-current parameters for ν -hadron, νe , and e-hadron processes. If radiative corrections are ignored, $\rho=\kappa=1,\ \lambda=0.$ At $\mathcal{O}(\alpha)$ in the on-shell scheme, $\rho_{\nu N}^{NC}=1.0095,\ \kappa_{\nu N}=1.0382,\ \lambda_{u_L}=-0.0032,\ \lambda_{d_L}=-0.0026,\ \mathrm{and}\ \lambda_{u_R}=1/2\ \lambda_{d_R}=3.6\times 10^{-5}$ for $m_t=180$ GeV, $M_H=300$ GeV, $M_Z=91.1884$ GeV, and $\langle Q^2\rangle=20$ GeV². For νe scattering, $\kappa_{\nu e}=1.0385$ and $\rho_{\nu e}=1.0143$ (at $\langle Q^2\rangle=0.$). For atomic parity violation, $\rho_{eq}'=0.9884$ and $\kappa_{eq}'=1.036.$ For the SLAC polarized electron experiment, $\rho_{eq}'=0.979,\ \kappa_{eq}'=1.034,\ \rho_{eq}=1.002,\ \mathrm{and}\ \kappa_{eq}=1.06$ after incorporating additional QED corrections, while $\lambda_{2u}=-0.013,\ \lambda_{2d}=0.003.$ The dominant m_t dependence is given by $\rho\sim1+\rho_t,$ while $\kappa\sim1+\rho_t/\tan^2\theta_W$ (on-shell) or $\kappa\sim1(\overline{\mathrm{MS}}).$

Quantity	Standard Model Expression
$\epsilon_L(u)$	$\rho_{\nu N}^{NC} \left(\frac{1}{2} - \frac{2}{3} \kappa_{\nu N} \sin^2 \theta_W + \lambda_{uL} \right)$
$\epsilon_L(d)$	$ ho_{ u N}^{NC} \left(-rac{1}{2} + rac{1}{3} \kappa_{ u N} \sin^2 heta_W + \lambda_{dL} ight)$
$\epsilon_R(u)$	$ ho_{ u N}^{NC} \left(-rac{2}{3} \kappa_{ u N} \sin^2 heta_W + \lambda_{uR} ight)$
$\epsilon_R(d)$	$ ho_{ u N}^{NC} \left(rac{1}{3} \kappa_{ u N} \sin^2 heta_W + \lambda_{dR} ight)$
$g_V^{ u e} \ g_A^{ u e}$	$\rho_{\nu e} \left(-\frac{1}{2} + 2\kappa_{\nu e} \sin^2 \theta_W \right)$ $\rho_{\nu e} \left(-\frac{1}{2} \right)$
C_{1u}	$\rho'_{eq}\left(-\frac{1}{2} + \frac{4}{3}\kappa'_{eq}\sin^2\theta_W\right)$
C_{1d}	$\rho_{eq}'\left(\frac{1}{2} - \frac{2}{3}\kappa_{eq}'\sin^2\theta_W\right)$
C_{2u}	$\rho_{eq} \left(-\frac{1}{2} + 2\kappa_{eq} \sin^2 \theta_W \right) + \lambda_{2u}$
C_{2d}	$\rho_{eq} \left(\frac{1}{2} - 2\kappa_{eq} \sin^2 \theta_W \right) + \lambda_{2d}$

uncertainty $\Delta \sin^2 \theta_W \sim \pm 0.004$. This would require a high-energy neutrino beam for improvement. (The experimental uncertainty is ± 0.003). The CCFR group quotes $s_W^2 = 0.2218 \pm 0.0059$ for $(m_t, M_H) = (150, 100)$, but this result is insensitive to (m_t, M_H) . Combining all of the precise deep-inelastic measurements, one obtains $s_W^2 = 0.2259 \pm 0.0043$ for (m_t, M_H) in the allowed range.

The laboratory cross section for $\nu_{\mu}e \to \nu_{\mu}e$ or $\overline{\nu}_{\mu}e \to \overline{\nu}_{\mu}e$ elastic scattering is

$$\frac{d\sigma_{\nu_{\mu},\overline{\nu}_{\mu}}}{dy} = \frac{G_F^2 m_e E_{\nu}}{2\pi}
\times \left[(g_V^{\nu e} \pm g_A^{\nu e})^2 + (g_V^{\nu e} \mp g_A^{\nu e})^2 (1 - y)^2 \right]
- (g_V^{\nu e 2} - g_A^{\nu e 2}) \frac{y m_e}{E_{\nu}} ,$$
(10.17)

where the upper (lower) sign refers to $\nu_{\mu}(\overline{\nu}_{\mu})$, and $y \equiv E_e/E_{\nu}$ [which runs from 0 to $(1+m_e/2E_{\nu})^{-1}$] is the ratio of the kinetic energy of the recoil electron to the incident ν or $\overline{\nu}$ energy. For $E_{\nu} \gg m_e$ this yields a total cross section

$$\sigma = \frac{G_F^2 \ m_e \ E_{\nu}}{2\pi} \left[(g_V^{\nu e} \pm g_A^{\nu e})^2 + \frac{1}{3} (g_V^{\nu e} \mp g_A^{\nu e})^2 \right] \ . \tag{10.18}$$

The most accurate leptonic measurements [32–34] of $\sin^2\theta_W$ are from the ratio $R \equiv \sigma_{\nu_\mu e}/\sigma_{\overline{\nu}_\mu e}$ in which many of the systematic uncertainties cancel. Radiative corrections (other than m_t effects) are small compared to the precision of present experiments and have negligible effect on the extracted $\sin^2\theta_W$. The most precise (CHARM II) experiment [34] determined not only $\sin^2\theta_W$ but $g_{V,A}^{\nu e}$ as well. The cross sections for $\nu_e e$ and $\overline{\nu}_e e$ may be obtained from

Eq. (10.17) by replacing $g_{V,A}^{\nu e}$ by $g_{V,A}^{\nu e}+1$, where the 1 is due to the charged-current contribution.

The SLAC polarized-electron experiment [35] measured the parity-violating asymmetry

$$A = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} , \qquad (10.19)$$

where $\sigma_{R,L}$ is the cross section for the deep-inelastic scattering of a right- or left-handed electron: $e_{R,L}N \to eX$. In the quark parton model

$$\frac{A}{Q^2} = a_1 + a_2 \, \frac{1 - (1 - y)^2}{1 + (1 - y)^2} \,, \tag{10.20}$$

where $Q^2 > 0$ is the momentum transfer and y is the fractional energy transfer from the electron to the hadrons. For the deuteron or other isoscalar target, one has, neglecting the s quark and antiquarks,

$$a_1 = \frac{3G_F}{5\sqrt{2}\pi\alpha} \left(C_{1u} - \frac{1}{2}C_{1d} \right) \approx \frac{3G_F}{5\sqrt{2}\pi\alpha} \left(-\frac{3}{4} + \frac{5}{3}\sin^2\theta_W \right) (10.21a)$$

$$a_2 = \frac{3G_F}{5\sqrt{2}\pi\alpha} \left(C_{2u} - \frac{1}{2}C_{2d}\right) \approx \frac{9G_F}{5\sqrt{2}\pi\alpha} \left(\sin^2\theta_W - \frac{1}{4}\right) \ . \ \ (10.21b)$$

Radiative corrections (other than m_t effects) lower the extracted value of $\sin^2 \theta_W$ by $\sim~0.005$.

There are now precise experiments measuring atomic parity violation [36] in cesium [37], bismuth [38], lead [39], and thallium [40]. The uncertainties associated with atomic wave functions are quite small for cesium, for which the theoretical uncertainty is $\sim 1\%$ [41] but somewhat larger for the other atoms. For heavy atoms one determines the "weak charge"

$$Q_W = -2 \left[C_{1u} \left(2Z + N \right) + C_{1d} (Z + 2N) \right]$$

$$\approx Z (1 - 4 \sin^2 \theta_W) - N . \tag{10.22}$$

Radiative corrections increase the extracted $\sin^2 \theta_W$ by ~ 0.008 .

In the future it should be possible to reduce the theoretical wave function uncertainties by taking the ratios of parity violation in different isotopes [36,42]. There would still be some residual uncertainties from differences in the neutron charge radii, however [43].

The forward-backward asymmetry for $e^+e^- \to \ell \bar{\ell}$, $\ell = \mu$ or τ , is defined as

$$A_{FB} \equiv \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B} \,\,, \tag{10.23}$$

where $\sigma_F(\sigma_B)$ is the cross section for ℓ^- to travel forward (backward) with respect to the e^- direction. A_{FB} and R, the total cross section relative to pure QED, are given by

$$R = F_1 \tag{10.24}$$

$$A_{FB} = 3F_2/4F_1 , (10.25)$$

where

$$F_1 = 1 - 2\chi_0 g_V^e g_V^\ell \cos \delta_R + \chi_0^2 \left(g_V^{e2} + g_A^{e2} \right) \left(g_V^{\ell2} + g_A^{\ell2} \right) \quad (10.26a)$$

$$F_2 = -2\chi_0 g_A^e g_A^\ell \cos \delta_R + 4\chi_0^2 g_A^e g_A^\ell g_V^\ell g_V^\ell , \qquad (10.26b)$$

where

$$\tan \delta_R = \frac{M_Z \Gamma_Z}{M_Z^2 - s} \tag{10.27}$$

$$\chi_0 = \frac{G_F}{2\sqrt{2}\pi\alpha} \frac{sM_Z^2}{\left[(M_Z^2 - s)^2 + M_Z^2\Gamma_Z^2\right]^{1/2}}$$
(10.28)

and \sqrt{s} is the CM energy. Eq. (10.26) is valid at tree level. If the data are radiatively corrected for QED effects (as described above),

then the remaining electroweak corrections can be incorporated [44] (in an approximation adequate for existing PEP, PETRA, and TRISTAN data, which are well below the Z pole) by replacing χ_0 by $\chi(s) \equiv (1+\rho_t)\chi_0(s)\alpha/\alpha(s)$, where $\alpha(s)$ is the running QED coupling, and evaluating g_V in the $\overline{\text{MS}}$ scheme. Formulas for $e^+e^- \to hadrons$ may be found in Ref. 45.

At LEP and SLC, there are high-precision measurements of various Z-pole observables [46–49]. These include the Z mass and total width Γ_{Z} , and partial widths $\Gamma(f\overline{f})$ for $Z \to f\overline{f}$ for fermion f ($f=e,\mu,\tau$, hadrons, b,c, and ν). The data is consistent with lepton-family universality $\Gamma(e^+e^-) = \Gamma(\mu^+\mu^-) = \Gamma(\tau^+\tau^-)$, so one may work with an average width $\Gamma(\ell\overline{\ell})$. It is convenient to use the variables M_Z , Γ_Z , $R \equiv \Gamma(\mathrm{had})/\Gamma(\ell\overline{\ell})$, $\sigma_{\mathrm{had}} \equiv 12\pi\Gamma(e^+e^-)\Gamma(\mathrm{had})/M_Z^2\Gamma_Z^2$, $R_b \equiv \Gamma(b\overline{b})/\Gamma(\mathrm{had})$, and $R_c \equiv \Gamma(c\overline{c})/\Gamma(\mathrm{had})$, most of which are weakly correlated experimentally. ($\Gamma(\mathrm{had})$ is the partial width into hadrons.) The largest correlation coefficient of -0.35 occurs between R_b and R_c . R is insensitive to m_t except for $Z \to b\overline{b}$ vertex and final state corrections and the implicit dependence through $\sin^2\theta_W$. Thus it is especially useful for constraining α_s . The width for invisible decays, $\Gamma(\mathrm{inv}) = \Gamma_Z - 3\Gamma(\ell\overline{\ell}) - \Gamma(\mathrm{had}) = 499.9 \pm 2.5$ MeV, can be used to determine the number of neutrino flavors lighter than $M_Z/2$, $N_{\nu} = \Gamma_{\mathrm{inv}}/\Gamma(\nu\overline{\nu}) = 2.991 \pm 0.016$.

There are also measurements of various asymmetries. These include the polarization or left-right asymmetry

$$A_{LR} \equiv \frac{\sigma_L - \sigma_R}{\sigma_L + \sigma_R} \; , \tag{10.29}$$

where $\sigma_L(\sigma_R)$ is the cross section for a left- (right)-handed incident electron. A_{LR} has been measured precisely by the SLD collaboration at SLC [48] and has the advantages of being extremely sensitive to $\sin^2\theta_W$ and insensitive to QED radiative corrections. Other asymmetries are the forward-backward asymmetries $A_{FB}^{(0,f)}$ for f=e, $\mu,$ $\tau,$ b, c $(A_{FB}^{(0,e)}, A_{FB}^{(0,\mu)}, A_{FB}^{(0,\tau)}$ are consistent with lepton-family universality, allowing an average value $A_{FB}^{(0,\ell)}$), the hadronic-charge asymmetry, the τ polarization P_{τ} , and its angular distribution. Further details, including references to the data from the LEP experiments (ALEPH, DELPHI, L3, OPAL) may be found in the Particle Listings in the 'Note on the Z Boson' and in [46–49]. At tree level and neglecting QED effects and terms of order $(\Gamma_Z/M_Z)^2$, one has

$$A_{FB}^{(0,f)} \approx \frac{3}{4} A_f \frac{A_e + P_e}{1 + P_e A_e}$$
 (10.30)

$$A_{LR} \approx A_e P_e \ , \tag{10.31}$$

where P_e is the initial e^- polarization and

$$A_f \equiv \frac{2g_V^f g_A^f}{g_V^{f2} + g_A^{f2}} \ . \tag{10.32}$$

Similarly, A_{τ} is given by the negative total τ polarization, and A_{e} can be extracted from the angular distribution of the polarization. In addition, the SLD collaboration [49] has extracted the final-state couplings A_{b} and A_{c} from the left-right forward-backward asymmetry, using

$$\frac{\sigma_{LF} - \sigma_{LB} - \sigma_{RF} + \sigma_{RB}}{\sigma_{LF} + \sigma_{LB} + \sigma_{RF} + \sigma_{RB}} = A_f , \qquad (10.33)$$

where, for example, σ_{LF} is the cross section for a left-handed incident electron to produce a fermion f traveling in the forward hemisphere.

It has become customary for the experimental groups to present corrected asymmetries A^0 , in which photon exchange and γ -Z interference, QED corrections, and corrections for $\sqrt{s} \neq M_Z$ are removed from the data, leaving the pure electroweak asymmetries. Ignoring negligible electroweak boxes, these corrected asymmetries are expressed using effective tree-level expression e.g., $A_{FB}^{(0,f)} = \frac{3}{4}\overline{A}_f\overline{A}_e$ (for $P_e=0$) and $A_{LR}^0 = \overline{A}_e$, where

$$\overline{A}_f = \frac{2\overline{g}_V^f \, \overline{g}_A^f}{\overline{g}_V^{f2} + \overline{g}_A^{f2}} \,, \tag{10.34a}$$

and

$$\overline{g}_V^f = \sqrt{\rho_f} \left(t_{3L}^{(f)} - 2q_f \kappa_f \sin^2 \theta_W \right) \tag{10.34b}$$

$$\overline{g}_A^f = \sqrt{\rho_f} \, t_{3L}^{(f)} \,. \tag{10.34c}$$

The electroweak-radiative corrections have been absorbed into corrections ρ_f-1 and κ_f-1 , which depend on the fermion f and on the renormalization scheme. In the on-shell scheme, the quadratic m_t dependence is given by $\rho_f\sim 1+\rho_t,\,\kappa_f\sim\kappa_f^{os}\sim 1+\rho_t/\tan^2\theta_W,$ while in $\overline{\rm MS},\,\rho_f\sim\widehat{\rho},\,\kappa_f\equiv\widehat{\kappa}_f\sim 1.$ In practice, additional bosonic loops, vertex corrections, etc., must be included. For example, in the $\overline{\rm MS}$ scheme one has, for $(m_t,M_H)=(180,300),\,\rho_\ell=1.0053$ and $\widehat{\kappa}_\ell=1.0012.$ It is convenient to define an effective angle $\overline{s}_f^2\equiv\sin^2\overline{\theta}_{Wf}\equiv\widehat{\kappa}_f\widehat{s}_Z^2=\kappa_f^{os}\,s_W^2$, in terms of which \overline{g}_V^f and \overline{g}_A^f are given by $\sqrt{\rho_f}$ times their tree-level formulae. Because \overline{g}_V^ℓ is very small, not only A_{LR}^0 $A_{FB}^{(0,\ell)}$, and P_τ^0 , but also $A_{FB}^{(0,b)}$, $A_{FB}^{(0,c)}$, and the hadronic-charge asymmetry are mainly sensitive to \overline{s}_ℓ^2 . One finds that $\widehat{\kappa}_f$ is almost independent of (m_t,M_H) , so that

$$\bar{s}_{\ell}^2 \sim \hat{s}_{Z}^2 + 0.00028$$
 (10.35)

using Ref. 20, or $\overline{s}_\ell^2 \sim \widehat{s}_Z^2 + 0.0002$ from Ref. 21 (the small difference is an indication of theoretical uncertainties from higher-order terms, etc.). In any case, the asymmetries determine values of \overline{s}_ℓ^2 and \widehat{s}_Z^2 almost independent of m_t , while the κ 's for the other schemes are m_t dependent.

10.3. W and Z decays

The partial decay width for gauge bosons to decay into massless fermions $f_1 \overline{f}_2$ is

$$\Gamma(W^+ \to e^+ \nu_e) = \frac{G_F M_W^3}{6\sqrt{2}\pi} \approx 226 \pm 1 \text{ MeV}$$
 (10.36a)

$$\Gamma(W^+ \to u_i \overline{d}_j) = \frac{CG_F M_W^3}{6\sqrt{2}\pi} |V_{ij}|^2 \approx (705 \pm 4) |V_{ij}|^2 \text{ MeV} \quad (10.36b)$$

$$\Gamma(Z \to \psi_i \overline{\psi}_i) = \frac{C G_F M_Z^3}{6\sqrt{2}\pi} \left[g_V^{i2} + g_A^{i2} \right]$$
 (10.36c)

$$\approx \begin{cases} 167.2 \pm 0.1 \text{ MeV } (\nu \overline{\nu}), & 84.0 \pm 0.1 \text{ MeV } (e^+e^-), \\ 300.6 \pm 0.3 \text{ MeV } (u\overline{u}), & 383.3 \pm 0.3 \text{ MeV } (d\overline{d}), \\ 375.9 \mp 0.2 \text{ MeV } (b\overline{b}). \end{cases}$$

For leptons C=1, while for quarks $C=3\Big(1+\alpha_s(M_V)/\pi+1.409\alpha_s^2/\pi^2\Big)$ $-12.77\alpha_s^3/\pi^3$), where the 3 is due to color and the factor in parentheses represents the universal QCD corrections for massless quarks [50]. The $Z \to f\overline{f}$ widths contain a number of additional corrections [51]: universal (non-singlet) top-mass contributions [52]; fermion mass effects and further QCD corrections proportional to m_q^2 [53] (m_q is the running quark mass evaluated at the Z scale) which are different for vector and axial-vector partial widths; and singlet contributions starting from two loop order which are large, strongly top-mass dependent, family universal and flavor non-universal [54]. All QCD effects are known and included up to three loop order with the exception of order $\alpha_s^3 m_b^2$ corrections which are very small. The QED factor $1 + 3\alpha q_f^2/4\pi$ and order $\alpha\alpha_s$ corrections [55] have to be included, as well. Expressing the widths in terms of $G_F M_{W,Z}^3$ incorporates the bulk of the low-energy radiative corrections [16,56] The electroweak corrections are incorporated by replacing $g_{V,A}^{i2}$ by $\overline{g}_{V,A}^{i2}$. Hence, the widths are proportional to $\rho_i \sim 1 + \rho_t$. There is additional (negative) quadratic m_t dependence in the $Z \to b\bar{b}$ vertex corrections [57] which causes $\Gamma(b\bar{b})$ to decrease with m_t . The dominant effect is to multiply $\Gamma(b\bar{b})$ by the vertex correction $1 + \delta \rho_{b\bar{b}}$, where

 $\delta \rho_{b\overline{b}} \sim 10^{-2} (-rac{1}{2} rac{m_t^2}{M_Z^2} + rac{1}{5})$. In practice, the corrections are included in ho_b and κ_b .

For 3 fermion families the total widths are predicted to be

$$\Gamma_Z \approx 2.497 \pm 0.002 \text{ GeV}$$
 (10.37)

$$\Gamma_W \approx 2.09 \pm 0.01 \text{ GeV}$$
 (10.38)

The numerical values for the widths assume $M_Z=91.1884\pm0.0022$ GeV, $M_W=80.26\pm0.16$ GeV, $\alpha_s=0.123$, and $m_t=180\pm7$ GeV, where the α_s and m_t values are predicted by the global fits for $M_H=300$ GeV. The uncertainties for Γ_W and Γ_Z are dominated by ΔM_W and Δm_t , respectively. The uncertainty in α_s , ±0.004 , introduces an additional uncertainty of 0.13% in the hadronic widths, corresponding to ±2 MeV in Γ_Z .

These predictions are to be compared with the experimental results $\Gamma_Z=2.4963\pm0.0032$ GeV and $\Gamma_W=2.08\pm0.07$ GeV.

10.4. Experimental results

The values of the principal Z-pole observables are listed in Table 10.3, along with the Standard Model predictions for M_Z = 91.1884 ± 0.0022 , $m_t = 180 \pm 7 \text{ GeV}$ (for $M_H = 300 \text{ GeV}$), 60 GeV $< M_H < 1$ TeV, and $\alpha_s = 0.123 \pm 0.004$. Note that, the values of the Z-pole observables (as well as M_W) differ from those in the Particle Listings because they include recent preliminary results [47,49,59]. The values and predictions of M_W [59], the Q_W for cesium [36,41], and recent results from deep inelastic and $\nu_{\mu}e$ scattering are also listed. The agreement is generally excellent. Major exceptions are $R_b = \Gamma(b\bar{b})/\Gamma(\text{had})$ which is 3.7 σ above the Standard Model prediction, and $R_c = \Gamma(c\overline{c})/\Gamma(\text{had})$ which is 2.4σ below. These are strongly correlated: if R_c is fixed at the Standard Model value of 0.172, then one obtains [47] $R_b = 0.2205 \pm 0.0016$, which is still 3.0σ too high. Within the Standard Model framework, these values must be considered large statistical fluctuations or systematic errors. However, R_b tends to favor small values of m_t , and when combined with other observables, small values for M_H . Many types of new physics could contribute to R_b (see also Sec. 14 on "Constraints on New Physics from Electroweak Analyses" in this Review). The implications of this possiblity for the value of $\alpha_s(M_Z)$ extracted from the fits are discussed below. The left-right asymmetry $A_{LR}^0=0.1551\pm0.0040$ [49] based on all data from 1992–1995 has moved closer to the Standard Model expectation of 0.144 ± 0.003 than the previous value 0.1637 ± 0.0075 , from 1992–1993. However, because of the smaller error A_{LR}^0 is still 2.3σ above the Standard Model prediction. There is also an experimental difference of $\sim 1.5\sigma$ between the SLD value of $A_e^0=A_{LR}^0$ and the LEP value $A_{\ell \rm LEP}^0 \sim 0.147 \pm 0.004$ obtained from $A_{FB}^{(0,\ell)}$, $A_e^0(P_\tau)$, $A_\tau^0(P_\tau)$ assuming lepton family universality. Finally, the forward-backward asymmetry into τ 's, $A_{FB}^{0\tau}=0.0206\pm0.0023$ [47], is 2.2σ above the Standard Model prediction and 1.6σ above the average 0.0162 ± 0.0014 of A_{FB}^{0e} and $A_{FB}^{0\mu}$. This is small enough to be a fluctuation, so lepton-family universality will be assumed. The observables in Table 10.3 (including correlations on the LEP observables), as well as all low-energy neutral-current data [14,15], are used in the global fits described below. The parameter $\sin^2 \theta_W$ can be determined from the Z-pole observables and M_W , and from a variety of neutral-current processes spanning a very wide Q^2 range. The results [14], shown in Table 10.4, are in impressive agreement with each other, indicating the quantitative success of the Standard Model. The one discrepancy is the value $\hat{s}_Z^2 = 0.2302 \pm 0.0005$ from A_{LR}^0 which is 2.1σ below the value (0.2315 $\stackrel{\sim}{\pm}$ 0.0004) from the global fit to all data and 2.6 σ below the value 0.2318 \pm 0.0004 obtained from all data other than A_{LR}^0 .

The data allow a simultaneous determination of $\sin^2\theta_W$, m_t , and the strong coupling $\alpha_s(M_Z)$. The latter is determined mainly from Γ_Z and R, and is only weaky correlated with the other variables. The global fit to all data, including the CDF/DØ value $m_t=180\pm12$ GeV, yields

$$\begin{split} \widehat{s}_Z^2 &= 0.2315 \pm 0.0002 \pm 0.0003 \\ m_t &= 180 \pm 7^{+12}_{-13} \text{ GeV} \\ \alpha_s(M_Z) &= 0.123 \pm 0.004 \pm 0.002 \;, \end{split} \tag{10.39}$$

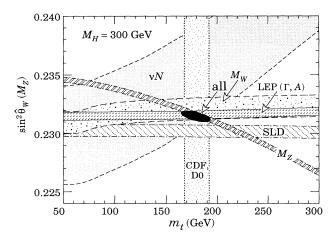


Figure 10.1: One-standard-deviation uncertainties in $\sin^2 \hat{\theta}_W$ as a function of m_t , the direct CDF and DØ range 180 ± 12 GeV, and the 90% CL region in $\sin^2 \hat{\theta}_W - m_t$ allowed by all data, assuming $M_H = 300$ GeV.

where the central values are for a Higgs mass of 300 GeV, and the second error bars are for $M_H \rightarrow 1000(+)$ or 60(-) GeV. In all fits, the errors include full statistical, systematic, and theoretical uncertainties. The \hat{s}_Z^2 error is dominated by m_t , and \hat{s}_Z^2 and m_t have a strong negative correlation of ~ -0.62 . In the on-shell scheme one has $s_W^2 = 0.2236 \pm 0.0008$, the larger error due to the stronger sensitivity to m_t . The extracted value of α_s is based on a formula which has almost no theoretical uncertainty (if one assumes the exact validity of the Standard Model), and is in excellent agreement with the values 0.122 ± 0.007 from jet-event shapes in e^+e^- annihilation, and the average 0.118 ± 0.003 from all data (including the Z-lineshape data), as described in our Section 9 on "Quantum Chromodynamics" in this Review. However, it is higher than some of the individual values extracted from low-energy data, such as deep-inelastic scattering $(0.112 \pm 0.002 ~({\rm exp}) \pm 0.004 ~({\rm scale}))$ or lattice calculations of the $b\bar{b}$ and $c\overline{c}$ spectra (0.115 \pm 0.003). It has been suggested [60] that there is a real discrepancy. However, caution is required since most of the determinations are dominated by theory errors.

The value of R_b is more than 3σ above the Standard Model expectation. If this is not just a fluctuation but is due to a new physics contribution to the $Z \to b\bar{b}$ vertex (many types would couple preferentially to the third family), the value of $\alpha_s(M_Z)$ extracted from the hadronic Z width would be reduced [15]. Allowing for this possibility one obtains $\alpha_s(M_Z) = 0.101 \pm 0.008$. (See also Sec. 14 on "Constraints on New Physics from Electroweak Analyses." in this Review

In principle the low value of R_c could also be due to new physics. However, allowing for new physics contributions to R_c alone, one obtains $\alpha_s(M_Z)=0.19\pm0.03$, which is clearly inconsistent with low-energy determinations. Allowing new contributions to both R_b and R_c yields the slightly lower but still high value of $\alpha_s(M_Z)=0.16\pm0.04$. We will, therefore, take the view that the R_c value is a fluctuation. We keep the experimental values $R_b=0.2219(17)$ and $R_c=0.1540(74)$ and their correlation (-0.35) in all fits, but do not allow any special vertex corrections for $Z\to c\overline{c}$. This is effectively equivalent to using the lower value 0.2205(16) that the LEP experimenters obtain for R_b when they constrain R_c to the Standard Model value of 0.172.

One can also carry out a fit to the indirect data alone, i.e., without including the value $m_t=180\pm12$ GeV observed directly by CDF and DØ. (The indirect prediction is for the pole mass, which should correspond approximately to the kinematic mass extracted from the collider events.) One obtains $m_t=179\pm8^{+17}_{-20}$ GeV, with little change in the $\sin^2\theta_W$ and α_s values, in remarkable agreement with the direct CDF/DØ value. The results of fits to various combinations of the data are shown in Table 10.5 and the relation between \hat{s}_Z^2 and m_t for various observables in Fig. 10.1.

The data indicate a preference for a small Higgs mass. This is because there is a strong correlation between the quadratic ρ_t terms and logarithmic M_H effects in all of the indirect data except the $Z o b\overline{b}$ vertex. The latter favor a smaller m_t and therefore a smaller M_H . The difference in χ^2 for the global fit is $\Delta \chi^2 = \chi^2(M_H = 1000 \text{ GeV}) - \chi^2(M_H = 60 \text{ GeV}) = 7.9$. Hence, the data favor a small value of M_H , as in supersymmetric extensions of the Standard Model, and m_t on the lower side of the allowed range; including the direct constraint $M_H \geq 60$ GeV, the best fit is for $M_H=60$ GeV, with the limit $M_H<320(430)$ GeV at 90(95)% CL. However, one should be cautious because the M_H constraint is driven almost entirely by R_b and A_{LR} , both of which deviate from the Standard Model prediction. Using $\alpha(M_Z)$ and \widehat{s}_Z^2 as inputs, one can predict $\alpha_s(M_Z)$ assuming grand unification. One predicts [61] $\alpha_s(M_Z) = 0.130 \pm 0.001 \pm 0.01$ for the simplest theories based on the minimal supersymmetric extension of the Standard Model, where the first (second) uncertainty is from the inputs (thresholds). This is consistent with the experimental $\alpha_s(M_Z) = 0.121(4)(1)$ from the Zlineshape (using the lower M_H range appropriate for supersymmetry) and with the average 0.118 ± 0.003 (see our Section 9 on "Quantum Chromodynamics" in this Review), but is high compared to some low-energy determinations of α_s [60]. Nonsupersymmetric unified theories predict the low value $\alpha_s(M_Z) = 0.073 \pm 0.001 \pm 0.001$.

One can also determine the radiative correction parameters Δr : including the CDF and DØ data, one obtains $\Delta r = 0.039 \pm 0.003$ and $\Delta \hat{r}_W = 0.068 \pm 0.0013$, where the error includes m_t and M_H , in excellent agreement with the predictions 0.038 ± 0.005 and 0.0705 ± 0.0007 .

Table 10.4: Values obtained for s_W^2 (on-shell) and $\hat{s}_Z^2(\overline{\rm MS})$ from various reactions assuming the global best fit value $m_t=180\pm07$ GeV (for $M_H=300$ GeV), and $\alpha_s=0.123\pm0.004$. The uncertainties include the effect of 60 GeV $< M_H < 1$ TeV. The determination from Γ_Z , R, and $\sigma_{\rm had}$ uses the experimental value of M_Z , so that the values obtained are from the vertices and not the overall scale.

Reaction	s_W^2	\widehat{s}_{Z}^{2}
M_Z	0.2237 ± 0.0010	0.2316 ± 0.0005
M_W	0.2242 ± 0.0011	0.2321 ± 0.0009
$\Gamma_Z, R, \sigma_{\rm had}$	0.2239 ± 0.0013	0.2317 ± 0.0013
$A_{FB}^{(0,\ell)}$	0.2228 ± 0.0009	0.2307 ± 0.0007
LEP asymmetries	0.2237 ± 0.0007	0.2316 ± 0.0003
A_{LR}^0	0.2223 ± 0.0008	0.2302 ± 0.0005
$\overline{A}_b, \overline{A}_c$	0.250 ± 0.021	0.259 ± 0.022
Deep inelastic (isocalar)	0.226 ± 0.004	0.234 ± 0.005
$\nu_{\mu}(\overline{\nu}_{\mu})p \to \nu_{\mu}(\overline{\nu}_{\mu})p$	0.205 ± 0.030	0.212 ± 0.031
$\nu_{\mu}(\overline{\nu}_{\mu})e \to \nu_{\mu}(\overline{\nu}_{\mu})e$	0.221 ± 0.007	0.228 ± 0.008
atomic parity violation	0.216 ± 0.008	0.223 ± 0.008
SLAC eD	0.216 ± 0.017	0.223 ± 0.018
All data	0.2236 ± 0.0008	0.2315 ± 0.0004

10.5. Deviations from the Standard Model

The Z pole, W mass, and neutral-current data can be used to search for and set limits on deviations from the Standard Model.

For example, the relation between M_W and M_Z is modified if there are Higgs multiplets with weak isospin > 1/2 with significant vacuum expectation values. In order to calculate to higher orders in such theories one must define a set of four fundamental renormalized parameters. It is convenient to take these as α , G_F , M_Z , and M_W ,

Table 10.3: Principal LEP and other recent observables, compared with the Standard Model predictions for $M_Z=91.1884\pm0.0022$ GeV, 60 GeV $< M_H < 1$ TeV, the global best fit value $m_t = 180 \pm 7$ GeV (for $M_H = 300$ GeV), $\alpha_s = 0.123 \pm 0.004$, and $\alpha_s(M_Z)^{-1} = 128.90 \pm 0.09$. The LEP averages [58] of the ALEPH, DELPHI, L3, and OPAL results include common systematic errors and correlations [58]. $\overline{s}_{\ell}^2(A_{FB}^{(0,q)})$ is the effective angle extracted from the hadronic-charge asymmetry. A_{LR}^0 includes all data from 1992–1995 [48,49]. The values of $\Gamma(\ell\ell)$, $\Gamma(\text{had})$, and $\Gamma(\text{inv})$ are not independent of Γ_Z , R, and σ_{had} . The M_W value is from CDF, UA2, and DØ [59]. M_W and M_Z are correlated, but the effect is negligible due to the tiny M_Z error. The two values of s_W^2 from deep-inelastic scattering are from CCFR [31] and the global average, respectively. The $g_{VA}^{\nu e}$ are from CHARM II [34]. The second error in Q_W (for cesium) is theoretical [41]. Older low-energy results are not listed but are included in the fits. In the Standard Model predictions, the first uncertainty is from M_Z and Δr , while the second is from m_t and M_H . The $\Delta \alpha_s = 0.004$ uncertainty leads to additional errors of $0.002 (\Gamma_Z), 0.02 (R), 0.02 (\sigma), 2.0 (\Gamma(had)).$

Quantity	Value	Standard Model
$\overline{M_Z \; ({ m GeV})}$	91.1884 ± 0.0022	input
$\Gamma_Z~({ m GeV})$	2.4963 ± 0.0032	$2.497 \pm 0.001 \pm 0.002$
R	20.788 ± 0.032	$20.77 \pm 0.004 \pm 0.002$
$\sigma_{ m had}(nb)$	41.488 ± 0.078	$41.45 \pm 0.002 \pm 0.004$
R_b	0.2219 ± 0.0017	$0.2156 \pm 0 \pm 0.0003$
R_c	0.1540 ± 0.0074	$0.172\pm0\pm0$
$A_{FB}^{(0,\ell)}$	0.0172 ± 0.0012	$0.0155 \pm 0.0004 \pm 0.0004$
$A_{ au}^{0}(P_{ au})$	0.1418 ± 0.0075	$0.144 \pm 0.002 \pm 0.002$
$A_e^0(P_{ au})$	0.1390 ± 0.0089	$0.144 \pm 0.002 \pm 0.002$
$A_{FB}^{(0,b)}$	0.0997 ± 0.0031	$0.101 \pm 0.001 \pm 0.001$
$A_{FB}^{(0,c)}$	0.0729 ± 0.0058	$0.072 \pm 0.001 \pm 0.001$
A_{LR}^0	0.1551 ± 0.0040	$0.144 \pm 0.002 \pm 0.002$
\overline{A}_b	0.841 ± 0.053	$0.934 \pm 0 \pm 0$
\overline{A}_c	0.606 ± 0.090	$0.667 \pm 0.001 \pm 0.001$
$\overline{s}_\ell^2(A_{FB}^{(0,q)})$	0.2325 ± 0.0013	$0.2319 \pm 0.0002 \pm 0.0002$
$\Gamma(\ell \overline{\ell}) ({ m MeV})$	83.93 ± 0.14	$83.97 \pm 0.01 \pm 0.06$
$\Gamma({\rm had})~({\rm MeV})$	1744.8 ± 3.0	$1743.8 \pm 0.2 \pm 1.2$
$\Gamma(\mathrm{inv})~(\mathrm{MeV})$	499.9 ± 2.5	$501.6 \pm 0 \pm 0.3$
$M_W \; ({ m GeV})$	80.26 ± 0.16	$80.34 \pm 0.01 \pm 0.04$
Q_W	$-71.04 \pm 1.58 \pm 0.88$	$-72.88 \pm 0.05 \pm 0.03$
$s_W^2 = 1 - \frac{M_W^2}{M_Z^2}$	$\begin{array}{c} 0.2218 \pm 0.0059 \\ 0.2260 \pm 0.0048 \end{array}$	$0.2237 \pm 0.0002 \pm 0.0008$
$g_A^{ u e}$	-0.503 ± 0.017	$-0.507 \pm 0 \pm 0.0004$
$g_V^{ u e}$	-0.035 ± 0.017	$-0.037 \pm 0.0005 \pm 0.0003$

since M_W and M_Z are directly measurable. Then \hat{s}_Z^2 and ρ_0 can be considered dependent parameters defined by

$$\hat{s}_Z^2 \equiv A_0^2 / M_W^2 (1 - \Delta \hat{r}_W) \tag{10.40}$$

and

$$\rho_0 \equiv M_W^2 / (M_Z^2 \,\hat{c}_Z^2 \,\hat{\rho}) \ . \tag{10.41}$$

Provided that the new physics which yields $\rho_0 \neq 1$ is a small perturbation which does not significantly affect the radiative corrections, ρ_0 can be regarded as a phenomenological parameter which multiplies G_F in Eqs. (10.12)–(10.14), (10.28), and Γ_Z in Eq. (10.36). (Also, the expression for M_Z is divided by $\sqrt{\rho_0}$;

Table 10.5: Values of \widehat{s}_Z^2 and s_W^2 (in parentheses), α_s , and m_t for various combinations of observables. The central values are for $M_H=300$ GeV, and the second set of errors is for $M_H\to 1000(+),\,60(-)$.

Data	$\widehat{s}_{Z}^{2} (s_{W}^{2})$	α_s (M_Z)	$m_t \; ({ m GeV})$
Indirect + CDF + DQ	0.2315(2)(3) $0.2236 \pm 0.0008)$	0.123(4)(2)	$180 \pm 7_{-13}^{+12}$
All indirect	0.2315(2)(2) (0.2236 ± 0.0009)	0.123(4)(2)	$179 \pm 8^{+17}_{-20}$
All LEP	0.2318(3)(2) (0.2246 ± 0.0011)	0.124(4)(2)	$171 \pm 10^{+18}_{-20}$
$SLD + M_Z$	$0.2302(5)(0) \\ (0.2184 \pm 0.0020)$		$220^{+14}_{-15}{}^{+19}_{-24}$
Z pole (LEP + SLD)	$0.2314(3)(1) (0.2234 \pm 0.0010)$	0.123(4)(2)	181 ⁺⁸⁺¹⁸ ₋₉₋₂₀

the M_W formula is unchanged.) There is now enough data to determine ρ_0 , $\sin^2\theta_W$, m_t , and α_s simultaneously. In particular, R_b and the direct CDF and DØ events yield m_t independent of ρ_0 , the asymmetries yield \widehat{s}_Z^2 , R gives α_s , and M_Z and the widths constrain ρ_0 . From the global fit (including CDF and DØ),

$$\rho_0 = 1.0012 \pm 0.0013 \pm 0.0018 \tag{10.42}$$

$$\hat{s}_Z^2 = 0.2314 \pm 0.0002 \pm 0.0002 \tag{10.43}$$

$$\alpha_s = 0.121 \pm 0.004 \pm 0.001 \tag{10.44}$$

$$m_t = 171 \pm 12 \;, \tag{10.45}$$

where the second error is from M_H . This is in remarkable agreement with the Standard Model expectation $\rho_0=1$, and constrains any higher-dimensional Higgs representation to have vacuum expectation values of less than a few percent of those of the doublets. The allowed regions in the $\rho_0 - \widehat{s}_Z^2$ plane are shown in Fig. 10.2. Allowing for new physics in R_b , one obtains $\rho_0=1.0002(14)(18)$ and $\alpha_s=0.101(8)(1)$. The effects of other types of new physics are described in Sec. 14 on "Constraints on New Physics from Electroweak Analyses" in this Review.

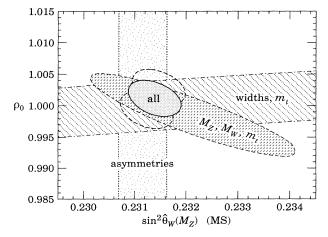


Figure 10.2: The allowed regions in $\sin^2 \widehat{\theta}_W - \rho_0$ at 90% CL. m_t is a free parameter and $M_H = 300$ GeV is assumed. (The upper (lower) dashed contours are for $M_H = 1000$ (60) GeV.) The horizontal (width) band uses the experimental value of M_Z in Eq. (10.36).

Most of the parameters relevant to ν -hadron, νe , e-hadron, and e^+e^- processes are determined uniquely and precisely from the data in "model independent" fits (i.e., fits which allow for an arbitrary electroweak gauge theory). The values for the parameters defined in Eqs. (10.12)–(10.14) are given in Table 10.6 along with the predictions of the Standard Model. The agreement is excellent. The low-energy e^+e^- results are difficult to present in a model-independent way because Z-propagator effects are non-negligible at TRISTAN, PETRA, and PEP energies. However, assuming $e^-\mu^-\tau$ universality, the lepton asymmetries imply [45] $4(g_A^e)^2=0.99\pm0.05$, in good agreement with the Standard Model prediction \simeq 1. The much more precisely measured Z-pole parameters in Table 10.3 are in excellent agreement with the Standard Model.

Table 10.6: Values of the model-independent neutral-current parameters, compared with the Standard Model prediction using $M_Z = 91.1884$ GeV for $m_t = 180 \pm 7$ GeV and $M_H = 300$ GeV. There is a second $g_{V,A}^{\nu e}$ solution, given approximately by $g_V^{\nu e} \leftrightarrow g_A^{\nu e}$, which is eliminated by e^+e^- data under the assumption that the neutral current is dominated by the exchange of a single Z. θ_i , i = L or R, is defined as $\tan^{-1}[\epsilon_i(u)/\epsilon_i(d)]$.

Quantity	Experimental Value	Standard Model Prediction	Correlation
$\epsilon_L(u)$	0.332 ± 0.016	$0.345 {\pm} 0.0003$	
$\epsilon_L(d)$	-0.438 ± 0.012	$-0.429{\pm}0.0004$	non-
$\epsilon_R(u)$	-0.178 ± 0.013	-0.156	Gaussian
$\epsilon_R(d)$	$-0.026 {}^{+0.075}_{-0.048}$	0.078	
g_L^2	0.3017 ± 0.0033	0.303 ± 0.0005	
g_R^2	$0.0326{\pm}0.0033$	0.030	small
$ heta_L$	2.50 ± 0.035	2.46	
θ_R	$4.58 ^{+0.46}_{-0.28}$	5.18	
$g_A^{ u e}$	-0.507 ± 0.014	-0.507 ± 0.0004	-0.04
$g_V^{ u e}$	-0.041 ± 0.015	-0.037 ± 0.0003	
C_{1u}	-0.214 ± 0.046	-0.190 ± 0.0005	-0.995 -0.79
C_{1d}	0.359 ± 0.041	$0.342{\pm}0.0004$	0.79
$C_{2u} - \frac{1}{2}C_{2d}$	-0.04 ± 0.13	-0.052 ± 0.0009	

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11. THE CABIBBO-KOBAYASHI-MASKAWA MIXING MATRIX

Updated 1995 by F.J. Gilman, K. Kleinknecht, and B. Renk.

In the Standard Model with $SU(2) \times U(1)$ as the gauge group of electroweak interactions, both the quarks and leptons are assigned to be left-handed doublets and right-handed singlets. The quark mass eigenstates are not the same as the weak eigenstates, and the matrix relating these bases was defined for six quarks and given an explicit parametrization by Kobayashi and Maskawa [1] in 1973. It generalizes the four-quark case, where the matrix is parametrized by a single angle, the Cabibbo angle [2].

By convention, the three charge 2e/3 quarks (u, c, and t) are unmixed, and all the mixing is expressed in terms of a 3×3 unitary matrix V operating on the charge -e/3 quarks (d, s, and b):

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix} . \tag{11.1}$$

The values of individual matrix elements can in principle all be determined from weak decays of the relevant quarks, or, in some cases, from deep inelastic neutrino scattering. Using the constraints discussed below together with unitarity, and assuming only three generations, the 90% confidence limits on the magnitude of the elements of the complete matrix are:

$$\begin{pmatrix} 0.9745 \text{ to } 0.9757 & 0.219 & \text{to } 0.224 & 0.002 & \text{to } 0.005 \\ 0.218 & \text{to } 0.224 & 0.9736 & \text{to } 0.9750 & 0.036 & \text{to } 0.046 \\ 0.004 & \text{to } 0.014 & 0.034 & \text{to } 0.046 & 0.9989 & \text{to } 0.9993 \end{pmatrix} \ . \ (11.2)$$

The ranges shown are for the individual matrix elements. The constraints of unitarity connect different elements, so choosing a specific value for one element restricts the range of others.

There are several parametrizations of the Cabibbo-Kobayashi-Maskawa matrix. In view of the need for a "standard" parametrization in the literature, we advocate:

$$V = \begin{pmatrix} c_{12}c_{13} & s_{12}c_{13} & s_{13}e^{-i\delta_{13}} \\ -s_{12}c_{23} - c_{12}s_{23}s_{13}e^{i\delta_{13}} & c_{12}c_{23} - s_{12}s_{23}s_{13}e^{i\delta_{13}} & s_{23}c_{13} \\ s_{12}s_{23} - c_{12}c_{23}s_{13}e^{i\delta_{13}} & -c_{12}s_{23} - s_{12}c_{23}s_{13}e^{i\delta_{13}} & c_{23}c_{13} \end{pmatrix} (11.3)$$

proposed by Chau and Keung [3]. The choice of rotation angles follows earlier work of Maiani [4], and the placement of the phase follows that of Wolfenstein [5]. The notation used is that of Harari and Leurer [6] who, along with Fritzsch and Plankl [7], proposed this parametrization as a particular case of a form generalizable to an arbitrary number of "generations." The general form was also put forward by Botella and Chau [8]. Here $c_{ij} = \cos\theta_{ij}$ and $s_{ij} = \sin\theta_{ij}$, with i and j being "generation" labels, $\{i,j=1,2,3\}$. In the limit $\theta_{23} = \theta_{13} = 0$ the third generation decouples, and the situation reduces to the usual Cabibbo mixing of the first two generations with θ_{12} identified with the Cabibbo angle [2].

The real angles θ_{12} , θ_{23} , θ_{13} can all be made to lie in the first quadrant by an appropriate redefinition of quark field phases. Then all s_{ij} and c_{ij} are positive, $|V_{us}| = s_{12}c_{13}$, $|V_{ub}| = s_{13}$, and $|V_{cb}| = s_{23}c_{13}$. As c_{13} is known to deviate from unity only in the fifth decimal place, $|V_{us}| = s_{12}$, $|V_{ub}| = s_{13}$, and $|V_{cb}| = s_{23}$ to an excellent approximation. The phase δ_{13} lies in the range $0 \le \delta_{13} < 2\pi$, with non-zero values generally breaking CP invariance for the weak interactions. The generalization to the n generation case contains n(n-1)/2 angles and (n-1)(n-2)/2 phases [6,7,8]. The range of matrix elements in Eq. (11.2) corresponds to 90% CL limits on the angles of $s_{12} = 0.219$ to $0.223, s_{23} = 0.036$ to 0.046, and $s_{13} = 0.002$ to 0.005.

Kobayashi and Maskawa [1] originally chose a parametrization involving the four angles, θ_1 , θ_2 , θ_3 , δ :

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} c_1 & -s_1 c_3 & -s_1 s_3 \\ s_1 c_2 & c_1 c_2 c_3 - s_2 s_3 e^{i\delta} & c_1 c_2 s_3 + s_2 c_3 e^{i\delta} \\ s_1 s_2 & c_1 s_2 c_3 + c_2 s_3 e^{i\delta} & c_1 s_2 s_3 - c_2 c_3 e^{i\delta} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix} , \qquad (11.4)$$

where $c_i=\cos\theta_i$ and $s_i=\sin\theta_i$ for i=1,2,3. In the limit $\theta_2=\theta_3=0$, this reduces to the usual Cabibbo mixing with θ_1 identified (up to a sign) with the Cabibbo angle [2]. Slightly different forms of the Kobayashi-Maskawa parametrization are found in the literature. The CKM matrix used in the 1982 Review of Particle Properties is obtained by letting $s_1\to -s_1$ and $\delta\to\delta+\pi$ in the matrix given above. An alternative is to change Eq. (11.4) by $s_1\to -s_1$ but leave δ unchanged. With this change in s_1 , the angle θ_1 becomes the usual Cabibbo angle, with the "correct" sign (i.e. $d'=d\cos\theta_1+s\sin\theta_1$) in the limit $\theta_2=\theta_3=0$. The angles $\theta_1,\theta_2,\theta_3$ can, as before, all be taken to lie in the first quadrant by adjusting quark field phases. Since all these parametrizations are referred to as "the" Kobayashi-Maskawa form, some care about which one is being used is needed when the quadrant in which δ lies is under discussion.

Other parametrizations, mentioned above, are due to Maiani [4] and to Wolfenstein [5]. Still other parametrizations [9] have come into the literature in connection with attempts to define "maximal CP violation". No physics can depend on which of the above parametrizations (or any other) is used as long as a single one is used consistently and care is taken to be sure that no other choice of phases is in conflict.

Our present knowledge of the matrix elements comes from the following sources: $% \left(1\right) =\left(1\right) \left(1\right) \left($

(1) New analyses have been performed comparing nuclear beta decay to muon decay. The previous radiative corrections [10] already included order $Z\alpha^2$ effects and more recent results [11–15] concentrate on nuclear mismatch and structure-dependent radiative corrections. The results in Ref. 15 violate CVC, and the updated [13] average ft values for superallowed 0^+ to 0^+ transitions of Refs. 11 and 12 do not agree with each other within the estimated uncertainties:

$$ft = 3150.8 \pm 1.7 \text{ sec}$$
 (Refs. 11 and 13),
 $ft = 3145.7 \pm 1.5 \text{ sec}$ (Refs. 12 and 13), (11.5)

The common experimental error is ± 0.82 . We have taken an average of the above values and scaled up the error to take account of the uncertainty in the nuclear structure dependent radiative corrections and corresponding inconsistency of the theoretical results. This transforms to

$$|V_{ud}| = 0.9736 \pm 0.0010 , (11.6)$$

which is almost one standard deviation smaller than the result in the previous Review of Particle Physics. It is consistent with the result $|V_{ud}| = 0.9734 \pm 0.0007$ from the update in Ref. 14.

(2) Analysis of K_{e3} decays yields [16]

$$|V_{us}| = 0.2196 \pm 0.0023 \ . \tag{11.7}$$

With isospin violation taken into account in K^+ and K^0 decays, the extracted values of $|V_{us}|$ are in agreement at the 1% level. A reanalysis [13] obtains essentially the same value, but quotes a somewhat smaller error which is only statistical. The analysis of hyperon decay data has larger theoretical uncertainties because of first order SU(3) symmetry breaking effects in the axial-vector couplings, but due account of symmetry breaking [17] applied to the WA2 data [18] gives a corrected value [19] of 0.222 ± 0.003 . We average these two results to obtain:

$$|V_{us}| = 0.2205 \pm 0.0018 \ . \tag{11.8}$$

(3) The magnitude of $|V_{cd}|$ may be deduced from neutrino and antineutrino production of charm off valence d quarks. The dimuon production cross sections of the CDHS group [20] yield $\overline{B}_c |V_{cd}|^2 = 0.41 \pm 0.07 \times 10^{-2}$, where \overline{B}_c is the semileptonic branching fraction of the charmed hadrons produced. The corresponding value from a more recent Tevatron experiment [21], where a next-to-leading-order

QCD analysis has been carried out, is $0.534 \pm 0.021^{+0.025}_{-0.051} \times 10^{-2}$, where the last error is from the scale uncertainty. Assuming a similar scale error for the CDHS result and averaging these two results gives $0.49 \pm 0.05 \times 10^{-2}$. Supplementing this with data [22] on the mix of charmed particle species produced by neutrinos and PDG values for their semileptonic branching fractions to give [21] $\overline{B}_c = 0.099 \pm 0.012$, yields

$$|V_{cd}| = 0.224 \pm 0.016 \tag{11.9}$$

(4) Values of $|V_{cs}|$ from neutrino production of charm are dependent on assumptions about the strange quark density in the parton-sea. The most conservative assumption, that the strange-quark sea does not exceed the value corresponding to an SU(3) symmetric sea, leads to a lower bound [20], $|V_{cs}| > 0.59$. It is more advantageous to proceed analogously to the method used for extracting $|V_{us}|$ from K_{e3} decay; namely, we compare the experimental value for the width of D_{e3} decay with the expression [23] that follows from the standard weak interaction amplitude:

$$\Gamma(D \to \overline{K}e^+\nu_e) = |f_+^D(0)|^2 |V_{cs}|^2 (1.54 \times 10^{11} \text{ s}^{-1}).$$
 (11.10)

Here $f_+^D(q^2)$, with $q=p_D-p_K$, is the form factor relevant to D_{e3} decay; its variation has been taken into account with the parametrization $f_+^D(t)/f_+^D(0)=M^2/(M^2-t)$ and $M=2.1~{\rm GeV}/c^2$, a form and mass consistent with Mark III and E691 measurements [24,25]. Combining data on branching ratios for D_{e3} decays from Mark III, E691, and CLEO experiments [24–26] with accurate values [27] for τ_{D^+} and τ_{D^0} , yields $(0.762\pm0.055)\times10^{11}~{\rm s}^{-1}$ for $\Gamma(D\to\overline{K}e^+\nu_e)$. Therefore

$$|f_{+}^{D}(0)|^{2} |V_{cs}|^{2} = 0.495 \pm 0.036$$
 (11.11)

A very conservative assumption is that $|f_+^D(0)| < 1$, from which it follows that $|V_{cs}| > 0.62$. Calculations of the form factor either performed [28,29] directly at $q^2 = 0$, or done [30] at the maximum value of $q^2 = (m_D - m_K)^2$ and interpreted at $q^2 = 0$ using the measured q^2 dependence, gives the value $f_+^D(0) = 0.7 \pm 0.1$. It follows that

$$|V_{cs}| = 1.01 \pm 0.18 \ . \tag{11.12}$$

The constraint of unitarity when there are only three generations gives a much tighter bound (see below).

(5) The ratio $|V_{ub}/V_{cb}|$ can be obtained from the semileptonic decay of B mesons produced on the $\Upsilon(4S)$ $b\bar{b}$ resonance by measuring the lepton energy spectrum above the endpoint of the $b \to c\ell\nu$ spectrum. There the $b \to u\ell\nu$ decay rate can be obtained by subtracting the background from nonresonant e^+e^- reactions. This continuum background is determined from auxiliary measurements off the $\Upsilon(4S)$. Both the CLEO [31] and ARGUS [32] collaborations have reported evidence for $b \to u$ transitions in semileptonic B decays. The interpretation of the result in terms of $|V_{ub}/V_{cb}|$ depends fairly strongly on the theoretical model used to generate the lepton energy spectrum, especially for $b \to u$ transitions [29,30,33]. Combining the experimental and theoretical uncertainties, we quote

$$|V_{ub}/V_{cb}| = 0.08 \pm 0.02 \ . \tag{11.13}$$

(6) The heavy quark effective theory [34](HQET) provides a nearly model-independent treatment of B semileptonic decays to charmed mesons. From measurements [35–37] of the exclusive decay $B \to \overline{D}^* \overline{\ell} \nu_\ell$, the value $|V_{cb}| = 0.041 \pm 0.003 \pm 0.002$ has been extracted [38] using corrections based on the HQET. A new analysis of inclusive decays [39], where the measured semileptonic bottom hadron partial width is assumed to be that of a b quark decaying through the usual V - A interaction, gives $|V_{cb}| \cdot (\tau_b/1.5 \text{ ps})^{1/2} = 0.041 \pm 0.002$. Using a value [40] for the b lifetime $\tau_b = 1.55 \pm 0.06$ ps and combining with the exclusive result, we obtain

$$|V_{cb}| = 0.041 \pm 0.003 \ . \tag{11.14}$$

The results for three generations of quarks, from Eqs. 11.6, 11.8, 11.9, 11.12, 11.13, and 11.14 plus unitarity, are summarized in the matrix in Eq. (11.2). The ranges given there are different from those given in Eqs. (11.6)–(11.14) because of the inclusion of unitarity, but are consistent with the one-standard-deviation errors on the input matrix elements. Note in particular that the unitarity constraint has pushed $|V_{ud}|$ about one standard deviation higher than given in Eq. (11.6).

The data do not preclude there being more than three generations. Moreover, the entries deduced from unitarity might be altered when the CKM matrix is expanded to accommodate more generations. Conversely, the known entries restrict the possible values of additional elements if the matrix is expanded to account for additional generations. For example, unitarity and the known elements of the first row require that any additional element in the first row have a magnitude $|V_{ub'}| < 0.08$. When there are more than three generations the allowed ranges (at 90% CL) of the matrix elements connecting the first three generations are

$$\begin{pmatrix} 0.9720 \text{ to } 0.9752 & 0.217 \text{ to } 0.223 & 0.002 \text{ to } 0.005 & \dots \\ 0.199 & \text{to } 0.234 & 0.818 \text{ to } 0.975 & 0.036 \text{ to } 0.046 & \dots \\ 0 & \text{to } 0.11 & 0 & \text{to } 0.52 & 0 & \text{to } 0.9993 \dots \\ \vdots & \vdots & \vdots & \vdots & \vdots \end{pmatrix}, (11.15)$$

where we have used unitarity (for the expanded matrix) and Eqs. 11.6, 11.8, 11.9, 11.12, 11.13, and 11.14.

Further information, particularly on CKM matrix elements involving the top quark, can be obtained from flavor-changing processes that occur at the one-loop level. We have not used this information in the discussion above since the derivation of values for V_{td} and V_{ts} in this manner from, for example, B mixing, $b \to s \gamma$, or $K \to \pi \nu \overline{\nu}$, requires an additional assumption that the top-quark loop, rather than new physics, gives the dominant contribution to the process in question.

The measured value [41] of $\Delta M_d = 0.496 \pm 0.032~{\rm ps}^{-1}$ from $B_d^0 - \overline{B}_d^0$ mixing can be turned in this way into information on $|V_{tb}^*V_{td}|$. Using $\widehat{B}_{Bd}f_{Bd}^2 = (1.2 \pm 0.2)(173 \pm 40~{\rm MeV})^2$ from lattice QCD calculations [42], next-to-leading-order QCD corrections [43], and $m_t = 174 \pm 16~{\rm GeV}$ as input,

$$|V_{tb}^* V_{td}| = 0.009 \pm 0.003 , \qquad (11.16)$$

where the error bar comes primarily from the theoretical uncertainty in the hadronic matrix elements.

In the ratio of B_s to B_d mass differences, many of the factors (such as the QCD correction and dependence on the t-quark mass) cancel, and we have

$$\frac{\Delta M_{B_s}}{\Delta M_{B_d}} = \frac{\widehat{B}_{B_s} f_{B_s}^2}{\widehat{B}_{B_d} f_{B_d}^2} \frac{|V_{tb}^* \cdot V_{ts}|^2}{|V_{tb}^* \cdot V_{td}|^2} \ . \tag{11.17}$$

With $\widehat{B}_{B_s} \approx \widehat{B}_{B_d}$ and $f_{B_s}/f_{B_d} = 1.16 \pm 0.10$ from lattice QCD [42] and the experimental limit [41] $\Delta M_{B_s}/\Delta M_{B_d} > 11.6$,

$$|V_{td}|/|V_{ts}| < 0.37. (11.18)$$

The CLEO observation [44] of $b \to s \gamma$ can be translated [45] similarly into $|V_{ts}|/|V_{cb}|=1.1\pm0.43$, where the large uncertainty is again dominantly theoretical. Ultimately $K\to \pi\nu\bar{\nu}$ decays offer high precision because the matrix elements can be directly measured, but experiment is presently several orders of magnitude away from the requisite sensitivity. All these additional indirect constraints are consistent with the matrix elements obtained from the direct measurements plus unitarity, assuming three generations; adding the indirect constraints to the fit leaves the ranges of CKM matrix elements in Eq. (11.2) essentially unchanged.

Direct and indirect information on the CKM matrix is neatly summarized in terms of the "unitarity triangle." The name arises since unitarity of the 3×3 CKM matrix applied to the first and third columns yields

$$V_{ud} V_{ub}^* + V_{cd} V_{cb}^* + V_{td} V_{tb}^* = 0. (11.19)$$

The unitarity triangle is just a geometrical presentation of this equation in the complex plane [46]. We can always choose to orient the triangle so that $V_{cd} V_{cb}^*$ lies along the horizontal; in the parametrization we have chosen, V_{cb} is real, and V_{cd} is real to a very good approximation in any case. Setting cosines of small angles to unity, Eq. (11.19) becomes

$$V_{ub}^* + V_{td} = s_{12} V_{cb}^* , (11.20)$$

which is shown as the unitarity triangle in Fig. 11.1(a). Rescaling the triangle by a factor $[1/|s_{12}|V_{cb}|]$, the coordinates of the vertices become

$$A(\text{Re}(V_{ub})/|s_{12}V_{cb}|, -\text{Im}(V_{ub})/|s_{12}V_{cb}|)$$
, $B(1,0)$, $C(0,0)$. (11.21)

In the approximation of the Wolfenstein parametrization [5], with matrix elements expressed in powers of the Cabibbo angle, $\lambda \sim s_{12}$:

$$V_{us} \sim \lambda$$

 $V_{ub} \sim \lambda^3 A(\rho - i\eta)$
 $V_{cb} \sim \lambda^2 A$
 $V_{td} \sim \lambda^3 A(1 - \rho - i\eta)$, (11.22)

the coordinates of the vertex A of the unitarity triangle are simply (ρ, η) , as shown in Fig. 11.1(b).

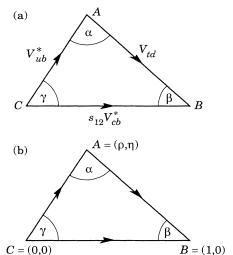


Figure 11.1: (a) Representation in the complex plane of the triangle formed by the CKM matrix elements V_{ub}^* , V_{td} , and $s_{12} V_{cb}^*$. (b) Rescaled triangle with vertices $A(\rho, \eta)$, B(1, 0), and C(0, 0).

CP-violating processes will involve the phase in the CKM matrix, assuming that the observed CP violation is solely related to a nonzero value of this phase. This allows additional constraints to be brought to bear. More specifically, a necessary and sufficient condition for \overline{CP} violation with three generations can be formulated in a parametrization-independent manner in terms of the non-vanishing of the determinant of the commutator of the mass matrices for the charge 2e/3 and charge -e/3 quarks [47]. CP violating amplitudes or differences of rates all are proportional to the CKM factor in this quantity. This is the product of factors $s_{12}s_{13}s_{23}c_{12}c_{13}^2c_{23}s_{\delta_{13}}$ in the parametrization adopted above, and is $s_1^2 s_2 s_3 c_1 c_2 c_3 s_\delta$ in that of Ref. 1. With the approximation of setting cosines to unity, this is just twice the area of the unitarity triangle. While hadronic matrix elements whose values are imprecisely known generally now enter, the constraints from CP violation in the neutral kaon system are tight enough to very much restrict the range of angles and the phase of the CKM matrix. For example, the constraint obtained from the

CP-violating parameter ϵ in the neutral K system corresponds to the vertex A of the unitarity triangle lying on a hyperbola for fixed values of the hadronic matrix elements. [48] For CP-violating asymmetries of neutral B mesons decaying to CP eigenstates, there is a direct relationship between the magnitude of the asymmetry in a given decay and $\sin 2\phi$, where $\phi = \alpha$, β , γ is an appropriate angle of the unitarity triangle [46].

The combination of all the direct and indirect information can be used to find the overall constraints on the CKM matrix and thence the implications for future measurements of CP violation in the B system [48].

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12. QUARK MODEL

12.1. Quantum numbers of the quarks

Each quark has spin 1/2 and baryon number 1/3. Table 12.1 gives the additive quantum numbers (other than baryon number) of the three generations of quarks. Our convention is that the flavor of a quark (I_z , S, C, B, or T) has the same sign as its charge. With this convention, any flavor carried by a charged meson has the same sign as its charge; e.g., the strangeness of the K^+ is +1, the bottomness of the B^+ is +1, and the charm and strangeness of the D_s^- are each -1.

By convention, each quark is assigned positive parity. Then each antiquark has negative parity.

Table 12.1: Additive quantum numbers of the quarks.

Property Quark	d	u	s	c	ь	t
Q – electric charge	$-\frac{1}{3}$	$+\frac{2}{3}$	$-\frac{1}{3}$	$+\frac{2}{3}$	$-\frac{1}{3}$	$+\frac{2}{3}$
I_z – isospin z-component	$-\frac{1}{2}$	$+\frac{1}{2}$	0	0	0	0
S – strangeness	0	0	-1	0	0	0
C – charm	0	0	0	+1	0	0
B – bottomness	0	0	0	0	-1	0
T – topness	0	0	0	0	0	+1

12.2. Mesons: $q\overline{q}$ states

Nearly all known mesons are bound states of a quark q and an antiquark \overline{q}' (the flavors of q and q' may be different). If the orbital angular momentum of the $q\overline{q}'$ state is L, then the parity P is $(-1)^{L+1}$. A state $q\overline{q}$ of a quark and its own antiquark is also an eigenstate of charge conjugation, with $C=(-1)^{L+S}$, where the spin S is 0 or 1. The L=0 states are the pseudoscalars, $J^P=0^-$, and the vectors, $J^P=1^-$. Assignments for many of the known mesons are given in Table 12.2. States in the "normal" spin-parity series, $P=(-1)^J$, must, according to the above, have S=1 and hence CP=+1. Thus mesons with normal spin-parity and CP=-1 are forbidden in the $q\overline{q}'$ model. The $J^{PC}=0^{--}$ state is forbidden as well. Mesons with such J^{PC} may exist, but would lie outside the $q\overline{q}'$ model.

The nine possible $q\overline{q}'$ combinations containing $u,\ d,$ and s quarks group themselves into an octet and a singlet:

$$\mathbf{3} \otimes \overline{\mathbf{3}} = \mathbf{8} \oplus \mathbf{1} \tag{12.1}$$

States with the same IJ^P and additive quantum numbers can mix. (If they are eigenstates of charge conjugation, they must also have the same value of C.) Thus the I=0 member of the ground-state pseudoscalar octet mixes with the corresponding pseudoscalar singlet to produce the η and η' . These appear as members of a nonet, which is shown as the middle plane in Fig. 12.1(a). Similarly, the ground-state vector nonet appears as the middle plane in Fig. 12.1(b).

A fourth quark such as charm can be included in this scheme by extending the symmetry to SU(4), as shown in Fig. 12.1. Bottom extends the symmetry to SU(5); to draw the multiplets would require four dimensions.

For the pseudoscalar mesons, the Gell-Mann-Okubo formula is

$$m_{\eta}^2 = \frac{1}{3}(4m_K^2 - m_{\pi}^2) , \qquad (12.2)$$

assuming no octet-singlet mixing. However, the octet η_8 and singlet η_1 mix because of SU(3) breaking. In general, the mixing angle is mass dependent and becomes complex for resonances of finite width.

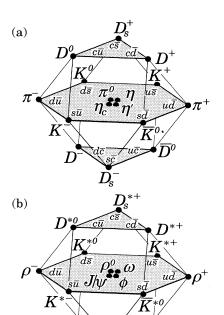


Figure 12.1: SU(4) 16-plets for the (a) pseudoscalar and (b) vector mesons made of u, d, s, and c quarks. The nonets of light mesons occupy the central planes, to which the $c\overline{c}$ states have been added. The neutral mesons at the centers of these planes are mixtures of $u\overline{u}$, $d\overline{d}$, $s\overline{s}$, and $c\overline{c}$ states.

 D_s^*

Neglecting this, the physical states η and η' are given in terms of a mixing angle θ_P by

$$\eta = \eta_8 \cos \theta_P - \eta_1 \sin \theta_P \tag{12.3a}$$

$$\eta' = \eta_8 \sin \theta_P + \eta_1 \cos \theta_P \ . \tag{12.3b}$$

These combinations diagonalize the mass-squared matrix

$$M^2 = \begin{pmatrix} M_{11}^2 & M_{18}^2 \\ M_{18}^2 & M_{88}^2 \end{pmatrix} , {12.4}$$

where $M_{88}^2 = \frac{1}{3}(4m_K^2 - m_\pi^2)$. It follows that

$$\tan^2 \theta_P = \frac{M_{88}^2 - m_{\eta}^2}{m_{\eta'}^2 - M_{88}^2} \,. \tag{12.5}$$

The sign of θ_P is meaningful in the quark model. If

$$\eta_1 = (u\overline{u} + d\overline{d} + s\overline{s})/\sqrt{3} \tag{12.6a}$$

$$\eta_8 = (u\overline{u} + d\overline{d} - 2s\overline{s})/\sqrt{6} , \qquad (12.6b)$$

then the matrix element M_{18}^2 , which is due mostly to the strange quark mass, is negative. From the relation

$$\tan \theta_P = \frac{M_{88}^2 - m_{\eta}^2}{M_{18}^2} \,, \tag{12.7}$$

we find that $\theta_P < 0$. However, caution is suggested in the use of the $\eta - \eta'$ mixing-angle formulas, as they are extremely sensitive to SU(3)

Table 12.2: Suggested $q\overline{q}$ quark-model assignments for most of the known mesons. Some assignments, especially for the 0^{++} multiplet and for some of the higher multiplets, are controversial. Mesons in bold face are included in the Meson Summary Table. Of the light mesons in the Summary Table, the $f_1(1420)$, $f_0(1500)$, $f_J(1710)$, $f_2(2300)$, $f_2(2340)$, and the two peaks in the $\eta(1440)$ entry are not in this table. Within the $q\overline{q}$ model, it is especially hard to find a place for the first three of these f mesons and for one of the $\eta(1440)$ peaks. See the "Note on Non- $q\overline{q}$ Mesons" at the end of the Meson Listings.

$N^{\ 2S+1}L_J$	J^{PC}	$u\overline{d}, u\overline{u}, d\overline{d}$ $I = 1$	$u\overline{u}, d\overline{d}, s\overline{s}$ $I = 0$	$c\overline{c}$ $I = 0$	I = 0	$\overline{s}u, \overline{s}d$ $I = 1/2$	$c\overline{u}, c\overline{d}$ $I = 1/2$	$c\overline{s}$ $I = 0$	$ \begin{array}{c c} \overline{b}u, \overline{b}d \\ I = 1/2 \end{array} $	
$1 \ ^{1}S_{0}$	0-+	π	η,η'	$oldsymbol{\eta}_c$		K	D	D_s	В	B_s
$1 \ ^3S_1$	1	ρ	ω, ϕ	$J/\psi(1S)$	$\Upsilon(1S)$	$K^*(892)$	$D^*(2010)$	$D_s^*(2110)$	$B^*(5330)$	
$1 {}^{1}P_{1}$	1+-	$b_1(1235)$	$h_1(1170), h_1(1380)$	$h_c(1P)$		K_{1B}^{\dagger}	$D_1(2420)$	$D_{s1}(2536)$		
$1 {}^{3}P_{0}$	0++	*	*	$\chi_{c0}(1P)$	$\chi_{b0}(1P)$	$K_0^*(1430)$				
$1 {}^{3}P_{1}$	1++	$a_1(1260)$	$f_1(1285), f_1(1510)$	$\chi_{c1}(1P)$	$\chi_{b1}(1P)$	K_{1A}^{\dagger}				
$1 {}^{3}P_{2}$	2++	$a_2(1320)$	$f_2(1270),f_2'(1525)$	$\chi_{c2}(1P)$	$\chi_{b2}(1P)$	$K_2^*(1430)$	$D_2^*(2460)$			
$1 \ ^{1}D_{2}$	2-+	$\pi_2(1670)$				$K_2(1770)$				
$1 \ ^{3}D_{1}$	1	ho(1700)	$\omega(1600)$	$\psi(3770)$		$K^*(1680)^{\ddagger}$				
$1 \ ^{3}D_{2}$	2					$K_2(1820)$				
$1 \ ^{3}D_{3}$	3	$ ho_3(1690)$	$\omega_3(1670),\phi_3(1850)$			$K_3^*(1780)$				
$1\ ^{3}F_{4}$	4++	$a_4(2040)$	$f_4(2050), f_4(2220)$			$K_4^*(2045)$				
$2 \ ^{1}S_{0}$	0-+	$\pi(1300)$	$\eta(1295)$	$oldsymbol{\eta_c(2S)}$		K(1460)				
2 ³ S ₁	1	ho(1450)	$\omega(1420),\phi(1680)$	$\psi(2S)$	$\Upsilon(2S)$	$K^*(1410)^{\ddagger}$		·		
$2 {}^{3}P_{2}$	2++		$f_2(1810), f_2(2010)$		$\chi_{b2}(2P)$	$K_2^*(1980)$				
3 ¹ S ₀	0-+	$\pi(1770)$	$\eta(1760)$			K(1830)				

^{*} See our scalar minireview in the Particle Listings. The candidates for the I=1 states are $a_0(980)$ and $a_0(1450)$, while for I=0 they are: $f_0(400-1200)$, $f_0(980)$, and $f_0(1370)$. The light scalars are problematic, since there may be two poles for one $q\bar{q}$ state and $a_0(980)$, $f_0(980)$ may be $K\bar{K}$ bound states.

If we allow $M_{88}^2 = \frac{1}{3}(4m_K^2 - m_\pi^2)$ $(1 + \Delta)$, the mixing angle is determined by

$$\tan^2 \theta_P = 0.0319(1 + 17\Delta) \tag{12.8}$$

$$\theta_P = -10.1^{\circ} (1 + 8.5\Delta) \tag{12.9}$$

to first order in Δ . A small breaking of the Gell-Mann-Okubo relation can produce a major modification of θ_P .

For the vector mesons, $\pi \to \rho$, $K \to K^*$, $\eta \to \phi$, and $\eta' \to \omega$, so

$$\phi = \omega_8 \cos \theta_V - \omega_1 \sin \theta_V \tag{12.10}$$

$$\omega = \omega_8 \sin \theta_V + \omega_1 \cos \theta_V \ . \tag{12.11}$$

For "ideal" mixing, $\phi=s\overline{s}$, so $\tan\theta_V=1/\sqrt{2}$ and $\theta_V=35.3^\circ$. Experimentally, θ_V is near 35°, the sign being determined by a formula like that for $\tan\theta_P$. Following this procedure we find the mixing angles given in Table 12.3.

Table 12.3: Singlet-octet mixing angles for several nonets, neglecting possible mass dependence and imaginary parts. The sign conventions are given in the text. The values of $\theta_{\rm quad}$ are obtained from the equations in the text, while those for $\theta_{\rm lin}$ are obtained by replacing m^2 by m throughout. Of the two isosinglets in a nonet, the mostly octet one is listed first.

J^{PC}	Nonet members	$\theta_{\rm quad}$	$\theta_{ m lin}$
0^{-+}	π,K,η,η'	-10°	-23°
1	$\rho, K^*(892), \phi, \omega$	39°	36°
2^{++}	$a_2(1320), K_2^*(1430), f_2'(1525), f_2(1270)$	28°	26°
$3^{}$	$\rho_3(1690), K_3^*(1780), \phi_3(1850), \omega_3(1670)$	29°	28°

 $^{^\}dagger$ The K_{1A} and K_{1B} are nearly equal (45°) mixes of the $K_1(1270)$ and $K_1(1400).$

[‡]The $K^*(1410)$ could be replaced by the $K^*(1680)$ as the 2 3S_1 state.

In the quark model, the coupling of neutral mesons to two photons is proportional to $\sum_i Q_i^2$, where Q_i is the charge of the *i*-th quark. This provides an alternative characterization of mixing. For example, defining

$$\operatorname{Amp}\left[P \to \gamma(k_1) \ \gamma(k_2)\right] = M \epsilon^{\mu\nu\alpha\beta} \ \epsilon_{1\mu}^* \ k_{1\nu} \ \epsilon_{2\alpha}^* \ k_{2\beta} \ , \tag{12.12}$$

where $\epsilon_{i\lambda}$ is the λ component of the polarization vector of the i^{th} photon, one finds

$$\begin{split} \frac{M(\eta \to \gamma \gamma)}{M(\pi^0 \to \gamma \gamma)} &= \frac{1}{\sqrt{3}} (\cos \theta_P - 2\sqrt{2} \sin \theta_P) \\ &= \frac{1.73 \pm 0.18}{\sqrt{3}} \end{split} \tag{12.13a}$$

$$\frac{M(\eta' \to \gamma \gamma)}{M(\pi^0 \to \gamma \gamma)} = 2\sqrt{2/3} \left(\cos \theta_P + \frac{\sin \theta_P}{2\sqrt{2}}\right)$$
$$= 2\sqrt{2/3} \left(0.78 \pm 0.04\right) , \qquad (12.13b)$$

where the numbers with errors are experimental. These data favor $\theta_P \approx -20^\circ$, which is compatible with the quadratic mass mixing formula with about 12% SU(3) breaking in M_{88}^2 .

12.3. Baryons: qqq states

All the established baryons are apparently 3-quark (qqq) states, and each such state is an SU(3) color singlet, a completely antisymmetric state of the three possible colors. Since the quarks are fermions, the state function for any baryon must be antisymmetric under interchange of any two equal-mass quarks (up and down quarks in the limit of isospin symmetry). Thus the state function may be written as

$$|qqq\rangle_A = |\operatorname{color}\rangle_A \times |\operatorname{space}, \operatorname{spin}, \operatorname{flavor}\rangle_S,$$
 (12.14)

where the subscripts S and A indicate symmetry or antisymmetry under interchange of any two of the equal-mass quarks. Note the contrast with the state function for the three nucleons in $^3\mathrm{H}$ or $^3\mathrm{He}$:

$$|NNN\rangle_A = |\operatorname{space}, \operatorname{spin}, \operatorname{isospin}\rangle_A$$
. (12.15)

This difference has major implications for internal structure, magnetic moments, etc. (For a nice discussion, see Ref. 1.)

The "ordinary" baryons are made up of u, d, and s quarks. The three flavors imply an approximate flavor SU(3), which requires that baryons made of these quarks belong to the multiplets on the right side of

$$\mathbf{3} \otimes \mathbf{3} \otimes \mathbf{3} = \mathbf{10}_S \oplus \mathbf{8}_M \oplus \mathbf{8}_M \oplus \mathbf{1}_A \tag{12.16}$$

(see Sec. 33, on "SU(n) Multiplets and Young Diagrams"). Here the subscripts indicate symmetric, mixed-symmetry, or antisymmetric states under interchange of any two quarks. The 1 is a uds state (Λ_1) and the octet contains a similar state (Λ_8). If these have the same spin and parity they can mix. An example is the mainly octet D_{03} $\Lambda(1690)$ and mainly singlet D_{03} $\Lambda(1520)$. In the ground state multiplet, the SU(3) flavor singlet Λ is forbidden by Fermi statistics. The mixing formalism is the same as for η - η' or ϕ - ω (see above), except that for baryons the mass M instead of M^2 is used. Section 32, on "SU(3) Isoscalar Factors and Representation Matrices", shows how relative decay rates in, say, $10 \to 8 \otimes 8$ decays may be calculated. A summary of results of fits to the observed baryon masses and decay rates for the best-known SU(3) multiplets is given in Appendix II of our 1982 edition [2].

The addition of the c quark to the light quarks extends the flavor symmetry to SU(4). Figures 12.2(a) and 12.2(b) show the (badly broken) SU(4) baryon multiplets that have as their "ground floors" the SU(3) octet that contains the nucleons and the SU(3) decuplet that contains the $\Delta(1232)$. All the particles in a given SU(4) multiplet have the same spin and parity. The only charmed baryons that have been discovered each contain one charmed quark. These belong to the first floor of the multiplet shown in Fig. 12.2(a); for details, see

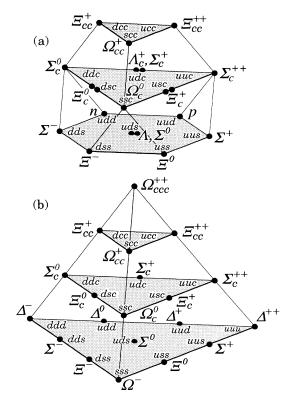


Figure 12.2: SU(4) multiplets of baryons made of u, d, s, and c quarks. (a) The 20-plet with an SU(3) octet. (b) The 20-plet with an SU(3) decuplet.

the "Note on Charmed Baryons" in the Baryon Particle Listings. The addition of a b quark extends the flavor symmetry to SU(5); it would require four dimensions to draw the multiplets.

For the "ordinary" baryons, flavor and spin may be combined in an approximate flavor-spin SU(6) in which the six basic states are $d\uparrow$, $d\downarrow$, \cdots , $s\downarrow$ (\uparrow , \downarrow = spin up, down). Then the baryons belong to the multiplets on the right side of

$$\mathbf{6} \otimes \mathbf{6} \otimes \mathbf{6} = \mathbf{56}_S \oplus \mathbf{70}_M \oplus \mathbf{70}_M \oplus \mathbf{20}_A . \tag{12.17}$$

These $\mathrm{SU}(6)$ multiplets decompose into flavor $\mathrm{SU}(3)$ multiplets as follows:

$$\mathbf{56} = {}^{4}\mathbf{10} \oplus {}^{2}\mathbf{8} \tag{12.18a}$$

$$70 = {}^{2}10 \oplus {}^{4}8 \oplus {}^{2}8 \oplus {}^{2}1 \tag{12.18b}$$

$$\mathbf{20} = {}^{2}\mathbf{8} \oplus {}^{4}\mathbf{1} , \qquad (12.18c)$$

where the superscript (2S+1) gives the net spin S of the quarks for each particle in the SU(3) multiplet. The $J^P=1/2^+$ octet containing the nucleon and the $J^P=3/2^+$ decuplet containing the $\Delta(1232)$ together make up the "ground-state" 56-plet in which the orbital angular momenta between the quark pairs are zero (so that the spatial part of the state function is trivially symmetric). The 70 and 20 require some excitation of the spatial part of the state function in order to make the overall state function symmetric. States with nonzero orbital angular momenta are classified in SU(6) \otimes O(3) supermultiplets. Physical baryons with the same quantum numbers do not belong to a single supermultiplet, since SU(6) is broken by spin-dependent interactions, differences in quark masses, etc. Nevertheless, the SU(6) \otimes O(3) basis provides a suitable framework for describing baryon state functions.

It is useful to classify the baryons into bands that have the same number N of quanta of excitation. Each band consists of a number of

supermultiplets, specified by (D, L_N^P) , where D is the dimensionality of the SU(6) representation, L is the total quark orbital angular momentum, and P is the total parity. Supermultiplets contained in bands up to N=12 are given in Ref. 3. The N=0 band, which contains the nucleon and $\Delta(1232)$, consists only of the $(56,0_0^+)$ supermultiplet. The N=1 band consists only of the $(70,1_1^-)$ multiplet and contains the negative-parity baryons with masses below about 1.9 GeV. The N=2 band contains five supermultiplets: $(56,0_2^+)$, $(70,0_2^+)$, $(56,2_2^+)$, $(70,2_2^+)$, and $(20,1_2^+)$. Baryons belonging to the $(20,1_2^+)$ supermultiplet are not ever likely to be observed, since a coupling from the ground-state baryons requires a two-quark excitation. Selection rules are similarly responsible for the fact that many other baryon resonances have not been observed [4].

In Table 12.4, quark-model assignments are given for many of the established baryons whose $SU(6)\otimes O(3)$ compositions are relatively unmixed. We note that the unestablished resonances $\mathcal{L}(1480)$, $\mathcal{L}(1560)$, $\mathcal{L}(1580)$, $\mathcal{L}(1770)$, and $\mathcal{L}(1620)$ in our Baryon Particle Listings are too low in mass to be accommodated in most quark models [4,5].

Table 12.4: Quark-model assignments for many of the known baryons in terms of a flavor-spin SU(6) basis. Only the dominant representation is listed. Assignments for some states, especially for the $\Lambda(1810)$, $\Lambda(2350)$, $\Xi(1820)$, and $\Xi(2030)$, are merely educated guesses.

$\overline{J^P}$	(D, L_N^P)	S		Octet n	nembers		Singlets
$1/2^{+}$	$(56,0_0^+)$	1/2	N(939)	Λ(1116)	$\Sigma(1193)$	$\Xi(1318)$	
$1/2^{+}$	$(56,0_2^+)$	1/2	N(1440)	$\Lambda(1600)$	$\Sigma(1660)$	$\Xi(?)$	
$1/2^{-}$	$(70,1_1^-)$	1/2	N(1535)	A(1670)	$\Sigma(1620)$	$\Xi(?)$	$\Lambda(1405)$
$3/2^{-}$	$(70,1_1^-)$	1/2	N(1520)	A(1690)	$\Sigma(1670)$	$\Xi(1820)$	$\Lambda(1520)$
$1/2^{-}$	$(70,1_1^-)$	3/2	N(1650)	A(1800)	$\Sigma(1750)$	$\Xi(?)$	
$3/2^{-}$	$(70,1_1^-)$	3/2	N(1700)	$\Lambda(?)$	$\Sigma(?)$	$\Xi(?)$	
$5/2^{-}$	$(70,1_1^-)$	3/2	N(1675)	A(1830)	$\Sigma(1775)$	$\Xi(?)$	
$1/2^{+}$	$(70,0_2^+)$	1/2	N(1710)	A(1810)	$\Sigma(1880)$	$\Xi(?)$	$\Lambda(?)$
$3/2^{+}$	$(56,2_2^+)$	1/2	N(1720)	$\Lambda(1890)$	$\Sigma(?)$	$\Xi(?)$	
$5/2^{+}$	$(56,2_2^+)$	1/2	N(1680)	$\Lambda(1820)$	$\varSigma(1915)$	$\Xi(2030)$	
$7/2^{-}$	$(70,3_3^-)$	1/2	N(2190)	$\Lambda(?)$	$\Sigma(?)$	$\Xi(?)$	$\Lambda(2100)$
$9/2^{-}$	$(70,3_3^-)$	3/2	N(2250)	$\Lambda(?)$	$\Sigma(?)$	$\Xi(?)$	
$9/2^{+}$	$(56,4_4^+)$	1/2	N(2220)	$\Lambda(2350)$	$\Sigma(?)$	$\Xi(?)$	
$3/2^{+}$	$(56,0_0^+)$	3/2	Δ (1232)	$\Sigma(1385)$	$\Xi(1530)$	$\Omega(1672)$	
$1/2^{-}$	$(70,1_1^-)$	1/2	$\Delta(1620)$	$\Sigma(?)$	$\Xi(?)$	$\Omega(?)$	
$3/2^{-}$	$(70,1_1^-)$	1/2	$\Delta(1700)$	$\Sigma(?)$	$\Xi(?)$	$\Omega(?)$	

The quark model for baryons is extensively reviewed in Ref. 6 and 7.

 $\Xi(?)$

 $\Xi(?)$

 $\Omega(?)$

 $\Omega(?)$

 $\Omega(?)$

 $(56,2^{+}_{2})$ 3/2 $\Delta(1905)$ $\Sigma(?)$

 $11/2^+$ (56,4⁺) 3/2 Δ (2420) Σ (?)

 $(56,2_2^+)$ 3/2 $\Delta(1950)$ $\Sigma(2030)$ $\Xi(?)$

 $7/2^{+}$

12.4. Dynamics

Many specific quark models exist, but most contain the same basic set of dynamical ingredients. These include:

- i) A confining interaction, which is generally spin-independent.
- ii) A spin-dependent interaction, modeled after the effects of gluon exchange in QCD. For example, in the S-wave states, there is a spin-spin hyperfine interaction of the form

$$H_{HF} = -\alpha_S M \sum_{i>j} (\overrightarrow{\sigma} \lambda_a)_i (\overrightarrow{\sigma} \lambda_a)_j , \qquad (12.19)$$

where M is a constant with units of energy, λ_a $(a=1,\cdots,8,)$ is the set of SU(3) unitary spin matrices, defined in Sec. 32, on "SU(3) Isoscalar Factors and Representation Matrices," and the sum runs over constituent quarks or antiquarks. Spin-orbit interactions, although allowed, seem to be small.

- iii) A strange quark mass somewhat larger than the up and down quark masses, in order to split the SU(3) multiplets.
- iv) In the case of isoscalar mesons, an interaction for mixing $q\overline{q}$ configurations of different flavors (e.g., $u\overline{u} \leftrightarrow d\overline{d} \leftrightarrow s\overline{s}$), in a manner which is generally chosen to be flavor independent.

These four ingredients provide the basic mechanisms that determine the hadron spectrum.

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13. CP VIOLATION

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The symmetries C (particle-antiparticle interchange) and P (space inversion) hold for strong and electromagnetic interactions. After the discovery of large C and P violation in the weak interactions, it appeared that the product CP was a good symmetry. Then CP violation was observed in K^0 decays at a level given by the parameter $\epsilon = 2.3 \times 10^{-3}$. Larger CP-violation effects are anticipated in B^0 decays.

The eigenstates of the K^0 – \overline{K}^0 system can be written

$$|K_S\rangle = p|K^0\rangle + q|\overline{K}^0\rangle , \qquad |K_L\rangle = p|K^0\rangle - q|\overline{K}^0\rangle .$$
 (13.1)

If CP invariance held, we would have q=p so that K_S would be CP even and K_L CP odd. (We define $|\overline{K}^0\rangle$ as CP $|K^0\rangle$). CP violation in $K^0-\overline{K}^0$ mixing gives

$$\frac{p}{q} = \frac{(1 + \widetilde{\epsilon})}{(1 - \widetilde{\epsilon})} \ . \tag{13.2}$$

CP violation can also occur in the decay amplitudes

$$A(K^0 \to \pi\pi(I)) = A_I e^{i\delta_I}$$
, $A(\overline{K}^0 \to \pi\pi(I)) = A_I^* e^{i\delta_I}$, (13.3)

where I is the isospin of $\pi\pi$, δ_I is the final-state phase shift, and A_I would be real if CP invariance held. The ratios of CP-violating to CP-conserving amplitudes $\eta_{+-} = A(K_L^0 \to \pi^+\pi^-)/A(K_S^0 \to \pi^+\pi^-)$ and $\eta_{00} = A(K_L^0 \to \pi^0\pi^0)/A(K_S^0 \to \pi^0\pi^0)$ can be written as

$$\eta_{+-} = \epsilon + \epsilon', \qquad \eta_{00} = \epsilon - 2\epsilon',$$
(13.4a)

$$\epsilon = \tilde{\epsilon} + i \left(\text{Im } A_0 / \text{Re } A_0 \right),$$
(13.4b)

$$|\sqrt{2}\epsilon'| = (\text{Re } A_2/\text{Re } A_0) \text{ (Im } A_2/\text{Re } A_2 - \text{Im } A_0/\text{Re } A_0) . (13.4c)$$

If CP violation is confined to the mass matrix, as in a superweak theory, ϵ' is zero and $\eta_{+-} = \eta_{00} = \epsilon = \widetilde{\epsilon}$. The measurement of ϵ'/ϵ has as its goal finding an effect that requires CP violation in the decay amplitude; this corresponds to a relative phase between A_2 and A_0 as seen in Eq. (13.4c).

In the Standard Model, CP violation arises as a result of a single phase entering the CKM matrix (q.v.). As a result in what is now the standard phase convention, two elements have large phases, $V_{ub} \sim e^{-i\gamma}$, $V_{td} \sim e^{-i\beta}$. Because these elements have small magnitudes and involve the third generation, CP violation in the K^0 system is small. A definite nonzero value for ϵ'/ϵ is expected but hadronic uncertainties allow theoretical values between 10^{-4} and 3×10^{-3} . On the other hand, large effects are expected in the B^0 system, which is a major motivation for B factories.

The most clear cut experiments would be those that measure asymmetries between B^0 and $\overline{B}{}^0$ decays. The time-dependent rate to a CP eigenstate a is given by

$$\Gamma_a \sim e^{-\Gamma t} \Big(\left[1 + |r_a|^2 \right] \pm \left[1 - |r_a|^2 \right] \cos(\Delta M t)$$

$$\mp 2\eta_a \text{Im } r_a \sin(\Delta M t) \Big) , \qquad (13.5)$$

where the top sign is for B^0 and the bottom for $\overline{B}{}^0$, η_a is the CP eigenvalue and

$$r_a = (q_B/p_B) \overline{A}_a/A_a . (13.6)$$

The quantity (q_B/p_B) comes from the analogue for B^0 of Eq. (13.1); however, for B^0 the eigenstates have a negligible lifetime difference and are distinguished only by the mass difference ΔM ; also as a result $|q_B/p_B| \approx 1$ so that $\widetilde{\epsilon}_B$ is purely imaginary. A_a (\overline{A}_a) are the decay amplitudes to a for B^0 (\overline{B}^0). If only one quark weak transition contributes to the decay $|\overline{A}_a/A_a| = 1$ so that $|r_a| = 1$ and the $\cos(\Delta Mt)$ term vanishes. The basic goal of the B factories is to observe the asymmetric $\sin(\Delta Mt)$ term. For B^0 (\overline{B}^0) $\to \psi K_s$ from the transition $b \to c\overline{c}s$, one finds in the Standard Model the asymmetry parameter

$$-2\operatorname{Im} r_a = \sin 2\beta \ . \tag{13.7}$$

The asymmetry is given directly in terms of a CKM phase with no hadronic uncertainty and is expected to be between 0.2 and 0.8. For B^0 ($\overline B{}^0$) $\to \pi^+\pi^-$ from the transition $b \to u\overline u d$

$$-2\operatorname{Im} r_a = \sin 2(\beta + \gamma) . \tag{13.8}$$

(This result has some hadronic uncertainty due to penguin contributions, but these should be able to be estimated from other observations.) While either of these asymmetries could be ascribed to $B^0 - \overline{B}{}^0$ mixing $(q_B/p_B \text{ or } \widetilde{\epsilon}_B)$, the difference between the two asymmetries is evidence for direct CP violation. From Eq. (13.6) (with $\overline{A}_a/A_a=1$) it is seen this corresponds to a phase difference between $A_{\psi K_S}$ and $A_{\pi^+\pi^-}$. Thus this is analogous to ϵ' . In the standard phase convention 2β in Eq. (13.7) and (13.8) arises from $B^0 - \overline{B}{}^0$ mixing whereas the 2γ comes from V_{bu} in the transition $b \to u \overline{u} d$.

CP violation in the decay amplitude is also revealed by the $\cos(\Delta Mt)$ in Eq. (13.5) or by a difference in rates of B^+ and B^- to charge-conjugate states. These effects, however, require two contributing amplitudes to the decay (such as a tree amplitude plus a penguin) and also require final-state interaction phases. Predicted effects are very uncertain and are generally small.

For further details, see the notes on CP violation in the K_L^0 , K_S^0 , and B^0 Particle Listings of this Review.

14. CONSTRAINTS ON NEW PHYSICS FROM ELECTROWEAK ANALYSES

This section revised September 1995 by P. Langacker and J. Erler.

Precision electroweak experiments are sensitive to loop effects, allowing a prediction of the top quark mass m_t , constraints on the Higgs mass M_H , and a search for certain types of new physics that have not been directly detected. This article will mainly discuss m_t , M_H , and the effects of exotic particles with masses large compared to M_Z on the gauge boson self-energies. Brief remarks are made on new physics which is not of this type. The effects of m_t and M_H on the radiative corrections are treated exactly to one-loop order. This can in principle be done for other types of new physics, but this necessitates a case-by-case discussion. Instead, the article will discuss in detail only the constraints on particles with heavy masses $M_{\rm new} \gg M_Z$ in an expansion in $M_Z/M_{\rm new}$. In this case, most of the effects on precision measurements can be described by three gauge self-energy parameters S, T, and U, and a $Zb\bar{b}$ vertex correction parameter γ_b .

A large value of $|m_t - m_b|$ breaks vector SU(2) symmetry and significantly affects many precision electroweak observables. The major sensitivity for processes involving light external fermions is through t- and b-quark loop contributions to the W and Z self-energies [1]. Most of the shift in M_W is absorbed into the measured value of the Fermi constant G_F , while the prediction for M_Z ,

$$M_Z = \frac{M_W}{\hat{\rho}^{1/2} \hat{c}_Z} \,, \tag{14.1}$$

decreases rapidly for large m_t . In Eq. (14.1) $\hat{\rho} \simeq 1 + \rho_t$, where

$$\rho_t = \frac{3G_F m_t^2}{8\sqrt{2}\pi^2} \sim 0.0100 \left(\frac{m_t}{180 \text{ GeV}}\right)^2 , \qquad (14.2)$$

and $\widehat{c}_Z = \cos\widehat{\theta}_W(M_Z)$, the cosine of the weak angle in the $\overline{\rm MS}$ scheme evaluated at M_Z [2]. In addition to M_Z itself, neutral current amplitudes and the coefficient of $G_FM_Z^3$ in the expression for Γ_Z are multiplied by $\widehat{\rho}$. There is additional logarithmic m_t dependence in these quantities and in M_W . Vertex and box diagrams also introduce large (quadratic) m_t dependence, which is especially important in quantities involving external b quarks (in order to avoid mixing angle suppressions), such as in the $Z \to b\overline{b}$ partial width or in $B - \overline{B}$ mixing. Finally, in the on-shell renormalization scheme, significant but somewhat artificial m_t dependence is introduced into Z vertices through the definition [2] $s_W^2 \equiv 1 - M_W^2/M_Z^2$.

As discussed in the section on the Standard Model of Electroweak Interactions (Sec. 10) (see especially Fig. 10.1), the consistency of the various observables allows a prediction for m_t . A global fit to all indirect data (see Table 10.5 of the Standard Model Section) yields

$$m_t = 179 \pm 8^{+17}_{-20} \text{ GeV} ,$$
 (14.3)

where the central value is for a Higgs mass $M_H=300$ GeV and the second uncertainty is from varying M_H in the range 60 GeV (-) to 1000 GeV (+). This is in remarkable agreement with the direct determination $m_t=180\pm12$ GeV by the CDF [3] and DØ [4] collaborations. (The indirect prediction is for the pole mass, which corresponds approximately to the kinematic mass determined by CDF and DØ.) A combined fit to both the indirect and direct data yields [2]

$$m_t = 180 \pm 7_{-13}^{+12} \text{ GeV}$$
 (14.4)

As discussed in Ref. 2, the combination of indirect data with the direct CDF and DØ value for m_t allows stringent limits on new physics. In particular, many extensions of the Standard Model are described by the ρ_0 parameter:

$$\rho_0 \equiv M_W^2 / (M_Z^2 \hat{c}_Z^2 \hat{\rho}) , \qquad (14.5)$$

which describes new sources of SU(2) breaking that cannot be accounted for by Higgs doublets or m_t effects. It has previously been difficult to distinguish ρ_0 from $\widehat{\rho} \simeq 1 + \rho_t$ experimentally, though some separation could be done utilizing R_b [5]. Using the direct m_t value as an independent constraint, however, one can calculate $\widehat{\rho}$

and thus obtain the precise value [2] $\rho_0=1.0002\pm0.0013\pm0.0018$, where the second error is from M_H . In Ref. 2, this result was used to constrain the vacuum expectation values of higher-dimensional Higgs representations. It can also be used to constrain other types of new physics. For example, nondegenerate multiplets of heavy fermions or scalars break the vector part of weak SU(2) and lead to a decrease in the value of M_Z/M_W . A nondegenerate SU(2) doublet $\binom{f_1}{f_2}$ yields a positive contribution to ρ_t of [1]

$$\frac{CG_F}{8\sqrt{2}\pi^2}\Delta m^2 , \qquad (14.6)$$

where

$$\Delta m^2 \equiv m_1^2 + m_2^2 - \frac{4m_1^2 m_2^2}{m_1^2 - m_2^2} \ln \frac{m_1}{m_2} \ge (m_1 - m_2)^2 , \qquad (14.7)$$

and C=1 (3) for color singlets (triplets). Thus, in the presence of such multiplets, one has

$$\frac{3G_F}{8\sqrt{2}\pi^2} \sum_i \frac{C_i}{3} \Delta m_i^2 = \rho_0 - 1 , \qquad (14.8)$$

where the sum includes fourth-family quark or lepton doublets, $\binom{t'}{b'}$ or $\binom{E^0}{E^-}$, and scalar doublets such as $\binom{\tilde{t}}{b}$ in supersymmetry (in the absence of L-R mixing). This implies

$$\sum_{i} \frac{C_i}{3} \Delta m_i^2 < (76 \text{ GeV})^2 , (98 \text{ GeV})^2 , (122 \text{ GeV})^2$$
 (14.9)

for $M_H=60,\,300,\,{\rm or}~1000~{\rm GeV}$ at 90% CL.

Nondegenerate multiplets usually imply $\rho_0>1$. Similarly, heavy Z' bosons decrease the prediction for M_Z due to mixing and generally lead to $\rho_0>1$ [6]. On the other hand, additional Higgs doublets which participate in spontaneous symmetry breaking [7], heavy lepton doublets involving Majorana neutrinos [8], and the vacuum expectation values of Higgs triplets or higher-dimensional representations can contribute to ρ_0 with either sign. Allowing for the presence of heavy degenerate chiral multiplets (the S parameter, to be discussed below) affects the determination of ρ_0 from the data, at present leading to a smaller value.

As discussed in the Standard Model of Electroweak Interactions section (Sec. 10), the indirect data exhibit a moderate preference for a smaller Higgs mass. The best fit to m_t as a function of M_H is roughly

$$m_t \sim 180 \pm 7 + 13 \ln \left(\frac{M_H}{300 \text{ GeV}} \right)$$
 (14.10)

including the direct CDF/DØ constraint. The χ^2 for $M_H=60~{\rm GeV}$ is lower by 7.9 than that for $M_H=1000~{\rm GeV}$, implying $M_H\lesssim 320(430)~{\rm GeV}$ at 90(95)% CL. This result is consistent with the minimal supersymmetric extension of the Standard Model, which acts much like the Standard Model with a light Higgs as far as precision experiments are concerned. However, the M_H constraint is largely driven by R_b and A_{LR}^0 , which differ significantly from the Standard Model predictions. In particular, the conclusions for M_H could be invalidated if other new physics modifies the precision observables significantly [9–15].

A number of authors have considered the general effects on neutral current and Z and W-pole observables of various types of heavy (i.e., $M\gg M_Z$) physics which contribute to the W and Z self-energies but which do not have any direct coupling to the ordinary fermions. In addition to nondegenerate multiplets, which break the vector part of weak SU(2), these include heavy degenerate multiplets of chiral fermions which break the axial generators. The effects of one degenerate chiral doublet are small, but in technicolor theories there may be many chiral doublets and therefore significant effects [9].

Such effects can be described by just three parameters, $S,\,T,$ and U at the one (electroweak) loop level. (Three additional parameters

are needed if the new physics scale is comparable to M_Z [16].) T is proportional to the difference between the W and Z self-energies at $Q^2=0$ (i.e., vector SU(2)-breaking), while S (S+U) is associated with the difference between the Z (W) self-energy at $Q^2=M_{Z,W}^2$ and $Q^2=0$ (axial SU(2)-breaking). In the $\overline{\rm MS}$ scheme [10]

$$\alpha(M_Z)T \equiv \frac{\Pi_{WW}^{\text{new}}(0)}{M_W^2} - \frac{\Pi_{ZZ}^{\text{new}}(0)}{M_Z^2}$$

$$\frac{\alpha(M_Z)}{4\hat{s}^2\hat{c}_Z^2}S \equiv \frac{\Pi_{ZZ}^{\text{new}}(M_Z^2) - \Pi_{ZZ}^{\text{new}}(0)}{M_Z^2}$$

$$\frac{\alpha(M_Z)}{4\hat{s}^2}(S+U) \equiv \frac{\Pi_{WW}^{\text{new}}(M_W^2) - \Pi_{WW}^{\text{new}}(0)}{M_W^2} , \qquad (14.11)$$

where Π_{WW}^{new} and Π_{ZZ}^{new} are respectively the contributions of the new physics to the W and Z self-energies, $\widehat{s}_Z^2 = \sin^2 \widehat{\theta}_W(M_Z)$, $\widehat{c}_Z^2 = 1 - \widehat{s}_Z^2$, and $\alpha(M_Z) \sim 1/129$ [2] is the running coupling evaluated at M_Z . S, T, and U are defined with a factor of α removed, so that they are expected to be of order unity in the presence of new physics. S, T, and U are related to other parameters ($\widehat{\epsilon}_i$, h_i , S_i) defined in [10–12] by

$$T = h_V = \hat{\epsilon}_1/\alpha$$

$$S = h_{AZ} = S_Z = 4\hat{s}_Z^2 \hat{\epsilon}_3/\alpha$$

$$U = h_{AW} - h_{AZ} = S_W - S_Z = -4\hat{s}_Z^2 \hat{\epsilon}_2/\alpha . \tag{14.12}$$

A heavy nondegenerate multiplet of fermions or scalars contributes positively to T as

$$\rho_0 = \frac{1}{1 - \alpha T} \simeq 1 + \alpha T \,\,, \tag{14.13}$$

where ρ_0 is given in Eq. (14.8). If there are non-doublet Higgs representations, their vacuum expectation values also contribute to ρ_0 . The effects of such nonstandard Higgs representations cannot be separated from heavy nondegenerate multiplets unless the new physics has other consequences, such as vertex corrections. Most of the original papers defined T to include the effects of loops only. However, we will redefine T to include all new sources of SU(2) breaking, including nonstandard Higgs, so that T and ρ_0 are equivalent by Eq. (14.13).

A multiplet of heavy degenerate chiral fermions yields

$$S = C \sum_{i} \left(t_{3L}(i) - t_{3R}(i) \right)^2 / 3\pi , \qquad (14.14)$$

where $t_{3L,R}(i)$ is the third component of weak isospin of the left-(right-) handed component of fermion i and C is the number of colors. For example, a heavy degenerate ordinary or mirror family would contribute $2/3\pi$ to S. In technicolor models with QCD-like dynamics, one expects [9] $S \sim 0.45$ for an isodoublet of technifermions, assuming N_{TC} =4 technicolors, while $S\sim 1.62$ for a full technique reation with N_{TC} =4; T is harder to estimate because it is model dependent. In these examples one has $S \geq 0$. However, the QCD-like models are excluded on other grounds (flavor-changing neutral currents, and too-light quarks and pseudo-Goldstone bosons [17]). In particular, these estimates do not apply to models of walking technicolor [17], for which S can be smaller or even negative [18]. Other situations in which S < 0, such as loops involving scalars or Majorana particles, are also possible [19]. Supersymmetric extensions of the Standard Model generally give very small effects [20]. Most simple types of new physics yield U = 0, although there are counter-examples, such as the effects of anomalous triple-gauge vertices [12].

It is also possible to parametrize the effects of large $m_t \gg M_Z$ (except for the $b\bar{b}$ vertex) or $M_H \gg M_Z$ in terms of $S,\ T$, and U. If one takes $m_t = m_t^{\rm ref}, M_H = M_H^{\rm ref}$ as a reference point, then other values of m_t and M_H can be expressed for large $m_t,\ M_H$ as [11]

$$\Delta T = \frac{\rho_t(m_t) - \rho_t(m_t^{\text{ref}})}{\alpha}$$

$$-\frac{3G_F}{4\sqrt{2}\alpha\pi^2}(M_Z^2 - M_W^2)\ln(M_H/M_H^{\text{ref}})$$

$$\Delta S = c_S \ln(m_t/m_t^{\text{ref}}) + \frac{1}{6\pi}\ln(M_H/M_H^{\text{ref}})$$

$$\Delta U = c_U \ln(m_t/m_t^{\text{ref}}) , \qquad (14.15)$$

where the coefficients c_S and c_U depend on the renormalization scheme. Prior to the direct obsevation of the t quark it was difficult to separate the effects of m_t and M_H from the new physics contributions to S, T, and U. Most authors therefore picked fixed arbitrary reference values for m_t and M_H , so that the values of S, T, U extracted from the data included both new physics and ΔS , ΔT , ΔU . Now that m_t is known independently this is no longer necessary [21]. In the following, S, T, and U will represent the contributions of new physics only. The full m_t and M_H dependence of all observables will be included in the fits separately, with the uncertainties in m_t and M_H appearing as uncertainties in the extracted S, T, U.

The Standard Model expressions for observables are replaced by

$$\begin{split} M_Z^2 &= M_{Z0}^2 \frac{1 - \alpha T}{\rho_0} \frac{1}{1 - G_F M_{Z0}^2 S / 2\sqrt{2}\pi} \\ M_W^2 &= M_{W0}^2 \frac{1}{1 - G_F M_{W0}^2 (S + U) / 2\sqrt{2}\pi} \ , \end{split} \tag{14.16}$$

where M_{Z0} and M_{W0} are the Standard Model expressions (as functions of m_t and M_H) in the $\overline{\rm MS}$ scheme. Furthermore,

$$\Gamma_Z = \frac{\rho_0}{1 - \alpha T} M_Z^3 \beta_Z$$

$$\Gamma_W = M_W^3 \beta_W$$

$$A_i = \frac{\rho_0}{1 - \alpha T} A_{i0} , \qquad (14.17)$$

where β_Z and β_W are the Standard Model expressions for the reduced widths Γ_{Z0}/M_{Z0}^3 and Γ_{W0}/M_{W0}^3 , M_Z and M_W are the physical masses, and A_i (A_{i0}) is a neutral current amplitude (in the Standard Model).

The $Z\to b\bar b$ vertex is sensitive to certain types of new physics which primarily couple to heavy families. It is useful to introduce an additional parameter γ_b by [22]

$$\Gamma(Z \to b\overline{b}) = \Gamma^0(Z \to b\overline{b})(1 + \gamma_b) , \qquad (14.18)$$

where Γ^0 is the Standard Model expression (or the expression modified by S, T, and U). Experimentally, $R_b \equiv \Gamma(Z \to b\bar{b})/\Gamma(\text{had})$ is more than 3σ above the Standard Model expectations, favoring a positive γ_b . (See the discussion in Ref. 2.) Extended technicolor interactions generally yield negative values of γ_b of a few percent [23], although it is possible to obtain a positive γ_b in models for which the extended technicolor group does not commute with the electroweak gauge group [24] or for which diagonal interactions related to the extended technicolor dominate [25]. Topcolor and topcolor-assisted technicolor models do not generally give a significant contribution to γ_b because the extended technicolor contribution to m_t is small [26]. Supersymmetry can yield (typically small) contributions of either sign [27,28].

The data allow a simultaneous determination of \widehat{s}_Z^2 (e.g., from the Z-pole asymmetries), S (from M_Z), U (from M_W), T (e.g., from the Z-decay widths), α_s (from $\Gamma(Z \to \text{had})/\Gamma(\ell \bar{\ell})$, m_t (from CDF and DØ), and γ_b (from R_b) with little correlation except between α_s and γ_b .

$$S = -0.28 \pm 0.19^{+0.08}_{+0.17}$$

$$T = -0.20 \pm 0.26^{+0.17}_{-0.12}$$

$$U = -0.31 \pm 0.54$$

$$\gamma_b = 0.032 \pm 0.010 , \qquad (14.19)$$

and $\hat{s}_Z^2 = 0.2311 \pm 0.0003$, $\alpha_s = 0.103 \pm 0.008$, $m_t = 181 \pm 12$ GeV, where the first uncertainties are from the inputs. The central values assume $M_H = 300$ GeV, and the second uncertainty, when given, is the change for $M_H = 1000$ GeV (upper) and 60 GeV (lower). S, T, and U, which are due to new physics only, are all consistent with the Standard Model value of zero at or near the 1σ level, although there is a slight tendency for negative S and T. Using Eq. (14.13) the value of ρ_0 corresponding to T is $0.9985 \pm 0.0019_{-0.0009}^{+0.0012}$. The values of the $\widehat{\epsilon}$ parameters defined in Eq. (14.12) are

$$\widehat{\epsilon}_3 = -0.0022 \pm 0.0015^{-0.0007}_{+0.0013}$$
,
 $\widehat{\epsilon}_1 = -0.0015 \pm 0.0019^{+0.0013}_{-0.0008}$,
 $\widehat{\epsilon}_2 = +0.0024 \pm 0.0033$. (14.20)

There is a strong correlation between γ_b and the predicted α_s , just as in the model with S=T=U=0 [2,21]. For $\gamma_b=0$ one obtains $\alpha_s=0.122\pm0.005$ and $T=-0.04\pm0.25^{+0.17}_{-0.11}$, with little change in the other parameters. The allowed region in S-T is shown in Fig. 14.1. From Eq. (14.19) one obtains S<0.12 (0.21) and T<0.29 (0.38) at 90 (95)% CL. If one requires the constraint $S\geq0$ (as in QCD-like technicolor models) then S<0.25 (0.30). Allowing arbitrary S, only one heavy generation of ordinary fermions is allowed at 95% CL. The favored value of S is problematic for simple technicolor models with many techni-doublets and QCD-like dynamics, as is the value of γ_b . Although S is consistent with zero, the electroweak asymmetries, especially the SLD left-right asymmetry, favor S<0. The simplest origin of S<0 would probably be an additional heavy Z' boson [6], which could mimic S<0. Similarly, there is a slight indication of negative T, while, as discussed above, nondegenerate scalar or fermion multiplets generally predict T>0.

There is no simple parametrization that is powerful enough to describe the effects of every type of new physics on every possible observable. The S, T, and U formalism describes many types of heavy physics which affect only the gauge self-energies, and it can be applied to all precision observables. However, new physics which couples directly to ordinary fermions, such as heavy Z' bosons or mixing with exotic fermions cannot be fully parametrized in the S, T. and U framework. It is convenient to treat these types of new physics by parametrizations that are specialized to that particular class of theories (e.g., extra Z' bosons), or to consider specific models (which might contain, e.g., Z' bosons and exotic fermions with correlated parameters). Constraints on various types of new physics are reviewed in [29,30,31]. Fits to models with technicolor, extended technicolor, and supersymmetry are described respectively in [32], [24], and [33]. Versions of these which allow $\gamma_b > 0$ can, for that reason, give better fits than the Standard Model. An alternate formalism [34] defines parameters, ϵ_1 , ϵ_2 , ϵ_3 , ϵ_b in terms of the specific observables M_W/M_Z , the leptonic Z width $\Gamma_{\ell\ell}$, the forward-backward asymmetry [2] at the Z pole $A_{FB}^{(0,\ell)}$, and R_b . The definitions coincide with those for $\widehat{\epsilon}_i$ in Eqs. (14.11) and (14.12) for physics which affects gauge self-energies only, but the ϵ 's now parametrize arbitrary types of new physics and can also incorporate all of the effects of m_t and M_H on the four basic observables. However, the ϵ 's are not related to other observables unless additional model-dependent assumptions are made. Another approach [35,36] parametrizes new physics in terms of gauge-invariant sets of operators. It is especially powerful in studying the effects of new physics on nonabelian gauge vertices. The most general approach introduces deviation vectors [29]. Each type of new physics defines a deviation vector, the components of which are the deviations of each observable from its Standard Model prediction, normalized to the experimental uncertainty. The length (direction) of the vector represents the strength (type) of new physics.

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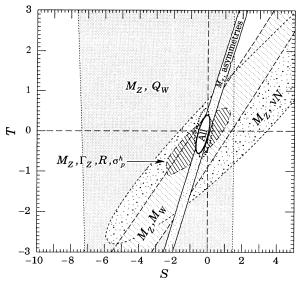


Figure 14.1: 90% CL limits on S and T from various inputs. S and T represent the contributions of new physics only: uncertainties from m_t are included in the errors. The contours assume $M_H=300$ GeV, with the exception of the two contours for all data which are displaced slightly upward (downward), corresponding to $M_H=1000$ (60) GeV. The fit to M_W and M_Z assumes U=0, while U is arbitrary in the other fits.

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15. BIG-BANG COSMOLOGY

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At early times, and today on a sufficiently large scale, our Universe is very nearly homogeneous and isotropic. The most general space-time metric for a homogeneous, isotropic space is the Friedmann-Robertson-Walker metric (with c=1) [1,2,3]:

$$ds^{2} = dt^{2} - R^{2}(t) \left[\frac{dr^{2}}{1 - \kappa r^{2}} + r^{2} (d\theta^{2} + \sin^{2}\theta \, d\phi^{2}) \right] . \tag{15.1}$$

R(t) is a scale factor for distances in comoving coordinates. With appropriate rescaling of the corrdinates, κ can be chosen to be +1, -1, or 0, corresponding to closed, open, or spatially flat geometries. Einstein's equations lead to the Friedmann equation

$$H^2 \equiv \left(\frac{\dot{R}}{R}\right)^2 = \frac{8\pi G_N \rho}{3} - \frac{\kappa}{R^2} + \frac{\Lambda}{3} ,$$
 (15.2)

as well as to

$$\frac{\ddot{R}}{R} = \frac{\Lambda}{3} - \frac{4\pi G_N}{3} \ (\rho + 3p) \ , \tag{15.3}$$

where H(t) is the Hubble parameter, ρ is the total mass-energy density, p is the isotropic pressure, and Λ is the cosmological constant. (For limits on Λ , see the Table of Astrophysical Constants; we will assume here $\Lambda=0$.) The Friedmann equation serves to define the density parameter Ω_0 (subscript 0 indicates present-day values):

$$\kappa/R_0^2 = H_0^2(\Omega_0 - 1) , \qquad \Omega_0 = \rho_0/\rho_c ;$$
 (15.4)

and the critical density is defined as

$$\rho_c \equiv \frac{3H^2}{8\pi G_N} = 1.88 \times 10^{-29} \, h^2 \, \text{g cm}^{-3} \,,$$
(15.5)

with

$$H_0 = 100 h_0 \text{ km s}^{-1} \text{ Mpc}^{-1} = h_0/(9.78 \text{ Gyr}).$$
 (15.6)

Observational bounds give $0.4 < h_0 < 1$. The three curvature signatures $\kappa = +1, -1$, and 0 correspond to $\Omega_0 > 1$, < 1, and = 1. Knowledge of Ω_0 is even poorer than that of h_0 . Luminous matter (stars and associated material) contribute $\Omega_{lum} \leq 0.01$. There is no lack of evidence for copious amounts of dark matter: rotation curves of spiral galaxies, virial estimates of cluster masses, gravitational lensing by clusters and individual galaxies, and so on. The minimum amount of dark matter required to explain the flat rotation curves of spiral galaxies only amounts to $\Omega_0 \sim 0.1$, while estimates for Ω_0 based upon cluster virial masses suggests $\Omega_0 \sim 0.2 - 0.4$. The highest estimates for the mass density come from studies of the peculiar motions of galaxies (including our own); estimates for Ω_0 obtained by relating peculiar velocity measurements to the distribution galaxies within a few hundred Mpc approach unity. A conservative range for the mass density is: $0.1 \le \Omega_0 \le 2$. The excess of Ω_0 over Ω_{lum} leads to the inference that most of the matter in the Universe is nonluminous dark matter.

In an expanding universe, the wavelength of light emitted from a distant source is shifted towards the red. The redshift z is defined such that 1+z is the ratio of the detected wavelength (λ) to emitted (laboratory) wavelength (λ_c) of some electromagnetic spectral feature. It follows from the metric given in Eq. (15.1) that

$$1 + z = \lambda/\lambda_{\rm e} = R_0/R_{\rm e} \tag{15.7}$$

where $R_{\rm c}$ is the value of the scale factor at the time the light was emitted. For light emitted in the not too distant past, one can expand $R_{\rm c}$ and write $R_{\rm c} \simeq R_0 + (t_{\rm c} - t_0) \dot{R}_0$. For small (compared to H_0^{-1}) $\Delta t = (t_{\rm c} - t_0)$, Eq. (15.7) takes the form of Hubble's law

$$z \approx \Delta t \frac{\dot{R}_0}{R_0} \approx \ell H_0 , \qquad (15.8)$$

where ℓ is the distance to the source.

Energy conservation implies that

$$\dot{\rho} = -3(\dot{R}/R)(\rho + p) ,$$
 (15.9)

so that for a matter-dominated (p=0) universe $\rho \propto R^{-3}$, while for a radiation-dominated $(p=\rho/3)$ universe $\rho \propto R^{-4}$. Thus the less singular curvature term κ/R^2 in the Friedmann equation can be neglected at early times when R is small. If the Universe expands adiabatically, the entropy per comoving volume $(\equiv R^3 s)$ is constant, where the entropy density is $s=(\rho+p)/T$ and T is temperature. The energy density of radiation can be expressed (with $\hbar=c=1$) as

$$\rho_r = \frac{\pi^2}{30} N(T)(kT)^4 , \qquad (15.10)$$

where N(T) counts the effectively massless degrees of freedom of bosons and fermions:

$$N(T) = \sum_{R} g_{B} + \frac{7}{8} \sum_{F} g_{F} . \tag{15.11}$$

For example, for $m_{\mu} > kT > m_e$, $N(T) = g_{\gamma} + 7/8 \, (g_e + 3g_{\nu}) = 2 + 7/8 \, [4 + 3(2)] = 43/4$. For $m_{\pi} > kT > m_{\mu}$, N(T) = 57/4. At temperatures less than about 1 MeV, neutrinos have decoupled from the thermal background, i.e., the weak interaction rates are no longer fast enough compared with the expansion rate to keep neutrinos in equilibrium with the remaining thermal bath consisting of γ , e^{\pm} . Furthermore, at temperatures $kT < m_e$, by entropy conservation, the ratio of the neutrino temperature to the photon temperature is given by $(T_{\nu}/T_{\gamma})^3 = g_{\gamma}/(g_{\gamma} + \frac{7}{8}g_e) = 4/11$.

In the early Universe when $\rho \approx \rho_r$, then $\dot{R} \propto 1/R$, so that $R \propto t^{1/2}$ and $Ht \to 1/2$ as $t \to 0$. The time-temperature relationship at very early times can then be found from the above equations:

$$t = \frac{2.42}{\sqrt{N(T)}} \left(\frac{1 \text{ MeV}}{kT}\right)^2 \text{ sec} .$$
 (15.12)

At later times, since the energy density in radiation falls off as R^{-4} and the energy density in non-relativistic matter falls off as R^{-3} , the Universe eventually became matter dominated. The epoch of matter-radiation density equality is determined by equating the matter density at $t_{\rm eq}$, $\rho_m = \Omega_0 \rho_c (R_0/R_{\rm eq})^3$ to the radiation density, $\rho_r = (\pi^2/30)[2 + (21/4)(4/11)^{4/3}](kT_0)^4(R_0/R_{\rm eq})^4$ where T_0 is the present temperature of the microwave background (see below). Solving for $(R_0/R_{\rm eq}) = 1 + z_{\rm eq}$ gives

$$z_{\text{eq}} + 1 = \Omega_0 h_0^2 / 4.2 \times 10^{-5} = 2.4 \times 10^4 \,\Omega_0 h_0^2 ;$$

$$kT_{\text{eq}} = 5.6 \,\Omega_0 h_0^2 \,\text{eV} ;$$

$$t_{\text{eq}} \approx 0.39 (\Omega_0 H_0^2)^{-1/2} (1 + z_{\text{eq}})^{-3/2}$$

$$= 3.2 \times 10^{10} (\Omega_0 h_0^2)^{-2} \,\text{sec} . \tag{15.13}$$

Prior to this epoch the density was dominated by radiation (relativistic particles; see Eq. (15.10)), and at later epochs matter density dominated. Atoms formed at $z\approx 1300$, and by $z_{\rm dec}\approx 1100$ the free electron density was low enough that space became essentially transparent to photons and matter and radiation were decoupled. These are the photons observed in the microwave background today.

The age of the Universe today, t_0 , is related to both the Hubble parameter and the value of Ω_0 (still assuming that $\Lambda=0$). In the Standard Model, $t_0\gg t_{\rm eq}$ and we can write

$$t_0 = H_0^{-1} \int_0^1 \left(1 - \Omega_0 + \Omega_0 x^{-1} \right)^{-1/2} dx . \tag{15.14}$$

Constraints on t_0 yield constraints on the combination $\Omega_0 h_0^2$. For example, $t_0 \ge 13 \times 10^9$ yr implies that $\Omega_0 h_0^2 \le 0.25$ for $h_0 \ge 0.5$,

or $\Omega_0 h_0^2 \leq 0.45$ for $h_0 \geq 0.4$, while $t_0 \geq 10 \times 10^9$ yr implies that $\Omega_0 h_0^2 \leq 0.8$ for $h_0 \geq 0.5$, or $\Omega_0 h_0^2 \leq 1.1$ for $h_0 \geq 0.4$.

The present temperature of the microwave background is $T_0=2.726\pm0.005$ K as measured by COBE [4], and the number density of photons $n_{\gamma}=(2\zeta(3)/\pi^2)(kT_0)^3\approx411$ cm⁻³. The energy density in photons (for which $g_{\gamma}=2$) is $\rho_{\gamma}=(\pi^2/15)(kT_0)^4$. At the present epoch, $\rho_{\gamma}=4.65\times10^{-34}$ g cm⁻³=0.26 eV cm⁻³. For nonrelativistic matter (such as baryons) today, the energy density is $\rho_B=m_Bn_B$ with $n_B\propto R^{-3}$, so that for most of the history of the Universe n_B/s is constant. Today, the entropy density is related to the photon density by $s=(4/3)(\pi^2/30)[2+(21/4)(4/11)](kT_0)^3=7.0\,n_{\gamma}$. Big Bang nucleosynthesis calculations limit $\eta=n_B/n_{\gamma}$ to $2.8\times10^{-10} \le \eta \le 4.0\times10^{-10}$. The parameter η is also related to the portion of Ω in baryons

$$\Omega_B = 3.66 \times 10^7 \eta \ h_0^{-2} (T_0/2.726 \ \text{K})^3 ,$$
 (15.15)

so that $0.010 < \Omega_B \ h_0^2 < 0.015$, and hence the Universe cannot be closed by baryons.

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16. BIG-BANG NUCLEOSYNTHESIS

Written July 1995 by K.A. Olive and D.N. Schramm.

Among the successes of the standard big-bang model is the agreement between the predictions of big-bang nucleosynthesis (BBN) for the abundances of the light elements, D, $^3{\rm He}$, $^4{\rm He}$, and $^7{\rm Li}$, and the primordial abundances inferred from observational data (see [1–3] for a more complete discussion). These abundances span some nine orders of magnitude: $^4{\rm He}$ has an abundance by number relative to hydrogen of about 0.08 (accounting for about 25% of the baryonic mass), while $^7{\rm Li}$, the least abundant of the elements with a big-bang origin, has a abundance by number relative to hydrogen of about $\sim 10^{-10}$.

16.1. Big-bang nucleosynthesis theory

The BBN theory matches the observationally determined abundances with a single well-defined parameter, the baryon-to-photon ratio, η . All the light-element abundances can be explained with η in the relatively narrow range $(2.8\text{-}4.5)\times 10^{-10}$, or $\eta_{10}\equiv \eta\times 10^{10}=2.8\text{-}4.5$. (When possible systematic errors are allowed to take extreme values, the range becomes $\eta_{10}=1.5\text{-}6.3$ [4]. We shall always quote this extreme range parenthetically following the best range.) Equivalently, this range can be expressed as the allowed range for the baryon mass density, $\rho_B=1.9\text{-}3.1$ (1.0–4.3) $\times 10^{-31}$ g cm⁻³, and can be converted to the fraction of the critical density, Ω .

The synthesis of the light elements was affected by conditions in the early Universe at temperatures $T\lesssim 1$ MeV, corresponding to an age as early as 1 s. At somewhat higher temperatures, weak-interaction rates were in equilibrium, thus fixing the ratio of the neutron and proton number densities. At $T\gg 1$ MeV, $n/p\approx 1$, since the ratio was given approximately by the Boltzmann factor, $n/p\approx e^{-Q/T}$, where Q is the neutron-proton mass difference. As the temperature fell, the Universe approached the point ("freeze-out") where the weak-interaction rates were no longer fast enough to maintain equilibrium. The final abundance of ⁴He is very sensitive to the n/p ratio at freeze-out.

The nucleosynthesis chain begins with the formation of deuterium in the process $pn \to D\gamma$. However, photo-dissociation by the high number density of photons $(n_\gamma/n_B = \eta^{-1} \sim 10^{10})$ delays production of deuterium (and other complex nuclei) well past the point where T reaches the binding energy of deuterium, $E_B = 2.2$ MeV. (The average photon energy in a blackbody is $\overline{E}_\gamma \approx 2.7$ T.) When the quantity $\eta^{-1} \exp(-E_B/T)$ reaches about 1 (at $T \approx 0.1$ MeV), the photo-dissociation rate finally falls below the nuclear production rate.

The 25% fraction of mass in $^4\mathrm{He}$ due to BBN is easily estimated by counting the number of neutrons present when nucleosynthesis begins. When the weak-interaction rates freeze-out at about $T\approx 0.8$ MeV, the n-to-p ratio is about 1/6. When free-neutron decays prior to deuterium formation are taken into account, the ratio drops to $n/p\lesssim 1/7$. Then simple counting yields a primordial $^4\mathrm{He}$ mass fraction

$$Y_p = \frac{2(n/p)}{1 + n/p} \lesssim 0.25 \ . \tag{16.1}$$

In the Standard Model, the ⁴He mass fraction depends primarily on the baryon-to-photon ratio η , as it is this quantity that determines when nucleosynthesis via deuterium production may begin. But because the n/p ratio depends only weakly on η , the ⁴He mass fraction is relatively flat as a function of η . The effect of the uncertainty in the neutron half-life, $\tau_n = 887 \pm 2$ s, is small. Lesser amounts of the other light elements are produced: D and ³He at the level of a few times 10^{-5} by number relative to H, and ⁷Li/H at the level of about 10^{-10} , when η is in the range $1 - 10 \times 10^{-10}$.

When we go beyond the Standard Model, the ⁴He abundance is very sensitive to changes in the expansion rate, which can be related to the effective number of neutrino flavors. This will be discussed below

The calculated abundances of the light elements are shown in Fig. 16.1 as a function of η_{10} . The curves for the ⁴He mass fraction, Y_p , bracket the range based on the uncertainty of the neutron mean-life, $\tau_n=887\pm2$ s. The spread in the ⁷Li curves is due to

the 1σ uncertainties in nuclear cross sections leading to $^7\mathrm{Li}$ and $^7\mathrm{Be}$ which subsequently decays to $^7\mathrm{Li}$ [4,5,6]. The uncertainties in the D and $^3\mathrm{He}$ predictions are small and have been neglected here. The boxes show to the observed abundances, discussed below. Since the observational boxes line up on top of each other, there is an overall agreement between theory and observations for η_{10} in the range 2.8–4.5 (1.5–6.3).

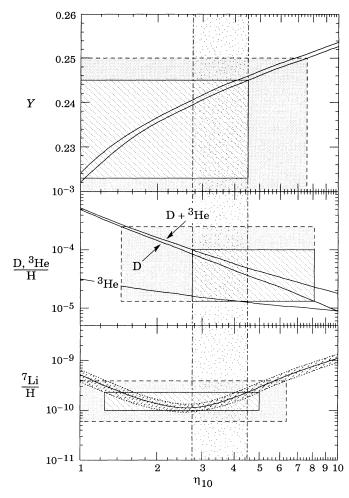


Figure 16.1: The abundances of D, ³He, ⁴He and ⁷Li as predicted by the standard model of big-bang nucleosynthesis. Also shown by a series of boxes is the comparison between these predictions and the observational determination of the light element abundances. See text for details.

16.2. Observations

Because stars produce helium as well as heavier elements, one must search for primordial helium in regions where stellar processing has been minimal, *i.e.*, in regions where abundances of elements such as carbon, nitrogen, and oxygen are very low. There are extensive compilations of observed abundances of $^4{\rm He}$, N, and O in many different extra-galactic regions of ionized H [7,8,9]. Extrapolating the $^4{\rm He}$ abundances from the data leads to a observational estimate for Y_p of [10,11]

$$Y_p = 0.234 \pm 0.003 \pm 0.005$$
 (16.2)

(Here and elsewhere, the first error is the statistical standard deviation, and the second systematic.) The large box in Fig. 16.1 bracketing the

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⁴He curves covers the range 0.223 to 0.245, where the half height is conservatively given as twice the statistical error plus the systematic error. There has been some debate on the size of systematic errors [4] and the dashed box is obtained using a larger systematic error of 0.01.

Observations for deuterium and ³He abundances present larger problems. All deuterium is primordial [12], but some of the primordial deuterium has been destroyed. Thus, as can be seen in the figure, the present deuterium abundance gives an upper limit to η . However, to get more information requires either an understanding of galactic chemical evolution of deuterium or a direct measurement of primordial deuterium. Even more problematical is ³He: Not only is primordial ³He destroyed in stars but it is very likely that low-mass stars are net producers of ³He. Neither the galactic chemical evolution of ³He nor the production of ³He in stars is well understood.

It appears that D/H has decreased over the age of the galaxy. Samples obtained deep inside meteorites provide measurements of the true (pre)-solar system abundance of ³He, while measurements on meteoritic near-surface samples, the solar wind, and lunar soil samples also contain ³He converted from deuterium in the early pre-main-sequence stage of the sun. The best current values are [13]

$$\left(\frac{D + {}^{3}\text{He}}{H}\right)_{\odot} = (4.1 \pm 1.0) \times 10^{-5} ,$$

$$\left(\frac{{}^{3}\text{He}}{H}\right)_{\odot} = (1.5 \pm 0.3) \times 10^{-5} .$$
(16.3)

The difference between these, D/H $\approx (2.6 \pm 1.0) \times 10^{-5}$, is the pre-solar D abundance.

On the other hand, the present interstellar-medium abundance of D/H is [14]

$$D/H = 1.60 \pm 0.09_{-0.10}^{+0.05} \times 10^{-5} . {(16.4)}$$

It is this lowest value of D/H that provides the most robust upper bound on η , since D is only destroyed. It is shown (decreased by $2\sigma_{\rm stat} + \sigma_{\rm syst}$) as the lower side of the D and ³He box in Fig. 16.1. If η_{10} is in the range 2.8–4.5 (1.5–6.3) then the primordial abundance of D/H is between 3.6–8 (2–25) ×10⁻⁵, and it would appear that significant destruction of deuterium has occurred. The upper side of the box in Fig. 16.1 comes from the upper limit on (D + ³He) $_{\odot}$ under the assumption that at least 25% of a star's initial D + ³He is returned to the interstellar medium [15].

Deuterium may have been detected in high-redshift, low-metallicity quasar absorption systems [16,17,18]. These measured abundances should represent the primordial value, but, they are not entirely consistent: One [16] gives D/H $\approx 1.9 - 2.5 \times 10^{-4}$ while the other [17] gives $D/H \approx 1-2 \times 10^{-5}$. Most recently, measurements in three absorption systems show consistent values of D/H around 10^{-4.0±0.25} [18] and corresponds to a value of η in good agreement with that discussed in the previous section. The upper limit on D/H from the first observation is shown by the dashed box in Fig. 16.1. As one can see, the corresponding value of Y_p (at the same value of η as inferred by the observation of a high D/H) is in excellent agreement with the data. ⁷Li is also acceptable at this value as well. However, due to the still somewhat preliminary status of this observation, it is premature to use it to fix the primordial abundance. A high value for the D abundance would require an even greater degree of D destruction over the age of the galaxy. The lower measurement for D/H is problematic for both ⁴He and ⁷Li and requires that systematics all work in the same direction to give a marginal overlap with this data.

Finally, we turn to $^7\mathrm{Li}$. In old, hot, population-II stars, $^7\mathrm{Li}$ is found to have a very nearly uniform abundance. For stars with a surface temperature T > 5500 K and a metallicity less than about 1/20th solar (so that effects such as stellar convection may not be important), the abundances show little or no dispersion beyond that consistent with the errors of individual measurements. Much data has been obtained recently from a variety of sources, and the best estimate for the mean $^7\mathrm{Li}$ abundance and its statistical uncertainty in halo stars is [19](the estimate of the systematic uncertainty discussed below is our own)

$$\text{Li/H} = (1.6 \pm 0.1^{+0.4+1.6}_{-0.3-0.5}) \times 10^{-10}$$
 (16.5)

The first error is statistical, and the second is a systematic uncertainty that covers the range of abundances derived by various methods. The box in Fig. 16.1 corresponds to these errors (as before, with a half height of $2\sigma_{\rm stat} + \sigma_{\rm syst}$). The third set of errors in Eq. (16.5) accounts for the possibility that as much as half of the primordial ⁷Li has been destroyed in stars, and that as much as 30% of the observed ⁷Li was produced in cosmic ray collisions rather than in the Big Bang. These uncertainties are shown by the dashed box in Fig. 16.1. Observations of ⁶Li, Be, and B help constrain the degree to which these effects play a role [20,21,22].

16.3. A consistent value for η

For the standard model of BBN to be deemed successful, theory and observation of the light element abundances must agree using a single value of η . We summarize the constraints on η from each of the light elements. From the ⁴He mass fraction, $Y_p < 0.240$ (0.245–0.250), we have $\eta_{10} < 2.9$ (4.5–7.6) as a 2σ upper limit (the highest values use possible systematic errors up to their extreme range). Because of the sensitivity to the assumed upper limit on γ , the upper limit on η from D/H, is still of value. From D/H > 1.3×10^{-5} , we have $\eta_{10} < 8.1$.

The lower limit on η_{10} comes from the upper limit on D + 3 He and is $\eta_{10} \gtrsim 2.8$ if one ignores 3 He production. We stress, however, that the upper limit on D + 3 He depends critically on models of galactic chemical evolution, which are far from being understood, and that one of the two measurements of D/H in quasar absorption systems indicates that $\eta_{10} \sim 1.5$.

Finally, ^{7}Li allows a broad range for η_{10} consistent with the other elements. When uncertainties in the reaction rates and systematic uncertainties in the observed abundances are both taken into account, ^{7}Li allows values of η_{10} between 1.3–5.0 (1–6.3). The resulting overall consistent range for η_{10} becomes 2.8–4.5 (1.5–6.3). These bounds on η_{10} constrain the fraction of critical density in baryons, Ω_B , to be

$$0.010 < \Omega_B h_0^2 < 0.016 \ (0.005 < \Omega_B h_0^2 < 0.023)$$
 (16.6)

for a Hubble parameter, h_0 , between 0.4 and 1.0. The corresponding range for Ω_B is 0.01–0.10 (0.005–0.14).

16.4. Beyond the Standard Model

Limits on particle physics beyond the Standard Model come mainly from the observational bounds on the $^4\mathrm{He}$ abundance. As discussed earlier, the neutron-to-proton ratio is fixed by its equilibrium value at the freeze-out of the weak-interaction rates at a temperature $T_f \sim 1$ MeV, with corrections for free neutron decay. Furthermore, freeze-out is determined by the competition between the weak-interaction rates and the expansion rate of the Universe,

$$G_F^2 T_f^5 \sim \Gamma_{\text{wk}}(T_f) = H(T_f) \sim \sqrt{G_N N(T_f)} T_f^2$$
, (16.7)

where $N(T_f)$ counts the total (equivalent) number of relativistic particle species. The presence of additional neutrino flavors (or of any other relativistic species) at the time of nucleosynthesis increases the energy density of the Universe and hence the expansion rate, leading to a larger value of T_f , n/p, and ultimately Y_p . It is clear that just as one can place limits [23] on N, any changes in the weak or gravitational coupling constants can be similarly constrained.

In the Standard Model, the number of particle species can be written as $N=5.5+\frac{7}{4}N_{\nu}$ at $T_f=1$ MeV; 5.5 accounts for photons and e^{\pm} ; and N_{ν} is the number of light neutrino flavors. The helium curves in Fig. 16.1 were computed assuming $N_{\nu}=3$, and the computed ⁴He abundance scales roughly as $\Delta Y_{\rm BBN}\approx 0.012-0.014$ ΔN_{ν} . Clearly the central value for N_{ν} from BBN will depend on η . If the best value for the observed primordial ⁴He abundance is 0.234, then, for $\eta_{10}\sim 1.7$, the central value for N_{ν} is very close to 3. For $\eta_{10}>2.8$ the central value for N_{ν} is less than 2.5. However, because of the uncertainties in the abundances, and thus in η , the upper limit on N_{ν} is more important here than the central value of N_{ν} . A straightforward propagation of errors leads to a 2σ upper limit of about 3.1 (3.5) on N_{ν} when systematic errors are included [10,24]. Other prescriptions,

which involve renormalization of the probability distributions when the central value of N_{ν} falls below 3, give even higher upper limits to N_{ν} [25].

The limits on N_{ν} can be translated into limits on other types of particles or particle masses that would affect the expansion rate of the Universe just prior to nucleosynthesis. In some cases, it is the interaction strengths of new particles which are constrained. Particles with less than full weak strength interactions contribute less to the energy density than particles that remain in equilibrium up to the time of nucleosynthesis [26].

We close with a simple example. Suppose there exist three right-handed neutrinos with only right-handed interactions of strength $G_R < G_F$. The standard left-handed neutrinos are no longer in equilibrium at temperatures below ~ 1 MeV. Particles with weaker interactions decouple at higher temperatures, and their number density ($\propto T^3$) relative to neutrinos is reduced by the annihilations of particles more massive than 1 MeV. If we use the upper bound N_{ν} < 3.1, then the three right-handed neutrinos must have a temperature $3(T_{\nu_R}/T_{\nu_L})^4 < 0.1$. Since the temperature of the decoupled ν_R 's is R. The property conservation, $T_{\nu_R}/T_{\nu_L} = [(43/4)/N(T_f)]^{1/3} < 0.4$, where T_f is the freeze-out temperature of the ν_R 's. Thus $N(T_f) > 100$ and decoupling must have occurred at $T_f > M_W$ (since in the Standard Model, $N(T > M_W) = 106.75$). Finally, the decoupling temperature is related to G_R by $(G_R/G_F)^2 \sim (T_f/3 \text{ MeV})^{-3}$, where 3 MeV corresponds to the decoupling temperature for ν_L . This yields a limit $G_R \lesssim 10^{-7} G_F$. Clearly these limits are strongly dependent on the assumed upper limit to N_{ν} ; for $N_{\nu} < 3.5$, the limit on G_R is relaxed to $G_R < 0.002$ G_F , since T_f is constrained only to be larger than the temperature corresponding to the QCD transition in the early Universe.

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17. THE HUBBLE CONSTANT

Written August 1995 by C.J. Hogan, University of Washington.

In a uniform expanding universe, the position r and velocity v of any particle relative to another obey Hubble's relation $v = H_0 r$, where H_0 is Hubble's constant.* As cosmological distances are measured in Mpc, the natural unit for H_0 is km s⁻¹ Mpc⁻¹, which has the dimensions of inverse time: $[100 \text{ km s}^{-1} \text{ Mpc}^{-1}]^{-1} = 9.78 \times 10^9 \text{ yr.}$

The real universe is nonuniform on small scales, and its motion obeys the Hubble relation only as a large scale average. But as typical non-Hubble motions ("peculiar velocities") are less than about 500 km s⁻¹, on scales more than about 5,000 km s⁻¹ the deviations from Hubble flow are less than about 10%, so the notion of a global Hubble constant is well defined. The value of H_0 averaged over the local 15,000 km s⁻¹ volume is known to lie within 10% of its global value even if H_0 itself is not known this precisely [1–3].

The Hubble constant is only meaningful on very large scales, but very large distances can only be measured indirectly. Distance ratios are measured with selected uniform types of astronomical systems ("Standard Candles") some examples of which are given below. These are used to tie distances to an absolute scale, either the nearby one based on trigonometric parallax or to some system where a physical model is precise enough to yield a distance directly from observed properties. There are many different ways to combine these tools to calibrate large distance, some of which are reviewed here. More complete reviews can be found in Refs. [4–7].

Using stars as standard candles and the Earth's orbit as a baseline, it is possible to tie distances throughout the Galaxy directly to trigonometric parallax measurements. A good landmark point for extragalactic studies is the Large Magellanic Cloud (LMC), a satellite galaxy of our Galaxy whose distance (50 kpc) is known to about 7% and provides confirmation and calibration of other measures. Beyond that, other galaxies in the Local Group (within about 1 Mpc) and other nearby groups provide stepping stones to the Virgo cluster (about 17 Mpc distant), and finally to the Coma cluster (about 100 Mpc distant) and others where the peculiar velocities introduce only small ambiguities. Most of the effort thus lies in obtaining an accurate ratio of distances in the range between Coma (or other similarly distant clusters) and the LMC.

Table 17.1 lists several candles and calibrators with a typical range of distance accessible to each. Usually the ends of the range are not precisely defined; the near end is plagued by small numbers of accessible objects and the far end by signal to noise. The precision quoted is a typical guideline which also varies depending on the sample used; it indicates the error in a distance ratio between an object and some standard reference, not including uncertainties in the absolute calibration of the reference distance (except for the first entry, which lists the typical absolute distance uncertainty in the Cepheid distance to a galaxy.) (The units are astronomical "distance modulus," given by $\mu = 5 \log_{10}(distance in parsecs) - 5.0$; a ± 0.1 magnitude error in magnitude or distance modulus corresponds to a 5% error in distance.) The verification of this precision is made by cross-checking against some other indicator on a galaxy-by-galaxy basis. This provides a control of systematic errors, since we do not expect detailed correlations between (for example) supernova brightness and host-galaxy rotation. Some examples are given in the next column, along with options often used for absolute calibration. The Hubble relation itself is included here, as it is the most precise indication of relative distance for large distances, and is used to verify the standardization of the other candles. As velocities are easy to measure at the relevant precision, a measurement of the Hubble constant is obtained from a calibrated distance measurement at a sufficiently large distance that the Hubble relation itself is precisely defined.

Table 17.1: Selected extragalactic distance indicators.

Technique	Range of distance	Precision	Verification/calibration
Cepheids	<lmc 17="" mpc<="" td="" to=""><td>0.15 mag</td><td>LMC/MWG</td></lmc>	0.15 mag	LMC/MWG
SNIa	4 Mpc to 2 Gpc	$0.1\text{-}0.2~\mathrm{mag}$	Hubble/Model,
			Cepheid
EPM/SNII	LMC to 200 Mpc	0.4 mag	Hubble/Model,
			Cepheid
PNLF	$1~{\rm Mpc~to~20~Mpc}$	0.1 mag	SBF/Cepheid
SBF	$1~{ m Mpc}$ to $60~{ m Mpc}$	0.1 mag	PNLF/Cepheid
TF	$1~{\rm Mpc~to~100~Mpc}$	0.3 mag	Hubble/Cepheid
$D_n - \sigma$	$10~\mathrm{Mpc}$ to $60~\mathrm{Mpc}$	0.4 mag	Hubble/SBF
BCG	50 Mpc to 1 Gpc	$0.2\text{-}0.3~\mathrm{mag}$	Hubble
GCLF	<LMC to 100 Mpc	0.4 mag	SBF/MWG
SZ	$100~\mathrm{Mpc}$ to $> 1~\mathrm{Gpc}$	-	Hubble/Model
GL	\sim 5 Gpc		Model
Hubble	20 Mpc to $\gtrsim 1 \mathrm{Gpc}$	$500 \text{ km s}^{-1} \div H_0 D$	BCG, SNeIa/ H_0

MWG = Milky Way Galaxy †Extracted from [4-7].

17.1. Cepheid variables

The best studied and most trusted of the standard candles, Cepheids are bright stars undergoing overstable oscillations driven by the variation of helium opacity with temperature. The period of oscillation is tightly correlated with the absolute brightness of the star. The calibration of this "period-luminosity relation" ties galaxies to geometrical parallax measurements with about 0.15 mag or 7% precision [8]. There may be some indications of nonuniformity in different populations, but no evidence yet that they are significant. Cepheids have been identified in the Galaxy, the LMC, and in galaxies as distant as M100 in the Virgo cluster, at 17.1 ± 1.8 Mpc [9]. More measurements at large distances are expected from Hubble Space Telescope data. This is an important development because it allows direct absolute calibration of the best distant indicator, SNIa, as well as other methods, to better than 10% accuracy.

17.2. Type Ia supernovae (SNIa)

A SNIa occurs when a degenerate dwarf, of the order of a solar mass and of CNO composition, undergoes explosive detonation or deflagration by nuclear burning to iron-group elements (Ni, Co, Fe). Their uniformity arises because the degenerate material only becomes unstable when it is gravitationally compressed to where the electrons become close to relativistic, which requires nearly a Chandrasekhar mass (1.4 solar masses). Theoretical models of the explosion predict approximately the right peak brightness, but cannot be relied upon for a precise calibration. SNIa are very bright, so their brightness distribution can be studied using the distant Hubble flow as a reference. Indeed, the Hubble diagram of distant SNIa (as well as cases of two SNIa in a single galaxy) shows that they can serve as remarkably precise standard candles; even though they display large variations in brightness, with detailed knowledge of the shape of the light curve, the relative intrinsic brightness of a single SNIa can be predicted to $\Delta m = 0.15$ mag or better and its distance estimated to better than 7% accuracy [10-12]. (Note that distant SNIa can even measure deviation from a linear Hubble law with precision $\Delta q_0 \simeq \Delta m/z$.) Supernovae of all types are fairly rare events, occurring in a typical galaxy every hundred years, so it is only recently that a direct absolute calibration to SNIa host galaxies with Cepheids has been possible.

17.3. Type II supernovae (SNII)

A SNII occurs when a massive star has accumulated 1.4 solar masses of iron group elements in its core; there is then no source of nuclear energy and the core collapses by the Chandrasekhar instability. The collapse to a neutron star releases a large gravitational binding energy, some of which powers an explosion. The large variety of envelopes around collapsing cores means that SNII are not at all uniform in their properties. However, their distances can be calibrated absolutely by the fairly reliable "expanding photosphere method" (EPM). The principle is most easily understood for an expanding spherical blackbody. Even if the disk is unresolved, the continuum spectrum yields the angular size from spectral temperature and absolute flux. Spectral lines yield the expansion velocity, which from knowledge of the elapsed time gives a physical size and hence a distance. Models of real photospheres are not so simple but yield individual distances accurate to about 20% [13]. This is in principle an independent absolute distance, but is precisely verified by comparison with Cepheids in several cases, the distant Hubble diagram and Tully Fisher distance ratios (described below) in several others, and by multiple-epoch fits of the same object.

17.4. Planetary nebula luminosity function (PNLF)

A planetary nebula (PN) forms when the gaseous envelope is ejected from a low-mass star as its core collapses to a white dwarf. We see bright fluorescent radiation from the ejected gas shell, excited by UV light from the hot new white dwarf. The line radiation makes PN's easy to find and measure even in far-away galaxies; a bright galaxy can have tens of thousands, of which hundreds are bright enough to use to construct a PNLF. It is found empirically that the range of PN brightnesses has a sharp upper cutoff that appears to provide a good empirical standard candle, verified by comparison with SBF distance ratios.

17.5. Surface brightness fluctuations (SBF)

When galaxies are farther away than the Local Group, atmospheric blurring causes stellar images to blend together. However, with modern linear detectors, it is still possible to measure the moments of the distribution of stellar brightness in a population (in particular, the brightness-weighted average stellar brightness) through spatial fluctuations in the light. Stellar populations in elliptical galaxies appear to be universal enough for this to be a remarkably good standard candle, as verified by comparison with PNLF distance ratios. Note the problem of absolute calibration: as there are no elliptical galaxies with Cepheids, instead one uses the bulge components of nearby spirals, which have similar populations.

17.6. Tully-Fisher (TF)

The TF relation refers to a correlation of the properties of whole spiral galaxies, between rotational velocity and total luminosity. In rough terms, the relation can be understood as a relation between mass and luminosity, but given the variation in structural properties and stellar populations the narrow relation is a surprisingly good standard candle. Looking at a whole galaxy gives a long range and wide applicability. The TF distance ratios and precision have been verified by cross-checking against all of the above candles, and against the Hubble flow, particularly galaxy cluster averages, which permit greater precision. The absolute calibration of TF is traditionally made by a handful of local galaxies, with Cepheid calibration, and a major thrust now is to extend Cepheid measurements to a larger, more representative, and more distant sample, especially to galaxies in the Virgo cluster.

17.7. $D_n-\sigma$

A rough equivalent to TF for elliptical galaxies, D_n – σ is a correlation between galaxy size and velocity dispersion. It has a larger dispersion than TF and less opportunity for local calibration, but it is particularly useful for verifying distance ratios of galaxy clusters, whose cores contain almost no spirals.

17.8. Brightest cluster galaxies (BCG)

As a result of agglomeration, rich clusters of galaxies have accumulated the largest and brightest galaxies in the universe in their centers. They are very nearly all the same brightness; when account is taken of their light profiles, they are even more uniform. These provide the best check on the approach to uniform Hubble flow on large scales. (Quasars, which are even brighter, are far too variable to be good standard candles).

17.9. Globular cluster luminosity function (GCLF)

Many galaxies have systems of globular clusters orbiting them, each of which contain hundreds of thousands of stars and hence is visible at large distances. It is assumed that similar galaxies ought to have similar distributions of globular cluster luminosity, and current work is centered on verifying the precision of this assumption.

17.10. Sunyaev-Zeldovich effect (SZ)

The electron density and temperature of the hot plasma in a cluster of galaxies can be measured in two ways which depend differently on distance: the thermal x-ray emission, which is mostly bremsstrahlung by hot electrons, and the Sunyaev-Zeldovich effect on the microwave background, caused by Compton scattering off the electrons. This provides in principle an absolute calibration. Although the model has other unconstrained parameters, such as the gas geometry, which limit the precision and reliability of distances, in the handful of cases which have been studied most recently the distances are broadly in accord with those obtained by the other techniques.

17.11. Gravitational lenses (GL)

The time delay δt between different images of a high redshift gravitationally lensed quasar is $\delta t = C(z_Q, z_l)\delta\theta^2/H_0 \approx 1$ yr for image separations $\delta\theta$ of the order of arcseconds, with a numerical factor C of order unity determined by the specific lens geometry (the angular distribution of the lensing matter) and background cosmology. Variability of the double quasar 0957+561 has permitted measurements of δt from time series correlation, but these remain controversial and ambiguous, yielding correlation peaks at both 415 and 540 days. Although lensing does not yet provide a precise measurement, it is an amazing sanity check that this system, which relies on no other intermediate steps for its calibration, gives estimates on the scale of the Hubble length which are broadly consistent with local measures of H_0 .

17.12. Estimates of H_0

The central idea is to find "landmark" systems whose distance is given by more than one technique. Systems are not always well defined, however. For example, the LMC size is a few percent of its distance, introducing errors of this order for any calibration based on an individual object within it. Nor are galaxy clusters as compact and well defined as individual galaxies; using galaxy clusters as calibrating systems often requires some assumptions and models about cluster membership (the most important example being the Virgo cluster, whose structure is somewhat amorphous, creating a $\pm 20\%$ or more distance ambiguity in some arguments). The best way to avoid this is to cross-correlate calibrators on a galaxy-by-galaxy basis, but this introduces problems of bias associated with sample selection that must be modeled. The basic difficulty remains that the nearby calibrators of any sort remain few and possibly anomalous.

The reason for the variable estimates of the Hubble constant lies in the many different ways to combine these techniques to obtain an absolute distance calibration in the Hubble flow, each involving several, usually individually reasonable, assumptions. Nevertheless there is broad agreement within the errors among a wide variety of independent ladders with different systematics. As examples, we cite a variety of (somewhat arbitrarily chosen) independent methods, which illustrate some of the choices and tradeoffs, summarized in Table 17.2.

- 1. Expanding photosphere method (EPM) distances give an absolute calibration to objects in the distant Hubble flow. A small sample of these direct distances with small flow corrections gives $H_0=73\pm6$ (statistical) ±7 (systematic).The distance estimates and limits on the systematic error component are verified by Cepheid distances in three cases, where the Cepheid/EPM distances come out to 1.02 ± 0.08 (LMC), $1.01^{+0.23}_{-0.17}$ (M101) and 1.13 ± 0.28 (M100).
- 2. With HST, it is now possible to calibrate SNIa directly with Cepheid distances to host galaxies. The light from brighter SNIa decays more slowly than from faint ones, so the best fits to the distant Hubble diagram include information about the light curve shape ("LCS") rather than simply assuming uniformity; low values of H_0 arise in the latter case. There are several options for empirical calibration, among them: (a) Three individual SNIa host galaxy distances have been calibrated directly with Cepheids. There is evidence from their light curves that two of these calibrators may indeed be unusually bright, which explains why the value of H_0 depends on whether or not the LCS correction is applied (a fourth, SN 1990N in N4639 is appearing as this goes to press, with more on the way). (b) Alternatively, assuming that the mean of six well-studied SNIa in the Virgo cluster lies at the Cepheid Virgo distance of 17 Mpc yields $H_0 = 71 \pm 7 \text{ km s}^{-1}$ Mpc^{-1} .
- 3. The distance to Virgo or any other local cluster is tied to H_0 via the distant Hubble diagram for TF or D_n - σ distances for galaxies in distant clusters. This can be done with a large scale flow model fit to many clusters. Using a Virgo distance of 17 Mpc yields $H_0 = 82 \pm 11 \text{ km s}^{-1} \text{ Mpc}^{-1}$. Alternatively, we can use the distance ratio to a fiducial reference such as the Coma cluster, for which such models predict almost vanishing peculiar velocity, and which is in any case distant enough for flow to be unimportant. (The flow models give its Hubble velocity as $7170 \pm 125 \text{ km s}^{-1}$; relative to the CMBR its velocity is $7197 \pm 73 \text{ km s}^{-1}$.) If (as estimated from TF, D_n - σ , SNeI) the Coma to Virgo ratio lies in the range 5.5 to 5.75, 17 Mpc for Virgo leads to $H_0 = 77$ to 73 km s⁻¹ Mpc⁻¹, subject to uncertainty over the Virgo depth. Nearly the same TF calibration is given by six local Cepheid calibrators, and by several more in the M101 group. This avoids the Virgo depth uncertainty, but replaces it with doubts about whether all of the local calibrators might be anomalous (although the apparent uniformity of galaxies elsewhere argues against this being a large effect.)
- 4. TF comparison with distant field galaxies in the Hubble flow (after corrections for Malmquist bias in the samples, which is worse than in cluster samples) yield $H_0=80\pm10~{\rm km~s^{-1}~Mpc^{-1}}$.
- 5. For completeness, some recent SZ and GL estimates are shown. The GL estimate in the best model [25] depends on the convergence κ added to the main galaxy lens by the cluster potential; κ probably lies between 0.1 and 0.2, and must be greater than zero, providing a firm upper limit on H_0 and an estimate squarely in the range of the other techniques.

The central values by most reliably calibrated methods lie in the range $H_0=65$ to 85 km s⁻¹ Mpc⁻¹, and indeed this corresponds roughly with the range of estimates expected from the internally estimated errors. Thus systematic errors are at least not dominant, although they could well be comparable to internal errors. The simplicity and apparent precision of the new Cepheid + SNIa ladder lead one to suspect a true value in the lower end of this range.

Footnote and References:

- * To first order in v. For discussion of the second-order term, including the "deceleration parameter" q_0 , see the Big-Bang Cosmology section (Sec. 15).
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Table 17.2: Some recent estimates of Hubble's constant

Technique	Calibration*	Ties to Hubble flow	Result* (km s ⁻¹ Mpc ⁻¹)	Ref.
EPM	Expanding photosphere model	Direct EPM Hubble Diagram + Flow model or TF	$73 \pm 6 \pm 7$	[13]
	Cepheids in 3 SNII hosts		same \times [0.88, 1.26]	[14]
SNeIa		Direct SNIa Hubble Diagram		
	Cepheids (N5253 $+$ SN1972E)	Direct + LCS correction	62 - 67	[11]
	Cepheids (N5253 $+$ SN1972E)	Direct + LCS correction	67 ± 7	[12]
	Cepheids (N5253 $+$ SN1972E)	Direct	54 ± 8	[15]
	Cepheids (IC4182 $+$ SN1937C)	Direct + LCS correction	6874 ± 6	[16]
	Cepheids (IC4182 $+$ SN1937C)	Direct	52 ± 9	[17]
	Cepheids (N4536 $+$ SN1981B)	Direct + LCS correction	67 ± 6	[18,19]
	Virgo mean (M100) + six Virgo SN hosts	Direct	$71\pm7^{\dagger}$	[14]
Clusters	Virgo mean (M100 Cepheids)	Virgo infall model	$81 \pm 11^{\dagger}$	[14]
	+ local + M101 Cepheids	Virgo/Coma ratio	$7377\pm10^\dagger$	[14]
		Cluster TF + LS flow model fit	$82\pm11^\dagger$	[14]
	M96 Cepheids	LeoI to Virgo and Coma	$69\pm8^{\dagger}$	[20]
Field TF	Local Cepheids [‡]	Field TF Hubble Diagram		
		+ Malmquist bias correction	$\approx 80 \pm 10$	[21]
SZ	SZ model + X-ray	Direct single cluster velocities:		
	maps + SZ maps	A2218	65 ± 25	[22]
		A2218,A665	55 ± 17	[22]
		Coma	74 ± 29	[23]
Gravitational lensing	Lens model, time delay	Direct, Q0957+561	< 70	[24]
	· · · · · · · · · · · · · · · · · · ·	82.5_{-3}^{+5}	$_{0}^{9}(1-\kappa)(\delta t/1.1 \text{yr})^{-1}$	[25]

^{*} For all methods based on Cepheids, add a common multiplicative error of ± 0.15 mag or 7% in H_0 .

[†] plus Virgo depth uncertainty (scales with M100/Virgo ratio)

[‡] TF calibration from 6 local Cepheid calibration is verified by M101 group galaxies and (less directly) by M100 and NGC 4571 distance to Virgo TF galaxies [9,14,26].

18. DARK MATTER

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There is strong evidence from a variety of different observations for a large amount of dark matter in the universe [1]. The phrase "dark matter" means matter whose existence has been inferred only through its gravitational effects. There is also extensive circumstantial evidence that at least some of this dark matter is nonbaryonic: that is, composed of elementary particles other than protons, neutrons, and electrons. These particles must have survived from the Big Bang, and therefore must either be stable or have lifetimes in excess of the current age of the universe.

The abundance of dark matter is usually quoted in terms of its mass density $\rho_{\rm dm}$ in units of the critical density, $\Omega_{\rm dm}=\rho_{\rm dm}/\rho_{\rm c}$; the critical density $\rho_{\rm c}$ is defined in Eq. (15.5) (in Section 15 on "Big-Bang Cosmology" in this Review). The total amount of visible matter (that is, matter whose existence is inferred from its emission or absorption of photons) is roughly $\Omega_{\rm vis}\simeq 0.005,$ with an uncertainty of at least a factor of two.

The strongest evidence for dark matter is from the rotation curves of spiral galaxies [1,2]. In these observations, the circular velocity v_c of hydrogen clouds surrounding the galaxy is measured (via Doppler shift) as a function of radius r. If there were no dark matter, at large rwe would find $v_c^2 \simeq G_N M_{\rm vis}/r$, since the visible mass $M_{\rm vis}$ of a spiral galaxy is concentrated at its center. However, observations of many spiral galaxies instead indicate a velocity v_c which is independent of r at large r, with a typical value $v_c \sim 200 \, \mathrm{km \ s^{-1}}$. Such a "flat rotation curve" implies that the total mass within radius r grows linearly with $r, M_{\rm tot}(r) \simeq G_N^{-1} v_{\rm c}^2 r$. A self-gravitating ball of ideal gas at a uniform temperature of $kT=\frac{1}{2}m_{\rm dm}v_{\rm c}^2$ would have this mass profile; here $m_{\rm dm}$ is the mass of one dark matter particle. The rotation curves are measured out to some tens of kiloparsecs, implying a total mass within this radius which is typically about ten times the visible mass. This would imply $\Omega_{\rm dm} \gtrsim 10\,\Omega_{\rm vis} \simeq 0.05.$ In our own galaxy, estimates of the local density of dark matter typically give $\rho_{\rm dm} \simeq 0.3\,{\rm GeV~cm^{-3}},$ but this result depends sensitively on how the halo of dark matter is modeled.

Other indications of the presence of dark matter come from observations of the motion of galaxies and hot gas in clusters of galaxies [3]. The overall result is that $\Omega_{\rm dm}\sim 0.2$. Studies of large-scale velocity fields result in $\Omega_{\rm dm}\gtrsim 0.3$ [4]. However, these methods of determining $\Omega_{\rm dm}$ require some astrophysical assumptions about how galaxies form.

None of these observations give us any direct indication of the nature of the dark matter. If it is baryonic, the forms it can take are severely restricted, since most forms of ordinary matter readily emit and absorb photons in at least one observable frequency band [5]. Possible exceptions include remnants (white dwarfs, neutron stars, black holes) of an early generation of massive stars, or smaller objects which never initiated nuclear burning (and would therefore have masses less than about $0.1\,M_\odot$). These massive compact halo objects are collectively called machos. Preliminary results [6] of a search for machos via gravitational lensing effects indicate that a standard halo has a mass fraction of no more than 0.66 of machos with mass less than $0.1\,M_\odot$ at the 95% confidence level, but it is possible to construct models of an all-macho halo which are consistent with all observations.

There are, however, several indirect arguments which argue for a substantial amount of nonbaryonic dark matter. First, nucleosynthesis gives the limits $0.010 \le \Omega_{\rm b}h_0^2 \le 0.016$ for the total mass of baryons; h_0 is defined in Eq. (15.6) (in Section 15 on "Big-Bang Cosmology" in this Review). The upper limit on $\Omega_{\rm b}$ is substantially below the value $\Omega_{\rm dm} \gtrsim 0.3$ given by large scale measurements, even if h_0 is near the lower end of its optimistically allowed range, $0.4 \le h_0 \le 1.0$. A second, purely theoretical argument is that inflationary models (widely regarded as providing explanations of a number of otherwise puzzling paradoxes) generically predict $\Omega_{\rm total} = 1$. Finally, without nonbaryonic dark matter it is difficult to construct a model of galaxy formation that predicts sufficiently small fluctuations in the cosmic microwave background radiation [7].

For purposes of galaxy formation models, nonbaryonic dark matter is classified as "hot" or "cold," depending on whether the dark matter particles were relativistic or nonrelativistic at the time when the horizon of the universe enclosed enough matter to form a galaxy. If the dark matter particles are in thermal equilibrium with the baryons and radiation, then only the mass of a dark matter particle is relevant to knowing whether the dark matter is hot or cold, with the dividing line being $m_{\rm dm} \sim 1\,{\rm keV}$. In addition, specifying a model requires giving the power spectrum of initial density fluctuations. Inflationary models generically predict a power spectrum which is nearly scale invariant. Given this, models with only cold dark matter are much more successful than models with only hot dark matter at reproducing the observed structure of our universe. Some lingering discrepancies in the cold dark matter model are removed in models with both kinds of dark matter [8]. Another class of models uses mass fluctuations due to topological defects, but these are much harder to analyze with comparable quantitative detail [9].

The best candidate for hot dark matter is one of the three neutrinos, endowed with a Majorana mass m_{ν} . Such a neutrino would contribute $\Omega_{\nu} = 0.56\,G_N\,T_0^3\,H_0^{-2}m_{\nu} = m_{\nu}/(92\,h_0^2\,\mathrm{eV})$, where T_0 is the present temperature of the cosmic microwave background radiation. There is another constraint on neutrinos (or any light fermions) if they are to comprise the halos of dwarf galaxies: the Pauli exclusion principle restricts the number that can fit into the phase space of a halo [10], which puts a lower limit on the neutrino mass of $m_{\nu} \gtrsim 80\,\mathrm{eV}$.

There are no presently known particles which could be cold dark matter. However, many proposed extensions of the Standard Model predict a stable (or sufficiently long lived) particle. The key question then becomes the predicted value of $\Omega_{\rm dm}$.

If the particle is its own antiparticle (or there are particles and antiparticles present in equal numbers), and these particles were in thermal equilibrium with radiation at least until they became nonrelativistic, then their relic abundance is determined by their annihilation cross section $\sigma_{\rm ann}\colon\Omega_{\rm dm}\sim G_N^{3/2}T_0^3H_0^{-2}\langle\sigma_{\rm ann}v_{\rm rel}\rangle^{-1}.$ Here $v_{\rm rel}$ is the relative velocity of the two incoming dark matter particles, and the angle brackets denote an averaging over a thermal distribution of velocities for each at the freezeout temperature $T_{\rm fr}$ when the dark matter particles go out of thermal equilibrium with radiation; typically $T_{\rm fr}\simeq\frac{1}{20}m_{\rm dm}.$ One then finds (putting in appropriate numerical factors) that $\Omega_{\rm dm}h_0^2\simeq 3\times 10^{-27}\,{\rm cm}^3\,{\rm s}^{-1}/\langle\sigma_{\rm ann}v_{\rm rel}\rangle}$. The value of $\langle\sigma_{\rm ann}v_{\rm rel}\rangle$ needed for $\Omega_{\rm dm}\simeq 1$ is remarkably close to what one would expect for a weakly interacting massive particle (wimp) with a mass of $m_{\rm dm}=100\,{\rm GeV}$: $\langle\sigma_{\rm ann}v_{\rm rel}\rangle\sim\alpha^2/8\pi m_{\rm dm}^2\sim 3\times 10^{-27}\,{\rm cm}^3\,{\rm s}^{-1}.$

If the dark matter particle is not its own antiparticle, and the number of particles minus antiparticles is conserved, then an initial asymmetry in the abundances of particles and antiparticles will be preserved, and can give relic abundances much larger than those predicted above.

If the dark matter particles were never in thermal equilibrium with radiation, then their abundance today must be calculated in some other way, and will in general depend on the precise initial conditions which are assumed.

The two best known and most studied cold dark matter candidates are the neutralino and the axion. The neutralino is predicted by supersymmetric extensions of the Standard Model [11,12]. It qualifies as a wimp, with a theoretically expected mass in the range of tens to hundreds of GeV. The axion is predicted by extensions of the Standard Model which resolve the strong CP problem [13]. Its mass must be approximately $10^{-5}\,\mathrm{eV}$ if it is to be a significant component of the dark matter. Axions can occur in the early universe in the form of a Bose condensate which never comes into thermal equilibrium; these axions are always nonrelativistic, despite their small mass.

There are prospects for direct experimental detection of both these candidates (and other wimp candidates as well). Wimps will scatter off nuclei at a calculable rate, and produce observable nuclear recoils [12,14]. This technique has been used to show that all the dark matter cannot consist of massive Dirac neutrinos or scalar neutrinos (predicted by supersymmetric models) with masses in the

range of $10\,\mathrm{GeV} \lesssim m_\mathrm{dm} \lesssim 4\,\mathrm{TeV}$ [15]. The neutralino is harder to detect because its scattering cross section with nuclei is considerably smaller. The axion can be detected by axion to photon conversion in an inhomogeneous magnetic field, and limits on the allowed axion-photon coupling have been set (which, however, do not exclude the theoretically favored value) [13]. Both types of detection experiments are in progress.

Wimp candidates can have indirect signatures as well, via present-day annihilations into particles which can be detected as cosmic rays [12]. The most promising possibility arises from the fact that wimps collect at the centers of the sun and the earth, thus greatly increasing their annihilation rate, and producing high energy neutrinos which can escape and arrive at the earth's surface in potentially observable numbers.

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19. COSMIC BACKGROUND RADIATION

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19.1. Introduction

The observed cosmic microwave background (CMB) radiation provides strong evidence for the hot big bang. The success of primordial nucleosynthesis calculations (see Sec. 16, "Big-bang nucleosynthesis") requires a cosmic background radiation (CBR) characterized by a temperature $kT\sim 1\,\mathrm{MeV}$ at a redshift of $z\simeq 10^9$. In their pioneering work, Gamow, Alpher, and Herman [1] realized this and predicted the existence of a faint residual relic, primordial radiation, with a present temperature of a few degrees. The observed CMB is interpreted as the current manifestation of the hypothesized CBR.

The CMB was serendipitously discovered by Penzias and Wilson [2] in 1965. Its spectrum is well characterized by a $2.73 \pm 0.01 \, \mathrm{K}$ black-body (Planckian) spectrum over more than three decades in frequency (see Fig. 19.1). A non-interacting Planckian distribution of temperature T_i at redshift z_i transforms with the universal expansion to another Planckian distribution at redshift z_r with temperature $T_r/(1+z_r) = T_i/(1+z_i)$. Hence thermal equilibrium, once established (e.g. at the nucleosynthesis epoch), is preserved by the expansion, in spite of the fact that photons decoupled from matter at early times. Because there are about 10^9 photons per nucleon, the transition from the ionized primordial plasma to neutral atoms at $z \sim 1000$ does not significantly alter the CBR spectrum [3].

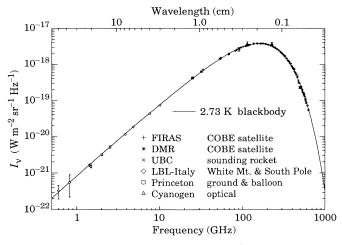


Figure 19.1: Precise measurements of the CMB spectrum. The line represents a 2.73 K blackbody, which describes the spectrum very well, especially around the peak of intensity. The spectrum is less well constrained at 10 cm and longer wavelengths. (References for this figure are at the end of this section under "CMB Spectrum References.")

19.2. Theoretical spectral distortions

The remarkable precision with which the CMB spectrum is fitted by a Planckian distribution provides limits on possible energy releases in the early Universe, at roughly the fractional level of 10^{-4} of the CBR energy, for redshifts $\lesssim 10^7$ (corresponding to epochs $\gtrsim 1\,\mathrm{year}$). The following three important classes of spectral distortions (see Fig. 19.2) generally correspond to energy releases at different epochs. The distortion results from the CBR photon interactions with a hot electron gas at temperature T_e .

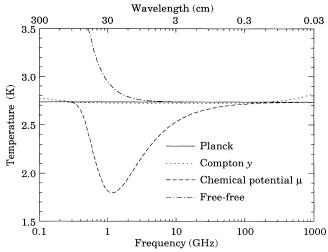


Figure 19.2: The shapes of expected, but so far unobserved, CMB distortions, resulting from energy-releasing processes at different epochs.

19.2.1. Compton distortion: Late energy release $(z \lesssim 10^5)$. Compton scattering $(\gamma e \to \gamma' e')$ of the CBR photons by a hot electron gas creates spectral distortions by transfering energy from the electrons to the photons. Compton scattering cannot achieve thermal equilibrium for y < 1, where

$$y = \int_0^z \frac{kT_e(z') - kT_{\gamma}(z')}{m_e c^2} \, \sigma_T \, n_e(z') \, c \, \frac{dt}{dz'} \, dz' \,, \tag{19.1}$$

is the integral of the number of interactions, $\sigma_T n_e(z) c dt$, times the mean-fractional photon-energy change per collision [4]. For $T_e \gg T_{\gamma}$ y is also proportional to the integral of the electron pressure $n_e k T_e$ along the line of sight. For standard thermal histories y < 1 for epochs later than $z \simeq 10^5$.

The resulting CMB distortion is a temperature decrement

$$\Delta T_{\rm RJ} = -2y T_{\gamma} \tag{19.2}$$

in the Rayleigh-Jeans $(h\nu/kT\ll 1)$ portion of the spectrum, and a rapid rise in temperature in the Wien $(h\nu/kT\gg 1)$ region, i.e. photons are shifted from low to high frequencies. The magnitude of the distortion is related to the total energy transfer [4] ΔE by

$$\Delta E/E_{\rm CBR} = e^{4y} - 1 \simeq 4y \ .$$
 (19.3)

A prime candidate for producing a Comptonized spectrum is a hot intergalactic medium. A hot $(T_e>10^5~{\rm K})$ medium in clusters of galaxies can and does produce a partially Comptonized spectrum as seen through the cluster, known as the Sunyaev-Zel'dovich effect. Based upon X-ray data, the predicted large angular scale total combined effect of the hot intracluster medium should produce $y\lesssim 10^{-6}$ [5].

19.2.2. Bose-Einstein or chemical potential distortion: Early energy release ($z \sim 10^5$ – 10^7). After many Compton scatterings (y > 1), the photons and electrons will reach statistical (not thermodynamic) equilibrium, because Compton scattering conserves photon number. This equilibrium is described by the Bose-Einstein distribution with non-zero chemical potential:

$$n = \frac{1}{e^{x + \mu_0} - 1} \,, \tag{19.4}$$

where $x \equiv h\nu/kT$ and $\mu_0 \simeq 1.4~\Delta E/E_{\rm CBR}$, with μ_0 being the dimensionless chemical potential that is required.

The collisions of electrons with nuclei in the plasma produce free-free (thermal bremsstrahlung) radiation: $eZ \rightarrow eZ\gamma$. Free-free

emission thermalizes the spectrum to the plasma temperature at long wavelengths. Including this effect, the chemical potential becomes frequency-dependent,

$$\mu(x) = \mu_0 e^{-2x_b/x} , \qquad (19.5)$$

where x_b is the transition frequency at which Compton scattering of photons to higher frequencies is balanced by free-free creation of new photons. The resulting spectrum has a sharp drop in brightness temperature at centimeter wavelengths [6]. The minimum wavelength is determined by Ω_B .

The equilibrium Bose-Einstein distribution results from the oldest non-equilibrium processes ($10^5 < z < 10^7$), such as the decay of relic particles or primordial inhomogeneities. Note that free-free emission (thermal bremsstrahlung) and radiative-Compton scattering effectively erase any distortions [7] to a Planckian spectrum for epochs earlier than $z \sim 10^7$.

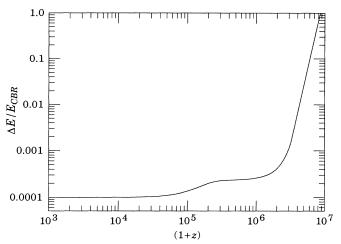


Figure 19.3: Upper Limits (95% CL) on fractional energy $(\Delta E/E_{\rm CBR})$ releases as set by lack of CMB spectral distortions resulting from processes at different epochs. These can be translated into constraints on the mass, lifetime and photon branching ratio of unstable relic particles, with some additional dependence on cosmological parameters such as Ω_B [9,10].

19.2.3. Free-free distortion: Very late energy release ($z \ll 10^3$). Free-free emission can create rather than erase spectral distortion in the late universe, for recent reionization ($z < 10^3$) and from a warm intergalactic medium. The distortion arises because of the lack of Comptonization at recent epochs. The effect on the present-day CMB spectrum is described by

$$\Delta T_{ff} = T_{\gamma} Y_{ff} / x^2, \tag{19.6}$$

where T_{γ} is the undistorted photon temperature, x is the dimensionless frequency, and Y_{ff}/x^2 is the optical depth to free-free emission:

$$Y_{ff} = \int_0^z \frac{T_e(z') - T_\gamma(z')}{T_e(z')} \frac{8\pi e^6 h^2 n_e^2 g}{3m_e(kT_\gamma)^3 \sqrt{6\pi m_e kT_e}} \frac{dt}{dz'} dz' . \quad (19.7)$$

Here h is Planck's constant, n_e is the electron density and g is the Gaunt factor [8].

19.2.4. Spectrum summary: The CMB spectrum is consistent with a blackbody spectrum over more than three decades of frequency around the peak. A least-squares fit to all CMB measurements yields:

$$\begin{split} T_{\gamma} &= 2.73 \pm 0.01 \text{ K} \\ n_{\gamma} &= (2\zeta(3)/\pi^2) T_{\gamma}^3 \simeq 413 \text{ cm}^{-3} \\ \rho_{\gamma} &= (\pi^2/15) T_{\gamma}^4 \simeq 4.68 \times 10^{-34} \, \text{g cm}^{-3} \simeq 0.262 \, \text{eV cm}^{-3} \\ |y| &< 1.5 \times 10^{-5} \qquad (95\% \text{ CL}) \\ |\mu_0| &< 9 \times 10^{-5} \qquad (95\% \text{ CL}) \\ |Y_{ff}| &< 1.9 \times 10^{-5} \qquad (95\% \text{ CL}) \end{split}$$

The limits here [11] correspond to limits [11–13] on energetic processes $\Delta E/E_{\rm CBR} < 2 \times 10^{-4}$ occurring between redshifts 10^3 and 5×10^6 (see Fig. 19.3). The best-fit temperature from the COBE FIRAS experiment is $T_{\gamma} = 2.728 \pm 0.002 \, {\rm K}$ [11].

19.3. Deviations from isotropy

Penzias and Wilson reported that the CMB was isotropic and unpolarized to the 10% level. Current observations show that the CMB is unpolarized at the 10^{-5} level but has a dipole anisotropy at the 10^{-3} level, with smaller-scale anisotropies at the 10^{-5} level. Standard theories predict anisotropies in linear polarization well below currently achievable levels, but temperature anisotropies of roughly the amplitude now being detected.

It is customary to express the CMB temperature on the sky in a spherical harmonic expansion,

$$T(\theta,\phi) = \sum_{\ell m} a_{\ell m} Y_{\ell m}(\theta,\phi) , \qquad (19.8)$$

and to discuss the various multipole amplitudes. The power at a given angular scale is roughly $\ell \sum_m \left|a_{\ell m}\right|^2/4\pi$, with $\ell \sim 1/\theta$.

19.3.1. The dipole: The largest anisotropy is in the $\ell=1$ (dipole) first spherical harmonic, with amplitude at the level of $\Delta T/T=1.23\times 10^{-3}$. The dipole is interpreted as the result of the Doppler shift caused by the solar system motion relative to the nearly isotropic blackbody field. The motion of the observer (receiver) with velocity $\beta=v/c$ relative to an isotropic Planckian radiation field of temperature T_0 produces a Doppler-shifted temperature

$$T(\theta) = T_0 (1 - \beta^2)^{1/2} / (1 - \beta \cos \theta)$$

= $T_0 \left(1 + \beta \cos \theta + (\beta^2/2) \cos 2\theta + O(\beta^3) \right)$. (19.9)

The implied velocity [11,14] for the solar-system barycenter is $\beta=0.001236\pm0.000002$ (68% CL) or $v=371\pm0.5\,\mathrm{km\,s^{-1}}$, assuming a value $T_0=2.728\pm0.002\,\mathrm{K}$, towards $(\alpha,\delta)=(11.20^{\mathrm{h}}\pm0.01^{\mathrm{h}},-7.0^{\mathrm{o}}\pm0.2^{\mathrm{o}}),$ or $(\ell,b)=(264.14^{\mathrm{o}}\pm0.15^{\mathrm{o}},48.26^{\mathrm{o}}\pm0.15^{\mathrm{o}}).$ Such a solar-system velocity implies a velocity for the Galaxy and the Local Group of galaxies relative to the CMB. The derived velocity is $v_{\mathrm{LG}}=627\pm22\,\mathrm{km\,s^{-1}}$ toward $(\ell,b)=(276^{\mathrm{o}}\pm3^{\mathrm{o}},30^{\mathrm{o}}\pm3^{\mathrm{o}}),$ where most of the error comes from uncertainty in the velocity of the solar system relative to the Local Group.

The Doppler effect of this velocity and of the velocity of the Earth around the Sun, as well as any velocity of the receiver relative to the Earth, is normally removed for the purposes of CMB anisotropy study. The resulting high degree of CMB isotropy is the strongest evidence for the validity of the Robertson-Walker metric.

19.3.2. The quadrupole: The rms quadrupole anisotropy amplitude is defined through $Q_{\rm rms}^2/T_\gamma^2=\sum_m |a_{2m}|^2/4\pi$. The current estimate of its value is $4\,\mu{\rm K}\leq Q_{\rm rms}\leq 28\,\mu{\rm K}$ for a 95% confidence interval [15]. The uncertainty here includes both statistical errors and systematic errors, which are dominated by the effects of galactic emission modelling. This level of quadrupole anisotropy allows one to set precise limits on anisotropic expansion, shear, and vorticity; all such dimensionless quantities are constrained to be less than about 10^{-5} .

19.3.3. Smaller angular scales: The COBE-discovered [16] higher-order $(\ell > 2)$ anisotropy is interpreted as being the result of perturbations in the energy density of the early Universe, manifesting themselves at the epoch of the CMB's last scattering. Hence the detection of these anisotropies has provided evidence for the existence of the density perturbations that seeded all the structure we observe today.

In the standard scenario the last scattering takes place at a redshift of approximately 1100, at which epoch the large number of photons was no longer able to keep the hydrogen sufficiently ionized. The optical thickness of the cosmic photosphere is roughly $\Delta z \sim 100$ or about 5 arcminutes, so that features smaller than this size are damped.

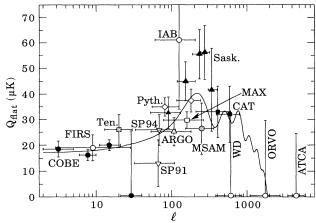


Figure 19.4: Current status of CMB anisotropy observations, adapted from Scott, Silk, & White (1995) [17]. This is a representation of the results from COBE, together with a wide range of ground- and balloon-based experiments which have operated in the last few years. Plotted are the quadrupole amplitudes for a flat (unprocessed scale-invariant spectrum of primordial perturbations, i.e., a horizontal line) anisotropy spectrum that would give the observed results for each experiment. In other words each point is the normalization of a flat spectrum derived from the individual experiments. The vertical error bars represent estimates of 68% CL, while the upper limits are at 95% CL. Horizontal bars indicate the range of ℓ values sampled. The curve indicates the expected spectrum for a standard CDM model ($\Omega_0 = 1, \Omega_B = 0.05, h = 0.5$), although true comparison with models should involve convolution of this curve with each experimental filter function. (References for this figure are at the end of this section under "CMB Anisotropy References.")

Anisotropies are observed on angular scales larger than this damping scale (see Fig. 19.4), and are consistent with those expected from an initially scale-invariant power spectrum (flat = independent of scale) of potential and thus metric fluctuations. It is believed that the large scale structure in the Universe developed through the process of gravitational instability, where small primordial perturbations in energy density were amplified by gravity over the course of time. The initial spectrum of density perturbations can evolve significantly in the epoch z>1100 for causally connected regions (angles $\lesssim 1^{\rm o} \, \Omega_{\rm tot}^{1/2}$). The primary mode of evolution is through adiabatic (acoustic) oscillations, leading to a series of peaks that encode information about the perturbations and geometry of the universe, as well as information on $\Omega_0, \, \Omega_B, \, \Omega_\Lambda$ (cosmological constant), and H_0 [17]. The location of the first acoustic peak is predicted to be at $\ell \sim 220 \, \Omega_{\rm tot}^{-1/2}$ or $\theta \sim 0.3^{\rm o} \, \Omega_{\rm tot}^{1/2}$ and its amplitude increases with increasing Ω_B .

Theoretical models often predict a power spectrum in spherical harmonic amplitudes, since the models lead to primordial fluctuations and thus $a_{\ell m}$ that are Gaussian random fields, and hence the power spectrum in ℓ is sufficient to characterize the results. The power at each ℓ is $(2\ell+1)C_\ell/(4\pi)$, where $C_\ell \equiv \langle |a_{\ell m}|^2 \rangle$. For an idealized full-sky observation, the variance of each measured C_ℓ is $[2/(2\ell+1)]C_\ell^2$. This sampling variance (known as cosmic variance) comes about because each C_ℓ is chi-squared distributed with $(2\ell+1)$ degrees of freedom for our observable volume of the Universe [18].

Figure 19.5 shows the theoretically predicted anisotropy power spectrum for a sample of models, plotted as $\ell(\ell+1)C_\ell$ versus ℓ which is the power per logarithmic interval in ℓ or, equivalently, the two-dimensional power spectrum. If the initial power spectrum of perturbations is the result of quantum mechanical fluctuations produced and amplified during inflation, then the shape of the anisotropy spectrum is coupled to the ratio of contributions from density (scalar) and gravity wave (tensor) perturbations. If the energy scale of inflation at the appropriate epoch is at the level of

 $\simeq 10^{16} {\rm GeV},$ then detection of the effect of gravitons is possible, as well as partial reconstruction of the inflaton potential. If the energy scale is $\lesssim 10^{14} {\rm GeV},$ then density fluctuations dominate and less constraint is possible.

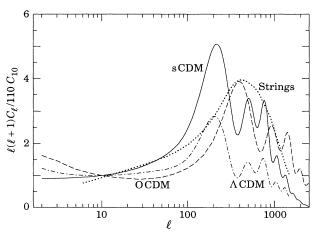


Figure 19.5: Examples of theoretically predicted $\ell(\ell+1)C_\ell$ or CMB anisotropy power spectra. sCDM is the standard cold dark matter model with h=0.5 and $\Omega_B=0.05$. Λ CDM is a model with $\Omega_{\rm tot}=\Omega_{\Lambda}+\Omega_0=1$, with $\Omega_{\Lambda}=0.3$ and h=0.8. OCDM is an open model with $\Omega_0=0.3$ and h=0.75 (see [19] for models). Strings is a model where cosmic strings are the primary source of large scale structure [20]. The plot indicates that precise measurements of the CMB anisotropy power spectrum could distinguish between current models.

Fits to data over smaller angular scales are often quoted as the expected value of the quadrupole $\langle Q \rangle$ for some specific theory, e.g. a model with power-law initial conditions (primordial density perturbation power spectrum $P(k) \propto k^n$). The full 4-year COBE DMR data give $\langle Q \rangle = 15.3^{+3.7}_{-2.8}~\mu \text{K}$, after projecting out the slope dependence, while the best-fit slope is $n=1.2\pm0.3$, and for a pure n=1 (scale-invariant potential perturbation) spectrum $\langle Q \rangle (n=1) = 18\pm1.6~\mu \text{K}$ [15,21]. The conventional notation is such that $\langle Q \rangle^2/T_\gamma^2 = 5C_2/4\pi$. The fluctuations measured by other experiments can also be quoted in terms of Q_{flat} , the equivalent value of the quadrupole for a flat (n=1) spectrum, as presented in Fig. 19.4.

It now seems clear that there is more power at sub-degree scales than at COBE scales, which provides some model-dependent information on cosmological parameters [17,22], for example Ω_B . In terms of such parameters, fits to the COBE data alone yield $\Omega_0 > 0.34$ at 95% CL [23] and $\Omega_{\rm tot} < 1.5$ also at 95% CL [24], for inflationary models. Only somewhat weak conclusions can be drawn based on the current smaller angular scale data (see Fig. 19.4). A sample preliminary fit [25] finds $\Omega_{\rm tot} = 0.7^{+1.0}_{-0.4}$ and $30 < H_0 < 70~{\rm km\,s^{-1}Mpc^{-1}}$ for a limited range of cosmological models.

However, new data are being acquired at an increasing rate, with a large number of improved ground- and balloon-based experiments being developed. It appears that we are not far from being able to distinguish crudely between currently favored models, and to begin a more precise determination of cosmological parameters. A vigorous suborbital and interferometric program could map out the CMB anisotropy power spectrum to about 10% accuracy and determine several parameters at the 10 to 20% level in the next few years. Ultimately, on the scale of a perhaps 5–10 years, there is the prospect of another satellite mission which could provide a precise measurement of the power spectrum down to scales of 10 arcminutes, allowing us to decode essentially all of the information that it contains [26].

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20. COSMIC RAYS

Written 1995 by T.K. Gaisser and T. Stanev

20.1. Primary spectra

The cosmic radiation incident at the top of the terrestrial atmosphere includes all stable charged particles and nuclei with lifetimes of order 10^6 years or longer. Technically, "primary" cosmic rays are those particles accelerated at astrophysical sources and "secondaries" are those particles produced in interaction of the primaries with interstellar gas. Thus electrons, protons and helium, as well as carbon, oxygen, iron, and other nuclei synthesized in stars, are primaries. Nuclei such as lithium, beryllium, and boron (which are not abundant end-products of stellar nucleosynthesis) are secondaries. Antiprotons and positrons are partly, if not entirely, secondaries, but the fraction of these particles that may be primary is a question of current interest.

Apart from particles associated with solar flares, the cosmic radiation comes from outside the solar system. The incoming charged particles are "modulated" by the solar wind, the expanding magnetized plasma generated by the Sun, which decelerates and partially excludes the lower energy galactic cosmic rays from the inner solar system. There is a significant anticorrelation between solar activity (which has an eleven-year cycle) and the intensity of the cosmic rays with energies below about 10 GeV. In addition, the lower-energy cosmic rays are affected by the geomagnetic field, which they must penetrate to reach the top of the atmosphere. Thus the intensity of any component of the cosmic radiation in the GeV range depends both on the location and time.

There are four different ways to describe the spectra of the components of the cosmic radiation: (1) By particles per unit rigidity. Propagation (and probably also acceleration) through cosmic magnetic fields depends on gyroradius or magnetic rigidity, R, which is gyroradius multiplied by the magnetic field strength:

$$R = \frac{p\,c}{Z\,e} = r_L\,B\ . \tag{20.1}$$

(2) By particles per energy-per-nucleon. Fragmentation of nuclei propagating through the interstellar gas depends on energy per nucleon, since that quantity is approximately conserved when a nucleus breaks up on interaction with the gas. (3) By nucleons per energy-per-nucleon. Production of secondary cosmic rays in the atmosphere depends on the intensity of nucleons per energy-per-nucleon, approximately independently of whether the incident nucleons are free protons or bound in nuclei. (4) By particles per energy-per-nucleus. Air shower experiments that use the atmosphere as a calorimeter generally measure a quantity that is related to total energy per particle.

The units of differential intensity I are $[\mathrm{cm}^{-2}\mathrm{s}^{-1}\mathrm{sr}^{-1}\mathcal{E}^{-1}]$, where \mathcal{E} represents the units of one of the four variables listed above.

The intensity of primary nucleons in the energy range from several ${\rm GeV}$ to somewhat beyond 100 ${\rm TeV}$ is given approximately by

$$I_N(E) \approx 1.8 E^{-\alpha} \frac{\text{nucleons}}{\text{cm}^2 \text{ s sr GeV}},$$
 (20.2)

where E is the energy-per-nucleon (including rest mass energy) and $\alpha \ (\equiv \gamma+1)=2.7$ is the differential spectral index of the cosmic ray flux and γ is the integral spectral index. About 79% of the primary nucleons are free protons and about 70% of the rest are nucleons bound in helium nuclei. The fractions of the primary nuclei are nearly constant over this energy range (possibly with small but interesting variations). Fractions of both primary and secondary incident nuclei are listed in Table 20.1. Figure 20.1 [1] shows the major components as a function of energy at a particular epoch of the solar cycle.

The spectrum of electrons and positrons incident at the top of the atmosphere is steeper than the spectra of protons and nuclei, as shown in Fig. 20.2 [2]. The positron fraction is about 10% in the region in which it is measured (< 20 GeV), but it is not yet fully understood [5].

Above 10 GeV the fraction of antiprotons to protons is about 10^{-4} , and there is evidence for the kinematic suppression at lower

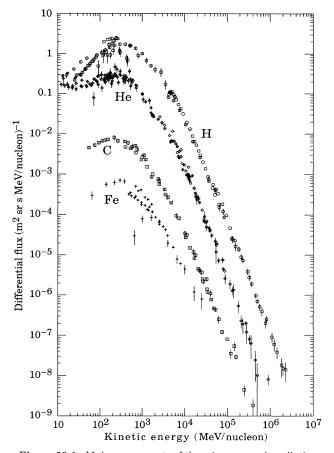


Figure 20.1: Major components of the primary cosmic radiation (from Ref. 1).

Table 20.1: Relative abundances F of cosmic-ray nuclei at 10.6 GeV/nucleon normalized to oxygen ($\equiv 1$) [3]. The oxygen flux at kinetic energy of 10.6 GeV/nucleon is 3.26×10^{-6} cm⁻² s⁻¹ sr⁻¹ (GeV/nucleon)⁻¹. Abundances of hydrogen and helium are from Ref. 4.

Z	Element	F	Z	Element	F
1	Н	730	13-14	Al-Si	0.19
2	He	34	15-16	P-S	0.03
3-5	Li-B	0.40	17 - 18	Cl-Ar	0.01
6-8	C-O	2.20	19 - 20	K-Ca	0.02
9-10	F-Ne	0.30	21 - 25	Sc-Mn	0.05
11-12	Na-Mg	0.22	26 - 28	Fe-Ni	0.12

energy expected for secondary antiprotons [5]. There is at this time no evidence for a significant primary component of antiprotons.

20.2. Cosmic rays in the atmosphere

Figure 20.3 shows the vertical fluxes of the major cosmic ray components in the atmosphere in the energy region where the particles are most numerous (except for electrons, which are most numerous near their critical energy, which is about 81 MeV in air). Except for protons and electrons near the top of the atmosphere, all particles are produced in interactions of the primary cosmic rays in the air. Muons and neutrinos are products of the decay of charged mesons, while electrons and photons originate in decays of neutral mesons.

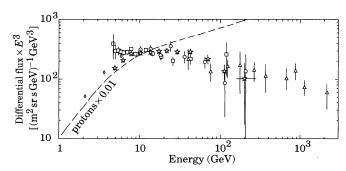


Figure 20.2: Differential spectrum of electrons plus positrons multiplied by E^3 (from Ref. 2).

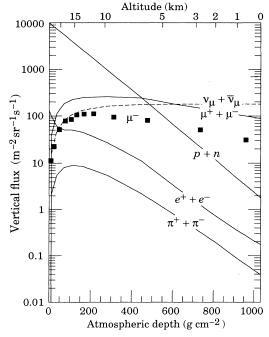


Figure 20.3: Vertical fluxes of cosmic rays in the atmosphere with E>1 GeV estimated from the nucleon flux of Eq. (20.2). The points show measurements of negative muons with $E_{\mu}>1$ GeV [7].

Most measurements are made at ground level or near the top of the atmosphere, but there are also measurements of muons and electrons from airplanes and balloons. Fig. 20.3 includes a recent measurement of negative muons [7]. Since $\mu^+(\mu^-)$ are produced in association with $\nu_\mu(\overline{\nu}_\mu)$, the measurement of muons near the maximum of the intensity curve for the parent pions serves to calibrate the atmospheric ν_μ beam [6]. Because muons typically lose almost two GeV in passing through the atmosphere, the comparison near the production altitude is important for the sub-GeV range of $\nu_\mu(\overline{\nu}_\mu)$ energies.

The flux of cosmic rays through the atmosphere is described by a set of coupled cascade equations with boundary conditions at the top of the atmosphere to match the primary spectrum. Numerical or Monte Carlo calculations are needed to account accurately for decay and energy-loss processes, and for the energy-dependences of the cross sections and of the primary spectral index γ . Approximate analytic solutions are, however, useful in limited regions of energy [8]. For example, the vertical intensity of nucleons at depth X (g cm⁻²) in the atmosphere is given by

$$I_N(E,X) \approx I_N(E,0) e^{-X/\Lambda}$$
, (20.3)

where Λ is the attenuation length of nucleons in air.

The corresponding expression for the vertical intensity of charged pions with energy $E_\pi\ll\epsilon_\pi=115$ GeV is

$$I_{\pi}(E_{\pi},X) \approx \frac{Z_{N\pi}}{\lambda_N} I_N(E_{\pi},0) e^{-X/\Lambda} \frac{X E_{\pi}}{\epsilon_{\pi}}$$
 (20.4)

This expression has a maximum at $t=\Lambda\approx 120~{\rm g~cm^{-2}}$, which corresponds to an altitude of 15 kilometers. The quantity $Z_{N\pi}$ is the spectrum-weighted moment of the inclusive distribution of charged pions in interactions of nucleons with nuclei of the atmosphere. The intensity of low-energy pions is much less than that of nucleons because $Z_{N\pi}\approx 0.079$ is small and because most pions with energy much less than the critical energy ϵ_{π} decay rather than interact.

20.3. Cosmic rays at the surface

20.3.1. Muons: Muons are the most numerous charged particles at sea level (see Fig. 20.3). Most muons are produced high in the atmosphere (typically 15 km) and lose about 2 GeV to ionization before reaching the ground. Their energy and angular distribution reflect a convolution of production spectrum, energy loss in the atmosphere, and decay. For example, $E_{\mu}=2.4~{\rm GeV}$ muons have a decay length of 15 km, which is reduced to 8.7 km by energy loss. The mean energy of muons at the ground is ≈ 4 GeV. The energy spectrum is almost flat below 1 GeV, steepens gradually to reflect the primary spectrum in the 10-100 GeV range, and steepens further at higher energies because pions with $E_{\pi} > \epsilon_{\pi} \approx 115$ GeV tend to interact in the atmosphere before they decay. Asymptotically $(E_{\mu} \gg 1 \text{ TeV})$, the energy spectrum of atmospheric muons is one power steeper than the primary spectrum. The integral intensity of vertical muons above 1 GeV/c at sea level is $\approx 70 \text{ m}^{-2}\text{s}^{-1}\text{sr}^{-1}$ [9,10]. Experimentalists are familiar with this number in the form $I \approx 1 \text{ cm}^{-2} \text{ min}^{-1}$ for horizontal detectors.

The overall angular distribution of muons at the ground is $\propto \cos^2 \theta$, which is characteristic of muons with $E_{\mu} \sim 3$ GeV. At lower energy the angular distribution becomes increasingly steeper, while at higher energy it flattens and approaches a $\sec \theta$ distribution for $E_{\mu} \gg \epsilon_{\pi}$ and $\theta < 70^{\circ}$.

Figure 20.4 shows the muon energy spectrum at sea level for two angles. At large angles low energy muons decay before reaching the surface and high energy pions decay before they interact, thus the average muon energy increases. An approximate extrapolation formula valid when muon decay is negligible $(E_{\mu}>100/\cos\theta~{\rm GeV})$ and the curvature of the Earth can be neglected $(\theta<70^{\circ})$ is

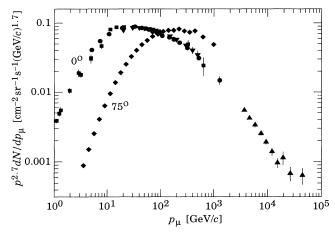


Figure 20.4: Spectrum of muons at $\theta = 0^{\circ}$ (■ [12], ● [13], ▼ [14], ▲ [15]), and $\theta = 75^{\circ}$ ♦ [16]).

$$\frac{dN_{\mu}}{dE_{\mu}} \approx \frac{0.14 E^{-2.7}}{\text{cm}^2 \text{ s sr GeV}}$$

$$\times \left\{ \frac{1}{1 + \frac{1.1 E_{\mu} \cos \theta}{115 \text{ GeV}}} + \frac{0.054}{1 + \frac{1.1 E_{\mu} \cos \theta}{850 \text{ GeV}}} \right\} , \tag{20.5}$$

where the two terms give the contribution of pions and charged kaons. Eq. (20.5) neglects a small contribution from charm and heavier flavors which is negligible except at very high energy [17].

The muon charge ratio reflects the excess of π^+ over π^- in the forward fragmentation region of proton initiated interactions together with the fact that there are more protons than neutrons in the primary spectrum. The charge ratio is between 1.2 and 1.3 from 250 MeV up to 100 GeV [9].

20.3.2. Electromagnetic component: At the ground, this component consists of electrons, positrons, and photons primarily from electromagnetic cascades initiated by decay of neutral and charged mesons. Muon decay is the dominant source of low-energy electrons at sea level. Decay of neutral pions is more important at high altitude or when the energy threshold is high. Knock-on electrons also make a small contribution at low energy [11]. The integral vertical intensity of electrons plus positrons is very approximately 30, 6, and $0.2~\mathrm{m}^{-2}\mathrm{s}^{-1}\mathrm{sr}^{-1}$ above 10, 100, and 1000 MeV respectively [10,18], but the exact numbers depend sensitively on altitude, and the angular dependence is complex because of the different altitude dependence of the different sources of electrons [11,18,19]. The ratio of photons to electrons plus positrons is approximately 1.3 above a GeV and 1.7 below the critical energy [19].

20.3.3. *Protons*: Nucleons above 1 GeV/c at ground level are degraded remnants of the primary cosmic radiation. The intensity is approximately represented by Eq. (20.3) with the replacement $t \to t/\cos\theta$ for $\theta < 70^\circ$ and an attenuation length $\Lambda = 123$ g cm⁻². At sea level, about 1/3 of the nucleons in the vertical direction are neutrons (up from $\approx 10\%$ at the top of the atmosphere as the n/p ratio approaches equilibrium). The integral intensity of vertical protons above 1 GeV/c at sea level is $\approx 0.9 \text{ m}^{-2} \text{s}^{-1} \text{sr}^{-1}$ [10,20].

20.4. Cosmic rays underground

Only muons and neutrinos penetrate to significant depths underground. The muons produce tertiary fluxes of photons, electrons, and hadrons.

20.4.1. *Muons*: As discussed in Section 22.9 of this *Review*, muons lose energy by ionization and by radiative processes: bremsstrahlung, direct production of e^+e^- pairs, and photonuclear interactions. The total muon energy loss may be expressed as a function of the amount of matter traversed as

$$-\frac{dE_{\mu}}{dX} = a + b E_{\mu} , \qquad (20.6)$$

where a is the ionization loss and b is the fractional energy loss by the three radiation processes. Both are slowly varying functions of energy. The quantity $\epsilon \equiv a/b$ (≈ 500 GeV in standard rock) defines a critical energy below which continuous ionization loss is more important the radiative losses. Table 20.2 shows a and b values for standard rock as a function of muon energy. The second column of Table 20.2 shows the muon range in standard rock ($A=22,Z=11,\rho=2.65$ g cm⁻³). These parameters are quite sensitive to the chemical composition of the rock, which must be evaluated for each experimental location.

The intensity of muons underground can be estimated from the muon intensity in the atmosphere and their rate of energy loss. To the extent that the mild energy dependence of a and b can be neglected, Eq. (20.6) can be integrated to provide the following relation between the energy $E_{\mu,0}$ of a muon at production in the atmosphere and its average energy E_{μ} after traversing a thickness X of rock (or ice or water):

$$E_{\mu} = (E_{\mu,0} + \epsilon) e^{-bX} - \epsilon . {(20.7)}$$

Table 20.2: Average muon range R and energy loss parameters calculated for standard rock. Range is given in km-water-equivalent, or 10^5 g cm⁻².

E_{μ} GeV	R km.w.e.	$\begin{array}{c} a \\ {\rm MeVg^{-1}cm^2} \end{array}$	b_{pair}		$b_{ m nucl}$ $-1 m cm^2$	
10	0.05	2.15	0.73	0.74	0.45	1.91
100	0.41	2.40	1.15	1.56	0.41	3.12
1000	2.42	2.58	1.47	2.10	0.44	4.01
10000	6.30	2.76	1.64	2.27	0.50	4.40

Especially at high energy, however, fluctuations are important and an accurate calculation requires a simulation that accounts for stochastic energy-loss processes [21].

Fig. 20.5 shows the vertical muon intensity versus depth. In constructing this "depth-intensity curve," each group has taken account of the angular distribution of the muons in the atmosphere, the map of the overburden at each detector, and the properties of the local medium in connecting measurements at various slant depths and zenith angles to the vertical intensity. Use of data from a range of angles allows a fixed detector to cover a wide range of depths. The flat portion of the curve is due to muons produced locally by charged-current interactions of ν_{μ} .

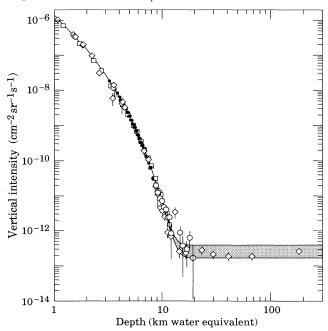


Figure 20.5: Vertical muon intensity vs. depth (1 km.w.e. = 10⁵ g cm⁻² of standard rock). The experimental data are from: ◊: the compilations of Crouch [29], □: Baksan [30], ○: LVD [31], ●: MACRO [32], ■: Frejus [33]. The shaded area at large depths represents neutrino induced muons of energy above 2 GeV. The upper line is for horizontal neutrino-induced muons, the lower one for vertically upward muons.

The energy spectrum of atmospheric muons underground can be estimated from Eq. (20.7). The muon energy spectrum at slant depth X is

$$\frac{dN_{\mu}(X)}{dE_{\mu}} = \frac{dN_{\mu}}{dE_{\mu,0}} e^{bX} , \qquad (20.8)$$

where $E_{\mu,0}$ is the solution of Eq. (20.7). For $X \ll b^{-1} \approx 2.5$ km water equivalent, $E_{\mu,0} \approx E_{\mu}(X) + aX$. Thus at shallow depths the differential muon energy spectrum is approximately constant for

 $E_{\mu} < aX$ and steepens to reflect the surface muon spectrum for $E_{\mu} > aX$. For $X \gg b^{-1}$ the differential spectrum underground is again constant for small muon energies but steepens to reflect the surface muon spectrum for $E_{\mu} > \epsilon \approx 0.5$ TeV. In this regime the shape is independent of depth although the intensity decreases exponentially with depth.

20.4.2. Neutrinos: Because neutrinos have small interaction cross sections, measurements of atmospheric neutrinos require a deep detector to avoid backgrounds. There are two types of measurements: contained (or semi-contained) events, in which the vertex is determined to originate inside the detector, and neutrino-induced muons. The latter are muons that enter the detector from zenith angles so large (e.g., nearly horizontal or upward) that they cannot be muons produced in the atmosphere. In neither case is the neutrino flux measured directly. What is measured is a convolution of the neutrino flux and cross section with the properties of the detector (which includes the surrounding medium in the case of entering muons).

Contained events reflect the neutrinos in the GeV region where the product of increasing cross section and decreasing flux is maximum. In this energy region the neutrino flux and its angular distribution depend on the geomagnetic location of the detector and to a lesser extent on the phase of the solar cycle. Naively, we expect $\nu_{\mu}/\nu_{e}=2$ from counting the neutrinos of the two flavors coming from the chain of pion and muon decay. This ratio is only slightly modified by the details of the decay kinematics. Experimental measurements have also to account for the ratio of $\overline{\nu}/\nu$, which have cross sections different by a factor of 3 in this energy range. In addition, detectors will generally have different efficiencies for detecting muon neutrinos and electron neutrinos. Even after correcting for these and other effects, some detectors [22,23] infer a ν_{μ}/ν_{e} ratio lower by $\approx 4\sigma$ from the expected value. (See Tables in the Particle Listings of this Review.) This effect is sometimes cited as possible evidence of neutrino oscillations and is a subject of current investigation. Figure 20.6 shows the data of Refs. 22,23 for the distributions of visible energy in electron-like and muon-like charged-current events, which appear to be nearly equal in number. Corrections for detection efficiencies and backgrounds are insufficient to account for the difference from the expected value of

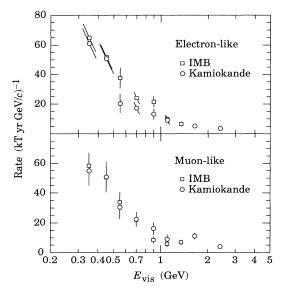


Figure 20.6: Contained neutrino interactions from IMB [23](\square) and Kamiokande [22].

Muons that enter the detector from outside after production in charged-current interactions of neutrinos naturally reflect a higher energy portion of the neutrino spectrum than contained events because the muon range increases with energy as well as the cross section. The relevant energy range is $\sim 10 < E_{\nu} < 1000$ GeV, depending somewhat

on angle. Like muons (see Eq. (20.5)), high energy neutrinos show a "secant theta" effect which causes the flux of horizontal neutrino induced muons to be approximately a factor two higher than the vertically upward flux. The upper and lower edges of the horizontal shaded region in Fig. 20.5 correspond to horizontal and vertical intensities of neutrino-induced muons. Table 20.3 gives the measured fluxes of neutrino induced muons.

Table 20.3: Measured fluxes $(10^{-13} \text{ cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1})$ of neutrino-induced muons as a function of the minimum muon energy E_{μ} .

$\overline{E_{\mu}} >$	1 GeV	1 GeV	1 GeV	2 GeV	$3~{ m GeV}$
Ref.	CWI [24]	Baksan [25]	MACRO [26]	IMB [27]	Kam [28]
F_{μ}	$2.17{\pm}0.21$	$2.77{\pm}0.17$	2.48 ± 0.27	$2.26{\pm}0.11$	$2.04{\pm}0.13$

20.5. Air showers

So far we have discussed inclusive or uncorrelated fluxes of various components of the cosmic radiation. An air shower is caused by a single cosmic ray with energy high enough for its cascade to be detectable at the ground. The shower has a hadronic core, which acts as a collimated source of electromagnetic subshowers, generated mostly from $\pi^0 \to \gamma \gamma$. The resulting electrons and positrons are the most numerous particles in the shower. The number of muons, produced by decays of charged mesons, is an order of magnitude lower.

Air showers spread over a large area on the ground, and arrays of detectors operated for long times are useful for studying cosmic rays with primary energy $E_0>100~{\rm TeV}$, where the low flux makes measurements with small detectors in balloons and satellites difficult.

Greisen [46] gives the following approximate expressions for the numbers and lateral distributions of particles in showers at ground level. The total number of muons N_{μ} with energies above 1 GeV is

$$N_{\mu}(> 1 \text{ GeV}) \approx 0.95 \times 10^5 \left(\frac{N_e}{10^6}\right)^{3/4} ,$$
 (20.9)

where N_e is the total number of charged particles in the shower (not just e^{\pm}). The number of muons per square meter, ρ_{μ} , as a function of the lateral distance r (in meters) from the center of the shower is

$$\rho_{\mu} = \frac{1.25 N_{\mu}}{2\pi \Gamma(1.25)} \left(\frac{1}{320}\right)^{1.25} r^{-0.75} \left(1 + \frac{r}{320}\right)^{-2.5} , \qquad (20.10)$$

where Γ is the gamma function. The number density of charged particles is

$$\rho_e = C_1(s, d, C_2) x^{(s-2)} (1+x)^{(s-4.5)} (1+C_2 x^d) . \tag{20.11}$$

Here s, d, and C_2 are parameters in terms of which the overall normalization constant $C_1(s, d, C_2)$ is given by

$$C_1(s, d, C_2) = \frac{N_e}{2\pi r_1^2} \left[B(s, 4.5 - 2s) + C_2 B(s + d, 4.5 - d - 2s) \right]^{-1},$$
(20.12)

where B(m,n) is the beta function. The values of the parameters depend on shower size (N_e) , depth in the atmosphere, identity of the primary nucleus, etc. For showers with $N_e\approx 10^6$ at sea level, Greisen uses s=1.25, d=1, and $C_2=0.088$. Finally, x is r/r_1 , where r_1 is the Molière radius, which depends on the density of the atmosphere and hence on the altitude at which showers are detected. At sea level $r_1\approx 78$ m. It increases with altitude.

The lateral spread of a shower is determined largely by Coulomb scattering of the many low-energy electrons and is characterized by

the Molière radius. The lateral spread of the muons (ρ_{μ}) is larger and depends on the transverse momenta of the muons at production as well as multiple scattering.

There are large fluctuations in development from shower to shower, even for showers of the same energy and primary mass—especially for small showers, which are usually well past maximum development when observed at the ground. Thus the shower size N_e and primary energy E_0 are only related in an average sense, and even this relation depends on depth in the atmosphere. One estimate of the relation is [35]

$$E_0 \sim 3.9 \times 10^6 \text{ GeV } (N_e/10^6)^{0.9}$$
 (20.13)

for vertical showers with $10^{14} < E < 10^{17}$ eV at 920 g cm⁻² (965 m above sea level). Because of fluctuations, N_e as a function of E_0 is not the inverse of Eq. (20.13). As E_0 increases the shower maximum (on average) moves down into the atmosphere and the relation between N_e and E_0 changes. At the maximum of shower development, there are approximately 2/3 particles per GeV of primary energy.

Detailed simulations and cross-calibrations between different types of detectors are necessary to establish the primary energy spectrum from air-shower experiments [35,36]. Figure 20.7 shows the "all-particle" spectrum. In establishing this spectrum, efforts have been made to minimize the dependence of the analysis on the primary composition. In the energy range above 10^{17} eV, the Fly's Eye technique [48] is particularly useful because it can establish the primary energy in a model-independent way by observing most of the longitudinal development of each shower, from which E_0 is obtained by integrating the energy deposition in the atmosphere.

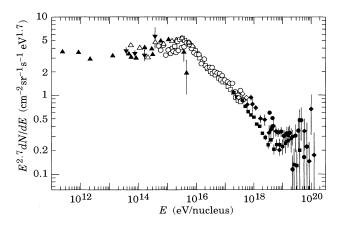


Figure 20.7: The all-particle spectrum: \blacktriangle [37], \blacktriangledown [38], \triangle [39], \Box [40], \bigcirc [35], \blacksquare [48], \spadesuit [42], \spadesuit [43].

In Fig. 20.7 the differential energy spectrum has been multiplied by $E^{2.7}$ in order to display the features of the steep spectrum that are otherwise difficult to discern. The steepening that occurs between 10^{15} and 10^{16} eV is known as the *knee* of the spectrum. The feature between 10^{18} and 10^{19} eV is called the *ankle* of the spectrum. Both these features are the subject of intense interest at present [44].

The ankle has the classical characteristic shape [45] of a higher energy population of particles overtaking a lower energy population. A possible interpretation is that the higher energy population represents cosmic rays of extragalactic origin. If this is the case and if the cosmic rays are cosmological in origin, then there should be a cutoff around 5×10^{19} eV, resulting from interactions with the microwave background [46,47]. It is therefore of special interest that several events have been assigned energies above 10^{20} eV [48,49,50].

If the cosmic ray spectrum below 10^{18} eV is of galactic origin, the knee could reflect the fact that some (but not all) cosmic accelerators have reached their maximum energy. Some types of expanding supernova remnants, for example, are estimated not to be able to accelerate particles above energies in the range of 10^{15} eV total energy

per particle. Effects of propagation and confinement in the galaxy [51] also need to be considered.

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21. HIGH-ENERGY COLLIDER PARAMETERS: e^+e^- Colliders (I)

None of the colliders on this page are any longer working in elementary-particle physics. Quantities are, where appropriate, r.m.s. H and V indicate horizontal and vertical directions. Many of the numbers of course changed over the lifetimes of the colliders; only the end-of-service values are given here.

	SPEAR (SLAC)	DORIS (DESY)	PETRA (DESY)	PEP (SLAC)	TRISTAN (KEK)
Physics start date	1972	1973	1978	1980	1987
Physics end date	1990	1993	1986	1990	1995
Maximum beam energy (GeV)	4	5.6	23.4	15	32
Luminosity $(10^{30} \text{ cm}^{-2} \text{s}^{-1})$	10 at 3 GeV	33 at 5.3 GeV	24 at 17.5 GeV	60	40
Time between collisions (μs)	0.75	0.965	3.8	2.44	5
Crossing half angle (μ rad)	0	0	0	0	0
Energy spread (units 10 ⁻³)	1	1.2 at 5 GeV	1.1 at 17.5 GeV	1	2.3
Bunch length (cm)	$\sigma_z \approx 4$	$\sigma \sim 2$ at 5 GeV	$\sigma \sim 1.3$ at 17.5 GeV	$\sigma_z = 2$	1.5
Beam radius (10 ⁻⁶ m)	H: 700 V: 50	$\left. \begin{array}{c} H\colon 740 \\ V\colon \sim 30 \end{array} \right\} \begin{array}{c} {\rm at}\ 5 \\ {\rm GeV} \end{array}$	$ \begin{array}{c} H\colon 430 \\ V\colon \ 13 \end{array} \right\} \begin{array}{c} \text{at } 17.5 \\ \text{GeV} \end{array} $	H: 340 V: 14	H: 280 V: 8
Free space at interaction point (m)	±2.5	±1.2	±4.5	±3.7	±2.51
Luminosity lifetime (hr)	≈ 3	1.0-1.5	4 at 17.5 GeV	4	2
Filling time (min)	15	≈ 15	20	15	40
Acceleration period (s)	≤ 100	_	_	≤ 100	300
Injection energy (GeV)	2.5	up to 5.6	7	15	8
Transverse emittance $(10^{-9}\pi \text{ rad-m})$	$H \approx 430$	$ \begin{array}{c} H: 500 \\ V: 5-50 \end{array} \right\} \begin{array}{c} \text{at 5} \\ \text{GeV} \end{array} $	H: 140 V: 2	$H \approx 120$	H: 80 at 29 GeV
β^* , amplitude function at interaction point (m)	H: 1.2 V: 0.08	H: 0.59/12.3 V: 0.04/0.79	H: 1.3 V: 0.08	H: 1.0 V: 0.05	H: 1.0 V: 0.04
Beam-beam tune shift per crossing (units 10 ⁻⁴)	300	≤ 280 (space charge limit at 5.3 GeV)	$ \begin{array}{c} H\colon 160 \\ V\colon 400 \end{array} \right\} \begin{array}{c} \text{at } 17.5 \\ \text{GeV} \end{array} $	550	340
RF frequency (MHz)	358	500	500	352	508.5808
Particles per bunch (units 10 ¹⁰)	15	27	26	35	22
Bunches per ring per species	1	1	2	3	2
Average beam current per species (mA)	30	45 at 5.3 GeV	11 at 17.5 GeV	21	7
Circumference (km)	0.234	0.2892	2.304	2.2	3.02
Interaction regions	2	2	4	1	4
Utility insertions	18	10	. 4	5	8
Magnetic length of dipole (m)	2.35	3.2/1.1	5.38	5.4	5.86
Length of standard cell (m)	11.4	13.2	14.4	14.35	16.1
Phase advance per cell (deg)	H: 79 V: 90	H: 140 V: 50	H: 47 V: 40	H: 56 V: 33	60
Dipoles in ring	36	H: 28 V: 6	224	192	264 +8 weak
Quadrupoles in ring	46	68	360	248	392
Peak magnetic field (T)	1.1	1.5	0.4 at 23 GeV	0.36	0.41 at 30 Ge

HIGH-ENERGY COLLIDER PARAMETERS: e^+e^- Colliders (II)

The numbers here were received from representatives of the colliders in 1996. Many of the numbers of course change with time, and only the latest values (or estimates) are given here; those in brackets are for coming upgrades. Quantities are, where appropriate, r.m.s. H and V indicate horizontal and vertical directions.

	VEPP-2M [round beams] (Novosibirsk)	DAΦNE (Frascati)	ϕ FACTORY (Novosibirsk)	BEPC (China)	VEPP-4M (Novosibirsk)
Physics start date	1974 [1997]	1997	?	1989	1994
Maximum beam energy (GeV)	0.7 [0.55]	0.510 (0.75 max.)	0.55	2.2	6
$\overline{\text{Luminosity } (10^{30} \text{ cm}^{-2} \text{s}^{-1})}$	5 [100]	135(→540)	2500	10	50
Time between collisions (μs)	0.03	0.0108(→0.0027)	0.007	0.8	0.6
Crossing angle (μ rad)	0	$\pm (1.0 \text{ to } 1.5) \times 10^4$	0 .	0	0
Energy spread (units 10 ⁻³)	0.6 [0.35]	0.40	0.5	0.58	1
Bunch length (cm)	. 3	3.0	1	≈ 5	5
Beam radius (10 ⁻⁶ m)	H/V: 400/10 [35 (round)]	H: 2100 V: 21	35 (beams are round)	H: 926 V: 61	H: 1000 V: 30
Free space at interaction point (m)	±1	±0.46 (±157 mrad cone)	±2	±2.5	±2
Luminosity lifetime (hr)	continuous	2	continuous	7–12	2
Filling time (min)	continuous	3 (topping up)	continuous	30	15
Acceleration period (s)		_	-	120	150
Injection energy (GeV)	$0.2 - 0.7 \\ [0.2 - 0.55]$	0.510		1.3	1.8
Transverse emittance $(10^{-9}\pi \text{ rad-m})$	H/V: 400/4 [150]	H: 1000 V: 10	125	H: 660 V: 43	H: 400 V: 20
β*, amplitude function at interaction point (m)	H/V: 0.48/0.04 [0.05]	H: 4.5 V: 0.045	0.01	H: 1.3 V: 0.085	H: 0.75 V: 0.05
Beam-beam tune shift per crossing (units 10 ⁻⁴)	H/V: 200/500 [1000]	400	1000	420	500
RF frequency (MHz)	200	368.25	700	199.53	180
Particles per bunch (units 10 ¹⁰)	4 [6.7]	8.9	5	20 at 2 GeV	15
Bunches per ring per species	1	30(→120)	11	1	2
Average beam current per species (mA)	100 [160]	1313(→5250)	550	40 at 2 GeV	80
Circumference or length (km)	0.018	0.0977	0.047	0.2404	0.366
Interaction regions	2	2	1	2	1
Utility insertions	1	2×2	1	4	1
Magnetic length of dipole (m)	1	e^+ : 1.21/0.99 e^- : 1.21/0.99	0.8	1.6	2
Length of standard cell (m)	4.5 [9.0]	_		6.6	7.2
Phase advance per cell (deg)	280 [560]			≈ 60	65
Dipoles in ring	8	e^+ : 8(+4 wigglers) e^- : 8(+4 wigglers)	22	40 + 4 weak	78
Quadrupoles in ring	20 [12]	e^+/e^- : 53/53	22	68	150
Peak magnetic field (T)	1.8 [1.5]	$1.2(\rightarrow 1.76)$ dipoles 1.8 wigglers	1.8	0.9028	0.6

HIGH-ENERGY COLLIDER PARAMETERS: e^+e^- Colliders (III)

The numbers here were received from representatives of the colliders in 1996. Many of the numbers of course change with time, and only the latest values (or estimates) are given here. Quantities are, where appropriate, r.m.s. H and V indicate horizontal and vertical directions; s.c. indicates superconducting.

	$egin{array}{c} ext{CESR} \ ext{(Cornell)} \end{array}$	KEKB (KEK)	PEP-II (SLAC)	SLC (SLAC)	$_{(\mathrm{CERN})}^{\mathrm{LEP}}$
Physics start date	1979	1999	1999	1989	1989
Maximum beam energy (GeV)	6	$e^- \times e^+ : 8 \times 3.5$	$e^- \times e^+ : 9 \times 3.1$ (6.5 GeV c.m. max)	50	87 in 1996 (97=max. foreseen)
Luminosity (10^{30} cm $^{-2}$ s $^{-1}$)	330 at 5.3 GeV (600 in mid-1996)	10000	3000	0.8	$24 \mathrm{\ at}\ Z^0$ $34 \mathrm{\ at}\ 68 \mathrm{\ GeV}$
Time between collisions (μs)	0.028 to 0.22	0.002	0.0042	8300	22
Crossing angle (μ rad)	±2000	±11,000	0	0	0
Energy spread (units 10 ⁻³)	0.6 at 5.3 GeV	0.7	e^{-}/e^{+} : 0.61/0.77	1.2	1.0
Bunch length (cm)	1.8	0.4	e^-/e^+ : 1.1/1.0	0.08	1.8
Beam radius (10 ⁻⁶ m)	H: 500 V: 11	H: 77 V: 1.9	H: 155 V: 6.2	H: 2.1 V: 0.6	H: 200 V: 8
Free space at interaction point (m)	$\pm 2.2~(\pm 0.6$ to REC quads)	± 0.4 , $(+300/-500)$ mrad cone	±0.2, ±300 mrad cone	±2.8	±3.5
Luminosity lifetime (hr)	3-4	2	2.5		20
Filling time (min)	10 (topping up)	8 (topping up)	3 (topping up)		90
Acceleration period (s)		-		-	420
Injection energy (GeV)	6	$e^-/e^+: 8/3.5$	2.5–12	45.64	22
Transverse emittance $(10^{-9}\pi \text{ rad-m})$	H: 240 V: 8	H: 18 V: 0.36	e ⁻ : 48 (H), 1.9 (V) e ⁺ : 64 (H), 2.6 (V)	H: 0.6 V: 0.1	$H: 12 \rightarrow 4$ $V: 0.5 \rightarrow 2$
β^* , amplitude function at interaction point (m)	H: 1.0 V: 0.018	H: 0.33 V: 0.01	e^- : 0.50 (H), 0.02 (V) e^+ : 0.375 (H), 0.015 (V)	H: 0.01 V: 0.002	H: 2.5 V: 0.05
Beam-beam tune shift per crossing (units 10 ⁻⁴)	420	H: 390 V: 520	300	_	490
RF frequency (MHz)	500	508.887	476.		352.2
Particles per bunch (units 10 ¹⁰)	11	1.3/3.2	e^{-}/e^{+} : 2.7/5.9	3.5	20 in collision 60 in single beam
Bunches per ring per species	9 trains of 2 bunches (of 3 bunches in mid-1996)	5120	1658	1	1995: 4 trains of 3 1996+: 4 trains of 2
Average beam current per species (mA)	120 (300 in mid-1996)	e^-/e^+ : 1100/2600	e^{-}/e^{+} : 990/2140	0.0007	4
Beam polarization (%)		_		e-: 80	55
Circumference or length (km)	0.768	3.016	2.2	1.45 +1.47	26.66
Interaction regions	1	1	1 (2 possible)	1	4
Utility insertions	3	3	5		4
Magnetic length of dipole (m)	1.6-6.6	$e^-/e^+: 5.86/0.915$	e^-/e^+ : 5.4/0.45	2.5	11.66/pair
Length of standard cell (m)	16	$e^-/e^+:75.7/76.1$	15.2	5.2	79
Phase advance per cell (deg)	45–90 (no standard cell)	450	e^-/e^+ : 60/90	108	108/60
Dipoles in ring	86	$e^-/e^+: 116/112$	e^{-}/e^{+} : 192/192	460+440	3280+24 inj. + 64 weak
Quadrupoles in ring	104	$e^-/e^+:452/452$	e^-/e^+ : 290/326		520+288 + 8 s.c.
Peak magnetic field (T)	$ \begin{array}{c} 0.3 \; \mathrm{normal} \\ 0.8 \; \mathrm{high} \; \mathrm{field} \end{array} \right\} \; \begin{array}{c} \mathrm{at} \; 8 \\ \mathrm{GeV} \end{array} $	$e^-/e^+: 0.25/0.72$	e^{-}/e^{+} : 0.18/0.75	0.597	0.135

HIGH-ENERGY COLLIDER PARAMETERS: $ep, \overline{p}p$, and pp Colliders

The numbers here were received from representatives of the colliders in 1996. Many of the numbers of course change with time, and only the latest values (or estimates) are given here. Quantities are, where appropriate, r.m.s. H, V, and, s.c. indicate horizontal and vertical directions, and superconducting. The SSC is kept for purposes of comparison.

	TIED A		mpy//mp.ov	T .		aaa
	HERA (DESY)	$Sp\overline{p}S$ (CERN)	TEVATRON (Fermilab)		HC ERN)	SSC (USA)
Physics start date	1992	1981	1987	2	004	Terminated
Physics end date	_	1990	_			
Particles collided	ep	$p\overline{p}$	$p\overline{p}$	pp	Pb Pb	pp
Maximum beam energy (TeV)	e: 0.030 p: 0.82	0.315 (0.45 in pulsed mode)	0.9-1.0	7.0	2.76 TeV/u	20
Luminosity $(10^{30} \text{ cm}^{-2} \text{s}^{-1})$	16	6	25 (1995) 200 (2000)	1.0×10^{4}	0.002	1000
Time between collisions (μs)	0.096	3.8	3.5	0.025	0.125	0.016678
Crossing angle (μ rad)	0	0	0	200	≤ 100	100 to 200 (135 nominal)
Energy spread (units 10 ⁻³)	e: 0.91 p: 0.2	0.35	0.15	0.1	0.1	0.055
Bunch length (cm)	e: 0.83 p: 8.5	20	50	7.5	7.5	6.0
Beam radius (10 ⁻⁶ m)	e: 280(H), 50(V) p: 265(H), 50(V)	p: 73(H), 36(V) $\bar{p}: 55(H), 27(V)$	36	16	15	4.8
Free space at interaction point (m)	±5.5	16	±6.5	38	38	±20
Luminosity lifetime (hr)	10	15	7-30	10	6.7	~24
Filling time (min)	e: 30 p: 120	0.5	120	6	20	72
Acceleration period (s)	600	10	86	1	200	1500
Injection energy (TeV)	e: 0.012 p: 0.040	0.026	0.15	0.450	177.4 GeV/u	2
Transverse emittance $(10^{-9}\pi \text{ rad-m})$	e: 39(H), 2(V) p: 7(H), 7(V)	p: 9 p : 5	p: 4 \bar{p} : 2.2	0.5	0.5	0.047
β*, amplitude function at interaction point (m)	e: 2(H), 0.9(V) p: 7(H), 0.7(V)	0.6 (H) 0.15 (V)	0.35	0.5	0.5	0.5
Beam-beam tune shift per crossing (units 10 ⁻⁴)	e: 190(H), 210(V) p: 12(H), 9(V)	50	p: 40 p̄: 75	34		8 head on 13 long range
RF frequency (MHz)	e: 499.7 p: 208.2/52.05	100+200	53	400.8	400.8	359.75
Particles per bunch (units 10 ¹⁰)	e: 3.65 p: 10	p: 15 \bar{p} : 8	p: 25 p̄: 7.5	10.5	0.0094	0.8
Bunches per ring per species	180	6	6	2835	608	17,424
Average beam current per species (mA)	e: 58 p: 158	p: 6 p : 3	p: 12.5 p̄: 3.7	536	7.8	71
Circumference (km)	6.336	6.911	6.28	26	.659	87.12
Interaction regions	ep: 2 e, p : 1 each, internal fixed target	2	$2 \text{ high } \mathscr{L}$	2 high £ +1	1	4
Utility insertions	4		4		4	2
Magnetic length of dipole (m)	e: 9.185 p: 8.82	6.26	6.12	1	4.2	Mostly 14.928
Length of standard cell (m)	e: 23.5 p: 47	64	59.5	10	6.92	180
Phase advance per cell (deg)	e: 60 p: 90	90	67.8		90	90
Dipoles in ring	e: 396 p: 416	744	774		232 dipoles	$\begin{array}{c} H \colon 8336 \\ V \colon 88 \end{array}$ in 2 rings
Quadrupoles in ring	e: 580 p: 280	232	216		ocussing 5 skew	2084 } 2 rings
Magnet type	e: C-shaped p: s.c., collared, cold iron	H type with bent-up coil ends	s.c. $\cos \theta$ warm iron	2	s.c. in 1 l iron	s.c. $\cos \theta$ cold iron
Peak magnetic field (T)	e: 0.274 p: 4.65	1.4 (2 in pulsed mode)	4.4		8.4	6.790
\overline{p} source accum. rate (hr ⁻¹)		6×10^{10}	7×10 ¹⁰		-	
Max. no. \overline{p} in accum. ring		1.2×10^{12}	2×10^{12}		nonena .	

22. PASSAGE OF PARTICLES THROUGH MATTER

Revised May 1996.

22.1. Notation

Table 22.1: Summary of variables used in this section. The kinematic variables β and γ have their usual meanings.

	·	
Symbol	Definition	Units or Value
α	Fine structure constant	1/137.035 989 5(61)
M	Incident particle mass	${ m MeV}/c^2$
E	Incident particle energy γMc^2	MeV
T	Kinetic energy	MeV
$m_e c^2$	Electron mass $\times c^2$	$0.51099906(15)~{ m MeV}$
r_e	Classical electron radius	2.817 940 92(38) fm
	$e^2/4\pi\epsilon_0 m_e c^2$	
N_A	Avogadro's number	$6.0221367(36)\times10^{23}\mathrm{mol^{-1}}$
ze	Charge of incident particle	
Z	Atomic number of medium	
A	Atomic mass of medium	$g \text{ mol}^{-1}$
K/A	$4\pi N_A r_e^2 m_e c^2 / A$	$0.307075~{ m MeV~g^{-1}~cm^2}$
		for $A = 1 \text{ g mol}^{-1}$
I	Mean excitation energy	eV
δ	Density effect correction to ioni	
$\hbar\omega_p$	Plasma energy	$28.816\sqrt{\rho\langle Z/A\rangle} \text{ eV}^{(a)}$
	$\sqrt{4\pi N_e r_e^3} \ m_e c^2/lpha$	
w_j	Weight fraction of the j th elem	ent in a compound or mixture
n_{j}	\propto number of $j{\rm th}$ kind of atoms	in a compound or mixture
X_0	Radiation length	$\mathrm{g}^{-1}~\mathrm{cm}^2$
_	$4\alpha re^2 N_A/A$	$(716.408 \text{ g cm}^{-2})^{-1}$
		for $A = 1 \text{ g mol}^{-1}$
E_c	Critical energy	MeV
E_s	Scale energy $\sqrt{4\pi/\alpha} \ m_e c^2$	$21.2052~\mathrm{MeV}$
R_M	Molière radius	$\mathrm{MeV}~\mathrm{g}^{-1}~\mathrm{cm}^2$

⁽a) For ρ in g cm⁻³.

$\textbf{22.2.} \quad \textbf{Ionization energy loss by heavy particles} \ \textbf{\scriptsize{[1-5]}}$

Moderately relativistic charged particles other than electrons lose energy in matter primarily by ionization. If the incident particle velocity βc is larger than that of orbital electrons ($\sim Z\alpha c$) and small enough that radiative effects do not dominate (for example, pion energy smaller than 100–200 GeV in iron), then the mean rate of energy loss (or stopping power) is given by the Bethe-Bloch equation,

$$-\frac{dE}{dx} = Kz^{2} \frac{Z}{A} \frac{1}{\beta^{2}} \left[\frac{1}{2} \ln \frac{2m_{e}c^{2}\beta^{2}\gamma^{2}T_{\text{max}}}{I^{2}} - \beta^{2} - \frac{\delta}{2} \right] . \tag{22.1}$$

Here $T_{\rm max}$ is the maximum kinetic energy which can be imparted to a free electron in a single collision, and the other variables are defined in Table 22.1. The units are chosen so that dx is measured in mass per unit area, e.g., in g cm⁻². The function as computed for pions on copper is shown by the solid curve in Fig. 22.1, and for pions on other materials in Fig. 22.2. A minor dependence on M at the highest energies is introduced through $T_{\rm max}$, but for all practical purposes in high-energy physics dE/dx in a given material is a function only of β . Except in hydrogen, particles of the same velocity have very similar rates of energy loss in different materials; there is a slow decrease in the rate of energy loss with increasing Z. The qualitative difference in stopping power behavior at high energies between a gas (He) and the other materials shown in Fig. 22.2 is due to the density effect correction, δ , discussed below. The stopping power functions are characterized by broad minima whose position drops from $\beta\gamma=3.5$ to 3.0 as Z goes from 7 to 100.

In practical cases, most relativistic particles (e.g., cosmic-ray muons) have energy loss rates close to the minimum, and are said to be minimum ionizing particles, or mip's.

Eq. (22.1) may be integrated to find the total range R for a particle which loses energy only through ionization. Since dE/dx depends only on β , R/M is a function of E/M or pc/M. In practice, range is a useful concept only for low-energy hadrons ($R \lesssim \lambda_I$, where λ_I is the nuclear interaction length), and for muons below a few hundred GeV (above which radiative effects dominate). R/M as a function of $\beta \gamma = pc/M$ is shown for a variety of materials in Fig. 22.3.

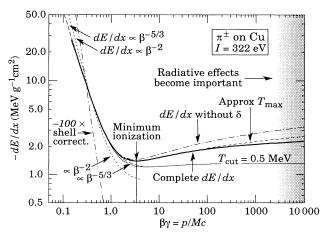


Figure 22.1: Energy loss rate in copper. The function without the density effect correction is also shown, as is the shell correction and two low-energy approximations.

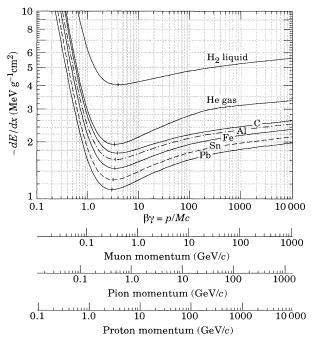


Figure 22.2: Energy loss rate in liquid (bubble chamber) hydrogen, gaseous helium, carbon, aluminum, tin, and lead.

For a particle with mass M and momentum $M\beta\gamma c$, T_{\max} is given by

$$T_{\text{max}} = \frac{2m_e c^2 \,\beta^2 \gamma^2}{1 + 2\gamma m_e / M + (m_e / M)^2} \ . \tag{22.2}$$

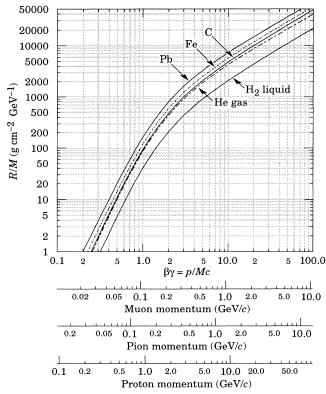


Figure 22.3: Range of heavy charged particles in liquid (bubble chamber) hydrogen, helium gas, carbon, iron, and lead. For example: For a K^+ whose momentum is 700 MeV/c, $\beta \gamma = 1.42$. For lead we read $R/M \approx 396$, and so the range is 195 g cm⁻².

It is usual [1,2] to make the "low-energy" approximation

 $T_{\rm max}=2m_ec^2\,\beta^2\gamma^2$, valid for $2\gamma m_e/M\ll 1$; this, in fact, is done implicitly in many standard references. For pion in copper, the error thus introduced into dE/dx is greater than 6% at 100 GeV. The correct expression should be used.

At energies of order 100 GeV, the maximum 4-momentum transfer to the electron can exceed 1 GeV/c, where structure effects significantly modify the cross sections. This problem has been investigated by J.D. Jackson [6], who concluded that for hadrons (but not for large nuclei) corrections to dE/dx are negligible below energies where radiative effects dominate. While the cross section for rare hard collisions is modified, the average stopping power, dominated by many softer collisions, is almost unchanged.

The mean excitation energy I is $(10\pm 1~{\rm eV})\times Z$ for elements heavier than oxygen. The values adopted by the ICRU for the chemical elements [7] are now in wide use; these are shown in Fig. 22.4. Machine-readable versions can also be found [8]. Given the availability of these constants and their variation with atomic structure, there seems little point to depending upon approximate formulae, as was done in the past.

A shell correction is often included in the square brackets of Eq. (22.1) [3,5,7], to correct for atomic binding having been neglected in calculating some of the contributions to Eq. (22.1). We show the Barkas form [3] in Fig. 22.1. For copper it contributes about 1% at $\beta\gamma=0.3$ (kinetic energy 6 MeV for a pion), and the correction decreases very rapidly with energy. While it is negligible for high-energy physics applications, this and other low-energy corrections must be taken into account at lower energies, such as those encountered in medical physics.

As the particle energy increases, its electric field flattens and extends, so that the distant-collision contribution to Eq. (22.1) increases as $\ln \beta \gamma$. However, real media become polarized, limiting the field extension and effectively truncating this part of the logarithmic

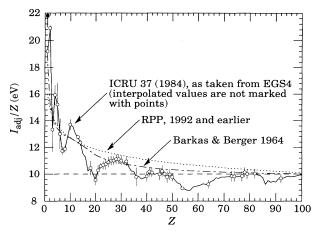


Figure 22.4: Excitation energies (divided by Z) as adopted by the ICRU [7]. Those based on measurement are shown by points with error flags; the interpolated values are simply joined. The solid point is for liquid H_2 ; the open point at 19.2 is for H_2 gas. Also shown are curves based on two approximate formulae.

rise [4,9-13]. At very high energies,

$$\delta/2 \to \ln(\hbar\omega_p/I) + \ln\beta\gamma - 1/2$$
, (22.3)

where $\delta/2$ is the density effect correction introduced in Eq. (22.1) and $\hbar\omega_p$ is the plasma energy defined in Table 22.1. A comparison with Eq. (22.1) shows that |dE/dx| then grows as $\ln\beta\gamma$ rather than $\ln\beta^2\gamma^2$, and that the mean excitation energy I is replaced by the plasma energy $\hbar\omega_p$. The stopping power as calculated with and without the density effect correction is shown in Fig. 22.1. Since the plasma frequency scales as the square root of the electron density, the correction is much larger for a liquid or solid than for a gas, as is illustrated by the examples in Fig. 22.2.

The remaining relativistic rise can be attributed to large energy transfers to a few electrons. If these escape or are otherwise accounted for separately, the energy deposited in an absorbing layer (in contrast to the energy lost by the particle) approaches a constant value, the Fermi plateau (see Sec. 22.3 below). The curve in Fig. 22.1 labeled " $T_{\rm cut}=0.5$ MeV" illustrates this behavior. At extreme energies (e.g., 400 GeV for muons or pions in iron), radiative effects become important. These are especially relevant for high-energy muons, as discussed in Sec. 22.9.

For particles moving more slowly than atomic electrons, the above discussion is inapplicable. At velocities $\alpha z \gtrsim \beta \gtrsim 10^{-3}$ or slightly lower, the total energy-loss rate is proportional to β , and non-ionizing nuclear recoil energy loss contributes substantially to the total [14]. For protons in silicon, $|dE/dx| = 61.2\,\beta$ GeV cm² g⁻¹ for $\beta < 0.005$; the peak occurs at $\beta = 0.0126$, where |dE/dx| = 522 MeV cm² g⁻¹. In neutron-scattering experiments, light output in scintillator has been observed for recoil protons with energies as low as 30 eV [15].

It is often stated that for $\beta \gtrsim z/137$, |dE/dx| falls as β^{-2} before reaching the broad minimum at $\beta\gamma \approx 3.0$ –3.5. In fact, the slope is nowhere this great, and $|dE/dx| \propto \beta^{-5/3}$ provides a very good approximation to the actual function out to $\beta\gamma > 1$. This behavior is shown in Fig. 22.1, along with the traditional β^{-2} proportionality.

The quantity $(dE/dx)\delta x$ is the mean energy loss via interaction with electrons in a layer of the medium with thickness δx . For finite δx , there are fluctuations in the actual energy loss. The distribution is skewed toward high values (the Landau tail) [1,16]. Only for a thick layer $[(dE/dx)\delta x\gg T_{\rm max}]$ is the distribution nearly Gaussian. The large fluctuations in the energy loss are due to the small number of collisions involving large energy transfers. The fluctuations are smaller for the so-called restricted energy loss rate, as discussed in Sec. 22.3 below.

A mixture or compound can be thought of as made up of thin layers of pure elements in the right proportion (Bragg additivity). In this case,

$$\frac{dE}{dx} = \sum w_j \left. \frac{dE}{dx} \right|_j \,, \tag{22.4}$$

where $dE/dx|_j$ is the mean rate of energy loss (in MeV g cm⁻²) in the jth element. Eq. (22.1) can be inserted into Eq. (22.4) to find expressions for $\langle Z/A \rangle$, $\langle I \rangle$, and $\langle \delta \rangle$; for example, $\langle Z/A \rangle = \sum w_j Z_j/A_j = \sum n_j Z_j/\sum n_j A_j$. However, $\langle I \rangle$ as defined this way is an underestimate, because in a compound electrons are more tightly bound than in the free elements, and $\langle \delta \rangle$ as calculated this way has little relevance, because it is the electron density which matters. If possible, one uses the tables given in Refs. 13 and 12, which include effective excitation energies and interpolation coefficients for calculating the density effect correction for the chemical elements and nearly 200 mixtures and compounds. If a compound or mixture is not found, then one uses the recipe for δ given in Ref. 10 (or Ref. 8), and calculates $\langle I \rangle$ according to the discussion in Ref. 11. (Note the "13%" rule!)

Ionization losses by electrons and positrons [12] are not discussed here. Above the critical energy, which is a few tens of MeV in most materials, bremsstrahlung is the dominant source of energy loss. This important case is discussed below. The contributions of various electron energy-loss processes in lead are shown in Fig. 23.4.

22.3. Restricted energy loss rates for relativistic ionizing particles

Fluctuations in energy loss are due mainly to the production of a few high-energy knock-on electrons. Practical detectors often measure the energy deposited, not the energy lost. When energy is carried off by energetic knock-on electrons, it is more appropriate to consider the mean energy loss excluding energy transfers greater than some cutoff $T_{\rm cut}$. The restricted energy loss rate is

$$-\frac{dE}{dx}\Big|_{T < T_{\text{cut}}} = Kz^2 \frac{Z}{A} \frac{1}{\beta^2} \left[\frac{1}{2} \ln \frac{2m_e c^2 \beta^2 \gamma^2 T_{\text{upper}}}{I^2} - \frac{\beta^2}{2} \left(1 + \frac{T_{\text{upper}}}{T_{\text{max}}} \right) - \frac{\delta}{2} \right]$$
(22.5)

where $T_{\rm upper} = {\rm MIN}(T_{\rm cut}, T_{\rm max})$. This form agrees with the equation given in previous editions of this Review [17] for $T_{\rm cut} \ll T_{\rm max}$ but smoothly joins the normal Bethe-Bloch function (Eq. (22.1)) for $T_{\rm cut} > T_{\rm max}$.

22.4. Energetic knock-on electrons (δ rays)

The distribution of secondary electrons with kinetic energies $T\gg I$ is given by [1]

$$\frac{d^2N}{dTdx} = \frac{1}{2} K z^2 \frac{Z}{A} \frac{1}{\beta^2} \frac{F(T)}{T^2}$$
 (22.6)

for $I \ll T \leq T_{\rm max}$, where $T_{\rm max}$ is given by Eq. (22.2). The factor F is spin-dependent, but is about unity for $T \ll T_{\rm max}$. For spin-0 particles $F(T) = (1-\beta^2 T/T_{\rm max})$; forms for spins 1/2 and 1 are also given by Rossi [1]. When Eq. (22.6) is integrated from $T_{\rm cut}$ to $T_{\rm max}$,one obtains the difference between Eq. (22.1) and Eq. (22.5). For incident electrons, the indistinguishability of projectile and target means that the range of T extends only to half the kinetic energy of the incident particle. Additional formulae are given in Ref. 18. Equation (22.6) is inaccurate for T close to I: for $2I \lesssim T \lesssim 10I$, the $1/T^2$ dependence above becomes approximately $T^{-\eta}$, with $3 \lesssim \eta \lesssim 5$ [19].

22.5. Ionization yields

Physicists frequently relate total energy loss to the number of ion pairs produced near the particle's track. This relation becomes complicated for relativistic particles due to the wandering of energetic knock-on electrons whose ranges exceed the dimensions of the fiducial volume. For a qualitative appraisal of the nonlocality of energy deposition in various media by such modestly energetic knock-on electrons, see Ref. 20. The mean local energy dissipation per local ion pair produced, W, while essentially constant for relativistic particles, increases at slow particle speeds [21]. For gases, W can be surprisingly sensitive to trace amounts of various contaminants [21]. Furthermore, ionization yields in practical cases may be greatly influenced by such factors as subsequent recombination [22].

22.6. Multiple scattering through small angles

A charged particle traversing a medium is deflected by many small-angle scatters. Most of this deflection is due to Coulomb scattering from nuclei, and hence the effect is called multiple Coulomb scattering. (However, for hadronic projectiles, the strong interactions also contribute to multiple scattering.) The Coulomb scattering distribution is well represented by the theory of Molière [23]. It is roughly Gaussian for small deflection angles, but at larger angles (greater than a few θ_0 , defined below) it behaves like Rutherford scattering, having larger tails than does a Gaussian distribution.

If we define

$$\theta_0 = \theta_{\text{plane}}^{\text{rms}} = \frac{1}{\sqrt{2}} \theta_{\text{space}}^{\text{rms}}$$
 (22.7)

then it is sufficient for many applications to use a Gaussian approximation for the central 98% of the projected angular distribution, with a width given by [24,25]

$$\theta_0 = \frac{13.6 \text{ MeV}}{\beta cp} z \sqrt{x/X_0} \left[1 + 0.038 \ln(x/X_0) \right]. \tag{22.8}$$

Here p, βc , and z are the momentum, velocity, and charge number of the incident particle, and x/X_0 is the thickness of the scattering medium in radiation lengths (defined below). This value of θ_0 is from a fit to Molière distribution [23] for singly charged particles with $\beta=1$ for all Z, and is accurate to 11% or better for $10^{-3} < x/X_0 < 100$.

Eq. (22.8) describes scattering from a single material, while the usual problem involves the multiple scattering of a particle traversing many different layers and mixtures. Since it is from a fit to a Molière distribution, it is incorrect to add the individual θ_0 contributions in quadrature; the result is systematically too small. It is much more accurate to apply Eq. (22.8) once, after finding x and X_0 for the combined scatterer.

Lynch and Dahl have extended this phenomenological approach, fitting Gaussian distributions to a variable fraction of the Molière distribution for arbitrary scatterers [25], and achieve accuracies of 2% or better.

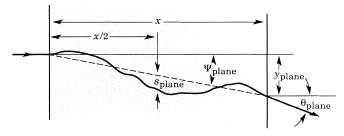


Figure 22.5: Quantities used to describe multiple Coulomb scattering. The particle is incident in the plane of the figure.

The nonprojected (space) and projected (plane) angular distributions are given approximately by [23]

$$\frac{1}{2\pi\,\theta_0^2}\,\exp\left(-\frac{\theta_{\rm space}^2}{2\theta_0^2}\right)d\Omega\;,\tag{22.9}$$

$$\frac{1}{\sqrt{2\pi}\,\theta_0} \exp\left(-\frac{\theta_{\text{plane}}^2}{2\theta_0^2}\right) d\theta_{\text{plane}} \,, \tag{22.10}$$

where θ is the deflection angle. In this approximation, $\theta_{\rm space}^2 \approx (\theta_{\rm plane,x}^2 + \theta_{\rm plane,y}^2)$, where the x and y axes are orthogonal to the direction of motion, and $d\Omega \approx d\theta_{\rm plane,x} d\theta_{\rm plane,y}$. Deflections into $\theta_{\rm plane,x}$ and $\theta_{\rm plane,y}$ are independent and identically distributed.

Figure 22.5 shows these and other quantities sometimes used to describe multiple Coulomb scattering. They are

$$\psi_{\text{plane}}^{\text{rms}} = \frac{1}{\sqrt{3}} \theta_{\text{plane}}^{\text{rms}} = \frac{1}{\sqrt{3}} \theta_0 , \qquad (22.11)$$

$$y_{\text{plane}}^{\text{rms}} = \frac{1}{\sqrt{3}} x \theta_{\text{plane}}^{\text{rms}} = \frac{1}{\sqrt{3}} x \theta_0$$
, (22.12)

$$s_{\text{plane}}^{\text{rms}} = \frac{1}{4\sqrt{3}} x \theta_{\text{plane}}^{\text{rms}} = \frac{1}{4\sqrt{3}} x \theta_0 . \qquad (22.13)$$

All the quantitative estimates in this section apply only in the limit of small $\theta_{\rm plane}^{\rm rms}$ and in the absence of large-angle scatters. The random variables $s,~\psi,~y,$ and θ in a given plane are distributed in a correlated fashion (see Sec. 27.1 of this Review for the definition of the correlation coefficient). Obviously, $y\approx x\psi$. In addition, y and θ have the correlation coefficient $\rho_{y\theta}=\sqrt{3}/2\approx 0.87.$ For Monte Carlo generation of a joint $(y_{\rm plane},\theta_{\rm plane})$ distribution, or for other calculations, it may be most convenient to work with independent Gaussian random variables (z_1,z_2) with mean zero and variance one, and then set

$$y_{\text{plane}} = z_1 x \,\theta_0 (1 - \rho_{y\theta}^2)^{1/2} / \sqrt{3} + z_2 \,\rho_{y\theta} x \,\theta_0 / \sqrt{3}$$
$$= z_1 x \,\theta_0 / \sqrt{12} + z_2 x \,\theta_0 / 2 ; \qquad (22.14)$$

$$\theta_{\text{plane}} = z_2 \, \theta_0 \ . \tag{22.15}$$

Note that the second term for $y_{\rm plane}$ equals $x\,\theta_{\rm plane}/2$ and represents the displacement that would have occurred had the deflection $\theta_{\rm plane}$ all occurred at the single point x/2.

For heavy ions the multiple Coulomb scattering has been measured and compared with various theoretical distributions [26].

22.7. Radiation length and associated quantities

In dealing with electrons and photons at high energies, it is convenient to measure the thickness of the material in units of the radiation length X_0 . This is the mean distance over which a high-energy electron loses all but 1/e of its energy by bremsstrahlung, and is the appropriate scale length for describing high-energy electromagnetic cascades. X_0 has been calculated and tabulated by Y.S. Tsai [27]:

$$\frac{1}{X_0} = 4\alpha r_e^2 \frac{N_A}{A} \left\{ Z^2 \left[L_{\rm rad} - f(Z) \right] + Z L'_{\rm rad} \right\}. \tag{22.16}$$

For A=1 g mol⁻¹, $4\alpha re^2 N_A/A=(716.408 \text{ g cm}^{-2})^{-1}$. $L_{\rm rad}$ and $L'_{\rm rad}$ are given in Table 22.2. The function f(Z) is an infinite sum, but for elements up to uranium can be represented to 4-place accuracy by

$$f(Z) = a^2 \left[(1+a^2)^{-1} + 0.20206 -0.0369 \, a^2 + 0.0083 \, a^4 - 0.002 \, a^6 \right] , \tag{22.17}$$

where $a = \alpha Z$ [28].

Table 22.2: Tsai's $L_{\rm rad}$ and $L'_{\rm rad}$, for use in calculating the radiation length in an element using Eq. (22.16).

Element	Z	$L_{ m rad}$	$L'_{ m rad}$
Н	1	5.31	6.144
${\rm He}$	2	4.79	5.621
Li	3	4.74	5.805
$_{ m Be}$	4	4.71	5.924
Others	> 4	$\ln(184.15Z^{-1/3})$	$\ln(1194Z^{-2/3})$

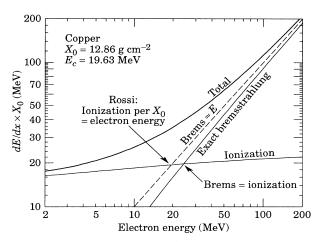


Figure 22.6: Two definitions of the critical energy E_c .

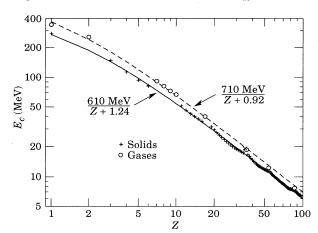


Figure 22.7: Electron critical energy for the chemical elements, using Rossi's definition [1]. The fits shown are for solids and liquids (solid line) and gases (dashed line). The rms deviation is 2.2% for the solids and 4.0% for the gases. (Computed with code supplied by A. Fassó.)

Although it is easy to use Eq. (22.16) to calculate X_0 , the functional dependence on Z is somewhat hidden. Dahl provides a compact fit to the data [29]:

$$X_0 = \frac{716.4 \text{ g cm}^{-2} A}{Z(Z+1) \ln(287/\sqrt{Z})}$$
 (22.18)

Results obtained with this formula agree with Tsai's values to better than 2.5% for all elements except helium, where the result is about 5% low.

The radiation length in a mixture or compound may be approxi-

$$1/X_0 = \sum w_j/X_j , \qquad (22.19)$$

where w_j and X_j are the fraction by weight and the radiation length for the jth element.

An electron loses energy by bremsstrahlung at a rate nearly proportional to its energy, while the ionization loss rate varies only logarithmically with the electron energy. The critical energy E_c is sometimes defined as the energy at which the two loss rates are equal [30]. Berger and Seltzer [30] also give the approximation $E_c = (800 \text{ MeV})/(Z+1.2)$. This formula has been widely quoted, and has been given in previous editions of this Review [17]. Among alternate definitions is that of Rossi [1], who defines the critical energy as the energy at which the ionization loss per radiation length is equal to the electron energy. Equivalently, it is the same as the first definition with the approximation $|dE/dx|_{\text{brems}} \approx E/X_0$. These definitions are illustrated in the case of copper in Fig. 22.6 [31].

The accuracy of approximate forms for E_c has been limited by the failure to distinguish between gases and solid or liquids, where there is a substantial difference in ionization at the relevant energy because of the density effect. We distinguish these two cases in Fig. 22.7. Fits were also made with functions of the form $a/(Z+b)^{\alpha}$, but α was essentially unity.

The transverse development of electromagnetic showers in different materials scales fairly accurately with the *Molière radius* R_M , given by [32,33]

$$R_M = X_0 E_s / E_c , (22.20)$$

where $E_s \approx 21$ MeV (see Table 22.1), and the Rossi definition of E_c is used.

In a material containing a weight fraction w_j of the element with critical energy E_{cj} and radiation length X_j , the Molière radius is given by

$$\frac{1}{R_M} = \frac{1}{E_s} \sum \frac{w_j E_{cj}}{X_j} \ . \tag{22.21}$$

For very high-energy photons, the total e^+e^- pair-production cross section is approximately

$$\sigma = \frac{7}{9}(A/X_0N_A) , \qquad (22.22)$$

where A is the atomic weight of the material and N_A is Avogadro's number. Equation Eq. (22.22) is accurate to within a few percent down to energies as low as 1 GeV. The cross section decreases at lower energies, as shown in Fig. 23.4 of this *Review*. As the energy decreases, a number of other processes become important, as is shown in Fig. 23.3 of this *Review*.

22.8. Electromagnetic cascades

When a high-energy electron or photon is incident on a thick absorber, it initiates an electromagnetic cascade as pair production and bremsstrahlung generate more electrons and photons with lower energy. The longitudinal development is governed by the high-energy part of the cascade, and therefore scales as the radiation length in the material. Electron energies eventually fall below the critical energy, and then dissipate their energy by ionization and excitation rather than by the generation of more shower particles. In describing shower behavior, it is therefore convenient to introduce the scale variables

$$t = x/X_0$$

$$y = E/E_c , (22.23)$$

so that distance is measured in units of radiation length and energy in units of critical energy.

Longitudinal profiles for an EGS4 [8] simulation of a 30 GeV electron-induced cascade in iron are shown in Fig. 22.8. The number of particles crossing a plane (very close to Rossi's II function [1]) is sensitive to the cutoff energy, here chosen as a total energy of 1.5 MeV for both electrons and photons. The electron number falls off more quickly than energy deposition. This is because, with increasing depth, a larger fraction of the cascade energy is carried by photons.

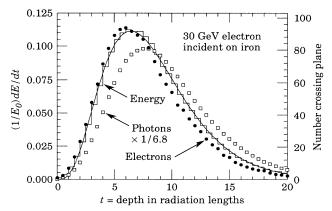


Figure 22.8: An EGS4 simulation of a 30 GeV electron-induced cascade in iron. The histogram shows fractional energy deposition per radiation length, and the curve is a gamma-function fit to the distribution. Circles indicate the number of electrons with total energy greater than 1.5 MeV crossing planes at $X_0/2$ intervals (scale on right) and the squares the number of photons with $E \geq 1.5$ MeV crossing the planes (scaled down to have same area as the electron distribution).

Exactly what a calorimeter measures depends on the device, but it is not likely to be exactly any of the profiles shown. In gas counters it may be very close to the electron number, but in glass Čerenkov detectors and other devices with "thick" sensitive regions it is closer to the energy deposition (total track length). In such detectors the signal is proportional to the "detectable" track length T_d , which is in general less than the total track length T_d . Practical devices are sensitive to electrons with energy above some detection threshold E_d , and $T_d = T \, F(E_d/E_c)$. An analytic form for $F(E_d/E_c)$ obtained by Rossi [1] is given by Fabjan [34]; see also Amaldi [35].

The mean longitudinal profile of the energy deposition in an electromagnetic cascade is reasonably well described by a gamma distribution [36]:

$$\frac{dE}{dt} = E_0 b \frac{(bt)^{a-1} e^{-bt}}{\Gamma(a)}$$
 (22.24)

The maximum $t_{\rm max}$ occurs at (a-1)/b. We have made fits to shower profiles in elements ranging from carbon to uranium, at energies from 1 GeV to 100 GeV. The energy deposition profiles are well described by Eq. (22.24) with

$$t_{\text{max}} = (a-1)/b = 1.0 \times (\ln y + C_i), \qquad j = e, \gamma,$$
 (22.25)

where $C_e = -0.5$ for electron-induced cascades and $C_{\gamma} = +0.5$ for photon-induced cascades. To use Eq. (22.24), one finds (a-1)/b from Eq. (22.25) and Eq. (22.23), then finds a either by assuming $b \approx 0.5$ or by finding a more accurate value from Fig. 22.9. The results are very similar for the electron number profiles, but there is some dependence on the atomic number of the medium. A similar form for the electron number maximum was obtained by Rossi in the context of his "Approximation B," [1] (see Fabjan's review in Ref. 34), but with $C_e = -1.0$ and $C_{\gamma} = -0.5$; we regard this as superseded by the EGS4 result.

The "shower length" $X_s=X_0/b$ is less conveniently parametrized, since b depends upon both Z and incident energy, as shown in Fig. 22.9. As a corollary of this Z dependence, the number of electrons crossing a plane near shower maximum is underestimated using Rossi's approximation for carbon and seriously overestimated for uranium. Essentially the same b values are obtained for incident electrons and photons. For many purposes it is sufficient to take $b\approx 0.5$.

The gamma distribution is very flat near the origin, while the EGS4 cascade (or a real cascade) increases more rapidly. As a result Eq. (22.24) fails badly for about the first two radiation lengths; it was necessary to exclude this region in making fits.

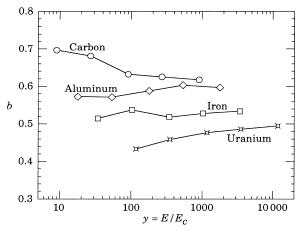


Figure 22.9: Fitted values of the scale factor b for energy deposition profiles obtained with EGS4 for a variety of elements for incident electrons with $1 \le E_0 \le 100$ GeV. Values obtained for incident photons are essentially the same.

Because fluctuations are important, Eq. (22.24) should be used only in applications where average behavior is adequate. Grindhammer $et\ al.$ have developed fast simulation algorithms in which the variance and correlation of a and b are obtained by fitting Eq. (22.24) to individually simulated cascades, then generating profiles for cascades using a and b chosen from the correlated distributions [37].

Measurements of the lateral distribution in electromagnetic cascades are shown in Refs. 32 and 33. On the average, only 10% of the energy lies outside the cylinder with radius R_M . About 99% is contained inside of $3.5R_M$, but at this radius and beyond composition effects become important and the scaling with R_M fails. The distributions are characterized by a narrow core, and broaden as the shower develops. They are often represented as the sum of two Gaussians, and Grindhammer [37] describes them with the function

$$f(r) = \frac{2r R^2}{(r^2 + R^2)^2} , \qquad (22.26)$$

where R is a phenomenological function of x/X_0 and $\ln E$.

22.9. Muon energy loss at high energy

At sufficiently high energies, radiative processes become more important than ionization for all charged particles. For muons and pions in materials such as iron, this "critical energy" occurs at several hundred GeV. Radiative effects dominate the energy loss of energetic muons found in cosmic rays or produced at the newest accelerators. These processes are characterized by small cross sections, hard spectra, large energy fluctuations, and the associated generation of electromagnetic and (in the case of photonuclear interactions) hadronic showers [40–47]. As a consequence, at these energies the treatment of energy loss as a uniform and continuous process is for many purposes inadequate.

It is convenient to write the average rate of muon energy loss as [38]

$$-dE/dx = a(E) + b(E)E. (22.27)$$

Here a(E) is the ionization energy loss given by Eq. (22.1), and b(E) is the sum of e^+e^- pair production, bremsstrahlung, and photonuclear contributions. To the approximation that these slowly-varying functions are constant, the mean range x_0 of a muon with initial energy E_0 is given by

$$x_0 \approx (1/b) \ln(1 + E_0/E_{\mu c})$$
, (22.28)

where $E_{\mu c}=a/b$. Figure 22.10 shows contributions to b(E) for iron. Since $a(E)\approx 0.002$ GeV g⁻¹ cm², b(E)E dominates the energy loss

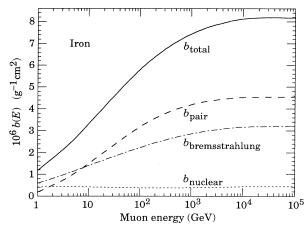


Figure 22.10: Contributions to the fractional energy loss by muons in iron due to e^+e^- pair production, bremsstrahlung, and photonuclear interactions, as obtained from Lohmann *et al.* [39].

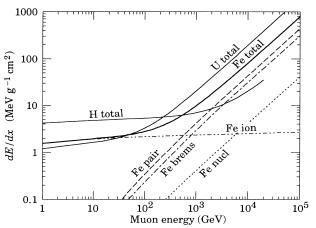


Figure 22.11: The average energy loss of a muon in hydrogen, iron, and uranium as a function of muon energy. Contributions to dE/dx in iron from ionization and the processes shown in Fig. 22.10 are also shown.

above several hundred GeV, where b(E) is nearly constant. The rate of energy loss for muons in hydrogen, uranium, and iron is shown in Fig. 22.11 [39].

The "muon critical energy" $E_{\mu c}$ can be defined more exactly as the energy at which radiative and ionization losses are equal, and can be found by solving $E_{\mu c} = a(E_{\mu c})/b(E_{\mu c})$. This definition corresponds to the solid-line intersection in Fig. 22.6, and is different from the Rossi definition we used for electrons. It serves the same function: below $E_{\mu c}$ ionization losses dominate, and above $E_{\mu c}$ dominate. The dependence of $E_{\mu c}$ on atomic number Z is shown in Fig. 22.12.

The radiative cross sections are expressed as functions of the fractional energy loss ν . The bremsstrahlung cross section goes roughly as $1/\nu$ over most of the range, while for the pair production case the distribution goes as ν^{-3} to ν^{-2} (see Ref. 50). "Hard" losses are therefore more probable in bremsstrahlung, and in fact energy losses due to pair production may very nearly be treated as continuous. The calculated momentum distribution of an incident 1 TeV/c muon beam after it crosses 3 m of iron is shown in Fig. 22.13. The most probable loss is 9 GeV, or 3.8 MeV g⁻¹cm². The full width at half maximum is 7 GeV/c, or 0.7%. The radiative tail is almost entirely due to bremsstrahlung; this includes most of the 10% that lost more than 2.8% of their energy. Most of the 3.3% that lost more than 10% of their incident energy experienced photonuclear interactions, which are concentrated in rare, relatively hard collisions. The latter can exceed nominal detector resolution [51], necessitating the reconstruction

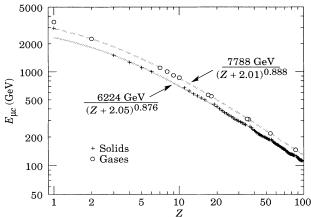


Figure 22.12: Muon critical energy for the chemical elements, defined as the energy at which radiative and ionization energy loss rates are equal. The equality comes at a higher energy for gases than for solids or liquids with the same atomic number because of a smaller density effect reduction of the ionization losses. The fits shown in the figure exclude hydrogen. Alkali metals fall 3-4% above the fitted function for alkali metals, while most other solids are within 2% of the function. Among the gases the worst fit is for neon (1.4% high). (Courtesy of N.V. Mokhov, using the MARS code system [48].)

of lost energy. Electromagnetic and hadronic cascades in detector materials can obscure muon tracks in detector planes and reduce tracking efficiency [52].

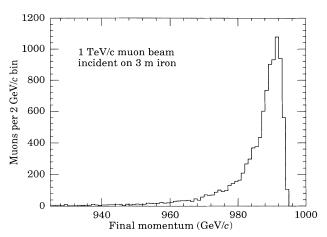


Figure 22.13: The momentum distribution of 1 TeV/c muons after traversing 3 m of iron, as obtained with Van Ginniken's TRAMU muon transport code [50].

22.10. Čerenkov and transition radiation [4,53,54]

A charged particle radiates if its velocity is greater than the local phase velocity of light (Čerenkov radiation) or if it crosses suddenly from one medium to another with different optical properties (transition radiation). Neither process is important for energy loss, but both are used in high-energy physics detectors.

<u>Čerenkov Radiation</u>. The half-angle θ_c of the Čerenkov cone for a particle with velocity βc in a medium with index of refraction n is

$$\theta_c = \arccos(1/n\beta)$$

$$\approx \sqrt{2(1-1/n\beta)} \text{ for small } \theta_c, e.g. \text{ in gases.}$$
(22.29)

The threshold velocity β_t is 1/n, and $\gamma_t = 1/(1 - \beta_t^2)^{1/2}$. Therefore, $\beta_t \gamma_t = 1/(2\delta + \delta^2)^{1/2}$, where $\delta = n - 1$. Values of δ for various

commonly used gases are given as a function of pressure and wavelength in Ref. 55. For values at atmospheric pressure, see Table 6.1. Data for other commonly used materials are given in Ref. 56.

The number of photons produced per unit path length of a particle with charge ze and per unit energy interval of the photons is

$$\frac{d^2 N}{dE dx} = \frac{\alpha z^2}{hc} \sin^2 \theta_c = \frac{\alpha^2 z^2}{r_e m_e c^2} \left(1 - \frac{1}{\beta^2 n^2(E)} \right)$$

$$\approx 370 \sin^2 \theta_c(E) \text{ eV}^{-1} \text{ cm}^{-1} \qquad (z = 1) , \qquad (22.30)$$

or, equivalently,

$$\frac{d^2N}{dxd\lambda} = \frac{2\pi\alpha z^2}{\lambda^2} \left(1 - \frac{1}{\beta^2 n^2(\lambda)}\right) \ . \tag{22.31}$$

The index of refraction is a function of photon energy E, as is the sensitivity of the transducer used to detect the light. For practical use, Eq. (22.30) must be multiplied by the the transducer response function and integrated over the region for which $\beta n(E) > 1$. Further details are given in the discussion of Čerenkov detectors in the Detectors section (Sec. 24 of this Review).

<u>Transition Radiation</u>. The energy radiated when a particle with charge ze crosses the boundary between vacuum and a medium with plasma frequency ω_p is

$$I = \alpha z^2 \gamma h \omega_p / 3 , \qquad (22.32)$$

where

$$h\omega_p = \sqrt{4\pi N_e r_e^3} \ m_e c^2/\alpha$$
$$= \sqrt{4\pi N_e a_\infty^3} \ 2 \times 13.6 \text{ eV} \ . \tag{22.33}$$

Here N_e is the electron density in the medium, r_e is the classical electron radius, and a_{∞} is the Bohr radius. For styrene and similar materials, $\sqrt{4\pi N_e a_{\infty}^3} \approx 0.8$, so that $\hbar \omega_p \approx 20$ eV. The typical emission angle is $1/\gamma$.

The radiation spectrum is logarithmically divergent at low energies and decreases rapidly for $\hbar\omega/\gamma\hbar\omega_p>1$. About half the energy is emitted in the range $0.1 \le \hbar\omega/\gamma\hbar\omega_p \le 1$. For a particle with $\gamma=10^3$, the radiated photons are in the soft x-ray range 2 to 20 eV. The γ dependence of the emitted energy thus comes from the hardening of the spectrum rather than from an increased quantum yield. For a typical radiated photon energy of $\gamma\hbar\omega_p/4$, the quantum yield is

$$N_{\gamma} \approx \frac{1}{2} \frac{\alpha z^{2} \gamma h \omega_{p}}{3} / \frac{\gamma h \omega_{p}}{4}$$
$$\approx \frac{2}{3} \alpha z^{2} \approx 0.5\% \times z^{2} . \tag{22.34}$$

More precisely, the number of photons with energy $\hbar\omega>\hbar\omega_0$ is given by [57]

$$N_{\gamma}(\hbar\omega > \hbar\omega_0) = \frac{\alpha z^2}{\pi} \left[\left(\ln \frac{\gamma \hbar\omega_p}{\hbar\omega_0} - 1 \right)^2 + \frac{\pi^2}{12} \right] , \qquad (22.35)$$

within corrections of order $(\hbar\omega_0/\gamma\hbar\omega_p)^2$. The number of photons above a fixed energy $\hbar\omega_0\ll\gamma\hbar\omega_p$ thus grows as $(\ln\gamma)^2$, but the number above a fixed fraction of $\gamma\hbar\omega_p$ (as in the example above) is constant. For example, for $\hbar\omega>\gamma\hbar\omega_p/10$, $N_\gamma=2.519\,\alpha z^2/\pi=0.59\%\times z^2$.

The yield can be increased by using a stack of plastic foils with gaps between. However, interference can be important, and the soft x rays are readily absorbed in the foils. The first problem can be overcome by choosing thicknesses and spacings large compared to the "formation length" $D = \gamma c/\omega_p$, which in practical situations is tens of μ m. Other practical problems are discussed in Sec. 24.

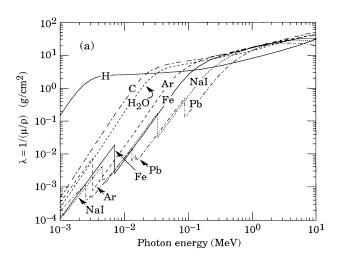
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23. PHOTON AND ELECTRON ATTENUATION

Photon Attenuation Length



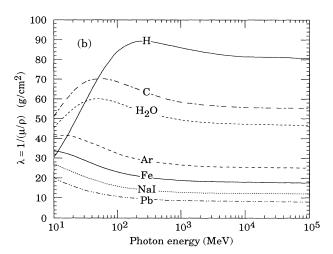


Figure 23.1: The photon mass attenuation length $\lambda = 1/(\mu/\rho)$ (also known as mfp, mean free path) for various absorbers as a function of photon energy, where μ is the mass attenuation coefficient. For a homogeneous medium of density ρ , the intensity I remaining after traversal of thickness t is given by the expression $I = I_0 \exp(-t\rho/\lambda)$. The accuracy is a few percent. Interpolation to other Z should be done in the cross section $\sigma = A/\lambda N_A \text{ cm}^2/\text{atom}$, where A is the atomic weight of the absorber material in grams and N_A is the Avogadro number. For a chemical compound or mixture, use $(1/\lambda)_{\text{eff}} \approx \sum w_i(1/\lambda)_i$, accurate to a few percent, where w_i is the proportion by weight of the i^{th} constituent. The processes responsible for attenuation are given in Fig. 23.4. Not all of these processes necessarily result in detectable attenuation. For example, coherent Rayleigh scattering off an atom may occur at such low momentum transfer that the change in energy and momentum of the photon may not be significant.

(a) Low-energy region.

(b) The photon mass attenuation length, high-energy range (note that ordinate is linear scale). The attenuation length is constant beyond the range shown for at least two decades in energy.

From Hubbell, Gimm, and Øverbø, J. Phys. Chem. Ref. Data 9, 1023 (80). See also J.H. Hubbell, Int. J. of Applied Rad. and Isotopes 33, 1269 (82). Data courtesy J.H. Hubbell.

Photon Pair Conversion Probability

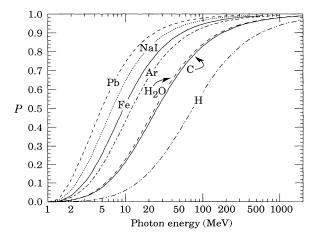


Figure 23.2: Probability P that a photon interaction will result in conversion to an e^+e^- pair. Except for a few-percent contribution from photonuclear absorption around 10 or 20 MeV, essentially all other interactions result in Compton scattering off an atomic electron. For a photon attenuation length λ (g/cm²) (Fig. 23.1), the probability that a given photon will produce an electron pair (without first Compton scattering) in thickness t (cm) of absorber of density ρ (g/cm³) is $P[1 - \exp(-t\rho/\lambda)]$.

Contributions to Photon Cross Section in Carbon and Lead

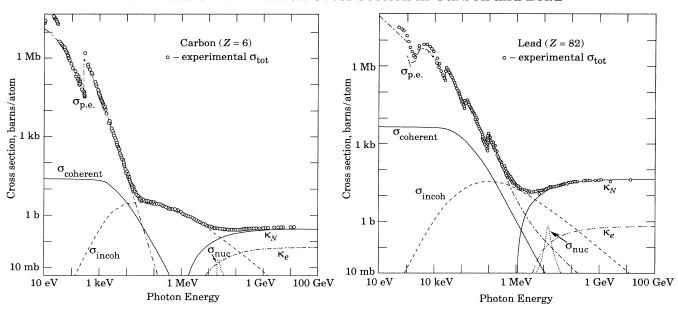


Figure 23.3: Photon total cross sections as a function of energy in carbon and lead, showing the contributions of different processes.

 $\sigma_{\rm p.e.}$ = Atomic photo-effect (electron ejection, photon absorption)

 $\sigma_{\mathrm{coherent}} = \mathrm{Coherent}$ scattering (Rayleigh scattering—atom neither ionized nor excited)

 $\sigma_{\rm incoherent} =$ Incoherent scattering (Compton scattering off an electron)

 κ_n = Pair production, nuclear field

 κ_e = Pair production, electron field

 $\sigma_{
m nuc}=$ Photonuclear absorption (nuclear absorption, usually followed by emission of a neutron or other particle)

From Hubbell, Gimm, and Øverbø, J. Phys. Chem. Ref. Data 9, 1023 (80). The photon total cross section is assumed approximately flat for at least two decades beyond the energy range shown. Figures courtesy J.H. Hubbell.

Fractional Energy Loss for Electrons and Positrons in Lead

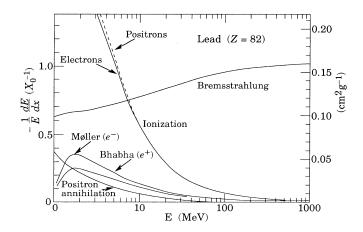


Figure 23.4: Fractional energy loss per radiation length in lead as a function of electron or positron energy. Electron (positron) scattering is considered as ionization when the energy loss per collision is below 0.255 MeV, and as Moller (Bhabha) scattering when it is above. Adapted from Fig. 3.2 from Messel and Crawford, Electron-Photon Shower Distribution Function Tables for Lead, Copper, and Air Absorbers, Pergamon Press, 1970. Messel and Crawford use $X_0(Pb) = 5.82 \text{ g/cm}^2$, but we have modified the figures to reflect the value given in the Table of Atomic and Nuclear Properties of Materials, namely $X_0(Pb)$ $= 6.4 \text{ g/cm}^2$. The development of electron-photon cascades is approximately independent of absorber when the results are expressed in terms of inverse radiation lengths (i.e., scale on left of plot).

24. PARTICLE DETECTORS

Contributed by D.G. Coyne, R.W. Fast, K. Johnson, R.D. Kephart, B. Mansoulie, H.F.W. Sadrozinski, H.G. Spieler, and C.L. Woody; revised 1995

In this section we give various parameters for common detector components. The quoted numbers are usually based on typical devices, and should be regarded only as rough approximations for new designs. A more detailed discussion of detectors can be found in Ref. 1. In Table 24.1 are given typical spatial and temporal resolutions of common detectors.

Table 24.1: Typical detector characteristics.

Detector Type	Accuracy (rms)	Resolution Time	Dead Time
Bubble chamber	10 to 150 μm	1 ms	50 ms
Streamer chamber	$300~\mu\mathrm{m}$	$2~\mu \mathrm{s}$	100 ms
Proportional chamber	$\geq 300 \ \mu \mathrm{m}^{b,c}$	50 ns	200 ns
Drift chamber	50 to 300 μm	2 ns^d	100 ns
Scintillator		150 ps	10 ns
Emulsion	$1~\mu\mathrm{m}$	_	annian and a second
Silicon strip	$\frac{\text{pitch}}{3 \text{ to } 7}^{e}$	f	f
Silicon pixel	$2~\mu\mathrm{m}^g$	f	f

- ^a Multiple pulsing time.
- ^b 300 μ m is for 1 mm pitch.
- c Delay line cathode readout can give $\pm 150~\mu\mathrm{m}$ parallel to a node wire.
- d For two chambers.
- ^e The highest resolution ("7") is obtained for small-pitch detectors ($\lesssim 25~\mu m$) with pulse-height-weighted center finding.
- f Limited at present by properties of the readout electronics. (Time resolution of ≤ 15 ns is planned for the SDC silicon tracker.)
- g Analog readout of 34 μm pitch, monolithic pixel detectors.

24.1. Organic scintillators

Organic scintillators are broadly classed into three types, crystalline, liquid, and plastic, all of which utilize the ionization produced by charged particles (see the section on "Passage of particles through matter" (Sec. 22.2) of this Review) to generate optical photons, usually in the blue to green wavelength regions [2]. Plastic scintillators are by far the most widely used and we address them primarily; however, most of the discussion will also have validity for liquid scintillators with obvious caveats. Crystal organic scintillators are practically unused in high-energy physics.

Densities range from 1.03 to 1.20 g cm⁻³. Typical photon yields are about 1 photon per 100 eV of energy deposit [3]. A one-cm-thick scintillator traversed by a minimum-ionizing particle will therefore yield $\approx 2\times 10^4$ photons. The resulting photoelectron signal will depend on the collection and transport efficiency of the optical package and the quantum efficiency of the photodetector.

Plastic scintillators do not respond linearly to the ionization density. Very dense ionization columns emit less light than expected on the basis of dE/dx for minimum-ionizing particles. A widely used semi-empirical model by Birks posits that recombination and quenching effects between the excited molecules reduce the light yield [9]. These effects are more pronounced the greater the density of the excited molecules. Birks' formula is

$$\frac{d\mathcal{L}}{dx} = \mathcal{L}_0 \frac{dE/dx}{1 + k_B dE/dx} , \qquad (24.1)$$

where \mathscr{L} is the luminescence, \mathscr{L}_0 is the luminescence at low specific ionization density, and k_B is Birks' constant, which must be determined for each scintillator by measurement.

Decay times are in the ns range; risetimes are much faster. The combination of high light yield and fast response time allows the possibility of sub-ns timing resolution [4]. The fraction of light emitted during the decay "tail" can depend on the exciting particle. This allows pulse shape discrimination as a technique to carry out particle identification. Because of the hydrogen content (carbon to hydrogen ratio ≈ 1) plastic scintillator is sensitive to proton recoils from neutrons. Ease of fabrication into desired shapes and low cost has made plastic scintillators a common detector component. Recently, plastic scintillators in the form of scintillating fibers have found widespread use in tracking and calorimetry [5].

24.1.1. Scintillation mechanism:

Scintillation: A charged particle traversing matter leaves behind it a wake of excited molecules. Certain types of molecules, however, will release a small fraction ($\approx 3\%$) of this energy as optical photons. This process, scintillation, is especially marked in those organic substances which contain aromatic rings, such as polystyrene, polyvinyltoluene, and napthalene. Liquids which scintillate include toluene and xylene.

Fluorescence: In fluorescence, the initial excitation takes place via the absorption of a photon, and de-excitation by emission of a longer wavelength photon. Fluors are used as "waveshifters" to shift scintillation light to a more convenient wavelength. Occurring in complex molecules, the absorption and emission are spread out over a wide band of photon energies, and have some overlap, that is, there is some fraction of the emitted light which can be re-absorbed [6]. This "self-absorption" is undesirable for detector applications because it causes a shortened attenuation length. The wavelength difference between the major absorption and emission peaks is called the Stokes' shift. It is usually the case that the greater the Stokes' shift, the smaller the self absorption—thus, a large Stokes' shift is a desirable property for a fluor.

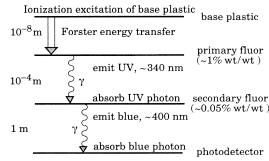


Figure 24.1: Cartoon of scintillation "ladder" depicting the operating mechanism of plastic scintillator. Approximate fluor concentrations and energy transfer distances for the separate sub-processes are shown.

Scintillators: The plastic scintillators used in high-energy physics are binary or ternary solutions of selected fluors in a plastic base containing aromatic rings. (See the appendix in Ref. 7 for a comprehensive list of plastic scintillator components.) Virtually all plastic scintillators contain as a base either polyvinyltoluene, polystyrene, or acrylic, whereby polyvinyltoluene-based scintillator can be up to 50% brighter than the others. Acrylic is non-aromatic and has therefore a very low scintillation efficiency. It becomes an acceptable scintillator when napthalene, a highly aromatic compound, is dissolved into the acrylic at 5% to 20% weight fraction. Thus, in "acrylic" scintillator the active component is napthalene. The fluors must satisfy additional conditions besides being fluorescent. They must be sufficiently stable, soluble, chemically inert, fast, radiation tolerant, and efficient.

The plastic base is the ionization-sensitive (i.e., the scintillator) portion of the plastic scintillator (see Fig. 24.1). In the absence of fluors the base would emit UV photons with short attenuation length (several mm). Longer attenuation lengths are obtained by dissolving a "primary" fluor in high concentration (1% by weight) into the

base, which is selected to efficiently reradiate absorbed energy at wavelengths where the base is more transparent.

The primary fluor has a second important function. The decay time of the scintillator base material can be quite long—in pure polystyrene it is 16 ns, for example. The addition of the primary fluor in high concentration can shorten the decay time by an order of magnitude and increase the total light yield. At the concentrations used (1% and greater), the average distance between a fluor molecule and an excited base unit is around 100 Å, much less than a wavelength of light. At these distances the predominant mode of energy transfer from base to fluor is not the radiation of a photon, but a resonant dipole-dipole interaction, first described by Foerster, which strongly couples the base and fluor [8]. The strong coupling sharply increases the speed and the light yield of the plastic scintillators.

Unfortunately, a fluor which fulfills other requirements is usually not completely adequate with respect to emission wavelength or attenuation length, so it is necessary to add yet another waveshifter (the "secondary" fluor), at fractional percent levels, and ocassionally a third (not shown in Fig. 24.1).

External wavelength shifters: Light emitted from a plastic scintillator may be absorbed in a (nonscintillating) base doped with a waveshifting fluor. Such wavelength shifters are widely used to aid light collection in complex geometries. The wavelength shifter must be insensitive to ionizing radiation and Čerenkov light. A typical wavelength shifter uses an acrylic base (without napthalene!) because of its good optical qualities, a single fluor to shift the light emerging from the plastic scintillator to the blue-green, and contains ultra-violet absorbing additives to deaden response to Čerenkov light.

24.1.2. Caveats and cautions: Plastic scintillators are reliable, robust, and convenient. However, they possess quirks to which the experimenter must be alert.

Aging and Handling: Plastic scintillators are subject to aging which diminishes the light yield. Exposure to solvent vapors, high temperatures, mechanical flexing, irradiation, or rough handling will aggravate the process. A particularly fragile region is the surface which can "craze"—develop microcracks—which rapidly destroy the capability of plastic scintillators to transmit light by total internal reflection. Crazing is particularly likely where oils, solvents, or fingerprints have contacted the surface.

Attenuation length: The Stokes' shift is not the only factor determining attenuation length. Others are the concentration of fluors (the higher the concentration of a fluor, the greater will be its self-absorption); the optical clarity and uniformity of the bulk material; the quality of the surface; and absorption by additives, such as stabilizers, which may be present.

<u>Afterglow</u>: Plastic scintillators have a long-lived luminescence which does not follow a simple exponential decay. Intensities at the 10^{-4} level of the initial fluorescence can persist for hundreds of ns [10].

Atmospheric quenching: Plastic scintillators will decrease their light yield with increasing partial pressure of oxygen. This can be a 10% effect in an artificial atmosphere [11]. It is not excluded that other gasses may have similar quenching effects.

<u>Magnetic field</u>: The light yield of plastic scintillators may be changed by a magnetic field. The effect is very nonlinear and apparently not all types of plastic scintillators are so affected. Increases of $\approx 3\%$ at 0.45 T have been reported [12]. Data are sketchy and mechanisms are not understood.

Radiation damage: Irradiation of plastic scintillators creates color centers which absorb light more strongly in the UV and blue than at longer wavelengths. This poorly understood effect appears as a reduction both of light yield and attenuation length. Radiation damage depends not only on the integrated dose, but on the dose rate, atmosphere, and temperature, before, during and after irradiation, as well as the materials properties of the base such as glass transition temperature, polymer chain length, etc. Annealing also occurs,

Table 24.2: Properties of several inorganic crystal scintillators.

NaI(Tl)	BGO	BaF_2	CsI(Tl)	CsI(pure)	PbWO ₄	CeF_3
Density	(g cm	⁻³):				
3.67	7.13	4.89	4.53	4.53	8.28	6.16
Radiation	on leng	gth (cm):				
2.59	1.12	2.05	1.85	1.85	0.89	1.68
Molière	radius	s (cm):				
4.5	2.4	3.4	3.8	3.8	2.2	2.6
dE/dx	(MeV/	cm) (per	mip):		***************************************	
4.8	9.2	6.6	5.6	5.6	13.0	7.9
Nucl. ir	ıt. len	gth (cm)				
41.4	22.0	29.9	36.5	36.5	22.4	25.9
Decay t	ime (n	s):				
250	300	0.7^{f}	1000	$10,36^{f}$	5-15	10 - 30
		620^{s}		$\sim 1000^s$		
Peak en	nission	λ (nm):				
410	480	$220^{f'}$	565	305^{f}	440-500	310-340
		310^{s}		$\sim 480^s$		
Refracti	ve ind	ex:				
1.85	2.20	1.56	1.80	1.80	2.16	1.68
Relative	light	output:			75 7767	
1.00	0.15	0.05^{f}	0.40	0.10^{f}	0.01	0.10
		0.20^{s}		0.02^{s}		
Hygroso	opic:					
very	no	slightly	somewhat	somewhat	no	no

f =fast component, s =slow component

accelerated by the diffusion of atmospheric oxygen and elevated temperatures. The phenomena are complex, unpredictable, and not well understood [13]. Since color centers are less intrusive at longer wavelengths, the most reliable method of mitigating radiation damage is to shift emissions at every step to the longest practical wavelengths, e.g., utilize fluors with large Stokes' shifts.

24.2. Inorganic scintillators

Table 24.2 gives a partial list of commonly-used inorganic scintillators in high-energy and nuclear physics [14-21]. These scintillating crystals are generally used where high density and good energy resolution are required. In a crystal which contains nearly all of the energy deposited by an incident particle, the energy resolution is determined largely, but not totally, by the light output. The table gives the light output of the various materials relative to NaI, which has an intrinsic light output of about 40000 photons per MeV of energy deposit. The detected signal is usually quoted in terms of photoelectrons per MeV produced by a given photodetector. The relationship between photons/MeV produced and p.e.'s/MeV detected involves factors for light collection efficiency (typically 10-50%, depending on geometry) and the quantum efficiency of the detector ($\sim 15-20\%$ for photomultiplier tubes and $\sim 70\%$ for silicon photodiodes for visible wavelengths). The quantum efficiency of the detector is usually highly wavelength dependent and should be matched to the particular crystal of interest to give the highest quantum yield at the wavelength corresponding to the peak of the scintillation emission. The comparison of the light output given in Table 24.2 is for a standard photomultiplier tube with a bialkali photocathode. For scintillators which emit in the UV, a detector with a quartz window should be used.

24.3. Čerenkov detectors

Čerenkov detectors utilize one or more of the properties of Čerenkov radiation discussed in the Passages of Particles through Matter section (Sec. 22 of this Review): the existence of a threshold for radiation; the dependence of the Čerenkov cone half-angle θ_c on the velocity of the particle; the dependence of the number of emitted photons on the particle's velocity. The presence of the refractive index n in the relations allows tuning these quantities for a particular experimental application (e.g., using pressurized gas and/or various liquids as radiators).

The number of photoelectrons (p.e.'s) detected in a given device or channel is

$$N_{\rm p.c.} = L \frac{\alpha^2 z^2}{r_e \, m_e c^2} \int \epsilon_{\rm coll}(E) \, \epsilon_{\rm det}(E) \sin^2 \theta_c(E) dE$$
, (24.2)

where L is the path length in the radiator, $\epsilon_{\rm coll}$ is the efficiency for collecting the Čerenkov light, $\epsilon_{\rm dct}$ is the quantum efficiency of the transducer (photomultiplier or equivalent), and $\alpha^2/(r_e\,m_ec^2)=370~{\rm cm}^{-1}{\rm eV}^{-1}$. The quantities $\epsilon_{\rm coll}$, $\epsilon_{\rm dct}$, and θ_c are all functions of the photon energy E, although in typical detectors θ_c (or, equivalently, the index of refraction) is nearly constant over the useful range of photocathode sensitivity. In this case,

$$N_{\rm p.e.} \approx L N_0 \left\langle \sin^2 \theta_c \right\rangle$$
 (24.3)

with

$$N_0 = \frac{\alpha^2 z^2}{r_e \, m_e c^2} \, \int \epsilon_{\text{coll}} \, \epsilon_{\text{dct}} dE \ . \tag{24.4}$$

We take z = 1, the usual case in high-energy physics, in the following discussion.

Threshold Čerenkov detectors make a simple yes/no decision based on whether the particle is above/below the Čerenkov threshold velocity $\beta_t=1/n.$ Careful designs give $\langle\epsilon_{\rm coll}\rangle\gtrsim90\%.$ For a photomultiplier with a typical bialkali cathode, $\int\epsilon_{\rm det}dE\approx0.27,$ so that

$$N_{\rm p.c.}/L \approx 90~{\rm cm}^{-1}~\left<\sin^2\theta_c\right>~(i.e.,~N_0=90~{\rm cm}^{-1})~.~(24.5)$$

Suppose, for example, that n is chosen so that the threshold for species a is p_t ; that is, at this momentum species a has velocity $\beta_a = 1/n$. A second, lighter, species b with the same momentum has velocity β_b , so $\cos \theta_c = \beta_a/\beta_b$, and

$$\frac{N_{\text{p.e.}}}{L} \approx 90 \text{ cm}^{-1} \frac{m_a^2 - m_b^2}{p_t^2 + m_a^2}$$
 (24.6)

For K/π separation at p=1 GeV/c, $N_{\rm p.c.}/L\approx 16$ cm⁻¹ for π 's and (by design) 0 for K's.

For limited path lengths $N_{\rm p.c.}$ can be small, and some minimum number is required to trigger external electronics. The overall efficiency of the device is controlled by Poisson fluctuations, which can be especially critical for separation of species where one particle type is dominant [22].

A related class of detectors uses the number of observed photoelectrons (or the calibrated pulse height) to discriminate between species or to set probabilities for each particle species [23].

<u>Differential Čerenkov detectors</u> exploit the dependence of θ_c on β , using optical focusing and/or geometrical masking to select particles having velocities in a specified region. With careful design, a velocity resolution of $\sigma_{\beta}/\beta \approx 10^{-4}$ - 10^{-5} can be obtained [22,24].

Ring-Imaging Čerenkov detectors use all three properties of Čerenkov radiation in both small-aperture and 4π geometries. They are principally used as hypothesis-testing rather than yes/no devices; that is, the probability of various identification possibilities is established from θ_c and $N_{\rm p.c.}$ for a particle of known momentum. In most cases

Table 24.3: Momentum range for 3σ separation in the SLD ring-imaging Čerenkov detector.

Particle pair	Mom. range for 3 σ separation
e/π	$p \lesssim 5 \text{GeV}/c$
π/K	$0.23 \lesssim p \lesssim 20 \mathrm{GeV}/c$
K/p	$0.82 \lesssim p \lesssim 30 \mathrm{GeV}/c$

the optics map the Čerenkov cone onto a circle at the photodetector, often with distortions which must be understood.

The 4π devices [25,26] typically have both liquid (C₆F₁₄, n=1.276) and gas (C₅F₁₂, n=1.0017) radiators, the light from the latter being focused by mirrors. They achieve 3 σ separation of $e/\pi/K/p$ over wide ranges, as shown in Table 24.3. Great attention to detail, especially with the minimization of UV-absorbing impurities, is required to get $\langle \epsilon_{\rm coll} \rangle \gtrsim 50\%$.

The phototransducer is typically a TPC/wire-chamber combination sensitive to single photoelectrons and having charge division or pads. This construction permits three-dimensional reconstruction of photoelectron origins, which is important for transforming the Čerenkov cone into a ring. Single photoelectrons are generated by doping the TPC gas (for instance, ethane/methane in some proportion) with $\sim 0.05\%$ TMAE [tetrakis(dimethylamino)ethylene] [27], leading to photon absorption lengths along the Čerenkov cone of ~ 30 mm. The readout wires must be equipped with special structures (blinds or wire gates) to prevent photon feedback from avalanches generating cross-talk photoelectrons in the TPC. Drift-gas purity must be maintained to assure mean drift lengths of the order of meters without recombination (i.e., lifetimes of $\gtrsim 100~\mu s$ at typical drift velocities of $\gtrsim 4~\rm cm/\mu s$). The net $\langle \epsilon_{\rm det} \rangle$'s reach 30%, with the limitation being the TMAE quantum efficiency.

Photon energy cutoffs are set by the TMAE $(E>5.4~{\rm eV})$, the UV transparency of fused silica glass $(E<7.4~{\rm eV})$, and the ${\rm C_6F_{14}}$ $(E<7.1~{\rm eV})$. With effort one gets $50\leq N_0\leq 100$ for complete rings using liquid or gas. This includes losses due to electrostatic shielding wires and window/mirror reflections, but not gross losses caused by total internal reflection or inadequate coverage by the TPC's.

Such numbers allow determination of ring radii to $\sim 0.5\%$ (liquid) and $\sim 2\%$ (gas), leading to the particle species separations quoted above. Since the separation efficiencies may have "holes" as a function of p, detailed calculations are necessary.

24.4. Transition radiation detectors (TRD's)

It is clear from the discussion in the Passages of Particles Through Matter section (Sec. 22 of this Review) that transition radiation (TR) only becomes useful for particle detectors when the Lorentz factor $\gamma \gtrsim 10^3$. In practice, TRD's are used to provide e/π separation when $p\gtrsim 1$ GeV/c. (The momentum is usually measured elsewhere in the detector.) Since a soft x ray is radiated with about 1% probability per boundary crossing, practical detectors use radiators with several hundred interfaces, e.g. foils of lithium or plastic in a gas. Absorption inside the radiator and interference effects between interfaces are important [28,29].

A practical detector is composed of several similar modules, each consisting of a radiator and an x-ray detector. The radiator is made of foils or fibers of a low-Z material (for low absorption) in a low-Z gas such as helium. The x-ray detector is usually a wire chamber operated with a xenon-rich mixture in order to obtain a high conversion efficiency. As transition radiation is emitted at small angles, the chamber usually detects the sum of the ionization of the particle and of converted TR photons. The discrimination between electrons and pions can be based on the charges measured in each set, or on more sophisticated methods using pulse-shape analysis.

The major factor in the performance of a TRD is its overall length. Very roughly, the pion rejection factor for a detector with 90% electron efficiency is $10\,(L/20\,$ cm), where L is the overall length of the detector.

Recent development work has aimed at adapting the technique to the very high particle rate at LHC, by distributing straw-tube detectors uniformly in the radiator foam, and using very fast electronics. The resulting detector is used as a tracking device as well as a TRD [30].

24.5. Silicon photodiodes and particle detectors

Silicon detectors are p-n junction diodes operated at reverse bias. This forms a sensitive region depleted of mobile charge and sets up an electric field that sweeps charge liberated by radiation to the electrodes. The thickness of the depleted region is

$$W = \sqrt{\frac{2\epsilon \left(V + V_{bi}\right)}{ne}} = \sqrt{2\rho\mu\epsilon(V + V_{bi})} , \qquad (24.7)$$

where V = external bias voltage

 $V_{bi}=$ "built-in" voltage ($\approx 0.8~\mathrm{V}$ for resistivities typically used in detectors

n =doping concentration

e = electron charge

 $\epsilon = \text{dielectric constant} = 11.9 \ \epsilon_0 \approx 1 \ \text{pF/cm}$

 $\rho = \text{resistivity (typically 1-10 k}\Omega \text{ cm)}$

 $\mu = \text{charge carrier mobility}$

= $1350 \text{ cm}^2 \text{ V}^{-1} \text{ s}^{-1}$ for electrons (*n*-type material)

= $450 \text{ cm}^2 \text{ V}^{-1} \text{ s}^{-1}$ for holes (p-type material)

or

$$W = 0.5 \ \mu \text{m} \times \sqrt{\rho(V + V_{bi})}$$
 for *n*-type material, (24.8)

and

$$W = 0.3 \ \mu \text{m} \times \sqrt{\rho (V + V_{bi})}$$
 for p-type material, (24.9)

where V is in volts and ρ is in Ω cm.

The corresponding capacitance per unit area is

$$C = \frac{\epsilon}{W} \approx 1 \,[\text{pF/cm}] \,\frac{1}{W} \,. \tag{24.10}$$

In strip detectors the capacitance is dominated by the strip-to-strip fringing capacitance of $\sim 1\text{--}1.5$ pF cm⁻¹ of strip length at a strip pitch of 25–50 μ m.

About 3.6 eV is required to create an electron-hole pair. For minimum-ionizing particles, the most probable charge deposition in a 300 μ m thick silicon detector is about 4 fC (25000 electrons). Readily available photodiodes have quantum efficiences > 70% for wavelengths between 600 nm and 1 μ m. UV extended photodiodes have useful efficiency down to 200 nm. In applications in which photodiodes detect light from scintillators, care must be taken so that signal from the scintillator is larger than that produced by particles going through the photodiode

Collection time decreases with increased depletion voltage, and can be reduced further by operating the detector with "overbias," *i.e.*, a bias voltage exceeding the value required to fully deplete the device. The collection time is limited by velocity saturation at high fields; at an average field of 10^4 V/cm, the collection times is about 15 ps/ μ m for electrons and 30 ps/ μ m for holes. In typical strip detectors of 300 μ m thickness, electrons are collected within about 8 ns, and holes within about 25 ns.

Position resolution is limited by transverse diffusion during charge collection (typically 5 μ m for 300 μ m thickness) and by knock-on electrons. Resolutions of 3–4 μ m (rms) have been obtained in beam tests. In magnetic fields, the Lorentz drift can increase the spatial spread appreciably (see "Hall effect" in semiconductor textbooks).

Radiation damage occurs through two basic mechanisms:

- Bulk damage due to displacement of atoms from their lattice sites.
 This leads to increased leakage current, carrier trapping, and changes in doping concentration. Displacement damage depends on the nonionizing energy loss, i.e., particle type and energy. The dose should be specified as a fluence of particles of a specific type and energy.
- 2. Surface damage due to charge build-up in surface layers, which leads to increased surface leakage currents. In strip detectors the inter-strip isolation is affected. The effects of charge build-up are strongly dependent on the device structure and on fabrication details. Since the damage is determined directly by the absorbed energy, the dose should be specified in these units (rad or Gray).

The increase in leakage current due to bulk damage is $\Delta i = \alpha \phi$ per unit volume, where ϕ is the particle fluence and α the damage coefficient ($\alpha \approx 2 \times 10^{-17}$ A/cm for minimum ionizing protons and pions after long-term annealing; roughly the same value applies for 1 MeV neutrons). The doping concentration in n-type silicon changes as $n = n_0 \exp(-\delta \phi) - \beta \phi$, where n_0 is the initial donor concentration, $\delta \approx 6 \times 10^{14}$ cm² determines donor removal, and $\beta \approx 0.03$ cm⁻¹ describes acceptor creation. This leads to an initial increase in resisitivity until type-inversion changes the net doping from n to p. At this point the resistivity decreases, with a corresponding increase in depletion voltage. The safe operating limit of depletion voltage ultimately limits the detector lifetime. Strip detectors have remained functional at fluences beyond 10^{14} cm⁻² for minimum ionizing protons. At this damage level, charge loss due to recombination and trapping also seems to become significant.

24.6. Proportional and drift chambers

<u>Proportional chamber wire instability</u>: The limit on the voltage V for a wire tension T, due to mechanical effects when the electrostatic repulsion of adjacent wires exceeds the restoring force of wire tension, is given by (SI units) [31]

$$V \le \frac{s}{\ell C} \sqrt{4\pi\epsilon_0 T} , \qquad (24.11)$$

where s, ℓ , and C are the wire spacing, length, and capacitance per unit length. An approximation to C for chamber half-gap t and wire diameter d (good for $s \lesssim t$) gives [32]

$$V \lesssim 59T^{1/2} \left[\frac{t}{\ell} + \frac{s}{\pi \ell} \ln \left(\frac{s}{\pi d} \right) \right] ,$$
 (24.12)

where V is in kV, and T is in grams-weight equivalent.

<u>Proportional and drift chamber potentials</u>: The potential distributions and fields in a proportional or drift chamber can usually be calculated with good accuracy from the exact formula for the potential around an array of parallel line charges q (coul/m) along z and located at $y=0,\,x=0,\,\pm s,\,\pm 2s,\,\ldots$,

$$V(x,y) = -\frac{q}{4\pi \epsilon_0} \ln \left\{ 4 \left[\sin^2 \left(\frac{\pi x}{s} \right) + \sinh^2 \left(\frac{\pi y}{s} \right) \right] \right\} . \tag{24.13}$$

Errors from the presence of cathodes, mechanical defects, TPC-type edge effects, etc., are usually small and are beyond the scope of this review

24.7. Calorimeters

Electromagnetic calorimeters: The development of electromagnetic showers is discussed in the "Passage of Particles Through Matter" section (Sec. 22 of this *Review*). Formulae are given for the approximate description of average showers, but since the physics of electromagnetic showers is well understood, detailed and reliable Monte Carlo simulation is possible. EGS4 has emerged as the standard [33].

The resolution of sampling calorimeters (hadronic and electromagnetic) is usually dominated by sampling fluctuations, leading to fractional resolution σ/E scaling inversely as the square root of the incident energy. Homogenous calorimeters, such as solid NaI(Tl), will

in general not have resolution varying as $1/\sqrt{E}$. At high energies deviations from $1/\sqrt{E}$ occur because of noise, pedestal fluctuations, nonuniformities, calibration errors, and incomplete shower containment. Such effects are usually included by adding a constant term to σ/E , either in quadrature or (incorrectly) directly. In the case of the hadronic cascades discussed below, noncompensation also contributes to the constant term.

In Table 24.4 we give resolution as measured in detectors using typical EM calorimeter technologies. In almost all cases the installed calorimeters yield worse resolution than test beam prototypes for a variety of practical reasons. Where possible actual detector performance is given. For a fixed number of radiation lengths, the FWHM in sandwich detectors would be expected to be proportional to \sqrt{t} for t (= plate thickness) \geq 0.2 radiation lengths [34].

Given sufficient transverse granularity early in the calorimeter, position resolution of the order of a millimeter can be obtained.

Table 24.4: Resolution of typical electromagnetic calorimeters. E is in GeV.

Detector	Resolution
$NaI(Tl)$ (Crystal Ball [35]; 20 X_0)	$2.7\%/E^{1/4}$
Lead glass (OPAL [36])	$5\%/\sqrt{E}$
Lead-liquid argon (NA31 [37]; 80 cells: 27 X_0 , 1.5 mm Pb + 0.6 mm Al + 0.8 mm G10 + 4 mm LA)	$7.5\%/\sqrt{E}$
Lead-scintillator sandwich (ARGUS [38], LAPP-LAL [39])	$9\%/\sqrt{E}$
Lead-scintillator spaghetti (CERN test module) [40]	$13\%/\sqrt{E}$
Proportional wire chamber (MAC; 32 cells: 13 X_0 , 2.5 mm typemetal + 1.6 mm Al) [41]	$23\%/\sqrt{E}$

<u>Hadronic calorimeters</u> [42,43]: The length scale appropriate for hadronic cascades is the nuclear interaction length, given very roughly by

$$\lambda_I \approx 35 \text{ g cm}^{-2} A^{1/3}$$
 (24.14)

Longitudinal energy deposition profiles are characterized by a sharp peak near the first interaction point (from the fairly local deposition of EM energy resulting from π^0 's produced in the first interaction), followed by a more gradual development with a maximum at

$$x/\lambda_I \equiv t_{\text{max}} \approx 0.2 \ln(E/1 \text{ GeV}) + 0.7 \tag{24.15}$$

as measured from the front of the detector.

The depth required for containment of a fixed fraction of the energy also increases logarithmically with incident particle energy. The thickness of iron required for 95% (99%) containment of cascades induced by single hadrons is shown in Fig. 24.2 [44]. Two of the sets of data are from large neutrino experiments, while the third is from a commonly used parametrization. Depths as measured in nuclear interaction lengths presumably scale to other materials. From the same data it can be concluded that the requirement that 95% of the energy in 95% of the showers be contained requires 40 to 50 cm (2.4 to $3.0 \ \lambda_I$) more material material than for an average 95% containment.

The transverse dimensions of hadronic showers also scale as λ_I , although most of the energy is contained in a narrow core.

The energy deposit in a hadronic cascade consists of a prompt EM component due to π^0 production and a slower component mainly due to low-energy hadronic activity. In general, these energy depositions are converted to electrical signals with different efficiencies [45]. The ratio of the conversion efficiencies is usually called the intrinsic e/h ratio. If e/h=1.0 the calorimeter is said to be compensating. If it differs from unity by more than 5% or 10%, detector performance is compromised because of fluctuations in the π^0 content of the cascades. Problems include:

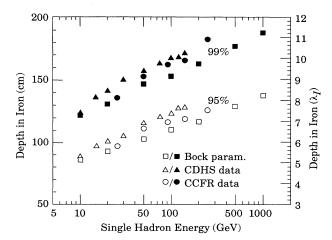


Figure 24.2: Required calorimeter thickness for 95% and 99% hadronic cascade containment in iron, on the basis of data from two large neutrino detectors and the parametrization of Bock et al. [44].

- a) A skewed signal distribution;
- b) A response ratio for electrons and hadrons (the " e/π ratio") which is different from unity and depends upon energy;
- c) A nonlinear response to hadrons (the response per GeV is proportional to the reciprocal of e/π);
- d) A constant contribution to detector resolution, almost proportional to the degree of noncompensation. The coefficient relating the constant term to |1-e/h| is 14% according to FLUKA simulations, and 21% according to Wigman's calculations [42].

In most cases e/h is greater than unity, particularly if little hydrogen is present or if the gate time is short. This is because much of the low-energy hadronic energy is "hidden" in nuclear binding energy release, low-energy spallation products, etc. Partial correction for these losses occurs in a sampling calorimeter with thick plates, because a disproportionate fraction of electromagnetic energy is deposited in the inactive region. For this reason, a fully sensitive detector such as BGO or glass cannot be made compensating.

Compensation has been demonstrated in calorimeters with 2.5 mm scintillator sheets sandwiched between 3 mm depleted uranium plates [47] or 10 mm lead plates [48]; resolutions σ/E of $0.34/\sqrt{E}$ and $0.44/\sqrt{E}$ were obtained for these cases (E in GeV). The former was shown to be linear to within 2% over three orders of magnitude in energy, with approximately Gaussian signal distributions.

24.8. Measurement of particle momenta in a uniform magnetic field [54]

The trajectory of a particle with momentum p (in GeV/c) and charge ze in a constant magnetic field \overrightarrow{B} is a helix, with radius of curvature R and pitch angle λ . The radius of curvature and momentum component perpendicular to \overrightarrow{B} are related by

$$p\cos\lambda = 0.3 z B R$$
, (24.16)

where B is in tesla and R is in meters.

The distribution of measurements of the curvature $k\equiv 1/R$ is approximately Gaussian. The curvature error for a large number of uniformly spaced measurements on the trajectory of a charged particle in a uniform magnetic field can be approximated by

$$(\delta k)^2 = (\delta k_{\rm res})^2 + (\delta k_{\rm ms})^2$$
, (24.17)

where $\delta k = \text{curvature error}$

 $\delta k_{
m res} = {
m curvature~error}$ due to finite measurement resolution $\delta k_{
m ms} = {
m curvature~error}$ due to multiple scattering.

If many (≥ 10) uniformly spaced position measurements are made along a trajectory in a uniform medium,

$$\delta k_{\rm res} = \frac{\epsilon}{L^2} \sqrt{\frac{720}{N+4}} \,, \tag{24.18}$$

where N = number of points measured along track

L'= the projected length of the track onto the bending plane $\epsilon=$ measurement error for each point, perpendicular to the

If a vertex constraint is applied at the origin of the track, the coefficient under the radical becomes 320.

The contribution due to multiple Coulomb scattering is approximately

$$\delta k_{\rm ms} \approx \frac{(0.016)({\rm GeV}/c)z}{Lp\beta\cos^2\lambda}\sqrt{\frac{L}{X_0}} \;,$$
 (24.19)

where $p={
m momentum}~({
m GeV}/c)$

trajectory.

z = charge of incident particle in units of e

L = the total track length

 X_0 = radiation length of the scattering medium (in units of length; the X_0 defined elsewhere must be multiplied by density)

 $\beta =$ the kinematic variable v/c.

More accurate approximations for multiple scattering may be found in the section on Passage of Particles Through Matter (Sec. 22 of this Review). The contribution to the curvature error is given approximately by $\delta k_{\rm ms} \approx 8 s_{\rm plane}^{\rm rms}/L^2$, where $s_{\rm plane}^{\rm rms}$ is defined there.

24.9. Superconducting solenoids for collider detectors

24.9.1. Basic (approximate) equations: In all cases SI units are assumed, so that B is in tesla, E is in joules, dimensions are in meters, and $\mu_0 = 4\pi \times 10^{-7}$.

<u>Magnetic field</u>: The magnetic field at the center of a solenoid of length L and radius R, having N total turns and a current I is

$$B(0,0) = \frac{\mu_0 NI}{\sqrt{L^2 + 4R^2}} \ . \tag{24.20}$$

Stored energy: The energy stored in the magnetic field of any magnet is calculated by integrating B^2 over all space:

$$E = \frac{1}{2\mu_0} \int B^2 dV \ . \tag{24.21}$$

For a solenoid with an iron flux return in which the magnetic field is < 2T, the field in the aperture is approximately uniform and equal to $\mu_0 NI/L$. If the thickness of the coil is small, (which is the case if it is superconducting), then

$$E \approx (\pi/2\mu_0)B^2R^2L$$
 (24.22)

Cost of a superconducting solenoid [55]:

Cost (in M\$) =
$$0.523 [(E/(1 \text{ MJ})]^{0.662}$$
 (24.23)

<u>Magnetostatic computer programs</u>: It is too difficult to solve the Biot-Savart equation for a magnetic circuit which includes iron components and so iterative computer programs are used. These include POISSON, TOSCA [56], and ANSYS [57].

24.9.2. Scaling laws for thin solenoids: For a detector in which the calorimetry is outside the aperture of the solenoid, the coil must be thin in terms of radiation and absorption lengths. This usually means that the coil is superconducting and that the vacuum vessel encasing it is of minimum real thickness and fabricated of a material with long radiation length. There are two major contributers to the thickness of a thin solenoid:

- 1. The conductor, consisting of the current-carrying superconducting material (usually Cu/Nb-Ti) and the quench protecting stabilizer (usually aluminum), is wound on the inside of a structural support cylinder (usually aluminum also). This package typically represents about 60% of the total thickness in radiation lengths. The thickness scales approximately as B^2R .
- 2. Approximately another 25% of the thickness of the magnet comes from the outer cylindrical shell of the vacuum vessel. Since this shell is susceptible to buckling collapse, its thickness is determined by the diameter, length, and the modulus of the material of which it is fabricated. When designing this shell to a typical standard, the real thickness is

$$t = P_c D^{2.5} [(L/D) - 0.45(t/D)^{0.5}] / 2.6Y^{0.4}, \qquad (24.24)$$

where t = shell thickness (in), D = shell diameter (in), L = shell length (in), Y = modulus of elasticity (psi), and $P_c =$ design collapse pressure (= 30 psi). For most large-diameter detector solenoids, the thickness to within a few percent is given by [58]

$$t = P_c D^{2.5} (L/D) / 2.6 Y^{0.4} (24.25)$$

24.9.3. Properties of collider detector solenoids: The physical dimensions, central field, stored energy and thickness in radiation lengths normal to the beam line of the superconducting solenoids associated with the major colliders are given in Table 24.5.

Table 24.5: Properties of superconducting collider detector solenoids.

Experiment-Lab	Field (T)	Bore Dia (m)	Length (m)	Energy (MJ)	Thickness (X_0)
CDF-Fermilab	1.5	2.86	5.07	30	0.86
Topaz-KEK	1.2	2.72	5.4	19.5	0.70
Venus-KEK	0.75	3.4	5.64	12	0.52
Cleo II-Cornell	1.5	2.9	3.8	25	2.5
Aleph-CERN	1.5	5.0	7.0	130	1.7
Delphi-CERN	1.2	5.2	7.4	109	4.0
H1-DESY	1.2	5.2	5.75	120	1.2
Zeus-DESY	1.8	1.72	2.85	10.5	0.9

The ratio of stored energy to cold mass (E/M) is a useful performance measure. One would like the cold mass to be as small as possible to minimize the thickness, but temperature rise during a quench must also be minimized. Ratios as large as 8 kJ/kg may be possible (final temperature of 80 K after a fast quench with homogenous energy dump), but some contingency is desirable. This quantity is shown as a function of total stored energy for some major collider detectors in Fig. 24.3.

24.10. Other observations

 $\underline{dE/dx}$ resolution in argon: Particle identification by dE/dx is dependent on the width of the distribution. For relativistic incident particles with charge e in a multiple-sample Ar gas counter with no lead [49],

$$\frac{dE}{dx}\Big|_{\text{FWHM}} / \frac{dE}{dx}\Big|_{\text{most probable}} = 0.96 \, N^{-0.46} \, (xp)^{-0.32} \, , \quad (24.26)$$

where N= number of samples, x= thickness per sample (cm), p= pressure (atm.). Most commonly used chamber gases (except Xe) give approximately the same resolution.

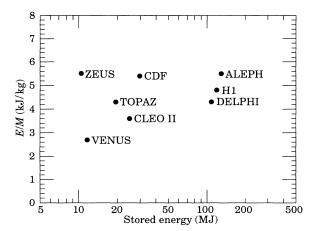


Figure 24.3: Ratio of stored energy to cold mass for existing thin detector solenoids.

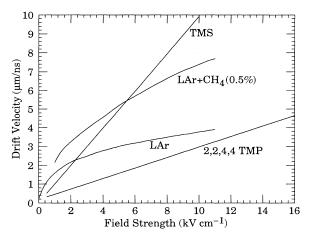


Figure 24.4: Electron drift velocity as a function of field strength for commonly used liquids.

<u>Free electron drift velocities in liquid ionization chambers</u> [50–53]: Velocity as a function of electric field strength is given in Fig. 24.4.

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25. RADIOACTIVITY & RADIATION PROTECTION

Revised Sept. 1995 by R.J. Donahue (LBNL) and A. Fasso (CERN).

25.1. Definitions

The International Commission on Radiation Units and Measurements (ICRU) recommends the use of SI units. Therefore we list SI units first, followed by cgs (or other common) units in parentheses, where they differ.

- Unit of activity = becquerel (curie):
 - 1 Bq = 1 disintegration $s^{-1} = 1/(3.7 \times 10^{10})$ Ci
- Unit of absorbed dose = gray (rad):
 - 1 Gy = 1 joule kg^{-1} (= 10^4 erg g^{-1} = 100 rad) = 6.24×10^{12} MeV kg^{-1} deposited energy
- Unit of exposure, the quantity of x- or γ radiation at a point in space integrated over time, in terms of charge of either sign produced by showering electrons in a small volume of air about the point:
 - = 1 coul kg⁻¹ of air (roentgen; 1 $R = 2.58 \times 10^{-4}$ coul kg⁻¹)
 - $= 1 \text{ esu cm}^{-3} (= 87.8 \text{ erg released energy per g of air})$

Implicit in the definition is the assumption that the small test volume is embedded in a sufficiently large uniformly irradiated volume that the number of secondary electrons entering the volume equals the number leaving. This unit is somewhat historical, but appears on many measuring instruments.

• Unit of equivalent dose (for biological damage) = sievert [= 100 rem (roentgen equivalent for man)]: Equivalent dose in Sv = absorbed dose in grays \times w_R , where w_R (radiation weighting factor, formerly the quality factor Q) expresses long-term risk (primarily cancer and leukemia) from low-level chronic exposure. It depends upon the type of radiation and other factors, as follows [2]:

Table 25.1: Radiation weighting factors.

Radiation	w_R
X - and γ -rays, all energies	1
Electrons and muons, all energies	1
Neutrons < 10 keV	5
10-100 keV	10
$> 100 \mathrm{\ keV}$ to 2 MeV	20
$2-20~{ m MeV}$	10
$> 20 \mathrm{MeV}$	5
Protons (other than recoils) > 2 MeV	5
Alphas, fission fragments, & heavy nuclei	20

25.2. Radiation levels [3]

- Natural annual background, all sources: Most world areas, whole-body equivalent dose rate $\approx (0.4\text{--}4)$ mSv (40–400 millirems). Can range up to 50 mSv (5 rems) in certain areas. U.S. average ≈ 3.6 mSv, including ≈ 2 mSv (≈ 200 mrem) from inhaled natural radioactivity, mostly radon and radon daughters (0.1–0.2 mSv in open areas. Average is for a typical house and varies by more than an order of magnitude. It can be more than two orders of magnitude higher in poorly ventilated mines).
- Cosmic ray background in counters (Earth's surface): $\sim 1~{\rm min^{-1}~cm^{-2}}$ sr. For more accurate estimates and details, see the Cosmic Rays section (Sec. 20 of this Review).
- Fluxes (per cm²) to deposit one Gy, assuming uniform irradiation: $\approx (\text{charged particles}) 6.24 \times 10^9/(dE/dx)$, where dE/dx (MeV g⁻¹ cm²), the energy loss per unit length, may be obtained from the Mean Range and Energy Loss figures.
- $\approx 3.5 \times 10^9~{\rm cm}^{-2}$ minimum-ionizing singly-charged particles in carbon.
- $\approx ({\bf photons})~6.24\times 10^9/[Ef/\lambda],$ for photons of energy E (MeV), attenuation length λ (g cm $^{-2})$ (see Photon Attenuation Length

figure), and fraction $f\lesssim 1$ expressing the fraction of the photon's energy deposited in a small volume of thickness $\ll \lambda$ but large enough to contain the secondary electrons.

 $\approx 2\times 10^{11}~\rm photons~cm^{-2}~for~1~MeV~photons~on~carbon~(\it f\approx 1/2).$

(Quoted fluxes are good to about a factor of 2 for all materials.)

ullet Recommended limits to exposure of radiation workers (whole-body dose):*

CERN: 15 mSv yr⁻¹ **U.K.:** 15 mSv yr⁻¹

U.S.: 50 mSv yr⁻¹ (5 rem yr⁻¹) †

• Lethal dose: Whole-body dose from penetrating ionizing radiation resulting in 50% mortality in 30 days (assuming no medical treatment) 2.5–3.0 Gy (250–300 rads), as measured internally on body longitudinal center line. Surface dose varies due to variable body attenuation and may be a strong function of energy.

25.3. Prompt neutrons at accelerators

25.3.1. Electron beams: At electron accelerators neutrons are generated via photonuclear reactions from bremsstrahlung photons. Neutron yields from semi-infinite targets per unit electron beam power are plotted in Fig. 25.1 as a function of electron beam energy [4]. In the photon energy range 10–30 MeV neutron production results from the giant photonuclear resonance mechanism. Neutrons are produced roughly isotropically (within a factor of 2) and with a Maxwellian energy distribution described as:

$$\frac{dN}{dE_n} = \frac{E_n}{T^2} e^{-E_n/T} \ , \tag{25.1}$$

where T is the nuclear temperature characteristic of the target nucleus, generally in the range of T=0.5–1.0 MeV. For higher energy photons the quasi-deuteron and photopion production mechanisms become important.

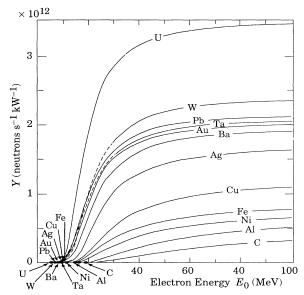


Figure 25.1: Neutron yields from semi-infinite targets, per kW of electron beam power, as a function of electron beam energy, disregarding target self-shielding.

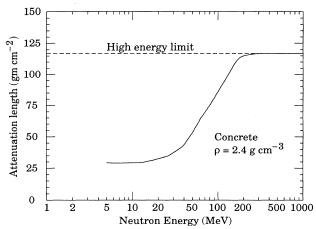


Figure 25.3: The variation of the attenuation length for monoenergetic neutrons in concrete as a function of neutron energy [5].

25.3.2. *Proton beams*: At proton accelerators neutron yields emitted per incident proton by different target materials are roughly independent [5] of proton energy between 20 MeV and 1 GeV and are given by the ratio C:Al:Cu-Fe:Sn:Ta-Pb = 0.3:0.6:1.0:1.5:1.7. Above 1 GeV neutron yield [6] is proportional to E^m , where $0.80 \le m \le 0.85$.

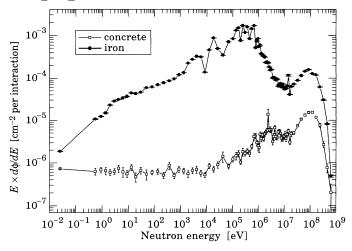


Figure 25.2: Calculated neutron spectrum from 205 GeV/c hadrons (2/3 protons and 1/3 π^+) on a thick copper target. Spectra are evaluated at 90° to beam and through 80 cm of normal density concrete or 40 cm of iron.

A typical neutron spectrum [7] outside a proton accelerator concrete shield is shown in Fig. 25.2. The shape of these spectra are generally characterized as having a thermal-energy peak which is very dependent on geometry and the presence of hydrogenic material, a low-energy evaporation peak around 2 MeV, and a high-energy spallation shoulder.

Letaw's [8] formula for the energy dependence of the inelastic proton cross-section (asymptotic values given in Table 6.1) for E < 2 GeV is:

$$\sigma(E) = \sigma_{\text{asympt}} \left[1 - 0.62e^{-E/200} \sin(10.9E^{-0.28}) \right] ,$$
 (25.2)

and for E > 2 GeV:

$$\sigma_{\text{asympt}} = 45A^{0.7} [1 + 0.016 \sin(5.3 - 2.63 \ln A)] ,$$
 (25.3)

where σ is in mb, E is the proton energy in MeV and A is the mass number.

The neutron-attenuation length, λ , is shown in Fig. 25.3 for monoenergetic broad-beam conditions. These values give a satisfactory representation at depths greater than 1 m in concrete.

25.4. Dose conversion factors

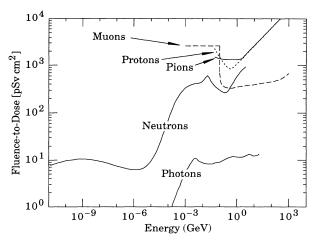


Figure 25.4: Fluence to dose equivalent conversion factors for various particles.

Fluence to dose equivalent factors are given in Fig. 25.4 for photons [9], neutrons [10], muons [11], protons and pions [12]. These factors can be used for converting particle fluence to dose for personnel protection purposes.

25.5. Accelerator-induced activity

The dose rate at 1 m due to spallation-induced activity by high energy hadrons in a 1 g medium atomic weight target can be estimated [13] from the following expression:

$$D = D_0 \Phi \ln[(T+t)/t] , \qquad (25.4)$$

where T is the irradiation time, t is the decay time since irradiation, Φ is the flux of irradiating hadrons (hadrons cm⁻² s⁻¹) and D_0 has a value of 5.2×10^{-17} [(Sv hr⁻¹)/(hadron cm⁻² s⁻¹)]. This relation is essentially independent of hadron energy above 200 MeV.

Dose due to accelerator-produced induced activity can also be estimated with the use of " ω factors" [5]. These factors give the dose rate per unit star density (inelastic reaction for E > 50 MeV) after a 30 day irradiation and 1 day decay. The ω factors for concrete and steel are 1.2×10^{-8} (Sv cm³/star) and 4.5×10^{-8} (Sv cm³/star), respectively. These do not include contributions from thermal-neutron activation. This can vary widely depending on concrete composition, particularly with the concentration of trace quantities such as sodium. Additional information can be found in Barbier [14].

25.6. Photon sources

The dose rate from a gamma point source of C Curies emitting one photon of energy 0.07 < E < 4 MeV per disintegration at a distance of 30 cm is 6CE (rem/hr), or 60CE (mSv/hr), $\pm 20\%$.

The dose rate from a semi-infinite uniform photon source of specific activity C (μ Ci/g) and gamma energy E (MeV) is 1.07CE (rem/hr), or 10.7CE (mSv/hr).

25.7. Radiation levels in detectors at hadron colliders

An SSC Central Design Group task force studied the radiation levels to be expected in SSC detectors [15]. The study focused on scaling with energy, distance, and angle. As such, it is applicable to future detectors such as those at the LHC. Although superior detector-specific calculations have since been made, the scaling is in most cases not evident, and so the SSC results have some relevance. The SSC/CDG model assumed

- The machine luminosity at $\sqrt{s}=40$ TeV is $\mathscr{L}=10^{33}$ cm⁻²s⁻¹, and the pp inelastic cross section is $\sigma_{\rm inel}=100$ mb. This luminosity is effectively achieved for 10^7 s yr⁻¹. The interaction rate is thus 10^8 s⁻¹, or 10^{15} yr⁻¹;
- All radiation comes from pp collisions at the interaction point;
- The charged particle distribution is (a) flat in pseudorapidity for $|\eta| < 6$ and (b) has a momentum distribution whose perpendicular component is independent of rapidity, which is taken as independent of pseudorapidity:

$$\frac{d^2 N_{\rm ch}}{d\eta dp_{\perp}} = H f(p_{\perp}) \tag{25.5}$$

(where $p_{\perp} = p \sin \theta$). Integrals involving $f(p_{\perp})$ are simplified by replacing $f(p_{\perp})$ by $\delta(p_{\perp} - \langle p_{\perp} \rangle)$; in the worst case this approximation introduces an error of less than 10%;

- Gamma rays from π^0 decay are as abundant as charged particles. They have approximately the same η distribution, but half the mean momentum:
- At the SSC ($\sqrt{s}=40$ TeV), $H\approx 7.5$ and $\langle p_{\perp}\rangle\approx 0.6$ GeV/c; assumed values at other energies are given in Table 25.3. Together with the model discussed above, these values are thought to describe particle production to within a factor of two or better.

It then follows that the flux of charged particles from the interaction point passing through a normal area da located a distance r_{\perp} from the beam line is given by

$$\frac{dN_{\rm ch}}{da} = \frac{1.2 \times 10^8 \,\mathrm{s}^{-1}}{r_\perp^2} \ . \tag{25.6}$$

In a typical organic material, a relativistic charged particle flux of $3 \times 10^9 \text{ cm}^{-2}$ produces an ionizing radiation dose of 1 Gy, where 1 Gy \equiv 1 joule kg⁻¹ (= 100 rads). The above result may thus be rewritten as dose rate.

$$\dot{D} = \frac{0.4 \text{ MGy yr}^{-1}}{(r_{\perp}/1 \text{ cm})^2} \ . \tag{25.7}$$

If a magnetic field is present, "loopers" may increase this dose rate by a factor of two ore more.

In a medium in which cascades can develop, the ionizing dose or neutron fluence is proportional to $dN_{\rm ch}/da$ multiplied by $\langle E \rangle^{\alpha}$, where $\langle E \rangle$ is the mean energy of the particles going through da and the power α is slightly less than unity. Since $E \approx p = p_{\perp}/\sin\theta$ and $r_{\perp} = r\sin\theta$, the above expression for $dN_{\rm ch}/da$ becomes

Dose or fluence
$$= \frac{A}{r^2} \cosh^{2+\alpha} \eta = \frac{A}{r^2 \sin^{2+\alpha} \theta}$$
. (25.8)

The constant A contains the total number of interactions $\sigma_{\rm inel} \int \mathscr{L} dt$, so the ionizing dose or neutron fluence at another accelerator scales as $\sigma_{\rm inel} \int \mathscr{L} dt \, H \, \langle p_{\perp} \rangle^{\alpha}$.

The dose or fluence in a calorimeter scales as $1/r^2$, as does the neutron fluence inside a central cavity with characteristic dimension r.

Under all conditions so far studied, the neutron spectrum shows a broad log-normal distribution peaking at just under 1 MeV. In a 2 m radius central cavity of a detector with coverage down to $|\eta|=3$, the average neutron flux is $2\times 10^{12}~{\rm cm}^{-2}{\rm yr}^{-1}$, including secondary scattering contributions.

Values of A and α are given in Table 25.2 for several relevant situations. Examples of scaling to other accelerators are given in Table 25.3. It should be noted that the assumption that all radiation comes from the interaction point does not apply to the present generation of accelerators.

The constant A includes factors evaluated with cascade simulation programs as well as constants describing particle production at the interaction point. It is felt that each could introduce an error as large as a factor of two in the results.

Table 25.2: Coefficients $A/(100 \text{ cm})^2$ and α for the evaluation of calorimeter radiation levels at cascade maxima under SSC nominal operating conditions. At a distance r and angle θ from the interaction point the annual fluence or dose is $A/(r^2 \sin^{2+\alpha} \theta)$.

Quantity	$A/(100 { m cm})^2$	Units	$\langle p_{\perp} \rangle$	α
Neutron flux	1.5×10^{12}	$\mathrm{cm}^{-2}\mathrm{yr}^{-1}$	$0.6~{ m GeV}/c$	0.67
Dose rate from photons	124	$\rm Gy~\rm yr^{-1}$	$0.3~{ m GeV}/c$	0.93
Dose rate from hadrons	29	$\mathrm{Gy}\ \mathrm{yr}^{-1}$	$0.6~{ m GeV}/c$	0.89

Table 25.3: A rough comparison of beam-collision induced radiation levels at the Tevatron, high-luminosity LHC, SSC, and a possible 100 TeV machine [16].

Tevatron	LHC	SSC	$100 \mathrm{TeV}$	
1.8	15.4	40	100	
2×10^{30}	$1.7 \times 10^{34^a}$	1×10^{33}	1×10^{34}	
$56~\mathrm{mb}$	84 mb	$100~\mathrm{mb}$	$134~\mathrm{mb}$	
3.9	6.2	7.5	10.6	
0.46	0.55	0.60	0.70	
5×10^{-4}	11	1	20	
	1.8 2×10^{30} 56 mb 3.9 0.46	$ \begin{array}{cccc} 1.8 & 15.4 \\ 2 \times 10^{30} & 1.7 \times 10^{34^a} \\ 56 \text{ mb} & 84 \text{ mb} \\ 3.9 & 6.2 \\ 0.46 & 0.55 \end{array} $	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	

 $[^]a$ High-luminosity option.

Footnotes:

- * The ICRP recomendation [2] is 20 mSv yr⁻¹ averaged over 5 years, with the dose in any one year \leq 50 mSv.
- [†] Many laboratories in the U.S. and elsewhere set lower limits.
- [‡] Dose is the time integral of dose rate, and fluence is the time integral of flux.

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 $[^]b$ Proportional to $\mathscr{L}_{\mathrm{nom}}\,\sigma_{\mathrm{inel}}\,H\,\left\langle p_{\perp}\right\rangle^{0.7}$

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26. COMMONLY USED RADIOACTIVE SOURCES

Table 26.1. Updated November 1993 by E. Browne.

			Parti		Photon
Nuclide		decay	(MeV)	Emission prob.	Energy Emission (MeV) prob.
²² Na	2.603 y	β^+ , EC	0.545	90%	0.511 Annih. 1.275 100%
64 Mn	0.855 y	EC			0.835 100% Cr K x rays 26%
55 Fe	2.73 y	EC			Mn K x rays: 0.00589 25% 0.00649 3.4%
57°Co	0.744 y	EC			0.014 9% 0.122 86% 0.136 11% Fe K x rays 58%
⁵⁰ 27Co	5.271 y	β^-	0.316	100%	1.173 100% 1.333 100%
$^{68}_{32}$ Ge	0.742 y	EC			Ga K x rays 44%
$ ightarrow ^{68}_{31} \mathrm{Ga}$		β^+ , EC	1.899	90%	0.511 Annih. 1.077 3%
90 38 Sr	28.5 у	β^-	0.546	100%	
$\rightarrow {}^{90}_{39} Y$		β^-	2.283	100%	
¹⁰⁶ Ru	1.020 y		0.039	100%	4.000
$ ightarrow ^{106}_{45} \mathrm{Rh}$	1	β^-	3.541	79%	$\begin{array}{ccc} 0.512 & 21\% \\ 0.622 & 10\% \end{array}$
¹⁰⁹ ₄₈ Cd	1.267 y	EC	$0.063 e^{-}$ $0.084 e^{-}$ $0.087 e^{-}$	45%	0.088 3.6% Ag K x rays 100
$^{113}_{50}{ m Sn}$	0.315 у	EC	$0.364 \ e^{-}$ $0.388 \ e^{-}$		0.392 65% In K x rays 97%
$^{137}_{55}\mathrm{Cs}$	30.2 у	β^-	$0.514 \ e^{-1}$ $1.176 \ e^{-1}$		0.662 85%
¹³³ ₅₆ Ba	10.54 y	EC	$0.045 \ e^{-}$ $0.075 \ e^{-}$		0.081 34% 0.356 62% Cs K x rays 121
²⁰⁷ 83Bi	31.8 у	EC	0.481 e ⁻ 0.975 e ⁻ 1.047 e ⁻	7%	0.569 98% 1.063 75% 1.770 7% Pb K x rays 78%
²²⁸ Th	1.912 y	6α : $3\beta^-$:	5.341 to 0.334 to		0.239 44% 0.583 31%
$(\rightarrow^{224}_{88} \mathrm{Ra}$	$ ightarrow {}^{220}_{86}I$	$\operatorname{Rn} \longrightarrow {}^{2}$	²¹⁶ ₈₄ Po -	→ ²¹² ₈₂ Pb –	2.614 36% 212 Bi 212 Po
$^{241}_{95}\mathrm{Am}$	432.7 у	α	5.443 5.486	13% 85%	0.060 36% Np L x rays 38%
²⁴¹ ₉₅ Am/Be	432.2 у			cons (4–8 Mc .43 MeV) pe	eV) and
²⁴⁴ Cm	18.11 y	α	5.763 5.805	24% 76%	Pu L x rays ~ 9
²⁵² ₉₈ Cf	2.645 y	α (97%)	6.118	15% 82%	
				sion; $80\% < 1$ s/fission; $\langle E_i \rangle$	1 MeV $\langle n \rangle = 2.14 \text{ MeV}$

"Emission probability" is the probability per decay of a given emission; because of cascades these may total more than 100%. Only principal emissions are listed. EC means electron capture, and e^- means monoenergetic internal conversion (Auger) electron. The intensity of 0.511 MeV e^+e^- annihilation photons depends upon the number of stopped positrons. Endpoint β^\pm energies are listed. In some cases when energies are closely spaced, the γ -ray values are approximate weighted averages. Radiation from short-lived daughter isotopes is included where relevant.

Half-lives, energies, and intensities are from E. Browne and R.B. Firestone, *Table of Radioactive Isotopes* (John Wiley & Sons, New York, 1986), recent *Nuclear Data Sheets*, and *X-ray and Gamma-ray Standards for Detector Calibration*, IAEA-TECDOC-619 (1991).

Neutron data are from Neutron Sources for Basic Physics and Applications (Pergamon Press, 1983).

27. PROBABILITY

Revised May 1996.

27.1. General [1-5]

Let x be a possible outcome of an observation. The probability of x is the relative frequency with which that outcome occurs out of a (possibly hypothetical) large set of similar observations. If x can take any value from a continuous range, we write $f(x;\theta)$ dx as the probability of observing x between x and x+dx. The function $f(x;\theta)$ is the probability density function (p.d.f.) for the random variable x, which may depend upon one or more parameters θ . If x can take on only discrete values (e.g., the non-negative integers), then $f(x;\theta)$ is itself a probability, but we shall still call it a p.d.f. The p.d.f. is always normalized to unit area (unit sum, if discrete). Both x and θ may have multiple components and are then often written as column vectors. If θ is unknown and we wish to estimate its value from a given set of data measuring x, we may use statistics (see Sec. 28).

The cumulative distribution function F(a) is the probability that $x \leq a$:

$$F(a) = \int_{-\infty}^{a} f(x) dx$$
 (27.1)

Here and below, if x is discrete-valued, the integral is replaced by a sum. The endpoint a is expressly included in the integral or sum. Then $0 \le F(x) \le 1$, F(x) is nondecreasing, and $\operatorname{Prob}(a < x \le b) = F(b) - F(a)$. If x is discrete, F(x) is flat except at allowed values of x, where it has discontinuous jumps equal to f(x).

Any function of random variables is itself a random variable, with (in general) a different p.d.f. The *expectation value* of any function u(x) is

$$E[u(x)] = \int_{-\infty}^{\infty} u(x) f(x) dx$$
, (27.2)

assuming the integral is finite. For u(x) and v(x) any two functions of x, E(u+v)=E(u)+E(v). For c and k constants, E(cu+k)=cE(u)+k.

The nth moment of a distribution is

$$\alpha_n \equiv E(x^n) = \int_{-\infty}^{\infty} x^n f(x) dx , \qquad (27.3a)$$

and the nth moment about the mean of x, α_1 , is

$$m_n \equiv E[(x - \alpha_1)^n] = \int_{-\infty}^{\infty} (x - \alpha_1)^n f(x) dx . \qquad (27.3b)$$

The most commonly used moments are the mean μ and variance σ^2 :

$$\mu \equiv \alpha_1 \tag{27.4a}$$

$$\sigma^2 \equiv \operatorname{Var}(x) \equiv m_2 = \alpha_2 - \mu^2 \ . \tag{27.4b}$$

The mean is the location of the "center of mass" of the probability density function, and the variance is a measure of the square of its width. Note that $Var(cx + k) = c^2 Var(x)$.

Any odd moment about the mean is a measure of the skewness of the p.d.f. The simplest of these is the dimensionless coefficient of skewness $\gamma_1 \equiv m_3/\sigma^3$.

Besides the mean, another useful indicator of the "middle" of the probability distribution is the $median \, x_{\rm med}$, defined by $F(x_{\rm med}) = 1/2; \, i.e.$, half the probability lies above and half lies below $x_{\rm med}$. For a given sample of events, $x_{\rm med}$ is the value such that half the events have larger x and half have smaller x (not counting any that have the same x as the median). If the sample median lies between two observed x values, it is set by convention halfway between them. If the p.d.f. for x has the form $f(x-\mu)$ and μ is both mean and median, then for a large number of events N, the variance of the median approaches $1/[4Nf^2(0)]$, provided f(0) > 0.

Let x and y be two random variables with a joint p.d.f. f(x,y). The marginal p.d.f. of x (the distribution of x with y unobserved) is

$$f_1(x) = \int_{-\infty}^{\infty} f(x, y) \, dy$$
, (27.5)

and similarly for the marginal p.d.f. $f_2(y)$. We define the *conditional* p.d.f. of x, given fixed y, by

$$f_3(y|x) f_1(x) = f(x,y)$$
 (27.6a)

Similarly, the conditional p.d.f. of y, given fixed x, is

$$f_4(x|y) f_2(y) = f(x,y)$$
. (27.6b)

From these definitions we immediately obtain Bayes' theorem [2]:

$$f_4(x|y) = \frac{f_3(y|x) f_1(x)}{f_2(y)} = \frac{f_3(y|x) f_1(x)}{\int f_3(y|x) f_1(x) dx} . \tag{27.7}$$

The mean of x is

$$\mu_x = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} x \, f(x, y) \, dx \, dy = \int_{-\infty}^{\infty} x \, f_1(x) \, dx \,, \tag{27.8}$$

and similarly for y. The *correlation* between x and y is a measure of the dependence of one on the other:

$$\rho_{xy} = E\left[(x - \mu_x)(y - \mu_y) \right] / \sigma_x \, \sigma_y = \operatorname{Cov}(x, y) / \sigma_x \, \sigma_y , \qquad (27.9)$$

where σ_x and σ_y are defined in analogy with Eq. (27.4b). It can be shown that $-1 \le \rho_{xy} \le 1$. Here "Cov" is the covariance of x and y, a 2-dimensional analogue of the variance.

Two random variables are independent if and only if

$$f(x,y) = f_1(x) f_2(y) . (27.10)$$

If x and y are independent then $\rho_{xy}=0$; the converse is not necessarily true except for Gaussian-distributed x and y. If x and y are independent, $E[u(x)\ v(y)]=E[u(x)]\ E[v(y)]$, and $\mathrm{Var}(x+y)=\mathrm{Var}(x)+\mathrm{Var}(y)$; otherwise, $\mathrm{Var}(x+y)=\mathrm{Var}(x)+\mathrm{Var}(y)+2\mathrm{Cov}(x,y)$, and $E(u\ v)$ does not factor.

In a change of continuous random variables from $\mathbf{x} \equiv (x_1, \ldots, x_n)$, with p.d.f. $f(\mathbf{x}) = f(x_1, \ldots, x_n)$, to $\mathbf{y} \equiv (y_1, \ldots, y_n)$, a one-to-one function of the x_i 's, the p.d.f. $g(\mathbf{y}) = g(y_1, \ldots, y_n)$ is found by substitution for (x_1, \ldots, x_n) in f followed by multiplication by the absolute value of the Jacobian of the transformation; that is,

$$g(\mathbf{y}) = f\left[w_1(\mathbf{y}), \dots, w_n(\mathbf{y})\right] |J| . \qquad (27.11)$$

The functions w_i express the *inverse* transformation, $x_i = w_i(\boldsymbol{y})$ for i = 1, ..., n, and |J| is the absolute value of the determinant of the square matrix $J_{ij} = \partial x_i/\partial y_j$. If the transformation from \boldsymbol{x} to \boldsymbol{y} is not one-to-one, the situation is more complex and a unique solution may not exist. For example, if the change is to m < n variables, then a given \boldsymbol{y} may correspond to more than one \boldsymbol{x} , leading to multiple integrals over the contributions [1].

To change variables for discrete random variables simply substitute; no Jacobian is necessary because now f is a probability rather than a probability density.

If f depends upon a parameter set α , a change to a different parameter set $\phi_i = \phi_i(\alpha)$ is made by simple substitution; no Jacobian is used

27.2. Characteristic functions

The characteristic function $\phi(u)$ associated with the p.d.f. f(x) is essentially its (inverse) Fourier transform, or the expectation value of $\exp(iux)$:

$$\phi(u) = E(e^{iux}) = \int_{-\infty}^{\infty} e^{iux} f(x) dx . \qquad (27.12)$$

It is often useful, and several of its properties follow [1].

It follows from Eqs. (27.3a) and (27.12) that the *n*th moment of the distribution f(x) is given by

$$i^{-n}\frac{d^n\phi}{du^n}\bigg|_{u=0} = \int_{-\infty}^{\infty} x^n f(x) dx = \alpha_n . \qquad (27.13)$$

Thus it is often easy to calculate all the moments of a distribution defined by $\phi(u)$, even when f(x) is difficult to obtain.

If $f_1(x)$ and $f_2(y)$ have characteristic functions $\phi_1(u)$ and $\phi_2(u)$, then the characteristic function of the weighted sum ax + by is $\phi_1(au)\phi_2(bu)$. The addition rules for common distributions (e.g., that the sum of two numbers from Gaussian distributions also has a Gaussian distribution) easily follow from this observation.

Let the (partial) characteristic function corresponding to the conditional p.d.f. $f_2(x|z)$ be $\phi_2(u|z)$, and the p.d.f. of z be $f_1(z)$. The characteristic function after integration over the conditional value is

$$\phi(u) = \int \phi_2(u|z) f_1(z) dz . \qquad (27.14)$$

Suppose we can write ϕ_2 in the form

$$\phi_2(u|z) = A(u)e^{ig(u)z} . (27.15)$$

Then

$$\phi(u) = A(u)\phi_1(g(u)) . (27.16)$$

The semi-invariants κ_n are defined by

$$\phi(u) = \exp\left(\sum_{1}^{\infty} \frac{\kappa_n}{n!} (iu)^n\right) = \exp\left(i\kappa_1 u - \frac{1}{2}\kappa_2 u^2 + \ldots\right) . (27.17)$$

The κ_n 's are related to the moments α_n and m_n . The first few relations are

$$\kappa_1=\alpha_1~(=\mu,\,{\rm the\ mean})$$

$$\kappa_2=m_2~=\alpha_2-\alpha_1^2~(=\sigma^2,\,{\rm the\ variance})$$

$$\kappa_3=m_3=\alpha_3-3\alpha_1\alpha_2+2\alpha_1^2~. \tag{27.18}$$

27.3. Some probability distributions

Table 27.1 gives a number of common probability density functions and corresponding characteristic functions, means, and variances. Further information may be found in Refs. 1–6; Ref. 6 has particularly detailed tables. Monte Carlo techniques for generating each of them may be found in our Sec. 29.4. We comment below on all except the trivial uniform distribution.

27.3.1. Binomial distribution: A random process with exactly two possible outcomes is called a Bernoulli process. If the probability of obtaining a certain outcome (a "success") in each trial is p, then the probability of obtaining exactly r successes $(r=0,1,2,\ldots,n)$ in n trials, without regard to the order of the successes and failures, is given by the binomial distribution f(r;n,p) in Table 27.1. If r successes are observed in n_r trials with probability p of a success, and if s successes are observed in n_s similar trials, then t=r+s is also binomial with $n_t=n_r+n_s$.

27.3.2. Poisson distribution: The Poisson distribution $f(r; \mu)$ gives the probability of finding exactly r events in a given interval of x (e.g., space and time) when the events occur independently of one another and of x at an average rate of μ per the given interval. The variance σ^2 equals μ . It is the limiting case $p \to 0$, $n \to \infty$, $np = \mu$ of the binomial distribution. The Poisson distribution approaches the Gaussian distribution for large μ .

Two or more Poisson processes (e.g., signal + background, with parameters μ_s and μ_b) that independently contribute amounts n_s and n_b to a given measurement will produce an observed number $n = n_s + n_b$, which is distributed according to a new Poisson distribution with parameter $\mu = \mu_s + \mu_b$.

27.3.3. Normal or Gaussian distribution: The normal (or Gaussian) probability density function $f(x; \mu, \sigma^2)$ given in Table 27.1 has mean $\overline{x} = \mu$ and variance σ^2 . Comparison of the characteristic function $\phi(u)$ given in Table 27.1 with Eq. (27.17) shows that all semi-invariants κ_n beyond κ_2 vanish; this is a unique property of the Gaussian distribution. Some properties of the distribution are:

```
rms deviation = \sigma probability x in the range \mu \pm \sigma = 0.6827 probability x in the range \mu \pm 0.6745\sigma = 0.5 expection value of |x - \mu|, E(|x - \mu|) = (2/\pi)^{1/2}\sigma = 0.7979\sigma half-width at half maximum = (2 \ln 2)^{1/2}\sigma = 1.177\sigma
```

The cumulative distribution, Eq. (27.1), for a Gaussian with $\mu=0$ and $\sigma^2=1$ is related to the error function $\mathrm{erf}(y)$ by

$$F(x;0,1) = \frac{1}{2} \left[1 + \operatorname{erf}(x/\sqrt{2}) \right] . \tag{27.19}$$

The error function is tabulated in Ref. 6 and is available in computer math libraries and personel computer spreadsheets. For a mean μ and variance σ^2 , replace x by $(x - \mu)/\sigma$. The probability of x in a given range can be calculated with Eq. (28.34).

For x and y independent and normally distributed, z = ax + by obeys $f(z; a\mu_x + b\mu_y, a^2\sigma_x^2 + b^2\sigma_y^2)$; that is, the weighted means and variances add.

The Gaussian gets its importance in large part from the central limit theorem: If a continuous random variable x is distributed according to any p.d.f. with finite mean and variance, then the sample mean, \overline{x}_n , of n observations of x will have a p.d.f. that approaches a Gaussian as n increases. Therefore the end result $\sum^n x_i \equiv n\overline{x}_n$ of a large number of small fluctuations x_i will be distributed as a Gaussian, even if the x_i themselves are not.

For a set of n Gaussian random variables x with means μ and corresponding Fourier variables u, the characteristic function for a one-dimensional Gaussian is generalized to

$$\phi(\mathbf{x}; \boldsymbol{\mu}, S) = \exp\left[i\boldsymbol{\mu} \cdot \boldsymbol{u} - \frac{1}{2}\boldsymbol{u}^T S \boldsymbol{u}\right] . \tag{27.20}$$

From Eq. (27.13), the covariance about the mean is

$$E[(x_j - \mu_j)(x_k - \mu_k)] = S_{jk}. (27.21)$$

If the x are independent, then $S_{jk}=\delta_{jk}\sigma_j^2$, and Eq. (27.20) is the product of the c.f.'s of n Gaussians.

The covariance matrix S can be related to the correlation matrix defined by Eq. (27.9) (a sort of normalized covariance matrix). With the definition $\sigma_k^2 \equiv S_{kk}$, we have $\rho_{jk} = S_{jk}/\sigma_j\sigma_k$.

The characteristic function may be inverted to find the corresponding p.d.f.

$$f(\mathbf{x}; \boldsymbol{\mu}, S) = \frac{1}{(2\pi)^{n/2} \sqrt{|S|}} \exp \left[-\frac{1}{2} (\mathbf{x} - \boldsymbol{\mu})^T S^{-1} (\mathbf{x} - \boldsymbol{\mu}) \right], (27.22)$$

where the determinant |S| must be greater than 0. For diagonal S (independent variables), $f(x; \mu, S)$ is the product of the p.d.f.'s of n Gaussian distributions.

Distribution	Probability density function f (variable; parameters)	Characteristic function $\phi(u)$	Mean	Variance σ
Uniform	$f(x; a, b) = \begin{cases} 1/(b-a) & a \le x \le b \\ 0 & \text{otherwise} \end{cases}$	$\frac{e^{ibu} - e^{iau}}{(b-a)iu}$	$\overline{x} = \frac{a+b}{2}$	$\frac{(b-a)^2}{12}$
Binomial	$f(r; n, p) = \frac{n!}{r!(n-r)!} p^r q^{n-r}$ $r = 0, 1, 2, \dots, n ; 0 \le p \le 1 ; q = 1-p$	$(q+pe^{iu})^n$	$\overline{r}=np$	npq
Poisson	$f(r;\mu) = \frac{\mu^r e^{-\mu}}{r!} \; ; r = 0, 1, 2, \dots \; ; \mu > 0$	$\exp[\mu(e^{iu}-1)]$	$\overline{r}=\mu$	μ
Normal (Gaussian)	$f(x; \mu, \sigma^2) = \frac{1}{\sigma\sqrt{2\pi}} \exp(-(x - \mu)^2/2\sigma^2)$ $-\infty < x < \infty ; -\infty < \mu < \infty ; \sigma > 0$	$\exp(i\mu u - \frac{1}{2}\sigma^2 u^2)$	$\overline{x} = \mu$	σ^2
Multivariate Gaussian	$f(\boldsymbol{x};\boldsymbol{\mu},S) = \frac{1}{(2\pi)^{n/2}\sqrt{ S }}$	$\exp\left[i\boldsymbol{\mu}\cdot\boldsymbol{u}-\frac{1}{2}\boldsymbol{u}^TS\boldsymbol{u}\right]$	μ	S_{jk}
	$\times \exp\left[-\frac{1}{2}(\boldsymbol{x} - \boldsymbol{\mu})^T S^{-1}(\boldsymbol{x} - \boldsymbol{\mu})\right]$ $-\infty < x_j < \infty; -\infty < x_j < \infty; \det S > 0$			
χ^2	$f(z;n) = \frac{z^{n/2-1}e^{-z/2}}{2^{n/2}\Gamma(n/2)}$; $z \ge 0$	$(1-2iu)^{-n/2}$	$\overline{z}=n$	2n
Student's t	$f(t;n) = \frac{1}{\sqrt{n\pi}} \frac{\Gamma[(n+1)/2]}{\Gamma(n/2)} \left(1 + \frac{t^2}{n}\right)^{-(n+1)/2}$ $-\infty < t < \infty ; \qquad n \text{ not required to be integer}$		$\bar{t} = 0$ for $n \ge 2$	$n/(n-2)$ for $n \ge 3$
Gamma	$f(x; \lambda, k) = rac{x^{k-1} \lambda^k e^{-\lambda x}}{\Gamma(k)} \; ; 0 < x < \infty \; ;$ $k \; ext{not required to be integer}$	$(1-iu/\lambda)^{-k}$	$\overline{x} = k/\lambda$	k/λ^2

Table 27.1: Some common probability density functions, with corresponding characteristic functions and means and variances. In the Table, $\Gamma(k)$ is the gamma function, equal to (k-1)! when k is an integer.

For n = 2, $f(\boldsymbol{x}; \boldsymbol{\mu}, S)$ is

$$f(x_1, x_2; \ \mu_1, \mu_2, \sigma_1, \sigma_2, \rho) = \frac{1}{2\pi\sigma_1\sigma_2\sqrt{1-\rho^2}}$$

$$\times \exp\left\{\frac{-1}{2(1-\rho^2)} \left[\frac{(x_1 - \mu_1)^2}{\sigma_1^2} - \frac{2\rho(x_1 - \mu_1)(x_2 - \mu_2)}{\sigma_1\sigma_2} + \frac{(x_2 - \mu_2)^2}{\sigma_2^2} \right] \right\}. \tag{27.23}$$

The marginal distribution of any x_i is a Gaussian with mean μ_i and variance S_{ii} . S is $n \times n$, symmetric, and positive definite. Therefore for any vector \mathbf{X} , the quadratic form $\mathbf{X}^T S^{-1} \mathbf{X} = C$, where C is any positive number, traces an n-dimensional ellipsoid as \mathbf{X} varies. If $X_i = (x_i - \mu_i)/\sigma_i$, then C is a random variable obeying the $\chi^2(n)$ distribution, discussed in the following section. The probability that \mathbf{X} corresponding to a set of Gaussian random variables x_i lies outside the ellipsoid characterized by a given value of $C = \chi^2$ is given by Eq. (27.24) and may be read from Fig. 27.1. For example, the "s-standard-deviation ellipsoid" occurs at $C = s^2$. For the two-variable case (n=2), the point \mathbf{X} lies outside the one-standard-deviation ellipsoid with 61% probability. (This assumes that μ_i and σ_i are correct.) For $X_i = x_i/\sigma_i$, the ellipsoids of constant χ^2 have the same size and orientation but are centered at μ . The use of these ellipsoids as indicators of probable error is described in Sec. 28.6.1.

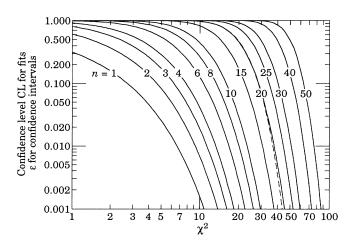


Figure 27.1: The confidence level versus χ^2 for n degrees of freedom, as defined in Eq. (27.24). The curve for a given n gives the probability that a value at least as large as χ^2 will be obtained in an experiment; e.g., for n=10, a value $\chi^2\gtrsim 18$ will occur in 5% of a large number of experiments. For a fit, the CL is a measure of goodness-of-fit, in that a good fit to a correct model is expected to yield a low χ^2 (see Sec. 28.5.0). For a confidence interval, α measures the probability that the interval does not cover the true value of the quantity being estimated (see Sec. 28.6). The dashed curve for n=20 is calculated using the approximation of Eq. (27.25).

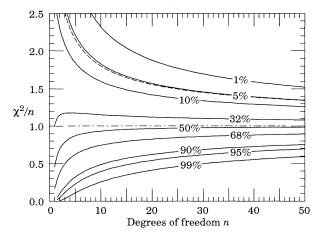


Figure 27.3: Confidence levels as a function of the "reduced χ^2 " $\equiv \chi^2/n$ and the number of degrees of freedom n. Curves are labeled by the probability that a measurement will give a value of χ^2/n greater than that given on the y axis; e.g., for n=10, a value $\chi^2/n \gtrsim 1.8$ can be expected 5% of the time.

27.3.4. χ^2 distribution: If x_1, \ldots, x_n are independent Gaussian distributed random variables, the sum $z = \sum^n (x_i - \mu_i)^2 / \sigma_i^2$ is distributed as a χ^2 with n degrees of freedom, $\chi^2(n)$. Under a linear transformation to n dependent Gaussian variables x_i' , the χ^2 at each transformed point retains its value; then $z = \mathbf{X}'^T V^{-1} \mathbf{X}'$ as in the previous section. For a set of z_i , each of which is $\chi^2(n_i)$, $\sum z_i$ is a new random variable which is $\chi^2(\sum n_i)$.

Fig. 27.1 shows the confidence level (CL) obtained by integrating the tail of f(z; n):

$$CL(\chi^2) = \int_{\chi^2}^{\infty} f(z; n) dz$$
 (27.24)

This is shown for a special case in Fig. 27.2, and is equal to 1.0 minus the cumulative distribution function $F(z=\chi^2;n)$. It is useful in evaluating the consistency of data with a model (see Sec. 28): The CL is the probability that a random repeat of the given experiment would observe a greater χ^2 , assuming the model is correct. It is also useful for confidence intervals for statistical estimators (see Sec. 28.6), in which case one is interested in the unshaded area of Fig. 27.2.

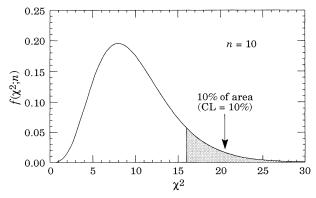


Figure 27.2: Illustration of the confidence level integral given in Eq. (27.24). This particlar example is for n = 10, where the area above 15.99 is 0.1.

Since the mean of the χ^2 distribution is equal to n, one expects in a "reasonable" experiment to obtain $\chi^2 \approx n$. While caution is necessary because of the width and skewness of the distribution, the "reduced χ^2 " $\equiv \chi^2/n$ is a sometimes useful quantity. Figure 27.3 shows χ^2/n for useful CL's as a function of n.

For large n, the CL is approximately given by [1,7]

$$CL(\chi^2) \approx \frac{1}{\sqrt{2\pi}} \int_y^\infty e^{-x^2/2} dx$$
, (27.25)

where $y = \sqrt{2\chi^2} - \sqrt{2n-1}$. This approximation was used to draw the dashed curves in Fig. 27.1 (for n=20) and Fig. 27.3 (for CL = 5%). Since all the functions and their inverses are now readily available in standard mathematical libraries (such as IMSL, used to generate these figures, and personal computer spreadsheets, such as Microsoft (Excel [8]), the approximation (and even figures and tables) are seldom needed.

27.3.5. Student's t distribution: Suppose that x and x_1, \ldots, x_n are independent and Gaussian distributed with mean 0 and variance 1. We then define

$$z = \sum_{i=1}^{n} x_i^2$$
, and $t = \frac{x}{\sqrt{z/n}}$. (27.26)

The variable z thus belongs to a $\chi^2(n)$ distribution. Then t is distributed according to a Student's t distribution with n degrees of freedom, f(t;n), given in Table 27.1.

The Student's t distribution resembles a Gaussian distribution with wide tails. As $n \to \infty$, the distribution approaches a Gaussian. If n=1, the distribution is a *Cauchy* or *Breit-Wigner* distribution. The mean is finite only for n>1 and the variance is finite only for n>2, so for n=1 or n=2, t does not obey the central limit theorem.

As an example, consider the sample mean $\overline{x} = \sum x_i/n$ and the sample variance $s^2 = \sum (x_i - \overline{x})^2/(n-1)$ for normally distributed random variables x_i with unknown mean μ and variance σ^2 . The sample mean has a Gaussian distribution with a variance σ^2/n , so the variable $(\overline{x} - \mu)/\sqrt{\sigma^2/n}$ is normal with mean 0 and variance 1. Similarly, $(n-1) s^2/\sigma^2$ is independent of this and is χ^2 distributed with n-1 degrees of freedom. The ratio

$$t = \frac{(\overline{x} - \mu)/\sqrt{\sigma^2/n}}{\sqrt{(n-1)\ s^2/\sigma^2\ (n-1)}} = \frac{\overline{x} - \mu}{\sqrt{s^2/n}}$$
(27.27)

is distributed as f(t; n-1). The unknown true variance σ^2 cancels, and t can be used to test the probability that the true mean is some particular value μ .

In Table 27.1, n in f(t;n) is not required to be an integer. A Student's t distribution with nonintegral n>0 is useful in certain applications.

27.3.6. Gamma distribution: For a process that generates events as a function of x (e.g., space or time) according to a Poisson distribution, the distance in x from an arbitrary starting point (which may be some particular event) to the k^{th} event belongs to a gamma distribution, $f(x; \lambda, k)$. The Poisson parameter μ is λ per unit x. The special case k = 1 (i.e., $f(x; \lambda, 1) = \lambda e^{-\lambda x}$) is called the exponential distribution. A sum of k' exponential random variables x_i is distributed as $f(\sum x_i; \lambda, k')$.

The parameter k is not required to be an integer. For $\lambda = 1/2$ and k = n/2, the gamma distribution reduces to the $\chi^2(n)$ distribution.

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- 8. Microsoft $\mathbb R$ is a registered trademark of Microsoft corporation.

28. STATISTICS

Revised May 1996.

28.1. General [1-6]

A probability density function with known parameters enables us to predict the frequency with which a random variable will take on a particular value (if discrete) or lie in a given range (if continuous). In parametric statistics we have the opposite problem of estimating the parameters of the p.d.f. from a set of actual observations.

We refer to the true p.d.f. as the *population*; the data form a *sample* from this population. A *statistic* is any function of the data, plus known constants, which does not depend upon any of the unknown parameters. A statistic is a random variable if the data have random errors. An *estimator* is any statistic whose value is intended as a meaningful guess for the value of an unknown parameter; we denote estimators with hats, e.g., $\widehat{\alpha}$.

Often it is possible to construct more than one reasonable estimator. Let α represent the true value of a parameter to be estimated; α is a vector α if there is more than one parameter. Then if $\widehat{\alpha}$ is an estimator for α , desirable properties for $\widehat{\alpha}$ are: (a) Unbiased; bias $b=E(\widehat{\alpha})-\alpha$, where the expectation value is taken over a hypothetical set of similar experiments in which $\widehat{\alpha}$ is constructed the same way. The bias may be due to statistical properties of the estimator or to systematic errors in the experiment. If we can estimate the average bias b we usually subtract it from $\widehat{\alpha}$ to obtain a new $\widehat{\alpha}' \equiv \widehat{\alpha} - b$. However, b may depend upon α or other unknowns, in which case we usually try to choose an estimator which minimizes its average size. (b) Minimum variance; the minimum possible value of $\mathrm{Var}(\widehat{\alpha})$ is given by the Rao-Cramér-Frechet bound:

$$Var_{\min} = \left[1 + \partial b/\partial \alpha\right]^{2} / I(\alpha) ;$$

$$I(\alpha) = E \left\{ \left[\frac{\partial}{\partial \alpha} \sum_{i=1}^{n} \ln f(x_{i}; \alpha) \right]^{2} \right\} .$$
(28.1)

(Compare with Eq. (28.6) below.) The sum is over all data and b is the bias, if any; the x_i are assumed independent and distributed as $f(x_i; \alpha)$, and the allowed range of x must not depend upon α . The ratio $\epsilon = \mathrm{Var_{min}}/\mathrm{Var}(\widehat{\alpha})$ is the efficiency. An efficient estimator (with $\epsilon = 1$) exists only for certain cases. The square root of the variance expresses the expected spread of $\widehat{\alpha}$ about its average value, as would be observed in a large number of repeats of the same measurement. (c) Minimum mean-squared error (mse); $\mathrm{mse} = E[(\widehat{\alpha} - \alpha)^2] = V(\widehat{\alpha}) + b^2$. The mse combines the error due to any bias quadratically with the variance, which expresses only the spread about $E(\widehat{\alpha})$, as distinct from α , the true value. (d) Robust; a robust estimator is not sensitive to errors in our assumptions, e.g., to departures from the assumed p.d.f. due to such factors as noise.

These criteria (and others) allow us to evaluate any procedure for obtaining $\widehat{\alpha}$. In many cases these criteria conflict. The bias, variance, and mse may depend on the unknown α . In this case the optimum prescription for $\widehat{\alpha}$ may depend on the range in which we assume α to lie.

Following are techniques in common use for obtaining estimators and their standard errors $\sigma(\widehat{\alpha}) = \sqrt{\mathrm{Var}(\widehat{\alpha})}$. When the conditions of the central limit theorem are satisfied, the interval $\widehat{\alpha} \pm \sigma(\widehat{\alpha})$ forms a 68.3% confidence interval. This is a random interval in that its endpoints depend upon the randomly sampled data; its meaning here will be taken to be that in 68.3% of all similar experiments the interval will include the true value α . One should be aware that in most practical cases the central limit theorem is only approximately satisfied and accordingly confidence intervals which depend on that are only approximate. Confidence intervals are discussed in Section 28.6 below.

28.2. Data with a common mean

Suppose we have a set of N independent measurements y_i assumed to be unbiased measurements of the same unknown quantity μ with a common, but unknown, variance σ^2 resulting from measurement error. Then

$$\widehat{\mu} = \frac{1}{N} \sum_{i=1}^{N} y_i = E(y)$$
(28.2)

$$\widehat{\sigma}^2 = \frac{1}{N-1} \sum_{i=1}^{N} (y_i - \widehat{\mu})^2 = \frac{N}{N-1} \left(E(y^2) - \widehat{\mu}^2 \right)$$
 (28.3)

are unbiased estimators of μ and σ^2 . The variance of $\widehat{\mu}$ is σ^2/N . If the common p.d.f. of the y_i is Gaussian, these statistics are independent. Then, for large N, the standard deviation of $\widehat{\sigma}$ (the "error of the error") is $\sigma/\sqrt{2N}$. If the y_i are Gaussian or N is large enough that the central limit theorem applies, then $\widehat{\mu}$ is an efficient estimator for μ . Otherwise $\widehat{\mu}$ is sometimes subject to large fluctuations, e.g., if the p.d.f. for y_i has long tails. In this case the median of the y_i may be a more robust estimator for μ , provided the median and mean are expected to lie at the same point in the p.d.f. for y. For Gaussian y, the median has asymptotic (large-N) efficiency $2/\pi \approx 0.64$. Student's t-distribution provides an example in which there are large tails. In this case, for large N the efficiency of the sample median relative to the sample mean is $(\infty, \infty, 1.62, 1.12, 0.96, 0.80, 0.64)$ for $(1, 2, 3, 4, 5, 8, \infty)$ degrees of freedom.

If σ^2 is known, $\widehat{\mu}$ as given in Eq. (28.2) is still the best estimator for μ ; if μ is known, substitute it for $\widehat{\mu}$ in Eq. (28.3) and replace N-1 by N, to obtain a somewhat better estimator $\widehat{\sigma}^2$.

If the y_i have different, known, variances σ_i^2 , then

$$\widehat{\mu} = \frac{1}{w} \sum_{i=1}^{N} w_i \ y_i \ , \tag{28.4}$$

is an unbiased estimator for μ with smaller variance than Eq. (28.2), where $w_i = 1/\sigma_i^2$ and $w = \sum w_i$. The standard deviation of $\widehat{\mu}$ is $1/\sqrt{w}$.

28.3. The method of maximum likelihood

28.3.1. General:

"From a theoretical point of view, the most important general method of estimation so far known is the *method of maximum likelihood*" [1]. We suppose that a set of independently measured quantities x_i came from a p.d.f. $f(x;\alpha)$, where α is an unknown set of parameters. The method of maximum likelihood consist of finding the set of values, $\widehat{\alpha}$, which maximizes the joint probability density for all the data, given by

$$\mathcal{L}(\alpha) = \prod_{i} f(x_i; \alpha) , \qquad (28.5)$$

where \mathscr{L} is called the likelihood. It is usually easier to work with $\ln \mathscr{L}$, and since both are maximized for the same set of α , it is sufficient to solve the *likelihood equation*

$$\frac{\partial \ln \mathcal{L}}{\partial \alpha_n} = 0 \ . \tag{28.6}$$

The solution is called the maximum likelihood estimate of α . The importance of the approach is shown by the following proposition, proved in Ref. 1:

If an efficient estimate $\hat{\alpha}$ of α exists, the likelihood equation will have a unique solution equal to $\hat{\alpha}$.

In evaluating \mathscr{L} , it is important that any normalization factors in the f's which involve α be included. However, we will only be interested in the maximum of \mathscr{L} and in ratios of \mathscr{L} at different α 's;

hence any multiplicative factors which do not involve the parameters we want to estimate may be dropped; this includes factors which depend on the data but not on α .

If the solution to Eq. (28.6) is at a maximum, $\partial \ln \mathcal{L}/\partial \alpha_n$ will have negative slope in its vicinity. In many practical problems, one often uses nonlinear algorithms for finding the maximum, and must be alert to various possibilities for error: (a) Eq. (28.6) may yield a minimum, therefore one must check the second derivative; (b) there may be more than one maximum—one must try to find the global maximum; (c) the global maximum may lie at a boundary of the physical region, in which case Eq. (28.6) will not find it.

If an unbiased, efficient estimator exists, this method will find it. If $\partial \ln \mathcal{L}/\partial \alpha_n$ is linear in the vicinity of the root, an efficient estimator is guaranteed; other efficient cases are discussed in the literature. For large data samples, the central limit theorem will usually assure this condition in some significant neighborhood of zero; hence the estimator is usually efficient in that case, provided certain conditions are met (e.g., that the solution does not lie on a boundary). In this case, in the neighborhood of the maximum $\ln \mathcal{L}$ is a downward-curving paraboloid and \mathcal{L} is proportional to a multivariate Gaussian.

The results of two or more experiments may be combined by forming the product of the \mathscr{L} 's, or the sum of the $\ln \mathscr{L}$'s.

Under a one-to-one change of parameters from α to $\beta = \beta(\alpha)$, the maximum likelihood estimate is simply $\beta(\widehat{\alpha})$, given the solution $\widehat{\alpha}$ for α . That is, the maximum likelihood solution for β is found by simple substitution of $\widehat{\alpha}$ into the transformation equation. It is possible that the new solution $\widehat{\beta}$ will be a biased solution for the true value of β even if $\widehat{\alpha}$ is not biased, and vice-versa. In the asymptotic limit (of large amounts of data) both $\widehat{\alpha}$ and $\widehat{\beta}$ will (usually) converge to unbiased solutions, but at different rates.

Except in special cases like the least-squares method, the value of the likelihood function at the solution does not necessarily tell us whether the final fit was a sensible description of the data or not. In special cases such as the one discussed in Sec. 28.3.3, one can define a quantity which approaches the χ^2 -distribution in the limit of a large number of counts in the experiment, but in general some other strategy must be used. For example, data generated by Monte Carlo simulations of the experiment can be analyzed by the same method. If the experimental likelihood is lower than that of some agreed-upon fraction of these results, one should question the appropriateness of the p.d.f. At the same time one can check for bias in the solution.

28.3.2. Error estimates:

The covariance matrix V may be estimated from

$$V_{nm} = \left(E \left[-\frac{\partial^2 \ln \mathcal{L}}{\partial \alpha_n \partial \alpha_m} \Big|_{\widehat{\Omega}} \right] \right)^{-1} . \tag{28.7}$$

If $\partial \ln \mathcal{L}/\partial \alpha_n$ is linear, the "expectation" operation in Eq. (28.7) has no effect because the second derivative of $\ln \mathcal{L}$ is constant. Otherwise, it may be approximated by taking the average of the quantity in square brackets over a range of α_n and α_m near the solution. For complex cases it may be more practical to evaluate s-standard-deviation errors from the contour

$$ln \mathcal{L}(\boldsymbol{\alpha}) = \ln \mathcal{L}_{\text{max}} - s^2/2 , \qquad (28.8)$$

where $\ln \mathscr{L}_{\max}$ is the value of $\ln \mathscr{L}$ at the solution point (compare with Eq. (28.32), below). The extreme limits of this contour parallel to the α_n axis give an approximate s-standard-deviation confidence interval in α_n . These intervals may not be symmetric and they may even consist of two or more disjoint intervals. This procedure gives one-standard-deviation errors in α_n equal to $\sqrt{V_{nn}}$ (not summed) of Eq. (28.7) if the estimator is efficient. If it is not efficient, the level of confidence implied by the value of s is only approximate.

28.3.3. Application to Poisson-distributed data:

In the case of Poisson-distributed data in a counting experiment, the unbinned maximum likelihood method (where the index i in Eq. (28.5) labels events) is preferred if the total number of events is very small. If there are enough events to justify binning them in a histogram, then one may alternatively maximize the likelihood function for the contents of the bins (so i labels bins). This is equivalent to minimizing [7]

$$\chi^{2} = \sum_{i} \left[2(N_{i}^{\text{th}} - N_{i}^{\text{obs}}) + 2N_{i}^{\text{obs}} \ln(N_{i}^{\text{obs}}/N_{i}^{\text{th}}) \right]. \tag{28.9}$$

where N_i^{obs} and N_i^{th} are the observed and theoretical (from f) contents of the ith bin. In bins where $N_i^{\text{obs}} = 0$, the second term is zero. This function asymptotically behaves like a classical χ^2 for purposes of point estimation, interval estimation, and goodness-of-fit. It also guarantees that the area under the fitted function f is equal to the sum of the histogram contents (as long as the overall normalization of f is effectively left unconstrained during the fit), which is not the case for χ^2 statistics based on a least-squares procedure with traditional weights.

28.4. Propagation of errors

Suppose that $F(x; \alpha)$ is some function of variable(s) x and the fitted parameters α , with a value \widehat{F} at $\widehat{\alpha}$. The variance matrix of the parameters is V_{mn} . To first order in $\alpha_m - \widehat{\alpha}_m$, F is given by

$$F = \hat{F} + \sum_{m} \frac{\partial F}{\partial \alpha_m} (\alpha_m - \hat{\alpha}_m) , \qquad (28.10)$$

and the variance of F about its estimator is given by

$$(\Delta F)^2 = E[(F - \hat{F})^2] = \sum_{mn} \frac{\partial F}{\partial \alpha_n} \frac{\partial F}{\partial \alpha_n} V_{mn} , \qquad (28.11)$$

evaluated at the x of interest. For different functions F_j and F_k , the covariance is

$$E[(F_j - \hat{F}_j)(F_k - \hat{F}_k)] = \sum_{mn} \frac{\partial F_j}{\partial \alpha_m} \frac{\partial F_k}{\partial \alpha_n} V_{mn} . \qquad (28.12)$$

If the first-order approximation is in serious error, the above results may be very approximate. \widehat{F} may be a biased estimator of F even if the $\widehat{\alpha}$ are unbiased estimators of α . Inclusion of higher-order terms or direct evaluation of F in the vicinity of $\widehat{\alpha}$ will help to reduce the bias.

28.5. Method of least squares

The method of least squares can be derived from the maximum likelihood theorem. We suppose a set of N measurements at points x_i . The ith measurement y_i is assumed to be chosen from a Gaussian distribution with mean $F(x_i; \boldsymbol{\alpha})$ and variance σ_i^2 . Then

$$\chi^2 = -2\ln\mathcal{L} + \text{constant} = \sum_{i=1}^{N} \frac{[y_i - F(x_i; \boldsymbol{\alpha})]^2}{\sigma_i^2} . \tag{28.13}$$

Finding the set of parameters α which maximizes $\mathcal L$ is the same as finding the set which minimizes χ^2 .

In many practical cases one further restricts the problem to the situation in which $F(x_i; \boldsymbol{\alpha})$ is a linear function of the α_m 's,

$$F(x_i; \boldsymbol{\alpha}) = \sum_{n} \alpha_n f_n(x) , \qquad (28.14)$$

where the f_n are k linearly independent functions (e.g., 1, x. x^2 , ..., or Legendre polynomials) which are single-valued over the allowed range of x. We require $k \leq N$, and at least k of the x_i must be distinct. We wish to estimate the linear coefficients α_n . Later we will discuss the nonlinear case.

If the point errors $\epsilon_i=y_i-F(x_i;\pmb{\alpha})$ are Gaussian, then the minimum χ^2 will be distributed as a χ^2 random variable with

n = N - k degrees of freedom. We can then evaluate the goodnessof-fit (confidence level) from Figs. 27.1 or 27.3, as per the earlier discussion. The confidence level expresses the probability that a worse fit would be obtained in a large number of similar experiments under the assumptions that: (a) the model $y = \sum \alpha_n f_n$ is correct and (b) the errors ϵ_i are Gaussian and unbiased with variance $\sigma_i^2.$ If this probability is larger than an agreed-upon value (0.001, 0.01, or 0.05 are common choices), the data are consistent with the assumptions; otherwise we may want to find improved assumptions. As for the converse, most people do not regard a model as being truly inconsistent unless the probability is as low as that corresponding to four or five standard deviations for a Gaussian $(6 \times 10^{-3} \text{ or } 6 \times 10^{-5})$; see Sec. 28.6.1). If the ϵ_i are not Gaussian, the method of least squares still gives an answer, but the goodness-of-fit test would have to be done using the correct distribution of the random variable which is still called " χ^2 ."

Finding the minimum of χ^2 in the linear case is straightforward:

$$-\frac{1}{2}\frac{\partial \chi^2}{\partial \alpha_m} = \sum_i f_m(x_i) \left(\frac{y_i - \sum_n \alpha_n f_n(x_i)}{\sigma_i^2} \right)$$
$$= \sum_i \frac{y_i f_m(x_i)}{\sigma_i^2} - \sum_n \alpha_n \sum_i \frac{f_n(x_i) f_m(x_i)}{\sigma_i^2} . \quad (28.15)$$

With the definitions

$$g_m = \sum_{i} y_i \ f_m(x_i) / \sigma_i^2 \tag{28.16}$$

and

$$V_{mn}^{-1} = \sum_{i} f_n(x_i) f_m(x_i) / \sigma_i^2 , \qquad (28.17)$$

the k-element column vector of solutions $\hat{\alpha}$, for which $\partial \chi^2/\partial \alpha_m = 0$ for all m, is given by

$$\widehat{\boldsymbol{\alpha}} = V \; \boldsymbol{g} \; . \tag{28.18}$$

With this notation, χ^2 for the special case of a linear fitting function (Eq. (28.14)) can be rewritten in the compact form

$$\chi^2 = \chi_{\min}^2 + (\boldsymbol{\alpha} - \widehat{\boldsymbol{\alpha}})^T V^{-1} (\boldsymbol{\alpha} - \widehat{\boldsymbol{\alpha}}) . \tag{28.19}$$

Nonindependent y_i 's

Eq. (28.13) is based on the assumption that the likelihood function is the product of independent Gaussian distributions. More generally, the measured y_i 's are not independent, and we must consider them as coming from a multivariate distribution with nondiagonal covariance matrix S, as described in Sec. 27.3.3. The generalization of Eq. (28.13) is

$$\chi^{2} = \sum_{jk} [y_{j} - F(x_{j}; \boldsymbol{\alpha})] S_{jk}^{-1} [y_{k} - F(x_{k}; \boldsymbol{\alpha})] .$$
 (28.20)

In the case of a fitting function that is linear in the parameters, one may differentiate χ^2 to find the generalization of Eq. (28.15), and with the extended definitions

$$g_m = \sum_{jk} y_j \ f_m(x_k) S_{jk}^{-1}$$

$$V_{mn}^{-1} = \sum_{jk} f_n(x_j) \ f_m(x_k) S_{jk}^{-1}$$
(28.21)

solve Eq. (28.18) for the estimators $\widehat{\alpha}$.

The problem of constructing the covariance matrix S is simplified by the fact that contributions to S (not to its inverse) are additive. For example, suppose that we have three variables, all of which have independent statistical errors. The first two also have a common error

resulting in a positive correlation, perhaps because a common baseline with its own statistical error (variance s^2) was subtracted from each. In addition, the second two have a common error (variance a^2), but this time the values are anticorrelated. This might happen, for example, if the sum of the two variables is a constant. Then

$$S = \begin{pmatrix} \sigma_1^2 & 0 & 0 \\ 0 & \sigma_2^2 & 0 \\ 0 & 0 & \sigma_3^2 \end{pmatrix} + \begin{pmatrix} s^2 & s^2 & 0 \\ s^2 & s^2 & 0 \\ 0 & 0 & 0 \end{pmatrix} + \begin{pmatrix} 0 & 0 & 0 \\ 0 & a^2 & -a^2 \\ 0 & -a^2 & a^2 \end{pmatrix} .$$
 (28.22)

If unequal amounts of the common baseline were subtracted from variables 1, 2, and 3—e.g., fractions f_1 , f_2 , and f_3 , then we would have

$$S = \begin{pmatrix} \sigma_1^2 & 0 & 0 \\ 0 & \sigma_2^2 & 0 \\ 0 & 0 & \sigma_3^2 \end{pmatrix} + \begin{pmatrix} f_1^2 s^2 & f_1 f_2 s^2 & f_1 f_3 s^2 \\ f_1 f_2 s^2 & f_2^2 s^2 & f_2 f_3 s^2 \\ f_1 f_3 s^2 & f_2 f_3 s^2 & f_2^2 s^2 \end{pmatrix} .$$
 (28.23)

While in general this "two-vector" representation is not possible, it underscores the procedure: Add zero-determinant correlation matrices to the matrix expressing the independent variation.

Care must be taken when fitting to correlated data, since off-diagonal contributions to χ^2 are not necessarily positive. It is even possible for all of the residuals to have the same sign.

Example: straight-line fit

For the case of a straight-line fit, $y(x) = \alpha_1 + \alpha_2 x$, one obtains, for independent measurements y_i , the following estimates of α_1 and α_2 ,

$$\widehat{\alpha}_1 = (g_1 \ V_{22}^{-1} - g_2 \ V_{12}^{-1})/D , \qquad (28.24)$$

$$\widehat{\alpha}_2 = (g_2 \ V_{11}^{-1} - g_1 \ V_{12}^{-1})/D \ , \tag{28.25}$$

where

$$(V_{11}^{-1}, V_{12}^{-1}, V_{22}^{-1}) = \sum (1, x_i, x_i^2) / \sigma_i^2,$$
 (28.26a)

$$(g_1, g_2) = \sum (1, x_i) y_i / \sigma_i^2 . \tag{28.26b}$$

respectively, and

$$D = V_{11}^{-1} V_{22}^{-1} - (V_{12}^{-1})^{2}. (28.27)$$

The covariance matrix of the fitted parameters is:

$$\begin{pmatrix} V_{11} & V_{12} \\ V_{12} & V_{22} \end{pmatrix} = \frac{1}{D} \begin{pmatrix} V_{22}^{-1} & -V_{12}^{-1} \\ -V_{12}^{-1} & V_{11}^{-1} \end{pmatrix} . \tag{28.28}$$

The estimated variance of an interpolated or extrapolated value of y at point x is:

$$(\hat{y} - y_{\text{true}})^2 \Big|_{\text{est}} = \frac{1}{V_{11}^{-1}} + \frac{V_{11}^{-1}}{D} \left(x - \frac{V_{12}^{-1}}{V_{11}^{-1}} \right)^2 .$$
 (28.29)

28.5.1. General comments:

If y is not linear in the fitting parameters α , the solution vector may have to be found by iteration. If we have a first guess α_0 , then we may expand to obtain

$$\frac{\partial \chi^2}{\partial \alpha} \bigg|_{\alpha} = \frac{\partial \chi^2}{\partial \alpha} \bigg|_{\alpha_0} + V_{\alpha_0}^{-1} \cdot (\alpha - \alpha_0) + \dots , \qquad (28.30)$$

where $\partial\chi^2/\partial\alpha$ is a vector whose mth component is $\partial\chi^2/\partial\alpha_m$, and $(V_{mn}^{-1})=\frac{1}{2}\partial^2\chi^2/\partial\alpha_m\partial\alpha_n$. (See Eqns. 28.7 and 28.17. When evaluated

at $\widehat{\alpha}$, V^{-1} is the inverse of the covariance matrix.) The next iteration toward $\widehat{\alpha}$ can be obtained by setting $\partial \chi^2/\partial \alpha_m|_{\alpha}=0$ and neglecting higher-order terms:

$$\alpha = \alpha_0 - V_{\alpha_0} \cdot \partial \chi^2 / \partial \alpha |_{\alpha_0} \tag{28.31}$$

If V is constant in the vicinity of the minimum, as it is when the model function is linear in the parameters, then χ^2 is parabolic as a function of α and Eq. (28.31) gives the solution immediately. Otherwise, further iteration is necessary. If the problem is highly nonlinear, considerable difficulty may be encountered. There may be secondary minima, and χ^2 may be decreasing at physical boundaries. Numerical methods have been devised to find such solutions without divergence [8,11]. In particular, the CERN program MINUIT [11] offers several iteration schemes for solving such problems.

Note that minimizing any function proportional to χ^2 (or maximizing any function proportional $\ln \mathcal{L}$) will result in the same parameter set $\hat{\alpha}$. Hence, for example, if the variances σ_j^2 are unknown but assumed equal and independent, one can still solve for $\hat{\alpha}$. One cannot, however, evaluate goodness-of-fit, and the covariance matrix is known only to within a constant multiplier. The scale can be estimated at least roughly from the size of χ^2 compared to its expected size.

Additional information can be extracted from the behavior of the (normalized) residuals, $r_j = (y_j - F(x_j; \alpha)/\sigma_j)$, which should themselves distribute normally with a mean of 0.

If the data covariance matrix S has been correctly evaluated (or, equivalently, the σ_j 's, if the data are independent), then the s-standard deviation limits on the parameters are given by a set α' such that

$$\chi^2(\alpha) = \chi^2_{\min} + s^2 \ . \tag{28.32}$$

This equation, a special case of 28.8, defines a contour in α -space; compare with the linear case in Eq. (28.19). It is often convenient for estimating errors in applications to nonlinear cases, where the matrix $V^{-1}|_{\alpha}$ may be a rapidly varying function of α . If the problem is highly nonlinear, such contours only approximately define the desired confidence regions which would have some given probability of covering the true value of α .

The method of least squares is sometimes used in cases where the distribution is not Gaussian or not known to be Gaussian. In such cases it can still be used, but it is then not a special case of the maximum-likelihood method, and the theorems having to do with that approach no longer apply. However, if (a) the distribution of $y_i - \sum \alpha_k f_k(x_i)$ has an expectation value of zero (unbiased) and (b) has a finite, known, fixed variance σ_i^2 (does not depend on α), then estimates of α obtained by minimizing χ^2 will be unbiased and have the smallest possible variance of all linear unbiased estimates (Gauss-Markov theorem). This statement is more general than the least-squares method as a special case of the maximum likelihood method in that the distributions do not have to be Gaussian, but more restrictive in that it applies only when the fitting function is linear in the α_k 's.

28.6. Errors and confidence intervals

We measure a mass, lifetime, or other physical quantity under the assumption that a "true answer" α exists. The conditions of the measurement introduce a random element, and our measurement (or combination of measurements) $\widehat{\alpha}_{\rm exp}$ samples a distribution with p.d.f. $f(\widehat{\alpha};\alpha)$. The unknown constant α appears as a parameter. We suppose that for every value of α we can find two values $\gamma_1(\alpha,\varepsilon)$ and $\gamma_2(\alpha,\varepsilon)$ such that repeated experiments would produce results in the interval $\gamma_1<\widehat{\alpha}<\gamma_2$ a fraction $1-\varepsilon$ of the time, where

$$1 - \varepsilon = \int_{\gamma_1}^{\gamma_2} f(\widehat{\alpha}; \alpha) \, d\widehat{\alpha} . \tag{28.33}$$

This situation is shown in Fig. 28.1 (ignore the "unphysical region" part of the graph for now), where the region between the curves $\gamma_1(\alpha,\varepsilon)$ and $\gamma_2(\alpha,\varepsilon)$ is indicated by the domain $D(\varepsilon)$. It can be argued that since the point $(\alpha_{\rm actual},\widehat{\alpha}_{\rm exp})$ belongs to D, then our statement that repeated experiments would produce values of $\widehat{\alpha}$ in the interval $\gamma_1<\widehat{\alpha}<\gamma_2$ is equivalent to the statement that the confidence interval $c_1<\alpha< c_2$ includes $\alpha_{\rm actual}$ with probability $1-\varepsilon$ [1,6]. (We will call ε the confidence coefficient.) In this "confidence interval" or frequentist approach, α is a parameter, not a statistical variable. Instead, c_1 and c_2 vary from experiment to experiment and are statistical variables. It is very different to say that a lifetime τ is to be found in the interval $\tau_0 \pm \sigma_\tau$ (which can vary from experiment to experiment) includes the actual, fixed, value of the lifetime with 68% probability.

The actual choice of γ_1 and γ_2 , such that $\int_{\gamma_1}^{\gamma_2} f(\widehat{\alpha}; \alpha) d\widehat{\alpha} = 1 - \varepsilon$, can be made in an infinite number of ways, but in practical situations there are usually additional criteria. For a Gaussian distribution, for example, choosing the limits symmetric about the mean minimizes the length of the interval. The area of the excluded tail on either side is then $\varepsilon/2$. For a Poisson distribution negative values cannot occur, so $\gamma(\widehat{\alpha},\alpha)$ (with $\widehat{\alpha}$ an integer and α the Poisson mean) might be taken as the curve below which ε of the area under the distribution lies. (In this case the curve really consists of discrete points, since $\widehat{\alpha}$ can have only discrete values.) For $\varepsilon=0.05$ the curve starts at $(\alpha,\widehat{\alpha})=(3.0,0)$. If in a given experiment no decays to a certain final state are seen, we might then conclude that $\alpha<3.0$ excludes the actual value of α with 95% probability. This statement can be converted to a similar statement about the branching fraction.

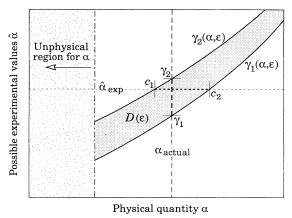


Figure 28.1: Confidence intervals for a single unknown parameter α . One might think of the p.d.f. $f(\widehat{\alpha};\alpha)$ as being plotted out of the paper as a function of $\widehat{\alpha}$ along each vertical line of constant α . The domain $D(\varepsilon)$ contains a fraction $1-\varepsilon$ of the area under each of these functions.

In Sec. 27 we discussed such confidence limits for a χ^2 distribution (where ε was called CL). Here we discuss confidence intervals for the Gaussian and Student's t-distribution, and confidence limits for the Poisson case. We then discuss the much more contentious situation in which the horizontal line at ordinate $\widehat{\alpha}$ in Fig. 28.1 enters $D(\varepsilon)$ at a boundary for unphysical values of α , so that at least c_1 is undefined—for example, if we find $\widehat{m}^2 = -30 \pm 50 \text{ eV}^2$.

Extensive tables and graphs were once used to find confidence intervals and limits, but by now their main function is to confirm that software is working. FORTRAN mathematical libraries (IMSL, NAG, CERNLIB) are readily available, and a wide range of distributions are available in personal computer spreadsheet applications such as Microsoft ® Excel [12]. Its built-in functions CHIDIST, NORMDIST, and TDIST (Student's t-distribution), along with "Solver," were used to produce or check the numbers given in this section.

Table 28.1: Area of the tails ε outside $\pm \delta$ from the mean of a Gaussian distribution.

ε (%)	δ	$\varepsilon~(\%)$	δ
31.73	1σ	20	1.28σ
4.55	2σ	10	1.64σ
0.27	3σ	5	1.96σ
6.3×10^{-3}	4σ	1	2.58σ
5.7×10^{-5}	5σ	0.1	3.29σ
2.0×10^{-7}	6σ	0.01	3.89σ

28.6.1. Gaussian errors:

If the data are such that the distribution of the estimator(s) satisfies the central limit theorem discussed in Sec. 27.3.3, the Gaussian distribution is the basis of the error analysis. If there is more than one parameter being estimated, the multivariate Gaussian is used. For the univariate case with known σ ,

$$1 - \varepsilon = \int_{\widehat{\mu} - \delta}^{\widehat{\mu} + \delta} f(x; \, \widehat{\mu}, \, \sigma^2) \, dx = \operatorname{erf}\left(\frac{\delta}{\sqrt{2} \, \sigma}\right)$$
 (28.34)

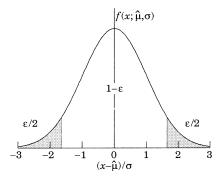


Figure 28.2: Illustration of a symetric 90% confidence interval (unshaded) for a measurement of a single quantity with Gaussian errors. Integrated probabilities, defined by ε , are as shown.

is the probability that the true value of μ will fall within $\pm \delta$ ($\delta > 0$) of the measured $\widehat{\mu}$. This interval will cover μ in a fraction $1 - \varepsilon$ of all similar measurements. Fig. 28.2 shows a $\delta = 1.64\sigma$ confidence interval unshaded. The choice $\delta = \sqrt{\mathrm{Var}(\widehat{\mu})} \equiv \sigma$ gives an interval called the standard error which has $1 - \varepsilon = 68.27\%$ if σ is known. Confidence coefficients ε for other frequently used choices of δ are given in Table 28.1. For other δ , find ε as the ordinate of Fig. 27.1 on the n=1 curve at $\chi^2=(\delta/\sigma)^2$. We can set a one-sided (upper or lower) limit by excluding above $\widehat{\mu}+\delta$ (or below $\widehat{\mu}-\delta$); ε 's for such limits are 1/2 the values in the table above.

We have increased confidence that the interval covers the true value as $1-\varepsilon$ increases, or χ^2 increases. We must be careful to distinguish this case from the other major use of Fig. 27.1, evaluation of goodness-of-fit (Sec. 28.5.0). In that case we have increased confidence in the fit as χ^2 decreases. In an attempt to reduce possible confusion in this discussion, we will use the ε notation (which corresponds to notation used in hypothesis testing [4]) when discussing confidence intervals and CL notation when discussing goodness-of-fit. Elsewhere in this *Review*, where the confusion between fit confidence level and interval (usually an upper or lower limit) confidence level does not arise, we follow the common practice of using "CL" to refer to the confidence level of the interval. This CL is understood to represent $1-\varepsilon$.

If the variance σ^2 of the estimator is not known, but must be estimated from the data, then we need to incorporate the error in $\widehat{\sigma}$ into our confidence interval using Student's t distribution. If we have

N data points with which we estimate k parameters, the Gaussian approximation is adequate for $N-k\gg 1$. Otherwise replace δ by a factor $T\widehat{\sigma}$, T being defined by

$$1 - \varepsilon = \int_{-T}^{T} f(t; N - k) dt , \qquad (28.35)$$

where f for the Student's t-distribution is defined in Table 27.1. T is tabulated in Ref. 13 and in Table 28.2.

Table 28.2: t limits containing $1 - \varepsilon$ of the area of Student's t-distribution f(t; N - k).

		ě	ε (%)			
$\overline{N-k}$	31.73	10.00	5.00	4.55	1.00	0.27
1	1.84	6.31	12.71	13.97	63.66	235.8
2	1.32	2.92	4.30	4.53	9.92	19.21
3	1.20	2.35	3.18	3.31	5.84	9.22
4	1.14	2.13	2.78	2.87	4.60	6.62
5	1.11	2.01	2.57	2.65	4.03	5.51
10	1.05	1.81	2.23	2.28	3.17	3.96
20	1.03	1.72	2.09	2.13	2.85	3.42
∞	1.00	1.64	1.96	2.00	2.58	3.00

For multivariate α we must consider pairwise correlations. Assuming a multivariate Gaussian, Eq. (27.22), and subsequent discussion the standard error ellipse for the pair $(\widehat{\alpha}_m, \widehat{\alpha}_n)$ may be drawn as in Fig. 28.3.

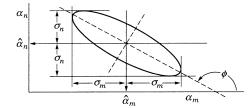


Figure 28.3: Standard error ellipse for the estimators $\widehat{\alpha}_m$ and $\widehat{\alpha}_n$. In this case the correlation is negative.

The minimum χ^2 or maximum likelihood solution is at $(\widehat{\alpha}_m, \widehat{\alpha}_n)$. The standard errors σ_m and σ_n are defined as shown, where the cllipse is at a constant value of $\chi^2 = \chi^2_{\min} + 1$ or $\ln \mathcal{L} = \ln \mathcal{L}_{\max} - 1/2$. The angle of the major axis of the cllipse is given by

$$\tan 2\phi = \frac{2\rho_{mn} \ \sigma_m \ \sigma_n}{\sigma_m^2 - \sigma_n^2} \ . \tag{28.36}$$

For non-Gaussian or nonlinear cases, one may construct an analogous contour from the same χ^2 or $\ln \mathscr{L}$ relations. Any other parameters $\widehat{\alpha}_\ell, \ell \neq m, n$ must be allowed freely to find their optimum values for every trial point.

For any unbiased procedure (e.g., least squares or maximum likelihood) being used to estimate k parameters α_i , $i=1,\ldots,k$, the probability $1-\varepsilon$ that the true values of all k lie within the s-standard deviation ellipsoid may be found from Fig. 27.1. Read the ordinate as ε ; the correct value of ε occurs on the n=k curve at $\chi^2=s^2$. For example, for k=2, the probability that the true values of α_1 and α_2 simultaneously lie within the one-standard-deviation error ellipse (s=1), centered on $\widehat{\alpha}_1$ and $\widehat{\alpha}_2$, is 39%. This probability only assumes Gaussian errors, unbiased estimators, and that the model describing the data in terms of the α_i is correct.

28.6.2. Poisson processes—upper limits:

Because the outcome of a Poisson process is an integral number of events, n_0 , it is usually not possible to set confidence intervals for the true Poisson parameter μ at a certain exact ε . For large n_0 an approximate interval can be set using the Gaussian approximation, in our section on Probability, Sec. 27.3.2, and the techniques of Sec. 28.6.1.

For small n_0 we can define an upper limit N for μ as being that value of μ such that it would be at least $1-\varepsilon$ (e.g., 90% or 95%) probable that a random observation of n would then lie above the observed n_0 . Thus

$$1 - \varepsilon = \sum_{n=n_0+1}^{\infty} f(n; N) ; \qquad \varepsilon = \sum_{n=0}^{n_0} f(n; N) .$$
 (28.37)

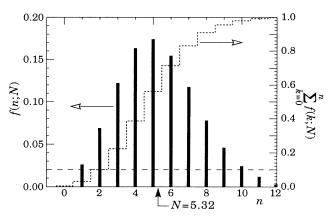


Figure 28.4: Illustration of Eq. (28.37) Poisson probabilities for an assumed mean of N. With an observed count $n_0=2$, N=5.32 as shown gives summed probability $\varepsilon=10\%$. The dotted summed probability curve (scale on right) has been displaced by -0.5 for clarity.

Fig. 28.4 illustrates the case with $n_0=2$ and $1-\varepsilon=90\%$, for which it may be shown that N=5.32. For any given n_0 and desired ε we can obtain N from the χ^2 Confidence Level figure because of a relation between the Poisson and the χ^2 distributions: read the ordinate as ε , find χ^2 on the curve for $n=2(n_0+1)$; then $N=\chi^2/2$. Some useful values are given in Table 28.3.

The meaning of these upper limits is that, for a given true μ , the probability is at least $1-\varepsilon$ that one will observe n_0 which will result in N which is $\geq \mu$. The probability for that to occur may be higher than $1-\varepsilon$; for example, if $\mu \leq 2.30$ a "90%" upper limit will actually exceed μ 100% of the time. Note from Eq. (28.37) that for $n_0 = 0$, $N = -\ln \varepsilon$

Table 28.3: Poisson upper limits N for n_0 observed events.

	$\varepsilon =$	$\varepsilon =$		$\varepsilon =$	$\varepsilon =$
n_0	10%	5%	n_0	10%	5%
0	2.30	3.00	6	10.53	11.84
1	3.89	4.74	7	11.77	13.15
2	5.32	6.30	8	13.00	14.44
3	6.68	7.75	9	14.21	15.71
4	7.99	9.15	10	15.41	16.96
5	9.27	10.51	11	16.60	18.21

28.6.3. Bounded physical region*:

The measurement of a physical constant α results in an estimator $\widehat{\alpha}$, together with some knowledge of experimental error and therefore knowledge of $f(\widehat{\alpha};\alpha)$, the parameterized p.d.f. that allows us to state the probability with which repeated experiments would produce results in a given range. It does not permit us to comment about α itself, which in this language is a constant, not a statistical variable. At the beginning of this section we introduced the confidence interval, or frequentist, approach to the problem, and were able to say that with a given probability the unknown parameter could be found between (statistical) limits c_1 and c_2 . But what if a physical boundary exists? Although polarization should be less than one and mass or its square should be greater than zero, experimental results do not always fall inside such a physical boundary because of statistical fluctuations.

However one might set a limit, there is little question about how to report and combine data [14]. A given experiment finds an unbiased estimator $\widehat{\alpha}=-5\pm 10$ for a physical constant (e.g. the square of the mass of a neutrino, in eV²). This value should be reported as the primary result. In case the true value is zero, for example, this "unphysical" result would not be unlikely. It can be combined with the results of other such experiments by forming the appropriately weighted average of unbiased results, including negative ones, to find an unbiased estimator which expresses our best knowledge of the parameter.

What if we wish to extend our concept of confidence limit to such a situation? The question of how to calculate an upper limit in the vicinity of a physical boundary is one of the most divisive in high-energy physics. We present two main approaches: The confidence interval, or frequentist, method, and the Bayesian method. "Classical method" is applied to one or the other by various writers, so we avoid the term.

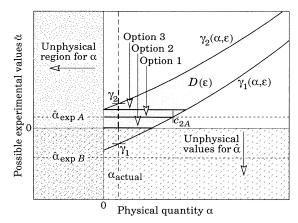


Figure 28.5: The situation near a physical boundary. In Fig. 28.1 the horizontal line for a given $\widehat{\alpha}_{\rm exp}$ crossed the domain $D(\varepsilon)$, bounded by $\gamma_1(\alpha, \epsilon)$ and $\gamma_2(\alpha, \epsilon)$ entirely in the physical region, entering at c_1 and leaving at c_2 . The limits γ_1 and γ_2 cannot be defined in a region where α is not defined, so the functions cannot be continued into the unphysical region. As a result c_1 (for experiment A) or c_1 and c_2 (for experiment B) cannot be defined. Options 1, 2, and 3 label the ways one might define confidence intervals, as described in the text.

1. The method of confidence intervals [1,15]. This is the approach described in the introduction, and requires little further explanation. It is presently the method in favor [1,6,14]. For a Gaussian distribution it gives the same result as the Bayesian approach with a flat prior distribution (see below) if the region containing α with the stated probability is far from an unphysical region, as in Fig. 28.1. Two cases in which this is untrue are shown in Fig. 28.5, where as a matter of convenience we assume that α must be positive. As before, we can define limits γ_1 and γ_2 for each value of the unknown parameter α , such that we can expect that a fraction $1-\varepsilon$ of repeated experiments to produce results between these limits. Since this can be done for

each value of α , the limits are described by the functions $\gamma_1(\alpha,\varepsilon)$ and $\gamma_2(\alpha,\varepsilon)$. However, these cannot be extended into a region in which α makes no sense. Experimental result $\widehat{\alpha}_{\exp A}$, indicated in Fig. 28.5, is positive, but if the true value is $\alpha_{\rm actual}$ a significant fraction of repetitions of the experiment would produce negative $\widehat{\alpha}$. In these cases there is no horizontal intercept c_1 , so without further assumptions we cannot make a statement about the region which would cover $\alpha_{\rm actual}$ in a given fraction of experiments. Experimental result $\widehat{\alpha}_{\exp B}$ presents a more serious problem, since it is so negative that there is no physical α for which the point $(\widehat{\alpha}, \alpha)$ lies in the domain $D(\varepsilon)$. The reason why the frequentist method gives no confidence interval is clear: This measured value of $\widehat{\alpha}$ would be unlikely no matter what the true value of α was.

There are several ad hoc ways to set confidence limits in such cases, although many frequentists would prefer to stop with the weighted average of unbiased results—if the outcome is exceedingly unlikely, one should look to the experiment, not to the statistics. The methods we list below all involve placing c_1 on the physical boundary, which in our example is at $\alpha = 0$.

- 1. If $\widehat{\alpha}_{\exp} > \gamma_1(0, \varepsilon)$, as in Experiment A, c_2 is defined. Use it for the upper limit, whether or not $\widehat{\alpha}_{\exp} > 0$.
- 2. If $\widehat{\alpha}_{\exp} < 0$, as in Experiment B, use the c_2 corresponding to $\widehat{\alpha}_{\exp} = 0$.
- 3. If c_1 is not defined, "lift up" $\hat{\alpha}$ to $\gamma_2(0,\varepsilon)$, where $c_1=0$. Use the corresponding c_2 as the upper limit.

These three options are shown in in Fig. 28.5; note that there are regions where more than one of them can be used, with different results. The third option is certainly the most conservative. For Gaussian $f(\widehat{\alpha};\alpha)$ the upper limit c_2 is a one-sided Gaussian confidence limit; read the tables for a 90% two-sided limit to obtain 95% one-sided limit. Alternatively, read the intercepts of the dotted lines in Fig. 28.7. (The horizontal axis is incorrectly labeled for this application.)

2. The Bayesian approach [3]. This is the approach favored in the older literature, and has (unfortunately and incorrectly) been referred to as the "PDG method" in certain papers. To begin with, it is argued that while α is not a statistical variable, our knowledge of α is less than complete, and it is fair to describe our uncertainty by treating α as a statistical variable. The parameterized p.d.f. $f(\widehat{\alpha}; \alpha)$ is replaced by the conditional p.d.f. $f(\widehat{\alpha}|\alpha)$. The confidence limit question can then be rephrased: Our measurements provide $f(\widehat{\alpha}|\alpha)$, that is, information about $\widehat{\alpha}$ for a fixed and unknown value of α , while we really want to know $g(\alpha|\widehat{\alpha})$, which tells us that, given our measurement $\widehat{\alpha}$, the "true answer" α lies between α and $\alpha+d\alpha$ with probability $g(\alpha|\widehat{\alpha}) d\alpha$. The connection is provided by Bayes' theorem (Eq. (27.7):

$$g(\alpha|\widehat{\alpha}) = \frac{f(\widehat{\alpha}|\alpha) \pi(\alpha)}{\int f(\widehat{\alpha}|\alpha) \pi(\alpha) d\alpha}.$$
 (28.38)

Here $\pi(\alpha)$ represents our "advance knowledge" of the value of α . In the usual case we claim no prior knowledge, so that before the experiment all physically reasonable values of α are equally probable: $\pi(\alpha)$ is a constant over the region of interest and zero in the unphysical region. This assumption leads to the conclusion that

$$g(\alpha|\widehat{\alpha}) = \begin{cases} f(\widehat{\alpha}|\alpha) / \int f(\widehat{\alpha}|\alpha) \, d\alpha & \text{if } \alpha \text{ is in the physical region;} \\ 0 & \text{otherwise;} \end{cases}$$

where this time the integral is over the physical region. In Fig. 28.6 we assume that an ensemble of experiments would produce values for $\hat{\alpha}$ which distribute as shown, with a significant probability of obtaining results with unphysical values. With our assumed step function $\pi(\alpha)$, the effect of Eq. (28.38) or (28.39) is to replace this distribution with the function shown by the shaded region, except that it is renormalized to unit area. By stating our confidence at the 90% level that α lies below the beginning of the dark shaded region, we mean that 90% of the area in the physical region is in the light shaded region.

In most cases of interest in this Review, $\hat{\alpha}$ is assumed to be a random value from a Gaussian distribution. Application of the procedure sketched in Fig. 28.6 then leads to the family of curves shown in Fig. 28.7. The confidence limit set by this method is always greater than the [one-sided] confidence interval set without the restriction of an unphysical region, and approaches it from above as the tail in the

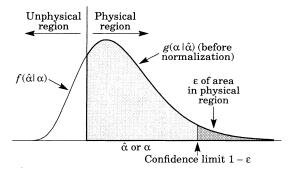


Figure 28.6: An example of a bounded physical region, in which a measurement $\widehat{\alpha}$ can fall in an unphysical region with significant probability. If we assume that α , the quantity we are trying to measure, cannot lie in the unphysical region (0 probability) but can lie anywhere in the physical region ("no prior knowledge"), then Bayes' theorem says that our new knowledge of the distribution of α , given our measurement $\widehat{\alpha}$, is given by the shaded function after appropriate renormalization.

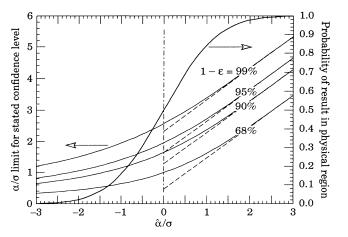


Figure 28.7: Application of the Bayesian scheme shown in Fig. 28.6 to the case of Gaussian $f(\widehat{\alpha}|\alpha)$. For example, if our measurement $\widehat{\alpha}$ is 1.0 standard deviations negative, then we conclude that $\alpha < 1.15\sigma$ with 90% probability—however, there is only a 31% probability that an experimental result as low as this would occur. Note that these are upper limits, so that the asymptote for large $\widehat{\alpha}/\sigma$ corresponds to a one-sided confidence interval, e.g., the asymptote for a 95% confidence level is $\alpha < \widehat{\alpha} + 1.64\sigma$, corresponding to a 90% confidence interval for a two-sided distribution. The dashed lines show the frequentist limit; if Option 3 is used, these are extended horizontally to the right for negative $\widehat{\alpha}/\sigma$.

unphysical region becomes unimportant. It is also greater than any of the limits shown in Fig. 28.5. With a small modification (exclusion of that portion of the negative tail inside the physical region in the confidence interval definition), it smoothly approaches the usual two-sided confidence interval for Gaussian distributions.

Even so, it is not a valid confidence limit. If it were, the interval would include the true value of α with exactly $1-\varepsilon$ probability no matter what the true value was. If the true answer is zero, our procedure, by guaranteeing a limit greater than zero for any experiment, also guarantees that the confidence interval for any ε includes $\alpha_{\rm actual}$ with 100% probability. Only as α increases does the probability decrease toward the α -independent Gaussian result.

The error function corresponding to the right axis of Fig. 28.7 shows the probability that $\widehat{\alpha}/\sigma$ at or below the given value should occur. If the experimental value is exceeding improbable, then the

formal confidence limit obtained by this or any other method means very little.

What about the arbitrariness of $\pi(\alpha)$? If the square of the neutrino mass is measured $(\alpha = m_{\nu}^2)$, then should we not take the prior knowledge distribution as proportional to $\sqrt{\alpha}$?[†] There are other attractive options. Jeffreys points out that if $\pi(\alpha) d\alpha = d\alpha/\alpha$, then the distributions for α and α^n are proportional [16], but there are practical difficulties with this approach. Lynch has investigated prior distributions that are constant in α , α^2 , and $\sqrt{\alpha}$ in the context of Gaussian $f(\widehat{\alpha}|\alpha)$, and has observed that assuming a prior distribution that is flat in α gives results that are much more satisfactory than one gets from the others [17]: All three methods have the property that the probability that the calculated limit contains the correct answer is 100\% when $\alpha = 0$ and approaches the proper value when $\alpha \gg \sigma$, but the approach to the proper value as α increases is much faster when the prior distribution is taken to be flat in α . In this case the approach is also monotonic, giving it the "conservative" property that for no value of α will the method produce a limit that has a probability of being correct that is less than the stated confidence limit. Although there is nothing unique about the limit calculated with a constant $\pi(\alpha)$, it has desirable features and no obvious replacement.

Summary: If there is a significant probability of obtaining an estimator corresponding to an unphysical value for a parameter, there is no universally accepted way way to make a statement of the sort " α is less that c_2 with probability $1-\varepsilon$." A variety of upper limits can be defined, but no method is entirely satisfactory. The Bayesian method with a flat prior distribution gives a reasonable upper limit which combines everything we know about the unknown quantity α into a physically reasonable value, but it does not give a complete summary of the information contained in the experiment.

28.6.4. Poisson processes with background [18]:

If we observe n_0 events in a Poisson process which has two components, signal and background, estimating a limit on the signal is more complicated. Let μ_S be the unknown mean (the Poisson parameter) for the signal and μ_B be the mean for the sum of all backgrounds. Assume μ_B is known with negligible error; however we don't know n_B , the actual number of events resulting from the background. We do know that $n_B \leq n_0$. If $\mu_B + \mu_S$ is large, the Gaussian approximation to the Poisson distribution (see Sec. 27.3.2) is usually adequate, and one can define confidence intervals or limits as above, assuming $\hat{n}_B \approx \mu_B$ and therefore $\hat{\mu}_S = n_0 - \mu_B$ with variance equal to n_0 (larger than $\hat{\mu}_S$ to allow for the error in \hat{n}_B).

Otherwise an upper limit can be defined by extension of the argument of the preceding section. Let N be the desired upper limit on μ_S with confidence coefficient ε . Set N to be that value of μ_S such that any random repeat of the current experiment with $\mu_S = N$ and the same μ_B would observe *more* than n_0 events in total and would have $n_B \leq n_0$, all with probability $1 - \varepsilon$. For any assumed N and μ_B we can calculate this probability:

$$1 - \varepsilon = 1 - \frac{e^{-(\mu_B + N)} \sum_{n=0}^{n_0} \frac{(\mu_B + N)^n}{n!}}{e^{-\mu_B} \sum_{n=0}^{n_0} \frac{\mu_B^n}{n!}}.$$
 (28.40)

We adjust N to obtain a desired ε . For $\mu_B=0$ this converges to Eq. (28.37). As in that case (see the last paragraph of Section 28.6.2) this gives a conservative upper limit in that for any given true μ_S we get a true probability $\geq 1-\varepsilon$ that $N\geq \mu_S$, averaged over a large set of identically performed experiments. For $\varepsilon=0.10$, Fig. 28.8 shows N as a function of n_0 and μ_B .

Averaging of experiments and other comparisons require that n_0 and μ_B be quoted and the technique used for upper limit extraction be given.

If $\mu_B \gg n_0$ the experimenter should question the probability of observing n_B as that n_0 . If this is very small the background, μ_B , may not have been calculated properly and the upper limit for μ_S obtained under those assumptions may be too low. For example, in

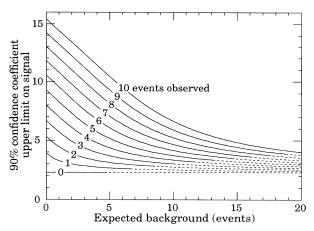


Figure 28.8: 90% confidence coefficient upper limit on the number of signal events as a function of the expected number of background events. For example, if the expected background is 8 events and 5 events are observed, then the signal is 4.0 (approximately) or less with 90% confidence. Dashed portions indicate regions where it is to be expected that the number observed would exceed the number actually observed \geq 99% of the time, even in the complete absence of signal.

Fig. 28.8, the dashed portions of the curves lie in the region where n_0 is expected to exceed the observed value 99% of the time (or more), even in the complete absence of signal. In these regions one should be cautious about accepting the results of the measurement.

As in the Gaussian case (Sec. 28.6.3), whenever $n_0 < \mu_B$ some experimenters may prefer to use N calculated as if $n_0 \approx \mu_B$ rather than the smaller value obtained from the observed n_0 .

28.7. Propagation of errors

Suppose we have a set of N random variables y_i which may be direct measurements or derived estimators $\widehat{\alpha}$, and we have a covariance matrix V(y) for these. We can make a transformation to a different set of variables $f_n \equiv f_n(y), \ j=1,\ldots,M \ (M\leq N)$ and obtain best estimates for the f_n from

$$\widehat{f}_n \approx f_n(\widehat{y}) + \frac{1}{2} \sum_{k,n}^{N} V_{kn}(\widehat{y}) \left[\frac{\partial^2 f_n}{\partial y_k \partial y_n} \right]_{\widehat{y}}$$
 (28.41)

with covariance matrix

$$V_{ij}(\hat{f}) \approx \sum_{n,m} \frac{\partial f_i}{\partial y_n} \Big|_{\widehat{y}} \left. \frac{\partial f_j}{\partial y_m} \Big|_{\widehat{y}} V_{nm}(\widehat{y}) \right.$$
 (28.42)

For a single-valued function f of a single measurement y with variance σ^2 (i.e., M=1,N=1), this becomes

$$\widehat{f} \approx f(\widehat{y}) + \frac{1}{2}\sigma^2 f''(\widehat{y})$$

$$V(\widehat{f}) \approx \sigma^2 [f'(\widehat{y})]^2 ,$$
(28.43)

where the primes denote differentiation with respect to y, evaluated at $\widehat{y}.$

These approximations are based on a Taylor expansion of f about the true value of y. If f is approximately linear in y over a range of roughly $\widehat{y}_i \pm \sigma(y_i)$, the approximation is good and the second-order terms in (28.41) and (28.43) can be neglected. This is what is usually done. However, if linearity is badly violated (e.g., $f \propto 1/y$ and \widehat{y} is no more than a few σ from zero), it should be recognized that propagation of errors will give very approximate results. In such cases $\widehat{f} \approx f(\widehat{y})$ may be a biased estimator for f even if \widehat{y} is unbiased for y, and the second-order terms in (28.41) and (28.43) will help to reduce that bias.

*In addition to the references cited, communications with R.D. Cousins, F. James, G. Lynch, and B. Roe have been invaluable in formulating this section.

[†]There is an additional problem: Even if we set a confidence limit on m_{ν}^2 by some particular recipe, it translates into a different confidence limit on $\sqrt{m_{\nu}^2}$ except when a Bayesian procedure with Jeffreys' $\pi(\alpha) \propto 1/\alpha$ prior distribution is used.

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29. MONTE CARLO TECHNIQUES

Revised July 1995 by S. Youssef.

Monte Carlo techniques are often the only practical way to evaluate difficult integrals or to sample random variables governed by complicated probability density functions. Here we describe an assortment of methods for sampling some commonly occurring probability density functions.

29.1. Sampling the uniform distribution

Most Monte Carlo sampling or integration techniques assume a "random number generator" which generates uniform statistically independent values on the half open interval [0, 1). Although such a generator is, strictly speaking, impossible on a finite digital computer, generators are nevertheless available which pass extensive batteries of tests for statistical independence and which have periods which are so long that, for practical purposes, values from these generators can be considered to be uniform and statistically independent. In particular, the lagged-Fibonacci based generator introduced by Marsaglia, Zaman, and Tsang [1] is efficient, has a period of approximately 10⁴³, produces identical sequences on a wide variety of computers and, passes the extensive "DIEHARD" battery of tests [2]. Many commonly available congruential generators fail these tests and often have sequences (typically with periods less than 2³²) which can be easily exhausted on modern computers and should therefore be avoided [3].

29.2. Inverse transform method

If the desired probability density function is f(x) on the range $-\infty < x < \infty$, its cumulative distribution function (expressing the probability that $x \le a$) is given by Eq. (27.1). If a is chosen with probability density f(a), then the integrated probability up to point a, F(a), is itself a random variable which will occur with uniform probability density on [0,1]. If x can take on any value, and ignoring the endpoints, we can then find a unique x chosen from the p.d.f. f(s) for a given u if we set

$$u = F(x) , (29.1)$$

provided we can find an inverse of F, defined by

$$x = F^{-1}(u) (29.2)$$

This method is shown in Fig. 29.1a.

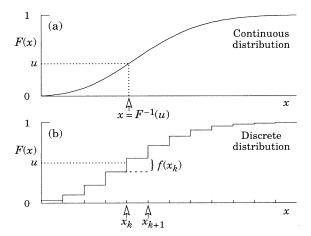


Figure 29.1: Use of a random number u chosen from a uniform distribution (0,1) to find a random number x from a distribution with cumulative distribution function F(x).

For a discrete distribution, F(x) will have a discontinuous jump of size $f(x_k)$ at each allowed $x_k, k = 1, 2, \cdots$. Choose u from a uniform distribution on (0,1) as before. Find x_k such that

$$F(x_{k-1}) < u \le F(x_k) \equiv \text{Prob}(x \le x_k) = \sum_{i=1}^k f(x_i);$$
 (29.3)

then x_k is the value we seek (note: $F(x_0) \equiv 0$). This algorithm is illustrated in Fig. 29.1b.

29.3. Acceptance-rejection method (Von Neumann)

Very commonly an analytic form for F(x) is unknown or too complex to work with, so that obtaining an inverse as in Eq. (29.2) is impractical. We suppose that for any given value of x the probability density function f(x) can be computed and further that enough is known about f(x) that we can enclose it entirely inside a shape which is C times an easily generated distribution h(x) as illustrated in Fig. 29.2.

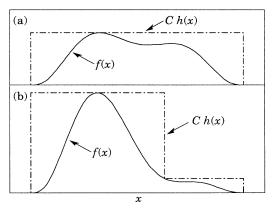


Figure 29.2: Illustration of the acceptance-rejection method. Random points are chosen inside the upper bounding figure, and rejected if the ordinate exceeds f(x). Lower figure illustrates importance sampling.

Frequently h(x) is uniform or is a normalized sum of uniform distributions. Note that both f(x) and h(x) must be normalized to unit area and therefore the proportionality constant C>1. To generate f(x), first generate a candidate x according to h(x). Calculate f(x) and the height of the envelope C h(x); generate u and test if $uCh(x) \leq f(x)$. If so, accept x; if not reject x and try again. If we regard x and uCh(x) as the abscissa and ordinate of a point in a two-dimensional plot, these points will populate the entire area Ch(x) in a smooth manner; then we accept those which fall under f(x). The efficiency is the ratio of areas, which must equal 1/C; therefore we must keep C as close as possible to 1.0. Therefore we try to choose Ch(x) to be as close to f(x) as convenience dictates, as in the lower part of Fig. 29.2. This practice is called importance sampling, because we generate more trial values of x in the region where f(x) is most important.

29.4. Algorithms

Algorithms for generating random numbers belonging to many different distributions are given by Press [4], Ahrens and Dieter [5], Rubinstein [6], Everett and Cashwell [7], Devroye [8], and Walck [9]. For many distributions alternative algorithms exist, varying in complexity, speed, and accuracy. For time-critical applications, these algorithms may be coded in-line to remove the significant overhead often encountered in making function calls. Variables named "u" are assumed to be independent and uniform on (0,1).

In the examples given below, we use the notation for the variables and parameters given in Table 27.1.

29.4.1. Sine and cosine of random angle:

Generate u_1 and u_2 . Then $v_1 = 2u_1 - 1$ is uniform on (-1,1), and $v_2 = u_2$ is uniform on (0,1). Calculate $r^2 = v_1^2 + v_2^2$. If $r^2 > 1$, start over. Otherwise, the sine (S) and cosine (C) of a random angle are given by

$$S = 2v_1v_2/r^2$$
 and $C = (v_1^2 - v_2^2)/r^2$. (29.4)

29.4.2. Gaussian distribution:

If u_1 and u_2 are uniform on (0,1), then

$$z_1 = \sin 2\pi u_1 \sqrt{-2 \ln u_2}$$
 and $z_2 = \cos 2\pi u_1 \sqrt{-2 \ln u_2}$ (29.5)

are independent and Gaussian distributed with mean 0 and $\sigma = 1$.

There are many faster variants of this basic algorithm. For example, construct $v_1=2u_1-1$ and $v_2=2u_2-1$, which are uniform on (-1,1). Calculate $r^2=v_1^2+v_2^2$, and if $r^2>1$ start over. If $r^2<1$, it is uniform on (0,1). Then

$$z_1 = v_1 \sqrt{\frac{-2 \ln r^2}{r^2}}$$
 and $z_2 = v_2 \sqrt{\frac{-2 \ln r^2}{r^2}}$ (29.6)

are independent numbers chosen from a normal distribution with mean 0 and variance 1. $z_i' = \mu + \sigma z_i$ distributes with mean μ and variance σ^2 .

For a multivariate Gaussian, see the algorithm in Ref. 10.

29.4.3. $\chi^2(n)$ distribution:

For n even, generate n/2 uniform numbers u_i ; then

$$y = -2 \ln \left(\prod_{i=1}^{n/2} u_i \right)$$
 is $\chi^2(n)$. (29.7)

For n odd, generate (n-1)/2 uniform numbers u_i and one Gaussian z as in Sec. 29.4.2; then

$$y = -2 \ln \left(\prod_{i=1}^{(n-1)/2} u_i \right) + z^2 \text{ is } \chi^2(n) .$$
 (29.8)

For $n \gtrsim 30$ the much faster Gaussian approximation for the χ^2 may be preferable: generate z as in Sec. 29.4.2 and use $y = \left[z + \sqrt{2n-1}\right]^2/2$; if $z < -\sqrt{2n-1}$ reject and start over.

${\bf 29.4.4.} \quad {\it Gamma~distribution}:$

All of the following algorithms are given for $\lambda=1.$ For $\lambda\neq 1,$ divide the resulting random number x by $\lambda.$

- If k = 1 (the exponential distribution), accept $x = -(\ln u)$.
- If 0 < k < 1, initialize with $v_1 = (e + k)/e$ (with e = 2.71828... being the natural log base). Generate u_1, u_2 . Define $v_2 = v_1u_1$.

Case 1: $v_2 \le 1$. Define $x = v_2^{1/k}$. If $u_2 \le e^{-x}$, accept x and step, else restart by generating new u_1, u_2 .

Case 2: $v_2 > 1$. Define $x = -\ln([v_1 - v_2]/k)$. If $u_2 \le x^{k-1}$, accept x and stop, else restart by generating new u_1 , u_2 . Note that, for k < 1, the probability density has a pole at x = 0, so that return values of zero due to underflow must be accepted or otherwise dealt with.

• Otherwise, if k > 1, initialize with c = 3k - 0.75. Generate u_1 and compute $v_1 = u_1(1 - u_1)$ and $v_2 = (u_1 - 0.5)\sqrt{c/v_1}$. If $x = k + v_2 - 1 \le 0$, go back and generate new u_1 ; otherwise generate u_2 and compute $v_3 = 64v_1^3u_2^2$. If $v_3 \le 1 - 2v_2^2/x$ or if $\ln v_3 \le 2\{[k-1]\ln[x/(k-1)] - v_2\}$, accept x and stop; otherwise go back and generate new u_1 .

29.4.5. Binomial distribution:

If $p \leq 1/2$, iterate until a successful choice is made: begin with k=1; compute $P_k=q^n$ [for $k\neq 1$ use $P_k\equiv f(r_k;n,p)$, and store P_k into B; generate u. If $u\leq B$ accept $r_k=k-1$ and stop; otherwise increment k by 1 and compute next P_k and add to B; generate a new u and repeat. If we arrive at k=n+1, stop and accept $r_{n+1}=n$. If p>1/2 it will be more efficient to generate r from f(r;n,q), i.e., with p and q interchanged, and then set $r_k=n-r$.

29.4.6. Poisson distribution:

Iterate until a successful choice is made: Begin with k=1 and set A=1 to start. Generate u. Replace A with uA; if now $A<\exp(-\mu)$, where μ is the Poisson parameter, accept $n_k=k-1$ and stop. Otherwise increment k by 1, generate a new u and repeat, always starting with the value of A left from the previous try. For large $\mu(\gtrsim 10)$ it may be satisfactory (and much faster) to approximate the Poisson distribution by a Gaussian distribution (see our Probability chapter, Sec. 27.3.3) and generate z from f(z;0,1); then accept $x=\max(0,[\mu+z\sqrt{\mu}+0.5])$ where $[\]$ signifies the greatest integer \le the expression.

29.4.7. Student's t distribution:

For n>0 degrees of freedom (n not necessarily integer), generate x from a Gaussian with mean 0 and $\sigma^2=1$ according to the method of 29.4.2. Next generate y, an independent gamma random variate with k=n/2 degrees of freedom. Then $z=x\sqrt{2n}/\sqrt{y}$ is distributed as a t with n degrees of freedom.

For the special case n=1, the Breit-Wigner distribution, generate u_1 and u_2 ; set $v_1=2u_1-1$ and $v_2=2u_2-1$. If $v_1^2+v_2^2\leq 1$ accept $z=v_1/v_2$ as a Breit-Wigner distribution with unit area, center at 0.0, and FWHM 2.0. Otherwise start over. For center M_0 and FWHM Γ , use $W=z\Gamma/2+M_0$.

References:

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30. MONTE CARLO PARTICLE NUMBERING SCHEME

Updated May 1996 by G.R. Lynch and T.G. Trippe.

• NOTE: We have received a proposal for a significant revision to our numbering scheme. The revision would include numbering for particles expected in the quark model but not yet discovered and for hypothetical states such as supersymmetric particles. The proposal was developed by the QCD Monte Carlo Event Generators working group of a LEP2 Workshop in 1995 and conveyed to us by Ian Knowles and Torbjorn Sjöstrand [1]. Lynn Garren, who is responsible for the STDHEP standard [2] at Fermilab, is also involved. We will put this proposal on the Particle Data Group WWW page (http://pdg.lbl.gov/) in the near future to invite comment and to provide information on the status of its acceptance.

Most particle physics Monte Carlo and analysis systems use a numbering scheme to represent particles. The lack of standardization of such schemes inhibits interfacing different programs. The following table proposes a standard numbering scheme. Some of the properties of this scheme are:

- Quarks and leptons are ordered by family, and within the family, by isospin. This puts the u and d in the opposite order than is often used in other numbering schemes. In our scheme we call the highest numbered quark the heaviest quark.
- 2. For multiple quark systems (mesons, baryons, and diquarks), the rightmost digit is generally L=2J+1. (The K^0_S and K^0_L are exceptions.) Particles with J>4 have not been assigned numbers.
- 3. Mesons are represented by the form NML and baryons by NMKL, where N, M, and K are quark numbers.
- 4. For these systems the highest quark number (see quark list below) is usually on the left and the quarks are in decreasing order of quark number from left to right. One exception to this convention is the K_L^0 - K_S^0 pair. A second exception is for the Λ 's for which we invert the up and down quarks to distinguish the Λ from the Σ^0 .
- 5. The other exception to this quark-number order rule is for some N's and Δ's. For N's, the u and d quark are reversed for spins 3/2 and 7/2. For Δ's, they are reversed for spins 1/2 and 5/2. The quarks are in the normal decreasing order when I + J is odd.
- Mesons, and only mesons, have the third digit nonzero and the fourth digit zero. (We designate the rightmost digit as the first digit.)

- 7. Only baryons and diquarks have the fourth digit nonzero.
- 8. Only quarks and diquarks have the second digit equal to zero.
- 9. Particles have positive numbers; each antiparticle has the negative of its counterpart.
- 10. The particle-antiparticle convention is the one used by the Particle Data Group, so that the K^+ and B^+ are particles.
- 11. The above rules imply that for mesons (as opposed to antimesons), when the number of the leftmost (heaviest) quark is even, it is a quark, and when the number of the leftmost quark is odd, it is an antiquark.
- 12. The gluon has two numbers. Its official number is 21 to place it with the other gauge bosons. Its number is also 9 so that a glueball is specified as 99.
- 13. The fifth digit is used to differentiate different particles with the same quark content and spin.
- 14. Although isospin is not manifest in this scheme, the isospin of any hadron can be determined from the number. Mesons with 11L are isospin 1 and those with 22L are isospin 0. For nonstrange baryons, if the quarks are in the normal decreasing order, then I+J is odd, otherwise I+J is even. If a strange baryon does not have the normal decreasing quark order, it has I=0.

More details about the motivation behind, and properties of, this scheme can be found in Ref. 3. Although this scheme has the advantage that a particle's number has considerable physics content, it has the disadvantage that it is not compact. An algorithm that translates this scheme into a more compact scheme is needed for its implementation. Contact the Berkeley Particle Data Group for further information on such an algorithm.

A list of particle numbers follows.

References:

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- 3. T.G. Trippe and G.R. Lynch, "Particle I.D. Numbers, Decay Tables, and Other Possible Contributions of the Particle Data Group to Monte Carlo Standards," LBL-24287, in *Proceedings of the Workshop on Detector Simulation for the SSC* (August 1987).

OH A DIVO	LEDMONG	MEGONIC	
QUARKS	LEPTONS	MESONS	
d 1	ν_e 12	π^{+} 211	
u 2	$ u_{\mu} = 14$	π^0 111	
s 3	$ u_{\tau} $ 16	η 221	
c 4	e 11	$f_0(400-1200)$ 60221	
b 5	μ 13	$\rho(770)$ 113, 2	13
t 6	au 15	$\omega(782)$ 223	
GAUGE AND	7 15	$\eta'(958)$ 331	
		17 (908) 551	
HIGGS BOSONS	DIQUARKS	$f_0(980)$ 10221	
γ 22	$(dd)_1$ 1103	$a_0(980)$ 10111, 102	11
W 24	$(ud)_0$ 2101	$\phi(1020)$ 333	
$egin{array}{cccc} Z & 23 & & & & & & & & & & & & & & & & & $	$(ud)_1$ 2103	$h_1(1170)$ 10223	
H_1^0 25	$(uu)_1$ 2203	$b_1(1235)$ 10113, 102	13
H_2^0 35	$(sd)_0$ 3101	$a_1(1260)$ 20113, 202	13
	$(sd)_1$ 3103	$f_2(1270)$ 225	
H_3^0 36	$(su)_0$ 3201	$f_1(1285)$ 20223	
H^+ 37	$(su)_1$ 3203		

MESONS (Cont'd)		MESONS (Cont'd)	BARYONS (Cont'd)	
$\eta(1295)$	20221	$\eta_c(1S)$ 441	Λ P ₀₁ 3122	
$\pi(1300)$	20111, 20211	$J/\psi(1S)$ 443	$\Lambda(1405)$ S ₀₁ 13122	
$a_2(1320)$	115, 215	$\chi_{c0}(1P) \qquad 10441$	$\Lambda(1520)$ D ₀₃ 3124	
$f_0(1370)$	30221	$\chi_{c1}(1P) \qquad 10443$	$\Lambda(1600)$ P ₀₁ 23122	
$f_1(1420)$	30223	$\chi_{c2}(1P) 445$	$\Lambda(1670)$ S ₀₁ 33122	
$\omega(1420)$	50223	$\psi(2S)$ 20443	$\Lambda(1690)$ D ₀₃ 13124	
$\eta(1440)$	40221	$\psi(3770)$ 30443	$\Lambda(1800)$ S ₀₁ 43122	
$\rho(1450)$	40113, 40213	$\psi(4040) \qquad 40443$	$\Lambda(1810)$ P ₀₁ 53122	
$f_0(1500)$	50221	$\psi(4160)$ 50443	$\Lambda(1820)$ F ₀₅ 3126	
$f_1(1510)$	40223	$\psi(4415)$ 60443	$\Lambda(1830)$ D ₀₅ 13126	
$f_2'(1525)$	335	$\Upsilon(1S)$ 553	$\Lambda(1890)$ P ₀₃ 23124	
$\omega(1600)$	60223	$\chi_{b0}(1P)$ 551	$\Lambda(2100)$ G ₀₇ 3128	
$\omega_3(1670)$	227	$\chi_{b1}(1P)$ 10553	$\Lambda(2110)$ F ₀₅ 23126	
$\pi_2(1670)$	10115, 10215	$\chi_{b2}(1P)$ 555	\varSigma^+ P $_{11}$ 3222	
$\phi(1680)$	10333	$\varUpsilon(2S)$ 20553	Σ^0 P ₁₁ 3212	
$\rho_3(1690)$	117, 217	$\chi_{b0}(2P)$ 10551	Σ^- P ₁₁ 3112	
$\rho(1700)$	30113, 30213	$\chi_{b1}(2P)$ 70553	$\Sigma(1385)$ P ₁₃ 3114, 3214, 3224	
$f_{J}(1710)$	30113, 30213	$\chi_{b2}(2P)$ 10555	$\Sigma(1660)$ P ₁₁ 13112, 13212, 13222	
$\phi_3(1850)$	337	$\varUpsilon(3S)$ 30553	$\Sigma(1670)$ D ₁₃ 13114, 13214, 13224	
$f_2(2010)$	20225	$\Upsilon(4S)$ 40553	$\Sigma(1750)$ S ₁₁ 23112, 23212, 23222	
$f_4(2050)$	229	$\Upsilon(10860)$ 50553	$\Sigma(1775)$ D ₁₅ 3116, 3216, 3226	
$f_2(2300)$	30225	$\Upsilon(11020)$ 60553	$\Sigma(1915)$ F ₁₅ 13116, 13216, 13226	
$f_2(2340)$	40225	` '	$\Sigma(1940)$ D ₁₃ 23114, 23214, 23224	
K^+	321	BARYONS	$\Sigma(2030)$ F ₁₇ 3118, 3218, 3228	
K_0^0	311	$p P_{11} 2212$	Ξ^{0} P ₁₁ 3322	
K_S^0	310	$n P_{11} 2112$	\varXi^- P ₁₁ 3312	
K_L^0	130	N(1440) P ₁₁ 12112, 12212	$\Xi(1530)$ P ₁₃ 3314, 3324	
$K^*(892)$	313, 323	N(1520) D ₁₃ 1214, 2124	$\Xi(1820)$ D ₁₃ 13314, 13324	
$K_1(1270)$	10313, 10323	N(1535) S ₁₁ 22112, 22212	Ω^- 3334	
$K_1(1400)$	20313, 20323	N(1650) S ₁₁ 32112, 32212	A_c^+ 4122	
$K^*(1410)$	30313, 30323	N(1675) D ₁₅ 2116, 2216	$A_c(2593)^+$ 14122	
$K_0^*(1430)$	10311, 10321	$N(1680)$ F_{15} 12116, 12216	$\Sigma_c(2455)$ 4112, 4212, 4222	
$K_2^*(1430)$	315, 325	N(1700) D ₁₃ 21214, 22124	\mathcal{Z}_c^+ 4322	
$K^*(1680)$	40313, 40323	N(1710) P ₁₁ 42112, 42212	Ξ_c^0 4312	
$K_2(1770)$	10315, 10325	N(1720) P ₁₃ 31214, 32124	Ω_c^0 4332	
$K_3^*(1780)$	317, 327	N(2190) G ₁₇ 1218, 2128	A_b^0 5122	
$K_2(1820)$	20315, 20325	$\Delta(1232)$ P ₃₃ 1114, 2114, 2214, 2224		
$K_4^*(2045)$	319, 329	$\Delta(1600)$ P ₃₃ 31114, 32114, 32214, 32224		
D_{0}^{+}	411	$\Delta(1620)$ S ₃₁ 1112, 1212, 2122, 2222		
$D^0 \\ D^* (2007)^0$	421 423	$\Delta(1700)$ $\dot{\mathrm{D}}_{33}$ 11114, 12114, 12214, 12224		
$D^*(2007)^+$	413	$\Delta(1900)$ S ₃₁ 11112, 11212, 12122, 12222		
$D_1(2420)^0$	10423	$\Delta(1905)$ F ₃₅ 1116, 1216, 2126, 2226		
$D_1(2420)$ $D_2^*(2460)^0$		$\Delta(1910)$ P ₃₁ 21112, 21212, 22122, 22222		
$D_2^*(2460)^+$	425	$\Delta(1920)$ P ₃₃ 21114, 22114, 22214, 22224		
	415	$\Delta(1930)$ D ₃₅ 11116, 11216, 12126, 12226		
D_s^+	431	$\Delta(1950)$ F ₃₇ 1118, 2118, 2218, 2228		
D_s^{*+}	433			
$D_{s1}(2536)^+$ B^+	10433			
B^0	521 511			
B^*	513, 523			
B_s^0	531			

31. CLEBSCH-GORDAN COEFFICIENTS, SPHERICAL HARMONICS, AND d FUNCTIONS

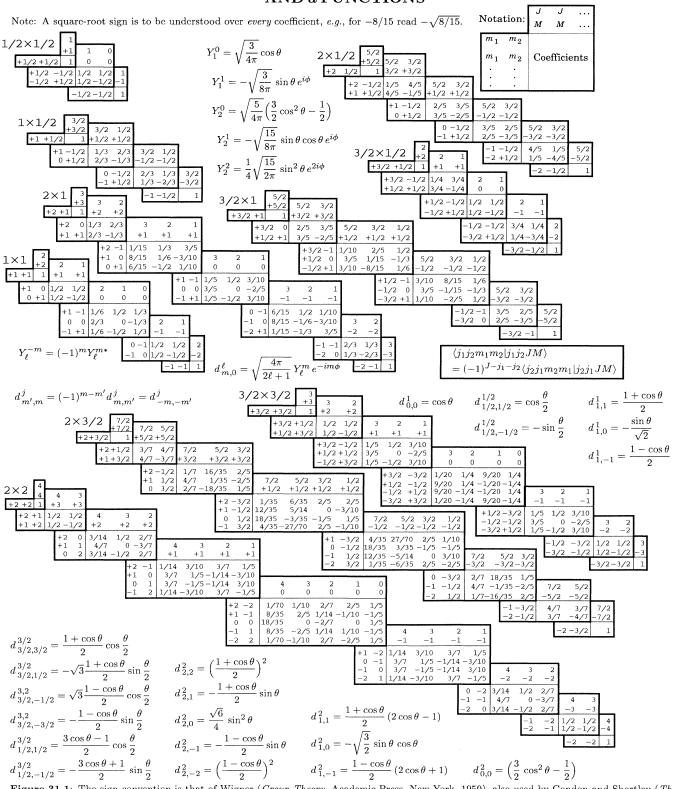


Figure 31.1: The sign convention is that of Wigner (*Group Theory*, Academic Press, New York, 1959), also used by Condon and Shortley (*The Theory of Atomic Spectra*, Cambridge Univ. Press, New York, 1953), Rose (*Elementary Theory of Angular Momentum*, Wiley, New York, 1957), and Cohen (*Tables of the Clebsch-Gordan Coefficients*, North American Rockwell Science Center, Thousand Oaks, Calif., 1974). The coefficients here have been calculated using computer programs written independently by Cohen and at LBNL.

32. SU(3) ISOSCALAR FACTORS AND REPRESENTATION MATRICES

The most commonly used SU(3) isoscalar factors, corresponding to the singlet, octet, and decuplet content of $8\otimes 8$ and $10\otimes 8$, are shown at the right. The notation uses particle names to identify the coefficients, so that the pattern of relative couplings may be seen at a glance. We illustrate the use of the coefficients below. See J.J de Swart, Rev. Mod. Phys. **35**, 916 (1963) for detailed explanations and phase conventions.

 $A \sqrt{\ }$ is to be understood over every integer in the matrices; the exponent 1/2 on each matrix is a reminder of this. For example, the $\Xi \to \Omega K$ element of the $10 \to 10 \otimes 8$ matrix is $-\sqrt{6}/\sqrt{24} = -1/2$.

Intramultiplet relative decay strengths may be read directly from the matrices. For example, in decuplet \to octet + octet decays, the ratio of $\Omega^* \to \varXi \overline{K}$ and $\Delta \to N\pi$ partial widths is, from the $10 \to 8 \times 8$ matrix,

$$\frac{\Gamma(\Omega^* \to \Xi \overline{K})}{\Gamma(\Delta \to N\pi)} = \frac{12}{6} \times \text{ (phase space factors)}.$$
 (32.1)

Including isospin Clebsch-Gordan coefficients, we obtain, e.g.,

$$\frac{\Gamma(\varOmega^{*-}\to \varXi^0 K^-)}{\Gamma(\varDelta^+\to p\,\pi^0)} = \frac{1/2}{2/3}\times \frac{12}{6}\times p.s.f. = \frac{3}{2}\times p.s.f. \tag{32.2}$$

Partial widths for $8 \to 8 \otimes 8$ involve a linear superposition of 8_1 (symmetric) and 8_2 (antisymmetric) couplings. For example,

$$\Gamma(\Xi^* \to \Xi \pi) \sim \left(-\sqrt{\frac{9}{20}} g_1 + \sqrt{\frac{3}{12}} g_2\right)^2$$
 (32.3)

The relations between g_1 and g_2 (with de Swart's normalization) and the standard D and F couplings that appear in the interaction Lagrangian,

$$\mathcal{L} = -\sqrt{2} D \operatorname{Tr} (\{\overline{B}, B\}M) + \sqrt{2} F \operatorname{Tr} ([\overline{B}, B]M) , \qquad (32.4)$$

where $[\overline{B}, B] \equiv \overline{B}B - B\overline{B}$ and $\{\overline{B}, B\} \equiv \overline{B}B + B\overline{B}$, are

$$D = \frac{\sqrt{30}}{40} g_1 , \qquad F = \frac{\sqrt{6}}{24} g_2 . \tag{32.5}$$

Thus, for example,

$$\Gamma(\Xi^* \to \Xi \pi) \sim (F - D)^2 \sim (1 - 2\alpha)^2$$
, (32.6)

where $\alpha \equiv D/(D+F)$.

The generators of SU(3) transformations, λ_a (a=1,8), are 3×3 matrices that obey the following commutation and anticommutation relationships:

$$[\lambda_a, \lambda_b] \equiv \lambda_a \lambda_b - \lambda_b \lambda_a = 2i f_{abc} \lambda_c \tag{32.7}$$

$$\{\lambda_a, \ \lambda_b\} \equiv \lambda_a \lambda_b + \lambda_b \lambda_a = \frac{4}{3} \delta_{ab} I + 2d_{abc} \lambda_c \ , \tag{32.8}$$

where I is the 3×3 identity matrix, and δ_{ab} is the Kronecker delta symbol. The f_{abc} are odd under the permutation of any pair of indices, while the d_{abc} are even. The nonzero values are

$$\mathbf{1} \to \mathbf{8} \otimes \mathbf{8}$$

$$(\Lambda) \rightarrow (N\overline{K} \Sigma \pi \Lambda \eta \Xi K) = \frac{1}{\sqrt{8}} (2 \ 3 \ -1 \ -2)^{1/2}$$

 $8_1 \rightarrow 8 \otimes 8$

$$\begin{pmatrix} N \\ \Sigma \\ \Lambda \\ \Xi \end{pmatrix} \rightarrow \begin{pmatrix} N\pi & N\eta & \Sigma K & \Lambda K \\ N\overline{K} & \Sigma\pi & \Lambda\pi & \Sigma\eta & \Xi K \\ N\overline{K} & \Sigma\pi & \Lambda\eta & \Xi K \\ \Sigma \overline{K} & \Lambda \overline{K} & \Xi\pi & \Xi\eta \end{pmatrix} = \frac{1}{\sqrt{20}} \begin{pmatrix} 9 & -1 & -9 & -1 \\ -6 & 0 & 4 & 4 & -6 \\ 2 & -12 & -4 & -2 \\ 9 & -1 & -9 & -1 \end{pmatrix}^{1/2}$$

 $8_2 \rightarrow 8 \otimes 8$

$$\begin{pmatrix} N \\ \Sigma \\ \Lambda \\ \Xi \end{pmatrix} \rightarrow \begin{pmatrix} N\pi & N\eta & \Sigma K & \Lambda K \\ N\overline{K} & \Sigma\pi & \Lambda\pi & \Sigma\eta & \Xi K \\ N\overline{K} & \Sigma\pi & \Lambda\eta & \Xi K \\ \Sigma\overline{K} & \Lambda\overline{K} & \Xi\pi & \Xi\eta \end{pmatrix} = \frac{1}{\sqrt{12}} \begin{pmatrix} 3 & 3 & 3 & -3 \\ 2 & 8 & 0 & 0 & -2 \\ 6 & 0 & 0 & 6 \\ 3 & 3 & 3 & -3 \end{pmatrix}^{1/2}$$

 $10 \rightarrow 8 \otimes 8$

$$\begin{pmatrix} \Delta \\ \Sigma \\ \Xi \\ \Omega \end{pmatrix} \rightarrow \begin{pmatrix} N\overline{K} \begin{array}{ccc} N\pi & \Sigma K \\ \Sigma \overline{K} \end{array} \begin{array}{ccc} N\pi & \Sigma K \\ \Sigma \overline{K} \end{array} \begin{array}{cccc} \Lambda \pi & \Sigma \eta & \Xi K \\ \Xi \overline{K} \end{array} \begin{array}{cccc} \Xi K \\ \Xi \overline{K} \end{array} \begin{array}{ccccc} = \frac{1}{\sqrt{12}} \begin{pmatrix} -6 & 6 & 6 & 6 \\ -2 & 2 & -3 & 3 & 2 \\ 3 & -3 & 3 & 3 & 12 \\ 12 & & & 12 & & 12 \end{pmatrix}^{1/2}$$

 $8 \rightarrow 10 \otimes 8$

$$\begin{pmatrix} N \\ \Sigma \\ \Lambda \\ \Xi \end{pmatrix} \rightarrow \begin{pmatrix} \Delta\pi & \Sigma K \\ \Sigma\overline{K} & \Sigma\pi & \Sigma\eta & \Xi K \\ \Sigma\overline{K} & \Xi\pi & \Xi\eta & \Omega K \end{pmatrix} \qquad = \frac{1}{\sqrt{15}} \begin{pmatrix} -12 & 3 \\ 8 & -2 & -3 & 2 \\ -9 & 6 \\ 3 & -3 & -3 & 6 \end{pmatrix}^{1/2}$$

 $10 \rightarrow 10 \otimes 8$

$$\begin{pmatrix} \Delta \\ \Sigma \\ \Xi \\ \Omega \end{pmatrix} \rightarrow \begin{pmatrix} \Delta \pi & \Delta \eta & \Sigma K \\ \Delta \overline{K} & \Sigma \pi & \Sigma \eta & \Xi K \\ \Sigma \overline{K} & \Xi \pi & \Xi \eta & \Omega K \\ \Xi \overline{K} & \Omega \eta \end{pmatrix} \qquad = \frac{1}{\sqrt{24}} \begin{pmatrix} 15 & 3 & -6 \\ 8 & 8 & 0 & -8 \\ 12 & 3 & -3 & -6 \\ 12 & -12 \end{pmatrix}^{1/2}$$

abc	f_{abc}	\underline{abc}	d_{abc}	abc	d_{abc}
123	1	118	$1/\sqrt{3}$	355	1/2
147	1/2	146	1/2	366	-1/2
156	-1/2	157	1/2	377	-1/2
246	1/2	228	$1/\sqrt{3}$	448	$-1/(2\sqrt{3})$
257	1/2	247	-1/2	558	$-1/(2\sqrt{3})$
345	1/2	256	1/2	668	$-1/(2\sqrt{3})$
367	-1/2	338	$1/\sqrt{3}$	778	$-1/(2\sqrt{3})$
458	$\sqrt{3}/2$	344	1/2	888	$-1/\sqrt{3}$
678	$\sqrt{3}/2$				

The λ_a 's are

$$\lambda_1 = \begin{pmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} \quad \lambda_2 = \begin{pmatrix} 0 & -i & 0 \\ i & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} \quad \lambda_3 = \begin{pmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

$$\lambda_4 = \begin{pmatrix} 0 & 0 & 1 \\ 0 & 0 & 0 \\ 1 & 0 & 0 \end{pmatrix} \quad \lambda_5 = \begin{pmatrix} 0 & 0 & -i \\ 0 & 0 & 0 \\ i & 0 & 0 \end{pmatrix} \quad \lambda_6 = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{pmatrix}$$

$$\lambda_7 = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & -i \\ 0 & i & 0 \end{pmatrix} \quad \lambda_8 = \frac{1}{\sqrt{3}} \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & -2 \end{pmatrix}$$

Equation (32.7) defines the Lie algebra of SU(3). A general d-dimensional representation is given by a set of $d \times d$ matrices satisfying Eq. (32.7) with the f_{abc} given above. Equation (32.8) is specific to the defining 3-dimensional representation.

33. SU(n) MULTIPLETS AND YOUNG DIAGRAMS

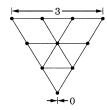
This note tells (1) how $\mathrm{SU}(n)$ particle multiplets are identified or labeled, (2) how to find the number of particles in a multiplet from its label, (3) how to draw the Young diagram for a multiplet, and (4) how to use Young diagrams to determine the overall multiplet structure of a composite system, such as a 3-quark or a meson-baryon system.

In much of the literature, the word "representation" is used where we use "multiplet," and "tableau" is used where we use "diagram."

33.1. Multiplet labels

An SU(n) multiplet is uniquely identified by a string of (n-1) nonnegative integers: $(\alpha, \beta, \gamma, \ldots)$. Any such set of integers specifies a multiplet. For an SU(2) multiplet such as an isospin multiplet, the single integer α is the number of steps from one end of the multiplet to the other (i.e., it is one fewer than the number of particles in the multiplet). In SU(3), the two integers α and β are the numbers of steps across the top and bottom levels of the multiplet diagram. Thus the labels for the SU(3) octet and decuplet





are (1,1) and (3,0). For larger n, the interpretation of the integers in terms of the geometry of the multiplets, which exist in an (n-1)-dimensional space, is not so readily apparent.

The label for the SU(n) singlet is $(0,0,\ldots,0)$. In a flavor SU(n), the n quarks together form a $(1,0,\ldots,0)$ multiplet, and the n antiquarks belong to a $(0,\ldots,0,1)$ multiplet. These two multiplets are conjugate to one another, which means their labels are related by $(\alpha,\beta,\ldots) \leftrightarrow (\ldots,\beta,\alpha)$.

33.2. Number of particles

The number of particles in a multiplet, $N=N(\alpha,\beta,\ldots)$, is given as follows (note the pattern of the equations).

In SU(2), $N = N(\alpha)$ is

$$N = \frac{(\alpha + 1)}{1} \tag{33.1}$$

In SU(3), $N = N(\alpha, \beta)$ is

$$N = \frac{(\alpha+1)}{1} \cdot \frac{(\beta+1)}{1} \cdot \frac{(\alpha+\beta+2)}{2} \ . \tag{33.2}$$

In SU(4), $N = N(\alpha, \beta, \gamma)$ is

$$N = \frac{(\alpha+1)}{1} \cdot \frac{(\beta+1)}{1} \cdot \frac{(\gamma+1)}{1} \cdot \frac{(\alpha+\beta+2)}{2} \cdot \frac{(\beta+\gamma+2)}{2} \cdot \frac{(\alpha+\beta+\gamma+3)}{3} . \tag{33.3}$$

Note that in Eq. (33.3) there is no factor with $(\alpha + \gamma + 2)$: only a consecutive sequence of the label integers appears in any factor. One more example should make the pattern clear for any SU(n). In SU(5), $N = N(\alpha, \beta, \gamma, \delta)$ is

$$\begin{split} N &= \frac{(\alpha + 1)}{1} \cdot \frac{(\beta + 1)}{1} \cdot \frac{(\gamma + 1)}{1} \cdot \frac{(\delta + 1)}{1} \cdot \frac{(\alpha + \beta + 2)}{2} \cdot \frac{(\beta + \gamma + 2)}{2} \\ &\times \frac{(\gamma + \delta + 2)}{2} \cdot \frac{(\alpha + \beta + \gamma + 3)}{3} \cdot \frac{(\beta + \gamma + \delta + 3)}{3} \cdot \frac{(\alpha + \beta + \gamma + \delta + 4)}{4} \ . \end{split} \tag{33.4}$$

From the symmetry of these equations, it is clear that multiplets that are conjugate to one another have the same number of particles, but so can other multiplets. For example, the SU(4) multiplets (3,0,0) and (1,1,0) each have 20 particles. Try the equations and see.

33.3. Young diagrams

A Young diagram consists of an array of boxes (or some other symbol) arranged in one or more left-justified rows, with each row being at least as long as the row beneath. The correspondence between a diagram and a multiplet label is: The top row juts out α boxes to the right past the end of the second row, the second row juts out β boxes to the right past the end of the third row, etc. A diagram in SU(n) has at most n rows. There can be any number of "completed" columns of n boxes buttressing the left of a diagram; these don't affect the label. Thus in SU(3) the diagrams



represent the multiplets (1,0), (0,1), (0,0), (1,1), and (3,0). In any SU(n), the quark multiplet is represented by a single box, the antiquark multiplet by a column of (n-1) boxes, and a singlet by a completed column of n boxes.

33.4. Coupling multiplets together

The following recipe tells how to find the multiplets that occur in coupling two multiplets together. To couple together more than two multiplets, first couple two, then couple a third with each of the multiplets obtained from the first two, etc.

First a definition: A sequence of the letters a,b,c,... is admissible if at any point in the sequence at least as many a's have occurred as b's, at least as many b's have occurred as c's, etc. Thus abcd and aabcb are admissible sequences and abb and acb are not. Now the recipe:

- (a) Draw the Young diagrams for the two multiplets, but in one of the diagrams replace the boxes in the first row with a's, the boxes in the second row with b's, etc. Thus, to couple two SU(3) octets (such as the π -meson octet and the baryon octet), we start with \square and
- $^{\rm a}_{\rm b}$ $^{\rm a}$. The unlettered diagram forms the upper left-hand corner of all the enlarged diagrams constructed below.
- (b) Add the a's from the lettered diagram to the right-hand ends of the rows of the unlettered diagram to form all possible legitimate Young diagrams that have no more than one a per column. In general, there will be several distinct diagrams, and all the a's appear in each diagram. At this stage, for the coupling of the two SU(3) octets, we have:

- (c) Use the b's to further enlarge the diagrams already obtained, subject to the same rules. Then throw away any diagram in which the full sequence of letters formed by reading right to left in the first row, then the second row, etc., is not admissible.
 - (d) Proceed as in (c) with the c's (if any), etc.

The final result of the coupling of the two SU(3) octets is:

Here only the diagrams with admissible sequences of a's and b's and with fewer than four rows (since n=3) have been kept. In terms of multiplet labels, the above may be written

$$(1,1) \otimes (1,1) = (2,2) \oplus (3,0) \oplus (0,3) \oplus (1,1) \oplus (1,1) \oplus (0,0)$$
.

In terms of numbers of particles, it may be written

$$\mathbf{8}\otimes\mathbf{8}=\mathbf{27}\oplus\mathbf{10}\oplus\overline{\mathbf{10}}\oplus\mathbf{8}\oplus\mathbf{8}\oplus\mathbf{1}$$
 .

The product of the numbers on the left here is equal to the sum on the right, a useful check. (See also Sec. 12 on the Quark Model.)

34. KINEMATICS

Revised May 1996.

Throughout this section units are used in which $\hbar=c=1$. The following conversions are useful: $\hbar c=197.3$ MeV fm, $(\hbar c)^2=0.3894$ (GeV)² mb.

34.1. Lorentz transformations

The energy E and 3-momentum p of a particle of mass m form a 4-vector p = (E, p) whose square $p^2 \equiv E^2 - |p|^2 = m^2$. The velocity of the particle is $\beta = p/E$. The energy and momentum (E^*, p^*) viewed from a frame moving with velocity β_f are given by

$$\begin{pmatrix} E^{*} \\ p_{\parallel}^{*} \end{pmatrix} = \begin{pmatrix} \gamma_{f} & -\gamma_{f}\beta_{f} \\ -\gamma_{f}\beta_{f} & \gamma_{f} \end{pmatrix} \begin{pmatrix} E \\ p_{\parallel} \end{pmatrix} \;, \quad p_{T}^{*} = p_{T} \;, \tag{34.1}$$

where $\gamma_f = (1-\beta_f^2)^{-1/2}$ and p_T (p_{\parallel}) are the components of p perpendicular (parallel) to β_f . Other 4-vectors, such as the spacetime coordinates of events, of course transform in the same way. The scalar product of two 4-momenta $p_1 \cdot p_2 = E_1 E_2 - p_1 \cdot p_2$ is invariant (frame independent).

34.2. Center-of-mass energy and momentum

In the collision of two particles of masses m_1 and m_2 the total center-of-mass energy can be expressed in the Lorentz-invariant form

$$E_{\rm cm} = \left[(E_1 + E_2)^2 - (p_1 + p_2)^2 \right]^{1/2} ,$$

= $\left[m_1^2 + m_2^2 + 2E_1E_2(1 - \beta_1\beta_2\cos\theta) \right]^{1/2} ,$ (34.2)

where θ is the angle between the particles. In the frame where one particle (of mass m_2) is at rest (lab frame),

$$E_{\rm cm} = (m_1^2 + m_2^2 + 2E_{1\,\rm lab}\,m_2)^{1/2} \ . \tag{34.3}$$

The velocity of the center-of-mass in the lab frame is

$$\boldsymbol{\beta}_{\rm cm} = \boldsymbol{p}_{\rm lab} / (E_{1\,\rm lab} + m_2) , \qquad (34.4)$$

where $p_{lab} \equiv p_{1 \, lab}$ and

$$\gamma_{\rm cm} = (E_{1\,\rm lab} + m_2)/E_{\rm cm} \ . \tag{34.5}$$

The c.m. momenta of particles 1 and 2 are of magnitude

$$p_{\rm cm} = p_{\rm lab} \frac{m_2}{E_{\rm cm}} \ . \tag{34.6}$$

For example, if a 0.80 ${\rm GeV}/c$ kaon beam is incident on a proton target, the center of mass energy is 1.699 ${\rm GeV}$ and the center of mass momentum of either particle is 0.442 ${\rm GeV}/c$. It is also useful to note that

$$E_{\rm cm} dE_{\rm cm} = m_2 dE_{1 \, \rm lab} = m_2 \, \beta_{1 \, \rm lab} \, dp_{\rm lab} \, .$$
 (34.7)

34.3. Lorentz-invariant amplitudes

The matrix elements for a scattering or decay process are written in terms of an invariant amplitude $-i\mathcal{M}$. As an example, the S-matrix for $2 \to 2$ scattering is related to \mathcal{M} by

$$\langle p'_1 p'_2 | S | p_1 p_2 \rangle = I - i(2\pi)^4 \, \delta^4(p_1 + p_2 - p'_1 - p'_2)$$

$$\times \frac{\mathscr{M}(p_1, p_2; p'_1, p'_2)}{(2E_1)^{1/2} \, (2E_2)^{1/2} \, (2E'_1)^{1/2} \, (2E'_2)^{1/2}} \,. \tag{34.8}$$

The state normalization is such that

$$\langle p'|p\rangle = (2\pi)^3 \delta^3(\boldsymbol{p} - \boldsymbol{p}') . \tag{34.9}$$

34.4. Particle decays

The partial decay rate of a particle of mass M into n bodies in its rest frame is given in terms of the Lorentz-invariant matrix element \mathcal{M} by

$$d\Gamma = \frac{(2\pi)^4}{2M} |\mathcal{M}|^2 d\Phi_n (P; p_1, \dots, p_n), \tag{34.10}$$

where $d\Phi_n$ is an element of n-body phase space given by

$$d\Phi_n(P; p_1, \dots, p_n) = \delta^4 \left(P - \sum_{i=1}^n p_i \right) \prod_{i=1}^n \frac{d^3 p_i}{(2\pi)^3 2E_i} . \tag{34.11}$$

This phase space can be generated recursively, viz.

$$d\Phi_n(P; p_1, \dots, p_n) = d\Phi_j(q; p_1, \dots, p_j)$$

$$\times d\Phi_{n-j+1}(P; q, p_{i+1}, \dots, p_n)(2\pi)^3 dq^2, \qquad (34.12)$$

where $q^2 = (\sum_{i=1}^j E_i)^2 - \left|\sum_{i=1}^j p_i\right|^2$. This form is particularly useful in the case where a particle decays into another particle that subsequently decays.

34.4.1. Survival probability: If a particle of mass M has mean proper lifetime τ (= $1/\Gamma$) and has momentum (E, p), then the probability that it lives for a time t_0 or greater before decaying is given by

$$P(t_0) = e^{-t_0 \Gamma/\gamma} = e^{-Mt_0 \Gamma/E} , \qquad (34.13)$$

and the probability that it travels a distance x_0 or greater is

$$P(x_0) = e^{-Mx_0 \Gamma/|\mathbf{p}|} . {(34.14)}$$

34.4.2. Two-body decays:

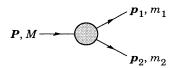


Figure 34.1: Definitions of variables for two-body decays.

In the rest frame of a particle of mass M, decaying into 2 particles labeled 1 and 2,

$$E_1 = \frac{M^2 - m_2^2 + m_1^2}{2M} \,, \tag{34.15}$$

 $|\boldsymbol{p}_1| = |\boldsymbol{p}_2|$

$$=\frac{\left[\left(M^2-(m_1+m_2)^2\right)\left(M^2-(m_1-m_2)^2\right)\right]^{1/2}}{2M},\quad (34.16)$$

and

$$d\Gamma = \frac{1}{32\pi^2} |\mathcal{M}|^2 \frac{|\mathbf{p}_1|}{M^2} d\Omega , \qquad (34.17)$$

where $d\Omega = d\phi_1 d(\cos \theta_1)$ is the solid angle of particle 1.

34.4.3. Three-body decays:

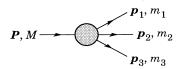


Figure 34.2: Definitions of variables for three-body decays.

Defining $p_{ij}=p_i+p_j$ and $m_{ij}^2=p_{ij}^2$, then $m_{12}^2+m_{23}^2+m_{13}^2=M^2+m_1^2+m_2^2+m_3^2$ and $m_{12}^2=(P-p_3)^2=M^2+m_3^2-2ME_3$, where E_3 is the energy of particle 3 in the rest frame of M. In that frame, the momenta of the three decay particles lie in a plane. The relative orientation of these three momenta is fixed if their energies are known. The momenta can therefore be specified in space by giving three Euler angles (α,β,γ) that specify the orientation of the final system relative to the initial particle. Then

$$d\Gamma = \frac{1}{(2\pi)^5} \frac{1}{16M} |\mathcal{M}|^2 dE_1 dE_2 d\alpha d(\cos\beta) d\gamma . \tag{34.18}$$

Alternatively

$$d\Gamma = \frac{1}{(2\pi)^5} \frac{1}{16M^2} |\mathcal{M}|^2 |\mathbf{p}_1^*| |\mathbf{p}_3| dm_{12} d\Omega_1^* d\Omega_3 , \qquad (34.19)$$

where $(|\boldsymbol{p}_1^*|, \Omega_1^*)$ is the momentum of particle 1 in the rest frame of 1 and 2, and Ω_3 is the angle of particle 3 in the rest frame of the decaying particle. $|\boldsymbol{p}_1^*|$ and $|\boldsymbol{p}_3|$ are given by

$$|\mathbf{p}_{1}^{*}| = \frac{\left[\left(m_{12}^{2} - (m_{1} + m_{2})^{2}\right)\left(m_{12}^{2} - (m_{1} - m_{2})^{2}\right)\right]^{1/2}}{2m_{12}},$$
(34.20a)

and

$$|\mathbf{p}_3| = \frac{\left[\left(M^2 - (m_{12} + m_3)^2\right)\left(M^2 - (m_{12} - m_3)^2\right)\right]^{1/2}}{2M}$$
 (34.20b)

[Compare with Eq. (34.16).]

If the decaying particle is a scalar or we average over its spin states, then integration over the angles in Eq. (34.18) gives

$$d\Gamma = \frac{1}{(2\pi)^3} \frac{1}{8M} |\mathcal{M}|^2 dE_1 dE_2$$

$$= \frac{1}{(2\pi)^3} \frac{1}{32M^3} |\mathcal{M}|^2 dm_{12}^2 dm_{23}^2.$$
(34.21)

This is the standard form for the Dalitz plot.

34.4.3.1. Dalitz plot: For a given value of m_{12}^2 , the range of m_{23}^2 is determined by its values when p_2 is parallel or antiparallel to p_3 :

$$(m_{23}^2)_{\text{max}} =$$

$$(E_2^* + E_3^*)^2 - \left(\sqrt{E_2^{*2} - m_2^2} - \sqrt{E_3^{*2} - m_3^2}\right)^2$$
, (34.22a)

 $(m_{23}^2)_{\min} =$

$$(E_2^* + E_3^*)^2 - \left(\sqrt{E_2^{*2} - m_2^2} + \sqrt{E_3^{*2} - m_3^2}\right)^2$$
 (34.22b)

Here $E_2^* = (m_{12}^2 - m_1^2 + m_2^2)/2m_{12}$ and $E_3^* = (M^2 - m_{12}^2 - m_3^2)/2m_{12}$ are the energies of particles 2 and 3 in the m_{12} rest frame. The scatter plot in m_{12}^2 and m_{23}^2 is called a Dalitz plot. If $|\mathcal{M}|^2$ is constant, the allowed region of the plot will be uniformly populated with events [see Eq. (34.21)]. A nonuniformity in the plot gives immediate information on $|\mathcal{M}|^2$. For example, in the case of $D \to K\pi\pi$, bands appear when $m_{(K\pi)} = m_{K^*(892)\pi}$, reflecting the appearance of the decay chain $D \to K^*(892)\pi \to K\pi\pi$.

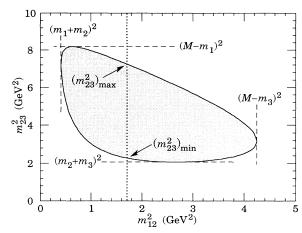


Figure 34.3: Dalitz plot for a three-body final state. In this example, the state is $\pi^+\overline{K}{}^0p$ at 3 GeV. Four-momentum conservation restricts events to the shaded region.

34.4.4. Kinematic limits: In a three-body decay the maximum of $|\mathbf{p}_3|$, [given by Eq. (34.20)], is achieved when $m_{12}=m_1+m_2$, i.e., particles 1 and 2 have the same vector velocity in the rest frame of the decaying particle. If, in addition, $m_3>m_1,m_2$, then $|\mathbf{p}_3|_{\max}>|\mathbf{p}_1|_{\max}$, $|\mathbf{p}_2|_{\max}$.

34.4.5. *Multibody decays*: The above results may be generalized to final states containing any number of particles by combining some of the particles into "effective particles" and treating the final states as 2 or 3 "effective particle" states. Thus, if $p_{ijk...} = p_i + p_j + p_k + \ldots$, then

$$m_{ijk...} = \sqrt{p^2_{ijk...}} , \qquad (34.23)$$

and $m_{ijk...}$ may be used in place of $e.g.,\ m_{12}$ in the relations in Sec. 34.4.3 or 34.4.3.1 above.

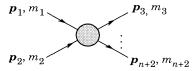


Figure 34.4: Definitions of variables for production of an n-body final state.

34.5. Cross sections

The differential cross section is given by

$$d\sigma = \frac{(2\pi)^4 |\mathcal{M}|^2}{4\sqrt{(p_1 \cdot p_2)^2 - m_1^2 m_2^2}} \times d\Phi_n(p_1 + p_2; p_3, \dots, p_{n+2}).$$
(34.24)

[See Eq. (34.11).] In the rest frame of $m_2(lab)$,

$$\sqrt{(p_1 \cdot p_2)^2 - m_1^2 m_2^2} = m_2 p_{1 \, \text{lab}} ; \qquad (34.25a)$$

while in the center-of-mass frame

$$\sqrt{(p_1 \cdot p_2)^2 - m_1^2 m_2^2} = p_{1\text{cm}} \sqrt{s} . \tag{34.25b}$$

34.5.1. Two-body reactions:

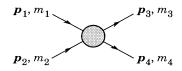


Figure 34.5: Definitions of variables for a two-body final state.

Two particles of momenta p_1 and p_2 and masses m_1 and m_2 scatter to particles of momenta p_3 and p_4 and masses m_3 and m_4 ; the Lorentz-invariant Mandelstam variables are defined by

$$s = (p_1 + p_2)^2 = (p_3 + p_4)^2$$

$$= m_1^2 + 2E_1E_2 - 2\mathbf{p}_1 \cdot \mathbf{p}_2 + m_2^2 , \qquad (34.26)$$

$$t = (p_1 - p_3)^2 = (p_2 - p_4)^2$$

$$= m_1^2 - 2E_1E_3 + 2\mathbf{p}_1 \cdot \mathbf{p}_3 + m_3^2 , \qquad (34.27)$$

$$u = (p_1 - p_4)^2 = (p_2 - p_3)^2$$

$$= m_1^2 - 2E_1E_4 + 2\mathbf{p}_1 \cdot \mathbf{p}_4 + m_4^2 , \qquad (34.28)$$

and they satisfy

$$s + t + u = m_1^2 + m_2^2 + m_3^2 + m_4^2 . (34.29)$$

The two-body cross section may be written as

$$\frac{d\sigma}{dt} = \frac{1}{64\pi s} \frac{1}{|\mathbf{p}_{1cm}|^2} |\mathcal{M}|^2.$$
 (34.30)

In the center-of-mass frame

$$t = (E_{1\text{cm}} - E_{3\text{cm}})^2 - (p_{1\text{cm}} - p_{3\text{cm}})^2$$
$$-4p_{1\text{cm}} p_{3\text{cm}} \sin^2(\theta_{\text{cm}}/2)$$
$$= t_0 - 4p_{1\text{cm}} p_{3\text{cm}} \sin^2(\theta_{\text{cm}}/2) , \qquad (34.31)$$

where $\theta_{\rm cm}$ is the angle between particle 1 and 3. The limiting values t_0 ($\theta_{\rm cm}=0$) and t_1 ($\theta_{\rm cm}=\pi$) for $2\to 2$ scattering are

$$t_0(t_1) = \left[\frac{m_1^2 - m_3^2 - m_2^2 + m_4^2}{2\sqrt{s}} \right]^2 - (p_{1\,\text{cm}} \mp p_{3\,\text{cm}})^2 . \tag{34.32}$$

In the literature the notation t_{\min} (t_{\max}) for t_0 (t_1) is sometimes used, which should be discouraged since $t_0 > t_1$. The center-of-mass energies and momenta of the incoming particles are

$$E_{1\text{cm}} = \frac{s + m_1^2 - m_2^2}{2\sqrt{s}} , \qquad E_{2\text{cm}} = \frac{s + m_2^2 - m_1^2}{2\sqrt{s}} ,$$
 (34.33)

For $E_{3\rm cm}$ and $E_{4\rm cm}$, change m_1 to m_3 and m_2 to m_4 . Then

$$p_{i\,{\rm cm}} = \sqrt{E_{i\,{\rm cm}}^2 - m_i^2}$$
 and $p_{1{\rm cm}} = \frac{p_{1\,{\rm lab}} \, m_2}{\sqrt{s}}$. (34.34)

Here the subscript lab refers to the frame where particle 2 is at rest. [For other relations see Eqs. (34.2)–(34.4).]

34.5.2. *Inclusive reactions*: Choose some direction (usually the beam direction) for the z-axis; then the energy and momentum of a particle can be written as

$$E = m_T \cosh y \; , \; p_x \; , \; p_y \; , \; p_z = m_T \sinh y \; , \qquad (34.35)$$

where m_T is the transverse mass

$$m_T^2 = m^2 + p_x^2 + p_y^2 \; , \tag{34.36} \label{eq:34.36}$$

and the rapidity y is defined by

$$\begin{split} y &= \frac{1}{2} \ln \left(\frac{E + p_z}{E - p_z} \right) \\ &= \ln \left(\frac{E + p_z}{m_T} \right) = \tanh^{-1} \left(\frac{p_z}{E} \right) \;. \end{split} \tag{34.37}$$

Under a boost in the z-direction to a frame with velocity β , $y \to y - \tanh^{-1} \beta$. Hence the shape of the rapidity distribution dN/dy is invariant. The invariant cross section may also be rewritten

$$E\frac{d^3\sigma}{d^3p} = \frac{d^3\sigma}{d\phi\,dy\,p_Tdp_T} \Longrightarrow \frac{d^2\sigma}{\pi\,dy\,d(p_T^2)}\;. \tag{34.38}$$

The second form is obtained using the identity $dy/dp_z = 1/E$, and the third form represents the average over ϕ .

Feynman's x variable is given by

$$x = \frac{p_z}{p_{z\,\mathrm{max}}} \approx \frac{E + p_z}{(E + p_z)_{\mathrm{max}}} \quad (p_T \ll |p_z|) \ . \tag{34.39} \label{eq:34.39}$$

In the c.m. frame

$$x \approx \frac{2p_{z\,\text{cm}}}{\sqrt{s}} = \frac{2m_T \sinh y_{\text{cm}}}{\sqrt{s}} \tag{34.40}$$

and

$$= (y_{\rm cm})_{\rm max} = \ln(\sqrt{s}/m)$$
 (34.41)

For $p \gg m$, the rapidity [Eq. (34.37)] may be expanded to obtain

$$y = \frac{1}{2} \ln \frac{\cos^2(\theta/2) + m^2/4p^2 + \dots}{\sin^2(\theta/2) + m^2/4p^2 + \dots}$$

$$\approx -\ln \tan(\theta/2) \equiv \eta$$
 (34.42)

where $\cos\theta = p_z/p$. The pseudorapidity η defined by the second line is approximately equal to the rapidity y for $p\gg m$ and $\theta\gg 1/\gamma$, and in any case can be measured when the mass and momentum of the particle is unknown. From the definition one can obtain the identities

$$\sinh \eta = \cot \theta$$
, $\cosh \eta = 1/\sin \theta$, $\tanh \eta = \cos \theta$. (34.43)

34.5.3. *Partial waves*: The amplitude in the center of mass for elastic scattering of spinless particles may be expanded in Legendre polynomials

$$f(k,\theta) = \frac{1}{k} \sum_{\ell} (2\ell + 1) a_{\ell} P_{\ell}(\cos \theta) ,$$
 (34.44)

where k is the c.m. momentum, θ is the c.m. scattering angle, $a_{\ell} = (\eta_{\ell}e^{2i\delta_{\ell}} - 1)/2i$, $0 \le \eta_{\ell} \le 1$, and δ_{ℓ} is the phase shift of the ℓ^{th} partial wave. For purely elastic scattering, $\eta_{\ell} = 1$. The differential cross section is

$$\frac{d\sigma}{d\Omega} = |f(k,\theta)|^2 \ . \tag{34.45}$$

The optical theorem states that

$$\sigma_{\text{tot}} = \frac{4\pi}{k} \text{Im} f(k,0) , \qquad (34.46)$$

and the cross section in the ℓ^{th} partial wave is therefore bounded:

$$\sigma_{\ell} = \frac{4\pi}{k^2} (2\ell + 1)|a_{\ell}|^2 \le \frac{4\pi (2\ell + 1)}{k^2} \ . \tag{34.47}$$

The evolution with energy of a partial-wave amplitude a_{ℓ} can be displayed as a trajectory in an Argand plot, as shown in Fig. 34.6.

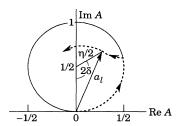


Figure 34.6: Argand plot showing a partial-wave amplitude a_{ℓ} as a function of energy. The amplitude leaves the unitary circle where inelasticity sets in $(\eta_{\ell} < 1)$.

The usual Lorentz-invariant matrix element \mathcal{M} (see Sec. 34.3 above) for the elastic process is related to $f(k,\theta)$ by

$$\mathcal{M} = -8\pi\sqrt{s} \ f(k,\theta) \ , \tag{34.48}$$

so

$$\sigma_{\text{tot}} = -\frac{1}{2p_{\text{lab}} m_2} \text{Im} \mathcal{M}(t=0) ,$$
 (34.49)

where s and t are the center-of-mass energy squared and momentum transfer squared, respectively (see Sec. 34.4.1).

34.5.3.1. Resonances: The Breit-Wigner (nonrelativistic) form for an elastic amplitude a_ℓ with a resonance at c.m. energy E_R , elastic width $\Gamma_{\rm el}$, and total width $\Gamma_{\rm tot}$ is

$$a_{\ell} = \frac{\Gamma_{\rm cl}/2}{E_R - E - i\Gamma_{\rm tot}/2} , \qquad (34.50)$$

where E is the c.m. energy. As shown in Fig. 34.7, in the absence of background the elastic amplitude traces a counterclockwise circle with center $ix_{\rm cl}/2$ and radius $x_{\rm cl}/2$, where the elasticity $x_{\rm cl}=\Gamma_{\rm cl}/\Gamma_{\rm tot}$. The amplitude has a pole at $E=E_R-i\Gamma_{\rm tot}/2$.

The spin-averaged Breit-Wigner cross section for a spin-J resonance produced in the collision of particles of spin S_1 and S_2 is

$$\sigma_{BW}(E) = \frac{(2J+1)}{(2S_1+1)(2S_2+1)} \frac{\pi}{k^2} \frac{B_{\rm in} B_{\rm out} \Gamma_{\rm tot}^2}{(E-E_R)^2 + \Gamma_{\rm tot}^2/4} \ , \ (34.51)$$

where k is the c.m. momentum, E is the c.m. energy, and $B_{\rm in}$ and $B_{\rm out}$ are the branching fractions of the resonance into the entrance and exit channels. The 2S+1 factors are the multiplicities of the incident spin states, and are replaced by 2 for photons. This expression is valid only for an isolated state. If the width is not small, $\Gamma_{\rm tot}$ cannot be treated as a constant independent of E. There are many other forms for σ_{BW} , all of which are equivalent to the one given here in the narrow-width case. Some of these forms may be more appropriate if the resonance is broad.

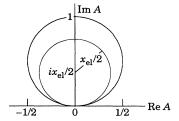


Figure 34.7: Argand plot for a resonance. The relativistic Breit-Wigner form corresponding to Eq. (34.50) is:

$$a_{\ell} = \frac{-m\Gamma_{\rm cl}}{s - m^2 + im\Gamma_{\rm tot}} \ . \tag{34.52} \label{eq:alpha}$$

A better form incorporates the known kinematic dependences, replacing $m\Gamma_{\rm tot}$ by $\sqrt{s}\,\Gamma_{\rm tot}(s)$, where $\Gamma_{\rm tot}(s)$ is the width the resonance particle would have if its mass were \sqrt{s} , and correspondingly $m\Gamma_{\rm cl}$ by $\sqrt{s}\,\Gamma_{\rm cl}(s)$ where $\Gamma_{\rm cl}(s)$ is the partial width in the incident channel for a mass \sqrt{s} :

$$a_{\ell} = \frac{-\sqrt{s} \Gamma_{\rm cl}(s)}{s - m^2 + i\sqrt{s} \Gamma_{\rm tot}(s)} \,. \tag{34.53}$$

For the Z boson, all the decays are to particles whose masses are small enough to be ignored, so on dimensional grounds $\Gamma_{\rm tot}(s) = \sqrt{s}\,\Gamma_0/m_Z$, where Γ_0 defines the width of the Z, and $\Gamma_{\rm cl}(s)/\Gamma_{\rm tot}(s)$ is constant. A full treatment of the line shape requires consideration of dynamics, not just kinematics. For the Z this is done by calculating the radiative corrections in the Standard Model.

35. CROSS-SECTION FORMULAE FOR SPECIFIC PROCESSES

35.1. Leptoproduction

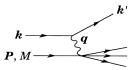


Figure 35.1: Kinematic quantities for description of lepton-nucleon scattering. k and k' are the four-momenta of incoming and outgoing leptons, P is the four-momentum of a nucleon with mass M. The exchanged particle is a γ , W^{\pm} , or Z^0 ; it transfers four-momentum q=k-k' to the target.

Invariant quantities:

 $\nu = \frac{q \cdot P}{M} = E - E' \text{is the lepton's energy loss in the lab (in earlier literature sometimes } \nu = q \cdot P). \text{ Here, } E \text{ and } E' \text{ are the initial and final lepton energies in the lab.}$

$$\begin{split} Q^2 = -q^2 = 2(EE' - \overrightarrow{k} \cdot \overrightarrow{k}') - m_\ell^2 - m_{\ell'}^2 \text{ where } m_\ell(m_{\ell'}) \text{ is the initial} \\ \text{(final) lepton mass. If } EE' \sin^2(\theta/2) \gg m_\ell^2, \, m_{\ell'}^2, \text{ then} \end{split}$$

 $\approx 4EE'\sin^2(\theta/2)$, where θ is the lepton's scattering angle in the lab.

 $x=rac{Q^2}{2M
u}$ In the parton model, x is the fraction of the target nucleon's momentum carried by the struck quark. [See section on Quantum Chromodynamics (Sec. 9 of this Review.]

 $y = \frac{q \cdot P}{k \cdot P} = \frac{\nu}{E}$ is the fraction of the lepton's energy lost in the lab.

 $W^2 = (P+q)^2 = M^2 + 2M\nu - Q^2$ is the mass squared of the system recoiling against the lepton.

$$s = (k+P)^2 = \frac{Q^2}{xy} + M^2$$

35.1.1. Leptoproduction cross sections:

$$\frac{d^2\sigma}{dx\,dy} = \nu \left(s - M^2\right) \frac{d^2\sigma}{d\nu\,dQ^2} = \frac{2\pi\,M\nu}{E'} \frac{d^2\sigma}{d\Omega_{\rm lab}\,dE'}$$
$$= x(s - M^2) \frac{d^2\sigma}{dx\,dQ^2} \,. \tag{35.1}$$

35.1.2. Electroproduction structure functions: The neutral-current process, $eN \to eX$, is parity conserving at low Q^2 and can be written in terms of two structure functions $F_1^{\rm NC}(x,Q^2)$ and $F_2^{\rm NC}(x,Q^2)$:

$$\frac{d^2\sigma}{dx\,dy} = \frac{4\pi\,\alpha^2(s-M^2)}{Q^4} \times \left[(1-y)\,F_2^{\rm NC} + \,y^2\,xF_1^{\rm NC} - \frac{M^2}{(s-M^2)}\,xy\,F_2^{\rm NC} \right] \,. \quad (35.2)$$

The charged-current processes, $e^-N \to \nu X$, $\nu N \to e^-X$, and $\overline{\nu}N \to e^+X$, are parity violating and can be written in terms of three structure functions $F_1^{\text{CC}}(x,Q^2)$, $F_2^{\text{CC}}(x,Q^2)$, and $F_3^{\text{CC}}(x,Q^2)$:

$$\frac{d^2\sigma}{dx\,dy} = \frac{G_F^2\,(s-M^2)}{2\pi} \frac{M_W^4}{(Q^2 + M_W^2)^2} \tag{35.3}$$

$$\times \ \left\{ \left[1 - y - \frac{M^2 x y}{(s - M^2)} \right] F_2^{\rm CC} + \frac{y^2}{2} \ 2x \, F_1^{\rm CC} \pm (y - \frac{y^2}{2}) \ x \, F_3^{\rm CC} \right\} \, ,$$

where the last term is positive for the e^- and ν reactions and negative for $\overline{\nu}N \to e^+ X$.

35.1.3. The QCD parton model: In the QCD parton model, the structure functions defined above can be expressed in terms of parton distribution functions. The quantity $f_i(x,Q^2)dx$ is the probability that a parton of type i (quark, antiquark, or gluon), carries a momentum fraction between x and x+dx of the nucleon's momentum in a frame where the nucleon's momentum is large. For the cross section corresponding to the neutral-current process $ep \to eX$, we have for $s \gg M^2$ (in the case where the incoming electron is either left- (L) or right- (R) handed):

$$\frac{d^2\sigma}{dx\,dy} = \frac{\pi\alpha^2}{sx^2\,y^2} \left[\sum_q (x\,f_q\,(x,\,Q^2) + x\,f_{\overline{q}}\,(x,\,Q^2)) \right]
\times \left[A_q + (1-y)^2\,B_q \right] .$$
(35.4)

Here the index q refers to a quark flavor (i.e., u, d, s, c, b, or t), and

$$A_q = \left(-q_q + g_{Lq} g_{Le} \frac{Q^2}{Q^2 + M_Z^2}\right)^2 + \left(-q_q + g_{Rq} g_{Re} \frac{Q^2}{Q^2 + M_Z^2}\right)^2,$$
(35.3)

$$B_q = \left(-q_q + g_{Rq} g_{Le} \frac{Q^2}{Q^2 + M_Z^2}\right)^2 + \left(-q_q + g_{Lq} g_{Re} \frac{Q^2}{Q^2 + M_Z^2}\right)^2.$$
(35.6)

Here q_q is the charge of flavor q. For a left-handed electron, $g_{Re}=0$ and $g_{Le}=(-1/2+\sin^2\theta_W)/(\sin\theta_W\cos\theta_W)$, while for a right-handed one, $g_{Le}=0$ and $g_{Re}=(\sin^2\theta_W)/(\sin\theta_W\cos\theta_W)$. For the quarks, $g_{Lq}=(T_3-q_q\sin^2\theta_W)/(\sin\theta_W\cos\theta_W)$, and $g_{Rq}=(-q_q\sin^2\theta_W)/(\sin\theta_W\cos\theta_W)$.

For neutral-current neutrino (antineutrino) scattering, the same formula applies with g_{Le} replaced by $g_{L\nu}=1/(2\sin\theta_W\cos\theta_W)$ ($g_{L\overline{\nu}}=0$) and g_{Re} replaced by $g_{R\nu}=0$ [$g_{R\overline{\nu}}=-1/(2\sin\theta_W\cos\theta_W)$].

In the case of the charged-current processes $e_L^- p \to \nu X$ and $\bar{\nu}p \to e^+ X$, Eq. (35.3) applies with

$$F_{2} = 2xF_{1} = 2x \left[f_{u}(x, Q^{2}) + f_{c}(x, Q^{2}) + f_{t}(x, Q^{2}) + f_{\overline{d}}(x, Q^{2}) + f_{\overline{b}}(x, Q^{2}) + f_{\overline{b}}(x, Q^{2}) \right], \quad (35.7)$$

$$F_{3} = 2 \left[f_{u}(x, Q^{2}) + f_{c}(x, Q^{2}) + f_{\overline{b}}(x, Q^{2}) - f_{\overline{b}}(x, Q^{2}) - f_{\overline{b}}(x, Q^{2}) \right]. \quad (35.8)$$

For the process $\nu p \to e^- X$:

$$\begin{split} F_2 &= 2x F_1 = 2x \Big[f_d(x,Q^2) + f_s(x,Q^2) \\ &+ f_b(x,Q^2) + f_{\overline{u}}\left(x,Q^2\right) + f_{\overline{c}}\left(x,Q^2\right) + f_{\overline{t}}\left(x,Q^2\right) \Big] \;, \; (35.9) \\ F_3 &= 2 \Big[f_d(x,Q^2) + f_s(x,Q^2) \\ &+ f_b(x,Q^2) - f_{\overline{u}}\left(x,Q^2\right) - f_{\overline{c}}\left(x,Q^2\right) - f_{\overline{t}}\left(x,Q^2\right) \Big] \;. (35.10) \end{split}$$

35.2. e^+e^- annihilation

For pointlike spin-1/2 fermions in the c.m., the differential cross section for $e^+e^-\to f\bar f$ via single photon annihilation is

$$\frac{d\sigma}{d\Omega} = \frac{\alpha^2}{4s} \beta \left[1 + \cos^2 \theta + (1 - \beta^2) \sin^2 \theta \right] Q_f^2 , \qquad (35.11)$$

where β is the velocity of the final state fermion in the center of mass and Q_f is the charge of the fermion in units of the proton charge. For $\beta \to 1$,

$$\sigma = \frac{4\pi\alpha^2}{3s} Q_f^2 = \frac{86.8 Q_f^2 nb}{s(\text{GeV}^2)} . \tag{35.12}$$

At higher energies the Z^0 (mass M_Z and width Γ_Z) must be included, and the differential cross section for $e^+e^-\to f\bar f$ becomes

$$\begin{split} \frac{d\sigma}{d\Omega} &= \frac{\alpha^2}{4s} \,\beta \, \left[Q_f^2 [1 + \cos^2 \theta + (1 - \beta^2) \, \sin^2 \theta \,] \right. \\ &- 2Q_f \,\chi_1 \bigg\{ VV_f \, [1 + \cos^2 \theta + (1 - \beta^2) \, \sin^2 \theta \,] - 2a_f \,\beta \cos \theta \bigg\} \\ &+ \chi_2 \bigg\{ V_f^2 \, (1 + V^2) \, [1 + \cos^2 \theta + (1 - \beta^2) \, \sin^2 \theta \,] \\ &+ \beta^2 \, a_f^2 (1 + V^2) \, [1 + \cos^2 \theta \,] - 8\beta \, VV_f \, a_f \cos \theta \bigg\} \bigg] \,\,, \end{split}$$
 (35.13)

$$\chi_1 = \frac{1}{16\sin^2\theta_W \cos^2\theta_W} \frac{s(s - M_Z^2)}{(s - M_Z^2)^2 + \Gamma_Z^2 M_Z^2},$$
 (35.14)

$$\chi_2 = \frac{1}{256 \sin^4 \theta_W \cos^4 \theta_W} \frac{s^2}{(s - M_Z^2)^2 + \Gamma_Z^2 M_Z^2} , \qquad (35.15)$$

$$V = -1 + 4\sin^2\theta_W , (35.16)$$

$$a_f = 2T_{3f} ag{5.17}$$

where the subscript f refers to the particular fermion and

$$T_3 = +1/2$$
 for ν_e , ν_μ , ν_τ , u , c , t , (35.19a)

$$T_3 = -1/2$$
 for $e^-, \mu^-, \tau^-, d, s, b.$ (35.19b)

35.3. Two-photon process at e^+e^- colliders

When an e^+ and an e^- collide with energies E_1 and E_2 , they emit dn_1 and dn_2 virtual photons with energies ω_1 and ω_2 and 4-momenta q_1 and q_2 . In the equivalent photon approximation, the cross section for $e^+e^- \to e^+e^-X$ is related to the cross section for $\gamma\gamma \to X$ by (Ref. 1)

$$d\sigma_{e^+e^-\to e^+e^-Y}(s) = dn_1 dn_2 d\sigma_{\gamma\gamma\to X}(W^2)$$
(35.20)

where $s = 4E_1E_2$, $W^2 = 4\omega_1\omega_2$ and

$$dn_i = \frac{\alpha}{\pi} \left[1 - \frac{\omega_i}{E_i} + \frac{\omega_i^2}{2E_i^2} - \frac{m_e^2 \omega_i^2}{(-q_i^2)E_i^2} \right] \frac{d\omega_i}{\omega_i} \frac{d(-q_i^2)}{(-q_i^2)} . \tag{35.21}$$

After integration (including that over q_i^2 in the region $m_e^2 \omega_i^2 / E_i(E_i - \omega_i) \le -q_i^2 \le (-q^2)_{\rm max}$), the cross section is

$$\begin{split} \sigma_{e^+e^-\to e^+e^-X}\left(s\right) = & \frac{\alpha^2}{\pi^2} \int_{z_{th}}^1 \frac{dz}{z} \left[f(z) \left(\ln \frac{(-q^2)_{\text{max}}}{m_e^2 z} - 1 \right)^2 \right. \\ & \left. - \frac{1}{3} \left(\ln \frac{1}{z} \right)^3 \right] \sigma_{\gamma\gamma\to X}\left(zs\right) \,; \end{split}$$

$$f(z) = \left(1 + \frac{1}{2}z\right)^2 \ln\frac{1}{z} - \frac{1}{2}(1 - z)(3 + z) ;$$

$$z = \frac{W^2}{s} . \tag{35.22}$$

The quantity $(-q^2)_{\max}$ depends on properties of the produced system X, in particular, $(-q^2)_{\max} \sim m_{\rho}^2$ for hadron production (X = h) and $(-q^2)_{\max} \sim W^2$ for lepton pair production $(X = \ell^+\ell^-, \ell^-, \ell^-, \ell^-)$.

For production of a resonance of mass m_R and spin $J \neq 1$

$$\begin{split} &\sigma_{e^+e^-\to e^+e^-R}\left(s\right) = (2J+1)\frac{8\alpha^2\Gamma_{R\to\gamma\gamma}}{m_R^3} \\ &\times \left[f(m_R^2/s) \left(\ln\frac{sm_V^2}{m_e^2m_R^2} - 1\right)^2 - \frac{1}{3} \left(\ln\frac{s}{m_P^2}\right)^3\right] \end{split} \tag{35.23}$$

where m_V is the mass that enters into the form factor of the $\gamma\gamma \to R$ transition: $m_V \sim m_\rho$ for $R=\pi^0,\,\rho^0,\,\omega,\,\phi,\,\ldots,\,m_V \sim m_R$ for $R=c\overline{c}$ or $b\overline{b}$ resonances.

35.4. Inclusive hadronic reactions

One-particle inclusive cross sections $Ed^3\sigma/d^3p$ for the production of a particle of momentum p are conveniently expressed in terms of rapidity (see above) and the momentum p_T transverse to the beam direction (defined in the center-of-mass frame)

$$E \frac{d^3 \sigma}{d^3 p} = \frac{d^3 \sigma}{d \phi \; dy \; p_T dp_T} \; . \tag{35.24}$$

In the case of processes where p_T is large or the mass of the produced particle is large (here large means greater than 10 GeV), the parton model can be used to calculate the rate. Symbolically

$$\sigma_{\text{hadronic}} = \sum_{ij} \int f_i(x_1, Q^2) f_j(x_2, Q^2) dx_1 dx_2 \, \hat{\sigma}_{\text{partonic}} ,$$
 (35.25)

where $f_i(x, Q^2)$ is the parton distribution introduced above and Q is a typical momentum transfer in the partonic process and $\widehat{\sigma}$ is the partonic cross section. Two examples will help to clarify. The production of a W^+ in pp reactions at rapidity y in the center-of-mass frame is given by

$$\begin{split} \frac{d\sigma}{dy} &= \frac{G_F \, \pi \sqrt{2}}{3} \\ &\times \tau \bigg[\cos^2 \theta_c \bigg(u(x_1 \, , \, M_W^2) \, \overline{d} \, (x_2, M_W^2) \\ &\quad + \, u(x_2 \, , \, M_W^2) \, \overline{d} \, (x_1, M_W^2) \bigg) \\ &\quad + \, \sin^2 \theta_c \bigg(u(x_1 \, , \, M_W^2) \, \overline{s} \, (x_2 \, , \, M_W^2) \\ &\quad + \, s(x_2, M_W^2) \, \overline{u} \, (x_1, M_W^2) \bigg) \bigg] \, , \end{split}$$
 (35.26)

where $x_1 = \sqrt{\tau} e^y$, $x_2 = \sqrt{\tau} e^{-y}$, and $\tau = M_W^2/s$. Similarly the production of a jet in pp (or $p\bar{p}$) collisions is given by

$$\frac{d^{3}\sigma}{d^{2}p_{T} dy} = \sum_{ij} \int f_{i}(x_{1}, p_{T}^{2}) f_{j}(x_{2}, p_{T}^{2})
\times \left[\widehat{s} \frac{d\widehat{\sigma}}{d\widehat{t}} \right]_{ij} dx_{1} dx_{2} \delta(\widehat{s} + \widehat{t} + \widehat{u}),$$
(35.27)

where the summation is over quarks, gluons, and antiquarks. Here

$$s = (p_1 + p_2)^2 (35.28)$$

$$t = (p_1 - p_{\text{jet}})^2 \,, \tag{35.29}$$

$$u = (p_2 - p_{\text{jet}})^2$$
, (35.30)

 p_1 and p_2 are the momenta of the incoming p and p (or \overline{p}) and \widehat{s} , \widehat{t} , and \widehat{u} are s, t, and u with $p_1 \to x_1 p_1$ and $p_2 \to x_2 p_2$. The partonic cross section $\widehat{s}[(d\widehat{\sigma})/(d\widehat{t})]$ can be found in Ref. 2. Example: for the process $gg \to q\overline{q}$,

$$\widehat{s} \, \frac{d\sigma}{dt} = 3\alpha_s^2 \, \frac{(\widehat{t}^{\,2} + \widehat{u}^2)}{8\widehat{s}} \, \left[\frac{4}{9\,\widehat{t}\,\widehat{u}} - \frac{1}{\widehat{s}^{\,2}} \right] \, . \tag{35.31}$$

The prediction of Eq. (35.27) is compared to data from the UA1 and UA2 collaborations in Fig. 36.7 in the Plots of Cross Sections and Related Quantities section of this *Review*.

35.5. One-particle inclusive distributions

In order to describe one-particle inclusive production in e^+e^- annihilation or deep inelastic scattering, it is convenient to introduce a fragmentation function $D_i^h\left(z,Q^2\right)$ where $D_i^h\left(z,Q^2\right)$ is the number of hadrons of type h and momentum between zp and (z+dz)p produced in the fragmentation of a parton of type i. The Q^2 evolution is predicted by QCD and is similar to that of the parton distribution functions [see section on Quantum Chromodynamics (Sec. 9 of this Review)]. The $D_i^h(z,Q^2)$ are normalized so that

$$\sum_{h} \int z D_i^h (z, Q^2) dz = 1 . {(35.32)}$$

If the contributions of the Z boson and three-jet events are neglected, the cross section for producing a hadron h in e^+e^- annihilation is given by

$$\frac{1}{\sigma_{\rm had}} \frac{d\sigma}{dz} = \frac{\sum_{i} e_{i}^{2} D_{i}^{h} (z, Q^{2})}{\sum_{i} e_{i}^{2}} , \qquad (35.33)$$

where e_i is the charge of quark-type i, $\sigma_{\rm had}$ is the total hadronic cross section, and the momentum of the hadron is $zE_{\rm cm}/2$.

In the case of deep inelastic muon scattering, the cross section for producing a hadron of energy E_h is given by

$$\frac{1}{\sigma_{\rm tot}} \, \frac{d\sigma}{dz} = \frac{\sum_i e_i^2 \, q_i(x,Q^2) \, D_i^h(z,Q^2)}{\sum_i e_i^2 \, q_i(x,Q^2)} \, , \tag{35.34} \label{eq:sigma}$$

where $E_h=\nu z$. (For the kinematics of deep inelastic scattering, see Sec. 34.4.2 of the Kinematics section of this *Review*.) The fragmentation functions for light and heavy quarks have a different z dependence; the former peak near z=0. They are illustrated in Fig. 36.13 in the section on Plots of Cross Sections and Related Quantities (Sec. 36 of this *Review*).

References:

- V.M. Budnev, I.F. Ginzburg, G.V. Meledin, and V.G. Serbo, Phys. Reports 15C, 181 (1975);
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- G.F. Owens, F. Reya, and M. Glück, Phys. Rev. **D18**, 1501 (1978).

36. PLOTS OF CROSS SECTIONS AND RELATED QUANTITIES

NOTE: THE FIGURES IN THIS SECTION ARE INTENDED TO SHOW THE REPRESENTATIVE DATA. THEY ARE NOT MEANT TO BE COMPLETE COMPILATIONS OF ALL THE WORLD'S RELIABLE DATA.

Structure Functions

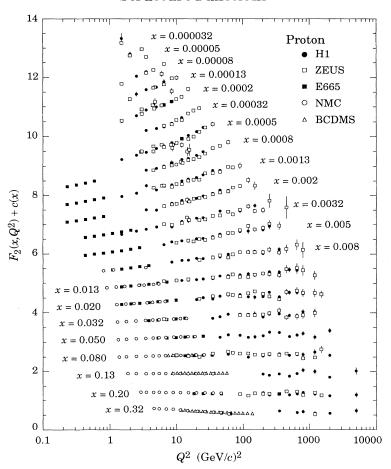


Figure 36.1: The proton structure function F_2^p measured in electromagnetic scattering of electrons (H1, ZEUS) and muons (BCDMS, E665, NMC), in the kinematic domain of the HERA data. Only statistical errors are shown. The data are plotted as a function of Q^2 in bins of fixed x. The H1 binning in x was chosen for this plot; the ZEUS, BCDMS, E665, and NMC data are rebinned to the x values of the H1 data using a phenomenological parametrization. For the purpose of plotting, a constant $c(x) = 0.6(i_x - 0.4)$ is added to F_2^p , where i_x is the number of the x bin ranging from $i_x = 1$ (x = 0.32) to $i_x = 21$ (x = 0.000032). References: H1—S. Aid et al., DESY 96-039 (1996), subm. to Nucl. Phys. B; ZEUS—M. Derrick et al., Z. Phys. C69, 607 (1996) and DESY 96-076 (1996), subm. to Z. Phys. C; BCDMS—A.C. Benvenuti et al., Phys. Lett. B223, 485 (1989); E665—M.R. Adams et al., FNAL-PUB-95/396-E, subm. to Phys. Rev. D; NMC—M. Arneodo et al., Phys. Lett. B364, 107 (1995). (Courtesy of R. Voss, 1996.)

Structure Functions

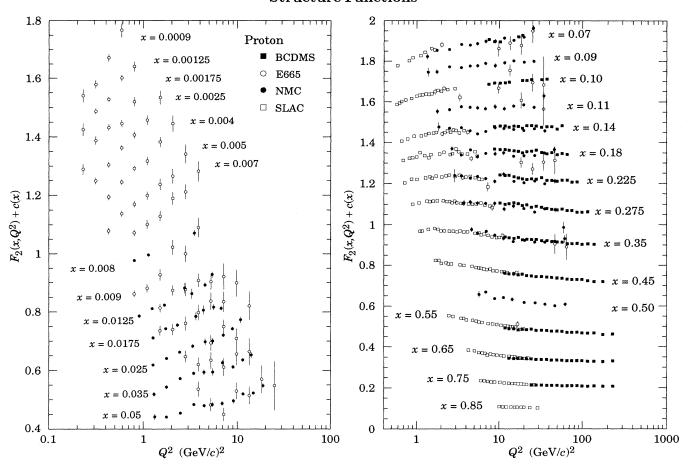


Figure 36.2: The proton structure function F_2^p measured in electromagnetic scattering of electrons (SLAC) and muons (BCDMS, E665, NMC), shown as a function of Q^2 for bins of fixed x. Only statistical errors are shown. For the purpose of plotting, a constant $c(x) = 0.1i_x$ is added to F_2^p where i_x is the number of the x bin, ranging from 1 (x = 0.05) to 14 (x = 0.0009) on the left-hand figure, and from 1 (x = 0.85) to 15 (x = 0.007) on the right-hand figure. For HERA data in the kinematic range of this figure, see Fig. 36.1. References: BCDMS—A.C. Benvenuti et al., Phys. Lett. B223, 485 (1989); E665—M.R. Adams et al., FNAL-PUB-95/396-E, subm. to Phys. Rev. D; NMC—M. Arneodo et al.Phys. Lett. B364, 107 (1995); SLAC—L.W. Whitlow et al., Phys. Lett. B282, 475 (1992). (Courtesy of R. Voss, 1996.)

Structure Functions

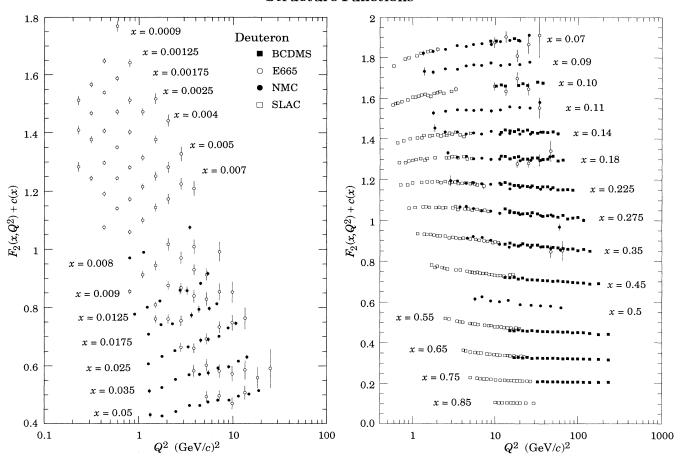


Figure 36.3: As Fig. 36.2, for the deuteron structure function F_2^d . References: BCDMS—A.C. Benvenuti *et al.*, Phys. Lett. B237, 592 (1990); E665, NMC, SLAC—same references as Fig. 36.2. (Courtesy of R. Voss, 1996.)

Structure Functions

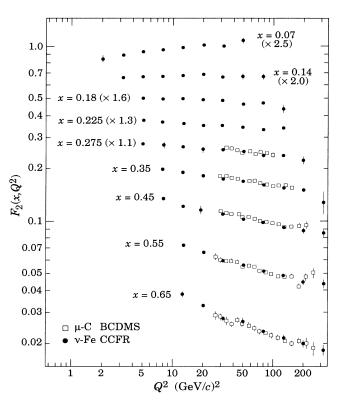


Figure 36.4: The nucleon structure function F_2 measured in deep inelastic scattering of muons on carbon (BCDMS) and neutrinos on iron (CCFR). The data are shown versus Q^2 , for bins of fixed x, and have been scaled by the factors shown in parentheses. References: BCDMS—A.C. Benvenuti *et al.*, Phys. Lett. B195, 91 (1987); CCFR—S.R. Mishra *et al.*, NEVIS-1465 (1992). (Courtesy of R. Voss, 1996.)

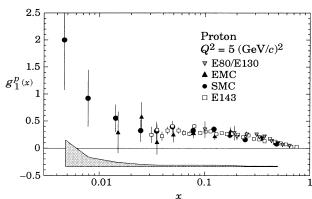


Figure 36.5: The spin-dependent structure function $g_1(x)$ of the proton measured in deep inelastic scattering of polarised electrons (E80, E130, E143) and muons (EMC, SMC), shown at $Q^2 = 5$ GeV². Only statistical

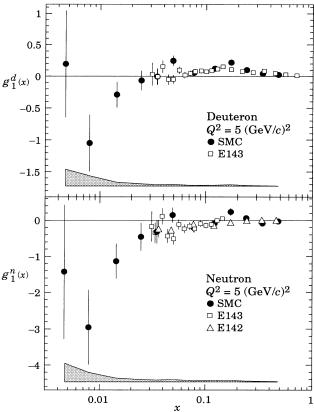


Figure 36.6: The spin-dependent structure function $g_1(x)$ of the deuteron and the neutron measured in deep inelastic scattering of polarised electrons (E142, E143) and muons (SMC), shown at $Q^2 = 5$ GeV². The SMC and E143 results for the neutron are evaluated from the difference of deuteron and proton data; the E142 results were obtained with a polarised ³He target. Only statistical errors are shown with the data points. As an example, the SMC systematic error is indicated by the shaded area. References: E142—P.L. Anthony et al., Phys. Rev. Lett. 71, 959 (1993); E143—K. Abe et al., Phys. Rev. Lett. 75, 25 (1995); SMC—D. Adams et al., Phys. Lett. B357, 248 (1995). (Courtesy of R. Voss, 1996.)

errors are shown with the data points. As an example, the SMC systematic error is indicated by the shaded area. References: **E80**—M.J. Alguard *et al.*, Phys. Rev. Lett. **37**, 1261 (1976); ibid. **41**, 70 (1978); **E130**—G. Baum *et al.*, Phys. Rev. Lett. **51**, 1135 (1983); **E143**—K. Abe *et al.*, Phys. Rev. Lett. **74**, 346 (1995); **EMC**—J. Ashman *et al.*, Nucl. Phys. **B328**, 1 (1989); **SMC**—D. Adams *et al.*, Phys. Lett. **B329**, 399 (1994) **B339**, 332 (1994) (E). In this plot, the E80, E130, and EMC data have been reevaluated using up-to-date parametrizations of F_2^p and $R = \sigma_L/\sigma_T$. (Courtesy of R. Voss, 1996.)

Jet Production in pp and $\bar{p}p$ Interactions

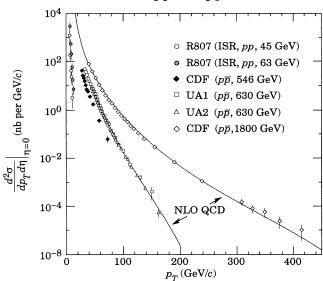


Figure 36.7: Differential cross sections for observation of a single jet of pseudorapidity $\eta=0$ as a function of the jet transverse momentum. CDF—F. Abe *et al.*, Phys. Rev. Lett. **70**, 1376 (1993); UA1—G. Arnison *et al.*, Phys. Lett. B172, 461 (1986); UA2—J. Alitti *et al.*, Phys. Lett. B257, 232 (1991); R807—T. Akesson *et al.*, Phys. Lett. B123, 133 (1983). Next-to-leading order QCD curves are shown for 630 GeV and 1800 GeV. (Courtesy of S. Geer, FNAL, 1995.)

Direct γ Production in $\overline{p}p$ Interactions

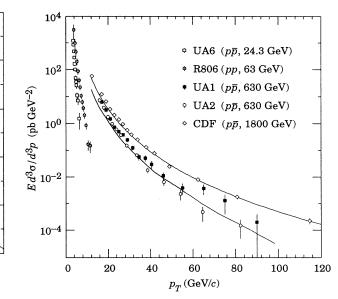


Figure 36.8: Differential cross sections for observation of a single photon of pseudorapidity $\eta=0$ as a function of the photon transverse momentum R806—E. Anassontzis et al., Z. Phys. C13, 277 (1982); UA6—A. Bernasconi et al., Phys. Lett. B206, 163 (1988); UA1—C. Albajar et al., Phys. Lett. B209, 385 (1988); UA2—J. Alitti et al., Phys. Lett. B288, 386 (1992); CDF—F. Abc et al., Phys. Rev. Lett. 73, 2662 (1994). Next-to-leading order QCD curves are shown for 630 GeV and 1800 GeV. (Courtesy of S. Geer, FNAL, 1995.)

Pseudorapidity Distributions in $\overline{p}p$ Interactions

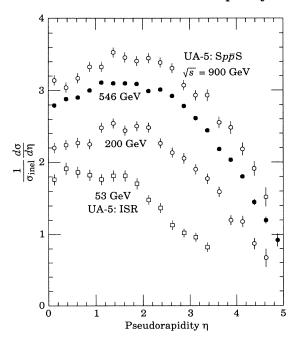


Figure 36.9: Charge particle pseudorapidity distributions in $p\overline{p}$ collisions for 53 GeV $\leq \sqrt{s} \leq$ 900 GeV. The number per pseudorapidity interval is about 10% higher if the rate is normalized excluding singly diffractive events rather than to the total inelastic rate. $Sp\overline{p}S$ data are from G.J. Alner et al., Z. Phys. C33, 1 (1986), and ISR data are from K. Alpgård et al., Phys. Lett. 112B, 193 (1982). CDF nonsingle-diffractive results at $\sqrt{s}=630$ and 1800 GeV are given in F. Abe et al., Phys. Rev. D41, 2330 (1990). (Courtesy of D.R. Ward, Cambridge Univ., 1991.)

Average Hadron Multiplicities in Hadronic e^+e^- Annihilation Events

Table 36.1: Average hadron multiplicity per e^+e^- annihilation event at $\sqrt{s}\approx 10$, 29–35, and 91 GeV. The rates given include decay products from resonances with $c\tau<10$ cm, and include charge conjugated states. (Updated July 1995 by O. Biebel.)

Particle	$\sqrt{s} \approx$	10 GeV	$\sqrt{s} =$	29–35 GeV	$\sqrt{s} =$	91 GeV
Pseudoscala						
π^+	6.6		10.3	± 0.4	17.1	± 0.4
π^0	3.2	$\pm~0.3$	5.83	$\pm~0.28$	9.18	± 0.73
K^+	0.90	$\pm~0.04$	1.48	$\pm \ 0.09$	2.39	± 0.12
K^0	0.91	$\pm~0.05$	1.48	$\pm~0.07$	2.01	± 0.04
η	0.20	$\pm~0.04$	0.61	$\pm~0.07$	0.95	± 0.11
$\eta\prime(958)$	0.03	$\pm~0.01$	0.26	$\pm~0.10$	0.17	± 0.06
D^+	0.16	$\pm~0.03$	0.17	$\pm~0.03$	0.20	$\pm~0.03$
D^0	0.37	$\pm~0.06$	0.45	$\pm~0.07$	0.40	$\pm~0.06$
D_s^+	0.13	± 0.02	0.45	$\pm \ 0.20^{(a)}$		
B^{+}, B_{d}^{0}		_			0.165	$\pm 0.026^{(b)}$
B_s^0		_			0.057	$\pm \ 0.013^{(b)}$
Scalar meso		1 0 000	0.05	$\pm 0.02^{(c)}$	0.14	$\pm 0.06^{(d)}$
$f_0(980)$	0.024	± 0.006	0.05	± 0.02(-)	0.14	± 0.06(=)
Vector meso		1.0.04	0.01	1.0.00	1 01	1.0.10
$\rho(770)^0$	0.35	± 0.04	0.81	± 0.08	1.21	± 0.16
$\omega(782)$	0.30	± 0.08	0.04		0.715	
$K^*(892)^+$	0.27	± 0.03	0.64	± 0.05	0.715	± 0.059
$K^*(892)^0$	0.29	± 0.03	0.56	± 0.06	0.742	± 0.042
$\phi(1020)$	0.044	$\pm \ 0.003$	0.085	$\pm \ 0.011$	0.100	± 0.008
$D^*(2010)^+$	0.22	± 0.04	0.43	± 0.07	0.180	$\pm \ 0.013$
$D^*(2007)^0$	0.23	$\pm \ 0.06$	0.27	± 0.11		_
B^{*} (e)					0.288	
$J/\psi(1S)$						4 ± 0.0005
$\psi(2S)$					0.0023	3 ± 0.0011
Pseudovecto $\chi_{c1}(1P)$	r mes	ons:			0.0087	$7 \pm 0.0028^{(}$
Tensor meso	ns:					
$f_2(1270)$	0.09	$\pm~0.02$	0.14	± 0.04	0.31	± 0.12
$K_2^*(1430)^+$		_	0.09	$\pm~0.03$,
$K_2^*(1430)^0$			0.12	± 0.06	0.19	$\pm 0.07^{(g)}$
B^{**} (h)		and the same of		-	0.12	$\pm~0.24$
Baryons:		-				
p	0.253	± 0.016	0.640	± 0.050	0.964	$\pm \ 0.102$
Λ	0.080	$\pm~0.007$	0.205	± 0.010	0.368	± 0.014
Σ^0	0.023	$\pm~0.008$				
Σ^{\pm}		difference .		Porton	0.170	$\pm~0.063$
\mathcal{Z}^-	0.0059	9 ± 0.0007	0.0176	6 ± 0.0027	0.0227	7 ± 0.0018
$\Delta(1232)^{++}$	0.040	$\pm~0.010$		- Companied and	0.022	± 0.06
$\Sigma(1385)^{-}$	0.006	$\pm~0.002$	0.017	$\pm \ 0.004$		
$\Sigma(1385)^{+}$	0.005	$\pm \ 0.001$	0.017	$\pm \ 0.004$		
$\Sigma(1385)^{\pm}$	0.0106	6 ± 0.0020	0.033	± 0.008	0.0380	0.0062
$\Xi(1530)^0$		5 ± 0.0006		_		3 ± 0.0005
Ω^-		7 ± 0.0004	0.014	± 0.007		0.0015
Λ_c^+		$\pm 0.030^{(i)}$		± 0.050		_
					0.001	1 0 010
A_b^0					0.031	$\pm \ 0.016$

All average multiplicites are per hadronic e^+e^- annihilation event.

- (a) $B(D_s \to \eta \pi, \eta' \pi)$ has been used (RPP 1994).
- (b) The Standard Model $B(Z \to b\overline{b}) = 0.217$ was used.
- (c) $x_p = p/p_{\text{beam}} > 0.1$ only.
- (d) Extrapolation to the unobserved region using the shape predicted by JETSET.
- (e) Any charge state (i.e., B_d^* , B_u^* , or B_s^*).
- (f) $B(Z \rightarrow hadrons) = 0.699$ has been used (RPP 1994).
- (g) $x_E = E[K_2^*(1430)0]/E_{\text{beam}} < 0.3 \text{ only}$
- (h) Any charge state (i.e., B_d^{**} , B_u^{**} , or B_s^{**}).
- (i) The value was taken from the cross section of the $\Lambda_c^+ \to p\pi K$, assuming the branching fraction to be $(3.2\pm0.7)\%$ (RPP 1992).

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Fragmentation in e^+e^- Annihilation

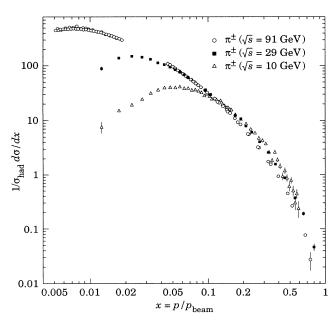
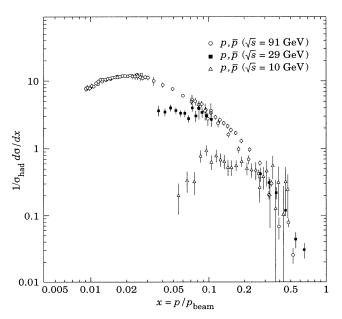


Figure 36.10: Fragmentation into π^{\pm} in e^+e^- annihilations: Inclusive cross sections $(1/\sigma_{\rm had})(d\sigma/dx)$, with $x=p/p_{\rm beam}$. The indicated errors are statistical and systematic errors added in quadrature.

 \triangle : rate at $\sqrt{s}=9.98$ GeV; an overall uncertainty of 1.8%: **ARGUS**—H. Albrecht *et al.*, Z. Phys. **C44**, 547 (1989).

 \blacksquare : rate at $\sqrt{s}=29$ GeV **TPC**—H. Aihara *et al.*, Phys. Rev. Lett. **61**, 1263 (1988).

 \bigcirc : rate for hadronic decays of the Z at $\sqrt{s}=91.2$ GeV **ALEPH**—D. Buskulic *et al.*, Z. Phys. **C66**, 355 (1995); **OPAL**—R. Akers *et al.*, Z. Phys. **C63**, 181 (1994). (Courtesy of O. Biebel, S. Bethke, and D. Lanske, RWTH, Aachen, 1995.)



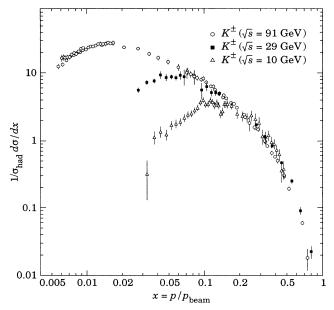


Figure 36.11: Fragmentation into K^{\pm} in e^+e^- annihilations: Inclusive cross sections $(1/\sigma_{\rm had})(d\sigma/dx)$, with $x=p/p_{\rm beam}$. The indicated errors are statistical and systematic errors added in quadrature.

 \triangle : rate at $\sqrt{s}=9.98$ GeV; an overall uncertainty of 1.8%: **ARGUS**—H. Albrecht *et al.*, Z. Phys. **C44**, 547 (1989).

 \blacksquare : rate at $\sqrt{s}=29$ GeV **TPC**—H. Aihara *et al.*, Phys. Rev. Lett. **61**, 1263 (1988).

 \bigcirc : rate for hadronic decays of the Z at $\sqrt{s}=91.2$ GeV **ALEPH**—D. Buskulic *et al.*, Z. Phys. **C66**, 355 (1995); **DELPHI**—P. Abreu *et al.*, Nucl. Phys. **B444**, 3 (1995); **OPAL**—R. Akers *et al.*, Z. Phys. **C63**, 181 (1994). (Courtesy of O. Biebel, S. Bethke, and D. Lanske, RWTH, Aachen, 1995.)

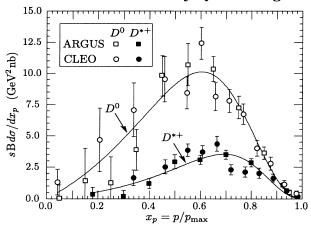
Figure 36.12: Fragmentation into $p\overline{p}$ in e^+e^- annihilations: Inclusive cross sections $(1/\sigma_{\rm had})(d\sigma/dx)$, with $x=p/p_{\rm beam}$. The indicated errors are statistical and systematic errors added in quadrature.

 \triangle : rate at $\sqrt{s} = 9.98$ GeV; an overall uncertainty of 1.8%. This rate is obtained from the measured \overline{p} rate by scaling with a factor of two: **ARGUS**—H. Albrecht *et al.*, Z. Phys. **C44**, 547 (1989).

 \blacksquare : rate at $\sqrt{s}=29$ GeV: **TPC**—H. Aihara *et al.*, Phys. Rev. Lett. **61**, 1263 (1988).

 \bigcirc : rate for hadronic decays of the Z at $\sqrt{s}=91.2$ GeV: **ALEPH**—D. Buskulic *et al.*, Z. Phys. **C66**, 355 (1995). **DELPHI**—P. Abreu *et al.*, Nucl. Phys. **B444**, 3 (1995). **OPAL**—R. Akers *et al.*, Z. Phys. **C63**, 181 (1994). (Courtesy of O. Biebel, S. Bethke, and D. Lanske, RWTH, Aachen, 1995.)

Heavy Quark Fragmentation in e^+e^- Annihilation



Average e^+e^- , pp, and $\bar{p}p$ Multiplicity

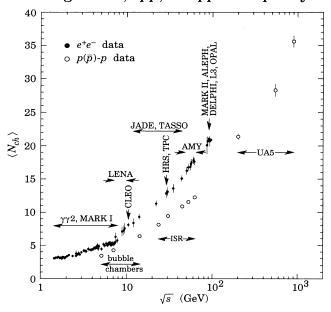


Figure 36.14: Average multiplicity as a a function of \sqrt{s} for e^+e^- and $p\overline{p}$ annihilations and and pp collisions. The indicated errors are statistical and systematic errors added in quadrature, except when no systematic errors are given.

 e^+e^- : All measurements include contributions from K_S^0 and Λ decays. The $\gamma\gamma 2$ and MARK I measurements contain a systematic 5% error. The five points at the Z resonance have been spread horizontally for clarity: **OPAL**—P.D. Acton *et al.*, Z. Phys. **C53**, 539 (1992) and references therein, R. Akers *et al.*, Z. Phys. **C68**, 203 (1995); **ALEPH**—D. Buskulic *et al.*, Z. Phys. C, CERN PPE/95-82.

 $p(\overline{p})$: The values measured by UA5 exclude single diffractive dissociation: J. Benecke *et al.* (bubble chamber), Nucl. Phys. **B76**, 29 (1976), W.M. Morse *et al.* (bubble chamber), Phys. Rev. **D15**, 66 (1977); **ISR**—A. Breakstone *et al.*, Phys. Rev. **D30**, 528 (1984); **UA5**—G.J. Alner *et al.*, Phys. Lett. **167B**, 476 (1986), Ansorge *et al.*, Z. Phys. **C43**, 357 (1989). (Courtesy of O. Biebel, S. Bethke, and D. Lanske, RWTH, Aachen, 1994.)

Figure 36.13: Heavy quark fragmentation: Shown are the CLEO—D. Bortoletto et~al., Phys. Rev. D37, 1719 (1988) and ARGUS—H. Albrecht et~al., Z. Phys. C52, 353 (1991) inclusive cross sections ($s~B~d\sigma/dx_p$, with $x_p=p/p_{\rm max}$) for the production of pseudoscalar D^0 and vector D^{*+} in e^+e^- annihilations at $\sqrt{s}\sim 10~{\rm GeV}$. For the D^0 , B is the branching ratio for $D^0\to K^-\pi^+$, while in the D^{*+} case B is the product branching ratio for $D^{*+}\to D^0\pi^+$ followed by $D^0\to K^-\pi^+$. These inclusive spectra have not been corrected for cascades from higher states, nor for radiative effects. Many functional forms have been suggested to describe these "hard" spectra, characteristic of charmed particles produced in e^+e^- annihilations. The parameterization given by Peterson e^+e^- (Phys. Rev. D27, 105, (1983)) in terms of just one variable ϵ_p has found the most use:

$$\frac{dN}{dx_p} = \frac{1}{x_p[1 - (1/x_p) - \epsilon_p/(1 - x_p)]^2} \ .$$

Fits to the combined CLEO and ARGUS D^0 and D^{*+} data give $\epsilon_p(D^0)=0.135\pm0.010$ and $\epsilon_p(D^*)=0.078\pm0.008$; these are indicated by the solid curves.

Spin-dependent effects have been observed in, e.g., the polarization of D^{*+} mesons as a function of x_p . Recent measurements of ϵ_p for D^{**} and D_{sJ} mesons by **CLEO**—J. Alexander et~al., Phys. Lett. **B303**, 377 (1993) and **ARGUS**—H. Albrecht et~al., Phys. Lett. **B221**, 422 (1989) and Phys. Lett. **B232**, 398, (1989) also indicate that the fragmentation functions of such orbitally excited charmed mesons are distinctly harder than for D or D^* mesons. How much of this is a mass effect and how much is truly a spin effect has not yet been fully determined. (Courtesy of D. Besson, Univ. of Kansas, 1994.)

Annihilation Cross Section Near M_Z

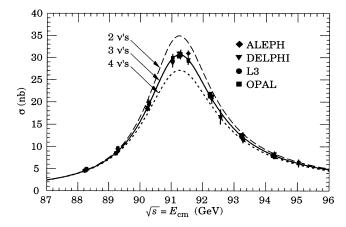


Figure 36.15: Data from the ALEPH, DELPHI, L3, and OPAL Collaborations for the cross section in e^+e^- annihilation into hadronic final states as a function of c.m. energy near the Z. LEP detectors obtained data at the same energies; some of the points are obscured by overlap. The curves show the predictions of the Standard Model with three species (solid curve) and four species (dashed curve) of light neutrinos. The asymmetry of the curves is produced by initial-state radiation. References:

ALEPH: D. Decamp et al., Z. Phys. C53, 1 (1992).
DEPHI: P. Abreu et al., Nucl. Phys. B367, 511 (1992).
L3: B. Adeva et al., Z. Phys. C51, 179 (1991).
OPAL: G. Alexander et al., Z. Phys. C52, 175 (1991).

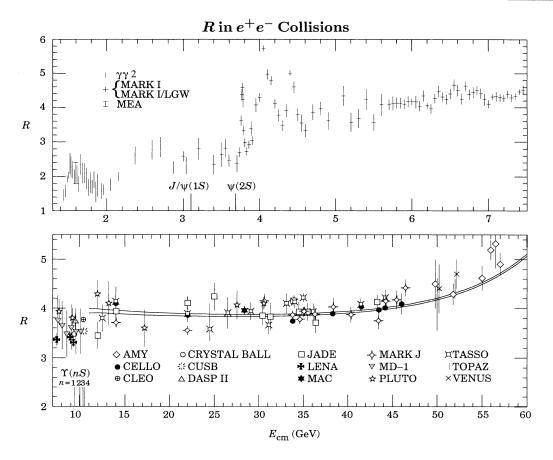


Figure 36.16: Selected measurements of $R \equiv \sigma(e^+e^- \to \text{hadrons})/\sigma(e^+e^- \to \mu^+\mu^-)$, where the annihilation in the numerator proceeds via one photon or via the Z. Measurements in the vicinity of the Z mass are shown in the following figure. The denominator is the calculated QED single-photon process; see the section on Cross-Section Formulae for Specific Processes. Radiative corrections and, where important, corrections for two-photon processes and τ production have been made. Note that the ADONE data $(\gamma\gamma^2)$ and MEA is for ≥ 3 hadrons. The points in the $\psi(3770)$ region are from the MARK I—Lead Glass Wall experiment. To preserve clarity only a representative subset of the available measurements is shown—references to additional data are included below. Also for clarity, some points have been combined or shifted slightly (<4%) in $E_{\rm cm}$, and some points with low statistical significance have been omitted. Systematic normalization errors are not included; they range from $\sim 5-20\%$, depending on experiment. We caution that especially the older experiments tend to have large normalization uncertainties. Note the suppressed zero. The horizontal extent of the plot symbols has no significance. The positions of the $J/\psi(1S)$, $\psi(2S)$, and the four lowest Υ vector-meson resonances are indicated. Two curves are overlaid for $E_{\rm cm} > 11$ GeV, showing the theoretical prediction for R, including higher order QCD [M. Dine and J. Sapirstein, Phys. Rev. Lett. 43, 668 (1979)] and electroweak corrections. The Λ values are for 5 flavors in the $\overline{\rm MS}$ scheme and are $\Lambda_{\rm MS}^{(5)} = 60$ MeV (lower curve) and $\Lambda_{\rm MS}^{(5)} = 250$ MeV (upper curve). (Courtesy of F. Porter, 1992.) References (including several references to data not appearing in the figure and some references to preliminary data):

AMY: T. Mori *et al.*, Phys. Lett. **B218**, 499 (1989); CELLO: H.-J. Behrend et al., Phys. Lett. 144B, 297 (1984); and H.-J. Behrend et al., Phys. Lett. 183B, 400 (1987); **CLEO**: R. Giles et al., Phys. Rev. **D29**, 1285 (1984); and D. Besson et al., Phys. Rev. Lett. 54, 381 (1985); CUSB: E. Rice et al., Phys. Rev. Lett. 48, 906 (1982); CRYSTAL BALL: A. Osterheld et al., SLAC-PUB-4160; and Z. Jakubowski et al., Z. Phys. C40, 49 (1988); **DASP**: R. Brandelik *et al.*, Phys. Lett. **76B**, 361 (1978); DASP II: Phys. Lett. 116B, 383 (1982); DCI: G. Cosme et al., Nucl. Phys. B152, 215 (1979); DHHM: P. Bock et al. (DESY-Hamburg-Heidelberg-MPI München Collab.), Z. Phys. C6, 125 (1980); $\gamma \gamma 2$: C. Bacci *et al.*, Phys. Lett. **86B**, 234 (1979); **HRS**: D. Bender *et al.*, Phys. Rev. **D31**, 1 (1985); JADE: W. Bartel et al., Phys. Lett. 129B, 145 (1983); and W. Bartel et al., Phys. Lett. 160B, 337 (1985); LENA: B. Niczyporuk et al., Z. Phys. C15, 299 (1982).

MAC: E. Fernandez et al., Phys. Rev. D31, 1537 (1985); MARK J: B. Adeva et al., Phys. Rev. Lett. 50, 799 (1983); and B. Adeva et al., Phys. Rev. **D34**, 681 (1986); MARK I: J.L. Siegrist et al., Phys. Rev. D26, 969 (1982); MARK I + Lead Glass Wall: P.A. Rapidis et al., Phys. Rev. Lett. 39, 526 (1977); and P.A. Rapidis, thesis, SLAC-Report-220 (1979); MARK II: J. Patrick, Ph.D. thesis, LBL-14585 (1982); MD-1: A.E. Blinov et al., Z. Phys. C70, 31 (1996); MEA: B. Esposito et al., Lett. Nuovo Cimento 19, 21 (1977); PLUTO: A. Bäcker, thesis Gesamthochschule Siegen, DESY F33-77/03 (1977); C. Gerke, thesis, Hamburg Univ. (1979); Ch. Berger et al., Phys. Lett. 81B, 410 (1979); and W. Lackas, thesis, RWTH Aachen, DESY Pluto-81/11 (1981); TASSO: R. Brandelik et al., Phys. Lett. 113B, 499 (1982); and M. Althoff et al., Phys. Lett. 138B, 441 (1984); TOPAZ: I. Adachi et al., Phys. Rev. Lett. 60, 97 (1988); and VENUS: H. Yoshida et al., Phys. Lett. 198B, 570 (1987).

Collis	sions: $pp,\overline{p}p,pn,a$	$nd \ \overline{p}n$	$p_{ m lab} >$	50 GeV	$V/c, \chi^2$	dof = 2	2.82	
	Value	X_{pn}	Y_{pp}	$Y_{\overline{p}p}$	Y_{pn}	$Y_{\overline{p}n}$	η	ε
$\overline{X_{pp}}$	22.0 ± 0.6	99.0	37.0	60.0	38.0	59.0	75.0	-98.0
X_{pn}^{rr}	22.3 ± 0.6		40.0	63.0	37.0	60.0	76.0	-97.0
Y_{pp}	56.1 ± 4.4			96.0	93.0	93.0	88.0	-21.0
$Y_{\overline{p}p}^{rr}$	98.2 ± 9.5				91.0	98.0	98.0	-45.0
Y_{pn}^{rr}	55.0 ± 4.1					94.0	86.0	-22.0
$Y_{\overline{p}n}$	92.7 ± 8.6						96.0	-44.0
η^{n}	0.46 ± 0.3							-62.0
ε	0.079 ± 0.003			(Correlati	ions %		
Collis	sions: pd and $\overline{p}d$, p	$p_{ m lab} > 5$	0 GeV	$/c, \chi^2$	/ dof =	1.77		
	Value				Y_{pd}	$Y_{\overline{p}d}$	η	ε
$\overline{X_{pd}}$	35.7 ± 2.5				-27.0	9.0	56.0	-99.0
Y_{pd}	179.0 ± 18.8					93.0	64.0	36.0
$Y_{\overline{p}d}^{pa}$	270.6 ± 29.3						87.0	1.0
η	0.45 ± 0.03							-47.0
ε	0.090 ± 0.008					Correla	tions %	
Collis	sions: $\pi^+ p$ and π^-	p, p_{lab}	> 10 (GeV/c ,	χ^2 / dof	= 1.66		
	Value				Y_{π^+}	Y_{π^-}	η	ε
\overline{X}	13.7 ± 0.6				-44.0	11.0	86.0	-99.0
Y_{π^+}	27.8 ± 0.8				11.0	83.0	8.0	52.0
$Y_{\pi^-}^{\pi^-}$	35.9 ± 1.1						60.0	-1.3
η^-	0.45 ± 0.01						00.0	-80.0
ε	0.079 ± 0.004					Correla	tions %	00.0
	sions: $\pi^+ d$ and π^-	d, p_{lab}	> 10 (GeV/c,	χ^2 / dof			
-	Value					Y	η	ϵ
\overline{X}	23.2 ± 2.1					73.0	95.0	-99.7
Y	85.5 ± 7.6					10.0	91.0	-68.0
η	0.43 ± 0.04						01.0	-92.0
ε	0.088 ± 0.010					Cor	relation	
Collis	sions: K^+p , K^+n ,	K^-p , a	and K	n, p_{la}	_b > 10 ($GeV/c, \chi$	$\frac{2}{\sqrt{dof}}$	= 4.23
	Value				Y_{+}		η	ε
\overline{X}	12.2 ± 0.6				-95.0	-59.0	13.0	-99.0
Y_{+}	8.3 ± 1.8				00.0	77.0	12.0	96.0
Y_{-}^{+}	26.4 ± 2.7						70.0	64.0
η	0.50 ± 0.03						. 0.0	-5.0
ε	0.079 ± 0.006					Correla	tions %	
Collis	sions: K^+d and K	$-d$, $p_{\rm lal}$	_b > 10	GeV/a	$e, \chi^2/de$	of = 1.9		
,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	Value				Y_{+}	Y_	η	ε
\overline{X}	21.7 ± 0.7				-92.0	-27.0	60.0	-99.7
Y_{+}	26.2 ± 2.8				· · · · ·	57.0	-30.0	94.0
Y_{-}^{+}	64.8 ± 3.4					0110	60.0	33.0
η	0.47 ± 0.01						00.0	-54.0
ε	0.082 ± 0.004					Correla	tions %	01. 0
Collis	sions: γp , $p_{\mathrm{lab}} > 1$	2 GeV/	$c, \chi^2/$	dof =	0.57			
-	Value					Y	η	ε
\overline{X}	0.071 ± 0.018	****				76.0	97.0	-99.5
Y	0.071 ± 0.018 0.12 ± 0.04					10.0	90.0	-70.0
	0.12 ± 0.04 0.46 ± 0.25						<i>3</i> 0.0	-94.0
η						Cor	rolation	
ε	0.075 ± 0.030					Cor	relation	5 70

Table 36.2: Regge theory provides a simple and compact description of total cross sections (A. Donnachie and P.V. Landshoff, Phys. Lett. B296, 227 (1992)): it is sufficient to write $\sigma_{\text{tot}} = X \, s^{\varepsilon} + Y \, s^{-\eta}$, where the first term arises from pomeron exchange and the second from ρ , ω , f, and a exchange. Simultaneous fits are shown below for groups of reactions within which ε and η have the same values, and $X_{ab} = X_{\overline{a}b}$. As can be seen from Fig. 36.17, the fitted exponents are consistent with having the same values for all reactions. The fitted functions are shown in the figures, along with the correlated one-standard-deviation error bands which, when the reduced χ^2 is greater than one, include a scale factor that is defined as the square root of the reduced χ^2 . Vertical arrows indicate lower limits on the momentum range used in the fits (these momenta are also given in the table). Curves and error bands are extrapolated to lower momenta; the user may decide on the range of applicability. Data used were extracted from the CS database of the Particle Physics Data System (PPDS), accessible through the WWW at http://pdg.lbl.gov/. Computer-readable data files are also available through http://pdg.lbl.gov/. (Courtesy of V.V. Ezhela, S.B. Lugovsky, and N.P. Tkachenko, COMPAS Group, IHEP, Protvino.)

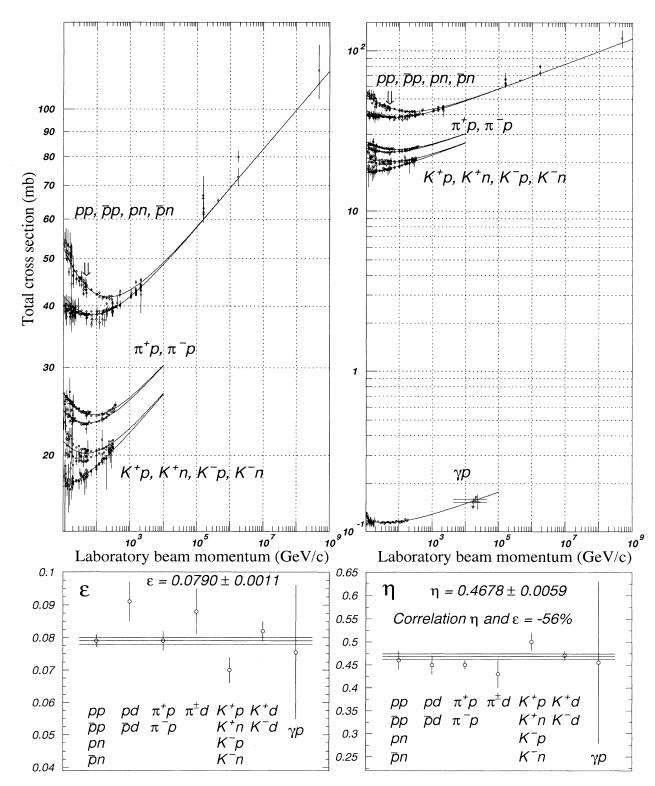


Figure 36.17: Summary of hadronic and γp total cross sections (top), and fit results to exponents for cross sections. (Courtesy of the COMPAS Group, IHEP, Protvino, Russia, 1996.)

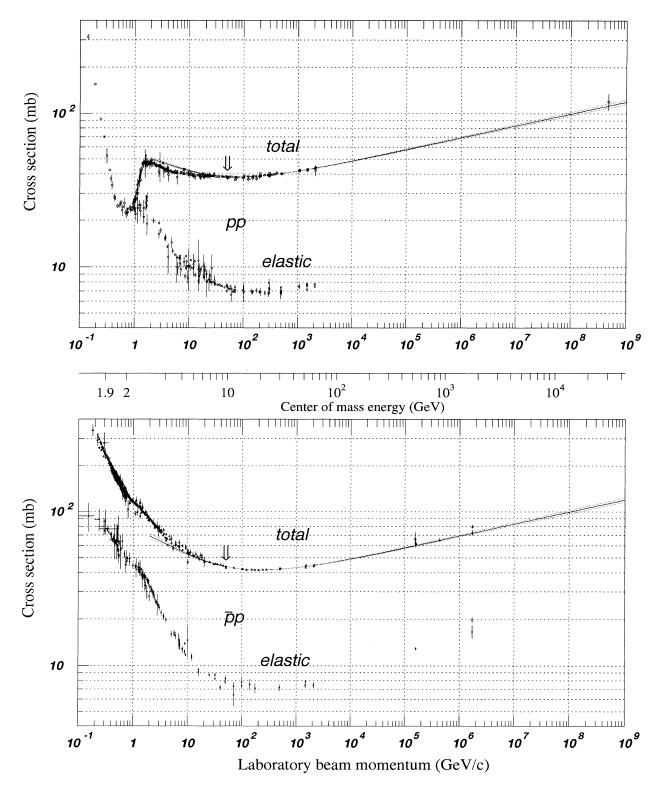


Figure 36.18: Total and clastic cross sections for pp and $\bar{p}p$ collisions as a function of laboratory beam momentum and total center-of-mass energy. Computer-readable data files may be found at http://pdg.lbl.gov/xsect/contents.html (Courtesy of the COMPAS Group, IHEP, Protvino, Russia, 1996.)

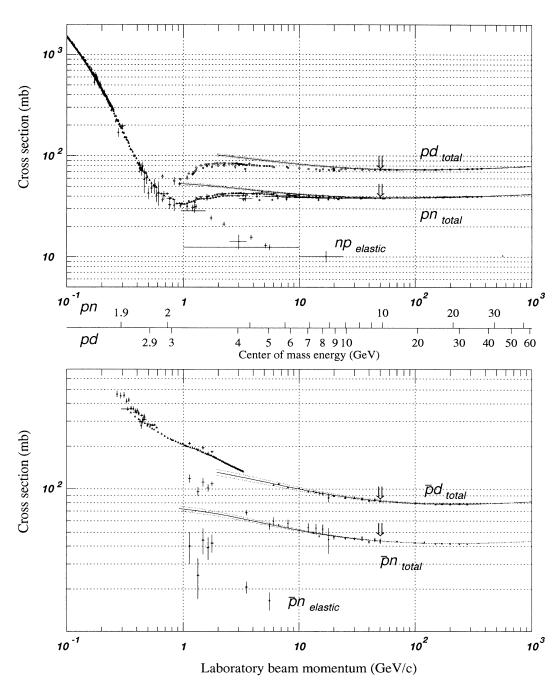


Figure 36.19: Total and elastic cross sections for pd (total only), np, $\overline{p}d$ (total only), and $\overline{p}n$ collisions as a function of laboratory beam momentum and total center-of-mass energy. Computer-readable data files may be found at http://pdg.lbl.gov/xsect/contents.html (Courtesy of the COMPAS Group, IHEP, Protvino, Russia, 1996.)

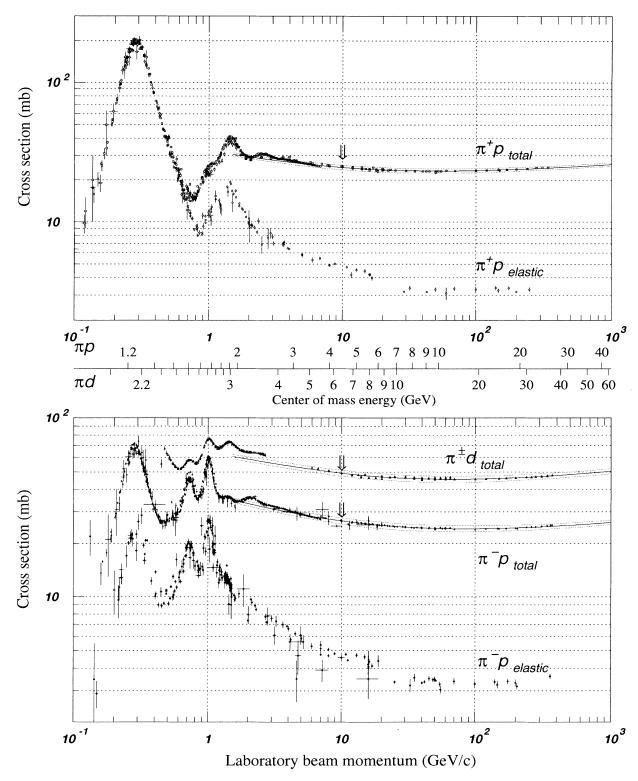


Figure 36.20: Total and elastic cross sections for π^+p , $\pi^\pm d$ (total only), and π^-p collisions as a function of laboratory beam momentum and total center-of-mass energy. Computer-readable data files may be found at http://pdg.lbl.gov/xsect/contents.html (Courtesy of the COMPAS Group, IHEP, Protvino, Russia, 1996.)

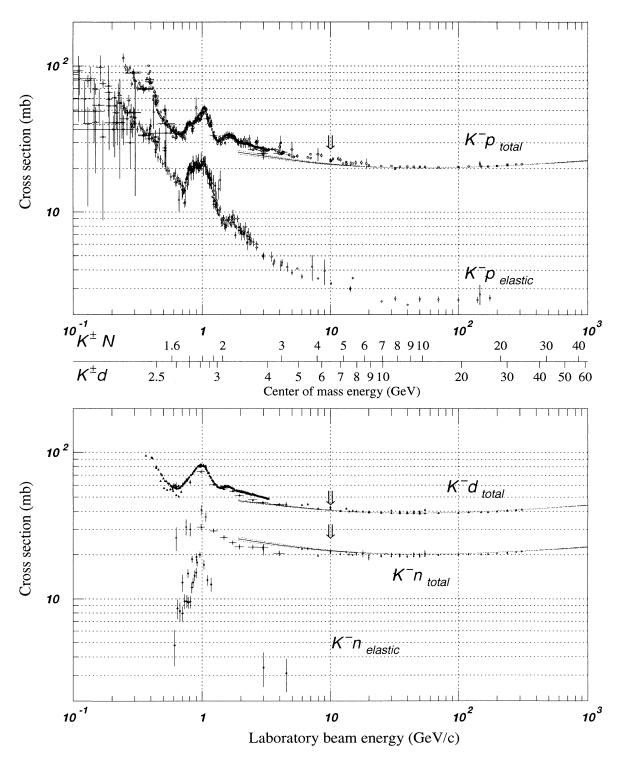


Figure 36.21: Total and elastic cross sections for K^-p , K^-d (total only), and K^-n collisions as a function of laboratory beam momentum and total center-of-mass energy. Computer-readable data files may be found at http://pdg.lbl.gov/xsect/contents.html (Courtesy of the COMPAS Group, IHEP, Protvino, Russia, 1996.)

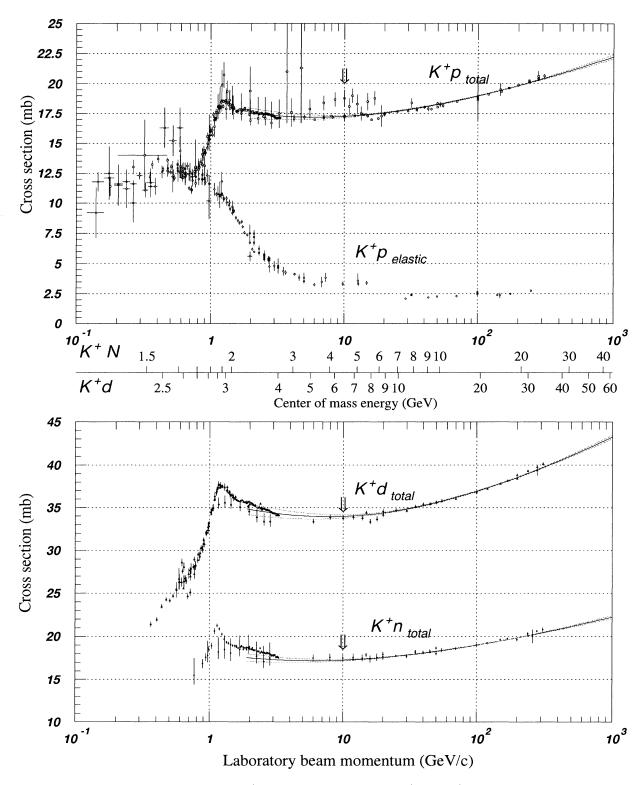


Figure 36.22: Total and elastic cross sections for K^+p and total cross sections for K^+d and K^+n collisions as a function of laboratory beam momentum and total center-of-mass energy. Computer-readable data files may be found at http://pdg.lbl.gov/xsect/contents.html (Courtesy of the COMPAS Group, IHEP, Protvino, Russia, 1996.)

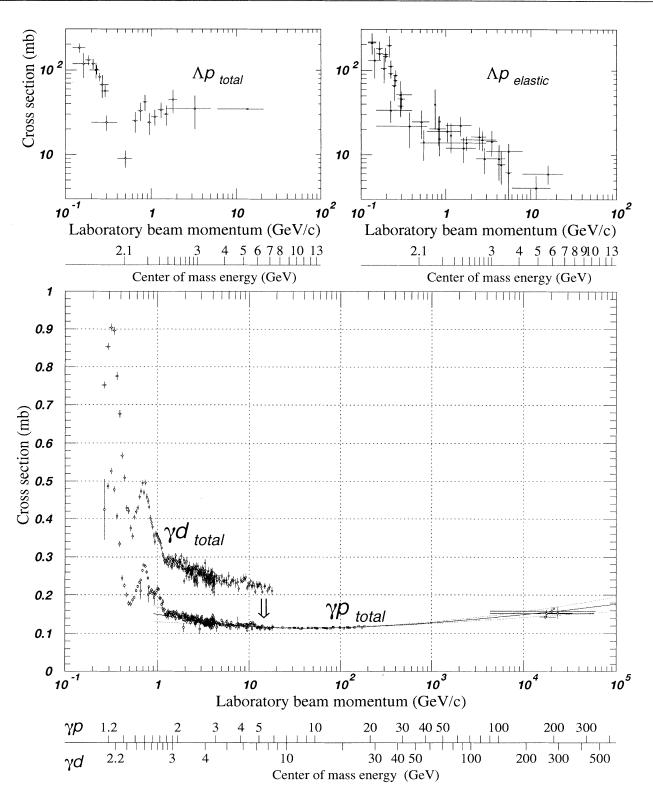
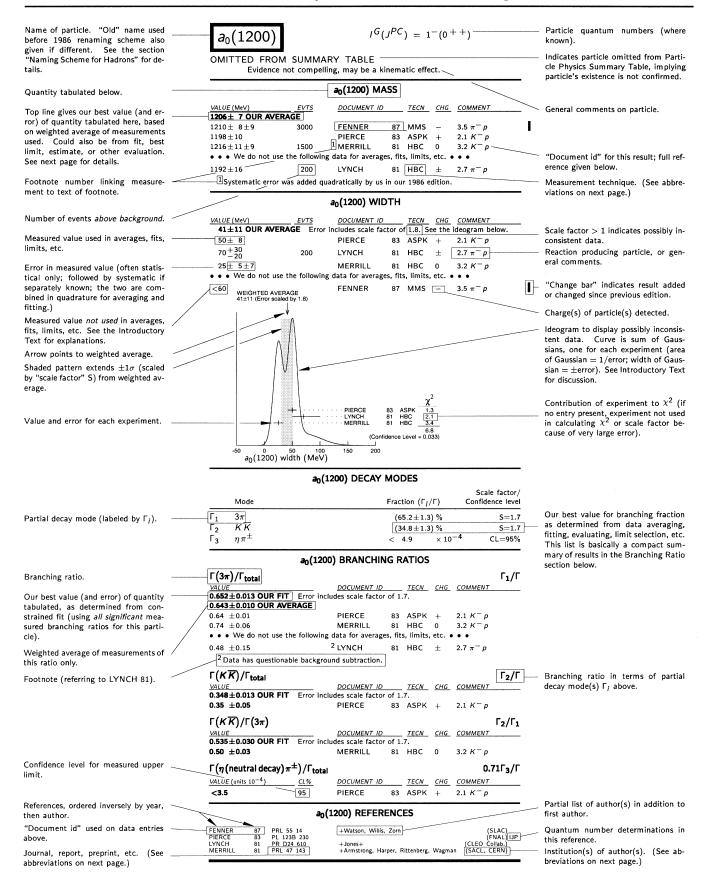


Figure 36.23: Total and elastic cross sections for Λp and total cross sections for γd and γp collisions as a function of laboratory beam momentum and total center-of-mass energy. Computer-readable data files may be found at http://pdg.lbl.gov/xsect/contents.html (Courtesy of the COMPAS Group, IHEP, Protvino, Russia, 1996.)

INTRODUCTION TO THE PARTICLE LISTINGS

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Illustrative Key to the Particle Listings



Abbreviations Osed in the Farticle Listings							
Indicator	r of Proc	edure Used to Obtain Our Result	E799	Fermilab E799 Spectrometer-Calorimeter			
OUR AVER	RAGE	From a weighted average of selected data.	EHS	Four-pi detector at CERN			
OUR FIT	aron.	From a constrained or overdetermined multipa-	ELEC	Electronic combination			
Och		rameter fit of selected data.	EMC	European muon collaboration detector at CERN			
OUR EVAL	LUATION	Not from a direct measurement, but evaluated	EMUL	Emulsions			
		from measurements of other quantities.	$_{ m FBC}$	Freon bubble chamber Fit to previously existing data			
OUR ESTI	MATE	Based on the observed range of the data. Not	FMPS	Fermilab Multiparticle Spectrometer			
		from a formal statistical procedure.		ADONE $B\overline{B}$ group detector			
OUR LIMIT	Т	For special cases where the limit is evaluated by		ADONE $\gamma\gamma$ group detector			
		us from measured ratios or other data. Not from a direct measurement.		ADONE MEA group detector			
		a direct measurement.	FREJ	FREJUS Collaboration – modular flash chamber detector			
Measure	ment Te	chniques		(calorimeter)			
(i.e., I	Detectors	s and Methods of Analysis)	GA24	Hodoscope Cherenkov γ calorimeter (IHEP GAMS-2000)			
ACCM AC	CMOR Co	llaboration	GALX	(CERN GAMS-4000) GALLEX solar neutrino detector in the Gran Sasso Under-			
		tive mass spectrometer	GALA	ground Lab.			
		RN LEP detector	GAM2	IHEP hodoscope Cherenkov γ calorimeter GAMS-2000			
		at KEK-TRISTAN		CERN hodoscope Cherenkov γ calorimeter GAMS-4000			
		tor at DORIS	GOLI	CERN Goliath spectrometer			
		cular amplitude path on Argand diagram	H1	H1 detector at DESY/HERA			
		ngle-photon detector ark chambers	$^{ m HBC}$	Hydrogen bubble chamber			
		sector at LEAR	HDBC	Hydrogen and deuterium bubble chambers			
	tronomy	action at BEITT	HEBC	Helium bubble chamber			
	_	ent 787 detector	HEPT	Helium proportional tubes			
B791 BN	IL experim	ent 791 detector	HLBC	Heavy-liquid bubble chamber Homestake underground scintillation detector			
B845 BN	VL experim	ent 845 detector	HPW	Harvard-Pennsylvania-Wisconsin detector			
		ground scintillation telescope	HRS	SLAC high-resolution spectrometer			
	ibble ch a mb	er		Hybrid: bubble chamber + electronics			
	am dump	DIGE G U I	IMB	Irvine-Michigan-Brookhaven underground Cherenkov detector			
		RICE Collab. bubble chamber at CERN	IMB3	Irvine-Michigan-Brookhaven underground Cherenkov detector			
		Spectrometer at Beijing Electron-Positron Collider	INDU	Magnetic induction			
		meter at Serpukhov	IPWA	Energy-independent partial-wave analysis			
	-	trometer system at KEK Proton Synchroton	JADE	JADE detector at DESY			
		nagnetic detector at DORIS	KAM2	KAMIOKANDE-II underground Cherenkov detector			
BPWA Ba	rrelet-zero	partial-wave analysis	KAMI	KAMIOKANDE underground Cherenkov detector KARMEN calorimeter at the ISIS neutron spallation source at			
	lorimeter		KAKWI	Rutherford			
		etector at SLAC-SPEAR or DORIS	KOLR	Kolar Gold Field underground detector			
CBOX Cry		detector at CERN-LEAR	L3	L3 detector at LEP			
	ystai box a oud chambe		LASS	Large-angle superconducting solenoid spectrometer at SLAC			
		cago-Fermilab-Rochester detector	LEBC LENA	Little European bubble chamber at CERN			
		tor at Fermilab	LEPS	Nonmagnetic lead-glass NaI detector at DORIS Low-Energy Pion Spectrometer at the Paul Scherrer Institute			
		o detector at CERN	MAC	MAC detector at PEP/SLAC			
		tor at DESY	MBR	Molecular beam resonance technique			
	ierenkov de TARM-II ne	eutrino detector (glass) at CERN	MCRO	MACRO detector in Gran Sasso			
		rino detector (marble) at CERN	MD1	Magnetic detector at VEEP-4, Novosibirsk			
		boson spectrometer	MDRP	Millikan drop measurement			
		ctor at CESR	MICA	Underground mica deposits			
CLEO Co:	rnell magne	etic detector at CESR	MLEV	Magnetic levitation			
		gnetic detector at VEPP-2M, Novosibirsk	MMS	Missing mass spectrometer			
-	,	gnetic detector 2 at VEPP-2M, Novosibirsk	MPS MPS2	Multiparticle spectrometer at BNL Multiparticle spectrometer upgrade at BNL			
	unters	d autoaphyraica	MPSF	Multiparticle spectrometer at Fermilab			
	ENGLOGY and	d astrophysics		Model-dependent partial-wave analysis			
		Stony Brook BGO calorimeter inserted in NaI	MRK1	SLAC Mark-I detector			
arr		V	MRK2	SLAC Mark-II detector			
CUSB Col	lumbia U.	Stony Brook segmented NaI detector at CESR	MRK3	SLAC Mark-III detector			
		t Fermilab Tevatron Collider	MRKJ	Mark-J detector at DESY			
		arm spectrometer	MRS NA14	Magnetic resonance spectrometer CERN			
		bble chamber tor at SLAC-SPEAR or SLAC-PEP	NA31	CERN NA31 Spectrometer-Calorimeter			
		ctor at LEP	NA32	CERN NA32 Spectrometer			
DM1 Ma	agnetic dete	ctor no. 1 at Orsay DCI collider	ND	NaI detector at VEPP-2M, Novosibirsk			
	.,	ctor no. 2 at Orsay DCI collider	NICE	Serpukhov nonmagnetic precision spectrometer			
	.,	dent partial-wave analysis	NMR	Nuclear magnetic resonance			
	rmilab E621		NUSX	Mont Blanc NUSEX underground detector			
	rmilab E65: rmilab E68'		OBLX OLYA	OBELIX detector at LEAR Detector at VEPP-2M and VEPP-4, Novosibirsk			
	rmilab E69			CERN OMEGA spectrometer			
		Spectrometer-Calorimeter	OPAL	OPAL detector at LEP			
		Spectrometer-Calorimeter	OSPK	Optical spark chamber			
	rmilab E761	l detector 3 Spectrometer-Calorimeter	PLAS	Plastic detector			
	rmilab E773	=	PLUT PWA	DESY PLUTO detector Partial-wave analysis			
	rmilab E791		· I WA	T GIOLOG MONG CHICANOLO			

-			
REDE	Resonance depolarization	MPL	Modern Physics Letters
RVUE	Review of previous data	NAT	Nature
SAGE	US - Russian Gallium Experiment	NC	Nuovo Cimento
SFM	CERN split-field magnet	NIM	Nuclear Instruments and Methods
SHF	SLAC Hybrid Facility Photon Collaboration	NP	Nuclear Physics
SIGM	Serpukhov CERN-IHEP magnetic spectrometer (SIGMA)		Nuclear Physics B Proceedings Supplement
SILI	Silicon detector	PAN	Physics of Atomic Nuclei (formerly SJNP)
SLD	SLC Large Detector for e^+e^- colliding beams at SLAC	$^{ m PD}$	Physics Doklady (Magazine)
SOUD	Soudan underground detector	PDAT	Physik Daten
SPEC	Spectrometer	$_{\mathrm{PL}}$	Physics Letters
SPED	From maximum of speed plot or resonant amplitude	PN	Particles and Nuclei
SPRK	Spark chamber	PPN	Physics of Particles and Nuclei (formerly SJPN)
SQID	SQUID device	PPNP	Progress in Particles and Nuclear Physics
STRC	Streamer chamber	PPSL	Proc. of the Physical Society of London
TASS	DESY TASSO detector	$_{\mathrm{PR}}$	Physical Review
THEO	Theoretical or heavily model-dependent result		Pramana
THY	Theory	PRL	Physical Review Letters
TOF	Time-of-flight	PRPL	Physics Reports (Physics Letters C)
TOPZ	TOPAZ detector at KEK-TRISTAN	PRSE	Proc. of the Royal Society of Edinburgh
TPC	TPC detector at PEP/SLAC	PRSL	Proc. of the Royal Society of London, Section A
TPS	Tagged photon spectrometer at Fermilab	$_{\mathrm{PS}}$	Physica Scripta
TRAP	Penning trap	PTP	Progress of Theoretical Physics
UA1	UA1 detector at CERN	PTRSL	Phil. Trans. Royal Society of London
UA2	UA2 detector at CERN	RA	Radiochimica Acta
UA5	UA5 detector at CERN	RMP	Reviews of Modern Physics
VES	Vertex Spectrometer Facility at 70 GeV IHEP accelerator	RNC	La Rivista del Nuovo Cimento
VNS	VENUS detector at KEK-TRISTAN	RPP	Reports on Progress in Physics
WA75	CERN WA75 experiment	RRP	Revue Roumaine de Physique
WA82	CERN WA82 experiment	SCI	Science
WA89	CERN WA89 experiment	SJNP	Soviet Journal of Nuclear Physics
WIRE	Wire chamber	SJPN	Soviet Journal of Particles and Nuclei
XEBC	Xenon bubble chamber	SPD	Soviet Physics Doklady (Magazine)
ZEUS	ZEUS detector at DESY/HERA	SPU	Soviet Physics - Uspekhi
a .		YAF	Yadernaya Fizika
Confe	rences	ZETF	Zhurnal Eksperimental'noi i Teoreticheskoi Fiziki
Confere	nces are generally referred to by the location at which they were	ZETFP	Zhurnal Eksperimental'noi i Teoreticheskoi Fiziki, Pis'ma v
held (e.	g., HAMBURG, TORONTO, CORNELL, BRIGHTON, etc.).	77 N. A. (T)	Redakts
		ZNAT	Zeitschrift fur Naturforschung
Journ	als	ZPHY	Zeitschrift fur Physik

AA Astronomy and Astrophysics

AA	Astronomy and Astrophysics
ADVP	Advances in Physics
AFIS	Anales de Fisica
AJP	American Journal of Physics
ANP	Annals of Physics
ANPL	Annals of Physics (Leipzig)
ANYAS	Annals of the New York Academy of Sciences
AP	Atomic Physics
APAH	Acta Physica Academiae Scientiarum Hungaricae
APJ	Astrophysical Journal
APJS	Astrophysical Journal Suppl.
APP	Acta Physica Polonica
ARNPS	Annual Review of Nuclear and Particle Science
ARNS	Annual Review of Nuclear Science
ASP	Astroparticle Physics
BAPS	Bulletin of the American Physical Society
BASUP	Bulletin of the Academy of Science, USSR (Physics)
$_{\rm CJNP}$	Chinese Journal of Nuclear Physics
CJP	Canadian Journal of Physics
CNPP	Comments on Nuclear and Particle Physics
CZJP	Czechoslovak Journal of Physics
DANS	Doklady Akademii nauk SSSR
EPL	Europhysics Letters
FECAY	Fizika Elementarnykh Chastits i Atomnogo Yadra
$_{\mathrm{HADJ}}$	Hadronic Journal
$_{\text{IJMP}}$	International Journal of Modern Physics
$_{\rm JAP}$	Journal of Applied Physics
JETP	English Translation of Soviet Physics ZETF
JETPL	English Translation of Soviet Physics ZETF Letters
JINR	Joint Inst. for Nuclear Research
JPA	Journal of Physics, A
JPB	Journal of Physics, B
JPCRD	Journal of Physical and Chemical Reference Data
JPG	Journal of Physics, G
JPSJ	Journal of the Physical Society of Japan
LNC MNRA	Lettere Nuovo Cimento
MARITIVI	Monthly Notices of the Royal Astronomical Society

Institutions

AACH	Phys. Inst. der Techn. Hochschule Aachen (Historical, use for general Inst. der Techn. Hochschule)	Aachen, Germany
AACH1	I Phys. Inst. der Techn. Hochschule Aachen	Aachen, Germany
AACH3	III Phys. Inst. der Techn. Hochschule Aachen	Aachen, Germany
AACHT	Institut für Theoretische Physik	Aachen, Germany
AARH	Univ. of Aarhus	Aarhus C, Denmark
ABO	Åbo Akademi University	Åbo (Turku), Finland
ADEL	Adelphi Univ.	Garden City, NY, USA
ADLD	The Univ. of Adelaide	Adelaide, SA, Australia
AERE	Atomic Energy Research Es-	Didcot, United Kingdom
	tab.	
AFRR	Armed Forces Radiobiology	Bethesda, MD, USA
AHMET	Res. Inst. Physical Research Lab.	Ahmedabad, Gujarat, India
AICH	Aichi Univ. of Education	Aichi, Japan
AKIT	Akita Univ.	Akita, Japan
ALAH	Univ. of Alabama	Huntsville, AL, USA
ALAII	(Huntsville)	Huntsvine, AL, OSA
ALAT	Univ. of Alabama	Tuscaloosa, AL, USA
	(Tuscaloosa)	, ,
ALBA	SUNY at Albany	Albany, NY, USA
ALBE	Univ. of Alberta	Edmonton, AB, Canada
AMES	Ames Lab.	Ames, IA, USA
AMHT	Amherst College	Amherst, MA, USA
AMST	Univ. van Amsterdam	Amsterdam, The Netherlands
ANIK	NIKHEF	Amsterdam, The Netherlands
ANKA	Middle East Technical Univ.	Ankara, Turkey
ANL	Argonne National Lab.	Argonne, IL, USA
ANSM	St. Anselm Coll.	Manchester, NH, USA
ARCBO	Arecibo Observatory	Arecibo, PR, USA
ARIZ	Univ. of Arizona	Tucson, AZ, USA

ARZS	Arizona State Univ.	Tempe, AZ, USA	CAPE	University of Capetown	Rondebosch, Cape, South
ASCI	Russian Academy of Sciences	Moscow, Russian Federation	CADA	Univ. Central de Venezuela	Africa Caracas, Venezuela
AST	Inst. of Phys.	Nankang, Taipei, The Republic		Carleton Univ.	Ottawa, ON, Canada
ACCENT	NGCD "Dl:t"	of China (Taiwan)		Carleton College	Northfield, MN, USA
ATEN	NCSR "Demokritos"	Aghia Paraskevi Attikis, Greece	CASE	Case Western Reserve Univ.	Cleveland, OH, USA
ATHU	Univ. of Athens	Athens, Greece	CAST	China Center of Advanced	Beijing, The People's Republic
AUCK	Univ. of Auckland	Auckland, New Zealand		Science and Technology	of China
BAKU	Inst. of Physics	Baku, Azerbaijan	CATA	Univ. di Catania	Catania, Italy
	B Bangabasi College	Calcutta, India		Catholic Univ. of America	Washington, DC, USA
BARC	Univ. Autónoma de	Bellaterra (Barcelona), Spain	CAVE CBNM	Cavendish Lab.	Cambridge, United Kingdom Geel, Belgium
BARI	Barcelona Univ. di Bari	Bari, Italy	CCAC	Allegheny College	Meadville, PA, USA
BART	Univ. of Delaware; Bartol	Newark, DE, USA	CDEF	Collège de France	Paris, France
	Research Inst.		CEA	Cambridge Electron Accelera-	Cambridge, MA, USA
BASL	Inst. für Physik der Univ.	Basel, Switzerland		tor (Historical)	3 , ,
BAYR	Basel Univ. Bayreuth	Bayreuth, Germany	CENG	Centre d'Etudes Nucleaires	Grenoble, France
BCEN	Centre d'Etudes Nucleaires de	Gradignan, France	CERN	CERN, European Laboratory	Genève, Switzerland
DOD.	Bordeaux-Gradignan		onn.	for Particle Physics	D 11 G1 TG1
BEIJT	Inst. of Theoretical	Beijing, The People's Repub-	CFPA	Univ. of California, (Berke-	Berkeley, CA, USA
	Physics	lic of China	CHIC	ley) Univ. of Chicago	Chicago, IL, USA
BELG	Inter-University Inst. for High	Bruxelles, Belgium	CIAE	China Institute of Atomic	Beijing, The People's Republic
DDII	Energies (ULB-VUB)	M. IT'II NIT LICA	OIAL	Energy	of China
BELL	AT & T Bell Labs	Murray Hill, NJ, USA	CINC	Univ. of Cincinnati	Cincinnati, OH, USA
BERG BERL	Univ. of Bergen DESY - Inst. für Hochen-	Bergen, Norway Zeuthen , Germany	CINV	CINVESTAV-IPN, Centro de	México, DF, Mexico
DEAL	ergiephysik Zeuthen	Zetthen, Germany		Investigacion y de Estudios	
BERN	Univ. of Berne	Berne, Switzerland	CIT	Avanzados del IPN California Inst. of Tech.	Pasadena, CA, USA
	Univ. di Bologna	Bologna, Italy	CLER	Univ. de Clermont-Ferrand	Aubière, France
BGUN	Ben-Gurion Univ.	Beer-Sheva, Israel	CLEV	Cleveland State Univ.	Cleveland, OH, USA
BHAB	Bhabha Atomic Research	Trombay, Bombay, India	CMNS	Comenius Univ.	Bratislava, Slovak Republic
DITED	Center	Dailing The Decole's Depub	CMU	Carnegie Mellon Univ.	Pittsburgh, PA, USA
BHEP	Inst. of High Energy Physics	Beijing, The People's Republic of China	CNEA	Comisión Nacional de En-	Buenos Aires, Argentina
BIEL	Univ. Bielefeld	Bielefeld, Germany		ergía Atómica	
BING	SUNY at Binghamton	Binghamton, NY, USA	CNRC	Centre for Research in Parti-	Ottawa, ON, Canada
BIRK	Birkbeck College, Univ. of	London, United Kingdom	COLO	cle Physics	Banklan GO HSA
	London			Univ. of Colorado	Boulder, CO, USA New York, NY, USA
BIRM	Univ. of Birmingham	Edgbaston, Birmingham,	COLU	Columbia Univ. Concordia University	Montreal, PQ, Canada
DICII	DI II.i.	United Kingdom Bloomsburg, PA, USA	CORN	Cornell Univ.	Ithaca, NY, USA
BLSU BNL	Bloomsburg Univ. Brookhaven National Lab.	Upton, NY, USA	COSU	Colorado State Univ.	Fort Collins, CO, USA
BOCH		Bochum, Germany	CPPM	Centre National de la	Marseille, France
	Niels Bohr Inst.	Copenhagen Ø, Denmark		Recherche Scientifique, Lu-	,
BOIS	Boise State Univ.	Boise, ID, USA		miny	
	Univ. of Bombay	Bombay, India	CRAC	Kraków Inst. of Nuclear	Kraków, Poland
BONN	Rheinische Friedr	Bonn, Germany	CDNI	Physics Chalk River Labs.	Chalk River, ON, Canada
	Wilhelms-Univ. Bonn	G E F	CRNL CSOK	Oklahoma Central State	Edmond, OK, USA
BORD	Univ. de Bordeaux I	Gradignan, France Calcutta, India	CSOR	Univ.	Editional, Ott, OST
BOSE	S.N. Bose National Centre for Basis Sciences	Calcutta, India	CST	Univ. of Science and Tech-	Hefei, Anhui 230027, The
BOSK	"Rudjer Bošković" Inst.	Zagreb, Croatia		nology of China	People's Republic of China
BOST	Boston Univ.	Boston, MA, USA		California State Univ.	Long Beach, CA, USA
	Brandeis Univ.	Waltham, MA, USA		City College of New York	New York, NY, USA
BRCO	Univ. of British Columbia	Vancouver, BC, Canada	CURIN	Univ. Pierre et Marie Curie (Paris VI), LPNHE	Paris, France
BRIS	Univ. of Bristol	Bristol, United Kingdom	CHETT	Univ. Pierre et Marie	Paris, France
	Brown Univ.	Providence, RI, USA	COMIT	Curie (Paris VI), LPTHE	i with i i with
BRUX	Univ. Libre de Bruxelles;	Bruxelles, Belgium	DALH	Dalhousie Univ.	Halifax, NS, Canada
	Service de Physique des Par- ticules Elémentaires		DARE	Daresbury Lab	Cheshire, United Kingdom
BRUX	Γ Univ. Libre de Bruxelles ;	Bruxelles, Belgium	DARM		Darmstadt, Germany
	Physique Théorique	, ,	DELA	Univ. of Delaware	Newark, DE, USA
	Univ. of Bucharest	Bucharest-Magurele, Romania	DELH	Univ. of Delhi	Delhi, India
BUDA	KFKI Research Inst. for Par-	Budapest, Hungary	DESY	DESY, Deutsches	Hamburg, Germany
ממוזם	ticle & Nuclear Physics SUNY at Buffalo	Buffalo, NY, USA	DEAD	Elektronen-Synchrotron	Bilbao, Spain
BUFF BURE	Inst. des Hautes Etudes Scien-	Bures-sur-Yvette, France	DFAB DOE	Escuela de Ingenieros Department of Energy	Germantown, MD, USA
DOVE	tifiques	Zaros sar-1 resse, france	DOE	Univ. Dortmund	Dortmund, Germany
CAEN	Lab. de Physique Corpuscu-	Caen, France	DUKE	Duke Univ.	Durham, NC, USA
	laire, ISMRA		DURH	Univ. of Durham	Durham City, United Kingdom
CAGL	_	Cagliari, Italy	DUUC	University College	Dublin, Ireland
CAIR	Cairo University	Orman, Giza, Cairo, Egypt	EDIN	Univ. of Edinburgh	Edinburgh, United Kingdom
CAIW	Carnegie Inst. of Washing-	Washington, DC, USA	EFI	Enrico Fermi Inst.	Chicago, IL, USA
CALC	ton Univ. of Calcutta	Calcutta, India	ELMT	Elmhurst College	Elmhurst, IL, USA
CAME		Cambridge, United Kingdom	ENSP	l'Ecole Normale	Paris, France
CAMP	. •	Campinas, SP, Brasil	EOTV	Supérieure Eötvös University	Budapest, Hungary
CANB		Canberra, ACT, Australia	EOIV	Edivos Oniversity	Datapost, Hungary

ERLA ETH FERR FIRZ FISK FLOR FNAL FOM FRAN FRAS FREIB	École Polytechnique Univ. Erlangen-Nürnberg Univ. Zürich Univ. di Ferrara Univ. di Firenze Fisk Univ. Univ. of Florida Fermilab FOM, Stichting voor Funda-	Palaiseau, France Erlangen, Germany Zürich, Switzerland Ferrara, Italy Firenze, Italy Nashville, TN, USA	ICTP IFIC IFRJ	Int'l Centre for Theoretical Physics Univ. de Valencia - CSIC Univ. Federal do Rio de	Trieste, Italy Burjassot, Valencia, Spain Rio de Janeiro, R.J., Brasil
ETH FERR FIRZ FISK FLOR FNAL FOM FRAN FRAS FREIB FREIE	Univ. Zürich Univ. di Ferrara Univ. di Firenze Fisk Univ. Univ. of Florida Fermilab	Zürich, Switzerland Ferrara, Italy Firenze, Italy	IFRJ	Univ. de Valencia – CSIC Univ. Federal do Rio de	
FERR FIRZ FISK FLOR FNAL FOM FRAN FRAS FREIB FREIE	Univ. di Ferrara Univ. di Firenze Fisk Univ. Univ. of Florida Fermilab	Ferrara, Italy Firenze, Italy	IFRJ	Univ. Federal do Rio de	
FIRZ FISK FLOR FNAL FOM FRAN FRAS FREIB FREIE	Univ. di Firenze Fisk Univ. Univ. of Florida Fermilab	Firenze, Italy			Rio de Janeiro, RJ, Brasil
FISK FLOR FNAL FOM FRAN FRAS FREIB FREIE	Fisk Univ. Univ. of Florida Fermilab	, ,			
FRAN FRAS FREIB FREIE	Univ. of Florida Fermilab	Nashville, TN, USA	IIT	Janeiro Illinois Inst. of Tech. Cen-	Chicago, IL, USA
FNAL FOM FRAN FRAS FREIB FREIE	Fermilab	Colorada III. Tel Tica		ter	
FRAN FRAS FREIB FREIE		Gainesville, FL, USA Batavia, IL, USA	ILL	Univ. of Illinois at Urbana-	Urbana, IL, USA
FRAN FRAS FREIB FREIE	row, stichting voor runda-	JP Utrecht, The Netherlands	TT T G	Champaign	CI: IT TICL
FRAS FREIB FREIE	menteel Onderzoek der Ma-	or otreem, the westerlands	ILLC	Univ. of Illinois at Chicago	Chicago, IL, USA
FRAS FREIB FREIE	terie		ILLG IND	Inst. Laue-Langevin Indiana Univ.	Grenoble, France
FREIB FREIE	Univ. Frankfurt	Frankfurt am Main, Germany	INEL	E G and G Idaho, Inc.	Bloomington, IN, USA Idaho Falls, ID, USA
FREIE	Lab. Nazionali de Frascati	Frascati (Roma), Italy	INFN	Ist. Nazionale di Fisica Nu-	Various places, Italy
FREIE	dell'INFN Albert-Ludwigs Univ.	Freiburg, Germany	1111 11	clear (Generic INFN, un-	various piaces, realy
	Freie Univ. Berlin	Berlin, Germany		known location)	
	Univ. de Fribourg	Fribourg, Switzerland	INNS	Leopold-Franzens Univ.	Innsbruck, Austria
FSU	Florida State University	Tallahassee, FL, USA	INRM	INR, Inst. for Nucl. Research	Moscow, Russian Federation
	Florida State Univ.	Tallahassee, FL, USA	INUS	Univ. of Tokyo; Inst. for	Tokyo, Japan
FUKI	Fukui Univ.	Fukui, Japan	TOAN	Nuclear Study	T
FUKU	Fukushima Univ.	Fukushima, Japan	IOAN	Univ. of Ioannina	Ioannina, Greece
	Univ. di Genova	Genova, Italy	IOFF	A.F. Ioffe Phys. Tech. Inst.	St. Petersburg , Russian Federation
GEOR	Georgian Academy of Sci-	Tbilisi, Republic of Georgia	IOWA	Univ. of Iowa	Iowa City, IA, USA
OECO	ences	Calamanta das NIV IICA	IPN	IPN, Inst. de Phys. Nucl.	Orsay, France
	General Electric Co. Univ. de Genève	Schenectady, NY, USA	IPNP	Univ. Pierre et Marie Curie	Paris, France
	Univ. de Geneve Univ. Giessen	Genève, Switzerland Giessen, Germany		(Paris VI)	
	Gifu Univ.	Gifu, Japan	IRAD	Inst. du Radium (Historical)	Paris, France
	Univ. of Glasgow	Glasgow, United Kingdom	ISNG	Inst. des Sciences Nucleaires	Grenoble, France
	George Mason Univ.	Fairfax, VA, USA		(ISN)	
	Univ. Göttingen	Göttingen, Germany	ISU	Iowa State Univ.	Ames, IA, USA
	3	Granada, Spain	ITEP	ITEP, Inst. of Theor. and	Moscow, Russian Federation
	Univ. Graz	Graz, Austria	ITHA	Exp. Physics Ithaca College	Ithaca, NY, USA
GRON	Univ. of Groningen	Groningen, The Netherlands	IUPU	Indiana Univ., Purdue	Indianapolis, IN, USA
GSCO	Geological Survey of	Ottawa, ON, Canada	101 0	Univ. Indianapolis	indianapons, iii, oori
CICI	Canada	D	JADA	Jadavpur Univ.	Calcutta, India
GSI	Darmstadt Gesellschaft fur Schwerionenforschung	Darmstadt, Germany	$_{ m JAGL}$	Jagiellonian Univ.	Kraków, Poland
	Univ. of Guelph	Guelph, ON, Canada	$_{ m JHU}$	Johns Hopkins Univ.	Baltimore, MD, USA
	George Washington Univ.	Washington, DC, USA	$_{ m JINR}$	JINR, Joint Inst. for Nucl.	Dubna, Russian Federation
	Hahn-Meitner Inst. Berlin	Berlin, Germany	TITT	Research	Inlink Commons
	GmbH	,	JULI	Julich, Forschungszentrum	Julich, Germany
HAIF	Technion - Israel Inst. of	Technion, Haifa, Israel	JYV KAGO	Univ. of Jyväskylä Univ. of Kagoshima	Jyväskylä, Finland Kagoshima-shi, Japan
TLAMD	Tech.	II	KAGO	Univ. of Kansas	Lawrence, KS, USA
	Univ. Hamburg ; I Inst. für Experimentalphysik; II Inst.	Hamburg, Germany		Univ. Karlsruhe (Historical)	Karlsruhe, Germany
	für Experimentalphysik			Univ. Karlsruhe; Inst. für	Karlsruhe, Germany
	Univ. Hannover	Hannover, Germany	KARDD	Experimentelle Kernphysik	italismic, definally
HARC	Houston Advanced Re-	The Woodlands, TX, USA	KARLK	Forschungszentrum Karl-	Karlsruhe, Germany
	search Ctr.			sruhe	· · · · · · ·
	Harvard Univ.	Cambridge, MA, USA	KARLT	Univ. Karlsruhe; Inst. für	Karlsruhe, Germany
	Univ. of Hawai'i	Honolulu, HI, USA	TZ A 77 A	Theoretische Teilchenphysik	Al At. IV
	Hebrew Univ.	Jerusalem, Israel	KAZA	Kazakh Inst. of High Energy Physics	Alma Ata, Kazakhstan
	Univ. Heidelberg (Historical)	Heidelberg, Germany	KEK	KEK, National Lab. for High	Ibaraki-ken Japan
	Univ. Heidelberg ; Inst. für Hochenergiephysik	Heidelberg, Germany	KEK	Energy Phys.	Total and Roll, Supul
	Univ. Heidelberg: Physik	Heidelberg, Germany	KENT	Univ. of Kent	Canterbury, United Kingdom
	Inst.	riolitolig, Collinary	KEYN	Open Univ.	Milton Keynes, United King-
	Univ. Heidelberg ; Inst. für	Heidelberg, Germany			dom
	Theoretische Physik		KFTI	Kharkov Inst. of Physics and	Kharkov, Ukraine
	Univ. of Helsinki	University of Helsinki, Finland	IZIATE	Tech. (KFTI)	Manager Bassian Endounties
	Hiroshima Univ.	Higashi-Hiroshima, Japan	KIAE	Kurchatov Inst.	Moscow, Russian Federation
	Univ. of Houston	Houston, TX, USA	KIAM	Keldysh Inst. of Applied Math., Acad. Sci., Russia	Moscow, Russian Federation
	Hewlett-Packard Corp.	Cupertino, CA, USA	KIDR	Inst. of Nuclear Sciences,	Beograd, Serbia, Yugoslavia
	Harvard-Smithsonian Center for Astrophysics	Cambridge, MA, USA	1111511	Vinča (Formerly Boris Kidrič	Dograd, Solbin, Tugoria
	Inst. for Advanced Study	Princeton, NJ, USA		Inst.)	
	Dublin Inst. for Advanced	Dublin, Ireland	KIEV	Institute for Nuclear Re-	Kiev, Ukraine
	Studies	Darmi, Iroland	7,773,777	search	
IBAR.	Ibaraki Univ.	Ibaraki, Japan	KINK	Kinki Univ.	Osaka, Japan
	IBM Corp.	Palo Alto, CA, USA		Univ. of Kentucky	Lexington, KY, USA
	IBM	Yorktown Heights, NY, USA		Kobe Univ. BUniv. of Tokyo, Komaba	Kobe, Japan Tokyo, Japan
	Inst. for Boson Studies	Pasadena, CA, USA		Konan Univ.	токуо, Japan Kobe, Japan
	Univ. of Tokyo ; Int. Cen-	Tokyo, Japan		Inst. of Experimental Physics	Košice, Slovak Republic
	ter for Elementary Particle Physics (ICEPP)			Kyoto Univ.	Kyoto, Japan
	Univ. of Tokyo; Inst. for	Tokyo, Japan		Kyoto Univ.; Yukawa Inst.	Kyoto, Japan
-01010	Cosmic Ray Research	and of tripping		for Theor. Physics	• •
	•		KYUN	Kyungpook National Univ.	Taegu, Republic of Korea

LALO	LAL, Laboratoire de	Orsay, France	MIYA	Miyazaki Univ.	Miyazaki-shi, Japan
T 1310	l'Accélérateur Linéaire	T 1 1 1 177 1		Univ. de Montpellier II	Montpellier, France
LANC	Univ. of Lancaster	Lancaster, United Kingdom Los Alamos, NM, USA		Univ. de Mons-Hainaut	Mons, Belgium
LANL	Los Alamos National Lab. (LANL)	Los Alamos, NVI, USA	MONT	Univ. de Montréal; Labora-	Montréal, PQ, Canada
LAPP	LAPP, Lab. d'Annecy-le-	Annecy-le-Vieux, France	MONTO	toire de physique nucléaire CUniv. de Montréal ; Centre	Montréal, PQ, Canada
	Vieux de Phys. des Particules	•	MONT	de recherches mathématiques	Montreal, 1 Q, Canada
LASL	U.C. Los Alamos Scientific	Los Alamos, NM, USA	MOSU	Moscow State Univ.	Moscow, Russian Federation
T 400X7	Lab. (Old name for LANL)	D: 1	MPCM	Max Planck Inst. fur Chemie	Mainz, Germany
LATV	Latvian State Univ. Univ. de Lausanne	Riga, Latvia	MPEI	Moscow Physical Engi-	Moscow, Russian Federation
LAUS LAVL	Univ. Laval	Lausanne, Switzerland Quebec, PQ, Canada	MDIA	neering Inst.	Carabina Caran
LBL	Lawrence Berkeley Na-	Berkeley, CA, USA	MPIA	Max-Planck-Institute für Astrophysik	Garching, Germany
БББ	tional Lab.	Bornolog, CII, CSII	MPIH	Max-Planck-Inst. für Kern-	Heidelberg, Germany
LCGT	Univ. di Torino	Turin, Italy		physik	relations, dormany
LEBD	Lebedev Physical Inst.	Moscow, Russian Federation	MPIM	Max-Planck-Inst. für	München, Germany
LECE	Univ. di Lecce	Lecce, Italy		Physik	D . T
LEED LEHI	Univ. of Leeds Lehigh Univ.	Leeds, United Kingdom Bethlehem, PA, USA	MSU	Michigan State Univ.	East Lansing, MI, USA
LEHM	Lehman College of CUNY	Bronx, NY, USA		Mount Holyoke College Centre Univ. du Haut-Rhin	South Hadley, MA, USA Mulhouse, France
LEID	Univ. of Leiden	Leiden, The Netherlands	MUNI	Univ. of München	Garching, Germany
LEMO	Le Moyne Coll.	Syracuse, NY, USA	MUNT		Garching, Germany
LEUV	Katholieke Univ. Leuven	Leuven, Belgium		Midwestern Univ. Research	Stroughton, WI, USA
LINZ	Univ. Linz	Linz, Austria		Assoc. (Historical)	, ,
LISB	Inst. Nacional de Investigacion	Lisboa CODEX, Portugal	NAAS	North Americal Aviation Sci-	Thousand Oaks, CA, USA
r rapm	Cientifica	Tisk as Dantourd		ence Center (Historical)	
LISBT	Univ. Técnica de Lisboa, Inst. Superior Técnico	Lisboa, Portugal		Nagoya Univ.	Nagoya, Japan
LIVP	Univ. of Liverpool	Liverpool, United Kingdom	NAPL	Univ. di Napoli	Napoli, Italy
LLL	Lawrence Livermore Lab.	Livermore, CA, USA	NASA NBS	NASA U.S National Bureau of	Greenbelt, MD, USA
	(Old name for LLNL)	, , , , , , , , , , , , , , , , , , , ,	NDS	Standards (Old name for	Gaithersburg, MD, USA
LLNL	Lawrence Livermore Na-	Livermore, CA, USA		NIST)	
LOCK	tional Lab.	D.I. All. CA. UCA	NBSB	National Inst. Standards	Boulder, CO, USA
LOCK	Lockheed Palo Alto Res. Lab	Palo Alto, CA, USA		Tech.	D 11 GO 1701
LOIC	Imperial College of Science	London, United Kingdom	NCAR	National Center for Atmospheric Research	Boulder, CO, USA
	Tech. & Medicine		NDAM	Univ. of Notre Dame	Notre Dame, IN, USA
LOQM	Univ. of London, Queen	London, United Kingdom	NEAS	Northeastern Univ.	Boston, MA, USA
LOUC	Mary & Westfield College University College London	London, United Kingdom		Univ. de Neuchâtel	Neuchâtel, Switzerland
LOUV	Univ. Catholique de Louvain	Louvain-la-Neuve, Belgium		Univ. de Nice	Nice, France
LOWC	Westfield College (Historical,	London, United Kingdom	NICEO	Observatoire de Nice	Nice, France
20	see LOQM (Queen Mary and	,,	NIHO	Nihon Univ.	Tokyo, Japan
	Westfield joined))		NIIG	Niigata Univ.	Niigata, Japan
LRL	U.C. Lawrence Radiation Lab.	Berkeley, CA, USA	NIJM	Univ. of Nijmegen	Nijmegen, The Netherlands
TOTT	(Old name for LBL)	D : D I A 110A	NIRS	Nat. Inst. Radiological Sci-	Chiba, Japan
LSU	Louisiana State Univ.	Baton Rouge, LA, USA	NIST	ences National Institute of Stan-	Gaithersburg, MD, USA
LUND LYON	Univ. of Lund Institute de Physique	Lund, Sweden Villeurbanne, France	11101	dards & Technology	control and, record
LION	Nucléaire de Lyon (IPN)	v metroame, Trance	NIU	Northern Illinois Univ.	De Kalb, IL, USA
MADE	Inst. de Estructura de la Ma-	Madrid, Spain	NMSU	New Mexico State Univ.	Las Cruces, NM, USA
	teria	· · ·	NORD		Copenhagen Ø, Denmark
	C.I.E.M.A.T	Madrid, Spain	NOTT	Univ. of Nottingham	Nottingham, United Kingdom
	Univ. Autónoma de Madrid	Madrid, Spain	NOVM	Inst. of Mathematics	Novosibirsk, Russian Federa- tion
	Univ. of Manitoba	Winnipeg, MB, Canada Mainz, Germany	NOVO	BINP, Budker Inst. of Nu-	Novosibirsk, Russian Federa-
	Johannes-Gutenberg-Univ. Univ. Marburg	Marburg, Germany		clear Physics	tion
MARS	Centre de Physique des Par-	Marseille, France	NPOL	Polytechnic of North Lon-	London, United Kingdom
WITHIG	ticules de Marseille	The control of the co	NDI	don Naval Research Lab	Washington, DC, USA
MASA	Univ. of Massachusetts	Amherst, MA, USA	NRL NSF	National Science Founda-	Arlington, VA, USA
MASB	Univ. of Massachusetts at	Boston, MA, USA	1101	tion	111111180011, 111, 0011
MASD	Boston Univ. of Massachusetts	N. Dartmouth, MA, USA	NTHU	National Tsing Hua Univ.	Hsinchu, The Republic of
MAOD	Dartmouth	The Barbinousis, many contraction			China (Taiwan)
MCGI	McGill Univ.	Montreal, QC, Canada	NTUA	National Tech. Univ. of Athens	Athens, Greece
MCHS	Univ. of Manchester	Manchester, United Kingdom	NWES	Northwestern Univ.	Evanston, IL, USA
	McMaster Univ.	Hamilton, ON, Canada	NYU	New York Univ.	New York, NY, USA
	A Mehta Research Inst.	Allahabad, India	OBER	Oberlin College	Oberlin, OH, USA
MEIS MELB	Meisei Univ. Univ. of Melbourne	Tokyo, Japan Parkville, Victoria, Australia	OHIO	Ohio Univ.	Athens, OH, USA
MEUD	Observatoire de Meudon	Meudon, France	OKAY	Okayama Univ.	Okayama, Japan
MICH	Univ. of Michigan	Ann Arbor, MI, USA	OKLA	Univ. of Oklahoma	Norman, OK, USA
MILA	Univ. di Milano	Milano, Italy	OKSU	Oklahoma State Univ.	Stillwater, OK, USA
MINN	Univ. of Minnesota	Minneapolis, MN, USA	OREG ORNL	_	Eugene, OR, USA Oak Ridge, TN, USA
MISS	Univ. of Mississippi	University, MS, USA	OUNT	tory	Oak ledge, 111, USA
MIT	MIT Massachusetts Inst.	Cambridge, MA, USA	ORSAY	Univ. de Paris Sud	Orsay, France
MITT	of Technology	Fairfield IA IISA	ORST	Oregon State Univ.	Corvallis, OR, USA
MIU	Maharishi International Univ.	Fairfield, IA, USA	OSAK	Osaka Univ.	Osaka, Japan
	**				

				<u> </u>	
OSKC	Osaka City Univ.	Osaka-shi, Japan	SAVO	Univ. de Savoie	Chambery, France
OSLO	Univ. of Oslo	Oslo, Norway	SBER	California State Univ.	San Bernardino, CA, USA
OSU	Ohio State Univ.	Columbus, OH, USA	SCIT	Science Univ. of Tokyo	Tokyo, Japan
OTTA	Univ. of Ottawa	Ottawa, ON, Canada	SCOT	Scottish Univ. Research and	Glasgow, United Kingdom
OXF	University of Oxford	Oxford, United Kingdom	SCUC	Reactor Ctr. Univ. of South Carolina	Columbia, SC, USA
	'Univ. of Oxford Univ. di Padova , "G. Galilei"	Oxford, United Kingdom	SEAT	Seattle Pacific Coll.	Seattle, WA, USA
	Univ. Paris VI et Paris	Padova, Italy Paris, France	SEIB	Austrian Research Center,	Seibersdorf, Austria
1 / LLCII	VII, IN ² P ³ /CNRS	Taris, France		Seibersdorf LTD.	,
PARIS	Univ. de Paris (Historical)	Paris, France	SEOU		Seoul, Republic of Korea
PARM	Univ. di Parma	Parma, Italy		Seoul National Univ.	Seoul, Republic of Korea
PAST	Institut Pasteur	Paris, France	SERP	IHEP, Inst. for High Energy Physics (Also known as Ser-	Protvino, Russian Federation
PATR.	Univ. of Patras	Patras, Greece		pukhov)	
PAVI	Univ. di Pavia	Pavia, Italy	SETO	Seton Hall Univ.	South Orange, NJ, USA
PENN	Univ. of Pennsylvania	Philadelphia, PA, USA	SFLA	Univ. of South Florida	Tampa, FL, USA
PGIA	Univ. di Perugia	Perugia, Italy	SFRA	Simon Fraser University	Burnaby, BC, Canada
PISA	Univ. di Pisa	Pisa, Italy	SFSU	California State Univ.	San Francisco, CA, USA
PISAI PITT	INFN, Sez. di Pisa	Pisa, Italy	SHEF	Univ. of Sheffield	Sheffield, United Kingdom
PLAT	Univ. of Pittsburgh SUNY at Plattsburgh	Pittsburgh, PA, USA Plattsburgh, NY, USA	SHMP	Univ. of Southampton	Southampton, United Kingdom
PLRM	Univ. di Palermo	Palermo, Italy	SIEG	UnivGesamthochschule-	Siegen, Germany
PNL	Battelle Memorial Inst.	Richland, WA, USA	SILES	Siegen Univ. of Silesia	Katowice, Poland
PNPI	Petersburg Nuclear Physics	Gatchina, Russian Federation	SIN	Swiss Inst. of Nuclear Re-	Villigen, Switzerland
	Inst.		DII.	search (Old name for VILL)	vinigen, bwieseriand
PPA	Princeton-Penn. Proton Accel-	Princeton, NJ, USA	SING	National Univ. of Singapore	Kent Ridge, Singapore
PRAG	erator (Historical) Inst. of Physics, ASCR	December Court Describition	SISSA	Scuola Internazionale Superi-	Trieste, Italy
PRIN	Princeton Univ.	Prague, Czech Republic Princeton, NJ, USA	GT 4.G	ore di Studi Avanzati	a
PSI	Paul Scherrer Inst.	Villigen PSI, Switzerland	SLAC	Stanford Linear Accelera- tor Center	Stanford, CA, USA
PSLL	Physical Science Lab	Las Cruces, NM, USA	SLOV	Inst. of Physics, Slovak Acad.	Bratislava, Slovak Republic
PSU	Penn State Univ.	University Park, PA, USA		of Sciences	
PUCB	Pontifícia Univ. Católica	Rio de Janeiro, RJ, Brasil	SMU	Southern Methodist Univ.	Dallas, TX, USA
	do Rio de Janeiro		SNSP	Scuola Normale Superiore	Pisa, Italy
PUEB	High Energy Physics Group, FCFM - BUAP	Puebla, Pue, Mexico	SOFI	Inst. for Nuclear Research and	Sofia, Bulgaria
PURD	Purdue Univ.	Lafayette, IN, USA	SOFU	Nuclear Energy Univ. of Sofia	Sofia, Bulgaria
QUKI	Queen's Univ.	Kingston, ON, Canada		Univ. de São Paulo	São Paulo, SP, Brasil
RAL	Rutherford Appleton Lab.	Chilton, Didcot, Oxon., United		Inst. de Física Teórica (IFT)	São Paulo, SP, Brasil
		Kingdom	SSL	Univ. of California (Berke-	Berkeley, CA, USA
REGE	Univ. Regensburg	Regensburg, Germany		ley); Space Sciences Lab	,
REHO	Weizmann Inst. of Science	Rehovot, Israel	STAN	Stanford Univ.	Stanford, CA, USA
RHBL	Royal Holloway & Bedford New College	Egham, Surrey, United Kingdom	STEV	Stevens Inst. of Tech.	Hoboken, NJ, USA
RHEL	Rutherford High Energy	Chilton, Didcot, Oxon., United	STLO	St. Louis Univ.	St. Louis, MO, USA
101122	Lab (Old name for RAL)	Kingdom	STOH	Stockholm Univ.	Stockholm, Sweden
RICE	Rice Univ.	Houston, TX, USA	STON STRB	SUNY at Stony Brook CRN, Centre des Recherches	Stony Brook, NY, USA Strasbourg, France
RIKEN	Riken Accelerator Research	Saitama, Japan	SILD	Nucl.	Strasbourg, France
	Facility (RARF)		STUT	Univ. Stuttgart	Stuttgart, Germany
RIKK	Rikkyo Univ.	Tokyo, Japan	STUTM	I Max-Planck-Inst.	Stuttgart, Germany
RIS	Rowland Inst. for Science	Cambridge, MA, USA	SUGI	Sugiyama Jogakuen Univ.	Aichi, Japan
RISC	Rockwell International	Thousand Oaks, CA, USA	SURR	Univ. of Surrey	Guildford, Surrey, United
RISL	Universities Research Re- actor	Risley, Warrington, United Kingdom	arraa	II : 6 G	Kingdom
RISO	Riso National Laboratory	Roskilde, Denmark	SUSS SYDN	Univ. of Sussex Univ. of Sydney	Brighton, United Kingdom Sydney, NSW, Australia
RL	Rutherford High Energy	Chilton, Didcot, Oxon., United	SYRA	Syracuse Univ.	Syracuse, NY, USA
	Lab (Old name for RAL)	Kingdom	TAJK	Acad. Sci., Tadzhik SSR	Dushanbe, Tadzhikstan
RMCS	Royal Military Coll. of Sci-	Swindon, Wilts., United King-	TAMU	Texas A&M Univ.	College Station, TX, USA
ROCH	ence Univ. of Rochester	dom	TATA	Tata Inst. of Fundamental	Bombay, India
	Rockefeller Univ.	Rochester, NY, USA New York, NY, USA	mr. **	Research	
	Univ. di Roma (Historical)	Roma, Italy	TBIL	Tbilisi State University	Tbilisi, Republic of Georgia
	Univ. di Roma, "Tor Ver-	Roma, Italy	${f TELA}$	Teledana Brown Engineer	Tel Aviv, Israel
	gata"	2000-100-100	1 151515	Teledyne Brown Engineer- ing	Huntsville, AL, USA
ROMAI	INFN, Sez. di Roma	Roma, Italy	TEMP	Temple Univ.	Philadelphia, PA, USA
ROSE	Rose-Hulman Inst. of Tech-	Terre Haute IN, USA	TENN	Univ. of Tennessee	Knoxville, TN, USA
DDI	nology	m NN HOA	TEXA	Univ. of Texas at Austin	Austin, TX, USA
RPI	Rensselaer Polytechnic Inst.	Troy, NY, USA	TGAK	Tokyo Gakugei Univ.	Tokyo, Japan
RUTG	Rutgers Univ.	Piscataway, NJ, USA	TGU	Tohoku Gakuin Univ.	Miyagi, Japan
SACL	CE Saclay	Gif-sur-Yvette, France	THES	Aristotle Univ. of Thessa- loniki	Thessaloniki, Greece
SACLD	CE Saclay; DAPNIA	Gif-sur-Yvette, France	TINT	Tokyo Inst. of Technology	Tokyo, Japan
SAGA	Saga Univ.	Saga-shi, Japan	TISA	Sagamihara Inst. of Space &	Kanagawa, Japan
SANG	Kyoto Sangyo Univ.	Kyoto-shi, Japan		Astronautical Sci.	
SANI	Physics Lab., Ist. Superiore di Sanità	Roma, Italy	TMSK	Inst. Nuclear Physics	Tomsk, Russian Federation
SASK	Univ. of Saskatchewan	Saskatoon, SK, Canada	TMTC	Tokyo Metropolitan Coll. Tech.	Tokyo, Japan
	Lab. Naz. del Gran Sasso	Assergi (L'Aquila), Italy	TMU	Tokyo Metropolitan Univ.	Tokyo, Japan
	dell'INFN			•	

	Univ. of Toronto Toho Univ.	Toronto, ON, Canada Chiba, Japan	URI USC	Univ. of Rhode Island Univ. of Southern Califor-	Kingston, RI, USA Los Angeles, CA, USA
	(Tohoku Univ.	Sendai, Japan		nia	g,,
	Tokai Univ.	Shimizu, Japan	USF	Univ. of San Francisco	San Francisco, CA, USA
	SUniv. of Tokyo ; Meson Sci-	Tokyo, Japan	UTAH	Univ. of Utah	Salt Lake City, UT, USA
	ence Laboratory		UTRE	Univ. of Utrecht	Utrecht, The Netherlands
TOKU	Univ. of Tokushima	Tokushima-shi, Japan	UTRO	Univ. of Trondheim	Dragvoll, Norway
TOKY	Univ. of Tokyo; Physics	Tokyo, Japan	UZINR	Acad. Sci., Ukrainian SSR	Uzhgorod, Ukraine
	Dept.		VALE	Univ. de Valencia	Burjassot, Valencia, Spain
TOKYO	Univ. of Tokyo ; Dept. of	Tokyo, Japan	VALP	Valparaiso Univ.	Valparaiso, IN, USA
	Chemistry		VAND	Vanderbilt Univ.	Nashville, TN, USA
TORI	Univ. degli Studi di Torino	Torino, Italy	VASS	Vassar College	Poughkeepsie, NY, USA
TPTI	Lab. of High Energy Phys.	Tashkent, Republic of Uzbek-	VICT	Univ. of Victoria	Victoria, BC, Canada
COLLEGE	m · · ·	istan	VIEN	Inst. für Hochenergiephysik	Vienna, Austria
TRIN	Trinity College	Dublin, Ireland		(HEPHY)	
TRIU	TRIUMF	Vancouver, BC, Canada	VILL	Inst. for Particle Physics of	Villigen PSI, Switzerland
TRST	Univ. degli Studi di Trieste	Trieste, Italy	MDC	ETH Zürich	Cl. 1 XX XXC A
	INFN, Sez. di Trieste	Trieste, Italy	VIRG	Univ. of Virginia	Charlottesville, VA, USA
	Univ. di Trieste	Trieste, Italy	VPI	Virginia Tech.	Blacksburg, VA, USA
	Univ. of Tsukuba	Ibaraki-ken, Japan	VRIJ	Vrije Univ.	HV Amsterdam, The Netherlands
	Tamagawa Univ.	Tokyo, Japan	WARR	NEidgenossisches Amt für Mess-	Waber, Switzerland
TUAT	Tokyo Univ. of Agriculture Tech.	Tokyo, Japan	WILDIG	wesen	Waber, Bwieseriand
THRIN	Univ. Tübingen	Tübingen, Germany	WARS	Warsaw Univ.	Warsaw, Poland
	Tufts Univ.	Medford, MA, USA	WASCI	R Waseda Univ.; Cosmic Ray	Tokyo, Japan
TUW	Technische Univ. Wien	Vienna, Austria		Division	
UCB	Univ. of California (Berke-	Berkeley, CA, USA		Univ. of Washington	Seattle, WA, USA
ОСБ	ley)	Berkeley, Ori, Corr		Waseda Univ.	Tokyo, Japan
UCD	Univ. of California (Davis)	Davis, CA, USA		Wayne State Univ.	Detroit, MI, USA
UCI	Univ. of California (Irvine)	Irvine, CA, USA	WESL		Middletown, CT, USA
UCLA	Univ. of California (Los	Los Angeles, CA, USA	WIEN	Univ. Wien	Vienna, Austria
COLLI	Angeles)	zw imgorou, cir, coir	WILL	Coll. of William and Mary	Williamsburg, VA, USA
UCND	Union Carbide Corp.	Oak Ridge, TN, USA		Inst. for Nuclear Studies	Warsaw, Poland
UCR	Univ. of California (River-	Riverside, CA, USA	WISC	Univ. of Wisconsin	Madison, WI, USA
	side)	1 -1		Univ. of the Witwatersrand	Wits, South Africa
UCSB	Univ. of California (Santa	Santa Barbara, CA, USA		Western Michigan Univ.	Kalamazoo, MI, USA
	Barbara)		WONT	The Univ. of Western On-	London, ON, Canada
UCSBT	Inst. for Theoretical	Santa Barbara, CA, USA	WOOD	tario Woodstock College (No	Woodstock, MD, USA
	Physics		WOOD	longer in existence)	Woodstock, MD, OSA
UCSC	Univ. of California (Santa	Santa Cruz, CA, USA	WIIPP	Univ. of Wuppertal	Wuppertal, Germany
	Cruz)			Univ. Würzburg	Würzburg, Germany
UCSD	Univ. of California (San	La Jolla, CA, USA		Washington Univ.	St. Louis, MO, USA
	Diego)			Univ. of Wyoming	Laramie, WY, USA
UMD	Univ. of Maryland	College Park, MD, USA	YALE	Yale Univ.	New Haven, CT, USA
UNC	Univ. of North Carolina	Greensboro, NC, USA	YARO	Yaroslavl State Univ.	Yaroslavl, Russian Federation
UNCCE	Univ. of North Carolina at	Chapel Hill, NC, USA	YCC	Yokohama Coll. of Com-	Yokohama, Japan
TINIOO	Chapel Hill	G I I I NAV TIGA		merce	
UNCS	Union College	Schenectady, NY, USA	YERE	Yerevan Physics Inst.	Yerevan, Armenia
UNH	Univ. of New Hampshire	Durham, NH, USA	YOKO	Yokohama National Univ.	Yokohama-shi, Japan
UNM	Univ. of New Mexico Univ. of Occupational and	Albuquerque, NM, USA	YORK	C York Univ.	North York, ON, Canada
OOEH	Environmental Health	Kitakyushu, Japan	ZAGR	Zagreb Univ.	Zagreb, Croatia
UPNJ	Upsala College	East Orange, NJ, USA	ZARA	Univ. de Zaragoza	Zaragoza, Spain
UPPS	Uppsala Univ.	Uppsala, Sweden	ZEEM	Univ. van Amsterdam	TV Amsterdam, The Nether-
UPR	Univ. of Puerto Rico	Rio Piedras, PR. USA	arm.		lands
		,,	ZURI	Univ. Zürich	Zürich, Switzerland

GAUGE AND HIGGS BOSONS

$egin{array}{ccc} \gamma & \ldots & g \ (ext{gluon}) \ ext{graviton} \ W & \ldots \ Z & \ldots \ ext{Higgs Bo} \end{array}$			 			 			•						 	 			207 207 207 207 210 225
Heavy Bo Axions (2	osons	Otl	her	tha	an	Hig	gs	Bc	so	ns									231
Notes in the	Gau	ıge	an	d l	Hig	ggs	Be	osc	on	L	ist	tir	ıgs	5					
The Z Boson The Higgs Bo The Z' Search Axions and C Invisible A^0 (son hes					 								•			;		$\begin{array}{c} 210 \\ 225 \end{array}$

GAUGE AND HIGGS BOSONS



 $I(J^{PC}) = 0.1(1^{-})$

γ MASS

For a review of the photon mass, see BYRNE 77.

VALUE (eV)		CL%	DOCUMENT ID		TECN	COMMENT
< 6	× 10 ⁻¹⁶	99.7	DAVIS	75		Jupiter magnetic field
• • • We de		following d	lata for averages, t	fits, I	limits, et	C. • • •
< 9	$\times 10^{-16}$	90	¹ FISCHBACH	94		Earth magnetic field
$< (4.73 \pm 0.4)$	$(5) \times 10^{-12}$		² CHERNIKOV	92	SQID	Ampere-law null test
<(9.0 ±8.1	$) \times 10^{-10}$		³ RYAN	85		Coulomb-law null test
< 3	$\times 10^{-27}$		⁴ CHIBISOV	76		Galactic magnetic field
< 7.3	$\times 10^{-16}$		HOLLWEG	74		Alfven waves
< 6	$\times 10^{-17}$		⁵ FRANKEN	71		Low freq. res. cir.
< 1	$\times 10^{-14}$		WILLIAMS	71	CNTR	Tests Gauss law
< 2.3	$\times 10^{-15}$		GOLDHABER	68		Satellite data
< 6	$\times 10^{-15}$		⁵ PATEL	65		Satellite data
< 6	$\times 10^{-15}$		GINTSBURG	64		Satellite data

- $^{1}\,\text{FISCHBACH}$ 94 report < 8 imes 10 $^{-16}$ with unknown CL. We report Baysian CL used
- FISCHBACH 94 report < 8 × 10 With unknown CL. We report Baysian CL used elsewhere in these Listings and described in the Statistics section.
 CHERNIKOV 92 measures the photon mass at 1.24 K, following a theoretical suggestion that electromagnetic gauge invariance might break down at some low critical temperature. See the erratum for a correction, included here, to the published result.
 RYAN 85 measures the photon mass at 1.36 K (see the footnote to CHERNIKOV 92).
- ACHIBISOV 76 depends in critical way on assumptions such as applicability of virial theorem. Some of the arguments given only in unpublished references.

 See criticism questioning the validity of these results in KROLL 71 and GOLDHABER 71.

γ CHARGE

VALUE (e)	DOCUMENT ID		TECN	COMMENT
$< 5 \times 10^{-30}$	6 RAFFELT	94	TOF	Pulsar $f_1 - f_2$
• • • We do not use the	e following data for average			
$<2 \times 10^{-28}$	⁷ COCCONI	92		VLBA radio telescope
$< 2 \times 10^{-32}$	COCCONI	88	TOF	resolution Pulsar $f_1 - f_2$ TOF

⁶ RAFFELT 94 notes that COCCONI 88 neglects the fact that the time delay due to disperis the coccount of the state of the coccount of the same photon energy dependence as that due to bending of a charged photon in the magnetic field. His limit is based on the assumption that the entire observed dispersion is due to photon charge. It is a factor of 200 less stringent than the COCCONI 88 limit.

7 See COCCONI 92 for less stringent limits in other frequency ranges. Also see RAFFELT 94 note.

γ REFERENCES

FISCHBACH	94	PRL 73 514	+Kloor, Langel+	(PURD, JHU+)
RAFFELT	94	PR D50 7729		(MPIM)
CHERNIKOV	92	PRL 68 3383	+Gerber, Ott, Gerber	`(ETH)
Also	92B	PRL 69 2999 (erratum) Chernikov, Gerber, Ott, Gerber	(ETH)
COCCONI	92	AJP 60 750		(ČERN)
COCCONI	88	PL B206 705		(CERN)
RYAN	85	PR D32 802	+Accetta, Austin	(PRIN)
BYRNE	77	Ast.Sp.Sci. 46 115		(LOIC)
CHIBISOV	76	SPU 19 624		(LEBD)
DAVIS	75	PRL 35 1402	+Goldhaber, Nieto	(CIT, STON, LASL)
HOLLWEG	74	PRL 32 961		(NCAR)
FRANKEN	71	PRL 26 115	+Ampulski	(MICH)
GOLDHABER	71	RMP 43 277	+Nieto	(STON, BOHR, UCSB)
KROLL	71	PRL 26 1395		(SLAC)
WILLIAMS	71	PRL 26 721	+Faller, Hill	(WESL)
GOLDHABER	68	PRL 21 567	+Nieto	(STON)
PATEL	65	PL 14 105		(DUKE)
GINTSBURG	64	Sov. Astr. AJ7 536		(ASCI)



 $I(J^P) = 0(1^-)$

SU(3) color octet

Mass m = 0. Theoretical value. A mass as large as a few MeV may not be precluded, see YNDURAIN 95.

VALUE	DOCUMENT ID	TECN	COMMENT	
• • • We do not use the follow	owing data for average	s, fits, limits,	etc. • • •	
	ABREU	92E DLPH	Spin 1, not 0	
	ALEXANDER	91H OPAL	Spin 1, not 0	
	BEHREND	82D CELL	Spin 1, not 0	
	BERGER	80D PLUT	Spin 1, not 0	
	BRANDELIK	80c TASS	Spin 1, not 0	

gluon REFERENCES

YNDURAIN	95	PL B345 524		(MADU)
ABREU	92E	PL B274 498	+Adam, Adami, Adye, Akesson+	(DELPHI Collab.)
ALEXANDER	91H	ZPHY C52 543	+Allison, Allport, Anderson+	(OPAL Collab.)
BEHREND	82D	PL B110 329	+Chen, Field, Guempel, Schroeder+	(ČELLO Collab.)
BERGER	80D	PL B97 459	+Genzel, Grigull, Lackas+	(PLUTO Collab.)
BRANDELIK	800	PI 897 453	±Braunschweig Gather Kadansky±	(TASSO Collab)

graviton

J = 2

OMITTED FROM SUMMARY TABLE

graviton MASS

All of the following limits are obtained assuming Yukawa potential in weak field limit. VANDAM 70 argue that a massive field cannot approach general relativity in the zero-mass limit; however, see GOLD-HABER 74 and references therein. h_0 is the Hubble constant in units of 100 km s $^{-1}$ Mpc $^{-1}$.

VALUE (eV)	DOCUMENT ID		COMMENT		
• • • We do not use the followi	ng data for average	s, fit:	s, limits, etc. • • •		
	¹ DAMOUR	91	Binary pulsar PSR 1913+16		
$< 2 \times 10^{-29} h_0^{-1} $ $< 7 \times 10^{-28}$	GOLDHABER	74	Rich clusters		
	HARE	73	Galaxy		
<8 × 10 ⁴	HARE	73	2√ decav		

¹ DAMOUR 91 is an analysis of the orbital period change in binary pulsar PSR 1913+16, and confirms the general relativity prediction to 0.8%. "The theoretical importance of the [rate of orbital period decay] measurement has long been recognized as a direct the [rate of orbital period decay] measurement has long been recognized as a direct confirmation that the gravitational interaction propagates with velocity c (which is the immediate cause of the appearance of a damping force in the binary pulsar system) and thereby as a test of the existence of gravitational radiation and of its quadrupolar nature." TAYLOR 93 adds that orbital parameter studies now agree with general relativity to 0.5%, and set limits on the level of scalar contribution in the context of a family of tensor [spin 2]-biscalar theories.

graviton REFERENCES

TAYLOR		Nature 355 132	+Wolszczan, Damour+	(PRIN, ARCBO, BURE, CARLC) J
DAMOUR		APJ 366 501	+Taylor	(BURE, MEUD, PRIN)
GOLDHABER		PR D9 119	+Nieto	(LANL, STON)
HARE VANDAM	73	CJP 51 431 NP B22 397	van Dam, Veltman	(SASK) (UTRE)



ı

J = 1

W MASS

OUR FIT uses the W and Z mass, mass difference, and mass ratio mea-

Because of the high current interest, we mention the following preliminary results here, but do not average them or include them in the Listings or Tables. Performing an overall fit (assuming the Standard Model) of published and unpublished (CDF and DØ) collider results ($M_W=80.33\pm$ 0.15 GeV), of the νN results $(1-M_W^2/M_Z^2=0.2257\pm0.0047)$ and of published and unpublished LEP and SLD preliminary electroweak results (as of end of March 1996), the W mass is fitted to be $M_W=(80.350\pm0.0016)$ $0.042^{+0.016}_{-0.025}$) GeV (the second errors correspond to varying the Higgs mass in the interval 60-1000 GeV).

VALUE				EVTS	DOCUMENT ID		TECN	COMMENT
80.33								
80.32	±	0.19	OUR A	WERAGE	Error includes sca	le fa	ctor of 1	· · -
80.410	± 0	0.180)	8986	¹ ABE	95 P	CDF	E_{cm}^{pp} = 1800 GeV
79.91	±	0.39		1722	² ABE	90G	CDF	$E_{CM}^{ar{p}} = 1800 \; GeV$
80.84	\pm	0.22	± 0.83	2065	³ ALITTI	92B	UA2	See W/Z ratio below
80.79	\pm	0.31	± 0.84		⁴ ALITTI	90B	UA2	$E_{\rm cm}^{p \overline{p}} = 546,630 \; {\rm GeV}$
0.08	\pm	3.3	± 2.4	22	⁵ ABE	891	CDF	$E_{cm}^{p\overline{p}} = 1800 \; GeV$
82.7	Ή.	1.0	±2.7	149	⁶ ALBAJAR	89	UA1	$E_{cm}^{p\overline{p}} = 546,630 \; GeV$
81.8	+	6.0 5.3	±2.6	46	⁷ ALBAJAR	89	UA1	$E_{cm}^{p\overline{p}} = 546,630 \; GeV$
89	\pm	3	± 6	32	⁸ ALBAJAR	89	UA1	$E_{Cm}^{p\overline{p}} = 546,630 \; GeV$
80.2	\pm	0.6	± 1.4	251	⁹ ANSARI	87	UA2	Repl. by ALITTI 908
81.2	\pm	1.0	± 1.4	119	⁹ APPEL	86	UA2	Repl. by ANSARI 87
83.5	+	1.1 1.0	±2.7	86	¹⁰ ARNISON	86	UA1	Repl. by ALBAJAR 89
81.	+	6. 7.		14	¹¹ ARNISON	8 4 D	UA1	Repl. by ALBAJAR 89
83.1	\pm	1.9	± 1.3	37	BAGNAIA	84	UA2	Repl. by ALITTI 90B
81.	\pm	5.		6	ARNISON	83	UA1	Repl. by ARNISON 83D
80.9	\pm	2.9		27	ARNISON	83D	UA1	Repl. by ARNISON 86
81.0	\pm	2.8			BAGNAIA	83	UA2	Repl. by BAGNAIA 84
80.	+1	10. 6.		4	BANNER	83B	UA2	Repl. by ALITTI 908

- 1 ABE 95P use 3268 $W\to \mu\nu_\mu$ events to find $M=80.310\pm0.205\pm0.130$ GeV and 5718 $W\to e\nu_e$ events to find $M=80.490\pm0.145\pm0.175$ GeV. The result given here combines these while accounting for correlated uncertainties.
- 2 ABE 90G result from $W\to e\nu$ is 79.91 \pm 0.35 \pm 0.24 \pm 0.19(scale) GeV and from $W\to \mu\nu$ is 79.90 \pm 0.53 \pm 0.32 \pm 0.08(scale) GeV.
- 3 ALITTI 92B result has two contributions to the systematic error (± 0.83); one (± 0.81) cancels in m_W/m_Z and one (± 0.17) is noncancelling. These were added in quadrature. We choose the ALITTI 92B value without using the LEP m_Z value, because we perform our own combined fit.

Gauge & Higgs Boson Particle Listings

W

- 4 There are two contributions to the systematic error (±0.84): one (±0.81) which cancels in m_W/m_Z and one (±0.21) which is non-cancelling. These were added in quadrature.
- ⁵ ABE 891 systematic error dominated by the uncertainty in the absolute energy scale.
- ⁶ ALBAJAR 89 result is from a total sample of 299 $W \rightarrow e\nu$ events.
- ALBAJAR 89 result is from a total sample of 67 $W \rightarrow \mu\nu$ events.

⁸ ALBAJAR 89 result is from $W \to \tau \nu$ events. ⁹ There are two contributions to the systematic error (±1.4): one (±1.3) which cancels in m_W/m_Z and one (±0.5) which is non-cancelling. These were added in quadrature. $^{10}\,\mathrm{This}$ is enhanced subsample of 172 total events.

 $^{11}\, {\rm Using}\,\, W^\pm \to \,\, \mu^\pm \nu.$

W/Z MASS RATIO

The fit uses the W and Z mass, mass difference, and mass ratio measure-

VALUE	EVTS	DOCUMENT I	ID TECN	COMMENT
0.8810±0.0016 OUR FIT				
$0.8813 \pm 0.0036 \pm 0.0019$	156	¹² ALITTI	92B UA2	$E_{CM}^{\overline{p}} = 630 \; GeV$
• • • We do not use the f	ollowing	data for average	s, fits, limits, et	c. • • •
$0.8831 \pm 0.0048 \pm 0.0026$		¹² ALITTI	90B UA2	$E_{\rm cm}^{p\overline{p}}=$ 546,630 GeV
12 Scale error cancels in th	his ratio.			

$m_Z - m_W$

The fit uses the W and Z mass, mass difference, and mass ratio measure

VALUE (GeV)	DOCUMENT ID		TECN	COMMENT				
10.85±0.15 OUR FIT								
10.4 ±1.4 ±0.8	ALBAJAR	89	UA1	$E_{cm}^{p\overline{p}} = 546,630 \; GeV$				
$11.3 \pm 1.3 \pm 0.9$	ANSARI	87	UA2	$E_{ m cm}^{ar{p}ar{p}}=$ 546,630 GeV				

$m_{W^+} - m_{W^-}$

Test of CPT invariance.

CL% EVTS

VALUE (GeV)

VALUE (GeV)	EVTS	DOCUMENT ID	TECN	COMMENT
-0.19±0.58	1722	ABE	90G CDF	$E_{\text{Cm}}^{p\overline{p}}$ = 1800 GeV

W WIDTH

The CDF and DØ widths labelled "extracted value" are obtained by mea-The CPF and by which stabletic extracted value are obtained by linear suring $R = [\sigma(W)/\sigma(Z)] [\Gamma(W \to e\nu_e)]/(B(Z \to ee)\Gamma(W))$ where the bracketed quantities can be calculated with plausible reliability. $\Gamma(W)$ is then extracted by using a value of $B(Z \to ee)$ measured at LEP. The UA1 and UA2 widths used $R = [\sigma(W)/\sigma(Z)] [\Gamma(W \to e\nu_e)/\Gamma(Z \to ee)]$ $\Gamma(Z)/\Gamma(W)$ and the measured value of $\Gamma(Z)$. The Standard Model resolutions in 2.06.7 + 0.031/P(DS)EP.04) prediction is 2.067 \pm 0.021 (ROSNER 94).

DOCUMENT ID TECN COMMENT

2.07	± 0.06	OUR A	AVERA	GE.					
2.044	± 0.093	3					95D	D0	Extracted value
2.11	± 0.28	± 0.16					95c	CDF	Direct meas.
2.064	± 0.060	± 0.059	€		15	ABE	95W	CDF	Extracted value
2.10	$^{+0.14}_{-0.13}$	± 0.09	:	3559	16	ALITTI	92	UA2	Extracted value
2.18	$^{+0.26}_{-0.24}$	±0.04			17	ALBAJAR	91	UA1	Extracted value
• • • \	We do n	ot use t	the foll	owing da	ta	for averages, fit	s, lin	nits, etc.	• • •
2.16	± 0.17				18	ABE	921	CDF	Repl. by ABE 95W
2.12	± 0.20				19	ABE	90	CDF	Repl. by ABE 921
2.30	± 0.19	± 0.06			20	ALITTI	90C	UA2	Extracted value
< 5.4			90	149	21	ALBAJAR	89	UA1	$E_{CM}^{p\overline{p}} = 546,630 \; GeV$
2.8	$^{+1.4}_{-1.5}$	±1.3		149	21	ALBAJAR	89		$E_{\rm cm}^{\rho \overline{p}} = 546,630 \; {\rm GeV}$
< 7			90	251		ANSARI	87		$E_{\text{cm}}^{p\overline{p}} = 546,630 \text{ GeV}$
< 7			90	119		APPEL	86	UA2	$E_{\rm cm}^{p\overline{p}} = 546,630 \; {\rm GeV}$
< 6.5			90	86	22	ARNISON	86	UA1	Repl. by ALBAJAR 89
<7			90	27		ARNISON	83D	UA1	Repl. by ARNISON 86

- 13 ABACHI 950 measured $R=10.90\pm0.49$ and used the measured value B(Z $\to \ell\ell)=(3.367\pm0.006)\%$ from LEP.
- ¹⁴ ABE 95C use the tall of the transverse mass distribution of $W \to e \nu_e$ decays.
- $^{15}\,\mathrm{ABE}$ 95W measured R = 10.90 \pm 0.32 \pm 0.29. They use $m_{\ensuremath{W}}{=}80.23$ \pm 0.18 GeV, $\sigma(W)/\sigma(Z)=3.35\pm0.03,~\Gamma(W\to e\nu)=225.9\pm0.9~{\rm MeV},~\Gamma(Z\to e^+e^-)=83.98\pm0.18~{\rm MeV},~{\rm and}~\Gamma(Z)=2.4969\pm0.0038~{\rm GeV}.$ 16 ALITTI 92 measured $R=10.4^+0.7_-0.6_-10.0038_-$
- $O(lpha_S^2)$ calculations using $m_W=$ 80.14 \pm 0.27 GeV, and $m_Z=$ 91.175 \pm 0.021 GeV along with the corresponding value of $\sin^2\theta_W=0.274$. They use $\sigma(W)/\sigma(Z)=3.26\pm0.07\pm0.05$ and $\Gamma(Z)=2.487\pm0.010$ GeV. 17 ALBAJAR 91 measured $R=9.5^{+1.1}_{-1.0}$ (stat. + syst.). $\sigma(W)/\sigma(Z)$ is calculated in QCD at the parton level using $m_W=80.18\pm0.28$ GeV and $m_Z=91.172\pm0.031$ GeV

- along with $\sin^2\!\theta_W=0.2322\pm0.0014$. They use $\sigma(W)/\sigma(Z)=3.23\pm0.05$ and $\Gamma(Z)=2.498\pm0.020$ GeV.
- = 2.498 \pm 0.020 GeV. 18 ABE 92I report 1216 \pm 38 $^{+27}_{-31}$ $W \rightarrow \mu \nu$ and 106 \pm 10 $^{+0.2}_{-1}$ $Z \rightarrow \mu^+ \mu^-$ events which are combined with 2426 $W \rightarrow e \nu$ events of ABE 91C to derive the ratio σ_W B($W \rightarrow e \nu$) $\ell \nu)/\sigma_Z$ B(Z \to $\ell^+\ell^-)=$ 10.0 \pm 0.6 \pm 0.4. Finally the value of $\Gamma(Z)$ measured by LEP 92 is used to extract $\Gamma(W)$.
- ¹⁹ ABE 90 extract $\Gamma(W)$. $= 2.19 \pm 0.20$ by using the value $\Gamma(Z) = 2.57 \pm 0.07$ GeV. However, in ABE 91c they update their analysis with a new LEP value $\Gamma(Z) = 2.496 \pm 0.016$; the value $\Gamma(W) = 2.12 \pm 0.20$ above reflects this update. They measured $R = 10.2 \pm 0.8 \pm 0.4$, assumed $\sin^2\theta_W = 0.229 \pm 0.007$, and took predicted values $\sigma(W)/\sigma(Z) = 3.23 \pm 0.03$ and $\Gamma(W \rightarrow ev)/\Gamma(Z \rightarrow ee) = 2.70 \pm 0.02$. This yields $\Gamma(W)/\Gamma(Z) = 0.02$ 0.85 \pm 0.08. The quoted error for $\Gamma(W)$ includes systematic uncertainties. $E_{\rm cm}^{p\overline{p}}=1800$
- $\rm ^{20}\,GeV.$ ALITTI 90C used the same technique as described for ABE 90. They measured R = $9.38^{+0.82}_{-0.72}\pm0.25$, obtained $\Gamma(W)/\Gamma(Z)=0.902\pm0.074\pm0.024$. Using $\Gamma(Z)=2.546\pm0.032$ GeV, they obtained the $\Gamma(W)$ value quoted above and the limits $\Gamma(W)$ $< 2.56 (2.64) \text{ GeV at the } 90\% (95\%) \text{ CL. } E_{\text{CM}}^{p\overline{p}} = 546,630 \text{ GeV}.$
- 21 ALBAJAR 89 result is from a total sample of 299 $W\to e\nu$ events. 22 If systematic error is neglected, result is 2.7 $^{+1.4}_{-1.5}$ GeV. This is enhanced subsample of

W ANOMALOUS MAGNETIC MOMENT (Δκ)

The full magnetic moment is given by $\mu_W=e(1+\kappa+\lambda)/2m_W$. In the Standard Model, at tree level, $\kappa=1$ and $\lambda=0$. Some papers have defined $\Delta\kappa=1-\kappa$ and assume that $\lambda=0$. Note that the electric quadrupole moment is given by $-e(\kappa-\lambda)/m_W^2$. A description of the parameterization of these moments and additional references can be found in HAGIWARA 87 and BAUR 88. The parameter Λ appearing in the theoretical limits below is a regularization cutoff which roughly corresponds to the energy scale where the structure of the W boson becomes manifest.

VALUE (e/2m _W)	DOCUMENT ID		TECN
• • • We do not use the following	ng data for average	s, fits,	limits, etc. • • •
	²³ ABE	95G	
	²⁴ ALITTI	92 C	UA2
	²⁵ SAMUEL	92	THEO
	²⁶ SAMUEL	91	THEO
	²⁷ GRIFOLS	88	THEO
	²⁸ GROTCH	87	THEO
	²⁹ VANDERBIJ	87	THEO
	³⁰ GRAU	85	THEO
	³¹ SUZUKI	85	THEO
	³² HERZOG	84	THEO

- 23 ABE 95G report $-1.3 < \kappa < 3.2$ for $\lambda=0$ and $-0.7 < \lambda < 0.7$ for $\kappa=1$ in $p\,\overline{p} \to e\,\nu_e\,\gamma\, X$ and $\mu \nu_{\mu} \gamma {\rm X}$ at $\sqrt{s}=$ 1800 GeV.
- 24 ALITTI 92C measure $\kappa=1+\frac{2.6}{2.2}$ and $\lambda=0+\frac{1.7}{1.8}$ in $p\overline{p}\to e\nu\gamma+$ X at $\sqrt{s}=630$ GeV. At 95%CL they report $-3.5<\kappa<5.9$ and $-3.6<\lambda<3.5$. 25 SAMUEL 92 use preliminary CDF and UA2 data and find $-2.4<\kappa<3.7$ at 96%CL and $-3.1<\kappa<4.2$ at 95%CL respectively. They use data for $W\gamma$ production and radiative W decay.
- ²⁶ SAMUEL 91 use preliminary CDF data for $p\overline{p}\to W\gamma X$ to obtain $-11.3 \le \Delta\kappa \le 10.9$. Note that their $\kappa=1-\Delta\kappa$.
- 27 GRIFOLS 88 uses deviation from ρ parameter to set limit $\Delta\kappa\lesssim 65~(M_W^2/\Lambda^2).$
- 28 GROTCH 87 finds the limit $-37~<~\Delta\kappa~<73.5$ (90% CL) from the experimental limits on $e^+e^- \to \nu \overline{\nu} \gamma$ assuming three neutrino generations and $-19.5 < \Delta \kappa < 56$ for four generations. Note their $\Delta \kappa$ has the opposite sign as our definition.
- 29 VANDERBIJ 87 uses existing limits to the photon structure to obtain $|\Delta\kappa| < 33$ (m_W/Λ). In addition VANDERBIJ 87 discusses problems with using the ρ parameter of the Standard Model to determine $\Delta\kappa$.
- the Standard Model to determine $\Delta\kappa$. 30 GRAU 85 uses the muon anomaly to derive a coupled limit on the anomalous magnetic dipole and electric quadrupole (λ) moments $1.05 > \Delta\kappa \ln(\Lambda/m_W) + \lambda/2 > -2.77$. In the Standard Model $\lambda=0$. 31 SUZUKI 85 uses partial-wave unitarity at high energies to obtain $|\Delta\kappa|\lesssim 190$
- $(m_W/\Lambda)^2$. From the anomalous magnetic moment of the muon, SUZUKI 85 obtains $|\Delta\kappa|\lesssim 2.2/{
 m ln}(\Lambda/m_W)$. Finally SUZUKI 85 uses deviations from the ho parameter and obtains a very qualitative, order-of-magnitude limit $|\Delta\kappa|\lesssim 150~(m_W/\Lambda)^4$ if $|\Delta\kappa|\ll$
- 32 HERZOG 84 consider the contribution of W-boson to muon magnetic moment including anomalous coupling of W W γ . Obtain a limit $-1~<~\Delta\kappa~<3$ for $\Lambda~\gtrsim~1$ TeV.

W+ DECAY MODES

W- modes are charge conjugates of the modes below.

	Mode	F	Fraction (Γ_i/Γ)			
Γ ₁	$\ell^+ \nu$	[a]	(10.8±	0.4) %		
Γ_2	$e^+ \nu$		$(10.8 \pm$	0.4) %		
Γ_3	$\mu^+ \nu$		$(10.4 \pm$	0.6) %		
Γ_4	$\tau^+ \nu$		$(10.9 \pm$	1.0) %		
Γ_5	hadrons		$(67.9 \pm$	1.5) %		
Γ_6	$\pi^+\gamma$		< 5	$\times 10^{-4}$	95%	

[a] ℓ indicates each type of lepton $(e, \mu, \text{ and } \tau)$, not sum over them.

CONSTRAINED FIT INFORMATION

An overall fit to 4 branching ratios uses 8 measurements and one constraint to determine 4 parameters. The overall fit has a χ^2 = 1.7 for 5 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv$ $\Gamma_i/\Gamma_{ ext{total}}$. The fit constrains the x_i whose labels appear in this array to sum to

W BRANCHING RATIOS

 $\Gamma(\ell^+\nu)/\Gamma_{
m total}$ ℓ indicates average over e, μ , and au modes, not sum over modes.

Currently only e and μ data enter this average because there are no absolute τ data, only the τ/e ratio.

 Γ_1/Γ

95W CDF $F^{p\overline{p}} = 1800 \text{ GeV}$

<u>VALUE</u> <u>EVTS</u> <u>DOCUMENT ID</u> <u>TECN COMMENT</u> **0.108±0.004 OUR AVERAGE** Includes data from the 2 datablocks that follow this one. $\bullet~\bullet~$ We do not use the following data for averages, fits, limits, etc. $\bullet~\bullet~$ 92I CDF $E_{\text{CM}}^{p\overline{p}}$ = 1.8 TeV ³³ ABE

 33 1216 \pm 38 $^{+}_{-31}$ W $\rightarrow ~\mu \nu$ events from ABE 921 and 2426W $\rightarrow ~e \nu$ events of ABE 91c. ABE 921 give the inverse quantity as 9.6 \pm 0.7 and we have inverted.

 $\Gamma(e^+\nu)/\Gamma_{\mathrm{total}}$ Γ_2/Γ

<u>VALUE</u> <u>EVTS</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u>
The data in this block is included in the average printed for a previous datablock.

34 ARE

$\begin{array}{ccc} 0.108 & \pm 0.004 & \text{OUR FIT} \\ 0.109 & \pm 0.004 & \text{OUR AVERAGE} \end{array}$ 0.1094 + 0.0033 + 0.0031

0.10311_0.00001_0.0001		,,,,,,	3011 CD1	- cm - 1000 GC1
0.10 ± 0.014 $^{+0.02}_{-0.03}$	248	³⁵ ANSARI	87C UA2	$E_{\rm cm}^{ ho\overline{ ho}}=$ 546,630 GeV
• • • We do not use the	following	data for averages	, fits, limits, et	C. • • •
0.106 ± 0.0096	2426	³⁶ ABE	91c CDF	Repl. by ABE 948
seen	299	³⁷ ALBAJAR	89 UA1	$E_{cm}^{p\overline{p}} = 546,630 \; GeV$
seen	119	APPEL	86 UA2	$E_{\rm cm}^{p\overline{p}}$ = 546,630 GeV
seen	172	ARNISON	86 UA1	Repl. by ALBA-
				JAR 89

34 ABE 95w result is from a measurement of $\sigma B(W \to e \nu)/\sigma B(Z \to e^+e^-) = 10.90 \pm 0.32 \pm 0.29$, the theoretical prediction for the cross section ratio, the experimental knowledge of $\Gamma(Z \rightarrow e^+e^-) = 83.98 \pm 0.18$ MeV, and $\Gamma(Z) = 2.4969 \pm 0.0038$.

knowledge of f ($Z \rightarrow e^+e^-$) = 83.98 ± 0.18 MeV, and 1(Z) = 2.4909 ± 0.0050. 35 The first error was obtained by adding the statistical and systematic experimental uncertainties in quadrature. The second error reflects the dependence on theoretical prediction of total W cross section: $\sigma(546 \text{ GeV}) = 4.7 \cdot 1.4^{\circ} \text{ nb}$ and $\sigma(630 \text{ GeV}) = 5.8 \cdot 1.8^{\circ} \text{ nb}$.

See ALTARELLI 858. 36 ABE 91C result is from a measurement of $\sigma B(W \to e \nu)/\sigma B(Z \to e^+e^-)$, the theoretical prediction for the cross section ratio, and the experimental knowledge of $\Gamma(Z \rightarrow e^+e^-)/\Gamma(Z \rightarrow all).$

37 ALBAJAR 89 experiment determines values of branching ratio times production cross

 $\Gamma(\mu^+\nu)/\Gamma_{\rm total}$ Γ_3/Γ

<u>VALUE</u> <u>EVTS</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u>
The data in this block is included in the average printed for a previous datablock.

1216 ³⁸ ABE 92I CDF $E_{\text{cm}}^{p\overline{p}} = 1.8 \text{ TeV}$ 0.10 ± 0.01

³⁸ ABE 92I quote the inverse quantity as 9.9 \pm 1.2 which we have inverted.

 $\Gamma(\tau^+\nu)/\Gamma_{\text{total}}$ Γ_4/Γ DOCUMENT ID 0.109±0.010 OUR FIT

 $\Gamma(hadrons)/\Gamma_{total}$ Γ_5/Γ DOCUMENT ID

0.679±0.015 OUR FIT

 $\Gamma(\mu^+\nu)/\Gamma(e^+\nu)$ Γ_3/Γ_2 $\begin{array}{c} \underline{\textit{VALUE}} & \underline{\textit{EVTS}} \\ \textbf{0.95} \!\pm\! \textbf{0.05} \; \textbf{OUR} \; \textbf{FIT} \end{array}$ DOCUMENT ID TECN COMMENT 0.97±0.06 OUR AVERAGE ³⁹ АВАСНІ 13k 95D D0 $E_{\rm cm}^{p\bar{p}} = 1.8 \text{ TeV}$

⁴⁰ ABE 921 CDF $E_{\text{CM}}^{\overline{p}\overline{p}} = 1.8 \text{ TeV}$ 1216 89 UA1 $E_{\rm cm}^{p\overline{p}} = 546,630 \, {\rm GeV}$ $1.00 \pm 0.14 \pm 0.08$ 67 ALBAJAR 14 ARNISON 84D UA1 Repl. by ALBAJAR 89

 39 ABACHI 950 obtain this result from the measured σ_W B(W $\rightarrow \; \mu\nu)$ = $2.09\pm0.23\pm0.11$ nb and σ_W B(W $\rightarrow \; e\nu)$ = $2.36\pm0.07\pm0.13$ nb in which the first error is the combined statistical and systematic uncertainty, the second reflects the uncertainty in the luminosity, 40 ABE 921 obtain σ_W B(W $\rightarrow \; \mu\nu$)= $2.21\pm0.07\pm0.21$ and combine with ABE 91c σ_W B((W $\rightarrow \; e\nu$)) to give a ratio of the couplings from which we derive this measurement.

$\Gamma(\tau^+ u) / \Gamma(e^+ u)$				Γ_4/Γ_2
VALUE	EVTS	DOCUMENT ID	TEC	N COMMENT
1.00 ±0.08 OUR FIT 1.00 ±0.08 OUR AVE	RAGE			
0.94 ±0.14	179	⁴¹ ABE	92E CD	$F = E_{CM}^{p\overline{p}} = 1.8 \text{ TeV}$
$1.04 \ \pm 0.08 \ \pm 0.08$	754	⁴² ALITTI		2 $E_{cm}^{p\overline{p}} = 630 \; GeV$
$1.02 \pm 0.20 \pm 0.12$	32	ALBAJAR	89 UA	1 $E_{cm}^{p\overline{p}} = 546,630 \; GeV$
• • • We do not use th	e followi	ng data for average	s, fits, lin	nits, etc. • • •
$\begin{array}{ccc} 0.995 \pm 0.112 \pm 0.083 \\ 1.02 \ \pm 0.20 \ \pm 0.10 \end{array}$	198 32	ALITTI ALBAJAR	91C UA 87 UA	, ,

41 ABE 92E use two procedures for selecting $W \to \tau \nu_{\tau}$ events. The missing E $_{T}$ trigger leads to 132 \pm 14 \pm 8 events and the τ trigger to 47 \pm 9 \pm 4 events. Proper statistical and systematic correlations are taken into account to arrive at σ B($W \to \tau \nu$) = 2.05 \pm 0.27 nb. Combined with ABE 91c result on σ B($W \to e \nu$), ABE 92E quote a ratio of the couplings from which we derive this measurement.

$\Gamma(\pi^+\gamma)/\Gamma(e^+\nu)$					Γ_6/Γ_2
VALUE	CL%	DOCUMENT ID		TECN	COMMENT
$< 7.5 \times 10^{-3}$	95	ABE	92K	CDF	$E_{cm}^{oldsymbol{p}\overline{oldsymbol{ ho}}}$ $= 1.8\;TeV$
$< 4.9 \times 10^{-3}$	95	43 ALITTI	92D	UA2	$E_{cm}^{oldsymbol{p}\overline{oldsymbol{ ho}}}=$ 630 GeV
$< 58 \times 10^{-3}$	95	⁴⁴ ALBAJAR	90	UA1	$E_{\rm cm}^{p\overline{p}}$ = 546, 630 GeV
⁴³ ALITTI 92D limit ⁴⁴ ALBAJAR 90 obta	is 3.8 × 10 nin < 0.04	⁻³ at 90%CL. 8 at 90%CL.			

W REFERENCES

		•	THE ENERGES	
ABACHI	95D	PRL 75 1456	+Abbott, Abolins, Acharya+	(D0 Collab.)
ABE	95C	PRL 74 341	+Albrow, Amidei, Antos, Anway-Wiese+	
ABE	95G	PRL 74 1936	+Albrow, Amidei, Antos+	(CDF Collab.)
ABE	95P	PRL 75 11	+Albrow, Amidei, Antos, Anway-Wiese+	
Also	95Q	PR D52 4784	Abe, Albrow, Amidei, Antos, Anway-W	
ABE	95W		+Albrow, Amendolia, Amidei, Antos+	(CDF Collab.)
Also	94B	PRL 73 220	Abe, Albrow, Amidei, Anway-Wiese+	(CDF Collab.)
ABE	94B	PRL 73 220	+Albrow, Amidei, Anway-Wiese+	(CDF Collab.)
ROSNER	94	PR D49 1363	+Worah, Takeuchi	(EFI, FNAL)
ABE	92E	PRL 68 3398	+Amidei, Apollinari, Atac+	(CDF Collab.)
ABE	921	PRL 69 28	+Amidei, Apollinari, Atac, Auchincloss+	(CDF Collab.)
ABE	92K	PRL 69 2160	+Amidei, Anway-Weiss+	(CDF Collab.)
ALITTI	92	PL B276 365	+Ambrosini, Ansari, Autiero, Bareyre+	(UA2 Collab.)
ALITTI	92B	PL B276 354	+Ambrosini, Ansari, Autiero, Bareyre+	(UA2 Collab.)
ALITTI	92C	PL B277 194	+Ambrosini, Ansari, Autiero, Bareyre+	(UA2 Collab.)
ALITTI	92D	PL B277 203	+Ambrosini, Ansari, Autiero, Bareyre+	(UA2 Collab.)
ALITTI	92F	PL B280 137	+Ambrosini, Ansari, Autiero, Bareyre+	(UA2 Collab.)
LEP	92	PL B276 247	+ALEPH, DELPHI, L3, OPAL	(LEP Collabs.)
SAMUEL	92	PL B280 124	+Li, Sinha, Sinha, Sundaresan	(ÒKSU, CARL)
ABE	91C	PR D44 29	+Amidei, Apollinari, Atac, Auchincloss+	(CDF Collab.)
ALBAJAR	91	PL B253 503	+Albrow, Allkofer, Ankoviak, Apsimon+	(UA1 Collab.)
ALITTI	91C	ZPHY C52 209	+Ambrosini, Ansari, Autiero+	(UA2 Collab.)
SAMUEL	91	PRL 67 9	+Li, Sinha, Sinha, Sundaresan	(OKSU, CARL)
Also	91C	PRL 67 2920 erratum		, ,
ABE	90	PRL 64 152	+Amidei, Apollinari, Atac, Auchincloss+	(CDF Collab.)
Also	91C	PR D44 29	Abe, Amidei, Apollinari, Atac, Auchinc	loss+ (CDF Collab.)
ABE	90G	PRL 65 2243	+Amidei, Apollinari, Atac+	(CDF Collab.)
Also	91B	PR D43 2070	Abe, Amidei, Apollinari, Atac, Auchinc	loss+ (CDF Collab.)
ALBAJAR	90	PL B241 283	+Albrow, Allkofer+	(UA1 Collab.)
ALITTI	90B	PL B241 150	+Ansari, Ansorge, Autiero+	(UA2 Collab.)
ALITTI	90C	ZPHY C47 11	+Ansari, Ansorge, Bagnaia+	(UA2 Collab.)
ABE	891	PRL 62 1005	+Amidei, Apollinari, Ascoli, Atac+	(CDF Collab.)
ALBAJAR	89	ZPHY C44 15	+Albrow, Allkofer, Arnison, Astbury+	(UA1 Collab.)
BAUR	88	NP B308 127	+Zeppenfeld	(FSU, WISC)
GRIFOLS	88	IJMP A3 225	+Peris, Sola	(BARC, DESY)
Also	87	PL B197 437	Grifols, Peris, Sola	(BARC, DESY)
ALBAJAR	87	PL B185 233	+Albrow, Allkofer, Arnison, Astbury+	(UA1 Collab.)
ANSARI	87 87C	PL B186 440	+Bagnaia, Banner, Battiston+	(UA2 Collab.)
ANSARI		PL B194 158	+Bagnaia, Banner, Battiston+	(UA2 Collab.)
GROTCH HAGIWARA	87 87	PR D36 2153 NP B282 253	+Robinett	(PSU)
VANDERBIJ	87	PR D35 1088	+Peccei, Zeppenfeld, Hikasa van der Bij	(KEK, UCLA, FSU) (FNAL)
APPEL.	86	ZPHY C30 1	+Bagnaia, Banner, Battiston+	(UA2 Collab.)
ARNISON	86	PL 166B 484	+Albrow, Allkofer, Astbury+	(UA1 Collab.) J
ALTARELLI	85B	ZPHY C27 617		ERN, FNAL, FRAS)
GRAU	85	PL 154B 283	+Grifols	(BARC)
SUZUKI	85	PL 153B 289	+0111013	(LBL)
ARNISON	84D	PL 134B 469	+Astbury, Aubert, Bacci+	(UA1 Collab.)
BAGNAIA	84	ZPHY C24 1	+Banner, Battiston, Blech+	(UA2 Collab.)
HERZOG	84	PL 148B 355	, Decision, Dicon ;	(WISC)
Also	84B	PL 155B 468 erratum	Herzog	(WISC)
ARNISON	83	PL 122B 103	+Astbury, Aubert, Bacci+	(UA1 Collab.)
ARNISON	83D	PL 129B 273	+Astbury, Aubert, Bacci+	(UA1 Collab.)
BAGNAIA	83	PL 129B 130	+Banner, Battiston, Bloch+	(UA2 Collab.)
BANNER	83B	PL 122B 476	+Battiston, Bloch, Bonaudi+	(UA2 Collab.)
				, ,



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THE Z BOSON

(by C. Caso, Univ. di Genova and A. Gurtu, Tata Inst.)

Precision measurements at the Z-boson resonance using electron-positron colliding beams began in 1989 at the SLC and at LEP. During 1989–95, the four CERN experiments have made high-statistics studies of the Z. The availability of longitudinally polarized electron beams at the SLC since 1993 has enabled a precision determination of the effective electroweak mixing angle $\sin^2 \overline{\theta}_W$ that is competitive with the CERN results on this parameter.

The Z-boson properties reported in this section may broadly be categorized as:

- The standard 'lineshape' parameters of the Z consisting of its mass, M_Z , its total width, Γ_Z , and its partial decay widths, $\Gamma(\text{hadrons})$ and $\Gamma(\ell \bar{\ell})$ where $\ell = e, \mu, \tau, \nu$;
- The b- and c-quark-related partial widths and charge asymmetries which require special techniques;
- Determination of rare Z decay modes and the search for modes that violate known conservation laws.

For the lineshape-related Z properties there are no new published LEP results after those included in the 1994 edition of this compilation. The reason for this is the identification in mid 1995 of a new systematic effect which shifts the LEP energy by a few MeV. This is due to a drift of the dipole field in the LEP magnets caused by parasitic currents generated by electrically powered trains in the Geneva area. The LEP Energy Working Group is studying the implications of this for the Z-lineshape properties which would be obtained after analysis of the high statistics 1993–95 data. The main consequence of this effect is expected to be in the determination of the Z mass.

Details on Z-parameter determination and the study of $Z\to b\bar{b}, c\bar{c}$ at LEP and SLC are given in this note.

The standard 'lineshape' parameters of the Z are determined with increasing precision from an analysis of the production cross sections of these final states in e^+e^- collisions. The $Z\to \nu\overline{\nu}(\gamma)$ state is identified directly by detecting single photon production and indirectly by subtracting the visible partial widths from the total width. Inclusion in this analysis of the forward-backward asymmetry of charged leptons, $A_{FB}^{(0,\ell)}$, of the τ polarization, $P(\tau)$, and its forward-backward asymmetry, $P(\tau)^{fb}$, enables the separate determination of the effective vector (\overline{g}_V) and axial vector (\overline{g}_A) couplings of the Z to these leptons and the ratio $(\overline{g}_V/\overline{g}_A)$ which is related to the effective electroweak mixing angle $\sin^2 \overline{\theta}_W$ (see the Standard Model review).

Determination of the b- and c-quark-related partial widths and charge asymmetries involves tagging the b and c quarks. Traditionally this was done by requiring the presence of a prompt lepton in the event with high momentum and high

transverse momentum (with respect to the accompanying jet). Precision vertex measurement with silicon detectors has enabled one to do impact parameter and lifetime tagging. Neural-network techniques have also been used to classify events as b or non-b on a statistical basis using event-shape variables. Finally, the presence of a charmed meson (D/D^*) has been used to tag heavy quarks.

Z-parameter determination

LEP is run at a few energy points on and around the Z mass constituting an energy 'scan.' The shape of the cross-section variation around the Z peak can be described by a Breit-Wigner ansatz with an energy-dependent total width [1]. The three main properties of this distribution, viz., the position of the peak, the width of the distribution, and the height of the peak, determine respectively the values of M_Z , Γ_Z , and $\Gamma(e^+e^-) \times$ $\Gamma(f\overline{f})$, where $\Gamma(e^+e^-)$ and $\Gamma(f\overline{f})$ are the electron and fermion partial widths of the Z. The quantitative determination of these parameters is done by writing analytic expressions for these cross sections in terms of the parameters and fitting the calculated cross sections to the measured ones by varying these parameters, taking properly into account all the errors. Singlephoton exchange (σ_{γ}^0) and γ -Z interference $(\sigma_{\gamma Z}^0)$ are included, and the large (\sim 25 %) initial-state radiation (ISR) effects are taken into account by convoluting the analytic expressions over a 'Radiator Function [1,2]' H(s,s'). Thus for the process $e^+e^- \to f\overline{f}$:

$$\sigma_f(s) = \int H(s, s') \ \sigma_f^0(s') \ ds' \tag{1}$$

$$\sigma_f^0(s) = \sigma_Z^0 + \sigma_\gamma^0 + \sigma_{\gamma Z}^0 \tag{2}$$

$$\sigma_{Z}^{0} = \frac{12\pi}{M_{Z}^{2}} \ \frac{\Gamma(e^{\pm}e^{-})\Gamma(f\overline{f})}{\Gamma_{Z}^{2}} \ \frac{s \ \Gamma_{Z}^{2}}{(s-M_{Z}^{2})^{2} \ + \ s^{2}\Gamma_{Z}^{2}/M_{Z}^{2}} \ (3)$$

$$\sigma_{\gamma}^{0} = \frac{4\pi\alpha^{2}(s)}{3s} Q_{f}^{2} N_{c}^{f} \tag{4}$$

$$\sigma^0_{\gamma Z} = -\; \frac{2\sqrt{2}\alpha(s)}{3}\;\; (Q_f G_F N_c^{\;f} g_{Ve} g_{Vf}) \label{eq:sigma_Z}$$

$$\times \frac{(s - M_Z^2)M_Z^2}{(s - M_Z^2)^2 + s^2\Gamma_Z^2/M_Z^2} \tag{5}$$

where Q_f is the charge of the fermion, $N_c^f = 3(1)$ for quark (lepton) and g_{Vf} is the neutral vector coupling of the Z to the fermion-antifermion pair $f\bar{f}$.

Since $\sigma_{\gamma Z}^0$ is expected to be much less than σ_Z^0 , the LEP collaborations have generally calculated the interference term in the framework of the Standard Model using the best known values of g_V . This fixing of $\sigma_{\gamma Z}^0$ leads to a tighter constraint on M_Z and consequently a smaller error on its fitted value.

Defining

$$A_f = 2 \frac{g_{Vf} \cdot g_{Af}}{(g_{Vf}^2 + g_{Af}^2)} \tag{6}$$

where g_{Af} is the neutral axial-vector coupling of the Z to $f\overline{f}$, the lowest-order expressions for the various lepton-related asymmetries on the Z pole are [3] $A_{FB}^{(0,\ell)}=(3/4)A_eA_f$, $P(\tau)=-A_{\tau}$,

 $P(\tau)^{fb}=-(3/4)A_e,~A_{LR}=A_e.$ The full analysis takes into account the energy dependence of the asymmetries. Experimentally A_{LR} is defined as $(\sigma_L-\sigma_R)/(\sigma_L+\sigma_R)$ where $\sigma_{L(R)}$ are the $e^+e^-\to Z$ production cross sections with left- (right)-handed electrons.

In terms of g_A and g_V , the partial decay width of the Z to $f\overline{f}$ can be written as

$$\Gamma(f\overline{f}) = \frac{G_F M_Z^3}{6\sqrt{2}\pi} (g_{Vf}^2 + g_{Af}^2) N_c^f (1 + \delta_{\text{QED}}) (1 + \delta_{\text{QCD}})$$
(7)

where $\delta_{\rm QED}=3\alpha Q_f^2/4\pi$ accounts for final-state photonic corrections and $\delta_{\rm QCD}=0$ for leptons and $\delta_{\rm QCD}=(\alpha_s/\pi)+1.409(\alpha_s/\pi)^2-12.77(\alpha_s/\pi)^3$ for quarks, α_s being the strong coupling constant at $\mu=M_Z$.

In the above framework, the QED radiative corrections have been explicitly taken into account by convoluting over the ISR and allowing the electromagnetic coupling constant to run [4]: $\alpha(s) = \alpha/(1 - \Delta \alpha)$. On the other hand, weak radiative corrections that depend upon the assumptions of the electroweak theory and on the values of the unknown M_{top} and M_{Higgs} are accounted for by absorbing them into the couplings, which are then called the effective couplings \bar{g}_V and \bar{g}_A (or alternatively the effective parameters of the * scheme of Kennedy and Lynn [5]).

S-matrix approach to the Z

While practically all experimental analyses of LEP/SLC data have followed the 'Breit-Wigner' approach described above, an alternative S-matrix-based analysis is also possible. The Z, like all unstable particles, is associated with a complex pole in the S matrix. The pole position is process independent and gauge invariant. The mass, \overline{M}_Z , and width, $\overline{\Gamma}_Z$, can be defined in terms of the pole in the energy plane via [6]

$$\overline{s} = \overline{M}_Z^2 - i\overline{M}_Z\overline{\Gamma}_Z \tag{8}$$

leading to the relations

$$\overline{M}_Z = M_Z / \sqrt{1 + \Gamma_Z^2 / M_Z^2} \tag{9}$$

$$\approx M_Z - 34 \; \mathrm{MeV}$$
 (10)

$$\overline{\Gamma}_Z = \Gamma_Z / \sqrt{1 + \Gamma_Z^2 / M_Z^2} \tag{11}$$

$$\approx \Gamma_Z - 0.9 \text{ MeV}$$
 (12)

Some authors [7] choose to define the Z mass and width via

$$\overline{s} = (\overline{M}_Z - \frac{i}{2}\overline{\Gamma}_Z)^2 \tag{13}$$

which yields $\overline{M}_Z \approx M_Z - 26$ MeV, $\overline{\Gamma}_Z \approx \Gamma_Z - 1.2$ MeV.

The L3 collaboration at LEP (ACCIARRI 96B) have analyzed their data using the S-matrix approach as defined in Eq. (8), in addition to the conventional one. They observe a downward shift in the Z mass as expected.

Handling the large-angle e^+e^- final state

Unlike other $f\overline{f}$ decay final states of the Z, the e^+e^- final state has a contribution not only from the s-channel but also

from the t-channel and s-t interference. The full amplitude is not amenable to fast calculation, which is essential if one has to carry out minimization fits within reasonable computer time. The usual procedure is to calculate the non-s channel part of the cross section separately using the Standard Model program ALIBABA [8] using the measured value of $M_{\rm top}$, and the 'central' value of $M_{\rm Higgs}$ (300 GeV) and add it to the s-channel cross section calculated as for other channels. This leads to two additional sources of error in the analysis: firstly, the theoretical calculation in ALIBABA itself is known to be accurate to $\sim 0.5\%$, and secondly, there is uncertainty due to the error on $M_{\rm top}$ and the unknown value of $M_{\rm Higgs}$ (60–1000 GeV). These additional errors are propagated into the analysis by including them in the systematic error on the e^+e^- final state

Errors due to uncertainty in LEP energy determination [9]

The systematic errors related to the LEP energy measurement can be classified as:

- The absolute energy scale error;
- Energy-point-to-energy-point errors due to the nonlinear response of the magnets to the exciting currents;
- Energy-point-to-energy-point errors due to possible higher-order effects in the relationship between the dipole field and beam energy;
- Energy reproducibility errors due to various unknown uncertainties in temperatures, tidal effects, corrector settings, RF status etc. Since one groups together data taken at 'nominally same' energies in different fills, it can be assumed that these errors are uncorrelated and are reduced by $\sqrt{N}_{\rm fill}$ where $\overline{N}_{\rm fill}$ is the (luminosity weighted) effective number of fills at a particular energy point.

At each energy point the last two errors can be summed into one point-to-point error.

$Choice\ of\ fit\ parameters$

The LEP collaborations have chosen the following primary set of parameters for fitting: M_Z , Γ_Z , $\sigma^0_{\rm hadron}$, $R({\rm lepton})$, $A^{(0,\ell)}_{FB}$, where $R({\rm lepton}) = \Gamma({\rm hadrons})/\Gamma({\rm lepton})$, $\sigma^0_{\rm hadron} = 12\pi\Gamma(e^+e^-)\Gamma({\rm hadrons})/M_Z^2\Gamma_Z^2$. With a knowledge of these fitted parameters and their covariance matrix, any other parameter can be derived. The main advantage of these parameters is that they form the least correlated set of parameters, so that it becomes easy to combine results from the different LEP experiments.

Thus, the most general fit carried out to cross section and asymmetry data determines the **nine parameters**: M_Z , Γ_Z , $\sigma^0_{\rm hadron}$, R(e), $R(\mu)$, $R(\tau)$, $A^{(0,e)}_{FB}$, $A^{(0,\mu)}_{FB}$, $A^{(0,\tau)}_{FB}$. Assumption of lepton universality leads to a **five-parameter fit** determining M_Z , Γ_Z , $\sigma^0_{\rm hadron}$, $R({\rm lepton})$, $A^{(0,\ell)}_{FB}$. The use of **only** cross-section data leads to six- or four-parameter fits if lepton

Gauge & Higgs Boson Particle Listings

Z

universality is or is not assumed, i.e., $A_{FB}^{(0,\ell)}$ values are not determined.

In order to determine the best values of the effective vector and axial vector couplings of the charged leptons to the Z, the above mentioned nine- and five-parameter fits are carried out with added constraints from the measured values of A_{τ} and A_e obtained from τ polarization studies at LEP and the determination of A_{LR} at SLC.

Combining results from the LEP and SLC experiments [10]

Each LEP experiment provides the values of the parameters mentioned above together with the full covariance matrix. The statistical and experimental systematic errors are assumed to be uncorrelated among the four experiments. The sources of **common** systematic errors are i) the LEP energy uncertainties, and ii) the effect of theoretical uncertainty in calculating the small-angle Bhabha cross section for luminosity determination and in estimating the non-s channel contribution to the large-angle Bhabha cross section. Using this information, a full covariance matrix, V, of all the input parameters is constructed and a combined parameter set is obtained by minimizing $\chi^2 = \Delta^T V^{-1} \Delta$, where Δ is the vector of residuals of the combined parameter set to the results of individual experiments.

Non-LEP measurement of a Z parameter, $(e.g., \Gamma(e^+e^-)$ from SLD) is included in the overall fit by calculating its value using the fit parameters and constraining it to the measurement.

Study of $Z \to b\overline{b}$ and $Z \to c\overline{c}$

In the sector of c- and b-physics the LEP experiments have measured the ratios of partial widths $R_b = \Gamma(Z \to b\bar{b})/\Gamma(Z \to \text{hadrons})$ and $R_c = \Gamma(Z \to c\bar{c})/\Gamma(Z \to \text{hadrons})$ and the forward-backward (charge) asymmetries $A_{FB}^{b\bar{b}}$ and $A_{FB}^{c\bar{c}}$. Several of the analyses have also determined other quantities, in particular the semileptonic branching ratios $B(b \to \ell)$ and $B(b \to c \to \ell^+)$ and the average $B^0 \overline{B}^0$ mixing parameter $\overline{\chi}$. The latter measurements do not concern properties of the Z boson and hence they are not covered in this section. However, they are correlated with the electroweak parameters, and since the mixture of b-hadrons is different from the one at the $\Upsilon(4S)$, their values might differ from those measured at the $\Upsilon(4S)$.

All the above quantities are correlated to each other since:

- Several analyses (for example the lepton fits) determine more than one parameter simultaneously;
- Some of the electroweak parameters depend explicitly on the values of other parameters (for example R_b depends on R_c);
- Common tagging and analysis techniques produce common systematic uncertainties.

The LEP Electroweak Heavy Flavour Working Group has then developed [11] a procedure for combining the measurements taking into account known sources of correlation. The combining procedure determines seven parameters: the four parameters of interest in the electroweak sector, R_b , R_c , $A_{FB}^{b\bar{b}}$, and $A_{FB}^{c\bar{c}}$ and, in addition, $B(b \to \ell)$, $B(b \to c \to \ell^+)$ and $\bar{\chi}$, to take into account their correlations with the electroweak parameters. Before the fit both the peak and off-peak asymmetries are translated to $\sqrt{s} = 91.26$ GeV using the predicted dependence from ZFITTER [2].

$Summary\ of\ the\ measurements\ and\ of\ the\ various\ kinds$ of analysis

The measurements of R_b and R_c fall into two classes. In the first, named single-tag measurement, a method for selecting b and c events is applied and the number of tagged events is counted. The second technique, named double-tag measurement, is based on the following principle: if the number of events with a single hemisphere tagged is N_t and with both hemispheres tagged is N_{tt} , then given a total number of N_{had} hadronic Z decays one has:

$$\frac{N_t}{2N_{\text{had}}} = \varepsilon_b R_b + \varepsilon_c R_c + \varepsilon_{uds} (1 - R_b - R_c)$$
 (14)

$$\frac{N_{tt}}{N_{\text{had}}} = \mathcal{C}_b \varepsilon_b^2 R_b + \varepsilon_c^2 R_c + \varepsilon_{uds}^2 (1 - R_b - R_c)$$
 (15)

where ε_b , ε_c , and ε_{uds} are the tagging efficiencies per hemisphere for b, c, and light quark events, and $\mathcal{C}_b \approx 1$ accounts for the fact that the tagging efficiencies between the hemispheres are correlated. Neglecting the c and uds background and the hemisphere correlation, these equations give:

$$\varepsilon_b = 2N_{tt}/N_t \tag{16}$$

$$R_b = N_t^2 / (4N_{tt}N_{\text{had}}) \tag{17}$$

The double-tagging method has thus the great advantage that the tagging efficiency is directly derived from the data, reducing the systematic error of the measurement. The backgrounds, dominated by $c\bar{c}$ events, obviously complicate this simple picture, and their level must still be inferred by other means. The rate of charm background in these analyses depends explicitly on the value of R_c . The correlations in the tagging efficiencies between the hemispheres (due for instance to correlations in momentum between the b-hadrons in the two hemispheres) are small but nevertheless lead to further systematic uncertainties.

The measurements in the b- and c-sector can be grouped in the following categories:

- Lepton fits which use hadronic events with one or more leptons in the final state. Each analysis usually gives several electroweak parameters chosen among: R_b , R_c , $A_{FB}^{b\bar{b}}$, $A_{FB}^{c\bar{c}}$, $B(b \rightarrow \ell)$, $B(b \to c \to \ell^+)$ and $\overline{\chi}$. The output parameters are then correlated. The dominant sources of systematics are due to lepton identification, to other semileptonic branching ratios and to the modelling of the semileptonic decay;
- ullet Event shape tag for R_b (both single and doubletagging have been used);
- Lifetime (and lepton) double-tagging measurements of R_b . These are the most precise measurements of R_b and obviously dominate the combined result. The main sources of systematics come from the assumed properties of the $c\overline{c}$ events and from estimating the hemisphere b-tagging efficiency cor-
- Measurements of $A_{FB}^{b\bar{b}}$ using lifetime tagged events with a measurement of the jet charge. Their contribution to the combined result has roughly the same weight as the lepton fits:
- Analyses with $D/D^{*\pm}$ to measure R_c . These measurements separate charmed hadrons coming from $b\bar{b}$ and $c\bar{c}$ decays on a statistical basis; thus R_c depends on properties of $b\bar{b}$ events but not on the
- Analyses with $D^{*\pm}$ to measure simultaneously $A_{FB}^{b\bar{b}}$ and $A_{FB}^{c\bar{c}}$.

Averaging procedure

All the measurements are provided by the LEP Collaborations in the form of tables with a detailed breakdown of the systematic errors of each measurement and its dependence on other electroweak parameters.

The average proceeds via the following steps:

- Define and propagate a consistent set of external inputs such as branching ratios, hadron lifetimes, fragmentation models etc. All the measurements are also consistently checked to ensure that all use a common set of assumptions (for instance for the lifetime/jet-charge measurements of asymmetries, where the QCD effects are already included as an inherent part of the analysis, a QCD correction is subtracted before combining);
- Form the full (statistical and systematic) covariance matrix of the measurements. The systematic correlations between different analyses are calculated from the detailed error breakdown in the measurement tables. The correlations relating several measurements made by the same analysis are also considered;

• Take into account any explicit dependence of a measurement on the other electroweak parameters. As an example of this dependence we illustrate the case of the double-tag measurement of R_h , where c-quarks constitute the main background. The normalization of the charm contribution is not fixed by the data and the measurement of R_b depends on the assumed value of R_c , which can

$$R_b = R_b^{\text{meas}} + a(R_c) \frac{(R_c - R_c^{\text{used}})}{R_c} , \qquad (18)$$

where R_b^{meas} is the result of the analysis which assumed a value of $R_c = R_c^{\text{used}}$ and $a(R_c)$ is the constant which gives the dependence on R_c . It is worth noting that the combining procedure shows that the only significant correlation between any of the resulting electroweak parameters turns out to be just between R_b and R_c . With the data contained in the present Listing the correlation coefficient between these two variables amounts to -0.39;

• Perform a χ^2 minimization with respect to the combined electroweak parameters.

After the fit the average peak asymmetries $A_{FB}^{c\bar{c}}$ and $A_{FB}^{b\bar{b}}$ are corrected for the energy shift and for QED, QCD, γ exchange, and γZ interference effects to obtain the corresponding pole asymmetries $A_{FB}^{0,c}$ and $A_{FB}^{0,b}$. A small correction is also applied to both R_b and R_c to account for the contribution of γ exchange.

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Z MASS

The fit is performed using the Z mass and width, the Z hadronic pole cross section, the ratios of hadronic to leptonic partial widths, and the Z pole forward-backward lepton asymmetries. We believe that this set is the most free of correlations. Common systematic errors are taken into account. For more details, see the 'Note on the Z Boson,'

The Z-boson mass listed here corresponds to a Breit-Wigner resonance parameter. The value is 34 MeV greater than the real part of the position of the pole (in the energy-squared plane) in the Z-boson propagator. Also the LEP experiments have generally assumed a fixed value of the $\gamma-Z$ interferences term based on the standard model. Keeping this term as free parameter leads to a somewhat larger error on the fitted $\it Z$ mass. See ACCIARRI 968 and ADRIANI 93H for a detailed investigation of both

A new source of LEP energy variation was discovered in mid 1995: an energy change of a few MeV is correlated with the passage of a train on nearby railway tracks. The LEP energy working group is studying the implications of this effect for the high statistics data recorded since 1993. The main consequence of this is expected to be a shift in the overall LEP energy values leading to a corresponding shift in the value of m_Z . The LEP collaborations have consequently deferred publication of their results on Z lineshape and lepton forward-backward asymmetries based on 1993 and later data.

VALUE (GeV)	EVTS	DOCUMENT ID	TE	CN COMMENT
91.187±0.007 OUR FI	-			
91.188±0.007 OUR AV		1		
$91.187 \pm 0.007 \pm 0.006$	1.16M	¹ ABREU	94 DL	PH <i>E</i> ^{ee} _{Cm} = 88–94 GeV
$91.195 \pm 0.006 \pm 0.007$	1.19M	¹ ACCIARRI	94 L3	<i>E</i> ^{ee} ⊂ 88−94 GeV
$91.182 \pm 0.007 \pm 0.006$	1.33M	¹ AKERS	94 OF	AL E_{Cm}^{ee} = 88–94 GeV
$91.187 \pm 0.007 \pm 0.006$	1.27M	¹ BUSKULIC	94 AL	EP <i>E</i> ^{ee} _{Cm} = 88–94 GeV
• • • We do not use t	he follow	ing data for averages	s, fits, lir	nits, etc. • • •
91.162 ± 0.011	1.2M	² ACCIARRI	96B L3	Eee = 88-94, 130-140 GeV
91.151 ± 0.008		³ MIYABAYASHI	95 TC	PZ $E_{\text{Cm}}^{ee} = 57.8 \text{ GeV}$
$91.181 \pm 0.007 \pm 0.006$	512k	⁴ ACTON	93D OF	AL Repl. by AKERS 94
91.195 ± 0.009	460k	⁵ ADRIANI	93F L3	Repl. by ACCIARRI 94
91.160 ± 0.010	463k	⁶ ADRIANI	93H L3	Repl. by ACCIARRI 96B
91.187 ± 0.009	520k	⁷ BUSKULIC	93J AL	EP Repl. by BUSKULIC 94
91.187 ± 0.007	2.2M	⁸ LEP	93 RV	'UE <i>E^{ee}</i> = 88–94 GeV
91.187 ± 0.007	1.9M	9 QUAST	93 RV	'UE <i>E^{ee}</i> _{Cm} = 88–94 GeV
$91.74 \ \pm 0.28 \ \pm 0.93$	156	¹⁰ ALITTI	928 UA	$E_{CM}^{p\overline{p}} = 630 \; GeV$
$89.2 \begin{array}{c} +2.1 \\ -1.8 \end{array}$		¹¹ ADACHI	90F RV	UE
90.9 ±0.3 ±0.2	188	¹² ABE	89C CE	F $E_{CM}^{p\overline{p}} = 1800 \; GeV$
91.14 ±0.12	480	¹³ ABRAMS	898 MI	RK2 $E_{\text{cm}}^{ee} = 89 – 93 \text{ GeV}$
93.1 ± 1.0 ± 3.0	24	^{14,15} ALBAJAR	89 UA	1 $E_{CM}^{p\overline{\overline{\rho}}} = 546,630 \; GeV$
88.6 +2.0 -1.8		¹¹ MORI	89 RV	'UE

- The second error of 6.3 MeV is due to a common LEP energy uncertainty.
- ACCIARRI 968 interpret the s-dependence of the cross sections and lepton forward-backward asymmetries in the framework of the S-matrix ansatz. The high-energy data constrains the γZ interference terms. As expected, this result is below the mass values obtained with a standard Breit-Wigner parametrization.
- ³ MIYABAYASHI 95 combine their low energy total hadronic cross-section measurement with the ACTON 93D data and perform a fit using an S-matrix formalism. As expected, this result is below the mass values obtained with the standard Breit-Wigner parametriza-
- ⁴ The systematic error in ACTON 93D is from the uncertainty in the LEP energy calibration. ⁵ The error in ADRIANI 93F includes 6 MeV due to the uncertainty in LEP energy calibra-
- 6 ADRIANI 93H use the S-matrix approach to determine the pole position for the Z boson. Note the shift of this result with respect to the standard Brelt-Wigner parametrization.

 7 BUSKULIC 93J supersedes DECAMP 92B. The error includes 6 MeV due to the uncertainty in LEP energy calibration.
- ⁸ The LEP 93 error due to the experiments is 4 MeV and the uncertainty due to the absolute LEP energy scale is 6 MeV.
- ⁹ QUAST 93 is a combined analysis of LEP results as of Feb. 1993. A common systematic error of 6 MeV is taken into account.

- 10 Enters fit through W/Z mass ratio given in the W Particle Listings. The ALITTI 92B systematic error (± 0.93) has two contributions: one (± 0.92) cancels in m_W/m_Z and one (± 0.12) is noncancelling. These were added in quadrature.
- 11 MORI 89, ADACHI 90F use a Breit-Wigner resonance shape fit and combine their results with published data of PEP and PETRA.
- 12 First error of ABE 89 is combination of statistical and systematic contributions; second is mass scale uncertainty.
- 13 ABRAMS 89B uncertainty includes 35 MeV due to the absolute energy measurement.
- 14 Enters fit through Z-W mass difference given in the W Particle Listings.
- 15 ALBAJAR 89 result is from a total sample of 33 $Z \rightarrow e^+e^-$ events.

VALUE (GeV) EVTS

3.8 +0.8 ±1.0

Z WIDTH

DOCUMENT ID TECN COMMENT

ı

2.490 ± 0.007 OUR FIT				
2.491 ±0.007 OUR AVE	ERAGE			
$2.483 \pm 0.011 \pm 0.0045$	1.16M	¹⁶ ABREU	94 DLPH	E ^{ee} _{cm} = 88–94 GeV
$2.494 \pm 0.009 \pm 0.0045$	1.19M	¹⁶ ACCIARRI	94 L3	E ^{ee} _{cm} = 88–94 GeV
$2.483 \pm 0.011 \pm 0.0045$	1.33M	¹⁶ AKERS	94 OPAL	E ^{ee} _{cm} = 88–94 GeV
$2.501 \pm 0.011 \pm 0.0045$	1.27M	¹⁶ BUSKULIC	94 ALEP	E ^{ee} _{cm} = 88–94 GeV
• • • We do not use t	he followi	ng data for average	es, fits, limits,	etc. • • •
2.492 ± 0.010	1.2M	¹⁷ ACCIARRI	968 L3	Eee = 88-94, 130-140 GeV
$2.483 \pm 0.011 \pm 0.004$	512k	¹⁸ ACTON	93D OPAL	Repl. by AKERS 94
2.490 ± 0.011	460k	¹⁹ ADRIANI	93F L3	Repl. by ACCIARRI 94
2.492 ± 0.012	463k	²⁰ ADRIANI	93H L3	Repl. by ACCIARRI 968
2.501 ± 0.012	520k	²¹ BUSKULIC	93J ALEP	Repl. by BUSKULIC 94
2.490 ± 0.007	1.9M	²² QUAST	93 RVUE	E ^{ee} _{cm} = 88–94 GeV

89C CDF $E_{\rm cm}^{p\overline{p}} = 1800 \text{ GeV}$ $2.42 \begin{array}{l} +0.45 \\ -0.35 \end{array}$ 480 ²³ ABRAMS 89B MRK2 $E_{cm}^{ee} = 89-93 \text{ GeV}$ 89 UA1 $E_{\rm cm}^{p\overline{p}} = 546,630 \, {\rm GeV}$ ²⁴ ALBAJAR 24

ABE

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- ²⁵ ANSARI 25 16 The second error of 4.5 MeV is due to a common LEP energy uncertainty.
 - The second error of 4.5 MeV is due to a common terrement and lepton forward-backward asymmetries in the framework of the S-matrix ansatz. The high-energy data constrains the γZ interference terms. The fitted width is expected to be 0.9 MeV less than that obtained using the standard Breit-Wigner parametrization (see 'Note on the Z Boson').
 - ¹⁸ The systematic error is from the uncertainty in the LEP energy calibration.
 - ¹⁹ The error in ADRIANI 93F includes 4 MeV due to the uncertainty in LEP energy calibra-
 - tion. 20 ADRIANI 93H use the S-matrix approach to determine the pole position for the Z boson. The fitted width is expected to be 0.9 MeV less than that obtained using the standard Breit-Wigner parametrization (see 'Note on the Z Boson').
 - 21 The error in BUSKULIC 93J includes 4 MeV due to the uncertainty in LEP energy
 - calibration.

 22 QUAST 93 is a combined analysis of LEP results as of Feb. 1993. A common systematic error of 4 MeV is taken into account
 - 23 ABRAMS 89B uncertainty includes 50 MeV due to the miniSAM background subtraction
 - error. 24 ALBAJAR 89 result is from a total sample of 33 $Z \rightarrow e^+e^-$ events.
 - Example of 33 $Z\to e^+e^-$ events. ANSARI 87 are from direct fit. Ratio of Z and W production gives either $\Gamma(Z)<(1.09\pm0.07)\times\Gamma(W)$, CL = 90% or $\Gamma(Z)=(0.82^{+}0.19\pm0.06)\times\Gamma(W)$. Assuming Standard-Model value $\Gamma(W)=2.65$ GeV then gives $\Gamma(Z)<2.89\pm0.19$ or $=2.17^{+}0.50_{-}0.37\pm0.16$.

Z DECAY MODES

	Mode	Fraction (Γ _i /Γ)	Confidence level
Γ ₁	e ⁺ e ⁻	(3.366 ± 0.008) %	
Γ_2	$\mu^+\mu^-$	(3.367 ± 0.013) %	
Гз	$\tau^+\tau^-$	(3.360 ± 0.015) %	
Γ_4	$\ell^+\ell^-$	[a] (3.366 ± 0.006) %	
Γ_5	invisible	(20.01 ±0.16) %	
Γ ₆	hadrons	(69.90 ±0.15)%	
Γ ₇	$(u\overline{u}+c\overline{c})/2$	(9.6 ±1.3) %	
Γ8	$(d\overline{d} + s\overline{s} + b\overline{b})/3$	(16.9 ±0.9)%	
Γ9	$c\overline{c}$	(11.0 ±0.7)%	
Γ_{10}	$b\overline{b}$	$(15.46 \pm 0.14)\%$	_
Γ_{11}	$\pi^0 \gamma$		10 ⁻⁵ 95%
Γ_{12}	$\eta \gamma$		10 ⁻⁵ 95%
Γ_{13}	$\omega \gamma$		10^{-4} 95%
Γ_{14}	$\eta'(958)\gamma$		10^{-5} 95%
Γ_{15}	$\gamma \gamma$		10^{-5} 95%
Γ_{16}	$\gamma\gamma\gamma$		10^{-5} 95%
Γ_{17}	$\pi^{\pm} W^{\mp}$		10^{-5} 95%
Γ_{18}	$ ho^{\pm}W^{\mp}$		10-5 95%
Γ_{19}	$J/\psi(1S)X$	(3.80 \pm 0.27) \times	10-3

ı

Γ ₂₂ Γ ₂₃	$\psi(2S)X$ $\chi_{c1}(1P)X$ $\uparrow X$ $(D_{\cdot}^{0}/\overline{D}^{0}) X$		(1.60 ± 0.3) (6.0 ± 1.9) (1.0 ± 0.5) (20.7 ± 2.0)	$) \times 10^{-3}$	
Γ ₂₄	D*X		(12.2 ±1.7	,	
	D*(2010)±X BX		[b] (11.4 ± 1.3)) %	
Γ ₂₆ Γ ₂₇	В* X				
Γ ₂₈	B ₀ X		seen		
Γ ₂₉	anomalous γ + hadrons		[c] < 3.2	× 10 ⁻³	95%
	$e^+e^-\gamma$		[c] < 5.2 $[c] < 5.2$	× 10 ⁻⁴	95%
	$\mu^+\mu^-\gamma$		[c] < 5.6	× 10 ⁻⁴	95%
	$\tau^+\tau^-\gamma$		[c] < 7.3	× 10 ⁻⁴	95%
	$\ell^+\ell^-\gamma\gamma$		[d] < 6.8	$\times 10^{-6}$	95%
	$q \overline{q} \gamma \gamma$		[d] < 5.5	$\times 10^{-6}$	95%
Γ ₃₅	$ u \overline{ u} \gamma \gamma$		[d] < 3.1	$\times 10^{-6}$	95%
	$e^{\pm}\mu^{\mp}$	LF	[b] < 1.7	\times 10 ⁻⁶	95%
Γ ₃₇	$e^{\pm} au^{\mp}$	LF	[b] < 9.8	\times 10 ⁻⁶	95%
Γ ₃₈	$\mu^{\pm} au^{\mp}$	LF	[b] < 1.7	\times 10 ⁻⁵	95%

- [a] ℓ indicates each type of lepton (e, μ , and τ), not sum over them.
- [b] The value is for the sum of the charge states of particle/antiparticle states indicated
- [c] See the Particle Listings below for the γ energy range used in this measurement.
- [d] For $m_{\gamma\gamma}=$ (60 \pm 5) GeV.

Z PARTIAL WIDTHS

 $\Gamma(e^+e^-)$ For the LEP experiments, this parameter is not directly used in the overall fit but is derived using the fit results; see the 'Note on the Z Boson.'

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
83.82 ± 0.30 OUR FIT					
$82.89 \pm 1.20 \pm 0.89$		²⁶ ABE	95J	SLD	E ^{ee} _{cm} = 91.31 GeV
\bullet \bullet We do not use	the followi	ng data for average	s, fits	, limits,	etc. • • •
83.31 ± 0.54	31.4k	ABREU	94	DLPH	Ecm = 88-94 GeV
83.43 ± 0.52	38k	ACCIARRI	94	L3	E ^{ee} _{cm} = 88-94 GeV
83.63 ± 0.53	42k	AKERS	94	OPAL	E ^{ee} _{cm} = 88-94 GeV
84.61 ± 0.49	45.8k	BUSKULIC	94	ALEP	E ^{ee} _{cm} = 88-94 GeV
83.03 ± 0.66	17k	ACTON	93D	OPAL	Repl. by AKERS 94
83.0 ±0.6	16k	ADRIANI	93M	L3	Repl. by ACCIARRI 94
84.43 ± 0.60		BUSKULIC	93J	ALEP	Repl. by BUSKULIC 94
83.30 ± 0.35	70k	²⁷ QUAST	93	RVUE	Eee = 88-94 GeV

²⁶ ABE 95J obtain this measurement from Bhabha events in a restricted fiducial region to improve systematics. They use the values 91.187 and 2.489 GeV for the Z mass and total decay width to extract this partial width.

²⁷ QUAST 93 is a combined analysis of LEP results as of Feb. 1993.

 $\Gamma(\mu^+\mu^-) \\ \text{This parameter is not directly used in the overall fit but is derived using the fit results;} \\ \text{see the 'Note on the Z Boson.'} \\ \text{VALUE (MAX')} \qquad FUTS \\ \text{DOCUMENT ID} \qquad \text{TECN} \qquad \text{COMMENT}$

VALUE (NIEV)	EVIS	DOCUMENTID	IECN	COMMENT
83.83 ± 0.39 OUR FI	Т			
• • • We do not us	e the followir	ng data for average	s, fits, limits,	etc. • • •
84.15 ± 0.77	45.6k	ABREU	94 DLPH	<i>E</i> ^{ee} cm = 88−94 GeV
83.20 ± 0.79	34k	ACCIARRI	94 L3	E ^{ee} _{cm} = 88–94 GeV
83.83 ± 0.65	57k	AKERS	94 OPAL	E ^{ee} _{cm} = 88–94 GeV
83.62 ± 0.75	46.4k	BUSKULIC	94 ALEP	<i>E</i> ^{ee} _{cm} = 88−94 GeV
84.43 ± 0.92	23k	ACTON	93D OPAL	Repl. by AKERS 94
82.8 ±1.0	14k	ADRIANI	93M L3	Repl. by ACCIARRI 94
83.66 ± 0.95		BUSKULIC	93J ALEP	Repl. by BUSKULIC 94
83.82 ± 0.52	70k	²⁸ QUAST	93 RVUE	E ^{ee} _{cm} = 88-94 GeV

²⁸ QUAST 93 is a combined analysis of LEP results as of Feb. 1993.

 $\Gamma(\tau^+\tau^-)$ This parameter is not directly used in the overall fit but is derived using the fit results; see the 'Note on the Z Boson.'

VALUE (MAY) EVTS

POCUMENT ID

TECN COMMENT

AVEOR (MEA)		DOCUMENT	1 L C IV	COMINENT
83.67±0.44 OUR F	IT			
• • • We do not us	se the following	g data for average	es, fits, limits	, etc. • • •
83.55 ± 0.91	25k	ABREU	94 DLPH	Eee = 88-94 GeV
84.04 ± 0.94	25k	ACCIARRI	94 L3	Eee = 88-94 GeV
82.90 ± 0.77	47k	AKERS	94 OPAL	<i>E</i> ^{ee} _{cm} = 88–94 GeV
84.18 ± 0.79	45.1k	BUSKULIC	94 ALEP	E ^{ee} _{cm} = 88–94 GeV
82.2 ±1.1	18k	ACTON	93D OPAL	Repl. by AKERS 94
84.6 ±1.2	10k	ADRIANI	93M L3	Repl. by ACCIARRI 94
84.09 ± 1.10		BUSKULIC	93J ALEP	Repl. by BUSKULIC 94
83.54 ± 0.62	50k	²⁹ QUAST	93 RVUE	<i>E</i> ^{ee} _{cm} = 88−94 GeV

 $^{^{\}rm 29}\,{\rm QUAST}$ 93 is a combined analysis of LEP results as of Feb. 1993.

$\Gamma(\ell^+\ell^-)$

Γ4

In our fit $\Gamma(\ell^+\ell^-)$ is defined as the partial Z width for the decay into a pair of massless charged leptons. This parameter is not directly used in the 5-parameter fit assuming lepton universality but is derived using the fit results. See the 'Note on the Z Boson.'

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
83.83±0.27 OUR	FIT				
ullet $ullet$ We do not	use the followi	ng data for average	es, fits	, limits,	etc. • • •
83.56 ± 0.45	102k	ABREU	94	DLPH	E ^{ee} _{cm} = 88-94 GeV
83.49 ± 0.46	97k	ACCIARRI	94	L3	E ^{ee} _{cm} = 88–94 GeV
83.55 ± 0.44	146k	AKERS	94	OPAL	E ^{ee} _{cm} = 88–94 GeV
84.40 ± 0.43	137.3k	BUSKULIC	94	ALEP	E ^{ee} _{cm} = 88–94 GeV
83.27 ± 0.50	58k	ACTON	93D	OPAL	Repl. by AKERS 94
83.1 ±0.5	40k	ADRIANI	93F	L3	Repl. by ACCIARRI 94
84.22 ± 0.48		BUSKULIC	93J	ALEP	Repl. by BUSKULIC 94
83.40 ± 0.29	190k	³⁰ QUAST	93	RVUE	Eem = 88-94 GeV

 $^{^{30}\,\}mathrm{QUAST}$ 93 is a combined analysis of LEP results as of Feb. 1993.

Γ(invisible)

F₅
We use only direct measurements of the invisible partial width to obtain the average value quoted below. The fit value is obtained as a difference between the total and

the observed partial widths assuming lepton universality.

VALUE (MeV) EVTS DOCUMENT ID TECH

ALCE (MICA)			DOCOMENT		1 2 2 1 4	COMMENT
498.3± 4.2	OUR	FIT				
517 ±22	OUR	AVERAGE				
539 ± 26	± 17	410	AKERS	95C	OPAL	E ^{ee} _{cm} = 88–94 GeV
450 ± 34	±34	258	BUSKULIC	93L	ALEP	E ^{ee} _{cm} = 88–94 GeV
540 ± 80	±40	52	ADEVA	92	L3	E ^{ee} _{cm} = 88-94 GeV
524 ± 40	± 20	172 31	^L ADRIANI	92E	L3	$E_{cm}^{ee} = 88-94 \text{ GeV}$
• • • We d	lo not	use the following o	data for average	es, fits	, limits,	etc. • • •
509.4 ± 7.0			ABREU	94	DLPH	E ^{ee} _{Cm} = 88-94 GeV
496.5 ± 7.9			ACCIARRI	94	L3	Ecm = 88-94 GeV
490.3 ± 7.3			AKERS	94	OPAL	E ^{ee} _{cm} = 88-94 GeV
501 ± 6			BUSKULIC	94	ALEP	E ^{ee} _{cm} = 88-94 GeV
495 ±10			ACTON	93D	OPAL	Repl. by AKERS 94
494 ± 10			ADRIANI	93M	L3	Repl. by ACCIARRI 94
498 ± 9			BUSKULIC	93J	ALEP	Repl. by BUSKULIC 94
$499\ \pm\ 6$		32	QUAST	93	RVUE	E ^{ee} _{Cm} = 88-94 GeV

 $^{
m 31}$ ADRIANI 92E improves but does not supersede ADEVA 92, obtained with 1990 data only.

F(hadrons)

This parameter is not directly used in the 5-parameter fit assuming lepton universality, but is derived using the fit results. See the 'Note on the Z Boson.'

VALUE (MeV)

EVTS DOCUMENT ID TECN COMMENT

1740.7± 5.9 OUR					
• • • We do not i	use the followi	ng data for averag	es, fits	, limits,	etc. • • •
1723 ± 10	1.05M	ABREU	94	DLPH	E ^{ee} _{cm} = 88–94 GeV
1748 ± 10	1.09M	ACCIARRI	94	L3	E ^{ee} _{cm} = 88–94 GeV
1741 ± 10	1.19M	³³ AKERS	94	OPAL	E ^{ee} _{cm} = 88-94 GeV
1746 ±10	1.27M	BUSKULIC	94	ALEP	Eee = 88-94 GeV
1738 ±12	454k	³⁴ ACTON	93D	OPAL	Repl. by AKERS 94
1747 ±11	420k	ADRIANI	93F	L3	Repl. by ACCIARRI 94
1751 ±11		BUSKULIC	931	ALEP	Repl. by BUSKULIC 94
1741 ± 7	1.7M	³⁵ QUAST	93	RVUE	<i>E</i> ^{ee} cm = 88−94 GeV

 $^{^{33}}$ AKERS 94 assumes lepton universality. Without this assumption, it becomes 1742 \pm 11

Z BRANCHING RATIOS

$\Gamma(\text{hadrons})/\Gamma(e^+$	e-)				Γ_6/Γ_1
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
20.77 ± 0.08 OUR	FIT				
20.74 ± 0.18	31.4k	ABREU	94 [DLPH	Ecm = 88-94 GeV
20.96 ± 0.15	38k	ACCIARRI	94 l	L3	<i>E</i> ^{ee} _{cm} = 88−94 GeV
20.83 ± 0.16	42k	AKERS	94 (OPAL	Eee = 88-94 GeV
20.59 ± 0.15	45.8k	BUSKULIC	94	ALEP	Eee = 88-94 GeV
• • • We do not us	e the following da	ta for averages, f	its, lim	its, etc	
20.99 ± 0.25	17k	ACTON	93D (OPAL	Repl. by AKERS 94
20.69 ± 0.21		BUSKULIC	931 /	ALEP	Repl. by
20.92 ± 0.12	70k	³⁶ QUAST	93 I	RVUE	BUSKULIC 94 E ^{ee} _{cm} = 88-94 GeV
$27.0 \begin{array}{c} +11.7 \\ -8.8 \end{array}$	12	³⁷ ABRAMS	89D I	MRK2	Ecm = 89-93 GeV

³⁶ QUAST 93 is a combined analysis of LEP results as of Feb. 1993.

³² QUAST 93 is a combined analysis of LEP results as of Feb. 1993. Assumes lepton universality.

MeV. 34 ACTON 93D assumes lepton universality. Without this assumption it becomes 1743 \pm 15 MeV

MeV.

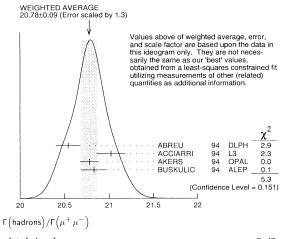
35 QUAST 93 is a combined analysis of LEP results as of Feb. 1993. Assumes lepton universality.

³⁷ ABRAMS 89D have included both statistical and systematic uncertainties in their quoted errors.

$\Gamma(\text{hadrons})/\Gamma(\mu^+\mu^-)$ VALUE 20.76 ± 0.07 OUR FIT	EVTS	DOCUMENT ID	<u>TECN</u>	Γ ₆ /Γ ₂
20.78±0.09 OUR AVERA	GE Error	includes scale fact	or of 1.3. See	the ideogram below.
20.54 ± 0.14	45.6k	ABREU	94 DLPH	E ^{ee} _{Cm} = 88–94 GeV
21.02 ± 0.16	34k	ACCIARRI	94 L3	E ^{ee} _{Cm} = 88–94 GeV
20.78 ± 0.11	57k	AKERS	94 OPAL	E ^{ee} _{CM} = 88–94 GeV
20.83 ± 0.15	46.4k	BUSKULIC	94 ALEP	E ^{ee} _{CM} = 88–94 GeV
• • • We do not use the	following da	ata for averages, f	its, limits, etc	. • • •
20.65 ± 0.17 20.88 ± 0.20	23k	ACTON BUSKULIC	93D OPAL 93J ALEP	Repl. by AKERS 94 Repl. by
20.79 ± 0.10	70k	³⁸ QUAST	93 RVUE	BUSKULIC 94 Eee = 88–94 GeV
$18.9 \begin{array}{c} +7.1 \\ -5.3 \end{array}$	13	³⁹ ABRAMS	89D MRK2	<i>E</i> ^{ee} _{cm} = 89−93 GeV

³⁸ QUAST 93 is a combined analysis of LEP results as of Feb. 1993.

³⁹ ABRAMS 89D have included both statistical and systematic uncertainties in their quoted



$\Gamma(\text{hadrons})/\Gamma(\tau^+\tau^-$)				Γ ₆ /Γ ₃
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
20.80±0.08 OUR FIT					
20.81 ± 0.08 OUR AVER	AGE				
20.68 ± 0.18	25k	ABREU	94	DLPH	<i>E</i> ^{ee} cm= 88–94 GeV
20.80 ± 0.20	25k	ACCIARRI	94	L3	E ^{ee} _{cm} = 88–94 GeV
21.01 ± 0.15	47k	AKERS	94	OPAL	E ^{ee} _{cm} = 88–94 GeV
20.70 ± 0.16	45.1k	BUSKULIC	94	ALEP	E ^{ee} _{Cm} = 88–94 GeV
• • • We do not use the	e following da	ata for averages, f	its, li	mits, etc	. • • •
21.22 ± 0.25	18k	ACTON	930	OPAL	Repl. by AKERS 94
20.77 ± 0.23		BUSKULIC	931	ALEP	Repl. by BUSKULIC 94
20.86 ± 0.13	50k	⁴⁰ QUAST	93	RVUE	E ^{ee} _{cm} = 88–94 GeV
$15.2 \begin{array}{c} +4.8 \\ -3.9 \end{array}$	21	⁴¹ ABRAMS	890	MRK2	<i>E</i> ^{ee} _{cm} = 89−93 GeV

⁴⁰ QUAST 93 is a combined analysis of LEP results as of Feb. 1993.

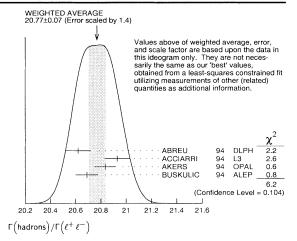
$\Gamma\big(\text{hadrons}\big)/\Gamma\big(\boldsymbol{\ell^+\ell^-}\big)$

 ℓ indicates each type of lepton $(e, \mu, \text{ and } \tau)$, not sum over them.

Our fit result is obtained requiring lepton universality.

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
20.76 ±0.05					
20.77 ±0.07	OUR AVERAGE	Error includes below.	scale 1	factor of	1.4. See the ideogram
20.62 ± 0.10	102k	ABREU	94	DLPH	E ^{ee} _{cm} = 88–94 GeV
20.93 ± 0.10	97k	ACCIARRI	94	L3	Ecm = 88-94 GeV
20.835 ± 0.086	146k	AKERS	94	OPAL	E ^{ee} _{cm} = 88-94 GeV
20.69 ± 0.09	137.3k	BUSKULIC	94	ALEP	E ^{ee} _{cm} = 88–94 GeV
• • • We do	not use the follow	ing data for ave	rages,	fits, limi	ts, etc. • • •
20.88 ± 0.13	58k	ACTON	93D	OPAL	Repl. by AKERS 94
21.00 ± 0.15	40k	ADRIANI	93N	1 L3	Repl. by ACCIARRI 94
20.78 ± 0.13		BUSKULIC	931	ALEP	Repl. by BUSKULIC 94
$20.87\ \pm0.07$	190k	⁴² QUAST	93	RVUE	E ^{ee} _{cm} = 88–94 GeV
$18.9 \begin{array}{r} +3.6 \\ -3.2 \end{array}$	46	ABRAMS	89B	MRK2	<i>E</i> ^{ee} _{cm} = 89−93 GeV

⁴² QUAST 93 is a combined analysis of LEP results as of Feb. 1993. Assumes lepton universality.



 $\Gamma(\text{hadrons})/\Gamma_{\text{total}}$ This parameter is not directly used in the overall fit but is derived using the fit results; see the 'Note on the Z Boson.' DOCUMENT ID TECN COMMENT

0.6990±0.0015 O	JR FIT			
• • • We do not	use the following data	for averages,	fits, limits, etc	. • • •
0.6983 ± 0.0023	1.14M	BUSKULIC	94 ALEP	$E_{cm}^{ee} = 88-94 \text{ Ge}^{-1}$

43 LEP 92 RVUE $E_{\text{Cm}}^{ee} = 88-94 \text{ GeV}$ 43 LEP 92 is combined analysis by the four LEP experiments as of December 1991. Systematic errors are included. Assumes lepton universality.

~ // 'total
This parameter is not directly used in the overall fit but is derived using the fit results; see the 'Note on the Z Boson.'

0.03366±0.00008 OUR FIT DOCUMENT ID TECN COMMENT • • • We do not use the following data for averages, fits, limits, etc. • •

 0.03383 ± 0.00013 45.8k BUSKULIC 94 ALEP *E*_{cm}^{ee} = 88-94 GeV 44 LEP 92 RVUE $E_{\text{cm}}^{ee} = 88-94 \text{ GeV}$ 0.03345 ± 0.00020

 44 LEP 92 is combined analysis by the four LEP experiments as of December 1991. Systematic errors are included.

 $\Gamma(\mu^+\mu^-)/\Gamma_{\text{total}}$ This parameter is not directly used in the overall fit but is derived using the fit results;

0.03367±0.00013 OUR FIT DOCUMENT ID TECN COMMENT

46.4k BUSKULIC 94 ALEP Ecm = 88-94 GeV 0.03344 ± 0.00026 ⁴⁵ LEP 92 RVUE $E_{\text{cm}}^{ee} = 88-94 \text{ GeV}$ 0.03351 ± 0.00034 21k

 $^{
m 45}$ LEP 92 is combined analysis by the four LEP experiments as of December 1991. Systematic errors are included.

 $\Gamma(\tau^+\tau^-)/\Gamma_{\text{total}}$ This parameter is not directly used in the overall fit but is derived using the fit results; see the 'Note on the Z Boson.'

WALUE EVIS DOCUMENT ID TECH CONSETT.

0.03360 ± 0.00015 OUR FIT

17k

 0.03366 ± 0.00028 45.1k BUSKULIC 94 ALEP Ecm = 88-94 GeV 46 LEP

92 RVUE $E_{\text{cm}}^{ee} = 88-94 \text{ GeV}$ $^{
m 46}$ LEP 92 is combined analysis by the four LEP experiments as of December 1991. Sys-

 $\Gamma(\ell^+\ell^-)/\Gamma_{\rm total} \atop \ell \ {\rm indicates\ each\ type\ of\ lepton\ } (e,\mu,{\rm\ and\ }\tau),{\rm\ not\ sum\ over\ them}.$ Γ_4/Γ

Our fit result assumes lepton universality.

This parameter is not directly used in the overall fit but is derived using the fit results; DOCUMENT ID TECN COMMENT

see the 'Note on the Z Boson.'

VALUE

0.03366±0.00006 OUR FIT

137.3k BUSKULIC 94 ALEP $E_{
m cm}^{ee} = 88-94 \; {
m GeV}$ 0.03375 ± 0.00009 57k 47 LEP 92 RVUE *E*^{ee}_{cm}= 88-94 GeV 0.03347 ± 0.00013

⁴⁷LEP 92 is combined analysis by the four LEP experiments as of December 1991. Systematic errors are included.

 Γ_5/Γ

 $\frac{\Gamma(invisible)}{\Gamma(total)}$ See the data, the note, and the fit result for the partial width, Γ_5 , above. DOCUMENT ID

<u>VALUE</u> 0.2001±0.0016 OUR FIT

 0.03328 ± 0.00040

 Γ_6/Γ_4

 $^{^{}m 41}$ ABRAMS 89D have included both statistical and systematic uncertainties in their quoted

see the 'Note on the Z Boson.'

<u>DOCUMENT ID</u>

1.000 ± 0.005 OUR FIT

 $\Gamma(\tau^+\tau^-)/\Gamma(e^+e^-)$ This parameter is not directly used in the overall fit but is derived using the fit results; see the 'Note on the ${\it Z}$ Boson.' DOCUMENT ID

0.998±0.005 OUR FIT

 $\Gamma((u\overline{u}+c\overline{c})/2)/\Gamma(\text{hadrons})$

This quantity is the branching ratio of $Z \to$ "up-type" quarks to $Z \to$ hadrons. The values of $Z \to$ "up-type" and $Z \to$ "down-type" branchings are extracted from measurements of $\Gamma(\text{hadrons})$, and $\Gamma(Z \to \gamma + \text{jets})$ where γ is a high-energy (>5 GeV) isolated photon. As the experiments use slightly different values of M_Z , $\Gamma(\text{hadrons})$ and α_s in their extraction procedures, our average has to be taken with caution.

VALUE	DOCUMENT ID	TECN	COMMENT
0.138±0.019 OUR AVERAGE			
$0.137 ^{+ 0.038}_{- 0.054}$	⁴⁸ ABREU	95x DLPH	<i>E</i> ^{ee} cm= 88−94 GeV
0.139 ± 0.026	⁴⁹ ACTON	93F OPAL	Ecm = 88-94 GeV
0.137 ± 0.033	⁵⁰ ADRIANI	93 L3	E ^{ee} _{Cm} = 91.2 GeV

- 48 ABREU 95x use $M_Z=$ 91.187 \pm 0.009 GeV, $\Gamma({\rm hadrons})=1725\pm12$ MeV and $\alpha_S=0.123\pm0.005$. To obtain this branching ratio we divide their value of $C_{2/3}=0.91^{+0.25}_{-0.36}$ by their value of (3 ${\it C}_{1/3}$ + 2 ${\it C}_{2/3}$) = 6.66 \pm 0.05.
- 49 ACTON 93F use the LEP 92 value of Γ(hadrons) = 1740 \pm 12 MeV and $lpha_{\mathcal{S}}$ = $0.122 + 0.006 \\ -0.005$
- 50 ADRIANI 93 use $M_Z=91.181\pm0.022$ GeV, $\Gamma({\rm hadrons})=1742\pm19$ MeV and $\alpha_S=0.125\pm0.009$. To obtain this branching ratio we divide their value of $C_{2/3}=0.92\pm0.22$ by their value of (3 $C_{1/3}$ + 2 $C_{2/3}$) = 6.720 \pm 0.076.

 $\Gamma((d\overline{d}+s\overline{s}+b\overline{b})/3)/\Gamma(\text{hadrons})$ This quantity is the branching ratio of $Z \to \text{"down-type"}$ quarks to $Z \to \text{hadrons}$. The values of $Z \to \text{"up-type"}$ and $Z \to \text{"down-type"}$ branchings are extracted from measurements of $\Gamma(\text{hadrons})$, and $\Gamma(Z \to \gamma + \text{jets})$ where γ is a high-energy (>5 GeV) isolated photon. As the experiments use slightly different values of M_Z , $\Gamma(\text{hadrons})$ and $\Gamma(Z \to \gamma + \text{jets})$ where $\Gamma(Z \to \gamma + \text{jets})$ is the taken with caution. and α_s in their extraction procedures, our average has to be taken with caution.

VALUE	DOCUMENT ID	TECN	COMMENT
0.242±0.012 OUR AVERAGE			
$0.243 + 0.036 \\ -0.026$	⁵¹ ABREU	95x DLPH	<i>E</i> ^{ee} _{CM} = 88–94 GeV
0.241 ± 0.017	⁵² ACTON	93F OPAL	<i>E</i> ^{ee} cm= 88−94 GeV
0.243 ± 0.022	⁵³ ADRIANI	93 L3	E ^{ee} _{CM} = 91.2 GeV

- 51 ABREU 95x use $M_Z=91.187\pm0.009$ GeV, $\Gamma({
 m hadrons})=1725\pm12$ MeV and $lpha_S$ 0.123 \pm 0.005. To obtain this branching ratio we divide their value of $C_{1/3}=1.62 {+0.24 \atop -0.17}$ by their value of (3 ${\it C}_{1/3}$ + 2 ${\it C}_{2/3}$) = 6.66 \pm 0.05.
- 52 ACTON 93F use the LEP 92 value of $\Gamma(\text{hadrons}) = 1740 \pm 12$ MeV and $\alpha_s =$ $0.122 + 0.006 \\ -0.005$
- $^{-0.005}$ ADRIANI 93 use $M_Z=91.181\pm0.022$ GeV, $\Gamma({\rm hadrons})=1742\pm19$ MeV and $\alpha_S=0.125\pm0.009$. To obtain this branching ratio we divide their value of $C_{1/3}=1.63\pm0.15$ by their value of (3 $C_{1/3}$ + 2 $C_{2/3}$) = 6.720 \pm 0.076.

 $R_c = \Gamma(c\overline{c})/\Gamma(\text{hadrons})$ OUR FIT is obtained by a simultaneous fit to several c- and b-quark measurements as explained in the "Note on the Z boson." As a cross check we have also performed a weighted average of the $R_{\mathcal{C}}$ measurements taking into account the various common systematic errors. Assuming that the smallest common systematic error is fully correlated, we obtain $R_{\it C} = 0.157 \pm 0.010$.

Because of the high current interest, we mention the following preliminary results here, but do not average them or include them in the Listings or Tables. Combining published and unpublished preliminary LEP and SLD electroweak results (as of end of March 1996) yields $R_c=0.1598\pm0.0069$. This value appears to be 1.8 s.d. below its Standard Model prediction of 0.1725 for $m_t=175$ GeV and $M_H=300$ GeV.

VALUE	DOCUMENT ID	TECN	COMMENT
0.158 ±0.010 OUR FIT			
$0.1623 \pm 0.0085 \pm 0.0209$	⁵⁴ ABREU	95D DLPH	E ^{ee} _{cm} = 88-94 GeV
$0.142 \pm 0.008 \pm 0.014$	⁵⁵ AKERS	950 OPAL	E ^{ee} _{cm} = 88-94 GeV
$0.165 \pm 0.005 \pm 0.020$	⁵⁶ BUSKULIC	94G ALEP	E ^{ee} _{cm} = 88–94 GeV
$0.187\ \pm0.031\ \pm0.023$	⁵⁷ ABREU	931 DLPH	<i>E</i> ^{ee} _{cm} = 88−94 GeV
• • We do not use the	following data for	averages, fits,	limits, etc. • • •
$0.151\ \pm0.008\ \pm0.041$	⁵⁸ ABREU	920 DLPH	E ^{ee} _{Cm} = 88–94 GeV

- 54 ABREU 95D perform a maximum likelihood fit to the combined p and $p_{\mathcal{T}}$ distributions does not single and dilepton samples. The second error includes an uncertainty of ± 0.0124 due to models and branching ratios.
- 55 AKERS 950 use the presence of a $D^{*\pm}$ to tag $Z \to c \bar{c}$ with $D^* \to D^0 \pi$ and $D^0 \to D^0 \pi$ $K\pi$. They measure $P_c*\Gamma(c\overline{c})/\Gamma(\text{hadrons})$ to be $(1.006\pm0.055\pm0.061)\times10^{-3}$, where P_c is the product branching ratio $B(c \to D^+)B(D^+ \to D^0\pi)B(D^0 \to K\pi)$. Assuming that P_c remains unchanged with energy, they use its value $(7.1\pm0.5)\times 10^{-3}$ determined at CESR/PETRA to obtain $\Gamma(c7)/\Gamma(\text{hadrons})$. The second error of AKERS 950 includes an uncertainty of ± 0.011 from the uncertainty on P_c .
- 56 BUSKULIC 94G perform a simultaneous fit to the p and $p_{\mathcal{T}}$ spectra of both single and dilepton events

- 57 ABREU 93I assume that the D_{S} and charmed baryons are equally produced at LEP and
- 58 ABREU 920 use the neural network techinque to tag heavy flavour events among a ABNEO 920 use the feeting flework technique to day fleavy indoor events among a sample of 123k selected hadronic events. The systematic error consists of three parts: due to Monte Carlo (MC) parametrization (0.023), choice of MC model (0.033) and detector effects (0.009) added in quadrature.

$R_b = \Gamma(b\overline{b})/\Gamma(\text{hadrons})$

 Γ_{10}/Γ_{6}

OUR FIT is obtained by a simultaneous fit to several c- and b-quark measurements as explained in the "Note on the Z boson." As a cross check we have also performed a weighted average of the $R_{m{b}}$ measurements taking into account the various common systematic errors. We have assumed that the smallest common systematic error is fully correlated. For $R_{\rm C}=0.158$ (as given by OUR FIT above), we obtain $R_{\rm b}=0.2213\pm$ 0.0019. For an expected Standard Model value of $R_C=0.172$, our weighted average gives $R_b=0.2200\pm0.0019$ while OUR FIT value becomes $R_b=0.2202\pm0.0018$.

Because of the high current interest, we mention the following preliminary results here, but do not average them or include them in the Listings or Tables. Combining published and unpublished preliminary LEP and SLD electroweak results (as of end of March 1996) yields $R_{\rm b}=0.2211\pm0.0016$. This value appears to be 3.5 s.d. above its Standard Model prediction of 0.2155 for $m_t=175$ GeV and $M_H=300$ GeV (this apparent discrepancy has led to some speculation concerning new physics beyond the

VALUE		/TS	DOCUMENT ID		TECN	COMMENT
0.2212 ± 0.0019	OUR FIT					
0.2216 ± 0.0016	± 0.0021	59	ABREU	96	DLPH	$E_{cm}^{ee} = 88-94 \text{ GeV}$
0.2145 ± 0.0089	± 0.0067	60	ABREU	95D	DLPH	Ecm = 88-94 GeV
0.2171 ± 0.0021	± 0.0021	61	AKERS	95в	OPAL	Eee = 88-94 GeV
0.219 ± 0.006	± 0.005	62	BUSKULIC	94G	ALEP	Eee = 88-94 GeV
0.222 ± 0.003	± 0.007	63	ADRIANI	93E	L3	Eee = 88-94 GeV
0.222 ± 0.011	± 0.007	64	AKERS	93B	OPAL	E ^{ee} _{cm} = 88-94 GeV
0.2192 ± 0.0022	± 0.0031	65	BUSKULIC	93м	ALEP	Ecm = 91.3 GeV
$0.228\ \pm0.005$	± 0.005	66	BUSKULIC	93N	ALEP	Eee = 88-94 GeV
0.251 ± 0.049	± 0.030	32 67	JACOBSEN	91	MRK2	Eee 91 GeV
• • • We do no	ot use the fo	ollowing d	ata for averages	, fits,	limits,	etc. • • •
0.2217 ± 0.0020	± 0.0033			95 D	DLPH	Repl. by ABREU 96
0.2241 ± 0.0063	± 0.0046			95 J	DLPH	Repl. by ABREU 96
0.218 ± 0.006	± 0.010			94D	OPAL	Repl. by AKERS 95B
0.220 ± 0.002	±0.013 118	393 71	ACTON	931	OPAL	Repl. by AKERS 95B
0.222 ± 0.007	± 0.008	72	ACTON	93м	OPAL	Repl. by AKERS 958
$0.222 \begin{array}{c} +0.033 \\ -0.031 \end{array}$	± 0.017	73	ABREU	92	DLPH	<i>E</i> ^{ee} _{cm} = 88−94 GeV
0.219 ± 0.014	± 0.019	74	ABREU	92K	DLPH	Eee = 88-94 GeV
$0.232\ \pm0.005$	± 0.017	75	ABREU	92 0	DLPH	E ^{ee} _{cm} = 88-94 GeV
$0.23 \begin{array}{c} +0.10 \\ -0.08 \end{array}$	+0.05 -0.04	₁₅ 76	KRAL	90	MRK2	E ^{ee} _{cm} = 89–93 GeV

- ⁵⁹ ABREU 96 obtain this result combining several analyses (double lifetime tag, mixed tag and multivariate analysis). This value is obtained assuming $R_c = \Gamma(c\,\overline{c})/\Gamma(\text{hadrons}) = 0.172$. For a value of R_c different from this by an amount ΔR_c the change in the value is given by $-0.087 \cdot \Delta R_c$.
- 60 ABREU 95D perform a maximum likelihood fit to the combined ρ and ρ_T distributions of single and dilepton samples. The second error includes an uncertainty of ± 0.0023 due to models and branching ratios.
- 61 AKERS 958 select events based on the lepton and/or vertex tag independently in each hemisphere. Comparing the numbers of single- and double-tagged events, they determine
- the b-tagging efficiency directly from data. ⁶² BUSKULIC 94G perform a simultaneous fit to the ρ and ρ_T spectra of both single and dilepton events.
- 63 ADRIANI 93E use a multidimensional analysis based on a neural network approach.
- 64 AKERS 93B use a simultaneous fit to single and dilepton events (electrons and muons) to tag $Z \to b \bar{b}$.
- 65 BUSKULIC 93M use a method which tags the $Z \to b\bar{b}$ decays through the lifetime of the produced heavy hadrons. The systematic error includes a contribution of ± 0.0016 due to the uncertainty of the charm partial width.
- 66 BUSKULIC 93N use event shape and high p_T lepton discriminators applied to both
- 67 JACOBSEN 91 tagged $b\overline{b}$ events by requiring coincidence of \geq 3 tracks with significant impact parameters using vertex detector. Systematic error includes lifetime and decay uncertainties (± 0.014).
- 68 ABREU 950 obtain this result combining several analyses (double-lifetime tag and mixed tags). The second error contains an uncertainty of ± 0.0029 due to the total systematics and an uncertainty of ± 0.0019 due to the total systematics and an uncertainty of ± 0.0016 due to an 8% variation of $\Gamma(c\overline{c})/\Gamma(hadrons)$ around its Standard Model value (0.171 ± 0.014). Combining with their own lepton analysis, ABREU 950 obtain 0.2210 $\pm 0.0033 \pm 0.0003$ (models) ± 0.0014 [$\Gamma(c\overline{c})/\Gamma(hadrons)$].
- particle trajectories near the interaction point. The second error contains an uncertainty of ± 0.0012 due to an 8% variation of $\Gamma(c\,\overline{c})/\Gamma(\text{hadrons})$ around its Standard Model value (0.171 $\pm\,0.014)$.
- value (0.171 \pm 0.014). 70 AKERS 94D perform an analysis based on a "mixed tag" method (impact parameter and lepton tagging). The systematic error includes a contribution (\pm 0.007) due to the $\Gamma(c\bar{c})/\Gamma(\text{hadrons})$ uncertainty. 71 ACTON 931 use both electrons and muons to tag B semileptonic decays. The systematic
- error includes components due to b and c quark fragmentation uncertainties, decay branching ratios, and $\Gamma(c\overline{c})/\Gamma(\text{hadrons})$.
- 72 ACTON 93M tagged $Z \to b\bar{b}$ events using the impact parameter technique. 73 ABREU 92 result is from an indirect technique. They measure the lifetime τ_B , but use a world average of au_B independent of $\Gamma(b\,\overline{b})$ and compare to their $\Gamma(b\,\overline{b})$ dependent lifetime from a hadron sample.
- The ABREU 92K use boosted—sphericity technique to tag and enrich the $b \cdot \overline{b}$ content with a sample of 50k hadronic events. Most of the systematic error is from hadronization uncertainty.

detector effects (0.	lo (MC) p	arametrization (0.0		or consists of three parts: of MC model (0.008), and	<u>VALUE (units 10⁻³) </u>
76 45 44 40 41 1	.011) adde	d in quadrature.) (E(1.1.1)	+ 0.07 ± 0.04	1.6 $\pm 0.3 \pm 0.2$ 46.9 ⁸⁴ ALEXANDER 96B OPAL $E_{\rm cm}^{\rm ee} = 88-94$ GeV
⁷⁶ KRAL 90 used isola	ated lepto	ns and found 1 (DD)/! (total) = !		1.60 ± 0.73 ± 0.33 5.4 85 ABREU 94P DLPH $E_{\text{CM}}^{ee} = 88-94 \text{ GeV}$
$(\pi^0 \gamma)/\Gamma_{\text{total}}$				Γ ₁₁ /Γ	84 ALEXANDER 96B measure this branching ratio via the decay channel $\psi(2S)$
ALUE 5	<u>CL%</u> _	DOCUMENT ID	TECN	COMMENT	$J/\psi \pi^+ \pi^-$, with $J/\psi \to \ell^+ \ell^-$.
<5.2 × 10 ⁻⁵	95	77 ACCIARRI	95G L3	E ^{ee} _{cm} = 88–94 GeV	85 ABREU 94P measure this branching ratio via decay channel $\psi(25) o J/\psi \pi^+ \pi^-$, v $J/\psi o \mu^+ \mu^-$.
(5.5×10^{-5}) (2.1×10^{-4})	95	ABREU		Ecm = 88-94 GeV	
	95	DECAMP		E ^{ee} _{cm} = 88–94 GeV	$\Gamma(\chi_{c1}(1P)X)/\Gamma_{total}$ Γ_{21}
(1.4×10^{-4})	95	AKRAWY		E ^{ee} _{Cm} = 88–94 GeV	VALUE (units 10 ⁻³) EVTS DOCUMENT ID TECN COMMENT
• • We do not use t					6.0±1.9 OUR AVERAGE
(1.2×10^{-4})	95	⁷⁸ ADRIANI	92B L3	Repl. by ACCIARRI 95G	$5.0 \pm 2.1 ^{+1.5}_{-0.9}$ 6.4 86 ABREU 94P DLPH $E^{ee}_{cm} = 88-94$ GeV
This limit is for bot	th decay n	nodes $Z \to \pi^{U} \gamma/\gamma$	γ which are i	ndistinguishable in ACCIA-	7.5 \pm 2.9 \pm 0.6 19 86 ADRIANI 93J L3 E_{cm}^{ee} = 88-94 GeV
RRI 95G. ⁷⁸ This limit is for bo ANI 92B.	th decay r	modes $Z \to \pi^0 \gamma/\gamma$	$\gamma\gamma$ which are	indistinguishable in ADRI-	⁸⁶ This branching ratio is measured via the decay channel $\chi_{c1} \to J/\psi + \gamma$, with $J/\psi = \mu^+\mu^-$.
$(\eta \gamma)/\Gamma_{total}$				Γ ₁₂ /Γ	
ALUE	CL%	DOCUMENT ID	TECN	COMMENT	• • • • • • • • • • • • • • • • • • • •
$< 7.6 \times 10^{-5}$	95	ACCIARRI	95G L3	<i>E</i> ee = 88–94 GeV	VALUE (units 10 ⁻⁴) EVTS DOCUMENT ID TECN COMMENT
$< 8.0 \times 10^{-5}$	95	ABREU	94B DLPH	<i>E</i> ^{ee} _{cm} = 88–94 GeV	1.0±0.4±0.22 6.4 87 ALEXANDER 96F OPAL Eee 88-94 GeV
<5.1 × 10 ⁻⁵	95	DECAMP		<i>E</i> ^{ee} _{cm} = 88−94 GeV	87 ALEXANDER 96F identify the Υ (which refers to any of the three lowest bound sta
$< 2.0 \times 10^{-4}$	95	AKRAWY	91F OPAL	E ^{ee} _{cm} = 88–94 GeV	through its decay into e^+e^- and $\mu^+\mu^-$. The systematic error includes an uncertainty e^+e^- and $e^+\mu^-$.
• • We do not use t	the followi	ng data for average	es, fits, limits,	etc. • • •	of ± 0.2 due to the production mechanism.
$<1.8 \times 10^{-4}$	95	ADRIANI	92B L3	Repl. by ACCIARRI 95G	$\Gamma((D^0/\overline{D^0})X)/\Gamma(\text{hadrons})$ VALUE EVIS DOCUMENT ID TECN COMMENT
$\Gamma(\omega \gamma)/\Gamma_{total}$				Γ ₁₃ /Γ	0.296±0.019±0.021 369 88 ABREU 931 DLPH Eee 88-94 GeV
<6.5 × 10 ⁻⁴	<u>CL%</u> 95	DOCUMENT ID ABREU		$\frac{COMMENT}{E_{CM}^{ee}} = 88-94 \text{ GeV}$	88 The (D^0/\bar{D}^0) states in ABREU 931 are detected by the $K\pi$ decay mode. This corrected result (see the erratum of ABREU 931).
$(\eta'(958)\gamma)/\Gamma_{\text{total}}$		0.0004547.10		Γ ₁₄ /Γ	$\Gamma(D^{\pm}X)/\Gamma(\text{hadrons})$
ALUE 5	CL%	DOCUMENT ID	TECN	COMMENT	VALUE EVTS DOCUMENT ID TECN COMMENT
<4.2 × 10 ⁻⁵	95	DECAMP	92 ALEP	E ^{ee} _{cm} = 88–94 GeV	0.174±0.016±0.018 539 ⁸⁹ ABREU 931 DLPH <i>E</i> ^{ee} _{CM} = 88–94 GeV
$(\gamma \gamma)/\Gamma_{\text{total}}$	4			Γ ₁₅ /Γ	⁸⁹ The D^{\pm} states in ABREU 931 are detected by the $K\pi\pi$ decay mode. This is a correct result (see the erratum of ABREU 931).
ALUE This decay would	d violate t 	he Landau-Yang th DOCUMENT ID	eorem. <u>TECN</u>	COMMENT	Γ(D*(2010)±V) /Γ(hadrone)
					$\Gamma(D^*(2010)^{\pm}X)/\Gamma(\text{hadrons})$ Γ_{25}
<5.2 × 10 ⁻⁵	95		956 3	F55 88-94 GeV	The value is for the sum of the charge states indicated.
	95 95	⁷⁹ ACCIARRI ABREU	95G L3 94B DI PH	Eem = 88-94 GeV	The value is for the sum of the charge states indicated. <u>VALUE</u> <u>EVTS</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u>
$< 5.5 \times 10^{-5}$	95	ABREU	948 DLPH	Eee = 88-94 GeV	VALUE EVTS DOCUMENT ID TECN COMMENT 0.163±0.019 OUR AVERAGE Error includes scale factor of 1.3.
$<5.5 \times 10^{-5}$ $<1.4 \times 10^{-4}$	95 95	ABREU AKRAWY	948 DLPH 91F OPAL	$E_{\text{Cm}}^{ee} = 88-94 \text{ GeV}$ $E_{\text{Cm}}^{ee} = 88-94 \text{ GeV}$	VALUEEVTSDOCUMENT IDTECNCOMMENT0.163 \pm 0.019 OUR AVERAGEError includes scale factor of 1.3.0.155 \pm 0.010 \pm 0.01335890 ABREU93 DLPH E_{CM}^{ee} = 88-94 GeV
$<5.5 \times 10^{-5}$ <1.4 × 10 ⁻⁴ • • We do not use to	95 95 the follow	ABREU AKRAWY ing data for average	948 DLPH 91F OPAL es, fits, limits,	$E_{\text{Cm}}^{ee} = 88-94 \text{ GeV}$ $E_{\text{Cm}}^{ee} = 88-94 \text{ GeV}$ etc. • •	VALUE EVTS DOCUMENT ID TECN COMMENT 0.163±0.019 OUR AVERAGE Error includes scale factor of 1.3. 20.155±0.010±0.013 358 90 ABREU 93I DLPH Ecm = 88-94 GeV 0.21 ±0.04 362 91 DECAMP 91J ALEP Ecm = 88-94 GeV
$<5.5 \times 10^{-5}$ $<1.4 \times 10^{-4}$ • • • We do not use the contraction of the contracti	95 95 the follow 95	ABREU AKRAWY ing data for averago ⁸⁰ ADRIANI	94B DLPH 91F OPAL es, fits, limits, 92B L3	$E_{\rm CM}^{ee}=88-94~{\rm GeV}$ $E_{\rm CM}^{ee}=88-94~{\rm GeV}$ etc. • • • Repl. by ACCIARRI 95G	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
<5.5 × 10 ⁻⁵ <1.4 × 10 ⁻⁴ • • We do not use to expension of the control of the	95 95 the followi 95 th decay n	ABREU AKRAWY ing data for average 80 ADRIANI modes $Z ightarrow \pi^0 \gamma/\gamma$	948 DLPH 91F OPAL es, fits, limits, 928 L3 ry which are i	$E_{\rm CM}^{\rm ee}=88-94~{\rm GeV}$ $E_{\rm CM}^{\rm ee}=88-94~{\rm GeV}$ etc. • • • Repl. by ACCIARRI 95G addistinguishable in ACCIA-indistinguishable in ADRI-	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
$<5.5 \times 10^{-5}$ $<1.4 \times 10^{-4}$ • • We do not use to $<1.2 \times 10^{-4}$ 79 This limit is for bot RRI 95G. 80 This limit is for bot ANI 92B. $= (\gamma \gamma \gamma)/\Gamma_{\text{total}}$	95 95 the followi 95 th decay n	ABREU AKRAWY ing data for average 80 ADRIANI modes $Z ightarrow \pi^0 \gamma/\gamma$	948 DLPH 91F OPAL es, fits, limits, 928 L3 ry which are i	$E_{\rm CM}^{\rm ee}=88-94~{\rm GeV}$ $E_{\rm CM}^{\rm ee}=88-94~{\rm GeV}$ etc. • • • Repl. by ACCIARRI 95G addistinguishable in ACCIA-indistinguishable in ADRI-	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
<5.5 × 10 ⁻⁵ <1.4 × 10 ⁻⁴ • • • We do not use to constant the constant that the	95 95 the following 95 th decay noth decay 1	ABREU AKRAWY ing data for average 80 ADRIANI nodes $Z ightarrow \pi^0 \gamma/\gamma$ modes $Z ightarrow \pi^0 \gamma/\gamma$	948 DLPH 91F OPAL es, fits, limits, 928 L3 γ which are i $\gamma\gamma$ which are	$E_{\rm CM}^{\rm ee} = 88-94~{\rm GeV}$ $E_{\rm CM}^{\rm ee} = 88-94~{\rm GeV}$ etc. • • • Repl. by ACCIARRI 95G addistinguishable in ACCIA-indistinguishable in ADRI- $\Gamma_{16}/\Gamma_{\rm COMMENT}$	December 1 December 2 December 3 De
<5.5 × 10 ⁻⁵ < 1.4 × 10 ⁻⁴ • • We do not use to the condition of the	95 95 the following 95 th decay noth decay 1	ABREU AKRAWY AKRAWY ing data for average 80 ADRIANI nodes $Z \rightarrow \pi^0 \gamma/\gamma$ nodes $Z \rightarrow \pi^0 \gamma/\gamma$	948 DLPH 91F OPAL es, fits, limits, 928 L3 $\gamma \gamma$ which are i $\gamma \gamma \gamma$ which are $\frac{TECN}{95C L3}$	$E_{\rm CM}^{\rm ee}=88-94~{\rm GeV}$ $E_{\rm CM}^{\rm ee}=88-94~{\rm GeV}$ etc. • • • Repl. by ACCIARRI 956 adistinguishable in ACCIA- indistinguishable in ADRI- $\Gamma_{16}/\Gamma_{COMMENT}$ $E_{\rm CM}^{\rm ee}=88-94~{\rm GeV}$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
<5.5 × 10 ⁻⁵ < 1.4 × 10 ⁻⁴ • • We do not use 1 < 1.2 × 10 ⁻⁴ 79 This limit is for bot RRI 956. 80 This limit is for bot ANI 928. $(\gamma\gamma\gamma)/\Gamma$ total ALUE < 1.0 × 10 ⁻⁵ < 1.7 × 10 ⁻⁵	95 95 the following 95 th decay noth decay noth decay nother decay not	ABREU AKRAWY ing data for average 80 ADRIANI modes $Z \rightarrow \pi^0 \gamma/\gamma$ modes $Z \rightarrow \pi^0 \gamma/\gamma$ $\frac{DOCUMENT~ID}{81}$ ACCIARRI 81 ABREU	948 DLPH 91F OPAL es, fits, limits, 928 L3 $\gamma \gamma$ which are i $\gamma \gamma \gamma$ which are TECN 95C L3 948 DLPH	$E_{\rm CM}^{\rm ee} = 88-94~{\rm GeV}$ $E_{\rm CM}^{\rm ee} = 88-94~{\rm GeV}$ etc. • • • Repl. by ACCIARRI 95G addistinguishable in ACCIA- indistinguishable in ADRI- $\frac{\Gamma_{16}/\Gamma}{E_{\rm CM}^{\rm em} = 88-94~{\rm GeV}}$ $E_{\rm CM}^{\rm ee} = 88-94~{\rm GeV}$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
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<5.5 × 10 ⁻⁵ <1.4 × 10 ⁻⁴ • • We do not use 19 <1.2 × 10 ⁻⁴ 79 This limit is for both RRI 95G. 80 This limit is for both ANI 92B. $(\gamma \gamma \gamma)/\Gamma_{\text{total}}$ $(ALUE)$ <1.0 × 10 ⁻⁵ <1.7 × 10 ⁻⁵ <6.6 × 10 ⁻⁵ • • We do not use 19 <3.3 × 10 ⁻⁵ 81 Limit derived in the control of the value is for ANI UE (7×10^{-5}) (7×10^{-5}) (7×10^{-5}) (81×10^{-5}) (81×10^{-5}) (81×10^{-5}) (7×10^{-5}) (81×10^{-5}) (83×10^{-5}) (83×10^{-5}) (83×10^{-5})	95 95 95 the followi 95 th decay n th decay n CL% 95 95 95 the followi 95 te context the sum o CL% 95 the sum o CL% 95	ABREU AKRAWY ing data for average 80 ADRIANI incides $Z \rightarrow \pi^0 \gamma/\gamma$ modes $Z \rightarrow \pi^0 \gamma/\gamma$ POCUMENT ID 81 ACCIARRI 81 ABREU AKRAWY ing data for average ADRIANI of composite Z mo of the charge states POCUMENT ID DECAMP of the charge states POCUMENT ID DECAMP	948 DLPH 91F OPAL es, fits, limits, 92B L3 γγ which are i γγγ which are i γγγ which are i 95C L3 94B DLPH 91F OPAL es, fits, limits, 92B L3 odel. indicated.	$E_{\rm cm}^{\rm ee} = 88-94~{\rm GeV}$ $E_{\rm cm}^{\rm ee} = 88-94~{\rm GeV}$ etc. • • • Repl. by ACCIARRI 95G addistinguishable in ACCIA- indistinguishable in ADRI- Γ_{16}/Γ $\frac{COMMENT}{E_{\rm cm}^{\rm ee}} = 88-94~{\rm GeV}$ $E_{\rm cm}^{\rm ee} = 88-94~{\rm GeV}$ etc. • • • Repl. by ACCIARRI 95C Γ_{17}/Γ $\frac{COMMENT}{E_{\rm cm}^{\rm ee}} = 88-94~{\rm GeV}$ Γ_{18}/Γ $\frac{COMMENT}{E_{\rm cm}^{\rm ee}} = 88-94~{\rm GeV}$ Γ_{18}/Γ $\frac{COMMENT}{E_{\rm cm}^{\rm ee}} = 88-94~{\rm GeV}$	0.163±0.019 OUR AVERAGE Error includes scale factor of 1.3. 0.155±0.010±0.013 358 90 ABREU 93! DLPH E_{CR}^{ep} = 88-94 GeV 0.21 ±0.04 362 91 DECAMP 91 J ALEP E_{CR}^{ep} = 88-94 GeV 0.21 ±0.04 362 91 DECAMP 91 J ALEP E_{CR}^{ep} = 88-94 GeV 0.21 ±0.04 362 91 DECAMP 91 J ALEP E_{CR}^{ep} = 88-94 GeV 0.20 P^{e} (2010) 10 In ABREU 93! are reconstructed from P^{e} 4. with P^{e} 68.1 ± 1.6) % is used. This corrected result (see the erratum of ABREU 93!). 91 DECAMP 91 report B(P^{e} (2010) + → P^{e} P^{e} 68.1 ± 1.6) % is used. This corrected result (see the erratum of ABREU 93!). 91 DECAMP 91 report B(P^{e} (2010) + → P^{e}
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$<5.5 \times 10^{-5}$ $<1.4 \times 10^{-4}$ • • We do not use if $<1.2 \times 10^{-4}$ 79 This limit is for bot RRI 95G. 80 This limit is for bot ANI 92B. $<(7\gamma\gamma)/\Gamma$ total ALUE $<1.0 \times 10^{-5}$ $<1.7 \times 10^{-5}$ $<1.6 \times 10^{-5}$ 81 Limit derived in the Tre value is for ALUE $<7\times 10^{-5}$ $<7\times 10$	95 95 95 the followings 95 th decay in the followings 95 the followings 95 the context the sum of	ABREU AKRAWY ing data for average 80 ADRIANI incides $Z \rightarrow \pi^0 \gamma/\gamma$ modes $Z \rightarrow \pi^0 \gamma/\gamma$ POCUMENT ID 81 ACCIARRI 81 ABREU AKRAWY ing data for average ADRIANI of composite Z mo of the charge states POCUMENT ID DECAMP of the charge states POCUMENT ID DECAMP	948 DLPH 91F OPAL es, fits, limits, 928 L3 γγ which are i γγγ which are i γγγ which are i β5C L3 948 DLPH 91F OPAL es, fits, limits, 928 L3 odel. indicated.	$E_{\rm cm}^{\rm ee} = 88-94~{\rm GeV}$ $E_{\rm cm}^{\rm ee} = 88-94~{\rm GeV}$ etc. • • • Repl. by ACCIARRI 95G addistinguishable in ACCIA- indistinguishable in ADRI- Γ_{16}/Γ $\frac{COMMENT}{E_{\rm cm}^{\rm ee}} = 88-94~{\rm GeV}$ $E_{\rm cm}^{\rm ee} = 88-94~{\rm GeV}$ etc. • • • Repl. by ACCIARRI 95C Γ_{17}/Γ $\frac{COMMENT}{E_{\rm cm}^{\rm ee}} = 88-94~{\rm GeV}$ Γ_{18}/Γ $\frac{COMMENT}{E_{\rm cm}^{\rm ee}} = 88-94~{\rm GeV}$ Γ_{18}/Γ $\frac{COMMENT}{E_{\rm cm}^{\rm ee}} = 88-94~{\rm GeV}$	0.163±0.019 OUR AVERAGE Error includes scale factor of 1.3. 0.155±0.010±0.013 358 90 ABREU 93! DLPH $E_{\rm CM}^{\rm ep}$ = 88–94 GeV 0.21 ±0.04 362 91 DECAMP 91 J ALEP $E_{\rm CM}^{\rm ep}$ = 88–94 GeV 0.21 ±0.04 362 91 DECAMP 91 J ALEP $E_{\rm CM}^{\rm ep}$ = 88–94 GeV 0.21 ±0.04 362 91 DECAMP 91 J ALEP $E_{\rm CM}^{\rm ep}$ = 88–94 GeV 0.20 $E_{\rm CM}^{\rm ep}$ 90 $E_{\rm CM}^{\rm ep}$ 91 ABREU 93! are reconstructed from $E_{\rm CM}^{\rm ep}$ 91 J ALEP $E_{\rm CM}^{\rm ep}$ 90 $E_{\rm CM}^{\rm ep}$ 91 ABREU 93! are reconstructed from $E_{\rm CM}^{\rm ep}$ 91 ALEP $E_{\rm CM}^{\rm ep}$ 92 (68.1 ± 1.6) % is used. This corrected result (see the eratum of ABREU 93!). 91 DECAMP 91J report B($E_{\rm CM}^{\rm ep}$ 90 $E_{\rm CM}^{\rm ep}$ 91 ABREU 92 MD OBMENT 92 ABREU 92 MD OBMENT 93 BUSKULIC 94 ABREU 94 ABREU 95 MD OBMENT
<5.5 × 10 ⁻⁵ <1.4 × 10 ⁻⁴ •• We do not use to close 1.2 × 10 ⁻⁴ 79 This limit is for both RRI 956. 80 This limit is for both ANI 928. $\Gamma(\gamma\gamma\gamma)/\Gamma$ total CALUE 1.0 × 10 ⁻⁵ <1.7 × 10 ⁻⁵ <6.6 × 10 ⁻⁵ •• We do not use to close 1.3 × 10 ⁻⁵ 81 Limit derived in the control of the contr	95 95 95 the followings 10	ABREU AKRAWY ing data for average 80 ADRIANI inodes $Z \rightarrow \pi^0 \gamma/\gamma$ modes $Z \rightarrow \pi^0 \gamma/\gamma$ POCUMENT ID ARRIVATION OF COMPOSITE Z modes of the charge states DOCUMENT ID DECAMP 181 ABREU AKRAWY ADRIANI OF COMPOSITE Z modes of the charge states DOCUMENT ID DECAMP 182 ALEXANDER	948 DLPH 91F OPAL es, fits, limits, 928 L3 γγ which are i γγγ which are i γγγ which are i β5C L3 948 DLPH 91F OPAL es, fits, limits, 928 L3 odel. indicated.	$E_{\rm cm}^{\rm ee}=88-94~{\rm GeV}$ $E_{\rm cm}^{\rm ee}=88-94~{\rm GeV}$ etc. • • • Repl. by ACCIARRI 95G ndistinguishable in ACCIA- indistinguishable in ADRI- Γ_{16}/Γ $\frac{COMMENT}{E_{\rm cm}^{\rm ee}=88-94~{\rm GeV}}$ $E_{\rm cm}^{\rm ee}=88-94~{\rm GeV}$ etc. • • • Repl. by ACCIARRI 95C Γ_{17}/Γ $\frac{COMMENT}{E_{\rm cm}^{\rm ee}=88-94~{\rm GeV}}$ Γ_{18}/Γ $\frac{COMMENT}{E_{\rm cm}^{\rm ee}=88-94~{\rm GeV}}$ Γ_{19}/Γ $\frac{COMMENT}{E_{\rm cm}^{\rm ee}=88-94~{\rm GeV}}$	0.163±0.019 OUR AVERAGE Error includes scale factor of 1.3. 0.155±0.010±0.013 358 90 ABREU 93! DLPH $E_{\rm CM}^{\rm ep}$ = 88–94 GeV 0.21 ±0.04 362 91 DECAMP 91 J ALEP $E_{\rm CM}^{\rm ep}$ = 88–94 GeV 0.21 ±0.04 362 91 DECAMP 91 J ALEP $E_{\rm CM}^{\rm ep}$ = 88–94 GeV 0.21 ±0.04 362 91 DECAMP 91 J ALEP $E_{\rm CM}^{\rm ep}$ = 88–94 GeV 0.20 $E_{\rm CM}^{\rm ep}$ = 80 J ABREU 93! are reconstructed from $E_{\rm CM}^{\rm ep}$ = 1.6) % is used. This corrected result (see the erratum of ABREU 93I). 0.10 DECAMP 91 J report B($E_{\rm CM}^{\rm ep}$ = 0.0 π + 1) B($E_{\rm CM}^{\rm ep}$ = 1.6) % is used. This corrected result (see the erratum of ABREU 93I). 0.11 DECAMP 91 J report B($E_{\rm CM}^{\rm ep}$ = 0.0 π + 1) B($E_{\rm CM}^{\rm ep}$ = 0.0 π + 1) F($E_{\rm CM}^{\rm ep}$ =
$<5.5 \times 10^{-5}$ $<1.4 \times 10^{-4}$ • • We do not use to $<1.2 \times 10^{-4}$ 79 This limit is for both RRI 95G. 80 This limit is for both Anni 92B. $(7\gamma\gamma)/\Gamma$ total MALUE $<1.0 \times 10^{-5}$ $<1.7 \times 10^{-5}$ $<6.6 \times 10^{-5}$ 81 Limit derived in the $(\pi^{\pm}W^{\mp})/\Gamma$ total The value is for MALUE $<7 \times 10^{-5}$ $<7 \times 10^{-5}$ $<1.7 \times 1$	95 95 95 the followings 10th decay in the decay in the decay in the followings 95 95 95 95 the followings 95 10th e sum of the sum	ABREU AKRAWY ing data for average 80 ADRIANI modes $Z \rightarrow \pi^0 \gamma/\gamma$ and 80 ADRIANI 80 ACCIARRI 81 ABREU AKRAWY ing data for average ADRIANI of composite Z modes if the charge states $\frac{DOCUMENT ID}{DECAMP}$ of the charge states $\frac{DOCUMENT ID}{DECAMP}$ and $\frac{DOCUMENT ID}{DECAMP}$ $\frac{DOCUMENT ID}{DECAMP}$ $\frac{82}{2}$ ALEXANDER $\frac{83}{2}$ ADRIANI	948 DLPH 91F OPAL es, fits, limits, 928 L3 γγ which are i γγγ which are i γγγ which are i β1 OPAL es, fits, limits, 928 L3 es, fits, limits, 928 L3 indicated. 1 TECN 92 ALEP Indicated. 1 TECN 92 ALEP 1 TECN 92 ALEP 1 968 OPAL 94P DLPH 93J L3	E ^{ee} _{CM} = 88-94 GeV E ^{ee} _{CM} = 88-94 GeV etc. • • • Repl. by ACCIARRI 95G ndistinguishable in ADRI- T16/F COMMENT E ^{ee} _{CM} = 88-94 GeV T18/F COMMENT E ^{ee} _{CM} = 88-94 GeV T18/F COMMENT E ^{ee} _{CM} = 88-94 GeV T19/F COMMENT E ^{ee} _{CM} = 88-94 GeV Ceemen E ^{ee} _{CM} = 88-94 GeV COMMENT E ^{ee} _{CM} = 88-94 GeV COMMENT E ^{ee} _{CM} = 88-94 GeV COMMENT E ^{ee} _{CM} = 88-94 GeV	0.163±0.019 OUR AVERAGE Error includes scale factor of 1.3. 0.155±0.010±0.013 358 90 ABREU 93! DLPH E_{CR}^{ce} = 88-94 GeV 0.21 ±0.04 362 91 DECAMP 91 J ALEP E_{CR}^{ce} = 88-94 GeV 0.21 ±0.04 362 91 DECAMP 91 J ALEP E_{CR}^{ce} = 88-94 GeV 0.21 ±0.04 362 91 DECAMP 91 J ALEP E_{CR}^{ce} = 88-94 GeV 0.20 P^{ce} 0.20 P^{c

 96 AKRAWY 90J report $\Gamma(\gamma \rm X)<8.2$ MeV at 95%CL. They assume a three-body $\gamma\,q\,\overline{q}$ distribution and use E($\gamma)>10$ GeV.

7

VALUE	2				Γ ₃₀ /Γ	$\langle N_{\eta} \rangle$			
5.2 × 10 ⁻⁴	<u>CL%_</u> 95	DOCUMENT ID 97 ACTON		COMMENT Ecm = 91.2 GeV	/	VALUE 0.93 ±0.01 ±0.09	<u>DOCUMENT ID</u> ACCIARRI	96 L3	COMMENT Fee — 91.2 GeV
						• • • We do not use the follo			<i>E</i> ^{ee} _{cm} = 91.2 GeV etc. • • •
ACTON 91B looke	eu for isola	tea protons with E	>2% of beam	energy (> 0.9 G	iev).	0.91 ±0.02 ±0.11	ACCIARRI	94B L3	Repl. by ACCIARRI
$(\mu^+\mu^-\gamma)/\Gamma_{\text{total}}$					Γ ₃₁ /Γ	$0.298 \pm 0.023 \pm 0.021$	103 BUSKULIC		$E_{\rm cm}^{ee} = 91.2 \text{ GeV}$
ALUE	<u>CL%</u>	DOCUMENT ID		COMMENT		¹⁰³ BUSKULIC 92D obtain thi	is value for $x > 0.1$.		
<5.6 × 10 ⁻⁴	95	⁹⁸ ACTON		E ^{ee} _{Cm} = 91.2 Ge\					
⁹⁸ ACTON 91B looke	ed for isola	ted photons with E	>2% of beam	n energy (> 0.9 G	ieV).	$\langle N_{\rho^0} \rangle$			
$(\tau^+\tau^-\gamma)/\Gamma_{total}$					Γ_{32}/Γ	VALUE 1.30 ± 0.12 OUR AVERAGE	DOCUMENT ID	TECN	COMMENT
ALUE	CL%_	DOCUMENT ID	TECN	COMMENT		$1.45 \pm 0.06 \pm 0.20$	BUSKULIC	96H ALEP	Eee = 91.2 GeV
<7.3 × 10 ⁻⁴	95	⁹⁹ ACTON	91B OPAL	Eee 91.2 GeV	/	$1.21 \pm 0.04 \pm 0.15$	ABREU		E ^{ee} _{Cm} = 91.2 GeV
⁹⁹ ACTON 91B looke	ed for isola	ted photons with E	>2% of beam	n energy (> 0.9 G	ieV).	• • We do not use the following the fol	wing data for averag	es, fits, limits,	etc. • • •
(a+ a) /F					г /г	$1.43 \pm 0.12 \pm 0.22$	ABREU	93 DLPH	Repl. by ABREU 95L
$(\ell^+\ell^-\gamma\gamma)/\Gamma_{\text{total}}$ The value is the		$\ell = e, \mu, \tau$			Г ₃₃ /Г	$\langle N_{\omega} \rangle$			
ALUE	CL%	DOCUMENT ID	TECN	COMMENT		VALUE	DOCUMENT ID	TECN	COMMENT
(6.8 × 10 ^{—6}	95	¹⁰⁰ ACTON	93E OPAL	Eee = 88-94 G	eV	1.07±0.06±0.13	BUSKULIC		Ecm = 91.2 GeV
00 For $m_{\gamma\gamma}=$ 60 \pm :	5 GeV.								CIII
						$\langle N_{\eta'} angle$			
$(q \overline{q} \gamma \gamma) / \Gamma_{total}$					Γ_{34}/Γ	VALUE	DOCUMENT ID		COMMENT
ALUE	<u>CL%</u>	DOCUMENT ID		COMMENT			-		
<5.5 × 10 ⁻⁶	95	101 ACTON	93E OPAL	E ^{ee} _{cm} = 88-94 G	eV	$0.068 \pm 0.018 \pm 0.016$	¹⁰⁴ BUSKULIC	92D ALEP	E ^{ee} _{cm} = 91.2 GeV
01 For $m_{\gamma\gamma}=$ 60 \pm !	5 GeV.					¹⁰⁴ BUSKULIC 92D obtain thi	is value for $x > 0.1$.		
					F /F	/AL			
$(\nu \overline{\nu} \gamma \gamma) / \Gamma_{\text{total}}$	CLOV	DOCUMENT IS	TECH	COMMENT	Γ ₃₅ /Γ	⟨ <i>N</i> _{f0} (980)⟩	DOCUMENT :-	TECH	COMMENT
<3.1 × 10 ⁻⁶	<u>CL%</u> 95	DOCUMENT ID 102 ACTON		<u>COMMENT</u> E ^{ee} _{cm} = 88-94 G	e\/	VALUE ■ ■ We do not use the folio	DOCUMENT ID		COMMENT
-		ACTON	JJE UPAL	-cm- 00-94 G	. •		owing data for averag ¹⁰⁵ ABREU		
02 For $m_{\gamma\gamma}=$ 60 \pm !	5 GeV.					0.098±0.016 0.10 ±0.03 ±0.019	105 ABREU 106 ABREU		E_{Cm}^{ee} = 91.2 GeV Repl. by ABREU 95L
$(e^{\pm}\mu^{\mp})/\Gamma(e^{+}e^{-}$	-)				Γ_{36}/Γ_{1}				nepi. by ABREU 951
		ber conservation.	The value is	for the sum of th		¹⁰⁵ ABREU 95L obtain this va ¹⁰⁶ ABREU 93 obtain this val	liue for $0.05 < x < 0.6$	•	
states indicated.					_				
	<u>CL%</u>	DOCUMENT ID	TECN CO			$\langle N_{\phi} \rangle$			
(0.07	90	ALBAJAR 8	9 UA1 <i>E</i>	<i>p</i> p = 546,630 Ge¹	V	VALUE 0.110±0.011 OUR AVERAGE	DOCUMENT ID	TECN	COMMENT
$(e^{\pm}\mu^{\mp})/\Gamma_{\text{total}}$					Γ ₃₆ /Γ	0.110±0.011 OUR AVERAGE 0.122±0.004±0.008	BUSKULIC		E ^{ee} _{cm} = 91.2 GeV
	family num	ber conservation.	The value is	for the sum of th		$0.122\pm0.004\pm0.008$ $0.100\pm0.004\pm0.007$	AKERS		$E_{\text{cm}}^{\text{ee}} = 91.2 \text{ GeV}$ $E_{\text{cm}}^{\text{ee}} = 91.2 \text{ GeV}$
states indicated.					6-	• • • We do not use the follo			
ALUE			TECN						
	<u>CL%</u>	DOCUMENT ID		COMMENT			-		
$< 1.7 \times 10^{-6}$	95	AKERS	95w OPAL	Eee = 88-94 G		0.086 ±0.015 ±0.010	ACTON		
<1.7 × 10 ⁻⁶ <3.2 × 10 ⁻⁵	95 95	AKERS ABREU	95W OPAL 93B DLPH	$E_{\rm cm}^{ee} = 88-94 \text{ G}$ $E_{\rm cm}^{ee} = 88-94 \text{ G}$	eV	$0.086 \pm 0.015 \pm 0.010$	-		Repl. by AKERS 95x
<1.7 × 10 ⁻⁶ <3.2 × 10 ⁻⁵ <0.6 × 10 ⁻⁵	95 95 95	AKERS ABREU ADRIANI	95W OPAL 93B DLPH 93I L3	$E_{\text{cm}}^{ee} = 88-94 \text{ G}$ $E_{\text{cm}}^{ee} = 88-94 \text{ G}$ $E_{\text{cm}}^{ee} = 88-94 \text{ G}$	eV eV		-	920 OPAL	
<1.7 × 10 ⁻⁶ <3.2 × 10 ⁻⁵ <0.6 × 10 ⁻⁵	95 95	AKERS ABREU	95W OPAL 93B DLPH 93I L3	$E_{\rm cm}^{ee} = 88-94 \text{ G}$ $E_{\rm cm}^{ee} = 88-94 \text{ G}$	eV eV	$0.086 \pm 0.015 \pm 0.010$ $\langle N_{f_2(1270)} \rangle$	ACTON	920 OPAL	Repl. by AKERS 95X
<1.7 × 10 ⁻⁶ <3.2 × 10 ⁻⁵ <0.6 × 10 ⁻⁵ <2.6 × 10 ⁻⁵	95 95 95	AKERS ABREU ADRIANI	95W OPAL 93B DLPH 93I L3	$E_{\text{cm}}^{ee} = 88-94 \text{ G}$ $E_{\text{cm}}^{ee} = 88-94 \text{ G}$ $E_{\text{cm}}^{ee} = 88-94 \text{ G}$	eV eV eV	0.086±0.015±0.010 ⟨N _{f2} (1270)⟩ VALUE	ACTON	920 OPAL TECN es, fits, limits,	Repl. by AKERS 95X
$<1.7 \times 10^{-6}$ $<3.2 \times 10^{-5}$ $<0.6 \times 10^{-5}$ $<2.6 \times 10^{-5}$ $<(e^{\pm}\tau^{\mp})/\Gamma_{\text{total}}$	95 95 95 95	AKERS ABREU ADRIANI	95W OPAL 93B DLPH 93I L3 92 ALEP	$E_{\text{cm}}^{ee} = 88-94 \text{ G}$	e∨ e∨ e∨ Γ ₃₇ /Γ	$\langle N_{f_2(1270)} \rangle$ VALUE • • • We do not use the follow	ACTON DOCUMENT ID wing data for averag	920 OPAL TECN es, fits, limits, 95L DLPH	Repl. by AKERS 95x $\frac{COMMENT}{\text{etc.} \bullet \bullet \bullet}$ $E_{Cm}^{ee} = 91.2 \text{ GeV}$
<1.7 × 10 ⁻⁶ <3.2 × 10 ⁻⁵ <0.6 × 10 ⁻⁵ <2.6 × 10 ⁻⁵ $<$ 1 ($e^{\pm}\tau^{\mp}$)/ Γ total Test of lepton for states indicated.	95 95 95 95 	AKERS ABREU ADRIANI DECAMP	95W OPAL 93B DLPH 93I L3 92 ALEP	$E_{\text{cm}}^{ee} = 88-94 \text{ G}$ for the sum of the	e∨ e∨ e∨ Γ ₃₇ /Γ	0.086±0.015±0.010 (N ₆ (1270)) <u>VALUE</u> • • • We do not use the follo 0.170±0.043 0.11 ±0.04 ±0.03 107 ABREU 95L obtain this va	ACTON DOCUMENT ID wing data for averag 107 ABREU 108 ABREU ilue for x> 0.05.	920 OPAL TECN es, fits, limits, 95L DLPH	Repl. by AKERS 95x $\frac{COMMENT}{\text{etc.} \bullet \bullet \bullet}$ $E_{Cm}^{ee} = 91.2 \text{ GeV}$
$<1.7 \times 10^{-6}$ $<3.2 \times 10^{-5}$ $<0.6 \times 10^{-5}$ $<2.6 \times 10^{-5}$ $<2.6 \times 10^{-5}$ Test of lepton f. states indicated.	95 95 95 95 	AKERS ABREU ADRIANI DECAMP aber conservation. DOCUMENT ID	95W OPAL 93B DLPH 93I L3 92 ALEP The value is	$E_{\rm cm}^{\rm ee} = 88-94 {\rm G}$ for the sum of th	eV eV eV F₃₇/F ne charge	$0.086 \pm 0.015 \pm 0.010$ $\langle N_{f_2(1270)} \rangle$ VALUE • • • We do not use the follo 0.170 ± 0.043 $0.11 \pm 0.04 \pm 0.03$	ACTON DOCUMENT ID wing data for averag 107 ABREU 108 ABREU ilue for x> 0.05.	920 OPAL TECN es, fits, limits, 95L DLPH	Repl. by AKERS 95x $\frac{COMMENT}{\text{etc.} \bullet \bullet \bullet}$ $E_{\text{Cm}}^{ee} = 91.2 \text{ GeV}$
$<1.7 \times 10^{-6}$ $<3.2 \times 10^{-5}$ $<0.6 \times 10^{-5}$ $<2.6 \times 10^{-5}$ $<2.6 \times 10^{-5}$ Test of lepton for states indicated. ALUE $<9.8 \times 10^{-6}$	95 95 95 95 ** ** ** ** ** ** ** ** ** ** ** ** **	AKERS ABREU ADRIANI DECAMP There conservation. DOCUMENT ID AKERS	95w OPAL 93B DLPH 93I L3 92 ALEP The value is TECN 95w OPAL	$E_{\rm cm}^{\rm ee} = 88-94 \text{ G}$ for the sum of	eV eV eV F37/F ne charge	0.086±0.015±0.010 (N _{f2} (1270)) VALUE • • • We do not use the folio 0.170±0.043 0.11 ±0.04 ±0.03 107 ABREU 95L obtain this val	ACTON DOCUMENT ID wing data for averag 107 ABREU 108 ABREU ilue for x> 0.05.	920 OPAL TECN es, fits, limits, 95L DLPH	Repl. by AKERS 95x $\frac{COMMENT}{\text{etc.} \bullet \bullet \bullet}$ $E_{Cm}^{ee} = 91.2 \text{ GeV}$
$<1.7 \times 10^{-6}$ $<3.2 \times 10^{-5}$ $<0.6 \times 10^{-5}$ $<2.6 \times 10^{-5}$ $<2.6 \times 10^{-5}$ Test of lepton for states indicated. ALUE $<9.8 \times 10^{-6}$ $<1.1 \times 10^{-4}$	95 95 95 95 	AKERS ABREU ADRIANI DECAMP There conservation. DOCUMENT ID AKERS ABREU	95w OPAL 93B DLPH 93I L3 92 ALEP The value is 	$E_{\rm cm}^{\rm ee} = 88-94 \text{ G}$ for the sum of	eV eV eV F37/F ne charge eV	0.086±0.015±0.010 ⟨N _{f2} (1270)⟩ VALUE • • • We do not use the follo 0.170±0.043 0.11 ±0.04 ±0.03 107 ABREU 95L obtain this valid ⟨N _{f2} (1525)⟩	DOCUMENT ID wing data for averag 107 ABREU 108 ABREU ilue for x> 0.05. ue for x> 0.1.	920 OPAL TECN es, fits, limits, 95L DLPH	Repl. by AKERS 95x $\frac{COMMENT}{\text{etc.} \bullet \bullet \bullet}$ etc. $\bullet \bullet \bullet$ $E_{\text{cm}}^{\text{em}} = 91.2 \text{ GeV}$ Repl. by ABREU 95L
$<1.7 \times 10^{-6}$ $<3.2 \times 10^{-5}$ $<0.6 \times 10^{-5}$ $<2.6 \times 10^{-5}$ $<2.6 \times 10^{-5}$ $<2.6 \times 10^{-5}$ $<2.6 \times 10^{-5}$ $<2.6 \times 10^{-5}$ $<2.6 \times 10^{-6}$ $<2.6 \times 10^{-6}$ $<2.8 \times 10^{-6}$ $<2.1 \times 10^{-4}$ $<2.3 \times 10^{-5}$	95 95 95 95 	AKERS ABREU ADRIANI DECAMP Ther conservation. DOCUMENT ID AKERS ABREU ADRIANI	95w OPAL 938 DLPH 931 L3 92 ALEP The value is ### TECN 95w OPAL 938 DLPH 931 L3	$E_{cm}^{ee} = 88-94 \text{ G}$ for the sum of the	eV eV eV F37/F ne charge eV eV	0.086±0.015±0.010 \(\begin{align*} \begin{align*}	DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID	920 OPAL TECN es, fits, limits, 95L DLPH 93 DLPH	Repl. by AKERS 95X $\frac{COMMENT}{\text{etc.} \bullet \bullet \bullet}$ etc. $\bullet \bullet \bullet$ $E^{ee}_{\text{Cm}} = 91.2 \text{ GeV}$ Repl. by ABREU 95L $\frac{COMMENT}{COMMENT}$
$<1.7 \times 10^{-6}$ $<3.2 \times 10^{-5}$ $<0.6 \times 10^{-5}$ $<2.6 \times 10^{-5}$ $<2.6 \times 10^{-5}$ Test of lepton f. states indicated. ALUE $<9.8 \times 10^{-6}$ $<1.1 \times 10^{-4}$ $<1.3 \times 10^{-5}$ $<1.2 \times 10^{-4}$	95 95 95 95 	AKERS ABREU ADRIANI DECAMP There conservation. DOCUMENT ID AKERS ABREU	95w OPAL 938 DLPH 931 L3 92 ALEP The value is ### TECN 95w OPAL 938 DLPH 931 L3	$E_{\rm cm}^{\rm ee} = 88-94 \text{ G}$ for the sum of	eV eV eV F37/F ne charge eV eV	0.086±0.015±0.010 ⟨N _{f2} (1270)⟩ VALUE • • • We do not use the follo 0.170±0.043 0.11 ±0.04 ±0.03 107 ABREU 95L obtain this valid ⟨N _{f2} (1525)⟩	DOCUMENT ID wing data for averag 107 ABREU 108 ABREU ilue for x> 0.05. ue for x> 0.1.	920 OPAL TECN es, fits, limits, 95L DLPH 93 DLPH	Repl. by AKERS 95X $\frac{COMMENT}{\text{etc.} \bullet \bullet \bullet}$ etc. $\bullet \bullet \bullet$ $E_{\text{cm}}^{\text{em}} = 91.2 \text{ GeV}$ Repl. by ABREU 95L
$<1.7 \times 10^{-6}$ $<3.2 \times 10^{-5}$ $<0.6 \times 10^{-5}$ $<0.6 \times 10^{-5}$ $<2.6 \times 10^{-5}$ Test of lepton for states indicated. ALUE $<9.8 \times 10^{-6}$ $<1.1 \times 10^{-4}$ $<1.3 \times 10^{-5}$ $<1.2 \times 10^{-4}$ $<1.2 \times 10^{-4}$	95 95 95 95 95 	AKERS ABREU ADRIANI DECAMP Ther conservation. DOCUMENT ID AKERS ABREU ADRIANI DECAMP	95w OPAL 93B DLPH 93I L3 92 ALEP The value is	Ecm = 88-94 G For the sum of th COMMENT Ecm = 88-94 G Ecm = 88-94 G Ecm = 88-94 G Ecm = 88-94 G	eV eV eV F37/F ne charge eV eV eV eV eV eV	$\langle N_{f_2(1270)} \rangle$ $\langle N_{f_2(1270)} \rangle$ $\langle N_{f_2(1270)} \rangle$ • • • We do not use the folice 0.170 \pm 0.04 \pm 0.03 107 ABREU 95L obtain this value 108 ABREU 93 obtain this value $\langle N_{f'_2(1525)} \rangle$ $\langle N_{LUE} \rangle$ 0.020 \pm 0.005 \pm 0.006	DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID	920 OPAL TECN es, fits, limits, 95L DLPH 93 DLPH	Repl. by AKERS 95X $\frac{COMMENT}{\text{etc.} \bullet \bullet \bullet}$ etc. $\bullet \bullet \bullet$ $E^{ee}_{\text{Cm}} = 91.2 \text{ GeV}$ Repl. by ABREU 95L $\frac{COMMENT}{COMMENT}$
$<1.7 \times 10^{-6}$ $<3.2 \times 10^{-5}$ $<0.6 \times 10^{-5}$ $<2.6 \times 10^{-5}$ $<2.6 \times 10^{-5}$ $<1.6 \times 10^{-5}$ Test of lepton from the states indicated. ALUE $<9.8 \times 10^{-6}$ $<1.1 \times 10^{-4}$ $<1.3 \times 10^{-5}$ $<1.2 \times 10^{-4}$ Test of lepton from $<1.2 \times 10^{-4}$ Test of lepton from $<1.2 \times 10^{-4}$	95 95 95 95 95 **Family num**	AKERS ABREU ADRIANI DECAMP Ther conservation. DOCUMENT ID AKERS ABREU ADRIANI	95w OPAL 93B DLPH 93I L3 92 ALEP The value is	Ecm = 88-94 G For the sum of th COMMENT Ecm = 88-94 G Ecm = 88-94 G Ecm = 88-94 G Ecm = 88-94 G	eV eV eV F37/F ne charge eV eV eV eV eV eV	0.086±0.015±0.010 \(\begin{align*} \begin{align*}	DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID	920 OPAL TECN es, fits, limits, 95L DLPH 93 DLPH TECN 96C DLPH	Repl. by AKERS 95X $\frac{COMMENT}{\text{etc.} \bullet \bullet \bullet}$ etc. $\bullet \bullet \bullet$ $E^{ee}_{\text{Cm}} = 91.2 \text{ GeV}$ Repl. by ABREU 95L $\frac{COMMENT}{COMMENT}$
(27×10^{-6}) (32×10^{-5}) (06×10^{-5}) (26×10^{-5}) Test of lepton f. states indicated. ALUE (212×10^{-6}) (212×10^{-6}) (22×10^{-4}) Test of lepton f. states indicated.	95 95 95 95 95 	AKERS ABREU ADRIANI DECAMP There conservation. DOCUMENT ID AKERS ABREU ADRIANI DECAMP	95w OPAL 938 DLPH 931 L3 92 ALEP The value is ### TECN 95w OPAL 938 DLPH 931 L3 92 ALEP The value is	$E_{\rm cm}^{ee} = 88-94 {\rm G}$ for the sum of th $\frac{COMMENT}{E_{\rm cm}^{ee} = 88-94 {\rm G}}$ $E_{\rm cm}^{ee} = 88-94 {\rm G}$ $E_{\rm cm}^{ee} = 88-94 {\rm G}$ for the sum of the	eV eV eV F37/F ne charge eV eV eV eV eV eV	0.086 \pm 0.015 \pm 0.010 $\langle N_{f_2(1270)} \rangle$ MALUE • • • We do not use the folion 0.170 \pm 0.04 \pm 0.03 107 ABREU 95L obtain this value 0.34 ABREU 93 obtain this value 0.020 \pm 0.005 \pm 0.006 $\langle N_{K\pm} \rangle$ MALUE 2.37 \pm 0.11 OUR AVERAGE	DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID	920 OPAL TECN es, fits, limits, 95L DLPH 93 DLPH TECN 96C DLPH	Repl. by AKERS 95X $\frac{COMMENT}{\text{etc.} \bullet \bullet \bullet}$ etc. $\bullet \bullet \bullet$ $E_{\text{Cm}}^{ee} = 91.2 \text{ GeV}$ Repl. by ABREU 95L $\frac{COMMENT}{E_{\text{Cm}}^{ee}} = 91.2 \text{ GeV}$
(27×10^{-6}) (32×10^{-5}) (06×10^{-5}) (26×10^{-5}) (26×10^{-5}) Test of lepton f. states indicated. (412×10^{-6}) (412×10^{-6}) (42×10^{-4}) Test of lepton f. states indicated.	95 95 95 95 95	AKERS ABREU ADRIANI DECAMP Ther conservation. DOCUMENT ID AKERS ABREU ADRIANI DECAMP Ther conservation. DOCUMENT ID	95w OPAL 938 DLPH 931 L3 92 ALEP The value is	$E_{\rm cm}^{ee} = 88-94 {\rm G}$ for the sum of th $\frac{{\rm COMMENT}}{{\rm E_{\rm cm}^{ee}} = 88-94 {\rm G}}$ $E_{\rm cm}^{ee} = 88-94 {\rm G}$ $E_{\rm cm}^{ee} = 88-94 {\rm G}$ $E_{\rm cm}^{ee} = 88-94 {\rm G}$ for the sum of th $\frac{{\rm COMMENT}}{{\rm COMMENT}}$	eV eV eV F37/F ne charge eV eV eV eV eV er eV ech charge	0.086±0.015±0.010 ⟨N _{f2} (1270)⟩ <u>MALUE</u> • • • We do not use the follo 0.170±0.043 0.11±0.04±0.03 107 ABREU 95L obtain this val 108 ABREU 93 obtain this val ⟨N _{f2} (1525)⟩ <u>MALUE</u> 0.020±0.005±0.006 ⟨N _{K±} ⟩ <u>MALUE</u> 2.37±0.11 OUR AVERAGE 2.26±0.01±0.18	DOCUMENT ID DOCUMENT ID ABREU 108 ABREU 109 ABREU 109 ABREU 100 ABREU DOCUMENT ID ABREU ABREU ABREU	920 OPAL TECN es, fits, limits, 951 DLPH 93 DLPH TECN 96C DLPH TECN 95F DLPH	Repl. by AKERS 95x $\begin{array}{c} \underline{COMMENT} \\ \text{etc.} \bullet \bullet \bullet \\ E_{\text{CM}}^{ee} = 91.2 \text{ GeV} \\ \text{Repl. by ABREU 95L} \\ \\ \underline{COMMENT} \\ E_{\text{CM}}^{ee} = 91.2 \text{ GeV} \\ \\ \underline{COMMENT} \\ E_{\text{CM}}^{ee} = 91.2 \text{ GeV} \\ \\ \end{array}$
\$\frac{1.7 \times 10^{-6}}{3.2 \times 10^{-5}}\$\$ \$\frac{(3.6 \times 10^{-5})}{(2.6 \times 10^{-5})}\$\$ \$\frac{(e^{\pmu} \tau^{\pmu})}{\text{F}} / \text{F total}\$\$ \$\text{ total lepton } f_0.5\$\$ \$\text{ total}\$\$ \$\frac{41.12}{1.3 \times 10^{-5}}\$\$ \$\frac{(1.1 \times 10^{-4})}{1.3 \times 10^{-5}}\$\$ \$\frac{(1.2 \times 10^{-4})}{1.2 \times 10^{-5}}\$\$ \$\text{ total}\$\$ \$\text{ total}\$ \text{ total}\$\$ \$\text{ total}\$\$	95 95 95 95 95 95 96 97 97 97 97 97 97 97 97 97 97 97 97 97	AKERS ABREU ADRIANI DECAMP There conservation. DOCUMENT ID AKERS ABREU ADRIANI DECAMP There conservation. DOCUMENT ID AKERS	95w OPAL 93B DLPH 93I L3 92 ALEP The value is	$E_{\rm cm}^{\rm ee} = 88-94 {\rm G}$ for the sum of th	eV eV eV F37/F ne charge eV F38/F ne charge	0.086 \pm 0.015 \pm 0.010 $\langle N_{f_2(1270)} \rangle$ MALUE • • • We do not use the folion 0.170 \pm 0.04 \pm 0.03 107 ABREU 95L obtain this value 0.34 ABREU 93 obtain this value 0.020 \pm 0.005 \pm 0.006 $\langle N_{K\pm} \rangle$ MALUE 2.37 \pm 0.11 OUR AVERAGE	DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID	920 OPAL TECN es, fits, limits, 951 DLPH 93 DLPH TECN 96C DLPH TECN 95F DLPH	Repl. by AKERS 95X $\frac{COMMENT}{\text{etc.} \bullet \bullet \bullet}$ etc. $\bullet \bullet \bullet$ $E_{\text{Cm}}^{ee} = 91.2 \text{ GeV}$ Repl. by ABREU 95L $\frac{COMMENT}{E_{\text{Cm}}^{ee}} = 91.2 \text{ GeV}$
$(1.7 \times 10^{-6} \times 1.7 \times 10^{-6} \times 1.7 \times 10^{-6} \times 1.7 \times 10^{-5} \times 1.2 \times 10^{-5} \times 1.2 \times 10^{-5} \times 1.1 \times 10^{-4} \times 1.3 \times 10^{-5} \times 1.2 \times 10^{-4} \times 1.3 \times 10^{-5} \times 1.4 \times 10^{-5} \times 1$	95 95 95 95 Family num 	AKERS ABREU ADRIANI DECAMP There conservation. DOCUMENT ID AKERS ABREU ADRIANI DECAMP There conservation. DOCUMENT ID AKERS ABREU ARES ABREU	95w OPAL 93B DLPH 93I L3 92 ALEP The value is	$E_{\rm cm}^{\rm ee} = 88-94 {\rm G}$ for the sum of th $\frac{{\rm COMMENT}}{E_{\rm cm}^{\rm ee} = 88-94 {\rm G}}$ for the sum of th $E_{\rm cm}^{\rm ee} = 88-94 {\rm G}$ for the sum of th $\frac{{\rm COMMENT}}{E_{\rm cm}^{\rm ee} = 88-94 {\rm G}}$ for the sum of th $\frac{{\rm COMMENT}}{E_{\rm cm}^{\rm ee} = 88-94 {\rm G}}$ $\frac{{\rm COMMENT}}{E_{\rm cm}^{\rm ee} = 88-94 {\rm G}}$ $E_{\rm cm}^{\rm ee} = 88-94 {\rm G}$	eV eV eV F37/F ne charge eV he charge	0.086±0.015±0.010 \(\begin{align*} \begin{align*} \begin{align*} \langle \begin{align*} \langle \langle \langle \cdot \text{ We do not use the folice} \\ 0.170±0.043 \\ 0.11±0.04±0.03 \\ 107 ABREU 95L obtain this value and the second of th	DOCUMENT ID DOCUMENT ID ABREU 108 ABREU 109 ABREU 109 ABREU 100 ABREU DOCUMENT ID ABREU ABREU ABREU	920 OPAL TECN es, fits, limits, 951 DLPH 93 DLPH TECN 96C DLPH TECN 95F DLPH	Repl. by AKERS 95x $\begin{array}{c} \underline{COMMENT} \\ \text{etc.} \bullet \bullet \bullet \\ E_{\text{CM}}^{ee} = 91.2 \text{ GeV} \\ \text{Repl. by ABREU 95L} \\ \\ \underline{COMMENT} \\ E_{\text{CM}}^{ee} = 91.2 \text{ GeV} \\ \\ \underline{COMMENT} \\ E_{\text{CM}}^{ee} = 91.2 \text{ GeV} \\ \\ \end{array}$
(1.7 × 10 ⁻⁶ (3.2×10^{-5}) (0.6×10^{-5}) (2.6×10^{-5}) ($e^{\pm}\tau^{\mp}$)/ Γ total Test of lepton final states indicated. (1.1 × 10 ⁻⁶ (1.1×10^{-4}) (1.3×10^{-5}) (1.2×10^{-4}) Test of lepton final states indicated. (1.7 × 10 ⁻⁵ (1.4×10^{-4}) (1.4×10^{-4}) (1.4×10^{-4}) (1.4×10^{-4}) (1.4×10^{-4})	95 95 95 95 	AKERS ABREU ADRIANI DECAMP Ther conservation. DOCUMENT ID AKERS ABREU ADRIANI DECAMP Ther conservation. DOCUMENT ID AKERS ABREU ADRIANI	95w OPAL 938 DLPH 931 L3 92 ALEP The value is	Ecm = 88-94 G Ecm = 88-94 G Ecm = 88-94 G Ecm = 88-94 G for the sum of th COMMENT Ecm = 88-94 G for the sum of th COMMENT Ecm = 88-94 G for the sum of th COMMENT Ecm = 88-94 G Ecm = 88-94 G	eV eV eV F37/F ne charge eV	0.086±0.015±0.010 ⟨N _{f2} (1270)⟩ <u>VALUE</u> • • • We do not use the folice 0.170±0.043 0.11 ±0.04 ±0.03 107 ABREU 95L obtain this value (N _{f2} (1525)⟩ <u>VALUE</u> 0.020±0.005±0.006 ⟨N _{K±} ⟩ <u>VALUE</u> 2.37±0.11 OUR AVERAGE 2.26±0.01±0.18 2.42±0.13	DOCUMENT ID ABREU DOCUMENT ID DOCUMENT ID ABREU DOCUMENT ID ABREU ABREU ABREU ABREU ABREU ABREU ABREU ABREU ABREU	920 OPAL TECN es, fits, limits, 95L DLPH 93 DLPH 96C DLPH TECN 96C DLPH 95F DLPH 94P OPAL	Repl. by AKERS 95X $\frac{COMMENT}{\text{etc.} \bullet \bullet \bullet}$ etc. $\bullet \bullet \bullet$ $E_{\text{CM}}^{ee} = 91.2 \text{ GeV}$ Repl. by ABREU 95L $\frac{COMMENT}{E_{\text{CM}}^{ee}} = 91.2 \text{ GeV}$ $\frac{COMMENT}{E_{\text{CM}}^{ee}} = 91.2 \text{ GeV}$ $E_{\text{CM}}^{ee} = 91.2 \text{ GeV}$ $E_{\text{CM}}^{ee} = 91.2 \text{ GeV}$
\$\frac{1.7 \times 10^{-6}}{63.2 \times 10^{-5}}\$\$\$ (2.6 \times 10^{-5})\$\$\$ (e^{\pmu}\tau^{\pmu})/\tau\tau \tau \tau \tau \tau \tau \tau \	95 95 95 95 Family num 	AKERS ABREU ADRIANI DECAMP There conservation. DOCUMENT ID AKERS ABREU ADRIANI DECAMP There conservation. DOCUMENT ID AKERS ABREU ARES ABREU	95w OPAL 938 DLPH 931 L3 92 ALEP The value is	$E_{\rm cm}^{\rm ee} = 88-94 {\rm G}$ for the sum of th $\frac{{\rm COMMENT}}{E_{\rm cm}^{\rm ee} = 88-94 {\rm G}}$ for the sum of th $E_{\rm cm}^{\rm ee} = 88-94 {\rm G}$ for the sum of th $\frac{{\rm COMMENT}}{E_{\rm cm}^{\rm ee} = 88-94 {\rm G}}$ for the sum of th $\frac{{\rm COMMENT}}{E_{\rm cm}^{\rm ee} = 88-94 {\rm G}}$ $\frac{{\rm COMMENT}}{E_{\rm cm}^{\rm ee} = 88-94 {\rm G}}$ $E_{\rm cm}^{\rm ee} = 88-94 {\rm G}$	eV eV eV F37/F ne charge eV	0.086±0.015±0.010 \(\begin{align*} \begin{align*} \begin{align*} \langle \begin{align*} \langle \langle \langle \cdot \text{ We do not use the folice} \\ 0.170±0.043 \\ 0.11±0.04±0.03 \\ 107 ABREU 95L obtain this value and the second of th	DOCUMENT ID ABREU DOCUMENT ID ABREU DOCUMENT ID ABREU DOCUMENT ID ABREU ABREU ABREU DOCUMENT ID ABREU ABREU ABREU ABREU ABREU ABREU ABREU ABREU ABREU	920 OPAL TECN es, fits, limits, 95L DLPH 93 DLPH 96C DLPH TECN 96C DLPH 95F DLPH 94P OPAL	Repl. by AKERS 95x $\frac{COMMENT}{\text{etc.} \bullet \bullet \bullet}$ etc. $\bullet \bullet \bullet$ $E_{\text{CM}}^{ee} = 91.2 \text{ GeV}$ Repl. by ABREU 95t $\frac{COMMENT}{E_{\text{CM}}^{ee}} = 91.2 \text{ GeV}$ $\frac{COMMENT}{E_{\text{CM}}^{ee}} = 91.2 \text{ GeV}$
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\$\frac{1.7 \times 10^{-6}}{(3.2 \times 10^{-5})}\$\$ (2.6 \times 10^{-5})\$\$ (4.10 \times 10^{-6})\$\$ (3.1 \times 10^{-6})\$\$ (3.1 \times 10^{-6})\$\$ (3.2 \times 10^{-5})\$\$ (3.2 \times 10^{-5})\$\$ (3.2 \times 10^{-5})\$\$ (3.4 \times 10^{-5})\$\$ (3.4 \times 10^{-5})\$\$ (3.4 \times 10^{-5})\$\$ (3.0 \times 10^{-5})\$\$ (3.0 \times 10^{-4})\$\$ Summed over \$N_{\pi^{\pm}}\$\$ (3.4 \times 10^{-5})\$\$ (3.0 \times 10^{-4})\$\$ (3.0 \times 1	95 95 95 95 75 mily num 95 95 95 95 95 95 97 87 TICLE	AKERS ABREU ADRIANI DECAMP There conservation. DOCUMENT ID AKERS ABREU ADRIANI DECAMP There conservation. DOCUMENT ID AKERS ABREU ADRIANI DECAMP MULTIPLICITIE and antiparticle, who AKERS DOCUMENT ID AKERS	95w OPAL 93B DLPH 931 L3 92 ALEP The value is	Eem = 88-94 G Eem = 88-94 G Eem = 88-94 G Eem = 88-94 G for the sum of the su	eV eV eV F37/F ne charge eV eV eV eV eV eV AY	0.086±0.015±0.010 ⟨N _{f2} (1270)⟩ <u>MALUE</u> • • • We do not use the folice 0.170±0.043 0.11 ±0.04 ±0.03 107 ABREU 95L obtain this value (N _{f2} (1525)⟩ <u>MALUE</u> 0.020±0.005±0.006 ⟨N _{K±} ⟩ <u>MALUE</u> 2.37±0.11 OUR AVERAGE 2.26±0.01±0.18 2.42±0.13 ⟨N _{K0} ⟩ <u>MALUE</u> 2.010±0.027 OUR AVERAGE 1.962±0.022±0.056 1.99 ±0.01 ±0.04 2.04 ±0.02 ±0.14 2.061±0.047 • • • We do not use the folice 2.12 ±0.05 ±0.04 ⟨N _K (892)±⟩ <u>MALUE</u> 0.72 ±0.05 OUR AVERAGE	DOCUMENT ID ABREU DOCUMENT ID ABREU DOCUMENT ID ABREU	920 OPAL TECN es, fits, limits, 95L DLPH 93 DLPH 96C DLPH 97 DLPH 94P OPAL TECN 95L DLPH 95U OPAL 948 L3 94K ALEP es, fits, limits, 92G DLPH	Repl. by AKERS 95X $\frac{COMMENT}{\text{etc.}} \bullet \bullet \bullet$ $E_{CM}^{ee} = 91.2 \text{ GeV}$ Repl. by ABREU 95L $\frac{COMMENT}{E_{CM}^{ee}} = 91.2 \text{ GeV}$ $\frac{E_{CM}^{ee}}{E_{CM}^{ee}} = 91.2 \text{ GeV}$
\$\frac{1.7 \times 10^{-6}}{(3.2 \times 10^{-5})}\$\$ (2.6 \times 10^{-5})\$\$ (4.10 \times 10^{-6})\$\$ (3.1 \times 10^{-6})\$\$ (3.1 \times 10^{-6})\$\$ (3.2 \times 10^{-5})\$\$ (3.2 \times 10^{-5})\$\$ (3.2 \times 10^{-5})\$\$ (3.4 \times 10^{-5})\$\$ (3.4 \times 10^{-5})\$\$ (3.4 \times 10^{-5})\$\$ (3.0 \times 10^{-5})\$\$ (3.0 \times 10^{-4})\$\$ Summed over \$N_{\pi^{\pm}}\$\$ (3.4 \times 10^{-5})\$\$ (3.0 \times 10^{-4})\$\$ (3.0 \times 1	95 95 95 95 75 mily num 95 95 95 95 95 95 97 87 TICLE	AKERS ABREU ADRIANI DECAMP There conservation. DOCUMENT ID AKERS ABREU ADRIANI DECAMP There conservation. DOCUMENT ID AKERS ABREU ADRIANI DECAMP MULTIPLICITIE and antiparticle, who	95w OPAL 93B DLPH 931 L3 92 ALEP The value is	Eem = 88-94 G Eem = 88-94 G Eem = 88-94 G Eem = 88-94 G for the sum of the s	eV eV eV F37/F ne charge eV eV eV eV eV eV AY	0.086±0.015±0.010 ⟨N _{f2} (1270)⟩ MALUE • • • We do not use the follo 0.170±0.043 0.11 ±0.04 ±0.03 107 ABREU 93 obtain this val (N _{f2} (1525)⟩ MALUE 0.020±0.005±0.006 ⟨N _{K±} ⟩ MALUE 2.37±0.11 OUR AVERAGE 2.26±0.01±0.18 2.42±0.13 ⟨N _{K0} ⟩ MALUE 2.010±0.027 OUR AVERAGE 1.962±0.022±0.056 1.99±0.01±0.04 2.04±0.047 • • We do not use the follo 2.12±0.05±0.04 ⟨N _{K*} (892)±⟩ MALUE 0.72±0.05 OUR AVERAGE 0.712±0.051 OUR AVERAGE	DOCUMENT ID ABREU	920 OPAL TECN es, fits, limits, 95L DLPH 93 DLPH 96C DLPH 96C DLPH 94P OPAL 95F DLPH 95U OPAL 948 L3 94K ALEP es, fits, limits, 92G DLPH 7ECN 95L DLPH 95U DLPH	Repl. by AKERS 95X $\begin{array}{l} \hline comment \\ etc. \bullet \bullet \bullet \\ E^{ee}_{Cm} = 91.2 \text{ GeV} \\ Repl. by ABREU 95L \\ \hline \\ \hline comment \\ E^{ee}_{Cm} = 91.2 \text{ GeV} \\ \hline \\ \hline comment \\ \hline \\ \hline comment \\ \hline \\ \hline central etc. \\ \hline \\ \hline \\ \hline \\ \hline central etc. \\ \hline \\ $
$<1.7 \times 10^{-6}$ $<3.2 \times 10^{-5}$ $<0.6 \times 10^{-5}$ $<0.6 \times 10^{-5}$ $<2.6 \times 10^{-5}$ $<2.6 \times 10^{-5}$ $<2.6 \times 10^{-5}$ Test of lepton for states indicated. ALUE $<9.8 \times 10^{-6}$ $<1.1 \times 10^{-4}$ $<1.3 \times 10^{-5}$ $<1.2 \times 10^{-4}$ Test of lepton for states indicated. ALUE $<1.1 \times 10^{-4}$ $<1.1 \times 10^{-5}$ $<1.2 \times 10^{-4}$ Test of lepton for states indicated. ALUE $<1.7 \times 10^{-5}$ $<1.4 \times 10^{-4}$ $<1.9 \times 10^{-5}$ $<1.0 \times 10^{-4}$ AVERAGE PA Summed over $N_{\pi^{\pm}}$ $> ALUE$ $<0.05 \times 10^{-4}$ $<0.05 \times 10^{-4}$ AUE $<0.05 \times 10^{-4}$ $<0.05 \times 10^{-4}$ AUE $<0.05 \times 10^{-4}$ $<0.05 \times 10^{-4}$ $<0.05 \times 10^{-4}$ AUE $<0.05 \times 10^{-4}$ $<0.05 \times 10^{-4}$ $<0.05 \times 10^{-4}$ AUE $<0.05 \times 10^{-4}$ $<0.05 \times 10^{-4}$ AUE $<0.05 \times 10^{-4}$ $<0.05 \times 10^{-4}$ AUE $<0.05 \times 10^{-4}$ $<0.05 \times 10^{-4}$ $<0.05 \times 10^{-4}$ AUE $<0.05 \times 10^{-4}$ AUE $<0.05 \times 10^{-4}$ $<0.05 \times 10^{-4}$ $<0.05 \times 10^{-4}$ $<0.05 \times 10^{-4}$ AUE $<0.05 \times 10^{-4}$ $<0.05 \times 10^$	95 95 95 95 75 mily num 95 95 95 95 95 95 97 87 TICLE	AKERS ABREU ADRIANI DECAMP There conservation. DOCUMENT ID AKERS ABREU ADRIANI DECAMP There conservation. DOCUMENT ID AKERS ABREU ADRIANI DECAMP MULTIPLICITIE and antiparticle, who AKERS DOCUMENT ID AKERS	95w OPAL 93B DLPH 931 L3 92 ALEP The value is	Eem = 88-94 G Eem = 88-94 G Eem = 88-94 G Eem = 88-94 G for the sum of the su	eV eV eV F37/F ne charge eV eV eV eV eV eV AY	0.086±0.015±0.010 ⟨N _{f2} (1270)⟩ VALUE • • • We do not use the folice 0.170±0.043 0.11 ±0.04 ±0.03 107 ABREU 95L obtain this val 108 ABREU 93 obtain this val ⟨N _{f2} (1525)⟩ VALUE 0.020±0.005±0.006 ⟨N _{K±} ⟩ VALUE 2.37±0.11 OUR AVERAGE 2.26±0.01±0.18 2.42±0.13 ⟨N _{K0} ⟩ VALUE 2.010±0.027 OUR AVERAGE 1.962±0.022±0.056 1.99 ±0.01 ±0.04 2.04 ±0.02 ±0.14 2.061±0.047 • • • We do not use the folice 2.12 ±0.05 ±0.04 ⟨N _{K*} (892)±⟩ VALUE 0.72 ±0.05 OUR AVERAGE 0.712±0.031±0.059 0.72 ±0.05 ±0.058	DOCUMENT ID ABREU	920 OPAL TECN es, fits, limits, 951 DLPH 93 DLPH 960 DLPH TECN 961 DLPH 94P OPAL 951 DLPH 950 OPAL 948 L3 94K ALEP es, fits, limits, 926 DLPH 7ECN 951 DLPH 950 DLPH	Repl. by AKERS 95X $\frac{COMMENT}{\text{etc.} \bullet \bullet \bullet}$ $\frac{E_{CM}^{ee} = 91.2 \text{ GeV}}{\text{Repl. by ABREU 95L}}$ $\frac{COMMENT}{E_{CM}^{ee} = 91.2 \text{ GeV}}$ $\frac{COMMENT}{E_{CM}^{ee} = 91.2 \text{ GeV}}$ $\frac{COMMENT}{E_{CM}^{ee} = 91.2 \text{ GeV}}$ $\frac{E_{CM}^{ee} = 91.2 \text{ GeV}}{E_{CM}^{ee} = 91.2 \text{ GeV}}$ $\frac{E_{CM}^{ee} = 91.2 \text{ GeV}}{E_{CM}^{ee} = 91.2 \text{ GeV}}$ $\frac{E_{CM}^{ee} = 91.2 \text{ GeV}}{E_{CM}^{ee} = 91.2 \text{ GeV}}$ $\frac{E_{CM}^{ee} = 91.2 \text{ GeV}}{E_{CM}^{ee} = 91.2 \text{ GeV}}$ $\frac{E_{CM}^{ee} = 91.2 \text{ GeV}}{E_{CM}^{ee} = 91.2 \text{ GeV}}$
<1.7 × 10 ⁻⁶ <3.2 × 10 ⁻⁵ <0.6 × 10 ⁻⁵ <2.6 × 10 ⁻⁵ <2.6 × 10 ⁻⁵ Test of lepton fistates indicated. ALUE <9.8 × 10 ⁻⁶ <1.1 × 10 ⁻⁴ <1.3 × 10 ⁻⁵ <1.2 × 10 ⁻⁴ Test of lepton fistates indicated. ALUE ($\mu^{\pm} \tau^{\mp}$)/\text{Total} Test of lepton fistates indicated. ALUE 4.17 × 10 ⁻⁵ <1.4 × 10 ⁻⁴ <1.9 × 10 ⁻⁵ <1.0 × 10 ⁻⁴ AVERAGE PA	95 95 95 95 95 6amily num 6. CL% 95 95 95 95 95 7 8TICLE 7 8TICLE 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	AKERS ABREU ADRIANI DECAMP There conservation. DOCUMENT ID AKERS ABREU ADRIANI DECAMP There conservation. DOCUMENT ID AKERS ABREU ADRIANI DECAMP MULTIPLICITIE and antiparticle, who AKERS DOCUMENT ID AKERS ACCIARRI ADAM	95w OPAL 938 DLPH 931 L3 92 ALEP The value is	Ecm = 88-94 G Ecm = 88-94 G Ecm = 88-94 G Ecm = 88-94 G for the sum of th COMMENT Ecm = 88-94 G for the sum of th COMMENT Ecm = 88-94 G for the sum of th COMMENT Ecm = 88-94 G Ecm = 88-94 G For the sum of th COMMENT Ecm = 88-94 G For the sum of th COMMENT Ecm = 88-94 G COMMENT Ecm = 88-94 G COMMENT Ecm = 88-94 G COMMENT Ecm = 91.2 Ge\ COMMENT	eV eV eV F37/F ne charge eV eV eV eV eV eV AY	0.086±0.015±0.010 ⟨N _{f2} (1270)⟩ MALUE • • • We do not use the follo 0.170±0.043 0.11 ±0.04 ±0.03 107 ABREU 93 obtain this val (N _{f2} (1525)⟩ MALUE 0.020±0.005±0.006 ⟨N _{K±} ⟩ MALUE 2.37±0.11 OUR AVERAGE 2.26±0.01±0.18 2.42±0.13 ⟨N _{K0} ⟩ MALUE 2.010±0.027 OUR AVERAGE 1.962±0.022±0.056 1.99±0.01±0.04 2.04±0.047 • • We do not use the follo 2.12±0.05±0.04 ⟨N _{K*} (892)±⟩ MALUE 0.72±0.05 OUR AVERAGE 0.712±0.051 OUR AVERAGE	DOCUMENT ID ABREU	920 OPAL TECN es, fits, limits, 951 DLPH 93 DLPH 96C DLPH TECN 95F DLPH 94P OPAL 95L DLPH 95U OPAL 94B L3 94K ALEP es, fits, limits, 92G DLPH 93 OPAL es, fits, limits, limits,	Repl. by AKERS 95X $\frac{COMMENT}{\text{etc.} \bullet \bullet \bullet}$ $\frac{E_{CM}^{ee} = 91.2 \text{ GeV}}{\text{Repl. by ABREU 95L}}$ $\frac{COMMENT}{E_{CM}^{ee} = 91.2 \text{ GeV}}$ $\frac{COMMENT}{E_{CM}^{ee} = 91.2 \text{ GeV}}$ $\frac{COMMENT}{E_{CM}^{ee} = 91.2 \text{ GeV}}$ $\frac{E_{CM}^{ee} = 91.2 \text{ GeV}}{E_{CM}^{ee} = 91.2 \text{ GeV}}$ $\frac{E_{CM}^{ee} = 91.2 \text{ GeV}}{E_{CM}^{ee} = 91.2 \text{ GeV}}$ $\frac{E_{CM}^{ee} = 91.2 \text{ GeV}}{E_{CM}^{ee} = 91.2 \text{ GeV}}$ $\frac{E_{CM}^{ee} = 91.2 \text{ GeV}}{E_{CM}^{ee} = 91.2 \text{ GeV}}$ $\frac{E_{CM}^{ee} = 91.2 \text{ GeV}}{E_{CM}^{ee} = 91.2 \text{ GeV}}$

Z

$\langle N_{K^*(892)^0} \rangle$	
0.76±0.04 OUR AVERAGE	DOCUMENT ID TECN COMMENT
$0.83 \pm 0.01 \pm 0.09$	BUSKULIC 96H ALEP $E_{\rm cm}^{ee} = 91.2 \; {\rm GeV}$
$0.74 \pm 0.03 \pm 0.03$	AKERS 95X OPAL E_{CM}^{ee} = 91.2 GeV
$0.97 \pm 0.18 \pm 0.31$	ABREU 93 DLPH E_{cm}^{ee} = 91.2 GeV
	ing data for averages, fits, limits, etc. • • •
$0.76 \pm 0.07 \pm 0.06$	ACTON 920 OPAL Repl. by AKERS 95x
$\langle N_{K_2^*(1430)} \rangle$	
VALUE	DOCUMENT ID TECN COMMENT
• • We do not use the follow	ring data for averages, fits, limits, etc. • • •
$0.19 \pm 0.04 \pm 0.06$	109 AKERS 95X OPAL $E_{\text{CM}}^{ee} = 91.2 \text{ GeV}$
¹⁰⁹ AKERS 95X obtain this val	te for $x < 0.3$.
$\langle N_{D^{\pm}} \rangle$	
VALUE	DOCUMENT ID TECN COMMENT
0.221±0.026 OUR AVERAGE	Error includes scale factor of 1.1.
$0.251 \pm 0.026 \pm 0.025$	BUSKULIC 94J ALEP E ^{ee} _{cm} = 91.2 GeV
$0.199 \pm 0.019 \pm 0.024$	110 ABREU 931 DLPH $E_{\rm cm}^{ee} = 91.2$ GeV
¹¹⁰ See ABREU 95 (erratum).	
$\langle N_{D^0} \rangle$	
VALUE	DOCUMENT ID TECN COMMENT
0.46 ±0.06 OUR AVERAGE	Error includes scale factor of 1.3.
$0.518 \pm 0.052 \pm 0.035$ $0.403 \pm 0.038 \pm 0.044$	BUSKULIC 94J ALEP $E_{\text{Cm}}^{ee} = 91.2 \text{ GeV}$ 111 ABREU 93I DLPH $E_{\text{Cm}}^{ee} = 91.2 \text{ GeV}$
	751 DEFTI ECM - 91.2 060
111 See ABREU 95 (erratum).	
$\langle N_{D^*(2010)^{\pm}} \rangle$	
VALUE VALUE	DOCUMENT ID TECN COMMENT
0.181±0.010 OUR AVERAGE 0.183±0.009±0.011	¹¹² AKERS 950 OPAL $E_{cm}^{ee} = 91.2 \text{ GeV}$
0.187±0.009±0.011	BUSKULIC 94J ALEP $\frac{ee}{Cm} = 91.2 \text{ GeV}$
0.171 ± 0.012 ± 0.016	113 ABREU 931 DLPH $\frac{ee}{ee}$ 91.2 GeV
	or includes an uncertainty of ± 0.008 due to the $D^{*\pm}$ an
	se B($D^* \rightarrow D^0 \pi$) = 0.681 \pm 0.016 and B($D^0 \rightarrow K\pi$) =
0.0401 ± 0.0014 to obtain	his measurement].
¹¹³ See ABREU 95 (erratum).	
$\langle N_{R^*} \rangle$	
VALUE	$\frac{DOCUMENT\ ID}{114}$ ABREU 95R DLPH $E_{\rm cm}^{\rm ee}=91.2\ { m GeV}$
$0.28 \pm 0.01 \pm 0.03$	114 ABREU 95R DLPH E_{cm}^{ee} = 91.2 GeV
114 ABREU 95R quote this val	e for a flavor-averaged excited state.
$\langle N_{J/\psi(1S)} \rangle$	
VALUE	DOCUMENT ID TECN COMMENT
$0.0056 \pm 0.0003 \pm 0.0004$	115 ALEXANDER 96B OPAL $E_{ m CM}^{\it ee}=$ 91.2 GeV
¹¹⁵ ALEXANDER 96B identify	$I/\psi(1\mathcal{S})$ from the decays into lepton pairs.
⟨N _{ψ(25)} ⟩ ^{VALUE}	DOCUMENT ID TECH COMMENT
0.0023±0.0004±0.0003	DOCUMENT ID TECN COMMENT ALEXANDER 968 OPAL Eee = 91.2 GeV
0.0023 ± 0.0004 ± 0.0003	ALEXANDER 908 OF AL Lom = 91.2 dev
$\langle N_p \rangle$	
VALUE	DOCUMENT ID TECN COMMENT
0.98±0.09 OUR AVERAGE	ABREU 95F DLPH $E_{ m CM}^{\it ee}=$ 91.2 GeV
$1.07 \pm 0.01 \pm 0.14$ 0.92 ± 0.11	ABREU 95F DLPH $E_{\text{cm}}^{\text{ee}} = 91.2 \text{ GeV}$ AKERS 94P OPAL $E_{\text{cm}}^{\text{ee}} = 91.2 \text{ GeV}$
	Street Commission
$\langle N_{\Delta(1232)^{++}} \rangle$	
VALUE	DOCUMENT ID TECN COMMENT
0.087±0.033 OUR AVERAGE 0.079±0.009±0.011	Error includes scale factor of 2.4. ABREU 95W DLPH $E_{m}^{ee} = 91.2 \text{ GeV}$
$0.079 \pm 0.009 \pm 0.011$ $0.22 \pm 0.04 \pm 0.04$	ABREU 95W DLPH $E_{\text{Cm}}^{\text{ee}} = 91.2 \text{ GeV}$ ALEXANDER 95D OPAL $E_{\text{Cm}}^{\text{ee}} = 91.2 \text{ GeV}$
J.22 10.04 10.04	ALEXANDER JOB OF AL LCM - J1.2 GCV
· · · · ·	
VALUE	DOCUMENT ID TECN COMMENT
VALUE 0.367±0.010 OUR AVERAGE	
VALUE 0.367±0.010 OUR AVERAGE 0.37 ±0.01 ±0.04	ACCIARRI 948 L3 $E_{ m Cm}^{ m ee}=$ 91.2 GeV
0.367 ±0.010 OUR AVERAGE 0.37 ±0.01 ±0.04 0.386 ±0.016	ACCIARRI 94B L3 $E_{ m Cm}^{ee}=$ 91.2 GeV BUSKULIC 94K ALEP $E_{ m Cm}^{ee}=$ 91.2 GeV
D.367±0.010 OUR AVERAGE D.37 ±0.01 ±0.04 D.386±0.016 D.357±0.003±0.017	ACCIARRI 94B L3 $E_{\rm CM}^{\it ee}=$ 91.2 GeV BUSKULIC 94K ALEP $E_{\rm CM}^{\it ee}=$ 91.2 GeV
0.367 ± 0.010 OUR AVERAGE 0.367 ± 0.01 ± 0.04 0.386 ± 0.016 0.357 ± 0.003 ± 0.017 0.351 ± 0.019	ACCIARRI 94B L3 $E_{ m Cm}^{ee}=91.2~{ m GeV}$ BUSKULIC 94K ALEP $E_{ m Cm}^{ee}=91.2~{ m GeV}$ ABREU 93L DLPH $E_{ m Cm}^{ee}=91.2~{ m GeV}$
XALUÉ 3.367±0.010 OUR AVERAGE 3.37±0.01±0.04 3.386±0.016 3.357±0.003±0.017 3.351±0.019 ⟨N _{∑±} ⟩	ACCIARRI 94B L3 $E_{ m Cm}^{ee} = 91.2 \ { m GeV}$ BUSKULIC 94K ALEP $E_{ m Cm}^{ee} = 91.2 \ { m GeV}$ ABREU 93L DLPH $E_{ m Cm}^{ee} = 91.2 \ { m GeV}$ ACTON 92J OPAL $E_{ m Cm}^{ee} = 91.2 \ { m GeV}$
VALUÉ 0.367 ± 0.010 OUR AVERAGE 0.367 ± 0.011 ± 0.04 0.386 ± 0.016 0.357 ± 0.003 ± 0.017 0.351 ± 0.019 (N_± ±) VALUE	ACCIARRI 94B L3 $E_{\rm CM}^{\rm ee}=91.2~{\rm GeV}$ BUSKULIC 94K ALEP $E_{\rm CM}^{\rm ee}=91.2~{\rm GeV}$ ABREU 93L DLPH $E_{\rm CM}^{\rm ee}=91.2~{\rm GeV}$ ACTON 92J OPAL $E_{\rm CM}^{\rm ee}=91.2~{\rm GeV}$
VALUÉ 0.367 ± 0.010 OUR AVERAGE 0.367 ± 0.011 ± 0.04 0.386 ± 0.016 0.357 ± 0.003 ± 0.017 0.351 ± 0.019 (N_± ±) VALUE	ACCIARRI 94B L3 $E_{ m Cm}^{ee} = 91.2 \ { m GeV}$ BUSKULIC 94K ALEP $E_{ m Cm}^{ee} = 91.2 \ { m GeV}$ ABREU 93L DLPH $E_{ m Cm}^{ee} = 91.2 \ { m GeV}$ ACTON 92J OPAL $E_{ m Cm}^{ee} = 91.2 \ { m GeV}$
\(\frac{\text{VALUE}}{\text{D.367} ± 0.010}\) OUR AVERAGE \(0.37 ± 0.01) ± 0.04 \(0.386 ± 0.016\) \(0.357 ± 0.003 ± 0.017\) \(0.351 ± 0.003 ± 0.017\) \(0.351 ± 0.019\) \(\frac{\text{V}_{\subset}}{\text{VALUE}}\) \(0.170 ± 0.014 ± 0.061\)	ACCIARRI 94B L3 $E_{\rm CM}^{\rm ee}=91.2~{\rm GeV}$ BUSKULIC 94K ALEP $E_{\rm CM}^{\rm ee}=91.2~{\rm GeV}$ ABREU 93L DLPH $E_{\rm CM}^{\rm ee}=91.2~{\rm GeV}$ ACTON 92J OPAL $E_{\rm CM}^{\rm ee}=91.2~{\rm GeV}$
⟨N _A ⟩ VALUE 0.367 ±0.010 OUR AVERAGE 0.37 ±0.01 ±0.04 0.386 ±0.016 0.357 ±0.003±0.017 0.351±0.019 ⟨N _{∑±} ⟩ VALUE 0.170±0.014±0.061 ⟨N _∑ 0⟩ VALUE	ACCIARRI 94B L3 $E_{\rm CM}^{\it ee}=91.2~{\rm GeV}$ BUSKULIC 94K ALEP $E_{\rm CM}^{\it ee}=91.2~{\rm GeV}$ ABREU 93L DLPH $E_{\rm CM}^{\it ee}=91.2~{\rm GeV}$ ACTON 92J OPAL $E_{\rm CM}^{\it ee}=91.2~{\rm GeV}$ DOCUMENT ID TECN COMMENT ABREU 950 DLPH $E_{\rm CM}^{\it ee}=91.2~{\rm GeV}$
\(\frac{\text{VALUE}}{\text{D.367} \pm 0.010}\) OUR AVERAGE \(0.37 \pm 0.01 \pm 0.04\) \(0.386 \pm 0.016\) \(0.357 \pm 0.003 \pm 0.017\) \(0.351 \pm 0.003 \pm 0.017\) \(0.351 \pm 0.019\) \(\frac{\text{N_\$\textsup \text{\text{\text{\text{D.4}}}}}{\text{D.170} \pm 0.014 \pm 0.061\)	ACCIARRI 94B L3 $E_{\text{Cm}}^{ee} = 91.2 \text{ GeV}$ BUSKULIC 94K ALEP $E_{\text{Cm}}^{ee} = 91.2 \text{ GeV}$ ABREU 93L DLPH $E_{\text{Cm}}^{ee} = 91.2 \text{ GeV}$ ACTON 92J OPAL $E_{\text{Cm}}^{ee} = 91.2 \text{ GeV}$ DOCUMENT ID TECN COMMENT ABREU 950 DLPH $E_{\text{Cm}}^{ee} = 91.2 \text{ GeV}$

$\langle N_{\Sigma(1385)^{\pm}} angle$				
VALUE	DOCUMENT ID		TECN	COMMENT
0.038 ±0.004 OUR AVERAGE				
$0.0382 \pm 0.0028 \pm 0.0045$	ABREU			$E_{cm}^{\mathit{ee}} = 91.2 \; GeV$
0.0380 ± 0.0062	ACTON	92J	OPAL	E ^{ee} _{cm} = 91.2 GeV
⟨ N ₌ -⟩				
0.0226±0.0022 OUR AVERAGE	DOCUMENT ID Error includes sca			
0.0250±0.0009±0.0021	ABREU			Eee = 91.2 GeV
0.0206±0.0021	ACTON			$E_{cm}^{ee} = 91.2 \text{ GeV}$
• • We do not use the following				CIII
$0.020 \pm 0.004 \pm 0.003$	ABREU	92G	DLPH	Repl. by ABREU 950
$\langle N_{\Xi(1530)^0} \rangle$				
VALUE	DOCUMENT ID		TECN	COMMENT
0.0044±0.0008 OUR AVERAGE	Error includes sca			
$0.0041 \pm 0.0004 \pm 0.0004$	ABREU	950	DLPH	E_{cm}^{ee} = 91.2 GeV
0.0063 ± 0.0014	ACTON	92J	OPAL	E ^{ee} _{CM} = 91.2 GeV
$\langle N_{O^-} \rangle$				
VALUE	DOCUMENT ID		TECN	COMMENT
0.0017±0.0010 OUR AVERAGE	Error includes sca	ale fa	ctor of 2	2.3.
$0.0014 \pm 0.0002 \pm 0.0004$	ADAM	96B	DLPH	$E_{\rm cm}^{\it ee}$ = 91.2 GeV
0.0050 ± 0.0015	ACTON	9 2J	OPAL	E ^{ee} _{cm} = 91.2 GeV
⟨N _{charged} ⟩				
VALUE	DOCUMENT ID		TECN	COMMENT
20.99 ± 0.14 OUR AVERAGE				
21.05 ± 0.20	AKERS	95Z	OPAL	E_{cm}^{ee} = 91.2 GeV
21.40 ± 0.43	ACTON	92B	OPAL	Eee = 91.2 GeV
$20.71\pm0.04\pm0.77$	ABREU	91H	DLPH	E ^{ee} _{cm} = 91.2 GeV
20.7 ±0.7	ADEVA	911	L3	Eee = 91.2 GeV
20.85±0.02±0.24	DECAMP	91K	ALEP	Eee 91.2 GeV
20.1 ±1.0 ±0.9	ABRAMS			Eee = 91.1 GeV
• • We do not use the following				CIII
21.3 ±0.1 ±0.6	DECAMP		ALEP	
21.3 ±0.1 ±0.0	DECAMIF	900	ALEP	Webi DA DECWINE ATK

Z HADRONIC POLE CROSS SECTION

This quantity is defined as

$$\sigma_h^0 = \frac{12\pi}{M_Z^2} \frac{\Gamma(e^+e^-)\Gamma(\text{hadrons})}{\Gamma_Z^2}$$

It is one of the parameters used in the Z lineshape fit. (See the 'Note on the Z Boson.')

VALUE (nb)	EVTS	DOCUMENT ID		TECN	COMMENT
41.54±0.14 OUR FIT					
41.49±0.10 OUR AVE	RAGE				
41.23 ± 0.20	1.05M	ABREU	94	DLPH	E ^{ee} _{cm} = 88–94 GeV
41.39 ± 0.26	1.09M	ACCIARRI	94	L3	E ^{ee} _{cm} = 88–94 GeV
41.70 ± 0.23	1.19M	AKERS	94	OPAL	E ^{ee} _{Cm} = 88–94 GeV
41.60 ± 0.16	1.27M	BUSKULIC	94	ALEP	<i>E</i> ^{ee} cm = 88−94 GeV
• • We do not use to	the following	data for average	s, fit	s, limits,	etc. • • •
41.45 ± 0.31	512k	ACTON	930	OPAL	Repl. by AKERS 94
41.34 ± 0.28	460k	ADRIANI	931	1 L3	Repl. by ACCIARRI 94
41.60 ± 0.27	520k	BUSKULIC	93J	ALEP	Repl. by BUSKULIC 94
42 ±4	450	ABRAMS	89E	MRK2	E ^{ee} _{Cm} = 89.2–93.0 GeV

Z VECTOR COUPLINGS TO CHARGED LEPTONS

These quantities are the effective vector couplings of the Z to charged leptons. Their magnitude is derived from a measurement of the Z line-shape and the forward-backward lepton asymmetries as a function of energy around the Z mass. The relative sign among the vector to axial-vector couplings is obtained from a measurement of the Z asymmetry parameters, A_e and A_τ , or ν_e scattering. The fit values quoted below correspond to global nine- or five-parameter fits to lineshape, lepton forward-backward asymmetry, and A_e and A_τ measurements. See "Note on the Z boson" for details.

Within the current data set, the reason for the smallness of $g_L^{\mathcal{U}}$ compared to $g_V^{\mathcal{U}}$ and $g_V^{\mathcal{T}}$ is due to the large value of A_e which is heavily weighted by the SLD result. This large value of A_e leads to a large value of $g_V^{\mathcal{U}}$. Since $g_V^{\mathcal{U}}$ is obtained using the relation $A_{FB}^{\mathcal{U}} = 0.75 \times A_e \times A_{\mu}$, a large value of $g_V^{\mathcal{U}}$. Each storage value of $g_V^{\mathcal{U}}$. Concerning the r, its g_V gets mainly determined directly from A_r which is obtained from a measurement of the τ polarization (see "Note on the Z boson").

ge _V				
<u>VALUE</u> -0.0393±0.0018 Ol	JR FIT	DOCUMENT ID	TECN	COMMENT
• • • We do not use	the follow	ing data for average	es, fits, limits	, etc. • • •
-0.0414 ± 0.0020		¹¹⁶ ABE	95J SLD	E ^{ee} _{Cm} = 91.31 GeV
$-0.0364^{+0.0096}_{-0.0082}$	38k	¹¹⁷ ACCIARRI	94 L3	Eee = 88-94 GeV
-0.036 ± 0.005	45.8k	¹¹⁸ BUSKULIC	94 ALEP	E ^{ee} _{cm} = 88–94 GeV
$-0.040 \begin{array}{l} +0.013 \\ -0.011 \end{array}$		¹¹⁹ ADRIANI	93M L3	Repl. by ACCIARRI 94
$-0.034 \begin{array}{l} +0.006 \\ -0.005 \end{array}$		¹¹⁷ BUSKULIC	93J ALEP	Repl. by BUSKULIC 94
-0.035 ± 0.005	70k	120 QUAST	93 RVUE	<i>E</i> ^{ee} _{cm} = 88–94 GeV

- 116 ABE 95J obtain this result combining polarized Bhabha results with the A_{LR} measurement of ABE 94C. The Bhabha results alone give 0.0507 \pm 0.0096 \pm 0.0020. 117 The τ polarization result has been included.
- $^{118}\, {\rm BUSKULIC}$ 94 use the added constraint of τ polarization.
- 119 ADRIANI 93M use their measurement of the au polarization in addition to forward-backward lepton asymmetries.
- 120 QUAST 93 is a combined analysis of LEP results as of Feb. 1993. QUAST 93 use also the average LEP values for au polarization and the forward–backward au polarisation asymmetry.

g_V^μ				
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT

$-0.0276^{\,+0.0056}_{\,-0.0057}$ OUR FIT

• • • We do not use the following data for averages, fits, limits, etc. • • •

$-0.0402 {}^{+ 0.0153}_{- 0.0211}$	34k	¹²¹ ACCIARRI	94 L3	$E_{ m cm}^{ee}=$ 88–94 GeV
-0.034 ± 0.013	46.4k	¹²² BUSKULIC	94 ALEP	<i>E</i> ^{ee} cm = 88−94 GeV
$-0.048 \begin{array}{l} +0.021 \\ -0.033 \end{array}$		¹²³ ADRIANI	93M L3	Repl. by ACCIARRI 94
$-0.019 \begin{array}{l} +0.018 \\ -0.019 \end{array}$		¹²¹ BUSKULIC	93J ALEP	Repl. by BUSKULIC 94
$-0.029\ \pm0.010$	70k	¹²⁴ QUAST	93 RVUE	<i>E</i> ^{ee} _{cm} = 88−94 GeV

- $^{121}\,\mathrm{The}\; au$ polarization result has been included.
- 122 BUSKULIC 94 use the added constraint of au polarization.
- 123 ADRIANI 93M use their measurement of the au polarization in addition to forward-backward lepton asymmetries.
- 124 QUAST 93 is a combined analysis of LEP results as of Feb. 1993. QUAST 93 use also the average LEP values for au polarization and the forward–backward au polarisation

8 V VALUE

- v				
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
-0.0374±0.0022 OUR	FIT			
Wa do not use th	o following	data for averages	fite limite	otc

125 ACCIARRI

-0.0384 ± 0.0078	25K	123 ACCIARRI	94 L3	Ecm = 88-94 GeV
-0.038 ± 0.005		¹²⁶ BUSKULIC	94 ALEP	E ^{ee} _{cm} = 88–94 GeV
-0.037 ± 0.008	7441	¹²⁷ ADRIANI	93M L3	Repl. by ACCIARRI 94
-0.039 ± 0.006		¹²⁵ BUSKULIC	93J ALEP	Repl. by BUSKULIC 94
-0.039 ± 0.004	50k	¹²⁸ QUAST	93 RVUE	<i>E</i> ee = 88–94 GeV

- $^{125}\,\mathrm{The}\ \tau$ polarization result has been included.
- 126 BUSKULIC 94 use the added constraint of au polarization. backward lepton asymmetries.
- 128 QUAST 93 is a combined analysis of LEP results as of Feb. 1993. QUAST 93 use also the average LEP values for au polarization and the forward-backward au polarisation asymmetry.

BV VALUE

0 V					
VALUE	EVTS	DOCUMENT ID	TE	CN C	OMMENT
-0.0376±0.0012 Ol	JR FIT				
• • • We do not use	the follow	ing data for average	es, fits, li	mits, et	tc. • • •
-0.039 ± 0.004	50.3k	¹²⁹ ABREU	94 DI	PH E	ee = 88–94 GeV
$-0.0378^{+0.0045}_{-0.0042}$	97k	¹³⁰ ACCIARRI	94 L3	E	ee = 88–94 GeV
-0.034 ± 0.004	146k	¹²⁹ AKERS	94 OF	PAL E	ee = 88-94 GeV
-0.038 ± 0.004	137.3k	¹²⁹ BUSKULIC	94 AL	EP E	ee = 88-94 GeV
-0.027 ± 0.008	58k	¹²⁹ ACTON	93D OF	PAL R	Repl. by AKERS 94
$-0.040 \begin{array}{l} +0.006 \\ -0.005 \end{array}$		¹³⁰ ADRIANI	93M L3	F	Repl. by ACCIARRI 94
$-0.034 \begin{array}{l} +0.004 \\ -0.003 \end{array}$		¹³⁰ BUSKULIC	93J AL	EP R	Repl. by BUSKULIC 94
-0.0355 ± 0.0025	190k	¹³¹ QUAST	93 R\	/UE E	ee = 88–94 GeV

- 129 Using forward-backward lepton asymmetries.
- $^{130}\,\mathrm{The}\;\tau$ polarization result has been included.
- 131 QUAST 93 is a combined analysis of LEP results as of Feb. 1993. QUAST 93 use also the average LEP values for au polarization and the forward–backward au polarisation asymmetry. Assumes lepton universality.

Z AXIAL-VECTOR COUPLINGS TO CHARGED LEPTONS

These quantities are the effective axial-vector couplings of the \boldsymbol{Z} to charged leptons. Their magnitude is derived from a measurement of the Z lineshape and the forward-backward lepton asymmetries as a function of energy around the Z mass. The relative sign among the vector to axial-vector couplings is obtained from a measurement of the Z asymmetry parameters, A_e and A_τ , or ν_e scattering. The fit values quoted below correspond to global nine- or five-parameter fits to lineshape, lepton forward-backward asymmetry, and A_e and A_τ measurements. See "Note on the Z boson" for details

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
-0.5007±0.0009 O	JR FIT			
 • • We do not use 	e the follow	ing data for averag	es, fits, limits	, etc. • • •
-0.4977 ± 0.0045		¹³² ABE	95J SLD	$E_{cm}^{\mathit{ee}} = 91.31 \; GeV$
-0.4998 ± 0.0016	38k	¹³³ ACCIARRI	94 L3	Eee = 88-94 GeV
-0.503 ± 0.002	45.8k	BUSKULIC	94 ALEP	Eee = 88-94 GeV
-0.4980 ± 0.0021		¹³³ ADRIANI	93M L3	Repl. by ACCIARRI 94
-0.5029 ± 0.0018		¹³³ BUSKULIC	93J ALEP	Repl. by BUSKULIC 94
132 ABE 95J obtain	this result o	ombining polarized	Bhabha resu	lts with the A _{LR} measur
ment of ABE 940	. The Bha	bha results alone gi	ve - 0.4968	\pm 0.0039 \pm 0.0027.
133 The $ au$ -polarizatio	n constrair	t has been included	1.	

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
-0.5015±0.0012 Ol	JR FIT				
• • • We do not use	the follow	ing data for averag	es, fit	s, limits,	etc. • • •
$-0.4987 ^{+0.0030}_{-0.0026}$	34k	¹³⁴ ACCIARRI	94	L3	<i>E</i> ^{ee} _{CM} = 88–94 GeV
-0.501 ± 0.002	46.4k	BUSKULIC	94	ALEP	E ^{ee} _{cm} = 88–94 GeV
$-0.4968 + 0.0050 \\ -0.0037$		¹³⁴ ADRIANI	931	1 L3	Repl. by ACCIARRI 94
-0.5014 ± 0.0029		¹³⁴ BUSKULIC	931	ALEP	Repl. by BUSKULIC 94

B A /ALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.5009±0.0013 Ol	JR FIT			
• • We do not use	the follow	ing data for averag	es, fits, limits,	, etc. • • •
-0.5014 ± 0.0029	25k	¹³⁵ ACCIARRI	94 L3	<i>E</i> ^{ee} _{cm} = 88−94 GeV
-0.502 ±0.003	45.1k	BUSKULIC	94 ALEP	E ^{ee} _{Cm} = 88–94 GeV
-0.5032 ± 0.0038	7441	¹³⁵ ADRIANI	93M L3	Repl. by ACCIARRI 94
		135 BUSKULIC	93J ALEP	Repl. by BUSKULIC 94

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.5008±0.0008 OL	IR FIT				
 • • We do not use 	the follow	ing data for average	es, fits	, limits,	etc. • • •
-0.4999 ± 0.0014	71k	ABREU	94	DLPH	Eee = 88-94 GeV
-0.4998 ± 0.0014	97k	¹³⁶ ACCIARRI	94	L3	E ^{ee} _{cm} = 88–94 GeV
-0.500 ± 0.001	146k	AKERS	94	OPAL	E ^{ee} _{cm} = 88–94 GeV
-0.502 ± 0.001	137k	BUSKULIC	94	ALEP	E ^{ee} _{cm} = 88-94 GeV
-0.4998 ± 0.0016	58k	ACTON	93D	OPAL	Repl. by AKERS 94
-0.4986 ± 0.0015		¹³⁶ ADRIANI	93M	L3	Repl. by ACCIARRI 94
-0.5022 ± 0.0015		¹³⁶ BUSKULIC	93J	ALEP	Repl. by BUSKULIC 9-

Z COUPLINGS TO NEUTRAL LEPTONS

These quantities are the effective couplings of the \boldsymbol{Z} to neutral leptons. $u_e\,e$ and $u_\mu\,e$ scattering results are combined with g_A^e and g_V^e measurements at the Z mass to obtain $g^{
u_e}$ and $g^{
u_\mu}$ following NOVIKOV 93c.

VALUE	DOCUMENT ID		TECN	COMMENT	
0.528±0.085	137 VILAIN	94	CHM2	From $\nu_{\mu} e$ and $\nu_{e} e$ scattering	I
137 VILAIN 94 derive this $^{1.05}_{-0.18}^{+0.15}$.	value from their value	of	$g^{ u_{\mu}}$ and		ı

$g^{ u_{\mu}}$					
V ALUE	DOCUMENT ID		TECN	COMMENT	
0.502±0.017	138 VILAIN	94	CHM2	From ν_{ii} e scattering	

 138 VILAIN 94 derive this value from their measurement of the couplings $g_A^{~e\,
u_{\mu}}=-$ 0.503 \pm 0.017 and $g_V^{e\,
u\mu}=-$ 0.035 \pm 0.017 obtained from $\nu_\mu\,e$ scattering. We have re-evaluated this value using the current PDG values for g_A^e and g_V^e .

Z ASYMMETRY PARAMETERS

For each fermion-antifermion pair coupling to the Z these quantities are

$$A_f = \frac{2g_V^f g_A^f}{(g_V^f)^2 + (g_A^f)^2}$$

where g_V^f and g_A^f are the effective vector and axial-vector couplings. For their relation to the various lepton asymmetries see the 'Note on the Z

Using polarized beams, this quantity can also be measured as $(\sigma_L - \sigma_R)/(\sigma_L + \sigma_R)$, where σ_L and σ_R are the e^+e^- production cross sections for Z bosons produced with left-handed and right-handed electrons respectively.

Because of the high current interest, we mention the following preliminary results here, but do not average them or include them in the Listings or Tables. An unpublished preliminary value of $A_{LR}~(=A_e)$ from SLD which includes all previous SLD data is 0.1551 \pm 0.0040 (combining statistical and systematic errors). If the ABE 94c value is replaced by this value, the average is 0.153 \pm 0.004 with no scale factor.

VALUE			EVTS		DOCUMENT ID		TECN	COMMENT
0.156	± 0.008	OUR AVE	RAGE		includes scale	factor	of 1.2.	
0.202	± 0.038	±0.008			ABE	95J	SLD	E_{cm}^{ee} = 91.31 GeV
0.136	±0.027	±0.003			ABREU	951	DLPH	Ecm= 88-94 GeV
0.122	± 0.030	±0.012	30663	140	AKERS	95	OPAL	Ecm = 88-94 GeV
0.129	± 0.016	± 0.005	33000	141	BUSKULIC	95Q	ALEP	Ecm = 88-94 GeV
0.1656	± 0.0071	± 0.0028	49392	142	ABE	940	SLD	Ecm = 91.26 GeV
0.157	± 0.020	± 0.005	86000	140	ACCIARRI	94E	L3	Eee = 88-94 GeV
0.097	± 0.044	± 0.004	10224	143	ABE	93	SLD	Ecm = 91.26 GeV
• • •	We do n	ot use the f	ollowing	data	for averages, fi	its, lin	nits, etc.	• • •
0.120	±0.026			140	BUSKULIC	93P	ALEP	Repl. by BUSKULIC 95Q

139 ABE 951 obtain this result from polarized Bhabha scattering.

140 Derived from the measurement of forward-backward au polarization asymmetry. 141 BUSKULIC 950 obtain this result fitting the au polarization as a function of the polar au

production angle. 142 ABE 94c measured the left-right asymmetry in Z production. This value leads to $\sin^2\!\theta_W$

 $_{143}^{=0.2292\pm0.0009\pm0.0004}.$ ABE 93 measured the left-right asymmetry in $\it Z$ production.



This quantity is derived from the measurement of the average τ polarization

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.145±0.009 OUR AV	ERAGE			
$0.148 \pm 0.017 \pm 0.014$		ABREU	95i DLPH	E ^{ee} _{cm} = 88-94 GeV
$0.153 \pm 0.019 \pm 0.013$	30663	AKERS	95 OPAL	E ^{ee} _{cm} = 88–94 GeV
$0.136 \pm 0.012 \pm 0.009$	33000	¹⁴⁴ BUSKULIC	95Q ALEP	Ecm = 88-94 GeV
$0.150 \pm 0.013 \pm 0.009$	86000	ACCIARRI	94E L3	E ^{ee} _{cm} = 88-94 GeV
• • • We do not use	the follow	ing data for average	s, fits, limits,	etc. • • •
0.132 ± 0.033	10732	ADRIANI	93M L3	Repl. by ACCIARRI 94E
0.143 ± 0.023		BUSKULIC	93P ALEP	Repl. by BUSKULIC 950
0.24 ±0.07	2021	ABREU	92N DLPH	Repl. by ABREU 951
144 BUSKULIC 950 of	tain this	result fitting the τ	nolarization a	s a function of the polar

This quantity is directly extracted from a measurement of the left-right forwardbackward asymmetry in $c\,\overline{c}$ production at SLC using polarized electron beam. This

	double asymmetry elimini	ates t	ne aepenaence	on tr	1e <i>∠-e-e</i>	coupling parameter A _e .
1	ALUE		DOCUMENT ID		TECN	COMMENT
- (0.59±0.19 OUR AVERAGE					
($0.37 \pm 0.23 \pm 0.21$	145	ABE	95L	SLD	Ecm = 91.26 GeV
($0.73 \pm 0.22 \pm 0.10$	146	ABE,K	95	SLD	$E_{\rm cm}^{ee} = 91.26 \; {\rm GeV}$

 145 ABE 95L tag $\it b$ and $\it c$ quarks through their semileptonic decays into electrons and muons.

A maximum likelihood fit is performed to extract A_b and A_c . 146 ABE,K 95 tag $Z \to c\overline{c}$ events using D^{*+} and D^+ meson production. To take care of the $b\overline{b}$ contamination in their analysis they use $A_b^D=0.64\pm0.11$ (which is A_b from D^*/D tagging). This is obtained by starting with a Standard Model value of 0.935, assigning it an estimated error of ±0.105 to cover LEP and SLD measurements, and finally taking into account $B \cdot \overline{B}$ mixing $(1-2\chi_{\rm mix}=0.72\pm0.09)$. Combining with ABE 95L they quote 0.59 ± 0.19 .

This quantity is directly extracted from a measurement of the left-right forwardbackward asymmetry in $b\overline{b}$ production at SLC using polarized electron beam. This double asymmetry eliminates the dependence on the Z-e-e coupling parameter A_e .

VALUE	EVTS	DOCUMENT	D TECN	COMMENT	·
0.89±0.11 OUR	VERAGE				
$0.87 \pm 0.11 \pm 0.09$	4032	¹⁴⁷ ABE	95k SLD	Eee 91.26 GeV	
$0.91 \pm 0.14 \pm 0.07$		¹⁴⁸ ABE	95L SLD	$E_{cm}^{ee} = 91.26 \text{ GeV}$	

 147 ABE 95к obtain an enriched sample of $b\overline{b}$ events tagging with the impact parameter. A momentum-weighted charge sum is used to identify the charge of the underlying b quark. 148 ABE 95L tag b and c quarks through their semileptonic decays into electrons and muons. A maximum likelihood fit is performed to extract A_b and A_c . Combining with ABE 95K, they quote $0.89 \pm 0.09 \pm 0.06$.

$A_{FB}^{(0,e)}$ CHARGE ASYMMETRY IN $e^+e^- ightarrow e^+e^-$ (including radiative corrections)

For the Z peak, we report the pole asymmetry defined by $(3/4)A_0^2$ as determined by the nine-parameter fit to cross-section and lepton forward-backward asymmetry data. For details see the "Note on the Z boson."

ASYMMETRY (%) 1.51±0.40 OUR FIT 1.5 ±0.4 OUR AVERAGE	STD. MODEL	(GeV)	DOCUMENT ID		TECN
2.5 ±0.9		91.2	ABREU	94	DLPH
1.04 ± 0.92		91.2	ACCIARRI	94	L3
0.62 ± 0.80		91.2	AKERS	94	OPAL
1.85 ± 0.66		91.2	BUSKULIC	94	ALEP

$A_{FB}^{(0,\mu)}$ CHARGE ASYMMETRY IN $e^+e^ightarrow \mu^+\mu^-$ (including radiative corrections)

For the Z peak, we report the pole asymmetry defined by $(3/4)A_eA_\mu$ as determined by the nine-parameter fit to cross-section and lepton forwardbackward asymmetry data. For details see the "Note on the Z boson."

ASYMMETRY (%)	STD. MODEL	(GeV)		DOCUMENT ID		TECN
1.33± 0.26 OUR FIT	MODEL	(OCV)		DOCOMENT ID		TECH
1.34 ± 0.24 OUR AVERAG	E					
1.4 ± 0.5		91.2		ABREU	94	DLPH
1.79± 0.61		91.2		ACCIARRI	94	L3
0.99 ± 0.42		91.2		AKERS	94	OPAL
1.46± 0.48		91.2		BUSKULIC	94	ALEP
• • • We do not use the follow	wing data for	averages			• •	
9 ±30	-2	20	149	ABREU	95M	DLPH
7 ± 26	- 10	40		ABREU	95M	DLPH
-11 ± 33	- 25	57		ABREU	95M	DLPH
-62 ±17	45	69	149	ABREU	95M	DLPH
-56 ±10	58	79	149	ABREU	95M	DLPH
-13 ± 5	-23	87.5	149	ABREU	95M	DLPH
$-29.0 \ \ \begin{array}{c} + \ 5.0 \\ - \ 4.8 \end{array} \ \pm 0.5$	- 32.1	56.9	150	ABE	901	VNS
$-$ 9.9 \pm 1.5 \pm 0.5	-9.2	35		HEGNER	90	JADE
0.05 ± 0.22	0.026	91.14	151	ABRAMS	89D	MRK2
-43.4 ± 17.0	- 24.9	52.0	152	BACALA	89	AMY
-11.0 ± 16.5	-29.4	55.0	152	BACALA	89	AMY
-30.0 ±12.4	-31.2	56.0	152	BACALA	89	AMY
-46.2 ± 14.9	-33.0	57.0	152	BACALA	89	AMY
-29 ±13	-25.9	53.3		ADACHI	88c	TOPZ
$+$ 5.3 \pm 5.0 \pm 0.5	-1.2	14.0		ADEVA	88	MRKJ
$-10.4 \pm 1.3 \pm 0.5$	-8.6	34.8		ADEVA	88	MRKJ
$-12.3 \pm 5.3 \pm 0.5$	-10.7	38.3		ADEVA	88	MRKJ
$-15.6~\pm~3.0~\pm0.5$	-14.9	43.8		ADEVA	88	MRKJ
$-$ 1.0 \pm 6.0	-1.2	13.9		BRAUNSCH	88D	TASS
$-$ 9.1 \pm 2.3 \pm 0.5	-8.6	34.5		BRAUNSCH	88D	TASS
$-10.6 {}^{+}_{-} {}^{2.2}_{2.3} \pm 0.5$	-8.9	35.0		BRAUNSCH	88D	TASS
$-17.6 \ ^{+}_{-} \ ^{4.4}_{4.3} \ \pm 0.5$	-15.2	43.6		BRAUNSCH	88D	TASS
$-$ 4.8 \pm 6.5 \pm 1.0	-11.5	39		BEHREND	87C	CELL
$-18.8 \pm 4.5 \pm 1.0$	-15.5	44		BEHREND	87c	CELL
$+$ 2.7 \pm 4.9	-1.2	13.9		BARTEL	86C	JADE
$-11.1 \pm 1.8 \pm 1.0$	-8.6	34.4		BARTEL	86C	JADE
$-17.3 \pm 4.8 \pm 1.0$	-13.7	41.5		BARTEL	86C	JADE
$-22.8 \pm 5.1 \pm 1.0$	-16.6	44.8		BARTEL	860	JADE
$-$ 6.3 \pm 0.8 \pm 0.2	-6.3	29		ASH	85	MAC
$-$ 4.9 \pm 1.5 \pm 0.5	- 5.9	29		DERRICK	85	HRS
$-$ 7.1 \pm 1.7	- 5.7	29		LEVI	83	MRK2
-16.1 ± 3.2	9.2	34.2		BRANDELIK	82C	TASS
149 ARREII 95M perform this n	neacurement	ucina radi	ative	muon nair ever	te se	cociated v

149 ABREU 95M perform this measurement using radiative muon-pair events associated with high-energy isolated photons. 153 ABE 901 measurements in the range $50 \le \sqrt{s} \le 60.8$ GeV.

151 ABRAMS 890 asymmetry includes both 9 $\mu^+\mu^-$ and 15 $\tau^+\tau^-$ events. 152 BACALA 89 systematic error is about 5%.

$A_{FB}^{(0, au)}$ CHARGE ASYMMETRY IN $e^+e^ightarrow~ au^+ au^-$ (including radiative corrections)

For the Z peak, we report the pole asymmetry defined by $(3/4)A_eA_{ au}$ as determined by the nine-parameter fit to cross-section and lepton forwardbackward asymmetry data. For details see the "Note on the Z boson."

ASYMMETRY (%)	STD. MODEL	√s (GeV)	DOCUMENT ID		TECN
2.12± 0.32 OUR FIT					
2.13± 0.31 OUR AVERAG	E				
2.2 ± 0.7		91.2	ABREU	94	DLPH
2.65 ± 0.88		91.2	ACCIARRI	94	L3
2.05± 0.52		91.2	AKERS	94	OPAL
1.97± 0.56		91.2	BUSKULIC	94	ALEP

• • • We do r	not use the follow	ving data for	averages,	fits	, limits, etc. • •	•	
$-32.8 \begin{array}{l} + & 6.4 \\ - & 6.2 \end{array}$	±1.5	-32.1	56.9	153	ABE	90ı	VNS
-8.1 ± 2.0	± 0.6	-9.2	35		HEGNER	90	JADE
-18.4 ± 19.2		-24.9	52.0		BACALA	89	AMY
-17.7 ± 26.1		-29.4	55.0		BACALA	89	AMY
-45.9 ± 16.6		-31.2	56.0		BACALA	89	AMY
-49.5 ± 18.0		-33.0	57.0	154	BACALA	89	AMY
-20 ± 14		- 25.9	53.3		ADACHI	88 C	TOPZ
$-10.6\ \pm\ 3.1$	± 1.5	- 8.5	34.7		ADEVA	88	MRKJ
$-~8.5~\pm~6.6$	± 1.5	-15.4	43.8		ADEVA	88	MRKJ
-6.0 ± 2.5	± 1.0	8.8	34.6		BARTEL	85F	JADE
$-11.8~\pm~4.6$	± 1.0	14.8	43.0		BARTEL	85F	JADE
-5.5 ± 1.2	± 0.5	-0.063	29.0		FERNANDEZ	85	MAC
-4.2 ± 2.0		0.057	29		LEVI	83	MRK2
$-10.3\ \pm\ 5.2$		-9.2	34.2		BEHREND	82	CELL
-0.4 ± 6.6		-9.1	34.2		BRANDELIK	82C	TASS

 $^{^{153}}$ ABE 901 measurements in the range 50 $\leq \sqrt{s} \leq$ 60.8 GeV.

$A_{FB}^{(0,\ell)}$ CHARGE ASYMMETRY IN $e^+e^ightarrow \ell^+\ell^-$ (including radiative corrections)

For the Z peak, we report the pole asymmetry defined by $(3/4)A_{\xi}^2$ as determined by the five-parameter fit to cross-section and lepton forwardbackward asymmetry data assuming lepton universality. For details see the "Note on the Z boson.

ASYMMETRY (%)	STD. MODEL	(GeV)	DOCUMENT ID		TECN
1.59±0.18 OUR FIT					
1.60±0.18 OUR AVERAGE					
1.77 ± 0.37		91.2	ABREU	94	DLPH
1.84 ± 0.45		91.2	ACCIARRI	94	L3
1.28 ± 0.30		91.2	AKERS	94	OPAL
1.71 ± 0.33		91.2	BUSKULIC	94	ALEP

$A_{ER}^{(0,s)}$ CHARGE ASYMMETRY IN $e^+e^- \rightarrow s\overline{s}$

The s-quark asymmetry is derived from measurements of the forwardbackward asymmetry of fast hadrons containing an s quark.

ASYMMETRY (%)	STD. MODEL	√s (GeV)	DOCUMENT IE) TECN
131+35+13		91.2	155 ARREII	95G DIPH

155 ABREU 95G require the presence of a high-momentum charged kaon or A^0 to tag the s quark. An unresolved s- and d-quark asymmetry of $(11.2\pm3.1\pm5.4)\%$ is obtained by tagging the presence of a high-energy neutron or neutral kaon in the hadron calorimeter.

$A_{FR}^{(0,c)}$ CHARGE ASYMMETRY IN $e^+e^- \rightarrow c\overline{c}$

OUR FIT, which is obtained by a simultaneous fit to several c- and bquark measurements as explained in the "Note on the Z boson," refers to the Z pole asymmetry. As a cross check we have also performed a weighted average of the "near peak" measurements taking into account the various common systematic errors. We have assumed that the smallest common systematic error is fully correlated. Applying to this combined "peak" measurement QCD, QED, and energy-dependence corrections, our weighted average gives a pole asymmetry of $(7.35 \pm 0.74)\%$

ASYMMETRY (%)	STD. MODEL	(GeV)	DOCUMENT ID	TECN
	5.4	91.24 91.27 91.27 91.24 91.24	156 ALEXANDER 157 ABREU 158 ABREU 159 BUSKULIC 160 BUSKULIC 161 AKERS	96 OPAL 95E DLPH 95K DLPH 95I ALEP 94G ALEP 93D OPAL
8.3 ± 3.8 ±2.7 • • • We do not use	5.6 the followin	91.24 g data fo	¹⁶² ADRIANI r averages, fits, limit	92D L3 s, etc. • • •
- 7.5 ± 3.4 ±0.6 14.1 ± 2.8 ±0.9 6.8 ± 4.2 ±0.9 1.4 ± 3.0 ±2.0	-3.5 12.0	89.52 92.94 91.25 91.24	156 ALEXANDER 156 ALEXANDER 163 BUSKULIC 164 ACTON	96 OPAL 96 OPAL 94J ALEP 93K OPAL
-14 ± 14 ± 3 18 ± 12 ± 3 -12.9 ± 7.8 ± 5.5	- 2 12 - 13.6	89.75 92.64 35	161 AKERS 161 AKERS BEHREND	93D OPAL 93D OPAL 90D CELL
7.7 ±13.4 ±5.0 -12.8 ± 4.4 ±4.1 -10.9 ±12.9 ±4.6 -14.9 ± 6.7	-22.1 -13.6 -23.2 -13.3	43 35 44 35	BEHREND ELSEN ELSEN OULD-SAADA	90D CELL 90 JADE 90 JADE

¹⁵⁶ ALEXANDER 96 tag heavy flavors using one or two identified leptons. This allows the simultaneous fitting of the b and c quark forward-backward asymmetries as well as the average $B^0 - \overline{B}^0$ mixing.

- 159 BUSKULIC 951 require the presence of a high momentum ${\it D^{*\pm}}$ to have an enriched
- 160 BUSKULIC 94G perform a simultaneous fit to the p and p_T spectra of both single and
- 161 AKERS 93D identify the b and c decays using D^* .
- 162 ADRIANI 92D use both electron and muon semileptonic decays.
- 163 BUSKULIC 94J Identify the b and c decays using D^* . Repl. by BUSKULIC 95i.
- 164 ACTON 93K use the lepton tagging technique. Repl. by ALEXANDER 96.

$A_{ER}^{(0,b)}$ CHARGE ASYMMETRY IN $e^+e^- \rightarrow b\overline{b}$

OUR FIT, which is obtained by a simultaneous fit to several c- and bquark measurements as explained in the "Note on the Z boson," refers to the Z pole asymmetry. As a cross check we have also performed a weighted average of the "near peak" measurements taking into account the various common systematic errors. We have assumed that the smallest common systematic error is fully correlated. Applying to this combined "peak" measurement QCD, QED, and energy-dependence corrections, our weighted average gives a pole asymmetry of (9.96 \pm 0.39)%. For the jetcharge measurements (where the QCD corrections are already included since they represent an inherent part of the analysis), we subtract the QCD correction before combining.

ASYMMETRY (%)	STD. MODEL	(GeV)	DOCUMENT ID		TECN
9.92± 0.35 OUR FIT					
$9.06 \pm 0.51 \pm 0.23$		91.24	¹⁶⁵ ALEXANDER	96	OPAL
$5.9 \pm 6.2 \pm 2.4$		91.27	166 ABREU	95E	DLPH
$10.4 \pm 1.3 \pm 0.5$		91.27	¹⁶⁷ ABREU	95K	DLPH
$11.5 \pm 1.7 \pm 1.0$		91.27	¹⁶⁸ ABREU	95K	DLPH
9.63 ± 0.67 ± 0.38		91.25	¹⁶⁹ AKERS	95 s	OPAL
$8.7 \pm 1.1 \pm 0.4$		91.3	¹⁷⁰ ACCIARRI	94D	L3
$8.7 \pm 1.4 \pm 0.2$		91.24	¹⁷¹ BUSKULIC	94G	ALEP
$9.92 \pm 0.84 \pm 0.46$		91.19	¹⁷² BUSKULIC	941	ALEP
13.9 \pm 9.7 \pm 4.9	9.4	91.28	¹⁷³ AKERS	93D	OPAL
• • • We do not use the	following da	ta for ave	rages, fits, limits, et	c. •	• •
$5.5 \pm 2.4 \pm 0.3$	5.5	89.52	¹⁶⁵ ALEXANDER	96	OPAL
$11.7 \pm 2.0 \pm 0.3$	11.4	92.94	¹⁶⁵ ALEXANDER	96	OPAL
$6.2 \pm 3.4 \pm 0.2$		89.52	¹⁶⁹ AKERS	955	OPAL
$17.2 \pm 2.8 \pm 0.7$		92.94	¹⁶⁹ AKERS	95 S	OPAL
$3.8 \pm 6.7 \pm 0.5$		88.24	¹⁷⁴ BUSKULIC	94G	ALEP
$-$ 1.7 \pm 7.6 \pm 0.3		89.24	¹⁷⁴ BUSKULIC	94G	ALEP
$4.5 \pm 6.0 \pm 0.5$		90.24	¹⁷⁴ BUSKULIC	94G	ALEP
$7.0~\pm~5.5~\pm~0.7$		92.24	¹⁷⁴ BUSKULIC	94G	ALEP
$12.1 \pm 6.9 \pm 1.1$		93.24	¹⁷⁴ BUSKULIC	94G	ALEP
$14.5 \pm 8.1 \pm 1.3$		94.24	¹⁷⁴ BUSKULIC	94 G	ALEP
$7.1 \pm 5.4 \pm 0.7$	5.2	89.66	¹⁷⁵ ACTON	93K	OPAL
$9.2 \pm 1.8 \pm 0.8$	8.5	91.24	175 ACTON		OPAL
$13.1 \pm 4.7 \pm 1.3$	10.8	92.75	175 ACTON	93K	OPAL
9.3 ± 1.1		91.2	176 QUAST	93	RVUE
$16.1 \pm 6.0 \pm 2.1$		91.2	177 ABREU		DLPH
$8.6 \pm 1.5 \pm 0.7$	8.2	91.24	178 ADRIANI	92D	
$2.5 \pm 5.1 \pm 0.7$	5.3	89.67	179 ADRIANI	92D	
$9.7 \pm 1.7 \pm 0.7$	8.2	91.24	179 ADRIANI	92 D	L3
$6.2 \pm 4.2 \pm 0.7$	10.8	92.81	¹⁷⁹ ADRIANI	92D	L3
-71 ± 34 $+ 7$ $- 8$	-58	58.3	SHIMONAKA	91	TOPZ
$-22.2 \pm 7.7 \pm 3.5$	-26.0	35	BEHREND		CELL
$-49.1 \pm 16.0 \pm 5.0$	- 39.7	43	BEHREND	90D	CELL
-28 ± 11	-23	35	BRAUNSCH	90	TASS
$-16.6~\pm~7.7~\pm~4.8$	-24.3	35	ELSEN	90	JADE
$-33.6 \pm 22.2 \pm 5.2$	-39.9	44	ELSEN	90	JADE
$3.4 ~\pm~ 7.0 ~\pm~ 3.5$	-16.0	29.0	BAND	89	MAC
-72 ± 28 ± 13	56	55.2	SAGAWA	89	AMY
165					

- $165\,\mathrm{ALEXANDER}$ 96 tag heavy flavors using one or two identified leptons. This allows the simultaneous fitting of the b and c quark forward-backward asymmetries as well as the average $B^0 - \overline{B}{}^0$ mixing.
- 166 ABREU 95E require the presence of a $D^{*\pm}$ to identify c and b quarks.
- 167 ABREU 95K identify c and b quarks using both electron and muon semileptonic decays. The systematic error includes an uncertainty of ± 0.3 due to the mixing correction ($X=0.115\pm0.011$).
- 168 ABREU 95K tag b quarks using lifetime; the quark charge is identified using jet charge. The systematic error includes an uncertainty of ± 0.3 due to the mixing correction ($\chi=$ 0.115 ± 0.011).
- 169 AKERS 95s tag b quarks using lifetime; the quark charge is measured using jet charge. These asymmetry values are obtained using $R_b = \Gamma(bb)/\Gamma(\text{hadrons}) = 0.216$. For a value of R_b different from this by an amount ΔR_b , the change in the asymmetry values of $R_b = \frac{1}{2} \frac{1}{2$ is given by $-K\Delta R_b$, where $K=0.082,\,0.471,\,{\rm and}\,\,0.855$ for \sqrt{s} values of 89.52, 91.25, and 92.94 GeV respectively.
- 170 ACCIARRI 94D use both electron and muon semileptonic decays.
- 171 BUSKULIC 94G perform a simultaneous fit to the p and $p_{\mathcal{T}}$ spectra of both single and
- 172 BUSKULIC 941 use the lifetime tag method to obtain a high purity sample of $Z \to b \, \overline{b}$ events and the hemisphere charge technique to obtain the jet charge. 173 AKERS 93D identify the b and c decays using D^* .
- 174 BUSKULIC 94G perform a high $p_{\mathcal{T}}$ lepton analysis using single- and double-tagged
- events.
 175 ACTON 93K use the lepton tagging technique. The systematic error includes the uncer-
- tainty on the mixing parameter. Replaced by ALEXANDER 96. ¹⁷⁶ QUAST 93 is a combined analysis of LEP results as of Feb. 1993.

¹⁵⁴ BACALA 89 systematic error is about 5%.

 $^{^{157}}$ ABREU 95E require the presence of a $D^{*\pm}$ to identify c and b quarks.

 $^{^{158}}$ ABREU 95K identify c and b quarks using both electron and muon semileptonic decays.

Ζ

- 177 B tagging via its semimuonic decay. Experimental value corrected using average LEP B^0 - \overline{B}^0 mixing parameter $X=0.143\pm0.023$. 178 ADRIANI 92D use both electron and muon semileptonic decays. For this measurement ADRIANI 92D average over all \sqrt{s} values to obtain a single result. 179 ADRIANI 92D use both electron and muon semileptonic decays. The quoted systematic error is common to all measurements. The peak value is superseded by ACCIARRI 94D.

CHARGE ASYMMETRY IN $e^+e^- \rightarrow q \overline{q}$

Summed over five lighter flavors.

Experimental and Standard Model values are somewhat event-selection dependent. Standard Model expectations contain some assumptions on $\mathcal{B}^0 \cdot \overline{\mathcal{B}}^0$ mixing and on other electroweak parameters.

ASYMMETRY (%)	STD. MODEL	(GeV)	DOCUMENT ID	TECN
• • • We do not use the f	ollowing data	for averages	s, fits, limits, etc. •	• •
3.93 ± 0.65		91.2	¹⁸⁰ QUAST	93 RVUE
$-0.76\pm0.12\pm0.15$		91.2	¹⁸¹ ABREU	92i DLPH
$4.0 \pm 0.4 \pm 0.63$	4.0	91.3	¹⁸² ACTON	92L OPAL
$9.1 \pm 1.4 \pm 1.6$	9.0	57.9	ADACHI	91 TOPZ
$-0.84\pm0.15\pm0.04$		91	DECAMP	91B ALEP
$8.3 \pm 2.9 \pm 1.9$	8.7	56.6	STUART	90 AMY
$11.4 \pm 2.2 \pm 2.1$	8.7	57.6	ABE	89L VNS
6.0 ±1.3	5.0	34.8	GREENSHAW	89 JADE
8.2 ±2.9	8.5	43.6	GREENSHAW	89 JADE

- 8.2 \pm 2.9 6.5 43.0 GRELLING CONTROLL STATES AND STATE

CHARGE ASYMMETRY IN $p \overline{p} \rightarrow Z \rightarrow e^+ e^-$

ASYMMETRY (%)	STD. MODEL	(GeV)	DOCUMENT ID	TECN
ullet $ullet$ We do not use the follo	wing data for	averages, fi	its, limits, etc. •	• •
$5.2 \pm 5.9 \pm 0.4$		91	ABE	91E CDF

Z REFERENCES

ABREU	96	ZPHY C70 531	+Adam, Adye+	(DELPHI Collab.)
ABREU	96C	PL B379 309	+Adam, Adye+	(DELPHI Collab.)
ACCIARRI	96	PL B371 126	+Adam, Adriani+	(L3 Collab.)
ACCIARRI	96B	PL B370 195	+Adam, Adriani+	(L3 Collab.)
ADAM	96	ZPHY C69 561	+Adye, Agasi+	(DELPHI Collab.)
ADAM	96B	ZPHY C70 371	+Adye, Agasi+	(DELPHI Collab.)
ALEXANDER	96	ZPHY C (submitted)	+Allison, Altekamp+	(OPAL Collab.)
CERN-PPE	/95-17	'9		
ALEXANDER	96B	ZPHY C70 197	+Allison, Altekamp+	(OPAL Collab.)
ALEXANDER	96F	PL B370 185	+Allison, Altekamp+	(OPAL Collab.)
BUSKULIC	96D	ZPHY C69 393	+Casper, De Bonis, Decamp+	(ALEPH Collab.)
BUSKULIC	96H	ZPHY C69 379	+Casper, De Bonis+	(ALEPH Collab.)
ABE	95 J	PRL 74 2880	+Abt, Ahn, Akagi+	(SLD Collab.)
ABE	95K	PRL 74 2890	+Abt, Ahn, Akagi+	(SLD Collab.)
ABE	95L	PRL 74 2895	+Abt, Ahn, Akagi+	(SLD Collab.)
ABE,K	95	PRL 75 3609	+Abt, Ahn, Akagi+	(SLD Collab.)
ABREU	95	ZPHY C65 709 erratum	ı+Adam, Adye, Agasi+	(DELPHI Collab.)
ABREU	95D	ZPHY C66 323	+Adam, Adye, Agasi+	(DELPHI Collab.)
ABREU	95E	ZPHY C66 341	+Adam, Adye, Agasi+	(DELPHI Collab.)
ABREU	95F	NP B444 3	+Adam, Adye, Agasi+	(DELPHI Collab.)
ABREU	95G	ZPHY C67 1	+Adam, Adye, Agasi+	(DELPHI Collab.)
ABREU	951	ZPHY C67 183	+Adam, Adye, Agasi+	(DELPHI Collab.)
ABREU	95J	ZPHY C65 555	+Adam, Adye, Agasi+	(DELPHI Collab.)
ABREU	95K	ZPHY C65 569	+Adam, Adye, Agasi+	(DELPHI Collab.)
ABREU	95L	ZPHY C65 587	+Adam, Adye, Agasi+	(DELPHI Collab.)
ABREU	95M	ZPHY C65 603	+Adam, Adye, Agasi, Ajinenko+	(DELPHI Collab.)
ABREU	950	ZPHY C67 543	+Adam, Adye, Agasi+	(DELPHI Collab.)
ABREU	95R	ZPHY C68 353	+Adam, Adye, Agasi+	(DELPHI Collab.)
ABREU	95W	PL B361 207	+Adam, Adye, Agasi+	(DELPHI Collab.)
ABREU	95X	ZPHY C69 1	+Adam, Adye, Agasi+	(DELPHI Collab.)
ACCIARRI	95B	PL B345 589	+Adam, Adriani, Aguilar-Benitez+	(L3 Collab.)
ACCIARRI	95C	PL B345 609	+Adam, Adriani, Aguilar-Benitez+	(L3 Collab.)
ACCIARRI	95G	PL B353 136	+Adam, Adriani, Aguilar-Benitez, Ahlen+	(L3 Collab.)
AKERS	95	ZPHY C65 1	+Alexander, Allison+	(OPAL Collab.)
AKERS	95B	ZPHY C65 17	+Alexander, Allison+	(OPAL Collab.)
AKERS	95C	ZPHY C65 47	+Alexander, Allison+	(OPAL Collab.)
AKERS	950	ZPHY C67 27	+Alexander, Allison+	(OPAL Collab.)
AKERS	955	ZPHY C67 365	+Alexander, Allison+	(OPAL Collab.)
AKERS	95U	ZPHY C67 389	+Alexander, Allison+	(OPAL Collab.)
AKERS	95W	ZPHY C67 555	+Alexander, Allison+	(OPAL Collab.)
AKERS	95X	ZPHY C68 1	+Alexander, Allison+	(OPAL Collab.)
AKERS	95Z	ZPHY C68 203	+Alexander, Allison+	(OPAL Collab.)
ALEXANDER	95D	PL B358 162	+Allison, Altekamp+	(OPAL Collab.)
BUSKULIC	951	PL B352 479	+Casper, De Bonis+	(ALEPH Collab.)
BUSKULIC	95Q	ZPHY C69 183	+Casper, De Bonis+	(ALEPH Collab.)
MIYABAYASHI	95	PL B347 171	+Adachi, Fujii+	(TOPAZ Collab.)
ABE	94C	PRL 73 25	+Abt, Ash, Aston, Bacchetta, Baird+	(SLD Collab.)
ABREU	94	NP B418 403	+Adam, Adye, Agasi+	(DELPHI Collab.)
ABREU	94B	PL B327 386	+Adam, Adye, Agasi+	(DELPHI Collab.)
ABREU	94P	PL B341 109	+Adam, Adye, Agasi, Ajinenko+	(DELPHI Collab.)
ACCIARRI	94	ZPHY C62 551	+Adam, Adriani, Aguilar-Benitez+	(L3 Collab.)
ACCIARRI	94B	PL B328 223	+Adam, Adriani, Aguilar-Benitez+	(L3 Collab.)

ACCIARRI	94D	PL B335 542		+Adam, Adriani, Aguilar-Benitez, Ahlen+	(L3 Collab.)
ACCIARRI AKERS	94E 94	PL B341 245 ZPHY C61 19		+Adam, Adriani+	(L3 Collab.) (OPAL Collab.)
AKERS	94D	ZPHY C61 357		+Alexander, Allison+ +Alexander, Allison+	(OPAL Collab.)
AKERS	94P	ZPHY C63 181		+Alexander, Allison+	(OPAL Collab.)
BUSKULIC	94	ZPHY C62 539		+Casper, De Bonis, Decamp, Ghez, Gov+	(ALEPH Collab.)
BUSKULIC	94G	ZPHY C62 179		+Casper, De Bonis, Decamp, Ghez, Goy+ +Casper, De Bonis, Decamp, Ghez+	(ALEPH Collab.)
BUSKULIC	941	PL B335 99		+Casper, De Bonis+	(ALEPH Collab.)
BUSKULIC	94J	ZPHY C62 1 ZPHY C64 361		+De Bonis, Decamp+	(ALEPH Collab.)
BUSKULIC	94K	ZPHY C64 361		+De Bonis, Decamp+	(ALEPH Collab.)
VILAIN	94	PL B320 203			HARM II Collab.)
ABE	93	PRL 70 2515		+Abt, Acton+	(SLD Collab.)
ABREU ABREU	93	PL B298 236		+Adam, Adye, Agasi+ +Adam, Adye, Agasi+	(DELPHI Collab.)
	93B	PL B298 247		+Adam, Adve, Agasi+	(DELPHI Collab.)
ABREU Also	931 95	ZPHY C59 533	orratum	+Adam, Adye, Agasi+	(DELPHI Collab.)
ABREU	93L	PI R318 249	ciratuii	Abreu, Adam, Adye, Agasi+ +Adam, Adami, Adye+	(DELPHI Collab.) (DELPHI Collab.)
ACTON	93	PL B305 407		+Alexander, Allison+	(OPAL Collab.)
ACTON	93D	ZPHY C58 219		+Alexander, Allison+	(OPAL Collab.)
ACTON	93E	PL B311 391		+Akers, Alexander+	(OPAL Collab.)
ACTON	93F	ZPHY C58 405		+Alexander, Allison+	(OPAL Collab.)
ACTON	931	ZPHY C58 523		+Alexander, Allison+	(OPAL Collab.)
ACTON	93K	ZPHY C60 19		+Akers, Alexander+	(OPAL Collab.) (OPAL Collab.)
ACTON	93M	ZPHY C60 579		+Akers, Alexander+	(OPAL Collab.)
ADRIANI	93	PL B301 136 PL B307 237		+Aguilar-Benitez, Ahlen+	(L3 Collab.)
ADRIANI	93E	PL B307 237		+Aguilar-Benitez, Ahlen+	(L3 Collab.)
ADRIANI	93F	PL B309 451		+Aguilar-Benitez, Ahlen+	(L3 Collab.)
ADRIANI ADRIANI	93H 93I	PL B315 494 PL B316 427		+Aguilar-Benitez, Ahlen+	(L3 Collab.)
ADRIANI	93J	PL B317 467		+Aguilar-Benitez, Ahlen+ +Aguilar-Benitez, Ahlen, Alcaraz+	(L3 Collab.)
ADRIANI	93M	PRPL 236 1		+Aguilar-Benitez, Ahlen, Alcaraz, Aloisio+	(L3 Collab.) (L3 Collab.)
AKERS	93B	ZPHY C60 199		+Alexander Allison Anderson Arcelli+	(OPAL Collab.)
AKERS	93D	ZPHY C60 601		+Alexander, Allison, Anderson, Arcelli+ +Alexander, Allison+	(OPAL Collab.)
BUSKULIC	93J	ZPHY C60 71		+Decamp, Goy, Lees, Minard+	(ALEPH Collab.)
BUSKULIC	93L	PL B313 520		+De Bonis, Decamp+	(ALEPH Collab.)
BUSKULIC	93M	PL B313 535		+De Bonis, Decamp+	(ALEPH Collab.)
BUSKULIC	93N	PL B313 549		+De Bonis, Decamp+	(ALEPH Collab.)
BUSKULIC	93P	ZPHY C59 369		+Decamp, Goy+	(ALEPH Collab.)
LEP	93	PL B307 187		+LEP Energy Group, LEP Collabs	(LEP Collabs.)
NOVIKOV	93C	PL B298 453		+Okun, Vysotsky	(ITEP)
QUAST	93	MPL A8 675			(DESY)
ABREU	92	ZPHY C53 567		+Adam, Adami, Adye+	(DELPHI Collab.)
ABREU	92G	PL B275 231		+Adam, Adami, Adye+	(DELPHI Collab.)
ABREU ABREU	92H 92I	PL B276 536		+Adam, Adami, Adye+	(DELPHI Collab.) (DELPHI Collab.)
ABREU	92K	PL B277 371 PL B281 383		+Adam, Adami, Adve+	(DELPHI Collab.)
ABREU	92M	PL B289 199		+Adam, Adami, Adye+ +Adam, Adye, Agasi, Alekseev+	(DELPHI Collab.)
ABREU	92N	ZPHY C55 555		+Adam, Adye, Agasi+	(DELPHI Collab.)
ABREU	920	PL B295 383		+Adam, Adami, Adye+	(DELPHI Collab.)
ACTON	92B	ZPHY C53 539		+Alexander, Allisson, Allport+	(OPAL Collab.)
ACTON	92 J	PL B291 503		+Alexander, Allison, Allport+	(OPAL Collab.)
ACTON	92L	PL B294 436		+Alexander, Allison, Allport+	(OPAL Collab.)
ACTON	920	ZPHY C56 521		+Alexander, Allison, Allport+ +Alexander, Allison+	(OPAL Collab.)
ADEVA	92	PL B275 209		+Adriani, Aguilar-Benitez+	(L3 Collab.)
ADRIANI	92B	PL B288 404		+Aguilar-Benitez, Ahlen, Akbari, Alcaraz+ +Aguilar-Benitez, Ahlen, Akbari+	(L3 Collab.)
ADRIANI	92D	PL B292 454		+Aguilar-Benitez, Ahlen, Akbari+	(L3 Collab.)
ADRIANI	92E	PL B292 463		+Aguilar-Benitez, Ahlen, Akbari, Alcaraz+	(L3 Collab.)
ALITTI	92B	PL B276 354		+Ambrosini, Ansari, Autiero, Bareyre+	(UA2 Collab.)
BUSKULIC	92D	PL B292 210		+Decamp, Goy, Lees+	(ALEPH Collab.) (ALEPH Collab.)
DECAMP DECAMP	92 92B	PRPL 216 253 ZPHY C53 1		+Deschizeaux, Goy, Lees, Minard+	(ALEPH Collab.)
LEP	926	PL B276 247		+Deschizeaux, Goy, Lees, Minard+ +ALEPH, DELPHI, L3, OPAL	(LED Collabs.)
ABE	91E	PRL 67 1502		+Amidei, Apollinari+	(LEP Collabs.) (CDF Collab.)
ABREU	91H	ZPHY C50 185		+Adam, Adami, Adye+	(DELPHI Collab.)
ACTON	91B	PL B273 338		+Alexander, Allison, Allport, Anderson+	(OPAL Collab.)
ADACHI	91	PL B255 613		+Anazawa, Doser, Enomoto+	(TOPAZ Collab.)
ADEVA	911	PL B259 199		+Adriani, Aguilar-Benitez, Akbari+	(L3 Collab.)
AKRAWY	91F	PL B257 531		+Alexander, Allison, Allport, Anderson+	(OPAL Collab.)
DECAMP	91B	PL B259 377		+Deschizeaux, Goy+	(ALEPH Collab.)
DECAMP	91 J	PL B266 218		+Deschizeaux, Goy, Lees+	(ALEPH Collab.)
DECAMP	91K	PL B273 181		+Deschizeaux, Goy, Lees, Minard+	(ALEPH Collab.)
JACOBSEN	91	PRL 67 3347		+Koetke, Adolphsen, Fujino+	(Mark II Collab.)
SHIMONAKA	91 90l	PL B268 457 ZPHY C48 13		+Fujii, Miyamoto+	(TOPAZ Collab.)
ABE ABRAMS	90	PRL 64 1334		+Amako, Arai, Asano, Chiba+ +Adolphsen, Averill, Ballam+	(VENUS Collab.) (Mark II Collab.)
ADACHI	90F	PL B234 525		+Doser, Enomoto, Fujii+	(TOPAZ Collab.)
AKRAWY	90J	PL B246 285		+Alexander, Allison, Allport, Anderson+	(OPAL Collab.)
BEHREND	90D	ZPHY C47 333		+Criegee, Field, Franke, Jung+	(CELLO Collab.)
BRAUNSCH	90	ZPHY C48 433		+Criegee, Field, Franke, Jung+ Braunschweig, Gerhards, Kirschfink+	(TASSO Collab.)
DECAMP	90Q	PL B234 209		+Deschizeaux, Lees, Minard+	(ALEPH Collab.)
ELSEN	90	ZPHY C46 349		+Allison, Ambrus, Barlow, Bartel+	(JADE Collab.)
HEGNER	90	ZPHY C46 547		+Naroska, Schroth, Allison+	(JADE Collab.)
KRAL	90	PRL 64 1211		+Abrams, Adolphsen, Averill, Ballam+	(Mark II Collab.)
STUART ABE	90 89	PRL 64 983 PRL 62 613		+Breedon, Kim, Ko, Lander, Maeshima+ +Amidei, Apollinari, Ascori, Atac+	(AMY Collab.) (CDF Collab.)
ABE	89C	PRL 63 720		+Amidei, Apollinari, Atac, Auchincloss+	(CDF Collab.)
ABE	89L	PL B232 425		+Amako, Arai, Asano, Chiba+	(VENUS Collab.)
ABRAMS	89B	PRL 63 2173		+Adoinhsen Averill Ballam Barish+	(Mark II Collab.)
ABRAMS	89D	PRL 63 2780		+Adolphsen, Averill, Ballam, Barish+	(Mark II Collab.)
ALBAJAR	89	ZPHY C44 15		+Albrow, Allkofer, Arnison, Astbury+	(UA1 Collab.)
BACALA	89	PL B218 112		+Malchow, Sparks, Imlay, Kirk+	(AMY Collab.)
BAND	89	PL B218 369		+Camporesi, Chadwick, Delfino, Desangro-	
GREENSHAW MORI	89 89	ZPHY C42 1		+Warming, Allison, Ambrus, Barlow+	(JADE Collab.)
OULD-SAADA	89	PL B218 499 ZPHY C44 567		+Nozaki, Blanis, Bodek, Budd+ +Allison, Ambrus, Barlow, Bartel	(AMY Collab.) (JADE Collab.)
SAGAWA	89	PRL 63 2341		+Allison, Ambrus, Barlow, Bartel+ +Lim, Abe, Fujii, Higashi+	(AMY Collab.)
ADACHI	88C	PL B208 319		+Aihara, Dijkstra, Enomoto, Fujii+	(TOPAZ Collab.)
ADEVA	88	PR D38 2665		+Anderhub, Ansari, Becker+	(Mark-J Collab.)
BRAUNSCH	88D	ZPHY C40 163		Braunschweig, Gerhards, Kirschfink+	(TASSO Collab.)
ANSARI	87	PL B186 440		+Bagnaia, Banner, Battiston+	(UA2 Collab.)
BEHREND	87C	PL B191 209		+Buerger, Criegee, Dainton+	(CELLO Collab.)
BARTEL	86C	ZPHY C30 371		+Becker, Cords, Felst, Haidt+	(JADE Collab.)
Also	85B	ZPHY C26 507		Bartel, Becker, Bowdery, Cords+	(JADE Collab.)
Also ASH	82	PL 108B 140		Bartel, Cords, Dittmann, Eichler+	(JADE Collab.)
ASH BARTEL	85 85F	PRL 55 1831 PL 161B 188		+Band, Blume, Camporesi+	(MAC Collab.) (JADE Collab.)
DERRICK	85F 85	PR D31 2352		+Becker, Cords, Felst+ +Fernandez, Fries, Hyman+	(JADE Collab.) (HRS Collab.)
FERNANDEZ	85	PRL 54 1624		+Ford, Qi, Read+	(MAC Collab.)
LEVI	83	PRL 51 1941		+Blocker, Strait+	(Mark II Collab.)
BEHREND	82	PL 114B 282		+Chen, Fenner, Field+	(CELLO Collab.)
BRANDELIK	82C	PL 110B 173		+Braunschweig, Gather	(TASSO Collab.)

Gauge & Higgs Boson Particle Listings Z, Higgs Bosons — H^0 and H^{\pm}

Higgs Bosons — H^0 and H^{\pm} , Searches for

THE HIGGS BOSON

(by I. Hinchliffe, LBNL)

The Standard Model [1] contains one neutral scalar Higgs boson, which is a remnant of the mechanism that breaks the $\mathrm{SU}(2) \times \mathrm{U}(1)$ symmetry and generates the W and Z boson masses. The Higgs couples to quarks and leptons of mass m_f with a strength $gm_f/2M_W$. Its coupling to W and Z bosons is of strength g, where g is the coupling constant of the $\mathrm{SU}(2)$ gauge theory. Consequently its coupling to stable matter is very small, and its production and detection in experiments is difficult. An exception is its production in the decay of the Z boson. Since large numbers of Z's can be produced and the coupling of the Z to the Higgs is unsuppressed, experiments at LEP are now able to rule out a significant range of Higgs masses. The branching ratio of the Higgs boson into various final states is shown in Fig. 1.

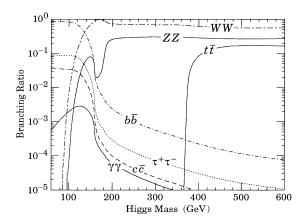


Figure 1: The branching ratio of the Higgs boson into $\gamma\gamma$, $\tau\bar{\tau}$, $b\bar{b}$, $t\bar{t}$, $c\bar{c}$, ZZ, and WW as a function of the Higgs mass. In the latter cases, if $M_H < 2M_Z$ (or $M_H < 2M_W$), the value indicated is the rate to ZZ^* (or WW^*) where Z^* (W^*) denotes a virtual Z (W). The $c\bar{c}$ rate depends sensitively on the poorly-determined charmed quark mass.

If the Higgs mass is very large, the couplings of the Higgs to itself and to longitudinally polarized gauge bosons become large. Requiring that these couplings remain weak enough so that perturbation theory is applicable implies that $M_H \lesssim 1$ TeV [2]. While this is not an absolute bound, it is an indication of the mass scale at which one can no longer speak of an elementary Higgs boson. This fact is made more clear if one notes that the width of the Higgs boson is proportional to the cube of its mass (for $M_H > 2M_Z$) and that a boson of mass 1 TeV has a width of 500 GeV.

It is believed that scalar field theories of the type used to describe Higgs self-interactions can only be effective theories valid over a limited range of energies if the Higgs self-coupling and hence Higgs mass is nonzero. A theory of this type that is valid at all energy scales must have zero coupling. The range of energies over which the interacting theory is valid is a function of the Higgs self-coupling and hence its mass. An upper bound on the Higgs mass can then be determined by requiring that the theory be valid (i.e., have a nonzero value of the renormalized Higgs self-coupling) at all scales up to the Higgs mass [3]. Nonperturbative calculations using lattice [4] gauge theory that can be used to compute at arbitrary values of the Higgs mass indicate that $M_H \lesssim 770~{\rm GeV}$.

If the Higgs mass were small, then the vacuum (ground) state with the correct value of M_W would cease to be the true ground state of the theory [5]. A theoretical constraint can then be obtained from the requirement that this is not the case, i.e., that our universe is in the true minimum of the Higgs potential. The constraint depends upon the top quark mass and upon the scale (Λ) up to which the Standard Model remains valid. This scale must be at least 1 TeV, resulting in the constraint [7] $M_H > 72 \text{ GeV} + 0.9 (m_{\text{top}} - 174 \text{ GeV})$. The bound increases monotonically with the scale, for $\Lambda = 10^{19} \text{ GeV}$, $M_H > 135 \text{ GeV} + 2.1 \text{ (}m_{\text{top}} - 174 \text{ GeV)}.$ This constraint may be too restrictive. Strictly speaking we can only require that the predicted lifetime of our universe, if it is not at the true minimum of the Higgs potential, be longer than its observed age [8,9]. For $\Lambda=1$ TeV there is no constraint; and for $\Lambda = 10^{19} \text{ GeV } M_H > 120 \text{ GeV} + 2.3 (m_{\text{top}} - 174 \text{ GeV}) [10].$

Experiments at LEP are able to exclude a large range of Higgs masses. They search for the decay $Z \to HZ^*$. Here Z^* refers to a virtual Z boson that can appear in the detector as e^+e^- , $\mu^+\mu^-$, $\tau^+\tau^-$, $\nu\overline{\nu}$ (i.e., missing energy) or hadrons. The experimental searches have considered both $H\to$ hadrons and $H\to \tau^+\tau^-$. The best limits are shown in the Particle Listings below.

Precision measurement of electroweak parameters such as M_W and the various asymmetries at LEP and SLC are becoming sensitive enough that they can in principle constrain the Higgs mass through its effect in radiative corrections. Currently, the precision tests allow the entire range from the direct LEP limit ($M_H \gtrsim 60$ GeV) to 1 TeV [11] at 95% confidence level although fits prefer the lower end of this range. The recent determination of the top mass has improved the constraint on M_H . See the article in this volume on the "Standard Model of Electroweak Interactions."

The search range for Higgs bosons will expand shortly when LEP begins operation at higher energy. The process $e^+e^- \to ZH$ [12] should enable neutral Higgs bosons of masses up to ~ 0.97 ($\sqrt{s}-M_Z$) to be discovered [13]. If the Higgs is heavier than this, its discovery will probably have to wait until experiments at the LHC have data. If the neutral Higgs boson has mass greater than $2M_Z$, it will likely be discovered via its decay to ZZ and the subsequent decay of the Z's to charged

Gauge & Higgs Boson Particle Listings Higgs Bosons — H^0 and H^{\pm}

leptons (electrons or muons) or of one Z to charged leptons and the other to neutrinos. A challenging region is that between the ultimate limit of LEP and $2M_Z$. At the upper end of this range the decay to a real and a virtual Z, followed by the decay to charged leptons is available. The decay rate of the Higgs boson into this channel falls rapidly as M_H is reduced and becomes too small for $M_H \lesssim 140$ GeV. For masses below this, the decays $H \to \gamma \gamma$ and possibly $H \to b\bar{b}$ [14] are expected to be used. The former has a small branching ratio and large background, the latter has a large branching ratio, larger background and a final state that is difficult to fully reconstruct [15].

Extensions of the Standard Model, such as those based on supersymmetry [16], can have more complicated spectra of Higgs bosons. The simplest extension has two Higgs doublets whose neutral components have vacuum expectation values v_1 and v_2 , both of which contribute to the W and Z masses. The physical particle spectrum contains one charged Higgs boson (H^{\pm}) , two neutral scalars (H_1, H_2) ,* and one pseudoscalar (A). In the simplest version of the supersymmetric model, the mass the lightest of these scalars depends upon the top quark mass, the ratio v_2/v_1 , and the masses of the other supersymmetric particles. For $m_t = 174$ GeV, there is a bound $M_{H_1} \lesssim 125$ GeV [18,19]. In models where all fermions of the same electric charge receive their masses from only one of the two doublets $(v_2 \text{ gives mass to the charge } 2/3 \text{ quarks, while } v_1 \text{ gives mass}$ to the charged leptons and the charge 1/3 quarks), there are, as in the Standard Model, no flavor-changing neutral currents at lowest order in perturbation theory. The H_1 , H_2^0 , and Acouplings to fermions depend on v_2/v_1 and are either enhanced or suppressed relative to the couplings in the Standard Model. Experiments at LEP are able to exclude ranges of masses for neutral Higgs particles in these models. These ranges depend on the values of v_2/v_1 . See the Particle Listings below on H_1^0 , Mass Limits in Supersymmetric Models.

Charged Higgs bosons can be pair produced in e^+e^- annihilation. Searches for charged Higgs bosons depend on the assumed branching fractions to $\nu\tau$, $c\overline{s}$, and $c\overline{b}$. Data from LEP now exclude charged Higgs bosons of mass less than 43.5 GeV [20]. See the Particle Listings for details of the H^\pm Mass Limit.

A charged Higgs boson could be produced in the decay of a top quark, $t \to H^+b$. Searches for this decay at hadron colliders should be possible [21].

Notes and References

- * H_1 and H_2 are usually called h and H in the literature.
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HO (Higgs Boson) MASS LIMITS

These limits apply to the Higgs boson of the three-generation Standard Model with the minimal Higgs sector. Limits that depend on the $Ht\bar{t}$ coupling may also apply to a Higgs boson of an extended Higgs sector whose couplings to up-type quarks are comparable to or larger than those of the standard one-doublet model H^0 couplings.

For comprehensive reviews, see Gunion, Haber, Kane, and Dawson, "The Higgs Hunter's Guide," (Addison-Wesley, Menlo Park, CA, 1990) and R.N. Cahn, Reports on Progress in Physics 52 389 (1989). For a review of theoretical bounds on the Higgs mass, see M. Sher, Physics Reports (Physics Letters C) 179 273 (1989).

Limits from Coupling to Z/W^{\pm}

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>55.7	95		g DLPH	$Z \rightarrow H^0 Z^*$
>56.9	95	² AKERS 94	B OPAL	
>57.7	95	³ ADRIANI 93	c L3	$Z \rightarrow H^0 Z^*$
>58.4	95	⁴ BUSKULIC 93	H ALEP	$Z \rightarrow H^0 Z^*$
• • • We do not use the	e followin	ng data for averages, fi	ts, limits,	etc. • • •
>60	95	⁵ GROSS 93	RVUE	$Z \rightarrow H^0 Z^*$
				$Z \rightarrow H^0 \gamma$
>38	95		J DLPH	
>52	95	8 ADEVA 92	B L3	
		⁹ ADRIANI 92	F L3	$Z \rightarrow H^0 \gamma$
>48	95	¹⁰ DECAMP 92	ALEP	$Z \rightarrow H^0 Z^*$
> 0.21	99		B DLPH	$Z \rightarrow H^0 Z^*$
>11.3	95	¹² ACTON 91	OPAL	$H^0 \rightarrow anything$
>41.8	95		L3	$Z \rightarrow H^0 Z^*$
		¹⁴ ADEVA 91	D L3	$Z \rightarrow H^0 \gamma$
none 3-44	95			$Z \rightarrow H^0 Z^*$
none 3-25.3	95		c OPAL	$Z \rightarrow H^0 Z^*$
none 0.21-0.818	90	¹⁷ ABE 90	E CDF	$\rho \overline{\rho} \rightarrow (W^{\pm}, Z) +$
		177		$H^{0} + X$
none 0.846-0.987	90	¹⁷ ABE 90	E CDF	$\rho \overline{\rho} \rightarrow (W^{\pm}, Z) +$
		18		$H^{0} + X$
none 0.21-14	95	10	c DLPH	
none 2-32	95		H L3	$Z \rightarrow H^0 Z^*$
> 2	99		N L3	$Z \rightarrow H^0 Z^*$
none 3.0-19.3	95	21 AKRAWY 90	C OPAL	$Z \rightarrow H^0 Z^*$
> 0.21	95	22 AKRAWY 90	P OPAL	$Z \rightarrow H^0 Z^*$
none 0.032-15	95	23 DECAMP 90	ALEP	$Z \rightarrow H^0 Z^*$
none 11-24	95	24 DECAMP 90		$Z \rightarrow H^0 Z^*$
> 0.057	95			$Z \rightarrow H^0 e e, H^0 \mu \mu$
none 11–41.6	95	²⁶ DECAMP 90	N ALEP	$Z \rightarrow H^0 Z^*$

- 1 ABREU 94G searched for $Z\to~H^0+(e^+e^-,\,\mu^+\mu^-,\,\tau^+\tau^-,\,\nu\overline{\nu})$ with $H^0\to~q\,\overline{q}$. Four $\ell^+\ell^-$ candidates were found (all yielding low mass) consistent with expected back-
- AKERS 94B searched for $Z \to H^0 + (e^+e^-, \mu^+\mu^-, \nu\overline{\nu})$ with $H^0 \to q\overline{q}$. One $\nu\overline{\nu}$ and one $\mu^+\mu^-$ candidate were found consistent with expected backgrounds. ³ ADRIANI 93C searched for $Z \to H^0 + (\nu \overline{\nu}, e^+e^-, \mu^+\mu^-)$ with H^0 decaying hadroni-
- cally or to $au \overline{ au}$. Two e^+e^- and one $\mu^+\mu^-$ candidates are found consistent with expected
- ⁴ BUSKULIC 93H searched for $Z \rightarrow H^0 \nu \overline{\nu}$ (acoplanar jets) and $Z \rightarrow H^0 + (e^+ e^-)$ $\mu^+\mu^-$) (lepton pairs in hadronic events).
- ⁵ GROSS 93 combine data taken by four LEP experiments through 1991.
- ⁶ ABREU 92D give $\sigma(e^+e^-\to Z\to H^0\gamma)$ ·B($H^0\to {\rm hadrons})$ <8 pb (95% CL) for m_{H^0} <75 GeV and E_γ >8 GeV.
- 7 ABREU 92J searched for $Z o H^0 + (ee, \mu\mu, au au,
 u\overline{
 u})$ with $H^0 o q\overline{q}$. Only one candidate was found, in the channel ee + 2jets, with a dijet mass 35.4 \pm 5 GeV/ c^2 , consistent with the expected background of 1.0 \pm 0.2 events in the 3 channels $e^+\,e^ \mu^+\mu^-$, $\tau^+\tau^-$, and of 2.8 \pm 1.3 events in all 4 channels. This paper excludes 12–38 GeV. The range 0–12 GeV is eliminated by combining with the analyses of ABREU 90C
- GeV. The range 0–12 GeV is eminimated 3, 2.... and ABREU 91B. 8 ADEVA 92B searched for $Z \to H^0 + (\nu \overline{\nu}, ee, \mu \mu, \tau \tau)$ with $H^0 \to$ anything, $Z \to H^0 + \tau \tau$ with $H^0 \to q \overline{q}$, and $Z \to H^0 + q \overline{q}$ with $H^0 \to \tau \tau$. The analysis excludes the range $30 < m_{H^0} < 52$ GeV.
- ⁹ ADRIANI 92F give $\sigma(e^+e^- \rightarrow Z \rightarrow H^0\gamma)$ ·B($H^0 \rightarrow$ hadrons) <(2–10) pb (95% CL) for $m_{\chi^0} = 25$ –85 GeV. Using $\sigma(e^+e^- \rightarrow Z) = 30$ nb, we obtain B($Z \rightarrow H^0\gamma$)B($H^0 \rightarrow H^0\gamma$)B(H^0 hadrons) $<(0.7-3) \times 10^{-4}$ (95% CL).
- 10 DECAMP 92 searched for most possible final states for $Z\to H^0\,Z^*.$ 11 ABREU 91B searched for $Z\to H^0+\ell\bar\ell$ with missing H^0 and $Z\to H^0+(\nu\bar\nu,\ell\bar\ell,$ $q\overline{q}$) with $H^0 \rightarrow ee$.
- ¹² ACTON 91 searched for $e^+e^- \rightarrow Z^*H^0$ where $Z^* \rightarrow e^+e^-$, $\mu^+\mu^-$, or $\nu\overline{\nu}$ and $H^0 \rightarrow e^+e^$ anything. Without assuming the minimal Standard Model mass-lifetime relationship, the limit is $m_{H^0} > 9.5~{\rm GeV}$.
- $H^0 + (\mu \mu, ee, \nu \overline{\nu})$. This paper only excludes 15 < 13 ADEVA 91 searched for Z $m_{H^0} \, < \,$ 41.8 GeV. The 0–15 GeV range is excluded by combining with the analyses of previous L3 papers.
- ¹⁴ ADEVA 91D obtain a limit B($Z \rightarrow H^0 \gamma$)·B($H^0 \rightarrow \text{hadrons}$) < 4.7 × 10⁻⁴ (95%CL) for $m_{H^0}=$ 30–86 GeV. The limit is not sensitive enough to exclude a standard H^0
- ¹⁵ AKRAWY 91 searched for the channels $Z \to H^0 + (\nu \overline{\nu}, ee, \mu \mu, \tau \tau)$ with $H^0 \to$ $q\overline{q}$, $\tau\tau$, and $Z \rightarrow H^0 q\overline{q}$ with $H^0 \rightarrow \tau\tau$.
- ¹⁶ AKRAWY 91C searched the decay channels $Z \to H^0 + (\nu \overline{\nu}, ee, \mu \mu)$ with $H^0 \to q \overline{q}$.

- 17 ABE 90E looked for associated production of H^0 with W^\pm or Z in $p\overline{p}$ collisions at \sqrt{s} = 1.8 TeV. Searched for H^0 decays into $\mu^+\mu^-$, $\pi^+\pi^-$, and K^+K^- . Most of the excluded region is also excluded at 95% CL.
- ¹⁸ ABREU 90c searched for the channels $Z \rightarrow H^0 + (\nu \overline{\nu}, ee, \mu \mu)$ and $H^0 + q \overline{q}$ for m_H < 1 GeV.
- ¹¹⁹ ADEVA 90H searched for $Z \rightarrow H^0 + (\mu \mu, ee, \nu \overline{\nu})$.
- ²⁰ ADEVA 90N looked for $Z \to H^0 + (ee, \mu\mu)$ with missing H^0 and with $H^0 \to ee$, $\mu\mu$, $\pi^{+}\pi^{-}$, $K^{+}K^{-}$.
- 21 AKRAWY 90C based on 825 nb $^{-1}$. The decay $Z \to H^0 \nu \overline{\nu}$ with $H^0 \to \tau \overline{\tau}$ or $q \overline{q}$ provides the most powerful search means, but the quoted results sum all channels.
- ²² AKRAWY 90P looked for $Z \to H^0 + (ee, \mu\mu)$ (H^0 missing) and $Z \to H^0 \nu \overline{\nu}$, $H^0 \to H^0 \nu \overline{\nu}$
- 23 DECAMP 90 limits based on 11,550 Z events. They searched for $Z \rightarrow H^0 + (\nu \overline{\nu}, ee,$ $\mu\mu$, $\tau\tau$, $q\overline{q}$). The decay $Z\to H^0 \nu\overline{\nu}$ provides the most powerful search means, but the quoted results sum all channels. Different analysis methods are used for $m_{H^0} < 2m_{\mu}$ where Higgs would be long-lived. The 99% confidence limits exclude $m_{H^0} = 0.040$ –12

- GeV. GeV. 24 DECAMP 90H limits based on 25,000 $Z \to {\rm hadron~events}$. 25 DECAMP 90M looked for $Z \to H^0 \, \ell \ell$, where H^0 decays outside the detector. 26 DECAMP 90N searched for the channels $Z \to H^0 + (\nu \overline{\nu}, \ ee, \ \mu \mu, \ \tau \tau)$ with $H^0 \to {\rm hadron}$

Limits from Other Techniques =

H⁰ Indirect Mass Limits from Electroweak Analysis

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use th	e followin	g data for averages	, fits	, limits,	etc. • • •
$63 + 97 \\ - 0$		²⁷ CHANKOWSK	195	RVUE	
<730	95	28 ERLER	95	RVUE	
<740 35 +205 - 26	95	²⁹ MATSUMOTO ³⁰ ELLIS	95 94	RVUE RVUE	
45 + 95 - 28		31 ELLIS	94B	RVUE	
69 + 188 - 9		³² GURTU	94	RVUE	
		³³ MONTAGNA	94	RVUE	
$73 \begin{array}{c} +178 \\ -13 \end{array}$		³⁴ BLONDEL	93	RVUE	
10 + 25 8		35 ELLIS	93 B	RVUE	
10 + 60		³⁶ NOVIKOV	93 B	RVUE	
> 1.4	68	³⁷ DELAGUILA ³⁸ ELLIS		RVUE RVUE	Electroweak
$25 \begin{array}{c} +275 \\ -19 \end{array}$		³⁹ ELLIS	92E	RVUE	
50 + 353		⁴⁰ RENTON	92	RVUE	
_		⁴¹ SCHAILE	92	RV/IIF	

- 27 CHANKOWSKI 95 fit to LEP, SLD, and W mass data available in the spring of 1995 plus $m_{t}=176\pm13$ GeV. Exclusion of the SLD data increases the mass to $m_{H}=121-\frac{207}{58}$ GeV (m_{H} <800 GeV at 95% CL).
- ²⁸ ERLER 95 fit to LEP, SLC, W mass, and various low-energy data available in the summer of 1994 plus m_t =174 ± 16 GeV from CDF. The limit without m_t is 880 GeV. However, the preference for lighter m_H is due to R_b and A_{LR} , both of which do not agree well with the Standard Model prediction.
- ²⁹ MATSUMOTO 95 fit to LEP, SLD, W mass, and various neutral current data available in the summer of 1994 plus $m_{\rm H}{=}180\pm13$ GeV from CDF/DØ, and the LEP direct limit $m_{\rm H}{>}63$ GeV. $\alpha_S(m_Z)=0.124$ is used. Fixing $\alpha_S(m_Z)=0.116$ lowers the upper limit to 440 GeV. Dependence on $\alpha(m_Z)$ is given in the paper.
- 30 ELLIS 94 fit to LEP, SLD, *W*-mass, and neutrino data available in the summer of 1993. The fit to m_H , m_t , and α_s yields m_t = 140 $^{+21}_{-22}$ GeV and $\alpha_s(m_Z)$ = 0.116 $^{+0.007}_{-0.006}$.
- 31 ELLIS 94B fit to LEP, SLD, W mass, neutral current data available in the spring of 1994 plus $m_{\tilde{t}}=167\pm12$ GeV determined from CDF/D0 $t\bar{t}$ direct searches. $\alpha_{\rm S}(m_Z)=0.118\pm0.007$ is used. The fit yields $m_{\tilde{t}}=162\pm9$ GeV. A fit without the SLD data gives $m_H = 130 + 320_{-90}$ GeV.
- 32 GURTU 94 fit to LEP, SLD, W mass, neutral current data available in the spring of 1994 as well as $m_t=174\pm16$ GeV. A fit without $\Gamma(Z\to b\overline{b})/\Gamma(Z\to hadrons)$ gives $m_H = 120 + 364_{-60}^{+364} \text{ GeV}.$
- 33 MONTAGNA 94 fit to LEP and SLD, W-mass data together with $m_{ au}$
- -- MOVI LAGNA 94 TIT to LEP and SLD, W-mass data together with $m_t=174\pm17$ GeV. Although the data favor smaller Higgs masses, the authors do not regard it significant. 34 BLONDEL 93 perform two dimensional (m_t-m_H) fit to LEP electroweak data available in the spring of 1993. $\alpha_S=0.117\pm0.005$ is used and $m_t>108$ GeV, $m_H>62.5$ GeV imposed. $m_{H^0}=1$ TeV is compatible with the data within two standard deviations.
- 35 ELLIS 93B fit to LEP and neutrino data available in the summer of 1993. m_t is adjusted to minimize χ^2 and $\alpha_S(m_Z)=0.123\pm0.006$ is used. 95% CL limit for m_H <250 GeV
- 36 NOVIKOV 93B use a subset of the most accurate and "gluon-free" data available in the spring of 1993. They use m_W , $\Gamma(\ell\ell)$, and $A_{FB}^{\ell\ell}$.
- 37 DELAGUILA 928 perform two dimensional (m_t-m_H) fit to various LEP, neutrino, eH, and $p\bar{p}$ data available through 1991 with direct limits on $m_t,~m_H.~$ The result m_H =65 $^+$ 24 $^+$ 24 is not expected from the statistical sensitivity of the data but due to deviation of the data from the Standard Model expectation.
- 38 ELLIS 92 result is from a fit to electroweak data from LEP and elsewhere. They also find $m_H <$ 160 GeV at 68%CL and 0.5 $< m_H <$ 1500 GeV at 90%CL with m_t unconstrained.
- 39 ELLIS 92E perform fit to electroweak data available in the spring of 1992. m_{t} is adjusted to minimize χ^2 and $\alpha_s(m_Z) = 0.118 \pm 0.008$ is used.

Higgs Bosons — H^0 and H^{\pm}

- $^{
 m 40}$ RENTON 92 use electroweak data available in 1991 and require m_{H} >50 GeV. The constraint α_s = 0.114 \pm 0.007 was used.
- 41 SCHAILE 92 performs fit to LEP electroweak data (as of summer 1991) as well as m_W (UA2/CDF) and ν N (CDHS/CHARM). The fit with the constraint m_H >50 GeV gives m_H =50 $^{+192}_{-0}$ GeV. However, the m_H dependence of the χ^2 is not consistent from that expected from the present statistics and the sensitivity to m_H arises from the fact that the measured values of g_A and A_{BB}^F deviate from the Standard Model expectation. Therefore, the result is not considered to be significant.

From Other Techniques

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use th	e followi	ng data for average	s, fits	, limits,	etc. • • •
		⁴² CASAS	95	THEO	Vacuum stability
		⁴³ ESPINOSA	95B	THEO	Vacuum metastability
		44 ALTARELLI	94	THEO	Vacuum stability
none 0.001-0.072	95	⁴⁵ BARABASH	92	BDMP	$\eta' \rightarrow \eta H^0$
none 0.0012-0.052	90	DAVIER	89	BDMP	$e^-Z \rightarrow eH^0Z$ $(H^0 \rightarrow e^+e^-)$
none 0.010-0.10	90	⁴⁶ EGLI	89	CNTR	$ \begin{array}{ccc} e^{-}Z \rightarrow eH^{0}Z \\ (H^{0} \rightarrow e^{+}e^{-}) \\ \pi^{+} \rightarrow e^{+}\nu H^{0} \\ (H^{0} \rightarrow e^{+}e^{-}) \end{array} $
		⁴⁷ LINDNER	89		Vacuum stability
none 0.015-0.04	90	⁴⁸ YEPES	89	RVUE	$ \begin{array}{ccc} \pi^{\pm} & \xrightarrow{e} & e^{\pm} \nu H^{\acute{0}} \\ (H^{0} & \xrightarrow{e} & e^{+} e^{-}) \end{array} $
		⁴⁹ DZHELYADIN	81		$\eta' \xrightarrow{\eta} \eta H^0 \atop (H^0 \mu^+ \mu^-)$
		⁵⁰ WITTEN	81	COSM	$(H^{\sigma} \rightarrow \mu^{+}\mu^{-})$
		⁵⁰ GUTH	80	COSM	
		⁵⁰ SHER	80	COSM	

- 42 CASAS 95 require stability of the vacuum in the <code>minimal</code> Standard Model up to the scale Λ and find $m_H>127.9+1.92 (m_t-174)-4.25 (\alpha_s(m_Z)-0.124)/0.0006$ (units in GeV) for $\Lambda=10^{19}$ GeV, and $m_H>$ 52 GeV for $\Lambda=1$ TeV, $m_t=174$ GeV, $\alpha_s(m_Z)$
- 43 ESPINOSA 95B require metastability of the vacuum in the <code>minimal</code> Standard Model up to the scale Λ and find $m_H>[2.278\ -\ 4.654(\alpha_s(m_Z)\ -\ 0.124)]m_t$ $-\ 277$ GeV for Λ
- 44 ALTARELLI 94 require the stability of the vacuum in the *minimal* Standard Model and find $m_H >$ 72 (135) GeV for the cut-off scale $\Lambda=1$ TeV (10¹⁹ GeV), if $m_t=1$ 74 GeV and $\alpha_S(m_Z)=0.118$. See paper for $m_t,\,\alpha_S$, and Λ dependence of the result.
- and $\alpha_{\rm S}(m_Z)=0.118$. See paper for m_t , $\alpha_{\rm S}$, and γ dependence of the result. 45 BARABASH 92 is a beam dump experiment that searched for $H^0 \to e^+e^-$ and $\gamma \gamma$ produced via the decays $\pi \to e \nu_e H^0$, $K \to e \nu_e H^0$, $K \to \pi H^0$, and $\eta' \to \eta H^0$. The last process gives the best limit if the theoretical calculation by RUSKOV 87 is used. 46 EGL1 89 give a limit for $B(\pi^+ \to e^+ \nu H^0) \cdot B(H^0 \to e^+ e^-)$ ranging from 10^{-9} to
- 10^{-11} for the mass range 10–110 MeV. The theoretical prediction they use is too large by a factor of 162/49 (see DAWSON 89, DAWSON 90, and CHENG 89). The lower limit given above is reevaluated by us.
- limit given above is reevaluated by us.

 47 LINDNER 89 require vacuum stability and numerically solve the renormalization equations to two-loop order. If m_{top} = 100, 110, 120 GeV, then m_{Higgs} > 20, 34, 50 GeV. However, it is possible that the vacuum is not stable but is very long-lived.

 48 YEPES 89 reanalyzed a BNL beam-dump experiment (JACQUES 80) which looked for the dump and found none.
- for $m_{H^0}=0.25$ –0.409 GeV. However, the number 0.409 is not well-determined due to theoretical uncertainties in B($H^0 \rightarrow \mu^+\mu^-$)
- 50 Limits from cosmological considerations of \$SU(2) \times U(1) symmetry-breaking phase transition occurring only after extreme supercooling, resulting in too high a ratio of entropy to baryon number. Limits apply to the standard one-doublet model H^0 , with 'zero bare mass' whose physical mass is determined by the Coleman-Weinberg mechanism of dynamical symmetry breakdown. These limits depend on the mass of the top quark approximately according to $m_{H^0} > 10.4[1-4m_t^4/(2m_W^4+m_Z^4)]^{1/2}$ GeV when $m_t < 80$ GeV. So for $m_t \approx 80$ GeV, there is no limit. If $m_t > 80$ GeV, then vacuum stability arguments may give bounds on m_H , see LINDNER 89 above.

H⁰ (Higgs Boson) MASS LIMITS in Extended Higgs Models

The parameter x denotes the Higgs coupling to charge -1/3 quarks and charged leptons relative to the value in the standard one-Higgs-doublet model.

In order to prevent flavor-changing neutral currents in models with more than one Higgs doublet, only one of the Higgs doublets can couple to quarks of charge 2/3. The same requirement applies independently to charge -1/3 quarks and to leptons. Higgs couplings can be enhanced or suppressed.

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use th	e followin	g data for averages	s, fits	, limits,	etc. • • •
		⁵¹ ABREU ⁵² BRAHMACH			$Z \rightarrow H^0 Z^*, H^0 A^0$
		⁵³ BUSKULIC	931	ALEP	$Z \rightarrow H^0 Z^*$
>65	95	⁵⁴ BUSKULIC			Invisible H ⁰
		55 LOPEZ-FERN.	93	RVUE	
		⁵⁶ ADRIANI	92G	L3	$Z \rightarrow H^0 Z^*$
		⁵⁷ PICH			Very light Higgs
> 3.57	95	⁵⁸ ACTON			$Z \rightarrow H^0 Z^*$
		⁵⁹ DECAMP	91F	ALEP	$Z \rightarrow H^0 \ell^+ \ell^-$
		60 DECAMP	911	ALEP	Z decay

> 0.21	95	⁶¹ AKRAWY ⁶² DAVIER		L $Z \rightarrow H^0 Z^*$ 1P $e^- Z \rightarrow e H^0 Z$ $(H^0 \rightarrow e^+ e^-)$
		⁶³ SNYDER	89 MRH	$(H^0 \rightarrow e^+e^-)$ $(2 B \rightarrow H^0 X)$ $(H^0 \rightarrow e^+e^-)$
none 0.6-6.2	90	64 FRANZINI	87 CUS	
none 0.6-7.9	90	⁶⁴ FRANZINI	87 CUS	B $\Upsilon(1S) \rightarrow \gamma H^0, x=4$
none 3.7-5.6	90	⁶⁵ ALBRECHT	85J ARG	$\gamma(1S) \rightarrow \gamma H^0, x=2$
none 3.7-8.2	90	65 ALBRECHT	851 ARG	$\gamma(15) \rightarrow \gamma H^0 \gamma - 4$

- $^{51}\mathrm{See}$ Fig. 4 of ABREU 95H for the excluded region in the $m_{\ensuremath{H^0}}-m_{\ensuremath{A^0}}$ plane for general two-doublet models. For aneta > 1, the region $m_{H^0} + m_{A^0} \lesssim 87$ GeV, $m_{H^0} < 47$ GeV is excluded at 95% CL
- 52 BRAHMACHARI 93 consider Higgs limit from Z decay when the Higgs decays to invisible modes. If H^0 coupling to Z is at least $1/\sqrt{2}$ of the Standard Model H^0 , the DECAMP 92 limit of 48 GeV changes within ± 6 GeV for arbitrary B($H^0 \rightarrow SM$ -like)+B($H^0 \rightarrow SM$ -like)
- 53 See Fig. 1 of BUSKULIC 93I for the limit on ZZH^0 coupling for a general Higgs having a similar decay signature to Standard Model Higgs boson or decaying invisibly. If the decay rate for $Z o H^0 Z^*$ is >10% of the minimal Standard Model rate, then $m_{H^0} >$ 40
- GeV. For the standard rate the limit is 58 GeV. 54 BUSKULIC 931 limit for H^0 with the standard coupling to Z but decaying to weakly interacting particles.
- 55 LOPEZ-FERNANDEZ 93 consider Higgs limit from Z decay when the Higgs decays to invisible modes. See Fig. 2 for excluded region in m_{H^0} -ZZH coupling plane with arbitrary B($H^0 \rightarrow SM$ -like)+B($H^0 \rightarrow invisible$)=1. $m_H > 50$ GeV is obtained if the H^0 coupling strength to the Z is greater than 0.2 times the Standard Model rate.
- 56 See Fig. 1 of ADRIANI 92G for the limit on ZZH^0 coupling for a general Higgs having a similar decay signature to Standard Model Higgs boson. For most masses below 30 GeV, the rate for $Z \rightarrow H_1^0 Z^*$ is less than 10% of the Standard Model rate.
- 57 PICH 92 analyse ${\it H^0}$ with m_{H^0} <2 m_{\mu} in general two-doublet models. Excluded regions in the space of mass-mixing angles from LEP, beam dump, and π^\pm , η rare decays are shown in Figs. 3,4. The considered mass region is not totally excluded.
- 58 ACTON 91 limit is valid for any H^0 having $\Gamma(Z \to H^0 Z^*)$ more than 0.24 (0.56) times that for the standard Higgs boson for Higgs masses below $2m_\mu~(2m_\tau)$.
- 59 DECAMP 91F search for $Z \to H^0 \, \ell^+ \ell^-$ where H^0 escapes before decaying. Combining this with DECAMP 90M and DECAMP 90N, they obtain $B(Z \to H^0 \ell^+ \ell^-)/B(Z)$ $\ell^{+}\ell^{-}) < 2.5 \times 10^{-3} \text{ (95\%CL) for } m_{H^0} < 60 \text{ GeV}.$
- 60 See Figs. 1, 3, 4, 5 of DECAMP 911 for excluded regions for the masses and mixing angles in general two-doublet models.
- 61 AKRAWY 90P limit is valid for any H^0 having $\Gamma(Z\to H^0\,Z^*)$ more than 0.57 times that for the Standard Higgs boson.
- 62 DAVIER 89 give excluded region in m_{H^0} -x plane for m_{H^0} ranging from 1.2 MeV to 50
- 63 SNYDER 89 give limits on B(B \rightarrow H⁰X)·B(H⁰ \rightarrow e⁺e⁻) for 100 < m_{H⁰} < 200
- 64 First order QCD correction included with $\alpha_s \approx 0.2$. Their figure 4 shows the limits vs.
- 65 ALBRECHT 85J found no mono-energetic photons in both $\varUpsilon(1S)$ and $\varUpsilon(2S)$ radiative decays in the range 0.5 GeV < E(γ)<4.0 GeV with typically BR< 0.01 for $\varUpsilon(1S)$ and BR< 0.02 for $\varUpsilon(2S)$ at 90% CL. These upper limits are 5–10 times the prediction of the standard Higgs-doublet model. The quoted 90% limit B($\varUpsilon(1S) \rightarrow H^0 \gamma) < 1.5 \times 10^{-3}$ at $E(\gamma)=1.07$ GeV contradicts previous Crystal Ball observation of $(4.7\pm1.1)\times10^{-3}$; see their reference 3. Their figure 8a shows the upper limits of x^2 as a function of $E(\gamma)$ by assuming no QCD corrections. We used $m_{H^0}=m\,\gamma\,\,(1-2{\it E}(\gamma)/m\,\gamma)^{1/2}.$

H₁⁰ (Higgs Boson) MASS LIMITS in Supersymmetric Models

The minimal supersymmetric model has two complex doublets of Higgs bosons. The resulting physical states are two scalars $[H_1^0 \text{ and } H_2^0]$, where we define $m_{H_1^0} < m_{H_2^0}]$,

a pseudoscalar (A^0), and a charged Higgs pair (H^\pm). H^0_1 and H^0_2 are also called h and H in the literature. There are two free parameters in the theory which can be chosen to be m_{A^0} and $\tan\beta=\nu_2/\nu_1$, the ratio of vacuum expectation values of the two Higgs doublets. Tree-level Higgs masses are constrained by the model to be $m_{H^0_1} \leq$

 $m_Z, m_{H^0} \geq m_Z, m_{A^0} \geq m_{H^0}$, and $m_{H^\pm} \geq m_W$. However, as described in the "Note on Supersymmetry," recent calculations of one-loop radiative corrections show that these relations may be violated. Many experimental analyses have not taken into account these corrections; footnotes indicate when these corrections are included. The results assume no invisible H^0 or A^0 decays.

VALUE (GEV)					COMMENT
>44	95	⁶⁶ ABREU	95H	DLPH	any $ aneta$
>44.5	95	⁶⁷ AKERS	941	OPAL	taneta > 1
>44	95	⁶⁸ BUSKULIC	931	ALEP	aneta > 1
>42	95	⁶⁹ ADRIANI	92G	L3	$1 < tan \beta < 50$
• • • We do not use the	e followir	ng data for averages	s, fits,	, limits,	etc. • • •
		70 ROSIEK	95	RVUE	
>44.4	95	⁷¹ ABREU	940	DLPH	$m_{H_1^0} = m_{A^0}$, any $\tan \beta$
>34	95	⁷² ABREU	92J	DLPH	$tan \hat{\beta} > 0.6$
>29	95	⁷² ABREU	92J	DLPH	any $tan \beta$
> 0.21	95	⁷³ ABREU	91B	DLPH	any $tan \beta$
>28	95	⁷⁴ ABREU	91B	DLPH	any $tan \beta$

Gauge & Higgs Boson Particle Listings Higgs Bosons — H^0 and H^{\pm}

none 3-38	95	75 AKRAWY	91c OPAL	taneta > 6
none 3-22	95	⁷⁵ AKRAWY	91c OPAL	$tan\beta > 0.5$
		76 BLUEMLEIN	91 BDMP	$pN \rightarrow H_1^0X$
				$(H_1^0 \rightarrow e^+e^-, 2\gamma)$
>41	95	77 DECAMP	91 ALEP	$tan \beta > 1$
> 9	95	⁷⁸ ABREU	90E DLPH	any $ aneta$
>13	95	⁷⁸ ABREU	90E DLPH	taneta > 1
>26	95	⁷⁹ ADEVA	90R L3	taneta > 1
none 0.05-3.1	95	⁸⁰ DECAMP	90E ALEP	any $tan \beta$
none 0.05-13	95	⁸⁰ DECAMP	90E ALEP	$tan\beta > 0.6$
none 0.006-20	95	⁸⁰ DECAMP	90E ALEP	tan eta > 2
>37.1	95	80 DECAMP	90E ALEP	$tan \beta > 6$
none 0.05-20	95	81 DECAMP	90H ALEP	$tan\beta > 0.6$
none 0.006-21.4	95	81 DECAMP	90H ALEP	tan eta > 2
> 3.1	95	82 DECAMP	90M ALEP	any $ aneta$
"		0 .	0 0	

- ⁶⁶ ABREU 95H search for $Z \to H_1^0 Z^*$ and $Z \to H_1^0 A^0$. Two-loop corrections are included with m_t =170 GeV, $m_{\widetilde{t}}$ =1 TeV. Including only one-loop corrections does not change the
- 67 AKERS 94I search for $Z \to H_1^0 Z^*$ and $Z \to H_1^0 A^0$. One-loop corrections are included with $m_t <$ 200 GeV, $m_{\widetilde{t}} <$ 1 TeV. See Fig. 10 for limits for $\tan \beta <$ 1.
- ⁶⁸ BUSKULIC 931 search for $Z \rightarrow H_1^0 Z^*$ and $Z \rightarrow H_1^0 A^0$. One-loop corrections are included with any m_t , $m_{\widetilde{t}} > m_t$.
- ⁶⁹ ADRIANI 92G search for $Z \to H_1^0 Z^*$, $Z \to H_1^0 A^0 \to 4b$, $bb\tau\tau$, 4τ , 6b (via $H^0 \to H_1^0 A^0 \to H_1^0 A^0 \to H_1^0 A^0 \to H_1^0 A^0$ A^0 A^0), and include constraints from $\Gamma(Z)$. One-loop corrections to the Higgs potential are included with $90 < m_t < 250$ GeV, $m_t < m_{\widetilde t} < 1$ TeV.
- ⁷⁰ ROSIEK 95 study the dependence of $m_{H_1^0}$ limit on various supersymmetry parameters.
- They argue that H_1^0 as light as 25 GeV is not excluded by ADRIANI 92G data in the region $m_{A^0}\sim$ 60 GeV If $m_{\widetilde{t}}\lesssim$ 200 GeV and $\widetilde{t}_L.\widetilde{t}_R$ mixing is large. ⁷¹ ABREU 940 study $H_1^0A^0\to$ four jets and combine with ABREU 94G analysis. The
- limit applies if the H_1^0 A mass difference is <4 GeV.
- 72 ABREU 92J searched for $Z\to H_1^0Z^*$ and $Z\to H_1^0A^0$ with H_1^0 , $A^0\to \tau\tau$ or jet-jet. Small mass values are excluded by ABREU 91B.
- 73 ABREU 91B result is based on negative search for $Z \rightarrow H_1^0 f \overline{f}$ and the limit on invisible Z width $\Gamma(Z \rightarrow H_1^0 A^0) < 39$ MeV (95%CL), assuming $m_{A^0} < m_{H_1^0}$
- 74 ABREU 91B result obtained by combining with analysis of ABREU 901. 75 AKRAWY 91C result from $Z\to H_1^0A^0\to 4{\rm jet}$ or $\tau^+\tau^-{\rm j}j$ or 4τ and $Z\to H_1^0Z^*$ ($H_1^0\to q\bar q,Z^*\to \nu\bar\nu$ or e^+e^- or $\mu^+\mu^-$). See paper for the excluded region for the case $\tan \beta < 1$. Although these limits do not take into account the one-loop radiative corrections, the authors have reported unpublished results including these corrections and showed that the excluded region becomes larger.
- 76 BLUEMLEIN 91 excluded certain range of $\tan\beta$ for $m_{H_1^0} <$ 120 MeV, $m_{A^0} <$ 80 MeV.
- ⁷⁷ DECAMP 911 searched for $Z \to H_1^0 Z^*$, and $Z \to H_1^0 A^0 \to 4$ jets or $\tau \tau jj$ or $3A^0$. Their limits take into account the one-loop radiative corrections to the Higgs potential with varied too and count more search. with varied top and squark masses.
- 78 ABREU 90E searched for $Z \rightarrow H_1^0 A^0$ and $Z \rightarrow H_1^0 Z^*$. $m_{H_1^0} < 210$ MeV is not excluded by this analysis.
- 79 ADEVA 90R result is from $Z \to H_1^0 A^0 \to 4$ jet or $\tau \tau jj$ or 4τ and $Z \to H_1^0 Z^*$. Some region of $m_{H_1^0} < 4$ GeV is not excluded by this analysis.
- ⁸⁰ DECAMP 90E look for $Z \to H_1^0 A^0$ as well as $Z \to H_1^0 \ell^+ \ell^-$, $Z \to H_1^0 \nu \overline{\nu}$ with 18610 Z decays. Their search includes signatures in which H_1^0 and A^0 decay to $\gamma \gamma$, $e^+ e^-$, $\mu^+\mu^-$, $\tau^+\tau^-$, or $q\,\overline{q}$. See their figures of $m_{H_1^0}$ vs. $\tan\beta$.
- 81 DECAMP 90H is similar to DECAMP 90E but with 25,000 Z decays.
- 82 DECAMP 90M looked for $Z \to H^0 \ell \ell$, where H^0_1 decays outside the detector. This excludes a region in the $(m_{H_1^0}, \tan\beta)$ plane centered at $m_{H_1^0} = 50$ MeV, $\tan\beta = 0.5$. This limit together with DECAMP 90E result excludes $m_{H_1^0} < 3$ GeV for any $\tan\beta$.

A⁰ (Pseudoscalar Higgs Boson) MASS LIMITS in Supersymmetric Models

Limits on the ${\it A}^{0}$ mass from $e^{+}\,e^{-}$ collisions arise from direct searches in the $e^{+}\,e^{-}$ $A^0\,H^0_1$ channel and indirectly from the relations valid in the minimal supersymmetric model between m_{A^0} and $m_{H^0_+}$. As discussed in the "Note on Supersymmetry," at the one-loop level and in the simplest cases, these relations depend on the masses of the t quark and \tilde{t} squarks. The limits are weaker for larger t and \tilde{t} masses, while they increase with the inclusion of two-loop radiative corrections. Some specific examples of these dependences are provided in the footnotes to the listed papers.

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>27	95	⁸³ ABREU	95H DLPH	$tan\beta > 1$, $m_t = 170$
>24.3	95	⁸⁴ AKERS	94I OPAL	GeV $tan\beta > 1$, $m_t < 200 GeV$
>21	95	⁸⁵ BUSKULIC	93I ALEP	$tan\beta > 1$, $m_t = 140$
>22	95	86 ADRIANI	92G L3	GeV $1 < \tan \beta < 50, m_t < 250$

 • We do not use the following data for averages, fits, limits, etc. • • 								
>44.4	95	⁸⁷ ABREU	940 DLPH	$m_{H_1^0}=m_{A^0}$, any $\tan \beta$				
>44.5	95	⁸⁴ AKERS	94I OPAL	$\tan \beta > 1$, $m_{H_1^0} = m_{A^0}$				
		88 ELLIS	93 RVUE	1				
>34	95	⁸⁹ ABREU	92J DLPH	tan eta > 3				
> 0.21	95	⁹⁰ BUSKULIC	92 ALEP	taneta > 1				
none 3-40.5	95	⁹¹ AKRAWY	91c OPAL	$tan \beta > 1$, if 3 GeV $<$				
				$m_{H_1^0} < m_{A^0}$				
>20	95	92 DECAMP	911 ALEP	$tan\beta > 1$				
>34	95	⁹³ ABREU	90E DLPH	$tan\beta > 1$,				
				$m_{H_1^0} < m_{A^0}$				
>12	95	⁹³ ABREU	90E DLPH	$tan\beta \stackrel{1}{<} 1$				
>39	95	⁹⁴ ADEVA	90R L3	$tan\beta > 1$,				
				$m_{H^0} < m_{A^0}$				

- 83 ABREU 95H search for $Z\to H_1^0Z^*$ and $Z\to H_1^0A^0$. One-loop corrections are included with $m_t=170$ GeV, $m_{\widetilde{t}}=1$ TeV. The limit becomes weak for larger m_t : at $m_t=190$ GeV, the limit is 14 GeV. The limit at $m_t=170$ GeV would increase to 39 GeV if two-loop radiative corrections were included. m_t and $m_{\widetilde{t}}$ dependences are shown in ...
- rig. o. 84 AKERS 94I search for $Z \to H_0^0 Z^*$ and $Z \to H_0^0 A^0$. One-loop corrections are included with $m_t <$ 200 GeV, $m_{\widetilde{t}} <$ 1 TeV. See Fig. 10 for limits for $\tan \beta <$ 1.
- 85 BUSKULIC 93I search for $Z \to H_1^0 Z^*$ and $Z \to H_1^0 A^0$. One-loop corrections to the Higgs potential are included with any m_t , $m_{\widetilde{t}} > m_t$. For $m_t =$ 140 GeV and $m_{\widetilde{t}} = 1$ TeV, the limit is $m_{A^0} > 45$ GeV. Assumes no invisible H^0 or A^0 decays.
- ⁸⁶ ADRIANI 92G search for $Z \rightarrow H_1^0 Z^*$, $Z \rightarrow H_1^0 A^0 \rightarrow 4b$, $bb\tau\tau$, 4τ , 6b (via $H^0 \to A^0 A^0$), and include constraints from $\Gamma(Z)$. One-loop corrections are included with $90 < m_t < 250$ GeV, $m_t < m_{\widetilde t} < 1$ TeV. The region $m_{A^0} < 11$ GeV is allowed if $42 < m_{H^0} < 62$ GeV, but is excluded by other experiments.
- ⁸⁷ABREU 940 study H_1^0 $A^0 o ext{ four jets and combine with ABREU 94G analysis. The}$ limit applies if the $H_1^{0-}A^0$ mass difference is <4 GeV.
- ⁸⁸ ELLIS 93 analyze possible constraints on the MSSM Higgs sector by electroweak precision measurements and find that m_{A0} is not constrained by the electroweak data.
- ⁸⁹ ABREU 92J searched for $Z \to H_1^0 Z^*$ and $Z \to H_1^0 A^0$ with $H_1^0 \cdot A^0 \to \tau \tau$ or jet-jet. Small mass values are excluded by ABREU 91B.
- ⁹⁰ BUSKULIC 92 limit is from $\Gamma(Z)$, $Z \rightarrow H_1^0 Z^*$, and $Z \rightarrow H_1^0 A^0$. The limit is valid for any $m_{H_1^0}$ below the the theoretical limit $m_{H_1^0}$ <64 GeV which holds for $m_{A^0} \sim 0$ in the minimal supersymmetric model. One-loop radiative corrections are included.
- the minimal supersymmetric model. One-loop radiative corrections are included. 91 AKRAWY 91C result from $Z \to H_1^0 A^0 \to 4$ jet or $\tau^+ \tau^- jj$ or 4τ . See paper for the excluded region for the case $\tan \beta < 1$. 92 DECAMP 91I searched for $Z \to H_1^0 Z^*$, and $Z \to H_1^0 A^0 \to 4$ jets or $\tau \tau jj$ or $3A^0$. Their limits take into account the one-loop radiative corrections to the Higgs potential with varied top and squark masses. For $m_t = 140$ GeV and $m_{\widetilde{q}} = 1$ TeV, the limit is $m_{A^0} > 31 \text{ GeV}.$
- ⁹³ ABREU 90E searched $Z \to H_1^0 A^0$ and $Z \to H_1^0 Z^*$. $m_{A^0} <$ 210 MeV is not excluded
- by this alrayshs. q^2A DEVA 90R result is from $Z\to H_1^0A^0\to 4$ jet or $\tau\tau jj$ or 4τ and $Z\to H_1^0Z^*$. Some region of $m_{A^0}<5$ GeV is not excluded by this analysis.

MASS LIMITS for Associated Higgs Production in e^+e^- Interactions

In multi-Higgs models, associated production of Higgs via virtual or real Z in e^+e^- annihilation, $e^+e^- \to H_1^0 H_2^0$, is possible if H_1^0 and H_2^0 have opposite CP eigenvalues. Limits are for the mass of the heavier Higgs H_2^0 in two-doublet models.

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not us	se the follow	ing data for average	s, fits	, limits,	etc. • • •
>53	95	⁹⁵ AKERS	941	OPAL	$m_{H_1^0} < 12 \text{ GeV}$
		⁹⁶ ADRIANI	92G	L3	1
>45	95	⁹⁷ DECAMP	90H	ALEP	$m_{H_1^0} < 20 \text{ GeV}$
>37.5	95	97 DECAMP	90H		$m_{H_1^0}^{-1} < m_{H_2^0}$
none 5-45	95	⁹⁸ KOMAMIYA	90		$m_{H_1^0}^1 < 0.5 \text{ GeV},$ $H_2^0 \rightarrow q \overline{q} \text{ or } \tau^+ \tau^-$
					$H_0^0 \rightarrow q \overline{q} \text{ or } \tau^+ \tau^-$
> 8	90	⁹⁹ KOMAMIYA	89	MRK2	$H_1^0 \stackrel{?}{\rightarrow} \mu^+\mu^-$
					$H_2^0 ightarrow q \overline{q}, au^+ au^-$
>28	95	¹⁰⁰ LOW	89	AMY	$m_{H_1^0} \lesssim 20 \text{ MeV},$
					$H_2^0 \rightarrow q \overline{q}$
none 2-9	90	¹⁰¹ AKERLOF	85	HRS	$m_{H_1^0} = 0,$
					$H_2^0 \rightarrow f\overline{f}$

Higgs Bosons — H^0 and H^{\pm}

none 4-10	90	¹⁰² ASH		$m_{H_1^0} = 0.2 \text{ GeV},$
				$H_2^0 \rightarrow \tau^+ \tau^-, c\overline{c}$ $m_{H_1^0} = 0.2 \text{ GeV}, H_2^0 \rightarrow$
none 1.3-24.7	95	¹⁰¹ BARTEL	85L JADE	$m_{H_1^0} = 0.2 \text{ GeV}, H_2^0 \rightarrow$
				$f\overline{f}$ or $f\overline{f}H_1^0$
none 1.2-13.6	95	¹⁰¹ BEHREND	85 CELL	$m_{H_1^0} = 0$,
				$H_2^0 \rightarrow f\overline{f}$
none 1-11	90	¹⁰¹ FELDMAN	85 MRK2	$m_{H_1^0} = 0, H_2^0 \rightarrow f\overline{f}$
none 1-9	90	¹⁰¹ FELDMAN	85 MRK2	$m_{H_1^0} = m_{H_2^0}$
				$H_2^0 \rightarrow f \overline{f}$

- 95 AKERS 94I search for $Z\to H_1^0\,H_2^0$ with various decay modes. See Fig.11 for the full excluded mass region in the general two-doublet model, from which the limit above is taken. In particular, for $m_{H_1^0}=m_{H_2^0}$ the limit becomes $>\!38$ GeV.
- 96 ADRIANI 92G excluded regions of the $m_{H_1^0}-m_{A^0}$ plane for various decay modes with
- limits B($Z \to H_1^0 H_2^0$) <(2–20) × 10⁻⁴ are shown in Figs. 2–5. 97 DECAMP 90H search for $Z \to H_1^0 e^+ e^-$, $H_1^0 \mu^+ \mu^-$, $H_1^0 \tau^+ \tau^-$, $H_1 q \overline{q}$, low multiplicity final states, τ - τ -jet-jet final states and 4-jet final states.
- 98 KOMAMIYA 90 limits valid for $\cos^2(\alpha-\beta)\approx 1$. They also search for the cases $H_1^0 \to 0$
- $\mu^+\mu^-$, $\tau^+\tau^-$, and $H_2^0\to H_1^0H_1^0$. See their Fig. 2 for limits for these cases. 99 KOMAMIYA 89 assume B($H_1^0\to\mu^+\mu^-$) = 100 %, $2m_\mu < m_{H_1^0} < m_\tau$. The limit is for maximal mixing. A limit of $m_{H_2^0} >$ 18 GeV for the case $H_2^0 \rightarrow H_1^0 H_1^0$ ($H_1^0 \rightarrow$ $\mu^+\,\mu^-)$ is also given. From PEP at $\tilde{E_{\rm CM}}=$ 29 GeV.
- $^{100}\mathrm{LOW}$ 89 assume that H_1^0 escapes the detector. The limit is for maximal mixing. A reduced limit of 24 GeV is obtained for the case $H_2^0 \to H_1^0 f \overline{f}$. Limits for a Higgs-triplet model are also discussed. $E_{
 m cm}^{\it ee}=$ 50–60.8 GeV.
- $^{101}\,\mathrm{The}$ limit assumes maximal mixing and that H_1^0 escapes the detector.
- $^{102}\mathrm{ASH}$ 85 assumes that H_1^0 escapes undetected. The bound applies up to a mixing suppression factor of 5.

H± (Charged Higgs or Techni-pion) MASS LIMITS

Most of the following limits assume B($H^+ \rightarrow \tau^+ \nu$) + B($H^+ \rightarrow c\overline{s}$) = 1. DE-CAMP 90i, BEHREND 87, and BARTEL 86 assume B($H^+
ightarrow au^+
u$) + B($H^+
ightarrow$ $c\overline{s}) + B(H^+ \rightarrow c\overline{b}) = 1$. All limits from Z decays as well as ADACHI 90B assume that H^+ has weak isospin $T_3=\pm1/2$. For a discussion of techni-particles, see EICHTEN 86.

VALUE (GeV)	CL%		DOCUMENT ID		TECN	COMMENT
>43.5	95		ABREU	940	DLPH	$B(\tau \nu) = 0-1$
>41	95	104	ADRIANI	92G	L3	$B(\tau \nu) = 0-1$
>41.7	95 105	,106	DECAMP	92	ALEP	$B(\tau \nu) = 0-1$
• • • We do not use th	e follow	ing c	lata for averages	, fits	, limits,	etc. • • •
			BUSKULIC	95	ALEP	$b \rightarrow \tau \nu_{\tau} X$
		108	ABE	94н	CDF	$t \rightarrow bH^+, H^+ \rightarrow$
		100				$\tau^+ u_{\tau}$.
		109	ABE	941	CDF	$t \to bH^+, H^+ \to$
		110	BARGER	0.3	BV/IIE	$ \begin{array}{c} \tau^+ \nu_{\tau} \\ b \to s \gamma \end{array} $
			BELANGER			$b \rightarrow s \gamma$ $b \rightarrow s \gamma$
		110	HEWETT			$b \rightarrow s \gamma$
		112	ALITTI	92F	UA2	$t \rightarrow bH^+$
						$H^+ \rightarrow \tau \nu_{ au}$
		113	ALBAJAR	91B	UA1	$t \rightarrow bH^+$,
		114				$H^+ \rightarrow \tau^+ \nu$
none 8.0-20.2	95		YUZUKI			$B(\ell\nu) = 0-1$
>29	95 105	,115	ABREU	90B	DLPH	$B(\tau \nu) = 0-1$

- 95 105,116 ADACHI 908 TOPZ $B(\tau \nu) = 0-1$ >19 95 ^{105,117} ADEVA 90M L3 $B(\tau \nu) = 0-1$ > 36.595 105,118 AKRAWY >35 90K OPAL $B(\tau \nu) = 0-1$ 95 105,119 DECAMP 901 ALEP $B(\tau \nu) = 0-1$ >35.4 120 SMITH 119 BEHREND 90B AMY $B(\tau \nu) > 0.7$ none 10-20 95 87 CELL $B(\tau \nu) = 0-1$ 121 BARTEL >18 86 JADE B($\tau \nu$)=0.1-1.0 121 ADEVA >17 95 85 MRKJ B $(\tau \nu)$ =0.25-1.0
- 103 ABREU 940 study $H^+H^-\to c\overline{s}\,s\overline{c}$ (four-jet final states) and $H^+H^-\to \tau\nu_{\tau}\,\tau\nu_{\tau}.$ Limit for B($\tau\nu_{\tau})=$ 1 is 45.4 GeV.
- $^{104}\,\mathrm{ADRIANI}$ 92G limit improves to 44 GeV if $\mathrm{B}(\tau\nu_{\tau})>$ 0.4.
- ¹⁰⁵ Studied $H^+H^- \rightarrow (\tau \nu) + (\tau \nu)$, $H^+H^- \rightarrow (\tau \nu) + \text{hadrons}$, $H^+H^- \rightarrow \text{hadrons}$.
- 106 DECAMP 92 limit improves to 45.3 GeV for B($\tau \nu$)=1. 107 BUSKULIC 95 give a limit $\tan \beta/m_{H^+} < 0.52 \text{ GeV}^{-1}$ (90%CL) for Type-II models from $b \rightarrow \tau \nu_{\tau} X$ branching ratio.
- 108 ABE 94H search for $t\overline{t}$ production in $p\overline{p}$ collisions at $E_{\rm cm}=1.8$ TeV, followed by the decay chain $t \to bH^+$, $H^+ \to \tau^+\nu_\tau$, τ decaying hadronically. The search is sensitive to the region $m_{H^+} < m_t - m_b < m_W$. See their Fig. 3 for the excluded region for $\tan \beta \ge 0.5$ and their Fig. 4 for that in the two-Higgs-doublet model. 109 ABE 94I search for $t\bar{t}$ production in $\rho\bar{p}$ collisions at $E_{\rm Cm} = 1.8$ TeV, followed by the
- decay chain $t\to bH^+$, $H^+\to \tau^+\nu_T$, τ decaying leptonically. For B($H^+\to \tau\nu_T$)=1 (0.5), the region $m_{H^+}< m_t-m_b$, $m_t<(95-110)$ GeV (70 GeV) is excluded at 95% CL. See Fig. 3 for the excluded parameter region in the two-Higgs-doublet model.

- 110 HEWETT 93 and BARGER 93 analyze charged Higgs contribution to $b
 ightarrow s \gamma$ in twodoublet models with the CLEO limit B($b \to s\gamma$) 8.4 × 10 –4 (99% CL) and find be limits on m_{H^\pm} in the type of model (model II) in which different Higgs are responsible for up-type and down-type quark masses. HEWETT 93 give m_{H^+} >110 (70) GeV for m_t >150 (120) GeV using m_b = 5 GeV. BARGER 93 give m_{H^+} >155 GeV for m_t = 150 GeV using m_b = 4.25 GeV. The authors employ leading logarithmic QCD corrections and emphasize that the limits are quite sensitve to m_b .
- 111 BELANGER 93 make an analysis similar to BARGER 93 and HEWETT 93 with an improved CLEO limit B($b \rightarrow s \gamma$) < 5.4 × 10⁻⁴ (95%CL). For the Type II model, the limit m_{H^+} >540 (300) GeV for m_t >150 (120) GeV is obtained. The authors employ leading logarithmic QCD corrections.
- 112 ALITTI 92F search for $t \to bH^+$, $H^+ \to \tau \nu_{\tau}$ with τ decaying hadronically in $p\overline{p}$ collisions at $E_{\rm cm}=630$ GeV. m_{H^+} between 40 and 65 GeV is excluded if m_t-m_H = m_b + (\lesssim a few-10 GeV). See Figs. 5, 6 for the excluded region for B(H^+ \to $\tau \nu_{\tau}$) = 1, 0.5.
- = 1, 0.5. 113 ALBAJAR 91B search for $W\to t\,\overline{b}$ and $t\,\overline{t}$ production in $p\,\overline{p}$ collisions with the decay chain $t\to H^+\,b$, $H^+\to \tau^+\nu$, in single muon plus jets and dimuon channels. For $m_t=60$ GeV, $m_{H^+}<47$ GeV is excluded at 95%CL if $\tan\beta>2.3$. The search is restricted to small values of m_t , and no limit on m_{H^+} is obtained if $m_t>61$ GeV. Note that existing limits on m_t are not valid if $t \to H^+ b$.
- 114 YUZUKI 91 assume photon exchange. The limit is valid for any decay mode $H^+ \to e \nu$, $\mu \nu$, $\tau \nu$, $q \overline{q}$ with five flavors. For B($\ell \nu$) = 1, the limit improves to 25.0 GeV.
- 115 ABREU 90B limit improves to 36 GeV for B(au
 u) = 1.
- $^{116}_{-}$ ADACHI 90B limit improves to 22 GeV for B($\tau\nu)=$ 0.6.
- 117 ADEVA 90M limit improves to 42.5 GeV for B(au
 u)=1.
- $^{118} \, {\rm AKRAWY}$ 90K limit improves to 43 GeV for ${\rm B}(\tau \, \nu) = 1.$
- 119 If B($H^+ \rightarrow \tau^+ \nu$) = 100%, the DECAMP 901 limit improves to 43 GeV.
- 120 SMITH 90B limit applies for $v_2/v_1\ > 2$ in a model in which H_2 couples to u-type quarks and charged leptons.
- 121 Studied $H^+H^ \rightarrow$ $(\tau \nu)$ + $(\tau \nu)$, $H^+H^- \rightarrow (\tau \nu)$ + hadrons. Search for muon opposite hadronic shower.

MASS LIMITS for H^{±±} (doubly-charged Higgs boson)

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>45.6	95	122 ACTON	92м ОРА	L
• • • We do not u	se the follov	ving data for averag	es, fits, limit	ts, etc. • • •
		123 ASAKA	95 THE	0
>30.4	95	124 ACTON	92M OPA	$L T_3(H^{++}) = +1$
>25.5	95	124 ACTON	92M OPA	$L T_3(H^{++}) = 0$
none 6.5-36.6	95	125 SWARTZ	90 MRK	$2 T_0(H^{++}) = \pm 1$

- 125 SWARTZ 90 MRK2 $T_3(H^{++}) = 0$ none 7.3-34.3 95 ¹²²ACTON 92M limit assumes $H^{\pm\pm} \rightarrow \ell^{\pm}\ell^{\pm}$ or $H^{\pm\pm}$ does not decay in the detector. Thus the region $g_{\ell\ell}\approx 10^{-7}$ is not excluded.
- 123 ASAKA 95 point out that H⁺⁺ decays dominantly to four fermions in a large region of parameter space where the limit of ACTON 92M from the search of dilepton modes does
- not apply. 124 ACTON 92M from $\Delta\Gamma_Z$ <40 MeV. 125 SWARTZ 90 assume $H^{\pm\pm}\to\ell^\pm\ell^\pm$ (any flavor). The limits are valid for the Higgslepton coupling ${\rm g}(H\ell\ell)\gtrsim 7.4\times 10^{-7}/[m_H/{\rm GeV}]^{1/2}$. The limits improve somewhat for ee and $\mu\mu$ decay modes.

HO and H± REFERENCES

ABREU	95H	ZPHY C67 69	+Adam, Adye, Agasi, Ajinenko, Aleksan+ (DELPHI Coll	ab.)
ASAKA	95	PL B345 36	+Hikasa (TOHO	
BUSKULIC	95	PL B343 444	+Casper, De Bonis, Decamp, Ghez. Goy+ (ALEPH Coll	ab.)
CASAS	95	PL B342 171	+Espinosa, Quiros (MA)	
CHANKOWSKI	95	PL B356 307	+Pokorski (WARS, MP	
ERLER	95	PR D52 441	+Langacker (PEI	
ESPINOSA	95B	PL B353 257	+Quiros (DESY, CE	
MATSUMOTO	95	MPL A10 2553		EK)
ROSIEK	95	PL B341 419	+Sopczak (IFIC, CEI	
ABE	94H	PRL 72 1977	+Albrow, Amidei, Anway-Wiese, Apollinari+ (CDF Coll	
ABE	941	PRL 73 2667	+Albrow, Amidei, Antos, Anway-Wiese+ (CDF Coll	
ABREU	94G	NP B421 3	+Adam, Adye, Agasi, Ajinenko+ (DELPHI Coll	
ABREU	940	ZPHY C64 183	+Adam, Adye, Agasi, Ajinenko, Aleksan+ (DELPHI Coll	
AKERS	94B	PL B327 397	+Alexander, Allison, Anderson, Arcelli+ (OPAL Coll	
AKERS	941	ZPHY C64 1	+Alexander, Allison, Anderson, Arcelli, Asai+(OPAL Coll	
ALTARELLI	94	PL B337 141	+Isidori (CERN, ROMA2, ROM	
ELLIS	94	PL B324 173	+Fogli, Lisi (CERN, BA	
ELLIS	94B	PL B333 118	+Fogli, Lisi (CERN, BA	
GURTU	94	MPL A9 3301	+rogii, cisi (CERN, BA	
MONTAGNA	94	PL B335 484	+Nicrosini, Passarino, Piccinini (INFN, PAVI, CERN, TO	
ADRIANI	93C	PL B303 391	+Aguilar-Benitez, Ahlen, Alcaraz, Aloiso+ (L3 Coll	
BARGER	93	PRL 70 1368	+Berger, Phillips (WISC, R	
BELANGER	93	PR D48 5419	+Geng, Turcotte (MONT, ISU, AM	
BLONDEL	93	PL B311 346	+Verzegnassi (EPOL, TRSTT, TRS	
BRAHMACH	93	PR D48 4224	Brahmachari, Joshipura, Rindani+(AHMED, TATA, CE	
BUSKULIC	93H	PL B313 299	+De Bonis, Decamp, Ghez, Gov+ (ALEPH Coll	
BUSKULIC	931	PL B313 249	+De Bonis, Decamp, Ghez, Goy, Lees+ (ALEPH Coll	
ELLIS	93	NP B393 3	+Fogli, Lisi (CERN, BA	
ELLIS	93B	PL B318 148	+Fogli, Lisi (CERN, BA	
GROSS	93	IJMP A8 407	+Yepes (CE	
HEWETT	93	PRL 70 1045	(ANL, OR	
LOPEZ-FERN		PL B312 240	Lopez-Fernandez, Romao+ (CERN, LISB, VA	
NOVIKOV	93B	PL B308 123	+Okun, Vysotsky, Yurov (SERP, CE	
ABREU	92D	ZPHY C53 555	+Adam, Adami, Adve. Akesson, Alekseev+(DELPHI Coll	
ABREU	92J	NP B373 3	+Adam, Adami, Adye, Akesson+ (DELPHI Coll	
ACTON	92M	PL B295 347	+Alexander, Allison, Allport, Anderson+ (OPAL Coll	
ADEVA	92B	PL B283 454	+Adriani, Aguilar-Benitez, Ahlen, Akbari+ (L3 Coll	
ADRIANI	92F	PL B292 472	+Aguilar-Benitez, Ahlen, Akbari, Alcarez+ (L3 Coll	
ADRIANI	92G	PL B294 457	+Aguilar-Benitez, Ahlen, Akbari, Alcaraz+ (L3 Coll	
Also	93B	ZPHY C57 355	Adriani, Aguilar-Benitez, Ahlen, Alcaraz+ (L3 Coll	
ALITTI	92F	PL B280 137	+Ambrosini, Ansari, Autiero, Bareyre+ (UA2 Coll	
BARABASH	92	PL B295 154	+Baranov+ (JINR, CERN, SERP, BUDA, BE	
Also	92B	SJNP 55 1810	Barabash+ (JINR, CERN, SERP, BUDA, BE	
	0	Translated from YA		/

Higgs Bosons — H^0 and H^{\pm} , Heavy Bosons Other than Higgs Bosons

BUSKULIC	92	PL B285 309	+Decamp, Goy, Lees, Minard+	(ALEPH Collab.)
DECAMP	92	PRPL 216 253	+Deschizeaux, Goy, Lees, Minard+	(ALEPH Collab.)
DELAGUILA	92B	NP B381 451	del Aguila, Martinez, Quiros	(GRAN, CERN)
	92	PL B274 456		
ELLIS			+Fogli, Lisi	(CERN, BARI)
ELLIS	92E	PL B292 427	+Fogli, Lisi	(CERN, BARI)
PICH	92	NP B388 31	+Prades, Yepes	(CERN, CPPM)
RENTON	92	ZPHY C56 355		(OXF)
SCHAILE	92	ZPHY C54 387		(FREIE)
ABREU	91 B	ZPHY C51 25	+Adam, Adami, Adye, Akesson+	(DELPHI Collab.)
ACTON	91	PL B268 122	+Alexander, Allison, Allport+	(OPAL Collab.)
ADEVA	91	PL B257 450	+Adriani, Aguilar-Benitez, Akbari, Alcaraz	
ADEVA	91D	PL B262 155	+Adriani, Aguilar-Benitez, Akbari, Alcaraz	+ (L3 Collab.)
AKRAWY	91	PL B253 511	+Alexander, Allison, Allport, Anderson+	(OPAL Collab.)
AKRAWY	91C	ZPHY C49 1	Alexander Allicon Alleget Anderson	
	91B		+Alexander, Allison, Allport, Anderson+	(OPAL Collab.)
ALBAJAR		PL B257 459	+Albrow, Allkofer, Ankoviak, Apsimon+	(UA1 Collab.)
BLUEMLEIN	91	ZPHY C51 341		IDA, JINR, SERP)
DECAMP	91F	PL B262 139	+Deschizeaux, Goy, Lees, Minard+	(ALEPH Collab.)
DECAMP	911	PL B265 475	+Deschizeaux, Goy, Lees, Minard+	(ALEPH Collab.)
YUZUKI	91	PL B267 309	+Haba, Abe, Amako, Arai, Asano+	(VENUS Collab.)
ABE	90E	PR D41 1717	+Amidei, Appollinari, Atac, Auchincloss+	(CDF Collab.)
ABREU	90B	PL B241 449	+Adam, Adami, Adye, Alekseev+	(DELPHI Collab.)
ABREU	90C	NP B342 1	+Adam, Adami, Adye, Alekseev+	(DELPHI Collab.)
ABREU	90E	PL B245 276	+Adam, Adami, Adye, Alekseev+	(DELPHI Collab.)
ABREU	901		unpubl-Adam, Adami, Adye, Alekseev+	(DELPHI Collab.)
CERN-PPI			anpula Adam, Adam, Adye, Alekseev+	(DEET III CONSU.)
ADACHI	90B	PL B240 513	Albert Description	(TODAT Cillet)
			+Aihara, Doeser, Enomoto+	(TOPAZ Collab.)
ADEVA	90H	PL B248 203	+Adriani, Aguilar-Benitez, Akbari, Alcaraz	+ (L3 Collab.)
ADEVA	90M	PL B252 511	+Adriani, Aguilar-Benitez, Akbari, Alcaraz	+ (L3 Collab.)
ADEVA	90N	PL B252 518	+Adriani, Aguilar-Benitez, Akbari, Alcaraz	+ (L3 Collab.)
ADEVA	90R	PL B251 311	+Adriani, Aguilar-Benitez, Akbari, Alcaraz	 + (L3 Collab.)
AKRAWY	90C	PL B236 224	+Alexander, Allison, Allport+	(OPAL Collab.)
AKRAWY	90K	PL B242 299	+Alexander, Allison, Allport, Anderson+	(OPAL Collab.)
AKRAWY	90P	PL B251 211	+Alexander, Allison, Allport, Anderson+	(OPAL Collab.)
DAWSON	90	PR D41 2844		BNL, UCD, UCSC)
DECAMP	90	PL B236 233	+Deschizeaux, Lees, Minard, Crespo+	(ALEPH Collab.)
DECAMP	90E	PL B237 291	+Deschizeaux, Lees, Minard+	(ALEPH Collab.)
DECAMP	90H	PL B241 141	+Deschizeaux, Lees, Minard+	(ALEPH Collab.)
	901	PL B241 623		
DECAMP			+Deschizeaux, Goy, Lees, Minard+	(ALEPH Collab.)
DECAMP	90M	PL B245 289	+Deschizeaux, Goy, Lees, Minard+	(ALEPH Collab.)
DECAMP	90N	PL B246 306	+Deschizeaux, Goy, Lees, Minard+	(ALEPH Collab.)
KOMAMIYA	90	PRL 64 2881	+Abrams, Adolphsen, Averill, Ballam+	(Mark II Collab.)
SMITH	90B	PR D42 949	+McNeil, Breedon, Kim, Ko+	(AMY Collab.)
SWARTZ	90	PRL 64 2877	+Abrams, Adolphsen, Averill, Ballam+	(Mark II Collab.)
CAHN	89	RPP 52 389		` ,
CHENG	89	PR D40 2980	+Yu	(AST)
DAVIER	89	PL B229 150	+Nguyen Ngoc	(LALO)
DAWSON	89	PL B222 143	(Mayon Mayor	(BNL)
EGLI	89	PL B222 533	+Engfer, Grab, Hermes, Kraus+ (S	SINDRUM Collab.)
KOMAMIYA	89	PR D40 721		(Mark II Callab.)
			+Fordham, Abrams, Adolphsen, Akerlof+	
LINDNER	89	PL B228 139	+Sher, Zaglauer	(FNAL, WUSL) (AMY Collab.)
LOW	89	PL B228 548	+Xu, Abashian, Gotow, Hu, Mattson+	(AMY Collab.)
SHER	89	PRPL 179 273		
SNYDER	89	PL B229 169	+Murray, Abrams, Adolphsen, Akerlof+	(Mark II Collab.)
YEPES	89	PL B227 182		(MCGI)
BEHREND	87	PL B193 376	+Buerger, Criegee, Dainton+	(CELLO Collab.)
FRANZINI	87	PR D35 2883	+Son, Tuts, Youssef, Zhao+	(CUSB Collab.)
RUSKOV	87	PL B187 165		(SOFI)
BARTEL	86	ZPHY C31 359	+Becker, Felst, Haidt+	(JADE Collab.)
EICHTEN	86	PR D34 1547		FNAL, LBL, OSU)
ADEVA	85	PL 152B 439	+Becker, Becker-Szendy+	(Mark-J Collab.)
AKERLOF		PL 156B 271		(HRS Collab.)
	85 85 J		+Bonvicini, Chapman, Errede+	
ALBRECHT ASH		ZPHY C29 167 PRL 55 1831	+Binder, Harder+	(ARGUS Collab.)
	85		+Band, Blume, Camporesi+	(MAC Collab.)
ASH	85C	PRL 54 2477	+Band, Blume, Camporesi+	(MAC Collab.)
BARTEL	85L	PL 155B 288	+Becker, Cords, Felst, Hagiwara+	(JADE Collab.)
BEHREND	85	PL 161B 182	+Burger, Criegee, Fenner+	(CELLO Collab.)
FELDMAN	85	PRL 54 2289	+Abrams, Amidei, Baden+	(Mark II Collab.)
DZHELYADIN	81	PL 105B 239	+Golovkin, Konstantinov, Kubarovski+	` (SERP)
WITTEN	81	NP B177 477		(HARV)
GUTH	80	PRL 45 1131	+Weinberg	(SLAC)
JACQUES	80	PR D21 1206		G, STEV, COLU)
SHER	80	PR D22 2989	, , , , , , , , , , , , , , , , , , , ,	(UCSC)
Also	83	ANP 148 95	Flores, Sher	(UCSC, UCI)
	00	,		(0000, 001)

Heavy Bosons Other Than Higgs Bosons, Searches for

We list here various limits on charged and neutral heavy vector bosons (other than W's and Z's), heavy scalar bosons (other than Higgs bosons), vector or scalar leptoquarks, and axigluons.

W_R (Right-Handed W Boson) MASS LIMITS

Assuming a light right-handed neutrino, except for BEALL 82, LANGACKER 89B and COLANGELO 91. $g_R=g_L$ assumed. [Limits in the section MASS LIMITS for W' below are also valid for W_R if $m_{\nu_R} \ll m_{W_R}$.] Some limits assume manifest left-right symmetry, *i.e.*, the equality of left- and right Cabibbo-Kobayashi-Maskawa matrices. For a comprehensive review, see LANGACKER 898. Limits on the $W_L\text{-}W_R$ mixing angle ζ are found in the next section. Values in brackets are from cosmological and astrophysical considerations and assume a light right-handed neutrino.

VALUE (GeV)	<u>CL%</u>	DOCUMENT ID		TECN	COMMENT
> 406	90	¹ JODIDIO	86	ELEC	Any ^Ç
• • • We do	not use the follow	ving data for avera	iges,	fits, lim	its, etc. • • •
> 281	90				Polarized neutron decay
> 282	90	³ KUZNETSOV	94B	CNTR	Polarized neutron decay
> 439	90	⁴ BHATTACH			
> 250	90	⁵ SEVERIJNS			
		⁶ IMAZATO	92	CNTR	K ⁺ decay
> 475	90	⁷ POLAK	92B	RVUE	μ decay

> 240	90	8 AQUINO	91	RVUE	Neutron decay
> 496	90	⁸ AQUINO	91	RVUE	Neutron and muon decay
> 700		⁹ COLANGELO	91	THEO	$m_{K_{I}^{0}} - m_{K_{S}^{0}}$
> 477	90	¹⁰ POLAK	91	RVUE	μ decay
[none 540-23000]		¹¹ BARBIERI	89B	ASTR	SN 1987A; light ν_R
> 300	90	¹² LANGACKER	89 B	RVUE	General
> 160	90	¹³ BALKE	88	CNTR	$\mu \rightarrow e \nu \overline{\nu}$
> 482	90	¹ JODIDIO	86	ELEC	$\zeta = 0$
> 800		MOHAPATRA	86	RVUE	$SU(2)_I \times SU(2)_R \times U(1)$
> 400	95	¹⁴ STOKER	85	ELEC	Any ⊊
> 475	95	¹⁴ STOKER	85	ELEC	ζ <0.041
		¹⁵ BERGSMA	83	CHRM	$\nu_{\mu} e \rightarrow \mu \nu_{e}$
> 380	90	¹⁶ CARR	83	ELEC	μ^+ decay
>1600		¹⁷ BEALL	82	THEO	$m_{K_I^0} - m_{K_S^0}$
[> 4000]		STEIGMAN	79	COSM	Nucleosynthesis; light ν_R

- ¹ JODIDIO 86 is the same TRIUMF experiment as STOKER 85 (and CARR 83); however, it uses a different technique. The results given here are combined results of the two techniques. The technique here involves precise measurement of the end-point e^{\pm}
- spectrum in the decay of the highly polarized μ^+ . ² KUZNETSOV 95 limit is from measurements of the asymmetry $\langle \vec{p}_{\nu} \cdot \sigma_{\eta} \rangle$ in the β decay of polarized neutrons. Zero mixing assumed. See also KUZNETSOV 94B.
- of polarized neutrons. Zero mixing assumed. See also NUZNETSOV 949.

 3 KUZNETSOV 94B limit is from measurements of the asymmetry $\langle \vec{p}_{\nu} \cdot \sigma_{n} \rangle$ in the β decay of polarized neutrons. Zero mixing assumed.

 4 BHATTACHARYYA 93 uses $Z \cdot Z'$ mixing limit from LEP '90 data, assuming a specific Higgs sector of $SU(2)_L \times SU(2)_R \times U(1)$ gauge model. The limit is for m_t =200 GeV and slightly improves for smaller m_t .
- 5 SEVERIJNS 93 measured polarization-asymmetry correlation in $^{107} \ln \beta^+$ decay. The listed limit assumes zero L-R mixing. Value quoted here is from SEVERIJNS 94 erratum. 6 IMAZATO 92 measure positron asymmetry in $K^+ \to -\mu^+ \nu_\mu$ decay and obtain
- $\xi P_{\mu}>$ 0.990 (90%CL). If W_R couples to $u\overline{s}$ with full weak strength $(V_{u\overline{s}}^R=1)$, the result corresponds to $m_{W_R}>$ 653 GeV. See their Fig. 4 for m_{W_R} limits for general $|V_{us}^R|^2 = 1 - |V_{ud}^R|^2$.
- ⁷ POLAK 92B limit is from fit to muon decay parameters and is essentially determined by JODIDIO 86 data assuming $\zeta=0$. Supersedes POLAK 91.
- 8 AQUINO 91 limits obtained from neutron lifetime and asymmetries together with unitarity of the CKM matrix. Manifest left-right symmetry assumed. Stronger of the two limits also includes muon decay results.
- ⁹COLANGELO 91 limit uses hadronic matrix elements evaluated by QCD sum rule and is less restrictive than BEALL 82 limit which uses vacuum saturation approximation. Manifest left-right symmetry assumed.
- 10 POLAK 91 limit is from fit to muon decay parameters and is essentially determined by JODIDIO 86 data assuming $\zeta=0$. Superseded by POLAK 92B.
- 11 BARBIERI 898 limit holds for $m_{\nu_R} \leq$ 10 MeV.
- 12 LANGACKER 898 limit is for any ν_R mass (either Dirac or Majorana) and for a general class of right-handed quark mixing matrices.
- class or right-handed quark mixing matrices.

 13 BALKE 88 limit is for $m_{\nu_{eR}} = 0$ and $m_{\nu_{\mu R}} \leq 50$ MeV. Limits come from precise measurements of the muon decay asymmetry as a function of the positron energy.
 14 STOKER 85 is same TRIUMF experiment as CARR 83. Here they measure the decay e^+ spectrum asymmetry above 46 MeV/c using a muon-spin-rotation technique. Assumed a light right-handed neutrino. Quoted limits are from combining with CARR 83.
- $^{15}\,\mathrm{BERGSMA}$ 83 set limit $m_{\,W_{\!2}}/m_{\,W_{\!1}}~>$ 1.9 at CL = 90%.
- 16 CARR 83 is TRIUMF experiment with a highly polarized μ^+ beam. Looked for deviation from V-A at the high momentum end of the decay e^+ energy spectrum. Limit from previous world-average muon polarization parameter is $m_{WR} >\!\!\! >\!\! 240$ GeV. Assumes a light right-handed neutrino.
- 17 BEALL 82 limit is obtained assuming that W_R contribution to κ_Q^0 + κ_S^0 mass difference is smaller than the standard one, neglecting the top quark contributions. Manifest left-right symmetry assumed.

Limit on W_L - W_R Mixing Angle ζ

CL%

VALUE

Lighter mass eigenstate $W_1=W_L\cos\zeta-W_R\sin\zeta$. Light ν_R assumed unless noted. Values in brackets are from cosmological and astrophysical considerations.

DOCUMENT ID

TECN COMMENT \bullet $\,\bullet\,$ We do not use the following data for averages, fits, limits, etc. $\,\bullet\,$ $\,\bullet\,$

```
<sup>18</sup> MISHRA
                                                      92 CCFR \nu N scattering
                                   19 AQUINO
  -0.0006 to 0.0028
                                                      91 RVUE
                          90
                                   <sup>20</sup> BARBIERI
                                                      898 ASTR SN 1987A
[none 0.00001-0.02]
                                   <sup>21</sup> JODIDIO
                                                      86 ELEC
                                                                   \mu decay
                                  <sup>21</sup> JODIDIO
   -0.056 to 0.040
                          90
                                                      86 ELEC
                                                                   \mu decay
```

- 18 MISHRA 92 limit is from the absence of extra large-x, large-y $\overline{\nu}_{\mu} N \to \overline{\nu}_{\mu} X$ events at Tevatron, assuming left-handed ν and right-handed $\overline{\nu}$ in the neutrino beam. The result gives $\zeta^2(1-2m_{W_1}^2/m_{W_2}^2)<$ 0.0015. The limit is independent of ν_R mass.
- ¹⁹AQUINO 91 limits obtained from neutron lifetime and asymmetries together with unitarity of the CKM matrix. Manifest left-right asymmetry is assumed 20 BARBIERI 898 limit holds for $m_{\nu_R} \leq 10$ MeV.
- $^{21}\,\mathrm{First}$ JODIDIO 86 result assumes $\stackrel{\sim}{m}_{W_{R}}=\infty$, second is for unconstrained $m_{W_{R}}$

Gauge & Higgs Boson Particle Listings Heavy Bosons Other than Higgs Bosons

MASS LIMITS for W' (A Heavy Charged Vector Boson Other Than W) in Hadron Collider Experiments

Couplings of W' to quarks and leptons are taken to be identical with those of W. The following limits are obtained from $p\overline{p}\to W'X$ with W' decaying to the mode indicated in the comments. New decay channels (e.g., $W'\to WZ$ are assumed to be suppressed. Experiments other than ABE 95M, ABACHI 95E, and ABE 91F assume that the $t\overline{b}$ channel is not open.

CL%	DOCUMENT ID	TECN	COMMENT	
95	²² ABE	95м CDF	$W' \rightarrow e \nu_e$	
e followi	ng data for averages,	fits, limits,	etc. • • •	
95	²³ ABACHI	95E D0	$W' \to e \nu_e$ and $W' \to \tau \nu_\tau \to e \nu \nu \overline{\nu}$	I
90	24 ALITTI 9	93 UA2	$W' \stackrel{'}{\rightarrow} q \overline{q}$	
95		3 RVUE	$W' \rightarrow q \overline{q}$	
95		91F CDF	$W' \rightarrow e \nu, \mu \nu$	
90		91 UA2	$W' \rightarrow q \overline{q}$	
90		39 UA1	$W' \rightarrow e \nu$	
90		37D UA2	$W' \rightarrow e \nu$	
90		36B UA1	$W' \rightarrow e \nu$	
90	³¹ ARNISON 8	B3D UA1	$W' \rightarrow e \nu$	
	95 e followi 95 90 95 95 95 90 90 90	95 22 ABE e following data for averages, 95 23 ABACHI 90 24 ALITTI 95 25 RIZZO 95 26 ABE 90 27 ALITTI 90 28 ALBAJAR 90 29 ANSARI 90 30 ARNISON	95 22 ABE 95M CDF e following data for averages, fits, limits, 95 23 ABACHI 95E D0 90 24 ALITTI 93 UA2 95 25 RIZZO 93 RVUE 95 26 ABE 91F CDF 90 27 ALITTI 91 UA2 90 28 ALBAJAR 89 UA1 90 30 ARNISON 86B UA1	95

- 22 ABE 95M assume that the decay $W'\to WZ$ is suppressed and the (right-handed) neutrino is light, noninteracting, and stable. If $m_{\nu}{=}60$ GeV, for example, the effect on the mass limit is neglibible.
- ²³ ABACHI 95E assume that the decay $W' \rightarrow WZ$ is suppressed and that the neutrino from W' decay is stable and has a mass significantly less $m_{W'}$.
- $^{24}\text{ALITTI 93}$ search for resonances in the two-jet invariant mass. The limit assumes $\Gamma(W')/m_{W'}=\Gamma(W)/m_W$ and $\text{B}(W'\to jj)=2/3$. This corresponds to W_{R} with $m_{\nu_R} > m_{W_R}$ (no leptonic decay) and $W_R \to t\, \overline{b}$ allowed. See their Fig. 4 for limits in the $m_{W'} - B(q\overline{q})$ plane.
- 25 RIZZO 93 analyses CDF limit on possible two-jet resonances. The limit is sensitive to the inclusion of the assumed K factor.
- 26 ABE 91F assume leptonic branching ratio of 1/12 for each lepton flavor. The limit from GeV and ν_R does not decay in the detector. Cross section limit $\sigma \cdot {\rm B} < (1-10)\,{\rm pb}$ is given for $m_{W'}=100$ –550 GeV; see Fig. 2.
- ²⁷ ALITTI 91 search is based on two-jet invariant mass spectrum, assuming B($W' o q \overline{q}$)
- = 67.6%. Limit on σ · B as a function of two-jet mass is given in Fig. 7. ²⁸ ALBAJAR 89 cross section limit at 630 GeV is $\sigma(W')$ B($e\nu$) < 4.1 pb (90% CL).
- ²⁹ See Fig. 5 of ANSARI 87D for the excluded region in the $m_{W'}$ -[$(g_{W'}q)^2$ B(W' \rightarrow $(e\overline{
 u})$ plane. Note that the quantity $(g_{W'q})^2$ B($W'
 ightharpoonup (e\overline{
 u})$ is normalized to unity for the standard W couplings.
- the standard W couplings. 30 ARNISON 868 find no excess at large p_T in 148 $W \rightarrow e \nu$ events. Set limit $\sigma \times B(e \nu) < 10$ pb at CL = 90% at $E_{\rm cm} = 546$ and 630 GeV. 31 ARNISON 83D find among 47 $W \rightarrow e \nu$ candidates no event with excess p_T . Also set $\sigma \times B(e \nu) < 30$ pb with CL = 90% at $E_{\rm cm} = 540$ GeV.

MASS LIMITS for Z' (Heavy Neutral Vector Boson Other Than Z) THE Z' SEARCHES

The mass bounds depend on the gauge group and the gauge coupling of a Z' boson. The limits listed below are not exhaustive but include only typical Z' bosons that appear frequently in the literature. The following notations are used for these Z' bosons.

 Z'_{SM} : Z'_{SM} is a clone of the Z and is introduced as a convenient way to gauge the limits rather than with a theoretical motivation. It is assumed to have exactly the same couplings as the Z but a different mass.

Left-right symmetric bosons: Z_{LR} is the extra neutral boson which appears in left-right symmetric models with the gauge group $SU(2)_L \times SU(2)_R \times U(1)_{B-L}$ or $SU(2)_L \times U(1)_R \times$ $U(1)_{B-L}$, where $U(1)_R$ is the third component of $SU(2)_R$ and the weak hypercharge $Y = T_{3R} + \frac{1}{2}(B-L)$. The Z_{LR} couples to $\alpha T_{3R} - (1/2\alpha)(B-L)$ with the coupling strength g' (the weak hypercharge gauge coupling). The parameter α is model dependent. For left-right symmetric coupling $g_L = g_R$, $\alpha = (1 - 2\sin^2\theta_W)^{1/2}/\sin\theta_W \approx 1.53$, which is used for the limits in the listing unless noted. Another typical case $\alpha = (2/3)^{1/2}$ is identical to Z_{χ} (discussed below) with the coupling $g_{\chi} = g'$.

E₆ bosons: Two new neutral gauge bosons appear in E₆ models. One is contained in the SO(10) subgroup and the other is not:

$$\mathrm{E}_{6} \longrightarrow \mathrm{SO}(10) \times \mathrm{U}(1)_{\psi}$$
 ,

$$SO(10) \longrightarrow SU(5) \times U(1)\chi$$
.

One Z' is assumed to be relatively light, which in general is a linear combination of the two:

$$Z_{\beta} = Z_{\chi} \cos \beta + Z_{\psi} \sin \beta .$$

The gauge quantum numbers of the ordinary quarks and leptons are shown in the table:

f	T_{3R}	Y	$B{-}L$	$\sqrt{24}Q\chi$	$\sqrt{\frac{72}{5}}Q_{\psi}$	Q_{η}
$\phantom{aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa$	0	$-\frac{1}{2}$	-1	+3	+1	$+\frac{1}{6}$
$ u_R$	$+\frac{1}{2}$	0	-1	+5	-1	$+\frac{5}{6}$
e_R^-	$-\frac{1}{2}$	-1	-1	+1	-1	$+\frac{1}{3}$
u_L, d_L	0	$+\frac{1}{6}$	$+\frac{1}{3}$	-1	+1	$-\frac{1}{3}$
u_R	$+\frac{1}{2}$	$+\frac{2}{3}$	$+\frac{1}{3}$	+1	-1	$+\frac{1}{3}$
d_R	$-\frac{1}{2}$	$-\frac{1}{3}$	$+\frac{1}{3}$	-3	-1	$-\frac{1}{6}$

In particular, the χ charge is related to others by $\sqrt{24}Q_{\chi} =$ 4Y - 5(B-L). Also notice that the Z_{ψ} coupling is pure axial for all quarks and leptons.

Another typical case Z_{η} is defined as

$$Z_{\eta} = \sqrt{\frac{3}{8}} Z_{\chi} - \sqrt{\frac{5}{8}} Z_{\psi} ,$$

which appears in a superstring-motivated model.

A reference gauge coupling for these bosons is g' = $e/\cos\theta_W$, which is predicted if there is no intermediate symmetry breaking scale.

In general, these Z' models require the existence of a set of new fermions (belonging to the 27 representation of E₆) to cancel gauge anomalies, and possibly superpartners. An exception is Z_{χ} , for which only right-handed neutrinos are necessary. For the direct limits from hadron colliders, it is often assumed that these new fermions are heavy and are not produced in the decay of the Z'.

Gauge & Higgs Boson Particle Listings Heavy Bosons Other than Higgs Bosons

Limits for Z'_{SM}

 $Z_{\rm SM}^{\prime}$ is assumed to have couplings with quarks and leptons which are identical to those of Z.

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>505	95	³² ABE	95	CDF	$p\overline{p}; Z'_{SM} \rightarrow e^+e^-$
>779	95 3	^{3,34} LANGACKER	92 B		Electroweak
• • • We do not use the	followi	ng data for average			
>398	95	35 VILAIN	94B	CHM2	$\begin{array}{ccc} u_{\mu} e \rightarrow & \nu_{\mu} e \text{ and} \\ \overline{\nu}_{\mu} e \rightarrow & \overline{\nu}_{\mu} e \\ p \overline{p}; Z'_{SM} \rightarrow & q \overline{q} \end{array}$
>237	90	36 ALITTI	93	UA2	$p\overline{p}; Z'_{SM} \rightarrow q\overline{q}$
>119	90	³⁷ ALLEN	93	CALO	$\nu e \rightarrow \nu e$
none 490-560	95	³⁸ RIZZO	93	RVUE	$p\overline{p}; Z'_{SM} \rightarrow q\overline{q}$
>412	95	ABE	92B	CDF	$p\overline{p}; Z'_{SM} \rightarrow q\overline{q}$ $p\overline{p}; Z'_{SM} \rightarrow e^+e^-,$
>387	95	39 ABE	91D	CDF	$p\overline{p}; Z'_{SM} \rightarrow e^+e^-$
>307	90	⁴⁰ GEIREGAT	91	CHM2	$ u_{\mu} \stackrel{e}{=} \rightarrow \begin{array}{c} u_{\mu} \stackrel{e}{=} \text{and} \\ \overline{ u}_{\mu} \stackrel{e}{=} \rightarrow \begin{array}{c} \overline{ u}_{\mu} \stackrel{e}{=} \end{array} $
>426	90	⁴¹ ABE	90F	VNS	e^+e^-
>208	90	⁴² HAGIWARA	90	RVUE	e^+e^-
>173	90	⁴³ ALBAJAR	89	UA1	$p\overline{p}; Z'_{SM} \rightarrow e^+e^-$
>180	90	⁴⁴ ANSARI	87D	UA2	$\rho \overline{\rho}; Z_{SM}^{r} \rightarrow e^+e^-$
>160	90	⁴⁵ ARNISON	86B	UA1	$p\overline{p}; Z'_{SM} \rightarrow e^+e^-$ $p\overline{p}; Z'_{SM} \rightarrow e^+e^-$ $p\overline{p}; Z'_{SM} \rightarrow e^+e^-$

- $^{32}\,\mathrm{ABE}$ 95 limit is obtained assuming that Z' decays to known fermions only.
- 33 LANGACKER 928 fit to a wide range of electroweak data including LEP results available early '91. m_t >89 GeV used.
- 34 LANGACKER 92B give 95%CL limits on the Z-Z' mixing -0.0086 < heta < 0.0005. $^{35}\,\mathrm{VILAIN}$ 94B assume $m_{\,t}=$ 150 GeV.
- ³⁶ ALITTI 93 search for resonances in the two-jet invariant mass. The limit assumes B($Z' \to q \overline{q}$)=0.7. See their Fig. 5 for limits in the $m_{Z'}$ -B($q \overline{q}$) plane.
- ³⁷ ALLEN 93 limit is from total cross section for $\nu e \to \nu e$, where $\nu = \nu_e$, ν_μ , $\overline{\nu}_\mu$.
- 38 RIZZO 93 analyses CDF limit on possible two-jet resonances. The limit is sensitive to
- the inclusion of the assumed K factor. 39 ABE 91D give $\sigma(Z') \cdot B(e^+e^-) < 1.31$ pb (95%CL) for $m_{Z'} > 200$ GeV at $E_{\rm cm} = 1.8$ TeV. Limits ranging from 2 to 30 pb are given for $m_{Z'} = 100$ –200 GeV.
- ⁴⁰ GEIREGAT 91 limit is from comparison of g_V^e from $\nu_\mu e$ scattering with $\Gamma(Z \to ee)$ from LEP. Zero mixing assumed.
- 41 ABE 90° use data for R, R_{ℓ} , and A_{ℓ} . They fix $m_W=80.49\pm0.43\pm0.24$ GeV and $m_Z=91.13\pm0.03$ GeV.
- 42 HAGIWARA 90 perform a fit to $e^+\,e^-$ data at PEP, PETRA, and TRISTAN including
- $\mu^+\,\mu^-$, $\tau^+\,\tau^-$, and hadron cross sections and asymmetries. ⁴³ ALBAJAR 89 cross section limit at 630 GeV is $\sigma(Z')$ B(ee) < 4.2 pb (90% CL).
- ⁴⁴ See Fig. 5 of ANSARI 87D for the excluded region in the $m_{Z'}$ -[$(g_{Z'q})^2$ B(Z' \to $e^+e^-)]$ plane. Note that the quantity $(g_{Z'q})^2$ B $(Z' o e^+e^-)$ is normalized to unity for the standard Z couplings.
- 45 ARNISON 86B find no excess e^+e^- pairs among 13 pairs from Z. Set limit $\sigma \times B(e^+e^-)$ <13 pb at CL = 90% at $E_{\rm cm}$ = 546 and 630 GeV.

Limits for Z_{LR}

 \mathcal{L}_{LR} is the extra neutral boson in left-right symmetric models. $g_L = g_R$ is assumed unless noted. Values in parentheses assume stronger constraint on the Higgs sector, usually motivated by superstring models. Values in brackets are from cosmological and astrophysical considerations and assume a light right-handed neutrino.

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>445	95	⁴⁶ ABE	95	CDF	$\rho \overline{p}; Z'_{LR} \rightarrow e^+ e^-$
>389	95 47	^{1,48} LANGACKER	92B	RVUE	Electroweak
• • • We do not use					
>253	95	⁴⁹ VILAIN	94B	CHM2	$ u_{\mu} \stackrel{e}{=} {=} \nu_{\mu} e \text{and} \overline{v}_{\mu} e \rightarrow $
>130	95	⁵⁰ ADRIANI	93D	L3	Z parameters
(> 1500)	90	⁵¹ ALTARELLI	93B	RVUE	Z parameters
none 490-560	95	52 RIZZO	93	RVUE	$p\overline{p}; Z_{LR} \rightarrow q\overline{q}$
>310	95	⁵³ ABE	92 8	CDF	ρp
>230	95	54 ABE	92B	CDF	$\rho \overline{p}$
(> 900)	90	⁵⁵ DELAGUILA	92	RVUE	
(> 1400)		⁵⁶ LAYSSAC	92B	RVUE	Z parameters
(> 564)	90	⁵⁷ POLAK	92	RVUE	μ decay
>474	90	⁵⁸ POLAK	92B	RVUE	Electroweak
(> 1340)		⁵⁹ RENTON	92	RVUE	
(> 800)	90	60 ALTARELLI	91B	RVUE	Z parameters
(> 795)	90	⁶¹ DELAGUILA			
>382	90	⁶² POLAK			Electroweak
[> 2000]		WALKER	91	COSM	Nucleosynthesis; light ν_R
[> 500]		63 GRIFOLS	90	ASTR	SN 1987A; light ν_R
(> 460)	90	64 HE		RVUE	
[> 2400-6800]		65 BARBIERI	89B	ASTR	SN 1987A; light ν_R
>189				RVUE	$\rho \overline{\rho}$
[> 10000]					SN 1987A; light ν_R
>325	90			RVUE	
>278	90			RVUE	
>150	95	⁶⁹ ADEVA	85B	MRKJ	$e^+e^- \rightarrow \mu^+\mu^-$

- $^{
 m 46}\,{
 m ABE}$ 95 limit is obtained assuming that Z' decays to known fermions only. See their Fig. 3 for the mass bound of Z' decaying to all allowed fermions and supersymmetric
- $^{\rm 47}$ LANGACKER 928 fit to a wide range of electroweak data including LEP results available early '91. m_t >89 GeV used.
- ⁴⁸LANGACKER 92B give 95%CL limits on the Z-Z' mixing $-0.0025 < \theta < 0.0083$.
- 49 VILAIN 94B assume $m_{ extit{t}}=$ 150 GeV and heta=0. See Fig.2 for limit contours in the mass-mixing plane.
- mass-mixing plane. 50 ADRIANI 93D give limits on the Z-Z' mixing $-0.002 < \theta < 0.015$ assuming the ABE 928 mass limit. 51 ALTARELLI 93B limit is from LEP data available in summer '93 and is for $m_t = 110$ GeV. $m_H = 100$ GeV and $\alpha_S = 0.118$ assumed. The limit improves for larger m_t (see their Fig. 5). The 90%CL limit on the Z-Z' mixing angle is in Table 4.
- their Fig. 5). The 90% of limit on the Z-Z mixing angle is in Jaure 4.

 52 RIZZO 93 analyses CDF limit on possible two-jet resonances. The limit is sensitive to the inclusion of the assumed K factor.

 53 These limits assume that Z' decays to known fermions only.

 54 These limits assume that Z' decays to all E₆ fermions and their superpartners.

- 55 See Fig. 7b and 8 in DELAGUILA 92 for the allowed region in $m_{Z^{\prime}}$ -mixing plane and $m_{Z'} - m_t$ plane from electroweak fit including '90 LEP data.
- 56 LAYSSAC 92B limit is from LEP data available spring '92. Specific Higgs sector is
- assumed. See also LAYSSAC 92. 57 POLAK 92 limit is from m_{W_R} >477 GeV, which is derived from muon decay parameters assuming light ν_R . Specific Higgs sector is assumed.
- assuming light ν_R . Specific rings sector is assumed. S8 POLAK 928 limit is from a simultaneous fit to charged and neutral sector in SU(2)_L×SU(2)_R×U(1) model using Z parameters, m_W , and low-energy neutral current data as of 1991. Light ν_R assumed and $m_t = m_H = 100$ GeV used. Supersedes POLAK 91. S9 RENTON 92 limits use LEP data taken up to '90 as well as m_W , ν N, and atomic parity with the data. Specific Higgs structure is assumed.
- NEUTON 22 mints use Let data taken up to 30 as well as m_W , DN, and atomic party violation data. Specific Higgs structure is assumed. 60 ALTARELLI 91B is based on Z mass, widths, and A_{FB} . The limits are for superstring motivated models with extra assumption on the Higgs sector. $m_t > 90$ GeV and $m_{H0} < 1$ TeV assumed. For large m_t , the bound improves drastically. Bounds for Z- Z^\prime mixing angle and Z mass shift without this model assumption are also given in the
- From ν N neutral current data with $m_Z=91.10\pm0.04$ GeV, $m_t>77$ GeV, $m_{H^0}<1$ TeV assumed.
- TeV assumed. GeV polark 91 limit is from a simultaneous fit to charged and neutral sector in $\mathrm{SU}(2)_L \times \mathrm{SU}(2)_R \times \mathrm{U}(1)$ model using $m_W, \, m_Z,$ and low-energy neutral current data as of 1990. Light ν_R assumed and $m_t = m_H = 100$ GeV used. Superseded by POLAK 928. Garrier Special Speci
- 64 HE 90B model assumes a specific Higgs sector. Neutral current data of COSTA 88 as well as m_Z is used. g_R is left free in the fit.
- $^{65}\,\mathrm{BARBIERI}$ 898 limit holds for $m_{\nu_R} \leq$ 10 MeV.
- ⁶⁶ DELAGUILA 89 limit is based on $\sigma(p\overline{p}\to Z')\cdot B(Z'\to e^+e^-)<1.8$ pb at CERN $p\overline{p}$
- collider.

 67 A wide range of neutral current data as of 1986 are used in the fit.
- $^{68}\,\mathrm{A}$ wide range of neutral current data as of 1985 are used in the fit.
- 69 ADEVA 85B measure asymmetry of μ -pair production, following formalism of RIZZO 81.

Limits for Z_{χ} Z_{χ} is the extra neutral boson in SO(10) \to SU(5) \times U(1) χ . $g_{\chi}=e/\cos\theta_{W}$ is assumed unless otherwise stated. We list limits with the assumption $\rho=1$ but with no further constraints on the Higgs sector. Values in parentheses assume stronger constraint on the Higgs sector motivated by superstring models. Values in brackets are from cosmological and astrophysical considerations and assume a light right-handed

VALUE (GeV)	CL%_	DOCUMENT ID		TECN	COMMENT
>425	95	⁷⁰ ABE	95	CDF	$p\overline{p}; Z'_{Y} \rightarrow e^{+}e^{-}$
>321	95 7	1,72 LANGACKER	92B	RVUE	Electroweak
• • • We do not	use the foll	owing data for avera	ages,	fits, lim	its, etc. • • •
>147	95	⁷³ ABREU	95N	DLPH	Z parameters and $e^+e^- \rightarrow \mu^+\mu^-(n\gamma)$
		⁷⁴ NARDI	95	RVUE	Z parameters
		⁷⁵ BUSKULIC	94		
>262	95	⁷⁶ VILAIN	94B	CHM2	$ u_{\mu} \stackrel{e}{=} \rightarrow \nu_{\mu} e \text{ and } \overline{\nu}_{\mu} e \rightarrow \overline{\nu}_{\mu} e $
>117	95	77 ADRIANI	93D	L3	Z parameters
(>900)	90	⁷⁸ ALTARELLI	93B	RVUE	
>340	95	⁷⁹ ABE	92B	CDF	$\rho \overline{\overline{\rho}}$
>280	95	⁸⁰ ABE	92B	CDF	$\rho \overline{\rho}$
(>650)	90	⁸¹ DELAGUILA	92	RVUE	
(>760)		⁸² LAYSSAC	92B	RVUE	Z parameters
>148	95	⁸³ LEIKE	92	RVUE	Z parameters
(>700)		⁸⁴ RENTON	92	RVUE	
(> 500)	90	⁸⁵ ALTARELLI			Z parameters
(> 570)		⁸⁶ BUCHMUEL	91	RVUE	Z parameters
(> 555)	90	⁸⁷ DELAGUILA	91	RVUE	
[>1470]		⁸⁸ FARAGGI	91	COSM	Nucleosynthesis; light ν_R

Heavy Bosons Other than Higgs Bosons

>320	90	⁸⁹ GONZALEZ-G91 RVUE
>221		90 MAHANTHAP91 RVUE Cs
>231	90	91,92 ABE 90F VNS $e^{+}e^{-}$
>206	90	92,93 ABE 90 F RVUE $^{e^+e^-}$, $^{\nu}_{\mu}$ e
>335		94 BARGER 90B RVUE pp
(> 650)	90	⁹⁵ GLASHOW 90 RVUE
[> 1140]		96 GONZALEZ-G90D COSM Nucleosynthesis; light ν_R
[> 2100]		97 GRIFOLS 90 ASTR SN 1987A; light ν_R
none $<$ 150 or $>$ 363	90	⁹⁸ HAGIWARA 90 RVUE e ⁺ e ⁻
>177		⁹⁹ DELAGUILA 89 RVUE ρ̄ρ
>280	95	100 DORENBOS 89 CHRM $g_\chi = g_Z$
>352	90	101 COSTA 88 RVUE
>170	90	102 ELLIS 88 RVUE $p\overline{p}$
>273	90	¹⁰¹ AMALDI 87 RVUE
>266	90	¹⁰³ MARCIANO 87 RVUE
>283	90	¹⁰⁴ DURKIN 86 RVUE

- $^{70}\,\mathrm{ABE}$ 95 limit is obtained assuming that Z' decays to known fermions only. See their Fig. 3 for the mass bound of Z^\prime decaying to all allowed fermions and supersymmetric
- 71 LANGACKER 92B fit to a wide range of electroweak data including LEP results available early '91. $m_t >$ 89 GeV used.
- 72 LANGACKER 92B give 95%CL limits on the Z-Z' mixing $-0.0048 < \theta < 0.0097$.
- T-LANGALKER 92B give 95%-CL limits on the Z-2' mixing −0.0048 < θ < 0.0097.
 3ABREU 95M limit is for α_S=0.123, m_F=150 GeV, and m_H=300 GeV. For the limit contour in the mass-mixing plane, see their Fig. 13.
 NARDI 95 give 90%CL limits on Z-Z' mixing −0.0032 < θ < 0.0031 for M_Z, >500 GeV, m_F=170 GeV, α_S=0.12. The bound is relaxed under the simultaneous presence of the mixing of the known fermions with new heavy states, −0.0032 < θ < 0.0070.
- 75 BUSKULIC 94 give 95%CL limits on the Z-Z' mixing -0.0091 < heta < 0.0023
- 76 VILAIN 94B assume $m_{ extit{t}}=$ 150 GeV and heta=0. See Fig. 2 for limit contours in the
- 77 ADRIANI 93D give limits on the Z- Z^{\prime} mixing $-0.004 < \theta < 0.015$ assuming the ABE 92B mass limit.
- 78 ALTARELI 938 limit is from LEP data available in summer '93 and is for $m_t=110$ GeV. $m_H=100$ GeV and $\alpha_S=0.118$ assumed. The limit improves for larger m_t (see their Fig. 5). The 90%CL limit on the Z-Z' mixing angle is in their Fig. 2.
- 79 These limits assume that Z' decays to known fermions only. 80 These limits assume that Z' decays to all E $_6$ fermions and their superpartners.
- 81 See Fig. 7a and 8 in DELAGUILA 92 for the allowed region in $m_{Z^{\prime}}$ -mixing plane and $m_{Z^{\prime}}-m_t$ plane from electroweak fit including '90 LEP data.
- 82 LAYSSAC 92B limit is from LEP data available spring '92. Specific Higgs sector is assumed. See also LAYSSAC 92.
 83 LEIKE 92 is based on '90 LEP data published in LEP 92.
- 84 RENTON 92 limits use LEP data taken up to '90 as well as m_W , ν N, and atomic parity violation data. Specific Higgs structure is assumed.
- ⁸⁵ ALTARELLI 91B is based on Z mass, widths, and A_{FB} . The limits are for superstring motivated models with extra assumption on the Higgs sector. $m_t > 90$ GeV and motivated models with extra assumption on the Higgs sector. $m_t > 90$ GeV and $m_{H^0} < 1$ TeV assumed. For large m_t , the bound improves drastically. Bounds for Z-Z' mixing angle and Z mass shift without this model assumption are also given in the
- 86 BUCHMUELLER 91 limit is from LEP data. Specific assumption is made for the Higgs
- sector. 87 DELAGUILA 91 bounds have extra assumption of superstring motivated Higgs sector. From ν N neutral current data with $m_Z=91.10\pm0.04$ GeV, $m_{t}>77$ GeV, $m_{H^0}<1$
- 88 FARAGGI 91 limit assumes the nucleosynthesis bound on the effective number of neutrinos $\Delta N_{
 u}~<~0.5$ and is valid for $m_{
 u_R}^{}~<~1$ MeV.
- 89 GONZALEZ-GARCIA 91 limit is based on low-energy neutral current data, Z mass and widths, m_W from ABE 90G, 100 $<\!m_t<\!$ 200 GeV, $m_{H^0}=\!$ 100 GeV assumed. Dependence on m_t is shown in Fig. 7.
- 90 MAHANTHAPPA 91 limit is from atomic parity violation in Cs with $m_W,\,m_Z.$
- $^{91}\,\mathrm{ABE}$ 90F use data for R, $R_{\ell\ell}$, and $A_{\ell\ell}.$
- 92 ABE 90F fix $m_{W}=80.49\pm0.43\pm0.24$ GeV and $m_{Z}=91.13\pm0.03$ GeV.
- $^{93}e^+e^-$ data for R, $R_{\ell\ell}$, $A_{\ell\ell}$, and $A_{c\overline{c}}$ below Z as well as $\nu_{\mu}e$ scattering data of GEIREGAT 89 is used in the fit. 94 BARGER 90B limit is based on CDF limit $\sigma(p\overline{p}\to Z')\cdot B(Z'\to e^+e^-)<1$ pb
- (Nodulman, EPS Conf. '89). Assumes no new threshold is open for Z' decay.
- 95 GLASHOW 90 model assumes a specific Higgs sector. See GLASHOW 90B.
- ⁹⁶ These authors claim that the nucleosynthesis bound on the effective number of light neutrinos ($\delta N_{
 u} < 1$) constrains Z' masses if $u_{\mathcal{R}}$ is light ($\lesssim 1$ MeV).
- 97 GRIFOLS 90 limit holds for $m_{\nu_R}\lesssim 1$ MeV. See also GRIFOLS 90D, RIZZO 91.
- 98 HAGIWARA 90 perform a fit to e^+e^- data at PEP, PETRA, and TRISTAN including $\mu^+\mu^-,~\tau^+\tau^-,$ and hadron cross sections and asymmetries. The upper mass limit disappears at 2.7 s.d.
- ⁹⁹ DELAGUILA 89 limit is based on $\sigma(p\bar{p}\to Z')$ B($Z'\to e^+e^-$) < 1.8 pb at CERN $p\bar{p}$
- 100 DORENBOSCH 89 obtain the limit $(g_\chi/g_Z)^2 \cdot (m_Z/m_{Z_\chi})^2 < 0.11$ at 95% CL from the processes $\overline{\nu}_{\mu}\,e\,\rightarrow\,\,\overline{\nu}_{\mu}\,e$ and $\nu_{\mu}\,e\,\rightarrow\,\,\overline{\nu_{\mu}}\,e$.
- $^{101}\,\mathrm{A}$ wide range of neutral current data as of 1986 are used in the fit.
- $^{102}\,Z^\prime$ mass limits from non-observation of an excess of $\ell^+\,\ell^-$ pairs at the CERN $p\,\overline{p}$ collider [based on ANSARI 87D and GEER Uppsala Conf. 87]. The limits apply when Z^\prime decays only into light quarks and leptons.
- 103 MARCIANO 87 limit from unitarity of Cabibbo-Kobayashi-Maskawa matrix.
- $104\,\mathrm{A}$ wide range of neutral current data as of 1985 are used in the fit.

Limits for Z_{ψ} Z_{ψ} is the extra neutral boson in E₆ \rightarrow SO(10) \times U(1) $_{\psi}$. $g_{\psi}=e/\cos\theta_W$ is assumed unless otherwise stated. We list limits with the assumption $\rho=1$ but with no further constraints on the Higgs sector. Values in brackets are from cosmological and astrophysical considerations and assume a light right-handed neutrino.

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>415	95	105 ABE	95		$p\overline{p}; Z'_{\psi} \rightarrow e^+e^-$
>160	95 106	,107 LANGACKER	92B	RVUE	Electroweak
• • We do not use	the foll	owing data for avera	ages,	fits, lim	its, etc. • • •
>105	95	¹⁰⁸ ABREU	95N	DLPH	Z parameters and
. 125	05	¹⁰⁹ NARDI ¹¹⁰ VILAIN			$e^+e^- \rightarrow \mu^+\mu^-(n\gamma)$ Z parameters
>135	95		948	СНМ2	$ u_{\mu} \stackrel{e}{=} {=} \nu_{\mu} e ext{and} \overline{ u}_{\mu} e \rightarrow $
>118	95	¹¹¹ ADRIANI	930	L3	Z parameters
>320	95	¹¹² ABE	92B	CDF	ρ p
>180	95	¹¹³ ABE	92B	CDF	$p\overline{p}$
>122	95	¹¹⁴ LEIKE	92	RVUE	Z parameters
>105		,116 ABE	90F	VNS	e+ e-
>146	90 116	^{,117} ABE	90F	RVUE	e^+e^- , $\nu_{\mu}e$
>320		¹¹⁸ BARGER		RVUE	pp
[> 160]		¹¹⁹ GONZALEZ-G	9 0D	COSM	Nucleosynthesis; light ν_R
[> 2000]		120 GRIFOLS	90D	ASTR	SN 1987A; light ν_R
>136	90	¹²¹ HAGIWARA	90	RVUE	e+e-
>154	90	¹²² AMALDI	87	RVUE	
>146	90	¹²³ DURKIN	86	RVUE	

- $^{105} \mathrm{ABE}$ 95 limit is obtained assuming that Z' decays to known fermions only. See their Fig. 3 for the mass bound of Z' decaying to all allowed fermions and supersymmetric fermions.
- 106 LANGACKER 928 fit to a wide range of electroweak data including LEP results available early '91. m_t >89 GeV used.
- 107 LANGACKER 92B give 95%CL limits on the Z-Z' mixing $-0.0025~<~\theta<~0.013$.
- 108 ABREU 95M limit is for α_{S} =0.123, m_{t} =150 GeV, and m_{H} =300 GeV. For the limit contour in the mass-mixing plane, see their Fig. 13.
- NARDI 95 give 90%CL limits on Z-Z' mixing $-0.0056 < \theta < 0.0055$ for $M_{Z'} >$ 500 GeV, m_t =170 GeV, m_H =250 GeV, α_S =0.12. The bound is relaxed under the simultaneous presence of the mixing of the known fermions with new heavy states, $-0.0066 < \theta <$
- 111 ADRIAN 930 give limits on the Z-Z' mixing $-0.003 < \theta < 0.020$ assuming the ABE 92B mass limit. 112 These limits assume that Z' decays to known fermions only.
- 113 These limits assume that Z^\prime decays to all E $_6$ fermions and their superpartners.
- 114 LEIKE 92 is based on '90 LEP data published in LEP 92.
- $^{115}\,\mathrm{ABE}$ 90F use data for R, $R_{\ell\,\ell}$, and $A_{\ell\,\ell}$
- $^{116} \mathrm{ABE}$ 90F fix $m_W = 80.49 \pm 0.43 \pm 0.24$ GeV and $m_Z = 91.13 \pm 0.03$ GeV.
- The Her Barrian W = 0.0.3 ± 0.0.3 ± 0.0.4 Gebox Z as well as $\nu_{\mu}e$ scattering data of GEIREGAT 89 is used in the fit.

 118 BARGER 908 limit is based on CDF limit $\sigma(p\bar{p}\to Z')\cdot B(Z'\to e^+e^-)<1$ pb (Nodulman, EPS Conf. '89). Assumes no new threshold is open for Z' decay.
- 119 These authors claim that the nucleosynthesis bound on the effective number of light neutrinos ($\delta N_{
 u} < 1$) constrains Z' masses if ν_R is light ($\lesssim 1$ MeV).
- 120 GRIFOLS 90D limit holds for $m_{\nu_R}\lesssim 1$ MeV. See also RIZZO 91. $\mu^+\mu^-$, $\tau^+\tau^-$, and hadron cross sections and asymmetries. 122A wide range of neutral current data as of 1986 are used in the fit.
- $^{123}\,\mathrm{A}$ wide range of neutral current data as of 1985 are used in the fit.

Limits for Z_n

 Z_{η} is the extra neutral boson in E $_{6}$ models, corresponding to $Q_{\eta}=\sqrt{3/8}~Q_{\chi}~ \sqrt{5/8}~Q_{\psi}\cdot~g_{\eta}=e/\cos\theta_W$ is assumed unless otherwise stated. We list limits with the assumption $\rho=1$ but with no further constraints on the Higgs sector. Values in parentheses assume stronger constraint on the Higgs sector motivated by superstring models. Values in brackets are from cosmological and astrophysical considerations and assume a light right-handed neutrino.

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>440	95	¹²⁴ ABE	95	CDF	$\rho \overline{\rho}; Z'_{\eta} \rightarrow e^+ e^-$
>182	95 ¹²⁵	,126 LANGACKER	9 2B	RVUE	Electroweak
• • • We do not use	the follo	owing data for avera	ges,	fits, limi	ts, etc. • • •
>109	95	127 ABREU	95M	DLPH	Z parameters and
		128 NARDI	95	RVUE	$e^+e^- \rightarrow \mu^+\mu^-(n\gamma)$ Z parameters
>100	95	¹²⁹ VILAIN	94 B	CHM2	Z parameters $\nu_{\mu} e \rightarrow \nu_{\mu} e$ and $\overline{\nu}_{\mu} e \rightarrow$
		130			$\overline{\nu}_{\mu} e$
>100	95	130 ADRIANI		L3	Z parameters
(>500)	90	131 ALTARELLI	93B	RVUE	Z parameters
>340	95	¹³² ABE	92B	CDF	PP
>230	95	¹³³ ABE	92B	CDF	p p
(>450)	90	¹³⁴ DELAGUILA	92	RVUE	• •
(>315)		135 LAYSSAC	92B	RVUE	Z parameters
>118	95	136 LEIKE	92	RVUE	Z parameters
(>470)		137 RENTON	92	RVUE	•
(> 300)	90	138 ALTARELLI			Z parameters
>120	90	139 GONZALEZ-G.			_ ,
>125		,141 ABE		VNS	e^+e^-

Gauge & Higgs Boson Particle Listings Heavy Bosons Other than Higgs Bosons

>115	90 141	,142 ABE	90F	RVUE	$e^{+}e^{-}$, $\nu_{\mu}e$
>340				RVUE	PP
[> 820]		144 GONZALEZ-G	90 D	COSM	Nucleosynthesis; light ν_R
[> 3300]		145 GRIFOLS		ASTR	SN 1987A; light ν_R
>100	90	¹⁴⁶ HAGIWARA	90	RVUE	e+e-
[> 1040]			90	COSM	Nucleosynthesis; light ν_R
>173			89	RVUE	$p\overline{p}$
>129	90	148 COSTA	88	RVUE	
>156	90	149 ELLIS	88	RVUE	
>167	90		88	RVUE	ρP
>111	90	¹⁴⁸ AMALDI	87	RVUE	
>143	90		86B	RVUE	PP
>130	90	¹⁵² DURKIN	86	RVUE	
[> 760]			86	COSM	Nucleosynthesis; light ν_R
[> 500]		¹⁴⁴ STEIGMAN	86	COSM	Nucleosynthesis; light ν_R
					• • • • • • • • • • • • • • • • • • • •

- 124 ABE 95 limit is obtained assuming that Z' decays to known fermions only. See their Fig. 3 for the mass bound of Z' decaying to all allowed fermions and supersymmetric
- fermions. 125 LANGACKER 92B fit to a wide range of electroweak data including LEP results available early '91. $m_t > 89$ GeV used.
- early 91. m_t >89 GeV used. 126 LANGACKER 928 give 95%CL limits on the Z-Z' mixing $-0.038 < \theta < 0.002$. 127 ABREU 95M limit is for α_s =0.123, m_t =150 GeV, and m_H =300 GeV. For the limit contour in the mass-mixing plane, see their Fig. 13. 128 NARDI 95 give 90%CL limits on Z-Z' mixing $-0.0087 < \theta < 0.0075$ for M_{Z^1} >500 GeV,
- m_t =170 GeV, m_H =250 GeV, α_s =0.12. The bound is relaxed under the simultaneous presence of the mixing of the known fermions with new heavy states, -0.0087 $< \theta <$
- 129 VILAIN 94B assume $m_t=$ 150 GeV and heta=0. See Fig. 2 for limit contours in the mass-mixing plane.
- 130 ADRIANI 930 give limits on the Z-Z' mixing $-0.029 < \theta < 0.010$ assuming the ABE 928 mass limit. 131 ALTARELLI 938 limit is from LEP data available in summer '93 and is for $m_t=110$
- GeV. $m_H=100$ GeV and $\alpha_S=0.118$ assumed. The 90%CL limit on the $\it Z-Z'$ mixing angle is in Fig. 2.
- These limits assume that Z' decays to known fermions only.
- 133 These limits assume that Z' decays to all E_6 fermions and their superpartners.
- 134 See Fig. 7d in DELAGUILA 92 for the allowed region in m_{7l} -mixing plane from elec-

- 134 See Fig. 7d in DELAGUILA 92 for the allowed region in m_{Z/r}-mixing plane from electroweak fit including '90 LEP data.
 135 LAYSSAC 92B limit is from LEP data available spring '92. Specific Higgs sector is assumed. See also LAYSSAC 92.
 136 LEIKE 92 is based on '90 LEP data published in LEP 92.
 137 RENTON 92 limits use LEP data taken up to '90 as well as m_W, νN, and atomic parity violation data. Specific Higgs structure is assumed.
 138 ALTARELLI 91B is based on Z mass, widths, and A_{FB}. The limits are for superstring motivated models with extra assumption on the Higgs sector. m_t > 90 GeV and m_{HO} < 1 TeV assumed. For large m_t, the bound improves drastically. Bounds for 2-z^r/z mixing angle and Z mass shift without this model assumption are also given in the Z-Z' mixing angle and Z mass shift without this model assumption are also given in the
- paper. 139 GONZALEZ-GARCIA 91 limit is based on low-energy neutral current data, LEP Z mass and widths, m_W from ABE 906. 100 $< m_t <$ 200 GeV, $m_{H^0} =$ 100 GeV assumed. Dependence on m_t is shown in Fig. 8.
- 140 ABE 90F use data for R, $R_{\ell\ell}$, and $A_{\ell\ell}$. 141 ABE 90F fix $m_W=80.49\pm0.43\pm0.24$ GeV and $m_Z=91.13\pm0.03$ GeV.
- 142 $_{e}^{+}e^{-}$ data for R, $R_{\ell\ell}$, $A_{\ell\ell}$, and $A_{C\overline{c}}$ below Z as well as $\nu_{\mu}e$ scattering data of GEIREGAT 89 is used in the fit. 143 BARGER 908 limit is based on CDF limit $\sigma(\rho\overline{\rho}\to Z')$.B($Z'\to e^+e^-$) < 1 pb
- (Nodulman, EPS Conf. '89). Assumes no new threshold is open for Z^\prime decay.
- 144 These authors claim that the nucleosynthesis bound on the effective number of light neutrinos ($\delta N_{\nu} < 1$) constrains Z' masses if ν_R is light ($\lesssim 1$ MeV). 145 GRIFOLS 90 limit holds for $m_{\nu_R} \lesssim 1$ MeV. See also GRIFOLS 90D, RIZZO 91. 146 HAGIWARA 90 perform a fit to e^+e^- data at PEP, PETRA, and TRISTAN including
- , and hadron cross sections and asymmetries.
- 147 DELAGUILA 89 limit is based on $\sigma(p\,\overline{p}\to Z')\cdot B(Z'\to e^+e^-)<1.8$ pb at CERN $p\,\overline{p}$
- 148 A wide range of neutral current data as of 1986 are used in the fit.
- $^{149}Z_{\eta}$ mass limits obtained by combining constraints from non-observation of an excess of $\ell^+\ell^-$ pairs at the CERN $p\bar{p}$ collider and the global analysis of neutral current data by COSTA 88. Least favorable spectrum of three (E_6 27) generations of particles and their superpartners are assumed.
- $^{150}Z'$ mass limits from non-observation of an excess of $\ell^+\ell^-$ pairs at the CERN $p\overline{p}$ collider [based on ANSARI 87D and GEER Uppsala Conf. 87]. The limits apply when Z^\prime decays only into light quarks and leptons. ¹⁵¹BARGER 868 limit is based on UA1/UA2 limit on $p\overline{p} \rightarrow Z'$, $Z' \rightarrow e^+e^-$ (Lepton
- Photon Symp., Kyoto, '85). Extra decay channels for Z^\prime are assumed not be open.
- $152\,\mathrm{A}$ wide range of neutral current data as of 1985 are used in the fit.

Limits for other Z' $Z_{\beta} = Z_{\chi} \cos \beta + Z_{\psi} \sin \beta$

VALUE (GeV)	CL%_	DOCUMENT ID		TECN	COMMENT
• • • We do not ι	ise the followin	g data for average	es, fits	, limits,	etc. • • •
		¹⁵³ DELAGUILA			
>360	1	^{L54} ALTARELLI	91	RVUE	Z_{eta} with $ aneta=\sqrt{3/5}$;
>190	_ 1	¹⁵⁵ MAHANTHAI	291	RVUE	Z_{β} with $\tan \beta = \sqrt{3/5}$;
	1	^{L56} GRIFOLS	90c	RVUE	Cs
		^{L57} DELAGUILA	89	RVUE	$\rho \overline{\rho}$
>180		^{L59} COSTA	88	RVUE	Z_{eta} with $ aneta=\sqrt{15}$
>158	90 1	¹⁶⁰ ELLIS	88	RVUE	Z_{β} (tan $\beta = \sqrt{15}$), $\rho \overline{\rho}$

- 153 Fig. 7c and 7e in DELAGUILA 92 give limits for $an\!eta\!=-1/\sqrt{15}$ and $\sqrt{15}$ from elec-
- troweak fit including '90 LEP data.

 154 ALTARELLI 91 limit is from atomic parity violation in Cs together with LEP, CDF data. Z-Z' mixing is assumed to be zero to set the limit.
- 155 MAHANTHAPPA 91 limit is from atomic parity violation in Cs with m_W , m_Z . See Table III of MAHANTHAPPA 91 (corrected in erratum) for limits on various Z' models.
- 156 GRIFOLS 90c obtains a limit for Z' mass as a function of mixing angle β (his $\theta=\beta-\pi/2$), which is derived from a LAMPF experiment on $\sigma(\nu_{\varrho}\,e)$ (ALLEN 90). The result is shown in Fig. 1.
- 157 See Table I of DELAGUILA 89 for limits on various Z^\prime models.
- 158 $g_{eta}=e/{{\cos} heta_W}$ and ho=1 assumed.

- $^{159}\,\mathrm{A}$ wide range of neutral current data as of 1986 are used in the fit.
- 160 Z' mass limits from non-observation of an excess of $\ell^+\ell^-$ pairs at the CERN $p\,\overline{p}$ collider [based on ANSARI 87D and GEER Uppsala Conf. 87]. The limits apply when Z^\prime decays only into light quarks and leptons.

MASS LIMITS for Leptoquarks from Pair Production

These limits rely only on the color or electroweak charge of the leptoquark.

VALUE (GeV)	CL% E	VTS	DOCUMENT ID		TECN	COMMENT
> 97	95	161	ABACHI	95G	D0	Second generation
> 96	95	162	ABE	95 U	CDF	Second generation
>116	95	163	³ ABACHI	94B	D0	First generation
> 80	95	164	ABE	931	CDF	First generation
> 45.5	95		ABREU	93.1	DLPH	First + second gen- eration
> 44.4	95	167	' ADRIANI	93M	L3	First generation
> 44.6	95	168	ADRIANI	93M	L3	Third generation
> 44	95		DECAMP	92	ALEP	First or second generation
> 45	95	167	DECAMP	92	ALEP	Third generation
> 44.2	95	167	ALEXANDER	91	OPAL	First or second generation
> 41.4	95	167	ALEXANDER	91	OPAL	Third generation
 ◆ ◆ We do not use 	the follo	wing data	for averages, fit	s, lin	nits, etc.	. • • •
> 44.5	95		ADRIANI	93M	L3	Second generation
> 42.1	95	169	ABREU	92F	DLPH	Second generation
> 74	95) ALITTI	92E	UA2	First generation
> 43.2	95	1.67	ADEVA	91B	L3	First generation
> 43.4	95	167	ADEVA	91B	L3	Second generation
none 8.9-22.6	95	171	KIM	90	AMY	First generation
none 10.2-23.2	95	171	KIM	90	AMY	Second generation
none 5-20.8	95	172	BARTEL	87B	JADE	
none 7-20.5	95	2 173	BEHREND	86B	CELL	

 161 ABACHI 95G search for scalar leptoquarks using $\mu\mu+{
m jets}$ and $\mu\nu_{\mu}+{
m jets}$ events in $ho\overline{
ho}$ collisions at $E_{\rm cm}=1.8$ TeV. The limit is for B(μq) = B(νq) = 0.5 and improves to >119 GeV for B(μq) = 1.

162 ABE 95U search for scalar leptoquarks of charge Q=2/3 and -1/3 using $\mu\mu jj$ events in $p\overline{p}$ collisions at $E_{\text{Cm}}=1.8$ TeV. The limit is for $\mathrm{B}(\mu\,q)=\mathrm{B}(\nu\,q)=0.5$ and improves to > 131 GeV for $\mathrm{B}(\mu\,q)=1$.

163 ABACHI 948 search for eejj and $e\nu jj$ events in $\rho\bar{\rho}$ collisions at $E_{\rm cm}=1.8$ TeV. ABACHI 948 obtain the limit >120 GeV for ${\rm B}(eq)={\rm B}(\nu q)=0.5$ and >133 GeV for ${\rm B}(eq)=1$. A change in the ${\rm D}^0$ luminosity monitor constant reduces the first bound to >116 GeV quoted above (see FERMILAB-TM-1911). This limit does not depend on the

164 ABE 93 search for $\ell\ell j$ events in $\rho \bar{p}$ collisions at $E_{cm} = 1.8$ TeV. The limit is for $B(eq) = B(\nu q) = 0.5$ and improves to >113 GeV for B(eq) = 1. This limit does not depend on electroweak quantum numbers of the leptoquark.

165 Limit is for charge -1/3 isospin-0 leptoquark with B(ℓq) = 2/3.

- 166 First and second generation leptoquarks are assumed to be degenerate. The limit is slightly lower for each generation.
- 167 Limits are for charge -1/3, isospin-0 scalar leptoquarks decaying to ℓ^-q or νq with any branching ratio. See paper for limits for other charge-isospin assignments of leptoquarks. 168 ADRIANI 93M limit for charge -1/3, isospin-0 leptoquark decaying to au b.
- 169 ADRIANI 93M limit for charge -1/3, isospin-0 leptoquark decaying to τb.
 169 ABREU 92F limit is for charge -1/3 isosin-0 leptoquark with B(μq)=2/3. If first and second generation leptoquarks are degenerate, the limit is 43.0 GeV, and for a charge 2/3 second generation leptoquark 43.4 GeV. Cross-section limit for pair production of states decaying to ℓq is given in the paper.
 170 ALITTI 92E search for ℓℓjj and ℓνjj events in pp̄ collisions at E_{CM}=630 GeV. The limit is for B(eq) = 1 and is reduced to 67 GeV for B(eq) = B(νq) = 0.5. This limit does not depend on electroweak quantum numbers of the leptoquark.
 171 KIM 90 assume pair production of charge 2/3 scalar-leptoquark via photon exchange. The decay of the first (second) generation leptoquark is assumed to be any mixture of de+ and uv̄ (su+ and cv̄). See paper for limits for specific branching ratios.
- $d\,e^+$ and $u\overline{\,}$ (s $\,\mu^+$ and $\,c\,\overline{\,}$). See paper for limits for specific branching ratios.
- 172 BARTEL 878 limit is valid when a pair of charge 2/3 spinless leptoquarks X is produced with point coupling, and when they decay under the constraint B(X ightarrow $c\overline{\nu}_{\mu}$) + B(X ightarrow
- $173\,\mathrm{BEHREND}$ 86B assumed that a charge 2/3 spinless leptoquark, χ , decays either into $s\mu^+$ or $c\overline{\nu}$: $B(X \to s\mu^+) + B(X \to c\overline{\nu}) = 1$.

MASS LIMITS for Leptoquarks from Single Production

These limits depend on the q- ℓ -leptoquark coupling g_{LQ} . It is often assumed that

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT	
>230	95	¹⁷⁴ AHMED	948 H1	First generation	1
> 73	95	¹⁷⁵ ABREU	93J DLPH	Second generation	

Heavy Bosons Other than Higgs Bosons

- \bullet $\,\bullet\,$ We do not use the following data for averages, fits, limits, etc. $\,\bullet\,$ $\,\bullet\,$
- > 65
 95
 175 ABREU
 93 DLPH
 First generation

 >181
 95
 176 ABT
 93 H1
 First generation

 >168
 95
 177 DERRICK
 93 ZEUS
 First generation
- 174 AHMED 94B limit is for the left-handed leptoquark decaying to eq and νq with $B(eq) = B(\nu q) = 1/2$. Electromagnetic coupling strength is assumed for the scalar leptoquark interaction. For limits on states with different quantum numbers and the limits in the coupling-mass plane, see their Table 2 and Fig. 6.
- Coupling-mass plane, see their radic 2 and rig. o. Coupling-mass plane, see their radic 2 and rig. o. The limit is for a leptoquark coupling of electromagnetic strength and assumes $B(\ell q)=2/3$. The limit is 77 GeV if first and second leptoquarks are degenerate.
- 176 ABT 93 search for single leptoquark production in ep collisions with the decays eq and νq . The limit is for a leptoquark coupling of electromagnetic strength and assumes $B(eq) = B(\nu q) = 1/2$. The limit for B(eq) = 1 is 178 GeV. For limits on states with different quantum numbers, see their Fig. 2. ABT 93 superseded by AHMED 948.
- different quantum numbers, see their Fig. 2. ABT 93 supersected by ATIMED 7-0. 177 DERRICK 93 search for single leptoquark production in ep collisions with the decay eq and νq . The limit is for leptoquark coupling of electromagnetic strength and assumes $B(eq) = B(\nu q) = 1/2$. The limit for B(eq) = 1 is 176 GeV. For limits on states with different quantum numbers, see their Table 3.

Indirect Limits for Leptoquarks

VALUE (TeV)	CL%	DOCUMENT ID		TECN	COMMENT
• • We do not i	use the follow	ing data for average	s, fits	, limits,	etc. • • •
> 0.31	95	178 AID	95	H1	First generation
		¹⁷⁹ MIZUKOSHI	95		Third generation lepto- quark
> 0.3	95	¹⁸⁰ BHATTACH	94	RVUE	Spin-0 leptoquark coupled to $\overline{e}_R t_I$
		¹⁸¹ DAVIDSON	94	RVUE	
> 18		¹⁸² KUZNETSOV	94	RVUE	Pati-Salam type
> 0.43	95	¹⁸³ LEURER	94	RVUE	First generation spin-1 leptoquark
> 0.44	95	¹⁸³ LEURER	948	RVUE	First generation spin-0 leptoquark
		¹⁸⁴ MAHANTA	94	RVUE	P and T violation
>350		¹⁸⁵ DESHPANDE	83	RVUE	Pati-Salam X-boson
> 1		¹⁸⁶ SHANKER	82	RVUE	Nonchiral spin-0 lepto- quark
>125		¹⁸⁶ SHANKER	82	RVUE	Nonchiral spin-1 lepto-

- 178 AID 95 limit is for the weak isotriplet spin-1 leptoquark with the electromagnetic coupling strength. For the limits of leptoquarks with different quantum number, see their Table 2. AID 95 limits are from the measurements of the Q^2 spectrum measurement of $ep \rightarrow eX$
- 179 MZUKOSHI 95 calculate the one-loop radiative correction to the Z-physics parameters in various leptoquark models. See their Fig. 4 for the exclusion plot of third generation leptoquark models in mass-coupling plane.
- in various ieptoquark models for mass-coupling plane. 180 BHATTACHARYYA 94 limit is from one-loop radiative correction to the leptonic decay width of the Z. m_H =250 GeV, $\alpha_S(m_Z)$ =0.12, m_t =180 GeV, and the electroweak strength of leptoquark coupling are assumed. For leptoquark coupled to $\overline{e}_L t_R$, $\overline{\mu}$, and $\overline{\tau}t$, see Fig. 2 in BHATTACHARYYA 94B erratum and Fig. 3.
- 181 DAVIDSON 94 gives an extensive list of the bounds on leptoquark-induced four-fermion insteractions from π , K, D, B, μ , τ decays and meson mixings, etc. See Table 15 of DAVIDSON 94 for detail.
- 182 KUZNETSOV 94 gives mixing independent bound of the Pati-Salam leptoquark from the cosmological limit on $\pi^0 \to \overline{\nu}\nu$.
- 183 LEURER 94, LEURER 94B limits are obtained from atomic parity violation and apply to any chiral leptoquark which couples to the first generation with electromagnetic strength. For a nonchiral leptoquark, universality in $\pi \ell_2$ decay provides a much more stringent bound. See also SHANKER 82.
- 184 MAHANTA 94 gives bounds of *P* and *T*-violating scalar-leptoquark couplings from atomic and molecular experiments.
- 185 DESHPANDE 83 used upper limit on $K_L^0 \to \mu e$ decay with renormalization-group equations to estimate coupling at the heavy boson mass. See also DIMOPOULOS 81. 186 From $(\pi \to e \nu)/(\pi \to \mu \nu)$ ratio. SHANKER 82 assumes the leptoquark induced
- 186 From $(\pi \to e \nu)/(\pi \to \mu \nu)$ ratio. SHANKER 82 assumes the leptoquark induced four-fermion coupling $4g^2/M^2$ $(\overline{v}_{eL}\ u_R)\ (\overline{d}_L e_R)$ with g=0.004 for spin-0 leptoquark and g^2/M^2 $(\overline{v}_{eL}\ \gamma_\mu u_L)\ (\overline{d}_R\ \gamma^\mu e_R)$ with g=0.6 for spin-1 leptoquark.

MASS LIMITS for Diquarks

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use th	e following	data for averages,	fits, limits,	etc. • • •
none 15-31.7	95 18	³⁷ ABREU	940 DLPH	SUSY E6 diquark

187 ABREU 940 limit is from $e^+e^- \to \overline{c}\,\overline{s}\,cs$. Range extends up to 43 GeV if diquarks are degenerate in mass.

MASS LIMITS for g_A (axigluon)

Axigluons are massive color-octet gauge bosons in chiral color models and have axial-vector coupling to quarks with the same coupling strength as gluons.

VALUE (GeV)

CLY

DOCUMENT ID

TECN

COMMENT

• • • We do not use t	the follow	ving data for averages	s, fits, limits	, etc. • • •
none 200-870	95	¹⁸⁸ ABE	95N CDF	$p\overline{p} \rightarrow g_A X, g_A \rightarrow q\overline{q}$
none 240-640	95	¹⁸⁹ ABE	93G CDF	$p\overline{p} \to g_A X, g_A \to$ 2 jets
>50	95	190 CUYPERS	91 RVUE	$\sigma(e^+e^- \rightarrow hadrons)$
none 120-210	95	¹⁹¹ ABE	90н CDF	$p\overline{p} \rightarrow g_A X, g_A \rightarrow$ 2 jets
>29		¹⁹² ROBINETT	89 THEO	Partial-wave unitarity
none 150-310	95	¹⁹³ ALBAJAR	88B UA1	$p\overline{p} g_A X, g_A $
>20		BERGSTROM		$p\overline{p} \rightarrow \Upsilon X \text{ via } g_A g$
> 9		194 CUYPERS	88 RVUE	γ decay
>25		¹⁹⁵ DONCHESKI	88B RVUE	au decay

- $^{188}\!$ ABE 95N assume axigluons decaying to quarks in the Standard Model only.
- 189 ABE 93G assume $\Gamma(g_A)=N\alpha_S m_{g_A}/6$ with N=10.
- 190 CUYPERS 91 compare $\alpha_{\rm S}$ measured in \varUpsilon decay and that from R at PEP/PETRA energies.
- 191 ABE 90H assumes $\Gamma(g_A) = N\alpha_5 m_{g_A}/6$ with N = 5 ($\Gamma(g_A) = 0.09 m_{g_A}$). For N = 10, the excluded region is reduced to 120–150 GeV.
- 192 ROBINETT 89 result demands partial-wave unitarity of J=0 t $\overline{t} \to t\overline{t}$ scattering amplitude and derives a limit $m_{g_A}>0.5$ m_t . Assumes $m_t>56$ GeV.
- 193 ALBAJAR 88B result is from the nonobservation of a peak in two-jet invariant mass distribution. $\Gamma(g_A)<0.4$ m_{g_A} assumed. See also BAGGER 88.
- 194 CUYPERS 88 requires $\Gamma(\Upsilon \to gg_A) < \Gamma(\Upsilon \to ggg)$. A similar result is obtained by
- DONCHESKI 88. requires $\Gamma(T \to g g_A) \setminus \Gamma(T \to g g g) \times S$ minimal result is obtained by DONCHESKI 88 requires $\Gamma(T \to g q \overline{q}) / \Gamma(T \to g g g) \times S$, where the former decay proceeds via axigluon exchange. A more conservative estimate of < 0.5 leads to $m_{g_A} > 21$ GeV.

X^0 (Heavy Boson) Searches in Z Decays

Searches for radiative transition of Z to a lighter spin-0 state X^0 decaying to hadrons, a lepton pair, or a photon pair as shown in the comments. The limits are for the product of branching ratios.

VALUE CL% DOCUMENT ID TECN COMMENT

• • • We do not us	se the follow	ing data for avera	ges, fits, limits,	etc. • • •
		¹⁹⁶ ACTON	93E OPAL	$X^0 \rightarrow \gamma \gamma$
		¹⁹⁷ ABREU	92D DLPH	$X^0 \rightarrow hadrons$
		¹⁹⁸ ADRIANI	92F L3	$X^0 \rightarrow hadrons$
		¹⁹⁹ ACTON	91 OPAL	$X^0 \rightarrow \text{anything}$
$< 1.1 \times 10^{-4}$	95	²⁰⁰ ACTON	91B OPAL	$X^0 \rightarrow e^+e^-$
$< 9 \times 10^{-5}$	95	²⁰⁰ ACTON	91B OPAL	$\chi^0 \rightarrow \mu^+ \mu^-$
$< 1.1 \times 10^{-4}$	95	²⁰⁰ ACTON	91B OPAL	$X^0 \rightarrow \tau^+ \tau^-$
$< 2.8 \times 10^{-4}$	95	²⁰¹ ADEVA	91D L3	$X^0 \rightarrow e^+ e^-$
$< 2.3 \times 10^{-4}$	95	²⁰¹ ADEVA	91D L3	$\chi^0 \rightarrow \mu^+ \mu^-$
$< 4.7 \times 10^{-4}$	95	²⁰² ADEVA	91D L3	$X^0 \rightarrow \text{hadrons}$
$< 8 \times 10^{-4}$	95	²⁰³ AKRAWY	90J OPAL	$X^0 \rightarrow hadrons$

- 196 ACTON 93E give $\sigma(e^+e^-\to X^0\gamma)$ -B(X $^0\to \gamma\gamma)<$ 0.4 pb (95%CL) for $m_{\chi0}=60\pm$ 2.5 GeV. If the process occurs via s-channel γ exchange, the limit translates to $\Gamma(X^0)$ -B(X $^0\to \gamma\gamma)^2<$ 20 MeV for $m_{\chi0}=60\pm$ 1 GeV.
- 197 ABREU 920 give σ_Z · B($Z \rightarrow \gamma X^0$) · B($X^0 \rightarrow$ hadrons) <(3–10) pb for $m_{X^0} = 10$ –78 GeV. A very similar limit is obtained for spin-1 X^0 .
- 198 ADRIANI 92F search for isolated γ in hadronic Z decays. The limit $\sigma_Z + \mathrm{B}(Z \to \gamma X^0) + \mathrm{B}(X^0 \to \mathrm{hadrons}) < (2-10) \,\mathrm{pb}$ (95%CL) is given for $m_{\chi 0} = 25$ –85 GeV.
- 199 ACTON 91 searches for $Z \to Z^* X^0$, $Z^* \to e^+ e^-$, $\mu^+ \mu^-$, or $\nu \overline{\nu}$. Excludes any new scalar X^0 with $m_{X^0} < 9.5$ GeV/c if it has the same coupling to ZZ^* as the MSM Higgs boson.
- 200 ACTON 91B limits are for $m_{\chi^0}=$ 60-85 GeV.
- 201 ADEVA 91D limits are for $m_{\chi^0}=$ 30–89 GeV.
- $^{202}\mathrm{ADEVA}$ 91D limits are for $m_{\ensuremath{\chi^0}} =$ 30–86 GeV.
- 203 AKRAWY 90.1 give $\Gamma(Z\to \gamma X^0)\cdot B(X^0\to hadrons)<1.9$ MeV (95%CL) for $m_{X^0}=32\text{--}80$ GeV. We divide by $\Gamma(Z)=2.5$ GeV to get product of branching ratios. For nonresonant transitions, the limit is $B(Z\to \gamma q\,\overline{q})<8.2$ MeV assuming three-body phase space distribution.

MASS LIMITS for a Heavy Neutral Boson Coupling to e+e-

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not	use the fol	owing data for aver	ages,	fits, lim	its, etc. • • •
none 55-61		²⁰⁴ ODAKA	89	VNS	$\Gamma(X^0 \rightarrow e^+e^-)$
					$B(X^0 \rightarrow \text{hadrons}) \gtrsim 0.2 \text{ MeV}$
>45	95	²⁰⁵ DERRICK	86	HRS	$\Gamma(X^0 \rightarrow e^+e^-)=6 \text{ MeV}$
>46.6	95	²⁰⁶ ADEVA			$\Gamma(X^0 \rightarrow e^+e^-)=10 \text{ keV}$
>48	95	²⁰⁶ ADEVA	85	MRKJ	$\Gamma(X^0 \rightarrow e^+e^-)=4 \text{ MeV}$
		²⁰⁷ BERGER		PLUT	
none 39.8-45.5		²⁰⁸ ADEVA			$\Gamma(X^0 \rightarrow e^+e^-)=10 \text{ keV}$
>47.8	95	²⁰⁸ ADEVA	84	MRKJ	$\Gamma(X^0 \rightarrow e^+e^-)=4 \text{ MeV}$
none 39.8-45.2		²⁰⁸ BEHREND		CELL	
>47	95	²⁰⁸ BEHREND	84C	CELL	$\Gamma(X^0 \rightarrow e^+e^-)=4 \text{ MeV}$

 204 ODAKA 89 looked for a narrow or wide scalar resonance in $e^+\,e^-\,
ightarrow\,$ hadrons at $E_{
m cm}$

= 55.0–60.8 GeV. $_{205\,\mathrm{DERRICK}}$ 86 found no deviation from the Standard Model Bhabha scattering at E_{Cm} = 29 GeV and set limits on the possible scalar boson e^+e^- coupling. See their figure 4 for excluded region in the $\Gamma(X^0 \to e^+e^-)$ - m_{X^0} plane. Electronic chiral invariance requires a parity doublet of X^0 , in which case the limit applies for $\Gamma(X^0 \to e^+e^-) =$

30 MeV. 206 ADEVA 85 first limit is from 2γ , $\mu^+\mu^-$, hadrons assuming X^0 is a scalar. Second limit is from e^+e^- channel. $E_{\rm cm}=40$ –47 GeV. Supersedes ADEVA 84.

²⁰⁷BERGER 85B looked for effect of spin-0 boson exchange in $e^+e^- \rightarrow e^+e^-$ and $\mu^+\mu^$ at $E_{\rm cm}=34.7$ GeV. See Fig. 5 for excluded region in the $m_{\chi^0}-\Gamma(\chi^0)$ plane.

 208 ADEVA 84 and BEHREND 84c have $E_{
m cm}=$ 39.8–45.5 GeV. MARK-J searched X^0 in $e^+e^- \to {\rm hadrons}, 2\gamma, \mu^+\mu^-, e^+e^- {\rm and}$ CELLO in the same channels plus τ pair. No narrow or broad X^0 is found in the energy range. They also searched for the effect of X^0 with $m_X > E_{\rm Cm}$. The second limits are from Bhabha data and for spin-0 singlet. The same limits apply for $\Gamma(X^0 \to e^+e^-) = 2$ MeV if X^0 is a spin-0 doublet. The second limit of BEHREND 84c was read off from their figure 2. The original papers also list limits in other channels.

Search for X^0 Resonance in e^+e^- Collisions

The limit is for $\Gamma(X^0 \to e^+e^-) \cdot B(X^0 \to f)$, where f is the specified final state. Spin 0 is assumed for X^0 .

VALUE (keV)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not	use the followin	g data for averag	ges, fits, limits	, etc. • • •
<10 ³		¹⁰⁹ ABE	93c VNS	Γ(<i>e e</i>)
<(0.4-10)		²¹⁰ ABE	93c VNS	$f = \gamma \gamma$
<(0.3-5)	95 211,2		93D TOPZ	$f = \gamma \gamma$
<(2-12)	95 ^{211,2}		93D TOPZ	f = hadrons
<(4-200)	95 ^{212,2}		93D TOPZ	f = ee
<(0.1-6)	₉₅ 212,2		93D TOPZ	$f = \mu \mu$
<(0.5-8)	90 2	¹⁴ STERNER	93 AMY	$f = \gamma \gamma$
200	0) -

209 Limit is for $\Gamma(X^0 \rightarrow e^+e^-)$ $m_{\chi^0} = 56-63.5$ GeV for $\Gamma(X^0) = 0.5$ GeV.

 210 Limit is for $m_{\chi^0}=56$ –61.5 GeV and is valid for $\Gamma(X^0)\ll 100$ MeV. See their Fig. 5 for limits for $\Gamma=1,2$ GeV.

 211 Limit is for $m_{\chi^0} = 57.2$ -60 GeV.

²¹²Limit is valid for $\Gamma(X^0)\ll 100$ MeV. See paper for limits for $\Gamma=1$ GeV and those for J=2 resonances. 213 Limit is for $m_{\chi^0}=56.6$ -60 GeV.

 214 STERNER 93 limit is for $m_{\chi^0}=$ 57–59.6 GeV and is valid for $\Gamma(X^0){<}100$ MeV. See their Fig. 2 for limits for $\Gamma=1.3$ GeV.

 \bullet $\,\bullet\,$ We do not use the following data for averages, fits, limits, etc. $\,\bullet\,$ $\,\bullet\,$ ²¹⁵ ACTON 93E OPAL $m_{\chi^0} = 60 \pm 1 \text{ GeV}$ < 2.6 95 BUSKULIC 93F ALEP $m_{\chi^0} \sim$ 60 GeV < 2.9 95 215 ACTON 93E limit for a J=2 resonance is 0.8 MeV.

Search for X^0 Resonance in $Z \to f\overline{f}X^0$ The limit is for $B(Z \to f\overline{f}X^0) \cdot B(X^0 \to F)$ where f is a fermion and F is the specified final state. Spin 0 is assumed for X^0 .

specified fillar	i state. Spin t	is assumed for A	•	
VALUE (MeV)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not us	se the followi	ng data for averag	es, fits, limits,	, etc. • • •
$<6.8 \times 10^{-6}$		²¹⁶ ACTON	93E OPAL	$f=e,\mu,\tau; F=\gamma\gamma$
$< 5.5 \times 10^{-6}$		²¹⁶ ACTON	93E OPAL	$f=q$; $F=\gamma\gamma$
$< 3.1 \times 10^{-6}$	95	²¹⁶ ACTON	93E OPAL	$f=\nu$; $F=\gamma\gamma$
$< 6.5 \times 10^{-6}$	95	²¹⁶ ACTON	93E OPAL	$f=e,\mu$; $F=\ell \overline{\ell}, q \overline{q}, \nu \overline{\nu}$
$< 7.1 \times 10^{-6}$		²¹⁶ BUSKULIC	93F ALEP	$f=e,\mu$; $F=\ell \bar{\ell}, q \bar{q}, \nu \bar{\nu}$
		217 ADRIANI	025 13	f-a F-aa

 $^{216}\,\mathrm{Limit}$ is for m_{χ^0} around 60 GeV.

²¹⁷ ADRIANI 92F give σ_Z · B($Z\to q\,\overline{q}\,X^0$) · B($X^0\to \gamma\gamma$)<(0.75–1.5) pb (95%CL) for $m_{X^0}=$ 10–70 GeV. The limit is 1 pb at 60 GeV.

Heavy Particle Production in Quarkonium Decays

Limits are for branching ratios to modes shown.

CL% DOCUMENT ID TECN COMMENT

• • • We do not use th	e follow	ing data for averages	s, fit	s, limits,	etc. • • •
$< 1.5 \times 10^{-5}$	90	²¹⁸ BALEST	95	CLE2	$egin{array}{ccc} \varUpsilon(1S) ightarrow & X^0 \gamma, \ m_{X^0} < 5 \; ext{GeV} \end{array}$
$< 3 \times 10^{-5} - 6 \times 10^{-3}$	90	²¹⁹ BALEST	95	CLE2	$r(1S) \rightarrow X^0 \overline{X}^0 \gamma$, $m_{X^0} < 3.9 \text{ GeV}$
$< 5.6 \times 10^{-5}$	90	220 ANTREASYAN	900	CBAL	$\Upsilon(1S) \rightarrow X^0 \gamma$
		221 ALBRECHT	89	ARG	$m_{X^0} < 7.2 \text{ GeV}$

 218 BALEST 95 two-body limit is for pseudoscalar X^{0} . The limit becomes < 10^{-4} for $m_{\chi^0} < 7.7 \text{ GeV}.$

^h χ_0 \subset 7.1 dev. ²¹⁹ BALEST 95 three-body limit is for phase-space photon energy distribution and angular distribution same as for $\mathcal{T} \to gg\gamma$. ²²⁰ ANTREASYAN 90c assume that X^0 does not decay in the detector. ²²¹ ALBRECHT 89 give limits for B($\mathcal{T}(1S)$, $\mathcal{T}(2S) \to X^0\gamma$)·B($X^0 \to \pi^+\pi^-$, K^+K^- , $p\overline{p}$) for $m_{X^0} < 3.5$ GeV.

REFERENCES FOR Searches for Heavy Bosons Other Than Higgs Bosons

ABACHI	95E	PL B358 405	+Abbott, Abolins, Acharya, Adam, Adams+ (D0 Collab.)
ABACHI	95G	PRL 75 3618	+Abbott, Abolins, Acharya, Adam, Adams+ (D0 Collab.)
ABE	95	PR D51 R949	+Abbott, Abolins, Acharya, Adam, Adams+ +Albrow, Amidei, Antos, Anway-Wiese+ (CDF Collab.)
ABE ABE	95M 95N	PRL 74 2900	+Albrow, Amidei, Antos, Anway-Wiese+ (CDF Collab.)
ABE	95N 95U	PRL 74 3538 PRL 75 1012	+Albrow, Amendolia, Amidei, Ántos+ +Albrow, Amendolia, Amidei, Antos+ (CDF Collab.)
ABREU	95M	ZPHY C65 603	+Adam, Adve. Agasi, Aiinenko+ (DELPHI Collab.)
AID	95	PL B353 578	+Andreev, Andrieu, Appuhn, Arpagaus+ (H1 Collab.)
BALEST	95	PR D51 2053	+Cho, Ford, Johnson+ +Serebrov, Stepanenko+ (CLEO Collab.) (PNPI, KIAE, HARV, NIST)
KUZNETSOV MIZUKOSHI	95 95	PRL 75 794 NP B444 20	+Serebrov, Stepanenko+ +Eboli, Gonzalez-Garcia (PNPI, KIAE, HARV, NIST) (SPAUL, CERN)
NARDI	95	PL B344 225	+Roulet, Tommasini (MICH, CERN)
ABACHI	94B	PRL 72 965	+Abbott, Abolins, Acharya, Adam+ (D0 Collab.)
ABREU	940	ZPHY C64 183	+Adam, Adye, Agasi, Ajinenko, Aleksan+ (DELPHI Collab.)
AHMED	94B 94	ZPHY C64 545 PL B336 100	+Aid, Andreev, Andrieu, Appuhn, Arpagaus+ (H1 Collab.)
BHATTACH Also	94 94B	PL B338 522 (erratum)	Bhattacharyya, Ellis, Sridhar (CERN) Bhattacharyya, Ellis, Sridhar (CERN)
BHATTACH	94B	PL B338 522 (erratum)) Bhattacharyya, Ellis, Sridhar (CERN)
BUSKULIC	94	ZPHY C62 539	+Casper, De Bonis, Decamp, Ghez, Goy+ (ALEPH Collab.)
DAVIDSON	94 94	ZPHY C61 613	+Bailey, Campbell (CFPA, TNTO, ALBE)
KUZNETSOV KUZNETSOV	94 94B	PL B329 295 JETPL 60 315	+Mikheev (YARO) +Serebrov, Stepanenko+ (PNPI, KIAE, HARV, NIST)
		JETPL 60 315 Translated from ZETFP	60 311.
LEURER	94	PR D50 536	(REHO)
LEURER	94B	PR D49 333	(REHO)
Also MAHANTA	93 94	PRL 71 1324 PL B337 128	Leurer (REHO) (MEHTA)
SEVERIJNS	94	PRL 73 611 (erratum)	+ (LOUV, WISC, LEUV, ETH, MASA)
VILAIN	94B	PL B332 465	+Wilquet, Beyer, Flegel, Grote+ (CHARM II Collab.)
ABE	93C	PL B302 119	+Amako, Arai, Arima, Asano, Chiba+ (VENUS Collab.)
ABE	93D	PL B304 373	+Adachi, Awa, Aoki, Belusevic, Emi+ (TOPAZ Collab.)
ABE ABE	93G	PRL 71 2542	+Albrow, Akimoto, Amidei, Anway-Wiese+ (CDF Collab.)
ABREU	93J	PR D48 R3939 PL B316 620	+Albrow, Amidei, Anway-Wiese, Apollinari+ (CDF Collab.) +Adam, Adye, Agasi, Aleksan, Alekseev+ (DELPHI Collab.)
ABT	93	NP B396 3	+Andreev, Andrieu, Appuhn, Arpagaus+ (H1 Collab.)
ACTON	93E	PL B311 391	+Akers, Alexander+ (OPAL Collab.)
ADRIANI	93D	PL B306 187	+Aguilar-Benitez, Ahlen, Alcaraz, Aloisio+ +Aguilar-Benitez, Ahlen, Alcaraz, Aloisio+ (L3 Collab.)
ADRIANI	93M 93	PRPL 236 1	+Aguilar-Benitez, Ahlen, Alcaraz, Aloisio+ (L3 Collab.)
ALITTI ALLEN	93	NP B400 3 PR D47 11	+Ambrosini, Ansari, Autiero, Bareyre+ (UA2 Collab.) +Chen, Doe, Hausammann+ (UCI, LANL, ANL, UMD)
ALTARELLI	93B	PL B318 139	+Casalbuoni+ (CERN, FIRZ, GEVA, PADO)
BHATTACH	93	PR D47 R3693	Bhattacharyya+ (CALC, JADA, ICTP, AHMED, BOSE)
BUSKULIC	93F	PL B308 425	+De Bonis, Decamp, Chez, Gov, Lees+ (ALEPH Collab.)
DERRICK	93	PL B306 173	+Krakauer, Magill, Musgrave, Repond+ (ZEUS Collab.)
RIZZO SEVERIJNS	93 93	PR D48 4470	(ANL) +Gimeno-Nogues+ (LOUV, WISC, LEUV, ETH, MASA)
Also	94	PRL 70 4047 PRL 73 611 (erratum)	+Gimeno-Nogues+ (LOUV, WISC, LEUV, ETH, MASA) Severijns+ (LOUV, WISC, LEUV, ETH, MASA)
STERNER	93	PL B303 385	+Abashian, Gotow, Haim, Mattson, Morgan+(AMY Collab.)
ABE	92B	PRL 68 1463	+Amidei, Apollinari, Atac, Auchincloss+ (CDF Collab.)
ABREU	92D	ZPHY C53 555	+Adam, Adami, Adye, Akesson, Alekseev+(DELPHI Collab.)
ABREU ADRIANI	92F 92F	PL B275 222 PL B292 472	+Adam, Adami, Adye, Akesson, Alekseev+(DELPHI Collab.) +Aguilar-Benitez, Ahlen, Akbari, Alcarez+ (L3 Collab.)
ALITTI	92E	PL B274 507	+Ambrosini, Ansari, Autiero, Bareyre+ (UA2 Collab.)
DECAMP	92	PRPL 216 253	+Deschizeaux Gov Lees Minard+ (ALEPH Collab.)
DELAGUILA	92	NP B372 3	del Aguila+ (CERN, GRAN, MPIM, BRUXT, MADE)
Also IMAZATO	91C 92	NP B361 45 PRL 69 877	del Aguila, Moreno, Quiros (BARC, MADE) +Kawashima, Tanaka+ (KEK, INUS, TOKY, TOKMS)
LANGACKER	92B	PR D45 278	+Luo (PENN)
LAYSSAC	92	ZPHY C53 97	+Renard, Verzegnassi (MONP, LAPP)
LAYSSAC	92B	PL B287 267	+Renard, Verzegnassi (MONP, TRSTT)
LEIKE	92	PL B291 187	+Riemann, Riemann (BERL, CERN)
LEP MISHRA	92 92	PL B276 247 PRL 68 3499	+ALEPH, DELPHI, L3, OPAL (LEP Collabs.) +Leung, Arroyo+ (COLU, CHIC, FNAL, ROCH, WISC)
POLAK	92	PL B276 492	+Leung, Arroyo+ (COLU, CHIC, FNAL, ROCH, WISC) +Zralek (SILES)
POLAK	92B	PR D46 3871	+Zralek (SILES)
RENTON	92	ZPHY C56 355	(OXF)
ABE	91D	PRL 67 2418	+Amidei, Apollinari, Atac, Auchincloss+ (CDF Collab.)
ABE ACTON	91F 91	PRL 67 2609 PL B268 122	+Amidei, Apollinari, Atac, Auchincloss+ +Alexander, Allison, Allport+ (CDF Collab.)
ACTON	91B	PL B273 338	+Alexander, Allison, Allport, Anderson+ (OPAL Collab.)
ADEVA	91B	PL B261 169	+Adriani, Aguilar-Benitez, Akbari, Alcaraz+ (L3 Collab.)
ADEVA	91D	PL B262 155	+Adriani, Aguilar-Benitez, Akbari, Alcaraz+ (L3 Collab.)
ALEXANDER	91 91	PL B263 123 ZPHY C49 17	+Allison, Aliport, Anderson, Arcelli+ +Ansari, Ansorge, Autiero, Bareyre+ (UA2 Collab.)
ALITTI ALTARELLI	91	PL B261 146	+Ansari, Ansorge, Autiero, Bareyre+ +Casalbuoni, De Curtis+ (CERN, FIRZ, GEVA)
ALTARELLI	91B	PL B263 459	+Casalbuoni, De Curtis+ (CERN, FIRZ, GEVA)
Also	90	PL B245 669	Altarelli, Casalbuoni, Feruglio, Gatto(CERN, LECE, GEVA)
AQUINO	91	PL B261 280	+Fernandez, Garcia (CINV, PUEB)
BUCHMUEL COLANGELO	91 91	PL B267 395 PL B253 154	Buchmueller, Greub, Minkowski (DESY, BERN) +Nardulli (BARI)
CUYPERS	91	PL B259 173	+Falk, Frampton (DURH, HARV, UNCCH)
DELAGUILA	91	PL B254 497	del Aguila, Moreno, Quiros (BARC, MADE, CERN)
FARAGGI	91	MPL A6 61	+Nanopoulos (TAMU)
GEIREGAT	91	PL B259 499	+Vilain, Wilquet, Binder, Burkard+ (CHARM II Collab.)
GONZALEZ-G Also	90C	PL B259 365 NP B345 312	Gonzalez-Garcia, Valle (VALE) Gonzalez-Garcia, Valle (VALE)
MAHANTHAP.	91	PR D43 3093	Mahanthappa, Mohapatra (COLO)
Also	91B	PR D44 1616 erratum	Mahanthappa, Mohapatra (COLO)

Heavy Bosons Other than Higgs Bosons, Axions (A^0) and Other Very Light Bosons

	91	NP B363 385	+Zralek (SILES)
	91	PR D44 202	(WISC, ISU)
	91	APJ 376 51	+Steigman, Schramm, Olive+ (HSCA, OSU, CHIC, MINN)
	90F	PL B246 297	+Amako, Arai, Asano, Chiba+ (VENUS Collab.)
	90G	PRL 65 2243	+Amidei, Apollinari, Atac+ (CDF Collab.)
	90H	PR D41 1722	+Amidei, Apollinari, Ascoli, Atac+ (CDF Collab.)
	90 J	PL B246 285	+Alexander, Allison, Allport, Anderson+ (OPAL Collab.)
ALLEN	90	PRL 64 1330	+Chen, Doe+ (UCI, LASL, UMD)
ANTREASYAN	90C	PL B251 204	+Bartels, Besset, Bieler, Bienlein+ (Crystal Ball Collab.)
BARGER	90B	PR D42 152	+Hewett, Rizzo (WISC, ISU)
GLASHOW	90	PR D42 3224	+Sarid (HARV)
GLASHOW	90B	PRL 64 725	+Sarid (HARV)
GONZALEZ-G	90D	PL B240 163	Gonzalez-Garcia, Valle (VALE)
GRIFOLS	90	NP B331 244	+Masso (BARC)
GRIFOLS	90C	MPL A5 2657	(BARC)
GRIFOLS	90D	PR D42 3293	+Masso, Rizzo (BARC, CERN, WISC, ISU)
HAGIWARA	90	PR D41 815	+Najima, Sakuda, Terunuma (KEK, DURH, YCC, HIRO)
HE	90B	PL B240 441	+ Joshi, Volkas (MELB)
	90C	PL B244 580 erratum	He, Joshi, Volkas (MELB)
KIM	90	PL B240 243	+Breedon, Ko, Lander, Maeshima, Malchow+(AMY Collab.)
	90	PL B241 392	+Nanopoulos (TAMU)
ALBAJAR	89	ZPHY C44 15	+Albrow, Allkofer, Arnison, Astbury+ (UA1 Collab.)
ALBRECHT	89	ZPHY C42 349	+Boeckmann, Glaeser, Harder+ (ARGUS Collab.)
	89B	PR D39 1229	+Mohapatra (PISA, UMD)
	89	PR D40 2481	del Aguila, Moreno, Quiros (BARC, MADE)
Also	90B	PR D41 134	del Aguila, Moreno, Quiros (BARC, MADE)
	90C	PR D42 262 erratum	del Aguila, Moreno, Quiros (BARC, MADE)
	89	ZPHY C41 567	Dorenbosch, Udo, Allaby, Amaldi+ (CHARM Collab.)
GEIREGAT	89	PL B232 539	+Vilain, Wilquet, Bergsma, Binder+ (CHARM II Collab.)
LANGACKER	89B	PR D40 1569	+Uma Sankar (PENN)
	89	JPSJ 58 3037	+Kondo, Abe, Amako+ (VENUS Collab.)
ROBINETT	89	PR D39 834	(PSU)
ALBAJAR	88B	PL B209 127	+Albrow, Alikofer, Astbury, Aubert+ (UA1 Collab.)
	88	PR D37 1188	+Schmidt, King (HARV, BOST)
	88	PR D37 587	+Gidal, Jodidio+ (LBL, UCB, COLO, NWES, TRIU)
	88	PL B212 386	(STOH)
	88	NP B297 244	+Ellis, Fogli+ (PADO, CERN, BARI, WISC, LBL)
CUYPERS	88	PRL 60 1237	+Frampton (UNCCH)
CUYPERS DONCHESKI	88 88	PRL 60 1237 PL B206 137	+Frampton (UNCCH) +Grotch, Robinett (PSU)
CUYPERS DONCHESKI DONCHESKI	88 88 88B	PRL 60 1237 PL B206 137 PR D38 412	+Frampton (UNCCH) +Grotch, Robinett (PSU) +Grotch, Robinett (PSU)
CUYPERS DONCHESKI DONCHESKI ELLIS	88 88 88B 88	PRL 60 1237 PL B206 137 PR D38 412 PL B202 417	+Frampton (UNCCH) +Grotch, Robinett (PSU) +Grotch, Robinett (PSU) Ellis, Franzini, Zwirner (CERN, UCB, LBL)
CUYPERS DONCHESKI DONCHESKI ELLIS RAFFELT	88 88 88B 88	PRL 60 1237 PL B206 137 PR D38 412 PL B202 417 PRL 60 1793	+ Frampton (UNCCH) + Grotch, Robinett (PSU) + Grotch, Robinett (PSU) Ellis, Franzini, Zwirner (CERN, UCB, LBL) + Seckel (UCB, LLL, UCSC)
CUYPERS DONCHESKI DONCHESKI ELLIS RAFFELT AMALDI	88 88 88B 88 88	PRL 60 1237 PL B206 137 PR D38 412 PL B202 417 PRL 60 1793 PR D36 1385	+Frampton (UNCCH) +Grotch, Robinett (PSU) +Grotch, Robinett (PSU) +Grotch, Robinett (PSU) -Ellis, Franzini, Zwirner (CERN, UGB, LBL) +Seckel (UCB, LLL, UCSU) +Bohm, Durkin, Langacker+ (CERN, AACH3, OSU+)
CUYPERS DONCHESKI DONCHESKI ELLIS RAFFELT AMALDI ANSARI	88 88 88B 88 88 87 87D	PRL 60 1237 PL B206 137 PR D38 412 PL B202 417 PRL 60 1793 PR D36 1385 PL B195 613	+Frampton (UNCCH) +Grotch, Robinett (PSU) +Grotch, Robinett (PSU) +Grotch, Robinett (PSU) +Bohm, Durkin, Langacker+ (CERN, UCB, LBL, UCSC) +Bohm, Durkin, Langacker+ (URZ, Ollab.) +Bagnaia, Banner+ (UAZ Collab.)
CUYPERS DONCHESKI DONCHESKI ELLIS RAFFELT AMALDI ANSARI BARTEL	88 88 88 88 88 87 87 87 87 87 87 87 87 8	PRL 60 1237 PL B206 137 PR D38 412 PL B202 417 PRL 60 1793 PR D36 1385 PL B195 613 ZPHY C36 15	+Frampton (UNCCH) +Grotch, Robinett (PSU) +Grotch, Robinett (PSU) +Grotch, Robinett (PSU) Ellis, Franzini, Zwirner (CERN, U.G., LBL) +Seckel (UCB, LLL, UCSC) +Bohm, Durkin, Langacker+ (ERN, AACH3, OSU+) +Bagnaia, Banner+ (UAZ Collab.) +Becker, Felst+ (JADE Collab.)
CUYPERS DONCHESKI DONCHESKI ELLIS RAFFELT AMALDI ANSARI BARTEL MARCIANO	88 88 88 88 88 87 87 87 87 87 87	PRL 60 1237 PL B206 137 PR D38 412 PL B202 417 PRL 60 1793 PR D36 1385 PL B195 613 ZPHY C36 15 PR D35 1672	+ Frampton (UNCCH) + Grotch, Robinett (PSU) + Grotch, Robinett (PSU) Ellis, Franzini, Zwirner (CERN, UCB, LBL) + Seckel (UCB, LLL, UCSC) + Bagnaia, Banner+ (UAZ Collab.) + Becker, Felst+ (JADE Collab.) + Sirlin (BNL, NYU)
CUYPERS DONCHESKI DONCHESKI ELLIS RAFFELT AMALDI ANSARI BARTEL MARCIANO ARNISON	88 88 88 88 88 87 87D 87B 87 86B	PRL 60 1237 PL B206 137 PR D38 412 PL B202 417 PRL 60 1793 PR D36 1385 PL B195 613 ZPHY C36 15 PR D35 1672 EPL 1 327	+Frampton (UNCCH) +Grotch, Robinett (PSU) +Grotch, Robinett (PSU) -Grotch, Robinett (PSU) -GERN, UCB, LLL, UCSC) -(UCB, LLL, UCSC) -(UCB, LLL, UCSC) -(UCB, LLL, UCSC) -(CERN, ACH3, OSU+ -(CERN, UCB, LLL, UCSC) -(CERN, UCSC) -(CER
CUYPERS DONCHESKI DONCHESKI ELLIS RAFFELT AMALDI ANSARI BARTEL MARCIANO ARNISON BARGER	88 88 88 88 88 87 87D 87B 87 86B 86B	PRL 60 1237 PL B206 137 PR D38 412 PL B202 417 PRL 60 1793 PR D36 1385 PL B195 613 ZPHY C36 15 PR D35 1672 EPL 1 327 PRL 56 30	+ Frampton (UNCCH) - Grotch, Robinett (PSU) - Grotch, Robinett (PSU) - Ellis, Franzini, Zwirner (CERN, UCB, LBL) + Seckel (UCB, LLL, UCSC) + Babm, Durkin, Langacker+ (URZ, Collab) + Bagnaia, Banner+ (UAZ Collab) + Sirlin (BNL, NYU) + Albrow, Allkofer+ (UAL Collab) - Deshpande, Whisnant (WISC, OREG, FSU)
CUYPERS DONCHESKI DONCHESKI ELLIS RAFFELT AMALDI ANSARI BARTEL MARCIANO ARNISON BARGER BEHREND	88 88 88 88 88 87 87D 87B 87B 86B 86B 86B	PRL 60 1237 PL B206 137 PR D38 412 PL B202 417 PRL 60 1793 PR D36 1385 PL B195 613 ZPHY C36 15 PR D35 1672 EPL 1 327 PRL 56 30 PL B198 452	+Frampton (UNCCH) +Grotch, Robinett (PSU) +Grotch, Robinett (PSU) -Ellis, Franzini, Zwirner (CERN, UCB, LBL) +Seckel +Bohm, Durkin, Langacker+ (UCB, LLL, UCSU) +Bagnaia, Banner+ (UCR, AACH3, OSU+) +Becker, Felst + (JADE Collab.) +Sirlin +Albrow, Allkofer+ +Deshpande, Whisnant +Deshpande, Whisnant +Buerger, Criegee, Fenner, Field+ (CELLO Collab.)
CUYPERS DONCHESKI DONCHESKI ELLIS RAFFELT AMALDI ANSARI BARTEL MARCIANO ARNISON BARGER BEHREND DERRICK	88 88 88 88 88 87 87D 87B 87 86B 86B 86B 86B	PRL 60 1237 PL B206 137 PR D38 412 PL B202 417 PRL 60 1793 PR D36 1385 PL B195 613 ZPHY C36 15 PR D35 1672 EPL 1 327 PRL 56 30 PL B178 452 PL 166B 463	+ Frampton (UNCCH) - Grotch, Robinett (PSU) - Grotch, Robinett (PSU) - Bills, Franzini, Zwirner (CERN, UGB, LBL) - Seckel - Bohm, Durkin, Langacker+ (UCB, LLL, UCSC) - Bagnaia, Banner+ (UAZ Collab.) - Becker, Felst+ (JADE Collab.) - Firlin (BNL, NY) - Alibrow, Allkofer+ (UMZ Collab.) - Deshpande, Whisnant - Buerger, Criegee, Fenner, Field+ (CELL Collab.) - Gan, Kooijinan, Loos+ (HRS Collab.)
CUYPERS DONCHESKI DONCHESKI ELLIS RAFFELT AMALDI ANSARI BARTEL MARCIANO ARNISON BARGER BEHREND DERRICK Also	88 88 88 88 88 87 87D 87B 87 86B 86B 86B 86B	PRL 60 1237 PL B206 137 PR D38 412 PL B202 417 PRL 60 1793 PR D36 1385 PL B195 613 ZPHY C36 15 PR D35 1672 EPL 1 327 PRL 56 30 PL B178 452 PL B178 452	+Frampton (UNCCH) +Grotch, Robinett (PSU) +Grotch, Robinett (PSU) -Grotch, Rob
CÜYPERS DONCHESKI DONCHESKI ELLIS RAFFELT AMALDI ANSARI BARTEL MARCIANO ARNISON BARGER BEHREND DERRICK AISO DURKIN	88 88 88 88 88 87 87D 87B 87 86B 86B 86B 86B 86B	PRI. 60 1237 PL 18206 137 PR D38 412 PL 8202 417 PRI. 60 1793 PR D36 1385 PL 8195 613 ZPHY C36 15 PR D35 1672 EPL 1 327 PRI. 56 30 PL 18178 452 PL 1668 463 PR D34 3286 PR D34 3286 PR D34 3286	+ Frampton (UNCCH) - Grotch, Robinett (PSU) - Grotch, Robinett (PSU) - Bills, Franzini, Zwirner (CERN, UGB, LBL) - Seckel - Bohm, Durkin, Langacker+ (CERN, AACH3, OSCH) - Bespanaia, Banner+ (UA2 Collab.) - Becker, Felst+ (JADE Collab.) - Sirlin (BNL, NYU) - Albrow, Allkofer+ (WISC, OREG, FSU) - Buerger, Criegee, Fenner, Field+ (CELL) Collab.) - Derrick, Gan, Kooijman, Loos, Musgrave+ (HRS Collab.) - Derrick, Gan, Kooijman, Loos, Musgrave+ (FENN) - (FENN)
CÜYPERS DONCHESKI DONCHESKI ELLIS RAFFELT AMALDI ANSARI BARTEL MARCIANO ARNISON BARGER BEHREND DERRICK AISO DURKIN ELLIS	88 88 88 88 88 87 87D 87B 87 86B 86B 86B 86B 86B 86B 86B	PRI. 60 1237 PL B306 137 PR D38 412 PL B302 417 PRI. 60 1793 PR D36 1385 PL B195 613 ZPHY C36 15 PR D35 1672 EPI. 1 377 PRI. 66 30 PL B178 452 PL B168 463 PL B168 463 PL B168 465 PL 1668 465 PL 1668 465	+Frampton (UNCCH) +Grotch, Robinett (PSU) +Grotch, Robinett (PSU) +Grotch, Robinett (PSU) -Ellis, Franzini, Zwirner (CERN, UCB, LLB, USC) +Bohm, Durkin, Langacker+ (UCB, LLL, UCSC) +Bagnaia, Banner+ (CERN, ACH3, OSU+) +Bagraia, Banner+ (CERN, ACH3, OSU+) +Albrow, Allkofer+ (BNL, NYU) +Albrow, Allkofer+ (WISC, OREG, FSU) +Desprace, Criegee, Fenner, Field+ +Gan, Kooijman, Loos + URSC, OREG, FSU) -Derrick, Gan, Kooijman, Loos, Musgrave+ (HRS Collab, Langacker (PENN) +Engvist, Nanopoulos, Sarkar (CERN, OXFTP)
CUYPERS DONCHESKI DONCHESKI ELLIS RAFFELT AMALDI ANSARI BARTEL MARCIANO ARNISON BARGER BEHREND DERRICK Also DURKIN ELLIS JODIDIO	88 88 88 88 88 87 87D 87B 87 86B 86B 86B 86B 86B 86B 86B 86B	PRI. 60 1237 PL 18206 137 PR D38 412 PL 8202 417 PRI. 60 1793 PR D36 1385 PL 8195 613 ZPHY C36 15 PR D35 1672 EPL 1 327 PRI. 56 30 PL 18178 452 PL 1668 463 PR D34 3286 PR D34 3286 PR D36 436 PL 1678 457 PL 1678 457	+ Frampton (UNCCH) - Grotch, Robinett (PSU) - Grotch, Robinett (PSU) - Bills, Franzini, Zwirner (CERN, UGB, LUL, UCSL) - Bohm, Durkin, Langacker+ (CERN, AACH3, OSL) - Becker, Felst+ (JADE Collab.) - Hecker, Felst+ (UA2 Collab.) - Herwick, Gan, Koojiman, Loost, Herwick, Gen, Koojiman, Loost, Herwick, Gan, Koojiman, Loost, Herwick, Gan, Koojiman, Loost, Musgrave+ (HRS Collab.) - Derrick, Gan, Koojiman, Loos, Musgrave+ (HRS Collab.) - Langacker - Langacker - Henwist, Nanopoulos, Sarkar - Halle, Carr, Gidal, Shinsky+ (BL, NWES, TRIU)
CUYPERS DONCHESKI DONCHESKI DONCHESKI ELIS RAFFELT AMALDI ANSARI BARTEL MARCIANO ARNISON BARGER BEHREND DERRICK AISO DURKIN ELLIS JODIDIOI Also	88 88 88 88 88 87 87D 87B 87B 86B 86B 86B 86B 86B 86B 86B 86B 86B 86	PRI. 60 1237 PL 8206 137 PR D38 412 PL 8202 417 PRI. 60 1793 PR D36 1385 PL 8195 613 ZPHY C36 15 PR D35 1672 EPI 1 377 PRI. 56 30 PL 8198 452 PL 1658 453 PL 1658 454 PL 1658 435 PL 1678 457 PR D34 1967 PR D34 1967 PR D37 237 erratum	+Frampton (UNCCH) +Grotch, Robinett (PSU) +Grotch, Robinett (PSU) +Grotch, Robinett (PSU) -Ellis, Franzini, Zwirner (CERN, UCB, LLL, UCSC) +Badma, Durkin, Langacker+ (UCB, LLL, UCSC) +Badgnaia, Banner+ (CERN, ACH3, OSC) +Becker, Felst+ (JADE Collab, +Sirlin (BNL, NYU) +Albrow, Allkofer+ (WISC, OREG, FSU) -Derrick, Gan, Kooijman, Loos, Hospacker (PENN) -Langacker (HRS Collab, +Langacker) -Enqvist, Nanopoulos, Sarkar +Balke, Carr, Gidal, Shinsky+ - Boddio, Balke, Carr+ (BL, NWES, TRIU)
CÜYPERS DONCHESKI DONCHESKI DONCHESKI DONCHESKI ELLIS RAFFELT AMALDI AMALDI AMARCIANO ARNISON BARGER BEHREND DERRICK AISO DURKIN ELLIS JODIDIO AISO MOHAPATRA	88 88 88 88 88 87 87D 87B 87 86B 86B 86B 86B 86B 86B 86B 86B 86B 86B	PRI. 60 1237 PL 18206 137 PR D38 412 PL 18206 147 PRI. 60 1793 PR D38 1385 PL 18195 613 PR D35 1672 EPL 1 327 PRI. 56 30 PRI. 56 30 PL 18178 452 PL 1658 463 PR D34 3286 PL 1678 457 PR D34 3787	+Frampton (UNCCH) +Grotch, Robinett (PSU) +Grotch, Robinett (PSU) +Grotch, Robinett (PSU) -Ellis, Franzini, Zwirner (CERN, UGB, LBL) +Seckel (UCB, LLL, UCSC) +Bagnaia, Banner+ (CERN, AGACH3, OSL) +Becker, Felst+ (JACE Collab, +Striin) +Bristin (BNL, NYU) +Albrow, Allkofer+ (WISC, OREG, FSL) + Buerger, Criegee, Fenner, Field + (CELU Collab, +Gan, Kooijman, Loos, +Gan, Kooijman, Loos, +Gan, Kooijman, Loos, +Gan, Kooijman, Loos, +Gan, Kooijman, Loosh -Derrick, Gan, Kooijman, Loos, Musgrave+ (HRS Collab, -Derrick, Gan, Kooijman, Loosh -Langacker -Enqvist, Nanopoulos, Sarkar +Balke, Carr, Gidal, Shinsky+ (CERN, OXFTP) -Balke, Carr, Gidal, Shinsky+ (BL, NWES, TRIU) -Jodidio, Balke, Carr+
CÜYPERS DONCHESKI DONCHESKI DONCHESKI DONCHESKI ELLIS RAFFELT AMALDI ANSARI BARTEL MARCIANO ARNISON BARGER BEHREND DERRICK AISO DURKIN ELLIS JODIDIO AISO MOHAPATRA STEIGMAN	88 88 88 88 88 87 87D 87B 87B 86B 86B 86B 86B 86B 86B 86B 86B 86B 86	PRI. 60 1237 PL B206 137 PR D38 412 PL B202 417 PRI. 60 1793 PR D36 1385 PL B195 613 ZPHY C36 15 PR D35 1672 EPL 1 377 PRI. 56 30 PL B178 452 PL 1658 453 PL 1658 454 PL 1658 435 PL 1678 457 PR D34 1967 PR D34 1967 PR D37 237 erratum PR D34 909 PL B178 33 34 909	+Frampton (UNCCH) +Grotch, Robinett (PSU) +Grotch, Robinett (PSU) +Grotch, Robinett (PSU) -Ellis, Franzini, Zwirner (CERN, UCB, LLL, UCSC) +Bahm, Durkin, Langacker+ (CERN, UCB, LLL, UCSC) +Bagnaia, Banner+ (CERN, ACH3, OSC) +Becker, Felst+ (JADE Collab, 1-Sirlin (BNL, NYU) +Albrow, Allkofer+ (WISC, OREG, FSU) -Buerger, Criegee, Fenner, Field+ +Gan, Kooijman, Loos+ (Musgrave+ (HRS Collab, 1-Langacker) -Enqvist, Nanopoulos, Sarkar +Balke, Carr, Gidal, Shinsky+ Joddich, Balke, Carr+ (LBL, NWES, TRIU) +Olive, Schramm, Turner (BART, MIMN) +Olive, Schramm, Turner (BART, MIMN)
CUYPERS DONCHESKI DONCHESKI DONCHESKI DONCHESKI ELLIS RAFFELT AMALDI AMALDI AMARCIANO ARNISON BARGER BEHREND DERRICK AISO DURKIN ELLIS JODIDIO AISO MOHAPATRA STEIGMAN ADEVA	88 88 88 88 88 87 87D 87B 87 86B 86B 86B 86B 86B 86B 86B 86B 86B 86B	PRI. 60 1237 PL 18206 137 PR D38 412 PL 18202 417 PRI. 60 1793 PR D38 1325 PR D38 1385 PL 1919 613 PPI C36 15 PR D35 1672 EPI 1 327 PPI 156 463 PR D34 3286 PR D34 1967 PR D37 237 erratum PR D34 999 PL 1816 33 PL 1528 439	+Frampton (UNCCH) +Grotch, Robinett (PSU) +Grotch, Robinett (PSU) +Grotch, Robinett (PSU) -Ellis, Franzini, Zwirner (CERN, UGB, LBL) +Seckel +Bahm, Durkin, Langacker+ (UAZ Collab, +Backer, Felst+ (JADE Collab, +Sirlin (BNL, NYU) +Albrow, Allkofer+ (MISC, OREG, FSU) +Burger, Criegee, Fenner, Field+ (WISC, OREG, FSU) +Burger, Criegee, Fenner, Field+ (HRS Collab, Derrick, Gan, Kooijman, Loos, Musgrave+ (HRS Collab, Derrick, Gan, Kooijman, Loos, Musgrave+ (HRS Collab, Langacker (ERN) +Balke, Carr, Gidal, Shinsky+ Jodidio, Balke, Carr+ (LBL, NWES, TRIU) +Olive, Schramm, Turner (BART, MINN+) +Becker, Becker-Szendy+ (Marx-J Collab, Marx-J Collab, Mar
CÜYPERS DONCHESKI DONCHESKI DONCHESKI DONCHESKI ELLIS RAFFELT AMALDI ANSARI BARTEL MARCIANO ARNISON BARGER BEHREND DERRICK AISO DURKIN ELLIS JODIDIO AISO MOHAPATRA STEIGMAN ADEVA ADEVA	88 88 88 88 88 87 87D 87B 86B 86B 86B 86B 86B 86B 86B 86B 86B 86	PRI. 60 1237 PL B206 137 PR D38 412 PL B202 417 PRI. 60 1793 PR D36 1385 PL B195 613 ZPHY C36 15 PR D35 1672 EPL 1 377 PRI. 56 30 PL B178 452 PL 1658 453 PL 1658 457 PR D34 1367 PR D34 1376 PR D34 1377 PRI. 52 8439 PR D37 237 erratum PR D34 909 PR D37 237 erratum PR D38 909 PRI. 1578 433 PL 1528 439 PRI. 1528 439 PRI. 1528 439 PRI. 1528 439	+Frampton (UNCCH) -Forotch, Robinett (PSU) -Fo
CUYPERS DONCHESKI DONCHESKI DONCHESKI DONCHESKI ELLIS RAFFELT AMALDI ANSARI BARTEL MARCIANO ARNISON BARGER BEHREND DERRICK AISO DURKIN ELIS JODIDIO AISO MOHAPATRA STEIGMAN ADEVA BERGER	88 88 88 88 87 87D 87B 86B 86B 86B 86B 86B 86B 86B 86B 86B 86	PRI. 60 1237 PL B206 137 PR D38 412 PL B202 417 PRI. 60 1793 PR D38 1385 PL B195 613 ZPHY C36 15 PR D35 1672 EPRI. 56 30 PL B197 452 PRI. 56 30 PL B168 453 PR D34 3286 PL 1678 457 PRI. 56 37 PR D34 737 PR D35 499 PR D35 499 PL B176 33 PR D35 499 PR D35 665 ZPHY C27 341	+Frampton (UNCCH) +Grotch, Robinett (PSU) +Grotch, Robinett (PSU) +Grotch, Robinett (PSU) -Ellis, Franzini, Zwirner (CERN, LGB, LBL, UCB, LLL, UCSC) +Bahm, Durkin, Langacker+ (UA2 Collab, LSC) +Backer, Felst+ (JADE Collab, LSF) +Sirlin (BNL, NYU) +Albrow, Allkofler+ (UA1 Collab, LSF) +Albrow, Allkofler+ (WISC, OREG, FSU) +Barger, Criegee, Fenner, Field+ (WISC, OREG, FSU) +Barger, Criegee, Fenner, Field+ (HRS Collab, LST) -Derirck, Gan, Kooljman, Loos, Musgrave+ (HRS Collab, LST) -Langacker (HRS Collab, LST) -Langacker (HRS Collab, LST) -Langacker (LBC, NSF) -LANGAC (LBC, NSF) -L
CÜYPERS DONCHESKI DONCHESKI DONCHESKI DONCHESKI ELLIS RAFFELT AMALDI ANSARI BARTEL MARCIANO ARNISON BARGER BEHREND DERRICK AISO DURKIN ELLIS JODIDIO AISO MOHAPATRA STEIGMAN ADEVA ADEVA BERGER STOKER	88 88 88 88 87 87D 87B 86B 86B 86B 86B 86B 86B 86B 86B 86B 86	PRI. 60 1237 PL B206 137 PR D38 412 PL B202 417 PRI. 60 1793 PR D38 1385 PL B195 613 ZPHY C36 15 PR D35 1672 EPL 1 377 PRI. 56 30 PL B178 452 PL 1658 453 PL 1658 453 PL 1658 453 PL 1528 439 PR D34 3286 PL 1658 453 PR D35 4967 PR D37 237 erratum PR D34 909 PR D37 237 erratum PR D38 4909 PR D37 256 665 ZPHY C27 341	+Frampton (UNCCH) +Grotch, Robinett (PSU) +Grotch, Robinett (PSU) +Grotch, Robinett (PSU) +Grotch, Robinett (PSU) +Bills, Franzini, Zwirner (CERN, UCB, LLL, UCSU) +Badma, Durkin, Langacker+ (UCB, LLL, UCSU) +Bagnaia, Banner+ (CERN, ACH3, OSU+) +Bagraia, Banner+ (CERN, ACH3, OSU+) +Albrow, Allkofer+ (BML, NYU) +Albrow, Allkofer+ (WISC, OREG, FSU) +Deurick, Gan, Kooijman, Loos, Musgrave+ (HRS Collab, Derrick, Gan, Kooijman, Loos, Musgrave+ (HRS Collab, Langacker (PENN) +Balke, Carr, Gidal, Shinsky+ (Ddilbe, Schramm, Turner (UMD) +Deuter, Genzel, Lackas, Pielorz+ (Balke, Carr, Gidal+) -Deuter, Gidal+ (PLUT) Collab, (PLUT) Collab
CUYPERS DONCHESKI DONCHESKI DONCHESKI DONCHESKI ELLIS RAFFELT AMALDI ANSARI BARTEL MARCIANO ARNISON BARGER BEHREND DERRICK AISO DURKIN ELIS JODIDIO AISO MOHSPATRA STEIGMAN ADEVA ADEVA ADEVA BERGER STOKER ADOVA	88 88 88 88 87 87D 87B 86B 86B 86B 86B 86B 86B 86B 86B 86B 86	PRI. 60 1237 PL B206 137 PR D38 412 PL B202 417 PRI. 60 1793 PR D38 1385 PL B195 613 ZPHY C36 15 PR D35 1672 EPL 1 327 PRI. 56 30 PL B178 452 PL 1668 463 PR D34 5286 PL 1678 457 PR D37 237 PRI. 56 30 PL 1678 457 PR D37 237 PRI. 58 30 PL 1678 457 PR D37 237 PRI. 58 30 PL 1678 457 PR D37 237 PRI. 58 30 PL 1678 457 PR D37 237 PR D34 999 PL B176 33 PR D34 999 PL B176 33 PRI. 55 665 ZPHY C27 341 PRI. 54 1887 PRI. 53 134	+Frampton (UNCCH) -Forotch, Robinett (PSU) -Forotch, Gan, July -Forotch, Gan, Kooljman, Loos, Musgravet (HRS Collab.) -Forotch, Gan, Man, Musgravet (HRS Collab.) -For
CUYPERS DONCHESKI DONCHESKI DONCHESKI DONCHESKI ELLIS RAFFELT AMALDI ANSARI BARTEL MARCIANO ARNISON BARGER BEHREND DERRICK AISO DURKIN ELLIS JODIDIO AISO MOHAPATRA STEIGMAN ADEVA ADEVA BERGER STOKER ADEVA BERGER STOKER ADEVA BEHREND	88 88 88 88 87 87D 87B 86B 86B 86B 86B 86B 86B 86B 86B 86B 86	PRI. 60 1237 PL 8206 137 PR D38 412 PL 8202 417 PRI. 60 1793 PR D38 1385 PL 8195 613 ZPHY C36 15 PR D35 1672 EPL 1 377 PRI. 56 30 PL 8198 452 PL 1678 452 PL 1668 463 PL 1668 436 PL 1628 437 PR D34 327 PR D37 237 erratum PR D34 909 PR D37 237 erratum PR D34 903 PL 1528 439 PRI. 55 665 ZPHY C27 341 PRI. 54 1887 PRI. 53 134 PL 1408 130	+Frampton (UNCCH) -Forotch, Robinett (PSU) -Fo
CUYPERS DONCHESKI DONCHESKI DONCHESKI DONCHESKI DONCHESKI DONCHESKI DONCHESKI DONCHESKI RAFELT AMALDI ANASARI BARTEL MARCIANO ARNISON BARGER BEHREND DERRICK AISO DURKIN ELIS JODIDIO AISO MOHAPATRA STEIGMAN ADEVA ADEVA BERGER STOKER ADEVA BEHREND DONCHESKI BERGER STOKER ADEVA BEHREND ARNISON	88 88 88 88 88 87 87D 87B 86B 86B 86B 86B 86B 86B 86B 86B 86B 86	PRI. 60 1237 PL B206 137 PR D38 412 PL B202 417 PRI. 60 1793 PR D38 1385 PL B195 613 ZPHY C36 15 PR D35 1672 EPL 1 377 PRI. 56 30 PL B178 452 PL 1668 463 PR D34 3286 PPL 1678 457 PR D34 1976 PR D37 237 erratum PR D34 909 PL B176 33 PR D34 497 PR D37 237 erratum PR D34 909 PL B176 33 PR D34 497 PR D37 237 erratum PR D34 909 PL B176 33 PRI. 55 665 ZPHY C27 341 PRI. 54 1887 PRI. 53 134 PL 1408 130	+Frampton (UNCCH) +Grotch, Robinett (PSU) +Seckel (LIL, UCSC) +Bahm, Durkin, Langacker+ (CERN, ACH3, OSCH) +Bagnaia, Banner+ (JADE Collab, LSIrilin (BNL, NYU) +Albrow, Allkofer+ (JADE Collab, LSIrilin (BNL, NYU) +Albrow, Allkofer+ (WISC, OREG, FSU) +Deshpande, Whisnant (WISC, OREG, FSU) +Derick, Gan, Kooijman, Loos, Musgrave+ (HRS Collab, Derrick, Gan, Kooijman, Loos, Musgrave+ (HRS Collab, Langacker) +Enqvist, Nanopoulos, Sarkar (CERN, OKFTP) +Balke, Carr, Gidal, Shinsky+ Jodidio, Balke, Carr+ (LBL, NWES, TRIU) +Olive, Schramm, Turner +Balke, Carr, Gidal, Shinsky+ +Becker, Becker-Szendy+ (Mark-J Collab, LBL, NWES, TRIU) +Barber, Becker, Berdgo+ +Barber, Becker, Berdgo+ +Barber, Becker, Berdgo+ +Barber, Becker, Berner+ +Astbury, Aubetr, Bacci+ (UAI Collab) (CELLO Collab)
CÜYPERS DONCHESKI DONCHESKI DONCHESKI DONCHESKI DONCHESKI DONCHESKI DONCHESKI DONCHESKI DONCHESKI RAFFELT AMALDI ANSARI BARTEL MARCIANO BARGER BEHREND DERRICK AISO DURKIN ELLIS JODIDIO AISO MOHAPATRA STEIGMAN ADEVA ADEVA BERGER STOKER ADEVA BERGER STOKER ADEVA BARNISON BEHREND ARNISON BERGSMA	88 88 88 88 88 87 87 87 86 87 86 86 86 86 86 86 86 86 86 86 88 86 88 86 88 86 88 88	PRI. 60 1237 PL 8206 137 PR D38 412 PL 8202 417 PRI. 60 1793 PR D38 412 PR D38 1412 PRI. 60 1793 PR D36 1385 PL 8195 613 PR D35 1672 PRI. 56 30 PL 8178 452 PL 1678 452 PL 1668 463 PL 1668 436 PL 1668 436 PL 1668 436 PL 1668 437 PR D34 1967 PR D37 237 erratum PR D34 909 PR 137 237 erratum PR D34 909 PRI. 55 665 ZPHY C27 341 PRI. 541 887 PRI. 53 134 PL 1408 130 PL 1298 273 PRI. 150 130 PL 1298 273 PRI. 150 130 PL 1298 273	+Frampton (UNCCH) +Grotch, Robinett (PSU) +Grotch, Robinett (PSU) +Grotch, Robinett (PSU) +Grotch, Robinett (PSU) +Bills, Franzini, Zwirner (CERN, UCB, LLL, UCSC) +Bohm, Durkin, Langacker+ (CERN, UCB, LLL, UCSC) +Bagnaia, Banner+ (CERN, UCB, LLL, UCSC) +Bagraia, Banner+ (CERN, UCB, LLL, UCSC) +Albrow, Allkofer+ (JADE Collab) +Sirlin (BNL, NYU) +Albrow, Allkofer+ (WISC, OREG, FSU) +Deburger, Criegee, Fenner, Field+ +Gan, Kooijman, Loos + UKSC, OREG, FSU) -Derrick, Gan, Kooijman, Loos, Musgrave+ (HRS Collab) +Langacker (PENN) +Bangacker (HRS Collab) +Langacker (HRS Collab) +Langacker (PENN) +Deuter, Gena, Kooijman, Loos, Musgrave+ (HRS Collab) +Langacker (PENN) +Bangke, Carr, Gidal + (BL, NWES, TRIU) +Olive, Schramm, Turner +Becker, Becker-Szendy+ (Mark-J Collab) +Deuter, Genzel, Lackas, Pielorz+ +Balke, Carr, Gidal + (Mark-J Collab) +Deuter, Genzel, Lackas, Pielorz+ +Balke, Carr, Gidal + (Mark-J Collab) +Deuter, Genzel, Lackas, Pielorz+ +Balke, Carr, Gidal + (Mark-J Collab) +Barger, Criege, Fenner+ +Gregee, Fenner- +Gregee, Fenn
CUYPERS DONCHESKI DONCHESKI DONCHESKI DONCHESKI DONCHESKI DONCHESKI ELLIS RAFFELT AMALDI AMALDI AMALDI AMALDI AMACIANO BARTEL MARCIANO BARTEL MARCIANO BEHREND DERRICK DURKIN ELLIS DURKIN BARTEL MASO MOHAPATRA STEIGMAN ADEVA ADEVA BEHREND BERGER STOKER AGNES BERGER AGNES BERGER STOKER AGNES BERGER STOKER AGNES BERGER AGNES BERGER AGNES BERGER	88 88 88 88 88 87 87D 87B 87B 86B 86B 86B 86B 86B 86B 86B 86B 86B 86	PRI. 60 1237 PL B206 137 PR D38 412 PL B202 417 PRI. 60 1793 PR D38 1412 PRI. 60 1793 PR D36 1385 PL B195 613 ZPHY C36 15 PR D35 1672 EPL 1 377 PRI. 56 30 PL B178 452 PL 166B 463 PL 167B 457 PR D34 1967 PR D37 237 erratum PR D34 997 PR 157 33 PL 152B 439 PRI. 55 665 ZPHY C27 341 PRI. 54 1887 PRI. 53 134 PL 140B 130 PRI. 53 134 PL 140B 130 PRI. 528 427 PL 122B 425 PL 122B 427	+Frampton (UNCCH) -Forotch, Robinett (PSU) -Forotch, Gan, Kooijman, Loos -Forotch, Gan, Kooijman, Loos, Musgrave+ (HRS Collab, Derrick, Gan, Kooijman, Loos, Musgrave+ (HRS Collab, Derrick, Gan, Kooijman, Loos, Musgrave+ (HRS Collab, Derrick, Gan, Kooijman, Loos, Musgrave+ (HRS Collab, Langacker, Gan, Kooijman, Loos, Musgrave+ (HRS Collab, Derrick, Gan, Kooijman, Loos, Musgrave+ (HRS Collab, Langacker, Gan, Langacker, G
CÜYPERS DONCHESKI DONCHESKI DONCHESKI DONCHESKI DONCHESKI DONCHESKI DONCHESKI DONCHESKI DONCHESKI RAFFELT AMALDI ANSARI BARTEL MARCIANO BARGER BEHREND DERRICK AISO DURKIN ELLIS JODIDIO AISO MOHAPATRA STEIGMAN ADEVA ADEVA BERGER STOKER ADEVA BERGER STOKER ADEVA BERGER STOKER ADEVA BERGER ADEVA BERGER STOKER ADEVA BERGER STOKER ADEVA BERGER BEHREND ARNISON BERGSMA CARR	88 88 88 88 88 88 87 87 86 87 86 86 86 86 86 86 86 88 85 85 88 85 88 88 88 88 88 88 88 88	PRI. 60 1237 PL 8206 137 PR D38 412 PL 8202 417 PRI. 60 1793 PR D38 1412 PRI. 60 1793 PR D36 1385 PL 8195 613 PR D35 1672 PRI. 56 30 PL 8176 452 PL 1678 452 PL 1668 463 PL 1668 463 PL 1668 436 PL 1668 437 PR D34 1967 PR D37 237 erratum PR D34 909 PR D37 237 erratum PR D34 909 PR 157 665 ZPHY C27 341 PRI. 55 1655 ZPHY C27 341 PRI. 54 1887 PRI. 53 134 PL 1408 130 PL 1298 273 PL 1298 273 PL 1228 465 PRI. 51 627 PR D 77 1193	+Frampton (UNCCH) -Forotch, Robinett (PSU) -Fo
CUYPERS DONCHESKI DONCHESKI DONCHESKI DONCHESKI DONCHESKI DONCHESKI DONCHESKI DONCHESKI RAFELT AMALDI ANSARI BARTEL MARCIANO BARGER BEHREND DERRICK AISO DURKIN ELLIS JODIJOI ANSAM MOHAPATRA STEIGMAN ADEVA ADEVA ADEVA BEHREND BERGER STOKER ADEVA BEHREND BERGER STOKER ADEVA BEHREND BERGSMA CARR DESHPANDE BEALL	88 88 88 88 88 87 87D 87B 87B 86B 86B 86B 86B 86B 86B 86B 86B 86B 86	PRI. 60 1237 PL B206 137 PR D38 412 PL B202 417 PRI. 60 1793 PR D38 1412 PRI. 60 1793 PR D36 1385 PL B195 613 ZPHY C36 15 PR D35 1672 EPL 1 377 PRI. 56 30 PL B178 452 PL 166B 463 PRI D31	+Frampton (UNCCH) +Grotch, Robinett (PSU) +Grotch, Robinett (PSU) +Grotch, Robinett (PSU) +Grotch, Robinett (PSU) +Seckel (URB, LLL, UCSC) +Bagnaia, Banner+ (CERN, ACHB, OSCH) +Bagnaia, Banner+ (CERN, ACHB, OSCH) +Bagraia, Banner+ (JADE Collab, JSIrilin (BNL, NYU) +Albrow, Allkofer+ (UAI Collab, JSIrilin (BNL, NYU) +Deshpande, Whisnant (WISC, OREG, FSU) +Derick, Gan, Kooijman, Loos+ (HRS Collab, Derrick, Gan, Kooijman, Loos+ (HRS Collab, Langacker (PENN) +Langacker (PENN) +Langacker (PENN) +Langacker (PENN) +Langacker (PENN) +Lordiolo, Balke, Carr, Gidal, Shinsky+ (LBL, NWES, TRIU) +Dollab, Secker-Szendy+ (Mark-J Collab, Peterker, Becker-Szendy+ (Mark-J Collab, Peterker, Becker-Szendy+ (Mark-J Collab, Peterker, Becker, Berdey+ (Mark-J Collab, LB, NWES, TRIU) +Barber, Becker, Berdigo+ (Mark-J Collab, LB, WES, TRIU) +Barber, Becker, Berdigo+ (Mark-J Collab, LB, WES, TRIU) +Barber, Becker, Berdigo+ (CELLO Collab, LB) +Burger, Criege, Fenner+ (CHAR Collab, LB) -Burger, Criege, Fenner+ (CHAR Collab, LB)
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Axions (A^0) and Other Very Light Bosons, Searches for

AXIONS AND OTHER VERY LIGHT BOSONS

In this section we list limits for very light neutral (pseudo) scalar bosons that couple weakly to stable matter. These have been proposed to solve a variety of mostly theoretical concerns. Typical examples are pseudo-Goldstone bosons like axions (A^0) [1], familons [2], and Majorons [3,4], associated, respectively, with spontaneously broken Peccei-Quinn [5], family, and lepton-number symmetries.

In QCD, SU(3) gauge invariance does not forbid a term $\theta(g_s^2/32\pi^2)F^{\mu\nu a}\widetilde{F}_{\mu\nu}^a$ in Lagrangian. However, CP invariance is broken if $\theta \neq 0$ or π , and the parameter θ has to be small $\lesssim 10^{-9}$ in order not to generate too large electric dilopole moment of neutron. This is called strong CP problem. Peccei-Quinn symmetry gives a natural solution to the strong CP problem. The axion mass and its coupling to stable particles are inversely proportional to the scale of Peccei-Quinn symmetry breaking, f_A . The original axion model [1,5] assumed $f_A \sim v$, where $v = (\sqrt{2}G_F)^{-1/2} = 247$ GeV is the scale of the electroweak

symmetry breaking, and had two Higgs doublets as minimal ingredients. By requiring tree-level flavor conservation, the axion mass and its couplings were completely fixed in terms of one parameter, the ratio of the vacuum expectation values of the two Higgs fields. The result of extensive experimental searches for such an axion have been negative [6].

Observation of a narrow-peak structure in positron spectra from heavy ion collisions [7] suggested a particle of mass 1.8 MeV that decays into e^+e^- . Variants of the original axion model, which keep $f_A \sim v$, but drop the constraints of tree-level flavor conservation, were proposed [8]. Extensive searches for this particle, $A^0(1.8 \text{ MeV})$, ended up with another negative result [9].

Another way to save the Peccei-Quinn idea is to introduce a new scale $f_A \gg v$. Then the A^0 mass becomes smaller and its coupling weaker, thus one can easily avoid all the existing experimental limits; such models are called invisible axion models [10,11]. See the note on Invisible Axions later in this section.

Familons arise when there is a global horizontal symmetry (a symmetry which interchanges different generations) broken spontaneously. They could be either scalars or pseudoscalars. An SU(3) horizontal symmetry among three generations is non-anomalous and hence the familons are exactly massless. In this case, familons are scalars. If one has larger horizontal symmetries with separate groups of left-handed and right-handed fields, one also has pseudo-scalar familons. Some of them have flavor-off-diagonal couplings such as $\partial_{\mu}\phi_{F}\bar{d}\gamma^{\mu}s/F$ or $\partial_{\mu}\phi_{F}\bar{e}\gamma^{\mu}\mu/F$, and the decay constant F can be different for individual operators. The decay constants have lower bounds constrained by flavor-changing processes. For instance, $B(K^+ \to \pi^+\phi_F) < 1.7 \times 10^{-9}$ [12] gives $F_{K\pi} > 1.3 \times 10^{11}$ GeV [2].

If there is a global lepton number symmetry and if it breaks spontaneously, there is a Majoron. The triplet Majoron model [4] has a weak-triplet Higgs boson, and the Majoron couples to Z. The original version is now excluded by the invisible Z decay width. The model would remain viable if there were an additional singlet Higgs boson and if the Majoron were mainly a singlet [13]. In the singlet Majoron model [3], lepton number symmetry is broken by a weak-singlet scalar field, and there are right-handed neutrinos that acquire Majorana masses. The left-handed neutrino masses are generated by a "seesaw" mechanism [14]. The scale of lepton number breaking can be much higher than the electroweak scale in this case. Astrophysical constraints require the decay constant to be $\gtrsim 10^9~{\rm GeV}$ [15].

Other light bosons (scalar, pseudoscalar or vector) are constrained by "fifth force" experiments. For a compilation of constraints, see [16].

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A⁰ (Axion) MASS LIMITS from Astrophysics and Cosmology

These bounds depend on model-dependent assumptions (i.e. — on a combination of axion parameters).

axion parameters)	•			
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
• • • We do not use the	e following data for average	s, fits	, limits,	etc. • • •
>0.2	BARROSO	82	ASTR	Standard Axion
>0.25	¹ RAFFELT	82	ASTR	Standard Axion
>0.2	² DICUS	78C	ASTR	Standard Axion
	MIKAELIAN	78	ASTR	Stellar emission
>0.3	² SATO	78	ASTR	Standard Axion
>0.2	VYSOTSKII	78	ASTR	Standard Axion

 $^{^{1}}_{2}$ Lower bound from 5.5 MeV γ -ray line from the sun.

A⁰ (Axion) and Other Light Boson (X⁰) Searches in Stable Particle Decays Limits are for branching ratios.

VALUE		CL% EVTS	DOCUMENT ID	TECN_	COMMENT
• • •	We do not a	use the following di	ata for averages, fi	ts, limits, etc.	• • •
<6	\times 10 ⁻⁵	90	³ AMSLER	94B CBAR	$\pi^0 \rightarrow \gamma X^0$,
					<i>m</i> _X 0=65−125 MeV
<6	\times 10 ⁻⁵	90	³ AMSLER	94B CBAR	$\eta \rightarrow \gamma X^0$,
					$m_{\chi_0=200-525}$

< 0.007	90		4 MEIJERDREES	S 94	CNTR	$\pi^0 \rightarrow \gamma X^0$, $m_{\times 0} = 25 \text{ MeV}$
< 0.002	90		⁴ MEIJERDREES	S 94	CNTR	m_{χ^0} =25 MeV $\pi^0 \rightarrow \gamma X^0$, m_{χ^0} =100 MeV
$< 1.7 \times 10^{-9}$	90		⁵ ATIYA	93	B787	$K^+ \xrightarrow{\Lambda^0} \pi^+ A^0$
$< 2 \times 10^{-7}$	90		6 ATIYA	93B		$K^+ \rightarrow \pi^+ A^0$
$< 3 \times 10^{-13}$			⁷ NG	93	COSM	$\pi^0 \rightarrow \gamma X^0$
<1.1 × 10 ⁻⁸	90		⁸ ALLIEGRO	92	SPEC	$ \begin{array}{c} K^+ \rightarrow \pi^+ A^0 \\ (A^0 \rightarrow e^+ e^-) \\ \pi^0 \rightarrow \gamma X^0 \end{array} $
$<$ 5 \times 10 ⁻⁴	90		9 ATIYA	92	B787	$\pi^0 \rightarrow \chi \chi^0$
<4 × 10 ⁻⁶	90		10 MEIJERDREES		SPEC	$\pi^0 \rightarrow \gamma X^0$
						$X^0 \rightarrow e^+e^-,$ $m_{\chi^0} = 100 \text{ MeV}$
<1 \times 10^{-7}	90		¹¹ ATIYA	90B	B787	$\kappa^+ \rightarrow \pi^+ A^0$
<1.3 × 10 ⁻⁸	90		12 KORENCHE	87	SPEC	$(A^{0} \rightarrow \gamma \gamma)$ $\pi^{+} \rightarrow e^{+} \nu A^{0}$ $(A^{0} \rightarrow e^{+} e^{-})$
$< 1 \times 10^{-9}$	90	0	¹³ EICHLER	86	SPEC	Stopped $\pi^+ \rightarrow$
$<\!2.000000000000000000000000000000000000$	90		¹⁴ YAMAZAKI	84	SPEC	$e^+ \nu A^0$ For 160 < m < 260
$<$ (1.5–4) \times 10 ⁻⁶	90		¹⁴ YAMAZAKI	84	SPEC	$^{\rm MeV}_{\rm K\ decay,\ m_{A^0}} \ll$
		0	¹⁵ ASANO	82	CNTR	
		0	¹⁶ ASANO	81B	CNTR	$\pi^+ A^0$ Stopped $K^+ \rightarrow$
2			¹⁷ ZHITNITSKII	79		$\pi^+ A^0$ Heavy axion

³ AMSLER 94B looked for a peak in missing-mass distribution.

The MEIJERDREES 94 limit is based on inclusive photon spectrum and is independent of X^0 decay modes. It applies to $\tau(X^0) > 10^{-23}\,\mathrm{sec}$.

 5 ATIYA 93 looked for a peak in missing mass distribution. The limit is for massless stable A^0 particles and extends to $m_{A^0}{=}80$ MeV at the same level. See paper for dependence on finite lifetime.

 6 ATIYA 93B looked for a peak in missing mass distribution. The bound applies for stable A^0 of m_{A^0} =150–250 MeV, and the limit becomes stronger (10 $^{-8}$) for m_{A^0} =180–240 MeV

MeV. 7 NG 93 studied the production of X^0 via $\gamma\gamma\to\pi^0\to\gamma X^0$ in the early universe at $T\simeq 1$ MeV. The bound on extra neutrinos from nucleosyntheis $\Delta N_{\nu}<0.3$ (WALKER 91) is employed. It applies to $m_{X^0}\ll 1$ MeV in order to be relativistic down to nucleosynthesis temperature. See paper for heavier X^0 .

⁸ ALLIEGRO 92 limit applies for m_{A0} =150–340 MeV and is the branching ratio times the decay probability. Limit is $< 1.5 \times 10^{-8}$ at 99%CL.

 $m_{\chi_0} = 0.130$ MeV in the narrow resonance limit. See paper for the dependence on lifetime. Covariance requires χ_0 to be a vector particle.

ilfetime. Covariance requires X^0 to be a vector particle. 10 MEJJERDREES 92 limit applies for $\tau_{X^0}=10^{-23}$ – 10^{-11} sec. Limits between 2×10^{-4} and 4×10^{-6} are obtained for $m_{X^0}=25$ –120 MeV. Angular momentum conservation requires that X^0 has spin ≥ 1 . 11 ATIYA 908 limit is for $\mathrm{B}(K^+\to\pi^+A^0)$ - $\mathrm{B}(A^0\to\gamma\gamma)$ and applies for $m_{A^0}=50$ MeV,

 11 ATIYA 908 limit is for B($K^+\to\pi^+A^0$)·B($A^0\to\gamma\gamma$) and applies for $m_{A^0}=$ 50 MeV, $\tau_{A^0}<10^{-10}$ s. Limits are also provided for 0 < $m_{A^0}<100$ MeV, $\tau_{A^0}<10^{-8}$ s. 12 KORENCHENKO 87 limit assumes $m_{A^0}=1.7$ MeV, $\tau_{A^0}\lesssim10^{-12}$ s, and B($A^0\to12$ K)

 $e^{+}e^{-})=1$. 13 EICHLER 86 looked for $\pi^{+}\to e^{+}\nu A^{0}$ followed by $A^{0}\to e^{+}e^{-}$. Limits on the branching fraction depend on the mass and and lifetime of A^{0} . The quoted limits are valid when $\tau(A^{0})\gtrsim 3$. $\times 10^{-10}$ s if the decays are kinematically allowed.

¹⁴ YAMAZAKI 84 looked for a discrete line in $K^+ \to \pi^+ X$. Sensitive to wide mass range (5–300 MeV), independent of whether X decays promptly or not.

 $\begin{array}{l} \text{(3-36) MeV}_{\text{i}} \text{ independent of Microst A Costys position)} \text{ of } m_{A^0} < \text{100 MeV as BR} \\ \text{(4. \times10^{-8}$ for $\tau(A^0 \to n\gamma'\text{s})$ > 1. \times10^{-9}$ s, BR < 1.4 \times10^{-6}$ for $\tau < 1. \times10^{-9}$ s.} \end{array}$

 16 ASANO 81B is KEK experiment. Set B($K^+ \to \pi^+ A^0) < 3.8 \times 10^{-8}$ at CL = 90%. 17 ZHITNITSKII 79 argue that a heavy axion predicted by YANG 78 (3 $<\!m$ $<\!40$ MeV) contradicts experimental muon anomalous magnetic moments.

A⁰ (Axion) Searches in Quarkonium Decays

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Decay or transition of quarkonium. Limits are for branching ratio.

VALUE	CL% EV	T <u>S</u>	DOCUMENT ID		<u>TECN</u>	COMMENT
ullet $ullet$ We do not	use the fo	llowing	g data for averages	, fits	, limits,	etc. • • •
$< 1.3 \times 10^{-5}$	90		¹⁸ BALEST	95	CLEO	$\Upsilon(1S) \rightarrow A^0 \gamma$
$< 4.0 \times 10^{-5}$	90		ANTREASYAN			$\Upsilon(1S) \rightarrow A^0 \gamma$
			¹⁹ ANTREASYAN	90c	RVUE	
$< 5 \times 10^{-5}$	90		²⁰ DRUZHININ	87	ND	$\phi \rightarrow A^0 \gamma$
						$(A^0 \rightarrow e^+e^-)$
$< 2 \times 10^{-3}$	90			87	ND	$\phi \rightarrow A^0 \gamma (A^0 \rightarrow \gamma \gamma)$
$< 7 \times 10^{-6}$	90		²² DRUZHININ	87	ND	$\phi \rightarrow A^0 \gamma$
						$(A^0 \rightarrow missing)$
$< 3.1 \times 10^{-4}$	90	0	²³ ALBRECHT	8 6 D	ARG	$\Upsilon(1S) \rightarrow A^0 \gamma$
						$(A^0 \rightarrow e^+e^-)$
$< 4 \times 10^{-4}$	90	0	²³ ALBRECHT	86D	ARG	$\gamma(1s) \rightarrow A^0 \gamma$
						$(A^0 \to \mu^+ \mu^-)$
						$\pi^{+}\pi^{-}, K^{+}K^{-})$
$< 8 \times 10^{-4}$	90	1	²⁴ ALBRECHT	86D	ARG	$\Upsilon(1S) \rightarrow A^0 \gamma$

 $^{^{2}\,\}mbox{Lower}$ bound from requiring the red giants' stellar evolution not be disrupted by axion emission.

Axions (A^0) and Other Very Light Bosons

$< 1.3 \times 10^{-3}$	90	0	²⁵ ALBRECHT	860	ARG	
<2. × 10 ⁻³	90		²⁶ BOWCOCK	06	CLEO	$(A^0 \rightarrow e^+e^-, \gamma\gamma)$ $\Upsilon(2S) \rightarrow \Upsilon(1S) \rightarrow$
	90					A^{0}
$< 5. \times 10^{-3}$	90			86	CUSB	$\Upsilon(1S) \rightarrow A^0 \gamma$
$< 3. \times 10^{-4}$	90					$\Upsilon(1S) \rightarrow A^0 \gamma$
$< 9.1 \times 10^{-4}$	90		²⁹ NICZYPORUK	83	LENA	$\Upsilon(1S) \rightarrow A^0 \gamma$
$<1.4 \times 10^{-5}$	90		³⁰ EDWARDS			$J/\psi \rightarrow A^0 \gamma$
$< 3.5 \times 10^{-4}$	90		³¹ SIVERTZ	82	CUSB	$\Upsilon(1S) \rightarrow A^0 \gamma$
$< 1.2 \times 10^{-4}$	90		³¹ SIVERTZ	82	CUSB	$\Upsilon(3S) \rightarrow A^0 \gamma$

 18 BALEST 95 looked for a monochromatic γ from $\varUpsilon(15)$ decay. The bound is for $m_{A0} < 5.0$ GeV. See Fig. 7 in the paper for bounds for heavier $m_{A^0}.$ They also quote a bound on branching ratios 10^3–10^5 of three-body decay $\gamma X \overset{A}{\overline{X}}$ for $0 < m_{\widetilde{X}} < 3.1$ GeV.

19 The combined limit of ANTREASYAN 90c and EDWARDS 82 excludes standard axion with m_{A^0} < 2 m_e at 90% CL as long as $C_{\varUpsilon}C_{J/\psi}$ > 0.09, where C_V ($V=\varUpsilon$, J/ψ) with $m_{A0} < 2m_e$ at 90% CL as long as ${\rm C} \gamma {\rm C} J/\psi > 0.07$, misses ${\rm C}_V < 1.07$, is the reduction factor for $\Gamma(V \to A^0 \gamma)$ due to QCD and/or relativistic corrections. The same data excludes 0.02 < x < 260 (90% CL) if $C\gamma = C_J/\psi = 0.5$, and further combining with ALBRECHT 86D result excludes $5 \times 10^{-5} < x < 260$. x is the ratio of the vacuum expectation values of the two Higgs fields. These limits use conventional assumption $\Gamma(A^0 \to ee) \propto x^{-2}$. The alternative assumption $\Gamma(A^0 \to ee) \propto x^2$ gives a somewhat different excluded region 0.00075 < x < 44.

 m_{A^0} < 20 MeV.

²¹ The second DRUZHININ 87 limit is valid when au_{A^0}/m_{A^0} < 5 imes 10 $^{-13}$ s/MeV and m_{A^0} < 20 MeV.

²² The third DRUZHININ 87 limit is valid when $au_{A^0}/m_{A^0} > 7 imes 10^{-12}$ s/MeV and $m_{A^0}~<$ 200 MeV.

 $^{23}\tau_{A0}^{AO}<1\times10^{-13}{\rm s}$ and $m_{A0}<1.5$ GeV. Applies for $A^0\to\gamma\gamma$ when $m_{A0}<100$ MeV. $^{24}\tau_{A0}>1\times10^{-7}{\rm s}$.

 25 Independent of τ_{A^0} .

²⁶BOWCOCK 86 looked for A^0 that decays into e^+e^- in the cascade decay \varUpsilon (2S) ightarrow $\Upsilon(1S)\pi^+\pi^-$ followed by $\Upsilon(1S)\to A^0\gamma$. The limit for B($\Upsilon(1S)\to A^0\gamma$)B($A^0\to A^0\gamma$) $e^+\,e^-$) depends on m_{A^0} and au_{A^0} . The quoted limit for m_{A^0} =1.8 MeV is at au_{A^0} \sim 2. \times 10⁻¹²s, where the limit is the worst. The same limit $2.\times$ 10⁻³ applies for all lifetimes for masses $2m_e < m_{A^0} < 2m_{\mu}$ when the results of this experiment are combined with the results of ALAM 83. 27 MAGERAS 86 looked for Υ (15) $\rightarrow \ \gamma A^0 \ (A^0 \rightarrow e^+e^-)$. The quoted branching fraction limit is for $m_{A^0} = 1.7$ MeV, at $\tau(A^0) \sim 4.\times$ 10⁻¹³s where the limit is the worst.

worst. 28 ALAM 83 is at CESR. This limit combined with limit for B $(J/\psi \to A^0 \gamma)$ (EDWARDS 82)

excludes standard axion.

29 NICZYPORUK 83 is DESY-DORIS experiment. This limit together with lower limit 9.2×10^{-4} of B($\Upsilon\to A^0\,\gamma$) derived from B(J/ ψ (1S) $\to A^0\,\gamma$) limit (EDWARDS 82) excludes standard axion.

excludes standard axion. 30 EDWARDS 82 looked for $J/\psi \to \gamma A^0$ decays by looking for events with a single To free graph $\sim 1/2$ the $J/\psi = 7\gamma$ decays by looking in the detector. The limit is inconsistent with the axion interpretation of the FAISSNER 81B result.

 31 SIVERTZ 82 is CESR experiment. Looked for $m au
ightarrow \gamma A^{0}$, A^{0} undetected. Limit for 1S (3S) is valid for m_{A^0} <7 GeV (4 GeV).

A⁰ (Axion) Searches in Positronium Decays

Decay or transition of positronium. Limits are for branching ratio. VALUE CL% DOCUMENT ID TECN COMMENT

 ◆ ◆ We do not use 	the follow	ing data for average	es, fit	s, limits,	etc. • • •
$< 2 \times 10^{-4}$	90	MAENO	95	CNTR	$o\text{-Ps} \rightarrow A^0 \gamma$
$< 3.0 \times 10^{-3}$	90	³² ASAI	94	CNTR	m_{A^0} =850-1013 keV o-Ps $\to A^0 \gamma$ m_{A^0} =30-500 keV
$< 2.8 \times 10^{-5}$	90	33 AKOPYAN	91	CNTR	$o\text{-Ps} \rightarrow A^0 \gamma$
					$(A^0 ightarrow \gamma \gamma)$, $m_{A^0} < 30$ keV
$<1.1 \times 10^{-6}$	90	³⁴ ASAI	91	CNTR	$o\text{-Ps} \rightarrow A^0 \gamma$,
$< 3.8 \times 10^{-4}$	90	GNINENKO	90	CNTR	m_{A^0} < 800 keV o-Ps \rightarrow $A^0 \gamma$, m_{A^0} <
<(1-5) × 10 ⁻⁴	95	³⁵ TSUCHIAKI	90	CNTR	$o\text{-Ps} \rightarrow A^0 \gamma, m_{A^0} =$
$< 6.4 \times 10^{-5}$	90	³⁶ ORITO	89	CNTR	0-900 keV $0-\text{Ps} \rightarrow A^0 \gamma$, $m_{\Delta^0} < 30 \text{ keV}$
		³⁷ AMALDI ³⁸ CARBONI	85 83	CNTR CNTR	

 32 The ASAI 94 limit is based on inclusive photon spectrum and is independent of A^0 decay

 33 The AKOPYAN 91 limit applies for a short-lived A^0 with $\tau_{A^0}<10^{-13}~m_{A^0}$ [keV] s. 34 ASAI 91 limit translates to $g_{A^0~e^+e^-}^2/4\pi<~1.1\times10^{-11}$ (90%CL) for $m_{A^0}<800$

35 The TSUCHIAKI 90 limit is based on inclusive photon spectrum and is independent of A^0 decay modes. $A^0 = \frac{1}{2} \left(\frac{1}{2} \right)^{1/2} = \frac{1}{2} \left(\frac{$

 $^{A'}$ decay modes. 36 ORITO 89 limit translates to $g_{A^0\,e\,e}^2/4\pi < 6.2\times 10^{-10}$. Somewhat more sensitive limits are obtained for larger m_{A^0} : $B<7.6\times 10^{-6}$ at 100 keV. 37 AMALDI 85 set limits $B(A^0\gamma)$ / $B(\gamma\gamma\gamma)<(1-5)\times 10^{-6}$ for $m_{A^0}=900$ –100 keV

which are about 1/10 of the CARBONI 83 limits.

 38 CARBONI 83 looked for orthopositronium $\to A^0 \gamma$. Set limit for A^0 electron coupling squared, $g(eeA^0)^2/(4\pi) < 6. \times 10^{-10}$ –7. $\times 10^{-9}$ for m_{A^0} from 150–900 keV (CL = 99.7%). This is about 1/10 of the bound from g–2 experiments.

A⁰ (Axion) Search in Photoproduction

DOCUMENT ID COMMENT

 39 BASSOMPIE... 95 $~m_{\ensuremath{A^0}} = 1.8 \pm 0.2 \; \mathrm{MeV}$

 39 BASSOMPIERRE 95 is an extension of BASSOMPIERRE 93. They looked for a peak in the invariant mass of $e^+\,e^-$ pairs in the region $m_{\,e^+\,e^-}=1.8\pm0.2$ MeV. They obtained bounds on the production rate A^0 for $\tau(A^0)=10^{-18}\text{-}10^{-9}\,\text{sec}$. They also obtained bounds on the production rate A^0 for $\tau(A^0)=10^{-18}$ found an excess of events in the range $m_{e^+e^-}=2.1$ –3.5 MeV.

A0 (Axion) Production in Hadron Collisions

Limits are for $\sigma(A^0) / \sigma(\pi^0)$.

VALUE	CL%		DOCUMENT ID			COMMENT
• • • We do no	t use th	e followi	ng data for average	s, fits	s, limits,	etc. • • •
			⁴⁰ BLUEMLEIN	92	BDMP	$A^0 N_Z \rightarrow \ell^+ \ell^- N_Z$
			⁴¹ MEIJERDREE	S 92	SPEC	$\pi^- p \rightarrow nA^0, A^0 \rightarrow$
			43			$A^0 \stackrel{e^+e^-}{\rightarrow e^+e^-}, 2\gamma$
			42 BLUEMLEIN	91		
			⁴³ FAISSNER	89	OSPK	Beam dump,
			44 DEBOER	88	RVUE	$A^0 \xrightarrow{e^+} e^-e^-$
			45 EL-NADI	88		$A^0 \rightarrow e^+e^-$
			46 FAISSNER	88	OSPK	Beam dump, $A^0 \rightarrow 2$
			47 BADIER	86		$A^0 \rightarrow e^+e^-$
$<$ 2. \times 10 ⁻¹¹	90	0	48 BERGSMA	85		CERN beam dump
<1. × 10 ⁻¹³	90	0	48 BERGSMA	85		CERN beam dump
(1. × 10	30	24	49 FAISSNER	83	OSPK	
		24	50 FAISSNER		RVUE	LAMPF beam dump
			⁵¹ FRANK		RVUE	LAMPF beam dump
			⁵² HOFFMAN	83	CNTR	$\pi p \rightarrow nA^0$
						$(A^0 \rightarrow e^+e^-)$
			⁵³ FETSCHER	82	RVUE	See FAISSNER 818
		12	⁵⁴ FAISSNER	81	OSPK	CERN PS ν wideband
		15	⁵⁵ FAISSNER	81B	OSPK	Beam dump, $A^0 \rightarrow 2$
		8	⁵⁶ KIM	81	OSPK	26 GeV $pN \rightarrow A^0X$
		0	⁵⁷ FAISSNER	80	OSPK	Beam dump, $A^0 \rightarrow e^+ e^-$
$<1. \times 10^{-8}$	90		58 JACQUES	80	HLBC	28 GeV protons
$<1. \times 10^{-14}$	90		⁵⁸ JACQUES	80	HLBC	Beam dump
			⁵⁹ SOUKAS	80	CALO	28 GeV p beam dump
			60 BECHIS	79	CNTR	
$<1. \times 10^{-8}$	90		61 COTEUS	79	OSPK	Beam dump
<1. × 10 ⁻³	95		⁶² DISHAW	79	CALO	400 GeV ρρ
$<1. \times 10^{-8}$	90		ALIBRAN	78	HYBR	Beam dump
$<6. \times 10^{-9}$	95		ASRATYAN		CALO	Beam dump
$<1.5 \times 10^{-8}$	90		63 BELLOTTI	78	HLBC	Beam dump
$< 5.4 \times 10^{-14}$	90		63 BELLOTTI	78	HLBC	$m_{\mathcal{A}^0} = 1.5 \text{ MeV}$
$<4.1 \times 10^{-9}$	90		63 BELLOTTI	78	HLBC	$m_{A^0}=1 \text{ MeV}$
$<1. \times 10^{-8}$	90		⁶⁴ BOSETTI ⁶⁵ DONNELLY	78B 78	HYBR	Beam dump
$< 0.5 \times 10^{-8}$	90		HANSL	78D	WIRE	Beam dump
			66 MICELMAC	78		•
			⁶⁷ VYSOTSKII	78		

 $^{
m 40}\,{\rm BLUEMLEIN}$ 92 is a proton beam dump experiment at Serpukhov with a secondary

target to induce Bethe-Heitler production of e^+e^- or $\mu^+\mu^-$ from the produce A^0 . See Fig. 5 for the excluded region in m_{A^0} -x plane. For the standard axion, 0.3 <x<25 is excluded at 95% CL. If combined with BLUEMLEIN 91, 0.008 <x<32 is excluded. 41 MEIJERDREES 92 give $\Gamma(\pi^-p \to nA^0)$ -B($A^0 \to e^+e^-$)/ $\Gamma(\pi^-p \to al)$) < 10-5 (90% CL) for $m_{A^0} = 100$ MeV, $\tau_{A^0} = 10^{-11}$ - 10^{-23} sec. Limits ranging from 2.5 × 10^{-3} to 10^{-7} are given for $m_{A^0} = 25$ -136 MeV. 10^{-3} to 10^{-7} are given for $m_{A^0} = 25-136$ MeV.

42 BLUEMLEIN 91 is a proton beam dump experiment at Serpukhov. No candidate event for $A^0 \rightarrow e^+e^-$, 2γ are found. Fig. 6 gives the excluded region in m_{A^0} -x plane ($x=\tan\beta=v_2/v_1$). Standard axion is excluded for $0.2 < m_{A^0} < 3.2$ MeV for most x>1, 0.2–11 MeV for most x<1. ⁴³ FAISSNER 89 searched for $A^0 \rightarrow e^+e^-$ in a proton beam dump experiment at SIN. No excess of events was observed over the background. A standard axion with mass $2m_e-20$

MeV is excluded. Lower limit on f_{A^0} of $\simeq 10^4$ GeV is given for $m_{A^0} = 2 m_e$ -20 MeV.

 44 DEBOER 88 reanalyze EL-NADI 88 data and claim evidence for three distinct states with mass $\sim 1.1, \sim 2.1,$ and ~ 9 MeV, lifetimes 10^{-16} – 10^{-15} s decaying to e^+e^- and note the similarity of the data with those of a cosmic-ray experiment by Bristol group (B.M. Anand, Proc. of the Royal Society of London, Section A A22 183 (1953)). criticism see PERKINS 89, who suggests that the events are compatible with π^0 Dalitz decay. DEBOER 898 is a reply which contests the criticism.

decay. DEBOLE 898 is a reply which contests the criticism. 45 EL-NADI 88 claim the existence of a neutral particle decaying into e^+e^- with mass 1.60 \pm 0.59 MeV, lifetime $(0.15\pm0.01)\times10^{-14}$ s, which is produced in heavy ion interactions with emulsion nuclei at \sim 4 GeV/c/nucleon. 46 FAISSNER 88 is a proton beam dump experiment at SIN. They found no candidate event

for $A^0 \to \gamma \gamma$. A standard axion decaying to 2γ is excluded except for a region $x \simeq 1$. Lower limit on f_{A^0} of $10^2 - 10^3$ GeV is given for $m_{A^0} = 0.1 - 1$ MeV.

Gauge & Higgs Boson Particle Listings Axions (A^0) and Other Very Light Bosons

- 47 BADIER 86 did not find long-lived A^0 in 300 GeV π^- Beam Dump Experiment that decays into e^+e^- in the mass range $m_{A^0}=$ (20–200) MeV, which excludes the A^0 decay constant $\mathit{f}(A^0)$ in the interval (60–600) GeV. See their figure 6 for excluded region on $f(A^0)$ - m_{A^0} plane.
- ⁴⁸BERGSMA 85 look for $A^0 \rightarrow 2\gamma$, e^+e^- , $\mu^+\mu^-$. First limit above is for $m_{A^0}=1$ MeV; second is for 200 MeV. See their figure 4 for excluded region on $f_{A0} - m_{A0}$ plane, where f_{A0} is A^0 decay constant. For Peccel-Quinn PECCEI 77 A^0 , m_{A0} <180 keV and τ >0.037 s. (CL = 90%). For the axion of FAISSNER 818 at 250 keV, BERGSMA 85 expect 15 events but observe zero.

49 FAISSNER 83 observed 19 1-γ and 12 2-γ events where a background of 4.8 and 2.3 respectively is expected. A small-angle peak is observed even if iron wall is set in front of the decay region.

50 FAISSNER 83B extrapolate SIN γ signal to LAMPF ν experimental condition. Resulting 370 γ 's are not at variance with LAMPF upper limit of 450 γ 's. Derived from LAMPF limit that $[\sigma r(A^0)/d\omega$ at $90^0]m_{A^0}/\tau_{A^0} < 14 \times 10^{-35}$ cm² sr⁻¹ MeV ms⁻¹. See

iimit that $\lfloor d\sigma(A^{\rm u})/d\omega$ at $90^{\rm o} \rfloor m_{A0}/\tau_{A0} < 14 \times 10^{-35}~{\rm cm}^2~{\rm sr}^{-1}$ MeV ms⁻¹. See comment on FRANK 838. 51 FRANK 838 stress the importance of LAMPF data bins with negative net signal. By statistical analysis say that LAMPF and SIN-A0 are at variance when extrapolation by phase-space model is done. They find LAMPF upper limit is 248 not 450 γ 's. See comment on FAISSNER 838. 40 FFMAN 83 set CL = 90% limit $d\sigma/dt$ B(e^+e^-) $< 3.5 \times 10^{-32}~{\rm cm}^2/{\rm GeV}^2$ for 140 $< m_{A0} < 160$ MeV. Limit assumes $\tau(A^0) < 10^{-9}$ s.

53 FETSCHER 82 reanalyzes SIN beam-dump data of FAISSNER 81. Claims no evidence for axion since 2-γ peak rate remarkably decreases if iron wall is set in front of the decay

54 FAISSNER 81 see excess μe events. Suggest axion interactions.

 55 FAISSNER 81B is SIN 590 MeV proton beam dump. Observed 14.5 \pm 5.0 events of 2γ decay of long-lived neutral penetrating particle with $m_{2\gamma}\lesssim$ 1 MeV. Axion interpretation with η - A^0 mixing gives $m_{A^0}=250\pm25$ keV, $\tau_{(2\gamma)}=(7.3\pm3.7)\times10^{-3}$ s from above rate. See critical remarks below in comments of FETSCHER 82, FAISSNER 83, FAISSNER 83B, FRANK 83B, and BERGSMA 85. Also see in the next subsection ALEKSEEV 82, CAVAIGNAC 83, and ANANEV 85. SEEV 82, CAVAIGNAC 83, and ANANEV 85. CERN with 26 GeV protons on Be. Estimated axion mass is about 300 keV and lifetime is $(0.86 \sim 5.6) \times 10^{-3}$ s depending on models. Faissner (private communication), says axion production underestimated and mass overestimated. Correct value around 200

axion production underestimated and mass overestimated. Correct value around 200

 $^{57}_{\rm KeV.S}^{\rm KeV.}$ RollsSNER 80 is SIN beam dump experiment with 590 MeV protons looking for $A^0 \rightarrow e^+e^-$ decay. Assuming $A^0/\pi^0=5.5\times 10^{-7}$, obtained decay rate limit $20/(A^0$ mass) MeV/s (CL = 90%), which is about 10^{-7} below theory and interpreted as upper limit to $m_{A^0} < 2m_{e^-}$

⁵⁸ JACQUES 80 is a BNL beam dump experiment. First limit above comes from nonobservation of excess neutral-current-type events $[\sigma(\text{production})\sigma(\text{interactaction}) < 7. \times 10^{-68}]$ cm⁴, CL = 90%]. Second limit is from nonobservation of axion decays into 2γ 's or e^+e^- , and for axion mass a few MeV. 59 SOUKAS 80 at BNL observed no excess of neutral-current-type events in beam dump.

60 BECHIS 79 looked for the axion production in low energy electron Bremsstrahlung and the subsequent decay into either 2γ or e^+e^- . No signal found. CL = 90% limits for model parameter(s) are given.

61 COTEUS 79 is a beam dump experiment at BNL.

62 DISHAW 79 is a calorimetric experiment and looks for low energy tail of energy distri-

butions due to energy lost to weakly interacting particles. 63 BELLOTTI 78 first value comes from search for 40 \rightarrow $^{e+}e^-$. Second value comes from search for 40 \rightarrow $^{e+}e^-$. For any mass satisfying this,

limit is above value $\times (\text{mass}^{-4})$. Third value uses data of PL 60B 401 and quotes $\sigma(\text{production})\sigma(\text{interaction}) < 10^{-67} \text{ cm}^4.$

64 BOSETTI 78B quotes $\sigma(\text{production})\sigma(\text{interaction}) < 2. \times 10^{-67} \text{ cm}^4$.

65 DONNELLY 78 examines data from reactor neutrino experiments of REINES 76 and GURR 74 as well as SLAC beam dump experiment. Evidence is negative.

66 MICELMACHER 78 finds no evidence of axion existence in reactor experiments of REINES 76 and GURR 74. (See reference under DONNELLY 78 below).
67 VYSOTSKII 78 derived lower limit for the axion mass 25 keV from luminosity of the sun and 200 keV from red supergiants.

A⁰ (Axion) Searches in Reactor Experiments

DOCUMENT ID TECN COMMENT ● ● • We do not use the following data for averages, fits, limits, etc. ● ● 95 CNTR Reactor; $A^0 \rightarrow e^+e^-$ ⁶⁸ ALTMANN 69 KETOV Reactor, $A^0 \rightarrow \gamma \gamma$ 86 SPEC 86 SPEC Reactor; $A^0 \rightarrow \gamma \gamma$ ⁷⁰ косн 71 DATAR 82 CNTR Light water reactor 72 VUILLEUMIER 81 CNTR Reactor, $A^0 \rightarrow 2\gamma$

- 68 ALTMANN 95 looked for A^0 decaying into e^+e^- from the Bugey 5 nuclear reactor. They obtain an upper limit on the A^0 production rate of $\omega(A^0)/\omega(\gamma) \times B(A^0)$ e+e-> $(10^{-16} \text{ for } m_{A^0} = 1.5 \text{ MeV}$ at 90% CL. The limit is weaker for heavier A^0 . In the case of a standard axion, this limit excludes a mass in the range $2m_e < m_{A^0} < 4.8$ MeV at 90% CL. See Fig. 5 of their paper for exclusion limits of axion-like resonances Z^0 in the (m_{X^0}, f_{X^0}) plane.
- 69 KETOV 86 searched for A^{0} at the Rovno nuclear power plant. They found an upper limit on the A^0 production probability of 0.8 [100 keV/ m_{A^0}]⁶ \times 10⁻⁶ per fission. In the standard axion model, this corresponds to $m_{A^0}~>$ 150 keV. Not valid for $m_{A^0}~\gtrsim$
- 70 $^{\rm I}$ MeV. 70 $^{\rm I}$ MeV. 70 $^{\rm I}$ MeV. 86 searched for $A^0 \to \gamma \gamma$ at nuclear power reactor Biblis A. They found an upper limit on the A^0 production rate of $\omega(A^0)/\omega(\gamma(M1)) < 1.5 \times 10^{-10}$ (CL=95%). Standard axion with $m_{A^0} = 250$ keV gives 10^{-5} for the ratio. Not valid for $m_{A^0} > 1022$

- 71 DATAR 82 looked for ${\it A}^0
 ightarrow 2\gamma$ in neutron capture (${\it np}
 ightarrow {\it d} {\it A}^0$) at Tarapur 500 MW reactor. Sensitive to sum of I=0 and I=1 amplitudes. With ZEHNDER 81 [(I=0)](I=1)] result, assert nonexistence of standard A^0 .
- 72 VUILLEUMIER 81 is at Grenoble reactor. Set limit m_{A^0} <280 keV.

A^0 (Axion) and Other Light Boson (X^0) Searches in Nuclear Transitions

	for branching ra	itio.				
VALUE	CL% EVTS		DOCUMENT ID		TECN	COMMENT
• • • We do not				es, fits	s, limits,	etc. • • •
$< 5.5 \times 10^{-1}$	0 95	73	³ TSUNODA	95	CNTR	²⁵² Cf fission, $A^0 \rightarrow ee$
$< 1.2 \times 10^{-6}$	95	74	[‡] MINOWA	93	CNTR	139 La* \rightarrow 139 La 0
$< 2 \times 10^{-4}$	90	75	HICKS	92	CNTR	35 S decay, $A^0 \rightarrow \gamma \gamma$
$< 1.5 \times 10^{-9}$	95	76	ASANUMA	90	CNTR	²⁴¹ Am decay
<(0.4-10) × 10 ⁻¹	3 ₉₅	77	DEBOER	90	CNTR	$^{8}\text{Be}^{*} \rightarrow ^{8}\text{Be}A^{0}$,
<(0.2–1) × 10 ⁻³	90	78	BINI	89	CNTR	$16_{O^*}^{A^0} \rightarrow e^+e^-$ $X^0 \rightarrow e^+e^-$
		79	AVIGNONE	88	CNTR	$Cu^* \rightarrow CuA^0 (A^0 \rightarrow 2\gamma, A^0 e \rightarrow \gamma e,$
< 1.5 × 10 ⁻⁴	90	80	DATAR	88	CNTR	$\begin{array}{c} A^0 Z \rightarrow \gamma Z) \\ 12_{C^*} \rightarrow 12_{C} A^0 \end{array}$
$< 5 \times 10^{-3}$	90	81	DEBOER	880	CNTR	$16_{O^*}^{A^0} \rightarrow e^+e^-$ $16_{O^*}^{A^0} \rightarrow 16_{O}X^0$, $X^0 \rightarrow e^+e^-$
$< 3.4 \times 10^{-5}$	95	82	DOEHNER	88	SPEC	$^{2}\text{H}^{*}$. $A^{0} \rightarrow e^{+}e^{-}$
$< 4 \times 10^{-4}$		83	SAVAGE	88	CNTR	Nuclear decay (isovec- tor)
$< 3 \times 10^{-3}$	95	83	SAVAGE	88	CNTR	Nuclear decay (isoscalar)
< 0.106	90	84	HALLIN	86	SPEC	⁶ Li isovector decay
<10.8	90	84	HALLIN	86	SPEC	¹⁰ B isoscalar decays
< 2.2	90	84	HALLIN	86	SPEC	¹⁴ N isoscalar decays
$< 4 \times 10^{-4}$	90 0	85	SAVAGE	86в	CNTR	14 _N *
		86	ANANEV	85	CNTR	Li^* , deut* $A^0 \rightarrow 2\gamma$
			CAVAIGNAC	83	CNTR	97 Nb*, deut* transition $^{0}_{A^0 \rightarrow 2\gamma}$
		88	ALEKSEEV	82B	CNTR	Li*, deut* transition $A^0 \rightarrow 2\gamma$
			LEHMANN	82	CNTR	$Cu^* \rightarrow CuA^0$ $(A^0 \rightarrow 2\gamma)$
	0		ZEHNDER	82	CNTR	Li*, Nb* decay, n-capt.
	0		ZEHNDER	81	CNTR	$Ba^* \rightarrow BaA^0$ $(A^0 \rightarrow 2\gamma)$
		92	CALAPRICE	79		Carbon
70						

- 73 TSUNODA 95 looked for axion emission when ²⁵²Cf undergoes a spontaneous fission, with the axion decaying into $e^+\,e^-$. The bound is for $m_{\mbox{$A^0$}}{=}$ 40 MeV. It improves to $\rm 2.5 \times 10^{-5}$ for $m_{A0}{=}200$ MeV.
- 74 MINOWA 93 studied chain process, 139 Ce \rightarrow 139 La* by electron capture and M1 transition of $^{139}\text{La}^*$ to the ground state. It does not assume decay modes of A^0 . The bound applies for $m_{A^{\scriptsize 0}} < 166$ keV.
- $^{75}\,\mathrm{HICKS}$ 92 bound is applicable for $\tau_{X^0}~<4\times10^{-11}$ sec.
- 76 The ASANUMA 90 limit is for the branching fraction of X^0 emission per $^{241}{\rm Am}\,\alpha$ decay and valid for $\tau_{X^0}~<~3\times 10^{-11}~{\rm s}.$
- ⁷⁷The DEBOER 90 limit is for the branching ratio 8 Be* (18.15 MeV, $^{1+}$) \rightarrow 8 Be 4 0, $A^0 \rightarrow e^+e^-$ for the mass range $m_{A^0} = 4$ –15 MeV.
- ⁷⁸ The BINI 89 limit is for the branching fraction of 16 O* (6.05 MeV, $^{0+}$) \rightarrow 16 O 0 , $X^0
 ightarrow e^+e^-$ for $m_X=$ 1.5–3.1 MeV. $au_{X^0} \lesssim 10^{-11}\,\mathrm{s}$ is assumed. The spin-parity
- of X is restricted to 0^+ or 1^- .

 79 AVIGNONE 88 looked for the 1115 keV transition $C^* \to CuA^0$, either from $A^0 \to 2\gamma$ in-flight decay or from the secondary A^0 interactions by Compton and by Primakoff processes. Limits for axion parameters are obtained for $m_{A^0} < 1.1$ MeV.
- ⁸⁰ DATAR 88 rule out light pseudoscalar particle emission through its decay $A^0 \rightarrow e^+e^-$ in the mass range 1.02–2.5 MeV and lifetime range 10^{-13} – 10^{-8} s. The above limit is for $\tau=5\times 10^{-13}$ s and m=1.7 MeV; see the paper for the τ -m dependence of the
- ⁸¹ The limit is for the branching fraction of $^{16}O^*(6.05 \text{ MeV}, 0^+) \rightarrow ^{16}OX^0, X^0 \rightarrow$ $e^+\,e^-$ against internal pair conversion for $m_{\chi^0}=$ 1.7 MeV and $\tau_{\chi^0}~<~10^{-11}\,{\rm s}.$ Similar limits are obtained for $m_{\chi^0}=1.3$ –3.2 MeV. The spin parity of χ^0 must be either 0+ or 1-. The limit at 1.7 MeV is translated into a limit for the x^0 -nucleon coupling constant: $g_{\chi 0\,NN}^2/4\pi~<~2.3\times10^{-9}$.
- ⁸² The DOEHNER 88 limit is for $m_{A^0}=1.7$ MeV, $au(A^0)<10^{-10}$ s. Limits less than
- $^{A^0}$ are obtained for $m_{A^0}=1.2$ –2.2 MeV. 83 SAVAGE 88 looked for A^0 that decays into $e^+\,e^-$ in the decay of the 9.17 MeV $J^P=2^+$ state in 14 N, 17.64 MeV state $J^P=1^+$ in 8 Be, and the 18.15 MeV state $J^P=1^+$ in 8 Be. This experiment constrains the isovector coupling of A^0 to hadrons, if m_{A^0} = (1.1 \rightarrow 2.2) MeV and the isoscalar coupling of A^0 to hadrons, if $m_{A^0} = (1.1)^{-1}$ 2.6) MeV. Both limits are valid only if $\tau({\it A}^0) \lesssim 1 \times 10^{-11}$ s.
- 84 Limits are for $\Gamma(A^0(1.8~{\rm MeV}))/\Gamma(\pi{\rm M1})$; i.e., for 1.8 MeV axion emission normalized to the rate for internal emission of e^+e^- pairs. Valid for au_{A^0} $< 2 imes 10^{-11} \mathrm{s}.$ $^6 ext{Li}$ isovector decay data strongly disfavor PECCEI 86 model I, whereas the ^{10}B and ^{14}N isoscalar decay data strongly reject PECCEI 86 model II and III.

Axions (A^0) and Other Very Light Bosons

- 85 SAVAGE 86B looked for A^0 that decays into $e^+\,e^-$ in the decay of the 9.17 MeV $J^P=$ 2+ state in 14 N. Limit on the branching fraction is valid if $\tau_{A^0}\lesssim$ 1. \times 10 $^{-11}{\rm s}$ for m_{A^0}
- = (1.1–1.7) MeV. This experiment constrains the iso-vector coupling of A^0 to hadrons. 86 ANANEV 85 with IBR-2 pulsed reactor exclude standard A^0 at CL = 95% masses below 470 keV (Li* decay) and below $2m_e$ for deuteron* decay.
- 87 CAVAIGNAC 83 at Bugey reactor exclude axion at any $m_{\rm 97}{\rm Nb^*decay}$ and axion with $m_{\ensuremath{A^0}}$ between 275 and 288 keV (deuteron* decay).
- 88 ALEKSEEV 82 with IBR-2 pulsed reactor exclude standard ${\it A}^{0}$ at CL = 95% mass-ranges $m_{A^{\scriptsize 0}}~<\!\!400$ keV (Li* decay) and 330 keV $<\!\!m_{A^{\scriptsize 0}}~<\!\!2.2$ MeV. (deuteron* decay).
- ⁸⁹ LEHMANN 82 obtained $A^0 \rightarrow 2\gamma$ rate $< 6.2 \times 10^{-5}/s$ (CL = 95%) excluding m_{A^0} between 100 and 1000 keV.

 90 ZEHNDER 82 used Goesgen 2.8GW light-water reactor to check A^0 production. No
- 2γ peak in Li*, Nb* decay (both single p transition) nor in n capture (combined with previous Ba* negative result) rules out standard A^0 . Set limit m_{A^0} <60 keV for any
- 91 ZHNDER 81 looked for Ba* \rightarrow A^0 Ba transition with $A^0 \rightarrow 2\gamma$. Obtained 2γ coincidence rate $< 2.2 \times 10^{-5}/s$ (CL = 95%) excluding $m_{A^0} >$ 160 keV (or 200 keV depending on Higgs mixing). However, see BARROSO 81.
- 92 CALAPRICE 79 saw no axion emission from excited states of carbon. Sensitive to axion mass between 1 and 15 MeV.

A⁰ (Axion) Limits from Its Electron Coupling

Limits are for $\tau(A^0 \rightarrow e^+e^-)$

VALUE (s)	CL%	DOCUMENT ID		TECN	COMMENT
• • We do not use the follow	ving da	ta for averages, fits	, limi	ts, etc.	• •
none $4 \times 10^{-16} - 4.5 \times 10^{-12}$	90	⁹³ BROSS	91	BDMP	$e \stackrel{N}{\rightarrow} e \stackrel{A}{\rightarrow} N$ $(\stackrel{A}{\rightarrow} e e)$
		⁹⁴ GUO	90	BDMP	$e \stackrel{N}{\rightarrow} e \stackrel{A}{\rightarrow} N$ $(\stackrel{A}{\rightarrow} e e)$
		⁹⁵ BJORKEN			$A \rightarrow e^+e^- \text{ or } 2\gamma$
		⁹⁶ BLINOV	88	MD1	$\begin{array}{ccc} e e \rightarrow & e e A^0 \\ (A^0 \rightarrow & e e) \end{array}$
none $1 \times 10^{-14} - 1 \times 10^{-10}$	90	⁹⁷ RIORDAN	87	BDMP	$\begin{array}{ccc} (A & \rightarrow & ee) \\ eN & \rightarrow & eA^0 N \\ (A^0 & \rightarrow & ee) \end{array}$
none $1 \times 10^{-14} - 1 \times 10^{-11}$	90	⁹⁸ BROWN	86	BDMP	$e \stackrel{N}{\rightarrow} e \stackrel{A^0}{\rightarrow} N$ $(\stackrel{A^0}{\rightarrow} e e)$
none $6 \times 10^{-14} - 9 \times 10^{-11}$	95	⁹⁹ DAVIER	86	BDMP	$e \stackrel{N}{\rightarrow} e \stackrel{A^0}{\rightarrow} N$ $\stackrel{(A^0}{\rightarrow} e e)$
none $3 \times 10^{-13} - 1 \times 10^{-7}$	90	¹⁰⁰ KONAKA	86	BDMP	$e N \rightarrow e A^0 N$ $(A^0 \rightarrow e e)$

- 93 The listed BROSS 91 limit is for $m_{A^0}=1.14$ MeV. B(A $^0\to e^+e^-)=1$ assumed. Excluded domain in the $\tau_{A^0}-m_{A^0}$ plane extends up to $m_{A^0}\approx 7$ MeV (see Fig. 5). Combining with electron g-2 constraint, axions coupling only to $e^+\,e^-$ ruled out for $m_{A^0} <$ 4.8 MeV (90%CL).
- $^{94}\,\mathrm{GUO}$ 90 use the same apparatus as BROWN 86 and improve the previous limit in the shorter lifetime region. Combined with g-2 constraint, axions coupling only to $e^+\,e^-$ are ruled out for $m_{A^0}~<~2.7$ MeV (90% CL).
- 95 BJORKEN 88 reports limits on axion parameters (f_A , m_A , au_A) for $m_{A^0} < 200$ MeV from electron beam-dump experiment with production via Primakoff photoproduction, bremsstrahlung from electrons, and resonant annihilation of positrons on atomic elec-
- $_{96}^{6}$ BLINOV 88 assume zero spin, m=1.8 MeV and lifetime $<5 imes 10^{-12}\,\mathrm{s}$ and find $\Gamma(A^0 \rightarrow \gamma \gamma) B(A^0 \rightarrow e^+ e^-) < 2 \text{ eV (CL=90\%)}.$
- 97 Assumes $A^0\gamma\gamma$ coupling is small and hence Primakoff production is small. Their figure 2 shows limits on axions for $m_{A^0}<15$ MeV.
- 98 Uses electrons in hadronic showers from an incident 800 GeV proton beam. Limits for $_{A0}$ < 15 MeV are shown in their figure 3.
- $^{99}\,m_{A^0}=$ 1.8 MeV assumed. The excluded domain in the $au_{A^0}-m_{A^0}$ plane extends up to $m_{A^0}^{A^0} \approx 14$ MeV, see their figure 4.
- 100 The limits are obtained from their figure 3. Also given is the limit on the $A^0\gamma\gamma-A^0e^+e^-$ coupling plane by assuming Primakoff production.

Search for A⁰ (Axion) Resonance in Bhabha Scattering

The limit is for $\Gamma(A^0)[B(A^0 \rightarrow e^+e^-)]^2$.

VALU	E (10 ⁻³ eV)	CL%		DOCUMENT ID		TECN	COMMENT
• • •	• We do not use the	followi	ng d	ata for averages	, fits	, limits,	etc. • • •
<	1.3	97		HALLIN	92	CNTR	$m_{\Delta^0} = 1.75 1.88 \text{ MeV}$
none	0.0016-0.47	90	102	HENDERSON	92c	CNTR	$m_{A0}^{7} = 1.5 - 1.86 \text{ MeV}$
<	2.0	90	103	WU			$m_{A0}^{2} = 1.56-1.86 \text{ MeV}$
<	0.013	95		TSERTOS	91	CNTR	$m_{\Delta^0} = 1.832 \text{ MeV}$
none	0.19-3.3	95	104	WIDMANN			$m_{\Delta 0} = 1.78 - 1.92 \text{ MeV}$
<	5	97		BAUER	90	CNTR	$m_{\Delta^0} = 1.832 \text{ MeV}$
none	0.09-1.5	95	105	JUDGE	90	CNTR	$m_{\Delta^0} = 1.832 \text{ MeV},$
<	1.9	97		TSERTOS	89	CNTR	elastic $m_{\Delta 0} = 1.82 \text{ MeV}$
<(10	-40)	97		TSERTOS	89	CNTR	$m_{\Delta 0} = 1.51 - 1.65 \text{ MeV}$
<(1-	2.5)	97	106	TSERTOS			$m_{\Delta^0} = 1.80 - 1.86 \text{ MeV}$

<	31	95	LORENZ	88	CNTR	$m_{\Delta^0} = 1.646 \text{ MeV}$
<	94	95	LORENZ	88	CNTR	$m_{A^0} = 1.726 \text{ MeV}$
<	23	95	LORENZ			$m_{A0} = 1.782 \text{ MeV}$
<	19	95	LORENZ	88	CNTR	$m_{A0} = 1.837 \text{ MeV}$
<	3.8	97	¹⁰⁷ TSERTOS	88	CNTR	$m_{A^0}^A = 1.832 \text{ MeV}$
			108 VANKLINKEN	88	CNTR	A-
			¹⁰⁹ MAIER	87	CNTR	
<2	500	90				$m_{A0} = 1.8 \text{ MeV}$
			110 VONWIMMER			Α-

- $^{101}\,\text{HALLIN}$ 92 quote limits on lifetime, 8 \times 10 $^{-14}$ –5 \times 10 $^{-13}$ sec depending on mass, assuming B(A^0 $\to e^+e^-)=$ 100%. They say that TSERTOS 91 overstated their sensitivity by a factor of 3.
- 102 HENDERSON 92C exclude axion with lifetime τ_{A0} =1.4 \times 10 $^{-12}$ –4.0 \times 10 $^{-10}$ s, assuming B($A^0\to e^+e^-$)=100%. HENDERSON 92c also exclude a vector boson with au=1.4 × 10^{-12} –6.0 × 10^{-10} s.
- 103 WU 92 quote limits on lifetime > 3.3 × 10⁻¹³ s assuming B($A^0 \rightarrow e^+e^-$)=100%. They say that TSERTOS 89 overestimate the limit by a factor of $\pi/2$. WU 92 also quote a bound for vector boson, $\tau > 8.2 \times 10^{-13}$ s.
- ¹⁰⁴WIDMANN 91 bound applies exclusively to the case B($A^0 \rightarrow e^+e^-$)=1, since the detection efficiency varies substantially as $\Gamma(A^0)_{\text{total}}$ changes. See their Fig. 6.
- 105 JUDGE 90 excludes an elastic pseudoscalar e^+e^- resonance for 4.5×10^{-13} s $< \tau(A^0)$ $<7.5\times10^{-12}\,\mathrm{s}$ (95% CL) at $m_{A^0}=1.832$ MeV. Comparable limits can be set for $m_{A^0} = 1.776 - 1.856 \text{ MeV}.$
- 106 See also TSERTOS 88B in references.

 107 The upper limit listed in TSERTOS 88 is too large by a factor of 4. See TSERTOS 88B, footnote 3.
- 108 VANKLINKEN 88 looked for relatively long-lived resonance ($au=10^{-10}$ – 10^{-12} s). The
- sensitivity is not sufficient to exclude such a narrow resonance. 109 MAIER 87 obtained limits $R\Gamma\lesssim 60$ eV (100 eV) at $m_{A0}\simeq 1.64$ MeV (1.83 MeV) for energy resolution $\Delta E_{\rm cm}\simeq 3$ keV, where R is the resonance cross section normalized to that of Bhabha scattering, and $\Gamma=\Gamma_{e\,e}^2/\Gamma_{total}.$ For a discussion implying that $\Delta E_{\rm cm} \simeq 10$ keV, see TSERTOS 89.
- 110 VONWIMMERSPERG 87 measured Bhabha scattering for $E_{\rm cm}=1.37$ –1.86 MeV and found a possible peak at 1.73 with $\int \sigma dE_{\rm cm}=14.5\pm6.8$ keV-b. For a comment and a reply, see VANKLINKEN 88B and VONWIMMERSPERG 88. Also see CONNELL 88.

Search for A^0 (Axion) Resonance in $e^+e^- ightarrow \gamma \gamma$

The limit is for $\Gamma(A^0 \rightarrow e^+e^-) \cdot \Gamma(A^0 \rightarrow \gamma \gamma) / \Gamma_{total}$

VALUE (10 ⁻³ eV)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not u	se the follow	ving data for averag	es, fit	s, Iimits,	etc. • • •
< 0.18	95	VO	94	CNTR	$m_{A0} = 1.1 \text{ MeV}$
< 1.5	95	VO	94	CNTR	m ₄₀ =1.4 MeV
<12	95	VO	94	CNTR	m _A 0=1.7 MeV
< 6.6	95	¹¹¹ TRZASKA			$m_{A0}^{7} = 1.8 \text{ MeV}$
< 4.4	95	WIDMANN	91	CNTR	$m_{\Delta 0} = 1.78 - 1.92 \text{ MeV}$
		¹¹² FOX	89	CNTR	,,
< 0.11	95	113 MINOWA	89	CNTR	$m_{\Delta^0} = 1.062 \text{ MeV}$
<33	97	CONNELL	88	CNTR	$m_{\Delta 0} = 1.580 \text{ MeV}$
<42	97	CONNELL	88	CNTR	$m_{\Delta^0} = 1.642 \text{ MeV}$
<73	97	CONNELL	88		$m_{A0}^{7} = 1.782 \text{ MeV}$
< 79	97	CONNELL	88	CNTR	$m_{A0} = 1.832 \text{ MeV}$

- $^{111}\,\mathrm{TRZASKA}$ 91 also give limits in the range (6.6–30) \times 10 $^{-3}\,\mathrm{eV}$ (95%CL) for m_{A0}
- $_{A^0}$ 1.6–2.0 MeV. 112 FOX 89 measured positron annihilation with an electron in the source material into two photons and found no signal at 1.062 MeV ($<9\times10^{-5}$ of two-photon annihilation at
- 113 Similar limits are obtained for $m_{A^0}=1.045$ –1.085 MeV.

Search for X^0 (Light Boson) Resonance in $e^+e^- \rightarrow \gamma\gamma\gamma$

The limit is for $\Gamma(X^0 \to e^+e^-) \cdot \Gamma(X^0 \to \gamma \gamma \gamma) / \Gamma_{\text{total}}$. C invariance forbids spin-0 X^0 coupling to both e^+e^- and $\gamma\gamma\gamma$.

VALUE (10 ⁻³ eV)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use	the follow	ing data for averag	es, fits	, limits,	etc. • • •
< 0.2	95	¹¹⁴ VO	94	CNTR	m _{×0} =1.1-1.9 MeV
< 1.0	95	¹¹⁵ VO			$m_{\chi^0}^{\lambda}=1.1 \text{ MeV}$
< 2.5	95	¹¹⁵ VO	94	CNTR	$m_{\chi^0}^{\uparrow}=1.4 \text{ MeV}$
<120	95	¹¹⁵ VO			m _{×0} =1.7 MeV
< 3.8	95	¹¹⁶ SKALSEY	92	CNTR	$m_{\chi^0} = 1.5 \text{ MeV}$

- 114 VO 94 looked for $X^0 \to \gamma \gamma \gamma$ decaying at rest. The precise limits depend on m_{X^0} . See Fig. 2(b) in paper.
- 115 VO 94 looked for $X^0 \rightarrow \gamma \gamma \gamma$ decaying in flight.
- $^{116}\,\mathrm{SKALSEY}$ 92 also give limits 4.3 for $m_{\chi0}=$ 1.54 and 7.5 for 1.64 MeV. The spin of X^{0}

Gauge & Higgs Boson Particle Listings Axions (A⁰) and Other Very Light Bosons

Light Boson (X^0) Search in Nonresonant e^+e^- Annihilation at Rest

Limits are for the ratio of $n\gamma + X^0$ production relative to $\gamma\gamma$.

VALUE (units 10 ⁻⁶)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the	following d	lata for averages,	fits,	limits,	etc. • • •
< 4			95	CNTR	γX^0
<40				RVUE	
< 0.18					$\gamma \gamma X^0, X^0 \rightarrow \gamma \gamma$
< 0.26					$\gamma \gamma X^0, X^0 \rightarrow \gamma \gamma$
< 0.33	90 121	ADACHI	94	CNTR	γX^0 , $X^0 \rightarrow \gamma \gamma \gamma$

- $^{117} {\sf SKALSEY}$ 95 looked for a monochromatic γ without an accompanying γ in $e^+ \, e^$ annihilation. The bound applies for scalar and vector X^0 with C=-1 and $m_{X^0}=$ 100–1000 keV. 118 SKALSEY 95 reinterpreted the bound on γA^0 decay of o-Ps by ASAI 91 where 3% of
- delayed annihilations are not from 3S_1 states. The bound applies for scalar and vector X^0 with C=-1 and $m_{X^0}=0$ -800 keV.
- 119 ADACHI 94 looked for a peak in the $\gamma\gamma$ invariant mass distribution in $\gamma\gamma\gamma\gamma$ production from $e^+\,e^-$ annihilation. The bound applies for $m_{\chi^0}=$ 70–800 keV.
- $^{120}\,\mathrm{ADACHI}$ 94 looked for a peak in the missing-mass mass distribution in $\gamma\gamma$ channel, using $\gamma\gamma\gamma\gamma$ production from e^+e^- annihilation. The bound applies for m_{χ^0} <800 keV.
- 121 ADACHI 94 looked for a peak in the missing mass distribution in $\gamma\gamma\gamma$ channel, using $\gamma\gamma\gamma\gamma$ production from e^+e^- annihilation. The bound applies for $m_{\chi0}=$ 200–900

Searches for Goldstone Bosons (X⁰)
(Including Horizontal Bosons and Majorons.) Limits are for branching ratios. VALUE CL% EVTS DOCUMENT ID TECN COMMENT

• • • We do not use the following data for averages, fits, limits, etc. • • •

				,	,,	
			¹²² BOBRAKOV	91		Electron quasi-magnetic
$< 3.3 \times 10^{-2}$	95		¹²³ ALBRECHT	90E	ARG	interaction $ au o \mu X^0$. Familon
$< 1.8 \times 10^{-2}$	95		123 ALBRECHT	90E	ARG	$\tau \rightarrow eX^0$. Familon
$<6.4 \times 10^{-9}$	90		124 ATIYA	90	B787	$K^+ \rightarrow \pi^+ X^0$.
<1.1 × 10 ⁻⁹	90		125 BOLTON	88	свох	$\mu^{+} \xrightarrow{\text{Familon}} e^{+} \gamma X^{0}$.
			126 CHANDA	88	ASTR	Familon Sun, Majoron
			¹²⁷ CHOI	88	ASTR	Majoron, SN 1987A
$< 5 \times 10^{-6}$	90		¹²⁸ PICCIOTTO	88	CNTR	$\pi \to e \nu X^0$, Majoron
$< 1.3 \times 10^{-9}$	90		¹²⁹ GOLDMAN	87	CNTR	$\mu \rightarrow e \gamma X^0$. Familion
$< 3 \times 10^{-4}$	90		¹³⁰ BRYMAN	86B	RVUE	$\mu \rightarrow e X^0$. Familon
$<1. \times 10^{-10}$	90	0	¹³¹ EICHLER	86	SPEC	$\mu^+ \rightarrow e^+ X^0$. Familon
$< 2.6 \times 10^{-6}$	90		132 JODIDIO	86	SPEC	$\mu^+ \rightarrow e^+ X^0$. Familon
			133 BALTRUSAIT	.85	MRK3	$\tau \to \ell X^0$. Familon
			134 DICUS	83	COSM	$\nu(\text{hvy}) \rightarrow \nu(\text{light})X^0$

- $^{122}\,\textsc{BOBRAKOV}$ 91 searched for anomalous magnetic interactions between polarized electrons expected from the exchange of a massless pseudoscalar boson (arion). A limit $x_a^2 < 2 \times 10^{-4}$ (95%CL) is found for the effective anomalous magneton parametrized as $x_e (G_F/8\pi\sqrt{2})^{1/2}$
- 123 ALBRECHT 90E limits are for B($au o \ell X^0$)/B($au o \ell
 u \overline{
 u}$). Valid for $m_{X^0} < 100$
- MeV. The limits rise to 7.1% (for μ), 5.0% (for e) for $m_{\chi 0}=500$ MeV. 124 ATIYA 90 limit is for $m_{\chi 0}=0$. The limit B $<1\times10^{-8}$ holds for $m_{\chi 0}=0$. For the reduction of the limit due to finite lifetime of X^0 , see their Fig. 3.
- 125 BOLTON 88 limit corresponds to $F>3.1\times10^9$ GeV, which does not depend on the chirality property of the coupling.
- 126 CHANDA 88 find $v_T~<$ 10 MeV for the weak-triplet Higgs vev. in Gelmini-Roncadelli model, and $v_S > 5.8 \times 10^6$ GeV in the singlet Majoron model.
- 127 CHOI 88 used the observed neutrino flux from the supernova SN 1987A to exclude the neutrino Majoron Yukawa coupling h in the range $2\times 10^{-5} < h < 3\times 10^{-4}$ for the interaction $L_{\rm int}=\frac{1}{2}ih\overline{\psi}_{\nu}^{c}\gamma_{5}\psi_{\nu}\phi_{\rm X}$. For several families of neutrinos, the limit applies for
- 128 PICCIOTTC 88 limit applies when $m_{\chi^0}~<$ 55 MeV and $\tau_{\chi^0}~>$ 2ns, and it decreases to 4×10^{-7} at $m_{\chi 0} = 125$ MeV, beyond which no limit is obtained.
- 129 GOLDMAN 87 limit corresponds to $F>2.9\times10^9$ GeV for the family symmetry breaking scale from the Lagrangian $L_{\rm int}=(1/F)\overline{\psi}_{\mu}\gamma^{\mu}$ $(a+b\gamma_5)$ $\psi_e\partial_{\mu}\phi_{\chi^0}$ with $a^2+b^2=1$. This is not as sensitive as the limit $F>9.9\times10^9$ GeV derived from the search for $\mu^+\to$ $^+$ χ^0 by JODIDIO 86, but does not depend on the chirality property of the coupling.
- 130 Limits are for $\Gamma(\mu \to e X^0)/\Gamma(\mu \to e \nu \overline{\nu})$. Valid when $m_{X^0} =$ 0–93.4, 98.1–103.5
- 131 EICHLER 86 looked for $\mu^+ o e^+ X^0$ followed by $X^0 o e^+ e^-$. Limits on the branching fraction depend on the mass and and lifetime of X^0 . The quoted limits are valid when $\tau_{X^0} \lesssim 3 \times 10^{-10}$ s if the decays are kinematically allowed.
- 132 JODIDIO 86 corresponds to $F > 9.9 \times 10^9$ GeV for the family symmetry breaking scale with the parity-conserving effective Lagrangian $L_{\rm int}=(1/\emph{F})~\overline{\psi}_{\mu}\gamma^{\mu}\psi_{e}\partial^{\mu}\phi_{\chi^{0}}.$
- 133 BALTRUSAITIS 85 search for light Goldstone boson(X^0) of broken U(1). CL = 95%
- SALTRUSAITIS 85 search for light Goldstone boson(X^0) of broken U(1). CL = 95% limits are $B(\tau \to \mu^+ \chi^0)/B(\tau \to \mu^+ \nu \nu)$ <0.125 and $B(\tau \to e^+ \chi^0)/B(\tau \to e^+ \nu \nu)$ <0.04. Inferred limit for the symmetry breaking scale is m > 3000 TeV. 134 The primordial heavy neutrino must decay into ν and familion, f_A , early so that the red-shifted decay products are below critical density, see their table. In addition, $K \to \pi^f f_A$ and $\mu \to e^f f_A$ are unseen. Combining these excludes $m_{\text{heavy}\nu}$ between 5×10^{-5} and 5×10^{-4} MeV (μ decay) and $m_{\text{heavy}\nu}$ between 5×10^{-5} and 0.1 MeV (K-decay).

Majoron Searches in Neutrinoless Double β Decay

imits are for the half-life of neutrinoless $\beta\beta$ decay with a Majoron emission Previous indications for neutrinoless double beta decay with majoron emission have been superseded. No experiment currently claims any such evidence. For a review, see

VALUE (ye	ars)	CL%	DOCUMENT ID		TECN	COMMENT
> 7.2	× 10 ²⁴	90	135 BERNATOW.	92	CNTR	¹²⁸ Te
• • • W	e do not use	the follow	ing data for average	es, fit	s, limits,	etc. • • •
> 1.7	× 10 ²²	90	BECK	93	CNTR	
> 7.9	$\times 10^{20}$	68	¹³⁶ TANAKA	93	SPEC	¹⁰⁰ Mo
> 1.9	$\times 10^{20}$	68	BARABASH	89	CNTR	¹³⁶ Xe
> 1.0	$\times 10^{21}$	90	FISHER	89	CNTR	⁷⁶ Ge
> 3.3	$\times 10^{20}$	90	ALSTON	88	CNTR	100 _{Mo}
(6 ±	$1) \times 10^{20}$		AVIGNONE	87	CNTR	⁷⁶ Ge
> 1.4	× 10 ²¹	90	CALDWELL	87	CNTR	⁷⁶ Ge
> 4.4	$\times 10^{20}$	90	ELLIOTT	87	SPEC	82 _{Se}
> 1.2	$\times 10^{21}$	90	FISHER	87	CNTR	⁷⁶ Ge
			137 VERGADOS	82	CNTR	

 τ^{135} BERNATOWICZ 92 studied double- β decays of τ^{128} Te and τ^{130} Te, and found the ratio τ^{130} Te)/ τ^{128} Te) = $(3.52\pm0.11)\times10^{-4}$ in agreement with relatively stable theoretical predictions. The bound is based on the requirement that Majoron-emitting decay cannot be larger than the observed double-beta rate of τ^{128} Te of $(7.7\pm0.4)\times10^{24}$ year.

We calculated 90% CL limit as $(7.7-1.28\times0.4-7.2)\times10^{24}$. 136 TANAKA 93 also quote limit 5.3 $\times10^{19}$ years on two Majoron emission. 137 VERGADOS 82 sets limit $g_H < 4\times10^{-3}$ for (dimensionless) lepton-number violating coupling, g_H , of scalar boson (Majoron) to neutrinos, from analysis of data on double β decay of ^{48}Ca .

INVISIBLE A^0 (AXION)

As discussed in the note on "Axions and Other Light Bosons," the so-called invisible axion models decouple the scale of the Peccei-Quinn symmetry breaking from the electroweak scale, and avoid the constraints from negative accelerator searches for the axion. Two classes of models are discussed commonly in the literature. One introduces new heavy quarks that carry Peccei-Quinn charge while the usual quarks and leptons do not (KSVZ axions or "hadronic" axions) [1]. The other does not need additional quarks but requires two Higgs doublets, and all quarks and leptons carry Peccei-Quinn charges (DFSZ axions or "GUT" axions) [2]. All models contain at least one electroweak singlet scalar boson that acquires an expectation value and breaks the Peccei-Quinn symmetry.

The common property of all axion models is the effective coupling

$$\mathcal{L} = \left(\theta_{\text{eff}} - \frac{\phi_A}{f_A}\right) \frac{g_s^2}{32\pi^2} F^{\mu\nu a} \widetilde{F}^a_{\mu\nu} , \qquad (1)$$

where ϕ_A is the axion field, θ_{eff} is the effective QCD vacuum angle after the diagonalization of the quark masses, g_s the QCD coupling constant, $F^{\mu\nu a}$ the gluon field strength and $\widetilde{F}^a_{\mu\nu}=$ $\frac{1}{2}\epsilon_{\mu\nu\rho\sigma} F^{\rho\sigma a}$. It is often convenient to define the axion decay constant f_A with this Lagrangian [3]. The QCD instanton effect induces a potential for ϕ_A whose minimum is at $\phi_A = \theta_{eff} f_A$, cancelling θ_{eff} and solving the strong CP problem. The mass of the axion is related to f_A by

$$m_A = 0.62 \times 10^{-3} \text{eV} \times (10^{10} \text{GeV}/f_A) \ .$$
 (2)

The constraints on the axion mass from various experiments, astrophysics, and cosmology are derived from the interactions of the axion with either photons, electrons, or nucleons. We use the following notation for their coupling constants $G_{A\gamma\gamma}$ and

$$\mathcal{L}_{A\gamma\gamma} = -\frac{1}{4} G_{A\gamma\gamma} \phi_A F^{\mu\nu} \widetilde{F}_{\mu\nu} = G_{A\gamma\gamma} \phi_A \mathbf{E} \cdot \mathbf{B} , \qquad (3)$$

$$\mathcal{L}_{Aff} = G_{Aff} \, \partial_{\mu} \phi_A \, \overline{f} \gamma^{\mu} \gamma_5 \, f \, , \tag{4}$$

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for f = e, p, n. The relations of these coupling constants to f_A (and m_A) are model dependent, and are listed in Table 1.

Table 1: The coupling constants of the axion to the matter particles in DFSZ and KSVZ models, taken from Ref. [5] where the results of Ref. [6] were used. These dimensionless coupling constants are related to those in the Lagrangian by $G_{Aii} = c_i/2f_A$ for $i = \gamma, e, p, n$. The parameter β is an arbitrary angle whose tangent is defined by the ratio between the expectation values of the two Higgs doublets in the DFSZ model. A rational number E/N in the KSVZ model depends on the number of new quarks and their charges. The coupling to nucleons are subject to certain ambiguities in hadronic matrix elements [4] that are not shown here. All entries have small uncertainties from the current quark masses.

	DFSZ	KSVZ
$\overline{c_{\gamma}}$	0.0017	0.0023(E/N - 1.92)
c_e	$(1/3)\cos^2\beta$	0
c_p	$-0.10 - 0.45\cos^2\beta$	-0.39
c_n	$-0.18 + 0.39\cos^2\beta$	+0.04

For illustrative purposes, we depict various constraints on f_A (and m_A) for the case of the KSVZ model in Fig. 1, using only representative constraints. What follows is a brief discussion of each of the constraints shown in the figure. The bounds on the DFSZ axion are similar.

Astrophysics puts a lower bound on f_A , because a small f_A leads to a large coupling of the axion to nucleons, electrons, and photons and thus to a large "exotic" energy-loss rate. In horizontal-branch (HB) stars, the Primakoff process γ + $(^4He, e^-) \rightarrow (^4He, e^-) + A^0$ would be the dominant axionic energy-loss mechanism. It would accelerate the consumption of nuclear fuel and thus shorten the helium-burning lifetime of these stars. The observable number fraction of HB stars in globular clusters would be significantly reduced relative to theoretical expectations unless $G_{A\gamma\gamma} < 0.6 \times 10^{-10} \text{ GeV}^{-1}$ [5]. The duration of the neutrino burst from supernova (SN) 1987A observed at the Kamiokande and IMB detectors was consistent with expectations, while axion emission would have cooled the core and shortened the burst duration [7]. The dominant emission process is axion bremsstrahlung in nucleonnucleon collisions, a process that needs to be calculated in a hot and dense nuclear medium where many-body effects are important. Early calculations overestimated the emission rate to some extent. A more realistic treatment leads to a somewhat diminished limit of about $f_A > 0.6 \times 10^9$ GeV [8], [9], although the treatment of many-body effects in this result is still under study. The cooling argument does not exclude $f_A \lesssim 0.6 \times 10^6$ GeV; in this range of f_A , the axions produced in the SN core are trapped [10]. Still, $f_A \lesssim 0.3 \times 10^6$ GeV is excluded because the trapped axions result in a burst similar to that of the neutrinos and can produce signals in water

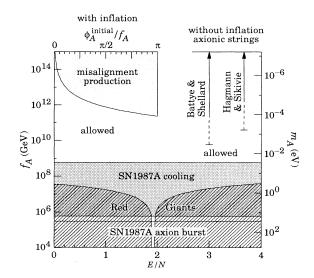


Figure 1: An illustration of the astrophysical and cosmological constraints on the axion decay constant f_A (and equivalently on m_A) in the KSVZ model. The constraint on the DSFZ model is similar except for the small window at $f_A \sim 10^6$ GeV, and one needs inflation. Shaded regions are excluded based on the arguments given in the text, though both sides have large uncertainties. The lower bound on f_A from red giants depends on the parameter E/N. All the other constraints do not. If there is inflation, there is an upper bound on f_A from misalignment production, which depends on the initial value of the axion field $\phi_A^{\rm initial}$ after inflation is over. If there is not, cosmic strings generated by Peccei-Quinn symmetry breaking produce axions, which contribute to the present mass density. Estimates of the resulting mass density vary. Here, upper bounds on f_A from two groups are shown, each of them with rather large ambiguity shown by dashed lines.

Cherenkov detectors [11]. For KSVZ axions with $E/N \approx 2$, there exists an apparent small window between these two SN arguments.

Cosmology usually puts an upper bound on f_A , because the predicted cosmic mass density in axions is proportional to $f_A^{1.175}$. The DFSZ model and the KSVZ model with more than one new quark leads to domain walls that have to be diluted away by inflation. On the other hand, the axion field does not know during inflation where the true minimum of its potential is, and is "misaligned" [12]. It begins a coherent oscillation from its misaligned initial value after the QCD phase transition and contributes to the present energy density [13] as $\Omega_a h^2 \simeq 0.2 (f_A/10^{12} \text{ GeV})^{1.175} (\phi_A^{\text{initial}}/2\pi f_A)^2 \leq 1$ for a small misalignment $\phi_A^{\text{initial}}/f_A \lesssim 1$. The KSVZ model with a single new quark does not produce domain walls and does not need inflation. Without inflation, there are cosmic strings created at

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the time of the Peccei–Quinn symmetry breaking, that emit axions and eventually decay (or collapse). There is an ongoing controversy on the estimate of the relic energy density of the emitted axions [14]. Furthermore, cosmological bounds change if there is additional entropy production [15] or a dissipation of the coherent oscillation into lighter particles [16].

It has been widely argued that a fundmental theory will not possess global symmetries; gravity, for example, is expected to violate them. Global symmetries such as baryon number typically arise as an indirect consequence of gauge symmetries and renormalizability (accidental symmetry). It has been noted [17] that the Peccei-Quinn symmetry, from this perspective, must also arise as an accidental one and must hold to an extraordinary degree of accuracy in order to solve the strong CP problem. See, for example, Ref. [17] for a possible resolution to this problem; string theory also provides sufficiently good symmetries (see for a review, [18]).

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Invisible A⁰ (Axion) MASS LIMITS from Astrophysics and Cosmology

 $v_1=v_2$ is usually assumed ($v_i=$ vacuum expectation values). For a review of these limits, see RAFFELT 90C and TURNER 90. In the comment lines below, D and K refer to DFSZ and KSVZ axion types, discussed in the above minireview. DE(eV) DOCUMENTID TECN COMMENT

VALUE (eV)	DOCUMENT IE	TECN_	COMMENT
• • We do not use the follow	ving data for avera	ges, fits, limits	, etc. • • •
< 0.018	138 RAFFELT	95 ASTR	D, red giant
< 0.010	¹³⁹ ALTHERR	94 ASTR	D, red giants, white dwarfs
< 0.01	WANG	92 ASTR	D, white dwarf
< 0.03	WANG	92C ASTR	D, C-O burning
none 3-8	¹⁴⁰ BERSHADY	91 ASTR	D, K, intergalactic light
<10	¹⁴¹ KIM	91c COSM	
	142 RAFFELT	918 ASTR	D,K, SN 1987A
$< 1 \times 10^{-3}$	143 RESSELL	91 ASTR	K, intergalactic light
none 10 ⁻³ -3	BURROWS	90 ASTR	D,K, SN 1987A
	144 ENGEL	90 ASTR	D,K, SN 1987A
< 0.02	145 RAFFELT	90D ASTR	D, red giant
$< 1 \times 10^{-3}$	¹⁴⁶ BURROWS	89 ASTR	D,K, SN 1987A
$<(1.4-10)\times10^{-3}$	147 ERICSON	89 ASTR	D,K, SN 1987A
< 3.6 × 10 ⁻⁴	148 MAYLE	89 ASTR	D,K, SN 1987A
<12	CHANDA	88 ASTR	D, Sun
$< 1 \times 10^{-3}$	RAFFELT	88 ASTR	D,K, SN 1987A
	149 RAFFELT	88B ASTR	red giant
< 0.07	FRIEMAN	87 ASTR	D, red giant
< 0.7	¹⁵⁰ RAFFELT	87 ASTR	K, red giant
< 2-5	TURNER	87 COSM	K, thermal production
< 0.01	¹⁵¹ DEARBORN	86 ASTR	D, red giant
< 0.06	RAFFELT	86 ASTR	D, red giant
< 0.7	¹⁵² RAFFELT	86 ASTR	K, red giant
< 0.03	RAFFELT	86B ASTR	D, white dwarf
< 1	¹⁵³ KAPLAN	85 ASTR	K, red giant
< 0.003-0.02	IWAMOTO	84 ASTR	D, K, neutron star
$> 1 \times 10^{-5}$	ABBOTT	83 COSM	D,K, mass density of the universe
$> 1 \times 10^{-5}$	DINE	83 COSM	D,K, mass density of the universe
< 0.04	ELLIS	83B ASTR	D, red giant
$> 1 \times 10^{-5}$	PRESKILL	83 COSM	
< 0.1	BARROSO	82 ASTR	D, red giant
< 1	¹⁵⁴ FUKUGITA	82 ASTR	D, stellar cooling
< 0.07	FUKUGITA	82B ASTR	D, red giant
120			

- 138 RAFFELT 95 reexamined the constraints on axion emission from red giants due to the axion-electron coupling. They improve on DEARBORN 86 by taking into proper account degeneracy effects in the bremsstrahlung rate. The limit comes from requiring the red giant core mass at helium ignition not to exceed its standard value by more than 5% (0.025 solar masses).
- 139 ALTHERR 94 bound is on the axion-electron coupling $g_{ae} < 1.5 \times 10^{-13}$, from energy loss via axion emission. 140 BERSHADY 91 searched for a line at wave length from 3100–8300 Å expected from 2 γ
- 140 BERSHADY 91 searched for a line at wave length from 3100–8300 Λ expected from 2γ decays of relic thermal axions in intergalactic light of three rich clusters of galaxies. 141 KIM 91C argues that the bound from the mass density of the universe will change dras-
- 141 KIM 91C argues that the bound from the mass density of the universe will change drastically for the supersymmetric models due to the entropy production of saxion (scalar component in the axionic chiral multiplet) decay. Note that it is an upperbound rather than a lowerbound.
- 142 RAFFELT 91B argue that previous SN 1987A bounds must be relaxed due to corrections to nucleon bremsstrahlung processes.
- 143 RESSELL 91 uses absence of any intracluster line emission to set limit.

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- 144 ENGEL 90 rule out $10^{-10}\lesssim$ $g_{AN}\lesssim10^{-3},$ which for a hadronic axion with EMC motivated axion-nucleon couplings corresponds to 2.5×10^{-3} eV $\lesssim m_{A^0} \lesssim 2.5 \times 10^{-3}$ 10⁴ eV. The constraint is loose in the middle of the range, i.e. for $g_{AN} \sim 10^{-6}$.
- 145 RAFFELT 90D is a re-analysis of DEARBORN 86.
- 146 The region $m_{A^0} \gtrsim$ 2 eV is also allowed.
- 147 ERICSON 89 considered various nuclear corrections to axion emission in a supernova core, and found a reduction of the previous limit (MAYLE 88) by a large factor.
- 148 MAYLE 89 limit based on naive quark model couplings of axion to nucleons. Limit based on couplings motivated by EMC measurements is 2-4 times weaker. The limit from axion-electron coupling is weak: see HATSUDA 888.
- 149 RAFFELT 888 derives a limit for the energy generation rate by exotic processes in helium-burning stars $\epsilon < 100$ erg g $^{-1}$ s $^{-1}$, which gives a firmer basis for the axion limits based on red giant cooling.
- $^{150}\,\mathrm{RAFFELT}$ 87 also gives a limit $g_{A\gamma}~<~1\times10^{-10}~\mathrm{GeV}^{-1}.$
- $^{151}\,\mathrm{DEARBORN}$ 86 also gives a limit $g_{A\gamma}~<~1.4\times10^{-11}~\mathrm{GeV}^{-1}.$
- 152 RAFFELT 86 gives a limit $g_{A\gamma}~<~1.1\times10^{-10}~{\rm GeV}^{-1}$ from red giants and $<2.4\times10^{-9}$
- $\rm GeV^{-1}$ from the sun. 153 KAPLAN 85 says $m_{A^0} <$ 23 eV is allowed for a special choice of model parameters.
- 154 FUKUGITA 82 gives a limit $g_{A\gamma}~<~2.3 \times 10^{-10}~{\rm GeV}^{-1}$.

Search for Relic Invisible Axions

Limits are for $[{\it G_{A\gamma\gamma}}/m_{A^0}]^2 \rho_A$ where ${\it G_{A\gamma\gamma}}$ denotes the axion two-photon coupling, $L_{\mathrm{int}}=rac{G_{A\gamma\gamma}}{4}\phi_AF_{\mu\nu}\widetilde{F}^{\mu\nu}=G_{A\gamma\gamma}\phi_A\mathbf{E}\cdot\mathbf{B}$, and ho_A is the axion energy density near the earth.

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not us	se the follow	ing data for averag	es, fit	s, limits,	etc. • • •
$< 2 \times 10^{-41}$		¹⁵⁵ HAGMANN	90	CNTR	$m_{A^0} =$
<1.3 × 10 ⁻⁴²	95	¹⁵⁶ WUENSCH	89	CNTR	$(5.4-5.9)10^{-6} \text{ eV}$ $m_{A^0} = (4.5-10.2)10^{-6}$
$< 2 \times 10^{-41}$	95	¹⁵⁶ WUENSCH			$m_{A^0}^{\text{ev}} =$
					(** 0 ** 0)*0-6 .)/

155 HAGMANN 90 experiment is based on the proposal of SIKIVIE 83.

156 WUENSCH 89 looks for condensed axions near the earth that could be converted to photons in the presence of an intense electromagetic field via the Primakoff effect, following the proposal of SIKIVIE 83. The theoretical prediction with $[G_{A\gamma\gamma}/m_{A^0}]^2=$ with $[G_{A\gamma\gamma}/m_{A0}]^2=2\times 10^{-14}~{
m MeV}^{-4}$ (the three generation DFSZ model) and $\rho_A=300~{
m MeV}/{
m cm}^3$ that makes up galactic halos gives $(G_{A\gamma\gamma}/m_{A0})^2~\rho_A=4\times 10^{-44}.$ Note that our definition of $G_{A\gamma\gamma}$ is $(1/4\pi)$ smaller than that of WUENSCH 89.

Invisible A⁰ (Axion) Limits from Photon Coupling

Limits are for the axion-two-photon coupling $G_{A\gamma\gamma}$ defined by $L=G_{A\gamma\gamma}\phi_A {f E}\cdot {f B}.$ Related limits from astrophysics can be found in the "Invisible A⁰ (Axion) Mass Limits from Astrophysics and Cosmology" section.

VALUE (GeV ⁻¹)	CL%	DOCUMENT ID		COMMENT
• • • We do not use the	e follow	ing data for averages	, fits	s, limits, etc. • • •
$< 3.6 \times 10^{-7}$	95	¹⁵⁷ CAMERON	93	$m_{A^0} < 10^{-3} \text{ eV}$,
$<6.7 \times 10^{-7}$	95	¹⁵⁸ CAMERON	93	optical rotation $m_{A^0} < 10^{-3} \text{ eV},$ photon regeneration
$< 3.6 \times 10^{-9}$	99.7	¹⁵⁹ LAZARUS	92	$m_{\Delta^0} < 0.03 \text{ eV}$
$< 7.7 \times 10^{-9}$	99.7	¹⁵⁹ LAZARUS		$m_{\Delta 0}^{\gamma} = 0.03 - 0.11 \text{ eV}$
$< 7.7 \times 10^{-7}$	99	¹⁶⁰ RUOSO		$m_{\Delta^0}^{\prime} < 10^{-3} \text{ eV}$
$< 2.5 \times 10^{-6}$		¹⁶¹ SEMERTZIDIS	90	$m_{A^0}^7 < 7 \times 10^{-4} \text{ eV}$

- 157 Experiment based on proposal by MAIANI 86.
- 158 Experiment based on proposal by VANBIBBER 87.
- 159 LAZARUS 92 experiment is based on proposal found in VANBIBBER 89.
- $^{160}\,\text{RUOSO}$ 92 experiment is based on the proposal by VANBIBBER 87.
- 161 SEMERTZIDIS 90 experiment is based on the proposal of MAIANI 86. The limit is obtained by taking the noise amplitude as the upper limit. Limits extend to $m_{A0}=$ $\rm 4\times10^{-3}~where~\it G_{A\,\gamma\,\gamma}~<~1\times10^{-4}~GeV^{-1}.$

Limit on Invisible A⁰ (Axion) Electron Coupling

The limit is for $G_{Aee}\partial_{\mu}\phi_{A}\overline{e}\gamma^{\mu}\gamma_{5}e$ in GeV $^{-1}$, or equivalenty, the dipole-dipole potential $\frac{G_{Aee}^2}{4\pi}$ $((\sigma_1 \cdot \sigma_2) - 3(\sigma_1 \cdot \mathbf{n}) (\sigma_2 \cdot \mathbf{n}))/r^3$ where $\mathbf{n} = \mathbf{r}/r$.

The limits below apply to invisible axion of $m_A \le 10^{-6}$ eV.

VALUE (GeV ⁻¹)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the	e follow	ing data for average	s, fits, limi	ts, etc. • • •
$< 5.3 \times 10^{-5}$	66	162 NI	94	Induced magnetism
$< 6.7 \times 10^{-5}$	66	¹⁶² CHUI	93	Induced magnetism
$< 3.6 \times 10^{-4}$	66	163 _{PAN}	92	Torsion pendulum
$< 2.7 \times 10^{-5}$	95	¹⁶² BOBRAKOV	91	Induced magnetism
$< 1.9 \times 10^{-3}$	66	¹⁶⁴ WINELAND	91 NMF	₹
$< 8.9 \times 10^{-4}$	66	163 RITTER	90	Torsion pendulum
$< 6.6 \times 10^{-5}$	95	¹⁶² VOROBYOV	88	Induced magnetism

- 162 These experiments measured induced magnetization of a bulk material by the spindependent potential generated from other bulk material with aligned electron spins, where the magnetic field is shielded with superconductor.
- These experiments used a torsion pendulum to measure the potential between two bulk matter objects where the spins are polarized but without a net magnetic field in either
- 164 WINELAND 91 looked for an effect of bulk matter with aligned electron spins on atomic hyperfine splitting using nuclear magnetic resonance.

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ALTMANN	95	ZPHY C68 221	+Declais, v. Feilitzsch+ (MUNT, LAPP, CPPM) +Cho, Ford, Johnson+ (CLEO Collab.)
BALEST BASSOMPIE	95 95	PR D51 2053 PL B355 584	+Declais, v. Feilitzsch+ +Cho, Ford, Johnson+ Bassompierre, Bologna+ (LAPP, LCGT, LYON)
MAENO	95	PL B351 574	+Fujikawa, Kataoka, Nishinara+ (IOKY)
RAFFELT SKALSEY	95 95		+Weiss (MPIM, MPIA) +Conti (MICH)
TSUNODA	95	EPL 30 273	+Nakamura, Orito, Minowa (TOKY)
ADACHI ALTHERR	94 94	PR A49 3201 ASP 2 175	+Chiba, Hirose, Nagayama+ (TMU) +Petitgirard, del Rio Gaztelurrutia (CERN, LAPP, DFAB)
AMSLER	94B	PL B333 271	+Armstrong, Ould-Saada+ (Crystal Barrel Collab.)
ASAI MEIJERDREES	94 94	PR D49 4937	+Shigekuni, Sanuki, Orito (TOKY) Meijer Drees, Waltham+ (BRCO, OREG, TRIU)
W	94	Physica B194 153 PR C49 1551	+Chui, Pan, Cheng (NTHU)
VO ATIYA	94 93	PRL 70 2521	+Kelly, Wohn, Hill+ (ISU, LBL, LLNL, UCD) +Chiang, Frank, Haggerty, Ito+ (BNL 787 Collab.)
Also	93C	PRL 71 305 (erratum)	Atiya, Chiang, Frank, Haggerty, Ito+ (BNL 787 Collab.)
ATIYA BASSOMPIE	93B 93	PR D48 R1 EPL 22 239	+Chiang, Frank, Haggerty, Ito+ (BNL 787 Collab.) Bassompierre, Bologna+ (LAPP, TORI, LYON) +Bensch, Bockholt, Heusser, Hirsch+(MPIH, KIAE, SASSO)
BECK	93 93	PRL 70 2853	+Bensch, Bockholt, Heusser, Hirsch+(MPIH, KIAE, SASSO) +Cantatore, Melissinos+ (ROCH, BNL, FNAL, TRST)
CAMERON CHUI	93	PRL 71 3247	+Ni (NTHU)
MINOWA NG	93 93	PRL 71 4120 PR D48 2941	+Inoue, Asanuma, Imamura (TOKY) (AST)
TANAKA	93	PR D48 5412	+Ejiri (OSAK)
ALLIEGRO ATIYA	92 92	PRL 68 278 PRL 69 733	+Campagnari+ (BNL, FNAL, PSI, WASH, YALE)
BERNATOW	92	PRL 69 2341 IJMP A7 3835	+Chiang, Frank, Haggerty, Ito+ (BNL, LANL, PRIN, TRIU) Bernatowicz, Brannon, Brazzle, Cowsik+ (WUSL, TATA) +Brunner, Grabosch+ (BERL, BUDA, JINR, SERP)
BLUEMLEIN HALLIN	92 92	IJMP A7 3835 PR D45 3955	+Brunner, Grabosch+ (BERL, BUDA, JINR, SERP) +Calaprice, McPherson, Saettler (PRIN)
HENDERSON	92C	PRL 69 1733	+Asoka-Kumar, Greenberg, Lynn+ (YALE, BNL)
HICKS LAZARUS	92 92	PRI 69 2333	+Alburger (OHIO, BNL) +Smith, Cameron, Melissinos+ (BNL, ROCH, FNAL)
MEIJERDREES	92	PRL 68 3845	Meijer Drees, Waltham+ (SINDRUM I Collab.)
PAN RUOSO	92 92	ZPHY C56 505	+Ni, Chen (NTHU) +Cameron, Cantatore+ (ROCH, BNL, FNAL, TRST)
SKALSEY	92 92	PRL 68 456 MPL A7 1497	+Kolata (MICH, NDAM)
WANG WANG	92 92C	PL B291 97	(ILL) (ILL)
WU	92	PRL 69 1729	+Asoka-Kumar, Greenberg, Henderson+(BNL, YALE, CUNY)
AKOPYAN ASAI	91 91	PL B272 443 PRL 66 2440	+Atoyan, Gninenko, Sukhov (INRM) +Orito, Yoshimura, Haga (ICEPP)
BERSHADY BLUEMLEIN	91		+Ressell, Turner (CHIC, FNAL, EFI) +Brunner, Grabosch+ (BERL, BUDA, JINR, SERP)
BOBRAKOV	91 91	JETPL 53 294	+Brunner, Grabosch+ (BERL, BUDA, JINR, SERP) +Borisov, Lasakov, Serebrov, Tal'daev, Trofimova (PNPI) 53 283.
BROSS	91	Translated from ZETFP PRL 67 2942	53 283. +Crisler, Pordes, Volk, Errede, Wrbanek (FNAL, ILL)
KIM	91C	PRL 67 3465	(SEOUL)
RAFFELT RESSELL	91B 91	PRL 67 2605 PR D44 3001	+Seckel (MPIM, BART) (CHIC, FNAL)
TRZASKA	91	PL B269 54	+Dejbakhsh, Dutta, Li, Cormier (TAMU)
TSERTOS WALKER	91 91	PL B266 259 APJ 376 51	+Kienle, Judge, Schreckenbach (ILLG, GSI) +Steigman, Schramm Olive+ (HSCA, OSU, CHIC, MINN)
WIDMANN	91	ZPHY A340 209	+Steigman, Schramm, Olive+ (HSCA, OSU, CHIC, MINN) +Bauer, Connell, Maier, Major+ (STUT, GSI, STUTM)
WINELAND ALBRECHT	91 90E	PRL 67 1735	+Bollinger, Heinzen, Itano, Raizen +Ehrlichmann, Harder, Krueger+ (ARGUS Collab.)
ANTREASYAN	90C	PL R251 204	#Rartels Reseat Rieler Rienlein # (Crystal Rall Collab.)
ASANUMA ATIYA	90 90	PL B237 588 PRI 64 21	+Minowa, Tsukamoto, Orito, Tsunoda +Chiang, Frank, Haggerty, Ito, Kycia+ (BNL 787 Collab.) +Chiang, Frank, Haggerty, Ito, Kycia+ (BNL 787 Collab.) +Briggmann, Carstanjen, Connell, (ARIZ, CHIC, FNAL)
ATIYA	90B	PRL 64 21 PRL 65 1188	+Chiang, Frank, Haggerty, Ito, Kycia+ (BNL 787 Collab.)
BAUER BURROWS	90 90	NIM B50 300 PR D42 3297	+Briggmann, Carstanjen, Connell, et al. (STUT, VILL, GSI) +Ressell, Turner (ARIZ, CHIC, FNAL)
DEBOER	90 90	JPG 16 L1	de Boer, Lehmann, Steyaert (LOUV)
ENGEL GNINENKO	90	PRL 65 960 PL B237 287 PR D41 2924	+Seckel, Hayes (BART, LANL) +Klubakov, Poblaguev, Postoev (INRM)
GUO HAGMANN	90 90	PR D41 2924 PR D42 1297	+Klubakov, Poblaguev, Postoev (INRM) +Kaplan, Alde+ (NIU, LANL, FNAL, CASE, TEXA) +Sikivie, Sullivan, Tanner (FLOR)
JUDGE	90	PRL 65 972	+Krusche, Schreckenbach, Tsertos, Kienle (ILLG, GSI)
RAFFELT RAFFELT	90C 90D	PRPL 198 1 PR D41 1324	(MPIM) (MPIM)
RITTER	90	PR D42 977	+Goldblum, Ni, Gillies, Speake +Cameron, Cantatore+ (ROCH, BNL, FNAL, TRST)
SEMERTZIDIS TSUCHIAKI	90 90	PRL 64 2988 PL B236 81	+Cameron, Cantatore+ (ROCH, BNL, FNAL, TRST) +Orito, Yoshida, Minowa (ICEPP)
TURNER	90	PRPL 197 67	(FNAL)
BARABASH BINI	89 89	PL B223 273 PL B221 99	+Kuzminov, Lobashev, Novikov+ (ITEP, INRM) +Fazzini, Giannatiempo, Poggi, Sona+(FIRZ, CERN, AARH)
BURROWS	89	PR D39 1020	+Turner, Brinkmann (ARIZ, CHIC, FNAL, BOCH)
Also DEBOER	88 89B	PRL 60 1797 PRL 62 2639	Turner (FNAL, EFI) de Boer, van Dantzig (ANIK)
ERICSON	89	PL B219 507	+Mathiot (CERN, IPN)
FAISSNER FISHER	89 89	ZPHY C44 557 PL B218 257	+Heinrigs, Preussger, Reitz, Samm+ (AACH3, BERL, PSI) +Boehm, Bovet, Egger+ (CIT, NEUC, PSI)
FOX	89	DD C30 288	+Kemper Cottle Zingarelli (ESII)
MAYLE Also	89 88	PL B219 515 PL B203 188	+Wilson, Ellis+ (LLL, CERN, MINN, FNAL, CHIC, OSU) Mayle, Wilson+ (LLL, CERN, MINN, FNAL, CHIC, OSU) +Orito, Tisuchiaki, Tisukamoto (ICEPP)
MINOWA	89	PL B203 188 PRL 62 1091	+Orito, Tlsuchiaki, Tlsukamoto (ICEPP)
ORITO PERKINS	89 89	PRL 63 597 PRL 62 2638	+Yoshimura, Haga, Minowa, Tsuchiaki (ICEPP) (OXF)
TSERTOS	89 89	PR D40 1397 PR D39 2089	+Kozhuharov Armbruster Kienle+ (GSL III G)
VANBIBBER WUENSCH	89	PR D40 3153	Van Bibber, McIntyre, Morris, Raffelt (LLL, TAMU, LBL) +De Panfilis-Wuensch, Semertzidis+ (ROCH, BNL, FNAL) De Panfilis, Melissinos, Moskowitz+ (ROCH, BNL, FNAL)
Also ALSTON	87 88	PRL 59 839 PRL 60 1928	De Panfilis, Melissinos, Moskowitz+ (ROCH, BNL, FNAL)
AVIGNONE	88	PR D37 618	De Parfilis, Melissinos, Moskowitz+ (ROCH, BNL, FNAL) Alston-Garnjost, Dougherty+ (LBL, MTHO, UNM) +Baktash, Barker, Calaprice+(PRIN, SCUC, ORNL, WASH) +Ecklund, Nelson, Abashian+ (FNAL, SLAC, VPI) +Bondar, Bukin, Vorobev, Groshev+
BJORKEN BLINOV	88 88	PR D38 3375 SJNP 47 563	+Ecklund, Nelson, Abashian+ (FNAL, SLAC, VPI) +Bondar, Bukin, Vorobyev, Groshev+ (NOVO)
		Translated from YAF 47	889
BOLTON Also	88 86	PR D38 2077 PRL 56 2461	+Cooper, Frank, Hallin+ (LANL, STAN, CHIC, TEMP) Bolton, Bowman, Cooper+ (LANL, STAN, CHIC, TEMP) Grosnick, Wright, Bolton+ (CHIC, LANL, STAN, TEMP)
Also	86 88	PRL 56 2461 PRL 57 3241 PR D37 2714	Grosnick, Wright, Bolton+ (CHIC, LANL, STAN, TEMP) +Nieves, Pal (UMD, UPR, MASA)
CHANDA CHOI	88	PR D37 3225	+Kim, Kim, Lam (JHU)
CONNELL DATAR	88 88	PRL 60 2242 PR C37 250	+Fearick, Hoernie, Sideras-Haddad, Sellschop (WITW) +Fortier, Gales, Hourani+ (IPN)
DEBOER	88	PRL 61 1274	de Boer, van Dantzig (ANIK)
Also Also	89 89	PRL 62 2644 erratum PRL 62 2638	Perkins (OXF)
Also	89B	PRL 62 2639	de Boer, van Dantzig (ANIK)
DEBOER	88C	JPG 14 L131	de Boer, Deutsch, Lehmann, Prieels, Steyaert (LOUV)

Gauge & Higgs Boson Particle Listings Axions (A^0) and Other Very Light Bosons

DOEHNER 88	PR D38 2722	+Last, Arnold, Freedman, Dubbers	(HEIDP, ANL, ILLG)	DINE	83	PL 120B 137	+Fischler	(IAS, PENN)
DOI 88	PR D37 2575	+Kotani, Takasugi	(OSAK)	ELLIS	83B	NP B223 252	+Olive	(CERN)
EL-NADI 88	PRL 61 1271	+Badawy	(CAIR)	FAISSNER	83	PR D28 1198		
							+Heinrigs, Preussger, Samm	(AACH)
FAISSNER 88	ZPHY C37 231	+Heinrigs, Preussger, Reitz, Samm+ ((AACH3, BERL, SIN)	FAISSNER	83B	PR D28 1787	+Frenzel, Heinrigs, Preussger+	(ÁACH3)
HATSUDA 88B	PL B203 469	+Yoshimura	(KEK)	FRANK	83B	PR D28 1790	 + (LANL, YALE, LBL, MIT, SACI 	L. SIN. CNRC. BERN)
LORENZ 88	PL B214 10	+Mageras, Stiegler, Huszar	(MPIM, PSI)	HOFFMAN	83	PR D28 660	+Frank, Mischke, Moir, Schardt	(LANL, ARZS)
MAYLE 88	PL B203 188		, FNAL, CHIC, OSU)	NICZYPORUK		ZPHY C17 197	+Jakubowski, Zeludziewicz+	
								(LENA Collab.)
PICCIOTTO 88	PR D37 1131	+Ahmad, Britton, Bryman, Clifford+	(TRIU, CNRC)	PRESKILL	83	PL 120B 127	+Wise, Wilczek	(HARV, UCSBT)
RAFFELT 88	PRL 60 1793	+Seckel	(UCB, LLL, UCSC)	SIKIVIE	83	PRL 51 1415		(FLOR)
RAFFELT 88B	PR D37 549	+Dearborn	(UCB, LLL)	Also	84	PRL 52 695 erratum	Sikivie	(FLOR)
SAVAGE 88	PR D37 1134	+Filippone, Mitchell	(CIT)	ALEKSEEV	82	JETP 55 591	+Kartamyshev, Makarin+	(KIAE)
TSERTOS 88	PL B207 273	+Kozhuharov, Armbruster, Kienle+	(GSI, ILLG)			Translated from ZETF	82 1007.	
TSERTOS 88B	ZPHY A331 103	+Kozhuharov, Armbruster, Kienle+	(GSI, ILLG)	ALEKSEEV	82B	JETPL 36 116	+Kalinina, Kruglov, Kulikov+	(MOSU, JINR)
						Translated from ZETER	36 04	()
VANKLINKEN 88	PL B205 223	van Klinken, Meiring, de Boer, Schaa	atsma+ (GRON, GSI)	ASANO	82	PL 113B 195		TOKAL INUIS OCAIK
VANKLINKEN 88B	PRL 60 2442	van Klinken	(GRON)				+Kikutani, Kurokawa, Miyachi+(KEK,	
VONWIMMER88	PRL 60 2443	von Wimmersperg	`(BNL)	BARROSO	82	PL 116B 247	+Branco	(LISB)
VOROBYOV 88	PL B208 146	+Gitarts	(NOVO)	DATAR	82	PL 114B 63	+Baba, Betigeri, Singh	(BHAB)
				EDWARDS	82	PRL 48 903	+Partridge, Peck, Porter+	(Crystal Ball Collab.)
AVIGNONE 87	AIP Conf. 1987	+Brodzinski, Miley, Reeves	(SCUĆ, PNL)	FETSCHER	82	JPG 8 L147	+1 artinuge, 1 cek, 1 ofter +	
	:. Salt Lake City, UT							(ETH)
CALDWELL 87	PRL 59 419	+Eisberg, Grumm, Witherell+	(UCSB, LBL)	FUKUGITA	82	PRL 48 1522	+Watamura, Yoshimura	(KEK)
DRUZHININ 87	ZPHY C37 1	+Dubrovin, Eidelman, Golubev+	(NOVO)	FUKUGITA	82B	PR D26 1840	+Watamura, Yoshimura	(KEK)
ELLIOTT 87	PRL 59 1649	+Hahn, Moe	(UCI)	LEHMANN	82	PL 115B 270	+Lesquoy, Muller, Zylberajch	(SACL)
				RAFFELT	82	PL 119B 323	+Stodolsky	(MPIM)
FISHER 87	PL B192 460	+Boehm, Bovet, Egger+	(CIT, NEUC, SIN)					(IVIPIM)
FRIEMAN 87	PR D36 2201	+Dimopoulos, Turner (SLAC	C, STAN, FNAL, EFI)	SIVERTZ	82	PR D26 717	+Lee-Franzini, Horstkotte+	(CUSB `Collab.)
GOLDMAN 87	PR D36 1543	+Hallin, Hoffman+ (LANL, C	CHIC, STAN, TEMP)	VERGADOS	82	PL 109B 96		(CERN)
KORENCHE 87	SJNP 46 192	Korenchenko, Kostin, Mzhaviya+		ZEHNDER	82	PL 110B 419	+Gabathuler, Vuilleumier	(ETH. SIN. CIT)
KORENCHE 87		Korenchenko, Kostin, iviznaviya+	(JINR)	ASANO		PL 107B 159	+Kikutani, Kurokawa, Miyachi+(KEK,	
	Translated from YAF 4							
MAIER 87	ZPHY A326 527	+Bauer, Briggmann, Carstanjen+	(STUT, GSI)	BARROSO	81	PL 106B 91	+Mukhopadhyay	(SIN)
MILLS 87	PR D36 707	+Levy	(BELL)	FAISSNER	81	ZPHY C10 95	+Frenzel, Grimm, Hansl, Hoffman+	(AACH3)
RAFFELT 87	PR D36 2211	+ Dearborn	(LLL, UCB)	FAISSNER	81B	PL 103B 234	+Frenzel, Heinrigs, Preussger+	(AACH3)
				KIM	81	Pl. 105B 55	+Stamm	(AACH3)
	PRL 59 755	+Krasny, Lang, Barbaro, Bodek+	(ROCH, CIT+)					
TURNER 87	PRL 59 2489		(FNAL, EFI)	VUILLEUMIER		PL 101B 341	+Boehm, Hahn, Kwon+	(CIT, MUNI)
VANBIBBER 87	PRL 59 759	Van Bibber, Dagdeviren, Koonin+(LL	.L. CIT. MIT. STAN)	ZEHNDER	81	PL 104B 494		(ETH)
VONWIMMER87	PRL 59 266	von Wimmersperg, Connell, Hoernle, S	Sideras-Haddad(M/ITM)	FAISSNER	80	PL 96B 201	+Frenzel, Heinrigs, Preussger, Samm+	⊦ (AÀCH3)
				JACQUES	80	PR D21 1206		
ALBRECHT 86D		+Binder, Boeckmann+	(ARGUS Collab.)					RUTG, STEV, COLU)
BADIER 86	ZPHY C31 21	+Bemporad, Boucrot, Callot+	(NA3 Collab.)	SOUKAS	80	PRL 44 564	+Wanderer, Weng+ (BNL, I	HARV, ORNL, PENN)
BOWCOCK 86	PRL 56 2676	+Giles, Hassard, Kinoshita+	(ČLEO Collab.)	BECHIS	79	PRL 42 1511	+Dombeck+	(UMD, COLU, AFRR)
	PRL 57 2101			CALAPRICE	79	PR D20 2708	+Dunford, Kouzes, Miller+	(PRIN)
BRYMAN 86B	PRL 57 2787	+Clifford	(TRIU)	COTEUS	79	PRL 42 1438	+Diesburg, Fine, Lee, Sokolsky+	(COLU, ILL, BNL)
DAVIER 86	PL B180 295	+Jeanjean, Nguyen Ngoc	(LALO)	DISHAW	79	PL 85B 142	+Diamant-Berger, Faessler, Liu+	(SLAC, CIT)
DEARBORN 86	PRL 56 26		CHIC, FNAL, BART)	ZHITNITSKII	79	SJNP 29 517	+Skovpen	(NOVO)
				ZIIITIVITSKII	1 2	Translated from YAF 2		(14040)
EICHLER 86	PL B175 101	+Felawka, Kraus, Niebuhr+	(SINDRUM Collab.)	41100411				(6
HALLIN 86	PRL 57 2105	+Calparice, Dunford, McDonald	(PRIN)	ALIBRAN	78	PL 74B 134	+Armenise, Arnold, Bartley	(Gargamelle Collab.)
JODIDIO 86	PR D34 1967	+Balke, Carr, Gidal, Shinsky+	(LBL. NWES, TRIU)	ASRATYAN	78B	PL 79B 497	+Epstein, Fakhrutdinov+	(ITEP, SERP)
Also 88	PR D37 237 erratum			BELLOTTI	78	PL 76B 223	+Fiorini, Zanotti	(MILA)
			(LBL, NWES, TRIU)	BOSETTI	78B	PL 74B 143	+Deden, Deutschmann, Fritze+	(BEBC Collab.)
KETOV 86	JETPL 44 146	+Klimov, Nikolaev, Mikaelyan+	(KIAE)					
	Translated from ZETFF			DICUS	78C	PR D18 1829	+Kolb, Teplitz, Wagoner	(TEXA, VPI, STAN)
KOCH 86	NC 96A 182	+Schult	(JULI)	DONNELLY	78	PR D18 1607	+Freedman, Lytel, Peccei, Schwartz	(STAN)
KONAKA 86	PRL 57 659	+Imai, Kobayashi, Masaike, Miyake+	(KYOT, KEK)	Also	76	PRL 37 315	Reines, Gurr, Sobel	` (UCI)
MAGERAS 86	PRL 56 2672		IPIM, COLU, STON)	Also	74	PRL 33 179	Gurr, Reines, Sobel	(uci)
MAIANI 86	PL B175 359	+Petronzio, Zavattini	(CERN)	HANSL		PL 74B 139	+Holder, Knobloch, May, Paar+	(CDHS Collab.)
PECCEI 86	PL B172 435	+Wu, Yanagida	(DESY)	MICELMAC		LNC 21 441	Micelmacher, Pontecorvo	(JINR)
RAFFELT 86	PR D33 897	•	(MPIM)	MIKAELIAN	78	PR D18 3605		(FNAL, NWES)
RAFFELT 86B			(MPIM)	SATO	78	PTP 60 1942		(KYOT)
							A Total Colon Material Charles	
SAVAGE 86B		+McKeown, Filippone, Mitchell	`(CIT)	VYSOTSKII	78	JETPL 27 502	+Zeldovich, Khlopov, Chechetkin	(ASCI)
AMALDI 85	PL 153B 444	+Carboni, Jonson, Thun	(CÉRN)			Translated from ZETFP	27 533.	
ANANEV 85	SJNP 41 585	+Kalinina, Lushchikov, Olshevskii+	(JINR)	YANG	78	PRL 41 523		(MASA)
	Translated from YAF 4		(5)	PECCEI	77	PR D16 1791	+Quinn	(STAN, SLAC)
BALTRUSAIT 85	PRL 55 1842	Baltrusaitis, Becker, Blaylock, Brown-	+ (Mark III Collab.)	Also	77B	PRL 38 1440	Peccei, Quinn	(STAN, SLAC)
		+Dorenbosch, Allaby, Amaldi+	(CHARM Collab.)	REINES	76	PRL 37 315	+Gurr, Sobel	(UCI)
BERGSMA 85	PL 157B 458		(HARV)	GURR	74	PRL 33 179	+Reines, Sobel	(UCI)
KAPLAN 85	NP B260 215			4.41.4.41D	53	PRSL A22 183		
KAPLAN 85	NP B260 215		(UCSR WUSL)					
KAPLAN 85 IWAMOTO 84	NP B260 215 PRL 53 1198	Hehikawa Taniguchi Vamanalia	(UCSB, WUSL)	ANAND		THISE MEE 103		
KAPLAN 85 IWAMOTO 84 YAMAZAKI 84	NP B260 215 PRL 53 1198 PRL 52 1089	+Ishikawa, Taniguchi, Yamanaka+	(UCSB, WUSL) (INUS, KEK)	ANAND				
KAPLAN 85 IWAMOTO 84 YAMAZAKI 84 ABBOTT 83	NP B260 215 PRL 53 1198 PRL 52 1089 PL 120B 133	+Sikivie	(UCSB, WUSL) (INUS, KEK) (BRAN, FLOR)	ANAND			RELATED PAPERS	
KAPLAN 85 IWAMOTO 84 YAMAZAKI 84 ABBOTT 83	NP B260 215 PRL 53 1198 PRL 52 1089 PL 120B 133	+Sikivie	(UCSB, WUSL) (INUS, KEK) (BRAN, FLOR)	ANAND			RELATED PAPERS	
KAPLAN 85 IWAMOTO 84 YAMAZAKI 84 ABBOTT 83 ALAM 83	NP B260 215 PRL 53 1198 PRL 52 1089 PL 120B 133 PR D27 1665	+Sikivie + (VAND, CORN, ITHA, HAI	(UCSB, WUSL) (INUS, KEK) (BRAN, FLOR) RV, OHIO, ROCH+)			OTHER	RELATED PAPERS	
KAPLAN 85 IWAMOTO 84 YAMAZAKI 84 ABBOTT 83 ALAM 83 CARBONI 83	NP B260 215 PRL 53 1198 PRL 52 1089 PL 120B 133 PR D27 1665 PL 123B 349	+Sikivie + (VAND, CORN, ITHA, HAI +Dahme	(UCSB, WUSL) (INUS, KEK) (BRAN, FLOR) .RV, OHIO, ROCH+) (CERN, MUNI)			OTHER	RELATED PAPERS	(UCSR)
KAPLAN 85 IWAMOTO 84 YAMAZAKI 84 ABBOTT 83 ALAM 83 CARBONI 83 CAVAIGNAC 83	NP B260 215 PRL 53 1198 PRL 52 1089 PL 120B 133 PR D27 1665 PL 123B 349 PL 121B 193	+Sikivie + (VAND, CORN, ITHA, HAI +Dahme +Hoummada, Koang, Ost+	(UCSB, WUSL) (INUS, KEK) (BRAN, FLOR) .RV, OHIO, ROCH+) (CERN, MUNI) (ISNG, LAPP)	SREDNICKI	85	OTHER		(UCSB)
KAPLAN 85 IWAMOTO 84 YAMAZAKI 84 ABBOTT 83 ALAM 83 CARBONI 83	NP B260 215 PRL 53 1198 PRL 52 1089 PL 120B 133 PR D27 1665 PL 123B 349	+Sikivie + (VAND, CORN, ITHA, HAI +Dahme	(UCSB, WUSL) (INUS, KEK) (BRAN, FLOR) .RV, OHIO, ROCH+) (CERN, MUNI)			OTHER	RELATED PAPERS	(UCSB) (FNAL)
KAPLAN 85 IWAMOTO 84 YAMAZAKI 84 ABBOTT 83 ALAM 83 CARBONI 83 CAVAIGNAC 83	NP B260 215 PRL 53 1198 PRL 52 1089 PL 120B 133 PR D27 1665 PL 123B 349 PL 121B 193	+Sikivie + (VAND, CORN, ITHA, HAI +Dahme +Hoummada, Koang, Ost+	(UCSB, WUSL) (INUS, KEK) (BRAN, FLOR) .RV, OHIO, ROCH+) (CERN, MUNI) (ISNG, LAPP)	SREDNICKI	85	OTHER		

LEPTONS

ν ν Ν	ι Heavy Cha 'e · · ·	Light Net	on Se	arch	nes													 249 250 256 274 280 283 284 286 287
	es in the l																	
	n Decay Pa anching Fr															•		$251 \\ 258$
au-Dec Neuti	cay Param	eters			•				•	•		•	•					271 275 280
The Massi Sum	Number of ive Neutra of Neutrin as from Ne	Light New Lid Leptons o Masses utrinoless	utrine & th Doul	o Ty e Ef 	pe: fec	s fr ts o	om of N	Co Ion	olli	de o	r E Ne	eut	oer rin	in 10	ner M	ats ass	ses	286 287 289 289

LEPTONS

e

 $J = \frac{1}{2}$

e MASS

The mass is known much more precisely in u (atomic mass units) than in MeV (see the footnote). The conversion from u to MeV, $1\,u=931.49432\pm0.00028$ MeV, involves the relatively poorly known electronic charge.

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
0.51099907±0.00000015	¹ FARNHAM	95	CNTR	Penning
• • We do not use the follow	wing data for average	s, fits	s, limits,	etc. • •
$0.51099906 \pm 0.00000015$	² COHEN	87	RVUE	1986 CODATA value
0.5110034 ± 0.0000014	COHEN	73	RVUE	1973 CODATA value

1 FARNHAM 95 compares cyclotron frequency of trapped electrons with that of a single trapped $^{12}\text{C}^{+6}$ ion. The result is $m_e=0.0005485799111(12)\,\text{u}$, where the figure in parenthesis is the 1σ uncertainty in the last digit. The uncertainty after conversion to MeV is dominated by the uncertainty in the electron charge.

² COHEN 87 (1986 CODATA) value in atomic mass units is 0.000548579903(13). See footnote on FARNHAM 95.

$$(m_{e^+}-m_{e^-}) / m_{\rm average}$$

A test of CPT invariance.

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
$< 4 \times 10^{-8}$	90	CHU 84	CNTR	Positronium spec-
				troscopy

$$|q_{e^+} + q_{e^-}|/e$$

A test of $\ensuremath{\textit{CPT}}$ invariance. See also similar tests involving the proton.

VALUE	DOCUMENT ID	TECN	COMMENT
< 4 × 10 ⁻⁸	³ HUGHES 92	RVUE	
• • We do not use the following	g data for averages, fits	, limits,	etc. • • •
<10-18	4 MUELLED 00	THEO	\(\frac{1}{2} = \frac{1}{2} =

³ HUGHES 92 uses recent measurements of Rydberg-energy and cyclotron-frequency ra-

e MAGNETIC MOMENT ANOMALY

$\mu_e/\mu_B - 1 = (g-2)/2$

For the most accurate theoretical calculation, see KINOSHITA 81.

Some older results have been omitted.

VALUE (units 10 ⁻⁶)	DOCUMENT ID		TECN	CHG	COMMENT
1159.652193 ±0.000010	⁵ COHEN	87	RVUE		1986 CODATA value
• • We do not use the follow	wing data for average	es, fit	s, limits,	etc.	• •
$1159.6521884 \pm 0.0000043$	VANDYCK	87	MRS	-	Single electron
$1159.6521879 \pm 0.0000043$	VANDYCK	87	MRS	+	Single positron
1159.652200 ±0.000040	VANDYCK	86	MRS	-	Single electron
1159.652222 ±0.000050	SCHWINBER	G 81	MRS	+	Single positron
⁵ The COHEN 87 value assu	mes the $g/2$ values t	or e+	and e	are e	equal, as required by

$(g_{e^+} - g_{e^-}) / g_{average}$

A test of CPT invariance.

VALUE (units 10-12)	CL%	DOCUMENT ID		TECN	COMMENT
-0.5 ± 2.1		⁶ VANDYCK	87	MRS	Penning trap
• • • We do not us	se the followin	g data for averages,	fits	, limits,	etc. • • •
< 12	95	⁷ VASSERMAN	87	CNTR	Assumes $m_{e^+} = m_{e^-}$
22 ±64		SCHWINBERG			
⁶ VANDYCK 87 n	neasured (g_	$/g_{+})-1$ and we con	vert	ed it.	
					lied by $(g-2)/g = 1.2 \times$
10 ⁻³ .		'			

e ELECTRIC DIPOLE MOMENT

A nonzero value is forbidden by both T invariance and P invariance.

VALUE (10 ⁻²⁶ ecm - 0.27± 0 • • • We do not	.83	8 ABDULLAH data for averages,	90 fits.	TECN MRS limits.	COMMENT 205 TI beams etc. • • •
- 14 ± 24 - 1.5 ± 5 - 50 ±110	.5 ±1.5	CHO MURTHY LAMOREAUX	89 89	NMR NMR	TI F molecules Cesium, no B field 199
190 ±340 70 ±220 < 300	90 90 90	SANDARS PLAYER WEISSKOPF	75 70 68	MRS MRS MRS	Thallium Xenon Cesium

 $^{\rm 8}$ ABDULLAH 90 uses the relativistic enhancement of a valence electron's electric dipole moment in a high-Z atom.

e MEAN LIFE / BRANCHING FRACTION

A test of charge conservation. See the "Note on Testing Charge Conservation and the Pauli Exclusion Principle" following this section in our 1992 edition (Physical Review **D45**, 1 June, Part II (1992), p. VI.10). We use the best "disappearance" limit for the Summary Tables. The best limit for the specific channel $e^- \to \nu \gamma$ is much better.

Note that we use the mean life rather than what is often reported, the half life.

VALUE	(yr)	CL%	DOCUMENT ID		TECN	COMMENT
>4.3	× 10 ²³	68	AHARONOV	95B (CNTR	Ge K-shll disappearance
• • •	We do not	use the follo	wing data for av	erages	s, fits, I	imits, etc. • • •
>3.7	$\times 10^{25}$	68	AHARONOV	95B (CNTR	$e^- \rightarrow \nu \gamma$
	$\times 10^{25}$	68	BALYSH	93 (CNTR	$e^- \rightarrow \nu \gamma$, ⁷⁶ Ge detector
	$\times 10^{23}$	68	REUSSER	91 (CNTR	Ge K-shell disappearance
	× 10 ²⁵	68	AVIGNONE	86 (CNTR	$e^- \rightarrow \nu \gamma$
>1	$\times 10^{39}$	•	ORITO	85 /	ASTR	Astrophysical argument
>3	$\times 10^{23}$	68	BELLOTTI	83B (CNTR	$e^- \rightarrow \nu \gamma$
>2	× 10 ²²	68	BELLOTTI	838 (CNTR	Ge K-shell disappearance

 9 ORITO 85 assumes that electromagnetic forces extend out to large enough distances and that the age of our galaxy is $10^{10}\,$ years.

e REFERENCES

AHARONOV Also	95B 95	PR D52 3785 PL B353 168		Aharonov, Avignone+ (SCUC	, PNL, ZAGR, TELA) , PNL, ZAGR, TELA)	
FARNHAM	95	PRL 75 3598		+Van Dyck, Schwinberg	(WASH)	
BALYSH	93	PL B298 278			(KIAE, MPIH, SASSO)	
HUGHES	92	PRL 69 578		+Deutch	(LANL, AARH)	
MUELLER	92	PRL 69 3432		+Thoma	(DUKE)	
PDG	92		Part	II Hikasa, Barnett, Stone+	(KEK, LBL, BOST+)	
REUSSER	91	PL B255 143		+Treichel, Boehm, Broggini+	(NEUC, CIT, PSI)	
ABDULLAH	90	PRL 65 2347		+Carlberg, Commins, Gould, Ross	(LBL, UCB)	
CHO	89	PRL 63 2559		+Sangster, Hinds	(YALE)	
MURTHY	89	PRL 63 965		+Krause, Li, Hunter	(AMHT)	
COHEN	87	RMP 59 1121		+Taylor	(RISC, NBS)	
LAMOREAUX	87	PRL 59 2275		+Jacobs, Heckel, Raab, Fortson	(WASH)	
VANDYCK	87	PRL 59 26		Van Dyck, Schwinberg, Dehmelt	(WASH)	
VASSERMAN	87	PL B198 302		+Vorobyov, Gluskin+	(NOVO)	
Also	87B	PL B187 172		Vasserman, Vorobyov, Gluskin+	(NOVO)	
AVIGNONE	86	PR D34 97		+Brodzinski, Hensley, Miley, Reeves+	(PNL, SCUC)	
VANDYCK	86	PR D34 722		Van Dyck, Schwinberg, Dehmelt	(WASH)	
ORITO	85	PRL 54 2457		+Yoshimura	(TOKÝ, KEKÍ	
CHU	84	PRL 52 1689		+Mills, Hall	(BELL, NBS, COLO)	
BELLOTTI	83B	PL 124B 435		+Corti, Fiorini, Liguori, Pullia+	(MILA)	
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SCHWINBERG	81	PRL 47 1679		+Van Dyck, Dehmelt	(WASH)	
SANDARS	75	PR A11 473		+Sternheimer	(OXF, BNL)	
COHEN	73	JPCRD 2 663		+Taylor	(RISC, NBS)	
PLAYER	70	JPB 3 1620		+Sandars	(OXF)	
WEISSKOPF	68	PRL 21 1645		+Carrico, Gould, Lipworth+	(BRAN)	
					(=/	

tios.

MUELLER 92 argues that an inequality of the charge magnitudes would, through higher-order vacuum polarization, contribute to the net charge of atoms.



 $J = \frac{1}{2}$

μ MASS

The mass is known more precisely in u (atomic mass units) than in MeV (see the footnote to COHEN 87). The conversion from u to MeV, 1 u 931.49432 ± 0.00028 MeV, involves the relatively poorly known electronic

Where $m_{\mu}/m_{\rm e}$ was measured, we have used the 1986 CODATA value for $m_{\rm e}=0.51099906\pm0.00000015$ MeV.

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
105.658389±0.000034	¹ COHEN	87	RVUE		1986 CODATA
• • • We do not use the fol	lowing data for average	s, fit	s, limits,	etc.	• •
105.65841 ±0.00033	² BELTRAMI	86	SPEC	_	Muonic atoms
105.658432 ± 0.000064	³ KLEMPT	82	CNTR	+	Incl. in MARIAM 82
105.658386 ± 0.000044	⁴ MARIAM	82	CNTR	+	W/ 11 W 02
105.65856 ±0.00015	⁵ CASPERSON	77	CNTR	+	
105.65836 ±0.00026	⁶ CROWE	72	CNTR		
105.65865 ±0.00044	⁷ CRANE	71	CNTR		
¹ The mass is known more makes use of the other e ² BELTRAMI 86 gives m	ntries below.		8913 ± 0	.00000	00017 u. COHEN 87

- 3 KLEMPT 82 gives $m_{\mu}/m_e =$ 206.76835(11).
- ⁴ MARIAM 82 gives $m_{\mu}/m_e = 206.768259(62)$.
- ⁵ CASPERSON 77 gives $m_{\mu}/m_{e} = 206.76859(29)$.
- ⁶ CROWE 72 gives $m_{\mu}/m_e = 206.7682(5)$.
- ⁷ CRANE 71 gives $m_{\mu}/m_e = 206.76878(85)$.

μ MEAN LIFE au

Measurements with an error $> 0.001 \times 10^{-6} \, \text{s}$ have been omitted.

VALUE (10 ⁻⁶ s)	DOCUMENT ID		TECN	CHG
2.19703 ±0.00004 OUR AVERAG	E			
2.197078 ± 0.000073	BARDIN	84	CNTR	+
2.197025 ± 0.000155	BARDIN	84	CNTR	-
2.19695 ±0.00006	GIOVANETTI	84	CNTR	+
2.19711 ±0.00008	BALANDIN	74	CNTR	+
2.1973 ±0.0003	DUCLOS	73	CNTR	+

au_{μ^+}/ au_{μ^-} MEAN LIFE RATIO

A test of CPT invariance.

VALUE		DOCUMENT ID		TECN	COMMENT
1.00002	4±0.000078	BARDIN	84	CNTR	
• • • V	Ve do not use the following	data for average	s, fit	s, limits,	etc. • • •
1.0008	± 0.0010	BAILEY	79	CNTR	Storage ring
1.000	± 0.001	MEYER	63	CNTR	Mean life μ^+/μ^-

$$(au_{\mu^+} - au_{\mu^-}) / au_{average}$$

A test of CPT invariance. Calculated from the mean-life ratio, above.

DOCUMENT ID $(2\pm8) \times 10^{-5}$ OUR EVALUATION

μ MAGNETIC MOMENT ANOMALY

 $\mu_\mu/(e\hbar/2m_\mu)-1=(g_\mu-2)/2$ For reviews of theory and experiments, see HUGHES 85, KINOSHITA 84, COMBLEY 81, FARLEY 79, and CALMET 77.

VALUE (units 10-6)	DOCUMENT ID		TECN	CHG	COMMENT
1165.9230±0.0084	COHEN	87	RVUE		1986 CODATA value
• • • We do not use the fo	ollowing data for averag	es, fit	s, limits,	etc.	• •
1165.910 ±0.011	8 BAILEY	79	CNTR	+	Storage ring
1165.937 ±0.012	⁸ BAILEY	79	CNTR		Storage ring
1165.923 ±0.0085	⁸ BAILEY	79	CNTR	\pm	Storage ring
1165.922 ±0.009	⁸ BAILEY	77	CNTR	±	Storage ring
1166.16 ±0.31	BAILEY	68	CNTR	±	Storage rings
1162 0 +5 0	CHARPAK	62	CNTR	+	

 8 BAILEY 79 is final result. Includes BAILEY 77 data. We use μ/p magnetic moment ratio = 3.1833452 and recalculate the BAILEY 79 values. Third BAILEY 79 result is first two combined.

$$(g_{\mu^+}-g_{\mu^-})$$
 / $g_{
m average}$

A test of CPT invariance. VALUE (units 10-8) -2.6 ± 1.6

DOCUMENT ID

μ ELECTRIC DIPOLE MOMENT

A nonzero value is forbidden by both T invariance and P invariance.

VALUE (10 ⁻¹⁹ ecm)	DOCUMENT ID		TECN	CHG	COMMENT
3.7±3.4	9 BAILEY	78	CNTR	\pm	Storage ring
• • • We do not use the t	following data for averages,	fits	, limits,	etc. •	• •
8.6 ± 4.5	BAILEY	78	CNTR	+	Storage rings
0.8 ± 4.3	BAILEY	78	CNTR	***	Storage rings
⁹ This is the combinatio	n of the two BAILEY 78 re	sult	s given t	elow.	

μ/p MAGNETIC MOMENT RATIO

This ratio is used to obtain a precise value of the muon mass. Measurements with an error > 0.00001 have been omitted.

VALUE	DOCUMENT ID		TECN	CHG	COMMENT
3.18334547±0.00000047	10 COHEN	87	RVUE		1986 CODATA
• • We do not use the follow	ving data for average	s, fit:	s, limits,	etc. •	• •
3.1833441 ±0.0000017	KLEMPT	82	CNTR	+	Precession strob
3.1833461 ±0.0000011	MARIAM	82	CNTR	+	HFS splitting
3.1833448 ±0.0000029	CAMANI	78	CNTR	+	See KLEMPT 82
3.1833403 ±0.0000044	CASPERSON	77	CNTR	+	HFS splitting
3.1833402 ±0.0000072	COHEN	73	RVUE		1973 CODATA value
3.1833467 ±0.0000082	CROWE	72	CNTR	+	Precession phase

10 COHEN 87 (1986 CODATA) value was fitted using their own selection of the following data. Because their value is from a multiparameter fit, correlations with other quantities may be important and one cannot arrive at this result by any average of these data alone.

μ- DECAY MODES

 μ^+ modes are charge conjugates of the modes below.

	Mode		Fraction ((F _i /F)	Confidence	level
Γ ₁	$e^- \overline{\nu}_e \nu_\mu$		≈ 100%			
	$e^- \overline{\nu}_e \nu_\mu \gamma$		[a] (1.4±0	0.4) %		
Γ3	$e^-\overline{ u}_e u_\mue^+e^-$		[b] (3.4±0	$0.4) \times 10^{-5}$		
	Lepton Far	nily number (LF) violatir	ng modes		
Γ_4	$e^- \nu_e \overline{\nu}_\mu$	LF	[c] < 1.2	%		90%
Γ_5	$e^-\gamma$	LF	< 4.9	$\times 10^{-11}$		90%
Γ_6	$e^{-}e^{+}e^{-}$	LF	< 1.0	$\times 10^{-12}$		90%
Γ7	$e^- 2\gamma$	LF	< 7.2	$\times 10^{-11}$		90%

- [a] This only includes events with the γ energy > 10 MeV. Since the $e^-\,\overline{\nu}_e\,\nu_\mu$ and $e^-\,\overline{
 u}_e\,
 u_\mu\gamma$ modes cannot be clearly separated, we regard the latter mode as a subset of the former.
- [b] See the Particle Listings below for the energy limits used in this measure-
- [c] A test of additive vs. multiplicative lepton family number conservation.

μ^- BRANCHING RATIOS

$\Gamma(e^-\overline{\nu}_e\nu_\mu\gamma)/\Gamma_{\rm to}$	tal						Γ_2/Γ
VALUE	EVTS	DOCUMENT ID		TECN	COM	MENT	
0.014 ±0.004		CRITTENDEN	61	CNTR	γ ΚΕ	> 10 MeV	
• • • We do not us	e the follow	ing data for averages	, fit	s, limits,	etc.	• •	
	862	BOGART	67	CNTR	γ ΚΕ	> 14.5 Me\	,
0.0033 ± 0.0013		CRITTENDEN	61	CNTR	γKE	> 20 MeV	
	27	ASHKIN [®]	59	CNTR			
$\Gamma(e^- \overline{\nu}_e \nu_\mu e^+ e^-)$ VALUE (units 10 ⁻⁵)		DOCUMENT ID		TECN	CHG	COMMENT	Γ3/Γ
3.4±0.2±0.3	7443			SPEC		SINDRUM	
• • • We do not us	e the follow	ing data for averages	, fit	s, limits,	etc.	• •	
2.2±1.5	7	12 CRITTENDEN	61	HLBC	+	E(e+e-)>	10
2	1	¹³ GUREVICH	60	EMUL	+	Wicv	
1.5 ± 1.0	3	¹⁴ LEE	59	HBC	+		
11 BERTL 85 has	transverse r	momentum cut $p_{\mathcal{T}}$	>	17 MeV	/c. S	ystematic er	ror was

- 12 CRITTENDEN 61 count only those decays where total energy of either $(e^+,\,e^-)$ combination is >10 MeV. 13 GUREVICH 60 interpret their event as either virtual or real photon conversion. e^+ and
- energies not measured. the energies of measured. The sum of energies $E(e^+) + E(e^-) + E(e^+)$ was 51 MeV, 55 MeV, and 33 MeV.

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law predicts ALUE	this branching	ratio to be 1/2. I		review se <u>TECN</u>		COMMENT
0.012	90	FREEDMAN	93	CNTR	+	u oscillation
• • We do not	use the followin	ng data for averag	es, fit	s, limits,	etc.	search
0.018	90	KRAKAUER		CALO	+	
0.05	90	¹⁵ BERGSMA	83	CALO		$\overline{\nu}_{\mu}e \rightarrow \mu^{-}\overline{\nu}_{e}$
0.09	90	JONKER	80	CALO		See BERGSMA 83
-0.001 ± 0.061		WILLIS	80	CNTR	+	
0.13 ± 0.15		BLIETSCHAL	J 78	HLBC	±	Avg. of 4 values
0.25	90	EICHTEN	73	HLBC	+	
¹⁵ BERGSMA 83	gives a limit o	on the inverse mu	on dec	ay cross	-sectio	on ratio $\sigma(\overline{ u}_{\mu}e^{-}$ —
$\mu^- \overline{\nu}_e)/\sigma(\nu_\mu$						$- u_e \overline{ u}_\mu)/\Gamma_{ m total}$ fo
$(e^-\gamma)/\Gamma_{\text{total}}$	v lenton family	number conservat	tion			Γ ₅ /Γ
ALUE (units 10 ⁻¹¹)	CL%_	DOCUMENT ID		TECN	CHG	COMMENT
4.9	90	BOLTON	88	CBOX	+	LAMPF
-		ng data for averag				
100	90	AZUELOS	83	CNTR	+	TRIUMF
(100	90 90	KINNISON	82	SPEC	+	LAMPF
(100	90	SCHAAF	80	ELEC	+	SIN
	30		20			
		number conservat	tion.			Γ ₆ /Γ
LUE (units 10 ⁻¹²)	CL%	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
1.0	90	¹⁶ BELLGARDT			+	SINDRUM
• We do not	use the followin	ng data for averag	es, fit	s, limits,	etc. •	• •
36	90	BARANOV	91	SPEC	+	ARES
35	90	BOLTON	88	CBOX	+	LAMPF
2.4	90	16 BERTL	85	SPEC	+	SINDRUM
160	90	16 BERTL	84	SPEC	+	SINDRUM
130	90	¹⁶ BOLTON constant matrix el	84	CNTR		LAMPF
$\left(e^{-}2\gamma ight)/\Gamma_{ m total}$,					Γ ₇ /Γ
Forbidden b	y lepton family	number conservat	ion.			-,
LUE (units 10 ⁻¹¹)	CL%	DOCUMENT ID		TECN	CHG	COMMENT
7.2	90	BOLTON	88	CBOX	+	LAMPF
• • We do not	use the followin	ng data for averag	es, fits	s, limits,	etc. •	• •
		¹⁷ AZUELOS	83	CNTR	+	TRIUMF
840	90 90	¹⁸ BOWMAN	78	CNTR		DEPOMMIER 77
840 5000 ⁷ AZUELOS 83	90 uses the phase	space distribution	of Bo	OWMAN		data
840 5000 ⁷ AZUELOS 83	90 uses the phase	space distribution	of Bo	OWMAN		
840 5000 ⁷ AZUELOS 83 ⁸ BOWMAN 78	90 uses the phase assumes an in	space distribution	of Bo	OWMAN	the sca	data
840 5000 ⁷ AZUELOS 83 ⁸ BOWMAN 78 mass.	90 uses the phase assumes an in LIMIT O	space distribution iteraction Lagrang $0 \ \mu^- ightarrow e^- \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \$	of Bogian Id	OWMAN ocal on t	the sca	data
840 5000 7 AZUELOS 83 8 BOWMAN 78 mass. Forbidder $(\mu^{-32}S \rightarrow e^{-3})$	90 uses the phase assumes an in LIMIT O To by lepton fam - 32S) / σ(μ	space distribution the space of the space o	of Bogian Id	OWMAN ocal on t	on	data alle of the inverse μ
840 5000 7 AZUELOS 83 8 BOWMAN 78 mass. Forbidder (µ−325 → e ² LUE	90 uses the phase assumes an in LIMIT Of the by lepton fam $\frac{-32}{6.6}$	space distribution iteraction Lagrang $N \mu^- o e^- C$ ily number conser $-32S o u_\mu ^{32}$	of Bo	VERSIC	ON COMM	data alle of the inverse μ
840 5000 7 AZUELOS 83 8 BOWMAN 78 mass. Forbidder $(\mu^{-32}S \rightarrow e^{i})$	90 uses the phase assumes an in LIMIT O h by lepton fam $\frac{-32\text{S}}{90} / \sigma(\mu \frac{\text{CL\%}}{90})$	space distribution iteraction Lagrang $N \mu^- \rightarrow e^- C$ ily number conser $-32_{S} \rightarrow \nu_{\mu} 32_{DOCUMENT ID}$ BADERT	of Bo	VERSIC	ON COMM	data ale of the inverse μ
840 5000 7 AZUELOS 83 8 BOWMAN 78 mass. Forbidder $(\mu^{-32}S \rightarrow e^{i})_{UUE}$ 7×10^{-11} • • We do not	uses the phase assumes an in LIMIT O h by lepton fam -32 S) $/\sigma(\mu^2 - 90)$ use the followin	space distribution iteraction Lagrang $N \mu^- \rightarrow e^- C$ ily number conser $-32S \rightarrow \nu_\mu 32$ $DOCUMENT ID$ BADERT	of Bogian Id	VERSIC	COMM SIN etc.	data ale of the inverse μ
840 5000 7 AZUELOS 83 8 BOWMAN 78 mass. Forbidder $(\mu^{-32}S \rightarrow e^{i})$ LUE 7 × 10 ⁻¹¹ • We do not 14 4 × 10 ⁻¹⁰	uses the phase assumes an in LIMIT O by lepton fam -32 S) $/\sigma(\mu)$ 0 0 use the followin 90	space distribution interaction Lagrang $N \mu^- \rightarrow e^- (0)$ ily number conser $-32S \rightarrow \nu_\mu 32$ DOCUMENT ID BADERT	of Bogian lo	VERSIC	ON COMM	data ale of the inverse μ
Forbidder $(\mu^{-32}S \rightarrow e^{-1})$ $(\mu^{-32}S \rightarrow e^{-1})$ $(\mu^{-1} \times 10^{-1})$ • We do not 4×10^{-10} $(\mu^{-1}Cu \rightarrow e^{-1})$	uses the phase assumes an in LIMIT O The by lepton fam -32 S) / $\sigma(\mu$ -32 S) / $\sigma(\mu$ go use the followin -32 Cu) / $\sigma(\mu$	space distribution iteraction Lagrang $N \mu^- \rightarrow e^- (1)$ ily number conser $-32S \rightarrow \nu_{\mu} 32$ $0 \rightarrow 0$ BADERT ig data for average BADERT $0 \rightarrow 0$ CCU $\rightarrow 0$ Capture $0 \rightarrow 0$ CCU $\rightarrow 0$ Capture $0 \rightarrow 0$ CCUMENT ID	of Bogian Id	VERSIC TECN STRC STRC STRC TECN	COMM SIN etc. •	data ale of the inverse ALENT
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840 5000 7 AZUELOS 83 8 BOWMAN 78 mass. Forbidder $(\mu^{-32}S \rightarrow e^{i})$ $(\mu^{-1}V = 0)$ • We do not 4 × 10 ⁻¹⁰ $(\mu^{-1}V = 0)$ • We do not 1.6 × 10 ⁻⁸	uses the phase assumes an in LIMIT O h by lepton fam -32 S) $/\sigma(\mu^2 - \frac{CL\%}{90}$ use the followin 90 $-\frac{CL\%}{90}$ use the followin 90 $-\frac{CL\%}{90}$ use the followin 90	space distribution interaction Lagrang $N \mu^- \rightarrow e^- C$ illy number conser $-32S \rightarrow \nu_\mu 32$ DOCUMENT ID BADERT ig data for average BADERT $Cu \rightarrow capture$ DOCUMENT ID ig data for average BRYMAN	of BO CONV vation 80 77 77 es, fits	VERSIC TECN STRC STRC STRC TECN TECN	COMM SIN etc. •	data ale of the inverse ALENT
840 5000 7 AZUELOS 83 8 BOWMAN 78 mass. Forbidder $(\mu^{-32}S \rightarrow e^{i})$ $(\mu^{-32}S \rightarrow e^{i})$ $(\mu^{-10} = 0)$	uses the phase assumes an in LIMIT O h by lepton fam -32 S) / $\sigma(\mu)$ use the followin 90 rCu) / $\sigma(\mu)$ use the followin 90 rTi) / $\sigma(\mu)$ Ti) / $\sigma(\mu)$ Ti) / $\sigma(\mu)$	space distribution iteraction Lagrang $ N \mu^- \rightarrow e^- (0) $ ily number conserved by μ and μ	of Bo glan lo CCONV vation 80 ees, fits 77	VERSICON STECK STRC STRC STRC STRC STRC STRC STRC STRC	COMM SIN etc. •	data data definition of the inverse μ
840 5000 7 AZUELOS 83 8 BOWMAN 78 mass. Forbidder $(\mu^{-32}S \rightarrow e^i)$ UUE $(T \times 10^{-11})$ • We do not UUE • UUE	uses the phase assumes an in LIMIT O h by lepton fam -32 S) / $\sigma(\mu^-)$ go use the followin 90 - Cu) / $\sigma(\mu^-)$ use the followin 90 - Ti) / $\sigma(\mu^-)$	space distribution iteraction Lagrang $ N \mu^- \rightarrow e^- $ (ily number conser $-32S \rightarrow \nu_{\mu} 32$) $ DOCUMENT ID $ $ BADERT$ $ BADERT$ $ BADERT$ Cu \rightarrow capture $ DOCUMENT ID $ $ BADERT ID $	of Bo CONVation P*) 80 87 77 72	VERSICOLONIA STRC STRC STRC STRC STRC STRC STRC STRC	COMM COMM SIN etc. •	data dele of the inverse MENT
840 5000 7 AZUELOS 83 8 BOWMAN 78 mass. Forbidder $(\mu^{-32}S \rightarrow e^i)$ UUE $(\mu^{-1}V = 0)$ $V = 0$	uses the phase assumes an in LIMIT On by lepton fam -32 S) / $\sigma(\mu^-)$ CU_3 use the followin 90 CU_4 use the followin 90 TI_1 / $\sigma(\mu^-)$ CU_3 TI_4 TI_5 TI_6 TI_7 TI_7 TI_7 TI_8 TI_7 TI_8	space distribution interaction Lagrang $ N \mu^- \rightarrow e^- $ (if in the property of the property o	of Bogglan lo	VERSICOLO TECN STRC STRC STRC SI limits, STRC TECN SPEC	COMM SIN etc. •	data ale of the inverse MENT RUM II
840 5000 83 8 BOWMAN 78 mass. Forbidder $(\mu^{-32}S \rightarrow e^i)$ 10 • We do not 4 × 10-10 μ^{-1} • We do not 1.6 × 10-8 μ^{-1} $(\mu^{-1} \rightarrow e^{-1})$ $(\mu^{-1} \rightarrow e^{-1})$ $(\mu^{-1} \rightarrow e^{-1})$ • We do not 1.6 × 10-8 μ^{-1} $(\mu^{-1} \rightarrow e^{-1})$ • We do not 1.6 × 10-8 μ^{-1} • We do not 1.6 × 10-8 μ^{-1} • We do not 1.6 × 10-8 μ^{-1}	uses the phase assumes an in LIMIT On by lepton fam -32 S) $/\sigma(\mu^ 0$ 0 use the followin 90 0 0 use the followin 90 0 1 0 1 0 2 0 3 use the followin 90 0 4 0 5 0 6 0 7 0 7 0 8 0 9 0 9 use the followin 90 0 9 use the followin	space distribution interaction Lagrang $ N \mu^- \rightarrow e^- $ (if in the property of the property o	of Boglan local of Boglan loca	VERSIC TECN STRC S, limits, STRC TECN STRC STRC STRC STRC STRC STRC STRC STRC	COMM SIN etc. •	data dele of the inverse MENT RUM II • •
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LIMIT ON $\mu^- \rightarrow e^+$ CONVERSION

Forbidden by total lepton number conservation.

$\sigma(\mu^{-32} S \rightarrow e^{+32} S I^*) / \sigma(\mu^{-32} S \rightarrow \nu_{\mu}^{32} P^*)$ VALUE <u>CL%</u> DOCUMENT ID TECN COMMENT <9 × 10⁻¹⁰ 90 BADERT... 80 STRC SIN \bullet $\,\bullet\,$ We do not use the following data for averages, fits, limits, etc. $\,\bullet\,$ $\,\bullet\,$ $< 1.5 \times 10^{-9}$ 90 BADERT... 78 STRC SIN $\sigma(\mu^{-\,127}\text{I}\,\rightarrow\,\,e^{+\,127}\text{Sb*})\;/\;\sigma(\mu^{-\,127}\text{I}\,\rightarrow\,\,\text{anything})$ DOCUMENT ID TECN COMMENT VALUE CL% <3 × 10⁻¹⁰ ²⁰ ABELA 80 CNTR Radiochemical tech. 90

 20 ABELA 80 is upper limit for $\mu^-\,e^+$ conversion leading to particle-stable states of 127 Sb. Limit for total conversion rate is higher by a factor less than 4 (G. Backenstoss, private

22 This DOHMEN 93 limit assumes the daughter Ca nucleus is left in the ground state. However, the probability of this is unknown

23 Assuming a giant-resonance-excitation model.

LIMIT ON MUONIUM -> ANTIMUONIUM CONVERSION

Forbidden by lepton family number conservation.

$R_{\mathbf{g}} = G_{\mathbf{C}} / G_{\mathbf{F}}$

The effective Lagrangian for the $\mu^+\,e^ \rightarrow$ $\mu^-\,e^+$ conversion is assumed to be

$$\mathcal{L} = 2^{-1/2} \ \textit{G}_{\textit{C}} \ [\overline{\psi}_{\mu} \gamma_{\lambda} \ (1 - \gamma_{5}) \ \psi_{e}] \ [\overline{\psi}_{\mu} \gamma_{\lambda} \ (1 - \gamma_{5}) \ \psi_{e}] \ + \ \text{h.c.}$$

The experimental result is then an upper limit on ${\it G_C/G_F}$, where ${\it G_F}$ is the Fermi coupling constant.

VALUE	<u>CL% E1</u>	115	DOCUMENTID	-	TECN CH	COMMENT
< 0.13	90		GORDEEV	93	SPEC	JINR phasotron
• • We do	not use the fe	ollowin	g data for average	s, fits	, limits, etc	. • • •
< 0.14	90	1	²⁴ GORDEEV	94	SPEC +	JINR phasotron
< 6.9	90		NI	93	CBOX	LAMPF
< 0.16	90		MATTHIAS	91	SPEC	LAMPF
< 0.29	90		HUBER	90B	CNTR	TRIUMF
< 0.88	90		HUBER	88	CNTR	See HUBER 90B
< 7.5	90		NI	87	CBOX	See NI 93
<20	95		BEER	86	CNTR	TRIUMF
<42	95		MARSHALL	82	CNTR	
24				_		

²⁴GORDEEV 94 quote limits on both $f=G_{M\overline{M}}/G_F$ and on the probability $W_{M\overline{M}}$ 5.1×10^{-7} (90% CL). Final results are based on the full data set.

MUON DECAY PARAMETERS

(by W. Fetscher and H.-J. Gerber, ETH Zürich)

All measurements in direct muon decay, $\mu^- \rightarrow e^- + 2$ neutrals, and its inverse, $\nu_{\mu} + e^{-} \rightarrow \mu^{-} + \text{neutral}$, are successfully described by the "V-A interaction," which is a particular case of a local, derivative-free, lepton-number-conserving, four-fermion interaction [1]. The matrix element is given below. The $V\!-\!A$ form and the nature of the neutrals $(\nu_{\mu}$ and $\overline{\nu}_{e})$, and hence the doublet assignments $(\nu_e \ e^-)_L$ and $(\nu_\mu \ \mu^-)_L$, can be determined from experiments [2,3].

All results in direct muon decay (energy spectra, polarizations, and angular distributions) and in inverse muon decay (the reaction cross section) at energies well below $m_W c^2$ may be

 μ

parametrized in terms of amplitudes $g_{\varepsilon\mu}^{2}$ and the Fermi coupling constant G_{F} , using the matrix element

$$\frac{4G_F}{\sqrt{2}} \sum_{\substack{\gamma = S, V, T\\ \epsilon, \mu = R}} g_{\epsilon\mu}^{\gamma} \langle \overline{e}_{\epsilon} \mid \Gamma^{\gamma} \mid (\nu_e)_n \rangle \langle (\overline{\nu}_{\mu})_m \mid \Gamma_{\gamma} \mid \mu_{\mu} \rangle . \tag{1}$$

We use the notation of Fetscher et al. [2], who in turn use the sign conventions and definitions of Scheck [4]. Here $\gamma = S, V, T$ indicate a scalar, vector, or tensor interaction; and $\varepsilon, \mu = R, L$ indicate a right- or left-handed chirality of the electron or muon. The chiralities n and m of the ν_e and $\overline{\nu}_{\mu}$ are then determined by the values of γ, ε , and μ . The particles are represented by fields of definite chirality [5].

As shown by Langacker and London [6], explicit lepton-number nonconservation still leads to a matrix element equivalent to Eq. (1). They conclude that it is not possible, even in principle, to test lepton-number conservation in (leptonic) muon decay if the final neutrinos are massless and are not observed.

The ten complex amplitudes $g_{\varepsilon\mu}^{\gamma}$ (g_{RR}^{T} and g_{LL}^{T} are identically zero) and G_{F} constitute 19 independent (real) parameters to be determined by experiment. The V-A interaction corresponds to the single amplitude g_{LL}^{V} being unity and all the others being zero.

C. Jarlskog [7] has noted that certain experiments observing the decay electron are especially informative if they yield the V-A values. Indeed, all (direct) muon decay experiments are compatible with an arbitrary mix of the scalar and vector amplitudes g_{LL}^S and g_{LL}^V —in the extreme, even with the purely scalar $g_{LL}^S = 2$, $g_{LL}^V = 0$. The decision in favor of V-A comes from the quantitative observation of inverse muon decay, which would be forbidden for pure g_{LL}^S [2].

The differential decay probability to obtain an e^{\pm} with (reduced) energy between x and x+dx, emitted in the direction \widehat{z} at an angle between θ and $\theta+d\theta$ with respect to the muon polarization vector \vec{P}_{μ} , and with its spin pointing in the arbitrary direction $\widehat{\zeta}$, is given by

$$\begin{split} \frac{d^2\Gamma}{dx\;d\cos\theta} &= \frac{m_\mu}{4\pi^3}\,W_{e\mu}^4\,G_F^2\,\sqrt{x^2-x_0^2} \\ &\quad \times \left(F_{IS}(x)\pm P_\mu\cos\theta\,F_{AS}(x)\right) \\ &\quad \times \left[1+\vec{P}_e(x,\theta)\cdot\widehat{\zeta}\right]\,. \end{split}$$

Here $W_{e\mu} = \max(E_e) = (m_{\mu}^2 + m_e^2)/2m_{\mu}$ is the maximum e^{\pm} energy, $x = E_e/W_{e\mu}$ is the reduced energy, and $x_0 = m_e/W_{e\mu} = 9.67 \times 10^{-3}$. The quantity $P_{\mu} = |\vec{P}_{\mu}| \cdot \hat{\zeta}$ has the significance of the direction in which a perfect polarization-sensitive electron detector would be most sensitive. The isotropic part of the spectrum, $F_{IS}(x)$, the anisotropic part, $F_{AS}(x)$, and the electron polarization, $\vec{P}_e(x,\theta)$, depend on bilinear combinations—called

decay parameters—of the coupling constants $g_{\varepsilon\mu}^{\gamma}$. Neglecting possible nonzero neutrino masses, we have, in terms of the decay parameters ρ , η , ξ , δ , etc.,

$$\begin{split} F_{IS}(x) &= x(1-x) + \frac{2}{9}\rho(4x^2 - 3x - x_0^2) + \eta \, x_0(1-x) \\ F_{AS}(x) &= \frac{1}{3}\xi \, \sqrt{x^2 - x_0^2} \\ &\qquad \times \left[1 - x + \frac{2}{3}\delta\Big(4x - 3 - (\sqrt{1 - x_0^2} - 1)\Big) \right] \\ \vec{P}_e(x,\theta) &= P_{T_1}\, \hat{x} + P_{T_2}\, \hat{y} + P_L\, \hat{z} \; . \end{split}$$

Here \widehat{x} , \widehat{y} , and \widehat{z} are orthogonal unit vectors defined as follows:

 \hat{z} is along the e momentum

 $\widehat{y} = [\widehat{z} \times \vec{P_{\mu}}]/|[\widehat{z} \times \vec{P_{\mu}}]|$ is transverse to the e momentum and perpendicular to the "decay plane" $\widehat{x} = \widehat{y} \times \widehat{z} \quad \text{is transverse to the } e \text{ momentum and in the "decay plane."}$

The components of \vec{P}_e then are given by

$$\begin{split} P_{T_1}(x,\theta) &= P_{\mu} \sin \theta \, F_{T_1}(x) \Big/ \Big(F_{IS}(x) \pm P_{\mu} \cos \theta \, F_{AS}(x) \Big) \\ P_{T_2}(x,\theta) &= P_{\mu} \sin \theta \, F_{T_2}(x) \Big/ \Big(F_{IS}(x) \pm P_{\mu} \cos \theta \, F_{AS}(x) \Big) \\ P_{L}(x,\theta) &= \pm F_{IP}(x) + P_{\mu} \cos \theta \\ &\qquad \times F_{AP}(x) \Big/ \Big(F_{IS}(x) \pm P_{\mu} \cos \theta \, F_{AS}(x) \Big) \;, \end{split}$$

where

$$F_{T_1}(x) = \frac{1}{12} \left\{ -2 \left[\xi'' + 12(\rho - \frac{3}{4}) \right] (1 - x) x_0 - 3\eta(x^2 - x_0^2) + \eta''(-3x^2 + 4x - x_0^2) \right\}$$

$$F_{T_2}(x) = \frac{1}{3} \sqrt{x^2 - x_0^2} \left\{ 3 \frac{\alpha'}{A} (1 - x) + 2 \frac{\beta'}{A} \sqrt{1 - x_0^2} \right\}$$

$$F_{IP}(x) = \frac{1}{54} \sqrt{x^2 - x_0^2} \left\{ 9 \xi' \left(-2x + 2 + \sqrt{1 - x_0^2} \right) + 4 \xi (\delta - \frac{3}{4}) \left(4x - 4 + \sqrt{1 - x_0^2} \right) \right\}$$

$$F_{AP}(x) = \frac{1}{6} \left\{ \xi''(2x^2 - x - x_0^2) + 4(\rho - \frac{3}{4}) (4x^2 - 3x - x_0^2) + 2 \eta''(1 - x) x_0 \right\}.$$

For the experimental values of the decay parameters ρ , ξ , ξ' , ξ'' , δ , η , η'' , α/A , β/A , α'/A , β'/A , which are not all independent, see the Data Listings below. Experiments in the past have also been analyzed using the parameters a, b, c, a', b', c', α/A , β/A , α'/A , β'/A (and $\eta = (\alpha - 2\beta)/2A$), as defined by Kinoshita and Sirlin [8]. They serve as a model-independent

summary of all possible measurements on the decay electron (see Listings below). The relations between the two sets of parameters are

$$\begin{split} \rho - \frac{3}{4} &= \frac{3}{4}(-a+2c)/A \;, \\ \eta &= (\alpha-2\beta)/A \;, \\ \eta'' &= (3\alpha+2\beta)/A \;, \\ \delta - \frac{3}{4} &= \frac{9}{4} \cdot \frac{(a'-2c')/A}{1-[a+3a'+4(b+b')+6c-14c']/A} \;, \\ 1 - \xi \frac{\delta}{\rho} &= 4 \frac{[(b+b')+2(c-c')]/A}{1-(a-2c)/A} \;, \\ 1 - \xi' &= [(a+a')+4(b+b')+6(c+c')]/A \;, \\ 1 - \xi'' &= (-2a+20c)/A \;, \end{split}$$

where

$$A = a + 4b + 6c.$$

The relations to the coupling constants are:

$$\begin{split} a &= 16(|g_{RL}^V|^2 + |g_{LR}^V|^2) + |g_{RL}^S + 6g_{RL}^T|^2 + |g_{LR}^S + 6g_{LR}^T|^2 \;, \\ a' &= 16(|g_{RL}^V|^2 - |g_{LR}^V|^2) + |g_{RL}^S + 6g_{RL}^T|^2 - |g_{LR}^S + 6g_{LR}^T|^2 \;, \\ \alpha &= 8\operatorname{Re}\left[g_{RL}^V(g_{LR}^S + 6g_{LR}^T)^* + g_{LR}^V(g_{RL}^S + 6g_{RL}^T)^*\right] \;, \\ \alpha' &= 8\operatorname{Im}\left[-g_{LR}^V(g_{RL}^S + 6g_{RL}^T)^* - g_{RL}^V(g_{LR}^S + 6g_{LR}^T)^*\right] \;, \\ b' &= 4(|g_{RR}^V|^2 + |g_{LL}^V|^2) + |g_{RR}^S|^2 + |g_{LL}^S|^2 \;, \\ b' &= 4(|g_{RR}^V|^2 - |g_{LL}^V|^2) + |g_{RR}^S|^2 - |g_{LL}^S|^2 \;, \\ \beta &= -4\operatorname{Re}\left[g_{RR}^V(g_{LL}^S)^* + g_{LL}^V(g_{RR}^S)^*\right] \;, \\ \beta' &= 4\operatorname{Im}\left[g_{RR}^V(g_{LL}^S)^* - g_{LL}^V(g_{RR}^S)^*\right] \;, \\ c &= \frac{1}{2}\left[|g_{RL}^S - 2g_{RL}^T|^2 + |g_{LR}^S - 2g_{LR}^T|^2\right] \;, \\ c' &= \frac{1}{2}\left[|g_{RL}^S - 2g_{RL}^T|^2 - |g_{LR}^S - 2g_{LR}^T|^2\right] \;. \end{split}$$

If also the electron mass is neglected, the energy and angular distribution of the electron in the rest frame of a polarized muon (μ^{\mp}) is given by the Michel spectrum:

$$\begin{split} d^2\Gamma \sim &\left\{3(1-x) + \frac{2\rho}{3}(4x-3)\right. \\ \mp &\xi \, \cos\theta[1-x + \frac{2\delta}{3}(4x-3)]\right\} x^2 dx \, d(\cos\theta) \ . \end{split}$$

Here θ is the angle between the electron momentum and the muon spin, and $x \equiv 2E_e/m_\mu$. For pure V-A coupling, we obtain $\rho = \xi \delta = 3/4$, $\xi = 1$, and the differential decay rate is

$$d^{2}\Gamma = \frac{G_{F}^{2}m_{\mu}^{5}}{192\pi^{3}} \left[3 - 2x \pm \cos\theta (1 - 2x) \right] x^{2} dx d(\cos\theta)$$

Here the coefficient in front of the square bracket is the total decay rate.

In order to determine the amplitudes $g_{\varepsilon\mu}^{\gamma}$ uniquely from experiment, Fetscher *et al.* [2] introduced four probabilities $Q_{\varepsilon\mu}(\varepsilon,\mu=R,L)$ for the decay of a μ -handed muon into an ε -handed electron and showed that there exist upper bounds on Q_{RR} , Q_{LR} , and Q_{RL} , and a lower bound on Q_{LL} . These probabilities are given in terms of the $g_{\varepsilon\mu}^{\gamma}$'s by

$$Q_{\varepsilon\mu} = \frac{1}{4} |g_{\varepsilon\mu}^S|^2 + |g_{\varepsilon\mu}^V|^2 + 3(1 - \delta_{\varepsilon\mu})|g_{\varepsilon\mu}^T|^2 , \qquad (2)$$

where $\delta_{\varepsilon\mu}=1$ for $\varepsilon=\mu$ and $\delta_{\varepsilon\mu}=0$ for $\varepsilon\neq\mu$. They are related to the parameters $a,\,b,\,c,\,a',\,b',$ and c' by

$$\begin{split} Q_{RR} &= 2(b+b')/A \ , \\ Q_{LR} &= [(a-a')+6(c-c')]/2A \ , \\ Q_{RL} &= [(a+a')+6(c+c')]/2A \ , \\ Q_{LL} &= 2(b-b')/A \ , \end{split}$$

with A = 16. In the pure V-A theory, $Q_{LL} = 1$ and the others are zero.

Since the upper bounds on Q_{RR} , Q_{LR} , and Q_{RL} are found to be small, and since the helicity of the ν_{μ} in pion decay is known from experiment [9,10] to very high precision to be -1 [11], the cross section S of *inverse* muon decay, normalized to the V-A value, yields [2]

$$|g_{LL}^S|^2 \le 4(1-S) \tag{3}$$

and

$$|g_{LL}^V|^2 = S (4)$$

Thus the Standard Model assumption of a pure V-A leptonic charged weak interaction for e and μ is confirmed (within errors) by experiments at energies far below the mass of the W^{\pm} : Eq. (4) gives a lower limit for V-A, and Eqs. (2) and (3) give upper limits for the other four-fermion interactions. The existence of such upper limits may also be seen from $Q_{RR} + Q_{RL} = (1 - \xi')/2$ and $Q_{RR} + Q_{LR} = \frac{1}{2}(1 + \xi/3 - 16\xi\delta/9)$. Table 1 gives the current experimental limits on the magnitudes of the $g_{\varepsilon\mu}^{\varepsilon}$'s.

Table 1. Ninety-percent confidence level experimental limits for the coupling constants $g_{\epsilon\mu}^{\gamma}$. The limits on $|g_{LL}^{S}|$ and $|g_{LL}^{V}|$ are from Ref. 12, and the others are from Ref. 13. The experimental uncertainty on the muon polarization in pion decay is included.

$ g_{RR}^S < 0.066$	$ g_{RR}^{V} < 0.033$	$ g_{RR}^T \equiv 0$
$ g_{LR}^S <0.125$	$ g_{LR}^{V} < 0.060$	$ g_{LR}^T < 0.036$
$ g_{RL}^S <0.424$	$ g_{RL}^V <0.110$	$ g_{RL}^{T} < 0.122$
$ g_{LL}^S <0.55$	$ g_{LL}^V > 0.96$	$ g_{LL}^T \equiv 0$

Limits on the "charge retention" coordinates, as used in the older literature (e.g., Ref. 14), are given by Burkard $et\ al.$ [15].

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μ DECAY PARAMETERS

ρ PARAMETER

(V-A) theory predicts $\rho = 0.75$.

VALUE	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
0.7518±0.0026		DERENZO	69	RVUE		
• • • We do not us	e the followi	ing data for average	s, fit	s, limits,	etc.	• •
0.762 ±0.008	170k	²⁵ FRYBERGER	68	ASPK	+	25–53 MeV e+
0.760 ±0.009	280k	²⁵ SHERWOOD	67	ASPK	+	25-53 MeV e+
0.7503 ± 0.0026	800k	²⁵ PEOPLES	66	ASPK	+	20-53 MeV e+
$^{25}\eta$ constrained = DERENZO 69.	0. These v	ralues incorporated	into	a two pa	aramet	er fit to $ ho$ and η by

η PARAMETER

(V-A) theory predicts $\eta = 0$.

<u>/TS</u>	DOCUMENT ID		TECN	CHG	COMMENT
SE .					
3M 26	BURKARD	85B	FIT	+	9–53 MeV e+
346	DERENZO	69	HBC	+	1.6-6.8 MeV
					e+
wing data	for averages, f	its, II	mits, etc	. • •	•
3M ²⁷	BURKARD	85B	CNTR	+	9-53 MeV e+
3M	BURKARD	85B	CNTR	+	9–53 MeV e ⁺
		68	ASPK	+	25-53 MeV e+
30k 28	SHERWOOD	67	ASPK	+	25-53 MeV e+
		66	ASPK	+	20-53 MeV e+
213 29	PLANO	60	HBC	+	Whole spec-
					trum
ired para	meters. Cor	relati	on coef	fficient	s are given in
	3M 70k 28 80k 28 90k 28 213 29	BURKARD 28 FRYBERGER 30k 28 SHERWOOD 28 PEOPLES 29 PLANO	BM BURKARD 85B 70k 28 FRYBERGER 68 10k 28 SHERWOOD 67 10k 28 PEOPLES 66 113 29 PLANO 60	BM BURKARD 85B CNTR 70k 28 FRYBERGER 68 ASPK 10k 28 SHERWOOD 67 ASPK 10k 28 PEOPLES 66 ASPK 113 29 PLANO 60 HBC	BURKARD 85B CNTR + 28 FRYBERGER 68 ASPK + 28 SHERWOOD 67 ASPK + 00k 28 PEOPLES 66 ASPK + 213 29 PLANO 60 HBC +

²⁹ Two parameter fit to ρ and η ; PLANO 60 discounts value for η .

δ PARAMETER

(V-A) theory predicts δ = 0.75. EVTS DOCUMENT ID TECN CHG COMMENT

0.7486±0.0026±0.0	002 8	³⁰ BALKE	88	SPEC	+	Surface μ^+ 's
• • • We do not us	se the following d	lata for averages,	fits, I	imits, et	с. • •	•
		³¹ VOSSLER	69			
0.752 ± 0.009	490k	FRYBERGER	68	ASPK	+	25–53 MeV e ⁺
0.782 ± 0.031		KRUGER	61			
0.78 ±0.05	8354	PLANO	60	HBC	+	Whole spec- trum

 $^{^{30}\, {\}sf BALKE}$ 88 uses $ho = 0.752 \pm 0.003$.

$|(\xi \text{ PARAMETER}) \times (\mu \text{ LONGITUDINAL POLARIZATION})|$

(V-A) theory predicts $\xi=1$, longitudinal polarization = 1. VALUE EVTS DOCUMENT ID TECN

VALUE	LVIJ	DOCUMENTID		TECIV C	HG COMMENT
1.0027±0.0079±0.0030		BELTRAMI	87	CNTR	SIN, π decay in flight
• • We do not use the	following	data for averages, f	its, I	imits, etc.	• • •
$1.0013 \pm 0.0030 \pm 0.0053$		³² IMAZATO	92	SPEC +	$\kappa^+ \rightarrow \mu^+ \nu_{\mu}$
0.975 ±0.015		AKHMANOV	68	EMUL	140 kG
0.975 ±0.030	66k	GUREVICH	64	EMUL	See AKHMA- NOV 68
0.903 ±0.027		³³ ALI-ZADE	61	EMUL +	
0.93 ±0.06	8354	PLANO	60	HBC +	- 8.8 kG
0.97 ±0.05	9k	BARDON	59	CNTR	Bromoform

 $^{32}\,\text{The corresponding 90\%}$ confidence limit from IMAZATO 92 is $|\xi P_{\mu}|>$ 0.990. This measurement is of K^+ decay, not π^+ decay, so we do not include it in an average, nor do we yet set up a separate data block for K results.

target

Bhabha + annihil

33 Depolarization by medium not known sufficiently well.

$\xi \times (\mu \text{ LONGITUDINAL POLARIZATION}) \times \delta / \rho$

VALUE	CL%	DOCUMENT ID		TECN	CHG	COMMENT	
>0.99682	90	34 JODIDIO	86	SPEC	+	TRIUMF	
• • • We do not u	se the follow	ing data for averag	ges, fits	s, limits,	etc. •	• •	
>0.9966	90	³⁵ STOKER	85	SPEC	+	μ -spin rotation	
>0.9959	90	CARR	83	SPEC	+	11 kG	

 34 JODIDIO 86 includes data from CARR 83 and STOKER 85. The value here is from the

erratum. 35 STOKER 85 find $(\xi P_{\mu} \delta/\rho)$ >0.9955 and >0.9966, where the first limit is from new μ spin-rotation data and the second is from combination with CARR 83 data. In V-A theory, $(\delta/\rho)=1.0.$

$\xi' = \text{LONGITUDINAL POLARIZATION OF } e^+$

(V-A) theory predicts the longitudinal polarization $=\pm 1$ for e^\pm , respectively. We have flipped the sign for e so our programs can average.

nave m	pped the sign for c	30 our programs	Can	avciage.		
VALUE	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
1.00 ±0.04	OUR AVERAGE					
0.998 ± 0.045	1M	BURKARD	85	CNTR	+	Bhabha + annihil
0.89 ± 0.28	29k	SCHWARTZ	67	OSPK	-	Moller scattering
0.94 ± 0.38		BLOOM	64	CNTR	+	Brems. transmiss.
1.04 ± 0.18		DUCLOS	64	CNTR	+	Bhabha scattering
1.05 ± 0.30		BUHLER	63	CNTR	+	Annihilation
ξ" PARAM	ETER					

VALUE EVTS DOCUMENT ID TECN CHG COMMENT 36 BURKARD 85 CNTR + 0.65±0.36 326k

³⁶ BURKARD 85 measure $(\xi'' - \xi \xi')/\xi$ and ξ' and set $\xi = 1$. TRANSVERSE e^+ POLARIZATION IN PLANE OF μ SPIN, e^+ MOMEN-

EVTS DOCUMENT ID TECN CHG COMMENT \bullet $\,\bullet\,$ We do not use the following data for averages, fits, limits, etc. $\,\bullet\,$ $\,\bullet\,$ $0.016 \pm 0.021 \pm 0.01$ 5.3M BURKARD 85B CNTR + Annihil 9-53 MeV

TRANSVERSE e^+ POLARIZATION NORMAL TO PLANE OF μ SPIN, e^+ MOMENTUM Zero if *T* invariance holds.

DOCUMENT ID TECN CHG COMMENT 0.007±0.022±0.007 5.3M BURKARD 85B CNTR + VALUE (units 10⁻³) EVTS DOCUMENT ID TECN CHG COMMENT 37 BURKARD 858 FIT

• • • We do not use the following data for averages, fits, limits, etc. • • 15 ±50 ±14 5.3M BURKARD 85B CNTR + 9-53 MeV e+ ³⁷Global fit to all measured parameters. BURKARD 85B. Correlation coefficients are given in

α'/A

Zero if T invaria	nce holds.					
VALUE (units 10 ⁻³)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
-0.2 ± 4.3		³⁸ BURKARD	85B	FIT		
• • • We do not use	the following	g data for averages	s, fits	, limits,	etc. •	• •
47 150 114	F 244	39 511514 55		CHITC		

 $^{\rm 38}\,{\rm Global}$ fit to all measured parameters. Correlation coefficients are given in 39 BURKARD 85B measure e^+ polarizations ${\sf P}_{T_1}$ and ${\sf P}_{T_2}$ versus e^+ energy.

VALUE (units 10⁻³) EVTS DOCUMENT ID TECN CHG COMMENT 40 BURKARD 858 FIT 3.9 ± 6.2 • • • We do not use the following data for averages, fits, limits, etc. • • • BURKARD 858 CNTR + 9-53 MeV e+ $^{
m 40}\,{
m Global}$ fit to all measured parameters. Correlation coefficients are given in BURKARD 858.

³¹ VOSSLER 69 has measured the asymmetry below 10 MeV. See comments about radiative corrections in VOSSLER 69.

β'/A	KRAKAUER	91B	PL B263 534	+Talaga, Allen, Chen, Doe+ (UMD, UCI, LANL)
Zero if T invariance holds.	MATTHIAS Also	91 91B	PRL 66 2716 PRL 67 932 erratum	+Ahn+ (YALE, HEIDP, WILL, GSI, VILL, BNL) Matthias, Ahn+ (YALE, HEIDP, WILL, GSI, VILL, BNL)
VALUE (units 10 ⁻³) EVTS DOCUMENT ID TECN CHG COMMENT	HUBER	90B	PR D41 2709	+ (WYOM, VICT, ARIZ, ROCH, TRIU, SFRA, BRCO)
1.5± 6.3 41 BURKARD 85B FIT	AHMAD Also	88 87	PR D38 2102 PRL 59 970	Ahmad+ (TRIU, VPI, VICT, BRCO, MONT, CNRC)
 • • We do not use the following data for averages, fits, limits, etc. 	BALKE	88	PR D37 587	+Gidal, Jodidio+ (LBL, UCB, COLO, NWES, TRIU)
17 \pm 17 \pm 6 5.3M ⁴² BURKARD 85B CNTR + 9–53 MeV e^+	BELLGARDT BOLTON	88 88	NP B299 1 PR D38 2077	+Otter, Eichler+ (SINDRUM Collab.) +Cooper, Frank, Hallin+ (LANL, STAN, CHIC, TEMP) Bolton, Bowman, Cooper+ (LANL, STAN, CHIC, TEMP)
⁴¹ Global fit to all measured parameters. Correlation coefficients are given in	Also Also	86 86	PRL 56 2461 PRL 57 3241	Bolton, Bowman, Cooper+ (LANL, STAN, CHIC, TEMP)
BURKARD 85B.	HUBER	88	PRL 61 2189	Grosnick, Wright, Bolton+ (CHIC, LANL, STAN, TEMP) +Beer+ (WYOM, VICT, ARIZ, ROCH, TRIU, BRCO)
42 BURKARD 85B measure e^+ polarizations P_{T_1} and P_{T_2} versus e^+ energy.	BELTRAMI COHEN	87 87	PL B194 326 RMP 59 1121	+Burkard, Von Dincklage+ (ETH, SIN, MANZ) +Taylor (RISC, NBS)
a/A	NI	87	PRL 59 2716	+Arnold, Chmely+ (YALE, LANL, WILL, MISS, HEIDP)
This comes from an alternative parameterization to that used in the Summary Table	BEER BELTRAMI	86 86	PRL 57 671 NP A451 679	+Marshall, Mason+ (VICT, TRIU, WYOM) +Aas, Beer, Dechambrier, Goudsmit+ (ETH, FRIB)
(see the "Note on Muon Decay Parameters" above).	JODIDIO	86	PR D34 1967 PR D37 237 erratum	+Balke, Carr, Gidal, Shinsky+ (LBL, NWES, TRIU)
VALUE (units 10 ⁻³) CL% DOCUMENT ID TECN	Also BERTL	88 85	NP B260 1	Jodidio, Balke, Carr+ (LBL, NWES, TRIU) +Egli, Eichler+ (SINDRUM Collab.)
• • • We do not use the following data for averages, fits, limits, etc. • •	BRYMAN BURKARD	85 85	PRL 55 465 PL 150B 242	+ (TRIU, CNRC, BRCO, LANL, CHIC, CARL+) +Corriveau, Egger+ (ETH, SIN, MANZ)
<15.9 90 ⁴³ BURKARD 85B FIT	BURKARD	85B	PL 160B 343	+Corriveau, Egger+ (ETH, SIN, MANZ)
•	Also Also	81B 83B	PR D24 2004 PL 129B 260	Corriveau, Egger, Fetscher+ (ETH, SIN, MANZ) Corriveau, Egger, Fetscher+ (ETH, SIN, MANZ)
43 Global fit to all measured parameters. Correlation coefficients are given in BURKARD 85B.	HUGHES	85	CNPP 14 341	+Kinoshita (YALE, CORN)
BONNAND 03B.	STOKER BARDIN	85 84	PRL 54 1887 PL 137B 135	+Balke, Carr, Gidal+ (LBL, NWES, TRIU) +Duclos, Magnon+ (SACL, CERN, BGNA, FIRZ)
a'/A	BERTL	84 84	PL 140B 299	+Eichler, Felawka+ (SINDRUM Collab.)
This comes from an alternative parameterization to that used in the Summary Table	BOLTON EICHENBER		PRL 53 1415 NP A412 523	Eichenberger, Engfer, VanderSchaff (ZURI)
(see the "Note on Muon Decay Parameters" above).	GIOVANETTI KINOSHITA	84 84	PR D29 343 PRL 52 717	+Dey, Eckhause, Hart+ (WILL) +Nizic, Okamoto (CORN)
VALUE (units 10 ⁻³) DOCUMENT ID TECN	AZUELOS	83	PRL 51 164	+Denommier, Leroy, Martin+ (MONT, TRIU, BRCO)
 ◆ We do not use the following data for averages, fits, limits, etc. 	Also BERGSMA	77 83	PRL 39 1113 PL 122B 465	Depommier+ (MONT, BRCO, TRIU, VICT, MELB) +Dorenbosch, Jonker+ (CHARM Collab.)
5.3 ± 4.1 44 BURKARD 85B FIT	CARR	83	PRL 51 627	+Gidal, Gobbi, Jodidio, Oram+ (LBL, NWES, TRIU) +Anderson, Matis, Wright+ (EFI, STAN, LANL)
44 Global fit to all measured parameters. Correlation coefficients are given in	KINNISON Also	82 79	PR D25 2846 PRL 42 556	Rowman Cooper, Hamm+ (LASI, EEL STAN)
BURKARD 85B.	KLEMPT	82	PR D25 652	+Schulze, Wolf, Camani, Gygax+ (MANZ, ETH)
(4) 14) / A	MARIAM MARSHALL	82 82	PRL 49 993 PR D25 1174	+Warren, Oram, Kiefl (BRCO)
(b'+b)/A This comes from an alternative parameterization to that used in the Summary Table	COMBLEY NEMETHY	81 81	PRPL 68 93 CNPP 10 147	+Farley, Picasso (SHEF, RMCS, CERN) +Hughes (LBL, YALE)
(see the "Note on Muon Decay Parameters" above).	ABELA	80	PL 95B 318	+Backenstoss, Simons, Wuest+ (BASL, KARLK, KARLE)
VALUE (units 10 ⁻³) CL% DOCUMENT ID TECN	BADERT Also	80 82	LNC 28 401 NP A377 406	Badertscher, Borer, Czapek, Flueckiger+ (BERN) Badertscher, Borer, Czapek, Flueckiger+ (BERN)
• • • We do not use the following data for averages, fits, limits, etc. • •	JONKER	80	PL 93B 203	+Panman, Udo, Allaby+ (CHARM Collab.)
<1.04 90 ⁴⁵ BURKARD 85B FIT	SCHAAF Also	80 77	NP A340 249 PL 72B 183	+Engfer, Povel, Dey+ (ZURI, ETH, SIN) Povel, Dey, Walter, Pfeiffer+ (ZURI, ETH, SIN) +Hughes+ (YALE, LBL, LASL, SACL, SIN, CNRC+)
	WILLIS	80 80B	PRL 44 522 PRL 45 1370	+Hughes+ (YALE, LBL, LASL, SACL, SIN, CNRC+) Willis+ (YALE, LBL, LASL, SACL, SIN, CNRC+)
45 Global fit to all measured parameters. Correlation coefficients are given in BURKARD 858.	Also BAILEY	79	NP B150 1	(CERN, DARE, MANZ)
BONNAND 036.	FARLEY BADERT	79 78	ARNPS 29 243 PL 79B 371	+Picasso (RMCS, CERN) Badertscher, Borer, Czapek, Flueckiger+ (BERN)
c/A	BAILEY	78	JPG 4 345	(DARE, BERN, SHEF, MANZ, RMCS, CERN, BIRM)
This comes from an alternative parameterization to that used in the Summary Table	Also BLIETSCHAU	79 78	NP B150 1 NP B133 205	Bailey (CERN, DARE, MANZ) +Deden, Hasert, Krenz+ (Gargamelle Collab.)
(see the "Note on Muon Decay Parameters" above).	BOWMAN CAMANI	78 78	PRL 41 442 PL 77B 326	+Deden, Hasert, Krenz+ (Gargamelle Collab.) +Cheng, Li, Matis (LASL, IAS, CMU, EFI) +Gygax, Klempt, Schenck, Schulze+ (ETH, MANZ)
VALUE (units 10 ⁻³) CL% DOCUMENT ID TECN	BADERT	77	PRL 39 1385	Badertscher, Borer, Czapek, Flueckiger+ (BERN)
• • • • • • •	BAILEY Also	77 77C	PL 67B 225 PL 68B 191	+ (CERN Muon Storage Ring Collab.) Bailey+ (CERN, DARE, BERN, SHEF, MANZ+)
<6.4 90 ⁴⁶ BURKARD 85B FIT	Also	75	PL 55B 420	Bailey+ (CERN Muon Storage Ring Collab., BIRM)
⁴⁶ Global fit to all measured parameters. Correlation coefficients are given in	CALMET CASPERSON	77 77	RMP 49 21 PRL 38 956	+Narison, Perrottet+ (CPPM) +Crane+ (BERN, HEIDH, LASL, WYOM, YALE) + (MONT, BRCO, TRIU, VICT, MELB)
BURKARD 85B.	DEPOMMIER	77	PRL 39 1113 JETP 40 811	+ (MONT, BRCO, TRIU, VICT, MELB) +Grebenyuk, Zinov, Konin, Ponomarev (JINR)
c'/A	BALANDIN	74	Translated from ZETF	67 1631.
This comes from an alternative parameterization to that used in the Summary Table	COHEN DUCLOS	73 73	JPCRD 2 663 PL 47B 491	+Taylor (RISC, NBS) +Magnon, Picard (SACI)
(see the "Note on Muon Decay Parameters" above).	EICHTEN	73	PL 46B 281	+Deden, Hasert, Krenz+ (Gargamelle Collab.)
VALUE (units 10 ⁻³) DOCUMENT ID TECN	BRYMAN CROWE	72 72	PRL 28 1469 PR D5 2145	+Blecher, Gotow, Powers (VPI) +Hague, Rothberg, Schenck+ (LBL, WASH)
	CRANE DERENZO	71 69	PRL 27 474 PR 181 1854	+Casperson, Crane, Egan, Hughes+ (YALE) (EFI)
3.5±2.0 47 BURKARD 85B FIT	VOSSLER	69	NC 63A 423	(EFI)
47 Global fit to all measured parameters. Correlation coefficients are given in	AKHMANOV	68	SJNP 6 230 Translated from YAF (+Gurevich, Dobretsov, Makarina+ (KIAE) 6 316.
BURKARD 858.	BAILEY Also	68 72	PL 28B 287 NC 9A 369	+Bartl, VonBochmann, Brown, Farley+ (CERN) Bailey, Bartl, VonBochmann, Brown+ (CERN)
	FRYBERGER	68	PR 166 1379	(EFI)
η PARAMETER	BOGART SCHWARTZ	67 67	PR 156 1405 PR 162 1306	+Dicapua, Nemethy, Strelzoff (CÓLU) (EFI)
$(V-A)$ theory predicts $\overline{\eta}=0$. $\overline{\eta}$ affects spectrum of radiative muon decay. VALUE DOCUMENT ID TECN CHG COMMENT	SHERWOOD	67	PR 156 1475	(EFI)
0.02 ±0.08 OUR AVERAGE	PEOPLES BLOOM	66 64	Nevis 147 unpub. PL 8 87	+Dick, Feuvrais, Henry, Macq, Spighel (CERN)
-0.014 ± 0.090 EICHENBER 84 ELEC + ρ free	DUCLOS	64	PL 9 62	+Heintze, DeRujula, Soergel (CERN)
+0.09 ±0.14 BOGART 67 CNTR +	GUREVICH BUHLER	64 63	PL 11 185 PL 7 368	+Makarina+ (KIAE) +Cabibbo, Fidecaro, Massam, Muller+ (CERN)
	MEYER	63	PR 132 2693	+Anderson, Bleser, Lederman+ (COLU)
-0.035 ± 0.098 EICHENBER 84 ELEC + ρ =0.75 assumed	CHARPAK CONFORTO	62 62	PL 1 16 NC 26 261	+Farley, Garwin+ (CERN) +Conversi, Dilella+ (INFN, ROMA, CERN)
	ALI-ZADE	61	JETP 13 313 Translated from ZETF	+Gurevich, Nikolski 40 452.
μ REFERENCES	CRITTENDEN		PR 121 1823	+Walker, Ballam (WISC, MSU)
•	KRUGER GUREVICH	61 60	UCRL 9322 unpub. JETP 10 225	+Nikolski, Surkova (LRL)
HONECKER 96 PRL 76 200 +Dohmen, Haan, Junker+ (SINDRUM II Collab.) GORDEEV 94 JETPL 59 589 +Kiselev, Aleshin+ (PNPI, JINR)	PLANO	60	Translated from ZETF PR 119 1400	37 318. (COLU)
Translated from ZETFP 59 565.	ASHKIN	59	NC 14 1266	+Fazzini, Fidecaro, Lipman, Merrison+ (CERN)
DOHMEN 93 PL B317 631 +Groth, Heer+ (PSI SINDRUM-II Collab.) FREEDMAN 93 PR D47 811 +Fujikawa, Napolitano, Nelson+ (LAMPF E645 Collab.)	BARDON LEE	59 59	PRL 2 56 PRL 3 55	+Berley, Lederman (COLU) +Samios (COLU)
GORDEEV 93 JETPL 57 270 +Savchenko, Abazov+ (PNPI, JINR) Translated from ZETFP 57 262.				()
NI 93 PR D48 1976 +Arnold, Chmely+ (LAMPF Crystal-Box Collab.)				
IMAZATO 92 PRL 69 877 +Kawashima, Tanaka+ (KEK, INUS, TOKY, TOKMS) 8ARANOV 91 SJNP 53 802 +Vanko, Glazov, Evtukhovich+ (JINR)				
Translated from YAF 53 1302.				

 τ



 $J = \frac{1}{2}$

 τ discovery paper was PERL 75. $e^+e^-\to \tau^+\tau^-$ cross-section threshold behavior and magnitude are consistent with pointlike spin-1/2 Dirac particle. BRANDELIK 78 ruled out pointlike spin-0 or spin-1 particle. FELDMAN 78 ruled out J=3/2. KIRKBY 79 also ruled out $J\!=\!$ integer, J=3/2.

τ MASS

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
1777.00 + 0.30 OUR AV	'ERAGE			
$1776.96 + 0.18 + 0.25 \\ -0.21 - 0.17$	65	¹ BAI	96 BES	E ^{ee} _{Cm} = 3.54–3.57 GeV
1777.8 ± 0.7 ± 1.7	35k	² BALEST	93 CLEO	$E_{\rm CM}^{ee} = 10.6 \text{ GeV}$
$1776.3 \ \pm 2.4 \ \pm 1.4$	11k	³ ALBRECHT	92M ARG	$E_{\rm CM}^{ee} = 9.4-10.6 \text{ GeV}$
1783 +3	692	⁴ BACINO	78B DLCO	E ^{ee} _{cm} = 3.1–7.4 GeV
• • • We do not use t	he followi	ng data for average	es, fits, limits	s, etc. • • •
1776.9 $^{+0.4}_{-0.5}$ ± 0.2	14	⁵ BAI	92 BES	Repl. by BAI 96
¹ BAI 96 fit $\sigma(e^+e^-$				nreshold.

- ² BALEST 93 fit spectra of minimum kinematically allowed τ mass in events of the type $e^+e^- \to \tau^+\tau^- \to (\pi^+n\pi^0\nu_{\tau})(\pi^-m\pi^0\nu_{\tau})$ $n \leq 2$, $m \leq 2$, $1 \leq n+m \leq 3$. If $m_{\nu_{\tau}} \neq 0$, result increases by $(m_{\nu_{\tau}}^2/1100 \text{ MeV})$.
- 3 ALBRECHT 92M fit τ pseudomass spectrum in $\tau^-\to 2\pi^-\pi^+\nu_\tau$ decays. Result assumes $m_{\nu_\tau}{=}0.$
- 4 BACINO 78 alue comes from $e^\pm X^\mp$ threshold. Published mass 1782 MeV increased by 1 MeV using the high precision $\psi(25)$ mass measurement of ZHOLENTZ 80 to eliminate the absolute SPEAR energy calibration uncertainty.
- ⁵BAI 92 fit $\sigma(e^+e^- \to \tau^+\tau^-)$ near threshold using $e\,\mu$ events.

au MEAN LIFE

A consistent treatment of systematic biases (see WASSERBAECH 93) yields a correction of $-0.03\,\mathrm{fs}$ on the average. In addition, BATTLE 92 assumes an obsolete value of the τ mass; the correction to be applied to the average is $-0.01\,\mathrm{fs}$. These corrections do not change the result within rounding errors, so that OUR EVALUATION is equal to OUR AVERAGE.

VALUE (10 ⁻¹⁵ s)	EVTS	DOCUMENT ID	TECN	COMMENT
291.0± 1.5 OUF	REVALUATION			
291.0± 1.5 OUF	RAVERAGE			
291.4± 3.0		ABREU	96B DLPH	1991-1993 LEP runs
289.2 ± 1.7 ± 1.	.2	ALEXANDER	96E OPAL	1990-1994 LEP runs
293.7± 2.7± 1.	.6 42k	BUSKULIC	96B ALEP	1989-1992 LEP runs
297 \pm 9 \pm 5	1671	ABE	95Y SLD	1992-1993 SLC runs
293 ± 9 ±12	5743	ADRIANI	93M L3	1991 LEP run
304 \pm 14 \pm 7	4100	BATTLE	92 CLEO	$E_{cm}^{ee} = 10.6 \text{ GeV}$
• • • We do not	use the following	g data for averag	es, fits, limit	s, etc. • • •
$309 \pm 23 \pm 30$	2817	ADEVA	91F L3	1990 LEP run
301 ± 29	3780	KLEINWORT	89 JADE	E ^{ee} _{cm} = 35–46 GeV
288 \pm 16 \pm 17	807	AMIDEI	88 MRK2	Ecm= 29 GeV
306 \pm 20 \pm 14	695	BRAUNSCH	88C TASS	E ^{ee} _{cm} = 36 GeV
299 \pm 15 \pm 10	1311	ABACHI	87c HRS	$E_{ m cm}^{\it ee}=$ 29 GeV
295 \pm 14 \pm 11	5696	ALBRECHT	87P ARG	$E_{\rm Cm}^{ee} = 9.3 10.6 \text{ GeV}$
$309 \pm 17 \pm 7$	3788	BAND	87B MAC	$E_{ m cm}^{ee}=$ 29 GeV
$325 \pm 14 \pm 18$	8470	BEBEK	87C CLEO	$E_{Cm}^{ee} = 10.5 \; GeV$
490 ±200	121	FORD	82 MAC	E ^{ee} _{Cm} = 29 GeV

au MAGNETIC MOMENT ANOMALY

$\mu_{ au}/(e\hbar/2m_{ au})-1=(g_{ au}-2)/2$

For a theoretical calculation $[(g_{\tau}-2)/2=11773(3)\times 10^{-7}]$, see SAMUEL 918. VALUE CL% DOCUMENT ID TECN COMMENT

CO.01 95 6 ESCRIBANO 93 RVUE $Z \to \tau^+\tau^-$ at LEP

• • We do not use the following data for averages, fits, limits, etc. • • •

<0.12 90 GRIFOLS 91 RVUE $Z \to \tau \tau \tau$ at LEP

<0.023 95 7 SILVERMAN 83 RVUE $Z \to \tau \tau \tau$ at LEP

PETRA

- 6 ESCRIBANO 93 limit derived from $\Gamma(Z\to\tau^+\tau^-)$, and is on the absolute value of the magnetic moment anomaly.
- Table Terman 83 limit is derived from $e^+e^- \rightarrow \tau^+\tau^-$ total cross-section measurements for q^2 up to $(37 \text{ GeV})^2$.

au ELECTRIC DIPOLE MOMENT

A nonzero value is forbidden by both ${\cal T}$ invariance and ${\cal P}$ invariance.

VALUE (ecm)	CL%	DOCUMENT ID		TECN	COMMENT
<5 × 10 ⁻¹⁷	95	⁸ ESCRIBANO	93	RVUE	$Z \rightarrow \tau^+ \tau^-$ at LEP
	ne followin	g data for average	s, fit:	s, limits,	etc. • • •
$< 7 \times 10^{-16}$	90	GRIFOLS			$Z \rightarrow au au au \gamma$ at LEP
$< 1.6 \times 10^{-16}$	90	DELAGUILA	90	RVUE	$e^+e^- \rightarrow \tau^+\tau^-$
					<i>E</i> ^{ee} cm = 35 GeV

 8 ESCRIBANO 93 limit derived from $\Gamma(Z\to \tau^+\tau^-)$, and is on the absolute value of the electric dipole moment.

τ WEAK DIPOLE MOMENT (d_{τ}^{w})

A nonzero value is forbidden by CP invariance.

$Re(d_{\tau}^{w})$

VALUE (ecm)	CL%	DOCUMENT ID		TECN	COMMENT
$< 0.78 \times 10^{-17}$	95	⁹ AKERS	95F	OPAL	1991-1993 LEP runs
• • • We do not use t	he followin	g data for averag	es, fits	, limits,	etc. • • •
$< 1.5 \times 10^{-17}$	95	⁹ BUSKULIC	95 C	ALEP	1990-1992 LEP runs
$< 7.0 \times 10^{-17}$	95	⁹ ACTON	92F	OPAL	$Z \rightarrow \tau^+ \tau^-$ at LEP
$< 3.7 \times 10^{-17}$	95	⁹ BUSKULIC	92J	ALEP	Repl. by BUSKULIC 95c

⁹Limit is on the absolute value of the real part of the weak dipole moment, and applies for $q^2=m_{\pi}^2$.

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VALUE (ecm)	CL%	DOCUMENT ID		TECN	COMMENT
$<4.5 \times 10^{-17}$	95	¹⁰ AKERS	95F (OPAL	1991-1993 LEP runs

 10 Limit is on the absolute value of the imaginary part of the weak dipole moment, and applies for $q^2=m_Z^2$.

au^- DECAY MODES

 au^+ modes are charge conjugates of the modes below. " h^\pm " stands for π^\pm or K^\pm . " ℓ " stands for e or μ . "Neutral" means neutral hadron whose decay products include γ 's and/or π^0 's.

Scale factor/

	Mode	F	Fraction (Γ_i/Γ)	Scale factor/ Confidence level
	Modes with one o	harg	ed particle	
Γ1	particle ⁻ \geq 0 neutrals \geq 0 $K_I^0 \nu_{\tau}$	_	(84.96 ± 0.14) %	S=1.3
•	("1-prong")			
Γ_2	particle ≥ 0 neutrals $\geq 0K^0\nu_{\tau}$		(85.53± 0.14) %	S=1.3
Γ_3	$\mu^- \overline{\nu}_\mu \nu_\tau$	[a]	$(17.35 \pm 0.10) \%$	
Γ_4			(2.3 ± 1.0) \times 1	0-3
	$\mu^- \overline{ u}_\mu u_ au \gamma \ ({\mathcal E}_\gamma > 37 \; {\sf MeV})$			
Γ_5	$e^{-}\overline{ u}_{e} u_{ au}$	[a]	(17.83 ± 0.08) %	
Γ ₆	$h^- \geq 0$ neutrals $\geq 0 K_I^0 \; u_ au$		(49.78 ± 0.17) %	S=1.2
Γ_7	$h^- \geq 0 K_I^0 \nu_{ au}$		(12.51 ± 0.13) %	S=1.1
Γ_8	$h^- u_{ au}$		(12.03 ± 0.14) %	S=1.1
Γg	$\pi^{\dot{-}} \nu_{ au}$	[a]	(11.31 ± 0.15) %	S=1.1
Γ ₁₀	$\mathcal{K}^- u_{oldsymbol{ au}}$	[a]	(7.1 ± 0.5) \times 1	$^{0-3}$
Γ_{11}	$h^- \geq 1\pi^0 u_ au$		(36.97 ± 0.18) %	S=1.1
Γ_{12}	$h^-\pi^0 u_ au$		$(25.76 \pm 0.15) \%$	S=1.1
Γ_{13}	$\pi^-\pi^0 u_{ au}$	[a]	(25.24 ± 0.16) %	S=1.1
Γ_{14}	$\pi^-\pi^0$ non- $ ho$ (770) $ u_ au$		(3.0 ± 3.2) \times 1	
Γ_{15}	$\mathcal{K}^-\pi^0 u_{\tau}$	[a]	(5.2 ± 0.5) $\times 1$	
Γ_{16}	$h^- \geq 2\pi^0 \nu_{ au}$		$(10.95 \pm 0.16) \%$	S=1.1
Γ_{17}	$h^{-}2\pi^{0}\nu_{\tau}$		(9.50 ± 0.14) %	S=1.1
Γ ₁₈	$h^{-}2\pi^{0}\nu_{\tau}(\text{ex}.K^{0})$		(9.35 ± 0.14) %	S=1.1
Γ ₁₉	$\pi^{-}2\pi^{0}\nu_{\tau}(ex.K^{0})$	[a]	(9.27± 0.14) %	S=1.1
Γ ₂₀	$K^{-} 2\pi^{0} \nu_{\tau} (ex.K^{0})$	[a]	(8.1 ± 2.7) × 1	
Γ ₂₁	$h^- \geq 3\pi^0 u_{ au} \ h^- 3\pi^0 u_{ au}$		(1.46± 0.11) %	S=1.1
Γ ₂₂	$\pi^{-3\pi^{0}}\nu_{\tau}$ (ex. K^{0})	[a]	(1.28± 0.10) % (1.14± 0.14) %	
Γ ₂₃			•	4
Γ_{24}	$K^{-} 3\pi^{0} \nu_{\tau} (ex. K^{0})$	[a]	$(5.0 \ ^{+10.0}_{-3.3}) \times 1$	
Γ_{25}	$h^{-} 4\pi^{0} \nu_{\tau} (\text{ex.} K^{0})$		(1.8 \pm 0.6) \times 1	
Γ ₂₆	$h^{-}_{0}4\pi^{0}\nu_{\tau}(\text{ex}.K^{0},\eta)$	[a]	(1.2 \pm 0.6) \times 1	
Γ_{27}	$\mathcal{K}^- \geq 1 \; (\pi^0 \; ext{or} \; \mathcal{K}^0) \; u_ au$		(9.4 \pm 1.0) \times 1	.0-3

	Modes wi	th <i>K</i> ⁰ 's			Miscellaneou	s other allowed mo	des	
Γ ₂₈	$h^-\overline{K}^0 \ge 0$ neutrals $\ge 0K_I^0\nu_{\tau}$	(1.54± 0.10) %	S=1.3	Γ ₇₆	$(5\pi)^-\nu_{\tau}$		$0.7) \times 10^{-3}$	
Γ29	$h^-\overline{K}{}^0\nu_{ au}$	$(9.2 \pm 0.8) \times 10^{-3}$	S=1.3	Γ ₇₇	$4h^-3h^+ \geq 0$ neutrals $ u_{ au}$	< 1.9	× 10 ⁻⁴	CL=90%
Γ ₃₀	$\pi^-\overline{\mathcal{K}}{}^{0} u_{oldsymbol{ au}}$	[a] $(7.7 \pm 0.8) \times 10^{-3}$	S=1.3		("7-prong")			
Γ31	$\pi^-\overline{\mathcal{K}}{}^0$	$< 1.7 \times 10^{-3}$	CL=95%	Γ ₇₈	$K^*(892)^- \geq 0(h^0 \neq K_S^0)\nu_{\tau}$. (1.94±	0.31) %	
	$(non\text{-}K^*(892)^-) u_ au$			Γ ₇₉	$K^*(892)^- \geq 0$ neutrals ν_{τ}	(1.33±	0.13) %	
Γ_{32}	$K^-K^0\nu_{\tau}$	[a] $(1.55 \pm 0.28) \times 10^{-3}$		Γ ₈₀	$K^*(892)^- \nu_{\tau}$	(1.28±	0.08) %	
Γ ₃₃	$h^- \overline{K}{}^0 \pi^0 \nu_{ au}^{'}$	$(5.5 \pm 0.5) \times 10^{-3}$		Γ ₈₁	$K^*(892)^0 K^- \ge 0$ neutrals	$\nu_{ au}$ (3.2 ±	$1.4) \times 10^{-3}$	
Γ ₃₄	$\pi^-\overline{K}{}^0\pi^0 u_ au$	[a] (4.1 ± 0.6) $\times 10^{-3}$		Γ ₈₂	$K^*(892)^0 K^- \nu_{\tau}$	(2.0 ±	$0.6) \times 10^{-3}$	
Γ ₃₅	$\mathcal{K}^-\mathcal{K}^0\pi^0 u_ au$	[a] $(1.38 \pm 0.32) \times 10^{-3}$		Γ ₈₃	$\overline{K}^*(892)^0\pi^- \geq 0$ neutrals ι	v_{τ} (3.8 ±	$1.7) \times 10^{-3}$	
Γ ₃₆	$h^-K^0_SK^0_S\nu_{ au}$	$(2.5 \pm 0.6) \times 10^{-4}$		Γ ₈₄	$\overline{K}^*(892)^0 \pi^- \nu_{\tau}$	(2.5 ±	$1.1) \times 10^{-3}$	
Γ ₃₇	$\pi^- {\mathsf K}^{ar{\mathsf O}} \overline{\mathsf K}{}^{ar{\mathsf O}} {}_{{\mathcal V}_{ar{\mathsf T}}}$	[a] $(1.01 \pm 0.23) \times 10^{-3}$		Γ ₈₅	$K_1(1270)^- \nu_{ au}$	(4 ±	4) \times 10 ⁻³	
Г ₃₈	$\mathcal{K}^-\mathcal{K}^0\geq 0$ neutrals $ u_ au$	$(2.9 \pm 0.4) \times 10^{-3}$		Γ ₈₆	$K_1(1400)^- \nu_{ au}$	(8 ±	4) $\times 10^{-3}$	
Γ39	$K^- \geq 0\pi^0 \geq 0K^0 \nu_ au$	(1.65 ± 0.10) %		Γ ₈₇	$K_2^*(1430)^- \nu_{\tau}$	< 3	× 10 ⁻³	CL=95%
Γ40	K^0 (particles) $^ u_ au$	(1.58 ± 0.10) %	S=1.2	Γ ₈₈	$a_0(980)^- \geq 0$ neutrals ν_{τ}			
Γ_{41}	$K^0h^+h^-h^-\geq 0$ neut. $ u_ au$	$< 1.7 \times 10^{-3}$	CL=95%	Γ ₈₉	$\eta \pi^- \nu_{\tau}$	< 1.4	× 10 ⁻⁴	CL=95%
	Nandan udah ahuna	sharmad marklalas		Γ ₉₀	$\eta \pi^- \pi^0 \nu_{\tau}$	[a] (1.71±	$0.28) \times 10^{-3}$	
_	Modes with three			Г ₉₁	$\eta \pi^{-} \pi^{0} \pi^{0} \nu_{\tau}$	< 4.3	× 10 ⁻⁴	CL=95%
Γ ₄₂	$h^- h^- h^+ \ge \text{ Oneut. } \nu_{\tau} ("3-$	$(14.91 \pm 0.14) \%$	S=1.3	Γ ₉₂	$\eta K^- \nu_{\tau}$	(2.6 \pm	$0.7) \times 10^{-4}$	
-	prong")	(11.05 0.11) 0/		Γ ₉₃	$\eta \pi^+ \pi^- \pi^- \geq 0$ neutrals $ u_ au$. < 3	× 10 ⁻³	CL=90%
Γ ₄₃	$h^-h^-h^+ \geq 0$ neutrals ν_{τ}	$(14.36 \pm 0.14) \%$	S=1.3	Γ_{94}	$\eta\eta\pi^-\nu_{ au}$	< 1.1	\times 10 ⁻⁴	CL=95%
_	$(ex. K_S^0 \rightarrow \pi^+\pi^-)$	(-, -, -, -, -, -, -, -, -, -, -, -, -, -		Г ₉₅	$\eta\eta\pi^-\pi^0\nu_{ au}$	< 2.0	\times 10 ⁻⁴	CL=95%
Γ ₄₄	$\pi^-\pi^+\pi^- \geq 0$ neutrals ν_{τ}	(14.09 ± 0.31) %		Γ ₉₆	$h^-\omega\geq$ 0 neutrals $ u_ au$	($2.32\pm$	0.11) %	
Γ ₄₅	$h^- h^- h^+ \nu_{\tau}$	(9.80 ± 0.10) %	S=1.1	Γ ₉₇	$h^- \omega u_{ au}$	[a] ($1.91\pm$	0.09) %	
Γ ₄₆	$h^- h^- h^+ \nu_{\tau} (ex. K^0)$	(9.48 ± 0.10) %	S=1.1	Γ ₉₈	$h^-\omega\pi^0 u_ au$	[a] (4.1 \pm	$0.6) \times 10^{-3}$	
Γ ₄₇	$h^-h^-h^+\nu_{\tau}$ (ex. K^0,ω)	[a] (9.44 ± 0.10) %	S=1.1		Lepton Family numb	or (IE) Lonton ni	mbor (1)	
Γ ₄₈	$h^-h^-h^+ \geq 1$ neutrals $\nu_{ au}$	(5.08 ± 0.11) %	S=1.2			ber (B) violating m		
Γ ₄₉	$h^-h^-h^+ \geq 1$ neutrals ν_{τ} (ex.	(4.88 ± 0.11) %	S=1.2		(In the modes below, ℓ n			
_	$K_s^0 \rightarrow \pi^+\pi^-)$				(III the modes below, 8 h	ileans a suili Over e	and & modes)	,
Γ_{50}	$h^-h^-h^+\pi^0\nu_{\tau}$	(4.44 ± 0.09) %	S=1.1		L means lepton number violati	ion (e.g. $ au^- ightarrow e^+$	$\tau^-\pi^-$). Followin	ng
Γ ₅₁	$h^- h^- h^+ \pi^0 \nu_{\tau} (\text{ex.} K^0)$	(4.25 ± 0.09) %	S=1.1		common usage, LF means lepto		not lepton numb	oer
Γ ₅₂	$h^- h^- h^+ \pi^0 \nu_{\tau} (\text{ex. } K^0, \omega)$	[a] (2.55 ± 0.09) %			violation (e.g. $\tau^- \rightarrow e^- \pi^+ \pi$	r).	_	
Γ ₅₃	$h^-(ho\pi)^0 u_ au$	(2.84 ± 0.34) %		Г99	$e^-\gamma$	LF < 1.1	× 10 ⁻⁴	CL=90%
Γ ₅₄	$(a_1(1260)h)^-\nu_{\tau}$	< 2.0 %	CL=95%	Γ ₁₀₀	$\mu^-\gamma$	LF < 4.2	× 10 ⁻⁶	CL=90%
Γ ₅₅	$h^{-}\rho\pi^{0}\nu_{\tau}$	(1.33 ± 0.20) %		Γ ₁₀₁	$e^-\pi^0$	LF < 1.4	× 10 ⁻⁴	CL=90%
Γ ₅₆	$h^-\rho^+h^-\nu_{ au}$	$(4.4 \pm 2.2) \times 10^{-3}$		Γ ₁₀₂	$\mu^{-}\pi^{0}$	LF < 4.4	× 10 ⁻⁵	CL=90%
Γ ₅₇	$h^-\rho^-h^+\nu_{\tau}$	(1.15 ± 0.23) %		Γ ₁₀₃	$e^{-}K^{0}$	LF < 1.3	× 10 ⁻³	CL=90%
Γ ₅₈	$h^-h^-h^+2\pi^0\nu_{\tau}$	$(5.2 \pm 0.5) \times 10^{-3}$			$\mu^- K^0$	LF < 1.0	× 10 ⁻³	CL=90%
Γ ₅₉	$h^- h^- h^+ 2\pi^0 \nu_{\tau} (ex.K^0)$	$(5.1 \pm 0.5) \times 10^{-3}$		Γ ₁₀₅	$e^-\eta$	LF < 6.3	× 10 ⁻⁵	CL=90%
L ₆₀	$h^- h^- h^+ 2\pi^0 \nu_{\tau} (ex. K^0, \omega, \eta)$			Γ ₁₀₆	$\mu^- \eta$	LF < 7.3	× 10 ⁻⁵	CL=90%
Γ ₆₁	$h^-h^-h^+ \ge 3\pi^0\nu_{\tau}$	[a] $(1.1 \pm 0.6) \times 10^{-3}$		Γ ₁₀₇	$e^-\rho^0$	LF < 4.2	× 10 ⁻⁶	CL=90%
Γ ₆₂	$\mathcal{K}^-h^+h^-\geq 0$ neutrals $ u_{ au}$	< 6 × 10 ⁻³	CL=90%	108	$\mu^-\rho^0$	LF < 5.7	× 10 ⁻⁶	CL=90%
Γ ₆₃	$\mathcal{K}^-\pi^+\pi^- \geq$ 0 neut. $ u_{ au}$	$(3.9 \ ^{+} \ ^{1.9} _{-}) \times 10^{-3}$	S=1.5	Г ₁₀₉	$e^{-}K^{*}(892)^{0}$	LF < 6.3	× 10 ⁻⁶	CL=90%
Γ ₆₄	$K^-\pi^+K^- \geq 0$ neut. $ u_{ au}$	< 9 × 10 ⁻⁴	CL=95%		$\mu^- K^*(892)^0$	LF < 9.4	× 10 ⁻⁶	CL=90%
-				Γ ₁₁₁	$\pi^-\gamma$	L < 2.8	× 10 ⁻⁴	CL=90%
Γ ₆₅	$K^-K^+\pi^- \geq 0$ neut. $ u_{ au}$	$(1.5 \begin{array}{c} + & 0.9 \\ - & 0.8 \end{array}) \times 10^{-3}$		Γ ₁₁₂	$\pi^- \pi^0$	L < 3.7	× 10 ⁻⁴	CL=90%
Γ ₆₆	$\mathcal{K}^-\mathcal{K}^+\pi^- u_ au$	$(2.2 + 1.8 \atop -1.2) \times 10^{-3}$		₁₁₃	e- e+ e-	LF < 3.3	× 10 ⁻⁶	CL=90%
Γ ₆₇	$\phi\pi^- u_{ au}$	< 3.5 × 10 ⁻⁴	CL=90%	<u> </u>	$e^{-}\mu^{+}\mu^{-}$	LF < 3.6	× 10 ⁻⁶	CL=90%
Γ ₆₈	$K^-K^+K^- \geq 0$ neut. ν_{τ}	< 2.1 × 10 ⁻³	CL=95%	115	$e^{+}\mu^{-}\mu^{-}$	<i>LF</i> < 3.5	× 10 ⁻⁶	CL=90%
Γ ₆₉	$\pi^- K^+ \pi^- \geq 0$ neut. ν_{τ}	< 2.5 × 10 ⁻³	CL=95%	116	$\mu^{-}e^{+}e^{-}$	LF < 3.4	× 10 ⁻⁶	CL=90%
Γ ₇₀	$e^-e^-e^+\overline{\nu}_e\nu_{\tau}$	$(2.8 \pm 1.5) \times 10^{-5}$	22-75/0	1117	$\mu^{+}e^{-}e^{-}$	L < 3.4	× 10 ⁻⁶	CL=90%
Γ ₇₁	$\mu^-e^-e^+\overline{\nu}_\mu\nu_\tau$	< 3.6 × 10 ⁻⁵	CL=90%	118	$\mu^-\mu^+\mu^-$	LF < 1.9	× 10 ⁻⁶	CL=90%
. /1	•		CC- 3070	1119	$e^{-}\pi^{+}\pi^{-}$	LF < 4.4	× 10 ⁻⁶	CL=90%
	Modes with five of			120	$e^{+}\pi^{-}\pi^{-}$	L < 4.4	× 10 ⁻⁶	CL=90%
Γ_{72}	$3h^-2h^+ \geq 0$ neutrals ν_{τ}	$(9.7 \pm 0.7) \times 10^{-4}$		121	$\mu^-\pi^+\pi^-$	LF < 7.4	× 10 ⁻⁶	CL=90%
	(ex. $K_S^0 \rightarrow \pi^-\pi^+$)			122	$\mu^{+}\pi^{-}\pi^{-}$	L < 6.9	× 10 ⁻⁶	CL=90%
	("5-prong")			123	e-π+K- c	LF < 7.7	× 10 ⁻⁶	CL=90%
Γ ₇₃	$3h^{-}2h^{+}\nu_{\tau}(ex.K^{0})$	[a] $(7.5 \pm 0.7) \times 10^{-4}$		124	e ⁻ π ⁻ Κ ⁺	LF < 4.6	× 10 ⁻⁶	CL=90%
Γ ₇₄	$3h^{-}2h^{+}\pi^{0}\nu_{\tau}(ex.K^{0})$	[a] (2.2 \pm 0.5) \times 10 ⁻⁴		125	$e^{+}\pi^{-}K^{-}$	L < 4.5	× 10 ⁻⁶	CL=90%
Γ ₇₅	$3h^- 2h^+ 2\pi^0 \nu_{\tau}$	$< 1.1 \times 10^{-4}$	CL=90%	126	$\mu^-\pi^+K^-$	LF < 8.7	× 10 ⁻⁶	CL=90%
				127	$\mu^{-}\pi^{-}K^{+}$	LF < 1.5	× 10 ⁻⁵	CL=90%
				128	μ ⁺ π ⁻ Κ ⁻	L < 2.0	× 10 ⁻⁵	CL=90%
				Γ ₁₂₉	$\frac{p\gamma}{5}$	L,B < 2.9	× 10 ⁻⁴	CL=90%
				Γ ₁₃₀		L,B < 6.6	× 10 ⁻⁴	CL=90%
				Γ ₁₃₁	prij o= \(\overline{K} * (802)^0	L,B < 1.30	× 10 ⁻³	CL=90%
				132	$e^{-}\overline{K}^{*}(892)^{0}$ $\mu^{-}\overline{K}^{*}(892)^{0}$	LF < 1.1	× 10 ⁻⁵	CL=90%
				133	μ Λ (032) a light boson	LF < 8.7	× 10 ⁻⁶ × 10 ⁻³	CL=90%
				134 T	e^- light boson μ^- light boson	LF < 2.7 LF < 5	× 10 3 × 10 ⁻³	CL=95% CL=95%
				135	h uRuc posou	. < 5	× 10 ,	CL=9576
				[5]	Basis mode for the $ au.$			
				[d]	Dasis infouction the 7.			

CONSTRAINED FIT INFORMATION

An overall fit to 57 branching ratios uses 128 measurements and one constraint to determine 25 parameters. The overall fit has a $\chi^2=115.2$ for 104 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\left<\delta \kappa_i \delta \kappa_j\right>/(\delta \kappa_i \cdot \delta \kappa_j)$, in percent, from the fit to the branching fractions, $\kappa_i \equiv \Gamma_i/\Gamma_{\rm total}$. The fit constrains the κ_i whose labels appear in this array to sum to one.

0

X73

X97

*X*98

0 - 1

0

au BRANCHING FRACTIONS

(by K.G. Hayes, Hillsdale College)

Significant improvements in experimental measurements of τ branching fractions have been made since the 1994 edition of these Listings. Measurements of many new branching fractions of 1-prong τ decays containing charged and/or neutral kaons have been published [1–6]. Other new high-precision measurements of other τ branching fractions have also appeared, including many by the ALEPH collaboration [6] that are more precise than the 1994 world averages. Consequently, there are many new branching fractions in the Listings. The number of conventional τ -decay modes has increased from 59 in the 1994 edition to 98 in the current edition, and most τ branching fractions now have an absolute uncertainty in the range of 0.1 to 0.2%, with improvements over the 1994 edition typically being a factor of two or more.

Our goal for internal consistency of the τ Listings is now at the 0.1% level. To add correctly a new experimental measurement of a branching fraction to the Listings, we must understand and account for the experimenter's definition of both the signal and any background corrections to it at the 0.1% level or better. This requires that many details be considered. Some examples are: (a) is $K_S^0 \to \pi^+\pi^-$ considered to be 0-prong or 2-prong; (b) are K_L^0 's included or excluded in a decay mode definition; (c) are $K_S^0 \to 2\pi^0$ decays background or signal; (d) how are photons from the decays of η and ω treated; (e) have particle ID requirements been applied to any charged prongs (either through direct detection or indirectly via cuts on invariant mass distributions); and (f) exactly what is meant by the word "neutral" in a decay mode definition?

The τ Listings have been updated in several ways to accommodate the new measurements and the need for higher precision. To help make explicit how the signal and background are defined, we have developed new notation for listing decay modes. First, invisible K_L^0 's are never implicitly included in any decay mode (this is a change from previous editions). Second, for decay modes where contributions from an intermediate state are excluded, a list is appended to the decay mode which explicitly gives the excluded intermediate states. For this edition, the only intermediate states whose decays are excluded from some branching fractions are K^0 , η , and ω . If there is no ambiguity as to which intermediate state decay modes are excluded, just the name of the intermediate state is given. Otherwise, the excluded intermediate state decay mode is explicitly listed. The list is appended to the decay mode using the notation "(ex. (list of excluded intermediate states))." For example, listed in Table 1 are a few decay modes from the current Listings and their fitted branching fractions:

One inconsistency that has existed in the data for several decay modes was the different manner in which experimenters treated $K_S^0 \to \pi^+\pi^-$ decays. Some chose to treat the pions as

Table 1: Examples of τ -decay modes and their fitted branching fractions.

particle ≥ 0 neutrals ≥ 0 $K_L^0 \nu_{\tau}$	$(84.96 \pm 0.14)\%$
$particle^- \ge 0 \text{ neutrals} \ge 0 K^0 \nu_{\tau}$	$(85.53 \pm 0.14)\%$
$h^-h^-h^+ \geq 0$ neutrals $\nu_{ au}$	$(14.91 \pm 0.14)\%$
$h^-h^-h^+ \geq 0$ neutrals ν_{τ} (ex. $K_S^0 \to \pi^+\pi^-$)	$(14.36 \pm 0.14)\%$
$h^-h^-h^+\pi^0 u_ au$	$(4.44 \pm 0.09)\%$
$h^- h^- h^+ \pi^0 \nu_{ au} \ (ext{ex.} \ K^0)$	$(4.25 \pm 0.09)\%$
$h^-h^-h^+\pi^0 u_ au$ (ex. K^0,ω)	$(2.55 \pm 0.09)\%$

charged prongs from the τ decay, while others rejected them as secondary tracks similar to electrons from photon conversion. To complicate the situation, some experimental papers make no mention as to how these decays were treated, even though different choices can affect some branching fractions by as much as 0.5%, as illustrated in the examples above.

In our definition of τ -decay modes, we treat pions from $K_S^0 \to \pi^+\pi^-$ as charged prongs from the τ decay. To correct branching fraction measurements for different choices, good knowledge of τ branching fractions for decays containing K^0 's is necessary, but until this edition experimental knowledge was meager. In the 1994 edition, the only branching fraction measurement of a τ decay mode containing a K^0 (apart from K^{0} 's used to reconstruct the $K^{*}(892)$) was the measurement, based on 44 detected decays, of B($\tau^- \to K^0 \ h^- \ge 0$ neutrals ν_{τ}) = $(1.3 \pm 0.3)\%$ by the HRS collaboration [7]. For this edition, there are 12 new measurements, based on more than 1800 detected decays, of τ -decay modes containing K^0 's. Consequently, sufficient information now exists, and we have reduced the inconsistency in branching fraction data by moving data to newly defined decay modes consistent with the way $K_S^0 \to \pi^+\pi^-$ decays were treated. Because of time limitations, we did this only for the most precise data.

To make best use of the new data, we have expanded the number of basis modes used in the constrained fit to branching fraction data from 12 in the 1994 edition to 25 in 1996. Consequently, the vast majority of branching fractions listed in the Summary Table are fit results (not averages) which is a significant change from previous editions. The only branching fractions which are not fit results are those which are either upper limits, 3-prong modes where one or more charged particles are identified, or modes containing resonances that are not included in the basis modes.

Selection of the basis modes was determined by several criteria. The basis modes must form an exclusive set whose branching fractions sum exactly to one. All measured branching fractions which contribute to the fit must be expressible in terms of a sum over basis mode branching fractions with accurately known coefficients, and all basis modes (except possibly one) must be constrained by one or more measured branching fractions. It is desirable to include a sufficient number of modes so that the largest number of branching fraction measurements can be included in the constrained fit. Finally,

any modes necessary to satisfy the accuracy requirement must be included. The selected basis modes are listed in Table 2. The coefficients used to define a particular τ branching fraction in terms of the sum over basis mode branching fractions appear in the Listings immediately below each branching fraction header.

Table 2: Basis modes used in the 1994 and 1996 constrained fit to τ branching fraction data.

RPP94	RPP96
$e^- \overline{ u}_e u_ au$	$*e^-\overline{ u}_e u_ au$
$\mu^- \overline{ u}_\mu u_ au$	$^*\mu^- \overline{ u}_\mu u_ au$
$\pi^- u_{ au}$	$*\pi^- u_ au$
$\pi^-\pi^0 u_ au$	$*\pi^-\pi^0 u_ au$
$h^-2\pi^0\nu_{ au}$	$\pi^{-}2\pi^{0}\nu_{\tau}({ m ex.}\ K^{0})$
$h^-3\pi^0 u_{ au}$	$\pi^{-}3\pi^{0} u_{ au}({ m ex.}\ K^{0})$
$h^-4\pi^0 u_ au$	$h^-4\pi^0 u_ au(ext{ex. }K^0,\eta)$
$K^- u_{ au}$	$*K^- u_ au$
_	$K^-\pi^0 u_ au$
	$K^- 2\pi^0 u_{ au}({ m ex.}\ K^0)$
_	$K^{-}3\pi^{0}\nu_{\tau}({\rm ex.}\ K^{0})$
	$\pi^- \overline{K}^0 u_ au$
	$\pi^-\overline{K}^0\pi^0 u_ au$
***************************************	$\pi^- K^0 \overline{K}^0 u_ au$
	$K^-K^0 u_ au$
MARIONOVA .	$K^-K^0\pi^0 u_ au$
$K^*(892)^-\nu_{\tau}$	
$h^-h^-h^+ u_ au$	$h^-h^-h^+ u_ au$ (ex. K^0,ω)
$h^-h^-h^+ \geq 1 \; \text{neut.} \; \nu_{\tau}$	$h^- h^- h^+ \pi^0 \nu_{\tau} \; (\text{ex. } K^0, \omega)$
and the second s	$h^- h^- h^+ 2\pi^0 u_{ au} \; (ext{ex.} \; K^0, \omega, \eta)$
	$h^-h^-h^+ \ge 3\pi^0\nu_\tau$
$3h^-2h^+ \geq 0$ neut. ν_{τ}	$3h^-2h^+\nu_{\tau} \; (\text{ex. } K^0)$
	$3h^-2h^+\pi^0\nu_{ au}({ m ex.}\ K^0)$
	$h^-\omega u_ au$
	$h^-\omega\pi^0 u_ au$
MANAGAMINI .	$\pi^-\eta\pi^0 u_ au$

^{*} Unchanged from RPP94.

In selecting the basis modes, various choices and assumptions were made. For example, we have assumed that branching fractions for the following τ -decay modes are small relative to $0.1\%: \tau^- \to \pi^- \overline{K}^0 \ge 2\pi^0 \nu_{\tau}, \ \tau^- \to \pi^- K^0 \overline{K}^0 \ge 1\pi^0 \nu_{\tau}, \ \tau^- \to \pi^- K^0 \overline{K}^0$ $h^-h^-h^+ \ge 1 \ K^0 \ge 0\pi^0\nu_{\tau}$, and $\tau^- \to h^- \ge 5\pi^0\nu_{\tau}$. Experimental upper limits on branching fractions exist for some of these modes, and comparison of measured inclusive and exclusive branching fractions allow limits to be determined for the others. The modes $\tau^- \to h^- \omega \nu_{\tau}, \ \tau^- \to h^- \omega \pi^0 \nu_{\tau}$, and $\tau^- \to \pi^- \eta \pi^0 \nu_{\tau}$ must be included in the basis set since their combined branching fraction to final states containing photons not from π^0 's is about 0.3%. We have not included in the basis set the mode $\tau^- \to K^*(892)^- \nu_{\tau}$. The branching fraction for this mode is usually determined from the branching fraction for either $\tau^- \to \pi^- \overline{K}^0 \nu_{\tau}$ or $\tau^- \to K^- \pi^0 \nu_{\tau}$ assuming these decays all originate in $\tau^- \to K^*(892)^- \nu_{\tau}$, but these two methods give

 τ

values for $B(\tau^- \to K^*(892)^- \nu_\tau)$ that are inconsistent at the 2.5 σ level irrespective of whether the world average or fit values are used.

The constrained fit to branching fractions assumes all input data are uncorrelated, and data which are very highly correlated are not used in the fit. For the next edition, we plan to enhance the fitting procedure so that data correlations can be properly included. To minimize the effects of older experiments which often have larger systematic errors, we have excluded from the fit 27 older measurements in decay modes which contain at least several of the newer data of much higher precision. As a rule, we exclude those experiments with large errors which together would contribute no more than 5% of the weight in the average.

The precise new measurements have significantly reduced the uncertainties on most fitted branching fractions. Also, some problems in the data noted in the 1994 edition now have reduced significance. Table 3 lists several important hadronic branching fractions that had fit values in both the 1994 and 1996 editions. The reduction of the scale factors for most of these branching fractions illustrates the internal consistency of the new data. Note the significant change in $B(h^-h^-h^+\nu_\tau~({\rm ex.}~K^0))$.

Table 3: Fit branching ratios (%) and scale factors for a sample of τ hadronic decays.

Mode	1994 Fit	Scale	1996 Fit	Scale
$\pi^- u_{ au}$	11.7 ± 0.4	1.3	11.31 ± 0.15	1.1
$K^- u_ au$	0.67 ± 0.23	1.3	0.71 ± 0.05	1.0
$h^-\pi^0 u_ au$	25.7 ± 0.4	1.7	25.76 ± 0.15	1.1
$h^-2\pi^0\nu_{ au}$	9.6 ± 0.4	1.5	9.50 ± 0.14	1.1
$h^-3\pi^0\nu_{ au}$	1.28 ± 0.24	1.7	1.28 ± 0.10	1.0
$h^- h^- h^+ \nu_{\tau} \ (\text{ex. } K^0)$	8.42 ± 0.31	1.3	9.48 ± 0.10	1.1
$h^-h^-h^+ \geq 1$ neutrals ν_{τ}	5.63 ± 0.30	1.2	5.08 ± 0.11	1.2

Other evidence for the improved internal consistency is the decrease in the difference between the fitted and average values for the leptonic branching fractions. In previous editions, the data exhibited a "deficit" in 1-prong exclusive branching fractions for which the fit compensated by systematically increasing all 1-prong fit branching fractions above their average values. Table 4 compares the average and fit values for $B_e \equiv B(\tau^- \to e^- \ \overline{\nu}_e \nu_\tau)$ and $B_\mu \equiv B(\tau^- \to \mu^- \ \overline{\nu}_\mu \nu_\tau)$ for the 1994 and 1996 editions.

Table 4: Fit and average branching fractions for $\tau^- \to e^- \, \overline{\nu}_e \nu_\tau$ and $\tau^- \to \mu^- \, \overline{\nu}_\mu \nu_\tau$.

Branching Fraction (%)		1994	1996		
$\overline{{ m B}_e}$	Fit	18.01 ± 0.18	17.83 ± 0.08		
B_e	Average	17.90 ± 0.17	17.80 ± 0.08		
B_{μ}	Fit	17.65 ± 0.24	17.35 ± 0.10		
B_{μ}	Average	17.44 ± 0.23	17.30 ± 0.10		

The charged-prong topological branching fractions changed significantly from their 1994 values. Although only two measurements of charged prong topological branching fractions have been published since the 1994 edition (both of $\mathrm{B}(h^-h^-h^+\geq 0$ neutrals ν_{τ} (ex. $K_S^0 \to \pi^+\pi^-$)), some new measurements of other modes influenced the fitted value of the topological branching fractions. The improved consistency of our treatment of $K_S^0 \to \pi^+\pi^-$ decays also influenced the results. Table 5 compares the average and fit values for $B_1 \equiv B(particle^- \geq 0$ neutrals $\geq 0 \ K_L^0 \ \nu_{\tau}$) and B₃ $\equiv B(h^-h^-h^+ \geq 0 \text{ neutrals } \nu_{\tau})$ for the 1994 and 1996 editions. Although the fit and average values for B₁ and B₃ were very similar in 1994, the new fit values differ significantly from their averages. As the averages of these two modes are formed from older measurements (1992 or earlier), the precise new measurements lead to charged prong topological branching fractions which are significantly different from the older values.

Table 5: Fit and average branching fractions for B_1 and B_3 .

Bran	ching Fraction (%)	1994	1996	
$\overline{\mathrm{B}_{1}}$	Fit	85.49 ± 0.24	84.96 ± 0.14	
B_1	Average	85.46 ± 0.30	85.90 ± 0.30	
B_3	Fit	14.38 ± 0.24	14.91 ± 0.14	
$_{\rm B_3}$	Average	14.32 ± 0.27	14.01 ± 0.29	

Conclusions: The precision of τ branching fraction measurements has increased significantly since the 1994 edition. Measurements of new 1-prong decay modes containing charged and/or neutral kaons have allowed a large expansion in the number of basis modes used in the constrained fit to τ branching fractions. Ambiguities and inconsistencies in the Listings caused by the lack of data on 1-prong modes containing neutral kaons have been significantly reduced. The new level of precision requires experimenters to be especially clear in describing their definition of signal and background in measurements of τ branching fractions. Future measurements of the charged and neutral kaon content in 3-prong τ decays will allow similar improvements in the understanding of those decay modes.

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TECN COMMENT

τ^- BRANCHING RATIOS

$\begin{array}{l} \Gamma \text{(particle}^- \geq 0 \text{ neutrals } \geq 0 \textit{K}_{L}^{\textit{U}} \nu_{r} \text{("1-prong"))} / \Gamma_{\text{total}} \\ \Gamma_1 / \Gamma = (\Gamma_3 + \Gamma_5 + \Gamma_9 + \Gamma_{10} + \Gamma_{13} + \Gamma_{15} + \Gamma_{19} + \Gamma_{20} + \Gamma_{23} + \Gamma_{24} + \Gamma_{26} + 0.6569\Gamma_{30} + 0.6569\Gamma_{32} + 0.6569\Gamma_{34} + 0.6569\Gamma_{35} + 0.4316\Gamma_{37} + 0.708\Gamma_{90} + 0.085\Gamma_{97} + 0.08$

The charged particle here can be e, μ , or hadron. In many analyses, the sum of the topological branching fractions (1, 3, and 5 prongs) is constrained to be unity. Since the 5-prong fraction is very small, the measured 1-prong and 3-prong fractions are highly correlated and cannot be treated as independent quantities in our overall fit. We arbitrarily choose to use the 3-prong fraction in our fit, and leave the 1-prong fraction out. We do, however, use these 1-prong measurements in our average below. The measurements used only for the average are marked "avg," whereas "f&a" marks a result used for the fit and the average.

VALUE (%)	EVTS	DOCUMENT ID	TECN	COMMENT
84.96 ± 0.14 OUR I	FIT Error in	cludes scale factor of	1.3.	
85.90 ± 0.30 OUR	AVERAGE	Error includes scale fa	ctor of 1.2.	
$85.6 \pm 0.6 \pm 0.3$	avg 3300	¹¹ ADEVA	91F L3	Eee = 88.3-94.3 GeV
86.4 ± 0.3 ± 0.3	avg	ABACHI	89B HRS	Eee = 29 GeV
84.9 ± 0.4 ± 0.3	avg		89B CELL	E ^{ee} _{cm} = 14-47 GeV
84.7 ± 0.8 ± 0.6	avg	¹² AIHARA	87B TPC	$E_{ m cm}^{\it ee}=$ 29 GeV
$87.2 \pm 0.5 \pm 0.8$	avg	SCHMIDKE	86 MRK2	$E_{CM}^{ee} = 29 \; GeV$
84.7 $\pm 1.1 {}^{+1.6}_{-1.3}$	avg 169	¹³ ALTHOFF	85 TASS	<i>E</i> ^{ee} _{Cm} = 34.5 GeV
86.1 ± 0.5 ± 0.9	avg	BARTEL	85F JADE	E ^{ee} _{cm} = 34.6 GeV
$86.7 \pm 0.3 \pm 0.6$	avg	FERNANDEZ	85 MAC	Eee = 29 GeV
• • • We do not u	ise the follow	ing data for averages,	fits, limits, e	etc. • • •
87.1 ±1.0 ±0.7		¹⁴ BURCHAT	87 MRK2	Eee = 29 GeV
87.8 $\pm 1.3 \pm 3.9$		¹⁵ BERGER	85 PLUT	E ^{ee} _{Cm} = 34.6 GeV
11 Not to do	+ - f A D E \ / A	015 5(4= 4= 4+ > 4	(112)

- ¹ Not independent of ADEVA 91F $\Gamma(h^-h^-h^+ \ge 0$ neut. ν_{τ} ("3-prong"))/ $\Gamma_{\rm total}$ value. $^{12}\,\mathrm{Not}$ independent of AIHARA 87B $\Gamma(\mu^-\,\overline{\nu}_\mu\,\nu_\tau)/\Gamma_{\mathrm{total}},~\Gamma(e^-\,\overline{\nu}_e\,\nu_\tau)/\Gamma_{\mathrm{total}},$ and $\Gamma(h^- \geq 0 \; {
 m neutrals} \; \geq 0 {\cal K}_L^0 \; \nu_{ au})/\Gamma_{
 m total} \; {
 m values}.$
- 13 Not independent of ALTHOFF 85 $\Gamma(\mu^-\,\overline{\nu}_\mu\,\nu_\tau)/\Gamma_{\rm total},\,\Gamma(e^-\,\overline{\nu}_e\,\nu_\tau)/\Gamma_{\rm total},\,\Gamma(h^-\geq 0)$ neutrals $\geq 0K_1^0 \ \nu_{ au})/\Gamma_{ ext{total}}$, and $\Gamma(h^- \ h^+ \geq ext{Oneut.} \ \nu_{ au} \ (ext{"3-prong"}))/\Gamma_{ ext{total}} \ ext{values.}$ ¹⁴ Not independent of SCHMIDKE 86 value (also not independent of BURCHAT 87 value for $\Gamma(h^-h^-h^+ \geq 0$ neut. ν_{τ} ("3-prong"))/ Γ_{total} .
- ¹⁵ Not independent of (1-prong + $0\pi^0$) and (1-prong + $\geq 1\pi^0$) values.

TECN COMMENT 85.53±0.14 OUR FIT Error includes scale factor of 1.3. 84.59±0.33 OUR AVERAGE ACTON 84.48 ± 0.27 ± 0.23 avg 92H OPAL 1990-1991 LEP runs $85.45 + 0.69 \pm 0.65$ DECAMP 92C ALEP 1989-1990 LEP runs

 $\Gamma(\mu^- \overline{\nu}_\mu \nu_\tau)/\Gamma_{ ext{total}}$ Data marked "a "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.

To minimize the effect of experiments with large systematic errors, we exclude experiments which together would contribute 5% of the weight in the average.

VALUE (%)		EVTS		DOCUMENT ID		TECN	COMMENT
17.35 ± 0.10 OUR	TI:						
17.30 ± 0.10 OUR	WER.	AGE					
$17.31 \pm 0.11 \pm 0.05$	f&∠a	20.7k		BUSKULIC	96C	ALEP	1991-1993 LEP runs
$17.02 \pm 0.19 \pm 0.24$	f&∠a	6586		ABREU	95T	DLPH	1991-1992 LEP runs
17.36 ± 0.27	f&a	7941		AKERS	951	OPAL	1990-1992 LEP runs
$17.6 \pm 0.4 \pm 0.4$	f&a	2148		ADRIANI	93M	L3	E ^{ee} cm= 88–94 GeV
$17.2 \ \pm 0.4 \ \pm 0.5$	avg		16	ALBRECHT	92D	ARG	Eee = 9.4-10.6 GeV
$17.35 \pm 0.41 \pm 0.37$	f&₂a			DECAMP	92c	ALEP	1989-1990 LEP runs
$17.7 \pm 0.8 \pm 0.4$	f&a	568		BEHREND	90	CELL	$E_{ m cm}^{\it ee}=$ 35 GeV
17.4 ± 1.0	f&a	2197		ADEVA	88	MRKJ	$E_{cm}^{ee} = 1416 \; GeV$
• • • We do not u	se the	e followi	ng d	ata for averages	, fits,	limits,	etc. • • •
$17.7 \ \pm 1.2 \ \pm 0.7$				AIHARA	87B	TPC	E ^{ee} _{cm} = 29 GeV
$18.3 \pm 0.9 \pm 0.8$				BURCHAT	87	MRK2	E ^{ee} cm= 29 GeV
$18.6 \ \pm 0.8 \ \pm 0.7$		558	17	BARTEL	86D	JADE	E ^{ee} _{cm} = 34.6 GeV
12.9 $\pm 1.7 ^{+0.7}_{-0.5}$				ALTHOFF	85	TASS	E ^{ee} _{cm} = 34.5 GeV
$18.0 \pm 0.9 \pm 0.5$		473	17	ASH	85B	MAC	E ^{ee} cm= 29 GeV
$18.0\ \pm 1.0\ \pm 0.6$			18	BALTRUSAIT.	85	MRK3	E ^{ee} _{cm} = 3.77 GeV
19.4 ± 1.6 ± 1.7		153		BERGER	85	PLUT	E ^{ee} _{cm} = 34.6 GeV
$17.6 \ \pm 2.6 \ \pm 2.1$		47		BEHREND	8 3 C	CELL	$E_{\rm cm}^{ee}=$ 34 GeV
$17.8 \pm 2.0 \pm 1.8$				BERGER	81B	PLUT	E ^{ee} _{cm} = 9–32 GeV
16 No. 1		ALDDE	CUT	000 5/ ==	3.71	-/	\ F(\ \ .

 $^{^{16}\,\}mathrm{Not}$ independent of ALBRECHT 92D $\Gamma(\mu^-\,\overline{\nu}_\mu\,\nu_\tau)/\Gamma(e^-\,\overline{\nu}_e\,\nu_\tau)$ and $\Gamma(\mu^-\,\overline{\nu}_\mu\,\nu_\tau)$ \times $\Gamma(e^-\overline{\nu}_e\nu_\tau)/\Gamma_{\rm total}.$ 17 Modified using B($e^-\overline{\nu}_e\nu_\tau)/{\rm B("1~prong")}$ and B("1 prong") ,= 0.855.

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 \begin{array}{l} \Gamma(\mu^-\overline{\nu}_\mu\nu_\tau)/\Gamma(\text{particle}^- \geq 0 \text{ neutrals } \geq 0K_1^0\nu_\tau(\text{``1-prong''})) & \Gamma_3/\Gamma\\ \Gamma_3/\Gamma_1 = \Gamma_3/(\Gamma_3+\Gamma_5+\Gamma_9+\Gamma_{10}+\Gamma_{13}+\Gamma_{15}+\Gamma_{19}+\Gamma_{20}+\Gamma_{23}+\Gamma_{24}+\Gamma_{26}+\\ 0.6569\Gamma_{30}+0.6569\Gamma_{32}+0.6569\Gamma_{34}+0.6569\Gamma_{35}+0.4316\Gamma_{37}+0.708\Gamma_{90}+0.085\Gamma_{97}+\\ 0.6569\Gamma_{30}+0.6569\Gamma_{32}+0.6569\Gamma_{34}+0.6569\Gamma_{35}+0.4316\Gamma_{37}+0.708\Gamma_{90}+0.085\Gamma_{97}+\\ 0.6569\Gamma_{30}+0.6569\Gamma_{32}+0.6569\Gamma_{34}+0.6569\Gamma_{35}+0.4316\Gamma_{37}+0.708\Gamma_{90}+0.085\Gamma_{97}+\\ 0.6569\Gamma_{30}+0.6569\Gamma_{32}+0.6569\Gamma_{34}+0.6569\Gamma_{35}+0.4316\Gamma_{37}+0.708\Gamma_{90}+0.085\Gamma_{97}+\\ 0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569\Gamma_{30}+0.6569
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                                                                                                                                                                            0.085F<sub>98</sub>)
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VALUE	<u>EVTS</u>	DOCUMENT ID	TECN	COMMENT
0.2042±0.0011 OUR FIT				
• • We do not use the f	ollowing	data for averages, fi	ts, limits, etc	C. • • •
$0.217 \pm 0.009 \pm 0.008$		BARTEL	86D JADE	Ecm = 34.6 GeV
$0.211 \pm 0.010 \pm 0.006$	390	ASH	85B MAC	Eee = 29 GeV
$\Gamma(\mu^- \overline{\nu}_\mu \nu_\tau \gamma) / \Gamma(\mu^- \overline{\nu}_\mu E_\gamma) > 37 \text{ MeV}.$	$(u_{ au})$			Γ ₄ /Γ:

DOCUMENT ID 19 WU 0.013 ± 0.006 10 90 MRK2 $E_{\rm cm}^{\it ee}$ = 29 GeV 19 Requirements on detected γ 's correspond to a au rest frame energy cutoff $E_{\gamma}~>$ 37 MeV.

EVTS

 Γ_5/Γ

 $\Gamma(e^-\overline{\nu_e\nu_r})/\Gamma_{\rm total} \qquad \qquad \Gamma_5/\Gamma_{\rm total}$ Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.

To minimize the effect of experiments with large systematic errors, we exclude experiments which together would contribute 5% of the weight in the average.

VALUE (%)		EVTS		DOCUMENT ID		TECN	COMMENT
17.83±0.08 OUR F							
17.80 ± 0.08 OUR A		-					
$17.78 \pm 0.10 \pm 0.09$		25.3k		ALEXANDER		OPAL	1991-1994 LEP runs
$17.79 \pm 0.12 \pm 0.06$		20.6k		BUSKULIC		ALEP	1991-1993 LEP runs
$17.51 \pm 0.23 \pm 0.31$	f&a	5059		ABREU	95T	DLPH	
$17.9 \pm 0.4 \pm 0.4$	f&a	2892		ADRIANI	93M	L3	$E_{cm}^{ee} = 88 – 94 \; GeV$
$17.97 \pm 0.14 \pm 0.23$	f&a	3970		AKERIB	92	CLEO	E_{cm}^{ee} = 10.6 GeV
17.3 ± 0.4 ± 0.5	avg		20	ALBRECHT	92D	ARG	Eee = 9.4–10.6 GeV
19.1 ± 0.4 ± 0.6	avg	2960	21	AMMAR	92	CLEO	$E_{cm}^{ee} = 10.5-10.9 \text{ GeV}$
$18.09 \pm 0.45 \pm 0.45$	f&∠a			DECAMP	9 20	ALEP	1989-1990 LEP runs
17.0 ± 0.5 ± 0.6	f&a	1.7k		ABACHI	90	HRS	Ecm = 29 GeV
• • • We do not u	se the	e followii	ng da	ata for averages,	fits,	limits,	etc. • • •
$18.4 \pm 0.8 \pm 0.4$		644		BEHREND	90	CELL	Eee = 35 GeV
$16.3 \pm 0.3 \pm 3.2$				JANSSEN	89	CBAL	Eee = 9.4-10.6 GeV
18.4 ± 1.2 ± 1.0				AIHARA	87в	TPC	Eee = 29 GeV
19.1 ± 0.8 ± 1.1				BURCHAT	87	MRK2	<i>E</i> ^{ee} _{cm} = 29 GeV
$16.8 \pm 0.7 \pm 0.9$		515	21	BARTEL	86D	JADE	E ^{ee} _{cm} = 34.6 GeV
20.4 $\pm 3.0 ^{+1.4}_{-0.9}$				ALTHOFF	85	TASS	E ^{ee} _{cm} = 34.5 GeV
$17.8 \pm 0.9 \pm 0.6$		390	21	ASH	85B	MAC	Eee = 29 GeV
18.2 ±0.7 ±0.5			22	BALTRUSAIT.	.85	MRK3	$E_{cm}^{ee} = 3.77 \text{ GeV}$
13.0 ±1.9 ±2.9				BERGER	85	PLUT	E ^{ee} _{cm} = 34.6 GeV
$18.3 \pm 2.4 \pm 1.9$		60		BEHREND	83 C	CELL	E_{cm}^{ee} = 34 GeV
16.0 ±1.3		459	23	BACINO	78B	DLCO	$E_{\rm cm}^{ee} = 3.1-7.4 {\rm GeV}$
²⁰ Not independer	nt of	ALBRE	СНТ	92D Γ(μ ⁻ ν	z_)/[(e ⁻ ⊽.	ν_{π}) and $\Gamma(\mu^{-} \overline{\nu}_{\mu} \nu_{\pi}) \times$

- Not independent of ALBRECHT 92D $\Gamma(\mu^-\overline{\nu}_\mu\nu_ au)/\Gamma(e^-\overline{\nu}_e\nu_ au)$ and $\Gamma(\mu^-\overline{\nu}_\mu\nu_ au)$ × $\Gamma(e^-\,\overline{\nu}_e\,\nu_ au)/\Gamma_{
 m total}.$
- ²¹ Modified using B($e^-\overline{\nu}_e\nu_{\tau}$)/B("1 prong") and B("1 prong") ,= 0.855.
- $^{22}\,\mathrm{Error}$ correlated with BALTRUSAITIS 85 $\Gamma(\mu^-\,\overline{\nu}_\mu\nu_\tau)/\Gamma_{\mathrm{total}}$
- 23 BACINO 78B value comes from fit to events with $^{'}e^{\pm}$ and one other nonelectron charged

$$\begin{split} & \Gamma \big(e^{-} \overline{\nu_e} \nu_\tau \big) / \Gamma \big(\text{particle}^{-} \geq 0 \text{ neutrals } \geq 0 K_0^0 \nu_\tau \big(\text{``1-prong''} \big) \big) \\ & \Gamma_5 / \Gamma_1 = \Gamma_5 / (\Gamma_3 + \Gamma_5 + \Gamma_9 + \Gamma_{10} + \Gamma_{13} + \Gamma_{15} + \Gamma_{19} + \Gamma_{20} + \Gamma_{23} + \Gamma_{24} + \Gamma_{26} + \\ & 0.6569 \Gamma_{30} + 0.6569 \Gamma_{32} + 0.6569 \Gamma_{34} + 0.6569 \Gamma_{35} + 0.4316 \Gamma_{37} + 0.708 \Gamma_{90} + 0.085 \Gamma_{97} + 0.085 \Gamma_{97}$$

VALUE	<u>EVTS</u>	DOCUMENT ID) TECN	COMMENT			
0.2099±0.0010 OUR FIT	Error inc	ludes scale facto	or of 1.1.				
$0.2231 \pm 0.0044 \pm 0.0073$	2856	AMMAR	92 CLEO	$E_{\rm cm}^{\it ee} = 10.5 - 10.9 \; {\rm GeV}$			
• • We do not use the following data for averages, fits, limits, etc. • •							
$0.196\ \pm0.008\ \pm0.010$		BARTEL	86D JADE	$E_{CM}^{\mathit{ee}} = 34.6 \; GeV$			
$0.208 \pm 0.010 \pm 0.007$	390	ASH	85B MAC	<i>E</i> ^{ee} _{cm} = 29 GeV			

$\Gamma(\mu^- \overline{\nu}_\mu \nu_\tau) \times 1$	$\Gamma(e^-\overline{ u}_e u_ au)/\Gamma_{ m tota}^2$	al		$\Gamma_3\Gamma_5/\Gamma^2$
VALUE	EVTS	DOCUMENT ID	TECN_	COMMENT
0.03094 ± 0.00022	OUR FIT			
0.0306 ±0.0005 ±	±0.0013 3230	ALBRECHT	93G ARG	E ^{ee} _{cm} = 9.4–10.6 GeV
• • • We do not u	ise the following dat	a for averages, f	its, limits, etc	. • • •
0.0288 ±0.0017 ±	±0.0019	ASH	85B MAC	<i>E</i> ^{<i>ee</i>} _{cm} = 29 GeV

 $\Gamma\big(\mu^-\,\overline{\nu}_\mu\,\nu_\tau\big)/\Gamma\big(e^-\,\overline{\nu}_e\,\nu_\tau\big)$ Predicted to be 1 for sequential lepton, 1/2 for para-electron, and 2 for para-muon. Para-electron also ruled out by HEILE 78.

DOCUMENT ID TECN COMMENT 0.973±0.007.0UR FIT $0.997 \pm 0.035 \pm 0.040$ ALBRECHT 92D ARG $E_{\rm cm}^{ee} = 9.4$ -10.6 GeV

 $^{^{18}\, {\}sf Error}$ correlated with BALTRUSAITIS 85 $e\, \nu\, \overline{\nu}$ value.

 Γ_6/Γ

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 \begin{array}{l} \Gamma \left(h^- \geq 0 \text{ neutrals } \geq 0 K_0^D \ \nu_\tau \right) / \Gamma_{\text{total}} & \Gamma_6 / \Gamma_6 \\ \Gamma_6 / \Gamma = (\Gamma_9 + \Gamma_{10} + \Gamma_{13} + \Gamma_{15} + \Gamma_{19} + \Gamma_{20} + \Gamma_{23} + \Gamma_{24} + \Gamma_{26} + 0.6569 \Gamma_{30} + 0.6569 \Gamma_{32} + 0.6569 \Gamma_{33} + 0.6569 \Gamma_{35} + 0.4316 \Gamma_{37} + 0.708 \Gamma_{90} + 0.085 \Gamma_{97} + 0.085 \Gamma_{98}) / \Gamma_6 \right) \\ \Gamma_6 / \Gamma_6 / \Gamma_{10} + \Gamma_{10} \Gamma_{10} \Gamma_{10} + \Gamma_{10} \Gamma_
                                                                    DOCUMENT ID
                                                                                                              TECN COMMENT
49.78±0.17 OUR FIT Error includes scale factor of 1.2.
48.6 ±1.2 ±0.9 avg 24 AIHARA
                                                                                                  87B TPC E_{cm}^{ee} = 29 \text{ GeV}
 <sup>24</sup> Not independent of AIHARA 87B e\nu\overline{\nu}, \mu\nu\overline{\nu}, and \pi^+2\pi^-(\geq 0\pi^0)\nu values.
\Gamma(h^- \geq 0K_L^0 \nu_{\tau})/\Gamma_{\text{total}}
                                                                                                                                                                                        \Gamma_7/\Gamma
             \Gamma_7/\Gamma = (\Gamma_9 + \Gamma_{10} + \frac{1}{2}\Gamma_{30} + \frac{1}{2}\Gamma_{32} + \frac{1}{4}\Gamma_{37})/\Gamma
             Data marked "avg" are highly correlated with data appearing elsewhere in the Listings,
             and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.
                                                             _EVTS
                                                                                         DOCUMENT ID
                                                                                                                                 TECN COMMENT
 12.51±0.13 OUR FIT Error includes scale factor of 1.1.
 12.44 ± 0.14 OUR AVERAGE
                                                                                  <sup>25</sup> BUSKULIC
                                                                                                                            96 ALEP 1991-1993 LEP run
95 L3 1992 LEP run
 12.44±0.11±0.11
                                                  f& a
                                                                 15k
                                                  f&a 2967
                                                                                   <sup>26</sup> ACCIARRI
12.47 \pm 0.26 \pm 0.43
 12.4 ±0.7 ±0.7
                                                                                   <sup>27</sup> ABREU
                                                                                                                            92N DLPH 1990 LEP run
                                                                                   28 DECAMP
12 98 + 0 44 + 0 33
                                                  f& a
                                                                                                                            92C ALEP 1989-1990 LEP runs
                                                                 309
                                                                                         ALEXANDER 91D OPAL 1990 LEP run
12.1 ±0.7 ±0.5
                                                 f&a
12.3 \ \pm 0.9 \ \pm 0.5
                                                  f&a
                                                            1338
                                                                                          BEHREND
                                                                                                                            90 CELL Eee = 35 GeV
11.3 \pm 0.5 \pm 0.8
                                                                798
                                                                                  <sup>29</sup> FORD
                                                                                                                            87 MAC E_{\rm cm}^{ee} = 29 GeV
                                                 avg
                                                                                   30 BARTEL
                                                                                                                            86D JADE E_{\mathrm{Cm}}^{ee} = 34.6 \; \mathrm{GeV}
12.3 \pm 0.6 \pm 1.1
                                                 avg
                                                                328

    • • We do not use the following data for averages, fits, limits, etc.

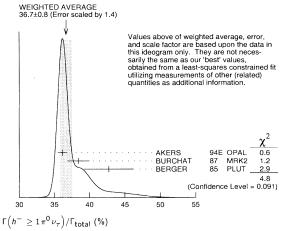
                                                                                  31 BURCHAT
11.1 \pm 1.1 \pm 1.4
                                                                                                                           87 MRK2 E<sup>ee</sup><sub>cm</sub>= 29 GeV
                                                                                                                           85 PLUT E_{
m cm}^{ee}= 34.6 GeV
                                                                                         BERGER
13.0 \pm 2.0 \pm 4.0
                                                                                32 BEHREND
11.2 \pm 1.7 \pm 1.2
                                                                    34
                                                                                                                          83C CELL E_{cm}^{ee} = 34 \text{ GeV}
   25\,\text{BUSKULIC} 96 quote 11.78 \pm 0.11 \pm 0.13 We add 0.66 to undo their correction for
         unseen K_I^0 and modify the systematic error accordingly.
   ^{26}\,\mathrm{ACCIARRI} 95 with 0.65% added to remove their correction for \pi^-\,K_L^0 backgrounds.
   ^{27} ABREU 92N with 0.5% added to remove their correction for K^*(892)^- backgrounds.
   ^{28}\, {\rm DECAMP} \,\, 92c \,\, {\rm quote} \,\, {\rm B}(h^- \, \geq \,\, 0 \,\, {\rm K}_L^0 \, \geq \,\, 0 \,\, ({\rm K}_S^0 \, \to \,\, \pi^+ \, \pi^-) \,\, \nu_{_{\scriptstyle {\cal T}}}) = 13.32 \pm 0.44 \pm 0.33.
         We subtract 0.35 to correct for their inclusion of the K_S^0 decays.
  ^{29} FORD 87 result for B(\pi^-\nu_{\tau}) with 0.67% added to remove their K^- correction and adjusted for 1992 B("1 prong").
   ^{30} BARTEL 86D result for B(\pi^-\nu_\tau) with 0.59% added to remove their K^- correction and adjusted for 1992 B("1 prong").
   ^{31} BURCHAT 87 with 1.1% added to remove their correction for K^- and K^*(892)^- back-
   <sup>32</sup> BEHREND 83C quote B(\pi^-\nu_{\tau}) = 9.9 \pm 1.7 \pm 1.3 after subtracting 1.3 \pm 0.5 to correct
         for B(K^-\nu_{\pi}).
 \Gamma(h^- \ge 0K_L^0 \nu_{\tau})/\Gamma(\text{particle}^- \ge 0 \text{ neutrals } \ge 0K_L^0 \nu_{\tau}(\text{"1-prong"}))
              \begin{array}{l} \Gamma_{7}/\Gamma_{1} = (\Gamma_{9} + \Gamma_{10} + \frac{1}{2} \Gamma_{30} + \frac{1}{2} \Gamma_{32} + \frac{1}{4} \Gamma_{37})/(\Gamma_{3} + \Gamma_{5} + \Gamma_{9} + \Gamma_{10} + \Gamma_{13} + \Gamma_{15} + \Gamma_{19} + \Gamma_{20} + \Gamma_{23} + \Gamma_{24} + \Gamma_{26} + 0.6569 \Gamma_{30} + 0.6569 \Gamma_{32} + 0.6569 \Gamma_{34} + 0.6569 \Gamma_{35} + 0.4316 \Gamma_{37} + 0.708 \Gamma_{90} + 0.085 \Gamma_{97} + 0.085 \Gamma_{98}) \end{array} 
<u>VALUE</u> <u>EVTS</u> <u>DOCUMENT ID</u> <u>TEC</u>
0.1473±0.0015 OUR FIT Error includes scale factor of 1.1.
                                                                                                                             TECN COMMENT
0.135 \pm0.009 OUR AVERAGE
                                                                          <sup>33</sup> FORD
0.131 \pm 0.006 \pm 0.009 798
                                                                                                                    87 MAC E_{cm}^{ee} = 29 GeV
                                                                        <sup>34</sup> BARTEL
                                                                                                                   86D JADE E_{cm}^{ee} = 34.6 \text{ GeV}
0.143 \pm 0.007 \pm 0.013 328
   ^{\rm 33}\,\text{FORD} 87 result divided by 0.865, their assumed value for B("1 prong").
   34 BARTEL 86D result with 0.6% added to remove their K<sup>-</sup> correction and then divided
by 0.866, their assumed value for B("1 prong").
                                                                                                                                                                                       \Gamma_7/\Gamma_5
 \Gamma(h^- \geq 0K_L^0 \nu_{\tau})/\Gamma(e^- \overline{\nu}_e \nu_{\tau})
             \Gamma_7/\Gamma_5 = (\Gamma_9 + \Gamma_{10} + \frac{1}{2}\Gamma_{30} + \frac{1}{2}\Gamma_{32} + \frac{1}{4}\Gamma_{37})/\Gamma_5
                                                     <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u>
Error includes scale factor of 1.1.
 0.702 + 0.008 OUR FIT
                                                                                   ALBRECHT 92D ARG E_{\text{CM}}^{ee} = 9.4–10.6 GeV
 • • We do not use the following data for averages, fits, limits, etc. • •
                                                                           <sup>35</sup> BARTEL
 0.647 \pm 0.039 \pm 0.061
                                                                                                                86D JADE E_{cm}^{ee} = 34.6 \text{ GeV}
   <sup>35</sup> Combined result of BARTEL 86D e \nu \overline{\nu}, \mu \nu \overline{\nu}, and \pi^- \nu assuming B(\mu \nu \overline{\nu})/B(e \nu \overline{\nu})=
 \Gamma(h^-\nu_{\tau})/\Gamma_{\text{total}}
                                                                                                                                                    \Gamma_8/\Gamma = (\Gamma_9 + \Gamma_{10})/\Gamma
 0.1203±0.0014 OUR FIT Error includes scale factor of 1.1.
               Data marked "avg" are highly correlated with data appearing elsewhere in the Listings,
               and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.
                                                              EVTS
                                                                                        DOCUMENT ID
                                                                                                                                   TECN COMMENT
 11.31±0.15 OUR FIT Error includes scale factor of 1.1.
 11.07\pm0.18 OUR AVERAGE
 11.06 ± 0.11 ± 0.14 avg
                                                                                  <sup>36</sup> BUSKULIC
                                                                                                                          96 ALEP LEP 1991-1993 data
                                                                                                                       82D MRK2 E_{\mathrm{CM}}^{ee} = 3.5–6.7 GeV
 11.7 ±0.4 ±1.8 f&a 1138
                                                                                      BLOCKER
   ^{36}\,\mathrm{Not} independent of BUSKULIC 96 \mathrm{B}(h^-\,\nu_\tau) and \mathrm{B}(K^-\,\nu_\tau) values.
```

$\Gamma(K^- u_ au)/\Gamma_{ m total}$				Γ ₁₀ /Γ
VALUE (%)	EVTS	DOCUMENT ID	TECN	COMMENT
0.71 ± 0.05 OUR FIT				
0.71±0.05 OUR AVER	\GE			
$0.72 \pm 0.04 \pm 0.04$	728	BUSKULIC	96 ALEP	LEP 1991–1993 data
0.85 ± 0.18	27	ABREU	94k DLPH	LEP 1992 Z data
$0.66 \pm 0.07 \pm 0.09$	99	BATTLE	94 CLEO	$E_{ m cm}^{\it ee} pprox 10.6 \ { m GeV}$
0.59 ± 0.18	16	MILLS	84 DLCO	$E_{ m cm}^{\it ee}$ = 29 GeV
1.3 ±0.5	15	BLOCKER	82B MRK2	E ^{ee} _{cm} = 3.9–6.7 GeV
• • We do not use the	e following d	ata for averages,	fits, limits, et	C. • • •
$0.64 \pm 0.05 \pm 0.05$	336	BUSKULIC	94E ALEP	Repl. by BUSKULIC 96

 $\Gamma\big(\hbar^- \geq 1\pi^0\,\nu_\tau\big)/\Gamma_{\underline{total}}$ $\begin{array}{l} -1.77 \\ -1.1/\Gamma = (\Gamma_{13} + \Gamma_{15} + \Gamma_{19} + \Gamma_{20} + \Gamma_{23} + \Gamma_{24} + \Gamma_{26} + 0.157\Gamma_{30} + 0.157\Gamma_{32} + 0.157\Gamma_{34} + 0.157\Gamma_{35} + 0.0246\Gamma_{37} + 0.708\Gamma_{90} + 0.085\Gamma_{97} + 0.085\Gamma_{98})/\Gamma \end{array}$

VALUE (%)	DOCUMENT ID	TECN	COMMENT
36.97 ± 0.18 OUR FIT Erro	r includes scale fa	ctor of 1.1.	
36.7 ±0.8 OUR AVERAGE	Error includes s	cale factor of	1.4. See the ideogram below.
$36.14 \pm 0.33 \pm 0.58$	AKERS	94E OPAL	1991-1992 LEP runs
38.4 ±1.2 ±1.0	37 BURCHAT	87 MRK2	Eee = 29 GeV
42.7 ± 2.0 ± 2.9	BERGER	85 PLUT	E ^{ee} _{cm} = 34.6 GeV

 37 BURCHAT 87 quote for B($\pi^{\pm} \geq$ 1 neutral $u_{ au}$) $= 0.378 \pm 0.012 \pm 0.010$. We add 0.006to account for contribution from $(K^{*-}\,\nu_{\tau})$ which they fixed at BR = 0.013.



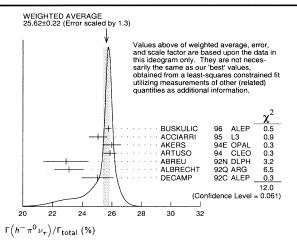
$\Gamma(h^-\pi^0\nu_{\tau})/\Gamma_{\text{total}}$					$\Gamma_{12}/\Gamma = (\Gamma_{13} + \Gamma_{15})/\Gamma$
VALUE (%)	EVTS	DOCUMENT ID		TECN	COMMENT
25.76±0.15 OUR FIT	Error in	ncludes scale factor	of 1.1		
25.62 ± 0.22 OUR AV	ERAGE	Error includes scale	factor	of 1.3.	See the ideogram below.
$25.76 \pm 0.15 \pm 0.13$	31k	BUSKULIC	96	ALEP	LEP 1991-1993 data
$25.05 \pm 0.35 \pm 0.50$	6613	ACCIARRI	95	L3	1992 LEP run
$25.98 \pm 0.36 \pm 0.52$		³⁸ AKERS	94E	OPAL	1991-1992 LEP runs
$25.87 \pm 0.12 \pm 0.42$	51k	³⁹ ARTUSO	94	CLEO	$E_{CM}^{ee} = 10.6 \; GeV$
22.9 ±0.8 ±1.3	283	⁴⁰ ABREU	92N	DLPH	$E_{\rm cm}^{ee} = 88.2 - 94.2 \; {\rm GeV}$
23.1 ±0.4 ±0.9	1249	⁴¹ ALBRECHT	92Q	ARG	$E_{cm}^{ee} = 10 \text{ GeV}$
25.02 ± 0.64 ± 0.88	1849	DECAMP	92C	ALEP	1989-1990 LEP runs
• • • We do not use	the follow	ving data for average	es, fits	, limits	, etc. • • •
22.0 ±0.8 ±1.9	779	ANTREASYA	N 91	CBAL	Eee = 9.4-10.6 GeV
22.6 ±1.5 ±0.7	1101	BEHREND	90	CELL	E ^{ee} _{cm} = 35 GeV
23.1 ±1.9 ±1.6		BEHREND	84	CELL	$E_{cm}^{ee} = 14,22 \text{ GeV}$

 $^{38}\,\text{AKERS}$ 94E quote (26.25 \pm 0.36 \pm 0.52) \times 10 $^{-2}$; we subtract 0.27% from their number to correct for $\tau^- \to h^- K^0_L \nu_{\tau}$.

 39 ARTUSO 94 reports the combined result from three independent methods, one of which (23% of the $\tau^-\to h^-\pi^0\nu_\tau$) is normalized to the inclusive one-prong branching fraction, taken as 0.854 \pm 0.004. Renormalization to the present value causes negligible change. 40 ABREU 92N with 0.5% added to remove their correction for $K^\star(892)^-$ backgrounds.

⁴¹ ALBRECHT 92Q with 0.5% added to remove their correction for $au^- o ext{ } K^*(892)^- ext{ }
u_{ au}$

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 $\Gamma(\pi^-\pi^0\nu_\tau)/\Gamma_{\rm total} \qquad \qquad \Gamma_{\rm 13}/\Gamma_{\rm Data\ marked\ "avg"} \ {\rm are\ highly\ correlated\ with\ data\ appearing\ elsewhere\ in\ the\ Listings, and are therefore\ used\ for\ the\ average\ given\ below\ but\ not\ in\ the\ overall\ fits.\ "f&a"\ marks\ results\ used\ for\ the\ fit\ and\ the\ average.}$

DOCUMENT ID

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25.31 ± 0.18 OUR AVERA	(GE				
$25.30 \pm 0.15 \pm 0.13$	avg	⁴² BUSKULIC	96	ALEP	LEP 1991-1993
25.36 ± 0.44	avg	⁴³ ARTUSO	94	CLEO	data Eee = 10.6 GeV
ullet $ullet$ We do not use the	following data	for averages, fits, li	mits,	etc. • •	•
$21.5 \pm 0.4 \pm 1.9$	4400 4	4,45 ALBRECHT	88L	ARG	$E_{CM}^{\mathit{ee}} = 10\;GeV$
$23.0 \pm 1.3 \pm 1.7$	582	ADLER	87B	MRK3	E_{cm}^{ee} = 3.77 GeV
$25.8 \pm 1.7 \pm 2.5$		⁴⁶ BURCHAT	87	MRK2	Eee = 29 GeV
$22.3 \pm 0.6 \pm 1.4$	629	⁴⁵ YELTON	86	MRK2	<i>E</i> ^{ee} _{Cm} = 29 GeV
42				٠.	

 42 Not independent of BUSKULIC 96 B($h^-\pi^0\nu_ au$) and B($K^-\pi^0\nu_ au$) values.

EVTS

25.24±0.16 OUR FIT Error includes scale factor of 1.1.

- 43 Not independent of ARTUSO 94 B($h^-\pi^0\nu_{\tau}$) and BATTLE 94 B($K^-\pi^0\nu_{\tau}$) values. 44 The authors divide by ($\Gamma_3+\Gamma_9+\Gamma_{10}$)/ $\Gamma=0.467$ to obtain this result.
- 45 Experiment had no hadron Identification. Kaon corrections were made, but insufficient information is given to permit their removal.
- 46 BURCHAT 87 value is not independent of YELTON 86 value. Nonresonant decays included.

$\Gamma(\pi^-\pi^0 \operatorname{non-}\rho(770)\nu_{\tau}$	-)/Γ _{total}				Γ_{14}/Γ
VALUE (%)	DOCUMENT ID		TECN	COMMENT	
$0.3 \pm 0.1 \pm 0.3$	47 BEHREND	84	CELL	$E_{cm}^{ee} = 14,22 \text{ GeV}$	

 47 BEHREND 84 assume a flat nonresonant mass distribution down to the $\rho(770)$ mass, using events with mass above 1300 to set the level.

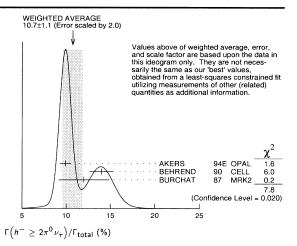
$\Gamma(K^-\pi^0 u_{ au})/\Gamma_{total}$					Γ ₁₅ /Γ
VALUE (%)	EVTS	DOCUMENT ID		TECN	COMMENT
0.52±0.05 OUR FIT					
0.52±0.06 OUR AVE	RAGE				
$0.52 \pm 0.04 \pm 0.05$	395	BUSKULIC	96	ALEP	LEP 1991-1993 data
$0.51 \pm 0.10 \pm 0.07$	37	BATTLE	94	CLEO	$E_{\rm cm}^{ee} \approx 10.6 {\rm GeV}$
 ● ● We do not use 	the followin	g data for averag	es, fit	s, limits	etc. • • •
$0.53 \pm 0.05 \pm 0.07$	220	BUSKULIC	94E	ALEP	Repl. by BUSKULIC 96

 $\begin{array}{l} \Gamma \left(h^- \geq 2\pi^0 \nu_\tau \right) / \Gamma_{\text{total}} & \Gamma_{16} / \Gamma_{16} / \Gamma_{16} / \Gamma_{19} + \Gamma_{20} + \Gamma_{23} + \Gamma_{24} + \Gamma_{26} + 0.157 \Gamma_{30} + 0.157 \Gamma_{32} + 0.157 \Gamma_{34} + 0.157 \Gamma_{35} + 0.0246 \Gamma_{37} + 0.319 \Gamma_{90}) / \Gamma_{10} \end{array}$

Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.

marks results used for	the fit and the average.				
VALUE (%)	VTS DOCUMENT ID	TECN COMMENT			
10.95 ± 0.16 OUR FIT Erro	or includes scale factor of	1.1.			
10.7 ±1.1 OUR AVERAGE		tor of 2.0. See the ideogram below.			
$9.89 \pm 0.34 \pm 0.55$ avg	⁴⁸ AKERS	94E OPAL 1991-1992 LEP runs			
14.0 \pm 1.2 \pm 0.6 f&a					
12.0 \pm 1.4 \pm 2.5 f&a	⁴⁹ BURCHAT	87 MRK2 <i>E</i> ^{ee} _{cm} = 29 GeV			
• • We do not use the form	llowing data for averages,	fits, limits, etc. • •			
$13.9 \ \pm 2.0 \ \begin{array}{c} +1.9 \\ -2.2 \end{array}$	⁵⁰ AIHARA	86E TPC			
48 AKERS 94E not independent of AKERS 94E B($h^- \ge 1\pi^0 \nu_{\tau}$) and B($h^-\pi^0 \nu_{\tau}$) measurements. 49 Error correlated with BURCHAT 87 $\Gamma(\rho^-\nu_{\rho})/\Gamma({\rm total})$ value.					

50 AIHARA 86E (TPC) quote B($2\pi^0\pi^-\nu_{\tau}$) + 1.6B($3\pi^0\pi^-\nu_{\tau}$) + 1.1B($\pi^0\eta\pi^-\nu_{\tau}$).



 $\Gamma \left(h^{-} 2\pi^{0} \nu_{\tau} \right) / \Gamma_{total}$ $\Gamma_{17} / \Gamma = (\Gamma_{19} + \Gamma_{20} + 0.157 \Gamma_{30} + 0.157 \Gamma_{32}) / \Gamma$

$$\Gamma \left(h^{-} 2\pi^{0} \nu_{\tau} (\text{ex.} K^{0}) \right) / \Gamma_{\text{total}}$$

$$\Gamma_{18} / \Gamma = (\Gamma_{19} + \Gamma_{20}) / \Gamma$$

Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. f&a marks results used for the fit and the average.

VALUE (%)		VTS	DOCUMENT ID		TECN	COMMENT
9.35±0.14 OUR I	FIT En	ror includ	les scale factor of	1.1.		
8.95±0.33 OUR /	AVERAG	E Erro	r includes scale fac	ctor	of 1.1.	
$8.88 \pm 0.37 \pm 0.42$	f&∠a 1					1992 LEP run
$8.96 \pm 0.16 \pm 0.44$	avg	5	⁵² PROCARIO	93	CLEO	$E_{\rm cm}^{ee} \approx 10.6 {\rm GeV}$
$10.38 \pm 0.66 \pm 0.82$	f&₂a	809 5	⁵³ DECAMP	92 C	ALEP	1989-1990 LEP runs
$5.7 \pm 0.5 \ ^{+1.7}_{-1.0}$	f&a	133	⁵⁴ ANTREASYAN	91	CBAL	Eee 9.4-10.6 GeV
$10.0 \ \pm 1.5 \ \pm 1.1$	f&a	333 5	55 BEHREND	90	CELL	E ^{ee} _{Cm} = 35 GeV
$8.7 \pm 0.4 \pm 1.1$	f&a	815 ⁵	⁵⁶ BAND	87	MAC	Eee = 29 GeV
$6.0 \pm 3.0 \pm 1.8$	f&a		BEHREND	84	CELL	Eee = 14,22 GeV
	ise the f	ollowing	data for averages,	fits,	limits, e	etc. • • •
$6.2 \pm 0.6 \pm 1.2$		5	⁵⁷ GAN	87	MRK2	Ecm = 29 GeV

 52 PROCARIO 93 entry is obtained from B($h^-\,2\pi^0\,\nu_\tau$)/B($h^-\,\pi^0\,\nu_\tau$) using ARTUSO 94 result for B($h^-\,\pi^0\,\nu_\tau$).

 53 We subtract 0.0015 to account for $\tau^- \to \ K^*(892)^- \nu_\tau$ contribution.

 54 ANTREASYAN 91 subtract 0.001 to account for the $\tau^-\to~K^*(892)^-\,\nu_\tau$ contribution.

 55 BEHREND 90 subtract 0.002 to account for the $\tau^- \to~ K^*(892)^- \nu_\tau$ contribution.

 56 BAND 87 assume B($\pi^ 3\pi^0$ ν_{τ}) = 0.01 and B($\pi^ \pi^0$ η ν_{τ}) = 0.005.

57 GAN 87 analysis use photon multiplicity distribution.

$$\Gamma \left(h^{-} 2\pi^{0} \nu_{\tau} (\textbf{ex.} \textbf{K}^{0}) \right) / \Gamma \left(h^{-} \pi^{0} \nu_{\tau} \right)$$

$$\Gamma_{18} / \Gamma_{12} = (\Gamma_{19} + \Gamma_{20}) / (\Gamma_{13} + \Gamma_{15})$$

$$\Gamma_{18} / \Gamma_{12}$$

 58 PROCARIO 93 quote 0.345 \pm 0.006 \pm 0.016 after correction for 2 kaon backgrounds assuming B(K*^- ν_τ)=1.42 \pm 0.18% and B(h^- $K^0\pi^0\nu_\tau$)=0.48 \pm 0.48%. We multiply by 0.990 \pm 0.010 to remove these corrections to B(h^- $\pi^0\nu_\tau$).

 $\Gamma(\pi^- 2\pi^0 \nu_\tau (\text{ex.K}^0))/\Gamma_{\text{total}} \\ \text{Data marked "avg" are highly correlated with data appearing elsewhere in the Listings,}$

and are therefore used for the average given below but not in the overall fits. "f&a"

marks results used for the fit and the average.

VALUE (%)

9.27 ± 0.14 OUR FIT

9.21 ± 0.13 ± 0.11

avg

9 BUSKULIC

9 ALEP

LEP 1991–1993 data

59 Not independent of BUSKULIC 96 B($h^-2\pi^0\nu_{ au}$ (ex. K^0)) and B($K^-2\pi^0\nu_{ au}$ (ex. K^0))

 τ

$\Gamma(K^-2\pi^0 u_{ au}({ m ex.}K^0))/\Gamma_{ m total}$ Γ_{20}/Γ	$\Gamma(h^-4\pi^0\nu_{\tau}(\mathbf{ex}.K^0,\eta))/\Gamma_{\text{total}}$ Γ_{26}/Γ
VALUE (%) EVTS DOCUMENT ID TECN COMMENT 0.081±0.027 OUR FIT	<u>VALUE (%)</u> <u>DOCUMENT ID</u> 0.12±0.06 OUR FIT
0.081±0.027 OUR AVERAGE 0.08 ±0.02 ±0.02 59 BUSKULIC 96 ALEP LEP 1991-1993 data 0.09 ±0.10 ±0.03 3 60 BATTLE 94 CLEO $E_{\rm Em}^{\rm em} \approx 10.6$ GeV	$\Gamma(K^{-} \ge 1 \begin{pmatrix} \pi^{0} \text{ or } K^{0} \end{pmatrix} \nu_{\tau}) / \Gamma_{\text{total}} $ $\Gamma_{27} / \Gamma = (\Gamma_{15} + \Gamma_{20} + \Gamma_{24} + \Gamma_{32} + \Gamma_{35}) / \Gamma$
• • • We do not use the following data for averages, fits, limits, etc. • • •	Data marked "avg" are highly correlated with data appearing elsewhere in the Listings,
0.04 ± 0.03 ± 0.02 11 BUSKULIC 94E ALEP Repl. by BUSKULIC 96	and are therefore used for the average given below but not in the overall fits. "f&a"
60 BATTLE 94 quote 0.14 \pm 0.10 \pm 0.03 or $<$ 0.3% at 90% CL. We subtract (0.05 \pm 0.02)% to account for $\tau^ \rightarrow$ K^- (K^0 \rightarrow $\pi^0\pi^0$) ν_τ background.	marks results used for the fit and the average. VALUE (%) EVTS
•	0.94±0.10 OUR FIT 0.76±0.23 OUR AVERAGE
$ \Gamma(h^{-} \ge 3\pi^{0}\nu_{\tau})/\Gamma_{\text{total}} \qquad \Gamma_{21}/\Gamma \\ \Gamma_{21}/\Gamma = (\Gamma_{23} + \Gamma_{24} + \Gamma_{26} + 0.157\Gamma_{34} + 0.157\Gamma_{35} + 0.0246\Gamma_{37} + 0.319\Gamma_{90})/\Gamma $	0.69 ± 0.25 avg 69 ABREU 94K DLPH LEP 1992 Z data
Data marked "avg" are highly correlated with data appearing elsewhere in the Listings,	1.2 $\pm 0.5 \stackrel{+0.2}{-0.4}$ f&a 9 AIHARA 87B TPC $E_{ m CM}^{\it ee}=$ 29 GeV
and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.	69 Not independent of ABREU 94K B $(K^- u_ au)$ and B $(K^-\ge 0$ neutrals $ u_ au)$ measurements.
VALUE (%) EVTS DOCUMENT ID TECN COMMENT	$\Gamma(h^{-}\overline{K}^{0} \ge 0 \text{ neutrals } \ge 0K_{\underline{L}}^{0}\nu_{\tau})/\Gamma_{\text{total}}$ Γ_{28}/Γ
1.46±0.11 OUR FIT Error includes scale factor of 1.1. 1.8 ±0.6 OUR AVERAGE Error includes scale factor of 1.1.	$\Gamma_{28}/\Gamma = (\Gamma_{30} + \Gamma_{32} + \Gamma_{34} + \Gamma_{35} + 0.657\Gamma_{37})/\Gamma$
1.53±0.40±0.46 f&a 186 DECAMP 92C ALEP 1989–1990 LEP	<u>VALUE (%)</u> <u>EVTS</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> 1.54±0.10 OUR FIT Error includes scale factor of 1.3.
3.2 \pm 1.0 \pm 1.0 avg 61 BEHREND 90 CELL $E_{\text{CM}}^{\text{eq}} =$ 35 GeV	1.3 ±0.3 44 TSCHIRHART 88 HRS $E_{\text{CM}}^{ee} = 29 \text{ GeV}$
⁶¹ Not independent of BEHREND 90 $\Gamma(h^- \ge 2\pi^0 \nu_{\tau})/\Gamma_{\rm total}$ and $\Gamma(h^- 2\pi^0 \nu_{\tau})/\Gamma_{\rm total}$ values.	$\Gamma(h^{-}\overline{K}^{0}\nu_{\tau})/\Gamma_{\text{total}}$ $\Gamma_{29}/\Gamma = (\Gamma_{30} + \Gamma_{32})/\Gamma$
	VALUE (%) EVTS DOCUMENT ID TECN COMMENT
$ \begin{array}{ll} \Gamma\left(h^{-}3\pi^{0}\nu_{\tau}\right)/\Gamma_{\text{total}} & \Gamma_{22}/\Gamma \\ \Gamma_{22}/\Gamma = (\Gamma_{23}+\Gamma_{24}+0.157\Gamma_{34}+0.157\Gamma_{35})/\Gamma \end{array} $	0.92 \pm0.08 OUR FIT Error includes scale factor of 1.3. 0.855 \pm0.036 \pm0.073 1242 COAN 96 CLEO $E_{cm}^{ee} \approx 10.6 \text{ GeV}$
Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.	$\Gamma(\pi^-\overline{K}^0 u_ au)/\Gamma_{ ext{total}}$ Data marked "avg" are highly correlated with data appearing elsewhere in the Listings,
<u>VALUE (%)</u> <u>EVTS</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> 1.28 ± 0.10 OUR FIT	and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.
1.22±0.10 OUR AVERAGE 1.24±0.09±0.11 f&a 2.3k 62 BUSKULIC 96 ALEP LEP 1991–1993 data	VALUE (%) EVTS DOCUMENT ID TECN COMMENT 0.77 ±0.08 OUR FIT Error includes scale factor of 1.3.
1.70±0.24±0.38 f&a 293 ACCIARRI 95 L3 1992 LEP run	0.76 ±0.06 OUR AVERAGE
1.15±0.08±0.13 avg ⁶³ PROCARIO 93 CLEO $E_{\text{Cm}}^{ee} \approx 10.6 \text{ GeV}$ • • • We do not use the following data for averages, fits, limits, etc. • • •	0.79 \pm 0.10 \pm 0.09 f&a 98 BUSKULIC 96 ALEP LEP 1991–1993 data 0.704 \pm 0.041 \pm 0.072 avg 70 COAN 96 CLEO $E_{\rm CM}^{\rm ep} \approx 10.6$ GeV
	$0.704 \pm 0.041 \pm 0.072$ avg 70 COAN 96 CLEO $E_{\rm CM}^{\rm eff} \approx 10.6$ GeV $0.95 \pm 0.15 \pm 0.06$ f&a 71 ACCIARRI 95F L3 1991–1993 LEP
-0.1 -0.1	runs • • • We do not use the following data for averages, fits, limits, etc. • • •
⁶² BUSKULIC 96 quote B($h^-3\pi^0\nu_{\tau}({\rm ex.}~K^0))=1.17\pm0.09\pm0.11.$ We add 0.07 to remove their correction for K^0 backgrounds.	$0.88 \pm 0.14 \pm 0.09$ 53 BUSKULIC 94F ALEP Repl. by
63 PROCARIO 93 entry is obtained from B $(h^-3\pi^0 u_ au)/$ B $(h^-\pi^0 u_ au)$ using ARTUSO 94	BUSKULIC 96 70 Not independent of COAN 96 B($h^-K^0\nu_{\tau}$) and B($K^-K^0\nu_{\tau}$) measurements.
result for B $(h^-\pi^0\nu_{ au})$. 64 Highly correlated with GAN 87 $\Gamma(\eta\pi^-\pi^0\nu_{ au})/\Gamma_{ m total}$ value. Authors quote	71 ACCIARRI 95F do not identify π^-/K^- and assume B($K^-K^0\nu_{ au}$) = (0.29 \pm 0.12)%.
$B(\pi^{\pm} 3\pi^{0} \nu_{\tau}) + 0.67 B(\pi^{\pm} \eta \pi^{0} \nu_{\tau}) = 0.047 \pm 0.010 \pm 0.011.$	$\Gamma(\pi^-\overline{K}^0\text{(non-}K^*(892)^-)\nu_{\tau})/\Gamma_{\text{total}}$ Γ_{31}/Γ
$\Gamma(h^-3\pi^0\nu_{\tau})/\Gamma(h^-\pi^0\nu_{\tau})$ Γ_{22}/Γ_{12}	VALUE (%) CL% DOCUMENT ID TECN COMMENT
$\Gamma_{22}/\Gamma_{12} = (\Gamma_{23} + \Gamma_{24} + 0.157\Gamma_{34} + 0.157\Gamma_{35})/(\Gamma_{13} + \Gamma_{15})$	<0.17 95 ACCIARRI 95F L3 1991–1993 LEP runs
VALUE DOCUMENT ID TECN COMMENT 0.050 ± 0.004 OUR FIT 0.044 ± 0.003 ± 0.005 65 PROCARIO 93 CLEO EEm ≈ 10.6 GeV	$\Gamma(K^-K^0 u_{ au})/\Gamma_{ ext{total}}$ $VALUE (%)$ $EVTS$ $OCCUMENT ID$ $TECN$ $COMMENT$ $TECN$ $COMMENT$
65 PROCARIO 93 quote 0.041 ± 0.003 ± 0.005 after correction for 2 kaon backgrounds	0.155±0.028 OUR FIT 0.162±0.032 OUR AVERAGE Error includes scale factor of 1.1.
assuming B($K^{*-}\nu_{\tau}$)=1.42 \pm 0.18% and B($h^-K^0\pi^0\nu_{\tau}$)=0.48 \pm 0.48%. We add 0.003 \pm 0.003 and multiply the sum by 0.990 \pm 0.010 to remove these corrections.	0.26 ±0.09 ±0.02 13 BUSKULIC 96 ALEP LEP 1991-1993 data 0.151±0.021±0.022 111 COAN 96 CLEO E ^{ee} _{CM} ≈ 10.6 GeV
$\Gamma(\pi^{-}3\pi^{0}\nu_{\tau}(\text{ex}.K^{0}))/\Gamma_{\text{total}}$ Γ_{23}/Γ	• • • We do not use the following data for averages, fits, limits, etc. • • • 0.29 ±0.12 ±0.03 8 BUSKULIC 94F ALEP Repl. by
VALUE (%) DOCUMENT ID 1.14±0.14 OUR FIT	BUSKULIC 96
	$\Gamma(h^{-}\overline{K}{}^{0}\pi^{0}\nu_{\tau})/\Gamma_{\text{total}} \qquad \qquad \Gamma_{33}/\Gamma = (\Gamma_{34} + \Gamma_{35})/\Gamma$
$\Gamma(K^{-}3\pi^{0}\nu_{\tau}(\text{ex.}K^{0}))/\Gamma_{\text{total}}$ VALUE (%) Tech COMMENT ID TECH COMMENT	<u>VALUE (%)</u> <u>EVTS</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u>
0.050 ⁺ 0.100 OUR FIT	0.562±0.050±0.048 264 COAN 96 CLEO $E_{ m CM}^{\it ee} ≈ 10.6 ~{ m GeV}$
0.05 ±0.13 66 BUSKULIC 94E ALEP 1991-1992 LEP runs	$\Gamma(\pi^-\overline{K}{}^0\pi^0 u_{ au})/\Gamma_{total}$ Γ_{34}/Γ
⁶⁶ BUSKULIC 94E quote B($K^- \ge 0\pi^0 \ge 0K^0\nu_{ au}$) $- [B(K^-\nu_{ au}) + B(K^-\pi^0\nu_{ au}) +]$	Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "f&a"
${\sf B}({\cal K}^-{\cal K}^0\nu_{ au})+{\sf B}({\cal K}^-\pi^0\pi^0\nu_{ au})+{\sf B}({\cal K}^-\pi^0{\cal K}^0\nu_{ au})]=0.05\pm0.13\%$ accounting for common systematic errors in BUSKULIC 94E and BUSKULIC 94F measurements of these modes. We assume ${\sf B}({\cal K}^-\geq 2{\cal K}^0\nu_{ au})$ and ${\sf B}({\cal K}^-\geq 4\pi^0\nu_{ au})$ are negligible.	marks results used for the fit and the average. VALUE (%) EVTS DOCUMENT ID TECN COMMENT 0.41 ±0.06 OUR FIT
$\Gamma(h^{-}4\pi^{0}\nu_{\tau}(\mathbf{ex}.K^{0}))/\Gamma_{\mathbf{total}}$ $\Gamma_{25}/\Gamma = (\Gamma_{26}+0.319\Gamma_{90})/\Gamma$	0.39 ±0.06 OUR AVERAGE 0.32 ±0.11 ±0.05 1&a 23 BUSKULIC 96 ALEP LEP 1991–1993 data
VALUE (%)EVTSDOCUMENT IDTECNCOMMENT	data 0.417±0.058±0.044 avg 72 COAN 96 CLEO E_c^{ee} ≈ 10.6 GeV 0.41 ±0.12 ±0.03 f&a 73 ACCIARRI 95F L3 1991–1993 LEP
0.18±0.06 OUR FIT 0.16±0.06 OUR AVERAGE	• • • We do not use the following data for averages, fits, limits, etc. • • •
0.16 \pm 0.04 \pm 0.09 232 67 BUSKULIC 96 ALEP LEP 1991–1993 data 0.16 \pm 0.05 \pm 0.05 68 PROCARIO 93 CLEO $E_{\rm cm}^{\rm em} \approx 10.6$ GeV	0.33 ±0.14 ±0.07 9 BUSKULIC 94F ALEP Repl. by BUSKULIC 96
⁶⁷ BUSKULIC 96 quote result for $\tau^-\to h^-\geq 4\pi^0\nu_{\tau}$. We assume B($h^-\geq 5\pi^0\nu_{\tau}$) is negligible.	72 Not independent of COAN 96 B($h^ K^0$ π^0 ν_{τ}) and B($K^ K^0$ π^0 ν_{τ}) measurements. 73 ACCIARRI 95F do not identify π^-/K^- and assume B($K^ K^0$ π^0 ν_{τ}) = (0.05 \pm 0.05)%.
⁶⁸ PROCARIO 93 quotes B($h^-4\pi^0\nu_{ au}$)/B($h^-\pi^0\nu_{ au}$) =0.006 ± 0.002 ± 0.002. We multiply by the ARTUSO 94 result for B($h^-\pi^0\nu_{ au}$) to obtain B($h^-4\pi^0\nu_{ au}$). PROCARIO 93	·
assume B($h^- \geq 5 \pi^0 u_T$) is small and do not correct for it.	

'(Κ [–] Κ⁰ π⁰ ν_τ)/Γ_{tot} 'ALUE (%)	al FVTS	DOCUMENT ID	TECN	COMMENT	Γ ₃₅ /Γ
.138±0.032 OUR FIT		DOCUMENT ID		337777	
.130±0.034 OUR AVE					
.10 ±0.05 ±0.03	5 32	BUSKULIC	96 ALEP	LEP 1991-1993	
.145 ± 0.036 ± 0.020 • • We do not use the		COAN	96 CLEO	$E_{\rm cm}^{ee} \approx 10.6 {\rm Ge}$	·V
.05 ±0.05 ±0.01	1	BUSKULIC	94F ALEP	Repl. by BUSKI	JLIC 96
	-				
E (h-K ⁰ ₅ K ⁰ ₅ ν _τ)/Γ _{tol} Bose-Einstein corre	elations mig	tht make the mix	ing fraction TECN		‡Г37/Г I.
.025±0.006 OUR FIT	EVTS	DOCUMENTID	TECIV	COMMENT	
.023±0.005±0.003	42	COAN	96 CLEO	$E_{\rm CM}^{\it ee} \approx 10.6 \; {\rm Ge}$	•V
$(\pi^- K^0 \overline{K}^0 \nu_{\tau}) / \Gamma_{\text{tot}}$	al				Γ_{37}/Γ
Data marked "avg"	" are highly	correlated with d	ata appearir	g elsewhere in the	Listings,
and are therefore i marks results used			elow but no	t in the overall fit	s. 182a
ALUE (%)	EVTS	DOCUMENT	ID TE	CN COMMENT	
.101 ± 0.023 OUR FIT					
.099±0.023 OUR AVE		74		50 566 to	
	ivg 42 &a	⁷⁴ COAN ACCIARRI		LEO $E_{\text{cm}}^{\text{ee}} \approx 10$. 3 1991–1993 runs	
⁷⁴ We multiply the COA	N 96 measi	urement B(h - K	${}^{0}_{6}K^{0}_{6}\nu_{-}) =$		0.0031%
by 4 to obtain the lis	ted value.	This factor of 1/4	S · S · τ / -	n, and might be a	s large as
1/2, due to Bose-Eir					
$(K^-K^0 \ge 0 \text{ neutra})$	ls ν_\ /Γ	4-1		$\Gamma_{38}/\Gamma = (\Gamma_{32} +$	-F2E1/F
ALUE (%)	τ)/ ' to	DOCUMENT ID		- 30/ - (1327	. 35// '
.29±0.04 OUR FIT					
$K^{-} \geq 0\pi^{0} \geq 0K^{0}$ $\Gamma_{39}/\Gamma = (\Gamma_{10} + \Gamma_{1})$	$(\nu_{\tau})/\Gamma_{\text{tot}}$	al			Г39/Г
Data marked "avg"					
and are therefore	used for the				
			elow but no	t in the overall in	5. 162 <i>a</i>
marks results used				CN COMMENT	.s. 162 <i>a</i>
marks results used ALUE (%) 65±0.10 OUR FIT	for the fit a	and the average.			a
marks results used (ALUE (%) 65±0.10 OUR FIT 69±0.07 OUR AVERA	for the fit a <u>EVTS</u> GE	and the average. <u>DOCUMENT I</u>	ID TE	CN COMMENT	
marks results used (ALUE (%) 65±0.10 OUR FIT 69±0.07 OUR AVERA 70±0.05±0.06	for the fit a <u>EVTS</u> AGE vg 1610	DOCUMENT I 75 BUSKULIC	96 AL	CN COMMENT EP LEP 1991-1	993 data
marks results used (ALUE (%) 65±0.10 OUR FIT 69±0.07 OUR AVERA 70±0.05±0.06 av 54±0.24 f8	for the fit a <u>EVTS</u> GE	and the average. <u>DOCUMENT I</u>	ID TE	CN COMMENT EP LEP 1991-1 PH LEP 1992 Z	993 data data
marks results used (ALUE (%) .65±0.10 OUR FIT .69±0.07 OUR AVERA .70±0.05±0.06 .54±0.24 .70±0.12±0.19 f8	for the fit a EVTS AGE vg 1610 ka	nd the average. DOCUMENT I 75 BUSKULIC ABREU	96 AL 94K DL	CN COMMENT EP LEP 1991–1 PH LEP 1992 Z EO Eem ≈ 10.6	993 data data 5 GeV
marks results used (ALUE (%) .65±0.10 OUR FIT .69±0.07 OUR AVERA .70±0.05±0.06 av .54±0.24 .70±0.12±0.19 f8 .6 ±0.4 ±0.2 f8	for the fit a EVTS AGE Vg 1610 ka 202 ka 35	75 BUSKULIC ABREU 76 BATTLE AIHARA	96 AL 94K DL 94 CL 878 TP	EP LEP 1991–1 PH LEP 1992 Z EO $E_{\text{cm}}^{\text{ee}} \approx 10.6$ CC $E_{\text{cm}}^{\text{ee}} = 29 \text{ G}$	993 data data 5 GeV eV
marks results used ####################################	for the fit a EVTS AGE vg 1610 2a 202 2a 35 2a 53	75 BUSKULIC ABREU 76 BATTLE AIHARA MILLS	96 AL 94K DL 94 CL 878 TP 84 DL	EP LEP 1991-1 PH LEP 1992 Z EO E€m ≈ 10.6 C E€m = 29 G CO E€m = 29 G	993 data data 5 GeV eV
marks results used ###################################	for the fit a EVTS AGE vg 1610 2a 202 2a 35 2a 53	75 BUSKULIC ABREU 76 BATTLE AIHARA MILLS	96 AL 94K DL 94 CL 878 TF 84 DL i, fits, limits	EP LEP 1991–1 PH LEP 1992 Z EC $E_{cm}^{ee} \approx 10.6$ C $E_{cm}^{ee} = 29 \text{ G}$ C $E_{cm}^{ee} = 29 \text{ G}$, etc. • •	993 data data 5 GeV eV
marks results used ###################################	for the fit a EVTS AGE yg 1610 2a 202 2a 35 2a 53 e following 967	75 BUSKULIC ABREU 76 BATTLE AIHARA MILLS data for averages 77 BUSKULIC	96 AL 94K DL 94 CL 878 TP 84 DL 5, fits, limits 94E AL	EP LEP 1991–1 PH LEP 1992 Z EO $E_{co}^{ee} \approx 10.0$ C $E_{co}^{ee} = 29$ G CO $E_{co}^{ee} = 29$ G , etc. • •	993 data data is GeV eV eV
marks results used ### ALUE (%)	for the fit a EVTS AGE Vg 1610 Va 202 Va 35 Va 53 e following of 967 of BUSKU	75 BUSKULIC ABREU 76 BATTLE AIHARA MILLS data for averages 77 BUSKULIC LIC 96 B(K ⁻	96 AL 94K DL 94 CL 878 TP 84 DL 5, fits, limits 94E AL	EP LEP 1991–1 PH LEP 1992 Z EO $E_{co}^{ee} \approx 10.0$ C $E_{co}^{ee} = 29$ G CO $E_{co}^{ee} = 29$ G , etc. • •	993 data data is GeV eV eV
marks results used $\frac{ALUE(\%)}{6.65\pm0.10}$ OUR FIT 6.9 ± 0.07 OUR AVERA .70 ± 0.05 ± 0.06 at .54 ± 0.24 ft .70 ± 0.12 ± 0.19 ft .6 ± 0.4 ± 0.2 ft .71 ± 0.29 ft .60 ± 0.07 ± 0.12 .12 .13 Not independent $\frac{1}{1000}$ R($K - \frac{K^0}{1000} W_{\odot}$), and $\frac{1}{1000}$ and $\frac{1}{1000}$ Average $\frac{1}{1000}$ and $\frac{1}{10000}$ and $\frac{1}{10000000000000000000000000000000000$	for the fit a EVTS AGE $V_{0}V_{0}V_{0}V_{0}$ $V_{0}V_{0}V_{0}$ $V_{0}V_{0}V_{0}$ $V_{0}V_{0}V_{0}$ $V_{0}V_{0}V_{0}$ $V_{0}V_{0}V_{0}$ $V_{0}V_{0}V_{0}$ $V_{0}V_{0}V_{0}$ $V_{0}V_{0}V_{0}$ $V_{0}V_{0}V_{0}V_{0}$	75 BUSKULIC ABREU 76 BATTLE AIHARA MILLS data for averages 77 BUSKULIC LIC 96 B(K ⁻	P_{T} 96 AL 94 CL 878 TP 84 DL P_{T} $P_{$	EP LEP 1991–1 PH LEP 1992 Z EO $E_{c}^{ee} \approx 10.6$ C $E_{c}^{ee} = 29$ G CO $E_{c}^{ee} = 29$ G EO $E_{c}^{ee} = 29$ G EO $E_{c}^{ee} = 29$ G BUSKUL $= \pi^{0} \nu_{\tau}$), B(K^{-}	993 data data data is GeV eV $^{ m C}$
marks results used $\frac{ALUE(\%)}{6.55\pm0.10}$ OUR FIT 6.55±0.10 OUR FIT 6.9±0.07 OUR AVERA .70±0.05±0.06 at .54±0.24 ft 6.54±0.24 ft 6.54±0.29 ft 6.50±0.07±0.12 ft 6.50±0.07±0.07±0.07±0.07±0.07±0.07±0.07±0	for the fit a EVTS of \mathbb{R} and \mathbb{R} and \mathbb{R} by \mathbb{R} 1610 and \mathbb{R} and \mathbb{R} 202 and \mathbb{R} and \mathbb{R} 53 are following a 967 of \mathbb{R} BUSKU \mathbb{R} ($\mathbb{R} - \mathbb{R}$ 0 \mathbb{R} 0.60 \pm 0.12 \pm	75 BUSKULIC ABREU 76 BATTLE AIHARA MILLS data for averages 77 BUSKULIC LIC 96 B(K ⁻	P_{T} 96 AL 94 CL 878 TP 84 DL P_{T} $P_{$	EP LEP 1991–1 PH LEP 1992 Z EO $E_{c}^{ee} \approx 10.6$ C $E_{c}^{ee} = 29$ G CO $E_{c}^{ee} = 29$ G EO $E_{c}^{ee} = 29$ G EO $E_{c}^{ee} = 29$ G BUSKUL $= \pi^{0} \nu_{\tau}$), B(K^{-}	993 data data data is GeV eV $^{ m C}$
marks results used $\frac{AUE(\%)}{6.5\pm0.10}$ OUR FIT	for the fit a EVTS LAGE Lag 1610 Lag 202 Lag 35 Lag 53 Lag 60llowing 6 P67 Lag $(K - K^0 \pi^0)$	and the average. POCUMENT I 75 BUSKULIC ABREU 76 BATTLE AIHARA MILLS data for averages 77 BUSKULIC LIC 96 $\mathrm{B}(K^{-})\nu_{\tau}$) values. E 0.19. We add 0	$\frac{96}{94}$ AL $\frac{94}{94}$ CL $\frac{878}{94}$ TF, $\frac{84}{94}$ DL $\frac{1}{94}$ AL $\frac{1}{94}$	EP LEP 1991–1 PH LEP 1992 Z EO $E_{\rm cm}^{\rm ex} \approx 10.6$ CO $E_{\rm cm}^{\rm ex} = 29.6$ CO $E_{\rm cm}^{\rm ex} = 29.6$, etc. • • EP Repl. by BUSKUL $= \pi^0 \nu_T$), B(K^- To correct for their	993 data data is GeV eV 2
marks results used $\frac{ALUE(\%)}{6.55\pm0.10}$ OUR FIT 6.55±0.10 OUR FIT 6.9±0.07 OUR AVERA .70±0.05±0.06 at .54±0.24 ft 6.54±0.24 ft 6.54±0.29 ft 6.50±0.07±0.12 ft 6.50±0.07±0.07±0.07±0.07±0.07±0.07±0.07±0	for the fit a EVTS AGE Vig 1610 $2a = 202$ $2a = 35$ $2a = 53$ e following a 967 of BUSKU $3(K - K^0 \pi^0$ $3(60 \pm 0.12 \pm 0.02 \pm 0.02$	75 BUSKULIC ABREU 76 BATTLE AIHARA MILLS data for averages 77 BUSKULIC LIC 96 B(K^-) ν_{τ}) values. ν_{τ}) values. ν_{τ}) we add 0 LIC 94E B(K^-)	$\frac{96}{94}$ AL $\frac{94}{94}$ CL $\frac{878}{94}$ TF, $\frac{84}{94}$ DL $\frac{1}{94}$ AL $\frac{1}{94}$	EP LEP 1991–1 PH LEP 1992 Z EO $E_{c}^{ee} \approx 10.6$ C $E_{c}^{ee} = 29$ G CO $E_{c}^{ee} = 29$ G EO $E_{c}^{ee} = 29$ G EO $E_{c}^{ee} = 29$ G BUSKUL $= \pi^{0} \nu_{\tau}$), B(K^{-}	993 data data is GeV eV 2
marks results used $\frac{AULE (\%)}{64.UE (\%)}$ ————————————————————————————————————	for the fit a variation of $\frac{1}{2}$ and $\frac{1}{2}$	75 BUSKULIC ABREU 76 BATTLE AIHARA MILLS data for averages 77 BUSKULIC LIC 96 B(K^-) ν_{τ}) values. ν_{τ}) values. ν_{τ}) we add 0 LIC 94E B(K^-)	$\frac{96}{94}$ AL $\frac{94}{94}$ CL $\frac{878}{94}$ TF, $\frac{84}{94}$ DL $\frac{1}{94}$ AL $\frac{1}{94}$	EP LEP 1991–1 PH LEP 1992 Z EO $E_{\rm cm}^{\rm ex} \approx 10.6$ CO $E_{\rm cm}^{\rm ex} = 29.6$ CO $E_{\rm cm}^{\rm ex} = 29.6$, etc. • • EP Repl. by BUSKUL $= \pi^0 \nu_T$), B(K^- To correct for their	993 data data data data data data data dat
marks results used MLUE (%) ———————————————————————————————————	for the fit a EVTS (GE 1052 1052 1053 1054 1055	and the average. DOCUMENT I 75 BUSKULIC ABREU 76 BATTLE AIHARA MILLS data for averages 77 BUSKULIC LIC 96 B($K^ D_{\nu_T}$) values. D_{ν_T} bush add 0 LIC 94E B($K^ D_{\nu_T}$) values.	$\frac{96}{94}$ AL $\frac{94}{94}$ CL $\frac{878}{94}$ TF, $\frac{84}{94}$ DL $\frac{1}{94}$ AL $\frac{1}{94}$	EP LEP 1991–1 PH LEP 1992 Z EO $E_{\rm cm}^{\rm ex} \approx 10.6$ CO $E_{\rm cm}^{\rm ex} = 29.6$ CO $E_{\rm cm}^{\rm ex} = 29.6$, etc. • • EP Repl. by BUSKUL $= \pi^0 \nu_T$), B(K^- To correct for their	993 data data is GeV eV 2
marks results used $\frac{AULE (\%)}{64.UE (\%)}$	for the fit a FVTS iGE FVTS	and the average. DOCUMENT I 75 BUSKULIC ABREU 76 BATTLE AIHARA MILLS data for averages 77 BUSKULIC LIC 96 B($K^ D_{\nu_T}$) values. E 0.19. We add 0 LIC 94E B($K^ D_{\nu_T}$) values.	96 AL 94K DL 94K DL 94K DL 94 CL 878 TF 84 DL $_{\rm T}$, $_{\rm T}$	EP LEP 1991–1 PH LEP 1992 Z EO $E_{\rm cm}^{\rm em} \approx 10.6$ C $E_{\rm cm}^{\rm ee} = 29$ G , etc. • • EP Repl. by BUSKUL $-\pi^0 \nu_{\tau}$), B(K^- co correct for their	993 data data data is GeV eV eV $(2\pi^0 u_{ au})$, rejection $(2\pi^0 u_{ au})$,
marks results used $\frac{AUE(\%)}{6.5\pm0.10}$ OUR FIT69 ±0.07 OUR AVERA70 ±0.05 ±0.06 as .54 ±0.24 ft54 ±0.12 ft69 ±0.12 ±0.19 ft60 ±0.07 ±0.12 ft60 ±0.07 ±0.07 ±0.12 ft60 ±0.07 ±	for the fit a EVTS GGE (λ_{2} λ_{3} λ_{2} λ_{3} $\lambda_$	and the average. DOCUMENT I 75 BUSKULIC ABREU 76 BATTLE AIHARA MILLS data for averages 77 BUSKULIC LIC 96 B($K^ D_{\nu_T}$) values. D_{ν_T} bush add 0 LIC 94E B($K^ D_{\nu_T}$) values.	$\frac{10}{1.2}$ $\frac{7E}{1.2}$ $\frac{96}{94}$ AL $\frac{94}{94}$ CL $\frac{94}{94}$ CL $\frac{878}{84}$ DL $\frac{1}{94}$ Fits, limits $\frac{94E}{1.0}$ AL $\frac{94E}{1.0}$ AL $\frac{94E}{1.0}$ B($\frac{1}{8}$	EP LEP 1991–1 PH LEP 1992 Z EO $E_{\rm cm}^{\rm ex} \approx 10.6$ CO $E_{\rm cm}^{\rm ex} = 29$ G CO $E_{\rm cm}^{\rm ex} = 29$ G , etc. • • • EP Repl. by $EP = R_{\rm co} = 20.6$ co correct for their $-\pi^0 v_{_T}), B(K^{-1})$	993 data data data s GeV eV eV 1C 96 $^{2\pi^0}\nu_{\tau}$), rejection $^{2\pi^0}\nu_{\tau}$),
marks results used $\frac{AULE(\%)}{6.5\pm0.10}$ OUR FIT	for the fit a variation of the fit a variation of $\frac{EVTS}{EVTS}$ (as $\frac{EVTS}{4}$) as $\frac{EVTS}{4}$ (b) $\frac{EVTS}{4}$ (c) $$	75 BUSKULIC ABREU 76 BATTLE AIHARA MILLS data for averages 77 BUSKULIC LIC 96 B(K-	96 AL 94K DL 94K DL 94K DL 94K DL 87B TF 84 DL 10, fifts, limits 94E AL ν_{τ}), B(K 1.10 \pm 0.02 t ν_{τ}), B(K 1.2 ν_{τ}), B(K 1.2 ν_{τ}), B(K 1.3 ν_{τ}), B(K 1.4	EP LEP 1991–1 PH LEP 1992 Z EO $E_{\rm cm}^{\rm em} \approx 10.6$ C $E_{\rm cm}^{\rm em} \approx 29$ G , etc. • • EP Repl. by BUSKUL $-\pi^0 \nu_{\tau}$), B(K^- co correct for their $-\pi^0 \nu_{\tau}$), B($K^ E^{\rm em} = 29$	993 data data s GeV eV eV 1C 96 2 0 0 0 1 rejection 2 0 0 1 1
marks results used $\frac{AUE(\%)}{6.5\pm0.10}$ OUR FIT69 ±0.07 OUR AVERA70 ±0.05 ±0.06 as .54 ±0.24 ft54 ±0.12 ft69 ±0.12 ±0.19 ft60 ±0.07 ±0.12 ft60 ±0.07 ±0.07 ±0.12 ft60 ±0.07 ±	for the fit a variable for the fit a variabl	75 BUSKULIC ABREU 76 BATTLE AIHARA MILLS data for averages 77 BUSKULIC LIC 96 B(K-	96 AL 94K DL 94K DL 94K DL 94K DL 87B TF 84 DL 10, fifts, limits 94E AL ν_{τ}), B(K 1.10 \pm 0.02 t ν_{τ}), B(K 1.2 ν_{τ}), B(K 1.2 ν_{τ}), B(K 1.3 ν_{τ}), B(K 1.4	EP LEP 1991–1 PH LEP 1992 Z EO $E_{\rm cm}^{\rm em} \approx 10.6$ C $E_{\rm cm}^{\rm em} \approx 29$ G , etc. • • EP Repl. by BUSKUL $-\pi^0 \nu_{\tau}$), B(K^- co correct for their $-\pi^0 \nu_{\tau}$), B($K^ E^{\rm em} = 29$	993 data data data s GeV eV eV 1C 96 $^{2\pi^0}\nu_{\tau}$), rejection $^{2\pi^0}\nu_{\tau}$),
marks results used $\frac{AULE(\%)}{6.5\pm0.10}$ OUR FIT	for the fit a EVTS GGE (χ_{0} = 1610 χ_{0} = 1610 χ_{0} = 202 χ_{0} = 35 χ_{0} = 53 χ_{0} = 610lowing χ_{0} = 70 of BUSKU1 χ_{0} = 60.0 ± 0.12 ± ecays. of BUSKU1 χ_{0} = 70.7 to all χ_{0} =	and the average. POCUMENT I The BUSKULIC ABREU The BATTLE AIHARA MILLS data for averages The BUSKULIC BUSKULIC LIC 96 B(K^-) ν_{τ}) values. End the buskulic	96 AL 94K DL 94K DPAL 94K OPAL 94K DPAL 9	EP LEP 1991–1 PH LEP 1992 Z EO $E_{\rm cm}^{\rm ex} \approx 10.6$ CO $E_{\rm cm}^{\rm ex} = 29$ G CO CORREST $= 1000000000000000000000000000000000000$	993 data data s GeV eV eV 1C 96 2 0 0 0 1 rejection 2 0 0 1 1
marks results used $\frac{AUE(\%)}{64.0E(\%)}$ marks results used $\frac{AUE(\%)}{65.000000000000000000000000000000000000$	for the fit a variable for the fit a variabl	and the average. 75 BUSKULIC ABREU 76 BATTLE AIHARA MILLS data for averages 77 BUSKULIC LIC 96 B($K^ \nu_{\tau}$) values. E 0.19. We add 0 LIC 94E B($K^ \nu_{\tau}$) values. $5+\Gamma_{37}/\Gamma$ $DOCUMENT ID$ 8 AKERS ticles) $-\nu_{\tau}$)/ Γ_{total} $DOCUMENT ID$	$\frac{10}{96}$ AL 94K DL	EP LEP 1991-1 PH LEP 1992 Z EO $E_{\rm cm}^{\rm em} \approx 10.6$ CO $E_{\rm cm}^{\rm em} \approx 29$ CO $E_{\rm cm}^{\rm em} \approx 20$ PH Repl. by EP Repl. by EO correct for their $-\pi^0 \nu_{\tau}), \ \ B(K^{-1})$ ECOMMENT $E_{\rm cm}^{\rm em} = 88-94 \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \$	993 data data s GeV eV eV 1C 96 $^{2\pi^0}\nu_{ au}$), rejection $^{2\pi^0}\nu_{ au}$), 6 6
marks results used $\frac{ALUE}{(\%)}$ marks results used $\frac{ALUE}{ALUE}$ (%)	for the fit a variable for the fit a variabl	TSCHIRRARN	96 AL 94K DL 94K DL 94K DL 94K DL 94K DL 94K DL 95K DL 95	EP LEP 1991–1 PH LEP 1992 Z EO $E_{\rm cm}^{\rm em} \approx 10.0$ C $E_{\rm cm}^{\rm em} \approx 29$ G , etc. • • EP Repl. by $= \pi^{0} \nu_{\tau}), \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \$	993 data data s GeV eV eV 1C 96 $^{2\pi^0}\nu_{ au}$), rejection $^{2\pi^0}\nu_{ au}$), 6 6
marks results used $\frac{AUE(\%)}{64.0E(\%)}$ marks results used $\frac{AUE(\%)}{65.000000000000000000000000000000000000$	for the fit a variable for the fit a variabl	and the average. 75 BUSKULIC ABREU 76 BATTLE AIHARA MILLS data for averages 77 BUSKULIC LIC 96 B($K^ D_{\nu_T}$) values. E 0.19. We add 0 LIC 94E B($K^ D_{\nu_T}$) values. E 5+ Γ_{37})/ Γ_{50} E Scale factor of 8 AKERS ticles)- ν_{τ})/ Γ_{tot} TSCHIRHARI data for averages	96 AL 94K DL 94	EP LEP 1991–1 PH LEP 1992 Z EO Ecm ≈ 10.0 C C Ecm ≈ 29 G , etc. • • EP Repl. by $-\pi^0 \nu_T$), B(K- C C C C C C C C C C C C C C C C C C C	993 data data for GeV eV eV eV $(2\pi^0 \nu_{ au})$, rejection $(2\pi^0 \nu_{ au})$, eV $(2\pi^0 \nu_{ au})$, rejection $(2\pi^0 \nu_{ au})$
marks results used $\frac{ALUE}{(\%)}$ marks results used $\frac{ALUE}{ALUE}$ (%)	for the fit a variable for the fit a variabl	TSCHIRRARN	96 AL 94K DL 94K DL 94K DL 94K DL 94K DL 94K DL 95K DL 95	EP LEP 1991–1 PH LEP 1992 Z EO $E_{\rm cm}^{\rm em} \approx 10.0$ C $E_{\rm cm}^{\rm em} \approx 29$ G , etc. • • EP Repl. by $= \pi^{0} \nu_{\tau}), \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \$	993 data data for GeV eV eV eV $(2\pi^0 \nu_{ au})$, rejection $(2\pi^0 \nu_{ au})$, eV $(2\pi^0 \nu_{ au})$, rejection $(2\pi^0 \nu_{ au})$
marks results used $\frac{ALUE(\%)}{6LUE(\%)}$ marks results used $\frac{AULE(\%)}{6.5\pm0.10}$ OUR FIT69±0.07 OUR AVERA. 70±0.05±0.06 at .54±0.24 ft .60±0.07±0.12 ft .60±0.07±0.07±0.07±0.07±0.07±0.07±0.07±0	for the fit a variable for the fit a variabl	and the average. $\frac{DOCUMENTI}{DOCUMENTI}$ 75 BUSKULIC ABREU ABREU AHARA MILLS data for averages 77 BUSKULIC LIC 96 B(K^-) ν_{τ}) values. E 0.19. We add 0 LIC 94E B(K^-) ν_{τ}) values. $\frac{5+\Gamma_{37}}{\Gamma}$ $\frac{DOCUMENTID}{\Gamma}$ S scale factor of 8 AKERS ticles) $-\nu_{\tau}$)/ Γ total $\frac{DOCUMENTID}{\Gamma}$ TSCHIRHART data for averages BELTRAMI	96 AL 94K DL 94K DL 94K DL 94K DL 94K DL 94K DL 95K DL 95	EP LEP 1991–1 PH LEP 1992 Z EO $E_{\rm cm}^{\rm em} \approx 10.0$ C $E_{\rm cm}^{\rm em} \approx 29$ G , etc. • • EP Repl. by BUSKUL $-\pi^0 \nu_{\tau}$), B(K^- C coorrect for their $-\pi^0 \nu_{\tau}$), B($K^ COMMENT$ $E_{\rm cm}^{\rm em} = 88–94$ G $COMMENT$ $E_{\rm cm}^{\rm em} = 29$ GeV , etc. • • $E_{\rm cm}^{\rm em} = 29$ GeV , etc. • •	993 data data data 5 GeV eV eV 1C 96 $^{2}\pi^{0}\nu_{\tau}$), rejection $^{2}\pi^{0}\nu_{\tau}$), $^{40}/\Gamma$
marks results used $\frac{AULE(\%)}{6.5\pm0.10}$ OUR FIT	for the fit a variable $\frac{EVTS}{EVTS}$ (GE variable $\frac{EVTS}{4}$ (36) $\frac{EVTS}{4}$ (37) $\frac{EVTS}{4}$ (37) $\frac{EVTS}{4}$ (37) $\frac{EVTS}{4}$ (37) $\frac{EVTS}{4}$ (37) $\frac{EVTS}{4}$ (37) $\frac{EVTS}{4}$ (47) $\frac{EVTS}{4}$ (47) $\frac{EVTS}{4}$ (47) $\frac{EVTS}{4}$ (57) $\frac{EVTS}{4}$ (57) $\frac{EVTS}{4}$ (67) $\frac{EVTS}{4}$ (77) $\frac{EVTS}{4}$ (78) $\frac{EVTS}{4}$ (79) $\frac{EVTS}{4}$	and the average. $\frac{DOCUMENTI}{DOCUMENTI}$ 75 BUSKULIC ABREU AHARA MILLS data for averages 77 BUSKULIC LIC 96 B($K^ v_{\tau}$) values. E 0.19. We add 0 LIC 94E B($K^ v_{\tau}$) values. 5+ Γ_{37})/ Γ DOCUMENT ID TSCHIRHARI DOCUMENT ID TSCHIRHARI data for averages BELTRAMI DOCUMENT ID TSCHIRHARI 32+0.3431 Γ_{34} +0.3431 Γ_{34} +0.3441 Γ_{44} +0.444	$\frac{10}{100}$ $\frac{7E}{100}$ $\frac{96}{94}$ AL $\frac{94}{94}$ CL $\frac{94}{94}$ CL $\frac{878}{94}$ TF $\frac{84}{94}$ DL $\frac{94}{94}$ DL $\frac{94}{94}$ AL $\frac{94}{94}$ AL $\frac{94}{94}$ AL $\frac{1.2}{94}$ $\frac{1.2}{94}$ $\frac{94}{94}$ GPAL $\frac{1.2}{94}$ $\frac{1.2}$	EP LEP 1991–1 PH LEP 1992 Z EO $E_{\rm cm}^{\rm em} \approx 10.0$ C $E_{\rm cm}^{\rm em} \approx 29$ G , etc. • • EP Repl. by BUSKUL $-\pi^0 \nu_{\tau}$), B(K^- C coorrect for their $-\pi^0 \nu_{\tau}$), B(K^- COMMENT $E_{\rm cm}^{\rm em} = 88-94$ E 0.09 \pm 0.06. $\frac{COMMENT}{E_{\rm cm}^{\rm em}} = 29$ GeV, etc. • • $E_{\rm cm}^{\rm em} = 29$ GeV, etc. • •	993 data data data 5 GeV eV eV 1C 96 $^{2}\pi^{0}\nu_{\tau}$), rejection $^{2}\pi^{0}\nu_{\tau}$), $^{40}/\Gamma$
marks results used $\frac{AULE(\%)}{64.UE(\%)}$ marks results used $\frac{AULE(\%)}{65.000}$ more $\frac{AULE(\%)}{60.000}$ more $\frac{AULE(\%)}{60.0000}$ more $\frac{AULE(\%)}{60.0000}$ more $\frac{AULE(\%)}{60.00000}$ more $\frac{AULE(\%)}{60.00000000000000000000000000000000000$	for the fit a variable for the fit a variabl	and the average. $POCUMENTI$ 75 BUSKULIC ABREU 76 BATTLE AIHARA MILLS data for averages 77 BUSKULIC LIC 96 B($K^ D^ D$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	EP LEP 1991-1 PH LEP 1992 Z EO $E_{\rm cm}^{\rm em} \approx 10.6$ CO $E_{\rm cm}^{\rm em} \approx 29.6$ CO $E_{\rm cm}^{\rm em} \approx 29.6$ CO $E_{\rm cm}^{\rm em} \approx 29.6$ EP Repl. by $= \pi^0 \nu_{\tau}), B(K^{-1})$ CO correct for their $= \pi^0 \nu_{\tau}), B(K^{-1})$ $= \frac{COMMENT}{E_{\rm cm}^{\rm em}} = 88-94.6$ $= 0.09 \pm 0.06.$ $= \frac{COMMENT}{E_{\rm cm}^{\rm em}} = 29.6$	993 data data data s GeV eV eV Γ_{41}/Γ eV $\Gamma_{52}+\Gamma_{52}+\Gamma_{52}$

VALUE (%)

14.91 ± 0.14 OUR FIT

Error includes scale factor of 1.3.

f&∠a

f&a

f&a

f&a

f& a

f&₂a

 $14.4 \ \pm \ 0.6 \ \pm 0.3$

 $13.5 \pm 0.3 \pm 0.3$

 $15.0 \pm 0.4 \pm 0.3$

 $15.1 \pm 0.8 \pm 0.6$

 $12.8 \ \pm \ 0.5 \ \pm 0.8$

 $15.3 \ \pm \ 1.1 \ ^{+1.3}_{-1.6}$

 $13.6 \ \pm \ 0.5 \ \pm 0.8$

 $13.3 \ \pm \ 0.3 \ \pm 0.6$

14.01± 0.29 OUR AVERAGE Error includes scale factor of 1.2.

1420

ADEVA

ABACHI

AIHARA

BEHREND

SCHMIDKE

ALTHOFF

BARTEL

FERNANDEZ 85 MAC

TECN COMMENT

86 MRK2 Ecm = 29 GeV

85 TASS $E_{\text{CM}}^{ee} = 34.5 \text{ GeV}$

85F JADE Ecm = 34.6 GeV

91F L3

89B HRS 89B CELL

87B TPC

 $E_{cm}^{ee} = 88.3-94.3$

Eee = 14-47 GeV

GeV Eee = 29 GeV

 $E_{\rm cm}^{ee}$ = 29 GeV

Eee = 29 GeV

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• • We do not use the following data for averages, fits, limits, etc. • •
                                                                                                                           87 MRK2 E<sup>ee</sup><sub>Cm</sub>= 29 GeV
                                                                                      <sup>79</sup> BURCHAT
 12.8 \pm 1.0 \pm 0.7
12.1 \pm 0.5 \pm 1.2
                                                                                            RUCKSTUHL 86 DLCO Ecm = 29 GeV
                                                                                      80 BERGER
                                                                                                                             85 PLUT Eee = 34.6 GeV
12.2 \pm 1.3 \pm 3.9
                                                                                            BRANDELIK 80 TASS E_{
m CM}^{\it ee}= 30 GeV
24\phantom{0}\pm\phantom{0}6
                                                                       35
                                                                                     <sup>81</sup> BACINO
32
         ± 5
                                                                                                                              78B DLCO E_{cm}^{ee} = 3.1-7.4
                                                                                      81 BRANDELIK 78 DASP Assumes V-A de-
35
          \pm 11
                                                                                                                              78 MRK1 E_{\text{Cm}}^{ee} > 6 \text{ GeV}
                                                                                     <sup>81</sup> JAROS
 18
          ± 6.5
  <sup>79</sup> BURCHAT 87 value is not independent of SCHMIDKE 86 value.
   80 Not independent of BERGER 85 \Gamma(\mu^-\overline{\nu}_\mu\nu_	au)/\Gamma_{\mathrm{total}}, \Gamma(e^-\overline{\nu}_e\nu_	au)/\Gamma_{\mathrm{total}}, \Gamma(h^-\geq 1)
         1\pi^0 \nu_	au)/\Gamma_{
m total}, and \Gamma(h^- \ge 0 K_L^0 \ \nu_	au)/\Gamma_{
m total}, and therefore not used in the fit.
  81 Low energy experiments are not in average or fit because the systematic errors in background subtraction are judged to be large.
 \Gamma \left( h^- \, h^- \, h^+ \geq 0 \text{ neutrals } \nu_\tau \left( \text{ex. } K^0_{\, \text{S}} \to \pi^+ \, \pi^- \right) \right) / \Gamma_{\text{total}} \\ \Gamma_{43} / \Gamma = (\Gamma_{47} + \Gamma_{52} + \Gamma_{60} + \Gamma_{61} + 0.285 \Gamma_{90} + 0.9101 \Gamma_{97} + 0.9101 \Gamma_{98}) / \Gamma_{\text{total}} 
                                                                                                                                                                                      \Gamma_{43}/\Gamma
              Data marked "avg" are highly correlated with data appearing elsewhere in the Listings,
              and are therefore used for the average given below but not in the overall fits. "f&a"
               marks results used for the fit and the average.
 VALUE (%) EVTS DOCUMENT ID

14.36±0.14 OUR FIT Error includes scale factor of 1.3.
                                                                                                                               TECN COMMENT
 14.63 ± 0.25 OUR AVERAGE Error includes scale factor of 1.4. See the ideogram below.
 14.96 \pm 0.09 \pm 0.22
                                              f&a 10.4k
                                                                                       AKERS
                                                                                                                          95Y OPAL 1991-1994 LEP runs
                                                                                 82 BALEST
 14.22 \pm 0.10 \pm 0.37
                                                                                                                           950 CLEO E_{
m cm}^{ee} pprox 10.6 GeV
                                                                                  83 ALBRECHT
 13.3 \pm 0.3 \pm 0.8
                                                 f&₂a
                                                                                                                          92D ARG Eee = 9.4-10.6 GeV
 14.35^{+0.40}_{-0.45} \pm 0.24 f&a
                                                                                       DECAMP
                                                                                                                          92C ALEP 1989-1990 LEP runs
 \bullet \bullet We do not use the following data for averages, fits, limits, etc. 
 \bullet \bullet
                                                                                       ACTON
                                                                                                                          92H OPAL Repl. by AKERS 95Y
   82 Not independent of BALEST 95C B( h^- h^- h^+ \nu_{\tau}) and B( h^- h^- h^+ \pi^0 \nu_{\tau}) values, and
         BORTOLETTO 93 B(h^-h^-h^+2\pi^0\nu_{	au})/B(h^-h^-h^+\geq 0 neutrals \nu_{	au}) value.
   <sup>83</sup> This ALBRECHT 92D value is not independent of their \Gamma(\mu^- \overline{\nu}_\mu \nu_\tau) \Gamma(e^- \overline{\nu}_e \nu_\tau) / \Gamma_{\rm total}^2
                                 WEIGHTED AVERAGE
14.63±0.25 (Error scaled by 1.4)
                                                                                                     Values above of weighted average, error, and scale factor are based upon the data in this ideogram only. They are not necessarily the same as our 'best' values, obtained from a least-squares constrained fit utilizing measurements of other (related)
                                                                                                      quantities as additional information.
                                                                                                                       AKERS
                                                                                                                                                          95C CLEO
92D ARG
92C ALEP
                                                                                                                        BALEST
                                                                                                                        DECAME
                                                                                                                                           (Confidence Level = 0.120)
                                              12
                                                             13
                                                                              14
                                                                                              15
                                                                                                              16
                                                                                                                              17
                       \Gamma(h^-h^-h^+ \geq 0 \text{ neutrals } \nu_{\tau}(\text{ex. } K_S^0 \rightarrow \pi^+\pi^-))/\Gamma_{	ext{total}} (%)
 \Gamma(\pi^-\pi^+\pi^- \geq 0 \text{ neutrals } \nu_\tau)/\Gamma(h^-h^-h^+ \geq 0 \text{ neut. } \nu_\tau\text{("3-prong")}) \Gamma_{44}/\Gamma_{42}
               \Gamma_{44}/\Gamma_{42} = \Gamma_{44}/(0.3431\Gamma_{30} + 0.3431\Gamma_{32} + 0.3431\Gamma_{34} + 0.3431\Gamma_{35} + 0.4508\Gamma_{37} + \Gamma_{47} + 0.4508\Gamma_{37} + \Gamma_{47} + 0.4508\Gamma_{37} + 0.4508\Gamma
                \Gamma_{52} + \Gamma_{60} + \Gamma_{61} + 0.285 \Gamma_{90} + 0.9101 \Gamma_{97} + 0.9101 \Gamma_{98} ) 
                                                 <u>EVTS</u>
                                                                                 DOCUMENT ID
                                                                                                                        TECN COMMENT
                                                     490 84 BAUER
                                                                                                                  94 TPC E<sub>CM</sub><sup>ee</sup> = 29 GeV
   ^{84} BAUER 94 quote B(\pi^-\pi^+\pi^-\geq 0 neutrals \nu_{\tau})=0.1329\pm 0.0027. We divide by 0.1406, their assumed value for B("3prong").
 \begin{array}{l} \Gamma \left( \textbf{h}^{-}\,\textbf{h}^{+}\,\nu_{\tau} \right) / \Gamma_{\text{total}} \\ \Gamma_{45} / \Gamma = (0.3431\Gamma_{30} + 0.3431\Gamma_{32} + \Gamma_{47} + 0.0221\Gamma_{97}) / \Gamma \end{array}
                                                                                                                                                                                       \Gamma_{45}/\Gamma
               Data marked "avg" are highly correlated with data appearing elsewhere in the Listings,
              and are therefore used for the average given below but not in the overall fits. "f&a"
               marks results used for the fit and the average.

    VALUE (%)
    EVTS
    DOCUMENT ID

    9.80 ± 0.10 OUR FIT
    Error includes scale factor of 1.1.

                                                                                                                             TECN COMMENT
 9.80 ± 0.18 OUR AVERAGE Error includes scale factor of 1.4. See the ideogram below.
                                                                            <sup>85</sup> BUSKULIC
 9.92 \pm 0.10 \pm 0.09 f&a 11.2k
                                                                                                                     96 ALEP LEP 1991-1993 data
                                                                                                                     92C ALEP 1989-1990 LEP runs
 9.49 ± 0.36 ± 0.63 f&a
                                                                                   DECAMP
                                                                             86 BEHREND
                                                          694
                                                                                                                     90 CELL Ecm = 35 GeV
 8.7 \pm 0.7 \pm 0.3
                                          f&∠a
```

SCHMIDKE 86 MRK2 Eee 29 GeV

 87 FERNANDEZ 85 MAC $E_{
m cm}^{ee} =$ 29 GeV

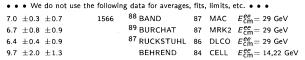
890

f&∠a

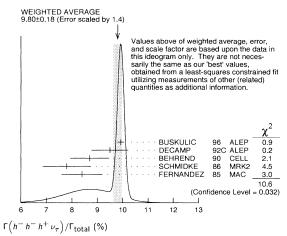
avg 1255

 $7.8 \pm 0.5 \pm 0.8$

 $8.4 \pm 0.4 \pm 0.7$



- 85 BUSKULIC 96 quote B($h^ h^+$ ν_{τ} (ex. K^0)) = 9.50 \pm 0.10 \pm 0.11. We add 0.42 to remove their $\ensuremath{\mathcal{K}}^0$ correction and reduce the systematic error accordingly.
- 86 BEHREND 90 subtract 0.3% to account for the $au^-
 ightarrow au^*(892)^-
 u_ au$ contribution to
- measured events. 87 Value obtained by multiplying paper's R= B($h^ h^ h^+$ $\nu_{ au}$)/B(3-prong) by B(3-prong) = 0.143 and subtracting 0.3% for $K^*(892)$ background.
- 88 BAND 87 subtract for charged kaon modes; not independent of FERNANDEZ 85 value.
- 89 BURCHAT 87 value is not independent of SCHMIDKE 86 value.



 $\Gamma(h^-h^-h^+\nu_{\tau})/\Gamma(h^-h^-h^+ \ge 0$ neut. ν_{τ} ("3-prong")) Γ_{45}/Γ_{42} $\begin{matrix} \Gamma_{45}/\Gamma_{42} = (0.3431\Gamma_{30} + 0.3431\Gamma_{32} + \Gamma_{47} + 0.0221\Gamma_{97})/(0.3431\Gamma_{30} + 0.3431\Gamma_{32} + 0.3431\Gamma_{34} + 0.3431\Gamma_{35} + 0.4508\Gamma_{37} + \Gamma_{47} + \Gamma_{52} + \Gamma_{60} + \Gamma_{61} + 0.285\Gamma_{90} + 0.9101\Gamma_{98}) \end{matrix}$

This branching fractions is not independent of values for $\Gamma(h^-\,h^-\,h^+\,
u_ au)/\Gamma_{
m total}$ and

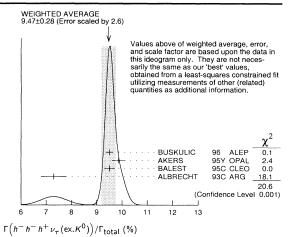
$\Gamma(h^-h^-h^+ \geq 0$ neut. ν_{τ} ("3-prong"))/ Γ_{total} .					
VALUE	DOCUMENT ID	TECN	COMMENT		
0.744±0.007 OUR FIT					
$0.61 \pm 0.03 \pm 0.05$	FERNANDEZ 85	MAC	E_{cm}^{ee} = 29 GeV		
	ing data for average:	s, fits, lin	nits, etc. • • •		
$0.47\ \pm0.03\ \pm0.06$	RUCKSTUHL 86	DLCO	E ^{ee} _{cm} = 29 GeV		

$$\begin{array}{ll} \Gamma\left(h^-h^-h^+\nu_{\tau}(\text{ex.}K^0)\right)/\Gamma_{\text{total}} \\ \Gamma_{46}/\Gamma = (\Gamma_{47} + 0.0221\Gamma_{97})/\Gamma \end{array} \hspace{3cm} \Gamma_{46}/\Gamma \end{array}$$

Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "f&a' marks results used for the fit and the average.

VALUE (%)		EVTS	DOCUMENT ID	TECN	COMMENT
9.48±0.10 OUR FIT	Erro	r includes	scale factor of 1.1.		
9.47±0.28 OUR AVE	RAGE	Error i		of 2.6. See	the ideogram below.
$9.50 \pm 0.10 \pm 0.11$	avg	11.2k	⁹⁰ BU S KULIC	96 ALEP	LEP 1991-1993 data
$9.87 \pm 0.10 \pm 0.24$	avg		⁹¹ AKERS	95Y OPAL	1991-1994 LEP runs
$9.51 \pm 0.07 \pm 0.20$	f&₂a	37.7k	BALEST	95c CLEO	$E_{\rm cm}^{\it ee} \approx 10.6~{\rm GeV}$
$7.3 \pm 0.1 \pm 0.5$	avg		⁹² ALBRECHT	93C ARG	Eee = 9.4-10.6 GeV

- ⁹⁰ Not independent of BUSKULIC 96 B($h^-h^-h^+\nu_{\tau}$) value.
- 91 Not independent of AKERS 95Y B($h^ h^ h^+$ \geq 0 neutrals ν_{τ} (ex. K_S^0 \rightarrow $~\pi^+$ π^-)) and $B(h^-h^-h^+\nu_{\tau}(ex. K^0))/B(h^-h^-h^+ \ge 0 \text{ neutrals } \nu_{\tau}(ex. K_S^0 \to \pi^+\pi^-)) \text{ values.}$
- 92 ALBRECHT 93c value with 0.5 \pm 0.3% added to remove their corrections for chargedkaon backgrounds.



$$\begin{array}{l} \Gamma\left(h^-h^-h^+\nu_\tau\left(\text{ex.}K^0\right)\right) \times \Gamma\left(\text{particle}^- \geq 0 \text{ neutrals } \geq 0K_1^0\nu_\tau\left(\text{"1-prong"}\right)\right)/\Gamma_{\text{total}}^2 \qquad \qquad \Gamma_{46}\Gamma_1/\Gamma^2 \\ \Gamma_{46}\Gamma_1/\Gamma^2 = (\Gamma_{47} + 0.0221\Gamma_{97})(\Gamma_3 + \Gamma_5 + \Gamma_9 + \Gamma_{10} + \Gamma_{13} + \Gamma_{15} + \Gamma_{19} + \Gamma_{20} + \Gamma_{23} + \Gamma_{24} + \Gamma_{26} + 0.6569\Gamma_{32} + 0.6569\Gamma_{32} + 0.6569\Gamma_{34} + 0.6569\Gamma_{35} + 0.4316\Gamma_{37} + 0.708\Gamma_{90} + 0.085\Gamma_{97})/\Gamma^2 \end{array}$$

<u>VALUE</u> <u>EVTS</u> <u>DOCUMENT ID</u> <u>TEC</u> **0.0805±0.0008 OUR FIT** Error includes scale factor of 1.1. TECN COMMENT

 93 ALBRECHT 93C ARG $E_{
m cm}^{\it ee}=$ 9.4–10.6 GeV $0.063 \pm 0.001 \pm 0.004$ 7.5k

 93 ALBRECHT 93c quote $B(\pi^-\pi^-\pi^+\nu_{\tau})=6.8\pm0.1\pm0.5\%.$ We add $0.5\pm0.3\%$ to remove their correction for charged kaon backgrounds, then multiply by 0.8613, their assumed value for B("1-prong").

$$\begin{split} & \Gamma \big(h^- \, h^- \, h^+ \, \nu_\tau \, (\text{ex.} K^0) \big) / \Gamma \big(h^- \, h^- \, h^+ \geq 0 \text{ neutrals } \nu_\tau \, (\text{ex.} \, K^0_{\, \S} \to \, \pi^+ \, \pi^-) \big) \\ & \Gamma_{46} / \Gamma_{43} = (\Gamma_{47} + 0.0221\Gamma_{97}) / (\Gamma_{47} + \Gamma_{52} + \Gamma_{60} + \Gamma_{61} + 0.285\Gamma_{90} + 0.9101\Gamma_{97} + 0.9101\Gamma_{98}) \end{split}$$

<u>VALUE</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> **0.660±0.006 OUR FIT** Error includes scale factor of 1.1. $0.660 \pm 0.004 \pm 0.014$ AKERS 95Y OPAL 1991-1994 LEP runs

$$\Gamma(h^-h^-h^+
u_{ au}(\mathrm{ex}.K^0,\omega))/\Gamma_{\mathrm{total}}$$

9.44±0.10 OUR FIT Error includes scale factor of 1.1.

$$\Gamma \left(h^- h^- h^+ \geq 1 \text{ neutrals } \nu_\tau \right) / \Gamma_{\text{total}}$$

$$\Gamma_{48} / \Gamma = (0.3431\Gamma_{34} + 0.3431\Gamma_{35} + 0.1077\Gamma_{37} + \Gamma_{52} + \Gamma_{60} + \Gamma_{61} + 0.285\Gamma_{90} + 0.888\Gamma_{97} + 0.9101\Gamma_{98}) / \Gamma$$

Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.

VALUE (%)		EVTS	DOCUMENT ID		TECN	COMMENT
5.08±0.11 OUR FIT	Error incli	udes sca	ale factor of 1.2.			
5.2 ±0.4 OUR AVE	RAGE					
$5.6 \pm 0.7 \pm 0.3$	avg	352	94 BEHREND			$E_{Cm}^{ee} = 35 \; GeV$
$4.2 \pm 0.5 \pm 0.9$	f&a	203	⁹⁵ ALBRECHT	87L	ARG	$E_{CM}^{ee} = 10 \; GeV$
$4.7 \pm 0.5 \pm 0.8$	avg	530	⁹⁶ SCHMIDKE	86	MRK2	E_{cm}^{ee} = 29 GeV
$5.6 \pm 0.4 \pm 0.7$	avg		⁹⁷ FERNANDEZ	85	MAC	$E_{\rm cm}^{\it ee}$ = 29 GeV
$6.2 \pm 2.3 \pm 1.7$	f&a		BEHREND	84	CELL	$E_{cm}^{ee} = 14,22$
						GeV

 \bullet $\,\bullet\,$ We do not use the following data for averages, fits, limits, etc. $\,\bullet\,$ $\,\bullet\,$

 98 BURCHAT 87 MRK2 $E_{
m Cm}^{ee}=$ 29 GeV 6.1 ±0.8 ±0.9 97,99 RUCKSTUHL 86 DLCO $E_{
m cm}^{ee} =$ 29 GeV $7.6 \pm 0.4 \pm 0.9$

- 94 BEHREND 90 value is not independent of BEHREND 90 B(3 $h
 u_{ au} \, \geq \, 1$ neutrals) +
- 95 ALBRECHT the product of branching measure tios B($3\pi^{\pm}\pi^{0}\nu_{\tau}$) B($(e\bar{\nu}$ or $\mu\bar{\nu}$ or π or Kor $\rho)\nu_{\tau}$) = 0.029 and use the PDG 86 values for the second branching ratio which sum to 0.69 \pm 0.03 to get the quoted value.
- ⁹⁶ Not independent of SCHMIDKE 86 $h^-h^-h^+\nu_{ au}$ and $h^-h^-h^+(\ge 0\pi^0)\nu_{ au}$ values.
- 97 Value obtained using paper's $R = B(h^- h^- h^+ \nu_{\tau})/B$ (3-prong) and current B(3-prong)
- 98 BURCHAT 87 value is not independent of SCHMIDKE 86 value. 99 Contributions from kaons and from $>1\pi^0$ are subtracted. Not independent of (3-prong + $0\pi^{0}$) and (3-prong + $\geq 0\pi^{0}$) values.

$\Gamma(h^-h^-h^+ \geq 1 \text{ neutrals } \nu_{\tau}(\text{ex. } K_S^0 \to \pi^+\pi^-))/\Gamma_{\text{total}}$ Γ_{49}/Γ						
$ \Gamma(h^-h^-h^+ \ge 1 \text{ neutrals } \nu_{\tau}(\text{ex. } K_S^0 \to \pi^+\pi^-))/\Gamma_{\text{total}} \Gamma_{49}/\Gamma = (\Gamma_{52} + \Gamma_{60} + \Gamma_{61} + 0.285\Gamma_{90} + 0.888\Gamma_{97} + 0.9101\Gamma_{98})/\Gamma $	$\Gamma(h^-h^-h^+2\pi^0\nu_{\tau})$ $\Gamma_{59}/\Gamma_{42} = (\Gamma_{60})$	$+0.236\Gamma_{90}+$	$0.888\Gamma_{98})/(0.34)$	$31\Gamma_{30} + 0.34$	$431\Gamma_{32} + 0.3431\Gamma_{3}$	4+
Data marked "avg" are highly correlated with data appearing elsewhere in the Listings,	0.3431F ₃₅ +0.45	08Г ₃₇ +Г ₄₇ ⊣	+F ₅₂ +F ₆₀ +F ₆₁ -	⊦0.285Γ ₉₀ +	+0.9101Г ₉₇ +0.91	01F ₉₈)
and are therefore used for the average given below but not in the overall fits. "f&a"	VALUE	EVTS	DOCUMENT ID	TECN	COMMENT	
marks results used for the fit and the average.	0.0341 ±0.0031 OUR F					
VALUE (%) EVTS DOCUMENT ID TECN COMMENT 4.88±0.11 OUR FIT Error includes scale factor of 1.2.	0.034 ±0.002 ±0.003	668	BORTOLETTO	93 CLEO	$E_{\rm cm}^{ee} \approx 10.6 {\rm Ge}$	eV
5.07±0.24 OUR AVERAGE	$\Gamma(h^-h^-h^+2\pi^0 u_{ au})$	· 1/0 \	N /F			- /-
5.09±0.10±0.23 avg 100 AKERS 95Y OPAL 1991–1994 LEP runs		$(ex. \wedge \gamma, \omega, \eta)$				Γ ₆₀ /Γ
4.95±0.29±0.65 f&a 570 DECAMP 92c ALEP 1989-1990 LEP runs	VALUE (%) 0.10±0.04 OUR FIT		DOCUMENT ID			
¹⁰⁰ Not independent of AKERS 95Y B($h^-h^-h^+\geq 0$ neutrals ν_{τ} (ex. $\kappa_{S}^0 \rightarrow \pi^+\pi^-$))						
and B($h^-h^-h^+ \geq 0$ neutrals ν_{τ} (ex. κ^0))/B($h^-h^-h^+ \geq 0$ neutrals ν_{τ} (ex. $\kappa^0_S \rightarrow$	$\Gamma(h^-h^-h^+ \geq 3\pi^0)$	$\nu_{\tau})/\Gamma_{\text{total}}$				Γ_{61}/Γ
$\pi^+\pi^-$)) values.	VALUE (%)	EVTS	DOCUMENT ID	TECN	COMMENT	
"	0.11 ± 0.06 OUR FIT					
$\Gamma(h^-h^-h^+\pi^0\nu_{\tau})/\Gamma_{\text{total}}$ Γ_{50}/Γ	$0.11 \pm 0.04 \pm 0.05$	440	BUSKULIC	96 ALEP	LEP 1991-1993	data
$\Gamma_{50}/\Gamma = (0.3431\Gamma_{34} + 0.3431\Gamma_{35} + \Gamma_{52} + 0.888\Gamma_{97} + 0.0221\Gamma_{98})/\Gamma$	$\Gamma(K^-h^+h^- \ge 0 \text{ ne}$	eutrals $\nu)$ /	/Feetal			Γ_{62}/Γ
VALUE (%) EVTS DOCUMENT ID TECN COMMENT	VALUE (%)	CL%	DOCUMENT ID	TECN	I COMMENT	. 62/ .
4.44±0.09 OUR FIT Error includes scale factor of 1.1.	<0.6	90	AIHARA	84C TPC		,
4.45±0.09±0.07 6.1k 101 BUSKULIC 96 ALEP LEP 1991–1993 data					-Ciii	
101 BUSKULIC 96 quote B($h^-h^-h^+\pi^0 u_{ au}$ (ex. K^0)) = $4.30\pm0.09\pm0.09$. We add 0.15	$\Gamma(K^-\pi^+\pi^- \ge 0 \text{ ne}$	eut. $ u_{ au})/\Gamma_1$	total			Γ_{63}/Γ
to remove their κ^0 correction and reduce the systematic error accordingly.	VALUE (%)	EVTS	DOCUMENT IL	TEC	N COMMENT	
$\Gamma(h^-h^-h^+\pi^0\nu_{ au}(\text{ex}.K^0))/\Gamma_{ ext{total}}$ Γ_{51}/Γ	0.39+0.19 OUR AVER	AGE Error	includes scale fac	tor of 1.5.		
$\Gamma_{51}/\Gamma = (\Gamma_{52} + 0.888\Gamma_{97} + 0.0221\Gamma_{98})/\Gamma$						
VALUE (%) EVTS DOCUMENT ID TECN COMMENT	$0.58^{+0.15}_{-0.13}\pm0.12$	20	105 BAUER	94 TP	C $E_{cm}^{ee} = 29 \; Ge$	eV .
2.25±0.09 OUR FIT Error includes scale factor of 1.1.	$0.22^{+0.16}_{-0.13}\pm0.05$	9	106 MILLS	85 DL0	CO <i>E</i> _{Cm} = 29 Ge	٠V
1.23\pm0.06\pm0.22 7.2k BALEST 95C CLEO $E_{ ext{cm}}^{ee} \approx 10.6 \text{ GeV}$						
	105 We multiply 0.58% the systematic error	r.				
$\Gamma(h^-h^-h^+\pi^0\nu_{\tau}(\text{ex. }K^0,\omega))/\Gamma_{\text{total}}$ Γ_{52}/Γ	106 Error correlated with	h MILLS 85 ($(KK\pi u)$ value. V	Ve multiply	0.22% by 0.23, th	ne relative
/ALUE (%)	systematic error que	oted by MILL	S 85, to obtain o	btain the s	ystematic error.	
2.55 ± 0.09 OOK FIT	$\Gamma(K^-\pi^+K^- \ge 0 \text{ ne}$	eut. ν_)/Γ	total			Γ_{64}/Γ
$\Gamma(h^{-}(\rho\pi)^{0}\nu_{\tau})/\Gamma(h^{-}h^{-}h^{+}\pi^{0}\nu_{\tau})$ Γ_{53}/Γ_{50}	VALUE (%)	CL%	DOCUMENT ID	TECN	COMMENT	• 04/ •
$\Gamma_{53}/\Gamma_{50} = (\Gamma_{55} + \Gamma_{56} + \Gamma_{57})/\Gamma_{50}$	<0.09	95		94 TPC	Ecm = 29 GeV	
ALUE DOCUMENT ID TECH COMMENT					CIII	•
102 ALBRECHT 91D ARG Ecm = 9.4-10.6 GeV	$\Gamma(K^-K^+\pi^- \ge 0 \text{ ne}$	eut. $\nu_{ au})/\Gamma$	total			Γ ₆₅ /Γ
02 ALBRECHT 91D not independent of their $\Gamma(h^-\rho^+h^-\nu_{ au})/\Gamma(h^-h^-h^+\pi^0\nu_{ au})$,	VALUE (%)	EVTS	DOCUMENT ID	TECN	COMMENT	
$\Gamma(h^-\rho^-h^+\nu_\tau)/\Gamma(h^-h^-h^+\pi^0\nu_\tau), \text{ and } \Gamma(h^-\rho\pi^0\nu_\tau)/\Gamma(h^-h^-h^+\pi^0\nu_\tau)$	$0.15^{+0.09}_{-0.07}\pm0.03$	4 107	⁷ BAUER	94 TPC	Ecm = 29 GeV	
values.	107 We multiply 0.15%	by 0.20 +bor	rolativo sustamati		ad by DALIED 04	
$\Gamma((a_1(1260)h)^-\nu_{\tau})/\Gamma(h^-h^-h^+\pi^0\nu_{\tau})$ Γ_{54}/Γ_{50}	the systematic error	'.	elative systemati	. error quoti	ed by BAULK 94,	to obtain
$\Gamma((a_1(1260)h)^- u_ au)/\Gamma(h^-h^-h^+\pi^0 u_ au)$	F/V-V+\\F					- /-
<0.44 95 103 ALBRECHT 91D ARG E ^{ee} _{CM} = 9.4–10.6 GeV	$\Gamma(K^-K^+\pi^- u_{ au})/\Gamma_{ au}$	t otal EVTS	DOCUMENT IE) TEC		Γ ₆₆ /Γ
03 ALBRECHT 91D not independent of their $\Gamma(h^-\omega\nu_{ au})/\Gamma(h^-h^-h^+\pi^0\nu_{ au}({\rm ex}.{\rm K}^0))$,			DOCUMENT			
			100			
$\Gamma(h^- o \pi^0 \nu) / \Gamma(h^- b^- h^+ \pi^0 \nu) \Gamma(h^- o + h^- \nu) / \Gamma(h^- b^- h^+ \pi^0 \nu)$	$0.22^{+0.17}_{-0.11}\pm0.05$		108 MILLS	85 DLC	CO <i>E</i> ^{ee} _{cm} = 29 Ge	
$\Gamma(h^- \rho \pi^0 \nu_{ au}) / \Gamma(h^- h^- h^+ \pi^0 \nu_{ au}), \Gamma(h^- \rho^+ h^- \nu_{ au}) / \Gamma(h^- h^- h^+ \pi^0 \nu_{ au}).$	108 Error correlated wit	th MILLS 85	$(K\pi\pi\pi^0\nu)$ val	85 DLC	$E_{\text{CM}}^{ee} = 29 \text{ Ge}$ ultiply 0.22% by	0.23, the
$ \begin{split} & \Gamma(h^- \rho \pi^0 \nu_\tau) / \Gamma(h^- h^- h^+ \pi^0 \nu_\tau), \Gamma(h^- \rho^+ h^- \nu_\tau) / \Gamma(h^- h^- h^+ \pi^0 \nu_\tau), \\ & \text{and } \Gamma(h^- \rho^- h^+ \nu_\tau) / \Gamma(h^- h^- h^+ \pi^0 \nu_\tau) \text{ values}. \end{split} $		th MILLS 85	$(K\pi\pi\pi^0\nu)$ val	85 DLC	$E_{\text{CM}}^{ee} = 29 \text{ Ge}$ ultiply 0.22% by	0.23, the
$ \begin{array}{l} \Gamma(h^-\rho\pi^0\nu_{\tau})/\Gamma(h^-h^-h^+\pi^0\nu_{\tau}), \ \Gamma(h^-\rho^+h^-\nu_{\tau})/\Gamma(h^-h^-h^+\pi^0\nu_{\tau}), \\ \text{and} \ \Gamma(h^-\rho^-h^+\nu_{\tau})/\Gamma(h^-h^-h^+\pi^0\nu_{\tau}) \ \text{values}. \end{array} $ $ \begin{array}{l} \Gamma(h^-\rho\pi^0\nu_{\tau})/\Gamma(h^-h^-h^+\pi^0\nu_{\tau}) \end{array} $	¹⁰⁸ Error correlated wit relative systematic e	th MILLS 85	$(K\pi\pi\pi^0\nu)$ val	85 DLC	$E_{\text{CM}}^{ee} = 29 \text{ Ge}$ ultiply 0.22% by	0.23, the error.
$ \begin{array}{c c} \Gamma(h^-\rho\pi^0\nu_{\tau})/\Gamma(h^-h^-h^+\pi^0\nu_{\tau}), \ \Gamma(h^-\rho^+h^-\nu_{\tau})/\Gamma(h^-h^-h^+\pi^0\nu_{\tau}), \\ \text{and} \ \Gamma(h^-\rho^-h^+\nu_{\tau})/\Gamma(h^-h^-h^+\pi^0\nu_{\tau}) \ \text{values}. \\ \hline -(h^-\rho\pi^0\nu_{\tau})/\Gamma(h^-h^-h^+\pi^0\nu_{\tau}) \\ \frac{\Gamma(h^-\rho\pi^0\nu_{\tau})}{EVTS} & \frac{DOCUMENT\ ID}{EVCM} & \frac{TECN}{EVCM} & \frac{COMMENT}{EVCM} \\ \end{array} $	108 Error correlated wit relative systematic e $\Gamma(\phi\pi^- u_ au)/\Gamma_{ ext{total}}$ $_{ ext{VALUE}}$	th MILLS 85	$(K\pi\pi\pi^0\nu)$ val	85 DLC	$E_{\text{CM}}^{ee} = 29 \text{ Ge}$ ultiply 0.22% by	0.23, the
$ \begin{array}{c c} \Gamma(h^-\rho\pi^0\nu_{\tau})/\Gamma(h^-h^-h^+\pi^0\nu_{\tau}), \ \Gamma(h^-\rho^+h^-\nu_{\tau})/\Gamma(h^-h^-h^+\pi^0\nu_{\tau}), \\ \text{and} \ \Gamma(h^-\rho^-h^+\nu_{\tau})/\Gamma(h^-h^-h^+\pi^0\nu_{\tau}) \ \text{values}. \\ \hline \Gamma(h^-\rho\pi^0\nu_{\tau})/\Gamma(h^-h^-h^+\pi^0\nu_{\tau}) & \Gamma_{55}/\Gamma_{50} \\ \hline \Gamma(h^-\rho\pi^0\nu_{\tau})/\Gamma(h^-h^-h^-h^+\pi^0\nu_{\tau}) & \Gamma_{55}/\Gamma_{50} \\ \hline \Gamma(h^-\rho\pi^0\nu_{\tau})/\Gamma(h^-h^-h^-h^-h^-h^-h^-h^-h^-h^-h^-h^-h^-h$	108 Error correlated wit relative systematic e $\Gamma(\phi\pi^- u_ au)/\Gamma_{ ext{total}}$	th MILLS 85 error quoted I	$(K\pi\pi\pi^0 u)$ val by MILLS 85, to	85 DLC ue. We mi obtain obta	$E_{\rm cm}^{ee} = 29 \; {\rm Ge}$ ultiply 0.22% by alin the systematic	0.23, the error. Γ₆₇/Γ
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	108 Error correlated wit relative systematic e $\Gamma(\phi\pi^{-}\nu_{\tau})/\Gamma_{\text{total}}$ $\frac{VALUE}{<3.5\times10^{-4}}$	th MILLS 85 error quoted I <u>CL%</u> 90	$(K\pi\pi\pi^0 u)$ val by MILLS 85, to $\frac{DOCUMENT\ ID}{ALBRECHT}$	85 DLC ue. We mi obtain obta	CO $E_{\rm cm}^{ee}=$ 29 Ge ultiply 0.22% by ain the systematic $\underline{COMMENT}$	0.23, the error. \(\begin{align*} \Gamma_{67} / \Gamma \\
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	108 Error correlated wit relative systematic expression of $\Gamma(\phi\pi^-\nu_{\tau})/\Gamma_{\text{total}}$ $\frac{VALUE}{<3.5\times10^{-4}}$ $\Gamma(K^-K^+K^-\geq0$ ne	th MILLS 85 error quoted I $=\frac{CL\%}{90}$ eut. $\nu_{ au})/\Gamma$	$(K\pi\pi\pi^0 u)$ val by MILLS 85, to <u>DOCUMENT ID</u> ALBRECHT total	85 DLC ue. We mi obtain obta	$E_{\rm CM}^{ee} = 29$ Ge ultiply 0.22% by in the systematic $E_{\rm CM}^{ee} = 9.4-10.6$	0.23, the error. Γ₆₇/Γ
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	108 Error correlated with relative systematic estables $\Gamma(\phi\pi^-\nu_{\tau})/\Gamma_{\text{total}}$ $\frac{VALUE}{<3.5\times10^{-4}}$ $\Gamma(K^-K^+K^-\geq0.00)$ $VALUE$ (%)	th MILLS 85 error quoted I	$(K\pi\pi\pi^0 u)$ val by MILLS 85, to <u>DOCUMENT ID</u> ALBRECHT - total <u>DOCUMENT ID</u>	85 DLC ue. We mi obtain obta <u>TECN</u> 95H ARG	$E_{\rm CM}^{ee} = 29 {\rm Ge}$ ultiply 0.22% by sin the systematic $E_{\rm CM}^{ee} = 9.4 - 10.6$	0.23, the error. \begin{align*} \Gamma_{67} / \Gamma & \Boxematilde{\Gamma} & \Boxematil
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	108 Error correlated wit relative systematic expression of $\Gamma(\phi\pi^-\nu_{\tau})/\Gamma_{\text{total}}$ $\frac{VALUE}{<3.5\times10^{-4}}$ $\Gamma(K^-K^+K^-\geq0$ ne	th MILLS 85 error quoted I $=\frac{CL\%}{90}$ eut. $\nu_{ au})/\Gamma$	$(K\pi\pi\pi^0 u)$ val by MILLS 85, to <u>DOCUMENT ID</u> ALBRECHT - total <u>DOCUMENT ID</u>	85 DLC ue. We mi obtain obta	$E_{\rm CM}^{ee} = 29$ Ge ultiply 0.22% by in the systematic $E_{\rm CM}^{ee} = 9.4-10.6$	0.23, the error. \begin{align*} \Gamma_{67} / \Gamma & \Boxematilde{\Gamma} & \Boxematil
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	108 Error correlated wit relative systematic of $\Gamma(\phi\pi^-\nu_{\tau})/\Gamma_{\text{total}}$ $\frac{VALUE}{<3.5\times10^{-4}}$ $\Gamma(K^-K^+K^-\geq 0 \text{ no})$ $\frac{VALUE(\%)}{<0.21}$	th MILLS 85 error quoted I $= \frac{CL\%}{90}$ $= \frac{CL\%}{25}$ $= \frac{CL\%}{95}$	$(K\pi\pi\pi^0\nu)$ val by MILLS 85, to <u>DOCUMENT ID</u> ALBRECHT 	85 DLC ue. We mi obtain obta <u>TECN</u> 95H ARG	$E_{\rm CM}^{ee} = 29 {\rm Ge}$ ultiply 0.22% by sin the systematic $E_{\rm CM}^{ee} = 9.4 - 10.6$	0.23, the error. \(\begin{align*} \Gamma_{67} / \Gamma & \\ \Gamma_{68} / \Gamma_{
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$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	108 Error correlated with relative systematic efficiency $\Gamma(\phi\pi^-\nu_{\tau})/\Gamma_{\rm total}$ and $\Gamma(\kappa^-\kappa^+\kappa^- \ge 0 \text{ not})$ and $\Gamma(\kappa^-\kappa^-\kappa^+\kappa^- \ge 0 \text{ not})$ and $\Gamma(\kappa^-\kappa^-\kappa^- \ge 0 \text{ not})$ and $\Gamma(\kappa^-\kappa^-\kappa^-\kappa^- \ge 0 \text{ not})$ and $\Gamma(\kappa^-\kappa^-\kappa^-\kappa^-\kappa^-\kappa^-\kappa^-\kappa^-\kappa^-\kappa^-\kappa^-\kappa^-\kappa^-\kappa$	th MILLS 85 error quoted $-\frac{CL\%}{90}$ eut. ν_{τ})/ Γ_{t} $-\frac{CL\%}{95}$ eut. ν_{τ})/ Γ_{t} $-\frac{CL\%}{95}$ fotal $-\frac{CL\%}{90}$ eut. ν_{τ})/ Γ_{t} $-\frac{CL\%}{95}$ $-\frac{CL\%}{90}$ eut. ν_{τ} /(ex. 74)/ Γ $-\frac{EVTS}{8}$ error quoted	$(K\pi\pi\pi^0\nu)$ value by MILLS 85, to DOCUMENT ID ALBRECHT Total DOCUMENT ID BAUER DOCUMENT ID BAUER DOCUMENT ID ALAM DOCUMENT ID ALAM $K_S^0 \to \pi^-\pi^+$ DOCUMENT ID GIBAUT ACTON DECAMP	85 DLC ue. We miobtain obtain	CO $E_{\rm cm}^{ee} = 29~{\rm Ge}$ ultiply 0.22% by in the systematic $\frac{{\rm COMMENT}}{{\rm E_{\rm cm}^{ee}}} = 9.4{\rm -}10.6$ $\frac{{\rm COMMENT}}{{\rm E_{\rm cm}^{ee}}} = 29~{\rm GeV}$ $\frac{{\rm COMMENT}}{{\rm E_{\rm cm}^{ee}}} = 29~{\rm GeV}$ $\frac{{\rm COMMENT}}{{\rm E_{\rm cm}^{ee}}} = 29~{\rm GeV}$ $\frac{{\rm COMMENT}}{{\rm E_{\rm cm}^{ee}}} = 10.6~{\rm GeV}$ $\frac{{\rm COMMENT}}{{\rm E_{\rm cm}^{ee}}} = 10.6~{\rm GeV}$ $\frac{{\rm COMMENT}}{{\rm COMMENT}}$ $\frac{{\rm COMMENT}}{{\rm E_{\rm cm}^{ee}}} = 10.6~{\rm GeV}$ $\frac{{\rm COMMENT}}{{\rm COMMENT}}$ $\frac{{\rm COMMENT}}{{\rm E_{\rm cm}^{ee}}} = 10.6~{\rm GeV}$ $\frac{{\rm COMMENT}}{{\rm COMMENT}}$ $\frac{{\rm COMMENT}}{{\rm E_{\rm cm}^{ee}}} = 10.6~{\rm GeV}$	0.23, the error. F67/F GeV
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	108 Error correlated with relative systematic efficiency of the systemati	th MILLS 85 error quoted I $ \frac{cL\%}{90} $ eut. ν_{τ})/ Γ_{t} $ \frac{cL\%}{95} $ eut. ν_{τ})/ Γ_{t} $ \frac{cL\%}{95} $ total $ \frac{EVTS}{90} $ trais ν_{τ} (ex. 74)/ Γ	$(K\pi\pi\pi^0\nu)$ val by MILLS 85, to DOCUMENT ID ALBRECHT total DOCUMENT ID BAUER otal DOCUMENT ID BAUER DOCUMENT ID ALAM DOCUMENT ID ALAM $K_S^0 \to \pi^-\pi^+$ DOCUMENT ID ALAM DOCUMENT ID ALAM ALAM DOCUMENT ID ALAM DOCUMENT ID ALAM	85 DLC ue. We minobtain obtain obtai	CO $E_{\rm cm}^{ee} = 29~{\rm Ge}$ ultiply 0.22% by the he systematic $\frac{COMMENT}{E_{\rm cm}^{ee}} = 9.4-10.6$ $\frac{COMMENT}{E_{\rm cm}^{ee}} = 29~{\rm GeV}$ $\frac{COMMENT}{E_{\rm cm}^{ee}} = 29~{\rm GeV}$ $\frac{COMMENT}{E_{\rm cm}^{ee}} = 10.6~{\rm GeV}$	0.23, the error. F67/F GeV
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	108 Error correlated with relative systematic efficiency $\Gamma(\phi\pi^-\nu_{\tau})/\Gamma_{\rm total}$ and $\Gamma(\kappa^-\kappa^+\kappa^- \ge 0 \text{ not})$ and $\Gamma(\kappa^-\kappa^-\kappa^+\kappa^- \ge 0 \text{ not})$ and $\Gamma(\kappa^-\kappa^-\kappa^- \ge 0 \text{ not})$ and $\Gamma(\kappa^-\kappa^-\kappa^-\kappa^- \ge 0 \text{ not})$ and $\Gamma(\kappa^-\kappa^-\kappa^-\kappa^-\kappa^-\kappa^-\kappa^-\kappa^-\kappa^-\kappa^-\kappa^-\kappa^-\kappa^-\kappa$	th MILLS 85 error quoted I $ \frac{cL\%}{90} $ eut. ν_{τ})/ Γ_{t} $ \frac{cL\%}{95} $ eut. ν_{τ})/ Γ_{t} $ \frac{cL\%}{95} $ total $ \frac{EVTS}{90} $ trais ν_{τ} (ex. 74)/ Γ	$(K\pi\pi\pi^0\nu)$ val by MILLS 85, to DOCUMENT ID ALBRECHT total DOCUMENT ID BAUER otal DOCUMENT ID BAUER DOCUMENT ID ALAM DOCUMENT ID ALAM $K_S^0 \to \pi^-\pi^+$ DOCUMENT ID ALAM DOCUMENT ID ALAM ALAM DOCUMENT ID ALAM DOCUMENT ID ALAM	85 DLC ue. We minobtain obtain obtai	CO $E_{\rm cm}^{ee} = 29~{\rm Ge}$ ultiply 0.22% by in the systematic $\frac{{\rm COMMENT}}{{\rm E_{\rm cm}^{ee}}} = 9.4{\rm -}10.6$ $\frac{{\rm COMMENT}}{{\rm E_{\rm cm}^{ee}}} = 29~{\rm GeV}$ $\frac{{\rm COMMENT}}{{\rm E_{\rm cm}^{ee}}} = 29~{\rm GeV}$ $\frac{{\rm COMMENT}}{{\rm E_{\rm cm}^{ee}}} = 29~{\rm GeV}$ $\frac{{\rm COMMENT}}{{\rm E_{\rm cm}^{ee}}} = 10.6~{\rm GeV}$ $\frac{{\rm COMMENT}}{{\rm E_{\rm cm}^{ee}}} = 10.6~{\rm GeV}$ $\frac{{\rm COMMENT}}{{\rm COMMENT}}$ $\frac{{\rm COMMENT}}{{\rm E_{\rm cm}^{ee}}} = 10.6~{\rm GeV}$ $\frac{{\rm COMMENT}}{{\rm COMMENT}}$ $\frac{{\rm COMMENT}}{{\rm E_{\rm cm}^{ee}}} = 10.6~{\rm GeV}$ $\frac{{\rm COMMENT}}{{\rm COMMENT}}$ $\frac{{\rm COMMENT}}{{\rm E_{\rm cm}^{ee}}} = 10.6~{\rm GeV}$	0.23, the error. F67/F GeV

 τ

• • We do not use the following data for averages, fits, limits, etc. • • •	
	$\Gamma(K^*(892)^-\nu_{\tau})/\Gamma_{\text{total}}$ $\Gamma_{80}/\Gamma_{\text{total}}$
6 $\pm 0.13 \pm 0.04$ BEHREND 898 CELL $E_{\text{cm}}^{\text{ee}} = 14$ –47 GeV	VALUE (%) EVTS DOCUMENT ID TECN COMMENT 1.28±0.08 OUR AVERAGE
± 0.1 ± 0.2 BARTEL 85F JADE $E_{\text{cm}}^{\text{ee}} = 34.6 \text{ GeV}$	1.39±0.09±0.10
3 ±0.04 10 BELTRAMI 85 HRS Repl. by BYLSMA 87 ±0.4 10 BEHREND 82 CELL Repl. by BEHREND 898	1.11 \pm 0.12 115 COAN 96 CLEO $E_{\rm cm}^{\rm ee} \approx 10.6 {\rm GeV}$
±0.4 10 BEHREND 82 CELL Repl. by BEHREND 89B	1.42±0.22±0.09
$(h^-h^-h^+ \geq 1 \text{ neutrals } \nu_{\tau}) + \Gamma(3h^-2h^+ \geq 0 \text{ neutrals } \nu_{\tau})$	1.23±0.21 ^{+0.11} _{-0.21} 54 ¹¹⁷ ALBRECHT 88L ARG E ^{ee} _{Cm} = 10 GeV
	448
$(\Gamma_{48} + \Gamma_{72})/\Gamma = (0.3431\Gamma_{34} + 0.3431\Gamma_{35} + 0.4507\Gamma_{37} + 0.1177\Gamma_{37} + \Gamma_{52} + \Gamma_{60} + \Gamma_{61} + 0.4507\Gamma_{37} + 0.1177\Gamma_{37} + \Gamma_{52} + \Gamma_{60} + \Gamma_{61} + 0.4507\Gamma_{37} + 0.1177\Gamma_{37} + 0.117\Gamma_{37} + 0.11$	
$(748+727)^{-1} = (0.5451734+0.5451735+0.4501737+0.1177737+152+760+761+0.774+0.29\Gamma_{90}+0.888\Gamma_{97}+0.9101\Gamma_{98})/\Gamma$	CIII
UE (%) EVTS DOCUMENT ID TECN COMMENT	1.3 ± 0.3 ± 0.3 31 YELTON 86 MRK2 $E_{CM}^{ee} = 29 \text{ GeV}$
1±0.11 OUR FIT Error includes scale factor of 1.2.	• • • We do not use the following data for averages, fits, limits, etc. • • •
±0.5 OUR AVERAGE	1.45±0.13±0.11 273 ¹²⁰ BUSKULIC 94F ALEP Repl. by BUSKULIC
5±0.29±0.65 570 DECAMP 92C ALEP 1989–1990 LEP runs	1.7 ± 0.7 11 DORFAN 81 MRK2 $E_{cm}^{ee} = 4.2-6.7 \text{ GeV}$
$\pm 0.7 \pm 0.2$ 352 ¹⁰⁹ BEHREND 90 CELL $E_{\rm cm}^{ee} = 35 \; {\rm GeV}$	114 Not independent of BUSKULIC 96 B $(\pi^-\overline{K}^0 u_{ au})$ and B $(K^-\pi^0 u_{ au})$ measurements.
BEHREND 90 not independent of their $\Gamma(h^-h^-h^+ \geq 1~{\rm neutrals}\nu_{\tau})/\Gamma_{\rm total}$ measurement.	¹¹⁵ Not independent of COAN 96 B($\pi^-\overline{K}^0\nu_{ au}$) and BATTLE 94 B($K^-\pi^0\nu_{ au}$) measu ments. $K\pi$ final states are consistent with and assumed to originate from K^* (892
	production.
$3h^-2h^+\nu_{\tau}(ex.K^0))/\Gamma_{total}$ Γ_{73}/Γ	116 This result is obtained from their B $(\pi^-\overline{K}^0 u_ au)$ assuming all those decays originate
UE (%) EVTS DOCUMENT ID TECN COMMENT	K*(892) decays.
175±0.007 OUR FIT 173±0.008 OUR AVERAGE	¹¹⁷ The authors divide by $\Gamma_1/\Gamma=0.865$ to obtain this result.
80±0.011±0.013 58 BUSKULIC 96 ALEP LEP 1991–1993 data	118 Not independent of TSCHIRHART 88 $\Gamma(au^- o h^- \overline{K}{}^0 \ge 0$ neutrals
$177 \pm 0.005 \pm 0.009$ 295 GIBAUT 948 CLEO $E_{cm}^{ee} = 10.6$ GeV	$0K_L^0 u_{ au})/\Gamma(ext{total}).$
$64\pm0.023\pm0.01$ 12 ALBRECHT 88B ARG $E_{ extst{cm}}^{ ext{ee}}=$ 10 GeV	¹¹⁹ Decay π^- identified in this experiment, is assumed in the others.
51 ± 0.020 7 BYLSMA 87 HRS $E_{ ext{cm}}^{ ext{ee}}=$ 29 GeV	120 BUSKULIC 94F obtain this result from BUSKULIC 94F B $(\overline{\kappa}^0\pi^- u_{ au})$ and BUSKULIC 9
■ • We do not use the following data for averages, fits, limits, etc. • • •	$B(K^-\pi^0 u_{ au})$ assuming all of those decays originate in $K^*(892)^-$ decays.
167±0.030 5 110 BELTRAMI 85 HRS Repl. by BYLSMA 87	$\Gamma(K^*(892)^-\nu_{\tau})/\Gamma(\pi^-\pi^0\nu_{\tau})$ Γ_{80}/Γ
The error quoted is statistical only.	VALUE DOCUMENT ID TECH COMMENT
	0.075±0.027 121 ABREU 94K DLPH LEP 1992 Z data
$3h^-2h^+\pi^0 u_{ au}(ext{ex}.K^0))/\Gamma_{ ext{total}}$ Γ_{74}/Γ	121 ABREU 94к quote B $(au^- o K^*(892)^- u_ au)$ B $(K^*(892)^- o K^-\pi^0)$ /B $(au^- o ho^- u_ au)$
UE (%) EVTS DOCUMENT ID TECN COMMENT	$= 0.025 \pm 0.009$. We divide by B($K^*(892)^- \rightarrow K^- \pi^0$) = 0.333 to obtain this resi
22±0.005 OUR FIT 21±0.005 OUR AVERAGE	
18 ± 0.007 ± 0.012 18 BUSKULIC 96 ALEP LEP 1991–1993 data	$\Gamma(K^*(892)^0 K^- \ge 0 \text{ neutrals } \nu_{\tau})/\Gamma_{\text{total}}$ Γ_{81}
$19\pm0.004\pm0.004$ 31 GIBAUT 94B CLEO $E_{\text{Cm}}^{ee}=10.6 \text{ GeV}$	VALUE (%) EVTS DOCUMENT ID TECN COMMENT
61 ± 0.022 6 BYLSMA 87 HRS $E_{\rm CM}^{\rm ee}=29~{\rm GeV}$	0.32±0.08±0.12 119 GOLDBERG 90 CLEO $E_{\text{Cm}}^{ee} = 9.4-10.9 \text{ GeV}$
We do not use the following data for averages, fits, limits, etc.	$\Gamma(K^*(892)^0 K^- \nu_{\tau})/\Gamma_{\text{total}}$
$_{067\pm0.030}$ 5 $_{111}^{111}$ BELTRAMI 85 HRS Repl. by BYLSMA 87	
¹ The error quoted is statistical only.	VALUE (%) EVTS DOCUMENT ID TECN COMMENT
•	0.20 \pm 0.05 \pm 0.04 47 ALBRECHT 95H ARG $E_{\text{cm}}^{ee} = 9.4 - 10.6 \text{ GeV}$
$3h^-2h^+2\pi^0 u_ au)/\Gamma_{ ext{total}}$ Γ_{75}/Γ	$\Gamma(\overline{K}^*(892)^0\pi^- \ge 0 \text{ neutrals } \nu_{\tau})/\Gamma_{\text{total}}$ Γ_{83}
LUE (%) CL% DOCUMENT ID TECN COMMENT	
0.011 90 GIBAUT 94B CLEO $E_{ m cm}^{\it ee} = 10.6 \; { m GeV}$	0.38±0.11±0.13 105 GOLDBERG 90 CLEO E_{cm}^{ee} = 9.4-10.9 GeV
·- > > - ·-	CIII
$(5\pi)^- \nu_{\tau})/\Gamma_{\text{total}}$ Γ_{76}/Γ	$\Gamma(\overline{K}^*(892)^0\pi^-\nu_{\tau})/\Gamma_{total}$
$\Gamma_{76}/\Gamma = (\Gamma_{26} + \frac{1}{4}\Gamma_{37} + \Gamma_{60} + \Gamma_{73})/\Gamma$	VALUE (%) EVTS DOCUMENT ID TECN COMMENT
Data marked "avg" are highly correlated with data appearing elsewhere in the Listings,	0.25 \pm 0.10 \pm 0.05 27 ALBRECHT 95H ARG $E_{\text{cm}}^{ee} = 9.4 - 10.6 \text{ GeV}$
and are therefore used for the average given below but not in the overall fits. "f&a"	
	$\Gamma(K_1(1270)^-\nu_{\tau})/\Gamma_{\text{total}}$ Γ_{85}
marks results used for the fit and the average.	
LUE (%) DOCUMENT ID TECN COMMENT	VALUE (%)EVTS DOCUMENT ID TECN COMMENT
LUE (%) DOCUMENT ID TECN COMMENT 33±0.07 OUR FIT	
LUE (%) DOCUMENT ID TECN COMMENT 13±0.07 OUR FIT 11±0.06±0.08 avg 112 GIBAUT 948 CLEO E cm = 10.6 GeV	0.41 $^{+0.41}_{-0.35}$ $^{\pm}$ 0.10 5 122 BAUER 94 TPC E^{ee}_{CM} = 29 GeV
$\frac{\text{LUE}(\%)}{\text{3$\pm0.07 OUR FIT}} \frac{\text{DOCUMENT ID}}{\text{1±0.06\pm0.08}} \frac{\text{TECN}}{\text{avg}} \frac{\text{COMMENT}}{\text{BIBAUT}} \frac{\text{TECN}}{\text{94B CLEO}} \frac{\text{COMMENT}}{\text{Cm}} = 10.6 \text{ GeV}$ $^2 \text{Not independent of GIBAUT 94B B} (3h^- 2h^+ \nu_{\tau}), \text{ PROCARIO 93 B} (h^- 4\pi^0 \nu_{\tau}), \text{ and } \frac{\text{Comment ID}}{\text{Cm}} = 10.6 \text{ GeV}$	0.41 $^{+0.41}_{-0.35}$ \pm 0.10 5 122 BAUER 94 TPC $E^{ee}_{\rm CM}$ = 29 GeV 122 We multiply 0.41% by 0.25, the relative systematic error quoted by BAUER 94, to obt.
$\frac{UE\left(\%\right)}{3\pm0.07\text{OUR}\text{FIT}} \frac{DOCUMENTID}{4B\text{B(3}h^{-}2h^{+}\nu_{\tau})}, \text{PROCARIO 93 B}(h^{-}4\pi^{0}\nu_{\tau}), \text{and BORTOLETTO 93 B}(2h^{-}h^{+}2\pi^{0}\nu_{\tau})/B("3prong") \text{measurements. Result is corrected}$	0.41 $^{+0.41}_{-0.35}\pm$ 0.10 5 122 BAUER 94 TPC $E^{ee}_{\rm CM}=$ 29 GeV 122 We multiply 0.41% by 0.25, the relative systematic error quoted by BAUER 94, to obt the systematic error.
$\frac{DCUMENT ID}{3\pm 0.07 \text{ QUR}} \frac{DOCUMENT ID}{12.06\pm 0.08} \frac{TECN}{\text{avg}} \frac{COMMENT}{12.06\pm 0.08} \frac{112 \text{ GIBAUT}}{\text{gIBAUT}} \frac{948 \text{ CLEO}}{948 \text{ CLEO}} \frac{E_{\text{CM}}^{\text{eq}}}{E_{\text{CM}}^{\text{eq}}} = 10.6 \text{ GeV}$ $\frac{1}{2} \text{ Not independent of GIBAUT} \frac{948 \text{ B}(3h^-2h^+\nu_{\tau})}{948 \text{ PROCARIO}}, \text{ PROCARIO} \frac{93 \text{ B}(h^-4\pi^0\nu_{\tau})}{948 \text{ GIBAUT}}, \text{ and BORTOLETTO} \frac{93 \text{ B}(2h^-h^+2\pi^0\nu_{\tau})}{948 \text{ GIBAUT}}, \text{ Brong") measurements. Result is corrected for η contributions.}$	0.41 $^{+0.41}_{-0.35}\pm0.10$ 5 122 BAUER 94 TPC $E^{ee}_{CM}=$ 29 GeV 122 We multiply 0.41% by 0.25, the relative systematic error quoted by BAUER 94, to obt the systematic error. $\Gamma(K_1(1400)^{-}\nu_T)/\Gamma_{total}$
$\frac{UE(\%)}{3\pm0.07\text{OUR FIT}} \frac{DOCUMENTID}{1\pm0.06\pm0.08} \frac{TECN}{\text{avg}} \frac{COMMENT}{112\text{GIBAUT}} \frac{TECN}{948\text{CLEO}} \frac{COMMENT}{E_c^m} = 10.6\text{GeV}$ $^2\text{Not independent of GIBAUT 948 B}(3h^-2h^+\nu_{\tau}), \text{PROCARIO 93 B}(h^-4\pi^0\nu_{\tau}), \text{ and BORTOLETTO 93 B}(2h^-h^+2\pi^0\nu_{\tau})/B("3\text{prong"}) \text{ measurements. Result is corrected for η contributions.}$ $4h^-3h^+ \ge 0 \text{ neutrals } \nu_{\tau} ("7\text{-prong"}))/\Gamma_{\text{total}} \qquad \Gamma_{77}/\Gamma$	0.41 $^{+0.41}_{-0.35}\pm0.10$ 5 122 BAUER 94 TPC $E^{ee}_{\text{CM}}=$ 29 GeV 122 We multiply 0.41% by 0.25, the relative systematic error quoted by BAUER 94, to obtthe systematic error. $\Gamma(K_1(1400)^-\nu_{\tau})/\Gamma_{\text{total}}$ VALUE (%) EVTS DOCUMENT ID TECN COMMENT
$\frac{\text{LUE}(\%)}{3\pm0.07\text{OUR}\text{FIT}} \frac{\text{DOCUMENT ID}}{\text{1$\pm0.06}\pm0.08} \frac{\text{TECN}}{\text{avg}} \frac{\text{COMMENT}}{\text{112}\text{GIBAUT}} \frac{\text{7$\pm0.06}}{\text{94B}\text{CLEO}} \frac{\text{See}}{\text{Cm}} = 10.6\text{GeV}}{\text{10.6}\text{GeV}}$ Not independent of GIBAUT 94B $\text{B}(3h^-2h^+\nu_\tau)$, PROCARIO 93 $\text{B}(h^-4\pi^0\nu_\tau)$, and BORTOLETTO 93 $\text{B}(2h^-h^+2\pi^0\nu_\tau)/\text{B}("3\text{prong"})$ measurements. Result is corrected for η contributions. $\frac{4h^-3h^+}{\text{20}\text{Cument}} \frac{\text{Comment}}{\text{CL}\%} \frac{\text{Comment}}{\text{DOCUMENT}} \frac{\text{TECN}}{\text{COMMENT}} \frac{\text{COMMENT}}{\text{COMMENT}}$	0.41 $^{+0.41}_{-0.35}\pm0.10$ 5 122 BAUER 94 TPC $E^{ee}_{\text{CM}}=$ 29 GeV 122 We multiply 0.41% by 0.25, the relative systematic error quoted by BAUER 94, to obtthe systematic error. $\Gamma(K_1(1400)^-\nu_{\tau})/\Gamma_{\text{total}}$ VALUE (%) EVTS DOCUMENT ID TECN COMMENT
$\frac{DOCUMENT ID}{13\pm0.07 \text{ OUR FIT}} \frac{DOCUMENT ID}{10\pm0.06\pm0.08} \frac{TECN}{\text{avg}} \frac{COMMENT}{112} \frac{COMMENT}{$	0.41 $^{+0.41}_{-0.35}\pm0.10$ 5 122 BAUER 94 TPC $E^{ee}_{cm}=29$ GeV 122 We multiply 0.41% by 0.25, the relative systematic error quoted by BAUER 94, to obtain the systematic error. $\Gamma(K_1(1400)^{-}\nu_T)/\Gamma_{total}$ $VALUE(\%)$ $EVTS$ $DOCUMENT ID$ $TECN$ $COMMENT$ $VALUE(\%)$ $EVTS$ $DOCUMENT ID$ $TECN$ $COMMENT$ $VALUE(\%)$ $VALUE(\%$
$\frac{LUE(\%)}{13\pm0.07 \text{ OUR FIT}} \frac{DOCUMENT ID}{11\pm0.06\pm0.08} \frac{TECN}{\text{avg}} \frac{COMMENT}{112} \frac{COMMENT}{1120 \text{ GIBAUT}} \frac{TECN}{948} \frac{COMMENT}{1120 \text{ GIBAUT}} \frac{TECN}{948} \frac{COMMENT}{1120 \text{ GIBAUT}} \frac{TECN}{948} \frac{COMMENT}{1120 \text{ GIBAUT}} \frac{TECN}{948} \frac{COMMENT}{1120 \text{ GIBAUT}} \frac{TTCN}{948} TTC$	0.41 $^{+0.41}_{-0.35}\pm0.10$ 5 122 BAUER 94 TPC $E^{ee}_{\text{CM}}=$ 29 GeV 122 We multiply 0.41% by 0.25, the relative systematic error quoted by BAUER 94, to obtthe systematic error. $\Gamma(K_1(1400)^-\nu_{\tau})/\Gamma_{\text{total}}$ VALUE (%) EVTS DOCUMENT ID TECN COMMENT
$\frac{\text{LUE}(\%)}{\text{13\pm0.07 OUR FIT}} \qquad \frac{\text{DOCUMENT ID}}{\text{112 GIBAUT}} \qquad \frac{\text{TECN}}{\text{948 CLEO}} \qquad \frac{\text{COMMENT}}{\text{Em}} = 10.6 \text{GeV}$ $\frac{1}{\text{11\pm0.06\pm0.08}} \qquad \text{avg} \qquad \frac{1}{\text{112 GIBAUT}} \qquad 948 \text{CLEO} \qquad \frac{\text{Fem}}{\text{Em}} = 10.6 \text{GeV}$ $\frac{2}{\text{Not independent of GIBAUT}} \qquad 948 \text{GLEO} \qquad \frac{\text{Fem}}{\text{Em}} = 10.6 \text{GeV}}{\text{10.06 GeV}} \qquad \frac{2}{\text{Not independent of GIBAUT}} \qquad 948 \text{GLEO} \qquad \frac{\text{Fem}}{\text{Em}} = 10.6 \text{GeV}}{\text{10.06 GeV}} \qquad \frac{2}{\text{Not independent of GIBAUT}} \qquad \frac{2}{Not indepe$	0.41 $^{+0.41}_{-0.35}\pm0.10$ 5 122 BAUER 94 TPC $E^{ee}_{cm}=29$ GeV 122 We multiply 0.41% by 0.25, the relative systematic error quoted by BAUER 94, to obtout the systematic error. $\Gamma(K_1(1400)^{-}\nu_{\tau})/\Gamma_{total} \qquad \qquad \Gamma_{86}, \qquad $
$\frac{ DE(\%) }{3\pm0.07 \text{ OUR FIT}} \qquad \frac{DOCUMENT ID}{3\pm0.07 \text{ OUR FIT}} \qquad \frac{TECN}{2} \qquad \frac{COMMENT}{2} = \frac{COMMENT}{2} = \frac{112 \text{ GIBAUT}}{2} = \frac{112 \text{ GIBAUT}}{2}$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$
$\frac{UE(\%)}{3\pm0.07\text{OUR}\text{FIT}} = \frac{DOCUMENTID}{12\text{GIBAUT}} = \frac{TECN}{406\pm0.08} = \frac{COMMENT}{12\text{GIBAUT}} = \frac{TECN}{406\pm0.08} = \frac{COMMENT}{12\text{GIBAUT}} = \frac{TECN}{406\pm0.08} = \frac{COMMENT}{12\text{GIBAUT}} = \frac{TECN}{406\pm0.08} = \frac{COMMENT}{406\pm0.08} = \frac{TECN}{406\pm0.08} = \frac{TECN}{406\pm0.08$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
	$\begin{array}{cccccccccccccccccccccccccccccccccccc$
$\frac{UE(\%)}{3\pm 0.07}$ OUR FIT LE 0.06±0.08 avg 112 GIBAUT 94B CLEO $E_{\rm cm}^{\rm ee}$ = 10.6 GeV Not independent of GIBAUT 94B B(3h ⁻ 2h ⁺ ν _τ), PROCARIO 93 B(h ⁻ 4π ⁰ ν _τ), and BORTOLETTO 93 B(2h ⁻ h ⁺ 2π ⁰ ν _τ)/β("3prong") measurements. Result is corrected for η contributions. 4h ⁻ 3h ⁺ ≥ 0 neutrals ν_{τ} ("7-prong"))/ $\Gamma_{\rm total}$ F77/ Γ UE (%) CL% DOCUMENT ID TECN COMMENT 1D EC (%) BYLSMA 87 HRS $E_{\rm cm}^{\rm ee}$ = 29 GeV K*(892) ⁻ ≥ 0 (h ⁰ ≠ K ⁰ ₅)ν _τ)/ $\Gamma_{\rm total}$ F78/ Γ UE (%) $EVTS$ DOCUMENT ID TECN COMMENT 1D TECN TECN COMMENT 1D TECN TECN TECN TECN TECN TECN TECN TECN	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
UE (%) 3±0.07 OUR FIT 1±0.06±0.08 avg 112 GIBAUT 94B CLEO $E_{\rm cm}^{ee}$ = 10.6 GeV Not independent of GIBAUT 94B B(3h ⁻ 2h ⁺ ν _τ), PROCARIO 93 B(h ⁻ 4π ⁰ ν _τ), and BORTOLETTO 93 B(2h ⁻ h ⁺ 2π ⁰ ν _τ)/B("3prong") measurements. Result is corrected for η contributions. 4h ⁻ 3h ⁺ ≥ 0 neutrals ν _τ ("7-prong"))/Γ _{total} UE (%) CL% DOCUMENT ID FECN COMMENT F77/Γ UE (%) EVTS DOCUMENT ID TECN COMMENT F78/Γ VE (%) EVTS DOCUMENT ID TECN COMMENT F78/Γ VE (%) EVTS DOCUMENT ID TECN COMMENT F79/Γ TECN COMMENT F79/Γ TECN COMMENT F79/Γ TECN COMMENT F79/Γ	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
$ \frac{UE(\%)}{3\pm 0.07} \frac{DOCUMENT ID}{120 GIBAUT} \frac{TECN}{948} \frac{COMMENT}{120 GIBAUT} \frac{TECN}{948} \frac{COMMENT}{120 GIBAUT} \frac{TECN}{948} \frac{COMMENT}{948} \frac{TECN}{93} \frac{COMMENT}{948} \frac{TECN}{93} \frac{COMMENT}{948} \frac{TECN}{93} \frac{COMMENT}{948} \frac{TECN}{93} \frac{COMMENT}{948} \frac{TECN}{93} \frac{COMMENT}{948} \frac{TECN}{949} \frac{COMMENT}{948} \frac{TECN}{949} \frac{TECN}{949} \frac{COMMENT}{948} \frac{TECN}{949} \frac{TECN}{9$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
$ \frac{(1.05)(\%)}{(3\pm0.07 \text{OUR FIT})} = \frac{DOCUMENT ID}{112 \text{GIBAUT}} = \frac{TECN}{4\pm0.05\pm0.08} \frac{COMMENT}{120 \text{GIBAUT}} = \frac{TECN}{120 \text{GIBBUT}} = \frac{TECN}{120 $	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
$ \frac{(1.05)(\%)}{(3\pm0.07 \text{OUR FIT})} = \frac{DOCUMENT ID}{112 \text{GIBAUT}} = \frac{TECN}{4\pm0.05\pm0.08} \frac{COMMENT}{120 \text{GIBAUT}} = \frac{TECN}{120 \text{GIBBUT}} = \frac{TECN}{120 $	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$

$\Gamma(a_0(980)^- \ge 0 \text{ ne}$	eutrals $ u_{ au}$	$/\Gamma_{\text{total}} \times B(a_0(980) \rightarrow F$	< ⁰ K−) Г ₈₈ /I	Γ×Β	$[\Gamma(h^-\rho\pi^0\nu_{\tau})+\Gamma($	h-ρ+h-	$\nu_{\tau}) + \Gamma(h^- \rho^-$	$h^+ \nu_{\tau}) + \Gamma$	$(h^-\omega \nu_{\tau})$	/
VALUE <2.8 × 10 ⁻⁴	<u>CL%</u> 90	DOCUMENT ID TECN GOLDBERG 90 CLEC	COMMENT	-V	$\Gamma(h^-h^-h^+\pi^0\nu_{\tau})$	CLOV		(F ₅₅		+Γ ₉₇)/Γ ₅₀
	,,	002552110 70 0221	- Cm - 311 2013 00	•	<u>VALUE</u> >0.81	95 1	DOCUMENT ID 28 ALBRECHT			10.6 GeV
$\Gamma(\eta \pi^- u_ au) / \Gamma_{total}$			Γ	₈₉ /Г	128 ALBRECHT 91D n				Citi	
VALUE (units 10 ⁻⁴)	CL% E	/TS DOCUMENT ID	TECN COMMENT		$\Gamma(h^-\rho\pi^0\nu_{\tau})/\Gamma(h^-\rho\pi^0)$	$-h-h+\pi^0$	(ν_{-}) . $\Gamma(h^{-} \rho^{+} h^{-})$	$(\nu_{\tau})/\Gamma(h^{-}h^{-})$	$-h + \pi^0 \nu$).	(ex.n)),
< 1.4	95		CLEO $E_{\rm cm}^{ee} \approx 10.6$	6 GeV	and $\Gamma(h^-\rho^-h^+\nu)$	_)/r(h= h=	$h^+\pi^0\nu_{\tau}$) values	· τ // · (·· ··	·· ·· · · · · · · · · · · · · · · · ·	
• • We do not use	the followin	g data for averages, fits, limit								- /-
< 3.4	95		CLEO $E_{\rm cm}^{ee} \approx 10.6$		$\Gamma(h^-\omega\nu_{\tau})/\Gamma(h^-h)$	¯ <i>ħ</i> ¯π [™] ν _τ	(ex.K°)) 85 ₉₇ +0.02215 ₉₈)			Γ_{97}/Γ_{51}
< 90	95		ARG $E_{\rm cm}^{ee} \approx 10$			(152+0.000				
<140	90	BEHREND 88	CELL E _{cm} = 14-4	6.8	VALUE 0.448±0.019 OUR FIT	EVTS	DOCUMENT I	D TECN	COMMENT	
<180	95	BARINGER 87	GeV CLEO $E_{\text{cm}}^{ee} = 10.5$	GeV	0.453±0.019 OUR AV					
<250	90		MRK3 $E_{cm}^{ee} = 3.77$		0.431 ± 0.033	2350	¹²⁹ BUSKULIC	96 ALEF	LEP 199	1−1993 data
$510 \pm 100 \pm 120$		65 DERRICK 87	HRS $E_{\rm cm}^{ee} = 29 {\rm Ge}$	eV	$0.464 \pm 0.016 \pm 0.017$	2223	130 BALEST		$E_{\rm cm}^{ee} \approx 1$	10.6 GeV
<100	95	GAN 87B	3 MRK2 Ecm = 29 G	eV	• • We do not use t					
-(- 0 \/-				- /	$0.37 \pm 0.05 \pm 0.02$		¹³¹ ALBRECHT		•	
$\Gamma(\eta\pi^-\pi^0\nu_{\tau})/\Gamma_{\rm tota}$				- ₉₀ /Γ	¹²⁹ BUSKULIC 96 qu					
VALUE (%) 0.171±0.028 OUR		EVTS DOCUMENT ID	TECN COMMENT		originate in a h			29. We divid	e this by th	ie $\omega(782) \rightarrow$
0.17 ±0.02 ±0.02		125 ARTUSO 92	2 CLEO Eee ≈ 1	0.6	$\pi^+\pi^-\pi^0$ branchir 130 BALEST 950 quot			- 4- 4+ -0	(0)	طماطين ميممما
			GeV		originate in a h					
		g data for averages, fits, limit			$\omega(782) \rightarrow \pi^{+}\pi^{-}$				o. We divid	e tills by the
<1.10	95	ALBRECHT 8	8M ARG E ^{ee} cm ≈	10	131 ALBRECHT 91D q	ote the frac	ction of $ au^- ightarrow h^-$	$^ _h _h+$ $_^0$ $_{ u_{ au}}$		
<2.10	95	BARINGER 8	GeV 7 CLEO <i>Eee</i> = 10.5	5 GeV	a $\pi^-\omega$ final state ϵ	quals 0.33 ±				
$4.20 \begin{array}{c} +0.70 \\ -1.20 \end{array} \pm 1.60$			7 MRK2 Eee = 29		branching fraction					
				00.	$\Gamma(h^-\omega\pi^0\nu_{ au})/\Gamma_{ m tota}$	ı				Γ ₉₈ /Γ
126 Highly correlated v	with GAN 8	7 $\Gamma(\pi^-3\pi^0 u_ au)/\Gamma(ext{total})$ value	e.		VALUE (%)		DOCUMENT ID			
$\Gamma(\eta\pi^-\pi^0\pi^0\nu_{\tau})/\Gamma$	total		Г	- ₉₁ /Γ	0.41±0.06 OUR FIT					
VALUE (units 10 ⁻⁴)	CL%	DOCUMENT ID TECN		31/	$\Gamma(h^-\omega\pi^0 u_ au)/\Gamma(h^-\omega\pi^0)$	- h- h+ >	Oneut 2/ ("3.	nrong"))		Γ98/Γ42
< 4.3	95		$E_{\rm cm}^{ee} \approx 10.6 {\rm GeV}$		$\Gamma_{98}/\Gamma_{42} = \Gamma_{98}/\Gamma_{43}$	(0.3431Γ ₃₀	$+0.3431\Gamma_{32}+0.36$	131F ₃₄ +0.343	31Γ ₃₅ +0.450	
		g data for averages, fits, limit					0.9101Γ ₉₇ +0.910		33	5
<120	95	ALBRECHT 88M ARG			Data marked "av	g" are highl	y correlated with o	data appearing	elsewhere ir	the Listings,
1220	,,,		-cm				ne average given b	elow but not	in the overa	II fits. "f&a"
$\Gamma(\eta K^- \nu_{\tau})/\Gamma_{\text{total}}$			Γ	₉₂ /Γ	marks results use VALUE	d for the fit <i>EVT</i>	and the average. S DOCUMEN	T ID TE	CN COMME	·NT
VALUE (units 10-4) CL%	6 EVTS	DOCUMENT ID TECN	COMMENT		0.028±0.004 OUR FIT 0.028±0.003±0.003					
<4.7 95 $\Gamma(\eta \pi^{+} \pi^{-} \pi^{-} \geq 0)$ VALUE (%)	ueutrals ع			₉₃ /Γ	$h^-h^-h^+2\pi^0 u_{ au}$ ($h^-\omega\pi^0 u_{ au}$)/ $\Gamma(h^-\omega^0 u_{ au})$ / $\Gamma(h^- u_$	h- h+ 2π	$^{0}\nu_{ au}(\mathrm{ex}.K^{0}))$			Γ ₉₈ /Γ ₅₉
<0.3	90	ABACHI 87B HRS			VALUE		DOCUMENT ID	TECN	COMMENT	
					0.81 ± 0.08 OUR FIT				n:00	
$\Gamma(\eta\eta\pi^-\nu_{\tau})/\Gamma_{total}$			Г	94/F	$0.81 \pm 0.06 \pm 0.06$		BORTOLETT	393 CLEO	Ecm ≈ 10.6	GeV
VALUE (units 10 ⁻⁴)	CL%	DOCUMENT ID TECN			$\Gamma(e^-\gamma)/\Gamma_{ m total}$					Г99/Г
< 1.1	95		$E_{\rm cm}^{ee} \approx 10.6 {\rm GeV}$		Test of lepton fa	mily numbe	r conservation.			. 33/ .
• • We do not use to	the followin	g data for averages, fits, limit			VALUE	CL%	DOCUMENT ID		COMMENT	
<83	95	ALBRECHT 88M ARG	$E_{ m cm}^{\it ee} \approx 10~{ m GeV}$		<1.1 × 10 ⁻⁴ • • • We do not use t	90 ha fallawina	ABREU		1990-1993	LEP runs
$\Gamma(\eta\eta\pi^-\pi^0\nu_{\tau})/\Gamma_{to}$			г	/Γ						Call
$VALUE$ (units 10^{-4})		DOCUMENT ID TECH		95/F	$<1.2 \times 10^{-4}$ $<2.0 \times 10^{-4}$	90 90	ALBRECHT KEH	92K ARG	$E_{cm}^{ee} = 10$ $E_{cm}^{ee} = 10$	
< 2.0	<u>CL%</u> 95		$E_{\text{cm}}^{ee} \approx 10.6 \text{ GeV}$		$< 2.0 \times 10^{-4}$	90	HAYES		$E_{\rm cm}^{ee} = 3.8$	
		g data for averages, fits, limit				,,,		02 WINN2	-cm- 5.0	2.0 00 0
	95		$E_{\rm cm}^{ee} \approx 10 \; {\rm GeV}$		$\Gamma(\mu^-\gamma)/\Gamma_{total}$					Γ_{100}/Γ
<90	70	ALDINECTI 80M AKG	rcm ~ 10 de∧		Test of lepton fa		r conservation. DOCUMENT ID	TECH	COMMENT	
$\Gamma(h^-\omega \ge 0 \text{ neutral})$	$(\mathbf{s} \ \nu_{\tau})/\Gamma_{to}$	tal	Г	96/F	< 0.42 × 10 ⁻⁵	<u>CL%</u> 90	BEAN		$\frac{COMMENT}{E_{cm}^{ee}} = 10.$	6 GeV
$\Gamma_{96}/\Gamma = (\Gamma_{97} + \Gamma_{96})$					• • • We do not use t					- UC V
Data marked "av	vg" are high	ly correlated with data appear	ing elsewhere in the Lis	stings,	$< 6.2 \times 10^{-5}$	90	ABREU		1990-1993	I FP runs
and are therefore	e used for t	he average given below but n			< 3.4 × 10 ⁻⁵	90	ALBRECHT	92K ARG	$E_{\rm cm}^{ee} = 10$	
		t and the average.			<55 × 10 ⁻⁵	90	HAYES		$E_{\rm cm}^{ee} = 3.8$	
VALUE (%) 2.32±0.11 OUR FIT	EVTS	DOCUMENT ID TECH	V COMMENT			-			Cili	
1.65 ± 0.3 ± 0.2 av	g 1513	ALBRECHT 88M ARG	$E_{\rm cm}^{\it ee} \approx 10~{\rm GeV}$		$\Gamma(e^-\pi^0)/\Gamma_{\text{total}}$ Test of lepton fa			T.C.	courses=	Γ ₁₀₁ /Γ
$\Gamma(h^-\omega\nu_{\tau})/\Gamma_{\text{total}}$				97/F	<u>VALUE</u> < 14 × 10 ^{−5}	<u>CL%</u>	DOCUMENT ID		COMMENT	GeV/
Data marked "av		ly correlated with data appear	ing elsewhere in the Lis	stings,	• • • We do not use t	90 he following	KEH data for average		$E_{\rm cm}^{ee} = 10$	GeV
		he average given below but n t and the average.	ot in the overall fits.	"f&a"	$< 17 \times 10^{-5}$	ne ronowing 90	, data for average ALBRECHT	92K ARG		GeV/
marks results use VALUE (%)	ed for the f EV		TECN COMMENT		$< 17 \times 10^{-5}$ $< 210 \times 10^{-5}$	90 90	HAYES		$E_{\text{cm}}^{ee} = 10$ $E_{\text{cm}}^{ee} = 3.8$	
1.91±0.09 OUR FIT						90	HALLS	OZ WINNZ	-cm- 3.8	J.U GC V
1.93±0.13 OUR AVER		127			$\Gamma(\mu^-\pi^0)/\Gamma_{ m total}$					Γ_{102}/Γ
1.95 ± 0.07 ± 0.11	avg 222		CLEO $E_{\rm cm}^{\rm ee} \approx 10.6$	GeV	Test of lepton fa				cour.:=::=	-•
1.60±0.27±0.41	f&a 13				<u>VALUE</u> < 4.4 × 10 ^{−5}	<u>CL%</u> 90	DOCUMENT ID ALBRECHT	92k ARG	$\frac{COMMENT}{E_{cm}^{ee}} = 10$	GeV/
^{1∠} / Not independent of	f BALEST 9	5c B($\tau^- \rightarrow h^- \omega \nu_{\tau}$)/B(τ^-	$\rightarrow h^- h^- h^+ \pi^0 \nu_{\tau})$	value.	• • • We do not use t					GC V
					<82 × 10 ⁻⁵	90	HAYES		$E_{\rm cm}^{ee} = 3.8$	-6.8 GeV
								2		

 τ

ALLIE	family number		TECN	Γ ₁₀₃ /Γ	ι (e μ ' μ Test <u>VALUE</u>	u ⁻)/Γ _{total} of lepton family num			TECN	Γ ₁₁ ,
<1.3 × 10 ⁻³	<u>CL%</u> 90	DOCUMENT ID		Eem = 3.8-6.8 GeV	< 0.36 × 1	CL% 10-5 90	138 BARTELT			$\frac{COMMENT}{E_{CM}^{ee}} = 9.4-10.6 \text{ Ge}^{\bullet}$
1.3 × 10	90	HATES	02 WIKIK2	-cm- 5.0 0.0 dcv		do not use the followi				
$\mu^- K^0)/\Gamma_{\text{total}}$				Γ ₁₀₄ /Γ	< 1.9 × 1		ALBRECHT		ARG	
Test of lepton					< 2.7 × 1		BOWCOCK			$E_{\text{Cm}}^{ee} = 10 \text{ GeV}$ $E_{\text{Cm}}^{ee} = 10.4-10.9$
.UE 2	CL%	DOCUMENT ID		COMMENT	<33 × 1	_	HAYES			$E_{\rm cm}^{ee} = 3.8-6.8 \text{ GeV}$
1.0 × 10 ⁻³	90	HAYES	82 MRK2	E Ecm = 3.8-6.8 GeV				02	WIKKZ	Ecm = 3.0-0.0 GeV
$e^-\eta)/\Gamma_{\rm total}$				Γ ₁₀₅ /Γ	. TOUBARTE	ELT 94 assume phase	space decays.			
	family number	r conservation.		105/	$\Gamma(e^+\mu^-)$	$\mu^-)/\Gamma_{\text{total}}$				Γ _{11!}
LUE	CL%	DOCUMENT ID	TECN	COMMENT	Test	of lepton number cor	servation.			
6.3×10^{-5}	90	ALBRECHT	92k ARG	Eee = 10 GeV	VALUE		DOCUMENT ID			COMMENT
• We do not use	e the following	data for average	s, fits, limits,	etc. • • •	<0.35 × 10		139 BARTELT			$E_{\rm cm}^{ee} = 9.4-10.6 {\rm Ge}^4$
24×10^{-5}	90	KEH	88 CBAL	Eee = 10 GeV		do not use the followi	ing data for averages	, fits,	limits, e	etc. • • •
				CIII	<1.8 × 10		ALBRECHT		ARG	
$(\mu^- \eta) / \Gamma_{\text{total}}$				Γ ₁₀₆ /Γ	<1.6 × 10	₀ -5 90	BOWCOCK	90	CLEO	$E_{cm}^{ee} = 10.4-10.9$
Test of lepton			TECH		139 BARTE	ELT 94 assume phase	space decays.			
7.3 × 10 ⁻⁵	<u>CL%</u>	DOCUMENT ID		COMMENT	-		, ,			_
7.3 × 10 °	90	ALBRECHT	92K ARG	$E_{cm}^{ee} = 10 \; GeV$	I (μ-e+e	e ⁻)/Γ _{total}				Γ ₁₁₀
$e^- ho^0)/\Gamma_{ m total}$				Γ ₁₀₇ /Γ		of lepton family num CL%	ber conservation. <u>DOCUMENT ID</u>		TECN	COMMENT
Test of lepton	family numbe	r conservation.		1077	< 0.34 x :	10 ⁻⁵ 90	140 BARTELT			Eee 9.4-10.6 Ge
UE	CL%	DOCUMENT ID	TECN	COMMENT						
0.42×10^{-5}	90	¹³³ BARTELT	94 CLEO	$E_{\rm cm}^{ee} = 9.4 - 10.6 \text{ GeV}$	< 1.4 × 1	do not use the followi				
	e the following	data for average	s, fits, limits,	etc. • • •		_	ALBRECHT		ARG	E _{cm} = 10 GeV
1.9×10^{-5}	90	ALBRECHT	92K ARG	$E_{cm}^{ee} = 10 \text{ GeV}$	< 2.7 × 1		BOWCOCK			Ecm = 10.4-10.9
7 × 10 ⁻⁵	90	HAYES	82 MRK2	2 E ^{ee} _{Cm} = 3.8–6.8 GeV	<44 × 3		HAYES	82	MRK2	E _{cm} = 3.8-6.8 GeV
BARTELT 94 as:				Cili	¹⁴⁰ BARTE	ELT 94 assume phase	space decays.			
BARIELI 94 as:	sume phase sp	ace decays.			Γ(u± a=.	e ⁻)/Γ _{total}				г
$\mu^- ho^0)/\Gamma_{ m total}$				Γ ₁₀₈ /Γ	. ι (μ. ε. t Test	of lepton family num	her conservation.			Г ₁₁
Test of lepton	family numbe				VALUE				TECN	COMMENT
JE _	CL%	DOCUMENT ID		COMMENT	<0.34 × 10		141 BARTELT			$E_{\rm cm}^{ee} = 9.4-10.6 \text{Ge}^{-1}$
0.57 × 10 ⁻⁵		¹³⁴ BARTELT		$E_{cm}^{ee} = 9.4-10.6 \text{ GeV}$	• • • We	do not use the follow				
 We do not use 	se the following	data for average	s, fits, limits,	etc. • • •	<1.4 × 10		ALBRECHT			Eee = 10 GeV
2.9×10^{-5}	90	ALBRECHT	92K ARG	$E_{CM}^{ee} = 10 \; GeV$	<1.6 × 10		BOWCOCK			$E_{\rm cm}^{ee} = 10.4-10.9$
44 × 10 ⁻⁵	90	HAYES	82 MRK2	2 E ^{ee} _{cm} = 3.8–6.8 GeV				90	CLLO	- cm - 10.4-10.9
⁴ BARTELT 94 as:	ssume phase sc	ace decays.			I THE BARTE	ELT 94 assume phase	space decays.			
		,			Γ(<i>u</i> - <i>u</i> +	$\mu^-)/\Gamma_{total}$				Γ ₁₁₀
e ⁻ K*(892) ⁰)/	/Γ _{total}			Γ ₁₀₉ /Γ	Test	of lepton family num	ber conservation.			- 11
Test of lepton			TECN	COMMENT	VALUE	CL%	DOCUMENT ID		TECN	COMMENT
	<u>CL%</u> 90	DOCUMENT ID 135 BARTELT		COMMENT	< 0.19 x :		ALBRECHT			$E_{cm}^{ee} = 10 \text{ GeV}$
				E ^{ee} _{cm} = 9.4–10.6 GeV	• • • We	do not use the follow	ing data for averages	, fits,	limits, e	etc. • • •
 We do not use 	e the following				< 0.43 × 3	10-5 90	¹⁴² BARTELT	94	CLEO	$E_{\rm cm}^{ee} = 9.4-10.6 {\rm Ge}^4$
E			92K ARG	$E_{ m cm}^{\it ee}$ = 10 GeV	< 1.7 ×	10 ⁻⁵ 90	BOWCOCK			$E_{cm}^{ee} = 10.4-10.9$
	90	ALBRECHT			<49 ×	10-5 90	HAYES			Eee = 3.8-6.8 GeV
						ELT 94 assume phase				CIII
BARTELT 94 as:	ssume phase sp			r /r	142		chace decays			
³ BARTELT 94 as: μ [—] Κ*(892)⁰) /	ssume phase sp /Γ _{total}	ace decays.		Γ ₁₁₀ /Γ	142	LI 94 assume phase	space decays.			
BARTELT 94 as: u= K*(892)⁰) /	ssume phase sp /Γ_{total} r family numbe	r conservation.	TECN		- ¹⁴² _{BARTE} Γ (e ⁻ π ⁺ 1	$\pi^-)/\Gamma_{total}$				Γ ₁₁ .
BARTELT 94 as: u [—] K*(892)⁰)/ Test of lepton UE	ssume phase sp /Γ _{total} I family numbe	r conservation. DOCUMENT ID		COMMENT	- 142 _{BARTE} - Γ(e ⁻ π ⁺ 1	$\pi^-)/\Gamma_{ ext{total}}$ of lepton family num	ber conservation.			
BARTELT 94 as: ************************************	/Γ _{total} family numbe <u>CL%</u> 90	r conservation. DOCUMENT ID BARTELT	94 CLEO	COMMENT Eee = 9.4-10.6 GeV	142 _{BARTE} Γ(e ⁻ π ⁺ 1 Test VALUE	π [—])/Γ _{total} of lepton family num <u>CL%</u>	ber conservation. <u>DOCUMENT ID</u>			COMMENT
BARTELT 94 as: "" K*(892) ⁰)/ Test of lepton UE 1.94 × 10 ⁻⁵ • We do not use	Γ_{total} family numbe $CL\%$ 90 se the following	r conservation. <u>DOCUMENT ID</u> 136 BARTELT (data for average	94 CLEO s, fits, limits,	$\frac{COMMENT}{E_{Cm}^{ee} = 9.4-10.6 \text{ GeV}}$ etc. • • •	142 BARTE $\Gamma(e^{-}\pi^{+}1)$ Test $VALUE$ <0.44 x 16	π^-)/ Γ_{total} of lepton family num $\frac{CL\%}{0^{-5}}$	ber conservation. DOCUMENT ID 143 BARTELT	94	CLEO	$\frac{COMMENT}{E_{Cm}^{ee}} = 9.4-10.6 \text{ Ge}$
BARTELT 94 as: $u^- K^* (892)^0 / \text{Test of lepton}$ UE • We do not use 0.5×10^{-5}	// total a family numbe CL% 90 se the following	r conservation. DOCUMENT ID BARTELT data for average ALBRECHT	94 CLEO s, fits, limits,	COMMENT Eee = 9.4-10.6 GeV	142 BARTE Γ(e-π+1 Τest <u>VALUE</u> <0.44 × 10 • • • We	π^{-})/ Γ_{total} of lepton family num $\frac{Cl \%}{0^{-5}}$ $\frac{90}{90}$ do not use the follow	ber conservation. <u>DOCUMENT ID</u> 143 BARTELT ing data for averages	94 s, fits,	CLEO limits, e	$\frac{COMMENT}{E_{CM}^{ee} = 9.4-10.6 \text{ Ge}}$ etc. • •
BARTELT 94 as: $u^- K^* (892)^0 / \text{Test of lepton}$ UE • We do not use 0.5×10^{-5}	// total a family numbe CL% 90 se the following	r conservation. DOCUMENT ID BARTELT data for average ALBRECHT	94 CLEO s, fits, limits,	$\frac{COMMENT}{E_{Cm}^{ee} = 9.4-10.6 \text{ GeV}}$ etc. • • •	Γ(e ⁻ π ⁺ π Test <u>VALUE</u> <0.44 × 10 • • • We <2.7 × 10	π^-)/ Γ_{total} of lepton family num 0^{-5} 0^{-5} 0^{-5} 0^{-5} 0^{-5} 0^{-5}	ber conservation. DOCUMENT ID 143 BARTELT ing data for averages ALBRECHT	94 s, fits, 92K	CLEO limits, e	$\frac{COMMENT}{E_{Cm}^{ee} = 9.4-10.6 \text{ Ge}}$ etc. • • • $E_{Cm}^{ee} = 10 \text{ GeV}$
BARTELT 94 as: $u^- K^*(892)^0)/Test of lepton$ UE UE UE UE UE UE UE UE	// total a family numbe CL% 90 se the following	r conservation. DOCUMENT ID BARTELT data for average ALBRECHT	94 CLEO s, fits, limits,	$E_{\text{CM}}^{ee} = 9.4-10.6 \text{ GeV}$ etc. • • • $E_{\text{CM}}^{ee} = 10 \text{ GeV}$	Γ(e ⁻ π+α Τest <u>VALUE</u> <0.44 × 10 • • • We <2.7 × 10	π^-)/ Γ_{total} of lepton family num 0^{-5} 0^{-5} 0^{-5} 0^{-5} 0^{-5} 0^{-5}	ber conservation. <u>DOCUMENT ID</u> 143 BARTELT ing data for averages	94 s, fits, 92K	CLEO limits, e	$\frac{COMMENT}{E_{CM}^{ee} = 9.4-10.6 \text{ Ge}}$ etc. • •
BARTELT 94 as: $u^{-} K^{*}(892)^{0}/\Gamma$ Test of lepton UE $.94 \times 10^{-5}$ • We do not us: $.5 \times 10^{-5}$ BARTELT 94 as: $\pi^{-} \gamma)/\Gamma_{\text{total}}$	// total a family numbe CL% 90 se the following	r conservation. DOCUMENT ID 136 BARTELT data for average ALBRECHT vace decays.	94 CLEO s, fits, limits,	$\frac{COMMENT}{E_{Cm}^{ee} = 9.4-10.6 \text{ GeV}}$ etc. • • •	142 BARTE Γ(e ⁻ π ⁺ π Test <u>VALUE</u> <0.44 × 10 • • We <2.7 × 10 <6.0 × 10	π^-)/ Γ_{total} of lepton family num 0^{-5} 0^{-5} 0^{-5} 0^{-5} 0^{-5} 0^{-5} 0^{-5} 0^{-5} 0^{-5} 0^{-5} 0^{-5} 0^{-5}	ber conservation. DOCUMENT ID 143 BARTELT ing data for averages ALBRECHT BOWCOCK	94 s, fits, 92K	CLEO limits, e	$\frac{COMMENT}{E_{Cm}^{ee} = 9.4-10.6 \text{ Ge}}$ etc. • • • $E_{Cm}^{ee} = 10 \text{ GeV}$
BARTELT 94 ass $u^-K^*(892)^0$ / $Test$ of lepton UE 0.94×10^{-5} • We do not use 0.5×10^{-5} BARTELT 94 ass π^-Y / Γ total Test of lepton UE	/ Ttotal family numbe	r conservation. DOCUMENT ID 136 BARTELT data for average ALBRECHT vace decays.	94 CLEO s, fits, limits,	$E_{\text{CM}}^{ee} = 9.4-10.6 \text{ GeV}$ etc. • • • $E_{\text{CM}}^{ee} = 10 \text{ GeV}$		π^-)/ Γ_{total} of lepton family num $CL\%$ 0^{-5} 90 do not use the follow 0^{-5} 90 0^{-5} 90 0^{-5} 90 0^{-5}	ber conservation. DOCUMENT ID 143 BARTELT ing data for averages ALBRECHT BOWCOCK	94 s, fits, 92K	CLEO limits, e	$E_{\rm cm}^{ee} = 9.4 - 10.6 \text{ Ge}$ etc. • • • $E_{\rm cm}^{ee} = 10 \text{ GeV}$ $E_{\rm cm}^{ee} = 10.4 - 10.9$
BARTELT 94 ass $u^-K^*(892)^0$ / $Test$ of lepton UE 0.94×10^{-5} • We do not use 0.5×10^{-5} BARTELT 94 ass π^-Y / Γ total Test of lepton UE	From the second	r conservation. DOCUMENT ID 136 BARTELT data for average ALBRECHT bace decays.	94 CLEO es, fits, limits, 92K ARG	$E_{\text{CM}}^{ee} = 9.4-10.6 \text{ GeV}$ etc. • • • $E_{\text{CM}}^{ee} = 10 \text{ GeV}$		π^-)/ Γ_{total} of lepton family num $CL\%$ 0^{-5} 90 do not use the follow 0^{-5} 90 0^{-5} 90 0^{-5} 90 0^{-5} ELT 94 assume phase π^-)/ Γ_{total}	ber conservation. DOCUMENT ID 143 BARTELT ing data for averages ALBRECHT BOWCOCK space decays.	94 s, fits, 92K	CLEO limits, e	$E_{\rm cm}^{ee} = 9.4 - 10.6 \text{ Ge}$ etc. • • • $E_{\rm cm}^{ee} = 10 \text{ GeV}$ $E_{\rm cm}^{ee} = 10.4 - 10.9$
$ μ^- K^*(892)^0 $ Test of lepton UE 9.94 × 10 ⁻⁵ 9.6 • We do not using the second se	// fotal family numbe cL% 90 se the following 90 ssume phase sp	r conservation. <u>DOCUMENT ID</u> 136 BARTELT ; data for average ALBRECHT vace decays. rvation. <u>DOCUMENT ID</u>	94 CLEO es, fits, limits, 92K ARG	$E_{\rm cm}^{ee} = 9.4$ –10.6 GeV etc. • • • $E_{\rm cm}^{ee} = 10$ GeV $F_{\rm 111}/\Gamma$ $\frac{COMMENT}{E_{\rm cm}^{ee}} = 10$ GeV	142 BARTE	π)/ Γ_{total} of lepton family num 0^{-5} 0^{-5	ber conservation. DOCUMENT ID 143 BARTELT ing data for averages ALBRECHT BOWCOCK space decays.	94 5, fits, 92K 90	CLEO limits, e ARG CLEO	$E_{\rm cm}^{ee} = 9.4 - 10.6 \text{ Ge}^{e}$ etc. • • • $E_{\rm cm}^{ee} = 10 \text{ GeV}$ $E_{\rm cm}^{ee} = 10.4 - 10.9$
BARTELT 94 as:	// Total family numbe CL% 90 se the following 90 ssume phase sp number conse CL% 90	r conservation. <u>DOCUMENT ID</u> 136 BARTELT g data for average ALBRECHT ace decays. rvation. <u>DOCUMENT ID</u> ALBRECHT	94 CLEO es, fits, limits, 92K ARG	$E_{\rm cm}^{ee} = 9.4$ –10.6 GeV etc. • • • $E_{\rm cm}^{ee} = 10$ GeV	142 BARTE	π^-)/ Γ_{total} of lepton family num 0.5	ber conservation. DOCUMENT ID 143 BARTELT ing data for averages ALBRECHT BOWCOCK space decays. nservation. DOCUMENT ID	94 5, fits, 92K 90	CLEO limits, e ARG CLEO	COMMENT $E_{cm}^{ee} = 9.4-10.6 \text{ Ge}$ $E_{cm}^{ee} = 10 \text{ GeV}$ $E_{cm}^{ee} = 10.4-10.9$ Γ_{12}
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BARTELT 94 as: $ \begin{array}{l} \mathbf{i} - K^*(892)^0 \\ \mathbf{i} - K^*(892)^0 \\ \mathbf{j} - K^*(892)^0 \\ j$	// total if amily numbe	r conservation. DOCUMENT ID 136 BARTELT data for average ALBRECHT vace decays. POCUMENT ID ALBRECHT ALBRECHT ALBRECHT ALBRECHT ALBRECHT POCUMENT ID DOCUMENT ID	94 CLEO s, fits, limits, 92k ARG TECN 92k ARG	$E_{\rm cm}^{ee} = 9.4$ –10.6 GeV etc. • • • $E_{\rm cm}^{ee} = 10$ GeV $F_{\rm 111}/\Gamma$ $\frac{COMMENT}{E_{\rm cm}^{ee} = 10}$ GeV $F_{\rm 112}/\Gamma$		π^-)/ Γ_{total} of lepton family num $\frac{CL\%}{0^{-5}}$ 90 do not use the follow 0^{-5} 90 ELT 94 assume phase π^-)/ Γ_{total} of lepton number con $\frac{CL\%}{0^{-5}}$ 90 do not use the follow	ber conservation. DOCUMENT ID 143 BARTELT ing data for averages ALBRECHT BOWCOCK space decays. nservation. DOCUMENT ID 144 BARTELT ing data for averages	94 5, fits, 92K 90 94 5, fits,	CLEO limits, e ARG CLEO	COMMENT $E_{\text{cm}}^{ee} = 9.4 - 10.6 \text{ Ge}$ etc. • • • $E_{\text{cm}}^{ee} = 10 \text{ GeV}$ $E_{\text{cm}}^{ee} = 10.4 - 10.9$ Γ_{12} COMMENT $E_{\text{cm}}^{ee} = 9.4 - 10.6 \text{ Ge}$ etc. • • •
BARTELT 94 as: $ \begin{array}{l} $	// Total family numbe CL% 90 se the following 90 ssume phase sp number conse CL% 90 number conse CL% 90 number conse	r conservation. DOCUMENT ID 136 BARTELT data for average ALBRECHT vace decays. rvation. DOCUMENT ID ALBRECHT	94 CLEO rs, fits, limits, 92k ARG TECN 92k ARG	$E_{\rm cm}^{ee} = 9.4$ –10.6 GeV etc. • • • $E_{\rm cm}^{ee} = 10$ GeV	142 BARTE	π)/ Γ_{total} of lepton family num 0^{-5} 90 do not use the follow 0^{-5} 90 0^{-5} 90 0^{-5} 90 ELT 94 assume phase π)/ Γ_{total} of lepton number cor 0^{-5}	ber conservation. DOCUMENT ID 143 BARTELT ing data for averages ALBRECHT BOWCOCK space decays. nservation. DOCUMENT ID 144 BARTELT ing data for averages ALBRECHT	94 5, fits, 92K 90 94 5, fits,	CLEO limits, e ARG CLEO	COMMENT $E_{\text{cm}}^{\text{ee}} = 9.4 - 10.6 \text{ Ge}$ etc. • • • $E_{\text{cm}}^{\text{ee}} = 10 \text{ GeV}$ $E_{\text{cm}}^{\text{ee}} = 10.4 - 10.9$ Γ_{12} COMMENT $E_{\text{cm}}^{\text{ee}} = 9.4 - 10.6 \text{ Ge}$ etc. • • • $E_{\text{cm}}^{\text{ee}} = 10 \text{ GeV}$
BARTELT 94 as:	// Total family number CL% 90 see the following 90 ssume phase spin number conse CL% 90 number conse CL% 90 number conse CL% 90	r conservation. DOCUMENT ID 136 BARTELT data for average ALBRECHT vace decays. POCUMENT ID ALBRECHT ALBRECHT ALBRECHT ALBRECHT ALBRECHT POCUMENT ID DOCUMENT ID	94 CLEO s, fits, limits, 92k ARG TECN 92k ARG	$E_{\rm cm}^{ee} = 9.4 - 10.6 \text{ GeV}$ etc. • • • $E_{\rm cm}^{ee} = 10 \text{ GeV}$ Γ_{111}/Γ $\frac{COMMENT}{E_{\rm cm}^{ee}} = 10 \text{ GeV}$ Γ_{112}/Γ $\frac{COMMENT}{E_{\rm cm}^{ee}} = 10 \text{ GeV}$	142 BARTE	π)/ Γ_{total} of lepton family num 0^{-5} 90 do not use the follow 0^{-5} 90 0^{-5} 90 ELT 94 assume phase π)/ Γ_{total} of lepton number cor 0^{-5} 90 do not use the follow 0^{-5} 90 0^{-5} 90	ber conservation. DOCUMENT ID 143 BARTELT ing data for averages ALBRECHT BOWCOCK space decays. nservation. DOCUMENT ID 144 BARTELT ing data for averages ALBRECHT BOWCOCK	94 5, fits, 92K 90 94 5, fits,	CLEO limits, e ARG CLEO	COMMENT $E_{\text{cm}}^{ee} = 9.4 - 10.6 \text{ Ge}$ etc. • • • $E_{\text{cm}}^{ee} = 10 \text{ GeV}$ $E_{\text{cm}}^{ee} = 10.4 - 10.9$ Γ_{12} COMMENT $E_{\text{cm}}^{ee} = 9.4 - 10.6 \text{ Ge}$ etc. • • •
BARTELT 94 as: $4^ K^*$ (892)°)/ Test of lepton UE .94 × 10-5 • We do not us: .5 × 10-5 BARTELT 94 as: $\tau^- \gamma$ / Γ total Test of lepton UE .7 × 10-5 $\tau^- \pi^0$ / Γ total Test of lepton UE .7 × 10-5 $\tau^- \pi^0$ / Γ total $\tau^- \pi^0$ / $\tau^- \tau^- \tau^- \tau^- \tau^- \tau^- \tau^- \tau^- \tau^- \tau^- $	// Total family numbe	r conservation. DOCUMENT ID 136 BARTELT data for average ALBRECHT vace decays. ALBRECHT ALBRECHT ALBRECHT ALBRECHT ALBRECHT ALBRECHT	94 CLEO s, fits, limits, 92k ARG TECN 92k ARG	$E_{\rm cm}^{ee} = 9.4$ –10.6 GeV etc. • • • $E_{\rm cm}^{ee} = 10$ GeV $F_{\rm 111}/\Gamma$ $\frac{COMMENT}{E_{\rm cm}^{ee} = 10}$ GeV $F_{\rm 112}/\Gamma$	142 BARTE	π)/ Γ_{total} of lepton family num 0^{-5} 90 do not use the follow 0^{-5} 90 0^{-5} 90 0^{-5} 90 ELT 94 assume phase π)/ Γ_{total} of lepton number cor 0^{-5}	ber conservation. DOCUMENT ID 143 BARTELT ing data for averages ALBRECHT BOWCOCK space decays. nservation. DOCUMENT ID 144 BARTELT ing data for averages ALBRECHT BOWCOCK	94 5, fits, 92K 90 94 5, fits,	CLEO limits, e ARG CLEO	COMMENT $E_{\text{cm}}^{\text{ee}} = 9.4 - 10.6 \text{ Ge}$ etc. • • • $E_{\text{cm}}^{\text{ee}} = 10 \text{ GeV}$ $E_{\text{cm}}^{\text{ee}} = 10.4 - 10.9$ Γ_{12} COMMENT $E_{\text{cm}}^{\text{ee}} = 9.4 - 10.6 \text{ Ge}$ etc. • • • $E_{\text{cm}}^{\text{ee}} = 10 \text{ GeV}$
μ - K *(892) ⁰)/ Test of lepton UE 1.94 × 10 ⁻⁵ 2.5 × 10 ⁻⁵ 2.5 × 10 ⁻⁵ 3.6 × 10 ⁻⁵ 3.7 × 10 ⁻⁵ 3.7 × 10 ⁻⁵ 3.8 × 10 ⁻⁵ 3.8 × 10 ⁻⁵ 3.9 × 10 ⁻⁵	// Total family number CL% 90 see the following 90 ssume phase spin number conse CL% 90 number conse CL% 90 number conse CL% 90	r conservation. DOCUMENT ID 136 BARTELT data for average ALBRECHT vace decays. ALBRECHT ALBRECHT ALBRECHT ALBRECHT ALBRECHT ALBRECHT	94 CLEO s, fits, limits, 92k ARG TECN 92k ARG	$E_{\rm cm}^{ee} = 9.4 - 10.6 \text{ GeV}$ etc. • • • $E_{\rm cm}^{ee} = 10 \text{ GeV}$ Γ_{111}/Γ $\frac{COMMENT}{E_{\rm cm}^{ee}} = 10 \text{ GeV}$ Γ_{112}/Γ $\frac{COMMENT}{E_{\rm cm}^{ee}} = 10 \text{ GeV}$	142 BARTE	π^-)/ Γ_{total} of lepton family num 0.5	ber conservation. DOCUMENT ID 143 BARTELT ing data for averages ALBRECHT BOWCOCK space decays. nservation. DOCUMENT ID 144 BARTELT ing data for averages ALBRECHT BOWCOCK	94 5, fits, 92K 90 94 5, fits,	CLEO limits, e ARG CLEO	COMMENT $E_{\text{cm}}^{ee} = 9.4 - 10.6 \text{ Ge}$ etc. • • • $E_{\text{cm}}^{ee} = 10 \text{ GeV}$ $E_{\text{cm}}^{ee} = 10.4 - 10.9$ F_{12} COMMENT $E_{\text{cm}}^{ee} = 9.4 - 10.6 \text{ Ge}$ etc. • • • $E_{\text{cm}}^{ee} = 10 \text{ GeV}$ $E_{\text{cm}}^{ee} = 10.4 - 10.9$
BARTELT 94 as: $u = K^*(892)^0 / Test of lepton$ UE $.94 \times 10^{-5}$ • We do not us: $.5 \times 10^{-5}$ BARTELT 94 as: $\pi^- \gamma) / \Gamma_{total}$ Test of lepton UE 17×10^{-5} $\pi^- \pi^0) / \Gamma_{total}$ Test of lepton UE 17×10^{-5} $e^- e^+ e^-) / \Gamma_{tot}$ Test of lepton UE UE UE UE UE UE UE UE	// ftotal family number CL% 90 ssume phase sp number conse CL% 90	r conservation. DOCUMENT ID 136 BARTELT g data for average ALBRECHT nace decays. rvation. DOCUMENT ID ALBRECHT ALBRECHT ALBRECHT ALBRECHT r conservation.	94 CLEO s, fits, limits, 92K ARG TECN 92K ARG	COMMENT $E_{\text{cm}}^{ee} = 9.4 - 10.6 \text{ GeV}$ etc. • • • $E_{\text{cm}}^{ee} = 10 \text{ GeV}$ Γ_{111}/Γ $\frac{COMMENT}{E_{\text{cm}}^{ee}} = 10 \text{ GeV}$ Γ_{112}/Γ $\frac{COMMENT}{E_{\text{cm}}^{ee}} = 10 \text{ GeV}$ Γ_{113}/Γ $\frac{COMMENT}{COMMENT}$	$\Gamma(e^{-}\pi^{+}x^{-})$ $\Gamma(e^{-}\pi^{+}x^{-})$ $\Gamma(e^{-}\pi^{+}x^{-})$ $\Gamma(e^{-}\pi^{+}x^{-})$ $\Gamma(e^{-}\pi^{-}x^{-})$ $\Gamma(e^{+}\pi^{-}x^{-})$ $\Gamma(e^{+}\pi^{-}x^{-})$ $\Gamma(e^{-}\pi^{+}x^{-})$ $\Gamma(e^{-}\pi^{+}x^{-})$ $\Gamma(e^{-}\pi^{+}x^{-})$ $\Gamma(e^{-}\pi^{+}x^{-})$ $\Gamma(e^{-}\pi^{+}x^{-})$ $\Gamma(e^{-}\pi^{+}x^{-})$ $\Gamma(e^{-}\pi^{+}x^{-})$	π)/ Γ_{total} of lepton family num 0^{-5} 90 do not use the follow 0^{-5} 90 0^{-5} 90 ELT 94 assume phase π)/ Γ_{total} of lepton number cor 0^{-5} 90 do not use the follow 0^{-5} 90 0^{-5} 90 ELT 94 assume phase π	ber conservation. DOCUMENT ID 143 BARTELT ing data for averages ALBRECHT BOWCOCK space decays. nservation. DOCUMENT ID 144 BARTELT ing data for averages ALBRECHT BOWCOCK space decays.	94 5, fits, 92K 90 94 5, fits,	CLEO limits, e ARG CLEO	COMMENT $E_{\text{cm}}^{ee} = 9.4 - 10.6 \text{ Ge}$ etc. • • • $E_{\text{cm}}^{ee} = 10 \text{ GeV}$ $E_{\text{cm}}^{ee} = 10.4 - 10.9$ F_{12} $E_{\text{cm}}^{ee} = 9.4 - 10.6 \text{ Ge}$ etc. • • • $E_{\text{cm}}^{ee} = 9.4 - 10.6 \text{ Ge}$ etc. • • • $E_{\text{cm}}^{ee} = 10 \text{ GeV}$ $E_{\text{cm}}^{ee} = 10.4 - 10.9$
## BARTELT 94 as: $u^- K^*(892)^0$ Test of lepton UE 1.94 × 10-5 • We do not us: 0.5×10^{-5} ## BARTELT 94 as: $u^- \gamma$ Total Test of lepton uE 1.75 × 10-5 $u^- \gamma$ Total Test of lepton uE 1.75 × 10-5 $u^- \gamma$ Total Test of lepton uE 1.75 × 10-5 $u^- \gamma$ Total Test of lepton uE 1.75 × 10-5 $u^- \gamma$ Total Test of lepton uE 1.75 × 10-5 $u^- \gamma$ Total Test of lepton	// Total family number CL% 90 ssume phase sp number conse CL% 90 some phase sp number conse CL% 90 stal family number CL% 90 stal point of the conse CL% 90	r conservation. DOCUMENT ID 136 BARTELT data for average ALBRECHT vace decays. ALBRECHT ALBRECHT ALBRECHT r conservation. DOCUMENT ID ALBRECHT r conservation. DOCUMENT ID ALBRECHT	94 CLEO es, fits, limits, 92k ARG 92k ARG 92k ARG 7ECN 92k ARG	COMMENT $E_{\rm cm}^{ee} = 9.4-10.6 \text{ GeV}$ etc. • • • $E_{\rm cm}^{ee} = 10 \text{ GeV}$ Γ_{111}/Γ $\frac{COMMENT}{E_{\rm cm}^{ee}} = 10 \text{ GeV}$ Γ_{112}/Γ $\frac{COMMENT}{E_{\rm cm}^{ee}} = 10 \text{ GeV}$ Γ_{113}/Γ $\frac{COMMENT}{E_{\rm cm}^{ee}} = 9.4-10.6 \text{ GeV}$		π)/ Γ_{total} of lepton family num 0^{-5} 90 do not use the follow 0^{-5} 90 0^{-5} 90 0^{-5} 90 ELT 94 assume phase π)/ Γ_{total} of lepton number cor 0^{-5} 90 do not use the follow 0^{-5} 90 0^{-5} 90 ELT 94 assume phase π)/ Γ_{total} of lepton family num	ber conservation. DOCUMENT ID 143 BARTELT ing data for averages ALBRECHT BOWCOCK space decays. 144 BARTELT ing data for averages ALBRECHT BOWCOCK space decays.	94 92k 90 94 5, fits, 92k 90	CLEO limits, e ARG CLEO TECN CLEO limits, e ARG CLEO	COMMENT $E_{cm}^{ee} = 9.4-10.6 \text{ Ge}$ etc. • • • $E_{cm}^{ee} = 10 \text{ GeV}$ $E_{cm}^{ee} = 10.4-10.9$ F_{12} COMMENT $E_{cm}^{ee} = 9.4-10.6 \text{ Ge}$ etc. • • • $E_{cm}^{ee} = 10 \text{ GeV}$
$μ^- K^*(892)^0/$ Test of lepton UE 1.94 × 10 ⁻⁵ • We do not use 1.5 × 10 ⁻⁵ BARTELT 94 as $π^- γ)/\Gamma$ 1.7 × 10 ⁻⁵ $π^- π^0/\Gamma$ 1.7 × 10 ⁻⁵ $π^- π^0/\Gamma$ 1.8 × 10 ⁻⁵ 1.9 × 10 ⁻⁵ 1.9 × 10 ⁻⁵ 1.9 × 10 ⁻⁵ 1.9 • We do not use	your phase sp // total family number	r conservation. DOCUMENT ID 136 BARTELT data for average ALBRECHT ALBRECHT ALBRECHT ALBRECHT ALBRECHT r conservation. DOCUMENT ID ALBRECHT r conservation. DOCUMENT ID ALBRECHT g data for average	94 CLEO s, fits, limits, 92k ARG 92k ARG 7ECN 92k ARG 7ECN 92k ARG	$E_{\rm cm}^{ee} = 9.4 - 10.6 \text{ GeV}$ etc. • • • $E_{\rm cm}^{ee} = 10 \text{ GeV}$ Γ_{111}/Γ $\frac{COMMENT}{E_{\rm cm}^{ee}} = 10 \text{ GeV}$ Γ_{112}/Γ $\frac{COMMENT}{E_{\rm cm}^{ee}} = 10 \text{ GeV}$ Γ_{113}/Γ $\frac{COMMENT}{E_{\rm cm}^{ee}} = 9.4 - 10.6 \text{ GeV}$ etc. • • •		π^-)/ Γ_{total} of lepton family num $CL\%$ 0^-5 90 do not use the follow 0^-5 90 0^-5 90 0^-5 90 0^-5 90 0^-5 90 do not use the follow 0^-5 0^-	ber conservation. DOCUMENT ID 143 BARTELT ing data for averages ALBRECHT BOWCOCK space decays. nservation. DOCUMENT ID 144 BARTELT ing data for averages ALBRECHT BOWCOCK space decays.	94 92K 90 94 55, fits, 92K 90	CLEO limits, e ARG CLEO CLEO CLEO CLEO CLEO CLEO CLEO CLEO	COMMENT $E_{cm}^{ee} = 9.4-10.6 \text{ GeV}$ etc. • • • $E_{cm}^{ee} = 10 \text{ GeV}$ $E_{cm}^{ee} = 10.4-10.9$ $E_{cm}^{ee} = 9.4-10.6 \text{ GeV}$ $E_{cm}^{ee} = 9.4-10.6 \text{ GeV}$ etc. • • • $E_{cm}^{ee} = 10 \text{ GeV}$ $E_{cm}^{ee} = 10.4-10.9$
$μ^- K^*(892)^0/$ Test of lepton UE 1.94 × 10 ⁻⁵ 1.5 × 10 ⁻⁵ 1.5 × 10 ⁻⁵ 1.6 BARTELT 94 as $π^- γ)/\Gamma_{total}$ Test of lepton UE 28 × 10 ⁻⁵ $π^- π^0/\Gamma_{total}$ Test of lepton UE 37 × 10 ⁻⁵ $e^- e^+ e^-/\Gamma_{total}$ Test of lepton UE 0.33 × 10 ⁻⁵ 1.9 We do not us 1.3 × 10 ⁻⁵	your phase sp. // Ftotal family number CL% 90 see the following 90 ssume phase sp	r conservation. DOCUMENT ID 136 BARTELT (data for average ALBRECHT PACE decays. PALBRECHT ALBRECHT ALBRECHT ALBRECHT POCUMENT ID ALBRECHT T conservation. DOCUMENT ID ALBRECHT T conservation. DOCUMENT ID ALBRECHT data for average ALBRECHT	94 CLEO s, fits, limits, 92k ARG 92k ARG 7ECN 92k ARG 7ECN 92k ARG 94 CLEO es, fits, limits, 92k ARG	$E_{\rm cm}^{ee} = 9.4 - 10.6 \text{ GeV}$ etc. • • • $E_{\rm cm}^{ee} = 10 \text{ GeV}$ Γ_{111}/Γ $\frac{COMMENT}{E_{\rm cm}^{ee}} = 10 \text{ GeV}$ Γ_{112}/Γ $\frac{COMMENT}{E_{\rm cm}^{ee}} = 10 \text{ GeV}$ Γ_{113}/Γ $\frac{COMMENT}{E_{\rm cm}^{ee}} = 9.4 - 10.6 \text{ GeV}$ etc. • • $E_{\rm cm}^{ee} = 10 \text{ GeV}$	142 BARTE	π^-)/ Γ_{total} of lepton family num 0.5	ber conservation. DOCUMENT ID 143 BARTELT ing data for averages ALBRECHT BOWCOCK space decays. nservation. DOCUMENT ID 144 BARTELT ing data for averages ALBRECHT BOWCOCK space decays. there conservation. DOCUMENT ID 145 BARTELT	94 92K 90 94 95, fits, 92K 90	CLEO limits, e ARG CLEO CLEO CLEO CLEO CLEO CLEO CLEO CLEO	COMMENT $E_{\text{cm}}^{ee} = 9.4 - 10.6 \text{ Ge}^{e}$ etc. • • • $E_{\text{cm}}^{ee} = 10 \text{ GeV}$ $E_{\text{cm}}^{ee} = 10.4 - 10.9$ $E_{\text{cm}}^{ee} = 9.4 - 10.6 \text{ Ge}^{e}$ etc. • • • $E_{\text{cm}}^{ee} = 9.4 - 10.6 \text{ Ge}^{e}$ etc. • • • $E_{\text{cm}}^{ee} = 10 \text{ GeV}$ $E_{\text{cm}}^{ee} = 10.4 - 10.9$ $E_{\text{cm}}^{ee} = 10.4 - 10.9$ $E_{\text{cm}}^{ee} = 10.4 - 10.6 \text{ Ge}^{e}$ $E_{\text{cm}}^{ee} = 10.4 - 10.6 \text{ Ge}^{e}$
$ μ^- K^*(892)^0 $ Test of lepton LUE 1.94 × 10 ⁻⁵ • We do not use 4.5 × 10 ⁻⁵ • BARTELT 94 as $π^- γ$)/Γtotal Test of lepton LUE 28 × 10 ⁻⁵ $π^- π^0$)/Γtotal Test of lepton LUE 37 × 10 ⁻⁵ • We do not use 1.3 × 10 ⁻⁵ • We do not use 1.3 × 10 ⁻⁵ 2.7 × 10 ⁻⁵	your phase sp. // Ttotal in family numbe	r conservation. DOCUMENT ID ALBRECHT ALBRECHT ALBRECHT ALBRECHT ALBRECHT ALBRECHT ALBRECHT ALBRECHT Tronservation. DOCUMENT ID ALBRECHT T conservation. DOCUMENT ID ALBRECHT T conservation. ALBRECHT ALBRECHT G data for average ALBRECHT BOWCOCK	94 CLEO s, fits, limits, 92k ARG 92k ARG 7ECN 92k ARG 7ECN 92k ARG 92k ARG 94 CLEO cs, fits, limits, 92k ARG	$E_{\rm cm}^{ee} = 9.4 - 10.6 \; {\rm GeV}$ etc. • • • $E_{\rm cm}^{ee} = 10 \; {\rm GeV}$ Γ_{111}/Γ $C_{\rm cm}^{oment}$ $E_{\rm cm}^{ee} = 10 \; {\rm GeV}$ Γ_{112}/Γ $C_{\rm cm}^{oment}$ $E_{\rm cm}^{ee} = 10 \; {\rm GeV}$ Γ_{113}/Γ $C_{\rm cm}^{oment}$ $E_{\rm cm}^{ee} = 10 \; {\rm GeV}$ $C_{\rm cm}^{oment} = 0 \; {\rm GeV}$ etc. • • • $E_{\rm cm}^{ee} = 10 \; {\rm GeV}$ $E_{\rm cm}^{ee} = 10 \; {\rm GeV}$ $E_{\rm cm}^{ee} = 10 \; {\rm GeV}$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	π $)/\Gamma_{total}$ of lepton family num 0^{-5} 90 do not use the follow 0^{-5} 90 0^{-5} 90 0^{-5}	ber conservation. DOCUMENT ID 143 BARTELT ing data for averages ALBRECHT BOWCOCK space decays. DOCUMENT ID 144 BARTELT ing data for averages ALBRECHT BOWCOCK space decays. December ID 145 BARTELT ing data for averages	94 94 95, fits, 90 94 94 95, fits, 90	CLEO limits, et ARG CLEO limits, et ARG CLEO	COMMENT $E_{cm}^{ee} = 9.4-10.6 \text{ Ge}^{e}$ etc. • • • $E_{cm}^{ee} = 10 \text{ GeV}$ $E_{cm}^{ee} = 10.4-10.9$ $E_{cm}^{ee} = 10.4-10.9$ COMMENT $E_{cm}^{ee} = 9.4-10.6 \text{ Ge}^{e}$ etc. • • • $E_{cm}^{ee} = 10 \text{ GeV}$ $E_{cm}^{ee} = 10.4-10.9$ $E_{cm}^{ee} = 10.4-10.9$ $E_{cm}^{ee} = 9.4-10.6 \text{ Ge}^{e}$ etc. • • •
0.94 × 10 ⁻⁵ • • We do not use 4.5 × 10 ⁻⁵ 6 BARTELT 94 as $(\pi^- \gamma)/\Gamma$ total Test of lepton LUE 28 × 10 ⁻⁵ $(\pi^- \pi^0)/\Gamma$ total Test of lepton LUE 37 × 10 ⁻⁵ (e - e + e -)/Γ _{tot} Test of lepton LUE 0.33 × 10 ⁻⁵ • • We do not use 1.3 × 10 ⁻⁵ 2.7 × 10 ⁻⁵ 40 × 10 ⁻⁵	// Total I family numbe	r conservation. DOCUMENT ID 136 BARTELT g data for average ALBRECHT DOCUMENT ID ALBRECHT ALBRECHT ALBRECHT ALBRECHT Troation. DOCUMENT ID ALBRECHT T conservation. DOCUMENT ID ALBRECHT g data for average ALBRECHT BOWCOCK HAYES	94 CLEO s, fits, limits, 92k ARG 92k ARG 7ECN 92k ARG 7ECN 92k ARG 92k ARG 94 CLEO cs, fits, limits, 92k ARG	$E_{\rm cm}^{ee} = 9.4 - 10.6 \text{ GeV}$ etc. • • • $E_{\rm cm}^{ee} = 10 \text{ GeV}$ Γ_{111}/Γ $\frac{COMMENT}{E_{\rm cm}^{ee}} = 10 \text{ GeV}$ Γ_{112}/Γ $\frac{COMMENT}{E_{\rm cm}^{ee}} = 10 \text{ GeV}$ Γ_{113}/Γ $\frac{COMMENT}{E_{\rm cm}^{ee}} = 9.4 - 10.6 \text{ GeV}$ etc. • • $E_{\rm cm}^{ee} = 10 \text{ GeV}$		π)/ Γ_{total} of lepton family num 0^{-5} 90 do not use the follow 0^{-5} 90 0^{-5} 90 0^{-5} 90 ELT 94 assume phase π)/ Γ_{total} of lepton number con 0^{-5}	ber conservation. DOCUMENT ID 143 BARTELT ing data for averages ALBRECHT BOWCOCK space decays. nservation. DOCUMENT ID 144 BARTELT ing data for averages ALBRECHT BOWCOCK space decays.	94 94 95, fits, 90 94 94 95, fits, 92 94 94 95, general paragraphic paragraphi	CLEO limits, et ARG CLEO CLEO CLEO CLEO CLEO CLEO CLEO CLEO	COMMENT $E_{\rm cm}^{\rm ee} = 9.4 - 10.6 {\rm Ge^{i}}$ etc. • • • $E_{\rm cm}^{\rm ee} = 10 {\rm GeV}$ $E_{\rm cm}^{\rm ee} = 10.4 - 10.9$ Γ_{12i} COMMENT $E_{\rm cm}^{\rm ee} = 9.4 - 10.6 {\rm Ge^{i}}$ etc. • • • $E_{\rm cm}^{\rm ee} = 10 {\rm GeV}$ $E_{\rm cm}^{\rm ee} = 10.4 - 10.9$ Γ_{12i} COMMENT $E_{\rm cm}^{\rm ee} = 10.4 - 10.9$ Γ_{12i} COMMENT $E_{\rm cm}^{\rm ee} = 9.4 - 10.6 {\rm Ge^{i}}$ etc. • • • $E_{\rm cm}^{\rm ee} = 10 {\rm GeV}$
μ - K *(892) ⁰)/ Test of lepton UE 1.94 × 10 ⁻⁵ 2.5 × 10 ⁻⁵ 2.6 ARTELT 94 as $π$ - $γ$)/ Ftotal Test of lepton UE 2.8 × 10 ⁻⁵ 2.8 × 10 ⁻⁵ 2.7 × 10 ⁻⁵ 2.7 × 10 ⁻⁵ 3.7 × 10 ⁻⁵ 3.8 × 10 ⁻⁵ 3.9 × 10 ⁻⁵ 3.1 × 10 ⁻⁵ 3.2 × 10 ⁻⁵ 3.3 × 10 ⁻⁵ 3.3 × 10 ⁻⁵ 3.3 × 10 ⁻⁵ 3.7 × 10 ⁻⁵ 3.7 × 10 ⁻⁵	// Total I family numbe	r conservation. DOCUMENT ID 136 BARTELT g data for average ALBRECHT DOCUMENT ID ALBRECHT ALBRECHT ALBRECHT ALBRECHT Troation. DOCUMENT ID ALBRECHT T conservation. DOCUMENT ID ALBRECHT g data for average ALBRECHT BOWCOCK HAYES	94 CLEO s, fits, limits, 92k ARG 92k ARG 7ECN 92k ARG 7ECN 92k ARG 92k ARG 94 CLEO cs, fits, limits, 92k ARG	$E_{\rm cm}^{ee} = 9.4 - 10.6 \; {\rm GeV}$ etc. • • • $E_{\rm cm}^{ee} = 10 \; {\rm GeV}$ Γ_{111}/Γ $C_{\rm cm}^{oment}$ $E_{\rm cm}^{ee} = 10 \; {\rm GeV}$ Γ_{112}/Γ $C_{\rm cm}^{oment}$ $E_{\rm cm}^{ee} = 10 \; {\rm GeV}$ Γ_{113}/Γ $C_{\rm cm}^{oment}$ $E_{\rm cm}^{ee} = 10 \; {\rm GeV}$ $C_{\rm cm}^{oment} = 0 \; {\rm GeV}$ etc. • • • $E_{\rm cm}^{ee} = 10 \; {\rm GeV}$ $E_{\rm cm}^{ee} = 10 \; {\rm GeV}$ $E_{\rm cm}^{ee} = 10 \; {\rm GeV}$		π)/ Γ_{total} of lepton family num 0^{-5} 90 do not use the follow 0^{-5} 90 0^{-5} 90 0^{-5} 90 ELT 94 assume phase π)/ Γ_{total} of lepton number con 0^{-5}	ber conservation. DOCUMENT ID 143 BARTELT ing data for averages ALBRECHT BOWCOCK space decays. 144 BARTELT ing data for averages ALBRECHT BOWCOCK space decays. 145 BARTELT ing data for averages ALBRECHT BOWCOCK Space decays.	94 94 95, fits, 90 94 94 95, fits, 92 94 94 95, general paragraphic paragraphi	CLEO limits, et ARG CLEO CLEO CLEO CLEO CLEO CLEO CLEO CLEO	COMMENT $E_{cm}^{ee} = 9.4-10.6 \text{ Ge}$ etc. • • • $E_{cm}^{ee} = 10 \text{ GeV}$ $E_{cm}^{ee} = 10.4-10.9$ $E_{cm}^{ee} = 10.4-10.9$ COMMENT $E_{cm}^{ee} = 9.4-10.6 \text{ Ge}$ etc. • • • $E_{cm}^{ee} = 10 \text{ GeV}$ $E_{cm}^{ee} = 10.4-10.9$ $E_{cm}^{ee} = 10.4-10.9$ $E_{cm}^{ee} = 10.4-10.9$ $E_{cm}^{ee} = 10.4-10.9$

rest or leptor	otal number conse	ervation.				Γ ₁₂₂ /Γ
<0.69 × 10 ⁻⁵	<u>CL%</u>	146 BARTELT		TECN	COMMENT	26.6-14
• • We do not us						J.b GeV
$< 6.3 \times 10^{-5}$	90	ALBRECHT		ARG		V
<3.9 × 10 ⁻⁵	90	BOWCOCK			$E_{\rm cm}^{ee} = 10.4-$	
46 BARTELT 94 a			,,,	CLLO	-cm- 10.1	
		Jace decays.				
$(e^-\pi^+K^-)/\Gamma_t$	otal					Γ ₁₂₃ /Γ
	n family numbe <u>CL%</u>	er conservation. DOCUMENT ID		TECN	COMMENT	
<0.77 × 10 ⁻⁵	90	147 BARTELT	94	CLEO	Eee = 9.4-1	0.6 GeV
• We do not us						
<2.9 × 10 ⁻⁵	90	ALBRECHT			Eee 10 Ge	V
<5.8 × 10 ⁻⁵	90	BOWCOCK			Eee = 10.4-	
47 BARTELT 94 a	ssume nhase sr	ace decays			CIII	
		acc decays.				
$(e^-\pi^-K^+)/\Gamma_t$	otal					Γ ₁₂₄ /Γ
lest of leptor ALUE	ramiiy numbe	er conservation. <u>DOCUMENT ID</u>		TECN	COMMENT	
<0.46 × 10 ⁻⁵	90 1	48 BARTELT	94	CLEO	$E_{cm}^{ee} = 9.4-10.$	6 GeV
• We do not us						
<5.8 × 10 ⁻⁵	90	BOWCOCK	90	CLEO	$E_{\rm cm}^{ee} = 10.4-10$).9
48 BARTELT 94 a	ssume phase sr	nace decays.				
		acc acceyo.				
$(e^+\pi^-K^-)/\Gamma_t$	o tal n number conse	mustion				Γ ₁₂₅ /Γ
AI UF	CL%	DOCUMENT ID		TECN	COMMENT	
<0.45 × 10 ⁻⁵	90	149 BARTELT	94	CLEO	$E_{cm}^{ee} = 9.4-10$	0.6 GeV
• • We do not us						
$< 2.0 \times 10^{-5}$	90	ALBRECHT	92K	ARG	$E_{\rm cm}^{ee} = 10$ Ge	V
$< 4.9 \times 10^{-5}$	90	BOWCOCK			Ecm = 10.4-	
49 BARTELT 94 as	ssume phase sp	ace decays.				
		•				- /-
$(\mu^-\pi^+K^-)/\Gamma_1$	total	er conservation.				Γ ₁₂₆ /Γ
ALUE	CL%	DOCUMENT ID		TECN	COMMENT	
< 0.87 × 10 ⁻⁵	90	150 BARTELT	94	CLEO	Eee = 9.4-1	0.6 GeV
• • We do not us	se the following					
<11 × 10 ⁻⁵	90	ALBRECHT		ARG	$E_{cm}^{ee} = 10 \text{ Ge}$	V
	90 90	ALBRECHT BOWCOCK	92K		E_{Cm}^{ee} = 10 Ge E_{Cm}^{ee} = 10.4-	
$< 11 \times 10^{-5}$ $< 7.7 \times 10^{-5}$ = 50 BARTELT 94 as	90	BOWCOCK	92K			
< 7.7 × 10 ⁻⁵ 50 BARTELT 94 as	90 ssume phase sp	BOWCOCK	92K			10.9
$< 7.7 imes 10^{-5}$ 50 BARTELT 94 as $^{6}(\mu^{-}\pi^{-}K^{+})/\Gamma_{1}$	90 ssume phase sp t otal	BOWCOCK pace decays.	92K 90	CLEO	E ^{ee} _{cm} = 10.4-	
$<7.7 \times 10^{-5}$ 50 BARTELT 94 a: $(\mu^-\pi^-K^+)/\Gamma_1$ Test of lepton	90 ssume phase sp t otal n family numbe 	BOWCOCK pace decays. er conservation. DOCUMENT ID	92K 90	CLEO TECN	Eem = 10.4-	^{10.9} Г ₁₂₇ /Г
$< 7.7 \times 10^{-5}$ 50 BARTELT 94 a: $(\mu^{-}\pi^{-}K^{+})/\Gamma_{1}$ Test of leptor ALUE $< 1.5 \times 10^{-5}$	90 ssume phase sp total family numbe	BOWCOCK pace decays. er conservation. DOCUMENT ID 51 BARTELT	92K 90	CLEO TECN CLEO	$E_{\text{cm}}^{ee} = 10.4 - \frac{COMMENT}{E_{\text{cm}}^{ee}} = 9.4 - 10.$	^{10.9} Г ₁₂₇ /Г
$< 7.7 \times 10^{-5}$ 50 BARTELT 94 a: $(\mu^{-}\pi^{-}K^{+})/\Gamma_{1}$ Test of leptor ALUE $< 1.5 \times 10^{-5}$ • • We do not us	90 ssume phase sp total family numbe	BOWCOCK pace decays. or conservation. <u>DOCUMENT ID</u> 51 BARTELT g data for average	92K 90	CLEO TECN CLEO	$E_{\text{cm}}^{ee} = 10.4 - \frac{COMMENT}{E_{\text{cm}}^{ee}} = 9.4 - 10.$	^{10.9} Г ₁₂₇ /Г
$< 7.7 \times 10^{-5}$ 50 BARTELT 94 a: $(\mu^{-}\pi^{-}K^{+})/\Gamma_{1}$ Test of leptor ALUE $< 1.5 \times 10^{-5}$ • • We do not us	90 ssume phase sp total family numbe	BOWCOCK pace decays. er conservation. DOCUMENT ID 51 BARTELT	92K 90 94 94 (ss, fits,	CLEO TECN CLEO limits,	$E_{\text{cm}}^{ee} = 10.4 - \frac{COMMENT}{E_{\text{cm}}^{ee}} = 9.4 - 10.$	Γ ₁₂₇ /Γ
(7.7×10^{-5}) 50 BARTELT 94 a: $(\mu^-\pi^-K^+)/\Gamma_1$ Test of leptor ALUE (1.5×10^{-5}) • • We do not us (7.7×10^{-5})	90 ssume phase sp total n family numbe	BOWCOCK or conservation. DOCUMENT ID 51 BARTELT g data for average BOWCOCK	92K 90 94 94 (ss, fits,	CLEO TECN CLEO limits,	$E_{\text{cm}}^{ee} = 10.4 - \frac{COMMENT}{E_{\text{cm}}^{ee}} = 9.4 - 10.$ etc. • • •	Γ ₁₂₇ /Γ
(7.7×10^{-5}) 50 BARTELT 94 a: $(\mu^-\pi^-K^+)/\Gamma_1$ Test of leptor ALUE $<1.5 \times 10^{-5}$ • • We do not us $<7.7 \times 10^{-5}$ 51 BARTELT 94 as	90 ssume phase sp total family numbe CL% 90 1 se the following 90 ssume phase sp	BOWCOCK or conservation. DOCUMENT ID 51 BARTELT g data for average BOWCOCK	92K 90 94 94 (ss, fits,	CLEO TECN CLEO limits,	$E_{\text{cm}}^{ee} = 10.4 - \frac{COMMENT}{E_{\text{cm}}^{ee}} = 9.4 - 10.$ etc. • • •	Γ ₁₂₇ /Γ 6 GeV
$< 7.7 \times 10^{-5}$ 50 BARTELT 94 a: $(\mu^-\pi^-K^+)/\Gamma_1$ Test of leptor ALUE $< 1.5 \times 10^{-5}$ • • We do not us $< 7.7 \times 10^{-5}$ 51 BARTELT 94 a: $(\mu^+\pi^-K^-)/\Gamma_1$	90 ssume phase sp total n family numbe	BOWCOCK or conservation. DOCUMENT ID BARTELT g data for average BOWCOCK or decays.	92K 90 94 94 (ss, fits,	CLEO TECN CLEO limits,	$E_{\text{cm}}^{ee} = 10.4 - \frac{COMMENT}{E_{\text{cm}}^{ee}} = 9.4 - 10.$ etc. • • •	Γ ₁₂₇ /Γ
$<7.7 \times 10^{-5}$ 50 BARTELT 94 at $(\mu^-\pi^-K^+)/\Gamma_1$ Test of leptor ALUE $<1.5 \times 10^{-5}$ • • We do not us $<7.7 \times 10^{-5}$ BARTELT 94 at $<1.5 \times 10^{-5}$ Test of leptor ALUE	90 ssume phase sp total I family numbe CL% 90 1 se the following 90 sssume phase sp	BOWCOCK crossed decays. From conservation. POCUMENT ID ST BARTELT g data for average BOWCOCK coace decays. From DOCUMENT ID	92K 90 94 (s, fits, 90 (TECN CLEO limits, CLEO	$E_{\text{cm}}^{ee} = 10.4 - 10.4$	Γ ₁₂₇ /Γ 6 GeV 0.9
$(7.7 \times 10^{-5})^{50}$ BARTELT 94 a: $(\mu^-\pi^-K^+)/\Gamma_1$ Test of leptor ALUE $(1.5 \times 10^{-5})^{60}$ • • We do not use $(7.7 \times 10^{-5})^{61}$ BARTELT 94 as $(\mu^+\pi^-K^-)/\Gamma_1$ Test of leptor ALUE	90 ssume phase sp total n family numbe	BOWCOCK concerded by the conservation. DOCUMENT ID 51 BARTELT 3 data for average BOWCOCK bace decays.	92K 90 94 (s, fits, 90 (TECN CLEO limits, CLEO	$E_{\text{CM}}^{ee} = 10.4 - 10.4$	Γ ₁₂₇ /Γ 6 GeV 0.9
$<7.7 \times 10^{-5}$ 50 BARTELT 94 at $(\mu^-\pi^-K^+)/\Gamma_1$ Test of leptor ALUE $<1.5 \times 10^{-5}$ • • We do not us $<7.7 \times 10^{-5}$ BARTELT 94 at $=1.5 \times 10^{-5}$ Test of leptor ALUE $<2.0 \times 10^{-5}$	90 ssume phase sp total In family number CL% 90 1 se the following 90 ssume phase sp total 1 number conse CL% 90	BOWCOCK pace decays. er conservation. <u>DOCUMENT ID</u> 51 BARTELT g data for average BOWCOCK pace decays. ervation. <u>DOCUMENT ID</u> 152 BARTELT	92K 90 94 94 90	TECN CLEO Imits, CLEO	$E_{\text{cm}}^{ee} = 10.4 - 10.4$	Γ ₁₂₇ /Γ 6 GeV 0.9
$<7.7 \times 10^{-5}$ 50 BARTELT 94 at $(\mu^-\pi^-K^+)/\Gamma_1$ Test of leptor ALUE $<1.5 \times 10^{-5}$ • • We do not use $<7.7 \times 10^{-5}$ 51 BARTELT 94 at $<\mu^+\pi^-K^-)/\Gamma_1$ Test of leptor ALUE $<2.0 \times 10^{-5}$ • • We do not use $<2.0 \times 10^{-5}$	90 ssume phase sp total In family number CL% 90 1 se the following 90 ssume phase sp total 1 number conse CL% 90	BOWCOCK pace decays. er conservation. <u>DOCUMENT ID</u> 51 BARTELT g data for average BOWCOCK pace decays. ervation. <u>DOCUMENT ID</u> 152 BARTELT	92K 90 94 (ss, fits, 90 (TECN CLEO Imits, CLEO	$E_{\text{cm}}^{ee} = 10.4 - 10.4$	Γ ₁₂₇ /Γ 6 GeV 0.9 Γ ₁₂₈ /Γ 0.6 GeV
$< 7.7 \times 10^{-5}$ 50 BARTELT 94 at 16 ($\mu - \pi - K^+$)/ Γ_1 Test of leptor ALUE 1.15 × 10 ⁻⁵ • • We do not us $< 7.7 \times 10^{-5}$ BARTELT 94 at 16 ($\mu + \pi - K^-$)/ Γ_1 Test of leptor ALUE 2.00 × 10 ⁻⁵ • • We do not us $< 5.8 \times 10^{-5}$	90 ssume phase sp total 1 family number	BOWCOCK pace decays. or conservation. <u>POCUMENT ID</u> 51 BARTELT g data for average BOWCOCK pace decays. or conservation. <u>DOCUMENT ID</u> 152 BARTELT g data for average	92K 90 94 6 95, fits, 90 6	TECN CLEO limits, CLEO TECN CLEO limits, ARG	$E_{\text{cm}}^{ee} = 10.4 - 10.4$	Γ ₁₂₇ /Γ 6 GeV 0.9 Γ ₁₂₈ /Γ 0.6 GeV
$<7.7 \times 10^{-5}$ $<7.7 \times 10^{-5}$ $<10 \text{MARTELT} = 94 \text{ as}$ $<10 \text{Marten} = 10^{-5}$ $<10 \text{Marten} = 1$	90 ssume phase sp total i family number	BOWCOCK pace decays. er conservation. <u>DOCUMENT ID</u> 51 BARTELT g data for average BOWCOCK pace decays. ervation. <u>DOCUMENT ID</u> 152 BARTELT g data for average ALBRECHT BOWCOCK	92K 90 94 6 95, fits, 90 6	TECN CLEO limits, CLEO TECN CLEO limits, ARG	$E_{\text{CM}}^{ee} = 10.4 - 10.4$	Γ ₁₂₇ /Γ 6 GeV 0.9 Γ ₁₂₈ /Γ 0.6 GeV
$<7.7 \times 10^{-5}$ 50 BARTELT 94 at $(\mu^-\pi^-K^+)/\Gamma_1$ Test of leptor ALUE $<1.5 \times 10^{-5}$ • • We do not us $<7.7 \times 10^{-5}$ BARTELT 94 at $<1.5 \times 10^{-5}$ Test of leptor ALUE $<2.0 \times 10^{-5}$ • • We do not us $<2.0 \times 10^{-5}$ • • We do not us $<2.0 \times 10^{-5}$ • • We do not us $<2.0 \times 10^{-5}$ $<3.0 \times 10^{-5}$ $<4.0 \times 10^{-5}$ 52 BARTELT 94 at $<3.0 \times 10^{-5}$	90 ssume phase sp total i family number	BOWCOCK pace decays. er conservation. <u>DOCUMENT ID</u> 51 BARTELT g data for average BOWCOCK pace decays. ervation. <u>DOCUMENT ID</u> 152 BARTELT g data for average ALBRECHT BOWCOCK	92K 90 94 6 95, fits, 90 6	TECN CLEO limits, CLEO TECN CLEO limits, ARG	$E_{\text{CM}}^{ee} = 10.4 - 10.4$	F ₁₂₇ /F 6 GeV 0.9 F ₁₂₈ /F 0.6 GeV
$<7.7 \times 10^{-5}$ $<7.7 \times 10^{-5}$ $<10 \text{MARTELT 94 a:}$ $<10 \text{Marten Melon of leptor}$ $<1.5 \times 10^{-5}$ $<1.5 \times 10^{-5$	90 ssume phase sp total I family number	BOWCOCK pace decays. er conservation. DOCUMENT ID 51 BARTELT g data for average BOWCOCK pace decays. ervation. DOCUMENT ID 152 BARTELT g data for average ALBRECHT BOWCOCK pace decays.	92K 90 94 (6 95, s, fits, 90 94 95, s, fits, 92K 90	TECN CLEO limits, CLEO CLEO limits, ARG CLEO	$E_{\text{CM}}^{ee} = 10.4 - 10.4$	Γ ₁₂₇ /Γ 6 GeV 0.9 Γ ₁₂₈ /Γ 0.6 GeV
$<7.7 \times 10^{-5}$ 50 BARTELT 94 at 250 BARTELT 94 at 26 feptor ALUE 1.5 × 10 ⁻⁵ • • We do not us $<7.7 \times 10^{-5}$ 51 BARTELT 94 at 26 feptor ALUE 2.0 × 10 ⁻⁵ • • We do not us $<5.8 \times 10^{-5}$ • • We do not us $<5.8 \times 10^{-5}$ 52 BARTELT 94 at 26 feptor ALUE 7 Test of leptor ALUE 7 Test of leptor Test of leptor ALUE 7 Test of leptor ALUE	90 ssume phase sp total I family number	BOWCOCK pace decays. er conservation. <u>DOCUMENT ID</u> 51 BARTELT g data for average BOWCOCK pace decays. ervation. <u>DOCUMENT ID</u> 152 BARTELT g data for average ALBRECHT BOWCOCK	92k 90 94 94 95 90 94 95 90 90 90 90 90	CLEO TECN CLEO TECN CLEO limits, CLEO limits, ARG CLEO	$E_{\text{cm}}^{ee} = 10.4 - 10.4$	F ₁₂₇ /F 6 GeV 0.9 F ₁₂₈ /F 0.6 GeV
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$(7.7 \times 10^{-5})^{50}$ BARTELT 94 a: $(\mu - \pi - K^{+})/\Gamma_{1}$ Test of leptor 4.105 • • We do not us $(7.7 \times 10^{-5})^{51}$ BARTELT 94 a: $(\mu + \pi - K^{-})/\Gamma_{1}$ Test of leptor 4.105 • • We do not us $(5.8 \times 10^{-5})^{52}$ SARTELT 94 a: $(5.8 \times 10^{-5})^{52}$ BARTELT 94 a: $(77)/\Gamma_{1}$ Test of leptor 4.105 $(77)/\Gamma_{2}$ Test of leptor 4.106 $(77)/\Gamma_{3}$ Test of leptor 4.106 $(77)/\Gamma_{3}$ Test of leptor 4.106 $(77)/\Gamma_{3}$	90 ssume phase sp total In family number CL% 90 1 see the following 90 ssume phase sp total number conse CL% 90 90 see the following 90 90 ssume phase sp	BOWCOCK concervation. DOCUMENT ID To data for average BOWCOCK concervation. DOCUMENT ID To data for average ALBRECHT BOWCOCK concervation. BOWCOCK concerv	94 (90) 94 (90) 94 (90) 94 (90) 94 (90) 94 (90) 94 (90)	CLEO TECN CLEO Ilmits, CLEO Ilmits, ARG CLEO	$E_{\text{cm}}^{ee} = 10.4 - 10.4$	Γ ₁₂₇ /Γ 6 GeV 0.9 Γ ₁₂₈ /Γ 0.6 GeV V 10.9
$< 7.7 \times 10^{-5}$ 50 BARTELT 94 a: $(\mu^-\pi^-K^+)/\Gamma_1$ Test of leptor ALUE $< 1.5 \times 10^{-5}$ $< 1.5 \times 1$	90 ssume phase sp total Infamily number CL% 90 1 see the following 90 ssume phase sp total In number conse CL% 90 see the following 90 90 ssume phase sp in number and the CL% 90	BOWCOCK pace decays. or conservation. DOCUMENT ID data for average BOWCOCK pace decays. ervation. DOCUMENT ID data for average ALBRECHT BOWCOCK pace decays. paryon number co DOCUMENT ID ALBRECHT	94 (90 94 94 95 95 95 95 95 95 95 95 95 95 95 95 95	TECN CLEO IImits, CLEO CLEO CLEO CLEO CLEO CLEO CLEO CLEO	$E_{\text{cm}}^{ee} = 10.4 - 10.4$	Γ ₁₂₇ /Γ 6 GeV 0.9 Γ ₁₂₈ /Γ 0.6 GeV V 10.9
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$<7.7 \times 10^{-5}$ $>50 \text{ BARTELT 94 a:}$ $(\mu - \pi - K^+)/\Gamma_1$ Test of leptor $<1.5 \times 10^{-5}$ $•• \text{ We do not u:}$ $<7.7 \times 10^{-5}$ $>51 \text{ BARTELT 94 a:}$ $<1.6 \times 10^{-5}$ $>52 \text{ BARTELT 94 a:}$ $<2.0 \times 10^{-5}$ $<2.0 \times 10^{-5}$ $<3.0 \times 10^{$	90 ssume phase sp total Infamily number CL% 90 1 see the following 90 ssume phase sp total In number conse CL% 90 see the following 90 90 ssume phase sp	BOWCOCK pace decays. or conservation. DOCUMENT ID data for average BOWCOCK pace decays. ervation. DOCUMENT ID data for average ALBRECHT BOWCOCK pace decays. paryon number co DOCUMENT ID ALBRECHT	92K 90 94 0 94 0 95 97 99 0 96 99 99 99 99 99 99 99 99 99 99 99 99 9	CLEO CLEO Ilimits, CLEO Ilimits, ARG CLEO Linits, ARG CLEO Linits, ARG CLEO	$E_{\text{cm}}^{ee} = 10.4 - 10.4$	Γ ₁₂₇ /Γ 6 GeV 0.9 Γ ₁₂₈ /Γ 0.6 GeV V 10.9 Γ ₁₂₉ /Γ
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$<7.7 \times 10^{-5}$ <50 BARTELT 94 a: $(\mu - \pi - K^+)/\Gamma_1$ Test of leptor ALUE 1.5 × 10 ⁻⁵ • • We do not us $<7.7 \times 10^{-5}$ 15 BARTELT 94 a: $(\mu + \pi - K^-)/\Gamma_1$ Test of leptor ALUE $<2.0 \times 10^{-5}$ • • We do not us $<5.8 \times 10^{-5}$ $<4.0 \times 10^{-5}$ 15 BARTELT 94 a: $<(\rho \gamma)/\Gamma_1$ Test of leptor ALUE $<29 \times 10^{-5}$ Test of leptor ALUE $<29 \times 10^{-5}$ Test of leptor ALUE $<266 \times 10^{-5}$	90 ssume phase sp total I family number CL% 90 1 see the following 90 ssume phase sp total I number conse CL% 90 90 ssume phase sp total 1 number and to CL% 90 n number and to CL% 90	BOWCOCK pace decays. or conservation. DOCUMENT ID 51 BARTELT g data for average BOWCOCK pace decays. ervation. DOCUMENT ID 152 BARTELT g data for average ALBRECHT BOWCOCK pace decays. oaryon number co DOCUMENT ID ALBRECHT Daryon number co DOCUMENT ID ALBRECHT DALBRECHT	92K 2	CLEO TTECN CLEO Ilimits, CLEO Ilimits, ARG CLEO ARG ARG ARG	$E_{\text{CM}}^{\text{ee}} = 10.4 - E_{\text{CM}}^{\text{ee}} = 10.4 - E_{\text{CM}}^{\text{ee}} = 9.4 - 10.4 - E_{\text{CM}}^{\text{ee}} = 10.4 - 10.4 - E_{\text{CM}}^{\text{ee}} = 10.4 - E_{C$	Γ ₁₂₇ /Γ 6 GeV 0.9 Γ ₁₂₈ /Γ 0.6 GeV V 10.9 Γ ₁₂₉ /Γ
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$< 7.7 \times 10^{-5}$ $> 50 \text{ BARTELT 94 a:}$ $(\mu^-\pi^-K^+)/\Gamma_1$ Test of leptor $< 1.5 \times 10^{-5}$ $< 1.5 $	90 ssume phase sp total I family number	BOWCOCK pace decays. For conservation, DOCUMENT ID To data for average BOWCOCK pace decays. For a data for average BOWCOCK pace decays. For a data for average ALBRECHT BOWCOCK pace decays. For a data for average ALBRECHT DOCUMENT ID ALBRECHT DOCUMENT ID ALBRECHT DOCUMENT ID ALBRECHT DOCUMENT ID ALBRECHT DOCUMENT ID ALBRECHT DOCUMENT ID ALBRECHT DOCUMENT ID ALBRECHT	94 0 94 94 94 95 95 95 95 95 95 95 95 95 95 95 95 95	TECN CLEO TECN CLEO Iimits, CLEO CLEO Iimits, ARG CLEO ARG ARG tion. TECN ARG	$E_{\text{cm}}^{\text{ee}} = 10.4 - 1$	Γ ₁₂₇ /Γ 6 GeV 0.9 Γ ₁₂₈ /Γ 0.6 GeV V 10.9 Γ ₁₂₉ /Γ
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$\Gamma(\mu^-\overline{K}^*(892)^0)$	Γ _{total}				Γ ₁₃₃ /Γ
VALUE	CL%	DOCUMENT ID			
<0.87 × 10 ⁻⁵	90	154 BARTELT	94	CLEO	Ecm = 9.4-10.6 GeV
¹⁵⁴ BARTELT 94 as	sume phase	e space decays.			
Γ(e ⁻ light boson) Test of lepton		$ u_{ au}$) ber conservation.			Γ ₁₃₄ /Γ ₅
VALUE		DOCUMENT ID		TECN	COMMENT
<0.015	95	¹⁵⁵ ALBRECHT	95G	ARG	Eee = 9.4-10.6 GeV
• • We do not us	e the follow	ing data for averag	es, fits	, limits,	etc. • • •
< 0.018	95	156 ALBRECHT	90E	ARG	$E_{cm}^{ee} = 9.4-10.6 \text{ GeV}$
< 0.040	95	157 BALTRUSAIT			
for a mass of 1.0 .56 ALBRECHT 90E 0.050 for mass =	ilimit holds GeV, then limit appli 500 MeV.	falls to 0.006 at th ies for spinless boso	e uppe on wit	er mass h mass	limit of 1.6 GeV. < 100 MeV, and rises to
for a mass of 1.0 $^{1.56}$ ALBRECHT 90E $^{0.050}$ for mass = $^{1.57}$ BALTRUSAITIS $^{-}$ (μ^{-} light boson)	i limit holds GeV, then I limit appli 500 MeV. 85 limit ap	falls to 0.006 at the dies for spinless boson plies for spinless booton ν_{τ})	e uppe on wit	er mass h mass	limit of 1.6 GeV. $<$ 100 MeV, and rises to $s<$ 100 MeV.
for a mass of 1.0 1.56 ALBRECHT 90E 0.050 for mass = .57 BALTRUSAITIS (\(\mu^{-1}\) light boson) Test of lepton	ilimit holds GeV, then Ilimit appli 500 MeV. 85 limit ap / \(e^-\overline{\nu}_e family num	falls to 0.006 at the dies for spinless boson polices for spinless bootons ν_{τ}) abore conservation.	e uppe on wit son wi	er mass h mass ith mass	limit of 1.6 GeV. $<$ 100 MeV, and rises to $<$ 100 MeV. Γ_{135}/Γ_{5}
for a mass of 1.0 1.56 ALBRECHT 90E 0.050 for mass = 1.57 BALTRUSAITIS (μ - light boson) Test of lepton ΔΑLUE	i limit holds GeV, then I limit appli 500 MeV. 85 limit ap	falls to 0.006 at the first for spinless boson polices for spinless boson polices for spinless boson polices for spinless boson polices. The first form ν_{τ}	e uppe on wit	er mass h mass ith mass <u>TECN</u>	limit of 1.6 GeV. $<$ 100 MeV, and rises to $<$ 100 MeV. Γ_{135}/Γ_{E}
156 ALBRECHT 90E 0.050 for mass = 157 BALTRUSAITIS (μ - light boson) Test of lepton MALUE <0.026	ilimit holds GeV, then Ilimit appli 500 MeV. 85 limit ap / \(\begin{align*} \be	falls to 0.006 at the dies for spinless boson polices for spinless boson polices for spinless boson polices for conservation. DOCUMENT ID 158 ALBRECHT	e uppe on wit son wi	er mass h mass ith mass TECN ARG	limit of 1.6 GeV. $<$ 100 MeV, and rises to $6 <$ 100 MeV. Γ_{135}/Γ_{5} $\frac{COMMENT}{E_{CM}^{e}} = 9.4 - 10.6 \text{ GeV}$
for a mass of 1.0 1.56 ALBRECHT 90E 0.050 for mass = 1.57 BALTRUSAITIS $\Gamma(\mu^{-} \text{ light boson})$	ilimit holds GeV, then Ilimit appli 500 MeV. 85 limit ap / \(\begin{align*} \be	falls to 0.006 at the dies for spinless boson polices for spinless boson polices for spinless boson polices for conservation. 158 ALBRECHT polices for average data for average for spinless for spinl	e uppe on wit son wi 95G es, fits	er mass h mass ith mass <u>TECN</u> ARG s, limits,	< 100 MeV, and rises to $s < 100$ MeV. $ \Gamma_{135}/\Gamma_5 $ $ \frac{COMMENT}{E_{cm}^{e}=9.4-10.6 \text{ GeV}} $ etc. • • •
for a mass of 1.0. 56 ALBRECHT 90E 0.050 for mass = 57 BALTRUSAITIS (μ - light boson) Test of lepton ALUE <0.026 • • • We do not us	ilimit holds of GeV, then ilimit applies 500 MeV. 85 limit applies $\Gamma(e^- \overline{\nu}_e)$ family num $\Gamma(e^- \overline{\nu}_e)$ 6 the follows	falls to 0.006 at the files for spinless boson poles for spinless for spin	e uppe on wit son wi 95G es, fits	er mass h mass ith mass TECN ARG i, limits,	limit of 1.6 GeV. $<$ 100 MeV, and rises to $6 <$ 100 MeV. Γ_{135}/Γ_{E} $\frac{COMMENT}{E_{CM}^{e}} = 9.4 - 10.6 \text{ GeV}$

au-DECAY PARAMETERS

Neglecting radiative corrections and terms proportional to m_ℓ^2/m_τ^2 , the energy spectrum of the charged decay lepton ℓ in the τ rest frame is given by

$$\frac{d^2\Gamma_{\tau \to \ell \nu \overline{\nu}}}{d\Omega \, dx} \propto x^2$$

$$\times \left\{ 12(1-x) + \rho_{\tau} \left(\frac{32}{3}x - 8 \right) + 24\eta_{\tau} \, \frac{m_{\ell}}{m_{\tau}} \, \frac{(1-x)}{x} \right.$$

$$\left. -P_{\tau} \, \xi_{\tau} \cos \theta \, \left[4(1-x) + \delta_{\tau} \left(\frac{32}{3}x - 8 \right) \right] \right\} . \tag{1}$$

Here $x=2E_\ell/m_\tau$ is the scaled lepton energy, P_τ is the τ polarization, and θ is the angle between the τ spin and the lepton momentum. With unpolarized τ 's or integrating over the full θ range, the spectrum depends only on ρ_τ and η_τ . Measurements of the other two Michel parameters, ξ_τ and δ_τ , require polarized τ 's. The Standard Model predictions for ρ_τ , η_τ , ξ_τ and δ_τ are $\frac{3}{4}$, 0, 1 and $\frac{3}{4}$. Where possible, we give separately the parameters for $\tau^- \to e^- \nu_\tau \overline{\nu}_e$ and $\tau^- \to \mu^- \nu_\tau \overline{\nu}_\mu$, to avoid assumptions about universality. Listings labelled "(e or μ)" contain either the results assuming lepton universality if quoted by the experiments or repeat the results from the "e" or " μ " section.

Hadronic two-body decays $\tau \to \nu_{\tau} h, \ h = \pi, \ \rho, \ a_1, \ \ldots$, can under minimal assumptions be written

$$\frac{1}{\Gamma} \frac{d\Gamma}{dz} = f_h(z) + P_\tau \, \xi_h \, g_h(z) \, , \qquad (2)$$

where the kinematic functions f_h , g_h and the definition of the variable z depend on the spin of the hadron h. For the simple case $h=\pi$, one has $z=E_\pi/E_\tau$, f(z)=1, and g(z)=2z-1. The parameter ξ_h is predicted to be unity and can be identified with twice the negative ν_τ helicity. Again ξ_h is listed, when available, separately for each hadron and averaged over all hadronic decays modes.

 τ

ρ^{T} (e or μ) PARAMETER	$(\delta \xi)^{T}(\mathbf{e} \text{ or } \mu)$ PARAMETER $(V-A)$ theory predicts $(\delta \xi) = 0.75$.
(V-A) theory predicts $ ho=0.75$. <u>VALUE</u> <u>EVTS</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u>	VALUE DOCUMENT ID TECN COMMENT
0.742±0.027 OUR AVERAGE	0.76±0.11 OUR AVERAGE Error includes scale factor of 1.3.
0.738 ± 0.038 161 ALBRECHT 95C ARG $E_{\text{cm}}^{ee} = 9.5 - 10.6 \text{ GeV}$	0.65±0.12
$0.751 \pm 0.039 \pm 0.022$ BUSKULIC 95D ALEP 1990–1992 LEP runs 0.79 $\pm 0.10 \pm 0.10$ 3732 FORD 87B MAC $E_{\rm cm}^{\rm ee}=29~{\rm GeV}$	0.88±0.11±0.07 BUSKULIC 95D ALEP 1990–1992 LEP runs
$0.71 \pm 0.09 \pm 0.03$ 1426 BEHRENDS 85 CLEO e^+e^- near $\Upsilon(4S)$	167 Combined fit to ARGUS tau decay parameter measurements in ALBRECHT 95c, ALBRECHT 93G, and ALBRECHT 94E. ALBRECHT 95c uses events of the type $ au^- au^+$ $ o$
• • • We do not use the following data for averages, fits, limits, etc. • •	$(\ell^- \overline{\nu}_\ell \nu_\tau)$ ($\hbar^+ h^- h^+ \overline{\nu}_\tau$) and their charged conjugates.
$0.732 \pm 0.034 \pm 0.020$ 8.2k 162 ALBRECHT 95 ARG $E_{\rm CM}^{\it ee} = 9.5 - 10.6$ GeV	
0.742±0.035±0.020 8000 ALBRECHT 90E ARG $E_{\text{CM}}^{\text{ee}}$ 9.4–10.6 GeV	$(\delta \xi)^{T}(e)$ PARAMETER
161 Combined fit to ARGUS tau decay parameter measurements in ALBRECHT 95c, AL-	$(V-A)$ theory predicts $(\delta \xi)=0.75$. VALUE DOCUMENT ID TECN COMMENT
BRECHT 93G, and ALBRECHT 94E.	1.11±0.17±0.07 BUSKULIC 95D ALEP 1990-1992 LEP runs
Value is from a simultaneous fit for the ρ^{τ} and η^{τ} decay parameters to the lepton energy	(4)7() 7.7.4(7)77
spectrum. Not independent of ALBRECHT 90E $ ho^{ au}(e \text{ or } \mu)$ value which assumes $\eta^{ au}$ =0. Result is strongly correlated with ALBRECHT 95C.	$(\delta \xi)^{T}(\mu)$ PARAMETER
•	$(V-A)$ theory predicts $(\delta \xi)=0.75$. VALUE DOCUMENT ID TECN COMMENT
ρ ^T (e) PARAMETER	0.71±0.14±0.06 BUSKULIC 95D ALEP 1990-1992 LEP runs
(V-A) theory predicts $ ho=0.75$. VALUEEVTSDOCUMENT IDTECNCOMMENT	ATT A PARAMETER
0.736±0.028 OUR AVERAGE	$\xi^{\tau}(\pi)$ PARAMETER
$0.735 \pm 0.036 \pm 0.020$ 4.7k 163 ALBRECHT 95 ARG $E_{ ext{cm}}^{ee} = 9.5 - 10.6$ GeV	$(V-A)$ theory predicts $\xi^{\mathcal{T}}(\pi)=1$. VALUE DOCUMENT ID TECN COMMENT
0.793±0.050±0.025 BUSKULIC 95D ALEP 1990–1992 LEP runs	0.987±0.057±0.027 BUSKULIC 95D ALEP 1990-1992 LEP runs
$0.79 \pm 0.08 \pm 0.06$ 3230 ¹⁶⁴ ALBRECHT 93G ARG $E_{\text{cm}}^{\text{ee}} = 9.4-10.6 \text{ GeV}$	
0.64 $\pm 0.06 \pm 0.07$ 2753 JANSSEN 89 CBAL $E_{\text{CM}}^{ee} = 9.4 - 10.6 \text{ GeV}$	0.95 \pm 0.11 \pm 0.05
0.62 $\pm 0.17 \pm 0.14$ 1823 FORD 87B MAC $E_{\text{CM}}^{\text{ee}} = 29 \text{ GeV}$	¹⁶⁸ Superseded by BUSKULIC 95D.
0.60 \pm 0.13 699 BEHRENDS 85 CLEO e^+e^- near $\Upsilon(4S)$ 0.72 \pm 0.10 \pm 0.11 594 BACINO 79B DLCO $E^{ee}_{Cm}=3.5$ -7.4 GeV	
• • • We do not use the following data for averages, fits, limits, etc. • •	$\xi^{\tau}(\rho)$ PARAMETER
0.747 ± 0.045 ± 0.028 5106 ALBRECHT 90E ARG Repl. by ALBRECHT 95	$(V-A)$ theory predicts $\xi^{ au}(ho)=1$.
1. 1	1.045±0.058±0.032 BUSKULIC 95D ALEP 1990-1992 LEP runs
¹⁶³ ALBRECHT 95 use tau pair events of the type $\tau^-\tau^+ \rightarrow (\ell^-\overline{\nu}_\ell\nu_\tau)$ $(h^+h^-h^+(\pi^0)\overline{\nu}_\tau)$ and their charged conjugates.	
$(n+n+n+(\pi^+)\nu_{\tau})$ and their charged conjugates. 164 ALBRECHT 93G use tau pair events of the type $\tau^-\tau^+ \to (\mu^-\overline{\nu}_{\mu}\nu_{\tau}) (e^+\nu_e\overline{\nu}_{\tau})$ and	1.03 ±0.11 ±0.05
their charged conjugates.	¹⁶⁹ Superseded by BUSKULIC 95D.
$\rho^{\tau}(\mu)$ PARAMETER	$\xi^{\tau}(a_1)$ PARAMETER
(V-A) theory predicts $ ho=0.75$. VALUE	$(V-A)$ theory predicts $\xi^{\tau}(a_1)=1$.
0.74 ±0.04 OUR AVERAGE	1.01 ±0.04 OUR AVERAGE
0.693±0.057±0.028 BUSKULIC 95D ALEP 1990-1992 LEP runs	
0.76 ± 0.07 ± 0.08 3230 ALBRECHT 93G ARG $E_{\sf cm}^{\it ee} = 9.4$ –10.6 GeV	-0.41 -0.25
$0.734 \pm 0.055 \pm 0.027$ 3041 ALBRECHT 90E ARG $E_{\text{cm}}^{ee} = 9.4 - 10.6 \text{ GeV}$	1.017 \pm 0.039 ALBRECHT 95C ARG $E_{\text{cm}}^{\text{ee}}$ = 9.5–10.6 GeV
0.89 $\pm 0.14 \pm 0.08$ 1909 FORD 87B MAC $E_{ m cm}^{ee} = 29 \; { m GeV}$	0.937±0.116±0.064 BUSKULIC 950 ALEP 1990−1992 LEP runs • • • We do not use the following data for averages, fits, limits, etc. • • •
0.81 \pm 0.13 727 BEHRENDS 85 CLEO e^+e^- near $\Upsilon(4S)$	$1.022\pm0.028\pm0.030$ 1.7 k 171 ALBRECHT 94E ARG $E_{\text{cm}}^{\text{ee}}=9.4$ – 10.6 GeV
$\xi^{\tau}(e \text{ or } \mu) \text{ PARAMETER}$	CIII
$(V-A)$ theory predicts $\xi=1$.	1.25 $\pm 0.23 {+0.15 \atop -0.08}$ 7.5k ALBRECHT 93C ARG $E_{\rm cm}^{\it ee} = 9.4$ –10.6 GeV
VALUE EVTS DOCUMENT ID TECN COMMENT	170 AKERS 95P obtain this result with a model independent fit to the hadronic structure
1.03 \pm 0.12 OUR AVERAGE 0.97 \pm 0.14 165 ALBRECHT 95C ARG $E_{\rm cm}^{ee} = 9.5$ -10.6 GeV	functions. Fitting with the model of Kuhn and Santamaria (ZPHY C48 , 445 (1990))
1.18±0.15±0.16 BUSKULIC 95D ALEP 1990–1992 LEP runs	gives $0.87 \pm 0.27 + 0.05$, and with the model of of Isgur <i>et al.</i> (PR D39 ,1357 (1989))
	they obtain $1.10 \pm 0.31 ^{+0.13}_{-0.14}$.
$0.90 \pm 0.15 \pm 0.10$ 3230 ¹⁶⁶ ALBRECHT 93G ARG $E_{\rm cm}^{ee} = 9.4 - 10.6$ GeV	ALBRECHT 94E measure the square of this quantity and use the sign determined by
Cili	ALBRECHT 901 to obtain the quoted result. Replaced by ALBRECHT 95c.
165 Combined fit to ARGUS tau decay parameter measurements in ALBRECHT 95C, ALBRECHT 93G, and ALBRECHT 94E. ALBRECHT 95C uses events of the type $\tau^-\tau^+$	ξ^{τ} (all hadronic modes) PARAMETER
$(\ell^- \overline{\nu}_\ell \nu_\tau)$ $(h^+ h^- h^+ \overline{\nu}_\tau)$ and their charged conjugates.	$(V-A)$ theory predicts $\xi^{T}=1$.
166 ALBRECHT 93G measurement determines $ \xi^{\tau} $ for the case $\xi^{\tau}(e)=\xi^{\tau}(\mu)$, but the	VALUE EVTS DOCUMENT ID TECN COMMENT 1.011±0.027 OUR AVERAGE
authors point out that other LEP experiments determine the sign to be positive.	10.46 10.14
$\xi^{ au}(e)$ PARAMETER	-0.41 -0.25
$(V-A)$ theory predicts $\xi = 1$.	1.017 \pm 0.039 173 ALBRECHT 95C ARG E_{cm}^{ee} = 9.5-10.6 GeV
VALUE DOCUMENT ID TECN COMMENT	1.006±0.032±0.019
1.03±0.23±0.09 BUSKULIC 95D ALEP 1990-1992 LEP runs	
$\xi^{\tau}(\mu)$ PARAMETER	1.022±0.028±0.030 1.7k ¹⁷⁵ ALBRECHT 94E ARG $E_{\rm CM}^{ee}$ = 9.4–10.6 GeV 0.99 ±0.07 ±0.04 ¹⁷⁶ BUSKULIC 94D ALEP 1990+1991 LEP run
$(V-A)$ theory predicts $\xi=1$.	
VALUE DOCUMENT ID TECN COMMENT	1.25 $\pm 0.23 ^{+0.15}_{-0.08}$ 7.5k 177 ALBRECHT 93c ARG $E^{ee}_{\text{cm}} =$ 9.4–10.6 GeV
1.23±0.22±0.10 BUSKULIC 95D ALEP 1990-1992 LEP runs	172 AKERS 95P use $ au ightarrow a_1 u_{ au}$ decays.
mT(a ar w) DADAMETED	173 Combined fit to ARGUS tau decay parameter measurements in ALBRECHT 95C, AL-
$ \eta^{\tau}(e \text{ or } \mu) \text{ PARAMETER} $ $(V-A) \text{ theory predicts } \eta = 0.$	BRECHT 93G, and ALBRECHT 94E. 174 BUSKULIC 95D use $ au o au u_{ au}$, $ au o au u_{ au}$, and $ au o a_1 u_{ au}$ decays.
VALUE EVTS DOCUMENT ID TECN COMMENT	175 ALBRECHT 94E measure the square of this quantity and use the sign determined by
-0.01±0.14 OUR AVERAGE	ALBRECHT 901 to obtain the quoted result. Uses $ au ightarrow a_1 u_{ au}$ decays. Replaced by
$0.03 \pm 0.18 \pm 0.12$ 8.2k ALBRECHT 95 ARG $E_{ m cm}^{\it ee} = 9.5 - 10.6$ GeV	ALBRECHT 95C.
-0.04±0.15±0.11 BUSKULIC 95D ALEP 1990-1992 LEP runs	176 BUSKULIC 94D use $ au \to \pi \nu_{\tau}$ and $ au \to \rho \nu_{\tau}$ decays. Superseded by BUSKULIC 95D. 177 Uses $ au \to a_1 \nu_{\tau}$ decays. Replaced by ALBRECHT 95C.
$\eta^{ au}(\mu)$ PARAMETER	oses i - a1 v _T decays, hepiaced by ALDRECH 1 35C.
$(V-A)$ theory predicts $\eta=0$.	
VALUE DOCUMENT ID TECN COMMENT	
−0.24±0.23±0.18 BUSKULIC 95D ALEP 1990–1992 LEP runs	

au REFERENCES	JANSSEN 89 PL B228 273 +Antreasyan, Bartels, Besset+ (Crystal Ball Collab.) KLEINWORT 89 ZPHY C42 7 +Allison, Ambrus, Barlow+ (JADE Collab.)
ABREU 96B PL B365 448 +Adam, Adye, Agasi+ (DELPHI Collab.)	ADEVA 88 PR D38 2665 +Anderhub, Ansari, Becker+ (Mark-J Collab.)
ALAM 96 PRL 76 2637 +Kim, Ling, Mahmood, O'Neill+ (CLEO Collab.)	ALBRECHT 88B PL B202 149 +Binder, Boeckmann+ (ARGUS Collab.) ALBRECHT 88L ZPHY C41 1 +Boeckmann, Glaeser, Harder+ (ARGUS Collab.)
ALEXANDER 96D PL B369 163 +Allison, Ältekamp, Ametewee+ (OPAL Collab.) ALEXANDER 96E PL B373 341 +Allison, Altekamp, Ametewee+ (OPAL Collab.)	ALBRECHT 88M ZPHY C41 405 + Boeckmann, Glaeser, Harder+ (ARGUS Collab.) ALBRECHT 88M ZPHY C41 405 + Boeckmann, Glaeser, Harder+ (ARGUS Collab.)
BAI 96 PR D53 20 +Bardon, Becker-Szendy, Blum+ (BES Collab.)	AMIDEI 88 PR D37 1750 +Trilling, Abrams, Baden+ (Mark II Collab.)
BARTELT 96 PRL 76 4119 +Csorna, Jain, Marka+ (CLEO Collab.)	BEHREND 88 PL B200 226 +Criegee, Dainton, Field+ (CELLO Collab.) BRAUNSCH 88C ZPHY C39 331 Braunschweig, Kirschfink, Martyn+ (TASSO Collab.)
BUSKULIC 96 ZPHY C (to be publ.) +Casper, De Bonis, Decamp+ (ALEPH Collab.) CERN-PPE/95-140	BRAUNSCH 88C ZPHY C39 331 Braunschweig, Kirschfink, Martyn+ (TASSO Collab.) KEH 88 PL B212 123 +Antreasyan, Bartels, Besset+ (Crystal Ball Collab.)
BUSKULIC 96B ZPHY C70 549 +Casper, De Bonis, Decamp+ (ALEPH Collab.)	TSCHIRHART 88 PL B205 407 +Abachi, Akerlof, Baringer+ (HRS Collab.)
BUSKULIC 96C ZPHY C70 561 +Casper, De Bonis, Decamp+ (ALEPH Collab.)	ABACHI 87B PL B197 291 +Baringer, Bylsma, De Bonte+ (HRS Collab.)
COAN 96 PR D53 6037 +Dominick, Fadeyev, Korolkov+ (CLEO Collab.) ABE 95Y PR D52 4828 +Abt, Ahn, Akagi, Allen+ (SLD Collab.)	ABACHI 87C PRL 59 2519 +Akerlof, Baringer, Blockus+ (HRS Collab.) ADLER 87B PRL 59 1527 +Becker, Blaylock, Bolton+ (Mark III Collab.)
ABREU 95T PL B357 715 +Adam, Adve, Agasi, Alinenko+ (DELPHI Collab.)	AIHARA 87B PR D35 1553 +Alston-Garnjost, Avery+ (TPC Collab.)
ABREU 95U PL B359 411 +Adam, Adye, Agasi, Ajinenko+ (DELPHI Collab.)	AIHARA 87C PRL 59 751 +Alston-Garnjost, Avery+ (TPC Collab.)
ACCIARRI 95 PL B345 93 +Adam, Adriani, Aguilar-Benitez+ (L3 Collab.) ACCIARRI 95F PL B352 487 +Adam, Adriani, Aguilar-Benitez+ (L3 Collab.)	ALBRECHT 87L PL B185 223 +Binder, Boeckmann, Glaser+ (ARGUS Collab.) ALBRECHT 87P PL B199 580 +Andam, Binder, Boeckmann+ (ARGUS Collab.)
ACCIARRI 95F PL B352 487 +Adam, Adriani, Aguilar-Benitez+ (L3 Collab.) AKERS 95F ZPHY C66 31 +Alexander, Allison, Ametewee+ (OPAL Collab.)	BAND 87 PL B198 297 +Camporesi, Chadwick, Delfino+ (MAC Collab.)
AKERS 95I ZPHY C66 543 +Alexander, Allison, Ametewee+ (OPAL Collab.)	BAND 87B PRL 59 415 +Bosman, Camporesi, Chadwick+ (MAC Collab.)
AKERS 95P ZPHY C67 45 +Alexander, Allison, Ametewee+ (OPAL Collab.) AKERS 95Y ZPHY C68 555 +Alexander, Allison, Altekamp+ (OPAL Collab.)	BARINGER 87 PRL 59 1993 +McIlwain, Miller, Shibata+ (CLEO Collab.) BEBEK 87C PR D36 690 +Berkelman, Blucher, Cassel+ (CLEO Collab.)
ALBRECHT 95 PL B341 441 +Hamacher, Hofmann, Kirchhoff+ (ARGUS Collab.)	BURCHAT 87 PR D35 27 +Feldman, Barklow, Boyarski+ (Mark II Collab.)
ALBRECHT 95C PL B349 576 +Hamacher, Hofmann, Kirchoff+ (ARGUS Collab.)	BYLSMA 87 PR D35 2269 +Abachi, Baringer, DeBonte+ (HRS Collab.)
ALBRECHT 95G ZPHY C68 25 +Hamacher, Hofmann, Kirchhoff+ (ARGUS Collab.)	COFFMAN 87 PR D36 2185 +Dubois, Eigen, Hauser+ (Mark III Collab.) DERRICK 87 PL B189 260 +Kooijman, Loos, Musgrave+ (HRS Collab.)
ALBRECHT 95H ZPHY C68 215 +Hamacher, Hofmann, Kirchhoff+ (ARGUS Collab.) BALEST 95C PRL 75 3809 +Cho, Ford, Lohner+ (CLEO Collab.)	FORD 87 PR D35 408 + Qi, Read, Smith+ (MAC Collab.)
BUSKULIC 95C PL B346 371 +Casper, De Bonis, Decamp+ (ALEPH Collab.)	FORD 87B PR D36 1971 +Qi, Read, Smith+ (MAC Collab.)
BUSKULIC 95D PL B346 379 +Casper, De Bonis, Decamp+ (ALEPH Collab.)	GAN 87 PRL 59 411 +Abrams, Amidei, Baden+ (Mark II Collab.)
Also 95P PL B363 265 erratum ABREU 94K PL B334 435 +Adam, Adve, Agasi+ (DELPHI Collab.)	GAN 87B PL B197 561 +Abrams, Amidei, Baden+ (Mark II Collab.) AIHARA 86E PRL 57 1836 +Alston-Garnjost, Avery+ (TPC Collab.)
ABREU 94K PL B334 435 +Adam, Adye, Agasi+ (DELPHI Collab.) AKERS 94E PL B328 207 +Alexander, Allison, Anderson+ (OPAL Collab.)	BARTEL 86D PL B182 216 +Becker, Felst, Haidt, Knies+ (JADE Collab.)
AKERS 94G PL B339 278 +Alexander, Allison, Anderson+ (OPAL Collab.)	PDG 86 PL 170B Aguilar-Benitez, Porter+ (CERN, CIT+)
ALBRECHT 94E PL B337 383 +Hamacher, Hofmann+ (ARGUS Collab.)	RUCKSTUHL 86 PRL 56 2132 +Stroynowski, Atwood, Barish+ (DELCO Collab.) SCHMIDKE 86 PRL 57 527 +Abrams, Matteuzzi, Amidei+ (Mark II Collab.)
ARTUSO 94 PRL 72 3762 +Goldberg, He, Horwitz+ (CLEO Collab.) BARTELT 94 PRL 73 1890 +Csorna, Egyed, Jain+ (CLEO Collab.)	YELTON 86 PRL 56 812 +Dorfan, Abrams, Amidei+ (Mark II Collab.)
BATTLE 94 PRL 73 1079 +Ernst, Kwon, Roberts+ (CLEO Collab.)	ALTHOFF 85 ZPHY C26 521 +Braunschweig, Kirschfink+ (TASSO Collab.)
BAUER 94 PR D50 R13 +Belcinski, Berg, Bingham+ (TPC/2gamma Collab.)	ASH 85B PRL 55 2118 +Band, Blume, Camporesi+ (MAC Collab.) BALTRUSAIT 85 PRL 55 1842 Baltrusaitis, Becker, Blaylock, Brown+ (Mark III Collab.)
BUSKULIC 94D PL B321 168 + De Bonis, Decamp, Ghez+ (ALEPH Collab.) BUSKULIC 94E PL B332 209 + Casper, De Bonis, Decamp+ (ALEPH Collab.)	BARTEL 85F PL 161B 188 + Becker, Cords, Felst+ (JADE Collab.)
BUSKULIC 94F PL B332 219 +Casper, De Bonis, Decamp+ (ALEPH Collab.)	BEHRENDS 85 PR D32 2468 +Gentile, Guida, Guida, Morrow+ (CLEO Collab.)
GIBAUT 94B PRL 73 934 +Kinoshita, Barish, Chadha+ (CLEO Collab.)	BELTRAMI 85 PRL 54 1775 +Bylsma, DeBonte, Gan+ (HRS Collab.) BERGER 85 ZPHY C28 1 +Genzel, Lackas, Pielorz+ (PLUTO Collab.)
ADRIANI 93M PRPL 236 1 +Aguillar-Benitez, Ahlen, Alcaraz, Aloisio+ (L3 Collab.) ALBRECHT 93C ZPHY C58 61 +Ehrlichmann, Hamacher+ (ARGUS Collab.)	BURCHAT 85 PRL 54 2489 +Schmidke, Yelton, Abrams+ (Mark II Collab.)
ALBRECHT 93G PL B316 608 +Ehrlichmann, Hamacher+ (ARGUS Collab.)	FERNANDEZ 85 PRL 54 1624 +Ford, Qi, Read+ (MAC Collab.)
BALEST 93 PR D47 R3671 +Daoudi, Ford, Johnson+ (CLEO Collab.)	MILLS 85 PRL 54 624 +Pal, Atwood, Baillon+ (DELCO Collab.) AIHARA 84C PR D30 2436 +Alston-Garnjost, Badtke, Bakken+ (TPC Collab.)
BEAN 93 PRL 70 138 +Gronberg, Kutschke+ (CLEO Collab.) BORTOLETTO 93 PRL 71 1791 +Brown, Fast, McIlwain+ (CLEO Collab.)	BEHREND 84 ZPHY C23 103 +Fenner, Schachter, Schroder+ (CELLO Collab.)
ESCRIBANO 93 PL B301 419 +Masso (BARC)	MILLS 84 PRL 52 1944 +Ruckstuhl, Atwood, Baillon+ (DELCO Collab.)
PROCARIO 93 PRL 70 1207 + Yang, Balest, Cho+ (CLEO Collab.)	BEHREND 83C PL 127B 270 +Chen, Fenner, Gumpel+ (CELLO Collab.) SILVERMAN 83 PR D27 1196 +Shaw (UCI)
WASSERBAECH93 PR D48 4216 (FSUSC) ABREU 92N ZPHY C55 555 +Adam, Adye, Agasi+ (DELPHI Collab.)	SILVERMAN 83 PR D27 1196 +Shaw (UCI) BEHREND 82 PL 114B 282 +Chen, Fenner, Field+ (CELLO Collab.)
ACTON 92F PL B281 405 +Alexander, Allison, Allport+ (OPAL Collab.)	BLOCKER 82B PRL 48 1586 +Abrams, Alam, Blondel+ (Mark II Collab.)
ACTON 92H PL B288 373 +Allison, Allport+ (OPAL Collab.)	BLOCKER 82D PL 109B 119 + Dorfan, Abrams, Alam+ (Mark II Collab.) J
AKERIB 92 PRL 69 3610 +Barish, Chadha, Cowen+ (CLEO Collab.) Also 93B PRL 71 3395 (erratum) Akerib, Barish, Chadha, Cowen+ (CLEO Collab.)	FORD 82 PRL 49 106 +Smith, Allaby, Ash (MAC Collab.) HAYES 82 PR D25 2869 +Perl, Alam, Boyarski+ (Mark II Collab.)
Also 93B PRL 71 3395 (erratum) Akerib, Barish, Chadha, Cowen+ (CLEO Collab.) ALBRECHT 92D ZPHY C53 367 +Ehrlichmann, Hamacher+ (ARGUS Collab.)	BERGER 81B PL 99B 489 +Genzel, Grigull, Lackas+ (PLUTO Collab.)
ALBRECHT 92K ZPHY C55 179 +Ehrlichmann, Hamacher, Krueger+ (ARGUS Collab.)	DORFAN 81 PRL 46 215 +Blocker, Abrams, Alam+ (Mark II Collab.)
ALBRECHT 92M PL B292 221 +Ehrlichmann, Hamacher, Hofmann+ (ARGUS Collab.)	BRANDELIK 80 PL 92B 199 +Braunschweig, Gather+ (TASSO Collab.) ZHOLENTZ 80 PL 96B 214 +Kurdadze, Lelchuk, Mishnev+ (NOVO)
ALBRECHT 92Q ZPHY C56 339 +Ehrlichmann, Hamacher+ (ARGUS Collab.) AMMAR 92 PR D45 3976 +Baringer, Coppage, Davis+ (CLEO Collab.)	Also 81 S.INP 34 814 Zholentz, Kurdadze, Leichuk+ (NOVO)
ARTUSO 92 PRL 69 3278 +Goldberg, Horwitz, Kennett+ (CLEO Collab.)	Translated from YAF 34 1471. BACINO 79B PRL 42 749 +Ferguson, Nodulman, Slater+ (DELCO Collab.)
BAI 92 PRL 69 3021 +Bardon, Becker-Szendy, Burnett+ (BES Collab.)	BACINO 79B PRL 42 749 +Ferguson, Nodulman, Slater+ (DELCO Collab.) KIRKBY 79 SLAC-PUB-2419 (SLAC) J
BATTLE 92 PL B291 488 +Ernst, Kroha, Roberts+ (ČLEO Collab.) BUSKULIC 92J PL B297 459 +Decamp, Goy, Lees+ (ALEPH Collab.)	Batavia Lepton Photon Conference.
DECAMP 92C ZPHY C54 211 + Deschizeaux, Goy, Lees+ (ALEPH Collab.)	BACINO 78B PRL 41 13 +Ferguson, Nodulman, Slater+ (DELCO Collab.) J Also 78 Tokyo Conf. 249 Kirz (STON)
ADEVA 91F PL B265 451 +Adriani, Aguilar-Benitez, Akbari+ (L3 Collab.)	Also 80 PL 96B 214 Zholentz, Kurdadze, Lelchuk, Mishnev+ (NOVO)
ALBRECHT 91D PL B260 259 + Ehrlichmann, Hamacher, Krueger+ (ARGUS Collab.) ALEXANDER 91D PL B266 201 + Allison, Allport, Anderson+ (OPAL Collab.)	BRANDELIK 78 PL 73B 109 +Braunschweig, Martyn, Sander+ (DASP Collab.) J
ANTREASYAN 91 PL 8259 216 +Bartels, Besset, Bieler+ (Crystal Ball Collab.)	FELDMAN 78 Tokyo Conf. 777 (SLAC) J HEILE 78 NP B138 189 +Perl, Abrams, Alam, Boyarski+ (SLAC, LBL)
GRIFOLS 91 PL B255 611 +Mendez (BARC)	HEILE 78 NP B138 189 + Perl, Abrams, Alam, Boyarski+ (SLAC, LBL) JAROS 78 PRL 40 1120 + Abrams, Alam+ (SLAC, LBL, NWES, HAWA)
SAMUEL 91B PRL 67 668 +Li, Mendel (OKSU, WONT) Also 92B PRL 69 995 Samuel, Li, Mendel (OKSU, WONT)	PERL 75 PRL 35 1489 +Abrams, Boyarski, Breidenbach+ (LBL, SLAC)
Erratum.	
ABACHI 90 PR D41 1414 +Derrick, Kooijman, Musgrave+ (HRS Collab.)	OTHER RELATED PAPERS
ALBRECHT 90E PL B246 278 +Ehrlichmann, Harder, Krueger+ (ARGUS Collab.) ALBRECHT 90I PL B250 164 +Ehrlichmann, Harder, Krueger+ (ARGUS Collab.)	Wennesday of April 1997
BEHREND 90 ZPHY C46 537 +Criegee, Field, Franke+ (CELLO Collab.)	WEINSTEIN 93 ARNPS 43 457 +Stroynowski (CIT, SMU) PERL 92 RPP 55 653 (SLAC)
BOWCOCK 90 PR D41 805 +Kinoshita, Pipkin, Procario+ (CLEO Collab.)	PICH 90 MPL A5 1995 (VALE)
DELAGUILA 90 PL B252 116 +Sher (BARC, WILL) GOLDBERG 90 PL B251 223 +Haupt, Horwitz, Jain+ (CLEO Collab.)	BARISH 88 PRPL 157 1 +Stroynowski (CIT)
WU 90 PR D41 2339 + Hayes, Perl, Barklow+ (Mark II Collab.)	GAN 88 IJMP A3 531 +Perl (SLAC) HAYES 88 PR D38 3351 +Perl (SLAC)
ABACHI 89B PR D40 902 +Derrick, Kooijman, Musgrave+ (HRS Collab.)	PERL 80 ARNPS 30 299 (SLAC)
BEHREND 89B PL 8222 163 +Criegee, Dainton, Field, Franke+ (CELLO Collab.)	(33.4)

Heavy Charged Lepton Searches

Heavy Charged Lepton Searches

Charged Heavy Lepton MASS LIMITS

Sequential Charged Heavy Lepton (L^{\pm}) MASS LIMITS

These experiments assumed that a fourth generation ι^\pm decayed to a fourth generation ι_L (or ι^0) where ι_L was stable. New data show that stable ι_L have $m_{\iota_L} > 42.7$ GeV so that the above assumption is not valid for any mass limit ≤ 42.7 GeV. One can instead assume that ${\it L}^{\pm}$ decays via mixing to ${\it
u}_{\it e}$, ${\it
u}_{\it \mu}$ and/or ${\it
u}_{\it au}$, and in that context the limits below are meaningful. DOCUMENT ID

VALUE (GeV)	CL%	DOCUMENT ID TECN COMMENT
>42.8	95	ADEVA 90s L3 Dirac
>44.3	95	AKRAWY 90g OPAL
>42.7	95	DECAMP 90F ALEP
• • • We do not use	the followi	ng data for averages, fits, limits, etc. • • •
none 10-225		¹ AHMED 94 CNTR H1 Collab. at HERA
none 12.6-29.6	95	KIM 918 AMY Massless ν assumed
none 0.5-10	95	2 RILES 90 MRK2 For $(m_{I} - m_{I}^{0}) >$
> 8		0.25-0.4 GeV 3 STOKER 89 MRK2 For $(m_{L^+} - m_{L^0}) = 0.4$
>12		³ STOKER 89 MRK2 For m ₁₀ =0.9 GeV
none 18.4-27.6	95	⁴ ABE 88 VNS
>25.5	95	⁵ ADACHI 88B TOPZ
none 1.5-22.0	95	BEHREND 88c CELL
>41	90	⁶ ALBAJAR 87B UA1
>22.5	95	⁷ ADEVA 85 MRKJ
>18.0	95	⁸ BARTEL 83 JADE
none 4-14.5	95	9 BERGER 818 PLUT
>15.5	95	10 BRANDELIK 81 TASS
>13.		11 AZIMOV 80
>16.	95	12 BARBER 80B CNTR
> 0.490		¹³ ROTHE 69 RVUE

- 1 The AHMED 94 limits are from a search for neutral and charged sequential heavy leptons at HERA via the decay channels $L^-\to e\gamma,\,L^-\to \nu W^-,\,L^-\to eZ;$ and $L^0\to \nu\gamma,\,L^0\to e^-W^+,\,L^-\to \nu Z,$ where the W decays to $\ell\nu_\ell,$ or to jets, and Z decays to $\ell^+\ell^-$ or jets.
- ² RILES 90 limits were the result of a special analysis of the data in the case where the mass difference $m_{L^-}-m_{L^0}$ was allowed to be quite small, where t^0 denotes the neutrino into which the sequential charged lepton decays. With a slightly reduced m_{L^\pm} range, the mass difference extends to about 4 GeV. 3 STOKER 89 (Mark II at PEP) gives bounds on charged heavy lepton (L^+) mass for
- the generalized case in which the corresponding neutral heavy lepton (L^0) in the SU(2) doublet is not of negligible mass.
- doublet is not of magnitude mass. 4 ABE 88 search for L^+ and $L^-\to$ hadrons looking for acoplanar jets. The bound is valid for $m_{\nu}<$ 10 GeV.
- $^{\bf 5}$ ADACHI 88B search for hadronic decays giving acoplanar events with large missing energy. ${\sf E_{cm}}^{ee}=$ 52 GeV.
- ⁶ Assumes associated neutrino is approximately massless.
- 7 ADEVA 85 analyze one-isolated-muon data and sensitive to au <10 nanosec. Assume B(lepton) = 0.30. $E_{cm} = 40-47 \text{ GeV}.$
- 8 BARTEL 83 limit is from PETRA $e^{+}\,e^{-}$ experiment with average $E_{\rm cm}=$ 34.2 GeV.

- 9 BERGER 81B is DESY DORIS and PETRA experiment. Looking for $e^+e^- \rightarrow L^+L^-$. 10 BRANDELIK 81 is DESY-PETRA experiment. Looking for $e^+e^- \rightarrow L^+L^-$. 11 AZIMOV 80 estimated probabilities for M+N type events in $e^+e^- \rightarrow L^+L^-$ deducing semi-hadronic decay multiplicities of L from e^+e^- annihilation data at $E_{cm}=(2/3)m_L$. Obtained above limit comparing these with e^+e^- data (BRANDELIK 80). 12 BARBER 808 looked for $e^+e^- \to L^+L^-$, $L \to \nu_L^+ X$ with MARK-J at DESY-PETRA.
- $^{13}\,\text{ROTHE}$ 69 examines previous data on μ pair production and π and K decays.

Stable Charged Heavy Lepton (L±) MASS LIMITS

VALUE (GeV)	CL%	DOCUMENT I) TECN
>42.8 (CL = 95%)	OUR LIMIT	Γ	
>28.2	95	¹⁴ ADACHI	90c TOPZ
none 18.5-42.8	95	AKRAWY	900 OPAL
• • • We do not us	e the follow	ing data for avera	ges, fits, limits, etc. • • •
>26.5	95	DECAMP	90F ALEP
none m -36.3	95	SODERSTR	OM90 MRK2

 14 ADACHI 90c put lower limits on the mass of stable charged particles with electric charge $\it Q$ satisying 2/3 $< \it Q/e < 4/3$ and with spin 0 or 1/2. We list here the special case for a stable charged heavy lepton.

Charged Long-Lived Heavy Lepton MASS LIMITS

VALUE (GeV)	<u>EVTS</u>	DOCUMENT ID		TECN	CHG	COMMENT	
• • • We do not u	se the following	data for averag	es, fits	limits,	etc. •	• •	
>0.1	0	¹⁵ ANSORGE	73B	нвс	_	Long-lived	
none 0.55-4.5		¹⁶ BUSHNIN	73	CNTR	_	Long-lived	
none 0.2-0.92		¹⁷ BARNA	68	CNTR	-	Long-lived	
none 0.97-1.03		¹⁷ BARNA	68	CNTR	_	Long-lived	

 $^{15}\,\mathrm{ANSORGE}$ 73B looks for electron pair production and electron-like Bremsstrahlung.

16 BUSHNIN 73 is SERPUKOV 70 GeV p experiment. Masses assume mean life above 7×10^{-10} and 3×10^{-8} respectively. Calculated from cross section (see "Charged Quasi-Stable Lepton Production Differential Cross Section" below) and 30 GeV muon pair production data.

17 BARNA 68 is SLAC photoproduction experiment.

Doubly-Charged Heavy Lepton MASS LIMITS

CL% DOCUMENT ID TECN CHG ¹⁸ CLARK none 1-9 GeV 90 81 SPEC ++

 18 CLARK 81 is FNAL experiment with 209 GeV muons. Bounds apply to μ_P which couples with full weak strength to muon. See also section on "Doubly-Charged Lepton Produciton Cross Section."

Doubly-Charged Lepton Production Cross Section (μN Scattering)

VALUE (cm ²)	EVTS	DOCUMENT IL		TECN	CHG	
• • • We do not use th	e followir	ng data for averag	ges, fits	s, limits,	etc. •	• •
$<6. \times 10^{-38}$	0	¹⁹ CLARK	81	SPEC	++	

 19 CLARK 81 is FNAL experiment with 209 GeV muon. Looked for μ^+ nucleon ightarrow $\overline{\mu}^0_P$ X, $\overline{\mu}^0_D \to \mu^+ \, \mu^- \overline{\nu}_\mu$ and $\mu^+ \, n \to \mu^+_D + X$, $\mu^+_D + \to 2 \mu^+ \, \nu_\mu$. Above limits are for $\sigma imes BR$ taken from their mass-dependence plot figure 2.

REFERENCES FOR Heavy Charged Lepton Searches

AHMED	94	PL B340 205	+	(H1 Collab.)
KIM	91B	IJMP A6 2583	+Smith, Breedon, Ko+	(AMY Collab.)
ADACHI	90C	PL B244 352	+Aihara, Doser, Enomoto+	(TOPAZ Collab.)
ADEVA	905	PL B251 321	+Adriani, Aguilar-Benitez, Akbari+	` (L3 Collab.)
AKRAWY	90G	PL B240 250	+Alexander, Allison, Allport+	(OPAL Collab.)
AKRAWY	900	PL B252 290	+Alexander, Allison, Allport, Anderson+	(OPAL Collab.)
DECAMP	90F	PL B236 511	+Deschizeaux, Lees, Minard+	(ALEPH Collab.)
RILES	90	PR D42 1	+Perl, Barklow+	(Mark II Collab.)
SODERSTROM	90	PRL 64 2980	+McKenna, Abrams, Adolphsen, Averill+	(Mark II Collab.)
STOKER	89	PR D39 1811	+Perl, Abrams+	(Mark II Collab.)
ABE	88	PRL 61 915	+Amako, Arai, Asano, Chiba	(VENUS Collab.)
ADACHI	88B	PR D37 1339	+Aihara, Dijkstra, Enomoto+	(TOPAZ Collab.)
BEHREND	88C	ZPHY C41 7	+Buerger, Criegee, Dainton+	(CELLO Collab.)
ALBAJAR	87B	PL B185 241	+Albrow, Allkofer, Arnison+	(UA1 Collab.)
ADEVA	85	PL 152B 439	+Becker, Becker-Szendy+	(Mark-J Collab.)
Also	84C	PRPL 109 131	Adeva, Barber, Becker+	(Mark-J Collab.)
BARTEL	83	PL 123B 353	+Cords, Dietrich, Eichler+	(JADE Collab.)
BERGER	81B	PL 99B 489	+Genzel, Grigull, Lackas+	(PLUTO Collab.)
BRANDELIK	81	PL 99B 163	+Braunschweig, Gather+	(TASSO Collab.)
CLARK	81	PRL 46 299	+Johnson, Kerth, Loken+ (UCB, I	BL, FNAL, PRIN)
Also	82	PR D25 2762	Smith, Clark, Johnson, Kerth+ (1	BL, FNAL, PRIN)
AZIMOV	80	JETPL 32 664	+Khoze	(PNPI)
		Translated from ZETFP		
BARBER	80B	PRL 45 1904	+Becker, Bei, Berghoff+	(Mark-J Collab.)
BRANDELIK	80	PL 92B 199	+Braunschweig, Gather+	(TASSO Collab.)
ANSORGE	73B	PR D7 26	+Baker, Krzesinski, Neale, Rushbrooke+	(CAVE)
BUSHNIN	73	NP B58 476	+Dunaitzev, Golovkin, Kubarovsky+	(SERP)
Also	72	PL 42B 136	Golovkin, Grachev, Shodyrev+	(SERP)
ROTHE	69	NP B10 241	+Wolsky	(PENN)
BARNA	68	PR 173 1391	+Cox, Martin, Perl, Tan, Toner, Zipf+	(SLAC, STAN)

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(SLAC)

NEUTRINOS

(by R.E. Shrock, State Univ. of New York, Stony Brook)

In addition to the ν_e , ν_μ , and ν_τ sections, the Review of Particle Physics includes sections on "Number of Light Neutrino Types," "Heavy Lepton Searches," and "Searches for Massive Neutrinos and Lepton Mixing."

Neutrino experiments are notoriously difficult, owing to the basic property that neutrinos are neutral, weakly interacting particles. Over the years, many experimental claims pertaining to neutrino properties have been refuted by subsequent data. The Review of Particle Physics is an archival compendium which includes references to older papers, even experimental claims which have now been ruled out. It will be clear from the various listings which experiments have later been refuted.

In view of the continuing unsettled nature of data pertaining to various neutrino properties, it is perhaps well to record some of the definite accomplishments in the history of the subject. Neutrinos were first proposed in 1930 by Pauli, to explain the observed continuous electron energy distribution in nuclear beta decay [1]. Tentative evidence for the observation of the electron (anti)neutrino was reported in 1953, and definite evidence in 1956, by Cowan, Reines, and coworkers, using the reaction $\overline{\nu}_e p \to e^+ n$ with $\overline{\nu}_e$'s from reactor fluxes [2]. The separate identity of ν_e and ν_μ was demonstrated experimentally in 1962 by Lederman, Schwartz, Steinberger, and coworkers in a Brookhaven experiment [3]. Neutrinos from the sun were first observed by R. Davis and coworkers via the reaction $\nu_e^{37}\text{Cl} \rightarrow e^{-37}\text{Ar}$, using an underground radiochemical experiment (which began operation in the late 1960's) in the Homestake Gold Mine [4]. Although we tabulate here only experiments with results pertaining to neutrino properties, it should be recalled that neutrino reactions played a crucial role in confirming the now-Standard Model when in 1973 neutral weak currents were first observed by the CERN Gargamelle bubble chamber experiment via the reactions $\nu_{\mu}e \rightarrow \nu_{\mu}e$ and $\nu_{\mu}(\overline{\nu}_{\mu}) + N \rightarrow \nu_{\mu}(\overline{\nu}_{\mu}) \ hadrons [6]$. Neutrino reactions have also provided an important input to the measurement of the weak mixing angle θ_W . The discovery of the τ lepton by Perl et al. at SPEAR in 1975 and the study of its decay implied the existence of the third neutrino, ν_{τ} [7]. The precise measurement of the width of the Z at LEP and SLC has shown that there are only three species of neutrinos (in the usual electroweak doublets) with masses $< m_Z/2$ [8].

The theoretical perspective concerning neutrino masses has changed considerably over the past 20 years. Before that time, a standard view was that there was no theoretical reason for neutrinos to have masses, which was in accord with the striking fact that the upper limits on their masses were much smaller than those of the associated charged leptons. It was also noted that experimental data were consistent with the "laws" of lepton family number and total lepton number conservation. (Some early discussions of of neutrino oscillations and lepton mixing are given in Refs. 9 and 10). In the literature through the

1970's one often finds statements asserting that in the standard $\mathrm{SU}(2)\,\times\,\mathrm{U}(1)$ electroweak theory (without electroweak-singlet neutrinos) the known neutrinos (in electroweak-doublets) are massless. This is true if one pretends that the Standard Model is applicable to arbitrarily high energies and requires the exact absence of any nonrenormalizable, higher-dimension operators in this theory. However, a more modern view is that the Standard Model is an effective field theory, which is a good description of nature only up to some energy scale where new physics occurs. Clearly a strict upper bound on this scale is given by the Planck mass, $\overline{M}_{Pl} \equiv \sqrt{\hbar c/(8\pi G_N)} = 2.4 \times 10^{18} \text{ GeV}$, since quantum gravity is not included in the Standard Model. However, there are strong arguments that new physics beyond the Standard Model actually occurs at a much lower scale, of order a TeV. This new physics may be able to be included in a generalization of the Standard Model which remains perturbative, as in supersymmetric extensions, or may be nonperturbative, as in dynamical electroweak symmetry breaking schemes. It has been appreciated that renormalizability and, in particular, the great success of the Standard Model with its exclusion of any higher-dimension nonrenormalizable operators, may well be due only to the fact that the electroweak scale $\boldsymbol{v}_{\scriptscriptstyle EW}$ is considerably smaller than the scale of new physics. A summary of this modern view is given, e.g., in Ref. 11.

Once one includes higher-dimension operators in the Lagrangian, nonzero neutrino masses can easily occur. The sizes of these masses reflect the scale(s) of the new physics. For example, given only the known left-handed neutrino fields of the Standard Model, there would be a gauge-invariant dimension-5 operator

$$\mathcal{O} = \frac{1}{M_X} \sum_{a,b} h_{a,b} (\epsilon_{ik} \epsilon_{jm} + \epsilon_{im} \epsilon_{jk}) \left[\mathcal{L}_{La}^{Ti} C \mathcal{L}_{Lb}^{j} \right] \phi^{k} \phi^{m} + h.c. (1)$$

where $\mathcal{L}_{La}=(\nu_{\ell_a},\ell_a)_L^T$ is the left-handed, $I=1/2,\ Y=-1$ lepton doublet with generation index a ($a=1,\ 2,\ {\rm or}\ 3$), where $\ell_a=e,\mu,\tau$, for a=1,2,3, and M_X denotes a generic mass scale characterizing the origin of this term. This operator involves a symmetric, I=1 combination of the two I=1/2 lepton doublets, contracted with an I=1 combination of the two Higgs doublets. The term arising from the vacuum expectation values (vev's) of the Higgs doublets yields a (left-handed) Majorana neutrino mass term (symmetric in generation indices). If $M_X>>v_{EW}$, where $v_{EW}=2^{-1/4}G_F^{-1/2}=246$ GeV is the electroweak symmetry breaking scale, this would explain the smallness of the resultant neutrino masses.

Because of the hierarchy problem plaguing the Higgs sector of the Standard Model, many physicists have concluded that either this sector is stabilized against large radiative corrections by supersymmetry, or the electroweak symmetry breaking originates not from the vacuum expectation value of a pointlike Higgs field, but instead dynamically, from the condensation of bilinear products of fermion fields without any fundamental Higgs field. In supersymmetric extensions of the Standard Model, one again finds dimension-5 operators analogous to

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Eq. (1). In approaches based on dynamical electroweak symmetry breaking, one can also get neutrino mass terms arising from higher-dimension multifermion operators.

In contrast to the higher-dimension operator (1), which involves only the known neutrinos, together with the hypothetical Higgs field of the Standard Model (or its supersymmetric extensions), another mechanism makes use only of renormalizable, dimension-4 operators, but requires the existence of electroweak-singlet neutrino fields. As will be discussed below, this mechanism produces light neutrino masses of order $m_{\nu} \sim M_D^2/M_R$, where M_D denotes a generic Dirac neutrino mass and M_R denotes a generic electroweak-singlet Majorana neutrino mass. Since the mass scale of the electroweak singlet neutrino mass term is naturally $>> v_{EW}$, this again yields, albeit for a different reason, very small m_{ν} [12].

In turn, a natural concomitant of (nondegenerate) neutrino masses is lepton mixing, which is thus also a general expectation. The lepton-mixing angles are functions of ratios of elements of neutrino-matrix elements and of charged lepton mass matrix elements, and even though left-handed neutrino masses are small, some of these ratios could, in principle, be $\mathcal{O}(1)$, which raises the issue of why such effects have not been seen. This question was answered as follows: a set of conditions for natural suppression of observable lepton flavor violation were formulated, and it was shown that the Standard Model (generalized to include nonzero m_{ν}) satisfies these [13]. This explains why the "law" of lepton family number conservation is obeyed to such high accuracy.

After these theoretical points, let us return to a description of the quantities upon which various experiments put limits. As an aid to understanding the limits on neutrino masses and lepton mixing, we recall that, in contrast to other particles in this Review, the neutrinos ν_e , ν_μ , and ν_τ are defined as weak eigenstates (the weak $I_3 = 1/2$ components of the $SU(2)_L$ lepton doublets) which couple with unit strength to e, μ , and τ , respectively. These neutrino weak eigenstates are not, in general, states of definite mass. If one assumes that neutrinos are massless, and hence degenerate, then it is possible to define the weak eigenstates to be simultaneously mass eigenstates. However, in the general case of possibly massive (nondegenerate) neutrinos, the weak eigenstates have no well-defined masses, but instead are linear combinations of mass eigenstates. Let us denote the charged leptons as the set $\{\ell_a\}$, $a=1,\ldots,n$, where $n\geq 3$, with $\ell_1 = e$, $\ell_2 = \mu$, and $\ell_3 = \tau$. From the LEP measurement of the Z width (see section on "Number of Light Neutrinos"), one knows that there are only three neutrinos which couple to the Z in the usual way and have masses $m_{\nu} < m_{Z}/2$. Of course, this measurement does not preclude the existence of electroweak-singlet neutrinos. The left-handed components of the weak eigenstates of the neutrinos, $(\nu_{\ell_a})_L$ can be expressed in terms of mass eigenstates by the transformation

$$(\nu_{\ell_a})_L = \sum_j U_{aj}(\nu_j)_L \tag{2}$$

where the $\{\nu_j\}$ denote these mass eigenstates. The mass eigenstates are, in general, linear combinations of the known I=1/2, $I_3=1/2$ neutrinos from electroweak doublets, and, in addition, possible electroweak-singlet neutrinos (sometimes called "sterile" neutrinos). The ordering of the mass eigenbasis can be defined so that U is as nearly diagonal as possible, *i.e.* (with no sum on j) $|U_{jj}| \geq |U_{jk}|$, $k \neq j$. Of course, this does not imply that $m(\nu_j) > m(\nu_k)$ for j > k.

Thus, as was noted in Ref. 14, decays such as $^3{\rm H}$ \rightarrow ³He $e^- \overline{\nu}_e$ and $\pi^+ \to \mu^+ \nu_\mu$, which have been used to set the best bounds on the respective neutrino masses, really consist of sums of the separate decay modes ${}^{3}\text{H} \rightarrow {}^{3}\text{He} \ e^{-} \ \overline{\nu}_{i}$ and $\pi^+ \to \mu^+ \nu_k$, where the ν_i and ν_k are mass eigenstates, and the indices j and k range over all of the values allowed by phase space in these respective decays. The coupling strengths for the jth mode in ${}^{3}\mathrm{H}\beta$ decay and the kth mode in π_{u2}^{+} decay are given, respectively, by $|U_{1j}|^2$ and $|U_{2k}|^2$. In general, these modes are incoherent, although in the limit in which the ν_i all become degenerate they would become coherent. There are, in addition certain kinematic factors depending on the m_{ν_i} which enter in determining the branching ratio for a given decay mode. Assuming that the off-diagonal elements of the lepton mixing matrix U are small relative to the diagonal elements, the dominantly coupled decays are the ones with coupling strength $|U_{ai}|^2$, a=j, i.e., ${}^3\mathrm{H} \rightarrow {}^3\mathrm{He} \ e^- \ \overline{\nu}_1$ and $\pi^+ \rightarrow \mu^+ \nu_2$.

Hence, it follows that the neutrino mass limits quoted in the literature for " m_{ν_e} ," " $m_{\nu_{\mu}}$," and " $m_{\nu_{\tau}}$ " should really be interpreted as limits on the corresponding mass eigenstates [14,15]. Specifically, a bound on " m_{ν_e} " from a study of tritium β decay, for example, really constitutes a weighted limit on each of the mass eigenstates ν_i in the weak eigenstate ν_e which are kinematically allowed to occur in tritium decay and which are coupled with strength $|U_{1j}|^2$ sufficiently large to make a significant contribution to the observed spectrum. It is thus certainly a limit on ν_1 , since this is, by the definition, of the order of the mass eigenbasis, the dominantly coupled neutrino. If lepton mixing is hierarchical, as quark mixing is known to be, i.e., if $|U_{ij}|^2 \gg |U_{ik}|^2$, $j \neq k$, then ν_1 is the only mass eigenstate significantly constrained by a bound on " m_{ν_e} ." Furthermore, strictly speaking, a neutrino mass limit cannot be stated in isolation; it always contains some implicit dependence on the relevant lepton-mixing angles. This dependence is fortunately relatively unimportant for the dominantly coupled decay modes, i.e., $e \overline{\nu}_1$, $\mu \overline{\nu}_2$, and $\tau \overline{\nu}_3$ and hence the mass limits on " m_{ν_e} ," " $m_{\nu_{\mu}}$," and " $m_{\nu_{\tau}}$ " can be reinterpreted as being limits on $m_{\nu_{i}}$, j = 1, 2, and 3, respectively.

There are three general types of (Lorentz-invariant) neutrino mass terms: Dirac masses of the form $m_D \, \overline{\nu}_L \, \chi_R + h.c.$, left-handed Majorana masses of the form $m_L \, \overline{\nu}_L \, \nu_R^c + h.c. = m_L^* \, \nu_L^T \, C \nu_L + h.c.$ and right-handed Majorana masses of the form $m_R \, \overline{\chi}_L^c \, \chi_R + h.c. = m_R \, \chi_R^T \, C \, \chi_R + h.c.$, where C is the Dirac charge conjugation matrix. Clearly, Dirac and right-handed Majorana mass terms require the existence of electroweak-singlet neutrinos. Our notation χ_R follows the usual practice of calling

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these "right-handed neutrino singlets", although since they are singlets, it is a convention whether one writes them as χ_R or $\chi'_L = (\chi_R)^c$. It is not known whether such electroweak-singlet neutrinos actually exist. Dirac mass terms conserve total lepton number L_{tot} , while Majorana mass terms violate L_{tot} . In the standard electroweak theory, extended to include massive neutrinos, (i) a Dirac mass term transforms as a weak I = 1/2operator, and is coupled to the I = 1/2 Higgs to make an SU(2) × U(1) singlet operator; (ii) a Majorana mass term involving the I = 1/2 left-handed neutrinos transforms as I = 1 and must be coupled to an operator with I = 1 (and Y = 2) to make a gauge-invariant singlet; (iii) a Majorana mass term involving the $SU(2) \times U(1)$ singlet neutral leptons, conventionally considered to be right-handed, is a singlet; it could be present as a bare mass term or couple to some other singlet operator. Note that in the minimal supersymmetric Standard Model (MSSM), which has two Higgs doublets, of hypercharge Y = 1 and Y = -1, the Dirac neutrino mass term arises from the cubic chiral superfield terms $\epsilon_{ij} \sum_{a,b} \hat{L}_a^i \hat{\chi}_b^c \hat{H}_u^j$ (all chiral superfields are taken as left-handed), where \hat{H}_u is the same Higgs that gives mass to the Q=2/3 quarks. The Dirac neutrino mass terms are thus proportional to $\sin \beta$, where $\tan \beta = v_u/v_d$ is the ratio of the vacuum expectation values of the two Higgs in the MSSM.

In general, in the Standard Model, in addition to the three known left-handed I=1/2 lepton doublets, there could be some number n_s of electroweak-singlet neutrinos. In a compact notation, one can then denote ν_L as the 3-component vector of left-handed I=1/2 neutrinos and χ_R to be the n_s -dimensional vector of electroweak-singlet singlets, taken to be right-handed. The general neutrino mass term in the Lagrangian is then given by

$$-\mathcal{L}_{m} = \frac{1}{2} (\overline{\nu}_{L}, \overline{\chi}_{L}^{c}) \begin{pmatrix} M_{L} & M_{D} \\ M_{D}^{T} & M_{R} \end{pmatrix} \begin{pmatrix} \nu_{R}^{c} \\ \chi_{R} \end{pmatrix} + h.c.$$
 (3)

where M_L is the 3×3 left-handed Majorana-mass matrix, M_R is a $n_s \times n_s$ right-handed Majorana-mass matrix, and ${\cal M}_D$ is the 3-row by n_s -column Dirac-mass matrix. In general, all of these mass matrices are complex. The anticommutativity of fermion fields and the property that $C\gamma_{\mu}C^{-1} = -\gamma_{\mu}^{T}$ together imply that the Majorana mass matrices are symmetric: $M_L = M_L^{\ T}, M_R = M_R^{\ T}$. The diagonalization of the full $(3 + n_s) \times (3 + n_s)$ mass matrix in Eq. (2) yields $3 + n_s$ mass eigenstates, which are, in general, of Majorana type. Since Majorana mass terms violate total lepton number, one sees from a general viewpoint that one does not expect conservation of total lepton number. In particular, the dimension-5 operators discussed above give rise to left-handed Majorana neutrino mass terms and violate total lepton number. Diracneutrinos can be constructed from two Majorana-neutrino mass eigenstates whose masses are equal in magnitude [16]. For this reason, Dirac neutrino masses may be considered to be a special (degenerate) case of Majorana neutrino masses, and the latter may be regarded as the generic case. From the transformation which diagonalizes the neutrino mass matrix, together with the transformation which diagonalizes the charged lepton mass matrix (where, of course, only Dirac masses are allowed by electric-charge conservation), one constructs the lepton-mixing matrix U. In general, since U is not the identity, neutrino masses naturally give rise to lepton family number violation.

In supersymmetric extensions of the Standard Model, the neutrinos could, a priori, mix with the neutralinos (higgsinos and neutral gauginos). However, the usual R parity which is invoked to forbid unacceptably rapid proton decay also prevents such mixing between neutrinos and neutralinos.

In addition to mass and lifetime limits, this Review includes limits on various other possible properties, including electric charge, the CPT-violating difference $m_{\nu_1}-m_{\overline{\nu}_1}$, and a magnetic dipole moment. These are of interest because a massless purely chiral Dirac neutrino cannot have a magnetic (or electric) dipole moment. In the standard electroweak theory, extended to allow for Dirac neutrino masses, the neutrino magnetic dipole moment is nonzero and given [13,17], as

$$\mu_{\nu_j} = \frac{3eG_F m_{\nu_j}}{8\pi^2 \sqrt{2}} = 3.2 \times 10^{-19} (m_{\nu_j}/1 \text{ eV}) \mu_B \tag{4}$$

where G_F is the Fermi constant and $\mu_B = e/2m_e$ is the Bohr magneton. The neutrino electric dipole moment violates both time-reversal invariance and parity; although it is nonzero in general, it is quite small (see, e.g. Ref. 18). Again, however, we note that Dirac neutrinos should be regarded as a special case; the generic case is Majorana neutrinos. Because of the properties

$$C\Gamma C^{-1} = -\Gamma$$
, $\Gamma = \sigma_{\alpha\beta}$, $\sigma_{\alpha\beta}\gamma_5$ (5)

it follows that the operator products which define the magnetic and electric dipole moments are of the respective forms

$$(\overline{\nu}_i \sigma_{\alpha\beta} \nu_i - \overline{\nu}_i \sigma_{\alpha\beta} \nu_i) F^{\alpha\beta} \tag{6}$$

and

$$(\overline{\nu}_i \sigma_{\alpha\beta} \gamma_5 \nu_j - \overline{\nu}_j \sigma_{\alpha\beta} \gamma_5 \nu_i) F^{\alpha\beta} \tag{7}$$

(where $F^{\alpha\beta}$ is the electromagnetic field strength tensor). Hence, if ν_i is a Majorana neutrino (mass eigenstate), its magnetic and electric dipole elements vanish identically. Although only the diagonal magnetic and electric dipole moments are static properties of a given neutrino mass eigenstate, transition magnetic and electric dipole moments may exist, in general, for both Dirac and Majorana neutrinos.

Occasionally, one also finds references to the "neutrino charge radius" in the literature. This is defined via the Taylor series expansion of the generalized vector Dirac form factor multiplying γ_{μ} in the electromagnetic current matrix element: $F_1^V(q^2) = F_1^V(0) + q^2 \, dF_1^V/dq^2|_{q^2=0} + \mathcal{O}[(q^2)^2]$, where q denotes the 4-momentum of the photon [see, e.g. Ref. 13 Eq. (2.20)]. The electric charge is $Q = F^V(0) = 0$ for a neutrino, and the charge radius is given by $\langle r^2 \rangle = (1/6)(F_1^V)'(0)$. However,

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since this is multiplied by q^2 in the Taylor series expansion, it never occurs for a real photon, where $q^2=0$, and hence is not an S-matrix element, *i.e.*, not a physical quantity. In a gauge theory, this is manifested in the fact that the charge radius is gauge-dependent.

If one considers the possibility of nonzero masses for neutrinos, for consistency one must then also consider the leptonic mixing which would in general occur concomitantly. Accordingly, this Review devotes a section to correlated bounds on neutrino masses and lepton mixing angles. These can be divided into two types. First, there are those due to decays involving neutrinos in the final state, which must be recognized to have the possible multimode structure pointed out above. In the two most sensitive cases suggested as tests for neutrino masses and mixing, one obtains a limit on m_{ν_i} and $|U_{aj}|^2$ individually for each j. The peak-search test proposed in Ref. 14 was applied to existing data in that paper and a subsequent one [15]; it was applied in new experiments on 2-body leptonic decays of K^+ and π^+ by several groups at SIN (PSI), KEK, and TRIUMF. The results are catalogued in corresponding subsections on limits on $|U_{1j}|^2$ and $|U_{2j}|^2$. The kink-search test was also applied by a number of groups. The experimental situation, which was controversial for many years, has recently been clarified (see below).

Second, there are those due to processes involving the propagation and subsequent interaction of neutrinos. The latter are often called neutrino-oscillation limits, although this term is strictly correct only if the differences in neutrino masses are sufficiently small relative to their momenta that the propagation is effectively coherent in a quantum mechanical sense; otherwise, the individual ν_j from a given decay such as $\pi_{\mu 2}$ or $K_{\mu 2}$ propagate in a measurably incoherent manner, and there is no oscillation. Experimentalists usually present their results in terms of a simplifying model in which mixing is assumed to occur only between two neutrino species. The relevant transformation equation becomes

$$\begin{pmatrix} \nu_{\ell_a} \\ \nu_{\ell_b} \end{pmatrix} = \begin{pmatrix} \cos \theta & \sin \theta \\ -\sin \theta & \cos \theta \end{pmatrix} \begin{pmatrix} \nu_i \\ \nu_j \end{pmatrix} \tag{8}$$

where ν_{ℓ_a} are the neutrino weak eigenstates, with $\nu_{\ell_1} = \nu_e$, etc., and ν_i are neutrino mass eigenstates. A given decay, such as $\pi^+ \to \mu^+ \nu_\mu$, produces, at time t=0, the neutrino mass eigenstates which are contained in the weak eigenstate ν_μ and are kinematically allowed to occur as decay products. Each mass eigenstate picks up a phase as it propagates, so that at time t, the jth eigenstate, as a quantum-mechanical state, has acquired a phase $\exp(-iE_jt)$, where E_j denotes its energy. Strictly speaking, E_j must be considered to be complex, since a massive neutrino will, in general, decay. Indeed such neutrino decays have been searched for in various experiments (see Listings). In the present discussion, we shall neglect this; for the ranges of neutrino masses of relevance to terrestrial neutrino oscillation experiments, such decays should have a

negligible effect on the observed oscillations. (Indeed, the observation of neutrinos at about the expected rate from the 1987 supernova places significant lower bounds on neutrino lifetimes.) According to basic quantum mechanics, one cannot measure the energies E_j or momenta $p_j = \sqrt{E_j^2 - m_{\nu_j^2}}$ to arbitrary precision; rather, $\Delta E_j \Delta t_j \gtrsim \hbar/2$ and $\Delta(p_x)_j \Delta x_j \gtrsim \hbar/2$. Correspondingly, the neutrinos actually propagate as wavepackets. As noted above, if the mass differences $|m_{\nu_i} - m_{\nu_k}|$ are sufficiently small relative to the energies $E_i \simeq E_k$, then the resultant velocities are sufficiently close that these wavepackets will continue to maintain a high degree of overlap during the relevant time that they propagate in the experiment, and hence the individual mass eigenstates will remain effectively coherent in the quantum mechanical sense. Their propagation may then be characterized by a single momentum p. Now assume that, after having propagated for a time t (and hence, for $1-v/c \ll 1$, a distance L = ct), the neutrino(s) scatter via a charged current weak interaction. This again projects out the weak interaction eigenstates. In particular, because of the different phases which the mass eigenstates pick up during the propagation, a neutrino which is emitted as ν_{ℓ_a} has a nonzero probability to produce

$$P = |\langle \nu_{\ell_b}(t) | \nu_{\ell_a}(0) \rangle|^2 = \sin^2(2\theta) \sin^2\left(\frac{\Delta m^2 L}{4E}\right)$$
 (9)

where

$$\Delta m^2 = m_{\nu_i}^2 - m_{\nu_i}^2 \tag{10}$$

Numerically, $\Delta m^2 L/(4E) = (1.266932...)\Delta m^2 L/E$, where Δm^2 is measured in eV^2 , L in m, and E in MeV (or L in km, E in GeV). Thus, neutrino oscillation experiments cannot measure individual neutrino masses, but only differences of masses squared, and indeed these are generally weighted in a more complicated way by lepton mixing matrix coefficients for the general case where there is mixing among more than just two species. Experimental results are presented as allowed regions on a plot, the axes of which are $|\Delta m^2|$ and $\sin^2 2\theta$. These are often summarized in terms of the upper limit on Δm^2 (the absolute value is usually suppressed in the notation) for maximal mixing, $\sin^2 2\theta = 1$, and the upper limit on $\sin^2 2\theta$ for "large" Δm^2 , i.e., sufficiently large $|\Delta m^2|$ that the detector averages over many cycles of oscillation (or there ceases to be any coherence). A more complete discussion is given in the "Note on Neutrino Oscillation Experiments" just before the tables reporting such results.

An important type of experiment is the search for neutrinoless double- β decay, which tests for total lepton number violation such as would result for Majorana-neutrino masses. This process takes place when a nucleus with Z protons and A=ZN nucleons decays according to $(Z,A) \to (Z+2,A)e^-e^-$, violating total lepton number by two units. In the case of neutrinos with masses which are sufficiently light, an upper limit

on neutrinoless double- β decay yields a correlated upper limit on the quantity

$$\overline{m} = \left| \sum_{j} U_{1j}^2 m_{\nu_j} \right| . \tag{11}$$

Cancellations may occur in the sum, since U_{1j} is, in general, complex. The situation is explored further in the minireview by Petr Vogel which prefaces the double- β decay sections. See Ref. 19 for some recent reviews of searches for neutrinoless double- β decay.

A brief summary of the current experimental situation follows (see previous editions for discussions of various positive claims for neutrino masses and mixing, and their refutations).

- 1. There is no evidence at present from direct searches for nonzero neutrino masses. These include the endpoint of the Kurie plot in nuclear beta decay for $m(\nu_e)$, $\pi^+ \to \mu^+ \nu_\mu$ for $m(\nu_\mu)$, and certain τ decays for $m(\nu_\tau)$ (where, as discussed above, the limits actually apply to the respective mass eigenstates ν_1 , ν_2 , and ν_3 in these three weak eigenstates).
- 2. There are no indications of any positive neutrino masses from any of the peak search experiments in π or K decay, or from any experiments on neutrino decays.
- 3. There are no indications of any positive neutrino masses from nuclear beta decay spectra. The 7-year controversy over the claim by Simpson, Hime, and others of a 17 keV neutrino is finally over, with retractions by these authors of their original claims after very strong refutations by a number of high-sensitivity experiments.
- 4. A number of positive claims for neutrino oscillations in reactor and accelerator neutrino experiments have either been refuted or retracted, or both (see previous editions for details). However, in one analysis, the LSND (Liquid Scintillator Neutrino Detector) group at Los Alamos has reported evidence for the neutrino oscillation $\overline{\nu}_{\mu} \rightarrow \overline{\nu}_{e}$ [20]. A dissenting analysis of the data by a member of the collaboration reports no evidence for neutrino oscillations [21]. More recently, the LSND group has increased its data sample and strengthened its evidence for neutrino oscillations [22].
- 5. There is no indication of Majorana neutrino masses from searches for neutrinoless double- β decay.
- 6. Several experiments have reported evidence for atmospheric neutrino oscillations. Other experiments report results consistent with no such oscillations. This situation is unsettled at present.
- 7. It is generally acknowledged that the strongest indirect evidence for neutrino masses and mixing is the observed deficit in the solar neutrino flux. The current situation is reviewed by K. Nakamura as a preface to the Solar Neutrino Listings.

For some recent reviews on neutrino physics and further references to the original literature, see Refs. 23–28.

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Neutrinos, ν_e

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 $J = \frac{1}{2}$

Not in general a mass eigenstate. See note on neutrino properties above.

These limits apply to ν_1 , the primary mass eigenstate in ν_e . They would also apply to any other ν_j which mixes strongly in ν_e and has sufficiently small mass that it can occur in the respective decay. The neutrino mass may be of a Dirac or Majorana type; the former conserves total lepton number while the latter violates it. Either would violate lepton family number, since nothing forces the neutrino mass eigenstates to coincide with the neutrino interaction eigenstates. For limits on a Majorana ν_e mass, see the section on "Searches for Massive Neutrinos and Lepton Mixing," part (C), entitled "Searches for Neutrinoless Double- β Decay."

The square of the neutrino mass $m_{\nu_e}^2$ is measured in tritium beta decay experiments by fitting the shape of the beta spectrum near the endpoint; results are given in one of the tables in this section. In many experiments, it has been found to be significantly negative. In the 1994 edition of this Review, it was noted that the combined probability of a positive result was 3.5%. The problem has been exacerbated by the precise and careful experiments reported in two new papers (BELESEV 95 and STOEFFL 95). Both groups conclude that unknown effects cause the accumulation of events in the electron spectrum near its end point. If the fitting hypothesis does not account for this, unphysical values for $m_{\nu_e}^2$ are obtained. BELESEV 95 obtain their value for $m_{\nu_e}^2$ and limit for m_{ν_e} (4.35 eV at 95% CL) under the assumption that a certain narrow region is free of both high-energy and low-energy anomalies. Including the endpoint accumulation (they find no low-energy anomaly), STOEFFL 95 find a value for $m_{\nu_e}^2$ which is more than 5 standard deviations negative, and report a Bayesian limit of 7 eV for m_{ν_e} which is obtained by setting $m_{\nu_e}^2 = 0$. Given the status of the tritium results, we find no clear way to set a meaningful limit on m_{ν_e} . On the other hand, a mass as large as $10-15~\mathrm{eV}$ would probably cause detectable spectrum distortions near the endpoint.

The spread of arrival times of the neutrinos from SN 1987A, coupled with the measured neutrino energies, should provide a simple time-of-flight limit on m_{ν_e} . This statement, clothed in various degrees of sophistication, has been the basis for a very large number of papers. The LOREDO 89 limit (23 eV) is among the most conservative and involves few assumptions; as such, it is probably a safe limit. We list this limit below as

"used," but conclude that a limit about half this size is justified by the tritium decay experiments.

ν_e MASS

Most of the data from which these limits are derived are from β^- decay experiments in which a $\overline{\nu}_e$ is produced, so that they really apply to $m_{\overline{\nu}_1}.$ Assuming CPT invariance, a limit on $m_{\overline{\nu}_1}$ is the same as a limit on $m_{\nu_1}.$ Results from studies of electron capture transitions, given below " $m_{\nu_1}-m_{\overline{\nu}_1}$ ", give limits on m_{ν_1} itself. OUR EVALUATION of the present status of the tritium decay experiments is discussed in the above minireview.

VALUE (eV)	CL%	DOCUMENT ID		TECN	COMMENT
< 15 OUR EVALUA < 23 • • • We do not use th		LOREDO data for averages	89 , fits	ASTR , limits,	
< 4.35 < 12.4 < 92	95 95 95	¹ BELESEV ² CHING ³ HIDDEMANN	95	SPEC SPEC SPEC	3 H eta decay 3 H eta decay 3 H eta decay
$\begin{array}{rr} +32 \\ -15 \end{array}$		HIDDEMANN	95	SPEC	3 H eta decay
< 19.6 < 7.0 <460 < 7.2 < 11.7 < 13.1 < 9.3 < 14	95 95 68 95 95 95 95	KERNAN 4 STOEFFL 5 YASUMI 6 WEINHEIMER 7 HOLZSCHUH 8 KAWAKAMI 9 ROBERTSON AVIGNONE	93 92B 91 91 90	SPEC SPEC SPEC ASTR	SN 1987A 3 H β decay e capture in 163 Ho 3 H β decay 3 H β decay 3 H β decay 3 H β decay 5 N 1987A
< 16 17 to 40		SPERGEL ¹⁰ BORIS	88 87	ASTR SPEC	SN 1987A $\overline{\nu}_e$, ³ H β decay

- 1 BELESEV 95 (Moscow) use an integral electrostatic spectrometer with adiabatic magnetic collimation and a gaseous triftium sources. A fit to a normal Kurie plot above 18300–18350 eV (to avoid a low-energy anomaly) plus a monochromatic line 7–15 eV below the endpoint yields $m_{\nu'}^2=-4.1\pm10.9~{\rm eV}^2$, leading to this Bayesian limit.
- ² CHING 95 quotes results previously given by SUN 93; no experimental details are given. A possible explanation for consistently negative values of m_{ν}^2 is given.
- ³ HIDDEMANN 95 (Munich) experiment uses atomic tritium embedded in a metal-dioxide lattice. Bayesian limit calculated from the weighted mean $m_{\nu}^2=221\pm4244~{\rm eV}^2$ from the two runs listed below.
- the two runs listed below. 4 STOEFFL 95 (LLNL) result is the Bayesian limit obtained from the m_{ν}^2 errors given below but with m_{ν}^2 set equal to 0. The anomalous endpoint accumulation leads to a value of m_{ν}^2 which is negative by more than 5 standard deviations.
- 5 The YASUMI 94 (KEK) limit results from their measurement $m_{\nu}{=}110 {+}\, ^{+350}_{-110}$ eV.
- ⁶ WEINHEIMER 93 (Mainz) is a measurement of the endpoint of the tritium β spectrum using an electrostatic spectrometer with a magnetic guiding field. The source is molecular tritium frozen onto an aluminum substrate.
- tritium frozen onto an aluminum substrate. 7 HOLZSCHUH 92B (Zurich) result is obtained from the measurement $m_{\nu}^2 = -24 \pm 48 \pm 61$ (1 σ errors), in eV², using the PDG prescription for conversion to a limit in m_{ν} .
- ⁸ KAWAKAMI 91 (Tokyo) experiment uses tritium-labeled arachidic acid. This result is the Bayesian limit obtained from the m_{ν}^2 limit with the errors combined in quadrature. This was also done in ROBERTSON 91, although the authors report a different procedure.
- 9 ROBERTSON 91 (LANL) experiment uses gaseous molecular tritium. The result is in strong disagreement with the earlier claims by the ITEP group [LUBIMOV 80, BORIS 87 (+ BORIS 88 erratum)] that m_{ν} lies between 17 and 40 eV. However, the probability of a positive m^2 is only 3% if statistical and systematic error are combined in quadrature. 10 See also comment in BORIS 87a and erratum in BORIS 88.

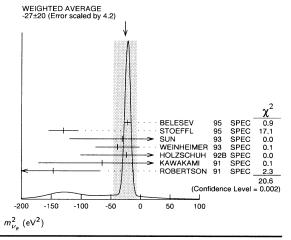
ν_e MASS SQUARED

The tritium experiments actually measure mass squared. A combined limit on mass must therefore be obtained from the weighted average of the results shown here. The recent results are in strong disagreement with the earlier claims by the ITEP group [LUBIMOV 80, BORIS 87 (+ BORIS 88, erratum)] that m_{ν_1} lies between 17 and 40 eV. The BORIS 87 result is excluded because of the controversy over the possibly large unreported systematic errors; see BERGKVIST 858, BERGKVIST 86, SIMPSON 84, and REDONDO 89. However, the average for the new experiments given below implies only a 3.5% probability that m^2 is positive. See HOLZSCHUH 92 for a review of the recent direct m_{ν_1} measurements.

VALUE (eV ²)	CL%	DOCUMENT ID		TECN	COMMENT
- 27± 20 OUR AV	ERAGE	Error includes scale	e fact	tor of 4.	2. See the ideogram
		below.			_
- 22± 4.8		¹¹ BELESEV	95	SPEC	3 H β decay
$-130\pm20\pm15$	95	¹² STOEFFL	95	SPEC	3 H β decay
$-31\pm75\pm48$		¹³ SUN	93	SPEC	3 H $_{\beta}$ decay
$-$ 39 \pm 34 \pm 15		¹⁴ WEINHEIMER	93	SPEC	3 H β decay
$-$ 24 \pm 48 \pm 61		¹⁵ HOLZSCHUH			
$-$ 65 \pm 85 \pm 65		¹⁶ KAWAKAMI			
$-147\pm68\pm41$		¹⁷ ROBERTSON	91	SPEC	3 H β decay
 ● ● We do not use the 	ne followin	g data for averages	, fits	, limits,	etc. • • •
129±6010		18 HIDDEMANN	95	SPEC	³ H β decay
313±5994		¹⁸ HIDDEMANN	95	SPEC	3 _H β decay

- 11 BELESEV 95 (Moscow) use an integral electrostatic spectrometer with adiabatic magnetic collimation and a gaseous tritium sources. This value comes from a fit to a normal Kurie plot above 18300–18350 eV (to avoid a low-energy anomaly), including the effects of an apparent peak 7-15 eV below the endpoint.

 12 STOEFFL 95 (LLNL) uses a gaseous source of molecular tritium. An anomalous pileup
- of events at the endpoint leads to the negative value for m_{ν}^2 . The authors acknowledge that "the negative value for the best fit of m_{ν}^2 has no physical meaning" and discuss possible explanations for this effect.
- 13 SUN 93 uses a tritiated hydrocarbon source. See also CHING 95.
- 14 WEINHEIMER 93 (Mainz) is a measurement of the endpoint of the tritium β spectrum using an electrostatic spectrometer with a magnetic guiding field. The source is molecular tritium frozen onto an aluminum substrate.
- 15 HOLZSCHUH 92B (Zurich) source is a monolayer of tritiated hydrocarbon.
- 16 KAWAKAMI 91 (Tokyo) experiment uses tritium-labeled arachidic acid.
- 17 ROBERTSON 91 (LANL) experiment uses gaseous molecular tritium. The result is in strong disagreement with the earlier claims by the ITEP group [LUBIMOV 80, BORIS 87 (+ BORIS 88 erratum)] that m_{ν} lies between 17 and 40 eV. However, the probability of a positive m_{ν}^2 is only 3% if statistical and systematic error are combined in quadrature.
- $^{18}\,\mathrm{HIDDEMANN}$ 95 (Munich) experiment uses atomic tritium embedded in a metal-dioxide lattice. They quote measurements from two data sets.



$m_{\nu_1}-m_{\overline{\nu}_1}$

These are measurement of m_{ν_1} (in contrast to $m_{\overline{\nu}_1}$, given above). The masses can be different for a Dirac neutrino in the absense of *CPT* invariance. ance. The test is not very strong.

VALUE (eV)	CL%	DOCUMENT ID		TECN	COMMENT
< 225	95	SPRINGER			
< 550	68	YASUMI	86	CNTR	$ u$, 163 Ho
• • We do not use the	following	data for average	s, fit	s, limits,	etc. • • •
$< 4.5 \times 10^{5}$	90	CLARK	74	ASPK	K_{e3} decay ν , 22 Na
<4100	67	BECK	68	CNTR	ν , 22 Na

ν₁ CHARGE

VALUE (units: electron charge)	DOCUMENT ID	TECN	COMMENT
• • • We do not use the follow	wing data for averages, fi	ts, limits	etc. • • •
-0 - 10-15	19 0 4 0 0 15 1 1 1 1 1 2	4.070	

 $<1 \times 10^{-13}$ BERNSTEIN 63 ASTR Solar energy losses

 $^{19}\,\mathrm{Precise}$ limit depends on assumptions about the intergalactic or galactic magnetic fields and about the direct distance and time through the field.

ν₁ MEAN LIFE

VALUE (s)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use	the follow	ing data for averag	es, fits	, limits,	etc. • • •
		²⁰ COWSIK	89	ASTR	$m_{11} = 1-50 \text{ MeV}$
		²¹ RAFFELT			
		22 RAFFELT	89B	ASTR	
>278	90	²³ LOSECCO	87B	IMB	
$> 1.1 \times 10^{25}$		²⁴ HENRY	81	ASTR	$m_{\nu} = 16-20 \text{ eV}$
$> 10^{22} - 10^{23}$		²⁵ KIMBLE	81	ASTR	$m_{\nu} = 10-100 \text{ eV}$

- 20 COWSIK 89 use observations of supernova SN 1987A to set the limit for the lifetime of a neutrino with 1 < m < 50 MeV decaying through ν_H \rightarrow $~\nu_1\,ee$ to be τ > 4×10^{15} exp(-m/5 MeV) s.
- ²¹ RAFFELT 89 uses KYULDJIEV 84 to obtain $\tau m^3 > 3 \times 10^{18} \, \mathrm{s} \, \mathrm{eV}^3$ (based on $\overline{\nu}_e \, \mathrm{e}^-$ cross sections). The bound is not valid if electric and magnetic transition moments are equal for Dirac neutrinos.
- 22 RAFFELT 89B analyze stellar evolution and exclude the region 3 imes 10 12 $\,<$ $\, au$ m^3
- 3 × 10²¹ seV³.
 23 LOSECCO 878 assumes observed rate of 2.1 SNU (solar neutrino units) comes from sun while 7.0 \pm 3.0 is theory.
- 24 HENRY 81 uses UV flux from clusters of galaxies to find limit for radiative decay.
- ²⁵ KIMBLE 81 uses extreme UV flux limits.

ν₁ (MEAN LIFE) / MASS

VALUE (s/eV)	CL%	DOCUMENT ID		TECN	COMMENT
>300	90	26 REINES	74	CNTR	\overline{v}
• • • We do not use the	follo	wing data for averages	s, fits	s, limits,	etc. • • •
$> 2.8 \times 10^{15}$		27,28 BLUDMAN	92	ASTR	$m_{1/} < 50 \text{ eV}$
> 6.4	90	²⁹ KRAKAUER	91		⊽ at LAMPF
$> 6.3 \times 10^{15}$		^{28,30} CHUPP	89	ASTR	$m_{\nu} < 20 \text{ eV}$
$> 1.7 \times 10^{15}$		²⁸ KOLB	89	ASTR	$m_{\nu} < 20 \text{ eV}$
$> 8.3 \times 10^{14}$		31 VONFEILIT	88	ASTR	•
> 22	68	32 OBERAUER	87		$\overline{\nu}_R$ (Dirac)
> 38	68	32 OBERAUER	87		▽ (Majorana)
> 59	68	³² OBERAUER	87		\overline{v}_L (Dirac)
> 30	68	KETOV	86	CNTR	$\overline{\nu}$ (Dirac)
> 20	68	KETOV	86		$\overline{ u}$ (Majorana)
> 7 × 10 ⁹		33 RAFFELT	85	ASTR	
$> 2 \times 10^{21}$		34 STECKER	80	ASTR	$m_{ u} = 10$ –100 eV

²⁶ REINES 74 looked for ν_e of nonzero mass decaying to a neutral of lesser mass + γ . Used liquid scintillator detector near fission reactor. Finds lab lifetime $6. \times 10^7$ s or more. Above value of (mean life)/mass assumes average effective neutrino energy of 0.2 MeV. To obtain the limit 6. x 10^7 s REINES 74 assumed that the full $\overline{\nu}_e$ reactor flux could be responsible for yielding decays with photon energies in the interval 0.1 MeV - 0.5 MeV. This represents some overestimate so their lower limit is an over-estimate of their lower limit is an over-estimate of the other lower limit is an over-estimate of their lower limit is an over-estimate of the other lower limit is an over-esti lab lifetime (P. Vogel, private communication, 1984).

27 BLUDMAN 92 sets additional limits by this method for higher mass ranges. Cosmological limits are also obtained. 28 Nonobservation of γ 's in coincidence with ν 's from SN 1987A.

 29 KRAKAUER 91 quotes the limit $\tau/m_{\nu_1}~>$ (0.3a^2 +~9.8a+15.9) s/eV, where a is a parameter describing the asymmetry in the neutrino decay defined as $dN_{\gamma}/d{\rm cos}\theta=$ $(1/2)(1 + a\cos\theta)$ a = 0 for a Majorana neutrino, but can vary from -1 to 1 for a Dirac neutrino. The bound given by the authors is the most conservative (which applies for

30 CHUPP 89 should be multiplied by a branching ratio (about 1) and a detection efficiency (about 1/4), and pertains to radiative decay of any neutrino to a lighter or sterile neutrino. 31 Model-dependent theoretical analysis of SN 1987A neutrinos.

32 OBERAUER 87 bounds are from comparison of observed and expected rate of reactor

33 RAFFELT 85 limit is from solar x- and γ -ray fluxes.

 34 STECKER 80 limit based on UV background; result given is $au > 4 imes 10^{22}\,\mathrm{s}$ at $m_{
u} = 20$

$|(v-c)/c| (v \equiv \nu_1 \text{ VELOCITY})$

Expected to be zero for massless neutrino, but tests also whether photons and neutrinos have the same limiting velocity in vacuum.

 35 STODOLSKY 88 result based on $<\!10$ hr between $\overline{\nu}_e$ detection in IMB and KAMI detectors and beginning of light signal. Inclusion of the problematic 5 neutrino events from FREJ (four hours later) does not change the result.

ν_1 MAGNETIC MOMENT

Must vanish for Majorana neutrino or purely chiral massless Dirac neutrino. The value of the magnetic moment for the standard $SU(2) \times U(1)$ electroweak theory extended to include massive neutrinos (see FUJIKAWA 80) troweak theory extended to include massive heutrinos (see FUJIKAVA 80) is $\mu_{\nu}=3eG_{F}m_{\nu}/(8\pi^{2}\sqrt{2})=(3.20\times10^{-19})m_{\nu}\mu_{B}$ where m_{ν} is in eV and $\mu_{B}=e\hbar/2m_{e}$ is the Bohr magneton. Given the upper bound $m_{\nu_{1}}<7.3$ eV, it follows that for the extended standard electroweak theory, $\mu(\nu_{1})<2.3\times10^{-18}~\mu_{B}$. Current experiments are not yet challenging this limit. There is considerable controversy over the validity of many of the claimed upper limits on the magnetic moment from the astrophysical data. For example, VOLOSHIN 90 states that "in connection with the astrophysical limits on μ_{ν} , ... there is by now a general consensus that contrary to the initial claims (BARBIERI 88, LATTIMER 88, GOLD-MAN 88, NOTZOLD 88), essentially no better than quoted limits (from previous constraints) can be derived from detection of the neutrino flux from the supernova SN1987A." See VOLOSHIN 88 and VOLOSHIN 88c.

VALUE $(10^{-10} \mu_B)$	CL%	DOCUMENT ID		TECN	COMMENT
< 1.8	₉₀ 3	6 DERBIN	94	CNTR	Reactor $\overline{v}_e e \rightarrow \overline{v}_e e$
• • • We do not us	e the following	data for average	s, fits	, limits,	etc. • • •
< 0.003-0.0005	3	⁷ GOYAL	95		SN 1987A
< 7.7	95	MOURAO	92	ASTR	HOME/KAM2 ν rates
< 2.4		⁸ VIDYAKIN	92	CNTR	Reactor $\overline{\nu}_e e \rightarrow \overline{\nu}_e e$
<10.8	90 3	⁹ KRAKAUER	90	CNTR	LAMPF $\nu_e e \rightarrow \nu_e e$
< 0.02	95 4	⁰ RAFFELT	90	ASTR	Red giant luminosity
< 0.1		1 RAFFELT	89B	ASTR	Cooling helium stars
< 0.02-0.08	41,42,4	³ BARBIERI	88	ASTR	SN 1987A
	40 40 4	⁴ FUKUGITA	88		Primordial magn. fields
< 0.01	42,43,4	5 GOLDMAN	88	ASTR	SN 1987A
< 0.005	41,4	3 LATTIMER	88	ASTR	SN 1987A
≤ 0.015	41,4	³ NOETZOLD	88	ASTR	SN 1987A
≤ .3	4	¹ RAFFELT	88B	ASTR	He burning stars
< 0.11	4	¹ FUKUGITA	87	ASTR	Cooling helium stars
< 0.4		LYNN	81	ASTR	
< 0.1-0.2		MORGAN	81	COSM	⁴ He abundance
< 0.85		BEG	78	ASTR	Stellar plasmons
< 0.6	4	⁶ SUTHERLANI	76	ASTR	Red giants + degen. dwarfs
< 1		BERNSTEIN	63	ASTR	Cooling white dwarfs
<14		COWAN	57	CNTR	Reactor $\overline{\nu}_e$
26					

³⁶ DERBIN 94 supersedes DERBIN 93.

NONSTANDARD CONTRIBUTIONS TO NEUTRINO SCATTERING

We report limits on the so-called neutrino charge radius squared in this section. This quantity is not an observable, physical quantity and this is reflected in the fact that it is gauge dependent (see LEE 77c). It is not necessarily positive. A more general interpretation of the experimental results is that they are limits on certain nonstandard contributions to neutrino scattering.

$VALUE (10^{-32} \text{ cm}^2)$	CL%	DOCUMENT ID		TECN	COMMENT
0.9±2.7		ALLEN	93	CNTR	LAMPF $\nu_e e \rightarrow \nu_e e$
• • • We do not i	use the followi	ng data for averag	es, fits	, limits,	etc. • • •
<2.3	95	MOURAO	92	ASTR	HOME/KAM2 ν rates
<7.3	90	⁴⁷ VIDYAKIN	92	CNTR	Reactor $\overline{v}_e e \rightarrow \overline{v}_e e$
1.1 ± 2.3		ALLEN	91	CNTR	Repl. by ALLEN 93
		48 GRIFOLS	898	ASTR	SN 1987A

 $^{^{47}}$ VIDYAKIN 92 limit is from a $e\overline{\nu}_e$ elastic scattering experiment. No experimental details are given except for the cross section from which this limit is derived. Signal/noise was 1/10. The limit uses $\sin^2\!\theta_W = 0.23$ as input. 48 GRIFOLS 89B sets a limit of $\left\langle r^2\right\rangle < 0.2\times 10^{-32}\,\mathrm{cm}^2$ for right-handed neutrinos.

ve REFERENCES

BELESEY 95					
XERNAM 95	BELESEV		PL B350 263	+Bleule, Geraskin, Golubev+	(INRM, KIAE)
XERNAM 95	CHING		IJMP A10 2841	+Ho, Liang, Mao, Chen, Sun	(CST, BEIJT, CIAE)
XERNAM 95	GOYAL	95	PL B346 312	+Dutta, Choudhury	(DELH)
STOEFFL 95 PRIL 75 3237	KEDNAN	95	ND B437 243	+Danier, Schwentker	(CASE)
DERBIN 94	STOFFFI	95	PRI 75 3237	+Decman	(LINI)
ASLUM 94			PAN 57 222		(PNPI)
WEINBEIMER 39 P.			Translated from YAF 57	236.	
WEINBEIMER 39 P.			PL B334 229	+Maezawa, Shima, Inagaki+	(KEK, TSUK, KYOT+)
WEINBEIMER 39 P.			PR D47 11	+Chen, Doe, Hausammann+	(UCI, LANL, ANL, UMD)
WEINBEIMER 39 P.	DERBIN	93	Translated from ZETEP	57 755	(PNPI)
Verlinteners 35			CJNP 15 261	+Liang, Chen, Si+	(CIAE, CST, BEIJT)
SLUDMAN 92 PR 794 794 795 79	WEINHEIMER	93	PL B300 210	+Przyrembel, Backe+	(MANZ)
HOLZSCHUH 928 Pl. B287 381			PR D45 4720		(CFPA)
KRAKAUER 90 PIL B352 177 +Talaga, Allen, Chen+ (LAMPF E225 Collab.) RAFFELT 90 PRL 64 2856 VOLOSHIN 90 NP B (Proc. Suppl.) 19 433 (ITEP) Neutrino 90 Conference CHUPP 89 PRL 62 505 +Vestrand, Reppin (UNH, MPIM) (GRIFOLS 89 PR L 62 509 +Schramm, Hoffich (WUSL, TATA, CHIC, MPIM) (BARC) (CHIC, FNA) (CHIC, F			RPP 55 1035		(ZURI)
KRAKAUER 90 PIL B352 177 +Talaga, Allen, Chen+ (LAMPF E225 Collab.) RAFFELT 90 PRL 64 2856 VOLOSHIN 90 NP B (Proc. Suppl.) 19 433 (ITEP) Neutrino 90 Conference CHUPP 89 PRL 62 505 +Vestrand, Reppin (UNH, MPIM) (GRIFOLS 89 PR L 62 509 +Schramm, Hoffich (WUSL, TATA, CHIC, MPIM) (BARC) (CHIC, FNA) (CHIC, F			PL B287 381	+Fritschi, Kuendig	(ZURI)
KRAKAUER 90 PIL B352 177 +Talaga, Allen, Chen+ (LAMPF E225 Collab.) RAFFELT 90 PRL 64 2856 VOLOSHIN 90 NP B (Proc. Suppl.) 19 433 (ITEP) Neutrino 90 Conference CHUPP 89 PRL 62 505 +Vestrand, Reppin (UNH, MPIM) (GRIFOLS 89 PR L 62 509 +Schramm, Hoffich (WUSL, TATA, CHIC, MPIM) (BARC) (CHIC, FNA) (CHIC, F			IETDI 55 206	+Fulldo, Raistoli (Li.	OB, LISBI, CERN, KANS)
KRAKAUER 90 PIL B352 177 +Talaga, Allen, Chen+ (LAMPF E225 Collab.) RAFFELT 90 PRL 64 2856 VOLOSHIN 90 NP B (Proc. Suppl.) 19 433 (ITEP) Neutrino 90 Conference CHUPP 89 PRL 62 505 +Vestrand, Reppin (UNH, MPIM) (GRIFOLS 89 PR L 62 509 +Schramm, Hoffich (WUSL, TATA, CHIC, MPIM) (BARC) (CHIC, FNA) (CHIC, F	VIDIANIN	72	Translated from ZETFP	55 212.	(KIAL)
KRAKAUER 90 PIL B352 177 +Talaga, Allen, Chen+ (LAMPF E225 Collab.) RAFFELT 90 PRL 64 2856 VOLOSHIN 90 NP B (Proc. Suppl.) 19 433 (ITEP) Neutrino 90 Conference CHUPP 89 PRL 62 505 +Vestrand, Reppin (UNH, MPIM) (GRIFOLS 89 PR L 62 509 +Schramm, Hoffich (WUSL, TATA, CHIC, MPIM) (BARC) (CHIC, FNA) (CHIC, F	ALLEN		PR D43 R1	+Chen, Doe, Hausammann	(UCI, LANL, UMD)
KRAKAUER 90 PIL B352 177 +Talaga, Allen, Chen+ (LAMPF E225 Collab.) RAFFELT 90 PRL 64 2856 VOLOSHIN 90 NP B (Proc. Suppl.) 19 433 (ITEP) Neutrino 90 Conference CHUPP 89 PRL 62 505 +Vestrand, Reppin (UNH, MPIM) (GRIFOLS 89 PR L 62 509 +Schramm, Hoffich (WUSL, TATA, CHIC, MPIM) (BARC) (CHIC, FNA) (CHIC, F			PL B256 105	+Kato, Ohshima+ (INUS, TO	HOK, TINT, KOBE, KEK)
KRAKAUER 90 PIL B352 177 +Talaga, Allen, Chen+ (LAMPF E225 Collab.) RAFFELT 90 PRL 64 2856 VOLOSHIN 90 NP B (Proc. Suppl.) 19 433 (ITEP) Neutrino 90 Conference CHUPP 89 PRL 62 505 +Vestrand, Reppin (UNH, MPIM) (GRIFOLS 89 PR L 62 509 +Schramm, Hoffich (WUSL, TATA, CHIC, MPIM) (BARC) (CHIC, FNA) (CHIC, F			PR D44 R6	+Talaga, Allen, Chen+	(LAMPF E225 Collab.)
KRAKAUER 90 PIL B352 177 +Talaga, Allen, Chen+ (LAMPF E225 Collab.) RAFFELT 90 PRL 64 2856 VOLOSHIN 90 NP B (Proc. Suppl.) 19 433 (ITEP) Neutrino 90 Conference CHUPP 89 PRL 62 505 +Vestrand, Reppin (UNH, MPIM) (GRIFOLS 89 PR L 62 509 +Schramm, Hoffich (WUSL, TATA, CHIC, MPIM) (BARC) (CHIC, FNA) (CHIC, F			PRL 67 957	+Bowles, Stephenson, Wark, Will	kerson, Knapp (LASL, LLL)
RAFFELT 90	AVIGNONE				(SCUC)
VOLOSHIN 90 NP B (Proc. Suppl) 19 433 (ITEP)	RAFFELT		PRI 64 2856	Traiaga, Alleli, Cilelit	(MPIM)
Neutrino 90 Conference CHUPP 89 PR 162 595			NP B (Proc. Suppl) 19	433	(ITEP)
GRIPCIOS	Moutrino Of	Cont	erence		, ,
GRIPCIOS	CHUPP	89	PRL 62 505	+Vestrand, Reppin	(UNH, MPIM)
More	COWSIK		PL B218 91	+Schramm, Hoflich (W	USL, TATA, CHIC, MPIM)
NATECLIT 89	GRIFOLS		PR D40 3819	+ Masso	(BARC)
REDUNDU	KOLB		ANIVAS 671 601		(CHIC, FNAL)
REDUNDU	RAFFELT		PR D39 2066	+Lamb	(PRIN LICE)
REDUNDU	RAFFELT		API 336 61	+Dearborn, Silk	(UCB. LLL)
BARBIERI 888	REDONDO				(LANL)
BARBIERI 888	BARBIERI	88	PRL 61 27	+Mohapatra	(PISA, UMD)
NOTZOLD	BARBIERI		PL B213 69	+Mohapatra, Yanagida	(PISA, UMD, MICH)
NOTZOLD			PRL 61 245 erratum	+Golutvin, Laptin+	(ITEP, ASCI)
NOTZOLD			PRL 60 879	+ Notzoid, Katreit, Silk	(KTOIT, MPIM, UCB)
NOTZOLD	LATTIMER		PRI 61 23	+Connerstein	(STON, BNI.)
NOETZOLD	Also		PRL 61 2633 erratum	Lattimer. Cooperstein	
SPERGEL 88		88	PR D38 1658		(MPIM)
SPERGEL 88	NOTZOLD		PR D38 1658		(MPIM)
VOLOSHIN 88			PR D37 549		(UCB, LLL)
VOLOSHIN 88			PL B200 366	+Bahcall	(IAS)
Also			PL B201 353		(MPIM)
Translated from ZETFP 47 421.			IETDI 47 501	Voloshin	(ITEP)
VOLOSHIN VONFEILIT. 88 BARBIELLINI BARBIELLINI BORIS 2 JETPL 68 690 Nature 329 21 FORCE BORIS Von Feilitzsch, Oberauer (MUNT) (ITEP, ACCCONI FORCE BORIS (ITEP, ASCI) BORIS BORIS 87 BFL 158 2019 PRL 61 245 erratum Translated from ZETFP 45 267. +Golutvin, Laptin+ FOILUVini,	A130	000	Translated from ZETED	47 421.	(1121)
BABIELLINI 87	VOLOSHIN		JETPL 68 690		(ITEP)
Also				Von Feilitzsch, Oberauer	(MUNT)
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FUNCISTA PR D36 3817			IFTPI 45 333	+Golutvin Lantin+	(ITEP, ASCI)
FUNCISTA PR D36 3817	DOMO		Translated from ZETFP	45 267.	
OBERAUER 87	FUKUGITA				(KYOTY, TOKY)
SERGKVIST 86			PR D35 2073	+Bionta, Blewitt, Bratton+	(IMB Collab.)
BERGKVIST 86			PL B198 113	+von Fellitzsch, Mossbauer	(INDIVI)
NASUM 86	BERGKVIST				(LLIVE)
NASUM 86	KETOV		JETPL 44 146	+Klimov, Nikolaev, Mikaelvan+	(KIAE)
NASUM 86			Translated from ZETFP	44 114.	
RAFELT			PL B181 169	+Ando+ (KEK, OSAK, TOHO	K, 15UK, KYOT, INUS+)
KYULDJIEV			PR D31 3002		(MPIMA)
SIMPSON 84			NP B243 387		(SOFI)
HENRY 81	SIMPSON	84	PR D30 1110		(GUEL)
LYNN 81	HENRY		PRL 47 618		(UHL)
MORGAN 81	KIMBLE		PRL 46 80	+Bowyer, Jakobsen	
FUJIKAWA 80			PK D23 2151	Manna	(COLU)
LUBIMOV 80	MURGAN			Shrock	(SUSS)
Also 81 JETP 54 616 Lubimov, Novikov, Nozik+ (TEP) Translated from ZETF 81 1158. STECKER 80 PRL 45 1460 BEG 78 PR D17 1395 + Marciano, Ruderman (ROCK, COLU) LEE 7C PR D16 1444 + Shrock (STON) SUTHERLAND 76 PR D13 2700 + Ng. Flowers+ (PENN, COLU, NYU) CLARK 74 PR D9 533 + Elioff, Frisch, Johnson, Kerth, Shen+ (UEI) Also 78 Private Comm. Barnes (PURD) BECK 68 ZPHY 216 229 + Daniel (MPIH) BERNSTEIN 63 PR 132 1227 + RUderman, Feinberg (NYU, COLU)			PI 94B 266	+Novikov, Nozik, Tretvakov Kosi	ik (ITEP)
Also 81 JETP 54 616 Lubimov, Novikov, Nozik+ (TEP) Translated from ZETF 81 1158. STECKER 80 PRL 45 1460 BEG 78 PR D17 1395 + Marciano, Ruderman (ROCK, COLU) LEE 7C PR D16 1444 + Shrock (STON) SUTHERLAND 76 PR D13 2700 + Ng. Flowers+ (PENN, COLU, NYU) CLARK 74 PR D9 533 + Elioff, Frisch, Johnson, Kerth, Shen+ (UEI) Also 78 Private Comm. Barnes (PURD) BECK 68 ZPHY 216 229 + Daniel (MPIH) BERNSTEIN 63 PR 132 1227 + RUderman, Feinberg (NYU, COLU)			SJNP 32 154	Kozik, Lubimov, Novikov+	(ITEP)
Also 81 JETP 54 616 Lubimov, Novikov, Nozik+ (TEP) Translated from ZETF 81 1158. STECKER 80 PRL 45 1460 BEG 78 PR D17 1395 + Marciano, Ruderman (ROCK, COLU) LEE 7C PR D16 1444 + Shrock (STON) SUTHERLAND 76 PR D13 2700 + Ng. Flowers+ (PENN, COLU, NYU) CLARK 74 PR D9 533 + Elioff, Frisch, Johnson, Kerth, Shen+ (UEI) Also 78 Private Comm. Barnes (PURD) BECK 68 ZPHY 216 229 + Daniel (MPIH) BERNSTEIN 63 PR 132 1227 + RUderman, Feinberg (NYU, COLU)			Translated from YAF 32	301.	
STECKER 80	Also	81	JETP 54 616	Lubimov, Novikov, Nozik+	(ITEP)
SUTHERLAND 76	STECKED	80	PRI 45 1460	31 1138.	(NIACA)
SUTHERLAND 76				+Marciano, Ruderman	(ROCK, COLU)
REINES 74 PRI. 32 180 +Sobel, Gurr (UCI) Also 78 Private Comm. Barnes (PURD) BECK 68 ZPHY 216 229 +Daniel (MPIH) BERNSTEIN 63 PR 132 1227 +Ruderman, Feinberg (NYU, COLU)	LEE	77C	PR D16 1444	+Shrock	(SION)
REINES 74 PRI. 32 180 +Sobel, Gurr (UCI) Also 78 Private Comm. Barnes (PURD) BECK 68 ZPHY 216 229 +Daniel (MPHH) BERNSTEIN 63 PR 132 1227 +Ruderman, Feinberg (NYU, COLU)	SUTHERLAND	76	PR D13 2700	+Ng, Flowers+	(PENN, COLU, NYU)
Also 78 Private Comm. Barnes (PURD) BECK 68 ZPHY 216 229 +Daniel (MPIH) BERNSTEIN 63 PR 132 1227 +Ruderman, Feinberg (NYU, COLU)	CLARK	74			Shen+ (LBL)
BECK 68 ZPHY 216 229 + Daniel (MPIH) BERNSTEIN 63 PR 132 1227 + Ruderman, Feinberg (NYU, COLU)			PKL 32 180	+Sone, Gurr	(UCI)
BERNSTEIN 63 PR 132 1227 +Ruderman, Feinberg (NYU, COLU)	BECK		7PHY 216 229		(MPIH)
COWAN 57 PR 107 528 + Reines (LANL)	BERNSTEIN		PR 132 1227	+Ruderman, Feinberg	(NYU, COLU)
			PR 107 528		(LANL)

³⁷ GOYAL 95 assume that helicity flip via μ_{ν} would result in faster cooling and hence shorter burst from SN1987A. Limit is based on the assumed presence of a pion condensate or

burst from \$1987A. Limit is based on the assumed presence of a pion condensate or quark core in the remanant.

38 VIDYAKIN 92 limit is from a $e\overline{\nu}_e$ elastic scattering experiment. No experimental details are given except for the cross section from which this limit is derived. Signal/noise was 1/10. The limit uses $\sin^2\theta_W = 0.23$ as input.

 ^{1/10.} The limit uses Sin - W = 0.23 as input.
 39 KRAKAUER 90 experiment fully reported in ALLEN 93.
 40 RAFFELT 90 limit applies for a diagonal magnetic moment of a Dirac neutrino, or for a transition magnetic moment of a Majorana neutrino. In the latter case, the same analysis gives < 1.4 × 10⁻¹². Limit at 95%CL obtained from δM_C.

 $^{^{41}}$ Significant dependence on details of stellar models. 42 A limit of 10^{-13} is obtained with even more model-dependence.

 $^{^{43}}$ These papers have assumed that the right-handed neutrino is inert; see BARBIERI 88B.

⁴⁴ FUKUGITA 88 find magnetic dipole moments of any two neutrino species are bounded by $\mu < 10^{-16} \left[10^{-9} \, G/B_0\right]$ where B_0 is the present-day intergalactic field strength.

⁴⁵ Some dependence on details of stellar models.

⁴⁶ We obtain above limit from SUTHERLAND 76 using their limit f < 1/3.



 $J = \frac{1}{2}$

Not in general a mass eigenstate. See note on neutrinos in the ν_a

u_{μ} MASS

Applies to ν_2 , the primary mass eigenstate in ν_μ . Would also apply to any other ν_j which mixes strongly in ν_μ and has sufficiently small mass that it can occur in the respective decays. (This would be nontrivial only for \geq 3, given the $u_{
m e}$ mass limit above.) Results based upon an obselete pion mass are no longer shown; they were in any cass less restrive than ASSAMAGAN 96.

VALUE (MeV)	CL%	DOCUMENT ID		TECN	COMMENT
<0.17	90	¹ ASSAMAGAN	96	SPEC	$m^2 = -0.016 \pm 0.023$
• • • We do not us	se the following	ng data for average	s, fits	, limits,	etc. • • •
< 0.15		² DOLGOV	95	COSM	Nucleosynthesis
< 0.48		³ ENQVIST	93	COSM	Nucleosynthesis
< 0.003		4,5 MAYLE	93	ASTR	SN 1987A cooling
< 0.025-0.030		^{5,6} BURROWS	92	ASTR	SN 1987A cooling
< 0.3		⁷ FULLER	91	COSM	Nucleosynthesis
< 0.42		⁷ LAM	91	COSM	Nucleosynthesis
< 0.028-0.15		⁸ NATALE	91	ASTR	SN 1987A
< 0.028		⁵ GANDHI	90	ASTR	SN 1987A
< 0.014		^{5,9} GRIFOLS	90B	ASTR	SN 1987A
< 0.06	Į.	^{5,10} GAEMERS	89		SN 1987A
< 0.50	90	¹¹ ANDERHUB	82	SPEC	$m^2 = -0.14 \pm 0.20$
< 0.65	90	CLARK	74	ASPK	K ₁₁₃ decay

- 1 ASSAMAGAN 96 measurement of ho_μ from $\pi^+
 ightarrow \ \mu^+
 u_\mu$ at rest combined with JECK-ELMANN 94 Solution B pion mass yields $m_{\nu}^2 = -0.016 \pm 0.023$ with corresponding
- bayesian limit listed above. If Solution A is used, $m_2=-0.143\pm0.024~{\rm MeV}^2$. Replaces ASSAMAGAN 94. 2 DOLGOV 95 removes earlier assumptions (DOLGOV 93) about thermal equilibrium below $T_{\rm QCD}$ for wrong-helicity Divac neutrinos (ENQVIST 93, FULLER 91) to set more stringent limits.
- gent limits.

 3 ENQVIST 93 bases limit on the fact that thermalized wrong-helicity Dirac neutrinos would speed up expansion of early universe, thus reducing the primordial abundance. FULLER 91 exploits the same mechanism but in the older calculation obtains a larger production rate for these states, and hence a lower limit. Neutrino lifetime assumed to exceed nucleosynthesis time, ~ 1 s.
- **MAYLE 39 recalculates cooling rate enhancement by escape of wrong-helicity Dirac neutrinos using the Livermore Supernova Explosion Code, obtains more restrictive result than the "very conservative" BURROWS 92 limit because of higher core temperature.

 5 There would be an increased cooling rate if Dirac neutrino mass is included; this does
- not apply for Majorana neutrinos. Limit is on $\sqrt{m^2_{\nu_{\mu}} + m^2_{\nu_{\tau}}}$, and error becomes very large if ν_{τ} is nonrelativistic, which occurs near the lab limit of 31 MeV. RAJPOOT 93 notes that limit could be evaded with new physics. 6 BURROWS 92 limit for Dirac neutrinos only.

- Assumes neutrino lifetime >1 s. For Dirac neutrinos only. See also ENQVIST 93.
- ⁸ NATALE 91 published result multiplied by $\sqrt{8}\sqrt{4}$ at the advice of the author.
- $^9\,\rm GRIFOLS$ 90B estimated error is a factor of 3. $^{10}\,\rm GAEMERS$ 89 published result (< 0.03) corrected via the GANDHI 91 erratum.
- $^{11}\,\mathrm{ANDERHUB}$ 82 kinematics is insensitive to the pion mass.

Test of CPT for a Dirac neutrino. (Not a very strong test.)

VALUE (MeV)	CL%	DOCUMENT ID	TECN	COMMENT
• • We do not use the	following	data for averages, fits	, limits,	etc. • • •
< 0.45	90	CLARK 74	ASPK	$\kappa_{\mu 3}$ decay

ν₂ (MEAN LIFE) / MASS

These limits often apply to $\nu_{ au}$ (ν_3) also.

VALUE (s/eV)	CL% EV	/TS	DOCUMENT ID		TECN	COMMENT
>15.4	90		¹² KRAKAUER	91	CNTR	ν_{μ} , $\overline{\nu}_{\mu}$ at LAMPF
• • • We do not use	the follow	ing	data for averages, fits			
$> 2.8 \times 10^{15}$			13,14 BLUDMAN	92	ASTR	$m_{11} < 50 \text{ eV}$
none $10^{-12} - 5 \times 10^{-12}$	₀ 4		15 DODELSON	92	ASTR	$m_{\nu}^{\nu} = 1 - 300 \text{ keV}$
$> 6.3 \times 10^{15}$			^{14,16} CHUPP	89	ASTR	$m_{\nu}^{\nu} < 20 \text{ eV}$
$> 1.7 \times 10^{15}$			¹⁴ KOLB	89	ASTR	$m_{\nu} < 20 \text{ eV}$
$> 3.3 \times 10^{14}$			17,18 VONFEILIT	88	ASTR	•
> 0.11	90	0	¹⁹ FRANK	81	CNTR	$ u \overline{ u}$ LAMPF
			20 HENRY	81	ASTR	$m_{\nu} = 16-20 \text{ eV}$
			21 KIMBLE	81	ASTR	$m_{\nu} = 10 - 100 \text{ eV}$
			²² REPHAELI	81	ASTR	$m_{\nu} = 30-150 \text{ eV}$
			²³ DERUJULA	80	ASTR	$m_{\nu} = 10 - 100 \text{ eV}$
$> 2 \times 10^{21}$			²⁴ STECKER	80	ASTR	$m_{\nu} = 10 - 100 \text{ eV}$
$> 1.0 \times 10^{-2}$	90	0	¹⁹ BLIETSCHAU	78	HLBC	ν_{μ} , CERN GGM
$> 1.7 \times 10^{-2}$	90	0	¹⁹ BLIETSCHAU	78	HLBC	\overline{v}_{μ} , CERN GGM
$> 2.2 \times 10^{-3}$	90	0	¹⁹ BARNES	77	DBC	ν, ANL 12-ft
$> 3. \times 10^{-3}$	90	0	¹⁹ BELLOTTI	76	HLBC	ν , CERN GGM
$> 1.3 \times 10^{-2}$	90	1	19 BELLOTTI	76	HLBC	v. CERN GGM

- $^{12}\,\mathrm{KRAKAUER}$ 91 quotes the limit $\tau/m_{\nu_1}~>$ (0.75a^2 ~+~ 21.65a +~ 26.3) s/eV, where a is a parameter describing the asymmetry in the neutrino decay defined as $dN_{\gamma}/d{\cos} heta$ $=(1/2)(1+a\cos\theta)$ The parameter a=0 for a Majorana neutrino, but can vary from -1 to 1 for a Dirac neutrino. The bound given by the authors is the most conservative (which applies for a=-1).
- 13 BLUDMAN 92 sets additional limits by this method for higher mass ranges. Cosmological limits are also obtained. 14 Nonobservation of γ^\prime s in coincidence with ν 's from SN 1987A. Results should be divided by the $\tau_\nu \rightarrow \gamma {\rm X}$ branching ratio.
- 15 DODELSON 92 range is for wrong-helicity keV mass Dirac ν 's from the core of neutron star in SN 1987A decaying to ν 's that would have interacted in KAM2 or IMB detectors.
- 16 CHUPP 89 should be multiplied by a branching ratio (about 1) and a detection efficiency (about 1/4), and pertains to radiative decay of any neutrino to a lighter or sterile neutrino.
- 17 Model-dependent theoretical analysis of SN 1987A neutrinos.
- 18 Limit applies to ν_{τ} also.
- 19 These experiments look for $\nu_{\mu} \to \ \nu_{e} \gamma$ or $\overline{\nu}_{\mu} \to \ \overline{\nu}_{e} \gamma$.
- 20 HENRY 81 uses UV flux from clusters of galaxies to find $au>~1.1 imes10^{25}\,\mathrm{s}$ for radiative
- 21 KIMBLE 81 uses extreme UV flux limits to find $au>10^{22}-10^{23}$ s. 22 REPHAELI 81 consider au decay au effect on neutral H in early universe; based on M31 HI concludes $au>10^{24}$ s. 23 DERUJULA 80 finds au>3 x 10^{23} s based on CDM neutrino decay contribution to UV
- 24 STECKER 80 limit based on UV background; result given is $\tau > 4 \times 10^{22}\,\mathrm{s}$ at $m_{\nu} = 20$

|(v-c)/c| (v $\equiv \nu_2$ VELOCITY)

Expected to be zero for massless neutrino, but also tests whether photons and neutrinos have the same limiting velocity in vacuum.

VALUE (units 10-4)	CL%	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
• • • We do not	use th	e following	data for averages, fi	ts, limits,	etc. •	• •
< 0.4	95	9800	KALBFLEISCH 79	SPEC		
<2.0	99	77	ALSPECTOR 76	SPEC	0	$>$ 5 GeV ν
<4.0	99	26	ALSPECTOR 76	SPEC	0	<5 GeV $ u$

ν_2 MAGNETIC MOMENT

Must vanish for Majorana neutrino or purely chiral massless Dirac neutrino. The value of the magnetic moment for the standard SU(2)×U(1) elec-The value of the Magliett model to the Standard SO(2)×O(1) electroweak theory extended to include massive neutrinos (see FUJIKAWA 80) is $\mu_{\nu}=3eG_{F}m_{\nu}/(8\pi^{2}\sqrt{2})=(3.2\times 10^{-19})m_{\nu}\mu_{B}$ where m_{ν} is in eV and $\mu_{B}=e\hbar/2m_{e}$ is the Bohr magneton. Given the upper bound $m_{\nu_{2}}<0.17$ MeV, it follows that for the extended standard electroweak theory, $\mu(\nu_{2})<0.51\times 10^{-13}~\mu_{B}$.

DOCUMENT ID

TECN COMMENT

74 RVUE $\overline{\nu}_{\mu}e \rightarrow \overline{\nu}_{\mu}e$

<	8.5	90	AHRENS	90	CNTR	$\nu_{\mu} e \rightarrow \nu_{\mu} e$
<	7.4	90	²⁵ KRAKAUER			LAMPF $(\nu_{\mu}, \overline{\nu}_{\mu})e$
						elast.
• •	We do not use the	e follo	wing data for averages	, fits	, limits,	etc. • • •
<	30	90				$\nu_{\mu} e \rightarrow \nu_{\mu} e$
<1	00	95	²⁶ DORENBOS	91	CHRM	$\nu_{\mu} e \rightarrow \nu_{\mu} e$
<	0.02	95	27 RAFFELT			Red giant luminosity
<	0.1		²⁸ RAFFELT	89B	ASTR	Cooling helium stars
<	0.11		^{28,29} FUKUGITA	87	ASTR	Cooling helium stars
<	0.0006		30 NUSSINOV	87	ASTR	Cosmic EM backgrounds
<	0.4		LYNN	81	ASTR	
<	0.85		²⁹ BEG	78	ASTR	Stellar plasmons

32 BERNSTEIN 63 ASTR Cooling white dwarfs

31 KIM

CL%

- 25 KRAKAUER 90 experiment fully reported in ALLEN 93. 26 DORENBOSCH 91 corrects an incorrect statement in DORENBOSCH 89 that the ν_2 magnetic moment is $< 1 imes 10^{-9}$ at the 95%CL. DORENBOSCH 89 measures both $u_{\mu}\,e$ and $\overline{
 u}_{\mu}$ e elastic scattering and assume $\mu(
 u_{\mu})=\mu(\overline{
 u}_{\mu}).$
- 27 RAFFELT 90 limit applies for a diagonal magnetic moment of a Dirac neutrino, or for a transition magnetic moment of a Majorana neutrino. In the latter case, the same analysis gives $<1.4\times10^{-12}$. Limit at 95%CL obtained from $\delta M_{\rm C}$.
- 28 Significant dependence on details of stellar properties.
- $^{29}\,\mathrm{lf}~m_{\nu_2}~<$ 10 keV.

VALUE ($10^{-10} \mu_B$)

< 81

< 1

- ³⁰ For $m_{
 u_2}^{}=$ 8–200 eV. NUSSINOV 87 examines transition magnetic moments for u_{μ} ightarrow ν_e and obtain < 3×10^{-15} for m_{ν_2} > 16 eV and < 6×10^{-14} for m_{ν_2} > 4 eV.
- $^{31}\,\mathrm{KIM}$ 74 is a theoretical analysis of $\overline{\nu}_{\mu}$ reaction data.
- 32 If $m_{
 u_2}$ $\,<\,1\,$ keV.

 ν_{μ} , ν_{τ}

NONSTANDARD CONTRIBUTIONS TO NEUTRINO SCATTERING

We report limits on the so-called neutrino charge radius squared in this section. This quantity is not an observable, physical quantity and this is reflected in the fact that it is gauge dependent (see LEE 77C). It is not necessarily positive. A more general interpretation of the experimental results is that they are limits on certain nonstandard contributions to neutrino scattering.

VALUE (10-32 cm ²)	CL%	DOCUMENT ID		TECN	COMMENT	
• • We do not use to	he followi	ng data for averages	, fits	, limits,	etc. • • •	
< 0.6	90	VILAIN	95B	CHM2	$\nu_{\mu}e$ elas scat	
-1.1 ± 1.0		³³ AHRENS	90	CNTR	ν_{μ}^{r} e elas scat	
-0.3 ± 1.5		33 DORENBOS	89	CHRM	ν e elas scat	

 $^{^{}m 33}$ Result is obtained from reanalysis given in ALLEN 91, followed by our reduction to obtain

ν,, Ι	RE	FE	RE	N	CES
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			r
ASSAMAGAN	96	PR D53 6065	+Broennimann, Daum+ (PSI, ZURI, VILL, VIRG)
DOLGOV	95	PR D51 4129	+Kainulainen, Rothstein (MICH, MINN, CERN)
VILAIN	95B	PL B345 115	+Wilguet, Beyer+ (CHARM II Collab.)
ASSAMAGAN	94	PL B335 231	+Broennimann, Daum+ (PSI, ZURI, VILL, VIRG)
JECKELMANN	94	PL B335 326	+Goudsmit, Leisi (WABRN, VILL)
ALLEN	93	PR D47 11	+Chen, Doe, Hausammann+ (UCI, LANL, ANL, UMD)
DOLGOV	93	PRL 71 476	+Rothstein (MICH)
ENQVIST	93	PL B301 376	+Uibo (NORD)
MAYLE	93	PL B317 119	+Schramm, Turner, Wilson (LLNL, CHIC)
RAJPOOT	93	MPL A8 1179	(CSULB)
BLUDMAN	92	PR D45 4720	(CFPA)
BURROWS	92	PRL 68 3834	+Gandhi, Turner (ARIZ, CHIC)
DODELSON	92	PRL 68 2572	+Frieman, Turner (FNAL, CHIC)
ALLEN	91	PR D43 R1	+Chen, Doe, Hausammann (UCI, LANL, UMD)
DORENBOS	91	ZPHY C51 142	Dorenbosch, Udo, Allaby, Amaldi+ (CHARM Collab.)
FULLER	91	PR D43 3136	+ Malaney (UCSD)
GANDHI	91		(erratum)-Burrows (ARIZ)
KRAKAUER	91	PR D44 R6	+Talaga, Allen, Chen+ (LAMPF E225 Collab.)
LAM	91	PR D44 3345	+Ng (AST)
NATALE	91	PL B258 227	(SPIFT)
AHRENS	90	PR D41 3297	 (BNL, BROW, HIRO, KEK, OSAK, PENN, STON)
GANDHI	90	PL B246 149	+Burrows (ARIZ)
Also	91		(erratum) Gandhi, Burrows (ARIZ)
GRIFOLS	90B	PL B242 77	+Masso (BARC, CERN)
KRAKAUER	90	PL B252 177	+Talaga, Allen, Chen+ (LAMPF E225 Collab.)
RAFFELT	90	PRL 64 2856	(MPIM)
CHUPP	89 89	PRL 62 505	+Vestrand, Reppin (UNH, MPIM)
DORENBOS		ZPHY C41 567	
GAEMERS KOLB	89 89	PR D40 309 PRL 62 509	+Gandhi, Lattimer (ANIK, STON) +Turner (CHIC, FNAL)
RAFFELT	89B	APJ 336 61	+Turner (CHIC, FNAL) +Dearborn, Silk (UCB, LLL)
VONFEILIT	88	PL B200 580	Von Feilitzsch, Oberauer (MUNT)
FUKUGITA	87	PR D36 3817	+Yazaki (KYOTY, TOKY)
NUSSINOV	87	PR D36 2278	+Rephaeli (TELA)
ANDERHUB	82	PL 114B 76	+Boecklin, Hofer, Kottmann+ (ETH, SIN)
FRANK	81	PR D24 2001	+Burman+ (LASL, YALE, MIT, SACL, SIN+)
HENRY	81	PRL 47 618	+Feldman (JHU)
KIMBLE	81	PRL 46 80	+Bowyer, Jakobsen (UCB)
LYNN	81	PR D23 2151	(COLU)
REPHAELI	81	PL 106B 73	+Szalay (UCSB, CHIC)
DERUJULA	80	PRL 45 942	+Glashow (MIT, HARV)
FUJIKAWA	80	PRL 45 963	+Shrock (STON)
STECKER	80	PRL 45 1460	(NASA)
KALBFLEISCH		PRL 43 1361	+Baggett, Fowler+ (FNAL, PURD, BELL)
BEG	78	PR D17 1395	+Marciano, Ruderman (ROCK, COLU)
BLIETSCHAU	78	NP B133 205	+Deden, Hasert, Krenz+ (Gargamelle Collab.)
BARNES	77	PRL 38 1049	+Carmony, Dauwe, Fernandez+ (PURD, ANL)
LEE	77C	PR D16 1444	+Shrock (STON)
ALSPECTOR	76	PRL 36 837	+ (BNL, PURD, CIT, FNAL, ROCK)
BELLOTTI CLARK	76 74	LNC 17 553 PR D9 533	+Cavalli, Fiorini, Rollier (MILA) +Elioff, Frisch, Johnson, Kerth, Shen+ (LBL)
KIM	74	PR D9 533 PR D9 3050	+Elioff, Frisch, Johnson, Kerth, Shen+ (LBL) +Mather, Okubo (ROCH)
BERNSTEIN	63	PR 132 1227	+Ruderman, Feinberg (NYU, COLU)
OCKIAS I CIM	0.5	111 132 1221	Thadeiman, removing (NTO, COLO)



 $J = \frac{1}{2}$

Existence indirectly established from au decay data combined with u reaction data. See for example FELDMAN 81. ALBRECHT 92Q rules out J=3/2 by establishing that the ρ^- is not in a pure $H_{\rho}{=}{-}1$ helicity state in $\tau^- \rightarrow \rho^- \nu_{\tau}$.

Not in general a mass eigenstate. See note on neutrinos in the ν_{e} section above.

ν_{τ} MASS

Applies to ν_3 , the primary mass eigenstate in ν_{τ} . Would also apply to any other ν_i which mixes strongly in ν_{τ} and has sufficiently small mass that it can occur in the respective decays. (This would be nontrivial only for a hypothetical $j \geq 4$, given the ν_e and ν_μ mass limits above.) See also the Listings in the Neutrino Bounds from Astrophysics and Cosmology section.

VALUE (MeV)	CL% EVT	S DOCUMENT ID	TE	CNCOMMENT
<24	95 2	¹ BUSKULIC	95H AL	EP 1991-1993 LEP runs
• • • We do r	not use the foll	owing data for average	es, fits, lin	nits, etc. • • •
<74	95	² AKERS	95D OF	AL $Z \rightarrow \tau^+ \tau^-$ at LEP
< 0.19		³ DOLGOV	95 CC	SM Nucleosynthesis
< 3		⁴ SIGL	95 AS	TR SN 1987A
< 0.4 or > 30		5 DODELSON	94 CC	SM Nucleosynthesis

< 0.1 or > 50			6 KAWASAKI	94	COSM	Nucleosynthesis
<75	95		7 BALEST	93		Ecm = 10.6 GeV
<32.6	95	113	⁸ CINABRO	93	CLEO	
₹32.0	93	113		93	CLEO	Ecm ≈ 10.6 GeV
< 0.3 or > 35			9 DOLGOV	93	COSM	Nucleosynthesis
< 0.74			¹⁰ ENQVIST	93	COSM	Nucleosynthesis
< 0.003			11,12 MAYLE	93	ASTR	SN 1987A cooling
<31	95	19		92N	1 ARG	Eee = 9.4-10.6 GeV
< 0.025-0.030			12,14 BURROWS	92	ASTR	SN 1987A cooling
< 0.3			¹⁵ FULLER	91	COSM	Nucleosynthesis
< 0.5 or > 25			¹⁶ KOLB	91	COSM	Nucleosynthesis
< 0.42			¹⁵ LAM	91	COSM	Nucleosynthesis
< 0.028-0.15			¹⁷ NATALE	91	ASTR	SN 1987A
< 0.028			¹² GANDHI	90	ASTR	SN 1987A
< 0.014 or > 34			12,18 GRIFOLS	90B	ASTR	SN 1987A
< 0.06			12,19 GAEMERS	89		SN 1987A

- 1 BUSKULIC 95H bound comes from a two-dimensional fit of the visible energy and invariant mass distribution of $\tau\to 5\pi (\pi^0)\nu_\tau$ decays. 2 AKERS 95D bound comes from analysis of $\tau^-\to 3\pi^-2\pi^+\nu_\tau$ decay mode.
- ³ DOLGOV 95 removes earlier assumptions (DOLGOV 93) about thermal equilibrium below T_{QCD} for wrong-helicity Divac neutrinos (ENQVIST 93, FULLER 91) to set more stringent limits.
- 4 SIGL 95 exclude massive Dirac or Majorana neutrinos with lifetimes between 10^{-3} and 10^8 seconds if the decay products are predominantly γ or $e^+\,e^-$
- 10° seconds if the decay products are predominantly γ or e · e · .

 5 DODELSON 94 calculate constraints on ν_τ mass and lifetime from nucleosynthesis for 4 generic decay modes. Limits depend strongly on decay mode. Quoted limit is valid for all decay modes of Majorana neutrinos with lifetime greater than about 300 s. For Dirac neutrinos limits change to < 0.3 or > 33.

 6 KAWASAKI 94 excluded region is for Majorana neutrino with lifetime > 1000 s. Other
- limits are given as a function of $u_{ au}$ lifetime for decays of the type $u_{ au}
 ightarrow
 u_{\mu} \phi$ where ϕ
- 7 BALEST 93 derive limit by comparing their m_{τ} measurement (which depends on $m_{\nu_-})$ to BAI 92 and BACINO 788 m_{τ} threshold measurements.
- 8 CINABRO 93 bound comes from analysis of au^{-} \rightarrow 3 π^- 2 π^+ ν_{τ} and $\tau^ \rightarrow$ $2\pi^-\pi^+2\pi^0\,
 u_ au$ decay modes.
- 9 DOLGOV 93 assumes neutrino lifetime >100 s. For Majorana neutrinos, the low mass limit is 0.5 MeV. KAWANO 92 points out that these bounds can be overcome for a Dirac
- imit is 0.5 MeV. NAWAND 92 points out that these bounds can be overcome for a Dirac neutrino if it possesses a magnetic moment.

 10 ENQVIST 93 bases limit on the fact that thermalized wrong-helicity Dirac neutrinos would speed up expansion of early universe, thus reducing the primordial abundance. FULLER 91 exploits the same mechanism but in the older calculation obtains a larger production rate for these states, and hence a lower limit. Neutrino lifetime assumed to exceed nucleosynthesis time. \sim 1 s.
- 11 MAYLE 93 recalculates cooling rate enhancement by escape of wrong-helicity Dirac neutrinos using the Livermore Supernova Explosion Code, obtains more restrictive result than the "very conservative" BURROWS 92 limit because of higher core temperature.
- 12 There would be an increased SN 1987A cooling rate if Dirac neutrino mass is included; this does not apply for Majorana neutrinos. Limit is on $\sqrt{m^2_{~\nu_{\mu}} + m^2_{~\nu_{\tau}}}$, and error becomes very large if ν_{τ} is nonrelativistic, which occurs near the lab limit of 31 MeV. RAJPOOT 93 notes that limit could be evaded with new physics.
- 13 ALBRECHT 92M reports measurement of a slightly lower au mass, which has the effect of reducing the $u_{ au}$ mass reported in ALBRECHT 88B. Bound is from analysis of $au^ 3\pi^-2\pi^+\nu_{\tau}$ mode. 14 BURROWS 92 limit for Dirac neutrinos only.
- 15 Assumes neutrino lifetime >1 s. For Dirac neutrinos. See also ENQVIST 93.
- 19 Assumes neutrino litetime >1 s. For Dirac neutrinos. See also ENQVIS1 y3. 16 KOLB 91 exclusion region is for Dirac neutrino with lifetime >1 s; other limits are given. 17 NATALE 91 published result multiplied by $\sqrt{8}\sqrt{4}$ at the advice of the author. 18 GRIFOLS 90B estimated error is a factor of 3. 19 GAEMERS 89 published result (< 0.03) corrected via the GANDHI 91 erratum.

ν_3 (MEAN LIFE) / MASS

These limits often apply to ν_{μ} (ν_2) also.

VALUE (s/eV)	DOCUMENT ID		TECN	COMMENT
ullet $ullet$ We do not use the follo	wing data for average	s, fits	s, limits,	etc. • • •
>1 × 10 ¹⁴	²⁰ SIGL	95	ASTR	$m_{\nu} > \text{few MeV}$
$>$ 2.8 \times 10 ¹⁵	21,22 BLUDMAN	92	ASTR	$m_{y} < 50 \text{ eV}$
$< 10^{-12} \text{ or } > 5 \times 10^4$	23 DODELSON	92	ASTR	m _v =1-300 keV
	²⁴ GRANEK	91		Decaying L ⁰
	²⁵ WALKER	90	ASTR	$m_{y} = 0.03 - \sim 2 \text{ MeV}$
$>6.3 \times 10^{15}$	^{22,26} CHUPP	89	ASTR	$m_{11}^{\nu} < 20 \text{ eV}$
$>1.7 \times 10^{15}$	²² KOLB	89	ASTR	$m_{11}^{\nu} < 20 \text{ eV}$
	²⁷ TERASAWA	88	COSM	m ₁₁ = 30-70 MeV
	²⁸ KAWASAKI	86		$m_{\nu} > 10 \text{ MeV}$
	²⁹ LINDLEY	85	COSM	$m_{\nu} > 10 \text{ MeV}$
	30 BINETRUY	84	COSM	$m_{\nu} \sim 1 \text{ MeV}$
	³¹ SARKAR	84	COSM	$m_{\nu} = 10-100 \text{ MeV}$
	32 HENRY	81	ASTR	$m_{\nu} = 16-20 \text{ eV}$
	³³ KIMBLE	81	ASTR	$m_{\nu} = 10-100 \text{ eV}$
	³⁴ REPHAELI	81	ASTR	$m_{\nu} = 30-150 \text{ eV}$
	³⁵ DERUJULA	80	ASTR	m _v = 10-100 eV
>2 × 10 ²¹	³⁶ STECKER	80	ASTR	$m_{\nu} = 10-100 \text{ eV}$
	³⁷ DICUS	78	COSM	$m_{\nu} = 0.5 - 30 \text{ MeV}$
$< 3 \times 10^{-11}$	³⁸ FALK	78	ASTR	m, <10 MeV
	³⁹ COWSIK	77	ASTR	V

- 20 SIGL 95 exclude 1 s $\lesssim \tau \lesssim 10^8$ s for MeV-mass τ nuetrinos from SN 1987A decaying radiatively, and eliminates the lower limit using other published results. 21 BLUDMAN 92 sets additional limits by this method for higher mass ranges. Cosmological
- limits are also obtained.
- limits are also obtained. 22 Nonobservation of γ 's in coincidence with ν 's from SN 1987A. Results should be divided by the $\tau_{\nu} \to \gamma {\rm X}$ branching ratio.
- 23 DODELSON 92 range is for wrong-helicity keV mass Dirac ν 's from the core of neutron star in SN 1987A decaying to ν 's that would have interacted in KAM2 or IMB detectors.
- 24 GRANEK 91 considers heavy neutrino decays to $\gamma\nu_L$ and $3\nu_L$, where m_{ν_l} <100 keV. Lifetime is calculated as a function of heavy neutrino mass, branching ratio into $\gamma\nu_L$,
- $^{25}\,\rm WALKER$ 90 uses SN 1987A γ flux limits after 289 days to find $m_{\tau}~>~1.1\times 10^{15}\,\rm eV\,s.$
- 26 CHUPP 89 should be multiplied by a branching ratio (about 1) and a detection efficiency (about 1/4), and pertains to radiative decay of any neutrino to a lighter or sterile neutrino. 27 TERASAWA 88 finds only $10^2 < \tau < 10^4$ allowed for 30–70 MeV ν 's from primordal
- 28 KAWASAKI 86 concludes that light elements in primordal nucleosynthesis would be destroyed by radiative decay of neutrinos with 10 MeV $<\!m_{\nu}<\!1$ GeV unless $\tau\lesssim10^4\,\mathrm{s}.$
- ²⁹LINDLEY 85 considers destruction of cosmologically-produced light elements, and finds
- The considers destination of cosmologically-produced in the elements, and finds $\tau < 2 \times 10^3$ s for 10 MeV $< m_{\nu} < 100$ MeV. See also LINDLEY 79.

 30 BINETRUY 84 finds $\tau < 10^8$ s for neutrinos in a radiation-dominated universe. 31 SARKAR 84 finds $\tau < 20$ s at $m_{\nu} = 10$ MeV, with higher limits for other m_{ν} , and claims that all masses between 1 MeV and 50 MeV are ruled out.
- 32 HENRY 81 uses UV flux from clusters of galaxies to find $au > 1.1 imes 10^{25} ext{ s}$ for radiative
- adecay. 33 KIMBLE 81 uses extreme UV flux limits to find $\tau>10^{22}-10^{23}$ s. 34 REPHAELI 81 consider ν decay γ effect on neutral H in early universe; based on M31 HI concludes $\tau>10^{24}$ s. 35 DERUJULA 80 finds $\tau>3\times10^{23}$ s based on CDM neutrino decay contribution to UV
- 36 STECKER 80 limit based on UV background; result given is $\tau > 4 \times 10^{22}\,\mathrm{s}$ at $m_{\nu} = 20\,$
- 37 DICUS 78 considers effect of ν decay photons on light-element production, and finds lifetime must be less than "hours." See also DICUS 77.

 38 FALK 78 finds lifetime constraints based on supernova energetics.
- 39 COWSIK 77 considers varity of scenarios. For neutrinos produced in the big bang, present limits on optical photon flux require $\tau>10^{23}\,\mathrm{s}$ for $m_{\nu}\sim 1$ eV. See also COWSIK 79 and GOLDMAN 79.

ν₃ MAGNETIC MOMENT

Must vanish for Majorana neutrino or purely chiral massless Dirac neutrino. The value of the magnetic moment for the standard $SU(2) \times U(1)$ electroweak theory extended to include massive neutrinos (see FUJIKAWA 80) is $\mu_{\nu}=3eG_Fm_{\nu}/(8\pi^2\sqrt{2})=(3.20\times 10^{-19})m_{\nu}\mu_B$ where m_{ν} is in eV and $\mu_B=e\hbar/2m_e$ is the Bohr magneton. Given the upper bound $m_{\nu_3}<35$ MeV, it follows that for the extended standard electroweak theory, $\mu(\nu_3)<1.1\times 10^{-11}~\mu_B$.

VALUE (μ _B)	CL%	DOCUMENT ID		TECN	COMMENT
$< 5.4 \times 10^{-7}$	90	⁴⁰ COOPER	92	BEBC	$\nu_{ au} e^- \rightarrow \nu_{ au} e^-$
• • • We do not use	the follow	wing data for averages	, fits	, limits,	etc. • • •
$<4.1 \times 10^{-6}$	90	ACCIARRI	95D	L3	$e^+e^- ightarrow u \overline{ u} \gamma$ at LEP
$< 5.5 \times 10^{-6}$	90	GOULD	94	RVUE	$e^+e^- ightarrow u \overline{ u} \gamma$ at LEP
\gtrsim 10 ⁻⁸		⁴¹ KAWANO			Primodial ⁴ He abun-
$< 5.6 \times 10^{-6}$	90	DESHPANDE	0.1	D\//15	dance $e^+e^- \rightarrow \nu \overline{\nu} \gamma$
<5.6 × 10	90		91		
$< 2 \times 10^{-12}$	95	⁴² RAFFELT	90	ASTR	Red giant luminosity
$< 1 \times 10^{-11}$		43 RAFFELT	89 B	ASTR	Cooling helium stars
$<4. \times 10^{-6}$	90	44 GROTCH	88	RVUE	$e^+e^- \rightarrow \nu \overline{\nu} \gamma$
$< 1.1 \times 10^{-11}$		^{43,45} FUKUGITA	87	ASTR	Cooling helium stars
$< 6 \times 10^{-14}$		⁴⁶ NUSSINOV	87	ASTR	Cosmic EM backgrounds
$< 8.5 \times 10^{-11}$		⁴⁵ BEG	78	ASTR	Stellar plasmons

- ⁴⁰ COOPER-SARKAR 92 assume $f_{D_s}/f_{\pi}=2$ and D_s , \overline{D}_s production cross section = 2.6 μb to calculate ν_{π} flux.
- $^{41}\,\mathrm{KAWANO}$ 92 lower limit is that needed to circumvent $^4\mathrm{He}$ production if $m_{\nu_{\tau}}$ is between 5 and \sim 30 MeV/ c^2
- 42 RAFFELT 90 limit valid if $m_{\nu_3} < 5$ keV. It applies for a diagonal magnetic moment of a Dirac neutrino, or for a transition magnetic moment of a Majorana neutrino. In the latter case, the same analysis gives $< 1.4 \times 10^{-12}$. Limit at 95%CL obtained from δM_{C} .
- 43 Significant dependence on details of stellar properties.
- 44 GROTCH 88 combined data from MAC, ASP, CELLO, and Mark J.
- 45 If $m_{\nu_3} < 10$ keV.
- ⁴⁶ For $m_{
 u_3}^{\sigma}=$ 8–200 eV. NUSSINOV 87 examines transition magnetic moments for $u_{ au}$ ightarrow u_e and obtain < 3 imes 10 $^{-15}$ for $m_{
 u_3}$ < 16 eV and < 6 imes 10 $^{-14}$ for $m_{
 u_3}$ > 4 eV.

ν_3 CHARGE

VALUE (units: electron charge)	nits: electron charge) DOCUMENT ID			COMMENT				
$< 4 \times 10^{-4}$	⁴⁷ BABU	94	RVUE	BEBC beam dump				
$< 3 \times 10^{-4}$	⁴⁸ DAVIDSON	91	RVUE	SLAC electron beam				

- 47 BABU 94 use COOPER-SARKAR 92 limit on u_3 magnetic moment to derive quoted
- 48 DAVIDSON 91 use data from early SLAC electron beam dump experiment to derive charge limit as a function of neutrino mass.

LIMIT ON $u_{ au}$ PRODUCTION IN BEAM DUMP EXPERIMENT

VALUE DOCUMENT ID • • We do not use the following data for averages, fits, limits, etc. • • 49 DORENBOS... 88 CHRM ⁵⁰ BOFILL 51 TALEBZADEH 87 BEBC ⁵² USHIDA 86c EMUL 53 ASRATYAN 81 HLBC 54 FRITZE 80 BEBC

- 49 DORENBOSCH 88 is CERN SPS beam dump experiment with the CHARM detector. $\nu_{\tau}+\overline{\nu}_{\tau}$ flux is <21% of the total prompt flux at 90% CL.
- 50 BOFILL 87 is a Fermilab narrow-band ν beam with a fine-grained neutrino detector.
- STALEBZADEH 87 is a CERN SPS beam dump experiment with the BEBC detector. Mixing probability $P(\nu_e \to \nu_\tau) < 18\%$ at 90% CL. SUSHIDA 86c is a Fermilab wide-band ν beam with a hybrid emulsion spectrometer. Mixing probabilities $P(\nu_e \to \nu_\tau) < 7.3\%$ and $P(\nu_\mu \to \nu_\tau) < 0.2\%$ at 90% CL.
- 53 ASRATYAN 81 is a Fermilab wide-band $\overline{
 u}$ beam with a 15 foot bubble chamber. Mixing probability $\textit{P}(\overline{\nu}_{\mu} \rightarrow \ \overline{\nu}_{\tau}) < 2.2\%$ at 90% CL.
- ⁵⁴ FRITZE 80 is CERN SPS experiment with BEBC. Neutral-current/charged-current ratio corresponds to $R=(\text{prompt-}\nu_{r})$ induced events)/(all prompt- ν events) <0.1. Mixing probability $P(\nu_{e}\rightarrow\nu_{\tau})$ <0.35 at CL = 90%.

$\nu_{ au}$ REFERENCES

ACCIARRI	95D	PL B346 190	+Adam, Adriani, Aguilar-Benitez+ (L3 Collab.)	
AKERS	95D	ZPHY C65 183	+Alexander, Allison, Anderson+ (OPAL Collab.)	
BUSKULIC	95H	PL B349 585	+Casper, De Bonis, Decamp+ (ALEPH Collab.)	
DOLGOV	95	PR D51 4129	+Kainulainen, Rothstein (MICH, MINN, CERN)	
			+Kamulainen, Kotiistein (WICH, WINN, CEKN)	
SIGL	95	PR D51 1499	+Turner (FNAL, EFI)	
BABU	94	PL B321 140	+Gould, Rothstein (BART, JHU, MICH)	
DODELSON	94	PR D49 5068	+Gyuk, Turner (FNAL, CHIC, EFI)	
GOULD	94	PL B333 545	+Rothstein (JHU, MICH)	
KAWASAKI	94	NP B419 105	+Kernan, Kang+ (OSU)	
BALEST	93	PR D47 R3671	+Daoudi, Ford, Johnson+ (CLEO Collab.)	
CINABRO	93	PRL 70 3700	+Henderson, Kinoshita+ (CLEO Collab.)	
DOLGOV	93	PRL 71 476	+Rothstein (MICH)	
ENQVIST	93	PL B301 376	+Uibo (NORD)	
MAYLE	93	PL B317 119	+Schramm, Turner, Wilson (LLNL, CHIC)	
RAJPOOT	93	MPL A8 1179	(CSULB)	
ALBRECHT		PL B292 221	+Ehrlichmann, Hamacher, Hofmann+ (ARGUS Collab.)	
		ZPHY C56 339	+Ehrlichmann, Hamacher+ (ARGUS Collab.)	
ALBRECHT	92Q		+Ellriichmann, Hamacher+ (ARGOS Collab.)	
BAI	92	PRL 69 3021	+Bardon, Becker-Szendy, Burnett+ (BES Collab.)	
BLUDMAN	92	PR D45 4720	(CFPA)	
BURROWS	92	PRL 68 3834	+Gandhi, Turner (ARIZ, CHIC)	
COOPER	92	PL B280 153	Cooper-Sarkar, Sarkar, Guy, Venus+(BEBC WA66 Collab.)	
			Cooper-Sarkar, Sarkar, Guy, Venus+(DEDC VVA00 Collab.)	
DODELSON	92	PRL 68 2572	+Frieman, Turner (FNAL, CHIC) +Fuller, Malaney, Savage (CIT, UCSD, LLL, RUTG) +Campbell, Bailey (ALBE, TNTO)	
KAWANO	92	PL B275 487	+Fuller, Malaney, Savage (CIT, UCSD, LLL, RUTG)	
DAVIDSON	91	PR D43 2314	+Campbell, Bailey (ALBE, TNTO)	
		DD D42 042	(ACDE, TATA)	
DESHPANDE	91	PR D43 943	+Sarma (OREG, TATA)	
FULLER	91	PR D43 3136	+Malaney (UCSD)	
GANDHI	91	PL B261 519E (erratun	n)-Burrows (ARIZ)	
GRANEK	91		+McKellar (MELB)	
KOLB	91	PRL 67 533	+Turner, Chakravorty, Schramm (FNAL, CHIC)	
LAM	91	PR D44 3345	+Ng (AST)	
NATALE	91	PL B258 227	(SPIFT)	
GANDHI	90	PL B246 149	+Burrows (ARIZ)	
Also	91	PL B261 519E (erratun	n) Gandhi, Burrows (ARIZ)	
GRIFOLS	90B	PL B242 77	+Masso (BARC, CERN)	
RAFFELT	90	PRL 64 2856	(MPIM)	
WALKER	90	PR D41 689	(HARV)	
CHUPP	89	PRL 62 505		
		FRL 02 303		
GAEMERS	89	PR D40 309	+Gandhi, Lattimer (ANIK, STON)	
KOLB	89	PRL 62 509	+Turner (CHIC, FNAL)	
RAFFELT	89B	APJ 336 61	+Dearborn, Silk (UCB, LLL)	
ALBRECHT	88B	PL B202 149	+Binder, Boeckmann+ (ARGUS Collab.)	
			Described Allahi Assetti Deskisiisi (CHADIA Cellah)	
DORENBOS		ZPHY C40 497	Dorenbosch, Allaby, Amaldi, Barbiellini+ (CHARM Collab.)	
GROTCH	88	ZPHY C39 553	+Robinett (PSU)	
TERASAWA	88	NP B302 697	+Kawasaki, Sato (TOKY)	
BOFILL	87	PR D36 3309	+Busza, Eldridge+ (MIT, FNAL, MSU)	
FUKUGITA	87	PR D36 3817	+Yazaki (KYOTY, TOKY)	
		PR D30 3017	Tidzaki (KTOTT, TOKT)	
NUSSINOV	87	PR D36 2278	+Rephaeli (TELA)	
TALEBZADEH	87	NP B291 503	+Guy, Venus+ (BEBC WA66 Collab.)	
KAWASAKI	86	PL B178 71	+Terasawa, Sato (TOKY)	
USHIDA	86C	PRL 57 2897	+Kondo, Tasaka, Park, Song+ (FNAL E531 Collab.)	
	85	APJ 294 1	(FNAL)	
BINETRUY	84	PL 134B 174	+Girardi, Salati (LAPP)	
SARKAR	84	PL 148B 347	+Cooper (OXF, CERN)	
	81	PL 105B 301	+Efremenko, Fedotov+ (ITEP, FNAL, SERP, MICH)	
	81	SLAC-PUB-2839		
			(SLAC, STAN)	
Santa Cruz				
HENRY	81	PRL 47 618	+Feldman (JHU)	
KIMBLE	81	PRL 46 80	+Bowyer, Jakobsen (UCB)	
		PL 106B 73	+Szalay (UCSB, CHIC)	
	81		+3Zalay (OC3B, CHIC)	
DERUJULA	80	PRL 45 942	+Glashow (MIT, HARV) (AACH3, BONN, CERN, LOIC, OXF, SACL)	
FRITZE	80	PL 96B 427	(AACH3, BONN, CERN, LOIC, OXF, SACL)	
FUJIKAWA	80	PRL 45 963	+Shrock (STON)	
STECKER	80	PRL 45 1460	(NASA)	
COWSIK	79	PR D19 2219	(TATA)	
	79	PR D19 2215	+Stephenson (LASL)	
LINDLEY	79	MNRAS 188 15P	(SUSS)	
	78B	PRL 41 13	+Ferguson, Nodulman, Slater+ (DELCO Collab.)	
	78	DD D17 1305	+Marciano, Ruderman (ROCK, COLU)	
		PR D17 1395		
	78	PR D17 1529	+Kolb, Teplitz, Wagoner (TEXA, VPI, STAN)	
	78	PL 79B 511	+Schramm (CHIC)	
COWSIK	77	PRL 39 784	+Schramm (CHIC) (MPIM, TATA)	
	77	PRL 39 168	+Kolb, Teplitz (TEXA, VPI)	
			(1200, 111)	

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Lepton Particle Listings

Number of Light Neutrino Types

Number of Light Neutrino Types

The neutrinos referred to in this section are those of the Standard SU(2)×U(1) Electroweak Model possibly extended to allow nonzero neutrino masses. Light neutrinos are those with $m_{\nu} < m_{Z}/2$. The limits are on the number of neutrino families or species, including

THE NUMBER OF LIGHT NEUTRINO TYPES FROM COLLIDER EXPERIMENTS

(by Dean Karlen, Carleton University)

The most precise measurements of the number of light neutrino types, N_{ν} , come from studies of Z production in e^+e^- collisions. At the time of this report, the most recent combined analysis of the four LEP experiments [1] included nearly 8 million visible Z decays. The invisible partial width, $\Gamma_{\rm inv}$, is determined from these data by subtracting the measured visible partial widths, corresponding to Z decays into quarks and charged leptons, from the total Z width. The invisible width is assumed to be due to N_{ν} light neutrino species each contributing the neutrino partial width Γ_{ν} as given by the Standard Model. In order to reduce the model dependence, the Standard Model value for the ratio of the neutrino to charged leptonic partial widths, $(\Gamma_{\nu}/\Gamma_{\ell})_{SM} = 1.992$, is used instead of $(\Gamma_{\nu})_{\rm SM}$ to determine the number of light neutrino types:

$$N_{\nu} = \frac{\Gamma_{\rm inv}}{\Gamma_{\ell}} \left(\frac{\Gamma_{\ell}}{\Gamma_{\nu}} \right)_{\rm SM}$$

The combined LEP result is $N_{\nu} = 2.991 \pm 0.016$.

In the past, when only small samples of Z decays had been recorded by the LEP experiments and by the Mark II at SLC, the uncertainty in N_{ν} was reduced by using Standard Model fits to the measured hadronic cross sections at several centerof-mass energies near the Z resonance. Since this method is much more dependent on the Standard Model, the approach described above is favored.

Before the advent of the SLC and LEP, limits on the number of neutrino generations were placed by experiments at lower-energy e^+e^- colliders by measuring the cross section of the process $e^+e^- \to \nu \overline{\nu} \gamma$. The ASP, CELLO, MAC, MARK J, and VENUS experiments observed a total of 3.9 events above background [2], leading to a 95% CL limit of N_{ν} < 4.8. This process has a much larger cross section at center-of-mass energies near the Z mass and has been measured at LEP by the ALEPH, L3, and OPAL experiments [3]. Each experiment has observed several hundred of these events, and the combined result is $N_{\nu} = 3.09 \pm 0.13$.

Experiments at $p\bar{p}$ colliders also placed limits on N_{ν} by determining the total Z width from the observed ratio of $W^{\pm} \to \ell^{\pm} \nu$ to $Z \to \ell^{+} \ell^{-}$ events [4]. This involved a calculation that assumed Standard Model values for the total W width and the ratio of W and Z leptonic partial widths, and used an estimate of the ratio of Z to W production cross sections. Now that the Z width is very precisely known from the LEP experiments, the approach is now one of those used to determine the W width.

References

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Number from e⁺e⁻ Colliders

Number of Light ν Types

Our evaluation uses the invisible and leptonic widths of the Z boson from our combined fit shown in the Particle Listings for the Z Boson, and the Standard Model value $\Gamma_{\nu}/\Gamma_{\ell}$ $= 1.992 \pm 0.003$.

<u>VALUE</u> <u>DOCUMENT ID</u> <u>TECN</u>
2.991±0.016 OUR EVALUATION 1995 combined fit to all LEP data. • • • We do not use the following data for averages, fits, limits, etc. • •

 $^{1}\,\mathrm{LEP}$ ¹ Simultaneous fits to all measured cross section data from all four LEP experiments.

Number of Light ν Types from Direct Measurement of Invisible Z Width

In the following, the invisible Z width is obtained from studies of single-photon events from the reaction $e^+e^ \rightarrow \nu \overline{\nu} \gamma$. All are obtained from LEP runs in the $E_{\rm CM}^{ee}$ range 88-94 GeV.

92 RVUE

VALUE	DOCUMENT ID	TECN	COMMENT
3.09±0.13 OUR AVERAGE			
$3.23 \pm 0.16 \pm 0.10$	AKERS	95c OPAL	1990-1992 LEP runs
$2.68 \pm 0.20 \pm 0.20$	BUSKULIC	93L ALEP	1990-1991 LEP runs
$3.24 \pm 0.46 \pm 0.22$	ADEVA	92 L3	1990 LEP run
$3.14 \pm 0.24 \pm 0.12$	ADRIANI	92E L3	1991 LEP run
• • • We do not use the following	data for average	es, fits, limits	etc. • • •
$3.0 \pm 0.4 \pm 0.2$	AKRAWY	91D OPAL	Repl. by AKERS 950

Limits from Astrophysics and Cosmology

Number of Light ν Types

("light" means < about 1 MeV). See also OLIVE 81. For a review of limits based on Nucleosynthesis, Supernovae, and also on terrestial experiments, see DENEGRI 90. DOCUMENT ID

• • We do not use the	ne following data for average	s, fits	, limits, etc. • •
< 3.6	² OLIVE	95	COSM
< 3.1	OLIVE	95B	COSM
< 3.04	KERNAN	94	COSM
< 3.3	WALKER	91	COSM
< 3.4	OLIVE	90	COSM
< 5.2	ELLIS	86	COSM
< 4	STEIGMAN	86	COSM
< 4	YANG	84	COSM
< 4	YANG	79	COSM
< 7	STEIGMAN	77	COSM
	PEEBLES	71	COSM
<16	³ SHVARTSMAI	V69	COSM
	HOYLE	64	COSM

²OLIVE 95 limit assumes the existence of at least three (massless) neutrinos. ³SHVARTSMAN 69 limit inferred from his equations.

Number Coupling with Less Than Full Weak Strength

DOCUMENT ID

• • • We do not use the following data for averages, fits, limits, etc. • • 4 OLIVE < 20 81C COSM ⁴ STEIGMAN <20 79 COSM

 $^{^4}$ Limit varies with strength of coupling. See also WALKER 91

Number of Light Neutrino Types, Massive Neutrinos and Lepton Mixing

REFERENCES FOR Limits on Number of Light Neutrino Types

AKERS	95C	ZPHY C65 47	+Alexander, Allison+	(OPAL Collab.)
OLIVE	95	PL B354 357	+Steigman	(MINN, OSU)
OLIVE	95B	APJS 97 49	+Steigman	(MINN, OSU)
KERNAN	94	PRL 72 3309	+Krauss	(CASE)
BUSKULIC	93L	PL B313 520	+De Bonis, Decamp+	(ALEPH Collab.)
ADEVA	92	PL B275 209	+Adriani, Aguilar-Benitez+	(L3 Collab.)
ADRIANI	92E	PL B292 463	+Aguilar-Benitez, Ahlen, Akbari, Alcaraz+	
LEP	92	PL B276 247	+ALEPH, DELPHI, L3, OPAL	(LEP Collabs.)
AKRAWY	91 D	ZPHY C50 373	+Alexander, Allison, Allport, Anderson+	
WALKER	91	APJ 376 51	+Steigman, Schramm, Olive+ (HSCA, C	
DENEGRI	90	RMP 62 1		ERN, UCB, SACL)
OLIVE	90	PL B236 454	+Schramm, Steigman, Walker (MINN, C	HIC, OSU, HARV)
ELLIS	86	PL 167B 457	+Engvist, Nanopoulos, Sarkar	(CERN, OXFTP)
STEIGMAN	86	PL B176 33	+Olive, Schramm, Turner	(BART, MINN+)
YANG	84	APJ 281 493	+Turner, Steigman, Schramm, Olive	(CHIC, BART)
OLIVE	81	APJ 246 557	+Schramm, Steigman, Turner, Yang+	(CHIC, BART)
OLIVE	81C	NP B180 497	+Schramm, Steigman	(EFI, BART)
STEIGMAN	79	PRL 43 239	+Olive, Schramm	(BART, EFI)
YANG	79	APJ 227 697	+Schramm, Steigman, Rood (C	HIC, YALE, VIRG)
STEIGMAN	77	PL 66B 202	+Schramm, Gunn (YALE, CHIC, CIT)
PEEBLES	71	Physical Cosmology		(PRIN)
Princeton		Press (1971)		
SHVARTSMAI	V 69	JETPL 9 184		(MOSU)
		Translated from ZETFP		
HOYLE	64	Nature 203 1108	+Tayler	(CAMB)

Massive Neutrinos and Lepton Mixing, Searches for

Searches for massive neutral leptons and the effects of nonzero neutrino masses are listed here. These results are divided into the following main sections:

- A. Heavy neutral lepton mass limits;
- B. Sum of neutrino masses;
- C. Searches for neutrinoless double- β decay (see the note by P. Vogel on "Searches for neutrinoless double- β decay" preceding this section);
- D. Other bounds from nuclear and particle decays;
- E. Bounds from particle decays;
- F. Solar ν experiments (see the note on "Solar Neutrinos" by K. Nakamura preceding this section);
- G. Astrophysical neutrino observations;
- H. Reactor $\overline{\nu}_e$ disappearance experiments;
- I. Accelerator neutrino appearance experiments;
- J. Disappearance experiments with accelerator and radioactive source neutrinos.

Direct searches for masses of dominantly coupled neutrinos are listed in the appropriate section on ν_e , ν_μ , or ν_τ . Searches for massive charged leptons are given elsewhere, and searches for the mixing of (μ^-e^+) and (μ^+e^-) are given in the muon listings.

Discussion of the ν_e and ν_μ mass limits and the theory of mixing are given in the note on "Neutrinos" by R.E. Shrock in the ν_e section near the beginning of these Particle Listings. Several reviews are also listed there.

Most of the results of the present section are correlated upper bounds on mixing matrix coefficients U_{aj} versus neutrino mass. In some of these cases (e.g. accelerator neutrino oscillation experiments), results are presented assuming that mixing occurs only between two neutrino species. In this case limits or results can be shown as allowed regions on a plot of $|\Delta m^2|$ as a function of $\sin^2 2\theta$, where $\Delta m^2 = m_{\nu_i}^2 - m_{\nu_j}^2$. Although there are three flavors, data are usually analyzed assuming an oscillation between just two of them, e.g., $\nu_{\tau} \leftrightarrow \nu_{e}$. The same remark applies to lepton-number violating mixing between two

states, e.g., $\nu_e \leftrightarrow \overline{\nu}_{\mu}$ or $\nu_{\mu} \leftrightarrow \overline{\nu}_{\mu}$. However, in a comprehensive analysis of all current data on limits on (or positive reports of) neutrino oscillations, one should use a three-generation mixing framework.

The simplest situation occurs in an "appearance" experiment, where one searches for interactions by neutrinos of a variety not expected in the beam. An example is the search for $\overline{\nu}_e$ interactions in a beam of neutrinos from the π^+ decay chain, which (among other possibilities) might be taken as evidence for $\overline{\nu}_{\mu} \to \overline{\nu}_{e}$. For oscillation between two states, the probability that the "wrong" state will appear is given by Eq. 5 in Shrock's "Note on Neutrinos" at the beginning of the Quark and Lepton Particle Listings. For our present purposes, this may be rewritten as

$$P = \sin^2 2\theta \, \sin^2(1.27\Delta m^2 L/E) \,, \tag{1}$$

where L is the distance from the neutrino's production point to its interaction point, and E is its energy. In the above, $|\Delta m^2|$ is in eV² and L/E is in km/GeV or m/MeV. Since in a real experiment L and E have some spread, one must average P over the appropriate distributions. As an example, let us make the somewhat unrealistic assumption that $b \equiv 1.27L/E$ has a Gaussian distribution with standard deviation σ_b about a central value b_0 . Then:

$$\langle P \rangle = \frac{1}{2} \sin^2 2\theta [1 - \cos(2b_0 \Delta m^2) \exp(-2\sigma_b^2 (\Delta m^2)^2)] \tag{2}$$

The value of $\langle P \rangle$ is set by the experiment. For example, if 230 interactions of the expected flavor are detected and none of the wrong flavor are seen, then P=0.010 at the 90% CL. We can then solve the above expression for $\sin^2 2\theta$ as a function of $|\Delta m^2|$. This function is shown in Fig. 1 for the parameter assumptions given in the caption. Note that:

- (a) since the fast oscillations are completely washed out by the resolution for large $|\Delta m^2|$, $\sin^2 2\theta = 2 \langle P \rangle$ in this region;
- (b) the maximum excursion to the left is to approximately $\langle P \rangle$, and it occurs at $|\Delta m^2| = \pi/2b_0 \text{ eV}^2$;
- (c) for large $\sin^2 2\theta$, $\Delta m^2 \propto (\sin^2 2\theta)^{-1/2}$; and
- (d) the intercept at $\sin^2 2\theta = 1$ is at $\sqrt{\langle P \rangle}/b_0$.

The intercept for large $|\Delta m^2|$ is just a measure of running time and backgrounds, while the intercept at $\sin^2 2\theta = 1$ also depends on the mean value of L/E. The wiggles depend on the experimental resolution, but aside from such details the two intercepts completely describe the exclusion region: For large $|\Delta m^2|$, $\sin^2 2\theta$ is constant, and for large $\sin^2 2\theta$ the constant slope is known. For these reasons, it is (nearly) sufficient to summarize the results of an experiment by stating the two intercepts, as is done in the following tables. The reader is referred to the original papers for the two-dimensional plots expressing the actual limits.

Lepton Particle Listings

Massive Neutrinos and Lepton Mixing

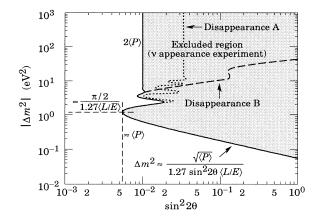


Figure 1: Neutrino oscillation parameter ranges excluded by a toy experiment in which one searches for the appearance of neutrinos not expected in the beam. The probability of appearance, in this case 0.5% at some specified CL, is set by the number of right-flavor events observed and/or information about the flux and cross sections. Here it is assumed that $\langle L/E \rangle = 1$ km GeV⁻¹, and that the distribution of L/E is Gaussian with a 20% standard deviation. The wiggle structure is determined by the resolution function, and the intercepts are determined by the appearance probability and $\langle L/E \rangle$. The leftmost excursion relative to the high- $|\Delta m^2|$ limit and the slope of the lower part of the curve are independent of the experiment. In a disappearance experiment, high- $|\Delta m^2|$ sensitivity is lost unless the incident flux is known. These two possibilities are shown qualitatively by the dashed lines marked "Disappearance A" and "Disappearance B."

If a positive effect is claimed, then the excluded region becomes an included region. This is the case for the HIRATA 92 analysis of $R(\mu/e)$ for atmospheric neutrinos.

In a "disappearance" experiment, one looks for the attenuation of the beam neutrinos (for example, ν_k) by mixing with at least one other neutrino eigenstate. (We label such experiments as $\nu_k \not\rightarrow \nu_k$.) These experiments fall into two general classes:

(a) Those in which the beam neutrino flux is known, from theory or other measurements. In the high- $|\Delta m^2|$ region, where the oscillation length is small compared to the size of the apparatus, the oscillations are in both directions and the beam intensity is reduced by a factor of two (for two-component mixing). In this case, indicated qualitatively by the "Disappearance A" curve in Fig. 1. sensitivity is maintained for large $|\Delta m^2|$, but with no simple rule relating this asymptote to the maximum excursion to the left. An example is provided by the VUILLEUMIER 82 measurements at the Gösgen reactor.

(b) Those in which the intensity must be measured in the apparatus itself (two detectors, or a "long" detector). Then above some minimum $|\Delta m^2|$ the equilibrium is established upstream, and there is no change in intensity over the length of the apparatus. As a result, sensitivity is lost at high $|\Delta m^2|$, as is qualitatively indicated by the curve "Disappearance B" in Fig. 1. See, for example, DYDAK 84.

Finally, there are more complicated cases, such as in the HIRATA 92B analysis of the Kamiokande II solar neutrino data in terms of the MSW parameters. An irregular region on the $|\Delta m^2|$ vs $\sin^2 2\theta$ is excluded for a combination of physical reasons. It is difficult to represent adequately these graphical data within the strictures of our tables.

(A) Heavy neutral leptons

Stable Neutral Heavy Lepton MASS LIMITS ——

Note that LEP results in combination with REUSSER 91 exclude a fourth stable neutrino with m < 2400 GeV.

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>45.0	95	ABREU	92B	DLPH	Dirac
>39.5	95	ABREU	92B	DLPH	Majorana
>44.1	95	ALEXANDER	91F	OPAL	Dirac
>37.2	95	ALEXANDER	91F	OPAL	Majorana
none 3-100	90	SATO	91	KAM2	Kamiokande II
>42.8	95	¹ ADEVA	90s	L3	Dirac
>34.8	95	¹ ADEVA	90s	L3	Majorana
>42.7	95	DECAMP	90F	ALEP	Dirac

 1 ADEVA 90s limits for the heavy neutrino apply if the mixing with the charged leptons satisfies $|U_1j|^2+|U_2j|^2+|U_3j|^2>6.2\times10^{-8}$ at $m_{L^0}=$ 20 GeV and $>5.1\times10^{-10}$ for $m_{L^0}=$ 40 GeV.

Neutral Heavy Lepton MASS LIMITS

Limits apply only to heavy lepton type given in comment at right of data Listings. See review above for description of types.

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
none 2.5-50	95	² ADRIANI	921	L3	$ U_{\tau \text{ or } \mu} ^2 < 3 \times 10^{-4}$
none 4-50	95	² ADRIANI	921	L3	$ U_{\tau} ^2 < 3 \times 10^{-4}$
>46.4	95	3 ADEVA	9 0s	L3	Dirac
>45.1	95	3 ADEVA	9 0s		Majorana
>46.5	95	4 AKRAWY		OPAL	Coupling to e or μ
>45.7	95	4 AKRAWY		OPAL	Coupling to $ au$
• • We do not use the	e followi	-	s, fits	, limits,	etc. • • •
>44.5	95	5 ABREU		DLPH	Dirac
>39.0	95	5 ABREU	92B	DLPH	Majorana
>41	95	^{6,7} BURCHAT	90	MRK2	Dirac, $ U_{\ell j} ^2$ >
		6.7			10-10
>19.6	95	6,7 BURCHAT	90	MRK2	Dirac, all $ U_{\ell j} ^2$
none 25-45.7	95	6,8 DECAMP	90F	ALEP	Dirac $ U_{\ell j} ^2 > 10^{-13}$
none 8.2-26.5	95	⁹ SHAW	89	AMY	Dirac L^0 ,
					$ U_{ej} ^2 > 10^{-6}$
none 8.3-22.4	95	⁹ SHAW	89	AMY	Majorana L^0 ,
					$ U_{ej} ^2 > 10^{-6}$
none 8.1-24.9	95	⁹ SHAW	89	AMY	Majorana 10
					$ U_{\mu j} ^2 > 10^{-6}$
none 1.8-6.7	90	¹⁰ AKERLOF	88	HRS	$ U_{ej} ^{2}=1$
none 1.8-6.4	90	¹⁰ AKERLOF	88	HRS	$ U_{\mu j} ^2 = 1$
none 2.5-6.3	80	¹⁰ AKERLOF	88	HRS	$ U_{\tau j} ^2 = 1$
none 0.25-14	90	¹¹ MISHRA	87	CNTR	$ U_{\mu j} ^2 = 1.$
none 0.25-10	90	¹¹ MISHRA	87	CNTR	$ U_{\mu j} ^2 = 0.1$
none 0.25-7.7	90	¹¹ MISHRA	87	CNTR	$ U_{\mu i} ^2 = 0.03$
none 12.	90	¹² WENDT	87	MRK2	$ U_{e \text{ or } ui} ^2 = 0.1$
none 2.2-4.	90	12 WENDT	87	MRK2	$ U_{e \text{ or } \mu j} ^2 = 0.001$
none 2.3-3.	90	¹² WENDT	87	MRK2	$ U_{\tau j} ^2 = 0.1$
none 3.2-4.8	90	12 WENDT	87	MRK2	$ U_{\tau j} ^2 = 0.001$
none 0.3-0.9	90	¹³ BADIER	86	CNTR	$ U_{ej} ^2 = 0.8$
none 0.33-2.0	90	13 BADIER	86	CNTR	$ U_{ej} ^2 = 0.03$
none 0.6-0.7	90	13 BADIER	86	CNTR	$ U_{\mu j} ^2 = 0.8$
none 0.6–2.0	90	13 BADIER	86	CNTR	
	90				$ U_{\mu j} ^2 = 0.01 - 0.001$
> 1.2		MEYER	77	MRK1	Neutral

Massive Neutrinos and Lepton Mixing

- 2 ADRIANI 92I is a search for isosinglet heavy lepton N_ℓ which might be produced from $Z\to\nu_\ell\,N_\ell$, then decay via a number of different channels. Limits are weaker for decay lengths longer than about 1 m.
- 3 ADEVA 90s limits for the heavy neutrino apply if the mixing with the charged leptons satisfies $|U_1j|^2 + |U_2j|^2 + |U_3j|^2 > 6.2 \times 10^{-8}$ at $m_{L^0} = 20$ GeV and $> 5.1 \times 10^{-10}$ for $m_{L^0} = 40$ GeV.
- 4 AKRAWY 90L limits valid if coupling strength is greater than a mass-dependent value, e.g., 4.9×10^{-7} at $m_{L^0}=20$ GeV, 3.5×10^{-8} at 30 GeV, 4×10^{-9} at 40 GeV.
- ⁵ ABREU 92B limit is for mixing matrix element ≈ 1 for coupling to e or μ . Reduced somewhat for coupling to τ , increased somewhat for smaller mixing matrix element. Replaces ABREU 91F.
- ⁶ Limits apply for $\ell=e,\,\mu,\,$ or au and for $V\!-\!A$ decays of Dirac neutrinos.
- 7 BURCHAT 90 searched for Z decay to unstable L^0 pairs at SLC. It includes the analyses reported in JUNG 90, ABRAMS 89C, and WENDT 87.
- ⁸ For 25 $< m_{I^0} <$ 42.7 GeV, DECAMP 90F exclude an L^0 for all values of $|U_{\ell\,\hat{I}}|^2$.
- 9 SHAW 89 also excludes the mass region from 8.0 to 27.2 GeV for Dirac L^0 and from 8.1 to 23.6 GeV for Majorana L^0 with equal full-strength couplings to e and μ . SHAW 89
- to 23.8 SeV for Majorana L^{-} with equal full-strength couplings to e and μ . Shaw 89 also gives correlated bounds on lepton mixing. 10 AKERLOF 88 is PEP e^+e^- experiment at $E_{\rm cm}=29$ GeV. The L^0 is assumed to decay via V-A to e or μ or τ plus a virtual W. 11 MISHRA 87 is Fermilab neutrino experiment looking for either dimuon or double vertex
- events (hence long-lived).
- 12 WENDT 87 is MARK-II search at PEP for heavy u with decay length 1–20 cm (hence
- long-inved). 13 BADIER 86 is a search for a long-lived penetrating sequential lepton produced in π^-- nucleon collisions with lifetimes in the range from $5\times 10^{-7}-5\times 10^{-11}\,\mathrm{s}$ and decaying into at least two charged particles. U_{ej} and $U_{m,j}$ are mixing angles to ν_e and ν_μ . See also the BADIER 86 entry in the section "Searches for Massive Neutrinos and Lepton Mixing".

Astrophysical Limits on Neutrino MASS for $m_{\nu} > 1$ GeV -

VALUE (GeV)	CL%		DOCUMENT ID		TECN	COMMENT
ullet $ullet$ We do not use the	follo	wing d	ata for averages	, fits	, limits,	etc. • • •
none 60-115			FARGION	95	ASTR	Dirac
none 26-4700			BECK	94	COSM	Dirac
none 6 – hundreds			MORI	92B	KAM2	Dirac neutrino
none 24 – hundreds			MORI	92B	KAM2	Majorana neutrino
none 10-2400	90	18	REUSSER	91	CNTR	HPGe search
none 3-100	90		SATO	91	KAM2	Kamiokande II
		19	ENQVIST	89	COSM	
none 12-1400			CALDWELL	88	COSM	Dirac ν
none 4-16	90	15,16	OLIVE	88	COSM	Dirac ν
none 4-35	90		OLIVE	88	COSM	Majorana ν
>4.2 to 4.7			SREDNICKI	88	COSM	Dirac ν
>5.3 to 7.4			SREDNICKI	88	COSM	Majorana ν
none 20-1000	95	15	AHLEN	87	COSM	Dirac v
>4.1			GRIEST	87	COSM	Dirac ν

- 14 FARGION 95 bound is sensitive to assumed u concentration in the Galaxy. See also
- KONOPLICH 94.

 15 These results assume that neutrinos make up dark matter in the galactic halo.
- $^{16}\mathrm{Limits}$ based on annihilations in the sun and are due to an absence of high energy neutrinos detected in underground experiments.
- 17 MORI 92B results assume that neutrinos make up dark matter in the galactic halo. Limits based on annihilations in earth are also given.
- 18 REUSSER 91 uses existing etaeta detector (see FISHER 89) to search for CDM Dirac
- 19 ENQVIST 89 argue that there is no cosmological upper bound on heavy neutrinos.

(B) Sum of neutrino masses

The limits on low mass $(m_{\nu} \lesssim 1 \text{ MeV})$ neutrinos apply to $m_{\rm tot}$ given by

$$m_{
m tot} = \sum_{
u} (g_{
u}/2) m_{
u} \; ,$$

where g_{ν} is the number of spin degrees of freedom for ν plus $\overline{\nu}$: $g_{\nu} = 4$ for neutrinos with Dirac masses; $g_{\nu} = 2$ for Majorana neutrinos. The limits on high mass $(m_{\nu} > 1 \text{ MeV})$ neutrinos apply separately to each neutrino type.

Limit on Total ν MASS, m_{tot}

(Defined in the above note), of effectively stable neutrinos (i.e., those with mean lives greater than or equal to the age of the universe). These papers assumed Dirac neutrinos. When necessary, we have generalized the results reported so they apply to $m_{
m tot}$ - For other limits, see SZALAY 76, VYSOTSKY 77, BERNSTEIN 81, FREESE 84, SCHRAMM 84, and COWSIK 85.

VALUE	eV) DOCUM	ENTID	TECN		
• • •	We do not use the following data for	averages, fits	, limits,	etc. •	• •
<180	SZALA	Y 74	COSM		
<132	COWSI	K 72	COSM		
<280	MARX	72	COSM		
<400	GERSH	TEIN 66	COSM		

Limits on MASSES of Light Stable Right-Handed u(with necessarily suppressed interaction strengths)

VALUE (eV)	DOCUMENT	ID	TECN	COMMENT	
• • • We do not use t	he following data for aver	ages, fits	, limits,	etc. • • •	
<100-200	²⁰ OLIVE	82	COSM	Dirac ν	
<200-2000	²⁰ OLIVE	82	COSM	Majorana $ u$	

²⁰ Depending on interaction strength G_R where $G_R < G_F$. Limits on MASSES of Heavy Stable Right-Handed v

(with necessarily s	uppressed interaction str	ength:	s)		
VALUE (GeV)	DOCUMENT II	<u> </u>	TECN	COMMENT	
• • • We do not use	the following data for average	ges, fits	s, limits,	etc. • • •	
> 10	²¹ OLIVE	82	COSM	G_R/G_F <0.1	
>100	²¹ OLIVE			$G_R/G_F < 0.01$	

 $^{\rm 21}\,{\rm These}$ results apply to heavy Majorana neutrinos and are summarized by the equation: >1.2 GeV (G_F/G_R) . The bound saturates, and if G_R is too small no mass range $m_{\nu} > 1.2$ is allowed

(C) Searches for neutrinoless double- β decay

LIMITS FROM NEUTRINOLESS $\beta\beta$ DECAY

(Revised 1995 by Petr Vogel, Caltech)

Limits on an effective Majorana neutrino mass and a leptonnumber violating current admixture can be obtained from lifetime limits on $0\nu\beta\beta$ nuclear decay. The derived quantities are model-dependent, so the half-life measurements are given first. Where possible we list the references for the matrix elements used in the subsequent analysis. Since rates for the more conventional $2\nu\beta\beta$ decay serve to calibrate the theory, results for this process are also given. As an indication of the spread among different ways of evaluating the matrix elements, we show in Fig. 1 some representative examples for the most popular nuclei. For further calculations, see, e.g., Ref. 1.

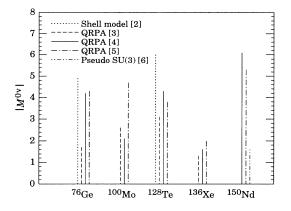


Figure 1: Nuclear matrix elements for $0\nu\beta\beta$ decay calculated by a subset of different methods and different authors for the most popular double-beta decay candidate nuclei. Recalculated from the published half-lives using consistent phase-space factors and $g_A = 1.25$. The QRPA [3] value is for $\alpha' = -390 \text{ MeV fm}^3$.

Lepton Particle Listings

Massive Neutrinos and Lepton Mixing

To define the limits on lepton-number violating right-handed current admixtures, we display the relevant part of a phenomenological current-current weak interaction Hamiltonian:

$$\begin{split} H_W = & (G_F/\sqrt{2}) \\ \times & (J_L \cdot j_L^\dagger + \kappa J_R \cdot j_L^\dagger + \eta J_L \cdot j_R^\dagger + \lambda J_R \cdot j_R^\dagger) + \text{h.c.} \end{split}$$

where $j_L^\mu=\bar{e}_L\gamma^\mu\nu_{eL},~j_R^\mu=\bar{e}_R\gamma^\mu\nu_{eR},$ and J_L^μ and J_R^μ are lefthanded and right-handed hadronic weak currents. Experiments are not sensitive to κ , but quote limits on quantities proportional to η and λ .* In analogy to $\langle m_{\nu} \rangle$ (see Eq. 11 in the "Note on Neutrinos" at the beginning of the Neutrino Particle Listings), the quantities extracted from experiments are $\langle \eta
angle = \eta \sum U_{1j} V_{1j}$ and $\langle \lambda
angle = \lambda \sum U_{1j} V_{1j},$ where V_{ij} is a matrix analogous to U_{ij} (see Eq. 2 in the "Note on Neutrinos"), but describing the mixing among right-handed neutrinos. The quantities $\langle \eta \rangle$ and $\langle \lambda \rangle$ therefore vanish for massless or unmixed neutrinos. Also, as in the case of $\langle m_{\nu} \rangle$, cancellations are possible in $\langle \eta \rangle$ and $\langle \lambda \rangle$. The limits on $\langle \eta \rangle$ are of order 10^{-8} while the limits on $\langle \lambda \rangle$ are of order 10^{-6} . The reader is warned that a number of earlier experiments did not distinguish between η and λ . Because of evolving reporting conventions and matrix element calculations, we have not tabulated the admixture parameters for experiments published earlier than 1989.

See the section on Majoron searches for additional limits set by these experiments.

Footnotes and References

- * We have previously used a less accepted but more explicit notation in which $\eta_{RL} \equiv \kappa$, $\eta_{LR} \equiv \eta$, and $\eta_{RR} \equiv \lambda$.
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Half-life Measurements and Limits for Double β Decay $(Z+2,A) + 2\beta^{-} + (0 \text{ or } 2)\overline{\nu}$

		s or dor	ible beta	decay,	$(Z,A) \rightarrow (Z$	(+2,A) + 2b + (or $2)\nu_e$.	
$t_{1/2}$	(10 ²¹ yr)	CL%	ISOTOPI	E TE	RANSITION	METHOD	DOCUMENT ID	
• •	• We do no	t use th	ne follow	ing data	for average	s, fits, limits, etc.	• • •	
0.03	$36^{+0.006}_{-0.005}$ ±	0.003	^{116}Cd	2ν	$0^+ \rightarrow 0^+$	NEMO	²² ARNOLD	95
>5	600	90	⁷⁶ Ge	0ν	$0^{+} \rightarrow 0^{+}$	Enriched HPGe	BALYSH	95
0.6	$1 + 0.18 \\ -0.11$		¹⁰⁰ Mo	2ν	$0^{+} \rightarrow 0^{+}$	γ in HPGe	²³ BARABASH	95
>	0.00013	99	160 Gd	2ν	$0^{+} \rightarrow 0^{+}$	Gd2SiO5:Ce scint	²⁴ BURACHAS	95
>	0.00012	99	$^{160}\mathrm{Gd}$	2ν	$0^+ \rightarrow 2^+$	Gd ₂ SiO ₅ :Ce scint	²⁴ BURACHAS	95
>	0.014	90	¹⁶⁰ Gd	0ν	$0^{+} \rightarrow 0^{+}$	Gd2SiO5:Ce scint	²⁴ BURACHAS	95
>	0.013	90	¹⁶⁰ Gd	0ν	$0^{+} \rightarrow 2^{+}$	Gd2SiO5:Ce scint	²⁴ BURACHAS	95
(9.5	5 ± 0.4 ± 0.9)E18	¹⁰⁰ Mo	2ν		NEMO 2	DASSIE	95
>	6.4	90	¹⁰⁰ Mo	0ν	$0^{+} \rightarrow 0^{+}$	NEMO 2	DASSIE	95
>	0.8	90	¹⁰⁰ Mo		$0^+ \rightarrow 2_1^+$	NEMO 2	DASSIE	95
>	0.6	90	¹⁰⁰ Mo	0ν	$0^+ \rightarrow 0_1^+$	NEMO 2	DASSIE	95
0.02	$26 + 0.009 \\ -0.005$		^{116}Cd	2ν	$0^{+} \rightarrow 0^{+}$	ELEGANT IV	EJIRI	95
> 2		90	¹¹⁶ Cd	0ν	$0^{+} \rightarrow 0^{+}$	ELEGANT IV	EJIRI	95
>	29	90	116 _{Cd}	0ν	$0^{+} \rightarrow 0^{+}$	116CdWO ₄ scint	²⁵ GEORGADZE	95
>	0.3	68	¹⁶⁰ Gd	0ν		Gd2SiO5: Ce scin	t KOBAYASHI	95
>	18	90	130 _{Te}	0ν	$0^{+} \rightarrow 0^{+}$	Bolometer	²⁶ ALESSAND	94
>	0.041	90	⁹⁶ Zr	$0\nu+2\nu$	$0^+ \rightarrow 2_1^+$	γ in HPGe	ARPESELLA	94

>	0.033	90	96 Zr	0ν+2ν	$0^+ \rightarrow 0_1^+$	γ in HPGe		ARPESELLA	94
>	0.024	90	96 Zr		$0^+ \rightarrow 2^+_2$	γ in HPGe		ARPESELLA	94
>	0.031	90	96 Zr		$0^+ \rightarrow 2^+_3$	γ in HPGe		ARPESELLA	94
	± 0.03 ± 0.13		76 _{Ge}	2ν	3	Enriched HPGe		BALYSH	94
>	2.37	90	¹¹⁶ Cd	$0\nu+2\nu$	$0^{+} \rightarrow 2^{+}$	γ in HPGe	27	PIEPKE	94
>	2.05	90			$0^+ \to 0_1^+$	γ in HPGe		PIEPKE	94
>	2.05	90	116Cd	$0\nu+2\nu$	$0^+ \to 0^{\bar{+}}_2$	γ in HPGe	27	PIEPKE	94
>	44	68	100 Mo		$0^+ \rightarrow 0^+$	Si(Li)		ALSTON	93
	$7^{+0.010}_{-0.005} \pm 0.0$	035	150 Nd	2ν	0 ⁺ → 0 ⁺	TPC		ARTEMEV	93
	± 0.009	90	96 _{Mo}	$0\nu+2\nu$	0 ⁺ → 0 ⁺	Geochem	28	KAWASHIMA	93
> 3 > 2		90	136 Xe	0ν 0ν	$0^+ \rightarrow 0^+$	TPC TPC	29	VUILLEUMIER VUILLEUMIER	93
> -	0.21	90	136Xe	2ν	$0^+ \rightarrow 0^+$	TPC		VUILLEUMIER	
>	0.093	90	136 _{Xe}	2ν	$0^+ \rightarrow 0^+$	Drift chamber		ARTEMJEV	92
>14		90	76 Ge	0ν	0 ⁺ → 0 ⁺	Enriched HPGe		BALYSH	92
> 4		90	⁷⁶ Ge ¹³⁰ Te	0ν	$0^{+} \rightarrow 2^{+}$	Enriched HPGe		BALYSH	92
2.7			128 Te			Geochem	30	BERNATOW	
>	± 400 0.5	90		01.2	$0^+ \rightarrow 2_1^+$	Geochem γ in HPGe	31	BERNATOW BLUM	92 92
	0.9	90	100	0	$0^+ \rightarrow 2_1^+$ $0^+ \rightarrow 0_1^+$	•		BLUM	
>			100.4	0\(\nu+2\(\nu\)	$0^+ \rightarrow 0_1^+$ $0^+ \rightarrow 2_2^+$	γ in HPGe			92
>	0.6	90	82 _{Se}		$0^+ \rightarrow 2^2$ $0^+ \rightarrow 0^+$	γ in HPGe	-	BLUM	92
> 0.109	27 3+0.026 0.006	68	82Se	0ν 2ν	$0^+ \rightarrow 0^+$	TPC TPC		ELLIOTT	92 92
			100 _{Mo}				32	KUDOMI	
>	0.15	68 68	100 _{Mo}		$0^+ \rightarrow 2_1^+$ $0^+ \rightarrow 2_1^+$	Spect Spect		KUDOMI	92 92
>	0.08	68	100 _{Mo}		$0^{+} \rightarrow 0^{+}_{1}$	Spect		KUDOMI	92
>	0.56	68	100 Mo		$0^+ \rightarrow 0_1^+$	Spect		KUDOMI	92
>	0.051	68	¹⁰⁰ Mo		$0^+ \rightarrow 4_1^+$	Spect		KUDOMI	92
>	0.63	68	¹⁰⁰ Mo		$0^+ \rightarrow 4_1^+$	Spect	32	KUDOMI	92
>	0.065	68	¹⁰⁰ Mo		$0^+ \rightarrow 2^+_2$	Spect		KUDOMI	92
>	0.12	68	100 _{Mo}	0ν	$0^+ \rightarrow 2_2^+$	Spect	32	KUDOMI	92
> 3	30	90	⁷⁶ Ge	0ν	$0^{+} \rightarrow 0^{+}$	HPGe	33	REUSSER	92
>	65 - 0.07	90	76 _{Ge}	0ν	$0^{+} \rightarrow 2^{+}$	HPGe		REUSSER	92
	+0.07 -0.04		76 Ge	2ν	0 ⁺ → 0 ⁺	Enriched HPGe		AVIGNONE	91
	12	95	136 _{Xe} 136 _{Xe}		0 ⁺ → 0 ⁺	Prop cntr 28	,35 35	BELLOTTI	91
>	10 3.3	95 95	136Xe	0ν 0ν	$0^+ \rightarrow 0^+$ $0^+ \rightarrow 2^+$	Prop cntr 29 Prop cntr	,35 35	BELLOTTI BELLOTTI	91 91
>	0.16	95	136 _{Xe}	2ν	0	Prop cntr		BELLOTTI	91
>	4.7	68	100 Mo	0ν		Spect		EJIRI	91
0.011	$5^{+0.0030}_{-0.0020}$		¹⁰⁰ Mo	2ν		Spect		EJIRI	91
2.0 ±			238 _U			Radiochem	36	TURKEVICH	91
>	9.5	76	⁴⁸ Ca	0ν		CaF ₂ scint.		YOU	91
>	0.14	68	100 Mo	$0\nu+2\nu$	0 ⁺ → 2 ⁺	γ in HPGe		BARABASH	9 0
>	0.042	68	100 Mo	$0\nu+2\nu$	$0^+ \to 0_1^+$	γ in HPGe		BARABASH	90
>	0.17	68	116Cd		0+ → 2+	γ in HPGe	27	BARABASH	90
	+0.48 -0.26		76 _{Ge}	2ν	0 ⁺ → 0 ⁺	HPGe		MILEY	90
>13		68	⁷⁶ Ge 76 _{Ge}	0ν	0 ⁺ → 0 ⁺	Enriched Ge(Li)	30	VASENKO	90
0.9 ±	0.40	68	100 _{Mo}	2ν	0 ⁺ → 2 ⁺	Enriched Ge(Li) Si(Li)		VASENKO ALSTON	90 89
>	3.3	68	136Xe	0ν	$0^+ \rightarrow 0^+$	lon chamber	28	BARABASH	89
>	2.9	68	136 Xe	0ν	0 ⁺ → 0 ⁺	lon chamber		BARABASH	89
>	1.5	68	136 Xe	0ν	$0^+ \rightarrow 2^+$	Ion chamber		BARABASH	89
>	0.084	68	136 Xe	2ν	$0^+ \rightarrow 0^+$	Ion chamber		BARABASH	89
>	1.3	68	116 _{Cd}	0ν	. 1	116CdWO ₄ scint	20	DANEVICH	89
	60	68	76 _{Ge}	0ν	$0^{+} \rightarrow 2^{+}$	HPGe	39	MORALES	88
>	4.7	68 68	¹²⁸ Te ¹³⁰ Te		$0^{+} \rightarrow 2^{+}$ $0^{+} \rightarrow 2^{+}$	Ge(Li)	24	BELLOTTI BELLOTTI	87
> 5	4.5 00	68	76 Ge	0ν	$0^+ \rightarrow 2^+$ $0^+ \rightarrow 0^+$	Ge(Li) HPGe	- '	CALDWELL	87 87
	30	68	76 _{Ge}	0ν	$0^+ \rightarrow 0^+$	HPGe		BELLOTTI	86
	27	68	⁷⁶ Ge	0ν	$0^{+} \rightarrow 2^{+}$	HPGe		BELLOTTI	86
>	2.3	68	76 Ge	0ν		Ge(Li)	40	HUBERT	85
	17	90	76 Ge	0ν		Intrinsic Ge	41	AVIGNONE	83
> 8		95	¹²⁸ Te ¹³⁰ Te			Geochem	41	KIRSTEN	83
2.60	± 0.28		1e	_		Geochem		KIRSTEN	83

 22 ARNOLD 95 final result, $(0.0375^{+0.0035}_{-0.0021})\times 10^{21}$ y, has been submitted for publication to 7. Phys.

Isotope. 25 GEORGADZE 95 result for this and other modes are also give in DANEVICH 95. Result for 2ν decay omitted because of authors' caveats.

To 2D decay of mitted because of authors careass.

ALESSANDRELLO 94 state that their present limit excludes a significant contribution from the 0ν channel of ¹³⁰Te even if the large lifetime obtained in the geochemical experiment of BERNATOWICZ 92 is assumed.

To 2. Figs. 23 BARABASH 95 cannot distinguish 0ν and 2ν , but it is inferred indirectly that the 0ν mode accounts for less than 0.026% of their event sample. They also note that their result disagrees with the previous experiment by the NEMO group (BLUM 92, but also see DASSIE 95).

 $^{^{24}}$ BELLOTTI 87 searches for γ rays for 2^+ state decays in corresponding Xe isotopes. Limit for 130 Te case argues for dominant $0^+\!\rightarrow 0^+$ transition in known decay of this isotope.

- 27 In PIEPKE 94, the studied excited states of 116 Sn have energies above the ground state of 1.2935 MeV for the 2^+ state, 1.7568 MeV for the 0_1^+ state, and 2.0273 for the 0_2^+ state. 28 Limit in the case of a transition induced by a Majorana mass.

- ²⁹Limit for lepton-number violating right-handed current-induced (RHC) decay.

 ³⁰ BERNATOWICZ 92 finds ¹²⁸Te/¹³⁰Te activity ratio from slope of ¹²⁸Xe/¹³²Xe vs. 130 Xe/132 Xe ratios during extraction, and normalizes to lead-dated ages for the 130 Te lifetime. The authors state that their results imply that "(a) the double beta decay of lifetime. The authors state that their results imply that "(a) the double beta decay of 128Te has been firmly established and its half-life has been determined ... without any ambiguity due to trapped Xe interferences... (b) Theoretical calculations ... underestimate the [long half-lives of 128Te 130Te] by 1 or 2 orders of magnitude, pointing to a real supression in the 2*v* decay rate of these isotopes. (c) Despite [this], most \$\beta\$-models predict a ratio of 2*v* decay widths ... in fair agreement with observation." Further details of the experiment are given in BERNATOWICZ 93. Our listed half-life has been revised downward from the published value by the authors, on the basis of reevaluated cosmic-ray ¹²⁸Xe production corrections.
- 31 BLUM 92 reports lifetime limits for the decay of ¹⁰⁰Mo to several excited states of 100 Ru. Limits for decay to the $^{+}_{1}$ state are about 30% higher if decay to the $^{+}$ states are assumed negligible. Uses 99.5% enriched 100 Mo.
- are assumed negligible. Uses 99.5% enriched $^{-2}$ Mo. $^{-2}$ KUDOMI 92 reports lifetime limits for 0ν and 2ν decays to four excited states of the daughter 10 Ru. The limits were obtained from searches for the two individual electrons in coincidence with photons from the decays of the excited states. The experiment was performed in the Kamioka underground laboratory. See EJIRI 91 for the group's ground-state transition measurement.
- 33 REUSSER 92 contains the final results for the search for neutrinoless double beta decay of $^{76}{\sf Ge}$ in the Gotthard tunnel underground laboratory. Supersedes FISHER 89
- ³⁴ AVIGNONE 91 reports confirmation of the MILEY 90 and VASENKO 90 observations of $2\nu\beta\beta$ decay of ⁷⁶Ge. Error is 2σ .
- 35 BELLOTTI 91 uses difference between natural and enriched 136 Xe runs to obtain etaeta0u
- 35 BELLOTTI 91 uses difference between natural and enriched 136 Xe runs to obtain $\beta\beta0\nu$ limits, leading to "less stringent, but safer limits." 36 TURKEVICH 91 observes activity in old U sample. The authors compare their results with theoretical calculations. They state "Using the phase-space factors of Boehm and Vogel (BOEHM 87) leads to matrix element values for the 238 U transition in the same range as deduced for 130 Te and 76 Ge. On the other hand, the latest theoretical estimates (STAUDT 90) give an upper limit that is 10 times lower. This large discrepancy implies either a defect in the calculations or the presence of a faster path than the standard two-neutrino mode in this case. "See BOEHM 87 and STAUDT 90. 37 MILEY 90 claims only "suggestive evidence" for the decay. Error is 2σ . 38 VASENKO 90 limit based on background statistics. Maximum likelihood solution is >2000.

- 39 MORALES 88 notes a 2.5 sigma coincidence rate between electrons with energy 1483.7 \pm 0.5 keV in the Ge detector and photons with energy 558 \pm 15 keV in the NaI detector, close to the region where neutrinoless 0⁺ \rightarrow 2⁺ 76 Ge decay should be expected. However, a further study reported in MORALES 91 rejects this peak at the 95% CL.
- 40 HUBERT 85 gives lifetime limits on neutrinoless double eta decay of 76 Ge to excited states
- 41 KIRSTEN 83 reports " 2σ " error. References are given to earlier determinations of the 130 Te lifetime.

$\langle m_{\nu} \rangle$, The Effective Weighted Sum of Majorana Neutrino Masses Contributing to Neutrinoless Double β Decay

 $\langle m_{
u} \rangle = |\Sigma| U_{1j}^2 m_{
u_j}|$, where the sum goes from 1 to n and where n= number of neutrino generations, and ν_j is a Majorana neutrino. Note that U_{1j}^2 , not $|U_{1j}|^2$, occurs in the sum. The possibility of cancellations has been stressed.

VALUE (eV)	CL%	ISOTOP.	E	TRANSITION	METHOD	DOCUMENT ID	
• • • We do	not us	e the foll	lowin	g data for avera	ages, fits, limits, etc	. • • •	
< 0.65	90	⁷⁶ Ge	0ν	$0^{+} \rightarrow 0^{+}$		BALYSH	95
< 4.1	90	116 Cd	0ν		116CdWO ₄ scint	⁴² DANEVICH	95
< 6.6	68	100 Mo	0ν	$0^{+} \rightarrow 0^{+}$	Si(Li)	⁴³ ALSTON	93
< 2.8-4.3	90	136 _{Xe}	0ν	$0^{+} \rightarrow 0^{+}$	TPC	44 VUILLEUMIER	93
< 1.5	90	76 _{Ge}			Enriched HPGe	⁴⁵ BALYSH	92
< 1.1-1.5		¹²⁸ Te			Geochem	46 BERNATOW	. 92
< 5	68	82 _{Se}			TPC	⁴⁷ ELLIOTT	92
< 1.9-6.7	68	⁷⁶ Ge		$0^{+} \rightarrow 0^{+}$	HPGe	⁴⁸ REUSSER	92
< 11-30	95	136 _{Xe}	0ν	$0^{+} \rightarrow 0^{+}$	Prop cntr	⁴⁹ BELLOTTI	91
< 3.3-5.0		136 _{Xe}	0ν	$0^{+} \rightarrow 0^{+}$	TPC	⁵⁰ WONG	91
< 8.3	76	48 _{Ca}	0ν		CaF ₂ scint.	YOU	91
< 1.4-8	68	⁷⁶ Ge	0ν	$0^{+} \rightarrow 0^{+}$	Enriched Ge(Li)	⁵¹ VASENKO	90
<4.3-28		136 Xe	0ν	$0^{+} \rightarrow 0^{+}$	Prop chamber	⁵² BELLOTTI	89
<12	68	¹¹⁶ Cd	0ν		116CdWO ₄ scint	⁵³ DANEVICH	89
< 1.8		76 Ge	0ν	$0^{+} \rightarrow 0^{+}$	HPGe	⁵⁴ CALDWELL	87
< 2.7	68	76 Ge	0ν	$0^{+} \rightarrow 0^{+}$	HPGe	BELLOTTI	86
<20	68	⁷⁶ Ge	0ν		Ge(Li)	⁵⁵ HUBERT	85
<22		76 _{Ge}	0ν	$0^{+} \rightarrow 0^{+}$	Ge	FORSTER	84
<10	90	76 Ge	0ν		Intrinsic Ge	AVIGNONE	83
< 5.6	95	¹²⁸ ⊤e			Geochem	KIRSTEN	83
12							

- 42 DANEVICH 95 is identical to GEORGADZE 95. 43 ALSTON-GARNJOST 93 use the "conservative matrix elements of Engel et al. (ENGEL 88).

- GEL 88). On the basis of these calculations, the BALYSH 92 mass range would be 45 BALYSH 92 uses the MUTO 89 matrix elements.
 46 BERNATOWICZ 92 finds these majoron mass limits assuming that the measured geochemical decay width is a limit on the 0ν decay width. The range is the range found using matrix elements from HAXTON 84, TOMODA 87, and SUHONEN 91. Further details of the experiment are given in BERNATOWICZ 93.
- 47 ELLIOTT 92 uses the matrix elements of HAXTON 84.

- 48 REUSSER 92 contains the final results for the search for neutrinoless double beta decay of ⁷⁶Ge in the Gotthard tunnel underground laboratory. Range comes from range of nuclear matrix elements used to relate neutrino mass to lifetime limit (ENGEL 88, HAXTON 84, and MUTO 89).
- 49 BELLOTTI 91 range of limits comes from range of theoretical calculations considered. Analysis uses difference between natural and enriched 136 Xe runs to obtain the $^{\beta}$ 80 $^{\nu}$ limits, leading to "less stringent, but safer limits."
- $^{50}\,\mathrm{WONG}$ 91 uses the quasiparticle random phase approximation of ENGEL 88 to extract
- the above limit for the case of a transition caused by a Majorana neutrino mass.

 51 VASENKO 90 range comes from range of nuclear matrix elements of HAXTON 84,
 ENGEL 88. On the basis of the MUTO 89 matrix element, the limit will be < 1.3 eV.
- 52 BELLOTTI 89 gives model-dependent upper bounds on Majorana neutrino masses and in the admixture of right-handed lepton-number-violating currents.

- on the admixture of right-handed lepton-number-violating currents.

 53 DANEVICH 80 uses calculations of GROTZ 86.

 54 CALDWELL 87 least stringent limit (using HAXTON 84) is listed. Limits given using other nuclear matrix element calculations are 1.5 eV and 0.7 eV.

 5 HUBERT 85 limit is obtained from analysis of data using theoretical calculations by HAXTON 81, HAXTON 82.

Limits on Lepton-Number Violating (V+A) Current Admixture

For reasons given in the discussion at the beginning of this section, we list only results from 1989 and later. $\langle \lambda \rangle = \lambda \sum U_{IJ} V_{IJ}$ and $\langle \eta \rangle = \eta \sum U_{IJ} V_{IJ}$, where the sum is over the number of neutrino generations. This sum vanishes for massless or unmixed neutrinos.

$\langle \lambda \rangle$ (10 $^-$	6) CL%	$\langle \eta \rangle$ (10 ⁻⁸) CL%	ISOTOPE	METHOD	DOCUMENT ID	
• • • V	Ve do n	ot use the f	ollowir	ng data for	averages, fits, limit	s, etc. • • •	
< 5.3	90	< 5.9	90	¹¹⁶ Cd	116CdWO ₄ scint	56 DANEVICH	95
<2.3	90	<1.5	90	76 Ge	Enriched HPGe	⁵⁷ BALYSH	92
		< 5.3		128⊤e	Geochem	58 BERNATOW	92
<3.6	68	<2.2	68	⁷⁶ Ge	HPGe	⁵⁹ REUSSER	92
<9	68	<8	68	76 _{Ge}	Ion chamber	BELLOTTI	89

- 56 DANEVICH 95 is identical to GEORGADZE 95. 57 BALYSH 92 uses the MUTO 89 matrix elements. 58 BERNATOWICZ 92 takes the measured geochemical decay width as a limit on the 0ν width, and uses the SUHONEN 91 coefficients to obtain the least restrictive limit on η . Further details of the experiment are given in BERNATOWICZ 93.
- ⁵⁹ REUSSER 92 uses the MUTO 89 matrix elements for this reduction.

(D) Other bounds from nuclear and particle decays

- Limits on $|U_{1J}|^2$ as Function of $m_{ u_I}$

Peak and kink search tests

Limits on $|U_{1j}|^2$ as function of m_{ν_i}

VALU.	E	CL%		DOCUMENT ID		TECN	COMMENT
<1	× 10 ⁻⁷	90	60	BRITTON	92B	CNTR	50 MeV $< m_{ u_i} < 130$
	 We do not use the 	مارينمالية .			414.	limita.	MeV
			g a	_		, mmts,	
<5	× 10 ⁻⁶	90		DELEENER	91		$m_{ u_j}=$ 20 MeV
<5	× 10 ⁻⁷	90		DELEENER	91		$m_{ u_j}=$ 40 MeV
<3	× 10 ⁻⁷	90		DELEENER	91		$m_{ u_j}=$ 60 MeV
<1	\times 10 ⁻⁶	90		DELEENER	91		$m_{\nu_j}=80~{ m MeV}$
<1	× 10 ⁻⁶	90		DELEENER	91		$m_{ u_j} = 100 \text{ MeV}$
<5	× 10 ⁻⁷	90		AZUELOS	86	CNTR	m_{ν_i} =60 MeV
<2	× 10 ⁻⁷	90		AZUELOS	86	CNTR	$m_{\nu_i} = 80 \text{ MeV}$
<3	× 10 ⁻⁷	90		AZUELOS	86	CNTR	$m_{\nu_i} = 100 \text{ MeV}$
<1	× 10 ⁻⁶	90		AZUELOS	86	CNTR	$m_{\nu_i} = 120 \text{ MeV}$
<2	$\times 10^{-7}$	90		AZUELOS	86	CNTR	$m_{\nu_i} = 130 \text{ MeV}$
<8	× 10 ⁻⁶			DELEENER	86	CNTR	$m_{\nu_i}^{\sigma}$ =20 MeV
<4	× 10 ⁻⁷			DELEENER	86	CNTR	
<2	× 10 ⁻⁶			DELEENER	86	CNTR	$m_{\nu_i} = 100 \text{ MeV}$
<7	× 10 ⁻⁶			DELEENER	86	CNTR	$m_{\nu_i} = 120 \text{ MeV}$
<1	× 10 ⁻⁴	90	61	BRYMAN			$m_{\nu_i} = 5 \text{ MeV}$
<1.5	6×10^{-6}	90		BRYMAN	83B	CNTR	$m_{\nu_i} = 53 \text{ MeV}$
<1	× 10 ⁻⁵	90		BRYMAN			$m_{\nu_i} = 70 \text{ MeV}$
<1	× 10 ⁻⁴	90		BRYMAN			$m_{\nu_i} = 130 \text{ MeV}$
<1	× 10 ⁻⁴	68	62	SHROCK			$m_{\nu_i} = 10 \text{ MeV}$
<5	× 10 ⁻⁶	68	62	SHROCK	81		$m_{\nu_i} = 60 \text{ MeV}$
<1	× 10 ⁻⁵	68	63	SHROCK	80		$m_{\nu_i}^{J}$ =80 MeV
<3	× 10 ⁻⁶	68	63	SHROCK			$m_{\nu_i} = 160 \text{ MeV}$
							•

- 60 BRITTON 92B is from a search for additional peaks in the e^+ spectrum from π^+ ightarrow $e^+\nu_a$ decay at TRIUMF. See also BRITTON 92.
- 61 BRYMAN 838 obtain upper limits from both direct peak search and analysis of B(π o $e\nu)/B(\pi\to\mu\nu).$ Latter limits are not listed, except for this entry (i.e. — we list the most stringent limits for given mass). 62 Analysis of $(\pi^+\to e^+\nu_e)/(\pi^+\to \mu^+\nu_\mu)$ and $(K^+\to e^+\nu_e)/(K^+\to \mu^+\nu_\mu)$
- decay ratios.
- ⁶³ Analysis of $(K^+ \rightarrow e^+ \nu_e)$ spectrum.

Lepton Particle Listings

Massive Neutrinos and Lepton Mixing

Kink search in nuclear β decay

High-sensitivity follow-up experiments show that indications for a neutrino with mass 17 keV (Simpson, Hime, and others) were not valid. Accordingly, we no longer list the experiments by these authors and some others which made positive claims of 17 keV neutrino emission. Complete listings are given in the 1994 edition (Physical Review **D50** 1173 (1994)). Limits on $|U_{1j}|^2$ as a function of m_{ν_j} .

VALUE (units 10 ⁻³)	CL%	m _{ν;} (keV)	ISOTO	PE METHOD		DOCUMENT ID	
• • • We do not	use th	ne following data for	averag	es, fits, limits, etc.		• •	
$< 1 \times 10^{-2}$	95	1	^{3}H	SPEC	64	HIDDEMANN	95
$< 6 \times 10^{-3}$	95	2	3 _H	SPEC		HIDDEMANN	95
$< 2 \times 10^{-3}$	95	3	3 _H	SPEC		HIDDEMANN	95
$< 2 \times 10^{-3}$	95	4	3 _H	SPEC		HIDDEMANN	95
0.3 ±1.5±0	0.8	17	35_{S}	Mag spect	65	BERMAN	93
< 2.8	99	17	^{3}H	Prop chamber	66	KALBFLEISCH	93
< 1	99	14.4-15.2	3 _H	Prop chamber	66	KALBFLEISCH	93
< 0.7	99	16.3-16.6	^{3}H	Prop chamber	66	KALBFLEISCH	93
< 2	95	13-40	35 S	Si(Li)	67	MORTARA	93
< 0.73	95	17	63 _{Ni}	Mag spect		OHSHIMA	93
< 1.5	95	10.5-25.0	63Ni	Mag spect		OHSHIMA	93
< 6	95	5-25	55 Fe	IBEC in Ge	69	WIETFELDT	93
< 2	90	17	35 _S	Mag spect.	70	CHEN	92
< 0.95	95	17	63 _{Ni}	Mag spect	71	KAWAKAMI	92
< 1.0	95	10-24	63 _{Ni}	Mag spect		KAWAKAMI	92
< 10	90	16-35	125	IBEC; γ det	72	BORGE	86
< 7.5	99	5-50	35 _S	Mag spect		ALTZITZOG	85
< 8	90	80	35 _S	Mag spect	73	APALIKOV	85
< 1.5	90	60	35 _S	Mag spect		APALIKOV	85
< 8	90	30	35 _S	Mag spect		APALIKOV	85
< 3	90	17	35 _S	Mag spect		APALIKOV	85
< 45	90	4	35 _S	Mag spect		APALIKOV	85
< 10	90	5-30	35 _S	Si(Li)		DATAR	85
< 3.0	90	5-50	25	Mag spect		MARKEY	85
< 0.62	90	48	35 _S	Si(Li)		ОНІ	85
< 0.90	90	30	35 _S	Si(Li)		ОНІ	85
< 1.30	90	20	35 _S	Si(Li)		ОНІ	85
< 1.50	90	17	35 _S	Si(Li)		OHI	85
< 3.30	90	10	35 _S	Si(Li)	~.	ОНІ	85
< 25	90	30	64 Cu	Mag spect	74	SCHRECK	83
< 4	90	140	64 Cu	Mag spect	74	SCHRECK	83
< 8	90	440	64Cu	Mag spect	75	SCHRECK	83
< 1	95	0.1			75	SIMPSON	818
< 4	95× 1			THEO	76	SIMPSON	818
<100	90	0.1-3000		THEO	77	SHROCK	80
< 0.1	68	80		THEO	٠.	SHROCK	80

- 64 In the beta spectrum from tritium eta decay nonvanishing or mixed $m_{\overline{
 u}_1}$ state in the mass region 0.01–4 keV. For $m_{
 u_j}$ <1 keV, their upper limit on $|U_{1j}|^2$ becomes less
- 65 BERMAN 93 uses an iron-free intermediate-image magnetic spectrometer to measure 35 S $_{\beta}$ decay over a large portion of the spectrum. Paper reports (0.01 \pm 0.15)%; above result revised by author on basis of analysis refinements.
- 66 KALBFLEISCH 93 extends the 17 keV neutrino search of BAHRAN 92, using an improved proportional chamber to which a small amount of 3H is added. Systematics are significantly reduced, allowing for an improved upper limit. The authors give a 99% confidence limit on $|U_1j|^2$ as a function of m_{ν_j} in the range from 13.5 keV to 17.5 keV. Typical upper limit. Typical upper limits are listed above. They report that this experiment in combination with BAHRAN 92 gives an upper limit of 2.4×10^{-3} at the 99% CL. See also the related papers BAHRAN 93, BAHRAN 938, and BAHRAN 95 on theoretical aspects of beta spectra and fitting methods for heavy neutrinos.
- beta spectra and fitting methods for neavy neutrinos.

 67 MORTARA 93 limit is from study using a high-resolution solid-state detector with a superconducting solenoid. The authors note that "The sensitivity to neutrino mass is verified by measurement with a mixed source of ³⁵S and ¹⁴C, which artificially produces a distortion in the beta spectrum similar to that expected from the massive neutrino."
- $^{68}\,\text{OHSHIMA}$ 93 is the full data analysis from this experiment. The above limit on the mixing strength for a 17 keV neutrino is obtained from the measurement $|U_{1\,j}|^2=$ $(-0.11\pm0.33\pm0.30)\times10^{-3}$ by taking zero as the best estimate and ignoring physical boundaries; see discussion in HOLZSCHUH 92s for a comparison of methods. An earlier report of this experiment was given in KAWAKAMI 92.
- 69 WIETFELDT 93 is an extension of the NORMAN 91 experiment. However, whereas NORMAN 91 reported indications for the emission of a neutrino with mass $m_{\nu_j}=$ 121 ± 2 keV and coupling strength = 0.0085 \pm 0.0045, the present experiment states that "We find no evidence for emission of a neutrino in the mass range 5–25 keV. In particular, a 17 keV neutrino with $\sin^2\theta \left(|U_1|^2 \right)$ in our notation) = 0.008 is excluded at the 7σ level." The listed limits can be obtained from the paper's Fig. 4. The authors acknowledge that this conclusion contradicts the one reported in NORMAN 91, based on a smaller data sample. In further tests, WIETFELDT 95 have shown that "the observed discretion are most likely covered by experiments effect. distortion was most likely caused by systematic effects... A new measurement with a smaller data sample shows no sign of this distortion." $\frac{1}{2} \left(\frac{1}{2} \right) \left(\frac{1$
- 70 CHEN 92 is a continuation and improvement of the Boehm et al. Caltech iron-free magnetic spectrometer experiment searching for emission of massive neutrinos in 35 S decay (MARKEY 85). The upper limit on $|U_{1j}|^2$ for $m_{\nu_j}=$ 17 keV comes from the measurement $|U_{1j}|^2=(-0.5\pm 1.4)\times 10^{-3}$. The authors state that their results "rule out, at the 6σ level, a 17 keV neutrino admixed at 0.85% (i.e. with $|U_{1\,i}|^2=$ 0.85×10^{-2} ." the level claimed by Hime and Jelly in HIME 91. They also state that "our data show no evidence for a heavy neutrino with a mass between 12 and 22 keV"

- with substantial admixture in the weak admixture in the weak eigenstate $u_{m{e}}$; see their Fig. 4 for a graphical set of measured values of $|U_{1\,i}|^2$ for various hypothetical values of $m_{
 u_i}$ in this range.
- 71 KAWAKAMI 92 experiment final results are given in OHSHIMA 93. The upper limit is improved to 0.73×10^{-3} , based on $|U_{1\,f}|^2=(-0.11\pm0.33\pm0.30)\times 10^{-3}.$ Ohshima notes that the result is 22 σ away from the value $|\mathit{U}_{1j}|^2=1\%$.
- 72 BORGE 86 results originally presented as evidence against the SIMPSON 85 claim of a 17 keV antineutrino emitted with $|U_{1f}|^2=0.03$ in $^3{\rm H}$ decay.
- 73 This limit was taken from the figure 3 of APALIKOV 85; the text gives a more restrictive limit of 1.7 \times 10^{-3} at CL = 90%. 74 SCHRECKENBACH 83 is a combined measurement of the β^+ and β^- spectrum.

DOCUMENT ID

- 75 Application of kink search test to tritium eta decay Kurie plot.
- To ship the same test to triain β decay for β decay for β decays to search for kinks in the Kurie plot.
- 77 Application of test to search for kinks in β decay Kurie plots.

Searches for Decays of Massive ν

Limits on $|U_{1j}|^2$ as function of m_{ν_i}

C1 %

VALUE	CL%		DOCUMENT ID		<u>TECN</u>	COMMENT
• • • We do not use the	followin			, fits	, limits,	etc. • • •
$< 1 \times 10^{-5}$	90	78	BARANOV	93		$m_{ u_i} = 100 \; \mathrm{MeV}$
$< 1 \times 10^{-6}$	90	78	BARANOV	93		$m_{\nu_i} = 200 \text{ MeV}$
$< 3 \times 10^{-7}$	90	78	BARANOV	93		$m_{\nu_i} = 300 \text{ MeV}$
$< 2 \times 10^{-7}$	90	78	BARANOV	93		$m_{\nu_i} = 400 \text{ MeV}$
$<6.2 \times 10^{-8}$	95		ADEVA	90 S	L3	$m_{\nu_i} = 20 \text{ GeV}$
$< 5.1 \times 10^{-10}$	95		ADEVA	90s	L3	$m_{\nu_i} = 40 \text{ GeV}$
all values ruled out	95	79	BURCHAT	90	MRK2	$m_{ u_j}$ < 19.6 GeV
$< 1 \times 10^{-10}$	95	79	BURCHAT	90	MRK2	$m_{\nu_j} = 22 \text{ GeV}$
$<1 \times 10^{-11}$	95	79	BURCHAT	90	MRK2	$m_{\nu_i} = 41 \text{ GeV}$
all values ruled out	95		DECAMP	90F	ALEP	$m_{\nu_i} = 25.0 - 42.7 \text{ GeV}$
$< 1 \times 10^{-13}$	95		DECAMP	90F	ALEP	$m_{\nu_i} = 42.7 - 45.7 \text{ GeV}$
<5 × 10 ⁻³	90		AKERLOF	88	HRS	$m_{\nu_i} = 1.8 \text{ GeV}$
$< 2 \times 10^{-5}$	90		AKERLOF	88	HRS	$m_{\nu_i} = 4 \text{ GeV}$
$< 3 \times 10^{-6}$	90		AKERLOF	88	HRS	$m_{\nu_j} = 6 \text{ GeV}$
$<1.2 \times 10^{-7}$	90		BERNARDI	88	CNTR	m_{ν_i} =100 MeV
<1 × 10 ⁻⁸	90		BERNARDI	88	CNTR	m_{ν_i} =200 MeV
$< 2.4 \times 10^{-9}$	90		BERNARDI	88	CNTR	m_{ν_i} =300 MeV
$< 2.1 \times 10^{-9}$	90		BERNARDI	88	CNTR	m_{ν_i} =400 MeV
$<2 \times 10^{-2}$	68	80	OBERAUER	87		$m_{\nu_i} = 1.5 \text{ MeV}$
$< 8 \times 10^{-4}$	68	80	OBERAUER	87		$m_{\nu_i} = 4.0 \text{ MeV}$
$< 8 \times 10^{-3}$	90		BADIER	86	CNTR	$m_{\nu_i} = 400 \text{ MeV}$
$< 8 \times 10^{-5}$	90		BADIER	86	CNTR	$m_{\nu_i} = 1.7 \text{ GeV}$
<8 × 10 ⁻⁸	90		BERNARDI	86	CNTR	$m_{\nu_i} = 100 \text{ MeV}$
$<4 \times 10^{-8}$	90		BERNARDI	86	CNTR	m_{ν_i} =200 MeV
$< 6 \times 10^{-9}$	90		BERNARDI	86	CNTR	m_{ν_i} =400 MeV
$< 3 \times 10^{-5}$	90		DORENBOS	86	CNTR	$m_{\nu_i} = 150 \text{ MeV}$
$<1 \times 10^{-6}$	90		DORENBOS	86	CNTR	m_{ν_i} =500 MeV
$<1 \times 10^{-7}$	90		DORENBOS	86	CNTR	$m_{\nu_i} = 1.6 \text{ GeV}$
$< 7 \times 10^{-7}$	90	81	COOPER	85	HLBC	$m_{\nu_i} = 0.4 \text{ GeV}$
<8 × 10 ⁻⁸	90	81	COOPER	85	HLBC	$m_{\nu_i} = 1.5 \text{ GeV}$
$<1 \times 10^{-2}$	90	82	BERGSMA	83 B	CNTR	$m_{\nu_i} = 10 \text{ MeV}$
$< 1 \times 10^{-5}$	90	82	BERGSMA	83B	CNTR	$m_{\nu_i} = 110 \text{ MeV}$
$< 6 \times 10^{-7}$	90	82	BERGSMA	83B	CNTR	$m_{\nu_i}^{J}$ =410 MeV
$< 1 \times 10^{-5}$	90		GRONAU	83		$m_{\nu_i}^{J}$ =160 MeV
$< 1 \times 10^{-6}$	90		GRONAU	83		$m_{\nu_i}^{J}$ =480 MeV

- 78 BARANOV 93 is a search for neutrino decays into $e^+e^-\,\nu_e$ using a beam dump experiment at the 70 GeV Serpukhov proton synchrotron. The limits are not as good as those achieved earlier by BERGSMA 83 and BERNARDI 86, BERNARDI 88.
- 79 BURCHAT 90 includes the analyses reported in JUNG 90, ABRAMS 89c, and WENDT 87. 80 OBERAUER 87 bounds from search for $\nu \rightarrow \nu' ee$ decay mode using reactor (anti)neutrinos.
- (anti-neutrinos.) 81 COOPER-SARKAR 85 also give limits based on model-dependent assumptions for ν_{τ} flux. We do not list these. Note that for this bound to be nontrivial, j is not equal to 3, i.e. ν_{I} cannot be the dominant mass eigenstate in ν_{τ} since $m_{\nu_{3}}$ <70 MeV to 3, i.e. ν_i cannot be the dominant mass eigenstate in $\nu_{ au}$ since $m_{
 u_3}$
- (ALBRECHT 851). Also, of course, J is not equal to 1 or 2, so a fourth generation would be required for this bound to be nontrivial. ⁸² BERGSMA 838 also quote limits on $|U_{13}|^2$ where the index 3 refers to the mass eigenstate dominantly coupled to the τ . Those limits were based on assumptions about the D_S mass and $D_S \rightarrow \tau \nu_{\tau}$ branching ratio which are no longer valid. See COOPERSARKAR 85.

— Limits on $|U_{2J}|^2$ as Function of m_{ν_I} Peak search test Limits on $|U_{2j}|^2$ as function of m_{ν_i} DOCUMENT ID

VALUE		CL%		DOCUMENT ID		<u>TECN</u>	COMMENT
• • •	We do not use the	followin	g d	ata for averages	, fits	, limits,	etc. • • •
>10	-16		83	ARMBRUSTER	95	KARM	$m_{ u_\chi}=$ 33.9 MeV
< 4	× 10 ⁻⁷	95		BILGER	95	LEPS	$m_{\overline{\nu}_\chi} = 33.9 \text{ MeV}$
< 7	× 10 ⁻⁸	95		BILGER	95	LEPS	$m_{\nu_{\scriptscriptstyle Y}}=$ 33.9 MeV
< 2.6	5×10^{-8}	95	84	DAUM	95 B	TOF	$m_{ u_{\chi}} = 33.9 \text{ MeV}$
< 2	× 10 ⁻²	90		DAUM	87		$m_{\nu_i}=1 \text{ MeV}$
< 1	× 10 ⁻³	90		DAUM	87		$m_{\nu_j} = 2 \text{ MeV}$
< 6	× 10 ⁻⁵	90		DAUM	87		3 MeV $< m_{ u_j} < 19.5$
< 3	\times 10 ⁻²	90	85	MINEHART	84		$m_{\nu_i}^{\text{MeV}}$ MeV
< 1	× 10 ⁻³	90	85	MINEHART	84		$m_{\nu_j}^{J}$ =4 MeV
< 3	\times 10 ⁻⁴	90	85	MINEHART	84		$m_{\nu_j} = 10 \text{ MeV}$
< 5	× 10 ⁻⁶	90	86	HAYANO	82		$m_{\nu_j} = 330 \text{ MeV}$
< 1	× 10 ⁻⁴	90	86	HAYANO	82		$m_{\nu_j}^{J}$ =70 MeV
< 9	× 10 ⁻⁷	90	86	HAYANO	82		$m_{\nu_j}^{J}$ =250 MeV
< 1	$\times 10^{-1}$	90		ABELA	81		$m_{\nu_j}^{J}$ =4 MeV
< 7	$\times 10^{-5}$	90	85	ABELA	81		$m_{\nu_i} = 10.5 \text{ MeV}$
< 2	× 10 ⁻⁴	90	85	ABELA	81		$m_{\nu_j}^{J}$ =11.5 MeV
< 2	\times 10 ⁻⁵	90	85	ABELA	81		$m_{\nu_{j}}^{J} = 16-30 \text{ MeV}$
< 2	\times 10 ⁻⁵	95		ASANO	81		$m_{\nu_j} = 170 \text{ MeV}$
< 3	× 10 ⁻⁶	95	86	ASANO	81		$m_{\nu_j}^{J}$ =210 MeV
< 3	× 10 ⁻⁶	95	86	ASANO	81		$m_{\nu_i} = 230 \text{ MeV}$
< 6	× 10 ⁻⁶	95		ASANO	81		$m_{\nu_j}^{J}$ =240 MeV
< 5	× 10 ⁻⁷	95	87	ASANO	81		$m_{\nu_{j}} = 280 \text{ MeV}$
< 6	$\times 10^{-6}$	95	87	ASANO	81		$m_{\nu_j} = 300 \text{ MeV}$
< 1	$\times 10^{-2}$	95	85	CALAPRICE	81		$m_{\nu_j} = 7 \text{ MeV}$
< 3	$\times 10^{-3}$	95	85	CALAPRICE	81		$m_{\nu_j}^{J}$ =33 MeV
< 1	× 10 ⁻⁴	68	88	SHROCK	81	THEO	$m_{\nu_j}^{J}$ =13 MeV
< 3	\times 10 ⁻⁵	68		SHROCK	81	THEO	$m_{\nu_j}^{J}$ =33 MeV
< 6	$\times 10^{-3}$	68	89	SHROCK	81	THEO	$m_{\nu_i}^{J}$ =80 MeV
< 5	× 10 ⁻³	68	89	SHROCK	81	THEO	$m_{\nu_i} = 120 \text{ MeV}$

 83 ARMBRUSTER 95 study the reactions $^{12}{\rm C}(\nu_e,e^-)$ $^{12}{\rm N}$ and $^{12}{\rm C}(\nu,\nu')$ $^{12}{\rm C}^*$ induced by neutrinos from π^+ and μ^+ decay at the ISIS neutron spallation source at the Rutherford-Appleton laboratory. An anomaly in the time distribution can be interpreted as the decay $\pi^+ \to \mu^+ \nu_{\rm X}$, where $\nu_{\rm X}$ is a neutral weakly interacting particle with mass ≈ 33.9 MeV and spin 1/2. The lower limit to the branching ratio is a function of the lifetime of the new massive neutral particle, and reaches a minimum of a few $\, imes\,10^{-16}$ for $au_{ imes}\sim5\,\mathrm{s}$.

 84 From experiments of π^+ and π^- decay in flight at PSI, to check the claim of the KARMEN Collaboration quoted above (ARMBRUSTER 95).

 $85 \, \pi^+
ightarrow \, \mu^+ \, \nu_{\mu}$ peak search experiment.

86 $K^+ \rightarrow \mu^+ \nu_\mu^{\nu}$ peak search experiment.

 87 Analysis of experiment on $K^+ \to ~\mu^+ \, \nu_\mu \, \nu_\chi \, \overline{\nu}_\chi$ decay.

 $88\,\text{Analysis}$ of magnetic spectrometer experiment, bubble chamber experiment, and emulsion experiment on $\pi^+ o \ \mu^+
u_\mu$ decay.

⁸⁹ Analysis of magnetic spectrometer experiment on $K \to ~\mu, ~\nu_{\mu}$ decay.

Peak Search in Muon Capture

Limits on $|U_{2j}|^2$ as function of m_{ν_i}

VALUE	DOCUMENT ID		COMMENT
• • • We do not use t	he following data for averages	, fits	i, limits, etc. • • •
$<1 \times 10^{-1}$	DEUTSCH	83	m_{ν_i} =45 MeV
$< 7 \times 10^{-3}$	DEUTSCH	83	$m_{\nu_i}^{J}$ =70 MeV
$< 1 \times 10^{-1}$	DEUTSCH	83	m _{v:} =85 MeV

Searches for Decays of Massive ν

Limits on $|U_{2i}|^2$ as function of m_{ν} .

		"		
VALUE	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do	not use the follow	ing data for average	s, fits, limits,	etc. • • •
$< 3 \times \ 10^{-6}$	90	GALLAS	95 CNTR	$m_{ u_i}=1~{\sf GeV}$
$<3 \times 10^{-5}$	90	⁹⁰ VILAIN	95c CHM2	$m_{\nu_i} = 2 \text{ GeV}$
$< 6.2 \times 10^{-8}$	95	ADEVA	90s L3	$m_{\nu_i} = 20 \text{ GeV}$
$< 5.1 \times 10^{-10}$	95	ADEVA	90s L3	$m_{\nu_i} = 40 \text{ GeV}$
all values ruled	out 95	⁹¹ BURCHAT	90 MRK2	$m_{\nu_{z}}^{J} < 19.6 \text{ GeV}$

$< 1 \times 10^{-10}$	95	⁹¹ BURCHAT 90 MRK2 $m_{\nu_i}=22~{\rm GeV}$
$< 1 \times 10^{-11}$	95	⁹¹ BURCHAT 90 MRK2 $m_{\nu_i}^{J} = 41$ GeV
all values ruled out	95	DECAMP 90F ALEP $m_{\nu_i}^{J} = 25.0-42.7 \text{ GeV}$
$< 1 \times 10^{-13}$	95	DECAMP 90F ALEP $m_{\nu_i} = 42.7-45.7 \text{ GeV}$
$< 5 \times 10^{-4}$	90	⁹² KOPEIKIN 90 CNTR $m_{\nu_i} = 5.2 \text{ MeV}$
$<$ 5 \times 10 ⁻³	90	AKERLOF 88 HRS $m_{ u_i}^{J} = 1.8 \text{ GeV}$
$< 2 \times 10^{-5}$	90	AKERLOF 88 HRS $m_{\nu_i}^{J} = 4 \text{ GeV}$
$< 3 \times 10^{-6}$	90	AKERLOF 88 HRS $m_{ u_j}^{J} = 6 \text{ GeV}$
$< 1 \times 10^{-7}$	90	BERNARDI 88 CNTR $m_{\nu_i}^{J}$ =200 MeV
<3 × 10 ⁻⁹	90	BERNARDI 88 CNTR $m_{\nu_i}^{j}$ =300 MeV
$< 4 \times 10^{-4}$	90	93 MISHRA 87 CNTR $m_{\nu_i} = 1.5 \text{ GeV}$
$< 4 \times 10^{-3}$	90	93 MISHRA 87 CNTR $m_{\nu_i}^{J}$ =2.5 GeV
$< 0.9 \times 10^{-2}$	90	93 MISHRA 87 CNTR $m_{\nu_i} = 5 \text{ GeV}$
< 0.1	90	93 MISHRA 87 CNTR $m_{\nu_i}^{J}$ =10 GeV
$< 8 \times 10^{-4}$	90	BADIER 86 CNTR $m_{\nu_i}^{J}$ =600 MeV
$< 1.2 \times 10^{-5}$	90	BADIER 86 CNTR $m_{\nu_i}^{J}$ =1.7 GeV
$< 3 \times 10^{-8}$	90	BERNARDI 86 CNTR $m_{ u_i}^{\ \ j}$ =200 MeV
$< 6 \times 10^{-9}$	90	BERNARDI 86 CNTR $m_{ u_i}^{j}$ =350 MeV
<1 \times 10 ⁻⁶	90	DORENBOS 86 CNTR $m_{ u_i}^{j}$ =500 MeV
$< 1 \times 10^{-7}$	90	DORENBOS 86 CNTR $m_{\nu_i}^{\ \ j}$ =1600 MeV
$< 0.8 \times 10^{-5}$	90	94 COOPER 85 HLBC m_{ν_i} =0.4 GeV
$< 1.0 \times 10^{-7}$	90	⁹⁴ COOPER 85 HLBC m_{ν_i} =1.5 GeV

90 VILAIN 95c is a search for the decays of heavy isosinglet neutrinos produced by neutral GeV. The best limit is listed above. 91 BURCHAT 90 includes the analyses reported in JUNG 90, ABRAMS 89C, and WENDT 87. 92 KOPEIKIN 90 find no m_{ν_j} in the interval 1–6.3 MeV at 90%CL for maximal mixing.

 93 See also limits on $|{\it U}_{3j}|$ from WENDT 87.

 94 COOPER-SARKAR 85 also give limits based on model-dependent assumptions for ν_{τ} flux. We do not list these. Note that for this bound to be nontrivial, j is not equal to 3, i.e. ν_{j} cannot be the dominant mass eigenstate in ν_{τ} since $m_{\nu_{3}}$ <70 MeV (ALBRECH † 851). Also, of course, j is not equal to 1 or 2, so a fourth generation would be required for this bound to be nontrivial.

Limits on $|U_{3J}|^2$ as a Function of m_{ν_J}

VALUE	CL%	DOCUMENT ID		<u>TECN</u>	COMMENT
• • • We do not use t	he followi	ng data for averages	s, fits	, limits,	etc. • • •
$< 6 \times 10^{-4}$	90	⁹⁵ HAGNER	95	WIRE	$m_{ u_i}= 2 \; { m MeV}$
$< 2.5 \times 10^{-4}$	90	⁹⁵ HAGNER	95	WIRE	$m_{\nu_i} = 4 \text{ MeV}$
$< 3.1 \times 10^{-4}$	90	⁹⁵ HAGNER	95	WIRE	$m_{\nu_i} = 6 \text{ MeV}$
$< 2 \times 10^{-3}$	90	⁹⁵ HAGNER	95	WIRE	$m_{\nu_i} = 8 \text{ MeV}$
$< 6.2 \times 10^{-8}$	95	ADEVA	905	L3	$m_{\nu_i} = 20 \text{ GeV}$
$<$ 5.1 \times 10 ⁻¹⁰	95	ADEVA	905	L3	$m_{\nu_i} = 40 \text{ GeV}$
all values ruled out	95	⁹⁶ BURCHAT	90	MRK2	m_{ν_i} < 19.6 GeV
$< 1 \times 10^{-10}$	95	⁹⁶ BURCHAT	90	MRK2	$m_{\nu_i}^{\ \ j}=$ 22 GeV
$< 1 \times 10^{-11}$	95	⁹⁶ BURCHAT	90	MRK2	$m_{\nu_i} = 41 \text{ GeV}$
all values ruled out	95	DECAMP	90F	ALEP	$m_{\nu_i} = 25.0 - 42.7 \text{ GeV}$
$< 1 \times 10^{-13}$	95	DECAMP	90F	ALEP	$m_{\nu_i} = 42.7 - 45.7 \text{ GeV}$
$<$ 5 \times 10 ⁻²	80	AKERLOF	88	HRS	$m_{\nu_i}^{\ \ j} = 2.5 \text{ GeV}$
$< 9 \times 10^{-5}$	80	AKERLOF	88	HRS	$m_{\nu_i}^{J}$ =4.5 GeV

 95 HAGNER 95 is a search at the Bugey reactor for the neutrino decay $u_e
ightarrow ~
u_j \, e^+ \, e^-.$ Upper limits were obtained for m_{ν_3} in the range from 1 to 9.5 MeV.

 $^{96}\,\mathrm{BURCHAT}$ 90 includes the analyses reported in JUNG 90, ABRAMS 89C, and WENDT 87.

Lepton Particle Listings

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Limits on $ U_{aj} ^2$				
Where $a=1$.	2 from	ρ parameter	in μ	decay.

 $< 4 \times 10^{-2}$

VALUE	CL%	DOCUMENT ID	TECN .	COMMENT
• • • We do not use	e the followin	ng data for averag	ges, fits, limits, e	etc. • • •
$<1 \times 10^{-2}$	68	SHROCK	81B THEO	$m_{ u_i} = 10 \; { m MeV}$
$< 2 \times 10^{-3}$	68	SHROCK	81B THEO	$m_{ u_i}^{}=$ 40 MeV

SHROCK

81B THEO $m_{\nu_i} = 70 \text{ MeV}$

Limits on $\left| \mathit{U}_{1J} \! \times \! \mathit{U}_{2J} \right|$ as Function of $\mathit{m}_{\nu_{\!J}}$

VALUE	CL%	DOCUMENT ID	<u>TECN</u>	COMMENT
• • • We do not use the	e following	g data for averages	, fits, limits,	etc. • • •
$<3 \times 10^{-5}$	90	⁹⁷ BARANOV	93	m_{ν_i} = 80 MeV
$< 3 \times 10^{-6}$	90	⁹⁷ BARANOV	93	$m_{\nu_i} = 160 \text{ MeV}$
$< 6 \times 10^{-7}$	90	⁹⁷ BARANOV	93	$m_{\nu_i} = 240 \text{ MeV}$
$< 2 \times 10^{-7}$	90	⁹⁷ BARANOV	93	$m_{\nu_i} = 320 \text{ MeV}$
$< 9 \times 10^{-5}$	90	BERNARDI	86 CNTR	$m_{\nu_i} = 25 \text{ MeV}$
$< 3.6 \times 10^{-7}$	90	BERNARDI	86 CNTR	$m_{\nu_i} = 100 \text{ MeV}$
$< 3 \times 10^{-8}$	90	BERNARDI	86 CNTR	$m_{\nu_i} = 200 \text{ MeV}$
$< 6 \times 10^{-9}$	90	BERNARDI	86 CNTR	$m_{\nu_i} = 350 \text{ MeV}$
$<1 \times 10^{-2}$	90	BERGSMA		$m_{\nu_i} = 10 \text{ MeV}$
$< 1 \times 10^{-5}$	90	BERGSMA		$m_{\nu_i} = 140 \text{ MeV}$
$< 7 \times 10^{-7}$	90	BERGSMA	83B CNTR	$m_{\nu_i} = 370 \text{ MeV}$

 $^{^{97}}$ BARANOV 93 is a search for neutrino decays into $e^+e^-\nu_e$ using a beam dump experiment at the 70 GeV Serpukhov proton synchrotron.

SOLAR NEUTRINOS

(by K. Nakamura, KEK, National Laboratory for High-Energy Physics, Japan)

The Sun is a main-sequence star at a stage of stable hydrogen burning. It produces an intense flux of electron neutrinos as a consequence of nuclear fusion reactions which generate solar energy, and whose combined effect is

$$4p + 2e^- \rightarrow {}^{4}\text{He} + 2\nu_e + 26.73 \text{ MeV} - E_{\nu}$$
, (1)

where E_{ν} represents the energy taken away by neutrinos, with an average value being $\langle E_{\nu} \rangle \sim 0.6$ MeV. Each neutrino-producing reaction and the resulting flux predicted by the two recent standard solar model (SSM) calculations [1,2] are listed in Table 1. Figure 1 shows the energy spectra of solar neutrinos from these reactions quoted from the SSM calculation by Bahcall and Ulrich [3]. All SSM calculations give essentially the same results for the same input parameters and physics. The Bahcall and Pinsonneault model [1] and the Turck-Chièze and Lopes model [2] listed in Table 1 differ primarily in that Bahcall and Pinsonneault include helium diffusion [4].

Observations of solar neutrinos directly addresses the SSM and, more generally, the theory of stellar structure and evolution which is the basis of the SSM. The Sun as a well defined neutrino source also provides extremely important opportunities to investigate nontrivial neutrino properties such as nonzero mass and mixing, because of the wide range of matter density and the very long distance from the Sun to the Earth. In fact, the currently available solar-neutrino data seem to require such neutrino properties, if one tries to understand them consistently.

At present, four solar-neutrino experiments are taking data. Three of them are radiochemical experiments using $^{37}{\rm Cl}$ (Homestake in USA) or $^{71}{\rm Ga}$ (GALLEX at Gran Sasso in Italy and SAGE at Baksan in Russia) to capture neutrinos: $^{37}{\rm Cl}~\nu_e \rightarrow ^{37}{\rm Ar}~e^-$ (threshold 814 keV) or $^{71}{\rm Ga}~\nu_e \rightarrow ^{71}{\rm Ge}~e^-$

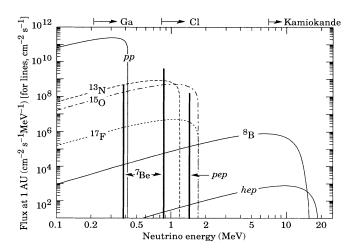


Figure 1: The solar neutrino spectrum predicted by the standard solar model. The neutrino fluxes from continuum sources are given in units of number $cm^{-2}s^{-1}MeV^{-1}$ at one astronomical unit, and the line fluxes are given in number $cm^{-2}s^{-1}$. Spectra for the pp chain are shown by solid lines, and those for the CNO chain by dotted or dashed lines. (Courtesy of J.N. Bahcall, 1995.)

Table 1: Neutrino-producing reactions in the Sun (the first column) and their abbreviations (second column). The neutrino fluxes predicted by Bahcall and Pinsonneault (B-P) [1] and by Turck-Chièze and Lopes (T-C-L) [2] are listed in the third and fourth columns, respectively. The errors associated with the B-P calculation are "theoretical" 3 standard deviations according to the authors.

Reaction	Abbr.	В-Р	T-C-L
$\frac{1}{pp \to d e^+ \nu}$	pp	$6.00(1 \pm 0.02)$ E10	6.02E10
$pe^-p \rightarrow d\nu$	pep	$1.43(1 \pm 0.04)$ E8	1.3E8
$^3{\rm He}~p \rightarrow ^4{\rm He}~e^+\nu$	hep	1.23E3	
$^7 \text{Be } e^- \rightarrow ^7 \text{Li } \nu + (\gamma)$	$^7\mathrm{Be}$	$4.89(1 \pm 0.18)$ E9	4.33E9
$^{8}\mathrm{B} \rightarrow {^{8}\mathrm{B}^{*}} \ e^{+}\nu$	$^8\mathrm{B}$	$5.69(1 \pm 0.43)$ E6	4.43E9
$^{13}\mathrm{N} ightharpoonup ^{13}\mathrm{C}~e^{+} u$	$^{13}\mathrm{N}$	$4.92(1 \pm 0.51)E8$	3.83E8
$^{15}{\rm O} \to ^{15}{\rm N}~e^+\nu$	$^{15}\mathrm{O}$	$4.26(1 \pm 0.58)$ E8	3.15 E8
$^{17}\mathrm{F} \rightarrow ^{17}\mathrm{O}~e^+ \nu$	$^{17}\mathrm{F}$	$5.39(1 \pm 0.48)$ E6	

(threshold 233 keV). The produced $^{37}\mathrm{Ar}$ and $^{71}\mathrm{Ge}$ are both radioactive nuclei with half lives $(\tau_{1/2})$ of 34.8 days and 11.43 days, respectively. After an exposure of the detector for two to three times $\tau_{1/2}$, the reaction products are extracted and introduced into a low-background proportional counter, and are counted for a sufficiently long period to determine the exponentially decaying signal and a constant background. In the chlorine experiment, the dominant contribution comes from $^8\mathrm{B}$ neutrinos, but $^7\mathrm{Be}$, pep, $^{13}\mathrm{N}$, and $^{15}\mathrm{O}$ neutrinos also contribute. At present, the most abundant pp neutrinos can be detected

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only in gallium experiments. Even so, almost half of the capture rate in these experiments is due to other solar neutrinos.

The fourth is a real-time experiment utilizing νe scattering in a large water-Čerenkov detector (Kamiokande in Japan). This experiment takes advantage of the directional correlation between the incoming neutrino and the recoil electron. This feature greatly helps the clear separation of the solar-neutrino signal from the background. Due to its high threshold (7 MeV at present), Kamiokande observes pure ⁸B solar neutrinos (hep neutrinos have too small a flux to be observed in the present generation of solar neutrino experiments.)

Solar neutrinos were first observed in the Homestake chlorine experiment around 1970. From the very beginning, it was recognized that the observed capture rate was significantly smaller than the SSM prediction. This deficit has been called "the solar-neutrino problem." The Kamiokande-II Collaboration started observing the ⁸B solar neutrinos at the beginning of 1987. Because of the strong directional correlation of νe scattering, this result gave the first direct evidence that the Sun emits neutrinos (no directional information is available in radiochemical solar-neutrino experiments.) The observed solarneutrino flux was also significantly less than the SSM prediction. In addition, Kamiokande-II obtained the energy spectrum of recoil electrons and the fluxes separately measured in the day time and nighttime. GALLEX presented the first evidence of pp solar-neutrino observation in 1992. Here also, the observed capture rate is significantly less than the SSM prediction. SAGE, after initial confusion which is ascribed to statistics by the group, observes a similar capture rate to that of GALLEX. The most recent results on the average capture rates or flux from these experiments [5-8] are compared with the recent SSM calculations [1,2] in Table 2.

Table 2: Recent results from the four solar-neutrino experiments. For Homestake [5], GALLEX [6], and SAGE [7], the data are capture rates given in SNU (Solar Neutrino Units; $1~\mathrm{SNU}=10^{-36}$ capture per atom per second). For Kamiokande [8], the datum is $^8\mathrm{B}$ solar-neutrino flux given in units of $10^6~\mathrm{cm}^{-2}~\mathrm{s}^{-1}$. The first errors are statistical and the second errors are systematic. The SSM predictions by Bahcall and Pinsonneault (B-P) [1] and by Turck-Chièze and Lopes (T-C-L) [2] are listed in the third and fourth columns, respectively. The errors associated with the B-P calculation are "theoretical" 3 standard deviations according to the authors.

Experiment	Data	В-Р	T-C-L
Homestake	$2.55 \pm 0.17 \pm 0.18$	8.0 ± 3.0	6.4
GALLEX	$79 \pm 10 \pm 6$	131.5^{+21}_{-17}	122.5
SAGE	73^{+18+5}_{-16-7}	131.5_{-17}^{+21}	122.5
Kamiokande	$2.89^{+0.22}_{-0.21} \pm 0.35$	5.7 ± 2.4	4.4

There was a controversy concerning whether the ³⁷Cl capture rate showed time variation, anticorrelated with the sunspot numbers which represent the 11-year solar-activity cycle. However, more than 7 years of the Kamiokande-II solar-neutrino observation does not show evidence for a statistically significant

correlation or anticorrelation between the solar-neutrino flux and sunspot number.

All results from the present solar-neutrino experiments indicate significantly less flux than expected from the SSM calculations. Is there any possible consistent explanation of all the results of solar-neutrino observations in the framework of the standard solar model? This is difficult because the Homestake result and the Kamiokande result, taken at face value, are mutually inconsistent if one assumes standard neutrino spectra. That is, with the reduction factor of the ⁸B solar-neutrino flux as determined from the Kamiokande result, the Homestake ³⁷Cl capture rate would be oversaturated, and there would be no room to accommodate the ⁷Be solar neutrinos. Several authors made more elaborate analyses using the constraint of observed solar luminosity, and found that not only the SSM but also nonstandard solar models are incompatible with the observed data. Now it is a common understanding that the solar-neutrino problem is not only the deficit of the ⁸B solar-neutrino flux, but also the deficit of ⁷Be solar-neutrino flux. The latter problem stems from the incompatibility between the Homestake and Kamiokande results and this makes astrophysical solutions untenable. There is another solar-neutrino problem concerning the low gallium capture rate observed by GALLEX and SAGE.

In view of the above situation, it is attractive to invoke nontrivial neutrino properties. Neutrino oscillation in matter (MSW mechanism) is particularly attractive in explaining all the experimental data on the average solar-neutrino flux consistently, without any a priori assumptions or fine tuning. Several authors made extensive MSW analyses using all the existing data and ended up with similar results. For example, Hata and Langacker [9] analyzed the solar-neutrino data as of mid-1993. They obtained solutions for various standard and nonstandard solar models taking the Earth effect and the Kamiokande daynight data into account. Assuming the Bahcall-Pinsonneault SSM [1], the small-mixing solution $(\Delta m^2 \sim 6 \times 10^{-6} \ {\rm eV}^2$ and $\sin^2 2\theta \sim 7 \times 10^{-3})$ gives an excellent fit to the data, but the large-mixing solution $(\Delta m^2 \sim 9 \times 10^{-6} \ {\rm eV}^2$ and $\sin^2 2\theta \sim 0.6)$ is marginally allowed at 90% confidence level.

Assuming that the solution to the solar-neutrino problem be provided by some nontrivial neutrino properties, how can one discriminate various scenarios? There are at least two very important things to do experimentally. One is the measurement of energy spectrum of the solar neutrinos and the other is the measurement of the solar-neutrino flux by utilizing neutral-current reactions. Two high-statistics solar-neutrino experiments which are under construction, SuperKamiokande and Sudbury Neutrino Observatory (SNO) are expected to provide such results within a few years. A 50 kton water-Čerenkov detector, SuperKamiokande is sensitive to the solar-neutrino spectrum through measurement of recoil electron energy. SNO will use 1,000 tons of heavy water (D₂O) to measure solar neutrinos through both inverse beta decay ($\nu_e d \rightarrow e^- pp$) and neutral current interactions ($\nu_x d \rightarrow \nu_x pn$). In addition, νe scattering events will also be measured. The Borexino experiment with 300 tons of ultra-pure liquid scintillator is approved for the Gran Sasso. The primary purpose of this experiment is

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the measurement of the ⁷Be solar neutrino flux, where possible deficit is now a key question, by lowering the detection threshold for the recoil electrons to 250 keV. It is hoped that these experiments will finally provide the key to solving the solar-neutrino problem.

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(E) Solar ν Experiments

VALUE		DOCUMENT ID		TECN	COMMENT
$77.1 \pm 8.5 ^{+4.4}_{-5.4}$ SNU	98	ANSELMANN	95B	GALX	$^{71}\text{Ga} \rightarrow ^{71}\text{Ge}$
73+18+5 SNU	99	ABDURASHI	94	SAGE	$^{71}\text{Ga} \rightarrow ^{71}\text{Ge}$
$(0.46 \pm 0.05 \pm 0.06) \times SSM$	100	HIRATA	90	KAM2	Water Cerenkov
2.33 ± 0.25 SNU	101	DAVIS	89	HOME	³⁷ CL radiochemical
• • • We do not use the following	owing	data for averag	ges, f	its, limit	s, etc. • • •
	102	ACKER	94	THEO	Solar ν decay
	103	BAHCALL	94	THEO	•
	104	BAHCALL	93		
	105	HAMPEL	93	RVUE	
6.4 ± 1.4 SNU	106	TURCK-CHI	93B	THEO	³⁷ CL radiochemical
$(4.4 \pm 1.1) \times 10^{-6} \text{ cm}^{-2}\text{s}^{-}$	1106	TURCK-CHI	93B	THEO	Water Cerenkov,
					$E \ge 7.5 \text{ MeV}$
123 \pm 7 SNU	106	TURCK-CHI	93B	THEO	71 Ga → 71 Ge
8.0 ± 3.0 SNU	107	BAHCALL	92		³⁷ CI prediction
132 ⁺²¹ ₋₁₇ SNU	107	BAHCALL	92		⁷¹ Ga prediction
2.	108	GARCIA	91	CNTR	Nuclear physics
	109	HIRATA	91	KAM2	
	110	FILIPPONE	90	THY	
		HIRATA	90B	KAM2	
$7.9\pm2.6~\text{SNU}$	112	BAHCALL	88	THEO	³⁷ CI prediction;
±20 ·	112				total theor, range
132 ⁺²⁰ ₋₁₇ SNU	112	BAHCALL	88	THEO	71 Ga prediction; total theor, range
5.8 ± 1.3 SNU		TURCK-CHI	88	THEO	37Cl prediction
125 ± 5 SNU		TURCK-CHI		THEO	⁷¹ Ga prediction
5.6 SNU	110	FILIPPONE	83	THEO	³⁷ CI prediction
7.6 ± 3.3 SNU	113	BAHCALL	82		³⁷ Cl prediction
106 + 13 SNU		BAHCALL	82		⁷¹ Ga prediction
7.0 ± 3.0 SNU		FILIPPONE	82	THEO	³⁷ CI prediction
$6.9\pm1.0~\text{SNU}$		FOWLER	82	THEO	³⁷ CI prediction
7.3 SNU		BAHCALL	80	THEO	³⁷ CL prediction
Construction to the state					KED OL The letter of the con-

See also the reviews by BAHCALL 92, DAVIS 89, and ACKER 94. The latter rules out neutrino decay as a solution to the solar neutrino problem at better than 98% using the existing solar neutrino as of mid-1993.

 98 ANSELMANN 95B result is for a total of 39 completed runs (GALLEX I and GALLEX II combined), which updates the ANSELMANN 94 result. The total run data, covering the period 14 May 1991 through 22 June 1994, are consistent with a 71 Ge production rate constant in time. The results are strengthened by a calibration run using a strong 51Cr source (ANSELMANN 95), where the (measured)/(expected) Cr-induced ⁷¹Ge rate was

found to be 1.04 \pm 0.12. 99 ABDURASHITOV 94 result is for a total of 15 runs from January 1990 through May 1992, using 30 tons of metallic gallium for the first 7 runs, increased to 57 tons for the rest of 8 runs. The first 5 runs in 1990 yielded $40 + \frac{31+5}{38-7}$ SNU which updates the

ABAZOV 91B result.

 $_{\rm ABAZOV}$ 918 result.
100 HIRATA 90 data consists of 1040 days with threshold $E_{\rm g} > 9.3$ MeV (first 450 days) or $E_{\rm g} > 7.5$ MeV. "The total data sample is also analyzed for short-term variations; within the statistical error, no significant variation is observed." The flux is scaled by the value relative to the standard solar model (SSM) prediction. A theoretical flux of $(5.8 \pm 2.1) \times 10^6 \, {\rm cm}^{-2} \, {\rm s}^{-1}$ is cited, with the central value corresponding to 7.9 SNU $^{3.5}$ for ³⁷Cl experiment (but see TURCK-CHIEZE 93B and other theoretical calculations.)

- The analysis is more fully reported in HIRATA 91B. Earlier analyses were reported by
- HIRATA 91 and HIRATA 90B.

 101 DAVIS 89 is the average from the ³⁷CL experiment at the Homestake Mine (HOME) from 1970–1988. Earlier averages are given in the references therein.
- 102 ACKER 94 rules out neutrino decay as a solution to the solar neutrino problem at better than 98% CL, using the existing solar neutrino data as of mid-1993.
- 103 BAHCALL 94 argues that there are really two solar neutrino problems: (1) incompatibility of the chlorine (Homestake) and Kamiokande experiments, (2) deficiency of the observed
- solar neutrino flux in the gallium experiments.

 104 BAHCALL 93 is a study of 1000 solar models in which each input parameter is chosen from a normal distribution with the appropriate mean and error. It is concluded that "Even if one abuses the solar models by artifically imposing consistency with the Kamlokande experiment, the resulting predictions of all 1000 of the 'fudged' solar models are inconsistency with the security of the experiment. are inconsistent with the result of the chlorine experiment.
- 105 HAMPEL 93, by a member of the GALLEX collaboration, is a discussion of possible scenarios to explain the combined solar neutrino experimental data.
- 106 TURCK-CHIEZE 93B proposes new results on the solar neutrino predictions and acoustic mode frequencies. See also TURCK-CHIEZE 93 for an extensive review (233 pages, 524 references) concerning the solar interior. Table 17 provides a particularly useful comparison of experiment and theory as of mid-1993.
- 107 BAHCALL 92 is an extensive discussion of theoretical neutrino flux calculations with predicted event rates for various different solar neutrino detectors. "The quoted errors represent the total theoretical range and include the effects on the model predictions of 3σ errors in measured input parameters." 108 GARCIA 91 reports a new study of 3^{7} Ca β decays, with the result that the BAHCALL 88 SSM prediction for 3^{7} Cl should be increased from 7.9 to 8.1 SNU.
- 109 HIRATA 91 reports a search for day-night and semi-annual variations in the solar neutrino flux observed in the Kamiokandel I Detector. The sample is the same 1040 day counting period used for HIRATA 90 and HIRATA 90s. "Within statistical error, no such short-time variations were observed." This result was used to constrain neutrino socillation parameters, in the framework of oscillations between two mass eigenstates. "A region defined by $\sin^2 2\theta > 0.02$ and 2×10^{-6} eV $^2 < \Delta(m^2) < 1\times 10^{-5}$ eV 2 is excluded at the 90% CL without any assumptions on the absolute value of the expected solar
- at the 90% CL without any assumptions on the absolute value of the expected solar neutrino flux."

 110 In a later unbiased analysis, FILIPPONE 90 show that the hypothesis of a time-independent ³⁷Cl neutrino capture rate is marginally rejected, having only 2% probability. However, it is disturbing that we are not able to find a simple hypothesis of time variation that would describe the data well. A capture rate anticorrelated with sunspot number, although more probable than the constant rate hypothesis, has a probability of only 6%. One possible explanation of these results is simply the poor statistics of the
- $^{111}\mathrm{HIRATA}$ 90B gives an analysis of the implications of these data for allowed values of $\Delta(m^2)$ and $\sin^2 2 heta$ describing neutrino mixing between two mass eigenstates, in the model of resonant (MSW) neutrino oscillations. The possibility of regeneration as the neutrinos pass through the earth is neglected. Two limits are given, the first from the measured event rate alone, and the second from the combination of the measured event rate and the recoil electron energy spectrum. The latter "disfavor the region of adiabatic solutions $\Delta(m^2)\sim 1.3\times 10^{-4}~\text{eV}^2$ and $7.2\times 10^{-4}~<\sin^22\theta~<6.3\times 10^{-3}$ at 90%CL." The allowed regions in $\sin^2 2\theta$ vs. $\Delta(m^2)$ are given graphically; see Figs. 2(a) and 2(b) in the paper.
- 112 BAHCALL 88 "total theoretical range is calculated by evaluating the 3σ uncertainties for all measured input parameters and using the full spread in calculated values for input quantitites that cannot be measured; the uncertainties from different quantities are combined quadratically." (Quotation from BAHCALL 89, p. 301.)
- 113 BAHCALL 82 quotes "effective 3σ errors." First extensive discussion of formal uncertainties in the problem.

(F) Astrophysical neutrino observations

Neutrinos and antineutrinos produced in the atmosphere induce $\mu\text{-like}$ and e-like events in underground detectors. The ratio of the numbers of the two kinds of events is defined as μ/e . It has the advantage that that systematic effects, such as flux uncertainty, tend to cancel, for both experimental and $% \left(1\right) =\left(1\right) \left(1$ theoretical values of the ratio. The "ratio of the ratios" of experimental to theoretical μ/e , $R(\mu/e)$, is reported below. If the actual value is not unity, the value obtained in a given experiment may depend on the experimental

$R(\mu/e) = (Measured Ratio \mu/e) / (Expected Ratio \mu/e)$

$R(\mu/\epsilon) = (\text{vicusured Ratio } \mu/\epsilon) / (\text{Expected Ratio } \mu/\epsilon)$							
VALUE	DOCUMENT ID		TECN	COMMENT			
• • • We do not use the follo	wing data for averages	s, fits	, limits,	etc. • • •			
$1.00 \pm 0.15 \pm 0.08$	114 DAUM	95	FREJ	Calorimeter			
$0.60^{+0.06}_{-0.05} \pm 0.05$	¹¹⁵ FUKUDA	94	KAM2	sub-GeV			
$0.57^{+0.08}_{-0.07}\pm0.07$	¹¹⁶ FUKUDA	94	KAM2	multi-Gev			
	117 BECKER-SZ	92B	IMB	Water Cerenkov			

- $^{114} {\sf DAUM}$ 95 results are based on an exposure of 2.0 ktonyr which includes the data used by BERGER 908. This ratio is for the contained and semicontained events. DAUM 95 also report $R(\mu/e) = 0.99 \pm 0.13 \pm 0.08$ for the total neutrino induced data sample
- also report $\kappa(\mu/e)=0.99\pm0.13\pm0.08$ for the total neutrino induced data sample which includes upward going stopping muons and horizontal muons in addition to the contained and semicontained events. 115 FUKUDA 94 result is based on an exposure of 7.7 kton yr and updates the HIRATA 92 result. The analyzed data sample consists of fully contained e-like events with 0.1 < $p_e < 1.33~{\rm GeV}/c$ and fully-contained μ -like events with 0.2 < $p_\mu < 1.5~{\rm GeV}/c$.
- 116 FUKUDA 94 analyzed the data sample consisting of fully contained events with visible
- energy > 1.33 GeV and partially contained μ -like events. ¹¹⁷BECKER-SZENDY 92B reports the fraction of nonshowering events (mostly muons from atomospheric neutrinos) as 0.36 \pm 0.02 \pm 0.02, as compared with expected fraction $R(\mu/e)$ very close to the KAM2 value.

$R(\nu_{\mu}) = (Measured Flux of \nu_{\mu}) / (Expected Flux of \nu_{\mu})$

\ \ \ \ \ \	μ,, , , ,		μ,	
VALUE	DOCUMENT ID	<u>TE</u>	CN COMMENT	
ullet $ullet$ We do not use the fo	llowing data for average	es, fits, li	mits, etc. • • •	
$0.73 \pm 0.09 \pm 0.06$	118 AHLEN	95 M	CRO Streamer tubes	
	¹¹⁹ CASPER	91 IM	IB Water Cherenkov	
	¹²⁰ AGLIETTA	89 NI	JSX	
0.95±0.22	¹²¹ BOLIEV	81	Baksan	
0.62 ± 0.17	CROUCH	78	Case Western/UCI	

- 118 AHLEN 95 result is for all nadir angles. The lower cutoff on the muon energy is 1 GeV. The errors are statistical / systematic. The Monte Carlo flux error is $\pm 0.12.$
- 119 CASPER 91 Correlates showering/nonshowering signature of single-ring events with parent atmospheric-neutrino flavor. They find nonshowering ($\approx \nu_{\mu}$ induced) fraction is $0.41\pm0.03\pm0.02$, as compared with expected 0.51 ± 0.05 (syst).
- 120 AGLIETTA 89 finds no evidence for any anomaly in the neutrino flux. They define $\rho=(\text{measured number of }\nu_e\text{'s})/(\text{measured number of }\nu_\mu\text{'s})$. They report $\rho(\text{measured})=\rho(\text{expected})=0.96\pm0.32$
- $^{121}\text{From this data BOLIEV 81 obtain the limit }\Delta(\textit{m}^2)~\leq~6\times10^{-3}~\text{eV}^2$ for maximal mixing, $\nu_{\mu}
 eq \nu_{\mu}$ type oscillation.

$\sin^2(2\theta)$ for given $\Delta(m^2)$ ($\nu_e \leftrightarrow \nu_\mu$)

For a re	view see B	BAHCALL 89.		
VALUE	CL%	DOCUMENT ID	TEC	N COMMENT
• • • We do	not use th	e following data for	averages,	fits, limits, etc. • •
>0.55	90	¹²² FUKUDA		M2 $\Delta(m^2) = 0.007 - 0.08 \text{ ev}^2$
>0.33	90	¹²³ HIRATA	92 KA	M2 $\Delta(m^2) > 0.004 \text{ eV}^2$
< 0.47	90	¹²⁴ BERGER	90B FRI	EJ $\Delta(m^2) > 1 \text{ eV}^2$
< 0.14	90	LOSECCO	87 IME	B $\Delta(m^2) = 0.00011 \text{ eV}^2$

- $^{122} {\sf FUKUDA}$ 94 obtained this result by a combined analysis of sub- and multi-GeV atmospheric neutrino events in Kamiokande.
- 123 HIRATA 92 states that the allowed region for $\nu_e \leftrightarrow \nu_\mu$ conflicts with the constraints from the solar neutrino data (HIRATA 90B).
- 124 BERGER 90B uses the Frejus detector to search for oscillations of atmospheric neutrinos. Bounds are for both neutrino and antinuetrino oscillations.

$\Delta(m^2)$ for $\sin^2(2\theta) = 1 (\nu_e \leftrightarrow \nu_\mu)$

VALUE (10 ⁻⁵ eV ²)	CL%	DOCUMENT ID		TECN
• • • We do not use th	e following	data for average	es, fits	, limits, etc. • • •
$700 < \Delta(m^2) < 7000$	90 1	²⁵ FUKUDA	94	KAM2
<150	90 1	²⁶ BERGER	90B	FREJ
125 FUKUDA 94 obtain	ed this resi	ult by a combine	d anal	ysis of sub- and multi-GeV atmos-

pheric neutrino events in Kamiokande.

126 BERGER 90B uses the Frejus detector to search for oscillations of atmospheric neutrinos. Bounds are for both neutrino and antinuetrino oscillations.

$\sin^2(2\theta)$ for given $\Delta(m^2)$ $(\overline{\nu}_e \leftrightarrow \overline{\nu}_\mu)$

VALUE (10 ⁻⁵ eV ²)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the	following	g data for averages, fits	s, limits,	etc. • • •
< 0.9				$\Delta(m^2) > 3 \times 10^{-4} \text{ eV}^2$
< 0.7	99 1	.27 SMIRNOV 94	THEO	$\Delta(m^2) < 10^{-11} \text{ eV}^2$

 127 SMIRNOV 94 analyzed the data from SN 1987A using stellar-collapse models. They also give less stringent upper limits on $\sin^2\!2\theta$ for $10^{-11}<\Delta(m^2)<3\times10^{-7}$ eV 2 and $10^{-5} < \Delta(m^2) < 3 \times 10^{-4} \ {
m eV}^2$. The same results apply to $\overline{\nu}_e \leftrightarrow \overline{\nu}_{\tau}, \ \nu_{\mu}$, and ν_{τ} .

$\sin^2(2\theta)$ for given $\Delta(m^2)$ $(\nu_{\mu} \leftrightarrow \nu_{\tau})$

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do no	t use th	e following data for	avera	ges, fits,	limits, etc. • • •
>0.65	90	¹²⁸ FUKUDA	94	KAM2	$\Delta(m^2) = 0.005 - 0.03 \text{ ev}^2$
>0.5	90	129 BECKER-SZ	92	IMB	$\Delta(m^2) = 1-2 \times 10^{-4} \text{ eV}^2$
< 0.6	90	130 BERGER	90B	FREJ	$\Delta(m^2) > 1 \text{ eV}^2$

- 128 FUKUDA 94 obtained this result by a combined analysis of sub-and multi-GeV atmospheric neutrino events in Kamiokande.
- 129 BECKER-SZENDY 92 uses upward-going muons to search for atomospheric u_{μ} oscillations. The fraction of muons which stop in the detector is used to search for deviations in the expected spectrum. No evidence for oscillations is found.
- 130 BERGER 90B uses the Frejus detector to search for oscillations of atmospheric neutrinos. Bounds are for both neutrino and antinuetrino oscillations.

$\Delta(m^2)$ for $\sin^2(2\theta) = 1 (\nu_+ \leftrightarrow \nu_-)$

_(/ (, /	- (- μ			
VALUE (10 ⁻⁵ eV ²)	CL%	DOCUMENT ID		TECN
• • • We do not use th	e following	g data for averages	, fits	, limits, etc. • • •
$500 < \Delta(m^2) < 2500$			94	KAM2
<350	90 ¹	.32 BERGER	90B	FREJ

- 131 FUKUDA 94 obtained this result by a combined analysis of sub-and multi-GeV atmosheric neutrino events in Kamiokande.
- 132 BERGER 90B uses the Frejus detector to search for oscillations of atmospheric neutrinos. Bounds are for both neutrino and antinuetrino oscillations.

$\Delta(\textit{m}^2) \text{ for } \sin^2(2\theta) = 1 \text{ } (\nu_{\mu} \rightarrow \nu_{\textit{s}})$ means ν_{τ} or any sterile (noninteracting) ν .

VALUE (10-5 eV2)	CL%	DOCUMENT I	2	TECN	COMMENT
• • • We do not use	the follow	ing data for avera	ges, fits	, limits	, etc. • • •
<3000 (or <550)	90	133 OYAMA	89		Kamiokande II
< 4.2 or > 54.	90	BIONTA	88	IMB	Flux has ν_{μ} , $\overline{\nu}_{\mu}$, ν_{e} ,
					and $\overline{\nu}_{\alpha}$

 $^{133}\mathrm{OYAMA}$ 89 gives a range of limits, depending on assumptions in their analysis. They argue that the region $\Delta(m^2)=(100-1000)\times 10^{-5}~\text{eV}^2$ is not ruled out by any data for large mixing

(G) Reactor v_e disappearance experiments

In most cases, the reaction $\overline{v}_e \, p \to \, e^+ \, n$ is observed at different distances from one or more reactors in a complex.

Events (Observed/Expected) from Reactor V. Experiments

VALUE	DOCUMENT I	D	COMMENT	
• • • We do not use the	following data for avera	ges, fit	s, limits, etc. • • •	
1.05 ±0.02 ±0.05		ER 82	Gösgen reactor	
$0.955 \pm 0.035 \pm 0.110$	¹³⁴ KWON	81	$\overline{\nu}_e p \rightarrow e^+ n$	
0.89 ±0.15	¹³⁴ военм	80	$\overline{\nu}_e p \rightarrow e^+ n$	
0.38 ±0.21	135,136 REINES	80		
0.40 ±0.22	135,136 REINES	80		
134 KMON OL represents				

- KWON 81 represents an analysis of a larger set of data from the same experiment as ${\tt BOEHM\,80}.$
- 135 REINES 80 involves comparison of neutral- and charged-current reactions $\overline{v}_e d \rightarrow n p \overline{v}_e$ and $\overline{v}_e d \to nne^+$ respectively. Combined analysis of reactor \overline{v}_e experiments was performed by SILVERMAN 81.
- 136 The two REINES 80 values correspond to the calculated $\overline{\nu}_e$ fluxes of AVIGNONE 80 and DAVIS 79 respectively.

DOCUMENT ID

$-\overline{\nu}_e eq \overline{\nu}_e -$

$\Delta(m^2)$ for $\sin^2(2\theta) = 1$

ı

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I

VALUE (eV-)	CL%	DOCUMENT ID		TECN	COMMENT
<0.0075	90	¹³⁷ VIDYAKIN	94		Krasnoyark reactors
• • • We do not us	se the follow	ing data for average	es, fit	s, limits,	etc. • • •
< 0.01	90	¹³⁸ ACHKAR	95	CNTR	Bugey reactor
< 0.0083	90	¹³⁷ VIDYAKIN	90		Krasnoyark reactors
< 0.04	90	¹³⁹ AFONIN	88	CNTR	Rovno reactor
< 0.014	68	¹⁴⁰ VIDYAKIN	87		$\overline{\nu}_e p \rightarrow e^+ n$
< 0.019	90	141 ZACEK	86		Gösgen reactor
< 0.02	90	142 ZACEK	85		Gösgen reactor
< 0.016	90	¹⁴³ GABATHULE	R 84		Gösgen reactor

- 137 VIDYAKIN 94 bound is for L=57.0 m, 57.6 m, and 231.4 m. Supersedes VIDYAKIN 90.
- 138 ACHKAR 95 bound is for L=15, 40, and 95 m. 139 AFONIN 86 and AFONIN 87 also give limits on $\sin^2(2\theta)$ for intermediate values of $\Delta(m^2)$. (See also KETOV 92). Supersedes AFONIN 87, AFONIN 86, AFONIN 85, AFONIN 83, and BELENKII 83. 140 VIDYAKIN 87 bound is for L=32.8 and 92.3 m distance from two reactors. 141 This bound is from data for L=37.9 m, 45.9 m, and 64.7 m.

- ¹⁴² See the comment for ZACEK 85 in the section on $\sin^2(2\theta)$ below.
- $^{143}\,\mathrm{This}$ bound comes from a combination of the VUILLEUMIER 82 data at distance 37.9 m and new data at 45.9 m.

$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$

VALUE	<u>CL%</u>	DOCUMENT ID		TECIV	COMMENT
<0.02	90	¹⁴⁴ ACHKAR	95	CNTR	For $\Delta(m^2) = 0.6 \text{ eV}^2$
• • • We do not	t use the follow	ing data for averag	es, fit	s, limits,	etc. • • •
< 0.087	68	145 VYRODOV	95	CNTR	For $\Delta(m^2) > 2 \text{ eV}^2$
< 0.15	90	¹⁴⁶ VIDYAKIN	94		For $\Delta(m^2) > 5.0 \times 10^{-2}$
					eV ²
< 0.2	90	¹⁴⁷ AFONIN	88	CNTR	$\overline{\nu}_e p \rightarrow e^+ n$
< 0.14	68	¹⁴⁸ VIDYAKIN	87		$\overline{\nu}_e p \rightarrow e^+ n$
< 0.21	90	¹⁴⁹ ZACEK	86		$\overline{\nu}_e p \rightarrow e^+ n$
< 0.19	90	¹⁵⁰ ZACEK	85		Gösgen reactor
< 0.16	90	¹⁵¹ GABATHULE	R 84		$\overline{\nu}_e p \rightarrow e^+ n$

- 144 ACHKAR 95 bound is from data for L=15, 40, and 95 m distance from the Bugey reactor.
- 145 The VYRODOV 95 bound is from data for L=15 m distance from the Bugey-5 reactor.
 146 The VIDYAKIN 94 bound is from data for L=57.0 m, 57.6 m, and 231.4 m from three reactors in the Krasnoyark Reactor complex.
- 147 Several different methods of data analysis are used in AFONIN 88. We quote the most stringent limits. Different upper limits on $\sin^2 2\theta$ apply at intermediate values of $\Delta(m^2)$. Supersedes AFONIN 87, AFONIN 85, and BELENKII 83.
- 148 VIDYAKIN 87 bound is for L=32.8 and 92.3 m distance from two reactors. 149 This bound is from data for L=37.9 m, 45.9 m, and 64.7 m distance from Gosgen reactor.
- 150 ZACEK 85 gives two sets of bounds depending on what assumptions are used in the data analysis. The bounds in figure 3(a) of ZACEK 85 are progressively poorer for large $\Delta(m^2)$ whereas those of figure 3(b) approach a constant. We list the latter. Both sets of bounds use combination of data from 37.9, 45.9, and 64.7m distance from reactor. ZACEK 85 states "Our experiment excludes this area (the oscillation parameter region allowed by the Bugey data, CAVAIGNAC 84) almost completely, thus disproving the indications of neutrino oscillations of CAVAIGNAC 84 with a high degree of confidence."
- 151 This bound comes from a combination of the VUILLEUMIER 82 data at distance 37.9m from Gosgen reactor and new data at 45.9m.

< 44

Lepton Particle Listings

Massive Neutrinos and Lepton Mixing

$\Delta(m^2)$	for	given	sin ²	(2θ)

 $^{-152}\sin^2(2 heta)=0.25\pm0.1$. These are from best fit to data; see CAVAIGNAC 84 for plot of allowed regions in these variables. These data from Bugey reactor.

(H) Accelerator neutrino appearance experiments $\frac{}{}\nu_e \rightarrow \nu_\tau \stackrel{}{-----}$

$\Delta(m^2)$ for $\sin^2(2\theta) = 1$

VALUE (eV²) CL% DOCUMENT ID TECN COMMENT

S
S
VSHIDA
S6C EMUL FNAL

S
We do not use the following data for averages, fits, limits, etc. S

$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$

90

SINT(20) FOR Large Active Joseph Jose

<0.36 90 TALEBZADEH 87 HLBC BEBC

153 USHIDA 86C published result is $\sin^2 2\theta < 0.12$. The quoted result is corrected for a numerical mistake incurred in calculating the expected number of ν_e CC events, normalized to the total number of neutrino interactions (3886) rather than to the total number of ν_e , CC events (1870).

$-\overline{\nu}_e \rightarrow \overline{\nu}_{\tau}$

TALEBZADEH 87 HLBC BEBC

$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$

 VALUE
 CL%
 DOCUMENT ID
 TECN
 COMMENT

 <0.7</td>
 90
 154 FRITZE
 80
 HYBR
 BEBC CERN SPS

 $^{154}\,\mathrm{Authors}$ give P($\nu_{e}\,\rightarrow\,\,\nu_{\tau})$ <0.35, equivalent to above limit.

---- $\nu_{\mu} \rightarrow \nu_{e}$ ---

$\Delta(m^2)$ for $\sin^2(2\theta) = 1$

VALUE (eV ²)	CL%	DOCUMENT ID		TECN	COMMENT
<0.09	90	ANGELINI	86	HLBC	BEBC CERN PS
• • • We do not use the	following of	data for averages	, fits	, limits,	etc. • • •
< 0.9	90	VILAIN	94c	CHM2	CERN SPS
< 0.1	90	BLUMENFELD	89	CNTR	
<1.3	90	AMMOSOV	88	HLBC	SKAT at Serpukhov
< 0.19	90	BERGSMA	88	CHRM	
	155	LOVERRE	88	RVUE	
<2.4	90	AHRENS	87	CNTR	BNL AGS
<1.8	90	BOFILL	87	CNTR	FNAL
<2.2	90 156	BRUCKER	86	HLBC	15-ft FNAL
< 0.43	90	AHRENS	85	CNTR	BNL AGS E734
< 0.20	90	BERGSMA	84	CHRM	
<1.7	90	ARMENISE	81	HLBC	GGM CERN PS
< 0.6	90	BAKER	81	HLBC	15-ft FNAL
<1.7	90	ERRIQUEZ	81	HLBC	BEBC CERN PS
<1.2	95	BLIETSCHAU	78	HLBC	GGM CERN PS
<1.2	95	BELLOTTI	76	HLBC	GGM CERN PS

155 LOVERRE 88 reports a less stringent, indirect limit based on theoretical analysis of neutral to charged current ratios.

neutral to charged current ratios. 156 15ft bubble chamber at FNAL.

$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$

` '					
VALUE (units 10 ⁻³)	CL%	DOCUMENT ID		TECN	COMMENT
< 2.5	90	AMMOSOV	88	HLBC	SKAT at Serpukhov
• • • We do not use the	following	data for averages	, fits	, limits,	etc. • • •
< 9.4	90	VILAIN	94C	CHM2	CERN SPS
< 5.6	90 15	⁷ VILAIN	94C	CHM2	CERN SPS
< 16	90	BLUMENFELD	89	CNTR	
< 8	90	BERGSMA	88	CHRM	$\Delta(m^2) \geq 30 \text{ eV}^2$
	15	⁸ LOVERRE	88	RVUE	
< 10	90	AHRENS	87	CNTR	BNL AGS
< 15	90	BOFILL	87	CNTR	FNAL
< 20		⁹ ANGELINI	86	HLBC	BEBC CERN PS
20 to 40	16	⁰ BERNARDI	86B	CNTR	$\Delta(m^2) = 5-10$
< 11	90 16	¹ BRUCKER	86	HLBC	15-ft FNAL
< 3.4	90	AHRENS	85	CNTR	BNL AGS E734
<240	90	BERGSMA	84	CHRM	
< 10	90	ARMENISE	81	HLBC	GGM CERN PS
< 6	90	BAKER	81	HLBC	15-ft FNAL
< 10	90	ERRIQUEZ	81	HLBC	BEBC CERN PS
< 4	95	BLIETSCHAU	78	HLBC	GGM CERN PS
< 10	95	BELLOTTI	76	HLBC	GGM CERN PS

 $^{157}\,{\rm VILAIN}$ 94C limit derived by combining the ν_{μ} and $\overline{\nu}_{\mu}$ data assuming CP conservation.

158 LOVERRE 88 reports a less stringent, indirect limit based on theoretical analysis of

neutral to charged current ratios. 159 ANGELINI 86 limit reaches 13×10^{-3} at $\Delta(m^2) \approx 2$ eV 2 .

160 BERNARDI 86B is a typical fit to the data, assuming mixing between two species. As the authors state, this result is in conflict with earlier upper bounds on this type of neutrino oscillation.

oscillations. 161 15ft bubble chamber at FNAL.

		μ

$\Delta(m^2)$ for $\sin^2(2\theta) = 1$

VALUE (eV ²)	CL% EVTS	DOCUMENT ID	TECN	COMMENT
<0.14	90	¹⁶² FREEDMAN	93 CNTR	LAMPF
• • • We do not	use the follow	ing data for averages	s, fits, limits	, etc. • • •
0.075 ± 0.030	9	163 ATHANASSO	.95	
< 0.07	90	164 HILL	95	
< 0.9	90	VILAIN	94c CHM2	CERN SPS
< 3.1	90	BOFILL	87 CNTR	FNAL
< 2.4	90	TAYLOR	83 HLBC	15-ft FNAL
< 0.91	90	165 NEMETHY	81B CNTR	LAMPF
<1	95	BLIETSCHAU	78 HIBC	GGM CERN PS

 162 FREEDMAN 93 is a search at LAMPF for $\overline{\nu}_e$ generated from any of the three neutrino types $\nu_\mu, \, \overline{\nu}_\mu$, and ν_e which come from the beam stop. The $\overline{\nu}_e$'s would be detected by the reaction $\overline{\nu}_e \, \rho \, \rightarrow \, e^+ \, n$. FREEDMAN 93 replaces DURKIN 88.

163 ATHANASSOPOULOS 95 error corresponds to the 2σ band in the plot, and is corrected for the 20% systematic error. The expected background is 2.1 ± 0.3 events. Corresponds to an oscillation probability of $(0.34^{+}0.20_{-}0.18_{-}0.1$

HILL 95. Preprint ATHANASOPOULOS 96 reports strengtnened conclusions based on an excess of 52 events. $164 \ \text{HILL} \ 95 \ \text{is} \ \text{a} \ \text{report} \ \text{by one} \ \text{member of the LSND Collaboration, reporting a different conclusion from the analysis of the data of this experiment (see ATHANASSOPOULOS 95).
Contrary to the rest of the LSND Collaboration, Hill finds no evidence for the neutrino oscillation <math>\overline{v}_{\mu} \rightarrow \overline{v}_{e}$ and obtains only upper limits.

165 In reaction $\overline{\nu}_e p \rightarrow e^+ n$.

$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$

VALUE	CL% E	/TS	DOCUMENT ID		TECN	COMMENT
<0.004	95	- 10	BLIETSCHAU	78		GGM CERN PS
		ollowing	data for average			
					, 111111123,	cic. • • •
0.007 ± 0.00	5		⁶⁶ ATHANASSO.	95		
< 0.006	90	10	⁶⁷ HILL	95		
<4.8	90		VILAIN	94C	CHM2	CERN SPS
< 5.6	90	11	⁶⁸ VILAIN	94C	CHM2	CERN SPS
< 0.024	90	1	⁶⁹ FREEDMAN	93	CNTR	LAMPF
< 0.04	90		BOFILL	87	CNTR	FNAL
< 0.013	90		TAYLOR	83	HLBC	15-ft FNAL
< 0.2	90	1	⁷⁰ NEMETHY	818	CNTR	LAMPF

166 ATHANASSOPOULOS 95 error corresponds to the 2σ band in the plot, and is corrected for the 20% systematic error. The expected background is 2.1 ± 0.3 events. Corresponds to an oscillation probability of $(0.34^{+}0.20 \pm 0.07)\%$. For a different interpretation, see HILL 95. Preprint ATHANASSOPOULOS 96 reports strengthened conclusions based on an excess of 52 events.

167 HILL 95 is a report by one member of the LSND Collaboration, reporting a different conclusion from the analysis of the data of this experiment (see ATHANASSOPOULOS 95).

167 HILL 95 is a report by one member of the LSND Collaboration, reporting a different conclusion from the analysis of the data of this experiment (see ATHANASSOPOULOS 95). Contrary to the rest of the LSND Collaboration, Hill finds no evidence for the neutrino oscillation $\overline{v}_{\mu} \rightarrow \overline{v}_{e}$ and obtains only upper limits.

 $^{168} {\rm VILAIN}$ 94C limit derived by combining the ν_{μ} and $\overline{\nu}_{\mu}$ data assuming CP conservation.

169 FREEDMAN 93 is a search at LAMPF for \overline{v}_e generated from any of the three neutrino types $\nu_\mu, \ \overline{v}_\mu$, and ν_e which come from the beam stop. The \overline{v}_e 's would be detected by the reaction $\overline{v}_e \, p \to e^+ \, n$. FREEDMAN 93 replaces DURKIN 88.

¹⁷⁰ In reaction $\overline{\nu}_e p \rightarrow e^+ n$.

$$---- \nu_{\mu}(\overline{\nu}_{\mu}) \rightarrow \nu_{e}(\overline{\nu}_{e})$$

$\Delta(m^2)$ for $\sin^2(2\theta) = 1$

 VALUE (eV²)
 CL%
 DOCUMENT ID
 TECN
 COMMENT

 <0.075 90
 BORODOV...
 92
 CNTR
 BNL E776

$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$

 VALUE (units 10⁻³)
 CL%
 DOCUMENT ID
 TECN
 COMMENT

 <3</td>
 90
 BORODOV...
 92
 CNTR
 BNL E776

 • • • We do not use the following data for averages, fits, limits, etc.
 • • •

 <3.8</td>
 90
 171 MCFARLAND
 95
 CCFR
 FNAL

 171 MCFARLAND 95 state that "This result is the most stringent to date for 250< $\Delta(m^2)$ <450 ev² and also excludes at 90%CL much of the high $\Delta(m^2)$ region favored by the recent LSND observation." See ATHANASSOPOULOS 95 and ATHANASSOPOULOS 96.

 $-\nu_{\mu} \rightarrow \nu_{\tau}$

$\Delta(m^2) \text{ for } \sin^2(2\theta) = 1$

VALUE (eV ²)	CL%	DOCUMENT ID		TECN	COMMENT	
< 0.9	90	USHIDA	86C	EMUL	FNAL	
ullet $ullet$ We do not	use the following	data for average	s, fits	, limits,	etc. • • •	
< 1.4	90	MCFARLAND	95	CCFR	FNAL	
< 4.5	90	BATUSOV	90B	EMUL	FNAL	
<10.2	90	BOFILL	87	CNTR	FNAL	
< 6.3	90	BRUCKER	86	HLBC	15-ft FNAL	
< 4.6	90	ARMENISE	81	HLBC	GGM CERN SPS	
< 3	90	BAKER	81	HLBC	15-ft FNAL	
< 6	90	ERRIQUEZ	81	HLBC	BEBC CERN SPS	
< 3	90	USHIDA	81	EMUL	FNAL	

Massive Neutrinos and Lepton Mixing

ALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.004	90	USHIDA	86C	EMUL	FNAL
• • We do no	t use the followin	g data for average	s, fits	, limits,	etc. • • •
<0.0081	90	MCFARLAND	95	CCFR	FNAL
< 0.06	90	BATUSOV	90B	EMUL	FNAL
< 0.34	90	BOFILL	87	CNTR	FNAL
<0.088	90	BRUCKER	86	HLBC	15-ft FNAL
< 0.11	90	BALLAGH	84	HLBC	15-ft FNAL
< 0.017	90	ARMENISE	81	HLBC	GGM CERN SPS
< 0.06	90	BAKER	81	HLBC	15-ft FNAL
< 0.05	90	ERRIQUEZ	81	HLBC	BEBC CERN SPS
< 0.013	90	USHIDA	81	EMUL	FNAL

$\Delta(m^2)$ for $\sin^2(2\theta)=1$

VALUE (eV2)	CL%	DOCUMENT ID		TECN	COMMENT
<2.2	90	ASRATYAN	81	HLBC	FNAL
• • • We do not use the	following d	ata for averages	, fits	, limits,	etc. • • •
<1.4	90	MCFARLAND	95	CCFR	FNAL
< 6.5	90	BOFILL	87	CNTR	FNAL
< 7.4	90	TAYLOR	83	HLBC	15-ft FNAL

 $\overline{
u}_{\mu}
ightarrow \overline{
u}_{ au} -$

$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$

ALUE	CL%	DOCUMENT ID		TECN	COMMENT	
<4.4 × 10 ⁻²	90	ASRATYAN	81	HLBC	FNAL	
• • We do not us	e the followin	g data for average:	s, fit	s, limits,	etc. • • •	
< 0.0081	90	MCFARLAND	95	CCFR	FNAL	
< 0.15	90	BOFILL	87	CNTR	FNAL	
<8.8 × 10 ⁻²		TAYLOR			15-ft FNAL	

$\Delta(m^2)$ for $\sin^2(2\theta) = 1$

VALUE (eV ²)	CL%	DOCUMENT ID		TECN	COMMENT	
<1.5	90	172 GRUWE	93	CHM2	CERN SPS	

 $^{172}\,\text{GRUWE}$ 93 is a search using the CHARM II detector in the CERN SPS wide-band neutrino beam for $\nu_{\mu}\to\nu_{\tau}$ and $\overline{\nu}_{\mu}\to\overline{\nu}_{\tau}$ oscillations signalled by quasi-elastic ν_{τ} and $\overline{\nu}_{\tau}$ interactions followed by the decay $\tau \to \nu_{\tau} \pi$. The maximum sensitivity in $\sin^2 2\theta$ (< 6.4 \times 10⁻³ at the 90% CL) is reached for $\Delta(m^2) \simeq 50 \text{ eV}^2$.

$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$

-0	00	173 CDUME 02	CUMA	CEDN CDC	
VALUE (units 10 ⁻³)	CL%	DOCUMENT ID	TECN	COMMENT	
		•			

 173 GRUWE 93 is a search using the CHARM II detector in the CERN SPS wide-band neutrino beam for $\nu_{\mu} \to \ \nu_{\tau}$ and $\overline{\nu}_{\mu} \to \ \overline{\nu}_{\tau}$ oscillations signalled by quasi-elastic ν_{τ} and $\overline{
u}_{ au}$ interactions followed by the decay $au
ightarrow
u_{ au} \pi$. The maximum sensitivity in $\sin^2 2 heta$ $(<6.4\times10^{-3}$ at the 90% CL) is reached for $\Delta(m^2)\simeq 50~{\rm eV}^2$.

$$----\nu_e \rightarrow (\overline{\nu}_e)_L$$

This is a limit on lepton family-number violation and total lepton-number violation. $(\overline{\nu}_e)_L$ denotes a hypothetical left-handed $\overline{\nu}_e$. The bound is quoted in terms of Δ (m^2) , $\sin(2\theta)$, and α , where α denotes the fractional admixture of (V+A) charged current.

$\alpha\Delta(m^2)$ for $\sin^2(2\theta)=1$

VALUE (eV ²)	CL%	DOCUMENT ID		TECN	COMMENT	
<0.14	90	¹⁷⁴ FREEDMAN	93	CNTR	LAMPF	
• • • We do not us	se the followin	g data for average	es, fit	s, limits,	etc. • • •	
<7	90	L75 COOPER	82	HLBC	BEBC CERN SPS	

174 FREEDMAN 93 is a search at LAMPF for $\overline{\nu}_e$ generated from any of the three neutrino types ν_μ , $\overline{\nu}_\mu$, and ν_e which come from the beam stop. The $\overline{\nu}_e$'s would be detected by the reaction $\overline{\nu}_e p \rightarrow e^+ n$.

 $^{175}\,\mathrm{COOPER}$ 82 states that existing bounds on V+A currents require α to be small.

$\alpha^2 \sin^2(2\theta)$ for "Large" $\Delta(m^2)$

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.032	90	176 FREEDMAN	93	CNTR	LAMPF
• • • We do not use the	follow	ing data for average	s, fits	, limits,	etc. • • •
< 0.05	90	177 COOPER	82	HLBC	BERC CERN SPS

176 FREEDMAN 93 is a search at LAMPF for \overline{v}_e generated from any of the three neutrino types $\nu_\mu,\ \overline{v}_\mu,$ and ν_e which come from the beam stop. The \overline{v}_e 's would be detected by the reaction $\overline{\nu}_e p \rightarrow e^+ n$.

 177 COOPER 82 states that existing bounds on V+A currents require α to be small.

$----\nu_{\mu} \rightarrow (\overline{\nu}_e)_L --$ See note above for $u_e ightarrow (\overline{ u}_e)_L \ \text{limit}$

$\alpha\Delta(m^2)$ for $\sin^2(2\theta)=1$

VALUE (eV ²)	CL%	DOCUMENT ID		TECN	COMMENT	
<0.16	90	¹⁷⁸ FREEDMAN	93	CNTR	LAMPF	
• • • We do not use	the follow	ing data for average	es, fits	s, limits,	etc. • • •	
< 0.7	90	179 COOPER	82	HLBC	BEBC CERN SPS	

 178 FREEDMAN 93 is a search at LAMPF for $\overline{\nu}_e$ generated from any of the three neutrino types ν_μ , $\overline{\nu}_\mu$, and ν_e which come from the beam stop. The $\overline{\nu}_e$'s would be detected by the reaction $\overline{\nu}_e \, p \to e^+ \, n$. The limit on $\Delta(m^2)$ is better than the CERN BEBC experiment, but the limit on $\sin^2\theta$ is almost a factor of 100 less sensitive.

 179 COOPER 82 states that existing bounds on V+A currents require lpha to be small.

$\alpha^2 \sin^2(2\theta)$ for "Large" $\Delta(m^2)$

VALUE	CL%	DOCUMENT ID		TECN	COMMENT	_
<0.001	90	¹⁸⁰ COOPER	82	HLBC	BEBC CERN SPS	
• • • We do not use th	e follow	ing data for average	s, fits	, limits,	etc. • • •	
< 0.07	90	¹⁸¹ FREEDMAN	93	CNTR	LAMPF	

 180 COOPER 82 states that existing bounds on V+A currents require α to be small. 181 FREEDMAN 93 is a search at LAMPF for $\overline{\nu}_e$ generated from any of the three neutrino types ν_μ , $\overline{\nu}_\mu$, and ν_e which come from the beam stop. The $\overline{\nu}_e$'s would be detected by the reaction $\overline{\nu}_e \, p \to e^+ \, n$. The limit on $\Delta(m^2)$ is better than the CERN BEBC experiment, but the limit on $\sin^2\theta$

(I) Disappearance experiments with accelerator & radioactive source neutrinos

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$\Delta(m^2)$ for $\sin^2(2\theta) = 1$

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VALUE (eV ²)	CL%_	DOCUMENT ID		TECN	COMMENT	
< 0.17	90	¹⁸² BAHCALL	95	THEO		
• • • We do not u	ise the followir	ng data for averag	es, fits	, limits,	etc. • • •	
<14.9	90	BRUCKER	86	HLBC	15-ft FNAL	
< 8	90	BAKER	81	HLBC	15-ft FNAL	
< 56	90	DEDEN	81	HLBC	BEBC CERN SPS	
<10	90	ERRIQUEZ	81	HLBC	BEBC CERN SPS	
<2.3 OR >8	90	NEMETHY	81B	CNTR	LAMPF	

 182 BAHCALL 95 analyzed the GALLEX 51 Cr source experiment (ANSELMANN 95). They

$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$

VALUE	CL%	DOCUMENT ID		TECN	COMMENT	
<7 × 10 ⁻²	90	¹⁸³ ERRIQUEZ	81	HLBC	BEBC CERN SPS	
	e follow	ing data for average	s, fits	s, limits,	etc. • • •	
< 0.38	90	¹⁸⁴ BAHCALL	95	THEO	⁵¹ Cr source	
< 0.54	90	BRUCKER	86	HLBC	15-ft FNAL	
< 0.6	90	BAKER	81	HLBC	15-ft FNAL	
< 0.3	90	¹⁸³ DEDEN	81	HLBC	BEBC CERN SPS	

 183 Obtained from a Gaussian centered in the unphysical region. 184 BAHCALL 95 analyzed the GALLEX $^{51}\mathrm{Cr}$ calibration source experiment (ANSELMANN 95). They also gave a 95% CL limit of <0.45.

$-\nu_{\mu} \not\rightarrow \nu_{\mu}$

$\Delta(m^2)$ for $\sin^2(2\theta) = 1$

These experiments also allow sufficiently large $\Delta(m^2)$.

VALUE (eV ²)	CL%	DOCUMENT ID		TECN	COMMENT	
<0.23 OR >1500 O	JR LIMIT					
<0.23 OR >100	90	DYDAK	84	CNTR		
<13 OR >1500	90	STOCKDALE	84	CNTR		
• • • We do not use	the following	g data for average	s, fit	s, limits,	etc. • • •	
< 0.29 OR >22	90	BERGSMA	88	CHRM		
<7	90	BELIKOV	85	CNTR	Serpukhov	
<8.0 OR >1250	90	STOCKDALE	85	CNTR		
<0.29 OR >22	90	BERGSMA	84	CHRM		
<8.0	90	BELIKOV	83	CNTR		

$\sin^2(2\theta)$ for $\Delta(m^2) = 100 \text{eV}^2$

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.02	90	¹⁸⁵ STOCKDALE	85	CNTR	FNAL
 ● ● We do not us 	e the follow	ing data for average	s, fit	s, limits,	etc. • • •
< 0.17	90	¹⁸⁶ BERGSMA	88	CHRM	
< 0.07	90	¹⁸⁷ BELIKOV	85	CNTR	Serpukhov
< 0.27	90	¹⁸⁶ BERGSMA	84	CHRM	CERN PS
< 0.1	90	¹⁸⁸ DYDAK			CERN PS
< 0.02	90	¹⁸⁹ STOCKDALE	84	CNTR	FNAL
< 0.1	90	¹⁹⁰ BELIKOV	83	CNTR	Serpukhov

¹⁸⁵ This bound applies for $\Delta(m^2)=100~{\rm eV}^2$. Less stringent bounds apply for other $\Delta(m^2)$; these are nontrivial for 8 < $\Delta(m^2)$ <1250 eV 2 .

¹⁸⁶ This bound applies for $\Delta(m^2)=0.7$ –9. eV². Less stringent bounds apply for other $\Delta(m^2)$; these are nontrivial for 0.28 $<\Delta(m^2)$ <22 eV 2 .

Lepton Particle Listings

Massive Neutrinos and Lepton Mixing

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187 This bound applies for a wide range of \Delta(m^2) > 7 \text{ eV}^2. For some values of \Delta(m^2), the value is less stringent; the least restrictive, nontrivial bound occurs approximately at \Delta(m^2) = 300 \text{ eV}^2 where \sin^2(2\theta) < 0.13 at \text{CL} = 90\%.

188 This bound applies for \Delta(m^2) = 1.-10. \text{eV}^2. Less stringent bounds apply for other \Delta(m^2); these are nontrivial for 0.23 < \Delta(m^2) < 90 \text{ eV}^2.

189 This bound applies for \Delta(m^2) = 110 \text{ eV}^2. Less stringent bounds apply for other \Delta(m^2); these are nontrivial for 13 < \Delta(m^2) < 1500 \text{ eV}^2.

190 Bound holds for \Delta(m^2) = 20-1000 \text{ eV}^2.

\overline{\nu_{\mu} \neq \overline{\nu_{\mu}}}
\Delta(m^2) \text{ for } \sin^2(2\theta) = 1
\frac{\Delta(M^2)}{\sqrt{7}} \text{ for } \sin^2(2\theta) = 1
\frac{\Delta(M^2)}{\sqrt{7}} \text{ for } 190 \text{ eV}^2 < \Delta(m^2) < 320 \text{ eV}^2
\frac{\Delta(M^2)}{\sqrt{24UE}} \text{ for } 190 \text{ eV}^2 < \Delta(m^2) < 320 \text{ eV}^2
\frac{\Delta(M^2)}{\sqrt{90}} \text{ for } 190 \text{ eV}^2 < \Delta(m^2) < 320 \text{ eV}^2
\frac{\Delta(M^2)}{\sqrt{90}} \text{ for } 190 \text{ eV}^2 < \Delta(m^2) < 320 \text{ eV}^2
\frac{\Delta(M^2)}{\sqrt{90}} \text{ for } 190 \text{ eV}^2 < \Delta(m^2) < 320 \text{ eV}^2
\frac{\Delta(M^2)}{\sqrt{90}} \text{ for } 190 \text{ eV}^2 < \Delta(m^2) < 320 \text{ eV}^2
\frac{\Delta(M^2)}{\sqrt{90}} \text{ for } 190 \text{ eV}^2 < \Delta(m^2) < 320 \text{ eV}^2
\frac{\Delta(M^2)}{\sqrt{90}} \text{ for } 190 \text{ eV}^2 < \Delta(m^2) < 320 \text{ eV}^2
\frac{\Delta(M^2)}{\sqrt{90}} \text{ for } 190 \text{ eV}^2 < \Delta(m^2) < 320 \text{ eV}^2
\frac{\Delta(M^2)}{\sqrt{90}} \text{ for } 190 \text{ eV}^2 < \Delta(m^2) < 320 \text{ eV}^2
\frac{\Delta(M^2)}{\sqrt{90}} \text{ eV}^2
\frac{\Delta(M^2)}{\sqrt{90}} \text{ for } 190 \text{ eV}^
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REFERENCES FOR Searches for Massive Neutrinos and Lepton Mixing

apply for other $\Delta(m^2)$; these are nontrivial for $7 < \Delta(m^2) < 1200 \text{ eV}^2$.

	06	DD D (***b=**)		Asharana Amahab Durana Cabas (ICAID Callab)
ATHANASSO nucl-ex/960		PR D (subm.)		Athanassopoulos, Auerbach, Burman, Cohen+(LSND Collab.)
ACHKAR	95	NP B434 503		+Aleksan+ +Ambrosio, Antolini, Auriemma+ (MACRO Collab.)
AHLEN	95	PL B357 481		+Ambrosio, Antolini, Auriemma+ (MACRO Collab.)
ANSELMANN	95	PL B342 440		+Fockenbrock, Hampel, Heusser+ (GALLEX Collab.)
ANSELMANN	95B	PL B357 237		+Hampel, Heusser, Kike+ (GALLEX Collab.)
ARMBRUSTER		PL B348 19		+Blair, Bodmann, Booth+ (KARMEN Collab.)
ARNOLD	95	JETPL 61 170	75750	+Caurier, Guyonnet, Linck+ (NEMO Collab.) 61 168.
ATHANASSO	O.E.	PRL 75 2650	ZETFP	Athanassopoulos, Auerbach+ (LSND Collab.)
BAHCALL	95	PL B348 121		+Krastev, Lisi (IAS)
BAHRAN	95	PI B354 481		+Kalbfleisch (OKLA)
BALYSH	95	PL B354 481 PL B356 450		+Beck, Belyaev+ (MPIH, KIAE, SASSO)
BARABASH	95	PL B345 408		+Avignone+ (ITEP, SCUC, PNL, MINN, LEBD)
BILGER	95	PL B363 41		+Clement, Denig, Fohl+ (TUBIN, KARLE, PSI)
BURACHAS	95	PAN 58 153		+Danevich, Zdesenko, Kobychev+ (KIEV)
		Translated from		i 195.
DANEVICH	95	PL B344 72		+Georgadze, Kobychev, Kropivyansky+ (KIEV) +Eschbach, Hubert, Isaac, Isaac+ (NEMO Collab.)
DASSIE	95 95	PR D51 2090		+Eschbach, Hubert, Isaac, Isac+ (NEMO Collab.)
DAUM DAUM	95B	ZPHY C66 417 PL B361 179		+Rhode, Bareyre, Barloutaud+ +Frosch, Hajdas, Janousch+ (PSI, VIRG)
EJIRI	950	JPSJ 64 339		+Fushmii, Hazama, Kawasaki+ (OSAK, KIEV)
FARGION	95	PR D52 1828		+Fushmii, Hazama, Kawasaki+ (OSAK, KIEV) +Khlopov, Konplich, Mignani (ROMA, KIAM, MPEI)
GALLAS	95	PR D52 6		+Khlopov, Konplich, Mignani +Abolins, Brock, Cobau+ (ROMA, KIAM, MPEI) (MSU, FNAL, MIT, FLOR)
GEORGADZE	95	PAN 58 1093		
		Translated from	YAF 58	3 1170.
HAGNER	95	PR D52 1343		+Altmann, Feilitzsch, Oberauer+ (MUNT, LAPP, CPPM)
HIDDEMANN	95	JP G21 639 PRL 75 2654		+Daniel, Schwentker (MUNT)
HILL	95	PRL 75 2654		(PENN)
KOBAYASHI	95	NP A586 457		+Kobayashi (KEK, SAGA) +Naples, Arroyo, Auchinchloss+ (CCFR Collab.)
MCFARLAND	95	PRL 75 3993		+Naples, Arroyo, Auchinchloss+ (CCFR Collab.)
VILAIN	95C	PL B351 387		+Wilquet, Petrak+ (CHARM II Collab.)
Also	95 95	PL B343 453		Vilain, Wilquet+ (CHARM II Collab.)
VYRODOV	95	JETPL 61 163 Translated from	7FTEP	+Kozlov, Martem'yanov, Machulin+ (KIAE, LAPP, CDEF)
WIETFELDT	95	PR C52 1028	22711	+Norman+ (LBL, UCB, SPAUL, IND, TENN)
ABDURASHI		PL B328 234		Abdurashitov, Faizov, Gavrin, Gusev+ (SAGE Collab.)
ACKER	94	PI R320 320		+Pakvasa (HAWA)
ALESSAND	94	PL B335 519 PL B327 377		Alessandrello, Brofferio,, Fiorini+ (MILA)
ANSELMANN	94	PL B327 377		+Hampel, Heusser, Kiko, Kirsten+ (GALLEX Collab.)
ARPESELLA	94	EPL 27 29		+Barabash, Bellotti+ (SASSO, ITEP, MOSU, MILA, LEBD)
BAHCALL	94	PL B338 276		(IAS)
BALYSH	94	PL B322 176		+Beck, Belyaev, Bensch+ (MPIH, KIAE, SASSO)
BECK	94	PL B336 141		+Bensch, Bockholt+ (MPIH, KIAE, SASSO)
FUKUDA	94	PL B335 237		+Hayakawa, Inoue, Ishida+ (Kamiokande Collab.)
KONOPLICH PDG	94	PAN 57 425 PR D50 1173		+Khlopov (MPEI) Montanet+ (CERN, LBL, BOST, IFIC+)
PIEPKE	94	NP A577 493		+, Klapdor-Kleingrothaus+ (MPIH, ITEP)
SMIRNOV	94	PR D49 1389		+, Klapdor-Kleingrothaus+ +Spergel, Bahcall (IAS, ICTP, INRM, PRIN)
VIDYAKIN	94	IFTPI 59 390		+Vyrodov, Kozlov+ (KIAE)
VIDIANII	54	Translated from	ZETFP	59 364
VILAIN	94 C	ZPHY C64 539		+Wilguet, Bever+ (CHARM II Collab.)
ALSTON	93	PRL 71 831		Alston-Garnjost+ (LBL, MTHO, UNM, INEL)
ARTEMEV	93	JETPL 58 262 Translated from		+Brakhman, Zeldofich, Karelin+ (ITEP, INRM)
DALLCALL		Franslated from	ZETFP	58 256. +Bethe (IAS, CORN)
BAHCALL	93	PR D47 1298 PR D47 R754		+Bethe (IAS, CORN) +Kalbfleisch (OKLA)
BAHRAN	93 93B	PR D47 R754 PR D47 R759		+Kalbfleisch (OKLA) +Kalbfleisch (OKLA)
BAHRAN BARANOV	93B 93	PL B302 336		
BERMAN	93	F L D302 330		(IMP SERD RUDA)
				(IMP SERD RUDA)
BERNATOW		PR C48 R1		+Batusov, Bunyatov, Klimov+ (JINR, SERP, BUDA) +Pitt, Calaprice, Lowry (PRIN)
BERNATOW	93	PR C47 806		+Batusov, Bunyatov, Klimov+ (JINR, SERP, BUDA) +Pitt, Calaprice, Lowry (PRIN)
FREEDMAN GRUWE		PR C47 806 PR D47 811 PL B309 463		+Batusov, Bunyatov, Klimov+ +Pitt, Calaprice, Lowry Bernatowicz, Brazzle, Cowsik+ +Fujikawa, Napolitano, Nelson+ +Mommaert, Vilain, Wilguet+ (CHARM II Collab.)
FREEDMAN GRUWE HAMPEL	93 93 93 93	PR C47 806 PR D47 811 PL B309 463 JPG 19 S209		+Batusov, Bunyatov, Klimov+ +Pitt, Calaprice, Lowry Bernatowicz, Brazzle, Cowsik+ +Fujikawa, Napolitano, Nelson + +Kujikawa, Napolitano, Nelson + (LAMPF E645 Collab.) (CHARM II Collab.) (MPI)
FREEDMAN GRUWE HAMPEL KALBFLEISCH	93 93 93 93 93	PR C47 806 PR D47 811 PL B309 463 JPG 19 S209 PL B303 355		+Batusov, Bunyatov, Klimov+ -Pitt, Calaprice, Lowry Bernatowicz, Brazzle, Cowsik+ -Fujikawa, Napolitano, Nelson+ +Mommaert, Vilain, Wilquet+ +Bahran (JINR, SERP, BUDA) (PRIN) (PRIN) (AMPF E645 Collab.) (CHARM II Collab.) (MPIH)
FREEDMAN GRUWE HAMPEL KALBFLEISCH KAWASHIMA	93 93 93 93 93 93	PR C47 806 PR D47 811 PL B309 463 JPG 19 S209 PL B303 355 PR C47 R2452		+Batusov, Bunyatov, Klimov+ +Pitt, Calaprice, Lowry Bernatowicz, Brazzle, Cowsik+ +Fujikawa, Napolitano, Nelson + +Kupikawa, Napolitano, Nelson + +Mommaert, Vilain, Wilquet+ +Bahran -Takahashi, Masuda -TOKYC, RIKEN
FREEDMAN GRUWE HAMPEL KALBFLEISCH KAWASHIMA MORTARA	93 93 93 93 93 93 93	PR C47 806 PR D47 811 PL B309 463 JPG 19 S209 PL B303 355 PR C47 R2452		+Batusov, Bunyatov, Klimov+ -Pitt, Calaprice, Lowry Bernatowicz, Brazzle, Cowsik+ +Fujikawa, Napolitano, Nelson+ +Mommaert, Vilain, Wilquet+ +Bahran +Takahashi, Masuda +Takahashi, Coulter, Freedman+ (JINR, SERP, BUDA) (PRIN) (PRIN) (PRIN) (CHARM II Collab.) (MPIH) (TOKYC, RIKEN)
FREEDMAN GRUWE HAMPEL KALBFLEISCH KAWASHIMA MORTARA OHSHIMA	93 93 93 93 93 93 93 93	PR C47 806 PR D47 811 PL B309 463 JPG 19 S209 PL B303 355 PR C47 R2452 PRL 70 394 PR D47 4840		+Batusov, Bunyatov, Klimov+ -Pitt, Calaprice, Lowry Bernatowicz, Brazzle, Cowsik+ +Fujikawa, Napolitano, Nelson+ +Mommaert, Vilain, Wilquet+ +Bahran +Takahashi, Masuda +Takahashi, Coulter, Freedman+ (JINR, SERP, BUDA) (PRIN) (PRIN) (PRIN) (CHARM II Collab.) (MPIH) (TOKYC, RIKEN)
FREEDMAN GRUWE HAMPEL KALBFLEISCH KAWASHIMA MORTARA OHSHIMA TURCK-CHI	93 93 93 93 93 93 93 93	PR C47 806 PR D47 811 PL B309 463 JPG 19 S209 PL B303 355 PR C47 R2452 PRL 70 394 PR D47 4840 PRPL 230 57		+Batusov, Bunyatov, Klimov+ +Pitt, Calaprice, Lowry Bernatowicz, Brazzle, Cowsik+ +Fujikawa, Napolitano, Nelson+ +Hujikawa, Napolitano, Nelson+ +Hujikawa, Napolitano, Nelson+ +Hujikawa, Napolitano, Nelson+ +Hujikawa, Napolitano, Nelson+ (WSUL, TATA) +Hujikawa, Napolitano, Nelson+ (HAMPI E645 Collab.) (MPIH) + Takahashi, Masuda - TrukryC, RIKEN, CULO, ROCH, TSUK, INUS) + (KEK, TUAT, RIKEN, SCUC, ROCH, TSUK, INUS) Turkr-K-Chiese+ (SACLD, USC, NICEA, NICEO, MEUD)
FREEDMAN GRUWE HAMPEL KALBFLEISCH KAWASHIMA MORTARA OHSHIMA TURCK-CHI TURCK-CHI	93 93 93 93 93 93 93 93 93 93	PR C47 806 PR D47 811 PL B309 463 JPG 19 S209 PL B303 355 PR C47 R2452 PRL 70 394 PR D47 4840 PRPL 230 57 APJ 408 347		+Batusov, Bunyatov, Klimov+ +Pitt, Calaprice, Lowry Bernatowicz, Brazzle, Cowsik+ +Fujikawa, Napolitano, Nelson + +Fujikawa, Napolitano, Nelson + +Mommaert, Vilain, Wilquet+ +Bahran - (OKLA) +Takahashi, Masuda +Ahmad, Coulter, Freedman+ - (KR, TUAT, RIKEN, SCUC, ROCK, TSUK, NUS, Turck-Chieze+ - (SACLD, USC, NICEA, NICEO, MEUD) - Turck-Chieze+ - (OKLA) - (SACLD)
FREEDMAN GRUWE HAMPEL KALBFLEISCH KAWASHIMA MORTARA OHSHIMA TURCK-CHI TURCK-CHI VUILLEUMIER	93 93 93 93 93 93 93 93 93 93B	PR C47 806 PR D47 811 PL B309 463 JPG 19 5209 PL B303 355 PR C47 R2452 PRL 70 394 PR D47 4840 PRPL 230 57 APJ 408 347 PR D48 1009		+Batusov, Bunyatov, Klimov+ +Pitt, Calaprice, Lowry Bernatowicz, Brazzle, Cowsik+ +Fujikawa, Napolitano, Nelson+ +Hommaert, Vilain, Wilquet+ +Bahran +Takahashi, Masuda +Torry, Riken, Scuc, Roch, Tsuk, INUS) -Turck-Chieze+ (SACLD, USC, NICEA, NICEO, MEUD) -Turck-Chieze, Lopez -Busto, Farine, Jorgens+
FREEDMAN GRUWE HAMPEL KALBFLEISCH KAWASHIMA MORTARA OHSHIMA TURCK-CHI TURCK-CHI VUILLEUMIER WIETFELDT	93 93 93 93 93 93 93 93 93 93 93 93	PR C47 806 PR D47 811 PL B309 463 JPG 19 S209 PL B303 355 PR C47 R2452 PRL 70 394 PR D47 4840 PRPL 230 57 APJ 408 347 PR D48 1009 PRL 70 1759		+Batusov, Bunyatov, Klimov+ +Pitt, Calaprice, Lowry Bernatowicz, Brazzle, Cowsik+ +Fujikawa, Napolitano, Nelson+ +Hommaert, Vilain, Wilquet+ +Bahran +Takahashi, Masuda +Torry, Riken, Scuc, Roch, Tsuk, INUS) -Turck-Chieze+ (SACLD, USC, NICEA, NICEO, MEUD) -Turck-Chieze, Lopez -Busto, Farine, Jorgens+
FREEDMAN GRUWE HAMPEL KALBFLEISCH KAWASHIMA MORTARA OHSHIMA TURCK-CHI VUILLEUMIER WIETFELDT ABREU	93 93 93 93 93 93 93 93 93 93 93 93 93	PR C47 806 PR D47 811 PL B309 463 JPG 19 S209 PL B303 355 PR C47 R2452 PRL 70 394 PR D47 4840 PRPL 230 57 APJ 408 347 PR D48 1009 PRL 70 1759		+Batusov, Bunyatov, Klimov+ +Pitt, Calaprice, Lowry Bernatowicz, Brazzle, Cowsik+ +Fujikawa, Napolitano, Nelson (+ MPF E645 Collab.) +Mommaert, Vilain, Wilquet+ +Bahran -Takahashi, Masuda +Almad, Coulter, Freedman+ -(KR, TUAT, RIKEN, SCUC, ROCH, TSUK, NUS) -Turck-Chieze+ -(SACLD, USC, NICEA, NICEO, MEUD) -Turck-Chieze(SACLD) -Busto, Farine, Jorgens+ -(KR, Curl, Garcia+ -(KR, Curl, Garcia+ -(LBL, UCB, SPAUL) -(CH, VILL)
FREEDMAN GRUWE HAMPEL KALBFLEISCH KAWASHIMA MORTARA OHSHIMA TURCK-CHI TURCK-CHI VUILLEUMIER WIETFELDT ABREU ADRIANI	93 93 93 93 93 93 93 93 93 93 93 93 92 92 92	PR C47 806 PR D47 811 PL B309 463 JPG 19 5209 PL B303 355 PR C47 R2452 PRL 70 394 PR D47 4840 PRPL 230 57 APJ 408 347 PR D48 1009 PRL 70 1759 PL B274 230 PL B295 371		+Batusov, Bunyatov, Klimov+ +Pitt, Calaprice, Lowry Bernatowicz, Brazzle, Cowsik+ +Fujikawa, Napolitano, Nelson (+ MPF E645 Collab.) +Mommaert, Vilain, Wilquet+ +Bahran -Takahashi, Masuda +Almad, Coulter, Freedman+ -(KR, TUAT, RIKEN, SCUC, ROCH, TSUK, NUS) -Turck-Chieze+ -(SACLD, USC, NICEA, NICEO, MEUD) -Turck-Chieze(SACLD) -Busto, Farine, Jorgens+ -(KR, Curl, Garcia+ -(KR, Curl, Garcia+ -(LBL, UCB, SPAUL) -(CH, VILL)
FREEDMAN GRUWE HAMPEL KALBFLEISCH KAWASHIMA MORTARA OHSHIMA TURCK-CHI TURCK-CHI VUILLEUMIER WIETTELDT ABREU ADRIANI ARTEMJEV	93 93 93 93 93 93 93 93 93 93 93 92 92 92	PR C47 806 PR D47 811 PL B309 463 JPG 19 5209 PL B303 355 PR C47 R2452 PRL 70 394 PR D47 4840 PRPL 230 57 APJ 408 347 PR D48 1009 PRL 70 1759 PL B274 230 PL B295 371 PL B295 159		+Batusov, Bunyatov, Klimov+ +Pitt, Calaprice, Lowry Bernatowicz, Brazzle, Cowsik+ +Fujikawa, Napolitano, Nelson (+ MPF E645 Collab.) +Mommaert, Vilain, Wilquet+ +Bahran -Takahashi, Masuda +Almad, Coulter, Freedman+ -(KR, TUAT, RIKEN, SCUC, ROCH, TSUK, NUS) -Turck-Chieze+ -(SACLD, USC, NICEA, NICEO, MEUD) -Turck-Chieze(SACLD) -Busto, Farine, Jorgens+ -(KR, Curl, Garcia+ -(KR, Curl, Garcia+ -(LBL, UCB, SPAUL) -(CH, VILL)
FREEDMAN GRUWE HAMPEL KALBFLEISCH KAWASHIMA MORTARA OHSHIMA TURCK-CHI TURCK-CHI VUILLEUMIER WIETFELDT ABREU ADRIANI	93 93 93 93 93 93 93 93 93 93 93 93 92 92 92	PR C47 806 PR D47 811 PL B309 463 JPG 19 5209 PL B303 355 PR C47 R2452 PRL 70 394 PR D47 4840 PRPL 230 57 APJ 408 347 PR D48 1009 PRL 70 1759 PL B274 230 PL B295 371		+Batussov, Bunyatov, Klimov+ +Pitt, Calaprice, Lowry Bernatowicz, Brazzle, Cowsik+ +Fujikawa, Napolitano, Nelson+ + Hommaert, Vilain, Wilquet+ +Bahran +Takahashi, Masuda +Takahashi, Masuda + (TOKYC, RIKEN) + (KEK, TUAT, RIKEN, SCUC, ROCH, TSUK, INUS) -Turck-Chieze+ - (SACLD, USC, NICEA, NICEO, MEUD) - (TURC, NICEA,
FREEDMAN GRUWE HAMPEL KALBFLEISCH KAWASHIMA MORTARA OHSHIMA TURCK-CHI VUILLEUMER WIETFELDT ABREU ADRIANI ARTEMJEV BAHCALL BAHCALL	93 93 93 93 93 93 93 93 93 93 93 92 92 92	PR C47 806 PR D47 811 PL B309 463 JPG J9 5209 PL B303 355 PR C47 R245 PRL 70 394 PR D47 4840 PRPL 230 57 PRL 70 1759 PL B274 230 PRL 70 1759 PL B274 230 PRL 70 1759 PL B274 230 PRL 70 1759 PL B274 230 PRL 70 1759 PL B280 159 RMP 64 885 PL B291 336		+Batusov, Bunyatov, Klimov+ +Pitt, Calaprice, Lowry Bernatowicz, Brazzle, Cowsik+ +Fujikawa, Napolitano, Nelson + +Kejikawa, Napolitano, Nelson + +Mommaert, Vilain, Wilquet+ +Bahran +Takahashi, Masuda +Takahashi, Masuda +Almad, Coulter, Freedman+ + (KEK, TUAT, RIKEN, SCUC, ROCH, TSUK, NUS, Turck-Chieze+ + (KEK, TUAT, RIKEN, SCUC, ROCH, TSUK, NUS, Turck-Chieze, Lopez +Busto, Farine, Jorgens+ +Chan, da Cruz, Garcia+ +Chan, da Cruz, Garcia+ +Aguliar-Bentiez, Ahlen, Akbari, Alcaraz+ +Prakachman, Ivanovsky, Karelin+ +Prinsonneault +Kalbfleisch - (KIAS) - (KIAS) - (KIAS) - (LAS) -
FREEDMAN GRUWE HAMPEL KALBFLEISCH KAWASHIMA MORTARA OHSHIMA TURCK-CHI VUILLEUMIER WIETFELDT ABREU ADRIANI ARTEMJEV BAHCALL BAHRAN BALYSH BECKER-SZ	93 93 93 93 93 93 93 93 93 93 93 92 92 92 92	PR C47 806 PR D47 811 PL B309 463 JPG 19 5209 PL B303 355 PR C47 R2452 PRL 70 394 PR D47 4840 PR D47 4840 PR D47 10759 PR D48 1009 PRL 70 1759 PL B274 230 PL B295 371 PL B280 159 RMP 64 885 PL B283 32 PL B283 32 PRL 69 1010		+Batusov, Bunyatov, Klimov+ +Pitt, Calaprice, Lowry Bernatowicz, Brazzle, Cowsik+ +Fujikawa, Napolitano, Nelson + +Kejikawa, Napolitano, Nelson + +Mommaert, Vilain, Wilquet+ +Bahran +Takahashi, Masuda +Takahashi, Masuda +Almad, Coulter, Freedman+ + (KEK, TUAT, RIKEN, SCUC, ROCH, TSUK, NUS, Turck-Chieze+ + (KEK, TUAT, RIKEN, SCUC, ROCH, TSUK, NUS, Turck-Chieze, Lopez +Busto, Farine, Jorgens+ +Chan, da Cruz, Garcia+ +Chan, da Cruz, Garcia+ +Aguliar-Bentiez, Ahlen, Akbari, Alcaraz+ +Prakachman, Ivanovsky, Karelin+ +Prinsonneault +Kalbfleisch - (KIAS) - (KIAS) - (KIAS) - (LAS) -
FREEDMAN GRUWE HAMPEL KALBELEISCH KAWASHIMA OHSHIMA TURCK-CHI TURCK-CHI VUILLEUMIER WIETFELDT ABREU ADRIANI ARTEMIEV BAHCALL BAHRAN BALYSH BECKER-SZ	93 93 93 93 93 93 93 93 93 93 92 92 92 92 92 92 92 92 92 92	PR C47 806 PR D47 811 PL 8309 463 JPG 19 S209 PL 8303 355 PR C47 R2452 PRL 70 394 PR D47 4840 PRPL 230 57 APJ 408 347 PR D48 1009 PRL 70 1759 PL 8274 230 PL 8295 371 PL 8280 159 RMP 64 885 PL 8291 336 PL 8293 32 PRL 69 1010 PR D46 3720		+Batusov, Bunyatov, Klimov+ +Pitt, Calaprice, Lowry Bernatowicz, Brazzle, Cowsik+ +Fujikawa, Napolitano, Nelson + +Fujikawa, Napolitano, Nelson + +Mommaert, Vilain, Wilquet+ +Bahran +Takahashi, Masuda +Takahashi, Masuda +Almad, Coulter, Freedman+ + (KEK, TUAT, RIKRN, SUCL, ROCH, TSUK, NUS, Turck-Chieze+ + (KEK, TUAT, RIKRN, SUCL, ROCH, TSUK, NUS, Turck-Chieze+ + (ACLD, USC, NICEA, NICEO, MEUD) Turck-Chieze, Lopez +Busto, Farine, Jorgens+ +Chan, da Cruz, Garcia+ +Chan, da Cruz, Garcia+ +Chan, da Cruz, Garcia+ +Agulian-Bentez, Ahlen, Akbari, Akcaraz+ +Agulian-Bentez, Ahlen, Akbari, Akcaraz+ +Brakchman, Ivanovsky, Karelin+ +Pinsonneault +Kalbfleisch +Belyaev, Bockholt, Demehin+ - (MPH, KIAE, SASSO) - Becker-Szendy, Bratton, Casper, Dye+ - (IMB Collab, - MRCHANGE, B
FREEDMAN GRUWE HAMPEL KALBFLEISCH KAWASHIMA OHSHIMA TURCK-CHII TURCK-CHII TURCK-CHII.ARE ABREU ADRIANI ARTEMJEV BAHCALL BAHRAN BALYSH BECKER-SZ BECKER-SZ BECKER-SZ	93 93 93 93 93 93 93 93 93 93 93 92 92 92 92 92 92 92 92 92 92 92 93	PR C47 806 PR D47 811 PL B309 463 JPG 19 5209 PL B303 355 PR C47 R2452 PR L70 394 PR D47 4840 PRPL 230 57 APJ 408 347 APJ 408 347 PR D48 1099 PRL 70 1759 PR D48 1099 PRL 70 1759 PR B295 371 PL B280 159 RMP 64 885 PL B283 32 PL B283 32 PRL 69 1010 PR D46 3720		+Batusov, Bunyatov, Klimov+ Pitt, Calaprice, Lowry Bernatowicz, Brazzle, Cowish +Hugikawa, Napolitano, Nelson+ +Hommaert, Vilain, Wilquet+ +Bahran +Bahran +Takahashi, Masuda +Takahashi, Masuda +Ahmad, Coulter, Freedman+ + (KEK, TUAT, RIKEN, SCUC, ROCH, TSUK, INUS) Turck-Chieze+ + (SACLD, USC, NICEA, NICEO, MEUD) Turck-Chieze, Lopez -Busto, Farine, Jorgens+ +Chan, da Cruz, Garcia+ +Agullar-Benitez, Ahlen, Akbari, Akrazet +Braschman, Ivanovsky, Karelin+ +Prisonneault -Kalbleisch -Bekaer-Sendy, Bratton, Casper, Dye+ - (KMZ) - (MA) - (MPIH, KIAE, SASSO) - (MS)
FREEDMAN GRUWE HAMPEL KALBFLEISCH KAWASHIMA OHSHIMA TURCK-CHI TURCK-CHI VUILLEUMIER ADRIANI ARTEMIEV BAHCALL BAHRAN BALCKER-SZ BECKER-SZ BEIER Also	93 93 93 93 93 93 93 93 93 93 93 92 92 92 92 92 92 92 92 92	PR C47 806 PR D47 811 PL B309 463 JPG 19 5209 PL B303 355 PR C47 R2452 PR L70 394 PR D47 4840 PRPL 230 57 PR J47 4840 PRPL 230 57 PR J48 347 PR D48 1009 PL B295 371 PL B280 159 PL B274 230 PR J69 1010 PR D46 332 PRL 69 1010 PR D46 3720 PL B283 446 PR D48 346 PR D48 347 PR D48 348 PR D46 3720 PL B283 446 PTRSL A346 6		+Batusov, Bunyatov, Klimov+ Pitt, Calaprice, Lowry Bernatowicz, Brazzle, Cowish +Hugikawa, Napolitano, Nelson+ +Hommaert, Vilain, Wilquet+ +Bahran +Bahran +Takahashi, Masuda +Takahashi, Masuda +Ahmad, Coulter, Freedman+ + (KEK, TUAT, RIKEN, SCUC, ROCH, TSUK, INUS) Turck-Chieze+ + (SACLD, USC, NICEA, NICEO, MEUD) Turck-Chieze, Lopez -Busto, Farine, Jorgens+ +Chan, da Cruz, Garcia+ +Agullar-Benitez, Ahlen, Akbari, Akrazet +Braschman, Ivanovsky, Karelin+ +Prisonneault -Kalbleisch -Bekaer-Sendy, Bratton, Casper, Dye+ - (KMZ) - (MA) - (MPIH, KIAE, SASSO) - (MS)
FREEDMAN GRUWE HAMPEL KALBFLEISCH KAWASHIMA OHSHIMA TURCK-CHII TURCK-CHII TURCK-CHII ABREU ADRIANI ARTEMIEV BAHCALL BAHRAN BALYSH BECKER-SZ BECKER-SZ BECKER-SZ BEERA	93 93 93 93 93 93 93 93 93 93 92 92 92 92 92 92 92 94 92	PR C47 806 PR D47 811 PL B309 463 JPG 19 5209 PL B303 355 PR C47 R2452 PR L70 394 PR D47 4840 PRPL 230 57 APJ 408 347 PR D48 1099 PRL 70 1759 PRL 8274 230 PL B274 230 PL B283 32 PL B283 32 PRL 69 234 PRL 69 234 PRL 52 3446 PTRSL A3464 PTRSL A3464 PTRSL A3464		+Batusov, Bunyatov, Klimov+ Pitt, Calaprice, Lowry Bernatowicz, Brazzle, Cowish +Hugikawa, Napolitano, Nelson+ +Hommaert, Vilain, Wilquet+ +Bahran +Bahran +Takahashi, Masuda +Takahashi, Masuda +Ahmad, Coulter, Freedman+ + (KEK, TUAT, RIKEN, SCUC, ROCH, TSUK, INUS) Turck-Chieze+ + (SACLD, USC, NICEA, NICEO, MEUD) Turck-Chieze, Lopez -Busto, Farine, Jorgens+ +Chan, da Cruz, Garcia+ +Agullar-Benitez, Ahlen, Akbari, Akrazet +Braschman, Ivanovsky, Karelin+ +Prisonneault -Kalbleisch -Bekaer-Sendy, Bratton, Casper, Dye+ - (KMZ) - (MA) - (MPIH, KIAE, SASSO) - (MS)
FREEDMAN GRUWE HAMPEL KALBELEISCH KAWASHIMA OHSHIMA TURCK-CHI TURCK-CHI TURCK-CHI ABRENNI ARTEMJEV BAHCALL BAHRAN BALYSH BECKER-SZ BEIER AISO BERNATOW BLUM	93 93 93 93 93 93 93 93 93 93 92 92 92 92 92 92 92 92 92 92 92 92 92	PR C47 806 PR D47 811 PL 8309 463 JPG 19 5209 PL 8303 355 PR C47 R2452 PR 170 394 PR D47 4840 PRPL 230 57 PR J47 4840 PRPL 230 57 PR J48 307 PR D48 1009 PRL 70 1759 PL 8274 230 PRL 829 371 PL 8280 159 PL 8293 346 PR J69 1010 PR D46 3720 PL 8283 446 PRL 69 2341 PR J68 2344 PR J68 2341 PR J68 2345 PR J69 2341 PR J69 2345		+Batusov, Bunyatov, Klimov+ +Pitt, Calaprice, Lowry Bernatowicz, Brazzle, Cowsik+ +Frankanbani, Masuda +Takahashi, Masuda + (TOKYC, RIKEN + (KEK, TUAT, RIKEN, SCUC, ROCH, TSUK, NUS) Turck-Chieze+ + (KEK, TUAT, RIKEN, SCUC, ROCH, TSUK, NUS) Turck-Chieze+ - (SACLD, USC, NICEA, NICEO, MEUD) Turck-Chieze, Lopez - (SACLD) +Busto, Farine, Jorgens+ - (Chan, da Cruz, Garcia+ - (LBL, UCB, SPAL) +Adams, Adami, Adye+ - (DELPHI Collab.) - Haguilar-Benitez, Ahlen, Akbari, Alcaraz+ - (Haguilar-Benitez, Ahlen, Alcaraz+ - (Haguil
FREEDMAN GRUWE HAMPEL KALBFLEISCH KAWASHIMA OHSHIMA TURCK-CHII TURCK-CHIII	93 93 93 93 93 93 93 93 93 93 92 92 92 92 92 94 92 94 92 92 92	PR C47 806 PR D47 811 PL 8309 463 JPG 19 5209 PL 8303 355 PR C47 R2452 PRL 70 394 PR D47 4840 PRPL 230 57 PR D47 4840 PRPL 230 57 PR D48 307 PR		+Batusov, Bunyatov, Klimov+ +Pitt, Calaprice, Lowry Bernatowicz, Brazzle, Cowisk +Hujikawa, Napolitano, Nelson+ +Hujikawa, Napolitano, Nelson+ +Hommaert, Vilain, Wilquet+ +Bahran +Bahran +Takahashi, Masuda + (KEK, TUAT, RIKEN, SCUC, ROCH, TSUK, NIUCB) + (KEK, TUAT, RIKEN, SCUC, ROCH, TSUK, NIUCB) -Turck-Chieze+ - (SACLD, USC, NICEA, NICEO, MEUD) -Turck-Chieze+ - (SACLD, USC, NICEA, NICEO, MEUD) -Turck-Chieze+ - (SACLD, USC, NICEA, NICEO, MEUD) -Turck-Chieze (SACLD, USC, NICEA, NICEO, MEUD) -Turck-Chieze (SACLD) -Turck-Chieze (SACLD
FREEDMAN GRUWE HAMPEL KALBELEISCH KAWASHIMA OHSHIMA TURCK-CHI TURCK-CHI TURCK-CHI ARRENJE ARRENJE ARRENJE BAHRAN BALYSH BECKER-SZ BEIER AISO BERNATOW BLUM BORODOW BRITTON	93 93 93 93 93 93 93 93 93 93 92 92 92 92 92 92 92 92 92 92 92 92 92	PR C47 806 PR D47 811 PL 8309 463 JPG 19 5209 PL 8303 355 PR C47 R2452 PRL 70 394 PR D47 4840 PRPL 230 57 PRL 70 394 PRL 70 1759 PL 8774 230 PRL 70 1759 PL 8274 230 PRL 829 371 PL 8280 159 PL 8295 371 PL 8280 159 PL 8281 332 PRL 69 1010 PR D46 3720 PL 8283 446 PRL 69 2341 PL 8275 506 PRL 66 274 PL B275 506 PRL 66 274 PRL 66 3000		+Batusov, Bunyatov, Klimov+ +Pitt, Calaprice, Lowry Bernatowicz, Brazzle, Cowsik+ +Fujikawa, Napolitano, Nelson + +Hommaert, Vilain, Wilquet+ +Bahran +Takahashi, Masuda +Takahashi, Masuda +Takahashi, Masuda + (KK, TUAT, RIKEN, SCUC, ROCH, TSUK, NUS) Turck-Chiere+ + (KEK, TUAT, RIKEN, SCUC, ROCH, TSUK, NUS) Turck-Chiere, Lopez +Busto, Farine, Jorgens+ +Chan, da Cruz, Garcia+ +Aguliar-Benitez, Ahlen, Akbari, Alcaraz+ +Aguliar-Benitez, Ahlen, Akbari, Alcaraz+ +Raguliar-Benitez, Ahlen, Akbari, Alcaraz+ +Raguliar-Benitez, Ahlen, Akbari, Alcaraz+ +Raguliar-Benitez, Ahlen, Akbari, Alcaraz+ +Rajuliar-Benitez, Ahlen, Akbari, Alcaraz- +Belyaev, Bockholt, Demehin+ -Belyaev, Bockholt, Demehin+ -Belyaev, Bockholt, Demehin+ -Belyaev, Bockholt, Demehin+ -Belyaev, Bockholt, Saper, Dye+ -Beick-Fszendy, Bratton, Casper, Dye+ -Bratton, Tubenderick DemeninBratton-
FREEDMAN GRUWE HAMPEL KALBFLEISCH KAWASHIMA OHSHIMA TURCK-CHII TURCK-CHII TURCK-CHII TURCK-CHII ABREU ADRIANI ARTEMJEV BAHCALL BAHRAN BALYSH BECKER-SZ BECKER-SZ BECKER-SZ BECKER-SZ BEIER AISO BERNATOW BUITTON AISO	93 93 93 93 93 93 93 93 93 93 92 92 92 92 92 92 92 92 92 92 92 92 92	PR C47 806 PR D47 811 PL 8309 463 JPG 19 5209 PL 8303 355 PR C47 R2452 PRL 70 394 PR D47 4840 PRPL 230 57 PR D47 4840 PRPL 230 57 PR D48 307 PR D49 350 PL 828 351 PR B28 352 PR B28 352 PR B28 353 PR B28 353 PR B28 354 PR B4 4 855 PR B4 4 855 PR B4 4 855 PR B5 354 PR B5 356 PR B6 356 PR B6 374 PR B6 3000 PR D46 3720 PR B7 68 3004 PR B6 374 PR B6 3004 PR B6 374 PR B6 3004 PR D49 28		+Batusov, Bunyatov, Klimov+ +Pitt, Calaprice, Lowry Bernatowicz, Brazzle, Cowisk +Hülkawa, Napolitano, Nelson+ +Hülkawa, Napolitano, Nelson+ +Hashran + Takahashi, Masuda + Takahashi, Masuda + Ker, Tudt, Riken, SCUC, Roch, TSUK, NIUCB + (KEK, TUdt, Riken, SCUC, Roch, TSUK, NIUCB + (KEK, TUdt, Riken, SCUC, Roch, TSUK, NIUCB +Chan, da Cruz, Garcia+ + (LSU, Carcia) +Busto, Farine, Jogens+ +Chan, da Cruz, Garcia+ + (Albinesio) + Aguilar-Beinlez, Ahlen, Akbari, Alcarazt + Aguilar-Beinlez, Ahlen, Akbari, Alcarazt + Rapilar-Beinlez, Ahlen, Akbari, Alcarazt + Rapilar-Being, Bratton, Casper, Dye+ + Rabhfesto + Belyaev, Bockholt, Demehin+ + Berker-Szendy, Bratton, Casper, Dye+ + (IMB Collab, - Becker-Szendy, Bratton, Casper, Dye+ + (IMB Collab, - Beinley, Frank - Bernatowicz, Brannon, Brazzle, Cowsik+ + (WSL), TATA + Busto, Campagne, Dassie, Hubert+ + (Soul), Jihl, Lill + Ahdand, Bryman, Burnham+ + (TRIU, CARL) - (TRIU, CARL)
FREEDMAN GRUWE HAMPEL KALBELEISCH KAWASHIMA OHSHIMA TURCK-CHI TURCK-CHI TURCK-CHI ARRENJE ARRENJE ARRENJE BAHRAN BALYSH BECKER-SZ BEIER AISO BERNATOW BLUM BORODOW BRITTON	93 93 93 93 93 93 93 93 93 93 92 92 92 92 92 92 92 92 92 92 92 92 92	PR C47 806 PR D47 811 PL 8309 463 JPG 19 5209 PL 8303 355 PR C47 R2452 PRL 70 394 PR D47 4840 PRPL 230 57 PRL 70 394 PRL 70 1759 PL 8774 230 PRL 70 1759 PL 8274 230 PRL 829 371 PL 8280 159 PL 8295 371 PL 8280 159 PL 8281 332 PRL 69 1010 PR D46 3720 PL 8283 446 PRL 69 2341 PL 8275 506 PRL 66 274 PL B275 506 PRL 66 274 PRL 66 3000		+Batusov, Bunyatov, Klimov+ +Pitt, Calaprice, Lowry Bernatowicz, Brazzle, Cowsik+ +Fujikawa, Napolitano, Nelson + +Hommaert, Vilain, Wilquet+ +Bahran +Takahashi, Masuda +Takahashi, Masuda +Takahashi, Masuda + (KK, TUAT, RIKEN, SCUC, ROCH, TSUK, NUS) Turck-Chiere+ + (KEK, TUAT, RIKEN, SCUC, ROCH, TSUK, NUS) Turck-Chiere, Lopez +Busto, Farine, Jorgens+ +Chan, da Cruz, Garcia+ +Aguliar-Benitez, Ahlen, Akbari, Alcaraz+ +Aguliar-Benitez, Ahlen, Akbari, Alcaraz+ +Raguliar-Benitez, Ahlen, Akbari, Alcaraz+ +Raguliar-Benitez, Ahlen, Akbari, Alcaraz+ +Raguliar-Benitez, Ahlen, Akbari, Alcaraz+ +Rajuliar-Benitez, Ahlen, Akbari, Alcaraz- +Belyaev, Bockholt, Demehin+ -Belyaev, Bockholt, Demehin+ -Belyaev, Bockholt, Demehin+ -Belyaev, Bockholt, Demehin+ -Belyaev, Bockholt, Saper, Dye+ -Beick-Fszendy, Bratton, Casper, Dye+ -Bratton, Todalon-Bratton, Calledon-Bratton-Br

ELLIOTT HIRATA HOLZSCHUH KAWAKAMI KETOV	92 92 92B 92 92	PR C46 1535 PL B280 146 PL B287 381 PL B287 45 JETPL 55 564	+Hahn, Moe+ (UCI) +Inoue, Ishida+ (Kamiokande II Collab.) +Fritschi, Kuendig (ZURI) + (INUS, KEK, SCUC, TUAT, RIKEN, ROCH, TSUK) +Machulin, Mikaelyan+
KUDOMI MORI REUSSER ABAZOV	92 92B 92 91B	JETPL 55 564 Translated from ZETFF PR C46 R2132 PL B289 463 PR D45 2548 PR D45 2548	+Ejiri, Nagata, Okada, Shibata+ (OSAK, INUS) +Hikasa, Nojiri, Oyama+ (KAM2 Collab.) Reussser, Treichel, Boehm+ (CIT, NEUC, VILL)
ABREU ALEXANDER AVIGNONE	91F 91F 91 91	PRL 67 3332 NP B367 511 ZPHY C52 175 PL B256 559 PL B266 193	+Anosov, Faizov+ (SAGE Collab.) +Adam, Adami, Adye, Akesson+ (DELPHI Collab.) +Brodzinski, Guerard+ (SCUC, PNL, ITEP, YERE) +Cremonesi, Florini, Gervasio+ (MILA, INFN)
BELLOTTI CASPER DELEENER	91 91	PRL 66 2561 PR D43 3611	De Leener-Rosier, Deutsch+ (LOUV, ZURI, LAUS)
EJIRI GARCIA HIME	91 91 91	PL B258 17 PRL 67 3654 PL B257 441	+Fushimi, Kamada, Kinoshita+ +Adelberger, Magnus, Swanson+ +Jelley (OSAK)
HIRATA HIRATA MORALES	91 91B 91	PRL 66 9 PR D44 2241 NC 104A 1581	+Inoue, Kajita, Kihara+ (Kamiokande II Collab.) +Morales, Nunez-Lagos, Puimedon+ (ZARA)
NORMAN REUSSER SATO	91 91 91	JPG 17 S291 PL B255 143 PR D44 2220	+Sur, Lesko+ (LBL) +Treichel, Boehm, Broggini+ (NEUC, CIT, PSI)
SUHONEN TURKEVICH	91 91	NP A535 509 PRL 67 3211	+Khadkikar, Faessler (JYV, AHMED, TUBIN) +Economou, Cowan (CHIC, LANL)
WONG YOU ADEVA	91 91 90S	PRL 67 1218 PL B265 53 PL B251 321	+Zhu, Lu+ (BHEP, CAST+) +Adriani, Aguilar-Benitez, Akbari+ (L3 Collab.)
AKRAWY BARABASH	90L 90	PL B247 448 PL B249 186	+Alexander, Allison, Allport+ (OPAL Collab.) +Kopylov, Cherehovsky (ITEP, INRM)
BATUSOV BERGER	90B 90B	ZPHY C48 209 PL B245 305	+Froehlich, Moench, Nisius+ (FREJUS Collab.)
BURCHAT DECAMP	90 90F 90	PR D41 3542 PL B236 511 PL B246 546	+King, Abrams, Adolphsen+ (Mark II Collab.) +Deschizeaux, Lees, Minard+ (ALEPH Collab.)
FILIPPONE HIRATA	90	PRL 65 1297	+Vogel +Inoue, Kajita+ (Kamiokande II Collab.)
HIRATA JUNG	90B 90	PRL 65 1301 PRL 64 1091	+Inoue, Kajita+ (Kamiokande II Collab.) +Inoue, Kajita+ (Kamiokande II Collab.) +Van Kooten, Abrams, Adolphsen+ (Mark II Collab.)
KOPEIKIN MILEY	90 90	JETPL 51 86 Translated from ZETFF PRL 65 3092	+Mikaziyan, Fayans (KIAE) 51 75. Avigana Bradzinski Callar Bayes (SCHC DNI)
STAUDT VASENKO	90	EPL 13 31	+Avignone, Brodzinski, Collar, Reeves +Muto, Klapdor-Kleingrothaus +Kirpichnikov, Kuznetsov, Starostin +Vyrodov, Gurevich, Koslov+ (KIAE)
VIDYAKIN	90 90	MPL A5 1299 JETP 71 424	+Kirpichnikov, Kuznetsov, Starostin +Vyrodov, Gurevich, Koslov+ 98 764. +Adolphsen, Averill, Ballam+ (Mark II Collab.)
ABRAMS AGLIETTA	89C 89	PRL 63 2447 EPL 8 611	+Adolphsen, Averill, Ballam+ (Mark II Collab.) +Battistoni, Bellotti+ (FREJUS Collab.)
ALSTON BAHCALL	89 89	PRL 63 1671	Alston-Garnjost, Dougherty+ (LBL, MTHO, UNM, INEL) Cambridge Univ. Press (IAS)
BARABASH BELLOTTI	89 89	Pl. B223 273	+Kuzminov, Lobashev, Novikov+ (ITEP, INRM)
BLUMENFELD DANEVICH		PL B221 209 PRL 62 2237 JETPL 49 476	+Cremonesi, Fiorini, Gervasio+ +Chi, Chichura, Chien+ +Zdesenko, Nikolaiko, Tretyak (UZINR)
DAVIS	89	Translated from ZETFF ARNPS 39 467	+Mann, Wolfenstein (BNL, PENN, CMU)
ENQVIST FISHER	89 89	NP B317 647 PL B218 257	+Kainulainen, Maalampi (HELS) +Boehm, Boyet, Egger+ (CIT, NEUC, PSI)
MUTO OYAMA	89 89	ZPHY A334 187 PR D39 1481	+Bender, Klapdor (TINT, MPIH) +Hirata, Kajita, Kifune+ +Blanis, Bodek, Budd+ (AMY Collab.)
SHAW AFONIN	89 88	PRL 63 1342 JETP 67 213	+Ketov, Kopeikin, Mikaelvan+ (KIAE)
AKERLOF	88	Translated from ZETF PR D37 577	+Chapman, Errede, Ken+ (HRS Collab.)
AMMOSOV BAHCALL	88 88	ZPHY C40 487 RMP 60 297	+Belikov+ (SKAT Collab.) +Ulrich (IAS, UCLA)
BERGSMA BERNARDI	88 88	ZPHY C40 171 PL B203 332	+Dorenbosch, Nieuwenhuis+ +Carugno, Chauveau+ (PARIN, CERN, INFN, ATEN)
BIONTA CALDWELL	88 88	PR D38 768 PRL 61 510	+Blewitt, Bratton, Casper+ (IMB Collab.)
DURKIN ENGEL	88 88	PRL 61 1811 PR C37 731	+Eisberg, Grumm, Witherell+ (UCSB, UCB, LBL) +Harper, Ling+ (OSU, ANL, CIT, LBL, LSU, LANL) +Vogel, Zimbene
LOVERRE MORALES	88 88	PL B206 711 NC 100A 525	+Morales, Nunez-Lagos, Puimedon+ (ZARA)
OLIVE SREDNICKI	88 88	PL B205 553 NP B310 693	+Srednicki (MINN, UCSB)
TURCK-CHI AFONIN	88 87	API 335 415	Turck-Chieze, Cahen, Casse, Doom (SACL BRUX)
AHLEN	87	Translated from ZETFI	TDOGATOV, VEISINIISKIIT (NIAC)
AHRENS BELLOTTI		PL B195 603	P 45 201.
	87 87	PR D36 702 EPL 3 889	+Avignone, Brodzinski+ (BOST, SCUC, HARV, CHIC) + (BNL, BROW, UCI, HIRO, KEK, OSAK, PENN, STON) +Cattadori, Cremonesi, Fiorini+ (MILA)
BOEHM Cambridge	87 87 Univ.	PR D36 702 EPL 3 889 Massive Neutrinos Press, Cambridge	+Avignone, Brodzinski+ (BOST, SCUC, HARV, CHIC) + (BNL, BROW, UCI, HIRO, KEK, OSAK, PENN, STON) +Cattadori, Cremonesi, Fiorini+ +Vogel (CIT)
BOEHM Cambridge BOFILL CALDWELL	87 87 Univ. 87 87	PR D36 702 EPL 3 889 Massive Neutrinos Press, Cambridge PR D36 3309 PRL 59 419	+Avignone, Brodzinski+ (BOST, SCUC, HARV, CHIC) + (BNL, BROW, UCI, HIRO, KEK, OSAK, PENN, STON) +Cattadori, Cremonesi, Fiorini+ +Vogel (CIT)
BOEHM Cambridge BOFILL CALDWELL DAUM GRIEST	87 87 Univ. 87 87 87	PR D36 702 EPL 3 889 Massive Neutrinos Press, Cambridge PR D36 3309 PRL 59 419 PR D36 2624	+Avignone, Brodzinski+ (BOST, SCUC, HARV, CHIC) + (BNL, BROW, UCI, HIRO, KEK, OSAK, PENN, STON) +Cattadori, Cremonesi, Fiorini+ +Vogel (CIT)
BOEHM Cambridge BOFILL CALDWELL DAUM GRIEST Also LOSECCO	87 87 Univ. 87 87 87 87 88	PR D36 702 EPL 3 889 Massive Neutrinos Press, Cambridge PR D36 3309 PRL 59 419 PR D36 2624 NP 8283 681 NP 8296 1034 erratun PL B184 305	+Avignone, Brodzinski+ (BOST, SCUC, HARV, CHIC) + (BNL, BROW, UCI, HIRO, KEK, OSAK, PENN, STO) +Cattadori, Cremonesi, Fiorini+ +Vogel (CIT) +Busza, Eldridge+ (MIT, FNAL, MSU) +Eisberg, Grumm, Witherell+ (UCSB, LBL) +Kettle, Jost+ (ISIN, VIRG) -Seckel (UCSC, CERN) -Griest, Seckel (UCSC, CERN) -Bilonta, Blewitt, Bratton+ (IMB Collab.)
BOEHM Cambridge BOFILL CALDWELL DAUM GRIEST Also LOSECCO MISHRA OBERAUER	87 87 Univ. 87 87 87 88 87 87 87	PR D36 702 EPL 3 889 Massive Neutrinos Press, Cambridge PR D36 3309 PRL 59 419 PR D36 2624 NP 8283 681 NP 8296 1034 erratun PL 8184 305 PRL 59 1397 PL 8198 113	+Avignone, Brodzinski+ (BOST, SCUC, HARV, CHIC) + (BNL, BROW, UCI, HIRO, KEK, OSAK, PENN, STO) +Cattadori, Cremonesi, Fiorini+ (MILA) +Vogel (CIT) +Biusza, Eldridge+ (MIT, FNAL, MSU) +Eisberg, Grumm, Witherell+ (UCSB, LBL) +Kettle, Jost+ (UCSC, CERN) -Keckel (USSC, CERN) -Griest, Seckel (USSC, CERN) -Hionta, Blewitt, Bratton+ (MID (IMB Collab.) +Auchincloss+ (COLU, CIT, FNAL, CHIC, ROCH) +von Feilitzsch, Mossbauer (MUNT)
BOEHM Cambridge BOFILL CALDWELL DAUM GRIEST Also LOSECCO MISHRA OBERAUER TALEBZADEH TOMODA	87 87 Univ. 87 87 87 88 87 87 87 87 87	PR D36 702 EPL 3 889 Massive Neutrinos Press, Cambridge PR D36 3309 PRL 59 419 PR D36 2624 NP 8283 681 NP 8296 1034 erratum PL B184 305 PRL 59 1397 PL B198 113 NP B291 503 PL B199 475	+Avignone, Brodzinski+ (BOST, SCUC, HARV, CHIC) + (BNL, BROW, UCI, HIRO, KEK, OSAK, PENN, STOM) +Cattadori, Cremonesi, Fiorini+ (MILA) +Vogel (CIT) +Busza, Eldridge+ (MIT, FNAL, MSU) +Eisberg, Grumm, Witherell+ (UCSB, LBL) -Kettle, Jost+ (USS, USK) -Seckel (USSC, CERN) -Seckel (UCSC, CERN) -Bionta, Blewitt, Bratton+ (MIB Collab.) +Auchincloss+ (COLU, CIT, FNAL, CHIC, ROCH) +Von Felitzsch, Mossbauer (MUSC) -Faessler (TUBIN)
BOEHM Cambridge BOFILL CALDWELL DAUM GRIEST Also LOSECCO MISHRA OBERAUER TALEBZADEH TOMODA VIDYAKIN	87 87 87 87 87 87 88 87 87 87 87 87	PR D36 702 EPL 3 889 Neutrinos Press, Cambridge PR D36 3309 PRL 59 419 PR D36 2624 NP B283 681 NP B298 1034 erratum PL B184 305 PRL 59 193 PR 199 193 NP B291 503 PL B199 475 JETP 66 243 Translated from ZETF PRI 58 1810	+Avignone, Brodzinski+ (BOST, SCUC, HARV, CHIC) + (BNL, BROW, UCL, HIRO, KEK, OSAK, PENN, STOM) +Cattadori, Cremonesi, Florini+ (MILA) +Vogel +Busa, Eldridge+ (MIT, FNAL, MSU) +Elsberg, Grumm, Witherell+ (UCSA, ERS) +Seckel (UCSC, CERN) +Borta, Blewitt, Bratton+ (USC, CERN) +Blonta, Blewitt, Bratton+ (MIM Collab.) +Auchincloss+ (COLU, CIT, FNAL, CHIC, ROCH) +COLVER, Venus+ (BEBC WA66 Collab.) +Faessler (TUBIN) +Vyrodow, Gurevich, Kozlov+ (KIAE) 93 424.
BOEHM Cambridge BOFILL CALDWELL DAUM GRIEST Also LOSECCO MISHRA OBERAUER TALEBZADEH TOMODA	87 87 Univ. 87 87 87 88 87 87 87 87 87	PR D36 702 EPL 3 889 Neutrinos Press, Cambridge PR D36 3309 PRL 59 419 PR D36 2624 NP B296 1034 erratun PL B184 305 PRL 59 1397 PL B198 113 NP B291 503 NP B291 503 PR 159 1297 PL B196 243 Translated from ZETF PRL 58 1810	+Avignone, Brodzinski+ (BOST, SCUC, HARV, CHIC) + (BNL, BROW, UCI, HIRO, KEK, OSAK, PENN, STOM) +Cattadori, Cremonesi, Fiorini+ (MILA) +Vogel +Busza, Eldridge+ (MIT, FNAL, MSU) +Eisberg, Grumm, Witherell+ (UCSB, LBL) -Kettle, Jost+ (USS, CERN) -Seckel (USS, CERN) -Griest, Seckel (USS, CERN) -HBionta, Blewitt, Bratton+ (IMB Collab.) +Auchinicloss+ (COLU, CIT, FNAL, CHIC, ROHL +von Felitzsch, Mossbauer (MUNT) -Foguy, Venus+ (BEBC WA66 Collab.) +Faessler -Wyrodov, Gurevich, Kozlov+ (KIAE) -93 424. +Abrams, Amidel, Baden+ (Mark II Collab.) +Bogatov, Borovoi, Vershinskii+ (KIAE)
BOEHM Cambridge BOFILL CALDWELL DAUM GRIEST Also LOSECCO MISHRA OBERRAUER TALEBZADEH TOMODA VIDYAKIN WENDT AFONIN ANGELINI AZUELOS	87 87 Univ. 87 87 87 88 87 87 87 87 87 87 87 87 87	PR D36 702 EPL 3 889 Massive Neutrinos Press, Cambridge PR D36 3309 PRL 59 419 PR D36 2624 NP B293 681 NP B296 1034 erratun PL B184 305 PRL 59 1397 PL B198 113 NP B291 503 PRL 59 1397 PL B198 113 NP B291 503 PRL 59 1397 PR 58 1810 PR 58 1810 PR 59 1817 PR 58 1810 PR 59 1817 Translated from ZETF PR 1817 307 PR 1819 307 PR 1819 307 PR 1819 307 PR 1819 307	+Avignone, Brodzinski+ (BOST, SCUC, HARV, CHIC) + (BNL, BROW, UCI, HIRO, KEK, OSAK, PENN, STOM) +Cattadori, Cremonesi, Fiorini+ (MILA) +Vogel +Bissza, Eldridge+ (MIT, FNAL, MSU) +Eisberg, Grumm, Witherell+ (UCSB, LBL) -Kettle, Jost+ (USS, CERN) -Seckel (USSC, CERN) -Seckel (USSC, CERN) -Griest, Seckel (USSC, CERN) -HBionta, Blewitt, Bratton+ (IMB Collab.) +Auchinicloss+ (COLU, CIT, FNAL, CHIC, ROCH) +von Felitzsch, Mossbauer (MUNT) -Foguy, Venus+ (BEBC WA66 Collab.) +Faessler -Vyrodov, Gurevich, Kozlov+ (KIAE) -93 474. +Bogatov, Borovoi, Vershinskii+ (Mark II Collab.) -44 111. +Apostolakis, Baldini+ (PISA, ATHU, PADO, WISC) -Britton, Bryman+ (TRU, CRC)
BOEHM Cambridge BOFILL CALDWELL DAUM GRIEST Also LOSECCO MISHRA OBERRAUER TALEBZADEH TOMODA VIDYAKIN WENDT AFONIN ANGELINI AZUELOS BADIER BELLOTTI	87 87 Univ. 87 87 87 88 87 87 87 87 87 87 87 87 87	PR D36 702 EPL 3 889 Massive Neutrinos Press, Cambridge PR D36 3309 PRL 59 419 PR D36 2624 NP B296 1034 erratun PL B184 305 PRL 59 1397 PL B198 113 NP B291 503 PPL B19 1475 JETP 66 243 JETP 66 243 JETP 66 245 JETP 46 142 Translated from ZETF PL B179 307 PRL 159 2241 ZPHY C31 2 1 ZPHY C41 2	+Avignone, Brodzinski+ (BOST, SCUC, HARW, CHIC) + (BNL, BROW, UCL, HIRO, KEK, OSAK, PENN, STOM) +Cattadori, Cremonesi, Fiorini+ (MILA) +Vogel +Busza, Eldridge+ (MIT, FNAL, MSU) +Eisberg, Grumm, Witherell+ (UCSB, LBL) -Kettle, Jost+ (USS, CERN) -Griest, Seckel (USSC, CERN) -Griest, Seckel (USSC, CERN) -HBionta, Blewitt, Bratton+ (IMB Collab.) +Auchincloss+ (COLU, CIT, FNAL, CHIC, ROCH) +von Feilitzsch, Mossbauer (MUNT) -Faessler -Vyrodow, Gurevich, Kozlov+ (BEBC WA66 Collab.) +Faessler -Wyrodow, Gurevich, Kozlov+ (KIAE) -93 424. +Bogatow, Borovoi, Vershinskii+ (Mark II Collab.) -44 111. +Apostolakis, Baldini+ (PISA, ATHU, PADO, WISC) -Britton, Bryman+ (RIG) -KIRO, STOM, CRIC,
BOEHM Cambridge BOFILL CALDWELL DAUM GRIEST AISO LOSECCO MISHRA OBERAUER TALEBZADEH TOMODA VIDVAKIN WENDT AFONIN ANGELINI AZUELOS BADIER BELLOTTI BERNARDI BERNARDI	87 87 87 87 87 87 87 88 87 87 87 87 87 8	PR D36 702 EPL 3 889 years Press, Cambridge PR D36 3309 PRL 59 419 PR D36 2624 NP B296 1034 erratun PL B184 305 PRL 59 1397 PL B198 113 NP B291 503 NP B291 503 PR 159 1397 PL B196 243 Translated from ZETF PRL 58 1810 JETPL 44 142 Translated from ZETF PRL 58 1207 PRL 56 2241 ZPHY C31 21 NC 95A 1 PL 1668 479	+ Avignone, Brodzinski+ (BOST, SCUC, HARV, CHIC) + (BNL, BROW, UCI, HIRO, KEK, OSAK, PENN, STOM) + Cattadori, Cremonesi, Fiorini+ (MILA) + Vogel + Busza, Eldridge+ (MIT, FNAL, MSU) + Eisberg, Grumm, Witherell+ (UCSB, LBL) - Kettle, Jost+ (USS, CERN) - Griest, Seckel (USSC, CERN) - Griest, Seckel (USSC, CERN) - HBionta, Blewitt, Bratton+ (IMB Coilab.) - HAuchinicloss+ (COLU, CIT, FNAL, CHIC, ROCH, - Hunder, Collab.) - Faessler - Horor, Gurevich, Kozlov+ (MUNT) - Horor, Gurevich, Kozlov+ (MICH) - 34 24 + Abrams, Amidei, Baden+ (Mark II Coilab.) - Hasgatov, Borovoi, Vershinskii+ (KIAE) - 44 111 Apostolakis, Baldini+ (PISA, ATHU, PADO, WISC) - Britton, Bryman+ (MIR) - Hemporad, Boucrot, Callot+ (MIR) - Hemporad, Fiorini, Liguori+ (MIR) - Hemporad, Guren, INFN, CDEF, ATEN, CERN) - Heard (CURIN, INFN, CDEF, ATEN, CERN) - Hermiden, Fiorini, Liguori+ (CRIN, INFN, CDEF, ATEN, CERN) - Hermiden, Fiorini, Liguori+ (CRIN, INFN, CDEF, ATEN, CERN)
BOEHM Cambridge BOFILL CALDWELL DAUM GRIEST AISO LOSECCO MISHRA OBERAUER TALEBZADEH TOMODA VIDVAKIN WENDT AFONIN ANGELINI AZUELOS BADIER BELLOTTI BERNARDI BORGE BRUCKER	87 87 Univ. 87 87 87 88 87 87 87 87 87 87 86 86 86 86 86 86 86 86 86 86 86 86	PR D36 702 EPL 3 889 Massive Neutrinos Press, Cambridge PR D36 3309 PRL 59 419 PR D36 2624 NP B296 1034 erratun PL B184 305 PRL 59 1397 PL B198 113 NP B291 503 PRL 59 1397 PL B198 113 NP B291 503 PRL 59 1397 PR D34 257 EFT P6 243 Translated from ZETF PRL 58 1810 IETPL 44 197 PRL 58 2241 ZPHY C31 21 ZPHY C31 21 PL 1666 479 PL B181 173 PS 34 591 PL B183 4591 PR D34 2183	+ Avignone, Brodzinski+ (BOST, SCUC, HARW, CHIC) + (BNL, BROW, UCL, HIRO, KEK, OSAK, PENN, STOM) + Cattadori, Cremonesi, Fiorini+ (MILA) + Vogel + Busza, Eldridge+ (MIT, FNAL, MSU) + Eisberg, Grumm, Witherell+ (UCSB, LBL) - Kettle, Jost+ (USSC, CERN) - Griest, Seckel (USSC, CERN) - Griest, Seckel (USSC, CERN) - Hellonta, Blewitt, Bratton+ (MB Collab.) - + Auchinicloss+ (COLU, CIT, FNAL, CHIC, ROCH) - + Von Feilitzsch, Mossbauer (MUNT) - Foguy, Venus+ (BEBC WA66 Collab.) - Faessler - Hyvrodow, Gurevich, Kozlov+ (BEBC WA66 Collab.) - 4 Horams, Amidei, Baden+ (Mark II Collab.) - Britton, Bryman+ (FISA, ATHU, PADO, WISC) - 44 H11 Apostolakis, Baldini+ (PISA, ATHU, PADO, WISC) - Hermonesi, Fiorini, Liguori+ (Curin, INFN, CDEF, ATEN, CERN) - Carugno+ (CURIN, INFN, CDEF, ATEN, CERN) - DeRujula, Hansen, Jonson+ (ISOLDE Collab.) - Hacques, Calleker, Koller+ (RICG, BNL, CENN)
BOEHM Cambridge BOFILL CALDWELL DAUM GRIEST AISO LOSECCO MISHRA OBERAUER TALEBZADEH TOMODA VIDVAKIN WENDT AFONIN ANGELINI AZUELOS BADIER BELLOTTI BERNARDI BERNARDI BORGE BRUCKER DELEENBER DORENBOS	87 87 87 87 87 88 87 88 87 87 87 87 87 8	PR D36 702 EPL 3 889 Massive Neutrinos Press, Cambridge PR D36 3309 PRL 59 419 PR D36 2624 NP B296 1034 erratun PL B184 305 PRL 59 1397 PL B198 113 NP B291 503 PRL 59 1397 PL B198 113 NP B291 503 PRL 59 1397 PRL 58 1810 IETPL 44 104 Translated from ZETF PRL 58 1810 IETPL 44 117 PRL 58 1810 IETPL 44 117 PRL 58 1810 IETPL 44 117 PRL 56 241 ZPHY C31 21 ZPHY C31 21 PL B166 479 PL B181 173 PS 34 591 PL B181 173 PS 34 591 PR D34 2183 PL B177 228 PL 1668 473	+Avignone, Brodzinski+ (BOST, SCUC, HARW, CHIC) + (BNL, BROW, UCL, HIRO, KEK, OSAK, PENN, STOM) +Cattadori, Cremonesi, Fiorini+ (MILA) +Vogel +Busza, Eldridge+ (MIT, FNAL, MSU) +Eisberg, Grumm, Witherell+ (UCSB, LBL) -Kettle, Jost+ (USSC, CERN) -Griest, Seckel (USSC, CERN) -Griest, Seckel (USSC, CERN) -Heinta, Blewitt, Bratton+ (IMB Collab.) +Auchincloss+ (COLU, CIT, FNAL, CHIC, ROCH) -Von Feilitzsch, Mossbauer (MUNT) -Faessler -Vyrodow, Gurevich, Kozlov+ (BEBC WA66 Collab.) +Faessler -Wyrodow, Gurevich, Kozlov+ (KIAE) -93 424. +Abrams, Amidei, Baden+ (Mark II Collab.) +Bogatow, Borovoi, Vershinskii+ (KIAE) -44 111. +Apostolakis, Baldini+ (PISA, ATHU, PADO, WISC) -44 111. +Apostolakis, Baldini+ (CRI) -Hemonesi, Fiorini, Liguori+ (TRIU, CNRC) +Cremonesi, Fiorini, Liguori+ +Carugno+ (CURIN, INFN, CDEF, ATEN, CERN) -Derugiula, Hansen, Jonson+ +Dacques, Kalelkar, Kolier+ (RICG, BIN, CEN) -Derehosch, Allaby, Amaldi+ (LARRM Collab.)
BOEHM Cambridge BOFILL CALDWELL DAUM GRIEST AISO LOSECCO MISHRA OBERAUER TALEBZADEH TOMODA VIDVAKIN WENDT AFONIN ANGELINI AZUELOS BADIER BELLOTTI BERNARDI BERNARDI BORGE BRUCKER DELEENBER DORENBOS GROTZ USHIDA	87 87 87 87 87 88 87 87 87 87 87 87 87 8	PR D36 702 EPL 3 889 Massive Neutrinos Press, Cambridge PR D36 3309 PRL 59 419 PR D36 2624 NP B296 1034 erratun PL B184 305 PRL 59 1397 PL B198 113 NP B291 503 PRL 59 1397 PL B198 113 NP B291 503 PRL 59 1397 PRL 58 1810 IETPL 44 197 PRL 58 1810 IETPL 44 197 PRL 58 241 ZPHY C31 21 ZPHY C31 21 PL 1666 479 PL B181 173 PS 34 591 PL B181 173 PS 34 591 PR D34 2183 PL B177 228 PL 1668 473 NC 9535 PRL 159 297	+Avignone, Brodzinski+ (BOST, SCUC, HARW, CHIC) + (BNL, BROW, UCL, HIRO, KEK, OSAK, PENN, STOM, +Cattadori, Cremonesi, Fiorini+ (MILA) +Vogel +Busza, Eldridge+ (MIT, FNAL, MSU) +Eisberg, Grumm, Witherell+ (UCSB, LBL) -Kettle, Jost+ (UCSC, CERN) -Griest, Seckel (UCSC, CERN) -Griest, Seckel (UCSC, CERN) -Haionta, Blewitt, Bratton+ (MB Collab.) +Auchincloss+ (COLU, CIT, FNAL, CHIC, ROCH, -Youn Feilitzsch, Mossbauer (MUNT) -Faessler -Vyrodow, Gurevich, Kozlov+ (BEBC WA66 Collab.) +Faessler -Wyrodow, Gurevich, Kozlov+ (KIAE) -93 424. +Abrams, Amidei, Baden+ (Mark II Collab.) +Bogatow, Borovoi, Vershinskii+ (KIAE) -44 111. +Apostolakis, Baldini+ (PISA, ATHU, PADO, WISC) -44 111. +Apostolakis, Baldini+ (TRIU, CNRC) +Bemporad, Boucrot, Callot- +Cremonesi, Fiorini, Liguori+ +Carugno+ (CURIN, INFN, CDEF, ATEN, CERN) -Derebosch, Filorini, Liguori+ +Carugno+ (CURIN, INFN, CDEF, ATEN, CERN) -Derebosch, Allaby, Amaldi+ (CHARM Collab.) -Klapdor -Kondo, Tasaka, Park, Song+ (FNAL ES31 Collab.) -(CHARM Collab.)
BOEHM Cambridge BOFILL CALDWELL DAUM GRIEST AISO LOSECCO MISHRA OBERAUER TALEBZADEH TOMODA VIDYAKIN WENDT AFONIN ANGELINI AZUELOS BADIER BELLOTTI BERNARDI BERNARDI BORGE BRUCKER DORENBOS GROTZ	87 87 101iv. 87 87 87 88 87 87 87 87 87 86 86 86 86 86 86 86 86 86 86 86 86 86	PR D36 702 EPL 3 889 Massive Neutrinos Press, Cambridge PR D36 3309 PRL 59 419 PR D36 2624 NP B296 1034 erratun PL B184 305 PRL 59 1397 PL B198 113 NP B291 503 PRL 59 1397 PL B198 113 NP B291 503 PRL 59 1397 PRL 58 1810 JETPL 44 142 Translated from ZETF PRL 58 1810 JETPL 44 142 PRH C31 21 PHY C31 21 PL 166B 479 PL B181 173 PS 34 591 PL 166B 479 PL 186B 473 NC 95 55 PRL 59 297 PR D34 2621 RL 166B 473 NC 95 55 PRL 57 2997 PRL 34 2627 PRL 57 2997 PRL 34 2621	+ Avignone, Brodzinski+ (BOST, SCUC, HARV, CHIC) + (BNL, BROW, UCL, HIRO, KEK, OSAK, PENN, STOM) + Cattadori, Cremonesi, Florini+ (MILA) + Vogel + Busza, Eldridge+ (MIT, FNAL, MSU) + Elsberg, Grumm, Witherell+ (USB, LBL) + Cecketl, Seckel (USC, CERN) + Blonta, Blewitt, Bratton+ (USC, CERN) + Blonta, Blewitt, Bratton+ (MIMB Collab.) + Auchincloss+ (COLU, CIT, FNAL, CHIC, ROCH) + Von Feilitzsch, Mossbauer + Guy, Venus+ (KIAE) + September (KIAE) + September (KIAE) + Vyrodov, Gurevich, Kozlov+ (KIAE) + 34 211. + Brogatov, Borrovi, Vershinskii+ (KIAE) + 44 111. + Brogatov, Borrovi, Vershinskii+ (KIAE) + Benproraf, Bourcrot, Callot+ (KIAE) + Cerugno+ (CURIN, INFN, CDEF, ATEN, CERN) + Carugno+ (LOUN, INFN, CERN, ATEN, CERN) + Carugno
BOEHM Cambridge BOFILL CALDWELL DAUM GRIEST AISO LOSECCO MISHRA OBERAUER TALEBZADEH TOMODA VIDYAKIN WENDT AFONIN ANGELINI AZUELOS BADIER BELLOTTI BERNARDI BERNARDI BORGE BRUCKER DORENBOS GROTZ USHIDA ZACEK	87 87 100 Univ. 87 87 887 887 887 887 887 887 886 886 8	PR D36 702 EPL 3 889 Neutrinos Press, Cambridge PR D36 3309 PRL 59 419 PR D36 2624 NP B296 1034 erratun PL 8184 305 PRL 59 1397 PL 8198 113 NP B291 503 NP B291 503 PR D39 1475 JETP 66 243 Translated from ZETF PRL 58 1810 JETPL 44 142 Translated from ZETF L B179 307 PRL 56 2241 ZPHY C31 21 NC 95A 1 PL 1669 479 PL B181 173 PL 1668 479 PL B181 173 PS 34 591 PR D34 2183 PR D34 2183 PR D34 2183 PR D37 289 PR 166 473 PR 166 479 PL 8166 479 PL 817 268 PL 167 269 PR 57 2697 PR 57 2697 PR 57 2697 PR 57 2697	+Avignone, Brodzinski+ (BNT, SCUC, HARV, CHIC) + (BNL, BROW, UCL, HIRV, KEK, OSAK, PENN, STOM) +Cattadori, Cremonesi, Fiorini+ +Vogel +Busza, Eldridge+ + (MIT, FNAL, MSU) +Eisberg, Grumm, Witherell+ + (UCSB, LBL) -Seckel (UCSC, CERN) -Seckel +Seckel -Seckel -S
BOEHM Cambridge BOFILL CALDWELL DAUM GRIEST AISO LOSECCO MISHRA OBERAUER TALEBZADEH TOMODA VIDVAKIN WENDT AFONIN ANGELINI AZUELOS BADIER BELLOTTI BERNARDI BORGE BRUCKER DELEENBER DORENBOS GROTZ USHIDA AISO AHRENS ALBRECHT	87 Univ. 87 87 87 87 88 87 87 87 87 87 87 86 86 86 86 86 86 86 86 86 86 86 86 86	PR D36 702 EPL 3 889 Massive Neutrinos Press, Cambridge PR D36 3309 PRL 59 419 PR D36 3209 PRL 59 419 PR D36 2624 PR D36 2624 PR D36 2624 PR D36 2624 PR D36 26309 PRL 59 1337 PR D37 22FF PR D37 247	+Avignone, Brodzinski+ (BOST, SCUC, HARW, CHIC) + (BNL, BROW, UCL, HIRO, KEK, OSAK, PENN, STOM) +Cattadori, Cremonesi, Fiorini+ (MILA) +Vogel +Biusza, Eldridge+ (MIT, FNAL, MSU) +Eisberg, Grumm, Witherell+ (UCSB, LBL) -Seckel (USSC, CERN) -Seckel (USSC, CERN) -Seckel (USSC, CERN) -Seckel (USSC, CERN) -Hainata, Blewitt, Bratton+ (MUSC, CERN) -Paussier (COLU, CIT, FNAL, CHIC, ROCH -von Feilitzsch, Mossbauer -Koup, Venus+ (BEBC WA66 Collab.) +Faessier -Vyrodow, Gurevich, Kozlov+ 93 424Partson, Bryman+ (MIRM) -Borgatow, Borrovoi, Vershinskii+ (KIAE) -Bertborad, Baucrot, Callot+ -Cerumonesi, Fiorini, Liguori+ -Cerumonesi, Portantonesi (MILA) -Cerumonesi, BaldiniCerumonesi, Cullani, NFN, CDEF, ATEN, CERN) -Derebusha, BaldiniCerumonesi, Cullani, NFN, CDEF, ATEN, CERN) -Derebusha, BaldiniCerumonesi, Cullani, NFN, CDEF, ATEN, CERN, -Cerumonesi, Cullani, NFN, CD
BOEHM Cambridge BOFILL CALDWELL DAUM GRIEST AISO LOSECCO MISHRA OBERAUER TALEBZADEH TOMODA VIDVAKIN WENDT AFONIN ANGELINI AZUELOS BADIER BELIOS BADIER BELIOS BADIER BELIOS BADIER BELIOS BADIER BELIOS BADIER DELEENER DORENBOS GROTZ USHIDA ZACEK AFONIN AISO AHRENS	87 Univ. 87 87 87 87 88 87 87 87 87 87 87 86 86 86 86 86 86 86 86 86 86 86 86 86	PR D36 702 EPL 3 889 Massive Neutrinos Press, Cambridge PR D36 3309 PRL 59 419 PR D36 2624 NP B296 1034 erratun PL B184 305 PRL 59 1397 PL B198 113 NP B291 503 PRL 59 1397 PL B198 113 NP B291 503 PRL 59 1397 PR D34 261 Translated from ZETF PRL 58 1810 Translated from ZETF PRL 58 241 ZPHY C31 21 ZPHY C31 2	+Avignone, Brodzinski+ (BOST, SCUC, HARY, CHIC) + (BNL, BROW, UCL, HIRO, KEK, OSAK, PENN, STOM) +Cattadori, Cremonesi, Fiorini+ +Vogel (CIT) +Busza, Eldridge+ (MIT, FNAL, MSU) +Eisberg, Grumm, Witherell+ (UCSB, LBL) -Seckel (USSC, CERN) -Griest, Seckel (USSC, CERN) -Hionta, Blewitt, Bratton+ (USSC, CERN) -Honta, Blewitt, Bratton+ (USSC, CERN) -Honta, Blewitt, Bratton+ (HIRO) -Facssler -Vyrodov, Gurevich, Kozlov+ (SIAE) -93 424Abrams, Amidei, Baden+ +Bogatov, Borovoi, Vershinskii+ (KIAE) -44 111Apostolakis, Baldini+ (PISA, ATHU, PADO, WISC) -Britton, Bryman+ (TRIU, CNRC) -Bremonsel, Fiorini, Liguori+ +Carugno+ (CURIN, INFN, CDEF, ATEN, CERN) -DerRobsch, Filorini, Liguori+ +Carugno+ (CURIN, INFN, CDEF, ATEN, CERN) -DerRobsch, Allaby, Amaldi- (CHARM Collab.) +Klapdor -Hondon, Tasaka, Park, Song+ -Felitzsch+ -Hondo, Tasaka, Park, Song+ -Felitzsch+ -Borson, Dobrynin+ - (KIAE) - (CHARM Collab.) - Hellitzsch+ - Hondon, Tasaka, Park, Song+ - Felitzsch+ - Hondon, Tasaka, Park, Song+ - Hellitzsch+ - Hondon, Dobrynin+ - Handro, Drescher, Schubert+ - Albard, Bogatov, Borovoi, Dobrynin+ - Handro, Drescher, Schubert+ - Handro, Drescher, Schubert Handro, Drescher
BOEHM Cambridge BOFILL CALDWELL DAUM GRIEST AISO LOSECCO MISHRA OBERAUER TALEBZADEH TOMODA VIDVAKIN WENDT AFONIN ANGELINI AZUELOS BORGE BERNARDI BERNARDI BERNARDI BORGE BRUCKER DELEENER DORENBOS GROTZ USHIDA ZACEK AFONIN AISO AHRENS ALBRECHT ALTZITZOG	87 Univ. 87 87 87 87 88 87 88 87 87 87 87 88 86 86 86 86 86 86 86 86 86 86 86 86	PR D36 702 EPL 3 889 Massive Neutrinos Press, Cambridge PR D36 3309 PRL 59 419 PR D36 2624 NP B296 1034 erratun PL B184 305 PRL 59 1397 PL B198 113 NP B291 503 PRL 59 1397 PL B198 113 NP B291 503 PRL 59 1397 PRL 58 1810 JETPL 44 142 Translated from ZETF PRL 58 1810 JETPL 47 142 Translated from ZETF PRL 58 1810 JETPL 47 142 Translated from ZETF PRL 58 120 PRL 59 24 59 PRL 59 24 59 PRL 59 34 59 PRL 59 34 59 PRL 59 34 59 PRL 57 2897 PRL	+Avignone, Brodzinski+ (BOST, SCUC, HARY, CHIC) + (BNL, BROW, UCL, HIRO, KEK, OSAK, PENN, STOM) +Cattadori, Cremonesi, Fiorini+ +Vogel +Busza, Eldridge+ (MIT, FNAL, MSU) +Eisberg, Grumm, Witherell+ (UCSB, LBL) -Seckel (UCSC, CERN) -Griest, Seckel (UCSC, CERN) -Griest, Seckel (UCSC, CERN) -Holnat, Blewitt, Bratton+ (UCSC, CERN) -Holnat, Blewitt, Bratton+ (HURT) -Faugh, Yenus+ (BEBC WA66 Collab.) +Vryordow, Gurevich, Kozlov+ 93 424Vyrodow, Gurevich, Kozlov+ 93 424Holnat, Albert, Mossbauer (MUNT) -Faessler -Vyrodow, Gurevich, Kozlov+ 93 424Holnat, Albert, Mossbauer -Holnat, Formon, Liguori+ -Hospatow, Borrovoi, Vershinskii+ -Hospatow, Borrovoi, Vershinskii+ -Hospatow, Borrovoi, Vershinskii+ -Hospatow, Borrovoi, Vershinskii+ -Carugno+ -Cremonesi, Fiorini, Liguori+ -Cremonesi, Fiorini, Liguori+ -Carugno+ -Carugno+ -Curlin, INFN, CDEF, ATEN, CERN) -DeRbosch, Allaby, AmaldiChard, Allaby, AmaldiChard, Allaby, AmaldiKondo, Tasaka, Park, Song+ -Fellitzsch+ -Horovoi, Dobrynin+ -Moroson+ -Moros

Lepton Particle Listings Massive Neutrinos and Lepton Mixing

COOPER	85	PL 160B 207	Cooper-Sarkar+ (CE	ERN, LOIC, OXF, SACL+
COWSIK	85	PL 151B 62		(TATA)
DATAR	85	Nature 318 547	+Baba, Bhattacherjee, Bhuinya, F	
HUBERT	85	NC 85A 19	+Leccia, Dassie, Mennrath+	(BCEN, ZARA)
MARKEY	85	PR C32 2215	+Boehm	(CIT)
OHI	85	PL 160B 322	+Nakajima, Tamura+	(TOKY, INUS, KEK)
SIMPSON	85	PRL 54 1891		(GUEL)
STOCKDALE	85	ZPHY C27 53		OCH, CHIC, COLU, FNAL
ZACEK	85	PL 164B 193	+Zacek, Boehm+	(MUNI, CIT, SIN
BALLAGH	84	PR D30 2271		AL, HAWA, WASH, WISC
BERGSMA	84	PL 142B 103	+Dorenbosch, Allaby, Abt+	(CHARM Collab.)
CAVAIGNAC	84	PL 148B 387	+Hoummada, Koang+	(ISNG, LAPP)
DYDAK	84	PL 134B 281		RT, HEIDH, SACL, WARS
FORSTER	84	PL 138B 301	+Kwon, Markey, Boehm, Henrikso	
FREESE	84	NP B233 167	+Schramm	(CHIC, FNAL)
GABATHULER	84	PL 138B 449	+Boehm+	(CIT, SIN, MUNI)
HAXTON	84	PPNP 12 409	+Stevenson	
MINEHART	84	PRL 52 804	+Ziock, Marshall, Stephens, Daun	n+ (VIRG, SIN)
SCHRAMM	84	PL 141B 337	+Steigman	(FNAL, BART)
STOCKDALE	84	PRL 52 1384	+Bodek+ (RC	CH, CHIC, COLU, FNAL
AFONIN	83	JETPL 38 436	+Bogatov, Borovoi, Vershinskii+	(KIAE)
		Translated from ZETFF		
AVIGNONE	83	PRL 50 721	+Brodzinski, Brown, Evans, Hensi	
BELENKII	83	JETPL 38 493	+Dobrynin, Zemlyakov, Mikaelyan	+ (KIAE)
		Translated from ZETFF		
BELIKOV	83	JETPL 38 661 Translated from ZETFF	+Volkov, Kochetkov, Mukhin, Svi	ridov+ (SERP)
BERGSMA	83	PL 122B 465	+Dorenbosch, Jonker+	(CHARM Collab.)
BERGSMA	83B	PL 122B 463	+Dorenbosch+	(CHARM Collab.)
BRYMAN	83B	PRL 50 1546	+Dubois, Numao, Olaniya, Olin+	
Also	83	PRL 50 1546	Bryman, Dubois, Numao, Olaniy	
DEUTSCH	83	PR D27 1644	+Lebrun, Prieels	
FILIPPONE	83	PRL 50 412	+Elwyn, Davids+	(LOUV)
GRONAU	83	PR D28 2762	+Elwyll, Davius+	(ANL, CHIC, VALP)
KIRSTEN	83	PRL 50 474	+Richter, Jessberger	(HAIF) (MPIH)
Also	83B	ZPHY 16 189	Kirsten, Richter, Jessberger	(MPIH)
SCHRECK	83	PL 129B 265	Schreckenbach, Colvin+	(ISNG, ILLG)
TAYLOR	83	PR D28 2705	+Cence, Harris, Jones+	(HAWA, LBL, FNAL)
BAHCALL	82	RMP 54 767		ANL, HPC, YALE, UCLA
COOPER	82	PL 112B 97	+Guy, Michette, Tyndel, Venus	(RL)
FILIPPONE	82	APJ 253 393	+Schramm	(ANL, EFI)
FOWLER	82	A.I.P. 96 80		(CIT)
HAXTON	82	PR D25 2360	+Stephenson, Strottman	(LANL, PURD)
HAYANO	82	PRL 49 1305	+Taniguchi, Yamanaka+	(TOKY, KEK, TSUK)
OLIVE	82	PR D25 213	+Turner	(CHIC, UCSB)
VUILLEUMIER		PL 114B 298	+Boehm, Egger+	(CIT, SIN, MUNI)

ABELA	81	PL 105B 263	+Daum, Eaton, Frosch, Jost, Kettle, Steiner (SIN)	
ARMENISE	81	PL 100B 182	+Fogli-Muciaccia+ (BARI, CERN, MILA, LÀLO)	
ASANO	81	PL 104B 84	+Hayano, Kikutani, Kurokawa+(KEK, TOKY, INUS, OSAK)	
Also	81	PR D24 1232	Shrock (STON)	
ASRATYAN	81	PL 105B 301	+Efremenko, Fedotov+ (ITEP, FNAL, SERP, MICH)	
BAKER	81	PRL 47 1576	+Connolly, Kahn, Kirk, Murtagh+ (BNL, COLU)	
Also	78	PRL 40 144	Cnops, Connolly, Kahn, Kirk+ (BNL, COLU)	
BERNSTEIN	81	PL 101B 39	+Feinberg (STEV, COLU)	
BOLIEV	81	SJNP 34 787	+Butkevich, Zakidyshev, Makoev+ (INRM)	
		Translated from YAF 3	4 1418.	
CALAPRICE	81	PL 106B 175	+Schreiber, Schneider+ (PRIN, IND)	
DEDEN	81	PL 98B 310	+Grassler, Boeckmann, Mermikides+ (BEBC Collab.)	
ERRIQUEZ	81	PL 102B 73	+Natali+ (BARI, BIRM, BRUX, EPOL, RHEL, SACL+)	
HAXTON	81	PRL 47 153	+Stephenson, Strottman (PURD, LASL)	
KWON	81	PR D24 1097	+Boehm, Hahn, Henrikson+ (CIT, ISNG, MUNI)	
NEMETHY	81B		+ (YALE, LBL, LASL, MIT, SACL, SIN, CNRC, BERN)	
SHROCK	81	PR D24 1232	(STON)	
SHROCK	81B		(STON)	
SILVERMAN	81	PRL 46 467	+Soni (UCI, UCLA)	
SIMPSON		PR D24 2971	(GUEL)	
USHIDA	81	PRL 47 1694	+ (AICH, FNAL, KOBE, SEOU, MCGI, NAGO, OSU+)	
AVIGNONE	80	PR C22 594	+Greenwood (SCUC)	
BAHCALL	80	PRL 45 945	+Lubow, Huebner+ (IAS, LASL, YALE, LLL, UCLA)	
Also	76	Science 191 264	Bahcall, Davis (IAS, EASE, TAEE, EEE, OCEA)	
BOEHM	80	PL 97B 310	+Cavaignac, Feilitzsch+ (ILLG, CIT, ISNG, MUNI)	
FRITZE	80	PL 96B 427	(AACH3, BONN, CERN, LOIC, OXF, SACL)	
REINES	80	PRL 45 1307	+Sobel, Pasierb (UCI)	
Also	59	PR 113 273	Reines, Cowan (LASL)	
Also	66	PR 142 852	Nezrick, Reines (CASE)	
Also	76	PRL 37 315	Reines, Gurr, Sobel (UCI)	
SHROCK	80	PL 96B 159	(STON)	
DAVIS	79	PR C19 2259	+Vogel, Mann, Schenter (CIT)	
BLIETSCHAU	78	NP B133 205	+Deden, Hasert, Krenz+ (Gargamelle Collab.)	
CROUCH	78	PR D18 2239	+Landecker, Lathrop, Reines+ (CASE, UCI, WITW)	
MEYER	77	PL 70B 469	+Nguyen, Abrams+ (SLAC, LBL, NWES, HAWA)	
VYSOTSKY	77	JETPL 26 188	+Dolgov, Zeldovich (ITEP)	
V13013K1		Translated from ZETEP		
BELLOTTI	76	LNC 17 553	+Cavalli, Fiorini, Rollier (MILA)	
SZALAY	76	AA 49 437	+Marx (EOTV)	
SZALAY	74	APAH 35 8	+Marx (EOTV)	
COWSIK	72	PRL 29 669	+McClelland (UCB)	
MARX	72	Nu Conf. Budapest	+Szalay (EOTV)	
GERSHTEIN	66	JETPL 4 120	+Zeldovich (KIAM)	
GEROITT EIN	00	Translated from ZETFP		

QUARKS Notes in the Quark Listings Quark Masses

QUARKS

QUARK MASSES

(by A. Manohar, University of California, San Diego)

A. Introduction

This note discusses some of the theoretical issues involved in the determination of quark masses. Unlike the leptons, quarks are confined inside hadrons and are not observed as physical particles. Quark masses cannot be measured directly, but must be determined indirectly through their influence on hadron properties. As a result, the values of the quark masses depend on precisely how they are defined; there is no one definition that is the obvious choice. Though one often speaks loosely of quark masses as one would of the electron or muon mass, any careful statement of a quark mass value must make reference to a particular computational scheme that is used to extract the mass from observations. It is important to keep this scheme dependence in mind when using the quark mass values tabulated in the data listings.

The simplest way to define the mass of a quark is by making a fit of the hadron mass spectrum to a nonrelativistic quark model. The quark masses are defined as the values obtained from the fit. The resulting masses only make sense in the limited context of a particular quark model. They depend on the phenomenological potential used, and on how relativistic effects are modelled. The quark masses used in potential models also cannot be connected with the quark mass parameters in the QCD Lagrangian. Fortunately, there exist other definitions of the quark mass that have a more general significance, though they also depend on the method of calculation. The purpose of this review is to explain the most important such definitions and their interrelations.

B. Mass parameters and the QCD Lagrangian

The QCD Lagrangian for N_F quark flavors is

$$\mathcal{L} = \sum_{k=1}^{N_F} \overline{q}_k (i \not\!\!\!D - m_k) q_k - \frac{1}{4} G_{\mu\nu} G^{\mu\nu} , \qquad (1)$$

where $\not D = (\partial_\mu - igA_\mu)\,\gamma^\mu$ is the gauge covariant derivative, A_μ is the gluon field, $G_{\mu\nu}$ is the gluon field strength, m_k is the mass parameter of the $k^{\rm th}$ quark, and q_k is the quark Dirac field. The QCD Lagrangian Eq. (1) gives finite scattering amplitudes after renormalization, a procedure that invokes a subtraction scheme to render the amplitudes finite, and requires the introduction of a dimensionful scale parameter μ . The mass parameters in the QCD Lagrangian Eq. (1) depend on the renormalization scheme used to define the theory, and also on the scale parameter μ . The most commonly used renormalization scheme for QCD perturbation theory is the $\overline{\rm MS}$ scheme.

The QCD Lagrangian has a chiral symmetry in the limit that the quark masses vanish. This symmetry is spontaneously broken by dynamical chiral symmetry breaking, and explicitly broken by the quark masses. The nonperturbative scale of dynamical chiral symmetry breaking, Λ_{χ} , is around 1 GeV. It is conventional to call quarks heavy if $m > \Lambda_{\chi}$, so that explicit chiral symmetry breaking dominates, and light if $m < \Lambda_{\chi}$, so that spontaneous chiral symmetry breaking dominates. The c, b, and t quarks are heavy, and the u, d and s quarks are light. The computations for light quarks involve an expansion in m_q/Λ_{χ} about the limit $m_q=0$, whereas for heavy quarks, they involve an expansion in Λ_{χ}/m_q about $m_q=\infty$. The corrections are largest for the s and c quarks, which are the heaviest light quark and the lightest heavy quark, respectively.

At high energies or short distances, nonperturbative effects such as chiral symmetry breaking are unimportant, and one can in principle analyze mass-dependent effects using QCD perturbation theory to extract the quark mass values. The QCD computations are conventionally performed using the $\overline{\rm MS}$ scheme at a scale $\mu\gg \Lambda\chi$, and give the $\overline{\rm MS}$ "running" mass $\overline{m}(\mu)$. The μ dependence of $\overline{m}(\mu)$ at short distances can be calculated using the renormalization group equations.

For heavy quarks, one can obtain useful information on the quark masses by studying the spectrum and decays of hadrons containing heavy quarks. One method of calculation uses the heavy quark effective theory (HQET), which defines a HQET quark mass m_Q . Other commonly used definitions of heavy quark masses such as the pole mass are discussed in Sec. C. QCD perturbation theory at the heavy quark scale $\mu=m_Q$ can be used to relate the various heavy quark masses to the $\overline{\rm MS}$ mass $\overline{m}(\mu)$, and to each other.

For light quarks, one can obtain useful information on the quark mass ratios by studying the properties of the light pseudoscalar mesons using chiral perturbation theory, which utilizes the symmetries of the QCD Lagrangian Eq. (1). The quark mass ratios determined using chiral perturbation theory are those in a subtraction scheme that is independent of the quark masses themselves, such as the $\overline{\rm MS}$ scheme.

A more detailed discussion of the masses for heavy and light quarks is given in the next two sections. The $\overline{\rm MS}$ scheme applies to both heavy and light quarks. It is also commonly used for predictions of quark masses in unified theories, and for computing radiative corrections in the Standard Model. For this reason, we use the $\overline{\rm MS}$ scheme as the standard scheme in reporting quark masses. One can easily convert the $\overline{\rm MS}$ masses into other schemes using the formulæ given in this review.

C. Heavy quarks

The commonly used definitions of the quark mass for heavy quarks are the pole mass, the $\overline{\rm MS}$ mass, the Georgi-Politzer mass, the potential model mass used in ψ and Υ spectroscopy, and the HQET mass.

The strong interaction coupling constant at the heavy quark scale is small, and one can compute the heavy quark propagator using QCD perturbation theory. For an observable particle such as the electron, the position of the pole in the propagator is the definition of the particle mass. In QCD this definition of the quark mass is known as the pole mass m_P , and is

Quarks

independent of the renormalization scheme used. It is known that the on-shell quark propagator has no infrared divergences in perturbation theory [1], so this provides a perturbative definition of the quark mass. The pole mass cannot be used to arbitrarily high accuracy because of nonperturbative infrared effects in QCD. The full quark propagator has no pole because the quarks are confined, so that the pole mass cannot be defined outside of perturbation theory.

The $\overline{\rm MS}$ running mass $\overline{m}(\mu)$ is defined by regulating the QCD theory using dimensional regularization, and subtracting the divergences using the modified minimal subtraction scheme. The $\overline{\rm MS}$ scheme is particularly convenient for Feynman diagram computations, and is the most commonly used subtraction scheme.

The Georgi-Politzer mass \widehat{m} is defined using the momentum space subtraction scheme at the spacelike point $-p^2 = \widehat{m}^2$ [2]. A generalization of the Georgi-Politzer mass that is often used in computations involving QCD sum rules [3] is $\widehat{m}(\xi)$, defined at the subtraction point $p^2 = -(\xi + 1)m_P^2$. QCD sum rules are discussed in more detail in the next section on light quark masses.

Lattice gauge theory calculations can be used to obtain heavy quark masses from ψ and Υ spectroscopy. The quark masses are obtained by comparing a nonperturbative computation of the meson spectrum with the experimental data. The lattice quark mass values can then be converted into quark mass values in the continuum QCD Lagrangian Eq. (1) using lattice perturbation theory at a scale given by the inverse lattice spacing. A recent computation determines the *b*-quark pole mass to be 5.0 ± 0.2 GeV, and the $\overline{\rm MS}$ mass to be 4.0 ± 0.1 GeV [4].

Potential model calculations of the hadron spectrum also involve the heavy quark mass. There is no way to relate the quark mass as defined in a potential model to the quark mass parameter of the QCD Lagrangian, or to the pole mass. Even in the heavy quark limit, the two masses can differ by nonperturbative effects of order $\Lambda_{\rm QCD}$. There is also no reason why the potential model quark mass should be independent of the particular form of the potential used.

Recent work on the heavy quark effective theory [5-9] has provided a definition of the quark mass for a heavy quark that is valid when one includes nonperturbative effects and will be called the HQET mass m_Q . The HQET mass is particularly useful in the analysis of the $1/m_Q$ corrections in HQET. The HQET mass agrees with the pole mass to all orders in perturbation theory when only one quark flavor is present, but differs from the pole mass at order α_s^2 when there are additional flavors [10]. Physical quantities such as hadron masses can in principle be computed in the heavy quark effective theory in terms of the HQET mass m_Q . The computations cannot be done analytically in practice because of nonperturbative effects in QCD, which also prevent a direct extraction of the quark masses from the original QCD Lagrangian, Eq. (1). Nevertheless, for heavy quarks, it is possible to parametrize the nonperturbative effects to a given order in the $1/m_Q$ expansion in terms of a few unknown constants that can be obtained from experiment. For example, the B and D meson masses in the heavy quark effective theory are given in terms of a single nonperturbative parameter $\overline{\Lambda}$,

$$M(B) = m_b + \overline{\Lambda} + \mathcal{O}\left(\frac{\overline{\Lambda}^2}{m_b}\right) ,$$

$$M(D) = m_c + \overline{\Lambda} + \mathcal{O}\left(\frac{\overline{\Lambda}^2}{m_c}\right) .$$
(2)

This allows one to determine the mass difference $m_b - m_c =$ M(B) - M(D) = 3.4 GeV up to corrections of order $\overline{\Lambda}^2/m_b - M(B) = 3.4 \text{ GeV}$ $\overline{\Lambda}^2/m_c$. The extraction of the individual quark masses m_b and m_c requires some knowledge of $\overline{\Lambda}$. An estimate of $\overline{\Lambda}$ using QCD sum rules gives $\overline{\Lambda} = 0.57 \pm 0.07$ GeV [11]. The HQET masses with this value of $\overline{\Lambda}$ are $m_b = 4.74 \pm 0.14$ GeV and $m_c = 1.4 \pm 0.2$ GeV, where the spin averaged meson masses $(3M(B^*) + M(B))/4$ and $(3M(D^*) + M(D))/4$ have been used to eliminate the spin-dependent $\mathcal{O}(\overline{\Lambda}^2/m_Q)$ correction terms. The errors reflect the uncertainty in $\overline{\Lambda}$ and the unknown spinaveraged $\mathcal{O}(\overline{\Lambda}^2/m_Q)$ correction. The errors do not include any theoretical uncertainty in the QCD sum rules, which could be large. A quark model estimate suggests that $\overline{\Lambda}$ is the constituent quark mass (≈ 350 MeV), which differs significantly from the sum rule estimate. In HQET, the $1/m_Q$ corrections to heavy meson decay form-factors are also given in terms of $\overline{\Lambda}$. Thus an accurate enough measurement of these form-factors could be used to extract $\overline{\Lambda}$ directly from experiment, which then determines the quark masses up to corrections of order $1/m_Q$.

The quark mass m_Q of HQET can be related to other quark mass parameters using QCD perturbation theory at the scale m_Q . The relation between m_Q and $\widehat{m}(\xi)$ at one loop is [12]

$$m_Q = \widehat{m}(\xi) \left[1 + \frac{\widehat{\alpha}_s(\xi)}{\pi} \frac{\xi + 2}{\xi + 1} \log(\xi + 2) \right], \tag{3}$$

where $\widehat{\alpha}_s(\xi)$ is the strong interaction coupling constant in the momentum space subtraction scheme. The relation between m_O and the $\overline{\text{MS}}$ mass \overline{m} is known to two loops [13],

$$m_Q = \overline{m}(m_Q) \left[1 + \frac{4\overline{\alpha}_s(m_Q)}{3\pi} + \left(16.11 - 1.04 \sum_k \left(1 - \frac{m_{Q_k}}{m_Q} \right) \right) \left(\frac{\overline{\alpha}_s(m_Q)}{\pi} \right)^2 \right], \quad (4)$$

where $\overline{\alpha}_s(\mu)$ is the strong interaction coupling constants in the $\overline{\text{MS}}$ scheme, and the sum on k extends over all flavors Q_k lighter than Q. For the b-quark, Eq. (4) reads

$$m_b = \overline{m}_b (m_b) [1 + 0.09 + 0.06],$$
 (5)

where the contributions from the different orders in α_s are shown explicitly. The two loop correction is comparable in size and has the same sign as the one loop term. There is

presumably an error of order 0.05 in the relation between m_b and $\overline{m}_b(m_b)$ from the uncalculated higher order terms.

D. Light quarks

For light quarks, one can use the techniques of chiral perturbation theory to extract quark mass ratios. The light quark part of the QCD Lagrangian Eq. (1) has a chiral symmetry in the limit that the light quark masses are set to zero, under which left- and right-handed quarks transform independently. The mass term explicitly breaks the chiral symmetry, since it couples the left- and right-handed quarks to each other. A systematic analysis of this explicit chiral symmetry breaking provides some information on the light quark masses.

It is convenient to think of the three light quarks u, d and s as a three component column vector Ψ , and to write the mass term for the light quarks as

$$\overline{\Psi}M\Psi = \overline{\Psi}_L M\Psi_R + \overline{\Psi}_R M\Psi_L, \tag{6}$$

where M is the quark mass matrix M,

$$M = \begin{pmatrix} m_u & 0 & 0 \\ 0 & m_d & 0 \\ 0 & 0 & m_s \end{pmatrix}. \tag{7}$$

The mass term $\overline{\Psi}M\Psi$ is the only term in the QCD Lagrangian that mixes left- and right-handed quarks. In the limit that $M\to 0$, there is an independent SU(3) flavor symmetry for the left- and right-handed quarks. This $G\chi=\mathrm{SU}(3)_L\times\mathrm{SU}(3)_R$ chiral symmetry of the QCD Lagrangian is spontaneously broken, which leads to eight massless Goldstone bosons, the π 's, K's, and η , in the limit $M\to 0$. The symmetry $G\chi$ is only an approximate symmetry, since it is explicitly broken by the quark mass matrix M. The Goldstone bosons acquire masses which can be computed in a systematic expansion in M in terms of certain unknown nonperturbative parameters of the theory. For example, to first order in M one finds that [14,15]

$$m_{\pi^0}^2 = B (m_u + m_d) ,$$

$$m_{\pi^{\pm}}^2 = B (m_u + m_d) + \Delta_{em} ,$$

$$m_{K^0}^2 = m_{\overline{K}^0}^2 = B (m_d + m_s) ,$$

$$m_{K^{\pm}}^2 = B (m_u + m_s) + \Delta_{em} ,$$

$$m_{\eta}^2 = \frac{1}{3} B (m_u + m_d + 4m_s) ,$$
(8)

with two unknown parameters B and Δ_{em} , the electromagnetic mass difference. From Eq. (8), one can determine the quark mass ratios [14]

$$\frac{m_u}{m_d} = \frac{2m_{\pi^0}^2 - m_{\pi^+}^2 + m_{K^+}^2 - m_{K^0}^2}{m_{K^0}^2 - m_{K^+}^2 + m_{\pi^+}^2} = 0.56 ,
\frac{m_s}{m_d} = \frac{m_{K^0}^2 + m_{K^+}^2 - m_{\pi^+}^2}{m_{K^0}^2 + m_{\pi^+}^2 - m_{K^+}^2} = 20.1 ,$$
(9)

to lowest order in chiral perturbation theory. The error on these numbers is the size of the second-order corrections, which are discussed at the end of this section. Chiral perturbation theory cannot determine the overall scale of the quark masses, since it uses only the symmetry properties of M, and any multiple of M has the same G_{χ} transformation law as M. This can be seen from Eq. (8), where all quark masses occur only in the form Bm, so that B and m cannot be determined separately.

The mass parameters in the QCD Lagrangian have a scale dependence due to radiative corrections, and are renormalization scheme dependent. Since the mass ratios extracted using chiral perturbation theory use the symmetry transformation property of M under the chiral symmetry G_X , it is important to use a renormalization scheme for QCD that does not change this transformation law. Any quark mass independent subtraction scheme such as $\overline{\rm MS}$ is suitable. The ratios of quark masses are scale independent in such a scheme.

The absolute normalization of the quark masses can be determined by using methods that go beyond chiral perturbation theory, such as QCD sum rules [3]. Typically, one writes a sum rule for a quantity such as B in terms of a spectral integral over all states with certain quantum numbers. This spectral integral is then evaluated by assuming it is dominated by one (or two) of the lowest resonances, and using the experimentally measured resonance parameters [16]. There are many subtleties involved, which cannot be discussed here [16].

Another method for determining the absolute normalization of the quark masses, is to assume that the strange quark mass is equal to the SU(3) mass splitting in the baryon multiplets [14,16]. There is an uncertainty in this method since in the baryon octet one can use either the Σ -N or the Λ -N mass difference, which differ by about 75 MeV, to estimate the strange quark mass. But more importantly, there is no way to relate this normalization to any more fundamental definition of quark masses.

One can extend the chiral perturbation expansion Eq. (8) to second order in the quark masses M to get a more accurate determination of the quark mass ratios. There is a subtlety that arises at second order [17], because

$$M\left(M^{\dagger}M\right)^{-1}\det M^{\dagger} \tag{10}$$

transforms in the same way under $G\chi$ as M. One can make the replacement $M\to M(\lambda)=M+\lambda M\left(M^\dagger M\right)^{-1}\det M^\dagger$ in all formulæ,

$$M(\lambda) = \operatorname{diag}(m_u(\lambda), m_d(\lambda), m_s(\lambda))$$

$$= \operatorname{diag}(m_u + \lambda m_d m_s, \ m_d + \lambda m_u m_s, \ m_s + \lambda m_u m_d), (11)$$

so it is not possible to determine λ by fitting to data. One can only determine the ratios $m_i(\lambda)/m_j(\lambda)$ using second-order chiral perturbation theory, not the desired ratios $m_i/m_j = m_i(\lambda = 0)/m_j(\lambda = 0)$.

Dimensional analysis can be used to estimate [18] that second-order corrections in chiral perturbation theory due to the

Quarks

strange quark mass are of order $\lambda m_s \sim 0.25$. The ambiguity due to the redefinition Eq. (11) (which corresponds to a second-order correction) can produce a sizeable uncertainty in the ratio m_u/m_d . The lowest-order value $m_u/m_d = 0.56$ gets corrections of order $\lambda m_s(m_d/m_u - m_u/m_d) \sim 30\%$, whereas m_s/m_d gets a smaller correction of order $\lambda m_s(m_u/m_d - m_u m_d/m_s^2) \sim 15\%$. A more quantitative discussion of second-order effects can be found in Refs. 17,19,20. Since the second-order terms have a single parameter ambiguity, the value of m_u/m_d is related to the value of m_s/m_d .

The ratio m_u/m_d is of great interest since there is no strong CP problem if $m_u=0$. To determine m_u/m_d requires fixing λ in the mass redefinition Eq. (11). There has been considerable effort to determine the chiral Lagrangian parameters accurately enough to determine m_u/m_d , for example from the analysis of the decays $\psi' \to \psi + \pi^0, \eta$, the decay $\eta \to 3\pi$, using sum rules, and from the heavy meson mass spectrum [16,21–24]. A recent paper giving a critique of these estimates is Ref. 25.

Eventually, lattice gauge theory methods will be accurate enough to be able to compute meson masses directly from the QCD Lagrangian Eq. (1), and thus determine the light quark masses. For a reliable determination of quark masses, these computations will have to be done with dynamical fermions, and with a small enough lattice spacing that one can accurately compute the relation between lattice and continuum Lagrangians.

The quark masses for light quarks discussed so far are often referred to as current quark masses. Nonrelativistic quark models use constituent quark masses, which are of order 350 MeV for the u and d quarks. Constituent quark masses model the effects of dynamical chiral symmetry breaking, and are not related to the quark mass parameters m_k of the QCD Lagrangian Eq. (1). Constituent masses are only defined in the context of a particular hadronic model.

E. Numerical values and caveats

The quark masses in the particle data listings have been obtained by using the wide variety of theoretical methods outlined above. Each method involves its own set of approximations and errors. In most cases, the errors are a best guess at the size of neglected higher-order corrections. The expansion parameter for the approximations is not much smaller than unity (for example it is $m_K^2/\Lambda_\chi^2 \approx 0.25$ for the chiral expansion), so an unexpectedly large coefficient in a neglected higher-order term could significantly alter the results. It is also important to note that the quark mass values can be significantly different in the different schemes. For example, assuming that the b-quark pole mass is 5.0 GeV, and $\overline{\alpha}_s(m_b) \approx 0.22$ gives the $\overline{\rm MS}$ b-quark mass $\overline{m}_b(\mu = m_b) = 4.6$ GeV using the one-loop term in Eq. (4), and $\overline{m}_b(\mu=m_b)=4.3$ GeV including the one-loop and two-loop terms. The heavy quark masses obtained using HQET, QCD sum rules, or lattice gauge theory are consistent with each other if they are all converted into the same scheme. When using the data listings, it is important to remember that

the numerical value for a quark mass is meaningless without specifying the particular scheme in which it was obtained. All non- $\overline{\rm MS}$ quark masses have been converted to $\overline{\rm MS}$ values in the data listings using one-loop formulæ, unless an explicit two-loop conversion is given by the authors in the original article.

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u, d, s, Light Quarks (u, d, s)

И

$$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$$

Mass m=2 to 8 MeV $m_u/m_d = 0.25 \text{ to } 0.70$

Charge
$$= \frac{2}{3} e$$
 $I_Z = +\frac{1}{2}$

$$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$$

Mass m = 5 to 15 MeV $m_s/m_d=17$ to 25

$$\mathsf{Charge} = -\frac{1}{3} \ e \qquad \mathsf{I}_{\mathsf{Z}} = -\frac{1}{2}$$

$$I(J^P) = 0(\frac{1}{2}^+)$$

DOCUMENT ID TECN COMMENT

Mass m=100 to 300 MeV Charge = $-\frac{1}{3}e$ Strangeness = -1 $(m_s - (m_u + m_d)/2)/(m_d - m_u) = 34 \text{ to } 51$

LIGHT QUARKS (u, d, s

OMITTED FROM SUMMARY TABLE

u-QUARK MASS

The u-, d-, and s-quark masses are estimates of so-called "current-quark masses," in a mass-independent subtraction scheme such as $\overline{\rm MS}$ at a scale $\mu \approx 1$ GeV. The ratios m_u/m_d and m_s/m_d are extracted from pion and kaon masses using chiral symmetry. The estimates of d and u masses are not without controversy and remain under active investigation. Within the literature there are even suggestions that the u quark could be essentially massless. The s-quark mass is estimated from SU(3) splittings in hadron masses.

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•	•	•	We do	not	use	the	following	data	for	averages.	fits.	limits.	etc.	

T T T TO GO HOL GOO THO TOHOUTHE	auta ioi avoiagos	,	,	
		95	THEO	Assumes MS scheme
		95C	THEO	Assumes MS scheme
		92 B	THEO	
	⁴ BARDUCCI	88	THEO	
		82	THEO	
1.8 ± 0.7	⁶ PAGELS	80	THEO	
		80	THEO	
	⁸ WEINBERG	77	THEO	
4	⁹ GASSER	75	THEO	

- ¹ JAMIN 95 uses QCD sum rules at next-to-leading order.
- 2 NARISON 95c determines the $\overline{\rm MS}$ mass at 1 GeV. 3 CHOI 92B argues that $m_{_{\cal U}}=0$ is okay based on instanton contributions to the chiral coefficients. Disagrees with DONOGHUE 92 and DONOGHUE 92B.
- ⁴BARDUCCI 88 renormalized quark mass at 1 GeV. Uses a calculation of the effective potential for $\overline{\psi}\,\psi$ in QCD, and estimates for $\Sigma(\rho^2).$
- FORSERS 82 uses chiral perturbation theory for the mass ratios, and uses QCD sum rules to extract the absolute values. The renormalization scale is 1 GeV. PAGELS 80 uses lowest-order chiral perturbation theory plus an estimate of $\langle \overline{q} \, q \rangle$.
- ⁷PAGELS 80 uses lowest-order chiral perturbation theory plus an estimate of $\langle \overline{q} q \overline{q} q \rangle$ correlation function
- 8 WEINBERG 77 assumes that the baryon SU(3) splittings are equal to m_s .
- ⁹ GASSER 75 uses inelastic electron scattering and SU(6).

d-QUARK MASS

See the comment for the u quark above.

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
5 to 15 OUR EVALUATION	ON			
• • • We do not use the fol	lowing data for average	s, fits	, limits,	etc. • • •
	¹⁰ BIJNENS	95	THEO	
9.4±1.5	11 JAMIN	95	THEO	Assumes MS scheme
10 ±1	¹² NARISON	95C	THEO	Assumes MS scheme
	¹³ ADAMI	93	THEO	
	¹⁴ NEFKENS	92	THEO	
8.4	¹⁵ BARDUCCI	88	THEO	
	¹⁶ DOMINGUEZ	87	THEO	
	¹⁷ KREMER	84	THEO	
8.9 ± 2.6	¹⁸ GASSER	82	THEO	
4.3 ± 0.7	¹⁹ PAGELS	80	THEO	
14.6±5.7	²⁰ PAGELS	80	THEO	
7.5	²¹ WEINBERG	77	THEO	
6	²² GASSER	75	THEO	

- 10 BIJNENS 95 determines $m_{\overline{u}} + m_{\overline{d}}$ (1 GeV) = 12 \pm 2.5 MeV using finite energy sum
- rules. 11 JAMIN 95 uses QCD sum rules at next-to-leading order.
- 12 NARISON 95C determines the $\overline{\rm MS}$ mass at 1 GeV. 13 ADAMI 93 obtain $m_d-m_u{=}3\pm1$ MeV at $\mu{=}0.5$ GeV using isospin-violating effects in QCD sum rules.

- 14 NEFKENS 92 results for m_d-m_u are 3.1 \pm 0.4 MeV from meson masses and 3.6 \pm 0.4 MeV from baryon masses.
- 15 BARDUCCI 88 renormalized quark mass at 1 GeV. Uses a calculation of the effective potential for $\overline{\psi}\psi$ in QCD, and estimates for $\Sigma(\rho^2)$.
- 16 DOMINGUEZ 87 uses QCD sum rules to obtain $m_u + m_d = 15.5 \pm 2.0$ MeV and m_d $m_{\,U}=6\pm 1.5$ MeV.
- 17 KREMER 84 obtain $m_u + m_d = 21 \pm 2$ MeV at $Q^2 = 1~{\rm GeV^2}$ using SVZ values for quark condensates; they obtain $m_U+m_d=35\pm3$ MeV at $Q^2=1$ GeV using factorization values for quark condensates.
- 18 GASSER 82 uses chiral perturbation theory for the mass ratios, and uses QCD sum rules to extract the absolute values. The renormalization scale is 1 GeV. 19 PAGELS 80 uses lowest-order chiral perturbation theory plus an estimate of $\langle \overline{q} \, q \rangle$.
- $^{20}\,\text{PAGELS}$ 80 uses lowest-order chiral perturbation theory plus an estimate of $\langle \overline{q}\,q\,\overline{q}\,q\rangle$
- correlation function.

 21 WEINBERG 77 assumes that the baryon SU(3) splittings are equal to m_{ς} .
- $^{\rm 22}\,{\rm GASSER}$ 75 uses inelastic electron scattering and SU(6).

s-QUARK MASS

See the comment for the \boldsymbol{u} quark above.

100 to 300 OUR EV	ALUATION			
• • We do not use t	he following data for average	s, fits	, limits,	etc. • • •
171 ± 15	²³ CHETYRKIN	95	THEO	Assumes MS schem
189± 32	²⁴ JAMIN	95	THEO	Assumes MS schem
197± 29	²⁵ NARISON	95C	THEO	Assumes MS schem
	²⁶ NEFKENS	92	THEO	
194± 4	²⁷ DOMINGUEZ	91	THEO	
118	²⁸ BARDUCCI	88	THEO	
	²⁹ KREMER	84	THEO	
175 ± 55	³⁰ GASSER	82	THEO	
>300	³¹ PENSO	82B	THEO	
112± 66	³² PAGELS	80	THEO	
378 ± 220	³³ PAGELS	80	THEO	
150	³⁴ WEINBERG	77	THEO	
135	³⁵ GASSER	75	THEO	

- S mass at 1 GeV. CHETYRKIN 95 uses QCD sum rules at next-to-leading order.
- 24 JAMIN 95 uses QCD sum rules at next-to-leading order.
- 25 NARISON 95C determines the MS mass at 1 GeV
- 26 NEFKENS 92 results for $m_s (m_b + m_d)/2$ are 111 ± 10 MeV from meson masses and 163 ± 15 MeV from baryon masses.
- 27 DOMINGUEZ 91 uses QCD sum rules with $\Lambda_{\rm QCD}=100$ –200 MeV and the SVZ value for the gluon condensate. The renormalization point is 1 GeV.
- 28 BARDUCCI 88 renormalized quark mass at 1 GeV. Uses a calculation of the effective
- potential for $\overline{\psi}\psi$ in QCD, and estimates for $\Sigma(p^2)$. ²⁹ KREMER 84 obtain m_u+m_s =245 \pm 10 MeV at $Q^2=1$ GeV 2 using SVZ values for quark condensates; they obtain m_u+m_s =270 \pm 10 MeV at $Q^2=1~{\rm GeV}^2$ using factorization values for quark condensates.
- 30 GASSER 82 uses chiral perturbation theory for the mass ratios, and uses QCD sum rules to extract the absolute values. The renormalization scale is 1 GeV.

 31 PENSO 82 uses SVZ sum rules to put a lower bound on the strange quark mass.
- ³² PAGELS 80 uses lowest-order chiral perturbation theory plus an estimate of $\langle \overline{q} q \rangle$.
- 33 PAGELS 80 uses lowest-order chiral perturbation theory plus an estimate of $\langle \overline{q}\,q\,\overline{q}\,q \rangle$ correlation function. $^{34}\,\rm WEINBERG$ 77 assumes that the baryon SU(3) splittings are equal to $m_{\rm S}.$
- $^{35}\,\text{GASSER}$ 75 is based on SU(6).

LIGHT QUARK MASS RATIOS

DOCUMENT ID

u/d MASS RATIO

0.25 to 0.70 OUR EVALUATION

< 0.3	³⁶ CHOI	92 THEO
0.26	³⁷ DONOGHUE	92 THEO
0.30 ± 0.07	³⁸ DONOGHUE	92B THEO
0.66	³⁹ GERARD	90 THEO
0.4 to 0.65	⁴⁰ LEUTWYLER	90в ТНЕО
0.05 to 0.78	⁴¹ MALTMAN	90 THEO
0.0 to 0.56	⁴² CHOI	89B THEO
0.0 to 0.8	⁴³ KAPLAN	86 THEO
0.57 ± 0.04	44 GASSER	82 THEO
0.38 ± 0.13	⁴⁵ LANGACKER	79 THEO
0.47 ± 0.11	46 LANGACKER	79B THEO
0.56	⁴⁷ WEINBERG	77 THEO

- 36 CHOI 92 result obtained from the decays $\psi(2S)\to J/\psi(1S)\pi$ and $\psi(2S)\to J/\psi(1S)\eta,$ and a dilute instanton gas estimate of some unknown matrix elements.
- and a dilute instanton gas estimate of some unknown matrix elements. ³⁷ DONOGHUE 92 result is from a combined analysis of meson masses, $\eta \to 3\pi$ using second-order chiral perturbation theory including nonanalytic terms, and $(\psi(2S) \to J/\psi(1S)\pi)/(\psi(2S) \to J/\psi(1S)\eta)$. ³⁸ DONOGHUE 92B computes quark mass ratios using $(\psi(2S) \to J/\psi(1S)\pi)/(\psi(2S) \to J/\psi(1S)\pi$
- $J/\psi(1s)\eta$), and an estimate of t_{14} using Weinberg sum rules. ³⁹ GERARD 90 uses large N and η - η' mixing. ⁴⁰ LEUTWYLER 90B determines quark mass ratios using second-order chiral perturbation
- theory for the meson and baryon masses, including nonanalytic corrections. Also uses Weinberg sum rules to determine ${\cal L}_7$.

Light Quarks (u, d, s), c, b

- 41 MALTMAN 90 uses second-order chiral perturbation theory including nonanalytic terms for the meson masses. Uses a criterion of "maximum reasonableness" that certain coefficients which are expected to be of order one are $\,\leq 3.$
- 42 CHOI 89 uses second-order chiral perturbation theory and a dilute instanton gas estimate of second-order coefficients in the chiral lagrangian.
- 43 KAPLAN 86 uses second-order chiral perturbation theory including nonanalytic terms for the meson masses. Assumes that less than 30% of the mass squared of the pion is due to second-order corrections.
- 44 GASSER 82 uses chiral perturbation theory for the meson and baryon masses.
- 45 LANGACKER 79 result is from a fit to the meson and baryon mass spectrum, and the decay $\eta \to 3\pi$. The electromagnetic contribution is taken from Socolow rather than from Dashen's formula.
- 46 LANGACKER 79B result uses LANGACKER 79 and also ho- ω mixing.
- 47 WEINBERG 77 uses lowest-order chiral perturbation theory for the meson and baryon masses and Dashen's formula for the electromagnetic mass differences.

s/d MASS RATIO

VALUE	DOCUMENT ID		TECN
17 to 25 OUR EVALUATION			
• • • We do not use the following	g data for averages,	fits	, limits, etc. • • •
21	⁴⁸ DONOGHUE	92	THEO
18	⁴⁹ GERARD	90	THEO
18 to 23	⁵⁰ LEUTWYLER	90B	THEO
15 to 26	⁵¹ KAPLAN	86	THEO
19.6 ± 1.5	⁵² GASSER		
22 ±5	⁵³ LANGACKER		
24 ±4	⁵⁴ LANGACKER	79B	THEO
20	⁵⁵ WEINBERG	77	THEO

- $^{48}\,\mathrm{DONOGHUE}$ 92 result is from a combined analysis of meson masses, η ing second-order chiral perturbation theory including nonanalytic terms, and $(\psi(2S) \rightarrow J/\psi(1S)\pi)/(\psi(2S) \rightarrow J/\psi(1S)\eta)$.
- 50 LEUTWYLER 908 determines quark mass ratios using second-order chiral perturbation theory for the meson and baryon masses, including nonanalytic corrections. Also uses Weinberg sum rules to determine L_7 .
- 51 KAPLAN 86 uses second-order chiral perturbation theory including nonanalytic terms for the meson masses. Assumes that less than 30% of the mass squared of the pion is due to second-order corrections.
- 52 GASSER 82 uses chiral perturbation theory for the meson and baryon masses.
- 53 LANGACKER 79 result is from a fit to the meson and baryon mass spectrum, and the decay $\eta \to 3\pi$. The electromagnetic contribution is taken from Socolow rather than from Dashen's formula.
- 54 LANGACKER 79B result uses LANGACKER 79 and also ho- ω mixing.
- 55 WEINBERG 77 uses lowest-order chiral perturbation theory for the meson and baryon masses and Dashen's formula for the electromagnetic mass differences.

$(m_s - m)/(m_d - m_u)$ MASS RATIO $m \equiv (m_u + m_d)/2$

34 to 51 OUR EVALU	<u>DOCUMENT ID</u>		TECN	
	he following data for average	s, fit:	s, limits, etc.	
36 ±5	⁵⁶ NEFKENS	92	THEO	
45 ±3	⁵⁷ NEFKENS			
38 ±9	⁵⁸ AMETLLER	84	THEO	
43.5 ± 2.2	GASSER	82	THEO	
34 to 51	GASSER	81	THEO	
48 ±7	MINKOWSKI	80	THEO	
56 NEEK FAIS OR FORM	t is from an analysis of moso	n m 1	sees miving a	nd doc

- NEFKENS 92 result is from an analysis of meson masses, mixing, and decay.
- 57 NEFKENS 92 result is from an analysis of of baryon masses 58 AMETLLER 84 uses $\eta \to \pi^+\pi^-\pi^0$ and ρ dominance.

LIGHT QUARKS (u, d, s) REFERENCES

BIJNENS	95	PL B348 226	+Prades, de Rafael	(NORD, BOHR, CPPM)
CHETYRKIN	95	PR D51 5090	+Dominguez, Pirjol, Schilche	
JAMIN	95	ZPHY C66 633	+Munz	(HEIDT, MUNT)
NARISON	95C	PL B358 113		(MONP)
ADAMI	93	PR D48 2304	+Drukarev, loffe	(CIT, ITEP, PNPI)
CHOI	92	PL B292 159		(UCSD)
CHOI	92B	NP B383 58		(UCSD)
DONOGHUE	92	PRL 69 3444	+Holstein, Wyler	(MASA, ZURI)
DONOGHUE	92B	PR D45 892	+Wyler	(MASA, ŽURI, ÚCSBT)
NEFKENS	92	CNPP 20 221	+Miller, Slaus	(UCLA, WASH, ZAGR)
DOMINGUEZ	91	PL B253 241	+van Gend, Paver	(CAPE, TRST, INFN)
GERARD	90	MPL A5 391		(MPIM)
LEUTWYLER	90B	NP B337 108		(BERN)
MALTMAN	90	PL B234 158	+Goldman, Stephenson Jr.	(YORKC, LANL)
CHOL	89	PRL 62 849	,,,	(,
CHOI	89B	PR D40 890	+Kim	(CMU, JHU)
BARDUCCI	88	PR D38 238	+Casalbuoni, De Curtis+	(FIRZ, INFN, LECE, GEVA)
Also	87	PL B193 305	Barducci, Casalbuoni+	(FIRZ, INFN, LECE, GEVA)
DOMINGUEZ	87	ANP 174 372	+de Rafael	(ICTP, MARS, WIEN)
KAPLAN	86	PRL 56 2004	+ Manohar	(HARV)
AMETLLER	84	PR D30 674	+Ayala, Bramon	(BARC)
KREMER	84	PL 143B 476	+Papadopoulos, Schilcher	(MANZ)
GASSER	82	PRPL 87 77	+Leutwyler	(BERN)
PENSO	82	NC 68A 213	+Penso, Truong	(ROMA, EPOL)
PENSO	82B	NC 72A 113	+Verzegnassi	(ROMA, INFN, TRST, SISSA)
GASSER	81	ANP 136 62		(BERN)
MINKOWSKI	80	NP B164 25	+Zepeda	(BERN)
PAGELS	80	PR D22 2876	+Stokar	(ROCK)
LANGACKER	79	PR D19 2070	+Pagels	(DESY, PRIN)
LANGACKER	79B	PR D20 2983	-	(PENN)
WEINBERG	77	ANYAS 38 185		(HARV)
GASSER	75	NP B94 269	+Leutwyler	(BERN)



$$I(J^P) = 0(\frac{1}{2}^+)$$

Charge = $\frac{2}{3}$ e Charm = +1

c-QUARK MASS

The c-quark mass is estimated from charmonium and D masses. It corresponds to the "running" mass in the MS scheme. We have converted masses in other schemes to the $\overline{\text{MS}}$ scheme using one-loop QCD pertubation theory with $\alpha_s(\mu=m_C)=0.39$. The range 1.0–1.6 GeV for the $\overline{\rm MS}$ mass corresponds to 1.2–1.9 GeV for the pole mass (see the "Note on Quark Masses").

VALUE (GeV)	DOCUMENT ID		IECIV	COMMENT
1.0 to 1.6 OUR EVALUA	ATION			
• • • We do not use the	following data for average:	s, fit:	s, limits,	etc. • • •
1.22 ± 0.06		94	THEO	Assumes MS scheme
≥ 1.23	² LIGETI	94	THEO	Assumes MS scheme
≥ 1.25	³ LUKE	94	THEO	Assumes MS scheme
1.23 ± 0.04	⁴ NARISON	94	THEO	Assumes MS scheme
1.31 ± 0.03	⁵ TITARD	94	THEO	Assumes MS scheme
$1.5 \begin{array}{c} +0.2 \\ -0.1 \end{array} \pm 0.2$	⁶ ALVAREZ	93	THEO	
1.27 ± 0.02	⁷ NARISON	89	THEO	
1.25 ± 0.05	⁸ NARISON	87	THEO	
1.27 ± 0.05	⁹ GASSER	82	THEO	

- 1 DOMINGUEZ 94 uses QCD sum rules for $J/\psi(1S)$ system and finds a pole mass of
- 1.46 ± 0.07 dec 2.06 ET 94 computes lower bound of 1.43 GeV on pole mass using HQET, and experimental data on inclusive B and D decays.
- 3 LUKE 94 computes lower bound of 1.46 GeV on pole mass using HQET, and experimental data on inclusive B and D decays.
- 4 NARISON 94 uses spectral sum rules to two loops, and $J/\psi(1S)$ and \varUpsilon systems.
- STITARD 94 uses one-loop computation of the quark potential with nonperturbative gluon condensate effects to fit $J/\psi(1S)$ and Υ states.
- 6 ALVAREZ 93 method is to fit the measured $x_{\rm F}$ and ρ_T^2 charm photoproduction distributions to the theoretical predictions of ELLIS 89C.
- 7 NARISON 89 determines the Georgi-Politzer mass at $p^2{=}{-}m^2$ to be 1.26 \pm 0.02 GeV using QCD sum rules.
- 8 NARISON 87 computes pole mass of 1.46 \pm 0.05 GeV using QCD sum rules, with $\Lambda(\overline{MS})$
- 9 GASSER 82 uses SVZ sum rules. The renormalization point is $\mu=$ quark mass.

c-QUARK REFERENCES

DOMINGUEZ	94	PL B333 184	+Gluckman, Paver	(CAPE, TRST, INFN)
LIGETI	94	PR D49 R4331	+Nir	(REHO)
LUKE	94	PL B321 88	+Savage	(TNTO, UCSD, CMU)
NARISON	94	PL B341 73	•	(CERN, MONP)
TITARD	94	PR D49 6007	+Yndurain	(MICH, MADU)
ALVAREZ	93	ZPHY C60 53	+Barate, Bloch, Bonamy+	(CERN NA14/2 Collab.)
ELLIS	89C	NP B312 551	+Nason	(FNAL, ETH)
NARISON	89	PL B216 191		(ICTP)
NARISON	87	PL B197 405		(ČERN)
GASSER	82	PRPL 87 77	+Leutwyler	(BERN)



$$I(J^P) = O(\frac{1}{2}^+)$$
 Charge $= -\frac{1}{3} e$ Bottom $= -1$

b-QUARK MASS

The b-quark mass is estimated from bottomonium and B masses. It corresponds to the "running" mass in the $\overline{\rm MS}$ scheme. We have converted masses in other schemes to the $\overline{\rm MS}$ scheme using one-loop QCD pertubation theory with $\alpha_{\rm S}(\mu{=}m_b)=0.22$. The range 4.1–4.5 GeV for the $\overline{\rm MS}$ mass corresponds to 4.5–4.9 GeV for the pole mass (see the "Note on Quark Masses").

VALUE (GeV)	DOCUMENT ID		TECN	COMMENT
4.1 to 4.5 OUR EVALU	IATION			
• • • We do not use the	following data for average	s, fits	, limits,	etc. • • •
4.22 ±0.05	¹ NARISON	95B	THEO	Assumes MS scheme
4.415 ± 0.006	² VOLOSHIN	95	THEO	Assumes MS scheme
4.0 ±0.1	³ DAVIES	94	THEO	Assumes MS scheme
> 4.26	⁴ LIGETI	94	THEO	Assumes MS scheme
≥ 4.2	⁵ LUKE	94	THEO	Assumes MS scheme
4.23 ±0.04	⁶ NARISON	94	THEO	Assumes MS scheme
4.397 ± 0.025	⁷ TITARD	94	THEO	Assumes MS scheme
4.32 ±0.05	⁸ DOMINGUEZ	92	THEO	
4.24 ±0.05	⁹ NARISON	89	THEO	
4.18 ±0.02	¹⁰ REINDERS	88	THEO	
4.30 ±0.13	¹¹ NARISON	87	THEO	
4.25 ±0.1	¹² GASSER	82	THEO	
1				

- 1 NARISON 958 uses finite energy sum rules to two-loop accuracy to determine a b-quark pole mass of 4.61 \pm 0.05 GeV. 2 VOLOSHIN 95 result was converted from a pole mass of 4827 \pm 7 MeV using the one-loop formula. Pole mass was extracted using moments of the total cross section for $e^+e^- \rightarrow b$ hadrons.

- 3 DAVIES 94 uses lattice computation of $^{\gamma}$ spectroscopy. They also quote a value of 5.0 \pm 0.2 GeV for the b-quark pole mass. The numerical computation includes quark vacuum polarization (unquenched); they find that the masses are independent of n_f to within their errors. Their error for the pole mass is larger than the error for the $\overline{\rm MS}$ mass, because both are computed from the bare lattice quark mass, and the conversion for the pole mass is less accurate.
- ⁴ LIGETI 94 computes lower bound of 4.66 GeV on pole mass using HQET, and experimental data on inclusive B and D decays.
- ⁵ LUKE 94 computes lower bound of 4.60 GeV on pole mass using HQET, and experimental data on inclusive B and D decays.
- 6 NARISON 94 uses spectral sum rules to two loops, and $J/\psi(1S)$ and Υ systems.
- 7 TITARD 94 uses one-loop computation of the quark potential with nonperturbative gluon condensate effects to fit $J/\psi(1S)$ and \varUpsilon states.
- ⁸ DOMINGUEZ 92 determines pole mass to be 4.72 \pm 0.05 using next-to-leading order in 1/m in moment sum rule.
- 9 NARISON 89 determines the Georgi-Politzer mass at $\rho^2\!=\!-m^2$ to be 4.23 \pm 0.05 GeV using QCD sum rules.
- 10 REINDERS 88 determines the Georgi-Politzer mass at $p^2=-m^2$ to be 4.17 \pm 0.02 using moments of $\overline{b}\gamma^\mu b$. This technique leads to a value for the mass of the B meson of 5.25 \pm 0.15 GeV.
- 11 NARISON 87 determines the pole mass to be 4.70 \pm 0.14 using QCD sum rules, with $\Lambda(\overline{\text{MS}})=180\pm80$ MeV.
- 12 GASSER 82 uses SVZ sum rules. The renormalization point is $\mu=$ quark mass.

$m_b - m_c$ MASS DIFFERENCE

The mass difference m_b-m_c in the HQET scheme is 3.4 \pm 0.2 GeV (see the "Note on Quark Masses").

VALUE (GEV)		<u> </u>		
• • • We do not use the follow	owing data for avera	ges, fits, limits, etc.	• •	•
> 3.29	13 GROSSE	78		

 13 GROSSE 78 obtain $(m_b-m_c)~\geq 3.29~{\rm GeV}$ based on eigenvalue inequalities in potential models.

b-QUARK REFERENCES

NARISON	95B	PL B352 122		(MONP)
VOLOSHIN	95	IJMP A10 2865		(MINN)
DAVIES	94	PRL 73 2654	+Hornbostel+	(GLAS, SMU, CORN, EDIN, OSÚ, FSÚ)
LIGETI	94	PR D49 R4331	+Nir	(REHO)
LUKE	94	PL B321 88	+Savage	(TNTO, UCSD, CMU)
NARISON	94	PL B341 73	•	(CERN, MONP)
TITARD	94	PR D49 6007	+Yndurain	(MICH, MADU)
DOMINGUEZ	92	PL B293 197	+Paver	(CAPE, TRST, INFN)
NARISON	89	PL B216 191		(ICTP)
REINDERS	88	PR D38 947		(BONN)
NARISON	87	PL B197 405		(CERN)
GASSER	82	PRPL 87 77	+Leutwyler	(BERN)
GROSSE	78	PL 79B 103	+Martin	(CERN)



$$I(J^P) = O(\frac{1}{2}^+)$$
Charge = $\frac{2}{3}$ e Top = +1

THE TOP QUARK

(by M. Mangano at CERN and T. Trippe at LBNL)

A. Introduction: The top quark is the Q = 2/3, $T_3 = +1/2$ member of the weak-isospin doublet containing the bottom quark (see our review on the "Standard Model of Electroweak Interactions" for more information). The existence of a sixth quark has been expected since the discovery of the bottom quark itself and has become an absolute theoretical necessity within the Standard Model (SM) after the measurement of the $T_3 = -1/2$ weak isospin of the bottom quark [1]. While models with additional quarks but quantum numbers different from the top quark have been constructed, the simplest hypothesis that the weak doublet containing the bottom be completed into a family structure similar to the first two generations has always been the most appealing. This idea has finally been confirmed with the recent announcement of the top discovery by the CDF and DØ experiments at the Fermilab 1.8 TeV Tevatron proton-antiproton collider.

We start this note by presenting a brief historical survey of top searches. Then we discuss in more detail the essential features of top production and decay properties which were exploited to perform the discovery. Finally, we discuss the experimental and theoretical issues involved in the determination of its parameters (mass, production cross section, decay branching ratios, *etc.*) and conclude with the prospects for future improvements.

B. Some history: The first expectations for the value of the top mass used a naive extrapolation of the up- to down-type quark mass ratios in the first two generations, leading to values in the range of 10–20 GeV. Direct searches for $t\bar{t}$ pair production in e^+e^- collisions in this mass range were performed beginning in the late 70's at DESY and SLAC (see the compilation of limits in our 1990 edition [2]). These searches looked for a sudden increase in the ratio $R = \sigma(e^+e^- \to \text{hadrons})/\sigma(e^+e^- \to \mu^+\mu^-)$ or for anomalies in the distributions of thrust and acoplanarity in hadronic events. The lower limit on the top mass was increased to 30 GeV and then to approximately 46 GeV between the end of the 80's and the beginning of the 90's, when the more powerful Tristan, SLC and LEP e^+e^- colliders began operations (see the t-Quark Particle Listings in the current edition).

In parallel to the searches in e^+e^- collisions, direct searches were performed during the 80's by the UA1 and UA2 experiments at the CERN $S\overline{p}pS$ proton-antiproton collider, $\sqrt{s}=630$ GeV. At this energy, and at the available luminosities, the CERN experiments were sensitive to top mass values not exceeding 70 GeV, the top quark being mostly produced via an intermediate on-shell W, decaying to $t\overline{b}$. A top quark with mass below the Wb threshold was then expected to undergo a 3-body weak decay to a $bf\overline{f}'$ final state, with $f\overline{f}'$ being a weak isospin doublet such as $\nu_\ell \overline{\ell}$ or $u\overline{d}$.

Because of the overwhelming QCD background to the detection of the purely hadronic final states, the experiments looked for final states including a high momentum isolated lepton, missing transverse energy (E_T) , and one or more jets. No evidence for top production was obtained (see the t-Quark Particle Listings in the current edition for the references): the 95% CL mass limits went from 41 GeV (UA1, 1988), to 60 GeV (UA1, 1990), to 69 GeV (UA2, 1990). The first limits from CDF at the Fermilab Tevatron also appeared in 1990: $m_t > 72$ GeV from searches in the $e\mu$ final states, and $m_t > 77$ GeV from searches in the e plus jets and missing E_T final states.

Further indications of a large top mass had come from the measurement of a significant B^0 – \overline{B}^0 mixing, performed in 1986 by UA1 and Argus.

Mass limits independent of the decay mode were also set in the range $m_t > 40$ GeV via the determination of the W boson width, from the measurement in hadronic collisions of the ratio $\sigma(W \to \ell \nu_\ell)/\sigma(Z \to \ell^+ \ell^-)$. With the advent of high-precision electroweak data (from deep-inelastic scattering, M_W , atomic parity violation and, most importantly, from the study of the Z-boson couplings at SLC and LEP), global fits of the SM parameters have become possible, and have provided significant indirect constraints on the value of the top mass, once more indicating a large value (see our review "Standard").

Model of Electroweak Interactions" in the current edition for more information).

In this edition we have shortened the Particle Listings of indirect top mass limits by omitting superseded limits and reviews published before 1994. For more complete listings see our 1994 edition [3].

C. Top quark searches at the Tevatron: The first direct limits on the top mass exceeding the threshold for the decay into real W and a bottom quark came in the early 90's from the Fermilab Tevatron collider: $m_t > 91$ GeV (CDF, 1992) and $m_t > 131$ GeV (D0, 1994).

At the Tevatron energy, 1.8 TeV, a top quark above the W mass is dominantly produced in pairs from pure QCD processes: $q\overline{q} \to t\overline{t}$ and $gg \to t\overline{t}$. For a top mass around 100 GeV, the production cross section is expected to be of the order of 100 pb and is evenly shared between the two above channels. At 150 (175, 200) GeV the cross section is about 10 (5, 2.5) pb, with approximately 80% (90%, 95%) of it due to the light quark annihilation.

For masses above the Wb threshold, and neglecting terms of order m_b^2/m_t^2 , the top quark decay width is predicted in the SM to be [4]:

$$\Gamma_t = \frac{G_F m_t^3}{8\pi\sqrt{2}} (1 - \frac{M_W^2}{m_t^2})^2 (1 + 2\frac{M_W^2}{m_t^2}) [1 - \frac{2\alpha_s}{3\pi} (\frac{2\pi^2}{3} - \frac{5}{2})].$$

The use of G_F in this equation accounts for the largest part of the 1-loop electroweak radiative corrections, providing an expression accurate to better than 2%. The width values increase from 302 MeV (for $m_t=120~{\rm GeV}$) to 1.04 GeV ($m_t=160~{\rm GeV}$) and 2.23 GeV ($m_t=200~{\rm GeV}$). With such a correspondingly short lifetime, the top quark is expected to decay before top-favoured hadrons or $t\bar{t}$ quarkonium bound states can form.

The top quark decay is expected to be largely dominated by the Wb final state. The Ws and Wd final states are suppressed relatively to Wb by the square of the CKM matrix elements V_{ts} and V_{td} , whose values can be estimated under the assumption of unitarity of the three-generation CKM matrix to be less than 0.046 and 0.014, respectively (see our review "The Cabibbo-Kobayashi-Maskawa Mixing Matrix" in the current edition for more information).

Typical final states therefore belong to three classes:

A.
$$t\bar{t} \to W b W \bar{b} \to q \bar{q}' b q'' \bar{q}''' \bar{b}$$
,

B.
$$t\bar{t} \to W b W \bar{b} \to q \bar{q}' b \ell \bar{\nu}_{\ell} \bar{b}$$
,

C.
$$t\bar{t} \to W b W \bar{b} \to \bar{\ell} \nu_{\ell} b \ell' \bar{\nu}_{\ell'} \bar{b}$$
.

The final state quarks emit radiation and evolve into jets of hadrons. The precise number of jets reconstructed by the detectors varies event by event, as it depends on the decay kinematics, as well as on the precise definition of jet used in the analysis. The neutrinos are reconstructed via the large imbalance in detected transverse momentum of the event (missing E_T).

The $t\bar{t}$ production signature is by itself quite clear in all possible decay channels, due to the many kinematical constraints

imposed by the sequential decay via a real W. However, the combination of the limited experimental resolution and of the large cross section for the production of 6 jets in the QCD continuum (several nb) make the search in the purely hadronic channel very difficult. Since the detection of τ leptons has small efficiency, studies have therefore mostly concentrated on final states where one (or both) W decays to either an electron or a muon. Potential physics backgrounds still exist, mainly due to associated production of one (or two) W and several jets, with the W decaying leptonically. The gain in the S/B ratio is by an approximate factor of 10 for each W which is required to decay leptonically.

The theoretical estimates of the physics backgrounds have large uncertainties, since only leading order QCD calculations are available for most of the relevant processes (W+3 and 4 jets, or WW+2 jets). While this limitation is known to affect the estimates of the overall production rates, it is believed that the LO determination of the event kinematics and of the fraction of W plus multi-jet events containing b quarks is rather accurate. In particular, one expects the E_T spectrum of these jets to fall rather steeply, the jet direction to point preferentially at small angles from the beams, and the fraction of events with b quarks to be of the order of few percent. In the case of the top signal, vice versa, the b fraction is $\sim 100\%$ and the jets are rather energetic, since they come from the decay of a massive object. It is therefore possible to improve the S/B ratio by either requiring the presence of a b quark, or by selecting very energetic and central kinematical configurations.

A detailed study of control samples with features similar to those of the relevant backgrounds, but free from possible top contamination (e.g., a sample of Z plus multi-jet events), is required to provide a reliable check on the background estimates.

D. Top observation at CDF and DØ: The CDF experiment and the DØ experiment independently observed the production and decay of the top quark at the Fermilab Tevatron collider in $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV.

The CDF experiment published the first direct experimental evidence for the top quark in 1994 [5]. They found 12 events consistent with top, containing 6 silicon vertex tags, 7 low- p_T lepton tags, and 3 dilepton events (these categories are discussed below in more detail) with estimated backgrounds of 2.3 ± 0.3 , 3.1 ± 0.3 , and $0.56^{+0.25}_{-0.13}$ respectively. The combined excess signal was inconsistent with backgrounds by $2.8~\sigma$, not enough to firmly establish the existence of the top quark. Interpreting the excess events as top, they found a $t\bar{t}$ production cross section of $13.9^{+6.1}_{-4.8}$ pb, larger than the expected QCD cross section discussed below. A mass analysis of seven of these events yielded $m_t = 174 \pm 10^{+13}_{-12}$ GeV. A sample of events selected according to the expected kinematical properties of top provided additional support for the top interpretation [6].

The DØ experiment [7] found nine top candidates in their data taken during the same Tevatron run with an estimated

background of 3.8 ± 0.9 . They found a probability of 2.7% that this yield was consistent with backgrounds, corresponding to a 1.9 σ effect. If they assumed that the observed excess was top production, they obtained a $t\bar{t}$ production cross section of 8.2 ± 5.1 pb at $m_t = 180$ GeV.

After accumulating more than three times the amount of data, both CDF and DØ reported in 1995 [8,9] that they had conclusively observed the top quark.

The CDF experiment [8] observed top signals in two classes of events: $\ell\ell + jets$ events, which have two high- p_T leptons (e or μ) of opposite charge, large missing E_T , and at least two jets; and $\ell + jets/b$ -tag events, which have one high- p_T lepton, large missing E_T , and at least three jets, of which at least one is tagged as a b jet. They tagged b jets by finding secondary vertices from b-quark decay with their silicon vertex detector or by finding low- p_T leptons from semileptonic b decay.

In 67 pb⁻¹ integrated luminosity, CDF observed 37 ℓ + jets/b-tag) events containing 27 secondary vertex b tags and 23 low- p_T lepton b tags with estimated backgrounds of 6.7 ± 2.1 and 15.4 ± 2.0 respectively. They also observed 6 $\ell\ell$ events with an estimated background of 1.3 ± 0.3 events. The combined excess signal observed in these three categories is inconsistent with the background prediction by $4.8 \ \sigma$.

In an integrated luminosity of approximately 50 pb⁻¹ DØ observed 3 $\ell\ell$ + jets events, 8 ℓ + jets events, and 6 ℓ + jets/b-tag events, a total of 17 top candidates. The total estimated background in these events is 3.8 ± 0.6 events. The excess signal is inconsistent with the background prediction by $4.6 \ \sigma$.

E. Measured top properties: CDF and DØ both measured the top mass using single lepton events with four or more jets. Each event was subjected to a two-constraint kinematic fit to the hypothesis $t\bar{t} \to W^+ b W^- \bar{b} \to \ell \nu_\ell q \bar{q}' b \bar{b}$, assuming that the four highest E_T jets were the $t\bar{t}$ daughters. All permutations of these jets were tried, with the restriction that b-tagged jets were assigned to b quarks in the fit.

CDF found that of their 37 $\ell + jets/b$ -tag events, 19 events had four or more jets. Of these 19, $6.9^{+2.5}_{-1.9}$ were expected to be background. A fit to the mass distribution of the 19 events by the sum of the expected distributions for the W + jets background and a top quark yielded $m_t = 176 \pm 8 \pm 10$ GeV where the second error is the estimated systematic uncertainty.

DØ found that of their $14 \ \ell + jets$ (with and without b-tags) events, 11 had four or more jets and passed the fit. To increase the statistics and reduce mass biases, the H_T requirement was removed, yielding $27 \ \ell + 4jets$ events, of which 24 passed the fit. A fit of the mass distribution to top and background contributions yielded $m_t = 199^{+19}_{-21} \pm 22$ GeV, where the second error is the estimated systematic error.

Preliminary results for the top mass based on the full (Run Ia+Ib) data set have been presented by CDF and DØ at conferences in early 1996 and are given in Table 1. Since these are preliminary results, we do not average them or include them in the data listings or summary tables.

Table 1: Preliminary top masses presented at conferences in early 1996. See for example Ref. 10 for CDF results and Ref. 11 for DØ results.

top quark mass	Expt.	Channel
$175.6 \pm 5.7 \pm 7.1 \text{ GeV}$	CDF	lepton + jets
$159^{+24}_{-22} \pm 17 \text{ GeV}$	CDF	dilepton
$187 \pm 8 \pm 12 \text{ GeV}$	CDF	hadronic
$170\pm15\pm10~\mathrm{GeV}$	DØ	lepton + jets
$158 \pm 24 \pm 10~\mathrm{GeV}$	DØ	$e\mu$

The current average of the CDF and DØ published results is $m_t = 180 \pm 12$ GeV, where statistical and systematic errors have been combined in quadrature and where CDF and DØ systematic errors have been assumed to be independent.

Given the experimental technique used to extract the top mass, this value should be taken as representing the top *pole mass* (see our review "Note on Quark Masses" in the current edition).

The extraction of the value of the top mass from the analyses described requires, in addition to an understanding of the absolute energy calibration and resolution of the detectors, also an a priori knowledge of the structure of the final state. Given the hardness of a $t\bar{t}$ production process, jets can in fact arise not only from the top decays, but also from the initial state gluon radiation. Furthermore, quarks from the top decays can radiate additional jets. The presence of these additional jets will affect the shape of the mass spectrum, depending on the details of how the samples used for the mass determination were defined. QCD calculations used to model top production and decay are expected to be rather reliable, but residual uncertainties remain and are accounted for in the overall systematic error on the top mass.

CDF [8] and DØ [9] determined the $t\bar{t}$ cross section in $p\bar{p}$ collisions at $\sqrt{s}=1.8$ TeV from their numbers of top candidates, their estimated background, their $t\bar{t}$ acceptance, and their integrated luminosity. The evaluation was done under the assumption of SM decays $t\to Wb$, with unity branching ratio. Based on their number of secondary-vertex b-tagged events, CDF determined the $t\bar{t}$ cross section to be $6.8^{+3.6}_{-2.4}$ pb at $m_t=175$ GeV. The next-to-leading-order QCD prediction [12],

t

allowing for a variation of the renormalization and factorization scales μ in the range $0.5 < \mu/m_t < 2$ and using the MRSA set of parton densities [13], gives $4.3 < \sigma_{t\bar{t}}(\mathrm{pb}) < 5.0$ at $m_t = 175$ GeV

Based on their 17 top candidates, DØ determined the $t\bar{t}$ cross section to be 6.4 ± 2.2 pb at their central mass value of 199 GeV or 8.2 ± 2.9 pb at 180 GeV. The QCD predictions are: $2.0 < \sigma_{t\bar{t}}(\text{pb}) < 2.4$ ($m_t = 199$ GeV), and $3.6 < \sigma_{t\bar{t}}(\text{pb}) < 4.3$ ($m_t = 180$ GeV).

More recent preliminary values of the $t\bar{t}$ cross section were given at early 1996 conferences CDF found $7.5^{+1.9}_{-1.7}$ pb at 175 GeV [14] and DØ found 5.2 ± 1.8 pb at 170 GeV [15].

The measurement of other properties of the top quark has just started. CDF reported the first direct measurement of the $t \to Wb$ branching ratio [16]. Their preliminary result, obtained by comparing the number of events with 1 and 2 tagged-b jets and using the known tagging efficiency, is: $R = \mathrm{B}(t \to Wb)/\sum_{q=d,s,b} \mathrm{B}(t \to Wq) = 0.87^{+0.13}_{-0.30}^{+0.13}^{+0.13}$

F. The future: With the discovery of the top quark, future studies will follow two main tracks. Theoretically, it is hoped that the large top mass, and the tantalizing coincidence between its current value and the fundamental scale of the electroweak symmetry breaking, will lead to some understanding of the structure of fermion masses and of the symmetry breaking mechanism itself. Experimentally, the work will concentrate on reducing the errors on the mass and cross section determinations and on the measurement of more specific properties of the top quark, namely its decay branching ratios and its couplings. With a smaller error on the top mass, and with yet improved measurements of the electroweak parameters, it will be possible to get important constraints on the value of the Higgs mass. Current global fits performed within the SM and its minimal supersymmetric extension, provide indications for a relatively light Higgs (see the " H^0 Indirect Mass Limits from Electroweak Analysis" in the Particle Listings of the current edition), possibly within the range of the upcoming LEP2 experiments.

The current Tevatron data, once fully analysed, should allow the first determination of limits on rare top decay modes, such as $t \to \gamma c$ or $t \to Zc$. Studies of the decay angular distributions will allow a first direct analysis of the V-A nature of the Wtb coupling, as well as providing direct information on the relative coupling of longitudinal and transverse W bosons to the top. In the SM, the fraction of decays to transversely polarized W bosons is expected to be $1/(1+m_t^2/2M_W^2)$ (29% for $m_t=180~{\rm GeV}$). Deviations from this value would challenge the Higgs mechanism of spontaneous symmetry breaking.

Over the longer term, a direct measurement of the Wtb coupling constant will be possible when enough data will be accumulated to detect the less frequent single-top production processes, such as $q\bar{q}' \to W^* \to t\bar{b}$ and $qb \to q't$ via W exchange.

A precise determination of the top production cross section will test the current theoretical understanding of the production mechanisms. The current state of the art amounts to complete calculations at the next-to-leading order in QCD [12], as well as efforts to resum classes of potentially large logarithmic corrections coming from multiple soft gluon emission in the intial state [17]. A precise understanding of top production at the Tevatron is important for the extrapolation to the higher energies of future colliders, like the LHC, where the expected large cross section will enable more extensive studies.

Discrepancies in rate between theory and data, on the other hand, would be more exciting and might indicate the presence of exotic production channels, as predicted in some models. In this case, one should also expect a modification of kinematical distributions such as the invariant mass of the top pair or the top quark transverse momentum.

As discussed in the previous sections, some of the current uncertainty in the determination of the top mass from the reconstruction of its final state jets arises from theoretical uncertainties in the modeling of the radiation in these very hard events. The current data, once fully analyzed, will presumably help improve our theoretical understanding. At the same time, the larger samples that will become available in the future will allow more strict selection criteria, leading to purer samples of top quarks. For example, requesting the presence of two secondary-vertex b tags in the event, in addition to two and only two central jets of high- E_T , should largely reduce the possibility of erroneously including jets not coming from the top decays into the mass reconstruction. This will significantly improve the mass resolution and will make it less sensitive to the theoretical uncertainties.

Finally, the large mass of the top quark leaves open the possibility of top decays into yet unobserved particles beyond the SM. For example, current limits on the masses of a charged Higgs (H^+) or of a supersymmetric scalar top quark (\tilde{t}) and neutralino $(\tilde{\chi}^0)$, cannot exclude the existence of decays such as $t \to H^+ b$ or $t \to \tilde{t} \tilde{\chi}^0$. The first channel, in particular, has been used extensively in the past in direct top searches (see the Particle Listings in the current edition). Both these exotic modes are currently under investigation at CDF and DØ.

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t-Quark Mass in pp Collisions

The t quark has now been observed. Its mass is sufficiently high that decay is expected to occur before hadronization.

Preliminary results for the top mass based on the full (Run la+lb) data set have been presented by CDF and DØ at conferences in early 1996:

$$\begin{split} m_t &= 175.6 \pm 5.7 \pm 7.1 \text{ GeV} & \text{CDF} & \text{ lepton + jets} \\ m_t &= 159 ^{+24}_{-22} \pm 17 \text{ GeV} & \text{CDF} & \text{ dilepton} \\ m_t &= 187 \pm 8 \pm 12 \text{ GeV} & \text{CDF} & \text{ hadronic} \\ \end{split}$$

$$m_t &= 170 \pm 15 \pm 10 \text{ GeV} & \text{DØ} & \text{ lepton + jets} \end{split}$$

 $m_{\,t}=$ 158 \pm 24 \pm 10 GeV Because of the high current interest, we mention these preliminary results here but do not average them or include them in the Listings or Tables. See the note on the top quark for references.

DØ

Search limits, which are now primarily of historical interest, are based on the assumption that no nonstandard decay modes such as $t \rightarrow bH^+$ are available, except as noted in the comments.

VALUE (GeV) 180±12 OUR AVER	CL%	DOCUMENT ID TECN	COMMENT
$199^{+19}_{-21} \pm 22$		¹ ABACHI 95 D0	ℓ + jet
176± 8±10		² ABE 95F CDF	$\ell + b$ -jet
• • • We do not use t	the follow	ing data for averages, fits, limits	
>128	95	3 ABACHI 95B D0 4 ABACHI 95F D0 5 ABE 950 CDF 6 ABE 95V CDF	$\ell\ell$ + jets, ℓ + jets $\ell\ell$ + jets, ℓ + jets
		⁷ ABE,F 95 CDF	$W + \geq 4$ jets
>131	95	⁸ ABACHI 94 D0	$\ell\ell$ + jets, ℓ + jets
$174 \pm 10 + \frac{13}{-12}$		⁹ ABE 94E CDF	$\ell + b$ -jet
>118	95	9 ABE 94E CDF 10 ABE 94H CDF	$\begin{array}{c} \ell\ell \\ t \to bH^+, \\ t \to -+ \end{array}$
		¹¹ ABE 941 CDF	$H^{+} \rightarrow \tau^{+} \nu_{\tau}$ $t \rightarrow bH^{+},$ $H^{+} \rightarrow \tau^{+} \nu_{\tau}$
> 91	95	12 ABE 92 CDF	$\ell\ell$, ℓ + <i>b</i> -jet
		13 ALITTI 92F UA2	$t \rightarrow bH^+, H^+ \rightarrow \tau^+ \nu_{\sigma}$
> 60	95	14 ALBAJAR 918 UA1	$t \xrightarrow{bH^+}, \\ H^+ \xrightarrow{\tau^+} \nu_{\tau}$
		¹⁵ BAER 918 RVUE	$t \rightarrow \tilde{t}_1 \tilde{\chi}_1^0$
> 72	95	16 ABE 90B CDF	
> 77	95	¹⁷ ABE 90c CDF	$e + \text{jets} + \text{missing } E_T$
> 69	95	¹⁸ AKESSON 90 UA2	$e + \text{jets} + \text{missing } E_T$
> 60	95	ALBAJAR 90B UA1	
> 41	95	¹⁹ BARGER 90E RVUE ²⁰ ALBAJAR 88 UA1	$t \rightarrow bH^+$ e or $\mu + \mathbf{j}$ ets

- ¹ ABACHI 95 search for $\ell\ell$ +jets ($e\mu$, ee, and $\mu\mu$) and ℓ +jets (ℓ =e or μ). The ℓ +jets search is done in two ways, using either topological cuts or requiring μ tagging. They observe 17 ($3\ell\ell$, 6ℓ -b-jets, and 8ℓ +jets topological) events with an expected background of 3.8 \pm 0.6. These seven analysis channels combine to give a 4.6 standard deviation effect. The mass fit is from 24 ℓ +4-jet events obtained with looser cuts.
- effect. The mass it is from 24.2+4-jet events obtained with noser cuts. 2 ABE 95F search for $\ell\ell$ (e.e. $e\mu$, and $\mu\mu$) final states and ℓ + b-jet final states. They find 37 ℓ + b-jet candidates containing 27 secondary vertex tags and 23 lepton tags with expected backgrounds of 6.7 \pm 2.1 and 15.4 \pm 2.0 respectively. They find 6 $\ell\ell$ events with an expected background of 1.3 \pm 0.3 These three observations combine to give a 4.8 standard deviation effect. The mass fit is from 19ℓ +4-jet events with a ℓ -tag. The shape of the mass distribution is consistant with top and this increases the significance of the effect to 5.0σ
- of the effect to 5.0 σ . 3 ABACH 195B searched for dilepton channels $e\mu+$ jets, ee+ jets, $\mu\mu+$ jets, and single-letpon channels e+ jets and $\mu+$ jets with and without b tagging. They found 9 events where 3.8 \pm 0.9 events are expected from background. Based on an integrated luminosity of 13.5 \pm 1.6 $\rm pb^{-1}$. These analyses combine to give a 1.9 standard deviation effect. Assuming that the observed excess signal is due to top quark production, the cross section is 8.2 \pm 5.1 $\rm pb$ for $m_t=$ 180 GeV.
- ABACH1 95F searched for dilepton channels $e\mu$ + jets, ee+ jets, $\mu\mu$ + jets, and single-lepton channels e+ jets and μ + jets with and without b tagging. The lower mass bound supersedes that of ABACH1 94 and is weaker as a result of a recalibration of the integrated luminosity. Assuming that the observed excess signal is due to top quark production, the cross section is 8.2 \pm 5.1 pb (9.2 \pm 5.7 pb) for m_t = 180 GeV (160 Ca).
- ⁵ABE 950 find evidence for top production in the jet $E_{\mathcal{T}}$ distributions of $W+\geq 3$ jet events, based on an integrated luminosity of 19,3pb $^{-1}$. The observed distributions are consistent with $m_t=170$ GeV. Supersed by ABE 95v.
- 6 ABE 95V find evidence for top production in the jet $E_{\mathcal{T}}$ distributions of $W+\geq 3$ jet events, based on an integrated luminosity of $67pb^{-1}$.
- ⁷ABE,F 95 compared the total transverse energy distribution of the $W+\geq 4$ -jet data with that expected from all known backgrounds and found 3.8 σ deviation in the shape. The distribution agrees well with a linear combination of background and $t\,\bar{t}$ events, the agreement being best for $m_{ extbf{\emph{t}}}=$ 180 GeV.
- ⁸ ABACHI 94 search for $e\mu$ + jets, ee + jets, e + jets, and μ + jets. Production cross section with soft-gluon resummation of LAENEN 94 is used. The limit decreases to >122 GeV if $\mathcal{O}(\alpha_s^{-3})$ cross section is employed for comparison with ABE 92. Superseded by ABACHI 95F.
- ABE 94E search for e.e., $e\mu$, and $\mu\mu$ dilepton final states and single lepton + b-jet final Table 94s search for ee, $e\mu$, and $\mu\mu$ dilepton final states and single lepton + b-jet final states. They observe a total of 15 top topology tags (12 events of which three are doubly tagged) with an expected background of $5.96^{+0.49}_{-0.44}$. The mass determination is from 7 single-lepton + b-jet events which have four jets. Their $\ell\ell$ limit uses the production cross section with soft gluon resummation from LAENEN 94. Superseded by ABE 95F. 10 ABE 944 searched for $t \to bH^+$, $H^+ \to \tau^+\nu_\tau$ with τ decaying hadronically. The search was done in the region $45\,\mathrm{GeV} < m_{H^+} < m_\ell - m_b$ and $55\,\mathrm{GeV} < m_t < m_{H^+} < m_\ell - m_b$ and $55\,\mathrm{GeV} < m_t < m_t$
- search was done in the region 45 GeV $< m_{H^+} < m_t m_b$ and 55 GeV $< m_t < m_{W^+} + m_b$. See their Fig. 3 for the 95% CL excluded regions in the (m_{H^+}, m_t) plane for ${\rm B}(H^+ \to ~ \tau^+ \, \nu_{ au}) =$ 1, 0.75, and 0.5.
- 11 ABE 94) searched for $t\to bH^+, H^+\to \tau^+\nu_\tau, \tau^+\to \ell^+\nu_\ell\bar{\nu}_\tau$. The search was done in the region 45 GeV $< m_{H^+} < m_t m_b$ and 62 GeV $< m_t < 110$ GeV. See their Fig. 2 for the 95% CL excluded regions in the (m_{H^+}, m_t) plane for ${\rm B}(H^+ \to ~ \tau^+ \nu_{ au})$ = 1, 0.75, and 0.5. The entire region of the plane is excluded for B($H^+
 ightarrow au^+
 u_ au$)
- $^{-12}$ ABE 92 search for e.e., e.g., $\mu\mu$ dilepton final states and (e or μ) plus a b-quark jet. The bjet is tagged by a soft muon. The 90%CL limit is 95 GeV. Superseded by ABE 94E $\ell\ell$
- ¹³ALITTI 92F search for $t o bH^+$, $H^+ o au^+
 u_ au$ with au^+ decaying hadronically. m_t between 50 and 70 GeV is excluded if $m_t-m_{H^+}=m_b+(\lesssim$ a few–10 GeV). See their Figs. 5,6 for the excluded region for B(H $^+ \rightarrow \stackrel{\prime\prime}{\tau}^+ \nu_{\tau}) =$ 1, 0.5.
- 14 ALBAJAR 91B searched for the decay $t
 ightarrow H^+ b$ using single muon and dimuon events and assuming B($H^+ \to \tau^+ \nu$) \geq 0.95. The limit holds for $m_{H^+} \lesssim m_t - m_b$ – (3-6) GeV.
- 15 BAER 918 argue that a top quark as light as 60 GeV (65 GeV, if the minimal SUSY framework is assumed) may have escaped detection at CDF if a supersymmetric decay mode is open.
- 16 ABE 90B exclude the region 28-72 GeV.
- 17 ABE 90C cannot exclude $m_{\tilde{t}} < 40$ GeV, but this region is ruled out by other experiments. They study events with an energetic electron, missing transverse energy and two or more jets. Only the $t\bar{t}$ contribution (not $W \to tb$) is relevant for these masses. See also
- ABE 91. 18 AKESSON 90 searched for events having an electron with $p_T>12$ GeV, missing momentum > 15 GeV, and a jet with $E_T>10$ GeV, $|\eta|<2.2$, and excluded m_t between 30 and 69 GeV. 19 BARGER 90E claim that ABE 90C data exclude most regions of two-Higgs-doublet models
- with $m_t < 80$ GeV even if $t \to bH^+$ decay is allowed.
- 20 ALBAJAR 88 value quoted here is revised using the full $O(lpha_s^3)$ cross section of ALTARELLI 88. Superseded by ALBAJAR 90B.

Indirect t-Quark Mass from Standard Model Electroweak Fit

'OUR EVALUATION" below is from the fit to electroweak data described in the "Standard Model of Electroweak Interactions" section of this Review. This fit result does not include direct measurements of m_t . The second error corresponds to m_H =300 $^+_-$ 2400.

The RVUE values are based on the data described in the footnotes. RVUE's published before 1994 and superseded analyses are now omitted. For more complete listings of earlier results, see the 1994 edition (Physical Review D50 1173 (1994)).

VALUE (GeV)	DOCUMENT ID	TECN	COMMENT
179 \pm 8 $^{+17}_{-20}$ OUR EVALUATION			

	G		,		
$175 \pm 11^{+17}_{-19}$	²¹ ERLER	95	RVUE	Z parameters, m_W , low	
$180 \pm 9^{+19}_{-21} \mp 2.6 \pm 4.8$	²² MATSUMOTO	95	RVUE	energy	
$157 + 36 + 19 \\ -48 - 20$	²³ ABREU	94	DLPH	Z parameters	
$158^{+32}_{-40}\pm19$	²⁴ ACCIARRI	94	L3	Z parameters	
$132 + 41 + 24 \\ -48 - 18$	²⁵ AKERS	94	OPAL	Z parameters	
$190 + 39 + 12 \\ -48 - 14$	²⁶ ARROYO	94	CCFR	$ u_{\mu}$ iron scattering	
$184 + 25 + 17 \\ -29 - 18$	²⁷ BUSKULIC	94	ALEP	Z parameters	
153±15	²⁸ ELLIS	94B	RVUE	Electroweak	
$177 \pm 9^{+16}_{-20}$	²⁹ GURTU	94	RVUE	Electroweak	
$174 + 11 + 17 \\ -13 - 18$	³⁰ MONTAGNA	94	RVUE	Electroweak	
$171 \pm 12 + 15 \\ -21$	31 NOVIKOV	94 8	RVUE	Electroweak	
160 + 50 - 60	³² ALITTI	92B	UA2	m_W , m_Z	
21					

- ²¹ ERLER 95 result is from fit with free m_t and $\alpha_s(m_Z)$, yielding $\alpha_s(m_Z) = 0.127(5)(2)$. 22 MATSUMOTO 95 result is from fit with free m_t to Z parameters, M_W , and low-energy neutral-current data. The second error is for $m_H=300^{+700}_{-240}$ GeV, the third error is for $\alpha_s(m_Z)=0.116\pm0.005$, the fourth error is for $\delta\alpha_{\rm had}=0.0283\pm0.0007$.
- $\alpha_s(m_Z) = 0.116 \pm 0.005$, the locality close is to sequence $\alpha_s(m_Z) = 0.016 \pm 0.005$. The second error corresponds to $m_H = 300 + 700$ GeV.
- 24 ACCIARRI 94 value is for $\alpha_{\rm S}(m_Z)$ constrained to 0.124 \pm 0.006. The second error corresponds to $m_H=300^{+700}_{-240}$ GeV.
- $^{25}\,\mathrm{AKERS}$ 94 result is from fit with free $\alpha_\mathrm{S}.$ The second error corresponds to $m_{H}\!\!=\!\!300\,^{+\,700}_{-\,240}$ GeV. The 95%CL limit is m_{t} <210 GeV.
- ²⁶ ARROYO 94 measures the ratio of the neutral-current and charged-current deep inelastic scattering of u_{μ} on an iron target. By assuming the SM electroweak correction, they obtain $1-m_W^2/m_Z^2=0.2218\pm0.0059$, yielding the quoted m_t value. The second error corresponds to $m_H = 300 + 700 \text{ GeV}$.
- 27 BUSKULIC 94 result is from fit with free $\alpha_{\rm S}$. The second error is from $m_{H}{=}300^{+700}_{-240}$
- GeV. 28 ELLIS 94B result is fit to electroweak data available in spring 1994, including the 1994 A_{LR} data from SLD. m_t and m_H are two free parameters of the fit for $\alpha_s(m_Z)=0.118\pm0.007$ yielding m_t above, and $m_H=35^{+70}_{-22}$ GeV. ELLIS 94B also give results for fits including constraints from CDF's direct measurement of m_t and CDF's and DØ's production cross-section measurements. Fits excluding the A_{LR} data from SLD are also given
- ²⁹ GURTU 94 result is from fit with free m_t and $\alpha_s(m_Z)$, yielding m_t above and $\alpha_s(m_Z)$ = $0.125\pm0.005^{+0.003}_{-0.001}$ The second errors correspond to $m_H=300^{+700}_{-240}$ GeV. Uses LEP, M_W , ν N, and SLD electroweak data available in spring 1994.
- ³⁰ MONTAGNA 94 result is from fit with free m_t and $\alpha_s(m_Z)$, yielding m_t above and $\alpha_S(m_Z)=0.124$. The second errors correspond to $m_H=300^{+700}_{-240}$ GeV. Errors in $\alpha(m_Z)$ and m_B are taken into account in the fit. Uses LEP, SLC, and M_W/M_Z data available in spring 1994. ³¹ NOVIKOV 948 result is from fit with free m_t and $\alpha_S(m_Z)$, yielding m_t above and
- $lpha_{
 m S}(m_Z)=$ 0.125 \pm 0.005 \pm 0.002. The second errors correspond to $m_H=$ 300 $^{+700}_{-240}$
- GeV. Uses LEP and CDF electroweak data available in spring 1994. 32 ALITTI 928 assume $m_H=$ 100 GeV. The 95%CL limit is $m_t<$ 250 GeV for $m_H<$

MASS LIMITS for t Quark or Hadron Independent of t Decay Mode

These limits are derived from $\Gamma(W)$ values shown in the W width section. Independent of the top decay mode, any W decay to $t\overline{b}$ would increase the total width of the Wboson. Since the discovery of top, this section is of historical interest only.

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT	
• • • We do not	use the follow	ing data for averag	ges, fits, limits	, etc. • • •	
>62	95	³³ ABE	95w CDF	$E_{\text{CM}}^{p\overline{p}} = 1800 \text{ GeV}$	
>62	95	³⁴ ABE	94B CDF	$E_{cm}^{\rho\overline{p}} = 1800 \; GeV$	
>45	95	35 ABE	92I CDF	$E_{Cm}^{p\overline{p}} = 1800 \; GeV$	
>53	95	36 ALITTI	92 UA2	$E_{cm}^{ar{p}} = 630\;GeV$	
>55	95	³⁷ ALITTI	92 RVUE		
>43	95	³⁸ ABE	91c CDF	$E_{cm}^{p\overline{p}} = 1800 \; GeV$	
>38	90	³⁹ ALBAJAR	91 UA1	$E_{\text{cm}}^{p\overline{p}} = 630 \text{ GeV}$	
√51	90	40 ΔΙ ΒΔΙΔΒ	91 R\/IIF	F(W/)	

- ³³ ABE 95W result is from $\Gamma(W \to e \nu_e)/\Gamma(W) = 0.1094 \pm 0.0033(\text{stat}) \pm 0.0031(\text{syst.})$. In addition they obtain $\Gamma(W) = 2.064 \pm 0.060(\text{stat}) \pm 0.059(\text{syst.})$.
- ³⁴ ABE 94B result is from $\Gamma(W) = 2.063 \pm 0.061 \pm 0.060$ GeV. Superseded by ABE 95W.
- 35 ABE 92I data include both e and μ final states. The result is derived from $\Gamma(W)$ =2.16 \pm 0.17 GeV. At 90%CL, the limit is >49 GeV.
- 36 ALITTI 92 result is derived from $\Gamma(W)=2.10\pm0.16$ GeV.
- 37 Limit is from combined data of ALBAJAR 91, ALITTI 92, and ABE 90: $\Gamma(W)=$
- 38 ABE 91C result is derived from $\Gamma(W)=2.12\pm0.20$ GeV. At 90%CL, the limit is >48
- ³⁹ ALBAJAR 91 result is derived from $\Gamma(W) = 2.18 ^{+0.26}_{-0.24} \pm 0.04$ GeV.
- 40 Limit is from combined data of ALBAJAR 91, ALITTI 90c, and ABE 90.

MASS LIMITS for Top Hadrons in e^+e^- Collisions

The last column specifies measured quantities: S = Sphericity, T = Thrust.

For limits prior to 1987, see our 1990 edition, Physics Letters B239, p. VII.167 (1990). Since the discovery of top, this section is of historical interest only.

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not u	se the followin	g data for average	s, fits, limits	, etc. • • •
		⁴¹ ADRIANI	93G L3	Quarkonium
>41.8	95	ADRIANI	93M L3	$\Gamma(Z)$
>43	95	⁴² ABREU	91F DLPH	Γ(Z)
>30.2	95	ABE	90D VNS	Event shape
>44.5	95	⁴² ABREU	90b DLPH	Event shape
>44.0	95 42	^{,43} ABREU	90D DLPH	$t \rightarrow bH^+, H^+ \rightarrow c\overline{s},$
		4.4		$\tau^+\nu$
>33.5	95	44 ABREU	90D DLPH	. (
>44.5	95	⁴⁵ AKRAWY	90B OPAL	Acoplanarity
>44.3	95	⁴⁶ AKRAWY	90B OPAL	$t \rightarrow bH^+, H^+ \rightarrow c\overline{s},$
>45.8	95	⁴² DECAMP	90F ALEP	τν isolated charged particle and aplanarity
>40.7	95	⁴⁷ ABRAMS	89c MRK2	
>42.5	95	ABRAMS	89c MRK2	$t \rightarrow bH^{+}$,
		40		$H^+ \rightarrow c \overline{s}$
>29.9	95	⁴⁸ ADACHI	89c TOPZ	μ
>29.9	95	⁴⁹ ENO	89 AMY	μ , e
>25.8	95	⁵⁰ ADACHI	88 TOPZ	R, T, Acoplanarity
>25.9	95	⁵¹ IGARASHI	88 AMY	$T + (\mu,e)$
>25.9	95	⁵² SAGAWA	88 AMY	R, T
none E _{cm} =50	95	⁵³ ABE	87 VNS	R, T, Acoplanarity
>25.5	95	⁵⁴ YOSHIDA	87 VNS	R, T, Acoplanarity

- 41 ADRIANI 93G search for vector quarkonium states near Z and give limit on quarkonium–Z mixing parameter $\delta m^2 < (10{\text -}30) \; \text{GeV}^2$ (95%CL) for the mass 88–94.5 GeV. Using Richardson potential, a 15 toponium state is excluded for the mass range 87.9–88.7, 89.1–94.3 GeV. This range is very sensitive to the potential choice.
- 42 Search was near the Z peak at LEP. 43 Assumed $m_{H^+} < m_t 6$ GeV.
- 44 Superseded by ABREU 91F.

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- 45 AKRAWY 90B search was restricted to data near the Z peak at $E_{
 m cm}=91.26$ GeV at LEP. The excluded region is between 23.4 and 44.5 GeV if no H^+ decays exist.
- ⁴⁶AKRAWY 908 limit applies for any H^+ branching ratio B($c\bar{s}$). Limit increases to 45.2 GeV if B($c\bar{s}$) = 1. The lower end of the excluded region is m_{H^+} + 5 GeV.
- 47 The ABRAMS 89C limit from an isolated track search is 40.0 GeV. 48 ADACHI 89C search was at $E_{\rm cm}=56.5$ –60.8 GeV at TRISTAN using multi-hadron events accompanying muons.
- events accompanying muons. 49 ENO 89 search at $E_{\rm cm} = 50$ –60.8 GeV at TRISTAN. 50 ADACHI 88 set limit $\sigma({\rm top}) < 8.2$ pb at CL=95% for top-flavored-hadron production from event shape analyses at $E_{\rm cm} = 52$ GeV. By using the quark-parton model cross-section formula with first-order QCD corrections near the threshold, the above limit leads to a lower mass limit of 25.8 GeV at 95% confidence level for top quarks.
- 51 [GARASHI188 searches for leptons in low-thrust events and gives $\Delta R(t) < 0.15$ (95% CL) at $E_{\rm cm} = 50$ –52 GeV.
- 52 SAGAWA 88 set limit $\sigma(\text{top}) < 6.1$ pb at CL=95% for top-flavored hadron production from event shape analyses at $E_{\text{cm}} = 52$ GeV. By using the quark parton model cross-section formula near threshold, the above limit leads to lower mass bounds of 25.9 GeV for charge 2/3 quarks.
- 53 ABE 87 set limit $\sigma(\text{top}) <$ 16 pb at CL=95% for top-flavored hadron production, which
- 93 ABE 87 set limit \(\sigma(\text{top}) < 16 \) pb at CL=95% for top-flavored hadron production, which should be compared with the full top-quark production cross section of 45.9 pb.</p>
 54 YOSHIDA 87 set limit \(\sigma(\text{top}) < 17 \) pb at CL=95% for top-flavored hadron production from event shape analyses at \(E_{cm} = 52 \) GeV. This limit should be compared with the full top-quark production cross section of 34 pb, which takes into account the effect of weak neutral current but neglects its axial-vector coupling contribution expected to be suppressed near threshold. After considering the radiative effects, top quarks of mass below 25.5 GeV can be excluded by the above limit.</p>

t-Quark REFERENCES

		-	
ABACHI	95	PRL 74 2632	+Abbott, Abolins, Acharya, Adam+ (D0 Collab.)
ABACHI	95B	PRL 74 2422	+Abbott, Abolins, Acharya, Adam, Adams+ (D0 Collab.)
ABACHI	95F	PR D52 4877	+Abbott, Abolins, Acharya, Adam, Adams+ (D0 Collab.)
ABE	95F	PRL 74 2626	+Akimoto, Akopian, Albrow, Amendolia+ (CDF Collab.)
ABE	950	PR D51 4623	+Albrow, Amendolia, Amidei, Antos+ (CDF Collab.)
ABE	95V	PR D52 R2605	+Akimoto, Akopian, Albrow, Amendolia+ (CDF Collab.)
ABE	95W		+Albrow, Amendolia, Amidei, Antos+ (CDF Collab.)
ABE.F	95	PRL 75 3997	Abe, Akimoto, Akopian, Albrow, Amendolia+(CDF Collab.)
ERLER	95	PR D52 441	+Langacker (PENN)
MATSUMOTO	95	MPL A10 2553	(KEK)
ABACHI	94	PRL 72 2138	+Abbott, Abolins, Acharva, Adam+ (D0 Collab.)
ABE	94B	PRL 73 220	+Albrow, Amidei, Anway-Wiese+ (CDF Collab.)
ABE	94E	PR D50 2966	+Albrow, Amendolia, Amidei, Antos+ (CDF Collab.)
Also	94F	PRL 73 225	Abe, Albrow, Amidei, Antos, Anway-Weise+ (CDF Collab.)
ABE	94H	PRL 72 1977	+Albrow, Amidei, Anway-Wiese, Apollinari+ (CDF Collab.)
ABE	941	PRL 73 2667	+Albrow, Amidei, Antos, Anway-Wiese+ (CDF Collab.)
ABREU	94	NP B418 403	+Adam, Adye, Agasi+ (DELPHI Collab.)
ACCIARRI	94	ZPHY C62 551	+Adam, Adriani, Aguilar-Benitez+ (L3 Collab.)
AKERS	94	ZPHY C61 19	+Alexander, Allison+ (OPAL Collab.)
ARROYO	94	PRL 72 3452	+King, Bachman+ (COLU, CHIC, FNAL, ROCH, WISC)
BUSKULIC	94	ZPHY C62 539	+Casper, De Bonis, Decamp, Ghez, Goy+ (ALEPH Collab.)
ELLIS	94B	PL B333 118	+Fogli, Lisi (CERN, BARI)
GURTU	94	MPL A9 3301	(TATA)
LAENEN	94	PL B321 254	+Smith, van Neerven (FNAL, UTRE, LEID)
MONTAGNA	94	PL B335 484	+Nicrosini, Passarino, Piccinini (INFN, PAVI, CERN, TORI)
NOVIKOV	94 B	MPL A9 2641	+Okun, Rozanov, Vysotsky (GUEL, CERN, ITEP)
PDG	94	PR D50 1173	Montanet+ (CERN, LBL, BOST, IFIC+)
ADRIANI	93G	PL B313 326	+Aguilar-Benitez, Ahlen, Alcaraz, Aloisio+ (L3 Collab.)
ADRIANI	93M		+Aguilar-Benitez, Ahlen, Alcaraz, Aloisio+ (L3 Collab.)
ABE	92	PRL 68 447	+Amidei, Apollinari, Atac, Auchincloss+ (CDF Collab.)
Also	92G	PR D45 3921	Abe, Amidei, Apollinari, Atac, Auchincloss+ (CDF Collab.)
ABE	921 92	PRL 69 28 PL B276 365	+Amidei, Apollinari, Atac, Auchincloss+ (CDF Collab.)
ALITTI ALITTI	92 92B	PL B276 354	+Ambrosini, Ansari, Autiero, Bareyre+ (UA2 Collab.) +Ambrosini, Ansari, Autiero, Bareyre+ (UA2 Collab.)
ALITTI	92F	PL B280 137	+Ambrosini, Ansari, Autiero, Bareyre+ (UA2 Collab.)
ABE	91	PR D43 664	+Amidei, Apollinari, Atac, Auchincloss+ (CDF Collab.)
ABE	91C	PR D44 29	+Amidei, Apollinari, Atac, Auchincloss+ (CDF Collab.)
ABREU	91F	NP B367 511	+Adam, Adami, Adye, Akesson+ (DELPHI Collab.)
ALBAJAR	91	PL B253 503	+Albrow, Allkofer, Ankoviak, Apsimon+ (UA1 Collab.)
ALBAJAR	91B	PL B257 459	+Albrow, Allkofer, Ankoviak, Apsimon+ (UA1 Collab.)
BAER	91B	PR D44 725	+Drees, Godbole+ (FSU, DESY, BOMB, UCD, HAWA)
ABE	90	PRL 64 152	+Amidei, Apollinari, Atac, Auchincloss+ (CDF Collab.)
ABE	90B	PRL 64 147	+Amidei, Apollinari, Atac, Auchincloss+ (CDF Collab.)
ABE	90C	PRL 64 142	+Amidei, Apollinari, Atac+ (CDF Collab.)
Also	91	PR D43 664	Abe, Amidei, Apollinari, Atac, Auchincloss+ (CDF Collab.)
ABE	90D	PL B234 382	+Amako, Arai, Asano+ (VENUS Collab.)
ABREU	90D	PL B242 536	+Adam, Adami, Adye, Alekseev, Allaby+ (DELPHI Collab.)
AKESSON	90	ZPHY C46 179	+Alitti, Ansari, Ansorge, Bagnaia+ (UA2 Collab.)
AKRAWY	90B	PL B236 364	+Alexander, Allison, Allport, Anderson+ (OPAL Collab.)
ALBAJAR	90B	ZPHY C48 1	+Albrow, Allkofer, Andrieu, Ankoviak+ (UA1 Collab.)
ALITTI	90C	ZPHY C47 11	+Ansari, Ansorge, Bagnaia+ (UA2 Collab.)
BARGER	90E	PR D41 3421	+Hewett, Phillips (WISC, RAL)
DECAMP	90F	PL B236 511	+Deschizeaux, Lees, Minard+ (ALEPH Collab.)
ABRAMS	89C	PRL 63 2447	+Adolphsen, Averill, Ballam+ (Mark II Collab.)
ADACHI	89C	PL B229 427	+Aihara, Doser, Enomoto, Fujii+ (TOPAZ Collab.)
ENO	89	PRL 63 1910	+Auchincloss, Blanis, Bodek, Budd+ (AMY Collab.)
ADACHI	88 88	PRL 60 97 ZPHY C37 505	+Aihara, Dijkstra+ (TOPAZ Collab.)
ALBAJAR ALTARELLI	88	NP B308 724	+Albrow, Allkofer+ (UA1 Collab.) +Diemoz, Martinelli, Nason (CERN, ROMA, ETH)
IGARASHI	88	PRL 60 2359	+Myung, Chiba, Hanaoka+ (AMY Collab.)
SAGAWA	88	PRL 60 93	+Mori, Abe+ (AMY Collab.)
ABE	87	JPSJ 56 3763	+Amako, Arai+ (VENUS Collab.)
YOSHIDA	87	PL B198 570	+Chiba, Endo+ (VENUS Collab.)

b' (4th Generation) Quark, Searches for

MASS LIMITS for b' (4th Generation) Quark or Hadron in $p\bar{p}$ Collisions

These experiments (except for MUKHOPADHYAYA 93) assume that no two-body modes such as $b' \to b \gamma$, $b' \to b g$, or $b' \to c H^+$ are available.

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>85	95	¹ ABE	92	CDF	$\ell\ell$
 ● ● We do not use 	the followin	g data for average	s, fits	, limits,	etc. • • •
>75	95	² MUKHOPAD	. 93	RVUE	FCNC
>72	95	³ ABE	90B	CDF	$e + \mu$
>54	95	⁴ AKESSON	90	UA2	e + jets + missing E_T
>43	95	⁵ ALBAJAR	90B	UA1	$\mu + \mathbf{j}ets$
>34	95	⁶ ALBAJAR	88	UA1	e or μ + jets

- 1 ABE 92 dilepton analysis limit of >85 GeV at CL=95% also applies to b^\prime quarks, as discussed in ABE 908. 2 MUKHOPADHYAYA 93 analyze CDF dilepton data of ABE 92G in terms of a new
- quark decaying via flavor-changing neutral current. The above limit assumes B(b^\prime $b\ell^+\ell^-)=1\%$. For an exotic quark decaying only via virtual Z [B($b\ell^+\ell^-$) = 3%], the limit is 85 GeV.
- 3 ABE 90B exclude the region 28-72 GeV.
- 4 AKESSON 90 searched for events having an electron with $p_{\mathcal{T}}>12$ GeV, missing momentum >15 GeV, and a jet with $E_{\mathcal{T}}>10$ GeV, $|\eta|<2.2$, and excluded $m_{b'}$
- between 30 and 69 GeV.

 For the reduction of the limit due to non-charged-current decay modes, see Fig. 19 of ALBATAR 90B.
- ALBAJAR 908. $^6 \text{ALBAJAR 88 study events at } E_{\text{cm}} = 546 \text{ and } 630 \text{ GeV} \text{ with a muon or isolated electron,} \\ \text{accompanied by one or more jets and find agreement with Monte Carlo predictions for the production of charm and bottom, without the need for a new quark. The lower mass limit is obtained by using a conservative estimate for the <math display="inline">b'\overline{b'}$ production cross section and by assuming that it cannot be produced in W decays. The value quoted here is revised using the full $O(\alpha_3^2)$ cross section of ALTARELLI 88.

MASS LIMITS for b' (4th Generation) Quark or Hadron in e^+e^- Collisions

Search for hadrons containing a fourth-generation -1/3 quark denoted b'.

The last column specifies the assumption for the decay mode (C C denotes the conventional charged-current decay) and the event signature which is looked for

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>46.0	95	⁷ DECAMP	90F ALEF	any decay
 • • We do not use t 	he follo	wing data for average	s, fits, limit	s, etc. • • •
		⁸ ADRIANI	93G L3	Quarkonium
>44.7	95	ADRIANI	93M L3	Γ(<i>Z</i>)
>45	95	ABREU	91F DLP	+ Γ(Z)
none 19.4-28.2	95	ABE	90D VNS	Any decay; event shape
>45.0	95	ABREU	90D DLPI	B(CC) = 1; event shape
>44.5	95	⁹ ABREU	90D DLPI	$b' \rightarrow cH^-, H^- \rightarrow \overline{c}s, \tau^- \nu$
>40.5	95	¹⁰ ABREU	900 DLPI	
>28.3	. 95	ADACHI	90 TOP:	
>41.4	95	¹¹ AKRAWY	90B OPAL	Any decay; acoplanarity
>45.2	95	¹¹ AKRAWY	90B OPAL	B(CC) = 1; acopla-narity
>46	95	¹² AKRAWY	90J OPAL	$b' \rightarrow \gamma + any$
>27.5	95	¹³ ABE	89E VNS	$B(CC) = 1; \mu, e$
none 11.4-27.3	95	¹⁴ ABE	89G VNS	$B(b' \rightarrow b\gamma) > 10\%;$ isolated γ
>44.7	95	¹⁵ ABRAMS	89c MRK	2 B(CC)= 100%; isol.
>42.7	95	¹⁵ ABRAMS	89c MRK	
>42.0	95	¹⁵ ABRAMS	89c MRK	
>28.4	95	16,17 ADACHI	89C TOP	$B(CC)=1; \mu$
>28.8	95	¹⁸ ENO	89 AMY	$B(CC) \gtrsim 90\%$; μ , e
>27.2	95	^{18,19} ENO	89 AMY	
>29.0	95	¹⁸ ENO	89 AMY	$B(b' \rightarrow bg) \gtrsim 85\%;$ event shape
>24.4	95	²⁰ IGARASHI	88 AMY	μ , e
>23.8	95	²¹ SAGAWA	88 AMY	event shape
>22.7	95	²² ADEVA	86 MRK	
>21		23 ALTHOFF	84c TASS	•
>19		²⁴ ALTHOFF	84I TASS	Aplanarity

- ⁷ DECAMP 90F looked for isolated charged particles, for isolated photons, and for four-jet final states. The modes $b'\to bg$ for B $(b'\to bg)>65\%$ $b'\to b\gamma$ for B $(b'\to b\gamma)>5\%$ are excluded. Charged Higgs decay were not discussed.
- A ADRIANI 93G search for vector quarkonium states near Z and give limit on quarkonium-Z mixing parameter $\delta m^2 < (10-30) \text{ GeV}^2$ (95%CL) for the mass 88–94.5 GeV. Using Richardson potential, a 1S $(b' \, \overline{b'})$ state is excluded for the mass range 87.7–94.7 GeV. This range depends on the potential choice.
- 9 ABREU 90D assumed $m_{H^{-}} < m_{b^{\prime}} 3$ GeV.
- $^{10}\,\mathrm{Superseded}$ by ABREU 91F.
- LEP. The excluded region is between 23.6 and 41.4 GeV if no H^\pm decays exist. For charged Higgs decays the excluded regions are between $(m_{H^\pm} + 1.5 \text{ GeV})$ and 45.5
- GeV. 12 AKRAWY 90J search for isolated photons in hadronic Z decay and derive B($Z \rightarrow b' \overline{b}'$)·B($b' \rightarrow \gamma X$)/B($Z \rightarrow hadrons$) < 2.2×10^{-3} . Mass limit assumes $B(b' \rightarrow \gamma X) > 10\%$.
- 13 ABE 89s search at $E_{\rm cm}=$ 56–57 GeV at TRISTAN for multihadron events with a spherical shape (using thrust and acoplanarity) or containing isolated leptons.
- $^{14}\,\mathrm{ABE}$ 89G search was at $E_\mathrm{cm}=$ 55–60.8 GeV at TRISTAN.
- 15 if the photonic decay mode is large (B($b'\to b\gamma$) > 25%), the ABRAMS 89C limit is 45.4 GeV. The limit for for Higgs decay ($b'\to cH^-, H^-\to \overline{c}s$) is 45.2 GeV.
- $^{16}\,\mathrm{ADACHI}$ 89c search was at $E_{\mathrm{CM}}=56.5\text{--}60.8$ GeV at TRISTAN using multi-hadron events accompanying muons.
- The ENO 89 search at $E_{\rm cm} = 50$ –60.8 at TRISTAN.
- ¹⁹ ENO 89 considers arbitrary mixture of the charged current, bg, and $b\gamma$ decays.
- 20 IGARASHI 88 searches for leptons in low-thrust events and gives $\Delta R(b') < 0.26$ (95% CL) assuming charged current decay, which translates to $m_{b'} > 24.4$ GeV.
- ²¹ SAGAWA 88 set limit $\sigma(\text{top}) < 6.1$ pb at CL=95% for top-flavored hadron production from event shape analyses at $E_{\text{cm}} = 52$ GeV. By using the quark parton model cross-section formula near threshold, the above limit leads to lower mass bounds of 23.8 GeV for charge -1/3 quarks.
- for charge -1/3 quarks. 22 ADEVA 86 give 95%CL upper bound on an excess of the normalized cross section, ΔR , as a function of the minimum c.m. energy (see their figure 3). Production of a pair of 1/3 charge quarks is excluded up to $E_{\rm cm}=45.4$ GeV. 2^3 ALTHOFF 84c narrow state search sets limit $\Gamma(e^+e^-)$ B(hadrons) <2.4 keV CL = 95% and heavy charge 1/3 quark pair production m>21 GeV, CL = 95%. 2^4 ALTHOFF 84i exclude heavy quark pair production for 7 < m < 19 GeV (1/3 charge) using aplanarity distributions (CL = 95%).

b' (Fourth Generation) Quark, Free Quark Searches

REFERENCES FOR Searches for (Fourth Generation) b' Quark

ADRIANI	93G	PL B313 326	+Aguilar-Benitez, Ahlen, Alcaraz, Aloisio+ (L3 Collab.)
ADRIANI	93M	PRPL 236 1	+Aguilar-Benitez, Ahlen, Alcaraz, Aloisio+ (L3 Collab.)
MUKHOPAD	93	PR D48 2105	Mukhopadhyaya, Roy (TATA)
ABE	92	PRL 68 447	+Amidei, Apollinari, Atac, Auchincloss+ (CDF Collab.)
Also	92G	PR D45 3921	Abe, Amidei, Apollinari, Atac, Auchincloss+ (CDF Collab.)
ABE	92G	PR D45 3921	+Amidei, Apollinari, Atac, Auchincloss+ (CDF Collab.)
ABREU	91F	NP B367 511	+Adam, Adami, Adye, Akesson+ (DELPHI Collab.)
ABE	90B	PRL 64 147	+Amidei, Apollinari, Atac, Auchincloss+ (CDF Collab.)
ABE	90D	PL B234 382	+Amako, Arai, Asano+ (VENUS Collab.)
ABREU	90D	PL B242 536	+Adam, Adami, Adye, Alekseev, Allaby+ (DELPHI Collab.)
ADACHI	90	PL B234 197	+Aihara, Doser, Enomoto+ (TOPAZ Collab.)
AKESSON	90	ZPHY C46 179	+Alitti, Ansari, Ansorge, Bagnaia+ (UA2 Collab.)
AKRAWY	90B	PL B236 364	+Alexander, Allison, Allport, Anderson+ (OPAL Collab.)
AKRAWY	90 J	PL B246 285	+Alexander, Allison, Allport, Anderson+ (OPAL Collab.)
ALBAJAR	90B	ZPHY C48 1	+Albrow, Allkofer, Andrieu, Ankoviak+ (UA1 Collab.)
DECAMP	90F	PL B236 511	+Deschizeaux, Lees, Minard+ (ALEPH Collab.)
ABE	89E	PR D39 3524	+Amako, Arai, Asano, Chiba, Chiba+ (VENUS Collab.)
ABE	89G	PRL 63 1776	+Amako, Arai, Asano, Chiba+ (VENUS Collab.)
ABRAMS	89C	PRL 63 2447	+Adolphsen, Averill, Ballam+ (Mark II Collab.)
ADACHI	89C	PL B229 427	+Aihara, Doser, Enomoto, Fujii+ (TOPAZ Collab.)
ENO	89	PRL 63 1910	+Auchincloss, Blanis, Bodek, Budd+ (AMY Collab.)
ALBAJAR	88	ZPHY C37 505	+Albrow, Allkofer+ (UA1 Collab.)
ALTARELLI	88	NP B308 724	+Diemoz, Martinelli, Nason (CERN, ROMA, ETH)
IGARASHI	88	PRL 60 2359	+Myung, Chiba, Hanaoka+ (AMY Collab.)
SAGAWA	88	PRL 60 93	+Mori, Abe+ (AMY Collab.)
ADEVA	86	PR D34 681	+Ansari, Becker, Becker-Szendy+ (Mark-J Collab.)
ALTHOFF	84C	PL 138B 441	+Braunschweig, Kirschfink+ (TASSO Collab.)
ALTHOFF	841	ZPHY C22 307	+Braunschweig, Kirschfink+ (TASSO Collab.)

Free Quark Searches

FREE QUARK SEARCHES

The basis for much of the theory of particle scattering and hadron spectroscopy is the construction of the hadrons from a set of fractionally charged constituents (quarks). A central but unproven hypothesis of this theory, Quantum Chromodynamics, is that quarks cannot be observed as free particles but are confined to mesons and baryons.

Experiments show that it is at best difficult to "unglue" quarks. Accelerator searches at increasing energies have produced no evidence for free quarks, while only a few cosmic-ray and matter searches have produced uncorroborated events.

This compilation is only a guide to the literature, since the quoted experimental limits are often only indicative. Reviews can be found in Refs. 1-3.

References

- 1. P.F. Smith, Ann. Rev. Nucl. and Part. Sci. 39, 73 (1989).
- L. Lyons, Phys. Reports 129, 225 (1985).
- M. Marinelli and G. Morpurgo, Phys. Reports 85, 161 (1982).

Quark Pro	duction	Cross S	ection –	– Accele	erator	Searches		
X-SECT	CHG	MASS	ENERGY					
(cm ²)	(e/3)	(GeV)	(GeV)	BEAM	EVTS	DOCUMENT ID		TECN
<2.E-35	+2	250	1800	$p \overline{p}$	0	¹ ABE	92J	CDF
< 1.E - 35	+4	250	1800	$p\overline{p}$	0	¹ ABE	92J	CDF
< 3.8E - 28			14.5A	²⁸ SI-Pb	0	² HE	91	PLAS
< 3.2E - 28			14.5A	²⁸ Si−Cu	0	² HE	91	PLAS
< 1.E - 40	$\pm 1,2$	<10		$p, \nu, \overline{\nu}$	0	BERGSMA		CHRM
<1.E-36	$\pm 1,2$	< 9	200	μ	0	AUBERT	83C	SPEC
< 2.E - 10	$\pm 2,4$	1-3	200	p	0	³ BUSSIERE	80	CNTR
< 5.E - 38	+1,2	>5	300	p	0	4,5 STEVENSON	79	CNTR
< 1.E - 33	± 1	< 20	52	pр	0	BASILE	78	SPEC
< 9.E - 39	$\pm 1,2$	<6	400	p	0	⁴ ANTREASYA	N 77	SPEC
< 8.E - 35	+1,2	<20	52	pр	0	⁶ FABJAN	75	CNTR
< 5.E - 38	-1,2	4-9	200	p	0	NASH	74	CNTR
< 1.E - 32	+2,4	4-24	52	pр	0	ALPER	73	SPEC
< 5.E - 31	+1,2,4	<12	300	p	0	LEIPUNER	73	CNTR
<6.E-34	± 1.2	<13	52	pp	0	BOTT	72	CNTR
< 1.E - 36	_ 4	4	70	p	0	_ ANTIPOV	71	CNTR
< 1.E - 35	\pm 1,2	2	28	p	0	7 ALLABY		CNTR
< 4.E - 37	- 2	< 5	70	p	0	3 ANTIPOV	69	CNTR
<3.E-37	-1,2	2-5	70	p	0	⁷ ANTIPOV		CNTR
< 1.E - 35	+1,2	< 7	30	p	0	DORFAN	65	CNTR
<2.E-35	- 2	< 2.5-5	30	p	0	⁸ FRANZINI		CNTR
<5.E-35	+1,2	<2.2	21	p	0	BINGHAM	64	HLBC
< 1.E - 32	+1,2	< 4.0	28	p	0	BLUM	64	HBC
< 1.E - 35	+1,2	< 2.5	31	p	0	⁸ HAGOPIAN	64	HBC
< 1.E - 34	+1	<2	28	p	0	LEIPUNER	64	CNTR
< 1.E - 33	+1,2	< 2.4	24	p	0	MORRISON	64	HBC

- 1 ABE 92J flux limits decrease as the mass increases from 50 to 500 GeV. 2 HE 91 limits are for charges of the form $\it N\pm1/3$ from 23/3 to 38/3.
- ³ Hadronic or leptonic quarks.
- 4 Cross section cm²/GeV². 5 3 × 10 $^{-5}$ < lifetime < 1 × 10 $^{-3}$ s. 6 Includes BOTT 72 results.
- Assumes isotropic cm production.

Quark Differential Production Cross Section — Accelerator Searches

X-SECT	CHG	MASS	ENERGY					
(cm ² sr ⁻¹ GeV	-1) e/3	(GeV)	(GeV)	BEAM	EVTS	DOCUMENT ID		TECN
<4.E-36	-2,4	1.5-6	70	p	0	BALDIN	76	CNTR
<2.E-33	± 4	5-20	52	pр	0	ALBROW	75	SPEC
< 5.E - 34	<7	7-15	44	pр	0	JOVANOV	75	CNTR
< 5.E - 35			20	γ	0	⁹ GALIK	74	CNTR
< 9.E - 35	-1,2		200	p	0	NASH	74	CNTR
< 4.E - 36	- 4	2.3-2.7	70	p	0	ANTIPOV	71	CNTR
<3.E-35	$\pm 1,2$	< 2.7	27	p	0	ALLABY	69 B	CNTR
< 7.E - 38	-1,2	< 2.5	70	p	0	ANTIPOV	69B	CNTR
⁹ Cross se	ction in c	m ² /sr/equ	ivalent q	uanta.				

Quark Flux — Accelerator Searches

The definition of FLUX depends on the experiment

- (a) is the ratio of measured free quarks to predicted free quarks if there is no "con-
- (b) is the probability of fractional charge on nuclear fragments.
- (c) is the 90%CL upper limit on fractionally-charged particles produced per interaction.
- (d) is quarks per collision.
- (e) is inclusive quark-production cross-section ratio to $\sigma(e^+e^- \to \mu^+\mu^-)$.
- (f) is quark flux per charged particle.
- (g) is the flux per ν -event.
- (h) is quark yield per π^- yield.
- (i) is 2-body exclusive quark-production cross-section ratio to $\sigma(e^+\,e^-\,\rightarrow$ $\mu^+\mu^-$).

	$\mu^+\mu^-$).							
FLUX	CHG (e/3)	MASS (GeV)	ENRGY (GeV)	BEAM EV	/TS	DOCUMENT ID		TECN
<0.94E-4 e	±2	2-30	88-94	e^+e^-	0	AKERS	95R	OPAL
<1.7E-4 e	±2	30-40	88-94	e^+e^-	0	AKERS	95R	OPAL
<3.6E-4 e	±4	5-30	88-94	e^+e^-	0	AKERS	95R	OPAL
<1.9E-4 e	±4	30-45	88-94	e^+e^-	0	AKERS	95R	OPAL
<2.E-3 e	+1	5-40	88-94	e^+e^-	0	¹⁰ BUSKULIC	93C	ALEP
<6.E-4 e	+2	5-30	88-94	e^+e^-	0	¹⁰ BUSKULIC	93C	ALEP
<1.2E-3 e	+4	15-40	88-94	e^+e^-	0	¹⁰ BUSKULIC	93C	ALEP
<3.6E-4 i	+4	5.0-10.2	88-94	e^+e^-	0	BUSKULIC	93C	ALEP
<3.6E-4	+4	16.5-26.0	88-94	e^+e^-	0	BUSKULIC	93 C	ALEP
<6.9E-4	+4	26.0-33.3	88-94	e^+e^-	0	BUSKULIC	93C	ALEP
<9.1E-4	+4	33.3-38.6	88-94	e^+e^-	0	BUSKULIC	93 C	ALEP
<1.1E-3	+4	38.6-44.9	88-94	e^+e^-	0	BUSKULIC	93C	ALEP
b	4.5.7.8		2.1A	16 _O 0,2	,0,6	¹¹ GHOSH	92	EMUL
<6.4E-5 g	1			$\nu, \overline{\nu}$	1	¹² BASILE	91	CNTR
<3.7E-5 g				$\nu,\overline{\nu}$	0	¹² BASILE	91	CNTR
<3.9E-5 g	1			$\nu,\overline{\nu}$	1	¹³ BASILE	91	CNTR
<2.8E-5 g	2			ν , $\overline{\nu}$	0	¹³ BASILE	91	CNTR
<1.9E-4 C	:		14.5A	²⁸ Si-Pb	0	¹⁴ HE	91	PLAS
<3.9E-4 C	:		14.5A	²⁸ Si–Cu	0	¹⁴ HE	91	PLAS
<1.E-9	±1,2,4		14.5A	¹⁶ 0–Ar	0	MATIS	91	MDRP
<5.1E-10 c	±1,2,4		14.5A	¹⁶ 0–Hg	0	MATIS	91	MDRP
<8.1E-9 C	±1,2,4		14.5A	Si-Hg	0	MATIS	91	MDRP
<1.7E-6	±1,2,4		60A	¹⁶ O-Hg	0	MATIS	91	MDRP
<3.5E-7 c	±1,2,4		200A	¹⁶ O-Hg	0	MATIS	91	MDRP
<1.3E-6 C	±1,2,4		200A	S-Hg	0	MATIS	91	MDRP
<5E−2 €	2	19-27	52-60	e^+e^-	0	ADACHI		TOPZ
<5E−2 €		<24	52-60	e^+e^-	0	ADACHI		TOPZ
<1.E-4 6	+2	<3.5	10	e^+e^-	0	BOWCOCK	89B	CLEO
<1.E-6	±1,2		60	16O-Hg	0	CALLOWAY	89	MDRP
< 3.5E - 7			200	¹⁶ O-Hg	0	CALLOWAY	89	MDRP
<1.3E-6 d			200	S-Hg	0	CALLOWAY	89	MDRP
<1.2E-10 d		1	800	p-Hg	0	MATIS	89	MDRP
<1.1E-10 d		1	800	p-Hg	0	MATIS	89	MDRP
<1.2E-10 d		1	800	$p-N_2$	0	MATIS	89	MDRP
< 7.7E - 11 c		1	800	$p-N_2$	0	MATIS	89	MDRP
<6.E-9 h		0.9-2.3	12	p	0	NAKAMURA	89	SPEC
<5.E-5 g		< 0.5		$\nu, \overline{\nu} d$	0	ALLASIA ¹⁵ HOFFMANN	88	BEBC
<3.E-4 t			14.5	16 _{O-Pb}	0		88	PLAS
<2.E-4 t		-200	200		0	16 HOFFMANN LYONS	88 87	PLAS MLEV
<2.E-4 a		<300	320 14.5	<i>pp</i> 16 _{O−Hg}	0	SHAW	87	MDRP
<1.E-9	$\pm 1,2,4,5$		14.5	- U-Hg	U	SHAVV	81	MUKP

<3.E-3	d	-1,2,3,4,6	<5	2	Si-Si	0	¹⁷ АВАСНІ	86c CNTR
<1.E-4	e	$\pm 1,2,4$	<4	10	e^+e^-	0	ALBRECHT	85G ARG
<6.E-5	b	$\pm 1,2$	1	540	$p\overline{p}$	0	BANNER	85 UA2
<5.E-3	e	-4	1-8	29	e ⁺ e ⁻	0	AIHARA	84 TPC
< 1.E - 2	е	\pm 1,2	1-13	29	e+ e-	0	AIHARA	84B TPC
< 2.E - 4	b	± 1		72	⁴⁰ Ar	0	¹⁸ BARWICK	84 CNTR
< 1.E - 4	e	±2	< 0.4	1.4	e^+e^-	0	BONDAR	84 OLYA
< 5.E - 1	e	\pm 1,2	<13	29	e^+e^-	0	GURYN	84 CNTR
<3.E-3	b	\pm 1,2	<2	540	$p\overline{p}$	0	BANNER	83 CNTR
<1.E-4	b	\pm 1,2		106	⁵⁶ Fe	0	LINDGREN	83 CNTR
< 3.E - 3	b	> ± 0.1		74	⁴⁰ Ar	0	¹⁸ PRICE	83 PLAS
< 1.E - 2	e	±1,2	<14	29	e^+e^-	0	MARINI	82B CNTR
< 8.E - 2	e	\pm 1,2	<12	29	e^+e^-	0	ROSS	82 CNTR
<3.E-4	e	±2	1.8-2	7	e^+e^-	0	WEISS	81 MRK2
< 5.E - 2	е	+1,2,4,5	2-12	27	e^+e^-	0	BARTEL	80 JADE
< 2.E - 5	g	1,2			ν	0 1	^{2,13} BASILE	80 CNTR
<3.E-10	f	\pm 2,4	1-3	200	p	0	¹⁹ BOZZOLI	79 CNTR
< 6.E - 11	f	± 1	<21	52	pр	0	BASILE	78 SPEC
<5.E-3	g				ν_{μ}	0	BASILE	78B CNTR
<2.E-9	f	± 1	<26	62	pр	0	BASILE	77 SPEC
< 7.E - 10	f	+1,2	<20	52	p	0	²⁰ FABJAN	75 CNTR
		+1,2	>4.5		γ	0 1	^{2,13} GALIK	74 CNTR
		+1,2	>1.5	12	e^-	0 1	^{2,13} BELLAMY	68 CNTR
		+1,2	>0.9		γ	0	13 BATHOW	67 CNTR
		+1,2	>0.9	6	γ	0	¹³ FOSS	67 CNTR

- $^{10}\,\mathrm{BUSKULIC}$ 93C limits for inclusive quark production are more conservative if the ALEPH
- 11 GHOSH 92 reports measurement of spallation fragment charge based on ionization in emulsion. Out of 650 measured tracks, 2 were consistent with charge 5e/3, and 4 with 7e/3.

 12 Hadronic quark.

 13 Leptonic quark.

- 14 HE 91 limits are for charges of the form N±1/3 from 23/3 to 38/3, and correspond to cross-section limits of 380µb (Pb) and 320µb (Cu).
 15 The limits apply to projectile fragment charges of 17, 19, 20, 22, 23 in units of e/3.
- 16 The limits apply to projectile fragment charges of 16, 17, 19, 20, 22, 23 in units of e/3.
- $^{\rm 17}\,{\rm Flux}$ limits and mass range depend on charge.

- 18 Bound to nuclei. 19 Quark lifetimes $> 1 \times 10^{-8}$ s. 20 One candidate m < 0.17 GeV.

Quark Flux — Cosmic Ray Searches

Shielding values followed with an asterisk indicate altitude in km. Shielding values not followed with an asterisk indicate sea level in kg/cm^2 .

			icate sea ievei	III Kg/CI	····
FLUX (cm - 2sr - 1s-	CHG 1) (e/3)	MASS (GeV)	SHIELDING	EVTS	DOCUMENT IDTECN_
<2.1E-15	± 1			0	MORI 91 KAM2
< 2.3E - 15	±2			0	MORI 91 KAM2
<2.E-10	$\pm 1, 2$		0.3	0	WADA 88 CNTR
	±4		0.3	12	²¹ WADA 88 CNTR
	±4		0.3	9	²² WADA 86 CNTR
<1.E-12	$\pm 2,3/2$		−70 .	0	²³ KAWAGOE 848 PLAS
< 9.E - 10	$\pm 1,2$		0.3	0	WADA 84B CNTR
< 4.E - 9	±4		0.3	7	WADA 84B CNTR
< 2.E - 12	$\pm 1,2,3$		-0.3 *	0	MASHIMO 83 CNTR
< 3.E - 10	±:1,2		0.3	0	MARINI 82 CNTR
< 2.E - 11	$\pm 1,2$			0	MASHIMO 82 CNTR
< 8.E - 10	±1,2		0.3	0	²³ NAPOLITANO 82 CNTR
				3	²⁴ YOCK 78 CNTR
< 1.E - 9				0	²⁵ BRIATORE 76 ELEC
< 2.E - 11	+1			0	²⁶ HAZEN 75 CC
< 2.E - 10	+1,2			0	KRISOR 75 CNTR
< 1.E - 7	+1,2			0	^{26,27} CLARK 748 CC
< 3.E - 10	+1	>20		0	KIFUNE 74 CNTR
< 8.E - 11	+1			0	²⁶ ASHTON 73 CNTR
<2.E-8	+1,2			0	HICKS 73B CNTR
<5.E-10	+4		2.8 *	0	BEAUCHAMP 72 CNTR
<1.E-10	+1,2			0	²⁶ BOHM 72B CNTR
< 1.E - 10	+1,2		2.8 *	0	COX 72 ELEC
<3.E-10	+2			0	CROUCH 72 CNTR
<3.E-8			7	0	25 DARDO 72 CNTR
<4.E-9	+1			0	26 EVANS 72 CC
<2.E-9		>10		0	²⁵ TONWAR 72 CNTR
<2.E-10	+1		2.8 *	0	CHIN 71 CNTR
<3.E-10	+1,2			0	26 CLARK 71B CC
<1.E-10	+1,2 .			0	²⁶ HAZEN 71 CC
< 5.E - 10	+1,2		3.5 *	0	BOSIA 70 CNTR
	+1,2	< 6.5		1	²⁶ CHU 70 HLBC
<2.E-9	+1			0	FAISSNER 70B CNTR
<2.E-10	+1,2		* 8.0	0	KRIDER 70 CNTR
<5.E-11	+2			4	CAIRNS 69 CC
<8.E-10	+1,2	<10		0	FUKUSHIMA 69 CNTR

	+2			1 4	^{26,28} MCCUSKER	69	CC
<1.E-10		>5	1.7,3.6	0	²⁵ BJORNBOE	68	CNTR
<1.E-8	$\pm 1,2,4$		6.3,.2 *	0	23 BRIATORE	68	CNTR
<3.E-8		>2		0	FRANZINI	68	CNTR
<9.E-11	$\pm 1,2$			0	GARMIRE	68	CNTR
< 4.E - 10	± 1			0	HANAYAMA	68	CNTR
<3.E-8		>15		0	KASHA	68	OSPK
< 2.E - 10	+2			0	KASHA	68B	CNTR
< 2.E - 10	+4			0	KASHA	68C	CNTR
< 2.E - 10	+2		6	0	BARTON	67	CNTR
< 2.E - 7	+4		0.008,0.5 *	0	BUHLER	67	CNTR
< 5.E - 10	1,2		0.008,0.5 *	0	BUHLER	67B	CNTR
< 4.E - 10	+1,2			0	GOMEZ	67	CNTR
<2.E-9	+2			0	KASHA	67	CNTR
< 2.E - 10	+2		220	0	BARTON	66	CNTR
<2.E-9	+1,2		0.5 *	0	BUHLER	66	CNTR
<3.E-9	+1,2			0	KASHA	66	CNTR
<2.E-9	+1,2			0	LAMB	66	CNTR
<2.E-8	+1,2	>7	2.8 *	0	DELISE	65	CNTR
<5.E-8	+2	>2.5	0.5 *	0	MASSAM	65	CNTR
<2.E-8	+1		2.5 *	0	BOWEN	64	CNTR
< 2.E - 7	+1		8.0	0	SUNYAR	64	CNTR

- ²¹ Distribution in celestial sphere was described as anisotropic. ²² With telescope axis at zenith angle 40° to the south.

- ²⁴ Urith telescope and 3.1 = 2.3 Leptonic quarks. 2.4 Lifetime $> 10^{-8}$ s; charge ± 0.70 , 0.68, 0.42; and mass >4.4, 4.8, and 20 GeV, respectively. tively.

 25 Time delayed air shower search.
- 26 Prompt air shower search. 27 Also e/4 and e/6 charges.
- 28 No events in subsequent experiments.

Quark Density — Matter Searches For a recent review, see SMITH 89. QUARKS/ CHG MASS

QUARKS/ NUCLEON	CHG (e/3)	MASS (GeV)	MATERIAL/METHOD L	EVTS	DOCUMENT ID
<8.E-22	+2		Si/infrared photoionization	n O	PERERA 93
<5.E-27	±1,2		sea water/levitation	0	HOMER 92
<4.E-20	±1,2		meteorites/mag. levitatio	_	JONES 89
<1.E-19	±1,2		various/spectrometer	0	MILNER 87
<5.E-22	±1,2		W/levitation	Ö	SMITH 87
<3.E-20	+1,2		org lig/droplet tower	0	VANPOLEN 87
<6.E-20	-1,2		org lig/droplet tower	0	VANPOLEN 87
<3.E-21	±1		Hg drops-untreated	0	SAVAGE 86
<3.E-22	±1,2		levitated niobium	0	SMITH 86
<2.E-26	±1,2		⁴ He/levitation	0	SMITH 86B
<2.E-20	>±1,2	0.2-250	niobium+tungs/ion	0	MILNER 85
<1.E-21	±1	0.2 200	levitated niobium	0	SMITH 85
\1.L 21	+1.2	<100		0	KUTSCHERA 84
<5.E-22	, 1,1	(100	levitated steel	0	MARINELLI 84
<9.E-20	± <13		water/oil drop	0	JOYCE 83
<2.E-21			levitated steel	0	LIEBOWITZ 83
<1.E-19	±1,2		photo ion spec	0	VANDESTEEG 83
<2.E-20	11,2		mercury/oil drop	0	29 HODGES 81
1.E-20	+1		levitated niobium	4	30 LARUE 81
1.E-20	-1		levitated niobium	4	30 LARUE 81
<1.E-20	-1		levitated steel	0	MARINELLI 80B
<6.E-16			helium/mass spec	0	BOYD 79
1.E-20	+1		levitated niobium	2	30 LARUE 79
<4.E-28	+1		earth+/ion beam	0	OGOROD 79
<4.E-26 <5.E-15			tungs./mass spec	0	BOYD 78
<5.E-15	+1	<1.7		0	BOYD 78B
<5.E-16 <1.E-21	+3	<1.7	, , , ,		
<1.E-21 <6.E-15	±2,4		water/ion beam levitated tungsten	0	LUND 78 PUTT 78
<1.E-22	>1/2			0	SCHIFFER 78
<1.E-22 <5.E-15			metals/mass spec	0	BLAND 77
<3.E-15			levitated tungsten ox levitated iron	0	GALLINARO 77
< 3.E – 21 2.E – 21	-1		levitated iron	1	30 LARUE 77
4.E-21	+1		levitated niobium	2	30 LARUE 77
				0	MULLER 77
<1.E-13 <5.E-27	+3	<7.7	, , ,	0	OGOROD 77
<5.E-21 <1.E-21			water+/ion beam lunar+/ion spec	0	STEVENS 76
		-60		0	
<1.E-15 <5.E-19	+1	< 60	oxygen+/ion spec	0	ELBERT 70 MORPURGO 70
			levitated graphite	0	COOK 69
<5.E-23 <1.E-17	112		water+/atom beam	0	
	$\pm 1,2$		levitated graphite		BRAGINSK 68
<1.E-17			water+/uv spec	0	RANK 68
<3.E-19	±1		levitated iron	0	STOVER 67 31 BENNETT 66
<1.E-10	. 1.2		sun/uv spec	0	
<1.E-17 <1.E-16	+1,2 ±1		meteorites+/ion beam	0	CHUPKA 66 GALLINARO 66
<1.E-16 <1.E-22	±1		levitated graphite	0	HILLAS 59
<1.E-22	-2		argon/electrometer levitated oil	0	MILLIKAN 10
20	2		icvitated oil	U	MILLINAIN 10

- 29 Also set limits for $Q=\pm e/6.$ 30 Note that in PHILLIPS 88 these authors report a subtle magnetic effect which could account for the apparent fractional charges. 31 Limit inferred by JONES 778.

Free Quark Searches

REFERENCES FOR	Free Quark	Searches
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AKERS	95R	ZPHY C67 203		+Alexander, Allison, Ametewee, Anderson+ (OPAL Collab.) +Decamp, Goy, Lees, Minard+ (ALEPH Collab.)
BUSKULIC	93C	PL B303 198		Decamo Goy Lees Minards (ALEPH Collab.)
PERERA	93	PRL 70 1053		+Betarbet, Byungsung, Coon (PITT)
ABE	92 J	PR D46 R1889		+Alexander, Allison, Ametewee, Anderson+ (OPAL Collab.) +Decamp, Goy, Lees, Minard+ (ALEPH Collab.) +Betarbet, Byungsung, Coon (PITT) +Amidei, Anway-Weiss+ (CDF Collab.)
		FR D40 R1009		+Amidei, Anway-Weiss+ (CDF Collab.) +Roy, Ghosh, Ghosh, Basu (JADA, BANGB) +Smith, Lewin, Robertson+ (RAL, SHMP, LOQM) +Berbiers, Cara Romeo+ (BGNA, INFN, CERN, PLRM+)
GHOSH	92	NC 105A 99	-	+Roy, Ghosh, Ghosh, Basu (JADA, BANGB)
HOMER	92	ZPHY C55 549		+Smith, Lewin, Robertson+ (RAL, SHMP, LOQM)
BASILE	91	NC 104A 405		+Berbiers, Cara Romeo+ (BGNA, INFN, CERN, PLRM+)
HE	91	PR C44 1672		+Price (UCB) +Pugh, Alba, Bland, Calloway+ (LBL, SFSU, UCI, LANL.) +Quama Suzuki, Takahashi (Kamiokande II. Collah.)
MATIS	91	NP A525 513c		+Pugh, Alba, Bland, Callowav+ (LBL, SFSU, UCI, LANL)
MORI	91	PR D43 2843		+Oyama, Suzuki, Takahashi+ (Kamiokande II Collab.) +Aihara, Doser, Enomoto+ (TOPAZ Collab.)
ADACHI	900	PL B244 352		+Aihara, Doser, Enomoto+ (TOPAZ Collab.)
	89B	PR D40 263		+Kinoshita, Mauskopf, Pipkin+ (CLEO Collab.)
BOWCOCK	89	FK D40 203		+Kinoshita, Mauskopf, Pipkin+ (CLEO Collab.)
CALLOWAY		PL B232 549		+Alba, Bland, Dickson, Hodges+ (SFSU, UCI, LBL, LANL)
JONES	89	ZPHY C43 349		+Smith, Homer, Lewin, Walford (LOIC, RAL) +Pugh, Bland, Calloway+ (LBL, SFSU, UCI, FNAL, LANL) +Kobayashi, Konaka, Imai, Masaike+ (KYOT, TMTC)
MATIS	89	PR D39 1851 PR D39 1261		+Pugh, Bland, Calloway+ (LBL, SFSU, UCI, FNAL, LANL)
NAKAMURA	89	PR D39 1261		+Kobayashi, Konaka, Imai, Masaike+ (KYOT, TMTC)
SMITH	89	ARNPS 39 73 PR D37 219		(RAL)
ALLASIA	88	PR D37 219		+Angelini, Baldini+ (WA25 Collab.)
HOFFMANN	88	PL B200 583		+Brechtmann, Heinrich, Benton (SIEG, USF)
PHILLIPS	88			+Fairbank, Navarro (STAN)
		NIM A264 125		+Fairbank, Ivavarro (STAIV)
WADA	88	NC 11C 229 ZPHY C36 363		+Yamashita, Yamamoto (OKAY)
LYONS	87	ZPHY C36 363		+Smith, Homer, Lewin, Walford+ (OXF, RAL, LOIC) +Cooper, Chang, Wilson, Labrenz, McKeown (CIT)
MILNER	87	PR D36 37		+Cooper, Chang, Wilson, Labrenz, McKeown (CIT)
SHAW	87	PR D36 3533		+Matis, Pugh, Slansky+ (UCI, LBL, LANL, SFSU)
SMITH	87	PL B197 447		+Homer, Lewin, Walford, Jones (RAL, LOIC)
VANPOLEN	87	PR D36 1983		+ Hagetrom Hirech (ANI 181)
ABACHI	86C	PR D33 2733		
SAVAGE	86	PL 167B 481		+Shor, Barasch, Carroll+ +Bland, Hodges, Huntington, Joyce+ +Homer, Lewin, Walford, Jones +Homer, Lewin, Walford, Jones (RAL, LOIC) +Homer, Lewin, Walford, Jones (RAL, LOIC)
		DI D171 100		Homer Louis Walford Japan (DAI 1010)
SMITH	86	PL B171 129		+nomer, Lewin, Wallord, Jones (RAL, LOIC)
SMITH	86B	PL B181 407		
WADA	86	NC 9C 358 PL 156B 134		(OKAY) +Binder, Harder, Hasemann+ (ARGUS Collab.)
ALBRECHT	85G	PL 156B 134		+Binder, Harder, Hasemann+ (ARGUS Collab.)
BANNER	85	PL 156B 129		+Bloch, Borer, Borghini+ (UA2 Collab.)
MILNER	85	PRL 54 1472		
SMITH	85	PL 153B 188		+Homer, Lewin, Walford, Jones (RAL, LOIC)
AIHARA	84	DDI 52 160		+Alston-Garnjost, Badtke, Bakker+ (TPC Collab.) +Alston-Garnjost, Badtke, Bakker+ (TPC Collab.)
		PRL 52 168 PRL 52 2332		+Alston-Garrijost, Bautke, Bakker+ (TPC Collab.)
AIHARA	84B	PRL 52 2332		+Homer, Lewin, Walford, Jones (RAL, LOIC) +Alston-Garnjost, Badtke, Bakker+ (TPC Collab.) +Alston-Garnjost, Badtke, Bakker+ (TPC Collab.)
BARWICK	84	PR D30 691		
BERGSMA	84B	ZPHY C24 217		+Musser, Stevenson (UCB) +Allaby, Abt, Gemanov+ (CHARM Collab.)
BONDAR	84	JETPL 40 1265		+Allaby, Abt, Gemanov+ (CHARM Collab.) +Kurdadze, Lelchuk, Panin, Sidorov+ (NOVO) 40 440.
		Translated from	ZETFP	40 440.
GURYN	84	PL 139B 313		+Parker, Fries+ (FRAS, LBL, NWES, STAN, HAWA)
KAWAGOE	84B	LNC 41 604 PR D29 791		+Mashimo, Nakamura, Nozaki, Orito (TOKY) +Schiffer, Frekers+ (ANL, FNAL)
KUTSCHERA	84	PR D29 791		+Schiffer, Frekers+ (ANL, FNAL)
MARINELLI	84	PL 137B 439		+Morpurgo (GENO)
WADA	84B	LNC 40 329		+Yamashita, Yamamoto (OKAY)
AUBERT	83C	PL 133B 461		+Bassompierre, Becks, Best+ (EMC Collab.)
	83	PL 133D 401		+ Dassonipierie, Decks, Dest+ (LIVIC Collab.)
BANNER		PL 121B 187		+Bloch, Bonaudi, Borer+ (UA2 Collab.) +Abrams, Bland, Johnson, Lindgren+ (SFSU) +Binder, Ziock (VIRG)
JOYCE	83	PRL 51 731		+Abrams, Bland, Johnson, Lindgren+ (SFSU)
LIEBOWITZ	83	PRL 50 1640		+Binder, Ziock (VIRG)
LINDGREN	83	PRL 51 1621		+Joyce+ (SFSU, UCR, UCI, SLAC, LBL, LANL)
MASHIMO	83	PL 128B 327		+Orito, Kawagoe, Nakamura, Nozaki (ICEPP)
PRICE	83	PRL 50 566		+Tincknell, Tarle, Ahlen, Frankel+ (UCB)
VANDESTEEG	83	PRL 50 1234		+ Jongbioets, Wyder (NIJM)
MARINI	82	PR D26 1777		+Peruzzi, Piccolo+ (FRAS, LBL, NWES, STAN, HAWA)
MARINI	82B	PRL 48 1649 JPSJ 51 3067		+Peruzzi, Piccolo+ +Peruzzi, Piccolo+ (FRAS, LBL, NWES, STAN, HAWA)
MASHIMO	82	IDC I 51 2067		+Kawagoe, Koshiba (INUS)
		JF 3J 31 3001		+ Nawagoe, Nosilida (INOS)
NAPOLITANO	82	PR D25 2837		+Besset+ (STAN, FRAS, LBL, NWES, HAWA)
ROSS	82	PL 118B 199		+Resset+ (STAN, FRAS, LBL, NWES, HAWA) +Ronga, Besset+ (FRAS, LBL, NWES, STAN, HAWA) +Abrams, Baden, Bland, Joyce+ (UCR, SFSU)
HODGES	81	PRL 47 1651		+Abrams, Baden, Bland, Joyce+ (UCR, SFSU)
LARUE	81	PRL 46 967		
WEISS	81	PL 101B 439		+Abrams, Alam, Blocker+ (SLAC, LBL, UCB)
BARTEL	80	7PHY C6 295		+Abrams, Alam, Blocker+ +(SAC, LBL, UCB) +(Canzler, Lords, Drumm+ +(Berbiers+ +(BGNA, CERN, FRAS, ROMA, BARI) +Giacomelli, Lesquoy+ (BGNA, SACL, LAPP)
BASILE	80	LNC 29 251		+Berbiers+ (BGNA, CERN, FRAS, ROMA, BARI)
BUSSIERE	80	NP B174 1		+Giacomelli Lesquov+ (RGNA SACI LAPP)
MARINELLI	80B	PL 94B 433		+Morpurgo (GENO)
Also	80	PL 94B 433 PL 94B 427		Marinelli Maraurgo (CENO)
BOYD	79	P.C. 94D 427		Marinelli, Morpurgo (GENO)
BOYD		PRL 43 1288		+Blatt, Donognue, Dries, Hausman, Suiter (USU)
BOZZOLI	79	NP B159 363		+Balt, Donghue, Dries, Hausman, Suiter (OSU) +Bussiere, Giacomelli+ (BGNA, LAPP, SACL, CERN) +Fairbank, Phillips (STAN)
LARUE	79	PRL 42 142		+Fairbank, Phillips (STAN)
Also	79B	PRL 42 1019		
OGOROD	79	JETP 49 953		Ogorodnikov, Samoilov, Solntsev (KIAE)
		Translated from	ZETF 7	6 1881.
STEVENSON	79	PR D20 82		(LBL)
BASILE	78	NC 45A 171		+Cara-Romeo, Cifarelli, Contin+ (CERN, BGNA)
BASILE	78B	NC 45A 171 NC 45A 281 PRL 40 216		+Cara-Romeo, Cifarelli, Contin+ (CERN, BGNA) +Cara-Romeo, Cifarelli, Contin+ (CERN, BGNA)
BOYD	78	PRI 40 216		+Elmore, Melissinos, Sugarbaker (ROCH)
BOYD	78B	PL 72B 484		+Elmore, Nitz, Olsen, Sugarbaker, Warren+ (ROCH)
LUND	78B	RA 25 75		+Emore, Ntz, Osen, Sugarbaker, Warren+ (NOCH) +Brandt, Fares (MARB)
		NA 20 /0		Totalius, rates (MARB)
PUTT	78	PR D17 1466		+Yock (AUCK)
SCHIFFER	78	PR D17 2241		+Renner, Gemmell, Mooring (CHIC, ANL)
YOCK	78	PR D18 641		(AUCK)
ANTREASYAN		PRL 39 513		+Cocconi, Cronin, Frisch+ (EFI, PRIN)
BASILE	77	NC 40A 41		+Romeo, Cifarelli, Giusti+ (CERN, BGNA)
BLAND	77	PRL 39 369		+Bocobo, Eubank, Royer (SFSU)
GALLINARO	77	PRL 38 1255		+Marinelli, Morpurgo (GENO)
JONES		DMD 60 717		(0010)
	77P			
LADILE	77B	DDI 39 1011		+ Epirhank Hebard (CTAM)
LARUE	77	RMP 69 717 PRL 38 1011		+Fairbank, Hebard (STAN)
MULLER	77 77	Science 521		+Alvarez, Holley, Stephenson (LBL)
	77	Science 521	7575 7	+Fairbank, Hebard (STAN) +Alvarez, Holley, Stephenson (LBL) Oggorodnikov, Samoilov, Solntsev (KIAE)
MULLER	77 77	Science 521	ZETF 7	+Fairbank, Hebard (STAN) +Alvarez, Holley, Stephenson (LBL) Ogorodnikov, Samoilov, Solntsev (KIAE) '2 1633.

BALDIN	76	SJNP 22 264	VAF 0	+Vertogradov, Vishnevsky, Grishkevich+ 2 512.	(JINR)
BRIATORE	76	NC 31A 553	TAF 2	+Vertogradov, Visinievsky, Grishkevich+ 2 512. +Dardo, Piazzoli, Mannocchi+ +Schiffer, Chupka	GT. FRAS. FREIB)
STEVENS	76	PR D14 716		+Schiffer, Chupka	(ANL)
ALBROW	75	NP B97 189		+Barber+ (CERN, DARE, FOM, LAN +Gruhn, Peak, Sauli, Caldwell+ +Hodson, Winterstein, Green, Kass+	IC, MCHS, ÚTRE)
FABJAN	75	NP B101 349 NP B95 189		+Gruhn, Peak, Sauli, Caldwell+	(CERN, MPIM)
HAZEN	75	NP B95 189		+Hodson, Winterstein, Green, Kass+	(MICH, LEED)
JOVANOV	75	PL 56B 105		Jovanovich+ (MANI, AACH, CERN	(AACH3)
KRISOR CLARK	74R	NC 27A 132 PR D10 2721		+Finn, Hansen, Smith	(LLL)
CALIII					(SLAC, FNAL)
KIFUNE	74	PR D9 1856 JPSJ 36 629		+Jordan, Richter, Seppi, Siemann+ +Hieda, Kurokawa, Tsunemoto+ +Yamanouchi, Nease, Sculli + (CERN LIVE LIND BOHR RHEI	(TOKY, KEK)
NASH	74	PRL 32 858		+Yamanouchi, Nease, Sculli (FN	IAL, CORN, NYU)
KIFUNE NASH ALPER ASHTON HICKS LEIPUNER	73	PL 46B 265		+ (CERN, LIVP, LUND, BOHR, RHEI +Cooper, Parvaresh, Saleh	., STOH, BERG+) (DURH)
HICKS	73R	NC 144 65		+Flint, Standil	(MAM)
LEIPUNER	73	PRL 31 1226		+Larsen, Sessoms, Smith, Williams+	(BNL, YALE)
				+Larsen, Sessoms, Smith, Williams+ +Bowen, Cox, Kalbach	(BNL, YALE) (ARIZ)
BOHM	72B	PRI 28 326		+Diemont, Faissner, Fasold, Krisor+	(ÁACH)
BOTT	72			+Diemont, Faissner, Fasold, Krisor+ +Caldwell, Fabjan, Gruhn, Peak+ +Beauchamp, Bowen, Kalbach	(CERN, MPIM)
COX	72	PR D6 1203		+Beauchamp, Bowen, Kalbach +Mori, Smith	(ARIZ) (CASE)
BOTT COX CROUCH DARDO EVANS TONWAR	72	PR D5 2667 NC 9A 319		+Navarra Penengo Sitte	(TORI)
EVANS TONWAR ANTIPOV	72	PRSF A70 143		+Navarra, Penengo, Sitte +Fancey, Muir, Watson	(TORI) (EDIN, LEED)
TONWAR	72	JPA 5 569		⊥Naranan Sreekantan	(ΤΔΤΔ)
ANTIPOV	71			+Kachanov, Kutjin, Landsberg, Lebedev+ +Hanayama, Hara, Higashi, Tsuji +Ernst, Finn, Griffin, Hansen, Smith+	(SERP)
CHIN . CLARK	71 D	NC 2A 419 PRL 27 51		+Hanayama, Hara, Higashi, Tsuji	(OSAK)
HAZEN	71	PRL 26 582		+Ernst, Finn, Grinn, Hansen, Smith+	(LLĹ, LBĹ) (MICH)
BOSIA	70	MC 66A 167		+Briatore	(TORI)
CHU	70	PRL 24 917		+Kim, Beam, Kwak (O	SIL ROSE, KANS)
Also	70B	PRL 25 550		Allison Derrick Hunt Simpson Voyyor	tic (ANL)
	70	NP B20 217		+Erwin, Herb, Nielsen, Petrilak, Weinberg	g (WISC)
FAISSNER KRIDER	70B 70	PRL 24 1357 PR D1 835		+Holder, Krisor, Mason, Sawaf, Umbach +Bowen, Kalbach	(AACH3) (ARIZ)
MORPURGO	70	NIM 70 OF		I Callinaro Palmieri	(CENO)
ALLABY	69B	NC 64A 75 PL 29B 245 PL 30B 576		+Bianchini, Diddens, Dobinson, Hartung+ +Karpov, Khromov, Landsberg, Lapshin+ +Bolotov, Devishev, Devisheva, Isakov+ +McCkusker, Peak, Woolcott +Depasquali, Frauenfelder, Peacock+	(CERN)
ANTIPOV	69	PL 29B 245		+Karpov, Khromov, Landsberg, Lapshin+	(SERP)
ANTIPOV	69B	PL 30B 576		+Bolotov, Devishev, Devisheva, Isakov+	(SERP)
CAIRNS COOK	69 69	PR 186 1394 PR 188 2092		+ Departuali Franchfelder Peacock+	(SYDN) (ILL)
FUKUSHIMA		PR 178 2058		+Kifune, Kondo, Koshiba+	HUKYI
MCCUSKER	69	PRL 23 658			(SYDN)
BELLAMY	68	PR 166 1391		+Hofstadter, Lakin, Perl, Toner	(STAN, SLAC)
BJORNBOE BRAGINSK	68 68	NC B53 241 JETP 27 51		+Damgard, Hansen+ (BOHR, TA +Zeldovich, Martynov, Migulin	(MOSU)
		Translated from	ZETF	54 91.	, ,
BRIATORE FRANZINI GARMIRE	68 68	NC 57A 850		+Castagnoli, Bollini, Massam+ (TC +Shulman	RI, CERN, BGNA)
GARMIRE	68	PRL 21 1013		+Snuman +Leong Sreekantan	(COLU) (MIT)
HANAYAMA	68	PR 166 166 CJP 46 S734		+Leong, Sreekantan +Hara, Higashi, Kitamura, Miono+	(OSAK)
KASHA	68	PR 172 1297		+ Stefanski	(BNL, YALE) (BNL, YALE) (BNL, YALE)
KASHA	68B	PRL 20 217 CJP 46 S730		+Larsen, Leipuner, Adair +Larsen, Leipuner, Adair	(BNL, YALE)
KASHA RANK	68C 68	PR 176 1635		+Larsen, Leipuner, Adair	(BNL, YALE) (MICH)
	67	PRSL 90 87			
BATHOW	67 67	PL 25B 163		+Freytag, Schulz, Tesch	(DESY)
BUHLER BUHLER	67	NC 49A 209 NC 51A 837		+Fortunato, Massam, Zichichi	(CERN, BGNA)
BUHLER	67B	NC 51A 837 PL 25B 166		+Dalpiaz, Massam, Zichichi (CEI	RN, BGNA, STRB)
FOSS COMEZ	67 67	PRL 18 1022		+Freytag, Schulz, Tesch +Fortunato, Massam, Zichichi +Dalpiaz, Massam, Zichichi (CEI +Garelick, Homma, Lobar, Osborne, Ugl +Kobrak, Moline, Mullins, Orth, VanPutt +Leipuner, Wangler, Alspector, Adair +Moran, Trischka	ım (IVIII)
	67	PR 154 1263		+Leinuner, Wangler, Alspector, Adair	(BNL. YALE)
STOVER	67	PR 164 1599		+Moran, Trischka	(SYRA)
	66	PL 21 360		+Stockel	(NPOL)
BENNETT BUHLER	66 66	PRL 17 1196 NC 45A 520		+Fortunato, Massam, Muller+ (CEI	(YALE)
CHUPKA	66	PRL 17 60		+Schiffer, Stevens	(ANL)
GALLINARO	66	Pl. 23 609		+ Morpurgo	(GENO)
KASHA	66	PR 150 1140 PRL 17 1068		+Leipuner, Adair	(BNL, YALE)
LAMB DELISE	66	PRL 17 1068 PR 140B 458		+Lundy. Novey, Yovanovitch +Bowen	(ANL) (ARIZ)
DORFAN	65 65	PRI 14 999			tè a coi
FRANZINI	65B	PRL 14 999 PRL 14 196		+Leontic, Rahm, Samios, Schwartz	(BNL, COLU)
MASSAM	65	NC 40A 589 PL 9 201		+Muller, Zichichi	(CERN)
BINGHAM BLUM	64 64	PL 9 201 PRL 13 353A		+Dickinson, Diebold, Koch, Leith+	(CERN, EPOL)
BOWEN	64	PRI 13 728		+Delise, Kalbach, Mortara	(ARIZ)
HAGOPIAN	64	PRL 13 728 PRL 13 280		+Eades, Lederman, Lee, Ing +Leontic, Rahm, Samios, Schwartz +Muller, Zichichi +Dickinson, Diebold. Koch, Leith+ +Brandt, Cocconi, Czyzewski, Danysz+ +Delise, Kalbach, Mortara +Selove, Ehrlich, Leboy, Lanza+ +Chu, Larsen, Adair	(PENN, BNL) (BNL, YALE)
LEIPUNER	64	PRL 12 423		+Chu, Larsen, Adair	
MORRISON SUNYAR	64 64	PL 9 199 PR 136B 1157		+Schwarzschild, Connors	(CERN) (BNL)
HILLAS	59	Nature 184 B92		+Cranshaw	(AERE)
MILLIKAN	10	Phil Mag 19 209	9		(CHIC)
				D DEL ATER D	
		от	HE	R RELATED PAPERS	_
LYONS	85	PRPL C129 225			(OXF)
Review	82	DDDL of 161			(GENO)
MARINELLI Review	82	PRPL 85 161		+Morpurgo	(GENO)

LIGHT UNFLAVORED MESONS $(S = C = B = 0)$	• $f_2(2010)$
$ullet$ π^{\pm}	$a_4(2040)$
$ullet$ π^0	• $f_4(2050)$
\bullet η	$\pi_2(2100)$
• $f_0(400-1200)$	$f_2(2150)$
\bullet $\rho(770)$	ho(2150)
\bullet $\omega(782)$	$f_0(2200)$
• $\eta'(958)$	$f_J(2220)$
• $f_0(980)$	$\eta(2225)$
• $a_0(980)$	$\rho_3(2250)$
• $\phi(1020)$	• $f_2(2300)$
• $h_1(1170)$	$f_4(2300)$
• $b_1(1235)$	• $f_2(2340)$
• $a_1(1260)$	$\rho_5(2350)$
• $f_2(1270)$	$a_6(2450)$
• $f_1(1285)$	$f_6(2510)$
• $\eta(1295)$	X(3250)
\bullet $\pi(1300)$	
• $a_2(1320)$	OTHER LIGHT UNFLAVORED $(S = C = B = 0)$
• $f_0(1370)$	$e^{+}e^{-}(1100-2200)$
$h_1(1380)$	$\overline{N}N(1100-3600)$
$\hat{\rho}(1405)$	X(1900-3600)
• $f_1(1420)$	
• $\omega(1420)$	STRANGE MESONS $(S=\pm 1, C=B=0)$
$f_2(1430)$	• K^{\pm}
• $n(1440)$	\bullet K^0 412
$a_0(1450)$	\bullet K^0_S 412
	• K_7^0
$\bullet \rho(1450) $	• K_L^{\emptyset}
• $\rho(1450)'$	D .
\bullet $\rho(1450)'$	• $K^{*}(892)$
ullet ho(1450)'	$K^*(892)$
ullet ho(1450)'	\bullet $K^*(892)$
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(continued on the next page)

[•] Indicates the particle is in the Meson Summary Table

CHARMED MESONS ($C=\pm 1$)	Notes in the Meson Listings
• D^{\pm}	Pseudoscalar-Meson Decay Constants 319 $\pi^{\pm} \to \ell^{\pm} \nu \gamma$ and $K^{\pm} \to \ell^{\pm} \nu \gamma$ Form Factors 322 The $\rho(770)$ 330 The $a_1(1260)$ 345 Scalar Mesons 355 The $f_1(1420)$ 358 The $\eta(1440)$ 361 The $\rho(1450)$ and the $\rho(1700)$ 376 The $f_J(1710)$ 379 The $X(1900-3600)$ Region 395 The Charged Kaon Mass 397 Rare Kaon Decays 399 Dalitz Plot Parameters for $K \to 3\pi$ Decays 406
	$K_{\ell 3}^{\pm}$ and $K_{\ell 3}^{0}$ Form Factors
BOTTOM MESONS $(B=\pm 1)$ • B^{\pm}	$CP \ \text{Violation in } K_L^0 \ \text{Decay} \qquad \qquad$
BOTTOM, STRANGE MESONS ($B=\pm 1, S=\mp 1$)	B ⁰ - \overline{B}^{0} Mixing and CP Violation in B Decay 507
• B_s^0	Width Determinations of the Υ States
$c\overline{c}$ MESONS	
$\begin{array}{llll} \bullet & \eta_c(1S) = \eta_c(2980) & 528 \\ \bullet & J/\psi(1S) = J/\psi(3097) & 530 \\ \bullet & \chi_{c0}(1P) = \chi_{c0}(3415) & 538 \\ \bullet & \chi_{c1}(1P) = \chi_{c1}(3510) & 539 \\ h_c(1P) & 540 \\ \bullet & \chi_{c2}(1P) = \chi_{c2}(3555) & 540 \\ \eta_c(2S) = \eta_c(3590) & 541 \\ \bullet & \psi(2S) = \psi(3685) & 542 \\ \bullet & \psi(3770) & 544 \\ \bullet & \psi(4040) & 545 \\ \bullet & \psi(4160) & 545 \\ \bullet & \psi(4415) & 546 \\ \end{array}$	
$b\bar{b}$ MESONS	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	
$\mathrm{NON} ext{-}q\overline{q} \ \mathrm{CANDIDATES}$	
Non- $q\overline{q}$ Candidates	

 \bullet Indicates the particle is in the Meson Summary Table

LIGHT UNFLAVORED MESONS (S = C = B = 0)

$$\begin{array}{ll} \text{For } \mathit{I} = 1 \; (\pi, \, \mathit{b}, \, \rho, \, \mathit{a}) \colon \; \mathit{u} \, \overline{\mathit{d}}, \, (\mathit{u} \, \overline{\mathit{u}} - \mathit{d} \, \overline{\mathit{d}}) / \sqrt{2}, \, \mathit{d} \, \overline{\mathit{u}}; \\ \text{for } \mathit{I} = 0 \; (\eta, \, \eta', \, \mathit{h}, \, \mathit{h'}, \, \omega, \, \phi, \, \mathit{f}, \, \mathit{f'}) \colon \; c_1(\mathit{u} \, \overline{\mathit{u}} + \mathit{d} \, \overline{\mathit{d}}) + c_2(\mathit{s} \, \overline{\mathit{s}}) \end{array}$$

PSEUDOSCALAR-MESON DECAY CONSTANTS

(by M. Suzuki, LBNL)

Charged mesons

The decay constant f_P for a charged pseudoscalar meson P is defined by

$$\langle 0|A_{\mu}(0)|P(\mathbf{q})\rangle = if_P q_{\mu}$$
,

where A_{μ} is the axial-vector part of the charged weak current after a Cabibbo-Kobayashi-Maskawa mixing-matrix element $V_{qq'}$ has been removed. The state vector is normalized by $\langle P(\mathbf{q})|P(\mathbf{q'})\rangle=(2\pi)^3$ $2E_q$ $\delta(\mathbf{q}-\mathbf{q'})$, and its phase is chosen to make f_P real and positive. Note, however, that in many theoretical papers our $f_P/\sqrt{2}$ is denoted by f_P .

In determining f_P experimentally, radiative corrections must be taken into account. Since the photon-loop correction introduces an infrared divergence that is canceled by soft-photon emission, we can determine f_P only from the combined rate for $P^{\pm} \to \ell^{\pm} \nu_{\ell}$ and $P^{\pm} \to \ell^{\pm} \nu_{\ell} \gamma$. This rate is given by

$$\begin{split} &\Gamma\left(P \to \ell \nu_{\ell} + \ell \nu_{\ell} \gamma\right) = \\ &\frac{G_F^2 |V_{qq'}|^2}{8\pi} f_P^2 \; m_{\ell}^2 \; m_P \left(1 - \frac{m_{\ell}^2}{m_P^2}\right)^2 \left[1 + \mathscr{O}(\alpha)\right] \; . \end{split}$$

Radiative corrections include inner bremsstrahlung, which is independent of the structure of the meson [1–3], and also a structure-dependent term [4,5]. After radiative corrections are made, there are ambiguities in extracting f_P from experimental measurements. In fact, the definition of f_P is no longer unique.

It is desirable to define f_P such that it depends only on the properties of the pseudoscalar meson, not on the final decay products. The short-distance corrections to the fundamental electroweak constants like $G_F|V_{qq'}|$ should be separated out. Following Marciano and Sirlin [6], we define f_P with the following form for the $\mathcal{O}(\alpha)$ corrections:

$$\begin{split} &1 + \mathcal{O}(\alpha) = \left[1 + \frac{2\alpha}{\pi} \ln\!\left(\frac{m_Z}{m_\rho}\right)\right] \left[1 + \frac{\alpha}{\pi} F(x)\right] \\ &\times \left\{1 - \frac{\alpha}{\pi} \left[\frac{3}{2} \ln\!\left(\frac{m_\rho}{m_P}\right) + C_1 + C_2 \frac{m_\ell^2}{m_\rho^2} \ln\left(\frac{m_\rho^2}{m_\ell^2}\right) + C_3 \frac{m_\ell^2}{m_\rho^2} + \ldots\right]\right\} \;. \end{split}$$

Here

$$F(x) = 3 \ln x + \frac{13 - 19x^2}{8(1 - x^2)} - \frac{8 - 5x^2}{2(1 - x^2)^2} x^2 \ln x$$
$$-2\left(\frac{1 + x^2}{1 - x^2} \ln x + 1\right) \ln(1 - x^2) + 2\left(\frac{1 + x^2}{1 - x^2}\right) L(1 - x^2) ,$$

with

$$x \equiv m_\ell/m_P \; , \;\;\;\; L(z) \equiv \int_0^z rac{\ln(1-t)}{t} \; dt \; .$$

The first bracket in the expression for $1+\mathscr{O}(\alpha)$ is the short-distance electroweak correction. The QCD correction reduces this factor by 0.00033. The second bracket together with the term $-(3\alpha/2\pi)\ln(m_\rho/m_P)$ in the third bracket corresponds to the radiative corrections to the point-like pion decay ($\Lambda_{\rm cutoff} \approx m_\rho$) [2]. The rest of the corrections in the third bracket are expanded in powers of m_ℓ/m_ρ . The expansion coefficients C_1 , C_2 , and C_3 depend on the hadronic structure of the pseudoscalar meson and in most cases cannot be computed accurately. In particular, C_1 absorbs the uncertainty in the matching energy scale between short- and long-distance strong interactions and thus is the main source of uncertainty in determining f_{π^+} accurately.

With the experimental value for the decay $\pi \to \mu \nu_{\mu} + \mu \nu_{\mu} \gamma$, one obtains

$$f_{\pi^+} = 130.7 \pm 0.1 \pm 0.36 \text{ MeV}$$
,

where the first error comes from the experimental uncertainty on $|V_{ud}|$ and the second comes from the uncertainty on C_1 (= 0 ± 0.24) [6]. Similarly, one obtains from the decay $K \to \mu\nu_{\mu} + \mu\nu_{\mu}\gamma$ the decay constant

$$f_{K^+} = 159.8 \pm 1.4 \pm 0.44 \text{ MeV}$$
,

where the first error is due to the uncertainty on $|V_{us}|$.

For the heavy pseudoscalar mesons, uncertainties in the experimental values for the decay rates are much larger than the radiative corrections. For the D^+ , only an upper bound can be obtained from the published data:

$$f_{D^+} < 310~{
m MeV}~({
m CL} = 90\%)$$
 .

Three groups have measured the $D_s^+ \to \mu^+ \nu_\mu$ branching fraction, leading to the following values of the decay constant:

$$f_{D^{+}} = 232 \pm 45 \pm 20 \pm 48 \text{ MeV}$$
 [7],

$$f_{D^{\pm}} = 344 \pm 37 \pm 52 \pm 42 \text{ MeV [8]}$$
 ,

$$f_{D_s^+} = 430^{+150}_{-130} \pm 40 \text{ MeV}$$
 [9]

where the first errors are statistical, the second errors are systematic, and the third errors are uncertainties involved in extracting the branching fraction $\mathrm{B}(D_s^+ \to \mu^+ \nu_\mu)$. We must wait for more data before drawing a conclusion on $f_{D_s^+}$.

There have been many attempts to extract f_P from spectroscopy and nonleptonic decays using theoretical models. Since it is difficult to estimate uncertainties for them, we have listed here only values of decay constants that are obtained directly from the observation of $P^\pm \to \ell^\pm \nu_\ell$.

 π^{\pm}

Light neutral mesons

The decay constants for the light neutral pseudoscalar mesons π^0 , η , and η' are defined by

$$\langle 0|A_{\mu}(0)|P^{0}(\mathbf{q})\rangle = \mathrm{i}(f_{P}/\sqrt{2})q_{\mu}$$

where A_{μ} is a neutral axial-vector current of octet or singlet. Values of f_{P} can be obtained from the two-photon decay $P^{0} \rightarrow \gamma \gamma$, since in the $m_{P}=0$ limit the decay matrix element is determined by the Adler-Bell-Jackiw anomaly [10,11]. However, large uncertainties enter values of f_{P} through extrapolation to the physical mass and, in the case of η and η' , through the mixing angle, too.

The CELLO Collaboration has obtained the values [12]

$$f_{\pi^0} = 119 \pm 4 \text{ MeV}$$

$$f_{\eta} = 133 \pm 10 \text{ MeV}$$

$$f_{\eta'} = 126 \pm 7 \text{ MeV}$$
,

while the TPC/2 γ Collaboration has obtained [13]

$$f_n = 129 \pm 8 \text{ MeV}$$

$$f_{n'} = 110 \pm 7 \text{ MeV}$$
.

(We have multiplied the published values by $\sqrt{2}$ to be in accord with our definition of f_P .)

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$$I^{G}(J^{P}) = 1^{-}(0^{-})$$

We have omitted some results that have been superseded by later experiments. The omitted results may be found in our 1988 edition Physics Letters **B204** (1988).

π^{\pm} MASS

The most accurate charged pion mass measurements are based upon x-ray wavelength measurements for transitions in π^- -mesonic atoms. The observed line is the blend of three components, corresponding to different K-shell occupancies. JECKELMANN 94 revisits the occupancy question, with the conclusion that two sets of occupancy ratios, resulting in two different pion masses (Solutions A and B), are equally probable. We choose the higher Solution B since only this solution is consistent with a positive mass-squared for the muon neutrino, given the precise muon momentum measurements now available (DAUM 91, ASSAMAGAN 94, and ASSAMAGAN 96) for the decay of pions at rest. Earlier mass determinations with pi-mesonic atoms may have used incorrect K-shell screening corrections.

Measurements with an error of > 0.005 MeV have been omitted from this Lieting

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
139.56995±0.00035 OUR FIT					
139.56995±0.00035	¹ JECKELMANN	94	CNTR	-	π^- atom, Soln. B
• • • We do not use the following	data for averages	, fits	, limits,	etc. •	• •
139.57022 ± 0.00014	² ASSAMAGAN	96	SPEC	+	$\pi^+ \rightarrow \mu^+ \nu_{\mu}$
139.56782 ± 0.00037	3 JECKELMANN	94	CNTR	_	π^- atom, Soln. A
139.56996 ± 0.00067	⁴ DAUM		SPEC	+	$\pi^+ \rightarrow \mu^+ \nu$
139.56752 ± 0.00037	⁵ JECKELMANN	86B	CNTR	_	Mesonic atoms
	⁴ ABELA	84	SPEC	4-	See DAUM 91
139.5664 ±0.0009	⁶ LU	80	CNTR		Mesonic atoms
139.5686 ±0.0020	CARTER	76	CNTR	_	Mesonic atoms
139.5660 ±0.0024 6	^{,7} MARUSHEN	76	CNTR	_	Mesonic atoms

- 1 JECKELMANN 94 Solution B (dominant 2-electron K-shell occupancy), chosen for consistency with positive $m_{\nu_n}^2$.
- ² ASSAMAGAN 96 measures the μ^+ momentum p_μ in $\pi^+ \to \mu^+ \nu_\mu$ decay at rest to be 29.79200 \pm 0.00011 MeV/c. Combined with the μ^+ mass and the assumption m_{ν_μ} = 0, this gives the π^+ mass above; if m_{ν_μ} > 0, m_{π^+} given above is a lower limit.
- Combined instead with m_μ and (assuming *CPT*) the π^- mass of JECKELMANN 94, ρ_μ gives an upper limit on m_{ν_μ} (see the ν_μ).
- 3 JECKELMANN 94 Solution A (small 2-electron K-shell occupancy) in combination with either the DAUM 91 or ASSAMAGAN 94 pion decay muon momentum measurement yields a significantly negative $m_{\nu_{\perp}}^2$. It is accordingly not used in our fits.
- 4 The DAUM 91 value includes the ABELA 84 result. The value is based on a measurement of the μ^+ momentum for π^+ decay at rest, $\rho_\mu=29.79179\pm0.00053$ MeV, uses $m_\mu=105.658389\pm0.000034$ MeV, and assumes that $m_{\nu_\mu}=0$. The last assumption means that in fact the value is a lower limit.
- that in fact the value is a lower limit. $^{-\mu}$ SIECKELMANN 86B gives $m_{\pi}/m_e = 273.12677(71)$. We use $m_e = 0.51099906(15)$ MeV from COHEN 87. The authors note that two solutions for the probability distribution of K-shell occupancy fit equally well, and use other data to choose the lower of the two possible π^{\pm} masses.
- These values are scaled with a new wavelength-energy conversion factor $V\lambda = 1.23984244(37) \times 10^{-6}$ eV m from COHEN 87. The LU 80 screening correction relies upon a theoretical calculation of inner-shell refilling rates.
- 7 This MARUSHENKO 76 value used at the authors' request to use the accepted set of calibration γ energies. Error increased from 0.0017 MeV to include QED calculation error of 0.0017 MeV (12 ppm).

$$m_{\pi^+} - m_{\mu^+}$$

Measurements with an error $> 0.05 \; \text{MeV}$ have been omitted from this Listing.

VALUE (MeV)	EVTS	DOCUMENT ID)	TECN C	CHG	COMMENT
• • • We do not use	the followin	g data for averag	ges, fit:	s, limits, e	tc. •	• •
33.91157 ± 0.00067		⁸ DAUM	91	SPEC -	+	$\pi^+ \rightarrow \mu^+ \nu$
33.9111 ± 0.0011		ABELA	84	SPEC		See DAUM 91
33.925 ±0.025		воотн	70	CNTR -	+	Magnetic spect.
33.881 ± 0.035	145	HYMAN	67	HEBC -	+	K− He
⁸ The DAUM 91 va	lue assumes	that $m_{ij} = 0$ an	d uses	our <i>m</i> ,, =	: 105	.658389 ± 0.000034

 8 The DAUM 91 value assumes that $m_{\nu_{\mu}}=$ 0 and uses our $m_{\mu}=$ 105.658389 \pm 0.00003 MeV.

$$(m_{\pi^+}-m_{\pi^-}) / m_{\text{average}}$$

A test of CPT invariance.

VALUE (units 10 ⁻⁴)	DOCUMENT ID	TECN	
2±5	AYRES	71	CNTR

 Γ_8/Γ

π^{\pm} MEAN LIFE

Measurements with an error $> 0.02 \times 10^{-8}$ s have been omitted.

VALUE (10 ⁻⁸ s)		DOCUMENT ID		TECN	CHG	COMMENT
2.6033	±0.0005	OUR AVERAGE	Error includes	scale	factor o	f 1.2.	
2.60361	± 0.00052		⁹ KOPTEV	95	SPEC	+	Surface μ^+ 's
2.60231	± 0.00050	± 0.00084	NUMAO	95	SPEC	+	Surface μ^+ 's
2.609	± 0.008		DUNAITSEV	73	CNTR	+	
2.602	± 0.004		AYRES	71	CNTR	±	
2.604	± 0.005		NORDBERG	67	CNTR	+	
2.602	± 0.004		ECKHAUSE	65	CNTR	+	
• • • \	Ne do not	use the following	data for average	s, fits	, limits,	etc. •	• •
2.640	±0.008	1	⁰ KINSEY	66	CNTR	+	

 $^{^{9}\,\}mbox{KOPTEV}$ 95 combines the statistical and systematic errors; the statistical error domi-

$$(au_{\pi^+} - au_{\pi^-}) / au_{ ext{average}}$$

A test of CPT invariance.

VALUE (units 10 ⁻⁴)	DOCUMENT ID TECN_
5.5± 7.1	AYRES 71 CNTR
• • • We do not use the fo	ollowing data for averages, fits, limits, etc. • •
-14 ±29	PETRUKHIN 68 CNTR
40 ±70	BARDON 66 CNTR
23 ±40	11 LOBKOWICZ 66 CNTR
¹¹ This is the most conser	vative value given by LOBKOWICZ 66.

π^+ DECAY MODES

 π^- modes are charge conjugates of the modes below.

	Mode	Fraction (Γ_i/Γ) Confidence level
Γ_1	$\mu^+ \nu_{\mu}$	[a] (99.98770±0.00004) %
Γ_2	$\mu^{\dot{+}} \nu_{\mu} \gamma$	[b] $(1.24 \pm 0.25) \times 10^{-4}$
Γ_3	$e^+ \nu_e$	[a] (1.230 ± 0.004) $\times 10^{-4}$
Γ_4	$e^+ u_e\gamma$	[b] $(1.61 \pm 0.23) \times 10^{-7}$
Γ_5	$e^+ u_e\pi^0$	$(1.025 \pm 0.034) \times 10^{-8}$
Γ_6	$e^{+} u_{e} e^{+} e^{-}$	$(3.2 \pm 0.5) \times 10^{-9}$
Γ_7	$e^+ \nu_e \nu \overline{\nu}$	$< 5 \times 10^{-6} 90\%$

Lepton Family number (LF) or Lepton number (L) violating modes

Γ8	$\mu^+ \overline{\nu}_e$		L	[c] <	1.5	$\times 10^{-3}$	90%
Г9	$\mu^+ \nu_e$		LF	[c] <	8.0	$\times 10^{-3}$	90%
Γ10	11-6+6+1	,	1 F		1.6	× 10-6	90%

- [a] Measurements of $\Gamma(e^+\nu_e)/\Gamma(\mu^+\nu_\mu)$ always include decays with γ 's, and measurements of $\Gamma(e^+\nu_e\gamma)$ and $\Gamma(\mu^+\nu_\mu\gamma)$ never include low-energy γ 's. Therefore, since no clean separation is possible, we consider the modes with γ 's to be subreactions of the modes without them, and let $[\Gamma(e^+ \nu_e)$ $+ \Gamma(\mu^+ \nu_\mu)]/\Gamma_{\text{total}} = 100\%.$
- [b] See the Particle Listings below for the energy limits used in this measurement; low-energy $\gamma \ensuremath{^{\prime}} \ensuremath{\mathrm{s}}$ are not included.
- [c] Derived from an analysis of neutrino-oscillation experiments.

π^+ BRANCHING RATIOS

 $\Gamma(e^+\nu_e)/\Gamma_{\rm total}$ Γ_3/Γ See note [a] in the list of π^+ decay modes just above, and see also the next block of

DOCUMENT ID 1.230 ± 0.004 OUR EVALUATION

 $\left[\Gamma(e^+\nu_e) + \Gamma(e^+\nu_e\gamma)\right] / \left[\Gamma(\mu^+\nu_\mu) + \Gamma(\mu^+\nu_\mu\gamma)\right]$

See note [a] in the list of π^+ decay modes above. See NUMAO 92 for a discussion of

VALUE (units 10-4)	EVTS	DOCUMENT ID		TECN	COMMENT	
1.230 ±0.004 OUR	RAVERAGE					
$1.2346 \pm 0.0035 \pm 0.0$	036 120k	CZAPEK	93	CALO	Stopping π ⁺	
$1.2265 \pm 0.0034 \pm 0.0$	044 190k	BRITTON	92	CNTR	Stopping π^+	
1.218 ± 0.014	32k	BRYMAN	86	CNTR	Stopping π^+	
• • • We do not use	e the following	data for averages,	fits,	limits,	etc. • • •	
1.273 ±0.028	11k	¹² DICAPUA	64	CNTR		
1.21 ±0.07		ANDERSON	60	SPEC		

 $^{^{\}rm 12}\,{\rm DICAPUA}$ 64 has been updated using the current mean life.

$\Gamma(\mu^+\nu_{\mu}\gamma)/\Gamma_{\text{total}}$ Note that mea	surements h	nere do not cover th	ne full	kinema	Γ ₂ /Γ
VALUE (units 10 ⁻⁴)	EVTS	DOCUMENT ID		TECN	COMMENT
1.24±0.25	26	CASTAGNOL	58	EMUL	$KE_{\mu} < 3.38 \text{ MeV}$
$\Gamma(e^+ \nu_e \gamma) / \Gamma_{\text{total}}$ Note that mea	surements h	ere do not cover th	ne full	kinema	Γ ₄ /Γ
VALUE (units 10 ⁻⁸)	EVTS	DOCUMENT ID		TECN	COMMENT
16.1±2.3		¹³ BOLOTOV	90B	SPEC	17 GeV $\pi^- \rightarrow e^- \overline{\nu}_e \gamma$
• • • We do not use	e the followi	ng data for average	s, fit	s, limits,	etc. • • •
5.6 ± 0.7	226	¹⁴ STETZ	78	SPEC	$P_e > 56 \text{ MeV}/c$

DEPOMMIER 63B CNTR $(\tilde{\text{KE}})_{e^+\gamma} >$ 48 MeV $^{13}\,\mathrm{BOLOTOV}$ 90B is for $E_{\gamma}~>$ 21 MeV, $E_{e}~>~70~-~0.8\,E_{\gamma}.$

143

3.0

 $^{14}\,\text{STETZ}$ 78 is for an $e^-\,\dot{\gamma}$ opening angle $>~132^{\circ}.$ Obtains 3.7 when using same cutoffs

$\Gamma(e^+\nu_e\pi^0)/\Gamma_{\rm tota}$	ıl					Γ₅/Γ
VALUE (units 10-8)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
1.025 ± 0.034 OUR	WERAGE					
1.026 ± 0.039	1224	¹⁵ MCFARLANE	85	CNTR	+	Decay in flight
1.00 +0.08 -0.10	332	DEPOMMIER	68	CNTR	+	
1.07 ±0.21	38	¹⁶ BACA \$ TOW				
1.10 ±0.26		¹⁶ BERTRAM	65	OSPK	+	
1.1 ±0.2	43	¹⁶ DUNAITSEV	65	CNTR	+	
0.97 ±0.20	36	¹⁶ BARTLETT	64	OSPK	+	
• • • We do not us	e the follow	ing data for average	s, fit	s, limits,	etc.	• •
1.15 ± 0.22	52	¹⁶ DEPOMMIER	63	CNTR	+	See DEPOM-

 $^{15}\,\text{MCFARLANE}$ 85 combines a measured rate (0.394 \pm 0.015)/s with 1982 PDG mean

life.

16 DEPOMMIER 68 says the result of DEPOMMIER 63 is at least 10% too large because of a systematic error in the π^0 detection efficiency, and that this may be true of all the previous measurements (also V. Soergel, private communication, 1972).

$\Gamma(e^+\nu_ee^+e^-)/\Gamma$	$(\mu^+ \nu_\mu)$				Γ ₆ /Γ ₁
VALUE (units 10-9)	CL% EVTS	DOCUMENT ID		TECN	COMMENT
3.2 ±0.5 ±0.2	98	EGLI	89	SPEC	Uses R _{PCAC} = 0.068 ± 0.004
• • • We do not us	e the following	data for averages, fi	its, li	mits, et	C. • • •
$0.46 \pm 0.16 \pm 0.07$	7	¹⁷ BARANOV	92	SPEC	Stopped π^+
< 4.8	90	KORENCHE	76B	SPEC	
<34	90	KORENCHE	71	OSPK	

¹⁷ This measurement by BARANOV 92 is of the structure-dependent part of the decay. The value depends on values assumed for ratios of form factors.

$\Gamma(e^+ u_e u\overline{ u})/\Gamma_{ m total}$				Γ ₇ /Γ
VALUE (units 10 ⁻⁶)	CL%	DOCUMENT ID	<u>TECN</u>	
_				

PICCIOTTO 88 SPEC 90 $\Gamma(\mu^+\overline{\nu}_e)/\Gamma_{\rm total}$

Forbidden by total lepton number conservation. VALUE (units 10⁻³) CL% DOCUMENT ID TECN COMMENT <1.5 90 COOPER 82 HLBC Wideband ν beam

 $\Gamma(\mu^+\nu_e)/\Gamma_{\text{total}}$ Forbidden by lepton family number conservation. VALUE (units 10⁻³) CL% DOCUMENT ID TECN COMMENT

 $\Gamma \big(\mu^-\,e^+\,e^+\,\nu\big)/\Gamma_{\rm total}$ Γ_{10}/Γ Forbidden by lepton family number conservation.

82 HLBC Wideband ν beam

COOPER

VALUE (units 10⁻⁶) CL% DOCUMENT ID TECN CHG 90 BARANOV 918 SPEC + • • • We do not use the following data for averages, fits, limits, etc. • • • 90 KORENCHE... 87 SPEC +

π^+ — POLARIZATION OF EMITTED μ^+

Tests the Lorentz structure of leptonic charged weak interactions. CL% DOCUMENT ID TECN CHG COMMENT \bullet $\,\bullet\,$ We do not use the following data for averages, fits, limits, etc. $\,\bullet\,$ $\,\bullet\,$ 18 FETSCHER 84 RVUE + 19 ABELA 83 SPEC $^{18}\,\text{FETSCHER}$ 84 uses only the measurement of CARR 83. 19 Sign of measurement reversed in ABELA 83 to compare with μ^+ measurements.

nates.

10 Systematic errors in the calibration of this experiment are discussed by NORDBERG 67.

 $\pi^{\pm} \to \ell^{\pm} \nu \gamma$ AND $K^{\pm} \to \ell^{\pm} \nu \gamma$ FORM FACTORS (by H.S. Pruys, Zürich University)

In the radiative decays $\pi^{\pm} \to \ell^{\pm}\nu\gamma$ and $K^{\pm} \to \ell^{\pm}\nu\gamma$, where ℓ is an e or a μ and γ is a real or virtual photon $(e^+e^-$ pair), both the vector and the axial-vector weak hadronic currents contribute to the decay amplitude. Each current gives a structure-dependent term $(\mathrm{SD}_V \text{ and } \mathrm{SD}_A)$ from virtual hadronic states, and the axial-vector current also gives a contribution from inner bremsstrahlung (IB) from the lepton and meson. The IB amplitudes are determined by the meson decay constants f_π and f_K [1]. The SD_V and SD_A amplitudes are parameterized in terms of the vector form factor F_V and the axial-vector form factors F_A and R [1–4]:

$$M(\mathrm{SD}_V) = \frac{-eG_F\,V_{qq'}}{\sqrt{2}\,m_P} \epsilon^\mu\,\ell^\nu\,F_V\,\epsilon_{\mu\nu\sigma\tau}\,k^\sigma\,q^\tau \;,$$

$$M({\rm SD}_A) = \frac{-ie\, G_F V_{qq'}}{\sqrt{2} \ m_P} \, \epsilon^\mu \, \ell^\nu \left\{ F_A \left[(s-t) g_{\mu\nu} - q_\mu \, k_\nu \right] + R \, t \, g_{\mu\nu} \right\} \; . \label{eq:MSDA}$$

Here $V_{qq'}$ is the Cabibbo-Kobayashi-Maskawa mixing-matrix element; ϵ^{μ} is the polarization vector of the photon (or the effective vertex, $\epsilon^{\mu}=(e/t)\overline{u}(p_{-})\gamma^{\mu}v(p_{+})$, of the $e^{+}e^{-}$ pair); $\ell^{\nu}=\overline{u}(p_{\nu})\gamma^{\nu}(1-\gamma_{5})v(p_{\ell})$ is the lepton-neutrino current; q and k are the meson and photon four-momenta, with $s=q\cdot k$ and $t=k^{2}(=(p_{+}+p_{-})^{2})$; and P stands for π or K. In the analysis of data, the s and t dependence of the form factors is neglected, which is a good approximation for pions [2] but not for kaons [4]. The pion vector form factor F_{V}^{π} is related via CVC to the π^{0} lifetime, $|F_{V}^{\pi}|=(1/\alpha)\sqrt{2\Gamma_{\pi^{0}}/\pi m_{\pi^{0}}}$ [1]. PCAC relates R to the electromagnetic radius of the meson [2,4], $R^{P}=\frac{1}{3}m_{P}f_{P}\langle r_{P}^{2}\rangle$. The calculation of the other form factors, F_{A}^{π} , F_{V}^{K} , and F_{A}^{K} , is model dependent [1,4].

When the photon is real, the partial decay rate can be given analytically [1,5]:

$$\frac{d^2\Gamma_{P\rightarrow\ell\nu\gamma}}{dxdy} = \frac{d^2\left(\Gamma_{\rm IB} + \Gamma_{\rm SD} + \Gamma_{\rm INT}\right)}{dxdy} \; , \label{eq:delta-de$$

where Γ_{IB} , Γ_{SD} , and Γ_{INT} are the contributions from inner bremsstrahlung, structure-dependent radiation, and their interference, and the Γ_{SD} term is given by

$$\frac{d^2\Gamma_{\rm SD}}{dxdy} = \frac{\alpha}{8\pi} \Gamma_{P \to \ell\nu} \frac{1}{r(1-r)^2} \left(\frac{m_P}{f_P}\right)^2 \times \left[(F_V + F_A)^2 \, \text{SD}^+ + (F_V - F_A)^2 \, \text{SD}^- \right] .$$

Here

$$SD^{+} = (x + y - 1 - r) [(x + y - 1)(1 - x) - r] ,$$

$$SD^{-} = (1 - y + r) [(1 - x)(1 - y) + r] ,$$

where $x = 2E_{\gamma}/m_P$, $y = 2E_{\ell}/m_P$, and $r = (m_{\ell}/m_P)^2$.

In $\pi^\pm\to e^\pm\nu\gamma$ and $K^\pm\to e^\pm\nu\gamma$ decays, the interference terms are small, and thus only the absolute values $|F_A+F_V|$ and $|F_A-F_V|$ can be obtained. In $K^\pm\to\mu^\pm\nu\gamma$ decay, the interference term is important, and thus the signs of F_V and F_A can be obtained. In $\pi^\pm\to\mu^\pm\nu\gamma$ decay, bremsstrahlung completely dominates. In $\pi^\pm\to e^\pm\nu e^+e^-$ and $K^\pm\to\ell^\pm\nu e^+e^-$ decays, all three form factors, F_V , F_A , and R, can be determined.

We give the π^{\pm} form factors F_V , F_A , and R in the Listings below. In the K^{\pm} Listings, we give the sum $F_A + F_V$ and difference $F_A - F_V$.

The electroweak decays of the pseudoscalar mesons are investigated to learn something about the unknown hadronic structure of these mesons, assuming a standard V-A structure of the weak leptonic current. The experiments are quite difficult, and it is not meaningful to analyse the results using parameters for both the hadronic structure (decay constants, form factors) and the leptonic weak current (e.g., to add pseudoscalar or tensor couplings to the V-A coupling). Deviations from the V-A interactions are much better studied in purely leptonic systems such as muon decay.

References

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- 3. W.T. Chu et al., Phys. Rev. 166, 1577 (1968).
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π^{\pm} FORM FACTORS

Fv. VECTOR FORM FACTOR

VALUE 0.017±0.008 OUR		DOCUMENT ID	TECN	COMMENT
0.014±0.009	AVENAGE	²⁰ BOLOTOV	908 SPEC	17 GeV $\pi^- \rightarrow e^- \overline{\nu}_e \gamma$
$0.023 {}^{+ 0.015}_{- 0.013}$	98	EGLI	89 SPEC	$\pi^+ \rightarrow e^+ \nu_e e^+ e^-$

20 BOLOTOV 90B only determines the absolute value.

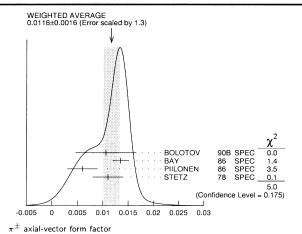
F_{A} , AXIAL-VECTOR FORM FACTOR

ra, ANIAL-VLCI	OK FORW	FACTOR		
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.0116±0.0016 OUR	AVERAGE	Error includes so below.	cale factor o	f 1.3. See the ideogram
0.0106 ± 0.0060		²¹ BOLOTOV	90B SPE	C 17 GeV $\pi^- \rightarrow e^- \overline{\nu}_e \gamma$
0.0135 ± 0.0016		²¹ BAY	86 SPE	$c \pi^+ \rightarrow e^+ \nu \gamma$
0.006 ±0.003		²¹ PIILONEN	86 SPE	$C \pi^+ \rightarrow e^+ \nu \gamma$
0.011 ± 0.003	21	^{,22} STETZ	78 SPE	$c \pi^+ \rightarrow e^+ \nu \gamma$
	the followin	g data for averag	es, fits, limi	ts, etc. • • •
0.021 + 0.011	98	EGLI	89 SPE	$C \pi^+ \rightarrow e^+ \nu_e e^+ e^-$

 $^{^{21}}$ Using the vector form factor from CVC prediction $F_V=$ 0.0259 \pm 0.0005. Only the absolute value of F_A is determined.

²² The result of STETZ 78 has a two-fold ambiguity. We take the solution compatible with later determinations.





R, SECOND AXIAL-VECTOR FORM FACTOR

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
$0.059 ^{+0.009}_{-0.008}$	98	EGLI	89	SPEC	$\pi^+ \rightarrow \ e^+ \nu_e e^+ e^-$

π^{\pm} REFERENCES

We have omitted some papers that have been superseded by later experiments. The omitted papers may be found in our 1988 edition Physics Letters **B204** (1988).

ASSAMAGAN 96			(PSI, ZURI, VILL, VIRG)
KOPTEV 95	JETPL 61 87	'7 +Mikirtych'yants, Shcherbakov+ om ZETFP 61 865.	(PNPI)
NUMAO 95			(TRIU, BRCO)
ASSAMAGAN 94			(PSI, ZURI, VILL, VIRG)
JECKELMANN 94			(WABRN, VILL)
CZAPEK 93	PRL 70 17	+Federspiel, Flueckiger, Frei+	(BERN, VILL)
BARANOV 92		4 +Vanko, Glazov, Evtukhovich+	(JINR)
BRITTON 92		om YAF 55 2940. +Ahmad, Bryman, Burnham+	(TRIU, CARL)
Also 94		Britton, Ahmad, Bryman+	(TRIU, CARL)
NUMAO 92			(TRIU)
BARANOV 91			(JINR)
	Translated fr	om YAF 54 1298.	, ,
DAUM 91			(VILL)
BOLOTOV 90			(INRM)
EGLI 89 Also 86			(SINDRUM Collab.)
Also 86 PDG 88		Egli, Engfer, Grab, Hermes+ (A Yost, Barnett+	ACH3, ETH, SIN, ZURI)
PICCIOTTO 88			(LBL+) (TRIU, CNRC)
COHEN 87			(RISC, NBS)
KORENCHE 87	SJNP 46 192	Korenchenko, Kostin, Mzhaviva+	(JINR)
		om YAF 46 313.	, ,
BAY 86			(LAUS, ZURI)
BRYMAN 86 Also 83			(TRIU, CNRC)
JECKELMANN 86		Bryman, Dubois, Numao, Olaniya+ +Beer, Chambrier, Elsenhans+	(TRIU, CNRC) (ETH, FRIB)
Also 86			(ETH, FRIB)
PIILONEN 86		+Bolton, Cooper, Frank+	(LANL, TEMP, CHIC)
MCFARLANE 85		+Auerbach, Gaille+	(TEMP, LANL)
ABELA 84	PL 146B 431		(SIN)
Also 78		Daum, Eaton, Frosch, Hirschmann+	(SIN)
Also 79			
FETSCHER 84			(ÉTH)
ABELA 83			BASL, KARLK, KARLE)
CARR 83		+Gidal, Gobbi, Jodidio, Oram+	(LBL, NWES, TRIU)
COOPER 82	PL 112B 97	+Guy, Michette, Tyndel, Venus	(RL)
111 00	DDI 45 1000	Dellas Dames Mr. Caffeen	
LU 80		+Delker, Dugan, Wu, Caffrey+	(YALE, COLU, JHU)
STETZ 78	NP B138 285	+Delker, Dugan, Wu, Caffrey+ +Carroll, Ortendahl, Perez-Mendez+	(YALE, COLU, JHU) (LBL, UCLA)
STETZ 78 CARTER 76	NP B138 285 PRL 37 1380	+Delker, Dugan, Wu, Caffrey+ +Carroll, Ortendahl, Perez-Mendez+ +Dixit, Sundaresan+ (CA	(YALE, COLU, JHU) (LBL, UCLA) ARL, CNRC, CHIC, CIT)
STETZ 78 CARTER 76 KORENCHE 76	NP B138 285 PRL 37 1380 B JETP 44 35 Translated fro	+Delker, Dugan, Wu, Caffrey+ +Carroll, Ortendahl, Perez-Mendez+	(YALE, COLU, JHU) (LBL, UCLA) ARL, CNRC, CHIC, CIT)
STETZ 78 CARTER 76	NP B138 285 PRL 37 1380 B JETP 44 35 Translated fro	+ Delker, Dugan, Wu, Caffrey+ + Carroll, Ortendahl, Perez-Mendez+ + Dixit, Sundaresan+ (C/ Korenchenko, Kostin, Micelmacher+ 50m ZETF 71 69. Marushenko, Mezentsev, Petrunin+	(YALE, COLU, JHU) (LBL, UCLA) ARL, CNRC, CHIC, CIT)
STETZ 78 CARTER 76 KORENCHE 76 MARUSHEN 76	NP B138 285 PRL 37 1380 B JETP 44 35 Translated fro JETPL 23 72 Translated fro	+ Delker, Dugan, Wu, Caffrey+ + Carroll, Ortendah, Perez-Mendez+ + Dixit, Sundaresan+ Korenchenko, Kostin, Micelmacher+ TOTAL STATE OF THE CONTROL OF TH	(YALE, COLU, JHU) (LBL, UCLA) ARL, CNRC, CHIC, CIT) (JINR) (PNPI)
STETZ 78 CARTER 76 KORENCHE 76 MARUSHEN 76	PRL 37 1380 B JETP 44 35 Translated fra JETPL 23 72 Translated fra Private Comm	+ Delker, Dugan, Wu, Caffrey+ + Carroll, Ottendahl, Perez-Mendez+ + Dixit, Sundaresan+ (C. Korenchenko, Kostin, Micelmacher+ 71 69. Marushenko, Mezentsev, Petrunin+ on ZETF 23 80. n. Shafer	(YALE, COLU, JHU) (LBL, UCLA) ARL, CNRC, CHIC, CIT) (JINR) (PNPI) (FNAL)
STETZ 78 CARTER 76 KORENCHE 76 MARUSHEN 76 Also 76 Also 78	NP B138 285 PRL 37 1380 B JETP 44 35 Translated fri JETPL 23 72 Translated fri Private Comm	+ Delker, Dugan, Wu, Caffrey+ + Carroll, Oftendahl, Perez-Mendez+ + Dixit, Sundaresan+ Korenenko, Kostin, Micelmacher+ om ZETF 71 69. Marushenko, Mezentsev, Petrunin+ om ZETF 93 hafer n. Shafer n. Smirnov	(YALE, COLU, JHU) (LBL, UCLA) ARL, CNRC, CHIC, CIT) (JINR) (PNPI) (FNAL) (PNPI)
STETZ	NP B138 285 PRL 37 1380 B JETP 44 35 Translated fri JETPL 23 72 Translated fri Private Comr Private Comr SJNP 16 292 Translated fri	+ Delker, Dugan, Wu, Caffrey+ + Carroll, Ortendahl, Perez-Mendez+ + Dixit, Sundaresan+ (Cr. born ZETF 71 69 Aroushenko, Kostin, Micelmacher+ som ZETF 92 38 Aroushenko, Mezentsev, Petrunin+ n. Shafer n. Smirnov + Prokoshkin, Razuvaev+ som YAF 16 524.	(YALE, COLU, JHU) ARL, CNRC, CHIC, CIT) (JINR) (PNPI) (FNAL) (SERP)
STETZ 78 CARTER 76 KORENCHE 76 MARUSHEN 76 Also 78 DUNAITSEV 73 AYRES 71	NP B138 285 PRL 37 1380 B JETP 44 35 Translated fri JETPL 23 72 Translated free Private Comm Private Comm SJNP 16 292 Translated free PR D3 1051	+ Delker, Dugan, Wu, Caffrey+ + Carroll, Ottendahl, Perez-Mendez+ + Dixit, Sundaresan+ (C/ Kornechenko, Kostin, Micelmacher+ 71 69. Marushenko, Mezentsev, Petrunin+ on ZETF 23 80. n. Shafer n. Shafer on YAF 16 524. + Cormack, Greenberg, Kenney+	(YALE, COLU, JHU) (LBL, UCLA) ARL, CNRC, CHIC, CIT) (JINR) (PNPI) (FNAL) (PNPI) (SERP) (LRL, UCSB)
STETZ	NP B138 205 PRL 37 1380 BJETP 44 35 Translated fri JETPL 23 72 Translated fri Private Comm Private Comm SJNP 16 292 Translated fre PR D3 1051 PR 157 1288	+ Delker, Dugan, Wu, Caffrey+ + Carroll, Ortendah, Perez-Mendez+ + Dixit, Sundaresan+ (Cr. born ZETF 71 69 Grundaresan+ Dixit, Sundaresan+ Dixit,	(YALE, COLU, JHU) (LBL, UCLA) ARL, CNRC, CHIC, CIT) (JINR) (PNPI) (FNAL) (SERP) (LRL, UCSB) Kurz+ (LRL)
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STETZ	NP B138 288 B LETP 44 35 FRI 37 1384 B LETP 44 35 Translated fr LETP 12 37 27 Translated fr Private Comm SJNP 16 292 Translated fr PR 03 1051 PR 157 1288 PRL 21 261 PR 123 1267 SJNP 13 189 Translated fr PR 03 1051 PR 157 1288 PR 21 261 PR 123 1267 PR 1889 Translated fr PL 32 1267 PL 32	+ Delker, Dugan, Wu, Caffrey+ + Carroll, Ortendahl, Perez-Mendez+ + Dixit, Sundaresan+ (Cr. Korenchenko, Kostin, Micelmacher+ 23 80. m ZETF7 1 69. m ZETF7 1 69. m ZETF7 2 80. m Smirov + Prokoshkin, Razuvaev+ + Cormack, Greenberg, Kenney+ + Cormack, Greenberg, Kenney, Ayres, Caldwell, Greenberg, Kenney, Ayres, Carmack, Greenberg, Ayres, Cormack+ Korenchenko, Kostin, Micelmacher+ + Johnson, Williams, Wormald + Duclos, Heintze, Kleinknecht+ 2 + Rykalin, Khazins, Cisek + Loken, Pewitt, McKenzie+ + Lokowicz, Burman	(YALE, COLU, JHU) (ELL, UCLA) ARL, CNRC, CHIC, CIT) (PNPI) (FNAL) (PNPI) (SERP) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LRL) (LRL, UCSB) (LRL) (LRL, UCSB) (LNR) (LNR) (LNR) (ERN) (JINR) (ANL, CMU, NWES) (ROCH)
STETZ	NP B138 288 B LETP 44 35 Translated fr	+ Delker, Dugan, Wu, Caffrey+ + Carroll, Ortendahl, Perez-Mendez+ + Dixit, Sundaresan+ (Cr. Som ZETF 71 69 Marushenko, Mezentsev, Petrunin+ m ZETFP 23 80. n. Smirnov + Prokoshkin, Razuvaev+ + Cormack, Greenberg, Kenney+ Ayres, Caldwell, Greenberg, Kenney- Ayres, Carmack, Greenberg, Kenney Ayres, Cormack, Greenberg+ Ayres, Cormack, Greenberg+ WAF 15 350 Ayres Greenberg, Ayres, Cormack+ University of the Common Co	(YALE, COLU, JHU) (LIBL, UCLA) ARL, CNRC, CHIC, CIT) (JINR) (PNPI) (FNAL) (PNPI) (SERP) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (JINR) (LIL) (LRL, UCSB) (JINR) (LIVP) (CERN) (ANL, CMU, NWES) (ROCH)
STETZ	NP B138 288 B LETP 44 35 FR 37 1384 B LETP 44 35 Translated fr LETP 12 37 27 Translated fr Private Comm SJNP 16 292 Translated fr PR 03 1051 Thesis UCRL PR 12 3 1267 SJNP 13 189 Translated fr PL 32 1267 SJNP 13 189 Translated fr PL 32 1267 PL 126 275 NP B4 189 PL 126 376 PL 258 376 PL 258 376 PL 258 376 PL 248 594 PR 14 1132	+ Delker, Dugan, Wu, Caffrey+ + Carroll, Ortendahl, Perez-Mendez+ + Dixit, Sundaresan+ (Cr. Korenchenko, Kostin, Micelmacher+ 169. Marushenko, Mezentsev, Petrunin+ 28 80. Marushenko, Mezentsev, Petrunin+ 29 80. Marushenko, Mezentsev, Petrunin+ - Salorinov - Priokoshkin, Razuvaev+ - Priokoshkin, Razuvaev+ - Horse, Cafdwell, Greenberg, Kenney, Ayres, Cardwell, Greenberg, Kenney, Ayres, Cardwell, Greenberg, Kenney, Ayres, Cormack, Greenberg, Ayres, Cormack+ Korenchenko, Kostin, Micelmacher+ - Johnson, Williams, Wormald - Duclos, Heintze, Kleinknecht+ - Rykalin, Khazins, Cisek - Loken, Pewitt, McKenzie+ - Lobkowicz, Burman - Dore, Dorfan, Krieger+ - Lubkowicz, Burman - Dore, Dorfan, Krieger+ - Lubkowicz, Burnah	(YALE, COLU, JHU) (ELB, UCLA) ARL, CNRC, CHIC, CIT) (PNPI) (FNAL) (PNPI) (SERP) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (JINR) (ERL, UCSB) (JINR) (ERN) (ANL, CMU, NWES) (ROCH) (COLU)
STETZ	NP B138 288 B LETP 44 35 FRI 37 1342 45 FI 128 24 25 FRI 37 138 24 FRI 37 138 25 FRI 37 128 FRI 38 366 FRI 38	+ Delker, Dugan, Wu, Caffrey+ + Carroll, Ortendahl, Perez-Mendez+ + Dixit, Sundaresan+ (Cr. Som ZETF 71 69 Marushenko, Mezentsev, Petrunin+ m ZETFP 23 80. n. Smirnov + Prokoshkin, Razuvaev+ + Cormack, Greenberg, Kenney+ Ayres, Caldwell, Greenberg, Kenney- Ayres, Carmack, Greenberg, Kenney Ayres, Cormack, Greenberg+ Ayres, Cormack, Greenberg+ WAF 15 350 Ayres Greenberg, Ayres, Cormack+ University of the Common Co	(YALE, COLU, JHU) (LIBL, UCLA) ARL, CNRC, CHIC, CIT) (JINR) (PNPI) (FNAL) (PNPI) (SERP) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (JINR) (LIRL) (LRL, UCSB) (JINR) (LIPL) (CERN) (JINR) (ANL, CMU, NWES) (ROCH) (ROCH) (ROCH, BNL)
STETZ	NP B138 288 B LETP 44 35 FRI 37 138436 fr LETP 24 37 Translated fr LETP 12 37 Translated fr Private Comr SJNP 16 292 FR 03 05 FR 03 05 FR 03 05 FR 157 1288 FR 12 128 FR 12 128 FR 12 128 FR 13 189 Translated fr PL 258 723 NP B4 189 JINR P1 366 FL 258 376 FL 128 775 FR 144 1138 FR 1398 407 FR 1398 617 FR 1398 617	+ Delker, Dugan, Wu, Caffrey+ + Carroll, Ortendahl, Perez-Mendez+ + Dixit, Sundaresan+ (Cr. Korenchenko, Kostin, Micelmacher+ Dixit, Sundaresan+ Cr. Marushenko, Mezentsev, Petrunin+ Dixit, Sundaresan+ Dixit, Sanirov + Prokoshkin, Razuvaev+ + Cormack, Greenberg, Kenney+ Ayres, Caldwell, Greenberg, Kenney- Ayres, Carmack, Greenberg, Kenney- Ayres, Carmack, Greenberg, Korney, Ayres, Cormack, Greenberg, Korney, Ayres, Cormack, Greenberg, Kenney- Ayres, Cormack, Greenberg, Kenney- Ayres, Cormack, Greenberg, Kenney- Ayres, Cormack, Greenberg, Kenney- Lobna, Milliams, Wormald + Duclos, Heintze, Kleinknecht+ + Rykalin, Khazins, Cisek + Loken, Pewitt, McKenzile+ + Lobkowicz, Burman + Dore, Dorfan, Krieger+ + Lobkowicz, Nordberg + Melissinos, Nagashima+ + Gnesquiere, Wiegand, Larsen + Meyer, Carrigan+	(YALE, COLU, JHU) (ELB, UCLA) ARL, CNRC, CHIC, CIT) (PNPI) (FNAL) (PNPI) (SERP) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (JINR) (ERL, UCSB) (JINR) (ERN) (ANL, CMU, NWES) (ROCH) (COLU)
STETZ	NP B138 288 B LETP 44 35 FRI 37 138436 fr LETP 24 37 Translated fr LETP 12 37 Translated fr Private Comr SJNP 16 292 FR 03 05 FR 03 05 FR 03 05 FR 157 1288 FR 12 128 FR 12 128 FR 12 128 FR 13 189 Translated fr PL 258 723 NP B4 189 JINR P1 366 FL 258 376 FL 128 775 FR 144 1138 FR 1398 407 FR 1398 617 FR 1398 617	+ Delker, Dugan, Wu, Caffrey+ + Carroll, Ortendahl, Perez-Mendez+ + Dixit, Sundaresan+ (Cr. Korenchenko, Kostin, Micelmacher+ Dixit, Sundaresan+ Cr. Marushenko, Mezentsev, Petrunin+ Dixit, Sundaresan+ Dixit, Sanirov + Prokoshkin, Razuvaev+ + Cormack, Greenberg, Kenney+ Ayres, Caldwell, Greenberg, Kenney- Ayres, Carmack, Greenberg, Kenney- Ayres, Carmack, Greenberg, Korney, Ayres, Cormack, Greenberg, Korney, Ayres, Cormack, Greenberg, Kenney- Ayres, Cormack, Greenberg, Kenney- Ayres, Cormack, Greenberg, Kenney- Ayres, Cormack, Greenberg, Kenney- Lobna, Milliams, Wormald + Duclos, Heintze, Kleinknecht+ + Rykalin, Khazins, Cisek + Loken, Pewitt, McKenzile+ + Lobkowicz, Burman + Dore, Dorfan, Krieger+ + Lobkowicz, Nordberg + Melissinos, Nagashima+ + Gnesquiere, Wiegand, Larsen + Meyer, Carrigan+	(YALE, COLU, JHU) (ELB, UCLA) ARL, CNRC, CHIC, CIT) (PNPI) (FNAL) (PNPI) (SERP) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LIV) (CERN) (JINR) (ANL, CMU, NWES) (ROCH) (ROCH, BNL) (LRC, SLC)
STETZ	N P B138 289 B LETP 44 35 Translated fr	+ Delker, Dugan, Wu, Caffrey+ + Carroll, Ortendah, Perez-Mendez+ + Dixit, Sundaresan+ (Cr. Korenchenko, Kostin, Micelmacher+ 10 Marushenko, Mezentsev, Petrunin+ 23 Marushenko, Mezentsev, Petrunin+ 23 Marushenko, Mezentsev, Petrunin+ 23 Marushenko, Mezentsev, Petrunin+ 23 Marushenko, Mezentsev, Petrunin+ 24 Marushenko, Mezentsev, Petrunin+ 25 Marushenko, Greenberg, Kenney- 26 Marushenko, Greenberg, Kenney- 27 Marushenko, Greenberg, Kenney- 28 Marushenko, Greenberg, Ayres, Cormack- 29 Marushenko, Kostin, Micelmacher+ + Donson, Williams, Wormald - Dore, Dorfan, Khazins, Cisek - Lokowicz, Burman - Dore, Dorfan, Khazins, Cisek - Lokowicz, Burman - Dore, Dorfan, Khieger+ - Lobkowicz, Burman - Dore, Dorfan, Knieger+ - Lobkowicz, Northerg - Melissinos, Nagashima+ - Ghesquiere, Wiegand, Larsen - Meyer, Carrigan+ - Petrukhin, Prokoshkin+ MT ZETF 47 84.	(YALE, COLU, JHU) (ELB, UCLA) ARL, CNRC, CHIC, CIT) (PNPI) (FNAL) (PNPI) (SERP) (LRL, UCSB) (LRL, UNP) (CERN) (CERN) (ROCH) (ROCH, SNL) (ROCH, SNL) (ROCH, SNL) (LRL, SLAC) (MICH, CMU, (JINR)
STETZ	NP B138 289 B JETP 44 35 Translated fr JETP 12 37 Translated fr Private Committee Private Private Committee Private Pr	+ Delker, Dugan, Wu, Caffrey+ + Carroll, Ortendahl, Perez-Mendez+ + Dixit, Sundaresan+ (Cr. Kornechenko, Kostin, Micelmacher+ 169. Marushenko, Mezentsev, Petrunin+ Marushenko, Mezentsev, Petrunin+ Marushenko, Mezentsev, Petrunin+ Smirnov m YAF 16 724. Cormack, Greenberg, Kenney+ + Cormack, Greenberg, Kenney, Ayres, Caldwell, Greenberg, Kenney, Ayres, Cardwell, Greenberg, Kenney, Ayres, Cormack, Greenberg, Ayres, Cormack+ Kornechenko, Kostin, Micelmacher+ + Johnson, Williams, Wormald + Duclos, Heintze, Kleinknecht+ 2 + Rykalin, Khazins, Cisek + Loken, Pewitt, McKenzie+ + Lokokowicz, Burman + Dore, Dorfan, Krieger+ + Lokokowicz, Burdberg + Melissinos, Nagashima+ - Ghesquiere, Wiegand, Larsen + Meyer, Carrigan+ + Petrukhin, Prokoshkin+ + Harris, Shuler+	(YALE, COLU, JHU) (ELB, UCLA) ARL, CNRC, CHIC, CIT) (PNPI) (FNAL) (PNPI) (SERP) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (JINR) (ERL) (CRL) (CRL) (CRU) (CERN) (JINR) (ANL, CMU, NWES) (COLU) (ROCH, BNL) (LICL, SLAC) (MICH, CMU) (MICH, CMU) (WILL)
STETZ	N P B138 228 PRI 37 1380 B LETP 44 35 Translated fir LETP 12 37 27 Translated fir Private Coming 15 12 12 12 12 12 12 12 12 12 12 12 12 12	+ Delker, Dugan, Wu, Caffrey+ + Carroll, Ortendahl, Perez-Mendez+ + Dixit, Sundaresan+ (Cr. Korenchenko, Kostin, Micelmacher+ 10 Shafer No. Smirnov + Prokoshkin, Razuvaev+ + Cormack, Greenberg, Kenney+ Ayres, Caidwell, Greenberg, Kenney- Ayres, Caidwell, Greenberg, Kenney- Ayres, Caidwell, Greenberg, Kenney- Ayres, Carmack, Greenberg- Mayres, Cormack, Greenberg- Mayres, Cormack, Greenberg- Houcins, Heinze, Kleinknecht+ + Duclos, Heinze, Kleinknecht+ + Rykslin, Khazis, Glek + Lobkowicz, Burmackenthe + Lobkowicz, Burmackenthe + Lobkowicz, Burmackenthe + Chesquieze, Wiegand, Larsen + Meyer, Carrigan+ + Petrukhin, Prokoshkin+ + Harris, Shuler+ + Donson, Kyeyr, Rosen	(YALE, COLU, JHU) (ELB, UCLA) ARL, CNRC, CHIC, CIT) (PNPI) (FNAL) (PNPI) (SERP) (LRL, UCSB) (LIVP) (CERN) (CERN) (ROCH) (ROCH, BNL) (ROCH, BNL) (LRL, SLAC) (MICH, CMU, (MICH, CMU)
STETZ	N P B138 238 B JETP 44 35 Translated fir JETP 12 37 Translated fir Private Commit Private Commit PR 33 1051 PR 157 1280 PR 157 1280 PR 157 1280 PR 157 1280 PR 158 1280 PR 128 1280 PR 128 1280 JINR P1 386 PL 255 36 PL 255 37 PR 140 1132 PR 14 1132 PR 14 1132 PR 14 1132 PR 14 1134 PR 1386 407 PR 1386 148 PR 1388 1438 PR 1388 1438	+ Delker, Dugan, Wu, Caffrey+ + Carroll, Ortendahl, Perez-Mendez+ + Dixit, Sundaresan+ (Cr. Kornechenko, Kostin, Micelmacher+ Tom ZETF 71 69. Marushenko, Mezentsev, Petrunin+ Marushenko, Mezentsev, Petrunin+ Shafe Marushenko, Mezentsev, Petrunin+ Shafe Shafe Marushenko, Mezentsev, Petrunin+ Shafe Marushenko, Mezentsev, Petrunin+ Shafe Marushenko, Mezentsev, Petrunin+ Cormack, Greenberg, Kenney, Ayres, Cormack, Greenberg, Kenney, Ayres, Cormack, Greenberg, Kenney, Ayres, Cormack, Greenberg, Ayres, Cormack+ Kornechenko, Kostin, Micelmacher+ Houldos, Heintze, Kleinknecht+ Publishin, Marians, Cisek + Loken, Pewitt, McKenzie+ + Lokokowicz, Nordberg + Melissinos, Nagashima+ + Ghesquiere, Wiegand, Larsen + Meyer, Carrigan+ + Petrukhin, Prokoshkin+ + Harris, Shuler+ + Devons, Meyer, Rosen 3 - Garland, Pondrom, Streizoff	(YALE, COLU, JHU) (ELB, UCLA) ARL, CNRC, CHIC, CIT) (PNPI) (FNAL) (PNPI) (SERP) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (JINR) (ERL) (CRL) (CRL) (CRU) (CERN) (JORN) (ANL, CMU, NWES) (COLU) (ROCH, BNL) (LRT, SLAC) (MICH, CMU) (WILL) (COLU)
STETZ	N P B138 238 B JETP 44 35 Translated fir JETP 12 37 Translated fir Private Comm S and S S S S S S S S S S S S S S S S S S S	+ Delker, Dugan, Wu, Caffrey+ + Carroll, Ortendah, Perez-Mendez+ + Dixit, Sundaresan+ (Cr. Korenchenko, Kostin, Micelmacher+ 1 59 Marushenko, Mezentsev, Petrunin+ Dixit, Sundaresan+ Dixit, Sundaresan+ Dixit, Sundaresan+ Dixit, Sundaresan+ Prokoshikin, Razuvaev+ + Cormack, Greenberg, Kenney+ Ayres, Caidwell, Greenberg, Kenney- Ayres, Caidwell, Greenberg, Kenney- Ayres, Carmack, Greenberg, Krenney- Ayres, Carmack, Greenberg, Ayres, Cormack+ Korenchenko, Kostin, Micelmacher+ Dixit, Sundaresan- Dixit, Sundaresan- Horte, Deviat, Miriger+ + Lobkowicz, Burman + Dore, Dorfan, Krieger+ + Lobkowicz, Burman + Dore, Dorfan, Krieger+ + Lobkowicz, Nordherg + Melissinos, Nagashima+ + Ghesquiere, Wiegand, Larsen + Meyer, Carrigan+ + Petrukhin, Prokoshkin+ 2 + Devons, Meyer, Rosen - Garland, Pondrom, Strelzoff Dondrom	(YALE, COLU, JHU) (ELB, UCLA) ARL, CNRC, CHIC, CIT) (PNPI) (FNAL) (PNPI) (SERP) (LRL, UCSB) (LIVP) (CERN) (CERN) (ROCH) (ROCH, BNL) (ROCH, BNL) (LRL, SLAC) (MICH, CMU, (MICH, CMU)
STETZ	N P B138 228 PRI 37 1380 B LETP 44 35 Translated fr LETP 12 37 27 Translated fr Private Commodification FR 157 1288 PRI 12 108 PRI 157 1288 PRI 157 1288 PRI 157 1288 PRI 157 1288 PRI 157 PRI 157 PRI 158 PRI 1588 PRI 158 PRI 1588 PRI 158 PRI 1588	+ Delker, Dugan, Wu, Caffrey+ + Carroll, Ortendah, Perez-Mendez+ + Dixit, Sundaresan+ (Cr. Korenchenko, Kostin, Micelmacher+ 10 Marchander Staffer Sta	(YALE, COLU, JHU) (ELB, UCLA) ARL, CNRC, CHIC, CIT) (PNPI) (FAAL) (PNPI) (SERP) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LRL) (CERN) (CERN) (CERN) (ANL, CMU, WECH) (ROCH, BNL) (ROCH, BNL) (LRL, SLAC) (MICH, CMU) (COLU) (COLU) (COLU) (COLU) (COLU) (COLU)
STETZ	N P B138 289 B JETP 44 35 Translated fir JETP 42 35 Translated fir JETP 12 37 Translated fir Private Comm S and 105 PR 137 1289 PR 127 1289 JINR P1 366 PL 255 376 PL 128 78 PR 147 1129 PR 137 1849 PR 138 139 PR 147 138 PR 138 139 PR 138 139 PR 138 139 PR 138 139 PR 138 138 PR 138 139 PR 19 2059	+ Delker, Dugan, Wu, Caffrey+ + Carroll, Ortendahl, Perez-Mendez+ + Dixit, Sundaresan+ (Cr. Kornechenko, Kostin, Micelmacher+ Tom ZETF 71 69. Marushenko, Mezentsev, Petrunin+ Marushenko, Mezentsev, Petrunin+ Smirnov m YAF 16 724 - Cormack, Greenberg, Kenney+ + Cormack, Greenberg, Kenney+ Ayres, Caldwell, Greenberg, Kenney, Ayres, Cormack, Greenberg, Kenney, Ayres, Cormack, Greenberg, Habdey - Greenberg, Ayres, Cormack+ Kornechenko, Kostin, Micelmacher+ - Hohnson, Williams, Wormald - Duclos, Heintze, Kleinknecht+ - Rykalin, Khazins, Cisek + Loken, Pewitt, McKenzie+ + Lokokowicz, Burman + Dore, Dorfan, Krieger+ + Lokokowicz, Wordberg + Melissinos, Nagashima+ - Ghesquiere, Wiegand, Larsen + Meyer, Carrigan+ + Petrukhin, Prokoshkin+ + Harris, Shuler+ - Devons, Meyer, Rosen - Heintze, Rubbia, Soergel	(YALE, COLU, JHU) (ELB, UCLA) ARL, CNRC, CHIC, CIT) (PNPI) (FNAL) (PNPI) (SERP) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LIV) (CERN) (JINR) (ANL, CMU, NWES) (COLU) (ROCH, BNL) (LRC, SLAC) (MICH, CMU) (WILL) (COLU) (WISC) (COLU) (WISC)



$$I^{G}(J^{PC}) = 1^{-}(0^{-})$$

We have omitted some results that have been superseded by later experiments. The omitted results may be found in our 1988 edition Physics Letters **B204** (1988).

π^0 MASS

The value is calculated from m_{π^\pm} and $(m_{\pi^\pm}-m_{\pi^0})$. See notes under the π^\pm Mass Listings concerning recent revision of the charged pion mass.

VALUE (MeV)
134.9764±0.0006 OUR FIT

DOCUMENT ID

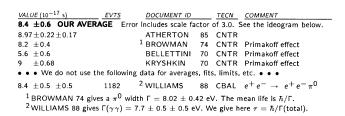
$m_{\pi^{\pm}}-m_{\pi^0}$

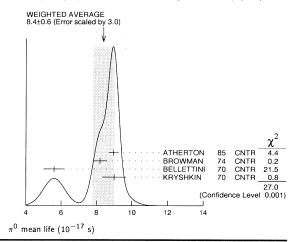
Measurements with an error > 0.01 MeV have been omitted.

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
4.5936 ±0.0005 OUR FIT				
4.5936 ±0.0005 OUR AVERAGE				
4.59364 ± 0.00048				$\pi^- p \rightarrow \pi^0 n$, n TOF
4.5930 ±0.0013	CRAWFORD	86	CNTR	$\pi^- p \rightarrow \pi^0 n$, n TOF
	lata for averages	, fits	, limits,	etc. • • •
4.59366±0.00048	CRAWFORD	88B	CNTR	See CRAWFORD 91
4.6034 ±0.0052	VASILEVSKY	66	CNTR	
4.6056 ±0.0055	CZIRR	63	CNTR	

π^0 MEAN LIFE

Measurements with an error $> 1 \times 10^{-17}\,\text{s}$ have been omitted.





π^0 DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Scale factor/ Confidence level
Γ ₁	2γ	(98.798±0.032) %	S=1.1
Γ_2	$e^+e^-\gamma$	(1.198±0.032) %	S=1.1
Γ_3	γ positronium	$(1.82 \pm 0.29) \times 1$	0-9
Γ_4	$e^{+}e^{+}e^{-}e^{-}$	$(3.14 \pm 0.30) \times 1$	0-5
Γ_5	$e^+ e^-$	$(7.5 \pm 2.0) \times 1$	0-8
Γ ₆	4 γ	< 2 × 1	0 ⁻⁸ CL=90%
Γ_7	$ u \overline{ u}$	$[a] < 8.3 \times 1$	0 ⁻⁷ CL=90%
Γ ₈	$\nu_e \overline{\nu}_e$	< 1.7 × 1	0 ⁻⁶ CL=90%
Γ_9	$ u_{\mu}\overline{ u}_{\mu}$	< 3.1 × 1	0 ^{−6} CL=90%
Γ_{10}	$ u_{\tau} \overline{\nu}_{\tau}$	< 2.1 × 1	0 ⁻⁶ CL=90%

 π^0

Charge conjugation (C) or	Lepton	Family number	(LF)	violating	modes
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Γ_{11}	3γ	C	<	3.1	$\times 10^{-8}$	CL=90%
Γ_{12}	$\mu^+ e^-$					
Γ_{13}	$\mu^{+} e^{-} + e^{-} \mu^{+}$	LF	<	1.72	$\times 10^{-8}$	CL=90%

[a] Astrophysical and cosmological arguments give limits of order 10^{-13} ; see the Particle Listings below.

CONSTRAINED FIT INFORMATION

An overall fit to 2 branching ratios uses 4 measurements and one constraint to determine 3 parameters. The overall fit has a χ^2 = 1.9 for 2 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv$ $\Gamma_i/\Gamma_{\mathsf{total}}$. The fit constrains the x_i whose labels appear in this array to sum to

π^0 BRANCHING RATIOS

$\Gamma(e^+e^-\gamma)/\Gamma(2\gamma)$						Γ_2/Γ_1
VALUE (%)	EVTS	DOCUMENT ID	T	ECN	COMMENT	
1.213 ± 0.033 OUR FIT	Error in	ncludes scale factor	of 1.1.			
1.213±0.030 OUR AVE	RAGE					
1.25 ±0.04		SCHARDT	81 S	PEC	$\pi^- p \rightarrow n \pi^0$	
1.166 ± 0.047	3071	3 SAMIOS	61 H	вс	$\pi^- p \rightarrow n \pi^0$	
1.17 ±0.15	27	BUDAGOV	60 H			
• • • We do not use th	e followi	ng data for average	es, fits, l	mits,	etc. • • •	

 3 SAMIOS 61 value uses a Panofsky ratio = 1.62.

$\Gamma(\gamma \operatorname{positronium})/\Gamma(2\gamma)$	Γ_3/Γ_1

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VALUE (units 10-9)	EVTS	DOCUMENT ID	TECN	COMMENT	
1.84±0.29	277	AFANASYEV 90	CNTR	pC 70 GeV	

$\Gamma(e^+e^+e^-e^-)/\Gamma$	(2γ)			Γ_4/Γ_1
VALUE (units 10 ⁻⁵)	EVTS	DOCUMENT I	TECN_	
3.18 ± 0.30 OUR FIT				
3.18 ± 0.30	146	4 SAMIOS	62B HBC	

 4 SAMIOS 628 value uses a Panofsky ratio = 1.62.

$\Gamma(e^+e^-)/\Gamma_{\text{total}}$				Γ ₅ /Γ
VALUE (units 10-8)	EVTS	DOCUMENT ID	TECN	COMMENT
7.5 ± 2.0 OUR AVER/	AGE			
$6.9 \pm 2.3 \pm 0.6$	21	⁵ DESHPANDE 93	SPEC	$K^+ \rightarrow \pi^+ \pi^0$
$8.8^{+4.5}_{22}\pm0.6$	8	6 MCFARLAND 93	SPEC	$K_L^0 \rightarrow 3\pi^0$ in flight

 $^5\,\text{The DESHPANDE}$ 93 result with bremsstrahlung radiative corrections is (8.0 \pm 2.6 \pm $0.6) \times 10^{-8}$.

 $^6\,{\rm The}$ MCFARLAND 93 result with radiative corrections and excluding $[m_{e\,e}/m_{\pi^0}]^2~<$ 0.95 is $(7.6^{+3.9}_{-2.8} \pm 0.5) \times 10^{-8}$.

$\Gamma(e^+e^-)/\Gamma(2\gamma)$	Γ_5/Γ_1

VALUE (units 10 ⁻⁷)	CL% E	VTS	DOCUMENT ID		TECN	COMMENT
• • • We do not us	e the follo	wing data	for averages, fit	s, li	nits, etc	. • • •
<1.3	90		NIEBUHR			$\pi^- p \rightarrow \pi^0 n$ at rest
< 5.3	90		ZEPHAT	87	SPEC	$\pi^- p \rightarrow \pi^0 n$
						0.3 GeV/c
$1.7 \pm 0.6 \pm 0.3$		59	FRANK	83	SPEC	$\pi^- \rho \rightarrow n \pi^0$
1.8 ±0.6		58	MISCHKE	82	SPEC	See FRANK 83
$2.23 + 2.40 \\ -1.10$	90	8	FISCHER	788	SPRK	$K^+ \rightarrow \pi^+ \pi^0$

$\Gamma(4\gamma)/\Gamma_{\text{total}}$					Γ ₆ /Γ
VALUE (units 10 ⁻⁸)	CL%	EVTS	DOCUMENT ID	TECN	COMMENT

< 2		90		MCDONOUG	H 88	свох	π^{-}	p at	rest
• • • \	We do no	t use	the following	data for average	s, fits	, limits,	etc.	• •	•
<160		90		BOLOTOV	86C	CALO			
<440		90	0	AUERBACH	80	CNTR			

 $\Gamma(\nu\overline{\nu})/\Gamma_{total}$ The astrophysical and cosmological limits are many orders of magnitude lower, but we have tabered to the summary Tables.

VALUE (units 10 ⁻⁶)	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
< 0.83	90		⁷ ATIYA	91	B787	$K^+ \rightarrow \pi^+ \nu \nu'$
	ise the foll	owing d	ata for averages, f	its, li	nits, etc.	. • • •
$< 2.9 \times 10^{-7}$				91		Cosmological limit
$< 3.2 \times 10^{-7}$			⁹ NATALE	91		SN 1987A
< 6.5	90		DORENBOS	. 88	CHRM	Beam dump, prompt
<24	90	0	⁷ HERCZEG	81	RVUE	$K^{+} \rightarrow \pi^{+} \nu \nu'$

 7 This limit applies to all possible u
u' states as well as to other massless, weakly interacting

states.
8 LAM 91 considers the production of right-handed neutrinos produced from the cosmic thermal background at the temperature of about the pion mass through the reaction $\gamma\gamma\to\pi^0\to\nu\overline{\nu}$.

 $\gamma\gamma \to \pi^{\vee} \to \nu \overline{\nu}$.

9 NATALE 91 considers the excess energy-loss rate from SN 1987A if the process $\gamma\gamma \to \pi^0 \to \nu \overline{\nu}$ occurs, permitted if the neutrinos have a right-handed component. As pointed out in LAM 91 (and confirmed by Natale), there is a factor 4 error in the NATALE 91 published result (0.8×10^{-7}) .

$\Gamma(\nu_e \overline{\nu}_e)/\Gamma_{\rm total}$ Γ_8/Γ VALUE (units 10⁻⁶) CL% DOCUMENT ID TECN COMMENT DORENBOS... 88 CHRM Beam dump, prompt ν

90 • • We do not use the following data for averages, fits, limits, etc.

90 10 HOFFMAN 88 RVUE Beam dump, prompt u<3.1 $^{\rm 10}\,{\rm HOFFMAN}$ 88 analyzes data from a 400-GeV BEBC beam-dump experiment.

$\Gamma(u_{\mu}\overline{ u}_{\mu})/\Gamma_{total}$				٦/و٢
VALUE (units 10 ⁻⁶)	CL%	DOCUMENT ID	TECN	COMMENT
<3.1	90	11 HOFFMAN 8	88 RVUE	Beam dump, prompt ν
• • • We do not use	the following	ig data for averages,	fits, limits	, etc. • • •
<7.8	90	DORENBOS 8	88 CHRM	Beam dump, prompt ν
¹¹ HOFFMAN 88 an	alyzes data	from a 400-GeV BEI	3C beam-	lump experiment.

$\Gamma(u_{oldsymbol{ au}}\overline{ u}_{oldsymbol{ au}})/\Gamma_{tota}$	I				Γ ₁₀ /Γ
VALUE (units 10 ⁻⁶)	CL%	DOCUMENT ID		TECN	COMMENT
<2.1	90	¹² HOFFMAN	88	RVUE	Beam dump, prompt ν
 ● ● We do not 	use the followin	ig data for average:	s, fit	s, limits,	etc. • • •
<4.1	90	DORENBOS	88	CHRM	Beam dump, prompt $ u$

 $^{12}\,\mathrm{HOFFMAN}$ 88 analyzes data from a 400-GeV BEBC beam-dump experiment.

Γ(3γ)/Γ _{tota} Forbidd	il en by Cinv	ariance					Γ ₁₁ /Γ
VALUE (units 10			DOCUMENT ID		TECN	COMMENT	
< 3.1	90		MCDONOUG				
● ● • We do	not use the	follow	ing data for average	es, fit	s, limits,	etc. • • •	
< 38	90	0	HIGHLAND	80	CNTR		
<150	90	0	AUERBACH	78	CNTR		
<490	90	0	¹³ DUCLOS	65	CNTR		
<490	90		¹³ KUTIN	65	CNTR		
13 These exp	eriments gi	ve B(3	$\gamma/2\gamma) < 5.0 \times 10^{-1}$	-6.			

Γ (μ ⁺ e ⁻)/I total Forbidden by I	epton family	number conservatior	١.		1 12/1
VALUE (units 10 ⁻⁹)	CL%	DOCUMENT ID	TECN	COMMENT	
• • • We do not us	e the followin	g data for averages,	fits, limits	, etc. • • •	
<16	90	LEE	90 SPEC	$K^+ \rightarrow \pi^+ \mu^-$	+ e
∠78	90	CAMPAGNARIA	RR SPEC	See LEE 90	

$[\Gamma(\mu^+e^-) + \Gamma(e^-)]$	u ⁺)]/Γ _{tot} ton family r	al iumber conservat	ion.		Γ ₁₃ /Γ
VALUE (units 10 ⁻⁹)	CL%	DOCUMENT ID		TECN	COMMENT
< 17.2	90	KROLAK	94	E799	In $K_I^0 \rightarrow 3\pi^0$
• • • We do not use t	he following	data for average	es, fit	s, limits,	etc. • • •
<140		HERCZEG	84	RVUE	$K^+ \rightarrow \pi^+ \mu e$
$< 2 \times 10^{-6}$		HERCZEG			$\mu^- ightarrow e^-$ conversion
< 70	90	BRYMAN	82	RVUE	$K^+ \rightarrow \pi^+ \mu e$

$\pi^{\rm 0}$ ELECTROMAGNETIC FORM FACTOR

The amplitude for the process $\pi^0 \to e^+ e^- \gamma$ contains a form factor F(x) at the $\pi^0\gamma\gamma$ vertex, where $x=[m_{e^+e^-}/m_{\pi^0}]^2$. The parameter a in the linear expansion ${\sf F}(x)=1+ax$ is listed below.

All the measurements except that of BEHREND 91 are in the time-like region of momentum transfer.

LINEAR COEFFICIENT OF π^0 ELECTROMAGNETIC FORM FACTOR

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.032 ±0.004 OUR AVE	RAGE			
+0.026 ±0.024 ±0.048	7548	FARZANPAY 9:	2 SPEC	$\pi^- \rho \rightarrow \pi^0 n$ at rest
$+0.025 \pm 0.014 \pm 0.026$	54k	MEIJERDREES 9:	2B SPEC	$\pi^- \rho \rightarrow \pi^0 n$ at rest
$+0.0326\pm0.0026\pm0.0026$	127	14 BEHREND 9	1 CELL	$e^+e^- \rightarrow e^+e^-\pi^0$
-0.11 ± 0.03 ± 0.08	32k	FONVIEILLE 8	SPEC	Radiation corr.

• • We do not use the following	data for averages,	fits, limits, etc. • •
---------------------------------	--------------------	------------------------

0.12	+0.05 -0.04		¹⁵ TUPPER	83	THEO	FISCHER 78 data	
+0.10	±0.03	31k	16 FISCHER	78	SPEC	Radiation corr.	
+0.01	± 0.11	2200	DEVONS	69	OSPK	No radiation corr.	
-0.15	± 0.10	7676	KOBRAK	61	HBC	No radiation corr.	
-0.24	± 0.16	3071	SAMIOS	61	HBC	No radiation corr.	

 $^{^{14}}$ BEHREND 91 estimates that their systematic error is of the same order of magnitude as their statistical error, and so we have included a systematic error of this magnitude. The value of a is obtained by extrapolation from the region of large space-like momentum transfer assuming vector dominance.

π^0 REFERENCES

We have omitted some papers that have been superseded by later experiments. The omitted papers may be found in our 1988 edition Physics Letters **B204** (1988).

KROLAK	94	PL B320 407	+Briere, Cheu, Harris+	(FNAL E799 Collab.)
DESHPANDE	93	PRL 71 27	+Alliegro, Chaloupka+	(BNL E851 Collab.)
MCFARLAND	93	PRL 71 31	+Briere, Cheu, Harris+	(FNAL E799 Collab.)
FARZANPAY	92	PL B278 413	 + (ORST, TRIU, BRCO, QL 	JKI, LBL, BIRM, OXF)
MEIJERDREES	92B	PR D45 1439	Meijer Drees, Waltham+ (PS	SI SINDRUM-I Collab.)
ATIYA	91	PRL 66 2189	+Chiang, Frank, Haggerty+ (BNI	L, LANL, PRIN, TRIU)
BEHREND	91	ZPHY C49 401	+Criegee, Field, Franke+	(CELLO Collab.)
CRAWFORD	91	PR D43 46	+Daum, Frosch, Jost, Kettle+	(VILL, VIRG)
LAM	91	PR D44 3345	+Ng	(AST)
NATALE	91	PL B258 227		(SPIFT)
AFANASYEV	90	PL B236 116	+Chvyrov, Karpukhin+	(JINR, MOSU, SERP)
Also	90B	SJNP 51 664	Afanasyev, Gorchakov, Karpukhin, Kor	marov+ (JINR)
A130	900	Translated from YAF 51	1040	marov+ (Jilvik)
LEE	90	PRL 64 165	+Alliegro, Campagnari+ (BNL, FNAL	VIII WACH VALEY
FONVIEILLE	89	PL B233 65		
NIEBUHR	89	PR D40 2796	+Eichler, Felawka, Kozlowski+	(CLER, LYON, SACL)
				(SINDRUM Collab.)
CAMPAGNARI		PRL 61 2062		L, PSI, WASH, YALE)
CRAWFORD	88B	PL B213 391	+Daum, Frosch, Jost, Kettle, Marshall+	
DORENBOS		ZPHY C40 497	Dorenbosch, Allaby, Amaldi, Barbiellini	
HOFFMAN	88	PL B208 149		(LANL)
MCDONOUGH		PR D38 2121		(TEMP, LANL, CHIC)
PDG	88	PL B204	Yost, Barnett+	(LBL+)
WILLIAMS	88	PR D38 1365	+Antreasyan, Bartels, Besset+	(Crystal Ball Collab.)
ZEPHAT	87	JPG 13 1375	+Playfer, van Doesburg, Bressani+	(OMICRON Collab.)
BOLOTOV	86C	JETPL 43 520	+Gninenko, Dzhilkibaev, Isakov	(INRM)
		Translated from ZETFP		
CRAWFORD	86	PRL 56 1043	+Daum, Frosch, Jost, Kettle+	(SIN, VIRG)
ATHERTON	85	PL 158B 81		J, LUND, CURIN, EFI)
HERCZEG	84	PR D29 1954	+Hoffman	(LANL)
FRANK	83	PR D28 423	+Hoffman, Mischke, Moir+	(LANL, ARZS)
TUPPER	83	PR D28 2905	+Grose, Samuel	(OKSU)
BRYMAN	82	PR D26 2538		(TRIU)
MISCHKE	82	PRL 48 1153	+Frank, Hoffman, Moir, Sarracino+	(LANL, ARZS)
HERCZEG	81	PL 100B 347	+Hoffman	(LANL)
SCHARDT	81	PR D23 639	+Frank, Hoffmann, Mischke, Moir+	(ARZS, LANL)
AUERBACH	80	PL 90B 317	+Haik, Highland, McFarlane, Macek+	(TEMP, LASL)
HIGHLAND	80	PRL 44 628	+Auerbach, Haik, McFarlane, Macek+	(TEMP, LASL)
AUERBACH	78	PRL 41 275	+Highland, Johnson+	(TEMP, LASL)
FISCHER	78	PL 73B 359	+Extermann, Guisan, Mermod+	(GEVA, SACL)
FISCHER	78B	PL 73B 364	+Extermann, Guisan, Mermod+	(GEVA, SACL)
BROWMAN	74	PRL 33 1400	+Dewire, Gittelman, Hanson+	
BELLETTINI	70	NC 66A 243	+Bemporad, Lubelsmey+	(CORN, BING)
KRYSHKIN				(PISA, BONN)
KKYSHKIN	70	JETP 30 1037 Translated from ZETF 5	+Sterligov, Usov	(TMSK)
DEVONS	69	PR 184 1356		(COLUL BOMA)
			+Nemethy, Nissim-Sabat, Capua+	(COLU, ROMA)
VASILEVSKY	66	PL 23 281	+Vishnyakov, Dunaitsev+	(JINR)
DUCLOS	65	PL 19 253	+Freytag, Heintze+	(CERN, HEID)
KUTIN	65	JETPL 2 243	+Petrukhin, Prokoshkin	(ANIL)
67100		Translated from unknow	n journal.	4 3
CZIRR	63	PR 130 341		(LRL)
SAMIOS	62B	PR 126 1844	+Plano, Prodell+	(COLU, BNL)
KOBRAK	61	NC 20 1115		(EFI)
SAMIOS	61	PR 121 275		(COLU, BNL)
BUDAGOV	60	JETP 11 755	+Viktor, Dzhelepov, Ermolov+	(JINR)
1005011		Translated from ZETF 3	8 1047.	
JOSEPH	60	NC 16 997		(EFI)



$$I^{G}(J^{PC}) = 0^{+}(0^{-})$$

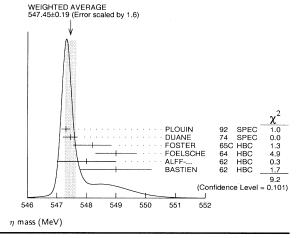
We have omitted some results that have been superseded by later experiments. The omitted results may be found in our 1988 edition Physics Letters B204 (1988).

η MASS

Measurements with an error ≥ 2 MeV are omitted from the average.

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
547.45±0.19 OUR	AVERAGE	Error includes scale	facto	or of 1.6	See the ideogram below
547.30 ± 0.15		PLOUIN	92	SPEC	$dp \rightarrow \eta^3 He$
547.45 ± 0.25		DUANE	74	SPEC	$\pi^- p \rightarrow n$ neutrals
548.2 ±0.65		FOSTER	65C	HBC	
549.0 ±0.7	148	FOELSCHE	64	HBC	
548.0 ±1.0	91	ALFF	62	HBC	
549.0 ±1.2	53	BASTIEN	62	HBC	





η WIDTH

This is the partial decay rate $\Gamma(\eta\to\gamma\gamma)$ divided by the fitted branching fraction for that mode. See the "Note on the Decay Width $\Gamma(\eta\to\gamma\gamma)$ " in our 1994 edition, Phys. Rev. **D50**, 1 August 1994, Part I, p. 1451.

<u>VALUE (keV)</u> <u>DOCUMENT ID</u> **1.18±0.11 OUR FIT** Error includes scale factor of 1.8.

η DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Scale factor/ Confidence level
Γ_1	neutral modes	(71.4 ±0.6) %	S=1.3
Γ_2	2γ	[a] (39.25±0.31) %	S=1.3
Γ_3	$3\pi^{0}$	(32.1 ±0.4) %	S=1.2
Γ_4	π^0 2 γ	$(7.1 \pm 1.4) \times 10^{\circ}$	-4
Γ_5	other neutral modes	< 2.8 %	CL=90%
Γ_6	charged modes	(28.6 ±0.6) %	S=1.3
Γ_7	$\pi^{+}\pi^{-}\pi^{0}$	(23.2 ± 0.5) %	S=1.3
Γ8	$\pi^+\pi^-\gamma$	(4.78±0.12) %	S=1.2
Γ9	$e^+e^-\gamma$	(4.9 ± 1.1) \times 10	-3
Γ_{10}	$\mu^+\mu^-\gamma$	(3.1 ± 0.4) \times 10	-4
Γ_{11}	e^+e^-	< 3 × 10	^{−4} CL=90%
Γ_{12}	$\mu^+\mu^-$	$(5.8 \pm 0.8) \times 10^{-3}$	-6
Γ_{13}	$\pi^{+}\pi^{-}e^{+}e^{-}$	$(1.3 \begin{array}{c} +1.2 \\ -0.8 \end{array}) \times 10^{-1}$	-3
Γ_{14}	$\pi^+\pi^-2\gamma$	< 2.1 × 10	-3
Γ ₁₅	$\pi^+\pi^-\pi^0\gamma$	< 6 × 10	-4 CL=90%
Γ ₁₆	$\pi^0 \mu^+ \mu^- \gamma$	< 3 × 10	-6 CL=90%

Charge conjugation (C), Parity (P), or Charge conjugation \times Parity (CP) violating modes

Γ ₁₇	$\pi^+\pi^-$	P,CP	<	1.5	× 10 ⁻³
Γ ₁₈	3γ	C	<	5	× 10 ⁻⁴ CL=95%
Γ19	$\pi^{0} e^{+} e^{-}$	C	[b] <	4	$\times 10^{-5}$ CL=90%
Γ ₂₀	$\pi^{0} \mu^{+} \mu^{-}$	С	[b] <	5	× 10 ⁻⁶ CL=90%

- [a] See the "Note on the Decay Width $\Gamma(\eta \to \gamma \gamma)$ " in our 1994 edition, Phys. Rev. **D50**, 1 August 1994, Part I, p. 1451.
- [b] C parity forbids this to occur as a single-photon process.

¹⁵ TUPPER 83 is a theoretical analysis of FISCHER 78 including 2-photon exchange in the

corrections.

16 The FISCHER 78 error is statistical only. The result without radiation corrections is

CONSTRAINED FIT INFORMATION

An overall fit to a decay rate and 15 branching ratios uses 43 measurements and one constraint to determine 9 parameters. The overall fit has a $\chi^2=33.2$ for 35 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\left\langle \delta x_i \delta x_j \right\rangle / (\delta x_i \cdot \delta x_j),$ in percent, from the fit to the branching fractions, $x_i \equiv \Gamma_i / \Gamma_{\text{total}}.$ The fit constrains the x_i whose labels appear in this array to sum to one

<i>x</i> ₃	45							
<i>x</i> ₄	3	2		•				
<i>x</i> ₇	-78	-83	5					
<i>x</i> ₈	-65	-70	-4	74				
<i>x</i> 9	-9	-10	-1	-8	-7			
x_{10}	0	0	0	-1	0	0		
<i>x</i> ₁₃	-3	-4	0	-16	-12	-2	0	
Γ	9	-4	0	7	6	1	0	0
	X2	X3	XΛ	X7	XΩ	Xα	X10	X13

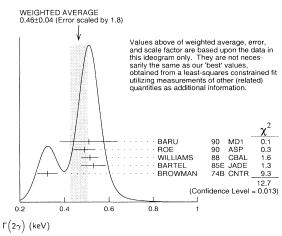
	Mode	Rate (keV)	Scale factor
Γ ₂	2γ	[a] 0.46 ±0.04	1.8
Гз	$3\pi^{0}$	0.380 ±0.035	1.8
Γ_4	$\pi^0 2\gamma$	$(8.4 \pm 1.9) \times 10^{-4}$	1.1
Γ_7	$\pi^{+}\pi^{-}\pi^{0}$	0.274 ±0.026	1.8
Γ8	$\pi^+\pi^-\gamma$	0.057 ± 0.005	1.7
Γ9	$e^+e^-\gamma$	0.0058 ± 0.0014	
Γ_{10}	$\mu^+ \mu^- \gamma$	$(3.7 \pm 0.6) \times 10^{-4}$	1.1
Γ_{13}	$\pi^+\pi^-e^+e^-$	$0.0015 + 0.0015 \\ -0.0009$	

η DECAY RATES

$\Gamma(2\gamma)$ See the "Note on D50 , 1 August 19			$\gamma\gamma$)," in our	1994 edition,	Phys.	Γ ₂ Rev.
VALUE (keV)	EVTS	DOCUMENT ID	TECN	COMMENT		
0.46 +0.04 OUR FIT	Error inclu	ides scale factor	of 1.8.			

U.40 ±U.U	OUR	LII ELLOL	includes scale facto	01 1.4	0.	
0.46 ±0.04	OUR	AVERAGE	Error includes scale	e facto	or of 1.8	. See the ideogram below.
0.51 ± 0.13	±0.05	36	BARU	90	MD1	$e^+ e^- \rightarrow e^+ e^- \eta$
0.490 ± 0.03	10±0.048	3 2287	ROE	90	ASP	$e^+e^ \rightarrow e^+e^-\eta$
0.514 ± 0.0	17±0.035	1295	WILLIAMS	88	CBAL	$e^+e^- \rightarrow e^+e^-\eta$
0.53 ± 0.04	±0.04		BARTEL	85E	JADE	$e^+e^- ightarrow e^+e^-\eta$
0.324 ± 0.04	16		BROWMAN	74B	CNTR	Primakoff effect
• • • We	do not us	e the follo	ving data for averag	es, fits	, limits,	etc. • • •
0.64 ±0.14	±0.13		AIHARA	86	TPC	$e^+e^- \rightarrow e^+e^-\eta$
0.56 ± 0.16	5	56	WEINSTEIN	83	CBAL	$e^+e^- \rightarrow e^+e^-\eta$
1.00 ±0.22	2		¹ BEMPORAD	67	CNTR	Primakoff effect

 $^{^1}$ BEMPORAD 67 gives $\Gamma(2\gamma)=1.21\pm0.26$ keV assuming $\Gamma(2\gamma)/\Gamma(\text{total})=0.314$. Bemporad private communication gives $\Gamma(2\gamma)^2/\Gamma(\text{total})=0.380\pm0.083$. We evaluate this using $\Gamma(2\gamma)/\Gamma(\text{total})=0.38\pm0.01$. Not included in average because the uncertainty resulting from the separation of the coulomb and nuclear amplitudes has apparently been underestimated.



η BRANCHING RATIOS

η 5	RANCHING R	AH	03	
$\Gamma(\text{neutral modes})/\Gamma_{\text{total}}$				$\Gamma_1/\Gamma = (\Gamma_2 + \Gamma_3 + \Gamma_4)/\Gamma$
<u>VALUE</u> <u>EVTS</u> 0.714±0.006 OUR FIT Error incl	DOCUMENT ID udes scale factor			COMMENT
0.705±0.008 16k	BASILE			MM spectrometer
• • • We do not use the following				
0.79 ±0.08	BUNIATOV	67	OSPK	
F(0) /F				- /-
$\Gamma(2\gamma)/\Gamma_{\text{total}}$				Γ ₂ /Γ
<u>VALUE</u> <u>EVTS</u> 0.3925±0.0031 OUR FIT Error in	DOCUMENT ID			COMMENT
0.3949±0.0017±0.0030 65k	ABEGG		SPEC	$pd \rightarrow ^3He\eta$
$\Gamma(2\gamma)/\Gamma(\text{neutral modes})$				$/\Gamma_1 = \Gamma_2/(\Gamma_2 + \Gamma_3 + \Gamma_4)$
VALUE EVTS 0.5497±0.0027 OUR FIT Error in	DOCUMENT ID	or of	1 1 1	COMMENT
0.549 ±0.004 OUR AVERAGE	rended dedic race		1,1,	
0.549 ±0.004	ALDE	84	GAM2	
0.535 ± 0.018	BUTTRAM	70	OSPK	
0.59 ±0.033	BUNIATOV	67		oto
• • We do not use the following				, etc. • • •
0.52 ± 0.09 88 0.60 ± 0.14 113	ABROSIMOV KENDALL	80 74	HLBC OSPK	
0.57 ±0.09	STRUGALSKI		HLBC	
0.579 ±0.052	FELDMAN	67	OSPK	
0.416 ±0.044	DIGIUGNO	66	CNTR	Error doubled
0.44 ±0.07	GRUNHAUS	66	OSPK	
0.39 ±0.06	² JONES	66		
² This result from combining cros	ss sections from t	two c	lifferent	experiments.
$\Gamma(3\pi^0)/\Gamma(\text{neutral modes})$			Гз	$/\Gamma_1 = \Gamma_3/(\Gamma_2 + \Gamma_3 + \Gamma_4)$
VALUE EVTS	DOCUMENT ID			COMMENT
	ncludes scale fact	or of	1.1.	
0.450 ±0.004 OUR AVERAGE 0.450 ±0.004	ALDE	84	GAM2	
0.439 ±0.004	BUTTRAM	70	OSPK	
• • We do not use the following				, etc. • • •
0.44 ±0.08 75	ABROSIMOV	80	HLBC	
0.32 ±0.09	STRUGALSKI	71	HLBC	
0.41 ±0.033	BUNIATOV	67	OSPK	Not indep. of $\Gamma(2\gamma)/$
	EE. B. 444		0001	Γ(neutral modes)
0.177 ±0.035 0.209 ±0.054	FELDMAN DIGIUGNO	67 66	OSPK	Error doubled
0.207 ± 0.054				Elloi doubica
0.29 ±0.10	GRUNHAUS	66	OSPK	
			OSPK	
$\Gamma(3\pi^0)/\Gamma(2\gamma)$	GRUNHAUS	66		Γ_3/Γ_2
$\Gamma(3\pi^0)/\Gamma(2\gamma)$ VALUE	GRUNHAUS	66	TECN	Γ ₃ /Γ ₂
Γ(3π ⁰)/Γ(2γ) <u>VALUE</u> 0.817±0.009 OUR FIT Error incl	GRUNHAUS	66	TECN	
$\Gamma(3\pi^0)/\Gamma(2\gamma)$ VALUE	GRUNHAUS	66 of 1	<u>TECN</u> .1.	
$\Gamma(3\pi^0)/\Gamma(2\gamma)$ $\frac{VALUE}{0.817\pm0.009}$ OUR FIT Error incl 0.841 ±0.030 OUR AVERAGE	GRUNHAUS <u>DOCUMENT ID</u> udes scale factor	of 1	<u>TECN</u> .1.	COMMENT
$\Gamma(3\pi^0)/\Gamma(2\gamma)$ VALUE 0.817 \pm 0.009 OUR FIT Error incl 0.841 \pm 0.030 OUR AVERAGE 0.841 \pm 0.034 0.91 \pm 0.14 0.75 \pm 0.09	DOCUMENT ID udes scale factor AMSLER COX DEVONS	of 1 93 708 70	TECN .1. CBAR B HBC OSPK	COMMENT
$\Gamma(3\pi^0)/\Gamma(2\gamma)$ VALUE 0.817 \pm 0.009 OUR FIT Error incl 0.841 \pm 0.030 OUR AVERAGE 0.841 \pm 0.034 0.91 \pm 0.14 0.75 \pm 0.09 0.88 \pm 0.16	DOCUMENT ID udes scale factor AMSLER COX DEVONS BALTAY	of 1 93 708 70 670	TECN .1. CBAR B HBC OSPK DBC	COMMENT
$ \begin{array}{lll} \Gamma(3\pi^0)/\Gamma(2\gamma) \\ & \xrightarrow{\mathit{VALUE}} \\ \hline \textbf{0.817} \pm 0.009 \ \textbf{OUR FIT} & \textbf{Error incl} \\ \textbf{0.841} \pm 0.030 \ \textbf{OUR AVERAGE} \\ \textbf{0.841} \pm 0.034 \\ \textbf{0.91} \ \pm 0.14 \\ \textbf{0.75} \ \pm 0.09 \\ \textbf{0.88} \ \pm 0.16 \\ \textbf{1.1} \ \ \pm 0.2 \\ \end{array} $	DOCUMENT ID udes scale factor AMSLER COX DEVONS BALTAY CENCE	of 1 93 70 67 67	TECN .1. CBAR B HBC OSPK OSPK OSPK	COMMENT $\overline{p} p \to \pi^+ \pi^- \eta$ at rest
$ \begin{array}{lll} \Gamma(3\pi^0)/\Gamma(2\gamma) \\ & & \\ \hline 0.817\pm0.009 \ \text{OUR FIT} & \text{Error incl} \\ 0.841\pm0.030 \ \text{OUR AVERAGE} \\ 0.841\pm0.034 \\ 0.91 \pm0.14 \\ 0.75 \pm0.09 \\ 0.88 \pm0.16 \\ 1.1 \pm0.2 \\ \bullet \ \bullet \ \text{We do not use the following} \\ \end{array} $	DOCUMENT ID udes scale factor AMSLER COX DEVONS BALTAY CENCE data for average	of 1 93 70 670 67 es, fit	TECN .1. CBAR HBC OSPK DBC OSPK s, limits	COMMENT $\overline{p} p \to \pi^+ \pi^- \eta$ at rest
$\begin{array}{l} \Gamma(3\pi^0)/\Gamma(2\gamma) \\ \hline \nu_{ALUE} \\ 0.817 \pm 0.009 \ \text{OUR FIT} \text{Error incl} \\ 0.841 \pm 0.030 \ \text{OUR AVERAGE} \\ 0.841 \pm 0.034 \\ 0.91 \ \pm 0.14 \\ 0.75 \ \pm 0.09 \\ 0.88 \ \pm 0.16 \\ 1.1 \ \ \pm 0.2 \\ \bullet \ \bullet \ \text{We do not use the following} \\ 0.822 \pm 0.009 \\ \end{array}$	DOCUMENT ID udes scale factor AMSLER COX DEVONS BALTAY CENCE data for average	of 1 93 70 67 67 es, fit	CBAR HBC OSPK OSPK OSPK s, limits GAM2	$\overline{p}p o \pi^+\pi^-\eta$ at rest
$\begin{array}{l} \Gamma(3\pi^0)/\Gamma(2\gamma) \\ \hline NALUE \\ 0.817\pm0.009 \ \text{OUR FIT} \\ 0.841\pm0.030 \ \text{OUR AVERAGE} \\ 0.94\pm0.14 \\ 0.75\pm0.09 \\ 0.88\pm0.16 \\ 1.1 \pm0.2 \\ \bullet \bullet \ \text{We do not use the following} \\ 0.822\pm0.009 \\ 1.25 \pm0.39 \\ \end{array}$	DOCUMENT ID udes scale factor AMSLER COX DEVONS BALTAY CENCE data for average 3 ALDE BACCI	of 1 93 70 67 67 es, fit 84 63	CBAR HBC OSPK OSPK S, limits GAM2 CNTR	$\overline{p}p ightarrow \pi^+ \pi^- \eta$ at rest etc. • • • Inverse BR reported
$\begin{array}{l} \Gamma(3\pi^0)/\Gamma(2\gamma) \\ \hline \nu_{ALUE} \\ 0.817 \pm 0.009 \ \text{OUR FIT} \text{Error incl} \\ 0.841 \pm 0.030 \ \text{OUR AVERAGE} \\ 0.841 \pm 0.034 \\ 0.91 \ \pm 0.14 \\ 0.75 \ \pm 0.09 \\ 0.88 \ \pm 0.16 \\ 1.1 \ \ \pm 0.2 \\ \bullet \ \bullet \ \text{We do not use the following} \\ 0.822 \pm 0.009 \\ \end{array}$	DOCUMENT ID udes scale factor AMSLER COX DEVONS BALTAY CENCE data for average 3 ALDE BACCI	of 1 93 70 67 67 es, fit 84 63	CBAR HBC OSPK OSPK S, limits GAM2 CNTR	$\overline{p}p ightarrow \pi^+ \pi^- \eta$ at rest etc. • • • Inverse BR reported
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$\Gamma(3\pi^0)/\Gamma(2\gamma)$ NALUE 0.817±0.009 OUR FIT Error incl 0.841±0.030 OUR AVERAGE 0.841±0.030 OUR AVERAGE 0.84±0.16 1.1 ±0.2 • • • We do not use the following 0.822±0.009 .25±0.39 3 This result is not independent of from the fit and average. $\Gamma(\pi^0 2\gamma)/\Gamma$ (neutral modes) NALUE (1.00 ±0.20) × 10 ⁻³ OUR .0010 ±0.0002 $\Gamma(\pi^0 2\gamma)/\Gamma$ total These results are summarized value (units 10 ⁻⁴) CL% EVTS 7.1±1.4 OUR FIT • • • We do not use the following 9.5±2.3 70 <30 90 0 Γ (neutral modes) / $\Gamma(\pi^+\pi^-\pi$ NALUE 2.51±0.07 OUR FIT Error includ 2.64±0.23 • • • We do not use the following 4.5±1.0 280 3.20±1.26 53	GRUNHAUS DOCUMENT ID udes scale factor AMSLER COX DEVONS BALTAY CENCE data for average 3 ALDE BACCI f other ALDE 84 DOCUMENT ID tin the review by DOCUMENT ID data for average BINON DAVYDOV DYTER TOLUMENT ID TI/(T7+T8+ DOCUMENT ID BALTAY data for average BALTAY data for average 4 JAMES 4 BASTIEN	of 1 93 70 67 67 67 67 68 84 63 resu 84 / LAI 82 81 7) 79) 1.4. 67 66 66	TECN CBAR B HBC OSPK S, limits GAM2 TECN GAM2 NDSBEF GAM2 FC GAM2 TECN GAM2 TECN GAM2 TECN GAM2 TECN GAM2 TECN GAM2 HF(e^+ = (Γ_2 TECN B DBC S, limits HBC HBC	COMMENT $\overline{p}p \to \pi^+\pi^-\eta \text{ at rest}$, etc. • • • Inverse BR reported is Listing, and so is omitted $\Gamma_1 = \Gamma_4/(\Gamma_2 + \Gamma_3 + \Gamma_4)$ Γ_4/Γ RG 85. $COMMENT$, etc. • • See ALDE 84 $\pi^-p \to \eta n$ $e^-\gamma$ $ +\Gamma_3 + \Gamma_4 /(\Gamma_7 + \Gamma_8 + \Gamma_9)$
$\Gamma(3\pi^0)/\Gamma(2\gamma)$ NALUE 0.817±0.009 OUR FIT Error incl 0.841±0.030 OUR AVERAGE 0.841±0.034 0.91±0.14 0.75±0.09 0.88±0.16 1.1±0.2 ••• We do not use the following 0.822±0.009 1.25±0.39 3 This result is not independent of from the fit and average. $\Gamma(\pi^0 2\gamma)/\Gamma$ (neutral modes) NALUE 1.00±0.002 $\Gamma(\pi^0 2\gamma)/\Gamma$ total These results are summarized VALUE (units 10-4) CL% EVTS 7.1±1.4 OUR FIT •• We do not use the following 9.5±2.3 70 <30 90 0 Γ (neutral modes)/ Γ ($\pi^+\pi^-\pi$ NALUE 2.5±±0.07 OUR FIT Error include 2.64±0.23 •• We do not use the following 4.5±1.0 280	GRUNHAUS DOCUMENT ID udes scale factor AMSLER COX DEVONS BALTAY CENCE data for average 3 ALDE BACCI f other ALDE 84 DOCUMENT ID the review by DOCUMENT ID data for average BINON DAVYDOV 10 + \(\(\pi + \pi - \pi - \pi) \) \(\pi \) \(\pi \) \(\pi - \pi - \pi) \) \(\pi \) \(\pi - \pi - \pi) \) \(\pi \) \(\pi - \pi - \pi) \) \(\pi \) \(\pi - \pi - \pi) \) \(\pi \) \(\pi - \pi - \pi) \) \(\pi \) \(\pi - \pi - \pi) \) \(\pi \) \(\pi - \pi - \pi) \) \(\pi \) \(\pi - \pi - \pi) \) \(\pi \) \(\pi - \pi - \pi) \) \(\pi \) \(\pi - \pi - \pi) \) \(\pi \) \(\pi - \pi - \pi) \) \(\pi \) \(\pi - \pi - \pi) \) \(\pi \) \(\pi - \pi - \pi) \) \(\pi \) \(\pi - \pi - \pi) \) \(\pi \) \(\pi - \pi - \pi) \) \(\pi \) \(\pi - \pi - \pi) \) \(\pi \) \(\pi - \pi - \pi) \) \(\pi \) \(\pi - \pi - \pi) \) \(\pi \) \(\pi - \pi - \pi) \) \(\pi \) \(\pi - \pi) \) \(\pi \) \(\pi - \pi) \) \(\pi \) \(\pi - \pi) \) \(\pi \) \(\pi - \pi) \) \(\pi \) \(\pi \) \(\pi - \pi) \) \(\pi	of 1 93 70 67 70 67 67 67 68 84 63 70 84 63 70 84 66 87 87 67 67 67 66 62 62 62	TECN CBAR B HBC OSPK B HBC OSPK CMTR GAM2 TECN GAM2 HBC GAM2 HBC HBC HBC	COMMENT $\overline{p}p \to \pi^+\pi^-\eta \text{ at rest}$, etc. • • • Inverse BR reported is Listing, and so is omitted $\Gamma_1 = \Gamma_4/(\Gamma_2 + \Gamma_3 + \Gamma_4)$ Γ_4/Γ RG 85. $COMMENT$, etc. • • • See ALDE 84 $\pi^-p \to \eta n$ $e^-\gamma$ $ +\Gamma_3 + \Gamma_4\rangle/(\Gamma_7 + \Gamma_8 + \Gamma_9)$, etc. • •

⁴ These experiments are not used in the averages as they do not separate clearly $\eta \to \pi^+\pi^-\pi^0$ and $\eta \to \pi^+\pi^-\gamma$ from each other. The reported values thus probably contain some unknown fraction of $\eta \to \pi^+\pi^-\gamma$.

		$+\pi^-\gamma$) + $\Gamma(e^+$			$\Gamma_2/(\Gamma_7$	+[8+[9]		μ ⁺ μ ⁻)/Γ(w.c		Γ _{12/}
ALUE .38±0.04 OUR FIT	<u>EVTS</u> Error incl	DOCUMENT ID		ECN				.UE (units 10 ⁻⁵			DOCUMENT .		TECN		
1 ±0.4 OUR AVE									ot use the	rollowing	data for avera	-		etc. • • •	
51 ± 0.93	75	KENDALL	74 O	SPK			5.9	±2.2			HYAMS	69	OSPK		
99±0.48		CRAWFORD	63 H	HBC			Γ($\pi^+\pi^-e^+e^-$							Γ ₁₃ ,
(neutral modes)/	$\Gamma(\pi^+\pi^-)$	•			$\Gamma_7 = (\Gamma_2 + \Gamma_3)$	3+F4)/F7	, <u>VAI</u>	.UE		<u>VTS</u>	DOCUMENT I	D	TECN		
10E 08±0.09 OUR FIT	EVTS Error incl	DOCUMENT ID udes scale factor o		ECN				27 ^{+0.026} 0	UR FIT						
6±0.30 OUR AVE							0.0	26±0.026		1	GROSSMAN	N 66	нвс		
54 ± 1.89	74	KENDALL	74 O				г(-	$\pi^{+}\pi^{-}e^{+}e$	-)/[tota						Γ ₁₃
1 ±1.1	29	AGUILAR 5 BLOODWO					,	UE (units 10 ⁻²	,		DOCUMENT I	D	TECN		. 1.
33±0.80 5 ±0.6	70 244	FLATTE	. 72в н 67в Н								<u> </u>		12011		
39±0.56	277	ALFF	66 H					0.13 ^{+0.12} _{-0.08} O	UR FIT						
5 ±0.8	50	KRAEMER	64 D				• •	• We do no	ot use the 1	ollowing	data for avera	ges, fits	, limits,	etc. • • •	
±1.1		PAULI	64 D				<0).7			RITTENBE	RG 65	нвс		
Error increased fro	m publishe	d value 0.5 by Blo	odworth	ı (privat	e communica	tion).	Γ(-	$\pi^+\pi^-2\gamma)$	$\Gamma(\pi^{+}\pi^{-}$	π^0)					Γ ₁₄
$(2\gamma)/\Gamma(\pi^+\pi^-\pi^0)$)					Γ_2/Γ_7	,		, , (,, ,,	,	DOCUMENT I	D	TECN		. 14
LUE	EVTS	DOCUMENT ID	T	ECN (COMMENT	- 2/ - /		.009			PRICE		НВС		
9±0.05 OUR FIT	Error incli						• •	• We do no	ot use the 1	ollowing	data for avera	ges, fits	, limits,	etc. • • •	
5±0.13 OUR AVE	RAGE							0.016	ģ	5	BALTAY	67B	DBC		
$8 \pm 0.10 \pm 0.13$	1077	AMSLER			$\bar{p} \rho \rightarrow \pi^+ \pi^-$	η at rest	· -,	_ n	\ /= / ±	- 0\					_
2±0.25	401	BAGLIN		ILBC			Г(:	$\pi^+\pi^-\pi^0\gamma$)/Γ(π ⁺ π	$-\pi^{0}$					Γ ₁₅ ,
1 ± 0.39		FOSTER	65 H	IRC				UE (units 10 ⁻²		<u>VTS</u>	DOCUMENT I		TECN		
$(3\pi^{0})/\Gamma(\pi^{+}\pi^{-}\pi^{-}\pi^{-}\pi^{-}\pi^{-}\pi^{-}\pi^{-}\pi^{-$	-0)					Γ_3/Γ_7).24	90	0	THALER		ASPK		
UE ,	EVTS	DOCUMENT ID	T	ECN C	COMMENT	3, ,	• •			ollowing	data for avera			etc. • • •	
9±0.04 OUR FIT							<1		90		ARNOLD		HLBC		
4±0.10 OUR AVE							<1 <7		95		BALTAY FLATTE		DBC HBC		
4±0.09±0.10	1627	AMSLER			$\bar{p} p \rightarrow \pi^+ \pi^-$	η at rest	<0				PRICE		HBC		
0+0.15 -0.29	199	BAGLIN	69 H	ILBC											
7 ^{+0.20} -0.17		BULLOCK	68 H	ILBC			Γ(:	$\pi^0 \mu^+ \mu^- \gamma$)/F _{total}						Γ ₁
±0.4		BAGLIN	67B H				VAL	UE (units 10 ⁻⁶)(L%	DOCUMENT I	D	TECN	COMMENT	
±0.4 0±0.24		FOSTER	65 H				<3	1	ç	0	DZHELYAD	IN 81	SPEC	$\pi^- \rho \rightarrow \tau$	n n
±1.0		FOELSCHE	64 H				-/	$\pi^+\pi^-)/\Gamma_{to}$							Γ ₁
±0.32		CRAWFORD	63 H	IBC			`	Forbidden	by P and	<i>CP</i> invar					-
other neutral mou															
other neutral mo	$des)/\Gamma_{tot}$	ai				Г ₅ /Г		UE (units 10 ⁻²) <u>E</u>	VTS	DOCUMENT I		TECN		
			0 and π^{0}	0 γγ: ne	early any such			<i>UE</i> (units 10 ⁻²)E	<i>VTS</i> 0	THALER		<u>TECN</u> ASPK		
	al modes o	ther than $\gamma\gamma$, $3\pi^0$, and π^0	⁰ γγ; ne	early any such		<0	.15		0			ASPK		/F . F
These are neutra can think of wou UE	al modes of uld violate of CL%	ther than $\gamma\gamma$, $3\pi^0$ P, or C, or both. DOCUMENT ID	<i>Tl</i>	ECN C	COMMENT		<0	0.15 $(3\gamma)/\Gamma$ (neut	tral mode	o s)			ASPK	$\Gamma_1 = \Gamma_{18}/($	(Γ ₂ +Γ ₃ +
These are neutra can think of wou	al modes o uld violate	ther than $\gamma \gamma$, $3\pi^{0}$ P, or C, or both.	<i>Tl</i>	ECN C			<0 Г(:	0.15 $(3\gamma)/\Gamma$ (neut	t ral mode by <i>C</i> invar	0 s) iance.	THALER	73	АSPK Г₁₈/Г	Γ ₁ = Γ ₁₈ /((Γ ₂ +Γ ₃ +
These are neutra can think of wou UE 0.028	al modes of uld violate CL% 90	ther than $\gamma\gamma$, $3\pi^0$ P, or C, or both. DOCUMENT ID	<i>Tl</i>	ECN C	COMMENT	mode one	<0 Γ(: 	1. 15 3γ)/Γ(neut Forbidden <i>UE</i> (units 10 ^{−4}	tral mode by C invar	o s)		73	ASPK	$\Gamma_1 = \Gamma_{18}/($	(Γ ₂ +Γ ₃ +
These are neutra can think of wou UE	al modes of uld violate $\frac{CL\%}{90}$	ther than γγ, 3π ^C P, or C, or both. <u>DOCUMENT ID</u> ABEGG	96 SI	ECN C	COMMENT		- (α Γ(: - <u>val</u>	(0.15) (0.15) (0.15) (0.15) (0.15) (0.15) (0.15) (0.15) (0.15) (0.15)	tral mode by C invar)	0 iance. <u>CL%</u> 5	THALER	73	ASPK	Γ ₁ = Γ ₁₈ /(
These are neutrican think of work UE 1.028 $\pi^+\pi^-\gamma$ $T^+\pi^-\gamma$	al modes of uld violate of $\frac{CL\%}{90}$ $\pi^{-}\pi^{0})$ EVTS	ther than $\gamma\gamma$, $3\pi^{C}$ P, or C, or both. DOCUMENT ID ABEGG	96 SI	ECN C	COMMENT	mode one	- (α Γ(: - <u>val</u>	$(3\gamma)/\Gamma$ (neut Forbidden <u>VE (units 10⁻⁴</u>) (7)	tral mode: by C invar $ \frac{C}{2} $ $ \Gamma(\pi^+\pi^-) $	ο iance. : <u>1.%</u> :5	THALER DOCUMENT II ALDE	73	ASPK F ₁₈ /F TECN GAM2	Γ ₁ = Γ ₁₈ /(
These are neutrican think of word UE .028 $\pi^{+}\pi^{-}\gamma)/\Gamma(\pi^{+}\eta)$ UE .07 ±0.004 OUR FIT	al modes of uld violate of $\frac{CL\%}{90}$ $\pi^{-}\pi^{0})$ $\frac{EVTS}{\Gamma}$ Error in	ther than $\gamma\gamma$, $3\pi^{C}$ P, or C, or both. DOCUMENT ID ABEGG	96 SI	ECN C	COMMENT	mode one	- (1 Γ(1 - (2) - (1) - (1)	0.15 βγ)/Γ(neut Forbidden <u>UE (units 10⁻⁴</u> π ⁰ e+ e ⁻)/ C parity fo	tral mode: by C invariance $\frac{C}{c}$ $\Gamma(\pi^{+}\pi^{-})$ orbids this	0 iance. :1.% -5 -5 to occur	THALER DOCUMENT II ALDE as a single-pho	73 84	ASPK F ₁₈ /F TECN GAM2 ocess.	$\Gamma_1 = \Gamma_{18}/($	
These are neutrican think of work think of work the control of th	al modes or uld violate of the polynomial of the	ther than $\gamma\gamma$, $3\pi^C$ P, or C, or both. <u>DOCUMENT ID</u> ABEGG <u>DOCUMENT ID</u> cludes scale factor Error includes scale THALER	96 SI 96 SI 77 r of 1.1. e factor c 73 A	PECN G PEC F ECN of 1.1. SPK	COMMENT	mode one	<0 F(: VAL <7 F(: VAL	3γ)/ Γ (neuton Forbidden Forbidden VE (units 10^{-4}) VE (units 10^{-4})	tral mode: by C invariable $C(\pi^+\pi^-)$ orbids this $C(\pi^+\pi^-)$	0 iance. :1.% -5 -5 to occur	DOCUMENT IL ALDE as a single-pho	73 84 oton pro	ASPK F ₁₈ /F FECN GAM2 Cess. TECN	$\Gamma_1 = \Gamma_{18}/($	
These are neutrican think of word UE 1.028 $\pi^+\pi^-\gamma$)/ $\Gamma(\pi^+\tau)$ 1.020 1.004 OUR FITO THE OLD OUR AV 1.004 OUR AV 1.004 OUR AV 1.006	al modes or uld violate of the color of the	ther than $\gamma\gamma$, $3\pi^C$ P, or C, or both. <u>DOCUMENT ID</u> ABEGG <u>DOCUMENT ID</u> cludes scale factor Error includes scale THALER GORMLEY	76 SI 96 SI r of 1.1. e factor of 73 A3 70 A3	PECN GECN of 1.1. SPK SPK	comment $comment$ $comm$	mode one	Γ(: 	5.15 3γ)/ Γ (neut Forbidden UE (units 10 ⁻⁴) Γ	tral mode: by C invar.) C	os) iance. 51.8 5 π^0) to occur	THALER DOCUMENT II ALDE as a single-pho DOCUMENT II JANE	73 84 oton pro	TECN GAM2 Cess. TECN OSPK		
These are neutrican think of word UE 1.028 $\pi^{+}\pi^{-}\gamma)/\Gamma(\pi^{+}\tau_{UE})$ 107±0.004 OUR FITO 7±0.004 OUR AV 109±0.004 01±0.006 • We do not use	al modes or uld violate of the color of the	ther than $\gamma\gamma$, $3\pi^C$ P, or C, or both. <u>DOCUMENT ID</u> ABEGG <u>DOCUMENT ID</u> cludes scale factor Error includes scale THALER GORMLEY	76 SI 96 SI 77 of 1.1. e factor of 73 A: 70 A: es, fits, li	ECN G PEC F ECN of 1.1. SPK SPK SPK imits, e	comment $comment$ $comm$	mode one	(3	Forbidden E (units 10 ⁻⁴ C parity for C (units 10 ⁻⁴ C parity for C (units 10 ⁻⁴ C we do not C We do not	tral mode: by C invar $C = \frac{C}{9}$ $C = \frac{C}{9}$ $C = \frac{C}{9}$ orbids this $C = \frac{C}{9}$ or use the f	os) iance. 51.8 5 π^0) to occur	DOCUMENT II ALDE as a single-phi DOCUMENT II JANE data for avera	73 84 oton pro 75 ges, fits	TECN GAM2 OCCESS. TECN OSPK , limits,		
These are neutrican think of word UE 1.028 $\pi^+\pi^-\gamma$)/ $\Gamma(\pi^+\pi^+\pi^-\gamma)$ / $\pi^+\pi^-\gamma$ 1.07±0.004 OUR FIT 1.07±0.004 OUR AV 1.09±0.004 1.006 • We do not use to the second sec	al modes or uld violate of the color of the	ther than $\gamma\gamma$, $3\pi^C$ P, or C, or both. <u>DOCUMENT ID</u> ABEGG <u>DOCUMENT ID</u> cludes scale factor Error includes scale THALER GORMLEY ag data for average BALTAY	96 SI 96 SI r of 1.1. e factor of 73 AS 70 AS es, fits, li	ECN CPECN SPK SPK imits, einer	comment $comment$ $comm$	mode one	Γ(: 	1.15 3γ)/Γ(neut Forbidden Forbidden UE (units 10 ⁻⁴ C parity fo UE (units 10 ⁻⁴ 1.9 • We do no	tral mode: by C invar $C(\pi^+\pi^-)$ orbids this $CL\% = \frac{E}{90}$ ot use the f	o) iance. $\frac{7.2\%}{5}$ π^{0} to occur $\frac{\sqrt{TS}}{\sqrt{TS}}$ ollowing	DOCUMENT II ALDE as a single-phi DOCUMENT II JANE data for avera BAGLIN	73 84 oton pro 75 ges, fits 67	TECN GAM2 OCCESS. TECN OSPK , limits, HLBC		
These are neutral can think of word with the control of the contr	al modes or uld violate of the color of the	ther than $\gamma\gamma$, $3\pi^C$, ρ , or C , or both. DOCUMENT ID. ABEGG DOCUMENT ID. Cludes scale factor THALER GORMLEY gd data for average. BALTAY LITCHFIELD	96 Si 96 Si r of 1.1. e factor c 73 A: 70 A: es, fits, li 67B D 67 D	ECN GPECN FECN of 1.1. SPK SPK SPK imits, et BC BC	comment $comment$ $comm$	mode one	(3	.15 3\gamma/\frac{\fir}\frac{\frac{\frac{\frac{\frac{\frac{\frac{\frac{\frac{\	tral mode: by C invar $C = \frac{C}{9}$ $C = \frac{C}{9}$ $C = \frac{C}{9}$ orbids this $C = \frac{C}{9}$ or use the f	os) iance. 51.8 5 π^0) to occur	DOCUMENT II ALDE as a single-phi DOCUMENT II JANE data for avera	73 84 oton pro 75 ges, fits 67 67	TECN GAM2 GESS. TECN OSPK, limits, HLBC HLBC		
These are neutrican think of word word with the second section $(T_{\rm c}) = T_{\rm c} =$	al modes or uld violate of the color of the	ther than $\gamma\gamma$, $3\pi^C$, or C, or both. <u>DOCUMENT ID.</u> ABEGG <u>DOCUMENT ID.</u> cludes scale factor <u>Error</u> includes scale THALER GORMLEY g data for average BALTAY LITCHFIELD CRAWFORD	76 Si 79 Si	ECN OF 1.1. SPK SPK imits, et BC BC BC	comment $comment$ $comm$	mode one	Γ(:	$\frac{3\gamma}{F} \left(\frac{15}{\text{C units } 10^{-4}} \right)$ Forbidden WE (units 10^{-4}) C parity for UE (units 10^{-4}) 1.9 • We do not 42 16 77	tral mode: by C invar $C(\pi^+\pi^-)$ orbids this $CL\% = \frac{E}{90}$ ot use the f	o) iance. $\frac{12.\%}{5}$ π^{0} to occur $\frac{VTS}{5}$ ollowing	DOCUMENT II ALDE as a single-phi DOCUMENT II JANE data for avera BAGLIN BILLING	73 84 oton pro 75 ges, fits 67 67 658	TECN GAM2 OCCESS. TECN OSPK , limits, HLBC		
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$\pi^+\pi^-\pi^0$ SEXTANT ASYMMETRY PARAMETER

Measurements with an error > 2	2.0×10^{-2} have been omitted
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VALUE (units 10-2)	EVTS	DOCUMENT ID		TECN
0.18±0.16 OUR AV	ERAGE			
0.20 ± 0.25	165k	JANE	74	OSPK
0.10 ± 0.22	220k	LAYTER	72	ASPK
0.5 ± 0.5	37k	GORMLEY	68C	WIRE

$\pi^+\pi^-\pi^0$ QUADRANT ASYMMETRY PARAMETER

VALUE (units 10-2)	EVTS	DOCUMENT I	D	TECN
-0.17±0.17 OUR	AVERAGE			
-0.30 ± 0.25	165k	JANE	74	OSPK
-0.07 ± 0.22	220k	LAYTER	72	ASPK

$\pi^+\pi^-\gamma$ LEFT-RIGHT ASYMMETRY PARAMETER

Measurements with an error $> 2.0 \times 10^{-2}$ have been omitted.

VALUE (units 10^{-2}) EVTS DOCUMENT ID TECN

0.9 ±0.4 OUR AVERAGE

10.10 10.00 10.

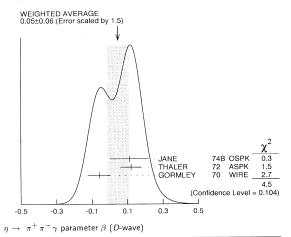
0.9 ±0.4	OUR AVERAGE			
1.2 ± 0.6	35k	JANE	74B	OSPK
0.5 ± 0.6	36k	THALER	72	ASPK
1.22 ± 1.56	7257	GÖRMLEY	70	ASPK

$\pi^+\pi^-\gamma$ PARAMETER β (*D*-wave)

Sensitive to a *D*-wave contribution: $dN/d\cos\theta = \sin^2\theta \ (1+\beta \ \cos^2\theta)$

VALUE	<u>EVTS</u>	DOCUMENT IL	<u>TECN_</u>
0.05 ±0.06	OUR AVERAGE	Error includes s	cale factor of 1.5. See the ideogram
		below.	
0.11 ± 0.11	35k	JANE	74B OSPK
0.12 ± 0.06		⁷ THALER	72 ASPK
-0.060 ± 0.065	7250	GORMLEY	70 WIRE

 $^{^7}$ The authors don't believe this indicates D-wave because the dependence of β on the γ energy is inconsistent with theoretical prediction. A $\cos^2\theta$ dependence may also come from P- and F-wave interference.



ENERGY DEPENDENCE OF $\eta \to ~\pi^+\pi^-\pi^0$ DALITZ PLOT

See the "Note on η Decay Parameters" in our 1994 edition, Phys. Rev. **D50**, 1 August 1994, Part I, p. 1454. The following experiments fit to one or more of the coefficients a, b, c, d, or e for $|\text{matrix element}|^2 = 1 + ay + by^2 + cx + dx^2 + exy$.

a, b, c, d, or e for matrix el	$ ement ^2 = 1 + ay$	y + t	$by^2 + cx + dx^2 + exy$.
VALUE EVTS	DOCUMENT ID		TECN COMMENT
• • • We do not use the following			
1077	⁸ AMSLER	95	CBAR $\overline{p}p \rightarrow \pi^+\pi^-\eta$ at rest
81k	LAYTER	73	ASPK
220k	LAYTER	72	ASPK
1138	CARPENTER	70	HBC
349	DANBURG	70	DBC
7250	GORMLEY	70	WIRE
526	BAGLIN	69	HLBC
7170	CNOPS	68	OSPK
37k	GORMLEY	68C	WIRE
1300	CLPWY	66	HBC
705	LARRIBE	66	HBC

⁸ AMSLER 95 fits to $(1+ay+by^2)$ and obtains a=- 0.94 \pm 0.15 and b=0.11 \pm 0.27.

lpha PARAMETER FOR $\eta \to ~3\pi^0$

NAMINETER FON $\eta \to 3\pi$ See the "Note on η Decay Parameters" in our 1994 edition, Phys. Rev. **D50**, 1 August 1994, Part I, p. 1454. The value here is of α in $|\text{matrix element}|^2 = 1 + 2\alpha z$.

VALUE	EVTS	DOCUMENT I	D	TECN
-0.022 ± 0.023	50k	ALDE	84	GAM2
• • • We do not use	the followin	g data for avera	ges, fits	s, limits, etc. • • •
-0.32 ± 0.37	192	BAGLIN	70	HLBC

η REFERENCES

			•
ABEGG	96	PR D53 11	+Abela, Boudard+ (Saclay SPES2 Collab.)
AMSLER ABEGG	95 94	PL B346 203 PR D50 92	+Armstrong, Heinsius+ (Crystal Barrel Collab.) +Baldisseri, Boudard+ (SPES-II Collab.)
AMSLER	93	ZPHY C58 175	+Armstrong, Merkei+ (Crystal Barrel Collab.)
KESSLER	93	PRL 70 892	+Abegg, Baldisseri+ (SPES-II Collab.)
PLOUIN BARU	92 90	PL B276 526 ZPHY C48 581	+ (SACL, EPOL, IPN, SACL, GWU, UCLA, BGUN, LOUC) +Blinov, Blinov+ (MD-1 Collab.)
ROE	90	PR D41 17	+Bartha, Burke, Garbincius+ (ASP Collab.)
PDG	88	PL B204	Yost, Barnett+ (LBL+)
WILLIAMS AIHARA	88 86	PR D38 1365 PR D33 844	+Antreasyan, Bartels, Besset+ (Crystal Ball Collab.) +Alston-Garnjost+ (TPC-2γ Collab.)
BARTEL	85E	PL 160B 421	+Becker, Cords, Felst+ (JADE Collab.)
LANDSBERG	85	PRPL 128 310	(SERP)
ALDE Also	84 84B	ZPHY C25 225 SJNP 40 918	+Binon, Bricman, Donskov+ (SERP, BELG, LAPP) Alde, Binon, Bricman+ (SERP, BELG, LAPP)
MISO	040	Translated from YA	F 40 1447.
WEINSTEIN	83	PR D28 2896	+Antreasyan, Gu, Kollman+ (Crystal Ball Collab.)
BINON	82	SJNP 36 391 Translated from YA	+Bricman, Gouanere+ (SERP, BELG, LAPP, CERN) F 36 670.
Also	82B	NC 71A 497 LNC 32 45	Binon, Bricman+ (SERP, BELG, LAPP, CERN)
DAVYDOV	81 81B	LNC 32 45 SJNP 33 825	+Donskov, Inyakin+ (SERP, BELG, LAPP, CERN) Davydov, Binon+ (SERP, BELG, LAPP, CERN)
Also	010	Translated from Y/	F 33 1534.
DZHELYADIN	81	PL 105B 239 SJNP 33 822	+Golovkin, Konstantinov, Kubarovski+ (SERP)
Also	81C	Translated Cons. V	E 22 1520
ABROSIMOV	80	SJNP 31 195	+ llina, Niszcz, Okhrimenko+ (JINR) F 31 371.
DZHELYADIN	80	PL 94B 548	+ 31 3/1. +Viktorov, Golovkin+ (SERP)
Also	80C	SJNP 32 516	Dzhelyadin, Golovkin, Kachanov+ (SERP)
DZHELYADIN	80B	Translated from Yo PL 97B 471	F 32 998. +Viktorov, Golovkin+ (SERP)
Also	80D	SJNP 32 518	Dzhelyadin, Golovkin, Kachanov+ (SERP)
		Translated from Y.	F 32 1002.
BUSHNIN Also	78 78B	PL 79B 147 SJNP 28 775	+Dzhelyadin, Golovkin, Gritsuk+ (SERP) Bushnin, Golovkin, Gritsuk, Dzhelyadin+ (SERP)
		Translated from Y.	F 28 1507.
MARTYNOV	76	SJNP 23 48 Translated from Y	+Saltykov, Tarasov, Uzhinskii (JINR)
JANE	75	PL 59B 99	+Grannis, Jones, Lipman, Owen+ (RHEL, LOWC)
JANE	75B	PL 59B 103	+Grannis, Jones, Lipman, Owen+ (RHEL, LOWC)
Also Erratum in	78B	PL 73B 503 te communication.	Jane
BROWMAN	74B	PRL 32 1067	+Dewire, Gittelman, Hanson, Loh+ (CORN, BING)
DAVIES	74	NC 24A 324 PRL 32 425	+Guy, Zia (BIRM, RHEL, SHMP)
DUANE JANE	74 74	PRL 32 425 PL 48B 260	+Binnie, Camilleri, Carr+ (LOIC, SHMP) +Jones, Lipman, Owen+ (RHEL, LOWC, SUSS)
JANE	74B	PL 48B 265	+ Iones, Lipman, Owen+ (RHEL, LOWC, SUSS)
KENDALL	74	PL 48B 265 NC 21A 387	+Lanou, Massimo, Shapiro+ (BROW, BARI, MIT)
LAYTER THALER	73 73	PR D7 2565 PR D7 2569	+Appel, Kotlewski, Lee, Stein, Thaler (COLU) +Appel, Kotlewski, Layter, Lee, Stein (COLU)
AGUILAR	72B	PR D6 29	Aguilar-Benitez, Chung, Eisner, Samios (BNL)
BLOODWO	72B	NP B39 525	Bloodworth, Jackson, Prentice, Yoon (INIO)
LAYTER	72	PRL 29 316 PRL 29 313	+Appel, Kotlewski, Lee, Stein, Thaler (COLU) +Appel, Kotlewski, Layter, Lee, Stein (COLU)
THALER BASILE	72 71D	NC 3A 796	+Bollini, Dalpiaz, Frabetti+ (CERN, BGNA, STRB)
STRUGALSKI	71	NP B27 429	+Chuvilo, Gemesy, Ivanovskaya+ (JINR)
BAGLIN	70 70	NP B22 66 PRL 25 1358	+Bezaguet, Degrange+ (EPOL, MADR, STRB) +Kreisler, Mischke (PRIN)
BUTTRAM CARPENTER	70	PR D1 1303	+Binkley, Chapman, Cox, Dagan+ (DUKE)
COX	70B	PRL 24 534	+Fortney, Golson (DUKE)
DANBURG	70 70	PR D2 2564 PR D1 1936	+Abolins, Dahl, Davies, Hoch, Kirz+ (LRL) +Grunhaus, Kozlowski, Nemethy+ (COLU, SYRA)
DEVONS GORMLEY	70	PR D2 501	±Hyman Lee Nash Peoples → (COLU BNI)
Also	70B	Thesis Nevis 181	Gormley (COLU)
BAGLIN	69	PL 29B 445 NP B22 66	+Bezaguet+ (EPOL, UCB, MADR, STRB) Baglin, Bezaguet, Degrange+ (EPOL, MADR, STRB) +Koch, Potter, VonLindern+ (CERN, MPIM)
Also HYAMS	70 69	PL 29B 128	+Koch, Potter, VonLindern+ (CERN, MPIM)
ARNOLD	68	PL 27B 466	+Paty, Baglin, Bingham+ (STRB, MADR, EPOL, UCB)
BAZIN	68	PRL 20 895	+Goshaw, Zacher+ (PRIN, QURI)
BULLOCK CNOPS	68 68	PL 27B 402 PRL 21 1609	+Esten, Fleming, Govan, Henderson+ (LOUC) +Hough, Cohn+ (BNL, ORNL, UCND, TENN, PENN)
GORMLEY	68C	PRL 21 402	+Hyman, Lee, Nash, Peoples+ (COLU, BNL)
WEHMANN	68	PRL 20 748	+Engels+ (HARV, CASE, SLAC, CORN, MCGI) +Bezaguet, Degrange+ (EPOL, UCB)
BAGLIN BAGLIN	67 67B	PL 24B 637 BAPS 12 567	Rezaguet Degrange (EPOL LICE)
BALTAY	67B	PRL 19 1498	+Franzini, Kim, Newman+ (COLU, STON)
BALTAY BEMPORAD	67D 67	PRL 19 1495 PL 25B 380	+Franzini, Kim, Newman+ (COLU, BRAN) +Braccini, Foa, Lubelsmey+ (PISA, BONN)
Also	67	Private Comm.	lon
BILLING	67	PL 25B 435	+Bullock, Esten, Govan+ (LOUC, OXF)
BUNIATOV CENCE	67 67	PL 25B 560 PRL 19 1393	+Zavattini, Deinet+ (ČERN, KARL) +Peterson, Stenger, Chiu+ (HAWA, LRL)
ESTEN	67	PL 24B 115	+Govan, Knight, Miller, Tovey+ (LOUC, OXF)
FELDMAN	67	PRL 18 868	+Frati, Gleeson, Halpern+ (PENN)
FLATTE	67 67B	PRL 18 976 PR 163 1441	+Wohl (LRL)
LITCHFIELD	67	PL 24B 486	+Rangan, Segar, Smith+ (RHEL, SACL)
PRICE	67	PRL 18 1207	+Crawford (LRL)
ALFF CLPWY	66 66	PR 145 1072 PR 149 1044	Alff-Steinberger, Berley+ (COLU, RUTG) (SCUC, LRL, PURD, WISC, YALE)
CRAWFORD	66	PRL 16 333	+Price (LRL)
DIGIUGNO	66	PRL 16 767	+Giorgi, Silvestri+ (NAPL, TRST, FRAS) +Price, Crawford (LRL)
GROSSMAN GRUNHAUS	66 66	PR 146 993 Thesis	+Price, Crawford (LRL) (COLU)
JAMES	66	PR 142 896	+Kraybill (YALE, BNL)
JONES	66	PL 23 597 PL 23 600	+Binnie, Duane, Horsey, Mason+ (LOIC, RHEL)
LARRIBE FOSTER	66 65	PL 23 600 PR 138B 652	+Leveque, Muller, Pauli+ (SACL, RHEL) +Peters, Meer, Loeffler+ (WISC, PURD)
FOSTER	65B	Athens Conf.	+Good, Meer (WISC)
FOSTER	65C	Thesis	(WISC)
PRICE	65	PRL 15 123	+Crawford (LRL) +Kalbfleisch (LRL, BNL)
RITTENBERG FOELSCHE	64	PRL 15 556 PR 134B 1138	+Kraybill (YALE)
KRAEMER	64	PR 136B 496	(IHII NWES WOOD)
PAULI BACCI	64 63	PL 13 351 PRL 11 37	+Muller (SACL) +Penso, Salvini+ (ROMA, FRAS)
CRAWFORD	63	PRL 10 546	+Lioya, Fowler (LRL, DOKE)
Also	66B	PRL 16 907	Crawford, Lloyd, Fowler (LRL, DUKE)
DELCOURT ALFF	63 62	PL 7 215 PRL 9 322	+Lefrancois, Perez-y-Jorba+ (ORSAY) Alff-Steinberger, Berley, Colley+ (COLU, RUTG)
BASTIEN	62	PRL 8 114	+Berge, Dahl, Ferro-Luzzi+ (LRL)
PICKUP	62	PRL 8 329	+Robinson, Salant (CNRC, BNL)

 $f_0(400-1200)$

$$I^{G}(J^{PC}) = 0^{+}(0^{+})$$

See "Note on scalar mesons" under $f_0(1370)$.

f_0 (400–1200) T-MATRIX POLE \sqrt{s}

Note that $\Gamma\approx 2~\text{Im}(\sqrt{s_{\mbox{pole}}}).$

(400 1000) //200 FOOL OF	DOCUMENT ID TECN COMMENT
(400—1200)—1(300—500) OI	UR ESTIMATE
• • We do not use the fo	following data for averages, fits, limits, etc. • • •
470 - i250	^{1,2} TORNQVIST 96 RVUE $\pi\pi \to \pi\pi$, $K\overline{K}$, $K\pi$,
	$\eta\pi$
$\sim (1100 - i300)$	AMSLER 95B CBAR $\overline{p}p \rightarrow 3\pi^0$
100 - i500	2,3 AMSLER 95D CBAR $\overline{p}p \rightarrow 3\pi^0$
1100 - i137	2,4 AMSLER 95D CBAR $\overline{p}p \rightarrow 3\pi^0$
387 - i305	^{2,5} JANSSEN 95 RVUE $\pi\pi \to \pi\pi$, $K\overline{K}$
525 - i269	6 ACHASOV 94 RVUE $\pi\pi \to \pi\pi$
370 - i356	7 ZOU 94B RVUE $\pi\pi \to \pi\pi$, $K\overline{K}$
108 - i342	2,7 ZOU 93 RVUE $\pi\pi \to \pi\pi$, $K\overline{K}$
370 £370	2,8 AU 87 RVUE $\pi\pi \to \pi\pi$, $K\overline{K}$
$750 \pm 50 - i(450 \pm 50)$	9 ESTABROOKS 79 RVUE $\pi\pi ightarrow \pi\pi$, K \overline{K}
$560 \pm 100 - i(320 \pm 70)$	PROTOPOP 73 HBC $\pi\pi o \pi\pi$, $K\overline{K}$
550 - i370	10 BASDEVANT 72 RVUE $\pi\pi o\pi\pi$
SON 83, ASTON 88, symmetry and all light to 2 Demonstrates explicitly 3 Coupled channel analysis 4 Coupled channel analysis 5 Analysis of data from F.	728, OCHS 73, HYAMS 73, GRAYER 74, ROSSELET 77, CA-and ARMSTRONG 918. Coupled channel analysis with flavor two-pseudoscalars systems. • that $f_0(400-1200)$ and $f_0(1370)$ are two different poles. • its of $\overline{p}p \to 3\pi^0$, $\pi^0\eta\eta$ and $\pi^0\pi^0\eta$ on sheet III. • is of $\overline{p}p \to 3\pi^0$, $\pi^0\eta\eta$ and $\pi^0\pi^0\eta$ on sheet III. • ALVARD 88. • DCHS 73, ESTABROOKS 75, ROSSELET 77, and MUKHIN 80. • DCHS 73, GRAYER 74, and ROSSELET 77.

The fit does not include $f_0(980)$. 12 Uses data from ASTON 88, OCHS 73, HYAMS 73, ARMSTRONG 918, GRAYER 74, CASON 83, ROSSELET 77, and BEIER 728. Coupled channel analysis with flavor symmetry and all light two-pseudoscalars systems. 13 Uses $\pi^0 \pi^0$ data from ANISOVICH 94, AMSLER 94D, and ALDE 958, $\pi^+ \pi^-$ data from OCHS 73, GRAYER 74 and ROSSELET 77, and $\eta \eta$ data from ANISOVICH 94.	VALUE (WEV)	DOCUMENT ID		7 2 4 7	COMMENT		
761 \pm 12	(400–1200) OUR ESTIMATE						
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	ullet $ullet$ We do not	use the following data	for a	verages,	fits, limits, etc. • • •		
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	$\textbf{761} \pm \textbf{12}$		96	RVUE	$6-17 \pi N_{polar} \rightarrow \pi^+\pi^- N$		
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	~ 860		96	RVUE	$\pi\pi \rightarrow \pi\pi, K\overline{K}, K\pi, \eta\pi$		
~ 1000 15 ACHASOV 94 RVUE $\pi\pi \to \pi\pi$ 11 AUGUSTIN 89 DM2 11 Breit-Wigner fit to S-wave intensity measured in $\pi N \to \pi^-\pi^+ N$ on polarized targets. The fit does not include $f_0(980)$. 12 Uses data from ASTON 88, OCHS 73, HYAMS 73, ARMSTRONG 918, GRAYER 74, CASON 83, ROSSELET 77, and BEIER 728. Coupled channel analysis with flavor symmetry and all light two-pseudoscalars systems. 13 Uses $\pi^0\pi^0$ data from ANISOVICH 94, AMSLER 94D, and ALDE 958, $\pi^+\pi^-$ data from OCHS 73, GRAYER 74 and ROSSELET 77, and $\eta\eta$ data fromANISOVICH 94. 14 The pole is on Sheet III. Demonstrates explicitly that $f_0(400-1200)$ and $f_0(1370)$ are two different poles.	1165 ± 50	^{13,14} ANISOVICH	95	RVUE			
414 \pm 20					$\overline{\rho}\rho \rightarrow \pi^0\pi^0\pi^0$, $\pi^0\pi^0\eta$, $\pi^0\eta\eta$		
11 Breit-Wigner fit to S-wave intensity measured in $\pi N \to \pi^- \pi^+ N$ on polarized targets. The fit does not include $f_0(980)$. 12 Uses data from ASTON 88, OCHS 73, HYAMS 73, ARMSTRONG 918, GRAYER 74, CASON 83, ROSSELET 77, and BEIER 728. Coupled channel analysis with flavor symmetry and all light two-pseudoscalars systems. 13 Uses $\pi^0 \pi^0$ data from ANISOVICH 94, AMSLER 94D, and ALDE 95B, $\pi^+ \pi^-$ data from OCHS 73, GRAYER 74 and ROSSELET 77, and $\eta \eta$ data fromANISOVICH 94. 14 The pole is on Sheet III. Demonstrates explicitly that $f_0(400-1200)$ and $f_0(1370)$ are two different poles.	~ 1000		94	RVUE	$\pi\pi \to \pi\pi$		
The fit does not include $f_0(980)$. 12 Uses data from ASTON 88, OCHS 73, HYAMS 73, ARMSTRONG 918, GRAYER 74, CASON 83, ROSSELET 77, and BEIER 728. Coupled channel analysis with flavor symmetry and all light two-pseudoscalars systems. 13 Uses $\pi^0\pi^0$ data from ANISOVICH 94, AMSLER 94D, and ALDE 95B, $\pi^+\pi^-$ data from OCHS 73, GRAYER 74 and ROSSELET 77, and $\eta\eta$ data fromANISOVICH 94. 14 The pole is on Sheet III. Demonstrates explicitly that $f_0(400-1200)$ and $f_0(1370)$ are two different poles.	414 ± 20	¹¹ AUGUSTIN	89	DM2			
CASON 83, ROSSELET 77, and BEIER 728. Coupled channel analysis with flavor symmetry and all light two-pseudoscalars systems. 13 Uses $\pi^0\pi^0$ data from ANISOVICH 94, AMSLER 94D, and ALDE 95B, $\pi^+\pi^-$ data from OCHS 73, GRAYER 74 and ROSSELET 77, and $\eta\eta$ data fromANISOVICH 94. 14 The pole is on Sheet III. Demonstrates explicitly that $f_0(400-1200)$ and $f_0(1370)$ are two different poles.	¹¹ Breit-Wigner fit to S-wave intensity measured in $\pi N \to \pi^- \pi^+ N$ on polarized targets. The fit does not include $f_0(980)$.						
OCHS 73, GRAYER 74 and ROSSELET 77, and $\eta\eta$ data fromANISOVICH 94.	¹² Uses data from ASTON 88, OCHS 73, HYAMS 73, ARMSTRONG 91B, GRAYER 74, CASON 83, ROSSELET 77, and BEIER 72B. Coupled channel analysis with flavor sym-						
two different poles.							
15 Analysis of data from OCHS 73, ESTABROOKS 75, ROSSELET 77, and MUKHIN 80.	14 The pole is on Sheet III. Demonstrates explicitly that $f_0(400-1200)$ and $f_0(1370)$ are two different poles.						
	15 Analysis of da	ta from OCHS 73, EST	ABF	ROOKS	75, ROSSELET 77, and MUKHIN 80.		
					···		

fo(400-1200) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
(600-1000) OU	R ESTIMATE			
• • • We do no	ot use the following data	for a	verages,	fits, limits, etc. • • •
290 ± 54	¹⁶ SVEC	96	RVUE	$6-17 \pi N_{polar} \rightarrow \pi^+ \pi^- N$
~ 880	¹⁷ TORNQVIST	96	RVUE	$\pi\pi \to \pi\pi, K\overline{K}, K\pi, \eta\pi$
460 ± 40	^{18,19} ANISOVICH	95	RVUE	$\pi^- \rho \rightarrow \pi^0 \pi^0 n$
				$\bar{p} \rho \rightarrow \pi^0 \pi^0 \pi^0, \pi^0 \pi^0 \eta, \pi^0 \eta \eta$
~ 3200	²⁰ ACHASOV	94	RVUE	$\pi \pi \rightarrow \pi \pi$
494 ± 58	¹⁶ AUGUSTIN	89	DM2	
16				

- 16 Breit-Wigner fit to S-wave intensity measured in $\pi\,{\it N}\,\rightarrow\,\pi^-\,\pi^+\,{\it N}$ on polarized targets. The fit does not include $f_0(980).$
- The fit does not include $f_0(980)$. 17 Uses data from ASTON 88, OCHS 73, HYAMS 73, ARMSTRONG 91B, GRAYER 74, CASON 83, ROSSELET 77, and BEIER 72B. Coupled channel analysis with flavor symmetry and all light two-pseudoscalars systems. 18 Uses $\pi^0\pi^0$ data from ANISOVICH 94, AMSLER 94D, and ALDE 95B, $\pi^+\pi^-$ data from OCHS 73, GRAYER 74 and ROSSELET 77, and $\eta\eta$ data fromANISOVICH 94. 19 The pole is on Sheet III. Demonstrates explicitly that $f_0(400$ –1200) and $f_0(1370)$ are two different poles. 20 Analysis of data from OCHS 73, ESTABROOKS 75, ROSSELET 77, and MUKHIN 80.

f₀(400-1200) DECAY MODES

	Mode	Fraction $(\Gamma_{\tilde{I}}/\Gamma)$
Γ ₁	ππ	dominant
Γ_2	$\gamma\gamma$	seen

f₀(400-1200) PARTIAL WIDTHS

$\Gamma(\gamma\gamma)$				Γ ₂
VALUE (keV)	DOCUMENT ID		TECN	COMMENT
seen	²¹ MORGAN	90	RVUE	$\gamma \gamma \rightarrow \pi^+ \pi^-$, $\pi^0 \pi^0$
• • • We do not use t	he following data for average	es, fits	s, limits,	etc. • • •
10±6	COURAU	86	DM1	$e^+e^{\pi^+\pi^-}e^+e^-$
21 Analysis of data fro	m BOYER 90 and MARSISH	KE 90).	

f₀(400-1200) REFERENCES

OTHER RELATED PAPERS -

96	PR D53 295	+Close	(ZURI, RAL)
95C	PL B353 571	+Armstrong, Hackman+	(Crystal Barrel Collab.)
95	PL B353 589	+Barberis, Bayes+ (ATF	IU, BARI, BIRM, CERN, JINR)
95	ZPHY C68 647	•	(HELS)
94	PL B322 431	+Armstrong, Meyer+	(Crystal Barrel Collab.)
93	NP A558 13C	+Agnello+	(OBELIX Collab.)
93	NP A562 407		(ROMAI)
93	PR D48 1185	+Pennington	(RAL, DURH)
93C	NC A Conf. Suppl.	Morgan	(RAL)
92	PR D45 55	+de Lesquen, van Rossum	(MCGI, SACL)
92B	PR D45 1518	+de Lesquen, van Rossum	(MCGI, SACL)
92C	PR D46 949	+de Lesquen, van Rossum	(MCGI, SACL)
89		+lsgur	(TNTO)
88D		+Awaji, Bienz+	(SLAC, NAGO, CINC, INUS)
84	ZPHY C22 53	+Devyanin, Shestakov	(NOVM)
83	NC 78A 313	+Donskov, Duteil+	(BELG, LAPP, SERP, CERN)
82B	PR D25 1786	+Foley, Lai+	(BNL, CUNY, TUFTS, VAND)
82	PRL 49 624		(HELS)
80	PR D22 2595	+Ayres, Diebold, Kramer, Pa	wlicki+ (ANL) IJP
79B	NP B150 301		(MPIM, CERN, ZEEM, CRAC)
79	PR D19 1317	Polychronakos, Cason, Bish	op+ (NDAM, ANL) IJP
76	NP B115 208	+Freudenreich, Beusch+	(ETH, CERN, LOIC)
	95C 95 95 94 93 93 93 93C 92B 92C 89 88D 84 83 82B 82 879B 79	9SC PL 8353 571 5 PL 8353 589 5 PL 8353 589 5 PL 8353 589 5 PL 870 589 6 PL 870 589 6 PL 870 589 6 PL 870 589 7 PL 870 589 88D NP 8301 525 84	95C PL 8353 571 + Armstrong, Hackman+ 57

 $\rho(770)$

$$\rho$$
(770)

 $I^{G}(J^{PC}) = 1^{+}(1^{-})$

THE $\rho(770)$

Because of its large width, determination of the parameters of the $\rho(770)$ is beset with many difficulties. In physicalregion fits, the line shape does not correspond to a relativistic Breit-Wigner function with a P-wave width, but requires some additional shape parameter. This dependence on parametrization was demonstrated long ago by PISUT 68, who showed that the mass was consistent with values between 761 MeV and 783 MeV to within two standard deviations. When mass values are quoted, as below, with one-standard-deviation errors, the conflicts between them are evident.

The same model dependence afflicts any other source of the resonance parameters, such as the energy dependence of the phase shift δ_1^1 or the pole position. It is therefore not surprising that a recent study of $\rho(770)$ dominance in the decays of the η and η' reveals the need for specific dynamical effects in addition to the $\rho(770)$ pole (BENAYOUN 93).

Recently LAFFERTY 93 has demonstrated that Bose-Einstein correlations are another source of shifts in the $\rho(770)$ line shape.

ρ(770) MASS

We no longer list S-wave Breit-Wigner fits, or data with high combinatorial background.

MIXED CHARGES

DOCUMENT ID

768.5±0.6 OUR AVERAGE Includes data from the 3 datablocks that follow this one. Error includes scale factor of 1.2.

DOCUMENT ID TECN CHG COMMENT The data in this block is included in the average printed for a previous datablock

100.9 ± 1.2 OUR AV	EKAGE				
768 ±9		AGUILAR	91	EHS	400 pp
767 ±3	2935	² CAPRARO	87	SPEC -	$^{200}_{\pi^-\pi^0\text{Cu}}^{-\text{Cu}} \rightarrow$
761 ±5	967	² CAPRARO	87	SPEC -	$ \begin{array}{c} \pi & \pi^{\circ} C u \\ 200 & \pi^{-} Pb \rightarrow \\ \pi^{-} & \pi^{0} Pb \end{array} $
771 ± 4		HUSTON	86	SPEC +	$202 \pi^{+} A \rightarrow \pi^{+} A \rightarrow A$
766 ±7	6500	3 BYERLY	73	OSPK -	5 π ⁻ ρ
$\textbf{766.8} \pm 1.5$	9650	⁴ PISUT	68	RVUE -	1.7-3.2 $\pi^- p$, t
767 ±6	900	2 FISNER	67	HBC -	<10

NEUTRAL ONLY, PHOTOPRODUCED

DOCUMENT ID TECN CHG COMMENT <u>VALUE (MeV)</u> <u>EVTS</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>CHG</u> <u>COMMENT</u>
The data in this block is included in the average printed for a previous datablock.

768.1 ± 1.3 OUR AVERAGE

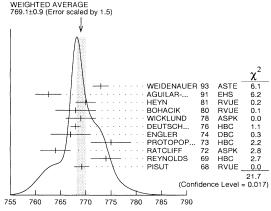
767.6 ± 2.7		BARTALUCCI	78	CNTR	0	$\gamma p \rightarrow e^+e^-p$
775 ± 5		GLADDING	73	CNTR	0	2.9-4.7 γp
767 ± 4	1930	BALLAM	72	HBC	0	2.8 γp
770 ± 4	2430	BALLAM	72	HBC	0	$4.7 \gamma p$
765 ±10		ALVENSLEBE	N70	CNTR	0	γ A, $t < 0.01$
767.7 ± 1.9	140k	BIGGS	70	CNTR	0	$<$ 4.1 γ C \rightarrow
						$\pi^{+}\pi^{-}C$
765 + 5	4000	ASBURY	67B	CNTR	0	$\gamma + Ph$

NEUTRAL ONLY, OTHER REACTIONS

<u>VALUE (MeV)</u> <u>EVTS</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>CHG</u> <u>COMMENT</u> The data in this block is included in the average printed for a previous datablock.

769.1±0.9 OUR AVER	AGE Erro	or includes scale fac	ctor	of 1.5. S	see the	
773 ±1.6		WEIDENAUER	. 93	ASTE		$\overline{\rho} \rho \rightarrow \pi^+ \pi^- \omega$
762.6 ± 2.6		_AGUILAR	91	EHS		400 pp
770 ±2		5 HEYN	81	RVUE		Pion form factor
768 ±4		6,7 BOHACIK	80	RVUE	0	
769 ±3		³ WICKLUND	78	ASPK	0	3,4,6 π^{\pm} N
768 ±1	76000	DEUTSCH	76	HBC	0	16 π ⁺ ρ
767 ±4	4100	ENGLER	74	DBC	0	6 π ⁺ π →
775 ±4	32000	6 PROТОРОР	73	нвс	0	$\pi^{+}\pi^{-}\rho$ 7.1 $\pi^{+}\rho$, $t < 0.4$
764 ±3	6800	RATCLIFF	72	ASPK	0	$15 \pi^- \rho, t < 0.3$
774 ±3	1700	REYNOLDS	69	HBC	0	2.26 π ⁻ p
769.2±1.5	13300	8 PISUT	68	RVUE	0	1.7-3.2 π ⁻ p, t
109.2 ± 1.3	13300	FISUI	00	KVOL	U	<10
• • • We do not use the	ne followin	g data for averages	i, fits	s, limits,	etc. •	
757.5 ± 1.5		¹ BERNICHA	94	RVUE		$e^+e^- \rightarrow \pi^+\pi^-$
761.1 ± 2.9		DUBNICKA	89	RVUE		π form factor
768 ±1		9 GESHKENBEIN	V 89	RVUE		π form factor
775.9 ± 1.1		¹⁰ BARKOV	85	OLYA	0	$e^+e^- \rightarrow \pi^+\pi^-$
777.4 ± 2.0		¹¹ CHABAUD	83	ASPK	0	17 $\pi^- p$ polarized
769.5 ± 0.7		^{6,7} LANG	79	RVUE	0	
770 ±9		⁷ ESTABROOKS	74	RVUE	0	$17 \pi^- p \rightarrow$
		2				$\pi^+\pi^-$
773.5 ± 1.7	11200	² JACOBS	72	HBC	0	$2.8 \pi^{-} \rho$
775 ±3	2250	HYAMS	68	OSPK	0	11.2 $\pi^- p$
¹ Applying the S-mat	rix formali	ism to the BARKO	√ 85	data.		





 $\rho(770)^{0}$ mass (MeV)

$m_{\rho(770)^0} - m_{\rho(770)^{\pm}}$

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
0.3±2.2 OUR		includes scale facto	r of 1.3.	See the	ideogram below.
-4 ±4			нвс	-0	2.26 π ⁻ p
-5 ±5			3 HBC	±0	$0.0 \overline{p} p$
2.4 ± 2.1	22950	¹³ PISUT 68	RVUI	Ξ	$\pi N \rightarrow \rho N$

¹² From quoted masses of charged and neutral modes.

² Mass errors enlarged by us to Γ/\sqrt{N} ; see the note with the $K^*(892)$ mass.

 $^{^3}$ Phase shift analysis. Systematic errors added corresponding to spread of different fits. ⁴ From fit of 3-parameter relativistic *P*-wave Breit-Wigner to total mass distribution. Includes BATON 68, MILLER 67B, ALFF-STEINBERGER 66, HAGOPIAN 66, HAGOPIAN 66B, JACOBS 66B, JAMES 66, WEST 66, BLIEDEN 65 and CARMONY 64.

 $^{^5}$ HEYN 81 includes all spacelike and timelike F_π values until 1978.

⁶ From pole extrapolation.

⁷ From phase shift analysis of GRAYER 74 data.

From phase simil, analysis of RATER 14 add.

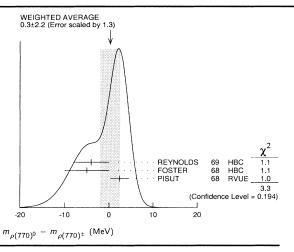
8 Includes MALAMUD 69, ARMENISE 68, BACON 67, HUWE 67, MILLER 67B, ALFF-STEINBERGER 66, HAGOPIAN 66, HAGOPIAN 66B, JACOBS 66B, JAMES 66, WEST 66, GOLDHABER 64, ABOLINS 63.

⁹ Includes BARKOV 85 data. Model-dependent width definition.

 $^{^{}m 10}$ From the Gounaris-Sakurai parametrization of the pion form factor.

¹¹ From fit of 3-parameter relativistic Breit-Wigner to helicity-zero part of P-wave intensity. CHABAUD 83 includes data of GRAYER 74.

¹³ Includes MALAMUD 69, ARMENISE 68, BATON 68, BACON 67, HUWE 67, MILLER 67B, ALFF-STEINBERGER 66, HAGOPIAN 66, HAGOPIAN 66B, JACOBS 66B, JAMES 66, WEST 66, BLIEDEN 65, CARMONY 64, GOLDHABER 64,



ρ (770) RANGE PARAMETER

The range parameter R enters an energy-dependent correction to the width, of the form $(1+q^2,R^2)$ / $(1+q^2,R^2)$, where q is the momentum of one of the pions in the $\pi\pi$ rest system. At resonance, q=

VALUE (GeV ⁻¹)	DOCUMENT ID		TECN	CHG	COMMENT
5.3 ^{+0.9}	CHABAUD	83	ASPK	0	17 $\pi^- p$ polarized

ρ (770) WIDTH

We no longer list S-wave Breit-Wigner fits, or data with high combinatorial

MIXED CHARGES

DOCUMENT ID

150.7±1.2 OUR AVERAGE Includes data from the 3 datablocks that follow this one.

CHARGED ONLY

VALUE (MeV) EVTS DOCUMENT ID TECN CHG COMMENT

The data in this block is included in the average printed for a previous datablock.

149.1 ± 2.9 OUR FIT 149.1 + 2.9 OUR AVERAGE

147.	LT 2.9 OUR AVER	MGE					
155	±11	2935	¹⁵ CAPRARO	87	SPEC	-	$^{200}_{\pi}$ $^{-}_{\pi}$ $^{0}_{Cu}$ $^{-}$
154	± 20	967	¹⁵ CAPRARO	87	SPEC	-	7 π Cu 200 π Pb → 0 pb
150	± 5		HUSTON	86	SPEC	+	$ \begin{array}{c} 200 \pi^{-} Pb \rightarrow \\ \pi^{-} \pi^{0} Pb \\ 202 \pi^{+} A \rightarrow \\ \pi^{+} \pi^{0} A \end{array} $
146	± 12	6500	16 BYERLY	73	OSPK	_	$5\pi^-p$
148.2	2± 4.1	9650	¹⁷ PISUT	68	RVUE	_	$1.7-3.2 \pi^- p$, t
146	+13	900	FISNER	67	HBC	_	<10 4.2 π^- p. $t < 10$

NEUTRAL ONLY, PHOTOPRODUCED

<u>VALUE (MeV)</u> <u>EVTS</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>CHG</u> <u>COMMEN</u>
The data in this block is included in the average printed for a previous datablock. TECN CHG COMMENT

150.9± 3.0		BARTALUCCI	78	CNTR	0	$\gamma p \rightarrow e^+e^-p$
• • • We do	not use the following	data for average:	s, fits	, limits,	etc. •	• •
147 ± 11		GLADDING	73	CNTR	0	2.9−4.7 γp
155 ± 12	2430	BALLAM	72	HBC	0	$4.7 \gamma p$
145 ± 13	1930	BALLAM	72	HBC	0	2.8 γp
140 ± 5		ALVENSLEBE	V7 0	CNTR	0	γ A, t < 0.01
146.1 ± 2.9	140k	BIGGS	70	CNTR	0	$<$ 4.1 γ C \rightarrow
						$\pi^+\pi^-$ C
160 ±10		LANZEROTTI	68	CNTR	0	γp
130 ± 5	4000	ASBURY	67B	CNTR	0	γ + Pb

NEUTRAL ONLY, OTHER REACTIONS

<u>VALUE (MeV)</u> <u>EVTS</u> <u>DOCUMENT ID</u> <u>TECN CHG COMMENT</u>
The data in this block is included in the average printed for a previous datablock.

 $151.0\pm~2.0$ OUR FIT Error includes scale factor of 1.3. $151.0\pm~1.7$ OUR AVERAGE Error includes scale factor of 1.1

101.01	III OOK MELINIO		mendes sedie it	CLO	01 1.1.			
$145.7\pm$	5.3		WEIDENAUER	93	ASTE		$\overline{\rho} \rho \rightarrow \pi^+ \pi^- \omega$	_
$144.9\pm$	3.7		DUBNICKA				π form factor	1
$148 \pm$	6		BOHACIK					
$152 \pm$	9	16	WICKLUND	78	ASPK	0	3,4,6 $\pi^{\pm} \rho N$	
$154 \pm$	2 760	00	DEUTSCH	76	HBC	0	16 $\pi^{+} \rho$	
157 ±	8 68	00	RATCLIFF	72	ASPK	0	15 $\pi^- \rho$, $t < 0.3$	
143 ±	8 17	00	REYNOLDS	69	HBC	0	2.26 π ⁻ p	

• • • We do not u	se the followi	ng data for averages	s, fit	s, limits	etc.	• • •
142.5 ± 3.5		14 BERNICHA	94			$e^+e^- \rightarrow \pi^+\pi^-$
138 ± 1		20 GESHKENBEII	N89	RVUE		π form factor
$\textbf{150.5} \pm \ \textbf{3.0}$		²¹ BARKOV	85	OLYA	0	$e^+e^- \rightarrow \pi^+\pi^-$
160.0^{+}_{-}		²² CHABAUD	83	ASPK	0	17 $\pi^- p$ polarized
155 ± 1		²³ HEYN	81	RVUE	0	π form factor
148.0 ± 1.3	1:	^{8,19} LANG	79	RVUE	0	
146 ±14	4100	ENGLER	74	DBC	0	$6 \frac{\pi^+ n}{\pi^+ \pi^- p}$
143 ±13		¹⁹ ESTABROOKS	74	RVUE	0	$ \begin{array}{c} 17 \ \pi^- \rho \rightarrow \\ \pi^+ \pi^- \rho \end{array} $
160 ±10	32000	18 PROTOPOP	73	нвс	0	$7.1 \pi^{+} p, t < 0.4$
145 ±12	2250		68	OSPK	0	11.2 π^{-} p
163 ±15	13300	²⁴ PISUT	68	RVUE	0	1.7-3.2 $\pi^- p$, t

- $^{14}\,\mathrm{Applying}$ the S-matrix formalism to the BARKOV 85 data.
- 15 Width errors enlarged by us to 4Γ/ $\sqrt{N};$ see the note with the $K^*(892)$ mass.
- 16 Phase shift analysis. Systematic errors added corresponding to spread of different fits.
 17 From fit of 3-parameter relativistic P-wave Breit-Wigner to total mass distribution. Includes BATON 68, MILLER 67B, ALFF-STEINBERGER 66, HAGOPIAN 66, HAGOPIAN 66, JACOBS 66B, JAMES 66, WEST 66, BLIEDEN 65 and CARMONY 64.
- ¹⁸ From pole extrapolation.
- ¹⁹ From phase shift analysis of GRAYER 74 data.
- ²⁰ Includes BARKOV 85 data. Model-dependent width definition.
- 21 From the Gounaris-Sakurai parametrization of the pion form factor.
- ²² From fit of 3-parameter relativistic Breit-Wigner to helicity-zero part of *P*-wave intensity.
- CHABAUD 83 includes data of GRAYER 74.
 ^23 HEYN 81 includes all spacelike and timelike F_π values until 1978.
- ²⁴ Includes MALAMUD 69, ARMENISE 68, BACON 67, HUWE 67, MILLER 67B, ALFF-STEINBERGER 66, HAGOPIAN 66, HAGOPIAN 66B, JACOBS 66B, JAMES 66, JACOBS 66B, JAMES 6BB, WEST 66, GOLDHABER 64, ABOLINS 63.

ρ (770) DECAY MODES

	Mode	Frac	tion (Γ_i/Γ)		Scale factor/ Ifidence level
Γ_1	ππ	~ 1	.00	%	
		$ ho$ (770) $^{\pm}$ decays			
Γ_2	$\pi^{\pm}\pi^{0}$	~ 1	00	%	
Γ3	$\pi^{\pm}\gamma$	(4.5 ±0.5)	× 10 ⁻⁴	S=2.2
ΓΔ	$\pi^{\pm}\eta$	<	6	\times 10 ⁻³	CL=84%
Γ ₅	$\pi^{\pm} \pi^{+} \pi^{-} \pi^{0}$	<	2.0		
		$\rho(770)^0$ decays			
Γ_6	$\pi^+\pi^-$	~ 1	.00	%	
Γ ₇	$\pi^+\pi^-\gamma$	(9.9 ±1.6)	$\times 10^{-3}$	
Γ8	$\pi^0 \gamma$	(7.9 ±2.0)	$\times 10^{-4}$	
Γ9	$\eta \gamma$	(3.8 ±0.7)	$\times 10^{-4}$	
Γ ₁₀	$\mu^+\mu^-$	[a] (4.60 ± 0.28)	$\times 10^{-5}$	
Γ_{11}	e^+e^-	[a] (4.48±0.22)	$\times 10^{-5}$	
Γ_{12}	$\pi^{+}\pi^{-}\pi^{0}$	<	1.2	\times 10 ⁻⁴	CL=90%
Γ_{13}	$\pi^{+}\pi^{-}\pi^{+}\pi^{-}$	<	2	$\times 10^{-4}$	CL:=90%
Γ ₁₄	$\pi^+\pi^-\pi^0\pi^0$	<	4	× 10 ⁻⁵	CL=90%

[a] The e^+e^- branching fraction is from $e^+e^- \to \pi^+\pi^-$ experiments only. The $\omega \rho$ interference is then due to $\omega \rho$ mixing only, and is expected to be small. If $e\mu$ universality holds, $\Gamma(\rho^0 \to \mu^+ \mu^-) = \Gamma(\rho^0 \to e^+ e^-)$ \times 0.99785.

CONSTRAINED FIT INFORMATION

An overall fit to the total width and a partial width uses 9 measurements and one constraint to determine 3 parameters. The overall fit has a $\chi^2=10.2$ for 7 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\left<\delta\rho_i\delta\rho_j\right>/(\delta\rho_i\cdot\delta\rho_j)\text{, in percent, from the fit to parameters }\rho_i\text{, including the branch-}$ ing fractions, $x_i \equiv \Gamma_i/\Gamma_{\rm total}$. The fit constrains the x_i whose labels appear in this array to sum to one.

$$x_3$$
 -100 Γ 18 -18 x_2 x_3

	Mode	Rate (MeV)	Scale factor	
Γ ₂	$\pi^{\pm}\pi^{0}$	149.1 ±2.9		
Гз	$\pi^{\pm}\gamma$	0.068 ± 0.007	2.3	

$\rho(770)$

CONSTRAINED FIT INFORMATION

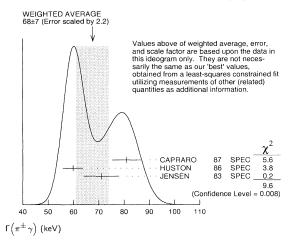
An overall fit to the total width, a partial width, and a branching ratio uses 9 measurements and one constraint to determine 4 parameters. The overall fit has a $\chi^2=7.8$ for 6 degrees of

The following off-diagonal array elements are the correlation coefficients $\left<\delta
ho_i \delta
ho_j \right>/(\delta
ho_i \cdot \delta
ho_j)$, in percent, from the fit to parameters ho_i , including the branching fractions, $x_i \equiv \Gamma_i/\Gamma_{\rm total}$. The fit constrains the x_i whose labels appear in this array to sum to one.

Mode		Rate (MeV)	Scale factor		
Γ ₆	$\pi^+\pi^-$	151.0 ±2.0	1.3		
Γ_{10}	$\mu^+\mu^-\ e^+e^-$	[a] 0.0069 ± 0.0004			
Γ_{11}	e^+e^-	[a] 0.00677 ± 0.00032			

ρ (770) PARTIAL WIDTHS

Γ(:	$\pi^{\pm}\gamma$)						Гз
VAL	UE (ke	V)		DOCUMENT ID		TECN	CHG	COMMENT
68	±7	OUR FIT	Error i	ncludes scale factor of	2.3.			
68	±7	OUR AVE	RAGE	Error includes scale fac	tor o	f 2.2. S	ee the	ideogram below.
81	±4	± 4		CAPRARO	87	SPEC		$200 \pi^- A \rightarrow$
59.	8 ± 4.	0		HUSTON	86	SPEC	+	$ \begin{array}{ccc} \pi & \pi^{0} A \\ 202 & \pi^{+} A \rightarrow \\ \pi^{+} & \pi^{0} A \end{array} $
71	±7			JENSEN	83	SPEC	~	$^{156-260}_{\pi^-\pi^0}{}_{A}^{\pi^-}A \rightarrow$



$\Gamma(e^+e^-)$					Γ ₁₁
VALUE (keV)	DOCUMENT ID		TECN	COMMENT	
6.77±0.32 OUR FIT					
$6.77 \pm 0.10 \pm 0.30$	BARKOV	85 (OLYA	$e^+e^- \rightarrow \tau$	τ+ π-
$\Gamma(\pi^0\gamma)$					Гв
VALUE (keV)	DOCUMENT ID		TECN	COMMENT	
121±31	DOLINSKY	89	ND	$e^+e^- \rightarrow \tau$	$\tau^0 \gamma$
$\Gamma(\eta \gamma)$					Г
VALUE (keV)	DOCUMENT ID		TECN	COMMENT	
• • • We do not use the follo	owing data for averages,	fits,	limits,	etc. • • •	
62±17	²⁵ DOLINSKY				
111 ± 22	²⁶ DOLINSKY	89	ND	$e^+e^- \rightarrow r$	$\gamma \gamma$

²⁵ Solution corresponding to constructive ω - ρ interference. The quark model predicts a relative decay phase of zero. Also much favored by the ALDE 93 model-independent measurement of B($\omega \to \eta \gamma$).

²⁶ Solution corresponding to destructive ρ - ω interference.

ρ(770) BRANCHING RATIOS

$\Gamma(\pi^{\pm}\eta)/\Gamma(\pi\pi)$						Γ4/	Γ ₁
VALUE (units 10-4)	CL%	DOCUMENT ID		TECN	CHG	COMMENT	
<60	84	FERBEL	66	HBC	±	$\pi^{\pm} p$ above 2.5	

$\Gamma(\pi^{\pm}\pi^{+}\pi^{-}\pi^{0})/\Gamma(\pi^{\pm}\pi^{+}\pi^{-}\pi^{0})$	ππ)			VI - 6-00-004		Γ ₅ /Γ ₁
VALUE (units 10 ⁻⁴)	CI.%	DOCUMENT ID		TECN	CHG	COMMENT
<20	84	FERBEL	66		\pm	$\pi^{\pm} ho$ above 2.5
• • We do not use the	ne following					
35±40		JAMES	66	нвс	+	$2.1 \pi^{+} p$
$\Gamma(\mu^+\mu^-)/\Gamma(\pi^+\pi^-)$)					Γ_{10}/Γ_{6}
VALUE (units 10 ⁻⁵)		DOCUMENT ID		TECN	COM	MENT
4.60 ± 0.28 OUR FIT 4.6 ± 0.2 ± 0.2 • • • We do not use the	ne following	ANTIPOV data for average	89 s, fits			$u \rightarrow \mu^{+}\mu^{-}\pi^{-}Cu$
$8.2 \begin{array}{c} +1.6 \\ -3.6 \end{array}$	2	27 ROTHWELL	69	CNTR	Phot	oproduction
5.6 ±1.5	2	²⁸ WEHMANN	69	OSPK	12 π	C, Fe
$9.7 \begin{array}{c} +3.1 \\ -3.3 \end{array}$	2	²⁹ HYAMS	67	OSPK	11 π	− Li, H
27 Possibly large $ρ-ω$ in 28 Result contains 11 correction takes acc upper limit of $ω \rightarrow$ 29 HYAMS 67's mass	\pm 11% core ount of pos $\mu^+\mu^-$ fro	rection using SU(sible $ ho ext{-} \omega$ interfere om this experimen	(3) fo ence a nt.	or centra and the	l valu upper	limit agrees with the
$\Gamma(e^+e^-)/\Gamma(\pi\pi)$						Γ_{11}/Γ_{1}
VALUE (units 10 ⁻⁴)		DOCUMENT ID		TECN	соми	
0.41±0.05	***************************************	BENAKSAS	72	OSPK	e ⁺ e	
$\Gamma(\eta\gamma)/\Gamma_{total}$						Г9/Г
VALUE (units 10 ⁻⁴)		DOCUMENT ID		TECN	CHG	COMMENT
3.8±0.7 OUR AVERAG						
4.0 ± 1.1 3.6 ± 0.9	3	³⁰ DOLINSKY ³⁰ ANDREWS	89 77	ND CNTR	0	$e^+e^- \rightarrow \eta \gamma$ 6.7–10 γ Cu
• • • We do not use the						
7.3 ± 1.5	3	31 DOLINSKY	89	ND		$e^+ e^- o \eta \gamma$
5.4 ± 1.1 30 Solution correspond		31 ANDREWS	77	CNTR		6.7-10 γCu
of B($\omega \rightarrow \eta \gamma$).	Also much	ravored by the AL	DE 9	3 modei	-inaep	endent measurement
31 Solution correspond $\Gamma(\pi^+\pi^-\pi^+\pi^-)/\Gamma.$		ructive ω - $ ho$ interfe	erenc	e.		Γ /Γ
$\Gamma(\pi^+\pi^-\pi^+\pi^-)/\Gamma_{\rm t}$	otal		erenc		СОМІ	Γ ₁₃ /Γ
	otal	ructive ω-ρ interfo <u>DOCUMENT ID</u> KURDADZE	erenc 88	e. <u>TECN</u> OLYA	<u>сомі</u> e ⁺ e	MENT
$\frac{\Gamma(\pi^{+}\pi^{-}\pi^{+}\pi^{-})/\Gamma_{t}}{\frac{VALUE \text{ (units }10^{-4})}{<2}}$	otal <u>CL%</u> 90	DOCUMENT ID		TECN		
$\frac{\Gamma(\pi^{+}\pi^{-}\pi^{+}\pi^{-})/\Gamma_{t}}{\stackrel{VALUE (units 10^{-4})}{<2}}$ $\Gamma(\pi^{+}\pi^{-}\pi^{+}\pi^{-})/\Gamma(\pi^{+}\pi^{-}\pi^{-}\pi^{+}\pi^{-})/\Gamma(\pi^{+}\pi^{-}\pi^{-}\pi^{+}\pi^{-})/\Gamma(\pi^{+}\pi^{-}\pi^{-}\pi^{-}\pi^{-}\pi^{-}\pi^{-}\pi^{-}\pi^{-$	otal $-\frac{CL\%}{90}$ $(\pi \pi)$	DOCUMENT ID		TECN		MENT
$\frac{\Gamma(\pi^{+}\pi^{-}\pi^{+}\pi^{-})/\Gamma_{t}}{<2}$ $\frac{VALUE \text{ (units }10^{-4})}{<2}$ $\Gamma(\pi^{+}\pi^{-}\pi^{+}\pi^{-})/\Gamma(\frac{VALUE \text{ (units }10^{-4})}{}$	otal <u>CL%</u> 90 (ππ) <u>CL%</u>	DOCUMENT ID KURDADZE	88	TECN OLYA	e ⁺ e π	$ \begin{array}{c} $
$\Gamma(\pi^{+}\pi^{-}\pi^{+}\pi^{-})/\Gamma_{t}$ $\stackrel{VALUE \text{ (units }10^{-4})}{<2}$ $\Gamma(\pi^{+}\pi^{-}\pi^{+}\pi^{-})/\Gamma_{t}$ $\stackrel{VALUE \text{ (units }10^{-4})}{\sim}$ • • • We do not use the	otal <u>CL%</u> 90 (ππ) <u>CL%</u> ne following	DOCUMENT ID KURDADZE DOCUMENT ID data for average	88	TECN OLYA TECN s, limits	e ⁺ e π	$ \begin{array}{c} $
$\frac{\Gamma(\pi^{+}\pi^{-}\pi^{+}\pi^{-})/\Gamma_{t}}{\sqrt{2}}$ <2 $\Gamma(\pi^{+}\pi^{-}\pi^{+}\pi^{-})/\Gamma_{t}$ $\frac{VALUE \text{ (units }10^{-4})}{\sqrt{2}}$ • • • We do not use the contraction of the contract	otal <u>CL%</u> 90 (ππ) <u>CL%</u>	DOCUMENT ID KURDADZE DOCUMENT ID data for average ERBE	88 es, fit:	TECN OLYA TECN s, limits	e+ e π <u>CHG</u> etc. •	MENT $ \begin{array}{c} $
$\Gamma(\pi^{+}\pi^{-}\pi^{+}\pi^{-})/\Gamma_{t}$ $\stackrel{VALUE \text{ (units }10^{-4})}{<2}$ $\Gamma(\pi^{+}\pi^{-}\pi^{+}\pi^{-})/\Gamma_{t}$ $\stackrel{VALUE \text{ (units }10^{-4})}{\sim}$ • • • We do not use the	otal <u>CL%</u> 90 (ππ) <u>CL%</u> ne following	DOCUMENT ID KURDADZE DOCUMENT ID data for average ERBE CHUNG HUSON	88	TECN OLYA TECN S, limits, HBC HBC HBC	e ⁺ e π	$_{+\pi^{-}\pi^{+}\pi^{-}}^{F_{13}/F_{1}}$ COMMENT 2.5-5.8 γ ρ 3.2,4.2 π ρ 16.0 π ρ
$\frac{VALUE \text{ (units } 10^{-4})}{<2}$ $\frac{VALUE \text{ (units } 10^{-4})}{<2}$ $\frac{VALUE \text{ (units } 10^{-4})}{VALUE \text{ (units } 10^{-4})}$ • • • We do not use the contraction of the contract	otal <u>CL%</u> 90 <u>CL%</u> ne following 90	DOCUMENT ID KURDADZE DOCUMENT ID data for average ERBE CHUNG	88 es, fit: 69 68	TECN OLYA TECN 5, limits, HBC HBC	e ⁺ e π CHG etc. 0 0	MENT $ \begin{array}{c} $
$\Gamma(\pi^{+}\pi^{-}\pi^{+}\pi^{-})/\Gamma_{t}$ $\frac{VALUE \text{ (units }10^{-4})}{<2}$ $\Gamma(\pi^{+}\pi^{-}\pi^{+}\pi^{-})/\Gamma_{t}$ $\frac{VALUE \text{ (units }10^{-4})}{<0} \cdot \bullet \cdot We do not use the second se$	otal	DOCUMENT ID KURDADZE DOCUMENT ID data for average ERBE CHUNG HUSON JAMES	88 es, fit: 69 68 68 66	TECN OLYA TECN 5, limits, HBC HBC HLBC HBC	e+e π CHG etc. 0 0 0	$ \begin{array}{c} \text{MENT} \\ - \\ + \pi^{-} \pi^{+} \pi^{-} \end{array} $ $ \begin{array}{c} \Gamma_{13}/\Gamma_{1} \\ \hline 0 \bullet \bullet$
$ \frac{\Gamma(\pi^{+}\pi^{-}\pi^{+}\pi^{-})/\Gamma_{t}}{<2} $ $ \frac{VALUE \text{ (units }10^{-4})}{<2} $ $ \Gamma(\pi^{+}\pi^{-}\pi^{+}\pi^{-})/\Gamma_{t} $ $ \frac{VALUE \text{ (units }10^{-4})}{<0} $ • • • We do not use the second sec	otal <u>CL%</u> 90 <u>CL%</u> ne following 90	DOCUMENT ID KURDADZE DOCUMENT ID data for average ERBE CHUNG HUSON	88 69 68 68 66	TECN OLYA TECN S, limits, HBC HBC HBC	e+e π CHG 0 0 0 0 0	$ \begin{array}{c} \text{MENT} \\ - \\ + \pi^{-} \pi^{+} \pi^{-} \end{array} $ $ \begin{array}{c} \Gamma_{13}/\Gamma_{1} \\ \hline 0 \bullet \bullet$
$\Gamma(\pi^{+}\pi^{-}\pi^{+}\pi^{-})/\Gamma_{t}$ $\frac{VALUE \text{ (units }10^{-4})}{<2}$ $\Gamma(\pi^{+}\pi^{-}\pi^{+}\pi^{-})/\Gamma_{t}$ $\frac{VALUE \text{ (units }10^{-4})}{<0.0}$ • • • We do not use the second se	Otal $\frac{cL\%}{90}$ $\frac{cL\%}{90}$	DOCUMENT ID KURDADZE DOCUMENT ID data for average ERBE CHUNG HUSON JAMES	88 69 68 68 66	TECN OLYA TECN 5, limits, HBC HBC HBC HBC	e+e π CHG 0 0 0 0 0	$\begin{array}{c} \text{MENT} \\ \hline \\ -\\ +\\ \pi^-\\ \pi^+\\ \pi^-\\ \pi^+\\ \pi^-\\ \pi^-\\ \pi^-\\ \hline \\ \begin{array}{c} \Gamma_{13}/\Gamma_1 \\ \hline \\ 0 \bullet \bullet \\ 2.5 - 5.8 \ \gamma \rho \\ 3.2, 4.2 \ \pi^-\\ \rho \\ 16.0 \ \pi^-\\ \rho \\ 2.1 \ \pi^+\\ \rho \\ \hline \\ \Gamma_{12}/\Gamma \\ \hline \\ -\\ -\\ \pi^+\\ \pi^-\\ \pi^0 \end{array}$
$\Gamma(\pi^{+}\pi^{-}\pi^{+}\pi^{-})/\Gamma_{t}$ $\frac{VALUE \text{ (units }10^{-4})}{<2}$ $\Gamma(\pi^{+}\pi^{-}\pi^{+}\pi^{-})/\Gamma_{t}$ $\frac{VALUE \text{ (units }10^{-4})}{\bullet \bullet \bullet \text{ (whits }10^{-4})}$ $\bullet \bullet \bullet \text{ (which is }0^{-4})$ <15 <20 <20 <20 <80 $\Gamma(\pi^{+}\pi^{-}\pi^{0})/\Gamma_{total}$ $\frac{VALUE \text{ (units }10^{-4})}{VALUE \text{ (units }10^{-4})}$	otal - <u>CL%</u> 90 (ππ) - <u>CL%</u> 90 90 90 - <u>CL%</u> 90	DOCUMENT ID KURDADZE DOCUMENT ID data for average ERBE CHUNG HUSON JAMES DOCUMENT ID VASSERMAN	88 69 68 68 66	TECN OLYA TECN S, limits, HBC HBC HBC HBC HBC	e ⁺ e π CHG 0 0 0 0 0 0 0	MENT
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$\Gamma(\pi^{+}\pi^{-}\pi^{+}\pi^{-})/\Gamma_{t}$ $\frac{VALUE \text{ (units }10^{-4})}{<2}$ $\Gamma(\pi^{+}\pi^{-}\pi^{+}\pi^{-})/\Gamma_{t}$ $\frac{VALUE \text{ (units }10^{-4})}{\cdot \cdot $	otal $ \frac{c \iota \%}{90} $ $ \frac{c \iota \%}{90} $ $ \frac{c \iota \%}{90} $ $ 90 $ $ 90 $ $ \frac{c \iota \%}{90} $	DOCUMENT ID KURDADZE DOCUMENT ID data for average ERBE CHUNG HUSON JAMES DOCUMENT ID VASSERMAN DOCUMENT ID data for average BRAMON 32 ABRAMS 1, 2, or 3 for the DOCUMENT ID AULCHENKO	888 69 68 66 68 66 71 870 870 870	TECN OLYA TECN S, limits, HBC HBC HBC ND ND TECN ND TECN ND TECN ND TECN ND ND S, limits RVUE HBC ND ND S, limits S	CHG etc. • 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	$\begin{array}{c} \text{MENT} \\ - \\ - \\ + \pi^{-} \pi^{+} \pi^{-} \\ \end{array}$ $\begin{array}{c} \Gamma_{13}/\Gamma_{1} \\ 0 \bullet \bullet \\ 2.5 - 5.8 \ \gamma \rho \\ 3.2, 4.2 \ \pi^{-} \rho \\ 16.0 \ \pi^{-} \rho \\ 2.1 \ \pi^{+} \rho \\ \end{array}$ $\begin{array}{c} \Gamma_{12}/\Gamma \\ - \\ - \\ - \\ \pi^{+} \pi^{-} \pi^{0} \\ \end{array}$ $\begin{array}{c} \Gamma_{12}/\Gamma_{1} \\ 0 \bullet \bullet \\ 1/\psi \rightarrow \omega \pi^{0} \\ 3.7 \ \pi^{+} \rho \\ \end{array}$ $\begin{array}{c} \Gamma_{14}/\Gamma \\ 0 \bullet \bullet \\ - \\ - \\ - \\ - \\ - \\ - \\ - \\ - \\ -$
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34 Superseded by DOLINSKY 91.

 $^{
m 33}\,{\rm Bremsstrahlung}$ from a decay pion and for photon energy above 50 MeV.

35 Structure radiation due to quark rearrangement in the decay.

$\Gamma(\pi^0\gamma)/\Gamma_{ ext{total}}$			Г ₈ /Г
VALUE (units 10 ⁻⁴)	DOCUMENT ID	TECN	COMMENT
7.9±2.0	DOLINSKY 89	ND	$e^+e^- \rightarrow \pi^0 \gamma$

o(770)	DECE	DEN	CEC
<i>n</i> (//U)	KEFE	REN	C.E.S

			, ,	,	
BERNICHA	94	PR D50 4454		+Lopez Castro, Pestieau (LOUV	(, CINV)
ALDE	93	PAN 56 1229		+Binon+ (SERP, LAPP, LANL, BELG, BRUX	
WEIDENAUED		Translated from	YAF 56	5 137.	Callan
WEIDENAUER AGUILAR	93	ZPHY C59 387 ZPHY C50 405		+Duch+ (ASTERIX Aguilar-Benitez, Allison, Batalor+ (LEBC-EHS	
DOLINSKY	91	PRPL 202 99		+Druzhinin, Dubrovin+	(NOVO)
ANTIPOV	89	ZPHY C42 185		+Batarin+ (SERP, JINR, BGNA, MILA	A, TBIL)
DOLINSKY	89	ZPHY C42 511		+Druzhinin, Dubrovin, Golubev+	(NOVO)
DUBNICKA	89	JPG 15 1349		+Martinovic+ \ (JINR	, SLOV)
GESHKENBEIN KURDADZE	88	ZPHY 45 351 JETPL 47 512		+Leltchouk, Pakhtusova, Sidorov+	(ITEP) (NOVO)
KOKDADZE	00	Translated from	ZETFP	47 432.	(14040)
VASSERMAN	88	SJNP 47 1035		+Golubey, Dolinsky+	(NOVO)
VASSERMAN	88B	Translated from SJNP 48 480	YAF 47	7 1635. +Golubev, Dolinsky+	(NOVO)
VASSERIVIAIN	000	Translated from	YAF 48	+Goldbev, Dollinsky+ 3 753.	(14040)
AULCHENKO	87C	IYF 87-90 Prep	rint	+Dolinsky, Druzhinin+	(NOVO)
CAPRARO	87	NP B288 659		+Levy+ (CLER, FRAS, MILA, PISA, LCGT,	
BRAMON HUSTON	86 86	PL B173 97 PR 33 3199		+Casulleras +Berg, Collick, Jonckheere+ (ROCH, FNAL	(BARC)
KURDADZE	86	JETPL 43 643			(NOVO)
		Translated from	ZETFP	43 497.	
BARKOV	85	NP B256 365			(NOVO)
CHABAUD JENSEN	83 83	NP B223 1 PR D27 26		+Gorlich, Cerrada+ (CERN, CRAC, +Berg, Biel, Collick+ (ROCH, FNAL	
HEYN	81	ZPHY C7 169		+Lang	(GRAZ)
BOHACIK	80	PR D21 1342			, WIEN)
LANG	79	PR D19 956		+Mas-Parareda	(GRAZ)
BARTALUCCI	78	NC 44A 587			, FRAS)
WICKLUND	78 77	PR D17 1197 PRL 38 198		+Ayres, Diebold, Greene, Kramer, Pawlicki	(ANL)
ANDREWS DEUTSCH	76	NP B103 426		+Fukushima, Harvey, Lobkowicz, May+ Deutschmann+ (AACH3, BERL, BONN,	(ROCH)
ENGLER	74	PR D10 2070		+Kraemer, Toaff, Weisser, Diaz+ (CMU	, CASE)
ESTABROOKS	74	NP B79 301		+Martin	(DURH) MPIM)
GRAYER	74	NP B75 189		+Hyams, Blum, Dietl+ (CERN	MPIM)
BYERLY GLADDING	73 73	PR D7 637 PR D8 3721		+Anthony, Coffin, Meanley, Meyer, Rice+ +Russell, Tannenbaum, Weiss, Thomson	(MICH) (HARV)
PROTOPOP	73	PR D7 1279		Protopopescu, Alston-Garnjost, Galtieri, Flatte+	(LBL)
BALLAM	72	PR D5 545		+Chadwick, Bingham, Milburn+ (SLAC, LBL,	TUFTS)
BENAKSAS	72	PL 39B 289		+Cosme, Jean-Marie, Jullian, Laplanche+ (ORSAY)
JACOBS RATCLIFF	72 72	PR D6 1291 PL 38B 345		+Bulos, Carnegie, Kluge, Leith, Lynch+	(SACL) (SLAC)
ABRAMS	71	PR D4 653		+Barnham, Butler, Coyne, Goldhaber, Hall+	(LBL)
ALVENSLEBEN		PRL 24 786		+Becker, Bertram, Chen, Cohen	(DESY)
BIGGS	70	PRL 24 1197		+Braben, Clifft, Gabathuler, Kitching+	(DARE)
ERBE MALAMUD	69	PR 188 2060	93	+Hilpert+ (German Bubble Chamber	
REYNOLDS	69 69	Argonne Conf. PR 184 1424	93	+Schlein +Albright, Bradley, Brucker, Harms+	(UCLA) (FSU)
ROTHWELL	69	PRL 23 1521		+Chase, Earles, Gettner, Glass, Weinstein+	(NEAS)
WEHMANN	69	PR 178 2095		+ (HARV, CASE, SLAC, CORN	, MCGI)
ARMENISE	68	NC 54A 999		+Ghidini, Forino+ (BARI, BGNA, FIRZ,	
BATON CHUNG	68 68	PR 176 1574 PR 165 1491		+Laurens +Dahl, Kirz, Miller	(SACL)
FOSTER	68	NP B6 107		+Gavillet, Labrosse, Montanet+ (CERN	(LRL) , CDEF)
HUSON	68	PL 28B 208		+Lubatti, Six, Veillet+ (ORSAY, MILA	UCLA)
HYAMS	68	NP B7 1		+Koch, Potter, Wilson, VonLindern+ (CERN,	MPIM)
LANZEROTTI	68	PR 166 1365		+Blumenthal, Ehn, Faissler+	(HARV)
PISUT ASBURY	68 67B	NP B6 325 PRL 19 865		+Roos +Becker, Bertram, Joos, Jordan+ (DESY	(CERN) COLU)
BACON	67	PR 157 1263		+Fickinger Hill Honkins Robinson+	(BNL)
EISNER	67	PR 164 1699		+Fickinger, Hill, Hopkins, Robinson+ +Johnson, Klein, Peters, Sahni, Yen+	(PURD)
HUWE	67	PL 24B 252		+Marquit, Oppenheimer, Schultz, Wilson	(COLU)
HYAMS	67	PL 24B 634			MPIM)
MILLER ALFF	67B 66	PR 153 1423 PR 145 1072			(PURD) RUTG)
FERBEL	66	PL 21 111		And Stemberger, Beney+ (COLO,	(ROCH)
HAGOPIAN	66	PR 145 1128		+Selove, Alitti, Baton+ (PENN	, SACL)
HAGOPIAN	66B	PR 152 1183			N, LRL)
JACOBS	66B 66	UCRL 16877		I Kensikili (MA)	(LRL) E, BNL)
JAMES WEST	66	PR 142 896 PR 149 1089		+Kraybill +Boyd, Erwin, Walker (YAL	(WISC)
BLIEDEN	65	PL 19 444		+Freytag, Geibel+ (CERN Missing Mass Spect.	Collab.)
CARMONY	64	PRL 12 254		+Lander, Rindfleisch, Xuong, Yager	(UCB) L, UCB)
GOLDHABER ABOLINS	64	PRL 12 336		+Brown, Kadyk, Shen+ (LR	L, UCB)
	63	PRL 11 381		+Lander, Mehlhop, Nguyen, Yager	(UCSD)

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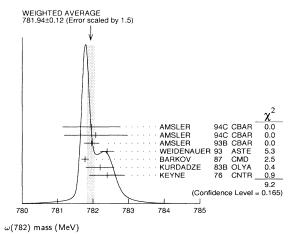


$$I^{G}(J^{PC}) = 0^{-}(1^{-})$$

ω (782) MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
781.94±0.12 OUR AV	/ERAGE	Error includes scale	facto	or of 1.5.	See the ideogram below.
$781.96 \pm 0.17 \pm 0.80$	11k	AMSLER			$0.0 \ \overline{p} p \rightarrow \omega \pi^0 \pi^0$
$782.08 \pm 0.36 \pm 0.82$	3463	AMSLER			$0.0 \overline{\rho} \rho \rightarrow \omega \eta \pi^0$
$781.96 \pm 0.13 \pm 0.17$	15k	AMSLER			$0.0 \overline{p} \rho \rightarrow \omega \pi^0 \pi^0$
782.4 ±0.2	270k	WEIDENAUER	93	ASTE	$\overline{p}p \rightarrow 2\pi^{+}2\pi^{-}\pi^{0}$
781.78 ± 0.10		BARKOV		CMD	
782.2 ±0.4	1488	KURDADZE	83B	OLYA	$e^+e^- \rightarrow \pi^+\pi^-\pi^0$
782.4 ±0.5	7000	1 KEYNE	76	CNTR	$\pi^- p \rightarrow \omega n$
• • • We do not use	the follow	ing data for averages	, fits	, limits,	etc. • • •
783.3 ±0.4		CORDIER	80	WIRE	$e^+e^- \rightarrow \pi^+\pi^-\pi^0$
782.5 ±0.8	33260	ROOS	80	RVUE	0.0−3.6 p p
782.6 ±0.8	3000	BENKHEIRI	79	OMEG	9-12 $\pi^{\pm} \rho$
781.8 ±0.6	1430	COOPER	78B	HBC	$0.7-0.8 \ \overline{\rho} \rho \rightarrow 5\pi$
782.7 ±0.9	535	VANAPEL	78	HBC	$7.2 \overline{\rho} \rho \rightarrow \overline{\rho} \rho \omega$
783.5 ±0.8	2100	GESSAROLI	77	HBC	11 $\pi^- \rho \rightarrow \omega n$
782.5 ± 0.8	418	AGUILAR	72B	HBC	3.9,4.6 K ⁻ p
783.4 ±1.0	248	BIZZARRI	71	HBC	$0.0 \ \rho \overline{\rho} \rightarrow K^+ K^- \omega$
781.0 ±0.6	510	BIZZARRI	71	HBC	$0.0 \ p \overline{p} \rightarrow K_1 K_1 \omega$
783.7 ±1.0	3583	² COYNE	71	HBC	$3.7 \pi^+ p \rightarrow$
					$\rho \pi^{+} \pi^{+} \pi^{-} \pi^{0}$
784.1 ±1.2	750	ABRAMOVI	70	HBC	3.9 π ⁻ p
783.2 ± 1.6		³ BIGGS	70B	CNTR	$<$ 4.1 γ C \rightarrow $\pi^+\pi^-$ C
782.4 ±0.5	2400	BIZZARRI	69	HBC	0.0 p p

- 1 Observed by threshold-crossing technique. Mass resolution = 4.8 MeV FWHM. 2 From best-resolution sample of COYNE 71. 3 From $\omega\text{-}\rho$ interference in the $\pi^+\pi^-$ mass spectrum assuming ω width 12.6 MeV.



ω (782) WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
8.43±0.10 OUR AV		DOCUMENT ID		/ LC/V	COMMENT
8.4 ±0.1		⁴ AULCHENKO	87 1	ND	$e^{+}e^{-} \rightarrow \pi^{+}\pi^{-}\pi^{0}$
8.30 ± 0.40		BARKOV	87 (CMD	$e^{+}e^{-} \rightarrow \pi^{+}\pi^{-}\pi^{0}$
9.8 ±0.9	1488	KURDADZE	83B (OLYA	$e^+e^- \rightarrow \pi^+\pi^-\pi^0$
9.0 ±0.8		CORDIER	80 V	WIRE	$e^+e^- \rightarrow \pi^+\pi^-\pi^0$
9.1 ±0.8		BENAKSAS	72B (OSPK	e^+e^-
• • • We do not use	the following	ng data for averages	, fits,	limits,	etc. • • •
12 ±2	1430	COOPER	78B F	нвс	$0.7-0.8 \ \overline{p} p \rightarrow 5\pi$
9.4 ±2.5	2100	GESSAROLI	77 F	нвс	$11 \pi^- p \rightarrow \omega n$
10.22 ± 0.43	20000	⁵ KEYNE	76 (CNTR	$\pi^- p \rightarrow \omega n$
13.3 ±2	418	AGUILAR	728 H	HBC	3.9,4.6 K ⁻ p
10.5 ± 1.5		BORENSTEIN	72 H	нвс	2.18 K ⁻ p
$7.70 \pm 0.9 \pm 1.15$	940	BROWN	72 1	MMS	$2.5 \pi^- p \rightarrow nMM$
10.3 ±1.4	510	BIZZARRI	71 H	HBC	$0.0 \ p \overline{p} \rightarrow K_1 K_1 \omega$
12.8 ±3.0	248	BIZZARRI	71 F	нвс	$0.0 \ p \overline{p} \rightarrow K^{+} K^{-} \omega$
9.5 ±1.0	3583	COYNE	71 H	нвс	$3.7 \pi^+ \rho \rightarrow$
					$0\pi^{+}\pi^{+}\pi^{-}\pi^{0}$

 $^{^4}$ Relativistic Breit-Wigner includes radiative corrections. 5 Observed by threshold-crossing technique. Mass resolution = 4.8 MeV FWHM.

 ω (782)

 0.084 ± 0.013

 0.109 ± 0.025

 0.081 ± 0.020 0.13 ± 0.04

	ω (782) DECAY MODES			$\Gamma(\pi^+\pi^-\gamma)/\Gamma(\pi^+$	$\pi^{-}\pi^{0}$				Γ ₁₀ /Γ
Mode	Fraction (F	:/F) Confid	ence level	VALUE ■ ■ We do not use	CL%	DOCUMENT ID		<u>COMMENT</u>	
$\frac{\pi^{+}\pi^{-}\pi^{0}}{\pi^{0}}$	(88.8 ±	····		<0.066	90	KALBFLEISC		2.18 K = p -	•
$\pi^0\gamma$	(8.5 ±	*						$\Lambda \pi^+ \pi^- \gamma$,
$\pi^+\pi^-$	(2.21 \pm			<0.05	90	FLATTE	66 HBC	$1.2 - 1.7 K^{-}$ $\Lambda \pi^{+} \pi^{-} \gamma$	
neutrals (excluding	$(\pi^0 \gamma)$ (5.3 \pm	$^{8.7}_{3.5}$) × 10 ⁻³		F(+ \)/F				,,, ,	
$\eta \gamma$	(8.3 ±	$2.1) \times 10^{-4}$		$\Gamma(\pi^+\pi^-\gamma)/\Gamma_{\text{total}}$	<u>CL%_</u>	DOCUMENT IE) TECN	COMMENT	Γ ₁₀ ,
$\pi^{0}e^{+}e^{-}$		1.9) × 10 ⁻⁴		<0.0036	95			$p\overline{p} \rightarrow \pi^{+}\pi$	- _{π+π} -
$\pi^0 \mu^+ \mu^- = e^+ e^-$		2.3×10^{-5} 0.19×10^{-5}		• • • We do not use	the following	ng data for averag			
$_{9}^{3}$ $_{\pi}^{+}$ $_{\pi}^{-}$ $_{\pi}^{0}$ $_{\pi}^{0}$	< 2	%	90%	< 0.004	95	BITYUKOV	88B SPEC	32 $\pi^- p \rightarrow$	$\pi^+\pi^-\gamma$
$_{0}$ $_{\pi^{+}\pi^{-}\gamma}$	< 3.6	× 10 ⁻³	95%	$\Gamma(\pi^{+}\pi^{-}\pi^{+}\pi^{-})/$	Γ _{total}				Γ ₁₁
$\frac{\pi^{+}\pi^{-}\pi^{+}\pi^{-}}{2\pi^{0}\pi^{0}\gamma}$	< 1	$\times 10^{-3}$ 2.5) $\times 10^{-5}$	90%	VALUE	CL%	DOCUMENT IE			
$\frac{12}{13} \mu^{+} \mu^{-}$	(7.2 ± < 1.8	× 10 ⁻⁴	90%	<1 × 10 ⁻³	90	KURDADZE	88 OLYA	$e^+e^{\pi^+\pi^-\pi^+}$	π-
4 3γ	< 2	× 10 ⁻⁴	90%	$\Gamma(\pi^+\pi^-\pi^0\pi^0)/\Gamma$					Го
	Charge conjugation (C)			VALUE (units 10 ⁻²)	CL%	DOCUMENT ID) TECN	COMMENT	' '
$\eta \pi^0$	C < 1	× 10 ⁻³	90%	<2	90	KURDADZE		$e^+e^- \rightarrow \pi$	$+\pi - \pi^{0}$
$3\pi^0$	C < 3	× 10 ⁻⁴	90%	r(+)/r(-+-	0\				r . /
CON	STRAINED FIT INFORMAT	ION		$\Gamma(\mu^+\mu^-)/\Gamma(\pi^+\pi^-)$ VALUE (units 10^{-3})	τ π^ο)	DOCUMENT IE) TECN	COMMENT	Γ ₁₃ /
				<0.2	90	WILSON		12 π [−] C →	Fe
	branching ratios uses 20 measu ermine 4 parameters. The overa			• • We do not use					
10.3 for 17 degree				<1.7	74	FLATTE	66 HBC	1.2 - 1.7 K	<i>p</i> →
ne following <i>off-diagor</i>	nal array elements are the	correlation co	efficients	<1.2		BARBARO	. 65 HBC	$\Lambda \mu^{+} \mu^{-}$ 2.7 $K^{-} \rho$	
	rcent, from the fit to the bra				`			, -·· ·· •	_
$_i/\Gamma_{total}$. The fit constr	ains the x_i whose labels appea			$\Gamma(\pi^0\pi^0\gamma)/\Gamma(\pi^0\gamma)$		_EVTS DOC	UMENT ID	TECN COM	Г _{12,} _{1МЕNТ}
e.				0.00085±0.00029		40 ± ALC		4B GAM2 38π	
x ₂ 13						14	es. 11 t.		$r^0\pi^0\gamma n$
x ₃ -39 -5				• • • We do not use < 0.005	e the following			1	
<i>x</i> ₄	**** <u>1</u>							7	$\vec{o}_{\pi}\vec{o}_{\gamma}$
<i>x</i> ₁ <i>x</i> ₂	<i>x</i> ₃			< 0.18 < 0.15	95 90	KE)		6 CNTR π^- 2C OSPK e^+	
	ω(782) PARTIAL WIDTHS			< 0.14	30			1 HLBC 2.9	
			Гв	< 0.1	90	BAF	RMIN 6	4 HLBC 1.3-	$-2.8 \pi^{-} \mu$
(e+e-) A <i>LUE</i> (keV)	DOCUMENT ID		18	$\Gamma(\eta\pi^0)/\Gamma_{ m total}$					Γ ₁₅
60±0.02 OUR EVALUATION	ON			Violates C con VALUE	servation. 	DOCUMENT ID	TECN	COMMENT	
	(782) BRANCHING RATIOS	:		<0.001	90	ALDE		$38\pi^- p \rightarrow r$	$\pi^0 n$
	•			$\lceil \Gamma(\eta \gamma) + \Gamma(\eta \pi^0) vert$	1/r/a+	0\		(r-	;+Γ ₁₅)/
$(\text{neutrals})/\Gamma(\pi^+\pi^-\pi^0)$		•	+Γ ₄)/Γ ₁	U (1/1) T (1/1/)]/1 (N N	DOCUMENT ID) TECN	COMMENT	ı⊤ı 15 <i>)</i> /
102±0.008 OUR FIT	3 DOCOMENT ID TECH	COMMENT		<0.016	90	8 FLATTE	66 HBC	1.2 - 1.7 K	,
$103^{+0.011}_{-0.010}$ OUR AVERAG	E			• • • We do not use	e the followin	ng data for averag	es, fits, limit	$\Lambda \pi^+ \pi^- N$ s. etc. • • •	ИΜ
15 ±0.04 4		3.9,4.6 K ⁻ p		< 0.045	95	JACQUET	69B HLBC		
10 ±0.03 1				⁸ Restated by us us	$singBR(\eta \rightarrow$	charged modes)	=(29.2)%.		
134±0.026 85 097±0.016 34		R 1.4 π ⁻ ρ 1.4 - 1.7 K ρ	\rightarrow	Γ(neutrals)/Γ(cha	arged partic	:les)		$(\Gamma_2 + \Gamma_4)$)/(F ₁ +1
		AMM		VALUE		DOCUMENT IE	<u>TECN</u>		.,
$06 \begin{array}{c} +0.05 \\ -0.02 \end{array}$ $08 \begin{array}{c} \pm 0.03 \end{array}$	JAMES 66 HBC 5 KRAEMER 64 DBC			0.099±0.008 OUR F 0.124±0.021	IT.	FELDMAN	67C OSP4	1.2 π ⁻ p	
	owing data for averages, fits, limit				ő.	ILLUWAN	UIC OSPN	1.2 n p	
11 ±0.02 2	-			$\Gamma(\pi^0\pi^0\gamma)/\Gamma(\pi^+)$	•				Γ _{12/}
$(\pi^+\pi^-)/\Gamma(\pi^+\pi^-\pi^0)$			Γ_3/Γ_1	<u>∨ALUE</u> <0.000 45	<u>CL%</u> 90	DOCUMENT IE DOLINSKY	89 ND	$e^+e^- \rightarrow \pi$	0 , 0 ~
See also $\Gamma(\pi^+\pi^-)/\Gamma_{t}$	otal·		J, 1	• • We do not use					" 1
0249±0.0035 OUR FIT	DOCUMENT ID TECN	COMMENT		< 0.08	95	JACQUET	69B HLBC		
026 ±0.005 OUR AVERA	AGE			$\Gamma(\eta\gamma)/\Gamma(\pi^0\gamma)$					Γ ₅ ,
$021 \begin{array}{c} +0.028 \\ -0.009 \end{array}$	6 RATCLIFF 72 ASP	$<$ 15 $\pi^- \rho \rightarrow n^2$	2π	VALUE		DOCUMENT IE	<u>TEÇN</u>	COMMENT	' 5/
028 ±0.006	BEHREND 71 ASPE	C Photoproduction of the contract of the co	n	0.0098±0.0024		9 ALDE	93 GAM2	$38\pi^-\rho \rightarrow \omega$	o n
$022 \begin{array}{c} +0.009 \\ -0.01 \end{array}$	7 ROOS 70 RVU	E		• • • We do not use	e the following				
⁶ Significant interference ef	fect observed. NB of $\omega \to 3\pi$ co	mes from an extra	polation.	0.0082 ± 0.0033 0.039 ± 0.007		10 DOLINSKY 11 DOLINSKY	89 ND 89 ND	$e^+e^- \rightarrow \eta$ e^+e^-	γ
	AMOVICH 70 and BIZZARRI 70.			0.010 ±0.045		APEL		4-8 π ⁻ ρ →	n3γ
$(\pi^0\gamma)/\Gamma(\pi^+\pi^-\pi^0)$			Γ_2/Γ_1	9 Model independe					
LUE 096±0.006 OUR FIT	DOCUMENT ID TECN	COMMENT		¹⁰ Solution correspondence of the second s		nstructive ω - ρ in	terference. T	he quark mod	el predic
96±0.006 OUR AVERAG	E DOLINSKY 89 ND	+ - 0		11 Solution correspo		tructive $ ho$ - ω inte	rference.		
099 ± 0.007									

 $\Gamma(\pi^0 \mu^+ \mu^-)/\Gamma_{
m total}$

VALUE (units 10⁻⁴)

0.96±0.23

 Γ_7/Γ

DOCUMENT ID TECN COMMENT

DZHELYADIN 81B CNTR 25-33 $\pi^- p \rightarrow \omega n$

DOLINSKY 89 ND $e^+e^- \rightarrow \pi^0 \gamma$ KEYNE 76 CNTR $\pi^- p \rightarrow \omega n$ BENAKSAS 72c OSPK e^+e^- BALDIN 71 HLBC 2.9 $\pi^+ p$ JACQUET 69B HLBC

 ω (782)

$\Gamma(\pi^0 e^+ e^-)/\Gamma_{\text{total}}$					Γ ₆ /Ι
/ALUE (units 10 ⁻⁴)	EVTS	DOCUMENT ID		TECN	COMMENT
5.9±1.9	43	DOLINSKY	88	ND	$e^+e^- \rightarrow \pi^0 e^+e^-$
$(e^+e^-)/\Gamma_{\text{total}}$					Г ₈ /I
ALUE (units 10 ⁻⁴)	EVTS	DOCUMENT ID		TECN	COMMENT
.715±0.019 OUR AVE	RAGE	DOLINSKY	89	ND	$e^+e^- \rightarrow \pi^+\pi^-\pi^0$
0.72 ±0.03		BARKOV	87	CMD	$e^+e^- \rightarrow \pi^+\pi^-\pi^0$
0.66 ±0.05		KURDADZE	84	OLYA	$e^+e^- \rightarrow \text{hadrons}$
0.675±0.069		CORDIER	80	WIRE	$e^+e^- \rightarrow 3\pi$
0.83 ±0.10 0.77 ±0.06		BENAKSAS ¹² AUGUSTIN		OSPK	$e^+e^- \rightarrow 3\pi$ $e^+e^- \rightarrow 2\pi$
• • We do not use the	he followir				
0.64 ±0.04	1488	¹³ KURDADZE		OLYA	$e^+e^- \rightarrow \pi^+\pi^-\pi^0$
.65 ±0.13	33	¹⁴ ASTVACAT		OSPK	Assume SU(3)+mixing
12 Rescaled by us to counties 13 Superseded by KUR 14 Not resolved from $ ho$	DADZE 8	34.			
	decay. L	nor statistical only	,.		/E \ E \ \ /r
"(neutrals)/Γ _{total}	EVTS	DOCUMENT ID		TECN	(Γ ₂ +Γ ₄)/Γ
.090±0.006 OUR FIT					
0.081±0.011 OUR AVE	RAGE	DIZZADDI	71	LIDC	00-=
0.075 ± 0.025 0.079 ± 0.019		BIZZARRI DEINET	71 69B	HBC OSPK	$0.0 \ \rho \overline{\rho}$ $1.5 \ \pi^- \rho$
$.084 \pm 0.015$		BOLLINI	68C	CNTR	2.1 π p
• • We do not use the	ne followir				
0.073 ± 0.018	42	BASILE	72B	CNTR	1.67 π ⁻ p
$(\pi^+\pi^-)/\Gamma_{\text{total}}$					Г ₃ /Г
See also $\Gamma(\pi^+\pi^-$	-)/Γ(π ⁺ π				2,
0.0221±0.0030 OUR F	IT	DOCUMENT ID		TECN	COMMENT
0.021 ±0.004 OUR A					
.023 ±0.005		BARKOV	85	OLYA	e^+e^-
$.016 \begin{array}{l} +0.009 \\ -0.007 \end{array}$		QUENZER	78	CNTR	e^+e^-
• We do not use the	ne followir	ig data for average	es, fits	, limits,	etc. • • •
.010 ±0.001		¹⁵ WICKLUND	~~		3,4,6 π^{\pm} N
		WICKLUND	78	ASPK	3,4,6 T-1V
$.0122 \pm 0.0030$					Photoproduction
$.0122 \pm 0.0030$ $.013 \begin{array}{c} +0.012 \\ -0.009 \end{array}$					
$.013 \begin{array}{l} +0.012 \\ -0.009 \end{array}$		ALVENSLEBE	71 71	CNTR HBC	Photoproduction
0.0080 + 0.0028 - 0.002 15 From a model-depe	ndent ana	ALVENSLEBE MOFFEIT 16 BIGGS lysis assuming con	71 708 70lete	CNTR HBC CNTR coherer	Photoproduction 2.8,4.7 $\gamma \rho$ 4.2 γ C $\rightarrow \pi^+\pi^-$ C
0.013 +0.012 -0.009 0.0080 +0.0028 -0.002	$\Gamma(\pi^+\pi^-)$	ALVENSLEBS MOFFEIT 16 BIGGS lysis assuming con $\frac{1}{\Gamma(\pi^+\pi^-\pi^0)}$ by	71 708 70lete	CNTR HBC CNTR coherer	Photoproduction 2.8,4.7 $\gamma \rho$ 4.2 γ C $\rightarrow \pi^+\pi^-$ C
0.013 + 0.012 - 0.009 0.0080 + 0.0028 - 0.002 0.0080 + 0.002 15 From a model-depe 16 Re-evaluated under ρ photoproduction of	Γ(π ⁺ π ⁻) cross-section	ALVENSLEBS MOFFEIT 16 BIGGS lysis assuming con $\frac{1}{\Gamma(\pi^+\pi^-\pi^0)}$ by	71 708 70lete	CNTR HBC CNTR coherer	Photoproduction $2.8,4.7\ \gamma\ p$ $4.2\gamma\ C\ \rightarrow\ \pi^+\pi^-\ C$ ince. $1\ \text{using more accurate }\omega\ -$
0.013 + 0.012 - 0.009 0.0080 + 0.0028 0.0080 - 0.002 15 From a model-depe 16 Re-evaluated under ρ photoproduction of $(\pi^0 \pi^0 \gamma)/\Gamma$ (neutra	Γ(π ⁺ π ⁻) cross-section	ALVENSLEBS MOFFEIT 16 BIGGS lysis assuming con $\frac{1}{\Gamma(\pi^+\pi^-\pi^0)}$ by	71 708 1 plete BEHI	CNTR HBC CNTR coherer REND 7	Photoproduction 2.8,4.7 γp 4.2 γ C $\rightarrow \pi^+\pi^-$ C area. 1 using more accurate ω – $\Gamma_{12}/(\Gamma_2+\Gamma_4)$
0.013 + 0.012 - 0.009 0.0080 + 0.0028 0.0080 - 0.002 15 From a model-depe 16 Re-evaluated under ρ photoproduction of $(\pi^0 \pi^0 \gamma)/\Gamma$ (neutra	$\Gamma(\pi^+\pi^-)$ cross-section (IS) $\frac{CL\%}{L}$	ALVENSLEBE MOFFEIT 16 BIGGS lysis assuming con $/\Gamma(\pi^+\pi^-\pi^0)$ by on ratio.	71 708 nplete BEHI	CNTR HBC CNTR coherer REND 7	Photoproduction 2.8,4.7 γp 4.2 γ C $\rightarrow \pi^+\pi^-$ C ince. 1 using more accurate ω – $\Gamma_{12}/(\Gamma_2+\Gamma_4)$ COMMENT
0.013 + 0.012 - 0.009 0.0080 + 0.0028 0.0080 + 0.0028 15 From a model-depe 0.0080 + 0.002 16 Re-evaluated under 0.0080 + 0.002 0.0080 + 0.002 0.0090 + 0.002	$\Gamma(\pi^+\pi^-)$ cross-section $\Gamma(\pi^+\pi^-)$ $\Gamma($	ALVENSLEBE MOFFEIT 16 BIGGS lysis assuming con $/\Gamma(\pi^+\pi^-\pi^0)$ by on ratio. $\frac{DOCUMENT\ ID}{\pi} \ data \ for average 17\ DAKIN$	71 70B 1 plete BEHI es, fits	CNTR HBC CNTR coherer REND 7	Photoproduction 2.8,4.7 γp 4.2 γ C $\rightarrow \pi^+\pi^-$ C ince. 1 using more accurate ω – $\Gamma_{12}/(\Gamma_2+\Gamma_4)$ COMMENT
.013 $^{+0.012}_{-0.009}$.0080 $^{+0.0028}_{-0.002}$ 15 From a model-depe for evaluated under p photoproduction of $(\pi^0\pi^0\gamma)/\Gamma$ (neutrandlue) • We do not use the opening of the op	$\Gamma(\pi^+\pi^-)$ cross-section $\Gamma(\pi^+\pi^-)$ $\Gamma($	ALVENSLEBE MOFFEIT 16 BIGGS lysis assuming con $//\Gamma(\pi^+\pi^-\pi^0)$ by on ratio. DOCUMENT ID ag data for average	71 70B 1 plete BEHI es, fits	CNTR HBC CNTR coherer REND 7	Photoproduction 2.8,4.7 γp 4.2 $\gamma C \rightarrow \pi^+\pi^- C$ ince. 1 using more accurate ω – $\Gamma_{12}/(\Gamma_2+\Gamma_4)$ etc. • • •
.013 $^{+0.012}_{-0.009}$.0080 $^{+0.0028}_{-0.002}$ 15 From a model-depe 16 Re-evaluated under $_{\rho}$ photoproduction of $_{\rho}$ ($\pi^0\pi^0\gamma$)/ Γ (neutrandlue) • We do not use the operation of $_{\rho}$	$\Gamma(\pi^+\pi^-)$ cross-section $\Gamma(\pi^+\pi^-)$ $\Gamma($	ALVENSLEBE MOFFEIT 16 BIGGS lysis assuming con $/\Gamma(\pi^+\pi^-\pi^0)$ by on ratio. $\frac{DOCUMENT\ ID}{\pi} \ data \ for average 17\ DAKIN$	71 70B 1 plete BEHI es, fits	CNTR HBC CNTR coherer REND 7	Photoproduction 2.8,4.7 γp 4.2 $\gamma C \rightarrow \pi^+\pi^- C$ ince. 1 using more accurate ω – $\Gamma_{12}/(\Gamma_2+\Gamma_4)$ etc. • • •
.013 $^{+0.012}_{-0.009}$.0080 $^{+0.0028}_{-0.002}$ 15 From a model-depe 16 Re-evaluated under ρ photoproduction of $(\pi^0\pi^0\gamma)/\Gamma$ (neutral ALUE) • • We do not use the 0.22 ± 0.07 <0.19 17 See $\Gamma(\pi^0\gamma)/\Gamma$ (neutral Γ) and Γ	$\Gamma(\pi^+\pi^-)$ cross-section $\Gamma(\pi^+\pi^-)$ $\Gamma($	ALVENSLEBE MOFFEIT 16 BIGGS lysis assuming con $/\Gamma(\pi^+\pi^-\pi^0)$ by on ratio. $\frac{DOCUMENT\ ID}{\pi} \ data \ for average 17\ DAKIN$	71 70B 1 plete BEHI es, fits	CNTR HBC CNTR coherer REND 7	Photoproduction 2.8,4.7 γp 4.2 γ C $\rightarrow \pi^+\pi^-$ C ince. 1 using more accurate ω – $\frac{\Gamma_{12}/(\Gamma_2+\Gamma_4)}{\text{etc.} \bullet \bullet \bullet}$ 1.4 $\pi^-p \rightarrow n$ MM
0.013 + 0.012 - 0.009 0.0080 + 0.0028 0.0080 + 0.0028 0.0080 + 0.0028 15 From a model-depe 0.0080 + 0.0028 0.0080 + 0.0028 0.	$\Gamma(\pi^+\pi^-)$ cross-section $\Gamma(\pi^+\pi^-)$ $\Gamma($	ALVENSLEBE MOFFEIT 16 BIGGS lysis assuming con $/\Gamma(\pi^+\pi^-\pi^0)$ by on ratio. $\frac{DOCUMENT\ ID}{\pi} \ data \ for average 17\ DAKIN$	71 70B 1plete BEHI es, fits 72 69B	CNTR HBC CNTR coherer REND 7 TECN ;, limits, OSPK OSPK	Photoproduction 2.8,4.7 γp 4.2 γ C $\rightarrow \pi^+\pi^-$ C ince. 1 using more accurate ω – $\frac{\Gamma_{12}/(\Gamma_2+\Gamma_4)}{\text{etc.} \bullet \bullet \bullet}$ 1.4 $\pi^-p \rightarrow n$ MM
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.013 $^{+0.012}_{-0.009}$.0080 $^{+0.0028}_{-0.002}$.0080 $^{+0.0028}_{-0.002}$.15 From a model-depe 16 Re-evaluated under ρ photoproduction of $(\pi^0\pi^0\gamma)/\Gamma$ (neutral ALUE) • • We do not use the 0.22 \pm 0.07 (0.19) .77 See $\Gamma(\pi^0\gamma)/\Gamma$ (neutrals) .84 LUE • • We do not use the 0.78 \pm 0.07 .0.81 .18 Error statistical only decay($\eta\gamma$)/ Γ total .44 LUE (units 10^{-4}) • • We do not use the 0.32 \pm 0.33 (1.33 \pm 0.41 \pm 0.	$\Gamma\left(\pi^{+}\pi^{-}\right)$ ross-sections) Solution (18) $\Gamma\left(\pi^{+}\pi^{-}\right)$ Position (18) Positio	ALVENSLEBE MOFFEIT 16 BIGGS lysis assuming con $/\Gamma(\pi^+\pi^-\pi^0)$ by on ratio. DOCUMENT ID 17 DAKIN DEINET DOCUMENT ID 18 DAKIN DEINET S obtain good fit DOCUMENT ID 18 DAKIN DEINET S obtain good fit DOCUMENT ID 20 DOLINSKY 21 DOLINSKY	71 708 nplete BEHI 72 698 also a 89 89	CNTR HBC CNTR coherer REND 7 TECN , limits, OSPK OSPK TECN , limits, OSPK TECN , limits, OSPK GSM , limits, OSPK TECN ND ND ND	Photoproduction 2.8,4.7 γp 4.2 γ C $\rightarrow \pi^+\pi^-$ C ace. 1 using more accurate ω – $\frac{\Gamma_{12}/(\Gamma_2+\Gamma_4)}{COMMENT}$ etc. • • • 1.4 $\pi^-p \rightarrow n$ MM $\frac{\Gamma_2/(\Gamma_2+\Gamma_4)}{COMMENT}$ etc. • • • 1.4 $\pi^-p \rightarrow n$ MM as $\pi^0 \gamma$ as the only neutral $\frac{\Gamma_5}{\Gamma_6}$ etc. • • • $\frac{\Gamma_5}{\Gamma_6}$ etc. • • • $\frac{\Gamma_5}{\Gamma_6}$
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0.013 + 0.012 - 0.009 $0.0080 + 0.0028$ $0.0080 + 0.0028$ $0.0080 + 0.0028$ $0.0080 + 0.0028$ $0.0080 + 0.0028$ $0.0080 + 0.0028$ $0.0080 + 0.0028$ $0.0080 + 0.0028$ $0.0080 + 0.008$ 0.008	\((π + π - \) \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	ALVENSLEBE MOFFEIT 16 BIGGS lysis assuming con $/\Gamma(\pi^+\pi^-\pi^0) \text{ by}$ on ratio. DOCUMENT ID g data for average 17 DAKIN DEINET DOCUMENT ID g data for average 18 DAKIN DEINET s obtain good fit DOCUMENT ID g data for average 19 ALDE 20 DOLINSKY 21 DOLINSKY 21 ANDREWS 21 ANDREWS 21 ANDREWS tion. nstructive ω - ρ interpretations.	71 708 BEHI Personal Properties of the Propertie	CNTR HBC CNTR coherer REND 7 TECN , limits, OSPK OSPK TECN , limits, OSPK OSPK TECN , limits, OSPK CNTR CNTR CNTR CNTR CNTR CNTR	Photoproduction 2.8,4.7 γp 4.2 γ C $\rightarrow \pi^+\pi^-$ C ace. 1 using more accurate ω — $ \Gamma_{12}/(\Gamma_2+\Gamma_4) $ $COMMENT$ etc. • • • 1.4 $\pi^-p \rightarrow n$ MM $ \Gamma_2/(\Gamma_2+\Gamma_4) $ $COMMENT$ etc. • • • 1.4 $\pi^-p \rightarrow n$ MM as $\pi^0 \gamma$ as the only neutral Γ_5/Γ etc. • • • Γ_5/Γ Γ_6/Γ etc. • • • Γ_6/Γ $\Gamma_6/$
1013 $+0.012$ -0.009 $-0.0080 +0.0028$ -0.002 15 From a model-depel 16 Re-evaluated under ρ photoproduction of $(\pi^0\pi^0\gamma)/\Gamma$ (neutral ALUE) • • We do not use the 0.22 ± 0.07 <0.19 17 See $\Gamma(\pi^0\gamma)/\Gamma$ (neutrals) ALUE • • We do not use the 0.78 ± 0.07 >0.81 18 Error statistical only decay. • ($(\pi^0\gamma)/\Gamma$ total ALUE (units 10^{-4}) • • We do not use the 0.78 ± 0.07 >0.81 18 Error statistical only decay. • 10 My Γ (Γ (Γ (Γ (Γ)) • • We do not use the Γ (Γ) • • We do not use the Γ (Γ) • • We do not use the Γ (Γ) • • We do not use the Γ (Γ) • • We do not use the Γ (Γ) • • We do not use the Γ (Γ) • • We do not use the Γ (Γ) • • We do not use the Γ (Γ) • • We do not use the Γ (Γ) • • We do not use the Γ (Γ) • • We do not use the Γ (Γ) • • We do not use the Γ (Γ) • • We do not use the Γ (Γ) • • We do not use the Γ (Γ) • • We do not use the Γ (Γ) • • We do not use the Γ (Γ) • • We do not use the Γ (Γ) • • We do not use the Γ (Γ) • • We do not use the Γ (Γ)	Γ(π+π-) ross-sections) (Iss) CL% poly rais). CL% poly poly poly determinating to coo of zero. ing to des u-)	ALVENSLEBE MOFFEIT 16 BIGGS lysis assuming con $(\Gamma(\pi^+\pi^-\pi^0)) \text{ by on ratio.}$ $\frac{DOCUMENT\ ID}{\text{g}} \text{ data for average}$ 17 DAKIN DEINET $\frac{DOCUMENT\ ID}{\text{g}} \text{ data for average}$ 18 DAKIN DEINET s obtain good fit $\frac{DOCUMENT\ ID}{\text{g}} \text{ data for average}$ 19 ALDE 20 DOLINSKY 21 DOLINSKY 21 DOLINSKY 21 ANDREWS 21 ANDREWS 21 ANDREWS 21 ANDREWS 31 ANDREWS 31 ANDREWS 41 TOLINSKY 41 DOLINSKY 52 ANDREWS 53 ANDREWS 54 ANDREWS 55 ANDREWS 56 ANDREWS 57 ANDREWS 58 ANDREWS 59 ANDREWS 50 ANDREWS 51 ANDREWS	71 70B BEHI PER PROPERTY PROPE	CNTR HBC CNTR coherer REND 7 TECN , limits, OSPK OSPK TECN , limits, OSPK OSPK TECN , limits, CNTR CNTR CNTR CNTR CNTR CNTR CNTR CNTR	Photoproduction 2.8,4.7 γp 4.2 γ C $\rightarrow \pi^+\pi^-$ C ace. 1 using more accurate ω —
.013 $+0.012$.008 $+0.0028$.0080 $+0.0028$.0080 $+0.0028$.15 From a model-depel Re-evaluated under ρ photoproduction of	T(π+π-) ross-section (π+π-) ross-section (π+π	ALVENSLEBE MOFFEIT 16 BIGGS lysis assuming con $/\Gamma(\pi^+\pi^-\pi^0) \text{ by on ratio.}$ $\frac{DOCUMENT\ ID}{ID}$ In data for average to the properties obtain good fit $\frac{DOCUMENT\ ID}{ID}$ In data for average to the properties obtain good fit $\frac{DOCUMENT\ ID}{ID}$ In data for average to the properties obtain good fit $\frac{DOCUMENT\ ID}{ID}$ In data for average to the properties obtain good fit $\frac{DOCUMENT\ ID}{ID}$ In ALDE 20 ANDREWS 21 ANDREWS 22 ANDREWS 23 ANDREWS 24 ANDREWS 25 ANDREWS 26 ANDREWS 27 ANDREWS 28 ANDREWS 29 ANDREWS 20 ANDREWS 20 ANDREWS 21 ANDREWS 21 ANDREWS 22 ANDREWS 23 ANDREWS 24 ANDREWS 25 ANDREWS 26 ANDREWS 27 ANDREWS 28 ANDREWS 29 ANDREWS 20 ANDREWS 20 ANDREWS 20 ANDREWS 21 ANDREWS 21 ANDREWS 22 ANDREWS 23 ANDREWS 24 ANDREWS 25 ANDREWS 26 ANDREWS 27 ANDREWS 28 ANDREWS 29 ANDREWS 20 ANDREWS 20 ANDREWS 20 ANDREWS 21 ANDREWS 21 ANDREWS 21 ANDREWS 22 ANDREWS 23 ANDREWS 24 ANDREWS 25 ANDREWS 26 ANDREWS 27 ANDREWS 28 ANDREWS 29 ANDREWS 20 ANDREWS 20 ANDREWS 20 ANDREWS 21 ANDREWS 21 ANDREWS 22 ANDREWS 23 ANDREWS 24 ANDREWS 25 ANDREWS 26 ANDREWS 27 ANDREWS 28 ANDREWS 28 ANDREWS 29 ANDREWS 20 ANDREWS 20 ANDREWS 20 ANDREWS 21 ANDREWS 21 ANDREWS 21 ANDREWS	71 708 PEH PER	CNTR HBC CNTR Coherer REND 7 TECN , limits, OSPK OSPK TECN , limits, OSPK OSPK CNTR CNTR CNTR CNTR CNTR CNTR CNTR CNT	Photoproduction 2.8,4.7 γp 4.2 γ C $\rightarrow \pi^+\pi^-$ C ace. 1 using more accurate ω — $\Gamma_{12}/(\Gamma_2+\Gamma_4)$ etc. • • • 1.4 $\pi^-p \rightarrow n$ MM $\Gamma_{2}/(\Gamma_2+\Gamma_4)$ $\frac{COMMENT}{\epsilon}$ etc. • • • 1.4 $\pi^-p \rightarrow n$ MM $\Gamma_{3}/\Gamma_{2}/\Gamma_{2}+\Gamma_{4}/\Gamma_{4}/\Gamma_{5}$ $\frac{COMMENT}{\epsilon}$ etc. • • • 1.4 $\pi^-p \rightarrow n$ MM $\Gamma_{5}/\Gamma_{$
1.013 $^{+0.012}_{-0.009}$ 1.0080 $^{+0.0028}_{-0.002}$ 1.0080 $^{+0.0028}_{-0.002}$ 1.5 From a model-depe 16 Re-evaluated under $_{\rho}$ photoproduction of $^{-1}$ ($^{-1}$	T(π+π-) ross-section (π+π-) ross-section (π+π	ALVENSLEBE MOFFEIT 16 BIGGS lysis assuming con $/\Gamma(\pi^+\pi^-\pi^0) \text{ by on ratio.}$ $\frac{DOCUMENT\ ID}{ID}$ In data for average to the properties obtain good fit $\frac{DOCUMENT\ ID}{ID}$ In data for average to the properties obtain good fit $\frac{DOCUMENT\ ID}{ID}$ In data for average to the properties obtain good fit $\frac{DOCUMENT\ ID}{ID}$ In data for average to the properties obtain good fit $\frac{DOCUMENT\ ID}{ID}$ In ALDE 20 ANDREWS 21 ANDREWS 22 ANDREWS 23 ANDREWS 24 ANDREWS 25 ANDREWS 26 ANDREWS 27 ANDREWS 28 ANDREWS 29 ANDREWS 20 ANDREWS 20 ANDREWS 21 ANDREWS 21 ANDREWS 22 ANDREWS 23 ANDREWS 24 ANDREWS 25 ANDREWS 26 ANDREWS 27 ANDREWS 28 ANDREWS 29 ANDREWS 20 ANDREWS 20 ANDREWS 20 ANDREWS 21 ANDREWS 21 ANDREWS 22 ANDREWS 23 ANDREWS 24 ANDREWS 25 ANDREWS 26 ANDREWS 27 ANDREWS 28 ANDREWS 29 ANDREWS 20 ANDREWS 20 ANDREWS 20 ANDREWS 21 ANDREWS 21 ANDREWS 21 ANDREWS 22 ANDREWS 23 ANDREWS 24 ANDREWS 25 ANDREWS 26 ANDREWS 27 ANDREWS 28 ANDREWS 29 ANDREWS 20 ANDREWS 20 ANDREWS 20 ANDREWS 21 ANDREWS 21 ANDREWS 22 ANDREWS 23 ANDREWS 24 ANDREWS 25 ANDREWS 26 ANDREWS 27 ANDREWS 28 ANDREWS 28 ANDREWS 29 ANDREWS 20 ANDREWS 20 ANDREWS 20 ANDREWS 21 ANDREWS 21 ANDREWS 21 ANDREWS	71 70B nplete BEHI 72 69B 28s, fits 72 69B 389 89 77 77 referer	CNTR HBC CNTR Coherer REND 7 TECN , limits, OSPK OSPK TECN , limits, OSPK CNTR CNTR CNTR CNTR CNTR CNTR CNTR CNTR	Photoproduction 2.8,4.7 γp 4.2 γ C $\rightarrow \pi^+\pi^-$ C are. 1 using more accurate ω —

$\Gamma(\pi^{+}\pi^{-}\pi^{0})/\Gamma_{to}$ $VALUE$ 0.8942±0.0062		DOCUMENT ID DOLINSKY 89	TECN ND	$\frac{\Gamma_1/\Gamma}{\frac{COMMENT}{e^+e^- \rightarrow \pi^+\pi^-\pi^0}}$
$\Gamma(3\pi^0)/\Gamma_{\text{total}}$ Violates C co	nservation.			Γ ₁₆ /Γ
	C1.0/	DOCUMENT ID	TECH	COLUMENT
VALUE	<u>CL%</u> 90	DOCUMENT ID PROKOSHKIN 95	TECN GAM2	$\frac{COMMENT}{38 \pi^{-} \rho \rightarrow 3\pi^{0} n}$
VALUE <0.0003				
VALUE				$38 \pi^- \rho \rightarrow 3\pi^0 n$

ω (782) REFERENCES

PROKOSHKIN 55 55 342 277 Translated from DAN \$3 42 01. Boutement (SERP) BLIG, LANL, LAPP, MOYAL AMBLER 94	PROKOSHKIN	95	SPD 342 273		+Samoilenko	(SERP)
AMSLER 94C	ALDE.	QAR	Translated from DA	INS	342 610.	LADD MONT)
ALDE			PL B327 425			
Also	ALDE		PAN 56 1229		+Binon+ (SERP, LAPP LANL BELG.	BRUX, CERN)
AMSLER 938 PL B311 362	A1		Translated from YA	F 56	37.	DDUV CEDAN
WEIDENAUER 93			ZPHY C61 35		Armetrong v Dombrowski (Crystal	Barrel Collab)
WEDIDAULER 90 ZPHY C47 353 +Duch, Heel, Kalinowsky+ (ASTERIX Collab.) COLINSKY 80 ZPHY C42 511 +Duch, Heel, Kalinowsky+ (ASTERIX Collab.) ENTYthinin, Dubrovin, Golubev+ (NOVO) Tanslated from Yaf 41 (AST.) Collab.) Tanslated from Yaf 43 (AST.) Collab.) Collab.			7PHY C59 387		+Duch+ (AS	TERIX Collab.)
BITYUROV SBB S.NP 47 800	WEIDENAUER		ZPHY C47 353		+Duch, Heel, Kalinowsky+ (AS	TERIX Collab.)
Tanslated from VFF 47 1258			ZPHY C42 511		+Druzhinin, Dubrovin, Golubev+	
DOLINSKY String	BITYUKOV	888	SJNP 47 800 Translated from VA	F 4	+Borisov, Viktorov, Golovkin+	(SERP)
Translated from YAF 48 442. WIRDADZE 8 JEFFL 47 512 ZFFF + Leitchouk, Pakhtusova, Sidorov+ (NOVO) AULCHENKO 87 FLETEL 46 164	DOLINSKY	88	SJNP 48 277		+Druzhinin, Dubrovin, Golubev+	(NOVO)
Translated from ZETFP 47 432.			Translated from YA	F 48	3 442.	
AULCHENKO 87	KURDADZE	88	JETPL 47 512 Translated from 7F	TEP	+Leltchouk, Pakhtusova, Sidorov+	(NOVO)
Translated from ZETFP 46 132.		87	PL B186 432		+Dolinsky, Druzhinin, Dubrovin+	
SARROV SARROW S	BARKOV	87	JETPL 46 164		+Vasserman, Vorobev, Ivanov	(NOVO)
## Non-Page 19	KURDADZE	86	JETPI 43 643		+Lelchuk, Pakhtusova, Sidorov, Skrinskii+	(NOVO)
VIVERDADZE 84 YF 847 Preprint +Leltchouk, Pakhtusova, Sidorov+ (NOVO)			Translated from ZE	TFP	43 497.	, ,
Surprise Sab Series First Series Ser					+Chilingarov, Eidelman, Khazin, Lelchuk+	
DZHELYADIN 81B PL 1028 296 CORDIER 80 N B127 13 ROOS 80 LNC 27 321 ROOS 80 RNC 24 1201 ROOS 80 LNC 27 321 ROOS 80 LNC 27 321 ROOS 80 LNC 27 32 12 ROO	KURDADZE KURDADZE		IFTPL 36 274		+Leitchouk, Pakhtusova, Sidorov+ +Pakhtusova Sidorov+	
DZHELYADIN 81B PL 1028 296 CORDIER 80 N B127 13 ROOS 80 LNC 27 321 ROOS 80 RNC 24 1201 ROOS 80 LNC 27 321 ROOS 80 LNC 27 321 ROOS 80 LNC 27 32 12 ROO			Translated from ZE	TFP	36 221.	
Property	DZHELYADIN		PL 102B 296		+Golovkin, Konstantinov+	(SERP)
BENNHEIRI 79			INC 27 321		+Delcourt, Eschstruth, Fulda+ +Pellinen	(LALO)
COPER 78B NP 845 143 COOPER 78B NP 8146 1 COOPER CANAPEL			NP B150 268			CDEF, LALO
QUENZER 78 PL 716 512 VANAPEL 78 NP 8133 245 WICKLUND 78 PR D17 1197 ANDREWS 77 PRL 38 198 GESSAROLI 77 NP 8126 382 KEYNE 76 PR D14 28 Also 738 PR D8 2789 KALBFLEISCH 75 PR D11 987 KALBFLEISCH 75 PR D1 1987 KALBFLEISCH 75 PR D11 987 KALBFLEISCH 75 PR D1 1987 HAUSIANDER 18 PL 418 234 HBIGGS 702 PR D1 1559 HD ABMANGA 71 PR D2 149 COYNE 71 NP B32 343 HBIGGS 708 PR L2 1201 BIZZARRI 70 PR D3 249 ABRAMOVI 70 NP B32 349 BIZZARRI 70 PR L2 1201 BIZZARRI 69 PR 178 2095 ASTYACATH 76 PR L2 1201 BIZZARRI 69 PR 18 199 FILDMAN 67C PR 159 1219 FICLIOMAN 67C PR 159 1219 FICLIOMAN 67C PR 159 1219 FICLIOMAN 67C PR 159 1219 TORGET 77 AND 872 876 FILE REPARCE NOT A 1166 FILE REPARCE NOT A 1167 FILE	DZHELYADIN	79	PL 84B 143		+Golovkin, Gritsuk+	(SERP)
WICKLUND 78			NP B146 1		+Ganguli+ (TATA, CERN,	
WICKLUND 78			PL 76B 512 ND R133 245		+Kides, Kumpt, Bertrand, Bizot, Chase+	
ANDREWS			PR D17 1197		+Ayres, Diebold, Greene. Kramer. Pawlicki	(ANL)
GESSAROLI 77	ANDREWS	77	PRL 38 198		+Fukushima, Harvey, Lobkowicz, May+	(ROCH)
AGUILAR 728 PR D1 1987 AGUILAR 728 PR D6 29 APEL 728 Pl. 418 234 Aguilar-Benitez, Chapman Aguilar-Bentius, Chapman Aguilar-Benitez, Chapm	GESSAROLI		NP B126 382		+ (BGNA FIRZ GENO MIL	A, OXF, PAVI)
AGUILAR 728 PR D1 1987 AGUILAR 728 PR D6 29 APEL 728 Pl. 418 234 Aguilar-Benitez, Chapman Aguilar-Bentius, Chapman Aguilar-Benitez, Chapm					+Binnie, Carr, Debenham, Garbutt+	(LOIC, SHMP)
AGUILAR 728 PR D6 29 APEL 728 PR L18 234 ASILE 728 Phil. Conf. 153 BENAKSAS 728 PL 428 507 BENAKSAS 728 PL 428 507 BENAKSAS 728 PL 428 507 BENAKSAS 727 BROWN 72 PL 428 117 BALDIN 71 SINP 13 758 BALDIN 71 SINP 13 758 BALDIN 71 SINP 13 758 BEHREND 71 PRL 27 61 BIZZARRI 71 NP B32 333 BIZZARRI 71 NP B32 333 BIGGS 70B PRL 27 120 BIGGS 70 BPRL 27 120 BIGGS 70 BPRL 28 120 BIZZARRI 70 PRL 25 1385 BOSTON PRO PRL 25 1385 BIGGS 70 BPRL 28 120 BIZZARRI 70 PRL 25 1385 BIGGS 70 BPRL 28 120 BIZZARRI 70 PRL 25 1385 BIZZARRI 69 PR 178 2095 BIZZARRI 70 PRL 25 1385 BIZZARRI 70 PRL 25 1385 BIZZARRI 69 PR 178 2095 BIZZARRI 70 PRL 25 1385 BIZZARRI 69 PR 178 2095 BIZZARRI 70 PRL 25 1385 BIZZARRI 69 PR 178 2095 BIZZARRI 70 PRL 25 1385 BIZZARRI 69 PR 178 2095 BIZZARRI 70 PRL 25 1385 BIZZARRI 69 PR 178 2095 BIZZARRI 70 PRL 25 1385 BIZZARRI 69 PR 178 2095 BIZZARRI 70 PRL 25 1385 BIZZARRI 69 PR 178 2095 BIZZARRI 70 PRL 25 1385 BIZZARRI 69 PR 178 2095 BIZZARRI 69 PR 178 2095 BIZZARRI 70 PRL 25 1385 BIZZARRI 69 PR 178 2095 BIZZARRI 70 PRL 25 1385 BIZZARRI 69 PR 178 2095 BIZZARRI 70 PRL 25 1385 BIZZARRI 70 PRL 26 120 BIZZARRI 70 PRL 27 120 BIZZA					+Strand, Chapman	(BNL. MICH)
SERNAKSAS 72B	AGUILAR	72B	PR D6 29		Aguilar-Benitez, Chung, Eisner, Samios	(BNL)
SERNAKSAS 72B			PL 41B 234		+Auslander, Muller, Bertolucci+ (KARLK,	KARLE, PISA)
BORENSTEIN 72	BASILE		Phil. Cont. 153			
BORENSTEIN 72	BENAKSAS		PL 42B 511		+Cosme, Jean-Marie, Jullian, Laplanche+	(ORSAY)
DAKIN 72	BORENSTEIN	72	PR D5 1559		+Danburg, Kalbfleisch+	(BNL, MICH)
SALDIN 71 SJNP 13 758 Translated from VFF 13 1318.					+Downing, Holloway, Huld, Bernstein+	(ILL, ILLC)
SALDIN 71 SJNP 13 758 Translated from VFF 13 1318.			PR D6 2321 PI 388 345		+Hauser, Kreisier, Mischke +Bulos Carperie Klure Leith Lynch+	(SLAC)
SALDIN 71 SJNP 13 758 Translated from VFF 13 1318.	ALVENSLEBEN	71C	PRI 27 888		+Becker, Busza, Chen, Cohen+	(DESY)
BEHREND 71	BALDIN	71	SJNP 13 758		+Yergakov, Trebukhovsky, Shishov	(ITEP)
BIZZARRI	BEHREND	71	PRI 27 61	F 13	1318. ⊥Lee Nordherg Wehmann⊥ (ROCH	CORN ENAL)
COYNE			NP B27 140		+Montanet, Nilsson, D'Andlau+	(CERN, CDEF)
ABRAMOVI 70 NP 820 209 Abramovich, Blumenfeld, Bruyant+ (CERN) BICZARRI 70 PRL 25 1385 CERN (CERN) PRL 25 1385 CERN (CERN) PRL 25 1385 CERN (CERN) PRO. Daresbury Study Weekend No. 1. Clifft, Bashuler, Kitching, Rand (ROMA, SYRA) Proc. Daresbury Study Weekend No. 1. Benaksas, Buon, Gracco, Haissinski + (CERN) BIZARRI 69 NP B14 169 Foster, Gavillet, Montanet+ (CERN, CDEF) Proster, Gavillet, Montanet+ (CERN, CERN, MCER) Proster, Gavillet, Montanet+ (CERN, CDEF) Proster, Gavillet, Montanet+ (CERN, CERN, MCERN, MCER	COYNE		NP B32 333		+Butler, Fang-Landau, MacNaughton	(LRL)
BIGGS 70B PRL 24 1201			NP B29 349		+Bingham, Fretter+ (LRL, UCB,	SLAC, TUFTS)
BIZZARRI 70			NP B20 209		Abramovich, Blumenteid, Bruyant+	(CERN)
ROOS 70 DNPL/R7 173 CCERN	BIZZARRI		PRI 25 1385		+Ciapetti, Dore, Gaspero, Guidoni+ (ROMA, SYRA)
AUGUSTIN 690 PL 288 513 HBenaksas, Buon, Gracco, Haissinski+ (ORSAY)			DNPL/R7 173			(CERN)
BIZZARRI	Proc. Dare		Study Weekend No.	1.	. Beerleen Beer Green Heinferlit	(ODC 4)()
DEINET 698 PL 308 426 Homezione, Muller, Buniatov+ (KARL, CERN) JACQUET 698 N. 63A 743 Hogwen-khac, Haatuft, Halsteinsid (EPOL, BERG) (HARV) Also 69 PR 178 2095 Halven-khac, Haatuft, Halsteinsid (EPOL, BERG) (HARV) Also 69 PR 178 2095 Halven-khac, Haatuft, Halsteinsid (EPOL, BERG) (HARV) BOLLINI 680 N. 65A 531 Astvacaturov, Azimov, Baldin+ (JINR, MOSU) BARASH 67C PR 196 1399 Halven-khac, Ha			NP B14 169		+Foster, Gavillet, Montanet+	(CERN, CDEF)
JACQUET 698 N.C 63A, 743 Hayven-Khac, Halsteinslid (EPOL, BERG)	DEINET	69B	PL 30B 426		+Menzione, Muller, Buniatov+	(KARL, CERN)
Also 69 PR 178 2095 ASTVACAT. 68 PL 278 45 BOLLINI 68C NC 56A 531 BARASH 67B PR 156 1399 FELDMAN 67C PR 159 1219 DIGIUGNO 66B NC 44A 1272 FLATTE 66 PR 145 1050 BARRABARO 65 PRL 14 279 BARRABARO 65 PRL 14 279 Translated from ZETF 45 1879. COTHER REATED PAPERS DOLINSKY 86 PL B174 453 BUSCHBECK 83 JETPL 37 733 Translated from ZETF 37 613. ALFF 68 PL B174 453 Translated from ZETF 37 613. COTHER RELATED PAPERS DOLINSKY 88 PL B174 453 Translated from ZETF 37 613. ALFF 68 PL B174 453 Translated from ZETF 37 613. ALFF 69 PR 145 687 AMGGLICH 61 PRL 71 78 ALFF 68 PL B176 687 AMGGLICH 61 PRL 71 78 AMGGLICH 61 PRL 71 78 AVAIVEZ, Rosenfeld, Stevenson (LRL) WAGNICH AVAIVEZ, Rosenfeld, Stevenson (LRL) WAGNICH AVAIVEZ, Rosenfeld, Stevenson (LRL) WAGNICH AVAIVEZ, Robardeld, Stevenson (LRL) WAGNICH AVAIVEZ, ROSENFELD, SUSPANSON (LRL) AVAIVEZ, MASSIAUM, ROSHERID (LRC) AVAIVEZ, MASSIAUM, ROSHERID (CERN, CDEF, EPOL) AMGGLICH 61 PRL 7 178 HAVAIVEZ, ROSENFELD, SUSPANSON (LRC) KYALE, BNL) BARDHARD, MIGHT, MOSUN, SIGNIN, SIGNI			NC 63A 743		+Nguyen-Khac, Haatuft, Halsteinslid	(EPOL, BERG)
BOLLINI 68					Webmann± (HARV CASE SIAC	(HARV)
BOLLINI 68	ASTVACAT		PL 27B 45		Astvacaturov, Azimov, Baldin+	(JINR, MOSU)
BARASH 67B PR 156 1399 Hirsch, Miller, Tan (COLU)	BOLLINI	68C	NC 56A 531		+Buhler, Dalpiaz, Massam+ (CERN,	BGNA, STRB)
DIGIUGNO 668 NC 44A 1272 +Peruzzi, Troise+ (NAPL, FRAS, TRST)		67B	PR 156 1399		+Kirsch, Miller, Tan	(COLU)
FLATTE	PELDMAN		PK 159 1219 NC 444 1272		+Frati, Gleeson, Halpern, Nussbaum+	(PENN) FRAS TOST)
JAMES					+Huwe, Murray, Button-Shafer, Solmitz+	(LRL)
BARBARO 65			PR 142 896		+Kraybill	(YALE, BNL)
Translated from ZETF 45 1879. Translated from ZETF 37 613. Translated from ZETF 37			PRL 14 279			(LRL)
Wilson W	DAKIVIIN	64	Translated from ZE	TF 4	+ Dorgolenko, Krestnikov+ IS 1879.	(HEP)
OTHER RELATED PAPERS			PR 136B 496		+Madansky, Fields+ (JHU, N	
DOLINSKY KURDADZE 83	BUSCHBECK	63	Siena Conf. 1 166		+Czapp+ (VIEN,	CERN, ANIK)
KURDADZE 83 JETPL 37 733 b. Lelchuk, Pakhtusova+ (ToVO) (NOVO) ALFF 628 PRL 9 325 b. Alff-Steinberger, Berley, Colley+ (COLU, RUTG) (COLU, RUTG) ARMENTEROS 62 CERN Conf. 90 b. Hadde+ (CERN, CDEF, EPOL) + Budde+ (CERN, CDEF, EPOL) STEVENSON 62 PR 125 687 b. Alvarez, Maglich, Rosenfeld (LRL) MAGLICH 61 PRL 7 178 b. Alvarez, Rosenfeld, Stevenson (LRL) PEVSNER 61 PRL 7 421 b. Kraemer, Nussbaum, Richardson+ (JHU)			отн	ER	RELATED PAPERS	
KURDADZE 83 JETPL 37 733 b. Lelchuk, Pakhtusova+ (ToVO) (NOVO) ALFF 628 PRL 9 325 b. Alff-Steinberger, Berley, Colley+ (COLU, RUTG) (COLU, RUTG) ARMENTEROS 62 CERN Conf. 90 b. Hadde+ (CERN, CDEF, EPOL) + Budde+ (CERN, CDEF, EPOL) STEVENSON 62 PR 125 687 b. Alvarez, Maglich, Rosenfeld (LRL) MAGLICH 61 PRL 7 178 b. Alvarez, Rosenfeld, Stevenson (LRL) PEVSNER 61 PRL 7 421 b. Kraemer, Nussbaum, Richardson+ (JHU)	DOLINGEN	86	DI D174 452		+Druzhinin Dubrovin Fidolman I	(NOVO)
Translated from ZETFP 37 613. Alff-Steinberger, Berley, Colley+ CERN, CDEF, EPOL.			JETPL 37 733		+Lelchuk, Pakhtusova+	(NOVO)
ARMENTEROS 62 CERN Conf. 90 +Budde+ (CERN, CDEF, EPOL) STEVENSON 62 PR 125 687 +Alvarez, Maglich, Rosenfeld (LRL) MAGLICH 61 PRL 7 178 +Alvarez, Rosenfeld, Stevenson (LRL) PEVSNER 61 PRL 7 421 +Kraemer, Nussbaum, Richardson+ (JHU)			Translated from ZE	TFP	37 613.	
STEVENSON 62 PR 125 687 + Alvarez, Maglich, Rosenfeld (LRL) MAGLICH 61 PRL 7 178 + Alvarez, Rosenfeld, Stevenson (LRL) PEVSNER 61 PRL 7 421 + Kraemer, Nussbaum, Richardson+ (JHU)			CERN Conf on		AIT-Steinberger, Berley, Colley+ (CERN)	CDEE EDOLL
MAGLICH 61 PRL 7 178 +Alvarez, Rosenfeld, Stevenson (LRL) PEVSNER 61 PRL 7 421 +Kraemer, Nussbaum, Richardson+ (JHU)			PR 125 687			(LRL)
PEVSNER 61 PRL 7 421 +Kraemer, Nussbaum, Richardson+ (JHU) XUONG 61 PRL 7 327 +Lynch (LRL)	MAGLICH		PRL 7 178		+Alvarez, Rosenfeld, Stevenson	(LRL)
ACONS OF THE 1 221 TENNEN (ERE)			PRL 7 421 PRI 7 327			
	AUDING	V1	1 11 1 321		: Lynco	(LIVE)

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$$I^{G}(J^{PC}) = 0^{+}(0^{-+})$$

			$\eta'(958)$ MAS	S		
VALUE	(MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
957.77	1±0.14 OUR AVE	ERAGE				
959	± 1	630	BELADIDZE	92C	VES	36 π^- Be $\rightarrow \pi^- \eta' \eta$ Be
958	± 1	340	ARMSTRONG	91B		300 $pp \rightarrow pp\eta \pi^+\pi^-$
958.2	± 0.4	622	AUGUSTIN	90		$J/\psi \rightarrow \gamma \eta \pi^+ \pi^-$
957.8	± 0.2	2420	AUGUSTIN	90	DM2	$J/\psi \rightarrow \gamma \gamma \pi^+ \pi^-$
956.3	± 1.0	143	GIDAL	87	MRK2	$e^+e^{e^+e^-} \xrightarrow{\eta\pi^+\pi^-}$
057.40	5+0.33		DUANE	74	MMS	$\pi^- \rho \rightarrow nMM$
957.46	±0.33					
958.2	± 0.5	1414	DANBURG	73	HBC	$2.2 K^- p \rightarrow \Lambda X^0$
958	± 1	400	JACOBS	73	HBC	$2.9 K^- p \rightarrow \Lambda X^0$
956.1	±1.1	3415	BASILE	71	CNTR	$1.6 \pi^- p \rightarrow n X^0$
957.4	± 1.4	535	BASILE	71	CNTR	$1.6 \pi^{-} p \rightarrow n X^{0}$
957	± 1		RITTENBERG	69	HBC	1.7-2.7 K ⁻ p

η' (958) WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
0.201±0.016 OUR FIT	Error	includes scale factor of	1.3	3.		
0.28 ±0.10	1000	BINNIE 7	9	MMS	0	$\pi^- p \rightarrow nMM$

$\eta'(958)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Scale factor/ Confidence level
Γ1	$\pi^+\pi^-\eta$	(43.7 ±1.5)%	6 S=1.1
Γ_2	$\rho^0 \gamma$	(30.2 ±1.3) %	6 S=1.1
Γ ₃	$\pi^0\pi^0\eta$	(20.8 ±1.3) %	6 S=1.2
Γ ₄	$\omega \gamma$	(3.02±0.30) %	6
Γ ₅	$\gamma \gamma$	(2.12 ± 0.13) %	6 S=1.2
Γ_6	$3\pi^{0}$	(1.55±0.26) ×	10-3
Γ ₇	$\mu^+\mu^-\gamma$	(1.04±0.26) ×	10-4
Γ ₈	$\pi^{+}\pi^{-}\pi^{0}$	< 5 %	6 CL=90%
Γ9	$\pi^{0} \rho^{0}$	< 4 %	6 CL=90%
Γ ₁₀	$\pi^+\pi^-$	< 2 %	6 CL=90%
Γ_{11}	$\pi^{0} e^{+} e^{-}$	< 1.3 %	-
Γ_{12}	$\eta e^+ e^-$	< 1.1 %	
Γ_{13}	$\pi^{+}\pi^{+}\pi^{-}\pi^{-}$	< 1 %	
Γ_{14}	$\pi^+\pi^+\pi^-\pi^-$ neutrals	< 1 %	
Γ_{15}	$\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0}$	< 1 %	-
Γ ₁₆	6π	< 1 %	
Γ_{17}	$\pi^{+}\pi^{-}e^{+}e^{-}$		CL=90%
Γ ₁₈	$\pi^{0}\pi^{0}$		10 ⁻⁴ CL=90%
Γ_{19}	$\pi^0 \gamma \gamma$		10 ⁻⁴ CL=90%
Γ_{20}	$4\pi^{0}$		CL=90%
Γ_{21}	3γ		<10 ^{−4} CL=90%
Γ_{22}	$\mu^{+}\mu^{-}\pi^{0}$	< 6.0 ×	CL=90%
Γ_{23}	$\mu^+\mu^-\eta$	< 1.5 ×	<10 ^{−5} CL=90%
Γ_{24}	$\pi^+\pi^-\gamma$ (including $ ho^0\gamma$)		_
Γ ₂₅	e ⁺ e ⁻	< 2.1 ×	<10 ⁻⁷ CL=90%

CONSTRAINED FIT INFORMATION

An overall fit to the total width, a partial width, 2 combinations of partial widths obtained from integrated cross section, and 16 branching ratios uses 45 measurements and one constraint to determine 7 parameters. The overall fit has a $\chi^2=33.4$ for 39 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\left\langle \delta \rho_i \delta \rho_j \right\rangle / (\delta \rho_i \cdot \delta \rho_j)$, in percent, from the fit to parameters ρ_i , including the branching fractions, $x_i \equiv \Gamma_i / \Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to one.

Mode	Rate (MeV)	Scale factor
$\pi^+\pi^-\eta$	0.088 ±0.009	1.2
$\rho^0 \gamma$	0.061 ± 0.005	1.3
$\pi^{0} \pi^{0} \eta$	0.042 ± 0.004	1.5
$\omega \gamma$	0.0061 ± 0.0008	1.2
$\gamma \gamma$	0.00426 ± 0.00019	1.1
$3\pi^0$	$(3.1 \pm 0.6) \times 1$	0-4 1.1
	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$

η' (958) PARTIAL WIDTHS

$\Gamma(\gamma\gamma)$						Γ ₅
VALUE (keV)	EVTS	DOCUMENT ID		TECN	COMMENT	
4.26±0.19 OUR FIT	Error inclu	ides scale factor o	f 1.1.			
4.34 ± 0.25 OUR AVE	RAGE					
$4.53 \pm 0.29 \pm 0.51$	266	KARCH	92	CBAL	$e^{+}e^{-}_{e^{+}e^{-}\eta\pi^{0}\pi^{0}}$	
3.62±0.14±0.48		¹ BEHREND	91	CELL	$e^{+}e^{-}_{e^{+}e^{-}\eta'(958)}$	
4.6 ±1.1 ±0.6	23	BARU	90	MD1	$e^+e^{e^+e^-\pi^+\pi^-\gamma}$	
$4.57 \pm 0.25 \pm 0.44$		BUTLER	90	MRK2	$e^{+}e^{-}_{e^{+}e^{-}\eta'(958)}$	
$4.94 \pm 0.23 \pm 0.72$	547	² ROE	90	ASP	$e^+e^- \rightarrow e^+e^-2\gamma$,
3.8 ±0.7 ±0.6	34	AIHARA			$e^+e^{e^+e^-\eta\pi^+\pi^-}$	
4.8 ±0.5 ±0.5	136	² WILLIAMS	88	CBAL	$e^+e^- \rightarrow e^+e^-2\gamma$	
 • • We do not use 	the following	g data for average	es, fit	s, limits,	etc. • • •	
4.7 ±0.6 ±0.9	143	³ GIDAL			$e^+e^{e^+e^-\eta\pi^+\pi^-}$	
4.0 ±0.9		⁴ BARTEL	85E	JADE	$e^+e^- \rightarrow e^+e^-2\gamma$	
1 Using B($\eta' \rightarrow \rho$) 2 Using B($\eta' \rightarrow \gamma$) 3 Superseded by BU 4 Systematic error in	γ) = (2.17 : JTLER 90.	± 0.17)%.				

$\eta'(958) \; \Gamma(i)\Gamma(\gamma\gamma)/\Gamma(total)$

This combination of a partial width with the partial width into $\gamma\gamma$ and with the total width is obtained from the integrated cross section into channel(i) in the $\gamma\gamma$ annihilation.

$\Gamma(\gamma\gamma) \times \Gamma(\rho^0\gamma)/\Gamma_{\rm t}$	otal			$\Gamma_5\Gamma_2/\Gamma$
VALUE (keV)	EVTS	DOCUMENT ID	TECN	COMMENT
1.29 ± 0.06 OUR FIT E	rror includes :	scale factor of 1.2.		
1.26±0.07 OUR AVERA	GE Error in	cludes scale factor of	of 1.2.	
$1.09 \pm 0.04 \pm 0.13$		BEHREND	91 CELL	$e^{+}e^{-}_{e^{+}e^{-}\rho(770)^{0}\gamma}$
$1.35 \pm 0.09 \pm 0.21$		AIHARA	87 TPC	$e^+e^- \rightarrow e^+e^-\rho\gamma$
$1.13 \pm 0.04 \pm 0.13$	867	ALBRECHT	87B ARG	$e^+e^- \rightarrow e^+e^-\rho\gamma$
$1.53 \pm 0.09 \pm 0.21$		ALTHOFF	84E TASS	$e^+e^- \rightarrow e^+e^-\rho\gamma$
$1.14 \pm 0.08 \pm 0.11$	243	BERGER	84B PLUT	$e^+e^- \rightarrow e^+e^-\rho\gamma$
$1.73 \pm 0.34 \pm 0.35$	95	JENNI	83 MRK2	$e^+e^- \rightarrow e^+e^-\rho\gamma$
$1.49 \pm 0.13 \pm 0.027$	213	BARTEL	82B JADE	$e^+e^- \rightarrow e^+e^-\rho\gamma$
• • • We do not use the	following da	ta for averages, fits	, limits, etc	. • • •
$1.85 \pm 0.31 \pm 0.24$	43	BEHREND	83B CELL	$e^+e^- \rightarrow e^+e^-\rho\gamma$
$\Gamma(\gamma\gamma) \times \Gamma(\pi^0\pi^0\eta)$	/Γ _{total}			$\Gamma_5\Gamma_3/\Gamma$
VALUE (keV)		UMENT ID TE	CN COMN	1ENT
0.88±0.07 OUR FIT E				
$0.93 \pm 0.06 \pm 0.11$				$- \rightarrow e^+e^-\eta\pi^0\pi^0$
 ● ● We do not use the 	following da	ta for averages, fits	, limits, etc	. • • •
$0.95 \pm 0.05 \pm 0.08$	6 KAF	RCH 90 CE	BAL e+e-	$- \rightarrow e^{+}e^{-}\eta \pi^{0}\pi^{0}$
$1.00\pm0.08\pm0.10$	5,6 AN1	TREASYAN 87 CE	BAL e+e-	$- \rightarrow e^{+}e^{-}\eta \pi^{0}\pi^{0}$
5 Using BR($\eta ightarrow 2\gamma$)= 6 Superseded by KARC		%.		

η' (958) α PARAMETER

$ MATRIX \; ELEMENT ^2 = (1 + \alpha y)^2 + cx^2$									
VALUE	DOCUMENT ID	TECN	COMMENT						
-0.058 ± 0.013	⁷ ALDE 86	GAM2	$38 \pi^- \rho \rightarrow n\eta 2\pi^0$						
• • • We do not use the following	g data for averages, fit	s, limits,	etc. • • •						
-0.08 ± 0.03	7 KALBFLEISCH 74	RVUE	$\eta' \rightarrow \eta \pi^+ \pi^-$						
⁷ May not necessarily be the same for $n' \rightarrow n\pi^+\pi^-$ and $n' \rightarrow n\pi^0\pi^0$.									

	η' (958) BRANCHING	G RA	ATIOS	
$\Gamma(\pi^+\pi^-\eta)$ (neutral de	,				$0.709\Gamma_1/\Gamma$
	EVTS	DOCUMENT ID			COMMENT
0.310±0.011 OUR FIT		includes scale factor			
0.314 ± 0.026	281	RITTENBERG	69	нвс	1.7-2.7 K ⁻ p
$\Gamma(\pi^+\pi^-\text{neutrals})/\Gamma$	total				1+0.291\(\Gamma_3+0.9\(\Gamma_4\)/\(\Gamma\)
VALUE	EVTS	DOCUMENT ID			COMMENT
0.398±0.009 OUR FIT 0.36 ±0.05 OUR AVE		includes scale factor	of 1.	.1.	
0.4 ± 0.1	39	LONDON	66	HBC	2.24 $K^-p \rightarrow$
					$\Lambda\pi^+\pi^-$ neutrals
0.35 ±0.06	33	BADIER	65E	HBC	3 K ⁻ p
$\Gamma(\pi^+\pi^-\eta)$ (charged d					$0.291\Gamma_1/\Gamma$
VALUE		DOCUMENT ID			COMMENT
0.127±0.004 OUR FIT		includes scale factor	of 1.	.1.	
0.116±0.013 OUR AVE		DITTEMPEDO		unc	
0.123 ± 0.014	107	RITTENBERG			
0.10 ± 0.04	10	LONDON	66	нвс	2.24 $K^- p \rightarrow \Lambda \pi^+ \pi^- \pi^+ \pi^- \pi^0$
0.07 ±0.04	7	BADIER	65B	нвс	$3K^{-}p$
$[\Gamma(\pi^0\pi^0\eta)$ (charged d	ecay)	$)+\Gamma(\omega)$ (charged d	lecay	/) ₂)]/	total
		, , , , -		, ,,,,,	(0.291Г₃+0.9Г₄)/Г
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.088±0.005 OUR FIT	Error	includes scale factor	of 1.	2.	
0.045 ± 0.029	42	RITTENBERG	69	HBC	1.7−2.7 K p
$\Gamma(\text{neutrals})/\Gamma_{\text{total}}$				(0.	709Γ ₃ +0.09Γ ₄ +Γ ₅)/Γ
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.171 ± 0.009 OUR FIT	Error	includes scale factor	of 1.	2.	
0.187±0.017 OUR AVE	RAGE				
0.185 ± 0.022	535	BASILE	71	CNTR	$1.6 \pi^- p \rightarrow nX^0$
0.189 ± 0.026	123	RITTENBERG	69	HBC	1.7−2.7 K p
$\Gamma(\rho^0\gamma)/\Gamma_{\text{total}}$					Γ ₂ /Γ
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.302±0.013 OUR FIT 0.319±0.030 OUR AVE		includes scale factor	of 1.	1.	
0.329±0.033	298	RITTENBERG	69	HBC	1.7-2.7 K ⁻ p
0.2 ±0.1	20	LONDON		HBC	2.24 K ⁻ p →
			- •		$\Lambda \pi^+ \pi^- \gamma$
0.34 ±0.09	35	BADIER	65B	нвс	3 K - p

$\Gamma(\rho^0\gamma)/\Gamma(\pi\pi\eta)$					$\Gamma_2/(\Gamma_1+\Gamma_3)$
VALUE 0.468±0.029 OUR FIT	Error inclu	DOCUMENT ID ides scale factor		.1.	COMMENT
0.31 ±0.15		DAVIS	68	нвс	5.5 K ⁻ p
$\Gamma(\pi^0 e^+ e^-)/\Gamma_{\text{total}}$					Г ₁₁ /Г
VALUE	CL%	DOCUMENT ID		TECN	
<0.013	90	RITTENBERG	65	нвс	2.7 K ⁻ p
$\Gamma(\eta e^+ e^-)/\Gamma_{\text{total}}$					Γ ₁₂ /Γ
VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.011	90	RITTENBERG	65	HBC	2.7 K ⁻ p
$\Gamma(\pi^0 ho^0)/\Gamma_{ m total}$					٦/و٦
VALUE	CL%	DOCUMENT ID			
<0.04	90	RITTENBERG	65	нвс	2.7 K ⁻ p
$\Gamma(\pi^+\pi^-e^+e^-)/\Gamma_{ m to}$	tal				Γ ₁₇ /Γ
VALUE	<u>CL%</u>	DOCUMENT ID			
<0.006	90	RITTENBERG	65	HBC	2.7 K ⁻ p
$\Gamma(6\pi)/\Gamma_{\text{total}}$					Γ ₁₆ /Γ
<u>VALUE</u> <0.01	<u>CL%</u> 90	DOCUMENT ID	66	TECN HBC	COMMENT Compilation
	90	LONDON	00	ПВС	Compliation
$\Gamma(\omega\gamma)/\Gamma(\pi^+\pi^-\eta)$	FVTC	DOCUMENT I		TECH	Γ_4/Γ_1
VALUE 0.069±0.008 OUR FIT	Error inclu	DOCUMENT ID Ides scale factor			COMMENT
0.068±0.013	68	ZANFINO	77	ASPK	8.4 $\pi^- \rho$
$\Gamma(ho^0\gamma)/[\Gamma(\pi^+\pi^-\eta)$	$+\Gamma(\pi^0\pi$	$(\alpha_0) + \Gamma(\omega_1)$	l		$\Gamma_2/(\Gamma_1+\Gamma_3+\Gamma_4)$
VALUE	`	DOCUMENT ID	·	TECN	COMMENT
0.447±0.028 OUR FIT 0.25 ±0.14	Error inclu	des scale factor DAUBER	of 1.	1. HBC	1.95 K ⁻ p
U.25 1U.14		DAUBLK	04	TIBC	
$\Gamma(\gamma\gamma)/\Gamma_{total}$					Γ ₅ /Γ
VALUE	<u>EVTS</u> T Error in	DOCUMENT ID	or of	<u>TECN</u>	COMMENT 15/1
VALUE 0.0212±0.0013 OUR FI 0.0196±0.0015 OUR AV	T Error in	cludes scale facto		1.2.	COMMENT
<u>value´</u> 0.0212±0.0013 OUR FI 0.0196±0.0015 OUR AV	T Error in		or of		COMMENT 8.45 $\pi^- p \rightarrow$
<u>VALUE</u> 0.0212±0.0013 OUR FI 0.0196±0.0015 OUR AV 0.0200±0.0018	T Error in	cludes scale facto		1.2.	COMMENT 8.45 $\pi^- p \rightarrow n\pi^+\pi^- 2\gamma$ $\pi^- p \rightarrow nMM$
VALUE 0.0013 OUR FI 0.0212±0.0013 OUR FI 0.0196±0.0015 OUR AV 0.0200±0.0018 0.025 ±0.007 0.0171±0.0033	T Error ind 'ERAGE 8	cludes scale factors STANTON DUANE DALPIAZ	80 74 72	1.2. SPEC MMS CNTR	COMMENT 8.45 $\pi^- \rho \rightarrow n\pi^+\pi^- 2\gamma$ $\pi^- \rho \rightarrow nMM$ 1.6 $\pi^- \rho \rightarrow nX^0$
VALUE 0.0212±0.0013 OUR FI 0.0196±0.0015 OUR AV 0.0200±0.0018 0.025 ±0.007 0.0171±0.0033 0.020 +0.008 0.026 -0.006	T Error ind 'ERAGE 8 68 31	cludes scale factors STANTON DUANE DALPIAZ HARVEY	80 74 72 71	1.2. SPEC MMS CNTR OSPK	COMMENT 8.45 $\pi^- \rho \rightarrow n\pi^+\pi^- 2\gamma$ $\pi^- \rho \rightarrow nMM$ 1.6 $\pi^- \rho \rightarrow nX^0$ 3.65 $\pi^- \rho \rightarrow nX^0$
VALUE	T Error ind FERAGE	cludes scale factors STANTON DUANE DALPIAZ HARVEY data for averages	80 74 72 71 s, fits	1.2. SPEC MMS CNTR OSPK 5, limits,	COMMENT 8.45 $\pi^- \rho \rightarrow n\pi^+\pi^- 2\gamma$ $\pi^- \rho \rightarrow nMM$ 1.6 $\pi^- \rho \rightarrow nX^0$ 3.65 $\pi^- \rho \rightarrow nX^0$ etc. • •
0.0212±0.0013 OUR FI 0.0212±0.0015 OUR AV 0.0200±0.0018 0.025±0.007 0.0171±0.0033 0.020±0.008 - • • We do not use the collection of	T Error in (FRAGE) 68 31 e following 6 6000	cludes scale factors STANTON DUANE DALPIAZ HARVEY	80 74 72 71	1.2. SPEC MMS CNTR OSPK	COMMENT 8.45 $\pi^- \rho \rightarrow n\pi^+\pi^- 2\gamma$ $\pi^- \rho \rightarrow nMM$ 1.6 $\pi^- \rho \rightarrow nX^0$ 3.65 $\pi^- \rho \rightarrow nX^0$
VALUE	T Error index/ERAGE	cludes scale factors STANTON DUANE DALPIAZ HARVEY data for averages	80 74 72 71 s, fits	1.2. SPEC MMS CNTR OSPK 5, limits,	COMMENT 8.45 $\pi^- \rho \rightarrow n\pi^+\pi^- 2\gamma$ $\pi^- \rho \rightarrow nMM$ 1.6 $\pi^- \rho \rightarrow nX^0$ 3.65 $\pi^- \rho \rightarrow nX^0$ etc. • •
VALUE 0.0212±0.0013 OUR FI 0.0196±0.0015 OUR AV 0.0200±0.0018 0.025±0.007 0.0171±0.0033 0.020±0.008 ■ ● We do not use the control of	T Error index/ERAGE	cludes scale factors STANTON DUANE DALPIAZ HARVEY data for averages	80 74 72 71 s, fits	1.2. SPEC MMS CNTR OSPK 5, limits,	COMMENT 8.45 $\pi^- p \rightarrow n\pi^+ \pi^- 2\gamma$ $\pi^- p \rightarrow nMM$ 1.6 $\pi^- p \rightarrow nX^0$ 3.65 $\pi^- p \rightarrow nX^0$ etc. • • 15–40 $\pi^- p \rightarrow n2\gamma$
$VALUE$ 0.0212±0.0013 OUR FI 0.0219±0.0015 OUR AV 0.0200±0.0018 0.025 ±0.007 0.0171±0.0033 0.020 ±0.008 • • • We do not use the 0.018 ±0.002 8 Includes APEL 79 rei 9 Data is included in S $\Gamma(e^+e^-)/\Gamma_{\text{total}}$	T Error index/ERAGE	cludes scale factors STANTON DUANE DALPIAZ HARVEY data for averages	80 74 72 71 s, fits	1.2. SPEC MMS CNTR OSPK 5, limits,	COMMENT 8.45 $\pi^- \rho \rightarrow n\pi^+\pi^- 2\gamma$ $\pi^- \rho \rightarrow nMM$ 1.6 $\pi^- \rho \rightarrow nX^0$ 3.65 $\pi^- \rho \rightarrow nX^0$ etc. • •
$VALUE$ 0.0212±0.0013 OUR FI 0.0219±0.0015 OUR AV 0.0200±0.0018 0.025 ±0.007 0.0171±0.0033 0.020 ±0.008 ••• We do not use the 0.018 ±0.002 8 Includes APEL 79 res 9 Data is included in S $\Gamma(e^+e^-)/\Gamma_{\text{total}}$	T Error inc /ERAGE 68 31 e following 6 6000 Sult. TANTON 8	Cludes scale factors STANTON DUANE DALPIAZ HARVEY data for averages APEL O evaluation.	80 74 72 71 s, fits	1.2. SPEC MMS CNTR OSPK 5, limits, NICE	COMMENT 8.45 $\pi^- \rho \rightarrow n\pi^+\pi^- 2\gamma$ $\pi^- \rho \rightarrow nMM$ 1.6 $\pi^- \rho \rightarrow nX^0$ 3.65 $\pi^- \rho \rightarrow nX^0$ etc. • • • 15–40 $\pi^- \rho \rightarrow n2\gamma$
VALUE (0.0212±0.0013 OUR FI) 0.0212±0.0015 OUR AV 0.0200±0.0018 0.025±0.007 0.0171±0.0033 0.020±0.008 0.020±0.008 0.0006 0.0006 0.0006 0.0006 0.0006 0.0006 0.0007 0.0018±0.002 0.0018±0.003 0.0020±0.	FERRAGE 68 31 e following 6 6000 Sult. TANTON 6	Cludes scale factors STANTON DUANE DALPIAZ HARVEY data for averages APEL O evaluation.	80 74 72 71 s, fits 79	SPEC MMS CNTR OSPK s, limits, NICE	$\begin{array}{c} \underline{COMMENT} \\ 8.45 \ \pi^- \ \rho \rightarrow \\ n\pi^+ \pi^- 2\gamma \\ \pi^- \ \rho \rightarrow nMM \\ 1.6 \ \pi^- \ \rho \rightarrow nX^0 \\ 3.65 \ \pi^- \ \rho \rightarrow nX^0 \\ \text{etc.} \bullet \bullet \bullet \\ 15-40 \ \pi^- \ \rho \rightarrow n2\gamma \\ \\ \hline \\ \underline{COMMENT} \\ e^+ e^- \rightarrow \pi^+ \pi^- \eta \end{array}$
VALUE $^{\prime\prime}$ 0.0212±0.0013 OUR FI 0.0195 OUR AV 0.0196±0.0015 OUR AV 0.0200±0.0018 0.025 ±0.007 0.0171±0.0033 0.020 ±0.008 0.006 0.006 0.006 0.006 0.006 0.006 0.007 0.0018 ±0.002 0.006 0.006 0.007	FERRAGE 68 31 e following 6 6000 Sult. TANTON 6	Cludes scale factors STANTON DUANE DALPIAZ HARVEY data for averages APEL O evaluation.	80 74 72 71 ss, fits 79	SPEC MMS CNTR OSPK 5, limits, NICE	$\begin{array}{c} \underline{COMMENT} \\ 8.45 \ \pi^- \ \rho \rightarrow \\ n\pi^+ \pi^- 2\gamma \\ \pi^- \ \rho \rightarrow nMM \\ 1.6 \ \pi^- \ \rho \rightarrow nX^0 \\ 3.65 \ \pi^- \ \rho \rightarrow nX^0 \\ \text{etc.} \bullet \bullet \bullet \\ 15-40 \ \pi^- \ \rho \rightarrow n2\gamma \\ \hline \\ \underline{COMMENT} \\ e^+ e^- \rightarrow \pi^+ \pi^- \eta \\ \hline \Gamma_{10}/\Gamma \end{array}$
VALUE 0.0212±0.0013 OUR FI 0.0212±0.0015 OUR AV 0.0200±0.0018 0.025 ±0.007 0.0171±0.0033 0.020 ±0.006 • • • We do not use the control of the cont	Error indiverse 1	Cludes scale factors STANTON DUANE DALPIAZ HARVEY data for averages APEL ROCUMENT ID VOROBYEV DOCUMENT ID RITTENBERG	80 74 72 71 ss, fits 79	1.2. SPEC MMS CNTR OSPK 5, limits, NICE TECN ND	$\begin{array}{c} \underline{COMMENT} \\ 8.45 \ \pi^- \ p \rightarrow \\ n\pi^+ \pi^- 2\gamma \\ \pi^- \ p \rightarrow nMM \\ 1.6 \ \pi^- \ p \rightarrow nX^0 \\ 3.65 \ \pi^- \ p \rightarrow nX^0 \\ \text{etc.} \bullet \bullet \bullet \\ 15-40 \ \pi^- \ p \rightarrow n2\gamma \\ \hline \\ \hline $
VALUE	Error indiverse 1	Cludes scale factors STANTON DUANE DALPIAZ HARVEY data for averages APEL O evaluation. DOCUMENT ID VOROBYEV POCUMENT ID RITTENBERG data for averages	80 74 72 71 85, fits 79 88	1.2. SPEC MMS CNTR OSPK s, limits, NICE TECN ND TECN HBC s, limits,	$\begin{array}{c} \underline{COMMENT} \\ 8.45 \ \pi^- \ \rho \to \\ n\pi^+ \pi^- 2\gamma \\ \pi^- \rho \to nMM \\ 1.6 \ \pi^- \rho \to nX^0 \\ 3.65 \ \pi^- \rho \to nX^0 \\ \text{etc.} \bullet \bullet \bullet \\ 15-40 \ \pi^- \rho \to n2\gamma \\ \hline \\ \hline $
VALUE 1. VA	Error indiverse 1	Cludes scale factors STANTON DUANE DALPIAZ HARVEY data for averages APEL O evaluation. DOCUMENT ID VOROBYEV RITTENBERG data for averages	80 74 72 71 85, fits 79 88	1.2. SPEC MMS CNTR OSPK s, limits, NICE TECN ND TECN HBC s, limits,	$\begin{array}{c} \underline{COMMENT} \\ 8.45 \ \pi^- \ p \rightarrow \\ n\pi^+ \pi^- 2\gamma \\ \pi^- \ p \rightarrow nMM \\ 1.6 \ \pi^- \ p \rightarrow nX^0 \\ 3.65 \ \pi^- \ p \rightarrow nX^0 \\ \text{etc.} \bullet \bullet \bullet \\ 15-40 \ \pi^- \ p \rightarrow n2\gamma \\ \hline \\ \hline $
VALUE	Error indiverse 1	Cludes scale factors STANTON DUANE DALPIAZ HARVEY data for averages APEL O evaluation. DOCUMENT ID VOROBYEV POCUMENT ID RITTENBERG data for averages	80 74 72 71 85, fits 79 88	1.2. SPEC MMS CNTR OSPK s, limits, NICE TECN ND TECN HBC s, limits,	$\begin{array}{c} \underline{COMMENT} \\ 8.45 \ \pi^- \ \rho \to \\ n\pi^+ \pi^- 2\gamma \\ \pi^- \rho \to nMM \\ 1.6 \ \pi^- \rho \to nX^0 \\ 3.65 \ \pi^- \rho \to nX^0 \\ \text{etc.} \bullet \bullet \bullet \\ 15-40 \ \pi^- \rho \to n2\gamma \\ \hline \\ \hline $
VALUE 1. V	68 31 e following 6 6000 5 SUIL. TANTON 8 90 e following 6 95 CL%	DUANE DALPIAZ HARVEY data for averages APEL OCUMENT ID RITTENBERG DANBURG DOCUMENT ID	80 74 72 71 55, fits 79 88 69 55, fits	SPEC MMS CNTR OSPK 5, limits, NICE TECN ND TECN HBC 5, limits, HBC	$\begin{array}{c} \frac{COMMENT}{R} \\ 8.45 \ \pi^- \ \rho \to \\ n\pi^+ \pi^- 2\gamma \\ \pi^- \ \rho \to nMM \\ 1.6 \ \pi^- \ \rho \to nX^0 \\ 3.65 \ \pi^- \ \rho \to nX^0 \\ \text{etc.} \bullet \bullet \bullet \\ 15-40 \ \pi^- \ \rho \to n2\gamma \\ \hline \\ \hline \begin{array}{c} \Gamma_{25}/\Gamma \\ \hline COMMENT \\ 1.7-2.7 \ K^- \ \rho \\ \text{etc.} \bullet \bullet \bullet \\ 2.2 \ K^- \ \rho \to \Lambda X^0 \\ \hline \end{array}$
$VALUE$ 0.0212±0.0013 OUR FI 0.0212±0.0015 OUR AV 0.0296±0.0015 OUR AV 0.0200±0.0018 0.025 ±0.007 0.0171±0.0033 0.020 ±0.006 • • • We do not use the 0.018 ±0.002 8 Includes APEL 79 re 9 Data is included in S $\Gamma(e^+e^-)/\Gamma_{\text{total}}$ VALUE (0.02 • • • We do not use the 0.018 ±0.002 Γ(π+π-)/Γ _{total} VALUE (0.02 • • • We do not use the 0.008 $\Gamma(π+π-π^0)/\Gamma_{\text{total}}$ VALUE (0.008 $\Gamma(π+π-π^0)/\Gamma_{\text{total}}$ VALUE (0.005	Error indicates Error indi	DUANE DALPIAZ HARVEY data for averages APEL OCUMENT ID VOROBYEV DOLUMENT ID AND	80 74 72 71 55, fits 79 88 88 69 73	SPEC MMS CNTR OSPK S, limits, NICE TECN ND TECN HBC S, limits, HBC TECN HBC	$\begin{array}{c} \frac{COMMENT}{R} \\ 8.45 \ \pi^- \ \rho \rightarrow \\ n\pi^+ \pi^- 2\gamma \\ \pi^- p \rightarrow n MM \\ 1.6 \ \pi^- p \rightarrow n X^0 \\ 3.65 \ \pi^- p \rightarrow n X^0 \\ \text{etc.} \bullet \bullet \\ 15-40 \ \pi^- p \rightarrow n 2\gamma \\ \hline \\ \frac{COMMENT}{e^+ e^- \rightarrow \pi^+ \pi^- \eta} \\ \hline \frac{\Gamma_{10}/\Gamma}{COMMENT} \\ 2.2 \ K^- p \rightarrow \Lambda X^0 \\ \hline \\ \frac{COMMENT}{R} \\ \frac{COMMENT}{1.7-2.7 \ K^- p} \\ \hline \end{array}$
$VALUE$ 0.0212±0.0013 OUR FI 0.0212±0.0015 OUR AV 0.0296±0.0015 OUR AV 0.0200±0.0018 0.025 ±0.007 0.0171±0.0033 0.020 ±0.006 • • • We do not use the 0.018 ±0.002 8 Includes APEL 79 re 9 Data is included in S $\Gamma(e^+e^-)/\Gamma_{\text{total}}$ VALUE (0.02 • • • We do not use the 0.018 ±0.002 Γ(π+π-)/Γ _{total} VALUE (0.02 • • • We do not use the 0.008 $\Gamma(π+π-π^0)/\Gamma_{\text{total}}$ VALUE (0.008 $\Gamma(π+π-π^0)/\Gamma_{\text{total}}$ VALUE (0.005	Error indicates Error indi	DOCUMENT ID RITTENBERG DOCUMENT ID RITTENBERG DOCUMENT ID RITTENBERG DOCUMENT ID RITTENBERG DANBURG	80 74 72 71 88 88 69 69 6, fits	SPEC MMS CNTR OSPK S, limits, NICE TECN ND TECN HBC S, limits, HBC TECN HBC S, limits,	$\begin{array}{c} \frac{COMMENT}{R} \\ 8.45 \ \pi^- \ \rho \rightarrow \\ n\pi^+ \pi^- 2\gamma \\ \pi^- p \rightarrow n MM \\ 1.6 \ \pi^- p \rightarrow n X^0 \\ 3.65 \ \pi^- p \rightarrow n X^0 \\ \text{etc.} \bullet \bullet \\ 15-40 \ \pi^- p \rightarrow n 2\gamma \\ \hline \\ \frac{COMMENT}{e^+ e^- \rightarrow \pi^+ \pi^- \eta} \\ \hline \frac{\Gamma_{10}/\Gamma}{COMMENT} \\ 2.2 \ K^- p \rightarrow \Lambda X^0 \\ \hline \\ \frac{COMMENT}{R} \\ \frac{COMMENT}{1.7-2.7 \ K^- p} \\ \hline \end{array}$
$VALUE$ 0.0196±0.0013 OUR FI 0.0196±0.0015 OUR AV 0.0200±0.0018 0.025 ±0.007 0.0171±0.0033 0.020 ±0.006 • • • We do not use the 0.018 ±0.002 8 Includes APEL 79 re 9 Data is included in S $\Gamma(e^+e^-)/\Gamma$ total $VALUE$ <0.02 • • • We do not use the <0.08 $\Gamma(\pi^+\pi^-)/\Gamma$ total $VALUE$ <0.09 • • • We do not use the <0.08 $\Gamma(\pi^+\pi^-\pi^0)/\Gamma$ total $VALUE$ <0.09	Error increase	DUANE DALPIAZ HARVEY data for averages APEL OCUMENT ID RITTENBERG DALBURG DOCUMENT ID RITTENBERG DANBURG DANBURG DANBURG DANBURG	80 74 72 71 88 88 69 69 6, fits	SPEC MMS CNTR OSPK S, limits, NICE TECN ND TECN HBC S, limits, HBC TECN HBC S, limits,	$\begin{array}{c} \frac{COMMENT}{R} \\ 8.45 \ \pi^- \ \rho \to \\ n\pi^+ \pi^- 2\gamma \\ \pi^- \ \rho \to nMM \\ 1.6 \ \pi^- \ \rho \to nX^0 \\ 3.65 \ \pi^- \ \rho \to nX^0 \\ \text{etc.} \bullet \bullet \bullet \\ 15-40 \ \pi^- \ \rho \to n2\gamma \\ \hline \\ \frac{COMMENT}{e^+ \ e^- \to \pi^+ \pi^- \eta} \\ \hline 1.7-2.7 \ K^- \ \rho \\ \text{etc.} \bullet \bullet \bullet \\ 2.2 \ K^- \ \rho \to \Lambda X^0 \\ \hline \\ \frac{COMMENT}{R} \\ 1.7-2.7 \ K^- \ \rho \\ \text{etc.} \bullet \bullet \bullet \\ 2.2 \ K^- \ \rho \to \Lambda X^0 \\ \hline \end{array}$
$VALUE$ 0.0212±0.0013 OUR FI 0.0212±0.0015 OUR AV 0.0200±0.0018 0.025±0.007 0.0171±0.0033 0.020±0.006 • • • We do not use the 0.018±0.002 8 Includes APEL 79 re 9 Data is included in S $\Gamma(e^+e^-)/\Gamma$ total $VALUE$ $VALUE$ 0.02 • • • We do not use the 0.018 $VALUE$ 0.02 • • • We do not use the 0.018 0.02 • • • We do not use the 0.03 Γ (π ⁺ π ⁻ η)/Γ total 0.04 0.05 • • • We do not use the 0.05 • • • We do not use the 0.09 Γ (π ⁺ π ⁺ π ⁻ π neutr	Error inc/PERAGE	Cludes scale factors STANTON DUANE DALPIAZ HARVEY data for averages APEL O evaluation. DOCUMENT ID VOROBYEV DOCUMENT ID RITTENBERG data for averages DANBURG DOCUMENT ID RITTENBERG data for averages DANBURG	80 74 72 71 s, fits 79 88 69 s, fits 73	SPEC MMS CNTR OSPK S, limits, NICE TECN ND TECN HBC S, limits, HBC TECN HBC S, limits, HBC HBC HBC HBC HBC HBC HBC HBC	$\begin{array}{c} \text{COMMENT} \\ 8.45 \ \pi^- \ \rho \rightarrow \\ n \pi^+ \pi^- 2 \gamma \\ \pi^- \ \rho \rightarrow n \text{MM} \\ 1.6 \ \pi^- \ \rho \rightarrow n \text{X}^0 \\ \text{etc.} \bullet \bullet \bullet \\ 15-40 \ \pi^- \ \rho \rightarrow n \text{2} \gamma \\ \\ \hline \\ \frac{COMMENT}{e^+ e^- \rightarrow \pi^+ \pi^- \eta} \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ 2.2 \ K^- \ \rho \rightarrow \Lambda \text{X}^0 \\ \hline \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ 2.2 \ K^- \ \rho \rightarrow \Lambda \text{X}^0 \\ \hline \\ \hline \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \\ \hline $
$VALUE$ 0.0212±0.0013 OUR FI 0.0212±0.0015 OUR AV 0.0200±0.0018 0.025±0.007 0.0171±0.0033 0.020±0.006 • • • We do not use the 0.018±0.002 8 Includes APEL 79 re 9 Data is included in S $\Gamma(e^+e^-)/\Gamma$ total $VALUE$ $VALUE$ 0.02 • • • We do not use the 0.018 $VALUE$ 0.02 • • • We do not use the 0.018 0.02 • • • We do not use the 0.03 Γ (π ⁺ π ⁻ η)/Γ total 0.04 0.05 • • • We do not use the 0.05 • • • We do not use the 0.09 Γ (π ⁺ π ⁺ π ⁻ π neutr	Error increase	DUANE DALPIAZ HARVEY data for averages APEL OCUMENT ID RITTENBERG DALBURG DOCUMENT ID RITTENBERG DANBURG DANBURG DANBURG DANBURG	80 74 72 71 79 88 69 69 5, fits 73	SPEC MMS CNTR OSPK S, limits, NICE TECN ND TECN HBC S, limits, HBC TECN HBC S, limits, HBC HBC HBC HBC HBC HBC HBC HBC	$\begin{array}{c} \text{COMMENT} \\ 8.45 \ \pi^- \ \rho \rightarrow \\ n \pi^+ \pi^- 2 \gamma \\ \pi^- \ \rho \rightarrow n \text{MM} \\ 1.6 \ \pi^- \ \rho \rightarrow n \text{X}^0 \\ \text{etc.} \bullet \bullet \bullet \\ 15-40 \ \pi^- \ \rho \rightarrow n \text{2} \gamma \\ \\ \hline \\ \frac{COMMENT}{e^+ e^- \rightarrow \pi^+ \pi^- \eta} \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ 2.2 \ K^- \ \rho \rightarrow \Lambda \text{X}^0 \\ \hline \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ 2.2 \ K^- \ \rho \rightarrow \Lambda \text{X}^0 \\ \hline \\ \hline \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \bullet \\ \hline \\ \frac{COMMENT}{1.7-2.7 \ K^- \ \rho} \\ \text{etc.} \bullet \\ \hline $
$VALUE$ 0.0212±0.0013 OUR FI 0.0212±0.0015 OUR AV 0.0200±0.0018 0.025±0.007 0.0171±0.0033 0.020±0.006 • • • We do not use the 0.018±0.002 8 Includes APEL 79 re 9 Data is included in S $\Gamma(e^+e^-)/\Gamma_{\text{total}}$ VALUE (units 10 ⁻⁷) <<.1. $\Gamma(\pi^+\pi^-)/\Gamma_{\text{total}}$ VALUE (0.05 • • • We do not use the <<.0.08 $\Gamma(\pi^+\pi^-\pi^0)/\Gamma_{\text{total}}$ VALUE <<.0.09 $\Gamma(\pi^+\pi^-\pi^0)/\Gamma_{\text{total}}$ VALUE <<.0.05 • • • We do not use the <<.0.09 $\Gamma(\pi^+\pi^-\pi^-\pi^0)/\Gamma_{\text{total}}$ VALUE <<.0.05 • • • We do not use the <<.0.09 $\Gamma(\pi^+\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi$	CL% 90 Cl% 95	Cludes scale factors STANTON DUANE DALPIAZ HARVEY data for averages APEL O evaluation. DOCUMENT ID VOROBYEV DOCUMENT ID RITTENBERG data for averages DANBURG DANBURG DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID ANDUROT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID DANBURG DOCUMENT ID DANBURG DOCUMENT ID DANBURG DOCUMENT ID DANBURG	80 74 72 71 5, fits 79 88 88 69 69 69 5, fits 73 73 5, fits	SPEC MMS CNTR OSPK 5, limits, NICE TECN ND TECN HBC 5, limits, HBC TECN HBC 5, limits, HBC	$\begin{array}{c} \underline{COMMENT} \\ 8.45 \ \pi^- \ \rho \to \\ n\pi^+ \pi^- 2\gamma \\ \pi^- \rho \to nMM \\ 1.6 \ \pi^- \rho \to nX^0 \\ 3.65 \ \pi^- \rho \to nX^0 \\ \text{etc.} \bullet \bullet \bullet \\ 15-40 \ \pi^- \rho \to n2\gamma \\ \hline \\ \hline \hline COMMENT \\ 1.7-2.7 \ K^- \rho \\ \text{etc.} \bullet \bullet \bullet \\ 2.2 \ K^- \rho \to \Lambda X^0 \\ \hline \hline \hline \Gamma_{10}/\Gamma \\ \hline COMMENT \\ 1.7-2.7 \ K^- \rho \\ \text{etc.} \bullet \bullet \bullet \\ 2.2 \ K^- \rho \to \Lambda X^0 \\ \hline \hline \hline \hline \Gamma_{10}/\Gamma \\ \hline \hline COMMENT \\ 1.7-2.7 \ K^- \rho \\ \text{etc.} \bullet \bullet \bullet \\ 2.2 \ K^- \rho \to \Lambda X^0 \\ \hline \hline \hline \hline \hline \hline \Gamma_{14}/\Gamma \\ \hline \hline \hline \hline \hline COMMENT \\ 1.7-2.7 \ K^- \rho \\ \text{etc.} \bullet \bullet \bullet \\ 2.2 \ K^- \rho \to \Lambda X^0 \\ \hline $
VALUE	CL% 90 Cl% 95	Cludes scale factors STANTON DUANE DALPIAZ HARVEY data for averages APEL O evaluation. DOCUMENT ID VOROBYEV DOCUMENT ID RITTENBERG data for averages DANBURG DANBURG I DOCUMENT ID RITTENBERG AND RITTENBERG DANBURG DANBURG DANBURG	80 74 72 71 5, fits 79 88 88 69 69 69 5, fits 73 73 5, fits	SPEC MMS CNTR OSPK 5, limits, NICE TECN ND TECN HBC 5, limits, HBC TECN HBC 5, limits, HBC	$\begin{array}{c} \underline{COMMENT} \\ 8.45 \ \pi^- \ \rho \to \\ n\pi^+ \pi^- 2\gamma \\ \pi^- \rho \to nMM \\ 1.6 \ \pi^- \rho \to nX^0 \\ 3.65 \ \pi^- \rho \to nX^0 \\ \text{etc.} \bullet \bullet \bullet \\ 15-40 \ \pi^- \rho \to n2\gamma \\ \hline \\ \hline \hline COMMENT \\ 1.7-2.7 \ K^- \rho \\ \text{etc.} \bullet \bullet \bullet \\ 2.2 \ K^- \rho \to \Lambda X^0 \\ \hline \hline \hline \Gamma_{10}/\Gamma \\ \hline COMMENT \\ 1.7-2.7 \ K^- \rho \\ \text{etc.} \bullet \bullet \bullet \\ 2.2 \ K^- \rho \to \Lambda X^0 \\ \hline \hline \hline \hline \Gamma_{10}/\Gamma \\ \hline \hline COMMENT \\ 1.7-2.7 \ K^- \rho \\ \text{etc.} \bullet \bullet \bullet \\ 2.2 \ K^- \rho \to \Lambda X^0 \\ \hline \hline \hline \hline \hline \hline \Gamma_{14}/\Gamma \\ \hline \hline \hline \hline \hline COMMENT \\ 1.7-2.7 \ K^- \rho \\ \text{etc.} \bullet \bullet \bullet \\ 2.2 \ K^- \rho \to \Lambda X^0 \\ \hline $
VALUE $VALUE$ VA	For indiverse in the control of the	Cludes scale factors STANTON DUANE DALPIAZ HARVEY data for averages APEL O evaluation. DOCUMENT ID VOROBYEV DOCUMENT ID RITTENBERG data for averages DANBURG DANBURG DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID ANDUROT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID DANBURG DOCUMENT ID DANBURG DOCUMENT ID DANBURG DOCUMENT ID DANBURG	80 74 72 71 5, fits 79 88 88 69 69 69 5, fits 73 73 5, fits	SPEC MMS CNTR OSPK 5, limits, NICE TECN ND TECN HBC 5, limits, HBC TECN HBC 5, limits, HBC	$\begin{array}{c} \underline{COMMENT} \\ 8.45 \ \pi^- \ \rho \to \\ n\pi^+ \pi^- 2\gamma \\ \pi^- \rho \to nMM \\ 1.6 \ \pi^- \rho \to nX^0 \\ 3.65 \ \pi^- \rho \to nX^0 \\ \text{etc.} \bullet \bullet \bullet \\ 15-40 \ \pi^- \rho \to n2\gamma \\ \hline \\ \hline \hline COMMENT \\ 1.7-2.7 \ K^- \rho \\ \text{etc.} \bullet \bullet \bullet \\ 2.2 \ K^- \rho \to \Lambda X^0 \\ \hline \hline \hline \Gamma_{10}/\Gamma \\ \hline COMMENT \\ 1.7-2.7 \ K^- \rho \\ \text{etc.} \bullet \bullet \bullet \\ 2.2 \ K^- \rho \to \Lambda X^0 \\ \hline \hline \hline \hline \Gamma_{10}/\Gamma \\ \hline \hline COMMENT \\ 1.7-2.7 \ K^- \rho \\ \text{etc.} \bullet \bullet \bullet \\ 2.2 \ K^- \rho \to \Lambda X^0 \\ \hline \hline \hline \hline \hline \hline \Gamma_{14}/\Gamma \\ \hline \hline \hline \hline \hline COMMENT \\ 1.7-2.7 \ K^- \rho \\ \text{etc.} \bullet \bullet \bullet \\ 2.2 \ K^- \rho \to \Lambda X^0 \\ \hline $
$VALUE$ 0.013 OUR FI' 0.00196±0.0015 OUR AV 0.0200±0.0018 OUR FI' 0.0196±0.0015 OUR AV 0.0200±0.003 0.020 $^{+0.008}$ 0.020 $^{+0.008}$ 0.020 $^{+0.008}$ 0.020 $^{+0.008}$ 0.018 ±0.002 $^{-8}$ Includes APEL 79 respond in Sincluded in Sinclude S	For indiverse in the control of the	Cludes scale factors STANTON DUANE DALPIAZ HARVEY data for averages APEL O evaluation. DOCUMENT ID VOROBYEV DOCUMENT ID RITTENBERG data for averages DANBURG DANBURG DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID ANDUROT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID DANBURG DOCUMENT ID DANBURG DOCUMENT ID DANBURG DOCUMENT ID DANBURG	80 74 72 71 88 88 69 69, fits 73 73 73 69	SPEC MMS CNTR OSPK 5, limits, NICE TECN ND TECN HBC 5, limits, HBC TECN HBC 5, limits, HBC TECN HBC 5, limits, HBC	$\begin{array}{c} \frac{COMMENT}{R} \\ 8.45 \ \pi^- \ p \rightarrow \\ n\pi^+ \pi^- 2\gamma \\ \pi^- p \rightarrow n \text{MM} \\ 1.6 \ \pi^- p \rightarrow n \text{X}^0 \\ 3.65 \ \pi^- p \rightarrow n \text{X}^0 \\ \text{etc.} \bullet \bullet \\ 15-40 \ \pi^- p \rightarrow n \text{2}\gamma \\ \hline \\ \frac{COMMENT}{COMMENT} \\ 1.7-2.7 \ K^- p \\ \text{etc.} \bullet \bullet \\ 2.2 \ K^- p \rightarrow \Lambda X^0 \\ \hline \\ \frac{COMMENT}{R} \\ 1.7-2.7 \ K^- p \\ \text{etc.} \bullet \bullet \\ 2.2 \ K^- p \rightarrow \Lambda X^0 \\ \hline \\ \frac{COMMENT}{COMMENT} \\ 1.7-2.7 \ K^- p \\ \text{etc.} \bullet \bullet \\ 1.7-2.7 \ K^- p \\ \text{etc.} \bullet \bullet \\ 1.7-2.7 \ K^- p \\ \hline \\ \frac{COMMENT}{COMMENT} \\ 1.7-2.7 \ K^- p \\ \hline \\ \frac{COMMENT}{COMMENT} \\ \frac$
VALUE $VALUE$ $VALU$	CL% 90 CL% 95 following (c) 95 follow	Cludes scale factors STANTON DUANE DALPIAZ HARVEY data for averages APEL O evaluation. DOCUMENT ID VOROBYEV DOCUMENT ID RITTENBERG data for averages DANBURG DANBURG I DOCUMENT ID RITTENBERG ANBURG ANBURG DANBURG ANBURG ANBUR	80 74 72 71 88 88 69 5, fits 73 73 73 69 69 69	SPEC MMS CNTR OSPK 5, limits, NICE TECN ND TECN HBC 5, limits, HBC TECN HBC 5, limits, HBC TECN HBC 5, limits, HBC	$\begin{array}{c} \frac{COMMENT}{R} \\ 8.45 \ \pi^- \ \rho \to \\ n\pi^+ \pi^- 2\gamma \\ \pi^- \ \rho \to nMM \\ 1.6 \ \pi^- \ \rho \to nX^0 \\ 3.65 \ \pi^- \ \rho \to nX^0 \\ \text{etc.} \bullet \bullet \bullet \\ 15-40 \ \pi^- \ \rho \to n2\gamma \\ \hline \\ \hline \begin{array}{c} \Gamma_{25}/\Gamma \\ \hline COMMENT \\ 1.7-2.7 \ K^- \ \rho \\ \text{etc.} \bullet \bullet \bullet \\ 2.2 \ K^- \ \rho \to \Lambda X^0 \\ \hline \hline \\ \hline \begin{array}{c} \Gamma_{10}/\Gamma \\ \hline COMMENT \\ 1.7-2.7 \ K^- \ \rho \\ \text{etc.} \bullet \bullet \bullet \\ 2.2 \ K^- \ \rho \to \Lambda X^0 \\ \hline \end{array} \\ \hline \begin{array}{c} \Gamma_{14}/\Gamma \\ \hline COMMENT \\ \hline \end{array}$
VALUE	CL% 90 CL% 95 e following of 95 e	Cludes scale factors cludes scale factors are cludes scale factors as a scale factor are cludes as a sc	80 74 72 71 88 88 69 5, fits 73 73 73 69 69 69	SPEC MMS CNTR OSPK 5, limits, NICE TECN ND TECN HBC 5, limits, HBC TECN HBC 5, limits, HBC TECN HBC 5, limits, HBC	$\begin{array}{c} \frac{COMMENT}{R} \\ 8.45 \ \pi^- \ \rho \to \\ n\pi^+ \pi^- 2\gamma \\ \pi^- \ \rho \to nMM \\ 1.6 \ \pi^- \ \rho \to nX^0 \\ 3.65 \ \pi^- \ \rho \to nX^0 \\ \text{etc.} \bullet \bullet \bullet \\ 15-40 \ \pi^- \ \rho \to n2\gamma \\ \hline \\ \hline \begin{array}{c} \Gamma_{25}/\Gamma \\ \hline COMMENT \\ 1.7-2.7 \ K^- \ \rho \\ \text{etc.} \bullet \bullet \bullet \\ 2.2 \ K^- \ \rho \to \Lambda X^0 \\ \hline \hline \\ \hline \begin{array}{c} \Gamma_{10}/\Gamma \\ \hline COMMENT \\ 1.7-2.7 \ K^- \ \rho \\ \text{etc.} \bullet \bullet \bullet \\ 2.2 \ K^- \ \rho \to \Lambda X^0 \\ \hline \end{array} \\ \hline \begin{array}{c} \Gamma_{14}/\Gamma \\ \hline COMMENT \\ \hline \end{array}$
VALUE' $VALUE'$ V	Error index/PERAGE & & & & & & & & & & & & & & & & & & &	Cludes scale factors STANTON DUANE DALPIAZ HARVEY data for averages APEL O evaluation. DOCUMENT ID RITTENBERG data for averages DANBURG DOCUMENT ID RITTENBERG data for averages DANBURG I DOCUMENT ID RITTENBERG data for averages DANBURG I DOCUMENT ID RITTENBERG ABLE DOCUMENT ID RITTENBERG ANBURG I DOCUMENT ID RITTENBERG ABLE DOCUMENT ID RITTENBERG DOCUMENT ID RITTENBERG	80 74 72 71 88 88 69 5, fits 73 73 73 69 69 69	SPEC MMS CNTR OSPK S, limits, NICE TECN ND TECN HBC S, limits, HBC TECN HBC S, limits, HBC TECN HBC S, limits, HBC TECN HBC TECN HBC TECN HBC TECN HBC TECN HBC TECN HBC	$\begin{array}{c} \frac{COMMENT}{R} \\ 8.45 \ \pi^- \ \rho \rightarrow \\ n\pi^+ \pi^- 2\gamma \\ \pi^- \ \rho \rightarrow nMM \\ 1.6 \ \pi^- \ \rho \rightarrow nX^0 \\ 3.65 \ \pi^- \ \rho \rightarrow nX^0 \\ \text{etc.} \bullet \bullet \bullet \\ 15-40 \ \pi^- \ \rho \rightarrow n2\gamma \\ \hline \\ \frac{COMMENT}{R} \\ 1.7-2.7 \ K^- \ \rho \\ \text{etc.} \bullet \bullet \bullet \\ 2.2 \ K^- \ \rho \rightarrow \Lambda X^0 \\ \hline \\ \frac{COMMENT}{R} \\ 1.7-2.7 \ K^- \ \rho \\ \text{etc.} \bullet \bullet \bullet \\ 2.2 \ K^- \ \rho \rightarrow \Lambda X^0 \\ \hline \\ \frac{COMMENT}{R} \\ 1.7-2.7 \ K^- \ \rho \\ \text{etc.} \bullet \bullet \bullet \\ 1.7-2.7 \ K^- \ \rho \\ \hline \\ \frac{COMMENT}{R} \\ 1.7-2.7 \ K^- \ \rho \\ \hline \\ \frac{COMMENT}{R} \\ 1.7-2.7 \ K^- \ \rho \\ \hline \\ \frac{COMMENT}{R} \\ 1.7-2.7 \ K^- \ \rho \\ \hline \\ \frac{COMMENT}{R} \\ 1.7-2.7 \ K^- \ \rho \\ \hline \\ \frac{COMMENT}{R} \\ 1.7-2.7 \ K^- \ \rho \\ \hline \\ \frac{COMMENT}{R} \\ 1.7-2.7 \ K^- \ \rho \\ \hline \\ \frac{COMMENT}{R} \\ 1.7-2.7 \ K^- \ \rho \\ \hline \\ \frac{COMMENT}{R} \\ \frac{COMMENT}{R} \\ 1.7-2.7 \ K^- \ \rho \\ \hline \\ \frac{COMMENT}{R} \\$
VALUE' $VALUE'$ V	CL% 90 CL% 95 following () 90 follow	Cludes scale factors cludes scale factors are scale factors as a scale factor are scale factors are scale factors.	80 74 72 71 88 88 69 5, fits 73 73 73 69 69 69	SPEC MMS CNTR OSPK S, limits, NICE TECN ND TECN HBC S, limits, HBC TECN HBC S, limits, HBC TECN HBC S, limits, HBC TECN HBC TECN HBC TECN HBC TECN HBC TECN HBC TECN HBC	$\begin{array}{c} \frac{COMMENT}{R} \\ 8.45 \ \pi^- \ \rho \rightarrow \\ n\pi^+ \pi^- 2\gamma \\ \pi^- \ \rho \rightarrow nMM \\ 1.6 \ \pi^- \ \rho \rightarrow nX^0 \\ 3.65 \ \pi^- \ \rho \rightarrow nX^0 \\ \text{etc.} \bullet \bullet \bullet \\ 15-40 \ \pi^- \ \rho \rightarrow n2\gamma \\ \hline \\ \frac{COMMENT}{R} \\ 1.7-2.7 \ K^- \ \rho \\ \text{etc.} \bullet \bullet \bullet \\ 2.2 \ K^- \ \rho \rightarrow \Lambda X^0 \\ \hline \\ \frac{COMMENT}{R} \\ 1.7-2.7 \ K^- \ \rho \\ \text{etc.} \bullet \bullet \bullet \\ 2.2 \ K^- \ \rho \rightarrow \Lambda X^0 \\ \hline \\ \frac{COMMENT}{R} \\ 1.7-2.7 \ K^- \ \rho \\ \text{etc.} \bullet \bullet \bullet \\ 1.7-2.7 \ K^- \ \rho \\ \hline \\ \frac{COMMENT}{R} \\ 1.7-2.7 \ K^- \ \rho \\ \hline \\ \frac{COMMENT}{R} \\ 1.7-2.7 \ K^- \ \rho \\ \hline \\ \frac{COMMENT}{R} \\ 1.7-2.7 \ K^- \ \rho \\ \hline \\ \frac{COMMENT}{R} \\ 1.7-2.7 \ K^- \ \rho \\ \hline \\ \frac{COMMENT}{R} \\ 1.7-2.7 \ K^- \ \rho \\ \hline \\ \frac{COMMENT}{R} \\ 1.7-2.7 \ K^- \ \rho \\ \hline \\ \frac{COMMENT}{R} \\ 1.7-2.7 \ K^- \ \rho \\ \hline \\ \frac{COMMENT}{R} \\ \frac{COMMENT}{R} \\ 1.7-2.7 \ K^- \ \rho \\ \hline \\ \frac{COMMENT}{R} \\$

 $\eta'(958)$, $f_0(980)$

	including $ ho$	⁰ γ))			Γ_2/Γ_{24}
VALUE	<u>EVTS</u>	DOCUMENT ID			
• • We do not use th	_	_			2.2 $K^- p \rightarrow \Lambda X^0$
1.15±0.10 1.01±0.15	473 137	DANBURG JACOBS	73 73	HBC HBC	$2.2 K p \rightarrow \Lambda X^0$ $2.9 K^- p \rightarrow \Lambda X^0$
0.94±0.20	151	AGUILAR		нвс	3.9-4.6 K ⁻ p
	\\				0.3105 /5
$\Gamma(\pi^0\pi^0\eta)$ ($3\pi^0$ decay)))/ total EVTS	DOCUMENT ID		TECN	0.319Γ ₃ /Γ
0.066±0.004 OUR FIT		des scale factor			COMMENT
0.11 ±0.06	4	BENSINGER	70	DBC	$2.2 \pi^+ d$
$\Gamma(ho^{0}\gamma)/\Gamma(\pi^{+}\pi^{-}\eta)$	neutral dec	av))			$\Gamma_2/0.709\Gamma_1$
VALUE	EVTS	DOCUMENT ID		TECN_	COMMENT
0.97±0.07 OUR FIT	rror include	s scale factor of	1.1.		
1.01±0.09 OUR AVERA	NGE	BELADIDZE	000	VES	24 -= Da -=/ Da
1.07±0.17 0.92±0.14	473	DANBURG		HBC	36 π^- Be $\rightarrow \pi^- \eta' \eta$ Be 2.2 $K^- p \rightarrow \Lambda X^0$
1.11±0.18	192	JACOBS	73		$2.9 K^- p \rightarrow \Lambda X^0$
					·
$\Gamma(\gamma\gamma)/\Gamma(\pi^0\pi^0\eta)$ (ne					Γ ₅ /0.709Γ ₃
0.144 ± 0.010 OUR FIT	EVTS Error inclu	DOCUMENT ID des scale factor		TECN_	COMMENT
0.188±0.058	16	APEL.	72		$3.8 \pi^- p \rightarrow n X^0$
			-		
$\Gamma(\mu^+\mu^-\gamma)/\Gamma(\gamma\gamma)$					Γ_7/Γ_5
VALUE (units 10 ⁻³)		DOCUMENT ID			COMMENT
1.9±1.2	33	VIKTOROV	80	CNTR	25,33 $\pi^- p \rightarrow 2\mu\gamma$
$-(\mu^+\mu^-\eta)/\Gamma_{\text{total}}$					Γ ₂₃ /Γ
ALUE (units 10 ⁻⁵)	CL%	DOCUMENT ID		TECN	COMMENT
<1.5	90	DZHELYADIN	81	CNTR	$30 \pi^- p \rightarrow \eta' n$
-() 0) (=					
$\Gamma(\mu^+\mu^-\pi^0)/\Gamma_{total}$					Γ ₂₂ /Γ
/ALUE (units 10 ⁻⁵)	CL%	DOCUMENT ID		TECN	COMMENT
<6.0	90	DZHELYADIN	81	CNTR	$30 \pi^- p \rightarrow \eta' n$
$\Gamma(3\pi^0)/\Gamma(\pi^0\pi^0\eta)$					Γ_6/Γ_3
ALUE (units 10 ⁻⁴)		DOCUMENT ID		TECN	COMMENT
74±12 OUR FIT					
74±12 OUR AVERAGE				C 4 4 4 2	20 =(-
		ALDE.	070		
		ALDE			$38 \pi^- p \rightarrow n6\gamma$ $30-40 \pi^- p \rightarrow n6\gamma$
75±18		ALDE BINON	87B 84		$30-40 \pi^- p \rightarrow n6\gamma$
75±18				GAM2	
$\Gamma(\gamma\gamma)/\Gamma(\pi^0\pi^0\eta)$ TALUE	Error inclu	BINON DOCUMENT ID	84	GAM2	$30-40 \pi^- p \rightarrow n6\gamma$
(75 ± 18) $(\gamma\gamma)/\Gamma(\pi^0\pi^0\eta)$ (75 ± 0.007)		BINON DOCUMENT ID des scale factor	84 of 1.	GAM2 <u>TECN</u> 6.	30-40 $\pi^- p \rightarrow n6\gamma$ Γ_5/Γ_3 COMMENT
$(75\pm18)^{-1} (\gamma\gamma)/\Gamma(\pi^0\pi^0\eta)^{-1} (\gamma\gamma)/\Gamma(\pi^0\pi^0\eta)^{-1} (102\pm0.007)^{-1} ext{OUR FIT} (105\pm0.010)^{-1} ext{OUR AVE}$		BINON DOCUMENT ID	of 1.0	GAM2 <u>TECN</u> 6.	$30-40 \pi^- p \rightarrow n6\gamma$ Γ_5/Γ_3 $COMMENT$
$(75\pm18)^{-1} (\gamma \gamma) / \Gamma (\pi^0 \pi^0 \eta)$ $(3.102\pm0.007 \text{ OUR FIT})$ $(3.102\pm0.010 \text{ OUR AVE})$ (3.091 ± 0.009)		BINON DOCUMENT ID des scale factor or includes scale	of 1.0 facto 93	GAM2 <u>TECN</u> 6. or of 1.9	$30-40 \pi^- p \rightarrow n6\gamma$ Γ_5/Γ_3 $COMMENT$
75 ± 18 $\Gamma(\gamma\gamma)/\Gamma(\pi^0\pi^0\eta)$ $ALUE$ 1.102 ± 0.007 OUR FIT 1.105 ± 0.010 OUR AVE 1.009 1.112 ± 0.009		DOCUMENT ID des scale factor or includes scale AMSLER	of 1.0 facto 93	GAM2 TECN 6. or of 1.9 CBAR	$30-40 \ \pi^- \rho \rightarrow n6\gamma$ Γ_5/Γ_3 $COMMENT$ $0.0 \ \overline{\rho}\rho$ $38 \ \pi^- \rho \rightarrow n2\gamma$
75 ± 18 $\Gamma(\gamma \gamma)/\Gamma(\pi^0 \pi^0 \eta)$ $ALUE$ 0.102 ± 0.007 OUR FIT 0.105 ± 0.010 OUR AVE 0.091 ± 0.009 $0.112 \pm 0.002 \pm 0.006$ $\Gamma(\omega \gamma)/\Gamma(\pi^0 \pi^0 \eta)$ $ALUE$		DOCUMENT ID des scale factor or includes scale AMSLER	of 1. facto 93 87B	TECN 6. or of 1.9 CBAR GAM2	$\begin{array}{cccccccccccccccccccccccccccccccccccc$
75 ± 18 $\Gamma(\gamma\gamma)/\Gamma(\pi^0\pi^0\eta)$ $\frac{ALUE}{L}$ 1.102 ± 0.007 OUR FIT. 1.105 ± 0.010 OUR AVE 1.091 ± 0.009 $1.112\pm0.002\pm0.006$ $\Gamma(\omega\gamma)/\Gamma(\pi^0\pi^0\eta)$ 1.145 ± 0.014 OUR FIT.		DOCUMENT ID des scale factor or includes scale AMSLER ALDE	of 1.1 factor 93 87B	TECN 6. cr of 1.9 CBAR GAM2	$30-40 \ \pi^- p \rightarrow n6\gamma$ $\hline \Gamma_5/\Gamma_3$ $COMMENT$ $0.0 \ \overline{p}p$ $38 \ \pi^- p \rightarrow n2\gamma$ $\hline \Gamma_4/\Gamma_3$ $COMMENT$
$^{\prime 5\pm 18}$ $^{\prime }$		DOCUMENT ID des scale factor or includes scale AMSLER ALDE	of 1.1 factor 93 87B	TECN 6. cr of 1.9 CBAR GAM2	$\begin{array}{cccccccccccccccccccccccccccccccccccc$
$^{\prime 2}$ 5±18 $^{\prime 2}$ $^{\prime 2}$ $^{\prime 2}$ $^{\prime 3}$ $^{\prime 4}$ $^{\prime 6}$		DOCUMENT ID des scale factor or includes scale AMSLER ALDE	of 1.1 factor 93 87B	TECN 6. cr of 1.9 CBAR GAM2	$30-40 \pi^- p \rightarrow n6\gamma$ Γ_5/Γ_3 $0.0 \overline{p}p$ $38 \pi^- p \rightarrow n2\gamma$ Γ_4/Γ_3 $0.0 \overline{p} \rightarrow n2\gamma$ Γ_4/Γ_3 $0.0 \overline{p} \rightarrow n4\gamma$
$^{75\pm18}$ $^{-7}(\gamma\gamma)/\Gamma(\pi^0\pi^0\eta)$ $^{-7}(\pi^0\pi^0\eta)$	RAGE Erri	DOCUMENT ID des scale factor or includes scale AMSLER ALDE	of 1.1 factor 93 87B	TECN 6. or of 1.9 CBAR GAM2 TECN GAM2	$30-40 \ \pi^- p \rightarrow \ n6\gamma$
75 ± 18 $\Gamma(\gamma\gamma)/\Gamma(\pi^0\pi^0\eta)$ $MALUE$ 0.102 ± 0.007 OUR FIT 0.105 ± 0.010 OUR AVE 0.091 ± 0.009 $0.112\pm0.002\pm0.006$ $\Gamma(\omega\gamma)/\Gamma(\pi^0\pi^0\eta)$ $MALUE$ 0.147 ± 0.014 OUR FIT 0.147 ± 0.016 $\Gamma(3\gamma)/\Gamma(\pi^0\pi^0\eta)$		BINON DOCUMENT ID des scale factor or includes scale AMSLER ALDE DOCUMENT ID ALDE	of 1.1 factor 93 87B	TECN 6. cr of 1.9 CBAR GAM2 TECN GAM2	$30-40 \ \pi^- \rho \rightarrow n6\gamma$ $\frac{\Gamma_5/\Gamma_3}{COMMENT}$ $0.0 \ \overline{\rho}\rho$ $38 \ \pi^- \rho \rightarrow n2\gamma$ $\frac{\Gamma_4/\Gamma_3}{COMMENT}$ $38 \ \pi^- \rho \rightarrow n4\gamma$ $\frac{\Gamma_{21}/\Gamma_3}{COMMENT}$
75 ± 18 $\Gamma(\gamma\gamma)/\Gamma(\pi^0\pi^0\eta)$ $\frac{ALUE}{1.102 \pm 0.007}$ OUR FIT. 1.105 ± 0.010 OUR AVE 0.091 ± 0.009 $1.112 \pm 0.002 \pm 0.006$ $\Gamma(\omega\gamma)/\Gamma(\pi^0\pi^0\eta)$ $\frac{ALUE}{1.145 \pm 0.014}$ OUR FIT. 1.145 ± 0.014 OUR FIT. 1.147 ± 0.016 $\Gamma(3\gamma)/\Gamma(\pi^0\pi^0\eta)$ $\frac{ALUE}{1.147 \pm 0.016}$ $\Gamma(3\gamma)/\Gamma(\pi^0\pi^0\eta)$ $\frac{ALUE}{1.147 \pm 0.016}$	CL% 90	DOCUMENT ID DOCUMENT ID DOCUMENT ID ALDE DOCUMENT ID	of 1.1 factor 93 87B	TECN 6. cr of 1.9 CBAR GAM2 TECN GAM2	$30-40 \ \pi^- p \rightarrow n6\gamma$ Γ_5/Γ_3 $COMMENT$ $0.0 \ \bar{p}p$ $38 \ \pi^- p \rightarrow n2\gamma$ $COMMENT$ $38 \ \pi^- p \rightarrow n4\gamma$ Γ_{21}/Γ_{3} $COMMENT$ $38 \ \pi^- p \rightarrow n3\gamma$
75 ± 18 $\Gamma(\gamma\gamma)/\Gamma(\pi^0\pi^0\eta)$ $\frac{AAUUE}{D.102\pm0.007}$ OUR FIT. 0.105 ± 0.010 OUR AVE. 0.091 ± 0.009 $0.112\pm0.002\pm0.006$ $\Gamma(\omega\gamma)/\Gamma(\pi^0\pi^0\eta)$ $\frac{AAUUE}{D.147\pm0.016}$ OUR FIT. 0.147 ± 0.016 $\Gamma(3\gamma)/\Gamma(\pi^0\pi^0\eta)$ $\frac{AAUUE}{D.147\pm0.016}$ $\Gamma(\alpha\gamma)/\Gamma(\pi^0\pi^0\eta)$ $\frac{AAUUE}{D.147\pm0.016}$ $\Gamma(\alpha\gamma)/\Gamma(\pi^0\pi^0\eta)$	PAGE Error	BINON DOCUMENT ID des scale factor or includes scale AMSLER ALDE DOCUMENT ID ALDE DOCUMENT ID ALDE	84 of 1 factor 93 87B	TECN 6. or of 1.9 CBAR GAM2 TECN GAM2 TECN GAM2	$30-40 \ \pi^- p \rightarrow n6\gamma$ Γ_5/Γ_3 $0.0 \ \bar{p}p$ $38 \ \pi^- p \rightarrow n2\gamma$ $COMMENT$ $38 \ \pi^- p \rightarrow n4\gamma$ Γ_{21}/Γ_3 $COMMENT$ $38 \ \pi^- p \rightarrow n3\gamma$ Γ_{19}/Γ_3
(75 ± 18) $(7(\gamma\gamma)/\Gamma(\pi^0\pi^0\eta))$ $(ALUE)$	CL% 90	BINON DOCUMENT ID des scale factor or includes scale AMSLER ALDE DOCUMENT ID ALDE DOCUMENT ID ALDE DOCUMENT ID ALDE	84 of 1. facto 93 87B 87B	TECN 6. TECN 6. TECN CBAR GAM2 TECN GAM2 TECN GAM2	$30-40 \pi^- \rho \rightarrow n6\gamma$ $\frac{\Gamma_5/\Gamma_3}{COMMENT}$ $0.0 \overline{\rho}\rho$ $38 \pi^- \rho \rightarrow n2\gamma$ $\frac{\Gamma_4/\Gamma_3}{COMMENT}$ $38 \pi^- \rho \rightarrow n4\gamma$ $\frac{\Gamma_{21}/\Gamma_3}{38 \pi^- \rho \rightarrow n3\gamma}$ $\frac{COMMENT}{38 \pi^- \rho \rightarrow n3\gamma}$ $\frac{\Gamma_{19}/\Gamma_3}{COMMENT}$
(75 ± 18) $(7(\gamma\gamma)/\Gamma(\pi^0\pi^0\eta))$ $(ALUE)$	PAGE Error	BINON DOCUMENT ID des scale factor or includes scale AMSLER ALDE DOCUMENT ID ALDE DOCUMENT ID ALDE	84 of 1. facto 93 87B 87B	TECN 6. TECN 6. TECN CBAR GAM2 TECN GAM2 TECN GAM2	$30-40 \ \pi^- \ \rho \rightarrow \ n6\gamma$ Γ_5/Γ_3 $0.0 \ \bar{p} \ \rho$ $38 \ \pi^- \ \rho \rightarrow \ n2\gamma$ $COMMENT$ $38 \ \pi^- \ \rho \rightarrow \ n4\gamma$ Γ_{21}/Γ_{3} $COMMENT$ $38 \ \pi^- \ \rho \rightarrow \ n3\gamma$ Γ_{19}/Γ_{3}
(75 ± 18) $(7(\gamma\gamma)/\Gamma(\pi^0\pi^0\eta))$ $(ALUE)$	CL% 90	BINON DOCUMENT ID des scale factor or includes scale AMSLER ALDE DOCUMENT ID ALDE DOCUMENT ID ALDE DOCUMENT ID ALDE	84 of 1. facto 93 87B 87B	TECN 6. TECN 6. TECN CBAR GAM2 TECN GAM2 TECN GAM2	$30-40 \ \pi^- \ p \rightarrow \ n6\gamma$ Γ_5/Γ_3 $COMMENT$ $0.0 \ \bar{p} \ p$ $38 \ \pi^- \ p \rightarrow \ n2\gamma$ $COMMENT$ $38 \ \pi^- \ p \rightarrow \ n4\gamma$ Γ_{21}/Γ_{3} $COMMENT$ $38 \ \pi^- \ p \rightarrow \ n3\gamma$ Γ_{19}/Γ_{3} $COMMENT$ $38 \ \pi^- \ p \rightarrow \ n4\gamma$
$^{75\pm18}$ $^{7}(\gamma\gamma)/\Gamma(\pi^{0}\pi^{0}\eta)$ 7ALUE $^{1.102\pm0.007}$ OUR FIT. $^{1.105\pm0.010}$ OUR AVE $^{1.091\pm0.009}$ $^{1.112\pm0.002\pm0.006}$ $^{7}(\omega\gamma)/\Gamma(\pi^{0}\pi^{0}\eta)$ $^{7}(\pi^{1})$	- CL% 90 - CL% 90	BINON DOCUMENT ID des scale factor or includes scale AMSLER ALDE DOCUMENT ID ALDE DOCUMENT ID ALDE DOCUMENT ID ALDE	84 of 1.4 factor 93 878 878	TECN 6. or of 1.9 CBAR GAM2 TECN GAM2 TECN GAM2 TECN GAM2	$30-40 \ \pi^- \rho \rightarrow n6\gamma$ $\frac{\Gamma_5/\Gamma_3}{COMMENT}$ $0.0 \ \overline{\rho}p \ 38 \ \pi^- p \rightarrow n2\gamma$ $\frac{\Gamma_4/\Gamma_3}{COMMENT}$ $38 \ \pi^- p \rightarrow n3\gamma$ $\frac{COMMENT}{38 \ \pi^- p \rightarrow n3\gamma}$ $\frac{\Gamma_{19}/\Gamma_3}{COMMENT}$ $38 \ \pi^- p \rightarrow n4\gamma$ $\frac{\Gamma_{18}/\Gamma_3}{18/\Gamma_3}$
(75 ± 18) $(7(\gamma))/\Gamma(\pi^0\pi^0\eta)$ $(ALUE)$		BINON DOCUMENT ID des scale factor or includes scale AMSLER ALDE DOCUMENT ID ALDE	84 of 1. factor 93 878 878	TECN GAM2 TECN GAM2 TECN GAM2 TECN GAM2 TECN GAM2	$30-40 \pi^- \rho \rightarrow n6\gamma$ Γ_5/Γ_3 $0.0 \bar{p}\rho$ $38 \pi^- \rho \rightarrow n2\gamma$ Γ_4/Γ_3 $0.0 \bar{p}\rho$ $0.0 p$
75 \pm 18 $\Gamma(\gamma\gamma)/\Gamma(\pi^{0}\pi^{0}\eta)$ $VALUE$ 1.102 \pm 0.007 OUR FIT 1.105 \pm 0.010 OUR AVE 0.091 \pm 0.009 1.112 \pm 0.002 \pm 0.006 $\Gamma(\omega\gamma)/\Gamma(\pi^{0}\pi^{0}\eta)$ $VALUE$ 1.145 \pm 0.014 OUR FIT 0.147 \pm 0.016 $\Gamma(3\gamma)/\Gamma(\pi^{0}\pi^{0}\eta)$ $VALUE (units 10^{-4}) VALUE (units 10^{-4})$	- CL% 90 - CL% 90	BINON DOCUMENT ID des scale factor or includes scale AMSLER ALDE DOCUMENT ID ALDE DOCUMENT ID ALDE DOCUMENT ID ALDE	84 of 1. factor 93 878 878	TECN GAM2 TECN GAM2 TECN GAM2 TECN GAM2 TECN GAM2	$30-40 \ \pi^- p \to n6\gamma$ $- \frac{\Gamma_5/\Gamma_3}{COMMENT}$ $0.0 \ \overline{p}p$ $38 \ \pi^- p \to n2\gamma$ $- \frac{\Gamma_4/\Gamma_3}{COMMENT}$ $38 \ \pi^- p \to n3\gamma$ $- \frac{COMMENT}{38 \ \pi^- p \to n4\gamma}$ $- \frac{\Gamma_{19}/\Gamma_3}{38 \ \pi^- p \to n4\gamma}$ $- \frac{\Gamma_{18}/\Gamma_3}{38 \ \pi^- p \to n4\gamma}$ $- \frac{COMMENT}{38 \ \pi^- p \to n4\gamma}$ $- \frac{COMMENT}{38 \ \pi^- p \to n4\gamma}$ $- \frac{COMMENT}{38 \ \pi^- p \to n4\gamma}$
75 \pm 18 $\Gamma(\gamma\gamma)/\Gamma(\pi^0\pi^0\eta)$ VALUE 1.102 \pm 0.007 OUR FIT 1.102 \pm 0.009 OUR AVE 0.091 \pm 0.006 $\Gamma(\omega\gamma)/\Gamma(\pi^0\pi^0\eta)$ VALUE 1.145 \pm 0.014 OUR FIT 0.147 \pm 0.016 $\Gamma(3\gamma)/\Gamma(\pi^0\pi^0\eta)$ VALUE (units 10 ⁻⁴) <37 $\Gamma(\pi^0\pi^0)/\Gamma(\pi^0\pi^0\eta)$ VALUE (units 10 ⁻⁴) <37		BINON DOCUMENT ID des scale factor or includes scale AMSLER ALDE DOCUMENT ID ALDE	84 of 1.: facto 93 878 878 878	GAM2 TECN of of 1.9 CBAR GAM2 TECN GAM2 TECN GAM2 TECN GAM2	$30-40 \pi^- p \rightarrow n6\gamma$ Γ_5/Γ_3 $COMMENT$ $0.0 \bar{p}p$ $38 \pi^- p \rightarrow n2\gamma$ Γ_4/Γ_3 $COMMENT$ $38 \pi^- p \rightarrow n3\gamma$ Γ_{19}/Γ_3 $COMMENT$ $38 \pi^- p \rightarrow n4\gamma$ Γ_{18}/Γ_3 $COMMENT$ $38 \pi^- p \rightarrow n4\gamma$ Γ_{18}/Γ_3 $COMMENT$ Γ_{18}/Γ_3 $COMMENT$ Γ_{18}/Γ_3 $COMMENT$ Γ_{18}/Γ_3 $COMMENT$ Γ_{18}/Γ_3 $COMMENT$ Γ_{19}/Γ_3 $COMMENT$ Γ_{19}/Γ_3 $COMMENT$ Γ_{19}/Γ_3
$\Gamma(\pi^0 \gamma \gamma)/\Gamma(\pi^0 \pi^0 \eta)$ $VALUE$ (units 10^{-4}) < 37 $\Gamma(\pi^0 \pi^0)/\Gamma(\pi^0 \pi^0 \eta)$ $VALUE$ (units 10^{-4})	- CL% 90 90 90 90 90	BINON DOCUMENT ID des scale factor or includes scale AMSLER ALDE DOCUMENT ID ALDE	84 of 1.4 factor 93 878 878 878	GAM2 TECN of of 1.9 CBAR GAM2 TECN GAM2 TECN GAM2 TECN GAM2 TECN GAM2 TECN GAM2 TECN GAM2	$30-40 \pi^- p \rightarrow n6\gamma$ Γ_5/Γ_3 $COMMENT$ $0.0 \bar{p}p$ $38 \pi^- p \rightarrow n2\gamma$ Γ_4/Γ_3 $COMMENT$ $38 \pi^- p \rightarrow n3\gamma$ Γ_{19}/Γ_3 $COMMENT$ $38 \pi^- p \rightarrow n4\gamma$ Γ_{18}/Γ_3 $COMMENT$ $38 \pi^- p \rightarrow n4\gamma$ Γ_{18}/Γ_3 $COMMENT$ Γ_{18}/Γ_3 $COMMENT$ Γ_{18}/Γ_3 $COMMENT$ Γ_{18}/Γ_3 $COMMENT$ Γ_{18}/Γ_3 $COMMENT$ Γ_{19}/Γ_3 $COMMENT$ Γ_{19}/Γ_3 $COMMENT$ Γ_{19}/Γ_3

η^{\prime} (958) C-NONCONSERVING DECAY PARAMETER

See the note on η decay parameters in the Stable Particle Particle Listings for definition of this parameter.

DECAY ASYMMETRY PARAMETER FOR $\pi^+\pi^-\gamma$

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
-0.01 ± 0.04	OUR AVERAGE				
-0.019 ± 0.056		AIHARA	87	TPC	$2\gamma \rightarrow \pi^{+}\pi^{-}\gamma$
-0.069 ± 0.078	295	GRIGORIAN	75	STRC	$2.1 \pi^{-} p$
0.00 ± 0.10	103	KALBFLEISCH	175	HBC	2.18 K ⁻ p →
					$\Lambda \pi^+ \pi^- \gamma$
0.07 ± 0.08	152	RITTENBERG	65	HBC	2.1-2.7 K ρ

$\eta'(958)$ REFERENCES

AMSLER	93	ZPHY C58 175		+Armstrong, Merkel+	(Crystal	Barrel Collab.)
BELADIDZE	92C	SJNP 55 1535		+Bityukov, Borisov		(SERP, TBIL)
		Translated from YAF	- 55			
KARCH	92	ZPHY C54 33		+Antreasyan, Bartels+		al Ball Collab.)
	91B	ZPHY C52 389				CERN, CDEF)
BEHREND	91	ZPHY C49 401		+Criegee, Field, Franke+	()	CELLO Collab.)
AUGUSTIN	90	PR D42 10		+Cosme+		(DM2 Collab.)
BARU	90	ZPHY C48 581		+Blinov, Blinov+		(MD-1 Collab.)
BUTLER	90	PR D42 1368		+Boyer+		Mark II Collab.)
KARCH	90	PL B249 353		+Antreasyan, Bartels+	(Cryst	al Ball Collab.)
ROE	90	PR D41 17		+Bartha, Burke, Garbincius+		(ASP Collab.)
AIHARA	88C	PR D38 1		+Alston-Garnjost+	(1	PC-2γ Collab.)
VOROBYEV	88	SJNP 48 273		+Golubev, Dolinsky, Druzhinin+		(NOVO)
MAIL LIA MAC	00	Translated from YAF	. 48		(Cauce	al Ball Collab.)
WILLIAMS	88	PR D38 1365		+Antreasyan, Bartels, Besset+		PC-2γ Collab.) JP
AIHARA	87	PR D35 2650		+Alston-Garnjost+		
ALBRECHT	87B	PL B199 457		+Andam, Binder+		ARGUS Collab.) , SERP, LAPP)
ALDE	87B	ZPHY C36 603				
ANTREASYAN		PR D36 2633		+Bartels, Besset+		al Ball Collab.)
GIDAL.	87	PRL 59 2012		+Boyer, Butler, Cords, Abrams+		SLAC, HARV) , LANL, LAPP)
ALDE	86	PL B177 115				(JADE Collab.)
BARTEL	85E	PL 160B 421		+Becker, Cords, Felst+		
ALTHOFF	84E 84B	PL 147B 487		+Braunschweig, Kirschfink, Luebelsm		PLUTO Collab.)
BERGER		PL 142B 125		Deselve Details (CED)		
BINON	84	PL 140B 264				LAPP, CERN)
BEHREND	83B	PL 125B 518		+D'Agostini+		CELLO Collab.)
Also	82C	PL 114B 378		Behrend, Chen, Fenner, Field+	(CELLO Collab.)
JENNI	83	PR D27 1031		+Burke, Telnov, Abrams, Blocker+		(SLAC, LBL)
BARTEL	82B	PL 113B 190		+Cords+		(JADE Collab.)
DZHELYADIN	81	PL 105B 239		+Golovkin, Konstantinov, Kubarovsk		(SERP)
STANTON	80	PL 92 B 353				MCGI, TNTO)
VIKTOROV	80	SJNP 32 520 Translated from YAI		+Golovkin, Dzhelyadin, Zaitsev, Muk	chin+	(SERP)
APEL	79	PL 83B 131	. 3.	Augenstein, Bertolucci(KARLK, KAF	DIE DIS	A SEDD WIEN)
BINNIE	79	PL 83B 141		+Carr, Debenham, Jones, Karami, k		(LOIC)
ZANFINO	77	PRL 38 930				OHIO, TNTO)
GRIGORIAN	75	NP B91 232		+Ladage, Mellema, Rudnick+	, wicui,	(UCLA)
KALBFLEISCH		PR D11 987		+Strand, Chapman		(BNL, MICH)
DUANE	74	PRL 32 425		+Binnie, Camilleri, Carr+		(LOIC, SHMP)
KALBFLEISCH		PR D10 916		+ Diffile, Califficit, Carri		(BNL)
DANBURG	73	PR D8 3744		+Kalbfleisch, Borenstein, Chapman+		(BNL, MICH) JP
JACOBS	73	PR D8 18				SYRA, TUFTS) JP
APEL	72	PL 40B 680				KARLE, PISA)
DALPIAZ	72	PL 42B 377		+Frabetti, Massam, Navarria, Zichic		(CERN)
BASILE	71	NC 3A 371				BGNA, STRB)
HARVEY	71	PRL 27 885		+Marquit, Peterson, Rhoades+		(MINN, MICH)
AGUILAR	70D	PRL 25 1635		Aguilar-Benitez, Bassano, Samios,		(BNL)
BENSINGER	70	PL 33B 505		+Erwin, Thompson, Walker	Darries	(WISC)
RITTENBERG		Thesis UCRL 18863		+CIWIII, THOMPSON, Warker		(LRL) I
DAVIS	68	PL 27B 532		+Ammar, Mott, Dagan, Derrick+		(NWES, ANL)
LONDON	66	PR 143 1034		+Rau, Goldberg, Lichtman+		(BNL, SYRA) IJP
BADIER	65B			+Demoulin, Barloutaud+	(EPOI	SACL, AMST)
RITTENBERG		PRL 15 556		+Kalbfleisch	(2.02)	(LRL. BNL)
DAUBER	64	PRL 13 449		+Slater, Smith, Stork, Ticho		(UCLA) JP
Also	64B	Dubna Conf. 1 418		Dauber, Slater, Smith, Stork, Tich	0	(UCLA)
MIDO	545	22200 2000 1 410		Sasser, Sinter, Stork, Tien	-	(000)

OTHER RELATED PAPERS -

GENOVESE 94 ZPHY C61 425 +Lichtenberg, Pedrazzi	(TORI, IND)
BENAYOUN 93 ZPHY 58 31 +Feindt, Girone+ (Cl	DEF, CERN, BARI)
KAMAL 92 PL B284 421 +Xu	(ALBE)
BICKERSTAFF 82 ZPHY C16 171 +McKellar	(MELB)
KIENZLE 65 PL 19 438 + Maglich, Levrat, Lefebvres+	(CERN)
TRILLING 65 PL 19 427 +Brown, Goldhaber, Kadyk, Scanio	(LRL)
GOLDBERG 64 PRL 12 546 +Gundzik, Lichtman, Connolly, Hart+	(SYRA, BNL)
GOLDBERG 64B PRL 13 249 +Gundzik, Leitner, Connolly, Hart+	(SYRA, BNL)
KALBFLEISCH 64 PRL 12 527 +Alvarez, Barbaro-Galtieri+	(LRL) JP
KALBFLEISCH 64B PRL 13 349 + Dahl, Rittenberg	(LRL) JP

 $f_0(980)$

$$I^{G}(J^{PC}) = 0^{+}(0^{+})$$

See also the minireview on scalar mesons under $f_0(1370)$ and on the non- $q\overline{q}$ candidates. (See the index for the page number.)

$f_0(980)$ MASS

VALUE (N	1eV)	EVTS	DOCUMENT ID		TECN	COMMENT
980	±10	OUR ESTIMATE				
• • • W	/e do r	not use the following o	data for averages,	fits, I	imits, et	:C. • • •
1006			TORNQVIST	96	RVUE	$ \pi \pi \to \pi \pi, K\overline{K}, K\pi, $ $ \eta \pi $
997	± 5	3k	¹ ALDE	958	GAM2	38 $\pi^- p \to \pi^0 \pi^0 n$
960	± 10	10k	² ALDE			38 $\pi^- p \to \pi^0 \pi^0 n$
994	± 5	*	AMSLER			$0.0 \ \overline{p} p \rightarrow 3\pi^{0}$
~ 996			³ AMSLER	95D	CBAR	$0.0 \overline{\rho} \rho \rightarrow \pi^0 \pi^0 \pi^0,$ $\pi^0 nn, \pi^0 \pi^0 n$
987	± 6		⁴ ANISOVICH		RVUE	. ,,, ,
1015			JANSSEN			$\pi\pi \to \pi\pi, K\overline{K}$
983			⁵ BUGG			$\overline{p} p \rightarrow \eta 2\pi^0$
988			⁶ ZOU		RVUE	
988	±10		⁷ MORGAN	93	RVUE	$\pi \pi (K\overline{K}) \to \\ \pi \pi (K\overline{K}), J/\psi \to \\ \phi \pi \pi (K\overline{K}), D_S \to \\ \pi (\pi \pi)$
971.1	L ± 4.0	0			EHS	400 pp
979	± 4		⁹ ARMSTRONG	91	OMEG	$\begin{array}{ccc} 300 \ \rho p \longrightarrow & \rho p \pi \pi, \\ \rho p K \overline{K} & \end{array}$

956 ±12				$\rho \rho \rightarrow \rho \rho \pi^+ \pi^-$
959.4± 6.5	⁸ AUGUSTIN	89	DM2	$J/\psi \rightarrow \omega \pi^+ \pi^-$
978 ± 9	⁸ ABACHI	86B	HRS	$e^+e^- \rightarrow \pi^+\pi^-X$
$985.0 + 9.0 \\ -39.0$	ETKIN	8 2B	MPS	23 $\pi^- p \rightarrow n2K_S^0$
974 ± 4	⁹ GIDAL	81	MRK2	$J/\psi \rightarrow \pi^+\pi^-X$
975	¹⁰ ACHASOV	80	RVUE	
986 ±10	⁹ AGUILAR	78	HBC	$0.7 \overline{p}p \rightarrow K_S^0 K_S^0$
969 ± 5	9 LEEPER			$2-2.4 \pi^- p \rightarrow$
	•			$\pi^{+}\pi^{-}$ n, $K^{+}K^{-}$ n
987 ± 7	⁹ BINNIE	73	CNTR	$\pi^- \rho \rightarrow nMM$
1012 ± 6				$17 \pi^- p \rightarrow \pi^+ \pi^- n$
1007 ±20	¹¹ HYAMS	73	ASPK	$17 \pi^- \rho \rightarrow \pi^+ \pi^- n$
997 ± 6	¹¹ РКОТОРОР	73	HBC	$7 \pi^+ \rho \rightarrow$
				$\pi^{+} \rho \pi^{+} \pi^{-}$
1 At high t				

- ² At low |t|.
- 3 On sheet II in a 4-pole solution, the other poles are found on sheet III at (953–55/) MeV and on sheet IV at (938–35/) MeV.
- Combined fit of ALDE 95B, ANISOVICH 94, AMSLER 94D.
- 5 On sheet II in a 2 pole solution. The other pole is found on sheet III at (996–103f) MeV.
 6 On sheet II in a 2 pole solution. The other pole is found on sheet III at (797–185f) MeV
- and can be interpreted as a shadow pole.

 On sheet II in a 2 pole solution. The other pole is found on sheet III at (978–28/) MeV.
- ⁸ From invariant mass fit. ⁹ From coupled channel analysis.
- 10 Coupled channel analysis with finite width corrections.
- 11 Included in AGUILAR-BENITEZ 78 fit.

f₀(980) WIDTH

Width determination very model dependent. Peak width is about 50 MeV, but decay width can be much larger.

VALUE (DC III	ucii	EVTS		DOCUMENT ID		TECN	COMMENT
			OUR I	EST	IMATE					
• • •	We	do n	ot use	the	following	dat	a for averages,	fits, I	imits, e	ic. • • •
34							TORNQVIST	96	RVUE	$ \pi \pi \to \pi \pi, K \overline{K}, K \pi, \\ \eta \pi $
48	±	10			3k		ALDE	95B	GAM2	$38 \pi^- \rho \rightarrow \pi^0 \pi^0 n$
95	\pm	20			10k	13	ALDE	95B	GAM2	$38 \pi^- \rho \rightarrow \pi^0 \pi^0 n$
26	\pm	10					AMSLER	95B	CBAR	$0.0 \ \overline{p} p \rightarrow 3\pi^0$
~ 112						14	AMSLER	95 D	CBAR	$0.0 \frac{\overline{\rho}\rho}{\pi^0} \xrightarrow{\pi^0} \pi^0 \pi^0,$ $\pi^0 \eta \eta, \pi^0 \pi^0 \eta$
80	±	12				15	ANISOVICH	95	RVUE	" ",", " " "
30							JANSSEN	95	RVUE	$\pi\pi \rightarrow \pi\pi$, $K\overline{K}$
74						16	BUGG	94	RVUE	$\overline{p}p \rightarrow \eta 2\pi^0$
46						17	ZOU	94B	RVUE	
48	\pm	12				18	MORGAN	93	RVUE	$\pi \pi (K \overline{K}) \rightarrow$
										$\pi\pi(K\overline{K}),\ J/\psi \to \phi\pi\pi(K\overline{K}),\ D_S \to$
						19			E	$\pi(\pi\pi)$
		10.6					AGUILAR			400 pp
72	±:	8				20	ARMSTRONG	91	OMEG	300 $\rho p \rightarrow \rho p \pi \pi$, $\rho p K \overline{K}$
110	±	30					BREAKSTONE	90	SFM	$pp \rightarrow pp\pi^{+}\pi^{-}$
29	±	13				19	ABACHI	868	HRS	$e^+e^- \rightarrow \pi^+\pi^-X$
120	±2	281	±20				ETKIN	82B	MPS	$23 \pi^- \rho \rightarrow n2K_S^0$
28	±	10				20	GIDAL	81	MRK2	$J/\psi \rightarrow \pi^+\pi^-X$
70		300				21			RVUE	-/+
100	±	80				22	AGUILAR	78	нвс	$0.7 \overline{p}p \rightarrow K_S^0 K_S^0$
30	±	8					LEEPER	77	ASPK	
										$\pi^{+}\pi^{-}n$, $K^{+}K^{-}n$
48	\pm	14				20	BINNIE	73	CNTR	$\pi^- \rho \rightarrow nMM$
32	\pm	10				23		73	ASPK	$17 \pi^- p \rightarrow \pi^+ \pi^- n$
30	\pm	10				23	HYAMS	73	ASPK	$17 \pi^- \rho \rightarrow \pi^+ \pi^- n$
54	±	16					РКОТОРОР	73	нвс	$7 \pi^+ \rho \rightarrow$
										$\pi^+ \rho \pi^+ \pi^-$
12 At	high	Itl.								

- At high |t|.
- $^{13}\,\mathrm{At}$ low |t|.
- ¹⁴ On sheet II in a 4-pole solution, the other poles are found on sheet III at (953–55*i*) MeV
- and on sheet IV at (938–35*i*) MeV.

 15 Combined fit of ALDE 95B, ANISOVICH 94,
- 16 On sheet II in a 2 pole solution. The other pole is found on sheet III at (996–103 \emph{i}) MeV. 17 On sheet II in a 2 pole solution. The other pole is found on sheet III at (996–103f) MeV.
 17 On sheet II in a 2 pole solution. The other pole is found on sheet III at (797–185f) MeV and can be interpreted as a shadow pole.
 18 On sheet II in a 2 pole solution. The other pole is found on sheet III at (978–28f) MeV.
 19 From invariant mass fit.
 20 From coupled channel analysis.
 21 Coupled channel analysis with finite width corrections.

- 22 From coupled channel fit to the HYAMS 73 and PROTOPOPESCU 73 data. With a simultaneous fit to the $\pi\pi$ phase-shifts, inelasticity and to the $\mathcal{K}^0_S\,\mathcal{K}^0_S$ invariant mass.
- 23 Included in AGUILAR-BENITEZ 78 fit.

f₀(980) DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Confidence level
Γ ₁	$\pi\pi$	(78.1 ±2.4) %	
Γ_2	KΚ	$(21.9 \pm 2.4)\%$	
Γ_3	$\gamma \gamma$	$(1.19\pm0.33)\times10$	
Γ_4	e^+e^-	< 3 × 10	₀ -7 90%

CONSTRAINED FIT INFORMATION

An overall fit to a branching ratio uses 3 measurements and one constraint to determine 2 parameters. The overall fit has a χ^2 = 2.0 for 2 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv$ $\Gamma_i/\Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to

$$x_2$$
 -100 x_1

fo(980) PARTIAL WIDTHS

$1(\gamma\gamma)$					ı	:
VALUE (keV)	EVTS	DOCUMENT ID		TECN	COMMENT	
0.56±0.11 OUR A	VERAGE					
0.63 ± 0.14		²⁴ MORGAN	90	RVUE	$\gamma \gamma \rightarrow \pi^{+}\pi^{-}$, $\pi^{0}\pi^{0}$	
$0.42\pm0.06\pm0.18$	60	²⁵ OEST	90	JADE	$e^+e^- \rightarrow e^+e^-\pi^0\pi^0$	D
 • • We do not ι 	use the followin	g data for averag	es, fits	, limits,	etc. • • •	
$0.29\!\pm\!0.07\!\pm\!0.12$	26	,27 BOYER	90	MRK2	$e^{+}e^{-}_{e^{+}e^{-}\pi^{+}\pi^{-}}_{e^{+}e^{-}\to e^{+}e^{-}\pi^{0}\pi^{0}}$	
$0.31 \pm 0.14 \pm 0.09$	26	,27 MARSISKE	90	CBAL	$e^{+\stackrel{e}{e}^-\stackrel{e}{-}\stackrel{\pi}{\rightarrow}\stackrel{\pi}{e}^+e^-\pi^0\pi^0}$	0
24 From amplitude	e analysis of BO	YER 90 and MAR	SISKE	90, dat	a corresponds to resonan	c

- parameters m = 989 MeV, $\Gamma = 61$ MeV.
- $^{25}\,\text{OEST}$ 90 quote systematic errors $^{+0.08}_{-0.18}.$ We use $\pm 0.18.$
- 26 From analysis allowing arbitrary background unconstrained by unitarity. 27 Data included in MORGAN 90 analysis.

Γ(e ⁺ e ⁻)							Γ4
VALUE (eV)	CL%	DOCUMENT ID		TECN	COMMENT		
<8.4	90	VOROBYEV	88	ND	$e^+e^-\rightarrow$	$\pi^0\pi^0$	

f₀(980) BRANCHING RATIOS

$\Gamma(\pi\pi)/[\Gamma(\pi\pi)+\Gamma(K\overline{K})]$				$\Gamma_1/(\Gamma_1+\Gamma_2)$
VALUE	DOCUMENT ID		TECN	COMMENT
0.781±0.024 OUR FIT				
0.781 +0.027 OUR AVERAGE				
$0.67\ \pm0.09$	²⁸ LOVERRE	80	нвс	$4 \pi^- p \rightarrow n2K_S^0$
$0.81 \begin{array}{c} +0.09 \\ -0.04 \end{array}$	²⁸ CASON	78	STRC	$7 \pi^- p \rightarrow n2K_S^0$
0.78 ±0.03	²⁸ WETZEL	76	OSPK	$8.9 \pi^{-} p \rightarrow n2K_{c}^{0}$

²⁸ Measure $\pi\pi$ elasticity assuming two resonances coupled to the $\pi\pi$ and $K\overline{K}$ channels

f₀(980) REFERENCES

 $f_0(980)$, $a_0(980)$

- OTHER RELATED PAPERS -

AU AKESSON	87 86	PR D35 1633 NP B264 154	+Morgan, Pennington +Albrow, Almehed+ (Axial	(DURH, RAL) Field Spec. Collab.)
MENNESSIER	83	ZPHY C16 241	,	(MONP)
BARBER	82	ZPHY C12 1	+Dainton, Brodbeck, Brookes+ (E	DARE, LANC, SHEF)
ETKIN	82C	PR D25 2446	+Foley, Lai+ (BNL, CU	NY, TUFTS, VAND)
BIGI	62	CERN Conf. 247	+Brandt, Carrara+	(CERN)
BINGHAM	62	CERN Conf. 240	+Bloch+	(EPOL, CERN)
ERWIN	62	PRL 9 34	+Hoyer, March, Walker, Wangler	`(WISC, BNL)
WANG	61	JETP 13 323 Translated from ZETE	+Veksler, Vrana+	(JINR)

$a_0(980)$

$$I^{G}(J^{PC}) = 1^{-}(0^{+})$$

See our minireview on scalar mesons under $f_0(1370)$ and on the non- $q\overline{q}$ candidates.

a₀(980) MASS

VALUE (MeV) DOCUMENT ID

983.5±0.9 OUR AVERAGE Includes data from the 2 datablocks that follow this one.

$\eta\pi$ FINAL STATE ONLY

VALUE (MeV) EVTS DOCUMENT ID TECN CHG COMMENT

The data in this block is included in the average printed for a previous datablock.

983.7	±	0.9	OUR	AVERAGE
004 45		1 22	102	

984.45	\pm	1.23 ± 0	.34	AMSLER	94C	CBAR		$0.0 \overline{p} p \rightarrow \omega \eta \pi^0$
982	\pm	2		¹ AMSLER	92	CBAR		$0.0 \ \overline{p} p \rightarrow \eta \eta \pi^0$
984	\pm	4	1040	¹ ARMSTRONG	91B	OMEG	±	300 $pp \rightarrow pp\eta\pi^{+}\pi^{-}$
976	\pm	6		ATKINSON	84E	OMEG	\pm	25–55 $\gamma p \rightarrow \eta \pi n$
986	\pm	3	500	² EVANGELISTA	81	OMEG	±	12 $\pi^- p \rightarrow$
				_				$\eta \pi^{+} \pi^{-} \pi^{-} \rho$
990	±:	7	145	² GURTU	79	HBC	\pm	$4.2 K^- p \rightarrow \Lambda \eta 2\pi$
977	\pm	7		GRASSLER	77	HBC	-	$16 \pi^{\mp} \rho \rightarrow \rho \eta 3\pi$
972	±1		150	DEFOIX	72	HBC	±	$0.7 \ \overline{p} p \rightarrow 7\pi$
• • •	W	e do not	use the foll	owing data for av	erag	es, fits, l	imits,	etc. • • •
987				TORNQVIST	96	RVUE		$\pi\pi \to \pi\pi$, $K\overline{K}$, $K\pi$,
001				JANSSEN	0.5	DVILLE		$\eta \pi$
991				JANSSEN	95	RVUE		$ \eta \pi \to \eta \pi, K\overline{K}, K\pi, \\ \eta \pi $
980	± 1	11	47	CONFORTO	78	OSPK	_	$4.5 \pi^- p \rightarrow p X^-$
978	±1	16	50	CORDEN	78	OMEG	\pm	$12-15 \pi^- p \rightarrow n\eta 2\pi$
989	\pm	4	70	WELLS	75	HBC	-	$3.1-6 K^- p \rightarrow \Lambda \eta 2\pi$
970	±:1	15	20	BARNES	69C	HBC	_	$4-5 K^- \rho \rightarrow \Lambda \eta 2\pi$
980	± 1	0		CAMPBELL	69	DBC	\pm	$2.7 \pi^{+} d$
980	±1	0	15	MILLER	69B	HBC	****	4.5 $K^- N \rightarrow \eta \pi \Lambda$
980	±1	.0	30	AMMAR	68	HBC	±	$5.5 K^- p \rightarrow \Lambda \eta 2\pi$

 $^{^{1}}$ From a single Breit-Wigner fit. 2 From $f_{1}(1285)$ decay.

KK ONLY

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
The data in this	block is	included in the average pr	inted for	a pre	vious datablock.

976 ± 6	316	DEBILLY	80	HBC	\pm	1.2–2 $\overline{p}p \rightarrow$	$f_1(1285) \omega$
• • • We do no	t use the	following data for a	verag	ges, fits,	limits,	etc. • • •	•
1016 ±10	100	³ ASTIER				0.0 p p	
1003.3 ± 7.0	143	⁴ ROSENFELD	65	RVUE	\pm		

 $^{^3}$ ASTIER 67 includes data of BARLOW 67, CONFORTO 67, ARMENTEROS 65. 4 Plus systematic errors.

a₀(980) WIDTH

VALUE (N	√eV)	EVTS	DOCL	IMENT ID	TECN	CHG	COMMENT	
50	to 100	OUR ESTI	MATE	Width det	termination v	ery m	odel dependent.	Peak
				width is a	about 60 Me	V, but	decay width ca	n be
				much lare	rer		-	

•	• • •	/e do not	use the fol	llov	wing data for av	erag	es, fits,	imits,	etc. • • •
\sim	100				TORNQVIST	96	RVUE		$\pi\pi \to \pi\pi, K\overline{K}, K\pi,$
:	202				JANSSEN	95	RVUE		$ \eta \pi \atop \eta \pi \to \eta \pi, K\overline{K}, K\pi, \\ \eta \pi $
	54.12	生 0.34±	0.12			94c	CBAR		$0.0 \frac{\eta \pi}{\overline{\rho} \rho} \rightarrow \omega \eta \pi^0$
	54	± 10		5	AMSLER	92	CBAR		$0.0 \ \overline{p} p \rightarrow \eta \eta \pi^0$
	95	±14	1040	5	ARMSTRONG	91B	OMEG	±	300 $pp \rightarrow pp\eta\pi^+\pi^-$
	62	± 15	500	6	EVANGELISTA	81	OMEG	\pm	12 $\pi^- \rho \rightarrow$
									$\eta \pi^{+} \pi^{-} \pi^{-} \rho$
	60	± 20	145	6	GURTU	79	HBC	±	$4.2 K^- p \rightarrow \Lambda \eta 2\pi$
	60	+50 -30	47		CONFORTO	78	OSPK	-	$4.5~\pi^-\rho \rightarrow \rhoX^-$
	86.0	$^{+60.0}_{-50.0}$	50		CORDEN	78	OMEG	±	$1215~\pi^-\rho\rightarrown\eta2\pi$
	44	± 22			GRASSLER	77	HBC		$16 \pi^{\mp} p \rightarrow p \eta 3\pi$
	80	to 300		7	FLATTE	76	RVUE	-	$4.2 K^- p \rightarrow \Lambda \eta 2\pi$
	16.0	$^{+25.0}_{-16.0}$	70		WELLS	75	нвс	-	3.1–6 $K^- p \rightarrow \Lambda \eta 2\pi$
	30	± 5	150		DEFOIX	72	HBC	\pm	$0.7 \ \overline{p} p \rightarrow 7\pi$
	40	± 15			CAMPBELL	69	DBC	±	$2.7 \pi^{+} d$
	60	± 30	15		MILLER	69B	HBC	-	4.5 $K^- N \rightarrow \eta \pi \Lambda$
	80	± 30	30		AMMAR	68	HBC	±	$5.5 K^- p \rightarrow \Lambda \eta 2\pi$

⁶ From $f_1(1285)$ decay.

VALUE (MeV) EVTS	DOCUMENT	ID	TECN	CHG		
• • • V	Ve do not use tl	ne following data fo	r average	es, fits,	limits, et	:. •	• •
~ 25	100				±		
57 ± 1	3 1/3	9 ROSENIEEL	D 65	DVIIE			

 8 ASTIER 67 includes data of BARLOW 67, CONFORTO 67, ARMENTEROS 65.

⁹ Plus systematic errors.

a₀(980) DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ_1	$\eta \pi$	dominant
Γ_2	$K\overline{K}$	seen
Γ_3	$ ho \pi$	
Γ_4	$\pi \eta'(958)$	
Γ_5	$\gamma \gamma$	seen
Γ_6	e^+e^-	

$a_0(980) \Gamma(i)\Gamma(\gamma\gamma)/\Gamma(total)$

$\Gamma(\eta\pi) \times \Gamma(\gamma\gamma)$	Γ _{total}				$\Gamma_1\Gamma_5/\Gamma$
VALUE (keV)	EVTS	DOCUMENT ID	TECN	COMMENT	
0.24 ^{+0.08} _{-0.07} OUR AV	ERAGE				
$0.28 \pm 0.04 \pm 0.10$	44	OEST 90	JADE	$e^+e^ \rightarrow$	$e^+e^-\pi^0\eta$
$0.19 \pm 0.07 ^{+0.10}_{-0.07}$		ANTREASYAN 86	CBAL	$e^+e^-\rightarrow$	$e^+e^-\pi^0\eta$
$\Gamma(\eta\pi) \times \Gamma(e^+e^-)$	-)/Γ _{total}				$\Gamma_1\Gamma_6/\Gamma$
VALUE (eV)	CL%	DOCUMENT ID	TECN	COMMENT	

a₀(980) BRANCHING RATIOS

VOROBYEV 88 ND $e^+e^- \rightarrow \pi^0 \eta$

$\Gamma(K\overline{K})/\Gamma(\eta\pi)$					Γ_2/Γ_1
VALUE	DOCUMENT ID		TECN	CHG	COMMENT
• • • We do not use t	he following data for averag	es, fit	s, limits,	etc.	• •
1.16 ± 0.18	¹⁰ BUGG	94	RVUE		$\overline{p} p \rightarrow \eta \eta \pi^0$
0.7 ±0.3	¹¹ CORDEN	78	OMEG		$12-15 \pi^- \rho \rightarrow n\eta 2\pi$
0.25 ± 0.08	¹¹ DEFOIX	72	HBC	±	$0.7 \overline{p} \rightarrow 7\pi$
10 PUCC 04 USOS A MA	SLED 040 data. This is a re				

 $^{10}\,\mathrm{BUGG}$ 94 uses AMSLER 94C data. This is a ratio of couplings. $^{11}\,\mathrm{From}$ the decay of $f_1(1285).$

$\Gamma(\rho\pi)/\Gamma(\eta\pi)$						Γ_3/Γ_1	
VALUE	CL%	DOCUMENT ID		TECN	CHG	COMMENT	
• • • We do not use t	he followin	g data for average	s, fit	s, limits	, etc. •	• •	
<0.25	70	AMMAR	70	нвс	±	4.1,5.5 $K^- p \rightarrow \Lambda \eta 2\pi$	

a₀(980) REFERENCES

TORNQVIST	96	PRL 76 1575	+Roos (HELS)
JANSSEN	95	PR D52 2690	+Pearce, Holinde, Speth (STON, ADLD, JULI) +Armstrong, Ravndal+ (Crystal Barrel Collab.)
AMSLER	94C	PL B327 425	+Armstrong, Ravndal+ (Crystal Barrel Collab.)
BUGG	94	PR D50 4412	+Anisovich+ (LOQM)
AMSLER	92	PL B291 347	+Augustin, Baker+ (Crystal Barrel Collab.)
ARMSTRONG	91B	ZPHY C52 389	+Barnes+ (ATHU, BARI, BIRM, CERN, CDEF)
OEST	90	ZPHY C47 343	+Olsson+ (JADE Collab.)
VOROBYEV	88	SJNP 48 273	+Golubev, Dolinsky, Druzhinin+ (NOVO)
		Translated from YAF 4	8 436.
ANTREASYAN		PR D33 1847	+Aschman, Besset, Bienlein+ (Crystal Ball Collab.)
ATKINSON	84E	PL 138B 459	 (BONN, CERN, GLAS, LANC, MCHS, CURIN+)
EVANGELISTA		NP B178 197	+ (BARI, BONN, CERN, DARE, LIVP+)
DEBILLY	80	NP B176 1	+Briand, Duboc, Levy+ (CURIN, LAUS, NEUC, GLAS)
GURTU	79	NP B151 181	+Gavillet, Blokzijl+ (CERN, ZEEM, NIJM, OXF)
CONFORTO	78	LNC 23 419	+Conforto, Key+ (RHEL, TNTO, CHIC, FNAL+)
CORDEN	78	NP B144 253	+Corbett, Alexander+ (BIRM, RHEL, TELA, LOWC)
GRASSLER	77	NP B121 189	+ (AACH3, BERL, BONN, CERN, CRAC, HEIDH+)
FLATTE	76	PL 63B 224	(CERN)
GAY	76B	PL 63B 220	+Chaloupka, Blokziji, Heinen+ (CERN, AMST, NIJM) JP
WELLS	75	NP B101 333	+Radojicic, Roscoe, Lyons (OXF) +Nascimento, Bizzarri+ (CDEF, CERN)
DEFOIX	72	NP B44 125	
AMMAR	70	PR D2 430	+Kropac, Davis+ (KANS, NWES, ANL, WISC)
BARNES	69C	PRL 23 610	+Chung, Eisner, Bassano, Goldberg+ (BNL, SYRA)
CAMPBELL	69	PRL 22 1204	+Lichtman, Loeffler+ (PURD)
MILLER		PL 29B 255	+Kramer, Carmony+ (PURD)
Also	69	PR 188 2011	Yen, Ammann, Carmony, Elsner+ (PURD)
AMMAR	68	PRL 21 1832	+Davis, Kropac, Derrick, Fields+ (NWES, ANL)
ASTIER	67	PL 25B 294	+Montanet, Baubillier, Duboc+ (CDEF, CERN, IRAD)
			TO 67, and ARMENTEROS 65.
BARLOW	67	NC 50A 701	+Lillestol, Montanet+ (CERN, CDEF, IRAD, LIVP)
CONFORTO	67	NP B3 469	+Marechal+ (CERN, CDEF, IPNP, LIVP)
ARMENTEROS		PL 17 344	+Edwards, Jacobsen+ (CERN, CDEF)
ROSENFELD	65	Oxford Conf. 58	(LRL)

⁵ From a single Breit-Wigner fit.

⁷ Using a two-channel resonance parametrization of GAY 76B data.

		отні	ER RELATED PAPERS	TO A CONTRACTOR OF THE STATE OF
TORNQVIST	90	NPBPS 21,196		(HELS)
WEINSTEIN	89	UTPT 89 03	+lsgur	(TNTO)
ACHASOV	88B	ZPHY C41 309	+Shestakov	(MOVM)
WEINSTEIN	83B	PR D27 588	+lsgur	(OTNT)
TORNOVIST	82	PRL 49 624	•	(HELS)
BRAMON	80	PL 93B 65	+Masso	(BARC)
TURKOT	63	Siena Conf. 1 661	+Collins, Fujii, Kemp+	(BNL, PITT)

$\phi(1020)$

$$I^{G}(J^{PC}) = 0^{-}(1^{-})$$

ϕ (1020) MASS

We average mass and width values only when the systematic errors have

VALUE (N			EVTS	DO	CUMENT ID		TECN	COMMENT
		8 OUR AVER						
1019.42	±0.06		55600	AK	HMETSHIN	95	CMD2	e ⁺ e [−] → hadrons
1019.7	±0.3		2012		VENPORT	86	MPSF	$400 pA \rightarrow 4KX$
1019.41	1±0.00	8	642k	¹ DI.	IKSTRA	86	SPEC	100–200 π^{\pm} , \bar{p} ,
1019.7	±0.1	±0.1	5079	AL	BRECHT	8 5 D	ARG	$p, K^{\pm}, \text{ on Be}$ 10 $e^+e^- \rightarrow K^+K^-X$
1019.3	±0.1		1500	AR	ENTON	82	AEMS	11.8 polar. $pp \rightarrow KK$
1019.67	±0.17		25080	² PE	LLINEN	82	RVUE	$pp \rightarrow KK$
1019.54	±0.12		1100	ВА	RKOV	79B	EMUL	e ⁺ e ⁻ →
1019.52	± 0.13		3681	BU	KIN	78 C	OLYA	$e^+e^- \rightarrow$ hadrons
• • • V	Ve do no	ot use the follo	owing data f	r ave	rages, fits, li	mits,	etc. •	• •
1019.8	± 0.7			AR	MSTRONG	86	OMEG	85 $\pi^+/\rho\rho \rightarrow \pi^+/\rho 4K\rho$
1020.1	±0.11		5526	3 AT	KINSON	86	OMEG	20-70 γp
1019.7	±1.0			BE	BEK	86	CLEO	$e^+e^- \rightarrow \infty$
1020.9	±0.2			3 FR.	АМЕ	86	OMEG	$ \begin{array}{c} \gamma(4S) \\ 13 K^+ p \rightarrow \end{array} $
1021.0	±0.2			³ AR	MSTRONG	83 B	OMEG	$ \begin{array}{c} \phi K^+ p \\ 18.5 K^- p \rightarrow \end{array} $
1020.0	±0.5			3 AR	MSTRONG	83B	OMEG	$ \begin{array}{c} K^- K^+ \Lambda \\ 18.5 K^- \rho \to \\ K^- K^+ \Lambda \end{array} $
1019.7	±0.3			³ BA	RATE	83	GOLI	$190 \pi^{-} \text{Be} \rightarrow 2\mu \text{X}$
1019.8	±0.2	± 0.5	766	IVA	NOV	81	OLYA	$1-1.4 e^+e^- \rightarrow K^+K^-$
1019.4	± 0.5		337	со	OPER	78B	нвс	$0.7-0.8 \overline{p}p \to \\ \kappa_S^0 \kappa_L^0 \pi^+ \pi^-$
1020	±1		383	³ BA	LDI	77	CNTR	$ \begin{array}{ccc} & & & & \\ & & & & \\ & & & & \\ & & & &$
1018.9	±0.6		800	со	HEN	77	ASPK	$ \begin{array}{c} $
1019.7	±0.5		454	KA	LBFLEISCH	76	нвс	$2.18 K^- p \rightarrow$
1019.4	±0.8		984	BE	SCH	74	CNTR	$ \begin{array}{c} \Lambda K K \\ 2 \gamma p \rightarrow \\ p K^+ K^- \end{array} $
1020.3	± 0.4		100	ВА	LLAM	73	нвс	2.8-9.3 γ p
1019.4	± 0.7			BIN	INIE	73B	CNTR	$\pi^- \rho \rightarrow \phi n$
1019.6	±0.5		120	⁴ AG	UILAR	72B	HBC	3.9,4.6 $K^- \rho \rightarrow$
1019.9	±0.5		100	⁴ AG	UILAR	72B	нвс	$3.9,4.6 \ K^- p \rightarrow K^- p K^+ K^-$
1020.4	±0.5		131	со	LLEY	72	нвс	$ \begin{array}{c} K + p \\ 10 K + p \\ K + p \\ \end{array} $
1019.9	± 0.3		410	ST	OTTLE	71	нвс	$ \begin{array}{c} K + p \varphi \\ 2.9 K - p \rightarrow \\ \Sigma / \Lambda K \overline{K} \end{array} $

ϕ (1020) WIDTH

We average mass and width values only when the systematic errors have been evalutated. $% \label{eq:controlled}$

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
4.43±0.05 OUR F	IT				
4.43±0.05 OUR A	VERAGE				
4.44 ± 0.09	55600	AKHMETSHI	N 95	CMD2	$e^+e^- \rightarrow hadrons$
4.45 ± 0.06	271k	DIJKSTRA	86	SPEC	100 π Be
4.5 ±0.7	1500	ARENTON	82	AEMS	11.8 polar. $pp \rightarrow KK$
4.2 ±0.6	766	⁵ IVANOV	81	OLYA	1-1.4 e ⁺ e ⁻ →
4.3 ±0.6		⁵ CORDIER	80	WIRE	$e^{+\stackrel{K}{e}^{-}\stackrel{K}{\longrightarrow}}\pi^{+}\pi^{-}\pi^{0}$

		5		1
4.58 ± 0.55	1100	⁵ BARKOV		$e^+e^- \rightarrow K^+K^-$
4.36 ± 0.29	3681	⁵ BUKIN	78C OLYA	$e^+e^- \rightarrow \text{hadrons}$
4.4 ± 0.6	984	⁵ BESCH	74 CNTR	$2 \gamma p \rightarrow pK^+K^-$
4.67 ± 0.72	681	⁵ BALAKIN	71 OSPK	$e^+e^- ightarrow hadrons$
4.09 ± 0.29		BIZOT	70 OSPK	$e^+e^- \rightarrow \text{hadrons}$
• • • We do not u	se the followi	ing data for average	s, fits, limits,	etc. • • •
4.08 ± 0.14	13714	KURDADZE	84 OLYA	$e^+e^- \rightarrow hadrons$
3.6 ± 0.8	337	⁵ COOPER	788 HBC	0.7−0.8 p p →
				$\kappa_{S}^{0} \kappa_{L}^{0} \pi^{+} \pi^{-}$
4.5 ±0.50	1300	^{5,6} AKERLOF	77 SPEC	$400 pA \rightarrow K^+K^-X$
4.5 ±0.8	500	5,6 AYRES	74 ASPK	3-6 π ⁻ p →
				K^+K^-n , $K^-p \rightarrow$
				$K^+K^-\Lambda/\Sigma^0$
3.81 ± 0.37		COSME	74B OSPK	$e^+e^- \rightarrow \kappa'^0_I \kappa^0_S$
3.8 ±0.7	454	5 BORENSTEIN		$2.18 K^- p \rightarrow K\overline{K}n$

 $^{^5}$ Width errors enlarged by us to $4\Gamma/\sqrt{N}$; see the note with the $K^*(892)$ mass.

ϕ (1020) DECAY MODES

	Mode	Fraction (Γ_i/Γ)		ale factor/ lence level
Γ_1	K ⁺ K ⁻	(49.1 ±0.6) %	S=1.2
Γ_2	$K_L^0 K_S^0$	(34.1 ±0.5) %	S=1.1
Γ_3	$ ho\pi$	(12.9 ± 0.7)) %	
Γ_4	$\pi^{+}\pi^{-}\pi^{0}$	(2.7 ± 0.9) %	S=1.1
Γ_5	$\eta \gamma$	$(1.26 \pm 0.06$) %	S=1.1
Γ_6	$\pi^0 \gamma$	$(1.31 \pm 0.13$	$) \times 10^{-3}$	
Γ_7	e^+e^-	$(3.00\pm0.06$		S=1.1
Γ8	$\mu^{+} \mu^{-}$	$(2.48\pm0.34$	$) \times 10^{-4}$	
Γ9	$\eta e^+ e^-$	$(1.3 \begin{array}{c} +0.8 \\ -0.6 \end{array}$) × 10 ⁻⁴	
Γ_{10}	$\pi^+\pi^-$	(8 +5) × 10 ⁻⁵	S=1.5
Γ_{11}	$\omega\gamma$	< 5	%	CL=84%
Γ_{12}	$ ho\gamma$	< 2	%	CL=84%
	$\pi^+\pi^-\gamma$	< 7	$\times 10^{-3}$	CL=90%
Γ_{14}	$f_0(980)\gamma$			
Γ_{15}	$\pi^0\pi^0\gamma$	< 1	\times 10 ⁻³	CL=90%
10	$\pi^+\pi^-\pi^+\pi^-$	< 8.7	× 10 ⁻⁴	CL=90%
Γ_{17}	$\eta'(958)\gamma$	< 4.1	\times 10 ⁻⁴	CL=90%
	$\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0}$	< 1.5	\times 10 ⁻⁴	CL=95%
	$\pi^{0} e^{+} e^{-}$	< 1.2	\times 10 ⁻⁴	CL=90%
Γ_{20}	$\pi^0 \eta \gamma$		_	
Γ ₂₁	$a_0(980)\gamma$	< 5	× 10 ⁻³	CL=90%

CONSTRAINED FIT INFORMATION

An overall fit to the total width, a partial width, and 9 branching ratios uses 43 measurements and one constraint to determine 6 parameters. The overall fit has a $\chi^2=28.9$ for 38 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\left<\delta p_i \delta p_j \right>/(\delta p_i \cdot \delta p_j)$, in percent, from the fit to parameters p_i , including the branching fractions, $x_i \equiv \Gamma_i/\Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to one.

	Mode	Rate (MeV)	Scale factor
Γ_1	K ⁺ K ⁻	2.18 ±0.04	1.1
Γ_2	$K_L^0 K_S^0$	1.510 ± 0.029	1.1
Γ ₃ Γ ₄	$ ho\pi$	0.570 ± 0.030	
Γ_4	$\pi^{+}\pi^{-}\pi^{0}$	0.12 ± 0.04	1.1
Γ_5	$\eta\gamma$	0.0561 ± 0.0025	1.1

 $^{^1}$ Weighted and scaled average of 12 measurements of DIJKSTRA 86. 2 PELLINEN 82 review includes AKERLOF 77, DAUM 81, BALDI 77, AYRES 74, DESCRIPTION 10 PROPERTY OF THE PROPERTY OF THE

GROOT 74.

3 Systematic errors not evaluated.

⁴ Mass errors enlarged by us to Γ/\sqrt{N} ; see the note with the $K^*(892)$ mass.

⁶ Systematic errors not evaluated.

 ϕ (1020)

	$\phi(10$	20) PARTIAL	חוטוייי	15				$\Gamma(\eta\gamma)/\Gamma_{\text{total}}$	E1 4940			*****		Γ ₅ /
$\Gamma(ho\pi)$						Гз		0.0126±0.0006 OUR				1.1.	COMMENT	
/ALUE (MeV) 0.570±0.030 OUR FIT		DOCUMENT ID		CN C	OMMENT			0.0126±0.0005 OUR 0.0118±0.0011	AVERAGE 279	AKHMETSHI		ctor of 1 CMD2		
0.57 ±0.03		JULLIAN	76 OS	SPK e	+ e-			0.0118 ± 0.0011 0.0130 ± 0.0006	219	9 DRUZHININ		ND		$\eta \gamma$ 3γ
						_		0.014 ±0.002		10 DRUZHININ		ND		6γ
-(e+e-)						Γ ₇		0.0088 ± 0.0020	290	KURDADZE	830	OLYA	$e^+e^- ightarrow$	3γ
/ALUE (keV)	IATION	DOCUMENT ID						0.0135 ± 0.0029		ANDREWS			6.7−10 γC	u
1.37±0.05 OUR EVALU	JATION							0.015 ±0.004	54	⁹ COSME	76	OSPK	e+ e-	
	φ(102	0) BRANCHIN	IG RATI	os				9 From 2γ decay mo 10 From $3\pi^0$ decay n	ode of η . node of η .					
$\Gamma(K^+K^-)/\Gamma_{\text{total}}$						Γ_1/Γ		$\Gamma(\pi^+\pi^-\gamma)/\Gamma_{\text{total}}$						Γ ₁₃ /
VALUE	EVTS	DOCUMENT ID		CN C	OMMENT			VALUE	<u>CL%</u>	DOCUMENT ID		TECN	COMMENT	
0.491±0.006 OUR FIT 0.493±0.010 OUR AVE		cludes scale factor	r of 1.2.					<0.007	90	COSME			$e^+e^- \rightarrow$	$\pi^+\pi^-\gamma$
0.493±0.010 OUR AVE	2913	AKHMETSHI	N 95 CA	/ID2 e	$e^+e^- \rightarrow K^+K$	_	ı	• • We do not use						
0.44 ± 0.05	321	KALBFLEISC			$2.18 K^- p \rightarrow \Lambda F$		•	< 0.06	90	KALBFLEISC	H 75	нвс	2.18 K ⁻ p	
0.49 ±0.06	270	DEGROOT	74 H	3C 4	$1.2 K^- p \rightarrow \Lambda \phi$			< 0.04	99	LINDSEY	65	нвс	$\Lambda \pi^{+} \pi^{-}$ 2.1–2.7 K	,
0.540 ± 0.034	565	BALAKIN			$e^+e^- \rightarrow K^+K$	-		0.04	99	LINDSET	05	HBC		neutrals
0.486 ± 0.044		CHATELUS			+ e-			r/ \ /r		•				
0.48 ±0.04	252	LINDSEY	66 HE	3C 2	$2.1-2.7 K^- p \rightarrow \Lambda K^+ K^-$			$\Gamma(\omega\gamma)/\Gamma_{\text{total}}$						Γ ₁₁ /
					71K · K			<u>VALUE</u> <0.05	<u>CL%</u> 84	DOCUMENT ID		HBC	2.1-2.7 K	
$\Gamma(K_L^0K_S^0)/\Gamma_{total}$						Γ_2/Γ		<0.05	84	LINDSEY	99	нвс		ρ → - neutrals
VALUE 0.341±0.005 OUR FIT	<u>EVTS</u>	DOCUMENT ID		CN C	OMMENT			=/ \/=						-
0.334±0.005 OUR AVE		cludes scale factor	01 1.1.					$\Gamma(ho\gamma)/\Gamma_{total}$						Γ ₁₂ /
0.335 ± 0.010	40644	AKHMETSHI	N 95 CN	ИD2 <i>е</i>	$e^+e^- \rightarrow K^0_1K^0_2$	2	1	VALUE	<u>CL%_</u>	DOCUMENT ID		TECN	COMMENT	
0.326±0.035		DOLINSKY	91 NE		$e^+e^- \rightarrow \kappa^0 \kappa^0$	}	•	<0.02	84	LINDSEY	66	нвс	2.1-2.7 K	p → neutrals
0.310±0.024		DRUZHININ	84 NI) ε	$e^+e^- \rightarrow \kappa^0 \kappa^0$	3							71 N N	neutrais
0.338 ± 0.010		KURDADZE			+ e KOK	3		$\Gamma(e^+e^-)/\Gamma_{ ext{total}}$						Γ ₇ /
	ne followin	g data for average			L :	>		VALUE (units 10 ⁻⁴)	EVTS	DOCUMENT ID		TECN	COMMENT	
0.27 ±0.03	133	KALBFLEISC			$2.18 \ K^- p \rightarrow \Lambda I$	κ0 κ0		3.00 ± 0.06 OUR AVE						
0.257 ± 0.030	95	BALAKIN			+ e- → K0 K0			2.88±0.09	55600	AKHMETSHI			$e^+e^- \rightarrow e^+e^- \rightarrow$	
0.40 ±0.04	167	LINDSEY	66 H		$2.1-2.7 \text{ K}^- \text{ p} \rightarrow$	5		3.05±0.12 3.00±0.21	13714 3681	KURDADZE BUKIN		OLYA	$e^+e^- \rightarrow$	
0.10 10.01					AKOKO			3.10±0.14	3001	11 PARROUR		OSPK	e+e-	Haurons
_					L 3			3.3 ±0.3		COSME	74	OSPK	$e^+e^- \rightarrow$	hadrons
$[\Gamma(\rho\pi) + \Gamma(\pi^+\pi^-\tau)]$	τ ⁰)]/Γ _{to}	tal				-Γ ₄)/Γ		$\begin{array}{c} 3.3 \ \pm 0.3 \\ 2.81 \pm 0.25 \end{array}$	681	BALAKIN	71	OSPK	e^+e^-	
VALUE	EVTS	DOCUMENT ID		CN C	(Г ₃ +	-Γ ₄)/Γ		$\begin{array}{c} 2.81 \pm 0.25 \\ 3.50 \pm 0.27 \end{array}$		BALAKIN CHATELUS	71 71	OSPK OSPK	$e^+e^- \rightarrow e^+e^-$	hadrons
VALUE 0.156±0.005 OUR FIT	Error in	<u>DOCUMENT ID</u> cludes scale factor	r of 1.3.			-Γ 4) /Γ		2.81 ± 0.25 3.50 ± 0.27 11 Using total width	4.2 MeV.	BALAKIN CHATELUS They detect 3π m	71 71 ode a	OSPK OSPK and obse	$e^+e^- \rightarrow e^+e^-$ rve significa	hadrons
VALUE 0.156±0.005 OUR FIT 0.152±0.005 OUR AVE	Error in	DOCUMENT ID	r of 1.3. e factor o	f 1.2.	COMMENT		ı	$\begin{array}{c} 2.81\pm0.25\\ 3.50\pm0.27 \end{array}$ 11 Using total width with ω tail. This i	4.2 MeV.	BALAKIN CHATELUS They detect 3π m	71 71 ode a	OSPK OSPK and obse	$e^+e^- \rightarrow e^+e^-$ rve significa	hadrons
VALUE 0.156±0.005 OUR FIT 0.152±0.005 OUR AVE 0.161±0.008	Error in	DOCUMENT ID cludes scale factor frror includes scale	r of 1.3. e factor o	f 1.2. dD2 ε	COMMENT		1	2.81 ± 0.25 3.50 ± 0.27 11 Using total width	4.2 MeV.	BALAKIN CHATELUS They detect 3π m	71 71 ode a	OSPK OSPK and obse	$e^+e^- \rightarrow e^+e^-$ rve significa	hadrons nt interferenc
VALUE 0.156±0.005 OUR FIT 0.152±0.005 OUR AVE 0.161±0.008 0.143±0.007 0.155±0.008	EVTS Error in ERAGE 11761	DOCUMENT ID cludes scale factor fror includes scale AKHMETSHI DOLINSKY KURDADZE	r of 1.3. e factor o N 95 CM 91 NI 84 Ol	f 1.2. MD2 ε Ο ε -YA ε	$\begin{array}{cccccccccccccccccccccccccccccccccccc$		1	$\begin{array}{c} 2.81\pm0.25\\ 3.50\pm0.27 \end{array}$ 11 Using total width with ω tail. This i	4.2 MeV.	BALAKIN CHATELUS They detect 3π m	71 71 ode a	OSPK OSPK and obse	$e^+e^- \rightarrow e^+e^-$ rve significa	hadrons nt interferenc
VALUE 0.156±0.005 OUR FIT 0.152±0.005 OUR AVE 0.161±0.008 0.143±0.007 0.155±0.008 • • • • We do not use the	EVTS Error in ERAGE 11761	DOCUMENT ID cludes scale factor fror includes scale AKHMETSHI DOLINSKY KURDADZE g data for average	r of 1.3. e factor o N 95 CM 91 NI 84 Ot es, fits, lii	f 1.2. MD2 e D e _YA e mits, e	$\begin{array}{cccccccccccccccccccccccccccccccccccc$		ı	2.81 \pm 0.25 3.50 \pm 0.27 11 Using total width with ω tail. This i $\Gamma(\pi^{0}\gamma)/\Gamma_{\text{total}}$ $\frac{VALUE\ (units\ 10^{-3})}{1.31\pm0.13\ OUR\ AVE}$	4.2 MeV. s accounted	BALAKIN CHATELUS They detect 3π m d for in the result o	71 71 ode a quote	OSPK OSPK and obse d above.	$e^+e^- \rightarrow e^+e^-$ rve significa	hadrons nt interferenc F ₆ /
VALUE 0.156±0.005 OUR FIT 0.152±0.005 OUR AVE 0.161±0.008 0.143±0.007 0.155±0.008 • • • We do not use th 0.139±0.007	EVTS Error in ERAGE E 11761	DOCUMENT ID cludes scale factor fror includes scale AKHMETSHI DOLINSKY KURDADZE g data for average 7 PARROUR	r of 1.3. e factor o N 95 CN 91 NI 84 Ol es, fits, lii 76B OS	of 1.2. MD2 e D e LYA e mits, e	COMMENT $ \begin{array}{ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c} -\pi^0 \\ -\pi^0 \\ -\pi^0 \end{array} $	I	2.81 \pm 0.25 3.50 \pm 0.27 11 Using total width with ω tail. This i $\Gamma(\pi^0\gamma)/\Gamma_{total}$ <u>VALUE (units 10^3)</u> 1.31 \pm 0.13 OUR AVE 1.30 \pm 0.13	4.2 MeV. s accounted	BALAKIN CHATELUS They detect 3π m d for in the result of DOCUMENT ID DRUZHININ	71 71 ode a quote	OSPK OSPK and obsed d above.	$e^{+}e^{-} \rightarrow e^{+}e^{-}$ rve significa $\frac{COMMENT}{e^{+}e^{-}} \rightarrow$	hadrons nt interferenc
<u>VALUE</u> 0.156±0.005 OUR FIT 0.152±0.005 OUR AVE 0.161±0.008 0.143±0.007 0.155±0.008 • • • We do not use th 0.139±0.007 7 Using total width 4.	EVTS Error in ERAGE E 11761	DOCUMENT ID cludes scale factor fror includes scale AKHMETSHI DOLINSKY KURDADZE g data for average 7 PARROUR	r of 1.3. e factor o N 95 CN 91 NI 84 Ol es, fits, lii 76B OS	of 1.2. MD2 e D e LYA e mits, e	COMMENT $ \begin{array}{ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c} -\pi^0 \\ -\pi^0 \\ -\pi^0 \end{array} $	i	2.81 \pm 0.25 3.50 \pm 0.27 11 Using total width with ω tail. This i $\Gamma(\pi^{0}\gamma)/\Gamma_{\text{total}}$ $\frac{VALUE\ (units\ 10^{-3})}{1.31\pm0.13\ OUR\ AVE}$	4.2 MeV. s accounted	BALAKIN CHATELUS They detect 3π m d for in the result o	71 71 ode a quote	OSPK OSPK and obse d above.	$e^{+}e^{-} \rightarrow e^{+}e^{-}$ rve significa $\frac{COMMENT}{e^{+}e^{-}} \rightarrow$	hadrons nt interferenc F ₆ /
<u>VALUE</u> 0.156±0.005 OUR FIT 0.152±0.005 OUR AVE 0.161±0.008 0.143±0.007 0.155±0.008 • • We do not use th 0.139±0.007 7 Using total width 4.1 level.	EVTS Error in ERAGE E 11761	DOCUMENT ID cludes scale factor fror includes scale AKHMETSHI DOLINSKY KURDADZE g data for average 7 PARROUR	r of 1.3. e factor o N 95 CN 91 NI 84 Ol es, fits, lii 76B OS	of 1.2. MD2 e D e LYA e mits, e	COMMENT $ \begin{array}{ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c} -\pi^0 \\ -\pi^0 \\ -\pi^0 \end{array} $	1	2.81 \pm 0.25 3.50 \pm 0.27 11 Using total width with ω tail. This i $\Gamma(\pi^0\gamma)/\Gamma_{total}$ <u>VALUE (units 10^3)</u> 1.31 \pm 0.13 OUR AVE 1.30 \pm 0.13	4.2 MeV. s accounted	BALAKIN CHATELUS They detect 3π m d for in the result of DOCUMENT ID DRUZHININ	71 71 ode a quote	OSPK OSPK and obsed d above.	$e^{+}e^{-} \rightarrow e^{+}e^{-}$ rve significa $\frac{COMMENT}{e^{+}e^{-}} \rightarrow$	hadrons nt interferenc F ₆ /
VALUE 0.156±0.005 OUR FIT 0.152±0.005 OUR AVE 0.161±0.008 0.143±0.007 0.155±0.008 • • • We do not use th 0.139±0.007 7 Using total width 4.	EVTS Error in ERAGE E 11761	DOCUMENT ID cludes scale factor fror includes scale AKHMETSHI DOLINSKY KURDADZE g data for average 7 PARROUR	r of 1.3. e factor o N 95 CN 91 NI 84 Ol es, fits, lii 76B OS	of 1.2. MD2 e D e LYA e mits, e	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c} -\pi^0 \\ -\pi^0 \\ -\pi^0 \end{array} $	İ	2.81 \pm 0.25 3.50 \pm 0.27 11 Using total width with ω tall. This i $\Gamma(\pi^0\gamma)/\Gamma_{\rm total}$ $\Lambda_{ALUE\ (units 10^{-3})}$ 1.31 \pm 0.13 OUR AVE 1.30 \pm 0.13 1.4 \pm 0.5	4.2 MeV. s accounted	BALAKIN CHATELUS They detect 3π m d for in the result of DOCUMENT ID DRUZHININ	71 71 ode a quote	OSPK OSPK and obsed d above.	$e^{+}e^{-} \rightarrow e^{+}e^{-}$ rve significa $\frac{COMMENT}{e^{+}e^{-}} \rightarrow$	hadrons nt interference $\Gamma_6/$ 3γ
$VALUE$ 0.156±0.005 OUR FIT 0.152±0.005 OUR AVE 0.161±0.008 0.143±0.007 0.155±0.008 • • • We do not use th 0.139±0.007 7 Using total width 4.: level. $\Gamma(K_S^0K_S^0)/\Gamma(K\overline{K})$ VALUE	EVTS Error in ERAGE E 11761 he followin 1 MeV. Th	DOCUMENT ID. Cludes scale factor irror includes scale AKHMETSHI DOLINSKY KURDADZE g data for average 7 PARROUR e $\rho\pi$ to 3π mode i	r of 1.3. e factor o N 95 CN 91 NE 84 Ot es, fits, lii 76B OS is more th	f 1.2. MD2 e O e LYA e mits, e SPK e an 80%	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$-\frac{\pi}{\pi}0$ $-\frac{\pi}{\pi}0$ $-\frac{\pi}{\pi}0$ $-\frac{\pi}{\pi}0$	I	2.81 \pm 0.25 3.50 \pm 0.27 11 Using total width with ω tall. This is $\Gamma(\pi^0\gamma)/\Gamma_{\text{total}}$ 1.31 \pm 0.13 OUR AVE 1.30 \pm 0.13 1.4 \pm 0.5 $\Gamma(\pi^+\pi^-)/\Gamma_{\text{total}}$ 1.44UE (units 10 ⁻⁴)	4.2 MeV. s accounted EVTS RAGE 32	BALAKIN CHATELUS They detect 3π m I for in the result of DOCUMENT ID DRUZHININ COSME DOCUMENT ID	71 71 ode a quote 84 76	OSPK OSPK and obse d above. TECN ND OSPK	$e^+e^- \rightarrow e^+e^-$ rve significa	hadrons nt interference $\Gamma_6/$ 3γ
VALUE 0.156±0.005 OUR FIT 0.152±0.005 OUR AVE 0.161±0.008 0.143±0.007 7 Using total width 4.: (K, K, V,	EVTS Error in ERAGE E 11761 the followin MeV. Th EVTS Error in	DOCUMENT ID. Cludes scale factor irror includes scale AKHMETSHI DOLINSKY KURDADZE g data for average 7 PARROUR e $\rho\pi$ to 3π mode i	r of 1.3. e factor o N 95 CN 91 NE 84 Ot es, fits, lii 76B OS is more th	f 1.2. MD2 e O e LYA e mits, e SPK e an 80%	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$-\frac{\pi}{\pi}0$ $-\frac{\pi}{\pi}0$ $-\frac{\pi}{\pi}0$ $-\frac{\pi}{\pi}0$	l	2.81 \pm 0.25 3.50 \pm 0.27 11 Using total width with ω tail. This is $\Gamma(\pi^0\gamma)/\Gamma_{\rm total} = \frac{MALUE\ (units\ 10^{-3})}{1.31 \pm 0.13\ 0.13\ 0.13}$ 1.4 \pm 0.5 $\Gamma(\pi^+\pi^-)/\Gamma_{\rm total} = \frac{MALUE\ (units\ 10^{-4})}{0.8 \pm 0.5\ 0.18}$ OUR AN	4.2 MeV. s accounted EVTS RAGE 32	BALAKIN CHATELUS They detect 3π m I for in the result of DOCUMENT ID DRUZHININ COSME DOCUMENT ID	71 71 ode a quote 84 76	OSPK OSPK and obse d above. TECN ND OSPK	$e^+e^- \rightarrow e^+e^-$ rve significa	hadrons nt interference $\Gamma_6/$ 3γ
$VALUE$ 0.156±0.005 OUR FIT 0.152±0.005 OUR AVE 0.161±0.008 0.143±0.007 0.155±0.008 • • • We do not use th 0.139±0.007 7 Using total width 4.: level. $\Gamma(K_1^0K_2^0)/\Gamma(K\overline{K})$ VALUE 0.409±0.006 OUR FIT 0.45 ±0.004 OUR AVE	EVTS Error in ERAGE E 11761 the followin MeV. Th EVTS Error in	DOCUMENT ID. COLUMENT ID.	r of 1.3. e factor o N 95 CN 91 Nf 84 Ol es, fits, lii 76B OS is more th	f 1.2. MD2 e D e LYA e mits, e SPK e aan 80%	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{c} -\pi 0 \\ -\pi 0 \\ -\pi 0 \\ -\pi 0 \end{array}$	I	2.81 \pm 0.25 3.50 \pm 0.27 11 Using total width with ω tail. This is $\Gamma(\pi^0\gamma)/\Gamma_{\text{total}} = \frac{MALUE (\text{units } 10^{-3})}{1.31 \pm 0.13 \text{ OUR AVE}} = \frac{1.30 \pm 0.13}{1.4 \pm 0.5} = \frac{1.30 \pm 0.13}{1.4 \pm 0.5} = \frac{MALUE (\text{units } 10^{-4})}{0.8 \pm 0.5 \text{ OUR AVE}} = \frac{1.30 \pm 0.13}{0.13 \pm 0.13} = 1.30 \pm 0.13$	4.2 MeV. s accounted EVTS RAGE 32	BALAKIN CHATELUS They detect 3π m I for in the result of DOCUMENT ID DRUZHININ COSME DOCUMENT ID	71 71 ode a quote 84 76	OSPK OSPK and obse d above. TECN ND OSPK	$e^+e^- \rightarrow e^+e^-$ rve significa	hadrons nt interference $\Gamma_6/$ 3γ
VALUE 0.156 \pm 0.005 OUR FIT 0.152 \pm 0.005 OUR AVE 0.161 \pm 0.008 0.143 \pm 0.007 0.155 \pm 0.008 • • • We do not use th 0.139 \pm 0.007 7 Using total width 4.: level. $\Gamma(K_L^0K_0^0)/\Gamma(K\overline{K})$ VALUE 0.409 \pm 0.006 OUR FIT 0.45 \pm 0.04 OUR AVE 0.44 \pm 0.07	EVTS Error in ERAGE E 11761 the followin MeV. Th EVTS Error in	DOCUMENT ID. Cludes scale factor irror includes scale AKHMETSHI DOLINSKY KURDADZE g data for average 7 PARROUR e $\rho\pi$ to 3π mode i	r of 1.3. e factor o N 95 CN 91 NE 84 Ot es, fits, lii 76B OS is more th	f 1.2. MD2 e D e LYA e mits, e SPK e aan 80%	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{c} -\pi 0 \\ -\pi 0 \\ -\pi 0 \\ -\pi 0 \end{array}$	I	2.81 \pm 0.25 3.50 \pm 0.27 11 Using total width with ω tail. This is $\Gamma(\pi^{0}\gamma)/\Gamma_{\text{total}}$ $\frac{VALUE (units 10^{-3})}{1.31\pm0.13}$ 1.30 \pm 0.13 1.4 \pm 0.5 $\Gamma(\pi^{+}\pi^{-})/\Gamma_{\text{total}}$ $\frac{VALUE (units 10^{-4})}{0.8 \pm 0.4}$ 0.63 \pm 0.37 0.63 \pm 0.37 0.28	4.2 MeV. s accounted EVTS RAGE 32	BALAKIN CHATELUS They detect 3π m of for in the result of DOCUMENT ID DRUZHININ COSME DOCUMENT ID Error includes scale 12 GOLUBEV	71 71 ode a quote 84 76	OSPK OSPK and obsed d above. TECN ND OSPK TECN OSPK	$e^+e^- \rightarrow e^+e^-$ rve significa	hadrons nt interference $\Gamma_6/$ 3γ
VALUE 0.156 ± 0.005 OUR FIT 0.152 ± 0.005 OUR AVE 0.161 ± 0.008 0.143 ± 0.007 0.155 ± 0.008 • • • We do not use th 0.139 ± 0.007 7 Using total width 4.: level. $\Gamma(K_0^0 K_0^0) / \Gamma(K\overline{K})$ VALUE 0.409 ± 0.006 OUR FIT 0.45 ± 0.04 OUR AVE 0.44 ± 0.07 0.48 ± 0.07	EVTS Error in ERAGE E 11761 MeV. Th EVTS Error in ERAGE	$\frac{DOCUMENT\ ID}{LOOP (CONTROL OF CONTROL O$	r of 1.3. e factor o N 95 CN 91 Nf 84 Ot es, fits, lii 76B OS is more th	f 1.2. MD2	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$-\frac{\pi}{\pi}0$ $-\frac{\pi}{\pi}0$ $-\frac{\pi}{\pi}0$ infidence $\frac{1+\Gamma_2}{KK}$	l	2.81 \pm 0.25 3.50 \pm 0.27 11 Using total width with ω tail. This is $\Gamma(\pi^0\gamma)/\Gamma_{\rm total}$. $\Gamma(\pi^0\gamma)/\Gamma_{\rm total}$ 1.31 \pm 0.13 OUR AVE 1.30 \pm 0.13 1.4 \pm 0.5 $\Gamma(\pi^+\pi^-)/\Gamma_{\rm total}$ 2.4 \times 0.6 \times 0.5 OUR AVE 0.63 \times 0.28 \times 0.28 \times 0.28 \times 0.28 \times 0.28 \times 0.29 \times 0.81	4.2 MeV. s accounted EVTS RAGE 32 CL% /ERAGE	BALAKIN CHATELUS They detect 3π m d for in the result of DOCUMENT ID. DRUZHININ COSME DOCUMENT ID Error includes scale 12 GOLUBEV 12 VASSERMAN	71 71 71 71 84 76 84 76	OSPK OSPK and obsed above. TECN ND OSPK TECN OSPK TECN OOSPK OOSPK OOSPK OOSPK OOSPK	$e^+e^- \rightarrow e^+e^-$ rve significa $\frac{COMMENT}{e^+e^-}$ $e^+e^- \rightarrow e^+e^ e^+e^- \rightarrow e^+e^ e^+e^- \rightarrow e^+e^-$	hadrons nt interference $\Gamma_6/$ 3γ $\Gamma_{10}/$ $\pi^+\pi^-$
VALUE 0.156±0.005 OUR FIT 0.152±0.005 OUR AVE 0.161±0.008 0.143±0.007 0.152±0.008 • • • We do not use th 0.139±0.007 7 Using total width 4.: level. Γ(Κ² Κ°)/Γ(ΚΚ) VALUE 0.409±0.006 OUR FIT 0.45±0.04 OUR AVE 0.44±0.07 0.48±0.07 0.40±0.10	Error in ERAGE Error in ERAGE 11761 MeV. Th EVTS Error in ERAGE 52 34	DOCUMENT ID. CONTROL OF THE PROPERTY OF THE	r of 1.3. e factor o N 95 CN 91 NI 84 OI es, fits, lii 76B OS is more th	f 1.2. MD2	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$-\frac{\pi^0}{\pi^0}$ $-\frac{\pi^0}{\pi^0}$ Infidence $\frac{1+\Gamma_2}{\kappa \kappa}$	I	$\begin{array}{c} 2.81 \pm 0.25 \\ 3.50 \pm 0.27 \\ 11 \text{ Using total width with } \omega \text{ tail. This i} \\ \hline \Gamma \left(\boldsymbol{\pi^0 \gamma} \right) / \Gamma \text{ total } \\ \underline{MALUE (units 10^{-3})} \\ 1.31 \pm 0.13 \text{ OUR AVE} \\ 1.30 \pm 0.13 \\ 1.4 \pm 0.5 \\ \hline \Gamma \left(\boldsymbol{\pi^+ \pi^-} \right) / \Gamma \text{ total } \\ \underline{MALUE (units 10^{-4})} \\ 0.8 \begin{subarray}{c} -0.5 \\ -0.4 \\ 0.63 \begin{subarray}{c} -0.28 \\ 1.94 \begin{subarray}{c} -0.81 \\ -0.81 \\ -0.81 \\ \end{array}$	4.2 MeV. s accounted EVTS RAGE 32 CL% /ERAGE	BALAKIN CHATELUS They detect 3π m I for in the result of DOCUMENT ID DRUZHININ COSME DOCUMENT ID Error includes scale 12 GOLUBEV 12 VASSERMAN BUKIN	71 71 71 ode a quote 84 76 86 81 788	OSPK OSPK and obsed above. TECN ND OSPK TECN OSPK OSPK OLYA OLYA	$e^+e^- \rightarrow e^+e^-$ rve significa	hadrons nt interference $\Gamma_6/$ 3γ $\Gamma_{10}/$ $\pi^+\pi^-$
VALUE 0.156 ± 0.005 OUR FIT 0.152 ± 0.005 OUR AVE 0.161 ± 0.008 0.143 ± 0.007 0.155 ± 0.008 • • • We do not use th 0.139 ± 0.007 7 Using total width 4.: level. Γ(ΚΩΚ)/Γ(ΚΚ) VALUE 0.409 ± 0.006 OUR FIT 0.45 ± 0.04 0.44 ± 0.07 0.48 ± 0.07	Error in ERAGE Error in ERAGE 11761 MeV. Th EVTS Error in ERAGE 52 34	DOCUMENT ID. CONTROL OF THE PROPERTY OF THE	r of 1.3. e factor o N 95 CN 91 NI 84 OI es, fits, lii 768 OS is more th TE r of 1.1.	f 1.2. MD2 e D e LYA e mits, e SPK e aan 80% SCN C BC 2 BC 3 BC 1	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	$-\frac{\pi^0}{\pi^0}$ $-\frac{\pi^0}{\pi^0}$ Infidence $\frac{1+\Gamma_2}{\kappa \kappa}$	1	2.81 \pm 0.25 3.50 \pm 0.27 11 Using total width with ω tail. This is $ \Gamma(\pi^0 \gamma)/\Gamma_{\text{total}} = \frac{MALUE (\text{units } 10^{-3})}{1.31 \pm 0.13 \text{ OUR AVE}} = \frac{1.30 \pm 0.13}{1.4 \pm 0.5} $ $ \Gamma(\pi^+ \pi^-)/\Gamma_{\text{total}} = \frac{MALUE (\text{units } 10^{-4})}{0.8 \pm 0.4} = \frac{4.5}{0.4} = \frac{0.5}{0.28} = \frac{0.37}{0.28} = \frac{0.37}{0.81} = \frac{0.63}{0.81} = 0.$	4.2 MeV. s accounted EVTS RAGE 32 CL% /ERAGE 95 the following	BALAKIN CHATELUS The detect 3\pi m for in the result of for in the result of the property of the process of the	71 71 71 ode a quote 84 76 86 81 788 788 788 788	OSPK OSPK and obsed above. TECN ND OSPK TECN ND OLYA S OLYA s, limits	$e^+e^- \rightarrow e^+e^-$ rve significa $\frac{COMMENT}{e^+e^- \rightarrow e^+e^-}$ $\frac{COMMENT}{e^+e^- \rightarrow e^+e^-}$ $e^+e^- \rightarrow e^+e^-$ $e^+e^- \rightarrow e^+e^-$ $e^+e^- \rightarrow e^-$ $e^-e^- \rightarrow e^-$	hadrons nt interference $\Gamma_6/$ 3γ $\Gamma_{10}/$ $\pi^+\pi^-$
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V_{ALUE} 0.156±0.005 OUR FIT 0.152±0.005 OUR AVE 0.161±0.008 0.143±0.007 0.155±0.008 • • • We do not use th 0.139±0.007 7 Using total width 4.: level. Γ($K_L^0 K_D^0$)/Γ($K_L^0 K_L^0$) V_{ALUE} 0.409±0.006 OUR FIT 0.45 ±0.04 0.40 ±0.10 [Γ($\rho \pi$) + Γ($\pi^+ \pi^- \tau^- \tau^- \tau^- \tau^- \tau^- \tau^- \tau^- \tau^- \tau^- \tau$	Error in Error Error in Error Error in Error Err	DOCUMENT ID Cludes scale factor Tror includes scale AKHMETSHI DOLINSKY KURDADZE g data for average 7 PARROUR e ρπ to 3π mode in DOCUMENT ID Cludes scale factor LONDON BADIER SCHLEIN KK) DOCUMENT ID	r of 1.3. e factor o N 95 CN 91 NI 84 Ol es, fits, li is more th TE r of 1.1.	f 1.2. MD2 6 YYA 6 mits, e	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	$-\frac{\pi}{\pi}0$ $-\frac{\pi}{\pi}0$ Infidence $\frac{1+\Gamma_2}{\kappa \kappa}$ $\frac{\kappa}{\kappa}$	I	2.81 \pm 0.25 3.50 \pm 0.27 11 Using total width with ω tail. This is $ \Gamma(\pi^0 \gamma)/\Gamma_{\text{total}} = \frac{VALUE (\text{units } 10^{-3})}{1.31 \pm 0.13 \text{ OUR AVE}} = \frac{VALUE (\text{units } 10^{-4})}{1.30 \pm 0.13} = \frac{VALUE (\text{units } 10^{-4})}{0.8 \pm 0.5} = \frac{VALUE (\text{units } 10^{-4})}{0.84 \pm 0.5} = \frac{0.37}{0.28} = \frac{0.37}{0.28} = \frac{0.37}{0.81} < 6.6$ •• We do not use < 4.0 < 2.7 12 Using $\Gamma(e^+e^-)/U$	4.2 MeV. s accounted EVTS RAGE 32 CL% /ERAGE 95 the followin 95 95 Fotal = 3.	BALAKIN CHATELUS They detect 3 π m of for in the result of DOCUMENT ID. DRUZHININ COSME DOCUMENT ID. Error includes scale 12 GOLUBEV 12 VASSERMAN BUKIN ng data for average JULIAN ALVENSLEBE	71 71 71 ode a quote 84 76 86 81 788 ess, fit	OSPK OSPK and obsed above. TECN ND OSPK TECN ND OLYA OLYA S, limits OSPK	$\begin{array}{c} e^+e^- \rightarrow e^+e^- \\ e^+e^- \end{array}$ rve significa $\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow e^+e^- \\ \vdots \\ \vdots \\ e^+e^- \rightarrow e^+e^- \\ \vdots \\ e^+e^- \rightarrow e^+e^- \\ \vdots \\ e^+e^- \rightarrow e^+e^- \\ \end{array}$	hadrons nt interference $\Gamma_6/$ 3γ $\Gamma_{10}/$ $\pi^+\pi^ \pi^+\pi^ C\pi^+\pi^-$
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VALUE 0.156 \pm 0.005 OUR FIT 0.152 \pm 0.005 OUR AVE 0.161 \pm 0.008 0.143 \pm 0.007 0.155 \pm 0.008 • • • We do not use th 0.139 \pm 0.007 7 Using total width 4.: level. $\Gamma(K_L^0K_S^0)/\Gamma(K\overline{K})$ VALUE 0.409 \pm 0.006 OUR FIT 0.409 \pm 0.006 OUR FIT 0.40 \pm 0.07 0.41 \pm 0.07 0.42 \pm 0.04 0.187 \pm 0.007 OUR FIT 0.24 \pm 0.04 OUR AVE 0.237 \pm 0.039 0.30 \pm 0.15 $\Gamma(\rho\pi) + \Gamma(\pi^+\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi$	Error in ERAGE 52 34 [Error in ERAGE 11761 1 MeV. Th EVTS Error in ERAGE 52 34 [Error in ERAGE 70]]/[(] EVTS	DOCUMENT ID CONTROL TO THE PROPERTY ID COLORS SCALE ACHMETSHI DOLINSKY KURDADZE g data for average 7 PARROUR e ρπ to 3π mode i DOCUMENT ID COLORS SCALE FACTOR COLORS SCALE FACTOR CERRADA LONDON KORNON KORNON CERRADA LONDON KORNON KORNON COLORS SCALE FACTOR CERRADA LONDON KORNON COLORS SCALE FACTOR CERRADA LONDON KORNON COLORS SCALE FACTOR COLORS S	r of 1.3. e factor o N 95 CN 91 NI 84 OI es, fits, lii 768 OS is more th 768 HI 63 HI 66 HI 66 HI	f 1.2. TOMMENT $ \begin{array}{ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c} -\pi^0 \\ -\pi^0 \\ -\pi^0 \end{array}$ Infidence $\begin{array}{c} \kappa_{1} + \Gamma_{2} \\ \kappa_{K} \\ \kappa_{K} \end{array}$	1	2.81 \pm 0.25 3.50 \pm 0.27 11 Using total width with ω tail. This is $\Gamma(\pi^0\gamma)/\Gamma_{\text{total}} = \frac{VALUE (\text{units }10^{-3})}{1.31 \pm 0.13 \text{ OUR AVE}} = \frac{VALUE (\text{units }10^{-4})}{0.8 \pm 0.5} = \frac{VALUE (\text{units }10^{-4})}{0.8 \pm 0.40} = \frac{4.03}{0.28} = \frac{4.03}{0.28} = \frac{4.03}{0.28} = \frac{4.03}{0.28} = \frac{4.03}{0.29} = 4$	4.2 MeV. s accounted EVTS RAGE 32 CL% /ERAGE 95 the followin 95 Ftotal = 3. (-) T EVTS Error in	BALAKIN CHATELUS They detect 3 π m of for in the result of form the result of the res	71 71 71 ode a quote 84 76 86 81 78 82 85, fit 76 EN72	OSPK OSPK and obsed above. TECN ND OSPK TECN OO of 1.5 ND OLYA S, limits OSPK CNTR	$\begin{array}{c} e^+e^- \rightarrow e^+e^- \\ e^+e^- \end{array}$ rve significal $\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow e^+e^- \\ \vdots \\ \vdots \\ e^+e^- \rightarrow e^+e^- \\ e^+e^- \rightarrow e^+e^- \\ \vdots \\ e^+e^- \rightarrow e^+e^- \\ e^+e^- \rightarrow e^+e^- \\ \vdots \\ e^+e^- \rightarrow e^- \\ \vdots \\ e^- \\ $	hadrons nt interference $\Gamma_{6}/\Gamma_$	
VALUE 0.156±0.005 OUR FIT 0.152±0.005 OUR AVE 0.161±0.008 0.143±0.007 7 Using total width 4.: level. $\Gamma(K_0^2K_0^5)/\Gamma(K\overline{K})$ VALUE 0.409±0.006 OUR FIT 0.45±0.07 0.40 ±0.07 0	EVTS Error in FRAGE 11761 the followin 1 MeV. Th EVTS Error in FRAGE 52 34 π ⁰)]/Γ(I Error in FRAGE π ⁰)]/Γ(I Error in FRAGE	DOCUMENT ID LONDON DOCUMENT ID COUNTY ID	r of 1.3. e factor o N 95 CM 91 NI 84 OI es, fits, lii 76B OS is more th 66 HI 65B HI 66 HI 66 HI 66 HI 77B HI 66 HI	f 1.2. $\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{c} -\pi^0 \\ -\pi^0 \\ -\pi^0 \end{array}$ Infidence $\begin{array}{c} \Gamma_1 + \Gamma_2 \\ \Gamma_2 \\ \Gamma_3 \end{array}$ $\begin{array}{c} \kappa \kappa \\ \kappa \kappa \\ \Gamma_4 + \Gamma_2 \end{array}$	1	2.81 \pm 0.25 3.50 \pm 0.27 11 Using total width with ω tail. This is $\Gamma(\pi^0\gamma)/\Gamma_{\rm total}$ 1.31 \pm 0.13 \pm 0.13 \pm 0.13 1.4 \pm 0.5 $\Gamma(\pi^+\pi^-)/\Gamma_{\rm total}$ 1.4 \pm 0.5 $\Gamma(\pi^+\pi^-)/\Gamma_{\rm total}$ 1.4 \pm 0.5 $\Gamma(\pi^+\pi^-)/\Gamma_{\rm total}$ 1.4 \pm 0.63 \pm 0.4 \pm 0.8 \pm 0.5 \pm 0.8 \pm 0.70 \pm 0.8 \pm 0.8 \pm 0.94 \pm 0.8 1.94 \pm 1.03 \pm 0.28 \pm 0.91	4.2 MeV. s accounted EVTS RAGE 32 CL% /ERAGE 95 the followin 95 95 Total = 3. (-) TError in /ERAGE	BALAKIN CHATELUS They detect 3π m of for in the result of DOCUMENT ID DRUZHININ COSME DOCUMENT ID Error includes scale 12 GOLUBEV 12 VASSERMAN BUKIN ALVENSLEBE 1 × 10 ⁻⁴ . DOCUMENT ID cludes scale factor BUKIN LOSTY	71 71 71 71 84 76 86 81 76 87 86 81 76 87 76 77 77 77 78	OSPK OSPK and obsed above. TECN ND OSPK TECN OLYA S OLYA S, limits OSPK CNTR TECN OLYA HBC	$\begin{array}{c} e^+ e^- \rightarrow \\ e^+ e^- \end{array}$ rve significa $\begin{array}{c} \underline{COMMENT} \\ e^+ e^- \rightarrow \\ e^+ e^- \end{array}$ $\begin{array}{c} \underline{COMMENT} \\ \vdots \\ e^+ e^- \rightarrow \\ e^+ e^- \\ e^+ e^- \end{array}$ etc. $\begin{array}{c} e^+ e^- \rightarrow \\ e^+ e^- \\ - e^+ e^- \end{array}$ $\begin{array}{c} e^+ e^- \rightarrow \\ e^+ e^- \\ - e^+ e^- \\ - e^+ e^- \end{array}$ $\begin{array}{c} e^+ e^- \rightarrow \\ - e^+ e^- \\ - e^- e^- e^- \\ - e^- e^- \\ - e^- e^- e^- \\ - e^- e^- \\ - e^- e^- e^- e^- \\ - e^- e^- e^- \\ - e^- e^-$	hadrons nt interference $\Gamma_6/$ 3γ $\Gamma_{10}/$ $\pi^+\pi^ \pi^+\pi^ C\pi^+\pi^ \Gamma_2/\Gamma$ $K_0^0K_S^0$ \rightarrow ϕ hyperon	
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VALUE 0.156 ± 0.005 OUR FIT 0.152 ± 0.005 OUR AVE 0.161 ± 0.005 OUR AVE 0.161 ± 0.008 0.143 ± 0.007 0.155 ± 0.008 • • • We do not use th 0.139 ± 0.007 7 Using total width 4.: level. $\Gamma(K_0^0 K_0^0) / \Gamma(K\overline{K})$ VALUE 0.44 ± 0.07 0.48 ± 0.07 0.40 ± 0.10 $\Gamma(\rho \pi) + \Gamma(\pi^+ \pi^- \tau)$ VALUE 0.237 ± 0.039 0.30 ± 0.15 $\Gamma(\rho \pi) + \Gamma(\pi^+ \pi^- \tau)$ VALUE 0.457 ± 0.018 OUR FIT 0.51 ± 0.05 OUR AVE 0.56 ± 0.07	EVTS Error in RAGE 11761 he followin 1 MeV. Th EVTS Error in ERAGE 52 34 π ⁰)]/Γ(J Error in ERAGE π ⁰)]/Γ(J EVTS Error in ERAGE	DOCUMENT ID LONDON DOCUMENT ID COUNTY ID	r of 1.3. e factor o N 95 CM 91 NI 84 OI es, fits, lii 76B OS is more th 66 HI 65B HI 66 HI 66 HI 66 HI 77B HI 66 HI	ff 1.2. ff	COMMENT $ \begin{array}{cccccccccccccccccccccccccccccccccc$	$\begin{array}{c} -\pi^{0} \\ -\pi^{0} \\ -\pi^{0} \end{array}$ Infidence $\begin{array}{c} \kappa_{1} + \Gamma_{2} \\ \kappa_{K} \\ \kappa_{K} \end{array}$ $\begin{array}{c} \kappa_{1} + \Gamma_{2} \\ -\pi^{0} \end{array}$	1	2.81 \pm 0.25 3.50 \pm 0.27 11 Using total width with ω tail. This is $\Gamma(\pi^0\gamma)/\Gamma$ total $\frac{VALUE}{1.31 \pm 0.13}$ OUR AVE 1.30 \pm 0.13 1.4 \pm 0.5 $\Gamma(\pi^+\pi^-)/\Gamma$ total $\frac{VALUE}{1.30 \pm 0.13}$ 0.8 \pm 0.5 OUR AVE 1.03 \pm 0.8 \pm 0.70 \pm 0.8 \pm 0.70 \pm 0.8 \pm 0.71 \pm 0.98 \pm 0.018 OUR FI 0.740 \pm 0.06 0.82 \pm 0.08 0.89 \pm 0.10	4.2 MeV. s accounted EVTS RAGE 32 CL% /ERAGE 95 the followin 95 95 T Error in /ERAGE 2732	BALAKIN CHATELUS THE GOLUMENT ID DOCUMENT ID ETROT INCIDENCE 12 GOLUBEV 12 VASSERMAN BUKIN NG data for average JULLIAN ALVENSLEBE 11 x 10 ⁻⁴ . DOCUMENT ID CICLIDES SCALE BUKIN LOSTY LAVEN LYONS AGUILAR	71 71 71 71 84 76 86 81 76 87 76 77	OSPK OSPK and obsed above. TECN ND OSPK TECN OO of 1.5 ND OLYA OSPK CNTR TECN OSPK OSP	$\begin{array}{c} e^+e^- \rightarrow e^+e^- \\ e^+e^- \end{array}$ rve signification $\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow e^+e^- \\ \hline \\ c \\ e^+e^- \rightarrow e^+e^- \\ \hline \\ e^+e^- \rightarrow e^-e^- \\ \hline \\ e^-e^- \rightarrow e^- \\$	hadrons nt interference $\Gamma_{6}/\Gamma_$
VALUE 0.156 ± 0.005 OUR FIT 0.152 ± 0.005 OUR FIT 0.152 ± 0.005 OUR AVE 0.161 ± 0.008 0.143 ± 0.007 0.155 ± 0.008 • • • We do not use th 0.139 ± 0.007 7 Using total width 4.: level. $\Gamma(K_L^0 K_S^0) / \Gamma(K\overline{K})$ VALUE 0.409 ± 0.006 OUR FIT 0.45 ± 0.04 OUR AVE 0.44 ± 0.07 0.49 ± 0.007 OUR FIT 0.24 ± 0.04 OUR AVE 0.237 ± 0.039 0.30 ± 0.15 $\Gamma(\rho\pi) + \Gamma(\pi^+\pi^-\tau^-\tau^-\tau^-\tau^-\tau^-\tau^-\tau^-\tau^-\tau^-\tau^-\tau^-\tau^-\tau^$	Error in ERAGE 52 34 TO] / [(DOCUMENT ID Cludes scale factor Tror includes scale AKHMETSHI DOLINSKY KURDADZE g data for average 7 PARROUR e ρπ to 3π mode in DOCUMENT ID Cludes scale factor LONDON BADIER SCHLEIN KK) DOCUMENT ID Cludes scale factor CERRADA LONDON KONDON CUMENT ID Cludes scale factor CERRADA LONDON KONDON COUMENT ID COUMENT	r of 1.3. e factor o N 95 CM 91 NI 84 OI es, fits, lii 768 OS is more th 768 OS is more th 768 OS is more th 776 HI 66 HI 66 HI 776 HI 778 OI	ff 1.2. ff	TOMMENT $ \begin{array}{cccccccccccccccccccccccccccccccccc$	$-\frac{\pi}{\pi}0$ $-\frac{\pi}{\pi}0$ Infidence $\frac{1+\Gamma_2}{\kappa \kappa}$ $\frac{\kappa}{\kappa}$ $\frac{1+\Gamma_2}{\kappa}$ $\frac{\pi}{\kappa}$ $\frac{(1+\Gamma_2)}{\kappa}$ $\frac{\pi}{\kappa}$ $\frac{(1+\Gamma_2)}{\kappa}$	1	2.81 \pm 0.25 3.50 \pm 0.27 11 Using total width with ω tail. This is $\Gamma(\pi^0\gamma)/\Gamma_{\text{total}}$ 1.31 \pm 0.13 OUR AVE 1.30 \pm 0.13 1.4 \pm 0.5 $\Gamma(\pi^+\pi^-)/\Gamma_{\text{total}}$ 1.4 \pm 0.5 $\Gamma(\pi^+\pi^-)/\Gamma_{\text{total}}$ 1.94 \pm 1.03 \pm 0.18 1.94 \pm 1.03 \pm 0.18 1.94 \pm 1.03 \pm 0.19 \pm 0.8 \pm 0.90 \pm 0.8 \pm 0.19 \pm 0.8 \pm 0.19 \pm 0.8 \pm 0.19 \pm	4.2 MeV. s accounted EVTS RAGE 32 CL% /ERAGE 95 the followin 95 95 T Error in /ERAGE 2732	BALAKIN CHATELUS THE GOLUMENT ID DOCUMENT ID ETROT INCIDENCE 12 GOLUBEV 12 VASSERMAN BUKIN NG data for average JULLIAN ALVENSLEBE 11 x 10 ⁻⁴ . DOCUMENT ID CICLIDES SCALE BUKIN LOSTY LAVEN LYONS AGUILAR	71 71 71 71 84 76 86 81 76 87 76 77	OSPK OSPK and obsed above. TECN ND OSPK TECN OO of 1.5 ND OLYA OSPK CNTR TECN OSPK OSP	$\begin{array}{c} e^+e^- \rightarrow e^+e^- \\ e^+e^- \end{array}$ rve signification $\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow e^+e^- \\ \hline \\ c \\ e^+e^- \rightarrow e^+e^- \\ \hline \\ e^+e^- \rightarrow e^- \\ \hline \\ e^- \rightarrow e^-$	hadrons nt interference $\Gamma_{6}/\Gamma_$
VALUE 0.156 ± 0.005 OUR FIT 0.152 ± 0.005 OUR FIT 0.152 ± 0.005 OUR AVE 0.161 ± 0.008 0.143 ± 0.007 0.155 ± 0.008 • • • We do not use th 0.139 ± 0.007 7 Using total width 4.: level. $\Gamma(K_{0}^{0}K_{0}^{0})/\Gamma(K\overline{K})$ VALUE 0.409 ± 0.006 OUR FIT 0.45 ± 0.04 OUR AVE 0.44 ± 0.07 0.49 ± 0.007 OUR FIT 0.24 ± 0.04 OUR AVE 0.237 ± 0.039 0.30 ± 0.15 $\Gamma(\rho\pi) + \Gamma(\pi^{+}\pi^{-}\tau^{-})$ VALUE 0.45 ± 0.04 OUR AVE 0.251 ± 0.05 OUR AVE 0.251 ± 0.05 OUR FIT 0.51 ± 0.05 OUR FIT 0.51 ± 0.05 OUR AVE 0.56 ± 0.07 0.47 ± 0.06 $\Gamma(\mu^{+}\mu^{-})/\Gamma_{\text{total}}$	Error in ERAGE 52 34 TO] / [(DOCUMENT ID CITIZENT STATE DOLINSKY KURDADZE g data for average 7 PARROUR e ρπ to 3π mode i CONDON BADIER SCHLEIN CERRADA LONDON CERRADA LONDON CERRADA LONDON CERRADA LONDON COSME	r of 1.3. e factor o N 95 CN 91 NI 84 OI es, fits, lii 768 OS is more th 768 OS is more th 768 HI 66 HI 66 HI 67 T of 1.3. 778 OI 74 OS	f 1.2. f	TOMMENT $ \begin{array}{cccccccccccccccccccccccccccccccccc$	$\begin{array}{c} -\pi^{0} \\ -\pi^{0} \\ -\pi^{0} \end{array}$ Infidence $\begin{array}{c} \kappa_{1} + \Gamma_{2} \\ \kappa_{K} \\ \kappa_{K} \end{array}$ $\begin{array}{c} \kappa_{1} + \Gamma_{2} \\ -\pi^{0} \end{array}$	1	2.81 \pm 0.25 3.50 \pm 0.27 11 Using total width with ω tail. This is $\Gamma(\pi^0\gamma)/\Gamma_{\rm total}$ 2.31 \pm 0.13 OUR AVE 1.31 \pm 0.13 OUR AVE 1.30 \pm 0.13 1.4 \pm 0.5 $\Gamma(\pi^+\pi^-)/\Gamma_{\rm total}$ 2.4 \times 0.8 \pm 0.5 OUR AVE 1.94 \pm 1.03 \pm 0.28 \pm 0.28 1.94 \pm 1.03 \pm 0.81 \pm 0.80 \pm 0.81 \pm 0.80 \pm 0.81 \pm 0.82 \pm 0.08 \pm 0.70 \pm 0.05 \pm 0.71 \pm 0.08 \pm 0.89 \pm 0.10 \pm 0.74 \pm 0.81	4.2 MeV. s accounted EVTS RAGE 32 CL% /ERAGE 95 the followin 95 95 Total = 3. (-) T EVTS T ETTS T/ERAGE 2732	BALAKIN CHATELUS They detect 3π m of for in the result of for includes scale for average of JULLIAN ALVENSLEBE 1 × 10 ⁻⁴ . **DOCUMENT ID** LOSTY LAVEN LYONS AGUILAR **K+K-) **DOCUMENT ID** DOCUMENT I	71 71 71 71 84 76 84 76 81 78 82 85, fit 76 77 77 72	OSPK OSPK OSPK and obsed above. TECN ND OSPK TECN ND OLYA OSPK OSPK OSPK OSPK OSPK OSPK OSPK OSPK	$\begin{array}{c} e^+e^- \rightarrow e^+e^- \\ e^+e^- \end{array}$ rve signification $\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow e^+e^- \\ \vdots \\ e^+e^- \rightarrow e^+e^- \\ \vdots \\ e^+e^- \rightarrow e^+e^- \\ e^-e^- \rightarrow e^-e^- \\ e^-e$	hadrons nt interference $\Gamma_{6}/\Gamma_$
V_{ALUE} = 0.156 ± 0.005 OUR FIT 0.152 ± 0.005 OUR FIT 0.152 ± 0.005 OUR FIT 0.152 ± 0.005 OUR AVE 0.161 ± 0.008 0.143 ± 0.007 7 Using total width 4.1 level. Γ(K_1^0 K_2^0)/Γ(K_1^0)/	EVTS Error in FRAGE 11761 he followin 1 MeV. Th EVTS Error in FRAGE 52 34 π ⁰)]/Γ(I Error in ERAGE 3681 516	DOCUMENT ID Cludes scale factor Tror includes scale AKHMETSHI DOLINSKY KURDADZE g data for average 7 PARROUR e ρπ to 3π mode in DOCUMENT ID Cludes scale factor LONDON BADIER SCHLEIN KK) DOCUMENT ID Cludes scale factor CERRADA LONDON KONDON CUMENT ID Cludes scale factor CERRADA LONDON KONDON COUMENT ID COUMENT	r of 1.3. e factor o N 95 CN 91 NI 84 OI es, fits, lii 768 OS is more th 768 OS is more th 768 HI 66 HI 66 HI 67 T of 1.3. 778 OI 74 OS	f 1.2. f	TOMMENT $ \begin{array}{cccccccccccccccccccccccccccccccccc$	$-\frac{\pi}{\pi}0$ $-\frac{\pi}{\pi}0$ Infidence $\frac{1+\Gamma_2}{\kappa \kappa}$ $\frac{\kappa}{\kappa}$ $\frac{1+\Gamma_2}{\kappa}$ $\frac{\pi}{\kappa}$ $\frac{(1+\Gamma_2)}{\kappa}$ $\frac{\pi}{\kappa}$ $\frac{(1+\Gamma_2)}{\kappa}$	1	2.81 \pm 0.25 3.50 \pm 0.27 11 Using total width with ω tail. This is $\Gamma(\pi^0\gamma)/\Gamma$ total MALUE (units 10^{-3}) 1.31 \pm 0.13 OUR AVE 1.30 \pm 0.13 1.4 \pm 0.5 $\Gamma(\pi^+\pi^-)/\Gamma$ total MALUE (units 10^{-4}) 0.8 \pm 0.4 OUR AVE 1.03 \pm 0.8 \pm 0.5 \pm 0.4 OUR AVE 1.03 \pm 0.8 \pm 0.7 \pm 0.8 \pm 0.7 \pm 0.8 \pm 0.7 \pm 0.8 \pm 0.7 \pm 0.8 \pm 0.8 \pm 0.9 OUR AVE 1.03 \pm 0.8 \pm 0.9 OUR AVE 1.04 \pm 0.63 \pm 0.7 \pm 0.8 \pm 0.8 \pm 0.8 \pm 0.9 \pm 0.8 \pm 0.9 \pm 0.8 \pm 0.8 \pm 0.9 \pm 0.8 \pm 0.9 \pm 0.9 \pm 0.9 \pm 0.9 \pm 0.01 OUR AVE 1.00 \pm 0.00 \pm	4.2 MeV. s accounted RAGE 32 CL% /FRAGE 95 the followin 95 95 T total = 3. (-) T EVTS 2732 144 T 0)]/\(\(\) \(\) \(\) \(\) EVTS Error in \(\) ETTS T EVTS BALAKIN CHATELUS They detect 3π m d for in the result of DOCUMENT ID DRUZHININ COSME DOCUMENT ID Error includes scale 12 GOLUBEV 12 VASSERMAN BUKIN ng data for average JULLIAN ALVENSLEBE 1 × 10-4. DOCUMENT ID Coludes scale factor BUKIN LOSTY LAVEN LYONS AGUILAR K+K-) DOCUMENT ID DOCUMENT ID Coludes scale factor AGUILAR CK+K-) DOCUMENT ID DOCU	71 71 71 71 71 71 71 84 76 84 76 81 786 81 76 61 77 77 77 77 72 6	OSPK OSPK OSPK and obsed dabove. TECN ND OSPK TECN OCO of 1.5 ND OLYA S, limits OSPK CNTR TECN .1. COLYA HBC	$\begin{array}{c} e^+e^- \rightarrow e^+e^- \\ e^+e^- \end{array}$ rve significa $\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow e^+e^- \\ \vdots \\ e^+e^- \rightarrow e^+e^- \\ \vdots \\ e^+e^- \rightarrow e^+e^- \\ e^- \rightarrow e^- \\ e^- \rightarrow e^$	hadrons nt interference $\Gamma_{6}/\Gamma_$	
VALUE (Units 10-4) $VALUE (Units 10-6) VALUE (UNITS 10-6) VALU$	EVTS Error in FRAGE 11761 he followin 1 MeV. Th EVTS Error in FRAGE 52 34 π ⁰)]/Γ(I Error in ERAGE 3681 516	DOCUMENT ID CITIZENT STATE DOLINSKY KURDADZE g data for average 7 PARROUR e ρπ to 3π mode i CONDON BADIER SCHLEIN CERRADA LONDON CERRADA LONDON CERRADA LONDON CERRADA LONDON COSME	r of 1.3. e factor o N 95 CM 91 NI 84 OI e se, fits, lii 768 OS is more th TE r of 1.1. 66 HI 65B HI 65B HI 66 HI 77B HI 66 HI 77B HI	f 1.2. f	TOMMENT $ \begin{array}{cccccccccccccccccccccccccccccccccc$	$\begin{array}{c} -\pi^{0} \\ -\pi^{0} \\ -\pi^{0} \end{array}$ Infidence $\begin{array}{c} (1+\Gamma_{2}) \\ KK \\ KK \\ -\pi^{0} \end{array}$ $\begin{array}{c} \pi \\ -\pi^{0} \\ F_{8}/\Gamma \\ \end{array}$	1	2.81 \pm 0.25 3.50 \pm 0.27 11 Using total width with ω tail. This is $\Gamma(\pi^0\gamma)/\Gamma_{\rm total}$ 2.31 \pm 0.13 OUR AVE 1.31 \pm 0.13 OUR AVE 1.30 \pm 0.13 1.4 \pm 0.5 $\Gamma(\pi^+\pi^-)/\Gamma_{\rm total}$ 2.4 \times 0.8 \pm 0.5 OUR AVE 1.94 \pm 1.03 \pm 0.28 \pm 0.28 1.94 \pm 1.03 \pm 0.81 \pm 0.80 \pm 0.81 \pm 0.80 \pm 0.81 \pm 0.82 \pm 0.08 \pm 0.70 \pm 0.05 \pm 0.71 \pm 0.08 \pm 0.89 \pm 0.10 \pm 0.74 \pm 0.81	4.2 MeV. s accounted EVTS RAGE 32 CL% /ERAGE 95 the followin 95 95 Total = 3. (-) T EVTS T ETTS T/ERAGE 2732	BALAKIN CHATELUS They detect 3π m of for in the result of for includes scale for average of JULLIAN ALVENSLEBE 1 × 10 ⁻⁴ . **DOCUMENT ID** LOSTY LAVEN LYONS AGUILAR **K+K-) **DOCUMENT ID** DOCUMENT I	71 71 71 71 71 71 71 84 76 84 76 81 786 81 76 61 77 77 77 77 72 6	OSPK OSPK OSPK and obsed above. TECN ND OSPK TECN ND OLYA OSPK OSPK OSPK OSPK OSPK OSPK OSPK OSPK	$\begin{array}{c} e^+e^- \rightarrow e^+e^- \\ e^+e^- \end{array}$ rve signification $\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow e^+e^- \\ \vdots \\ e^+e^- \rightarrow e^+e^- \\ \vdots \\ e^+e^- \rightarrow e^+e^- \\ e^-e^- \rightarrow e^-e^- \\ e^-e$	hadrons nt interference $\Gamma_{6}/\Gamma_$
VALUE 0.156 ± 0.005 OUR FIT 0.152 ± 0.005 OUR FIT 0.152 ± 0.005 OUR AVE 0.161 ± 0.005 OUR AVE 0.161 ± 0.008 0.143 ± 0.007 7 Using total width 4.1 level. $\Gamma(K_1^0 K_3^0) / \Gamma(K\overline{K})$ VALUE 0.409 ± 0.006 OUR FIT 0.45 ± 0.04 OUR AVE 0.48 ± 0.07 0.40 ± 0.01 $\Gamma(\rho \pi) + \Gamma(\pi^+ \pi^- \tau)$ VALUE 0.187 ± 0.007 OUR FIT 0.24 ± 0.04 OUR AVE 0.237 ± 0.039 0.30 ± 0.15 $\Gamma(\rho \pi) + \Gamma(\pi^+ \pi^- \tau)$ VALUE 0.457 ± 0.018 OUR FIT 0.51 ± 0.05 OUR AVE 0.56 ± 0.07 0.47 ± 0.06 $\Gamma(\mu^+ \mu^-) / \Gamma_{\text{total}}$ VALUE (units 10 ⁻⁴) VALUE (units 10 ⁻⁴) 2.48± 0.34 OUR AVER. 2.69 ± 0.46	EVTS Error in FRAGE 11761 he followin 1 MeV. Th EVTS Error in FRAGE 52 34 π ⁰)]/Γ(I Error in ERAGE 3681 516	DOCUMENT ID COLOREST CONTROL TO THE COLOR TO THE COLOR TO THE COLOR TO THE COLOR TO THE	r of 1.3. e factor o N 95 CM 91 NI 84 OI es, fits, lii 768 OS is more th 768 OS 768 OS 768 OS 778 HI 66 HI 778 OI 74 OS 768 OI 779 CF 70 CF	f 1.2. COMMENT $ \begin{array}{cccccccccccccccccccccccccccccccccc$	of the second s	1	2.81 \pm 0.25 3.50 \pm 0.27 11 Using total width with ω tail. This is $\Gamma(\pi^0\gamma)/\Gamma_{\rm total}$ 2.13 \pm 0.13 OUR AVE 1.30 \pm 0.13 1.4 \pm 0.5 $\Gamma(\pi^+\pi^-)/\Gamma_{\rm total}$ 2.26 \times 0.8 \pm 0.70 \times 0.8 \pm 0.70 \times 0.8 \pm 0.8 \pm 0.8 \pm 0.8 1.94 \pm 1.03 \pm 1.03 \pm 0.8 \pm 0.8 1.94 \pm 1.03 \pm 0.81 \pm 0.81 \pm 0.80 \pm 0.81 \pm 0.82 \pm 0.83 \pm 0.89 \pm 0.10 \pm 0.83 \pm 0.013 OUR FI 0.83 \pm 0.013 OUR FI 0.88 \pm 0.09	4.2 MeV. s accounted RAGE 32 CL% /FRAGE 95 the followin 95 95 T total = 3. (-) T EVTS 2732 144 T 0)]/\(\(\) \(\) \(\) \(\) EVTS Error in \(\) ETTS T EVTS BALAKIN CHATELUS They detect 3π m d for in the result of DOCUMENT ID DRUZHININ COSME DOCUMENT ID Error includes scale 12 GOLUBEV 12 VASSERMAN BUKIN ng data for average JULLIAN ALVENSLEBE 1 × 10-4. DOCUMENT ID Coludes scale factor BUKIN LOSTY LAVEN LYONS AGUILAR K+K-) DOCUMENT ID DOCUMENT ID Coludes scale factor AGUILAR CK+K-) DOCUMENT ID DOCU	71 71 71 71 71 71 71 84 76 84 76 81 786 81 76 61 77 77 77 77 72 6	OSPK OSPK OSPK and obsed dabove. TECN ND OSPK TECN OCO of 1.5 ND OLYA S, limits OSPK CNTR TECN .1. COLYA HBC	$\begin{array}{c} e^+e^- \rightarrow e^+e^- \\ e^+e^- \end{array}$ rve significa $\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow e^+e^- \\ \vdots \\ e^+e^- \rightarrow e^+e^- \\ \vdots \\ e^+e^- \rightarrow e^+e^- \\ e^- \rightarrow e^- \\ e^- \rightarrow e^$	hadrons nt interference $\Gamma_{6}/\Gamma_$		
VALUE 0.156 ± 0.005 OUR FIT 0.152 ± 0.005 OUR AVE 0.161 ± 0.005 OUR AVE 0.161 ± 0.008 0.143 ± 0.007 0.155 ± 0.008 0.143 ± 0.007 7 Using total width 4.1 level. $\Gamma(K_L^0 K_S^0)/\Gamma(K\overline{K})$ VALUE 0.409 ± 0.006 OUR FIT 0.45 ± 0.04 OUR AVE 0.44 ± 0.07 0.48 ± 0.07 0.49 ± 0.010 $\Gamma(\rho\pi) + \Gamma(\pi^+\pi^-\tau_L^0)$ VALUE 0.187 ± 0.007 OUR FIT 0.24 ± 0.04 OUR AVE 0.237 ± 0.039 0.30 ± 0.15	EVTS Error in FRAGE 11761 he followin 1 MeV. Th EVTS Error in FRAGE 52 34 π ⁰)]/Γ(I Error in ERAGE 3681 516	DOCUMENT ID COLORS Scale factor AKHMETSHI DOLINSKY KURDADZE g data for average 7 PARROUR e ρπ to 3π mode i COLOMENT ID COLO	r of 1.3. e factor o N 95 CM 91 NI 84 OI es, fits, lii 768 OS is more th 768 OS 768 OS 768 OS 778 HI 66 HI 778 OI 74 OS 768 OI 779 CF 70 CF	f 1.2. TOMMENT $ \begin{array}{cccccccccccccccccccccccccccccccccc$	of the second s	1	2.81 \pm 0.25 3.50 \pm 0.27 11 Using total width with ω tail. This is $\Gamma(\pi^0\gamma)/\Gamma$ total MALUE (units 10^{-3}) 1.31 \pm 0.13 OUR AVE 1.30 \pm 0.13 1.4 \pm 0.5 $\Gamma(\pi^+\pi^-)/\Gamma$ total MALUE (units 10^{-4}) 0.8 \pm 0.4 OUR AVE 1.03 \pm 0.8 \pm 0.5 \pm 0.4 OUR AVE 1.03 \pm 0.8 \pm 0.7 \pm 0.8 \pm 0.7 \pm 0.8 \pm 0.7 \pm 0.8 \pm 0.7 \pm 0.8 \pm 0.8 \pm 0.9 OUR AVE 1.03 \pm 0.8 \pm 0.9 OUR AVE 1.04 \pm 0.63 \pm 0.7 \pm 0.8 \pm 0.8 \pm 0.8 \pm 0.9 \pm 0.8 \pm 0.9 \pm 0.8 \pm 0.8 \pm 0.9 \pm 0.8 \pm 0.9 \pm 0.9 \pm 0.9 \pm 0.9 \pm 0.01 OUR AVE 1.00 \pm 0.00 \pm	4.2 MeV. s accounted RAGE 32 CL% /FRAGE 95 the followin 95 95 T total = 3. (-) T EVTS 2732 144 T 0)]/\(\(\) \(\) \(\) \(\) EVTS Error in \(\) ETTS T EVTS BALAKIN CHATELUS They detect 3π m d for in the result of DOCUMENT ID DRUZHININ COSME DOCUMENT ID Error includes scale 12 GOLUBEV 12 VASSERMAN BUKIN ng data for average JULLIAN ALVENSLEBE 1 × 10-4. DOCUMENT ID Coludes scale factor BUKIN LOSTY LAVEN LYONS AGUILAR K+K-) DOCUMENT ID DOCUMENT ID Coludes scale factor AGUILAR CK+K-) DOCUMENT ID DOCU	71 71 71 71 71 71 71 84 76 84 76 81 786 81 76 61 77 77 77 77 72 6	OSPK OSPK OSPK and obsed dabove. TECN ND OSPK TECN OCO of 1.5 ND OLYA S, limits OSPK CNTR TECN .1. COLYA HBC	$\begin{array}{c} e^+e^- \rightarrow e^+e^- \\ e^+e^- \end{array}$ rve significa $\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow e^+e^- \\ \vdots \\ e^+e^- \rightarrow e^+e^- \\ \vdots \\ e^+e^- \rightarrow e^+e^- \\ e^- \rightarrow e^- \\ e^- \rightarrow e^$	hadrons nt interference $\Gamma_{6}/\Gamma_$		

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F(//oFo) \ /F							r /r
$\Gamma(\eta'(958)\gamma)/\Gamma_{\text{total}}$							Γ ₁₇ /Γ
VALUE (units 10 ⁻⁴)	<u>CL%</u> 90	DRUZHININ	87	ND.	$e^+e^- \rightarrow$		
•	90	DROZHININ	01	ND	e · e →	γηπ.	м
$\Gamma(\pi^0\pi^0\gamma)/\Gamma_{total}$							Γ_{15}/Γ
VALUE (units 10 ⁻³)	CL%	DOCUMENT ID		TECN	COMMENT		
<1	90	DRUZHININ	87	ND	e^+e^-	5γ	
$\Gamma(\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0})/$	Ttotal						Г18/Г
VALUE (units 10 ⁻⁴)	CL%	DOCUMENT ID		TECN	COMMENT		10,
<1.5	95	BARKOV	88	CMD	$e^+e^{\pi^+\pi^-}$	_+	_0
$\Gamma(\pi^+\pi^-\pi^+\pi^-)/\Gamma_{tc}$					и · и		″ Г ₁₆ /Г
VALUE (units 10 ⁻⁴)		DOCUMENT ID		TECN	COMMENT		16/
<8.7	90	CORDIER	79	WIRE	e+e- →	4π	
F(£(000)a)/F							Γ ₁₄ /Γ
$\Gamma(f_0(980)\gamma)/\Gamma_{\text{total}}$							14/1
	CL%	DOCUMENT ID					
• We do not use th		ng data ior average ¹³ DRUZHININ				0 0	
<2	90					ποπο	γ
¹³ Uses narrow width a	pproxima	ition which is quest	ionec	by ACI	HASOV 95		
$\Gamma(\pi^0 e^+ e^-)/\Gamma_{ m total}$							Γ_{19}/Γ
VALUE	CL%	DOCUMENT ID		TECN	COMMENT		
<1.2 × 10 ⁻⁴	90	DOLINSKY	88	ND	$e^+e^- \rightarrow$	$\pi^0 e^+$	e
$\Gamma(\pi^0\eta\gamma)/\Gamma_{ m total}$							Γ ₂₀ /Γ
VALUE (units 10 ⁻³)	CL%	DOCUMENT ID		TECN	COMMENT		
• • • We do not use th	e followi	ng data for average	s, fits	s, limits,	etc. \bullet \bullet		
<2.5	90	DOLINSKY	91	ND	$e^+e^- \rightarrow$	$\pi^0 \eta \gamma$	
$\Gamma(a_0(980)\gamma)/\Gamma_{ ext{total}}$							Γ21/Γ
VALUE (units 10 ⁻³)	CL%	DOCUMENT ID		TECN	$\frac{COMMENT}{e^+ e^-} \rightarrow$		
<5	90	¹⁴ DOLINSKY	91	ND	e^+e^-	$\pi^0 \eta \gamma$	
14 Uses narrow width a	pproxim a	ition which is quest	ioned	by ACI	HASOV 95		

ϕ (1020) REFERENCES

ACHASOV	95	PLB 363 106 +Gubin (NOVM)
AKHMETSHIN	95	PL B364 199 +Akesnov+ (NOVO, BOST, PITT, MINN, YALE)
DOLINSKY	91	PRPL 202 99 +Druzhinin, Dubrovin+ (NOVO)
BARKOV	88	SJNP 47 248 +Vasserman, Vorobyev, Ivanov+ (NOVO)
		Translated from YAF 47 393.
DOLINSKY	88	SJNP 48 277 +Druzhinin, Dubrovin, Golubev+ (NOVO)
0.011711111111		Translated from YAF 48 442.
DRUZHININ	87 86	ZPHY C37 1 + Dubrovin, Eidelman, Golubev+ (NOVO)
ARMSTRONG		PL 166B 245 +Bloodworth, Carney+ (ATHU, BARI, BIRM, CERN)
ATKINSON BEBEK	86 86	ZPHY C30 521 + (BONN, CERN, GLAS, LANC, MCHS, CURIN+) PRL 56 1893 + Berkelman, Blucher, Cassel+ (CLEO Collab.)
DAVENPORT	86	PR 33 2519 (TUFTS, ARIZ, FNAL, FSU, NDAM, VAND)
DIJKSTRA	86	ZPHY C31 375 +Bailey+ (ANIK, BRIS, CERN, CRAC, MPIM, RAL)
FRAME	86	NP B276 667 +Hughes, Lynch, Minto, McFadzean+ (GLAS)
GOLUBEV	86	SJNP 44 409 +Druzhinin, Ivanchenko, Perevedentsev+ (NOVO)
GOLOBEV	00	Translated from YAF 44 633.
ALBRECHT	85D	PL 153B 343 + Drescher, Binder, Drews+ (ARGUS Collab.)
GOLUBEV	85	SJNP 41 756 +Druzhinin, Ivanchenko, Peryshkin+ (NOVO)
000000	-	Translated from YAF 41 1183.
DRUZHININ	84	PL 144B 136 +Golubev, Ivanchenko, Peryshkin+ (NOVO)
KURDADZE	84	IYF 84-7 Preprint +Leltchouk, Pakhtusova, Sidorov+ (NOVO)
ARMSTRONG	83B	NP B224 193 + (BARI, BIRM, CERN, MILA, CURIN+)
BARATE	83	PL 121B 449 +Bareyre, Bonamy+ (SACL, LOIC, SHMP, IND)
KURDADZE	83C	JETPL 38 366 +Lelchuk, Root+ (NOVO)
		Translated from ZETFP 38 306.
ARENTON	82	PR D25 2241 +Ayres, Diebold, May, Swallow+ (ANL, ILL)
PELLINEN	82	PS 25 599 +Roos (HELS)
DAUM	81	PL 100B 439 +Bardsley+ (AMST, BRIS, CERN, CRAC, MPIM+)
IVANOV	81	PL 107B 297 +Kurdadze, Lelchuk, Sidorov, Skrinsky+ (NOVO)
Also	82	Private Comm. Eidelman (NOVO)
VASSERMAN	81	PL 99B 62 +Kurdadze, Sidorov, Skrinsky+ (NOVO)
CORDIER	80 79B	NP B172 13 +Delcourt, Eschstruth, Fulda+ (LALO)
BARKOV CORDIER	79B	IYF 79-93 Preprint +Zolotorev, Makarina, Mishakova+ (NOVO) PL 81B 389 +Delcourt, Eschstruth, Fulda+ (LALO)
BUKIN	78B	
BUKIN	100	SJNP 27 521 +Kurdadze, Sidorov, Skrinsky+ (NOVO) Translated from YAF 27 985.
BUKIN	78C	SJNP 27 516 +Kurdadze, Serednyakov, Sidorov+ (NOVO)
		Translated from YAF 27 976.
COOPER	78B	NP B146 1 +Ganguli+ (TATA, CERN, CDEF, MADR)
LOSTY	78	NP B133 38 +Holmgren, Blokzijl+ (CERN, AMST, NIJM, OXF)
AKERLOF	77	PRL 39 861 +Alley, Bintinger, Ditzler+ (FNAL, MICH, PURD)
ANDREWS	77	PRL 38 198 +Fukushima, Harvey, Lobkowicz, May+ (ROCH)
BALDI	77	PL 68B 381 +Bohringer, Dorsaz, Hungerbuhler+ (GEVA)
CERRADA	77B	NP B126 241 +Blockzijl, Heinen+ (AMST, CERN, NIJM, OXF)
COHEN	77	PRL 38 269 +Ayres, Diebold, Kramer, Pawlicki, Wicklund (ANL)
LAVEN	77	NP B127 43 +Otter, Klein+ (AACH3, BERL, CERN, LOIC, WIEN)
LYONS	77	NP B125 207 +Cooper, Clark (OXF)
COSME	76	PL 63B 352 +Courau, Dudelzak, Grelaud, Jean-Marie+ (ORSAY)
JULLIAN	76	Tbilisi 2 B19 (ORSAY)
KALBFLEISCH		PR D13 22 +Strand, Chapman (BNL, MICH)
PARROUR	76	PL 63B 357 +Grelaud, Cosme, Courau, Dudelzak+ (ORSAY)
PARROUR	76B	PL 63B 362 +Grelaud, Cosme, Courau, Dudelzak+ (ORSAY)
KALBFLEISCH	10	PR D11 987 +Strand, Chapman (BNL, MICH)

AVRES		ϕ (1020), h	$_{1}(1170)$
The related papers of the relation papers of	BESCH 74 NP B70 257 COSME 74 PL 488 159 DEGROOT 74 NP B74 77 BALLAM 73 PR 07 3150 BININIE 738 PR 06 29 AUVENSLEBEN 72 PR 128 66 BORENSTEIN 72 PR 128 66 BORENSTEIN 72 PR 05 1559 COLLEY 72 NP B50 1 BALAKIN 71 PL 348 328 CHATELUS 71 TRESI LAL 1247 Also 70 PL 32 416 HAYES 71 PR 04 899 STOTTLE 71 TRESI CAL 1247 Also 69 Liverpool Sym. 69 EARLES MOY 69 TRESI LINDSEY 66 PR 143 1034 BADIER 16 563B PL 17 337 LINDSEY 65 6581 AL 154 1312 LINDSEY 65 6581 AL 17 337 LINDSEY 65 6581 AL 17 317 LINDSEY 65 6581 AL 164 AL 17 315 LINDSEY 65 6581 AL 17 317 LINDSEY 65 6581 AL 164 AL 17 317 LINDSEY 65 6581 AL 164 AL 11 AL 17 317 LINDSEY 65 6581 AL 164 AL 11 AL 17 317 LINDSEY 65 6581 AL 164 AL 11 AL 18 AL	+Hartmann, Kose, Krautschneider, Paul+ - Haen-Marie, Jullian, Laplanche+ - Haen-Marie, Jullian, Laplanche+ - Hoogland, Jongejans, Mettzger+ - Hoogland, Jongejans, Mettzger+ - Carr, Debenham, Duane+ - Agullar-Benitez, Chung, Eisner, Samios - Becker, Biggs, Binkley+ - Danburg, Kalbfleisch+ - Jobes, Riddford, Griffiths+ - Budker, Pakhtusova, Sidorov, Skrinsky+ - Bizot, Buon, Chatelus, Jeanjean+ - Hmlay, Joseph, Keizer, Stein - Stottlemyer - Buon, Chatelus, Jeanjean+ - Perezy-Jorba - Faissler, Gettner, Lutz, Moy, Tang+ - + Smith - Rau, Goldberg, Lichtman+ - Demoulin, Barloutaud+ - Smith - Smith - Smith - Smith - Rau, Goldberg, Lichtman+ - Demoulin, Barloutaud+ - Smith - Smi	(BÖNN) (ORSAY) (ORSAY) (ORSAY) (ORSAY) (ORSAY) (SLAC, LBL LOIC, SHMP) (MIT, DESY) (MIT, DESY) (MIT, DESY) (MIN, MICH) BIRM, GLAS) (NOVO) (STRB) (ORSAY) (CORN) (UMD) (ORSAY) (NEAS) (NEAS) (LRL) (BNL, SYRA) IGJP SACL, AMST)
KAMAL 92 PL B284 421 GEORGIO 85 PL 1528 428 ARMENTEROS 638 Siena Conf. 270 FEbwards, Astier+ Hailer, Nussbaum, Kirsch+			(OCLA) IGJP
VALUE (MeV)DOCUMENT IDTECNCHGCOMMENT1170±20 OUR ESTIMATE• • • We do not use the following data for averages, fits, limits, etc. • • •1168± 4ANDO92SPEC8 $\pi^- \rho \rightarrow \pi^+ \pi^- \pi^0 n$ 1166± 5±31 ANDO92SPEC8 $\pi^- \rho \rightarrow \pi^+ \pi^- \pi^0 n$ 1190±602 DANKOWY81SPEC08 $\pi \rho \rightarrow 3\pi n$ 1 Average and spread of values using 2 variants of the model of BOWLER 75.	GEORGIO 85 PL 1528 428 ARMENTEROS 638 Siena Conf. 2 70 GELFAND 638 PRL 11 438 BERTANZA 62 PRL 9 180	Georgiopoulos+ (TUFTS, ARIZ, FNAL, F. +Edwards, Astier+ (V. +Miller, Nussbaum, Kirsch+ +Brisson, Connolly, Hart+	SU, NĎAM+) CERN, CDEF) COLU, RUTG) (BNL, SYRA)
1170±20 OUR ESTIMATE • • • We do not use the following data for averages, fits, limits, etc. • • • 1168± 4 ANDO 92 SPEC $8\pi^-p \rightarrow \pi^+\pi^-\pi^0n$ 1166± 5±3 1 ANDO 92 SPEC $8\pi^-p \rightarrow \pi^+\pi^-\pi^0n$ 1190±60 2 DANKOWY 81 SPEC 0 $8\pi^-p \rightarrow 3\pi n$ 1 Average and spread of values using 2 variants of the model of BOWLER 75.	h	P ₁ (1170) MASS	
1168 ± 4 ANDO 92 SPEC $8 \pi^- \rho \rightarrow \pi^+ \pi^- \pi^0 n$ 1166 ± 5 ± 3 1 ANDO 92 SPEC $8 \pi^- \rho \rightarrow \pi^+ \pi^- \pi^0 n$ 1190 ± 60 2 DANKOWY 81 SPEC 0 $8 \pi \rho \rightarrow 3\pi n$ 1 Average and spread of values using 2 variants of the model of BOWLER 75.	1170±20 OUR ESTIMATE		IMENT
1166 \pm 5 \pm 3	•		- p →
1190 \pm 60 2 DANKOWY 81 SPEC 0 $8\pi\rho \rightarrow 3\pi n$ 1 Average and spread of values using 2 variants of the model of BOWLER 75.	1166± 5±3	ANDO 92 SPEC $8 \pi^{7}$	$\frac{\pi^{+}\pi^{-}\pi^{0}n}{p\rightarrow}$
¹ Average and spread of values using 2 variants of the model of BOWLER 75.	1190±60 2	•	$p^+\pi^-\pi^0 n$ $p \rightarrow 3\pi n$
		g 2 variants of the model of BOWLER	75.

$h_1(1170)$ WIDTH

VALUE (MeV) 360±40 OUR ESTIMA	DOCUMENT ID		TECN CH	G COMMENT
• • • We do not use th	e following data for average	s, fit	s, limits, etc.	• • •
345 ± 6	ANDO	92	SPEC	$ \begin{array}{c} 8 \pi^- p \rightarrow \\ \pi^+ \pi^- \pi^0 p \end{array} $
375± 6±34	³ ANDO	92	SPEC	$ \begin{array}{c} \pi^{+} \pi^{-} \pi^{0} n \\ 8 \pi^{-} p \rightarrow \\ \pi^{+} \pi^{-} \pi^{0} n \end{array} $
320 ± 50	⁴ DANKOWY	81	SPEC 0	$\pi^+\pi^-\pi^0n$ 8 $\pi p \rightarrow 3\pi n$
³ Average and spread	of values using 2 variants of	the	model of BC	WLER 75.

⁴ Uses the model of BOWLER 75.

$h_1(1170)$ DECAY MODES

		Mode	Fraction (Γ_i/Γ)
Ī	Γ ₁	$\rho\pi$	seen

h_1 (1170) BRANCHING RATIOS

$\Gamma(ho\pi)/\Gamma_{total}$					Γ_1/Γ			
VALUE	DOCUMENT ID		TECN	COMMENT				
seen	ATKINSON	84	OMEG	20-70 $\gamma p \rightarrow$				
				$\pi^{+}\pi^{-}\pi^{0}p$				
seen	DANKOWY	81	SPEC	$8 \pi p \rightarrow 3\pi n$				
• • We do not use the following								
seen	ANDO	92	SPEC	$8 \pi^- \rho \rightarrow \pi^+ \pi^-$	$-\pi^0 n$			

h₁(1170) REFERENCES

ANDO	92	PL B291 496	+lmai+ (KEK, KYOT, NIRS	, SAGA, INUS, AKIT)
ATKINSON	84	NP B231 15	+ (BONN	, CERN, GLAS, LA	NC, MCHS, CURIN+)
DANKOWY	81	PRL 46 580	Dankowych+	(TNTO, BNL,	CARL, MCGI, OHIO)
BOWLER	75	NP B97 227	+Game, Aitchison,	Dainton	(OXFTP, DARE)

$b_1(1235)$

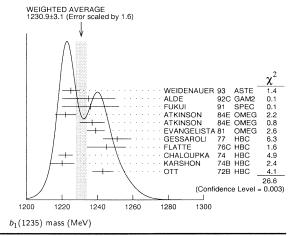
$b_1(1235)$

$I^{G}(J^{PC}) = 1^{+}(1^{+})$

b1(1235) MASS

VALUE	(MeV)	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
1231	±10	OUR ESTIMATE	This is only an educ			
						he published values.
1230.9)± 3.1	OUR AVERAGE	Error includes scale f	actor of 1.6	. See t	the ideogram below
1225	± 5		WEIDENAUER	93 ASTE		$\overline{p} p \rightarrow$
						$2\pi^{+}2\pi^{-}\pi^{0}$
1235	± 15		ALDE	92c GAM2		38,100 $\pi^- p \rightarrow$
						$\omega \pi^0 n$
1236	± 16		FUKUI	91 SPEC		8.95 $\pi^- p \rightarrow$
						$\omega \pi^0 n$
1222	± 6		ATKINSON	84E OMEG	±	25-55 $\gamma p \rightarrow$
						$\omega \pi X$
1237	± 7		ATKINSON	84E OMEG	0	$25-55 \gamma p \rightarrow$
			EVANCELICEA	0. 01456		$\omega \pi X$
1239	± 5		EVANGELISTA		-	12 $\pi^- p \rightarrow \omega \pi p$
1251	± 8	450	GESSAROLI	77 HBC	-	11 $\pi^- \rho \rightarrow$
						$\pi^- \omega p$
1245	± 11	890	FLATTE	76c HBC	_	$4.2 K^- p \rightarrow$
						$\pi^-\omega \Sigma^+$
1222	± 4	1400	CHALOUPKA	74 HBC		$3.9 \pi^{-} p$
1220	+ 7	600	KARSHON	74B HBC	+	4.9 π^{+} p
1243	± 6	1163	¹ OTT	72B HBC	+	7.1 π^{+} p
			ing data for averages,			
		not use the follow	-			
1311	± 10		² TAKAMATSU	90 SPEC	0	$8 \pi^- p \rightarrow \eta \rho n$
1190	± 10		AUGUSTIN	89 DM2	±	$e^+e^- \rightarrow 5\pi$
1213	± 5		ATKINSON	84c OMEG	0	20-70 γp
1271	± 11		COLLICK	84 SPEC	+	200 π ⁺ Z →
						Ζπω

 $^{^{1}}$ From fit of the mass spectrum. 2 Breit—Wigner fitting of PWA of $\eta\,\pi\,\pi$ system.



b₁(1235) WIDTH

		-				
VALUE (MeV) 142± 8 OUR AVERAGE	EVTS	DOCUMENT ID	6	TECN	CHG	COMMENT
	Error Inc					_
113±12		WEIDENAUER	93	ASTE		$\overline{\rho} \rho \rightarrow$
						$2\pi^{+}2\pi^{-}\pi^{0}$
160 ± 30		ALDE	92C	GAM2		38,100 $\pi^- \rho \rightarrow$
						$\omega \pi^0 n$
151 ± 31		FUKUI	91	SPEC		$8.95 \pi^- p \rightarrow$
						$\omega \pi^0 n$
170 ± 15		EVANGELISTA	81	OMEG	-	$12 \pi^- p \rightarrow \omega \pi p$
170±50	225	BALTAY	78B	HBC	+	$15 \pi^+ p \rightarrow p4\pi$
155 ± 32	450	GESSAROLI	77	HBC	_	11 $\pi^- p \rightarrow$
						$\pi^-\omega p$
182±45	890	FLATTE	76c	нвс	_	4.2 K ⁻ p →
101110	0.70					$\pi^-\omega \Sigma^+$
135 ± 20	1400	CHALOUPKA	74	нвс		$3.9 \pi^{-} p$
156 ± 22	600	KARSHON	74B	HBC	+	$4.9 \pi^{+} p$
+23	3	3 отт				+
134^{+23}_{-26}	1163	,011	728	HBC	+	7.1 $\pi^+ \rho$
• • • We do not use the	e following o	data for averages	, fits	, limits,	etc. •	• •
126±10	4	TAKAMATSU	90	SPEC	0	$8 \pi^- \rho \rightarrow \eta \rho n$
210±19		AUGUSTIN	89	DM2	±	$e^+e^- \rightarrow 5\pi$
231 ± 14		ATKINSON	84c	OMEG	0	20-70 γp
232±29		COLLICK	84	SPEC	+	200 π ⁺ Z →
202 2 2 7			•	0		$Z\pi\omega$
³ From fit of the mass	spectrum.					
⁴ Breit-Wigner fitting		$n\pi\pi$ system.				
Breit Wigher Methig	0, , ,,,, 0,	., oyoto				

b₁(1235) DECAY MODES

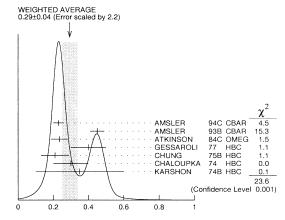
	Mode	Fraction (Γ	_i /୮)	Confidence level
Γ ₁	$\omega \pi$ [D/S amplitude ratio = 0.26 \pm 0.04]	dominar	nt	
Γ_2	$\pi^{\pm}\gamma$	(1.6±0	$(4) \times 10^{-3}$,
Γ_3	ηho	seen		
Γ_4	$\pi^{+} \pi^{+} \pi^{-} \pi^{0}$	< 50	%	84%
Γ_5	$(\kappa \overline{\kappa})^{\pm} \pi^{0}$	< 8	%	90%
Γ_6	$K_S^0 K_I^0 \pi^{\pm}$	< 6	%	90%
Γ_7	$K_{S}^{ar{0}}K_{S}^{ar{0}}\pi^{\pm}$	< 2	%	90%
Γ8	$\piar{\phi}$	< 1.5	%	84%

b1(1235) PARTIAL WIDTHS

$\Gamma(\pi^{\pm}\gamma)$						Γ2
VALUE (keV)	DOCUMENT ID		TECN	CHG	COMMENT	
230±60	COLLICK	84	SPEC	+	$200 \pi^+ Z \rightarrow$	

$b_1(1235)$ *D*-wave/*S*-wave AMPLITUDE RATIO IN DECAY OF $b_1(1235) ightarrow \omega \pi$

VALUE 0.29 ±0.04	OUR AVERAGE	DOCUMENT ID Error includes scale		CHG See	
0.23 ± 0.03		AMSLER	94c CBAR		$0.0 \ \overline{p} p \rightarrow \omega \eta \pi^0$
0.45 ± 0.04		AMSLER	93B CBAR		$0.0 \ \overline{p} \ p \rightarrow$
0.235±0.047		ATKINSON	84c OMEG		ωπ ⁰ π ⁰ 20-70 γ <i>p</i>
$0.4 \begin{array}{c} +0.1 \\ -0.1 \end{array}$		GESSAROLI	77 HBC	_	11 $\pi^- \rho \rightarrow$
0.1					$\pi^-\omega \rho$
0.21 ± 0.08		CHUNG	75B HBC	+	7.1 $\pi^{+} \rho$
0.3 ± 0.1		CHALOUPKA	74 HBC		$3.9-7.5 \pi^- p$
0.35 ± 0.25	600	KARSHON	74B HBC	+	4.9 $\pi^{+} \rho$



 $b_1(1235)~D$ -wave/S-wave amplitude ratio in decay of $b_1(1235)
ightarrow \ \omega \, \pi$

b1(1235) BRANCHING RATIOS

$\Gamma(\eta \rho)/\Gamma(\omega \pi)$		DOCUMENT ID		TECN	соми	1ENT	Γ_3/Γ_1
• • We do not use the	e following		s, fits				
seen <0.10		TAKAMATSU ATKINSON	90 84D	SPEC OMEG	20-70	γρ	
$\Gamma(\pi^+\pi^+\pi^-\pi^0)/\Gamma(\omega$	$\sigma\pi$						Γ_4/Γ_1
VALUE		DOCUMENT ID		TECN	CHG	COMMENT	
<0.5		ABOLINS	63	HBC	+	3.5 $\pi^{+} \rho$	
$\Gamma((K\overline{K})^{\pm}\pi^{0})/\Gamma(\omega\pi)$)						Γ ₅ /Γ ₁
VALUE	CL%	DOCUMENT ID		TECN	CHG	COMMENT	
<0.08	90	BALTAY	67	HBC	\pm	0.0 p p	
$\Gamma(K_S^0 K_L^0 \pi^\pm)/\Gamma(\omega \pi)$)						Γ ₆ /Γ ₁
VALUE	CL%	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT	
<0.06	90	BALTAY	67	HBC	±	0.0 \overline{p} p	
$\Gamma(K_S^0 K_S^0 \pi^\pm)/\Gamma(\omega \pi)$	•						Γ ₇ /Γ ₁
VALUE	CL%	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT	
<0.02	90	BALTAY	67	HBC	±	0.0 \overline{p} p	

ivieson	Particle	Listings
	$b_1(1235)$,	$a_1(1260)$

Γ(πφ)/Γ(α <u>VALUE</u>	υπ)	<u>CL%</u>	DOCUMENT ID		TECN	<u>CHG</u>		
<0.015 • • • We do	o not	use the following	DAHL data for average	67 s, fit	HBC s, limits	etc.	1.6-4.2 π	p
< 0.04		95	BIZZARRI	69	нвс	±	0.0 \overline{p} p	
		b 1	(1235) REFER	ENC	ES			
AMSLER AMSLER AMSLER WEIDENAUER ALDE TAKAMATSU AUGUSTIN ATKINSON COLLICK EVANGELISTA BALTAY GESSAROLI FLATTE CHUNG CHALOUPKA KARSHON OTT BIZZARRI BALTAY BALTAY BALTAY ABOLINS	92C 91 90 89 84C 84D 84E 84	PL B327 425 PL B311 362 ZPHY C59 387 ZPHY C54 553 PL B257 241 Hadron 89 Conf. p NP B320 1 NP B243 1 NP B243 1 NP B243 269 PL 138B 459 PL 138B 459 PL 138B 459 PL 158 2374 NP B176 197 NP B176 582 PR D17 62 PR D17 64 PR D17 64 PR D17 64 PR D17 64 PR D18 688 PR D18 14 169 PR D19 14 169 PR D19 14 169 PR D19 14 169 PR D18 18 137 PR L18 137 PR L18 137 PR L11 381	+Cosme + (BON + (BON	IN, CEIN, Monterge, Monterge, Monters, Yeirz,	(BELG, (SUGI, N ERN, GLA ERN, GLA ERN, GLA BARI, BO a+ NA, FIRZ, r+ ttanet , Pitluck, tanet+ 'éeh, Zanel liller	Cr SERP, I NAGO, H S, LANC S, LANC (MI NN, CEI GENO, CERN, A Ronat+	(CERN, CERN, CERN, CERN, COLUMN (COLUMN) (CERN, (CERN, MAST, NIJM, (CERN, (CERN, (CERN, MAST, NIJM, (CERN, (CERN, (CERN, MAST, NIJM, (CERN, (CER	Collab.) Collab.) Collab.) LAPP) MIYA) (KEK) Collab.) Collab.) FRIN+) FRIN+) FRIN+) BING) PAVI) PAVI) UCSC) JP CCERN) JP CCERN) JP (LBL) JP (LBL) JP

OTHER RELATED PAPERS

BRAU		PR D37 2379	+Franek+ (SLAC Hybrid Facility Photon Collab.) JP
ATKINSON	84C	NP B243 1	+ (BONN, CERN, GLAS, LANC, MCHS, CURIN+) JP
GOLDHABER	65	PRL 15 118	+Goldhaber, Kadyk, Shen (LRL)
CARMONY	64	PRL 12 254	+Lander, Rindfleisch, Xuong, Yager (UCB) JP
BONDAR	63B	PL 5 209	+Dodd+ (AACH, BĪRM, HAMB, LOIC, MPIM)

$$a_1(1260)$$

$$I^{G}(J^{PC}) = 1^{-}(1^{+})$$

THE $a_1(1260)$

The main experimental data on the $a_1(1260)$ may be grouped into two classes:

(1) Hadronic production: This comprises diffractive production with incident π^- (DAUM 80, 81B) and charge-exchange production with low-energy π^- (DANKOWYCH 81, ANDO 92). The 1980's experiments explain the $I^GLJ^P = 1^+S0^+$ data using a phenomenological amplitude consisting of a rescattered Deck amplitude plus a direct resonance-production term. They agree on an $a_1(1260)$ mass of about 1270 MeV and a width of 300-380 MeV. ANDO 92 finds rather lower values for the mass (1121 MeV) and width (239 MeV) in a partial-wave analysis based on the isobar model of the $\pi^+\pi^-\pi^0$ system. However, in this analysis, only Breit-Wigner terms were considered.

(2) τ decay: Five experiments have reported good data on $\tau \to a_1(1260)\nu_{\tau} \to \rho\pi\nu_{\tau}$ (RUCKSTUHL 86, SCHMIDKE 86, ALBRECHT 86B, BAND 87, and AKERS 95P). They are somewhat inconsistent concerning the $a_1(1260)$ mass, which can, however, be attributed to model-dependent systematic uncertainties (BOWLER 86, ALBRECHT 93C, AKERS 95P). They all find a width greater than 400 MeV.

The discrepancies between the early hadronic and τ decay results have stimulated several reanalyses. BOWLER 86, TORNQVIST 87, ISGUR 89, and IVANOV 91 have studied the process $\tau \to 3\pi\nu_{\tau}$. Despite quite different approaches, they all found a good overall description of the τ decay data with an $a_1(1260)$ mass near 1230 MeV, consistent with the hadronic data. However, their widths remain significantly higher (400-600 MeV) than those extracted from diffractive-hadronic data. This is also the case with the later OPAL experiment (AKERS 95P).

BOWLER 88 showed that good fits to both the hadronic and the τ -decay data could be obtained with a width of about 400 MeV. However, applying the same type of analysis to the ANDO 92 data, the low mass and narrow width they obtained with the Breit-Wigner PWA do not change appreciably.

CONDO 93 found no evidence for charge-exchange photoproduction of the $a_1(1260)$ (but found a clear signal of $a_2(1320)$ photoproduction). They show that this is consistent with either an extremely large $a_1(1260)$ hadronic width or with a small radiative width to $\pi\gamma$, which could be accommodated if the a_1 mass is somewhat below 1260 MeV.

a ₁ (1260) MASS						
VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT	
1230±40 OUR ESTIMATE						
• • We do not use the following	g data for average	es, fits	, limits,	etc.	• •	
$1266 \pm 14 + 12 \\ -2$	¹ AKERS	95P	OPAL		E ^{ee} _{cm} = 88-94	
$1202 \pm 9 + 9 \\ - 1$	² AKERS	95P	OPAL		E ^{ee} _{cm} = 88-94	
1211± 7	ALBRECHT	93 C	ARG		$\tau^+_{\pi^+\pi^+\pi^-\nu}$	
1121± 8	³ ANDO	92	SPEC		$8 \pi^- p \rightarrow$	
1242±37	4 IVANOV	91	RVUE		$ \begin{array}{ccc} \pi^{+}\pi^{-}\pi^{0}n\\ \tau \to \pi^{+}\pi^{+}\pi^{-}\nu \end{array} $	
1260 ± 14	⁵ IVANOV	91	RVUE		$\tau \rightarrow \pi^{+}\pi^{+}\pi^{-}\nu$	
1250 ± 9	⁶ IVANOV	91	RVUE		$\tau \rightarrow \pi^{+}\pi^{+}\pi^{-}\nu$	
1208 ± 15	ARMSTRONG	90	OMEG	0	$300.0pp \rightarrow$	
					$ \begin{array}{c} 300.0pp \rightarrow \\ pp\pi^{+}\pi^{-}\pi^{0} \\ \tau^{+} \rightarrow \end{array} $	
1220 ± 15	⁷ ISGUR	89	RVUE		$\tau^+_{\pi^+\pi^+\pi^-\nu}$	
1260±25	⁸ BOWLER	88	RVUE		π'π'π ν	
$1166 \pm 18 \pm 11$	BAND	87	MAC		$ au^+ o$	
$1164 \pm 41 \pm 23$	BAND	87	MAC		$ \begin{array}{c} \tau^{+} \xrightarrow{\pi^{+} \pi^{+} \pi^{+} \pi^{-} \nu} \\ \tau^{+} \xrightarrow{\pi^{+} \pi^{0} \pi^{0} \nu} \end{array} $	
1250±40	7 TORNOVIST	87	RVUE		π ' π ' π ' ν	
1046±11	ALBRECHT		ARG		$\tau^+ \rightarrow$	
					$ \begin{array}{c} \tau^+ \to \\ \pi^+ \pi^+ \pi^+ \pi^- \nu \end{array} $	
$1056 \pm 20 \pm 15$	RUCKSTUHL	86	DLCO		$\tau^{\top} \xrightarrow{\pi^{+}} \pi^{+} \pi^{-} \nu$	
$1194 \pm 14 \pm 10$	SCHMIDKE	86	MRK2		τ^{+}	
1240 ± 80	⁹ DANKOWY	81	SPEC	0	8.45 $\pi^- p \rightarrow$	
1280 ± 30	⁹ DAUM	81B	CNTR		$ \begin{array}{c} n3\pi \\ 63,94 \pi^{-} \rho \rightarrow \\ \rho3\pi \end{array} $	
1041 ± 13	¹⁰ GAVILLET	77	нвс	+	$4.2 \stackrel{p3\pi}{K^-} p \rightarrow$ $53-$	

- Uses the model of Kuhn and Santamaria
- ² Uses the model of Isgur, Morningstar, and Reader
- 3 Average and spread of values using 2 variants of the model of BOWLER 75.
- ⁴ Reanalysis of RUCKSTUHL 86. ⁵ Reanalysis of SCHMIDKE 86.
- ⁶ Reanalysis of ALBRECHT 86B
- ⁷ From a combined reanalysis of ALBRECHT 86B, SCHMIDKE 86, and RUCKSTUHL 86.
- ⁸ From a combined reanalysis of ALBRECHT 86B and DAUM 81B
- 9 Uses the model of BOWLER 75. 10 Produced in K^- backward scattering.

a₁(1260) WIDTH

VALUE (MeV)	DOCUMENT ID	TECN CH	G COMMENT
 ~ 400 OUR ESTIMATE • • • We do not use the follow 	wing data for average	s fits limits atc	
T T T THE GO HOT USE THE FORM	and data for average	3, 1113, 11111113, 010	
$610 \pm 49 ^{+53}_{-19}$	¹¹ AKERS	95P OPAL	E ^{ee} _{cm} = 88–94
$422 \pm 23 + 33 - 4$	¹² AKERS	95P OPAL	$E_{\rm cm}^{ee} = 88-94$
446± 21	ALBRECHT	93C ARG	$\tau^+_{\pi^+\pi^+\pi^-\nu}$
239± 11	ANDO	92 SPEC	$8 \pi^- p \rightarrow$
$266\pm~13\pm~4$	¹³ ANDO	92 SPEC	$ \begin{array}{c} \pi^{+}\pi^{-}\pi^{0}n\\ 8\pi^{-}\rho\rightarrow\\ \pi^{+}\pi^{-}\pi^{0}n \end{array} $
$465 + 228 \\ -143$	¹⁴ IVANOV	91 RVUE	$\tau \rightarrow \pi^+\pi^+\pi^-\nu$
298 ⁺ 40 - 34	¹⁵ IVANOV	91 RVUE	$r \rightarrow \pi^+\pi^+\pi^-\nu$
488± 32	¹⁶ IVANOV	91 RVUE	$ au ightarrow \pi^+ \pi^+ \pi^- u$
430± 50	ARMSTRONG	90 OMEG 0	$300.0pp \rightarrow$
420± 40	¹⁷ ISGUR	89 RVUE	$ \begin{array}{c} \rho \rho \pi^{+} \pi^{-} \pi^{0} \\ \tau^{+} \stackrel{\rightarrow}{\xrightarrow{\pi^{+}}} \pi^{+} \pi^{-} \nu \end{array} $

 $a_1(1260)$, $f_2(1270)$

396± 43 405± 75±25	¹⁸ BOWLER BAND	88 RVUE 87 MAC	$\tau^+ \rightarrow + -$
$419\pm 108\pm 57$	BAND	87 MAC	$\tau^{+} \xrightarrow{\pi^{+}\pi^{+}\pi^{-}\nu}$
521± 27	ALBRECHT	86B ARG	$ \begin{array}{ccccc} \tau^{+} & \xrightarrow{\pi^{+}} \pi^{+} \pi^{-} \nu \\ \tau^{+} & \xrightarrow{\pi^{+}} \pi^{0} \pi^{0} \nu \\ \tau^{+} & \xrightarrow{\pi^{+}} \pi^{+} \pi^{-} \nu \end{array} $
$476^{+132}_{-120}\pm54$	RUCKSTUHL	86 DLCO	τ ⁺ _ + _ +
462± 56±30	SCHMIDKE	86 MRK2	$ \begin{array}{c} \tau^{+} \xrightarrow{\pi^{+} \pi^{+} \pi^{+} \pi^{-} \nu} \\ \tau^{+} \xrightarrow{\pi^{+} \pi^{+} \pi^{-} \nu} \end{array} $
380 ± 100	¹⁹ DANKOWY	81 SPEC 0	$8.45 \pi^{-} p \rightarrow 0.3\pi$
300± 50	¹⁹ DAUM	81B CNTR	$63,94 \pi^- p \rightarrow p3\pi$
230± 50	²⁰ GAVILLET	77 HBC +	$4.2 \begin{array}{c} F3\pi \\ K^{-} p \rightarrow \\ \Sigma 3\pi \end{array}$
11 11 11 4.1 .6 12.15			2 3/1

- 11 Uses the model of Kuhn and Santamaria. 12 Uses the model of Isgur, Morningstar, and Reader. 13 Average and spread of values using 2 variants of the model of BOWLER 75.
- ¹⁴ Reanalysis of RUCKSTUHL 86.
- 15 Reanalysis of SCHMIDKE 86. 16 Reanalysis of ALBRECHT 86B.
- $^{17}{
 m From\ a\ combined\ reanalysis}$ of ALBRECHT 868, SCHMIDKE 86, and RUCKSTUHL 86.
- 18 From a combined reanalysis of ALBRECHT 86B and DAUM 81B.
- 19 Uses the model of BOWLER 75.
 20 Produced in K⁻ backward scattering.

a₁(1260) DECAY MODES

	Mode	Fraction (Γ_i/Γ)	
Γ1	$\rho\pi$	dominant	
Γ_2	$\pi \gamma$	seen	
Гз	$\pi(\pi\pi)_{S ext{-wave}}$ $K\overline{K}^*(892)$		
Γ_4	K ₹*(892)	possibly seen	

a₁(1260) PARTIAL WIDTHS

$\Gamma(\pi\gamma)$				Γ2
VALUE (keV)	DOCUMENT ID	TECN	COMMENT	
640±246	ZIELINSKI	84c SPEC	$200 \pi^+ Z \rightarrow Z3\pi$	

D-wave/S-wave AMPLITUDE RATIO IN DECAY OF $a_1(1260) \rightarrow \rho \pi$

VALUE	DOCUMENT ID	TECN	COMMENT
$-0.09 \pm 0.03 \pm 0.01$	²¹ AKERS	95P OPAL	E ^{ee} _{cm} = 88-94
²¹ Uses the model of Isgur, N	Morningstar, and Read	er.	

a₁(1260) BRANCHING RATIOS

$\Gamma(\pi(\pi\pi)_{s\text{-wave}})/\Gamma(\rho$	$\sigma\pi$)	Γ_3/Γ_1
VALUE	DOCUMENT ID TECN	
• • • We do not use the	following data for averages, fits, limits, etc. •	• •
0.003 ± 0.003	22 LONGACRE 82 RVIJE	

²² Uses multichannel Altchison-Bowler model (BOWLER 75). Uses data from GAVIL-LET 77, DAUM 80, and DANKOWYCH 81.

a₁(1260) REFERENCES

AKERS	95P	ZPHY C67 45	+Alexander, Allison, Ametewee+ (OPAL Collab.)
ALBRECHT	93C	ZPHY C58 61	+Ehrlichmann, Hamacher+ (ARGUS Collab.)
ANDO	92	PL B291 496	+Imai+ (KEK, KYOT, NIRS, SAGA, INUS, AKIT)
IVANOV	91	ZPHY C49 563	+Osipov, Volkov (JINR)
ARMSTRONG	90	ZPHY C48 213	+Benayoun, Beusch (WA76 Collab.)
ISGUR	89	PR D39 1357	+Morningstar, Reader (TNTO)
BOWLER	88	PL B209 99	(OXF)
BAND	87	PL B198 297	+Camporesi, Chadwick, Delfino+ (MAC Collab.)
TORNOVIST	87	ZPHY C36 695	(HELS)
ALBRECHT	86B	ZPHY C33 7	+Donker, Gabriel, Edwards+ (ARGUS Collab.)
RUCKSTUHL	86	PRL 56 2132	+Strovnowski, Atwood, Barish+ (DELCO Collab.)
SCHMIDKE	86	PRL 57 527	+Abrams, Matteuzzi, Amidei+ (Mark II Collab.)
ZIELINSKI	84 C	PRL 52 1195	+Berg, Chandlee, Cihangir+ (ROCH, MINN, FNAL)
LONGACRE	82	PR D26 83	(BNL)
DANKOWY	81	PRL 46 580	Dankowych+ (TNTO, BNL, CARL, MCGI, OHIO)
DAUM	81B	NP B182 269	+Hertzberger+ (AMST, CERN, CRAC, MPIM, OXF+)
DAUM	80	PL 89B 281	+Hertzberger+ (AMST, CERN, CRAC, MPIM, OXF+) JP
GAVILLET	77	PL 69B 119	+Blockzijl, Engelen+ (AMST, CERN, NIJM, OXF) JP
BOWLED.	75	NP R97 227	+Game, Aitchison, Dainton (OXFTP, DARE)

OTHER RELATED PAPERS

95	PAN 58 1535	+Vladimirskii, Erofeeva+	(ITEP)
95	PRL 74 4596	+De Grand	(COLO, FSU)
89	PR D39 3357	+Koibuchi, Masuda	(NAGO, ÎBAR, TSUK)
87	ZPHY C36 695		(HELS)
86	PL B182 400		(OXF)
64	Pl. 10 226	+ (AACH3, BERL, BIR	M, BONN, DESY, HAMB+)
64	PRL 12 336	+Brown, Kadyk, Shen+	(LRL, UCB)
64	PRL 13 346A	+Abolins, Carmony, Hendricks,	Xuong+ (UCSD) JP
63	NC 29 896	+Fiorini, Herz, Negri, Ratti	(MILA)
	95 89 87 86 64 64	Translated from YA PRL 74 4596 PR D39 3357 PHY C36 695 PL B182 400 PL 10 226 PRL 12 336 PRL 13 346A	Translated from YAF 58 1628. PRI. 74 4596 + De Grand PR D39 3357 + Koibuchi, Masuda 7 ZPHY C36 695 PI, B182 400 PI, B182 400 PRI. 12 336 + Brown, Kadyk, Shen+ +Abolins, Carmony, Hendricks,

 $f_2(12\overline{70})$

 $I^{G}(J^{PC}) = 0^{+}(2^{+})$

f2(1270) MASS

VALUE	(MeV)	EVTS		DOCUMENT ID		TECN	COMMENT
	± 5 OUR ES						
1274.8	B± 1.2 OUR AV	ERAGE					0.0
1272	± 8	200k		PROKOSHKIN			38 $\pi^- p \to \pi^0 \pi^0 n$
1269.7	7± 5.2	5730		AUGUSTIN	89	DM2	$e^+e^- \rightarrow 5\pi$
1283	± 8	400		ALDE	87	GAM4	
1274	± 5			AUGUSTIN	87	DM2	$J/\psi \rightarrow \gamma \pi^+ \pi^-$
1283	± 6		2	LONGACRE	86	MPS	$22 \pi^- \rho \rightarrow n2K_S^0$
1276	± 7			COURAU	84	DLCO	$e^+e^{e^+e^-\pi^+\pi^-}$
1273.3	3± 2.3		3	CHABAUD	83	ASPK	$e^+e^-\pi^+\pi^-$ 17 π^-p polarized
1280	+ 4			CASON	82	STRC	$8 \pi^+ \rho \rightarrow \Delta^{++} \pi^0 \pi^0$
1281	± 7	11600		GIDAL	81	MRK2	
1282	+ 5			CORDEN	79		$12-15 \pi^- p \rightarrow n2\pi$
1269	± 4	10k		APEL	75	NICE	$40 \pi^{-} p \rightarrow n2\pi^{0}$
1272	+ 4	4600		ENGLER	74	DBC	$6 \pi^+ n \rightarrow \pi^+ \pi^- p$
1277	± 4	5300		FLATTE	71	нвс	7.0 π^{+} p
1273	± 8		1	STUNTEBECK	70	нвс	$8 \pi^{-} p$, 5.4 $\pi^{+} d$
1265	± 8			BOESEBECK	68	нвс	8 π ⁺ p
	We do not use	the following	g da	ata for averages	, fits	, limits,	etc. • • •
1281	± 6			ADAMO	91	OBLX	$\overline{n} p \rightarrow \pi^+ \pi^+ \pi^-$
1262	±11			AGUILAR	91	EHS	400 pp
1275	±10			AKER	91	CBAR	$0.0 \overline{p} p \rightarrow 3\pi^0$
1220	±10			BREAKSTONE	90	SFM	$pp \rightarrow pp\pi^{+}\pi^{-}$
1288	±12			ABACHI	86B	HRS	$e^+e^- \rightarrow \pi^+\pi^-X$
1284	± 30	3k		BINON	83	GAM2	$38 \pi^- p \rightarrow n2\eta$
1280	± 20	3k		APEL	82	CNTR	$25 \pi^- p \rightarrow n 2\pi^0$
1284	± 10	16000		DEUTSCH	76	нвс	16 π ⁺ p
1258	± 10	600		TAKAHASHI	72	нвс	$8 \pi^- p \rightarrow n2\pi$
1275	±13			ARMENISE	70	HBC	$9 \pi^+ n \rightarrow p \pi^+ \pi^-$
1261	± 5	1960		ARMENISE	68	DBC	$5.1 \pi^+ n \rightarrow p \pi^+ MM^-$
1270	± 10	360	1	ARMENISE	68	DBC	$5.1 \pi^+ n \rightarrow p \pi^0 MM$
1268	± 6		6	JOHNSON	68	нвс	3.7-4.2 $\pi^- p$
1276	±11			RABIN	67	нвс	8.5 $\pi^{+}p$
			-/	(N), see the net		th tha 1/	*(902) mass

- 1 Mass errors enlarged by us to $\Gamma/\sqrt{N};$ see the note with the $K^*(892)$ mass.
- ¹ Mass errors enlarged by us to 1/ ν / ν ; see the note with the κ (σz_2) mass.
 ² From a partial-wave analysis of data using a K-matrix formalism with 5 poles.
 ³ From an energy-independent partial-wave analysis.
 ⁴ From an amplitude analysis of the reaction $\pi^+\pi^- \to 2\pi^0$.
 ⁵ From an amplitude analysis of $\pi^+\pi^- \to \pi^+\pi^-$ scattering data.
 ⁶ From an amplitude analysis of $\pi^+\pi^- \to \pi^+\pi^-$ scattering data.

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- 6 JOHNSON 68 includes BONDAR 63, LEE 64, DERADO 65, EISNER 67.

f2(1270) WIDTH

VALU	E (MeV)	EVTS		DOCUMENT ID		TECN	COMMENT
		OUR ESTIMATE					
185.4	4± 2.8 (OUR FIT Error i	include	es scale factor of	1.5.		
184.5	5 + 4.4 - 2.7	OUR AVERAGE	Error	includes scale fa	ctor	of 1.7.	See the ideogram below.
192	± 5	200k		PROKOSHKIN	94	GAM2	38 $\pi^- p \to \pi^0 \pi^0 n$
180	± 24			AGUILAR	91	EHS	400 pp
169	± 9	5730					$e^+e^- \rightarrow 5\pi$
150	± 30	400	7	ALDE	87	GAM4	$100 \pi^{-} p \rightarrow 4\pi^{0} n$
186	+ 9 - 2		8	LONGACRE	86	MPS	$22 \pi^- p \rightarrow n2K_S^0$
179.2	2 + 6.9 - 6.6		9	CHABAUD	83	ASPK	17 $\pi^- p$ polarized
160	± 11			DENNEY	83	LASS	10 π ⁺ N
196	± 10	. 3k			82		$25 \pi^- p \rightarrow n2\pi^0$
152	± 9		10	CASON	82	STRC	$8 \pi^{+} \rho \rightarrow \Delta^{++} \pi^{0} \pi^{0}$
186	± 27	11600			81	MRK2	J/ψ decay
216	± 13		11	CORDEN	79		$12-15 \pi^- p \rightarrow n2\pi$
190	± 10	10k		APEL	75		$40 \pi^- \rho \rightarrow n2\pi^0$
192	± 16	4600		ENGLER	74		$6 \pi^+ n \rightarrow \pi^+ \pi^- p$
183	± 15	5300		FLATTE	71	нвс	$7 \pi^+ \rho \rightarrow \Delta^{++} f_2$
196	± 30		7	STUNTEBECK			$8 \pi^- p$, 5.4 $\pi^+ d$
216	± 20	1960			68	DBC	$5.1 \pi^+ n \rightarrow p \pi^+ MM^-$
128	± 27			BOESEBECK	68	HBC	8 π ⁺ ρ
176	± 21		7,12	JOHNSON	68	HBC	3.7-4.2 π ⁻ ρ
• •	 We do 	not use the follow	wing d	ata for averages	, fits	, limits,	etc. • • •
206	±19			ADAMO	91	OBLX	$\overline{n}\rho \rightarrow \pi^{+}\pi^{+}\pi^{-}$
200	±10			AKER	91	CBAR	$0.0 \overline{p} p \rightarrow 3\pi^0$
240	±40	3k		BINON	83	GAM2	$38 \pi^- p \rightarrow n2\eta$
187	±30	650	7	ANTIPOV	77	CIBS	$25 \pi^- p \rightarrow p3\pi$
225	± 38	16000		DEUTSCH	76	HBC	16 π ⁺ ρ
166	± 28	600	7	TAKAHASHI	72	HBC	$8 \pi^- p \rightarrow n2\pi$
173	± 53		7	ARMENISE	70	HBC	$9 \pi^+ n \rightarrow p \pi^+ \pi^-$
155	± 17			RABIN	67	HBC	8.5 $\pi^+ p$

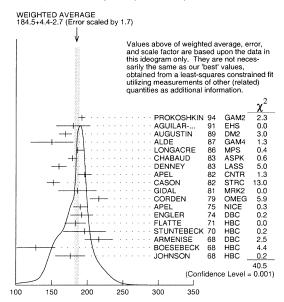
 $^{^7 \}text{Width errors enlarged by us to } 4\Gamma/\sqrt{\textit{N}};$ see the note with the $\textit{K}^*(892)$ mass.

 8 From a partial-wave analysis of data using a K-matrix formalism with 5 poles.

⁹ From an energy-independent partial-wave analysis.

10 From an amplitude analysis of the reaction $\pi^+\pi^- \to 2\pi^0$. 11 From an amplitude analysis of $\pi^+\pi^- \to \pi^+\pi^-$ scattering data.

12 JOHNSON 68 includes BONDAR 63, LEE 64, DERADO 65, EISNER 67.



 $f_2(1270)$ width (MeV)

fэl	(1270)) DECAY	MODES

	Mode	Fraction $(\Gamma_{\vec{i}}/\Gamma)$	Scale factor/ Confidence level
Γ ₁	ππ	(84.7 +2.6) %	S=1.3
Γ_2	$\pi^{+}\pi^{-}2\pi^{0}$	$(7.2 \begin{array}{c} +1.4 \\ -2.9 \end{array}) \%$	S=1.3
Γ_3	Κ \overline{K}	(4.6 ±0.5) %	S=2.8
Γ4	$2\pi^{+}2\pi^{-}$	(2.8 \pm 0.4) %	S=1.2
Γ_5	$\eta\eta_{_}$	(4.5 ± 1.0) \times 10^{-1}	-3 S=2.4
Γ_6	$4\pi^{0}$	$(3.0 \pm 1.0) \times 10^{-3}$	-3
Γ_7	$\gamma \gamma$	$(1.32^{+0.18}_{-0.16}) \times 10^{-1}$	-5
Γ8	$\eta \pi \pi$	< 8 × 10	-3 CL=95%
Γ9	$K^{0}K^{-}\pi^{+}$ + c.c.	< 3.4 × 10	
Γ_{10}	e^+e^-	< 9 × 10	-9 CL=90%

CONSTRAINED FIT INFORMATION

An overall fit to the total width, 4 partial widths, a combination of partial widths obtained from integrated cross sections, and 6 branching ratios uses 38 measurements and one constraint to determine 8 parameters. The overall fit has a $\chi^2 = 69.8$ for 31 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\langle \delta p_i \delta p_j \rangle / (\delta p_i \cdot \delta p_j)$, in percent, from the fit to parameters p_i , including the branching fractions, $x_i \equiv \Gamma_i/\Gamma_{\rm total}$. The fit constrains the x_i whose labels appear in this array to sum to one.

	Mode	Rate (Me	V)	Scale factor	
Γ1	ππ	156.9	$+3.7 \\ -1.3$		
Γ_2	$\pi^{+}\pi^{-}2\pi^{0}$	13.3	$^{+ 2.8}_{- 5.4}$	1.3	
Γ_3	$\kappa \overline{\kappa}$	8.6	± 0.8	2.9	
Γ_4	$2\pi^{+}2\pi^{-}$	5.2	± 0.7	1.2	
Γ_5	$\eta \eta$	0.83	± 0.18	2.4	
Γ ₅ Γ ₆	$4\pi^{0}$	0.55	±0.19		
Γ ₇	$\gamma \gamma$	0.00244	$1^{+0.00032}_{-0.00029}$		

f2(1270) PARTIAL WIDTHS

$\Gamma(\pi\pi)$		Γ_1
VALUE (MeV)	DOCUMENT ID TECN COMMENT	
156.9 ^{+3.7} _{-1.3} OUR FIT 157.0 ^{+6.0} _{-1.0}	13 LONGACRE 86 MPS 22 $\pi^- p ightarrow n2K^0$) S
$\Gamma(K\overline{K})$		Гз
VALUE (MeV)	DOCUMENT ID TECN COMMENT	
8.6 ±0.8 OUR FIT	Error includes scale factor of 2.9.	
9.0 +0.7	¹³ LONGACRE 86 MPS 22 $\pi^- p \rightarrow n2K^0$	S
$\Gamma(\eta \eta)$		Γ ₅
VALUE (MeV)	DOCUMENT ID TECN COMMENT	
0.83 ± 0.18 OUR FIT	Error includes scale factor of 2.4.	
1.0 ±0.1	¹³ LONGACRE 86 MPS 22 $\pi^- p \rightarrow n2K$	s S

 $\Gamma(\gamma\gamma)$ Γ_7 The value of this width depends on the theoretical model used. Unitarised models with scalars give values clustering around \simeq 2.6; without an S-wave contribution, values are systematically higher (typically around 3). Since it is used to average results obtained with variety of models, we prefer to quote our own estimate.

TECN COMMENT VALUE (keV) EVT 2.8 ±0.4 OUR ESTIMATE DOCUMENT ID $2.44^{+0.32}_{-0.29}$ OUR FIT 92 CELL $e^+e^-_{e^+e^-}$ $2.58\pm0.13^{+0.36}_{-0.27}$ ¹⁴ BEHREND \bullet $\,\bullet\,$ We do not use the following data for averages, fits, limits, etc. $\,\bullet\,$ ¹⁵ BLINOV 92 MD1 e⁺e⁻ $3.10 \pm 0.35 \pm 0.35$ $2.27 \pm 0.47 \pm 0.11$ ADACHI 90D TOPZ $\,e^+$ 90 MRK2 e^{+} $3.15 \pm 0.04 \pm 0.39$ BOYER $3.19 \pm 0.16 \, {}^{+\, 0.29}_{-\, 0.28}$ MARSISKE 90 RVUE $\gamma\gamma \rightarrow \pi^+\pi^-$, $\pi^0\pi^0$ 2.35 ± 0.65 $^{16}\,\mathrm{MORGAN}$ $3.19 \pm 0.09 ^{+0.22}_{-0.38}$ OEST 90 JADE $e^+e^- \rightarrow e^+e^-\pi^0\pi^0$ 868 TPC $e^{+}e^{-} \rightarrow e^{+}e^{-} + \pi^{-}$ 848 CELL $e^{+}e^{-} \rightarrow e^{+}\pi^{-}$ $e^{+}e^{-}\pi^{+}\pi^{-}$ 84 PLUT $e^{+}e^{-} \rightarrow e^{+}e^{-}2\pi$ $3.2 \pm 0.1 \pm 0.4$ ¹⁷ AIHARA 2.5 ±0.1 ±0.5 BEHREND $2.85 \pm 0.25 \pm 0.5$ ¹⁸ BERGER

$f_2(1270)$

$2.70 \pm 0.05 \pm 0.20$	COURAU	84 DLCO	e ⁺ e ⁻ →		$\Gamma(2\pi^+2\pi^-)$	⁻)/r(·	•		
$2.52 \pm 0.13 \pm 0.38$	¹⁹ SМІТН	84c MRK2	$e^+e^\perp \xrightarrow{\sigma}$	π	VALUE 0.033±0.00	5 OUR	FIT Error in	DOCUMENT ncludes scale fac	
2.3 ±0.2 ±0.5	FRAZER	83 JADE	$e^+e^+\stackrel{e^-e^-}{\to}$	π	0.033 ± 0.00	4 OUR	AVERAGE	Error includes se	cale factor of 1
2.7 ±0.2 ±0.6	EDWARDS	82F CBAL	$e^+e^-e^-\pi^-$	$^{\pi^{-}}_{e^{-}2\pi^{0}}$	0.024 ± 0.00 0.051 ± 0.02		160 70	EMMS EISENBER	75D DBC G 74 HBC
$2.9 \begin{array}{c} +0.6 \\ -0.4 \end{array} \pm 0.6$	²⁰ EDWARDS	82F CBAL	$e^+e^- ightarrow e^-$	$+e^{-2\pi^{0}}$	0.043 + 0.00		285	LOUIE	74 HBC
3.2 ±0.2 ±0.6	BRANDELIK	81B TASS	$e^+e^\perp \rightarrow$	_	0.037 ± 0.00		154	ANDERSO	
3.6 ±0.3 ±0.5	ROUSSARIE	81 MRK2	$e^+e^ \xrightarrow{e^-} \pi^+$	π	0.047 ± 0.01			ОН	70 HBC
2.3 ±0.8	²¹ BERGER	80B PLUT	$e^{+}e^{-}e^{-\pi}$	π	$\Gamma(\eta\eta)/\Gamma_{\rm to}$	otal			
Γ(e ⁺ e ⁻)				Γ ₁₀	VALUE (units			DOCUMENT	
` '	CL% DOCUMENT ID	TECN	COMMENT	. 10				es scale factor of includes scale f	
	90 VOROBYEV	88 ND	$e^+e^- \rightarrow \pi^0$		2.8±0.7	,,,,,,,,	INTO	ALDE	86D GAM
13 From a partial-wave a	nalysis of data using a K-	matrix forma	lism with 5 pole	es.	5.2 ± 1.7			BINON	83 GAM
¹⁴ Using a unitarized mo ¹⁵ Using the unitarized n					$\Gamma(\eta\eta)/\Gamma($	$\pi\pi$)			
	of different solutions. Dat irs report strong correlation				VALUE	<u> </u>	CL%	DOCUMENT	
$1/4 \Gamma(f^0) = 3.6 \pm 0.$		nis with yy v	vidtii oi 10(1370). ((2) +		lo not ι		ng data for aver	_
17 Radiative corrections	modify the partial width	ns; for instan	ce the COURA	U 84 value	<0.05 <0.016		95 95	EDWARDS EMMS	82F CBA 75D DBC
¹⁸ Using the MENNESSI	in the calculation of LAN ER 83 model.	DKO 86.			< 0.09		95	EISENBER	
¹⁹ Superseded by BOYER ²⁰ If helicity = 2 assump	R 90.				$\Gamma(4\pi^0)/\Gamma$	total			
	of tion is not made. d B($f_2(1270) o 2\pi$) from	n PDG 78.			VALUE		EVTS	DOCUMENT	ID TECN
					0.0030±0.0 0.003 ±0.0		JR FIT 400±	ALDE	87 GAM
	$f_2(1270) \Gamma(i)\Gamma(\gamma\gamma)$)/Γ(total)			0.003 ±0.0	01	50	ALDL	07 GAIV
$\Gamma(K\overline{K}) \times \Gamma(\gamma\gamma)/\Gamma_{to}$	otal			$\Gamma_3\Gamma_7/\Gamma$	$\Gamma(\eta\pi\pi)/\Gamma$	$(\pi\pi)$			
VALUE (keV)	DOCUMENT ID		COMMENT		VALUE		CL%	DOCUMENT	
0.113 ^{+0.016} OUR FIT	Error includes scale facto	r of 1.1.			<0.010		95	EMMS	75D DBC
$0.091 \pm 0.007 \pm 0.027$	²² ALBRECHT	90G ARG	$e^+e^- \rightarrow$	- v-	Γ(Κ⁰ Κ ⁻	r ⁺ + c	.c.)/Γ(ππ)		
0.031 ± 0.001 ± 0.021							CL%	DOCUMENT	ID TECN
• • We do not use the	following data for averag	es, fits, limits	$e^+e^-K^+$ s, etc. • • •	^	VALUE				
• • • We do not use the	following data for averag ²³ ALBRECHT	es, fits, limits 90G ARG	$e^+e^- \rightarrow$		<0.004		95	EMMS	75D DBC
• • • We do not use the $0.104 \pm 0.007 \pm 0.072$	23 ALBRECHT ackground.		s, etc. • • •				95		
\bullet \bullet We do not use the $0.104 \pm 0.007 \pm 0.072$	23 ALBRECHT ackground.		$e^+e^- \rightarrow$			94 S	95 f	EMMS (1270) REFE	
• • • We do not use the $0.104 \pm 0.007 \pm 0.072$	23 ALBRECHT wackground.	90G ARG	$e^+e^- \xrightarrow{e^+e^- K^+}$		PROKOSHKIN	92 7	95 PD 39 420 ranslated from E PHY C56 381	EMMS 2(1270) REFE +Kondashov 2000 ANS 336 613.	ERENCES
• • • We do not use the $0.104 \pm 0.007 \pm 0.072$ 22 Using an incoherent b 23 Using a coherent back	23 ALBRECHT ackground.	90G ARG	$e^+e^- \xrightarrow{e^+e^- K^+}$	κ-	PROKOSHKIN BEHREND BLINOV ADAMO	92 Z 92 Z 91 H	95 PD 39 420 ranslated from E PHY C56 381 PHY C53 33 ladron 91 Conf.	EMMS EMMS Factorial Empty State Factorial	ERENCES
• • • We do not use the $0.104 \pm 0.007 \pm 0.072$ 22 Using an incoherent b 23 Using a coherent back	23 ALBRECHT rackground.	90G ARG	$e^+e^- \xrightarrow{e^+e^- K^+}$		PROKOSHKIN BEHREND BLINOV ADAMO AGUILAR AKER	92 Z 92 Z 91 H 91 Z 91 F	95 PD 39 420 ranslated from E PHY C53 381 PHY C53 33 ladron 91 Conf. PHY C50 405 L B260 249	EMMS +Kondashov ANS 336 613. +Bondar, Bi +Agnello, Bi Aguilar-Ber +Amsler, Pe	Ikin+ alestra+ itez, Allison, Bat
• • • We do not use the $0.104 \pm 0.007 \pm 0.072$ 22 Using an incoherent b 23 Using a coherent back $\Gamma(\pi\pi)/\Gamma_{\text{total}}$ WALUE	23 ALBRECHT background. sground. f ₂ (1270) BRANCHIN EVTS DOCUMENT ID	90G ARG NG RATIOS	$e^+e^- \xrightarrow{e^+e^- K^+}$	κ-	PROKOSHKIN BEHREND BLINOV ADAMO AGUILAR AKER ADACHI ALBRECHT	92 Z 92 Z 91 H 91 Z 91 F 90D F 90G Z	95 PD 39 420 ranslated from E PHY C53 381 ladron 91 Conf. PHY C58 405 L B206 249 L B234 185 PHY C48 183	EMMS +Kondashov ANS 336 613. +Bondar, Bi +Agnello, Bi Aguilar-Ber +Amsler, Pe +Doser+ +Ehrlichman	Ikin+ elestra+ elestra, Allison, Bat ters+
• • • We do not use the 0.104 \pm 0.007 \pm 0.072 22 Using an incoherent b 23 Using a coherent back $\Gamma(\pi\pi)/\Gamma_{\text{total}}$ VALUE 0.847 \pm 0.026 OUR FIT	23 ALBRECHT ackground. f2(1270) BRANCHIN EVTS DOCUMENT ID Error includes scale facto	90G ARG NG RATIOS	$e^+e^- \xrightarrow{e^+e^- K^+}$	κ-	PROKOSHKIN BEHREND BLINOV ADAMO AGUILAR AKER ADACHI ALBRECHT BOYER BREAKSTONI	92 Z 92 Z 91 H 91 Z 91 F 90D F 90G Z 90 F	95 PD 39 420 ranslated from E PHY C56 381 Jadron 91 Conf. PHY C50 405 L B200 249 L B234 185 PHY C48 183 R D42 1350	EMMS	ikin+ alestra+ itiez, Allison, Bat ters+ n, Harder+ (ISU, BGNA, C
• • • We do not use the $0.104 \pm 0.007 \pm 0.072$ 22 Using an incoherent b 23 Using a coherent back $\Gamma(\pi\pi)/\Gamma_{\text{total}}$ VALUE 0.847 ± 0.026 OUR FIT 0.837 ± 0.020 OUR AVER 0.849 ± 0.025	23 ALBRECHT background. f2(1270) BRANCHIN EVTS DOCUMENT ID Error includes scale facto AGE CHABAUD	90G ARG NG RATIOS TECN r of 1.3. 83 ASPK	is, etc. $\bullet \bullet \bullet$ $e^+e^- _{K^+}$ $e^+e^- K^+$ COMMENT 17 $\pi^- p$ pola	Γ ₁ /Γ	PROKOSHKIN BEHREND BLINOV ADAMO AGUILAR AKER ADACH ALBRECHT BOYER BREAKSTONI MARSISKE MORGAN	92 Z 92 Z 91 H 91 Z 91 F 90D F 90G Z 90 F 90 F 90 F	95 PD 39 420 ranslated from E PHY C56 381 Jadron 91 Conf. PHY C80 249 L 8234 185 PHY C48 183 R D42 1350 PHY C48 569 R D41 3324 PHY C48 659 R D41 3324 PHY C48 6623	+Kondashov DANS 336 613. +Bondar, Bi +Agnello, Bi Aguilar-Ber +Amsier +Dhriichman +Butler+ + +Antreasyan +Pennington	ikin+ llestra+ itez, Allison, Bat ters+ n, Harder+ (ISU, BGNA, C+
• • • We do not use the $0.104 \pm 0.007 \pm 0.072$ 22 Using an incoherent b 23 Using a coherent back $\Gamma(\pi\pi)/\Gamma_{\text{total}}$ VALUE 0.847 ± 0.026 OUR FIT 0.837 ± 0.025 OUR AVER 0.849 ± 0.025 0.85 ± 0.05	23 ALBRECHT ackground. f2(1270) BRANCHIN EVTS DOCUMENT ID Error includes scale facto AGE CHABAUD 250 BEAUPRE	90G ARG NG RATIOS TECN r of 1.3. 83 ASPK 71 HBC	i, etc. $\bullet \bullet \bullet$ $e^+e^- \rightarrow e^+e^- K^+$ 0 0 0 0 0 0 0 0 0 0	Γ ₁ /Γ	PROKOSHKIN BEHREND BLINOV ADAMO AGUILAR AKER ADACHI ALBRECHT BOYER BREAKSTONI MARSISKE MORGAN OEST AUGUSTIN	92 Z 92 Z 91 H 91 Z 91 F 90 Z 90 F 90 Z 90 F 90 Z 90 F 90 Z 90 S	PD 39 420 ranslated from IC PHY C53 33 ladron 91 Conf. PHY C50 405 I. B262 49 I. B234 185 PHY C48 183 rR D42 1350 PHY C48 569 rR D41 3324 PHY C48 623 PHY C47 343 PHY C47 343 PHY C47 343 PHY C47 343 PHS B320 I	+Kondashov DANS 336 613. +Bondar, Bi +Agnello, Bi Aguilar-Ber +Amsier, Pethichman +Butler+ + +Antreasyan -Pennington -Olsson+ -Cosme	ikin+ elestra+ itez, Allison, Bat ters+ n, Harder+ (ISU, BGNA, C
• • • We do not use the $0.104 \pm 0.007 \pm 0.072$ 22 Using an incoherent b 23 Using a coherent back $\Gamma(\pi\pi)/\Gamma_{\text{total}}$ $\frac{VALUE}{-0.025}$ 0.847 ± 0.026 OUR FIT 0.837 ± 0.020 OUR AVER 0.849 ± 0.025 0.85 ± 0.05 0.8 ± 0.04	23 ALBRECHT background. f2(1270) BRANCHIN EVTS DOCUMENT ID Error includes scale facto AGE CHABAUD	90G ARG NG RATIOS TECN r of 1.3. 83 ASPK 71 HBC	is, etc. $\bullet \bullet \bullet$ $e^+e^- _{K^+}$ $e^+e^- K^+$ COMMENT 17 $\pi^- p$ pola	Γ_1/Γ rized $++f_2$ $\pi^+\pi^ n$	PROKOSHKIN BEHREND BLINOV ADAMO AGUILAR AKER ADACHI ALBRECHT BOYER BREAKSTONI MARSISKE MORGAN OEST AUGUSTIN VOROBYEV	92 Z Z Z Z Z Z Z Z Z Z Z Z Z Z Z Z Z Z Z	PD 39 420 ranslated from IPHY C53 33 ladron 91 Conf. PHY C54 0351 PHY C54 054 L B234 185 PHY C48 183 rR D42 1350 PHY C48 569 rR D41 3324 PHY C47 343 PHY C47 343 P	**EMMS **Lond REFE **Kondashov DANS 336 613.** **Bondar, Bi **Agnello, Bi **Agnila-Ber **Amsier, Pe **Lond Poser+ **Lond Poser+ **Henrichman **Butler+ **Henrichman **Pennington **Olsson+ **Cosme **Lolubev, D **GAF 48 436.**	ikin + elestra +
• • • We do not use the $0.104 \pm 0.007 \pm 0.072$ ²² Using an incoherent be 23 Using a coherent back $\Gamma(\pi\pi)/\Gamma_{\text{total}}$ VALUE 0.847 $^+$ 0.026 OUR FIT 0.837 $^+$ 0.020 OUR AVER 0.849 $^+$ 0.05 0.8 $^+$ 0.04 $\Gamma(\pi^+\pi^-2\pi^0)/\Gamma(\pi\pi)$	23 ALBRECHT Dackground. F2(1270) BRANCHIN EVTS DOCUMENT ID Error includes scale facto AGE CHABAUD 250 BEAUPRE 600 OH	90G ARG NG RATIOS TECN r of 1.3. 83 ASPK 71 HBC 70 HBC	is, etc. $\bullet \bullet \bullet$ $e^+e^- \longrightarrow e^+e^- K^+$ $e^+e^- K^+$ $17 \pi^- p \text{ pola}$ $8 \pi^+ p \longrightarrow \mathcal{L}$ $1.26 \pi^- p \longrightarrow$	Γ ₁ /Γ	PROKOSHKIM BEHREND BLINOV ADAMO AGUILAR AKER ADACHI ALBRECHT BOYER BREAKSTONI MARSISKE MORGAN OEST AUGUSTIN VOROBYEV ALDE AUGUSTIN	92 Z Z Z Z Z Z Z Z Z Z Z Z Z Z Z Z Z Z Z	PD 39 420 ranslated from IC PHY CS3 33 ladron 91 Conf. PHY CS0 405 I. B234 185 PHY C84 183 rR D42 1350 PHY C48 569 rR D41 3324 PHY C47 343 PHY C47 343	+Kondashov DANS 336 613. +Bondar, Bi +Agnello, Bi Aguilar-Ber +Amsier, Pe +Doser+ +Ehrlichman +Butler+ + +Antreasyan -Pennington -Olsson+ -Cosme -Golubev, E +Binon, Brid +Cosme	ikin + elestra + elestra + etres + n, Harder + (ISU, BGNA, C) + toolinsky, Druzhininman +
• • • We do not use the 0.104 \pm 0.007 \pm 0.072 22 Using an incoherent b 23 Using a coherent back $\frac{\Gamma(\pi\pi)/\Gamma_{\text{total}}}{V^{AUE}}$ 0.847 \pm 0.026 OUR FIT 0.837 \pm 0.020 OUR AVER 0.849 \pm 0.025 0.8 \pm 0.05 0.8 \pm 0.04 $\Gamma(\pi^{+}\pi^{-}2\pi^{0})/\Gamma(\pi\pi)$ Should be twice $\Gamma(2\pi^{-}2\pi^{-}1)$	23 ALBRECHT ackground. $f_2(1270)$ BRANCHIN EVTS DOCUMENT ID Error includes scale facto AGE 250 BEAUPRE $_{600}$ OH 2 $^{+}$ 2 $^{-}$ $)/\Gamma(\pi\pi)$ if deca	90G ARG NG RATIOS TECN r of 1.3. 83 ASPK 71 HBC 70 HBC y is ρρ. (See	is, etc. $\bullet \bullet \bullet$ $e^+e^- \rightarrow e^+e^- K^+$ $\frac{COMMENT}{17 \pi^- p \text{ pola}}$ $8 \pi^+ p \rightarrow 2$ $1.26 \pi^- p \rightarrow ASCOLI 680.)$	Γ_1/Γ rized $++f_2$ $\pi^+\pi^ n$	PROKOSHKIN BEHREND BLINOV ADAMO AGUILAR AKER ADACHI ALBRECHT BOYER BREAKSTONI MARSISKE MORGAN OEST AUGUSTIN VOROBYEV ALDE AUGUSTIN ABACHI AIHARA	92 2 2 9 1	PD 39 420 ranslated from IC PHY C53 33 ladron 91 Conf. PHY C50 405 I. B234 185 PHY C68 183 R. D42 1350 PHY C48 569 R. D41 3324 PHY C47 343 PHY C47 344 PHY C47 344	+Kondashov DANS 336 613. +Bondar, Bi +Agnello, Bi Aguilar-Ber +Amsier, Pethichman +Butler+ + +Antreasyan +Pennington +Olsson+ +Cosme +Golubev, Casme +Golubev, Casme +Cosme +Come +Cosme +Cosm	ikin + lestra + lestra + leters + n, Harder + (ISU, BGNA, C) + tolinsky, Druzhinin man + plotter + (P
• • • We do not use the 0.104 \pm 0.007 \pm 0.072 22 Using an incoherent be 23 Using a coherent back $\Gamma(\pi\pi)/\Gamma$ total VALUE 0.847 \pm 0.026 OUR FIT 0.837 \pm 0.020 OUR AVER. 0.849 \pm 0.05 0.8 \pm 0.05 0.8 \pm 0.04 $\Gamma(\pi^+\pi^-2\pi^0)/\Gamma(\pi\pi)$ Should be twice $\Gamma(2)$ VALUE	23 ALBRECHT ackground. ground. $f_2(1270)$ BRANCHINEVTS DOCUMENT ID Error includes scale factors age CHABAUD BEAUPRE 600 OH $^{2\pi^+2\pi^-)/\Gamma(\pi\pi)}$ if decaptors DOCUMENT ID	90G ARG NG RATIOS r of 1.3. 83 ASPK 71 HBC 70 HBC y is ρρ. (See	is, etc. $\bullet \bullet \bullet$ $e^+e^- \rightarrow e^+e^- K^+$ $\frac{COMMENT}{17 \pi^- p \text{ pola}}$ $8 \pi^+ p \rightarrow 2$ $1.26 \pi^- p \rightarrow ASCOLI 680.)$	Γ_1/Γ rized $++f_2$ $\pi^+\pi^ n$	PROKOSHKIN BEHREND BLINOV ADAMO AGUILAR AKER ADACHI ALBRECHT BOYER BREAKSTONI MARSISKE MORGAN OEST AUGUSTIN VOROBYEV ALDE AUGUSTIN BASCHI	92 2 2 9 9 9 9 9 9 9 9 9 9 8 8 8 9 8 8 8 8	95 PD 39 420 ranslated from E PHY CS6 381 PHY CS6 381 ladron 91 Conf. PHY CS0 249 L B260 249 L B260 249 L B260 249 L B231 185 PHY C48 183 R D42 1350 PHY C48 569 PHY C48 569 PHY C47 343 PB 3320 1 JNP 48 273 ranslated from 1 L B198 286 PHY (23 63 69) PHY C36 369 PHY C37 363 59	EMMS 2(1270) REFE 4 Kondashov ANS 336 613. + Bondar, Bi + Agnello, Bi Aguilar-Ber + Amsler, Pe + Doser+ + Ehrlichman + Butler+ + Antreasyan + Pennington - Cosme - Golubev, C AF 48 436. + Biono, Brid + Cosme+ - Derrick, Bi	ikin + plestra +
• • • We do not use the $0.104 \pm 0.007 \pm 0.072$ 22 Using an incoherent be 23 Using a coherent back $\Gamma(\pi\pi)/\Gamma_{\text{total}}$ VALUE 0.847 $^+$ 0.026 OUR FIT 0.837 $^+$ 0.025 0.85 $^+$ 0.05 0.8 $^+$ 0.05 Should be twice $\Gamma(X_{\text{total}})$ VALUE 0.085 $^+$ 0.018 OUR FIT	23 ALBRECHT ackground. $f_2(1270)$ BRANCHIN EVTS DOCUMENT ID Error includes scale facto AGE 250 BEAUPRE 600 OH $^{2\pi^+2\pi^-)/\Gamma(\pi\pi)$ if deca EVTS DOCUMENT ID Error includes scale facto	90G ARG NG RATIOS TECN r of 1.3. 83 ASPK 71 HBC 70 HBC y is ρρ. (See TECN r of 1.3.	is, etc. $\bullet \bullet \bullet$ $e^+e^- \rightarrow e^+e^- K^+$ $\frac{COMMENT}{17 \pi^- p \text{ pola}} 8 \pi^+ p \rightarrow 2$ $1.26 \pi^- p \rightarrow 2$ ASCOLI 68D.)	Γ_1/Γ rized $t^{++}f_2$ $t^{-}\pi^+\pi^-n$ $t^{-}\pi^-$	PROKOSHKIN BEHREND BLINOV ADAMO AGUILAR AKER ADACHI ALBRECHT BOYER BREAKSTONI MARSISKE MORGAN OEST AUGUSTIN VOROBYEV ALDE AUGUSTIN ABACHI AIHARA ALDE LANDRO	92 2 2 9 9 9 9 9 9 9 9 9 9 8 9 8 8 8 8 8	PD 39 420 ranslated from IC PHY C53 331 PHY C53 331 Addron 91 Conf. PHY C54 055 IL B260 249 IL B234 185 PHY C48 183 R D42 1350 PHY C48 569 R D41 3324 PHY C47 343 PHY C47 343 PHY C47 366 Tanslated from IL B18 286 PHY C48 623 PHY C47 344 PB 3206 186 PHY C47 343 PHY C47 344 PB 266 485 IL ST 1990 PHY C36 369 PRL ST 1990 PHY C36 369 PRL ST 1990 PHY C36 369 PRL ST 1990 PHY C36 369 PRL ST 1990 PHY C36 369 PHY C37 344 PB 266 485 IL B172 445	+ Kondashov DANS 356 613. + Bondar, Bi + Agnello, Bi - Aguilar-Ber + Amsier, + Ehrlichman + Butler+ + Antreasyan + Pennington + Olsson+ + Cosme + Golubev, Casme + Derrick, Bi - Alston, Bid + Alston, Bid + Morko, Olse + Etkin +	ikin + lestra + lestra + lestra + litz, Allison, Bat ters + (ISU, BGNA, C + loolinsky, Druzhinin man + lookus +
• • • We do not use the 0.104 \pm 0.007 \pm 0.072 22 Using an incoherent b 23 Using a coherent back $\Gamma(\pi\pi)/\Gamma_{\text{total}}$ $\frac{VALUE}{0.847 \pm 0.026}$ OUR FIT 0.837 \pm 0.020 OUR AVER. 0.849 \pm 0.025 0.8 \pm 0.04 $\Gamma(\pi^{+}\pi^{-}2\pi^{0})/\Gamma(\pi\pi)$ Should be twice $\Gamma(2 VALUE)$ 0.085 \pm 0.016 OUR FIT 0.036 OUR FIT 0.15 \pm 0.006	23 ALBRECHT ackground. ground. $f_2(1270)$ BRANCHIN EVTS DOCUMENT ID Error includes scale facto AGE CHABAUD 250 BEAUPRE 600 OH $2\pi^+2\pi^-)/\Gamma(\pi\pi)$ if deca EVTS DOCUMENT ID Error includes scale facto 600 EISENBERG	90G ARG NG RATIOS r of 1.3. 83 ASPK 71 HBC 70 HBC y is ρρ. (See TECN r of 1.3. 74 HBC	is, etc. $\bullet \bullet \bullet$ $e^+e^- \rightarrow e^+e^- K^+$ $\frac{COMMENT}{17 \pi^- p \text{ pola}}$ $8 \pi^+ p \rightarrow 2$ $1.26 \pi^- p \rightarrow 2$ ASCOLI 68D.) $\frac{COMMENT}{4.9 \pi^+ p \rightarrow 4}$	Γ_1/Γ rized $t^{++}f_2$ $t^{-}\pi^+\pi^-n$ $t^{-}\pi^-$	PROKOSHKIN BEHREND BLINOV ADAMO AGUILAR AKER ADACHI ALBRECHT BOYER BREAKSTONI MARSISKE MORGAN OEST AUGUSTIN VOROBYEV ALDE AUGUSTIN ABACHI AIHARA ALDE LANDRO LONGACRE LYTH BEHREND BERGER	92 2 2 9 9 9 2 9 9 9 9 9 9 9 9 9 9 9 9	PD 39 420 ranslated from IC PHY C53 331 PHY C53 331 Adron 91 Conf. PHY C50 405 IL B200 249 IL B234 185 PHY C48 183 R D42 1350 PHY C48 559 R D41 3324 PHY C47 343 PHY C47 345 PHY C47 245 PHY C48 245 P	+ Kondashov 2(1270) REFE + Kondashov ANS 336 613. + Bondar, Bi + Agnello, Bi - Aguilar-Ber + Amsier, + Ehrlichman + Butler+ + Hantreasyan + Pennington + Olsson+ + Cosme + Golubev, Derrick, Bi - Halson, Bric + Derrick, Bi - Alston-Gart + Binon, Bric + Horrick, Bi -	ERENCES ukin + lestra + lestra + itez, Allison, Bat ters + (ISU, BGNA, C + toolinsky, Druzhinir man + liman + (BELG man + (BNL, E man + hachter, Schroede Burger +
• • • We do not use the 0.104 \pm 0.007 \pm 0.072 22 Using an incoherent b 23 Using a coherent back $\Gamma(\pi\pi)/\Gamma_{\text{total}}$ $\frac{VALUE}{0.847 \pm 0.026}$ OUR FIT 0.837 \pm 0.020 OUR AVER. 0.849 \pm 0.025 0.8 \pm 0.04 $\Gamma(\pi^{+}\pi^{-}2\pi^{0})/\Gamma(\pi\pi)$ Should be twice $\Gamma(2\pi)$ $\frac{VALUE}{0.085 \pm 0.036}$ OUR FIT 0.085 \pm 0.018 OUR FIT 0.15 \pm 0.06 • • • We do not use the	23 ALBRECHT ackground. ground. $f_2(1270)$ BRANCHIN EVTS DOCUMENT ID Error includes scale facto AGE CHABAUD 250 BEAUPRE 600 OH $2\pi^+2\pi^-)/\Gamma(\pi\pi)$ if deca EVTS DOCUMENT ID Error includes scale facto 600 EISENBERG	90G ARG TECN r of 1.3. 83 ASPK 71 HBC 70 HBC y is ρρ. (See TECN r of 1.3. 74 HBC es, fits, limits	is, etc. $\bullet \bullet \bullet$ $e^+e^- \rightarrow e^+e^- K^+$ $\frac{COMMENT}{17 \pi^- p \text{ pola}}$ $8 \pi^+ p \rightarrow 2$ $1.26 \pi^- p \rightarrow 2$ ASCOLI 68D.) $\frac{COMMENT}{4.9 \pi^+ p \rightarrow 4}$	Γ_1/Γ rized $+++f_2$ $\pi^+\pi^ \Gamma_2/\Gamma_1$ $\Delta^{++}f_2$	PROKOSHKIN BEHREND BLINOV ADAMO AGUILAR AKER ADACHI ALBRECHT BOYER BREAKSTONI MARSISKE MORGAN OEST AUGUSTIN VOROBYEV ALDE AUGUSTIN ABACHI AIHARA ALDE LANDRO LONGACRE LYTH BEHREND	92 2 2 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	95 PD 39 420 ranslated from E PHY CS6 381 PHY CS6 381 ladron 91 Conf. PHY CS0 405 PHY CS8 0405 PHY CS8 0405 PHY CS8 0405 PHY CS8 185 PHY C48 185 PHY C48 183 PHY C47 343 PHY C48 629 PHY C	EMMS 4 Kondashov ANS 336 613. Bondar, Bi Agnello, Bi Aguilar-Ber Amsler, Pe Doser+ Ehrlichman Butler+ Pennington Cosme Golubev, C AF 48 436. HBinon, Brid HCosme+ Derrick, Bi HAlston-Gari HBinon, Brid HOrk, Oise Etkin+ Fenner, Sc Klovning, E J-Johnson, S	ERENCES ukin + lestra + lestra + itez, Allison, Bat ters + (ISU, BGNA, C + (ISU, BGNA, C + teman + loolinsky, Druzhinir teman + (BELG man + (BNL, E man + hachter, Schroede Burger + herman, Ackwood, ams, Blocker, Lev
• • • We do not use the 0.104 \pm 0.007 \pm 0.072 22 Using an incoherent b 23 Using a coherent back $\Gamma(\pi\pi)/\Gamma_{\text{total}}$ $\frac{VALUE}{0.847 \pm 0.026}$ OUR FIT 0.837 \pm 0.020 OUR AVER. 0.849 \pm 0.025 0.8 \pm 0.05 0.8 \pm 0.04 $\Gamma(\pi^+\pi^-2\pi^0)/\Gamma(\pi\pi)$ Should be twice $\Gamma(\frac{VALUE}{0.035 \pm 0.036}$ OUR FIT 0.15 \pm 0.016 OUR FIT 0.15 \pm 0.06 • • We do not use the 0.07	23 ALBRECHT ackground. $f_2(1270)$ BRANCHIN EVTS DOCUMENT ID Error includes scale facto AGE 250 BEAUPRE 600 OH $^{2\pi^+2\pi^-)/\Gamma(\pi\pi)$ if deca EVTS DOCUMENT ID Error includes scale facto 600 EISENBERG following data for average	90G ARG TECN r of 1.3. 83 ASPK 71 HBC 70 HBC y is ρρ. (See TECN r of 1.3. 74 HBC es, fits, limits	is, etc. $\bullet \bullet \bullet$ $e^{+}e^{-} \xrightarrow{e^{+}e^{-}K^{+}}$ $17 \pi^{-}p \text{ pola}$ $8 \pi^{+}p \rightarrow \angle$ $1.26 \pi^{-}p \rightarrow$ ASCOLI 68D.) $\underline{comment}$ $4.9 \pi^{+}p \rightarrow \underline{c}$ is, etc. $\bullet \bullet \bullet$	rized $ \frac{\Gamma_1/\Gamma}{\pi^{+}f_2} $ $ \frac{\Gamma_2/\Gamma_1}{\pi^{+}f_2} $ $ \frac{\Delta^{++}f_2}{\pi^{+}f_2} $	PROKOSHKIN BEHREND BLINOV ADAMO AGUILAR AKER ADACHI ALBRECHT BOYER BREAKSTONI MARSISKE MORGAN OEST AUGUSTIN VOROBYEV ALDE AUGUSTIN ABACHI AIHARA ALDE LANDRO LONGACRE LYTH BEHREND BERGER COURAU SMITH BINON Also	92 Z Z 91 F 91 F 90 F 90 F 90 Z 2 90 F 90 Z 88 S 7 F 87 Z 88 B 86 F 86 B 6 F 86 B 86 F 86 F	PD 39 420 Finalsted from IC PHY CS6 381 PHY CS6 381 Jadron 91 Conf. PHY CS3 33 Jadron 91 Conf. PHY CS0 405 L B260 249 L B260 249 L B234 185 PHY C48 183 R D42 1350 PHY C48 183 PH C47 343 PH C48 569 PHY C36 369 PHY C47 343 PB 320 PHY C47 343 PB 320 PHY C36 369 PHY C36 369 PHY C36 369 PHY C36 369 PHY C37 203 PHY C47 203 PHY C37 203 PHY C48 183 PHY C47 203 PHY C38 308 PHY C48 308	EMMS 2(1270) REFE 4 Kondashov ANS 336 613. + Bondar, Bı + Agnello, Bı Aguilar-Ber + Amsier, Pe + Doser+ + Ehrlichman + Butler+ + Antreasyan + Pennington - Cosme+ - Cosme+ - Cosme+ - Derrick, Bl + Alston-Gar + Blinon, Brid + Mork, Olse + Etkin + Fenner, SC + Klowning, I - Johnson, So - Burke, Abr - Donskov, Cas - Binon, Go (AF 48 Bruke, Abr - Binon, Go (AF 58 934.	ikin+ lestra+ lestra+ letz, Allison, Bat tets+ n, Harder+ (ISU, BGNA, C+ + (ISU, BGNA, C+) hollinsky, Druzhinir man+ ockus+ nockus+ n
• • • We do not use the $0.104 \pm 0.007 \pm 0.072$ 22 Using an incoherent be 23 Using a coherent back $\Gamma(\pi\pi)/\Gamma_{\text{total}}$ $\frac{VALUE}{0.847 \pm 0.026}$ 0.847 ± 0.026 0.87 ± 0.020 0.89 ± 0.025 0.89 ± 0.04 $\Gamma(\pi^{+}\pi^{-}2\pi^{0})/\Gamma(\pi\pi)$ Should be twice $\Gamma(2\pi)$ $\frac{VALUE}{0.085 \pm 0.036}$ 0.085 ± 0.04 $\Gamma(\pi^{+}\pi^{-}2\pi^{0})/\Gamma(\pi\pi)$ 0.085 ± 0.036 0.08 0UR FIT 0.15 ± 0.06 • • • We do not use the 0.07 $\Gamma(KK)/\Gamma(\pi\pi)$	23 ALBRECHT ackground. $f_2(1270)$ BRANCHIN EVTS DOCUMENT ID Error includes scale facto AGE 250 BEAUPRE 600 OH $^{2\pi^+2\pi^-)/\Gamma(\pi\pi)$ if deca EVTS DOCUMENT ID Error includes scale facto 600 EISENBERG following data for average	90G ARG NG RATIOS TECN r of 1.3. 83 ASPK 71 HBC 70 HBC y is ρρ. (See TECN r of 1.3. 74 HBC es, fits, limits 750 DBC	is, etc. $\bullet \bullet \bullet$ $e^{+}e^{-} \xrightarrow{e^{+}e^{-} K^{+}}$ $17 \pi^{-} p \text{ pola}$ $8 \pi^{+} p \rightarrow 2$ $1.26 \pi^{-} p \rightarrow 4$ ASCOLI 68D.) $\underline{COMMENT}$ $4.9 \pi^{+} p \rightarrow 5$ is, etc. $\bullet \bullet \bullet$ $4 \pi^{+} n \rightarrow p$	Γ_1/Γ rized $1++f_2$ $\pi^+\pi^-\pi$ Γ_2/Γ_1 $\Delta^{++}f_2$ f_2 Γ_3/Γ_1	PROKOSHKIN BEHREND BLINOV ADAMO AGUILAR AKER ADACHI ALBRECHT BOYER BREAKSTONI MARSISKE MORGAN OEST AUGUSTIN VOROBYEV ALDE AUGUSTIN ABACHI AIHARA ALDE LANDRO LONGACRE LYTH BEHREND BERGER COURAU SMITH BINON AISO CHABAUD DENNEY	92	PD 39 420 Finalsted from EPHY CS6 381 FPHY CS6 381 Iadron 91 Conf. FPHY CS3 33 Iadron 91 Conf. FPHY CS8 405 F	EMMS 2(1270) REFE + Kondashov ANS 336 613. + Bondar, Bi + Agnello, Bi Aguilar-Ber + Amsler, Pe + Doser+ + Ehrlichman + Butler+ + + Anterasyan + Pennington + Osson+ + Cosme + Golubev, D (AF 48 436. + Binon, Brid + Cosme+ + Derrick, Bi + Aston-Gari + Mork, Oss + Etkin+ + Fenner, Sc. Klovning, I + Johnson, S + Burke, Abr + Donskov, I Binon, Orif (AF 38 934. + Gorifich, Ce 76 934.	ikin+ lestra+ lestra+ letz, Allison, Bat tets+ n, Harder+ (ISU, BGNA, C+ + (ISU, BGNA, C+) hollinsky, Druzhinir man+ ockus+ nockus+ n
• • • We do not use the 0.104 \pm 0.007 \pm 0.072 22 Using an incoherent b 23 Using a coherent back $\Gamma(\pi\pi)/\Gamma_{\text{total}}$ $\frac{VALUE}{0.847} = \frac{1}{0.012} \text{ OUR FIT}$ 0.849 \pm 0.025 0.85 \pm 0.05 0.8 \pm 0.04 $\Gamma(\pi^{+}\pi^{-}2\pi^{0})/\Gamma(\pi\pi)$ Should be twice $\Gamma(2\pi^{-}2\pi^{$	23 ALBRECHT ackground. $f_2(1270)$ BRANCHIN EVTS DOCUMENT ID Error includes scale factor AGE 250 BEAUPRE 600 OH $^{2\pi^+2\pi^-)/\Gamma(\pi\pi)$ if decaution between $^{2\pi^+2\pi^-}$ DOCUMENT ID Error includes scale factor 600 EISENBERG following data for average EMMS	90G ARG NG RATIOS TECN r of 1.3. 83 ASPK 71 HBC 70 HBC y is ρρ. (See <u>TECN</u> r of 1.3. 74 HBC es, fits, limits 750 DBC ke into accou	is, etc. $\bullet \bullet \bullet$ $e^+e^- \rightarrow e^+e^- K^+$ $e^+e^- K^+$ $17 \pi^- p \text{ pola}$ $8 \pi^+ p \rightarrow \Delta$ $1.26 \pi^- p \rightarrow \Delta$ ASCOLI 68D.) $COMMENT$ $4.9 \pi^+ p \rightarrow 6$ 6 , etc. $\bullet \bullet \bullet$ $4 \pi^+ n \rightarrow p$ and $f_2(1270) - a_2(n \text{ is negligible.}$	Γ_1/Γ rized $1++f_2$ $\pi^+\pi^-\pi$ Γ_2/Γ_1 $\Delta^{++}f_2$ f_2 Γ_3/Γ_1	PROKOSHKIN BEHREND BLINOV ADAMO AGUILAR AKER ADACHI ALBRECHT BOYER BREAKSTONI MARSISKE MORGAN OEST AUGUSTIN VOROBYEV ALDE AUGUSTIN ABACHI AIHARA ALDE LANDRO LONGACRE LUNDRO LONGACRE LUNDRO BEHREND BEHRE	92	PD 39 420 ranslated from E PHY CS6 381 pHY CS6 381 ladron 91 Conf, PHY CS9 405 r. B260 249 r. B260 249 r. B260 249 r. B260 249 r. B232 1350 pHY C48 183 r. D42 1350 pHY C48 153 pHY C48 253 ranslated from Y RD 41 327 ranslated from Y RL 57 1990 RL 57 404 r. B198 266 r. B177 463 r. B174 673 r. B174 674 r. B1	EMMS 2(1270) REFE 4 Kondashov ANS 336 613. Bondar, Bi Agnello, Bi Aguilar-Ber 4 Amsler, Pe Doser+ Ebriichman Butler+ Antreasyan Pennington (AF 48 436. + Cosme+ Dorrick, Bi Alston-Gari Horrick, Bi Alston-Gari Fenner, SC Klowing, I Johnson, Gari Fenner, SC Binon, Gor (AF 38 934. Gorlich, Ce + Cranley, Fi	ikin+ ilestra+ ilestra+ itez, Allison, Bat tetes+ n, Harder+ (ISU, BGNA, C+ + (ISU, BGNA, C+) tollinsky, Druzhinir tman+ ockus+ nockus+ nocku
• • • We do not use the 0.104 \pm 0.007 \pm 0.072 22 Using an incoherent b 23 Using a coherent back $\Gamma(\pi\pi)/\Gamma$ total $\frac{VALUE}{0.847-0.012}$ OUR FIT 0.837 \pm 0.020 OUR AVER. 0.849 \pm 0.025 0.85 \pm 0.05 0.8 \pm 0.04 $\Gamma(\pi^+\pi^-2\pi^0)/\Gamma(\pi\pi)$ Should be twice $\Gamma(2000000000000000000000000000000000000$	23 ALBRECHT ackground. $f_2(1270)$ BRANCHIN EVTS DOCUMENT ID Error includes scale facto AGE CHABAUD 250 BEAUPRE 600 OH $2\pi^+2\pi^-)/\Gamma(\pi\pi)$ if deca EVTS DOCUMENT ID Error includes scale facto 600 EISENBERG following data for averag EMMS periments which either ta demonstrate that $a_2(132$ EVTS DOCUMENT ID	90G ARG NG RATIOS 1 TECN 1 TO 1.3. 83 ASPK 71 HBC 70 HBC 70 HBC 70 HBC 1 TECN 74 HBC es, fits, limits 750 DBC ke into accounce) production 1 TECN	is, etc. $\bullet \bullet \bullet$ $e^+e^- \rightarrow e^+e^- K^+$ $e^+e^- K^+$ $17 \pi^- p \text{ pola}$ $8 \pi^+ p \rightarrow \Delta$ $1.26 \pi^- p \rightarrow \Delta$ ASCOLI 68D.) $COMMENT$ $4.9 \pi^+ p \rightarrow 6$ 6 , etc. $\bullet \bullet \bullet$ $4 \pi^+ n \rightarrow p$ and $f_2(1270) - a_2(n \text{ is negligible.}$	Γ_1/Γ rized $1++f_2$ $\pi^+\pi^-\pi$ Γ_2/Γ_1 $\Delta^{++}f_2$ f_2 Γ_3/Γ_1	PROKOSHKIN BEHREND BLINOV ADAMO AGUILAR AKER ADACHI ALBRECHT BOYER BREAKSTONI MARSISKE MORGAN OEST OEST AUGUSTIN VOROBYEV ALDE AUGUSTIN ABACHI AIHARA ALDE LANDRO LONGACRE LYTH BEHREND BERGER COURAU SMITH BINON AISO CHABAUD DENNEY FRAZER MENNESSIER APEL CASON	92	PD 39 420 ranslated from IC PHY CS6 381 PHY CS6 381 ladron 91 Conf. PHY CS7 333 ladron 91 Conf. PHY CS8 381 ladron 92 Conf. B 260 249 L B234 185 PHY C48 183 R D42 1350 PHY C48 183 R D42 1350 PHY C48 733 PHY C47 324 PHY C48 623 PHY C36 369 PHY C37 300 PHY C37 300 PHY C38 223 PHY C38 128 PHY C38 223 PHY C46 199 PHY C38 221 PHY C46 199 PHY C46 241 PB 260 197 PHY C46 241	EMMS 2(1270) REFE *Kondashov ANS 336 613. +Bondar, B; +Agnello, B; Aguilar-Ber +Ausler, Pennington -Cosme -Cosme +Cosme +Derick, Bi +Alston-Gar +Binon, Brit +Mork, Olse +Ekin -Ekin -Ekin -Cosme -	ikin+ lestra+ lestra+ letz, Allison, Bat tets+ n, Harder+ (ISU, BGNA, C+ + (ISU, BGNA, C+ tets+ n, Harder+ (ISU, BGNA, C+ tets+ n, Harder+ (ISU, BGNA, C+ tets+ n, Harder+ (ISU, BGNA, C+ tets+ lookinsky, Druzhinin teman+ (BRUL, Banachter, Schroede Burger+ man+ hachter, Schroede Burger+ rada+ tetshachter, Chapman tetshachter, Chapman tetshachter, Chapman tetshachter, Karl
• • • We do not use the 0.104 \pm 0.007 \pm 0.072 22 Using an incoherent b 23 Using a coherent back $\Gamma(\pi\pi)/\Gamma$ total VALUE 0.847 \pm 0.026 OUR FIT 0.837 \pm 0.020 OUR AVER 0.849 \pm 0.05 \pm 0.04 $\Gamma(\pi^+\pi^-2\pi^0)/\Gamma(\pi\pi)$ Should be twice $\Gamma(2\times \Delta LUE)$ 0.085 \pm 0.06 OUR FIT 0.15 \pm 0.06 \pm 0.07 $\Gamma(KK)/\Gamma(\pi\pi)$ We average only experience explicitly or VALUE 0.055 \pm 0.006 OUR FIT 0.055 \pm 0.005 OUR FIT 0.055 \pm 0.095 \pm 0.096 OUR FIT 0.097 \pm 0.097	23 ALBRECHT ackground. $f_2(1270)$ BRANCHIN EVTS DOCUMENT ID Error includes scale facto AGE CHABAUD $^{2\pi}+^{2\pi}-)/\Gamma(\pi\pi)$ if deca EVTS DOCUMENT ID Error includes scale facto 600 EISENBERG following data for averag EMMS periments which either ta demonstrate that 2 (132 EVTS DOCUMENT ID Error includes scale facto	90G ARG NG RATIOS 1 TECN 1 TO 1.3. 83 ASPK 71 HBC 70 HBC 70 HBC 70 HBC 1 TECN 74 HBC es, fits, limits 750 DBC ke into accounce) production 1 TECN	is, etc. $\bullet \bullet \bullet$ $e^+e^- \rightarrow e^+e^- K^+$ $e^+e^- K^+$ $17 \pi^- p \text{ pola}$ $8 \pi^+ p \rightarrow \Delta$ $1.26 \pi^- p \rightarrow \Delta$ ASCOLI 68D.) $COMMENT$ $4.9 \pi^+ p \rightarrow 6$ 6 , etc. $\bullet \bullet \bullet$ $4 \pi^+ n \rightarrow p$ and $f_2(1270) - a_2(n \text{ is negligible.}$	Γ_1/Γ rized $1++f_2$ $\pi^+\pi^-\pi$ Γ_2/Γ_1 $\Delta^{++}f_2$ f_2 Γ_3/Γ_1	PROKOSHKIN BEHREND BLINOV ADAMO AGUILAR ADAMO AGUILAR ALBRECHT BOYER BREAKSTONI MARSISKE MORGAN OEST OEST AUGUSTIN VOROBYEV ALDE AUGUSTIN ABACHI AIHARA ALDE LANDRO LONGACRE LYTH BEHREND BERGER COURAU SMITH BINON AISO CHABAUD DENNEY FRAZER MENNESSIER APEL CASON EDWARDS ETKIN	92	95 PD 39 420 ranslated from IC PHY CS6 381 PHY CS3 33 ladron 91 Conf. PHY CS3 33 ladron 91 Conf. PHY CS0 405 IL B260 249 IL B234 185 PHY C48 183 R D42 1350 PHY C48 183 PH C47 3324 PH C48 569 PHY C48 569 PHY C48 569 PHY C47 343 PB 320 1 JNP 48 273 ranslated from V1 B198 266 PHY C36 369 PHY C36 369 PHY C36 369 PHY C37 300 PHY C37 404 PB 269 485 IL B177 223 PHY C36 199 PHY C38 223 PHY C37 187 PHY C38 223 PHY C48 229 PHY C48 221 PHY C48	EMMS 2(1270) REFE *Kondashov ANS 336 613. +Bondar, B; +Agnello, B; Aguilar-Ber +Augnello, B; Aguilar-Ber +Butler+ -Bhriichman +Butler+ -Antreasyan -Pennington -Oisuber, D; -Cosme -Colluber, D; -Cosme + Derrick, Bi +Alston-Gar +Binon, Brit +Mork, Olse +Ekin+ Fenner, Sc +Klowning, I; -Johnson, Gor (AF 48 39 34. Gorlich, Ce +Cranley, Fi Bison, Gor (AF 38 934. Gorlich, Ce +Cranley, Fi +Augenstein -Biswas, Ba +Partridge, +Biswas, Ba +Partridge, +Foley, Lai-	ikin + plestra +
• • • We do not use the 0.104 \pm 0.007 \pm 0.072 22 Using an incoherent b 23 Using a coherent back $\Gamma(\pi\pi)/\Gamma_{\text{total}}$ $\frac{VALUE}{0.847 \pm 0.026}$ OUR FIT 0.837 \pm 0.020 OUR AVER. 0.849 \pm 0.025 0.8 \pm 0.04 $\Gamma(\pi^{+}\pi^{-}2\pi^{0})/\Gamma(\pi\pi)$ Should be twice $\Gamma(2\pi^{0}M_{\odot})$ Should be twice $\Gamma(2\pi^{0}M_{\odot})$ We average only experience explicitly or $\frac{VALUE}{0.055 \pm 0.06}$ OUR FIT 0.055 \pm 0.006 OUR FIT 0.005 OUR AVER	23 ALBRECHT ackground. $f_2(1270)$ BRANCHIN EVTS DOCUMENT ID Error includes scale facto AGE CHABAUD 250 BEAUPRE 600 OH $^{2\pi^+2\pi^-)/\Gamma(\pi\pi)$ if deca EVTS DOCUMENT ID Error includes scale facto 600 EISENBERG following data for averag EMMS periments which either ta demonstrate that 2 (132 EVTS DOCUMENT ID Error includes scale facto AGE	90G ARG NG RATIOS TECN r of 1.3. 83 ASPK 71 HBC 70 HBC y is ρρ. (See <u>TECN</u> r of 1.3. 74 HBC es, fits, limits 750 DBC ke into accou	is, etc. $\bullet \bullet \bullet$ $e^+e^- \rightarrow e^+e^- \rightarrow e^- \rightarrow e^-e^- \rightarrow e^-e^$	rized $ \frac{\Gamma_1/\Gamma}{\Gamma_1/\Gamma} $ rized $ \frac{++f_2}{\pi^+\pi^- n} $ $ \frac{\Gamma_2/\Gamma_1}{\Gamma_2/\Gamma_1} $ $ \frac{\Delta^{++}f_2}{\Gamma_2} $ $ \frac{\Gamma_3/\Gamma_1}{\Gamma_1} $ 1320) inter-	PROKOSHKIN BEHREND BLINOV ADAMO AGUILAR ALBRECHT BOYER BREAKSTONI MARSISKE MORGAN OEST AUGUSTIN VOROBYEV ALDE AUGUSTIN ABACHI AIHARA ALDE LANDRO LONGACRE LYTH BEHREND BERGER COURAU SMITH BINON AISO CHABAUD DENNEY FRAZER MENNESSIER APEL CASON EDWARDS ETKIN BRANDELIK CHABAUD ETKINDELIK CHABAUD ETKINDELIK CHABAUD EHRENDELIK CHABAUD ETKINDELIK CHABAUD ETKINDELIK CHABAUD ETKINDELIK CHABAUD EHRENDELIK CHABAUD ETKINDELIK CHABAUD ETKINDELIK CHABAUD ETKINDELIK CHABAUD EHRENDELIK CHABAUD ETKINDELIK CHABAUD ETKINDELIK CHABAUD EHRENDELIK CHABAUD ETKINDELIK CHABAUD ETKINDELIK CHABAUD EHRENDELIK CHABAUD ETKINDELIK CHABAUD EHRENDELIK E	92 7 7 9 9 9 9 1	PD 39 420 ranslated from E PHY CS6 381 PHY CS6 381 ladron 91 Conf. PHY CS3 33 ladron 91 Conf. PHY CS8 381 ladron 91 Conf. B 260 249 tl B234 185 PHY C48 183 R D42 1350 PHY C48 183 RD 42 1350 PHY C47 343 PB 320 1 JNP 48 273 ranslated from 1/8 The B 273 The B 273 The B 274 The B 274 The B 275 The B 27	EMMS 2(1270) REFE *Kondashov ANS 336 613. +Bondar, B; +Agnello, B; Aguilar-Ber +Augnello, B; Aguilar-Ber +Butler+ -Bhriichman +Butler+ -Antreasyan -Pennington -Colubev, D; (AF 48 436, be.) -Cosme+ -Derrick, Bi +Alston-Gar +Binon, Brit +Mork, Olse +Ekin+ -Berner, Sc +Klowning, I; -Johnson, Gor (AF 38 934. -Gorlich, Ce +Cranley, Fi Bison, Gor -Augenstein -Biswas, Ba -Bartridge, Brit -Biswas, Ba -Brit -Biswas, Ba -Biswas, Ba -Brit -Biswas, Ba -Brit -Biswas, Ba -Brit -Biswas, Ba	ikin+ lestra+ lestra+ letz, Allison, Bat tets+ n, Harder+ (ISU, BGNA, C+ + (ISU, BGNA, C+ teman+ ockus+ man+ (BELG n (BNL, Ed Burger+ machter, Schroede Blocker, Lev Duteil+ rrada+ restone, Chapman e(KARLK, KARL mbaugh, Bishop Peck+ (ISU, BGNA, C+ teman, Atwood, ams, Blocker, Lev Duteil+ comman, Atwood, ams, Blocker, Lev Duteil+ letteran, Atwood, ams, Blocker, Lev Duteil+ (KARLK, KARL mbaugh, Bishop Peck+ (ISU, Becker+ (ISU, Becker+ (ISU, BELG (ISU
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• • • We do not use the 0.104 \pm 0.007 \pm 0.072 22 Using an incoherent b 23 Using a coherent back $\Gamma(\pi\pi)/\Gamma$ total $\frac{VALUE}{0.847} = 0.026$ OUR FIT 0.847 \pm 0.020 OUR AVER. 0.849 \pm 0.025 0.8 \pm 0.04 $\Gamma(\pi^+\pi^-2\pi^0)/\Gamma(\pi\pi)$ Should be twice $\Gamma(2 \frac{VALUE}{0.005} = 0.05$ OUR FIT 0.15 \pm 0.06 • • We do not use the 0.07 $\Gamma(K\overline{K})/\Gamma(\pi\pi)$ We average only experience explicitly or $\frac{VALUE}{0.055} = 0.06$ OUR FIT 0.055 \pm 0.06 OUR FIT 0.055 \pm 0.06 OUR AVER 0.037 \pm 0.005 OUR AVER 0.037 \pm 0.005 OUR AVER 0.037 \pm 0.008 OUR OUR OUR 0.039 \pm 0.008 • • We do not use the 0.039 \pm 0.008	23 ALBRECHT ackground. $f_2(1270)$ BRANCHIN EVTS DOCUMENT ID Error includes scale facto AGE CHABAUD $^{2\pi^+2\pi^-}$ / $^{\Gamma}(\pi\pi)$ if deca EVTS DOCUMENT ID Error includes scale facto 600 BEAUPRE 600 OH Error includes scale facto 600 EISENBERG following data for averag EMMS periments which either ta demonstrate that $^{2}(132$ EVTS DOCUMENT ID ETROR INCLUDENT ID ETROR IN	90G ARG FOR INGRATIOS TECN T of 1.3. 83 ASPK 71 HBC 70 HBC y is ρρ. (See TECN T of 1.3. 74 HBC es, fits, limits 75D DBC kee into accounce to production TECN TECN TO 2.8. 82B MPS 81 ASPK 80 HBC es, fits, limits	is, etc. $\bullet \bullet \bullet$ $e^+e^- \rightarrow e^+e^- \rightarrow e^- \rightarrow e^-e^- ^- \rightarrow e^-e^- \rightarrow e^- \rightarrow$	rized $ \frac{\Gamma_1/\Gamma}{\Gamma_1/\Gamma} $ rized $ \frac{++f_2}{\pi^+\pi^-} = \frac{\Gamma_2/\Gamma_1}{\Gamma_1} $ $ \frac{\Delta^{++}f_2}{\Gamma_1} $ $ \frac{\Gamma_3/\Gamma_1}{\Gamma_1} $ 1320) inter- $ \frac{\pi_2K_0^0}{K_N} $ rized $ \frac{\pi_2K_0^0}{K_N} $	PROKOSHKIN BEHREND BLINOV ADAMO AGUILAR ADAMO AGUILAR ALBRECHT BOYER BREAKSTONI MARSISKE MORGAN OEST OST AUGUSTIN VOROBYEV ALDE AUGUSTIN ABACHI AIHARA ALDE LANDRO LONGACRE LYTH BEHREND BERGER COURAU SMITH BINON AISO CHABAUD DENNEY FRAZER MENNESSIER APEL CASON EDWARDS ETKIN BRANDELIC HABAUD GIDAL ROUSSARIE BERGER COSTA LOVERRE CORDEN MARTIN POLYCHRO	92	PD 39 420 ranslated from IC PHY CS6 381 PHY CS6 381 ladron 91 Conf. PHY CS3 33 ladron 91 Conf. PHY CS7 481 PHY CS8 405 PHY CS8	EMMS 2(1270) REFE 4 Kondashov ANS 336 613. Bondar, Bi Agnello, Bi Aguilar-Ber Amsler, Pe Doser+ Ehrlichman Butler+ Hantrasayan Pennington Olssan Cosme+ Cosme+ Dorrick, Bi Alston-Gari Horrick, Bi Alston-Gari Horrick, Bi Alston-Gari Horrick, Bi Fenner, SC Klowning, I Johnson, Gari Fenner, SC Klowning, I Horrick, Bi Horryporuk Goldhaber, Horryporuk Goldhaber, Horryporuk Goldhaber, Horryporuk Goldhaber, Horryporuk Goldhaber, Horryporuk Goldhaber, Horrick Horryporuk Goldhaber, Horryporuk Horryp	ikin + liestra +
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• • • We do not use the 0.104 \pm 0.007 \pm 0.072 22 Using an incoherent b 23 Using a coherent back $\Gamma(\pi\pi)/\Gamma_{\text{total}}$ $\frac{VALUE}{VALUE}$ 0.847 \pm 0.026 OUR FIT 0.837 \pm 0.020 OUR AVER. 0.849 \pm 0.025 0.8 \pm 0.04 $\Gamma(\pi^+\pi^-2\pi^0)/\Gamma(\pi\pi)$ Should be twice $\Gamma(\frac{VALUE}{VALUE}$ 0.085 \pm 0.05 OUR FIT 0.15 \pm 0.06 • • We do not use the 0.07 $\Gamma(K\overline{K})/\Gamma(\pi\pi)$ We average only experience explicitly or $\frac{VALUE}{VALUE}$ 0.005 \pm 0.006 OUR FIT 0.040 \pm 0.005 OUR AVER 0.037 \pm 0.008 \pm 0.009 OUR AVER 0.039 \pm 0.008 • • We do not use the 0.036 \pm 0.009 \pm 0.009 \pm 0.009 OUR AVER 0.036 \pm 0.005 OUR AVER 0.036 \pm 0.005 OUR OUS THE 0.009 OUS	23 ALBRECHT ackground. $f_2(1270)$ BRANCHIN EVTS DOCUMENT ID Error includes scale facto AGE CHABAUD 250 BEAUPRE 600 OH $^{2\pi^+2\pi^-})/\Gamma(\pi\pi)$ if deca EVTS DOCUMENT ID Error includes scale facto 600 EISENBERG following data for averag EMMS periments which either ta demonstrate that $^{2}_{2}(132)$ EVTS DOCUMENT ID Error includes scale facto AGE ETKIN CHABAUD LOVERRE following data for averag 24 COSTA 25 MARTIN 26 POLYCHRO	90G ARG FECN TECN TECN	is, etc. $\bullet \bullet \bullet$ $e^+e^- \longrightarrow e^+e^- K^+$ $e^+e^- K^+$ $e^+e^- K^+$ 17 π^-p pola $8\pi^+p \to 2$ 1.26 $\pi^-p \to 2$ 1.26 $\pi^-p \to 2$ ASCOLI 68D.) COMMENT 4.9 $\pi^+p \to 6$ is, etc. $\bullet \bullet \bullet$ 4 $\pi^+n \to p$ nt $f_2(1270)$ -a ₂ (n is negligible. COMMENT 23 $\pi^-p \to K$ 5, etc. $\bullet \bullet \bullet$ 6, etc. $\bullet \bullet \bullet$ 6, etc. $\bullet \bullet \bullet$ 7 $\pi^-p \to K$	rized $ \frac{\Gamma_{1}/\Gamma}{\Gamma_{1}/\Gamma} $ rized $ \frac{1}{1} + \frac{1}{1} + \frac{1}{1} + \frac{1}{1} = \frac{1}{1} $ $ \frac{\Gamma_{2}/\Gamma_{1}}{\Gamma_{2}/\Gamma_{1}} $ $ \frac{\Gamma_{3}/\Gamma_{1}}{\Gamma_{1}/\Gamma_{2}/\Gamma_{2}} $ $ \frac{\Gamma_{3}/\Gamma_{1}}{\Gamma_{3}/\Gamma_{1}/\Gamma_{2}/\Gamma_{2}} $ rized $ \frac{\Gamma_{3}/\Gamma_{1}}{\Gamma_{3}/\Gamma_{1}/\Gamma_{2}/\Gamma_$	PROKOSHKIN BEHREND BLINOV ADAMO AGUILAR AKER ADACHI ALBRECHT BOYER BREAKSTONI MARSISKE MORGAN OEST AUGUSTIN VOROBYEV ALDE AUGUSTIN ABACHI AIHARA AIHARA AIHARA AILDE LANDRO LONGACRE LYTH BEHREND BERGER COURAU SMITH BINON AISO CHABAUD DENNEY FRAZER MENNESSIER APEL CASON EDWARDS EKINDELIK CHABAUD GIDAL ROUSSARIE BERGER COSTA LOVERRE CORDEN MARTIN POLYCHRO PDG ANTIPOV PAWLICKI POLYCHRO PDG ANTIPOV PAWLICKI DEUTSCH	92	95 PD 39 420 ranslated from E PHY CS6 381 PHY CS6 381 ladron 91 Conf. PHY CS3 33 ladron 91 Conf. PHY CS8 381 ladron 91 Conf. R 260 249 L 8234 185 PHY C48 183 PHY C48 183 PHY C48 183 PHY C47 343 PHY C48 59 PHY C48 629 RL 57 1990 RL 57 1990 RL 57 1990 PHY C36 369 RL 57 1990 PHY C36 369 RL 57 1990 PHY C36 369 RL 57 1990 RL 58 1990 RL 57 1990 RL 58 1990 RL 57 1990 RL 57 1990 RL 58 1990 RL 59	EMMS 2(1270) REFE (1270) REFE (1270) REFE + Kondashov ANS 336 613. + Bondar, Bi + Agnello, Bi + Agnello, Bi + Agnello, Bi - Agnello, Bi - Agnello, Bi - Hehrichman - Heutler+ + Henrishman - Henri	ERENCES Jakin + Jestra +
• • • We do not use the $0.104 \pm 0.007 \pm 0.072$ 22 Using an incoherent be 23 Using a coherent back $\Gamma(\pi\pi)/\Gamma_{\text{total}}$ $\frac{VALUE}{0.847 + 0.026} \text{ OUR FIT}$ $0.847 + 0.020 \text{ OUR AVER}$ 0.849 ± 0.025 0.85 ± 0.05 0.8 ± 0.04 $\Gamma(\pi^{+}\pi^{-}2\pi^{0})/\Gamma(\pi\pi)$ Should be twice $\Gamma(X)$ $\frac{VALUE}{0.085 + 0.036} \text{ OUR FIT}$ 0.15 ± 0.06 0.07 $\Gamma(KK)/\Gamma(\pi\pi)$ We average only experience explicitly or	23 ALBRECHT ackground. $f_2(1270)$ BRANCHIN EVTS DOCUMENT ID Error includes scale facto AGE CHABAUD $^{2\pi^+2\pi^-})/\Gamma(\pi\pi)$ if deca EVTS DOCUMENT ID Error includes scale facto 600 EISENBERG following data for averag EMMS Periments which either ta demonstrate that 2 (132 EVTS DOCUMENT ID Error includes scale facto AGE ETKIN CHABAUD LOVERRE following data for averag 24 COSTA 25 MARTIN	90G ARG FECN F of 1.3. 83 ASPK 71 HBC 70 HBC y is ρρ. (See FECN F of 1.3. 74 HBC es, fits, limits 750 DBC kee into accounce to production FECN F of 2.8. 82B MPS 81 ASPK 80 HBC es, fits, limits 80 OMEC	is, etc. $\bullet \bullet \bullet$ $e^+e^- \longrightarrow e^+e^- K^+$ $e^+e^- \longrightarrow K^+$ 17 $\pi^- p$ pola $8 \pi^+ p \longrightarrow \Delta$ 1.26 $\pi^- p \longrightarrow \Delta$ ASCOLI 68D.) COMMENT 4.9 $\pi^+ p \longrightarrow \phi$ is, etc. $\bullet \bullet \bullet$ 4 $\pi^+ n \longrightarrow p$ nt $f_2(1270)$ -a ₂ (n is negligible. COMMENT 23 $\pi^- p \longrightarrow K$ 5, etc. $\bullet \bullet \bullet$ 6, etc. $\bullet \bullet \bullet$ 6, etc. $\bullet \bullet \bullet$ 7. $\bullet \bullet$ 8. \bullet 17 $\bullet \bullet$ 17 $\bullet \bullet$ 18 \bullet 19 \bullet 18 \bullet 19 \bullet 19 \bullet 10 \bullet 10 \bullet 10 \bullet 11 \bullet 12 \bullet 13 \bullet 15 \bullet 16 \bullet 16 \bullet 17 \bullet 17 \bullet 18 \bullet 19 \bullet 18 \bullet 19 \bullet 19 \bullet 19 \bullet 10 \bullet 10 \bullet 10 \bullet 10 \bullet 11 \bullet 12 \bullet 13 \bullet 14 \bullet 15 \bullet 16 \bullet 16 \bullet 17 \bullet 18 \bullet 19 \bullet 18 \bullet 19 \bullet 19 \bullet 10	rized $ \frac{\Gamma_{1}/\Gamma}{\Gamma_{1}/\Gamma} $ rized $ \frac{1}{1} + \frac{1}{1} + \frac{1}{1} + \frac{1}{1} = \frac{1}{1} $ $ \frac{\Gamma_{2}/\Gamma_{1}}{\Gamma_{2}/\Gamma_{1}} $ $ \frac{\Gamma_{3}/\Gamma_{1}}{\Gamma_{1}/\Gamma_{2}/\Gamma_{2}} $ $ \frac{\Gamma_{3}/\Gamma_{1}}{\Gamma_{3}/\Gamma_{1}/\Gamma_{2}/\Gamma_{2}} $ rized $ \frac{\Gamma_{3}/\Gamma_{1}}{\Gamma_{3}/\Gamma_{1}/\Gamma_{2}/\Gamma_$	PROKOSHKIN BEHREND BLINOV ADAMO AGUILAR AKER ADACHI ALBRECHT BOYER BREAKSTONI MARSISKE MORGAN OEST AUGUSTIN VOROBYEV ALDE AUGUSTIN ABACHI AIHARA ALDE LANDRO LONGACRE LYTH BEHREND BERGER COURAU SMITH BINON AISO CHABAUD	92	95 PD 39 420 Translated from E PHY CS6 381 Jadron 91 Conf. PHY CS6 381 Jadron 91 Conf. L B260 249 L B230 139 PHY C48 183 PHY C48 183 PHY C48 183 PHY C48 273 Translated from 14 L B198 286 PHY C36 369 PHY C47 343 PHY C48 623 PHY C36 369 PHY C37 364 The Second Seco	EMMS 2(1270) REFE (1270) REFE (1270) REFE + Kondashov ANS 336 613. + Bondar, Bi + Agnello, Bi + Agnello, Bi + Agnello, Bi - Agnello, Bi - Agnello, Bi - Hehrichman - Heutler+ + Henrishman - Henri	ikin + plestra + plost + plo

$\Gamma(2\pi^+2\pi^-)/\Gamma(\pi\pi$	·)				Γ_4/Γ_1
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.033±0.005 OUR FI		udes scale factor	of 1.	2.	
0.033±0.004 OUR AV	ERAGE Er	ror includes scale			
0.024 ± 0.006	160	EMMS	75 D	DBC	$4 \pi^+ n \rightarrow p f_2$
0.051 ± 0.025	70	EISENBERG	74	нвс	$4.9 \pi^+ p \rightarrow \Delta^{++} f_2$
$0.043^{+0.007}_{-0.011}$	285	LOUIE	74	HBC	$3.9 \pi^- p \rightarrow n f_2$
0.037 ± 0.007	154	ANDERSON	73	DBC	$6 \pi^+ n \rightarrow p f_2$
0.047 ± 0.013		ОН	70	нвс	1.26 $\pi^- \rho \to \pi^+ \pi^- n$
$\Gamma(\eta\eta)/\Gamma_{total}$					Γ ₅ /Γ
VALUE (units 10-3)		DOCUMENT ID		TECN	COMMENT
4.5±1.0 OUR FIT	rror includes	scale factor of 2	.4.		
3.1±0.8 OUR AVERA	GE Error in	cludes scale fact	or of	1.3.	
2.8 ± 0.7		ALDE	86D	GAM4	$100 \pi^- p \rightarrow 2\eta n$
5.2 ± 1.7		BINON	83	GAM2	$38 \pi^- p \rightarrow 2\eta n$
-() (-()					
$\Gamma(\eta\eta)/\Gamma(\pi\pi)$					Γ_5/Γ_1
VALUE	CL%	DOCUMENT ID		TECN	COMMENT
 ◆ ◆ We do not use 	the following	data for average	s, fits	, limits,	etc. • • •
< 0.05	95	EDWARDS		CBAL	,
< 0.016	95	EMMS	75 D	DBC	$4 \pi^+ n \rightarrow p f_2$
< 0.09	95	EISENBERG	74	HBC	$4.9 \pi^+ \rho \rightarrow \Delta^{++} f_2$
$\Gamma(4\pi^0)/\Gamma_{\rm total}$					Г ₆ /Г
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.0030±0.0010 OUR					
0.003 ±0.001	400 \pm	ALDE	87	GAM4	$100 \pi^- p \rightarrow 4\pi^0 n$
	50				
$\Gamma(\eta\pi\pi)/\Gamma(\pi\pi)$					Γ_8/Γ_1
VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.010	95	EMMS	75D	DBC	$4 \pi^+ n \rightarrow pf_2$
=(14014-1	\				
$\Gamma(K^0K^-\pi^++c.c.$					Γ_9/Γ_1
VALUE	CL%_	DOCUMENT ID		TECN	COMMENT
<0.004	95	EMMS	75D	DBC	$4 \pi^+ n \rightarrow \rho f_2$

		72(14	TO) KEI EKENCES
PROKOSHKIN	94	SPD 39 420	+Kondashov (SERP)
		Translated from DANS	
BEHREND	92	ZPHY C56 381	(CELLO Collab.)
BLINOV	92	ZPHY C53 33	+Bondar, Bukin+ (NOVO)
ADAMO	91	Hadron 91 Conf.	+Agnello, Balestra+ (OBELIX Collab.)
AGUILAR	91	ZPHY C50 405	Aguilar-Benitez, Allison, Batalor+ (LEBC-EHS Collab.)
AKER	91	PL B260 249	+Amsler, Peters+ (Crystal Barrel Collab.)
ADACHI	90D	PL B234 185	+Doser+ (TOPAZ Collab.)
ALBRECHT	90G	ZPHY C48 183	+Ehrlichmann, Harder+ (ARGUS Collab.)
BOYER	90	PR D42 1350	+Butler+ (Mark II Collab.)
BREAKSTONE		ZPHY C48 569	+ (ISU, BGNA, CERN, DORT, HEIDH, WARS)
MARSISKE	90	PR D41 3324	+Antreasyan+ (Crystal Ball Collab.)
MORGAN	90	ZPHY C48 623	+Pennington (RAL, DURH)
OEST	90	ZPHY C47 343	+Olsson+ (JADE Collab.)
AUGUSTIN	89	NP B320 1	+Cosme (DM2 Collab.)
VOROBYEV	88	SJNP 48 273 Translated from YAF 4	+Golubev, Dolinsky, Druzhinin+ (NOVO)
ALDE	87	PL B198 286	+Binon, Bricman+ (LANL, BRUX, SERP, LAPP)
AUGUSTIN	87	ZPHY C36 369	+Cosme+ (LALO, CLER, FRAS, PADO)
ABACHI	86B	PRL 57 1990	+Derrick, Blockus+ (PURD, ANL, IND, MICH, LBL)
AIHARA	86B	PRL 57 404	+Alston-Garnjost+ (TPC-2γ Collab.)
ALDE	86D	NP B269 485	+Binon, Bricman+ (BELG, LAPP, SERP, CERN, LANL)
LANDRO	86	PL B172 445	+Mork, Olsen (UTRO)
LONGACRE	86	PL B177 223	+Etkin+ (BNL, BRAN, CUNY, DUKE, NDAM)
LYTH	85	JPG 11 459	
BEHREND	84B	ZPHY C23 223	+Fenner, Schachter, Schroeder+ (CELLO Collab.)
BERGER	84	ZPHY C26 199	+Klovning, Burger+ (PLUTO Collab.)
COURAU	84	PL 147B 227	+Johnson, Sherman, Atwood, Baillon+ (CIT, SLAC)
SMITH	84 C	PR D30 851 .	+Burke, Abrams, Blocker, Levi+ (SLAC, LBL, HARV)
BINON	83	NC 78A 313	+Donskov, Duteil+ (BELG, LAPP, SERP, CERN)
Also	83B	SJNP 38 561	Binon, Gouanere+ (BELG, LAPP, SERP, CERN)
CHADAHD	83	Translated from YAF 3 NP B223 1	
CHABAUD DENNEY	83	PR D28 2726	+Gorlich, Cerrada+ (CERN, CRAC, MPIM) +Cranley, Firestone, Chapman+ (IOWA, MICH)
FRAZER	83	Aachen Conf.	(UCSD)
MENNESSIER	83	ZPHY C16 241	(MONP)
APEL.	82	NP B201 197	+Augenstein+(KARLK, KARLE, PISA, SERP, WIEN, CERN)
CASON	82	PRL 48 1316	+Biswas, Baumbaugh, Bishop+ (NDAM, ANL)
EDWARDS	82F	PL 110B 82	+Partridge, Peck+ (CIT, HARV, PRIN, STAN, SLAC)
ETKIN	82B	PR D25 1786	+Foley, Lai+ (BNL, CUNY, TUFTS, VAND)
BRANDELIK	81B	ZPHY C10 117	+Boerner+ (TASSO Collab.)
CHABAUD	81	APP B12 575	+Niczyporuk, Becker+ (CERN, CRAC, MPIM)
GIDAL	81	PL 107B 153	+Goldhaber, Guy, Millikan, Abrams+ (SLAC, LBL)
ROUSSARIE	81	PL 105B 304	+Burke, Abrams, Alam+ (SLAC, LBL)
BERGER	80B	PL 94B 254	+Genzer+ (PLÚTO Collab.)
COSTA	80	NP B175 402	Costa De Beauregard+ (BARI, BONN, CERN+)
LOVERRE	80	ZPHY C6 187	+Armenteros, Dionisi+ (CERN, CDEF, MADR, STOH)
CORDEN	79	NP B157 250	+Dowell, Garvey+ (BIRM, RHEL, TELA, LOWC)
MARTIN	79	NP B158 520	+Ozmutlu (DURH)
POLYCHRO	79	PR D19 1317	Polychronakos, Cason, Bishop+ (NDAM, ANL)
PDG	78	PL 75B	Bricman+
ANTIPOV	77	NP B119 45	+Busnello, Damgaard, Kienzle+ (SERP, GEVA)
PAWLICKI	77	PR D15 3196	+Ayres, Cohen, Diebold, Kramer, Wicklund (ANL)
DEUTSCH	76	NP B103 426	Deutschmann+ (AACH3, BERL, BONN, CERN+)
APEL.	75	PL 57B 398	+Augenstein+(KARLK, KARLE, PISA, SERP, WIEN, CERN)

 $^{^{24}}$ Re-evaluated by CHABAUD 83. 25 Includes PAWLICKI 77 data. 26 Takes into account the $f_2(1270)$ - $f_2^{\prime}(1525)$ interference.

EMMS	75D	NP B96 155	+Kinson, Stacey, Votruba+ (BIRM, DURH, RHEL)
EISENBERG	74	PL 52B 239	+Engler, Haber, Karshon+ (REHO)
ENGLER	74	PR D10 2070	+Engler, Haber, Karshon+ (REHO) +Kraemer, Toaff, Weisser, Diaz+ (CMU, CASE)
LOUIE	74	PL 48B 385	+Alitti, Gandois, Chaloupka+ (SACL, CERN)
ANDERSON	73	PRL 31 562	+Engler, Kraemer, Toaff, Diaz+ (CMU, CASE)
TAKAHASHI	72	PR D6 1266	+Barish+ (TOHOK, PENN, NDAM, ANL)
BEAUPRE	71	NP B28 77	+Deutschmann, Graessler+ (AACH, BERL, CERN)
FLATTE		PL 34B 551	+Alston-Garniost Barbaro-Galtieri+ (IRI)
ARMENISE		LNC 4 199	+Alston-Garnjost, Barbaro-Galtieri+ +Ghidini, Foring, Cartacci+ +Garfinkel, Morse, Walker, Prentice (WISC, TNTO) JP
OH	70	PR D1 2494	+Garfinkel Morse Walker Prentice (MISC TNTO) ID
STUNTEBECK		PL 32B 391	+Kenney, Deery, Biswas, Cason+ (NDAM)
			+ Keilley, Deery, Diswas, Casoli+ (NDAW)
ADERHOLZ	69	NP B11 259	+Bartsch+ (AACH3, BERL, CERN, JAGL, WARS)
ARMENISE	68	NC 54A 999	+Bartsch+ (AACH3, BERL, CERN, JAGL, WARS) +Ghidini, Forino+ (BARI, BGNA, FIRZ, ORSAY)
ASCOLI	68D	PRL 21 1712	+Crawley, Mortara+ (ILL)
BOESEBECK	68	NP B4 501	+Deutschmann+ (AACH, BERL, CERN)
JOHNSON	68	PR 176 1651	+Crawley, Mortara+ (ILL) +Deutschmann+ (AACH, BERL, CERN) +Poirier, Biswas, Gutay+ (NDAM, PURD, SLAC)
EISNER	67	PR 164 1699	+Johnson, Klein, Peters, Sahni, Yen+ (PURD)
RABIN .	67	Thesis	(RUTG)
DERADO	65	PRL 14 872	+Kenney, Poirier, Shephard (NDAM) +Roe, Sinclair, VanderVelde (MICH)
LEE	64	PRL 12 342	+Roe Sinclair VanderVelde (MICH)
BONDAR	63	PL 5 153	+ (AACH, BIRM, BONN, DESY, LOIC, MPIM)
DONORIN	03	1 6 3 133	(AACH, DINN, DONN, DEST, LOIC, MIT IN)

 $f_1(1285)$

$$I^{G}(J^{PC}) = 0^{+}(1^{+})$$

f. ((1285)	MASS

f ₁ (1285) MASS									
VALUE (N			EVTS		DOCUMENT ID		TECN CHG		
1282.	2±	0.7	OUR AVERAGE		ror includes sca below.	le fa	ctor of 1.7. Se	e the ideogram	
1280	±	2			ANTINORI	95	OMEG	300,450 $pp \rightarrow pp2(\pi^{+}\pi^{-})$	
1282.	2 ±	1.5			LEE	94	MPS2	$18 \frac{\pi^{-} \rho}{K^{+} \overline{K}^{0} 2\pi^{-} \rho}$	
1279	±	5			FUKUI	9 10	SPEC	$8.95 \pi^- p \rightarrow \\ \eta \pi^+ \pi^- n$	
1278	±	2	140		ARMSTRONG	89	OMEG	$300 pp \rightarrow K\overline{K}\pi pp$	
1278	±	2			ARMSTRONG	89G	OMEG	85 $\pi^+ \rho \rightarrow 4\pi \pi \rho, \rho \rho \rightarrow 4\pi \rho \rho$	
1280.	1 ±	2.1	60		RATH	89	MPS	$ \begin{array}{c} 21.4 \ \pi^{-} p \rightarrow \\ K_{S}^{0} K_{S}^{0} \pi^{0} n \end{array} $	
1285	±	1	4750	2	BIRMAN	88	MPS	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	
1280	±	1	504		BITYUKOV	88	SPEC	32.5 $\pi^- \rho \rightarrow K^+ K^- \pi^0 n$	
1280	±	4			ANDO	86	SPEC	$ \begin{array}{c} 8 \pi^- \rho \to \\ n\eta \pi^+ \pi^- \end{array} $	
1277	±	2	420		REEVES	86	SPEC	6.6 <i>p</i> p → <i>K K</i> π X	
1285	\pm	2			CHUNG	85	SPEC	$8 \pi^- \rho N K \overline{K} \pi$	
1279	±	2	604		ARMSTRONG	84	OMEG	85 $\pi^+ p \rightarrow K \overline{K} \pi \pi p, p \rightarrow$	
1287	±	5	353		вітикоу	84	SPEC	$ \begin{array}{c} K\overline{K}\pi\rho\rho\\ 32\pi^{-}\rho\rightarrow\\ K^{+}K^{-}\pi^{0}n \end{array} $	
1286	\pm	1			CHAUVAT	84	SPEC	ISR 31.5 pp	
1278	±	4		-	EVANGELISTA	81	OMEG	$12 \pi^- p \rightarrow \\ \eta \pi^+ \pi^- \pi^- p$	
1283	±	3	103		DIONISI	80	HBC	$ \begin{array}{c} 4 \ \pi^{-} p \rightarrow \\ K \overline{K} \pi n \end{array} $	
1282		2	320		NACASCH	78	HBC	$\begin{array}{c} 0.7, 0.76 \ \overline{p}p \rightarrow \\ K\overline{K}3\pi \end{array}$	
1279 1286	土	5 3	210 180		GRASSLER DUBOC	77 72	HBC HBC	$16 \pi^{\mp} p$ $1.2 \overline{p} p \rightarrow 2K4\pi$	
1283	±:		100		DAHL	67	HBC	$1.6-4.2 \pi^{-} p$	
• • • V	√e d	o no	ot use the following	da	ita for averages	, fits	, limits, etc. •		
1270	± 1	.0			AMELIN	95	VES	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	
1280	±	2		,	ABATZIS	94	OMEG	$450 pp \rightarrow pp2(\pi^{+}\pi^{-})$	
1282	±				ARMSTRONG			$\overline{p} p \rightarrow \pi^0 \eta \eta \rightarrow 6\gamma$	
1270			±10		ARMSTRONG			$\begin{array}{c} 300 \ \rho \rho \rightarrow \\ \rho \rho \pi^{+} \pi^{-} \gamma \end{array}$	
1264	±	8		,	AUGUSTIN	90	DM2	$J/\psi \rightarrow \gamma \eta \pi^+ \pi^-$	
1284	±	4			TAKAMATSU	90	SPEC 0	$8 \pi^- \rho \rightarrow K K \pi n$	
1281	±	1		,	ARMSTRONG	89E	OMEG	$300 \stackrel{p}{p} \stackrel{\rightarrow}{\rightarrow} p p 2(\pi^+ \pi^-)$	
1279	±	6	±10 16		BECKER	87	MRK3	$e^+e^- \rightarrow \phi K \overline{K} \pi$	
1286	±	9		(GIDAL	87	MRK2	$e^+e^{e^+e^-\eta\pi^+\pi^-}$	
$\sim 1279\\1275$	±	6	31		TORNQVIST BROMBERG	82B 80	RVUE SPEC	$100 \pi^{-} p \rightarrow K\overline{K}\pi X$	

1288	± 9	200	GURTU	79	нвс	$4.2 K^- p \rightarrow$
~ 1275.0)	46	STANTON	79	CNTR	$ \begin{array}{c} n\eta 2\pi \\ 8.5 \pi^- p \rightarrow \\ 72 \times 2^- \end{array} $
1271	± 10	34	CORDEN	78	OMEG	$ \begin{array}{c} n2\gamma 2\pi \\ 12-15 \pi^{-} \rho \rightarrow \\ K^{+} K^{-} \pi n \end{array} $
1295	± 12	85	CORDEN	78	OMEG	$K^+K^-\pi n$ $12-15 \pi^-\rho \rightarrow$ $n5\pi$
1292	±10	150	DEFOIX	72	HBC	$0.7 \overline{p}p \rightarrow 7\pi$
1280	± 3	500	THUN	72	MMS	13.4 $\pi^{-}p$
1303	± 8		BARDADIN	71	нвс	$8 \pi^+ p \rightarrow p6\pi$
1283	± 6		BOESEBECK	71	HBC	$16.0 \pi p \rightarrow p5\pi$
1270	± 10		CAMPBELL	69	DBC	$2.7 \pi^{+} d$
1285	± 7		LORSTAD	69	HBC	0.7 \overline{p} p, 4,5-body
1290	± 7		D'ANDLAU	68	HBC	1.2 p̄ p, 5−6 body

WEIGHTED AVERAGE 1282.2±0.7 (Error scaled by 1.7)			
——————————————————————————————————————	95	OMEG ⁻	χ ²
- 1- · · · · · · LEE	94	MPS2	0.0
	91C	SPEC	0.4
— I ↑ · · · · · · · · · ARMSTRONG	89	OMEG	4.4
-+/ \········ARMSTRONG		OMEG	4.4
-/+\- · · ∧ · · · · · RATH	89	MPS	1.0
/ \ BIRMAN	88	MPS	7.9
H BITYUKOV	88	SPEC	4.8
- I - ANDO	86	SPEC	0.3
-++ ·\··············REEVES	86	SPEC	6.7
/ CHUNG	85	SPEC	2.0
+ V······ ARMSTRONG	84	OMEG	2.5
BITUKOV	84	SPEC	0.9
+ CHAUVAT	84	SPEC	14.6
- + - EVANGELISTA		OMEG	1.1 0.1
- I DIONISI	80 78	HBC HBC	0.0
- GRASSLER	77	HBC	0.0
- DUBOC	72	HBC	1.6
/ DOBOC	67	HBC	0.0
) DANE	07	HBC _	
/ / /			54.3
(Cor	maen	ce Level	0.001)
1265 1270 1275 1280 1285 1290 1295 1300			
$f_1(1285) \; {\sf mass} \; ({\sf MeV})$			

f₁(1285) WIDTH

Only experiments giving width error less than 20 MeV are kept for aver-

24.8± 1.3 OUR	AVERAGE	DOCUMENT ID Error includes scale	fact	<u>TECN</u> <u>CH</u> or of 1.3. Se	
36 ± 5		⁶ ANTINORI	95	OMEG	300,450 pp →
					$pp2(\pi^{+}\pi^{-})$
29.0 ± 4.1		LEE	94	MPS2	18 π ⁻ p →
					$K^+\overline{K}^02\pi^-$
25 ± 4	140	ARMSTRONG	89	OMEG	300 pp →
		7			$KK\pi pp$
22 ± 2	4750	⁷ BIRMAN	88	MPS	$8 \pi^- p \rightarrow$
25 ± 4	504	BITYUKOV	88	SPEC	$K^+\overline{K}^0\pi^-n$ 32.5 $\pi^-p \rightarrow$
25 1 4	304	BITTOROV	00	31 LC	$K^+K^-\pi^0$
19 ± 5		ANDO	86	SPEC	$8\pi^-p \rightarrow$
					$n\eta\pi^{+}\pi^{-}$
32 ± 8	420	REEVES	86	SPEC	6.6 $p\overline{p} \rightarrow$
22 + 2		CHUNG	85	SPEC	$KK\pi X$ 8 $\pi^- p \rightarrow$
22 ± 2		CHUNG	00	SPEC	$NK\overline{K}\pi$
32 ± 3	604	ARMSTRONG	84	OMEG	85 $\pi^+ p \rightarrow$
					$K \overline{K} \pi \pi \rho$,
					$p p \rightarrow$
24 ± 3		CHAUVAT	84	SPEC	$K\overline{K}\pi pp$ ISR 31.5 pp
24 ± 3 29 ±10	103	DIONISI	80	HBC	$4 \pi^- \rho \rightarrow$
27 X 1U	103	DIOMISI .	00	пьс	$4 \pi \rho \rightarrow K K \pi n$
28.3± 6.7	320	NACASCH	78	HBC	$0.7,0.76 \overline{p}p \rightarrow$
		ng data for averages			$K\overline{K}3\pi$

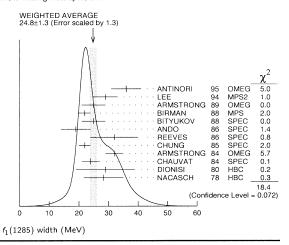
¹ Supersedes ABATZIS 94, ARMSTRONG 89E. 2 From partial wave analysis of $K^+\overline{K}^0\pi^-$ system. 3 From a unitarized quark-model calculation. 4 From phase shift analysis of $\eta\pi^+\pi^-$ system. 5 Seen in the missing mass spectrum.

$f_1(1285)$

40	± 5					ABATZIS	94	OMEG		450 <i>pp</i> →
44	±20					AUGUSTIN	90	DM2		$\rho \rho 2(\pi^+\pi^-)$ $J/\psi \rightarrow$
										$\gamma \eta \pi^+ \pi^-$
22	± 5					TAKAMATSU	90	SPEC	0	$8 \pi^- p \rightarrow KK\pi p$
<20			90			TAKAMATSU	90	SPEC	0	$8.95 \pi^- p \rightarrow$
(=0										$\eta \pi^+ \pi^- \eta$
31	± 5					ARMSTRONG	89E	OMEG		300 pp →
										$pp2(\pi^{+}\pi^{-})$
41	± 12					ARMSTRONG	89G	OMEG		85 $\pi^+ p \rightarrow$
										$4\pi\pi\rho, \rho\rho \rightarrow$
						DATU	00	MDC		4πρρ
17.	9 ± 10 .	9		60		RATH	89	MPS		$21.4 \pi^- p \rightarrow 0.00$
										$K_{S}^{0}K_{S}^{0}\pi^{0}$ n
14	+20	± 10		16		BECKER	87	MRK3		e+e→
						E) /4 11 CE 1 CE 1		01456		$\phi K \overline{K} \pi$
26	±12					EVANGELISTA	81	OMEG		$12 \pi^- p \rightarrow$
25	1.15			200		GURTU	79	нвс		$\eta \pi^+ \pi^- \pi^- p$ 4.2 $K^- p \rightarrow$
25	± 15			200		GURIU	19	нвс		$n\eta 2\pi$
~ 10					8	STANTON	79	CNTR		8.5 π ⁻ p →
										$n2\gamma 2\pi$
24	± 18			210	-	GRASSLER	77	HBC		16 π [∓] p
28	± 5			150		DEFOIX	72	HBC		$0.7 \overline{p} p \rightarrow 7\pi$
46	± 9			180		DUBOC	72	HBC		$1.2 \overline{p} p \rightarrow 2K4\pi$
37	± 5			500	10	THUN	72	MMS		13.4 $\pi^{-}p$
10	± 10					BOESEBECK		HBC		$16.0 \pi p \rightarrow p5\pi$
30	± 15				_	CAMPBELL		DBC		$2.7 \pi^{+} d$
60	± 15					LORSTAD		HBC		0.7 \overline{p} p , 4,5-body
35	± 10				9	DAHL	67	HBC		$1.6-4.2 \pi^{-} p$

⁶ Supersedes ABATZIS 94, ARMSTRONG 89E.

 $^{^{10}}$ Seen in the missing mass spectrum.



f₁(1285) DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Scale factor/ Confidence level
Γ_1	4π	(29 ± 6)%	
Γ_2	$\pi^0 \pi^0 \pi^+ \pi^-$	(15 + 9) %	S=1.1
Γ_3	$2\pi^+2\pi^-$	(15 \pm 6) %	
Γ4	$ \rho^{0} \pi^{+} \pi^{-} $	dominates $2\pi^+$ $2\pi^-$	
Γ ₅	$4\pi^0$	< 7 × 10	-4 CL=90%
Γ_6	$\eta \pi \pi$	(54 ±15)%	
Γ ₇	$a_0(980)\pi$ [ignoring $a_0(980) \rightarrow K\overline{K}$]	(44 ± 7)%	S=1.1
Γ ₈	$\eta \pi \pi$ [excluding $a_0(980)\pi$]	$(10 + \frac{7}{6})\%$	S=1.1
Г9	$K\overline{K}\pi$	(9.7 ± 1.6) %	S=1.2
Γ ₁₀	K K *(892)	not seen	
Γ11	$\gamma \rho^0$	(6.6 ± 1.3) %	S=1.5
Γ ₁₂	$\phi \gamma$	$(8.0 \pm 3.1) \times 10^{-1}$	- 4
Γ_{13}	$\gamma \gamma^*$		
Γ_{14}	$\gamma \gamma$		

CONSTRAINED FIT INFORMATION

An overall fit to 7 branching ratios uses 13 measurements and one constraint to determine 6 parameters. The overall fit has a χ^2 = 11.4 for 8 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\left<\delta x_i \delta x_j \right>/(\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv$ $\Gamma_i/\Gamma_{
m total}$. The fit constrains the x_i whose labels appear in this array to sum to

$f_1(1285) \Gamma(i)\Gamma(\gamma\gamma)/\Gamma(total)$

$\Gamma(\eta \pi \pi) \times \Gamma(\gamma \gamma) / \Gamma_{\text{total}}$					$\Gamma_6\Gamma_{14}/\Gamma = (\Gamma_7 + \Gamma_8)\Gamma_{14}/\Gamma$		
VALUE (keV)	CL%	DOCUMENT ID		TECN	COMMENT		
<0.62	95	GIDAL	87	MRK2	$\frac{e^+e^-}{e^+e^-\eta\pi^+\pi^-}$		

$\Gamma(\eta\pi\pi)\times\Gamma(\gamma\gamma^*)$	/Γ _{total}			Γ ₆ Γ	$_{13}/\Gamma = (\Gamma_7 + \Gamma_8)\Gamma_{13}/\Gamma$
VALUE (keV)	EVTS	DOCUMENT ID		TECN	COMMENT
1.4 ±0.4 OUR AVERA		ncludes scale fac	ctor	of 1.4.	
$1.18 \pm 0.25 \pm 0.20$	26 11,12	AIHARA	88B	TPC	$e^+e^{e^+e^-\eta\pi^+\pi^-}$
$2.30 \pm 0.61 \pm 0.42$	11,13	GIDAL	87	MRK2	$e^{+}e^{-}\eta\pi^{+}\pi^{-}$ $e^{+}e^{-}_{e^{+}e^{-}\eta\pi^{+}\pi^{-}}$

 11 Assuming a $\rho\text{-pole}$ form factor.

1

- Published value multiplied by $\eta \pi \pi$ branching ratio 0.49.
- $^{13}\,\text{Published}$ value divided by 2 and multiplied by the $\eta\,\pi\,\pi$ branching ratio 0.49.

f1(1285) BRANCHING RATIOS

$\Gamma(KK\pi)/\Gamma(4\pi)$			$\Gamma_9/\Gamma_1 = \Gamma_9/(\Gamma_2 + \Gamma_3)$
VALUE	DOCUMENT ID	TECN	COMMENT
0.33 ± 0.04 OUR FIT	Error includes scale factor of 1.2.		
0.32 ± 0.04 OUR AVE	RAGE Error includes scale factor of	of 1.2.	
0.28 ± 0.05			$300 pp \rightarrow ppf_1(1285)$
$0.37 \pm 0.03 \pm 0.05$	¹⁵ ARMSTRONG 89G	OMEG	$85 \pi \rho \rightarrow 4\pi X$
14 Assuming $\rho\pi\pi$ an	d $a_0(980)\pi$ intermediate states.		
$^{15}4\pi$ consistent with			

 $\Gamma\big(\boldsymbol{K}\,\overline{\boldsymbol{K}}\,\boldsymbol{\pi}\big)/\Gamma\big(\eta\,\boldsymbol{\pi}\,\boldsymbol{\pi}\big)$ $\Gamma_9/\Gamma_6=\Gamma_9/(\Gamma_7{+}\Gamma_8)$ 0.18±0.04 OUR FIT Error includes scale factor of 1.1. COMMENT

0.23±0.06 OUR AVERAGE Error includes scale factor of 1.2. 0.42 ± 0.15 GURTU 79 HBC CORDEN 78 OMEG 12-15 π⁻ p 0.5 ± 0.2 0.20 ± 0.08 ¹⁶ DEFOIX 72 HBC $0.7 \, \overline{p} \, p \rightarrow 7\pi$ CAMPBELL 69 DBC $2.7 \pi^{+} d$ 0.16 ± 0.08

 $^{16}\, \kappa\, \overline{K}$ system characterized by the I=1 threshold enhancement. (See under $a_0(980)$).

 $\Gamma(a_0(980)\pi \text{ [ignoring } a_0(980) \rightarrow K\overline{K}])/\Gamma(\eta\pi\pi)$ $\Gamma_7/\Gamma_6 = \Gamma_7/(\Gamma_7 + \Gamma_8)$
 VALUE
 DOCUMENT ID
 TECN
 COMMENT

 0.82±0.12 OUR FIT
 Error includes scale factor of 1.1.
 TECN
 COMMENT

 $0.69^{+0.13}_{-0.12}$ OUR AVERAGE

 $1.0\ \pm0.3$

 0.72 ± 0.15 GURTU 79 HBC 4.2 K-p $0.6 \begin{array}{c} +0.3 \\ -0.2 \end{array}$ CORDEN 78 OMEG 12-15 $\pi^- p$

• • • We do not use the following data for averages, fits, limits, etc. • • GRASSLER 77 HBC 16 $\pi^{\mp}\,p$

 $\Gamma(4\pi)/\Gamma(\eta\pi\pi)$ $\Gamma_1/\Gamma_6 = (\Gamma_2 + \Gamma_3)/(\Gamma_7 + \Gamma_8)$
 VALUE
 DOCUMENT ID

 0.54±0.12 OUR FIT
 Error includes scale factor of 1.1.
 TECN COMMENT 0.41 ± 0.14 OUR AVERAGE $0.37 \pm 0.11 \pm 0.11$ ROLTON 92 MRK3 $J/\psi
ightarrow \gamma f_1(1285)$ 0.64 ± 0.40 GURTU 79 HBC 4.2 K - p • • • We do not use the following data for averages, fits, limits, etc. • • •

 17 GRASSLER 77 HBC 16 π^{\mp} p $^{17}\,\mathrm{Assuming}\;\rho\,\pi\,\pi$ and $a_0(980)\,\pi$ intermediate states.

 $\Gamma(K\overline{K}^*(892))/\Gamma_{total}$ Γ_{10}/Γ VALUE DOCUMENT ID TECN COMMENT 78 HBC 0.7,0.76 $\overline{p}p \rightarrow K\overline{K}3\pi$ not seen NACASCH

 $^{^7\,\}mathrm{From}$ partial wave analysis of $K^+\,\overline{K}{}^0\,\pi^-$ system.

 $^{^{8}\,\}mathrm{From}$ phase shift analysis of $\eta\,\pi^{+}\,\pi^{-}$ system.

Resolution is not unfolded.

$\Gamma(ho^0\pi^+\pi^-)/\Gamma(2\pi$	$^{-}2\pi^{-})$					Γ_4/Γ_3
• • • We do not use	the following	DOCUMENT ID			COMMENT	
1.0±0.4	the following	GRASSLER	77	HBC	16 GeV π [±] μ	
		GRASSLER	"	пвс	10 GeV % p	
$\Gamma(4\pi^0)/\Gamma_{ ext{total}}$						Γ ₅ /Γ
VALUE (units 10 ⁻⁴)	CL%	DOCUMENT ID		TECN	COMMENT	
<7	90	ALDE	87	GAM4	100 $\pi^- p \rightarrow$	$4\pi^0 n$
$\Gamma(\phi\gamma)/\Gamma(K\overline{K}\pi)$						Γ_{12}/Γ_{9}
VALUE (units 10 ⁻²)		DOCUMEN			CN COMMEN	
0.82±0.21±0.20	19	BITYUKO				$(-\pi^0)_n$
• • We do not use			s, tits			
<0.93	95	AMELIN		95 V	ES 37 π N π π	$+\stackrel{\rightarrow}{\pi} - \gamma N$
$\Gamma(\gamma \rho^0)/\Gamma(K\overline{K}\pi)$						Γ_{11}/Γ_{9}
VALUE	CL%	DOCUMENT ID		TECN	COMMENT	
• • We do not use				, limits,	etc. • • •	
>0.035	90 1	⁸ COFFMAN	90	MRK3	$J/\psi ightarrow \gamma \gamma \pi$	$+\pi^-$
¹⁸ Using B($J/\psi \rightarrow \gamma K \overline{K} \pi$)=< 0.72 >	$\gamma f_1(1285) = 10^{-3}$.	$\gamma \gamma \rho^0$)=0.25	× 10	−4 and	$B(J/\psi \rightarrow \gamma)$	$f_1(1285) \rightarrow$
$\Gamma(\gamma \rho^0)/\Gamma(2\pi^+2\pi^-)$	-)	DOCUMENT ID		TECH	COLUMENT	Γ_{11}/Γ_3
VALUE 0.45±0.18 OUR FIT		DOCUMENT ID		IECN	COMMENT	
0.45±0.18	1	⁹ COFFMAN	90	MRK3	$J/\psi \rightarrow \gamma \gamma \pi$	+ _π -
¹⁹ Using B($J/\psi \rightarrow \gamma 2\pi^+ 2\pi^-$)=0.55			× 10	-4 and	$B(J/\psi \rightarrow \gamma)$	$f_1(1285) \rightarrow$
$\Gamma(\gamma \rho^0)/\Gamma(a_0(980)$	_	-	K])			Γ ₁₁ /Γ ₇
VALUE		DOCUMENT ID		<u>TECN</u>	COMMENT	
0.15±0.04 OUR FIT 0.10±0.03±0.02		es scale factor of DBURCHELL		MDIZA	$J/\psi \rightarrow \gamma \eta \pi$	+
²⁰ Uses a result from $a_0(980) \rightarrow \eta \pi$.	m COFFMAI	N 90, and incli	ides	an unk	nown branchir	ig ratio for
$\Gamma(\gamma ho^0)/\Gamma_{ m total}$						Γ_{11}/Γ
VALUE	<u>CL%</u>	DOCUMENT ID		TECN	COMMENT	
0.028±0.007±0.006	5	AMELIN	95	VES	37 π N →	γΝ
• • We do not use t	he following	data for average	s, fits	, limits,		· γ / V
<0:05	95				32 π ⁻ p → 3	$\pi^+\pi^-\gamma n$
$\Gamma(\eta\pi\pi)/\Gamma(\gamma ho^0)$					$_{6}/\Gamma_{11} = (\Gamma_{7}$	+Γ ₈)/Γ ₁₁
VALUE		DOCUMENT ID		TECN	COMMENT	***************************************
8.2±1.6 OUR FIT E 7.5±1.0		scale factor of 1. ARMSTRONG		OMEG	$300 pp \rightarrow p$ $ppn\pi^{+}\pi$	
21 Published value mu	ultiplied by 1.	5.			ρρηπ · π	
	£/1	285) REFERE	NCE	:<		
MELIN 95 7PHS	C66 71	+Berdnikov+				S Collab)

AMELIN	95	ZPHY C66 71	+Berdnikov+	(VES Collab.)
ANTINORI	95	PL B353 589		THU, BARI, BIRM, CERN, JINR)
ABATZIS	94	PL B324 509		THU, BARI, BIRM, CERN, JINR)
LEE	94	PL B323 227		(BNL, IND, KYUN, MASD, RICE)
ARMSTRONG	93C	PL B307 394		AL, FERR, GENO, UCI, NWES+)
ARMSTRONG	92C	ZPHY C54 371		THU, BARI, BIRM, CERN, CDEF)
BOLTON	92	PL B278 495	+Brown, Bunnell+	(Mark III Collab.)
BITYUKOV	91B	SJNP 54 318	+Borisov, Viktorov+	(SERP)
5	,,,	Translated from YAF 5		(SEM)
BURCHELL	91	NP B21 132 (suppl)		(Mark III Collab.)
FUKUI	91C	PL B267 293	+ (SUGI, N	IAGO, KEK, KYÖT, MIYA, AKIT)
AUGUSTIN	90	PR D42 10	+Cosme+	(DM2 Collab.)
COFFMAN	90	PR D41 1410	+De Jongh+	(Mark III Collab.)
TAKAMATSU	90	Hadron 89 Conf. p 71		(KEK)
ARMSTRONG	89	PL B221 216		F, BIRM, BARI, ATHU, CURIN+) JPC
ARMSTRONG	89E	PL B228 536		I, BIRM, CERN, CDEF, CURIN+)
ARMSTRONG	89G	ZPHY C43 55		N, BIRM, BARI, ATHU, CURIN+)
RATH	89	PR D40 693		AM, BRAN, BNL, CUNY, DUKE)
AIHARA	88B	PL B209 107	+Alston-Garniost+	(TPC-2γ Collab.)
BIRMAN	88	PRL 61 1557	+Chung, Peaslee+	(BNL, FSU, IND, MASD) JP
BITYUKOV	88	PL B203 327	+Borisov, Dorofeev+	(SERP)
MIR	88	Photon-Photon 88 Cont		(Mark III Collab.)
ALDE	87	PL B198 286	+Binon, Bricman+	(LANL, BRUX, SERP, LAPP)
BECKER	87	PRL 59 186	+Blaylock, Bolton, Brown	
GIDAL	87	PRL 59 2012	+Boyer, Butler, Cords, Ab	orams+ (LBL, SLAC, HARV)
ANDO	86	PRL 57 1296		OT, NIRS, SAGA, INUS, TSUK+) IJP
REEVES	86	PR 34 1960	+Chung, Crittenden+	(FLOR, BNL, IND, MASD) JP
CHUNG	85	PRL 55 779	+Fernow, Boehnlein+	(BNL, FLOR, IND, MASD) JP

			<u> </u>
ARMSTRONG BITUKOV CHAUVAT TORNQVIST EVANGELISTA BROMBERG DIONISI GURTU STANTON CORDEN NACASCH GRASSLER DEFOIX DUBOC THUN BARDADIN BOESEBECK CAMPBELL LORSTAD D'ANDLAU DAHL	84 84 82B	PL 146B 273 PL 144B 133 PL 144B 133 PL 148B 382 NP 8103 268 NP 8178 197 PR D22 1513 NP 8169 1 NP 8151 181 PRL 42 346 NP 8113 203 NP 8152 189 NP 844 125 NP 8164 299 PRL 28 1733 PR 04 7271 PL 34B 659 RP 04 7271 PL 34B 659 NP 814 66 NP 85 693 NP 815 693 NP 815 693	+Bloodworth, Burns+ (ATHU, BARI, BIRM, CERN) JP +Dorofeev, Dzhejyadin, Golovkin, Kulik+ (SERP) +Meritet, Bonino+ (CERN, CLER, UCLA, SACL) + (BARI, BONN, CERN, DARE, LIVP+) +Haggerty, Abrams, Dzierba (CT, FNAL, ILLC, IND) +Gavillet+ (CERN, MADR, CDEF, STOH) +Gavillet, Blokzij+ (CERN, MADR, CDEF, STOH) +Brockman+ (OSU, CARL, MCGI, TNTO) JP +Corbett, Alexander+ (BIRM, RHEL, TELA, LOWC) JP +Defoix, Dobrzynski+ (PARIS, MADR, CERN) + (AACH3, BERL, BONN, CERN, CRAC, HEIDH+) +Nascimento, Bizzarri+ (CDEF, CERN) +Bileden, Finocchiaro, Bowen+ (STON, NEAS) Bardadin-Otwinowski, Mornokl+ (WARS) (AACH, BERL, BONN, CERN, CRAC, HEID, WARS) +Lichtman, Loeffler+ +D'Andlau, Astier+ +Astier, Barlow+ +Hardy, Hess, Kirz, Miller (CDEF, CERN) JP +Hardy, Hess, Kirz, Miller
		отн	HER RELATED PAPERS
AIHARA ASTON ATKINSON GAVILLET D'ANDLAU MILLER	85	PR D38 1 PR D32 2255 PL 138B 459 ZPHY C16 119 PL 17 347 PRL 14 1074	+Alston-Garnjost+ (TPC-2γ Collab.) JPC +Carnegie, Dunwoodie+ (SLAC, CARL, CNRC) + (BONN, CERN, GLAS, LANC, MCHS, CURIN+) +Armenteros+ (CERN, CDEF, PADO, ROMA) +Barlow, Adamson+ (CDEF, CERN, IRAD, LIVP) +Chung, Dahl, Hess, Hardy, Kirz+ (LRL, UCB)
η (129			$I^G(J^{PC}) = 0^+(0^{-+})$ ew under non- $q\overline{q}$ candidates. (See the index
DEFOIX DUBOC THUN BARDADIN BOESEBECK CAMPBELL LORSTAD D'ANDLAU D'ANDLAU D'ANDLAU AIHARA ASTON ATKINSON GAVILLET D'ANDLAU MILLER 7(129	72 72 72 71 71 69 69 68 67 88 85 85 84 82 65 65	NP B44 125 NP B46 429 PRL 28 1733 PR D4 2711 PL 348 659 PRL 22 1204 NP B14 63 NP B5 693 PR 163 1377 OTH PR D38 1 PR D32 2255 PL 1388 459 ZPHY C16 119 PL 17 347 PRL 14 1074	+ (AACH, BERL, BONN, CERN, CRAC, HEIDH-I) + Nascimento, Bizzario, Bonald+ (CDEF, CERN) + Glolberg, Makowski, Donald+ (CPARIS, LIVP) + Bileden, Finocchiano, Bowen+ (STON, NEAS) Bardadin-Otwinowska, Hofmokl+ (WARS) (AACH, BERL, BONN, CERN, CRAC, HEIDH-I) + CHORN, CERN, CRAC, HEIDH-I - (WARS) + Lichtman, Loeffler+ (PURD) + CDEF, CERN, CRAC, HEIDH-I - (PARIS) + CDEF, CERN, CRAC, HEIDH-I - (PARIS) + CDEF, CERN, CRAC, HEIDH-I - (WARS) + Lichtman, Loeffler+ (PAR) + CDEF, CERN, IRAD, LIVP) + Hardy, Hess, Kirz, Miller + Alston-Garnjost+ (SLAC, CARL, CNRC) + Carnegie, Dunwoodie+ (SLAC, CARL, CNRC) + Carnegie, Dunwoodie+ (SLAC, CARL, CNRC) + (BONN, CERN, GLAS, LANC, MCHS, CURIN+) + Armenteros+ (CERN, CDEF, PADO, ROMA) + Armenteros+ (CERN, CDEF, PADO, ROMA) + CPC (CERN, IRAD, LIVP) + Chung, Dahl, Hess, Hardy, Kirz+ (LRL, UCB)

for the page number.)

η(1295) MASS

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT	
1295±4	FUKUI	91c SPEC	8.95 $\pi^- p \rightarrow \eta$	$\pi^+\pi^-n$
• • We do not use the s	following data for averages	, fits, limits,	etc. • • •	
\sim 1275	STANTON	79 CNTR	8.4 $\pi^- p \rightarrow n\eta$	2π

η (1295) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
53±6	FUKUI	91 C	SPEC	8.95 $\pi^- p \rightarrow \eta \pi^+ \pi^- n$
• • We do not use the following the fol	owing data for averages	, fits	, limits,	etc. • • •
~ 70	STANTON	79	CNTR	$8.4 \pi^- p \rightarrow nn2\pi$

η (1295) DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ ₁ Γ ₂	$\eta \pi^+ \pi^ a_0(980)\pi$	seen seen
13	$\gamma \gamma$	

$\eta(1295) \Gamma(i)\Gamma(\gamma\gamma)/\Gamma(total)$

$\Gamma(\eta \pi^+ \pi^-) \times \Gamma(\gamma \gamma)/\Gamma_{total}$							
VALUE (keV)	CL%	DOCUMENT ID	TECN	COMMENT			
• • • We do not	t use the followin	g data for averages	, fits, limit	s, etc. • • •			
< 0.6	90	AIHARA	88C TPC	$e^+e^- \rightarrow e^+e^- \eta \pi^+$			
< 0.3		ANTREASYAN	87 CBAL	$e^+e^-\eta\pi^+$ $e^+e^-\to e^+$	$e^-\eta\pi\pi$		

$\eta(1295)$ BRANCHING RATIOS

$\Gamma(a_0(980)\pi)/\Gamma_{ ext{total}}$				Γ_2/Γ
VALUE	DOCUMENT ID		TECN	COMMENT
seen	BIRMAN	88	MPS	$8 \pi^- p \rightarrow K^+ \overline{K}{}^0 \pi^- n$
large	ANDO	86	SPEC	$8 \pi^- \rho \rightarrow n \eta \pi^+ \pi^-$
large	STANTON	79	CNTR	$8.4 \pi^- p \rightarrow n\eta 2\pi$

η (1295) REFERENCES

FUKUI AIHARA BIRMAN ANTREASYAN ANDO	88C 88	PL B267 293 PR D38 1 PRL 61 1557 PR D36 2633 PRL 57 1296	+Alston-Garnjost+ +Chung, Peaslee+ +Bartels, Besset+	D, KEK, KYOT, MIYA, AKIT) (TPC-2γ Collab.) (BNL, FSU, IND, MASD) JP (Crystal Ball Collab.) NIRS. SAGA. INUS. TSUK+) IJP
ANDO	86	PRL 57 1296	+Imai+ (KEK, KYOT,	NIRS, SAGA, INUS, TSUK+) IJP
STANTON	79	PRL 42 346	+Brockman+	(OSU, CARL, MCGI, TNTO) JP

 $\pi(1300)$, $a_2(1320)$

 $\pi(1300)$

VALUE (MeV)

$$I^{G}(J^{PC}) = 1^{-}(0^{-+})$$

TECN COMMENT

π (1300) MASS DOCUMENT ID

1300 ± 100 OUR ESTI	MATE			
• • • We do not use the	following data for averag	es, fits	, limits,	etc. • • •
1190 ± 30	ZIELINSKI	84	SPEC	$200 \pi^+ Z \rightarrow Z3\pi$
1240± 30	BELLINI	82	SPEC -	$40 \pi^- A \rightarrow A3\pi$
1273± 50	¹ AARON	81	RVUE	
1342 ± 20	BONESINI	81	OMEG	$12 \pi^- p \rightarrow p 3\pi$
a. 1400	DAHM	81R	SPEC	63 94 m n

 $^{\rm 1}$ Uses multichannel Aitchison-Bowler niodel (BOWLER 75). Uses data from DAUM 80 and DANKOWYCH 81.

π (1300) WIDTH

VALUE (MeV) 200 to 600 OUR EST	DOCUMENT ID		TECN	COMMENT
	he following data for averag	es, fits	, limits,	etc. • • •
440 ± 80	ZIELINSKI	84	SPEC	200 $\pi^+ Z \rightarrow Z 3\pi$
360 ± 120	BELLINI	82	SPEC	40 π^- A \rightarrow A 3π
580 ± 100	² AARON	81	RVUE	
220 ± 70	BONESINI	81	OMEG	$12 \pi^- p \rightarrow p3\pi$
~ 600	DAUM	81B	SPEC	63,94 m ⁻ p
~ 600 ² Uses multichannel	Aitchison-Bowler model (BC			

π (1300) DECAY MODES

	Mode	Fraction $(\Gamma_{\hat{I}}/\Gamma)$	
Γ ₁	ρπ	seen	
Γ_2	$\pi(\pi\pi)_{S\text{-wave}}$	seen	
Γ_3	$f_0(1370)\pi$		

π (1300) BRANCHING RATIOS

	` '	
$\Gamma(\pi(\pi\pi)_{S\text{-wave}})/$	$\Gamma(ho\pi)$	Γ_2/Γ_1
VALUE	DOCUMENT ID TECN	
• • • We do not use	the following data for averages, fits, limits, etc	. • • •
2.12	³ AARON 81 RVUE	

³ Uses multichannel Aitchison-Bowler model (BOWLER 75). Uses data from DAUM 80

π (1300) REFERENCES

ZIELINSKI BELLINI	84 82	PR D30 1855 PRL 48 1697	+Berg, Chandlee, Cihangir+ (ROCH, MINN, FNAL) +Frabetti, Ivanshin, Litkin+ (MILA, BGNA, JINR)
AARON	81	PR D24 1207	+Longacre (NEAS, BNL)
BONESINI	81	PL 103B 75	+Donald+ (MILA, LIVP, DARE, CERN, BARI, BONN)
DANKOWY	81	PRL 46 580	Dankowych+ (TNTO, BNL, CARL, MCGI, OHIO)
DAUM	81B	NP B182 269	+Hertzberger+ (AMST, CERN, CRAC, MPIM, OXF+)
DAUM	80	PL 89B 281	+Hertzberger+ (AMST, CERN, CRAC, MPIM, OXF+)
BOWLER	75	NP B97 227	+Game, Aitchison, Dainton (OXFTP, DARE)

 $a_2(1320)$

$$I^{G}(J^{PC}) = 1^{-}(2^{+})$$

a₂(1320) MASS

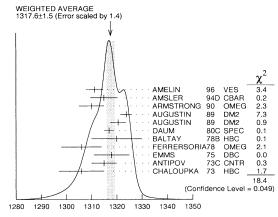
| VALUE (MeV) | DOCUMENT ID | Includes data from the 4 datablocks that follow this one. Error includes scale factor of 1.2.

3π MODE VALUE (MeV)

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
The data in this ble	ock is includ	ed in the average	print	ed for a	previo	ous datablock.
1317.6± 1.5 OUR	AVERAGE	Error includes so	ale fa	actor of	1.4. 9	See the ideogram below.
$1311.3 \pm 1.6 \pm 3.0$	72400	AMELIN	96	VES		$36 \pi^- p \rightarrow$
1315 + 5 +2		¹ AMSLER	94D	CBAR		$0.0 \overline{p} p \rightarrow \pi^0 \pi^0 \eta$
1310 ± 5		ARMSTRONG	90	OMEG	0	$300.0pp \rightarrow$
						$\rho \rho \pi^{+} \pi^{-} \pi^{0}$
1323.8 ± 2.3	4022	AUGUSTIN	89	DM2	±	$J/\psi ightarrow ho^{\pm} a_{2}^{\mp}$
1320.6 ± 3.1	3562	AUGUSTIN	89	DM2	0	$J/\psi \rightarrow \rho^{\pm} a_{2}^{\mp}$ $J/\psi \rightarrow \rho^{0} a_{2}^{0}$
1317 ± 2	25000	² DAUM	80C	SPEC		63,94 $\pi^- p \rightarrow 3\pi p$
1320 ±10	1097	² BALTAY	78B	HBC	+0	$15 \pi^+ \rho \rightarrow \rho 4\pi$
1306 ± 8		FERRERSORIA	78	OMEG	_	$9 \pi^- p \rightarrow p 3\pi$
1318 ± 7	1600	² EMMS	75	DBC	0	$4 \pi^{+} n \rightarrow p(3\pi)^{0}$
1315 ± 5		² ANTIPOV	73C	CNTR	_	25,40 $\pi^- p \rightarrow$
						$\rho \eta \pi^-$
1206 0	1500	CHALOHBKA	72	LIDC		20 0

• • •	We	do not us	e the followir	ng data for avera	iges,	fits, lim	its, etc	. • • •
1305	± 1	.4		CONDO	93	SHF		$\gamma p \rightarrow \eta \pi^+ \pi^+ \pi^-$
1310	\pm	2	2	EVANGELISTA	81	OMEG	-	$12 \pi^- p \rightarrow 3\pi p$
1343	± 1	.1	490	BALTAY	78B	HBC	0	$15 \pi^+ \rho \rightarrow \Delta 3\pi$
1309	\pm	5	5000	BINNIE	71	MMS	-	$\pi^- p$ near a_2 thresh-
1299	.1.	c	28000	BOWEN	71	MMS		old 5 π ⁻ p
1799	I	0	20000	BOWEN	/ L	MINIS		
1300	\pm	6	24000	BOWEN	71	MMS	+	$5 \pi^{+} p$
1309	\pm	4	17000	BOWEN	71	MMS	_	7 π ⁻ p
1306	\pm	4	941	ALSTON	70	HBC	+	$7.0 \pi^+ p \rightarrow 3\pi p$

 1 The systematic error of 2 MeV corresponds to the spread of solutions. 2 From a fit to $J^P=2^+~\rho\pi$ partial wave.



 $a_2(1320)$ mass, 3π mode (MeV)

K±KS MODE

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
The data in this blo	ock is include	d in the average prin	ted for a	previo	us datablock.

1318.1± 0.7 Ol	JR AVERAG	E			
1319 ± 5	4700	^{3,4} CLELAND	828 SPEC	+	$50 \pi^+ \rho \rightarrow K_S^0 K^+ \rho$
1324 ± 6	5200	^{3,4} CLELAND	828 SPEC	_	$50 \pi^+ p \rightarrow K_5^0 K^+ p$ $50 \pi^- p \rightarrow K_5^0 K^- p$
$1320 \ \pm \ 2$	4000	CHABAUD	80 SPEC	-	$\begin{array}{c} 17 \ \pi^{-} A \rightarrow \\ K_{S}^{0} K^{-} A \end{array}$
1312 ± 4	11000	CHABAUD	78 SPEC	-	9.8 $\pi^- p \rightarrow K^- K_5^0 p$
1316 \pm 2	4730	CHABAUD	78 SPEC		$18.8 \pi^{-} \stackrel{-}{p} \rightarrow K^{-} \stackrel{+}{K_{5}^{0}} \stackrel{-}{p}$
1318 ± 1		3,5 MARTIN	78D SPEC	-	$10 \pi^- \rho \rightarrow K_S^0 K^- \rho$
$1320\ \pm\ 2$	2724	MARGULIE	76 SPEC	_	$23 \pi^- p \rightarrow K^- K_S^0 p$
1313 ± 4	730	FOLEY	72 CNTR		$\begin{array}{c} 20.3 \ \pi^- \ \rho \rightarrow \\ K^- \ K_0^0 \ \rho \end{array}$
1319 ± 3	1500	⁵ GRAYER	71 ASPK	-	3
• • • We do no	t use the fol	lowing data for ave	erages, fits, lir	nits, e	etc. • • •
		3.4			aa ± 160 16±

 3,4 CLELAND 828 SPEC + 1330 ±11 30 $\pi^+ p \to K_S^0 K^+ p$ $\begin{array}{c}
12.7 \ \pi^+ \ p \rightarrow \\
K^+ \ K_5^0 \ p
\end{array}$ HYAMS 78 ASPK + 1324 ± 5 350

$\eta\pi$ MODE

The data in this block is included in the average printed for a previous datablock.

1319.4±2.1 OUR AVERAGE

1325.1 ± 5	1	AOYAGI	93 B	KEI	$\pi^- \rho \rightarrow \eta \pi^- \rho$
1317.7 ± 1	4 ± 2.0	BELADIDZE	93 V	ES	$37\pi^- N \rightarrow \eta \pi^- N$
1323 ±8	1000	⁶ KEY	73 O	SPK -	$6 \pi^- \rho \rightarrow \rho \pi^- \eta$
• • • We	do not use the	following data for ave	erages, fit	ts, limits,	etc. • • •
1324 ±5		ARMSTRON	G 93c SI	PEC 0	$\overline{\rho} \rho \rightarrow \pi^0 \eta \eta \rightarrow 6\gamma$
1336.2 ± 1	7 2561	DELFOSSE	81 SI	PEC +	$\pi^{\pm} p \rightarrow p \pi^{\pm} \eta$
1330.7 ± 2	4 1653	DELFOSSE	81 S	PEC -	$\pi^{\pm} p \rightarrow p \pi^{\pm} \eta$
1324 ±8	6200	6,7 CONFORTO	73 O	SPK -	$6 \pi^- p \rightarrow pMM^-$

 $^{^6}_{-}$ Error includes 5 MeV systematic mass-scale error.

 $^{^3\,\}mathrm{From}$ a fit to $J^P=2^+$ partial wave.

⁴ Number of events evaluated by us. ⁵ Systematic error in mass scale subtracted.

 $^{^7\,\}mathrm{Missing}$ mass with enriched MMS $=\eta\,\pi^-$, $\eta=2\gamma.$

$\eta'\pi$	MODE
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VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
The data in this block is included	in the average printed	for a pre	vious datablock.

1327.0±10.7 BELADIDZE 93 VES $37\pi^- N \rightarrow \eta' \pi^- N$

$a_2(1320)$) WIDTH
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3π	MODE							
	IE (MeV)	EVTS		DOCUMENT ID		TECN	CHG	COMMENT
105.	5± 1.8 OUR	AVERAGE	Ξ					
103.	0± 6.0±3.3	72400		AMELIN	96	VES		36 $\pi^- p \to -+0$
112	\pm 3 \pm 2		8	AMSLER	94D	CBAR		$0.0 \frac{\pi^+ \pi^- \pi^0}{\overline{\rho} \rho \rightarrow \pi^0 \pi^0 \eta}$
120	±10			ARMSTRONG	90	OMEG	0	$300.0pp \rightarrow$
								$\rho \rho \pi^{+} \pi^{-} \pi^{0}$
107.	0 ± 9.7	4022		AUGUSTIN	89	DM2	±	$J/\psi \rightarrow \rho^{\pm} a_{2}^{\mp}$
118.	5 ± 12.5	3562		AUGUSTIN	89	DM2	0	$J/\psi \to \rho^{\pm} a_2^{\mp}$ $J/\psi \to \rho^0 a_2^0$
97	± 5		9	EVANGELISTA	81	OMEG	-	$12 \pi^- p \rightarrow 3\pi p$
96	± 9	25000	9	DAUM	80C	SPEC		63,94 $\pi^- p \rightarrow 3\pi p$
110	± 15	1097	9	BALTAY	78B	HBC	+0	$15 \pi^+ \rho \rightarrow \rho 4\pi$
112	± 18	1600		EMMS	75	DBC	0	$4 \pi^{+} n \rightarrow \rho (3\pi)^{0}$
122	± 14	1200	9,10	WAGNER	75	HBC	0	$7 \pi^+ \rho \rightarrow$
								$\Delta^{++}(3\pi)^{0}$
115	±15		9	ANTIPOV	7 3C	CNTR	-	25,40 $\pi^- p \rightarrow$
								$\rho \eta \pi^-$
99	± 15	1580		CHALOUPKA	73	HBC	-	3.9 $\pi^{-}p$
105	± 5 ·	28000		BOWEN	71	MMS	-	5 π ⁻ ρ
99	± 5	24000		BOWEN	71	MMS	+	5 π ⁺ ρ
103	± 5	17000		BOWEN	71	MMS	-	7 π ρ
• •	 We do not ι 	ise the fol	llowir	ng data for avera	iges,	fits, lim	its, etc	£. • • •
120	±40			CONDO	93	SHF		$\gamma \rho \rightarrow \eta \pi^+ \pi^+ \pi^-$
115	±14	490		BALTAY	78 B	нвс	0	$15 \pi^+ \rho \rightarrow \Delta 3\pi$
72	± 16	5000		BINNIE	71	MMS	-	$\pi^- p$ near a_2 thresh-
79	±12	941		ALSTON	70	нвс	+	7.0 $\pi^+ p \rightarrow 3\pi p$
19	112	741		ALS 1 0 14	10	HIDC	7	$7.0 \text{ n} \text{ p} \rightarrow 3\pi \text{ p}$

$\mathit{K}^{\pm}\mathit{K}^{0}_{\mathit{S}}$ AND $\eta\pi$ MODES

VALUE (MeV)

107 ±5 OUR ESTIMATE

109.8±2.0 OUR AVERAGE Includes data from the 2 datablocks that follow this one.

$K^{\pm}K_S^0$ MODE

	JE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	
The	data in this b	olock is include	d in the average	print	ed for a	previo	ous datablock.
109.	8± 2.4 OUR	AVERAGE					
112	±20		² CLELAND	82B	SPEC	+	$50 \pi^{+} p \to K_{S}^{0} K^{+} p$ $50 \pi^{-} p \to K_{S}^{0} K^{-} p$
120	± 25	5200 11,13	² CLELAND	82B	SPEC		$50 \pi^- p \rightarrow K_S^{0} K^- p$
106	± 4	4000	CHABAUD	80	SPEC	-	$\begin{array}{c} 17 \ \pi^{-} A \rightarrow \\ K_{S}^{0} K^{-} A \end{array}$
							KSK-A
126	± 11	11000	CHABAUD	78	SPEC	_	$9.8 \pi^- p \rightarrow$
							$\kappa^- \kappa_S^0 \rho$
101	± 8	4730	CHABAUD	78	SPEC	_	18.8 π ⁻ p →
							$K = K_S^0 p$
113	± 4	11,13	3 MARTIN	78D	SPEC	_	$10 \pi^- p \rightarrow K_S^0 K^- p$
105	± 8	2724 13	³ MARGULIE	76	SPEC	_	
113	± 19	730	FOLEY	72	CNTR	-	$20.3 \pi^- p \rightarrow$
							$K = K_{SP}^{0}$
123	±13	1500 13	GRAYER	71	ASPK		$17.2 \pi^- p \rightarrow$
							κ- κ'0 p
• •	• We do not	use the followi	ng data for ave	rages,	fits, lim	its, et	
			2 CLELAND				
121	±51						30 $\pi^+ \rho \rightarrow K_S^0 K^+ \rho$
110	± 18	350	HYAMS	78	ASPK	+	$12.7 \pi^+ \rho \rightarrow$

¹¹ From a fit to $J^P = 2^+$ partial wave.

$\eta\pi$ MODE

VALUE (MeV) EVTS DOCUMENT ID TECN CHG COMMENT

The data in this block is included in the average printed for a previous datablock.

110.0 ± 3.5 OUR AVERAGE

$103 \pm 6 \pm 3$		BELADIDZE	93	VES		$37\pi^- N \rightarrow \eta \pi^- N$
112.2 ± 5.7	2561	DELFOSSE	81	SPEC	+	$\pi^{\pm} \rho \rightarrow \rho \pi^{\pm} \eta$
116.6 ± 7.7	1653	DELFOSSE	81	SPEC	-	$\pi^{\pm} \rho \rightarrow \rho \pi^{\pm} \eta$
108 ± 9	1000	KEY	73	OSPK	-	$6 \pi^- \rho \rightarrow \rho \pi^- \eta$
• • • We do no	t use the follov	ving data for aver	ages,	fits, lim	its, et	C. • • •
118 ±10		ARMSTRONG	93c	SPEC	0	$\overline{p}p \rightarrow \pi^0 \eta \eta \rightarrow 6\gamma$
104 ± 9	6200	^{L4} CONFORTO	73	OSPK		$6 \pi^- \rho \rightarrow \rho MM^-$
14 Model deper	ident.					
•						

 $[\]eta'\pi$ MODE

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
106±32	BELADIDZE 93	VES	$37\pi^- N \rightarrow \eta' \pi^- N$

a₂(1320) DECAY MODES

	Mode	$\begin{array}{ccc} & & \text{Scale factor}/\\ & & \text{Fraction } (\Gamma_{j}/\Gamma) & & \text{Confidence level} \end{array}$
Γ_1	$\rho\pi$	(70.1±2.7) % S=1.2
Γ_2	$\eta \pi$	(14.5±1.2) %
Γ_3	$\omega \pi \pi$	(10.6±3.2) % S=1.3
Γ_4	κ \overline{K}	(4.9±0.8) %
Γ_5	$\eta'(958)\pi$	$(5.7\pm1.1)\times10^{-3}$
Γ_6	$\pi^{\pm}\gamma$	$(2.8\pm0.6)\times10^{-3}$
Γ_7	$\gamma \gamma$	$(9.7\pm1.0)\times10^{-6}$
Γ ₈	$\pi^{+}\pi^{-}\pi^{-}$	< 8 % CL=90%
Γ9	e ⁺ e ⁻	$< 2.3 \times 10^{-7} $ CL=90%

CONSTRAINED FIT INFORMATION

An overall fit to 5 branching ratios uses 18 measurements and one constraint to determine 4 parameters. The overall fit has a $\chi^2 =$ 9.3 for 15 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv$ $\Gamma_i/\Gamma_{\mathrm{total}}$. The fit constrains the x_i whose labels appear in this array to sum to

$$\begin{array}{c|ccccc} x_2 & & 10 & & \\ x_3 & & -89 & -46 & & \\ x_4 & & -1 & -2 & -24 \\ \hline & x_1 & x_2 & x_3 & & \end{array}$$

ı

a2(1320) PARTIAL WIDTHS

$\Gamma(\pi^{\pm}\gamma)$						Γε
VALUE (keV)	DOCUMENT ID		TECN	CHG	COMMENT	
295± 60	CIHANGIR	82	SPEC	+	200 π^{+} A	
• • • We do not use th	e following data for average	s, fits	s, limits,	etc.	• •	
461 ± 110	14 MAY	77	SPEC	+	9.7 ~ A	

$\Gamma(\gamma\gamma)$						Γ ₇
VALUE (keV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
1.04 ± 0.09 OUR A	/ERAGE					
$1.26\pm0.26\pm0.18$	36	BARU	90	MD1		$e^{+}e^{-}_{e^{+}e^{-}\pi^{+}\pi^{-}\pi^{0}}$
$1.00\pm0.07\pm0.15$	415	BEHREND	90C	CELL	0	$e^{+}e^{-}_{e^{+}e^{-}\pi^{+}\pi^{-}\pi^{0}}$
$1.03 \pm 0.13 \pm 0.21$		BUTLER	90	MRK2		$e^+e^- \rightarrow \pi^+\pi^-\pi^0$
$1.01\pm0.14\pm0.22$	85	OEST	90	JADE		$e^+e^- \rightarrow \pi^0 n$
$0.90 \pm 0.27 \pm 0.15$	56	¹⁵ ALTHOFF	86	TASS	0	$e^+e^- \rightarrow e^+e^-3\pi$
$1.14 \pm 0.20 \pm 0.26$		¹⁶ ANTREASYAN	86	CBAL	0	$\stackrel{e^+e^-}{_{e^+e^-\pi^0}}_{\pi^0\eta}$
$1.06 \pm 0.18 \pm 0.19$		BERGER	84C	PLUT	0	$e^+e^- \rightarrow e^+e^-3\pi$
• • • We do not u	se the follo	wing data for avera	ges,	fits, lim	its, etc	. • • •
$0.81 \pm 0.19 ^{+0.42}_{-0.11}$	35	¹⁵ BEHREND	83B	CELL	0	$e^+e^- ightarrowe^+e^-3\pi$
$0.84 \pm 0.07 \pm 0.15$		¹⁵ FRAZER	83	JADE	0	$e^+e^- \rightarrow e^+e^-3\pi$
$0.77 \pm 0.18 \pm 0.27$	22	¹⁶ EDWARDS	82F	CBAL	0	$e^+e^{e^+e^-\pi^0}$

 $^{^{15}\,\}mathrm{From}\;\rho\pi$ decay mode. $^{16}\,\mathrm{From}\;\eta\pi^0$ decay mode.

Γ(e ⁺	e_)							Г9
VALUE (eV)	CL%	DOCUMENT ID		TECN	COMMENT		
<25		90	VOROBYEV	88	ND	$e^+e^- \rightarrow$	$\pi^0 \eta$	

$a_2(1320) \Gamma(i)\Gamma(\gamma\gamma)/\Gamma(total)$

$\Gamma(K\overline{K}) \times \Gamma(\gamma\gamma)/\Gamma_{\text{tota}}$	ıl		Γ ₄ Γ _{7/}	۲
VALUE (keV)	DOCUMENT ID		COMMENT	
$0.126\!\pm\!0.007\!\pm\!0.028$	¹⁷ ALBRECHT	90G ARG	$e^+e^{e^+e^-K^+K^-}$	
• • • We do not use the fo	llowing data for average	es, fits, limits	, etc. • • •	
$0.081 \pm 0.006 \pm 0.027$	¹⁸ ALBRECHT	90G ARG	$e^+ e^{e^+ e^- K^+ K^-}$	
17 Using an incoherent bac 18 Using a coherent backgr				

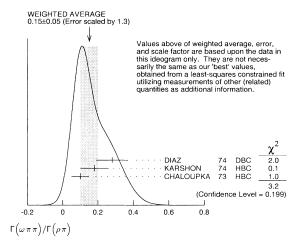
 $^{^8}$ The systematic error of 2 MeV corresponds to the spread of solutions. 9 From a fit to $J^P=2^+~\rho\pi$ partial wave. 10 Width errors enlarged by us to $4\Gamma/\sqrt{N};$ see the note with the $K^*(892)$ mass.

¹³ Number of events evaluated by us. 13 Width errors enlarged by us to $4\Gamma/\sqrt{N}$; see the note with the $K^*(892)$ mass.

 $a_2(1320)$

	a ₂ (1320) BRANCHIN	G R	ATIOS		
$\Gamma(K\overline{K})/\Gamma(\rho\pi)$						Γ_4/Γ_1
VALUE 0.070±0.012 OUR FIT	<u>EVTS</u>	DOCUMENT ID		<u>TECN</u>	<u>CHG</u>	COMMENT
0.078 ± 0.017	. fallandarı	CHABAUD	78	RVUE		
• • We do not use the					eic. •	
0.056 ± 0.014		CHALOUPKA	73	HBC	-	3.9 π p
0.097 ± 0.018		ALSTON ABRAMOVI	71	HBC	+	7.0 $\pi^+ p$
0.06 ±0.03		CHUNG	68	HBC	_	3.93 π ⁻ p
0.054 ± 0.022			00	нвс		3.2 π ⁻ p
¹⁹ Included in CHABAU	D 78 review	v.				
$\Gamma(\eta\pi)/[\Gamma(\rho\pi)+\Gamma(\eta)]$	$(\pi) + \Gamma(\kappa)$	(K)]		<u>TECN</u>	<u>CHG</u>	$\Gamma_2/(\Gamma_1+\Gamma_2+\Gamma_4)$ COMMENT
0.162±0.012 OUR FIT 0.140±0.028 OUR AVER		DOCOMENT NO		<u>JECIV</u>	<u>c/10</u>	COMMENT
0.13 ± 0.04		ESPIGAT	72	HBC	±	0.0 p p
0.15 ± 0.04	34	BARNHAM	71	HBC	+	3.7 $\pi^+ p$
m/ \/m/ \						- /-
$\Gamma(\eta\pi)/\Gamma(\rho\pi)$						Γ_2/Γ_1
VALUE	<u>EVTS</u>	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
0.207±0.018 OUR FIT 0.213±0.020 OUR AVER	RAGE					
0.18 ±0.05		FORINO	76	HBC		11 π ⁻ ρ
0.22 ± 0.05	52	ANTIPOV	73	CNTR	-	40 π p
0.211 ± 0.044	149	CHALOUPKA	73	HBC	-	3.9 π ⁻ p
0.246 ± 0.042	167	ALSTON	71	HBC	+	7.0 $\pi^+ p$
0.25 ±0.09	15	BOECKMANN	70	HBC	+	5.0 $\pi^{+} \rho$
0.23 ±0.08	22	ASCOLI	68	HBC	-	5 π ⁻ p
0.12 ±0.08		CHUNG	68	HBC	_	3.2 $\pi^- p$
0.22 ±0.09		CONTE	67	HBC	_	$11.0 \pi^{-} \rho$
$\Gamma(\eta'(958)\pi)/\Gamma_{\text{total}}$						Γ ₅ /Γ
VALUE	CL%	DOCUMENT ID		TECN	CHG	
• • We do not use the						
		ALDE		GAM2		
< 0.006	95	ALDE	928	GAIVI2		38,100 $\pi^- p \rightarrow \eta' \pi^0 n$
< 0.02	97	BARNHAM	71	нвс	+	$3.7 \pi^{+} p$
0.004 ± 0.004	,,	BOESEBECK	68	нвс	+	8 π ⁺ p
		BOLGEBLER	00	1100		
$\Gamma(\eta'(958)\pi)/\Gamma(\rho\pi)$						Γ_5/Γ_1
	CL%	DOCUMENT ID				COMMENT
• • We do not use the	e following o	data for averages	s, fits	, limits,	etc. •	• •
< 0.011	90	EISENSTEIN	73	HBC	_	5 π ⁻ p
< 0.04		ALSTON	71	HBC	+	7.0 $\pi^+ p$
$0.04 \begin{array}{c} +0.03 \\ -0.04 \end{array}$		BOECKMANN	70	нвс	0	5.0 π^{+} p
-0.04						,
$\Gamma(K\overline{K})/[\Gamma(\rho\pi)+\Gamma($	$(n\pi) + \Gamma($	$\kappa \overline{\kappa}$				$\Gamma_4/(\Gamma_1+\Gamma_2+\Gamma_4)$
VALUE	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
0.054±0.009 OUR FIT	2015	DOCOMENT ID		1667		COMMENT
0.048±0.012 OUR AVER	RAGE					
0.05 ±0.02		TOET	73	HBC	+	5 π ⁺ ρ
0.09 ±0.04		TOET	73	нвс	0	5 π ⁺ ρ
0.03 ±0.02	8	DAMERI	72	нвс		11 π - p
0.06 ±0.03	17	BARNHAM	71	нвс	+	3.7 π ⁺ p
• • • We do not use the	following o			, limits,	etc. •	• •
0.020±0.004		ESPIGAT	72	нвс	±	$0.0 \ \overline{p} p$
²⁰ Not averaged becaus	e of discrep	ancy between m	asses	from K	Kand	$1 ho\pi$ modes.
$\Gamma(\pi^+\pi^-\pi^-)/\Gamma(\rho\pi)$						Γ_8/Γ_1
VALUE	CL%	DOCUMENT ID		TECN	CHG	COMMENT
<0.12	90				<u> </u>	3.93 $\pi^- \rho$
	90	ABRAMOVI				
	90	ABRAMOVI				Г ₆ /Г
$\Gamma(\pi^{\pm}\gamma)/\Gamma_{\text{total}}$	90	DOCUMENT ID			COMN	Γ ₆ /Γ
$\Gamma(\pi^{\pm}\gamma)/\Gamma_{ ext{total}}$	A A A A A A A A A A A A A A A A A A A	DOCUMENT ID		<u>TECN</u>		1ENT
$\frac{\Gamma(\pi^{\pm}\gamma)/\Gamma_{\text{total}}}{\text{VALUE}}$ • • • We do not use the	e following	DOCUMENT ID	 s, fits	<u>TECN</u> s, limits,	etc. •	1ENT • •
$\Gamma(\pi^{\pm}\gamma)/\Gamma_{ ext{total}}$	e following	DOCUMENT ID	 s, fits	<u>TECN</u> s, limits,	etc. •	1ENT • •
$\frac{\Gamma(\pi^{\pm}\gamma)/\Gamma_{\text{total}}}{\text{VALUE}}$ • • • We do not use the	e following o	<u>DOCUMENT ID</u> data for average: ^L EISENBERG	 s, fits	<u>TECN</u> s, limits,	etc. •	1ENT • •
$\Gamma(\pi^{\pm}\gamma)/\Gamma_{\text{total}}$ • • • We do not use the $0.005^{+0.005}_{-0.003}$ 21 Pion-exchange mode	e following o	<u>DOCUMENT ID</u> data for average: ^L EISENBERG	 s, fits	<u>TECN</u> s, limits,	etc. •	<u>4ENT</u> •• 25,7.5 γ p
$\Gamma(\pi^{\pm}\gamma)/\Gamma_{\text{total}}$ $VALUE$ • • • We do not use the $0.005^{+0.005}_{-0.003}$ $VALUE$ V	e following o	DOCUMENT ID data for averages EISENBERG s estimation.	 s, fits 72	<u>TECN</u> 5, limits, HBC	etc. • 4.3,5.	νεντ • • .25,7.5 γρ Γ3/Γ1
$\Gamma(\pi^{\pm}\gamma)/\Gamma_{\text{total}}$ $\sim \bullet \sim \text{We do not use the}$ $0.005^{+0.005}_{-0.003}$ $\sim 0.005^{+0.005}_{-0.003}$ $\sim 0.005^{+0.005}_{-0.003}$ $\sim 0.005^{+0.005}_{-0.003}$	e following of 2: I used in this	DOCUMENT ID data for averages EISENBERG is estimation.	72	<u>TECN</u> 5, limits, HBC	etc. • 4.3,5.	νεντ • • .25,7.5 γρ Γ3/Γ1
$\Gamma(\pi^{\pm}\gamma)/\Gamma_{\text{total}}$ $VALUE$ • • • We do not use the $0.005^{+0.005}_{-0.003}$ 21 Pion-exchange mode $\Gamma(\omega\pi\pi)/\Gamma(\rho\pi)$ $VALUE$ 0.15 ± 0.05 OUR FIT E	e following of 2: I used in this	DOCUMENT ID data for averages EISENBERG s estimation. DOCUMENT ID s scale factor of	72 1.3.	TECN s, limits, HBC	etc. • 4.3,5.	VENT • • 25,7.5 γ p Γ ₃ /Γ ₁ COMMENT
$\Gamma(\pi^{\pm}\gamma)/\Gamma_{\text{total}}$ $VALUE$ • • • We do not use the $0.005^{+0.005}_{-0.003}$ 21 Pion-exchange mode $\Gamma(\omega\pi\pi)/\Gamma(\rho\pi)$ $VALUE$ 0.15 ± 0.05 OUR FIT E 0.15 ± 0.05 OUR AVERA	e following of 2: I used in this EVTS rror include GE Error	DOCUMENT ID data for averages EISENBERG is estimation. DOCUMENT ID s scale factor of includes scale factor.	72 1.3.	TECN s, limits, HBC	etc. • 4.3,5. <u>CHG</u> See the	νεντ • • .25,7.5 γρ Γ3/Γ1
$\Gamma(\pi^{\pm}\gamma)/\Gamma_{\text{total}}$ $\sim \bullet$ • We do not use the $0.005^{+0.005}_{-0.003}$ $\sim 0.005^{+0.005}_{-0.003}$ $\sim 0.005^{+0.005}_{-0.003}$ $\sim 0.005^{+0.005}_{-0.003}$ $\sim 0.005^{+0.005}_{-0.005}$ $\sim 0.15\pm 0.05$ OUR FIT EQUIPMENT $\sim 0.15\pm 0.05$ OUR AVERA $\sim 0.28\pm 0.09$	e following of 2: I used in this EVTS rror include GE Error 60	DOCUMENT ID data for averages EISENBERG s estimation. DOCUMENT ID s scale factor of includes scale fa	1.3. ctor (TECN TECN of 1.3. S DBC	etc. • 4.3,5.	$\bullet \bullet$ 25,7.5 γp Γ_3/Γ_1 COMMENT 1: ideogram below. $6 \pi^+ n$
$\Gamma(\pi^{\pm}\gamma)/\Gamma_{\text{total}}$ $VALUE$ • • • We do not use the $0.005^{+0.005}_{-0.003}$ 21 Pion-exchange mode $\Gamma(\omega\pi\pi)/\Gamma(\rho\pi)$ $VALUE$ 0.15 ± 0.05 OUR FIT E 0.15 ± 0.05 OUR AVERA	e following of 2: I used in this EVTS rror include GE Error 60	DOCUMENT ID data for averages EISENBERG is estimation. DOCUMENT ID s scale factor of includes scale factor.	1.3. ctor (74	TECN HBC TECN of 1.3. S	etc. • 4.3,5. <u>CHG</u> See the	1.25,7.5 γ p Γ ₃ /Γ ₁ COMMENT tideogram below.

 22 KARSHON 74 suggest an additional I=0 state strongly coupled to $\omega\pi\pi$ which could explain discrepancies in branching ratios and masses. We use a central value and a systematic spread.



$\Gamma(\eta'(958)\pi)/\Gamma(\eta\pi)$				Γ ₅	$/\Gamma_2$
VALUE	DOCUMENT ID		TECN	COMMENT	
0.040 ± 0.007 OUR AVERAGE					
$0.047 \pm 0.010 \pm 0.004$	²³ BELADIDZE	93	VES	$37\pi^- N \rightarrow a_2^- N$	
$0.034 \pm 0.008 \pm 0.005$	BELADIDZE	92	VES	$36\pi^- C \rightarrow a_2^- C$	
23 Using B($\eta' \to \pi^+ \pi^- \eta$) 0.236.	= 0.441, B($\eta \rightarrow \gamma \gamma$	γ) =	0.389	and B($\eta \rightarrow \pi^+\pi^-\pi^0$)) =

a_2 (1320) REFERENCES

AMELIN	96	ZPHY C70 71	+Berdnikov, Bityukov+ (SERP, TBIL)
AMSLER	94D	PL B333 277	+Anisovich, Spanier+ (Crystal Barrel Collab.)
AOYAGI	93	PL B314 246	+Fukui, Hasegawa+ (BKEI Collab.)
ARMSTRONG		PL B307 394	
BELADIDZE	93	PL 313 276	+Berdnikov, Bityukov+ (VES Collab.)
CONDO	93	PR D48 3045	+Handler, Bugg+ (SLAC Hybrid Collab.)
ALDE	92B	ZPHY C54 549	+Binon+ (SERP, BELG, LANL, LAPP, PISA, KEK)
BELADIDZE	92	ZPHY C54 235	+Bityukov, Borisov+ (VES Collab.)
ALBRECHT	90G	ZPHY C48 183	+Ehrlichmann, Harder+ (ARGUS Collab.)
ARMSTRONG	90	ZPHY C48 213	
BARU	90	ZPHY C48 581	+Blinov, Blinov+ (MD-1 Collab.)
BEHREND	90C	ZPHY C46 583	+Criegee+ (CELLO Collab.)
BUTLER	90	PR D42 1368	+Boyer+ (Mark II Collab.)
OEST	90	ZPHY C47 343	+Olsson+ (JADE Collab.)
AUGUSTIN	89	NP B320 1	+Cosme (DM2 Collab.)
VOROBYEV	88	SJNP 48 273	+Golubev, Dolinsky, Druzhinin+ (NOVO)
		Translated from YAF	
ALTHOFF	86	ZPHY C31 537	+Boch, Foster, Bernardi+ (TASSO Collab.)
ANTREASYAN		PR D33 1847	+Aschman, Besset, Bienlein+ (Crystal Ball Collab.)
	84C		
BERGER		PL 149B 427	+Klovning, Burger+ (PLUTO Collab.)
BEHREND	83B	PL 125B 518	+D'Agostini+ (CELLO Collab.)
FRAZER	83	Aachen Conf.	(UCSD)
CIHANGIR	82	PL 117B 123	+Berg, Biel, Chandlee+ (FNAL, MINN, ROCH)
CLELAND	82B	NP B208 228	+Delfosse, Dorsaz, Gloor (DURH, GEVA, LAUS, PITT)
EDWARDS	82F	PL 110B 82	+Partridge, Peck+ (CIT, HARV, PRIN, STAN, SLAC)
DELFOSSE	81	NP B183 349	+Guisan, Martin, Muhlemann, Weill+ (GEVA, LAUS)
EVANGELISTA		NP B178 197	+ (BARI, BONN, CERN, DARE, LIVP+)
CHABAUD	80	NP B175 189	+Hyams, Papadopoulou+ (CERN, MPIM, AMST)
DAUM	80C	PL 89B 276	+Hertzberger+ (AMST, CERN, CRAC, MPIM, OXF+) JP
BALTAY	78B	PR D17 62	+Cautis, Cohen, Csorna+ (COLU, BING)
CHABAUD	78	NP B145 349	+Hyams, Jones, Weilhammer, Blum+ (CERN, MPIM)
FERRERSORIA	78	PL 74B 287	+Treille+ (ORSAY, CERN, CDEF, EPOL)
HYAMS	78	NP B146 303	+Jones, Weilhammer, Blum+ (CERN, MPIM, ATEN)
MARTIN	78D	PL 74B 417	+Ozmutlu, Baldi, Bohringer, Dorsaz+ (DURH, GEVA) JP
MAY	77	PR D16 1983	+Abramson, Andrews, Busnello+ (ROCH, CORN)
FORINO	76	NC 35A 465	+Gessaroli+ (BGNA, FIRZ, GENO, MILA, OXF, PAVI)
MARGULIE	76	PR D14 667	+Kramer, Foley, Love, Lindenbaum+ (BNL, CUNY)
EMMS	75	PL 58B 117	+Jones, Kinson, Stacey, Bell+ (BIRM, DURH, RHEL) JP
WAGNER	75	PL 58B 201	+Tabak, Chew (LBL) JP
DIAZ	74	PRL 32 260	+Dibianca, Fickinger, Anderson+ (CASE, CMU)
KARSHON	74	PRL 32 852	+Mikenberg, Pitluck, Eisenberg, Ronat+ (REHO)
ANTIPOV	73	NP B63 175	+Ascoli, Busnello, Focacci+ (CERN, SERP) JP
ANTIPOV	73C	NP B63 153	+Ascoli, Busnello, Focacci+ (CERN, SERP) JP
CHALOUPKA	73	PL 44B 211	+Dobrzynski, Ferrando, Losty+ (CERN)
CONFORTO	73	PL 45B 154	
	73		
DEFOIX		PL 43B 141	+Dobrzynski, Espigat, Nascimento+ (CDEF)
EISENSTEIN	73	PR D7 278	+Schultz, Ascoli, loffredo+ (ILL)
KEY	73	PRL 30 503	+Conforto, Mobley+ (TNTO, EFI, FNAL, WISC)
TOET	73	NP B63 248	+Thuan, Major+ (NIJM, BONN, DURH, TORI)
DAMERI	72	NC 9A 1	+Borzatta, Goussu+ (GENO, MILA, SACL)
EISENBERG	72	PR D5 15	+Ballam, Dagan+ (REHO, SLAC, TELA)
ESPIGAT	72	NP B36 93	+Ghesquiere, Lillestol, Montanet (CERN, CDEF)
FOLEY	72	PR D6 747	+Love, Ozaki, Platner, Lindenbaum+ (BNL, CUNY)
ALSTON	71	PL 34B 156	Alston-Garnjost, Barbaro, Buhl, Derenzo+ (LRL)
MLSTOW	1.7	LC 240 130	Alaton-damjost, Darvaro, Dami, Deletizo+ (ENE)

BARNHAM BINNIE BOWEN GRAYER ABRAMOVI ALSTON BOECKMANN ASCOLI BOESEBECK CHUNG CONTE	71 70B 70	PRL 26 1494 PL 368 257 PRL 26 1663 PL 34B 333 NP B23 466 PL 33B 607 NP B16 221 PRL 20 1321 NP B4 501 PR 165 1491 NC 51A 175	+ Abzams, Butler, Coyne, Goldhaber, Hall+ - (LDIC, SHMD) - (LOIC,
JENNI BEHREND ABOLINS ADERHOLZ ALITTI CHUNG FORINO LEFEBVRES SEIDLITZ ADERHOLZ CHUNG GOLDHABER AISO LANDER	83 82C 65 65 65 65 65 65 64 64 64 64 64	PR D27 1031 PL 114B 378 Athens Conf. PR 138B 897 PL 15 69 PRL 15 325 PL 19 68 PL 19 434 PRL 15 217 PL 10 226 PRL 12 621 Dubna Conf. 1 480 PRL 13 346A	+Burke, Telnov, Abrams, Blocker+ (SLAC, LBL) +Chen, Fenner, Field+ (CELLO Collab) +Cammon, Lander, Xuong, Yager (UCSD) (U

 $f_0(1370)$ was $f_0(1300)$

$$I^{G}(J^{PC}) = 0^{+}(0^{+})$$

NOTE ON SCALAR MESONS

The analysis of the scalar resonances in the $\pi\pi$ S-wave is notoriously difficult. In other partial waves, a resonance may be identified by the behavior of a single dominant channel across a mass range of a few hundred MeV. In contrast, the scalar waves couple strongly to more than one channel, and have overlapping and interfering broad resonances, often extending over more than 1 GeV. In addition, the $K\overline{K}$ and $\eta\eta$ thresholds produce sharp cusps in the partial waves. Thus, given experimental results in one channel, one can derive conclusions affecting the other scalar resonances. For this reason we discuss in this one Note all light scalars, organized in the Listings under the entries $f_0(400\text{-}1200)$, $f_0(980)$, $f_0(1370)$, $f_0(1500)$, $a_0(980)$, $a_0(1450)$, and $K_0^*(1430)$. This list is "minimal:" it does not necessarily exhaust the list of actual resonances.

The I=0 states and the $\pi\pi$ S-wave: From the $\pi\pi$ threshold to about 1500 MeV, the claimed isoscalar resonances are found under four separate entries: $f_0(400\text{-}1200)$, $f_0(980)$, $f_0(1370)$, and $f_0(1500)$. The data are obtained from resonance decays into the channels $\pi\pi$, $K\overline{K}$, $\eta\eta$, $\eta\eta'$, and 4π .

Below 1100 MeV, the essential contributions come from $\pi\pi$ and $K\overline{K}$ final states. The $\pi\pi$ phase shift δ^0_0 is well known to rise smoothly (GRAYER 74, ROSSELET 77) to 90° at around 900 MeV (HYAMS 73, CASON 76), then shows a rapid step of 180° near the $K\overline{K}$ threshold, due to the $f_0(980)$ resonance, which is superimposed over a large background. Above 1 GeV, the $\pi\pi$ phase shift continues to grow slowly, as expected for a very broad resonance. The $\pi\pi$ S-wave inelasticity is not accurately known, and the reported $\pi\pi \to K\overline{K}$ cross sections (WETZEL 76, POLYCHRONAKOS 79, COHEN 80, ETKIN 82B) may have large uncertainties.

In our editions from 1976 to 1994, this behavior of the phase shift was thought to be due mainly to the narrow $f_0(980)$ and the broad $f_0(1370)$, the latter variously named in earlier editions the $\epsilon(1200)$ and the $f_0(1300\text{-}1400)$. It was, however, always uncertain whether there also exists a very

broad structure mostly called σ in the literature. Before 1974, when the phase shift was known only up to about 900 MeV, one generally believed in a light σ (also called ϵ or η_{0+}) with a very large and uncertain width.

BECKER 79B excluded a narrow resonance behavior for δ_0^0 in their $\pi^- p$ (polarized) $\to \pi^+ \pi^- n$ data below 900 MeV. In contrast, SVEC 92, 96, using their data on $\pi^+ n$ (polarized) $\rightarrow \pi^+\pi^- p$ from 600 to 900 MeV, suggest a narrow scalar state at 750 MeV with a width of 100 to 200 MeV; the $f_0(980)$ was not included, which can explain the very narrow width obtained. Furthermore, the associated δ_0^0 values differ substantially from recent consensus and would reopen the old Up-Down ambiguity of the early 1970's (see our 1984 edition). Thus, the interpretation of SVEC 92 and others who claim a narrow σ must be treated with reservation, although, as SVEC 96 emphasize, the contribution from a_1 exchange in the $\pi N \to \pi \pi N$ processes has not been included in most analyses. New data resolving these important ambiguities would be most welcome. For further discussions of earlier analyses on the $\pi\pi$ S-wave, see our Notes in earlier editions and AU 87, MORGAN 93, and ZOU 93.

It has now become evident that the simplest understanding of the conventional $\pi\pi$ S-wave is obtained if one includes, in addition to the $f_0(980)$ and $f_0(1370)$ resonances, a very broad σ with a mass in the region 400-1200 MeV and a width exceeding 500 MeV (AU 87, MORGAN 93, ZOU 93, 94B, ACHASOV 94, TORNQVIST 95, 96, AMSLER 95B, AMSLER 95D, JANSSEN 95). The large spread in the resonance parameters obtained by these groups is due less to differences in the data used than to differences in the models employed. Important input in all analyses for the $f_0(400\text{-}1200)$ are the standard $\pi\pi$ phase shifts below 1200 MeV, the same for all groups.

As to the $f_0(1370)$, all analyses of $\pi\pi$ and $K\overline{K}$ data claim a mainly elastic resonance around 1400 MeV. This still depends strongly on the standard $\pi\pi$ phase shift solution above 1100 MeV, and in particular on the small inelasticity of that solution, as mentioned above.

Above 1300 MeV, there is also evidence for a scalarisoscalar resonance decaying to 4π . Whether this is the same resonance as the $f_0(1370)$ remains unsettled. There may be two resonances, one seen in elastic $\pi\pi$ scattering and coupling predominantly to $\pi\pi$, and another coupling mainly to 4π via $\rho\rho$ and two $\pi\pi$ S-waves. For now, we list both under the $f_0(1370)$. The 4π decay mode would, however, point to a large inelasticity. The information on the 4π channel comes mainly from the analysis of $\bar{p}n$ or $\bar{p}p \to 5\pi$ (GASPERO 93, ADAMO 93, AMSLER 94). AMSLER 94 finds a large production of a 0^{++} resonance decaying into 4π , mostly $\rho\rho$, with $M=1374\pm38$ MeV and $\Gamma=375\pm61$ MeV, and quotes a $4\pi:2\pi$ branching ratio of order 5:1.

Above the $f_0(1370)$ there is at least one resonance, the $f_0(1500)$, seen by the Crystal Barrel Collaboration (ANTINORI 95, AMSLER 95B, 95C). The $f_0(1590)$ of GAMS (BINON 83) in our 1994 edition is now listed under the same entry as the

$f_0(1370)$

 $f_0(1500)$. For the determination of the resonance parameters, we use only the analyses in terms of T-matrix poles. See also our Note on Non- $q\overline{q}$ Mesons.

The I=1 states: Two states are known, the $a_0(980)$ and the $a_0(1450)$ seen by the Crystal Barrel (AMSLER 94D). For a longer Note on the $a_0(980)$, see our 1994 edition, which includes comments on the nature of this resonance.

The most important fact about the $a_0(980)$ is that it lies very close to the $K\overline{K}$ threshold (like the $f_0(980)$); its shape, mass, and width are strongly distorted by this threshold. A naive Breit-Wigner fit to the resonance bump cannot reveal its true coupling constants to $\eta\pi$ and $K\overline{K}$. To obtain these, one must use a coupled-channel model with energy-dependent widths and mass-shift contributions. For the same reason, the branching ratios to $K\overline{K}$ and $\eta\pi$ are strongly energy dependent and one cannot use quoted width parameters in a naive way to determine the strength of the couplings.

Independently of any model about the nature of the $a_0(980)$ (or the $f_0(980)$), the $K\overline{K}$ component in the wave function of the state must be large. By general quantum mechanical arguments, any state (be it $q\overline{q}$ or whatever) that lies at the Swave $K\overline{K}$ threshold and to which it couples strongly must have significant mixing with the $K\overline{K}$ continuum. Therefore, one cannot discuss the $a_0(980)$ (or the $f_0(980)$) without taking into account this large continuum component, e.q. when calculating $\gamma\gamma$ widths. The $\gamma\gamma$ width will always be suppressed by the $K\overline{K}$ component of the state.

The I=1/2 sector: The $K_0^*(1430)$ (ASTON 88) is certainly the least controversial of the light scalar mesons. The phase shift rises smoothly from threshold, passes 90° at 1350 MeV, and then continues to rise to about 170° at 1600 MeV at the first important inelastic threshold, $K\eta'$. Thus, it behaves just as expected of a single broad, nearly elastic resonance. All analyses agree on a pole mass of about 1430 MeV and a width of about 300 MeV.

Interpretation of the nature of the scalars: Almost every model of the scalar states agrees that the $K_0^*(1430)$ is the 1^3P_0 quark model $s\overline{u}$ (or $s\overline{d}$) state. For the interpretation of the other light scalars, there are two main classes of models:

- (i) The two states near the $K\overline{K}$ threshold, the $f_0(980)$ and the $a_0(980)$, are $K\overline{K}$ bound states (WEINSTEIN 89). The $f_0(1370)$ is the 1^3P_0 $u\overline{u}+d\overline{d}$ state, the $a_0(1450)$ is the $u\overline{d}$ state, and the mainly $s\overline{s}$ is still missing. The last is perhaps the state reported by LASS at 1525 MeV (ASTON 88D) or the $f_J(1710)$. The $f_0(400-1200)$ is then left as a background structure. The $f_0(1500)$ is too light and too narrow to be the second radially excited $u\overline{u} + d\overline{d}$ state, and it is not the missing $s\overline{s}$ state, due to its small $K\overline{K}$ branching ratio. A non- $q\overline{q}$ (gluonium) interpretation seems likely (AMSLER 96); see our Note on Non- $q\overline{q}$ Mesons.
- (ii) Most, if not all, light scalars are different manifestations of the quark model ${}^{3}P_{0}$ $q\bar{q}$ states. The most economic model for this second alternative is that of TORNQVIST 82, 95,

and 96, who fits the $f_0(400-1200)$, $f_0(980)$, $f_0(1370)$, $a_0(980)$, $a_0(1450)$, and $K_0^*(1430)$, as unitarized remnants of $q\bar{q}$ 1^3P_0 states with six parameters and theoretical constraints including flavor symmetry, the OZI rule, the equal-spacing rule for bare $q\overline{q}$ states, Adler zeroes, unitarity, and analyticity. Here the $f_0(400-1200)$ is at the same time the $u\overline{u} + d\overline{d}$ state, the chiral partner of the π , and the Higgs boson of QCD. The $f_0(980)$ and the $f_0(1370)$ are two different manifestations of the unitarized $s\bar{s}$ state, while the $a_0(980)$ and the $a_0(1450)$ are two manifestations of $u\overline{d}$. The interpretation of $f_0(1500)$ is in this scheme an open

For other models and more details discussing the interpretations of the scalar resonances, see AU 87, MORGAN 93, ZOU 93, 94B, and JANSSEN 95.

fo(1370) T-MATRIX POLE POSITION

Note that $\Gamma \approx 2 \text{ Im}(\sqrt{s_{pole}})$.

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
(1200-1500)-i(150-250) Ol	JR ESTIMATE		
• • We do not use the fol	lowing data for average	s, fits, limits,	etc. • • •
$(1330 \pm 50) - i(150 \pm 40)$	¹ AMSLER		$\overline{\rho} \rho \rightarrow 3\pi^0$
$(1360 \pm 35) - i(150 - 300)$	¹ AMSLER	95c CBAR	$\overline{\rho} \rho \rightarrow \pi^0 \eta \eta$
$1390 \pm 30 - i(190 \pm 40)$	² AMSLER	95D CBAR	$\overline{\rho} \rho \rightarrow 3\pi^0, \pi^0 \eta \eta,$
			$\pi^0\pi^0\eta$
1346 - i249	^{3,4} JANSSEN	95 RVUE	$\pi\pi \to \pi\pi$, $K\overline{K}$
1214 - i168	^{4,5} TORNQVIST		$\pi\pi \to \pi\pi$, $K\overline{K}$, $K\pi$,
1364 - i139	AMSLER	OND CDAD	$\overline{\rho} \stackrel{\eta}{\rho} \stackrel{\pi}{\rightarrow} \pi^0 \pi^0 \eta$
$(1365 + 20) - i(134 \pm 35)$	ANISOVICH		$\overline{p}p \rightarrow \pi \pi \eta$ $\overline{p}p \rightarrow 3\pi^0, \pi^0 \eta \eta$
$1340 \pm 40 - i(127 + \frac{30}{20})$	⁶ BUGG		$\overline{p} p \rightarrow 3\pi^0, \eta \eta \pi^0,$ $\eta \pi^0 \pi^0$
1515 - i214	4,7 ZOU	93 RVUE	$\eta \pi^- \pi^-$ $\pi \pi \rightarrow \pi \pi, K \overline{K}$
1420 - i220	8 AU	87 RVUE	$\pi\pi \to \pi\pi$, $K\overline{K}$
 Supersedes ANISOVICH Coupled-channel analysis explicitly that f₀ (400-12) 	of $\overline{p} p \rightarrow 3\pi^0$, $\pi^0 \eta \eta$,		

- ³ Analysis of data from FALVARD 88.
- The pole is on Sheet III. Demonstrates explicitly that $f_0(400-1200)$ and $f_0(1370)$ are two different poles
- ⁵ Uses data from BEIER 72B, OCHS 73, HYAMS 73, GRAYER 74, ROSSELET 77, CA SON 83, ASTON 88, and ARMSTRONG 91B. Coupled channel analysis with flavor symmetry and all light two-pseudoscalars systems.
- ⁶ Reanalysis of ANISOVICH 94 data.
- Analysis of data from OCHS 73, GRAYER 74, and ROSSELET 77, ⁸ Analysis of data from OCHS 73, GRAYER 74, BECKER 79, and CASON 83.

fo(1370) BREIT-WIGNER MASS OR K-MATRIX POLE PARAMETER

DOCUMENT ID 1200 to 1500 OUR ESTIMATE

$\pi\pi$ MODE

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
• • • We do not use th	ne following data for averages, f	its, limits,	etc. • • •
1186	9 TORNQVIST 9	5 RVUE	$\pi\pi \to \pi\pi$, $K\overline{K}$, $K\pi$,
1472 ± 12	ARMSTRONG 9	1 OMEG	$300 pp \rightarrow pp\pi\pi,$
1275±20	BREAKSTONE 9	D SFM	$\begin{array}{c} \rho p K \overline{K} \\ 62 \ \rho p \rightarrow \rho p \pi^+ \pi^- \end{array}$
1420 ± 20	AKESSON 8	6 SPEC	63 $pp \rightarrow pp\pi^{+}\pi^{-}$
1256	FROGGATT 7	7 RVUE	$\pi^{+}\pi^{-}$ channel

⁹ Uses data from BEIER 72B, OCHS 73, HYAMS 73, GRAYER 74, ROSSELET 77, CASON 83, ASTON 88, and ARMSTRONG 91B. Coupled channel analysis with flavor symmetry and all light two-pseudoscalars systems.

KK MODE

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
• • • We do not use th	ne following data for averages	s, fits, limits,	etc. • • •
1440 ± 20	CHEN	91 MRK3	$J/\psi \rightarrow \gamma \pi^+ \pi^-, \gamma K \overline{K}$
1440 ± 50	BOLONKIN	88 SPEC	$40 \pi^- p \rightarrow K_S^0 K_S^0 n$
1463± 9	ETKIN		$23 \pi^{-} p \rightarrow n2K_{S}^{0}$
1425 ± 15	WICKLUND	80 SPEC	$6 \pi N \rightarrow K^+ K^- N$
~ 1300	POLYCHRO	79 STRC	$7 \pi^- p \rightarrow n2K_c^0$

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
 • • We do not use th 	ne following data for average	s, fits	, limits,	etc. • • •
1374±38	AMSLER	94	CBAR	$0.0 \overline{p}p \rightarrow \pi^{+}\pi^{-}3\pi^{0}$
1345±12	ADAMO	93	OBLX	$\overline{n}p \rightarrow 3\pi^{+}2\pi^{-}$
1386±30	GASPERO	93	DBC	$0.0 \; \overline{p} n \rightarrow \; 2\pi^{+} 3\pi^{-}$
ηη MODE				
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
• • • We do not use th	ne following data for average	s, fits	, limits,	etc. • • •
1430	AMSLER	92	CBAR	$0.0 \ \overline{p} p \rightarrow \pi^0 \eta \eta$
1220 ± 40	ALDE	86D	GAM4	$100 \pi^- p \rightarrow n2n$

fo(1370) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID
300 to 500 OUR ESTIMATE	

$\pi\pi$ MODE

VALUE (MeV)	DOCUMENT ID	TECN_	COMMENT
• • • We do not use the following	ng data for averages, f	its, limits,	etc. • • •
350	¹⁰ TORNQVIST 95	RVUE	$\pi\pi \to \pi\pi$, $K\overline{K}$, $K\pi$,
195 ± 33	ARMSTRONG 91	OMEG	$\eta \pi$ $300 pp \rightarrow pp \pi \pi$, $pp K \overline{K}$
285 ± 60	BREAKSTONE 90	SFM	$62 pp \rightarrow pp\pi^{+}\pi^{-}$
460 ± 50			$63 pp \rightarrow pp\pi^{+}\pi^{-}$
~ 400	11 FROGGATT 77	RVUE	$\pi^+\pi^-$ channel

10 Uses data from BEIER 72B, OCHS 73, HYAMS 73, GRAYER 74, ROSSELET 77, CA-SON 83, ASTON 88, and ARMSTRONG 91B. Coupled channel analysis with flavor symmetry and all light two-pseudoscalars systems.

11 Width defined as distance between 45 and 135° phase shift.

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
• • We do not use the following of	data for averages	, fits	, limits,	etc. • • •
160 ± 40	CHEN	91	MRK3	$J/\psi \rightarrow \gamma \pi^+ \pi^-, \gamma K \overline{K}$
250 ± 80	BOLONKIN	88	SPEC	$40 \pi^- p \rightarrow K_S^0 K_S^0 n$
118 + 138 - 16	ETKIN	82B	MPS	$23 \pi^- \rho \rightarrow n2K_S^0$
160± 30				$6 \pi N \rightarrow K^+ K^- N$
~ 150	POLYCHRO	79	STRC	$7 \pi^- p \rightarrow n2K_S^0$

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
• • • We do not use t	he following data for average	s, fits	, limits,	etc. • • •
375 ± 61	AMSLER			$0.0 \ \overline{p}p \rightarrow \pi^{+}\pi^{-}3\pi^{0}$
398±26	ADAMO	93	OBLX	$\overline{n} p \rightarrow 3\pi^{+} 2\pi^{-}$
310±50	GASPERO	93	DBC	$0.0 \ \overline{p} n \rightarrow 2\pi^{+} 3\pi^{-}$
ηη MODE				
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
• • We do not use t	he following data for average	s, fits	, limits,	etc. • • •
250	AMSLER	92	CBAR	$0.0 \overline{p} \rho \rightarrow \pi^0 \eta \eta$
320 ± 40	ALDE	86D	GAM4	$100 \pi^- p \rightarrow n2n$

f₀(1370) DECAY MODES

In two-particle decay modes the $\pi\pi$ decay is dominant. We include here the resonance observed in 4π under the same entry as the one decaying to 2 pseudoscalars. See also the minireview under non- $q \bar{q}$ candidates.

	Mode	Fraction (Γ_i/Γ)
Γ_1	ππ	seen
Γ_2	4π	seen
Γ_3	$4\pi^{0}$	
Γ ₂ Γ ₃ Γ ₄	$4\pi^{0} \ 2\pi^{+}2\pi^{-} \ \pi^{+}\pi^{-}2\pi^{0}$	seen
Γ_5	$\pi^{+} \pi^{-} 2\pi^{0}$	seen
Γ ₆ Γ ₇	ho ho	
Γ_7	$2(\pi\pi)_S$	
Γ8	$rac{\eta\eta}{{\mathsf K}\overline{\mathsf K}}$	seen
Γ9	$K\overline{K}$	seen
Γ_{10}	$\gamma\gamma$	seen
Γ ₈ Γ ₉ Γ ₁₀ Γ ₁₁	e ⁺ e ⁻	not seen

fo(1370) PARTIAL WIDTHS

$\Gamma(\gamma\gamma)$						Γ ₁₀
VALUE (eV)		DOCUMENT ID		TECN	COMMENT	
• • • We do not us	e the followin	g data for average	s, fits	s, limits	, etc. • • •	
5.4 ± 2.3		MORGAN	90	RVUE	$\gamma\gamma ightarrow \pi^+\pi^-$,	$\pi^0\pi^0$
Γ(e ⁺ e ⁻)						Γ11
VALUE (eV)	CL%	DOCUMENT ID		TECN	COMMENT	
<20	90	VOROBYEV	88	ND	$e^+e^- \rightarrow \pi^0\pi^0$	0

fo(1370) BRANCHING RATIOS

ALUE	DOCUMENT ID		TECN	COMMENT
 We do not use the 	following data for averag	es, fit	s, Iimits,	etc. • • •
< 0.15	¹² AMSLER	94	CBAR	$\overline{p}p \rightarrow \pi^{+}\pi^{-}3\pi^{0}$
< 0.20	GASPERO	93	DBC	$0.0 \overline{D} n \rightarrow \text{hadrons}$

$\Gamma(4\pi)/\Gamma_{\text{total}}$			- 1	$\Gamma_2/\Gamma = (\Gamma_3$	₃ +Γ ₄ +Γ ₅)/Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
• • • We do not use the following	data for averages	, fits	, limits,	etc. • • •	
0.80 ± 0.04	GASPERO	93	DBC	$0.0 \ \overline{p} n \rightarrow$	hadrons

$\Gamma(2\pi^+2\pi^-)/\Gamma(4\pi)$			Γ4/	$\Gamma_2 = \Gamma_4/($	$\Gamma_3+\Gamma_4+\Gamma_5$)
VALUE	DOCUMENT ID		ECN	COMMENT	
• • We do not use the following the fol	lowing data for average	s, fits,	limits,	etc. • • •	
0.420 ± 0.014	¹³ GASPERO	93 E	DBC	$0.0~\overline{p}n\rightarrow$	$2\pi^{+}3\pi^{-}$

 $^{13}\, {\rm Model\text{-}dependent\,\, evaluation.}$

$\Gamma(\pi^+\pi^-2\pi^0)/\Gamma(4\pi)$		Γ ₅ ,	$/\Gamma_2 = \Gamma_5/(\Gamma_3 + \Gamma_4 + \Gamma_5)$
VALUE	DOCUMENT ID	TECN	COMMENT
• • • We do not use the	following data for averages, f	its, limits	, etc. • • •
0.512 ± 0.019	¹⁴ GASPERO 9:	3 DBC	$0.0 \ \overline{p} n \rightarrow \text{hadrons}$

¹⁴ Model-dependent evaluation.

ı

F(--)/F

$\Gamma\big(\rho\rho\big)/\Gamma\big(2(\pi\pi)_{\mathcal{S}}\big)$ Γ_6/Γ_7 VALUE DOCUMENT ID TECN COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • 94 CBAR $\overline{p} p \rightarrow \pi^+ \pi^- 3\pi^0$ 93 DBC 0.0 $\overline{p} n \rightarrow 2\pi^+ 3\pi^-$ 1.6 ±0.2 AMSLER GASPERO

f₀(1370) REFERENCES

AMSLER	95B	PL B342 433	+Armstrong, Brose+	(Crystal Barrel Collab.)		
AMSLER	95C	PL B353 571	+Armstrong, Hackman+	(Crystal Barrel Collab.)		
AMSLER	95D	PL B355 425	+Armstrong, Spanier+	(Crystal Barrel Collab.)		
JANSSEN	95	PR D52 2690	+Pearce, Holinde, Speth	(STON, ADLD, JULI)		
TORNQVIST	95	ZPHY C68 647		(HELS)		
AMSLER	94	PL B322 431	+Armstrong, Meyer+	(Crystal Barrei Collab.) JPC		
AMSLER	94D	PL B333 277	+Anisovich, Spanier+	(Crystal Barrel Collab.)		
ANISOVICH	94	PL B323 233	+Armstrong+	(Crystal Barrel Collab.) JPC		
BUGG	94	PR D50 4412	+Anisovich+	(LOQM)		
ADAMO	93	NP A558 13C	+Agnello+	(OBELIX Collab.) JPC		
GASPERO	93	NP A562 407		(ROMAI) JPC		
ZOU	93	PR D48 R3948	+Bugg	(LOQM)		
AMSLER	92	PL B291 347	+Augustin, Baker+	(Crystal Barrel Collab.)		
ARMSTRONG	91	ZPHY C51 351		, BIRM, CERN, CDEF)		
ARMSTRONG	91B	ZPHY C52 389		, BIRM, CERN, CDEF)		
CHEN	91	Hadron 91 Conf.		(Mark III Collab.)		
SLAC-PUB	-5669			, ,		
BREAKSTONE	90	ZPHY C48 569	+ (ISU, BGNA, CERN, I	DORT, HEIDH, WARS)		
MORGAN	90	ZPHY C48 623	+Pennington	(RAL, DURH)		
ASTON	88	NP B296 493	+Awaji, Bienz, Bird+ (SLAC	, NAGO, CINC, INUS)		
BOLONKIN	88	NP B309 426	+Bloshenko, Gorin+	(ITEP, SERP)		
FALVARD	88	PR D38 2706	+Ajaltouni+ (CLER	, FRAS, LALO, PADO)		
VOROBYEV	88	SJNP 48 273	+Golubev, Dolinsky, Druzhinin+	(NOVO)		
		Translated from YAF 4		(811811 811)		
AU	87	PR D35 1633	+Morgan, Pennington	(DURH, RAL)		
AKESSON	86	NP B264 154		ial Field Spec. Collab.)		
ALDE	86D	NP B269 485		, SERP, CERN, LANL)		
CASON ETKIN	83 82B	PR D28 1586 PR D25 1786	+Cannata, Baumbaugh, Bishop+ +Foley, Lai+ (BNL, 0	(NDAM, ANL) CUNY, TUFTS, VAND)		
WICKLUND	82B	PRL 45 1469	+Ayres, Cohen, Diebold, Pawlicki	(ANL)		
BECKER	79	NP B151 46		CERN, ZEEM, CRAC)		
POLYCHRO	79	PR D19 1317	Polychronakos, Cason, Bishop+	(NDAM, ANL)		
FROGGATT	77	NP B129 89	+Petersen	(GLAS, NORD)		
ROSSELET	77	PR D15 574	+Extermann, Fischer, Guisan+	(GEVA, SACL)		
GRAYER	74	NP B75 189	+Hyams, Blum, Dieti+	(CERN, MPIM)		
HYAMS	73	NP B64 134	+Jones, Weilhammer, Blum, Dietl+	(CERN, MPIM)		
OCHS	73	Thesis	1 sones, weimannier, blann, blett	(MPIM, MUNI)		
BEIER	72B	PRL 29 511	+Buchholtz, Mann+	(PENN)		
		OTHER	R RELATED PAPERS			
	OTHER REEN ED TAI ENS					

TORNQVIST	96	PRL 76 1575	+Roos	(HELS)
LI	91	PR D43 2161	+Close, Barnes+	(TENN)
BIZZARRI	69	NP B14 169	+Foster, Gavillet, Montanet+	(CERN, CDEF)
BETTINI	66	NC 42A 695	+Cresti, Limentani, Bertanza, Bigi+	(PADO, PISA)

 $h_1(1380), \hat{\rho}(1405), f_1(1420)$

1 1 1

$$I^{G}(J^{PC}) = ?^{-}(1^{+?})$$

OMITTED FROM SUMMARY TABLE Seen in partial-wave analysis of the K_S^0 $K^\pm\pi^\mp$ system. Evidence for $K^*\overline{K} + \overline{K}^*K$ decays (ASTON 88C). Needs confirmation.

h.,	(1380)	MASS
111	113001	MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1380±20	ASTON	88C	LASS	11 K [−] p →
				$\kappa_S^0 \kappa^{\pm} \pi^{\mp} \Lambda$

h₁(1380) WIDTH

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
80±30	ASTON	88c LASS	11 $K^- \rho \rightarrow K_S^0 K^{\pm} \pi^{\mp} \Lambda$

h1(1380) DECAY MODES

Mode $K\overline{K}^*(892) + c.c.$

h₁(1380) REFERENCES

88C PL B201 573

+Awaji, Bienz+

(SLAC, NAGO, CINC, INUS)

 $\hat{\rho}(1405)$

$$I^{G}(J^{PC}) = 1^{-}(1^{-+})$$

OMITTED FROM SUMMARY TABLE

 $\eta \pi^0 n$ amplitude analysis. Not Seen by ALDE 88B in $\pi^- p \to \eta \pi^0 n$ ampliconfirmed by reanalysis of PROKOSHKIN 95B.

See also the mini-review under non- $q\overline{q}$ candidates. (See the index

ρ(1405) MASS

VALUE (MeV)	DOCUMENT I	D	TECN	CHG	COMMENT
1406 ±20	¹ ALDE	88B	GAM4	0	$\begin{array}{c} 100 \ \pi^- p \rightarrow \\ \eta \pi^0 n \end{array}$
• • • We do not use the followi	ng data for avera	ges, fits	, limits,	etc. •	• •
1323.1 ± 4.6	AOYAGI	93	BKEI		$\pi^- \rho \rightarrow \eta \pi^- \rho$
1 Seen in the P_{Ω} -wave intensit	y of the $\eta\pi^0$ syst	tem.			

ρ(1405) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
180 ±20	² ALDE	88B	GAM4	0	100 $\pi^- \rho \rightarrow$
We do not use the following	data far avaraga		lim iko		$\eta \pi^0 n$

AOYAGI 93 BKEI 143.2 ± 12.5

 2 Seen in the P_0 -wave intensity of the $\eta \pi^0$ system.

$\hat{\rho}$ (1405) DECAY MODES

	Mode	Fraction $(\Gamma_{\tilde{I}}/\Gamma)$	
Γ_1	$\eta \pi^0$	possibly seen	
Γ_2	$\eta \pi^-$		
Γ3	$\rho \pi$	not seen	
Γ_4	$\eta' \pi$		

ρ̂(1405) BRANCHING RATIOS

$\Gamma(\eta \pi^0)/\Gamma_{\text{total}}$					Γ_1/Γ
VALUE	DOCUMENT ID		TECN	CHG	COMMENT
possibly seen	³ ALDE	88B	GAM4	0	100 π ⁻ p →
					$\eta \pi^0 n$
 ◆ ◆ We do not use th 	ne following data for averages,	, fits	, limits,	etc. •	• •
not seen	PROKOSHKIN	95B	GAM4		100 $\pi^- p \rightarrow$
					$\eta \pi^0 n$ $\overline{p} p \rightarrow \eta 2\pi^0$
not seen		94	RVUE		$\overline{p}p \rightarrow \eta 2\pi^0$
not seen	⁵ APEL	81	NICE	0	40 $\pi^- p \rightarrow$
					$n\pi^0\pi$

 $^{^3 \, \}mathrm{Seen}$ in the $P_0 \text{-wave intensity of the } \eta \, \pi^0 \, \, \mathrm{system}.$

$\Gamma(\eta \pi^-)/\Gamma$	total						Γ_2/Γ
VALUE			DOCUMENT ID				
• • • We d	o not	use the following	data for average	s, fit	s, limits,	etc. • • •	
possibly seer	1		AOYAGI	93	BKEI	$\pi^- p \rightarrow \eta \pi^- p$	
$\Gamma(\rho\pi)/\Gamma_{to}$	tal						Γ_3/Γ
VALUE			DOCUMENT ID		СОММЕ	NT	
not seen			ZIELINSKI	86	200 π	Cu,Pb $\rightarrow \pi^+\pi^-$	+ π- X
⁶ A genera statistics	al fit a	allowing S, D, and	P waves (includi	ng m	=0) is n	ot done because o	of limited
$\Gamma(\eta'\pi)/\Gamma($							Γ_4/Γ_1
VALUE		CL%	DOCUMENT ID		TECN	COMMENT	
• • • We d	o not	use the following	data for average	s, fit	s, limits,	etc. • • •	
< 0.80		95	BOUTEMEUR	90	GAM4	$100 \pi^- p \rightarrow 4\gamma$	n
		ρ̂(1	405) REFERE	NCI	ES .		
		DAM TO COC	+Sadovski			(!	SERP)
PROKOSHKIN	95B						
	95B 94	Translated from YAF	58 662. +Anisovich+				OQM)
BUGG AOYAGI	94 93	Translated from YAF PR D50 4412 PL B314 246	+Anisovich+ +Fukui, Hasegaw	a+	D DELC	(BKEI C	ollab.)
BUGG AOYAGI BOUTEMEUR	94 93 90	Translated from YAF PR D50 4412 PL B314 246	+Anisovich+ +Fukui, Hasegaw 19+Poulet	(SER		(BKEI C LANL, LAPP, PISA,	ollab.) KEK)
BUGG AOYAGI BOUTEMEUR ALDE ZIELINSKI	94 93 90 88B 86	Translated from YAF PR D50 4412 PL B314 246 Hadron 89 Conf. p 1 PL B205 397 Berkeley HEP 1 736	+Anisovich+ +Fukui, Hasegaw 19+Poulet +Binon, Boutem +Berg+	(SER eur+	(9	(BKEI`C LANL, LAPP, PISA, SERP, BELG, LANL, I (ROCH, MINN, F	ollab.) KEK) ,APP) IGJP(FNAL)
PROKOSHKIN BUGG AOYAGI BOUTEMEUR ALDE ZIELINSKI APEL	94 93 90 88B	Translated from YAF PR D50 4412 PL B314 246 Hadron 89 Conf. p 1 PL B205 397 Berkeley HEP 1 736	+Anisovich+ +Fukui, Hasegaw 19+Poulet +Binon, Boutem	(SER eur+	(9	(BKEI`C LANL, LAPP, PISA, SERP, BELG, LANL, I (ROCH, MINN, F	ollab.) KEK) ,APP) IGJP(FNAL)
BUGG AOYAGI BOUTEMEUR ALDE ZIELINSKI	94 93 90 88B 86	Translated from YAF PR D50 4412 PL B314 246 Hadron 89 Conf. p 1 PL B205 397 Berkeley HEP 1 736 NP B193 269	+Anisovich+ +Fukui, Hasegaw 19+Poulet +Binon, Boutem +Berg+	(SER eur+ rtolucc	(S i, Donsko	(BKEI`C LANL, LAPP, PISA, SERP, BELG, LANL, I (ROCH, MINN, F	ollab.) KEK) ,APP) IGJP(FNAL)
BUGG AOYAGI BOUTEMEUR ALDE ZIELINSKI	94 93 90 88B 86 81	Translated from YAF PR D50 4412 PL B314 246 Hadron 89 Conf. p 1 PL B205 397 Berkeley HEP 1 736 NP B193 269 OTHE	+Anisovich + +Fukui, Hasegaw 19+Poulet +Binon, Boutem +Berg+ +Augenstein, Bei	(SER eur+ rtolucc	(S i, Donsko	(BKEL'C LANL, LAPP, PISA, SERP, BELG, LANL, I (ROCH, MINN, I v+ (SERP, C	ollab.) KEK) ,APP) IGJP(FNAL)
BUGG AOYAGI BOUTEMEUR ALDE ZIELINSKI APEL PROKOSHKIN	94 93 90 88B 86 81	Translated from YAF PR D50 4412 PL B314 246 Hadron 89 Conf. p. 1 PL B205 397 Berkeley HEP 1 736 NP B193 269 PAN 58 853 Translated from YAF ZPHY C62 323	+ Anisovich+ + Fukui, Hasegaw 19+Poulet + Binon, Boutem + Berg+ + Augenstein, Bei R RELATED + Sadovski 58 921. Kalashnikova	(SER eur+ rtolucc	(S i, Donsko	(BKEI C LANL, LAPP, PISA, SERP, BELG, LANL, I (ROCH, MINN, I V+ (SERP, C	ollab.) KEK) .APP) IGJPO FNAL) :ERN)
BUGG AOYAGI BOUTEMEUR ALDE ZIELINSKI APEL	94 93 90 88B 86 81	Translated from YAF PR D50 4412 PL B314 246 Hadron 89 Conf. p. 1 PL B205 397 Berkeley HEP 1 736 NP B193 269 OTHE PAN 58 853 Translated from YAF ZPHY C62 323 PL B205 564	+Anisovich + +Fukui, Hasegaw 19+Poulet +Binon, Boutem +Berg+ +Augenstein, Bei	(SER eur+ rtolucc	(S i, Donsko	(BKEI C LANL, LAPP, PISA, SERP, BELG, LANL, I (ROCH, MINN, I V+ (SERP, C	ollab.) KEK) KEK) APP) IGJPC NAL) ERN) SERP) ITEP) OKY)

 $f_1(1420)$

$$I^{G}(J^{PC}) = 0^{+}(1^{+})$$

See also minireview under non- $q\overline{q}$ candidates.

THE $f_1(1420)$

ı

This particle is the axial-vector component of the old puzzling E/ι , which has caused much trouble.

In hadron-induced reactions, the $f_1(1420)$ is observed in centrally produced $K\overline{K}\pi$ systems obtained with π and p beams (DIONISI 80, ARMSTRONG 84, 89). A Dalitz-plot analysis gives its quantum numbers and the dominant decay mode. For instance, ARMSTRONG 89 finds that the signal is totally consistent with being an 1++ state with a dominant quasitwo-body S-wave decay into $K^*(892)\overline{K}$; furthermore, no 0^{-+} or 1^{+-} waves are required to fit the data. A G parity of +1 is suggested by the positive interference between the two overlapping $K^*(892)$ (ARMSTRONG 84). No significant signals in the $\eta\pi\pi$ or 4π decay modes are found in centrally produced 4π systems (ARMSTRONG 89G). All of this is in line with the previous observations made in $\overline{p}p$ annihilations.

In $\gamma\gamma$ fusion from e^+e^- annihilations, a signal at about 1420 MeV is seen only in single-tag events (AIHARA 86C, GIDAL 87B, BEHREND 89, HILL 89), where one of the two photons is off the mass shell; by contrast, it is totally absent in the untagged events where both photons are real and hence they cannot produce a spin-1 meson, because of the Yang-Landau theorem. This clearly implies J=1 and C=+1. As for the parity, AIHARA 88B, 88C (same analysis as AIHARA 86C, with 25% more events) and BEHREND 89 all find angular distributions with positive parity preferred, but negative parity not excluded.

Although some uncertainties still remain, the state seen in hadronic interactions and that seen in spacelike virtual photon fusion from e^+e^- annihilations are often identified with

⁴ Using Crystal Barrel data

⁵ A general fit allowing S, D, and P waves (including m=0) is not done because of limited statistics.

one another since there are more similarities than differences. In particular, all experiments agree that this state appears only in $K^*(892)\overline{K}$. The same conclusions are obtained from partial wave analyses of $J/\psi(1S) \to \gamma K\overline{K}\pi$ (BAI 90C, AUGUSTIN 91).

BITYUKOV 88 studied the radiative decay $1^{++} \to \phi \gamma$. Since the ϕ is (almost) a pure $s\overline{s}$ state, the $\phi \gamma$ decay seems to be a good analyser to extract the $s\overline{s}$ component in the wave function of the decaying meson. Finding the $f_1(1285)$ but not the $f_1(1420)$, BITYUKOV 88 concludes that the $f_1(1420)$ cannot be the $s\overline{s}$ isoscalar member of the $q\overline{q}$ nonet containing the $f_1(1285)$. On the other hand, AIHARA 88C argues that, assuming they both belong to the same nonet and using several hypotheses, the octet-singlet mixing angle obtained is compatible with the $f_1(1420)$ being mostly $s\overline{s}$ and the $f_1(1285)$ being mostly $(u\overline{u}+d\overline{d})/\sqrt{2}$, although both require large admixtures of other $q\overline{q}$ components.

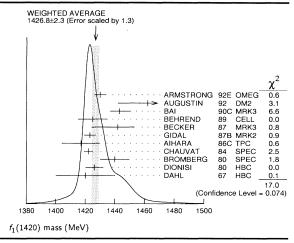
Arguments favoring the possibility the $f_1(1420)$ is a hybrid $q\bar{q}g$ meson or a four-quark state are put forward by ISHIDA 89 and by CALDWELL 90, respectively.

LONGACRE 90 argues that this particle is inconsistent with a QCD arrangement of quarks and gluons. He then develops a final-state rescattering mechanism with successive interactions between a K, a \overline{K} , and a π . The $f_1(1420)$ would then be a molecular state formed by the π orbiting in a P wave around an S-wave $K\overline{K}$ state.

$f_1(1420)$ MASS

VALUE (N			EVTS	DOCUMENT ID		TECN	COMMENT
1426.8±	2.3	OUR AVE	RAGE	Error includes scale	facto	r of 1.3.	See the ideogram below.
1430 ±	4			¹ ARMSTRONG	92E	OMEG	85,300 $\pi^+ \rho$, $\rho \rho \rightarrow$
				_			$\pi^+ \rho$, $\rho \rho (K \overline{K} \pi)$
$1462 \pm$	20			² AUGUSTIN	92	DM2	$J/\psi \rightarrow \gamma K \overline{K} \pi$
1443 +	· 7	+ 3 - 2	1100	BAI	9 0c	MRK3	$J/\psi \rightarrow \gamma K_S^0 K^{\pm} \pi^{\mp}$
1425 \pm	10		17	BEHREND	89	CELL	$\gamma \gamma \rightarrow \kappa_S^0 \kappa^{\pm} \pi^{\mp}$
1442 ±	5	$^{+10}_{-17}$	111	BECKER	87	MRK3	e^+e^- , $\omega K \overline{K} \pi$
1423 ±	4			GIDAL	87B	MRK2	$e^+e^- \rightarrow e^+e^- K \overline{K} \pi$
1417 ±	13		13	AIHARA	86C	TPC	$e^+e^- \rightarrow e^+e^- K \overline{K} \pi$
$1422 \pm$	3			CHAUVAT	84	SPEC	ISR 31.5 pp
1440 ±	10			³ BROMBERG	80	SPEC	$100 \pi^- p \rightarrow K\overline{K}\pi X$
1426 ±	6		221	DIONISI	80	HBC	$4 \pi^- p \rightarrow K \overline{K} \pi n$
1420 ±	20			DAHL	67	HBC	1.6-4.2 π ⁻ p
• • • W	∕e do	not use th	ne followin	ng data for averages	, fits	, limits,	etc. • • •
1429 ±	3		389	ARMSTRONG	89	OMEG	300 $pp \rightarrow K\overline{K}\pi pp$
1425 ±	2		1520	ARMSTRONG	84	OMEG	85 $\pi^+ \rho$, $\rho \rho \rightarrow$
							$(\pi^+, \rho)(K\overline{K}\pi)\rho$

 $^{^{\}mathrm{1}}\,\mathrm{This}$ result supersedes ARMSTRONG 84, ARMSTRONG 89.



f1(1420) WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
53± 5 OUR A	VERAGE				
58 ± 10	4	⁴ ARMSTRONG	92E	OMEG	85,300 $\pi^+ p$, $pp \rightarrow$
		-			$\pi^+ p$, $pp(K\overline{K}\pi)$
129 ± 41	;	⁵ AUGUSTIN	92	DM2	$J/\psi \rightarrow \gamma K \overline{K} \pi$
$68 + 29 + 8 \\ -18 - 9$	1100	BAI	90c	MRK3	$J/\psi \rightarrow \gamma K_S^0 K^{\pm} \pi^{\mp}$
$\textbf{42}\pm\textbf{22}$	17	BEHREND	89	CELL	$\gamma \gamma \rightarrow K_S^0 K^{\pm} \pi^{\mp}$
$40^{+17}_{-13}\pm5$	111	BECKER	87	MRK3	$e^+e^- ightarrow \omega K \overline{K} \pi$
$35 + 47 \\ -20$	13	AIHARA	86 C	TPC	$e^+e^-\rightarrowe^+e^-K\overline{K}\pi$
47 ± 10		CHAUVAT	84	SPEC	ISR 31.5 pp
62 ± 14		BROMBERG	80	SPEC	$100 \pi^- p \rightarrow K \overline{K} \pi X$
40 ± 15	221	DIONISI	80	HBC	$4 \pi^- p \rightarrow K \overline{K} \pi n$
60 ± 20		DAHL	67	HBC	1.6-4.2 π ⁻ p
	t use the following	data for averages	, fits	, limits,	etc. • • •
58± 8	389	ARMSTRONG	89	OMEG	$300 pp \rightarrow K\overline{K}\pi pp$
62 ± 5	1520	ARMSTRONG	84	OMEG	85 $\pi^+ \rho$, $\rho \rho \rightarrow$
					$(\pi^+, \rho)(K\overline{K}\pi)\rho$

⁴ This result supersedes ARMSTRONG 84, ARMSTRONG 89.

f_1 (1420) DECAY MODES

	Mode	Fraction (Γ_i/Γ)	
Γ ₁	$K\overline{K}\pi$	dominant	
Γ_2	$\eta \pi \pi$	possibly seen	
Γ_3	$a_0(980)\pi$		
Γ_4	$\pi \pi \rho$		
Γ_5	$K\overline{K}^*(892) + \text{c.c.}$		
Γ_6	4π		
Γ_7	$\gamma \gamma^*$		
Γ ₈	$ ho^0 \gamma$		

$f_1(1420) \Gamma(i)\Gamma(\gamma\gamma)/\Gamma(total)$

$\Gamma(K\overline{K}\pi) \times \Gamma(\gamma\gamma)$	*)/F _{total}				$\Gamma_1\Gamma_7/\Gamma$
VALUE (keV)	CL%	DOCUMENT ID		TECN	COMMENT
1.7±0.4 OUR AVE	RAGE				
$3.0\pm0.9\pm0.7$	6	⁷ BEHREND	89	CELL	$e^+e^{e^+e^-}\overset{ ightarrow}{\kappa^0_5}\kappa_\pi$
$2.3^{+1.0}_{-0.9}\pm0.8$		HILL			$e^+e^{e^+e^-} \xrightarrow{\kappa^{\pm}\kappa^0_{5}\pi^{\mp}}$
$1.3 \pm 0.5 \pm 0.3$		AIHARA			$e^{+}e^{-}_{e^{+}e^{-}}$ $K^{\pm}K^{0}_{5}\pi^{\mp}$
1.6 ± 0.7 ± 0.3 • • • We do not use		⁸ GIDAL	87B	MRK2	$e^+e^- \rightarrow e^+e^- \kappa \overline{\kappa} \pi$
• • • We do not use	the following	uata ioi average			
∠8 O	95	LENINI	83	MRK2	e+e e+e-KK

 $^{^{6}\,\}mathrm{Assume}$ a $\,\rho\text{-pole}$ form factor.

² From fit to the $K^*(892)K$ 1 + + partial wave.

³ Mass error increased to account for $a_0(980)$ mass cut uncertainties.

⁵ From fit to the $K^*(892)K$ 1 + + partial wave.

 $^{^{7}}$ A ϕ - pole form factor gives considerably smaller widths.

⁸ Published value divided by 2.

 $f_1(1420)$, $\omega(1420)$, $f_2(1430)$

$t_1(1420)$	BRANCHING	RATIOS

/ALUE	′Γ(<i>ΚҠ̄π</i>) 	DOCUMENT ID		TECN		5/F
• • We do not use the	e following	data for average	s, fits	, limits,	etc. • • •	
0.76±0.06		BROMBERG	80	SPEC	$100 \ \pi^- p \rightarrow \ K \overline{K} \pi$	·X
0.86 ± 0.12		DIONISI	80	нвс	$4 \pi^- \rho \rightarrow K \overline{K} \pi n$	
$\Gamma(\pi\pi\rho)/\Gamma(K\overline{K}\pi)$					Γ	4/F
	CL%	DOCUMENT ID		TECN	COMMENT	
• • We do not use the	following	data for average	s, fits	, limits,	etc. • • •	
< 0.3	95	CORDEN	78		12-15 π p	
<2.0		DAHL	67	HBC	$1.6-4.2 \pi^{-} p$	
$\Gamma(\eta\pi\pi)/\Gamma(K\overline{K}\pi)$					Γ:	2/Г
ALUE	CL%	DOCUMENT ID		TECN	-	
<0.1	95	ARMSTRONG	91B	OMEG	300 $\rho \rho \rightarrow \rho \rho \eta \pi^+$	π-
• We do not use the	e following	data for average	s, fits	, limits,	etc. • • •	
1.35 ± 0.75		KOPKE	89	MRK3	$J/\psi \rightarrow \omega \eta \pi \pi (K\overline{K})$	₹π)
<0.6	90	GIDAL	87	MRK2	$e^+e^{e^+e^-\eta\pi^+\pi^-}$	
< 0.5	95	CORDEN	78	OMEG	$12-15 \pi^{-} \rho$	
1.5 ±0.8	-	DEFOIX	72	нвс	0.7 p p	
· (- (000) -) /F(١				-	/-
$(a_0(980)\pi)/\Gamma(\eta\pi\pi)$)	DOCUMENT ID		TECN		з/Г
• We do not use the	following	DOCUMENT ID				
ot seen in either mode	. Tollowing	ANDO	86		8 π ⁻ p	
ot seen in either mode		CORDEN	78		0 π p 12-15 π p	
.4±0.2		DEFOIX	72	HBC	$0.7 \overline{p}p \rightarrow 7\pi$	
					• •	
「(A+1)/F(<i>K K*</i> (20つ)、	1 c c l					
						6/F
ALUE	CL%	DOCUMENT ID			COMMENT	6/F
• We do not use the	CL% e following	data for average	s, fits	, limits,	COMMENT etc. • • •	6/F
• We do not use the	CL%		s, fits		COMMENT	6/Г
• We do not use the <0.90	CL% e following 95	data for average DIONISI	s, fits 80	, limits,	COMMENT etc. • • • $4 \pi^- p$	
• • We do not use the <0.90	CL% e following 95	data for average DIONISI	s, fits 80 .c.)]	s, limits, HBC	etc. \bullet \bullet \bullet 4 $\pi^- p$	
ALUE • • We do not use the <0.90 $(K\overline{K}\pi)/[\Gamma(a_0(980))]$ ALUE	$\frac{CL\%}{\text{e following}}$ 95 $(\pi) + \Gamma(F)$	data for average DIONISI (K*(892)+c. DOCUMENT ID	s, fits 80 .c.)]	s, limits, HBC <u>TECN</u>	COMMENT etc. • • • $4 \pi^- p$ $\Gamma_1/(\Gamma_3 + COMMENT)$	
ALUE • • We do not use the $\langle 0.90 \rangle$ • $(K\overline{K}\pi)/[\Gamma(a_0(980))]$ • • We do not use the	e following $ \begin{array}{c} CL\% \\ 95\\ \end{array} $ $ \begin{array}{c} \pi \\ \end{array} $ + $\Gamma(I)$ e following	data for average DIONISI (K*(892)+c. DOCUMENT ID	s, fits 80 .c.)]	s, limits, HBC <u>TECN</u>	COMMENT etc. • • • $4 \pi^- p$ $\Gamma_1/(\Gamma_3 + COMMENT)$	
ALUE • • We do not use the <0.90 $((K\overline{K}\pi))/[\Gamma(a_0(980))$ ALUE • • We do not use the $.65\pm0.27$	e following 95 $\pi + \Gamma(F)$ e following	data for average DIONISI $\langle \overline{K}^*(892) + c.$ DOCUMENT ID data for average:	s, fits 80 .c.)] s, fits	HBC TECN Ilmits, HBC	COMMENT etc. • • • $4 \pi^{-} p$ $\Gamma_{1}/(\Gamma_{3} + C_{1})$ etc. • • • $4 \pi^{-} p$	
ALUE • • We do not use the <0.90 ($(K\overline{K}\pi)/[\Gamma(a_0(980))]$ • We do not use the $.65\pm0.27$ 9 Calculated using $\Gamma(K)$	e following 95 $(\pi K)/\Gamma(\eta \pi)$	data for average DIONISI $(\overline{K}^*(892) + c. \frac{DOCUMENT ID}{c}$ data for average DIONISI $= 0.24 \pm 0.07$	s, fits 80 .c.)] s, fits	HBC TECN Ilmits, HBC	COMMENT etc. • • • • $4 \pi^- p$ $\Gamma_1/(\Gamma_3 + COMMENT)$ etc. • • • $4 \pi^- p$ ractions.	+Г5
ALUE • We do not use the <0.90 ($(K\overline{K}\pi)/[\Gamma(a_0(980))]$ • We do not use the $.65\pm0.27$ 9 Calculated using $\Gamma(K\overline{K})$ ($a_0(980)\pi)/\Gamma(K\overline{K})$	e following 95 $(K)/\Gamma(\eta \pi)$ (892) + C	data for average DIONISI $(\overline{K}^*(892) + c.$ DOCUMENT ID data for average: DIONISI $= 0.24 \pm 0.07$ C.C.)	s, fits 80 c.)] s, fits 80 for a	TECN s, limits, HBC s, limits, HBC 0(980) f	COMMENT etc. • • • $4 \pi^{-} p$ $\Gamma_{1}/(\Gamma_{3} + \Gamma_{4})$ etc. • • • $4 \pi^{-} p$ ractions.	+Г5
ALUE • • We do not use the <0.90 ($(K\overline{K}\pi)/[\Gamma(a_0(980))]$ • • We do not use the $.65\pm0.27$ 9 Calculated using $\Gamma(K\overline{K})$ ($a_0(980)\pi)/\Gamma(K\overline{K})$ ALUE	e following 95 $ \begin{array}{c} CL\% \\ 95 \end{array} $ e following 95 e following 6 $ \begin{array}{c} (\overline{K})/\Gamma(\eta\pi) \\ *(892) + C \end{array} $	data for average DIONISI (**K**(892) + c. DOCUMENT ID data for average DIONISI = 0.24 ± 0.07 c.c.)	s, fits 80 .c.)] s, fits 80 for a	TECN HBC TECN HBC HBC TECN HBC (980) f	COMMENT etc. • • • $4 \pi^{-} p$ $\Gamma_{1}/(\Gamma_{3} + \Gamma_{2})$ etc. • • • $4 \pi^{-} p$ ractions. Γ_{3} COMMENT	+Г5
ALUE • We do not use the <0.90 ($(K\overline{K}\pi)/[\Gamma(a_0(980ALUE) - • We do not use the .65\pm0.27 9 Calculated using \Gamma(K\overline{K}^2ALUE) - • We do not use the .65\pm0.27$	e following 95 $(K) / \Gamma(\eta \pi)$ *(892) + C • following 95	data for average DIONISI K**(892) + c. DOCUMENT ID data for average DIONISI = 0.24 ± 0.07 C.C.) DOCUMENT ID data for average	s, fits 80 .c.)] s, fits 80 for a	TECN S, limits, HBC S, limits, HBC (980) f	COMMENT etc. • • • $4 \pi^{-} p$ $\Gamma_{1}/(\Gamma_{3} + \Gamma_{2})$ etc. • • • $4 \pi^{-} p$ ractions. Γ_{3} COMMENT etc. • • •	+Г5
ALUE • We do not use the <0.90 ($(K\overline{K}\pi)/[\Gamma(a_0(980ALUE) - • We do not use the .65\pm0.27 9 Calculated using \Gamma(K\overline{K}^2ALUE) - • We do not use the .65\pm0.27$	e following 95 $ \begin{array}{c} CL\% \\ 95 \end{array} $ e following 95 e following 6 $ \begin{array}{c} (\overline{K})/\Gamma(\eta\pi) \\ *(892) + C \end{array} $	data for average DIONISI (**K**(892) + c. DOCUMENT ID data for average DIONISI = 0.24 ± 0.07 c.c.)	s, fits 80 .c.)] s, fits 80 for a	TECN S, limits, HBC S, limits, HBC (980) f	COMMENT etc. • • • $4 \pi^{-} p$ $\Gamma_{1}/(\Gamma_{3} + \Gamma_{2})$ etc. • • • $4 \pi^{-} p$ ractions. Γ_{3} COMMENT etc. • • •	+Г5
ALUE • We do not use the <0.90 $(K\overline{K}\pi)/[\Gamma(a_0(980M_LUE) - \bullet) \text{ We do not use the } 6.65\pm0.27$ • Calculated using $\Gamma(K\overline{K}^{\prime}M_LUE) - \bullet$ • We do not use the <0.00	e following 95 $(K) / \Gamma(\eta \pi)$ *(892) + C • following 95	data for average DIONISI K**(892) + c. DOCUMENT ID data for average DIONISI = 0.24 ± 0.07 C.C.) DOCUMENT ID data for average	s, fits 80 .c.)] s, fits 80 for a	TECN S, limits, HBC S, limits, HBC (980) f	COMMENT etc. • • • $4 \pi^{-} \rho$ $\Gamma_{1}/(\Gamma_{3} + \Gamma_{4})$ etc. • • • $4 \pi^{-} \rho$ ractions. Γ_{3} $COMMENT$ etc. • • • $85 \pi^{+} \rho$	+Γ _ε
ALUE • • We do not use the <0.90 • ($K\overline{K}\pi$)/ $[\Gamma(a_0(980))$ • We do not use the $.65\pm0.27$ • Calculated using $\Gamma(K\overline{K})$ • We do not use the $.65\pm0.27$ • We do not use the $.65\pm0.27$ • Ve do not use the $.65\pm0.27$ • We do not use the $.65\pm0.27$	e following 95 $(K) / \Gamma(\eta \pi)$ *(892) + C • following 95	data for average DIONISI \(\vec{K}^*(892) + \text{c.} \) \(\text{DOCUMENT ID} \) data for average \(\text{DIONISI} \) \(= 0.24 \pm 0.07 \) \(\text{c.c.} \) \(\text{DOCUMENT ID} \) data for average ARMSTRONG	s, fits 80 .c.)]] s, fits 80 for a	TECN (1) (1) (1) (1) (1) (1) (1) (1) (1) (1)	COMMENT etc. • • • $4 \pi^- p$ $\Gamma_1/(\Gamma_3 + C_1)$ etc. • • • $4 \pi^- p$ ractions. Γ_3 COMMENT etc. • • • $85 \pi^+ p$	+Γ _ε
ALUE • We do not use the <0.90 • We do not use the <0.90 • We do not use the $.65\pm0.27$ • Calculated using $\Gamma(K\overline{K}^{\prime})$ • We do not use the $.65\pm0.27$ • Calculated using $\Gamma(K\overline{K}^{\prime})$ • We do not use the $.90$ • We do not use the $.90$	c. CL% e following 95 $m + \Gamma(h)$ e following $K / \Gamma(\eta \pi)$ *(892) + C $K / \Gamma(\eta \pi)$ e following 68	data for average DIONISI K**(892) + C. DOCUMENT ID data for average DIONISI = 0.24 ± 0.07 C.C.) DOCUMENT ID data for average ARMSTRONG	s, fits 80 .c.)]] s, fits 80 for a ₀	TECN TECN (980) f TECN TECN (980) f TECN TECN TECN TECN TECN TECN TECN	COMMENT etc. • • • $4 \pi^- p$ $\Gamma_1/(\Gamma_3 + C_1)$ etc. • • • $4 \pi^- p$ ractions. Γ_3 COMMENT etc. • • • $85 \pi^+ p$	+Γ _ε
ALUE • We do not use the <0.90 $((K\overline{K}\pi))/[\Gamma(a_0(980 \times 1.00))]$ • • We do not use the $.65\pm0.27$ • Calculated using $\Gamma(K\overline{K})$ ($a_0(980)\pi$)/ $\Gamma(K\overline{K})$ ALUE • We do not use the <0.04 $(4\pi)/\Gamma(K\overline{K}\pi)$ ALUE <0.04	c.t.% e following 95 $)\pi) + \Gamma(f)$ e following $(\overline{K})/\Gamma(\eta \pi)$ *(892) + c (\overline{L}) e following 68	data for average DIONISI K**(892) + C. DOCUMENT ID data for average DIONISI = 0.24 ± 0.07 C.C.) DOCUMENT ID data for average ARMSTRONG	s, fits 80 .c.)]] s, fits 80 for a ₀	TECN TECN (980) f TECN TECN (980) f TECN TECN TECN TECN TECN TECN TECN	COMMENT etc. • • • • $4\pi^-p$ $\Gamma_1/(\Gamma_3+\frac{COMMENT}{4\pi^-p})$ ractions. Γ_3 $\frac{COMMENT}{4\pi^-p}$ etc. • • • π^+p $\frac{COMMENT}{85\pi^-p}$	+Γ _ξ
ALUE • We do not use the <0.90 $(K\overline{K}\pi)/[\Gamma(a_0(980 \times 1.00))/\Gamma(K\overline{K}\pi)/[\Gamma(a_0(980 \times 1.00))/\Gamma(K\overline{K}\pi)/$	c.t.% e following 95 $(\overline{K})/\Gamma(\eta \pi)$ • (892) + c c.t.% e following 68 $(\overline{K})/\Gamma(\eta \pi)$	data for average DIONISI **\tilde{K**(892)} + c. DOCUMENT ID data for average DIONISI = 0.24 ± 0.07 c.) DOCUMENT ID data for average ARMSTRONG DOCUMENT ID ARMSTRONG	s, fits 80 .c.)] s, fits 80 for a ₀ ss, fits 84	TECN (1) (1) (1) (1) (1) (1) (1) (1) (1) (1)	COMMENT etc. • • • $4\pi^-p$ $\Gamma_1/(\Gamma_3 + \frac{COMMENT}{4\pi^-p})$ etc. • • • $4\pi^-p$ ractions. Γ_3 $\frac{COMMENT}{4\pi^-p}$ etc. • • • $\frac{COMMENT}{4\pi^-p}$ etc. • • • $\frac{COMMENT}{4\pi^-p}$	+Γ _ξ
• • We do not use the <0.90 $ \frac{\Gamma(K\overline{K}\pi)}{\Gamma(a_0(980))} \frac{\Gamma(a_0(980)\pi)}{\Gamma(K\overline{K}^n)} \frac{\Gamma(a_0(980)\pi)}{\Gamma(K\overline{K}^n)} \frac{\Gamma(a_0(980)\pi)}{\Gamma(K\overline{K}^n)} \frac{\Gamma(A_0(980)\pi)}{\Gamma(K\overline{K}^n)} \frac{\Gamma(A_0(980)\pi)}{\Gamma(K\overline{K}^n)} \frac{\Gamma(A_0(980)\pi)}{\Gamma(A_0(980)\pi)} \frac{\Gamma(K\overline{K}^n)}{\Gamma(A_0(980)\pi)} \frac{\Gamma(A_0(980)\pi)}{\Gamma(A_0(980)\pi)} \frac{\Gamma(A_0(980)\pi)}{\Gamma(A$	c.t.% e following 95 $(\overline{K})/\Gamma(\eta \pi)$ • (892) + c c.t.% e following 68 c.t.% 95	data for average DIONISI K**(892) + C. DOCUMENT ID data for average DIONISI = 0.24 ± 0.07 C.C.) DOCUMENT ID data for average ARMSTRONG	s, fits 80 .c.)] ss, fits 80 for a 85 84	TECN OMEG	COMMENT etc. • • • $4\pi^-p$ $\Gamma_1/(\Gamma_3 + \frac{COMMENT}{4\pi^-p})$ etc. • • • $4\pi^-p$ ractions. Γ_3 $\frac{COMMENT}{4\pi^-p}$ etc. • • • $\frac{COMMENT}{4\pi^-p}$ etc. • • • $\frac{COMMENT}{4\pi^-p}$	₃ /Γ ₆ /Γ

f₁(1420) REFERENCES

	- ,	•
ARMSTRONG 92C ARMSTRONG 91B ARMSTRONG 91B BAI 90C ARMSTRONG 95G BEHRRND 89G HILL 89 AHARA 88B BECKER 87 GIDAL 87 GIDAL 87 GIDAL 87 AIHARA 86 ARMSTRONG 86 ARMSTRONG 86 ARMSTRONG 86 CORDEN 78 DEFOIX 72 Aliso 65	ZPHY 56 29 PR D46 1951 ZPHY (52 389 PRL 56 2507 PL 8221 216 ZPHY (43 55 ZPHY (43 55 ZPHY (42 367 ZPHY (42 367 ZPHY (42 367 ZPHY (42 367 ZPHY (46 367 PRL 59 2016 PRL 59 2016 PRL 57 2500 PRL 57 2500 PRL 57 1296 PL 146B 273 PR 152 1513 NP 5169 1 NP 5144 125 NP 5144 125 NP 5144 125 NP 514 1074	+Barnes, Benayoun++ (ATHU, BARI, BIRM, CERN, CDEF) JPC +Cosme (ATHU, BARI, BIRM, CERN, CDEF) JPC +Cosme (DMZ Collab, +Barnes+ (ATHU, BARI, BIRM, CERN, CDEF) +Blaylock+ +Benayoun+(CERN, CDEF, BIRM, BARI, ATHU, CURIN+) +Criegee+ +Criegee+ +Criegee+ +Criegee+ +Alston-Garnjost+ +Wermes+ +Alston-Garnjost+ +Blaylock, Bolton, Brown+ +Boyer, Butler, Cords, Abrams+ +Boyer, Butler, Cords, Abrams+ +Boyer, Butler, Cords, Abrams+ +Boyer, Butler, Cords, Abrams+ +Alston-Garnjost+ +(KEK, KYOT, NIRS, SAGA, INUS, TSUK+) +Bloodworth, Burns+ +Bloodworth, Burns- +Bloodworth, Burns
	OTHE	R RELATED PAPERS
IIZUKA 91 CALDWELL 90 ISHIDA 89 AIHARA 88C BITYUKOV 88 PROTOPOP 87B	PL B203 327	+ Koibuchi (NAGO) (VCSB) (T + Oda, Sawazaki, Yamada (NHO) + Alston-Garnjost+ (SER) P + Portopopescu, Chung (BNL)

 $\omega(1420)$

 $I^{G}(J^{PC}) = 0^{-}(1^{-})$

See also $\omega(1600)$.

ω (1420) MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
1419±31	315	¹ ANTONELLI	92	DM2	$1.34-2.4e^{+}e^{-} \rightarrow \rho\pi$
• • • We do not	use the following	g data for averag	es, fit	s, limits,	etc. • • •
1440 ± 70		² CLEGG	94	RVUE	
¹ From a fit to t with fixed (+,	-,+) phases.		ring b	etween t	them and with the ω , ϕ tails

ω (1420) WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
174±59	315	³ ANTONELLI	92	DM2	$1.34-2.4e^{+}e^{-} \rightarrow \rho\pi$
• • • We do not use t	he following	data for averages	s, fits	s, limits,	etc. • • •
240 ± 70		⁴ CLEGG	94	RVUE	
3		c			

³ From a fit to two Breit-Wigner functions interfering between them and with the ω , ϕ tails with fixed (+,-,+) phases.

⁴Using data published by ANTONELLI 92.

ω (1420) DECAY MODES

	Mode	Fraction (Γ_i/Γ)	
Γ_1	ρπ	dominant	
Γ_2	$\omega \pi \pi$		
Γ_3	e ⁺ e ⁻		

ω(1420) Γ(i)Γ(e^+e^-)/Γ(total)

$\Gamma(\rho\pi) \times \Gamma(e^+$	$e^-)/\Gamma_{\mathrm{total}}$					$\Gamma_1\Gamma_3/\Gamma$
VALUE (eV)	EVTS	DOCUMENT ID		TECN	COMMENT	
81 ± 31	315	⁵ ANTONELLI	92	DM2	1.34-2.4 <i>e</i> + <i>e</i> -	$\rightarrow \rho \pi$

 5 From a fit to two Breit-Wigner functions interfering between them and with the ω,ϕ tails with fixed (+,-,+) phases.

ω (1420) REFERENCES

CLEGG 94 ZPHY C62 455 ANTONELLI 92 ZPHY C56 15

- OTHER RELATED PAPERS -

87 ZPHY C34 157 84 NP B231 15 83B PL 127B 132 (BONN, CERN, GLAS, LANC, MCHS, CURIN) (BONN, CERN, GLAS, LANC, MCHS, CURIN+) (BONN, CERN, GLAS, LANC, MCHS, CURIN+)

 $f_2(1430)$

 $I^{G}(J^{PC}) = 0^{+}(2^{+})$

OMITTED FROM SUMMARY TABLE

This entry lists nearby peaks observed in the D wave of the $K\,\overline{K}$ and $\pi^+\pi^-$ systems. Needs confirmation.

f2(1430) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 1430 OUR ESTIMAT • • We do not use the 	E e following data for average	s, fit	s, limits,	etc. • •
1421 ± 5	AUGUSTIN	87	DM2	$J/\psi \rightarrow \gamma \pi^{+} \pi^{-}$
1410 ± 50	AKESSON	86	SPEC	$\rho \rho \rightarrow \rho \rho \pi^+ \pi^-$
$1436 + 26 \\ -16$	DAUM			17-18 π ⁻ p → K ⁺ K ⁻ p
1412± 3	DAUM	84	CNTR	$63 \begin{array}{c} K^{+} K^{-} n \\ \pi^{-} p \rightarrow K_{S}^{0} K_{S}^{0} n, \\ K^{+} K^{-} n \end{array}$
1439 + 5	¹ BEUSCH	67	OSPK	$5,7,12 \pi^{+} \rho \rightarrow K_{S}^{0} K_{S}^{0} n$
¹ Not seen by WETZE	EL 76.			

f ₂ (1430) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following	ing data for averag	es, fit	s, limits,	etc. • • •
30 ± 9	AUGUSTIN			$J/\psi \rightarrow \gamma \pi^+ \pi^-$
80 ± 40	AKESSON	86	SPEC	$\rho \rho \rightarrow \rho \pi^+ \pi^-$
81 + 56 - 29	DAUM			$17-18 \pi^- \rho \rightarrow \kappa^+ \kappa^- \rho$
14± 6	DAUM	84	CNTR	63 $\pi^{-} p \to K_{S}^{0} K_{S}^{0} n$, $K^{+} K^{-} n$
43^{+17}_{-18}	² BEUSCH	67	OSPK	$5,7,12 \pi^- \rho \rightarrow K_0^0 K_0^0 n$
² Not seen by WETZEL 76.				5 5

f2(1430) DECAY MODES

	Mode
-	ΚK
Γ_2	$\pi\pi$

f2(1430) REFERENCES

AUGUSTIN AKESSON	87 86	ZPHY C36 369 NP B264 154	+Cosme+ +Albrow, Almehed+	(LALO, CLER, FRAS, PADO) (Axial Field Spec. Collab.)
DAUM	84	ZPHY C23 339	+Hertzberger+ (AMST,	CERN, CRAC, MPIM, OXF+) JP
WETZEL	76	NP B115 208	+Freudenreich, Beusch+	(ETH, CERN, LOIC)
BEUSCH	67	PL 25B 357	+Fischer, Gobbi, Astbury+	(ETH, CERN)

$\eta(1440)$

$$I^{G}(J^{PC}) = 0^{+}(0^{-}+)$$

See also the mini-review under non- $q\overline{q}$ candidates. (See the index for the page number.)

THE $\eta(1440)$

The first observation of a meson with $I^G J^{PC} = 0^+0^{-+}$ in the 1400-MeV mass region was made in $p\bar{p} \to K\bar{K}3\pi$ annihilations at rest (BAILLON 67). The $\eta(1440)$ was reported to decay into $K\overline{K}\pi$, equally through $a_0(980)\pi$ and $K^*(892)\overline{K}$.

The $\eta(1440)$ has since also been seen in a partial-wave analysis of the $K\overline{K}\pi$ system (CHUNG 85, BIRMAN 88), in 6-GeV $p\bar{p}$ annihilations (REEVES 86), and in nonperipherally selected $\pi^- p \to K_S^0 K_S^0 \pi^0 n$ (RATH 89). RATH 89 favors two η resonances in the 1410-1480 MeV region. This is also observed at LEAR in $\overline{p}p \to K\overline{K}3\pi$ annihilations at rest (BERTIN 95).

In a partial-wave analysis of $\pi^- p \to \eta \pi^+ \pi^-$, FUKUI 91C confirms the decay $\eta(1440) \rightarrow a_0(980)\pi$. In $\bar{p}p \rightarrow \eta\pi\pi$ annihilations at rest, AMSLER 95F finds roughly equal contributions from $a_0(980)\pi$ and $\eta(\pi\pi)_S$.

Neither the $\eta(1440)$ nor the $f_1(1420)$ are observed in the $s\bar{s}$ -enriched peripheral reaction $K^-p\to K\overline{K}\pi\Lambda$ at 11 GeV/c (ASTON 87), which speaks against an $s\bar{s}$ interpretation of either state. ARMSTRONG 84, 89, studying $K\overline{K}\pi$ central production in $\pi^+p \to \pi^+(K\overline{K}\pi)p$ and $pp \to p(K\overline{K}\pi)p$ at 85 and 300 GeV/c, observed the $f_1(1420)$ but not the $\eta(1440)$.

The $\eta(1440)$ is also seen as a broad enhancement in $J/\psi(1S)$ radiative decay. BUGG 95 has reanalyzed the MARK-III data and finds a contribution to 4π in agreement with DM2 (BISELLO 89B). The $\eta \pi^+ \pi^-$ channel peaks near 1400 MeV (AUGUSTIN 90, BOLTON 92B), in agreement with observations in $\overline{p}p$ annihilation at rest (AMSLER 95F). It has been shown (TOKI 87, BAI 90C) that two pseudoscalar resonances at ≈ 1420 and ≈ 1490 MeV, together with a 1⁺⁺ around 1440 MeV, give a better description of the $K\overline{K}\pi$ data. These results, together with RATH 89 and BERTIN 95, suggest the existence of two overlapping pseudoscalar states, one around 1400 MeV

decaying into both $K\overline{K}\pi$ and $\eta\pi\pi$, the other one around 1480 MeV decaying only to $K\overline{K}\pi$.

We continue to list under the $\eta(1440)$ all the results on the 0^{-+} system in the 1380-1490 MeV region, but there is probably more than one resonance present in the observations. It is thus difficult to give reliable \overline{K}^*K or $a_0\pi$ branching ratios. The masses and widths are given separately according to the various decay modes. See also our Note on "Non- $q\bar{q}$ Mesons."

η(1440) MASS

VALUE (MeV)

1415±10 OUR ESTIMATE

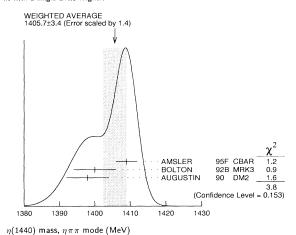
This is only an educated guess; the error given is larger than the error on the average of the published values.

$\eta\pi\pi$ MODE

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
1405.7± 3.4 OUR	AVERAGE	Error includes scale	facto	r of 1.4.	See the ideogram below.
1409 ± 3		AMSLER	95F	CBAR	$0 \overline{p} p \rightarrow \pi^+ \pi^- \pi^0 \pi^0 \eta$
1400 ± 6		$^{ m 1}$ BOLTON	92B	MRK3	$J/\psi \rightarrow \gamma \eta \pi^+ \pi^-$
1398 ± 6	261	² AUGUSTIN	90	DM2	$J/\psi \rightarrow \gamma \eta \pi^+ \pi^-$
• • • We do not u	se the following	ng data for average	s, fits	, limits,	etc. • • •
1385 ±15		¹ BEHREND	92	CELL	$J/\psi \rightarrow \gamma \eta \pi^+ \pi^-$
1388 ± 4		FUKUI	91C	SPEC	8.95 $\pi^- p \to \eta \pi^+ \pi^- n$
1420 + 5		ANDO	86	SPEC	$8 \pi^- p \rightarrow nn\pi^+\pi^-$

 $^{^{1}}$ From fit to the $a_{0}(980)\pi$ 0 $^{-}$ + partial wave.

² Best fit with a single Breit Wigner.



$\pi\pi\gamma$ MODE

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
• • • We do not use th	e following data for averages,	fits	, limits,	etc. • • •
1401 ± 18	3,4 AUGUSTIN	90	DM2	$J/\psi \rightarrow \pi^+\pi^-\gamma\gamma$
1440 ± 20	⁴ COFFMAN	90	MRK3	$J/\psi \rightarrow \pi^{+}\pi^{-}2\gamma$

³Best fit with a single Breit Wigner.

4π MODE VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMEN	TT.
• • • We do not use	the followin	g data for averag	es, fits,	limits,	etc. • •	•
1420 ± 20		BUGG	95	MRK3	$J/\psi \rightarrow$	$\gamma \pi^+ \pi^- \pi^+ \pi^-$
1489 ± 12	3270	⁵ BISELLO	89B	DM2	$J/\psi \rightarrow$	$4\pi\gamma$

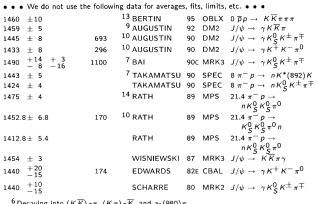
⁵ Estimated by us from various fits.

$K\overline{K}\pi$ MODE

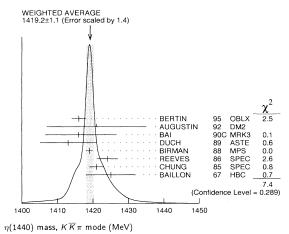
M M M INIODE					
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
1419.2± 1.1 OUR AV	/ERAGE	Error includes scale	facto	or of 1.4	. See the ideogram below.
1416 ± 2		⁶ BERTIN			$0 \overline{p} p \rightarrow K \overline{K} \pi \pi \pi$
1421 ± 14		⁷ AUGUSTIN	92	DM2	$J/\psi \rightarrow \gamma K \overline{K} \pi$
1416 \pm 8 $^{+}$ 7	700	8 BAI	90c	MRK3	$J/\psi \rightarrow \gamma K_S^0 K^{\pm} \pi^{\mp}$
1413 ± 8	500	DUCH	89	ASTE	$\overline{p} p \rightarrow$
					$ \begin{array}{c} \pi^{+}\pi^{-}K^{\pm}\pi^{\mp}K^{0} \\ 8\pi^{-}\rho \to K^{+}\overline{K}^{0}\pi^{-}n \end{array} $
1419 ± 1		9,10 BIRMAN	88	MPS	$8\pi^- p \rightarrow K^+ \overline{K}{}^0 \pi^- n$
1424 ± 3	620	10,11 REEVES	86	SPEC	6.6 $p\overline{p} \rightarrow K\overline{K}\pi X$
1421 ± 2		CHUNG	85	SPEC	$8 \pi^- p \rightarrow K \overline{K} \pi n$
1425 + 7	800	10,12 BAILLON	67	HBC	$0.0 \overline{\rho} \rho \rightarrow K \overline{K} \pi \pi \pi$

⁴ This peak in the $\gamma \rho$ channel may not be related to the $\eta(1440)$.

$\eta(1440)$



- 6 Decaying into $(K\,\overline{K})_S\pi$, $(K\,\pi)_S\overline{K}$, and $a_0(980)\pi$.
- 7 From fit to the $K^*(892)K$ 0 $^-$ + partial wave. 8 From fit to the $a_0(980)\pi$ 1 $^+$ + partial wave. cannot rule out a $a_0(980)\pi$ 1 $^+$ + partial wave. 9 From fit to the $a_0(980)\pi$ 0 $^{-+}$ partial wave.
- 10 Best fit with a single Breit Wigner.
- 11 From fit of the 0^-+ partial wave , mainly $a_0(980)\pi$. 12 From best fit of 0^-+ partial wave , $50\%~K^*(892)K$, $50\%~a_0(980)\pi$.
- 13 Decaying into $K^*(892)K$.
- The fit is also consistent with one resonance at 1453 MeV.



η(1440) WIDTH

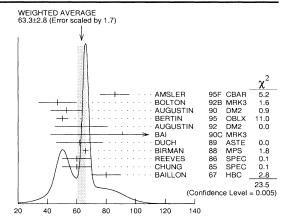
DOCUMENT ID

60±20 OUR ESTIMATE This is only an educated guess; the error given is larger than the error on the average of the published values.

$\eta\pi\pi$ MODE

1/4/1/5	(11.11)	DOCU	MENT ID	TECH	COMMENT	
VALUE	(MeV)	<u>DOCU</u>	MENTID	TECN	COMMENT	
63.3	3± 2.8	OUR AVERAGE	Includes da	ta from t	he datablock that !	follows this one.
			Error i	ncludes s	cale factor of 1.7.	See the ideogram
			below.			
86	± 10				$0 \overline{\rho} \rho \rightarrow \pi^+ \pi^-$	
47	± 13				$J/\psi \rightarrow \gamma \eta \pi^+ \pi$	
53	± 11	¹⁶ AUGI	JSTIN 90	DM2	$J/\psi \rightarrow \gamma \eta \pi^+ \pi$	
• • •	We do	not use the follow	ving data for	averages	, fits, limits, etc. •	• •
~ 50		16 BEH	REND 92	CELL	$J/\psi \rightarrow \gamma \eta \pi^+ \pi$	
59	± 4	FUKI	JI 91	c SPEC	$8.95 \pi^- \rho \rightarrow \eta \tau$	$\pi^+\pi^-n$
31	± 7	AND	O 86	SPEC	$8 \pi^- \rho \rightarrow n \eta \pi$	+ _π -
1 5						

 $^{^{15}\,\}mathrm{From}$ fit to the $a_0(980)\,\pi$ 0 $^-$ + partial wave.



 $\eta(1440)$ width $\eta\pi\pi$ mode (MeV)

$\pi\pi\gamma$ MODE

" " WODE					
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	_
• • We do not use the follow	ving data for average	s, fits	s, limits,	etc. • • •	
174±44	AUGUSTIN			$J/\psi \rightarrow \pi^+\pi^-\gamma\gamma$	
60 ± 30	¹⁷ COFFMAN	90	MRK3	$J/\psi \rightarrow \pi^+\pi^-2\gamma$	

¹⁷ This peak in the $\gamma \rho$ channel may not be related to the η (1440).

A- MODE

VALUE (MeV)	EVTS	DOCUMENT IE)	TECN	COMMEN	IT
• • • We do not	use the followin	g data for averag	ges, fits,	limits,	etc. • •	•
160 ± 30		BUGG	95	MRK3	$J/\psi \rightarrow$	$\gamma \pi^{+} \pi^{-} \pi^{+} \pi^{-}$
144 ± 13	3270	¹⁸ BISELLO	89B	DM2	$J/\psi \rightarrow$	$4\pi\gamma$
18 Estimated by 1	ıs from various	fits.				

$K\overline{K}\pi$ MODE

VALUE (MeV) EVTS DOCUMENT ID TECN COMMENT

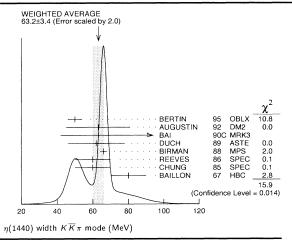
The data in this block is included in the average printed for a previous datablock.

63.	2± 3.4	OUR	AVERAGE	Error	includes scale	factor	of 2.0.	See the ideogram below.
50	± 4			19	BERTIN	95	OBLX	$0 \overline{p} p \rightarrow K \overline{K} \pi \pi \pi$
63	± 18				AUGUSTIN	92	DM2	$J/\psi \rightarrow \gamma K \overline{K} \pi$
91	$+67 \\ -31$	+15 -38			BAI	90c	MRK3	$J/\psi \rightarrow \gamma K_S^0 K^{\pm} \pi^{\mp}$
62	± 16		500		DUCH	89		$\overline{p} p \rightarrow K \overline{K} \pi \pi \pi$
66	± 2		8800		BIRMAN	88	MPS	$8\pi^- p \rightarrow K^+ \overline{K}^0 \pi^- n$
60	± 10		620	20	REEVES	86	SPEC	$6.6 p\overline{p} \rightarrow KK\pi X$
60	± 10				CHUNG	85	SPEC	$8\pi^- p \rightarrow K\overline{K}\pi n$
80	± 10		800	21	BAILLON	67	HBC	$0.0 \overline{p}p \rightarrow K\overline{K}\pi\pi\pi$
• •	• We	do not	use the follow	ving d	ata for average	es, fits	, limits,	etc. • • •
105	± 15			22	BERTIN	95	OBLX	$0 \overline{p} \rho \rightarrow K \overline{K} \pi \pi \pi$
75	± 9			23	AUGUSTIN	92	DM2	$J/\psi \rightarrow \gamma K \overline{K} \pi$
75	± 9		693	23	AUGUSTIN	90	DM2	$J/\psi \rightarrow \gamma K_S^0 K^{\pm} \pi^{\mp}$
93	± 14		296		AUGUSTIN	90	DM2	$J/\psi \rightarrow \gamma K^+ K^- \pi^0$
105	± 10		693		AUGUSTIN	90	DM2	$J/\psi \rightarrow \gamma K_S^0 K^{\pm} \pi^{\mp}$
54	$+37 \\ -21$	$^{+13}_{-24}$		24	BAI	90c	MRK3	$J/\psi \rightarrow \gamma K_S^0 K^{\pm} \pi^{\mp}$
59	士 4			24	TAKAMATSU	90	SPEC	$9 \pi^- p \rightarrow n \eta \pi^+ \pi^-$
82	± 8				TAKAMATSU	90		$8\pi^-p \rightarrow nK_S^0K^{\pm}\pi^{\mp}$
57	± 8				TAKAMATSU	90	SPEC	$8 \pi^- p \rightarrow nK^*(892)K$
51	± 13			25	RATH	89	MPS	21.4 $\pi^- p \rightarrow$
								$nK_{c}^{0}K_{c}^{0}\pi^{0}$
99.	9±11.4	1	170	26	RATH	89	MPS	$21.4 \pi^{-} \rho \rightarrow$
								K ⁰ ₆ K ⁰ ₆ π ⁰ π
19	± 7				RATH	89	MPS	
								21.4 $\pi^- p \rightarrow n K_5^0 K_5^0 \pi^0$
160	± 11				WISNIEWSKI	87	MRK3	
55	$+20 \\ -30$		174		EDWARDS	82E	CBAL	$J/\psi \rightarrow \gamma K^+ K^- \pi^0$
50	$+30 \\ -20$				SCHARRE	80	MRK2	$J/\psi \rightarrow \gamma K_S^0 K^{\pm} \pi^{\mp}$

- 19 Decaying into $(K\overline{K})_S\pi$, $(K\pi)_S\overline{K}$, and $a_0(980)\pi$. 20 From best fit to 0 $^{-}$ + partial wave , 50% $K^*(892)K$, 50% $a_0(980)\pi$.
- $^{21}\,\mathrm{From}$ fit to the 0 $^-$ + partial wave , mainly $a_0(980)\pi.$
- ²² Decaying into $K^*(892)K$.
- 23 From fit to the $a_0(980)\pi$ 0 $^-$ + partial wave.
- ²⁴ From fit to the $K^*(892)K$ 0 $^{-+}$ partial wave.
- 25 From fit to the $a_0(980)\pi$ 0 $^-$ partial wave , but $a_0(980)\pi$ 1 $^+$ + cannot be excluded. The fit is also consistent with one resonance at 1453 MeV. 26 Best fit with a single Breit Wigner.

 $^{^{16}}$ From $\eta\pi^+\pi^-$ mass distribution - mainly $a_0(980)\pi$ - no spin–parity determination avail-





$\eta(1440)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ ₁	$K\overline{K}\pi$	seen
Γ_2	$\eta \pi \pi$	seen
Γ3	$a_0(980)\pi$	seen
	$\pi\pi\rho$	
Γ ₄ Γ ₅	$K\overline{K}^*$ (892) + c.c.	
Γ_6	4π	seen
Γ_7	$\gamma \gamma$	
Γ8	$\rho^0 \gamma$	

$\eta(1440) \Gamma(i)\Gamma(\gamma\gamma)/\Gamma(total)$

$\Gamma(K\overline{K}\pi) \times \Gamma(\gamma)$	$(\gamma)/\Gamma_{total}$					$\Gamma_1\Gamma_7/\Gamma$
VALUE (keV)	CL%	DOCUMENT ID		TECN		
<1.2	95	BEHREND	89	CELL	$\gamma\gamma \rightarrow K_{S}^{0}$	$5K^{\pm}\pi^{\mp}$
• • • We do not us	se the followin	g data for average				
<1.6	95	AIHARA	86D	TPC	$e^+e^{e^+e^-}$	$\kappa_S^0 \kappa^{\pm} \pi^{\mp}$
<2.2	95	ALTHOFF	85B	TASS	$e^+e^- \rightarrow$	$e^+e^-K\overline{K}\pi$
<8.0	95	JENNI	83	MRK2	$e^+e^- \rightarrow$	$e^+e^-K\overline{K}\pi$
$\Gamma(\eta\pi\pi)\times\Gamma(\gamma\gamma)$	γ)/Γ _{total}			T=011	COLUMENT	$\Gamma_2\Gamma_7/\Gamma$
VALUE (keV)		DOCUMENT ID		TECN	COMMENT	
• • • We do not u	se the following	-				
< 0.3		ANTREASYA	1 87	CBAL	e ⁺ e [−] →	$e^+e^-\eta\pi\pi$
$\Gamma(\rho^0\gamma) \times \Gamma(\gamma\gamma)$	$)/\Gamma_{ ext{total}}$					$\Gamma_8\Gamma_7/\Gamma$
VALUE (keV)	CL%	DOCUMENT ID		TECN	COMMENT	
• • • We do not u	se the followin	g data for average	s, fits	, limits,	etc. • • •	
<1.5	95	ALTHOFF	84E	TASS	$e^+e^{e^+e^-}$	$\pi^+\pi^-\gamma$

η (1440) BRANCHING RATIOS

$\Gamma(\eta\pi\pi)/\Gamma(K\overline{K}\pi)$						Γ_2/Γ_1
VALUE	CL%	DOCUMENT ID		TECN	COMMENT	
• • • We do not use th	ne followi	ng data for average	s, fits	, limits,	etc. • • •	
< 0.5	90	EDWARDS	83B	CBAL	$J/\psi \rightarrow \eta \pi \pi \gamma$	
<1.1	90	SCHARRE	80	MRK2	$J/\psi \rightarrow \eta \pi \pi \gamma$	
<1.5	95	FOSTER	68B	нвс	0.0 p p	
$\Gamma(a_0(980)\pi)/\Gamma(K\overline{K})$	(π)					Γ_3/Γ_1
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT	
~ 0.8	500	²⁷ DUCH	89	ASTE		
					$\pi^+\pi^-K^{\pm}\pi$	$\mp \kappa^0$
 ● ● We do not use the 	ne followi	ng data for average	s, fits	, limits,	etc. • • •	
~ 0.15					$0 \overline{p} p \rightarrow K \overline{K} \pi \tau$	
~ 0.75		²⁷ REEVES	86	SPEC	$6.6 p\overline{p} \rightarrow KK$	rΧ
²⁷ Assuming that the a	a ₀ (980) d	ecays only into $K\overline{k}$				
$\Gamma(a_0(980)\pi)/\Gamma(\eta\pi\pi$	π)					Γ_3/Γ_2
VALUE		DOCUMENT ID		TECN_	COMMENT	
0.56±0.04±0.03		²⁸ AMSLER	95F	CBAR	$0 \overline{p} p \rightarrow \pi^+ \pi^-$	$\pi^{0}\pi^{0}\eta$
28 Assuming that the a	e _∩ (980) d	lecays only into $\eta\pi$.				

$\Gamma(K\overline{K}^*(892) + c.c.)$	$/\Gamma(K\overline{K}\pi)$)				Γ_5/Γ_1
VALUE		DOCUMENT ID		TECN	COMMENT	
0.50±0.10		BAILLON	67	нвс	0.0 <u>p</u> ρ →	$\kappa \overline{K} \pi \pi \pi$
Γ(<i>K</i> K *(892) + c.c.)	/[Γ(<i>a</i> ₀ (98	$(80)\pi)+\Gamma(K\overline{k})$	₹(8	92)+c	.c.)]	$\Gamma_5/(\Gamma_3+\Gamma_5)$
VALUE	CL%	DOCUMENT ID		TECN	COMMENT	
• • • We do not use t	he following	data for average	es, fit	s, limits	, etc. • • •	•
< 0.25	90	EDWARDS	82E	CBAL	$J/\psi ightarrow I$	$\kappa^+ \kappa^- \pi^0 \gamma$
$\Gamma(ho^0\gamma)/\Gamma(K\overline{K}\pi)$						Γ_8/Γ_1
VALUE		DOCUMENT ID		TECN	COMMENT	
0.0152±0.0038	2	⁹ COFFMAN	90	MRK3	$J/\psi ightarrow ight$	$\gamma \gamma \pi^+ \pi^-$
²⁹ Using B($J/\psi \rightarrow \gamma \gamma \rho^0$)=6.4 × 10 ⁻⁵						

η(1440) REFERENCES

AMSLER	95F	PL B358 389	+Armstrong, Urner+	(Crystal Barrel Collab.)
BERTIN	95	PL B361 187	+Bruschi+	(OBELIX Collab.)
BUGG	95	PL B353 378	+Scott, Zoli+	(LOQM, PNPI, WASH)
AUGUSTIN	92	PR D46 1951	+Cosme	(DM2 Collab.)
BEHREND	92	ZPHY C56 381		(CELLO Collab.)
BOLTON	92B	PRL 69 1328	+Brown, Bunnell+	(Mark III Collab.)
FUKUI	91C	PL B267 293	+ (SUGI, NAGO), KEK, KYOT, MIYA, AKIT)
AUGUSTIN	90	PR D42 10	+Cosme+	(DM2 Collab.)
BAI	90C	PRL 65 2507	+Blaylock+	(Mark III Collab.)
COFFMAN	90	PR D41 1410	+De Jongh+	(Mark III Collab.)
TAKAMATSU	90	Hadron 89 Conf. p 71	+Ando+	(KEK)
BEHREND	89	ZPHY C42 367	+Criegee+	(CELLO Collab.)
BISELLO	89B	PR D39 701	Busetto+	(DM2 Collab.)
DUCH	89	ZPHY 45 223	+Heel, Bailey+	(ASTERIX Collab.) JP
RATH	89	PR D40 693		BRAN, BNL, CUNY, DUKE)
BIRMAN	88	PRL 61 1557	+Chung, Peaslee+	(BNL, FSU, IND, MASD) JP
ANTREASYAN		PR D36 2633	+Bartels, Besset+	(Crystal Ball Collab.)
WISNIEWSKI	87	Hadron 87 Conf.		(Mark III Collab.)
AIHARA	86D	PRL 57 51	+Alston-Garnjost+	(TPC-2γ Collab.)
ANDO	86	PRL 57 1296		NIRS, SAGA, INUS, TSUK+) IJP
REEVES	86	PR 34 1960		(FLOR, BNL, IND, MASD) JP
ALTHOFF	85B	ZPHY C29 189	+Braunschweig, Kirschfink+	
CHUNG	85	PRL 55 779		(BNL, FLOR, IND, MASD) JP
ALTHOFF	84E	PL 147B 487	+Braunschweig, Kirschfink, Lu	iebelsmeyer+ (TASSO Collab.)
EDWARDS	83B	PRL 51 859		, HARV, PRIN, STAN, SLAC)
JENNI	83	PR D27 1031	+Burke, Telnov, Abrams, Bloc	
EDWARDS	82E	PRL 49 259		, HARV, PRIN, STAN, SLAC)
Also	83	PRL 50 219		(CIT, HARV, PRIN, STAN+)
SCHARRE	80	PL 97B 329		ker+ (SLAC, LBL)
FOSTER	68B	NP B8 174		+ (CERN, CDEF)
BAILLON	67	NC 50A 393	+Edwards, D Andiau, Astier+	(CERN, CDEF, IRAD)

OTHER RELATED PAPERS -

GENOVESE	94	ZPHY C61 425	+Lichtenberg, Pedrazzi	(TORI, IND)
AHMAD	89	NP B (PROC.)8 50	+Amsler, Auld+	(ASTERIX Collab.)
ARMSTRONG	89	PL B221 216	+Benayoun+(CERN, CDEF,	BIRM, BARI, ATHU, CURIN+)
ZIEMINSKA	88	AIP Conf.		(IND)
ARMSTRONG	87	ZPHY C34 23	+Bloodworth+ (CERN,	BIRM, BARI, ATHU, CURIN+)
ASTON	87	NP B292 693	+Awaji, D'Amore+	(SLAC, NAGO, CINC, INUS)
PROTOPOP	87B	Hadron 87 Conf.	Protopopescu, Chung	(BNL)
TOKI	87	Hadron 87 Conf.		(SLAC)
ARMSTRONG	84	PL 146B 273	+Bloodworth, Burns+	(ATHU, BARI, BIRM, CERN)
DIONISI	80	NP B169 1	+Gavillet+	(CERN, MADR, CDEF, STOH)
DEFOIX	72	NP B44 125	+Nascimento, Bizzarri+	(CDEF, CERN)
DUBOC	72	NP B46 429	+Goldberg, Makowski, Dona	ild+ (PARIS, LIVP)
LORSTAD	69	NP B14 63	+D'Andlau, Astier+	(CDEF, CERN)
ASTON PROTOPOP TOKI ARMSTRONG DIONISI DEFOIX DUBOC	87 87B 87 84 80 72 72	NP B292 693 Hadron 87 Conf. Hadron 87 Conf. PL 146B 273 NP B169 1 NP B44 125 NP B46 429	+Awaji, D'Amore+ Protopopescu, Chung +Bloodworth, Burns+ +Gavillet+ +Nascimento, Bizzarri+ +Goldberg, Makowski, Dona	(SLAC, NAGO, CINC, INUS) (BNL) (SLAC) (ATHU, BARI, BIRM, CERN) (CERN, MADR, CDEF, STOH) (CDEF, CERN) id+ (PARIS, LIVP)

$a_0(1450)$

$$I^{G}(J^{PC}) = 1^{-}(0^{+})$$

OMITTED FROM SUMMARY TABLE

From a partial-wave analysis of the $\pi\eta$ system. Needs confirmation. See minireview on scalar mesons under $f_0(1370)$.

a₀(1450) MASS

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
1450±40	AMSLER	94D CBAR	$0.0 \ \overline{p} p \rightarrow \pi^0 \pi^0 \eta$
• • • We do not use t	he following data for averag	es, fits, limits,	etc. • • •
1470±25	¹ AMSLER	95D CBAR	$0.0 \overline{p}p \rightarrow \pi^{0}\pi^{0}\pi^{0},$ $\pi^{0}\eta\eta, \pi^{0}\pi^{0}\eta$ $\overline{p}p \rightarrow \eta^{2}\pi^{0}$
1435±40	BUGG	94 RVUE	$\overline{p}p \rightarrow \eta 2\pi^0$
1 Coupled-channel ar	alysis of AMSLER 95B, AM	SLER 95c. and	d AMSLER 94D.

$a_0(1450)$ WIDTH

VALUE (MeV)	DOCUMENT ID	TEC	N COMMENT
270±40	AMSLER	94D CBA	AR $0.0 \overline{p}p \rightarrow \pi^0 \pi^0 \eta$
• • • We do not use th	e following data for average	s, fits, lim	its, etc. • • •
265±30	² AMSLER	950 CB/	AR $0.0 \overline{p}p \rightarrow \pi^0 \pi^0 \pi^0$, $\pi^0 \eta \eta$, $\pi^0 \pi^0 \eta$ JE $\overline{p}p \rightarrow \eta 2\pi^0$
270 ± 40	BUGG	94 RVI	JE $\overline{p}p \rightarrow \eta 2\pi^0$
² Coupled-channel ana	lysis of AMSLER 95B, AMS	SLER 95c,	and AMSLER 94D.

 $a_0(1450)$, $\rho(1450)$

$a_0(1450)$ DECAY MO	DES
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I	Mode	Fraction $(\Gamma_{\hat{I}}/\Gamma)$
Γ_1	$\pi \eta$	seen

a₀(1450) REFERENCES

AMSLER AMSLER AMSLER AMSLER	95B PL B34 95C PL B35 95D PL B35 94D PL B33	3 571 5 425 3 277	+Armstrong, E +Armstrong, F +Armstrong, S +Anisovich, Sp	lackman+ panier+	(Crystal (Crystal	Barrel Collab.) Barrel Collab.) Barrel Collab.) Barrel Collab.) IGJPC	
BUGG	94 PR D50		+Anisovich+	James F	(Ciystoi	(LOQM)	



$$I^{G}(J^{PC}) = 1^{+}(1^{-})$$

See the mini-review under the ho(1700).

ρ(1450) MASS DOCUMENT ID

1465±25 OUR ESTIMATE	This is only an educated guess; the error given is larger than the error on the average of the published values.
1449± 8 OUR AVERAGE	Includes data from the 4 datablocks that follow this one.
MIXED MODES	
VALUE (MeV)	DOCUMENT ID TECN COMMENT
The data in this block is incl	uded in the average printed for a previous datablock.

• • We do not use the following data for averages, fits, limits, etc. • •

 1265.5 ± 75.3

$\eta \, ho^0$ MODE

VALUE (MeV)

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
The data in this block is included in	the average printed	for a prev	vious datablock.

ANTONELLI 88 DM2 $e^+e^- \rightarrow \eta \pi^+\pi^-$ 1446 ± 10 FUKUI 88 SPEC 8.95 $\pi^- p \rightarrow \eta \pi^+ \pi^- n$

$\pi^+\pi^-$ MODE

DOCUMENT ID The data in this block is included in the average printed for a previous datablock.

 1424 ± 25 BISELLO 89 DM2 $e^+e^- \to \pi^+\pi^-$

$\omega\pi$ MODE

DOCUMENT ID TECN COMMENT The data in this block is included in the average printed for a previous datablock.

 $^{
m 1}$ CLEGG • • • We do not use the following data for averages, fits, limits, etc. • •

² ASTON 80C OMEG 20-70 $\gamma p \rightarrow \omega \pi^0 p$ ² BARBER 80C SPEC 3-5 $\gamma \rho \rightarrow \omega \pi^0 \rho$ 1290 ± 40

 $^{\rm 1}\,\rm Using$ data from BISELLO 91B, DOLINSKY 86 and ALBRECHT 87L.

² Not separated from b_1 (1235), not pure $J^P = 1^-$ effect.

DOCUMENT ID TECN CHG COMMENT \bullet $\,\bullet\,$ We do not use the following data for averages, fits, limits, etc. $\,\bullet\,$ $\,\bullet\,$ ³ BITYUKOV 87 SPEC 0 32.5 $\pi^- p \rightarrow$

 $^3\,\text{See}$ the minireview for $\rho(1700)$ and ACHASOV 88 for a non-exotic interpretation. DON-NACHIE 91 suggests this is a different particle.

ρ(1450) WIDTH

DOCUMENT ID

310±60 OUR ESTIMATE This is only an educated guess; the error given is larger than the error on the average of the published values.

$\omega\pi$ MODE

VALUE (MeV) DOCUMENT ID TECN COMMENT

The data in this block is included in the average printed for a previous datablock.

⁴ CLEGG \bullet $\,\bullet\,$ We do not use the following data for averages, fits, limits, etc. $\,\bullet\,$ $\,\bullet\,$ ⁵ ASTON 80c OMEG 20-70 $\gamma \rho \rightarrow \omega \pi^0 \rho$ 300 ⁵ BARBER 80C SPEC 3-5 $\gamma \rho \rightarrow \omega \pi^0 \rho$ $320\pm100\,$

⁴ Using data from BISELLO 91B, DOLINSKY 86 and ALBRECHT 87L.

⁵ Not separated from $b_1(1235)$, not pure $J^P = 1^-$ effect.

MIXED MODES

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
ullet $ullet$ We do not use the following	data for averages, fits	, limits,	etc. • • •
391 ± 70	DUBNICKA 89	RVUE	$e^+e^- \rightarrow \pi^+\pi^-$

ηho^0 MODE			
VALUE (MeV)	DOCUMENT ID	TECN	COMMEN
• • • We do not use the following	data for averages, fits	s, limits,	etc. • •

 230 ± 30 ANTONELLI 88 DM2 $e^+e^-
ightarrow \eta \pi^+\pi^-$ 88 SPEC 8.95 $\pi^- p \to \eta \pi^+ \pi^- n$ $60\pm15\,$ FUKUL

 $\pi^+\pi^-$ MODE DOCUMENT ID TECN COMMENT

 \bullet \bullet \bullet We do not use the following data for averages, fits, limits, etc. \bullet \bullet BISELLO 89 DM2 $e^{+}e^{-} \rightarrow \pi^{+}\pi^{-}$

$\phi\pi$ MODE

VALUE (MeV) DOCUMENT ID TECN CHG COMMENT \bullet $\,\bullet\,$ We do not use the following data for averages, fits, limits, etc. $\,\bullet\,$ $\,\bullet\,$ ⁶ BITYUKOV 87 SPEC 0 32.5 π $\phi \pi^0 n$

 6 See the minireview for $\rho(1700)$ and ACHASOV 88 for a non-exotic interpretation. DONNACHIE 91 suggests this is a different particle.

ρ(1450) DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Confidence level
Γ_1	ππ	seen	
Γ_2	4π	seen	
Γ3	$e^{+}e^{-}$	seen	
Γ_4	ηho	<4 %	
Γ ₅	$\omega \pi$	<2.0 %	95%
Γ6	$\phi \pi$	<1 %	
Γ ₇	$K\overline{K}$	$< 1.6 \times 10^{-3}$	95%

ρ (1450) Γ (i) Γ (e^+e^-)/ Γ (total)

$\Gamma(\pi\pi) \times \Gamma(e^+e^-)/\Gamma_{\text{total}}$	$(\pi\pi) \times \Gamma(e^+e^-)/\Gamma_{\text{total}}$			$\Gamma_1\Gamma_3/\Gamma$
VALUE (keV)	DOCUMENT ID	TECN	COMMENT	
• • • We do not use the following	ng data for averages, fit	ts, limits,	etc. • • •	
0.12	⁷ DIEKMAN 88	RVUE	$e^+e^ \rightarrow$	$\pi^+\pi^-$
⁷ Using total width = 235 MeV	<i>'</i> .			

 $\Gamma(\eta \rho) \times \Gamma(e^+e^-)/\Gamma_{\text{total}}$ $\Gamma_4\Gamma_3/\Gamma$ VALUE (eV) DOCUMENT ID TECN COMMENT 91±19 ANTONELLI 88 DM2 $e^+\,e^-
ightarrow \, \eta\,\pi^+\,\pi^-$

 $\Gamma(\phi\pi) \times \Gamma(e^+e^-)/\Gamma_{\rm total}$ $\Gamma_6\Gamma_3/\Gamma$ VALUE (eV) DOCUMENT ID TECN COMMENT ⁸ AULCHENKO 878 ND $e^+e^- \rightarrow \kappa_5^0 \kappa_I^0 \pi^0$ <70 90

 $^{8}\,\text{Using mass}$ 1480 \pm 40 MeV and total width 130 \pm 60 MeV of BITYUKOV 87.

ρ (1450) BRANCHING RATIOS

$\Gamma(\eta \rho)/\Gamma_{\text{total}}$					Γ ₄ /Γ
VALUE		DOCUMENT ID	TECN		
<0.04		DONNACHIE	87B RVUE		
$\Gamma(\phi\pi)/\Gamma(\omega\pi)$					Γ_6/Γ_5
VALUE	CL%	DOCUMENT ID	TECN	CHG	COMMENT
>0.5	95	BITYUKOV	87 SPEC	0	32.5 $\pi^- \rho \rightarrow \phi \pi^0 n$
$\Gamma(\omega\pi)/\Gamma(4\pi)$					Γ_5/Γ_2

DOCUMENT ID < 0.14 CLEGG 88 RVIIE

 $\Gamma(\eta \rho)/\Gamma(\omega \pi)$ Γ_4/Γ_5 DOCUMENT ID 9 DONNACHIE 91 RVUE ~ 0.24 • • • We do not use the following data for averages, fits, limits, etc. • • •

91 SPEC 8.95 $\pi^- p \rightarrow \omega \pi^0 n$ >2

 $\Gamma(\omega\pi)/\Gamma_{\text{total}}$ Γ_5/Γ DOCUMENT ID VALUE TECN CLEGG ~ 0.21

 $\Gamma(\pi\pi)/\Gamma(\omega\pi)$ Γ_1/Γ_5 DOCUMENT ID VALUE TECN ~ 0.32 94 RVUE

 $\Gamma(\phi\pi)/\Gamma_{\text{total}}$ Γ_6/Γ DOCUMENT ID TECN VALUE 9 DONNACHIE 91 RVUE <0.01

$\Gamma(K\overline{K})/\Gamma(\omega\pi)$		Γ_7/Γ_5
VALUE	DOCUMENT ID TECN	
< 0.08	⁹ DONNACHIE 91 RVUE	
⁹ Using data from BISELLO 9	1B, DOLINSKY 86 and ALBRECHT 87L.	

ρ (1450) REFERENCES

		+Donnachie		(LANC, MCHS)
	B21 111 (suppl)			(DM2 Collab.)
		+Clegg		(MCHS, LANC)
		+Horikawa+	(SUGI, NAGO, KER	
BISELLO 89 PL	B220 321	+Busetto+		(DM2 Collab.)
DUBNICKA 89 JPG	3 15 1349	+Martinovic+		(JINR, SLOV)
ACHASOV 88 PL	B207 199	+Kozhevnikov		(NOVM)
ANTONELLI 88 PL	B212 133	+Baldini+		(DM2 Collab.)
CLEGG 88 ZPF	HY C40 313	+Donnachie		(MCHS, LANC)
DIEKMAN 88 PRE	PL 159 101			(BONN)
FUKUI 88 PL	B202 441	+ Horikawa +	(SUGI, NAGO, KER	(, KYOT, MIYA)
	B185 223	+Binder, Boeckmann,	Glaser+	(ARGUS Collab.)
AULCHENKO 87B JET	TPL 45 145	+Dolinsky, Druzhinin, 1 45 118.	Dubrovin+	(NOVO)
	B188 383	+Dzhelyadin, Dorofeev,	Golovkin+	(SERP)
DONNACHIE 87B ZPH		+Clegg		(MCHS, LANC)
		+Druzhinin, Dubrovin,	Fidelman+	(NOVO)
	92B 211		ERN, EPOL, GLAS,	
		+Dainton, Brodbeck, F		

- OTHER RELATED PAPERS -

MURADOV 94	PAN 57 864	(BAKU)
LANDSBERG 92	SJNP 55 1051	(SERP)
	Translated from YAF 5	
BRAU 88	PR D37 2379	+Franek+ (SLAC Hybrid Facility Photon Collab.)
ASTON 87	NP B292 693	+Awaji, D'Amore+ (SLAC, NAGO, CINC, INUS)
KURDADZE 86	JETPL 43 643	+Lelchuk, Pakhtusova, Sidorov, Skrinskii+ (NOVO)
	Translated from ZETFI	
BARKOV 85	NP B256 365	+Chilingarov, Eidelman, Khazin, Lelchuk+ (NOVO)
BISELLO 85	LAL 85-15	+Augustin, Ajaltouni+ (PADO, LALO, CLER, FRAS)
ABE 84B	PRL 53 751	+Bacon, Ballam+ (SLAC Hybrid Facility Photon Collab.)
ATKINSON 84C	NP B243 1	+ (BONN, CÈRN, GLÁS, LANC, MCHS, CURIN+)
CORDIER 82	PL 109B 129	+Bisello, Bizot, Buon, Delcourt (LALO)
KILLIAN 80	PR D21 3005	+Treadwell, Ahrens, Berkelman, Cassel+ (CORN)
COSME 76	PL 63B 352	+Courau, Dudelzak, Grelaud, Jean-Marie+ (ORSAY)
BINGHAM 72B	PL 41B 635	+Rabin, Rosenfeld, Smadja+ (LBL, UCB, SLAC)
FRENKIEL 72	NP B47 61	+Ghesquiere, Lillestol, Chung+ (CDEF, CERN)
LAYSSAC 71	NC 6A 134	+Renard (MONP)

 $f_0(1500)$ was $f_0(1525)$ and $f_0(1590)$

 $I^G(J^{PC})=0^+(0^{++})$ See also the mini-reviews on scalar mesons under $f_0(1370)$ and on non- $q\overline{q}$ candidates. (See the index for the page number.)

ALUE (MeV) 1503±11 OUR AV	EVTS FRACE	DOCUMENT ID		TECN	COMMENT
1500±15	LINAGE	¹ AMSLER	958	CBAR	$0.0 \ \overline{p}p \rightarrow 3\pi^0$
1505 ± 15		² AMSLER			$0.0 \overline{p}p \rightarrow \eta \eta \pi^0$
We do not us	e the followi				
1460 ± 20	120	3 AMELIN		VES	$37 \pi^- A \rightarrow \eta \eta \pi^- A$
1500 ± 10		⁴ AMSLER	95D	CBAR	$0.0 \overline{p}p \rightarrow \pi^0 \pi^0 \pi^0,$ $\pi^0 nn, \pi^0 \pi^0 n$
1445± 5		⁵ ANTINORI	95	OMEG	300,450 $pp \rightarrow$
1497 ± 30		³ ANTINORI	95	OMEG	$pp2(\pi^{+}\pi^{-})$ 300,450 $pp \rightarrow$
1505		BUGG	95	MRK3	$J/\psi \rightarrow \gamma \pi^+ \pi^- \pi^+ \tau$
1446± 5		3 ABATZIS	94		450 <i>p p</i> →
1545 ± 25		³ AMSLER	94F	CBAR	$\begin{array}{c} \rho \rho 2(\pi^+\pi^-) \\ 0.0 \ \overline{\rho} \rho \rightarrow \pi^0 \eta \eta' \end{array}$
1520 ± 25		6,7 ANISOVICH	94		
1505±20		^{7,8} BUGG	94	RVUE	$\overline{p}p \xrightarrow[\eta\pi]{} 3\pi^0, \eta\eta\pi^0,$
1560±25		³ AMSLER	92	CBAR	.,
$1550 \pm 45 \pm 30$		3 BELADIDZE		VES	$36 \pi^- Be \rightarrow \pi^- \eta' \eta$
1449± 4		3 ARMSTRON	G 89E	OMEG	
		³ ALDE			$pp2(\pi^{+}\pi^{-})$
1610±20			88		
1525		ASTON		LASS	$11 K^{-} \rho \rightarrow K_{S}^{0} K_{S}^{0} \Lambda$
1570 ± 20	600	3 ALDE	87		
1575 ± 45		9 ALDE		GAM4	
1568 ± 33		3 BINON		GAM2	
1592 ± 25		3 BINON		GAM2	
1525 ± 5		³ GRAY	83	DBC	$0.0 \ \overline{p} \ N \rightarrow 3\pi$
T-matrix pole, su	persedes Af	VISOVICH 94.			
² T-matrix pole, su	ipersedes Al	NISOVICH 94 and	AMSL	ER 92.	
	ss. Coupled-cha	nnel analysis of A	MSLE	ER 95B,	AMSLER 95C, and A
SLER 94D. Supersedes ABA	ΓZIS 94, AR	MSTRONG 89E. E	3reit-V	Vigner n	nass.
From a simultane	eous analysis	of the annihilatio	ns $\overline{p} p$	$\rightarrow 3\pi^0$	$,\pi^{\cup}\eta\eta$.
⁷ T-matrix pole.					
⁸ Reanalysis of AN	ISOVICH 94	l data. d of two solutions.			

f₀(1500) WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID	TE	COMMENT
120±19 OUR AVER	\GE	10		0
120 ± 25		10 AMSLER		AR $0.0 \overline{p}p \rightarrow 3\pi^0$
120 ± 30		¹¹ AMSLER		AR $0.0 \overline{p}p \rightarrow \eta \eta \pi^0$
 • • We do not use 	the following		s, fits, lin	nits, etc. • • •
100±30	120	¹² AMELIN		S 37 $\pi^- A \rightarrow \eta \eta \pi^- A$
154±30		¹³ AMSLER	95D CB	AR $0.0 \overline{\rho} \rho \rightarrow \pi^0 \pi^0 \pi^0$,
		1.4		$\pi^{0}\eta^{\eta}, \pi^{0}\pi^{0}\eta$
65 ± 10		¹⁴ ANTINORI	95 ON	1EG 300,450 pp →
		12		$pp2(\pi^{+}\pi^{-})$
199±30		12 ANTINORI	95 ON	1EG 300,450 pp →
56±12		12 ABATZIS	94 ON	$p p \pi^+ \pi^-$ 1EG 450 $p p \rightarrow$
30 ± 12		ABAT ZIS	94 OIV	$p p 2(\pi^+\pi^-)$
100 ± 40		¹² AMSLER	94F CB	AR $0.0 \overline{p}p \rightarrow \pi^0 \eta \eta'$
	15	^{5,16} ANISOVICH		AR $0.0 \overline{p}p \rightarrow 3\pi^0, \pi^0\eta\eta$
148 ⁺ 20 - 25				
150±20	16	^{5,17} BUGG	94 RV	UE $\overline{p} \rho \rightarrow 3\pi^0, \eta \eta \pi^0, \eta \pi^0$
245±50		12 AMSLER	92 CB	AR $0.0 \overline{p}p \rightarrow \pi^0 \eta \eta$
153±67±50		12 BELADIDZE	920 VE	
78±18		12 ARMSTRONG		
				$\rho \rho 2(\pi^{+}\pi^{-})$
170±40		¹² ALDE	88 GA	M4 300 $\pi^-N \rightarrow \pi^-N2\eta$
150 ± 20	600	¹² ALDE	87 GA	M4 100 $\pi^- \rho \to 4\pi^0 n$
265 ± 65		¹⁸ ALDE	86D GA	M4 100 $\pi^- \rho \rightarrow 2\eta n$
260±60		¹² BINON	84C GA	M2 38 $\pi^- p \rightarrow \eta \eta' n$
210 ± 40		¹² BINON	83 GA	M2 38 $\pi^- p \rightarrow 2\eta n$
101 ± 13		¹² GRAY	83 DB	C $0.0 \ \overline{p} \ N \rightarrow 3\pi$
10 T-matrix pole, su	persedes AN	IISOVICH 94.		
11 T-matrix pole, su	persedes AN	IISOVICH 94 and A	MSLER	92.
12 Breit-Wigner mas				
	Coupled-cha	nnel analysis of Af	MSLER '	95B, AMSLER 95C, and AM-
SLER 94D.	710 04 15	MCTDONG OOF S		
14 Supersedes ABAT	ZIS 94, AR	MS I KONG 89E. Br	eit-Wign	er mass.

- 15 From a simultaneous analysis of the annihilations $\overline{\rho} p \to 3\pi^0$, $\pi^0 \eta \eta$. 16 T-matrix pole. 17 Reanalysis of ANISOVICH 94 data.

- 18 From central value and spread of two solutions. Breit-Wigner mass.

f₀(1500) DECAY MODES

	Mode	Fraction (Γ_j/Γ)
$\overline{\Gamma_1}$	$\eta \eta'(958)$	seen
Γ_2	$\eta\eta$	seen
Γ_3	$4\pi^0$	seen
Γ_4	$\pi^{0} \pi^{0}$	seen
Γ ₅	$4\pi^{0}$ $\pi^{0}\pi^{0}$ $2\pi^{+}2\pi^{-}$	seen
Γ ₆	KΚ	

f₀(1500) BRANCHING RATIOS

$\Gamma(\eta\eta'(958))/\Gamma(\eta\eta)$				Γ_1/Γ
VALUE	DOCUMENT I	D TECN	COMMENT	
• • • We do not use the fol	lowing data for avera	ges, fits, limits,	etc. • • •	
0.29 ± 0.10	¹⁹ AMSLER	95c CBAR	$0.0 \ \overline{p} p \rightarrow \eta$	$\eta \pi^0$
2.7 ±0.8	BINON	84c GAM2	38 π ⁻ p →	$\eta \eta' \eta$
19 Using AMSLER 94E ($\eta\eta$	$'\pi^{0}$).			

' (ηη)/ ' total				1 2/1	
VALUE	DOCUMENT ID		TECN	COMMENT	_
• • • We do not use the fol	lowing data for average	s, fit	s, limits,	etc. • • •	
large	ALDE	88	GAM4	300 $\pi^- N \rightarrow \eta \eta \pi^- N$	
large	BINON	83	GAM2	38 $\pi^- \rho \rightarrow 2\eta n$	
$\Gamma(4\pi^0)/\Gamma(\eta\eta)$				Г ₃ /Г;	2
VALUE	DOCUMENT ID		TECN	COMMENT	
• • • We do not use the fol	lowing data for average	es, fit	s, limits,	etc. • • •	
0.8 ± 0.3	ALDE	87	GAM4	$100 \ \pi^- p \rightarrow 4\pi^0 n$	

$\Gamma(\pi^0\pi^0)/\Gamma(\eta\eta)$			Γ_4/Γ_2
VALUE	DOCUMENT IL	TECN_	COMMENT
	following data for averag	ges, fits, limits,	etc. • • •
1.45 ± 0.61	²⁰ AMSLER	95c CBAR	$0.0 \overline{p}p \rightarrow \eta \eta \pi^0$
2.12 ± 0.81	²¹ AMSLER	950 CBAR	$0.0 \; \overline{p} p \rightarrow \; \pi^0 \pi^0 \pi^0,$
	20		$\pi^{0} \eta \eta$, $\pi^{0} \pi^{0} \eta$
< 0.3	²² BINON	83 GAM2	$38 \pi^- p \rightarrow 2\eta n$

- 20 Using AMSLER 95B (3 π^0). 21 Coupled-channel analysis of AMSLER 95B, AMSLER 95C, and AMSLER 94D. 22 Superseded by PROKOSHKIN 90.

 $f_0(1500), f_1(1510), f'_2(1525)$

$\Gamma(K\overline{K})/\Gamma(\eta\eta)$ VALUE CL%	Γ ₆ /Γ ₂	$f_2'(1525)$	$I^{G}(J^{PC}) = 0^{+}(2^{+})$
<0.6	23 BINON 83 GAM2 38 $\pi^- p \rightarrow 2\eta n$	72(1323)	
	data for averages, fits, limits, etc. \bullet \bullet \bullet \bullet \bullet \bullet PROKOSHKIN 91 GAM4 300 $\pi^-p \to \pi^-p\eta\eta$		f ₂ (1525) MASS
$<$ 0.4 90 2 Using ETKIN 82B and COHEN			<u>-</u> .
24 Combining results of GAM4 with	th those of WA76 on $K\overline{K}$ central production.	VALUE (MeV) 1525±5 OUR ESTIMATE T	his is only an educated guess; the error given is larger than
f ₀ (1500) REFERENCES		the error on the average of the published values.
MELIN 96B YAF 59 1021	+Berdnikov, Bityukov+ (SERP, TBIL)	PRODUCED BY PION BI	
MSLER 95B PL B342 433 MSLER 95C PL B353 571	+Armstrong, Brose+ (Crystal Barrel Collab.) +Armstrong, Hackman+ (Crystal Barrel Collab.)	• • We do not use the followard	wing data for averages, fits, limits, etc. ● ●
MSLER 95D PL B355 425 NTINORI 95 PL B353 589	+Armstrong, Spanier+ (Crystal Barrel Collab.) +Barberis, Bayes+ (ATHU, BARI, BIRM, CERN, JINR) +Scott, Zoli+ (LOQM, PNPI, WASH)	$1547 + 10 \\ - 2$	1 LONGACRE 86 MPS 22 π^{-} $ ho ightarrow \kappa_{S}^{0} \kappa_{S}^{0}$ n
BATZIS 95 PL B353 378 BATZIS 94 PL B324 509 MSLER 94D PL B333 277	+Scott, Zoli+ +Antionri, Barberis+ (ATHU, BARI, BIRM, CERN, JINR) +Anisovich, Spanier+ (Crystal Barrel Collab.)	1496 + 9	² CHABAUD 81 ASPK 6 $\pi^- p \rightarrow K^+ K^- n$
MSLER 94E PL B340 259 NISOVICH 94 PL B323 233	+Armstrong, Hackman+ (Crystal Barrel Collab.) +Armstrong+ (Crystal Barrel Collab.)	1497 + 8 9	CHABAUD 81 ASPK 18.4 $\pi^- \rho \rightarrow K^+ K^-$
UGG 94 PR D50 4412 MSLER 92 PL B291 347	+Anisovich+ (LOQM) +Augustin, Baker+ (Crystal Barrel Collab.)	1492±29	GORLICH 80 ASPK 17 $\pi^- p$ polarized \rightarrow
ELADIDZE 92C SJNP 55 1535 Translated from YAF	+Bityukov, Borisov (SERP, TBIL) 55 2748.	1502±25	K^+K^-n 3 CORDEN 79 OMEG 12–15 $\pi^-p \rightarrow$
ROKOSHKIN 91 SPD 36 155 Translated from DAI ROKOSHKIN 90 Hadron 89 Conf. p	VS 316 900. (GAM2, GAM4 Collab.) 27 (SERP, BELG, LANL, LAPP, PISA, KEK)		$\pi^+\pi^-n$
RMSTRONG 89E PL B228 536 LDE 88 PL B201 160	+Benayoun (ATHU, BARI, BIRM, CERN, CDEF, CURIN+) +Bellazzini, Binon+ (SERP, BELG, LANL, LAPP, PISA)	1480 14	CRENNELL 66 HBC 6.0 $\pi^- \rho \rightarrow \kappa_S^0 \kappa_S^0 n$
STON 88D NP B301 525 LDE 87 PL B198 286	+ Awaji, Bienz+ (SLAC, NAGO, CINC, INUS) +Binon, Bricman+ (LANL, BRUX, SERP, LAPP)	PRODUCED BY K [±] BEA VALUE (MeV) EVTS	AM DOCUMENT ID TECN COMMENT
LDE 86D NP B269 485 INON 84C NC 80A 363	+Binon, Bricman+ (BELG, LAPP, SERP, CERN, LANL) +Bricman, Donskov+ (BELG, LAPP, SERP, CERN)		Includes data from the datablock that follows this one.
INON 83 NC 78A 313 Also 83B SJNP 38 561	+Donskov, Duteil+ (BELG, LAPP, SERP, CERN) Binon, Gouanere+ (BELG, LAPP, SERP, CERN)	1526.8± 4.3	ASTON 88D LASS $11 K^- p \rightarrow K_0^0 K_0^0 A$ BOLONKIN 86 SPEC $40 K^- p \rightarrow K_0^0 K_0^0 Y$
Translated from YAF	+Kalogeropoulos, Nandy, Roy, Zenone (SYRA)	1504 ± 12 1529 ± 3	BOLONKIN 86 SPEC 40 $K^-p \rightarrow K_S^{0}K_S^{0}Y$ ARMSTRONG 83B OMEG 18.5 $K^-p \rightarrow K^-K^+$
TKIN 82B PR D25 1786 OHEN 80 PR D22 2595	+Foley, Lai+ (BNL, CUNY, TUFTS, VAND) +Ayres, Diebold, Kramer, Pawlicki+ (ANL)	1521 ± 6 650	AGUILAR 81B HBC 4.2 $K^- p \rightarrow \Lambda K^+ K^-$
отн	ER RELATED PAPERS ———	1521 ± 3 572	
MSLER 96 PR D53 295	+Close (ZURI, RAL)	1522 ± 6 123 1528 ± 7 166	BARREIRO 77 HBC 4.15 $K^-p \rightarrow \Lambda K_S^0 K_S^0$ EVANGELISTA 77 OMEG 10 $K^-p \rightarrow$
MSLER 95E PL B353 385 LAUGHTER 88 MPL A3 1361	+Close (ZURI, RAL) (LANL)		$K^+K^-(\Lambda,\Sigma)$
		1527 ± 3 120	BRANDENB 76C ASPK 13 $K^- p \rightarrow K^+ K^- (\Lambda, \Sigma)$
$f_1(1510)$	$I^{G}(J^{PC}) = 0^{+}(1^{+})$	1519 ± 7 100	AGUILAR 72B HBC 3.9,4.6 $K = p \rightarrow K\overline{K}(\Lambda, \Sigma)$
	£ (1E10) MACC	PRODUCED IN e+e- A!	DOCUMENT ID TECN COMMENT
	f ₁ (1510) MASS	The data in this block is include	ded in the average printed for a previous datablock.
/ALUE (MeV) EVTS	DOCUMENT ID TECN COMMENT	1520 ± 4 OUR AVERAGE	
1512 ± 4 600 • • • We do not use the following	¹ BIRMAN 88 MPS $8 \pi^- p \rightarrow K^+ \overline{K}{}^0 \pi^- n$ data for averages, fits, limits, etc. • •	1529 ± 10 1531.6 ± 10.0	ACCIARRI 95J L3 $E_{ m CM}^{ee}=$ 88–94 GeV AUGUSTIN 88 DM2 $J/\psi ightarrow \gamma K^+ K^-$
~ 1525	² BAUER 93B $\gamma \gamma^* \rightarrow \pi^+ \pi^- \pi^0 \pi^0$	1515 ± 5	⁴ FALVARD 88 DM2 $J/\psi \rightarrow \phi K^+ K^-$
1530±10	ASTON 88C LASS 11 $K^-p \rightarrow K_S^0 K^{\pm} \pi^{\mp} \Lambda$	1525 ±10 ±10	BALTRUSAIT87 MRK3 $J/\psi \rightarrow \gamma K^+ K^-$
1526± 6 271	$K_{S}^{V}K^{\pm}\pi^{+}\Lambda$ GAVILLET 82 HBC 4.2 $K^{-}p \rightarrow \Lambda KK\pi$	1496 ± 2	wing data for averages, fits, limits, etc. \bullet \bullet 5 FALVARD 88 DM2 $J/\psi \rightarrow \phi K^+ K^-$
¹ From partial wave analysis of <i>P</i>			sis of data using a K-matrix formalism with 5 poles.
	han that seen in $K\overline{K}\pi$, isospin and spin uncertain.	² CHABAUD 81 is a reanaly	sis of PAWLICKI 77 data.
	f ₁ (1510) WIDTH	disagreement with the value	is where the $f_2'(1525)$ width and elasticity are in comple ses obtained from $K\overline{K}$ channel, making the solution dubiou
	71(1510) WID 111	From an analysis ignoring i	interference with $f_J(1710)$.
VALUE (MeV) EVTS	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	⁵ From an analysis including	interference with $f_J(1710)$.
35±15 600 • • • We do not use the following	³ BIRMAN 88 MPS $8 \pi^- p \rightarrow K^+ \overline{K}{}^0 \pi^- n$ data for averages, fits, limits, etc. • •		f' ₂ (1525) WIDTH
100±40	ASTON 88C LASS 11 $K^-p \rightarrow$		72(1323) WID 111
	$\kappa_{\mathcal{S}}^{0} \kappa^{\pm} \pi^{\mp} \Lambda$	VALUE (MeV)	DOCUMENT ID COMMENT is is only an educated guess; the error given is larger than
107±15 271	GAVILLET 82 HBC 4.2 $K^- p \rightarrow \Lambda K K \pi$	76±10 OUR ESTIMATE IN	the error on the average of the published values.
³ From partial wave analysis of <i>P</i>	$K + K^0 \pi^-$ state.	73 + 6 OUR FIT	
f ₁ (1	510) DECAY MODES	76±10	PDG 90 For fitting
Mada	Fraction (F (F)	PRODUCED BY PION B	EAM
Mode	Fraction (Γ_i/Γ)	VALUE (MeV)	DOCUMENT ID TECN COMMENT wing data for averages, fits, limits, etc. • • •
\overline{K} K \overline{K} *(892) + c.c.	seen		· .
f ₁ (1510) REFERENCES	108 + 5 + 2 + 22	⁶ LONGACRE 86 MPS 22 $\pi^- p \rightarrow K_S^0 K_S^0 n$
3AUER 93B PR D48 3976	+Belcinski, Berg, Bingham+ (SLAC)	69+22	⁷ CHABAUD 81 ASPK $6 \pi^- p \rightarrow K^+ K^- n$
STON 88C PL B201 573 BIRMAN 88 PRL 61 1557	+Awaji, Bienz+ (SLAC, NAGO, CINC, INUS) JP +Chung, Peaslee+ (BNL, FSU, IND, MASD) JP	$137 + 23 \\ -21$	CHABAUD 81 ASPK 18.4 $\pi^- \rho \rightarrow K^+ K^-$
GAVILLET 82 ZPHY C16 119	+Armenteros+ (CERN, CDEF, PADO, ROMA)	$150 + 83 \\ -50$	GORLICH 80 ASPK 17 $\pi^- \rho$ polarized \rightarrow
		165 ± 42	⁸ CORDEN 79 OMEG 12-15 $\pi^- p \rightarrow$
		oo ± 39	$\pi^{+}\pi^{-}n$
		165 ± 42 $92 + 39$ -22	⁸ CORDEN 79 OMEG 12–15 π ⁻

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
77± 5 OUR AVE	RAGE Includes				
90 ± 12		ASTON	88D	LASS	$11 K^- p \rightarrow K_S^0 K_S^0 \Lambda$
73 ± 18		BOLONKIN	86	SPEC	11 $K^- p \to K_S^0 K_S^0 \Lambda$ 40 $K^- p \to K_S^0 K_S^0 Y$
83±15		ARMSTRONG	83B	OMEG	$18.5 K^- p \rightarrow K^- K^+ \Lambda$
85±16	650	AGUILAR	81B	HBC	$4.2~K^-p \rightarrow \Lambda K^+ K^-$
80 ⁺¹⁴	572	ALHARRAN	81	нвс	8.25 $K^- p \rightarrow \Lambda K \overline{K}$
72 ± 25	166	EVANGELISTA	77	OMEG	10 $K^- p \rightarrow K^+ K^- (\Lambda, \Sigma)$
69±22	100	AGUILAR	72B	нвс	3.9,4.6 $K^- p \rightarrow K\overline{K}(\Lambda, \Sigma)$
• • • We do not a	use the following	data for averages	s, fits	, limits,	etc. • • •
62 ⁺¹⁹ -14	123	BARREIRO	77	нвс	4.15 $K^- p \rightarrow \Lambda K_S^0 K_S^0$
61± 8	120	BRANDENB	76 C	ASPK	13 $K^- p \rightarrow K^+ K^- (\Lambda, \Sigma)$

PRODUCED IN e^+e^- ANNIHILATION

VALUE (MeV) DOCUMENT ID TECN COMMENT

The data in this block is included in the average printed for a previous datablock.

67± 9 OUR AVERAGE

103 ± 30	AUGUSTIN 88	DM2	$J/\psi \rightarrow$	$\gamma K^+ K^-$
62 ± 10	¹⁰ FALVARD 88	DM2	$J/\psi \rightarrow$	$\phi K^+ K^-$
85 ± 35	BALTRUSAIT87	MRK3	$J/\psi \rightarrow$	$\gamma K^+ K^-$

• • • We do not use the following data for averages, fits, limits, etc. • • • 76 ± 40 ACCIARRI 95J L3 Eee = 88-94 GeV ¹¹ FALVARD 100± 3 88 DM2 $J/\psi \rightarrow \phi K^+ K^-$

$f_2'(1525)$ DECAY MODES

	Mode	Fraction (Γ_j/Γ)
$\overline{\Gamma_1}$	κ κ	(88.8 ± 3.1) %
Γ_2	$\eta \eta$	(10.3 \pm 3.1) %
Γ_3	$\pi\pi$	$(8.2 \pm 1.5) \times 10^{-3}$
Γ_4	$\gamma \gamma$	$(1.32\pm0.21)\times10^{-6}$
Γ_5	$K\overline{K}^*(892) + \text{c.c.}$	
Γ_6	$\pi\pi\eta$	
Γ_7	$\pi K \overline{K}$	
Γ_8	$\pi^{+}\pi^{+}\pi^{-}\pi^{-}$	

CONSTRAINED FIT INFORMATION

An overall fit to the total width, 2 partial widths, a combination of partial widths obtained from integrated cross sections, and 3 branching ratios uses 14 measurements and one constraint to determine 5 parameters. The overall fit has a $\chi^2=11.4$ for 10

The following off-diagonal array elements are the correlation coefficients $\langle \delta p_i \delta p_j \rangle / (\delta p_i \cdot \delta p_j)$, in percent, from the fit to parameters p_i , including the branching fractions, $x_i \equiv \Gamma_i/\Gamma_{\rm total}$. The fit constrains the x_i whose labels appear in this array to sum to one.

	Mode	Rate (MeV)
Γ ₁	κ κ	65 ⁺⁵ -4
Γ_2	$\eta \eta$	7.6 ±2.6
Γ ₂ Γ ₃	$\pi\pi$	0.60 ± 0.12
Γ_4	$\gamma \gamma$	$(9.7 \pm 1.4) \times 10^{-5}$

f'2(1525) PARTIAL WIDTHS

Γ(<i>κ</i> κ)					Г1
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
65 ⁺⁵ ₋₄ OUR FIT					
63 ⁺⁶ ₋₅	¹² LONGACRE	86	MPS	22 $\pi^- \rho \rightarrow$	$\kappa_S^0 \kappa_S^0$ n
$\Gamma(\pi\pi)$					Гз
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
0.60±0.12 OUR FIT					
$1.4 \begin{array}{c} +1.0 \\ -0.5 \end{array}$	¹² LONGACRE	86	MPS	22 $\pi^- p \rightarrow$	$\kappa_S^0 \kappa_S^0$ n
$\Gamma(\eta\eta)$					Γ ₂
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
7.6 ± 2.5 OUR FIT					
	ring data for average	s, fit	s, limits,	etc. • • •	
24 +3	¹² LONGACRE	86	MPS	22 π ⁻ p →	$\kappa_S^0 \kappa_S^0 n$

$^{\rm 12}\,{\rm From}$ a partial-wave analysis of data using a K-matrix formalism with 5 poles.

$f_2'(1525) \Gamma(i)\Gamma(\gamma\gamma)/\Gamma(total)$

$\Gamma(K)$	R̄)×Γ	$(\gamma \gamma)/\Gamma_{\text{total}}$				$\Gamma_1\Gamma_4/\Gamma$
VALUE		` '	DOCUMENT ID		TECN	COMMENT
0.086	±0.012	OUR FIT				
0.086	± 0.012	OUR AVERAGE				
0.093	±0.018	± 0.022	¹³ ACCIARRI	95 J	L3	E ^{ee} _{cm} = 88–94 GeV
0.067	±0.008	±0.015	¹³ ALBRECHT	90G	ARG	$e^+e^{e^+e^-K^+K^-}$
0.11	+0.03 -0.02	±0.02	BEHREND	8 9 C	CELL	$\stackrel{e^+e^-}{{}_{e^+e^-}} \stackrel{\rightarrow}{\kappa^0_S} \kappa^0_S$
0.10	$^{+0.04}_{-0.03}$	$^{+0.03}_{-0.02}$	BERGER	88	PLUT	$e^+e^- \rightarrow e^+e^- \kappa_S^0 \kappa_S^0$
0.12	±0.07	±0.04	¹³ AIHARA	86B	TPC	$ \begin{array}{c} e^{+}e^{-} \rightarrow \\ e^{+}e^{-} \rightarrow K^{+}K^{-} \\ e^{+}e^{-} \rightarrow e^{+}e^{-} K\overline{K} \end{array} $
0.11	± 0.02	± 0.04	¹³ ALTHOFF	83	TASS	$e^+e^- \rightarrow e^+e^- \kappa \overline{\kappa}$
• • •	We do r	ot use the following	ng data for average	s, fits	, limits,	etc. • • •
		0±0.0077		90 G	ARG	$e^+e^{e^+e^-K^+K^-}$
13116	ing an in	coherent backgrou	ınd			

1

$f_2'(1525)$ BRANCHING RATIOS

$\Gamma(\eta\eta)/\Gamma(K\overline{K})$				Γ_2/Γ_1
VALUE	DOCUMENT ID	TECN	COMMENT	
0.12 ± 0.04 OUR FIT				
0.11 ± 0.04	¹⁵ PROKOSHKIN	91 GAM4	300 π [−] p → 7	$\tau^- p \eta \eta$
• • • We do not use th	ne following data for averages	, fits, limits	, etc. • • •	
< 0.50	BARNES	67 HBC	4.6,5.0 K-p	
¹⁵ Combining results o	f GAM4 with those of WA76	on $K\overline{K}$ cer	tral production a	and results

of CBAL, MRK3 and DM2 on $J/\psi \to \gamma \eta \eta$. $\Gamma(\pi\pi)/\Gamma_{\text{total}}$ Γ_3/Γ

ALUE	CL%	DOCUMENT ID	IECN	COMMENT
0.0082±0.0016 O	JR FIT			
0.0075±0.0016 O	JR AVERAG	E		
0.007 ± 0.002		COSTA	80 OMEG	$10 \pi^- \rho \rightarrow K^+ K^- n$
$0.027 \begin{array}{c} +0.071 \\ -0.013 \end{array}$		¹⁶ GORLICH	80 ASPK	17,18 $\pi^- \rho$
0.0075 ± 0.0025	16	^{,17} MARTIN	79 RVUE	
• • We do not use	the followin	g data for average	s, fits, limits	, etc. • • •
< 0.06	95	AGUILAR	81B HBC	$4.2 K^- \rho \rightarrow \Lambda K^+ K^-$
0.19 ± 0.03		CORDEN	79 OMEG	12-15 $\pi^- \rho \rightarrow$
				$\pi^{+}\pi^{-}n$
(0.045	95	BARREIRO	77 HBC	$4.15 K^{-} p \rightarrow \Lambda K_{S}^{0} K_{S}^{0}$
0.012 ± 0.004		¹⁶ PAWLICKI		$6 \pi N \rightarrow K^+ K^- N$
< 0.063	90	BRANDENB	76c ASPK	13 $K^- p \rightarrow$
				$K^+K^-(\Lambda,\Sigma)$
-0.0086		16 BEUSCH	75B OSPK	$89\pi^ n \rightarrow \kappa^0 \overline{\kappa}^0 n$

 16 Assuming that the $f_2^\prime(1525)$ is produced by an one-pion exchange production mechanism. 17 MARTIN 79 uses the PAWLICKI 77 data with different input value of the $f_2'(1525)$ ightharpoonup

$\Gamma(\pi\pi)/\Gamma(K\overline{K})$			Γ_3/Γ_1
VALUE	DOCUMENT ID	TECN	COMMENT
0.0092±0.0018 OUR FIT			
0.075 +0.035	AUGUSTIN 8	7 DM2	$J/\psi \rightarrow \gamma \pi^{+} \pi^{-}$

 $^{^6\,\}text{From a partial-wave analysis of data using a K-matrix formalism with 5 poles.}$ $^7\,\text{CHABAUD 81}$ is a reanalysis of PAWLICKI 77 data.

 $^{^8\}mathrm{From}$ an amplitude analysis where the $f_2^\prime(1525)$ width and elasticity are in complete disagreement with the values obtained from $K\overline{K}$ channel, making the solution dubious.

⁹ From a fit to the D with $f_2(1270)$ - $f_2'(1525)$ interference. Mass fixed at 1516 MeV.

¹⁰ From an analysis ignoring interference with $f_f(1710)$.

¹¹ From an analysis including interference with $f_f(1710)$.

¹⁴ Using a coherent background.

 $f_2'(1525), f_2(1565)$

$\Gamma(\pi\pi\eta)/\Gamma(K\overline{K})$					Γ_6/Γ_1
VALUE	CL%	DOCUMENT ID	TE	CN COMMEN	T
• • • We do not use	the followin	ig data for average	s, fits, li	mits, etc. • •	•
< 0.41	95	AGUILAR	72B HE	3C 3.9,4.6 F	⟨- _p
< 0.3	67	AMMAR	67 H	3C	
$\Gamma(K\overline{K}^*(892) + c.c)$	c.) + Γ(π	$(\kappa \overline{K})]/\Gamma(\kappa \overline{K})$			$(\Gamma_5+\Gamma_7)/\Gamma_1$
VALUE	CL%	DOCUMENT ID	TE	CN COMMEN	T
• • • We do not use	the followin	ng data for average	s, fits, li	mits, etc. • •	•
< 0.35	95	AGUILAR	728 HE	3C 3.9,4.6 F	(-p
< 0.4	67	AMMAR	67 H	зс	
$\Gamma(\pi^+\pi^+\pi^-\pi^-)/\Gamma$	(K <u>K</u>)				Γ_8/Γ_1
VALUE	CL%	DOCUMENT ID	<u>TE</u>	CN COMMEN	Τ
\bullet \bullet We do not use	the followin	ng data for average	s, fits, li	mits, etc. • •	•
< 0.32	95	AGUILAR	72B H	3.9,4.6 <i>F</i>	<- p
$\Gamma(\eta\eta)/\Gamma_{total}$					Γ_2/Γ
VALUE		DOCUMENT ID	TE	CN COMMEN	T
ullet $ullet$ We do not use	the followin	ng data for average	s, fits, li	mits, etc. • •	•
0.10 ± 0.03		¹⁸ PROKOSHKII	V 91 G	AM4 300 π ⁻	$\rho \rightarrow \pi^- \rho \eta \eta$
18 Combining results of CBAL, MRK3 a			5 on K \overline{K}	central produ	ction and results

$f_2'(1525)$ REFERENCES

ACCIARRI 95	J PL B363 118	+Adam, Adriani, Aguilar-Benitez+ (L3 Collab.)
PROKOSHKIN 91		(GAM2, GAM4 Collab.)
FRONOSIINII 71		DANS 316 900.
ALBRECHT 90	G ZPHY C48 183	+Ehrlichmann, Harder+ (ARGUS Collab.)
PDG 90		Hernandez, Stone, Porter+ (IFIC, BOST, CIT+)
REHREND 89		+Criegee, Dainton+ (CELLO Collab.)
ASTON 88		+Awaji, Bienz+ (SLAC, NAGO, CINC, INUS)
AUGUSTIN 88		+Calcaterra+ (DM2 Collab.)
BERGER 88		+Genzel, Lackas+ (PLUTO Collab.)
FAIVARD 88		+Ajaltouni+ (CLER, FRAS, LALO, PADO)
AUGUSTIN 87		+Cosme+ (LALO, CLER, FRAS, PADO)
BALTRUSAIT 87		Baltrusaitis, Coffman, Dubois+ (Mark III Collab.)
AIHARA 86		+Alston-Garnjost+ (TPC-2γ Collab.)
BOLONKIN 86		+Bloshenko+ (ITEP) JP
DOLONIKIN 00	Translated from	
LONGACRE 86		+Etkin+ (BNL, BRAN, CUNY, DUKE, NDAM)
ALTHOFF 83	PL 121B 216	+Brandelik, Boerner, Burkhardt+ (TASSO Collab.)
ARMSTRONG 83	B NP B224 193	+ (BARI, BIRM, CERN, MILA, CURIN+)
AGUILAR 81	B ZPHY C8 313	Aguilar-Benitez, Albajar+ (CERN, CDEF, MADR+)
ALHARRAN 81	NP B191 26	+Baubillier+ (BIRM, CERN, GLAS, MICH, CURIN)
CHABAUD 81	APP B12 575	+Niczyporuk, Becker+ (CERN, CRAC, MPIM)
COSTA 80	NP B175 402	Costa De Beauregard+ (BARI, BONN, CERN+)
GORLICH 80	NP B174 16	+Niczyporuk+ (CRAC, MPIM, CERN, ZEEM)
CORDEN 79	NP B157 250	+Dowell, Garvey+ (BIRM, RHEL, TELA, LOWC) JP
MARTIN 79	NP B158 520	+Ozmutlu (DURH)
POLYCHRO 79	PR D19 1317	Polychronakos, Cason, Bishop+ (NDAM, ANL)
BARREIRO 77	NP B121 237	+Diaz, Gay, Hemingway+ (CERN, AMST, NIJM, OXF)
EVANGELISTA 77	NP B127 384	+ (BARI, BONN, CERN, DARE, GLAS+)
PAWLICKI 77	PR D15 3196	+Ayres, Cohen, Diebold, Kramer, Wicklund (ANL) IJP
BRANDENB 76	C NP B104 413	Brandenburg, Carnegie, Cashmore+ (SLAC)
BEUSCH 75	B PL 60B 101	+Birman, Websdale, Wetzel (CERN, ETH)
AGUILAR 72	B PR D6 29	Aguilar-Benitez, Chung, Eisner, Samios (BNL)
AMMAR 67	PRL 19 1071	+Davis, Hwang, Dagan, Derrick+ (NWES, ANL) JP
BARNES 67	PRL 19 964	+Dornan, Goldberg, Leitner+ (BNL, SYRA) IJPC
CRENNELL 66	PRL 16 1025	+Kalbfleisch, Lai, Scarr, Schumann+ (BNL) I
		* *

- OTHER RELATED PAPERS -

JENNI		PR D27 1031	+Burke, Teinov, Abrams, Blocker+ (SLAC, LBL)
ARMSTRONG		PL 110B 77	+Baubillier+ (BARI, BIRM, CERN, MILA, CURIN+)
ETKIN		PR D25 1786	+Foley, Lai+ (BNL, CUNY, TUFTS, VAND)
LUKE ABRAMS BARNES	82 67B	DESY 82/073 PRL 18 620 PRL 15 322	+Kehoe, Glasser, Sechi-Zorn, Wolsky (UMD) +Culwick, Guidoni, Kalbfleisch, Goz+ (BNL, SYRA)

 $f_2(1565)$ was $f_2(1520)$

 $I^{G}(J^{PC}) = 0^{+}(2^{+})$

OMITTED FROM SUMMARY TABLE

Seen in antinucleon-nucleon annihilation at rest. See also minireview under non- $q\overline{q}$ candidates. Needs confirmation.

f₂(1565) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1565±20	MAY	90	ASTE	$\overline{p}_{p} \rightarrow \pi^{+}\pi^{-}\pi^{0}$
• • We do not use the following	data for averages	, fits	, limits,	etc. • • •
~ 1552	¹ AMSLER	95D	CBAR	$0.0 \overline{p}p \rightarrow \pi^0 \pi^0 \pi^0,$ $\pi^0 nn, \pi^0 \pi^0 n$
1598 ± 72	BALOSHIN	95	SPEC	$40 \pi^{-} C \rightarrow K_S^0 K_S^0 X$
1566^{+80}_{-50}	² ANISOVICH			$0.0 \; \overline{p} \rho \; \rightarrow \; 3\pi^0 , \eta \eta \pi^0$
1502 ± 9	ADAMO	93	OBLX	$\overline{n} \rho \rightarrow \pi^+ \pi^+ \pi^-$
1488 ± 10				$\overline{p}p \rightarrow \pi^0 \eta \eta \rightarrow 6\gamma$
1508 ± 10				$\overline{p}p \rightarrow 3\pi^0 \rightarrow 6\gamma$
1525 ± 10	³ ARMSTRONG	93D	SPEC	$\overline{p}p \rightarrow \eta \pi^0 \pi^0 \rightarrow 6\gamma$
~ 1504		93	ASTE	$0.0 \overline{p} N \rightarrow 3\pi^- 2\pi^+$
1540 ± 15			OBLX	
1515 ± 10	⁵ AKER	91	CBAR	$0.0 \overline{p}p \rightarrow 3\pi^{0}$
1477 ± 5	BRIDGES	86C	DBC	$0.0 \overline{p} N \rightarrow 3\pi^- 2\pi^+$
 Coupled-channel analysis of AN From a simultaneous analysis of data. 	f the annihilations			
data. 3 J^P not determined, could be p	artly $f_0(1500)$.			
_ J not determined.				
⁵ Superseded by AMSLER 95B,				

f₂(1565) WIDTH

	72(1303) W 1D11	•	
VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
170 ± 40	MAY 9	0 ASTE	$\overline{\rho} \rho \rightarrow \pi^+ \pi^- \pi^0$
• • We do not use the f	following data for averages,	fits, limits,	etc. • • •
\sim 142			$0.0 \overline{p}p \rightarrow \pi^0 \pi^0 \pi^0,$ $\pi^0 nn, \pi^0 \pi^0 n$
263 ± 101	BALOSHIN 9	5 SPEC	$40 \pi^- C \rightarrow K_S^0 K_S^0 X$
166 ⁺ 80 - 20			$0.0 \; \overline{\rho} \rho \rightarrow 3\pi^0, \eta \eta \pi^0$
130 ± 10 148 ± 27 103 ± 15 111 ± 10 ~ 206 132 ± 37 120 ± 10 116 ± 9	⁹ ARMSTRONG 9 ⁹ ARMSTRONG 9 ⁹ ARMSTRONG 9 ¹⁰ WEIDENAUER 9	3C SPEC 3D SPEC 3D SPEC 3 ASTE 2 OBLX 1 CBAR	$\begin{array}{l} \overline{n} p \rightarrow \ \pi^+ \pi^+ \pi^- \\ \overline{p} \rho \rightarrow \ \pi^0 \eta \eta \rightarrow \ 6\gamma \\ \overline{p} \rho \rightarrow \ 3\pi^0 \rightarrow \ 6\gamma \\ \overline{p} \rho \rightarrow \ \eta\pi^0 \pi^0 \rightarrow \ 6\gamma \\ 0.0 \overline{p} N \rightarrow \ 3\pi^- 2\pi^+ \\ \overline{n} \rho \rightarrow \ \pi^+ \pi^+\pi^- \\ 0.0 \overline{p} \rho \rightarrow \ 3\pi^0 \\ 0.0 \overline{p} N \rightarrow \ 3\pi^- 2\pi^+ \end{array}$
	uld be partly $f_0(1500)$.		

f2(1565) DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ ₁	$\pi^+\pi^-$	seen
Γ_2	$\rho^0 \rho^0$	seen
Γ_3	$\pi^{0} \pi^{0}$ $2\pi^{+} 2\pi^{-}$	seen
Γ_4	$2\pi^{+}2\pi^{-}$	seen
Γ ₅	ηη	seen

f_2 (1565) BRANCHING RATIOS

$\Gamma(\pi^+\pi^-)/\Gamma_{\text{total}}$				Γ_1/Γ
VALUE	DOCUMENT ID	TEC	N COMMENT	
• • • We do not use the foll	lowing data for average	s, fits, lim	its, etc. • • •	
not seen	¹² ANISOVICH	94B RVI	JE $\overline{p}p \rightarrow \pi^+\pi^-$	π^0
seen	MAY	89 AST	TE $\overline{p}p \rightarrow \pi^+\pi^-$	π^0
$^{12}\mathrm{ANISOVICH}$ 948 is from	a reanalysis of MAY 9	ο.		
$\Gamma(\pi^+\pi^-)/\Gamma(ho^0 ho^0)$				Γ_1/Γ_2
VALUE	DOCUMENT ID	TEC	N COMMENT	

 VALUE
 DOCUMENT ID
 TECN
 COMMENT

 • • • We do not use the following data for averages, fits, limits, etc. • • •

 0.042 ± 0.013
 BRIDGES
 86B DBC
 \overline{p} N → $3\pi^- 2\pi^+$

$\Gamma(\pi^0\pi^0)/\Gamma_{ m total}$			Г ₃ /Г
VALUE	DOCUMENT ID TECN	COMMENT	
seen	AMSLER 958 CBAR	$0.0 \ \overline{p} p \rightarrow 3\pi^{0}$	ı
$\Gamma(\eta\eta)/\Gamma(\pi^0\pi^0)$	DOCUMENT ID TECN	COMMENT	₅ /Г ₃
0.024±0.005±0.012	13 ARMSTRONG 93C SPEC		γ
13 JP not determined, could	be partly f ₀ (1500).		I

f₂(1565) REFERENCES

AMSLER AMSLER AMSLER	95B 95C 95D	PL B342 433 PL B353 571 PL B355 425	4	Armstrong	, Hackma			(Crystal (Crystal (Crystal	Barrel	Collab.)	
BALOSHIN	95	PAN 58 46		-Bolonkin,				(C) 3101	Currer	(ITEP)	
		Translated from	YAF 58	50.						` '	
AMSLER	94D	PL B333 277	4	-Anisovich,	Spanier+			(Crystal	Barrel	Collab.)	
ANISOVICH	94	PL B323 233	+	-Armstrong	+			(Crystal	Barrel	Collab.)	
ANISOVICH	94B	PR D50 1972	+	+Bugg+						(LOQM)	
ADAMO	93	NP A558 13C	4	+Agnello+				(OE	BELIX	Collab.)	
ARMSTRONG	93C	PL B307 394	+	-Bettoni+		(FNAL,	FERR,	GENÒ, I	JCI, N	IWES+)	
ARMSTRONG	93D	PL B307 399	4	-Bettoni+		(FNAL,	FERR,	GENO, I	JCI, N	IWES+)	
WEIDENAUER	93	ZPHY C59 387	+	-Duch+				(AST	'ERIX	Collab.)	
ADAMO	92	PL B287 368	-4	-Agnello, B	alestra+			(OE	3ELIX	Collab.)	
AKER	91	PL B260 249	4	-Amsler, Pe	eters+			(Crystal	Barrel	Collab.)	
MAY	90	ZPHY C46 203	4	-Duch, Hee	1+					Collab.)	
MAY	89	PL B225 450	4	Duch, Hee	1+			(AST	ERIX	Collab.)	IJP
BRIDGES	86B	PRL 56 215	4	-Daftari, Ka	alogeropou	ılos, Det	be+	. (SYRA	, CASE)	
BRIDGES	86C	PRL 57 1534	+	-Daftari, Ka	alogeropou	ilos+				(SYRA)	

$\omega(1600)$

$$I^{G}(J^{PC}) = 0^{-}(1^{-})$$

See also $\omega(1420)$.

ω (1600) MASS

		` '			
VALUE (MeV)	EVTS	DOCUMENT ID		TECN CHG	COMMENT
1649 ± 24 OUR AVER	AGE Error	includes scale fac	tor of	f 2.3.	
1609 ± 20	315	¹ ANTONELLI	92	DM2	$1.34-2.4e^{+}e^{-} \rightarrow$
$1663\!\pm\!12$	435	² ANTONELLI	92	DM2	$\begin{array}{c} \rho\pi\\1.34-2.4e^+e^-\rightarrow\\\omega\pi\pi\end{array}$
• • • We do not use	the followin	g data for average	s, fits	s, limits, etc.	
1600 ± 30		¹ CLEGG	94	RVUE	$e^+e^- ightarrow ho\pi$
1607 ± 10		² CLEGG	94	RVUE	$e^+e^- \rightarrow \omega \pi \pi$
1635 ± 35		³ CLEGG	94	RVUE	$e^+e^- \rightarrow \rho\pi$
1625 ± 21		³ CLEGG	94	RVUE	$e^+e^- \rightarrow \omega \pi \pi$
1670 ± 20		ATKINSON	83B	OMEG	20-70 $\gamma p \rightarrow$
1657 ± 13		CORDIER	81	DM1	$e^+e^- \rightarrow \omega 2\pi$
1679 ± 34	21	ESPOSITO	80	FRAM	$e^+e^- \rightarrow 3\pi$
1652 ± 17		COSME	79	OSPK 0	$e^+e^- \rightarrow 3\pi$
1					

- $^1\,\mathrm{From}$ a two Breit-Wigner fit. $^2\,\mathrm{From}$ a single Breit-Wigner plus background fit. $^3\,\mathrm{From}$ a single Breit-Wigner fit.

ω (1600) WIDTH

	EVTS	DOCUMENT ID			G COMMENT
220±35 OUR AVERAGE	Error ir	ncludes scale facto	r of	1.6.	
159 ± 43	315	⁴ ANTONELLI	92	DM2	$1.34-2.4e^{+}e^{-} \rightarrow$
240 ± 25	435	⁵ ANTONELLI	92	DM2	$^{\rho\pi}_{1.34-2.4e^+e^-}$
• • • We do not use the	following	data for averages	, fits	, limits, etc.	$\omega \pi \pi$
140 ± 50		⁴ CLEGG	94	RVUE	$e^+e^- \rightarrow \rho\pi$
86 ± 20		⁵ CLEGG	94	RVUE	$e^+e^- \rightarrow \omega \pi \pi$
350 ± 80		⁶ CLEGG	94	RVUE	$e^+e^- \rightarrow \rho \pi$
401 ± 63		⁶ CLEGG	94	RVUE	$e^+e^- \rightarrow \omega \pi \pi$
160 ± 20		ATKINSON	83 B	OMEG	20–70 $\gamma p \rightarrow$
136 ± 46		CORDIER	81	DM1	$e^{+}e^{-} \rightarrow \omega 2\pi$
99±49	21	ESPOSITO	80	FRAM	$e^+e^- \rightarrow 3\pi$
42 ± 17		COSME	79	OSPK 0	$e^+e^- ightarrow 3\pi$

- 4 From a two Breit-Wigner fit. 5 From a single Breit-Wigner plus background fit. 6 From a single Breit-Wigner fit.

ω (1600) DECAY MODES

	Mode	Fraction (Γ_i/Γ)	
Γ_1	ρπ	seen	
Γ_2	$\omega \pi \pi$	seen	
Γ ₃	e+ e-	seen	

$\omega(1600) \Gamma(i)\Gamma(e^+e^-)/\Gamma(total)$

$\Gamma(\rho\pi) \times \Gamma(e^{-})$	$^+e^-)/\Gamma_{ m total}$					$\Gamma_1\Gamma_3/\Gamma$
VALUE (eV)	EVTS	DOCUMENT ID		TECN	COMMENT	
134±14	435	⁷ ANTONELLI	-		hadrons	
 ● ● We do not 	use the following	g data for average	s, fit	s, limits,	etc. • • •	
93 ± 27	315	ANTONELLI	92	DM2	1.34-2.4e+e-	$\rightarrow \rho \pi$
96 ± 35		DONNACHIE	89	RVUE	$e^+e^- \rightarrow \rho\pi$	
7						

⁷ From a coupled fit of $\rho\pi$ and $\omega\pi\pi$ channels.

$\Gamma(\omega\pi\pi) \times \Gamma(\frac{VALUE \text{ (keV)}}{})$	EVTS	DOCUMENT ID		TECN	Γ ₂ Γ ₃	•, •
170±17	435	⁸ ANTONELLI	92	DM2	1.34-2.4e ⁺ e ⁻ →	
 ● ● We do not 	use the following	ng data for average	s, fit	s, limits,	etc. • • •	
		9		D142	$1.34-2.4e^{+}e^{-} \rightarrow \omega$	
135 ± 16	435				$e^+e^- \rightarrow \omega 2\pi$	$\pi \pi$

ω (1600) REFERENCES

CLEGG 94 ANTONELLI 92 DONNACHIE 89 ATKINSON 83E CORDIER 81 ESPOSITO 80 COSME 79	ZPHY C62 455 ZPHY C56 15 ZPHY C42 663 B PL 127B 132 PL 106B 155 LNC 28 195 NP B152 215	+ Donnachie + Baldini+ + Clegg + (BONN, CERN, GLAS, LANC, + Bisello, Bizot, Buon, Delcourt, Mane + Marini, Patteri+ (FRAS, NAP) + Dudelzak, Grelaud, Jean-Marie, Julian+	(ORSAY) L, PADO, ROMA)
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OTHER RELATED PAPERS -

DOLINSKY	91	PRPL 202 99	+Druzhinin, Dubrovin+ (N	OVO)
ATKINSON	87	ZPHY C34 157	+ (BONN, CERN, GLAS, LANC, MCHS, CI	JRIN)
ATKINSON	84	NP B231 15	 + (BONN, CERN, GLAS, LANC, MCHS, CUF 	(+NI)



$$I^{G}(J^{PC}) = 2^{+}(2^{+})$$

OMITTED FROM SUMMARY TABLE

Observed in the reaction $\gamma\gamma\to~\rho\rho$ near threshold. See also minireview under non- $q\overline{q}$ candidates.

X(1600) MASS

,VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
1600±100	¹ ALBRECHT	91F	ARG	0	$ \begin{array}{c} 10.2 \ e^{+} e^{-} \rightarrow \\ e^{+} e^{-} 2(\pi^{+} \pi^{-}) \end{array} $
1 Our estimate					

X(1600) WIDTH

VALUE (MeV)	DOCUMENT ID	TECN	CHG	COMMENT
400±200	² ALBRECHT	91F ARG	0	$10.2 \ e^{+} e^{-} _{e^{-} 2(\pi^{+} \pi^{-})}$

² Our estimate.

X(1600) REFERENCES 91F ZPHY C50 1 +Appuan, Paulini, Funk+ (ARGUS Collab.)

OTHER RELATED PAPERS

89M PL B217 205 89D PL B218 494 +Bockmann+ +Criegee+ (ARGUS Collab.) (CELLO Collab.)

 $f_2(1640)$, $\omega_3(1670)$

 $f_2(1640)$

$$I^{G}(J^{PC}) = 0^{+}(2^{++})$$

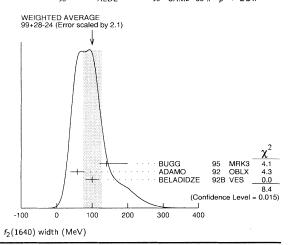
OMITTED FROM SUMMARY TABLE

f2(1640) MASS

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
1638± 6 OUR AVERAGE	Error includes scale factor of	f 1.2.	
1620 ± 16			$J/\psi \rightarrow \gamma \pi^+ \pi^- \pi^+ \pi^-$
1647± 7	ADAMO 92	OBLX	$\overline{n} p \rightarrow 3\pi^+ 2\pi^-$
1590 ± 30	BELADIDZE 92	3 VES	36 $\pi^- p \rightarrow \omega \omega n$
1635± 7	ALDE 90	GAM2	$38 \pi^- p \rightarrow \omega \omega n$

f₂(1640) WIDTH

VALUE (MeV)	CL%	DOCUMENT ID		TECN	COMMENT
99 ⁺²⁸ OUR AVERAG	E Error i	ncludes scale fac	tor	of 2.1. S	see the ideogram below.
$140 + 60 \\ -20$		BUGG	95	MRK3	$J/\psi \rightarrow \gamma \pi^+ \pi^- \pi^+ \pi^-$
58 ± 20		ADAMO	92	OBLX	$\overline{n}p \rightarrow 3\pi^{+}2\pi^{-}$
100 ± 20		BELADIDZE	92B	VES	$36 \pi^- \rho \rightarrow \omega \omega n$
• • We do not use the	following o	lata for averages	, fits	i, limits,	etc. • • •
< 70	00	ALDE	QΩ	CAMA	39 m n



f2(1640) DECAY MODES

	Mode	Fraction (Γ_j/Γ)
Γ_1	ωω	seen
Γ_2	4π	seen

f₂(1640) REFERENCES

BUGG	95	PL B353 378	+Scott, Zoli+		(LOQM, PNPI,	WASH) JP
ADAMO	92	PL B287 368	+Agnello, Balestra	+	(OBELIX	Collab.)
BELADIDZE	92B	ZPHY C54 367	+Bityukov, Borisov	+	(VES	Collab.)
ALDE	90	PL B241 600	+Binon+	SERP. BELG.	LANL, LAPP, PIS	A. KFKÍ

 $\omega_3(1670)$

 $I^{G}(J^{PC}) = 0^{-}(3^{-})$

ω_3 (1670) MASS

v	ALUE (N	1eV)	EVTS	DOCUMENT ID		TECN	COMMENT	
	1667	± 4 OI	JR AVERAGE					_
	1665.3	3 ± 5.2 ± 4	.5 23400	AMELIN	96	VES	$36 \pi^- \rho \rightarrow \pi^+ \pi^- \pi^0 n$	ı
	1685	± 20	60	BAUBILLIER	79	HBC	8.2 $K^- p$ backward	
	1673	± 12	430	1,2 BALTAY	78E	HBC	$15 \pi^+ \rho \rightarrow \Delta 3\pi$	
	1650	± 12		CORDEN	78B	OMEG	$8-12 \pi^- p \rightarrow N3\pi$	
	1669	± 11	600	² WAGNER			$7 \pi^+ \rho \rightarrow \Delta^{++} 3\pi$	
	1678	± 14	500	DIAZ			$6 \pi^+ n \rightarrow p3\pi^0$	
	1660	± 13	200	DIAZ	74	DBC	$6 \pi^+ n \rightarrow p \omega \pi^0 \pi^0$	
	1679	± 17	200	MATTHEWS	71D	DBC	$7.0 \pi^+ n \rightarrow p3\pi^0$	
	1670	± 20		KENYON	69	DBC	$8 \pi^+ n \rightarrow p 3\pi^0$	
•	• • W	Ve do not i	se the following	ng data for average:	s, fits	, limits,	etc. • • •	

77B HBC 4.2 $K^- p \to \Lambda 3\pi$ 69B HBC 4.6 $K^- p \to \omega 2\pi X$ 68B DBC 5.1 $\pi^+ n \to \rho 3\pi^0$ ~ 1700 ¹ CERRADA $1695\ \pm 20$ BARNES 1636 ± 20 ARMENISE

 1 Phase rotation seen for $J^{P}=3^{-}$ $\rho\pi$ wave. 2 From a fit to $I(J^{P})=0(3^{-})$ $\rho\pi$ partial wave.

ω_3 (1670) WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
168±10 OUR AVE				
$149 \pm 19 \pm 7$	23400	AMELIN	96 VES	$36 \pi^- \rho \rightarrow \pi^+ \pi^- \pi^0 n$
160 ± 80	60	³ BAUBILLIER	79 HBC	8.2 K^-p backward
173 ± 16	430	^{4,5} BALTAY	78E HBC	$15 \pi^+ \rho \rightarrow \Delta 3\pi$
253 ± 39		CORDEN	78B OME	G 8-12 $\pi^- p \rightarrow N3\pi$
173 ± 28	600	^{3,5} WAGNER	75 HBC	$7 \pi^+ \rho \rightarrow \Delta^{++} 3\pi$
167 ± 40	500	DIAZ		$6 \pi^+ n \rightarrow \rho 3\pi^0$
122 ± 39	200			$6 \pi^+ n \rightarrow \rho \omega \pi^0 \pi^0$
$\textbf{155} \pm \textbf{40}$	200	³ MATTHEWS	710 DBC	$7.0 \pi^{+} n \rightarrow p3\pi^{0}$
• • • We do not a	ise the followi	ng data for average	s, fits, limit	s, etc. • • •
90 ± 20		BARNES	69B HBC	4.6 $K^- p \rightarrow \omega 2\pi$
100 ± 40		KENYON	69 DBC	$8 \pi^+ n \rightarrow p 3\pi^0$
112 ± 60		ARMENISE	68B DBC	$5.1 \pi^+ n \rightarrow p3\pi^0$
³ Width errors er	nlarged by us	to $4\Gamma/\sqrt{N}$; see the	note with t	he K*(892) mass.

⁴ Phase rotation seen for $J^P=3^ \rho\pi$ wave. ⁵ From a fit to $I(J^P)=0(3^-)$ $\rho\pi$ partial wave.

ω_3 (1670) DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ ₁	$\rho\pi$	seen
Γ_2	$\omega \pi \pi$	seen
Γ_3	$b_1(1235)\pi$	possibly seen

ω_3 (1670) BRANCHING RATIOS

$\Gamma(\omega\pi\pi)/\Gamma(\rho\pi)$							Γ_2/Γ_1
VALUE	EVTS	DOCUMEN	T ID	TECN	COMMENT		
• • • We do not us	se the followin	g data for ave	erages, fit	s, limits	, etc. • • •		
$\textbf{0.71} \pm \textbf{0.27}$	100	DIAZ	74	DBC	6 π^+ n \rightarrow	$p5\pi^0$	

$\Gamma(b_1(1235)\pi)/\Gamma(\rho\pi)$

$\Gamma(b_1(1235)\pi)/\Gamma(\rho\pi)$					Γ_3/Γ_1
VALUE	DOCUMENT ID		TECN	COMMENT	
possibly seen	DIAZ	74	DBC	6 π^+ $n \rightarrow$	$\rho 5\pi^0$
$\Gamma(b_1(1235)\pi)/\Gamma(\omega\pi\pi)$					Γ_3/Γ_2

$\Gamma(b_1(1235)\pi)/\Gamma(\omega\pi\pi)$

VAL	UE						CL%	DO	CUM	ENT ID		TECN	COM	<i>ИМЕ</i>	N7	r	
•	•	We	do	not	use	the	following	data	for	average	s, fits	, limits,	etc.	• •	•	•	
>0	.75	;					68	BA	UBI	LLIER	79	HBC	8.2	ĸ-	. р	backward	

ω_3 (1670) REFERENCES

AMELIN	96	ZPHY C70 71	+Berdnikov, Bityukov+ (SERP, TBIL)
BAUBILLIER	79	PL 89B 131	+ (BIRM, CERN, GLAS, MSU, ORSAY)
BALTAY	78E	PRL 40 87	+Cautis, Kalelkar (COLU) JP
CORDEN	78B	NP B138 235	+Corbett, Alexander+ (BIRM, RHEL, TELA, LOWC)
CERRADA	77B	NP B126 241	+Blockziji, Heinen+ (AMST, CERN, NIJM, OXF) JP
WAGNER	75	PL 58B 201	+ Tabak, Chew (LBL) JP
DIAZ	74	PRL 32 260	+Dibianca, Fickinger, Anderson+ (CASE, CMU)
MATTHEWS	71D	PR D3 2561	+Prentice, Yoon, Carroll+ (TNTO, WISC)
BARNES	69B	PRL 23 142	+Chung, Eisner, Flaminio+ (BNL)
KENYON	69	PRL 23 146	+Kinson, Scarr+ (BNL, UCND, ORNL)
ARMENISE	68B	PL 26B 336	+Forino, Cartacci+ (BARI, BGNA, FIRZ, ORSAY)

- OTHER RELATED PAPERS -----

MATTHEWS	71	LNC 1 361	+Prentice, Yoon, Carroll+	(TNTO, WISC)
ARMENISE	70	LNC 4 199	+Ghidini, Foring, Cartacci+	(BARI, BGNA, FIRZ)

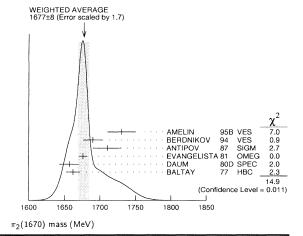
 $\pi_2(1670)$

$$I^{G}(J^{PC}) = 1^{-}(2^{-+})$$

π_2 (1670) MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
1670 ± 20 OUR E	STIMATE 1					or given is larger than
		the error on	the a	everage	of the	published values.
1677± 8 OUR A	VERAGE Er	ror includes scale t	factor	of 1.7.	See th	ne ideogram below.
1730 ± 20		¹ AMELIN	95B	VES		36 $\pi^- A \rightarrow$
		•				$\pi^+\pi^-\pi^-A$
1690 ± 14		2 BERDNIKOV	94	VES		$37 \pi^- A \rightarrow$
						$\kappa^+ \kappa^- \pi^- A$
1710 ± 20	700	ANTIPOV	87	SIGM	-	50 π^- Cu \rightarrow
						$\mu^{+}\mu^{-}\pi^{-}$ Cu
1676± 6		² EVANGELISTA	8 1	OMEG	_	$12 \pi^- p \rightarrow 3\pi p$
1657 ± 14		^{2,3} DAUM	80D	SPEC	_	$63-94 \pi p \rightarrow 3\pi X$
1662 ± 10	2000	² BALTAY	77	HBC	+	$15 \pi^+ \rho \rightarrow \rho 3\pi$
• • • We do not	use the follow	wing data for avera	res.	fits. lim	its, etc.	
		g aata arara	.0001		,	
$1742 \pm 31 \pm 49$		ANTREASYAN	1 90	CBAL		$e^{+}e^{-}_{e^{+}e^{-}\pi^{0}\pi^{0}\pi^{0}}$
1710 ± 20		⁴ DAUM	81B	SPEC	_	$63.94 \pi^{-} p$
1640 ± 10	575	KALELKAR	75	нвс	+	$15 \pi^+ p \rightarrow p \pi^+ f_2$
	5/5				+	
1660 ± 10		² ASCOLI	73	HBC		$5-25 \pi^- p \rightarrow p \pi_2$
4	DC I					-

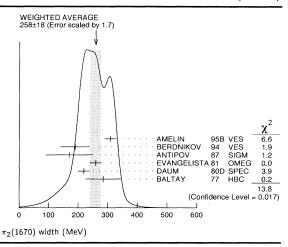
- ¹ From a fit to $J^{PC} = 2^{-} + f_2(1270)\pi$, $f_0(1370)\pi$ waves.
- ² From a fit to $J^P = 2^- S$ -wave $f_2(1270)\pi$ partial wave.
- 3 Clear phase rotation seen in 2 = 5, 2 = P, 2 = D waves. We quote central value and spread of single-resonance fits to three channels.
 4 From a two-resonance fit to four 2 = 0 + waves. This should not be averaged with all the single resonance fits.



$\pi_2(1670)$ WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID	TE	CN CHG	COMMENT
258±18 OUR AVI	ERAGE Erro		ctor of 1	.7. See the	e ideogram below.
310±20		⁵ AMELIN	95B VE	ES	$\begin{array}{ccc} 36 & \pi^- A \rightarrow \\ \pi^+ & \pi^- & \pi^- A \end{array}$
190±50		⁶ BERDNIKOV	94 VE	ES .	$\begin{array}{c} 37 \ \pi^- A \rightarrow \\ K^+ K^- \pi^- A \end{array}$
170±80	700	ANTIPOV	87 SI	GM -	50 π^- Cu \rightarrow μ^+ $\mu^ \pi^-$ Cu
260 ± 20		⁶ EVANGELISTA	81 ON	ИEG −	$12 \pi^- \rho \rightarrow 3\pi \rho$
219±20		5,7 DAUM	80D SP	EC -	$63-94 \pi p \rightarrow 3\pi X$
285 ± 60	2000	⁶ BALTAY	77 HE	3C +	$15 \pi^+ p \rightarrow p3\pi$
• • • We do not	use the follow	ing data for avera	ges, fits	limits, etc	. • • •
236 ± 49 ± 36		ANTREASYAN	190 CE	BAL	$e^{+}e^{-}_{e^{+}e^{-}\pi^{0}\pi^{0}\pi^{0}}$
312 ± 50		⁸ DAUM	818 SP	EC -	63,94 π ⁻ p
240±30	575	KALELKAR	75 HE	BC +	$15 \pi^+ \rho \rightarrow \rho \pi^+ i$
270 ± 60		⁶ ASCOLI	73 HE	3C –	$5-25 \pi^- p \rightarrow p \pi$
⁶ From a fit to J	$I^P = 2^- f_2($	$f_2(1270)\pi$, $f_0(131270)\pi$ partial way 2^-S , 2^-P , 2^-D	e.		entral value and spre

- $^8\mathrm{From}$ a two-resonance fit to four 2^-0^+ waves. This should not be averaged with all the single resonance fits.



π_2 (1670) DECAY MODES

	Mode	Fraction (Γ_j/Γ)	
Γ ₁	3π	(95.8±1.4) %	_
Γ_2	$f_2(1270)\pi$	(56.2±3.2) %	
Γ_3	$ ho\pi$	(31 ±4)%	
Γ4	$f_0(1370)\pi$	(8.7±3.4) %	
Γ_5	$K\overline{K}^*(892) + \text{c.c.}$	(4.2 ± 1.4) %	
Γ_6	$\gamma\gamma$	$(5.2\pm1.1)\times10^{-6}$	
Γ_7	$\eta\pi$		
Γ8	$\pi^{\pm} 2\pi^{+} 2\pi^{-}$		

CONSTRAINED FIT INFORMATION

An overall fit to 4 branching ratios uses 6 measurements and one constraint to determine 4 parameters. The overall fit has a χ^2 = 1.9 for 3 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv$ $\Gamma_i/\Gamma_{\rm total}$. The fit constrains the x_i whose labels appear in this array to sum to one.

$$\begin{array}{c|ccccc} x_3 & -53 & & \\ x_4 & -29 & -59 & & \\ x_5 & -8 & -21 & -9 & \\ \hline & x_2 & x_3 & x_4 & & \end{array}$$

ı

$\pi_2(1670)$ PARTIAL WIDTHS

$\Gamma(\gamma\gamma)$				Г ₆
VALUE (keV)	DOCUMENT ID	TECN	CHG	COMMENT
1.35 ± 0.26 OUR AVE	RAGE			
$1.41 \pm 0.23 \pm 0.28$	ANTREASYAN	90 CBAL	0	$e^{+}e^{-} \rightarrow e^{+}e^{-}\pi^{0}\pi^{0}\pi^{0}$
$1.3 \pm 0.3 \pm 0.2$	9 BEHREND	90c CELL	0	$e^+e^{e^+e^-\pi^+\pi^-\pi^0}$
• • • We do not use	the following data for	averages, fi	ts, lim	its, etc. • • •
$0.8 \pm 0.3 \pm 0.12$	¹⁰ BEHREND	90c CELL	0	$e^{+}e^{-}_{e^{+}e^{-}\pi^{+}\pi^{-}\pi^{0}}$
9 Incoherent Ansat:				

π_2 (1670) BRANCHING RATIOS

$\Gamma(3\pi)/\Gamma_{\text{total}}$ $VALUE$ 0.958±0.014 OUR FIT	DOCUMENT ID		1	1/Γ =	$= (\Gamma_2 + \Gamma_3 + \Gamma_4)/\Gamma$
$\Gamma(ho\pi)/\Gamma(\pi^{\pm}\pi^{+}\pi^{-})$		1/2	Γ ₃ /(0.	567Γ2	$_{2}+\frac{1}{2}\Gamma_{3}+0.624\Gamma_{4})$
VALUE	DOCUMENT ID		TECN		COMMENT
0.29±0.04 OUR FIT					
0.29±0.05	¹¹ DAUM	81B	SPEC		63,94 $\pi^- p$
ullet $ullet$ We do not use the following	wing data for average	s, fits	s, limits,	etc.	• •
< 0.3	BARTSCH	68	нвс	+	$8 \pi^+ p \rightarrow 3\pi p$
< 0.4	FERBEL	68	RVUE	±	
¹¹ From a two-resonance fit	to four 2^-0^+ waves.				

 $\pi_2(1670), \phi(1680)$

$\Gamma(f_2(1270)\pi)/\Gamma(\pi^{\pm}\pi^{+}\pi^{-})$ $0.567\Gamma_2/(0.567\Gamma_2+\frac{1}{2}\Gamma_3+0.624\Gamma_4)$ (With $f_2(1270) \rightarrow \pi^+\pi^-$.) DOCUMENT ID TECN CHG COMMENT 0.604±0.035 OUR FIT **0.60** \pm **0.05 OUR AVERAGE** Error includes scale factor of 1.3. See the ideogram below. ¹² DAUM 0.61 ± 0.04 81B SPEC 63,94 $\pi^- p$ $0.76 \begin{array}{l} +0.24 \\ -0.34 \end{array}$ ARMENISE 69 DBC + $5.1 \pi^+ d \rightarrow d3\pi$ 0.35 ±0.20 BALTAY 68 HBC + 7-8.5 $\pi^+ p$ \bullet \bullet We do not use the following data for averages, fits, limits, etc. \bullet \bullet BARTSCH 68 HBC + 8 $\pi^+ \rho \rightarrow 3\pi \rho$ 0.59 $^{\rm 12}\,{\rm From}$ a two-resonance fit to four ${\rm 2^-0^+}$ waves. WEIGHTED AVERAGE 0.60±0.05 (Error scaled by 1.3) Values above of weighted average, error vanues above of weighted average, error, and scale factor are based upon the data in this ideogram only. They are not necessarily the same as our 'best' values, obtained from a least-squares constrained fit utilizing measurements of other (related) quantities as additional information. ARMENISE 69 DBC BALTAY 68 HBC 0.2 0.4 $\Gamma(f_2(1270)\pi)/\Gamma(\pi^{\pm}\pi^{+}\pi^{-})$ $\Gamma(\eta\pi)/\Gamma(\pi^{\pm}\pi^{+}\pi^{-})$ $\Gamma_7/(0.567\Gamma_2+\frac{1}{2}\Gamma_3+0.624\Gamma_4)$ (All $\hat{\eta}$ decays.) VALUE DOCUMENT ID TECN CHG COMMENT 68 HBC + 7-8.5 $\pi^+ \rho$ <0.09 BALTAY CRENNELL 70 HBC - 6 $\pi^- p$ - $\Gamma(\pi^{\pm} 2\pi^{+} 2\pi^{-})/\Gamma(\pi^{\pm} \pi^{+} \pi^{-})$ $\Gamma_8/(0.567\Gamma_2+\frac{1}{2}\Gamma_3+0.624\Gamma_4)$ VALUE DOCUMENT ID TECN CHG COMMENT 6 π[−] p → < 0.10 CRENNELL 70 HBC $\Gamma(f_0(1370)\pi)/\Gamma(\pi^{\pm}\pi^{+}\pi^{-})$ $0.624\Gamma_4/(0.567\Gamma_2+\frac{1}{2}\Gamma_3+0.624\Gamma_4)$ (With $f_0(1370) \rightarrow \pi^+\pi^-$.) DOCUMENT ID TECN COMMENT 0.10±0.04 OUR FIT 13 DAUM 81B SPEC 63.94 π⁻ p 0.10 ± 0.05 $^{13}\,\mathrm{From}$ a two-resonance fit to four 2^-0^+ waves. $\Gamma(K\overline{K}^*(892) + \text{c.c.})/\Gamma(f_2(1270)\pi)$ Γ_5/Γ_2 DOCUMENT ID TECN CHG COMMENT VALUE 0.075±0.025 OUR FIT ¹⁴ ARMSTRONG 82B OMEG - 0.075 ± 0.025 16 π⁻ p -¹⁴ From a partial-wave analysis of $K^+K^-\pi^-$ system. D-wave/S-wave RATIO FOR $\pi_2(1670) \rightarrow f_2(1270)\pi$ DOCUMENT ID TECN COMMENT ¹⁵ DAUM 0.22 ± 0.10 81B SPEC 63,94 $\pi^- p$ $^{15}\,\mathrm{From}$ a two-resonance fit to four 2^-0^+ waves.

π_2 (1670) REFERENCES

AMELIN BERDNIKOV	95B 94	PL B356 595 PL B337 219	+Berdnikov, Bityukov +Bityukov+	+ (SERP, TBIL) (SERP, TBIL)
ANTREASYAN	90	ZPHY C48 561	+Bartels, Besset+	(Crystal Ball Collab.)
BEHREND	90C	7PHY C46 583	+Criegee+	(CELLO Collab.)
ANTIPOV	87	EPL 4 403		RP, JINR, INRM, TBIL, BGNA, MILA)
ARMSTRONG	82B	NP B202 1		ACH3, BARI, BONN, CERN, GLAS+)
DAUM	81B	NP B182 269	+Hertzberger+	(AMST, CERN, CRAC, MPIM, OXF+)
EVANGELISTA	81	NP B178 197	+	(BARI, BONN, CERN, DARE, LIVP+)
Also	81B	NP B186 594	Evangelista	
DAUM	80D	PL 89B 285	+Hertzberger+	AMST, CERN, CRAC, MPIM, OXF+) JP
BALTAY	77	PRL 39 591	+Cautis, Kalelkar	(COLU) JP
KALELKAR	75	Thesis Nevis 207		(COLU)
ASCOLI	73	PR D7 669	(ILL,	TNTO, GENO, HAMB, MILA, SACL) JP
CRENNELL	70	PRL 24 781	+Karshon, Lai, Scarr,	Sims (BNL)
ARMENISE	69	LNC 2 501	+Ghidini, Forino, Car	tacci+ (BARI, BGNA, FIRZ)
BALTAY	68	PRL 20 887	+Kung, Yeh, Ferbel+	(COLU, ROCH, RUTG, YALE) I
BARTSCH	68	NP B7 345	+Keppel, Kraus+	(AACH, BERL, CERN) JP
FERBEL	68	Phil. Conf. 335		(ROCH)

OTHER RELATED PAPERS -

CHEN LEEDOM BELLINI FOCACCI LEVRAT LUBATTI	83 82B 66 66 66	PR D28 2304 PR D27 1426 NP B199 1 PRL 17 890 PL 22 714 Thesis Berkeley	+DeBonte, Gaidos + (CERN, M +Kienzle, Levrat, +Tolstrup+	(ARIZ, FNAL, FLOR, NDAM, TUFTS+) For Wong+ (PURD, TNTO) LA, JINR, BGNA, HELS, PAVI, WARS+) Maglich, Martin (CERN Missing Mass Spect. Collab.) (LRL)
VETLITSKY	66	PL 21 579	+Guszavin, Kliger,	
FORINO	65B	PL 19 68	+Gessaroli+	

 $\phi(1680)$

$$I^{G}(J^{PC}) = 0^{-}(1^{-})$$

ϕ (1680) MASS

VALUE (MeV)	EVTS	DOCUMENT II		TECN	COMMENT
1680 ± 20 OUR E	STIMATE				
1681 ± 8 OUR A	WERAGE				
1700 ± 20		¹ CLEGG	94	RVUE	$e^+e^- \rightarrow K^+K^-$,
					$K_c^0 K \pi$
1657±27	367	BISELLO	91C	DM2	$e^+e^- \rightarrow \kappa_S^0 \kappa^{\pm} \pi^{\mp}$
1680 ± 10		² BUON	82	DM1	$e^+e^- \rightarrow hadrons$
• • • We do not	t use the following	ng data for averag	ges, fits	, limits,	etc. • • •
1655±17		³ BISELLO	88B	DM2	$e^+e^- \rightarrow K^+K^-$
1677 ± 12		4 MANE	82	DM1	$e^+e^- \rightarrow K_S^0 K \pi$

 $^{1}\,\mbox{Using BISELLO}$ 88B and MANE 82 data.

PHOTOPRODUCTION

VALUE (MeV)	DOCUMENT ID	TECIV	COMMENT
• • We do not use the follow	ving data for average:	s, fits, limits,	etc. • • •
1726±22	BUSENITZ	89 TPS	$\gamma p \rightarrow K^+ K^- X$
1760 ± 20	ATKINSON		20–70 $\gamma p \rightarrow K\overline{K}X$
1690 ± 10	ASTON	81F OMEG	25-70 $\gamma p \rightarrow K^+K^-X$
2			

 2 From global fit of $\rho,~\omega,~\phi$ and their radial excitations to channels $\omega\,\pi^+\,\pi^-,~K^+K^-,~K^0_S\,K^0_I,~K^0_S\,K^\pm\,\pi^\mp.$ Assume mass 1570 MeV and width 510 MeV for ρ radial excitations, mass 1570 and width 500 MeV for ω radial excitation.

From global fit including ρ , ω , ϕ and ρ (1700) assume mass 1570 MeV and width 510 MeV for ρ radial excitation.

⁴ Fit to one channel only, neglecting interference with ω , $\rho(1700)$.

ϕ (1680) WIDTH							
e ⁺ e ⁻ PRODU VALUE (MeV) 150±50 OUR EST	EVTS		D TECN COMMENT ated guess; the error given is larger that the average of the published values.				
• • • We do not	use the following	ng data for avera	ges, fits, limits, etc. • •				
300 ± 60		⁵ CLEGG	94 RVUE $e^+e^- \rightarrow K^+K^-$, $K^0_c K \pi$				
146±55	367	BISELLO	91C DM2 $e^{+}e^{-} \rightarrow K_{S}^{0}K^{\pm}\pi^{\mp}$ 88B DM2 $e^{+}e^{-} \rightarrow K^{+}K^{-}$				
207 ± 45		⁶ BISELLO	888 DM2 $e^+e^- \rightarrow K^+K^-$				
185 ± 22		⁷ BUON	82 DM1 $e^+e^- \rightarrow hadrons$				
102 ± 36		⁸ MANE	82 DM1 $e^+e^- \rightarrow K^0_S K \pi$				
⁵ Using BISELL	O 88B and MA	NE 82 data.					

PHOTOPRODUCTION

VALUE (IVIEV)	DOCUMENT ID	TECIV	COMMENT
	g data for averag	es, fits, limits	, etc. • • •
121 ± 47	BUSENITZ		$\gamma p \rightarrow K^+ K^- X$
80 ± 40	ATKINSON		$6 20-70 \gamma p \rightarrow K\overline{K}X$
100 ± 40	ASTON	81F OME	$6 25-70 \gamma p \rightarrow K^+K^-X$

6 From global fit including ρ , ω , ϕ and ρ (1700) assume mass 1570 MeV and width 510 MeV for ρ radial excitation. 7 From global fit of ρ , ω , ϕ and their radial excitations to channels $\omega\pi^+\pi^-$. K^+K^- . K^0_0 , K^0_1 , K^0_3 , K^0_4 , K^0_7 . Assume mass 1570 MeV and width 510 MeV for ρ radial excitations, mass 1570 and width 500 MeV for ω radial excitations. ⁸ Fit to one channel only, neglecting interference with ω , $\rho(1700)$.

ϕ (1680) DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ_1	$K\overline{K}^*(892) + \text{c.c.}$	dominant
Γ_2	$K_S^0 K \pi$	seen
Γ_3	$\kappa \overline{\kappa}$	seen
Γ_4	e^+e^-	seen
Γ_5	$\omega\pi\pi$ $K^+K^-\pi^0$	not seen
Γ _{6.}	$K^+K^-\pi^0$	

$\phi(1680) \Gamma(i)\Gamma(e^+e^-)/\Gamma(total)$

This combination of a partial width with the partial width into $e^+e^$ and with the total width is obtained from the integrated cross section into channel (I) in e^+e^- annihilation. We list only data that have not been used to determine the partial width $\Gamma(I)$ or the branching ratio $\Gamma(I)/total$.

$\Gamma(K\overline{K}^*(892) + \text{c.c.})$	× Γ(e ⁺	e ⁻)/Γ _{total}			$\Gamma_1\Gamma_4/\Gamma$
VALUE (keV)	EVTS	DOCUMENT ID	TECN	COMMENT	
• • • We do not use t	ne following	data for average	s, fits, limits	etc. • • •	
0.48 ± 0.14	367	BISELLO	91C DM2	$e^+e^- \to$	$\kappa_S^0 \kappa^{\pm} \pi^{\mp}$

A(1680) BRANCHING RATIOS

φ(1000) BRANCHING RATIOS							
$\Gamma(K\overline{K}^*(892) + \text{c.c.})/\Gamma(K_S^0K\pi$	DOCUMENT ID		TECN	COMMENT	Γ_1/Γ_2		
VALUE	DOCUMENT ID						
dominant	MANE	82	DM1	e+e- →	$\kappa_S^0 \kappa^\pm \pi^\mp$		
$\Gamma(K\overline{K})/\Gamma(K\overline{K}^*(892)+\text{c.c.})$					Γ_3/Γ_1		
VALUE	DOCUMENT ID		TECN	COMMENT			
0.07 ±0.01	BUON	82	DM1	e^+e^-			
$\Gamma(\omega\pi\pi)/\Gamma(K\overline{K}^*(892)+c.c.)$					Γ_5/Γ_1		
VALUE	DOCUMENT ID		TECN	COMMENT			
<0.10	BUON	82	DM1	e+ e-			

φ(1680) REFERENCES

BISELLO 9 BUSENITZ 8 BISELLO 8 ATKINSON 8 BUON 8 MANE 8	91C 89 88B 85C 82	ZPHY C62 455 ZPHY C52 227 PR D40 1 ZPHY C39 13 ZPHY C27 233 PL 118B 221 PL 112B 178 PL 104B 231	+Donnachie +Busetto, Castro, Nigro, Pescara+ +Olszewski, Callahan+ +Busetto+ + (BONN, CERN, GLAS, LANC, 1 +Bisello, Bizot, Cordier, Delcourt, + +Bisello, Bizot, Buon, Delcourt, Fayard+ BONN, CERN, FPOL, GLAS,	MCHS, CURIN+) (LALO, MONP) (LALO)
ASTON 8	31F	PL 104B 231	(BONN, CERN, EPOL, GLAS,	LANC, MCHS+)

OTHER RELATED PAPERS ---

ATKINSON ATKINSON ATKINSON ATKINSON CORDIER	84 84B 83C	ZPHY C30 541 NP B231 15 NP B231 1 NP B229 269 PL 106B 155		(BONN, CERN, GLAS, LANC, MCHS, (BONN, CERN, GLAS, LANC, MCHS, (BONN, CERN, GLAS, LANC, MCHS, (BONN, CERN, GLAS, LANC, MCHS, Bizot, Buon, Delcourt, Mane	CURIN+) CURIN+) CURIN+) (ORSAY)
CORDIER	81	PL 106B 155			
MANE	81	PL 99B 261	+Bisello,	Bizot, Buon, Cordier, Delcourt	
ASTON	80F	NP-B174 269		(BONN, CERN, EPOL, GLAS, LANC,	MCHS+)



$$I^{G}(J^{PC}) = 1^{+}(3^{-})$$

$\rho_{3}(1690)$ MASS

VALUE	(MeV)		DO	CUMENT	· ID	

1691 ±5 OUR ESTIMATE
This is only an educated guess; the error given is larger than the error on the average of the published values.

1688.8±2.1 OUR AVERAGE
Includes data from the 5 datablocks that follow this one.

2π MODF

VALUE (MeV) EVTS DOCUMENT ID TECN CHG COMMENT

The data in this block is included in the average printed for a previous datablock.

1686 ± 4 OUR AVE	RAGE					
1677 ± 14		EVANGELISTA	81	OMEG	_	$12 \pi^- \rho \rightarrow 2\pi \rho$
1679 ± 11	476	BALTAY	78B	HBC	0	15 $\pi^+ \rho \rightarrow$
						$\pi^+\pi^-n$
1678 ± 12	175	¹ ANTIPOV	77	CIBS	0	
1690 ± 7	600	¹ ENGLER	74	DBC	0	$ 6 \frac{\pi^+ n}{\pi^+ \pi^-} \xrightarrow{p} $
		•				
1693± 8		² GRAYER	74	ASPK	0	17 $\pi^- \rho \rightarrow$
						$\pi^+\pi^-n$
1678 + 12		MATTHEWS	71c	DRC	Ω	7 π ⁺ N

ullet $ullet$ We do not use the	following o	data for averages	, fits	, limits,	etc. •	• •
1734 ± 10	3	CORDEN	79	OMEG		12-15 $\pi^- p \rightarrow$
1692 ± 12	2,4	ESTABROOKS	75	RVUE		$ \begin{array}{c} n2\pi \\ 17 \pi^{-} \rho \rightarrow \end{array} $
1737±23		ARMENISE	70	DBC	0	$_{9 \pi^{+} N}^{\pi^{+} \pi^{-} n}$
1650 ± 35	122	BARTSCH	70B	HBC	+	$8 \pi^+ p \rightarrow N2\pi$
1687 ± 21		STUNTEBECK	70	HDBC	0	$8 \pi^- p$, 5.4 $\pi^+ d$
1683±13		ARMENISE	68	DBC	0	5.1 $\pi^+ d$
1670 ± 30		GOLDBERG	65	HBC	0	$6 \pi^+ d$, $8 \pi^- p$

¹ Mass errors enlarged by us to Γ/\sqrt{N} ; see the note with the $K^*(892)$ mass.

$K\overline{K}$ AND $K\overline{K}\pi$ MODES

A A AND A A A	IODES				
VALUE (MeV)	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
The data in this block	is include	ed in the average pri	inted for a pre	evious	datablock.
1696± 4 OUR AVER	AGE				
1699± 5		ALPER	80 CNTR	0	$\begin{array}{c} 62 \pi^- p \rightarrow \\ K^+ K^- n \end{array}$
1698±12	6k	5,6 MARTIN	78D SPEC		$ \begin{array}{c} K^+K^-n \\ 10 \pi p \rightarrow \\ K_5^0K^-p \end{array} $
1692± 6		BLUM	75 ASPK	0	18.4 $\pi^- \rho \rightarrow$
					n,K+K-

ADERHOLZ 69 HBC + $8 \pi^{+} p \rightarrow K \overline{K} \pi$ 1690 ± 16 • • • We do not use the following data for averages, fits, limits, etc. • • • 1694 ± 8 10 $\pi^- \rho \rightarrow$

⁷ COSTA... 80 OMEG K+K-n

$(4\pi)^{\pm}$ MODE

<u>VALUE (MeV)</u> <u>EVTS</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>CHG</u> <u>COMMENT</u>
The data in this block is included in the average printed for a previous datablock.

1686± 5 OUR AVERAGE	Error i	ncludes scale fact	or of	1.1.		
1694± 6		⁸ EVANGELISTA	81	OMEG		12 $\pi^- p \rightarrow p 4\pi$
1665 ± 15	177	BALTAY	78B	HBC	+	$15 \pi^+ p \rightarrow p 4\pi$
1670 ± 10		THOMPSON	74	HBC	+	13 $\pi^{+} \rho$
1687 ± 20		CASON	73	HBC	-	8,18.5 $\pi^- \rho$
1685 ± 14		⁹ CASON	73	HBC		8,18.5 $\pi^{-}p$
1680 ± 40	144	BARTSCH	70B	HBC		$8 \pi^+ \rho \rightarrow N4\pi$
1689±20	102	⁹ BARTSCH	70B	HBC	+	$8 \pi^+ p \rightarrow N2\rho$
1705 ± 21		CASO	70	HBC	-	11.2 $\pi^- p \rightarrow$

• • • We do not use the following data for averages, fits, limits, etc. • • •

1718 ± 10		¹⁰ EVANGELIST.	A 81	OMEG	_	$12 \pi^- p \rightarrow p4\pi$
1673± 9		11 EVANGELIST.	A 81	OMEG		$12 \pi^- p \rightarrow p4\pi$
1733± 9	66	⁹ KLIGER	74	HBC	_	$4.5 \pi^- \rho \rightarrow \rho 4\pi$
1630 ± 15		HOLMES	72	HBC	+	$10-12 K^+ p$
1720 ± 15		BALTAY	68	HBC	+	7, 8.5 $\pi^+ p$

VALUE (MeV) DOCUMENT ID TECN CHG COMMENT

The data in this block is included in the average printed for a previous datablock.

1681± 7 OUR AVERAGE

1670 ± 25	12 ALDE	95	GAM2		38 π p →
					$\omega \pi^{0} n$
1690 ± 15	EVANGELISTA	81	OMEG	_	$12 \pi^- p \rightarrow \omega \pi p$
1666±14	GESSAROLI	77	HBC		$11 \pi^- p \rightarrow \omega \pi \rho$
1686± 9	THOMPSON	74	HBC	+	13 $\pi^{+} p$
• • • We do not use the fol	owing data for averages	, fits	s, limits, e	etc. •	• •
1654±24	BARNHAM	70	HBC	+	10 $K^+ p \rightarrow \omega \pi X$
¹² Supersedes ALDE 92C.					

$\eta \pi^+ \pi^-$ MODE

(For difficulties with MMS experiments, see the $a_2(1320)$ mini-review in the 1973 edition.)

VALUE (MeV)	DOCUMENT ID	TECN CH	G COMMENT
The data in this block is included	in the average pr	inted for a previou	us datablock.
1680 + 15	FUKIII	88 SPEC 0	8.95 π ⁻ n →

² Uses same data as HYAMS 75. ³ From a phase shift solution containing a $f_2'(1525)$ width two times larger than the $K\overline{K}$ result.

4 From phase-shift analysis. Error takes account of spread of different phase-shift solutions.

⁵ From a fit to $J^P = 3^-$ partial wave. ⁶ Systematic error on mass scale subtracted.

⁷ They cannot distinguish between $ho_3(1690)$ and $\omega_3(1670)$.

 $^{^8}$ From $\rho^-\,\rho^0$ mode, not independent of the other two EVANGELISTA 81 entries. 9 From $\rho^\pm\,\rho^0$ mode. 10 From $a_2(1320)^-\,\pi^0$ mode, not independent of the other two EVANGELISTA 81 entries.

 $^{^{11}}$ From $a_2(1320)^0\pi^-$ mode, not independent of the other two EVANGELISTA 81 entries.

$\rho_3(1690)$

• • • We do not use	the following data for average	s, fit	s, limits	etc.	• • •
1700 ± 47	¹³ ANDERSON	69	MMS		16 $\pi^- p$ backward
1632 ± 15	13,14 FOCACCI	66	MMS	-	$7-12 \pi^- \rho \rightarrow \rho MM$
1700 ± 15	13,14 FOCACCI	66	MMS	-	$7-12 \pi^- \rho \rightarrow \rho MM$
1748 ± 15	13,14 FOCACCI	66	MMS	-	$7-12 \pi^- p \rightarrow p MM$

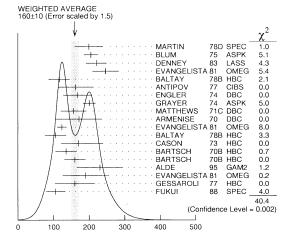
 $^{^{13}}$ Seen in 2.5–3 GeV/c $\overline{\rho}\rho.~2\pi^+2\pi^-$, with 0, 1, 2 $\pi^+\pi^-$ pairs in ρ band not seen by OREN 74 (2.3 GeV/c $\overline{\rho}\rho)$ with more statistics. (Jan. 1976) ¹⁴ Not seen by BOWEN 72.

ρ_3 (1690) WIDTH

2π , $K\overline{K}$, AND $K\overline{K}\pi$ MODES

 VALUE (MeV)
 DOCUMENT ID

 160±10 OUR AVERAGE
 Includes data from the 5 datablocks that follow this one. Error includes scale factor of 1.5. See the ideogram below.

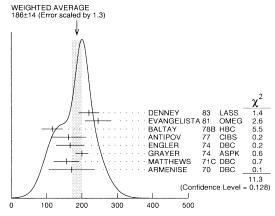


 $\rho_{3}(1690)$ width, $2\pi,\,K\,\overline{K}$, and $K\,\overline{K}\,\pi$ modes (MeV)

2π	MC	DDE
2/1	141	,,,

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	CHG	COMMENT	
The data in this blos	k is included in	the average printed t	for a pre	vious o	tatablock	

186±14 OUR AVERAGE	Error inc	ludes scale facto	r of	1.3. See	the ic	leogram below.
220 ± 29		DENNEY	83	LASS		10 π ⁺ N
246±37		EVANGELISTA	81	OMEG	_	$12 \pi^- \rho \rightarrow 2\pi \rho$
116 ± 30	476	BALTAY	78B	HBC	0	15 $\pi^+ \rho \rightarrow$
		_				$\pi^+\pi^-n$
162 ± 50	175	ANTIPOV	77	CIBS	0	$25 \pi^- p \rightarrow p3\pi$
167 ± 40	600	ENGLER	74	DBC	0	$6 \pi^+ n \rightarrow$
000 1 40	16	GRAYER	7.4	ASPK	^	$\pi^{+}\pi^{-}\rho$
200±18		GRAYER	74	ASPK	0	$17 \pi^- p \rightarrow \pi^+ \pi^- p$
156 ± 36		MATTHEWS	710	DBC	0	7 π ⁺ N
171 ± 65		ARMENISE	70	DBC	0	$9 \pi^+ d$
• • • We do not use the	following	data for average:	s, fits	s, limits,	etc.	• •
322±35	17	CORDEN	79	OMEG		$12-15 \pi^- p \rightarrow$
322 ± 33						n2π
240 ± 30	16,18	B ESTABROOKS	75	RVUE		17 $\pi^- p \rightarrow$
						$\pi^+\pi^-n$ 8 $\pi^+p \rightarrow N2\pi$
180 ± 30	122	BARTSCH	70B	HBC	+	$8 \pi^{\top} p \rightarrow N2\pi$
267 ^{+ 72} - 46		STUNTEBECH	70	HDBC	0	$8 \pi^{-} p$, 5.4 $\pi^{+} d$
188 ± 49		ARMENISE	68	DBC	0	5.1 $\pi^{+} d$
180 ± 40		GOLDBERG	65	HBC	0	$6 \pi^{+} d$, $8 \pi^{-} \rho$
15 Midth array onlarge	l bu us to 4	F / /Ni soo thou		with the	V*/0	02) mass



 $ho_3(1690)$ width, 2π mode (MeV)

$K\overline{K}$ AND $K\overline{K}\pi$ MODES

VALUE (MeV) EVTS DOCUMENT ID TECN CHG COMMENT
The data in this block is included in the average printed for a previous datablock.

204±18 OUR AVERA	GE				
$199\!\pm\!40$	6000	¹⁹ MARTIN	780	SPEC	$ \begin{array}{c} 10 \ \pi \ \rho \rightarrow \\ K_{S}^{0} \ K^{-} \ \rho \end{array} $
205 ± 20		BLUM	75	ASPK 0	18.4 $\pi^- p \rightarrow \kappa^+ \kappa^-$
• • • We do not use	the following	g data for average	s, fit	s, limits, etc.	
219± 4		ALPER	80	CNTR 0	62 $\pi^- p \rightarrow K^+ K^- p$
186 ± 11		²⁰ COSTA	80	OMEG	$10 \pi^- \rho \rightarrow$
112±60		ADERHOLZ	69	HBC +	$8 \pi^{+} \rho \rightarrow K \overline{K} \pi$

 $^{^{19}}$ From a fit to ${\it J^P}=3^-$ partial wave. $^{20}\,\text{They cannot distinguish between }\rho_3(1690)$ and $\omega_3(1670).$

$(4\pi)^{\pm}$ MODE

The data in this block is included in the average printed for a previous datablock.

129±10 OUR AVERAGE							
123 ± 13		21	EVANGELISTA	81	OMEG	-	$12~\pi^-p\top4\pi$
105 ± 30	177		BALTAY	78B	HBC	+	$15 \pi^+ p \rightarrow p 4\pi$
$169 + 70 \\ -48$			CASON	73	нвс	-	8,18.5 $\pi^- \rho$
135 ± 30	144		BARTSCH	70B	HBC	+	$8 \pi^+ p \rightarrow N4\pi$
160 ± 30	102		BARTSCH	70B	HBC	+	$8 \pi^+ p \rightarrow N2\rho$
ullet $ullet$ We do not use the	followin	g d	ata for averages	, fits	, limits,	etc. •	• •
230 ± 28			EVANGELISTA				$12 \pi^- \rho \rightarrow \rho 4\pi$
184 ± 33			EVANGELISTA	81	OMEG	-	$12~\pi^-\rho\top4\pi$
150	66	24	KLIGER	74	HBC	-	$4.5 \pi^- \rho \rightarrow \rho 4\pi$
106±25			THOMPSON	74	HBC	+	13 $\pi^{+} \rho$
$125 + 83 \\ -35$		24	CASON	73	нвс	_	8,18.5 $\pi^- p$
130 ± 30			HOLMES	72	HBC	+	10−12 K ⁺ p
180 ± 30	90	24	BARTSCH	70B	HBC	+	$8 \pi^+ p \rightarrow N a_2 \pi$
100 ± 35			BALTAY	68	HBC	+	7, 8.5 $\pi^+ \rho$

$\omega\pi$ MODE

The data in this block is included in the average printed for a previous datablock.

190±40 OUR AVERAGE				
230 ± 65	²⁵ ALDE	95	GAM2	$38 \pi^- \rho \rightarrow \omega \pi^0 n$
190 ± 65	EVANGELIST/	81	OMEG -	$12 \pi^{-} \rho \rightarrow \omega \pi \rho$
160 ± 56	GESSAROLI	77	HBC	11 $\pi^- \rho \rightarrow \omega \pi \rho$
• • We do not use the follow	ing data for average	s, fit	s, limits, etc.	• • •
89 ± 25	THOMPSON	74	HBC +	13 $\pi^{+} p$
130^{+73}_{-43}	BARNHAM	70	HBC +	10 $K^+ \rho \rightarrow \omega \pi X$
²⁵ Supersedes ALDE 92C.				

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 $^{^{15}}$ Width errors enlarged by us to $4\Gamma/\sqrt{N};$ see the note with the $K^*(892)$ mass. 16 Uses same data as HYAMS 75 and BECKER 79. 17 From a phase shift solution containing a $f_2'(1525)$ width two times larger than the $K\overline{K}$ result.

18 From phase-shift analysis. Error takes account of spread of different phase-shift solutions.

 $^{^{21}}$ From $\rho^-\rho^0$ mode, not independent of the other two EVANGELISTA 81 entries. 22 From $_{2}(1320)^-\pi^0$ mode, not independent of the other two EVANGELISTA 81 entries.

 $^{^{23}}$ From $_{\rho}^{2}(1320)^{0}$ π^{-} mode, not independent of the other two EVANGELISTA 81 entries. 24 From $_{\rho}^{\pm}$ $_{\rho}^{0}$ mode.

ρ_3 (1	6	9	0)
P3(_	_	_	_	,

edition.)		tile	<i>a</i> 2(1320	, mini	-review in the 1973
VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
The data in this bloc	k is included in the average pri	nted	for a pre	evious	datablock.
106±27	FUKUI	88	SPEC	0	8.95 π ⁻ ρ →
					$\eta \pi^+ \pi^- \eta$
• • • We do not us	e the following data for average	s, fit	s, limits	etc.	• • •
195	²⁶ ANDERSON	69	MMS		16 $\pi^- p$ backward
< 21	^{26,27} FOCACCI	66	MMS	_	
< 30	26,27 FOCACCI	66	MMS	_	ρΜΜ 7-12 π ⁻ ρ →
					ρ MM
< 38	^{26,27} FOCACCI	66	MMS		$7-12 \pi^- p \rightarrow pMM$

 26 Seen in 2.5–3 GeV/c $\overline{p}\,\rho$. $2\pi^+2\pi^-$, with 0, 1, 2 $\pi^+\pi^-$ pairs in ρ^0 band not seen by OREN 74 (2.3 GeV/c $\overline{p}\,\rho$) with more statistics. (Jan. 1979) 27 Not seen by BOWEN 72.

ρ_3 (1690) DECAY MODES

	Mode	Fraction (Γ_f/Γ)	Scale factor
Γ ₁	4π	(71.1 ± 1.9)%	
Γ ₂ Γ ₃	$\pi^{\pm} \pi^{+} \pi^{-} \pi^{0}$	(67 ± 22) %	
Гз	$\pi \pi$	$(23.6 \pm 1.3)\%$	
Γ_4	$\omega \pi$	(16 ± 6)%	
Γ_5	$K\overline{K}\pi$	$(3.8 \pm 1.2)\%$	
Γ ₅ Γ ₆	$\kappa \overline{\kappa}$	(1.58 ± 0.26) %	1.2
Γ ₇	$\eta \pi^+ \pi^-$	seen	
Γ8	$\pi \pi \rho$		
	Excluding 2ρ and $a_2(1320)\pi$.		
Г9	$a_2(1320)\pi$		
Γ_{10}	$\rho \rho$		
Γ_{11}	$\phi\pi$		
Γ ₁₂	$\eta \pi$		
Γ ₁₃	$\pi^{\pm} 2\pi^{+} 2\pi^{-} \pi^{0}$		

CONSTRAINED FIT INFORMATION

An overall fit to 5 branching ratios uses 10 measurements and one constraint to determine 4 parameters. The overall fit has a $\chi^2=$ 14.7 for 7 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\left\langle \delta x_i \delta x_j \right\rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv \Gamma_i / \Gamma_{\rm total}$. The fit constrains the x_i whose labels appear in this array to sum to one.

ho_3 (1690) BRANCHING RATIOS

$\Gamma(\pi\pi)/\Gamma_{\text{total}}$	DOCUMENT ID		TECN	СНБ	Γ ₃ /Γ
0.236±0.013 OUR FIT					
0.243±0.013 OUR AVE	RAGE				
$0.259^{+0.018}_{-0.019}$	BECKER	79	ASPK	0	17 $\pi^- p$ polarized
0.23 ±0.02	CORDEN	79	OMEG		$12-15 \pi^- p \rightarrow p^2 \pi$
0.22 ±0.04	²⁸ MATTHEWS	71c	HDBC	0	$7 \pi^{+} n \rightarrow \pi^{-} p$
• • • We do not use th	e following data for average	s, fits	, limits,	etc. •	
0.245 ± 0.006	²⁹ ESTABROOK	3 75	RVUE		$\begin{array}{c} 17 \pi^- p \rightarrow \\ \pi^+ \pi^- p \end{array}$

 $^{^{28}}$ One-pion-exchange model used in this estimation.

²⁹ From phase-shift analysis of HYAMS 75 data.

$\Gamma(\pi\pi)/\Gamma(\pi^{\pm}\pi^{+}\pi^{-}\pi^{0})$					Γ_3/Γ_2
VALUE	DOCUMENT ID		TECN	CHG	COMMENT
0.35 ± 0.11	CASON	73	нвс		8,18.5 $\pi^- p$
• • We do not use the follow	wing data for average	s, fits	, limits	, etc. 🛭	• •
< 0.2	HOLMES	72	нвс	+	10-12 K ⁺ p
< 0.12	BALLAM	71B	нвс	-	16 π ⁻ p
$\Gamma(\pi\pi)/\Gamma(4\pi)$					Γ_3/Γ_1
VALUE	DOCUMENT ID		TECN	CHG	COMMENT
0.332 ± 0.026 OUR FIT Error	includes scale factor	of 1.1	١.		
0.30 ±0.10	BALTAY	78B	нвс	. 0	$15 \pi^+ p \rightarrow p4\pi$

$\Gamma(K\overline{K})/\Gamma(\pi\pi)$	DOCUMENT ID		Γ ₆ /Γ ₃
	udes scale factor	of 1.2.	
0.002	ror includes scale below.	factor of 1.7. See	the ideogram
$0.191 {}^{+ 0.040}_{- 0.037}$	GORLICH	80 ASPK 0	17,18 $\pi^- p$ polarized
0.08 ±0.03	BARTSCH	70B HBC +	8 π ⁺ ρ
$0.08 \begin{array}{l} +0.08 \\ -0.03 \end{array}$	CRENNELL	68B HBC	6.0 $\pi^- p$
WEIGHTED AVERAG 0.118+0.039-0.032 (B		7)	
	and s this id sarily obtair utilizi	es above of weightescale factor are base deogram only. They the same as our 'b need from a least-squ gmeasurements o titles as additional ir	ed upon the data in are not neces- est' values, uares constrained fit f other (related)
		BARTSCH	80 ASPK 3.8 70B HBC 1.6 58B HBC 0.4
		(Confid	5.9 lence Level = 0.053)
-0.1 0 0.1	0.2 0.3	0.4 0.5	
$\Gamma(\kappa \overline{\kappa})/\Gamma(\pi \pi)$			
, , , ,			
$\Gamma(K\overline{K}\pi)/\Gamma(\pi\pi)$ VALUE	DOCUMENT ID	TECN CHG	Γ ₅ /Γ ₃

$\Gamma(K\overline{K}\pi)/\Gamma(\pi\pi)$					Γ_5/Γ_3
VALUE	DOCUMENT ID	TECN	CHG	COMMENT	
0.16±0.05 OUR FIT					
0.16±0.05	³⁰ BARTSCH	70B HBC	+	$8 \pi^+ p$	
30 Increased by us to correspond	d to B(ρ_3 (1690) \rightarrow	$\pi\pi$)=0.24.			

$[\Gamma(\pi\pi\rho) + \Gamma(a_2(1320)\pi) + \Gamma(\rho\rho)]/\Gamma(\pi^{\pm}\pi^{+}\pi^{-}\pi^{0})$				$(\Gamma_8 + \Gamma_9 + \Gamma_{10})/\Gamma_2$		
VALUE	DOCUMENT ID		TECN	CHG	COMMENT	
0.94±0.09 OUR AVERAGE						
0.96 ± 0.21	BALTAY	78 B	HBC	+	$15 \pi^+ p \rightarrow p 4\pi$	
0.88 ± 0.15	BALLAM	71B	HBC		16 π p	
1 ±0.15	BARTSCH	70B	HBC	+	8 π ⁺ p	
consistent with 1	CASO	68	HBC		11 π ⁻ ρ	

$\Gamma(\rho\rho)/\Gamma(\pi^{\pm}\pi^{+}\pi^{-}$	π^0)					Γ_{10}/Γ_{2}
VALUE	EVTS	DOCUMENT ID	3	TECN	<u>CHG</u>	COMMENT
	ne followii	ng data for average	s, fits,	limits,	etc. •	• •
0.12 ± 0.11		BALTAY	788 H	нвс	+	$15 \pi^+ p \rightarrow p 4\pi$
0.56	66	KLIGER	74 F	HBC		$4.5 \pi^- p \rightarrow p4\pi$
0.13 ± 0.09		31 THOMPSON	74 H	нвс	+	13 $\pi^{+} p$
0.7 ±0.15		RARTSCH	70R F	HBC	+	8 π ⁺ n

 $^{31}\,\varrho\varrho$ and $^{22}(1320)\pi$ modes are indistinguishable.

	$\Gamma(a_2(1320)\pi) + \Gamma(\rho\rho)$				₁₀ /(Г ₈ +Г ₉ +Г ₁₀
VALUE	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
• • • We do not use	the following data for average	s, fits	, limits,	etc.	• •
0.48 ± 0.16	CASO	68	нвс	-	11 $\pi^-\rho$
$\Gamma(a_2(1320)\pi)/\Gamma(\pi$	$\pm \pi^{+}\pi^{-}\pi^{0}$				٦/و٦
VALUE	DOCUMENT ID		TECN	CHG	COMMENT
• • • We do not use	the following data for average	s, fits	, limits,	etc.	• •
	BALTAY	78B	HBC	+	$15 \pi^+ \rho \rightarrow \rho 4\pi$
0.66 ± 0.08	32 THOMPSON	74	HBC	+	13 $\pi^{+} p$
0.66 ± 0.08 0.36 ± 0.14			HBC	_	8,18.5 $\pi^- p$
	CASON	73	1100		
0.36 ± 0.14	CASON BARTSCH			+	8 π ⁺ p

$\Gamma(\omega\pi)/\Gamma(\pi^{\pm}\pi^{+}\pi^{-}\pi^{-}\pi^{-}\pi^{-}\pi^{-}\pi^{-}\pi^{-}\pi^{-$	o)					Γ_4/Γ_2
VALUE	CL%	DOCUMENT ID		TECN	CHG	COMMENT
0.23±0.05 OUR AVER	AGE Err	or includes scale	facto	or of 1.2.		
0.33 ± 0.07		THOMPSON	74	HBC	+	13 $\pi^{+} p$
0.12 ± 0.07		BALLAM	71B	HBC	-	16 π ⁻ ρ
0.25 ± 0.10		BALTAY	68	HBC	+	7,8.5 $\pi^+ p$
0.25 ± 0.10		JOHNSTON	68	HBC	-	7.0 $\pi^{-}p$
• • We do not use the	following	data for averages	, fits	, limits,	etc. •	• •
< 0.11	95	BALTAY	78B	нвс	+	$15 \pi^+ \rho \rightarrow \rho 4\pi$
< 0.09		KLIGER	74	HBC	-	$4.5 \pi^- \rho \rightarrow \rho 4\pi$

 $\rho_3(1690)$, $\rho(1700)$

$\Gamma(\phi\pi)/\Gamma(\pi^{\pm}\pi^{+}\pi^{-}\pi^{0})$					Γ_{11}/Γ_{2}
VALUE	DOCUMENT ID				COMMENT
• • We do not use the following	g data for average	es, fits	s, limits,	etc. •	• •
< 0.11	BALTAY	68	HBC	+	7,8.5 $\pi^+ p$
$\Gamma(\pi^{\pm}2\pi^{+}2\pi^{-}\pi^{0})/\Gamma(\pi^{\pm}\pi^{+})$	$\pi^-\pi^0$)		TECN	cuc	Γ ₁₃ /Γ ₂
• • We do not use the following					
<0.15	BALTAY				7,8.5 $\pi^+ p$
$\Gamma(\eta\pi)/\Gamma(\pi^{\pm}\pi^{+}\pi^{-}\pi^{0})$					Γ_{12}/Γ_{2}
	DOCUMENT ID				
• • We do not use the following					
< 0.02	THOMPSON	74	нвс	+	13 π [¬] ρ
$\Gamma(K\overline{K})/\Gamma_{\text{total}}$					Γ ₆ /Γ
VALUE	DOCUMENT ID			CHG	COMMENT
0.0158±0.0026 OUR FIT Error 0.0130±0.0024 OUR AVERAGE	includes scale fact	tor of	1.2.		
0.0130 ±0.0024 OUR AVERAGE	COSTA	80	OMEG	n	10 π ⁻ ρ →
					K^+K^-n
0.013 ±0.004	33 MARTIN	78B	SPEC	****	$ \begin{array}{c} 10 \ \pi p \rightarrow \\ K_{c}^{0} \ K^{-} p \end{array} $
22 1/2					s .
33 From $(\Gamma_3\Gamma_6)^{1/2} = 0.056 \pm 0$	0.034 assuming B($\rho_3(16$	590) →	$\pi\pi) =$	= 0.24.
$\Gamma(\omega\pi)/igl[\Gamma(\omega\pi)+\Gamma(ho ho)igr]$					$\Gamma_4/(\Gamma_4+\Gamma_{10})$
VALUE	DOCUMENT ID				
• • We do not use the following	g data for average	es, fits	s, limits,	etc. •	• •
0.22 ± 0.08	CASON	73	HBC	_	8,18.5 $\pi^- p$
$\Gamma(\eta \pi^+ \pi^-)/\Gamma_{\text{total}}$	DOCUMENT ID		TECN	COM	Γ ₇ /Γ
seen	FUKUI	88		PRODUCTION OF THE PRODUCTION O	$\pi^- p \rightarrow n \pi^+ \pi^- p$
$ ho_3$	(1690) REFER	ENC	ES		

ALDE 95	ZPHY C66 379	+Binon, Bricman+ (GAMS Collab.) JP
ALDE 92C	ZPHY C54 553	+Bencheikh, Binon+ (BELG, SERP, KEK, LANL, LAPP)
FUKUI 88	PL B202 441	+Horikawa+ (SUGI, NAGO, KEK, KYOT, MIYA)
DENNEY 83	PR D28 2726	+Cranley, Firestone, Chapman+ (IOWA, MICH)
EVANGELISTA 81	NP B178 197	+ (BARI, BONN, CERN, DARE, LIVP+)
ALPER 80	PL 94B 422	+Becker+ (AMST, CERN, CRAC, MPIM, OXF+)
COSTA 80	NP B175 402	Costa De Beauregard+ (BARI BONN CERN+)
GORLICH 80	NP B174 16	Costa De Beauregard+ (BARI, BONN, CERN+) +Niczyporuk+ (CRAC, MPIM, CERN, ZEEM)
BECKER 79	NP B151 46	+Niczyporuk+ (CRAC, MPIM, CERN, ZEEM) +Blanar, Blum+ (MPIM, CERN, ZEEM, CRAC)
CORDEN 79	NP B157 250	+Dowell, Garvey+ (BIRM, RHEL, TELA, LOWC) JP
BALTAY 78B	PR D17 62	+Cautis, Cohen, Csorna+ (COLU, BING)
MARTIN 78B	NP B140 158	+Ozmutlu, Baldi, Bohringer, Dorsaz+ (DURH, GEVA)
MARTIN 78D	PL 74B 417	+Ozmutlu, Baldi, Bohringer, Dorsaz+ (DURH, GEVA)
ANTIPOV 77	NP B119 45	+Busnello, Damgaard, Kienzle+ (SERP, GEVA)
GESSAROLI 77	NP B126 382	+ (BGNA, FIRZ, GENO, MILÀ, OXF, PAVI)
BLUM 75	PL 57B 403	+Chabaud, Dietl, Garelick, Grayer+ (CERN, MPIM) JP
ESTABROOKS 75	NP B95 322	+Martin (DURH)
HYAMS 75	NP B100 205	+Jones, Weilhammer, Blum, Dietl+ (CERN, MPIM)
ENGLER 74	PR D10 2070	+Kraemer, Toaff, Weisser, Diaz+ (CMU, CASE)
GRAYER 74	NP B75 189	+Hyams, Blum, Dietl+ (CERN, MPIM)
KLIGER 74	SJNP 19 428	+Beketov, Grechko, Guzhavin, Dubovikov+ (ITEP)
	Translated from YAF 1	
OREN 74	NP B71 189	+Cooper, Fields, Rhines, Allison+ (ANL, OXF)
THOMPSON 74	NP B69 220	+Gaidos, McIlwain, Miller, Mulera+ (PURD)
CASON 73	PR D7 1971	+Biswas, Kenney, Madden+ (NDAM)
BOWEN 72 HOLMES 72	PRL 29 890	+Earles, Faissler, Blieden+ (NEAS, STON)
HOLMES 72 BALLAM 71B	PR D6 3336 PR D3 2606	+Ferbel, Slattery, Werner (ROCH) +Chadwick, Guiragossian, Johnson+ (SLAC)
MATTHEWS 71C	NP B33 1	+Prentice, Yoon, Carroll+ (TNTO, WISC) JP
ARMENISE 70	LNC 4 199	+Ghidini, Foring, Cartacci+ (BARI, BGNA, FIRZ)
BARNHAM 70	PRL 24 1083	+Colley, Jobes, Kenyon, Pathak, Riddiford (BIRM)
BARTSCH 70B	NP B22 109	+Kraus, Tsanos, Grote+ (AACH, BERL, CERN)
CASO 70	LNC 3 707	+Conte, Tomasini+ (GENO, HAMB, MILA, SACL)
STUNTEBECK 70	PL 32B 391	+Kenney, Deery, Biswas, Cason+ (NDAM)
ADERHOLZ 69	NP B11 259	+Bartsch+ (AACH3, BERL, CERN, JAGL, WARS)
ANDERSON 69	PRL 22 1390	+Collins+ (BNL, CMU)
ARMENISE 68	NC 54A 999	+Ghidini, Forino+ (BARI, BGNA, FIRZ, ORSAY) I
BALTAY 68	PRL 20 887	+Kung, Yeh, Ferbel+ (COLU, ROCH, RUTG, YALE) I
CASO 68	NC 54A 983	+Conte, Cords, Diaz+ (GENO, HAMB, MILA, SACL) +Karshon, Lai, Scarr, Skillicorn (BNL) +Prentice, Steenberg, Yoon (TNTO, WISC) IJP
CRENNELL 68B	PL 28B 136	+Karshon, Lai, Scarr, Skillicorn (BNL)
JOHNSTON 68	PRL 20 1414	+Prentice, Steenberg, Yoon (TNTO, WISC) IJP
FOCACCI 66	PRL 17 890	+Kienzle, Levrat, Maglich, Martin (CERN)
GOLDBERG 65	PL 17 354	 (CERN, EPOL, ORSAY, MILA, CEA, SACL)
	OTHE	R RELATED PAPERS

OTHER RELATED PAPERS

BARNETT	83B	PL 120B 455	+Blockus, Burka, Chien, Ch	ristian+ (JHU)
EHRLICH	66	PR 152 1194	+Selove, Yuta	(PENN)
LEVRAT	66	PL 22 714		N Missing Mass Spect. Collab.)
SEGUINOT	66	PL 19 712		N Missing Mass Spect. Collab.)
BELLINI	65	NC 40A 948		(MILA)
DEUTSCH	65	PL 18 351	Deutschmann+	(AACH3, BERL, CERN)
FORINO	65	PL 19 65	+Gessaroli+	(BGNA, ORSAY, SACL)



$$I^{G}(J^{PC}) = 1^{+}(1^{-})$$

THE $\rho(1450)$ AND THE $\rho(1700)$

In our 1988 edition, we replaced the $\rho(1600)$ entry with two new ones, the $\rho(1450)$ and the $\rho(1700)$, because there was emerging evidence that the 1600-MeV region actually contains two ρ -like resonances. ERKAL 86 had pointed out this possibility with a theoretical analysis on the consistency of 2π and 4π electromagnetic form factors and the $\pi\pi$ scattering length. DONNACHIE 87, with a full analysis of data in the annihilation reactions $e^+e^- \to \pi^+\pi^-$, $2\pi^+2\pi^-$, and $\pi^+\pi^-\pi^0\pi^0$, and in the photoproduction reactions $\gamma p \to \pi^+\pi^- p$, $2\pi^+2\pi^- p$, and $\pi^+\pi^-\pi^0\pi^0p$, had also argued that to obtain a consistent picture two resonances, whose masses and widths could be fixed reasonably well, were necessary. This picture was supported by the analysis of DONNACHIE 87B of $J^P = 1^- \eta \rho^0$ mass spectra obtained in photoproduction and in e^+e^- annihilations; the analysis showed the need for a contribution from a ρ meson with a mass of about 1470 MeV, but could say little about a higher-mass resonance (actually the data could be explained without it). Confirmation of the decay $\rho(1450) \rightarrow \omega \pi$, and a tight constraint on the mass due to strong interference with the $\rho(770)$ tail, was found by DONNACHIE 91 in an analysis of $e^+e^- \to \omega\pi$.

The analysis of DONNACHIE 87 was extended by CLEGG 88 to include new data on 4π systems produced in e^+e^- annihilation and in τ decay (4π τ decays and 4π annihilation reactions can be related by the Conserved Vector Current assumption). These systems were successfully analyzed using interfering contributions from two ρ -like states, and from the tail of the $\rho(770)$ decaying into two-body states. While specific conclusions on $\rho(1450) \rightarrow 4\pi$ were obtained, the quality of the data used by CLEGG 88 prevented any conclusion on $\rho(1700) \rightarrow 4\pi$ decay.

An analysis by CLEGG 90 of 6π mass spectra from $e^+e^$ annihilation and from diffractive photoproduction provides evidence for two ρ mesons, at about 2.1 and 1.8 GeV, that decay strongly into 6π states. While the former is a candidate for a new resonance, the latter could be a manifestation of the $\rho(1700)$ distorted by threshold effects.

Independent evidence for two 1⁻ states is provided by KILLIAN 80 in 4π electroproduction at $\langle Q^2 \rangle = 1 \ (\text{GeV}/c)^2$, and by FUKUI 88 in a high-statistics sample of the $\eta\pi\pi$ system in $\pi^- p$ charge exchange.

This picture with two overlapping resonances is supported by other data. BISELLO 89 measured the pion form factor in the interval 1.35-2.4 GeV with significant statistics (280 $e^+e^- \rightarrow$ $\pi^+\pi^-$ events with very low background). A deep minimum is observed around 1.6 GeV, and the best fit to the form factor is obtained with the hypothesis of ρ -like resonances at 1420 and 1770 MeV with widths of about 250 MeV. ANTONELLI 88 found that the $e^+e^- \rightarrow \eta \pi^+\pi^-$ cross section (using three different η decay modes) is better fitted with two fully interfering Breit-Wigners, with parameters in fair agreement with those of DONNACHIE 87 and BISELLO 89.

These results (although ANTONELLI 88 is statistically less significant than BISELLO 89) have also resolved the disagreement between DONNACHIE 87 and FUKUI 88 on the $\rho(1450)$ width in favor of the DONNACHIE 87 value. From this point of view, BISELLO 89 and ANTONELLI 88 can be considered as solid confirmation of the $\rho(1450)$. For the possibility that its $\phi\pi$ mode actually contains two independent vector states, see LANDSBERG 92.

Several observations on the $\omega\pi$ system in the 1200-MeV region (FRENKIEL 72, COSME 76, BARBER 80C, ASTON 80C, ATKINSON 84C, BRAU 88, AMSLER 93B) may be interpreted in terms of either $J^P = 1^- \rho(770) \rightarrow \pi \omega$ production (LAYSSAC 71) or $J^P = 1^+ b_1(1235)$ production (BRAU 88, AMSLER 93B). We argue that no special entry for a $\rho(1250)$ is needed. The LASS amplitude analysis (ASTON 91B) showing evidence for a $\rho(1270)$ is preliminary and needs confirmation. For completeness, these various observations are listed under the $\rho(1450)$.

ρ (1700) MASS

$\eta \rho^0$ AND $\pi^+\pi^-$ MODES

VALUE (MeV) 1700+20 OUR ESTIMATE DOCUMENT ID

1717±13 OUR AVERAGE Includes data from the 2 datablocks that follow this one. Error includes scale factor of 1.2

$\eta \rho^0$ MODE

VALUE (MeV)	DOCUMENT ID	T	ECN	COMMENT	
The data in this block is include	ded in the average pri	nted for	a pre	vious datablock.	
1740 ± 20	ANTONELLI	88 D	M2	$e^+e^- \rightarrow \eta \pi^+\pi^-$	
1701 ± 15	¹ FUKUI	88 SI	PEC	8.95 $\pi^- p \to \eta \pi^+ \pi^- n$	
¹ From a two Breit-Wigner f	it.				l

π+π- MODE

VALUE (IVIEV)	DOCUMENT ID	TECIV COMMENT
The data in this block is included in	the average printed	for a previous datablock.

1730	±30		CLEGG	94	RVUE	$e^+e^- \rightarrow \pi^+\pi^-$
• • •	We do not use the following	d	lata for averages	, fits	, limits,	etc. • • •
1768	± 21		BISELLO			$e^+e^ \rightarrow$ $\pi^+\pi^-$
1745.7	±91.9		DUBNICKA	89	RVUE	$e^+e^- \rightarrow \pi^+\pi^-$
1546	±26		GESHKENBEIN	V 89	RVUE	
1650		2	ERKAL	85	RVUE	20-70 $\gamma p \rightarrow \gamma \pi$
1550	±70		ABE	84B	HYBR	$20 \gamma p \rightarrow \pi^+ \pi^- p$
1590	±20	3	ASTON	80	OMEG	$20-70 \gamma p \rightarrow p2\pi$
1600	±10	4	ATIYA	79 B	SPEC	$50 \gamma C \rightarrow C 2\pi$
1598	+24 -22		BECKER	79	ASPK	17 $\pi^- p$ polarized
1659	± 25	2	LANG	79	RVUE	
1575		2	MARTIN	78C	RVUE	$17 \pi^- p \rightarrow \pi^+ \pi^- n$
1610	±30	2	FROGGATT	77	RVUE	$17 \pi^{-} p \rightarrow \pi^{+} \pi^{-} n$
1590	±20	5	HYAMS			$17 \pi^- p \rightarrow \pi^+ \pi^- n$
vT.	MODE					

TALUE (INICV)					
• • • We do not u	se the following	data for averag	es, fits, limits,	etc. •	• •
1582 ± 36	1600	CLELAND	82B SPEC	±	$50 \pi p \rightarrow \kappa^0 \kappa^{\pm} p$

$2(\pi^+\pi^-)$ MODE

VALUE (MeV)	EVTS	DOCUMENT ID	TEC	N COMMENT
• • • We do no	t use the following	g data for average	s, fits, lim	its, etc. • • •
1570 ± 20		⁶ CORDIER	82 DM	$1 e^+e^- \rightarrow 2(\pi^+\pi^-)$
1520 ± 30		³ ASTON	81E OM	EG 20-70 $\gamma p \rightarrow p4\pi$
1654 ± 25		⁷ DIBIANCA	81 DB	$c \pi^+ d \rightarrow \rho \rho 2(\pi^+ \pi^-)$
1666± 39		⁶ BACCI	80 FRA	$AG e^+e^- \rightarrow 2(\pi^+\pi^-)$
1.780	34	KILLIAN	80 SPE	$11 e^- \rho \rightarrow 2(\pi^+ \pi^-)$
1500		⁸ ATIYA	79B SPE	$C 50 \gamma C \rightarrow C4\pi^{\pm}$
1570 ± 60	65	⁹ ALEXANDER	75 HB	$7.5 \gamma p \rightarrow p4\pi$
1550 ± 60		³ CONVERSI	74 OSI	$PK e^{+}e^{-} \rightarrow 2(\pi^{+}\pi^{-})$
1550 ± 50	160	SCHACHT	74 STF	RC 5.5-9 $\gamma p \rightarrow p 4\pi$
1450 ± 100	340	SCHACHT	74 STF	RC 9-18 $\gamma p \rightarrow p4\pi$
1430 ± 50	400	BINGHAM	728 HB	$0.3 \gamma p \rightarrow p4\pi$

$\pi^+\pi^-\pi^0\pi^0$ MODE

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following	g data for averages, fit	s, limits,	etc. • • •

85B OMEG 20-70 γρ

$3(\pi^{+}\pi^{-})$ AND $2(\pi^{+}\pi^{-}\pi^{0})$ MODES

DOCUMENT ID TECN COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • • 1783 ± 15 CLEGG 90 RVUE $3(\pi^{+}\pi^{-})2(\pi^{+}\pi^{-}\pi^{0})$

² From phase shift analysis of HYAMS 73 data

³Simple relativistic Breit-Wigner fit with constant width.

An additional 40 MeV uncertainty in both the mass and width is present due to the choice of the background shape.

⁵ Included in BECKER 79 analysis

⁶ Simple relativistic Breit-Wigner fit with model dependent width.

⁷One peak fit result.

⁸ Parameters roughly estimated, not from a fit.

⁹ Skew mass distribution compensated by Ross-Stodolsky factor.

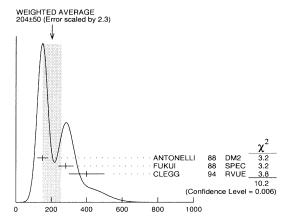
ρ (1700) WIDTH

$\eta \rho^0$ AND $\pi^+\pi^-$ MODES

VALUE (MeV)
235±50 OUR ESTIMATE

DOCUMENT ID

204±50 OUR AVERAGE Includes data from the 2 datablocks that follow this one. Error includes scale factor of 2.3. See the ideogram below.



 ρ (1700) width, $\eta \rho^0$ and $\pi^+ \pi^-$ modes (MeV)

$\eta \rho^0$ MODE

<u>VALUE (MeV)</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u>

The data in this block is included in the average printed for a previous datablock. ANTONELLI 88 DM2 150 ± 30 ¹⁰ FUKUI 282 ± 44 88 SPEC 8.95 $\pi^- p \to \eta \pi^+ \pi$ $^{\rm 10}\,{\rm From}$ a two Breit-Wigner fit.

$\pi^+\pi^-$ MODE

VALUE (MeV) DOCUMENT ID TECN COMMENT

The data in this block is included in the average printed for a previous datablock.

400 ±100		CLEGG	94 RV	UE $e^+e^- \rightarrow \pi^+\pi^-$	
 ● ● We do not us 	e the following	g data for averag	es, fits, lim	nits, etc. • • •	
$\begin{array}{cccc} 224 & \pm & 22 \\ 242.5 \pm 163.0 \end{array}$		BISELLO DUBNICKA	89 RV	12 $e^+e^- \rightarrow \pi^+\pi^-$ UE $e^+e^- \rightarrow \pi^+\pi^-$	
620 ± 60 <315		GESHKENBE ¹¹ ERKAL	85 RV	UE 20-70 $\gamma p \rightarrow \gamma \pi$	
$280 \begin{array}{c} + & 30 \\ - & 80 \end{array}$ $230 \begin{array}{c} \pm & 80 \end{array}$ $283 \begin{array}{c} \pm & 14 \end{array}$		ABE ¹² ASTON ¹³ ATIYA	80 OM	BR $20 \gamma p \rightarrow \pi^+ \pi^- p$ 1EG $20-70 \gamma p \rightarrow p2\pi$ EC $50 \gamma C \rightarrow C2\pi$	
$175 \begin{array}{c} + & 98 \\ - & 53 \end{array}$		BECKER	79 ASF	PK $17 \pi^- p$ polarized	
232 ± 34 340 300 ± 100		¹¹ LANG ¹¹ MARTIN ¹¹ FROGGATT		UE $17 \pi^- p \rightarrow \pi^+ \pi^- n$ UE $17 \pi^- p \rightarrow \pi^+ \pi^- n$	
180 ± 50		¹⁴ HYAMS	73 ASF	PK 17 $\pi^{-}p \to \pi^{+}\pi^{-}n$	
VALUE (MeV) • • We do not us		DOCUMENT ID		CN CHG COMMENT	
265 + 120	1600	CLELAND		EC + 50 πρ →	

KOK±p

$\rho(1700)$

$2(\pi^+\pi^-)$ MOD	E				
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not	use the followi	ng data for average	s, fits,	, limits,	etc. • • •
510 ± 40		¹⁵ CORDIER	82	DM1	$e^+e^- \to 2(\pi^+\pi^-)$
400 ± 50		¹² ASTON	81E	OMEG	$20-70 \gamma p \rightarrow p 4\pi$
400 ± 146		¹⁶ DIBIANCA	81	DBC	$\pi^+ d \rightarrow pp2(\pi^+\pi^-)$
700 ± 160		¹⁵ BACCI	80	FRAG	$e^+ e^- \rightarrow 2(\pi^+ \pi^-)$
100	34	KILLIAN	80	SPEC	11 $e^- p \rightarrow 2(\pi^+ \pi^-)$
600		¹⁷ ATIYA	79B	SPEC	$50 \gamma C \rightarrow C4\pi^{\pm}$
340 ± 160	65	¹⁸ ALEXANDER		HBC	$7.5 \gamma p \rightarrow p4\pi$
360±100		12 CONVERSI			$e^{+}e^{-} \rightarrow 2(\pi^{+}\pi^{-})$
400 ± 120	160		74	STRC	5.5-9 $\gamma p \rightarrow p 4\pi$
850 ± 200	340	¹⁹ SCHACHT	74	STRC	$9-18 \gamma p \rightarrow p4\pi$
650 ± 100	400	BINGHAM	72B	HBC	$9.3 \gamma p \rightarrow p4\pi$
π ⁺ π ⁻ π ⁰ π ⁰ Μ(VALUE (MeV)	DDE	DOCUMENT ID		TECN	COMMENT
• • • We do not	use the followi	ng data for average	s, fits,	limits,	etc. • • •
300±50		ATKINSON	858	OMEG	20-70 γp
3(π ⁺ π ⁻) AND VALUE (MeV)	$2(\pi^{+}\pi^{-}\pi^{0})$) MODES	TE	CN CC	DMMENT
• • We do not	usa tha fallawi				
	ase the followi				
285±20		CLEGG 9) RV	UE e∃	$^{+}e^{-}_{3(\pi^{+}\pi^{-})2(\pi^{+}\pi^{-}\pi^{0})}$
11 From phase sh		HYAMS 73 data. Her fit with constan	t widtl	h	

- 12 Simple relativistic Breit-Wigner fit with constant width.

 13 An additional 40 MeV uncertainty in both the mass and width is present due to the choice of the background shape.

 14 Included in BECKER 79 analysis.

 15 Simple relativistic Breit-Wigner fit with model-dependent width.

 16 One peak fit result.

 17 Parameters roughly estimated, not from a fit.

 18 Skew mass distribution compensated by Ross-Stodolsky factor.

 19 Width errors enlarged by us to 4 \(\Gamma \subseteq \overline{N}\); see the note with the \(K^*(892)\) mass.

ρ (1700) DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ ₁	ρππ	dominant
Γ ₂ Γ ₃	$\rho^0 \pi^+ \pi^-$	large
Γ_3	$ \rho^0 \pi^0 \pi^0 $ $ \rho^{\pm} \pi^{\mp} \pi^0 $	
Γ ₄	$\rho^{\pm}\pi^{+}\pi^{0}$	large
Γ ₅	$2(\pi^{+}\pi^{-})$	large
Γ ₅ Γ ₆ Γ ₇	$\pi^+\pi^-$	seen
[₇	$K\overline{K}^*(892) + \text{c.c.}$	seen
Г ₈ Г9	$\eta \rho$	seen
19	KK	seen
Γ ₁₀ Γ ₁₁	$e^{+} e^{-} \\ ho^{0} ho^{0}$	seen
Γ ₁₂	$\pi \omega$	

ρ (1700) Γ (i) Γ (e^+e^-)/ Γ (total)

This combination of a partial width with the partial width into $e^+\,e^-$ and with the total width is obtained from the cross-section into channel in

$\Gamma(2(\pi^+\pi^-)) \times \Gamma(e^+e^-)/\Gamma$					$\Gamma_5\Gamma_{10}/\Gamma$
VALUE (keV)	DOCUMENT ID		TECN	COMMENT	
2.83±0.42	BACCI	80	FRAG	$e^+e^- \rightarrow$	$2(\pi^{+}\pi^{-})$
• • • We do not use the following	ng data for average	es, fit	s, limits,	etc. • • •	
$2.6\ \pm0.2$	DELCOURT	818	DM1	$e^+e^ \rightarrow$	$2(\pi^{+}\pi^{-})$
$\Gamma(\pi^+\pi^-) \times \Gamma(e^+e^-)/\Gamma_{\text{tot}}$;al				$\Gamma_6\Gamma_{10}/\Gamma$
VALUE (keV)	DOCUMENT ID		TECN	COMMENT	
• • We do not use the following	ng data for average	es, fit	s, limits,	etc. • • •	
0.13	²⁰ DIEKMAN				#+ #-
²⁰ Using total width = 220 MeV		00	KVOL		<i>n n</i>
$\Gamma(K\overline{K}^*(892) + \text{c.c.}) \times \Gamma(e^{-1})$	$^+e^-)/\Gamma_{ m total}$				$\Gamma_7\Gamma_{10}/\Gamma$
VALUE (keV)	DOCUMENT ID		TECN	COMMENT	
• • We do not use the following	ng data for average	es, fit	s, limits,	etc. • • •	
0.305 ± 0.071	²¹ BIZOT	80	DM1	e^+e^-	
$\Gamma(\eta ho) imes \Gamma(e^+ e^-) / \Gamma_{ m total}$					$\Gamma_8\Gamma_{10}/\Gamma$
VALUE (eV)	DOCUMENT ID		TECN	COMMENT	
7 ±3	ANTONELLI	88	DM2	$e^+e^- \rightarrow$	$\eta \pi^+ \pi^-$

$\Gamma(K\overline{K}) \times \Gamma(e^+e^-)/\Gamma_{to}$		_		Γ ₉ Γ ₁₀ /
VALUE (keV) • • • We do not use the following the followi			CN <u>COMMEN</u> nits, etc. • •	
0.035 ± 0.029	²¹ BIZOT	80 DN		
$\Gamma(ho\pi\pi) imes\Gamma(e^+e^-)/\Gamma_{ m to}$	otal			Γ ₁ Γ ₁₀ ,
VALUE (keV) ■ ■ We do not use the follo	DOCUMENT I			•
3.510±0.090	²¹ BIZOT	80 DN		
²¹ Model dependent.				
ρ(1700) BRANCHI	NG RATI	OS	
$\Gamma(\pi^+\pi^-)/\Gamma_{\text{total}}$	DOCUMENT	ID 75	country	Γ ₆ ,
• • We do not use the folion			CN <u>COMMEN</u> nits, etc. • •	
0.287 + 0.043	BECKER	79 AS	PK 17 π ⁻ p	polarized
0.267 - 0.042 0.15 to 0.30	22 MARTIN	78c RV		$\rightarrow \pi^{+}\pi^{-}n$
<0.20	²³ COSTA	77B RV	UE e ⁺ e ⁻ -	
0.30 ± 0.05	²² FROGGATT	77 RV	UE 17 π ⁻ ρ	$\rightarrow \pi^+\pi^-n$
<0.15	24 EISENBERG			$\rightarrow \Delta^{++}2\pi$
0.25 ±0.05 0.20 ±0.05	²⁵ HYAMS MONTANE			$\rightarrow \pi^+\pi^-n$
22 From phase shift analysis	of HYAMS 73 data.			
23 Estimate using unitarity, t 24 Estimated using one-pion- 25 Included in BECKER 79 a	ime reversal invariar -exchange model.	nce, Breit-V	/igner.	
$\Gamma(\pi^+\pi^-)/\Gamma(2(\pi^+\pi^-))$	•			Γ ₆ /
ι (π'π)/ι (2(π'π)) VALUE	DOCUMENT I	D TE	CN COMMEN	
• • We do not use the following the fol				
0.13 ± 0.05	ASTON	80 ON	1EG 20-70 γ	p → p2π
< 0.14	26 DAVIER		RC 6-18 γ p	
<0.2 26 Upper limit is estimate.	²⁷ BINGHAM	728 HB	C 9.3 γ p –	→ p2π
$^{27}2\sigma$ upper limit is estimate.				
	(_+\)			Г_/
VALUE • • • We do not use the following th	DOCUMENT I owing data for avera	ges, fits, lir		•
VALUE • • • We do not use the follou.15 \pm 0.03 28 Assuming $ ho$ (1700) and ω	DOCUMENT I owing data for avera ²⁸ DELCOURT	ges, fits, lir 81B DN	nits, etc. $ullet$ e^+e^-	r • →
$\Gamma(\eta ho)/\Gamma_{total}$	<u>DOCUMENT I</u> owing data for avera 28 DELCOURT radial excitations to	ges, fits, lir 81B DN be degener	nits, etc. $ullet$ $ullet$ $e^+e^ -$ ate in mass.	<u>r</u> • → <i>K</i> κπ
VALUE • • We do not use the folk 0.15 ± 0.03 28 Assuming $\rho(1700)$ and ω $\Gamma(\eta \rho)/\Gamma_{\text{total}}$	DOCUMENT I owing data for avera 28 DELCOURT radial excitations to DOCUMENT I	ges, fits, lir 81B DN be degener	nits, etc. • • 11 e^+e^- - ate in mass.	<u>r</u> • → <i>K</i> κπ
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$\Gamma(ho^0\pi^0\pi^0)/\Gamma(ho^\pm\pi^\mp\pi^0)$			Γ_3/Γ_4
VALUE	DOCUMENT ID	TECN CHG	COMMENT
	ig data for averages, f	its, limits, etc. •	• • •
< 0.10	ATKINSON 8	5B OMEG	20-70 γp
< 0.15	ATKINSON 8:	2 OMEG 0	20–70 $\gamma p \rightarrow p 4\pi$

ρ (1700) REFERENCES

CLEGG 94	ZPHY C62 455	+Donnachie (LANC, MCHS)
CLEGG 90	ZPHY C45 677	+Donnachie (LANC, MCHS)
BISELLO 89	PL B220 321	+Busetto+ (DM2 Collab.)
DUBNICKA 89	JPG 15 1349	+Martinovic+ (JINR, SLOV)
GESHKENBEIN 89	ZPHY 45 351	(ITEP)
ANTONELLI 88	PL B212 133	+Baldini+ (DM2 Collab.)
DIEKMAN 88	PRPL 159 101	(BONN)
FUKUI 88	PL B202 441	+Horikawa+ (SUGI, NAGO, KEK, KYOT, MIYA)
DONNACHIE 87E	ZPHY C34 257	+Clegg (MCHS, LANC)
ATKINSON 86E		+ (BONN, CERN, GLAS, LANC, MCHS, CURIN+)
ATKINSON 85B	ZPHY C26 499	+ (BONN, CERN, GLAS, LANC, MCHS, CURIN+)
ERKAL 85	ZPHY C29 485	+Olsson (WISC)
ABE 84B	PRL 53 751	+Bacon, Ballam+ (SLAC Hybrid Facility Photon Collab.)
ATKINSON 82	PL 108B 55	+ (BONN, CERN, GLAS, LANC, MCHS, CURIN+)
BUON 82	PL 118B 221	+Bisello, Bizot, Cordier, Delcourt+ (LALO, MONP)
CLELAND 82B	NP B208 228	+Delfosse, Dorsaz, Gloor (DURH, GEVA, LAUS, PITT)
CORDIER 82	PL 109B 129	+Bisello, Bizot, Buon, Delcourt (LALO)
DELCOURT 82	PL 113B 93	+Bisello, Bizot, Buon, Cordier, Mane (LALO)
ASTON 81E	NP B189 15	(BONN, CERN, EPOL, GLAS, LANC, MCHS+)
DELCOURT 81B	Bonn Conf. 205	(ORSAY)
Also 82	PL 109B 129	Cordier, Bisello, Bizot, Buon, Delcourt (LALO)
DIBIANCA 81	PR D23 595	+Fickinger, Malko, Dado, Engler+ (CASE, CMU)
ASTON 80	PL 92B 215	(BONN, CERN, EPOL, GLAS, LANC, MCHS+)
BACCI 80	PL 95B 139	+DeZorzi, Penso, Baldini-Celio+ (ROMA, FRAS)
BIZOT 80	Madison Conf. 546	+Bisello, Buon, Cordier, Delcourt+ (LALO, MONP)
KILLIAN 80	PR D21 3005	+Treadwell, Ahrens, Berkelman, Cassel+ (CORN)
ATIYA 79B	PRL 43 1691	+Holmes, Knapp, Lee, Seto+ (COLU, ILL, FNAL)
BECKER 79	NP B151 46	+Blanar, Blum+ (MPIM, CERN, ZEEM, CRAC)
LANG 79	PR D19 956	+Mas-Parareda (GRAZ)
MARTIN 78C	ANP 114 1	+Pennington (CERN)
COSTA 77B	PL 71B 345	Costa De Beauregard, Pire, Truong (EPOL)
FROGGATT 77	NP B129 89	+Petersen (GLAS, NORD)
ALEXANDER 75	PL 57B 487	+Benary, Gandsman, Lissauer+ (TELA)
BALLAM 74	NP B76 375	+Chadwick, Bingham, Fretter+ (SLAC, LBL, MPIM)
CONVERSI 74	PL 52B 493	+Paoluzi, Ceradini, Grilli+ (ROMA, FRAS)
SCHACHT 74	NP B81 205	+Derado, Fries, Park, Yount (MPIM)
DAVIER 73	NP B58 31	+Derado, Fries, Liu, Mozley, Odian, Park+ (SLAC)
EISENBERG 73	PL 43B 149	+Karshon, Mikenberg, Pitluck+ (REHO)
HYAMS 73	NP B64 134	+Jones, Weilhammer, Blum, Dietl+ (CERN, MPIM)
MONTANET 73	Erice School 518	(CERN)
BINGHAM 72B	PL 41B 635	+Rabin, Rosenfeld, Smadja+ (LBL, UCB, SLAC) IGJI

OTHER RELATED PAPERS

AMSLER 93F	DI B211 262	
	3 PL B311 362 SJNP 55 1051	+Armstrong, v.Dombrowski+ (Crystal Barrel Collab.)
LANDSBERG 92	Translated from YAF 5	(SERP)
ASTON 91E		
ACHASOV 880		
BRAU 88	PR D37 2379	+Franek+ (SLAC Hybrid Facility Photon Collab.) JP
CLEGG 88	ZPHY C40 313	+Donnachie (MCHS, LANC)
ASTON 87	NP B292 693	+Awaji, D'Amore+ (SLAC, NAGO, CINC, INUS)
ERKAL 86	ZPHY C31 615	+Olsson (WISC)
BARKOV 85	NP B256 365	+Chilingarov, Eidelman, Khazin, Lelchuk+ (NOVO)
BISELLO 85	LAL 85-15	+Augustin, Ajaltouni+ (PADO, LALO, CLER, FRAS)
ATKINSON 840	NP B243 1	+ (BONN, CERN, GLAS, LANC, MCHS, CURIN+) JP
ATKINSON 83E	B PL 127B 132	+ (BONN, CERN, GLAS, LANC, MCHS, CURIN+)
ATKINSON 830	NP B229 269	 (BONN, CERN, GLAS, LANC, MCHS, CURIN+)
AUGUSTIN 83	LAL 83-21	+Ayach, Bisello, Baldini+ (LALO, PADO, FRAS)
SHAMBROOM 82	PR D26 1	+Wilson, Anderson, Francis+ (HARV, EFI, ILL, OXF)
BARBER 800		+Dainton, Brodbeck, Brookes+ (DARE, LANC, SHEF)
KILLIAN 80	PR D21 3005	+Treadwell, Ahrens, Berkelman, Cassel+ (CORN)
COSME 76	PL 63B 352	+Courau, Dudelzak, Grelaud, Jean-Marie+ (ORSAY)
FRENKIEL 72	NP B47 61	+Ghesquiere, Lillestol, Chung+ (CDEF, CERN)
ALVENSLEBEN 71	PRL 26 273	+Becker, Bertram, Chen+ (DESY, MIT) G
	NP B30 213	+Fridman, Gerber, Givernaud+ (STRB) G
BULOS 71	PRL 26 149	+Busza, Kehoe, Beniston+ (SLAC, UMD, IBM, LBL) G
LAYSSAC 71	NC 6A 134	+Renard (MONP)

$f_J(1710)$

 $I^G(J^{PC}) = 0^+(\text{even}^{++})$

THE $f_J(1710)$

The $f_J(1710)$ is seen in the gluon-rich radiative decay $J/\psi(1S) \to \gamma f_J(1710)$; therefore C=+1. It decays into 2η and $K_S^0K_S^0$, which implies $I^GJ^{PC}=0^+(\text{even})^{++}$. In an amplitude analysis of the $K\overline{K}$ and $\pi^+\pi^-$ systems produced in $J/\psi(1S)$ radiative decay, CHEN 91 finds a large spin-0 component for this particle, but ARMSTRONG 89D favors spin 2 in central production. The spin is thus uncertain. This resonance is also observed in $K\overline{K}$ systems recoiling against a ϕ or an ω in hadronic $J/\psi(1S)$ decay. However, according to FALVARD 88, $J/\psi(1S) \to \omega f_J(1710)$ is rather controversial. The $f_J(1710)$ is not seen by DM2 (BISELLO 89B) in $J/\psi(1S) \to \gamma \rho^0 \rho^0$,

in agreement with the indication from MARK III (BALTRU-SAITIS 86B) that the $\rho\rho$ enhancement in this region has $J^P=0^-$, and hence is unrelated to the $f_J(1710)$. However, a reanalysis (BUGG 95) of the 4π channel from MARK III, including now two $\pi\pi$ S-waves in addition to $\rho\rho$, finds 0^{++} .

Clear evidence is seen in 300-GeV/c pp central production in both K^+K^- and $K_S^0K_S^0$ (ARMSTRONG 89D). Mass and width determinations are complicated because the spectra are dominated by overlap with the $f_2'(1525)$. The apparent large disagreement between the widths found by ARMSTRONG 89D in the two channels (≈ 180 MeV in K^+K^- and ≈ 100 MeV in $K_S^0K_S^0$) can be explained by the arbitrariness of the polynomial-exponential background shape, which leads to a large systematic error for the width. ARMSTRONG 93C also sees in $\eta\eta$ a broad peak at 1747 MeV, which may be the $f_J(1710)$. This resonance is not observed in the hypercharge-exchange reactions $K^-p \to K_S^0K_S^0\Lambda$ (ASTON 88D) and $K^-p \to K_S^0K_S^0Y^*$ (BOLONKIN 86)

A partial-wave analysis of the $\pi^-p \to K_S^0 K_S^0$ system (BOLONKIN 88) finds a D_0 wave behavior ($J^{PC}=2^{++}$) near 1700 MeV, but the width (≈ 30 MeV) is much narrower than that observed in $J/\psi(1S)$ decays and in hadroproduction.

Note that in our 1992 edition this particle was named the $f_2(1710)$. See also our Note on "Non- $q\overline{q}$ Mesons."

$f_J(1710)$ MASS

VALUE (MeV)	DOCUMENT ID TECN COMMENT
1697± 4 OUR AVERAGE	Error includes scale factor of 1.4. See the ideogram below.
1713 ± 10	ARMSTRONG 89D OMEG 300 $pp \rightarrow ppK^+K^-$
1706 ± 10	ARMSTRONG 89D OMEG 300 $pp \rightarrow ppK_S^0K_S^0$
1707 ± 10	AUGUSTIN 88 DM2 $J/\psi \rightarrow \gamma K^+ K^-$
1690± 4	¹ FALVARD 88 DM2 $J/\psi \rightarrow \phi K^+ K^-$
1698 ± 15	AUGUSTIN 87 DM2 $J/\psi ightarrow \gamma \pi^+ \pi^-$
$1720 \pm 10 \pm 10$	BALTRUSAIT87 MRK3 $J/\psi ightarrow \gamma K^+ K^-$
We do not use the following	wing data for averages, fits, limits, etc. • • •
1768 ± 14	BALOSHIN 95 SPEC 40 π^- C $\rightarrow \kappa_S^0 \kappa_S^0 X$
1750±15	² BUGG 95 MRK3 $J/\psi \rightarrow \gamma \pi^{+} \pi^{-} \pi^{+} \pi^{-}$
1748 ± 10	ARMSTRONG 93C SPEC $\overline{p}p \rightarrow \pi^{\hat{0}}\eta\eta \rightarrow 6\gamma$
1750	BREAKSTONE93 SFM pp →
	$\rho \rho \pi^+ \pi^- \pi^+ \pi^-$
1710 ± 20	CHEN 91 MRK3 $J/\psi \rightarrow \gamma \pi^+ \pi^-, \gamma K \overline{K}$
1700 ± 15	BOLONKIN 88 SPEC $40 \pi^- p \rightarrow K_S^0 K_S^0 n$
1720 ± 60	BOLONKIN 88 SPEC $40 \pi^- p \rightarrow \kappa_S^0 \kappa_S^0 n$ BOLONKIN 88 SPEC $40 \pi^- p \rightarrow \kappa_S^0 \kappa_S^0 n$
1638 ± 10	³ FALVARD 88 DM2 $J/\psi \rightarrow \phi K^+ K^-$
$1730 + 2 \\ -10$	^{4,5} LONGACRE 86 MPS 22 $\pi^- p \rightarrow n2K_S^0$
1742 ± 15	WILLIAMS 84 MPSF 200 $\pi^- N \rightarrow 2K_S^0 X$
1670 ± 50	BLOOM 83 CBAL $J/\psi ightarrow \gamma 2\eta$
1700 ± 45	EDWARDS 83B CBAL $J/\psi ightarrow \eta \gamma 2\pi$
1650 ± 50	BURKE 82 MRK2 $J/\psi ightarrow \gamma 2 ho$
$1730 \pm 10 \pm 20$	ETKIN 82C MPS $23 \pi^- p \rightarrow n2K_S^0$
1708 ± 30	FRANKLIN 82 MRK2 $e^+e^- \rightarrow \gamma K^+ K^-$

 $^{^{1}}$ From an analysis including interference with $f_{2}^{\prime}($ 1525).

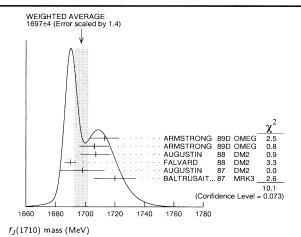
 $[\]frac{2}{3}$ From a fit to the 0^+ partial wave.

³ From an analysis ignoring interference with $f_2'(1525)$.

⁴ From a partial-wave analysis of data using a K-matrix formalism with 5 poles, but assuming soin 2.

⁵ Fit with constrained inelasticity.

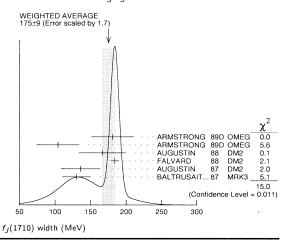
Meson Particle Listings $f_J(1710)$



$f_J(1710)$ WIDTH

VALU	E (N	leV)		DOCUMENT ID		TECN	COMMENT
175	±	9	OUR AVERAGE Erro	or includes scale	facto	r of 1.7.	See the ideogram below.
181	\pm	30		ARMSTRONG	89D	OMEG	$300 pp \rightarrow ppK^+K^-$
104	\pm	30		ARMSTRONG	89D	OMEG	$300 pp \rightarrow ppK_S^0K_S^0$
166.4	4 ±	33.2		AUGUSTIN			$J/\psi \rightarrow \gamma K^+ K^-$
184	\pm	6	•	⁶ FALVARD	88	DM2	$J/\psi \rightarrow \phi K^+ K^-$
136	\pm	28		AUGUSTIN	87	DM2	$J/\psi \rightarrow \gamma \pi^+ \pi^-$
130	_	20					$J/\psi \rightarrow \gamma K^+ K^-$
• •	V	Ve do	not use the following	data for averages	, fits	, limits,	etc. • • •
56	\pm	19		BALOSHIN	95	SPEC	40 π^{-} C $\rightarrow K_{S}^{0}K_{S}^{0}X$
160	\pm	40		⁷ BUGG	95	MRK3	$J/\psi \rightarrow \gamma \pi^+ \pi^- \pi^+ \pi^-$
264	\pm	25		ARMSTRONG	93C	SPEC	$\overline{p}p \rightarrow \pi^0 \eta \eta \rightarrow 6\gamma$
200	to	300		BREAKSTONE	93	SFM	$\rho \rho \rightarrow$
							ρρπ+π-π+π-
186		30		CHEN		MRK3	$J/\psi \rightarrow \gamma \pi^+ \pi^-, \gamma K \overline{K}$
30	±	20		BOLONKIN	88	SPEC	$40 \pi^{-} p \to K_{S}^{0} K_{S}^{0} n$ $40 \pi^{-} p \to K_{S}^{0} K_{S}^{0} n$
350	±:	150		BOLONKIN	88	SPEC	$40 \pi^- p \rightarrow K_S^0 K_S^0 n$
148		17	1	⁸ FALVARD	88	DM2	$J/\psi \rightarrow \phi K^+ K^-$
122	+	74 15	9,10	⁰ LONGACRE	86	MPS	$22 \pi^- \rho \rightarrow n2K_S^0$
57	\pm	38		WILLIAMS	84	MPSF	$200 \pi^{-} N \rightarrow 2K_{5}^{0} X$
160	\pm	80		BLOOM	83	CBAL	$J/\psi \rightarrow \gamma 2\eta$
520	±:	110		EDWARDS	83B	CBAL	$J/\psi \rightarrow \eta \gamma 2\pi$
200	±:	100		BURKE	82	MRK2	$J/\psi \rightarrow \gamma 2\rho$
200.0) -	156.0 9.0	1:	¹ ETKIN			$23 \pi^- p \rightarrow n2K_S^0$
156	\pm	60		FRANKLIN	82	MRK2	$e^+e^- \rightarrow \gamma K^+K^-$

⁶ From an analysis including interference with $f_2'(1525)$.



$f_J(1710)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ ₁	κ κ	seen
Γ_2	$\eta \eta$	seen
Γ_3	$\pi \pi$	seen
Γ_4	ho ho	
Γ ₅	$\gamma\gamma$	

$f_J(1710) \Gamma(i)\Gamma(\gamma\gamma)/\Gamma(total)$

$\Gamma(K\overline{K}) \times \Gamma(\gamma\gamma)/\Gamma$	total					$\Gamma_1\Gamma_5/\Gamma$
VALUE (keV)	CL%	DOCUMENT ID	<u></u>	ECN	COMMENT	
<0.11	95	12 BEHREND 8	89c C	ELL	$\gamma \gamma \rightarrow K_S^0 K_S^0$	
• • We do not use the	ne follow	ring data for averages,	fits, I	limits, e	etc. • • •	
< 0.48	95		90G A	RG	$\gamma \gamma \rightarrow K^+ K^-$	
< 0.28	95	12 ALTHOFF 8	858 T.	ASS	$\gamma \gamma \rightarrow K \overline{K} \pi$	
¹² Assuming helicity 2.						

f_J(1710) BRANCHING RATIOS

$\Gamma(\overline{K}\overline{K})/\Gamma_{\text{total}}$		DOCUMENT ID		TECN	COMMENT	Γ_1/Γ
• • We do not use the	following		es, fit			
$0.38^{+0.09}_{-0.19}$	13,	¹⁴ LONGACRE	86	MPS	22 π ⁻ ρ →	$n2K_S^0$
$\Gamma(\eta\eta)/\Gamma_{\text{total}}$		DOCUMENT ID		TECN		Γ_2/Γ
• • We do not use the	following		es. fit	-	etc. • • •	
$0.18^{+0.03}_{-0.13}$	-	¹⁴ LONGACRE				
$\Gamma(\pi\pi)/\Gamma_{\text{total}}$		DOCUMENT ID		TECN		Г ₃ /Г
• • We do not use the	following		es, fit	<i>TECN</i> s. limits.	etc. • • •	
$0.039^{+0.002}_{-0.024}$	_	¹⁴ LONGACRE				
$\Gamma(\pi\pi)/\Gamma(K\overline{K})$						Γ_3/Γ_1
VALUE		DOCUMENT ID		TECN	COMMENT	
0.39±0.14		ARMSTRONG	91	OMEG	$\begin{array}{c} 300 \ pp \longrightarrow \\ pp K \overline{K} \end{array}$	ρρππ,
$\Gamma(\eta\eta)/\Gamma(K\overline{K})$						Γ_2/Γ_1
VALUE	CL%	DOCUMENT ID		TECN	COMMENT	

13 From a partial-wave analysis of data using a K-matrix formalism with 5 poles, but assuming spin 2. 14 Fit with constrained inelasticity. 15 Combining results of GAM4 with those of ARMSTRONG 89D.

 \bullet $\,\bullet\,$ We do not use the following data for averages, fits, limits, etc. $\,\bullet\,$ $\,\bullet\,$

90

f_J(1710) REFERENCES

15 PROKOSHKIN 91 GA24 300 $\pi^- p \rightarrow \pi^- p \eta \eta$

BALOSHIN	95	PAN 58 46 Translated from YAF 58	+Bolonkin, Vladimirskii+ (ITE	EP)
BUGG	95	PL B353 378	+Scott, Zoli+ (LOQM, PNPI, WAS	SHY
ARMSTRONG		PL B307 394	+Bettoni+ (FNAL, FERR, GENO, UCI, NWES	
BREAKSTONE		ZPHY C58 251	+Campanini+ (IOWA, CERN, DORT, HEIDH, WAI	
		ZPHY C51 351	+Benayoun+ (ATHU, BARI, BIRM, CERN, CDI	
CHEN	91	Hadron 91 Conf.		
SLAC-PUB-		madron 91 Cont.	(Mark III Colla	10.)
PROKOSHKIN		SPD 36 155	(GAM2, GAM4 Colla	ah l
, nonosimin	,.	Translated from DANS	316 900.	10. j
ALBRECHT	90G	ZPHY C48 183	+Ehrlichmann, Harder+ (ARGUS Colla	ab.)
ARMSTRONG	89D	PL B227 186	+Benavour (ATHU BARI BIRM CERN CDI	
BEHREND	89C	ZPHY C43 91	+Criegee, Dainton+ (CELLO Colla	
AUGUSTIN	88	PRL 60 2238	+Calcaterra+ (DM2 Colla	
BOLONKIN	88	NP B309 426	+ Criegee, Dainton+ (CELLO Colla + Calcaterra+ (DM2 Colla + Bloshenko, Gorin+ (ITEP, SEF + Ajaltouni+ (CLER, FRAS, LALLO, PAE	
FALVARD	88	PR D38 2706	+Ajaltouni+ (CLER, FRAS, LALO, PAE	
AUGUSTIN	87	ZPHY C36 369	+Cosme+ (LALO, CLER, FRAS, PAD	
BALTRUSAIT		PR D35 2077	Baltrusaitis, Coffman, Dubois+ (Mark III Colla	
LONGACRE	86	PL B177 223	+Etkin+ (BNL, BRAN, CUNY, DUKE, NDA	
ALTHOFF	85B	ZPHY C29 189	+Braunschweig, Kirschfink+ (TASSO Colla	
WILLIAMS	84	PR D30 877	+Diamond+ (VAND, NDAM, TUFTS, ARIZ, FNAL	
BLOOM	83	ARNS 33 143	+Peck (SLAC, C	
EDWARDS	83B	PRL 51 859	+Partridge, Peck+ (CIT, HARV, PRIN, STAN, SLA	
BURKE	82	PRL 49 632	+Trilling, Abrams, Alam, Blocker+ (LBL, SLA	
	82B	PR D25 1786	LEGIAN INTL. (DNI CHNY THETE WAS	10)
ETKIN	82C	PR D25 2446	+Foley, Lai+ (BNL, CUNY, TUFTS, VAN +Foley, Lai+ (BNL, CUNY, TUFTS, VAN	iD)
FRANKLIN	82	SLAC-254	(SL/	AC)
TRANSCIN	02	3EAC-254	(30)	١٠)

OTHER RELATED PAPERS -

BISELLO	89B	PR D39 701	Busetto+		(DM2	Collab.)
ASTON	88D	NP B301 525	+Awaji, Bienz+	(SLAC,	NAGO, CINO	c, INUS)
AKESSON	86	NP B264 154	+Albrow, Almehed+	(Axial	Field Spec.	Collab.)
ARMSTRONG	86B	PL 167B 133	+Bloodworth, Carney+	(ATHU,	BARI, BIRM	, CERN)
BALTRUSAIT	86B	PR D33 1222	Baltrusaitis, Coffman, Hause	r+	(Mark III	Collab.)
ALTHOFF	83	PL 121B 216	+Brandelik, Boerner, Burkhar	dt+	(TASSO	Collab.)
BARNETT	83B	PL 120B 455	+Blockus, Burka, Chien, Chri	stian+		(JHU)
ALTHOFF	82	ZPHY C16 13	+Boerner, Burkhardt+		(TASSO	Collab.)
BARNES	82	PL B116 365	+Close			(RHEL)
BARNES	82B	NP B198 360	+Close, Monaghan		(RHEL,	OXFTP)
TANIMOTO	82	PL 116B 198				(BIEL)

⁷ From a fit to the 0⁺ partial wave.

⁸ From an analysis ignoring interference with $f_2'(1525)$.

⁹ From a partial-wave analysis of data using a K-matrix formalism with 5 poles, but as-

X(1740)

 $I^{G}(J^{PC}) = 0^{+}(even^{+})$

OMITTED FROM SUMMARY TABLE

Seen as a narrow state decaying to $\eta\eta$. $J^P=0^+$ or 2^+ , needs confirmation.

X(1740) MASS

 VALUE (MeV)
 DOCUMENT ID
 TECN
 COMMENT

 1744±15
 1 ALDE
 920 GAM2
 $38 \pi^- \rho \to \eta \eta N^+$

 $^{1}\,\mathrm{ALDE}$ 92D combines all the GAMS-2000 data.

X(1740) WIDTH

VALUE (MeV)	CL%	DOCUMENT ID	TECN	COMMENT
<80	90	² ALDE	92D GAM2	$38 \pi^- p \rightarrow \eta \eta N^*$
•				

 $^2\,\mbox{ALDE}$ 92D combines all the GAMS-2000 data.

X(1740) DECAY MODES

	Mode
$\overline{\Gamma_1}$	$\eta\eta$
Γ_2	$\pi^{0}\pi^{0}$
Γ3	$\eta\eta'$

X(1740) BRANCHING RATIOS

$\Gamma(\pi^0\pi^0)/\Gamma(\eta\eta)$					Γ_2/Γ_1
VALUE	CL%	DOCUMENT ID	TECN	COMMENT	
• • • We do not use the	following o	data for averages	, fits, limits,	etc. • • •	
<1	90	ALDE	92D GAM2	38 $\pi^- \rho \rightarrow$	$\eta \eta N^*$
$\Gamma(\eta\eta')/\Gamma(\eta\eta)$					Γ_3/Γ_1
VALUE	CL%	DOCUMENT ID	TECN	COMMENT	
• • • We do not use the	following o	data for averages	, fits, limits,	etc. • • •	
<1	90	ALDE	92D GAM2	38 $\pi^- p \rightarrow$	$\eta \eta N^*$

X(1740) REFERENCES

ALDE 92D PL B284 451 +Binon, Bricman+ (GAM2 Collab.)
Also 91 SJNP 54 451 Alde. Binon, Bricman+ (GAM2 Collab.)
Translated from YAF 54 745.

— OTHER RELATED PAPERS —

ALDE 86C PL B182 105 +Binon, Bricman+ (SERP, BELG, LANL, LAPP)

 $\eta(1760)$

 $I^{G}(J^{PC}) = 0^{+}(0^{-+})$

OMITTED FROM SUMMARY TABLE

Seen by DM2 in the $\rho\rho$ system BISELLO 89B. Structure in this region has been reported before in the same system BALTRUSAITIS 86B and in the $\omega\omega$ system BALTRUSAITIS 85C, BISELLO 87. Needs confirmation.

η(1760) MASS

VALUE (MeV)EVTSDOCUMENT IDTECNCOMMENT1760±11320 1 BISELLO898 DM2 $J/\psi \rightarrow 4\pi\gamma$

 $^{1}\,\mathrm{Estimated}$ by us from various fits.

η (1760) WIDTH

 VALUE (MeV)
 EVTS
 DOCUMENT ID
 TECN
 COMMENT

 60 ± 16 320
 2 BISELLO
 898 DM2
 $J/\psi \rightarrow 4\pi\gamma$

² Estimated by us from various fits.

$\eta(1760)$ REFERENCES

 BISELLO
 898
 PR D39 701
 Busetto+
 (DM2 Collab.)

 BISELLO
 87
 PL B192 239
 +Ajaltouni, Baldini+
 (PADO, CLER, FRAS, LALO)

 BALTRUSAIT... 868
 PR D33 1222
 Baltrusaitis, Coffman, Hauser+
 (Mark III Collab.)

 BALTRUSAIT... 85C
 PR D5 1723
 Baltrusaitis+
 (CIT, UCSC, ILL, SLAC, WASH)

 $\pi(1800)$

was $\pi(1770)$ and X(1830)

 $I^{G}(J^{PC}) = 1^{-}(0^{-+})$

OMITTED FROM SUMMARY TABLE

Needs confirmation. See also minireview under non- $q\overline{q}$ candidates.

π (1800) MASS

VALUE (MeV) 1795±10 OUR ESTI • • • We do not use		DOCUMENT ID		TECN	<u>CHG</u> etc. •	<u>COMMENT</u>
$1840 \pm 10 \pm 10$	1200	AMELIN	96B √	/ES	_	37 $\pi^- A \rightarrow$
1775 ± 7±10		¹ AMELIN	95B √	/ES	_	$ \eta \eta \pi^- A $ 36 $\pi^- A \rightarrow$
1790 ± 14		² BERDNIKOV	94 V	/ES	-	$ \begin{array}{c} \pi^{+}\pi^{-}\pi^{-}A \\ 37\pi^{-}A \rightarrow \\ \end{array} $
$1873 \pm 33 \pm 20$		BELADIDZE	92c V	/ES	-	36 π^- Be \rightarrow
$1814 \pm 10 \pm 23$	426±	BITYUKOV	91 V	/ES	-	36 π ⁻ C →
1770 ± 30	1100	BELLINI	82 S	SPEC	_	$\begin{array}{ccc} \pi & \eta \eta C \\ 40 & \pi^- A \rightarrow 3\pi A \end{array}$
¹ From a fit to J^{PO} ² From a fit to J^{PO}					aves.	
$1873 \pm 33 \pm 20$ $1814 \pm 10 \pm 23$ 1770 ± 30	$\begin{array}{c} 57 \\ 1100 \\ C = 0 - + f_0 \end{array}$	BELADIDZE BITYUKOV BELLINI $f_0(980)\pi, f_0(1370)$	92c V 91 V 82 S π wave	/ES /ES SPEC es.	_ _ _ _ aves.	$K^+K^-\pi^-A$ 36 π^- Be \rightarrow $\pi^-\eta^\prime\eta$ Be 36 π^- C \rightarrow $\pi^-\eta\eta$ C

π (1800) WIDTH

		•			
VALUE (MeV)	EVTS	DOCUMENT ID	TEC	N CHG	COMMENT
212±37 OUR EST	IMATE				
• • • We do not u	ise the followin	g data for average	s, fits, lin	nits, etc. 🤇	• • •
$210 \pm 30 \pm 30$	1200	AMELIN	968 VE	S –	$37 \pi^- A \rightarrow \eta \eta \pi^- A$
$190\pm15\pm15$		³ AMELIN	958 VE	S	$36 \begin{array}{c} \pi^- A \rightarrow \\ \pi^+ \pi^- \pi^- A \end{array}$
210 ± 70		⁴ BERDNIKOV	94 VE	S –	$37 \begin{array}{c} \pi^+ \pi^- A \rightarrow \\ K^+ K^- \pi^- A \end{array}$
$225 \pm 35 \pm 20$		BELADIDZE	92c VE	S –	$36 \pi^{-} \text{Be} \rightarrow \pi^{-} \eta' \eta \text{Be}$
205 ± 18 ± 32	426± 57	BITYUKOV	91 VE	s –	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$
310 ± 50	1100	BELLINI	82 SP	EC -	$40 \pi^- A \rightarrow 3\pi A$
		$f_0(980)\pi$, $f_0(1370)$ $f_0^*(1430)K^-$ and		– waves.	

π (1800) DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ_1	$\pi^{+}\pi^{-}\pi^{-}$	seen
Γ_2	$f_0(980)\pi^-$	seen
Γ_3	$f_0(1370)\pi^-$	seen
Γ_4	$\eta \eta \pi^-$	seen
Γ_5	$a_0(980)\eta$	seen
Γ_6	$f_0(1500)\pi^-$	seen
Γ_7	$\eta \eta'(958) \pi^-$	seen
Γ ₈	$K_0^*(1430)K^-$	seen
Γ9	$K^*(892)K^-$	not seen
Γ_{10}	$ ho \pi^-$	not seen

π (1800) BRANCHING RATIOS

$\Gamma(f_0(980)\pi^-)/\Gamma(f_0(980)\pi^-)$	$(1370)\pi^{-})$	DOCUMENT ID		TECN	CHG	Γ_2/Γ_3
1.7±1.3		AMELIN	95B	VES	-	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$
$\Gamma(f_0(1370)\pi^-)/\Gamma_{\text{tot}}$:al	DOCUMENT ID		TECN	СНБ	Γ ₃ /Γ
seen		BELLINI	82	SPEC	-	40 π ⁻ A → 3π A
$\Gamma(\eta\eta\pi^-)/\Gamma(\pi^+\pi^-$	$\pi^-)$					Γ_4/Γ_1
$\Gamma(\eta\eta\pi^-)/\Gamma(\pi^+\pi^-)$	π ⁻) _ <u>EVTS</u>	DOCUMENT ID		TECN	<u>CHG</u>	Γ ₄ /Γ ₁
	•	DOCUMENT ID	96B	<u>TECN</u> VES	<u>CHG</u> –	
VALUE	1200		96B		<u>СНС</u> —	$\frac{COMMENT}{37 \pi^{-} A \rightarrow}$
0.5 ±0.1	1200		968		CHG - CHG	$ \begin{array}{c} COMMENT \\ 37 \pi^{-} A \rightarrow \\ \eta \eta \pi^{-} A \end{array} $

 $^{^5}$ Assuming that $f_0(1500)$ decays only to $\eta\,\eta$ and $a_0(980)$ decays only to $\eta\,\pi.$

 $\pi(1800), X(1775), f_{5}(1810)$

		-				***********	
	$^{-})/\Gamma(\eta\eta\pi^{-})$	DOCUMENT ID		TECN	CUC	COMMENT	Γ_7/Γ_4
VALUE 0.29±0.06 OU	R AVERAGE	DOCUMENT ID		TECIV	CHG	CONINCENT	
0.29 ± 0.07		BELADIDZE	920	VES	_	36 π^- Be $\pi^ \eta'$ η	
0.3 ±0.1	426± 57	BITYUKOV	91	VES	-	36 π C - π ηη C	→
Γ(K ₀ *(1430) I	$(K^-)/\Gamma_{total}$	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT	Г ₈ /Г
seen		BERDNIKOV	94	VES	-	37 π ⁻ A - K ⁺ K ⁻	· - 4
F(V*(002) V	—) /r					K · K	π Α Γ₉/ Γ
Γ(K*(892) <i>K</i> VALUE	// total	DOCUMENT ID		TECN	CHG	COMMENT	19/1
• • • We do n	ot use the following	g data for average	s, fits	, limits,	etc.	• •	
not seen		BERDNIKOV	94	VES		37 π ⁻ A K ⁺ K ⁻	$\pi^- A$
$\Gamma(\rho\pi^-)/\Gamma(f_0$							Γ ₁₀ /Γ ₂
VALUE	CL%	DOCUMENT ID				COMMENT	
	ot use the following	-			eic.		
< 0.14	90	AMELIN	95B	VES	_	$36 \pi^{-} A - \pi^{-} \pi^{+} \pi^{-}$	$\pi^- A$
$\Gamma(ho\pi^-)/\Gamma_{ ext{tot}}$	al	DOCUMENT ID		TECN_	CHG	COMMENT	Γ_{10}/Γ
not seen		BELLINI	82	SPEC	_	40 π ⁻ A -	→ 3πA
	π((1800) REFERE	ENCI	====== ES			
AMELIN 96 AMELIN 95 BERDNIKOV 94 BELADIDZE 92	B PL B356 595 PL B337 219	+Berdnikov, Bity +Berdnikov, Bity +Bityukov+ +Bityukov, Boris	rukov+			(SERP, SERP,	TBIL) IGJ TBIL) TBIL) TBIL)
BITYUKOV 91 BELLINI 82	PL B268 137 PRL 48 1697	+Borisov+ +Frabetti, Ivansi	nin, Lit	kin+	(1)	(SERP, 1 MILA, BGNA, 1	
	отн	IER RELATED	PAF	PERS -			
BORISOV 92	SJNP 55 1441 Translated from YA	+Gershtein, Zait F 55 2583.	sev			(S	ERP)
X(177	5)	1 ^G (.	_J PC) = 1	-(?-	+)	
OMITTED F	ROM SUMMA	RY TABLE					
		X(1775) MA	SS				
VALUE (MeV)		DOCUMENT ID		TECN	соми	MENT	
1776±13 OUR 1763±20	AVERAGE	CONDO	91	SHF	γp -		,
1787±18		CONDO	91	SHF		$(\pi^+)(\pi^+\pi^-)$ $\rightarrow n\pi^+\pi^+$	

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1776±13 OUR AVERAGE				
1763±20	CONDO	91	SHF	$\gamma p \rightarrow$
				$(p\pi^+)(\pi^+\pi^-\pi^-)$
1787 ± 18	CONDO	91	SHF	$\gamma \rho \rightarrow n\pi^{+}\pi^{+}\pi^{-}$

X(1775) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
155±40 OUR AVERAGE				
192 ± 60	CONDO		SHF	
				$\begin{array}{c} (p\pi^+)(\pi^+\pi^-\pi^-) \\ \gamma p \to n\pi^+\pi^+\pi^- \end{array}$
118 ± 60	CONDO	91	SHF	$\gamma p \rightarrow n\pi^{+}\pi^{+}\pi^{-}$

X(1775) DECAY MODES

	Mode
Г	$ ho \pi$ $f_2(1270) \pi$

X(1775) BRANCHING RATIOS

$\Gamma(\rho\pi)/\Gamma(f_2(1270)\pi)$	DOCUMENT ID		TECN	Γ_1/Γ_2			
1.43±0.26 OUR AVERAGE							
1.3 ±0.3	CONDO		SHF				
1.8 ±0.5	CONDO	91	SHF	$(\rho \pi^+)(\pi^+\pi^-\pi^-)$ $\gamma \rho \rightarrow n\pi^+\pi^+\pi^-$			

X(1775) REFERENCES

(SLAC Hybrid Collab.) CONDO 91 PR D43 2787 +Handler+

 $f_2(1810)$

 $I^{G}(J^{PC}) = 0^{+}(2^{+})$

OMITTED FROM SUMMARY TABLE Needs confirmation.

f2(1810) MASS

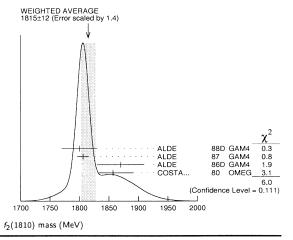
VALUE (MeV)	EVTS	DOCUMENT ID	TECI	V COMMENT
1815±12 OUR AV	ERAGE Error	includes scale fac	ctor of 1.4.	See the ideogram below.
1800 ± 30	40	ALDE		14 300 $\pi^- p \to \pi^- p 4 \pi^0$
1806 ± 10	1600	ALDE	87 GAN	$14 \ 100 \ \pi^- p \rightarrow 4\pi^0 n$
1870 ± 40		¹ ALDE	86D GAN	$14 100 \; \pi^- \rho \rightarrow \; \eta \eta n$
$1857 + 35 \\ -24$		² COSTA	80 OM	EG 10 $\pi^- p \rightarrow K^+ K^- n$
• • • We do not i	use the followin	g data for averag	es, fits, lim	its, etc. • • •
$1858 + 18 \\ -71$		³ LONGACRE	86 RVL	JE Compilation
1799 ± 15		⁴ CASON	82 STR	$C 8 \pi^+ \rho \rightarrow \Delta^{++} \pi^0 \pi^0$

 $\frac{1}{2}$ Seen in only one solution.

² Error increased by spread of two solutions. Included in LONGACRE 86 global analysis.

³ From a partial-wave analysis of data using a K-matrix formalism with 5 poles. Includes compilation of several other experiments.

from an amplitude analysis of the reaction $\pi^+\pi^- \to 2\pi^0$. The resonance in the $2\pi^0$ final state not confirmed by PROKOSHKIN 94.



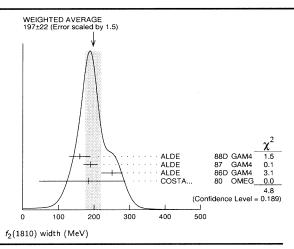
f2(1810) WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
197± 22 OUR A	/ERAGE Erro	r includes scale fac	tor of	1.5. Se	e the ideogram below.
160± 30	40	ALDE	88D	GAM4	$300 \pi^- \rho \rightarrow \pi^- \rho 4\pi^0$
190± 20	1600	ALDE	87	GAM4	$100 \ \pi^- p \rightarrow 4\pi^0 n$
250 ± 30		⁵ ALDE	8 6 D	GAM4	$100 \pi^- p \rightarrow \eta \eta n$
$185 + 102 \\ -139$		⁶ COSTA	80	OMEG	10 $\pi^- p \rightarrow K^+ K^- n$
• • • We do not	use the followin	ig data for average	es, fits	, limits,	etc. • • •
388 ⁺ 15 - 21		⁷ LONGACRE	86	RVUE	Compilation
280 + 42 - 35		⁸ CASON	82	STRC	$8~\pi^+\rho \rightarrow \Delta^{++}\pi^0\pi^0$

⁵ Seen in only one solution.

 $^6\mathrm{Error}$ increased by spread of two solutions. Included in LONGACRE 86 global analysis.

From an amplitude analysis of the reaction $\pi^+\pi^- \to 2\pi^0$. The resonance in the $2\pi^0$ final state not confirmed by PROKOSHKIN 94.



f2(1810) DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ ₁	ππ	
Γ_2	$\eta \eta_{\downarrow}$	
Гз	$\eta \eta \atop 4\pi^0 \atop \mathcal{K}^+ \mathcal{K}^-$	seen
Γ_4	K^+K^-	

f2(1810) BRANCHING RATIOS

'2	(1910) BUNICHIN	IG K	A1103	
$\Gamma(\pi\pi)/\Gamma_{\text{total}}$	DOCUMENT ID		TECN	Γ_1/Γ
• • We do not use the following the fol				***************************************
not seen	PROKOSHKI	N 94	GAM2	38 $\pi^- p \rightarrow \pi^0 \pi^0 n$
$0.21^{+0.02}_{-0.03}$	⁹ LONGACRE	86	RVUE	Compilation
0.44 ± 0.03	¹⁰ CASON	82	STRC	$8 \pi^+ \rho \rightarrow \Delta^{++} \pi^0 \pi^0$
Γ(ηη)/Γ _{total}	DOCUMENT ID		TECN	Γ_2/Γ
• • We do not use the following the fol				
$0.008 {}^{+ 0.028}_{- 0.003}$	9 LONGACRE	86	RVUE	Compilation
$\Gamma(\pi\pi)/\Gamma(4\pi^0)$				Γ_1/Γ_3
• • • We do not use the following the follo	DOCUMENT ID			
<0.75	ALDE			$100 \pi^- \rho \rightarrow 4\pi^0 n$
$\Gamma(4\pi^0)/\Gamma(\eta\eta)$				Γ_3/Γ_2
VALUE	DOCUMENT ID		TECN	
• • We do not use the following the fol	lowing data for average	es, fit	s, limits,	etc. • • •
0.8 ± 0.3	ALDE	87	GAM4	$100 \pi^- \rho \rightarrow 4\pi^0 n$
$\Gamma(K^+K^-)/\Gamma_{\text{total}}$				Γ ₄ /Γ
• • • We do not use the fol	DOCUMENT ID		TECN s limits	etc • • •
0.003 + 0.019 - 0.002	-			Compilation
seen	COSTA	80	OMEG	$10 \pi^- p \rightarrow K^+ K^- n$
⁹ From a partial-wave anal compilation of several ot		matri	ix formal	ism with 5 poles. Includes

f₂(1810) REFERENCES

10 Included in LONGACRE 86 global analysis.

PROKOSHKIN	94	SPD 39 420	+Kondashov	(SERP)
		Translated from	DANS 336 613.	
ALDE	88D	SJNP 47 810	+Bellazzini, Binon+	(SERP. BELG. LANL, LAPP, PISA)
		Translated from	YAF 47 1273.	,
ALDE	87	PL B198 286	+Binon, Bricman+	(LANL, BRUX, SERP, LAPP)
ALDE	86D	NP B269 485	+Binon, Bricman+	(BELG, LAPP, SERP, CERN, LANL)
LONGACRE	86	PL B177 223	+Etkin+	(BNL. BRAN, CUNY, DUKE, NDAM)
CASON	82	PRL 48 1316	+Biswas, Baumbaugh,	Bishop+ (NDAM, ANL)
COSTA	80	NP B175 402	Costa De Beauregar	d+ (BARI, BÒNN, CERN+)
			•	,
		_		

- OTHER RELATED PAPERS ----

AKER CASON	91 PL B26 83 PR D2	8 1586	+Amsler, Peters+ +Cannata, Baumbaugh,			(NDAN	Collab.)
ETKIN	82B PR D2	5 1786	+Foley, Lai+	(BNL,	CUNY,	TUFTS,	VAND)

 $\phi_3(\overline{1850})$

$$I^{G}(J^{PC}) = 0^{-}(3^{-})$$

ϕ_3 (1850) MASS							
<u>VALUE (MeV)</u> 1854 ± 7 OUR AV	EVTS ERAGE	DOCUMENT ID		TECN	COMMENT		
1855 ± 10		ASTON	88E	LASS	$ \begin{array}{c} 11 \ K^- p \to F \\ K_S^0 K^{\pm} \pi^{\mp} \end{array} $		
$1870 + 30 \\ -20$	430	ARMSTRONG	82	OMEG	18.5 $K^-p \rightarrow$	$\kappa^- \kappa^+ \Lambda$	
1850 ± 10	123	ALHARRAN	81B	нвс	8.25 $K^-p \rightarrow$	$K\overline{K}\Lambda$	
$\phi_3(1850)$ WIDTH							

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
87 ⁺²⁸ OUR AVERAGE	E Error inc	ludes scale facto	r of	1.2.	
64±31		ASTON	88E	LASS	11 $K^- p \rightarrow K^- K^+ \Lambda$, $K_S^0 K^{\pm} \pi^{\mp} \Lambda$
$160 + 90 \\ -50$	430	ARMSTRONG	82	OMEG	$18.5~\textrm{K}^-\textrm{p} \rightarrow~\textrm{K}^-\textrm{K}^+\textrm{\Lambda}$
80 ^{+ 40} - 30	123	ALHARRAN	81B	нвс	8.25 $K^- p \rightarrow K \overline{K} \Lambda$

ϕ_3 (1850) DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ ₁	κK	seen
Γ_2	$K\overline{K}^*(892) + \text{c.c.}$	seen

ϕ_3 (1850) BRANCHING RATIOS

$\Gamma(K\overline{K}^*(892)+c.c.)/$	Γ(<i>κҠ</i>)			Γ_2/Γ_1
VALUE	DOCUMENT ID	TECN	COMMENT	
$0.55^{+0.85}_{-0.45}$	ASTON	88E LASS	11 $K^- p \rightarrow K_S^0 K^{\pm} \pi$	κ-κ+ <i>Λ</i> , ∓ <i>Λ</i>
• • • We do not use the	following data for average	s, fits, limits,	etc. • • •	
0.8 ±0.4	ALHARRAN	81B HBC	8.25 K ⁻ p -	$\rightarrow K\overline{K}\pi\Lambda$

φ₃(1850) REFERENCES

\$3(1000) NET ENERGES						
ASTON			3208 3			
ARMSTRONG	82	PL 1	10B 7	+Baubillier+	(BARI, BIRM, CERN, MILA, CURIN+) JP	
ALHARRAN	81 R	PI 1	01R 3	.7 ⊥Δmirzadeh⊥	(BIRM CERN GLAS MICH CURIN)	

----- OTHER RELATED PAPERS ---

 CORDIER
 82B
 PL
 110B
 335
 +Bisello,
 Bizot,
 Buon,
 Delcourt,
 Fayard+
 (LALO)

 ASTON
 80B
 PL
 92B
 219
 (BONN,
 CERN,
 EPOL,
 GLAS,
 LANC,
 MCHS+)

 $\eta_2(1870)$

$$I^{G}(J^{PC}) = 0^{+}(2^{-})$$

OMITTED FROM SUMMARY TABLE Needs confirmation.

η₂(1870) MASS

VALUE (MeV)	EVTS	DOCUMENT I	0	TECN	COMMENT
$1881 \pm 32 \pm 40$	26	KARCH	92	CBAL	$e^{+}e^{-}_{e^{+}e^{-}\eta\pi^{0}\pi^{0}}$
• • • We do not us	e the followin	g data for avera			
1850 ± 50		FEINDT	91	CELL	$\gamma \gamma \rightarrow \eta \pi^+ \pi^-$

η₂(1870) WIDTH

VALUE (MeV)	EVTS	DOCUMENT I	D	TECN	COMMENT
221± 92±44	26	KARCH	92	CBAL	$ \begin{array}{c} e^+e^- \rightarrow \\ e^+e^- \eta \pi^0 \pi^0 \end{array} $
• • • We do not use	the followin	g data for avera	ges, fits	, limits,	etc. • • •
~ 360		FEINDT	91	CELL	$\gamma \gamma \rightarrow \eta \pi^+ \pi^-$

η_2 (1870) DECAY MODES

	Mode
Γ ₁ Γ ₂ Γ ₃	$\eta \pi \pi$ $a_2(1320)\pi$ $f_0(980)\pi^-$

 $\eta_2(1870), X(1910), f_2(1950)$

η_2 (1870) REFERENCES	$\Gamma(K_S^0, K_S^0)/\Gamma(\eta \eta')$ Γ_2/Γ_5
KARCH 92 ZPHY C54 33 +Antreasyan, Bartels+ (Crystal Ball Collab.) FEINDT 91 Singapore Conf. 537	<u>VALUE</u> <u>CL%</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> • • • We do not use the following data for averages, fits, limits, etc. • • •
OTHER RELATED PAPERS	<0.066 , 90 BALOSHIN 86 SPEC $40\pi ho ightarrow \kappa_{ S}^{ 0} \kappa_{ S}^{ 0} n$
KARCH 90 PL B249 353 +Antreasyan, Bartels+ (Crystal Ball Collab.)	Γ(η'η')/Γ _{total} Γ ₆ /Γ VALUE DOCUMENT ID TECN COMMENT
C DC 1 21	• • • We do not use the following data for averages, fits, limits, etc. • • •
$X(1910)$ $I^{G}(J^{PC}) = 0^{+}(?^{?+})$	possibly seen BELADIDZE 92D VES 37 $\pi^- p o \eta' \eta' n$
OMITTED FROM SUMMARY TABLE	X(1910) REFERENCES
We list here two different peaks with close masses and widths seen in the mass distributions of $\omega\omega$ and $\eta\eta'$ final states. ALDE 91B	BELADIDZE 92B ZPHY C54 367 +Bityukov, Borisov+ (VES Collab.) BELADIDZE 92D ZPHY C57 13 +Berdnikov+ (VES Collab.)
argues that they are of different nature. See also minireview under non- $q\overline{q}$ candidates.	ALDE 91B SJNP 54 455 +Binon+ (SERP, BELG, LANL, LAPP, PISA, KEK) Translated from YAF 54 751. Also 92 PL BZF6 375 Alde, Binon+ (BELG, SERP, KEK, LANL, LAPP)
X(1910) MASS	ALDE 90 PL B241 600 +Binon+ (SERP, BELG, LANL, LAPP, PISA, KEK) ALDE 89 PL B216 447 +Binon, Britzman, Donskov+ (SERP, BELG, LANL, LAPP) Also 88E SJNP 48 1035 Alde, Binon, Britzman+ (BELG, SERP, ANL, LAPP)
` ,	Translated from YAF 48 1724. ALDE 89B PL B216 451 +Binon, Bricman+ (SERP, BELG, LANL, LAPP, TBIL)
VALUE (MeV) DOCUMENT ID 1810 to 1920 OUR ESTIMATE DOCUMENT ID	BALOSHIN 86 S.JNP 43 959 +Barkov, Bolonkin, Vladimirskii, Grigoriev+ (ITEP) Translated from YAF 43 1487.
$X(1910) \omega \omega$ MODE	OTHER RELATED PAPERS
VALUE (MeV) 1921± 8 OUR AVERAGE DOCUMENT ID TECN COMMENT COMMENT	LEE 94 PL B323 227 +Chung, Kirk+ (BNL, IND, KYUN, MASD, RICE)
1920±10	$f_2(1950)$ $I^G(J^{PC}) = 0^+(2^{++})$
X(1910) ηη' MODE	OMITTED FROM SUMMARY TABLE
<u>VALUE (MeV)</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> • • • We do not use the following data for averages, fits, limits, etc. • •	Needs confirmation.
1911 \pm 10 ALDE 918 GAM2 38 $\pi^- p \to \eta \eta' n$	f ₂ (1950) MASS
X(1910) WIDTH	TOTALUE (MeV) DOCUMENT ID TECN CHG COMMENT 1950±15 1 ASTON 91 LASS 0 11 K^-p $AK\bar{K}\pi\pi$
VALUE (MeV) DOCUMENT ID 90 to 250 OUR ESTIMATE	• • • We do not use the following data for averages, fits, limits, etc. • • • 1918±12 ANTINORI 95 OMEG 300,450 pp →
X(1910) ωω MODE	$\rho p2(\pi^+\pi^-)$ \sim 1996 HASAN 94 RVUE $p p \rightarrow \pi \pi$
VALUE (MeV) DOCUMENT ID TECN COMMENT 90±19 OUR AVERAGE	- 1 Cannot determine spin to be 2.
90 \pm 20 2 BELADIDZE 92B VES 36 $\pi^-p \rightarrow \omega\omega n$ 91 \pm 50 2 ALDE 90 GAM2 38 $\pi^-p \rightarrow \omega\omega n$	
$2 J^{PC} = 2 + +.$	VALUE (MeV) DOCUMENT ID TECN CHG COMMENT
X(1910) ηη' MODE	250±50
<u>VALUE (MeV)</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> • • • We do not use the following data for averages, fits, limits, etc. • •	_ • • • We do not use the following data for averages, fits, limits, etc. • • • $390\pm60 \qquad \qquad \text{ANTINORI} \qquad 95 \text{OMEG} \qquad 300,450 \ \textit{pp} \rightarrow$
90 \pm 35 ALDE 91B GAM2 38 $\pi^- p \rightarrow \eta \eta' n$	$\rho \rho 2(\pi^+\pi^-)$
X(1910) DECAY MODES	$ \sim$ 134 HASAN 94 RVUE $\overline{ ho} ho ightarrow \pi \pi$ 2 Cannot determine spin to be 2.
Mode	f ₂ (1950) DECAY MODES
$\Gamma_1 = \pi^0 \pi^0$	Mode
	$\Gamma_1 = K^*(892)\overline{K}^*(892)$
$\Gamma_4^{\prime} = \omega \omega$ $\Gamma_5 = \eta \eta^{\prime}$	$\Gamma_{2} = \pi^{0}\pi^{0}$ $\Gamma_{3} = \pi^{+}\pi^{-}\pi^{+}\pi^{-}$
$\Gamma_6 = \eta' \eta'$	
X(1910) BRANCHING RATIOS	f_{c} (1950) BRANCHING RATIOS $\Gamma(K^{*}(892)\overline{K}^{*}(892))/\Gamma_{total} \qquad \qquad \Gamma_{1}/\Gamma_{c}$
$\Gamma(\omega\omega)/\Gamma_{total}$	VALUE DOCUMENT ID TECN CHG COMMENT
VALUE DOCUMENT ID TECN COMMENT • • • • We do not use the following data for averages, fits, limits, etc. • •	_ seen ASTON 91 LASS 0 11 $K^- ho ightarrow \Lambda K \overline{K} \pi \pi$
seen ALDE 898 GAM2 38 $\pi^- p ightarrow \omega v n$	f ₂ (1950) REFERENCES
$\Gamma(\pi^0\pi^0)/\Gamma(\eta\eta')$ Γ_1/Γ_2	_· ·
• • • We do not use the following data for averages, fits, limits, etc. • • • <0.1 ALDE 89 GAM2 $38\pi^-p \to \eta\eta' n$	OTHER RELATED PAPERS
$\Gamma(\eta\eta)/\Gamma(\eta\eta')$ Γ_3/Γ	_ BIENZ 90 SLAC 369 (LASS Collab.)
VALUE CL% DOCUMENT ID TECN COMMENT	5 ALBRECHT 88N PL B212 528 + (ARGUS Collab.) ALBRECHT 87Q PL B198 255 + Binder+ (ARGUS Collab.) ARMSTRONG 87C ZPHY C34 33 +Bloodworth+ (CERN, BIRM, BARI, ATHU, CURIN+)
• • • We do not use the following data for averages, fits, limits, etc. • • • <0.05 90 ALDE 91B GAM2 38 $\pi^- p \rightarrow \eta \eta' n$	

X(2000) was $a_3(2050)$

 $I^{G}(J^{PC}) = 1^{-}(?^{?+})$

OMITTED FROM SUMMARY TABLE BALTAY 77 favors $J^P = 3^+$. Needs confirmation.

X(2000)	MASS
---------	------

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
• • We do not i	ise the follow	ing data for averag	es, f	its, limii	s, etc.	• • •
1964 ± 35		¹ ARMSTRONG	93D	SPEC		$\overline{p} p \rightarrow 3\pi^0 \rightarrow 6\gamma$
~ 2100		¹ ANTIPOV	77	CIBS		25 $\pi^- \rho \rightarrow$
						$\rho\pi^-\rho_3$
2214 ± 15		BALTAY	77	нвс	0	15 $\pi^- \rho \rightarrow$
2222 42	200	KALELKAD	75	LIDG		$\begin{array}{c} \Delta^{++} 3\pi \\ 15 \pi^{+} \rho \rightarrow \end{array}$
2080 ± 40	208	KALELKAR	15	HBC	+	$p\pi^+\rho_2$
						$\rho\pi$ · ρ_3

X(2000) WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID	TE	CN CHG	COMMENT	
• • • We do not us	e the follow	ing data for averag	es, fits,	limits, etc.	• • •	
225 ± 50		² ARMSTRONG			$\overline{p}p \rightarrow 3\pi^0 \rightarrow 6\gamma$	ı
~ 500		² ANTIPOV	77 CI	BS -		
					$p\pi^-\rho_3$	
355 ± 21		BALTAY	77 HE	3C 0	15 $\pi^- \rho \rightarrow$	
340 ± 80	208	KALELKAR	75 H	3C +	$\begin{array}{c} \Delta^{++} 3\pi \\ 15 \pi^{+} \rho \rightarrow \end{array}$	
					$p\pi^+\rho_3$	
² Cannot determin	ne spin to be	3.				ı

X(2000) DECAY MODES

	Mode	Fraction $(\Gamma_{\hat{I}}/\Gamma)$
$\overline{\Gamma_1}$	3π	
Γ_2	$\rho_3(1690)\pi$	dominant

X(2000) BRANCHING RATIOS

$\Gamma(\rho_3(1690)\pi)/\Gamma(3\pi)$						Γ_2/Γ_1
VALUE	DOCUMENT ID		TECN	CHG	COMMENT	
dominant	KALFIKAR	75	HRC	4	$15 \pi^+ \rho \rightarrow \rho 3\pi$	

X(2000) REFERENCES

ARMSTRONG ANTIPOV BALTAY KALELKAR	93D 77 77 75	PL B307 399 NP B119 45 PRL 39 591 Thesis Nevis 207	+Bettoni+ (FNAL, FERR, GENO, U +Busnello, Damgaard, Kienzle+ (S +Cautis, Kalelkar	JCI, NWES+) SERP, GEVA) (COLU) JP (COLU)		
OTHER RELATED PAPERS						

HARRIS	81	ZPHY C9 275	+Dunn, Lubatti, Moriyasu,	Podolsky+ (SEAT, UCB)
HUSON	68	PL 28B 208	+Lubatti, Six, Veillet+	(ORSAY, MILA, UCLA)
DANYSZ	67B	NC 51A 801	+French, Simak	(CERN)

 $f_2(2010)$

$$I^{G}(J^{PC}) = 0^{+}(2^{++})$$

See also the mini-review under ${\rm non\text{-}}q\,\overline{q}$ candidates. (See the index for the page number.)

f2(2010) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
2011 ⁺ 62 76	$^{ m 1}$ ETKIN	88	MPS	22 $\pi^- p \rightarrow$	$\phi\phi n$
• • • We do not use the following	data for average	s, fit	s, limits,	etc. • • •	
1980± 20	² BOLONKIN	88	SPEC	40 $\pi^- \rho \rightarrow$	$K_S^0 K_S^0 n$
2050 + 90	ETKIN	85	MPS	22 $\pi^- \rho \rightarrow$	$2\phi n$
$2120 + 20 \\ -120$	LINDENBAUM	1 84	RVUE		
2160 ± 50	ETKIN	82	MPS	22 $\pi^- \rho \rightarrow$	$2\phi n$
1 Includes data of ETKIN 85. T	he percentage of	the r	esonance	going into d	$\phi 2^{+} + S_2$

 D_2 , and D_0 is 98 $^{+1}_{-3}$, 0 $^{+1}_{-0}$, and 2 $^{+2}_{-1}$, respectively.

£(2010) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
202 ⁺ 67 - 62	³ ETKIN	88	MPS	22 $\pi^- p \rightarrow \phi \phi n$	
• • • We do not use the follow	ing data for average	es, fit	s, limits	etc. • • •	
145 ± 50	⁴ BOLONKIN	88	SPEC	40 $\pi^- p \to K_S^0 K_S^0 n$	
$200 + 160 \\ -50$	ETKIN	85	MPS	$22 \pi^- p \rightarrow 2\phi n$	
300 ^{+ 150} _{- 50}	LINDENBAUM	√ 184	RVUE		
310± 70	ETKIN	82	MPS	$22 \pi^- p \rightarrow 2\phi n$	

 $^{^3}$ Includes data of ETKIN 85. 4 Statistically very weak, only 1.4 s.d.

f2(2010) DECAY MODES

Mode	Fraction (Γ_j/Γ)			
$\Gamma_1 = \phi \phi$	seen			

f₂(2010) REFERENCES

BOLONKIN	88	NP B309 426	+Bloshenko, Gorin+	(ITEP, SERP)
ETKIN	88	PL B201 568	+Foley, Lindenbaum+	(BNL, CUNY)
ETKIN	85	PL 165B 217	+Foley, Longacre, Lindenbaum+	(BNL, CUNY)
LINDENBAUM	84	CNPP 13 285	, , ,	(CUNY)
ETKIN	82	PRL 49 1620	+Foley, Longacre, Lindenbaum+	(BNL, CUNY)
Also	83	Brighton Conf. 351	Lindenhaum	(BNL CUNY)

- OTHER RELATED PAPERS -

ARMSTRONG	89B	PL B221 221	+Benayoun+(CERN, CDEF, BIRM, BARI, ATHU, CURIN
GREEN	86	PRL 56 1639	+Lai+ (FNAL, ARIZ, FSU, NDAM, TUFTS, VAND
BOOTH	84	NP B242 51	+Ballance, Carroll, Donald+ (LIVP, GLAS, CER

 $a_4(2040)$

$$I^{G}(J^{PC}) = 1^{-}(4^{+})$$

OMITTED FROM SUMMARY TABLE Needs confirmation.

a4(2040) MASS

VALUE (MeV) 2037±26 OUR AVERAGE	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
					0 1
2040±30	CLELAND	82B	SPEC	±	$50 \pi p \rightarrow K_S^0 K^{\pm} p$
2030 ± 50	CORDEN	78C	OMEG	0	$15 \pi^- \rho \rightarrow 3\pi n$
• • • We do not use the following	ng data for avera	ges,	fits, lim	its, etc	. • • •
1903±10 3	BALDI	78	SPEC	_	$ \begin{array}{c} 10 \ \pi^- p \rightarrow \\ p \kappa_5^0 \kappa^- \end{array} $
					pKOK-

 1 From an amplitude analysis. 2 $J^P=4^+$ is favored, though $J^P=2^+$ cannot be excluded. 3 From a fit to the Y^0_8 moment. Limited by phase space.

² Statistically very weak, only 1.4 s.d.

 $a_4(2040)$, $f_4(2050)$

a₄(2040) WIDTH

ELAND 82	2B SPEC		50 · (0 (x+ -
ELAND 82	B SPEC		50 - 40 44 -
		· 1	$50 \pi p \rightarrow K_S^0 K^{\pm} p$
RDEN 78	вс ОМЕ	G 0	$15 \pi^- p \rightarrow 3\pi n$
ita for averages	s, fits, li	mits, etc	. • • •
LDI 78	SPEC	-	$ \begin{array}{c} 10 \ \pi^- \ \rho \rightarrow \\ \rho \ K^0 \ K^- \end{array} $
	ata for average	ata for averages, fits, li	ata for averages, fits, limits, etc

 $J^P=4^+$ is favored, though $J^P=2^+$ cannot be excluded. 6 From a fit to the Y_8^0 moment. Limited by phase space.

a₄(2040) DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ ₁	$\frac{K\overline{K}}{\pi^+\pi^-\pi^0}$	seen seen

a₄(2040) BRANCHING RATIOS

$\Gamma(\overline{K})/\Gamma_{\text{total}}$						Γ_1/Γ
VALUE	DOCUMENT ID		TECN	CHG	COMMENT	
seen			SPEC	±	$10 \pi^- \rho \rightarrow K_S^0 K^- \rho$	

$\Gamma(\pi^+\pi^-\pi^0)/\Gamma_{ ext{total}}$					Γ_2/Γ
VALUE	DOCUMENT ID	TECN	CHG	COMMENT	
seen	CORDEN	78c OMEG	0	$15~\pi^-\rho\rightarrow$	$3\pi n$

a₄(2040) REFERENCES

CLELAND	82B	NP B208 228	+Delfosse, Dorsaz, Gloor (DUR	H, GEVA, L	.AUS, PITT)
BALDI		PL 74B 413	+Bohringer, Dorsaz, Hungerbuhler+		(GEVA) JF
CORDEN	78C	NP B136 77	+Dowell, Garvey+ (BIRM	, RHEL, TE	ELA, LOWC) JF

OTHER RELATED PAPERS

DELFOSSE 81 NP B183 349 +Guisan, Martin, Muhlemann, Weill+ (GEVA, LAUS)

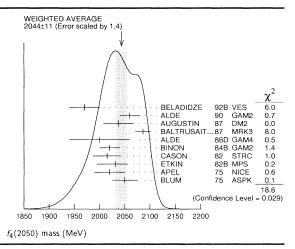


$$I^{G}(J^{PC}) = 0^{+}(4^{+})$$

f4(2050) MASS

VALUE (MeV)	EVTS		DOCUMENT ID		TECN	COMMENT
2044±11 OUR AVERAGE	Error	ind	ludes scale fact	or of	1.4. Se	e the ideogram below.
1970 ± 30			BELADIDZE	92B	VES	36 $\pi^- p \rightarrow \omega \omega n$
2060 ± 20			ALDE	90	GAM2	38 $\pi^- p \rightarrow \omega \omega n$
2038 ± 30			AUGUSTIN			$J/\psi \rightarrow \gamma \pi^+ \pi^-$
2086 ± 15			BALTRUSAIT	.87	MRK3	$J/\psi \rightarrow \gamma \pi^+ \pi^-$
2000 ± 60			ALDE	86D	GAM4	$100 \pi^- \rho \rightarrow n2\eta$
2020 ± 20	40k					$38 \pi^- p \rightarrow n2\pi^0$
2015 ± 28		2	CASON	82	STRC	$8 \pi^{+} p \rightarrow \Delta^{++} \pi^{0} \pi^{0}$
2031 + 25			ETKIN	82B	MPS	23 $\pi^- p \rightarrow n2K_S^0$
2020 ± 30	700		APEL	75	NICE	$40 \pi^{-} p \rightarrow n2\pi^{0}$
2050 ± 25			BLUM	75	ASPK	18.4 $\pi^- p \rightarrow nK^+K^-$
\bullet \bullet \bullet We do not use the	following	d	ata for averages	, fits	, limits,	etc. • • •
1978± 5		3	ALPER	80	CNTR	62 $\pi^- p \to K^+ K^- n$
2040 ± 10		3	ROZANSKA	80	SPRK	$18 \pi^- p \rightarrow p \overline{p} n$
1935 ± 13		3	CORDEN	79	OMEG	12-15 $\pi^- p \rightarrow n2\pi$
1988 ± 7			EVANGELISTA	79B	OMEG	$10 \pi^- p \rightarrow K^+ K^- n$
1922 ± 14		4	ANTIPOV	77	CIBS	$25 \pi^- p \rightarrow p 3\pi$

 $^{^{\}rm 1}\,{\rm From}$ a partial-wave analysis of the data.



f4(2050) WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
208± 13 OUR AVERA	GE Error	includes scale fac	tor of 1.2.	
300 ± 50		BELADIDZE	92B VES	$36 \pi^- p \rightarrow \omega \omega n$
170 ± 60		ALDE	90 GAM2	38 $\pi^- p \rightarrow \omega \omega n$
304 ± 60				$J/\psi \rightarrow \gamma \pi^{+} \pi^{-}$
210 ± 63		BALTRUSAIT	87 MRK3	$J/\psi \rightarrow \gamma \pi^+ \pi^-$
400 ± 100		ALDE	86D GAM4	$100 \pi^- p \rightarrow n2\eta$
240 ± 40	40k	⁵ BINON		$38 \pi^- p \rightarrow n2\pi^0$
190 ± 14		DENNEY	83 LASS	10 $\pi^{+} n/\pi^{+} \rho$
$186 + 103 \\ -58$		⁶ CASON	82 STRC	$8 \pi^+ \rho \rightarrow \Delta^{++} \pi^0 \pi^0$
$305 + 36 \\ -119$		ETKIN	82B MPS	$23 \pi^- p \rightarrow n2K_S^0$
180 ± 60	700	APEL	75 NICE	$40 \pi^- \rho \rightarrow n2\pi^0$
$225 + 120 \\ -70$		BLUM	75 ASPK	18.4 $\pi^- \rho \rightarrow nK^+K^-$
• • • We do not use the	ne followin	g data for average	s, fits, limits,	etc. • • •
243± 16		⁷ ALPER	80 CNTR	$62 \pi^- p \rightarrow K^+ K^- n$
140 ± 15		⁷ ROZANSKA	80 SPRK	$18 \pi^- p \rightarrow p \overline{p} n$

243 ± 16	ALPER 80 CNTR 62 π $p \rightarrow K^{+}K^{-}R^{-}$
140 ± 15	7 ROZANSKA 80 SPRK 18 π^{-} $p \rightarrow p\overline{p}$ n
263± 57	⁷ CORDEN 79 OMEG 12–15 $\pi^- p \rightarrow n2\pi$
100 ± 28	EVANGELISTA 79B OMEG 10 $\pi^- p \rightarrow K^+ K^- n$
107 ± 56	⁸ ANTIPOV 77 CIBS $25 \pi^- p \rightarrow p3\pi$
_	

⁵ From a partial-wave analysis of the data.

f4(2050) DECAY MODES

	Mode	Fraction $(\Gamma_{\hat{I}}/\Gamma)$
Γ ₁	ωω	(26 ±6)%
Γ_2	$\pi \pi$	(17.0 ± 1.5) %
Γ_3	$K\overline{K}$	$(6.8^{+3.4}_{-1.8}) \times 10^{-3}$
Γ_4	$\eta \eta$	$(2.1\pm0.8)\times10^{-3}$
Γ_5	$\eta \eta$ $4\pi^0$	< 1.2 %
Γ ₆	$\gamma \gamma$	

$f_4(2050) \Gamma(i)\Gamma(\gamma\gamma)/\Gamma(total)$

$\Gamma(K\overline{K}) \times \Gamma$	$(\gamma \gamma)/\Gamma$	total					$\Gamma_3\Gamma_6/\Gamma$
VALUE (keV)		CL%	DOCUMENT ID		TECN	COMMENT	
• • • We do	not use th	ne followin	g data for average	s, fits	, limits	etc. • • •	
< 0.29		95	ALTHOFF	85B	TASS	$\gamma \gamma \rightarrow K \overline{K} \gamma$	T
$\Gamma(\pi\pi) \times \Gamma$	$(\gamma \gamma)/\Gamma_{\rm t}$	otal					$\Gamma_2\Gamma_6/\Gamma$
VALUE (keV)	CL%	EVTS	DOCUMENT ID		TECN	COMMENT	
< 1.1	95	13 ±	OEST	90	JADE	$e^+e^- \rightarrow e$	$+e^{-\pi^0\pi^0}$

f4(2050) BRANCHING RATIOS

$\Gamma(\omega\omega)/\Gamma(\pi\pi)$					Γ_1/Γ_2
VALUE	DOCUMENT ID		TECN	COMMENT	
1.5 ±0.3	ALDE	90	GAM2	38 $\pi^- p \rightarrow$	$\omega \omega n$

From an amplitude analysis of the reaction $\pi^+\pi^- \to 2\pi^0$. $^3I(J^P)=0$ (4⁺) from amplitude analysis assuming one-pion exchange. 4 Width errors enlarged by us to $4\Gamma/\sqrt{N}$; see the note with the K^* (892) mass.

⁶ From an amplitude analysis of the reaction $\pi^+\pi^- \rightarrow 2\pi^0$.

 $⁷I(J^P) = 0(4^+)$ from amplitude analysis assuming one-pion exchange. ⁸ Width errors enlarged by us to $4\Gamma/\sqrt{N}$; see the note with the $K^*(892)$ mass.

r/ \/r		
Γ(ππ)/Γ _{total} VALUE	Γ ₂ /Γ	$\Gamma(f_2(1270)\pi)/\Gamma(3\pi)$ VALUE DOCUMENT ID TECH COMMENT
0.170±0.015 OUR AVERAGE		0.36 \pm 0.09 5 DAUM 818 CNTR 63,94 $\pi^- p$
1.18 ±0.03 1.16 ±0.03	9 BINON 83C GAM2 $38 \pi^- p \rightarrow n4\gamma$ 9 CASON 82 STRC $8 \pi^+ p \rightarrow \Delta^{++} \pi^0 \pi^0$	$\Gamma((\pi\pi)_s\pi)/\Gamma(3\pi)$ Γ_4/Γ_5
.17 ±0.02	9 CORDEN 79 OMEG 12–15 $\pi^- p \to n2\pi$	<u>VALUE</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> 0.45±0.07
⁹ Assuming one pion exchange.		
$\Gamma(K\overline{K})/\Gamma(\pi\pi)$	Γ ₃ /Γ ₂ DOCUMENT ID TECN COMMENT	D-wave/S-wave RATIO FOR $\pi_2(2100) \rightarrow f_2(1270)\pi$ VALUE DOCUMENT ID TECN COMMENT
0.04 +0.02 -0.01	ETKIN 828 MPS $23 \pi^- \rho \rightarrow n2K_S^0$	0.39 \pm 0.23
$\Gamma(\eta\eta)/\Gamma_{total}$	Γ ₄ /Γ	π_2 (2100) REFERENCES
VALUE (units 10 ⁻³) 2.1±0.8	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	AMELIN 958 PL B356 595 +Berdnikov, Bityukov+ (SERP, TBIL) DAUM 81B NP B182 269 +Hertzberger+ (AMST, CERN, CRAC, MPIM, OXF+)
$\Gamma(4\pi^0)/\Gamma_{\text{total}}$	Γ_5/Γ	C PC
<0.012	ALDE 87 GAM4 $100 \pi^- p \rightarrow 4\pi^0 n$	$f_2(2150)$ $I^G(J^{PC}) = 0^+(2^{++})$
f ₄	(2050) REFERENCES	OMITTED FROM SUMMARY TABLE This entry was previously called T_0 .
BELADIDZE 92B ZPHY C54 367 ALDE 90 PL B241 600	+Bityukov, Borisov+ +Binon+ (SERP, BELG, LANL, LAPP, PISA, KEK)	6(2150) MASS
DEST 90 ZPHY C47 343 ALDE 87 PL B198 286	+Olsson+ (JADE Collab.) +Binon, Bricman+ (LANL, BRUX, SERP, LAPP) +Cosme+ (LALO, CLER, FRAS, PADO)	72(2130) WASS
AUGUSTIN 87 ZPHY C36 369 BALTRUSAIT 87 PR D35 2077 ALDE 86D NP B269 485	+Cosme+- Baltrusaitis, Coffman, Dubois+ (Mark III Collab.) +Binon, Bricman+ (BELG, LAPP, SERP, CERN, LANL)	00 -> ##
ALTHOFF 85B ZPHY C29 189 BINON 84B LNC 39 41	+Braunschweig, Kirschfink+ (TASSO Collab.) +Donskov, Duteil, Gouanere+ (SERP, BELG, LAPP)	$\overline{ ho} ho o \pi \pi$ VALUE (MeV) DOCUMENT ID TECN COMMENT
BINON 83C SJNP 38 723 Translated from YA	+Gouanere, Donskov, Duteil+ (SERP, BRUX+) (AF 38 1199.	• • • We do not use the following data for averages, fits, limits, etc. • • •
DENNEY 83 PR D28 2726 DASON 82 PRL 48 1316	+Cranley, Firestone, Chapman+ (IOWA, MICH) +Biswas, Baumbaugh, Bishop+ (NDAM, ANL)	\sim 2226 HASAN 94 RVUE $\overline{p}p ightarrow \pi\pi$ \sim 2170 1 MARTIN 80B RVUE
TKIN 82B PR D25 1786 LPER 80 PL 94B 422	+Foley, Lai+ (BNL, CUNY, TUFTS, VAND) +Becker+ (AMST, CERN, CRAC, MPIM, OXF+)	\sim 2150 $^{\circ}$ MARTIN 80C RVUE
OZANSKA 80 NP B162 505 ORDEN 79 NP B157 250	+Blum, Dietl, Grayer, Lorenz+ (MPIM, CERN) +Dowell, Garvey+ (BIRM, RHEL, TELA, LOWC) JP	\sim 2150 2 DULUDE 788 OSPK 1–2 $\overline{p} ho ightarrow \pi^0 \pi^0$
VANGELISTA 79B NP B154 381	+ (BARI, BONN, CERN, DARE, GLAS, LIVP+) +Busnello, Damgaard, Kienzle+ (SERP, GEVA)	${}^1I(J^P)=0$ (2+) from simultaneous analysis of $\rho\overline{\rho}\to\pi^-\pi^+$ and $\pi^0\pi^0$.
PEL 75 PL 57B 398	+Busnein, Damgadd, Nieitzie+ +Augenstein+(KARLK, KARLE, PISA, SERP, WIEN, CERN)JP +Chabaud, Dietl, Garelick, Grayer+ (CERN, MPIM) JP	$^2I^G(J^P)=0^+(2^+)$ from partial-wave amplitude analysis.
LUM 75 PL 57B 403		S-CHANNEL $\overline{p}p$ or $\overline{N}N$
—— отн	HER RELATED PAPERS ———	VALUE (MeV) DOCUMENT ID TECN CHG COMMENT
CASON 83 PR D28 1586 GOTTESMAN 80 PR D22 1503 WAGNER 74 London Conf. 2 2	+Cannata, Baumbaugh, Bishop+ (NDAM, ANL) +Jacobs+ (SYRA, BRAN, BNL, CINC) (MPIM)	• • • We do not use the following data for averages, fits, limits, etc. • • • ~ 2190 3 CUTTS 788 CNTR $0.97-3\ \bar{p}\ p \rightarrow 0.97-3\ \bar{p}\ $
VACINETY 17 EURODI COM. 2 2	()	2155±15 3.4 COUPLAND 77 CNTR 0 $0.7-2.4 \ \overline{p} p \rightarrow \overline{p}$
$\pi_2(2100)$	$I^{G}(J^{PC}) = 1^{-}(2^{-+})$	$2193\pm~2$ 3.5 ALSPECTOR 73 CNTR $\overline{p}p$ S channel 3 Isospins 0 and 1 not separated.
$\pi_2(2100)$. (0,) - (-)	⁴ From a fit to the total elastic cross section.
DMITTED FROM SUMMA	ARY TABLE	⁵ Referred to as <i>T</i> or <i>T</i> region by ALSPECTOR 73.
Moode confirmation		
Needs confirmation.		ηη MODE VALUE (MeV) DOCUMENT ID TECN COMMENT
weeus commation.	π ₂ (2100) MASS	
		$VALUE (MeV)$ DOCUMENT ID TECN COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • 2175 ±20 PROKOSHKIN 95D GAM4 300 π ⁻ N → π ⁻ N2η,
⁄ALUE (MeV)	π ₂ (2100) MASS DOCUMENT ID TECN COMMENT	VALUE (MeV) DOCUMENT ID TECN COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • • 2175±20 PROKOSHKIN 95D GAM4 300 π ⁻ N → π ⁻ N2η, 450 ρρ → ρρ2η 2130±35 SINGOVSKI 94 GAM4 450 ρρ → ρρ2η
/ALUE (MeV) 2090± 29 OUR AVERAGE	DOCUMENT ID TECN COMMENT 1 AMELIN 958 VES $36 \pi^- A \rightarrow$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
//ALUE (MeV) 1090± 29 OUR AVERAGE 1090± 30 1100±150	DOCUMENT ID TECN COMMENT 1 AMELIN 958 VES $36 \pi^{-} A \rightarrow \pi^{+} \pi^{-} A \rightarrow \pi^{+} \pi^{-} A$ 2 DAUM 81B CNTR 63,94 $\pi^{-} p \rightarrow 3\pi X$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
$ALUE (\text{MeV})$ $090\pm 29 \text{OUR AVERAGE}$ 090 ± 30 100 ± 150 $1 \text{From a fit to } J^{PC} = 2^{-} + f$	DOCUMENT ID TECN COMMENT 1 AMELIN 95B VES $36 \begin{array}{ccc} \pi^- A \rightarrow & \\ \pi^+ \pi^- \pi^- A \end{array}$ 2 DAUM 81B CNTR $63,94 \begin{array}{ccc} \pi^- p \rightarrow & 3\pi \end{array}$ X $f_2(1270)\pi$, $(\pi\pi)_S\pi$ waves.	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
/ALUE (MeV) 1090± 29 OUR AVERAGE 1090± 30 1100±150	DOCUMENT ID TECN COMMENT 1 AMELIN 95B VES $36 \begin{array}{ccc} \pi^- A \rightarrow & \\ \pi^+ \pi^- \pi^- A \end{array}$ 2 DAUM 81B CNTR $63,94 \begin{array}{ccc} \pi^- p \rightarrow & 3\pi \end{array}$ X $f_2(1270)\pi$, $(\pi\pi)_S\pi$ waves.	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
$ALUE (\text{MeV})$ $090\pm 29 \text{OUR AVERAGE}$ 090 ± 30 100 ± 150 $1 \text{From a fit to } J^{PC} = 2^{-} + f$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
2090 ± 29 OUR AVERAGE 2090 ± 30 2100 ± 150 1 From a fit to $J^{PC} = 2^{-} + f$	DOCUMENT ID TECN COMMENT 1 AMELIN 95B VES $36 \begin{array}{ccc} \pi^- A \rightarrow & \\ \pi^+ \pi^- \pi^- A \end{array}$ 2 DAUM 81B CNTR $63,94 \begin{array}{ccc} \pi^- p \rightarrow & 3\pi \end{array}$ X $f_2(1270)\pi$, $(\pi\pi)_S\pi$ waves.	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
WALUE (MeV) 2090 \pm 30 2090 \pm 30 1 From a fit to $J^{PC} = 2^{-} + f$ 2 From a two-resonance fit to forward the fit of the fit o	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
ALUE (MeV) $2090 \pm 29 OUR AVERAGE$ 2090 ± 30 2100 ± 150 $1 \text{From a fit to} J^{PC} = 2^{-+} f$ 2 From a two-resonance fit to f 2 From a two-resonance f to $f2 From a two-resonance f$ to $f2 From a two-resonance f$ to f	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
MALUE (MeV) 1090 \pm 29 OUR AVERAGE 1090 \pm 30 1100 \pm 150 2 From a fit to $J^{PC} = 2^{-} + f$ 2 From a two-resonance fit to form 14 LUE (MeV) 125 \pm 50 OUR AVERAGE Error 1090 \pm 100	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
MLUE (MeV) $1090 \pm 29 OUR AVERAGE$ 1000 ± 150 $1 From a fit to J^{PC} = 2^{-} + f$ 2 From a two-resonance fit to fo 1 From a two-resonance fit to fo 2 From a two-resonance fit to fo	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
$ALUE (MeV)$ $090 \pm 29 OUR AVERAGE$ 090 ± 30 100 ± 150 $^{1} From a fit to J^{PC} = 2^{-} + f$ $^{2} From a two-resonance fit to fo$ $2 From a two-resonance fit to fo$ $3 From a fit to J^{PC} = 2^{-} + fo$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
$MLUE (MeV)$ $090 \pm 29 OUR AVERAGE$ 090 ± 30 100 ± 150 $1 From a fit to J^{PC} = 2^{-} + f$ $2 From a two-resonance fit to fo$ $MLUE (MeV)$ $25 \pm 50 OUR AVERAGE Error 20 \pm 100$ 51 ± 50	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
MALUE (MeV) 1090 \pm 29 OUR AVERAGE 1090 \pm 30 1100 \pm 150 1 From a fit to $J^{PC} = 2^{-} + f$ 2 From a two-resonance fit to for 125 \pm 50 OUR AVERAGE 13 From a fit to $J^{PC} = 2^{-} + f$ 4 From a two-resonance fit to for	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
MALUE (MeV) $1090 \pm 29 OUR AVERAGE$ 1090 ± 30 1100 ± 150 $1 From a fit to J^{PC} = 2^{-} + f$ 2 From a two-resonance fit to fo 1 From a two-resonance fit to fo $1 From a fit to J^{PC} = 2^{-} + f$ $1 From a fit to J^{PC} = 2^{-} + f$ 1 From a two-resonance fit to fo	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
2090 \pm 29 OUR AVERAGE 2090 \pm 30 \pm 150 \pm 150 \pm 16 From a fit to $J^{PC} = 2^{-} + f$ 2 From a two-resonance fit to for 2000 \pm 100	1 AMELIN 958 VES $36 \pi^- A \xrightarrow{\pi^+ \pi^- \pi^-} A$ 2 DAUM 818 CNTR $63,94 \pi^- \rho \rightarrow 3\pi X$ $f_2(1270)\pi, (\pi\pi)_S \pi$ waves. our 2^-0^+ waves. $\pi_2(2100) \text{ WIDTH}$ $DOCUMENT ID \qquad TECN \qquad COMMENT$ or includes scale factor of 1.2. 3 AMELIN 958 VES $36 \pi^- A \xrightarrow{\pi^+ \pi^- \pi^-} A$ 4 DAUM 818 CNTR $63,94 \pi^- \rho \rightarrow 3\pi X$ $f_2(1270)\pi, (\pi\pi)_S \pi$ waves. four 2^-0^+ waves. (2100) DECAY MODES Fraction (Γ_i/Γ)	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
2090 \pm 29 OUR AVERAGE 2090 \pm 30 2100 \pm 150 1 From a fit to $J^{PC} = 2^{-} + f$ 2 From a two-resonance fit to for 225 \pm 50 OUR AVERAGE 250 \pm 100 3 From a fit to $J^{PC} = 2^{-} + f$ 4 From a two-resonance fit to for 4 Mode Mode	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
MALUE (MeV) 1090 \pm 29 OUR AVERAGE 1000 \pm 150 1 From a fit to $J^{PC} = 2^{-} + f$ 2 From a two-resonance fit to for 120 \pm 100 151 \pm 50 3 From a fit to $J^{PC} = 2^{-} + f$ 4 From a two-resonance fit to for 14 From a two-resonance fit to for 151 \pm 50 Mode 1 3π 2 $\rho\pi$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
MALUE (MeV) 090 \pm 29 OUR AVERAGE 090 \pm 30 100 \pm 150 1 From a fit to $J^{PC} = 2^{-} + f$ 2 From a two-resonance fit to form MALUE (MeV) 25 \pm 50 OUR AVERAGE Error 20 \pm 100 3 From a fit to $J^{PC} = 2^{-} + f$ 4 From a two-resonance fit to form 72 (Mode) 1 3π 2 $\rho\pi$ 3 $f_2(1270)\pi$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	• • We do not use the following data for averages, fits, limits, etc. • • • • • • • We do not use the following data for averages, fits, limits, etc. • • • • • • • • • • • • • • • • • • •
MALUE (MeV) 1090 \pm 29 OUR AVERAGE 1000 \pm 150 1 From a fit to $J^{PC} = 2^{-} + f$ 2 From a two-resonance fit to for 125 \pm 50 OUR AVERAGE 120 \pm 100 13 From a fit to $J^{PC} = 2^{-} + f$ 4 From a two-resonance fit to for 14 From a two-resonance fit to for 15 \pm 50 Mode 1 \pm 3 π 2 \pm μ π 3 \pm	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
$MLUE (\text{MeV})$ $090\pm 29 \text{OUR AVERAGE}$ 090 ± 30 100 ± 150 $1 \text{From a fit to } J^{PC} = 2^{-} + f$ $2 \text{From a two-resonance fit to fo}$ 20 ± 100 20 ± 100 $3 \text{From a fit to } J^{PC} = 2^{-} + f$ $4 \text{From a two-resonance fit to fo}$ $4 \text{From a two-resonance fit to fo}$ $mathridge Mode$ m	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
2090 ± 29 OUR AVERAGE 2090 ± 30 2100 ± 150 1 From a fit to $J^{PC} = 2^{-} + f$ 2 From a two-resonance fit to for 22 From a fit to $J^{PC} = 2^{-} + f$ 3020 ± 100 515 ± 50 OUR AVERAGE Error 33 From a fit to $J^{PC} = 2^{-} + f$ 4 From a two-resonance fit to for 4 From a $J^{PC} = 2^{-} + f$ 6 From a $J^{PC} = 2^{-} + f$ 7 From a $J^{PC} = 2^{-} + f$ 8 From a $J^{PC} = 2^{-} + f$ 9 From a $J^{$	1 AMELIN 958 VES $36 \pi^- A \rightarrow \pi^+ \pi^- \pi^- A$ 2 DAUM 818 CNTR $63,94 \pi^- \rho \rightarrow 3\pi X$ Four 2^-0^+ waves. Full 1 AMELIN 958 VES $36 \pi^- A \rightarrow \pi^+ \pi^- \pi^- A$ Four 2^-0^+ waves. Full 1 AMELIN 958 VES $36 \pi^- A \rightarrow \pi^- A$ A DAUM 818 CNTR $63,94 \pi^- \rho \rightarrow 3\pi X$ Full 1 AMELIN 958 VES $36 \pi^- A \rightarrow \pi^- A$ A DAUM 818 CNTR $63,94 \pi^- \rho \rightarrow 3\pi X$ Full 1 AMELIN 958 VES $36 \pi^- A \rightarrow \pi^- A$ A DAUM 818 CNTR $63,94 \pi^- \rho \rightarrow 3\pi X$ Full 1 AMELIN 958 VES $36 \pi^- A \rightarrow \pi^- A$ A DAUM 818 CNTR $63,94 \pi^- \rho \rightarrow 3\pi X$ Full 1 AMELIN 958 VES $36 \pi^- A \rightarrow \pi^- A$ Full 1 AMELIN 958 VES $36 \pi^- A \rightarrow \pi^- A$ A DAUM 818 CNTR $63,94 \pi^- \rho \rightarrow 3\pi X$ Full 1 AMELIN 958 VES $36 \pi^- A \rightarrow \pi^- A$ Full 1 AMELIN 958 VES $36 \pi^- A \rightarrow \pi^- A$ A DAUM 818 CNTR $63,94 \pi^- \rho \rightarrow 3\pi X$ Full 1 AMELIN 958 VES $36 \pi^- A \rightarrow \pi^- A$ Full 1 AMELIN 958 VES $36 \pi^- A \rightarrow \pi^- A$ A DAUM 818 CNTR $63,94 \pi^- \rho \rightarrow 3\pi X$ Full 1 AMELIN 958 VES $36 \pi^- A \rightarrow \pi^- A$ Full 2 AMELIN 958 VES $36 \pi^- A \rightarrow \pi^- A$ Full 2 AMELIN 958 VES $36 \pi^- A \rightarrow \pi^- A$ Full 2 AMELIN 958 VES $36 \pi^- A \rightarrow \pi^- A$ Full 2 AMELIN 958 VES $36 \pi^- A \rightarrow \pi^- A$ Full 2 AMELIN 958 VES $36 \pi^- A \rightarrow \pi^- A$ Full 2 AMELIN 958 VES $36 \pi^- A \rightarrow \pi^- A$ Full 2 AMELIN	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
VALUE (MeV) 2090 \pm 29 OUR AVERAGE 2090 \pm 30 2100 \pm 150 ¹ From a fit to $J^{PC} = 2^{-} + f$ ² From a two-resonance fit to for VALUE (MeV) 625 \pm 50 OUR AVERAGE Error 520 \pm 100 651 \pm 50 ³ From a fit to $J^{PC} = 2^{-} + f$ ⁴ From a two-resonance fit to for Mode 1 3π 2 $\rho\pi$ 1 3π 2 $\rho\pi$ 1 3π 2 0π 1 3π 2 0π 3 0π 4 0π 6 0π 7 0π 8 0π	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$

Meson Particle Listings

 $f_2(2150)$, $\rho(2150)$, $f_0(2200)$

f ₂ (2150)	DECAY	MODES

Mode	
ππ $ηη$ $κ$	_

f2(2150) BRANCHING RATIOS

$\Gamma(K\overline{K})/\Gamma(\eta\eta)$					Γ_3/Γ_2
VALUE	CL%	DOCUMENT ID	TECN	COMMENT	
• • • We do not use the	following	g data for averages, fits	, limits,	etc. • • •	
< 0.1	95	¹⁰ PROKOSHKIN 95D	GAM4	$\begin{array}{c} 300 \ \pi^- \ N \rightarrow \\ 450 \ p \ p \rightarrow \end{array}$	
¹⁰ Using data from ARM	ISTRON	G 89D.			· · ·
$\Gamma(\pi\pi)/\Gamma(\eta\eta)$					Γ_1/Γ_2
VALUE	CL%	DOCUMENT ID	TECN	COMMENT	
• • • We do not use the	following	g data for averages, fits	, limits,	etc. • • •	
<0.33	95	11 PROKOSHKIN 95D	GAM4	$\begin{array}{c} 300~\pi^-~N \rightarrow \\ 450~\rho\rho \rightarrow \end{array}$	

$^{11}\,\mathrm{Derived}$ from a $\pi^0\,\pi^0/\eta\,\eta$ limit. f2(2150) REFERENCES

PROKOSHKIN	95D	SPD 40 495 Translated from	DANS	344 469		(SERP)	IGJP
HASAN	94	PL B334 215		+Bugg		(LOQM)	
SINGOVSKI	94	NC 107 1911			(ENIAL EEDD	(SERP)	
ARMSTRONG	93C 89D	PL B307 394 PL B227 186		+Bettoni+ +Benavoun		GENO, UCI, NWES+) BIRM, CERN, CDEF)	
MARTIN	80B	NP B176 355		+Morgan	(ATHU, DARI,	(LOUC, RHEL)	ID
MARTIN	80C	NP B169 216		+Pennington		(DURH)	
CUTTS	78B	PR D17 16		+Good, Grannis, Gre		(STON, WISC)	
DULUDE	78B	PL 79B 335		+Lanou, Massimo, P.		(BROW, MIT, BARI)	JP
COUPLAND	77	PL 71B 460		+Eisenhandler, Gibson		(LOQM, RHEL)	
ALSPECTOR	73	PRL 30 511		+Cohen, Cvijanovich-	+	(RUTG, UPNJ)	

- OTHER RELATED PAPERS -

FIELDS	71	PRL 27	1749	+Cooper,	Rhines, Allison		(ANL	., OXF)
YOH	71	PRL 26	922	+Barish,	Caroll, Lobkowicz+	(CIT,		ROCH)

$\rho(2150)$

$$I^{G}(J^{PC}) = 1^{+}(1^{-})$$

OMITTED FROM SUMMARY TABLE This entry was previously called $T_1(2190)$.

ρ (2150) MASS

$e^{+}e^{-} \rightarrow \pi^{+}\pi^{-}, K^{+}K^{-}, 6\pi$

VALUE (MeV)	DOCUMENT ID	TECN	CHG COMMENT
2149±17 OUR AVERAGE	Includes data from the	datablock th	at follows this one.
2153±37	BIAGINI	91 RVUE	e+ e _ →
			$\pi^+\pi^-$,
	1		K+K-
2110±50	¹ CLEGG	90 RVUE	0 $e^+e^- \rightarrow 3(\pi^+\pi^-)$
			$2(\pi^{+}\pi^{-}\pi^{0})$

$\overline{p}p \rightarrow \pi\pi$

VALUE (MeV)	DOCUMENT II	<u> </u>	ECN	COMME	:NI
	ne following data for avera	ges, fits,	limits,	etc. •	• •
~ 2191	HASAN	94 F	VUE	$\overline{p}p \rightarrow$	$\pi\pi$
\sim 1988	HASAN	94 F	VUE	$\overline{p}p \rightarrow$	$\pi\pi$
~ 2170	² MARTIN	80B F	VUE		
~ 2100	² MARTIN	80c F	VUE		

S-CHANNEL NN

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT	
• • • We do not use t	he following data for average	s, fits	, limits,	etc. •	• •	
~ 2190	³ CUTTS	78B	CNTR		$0.97-3 \overline{p} p \rightarrow \overline{N} N$	
2155 ± 15	^{3,4} COUPLAND			0	0.7-2.4 pp →	$\overline{p}p$
2193± 2	^{3,5} ALSPECTOR	73	CNTR		$\overline{p}p$ S channel	
2190 ± 10	⁶ ABRAMS	70	CNTR		S channel $\overline{p}N$	

$\pi^- p \rightarrow \omega \pi^0 n$

VALUE (MeV) DOCUMENT ID TECN COMMENT

The data in this block is included in the average printed for a previous datablock.

2155±21 OUR AVERAGE

2140±30	ALDE	95 GAM2 38 $\pi^- p \rightarrow \omega \pi^0 n$
2170 ± 30	ALDE	92C GAM4 $100 \pi^- p \rightarrow \omega \pi^0 n$

ρ (2150) WIDTH

$e^+e^- \rightarrow \pi^+\pi^-, K^+K$ VALUE (MeV)	DOCUMENT II	O TECN (CHG COMMENT
363 ± 50 OUR AVERAGE	Includes data from th	e datablock that	follows this one.
389± 79	BIAGINI	91 RVUE	$e^+e^{\pi^+\pi^-}$
410 ± 100	⁷ CLEGG	90 RVUE 0	$e^{+\stackrel{K}{e^{-}} \xrightarrow{\rightarrow} 3(\pi^{+}\pi^{-}),}$ $2(\pi^{+}\pi^{-}\pi^{0})$

$\overline{\rho} \rho \rightarrow \pi \pi$	
VALUE (MeV)	DOCUMENT ID
• • • We do not use the following	g data for averages, f

VALUE (MeV)	DOCUMENT I	D	TECN	COMMENT	
• • • We do not use the follow	ling data for avera	ges, fits	, limits,	etc. • • •	
~ 296	HASAN	94	RVUE	$\overline{p}p \rightarrow \pi \pi$	
~ 244	HASAN	94	RVUE	$\overline{p}p \rightarrow \pi\pi$	
~ 250	⁸ MARTIN	80B	RVUE		
~ 200	⁸ MARTIN	80C	RVUE		

S-CHANNEL ₩N

V	ALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT	
٠	• • We do not use the f	ollowing data for averages	, fits	, limits,	etc. •	• •	
	135 ± 75	9,10 COUPLAND			0	0.7-2.4 p p →	$\overline{p}p$
	98± 8	¹⁰ ALSPECTOR	73	CNTR		$\overline{p}p$ S channel	
~	85	¹¹ ABRAMS	70	CNTR		S channel $\overline{p}N$	

<u>VALUE (MeV)</u> <u>DOCUMENT ID</u> <u>TECN_COMMENT</u>
The data in this block is included in the average printed for a previous datablock.

320±70 • • • We do not use the follo	ALDE	95 GAM2 38 $\pi^- p \rightarrow$	$\omega \pi^0 n$
~ 300	ALDE	92c GAM4 100 π ⁻ ρ	$\omega \pi^0 n$

- $^{7}_{8}$ Includes ATKINSON 85.
 8 $I(J^{P})=1(1^{-})$ from simultaneous analysis of $p\overline{p}\to\pi^-\pi^+$ and $\pi^0\pi^0$.
 9 From a fit to the total elastic cross section.
 10 Isospins 0 and 1 not separated.
 11 Seen as bump in I=1 State. See also COOPER 68. PEASLEE 75 confirm $\overline{p}p$ results of ABRAMS 70, no narrow structure.

ρ (2150) REFERENCES

ALDE HASAN ALDE BIAGINI CLEGG ATKINSON MARTIN MARTIN CUTTS COUPLAND PEASLEE	95 94 92C 91 90 85 80B 80C 78B 77	ZPHY C66 379 PL B334 215 ZPHY C54 553 NC 104A 363 ZPHY C45 677 ZPHY C29 333 NP B176 355 NP B169 216 PR D17 16 PL 71B 460 PL 57B 189	+ Binon, Bricman+ (GAMS Collab,) JE + Bugg + Bencheikh, Binon+ (BELG, SERP, KEK, LANL, LAPP) + Dubnicka+ (FRAS, PRAG) + Domachie (LANC, MCHS) + Morgan (BONN, CERN, GLAS, LANC, MCHS, PPP+) + Pennington (DURH) JF - Good, Grannis, Green, Lee+ (STON, WISC) + Eisenhandler, Gibson, Astbury+ (LOQM, RHEL) JF - Demarzo, Guerriero+ (CANB, BARI, BROW, MIT)
ALSPECTOR	73	PRL 30 511	+Cohen, Cvijanovich+ (RUTG, UPNJ)
ABRAMS	70	PR D1 1917	+Cool, Giacomelli, Kycia, Leontic, Li+ (BNL)
COOPER	68	PRL 20 1059	+Hyman, Manner, Musgrave+ (ANL)

OTHER RELATED PAPERS -

BRICMAN	69	PL 29B 451	+Ferro-Luzzi, Bizard+	(CERN,	CAEN, SACL)
ABRAMS	67C	PRL 18 1209	+Cool, Giacomelli, Kycia, Leontic,		(BNL)

$f_0(2200)$

$$I^{G}(J^{PC}) = 0^{+}(0^{+})$$

OMITTED FROM SUMMARY TABLE Seen at DCI in the $K_0^0K_0^0$ system. Not seen in Υ radiative decays (BARU 89). Needs confirmation.

f₀(2200) MASS

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
2197±17	¹ AUGUSTIN	88	DM2	0	$J/\psi \rightarrow \gamma K_S^0 K_S^0$
• • • We do not use the fo	ollowing data for average	s, fits	s, limits,	etc. •	• •
\sim 2122	HASAN	94	RVUE		$\overline{p} p \rightarrow \pi \pi$
~ 2321	HASAN	94	RVUE		$\overline{p}p \rightarrow \pi \pi$
$^{ m 1}$ Cannot determine spin t	to be 0.				

f₀(2200) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
201±51	² AUGUSTIN	88	DM2	0	$J/\psi \rightarrow \gamma K_5^0 K_5^0$
• • We do not use the foll	owing data for average	es, fit	s, limits,	etc. •	• •
~ 273	HASAN	94	RVUE		$\overline{\rho} \rho \rightarrow \pi \pi$
~ 223	HASAN	94	RVUE		$\overline{\rho} \rho \rightarrow \pi \pi$
² Cannot determine spin to	be 0.				

f₀(2200) REFERENCES

HASAN 94 PL B334 215 +Bugg	(LOQM)
BARU 89 ZPHY C42 505 +Beilin, Blinov, Blinov+	(NOVO)
AUGUSTIN 88 PRL 60 2238 +Calcaterra+	(DM2 Collab.)

Includes ATKINSON 85. $2(D^p) = 1(1^-)$ from simultaneous analysis of $\rho \overline{\rho} \to \pi^- \pi^+$ and $\pi^0 \pi^0$. 3 Isospins 0 and 1 not separated. From a fit to the total elastic cross section. Referred to as T or T region by ALSPECTOR 73. Seen as bump in I = 1 state. See also COOPER 68. PEASLEE 75 confirm $\overline{\rho} \rho$ results of ABRAMS 70, no narrow structure.

 $f_{J}(2220)$ was $\xi(2220)$

$$I^{G}(J^{PC}) = 0^{+}(2^{++} \text{ or } 4^{++})$$

OMITTED FROM SUMMARY TABLE

This state has been seen at SPEAR in the $K\overline{K}$ systems ($K^+K^$ and $K^0_S\,K^0_S)$ produced in the radiative decay of $J/\psi(1S)$. Seen in $\eta\eta'$ (ALDE 86B), in $K_0^SK_0^S$ (ASTON 88D), and in K^+K^- (ASTON 88F). Not seen in Υ radiative decays (BARU 89) nor in Binclusive decay (BEHRENDS 84). Not seen in $\overline{p}p \rightarrow K^+K^-$ formation experiment (BARDIN 87,SCULLI 87) and $\bar{p}p \to K_S^0 K_S^0$ formation experiment (BARNES 93). Not seen at DCI in either K^+K^- or $K_S^0 K_S^0$ systems (AUGUSTIN 88). Needs confirmation.

$f_J(2220)$ MASS

VALUE (MeV)	EVTS RAGE	DOCUMENT ID	TECN	COMMENT
2209 + 17 ± 10		ASTON	88F LASS	11 $K^- p \rightarrow K^+ K^- \Lambda$
2230±20				$40 \pi^- p \rightarrow K_5^0 K_5^0 n$
2220 ± 10	41			$38-100 \pi p \rightarrow n\eta \eta'$
2230 ± 6 ± 14	93			$e^+e^- \rightarrow \gamma K^+K^-$
$2232\pm7\pm7$	23	BALTRUSAIT.	.86D MRK3	$e^+e^- \rightarrow \gamma K_S^0 K_S^0$
¹ ALDE 86B uses of	lata from bol	th the GAMS-2000	and GAMS-	4000 detectors.

$f_J(2220)$ WIDTH

		*, ,
VALUE (MeV)	EVTS	DOCUMENT ID TECN COMMENT
38 + 15 OUR AVERAG	Ε	
60 ^{+ 107} - 57		ASTON 88F LASS 11 $K^- \rho \rightarrow K^+ K^- \Lambda$
80± 30		BOLONKIN 88 SPEC 40 $\pi^- p ightarrow K_S^0 K_S^0 n$
$26^{+}_{-16}^{20}\pm 17$	93	BALTRUSAIT86D MRK3 $e^+e^- \rightarrow \gamma K^+K^-$
$18 + 23 \pm 10$	23	BALTRUSAIT86D MRK3 $e^+e^- ightarrow \gamma K_S^0 K_S^0$

f_J(2220) DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Confidence level
Γ ₁	ΚK		
Γ_2	p p	$< 1.1 \times 10^{-3}$	99.7%
Γ_3	$\gamma \gamma$		
Γ_4	$\eta \eta'(958)$		

$f_J(2220) \Gamma(i)\Gamma(\gamma\gamma)/\Gamma(total)$

VALUE (keV)	CL%	DOCUMENT ID	TECN	COMMENT
<0.086	95	² ALBRECHT	90g ARG	$\gamma \gamma \rightarrow K^+ K^-$
• • We do not	use the followi	ng data for average	s, fits, limits	, etc. • • •
	95	3 ALTHOFF	OFD TACC	KV-

f_J(2220) BRANCHING RATIOS

$\Gamma(p\overline{p})/\Gamma_{\text{total}}$						Γ_2/Γ
VALUE (units 10-3)	CL%	DOCUMENT I	D	TECN	COMMENT	
<1.1	99.7	4 BARNES	93	SPEC	$1.3-1.57\overline{p}p$ \rightarrow	$\kappa_5^0 \kappa_5^0$
• • • We do not u	ise the followir	ng data for avera	ges, fit	s, limits,	etc. • • •	
<2.6	99.7	⁴ BARDIN	87	CNTR	$1.3-1.5\overline{p}p \rightarrow$	$\kappa^+ \kappa^-$
< 3.6	99.7	⁴ SCULLI	87	CNTR	1.29-1.55 <i>pp</i> −	→ K+K-
4 Assuming $\Gamma =$	30-35 MeV, <i>J</i>	$P=2^+$ and B(1	J(2220) → K	\overline{K}) = 10%.	

f_I(2220) REFERENCES

BARNES 93	PL B309 469	+Birien, Breunlich	(PS185 Collab.)
ALBRECHT 90G	ZPHY C48 183	+Ehrlichmann, Harder+	(ARGUS Collab.)
BARU 89	ZPHY C42 505	+Beilin, Blinov, Blinov+	(NOVO)
ASTON 88D	NP B301 525	+Awaji, Bienz+	(SLAC, NAGO, CINC, INUS)
ASTON 88F	PL B215 199	+Awaji+	(SLAC, NAGO, CINC, INUS) JF
AUGUSTIN 88	PRL 60 2238	+Calcaterra+	(DM2 Collab.)
BOLONKIN 88	NP B309 426	+Bloshenko, Gorin+	(ITEP, SERP)
BARDIN 87	PL B195 292	+Burgun+ (SACL,	FERR, CERN, PADO, TORI)
SCULLI 87	PRL 58 1715	+Christenson, Kreiter, Nemeth	y, Yamin (NYU, BNL)
ALDE 86B	PL B177 120	+Binon, Bricman+	(SERP, BELG, LANL, LAPP)
BALTRUSAIT 86D	PRL 56 107	Baltrusaitis (CI	T, UCSC, ILL, SLAC, WASH)
ALTHOFF 85B	ZPHY C29 189	+Braunschweig, Kirschfink+	(TASSO Collab.)
BEHRENDS 84	PL 137B 277	+Chadwich, Chauveau, Gentile	

OTHER RELATED PAPERS -

BARDIN	87	PL B195 292	+Burgun+ (SACL, FERR,	CERN, PADO, TORI)
YAOUANC	85	ZPHY C28 309	+Oliver, Pene, Raynal, Ono	(ORSAY, TOKY)
GODFREY	84	PL 141B 439	+Kokoski, Isgur	(TNTO)
SHATZ	84	PL 138B 209		(CIT)
WILLEY	84	PRL 52 585		(PITT)
EINSWEILER	83	Brighton Conf. 348		(Mark III Collab.)
HITLIN	83	Cornell Conf. 746		(CIT)

$\eta(2225)$

$$I^{G}(J^{PC}) = 0^{+}(0^{-})$$

OMITTED FROM SUMMARY TABLE

Seen in $J/\psi \to \gamma \phi \phi$. Needs confirmation.

η(2225) MASS

VALUE (MeV)	DOCUMENT II	TECN COMMENT
• • We do not use the follo	wing data for averag	ges, fits, limits, etc. • • •
$2230 \pm 25 \pm 15$	BAI	908 MRK3 $J/\psi ightarrow$
		$\gamma K^+ K^- K^+ K^-$
$2214 \pm 20 \pm 13$	BAI	90B MRK3 $J/\psi \rightarrow$
		$\gamma K^+ K^- K^0_S K^0_L$
~ 2220	BISELLO	86B DM2 $J/\psi \rightarrow \gamma K^+ K^- K^+ K^-$
		γκικ κικ

η(2225) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
$150^{\pm300}_{-60}_{-60}$	BAI	90B	MRK3	J/ψ $ ightarrow$
• • We do not use the following	data for average	s fits	limits	γ K ⁺ K ⁻ K ⁺ K ⁻

 $\gamma K^+ K^- K^+ K^-$

η(2225) REFERENCES

+Blaylock+ +Busetto, Castro, Limentani+ BAI BISELLO 90B PRL 65 1309 86B PL B179 294 (Mark III Collab.) (DM2 Collab.)

$\rho_3(2250)$

$$I^{G}(J^{PC}) = 1^{+}(3^{-})$$

OMITTED FROM SUMMARY TABLE

Contains results only from formation experiments. For production experiments see the $\overline{N}N(1100{-}3600)$ entry. See also $\rho(2150)$, $f_2(2150), f_4(2300), \rho_5(2350).$

ρ_3 (2250) MASS

$\overline{p}p \rightarrow \pi\pi \text{ or } K\overline{K}$

VALUE (MeV)	DOCUMENT ID		TECN CHG	COMMENT
• • • We do not use t	he following data for averag	es, fit	s, limits, etc.	• • •
~ 2232	HASAN	94	RVUE	$\overline{\rho} p \rightarrow \pi \pi$
~ 2007	HASAN	94	RVUE	$\overline{p}p \rightarrow \pi\pi$
\sim 2250	¹ MARTIN	80B	RVUE	
~ 2300	¹ MARTIN	800	RVUE	
~ 2140	² CARTER	78B	CNTR 0	$0.7-2.4 \overline{p}p \rightarrow K^-K^+$
~ 2150	³ CARTER	77	CNTR 0	$0.7 - 2.4 \overline{p} p \rightarrow \pi \pi$

 $^1I(J^P)=1(3^-)$ from simultaneous analysis of $p\overline{p}\to\pi^-\pi^+$ and $\pi^0\pi^0$. $^2I=0,1,J^P=3^-$ from Barrelet-zero analysis.

 $^{3}I(J^{P})=1(3^{-})$ from amplitude analysis.

S-CHANNEL NN

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
• • • We do not use the following	ing data for average	s, fits	, limits,	etc. •	• •
~ 2190	⁴ CUTTS	78B	CNTR		$\begin{array}{c} 0.97-3 \ \overline{p} p \rightarrow \\ \overline{N} N \end{array}$
2155 ± 15 2193 ± 2 2190 ± 10	4,5 COUPLAND 4,6 ALSPECTOR 7 ABRAMS	73		0	$0.7-2.4 \ \overline{p}p \rightarrow \overline{p}p$ $\overline{p}p \ S \ \text{channel}$ $S \ \text{channel} \ \overline{p}N$

⁴ Isospins 0 and 1 not separated.

From a fit to the total elastic cross section.
Referred to as T or T region by ALSPECTOR 73.

⁷ Seen as bump in I=1 state. See also COOPER 68. PEASLEE 75 confirm $\overline{p}p$ results of ABRAMS 70, no narrow structure.

 $\rho_3(2250)$, $f_2(2300)$, $f_4(2300)$

ρ_3 (2250) WIDTH

P	p	\rightarrow	$\pi\pi$	or	κ	K

VALUE (MeV)	DOCUMENT ID		TECN CI	4G	COMMENT
• • • We do not use t	he following data for averages	, fits	, limits, et	с. •	• •
~ 220	HASAN	94	RVUE		$\overline{p} p \rightarrow \pi \pi$
~ 287	HASAN	94	RVUE		$\overline{p} p \rightarrow \pi \pi$
~ 250	⁸ MARTIN	80B	RVUE		
~ 200	⁸ MARTIN	80c	RVUE		
~ 150	⁹ CARTER	78B	CNTR 0		$0.7-2.4 \overline{p}p \rightarrow$
~ 200	¹⁰ CARTER	77	CNTR 0		$0.7-2.4 \overline{p}p \rightarrow \pi \pi$

 $^8 I(J^P)=1(3^-)$ from simultaneous analysis of $p\overline{p}\to\pi^-\pi^+$ and $\pi^0\pi^0$. $^9 I=0,~1.~J^P=3^-$ from Barrelet-zero analysis. $^{10} I(J^P)=1(3^-)$ from amplitude analysis.

S-CHANNEL NN

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT	
• • • We do r	not use the following data for averages	, fit	s, limits,	etc. •	• •	
135 ± 75	11,12 COUPLAND	77	CNTR	0	$0.7-2.4 \overline{p}p \rightarrow$	$\overline{p}p$
98± 8	¹² ALSPECTOR	73	CNTR		$\overline{p}p$ S channel	
~ 85	¹³ ABRAMS	70	CNTR		S channel $\overline{p} N$	

- 11 From a fit to the total elastic cross section. 12 Isospins 0 and 1 not separated. 13 Seen as bump in I=1 state. See also COOPER 68. PEASLEE 75 confirm $\overline{p}p$ results of ABRAMS 70, no narrow structure.

ρ_3 (2250) REFERENCES

HASAN	94	PL B334 215	+Bugg	(LOQM)
MARTIN	80B	NP B176 355	+Morgan	(LOUC, RHEL) JP
MARTIN	80C	NP B169 216	+Pennington	` (DURH) JP
CARTER	78B	NP B141 467		(LOQM)
CUTTS	78B	PR D17 16	+Good, Grannis, Green, Lee+	(STON, WISC)
CARTER	77	PL 67B 117	+Coupland, Eisenhandler, Astbury+	(LOQM, RHEL) JP
COUPLAND	77	PL 71B 460	+Eisenhandler, Gibson, Astbury+	(LOQM, RHEL)
PEASLEE	75	PL 57B 189	+Demarzo, Guerriero+ (CANB,	BARI, BROW, MIT)
ALSPECTOR	73	PRL 30 511	+Cohen, Cvijanovich+	(RUTG, UPNJ)
ABRAMS	70	PR D1 1917	+Cool, Giacomelli, Kycia, Leontic, Li+	(BNL)
COOPER	68	PRL 20 1059	+Hyman, Manner, Musgrave+	(ANL)

- OTHER RELATED PAPERS -

MARTIN CARTER	79B 78	PL 86B 93 NP B132 176	+Pennington	(DURH) (LOQM) JP
CARTER	77B	PL 67B 122		(LOQM) JP
CARTER	77C	NP B127 202	+Coupland, Atkinson+	(LOQM, DARE, RHEL)
MONTANET	77	Boston Conf. 260		(CERN)
ZEMANY	76	NP B103 537	+MingMa, Mountz, Smith	(MSU)
BERTANZA	74	NC 23A 209	+Bigi, Casali, Lariccia+	(PISA, PADO, TORI)
BETTINI	73	NC 15A 563	+Alston-Garnjost, Bigi+	(PADÓ, LBL, PISA, TORI)
DONNACHIE	73	LNC 7 285	+Thomas	(MCHS)
NICHOLSON	73	PR D7 2572	+Delorme, Carroll+	(CIT, ROCH, BNL)
FIELDS	71	PRL 27 1749	+Cooper, Rhines, Allison	(ANL. OXF)
YOH	71	PRL 26 922	+Barish, Caroll, Lobkowicz+	(CIT, BNL, ROCH)
ABRAMS	67C	PRL 18 1209	+Cool, Giacomelli, Kycia, Leont	tic, Li+ (BNL)

 $f_2(2300)$

$$I^{G}(J^{PC}) = 0^{+}(2^{++})$$

See also the mini-review under non- $q \, \overline{q}$ candidates. (See the index for the page number.)

f₂(2300) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
2297±28	¹ ETKIN	88	MPS	$22 \pi^- p \rightarrow \phi \phi n$
$\bullet~\bullet~$ We do not use the following	data for averages	, fits	, limits,	etc. • • •
2231 ± 10	воотн	86	OMEG	85 π^- Be → 2ϕ Be
2220 + 90	LINDENBAUM	84	RVUE	
2320 ± 40	ETKIN	82	MPS	$22 \pi^- p \rightarrow 2\phi n$
¹ Includes data of ETKIN 85. The	e percentage of t	he re	sonance	going into $\phi \phi$ 2 + + S_7

 D_2 , and D_0 is $6 + \frac{15}{5}$, $25 + \frac{18}{14}$, and $69 + \frac{16}{27}$, respectively.

f2(2300) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
149±41	² ETKIN	88	MPS	$22 \pi^- p \rightarrow \phi \phi n$
• • • We do not use the following	data for averages	, fits	s, limits,	etc. • • •
133±50	воотн	86	OMEG	85 π [−] Be \rightarrow 2 ϕ Be
200 ± 50	LINDENBAUM	84	RVUE	
220±70	ETKIN	82	MPS	$22 \pi^- p \rightarrow 2\phi n$
² Includes data of ETKIN 85.				

f2(2300) DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ_1	$\phi \phi$	seen

f₂(2300) REFERENCES

ETKIN BOOTH ETKIN LINDENBAUM ETKIN Also	88 86 85 84 82 83	PL B201 568 NP B273 677 PL 165B 217 CNPP 13 285 PRL 49 1620 Brighton Conf. 3		+Foley, Lindenbaum+ +Carroll, Donald, Edwards+ +Foley, Longacre, Lindenbaum+ +Foley, Longacre, Lindenbaum+ Lindenbaum	(BNL, CUNY) (LIVP, GLAS, CERN) (BNL, CUNY) (CUNY) (BNL, CUNY) (BNL, CUNY) (BNL, CUNY)
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OTHER RELATED PAPERS -

ARMSTRONG 89B PL B221 221 +Benayoun+(CERN, CDEF, BIRM, BAR	I. ATHU. CURIN+)
GREEN 86 PRL 56 1639 +Lai+ (FNAL, ARIZ, FSU, NDAM	. TUFTS, VAND+)
BOOTH 84 NP B242 51 +Ballance, Carroll, Donald+ (L	IVP, GLAS, CERN)

$f_4(2300)$

$$I^{G}(J^{PC}) = 0^{+}(4^{++})$$

OMITTED FROM SUMMARY TABLE

This entry was previously called $U_0(2350)$. Contains results only from formation experiments. For production experiments see the $\overline{N}N(1100-3600)$ entry. See also $\rho(2150),\ f_2(2150),\ \rho_3(2250),$ $\rho_5(2350)$.

f4(2300) MASS

$\overline{p}p \rightarrow \pi\pi \text{ or } \overline{K}K$

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
• • • We do not use to	he following data for average	s, fits	, limits,	etc. • • •
\sim 2314	HASAN	94	RVUE	$\overline{p}p \rightarrow \pi \pi$
~ 2300	¹ MARTIN	80B	RVUE	
~ 2300	¹ MARTIN	80C	RVUE	
~ 2340	² CARTER			$0.7-2.4 \ \overline{p} p \rightarrow K^- K^+$
~ 2330	DULUDE	78B	OSPK	$1-2 \overline{p} p \rightarrow \pi^0 \pi^0$
~ 2310	³ CARTER	77	CNTR	$0.7-2.4 \overline{p}p \rightarrow \pi\pi$
${1 \atop 2} I(J^P) = 0(4^+)$ from ${2 \atop 2} I(J^P) = 0(4^+)$ from ${3 \atop 3} I(J^P) = 0(4^+)$ from	m simultaneous analysis of <i>p</i> m Barrelet-zero analysis. m amplitude analysis.	<u>p</u> →	π-π+	and $\pi^0 \pi^0$.

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
• • We do not use th	ne following data for average	s, fits	, limits,	etc. • • •
∼ 2380	⁴ CUTTS	78B	CNTR	$0.97-3 \ \overline{p} p \rightarrow \overline{N} N$
2345 ± 15	^{4,5} COUPLAND	77	CNTR	$0.7-2.4 \overline{p}p \rightarrow \overline{p}p$
2359 ± 2	^{4,6} ALSPECTOR	73	CNTR	p̄p S channel
2375 ± 10	ABRAMS	70	CNTR	S channel $\overline{N}N$

f4(2300) WIDTH

$\overline{p}p \rightarrow \pi\pi \text{ or } \overline{K}K$

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
• • • We do not u	ise the following data for averages	, fits	, limits,	etc. • • •
~ 278		94	RVUE	$\overline{\rho} \rho \rightarrow \pi \pi$
~ 200	⁷ MARTIN	80C	RVUE	
~ 150		78B	CNTR	$0.7-2.4 \overline{p}p \rightarrow K^-K^+$
~ 210	⁹ CARTER	77	CNTR	0.7-2.4 $\overline{p}p \rightarrow \pi \pi$
$^{8}I(J^{P})=0(4^{+})$) from simultaneous analysis of $ ho \overline{ ho}$) from Barrelet-zero analysis.) from amplitude analysis.	5 →	$\pi^-\pi^+$	and $\pi^0 \pi^0$.

S-CHANNEL $\overline{p}p$ or $\overline{N}N$

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
• • • We do not use t	he following data for averages	, fits	s, limits,	etc. • • •
$135 + 150 \\ - 65$	10,11 COUPLAND	77	CNTR	$0.72.4~\overline{p}\rho~\rightarrow~\overline{p}\rho$
165 ⁺ 18	¹¹ ALSPECTOR	73	CNTR	$\overline{p}p$ S channel
~ 190	ABRAMS	70	CNTR	S channel $\overline{N}N$
10 From a fit to the to 11 Isospins 0 and 1 no	otal elastic cross section. it separated.			

f₄(2300) REFERENCES

HASAN 94 MARTIN 80B MARTIN 80C CARTER 78B CUTTS 78B DULUDE 78B CARTER 77 COUPLAND 77 ALSPECTOR 73 ABRAMS 70	PL 8334 215 NP B176 355 NP B169 216 NP B141 467 PR D17 16 PL 798 335 PL 678 117 PL 71B 460 PRL 30 511 PR D1 1917	+Bugg +Morgan +Pennington +Good, Grannis, Green, Lee+ +Lanou, Massimo, Peaslee+ +Coupland, Eisenhandler, Astbury+ +Eisenhandler, Gibson, Astbury+ +Cohen, Cvijanovich+ +Cool, Giacomelli, Kycia, Leontic, Li+	(LOQM) (LOUC, RHEL) JP (DURH) JP (LOQM) (STON, WISC) (BROW, MIT, BARI) JP (LOQM, RHEL) JP (LOQM, RHEL) (RUTG, UPNJ) (BUL)
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OTHER RELATED PAPERS -

FIELDS	71	PRL 27 1749	+Cooper, Rhines, Allison	(ANL, OXF)
YOH	71	PRL 26 922	+Barish, Caroll, Lobkowicz+	(CIT, BNL, ROCH)
BRICMAN		PL 29B 451	+Ferro-Luzzi, Bizard+	(CERN, CAEN, SACL)

 $f_2(2340)$

$$I^{G}(J^{PC}) = 0^{+}(2^{+})$$

See also the mini-review under non- $q\overline{q}$ candidates. (See the index for the page number.)

f2(2340)) MASS
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VALUE (MeV)	DOCUMENT ID	1	TECN	COMMENT
2339±55 • • • We do not use the following				$22 \pi^{-} p \rightarrow \phi \phi n$ etc. • •
2392±10 2360±20		6 C	OMEG	$85 \pi^- \text{Be} \rightarrow 2\phi \text{Be}$

 1 Includes data of ETKIN 85. The percentage of the resonance going into $\phi\phi$ 2 $^+$ + S_2 , D_2 , and D_0 is 37 \pm 19, $4^+_ \frac{12}{4}$, and $59^+_ \frac{21}{19}$, respectively.

f₂(2340) WIDTH

VALUE (MeV)	DOCUMENT ID		TEÇN	COMMENT
319 ⁺ 81 - 69	² ETKIN	88	MPS	22 $\pi^- p \rightarrow \phi \phi n$
• • We do not use the following	data for averages	s, fit	s, limits,	etc. • • •
198± 50	воотн	86	OMEG	85 π^- Be $\rightarrow 2\phi$ Be
$150 + 150 \\ - 50$	LINDENBAUM	84	RVUE	
² Includes data of ETKIN 85.				

f2(2340) DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ.	φφ.	seen

f₂(2340) REFERENCES

ETKIN BOOTH	PL B201 NP B273	+Foley, Lindenbaum+ +Carroll, Donald, Edwards+		(BNL, CU GLAS, CE	
ETKIN LINDENBAUM	PL 165B CNPP 13	+Foley, Longacre, Lindenbaum+	(=	(BNL, CU (CU	INY)

OTHER RELATED PAPERS -

ARMSTRONG	89B	PL B221 221	+Benayoun+(CERN,	CDEF, BIRM, B.	ARI, ATHU, CURIN+)
GREEN	86	PRL 56 1639	+Lai+ (FNAL,	ARIZ, FSU, NDA	M, TUFTS, VAND+)
BOOTH	84	NP B242 51	+Ballance, Carroll, I	Oonald+	(LIVP, GLAS, CERN)

 $\rho_{5}(2350)$

$$I^{G}(J^{PC}) = 1^{+}(5^{-})$$

OMITTED FROM SUMMARY TABLE This entry was previously called $U_1(2400)$. See also the $\overline{NN}(1100-3600)$ and X(1900-3600) entries. See also $\rho(2150)$, $f_2(2150), \rho_3(2250), f_4(2300).$

ρ_{5} (2350) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMI	MENT
2330±35	ALDE	95	GAM2	38 π	$- \rho \rightarrow \omega \pi^0 n$
$\overline{p}p \rightarrow \pi\pi \text{ or } \overline{K}K$					
VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
• • • We do not use t	ne following data for average	s, fits	, limits,	etc.	• • •
~ 2303	HASAN	94	RVUE		$\overline{p} p \rightarrow \pi \pi$
~ 2300	¹ MARTIN	80B	RVUE		
~ 2250	¹ MARTIN	80C	RVUE		
~ 2500	² CARTER	78B	CNTR	0	$0.7-2.4 \ \overline{p} p \rightarrow$
~ 2480	³ CARTER	77	CNTR	0	$ \begin{array}{c} K^- K^+ \\ 0.7-2.4 \ \overline{\rho} \rho \to \\ \pi \pi \end{array} $
S-CHANNEL NN VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
	ne following data for average	s, fits			
~ 2380	⁴ CUTTS		CNTR		$0.97-3 \overline{\rho} \rho \rightarrow \overline{N} N$
2345 ± 15	^{4,5} COUPLAND	77	CNTR	0	$0.7-2.4 \ \overline{p}p \rightarrow \overline{p}$
2359± 2	4,6 ALSPECTOR	73	CNTR		Dp S channel
2350 ± 10	⁷ ABRAMS	70	CNTR		S channel $\overline{N}N$
2360 ± 25	8 OH	70B	HDBC	-0	$\overline{p}(pn), K^*K2\pi$
$2I = 0(1)$; $J^P = 5^-$ $3I(J^P) = 1(5^-)$ from 4 Isospins 0 and 1 not 5 From a fit to the to 6 Referred to as U or $\frac{7}{2}$ For $I = 1 \overline{N}N$.	separated. tal elastic cross section. U region by ALSPECTOR 7 bump seen in the $\overline{p}p$ data	3.			

ρ_{5} (2350) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COM	1ENT
400±100	ALDE	95	GAM2	38 π	$p \rightarrow \omega \pi^0 n$
$\overline{p}p \rightarrow \pi\pi \text{ or } \overline{K}K$					
VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
• • • We do not use the f	following data for average	s, fits	, limits,	etc. •	• •
~ 169	HASAN	94	RVUE		$\overline{\rho} \rho \rightarrow \pi \pi$
~ 250	⁹ MARTIN	80B	RVUE		
~ 300	⁹ MARTIN	80c	RVUE		
~ 150	¹⁰ CARTER	78B	CNTR	0	$0.7-2.4 \ \overline{p} p \rightarrow$
	11				$\kappa^-\kappa^+$
~ 210	¹¹ CARTER	77	CNTR	0	$0.7-2.4 \overline{p}p \rightarrow$
					$\pi\pi$
S-CHANNEL ₩N					
VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
• • • We do not use the f	ollowing data for average	s, fits	, limits,	etc. •	• •
$135 + 150 \\ - 65$	12,13 COUPLAND	77	CNTR	0	$0.7-2.4 \ \overline{p}p \rightarrow \overline{p}p$
165 + 18 - 8	¹³ ALSPECTOR	73	CNTR		pp S channel
-	14 011	=	1100		
< 60 ~ 140	¹⁴ OH ABRAMS		HDBC CNTR	-0	$\overline{p}(pn)$, $K^*K2\pi$ S channel $\overline{p}N$

- 10 I = 0(1); $J^P = 5^-$ from Barrelet-zero analysis. $11 I(J^P) = 1(5^-)$ from amplitude analysis.
- 12 From a fit to the total elastic cross section.
 13 Isospins 0 and 1 not separated.

 $\pi^- p \rightarrow \omega \pi^0 n$

14 No evidence for this bump seen in the p̄ρ data of CHAPMAN 71B. Narrow state not confirmed by OH 73 with more data.

ρ_5 (2350) REFERENCES

ALDE HASAN	95 94	ZPHY C66 379 PL B334 215	+Binon, Bricman+ +Bugg	(GAMS Collab.) JP (LOQM)
MARTIN	80B	NP B176 355	+Morgan	(LOUC, RHEL) JP
MARTIN	80C	NP B169 216	+Pennington	(DURH) JP
CARTER	788	NP B141 467		(LOQM)
CUTTS	78B	PR D17 16	+Good, Grannis, Green, Lee+	(STON, WISC)
CARTER	77	PL 67B 117	+Coupland, Eisenhandler, Astbury+	(LOQM, RHEL) JP
COUPLAND	77	PL 71B 460	+Eisenhandler, Gibson, Astbury+	(LOQM, RHEL)
ALSPECTOR	73	PRL 30 511	+Cohen, Cvijanovich+	(RUTG, UPNJ)
ОН	73	NP B51 57	+Eastman, MingMa, Parker, Smith+	(MSU)
CHAPMAN	71B	PR D4 1275	+Green, Lys, Murphy, Ring+	(MICH)
ABRAMS	70	PR D1 1917	+Cool, Giacomelli, Kycia, Leontic, Li+	(BNL)
OH	70B	PRL 24 1257	+Parker, Eastman, Smith, Sprafka, Ma	(MSU)
ABRAMS	67C	PRL 18 1209	+Cool, Giacomelli, Kycia, Leontic, Li+	(BNL)

- OTHER RELATED PAPERS -

+Conte, Tomasini+ +Ferro-Luzzi, Bizard+ (GENO, HAMB, MILA, SACL) (CERN, CAEN, SACL) 70 LNC 3 707 69 PL 29B 451

$a_6(2450)$

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$$I^{G}(J^{PC}) = 1^{-}(6^{++})$$

OMITTED FROM SUMMARY TABLE

Needs confirmation.

a₆(2450) MASS

VALUE (MeV)	DOCUMENT ID	TECN	CHG	COMMENT	
2450±130	¹ CLELAND	82B SPEC	\pm	$50~\pip~\rightarrow$	$K_S^0 K^{\pm} p$

¹ From an amplitude analysis.

a₆(2450) WIDTH

VALUE (MeV)	DOCUMENT ID	TECN	CHG	COMMENT
400±250	² CLELAND 82	B SPEC	±	$50 \pi p \rightarrow K_S^0 K^{\pm} p$

² From an amplitude analysis.

a₆(2450) DECAY MODES

Mode $K\overline{K}$

a₆(2450) REFERENCES

CLELAND 82B NP B208 228 +Delfosse, Dorsaz, Gloor (DURH, GEVA, LAUS, PITT)

 $f_6(2510), X(3250)$

 $f_6(2510)$

 $I^{G}(J^{PC}) = 0^{+}(6^{+})$

		f ₆ (2510) MASS					
VALUE (MeV)		DOCUMENT ID	TECN	COMMENT			
2510±30		BINON 8	4B GAM2	$38 \pi^- \rho \rightarrow n2\pi^0$			
		f ₆ (2510) WIDTH	1				
VALUE (MeV))	DOCUMENT ID	TECN	COMMENT			
240±60		BINON 8	4в САМ2	$23 \pi^- p \rightarrow n2\pi^0$			
	fe	(2510) DECAY MO	DDES				
Мос	de	Fra	action (Γ_i)	′Г)			
$\Gamma_1 = \pi \pi$		(6.0±1.0) %					
	f ₆ (2!	510) BRANCHING	RATIOS				
				Γ ₁ /Γ			
$\Gamma(\pi\pi)/\Gamma_1$	total	DOCUMENT ID	TECN	COMMENT			
VALUE		DOCUMENT ID		$\frac{COMMENT}{38 \pi^{-} p \rightarrow n4\gamma}$			
VALUE 0.00	1		3c GAM2	$38 \pi^- \rho \rightarrow n4\gamma$			
VALUE 0.00	1 ng one pion exchange	¹ BINON 8	3c GAM2 LOTOV 7	$38 \pi^- \rho \rightarrow n4\gamma$			
0.06 ±0.0	1 ng one pion exchange	BINON 8 e and using data of BC (2510) REFEREN + Donskov, Duteil, C + Gouanere, Donskov	3C GAM2 LOTOV 7 CES	$38 \pi^- \rho \rightarrow n4\gamma$			

X(3250)

 $I^{G}(J^{PC}) = ?^{?}(?^{??})$

OMITTED FROM SUMMARY TABLE Narrow peak observed in several final states with hidden strangeness $(\Lambda \overline{\rho} K^+, \Lambda \overline{\rho} K^+ \pi^\pm, K^0 p \overline{\rho} K^\pm)$. Needs confirmation. See also under non- $q \overline{q}$ candidates. (See the index for the page number.)

X(3250) MASS

3-BODY DECAYS VALUE (MeV)	DOCUMENT II	o	TECN	COMMENT
• • • We do not use the f	ollowing data for averag	ges, fit	s, limits	s, etc. • • •
3250 ± 8 ± 20	¹ ALEEV	93	BIS2	$X(3250) \rightarrow \Lambda \overline{\rho} K^{+}$
$3265 \pm 7 \pm 20$	¹ ALEEV	93	BIS2	$X(3250) \rightarrow \overline{\Lambda} p K^-$
¹ Supersedes KEKELIDZ	E 90.			
4-BODY DECAYS	DOCUMENT I		* FCN	COLUMENT

VALUE (MeV)	DOCUMENT IE)	TECN	COMMENT	
• • • We do not use the	following data for averag	ges, fits	, limits	, etc. • • •	
$3245 \pm 8 \pm 20$	¹ ALEEV	93	BIS2	X(3250) →	$\Lambda \overline{\rho} K^+ \pi^\pm$
$3250 \pm 9 \pm 20$	¹ ALEEV		BIS2	X(3250) →	
$3270 \pm 8 \pm 20$	¹ ALEEV	93	BIS2	$X(3250) \rightarrow$	$K_S^0 p \overline{p} K^{\pm}$

X(3250) WIDTH

3-BODY DECAYS

VALUE (MeV)	DOCUMENT	D	TECN	COMMENT	
• • We do not use the following	ng data for avera	ges, fits	, limits	, etc. • • •	
45 ± 18	² ALEEV	93	BIS2	$X(3250) \rightarrow \Lambda \tilde{p}$	κ^+
40 ± 18	² ALEEV	93	BIS2	$X(3250) \rightarrow \overline{\Lambda} p$	K-

² Supersedes KEKELIDZE 90.

4-BODY DECAYS VALUE (MeV)	DOCUMENT	ID	TECN	COMMENT	
• • We do not use the foll	owing data for avera	ges, fits	s, limits	, etc. • • •	
25 ± 11	² ALEEV	93	BIS2	X(3250) →	$\Lambda \bar{p} K^{+} \pi^{\pm}$
50 ± 20	² ALEEV	93	BIS2	X(3250) →	$\overline{\Lambda}_{P}K^{-}\pi^{\mp}$
25 ± 11	² ALEEV	93	BIS2	X(3250) →	$\kappa_S^0 p \bar{p} \kappa^{\pm}$

X(3250) DECAY MODES

	Mode
Γ ₁ Γ ₂	$ \Lambda \bar{\rho} K^+ $ $ \Lambda \bar{\rho} K^+ \pi^{\pm} $ $ K^0 \rho \bar{\rho} K^{\pm} $
Γ ₃	Κ ⁰ ρ ̄Κ [±]

X(3250)	REFERENCES
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ALEEV	93	PAN 56 1358 +Balandin+ Translated from YAF 56 100.	(BIS-2 Collab.)
KEKELIDZE	90	Hadron 89 Conf. p 551+Aleev+	(BIS-2 Collab.)

OTHER LIGHT UNFLAVORED MESONS (S = C = B = 0)

 $e^+e^-(1100-2200)$

 $I^{G}(J^{PC}) = ?^{?}(1^{-})$

OMITTED FROM SUMMARY TABLE

This entry contains unflavored vector mesons coupled to e^+e^- (photon) between the ϕ and $J/\psi(15)$ mass regions. See also $\omega(1420), \, \rho(1450), \, \omega(1600), \, \phi(1680), \, {\rm and} \, \, \rho(1700).$

e^+e^- (1100-2200) MASSES AND WIDTHS

We do not use the following data for averages, fits, limits, etc.

VALUE (MeV) 1100 to 2200 OUR LIMIT	DOCUMENT ID		
VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
$1097.0 {}^{+ 16.0}_{- 19.0}$	BARTALUCCI 79	OSPK	$7 \gamma p \rightarrow e^+ e^- p$
$31.0^{+24.0}_{-20.0}$	BARTALUCCI 79	OSPK	$7 \gamma \rho \rightarrow e^+ e^- \rho$
VALUE (MeV)	DOCUMENT ID	TECN	CHG COMMENT
1266.0 ± 5.0	BARTALUCCI 79	DASP	$0 \qquad 7 \ \gamma p \rightarrow e^+ e^- p$
110.0 ± 35.0	BARTALUCCI 79	DASP	$0 7 \gamma \rho \rightarrow e^+ e^- \rho$
VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
~ 1830.0	PETERSON 78	SPEC	$\gamma p \rightarrow K^+ K^- p$
~ 120.0	PETERSON 78	SPEC	$\gamma p \rightarrow K^+ K^- p$
VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
~ 1820	¹ SPINETTI 79	RVUE	$e^+e^- \rightarrow 4\pi^{\pm}2\gamma$
~ 30	¹ SPINETTI 79	RVUE	$e^+e^- \rightarrow 4\pi^{\pm}2\gamma$
VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
• • • We do not use the fo	llowing data for averages, fit	s, limits,	etc. • • •
1870 ± 10	ANTONELLI 96	SPEC	$e^+e^- \rightarrow \text{hadrons}$
10± 5	ANTONELLI 96	SPEC	$e^+e^- ightarrow hadrons$
VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
~ 2130	² ESPOSITO 78	FRAM	$e^+e^- \rightarrow K^*(892)^+$
~ 30	² ESPOSITO 78	FRAM	$e^{+}e^{-} \rightarrow K^{*}(892)^{+}$
¹ Integrated cross section ² Not seen by DELCOURT	of BACCI 77, BARBIELLINI Г 79.	77, ESP	OSITO 77.

$e^{+}e^{-}$ (1100-2200) REFERENCES

96	PL B365 427	+Baldini, Bertani+	(FENICE Collab.)
79	NC 49A 207	+Basini, Bertolucci+	(DESY, FRAS)
79	PL 86B 395	+Derado, Bertrand, Bisello, Bizot, Buo	n+ (LALO)
79	Batavia Conf. 506		(FRAS)
78	LNC 22 305	+Felicetti (FRAS, N.	APL, PADO, ROMA)
78	PR D18 3955	+Dixon, Ehrlich, Galik, Larson	(CORN, HARV)
77	PL 68B 393	+DeZorzi, Penso, Stella, Baldini+	(ROMA, FRAS)
77	PL 68B 397	+Barletta+ (FRAS.	NAPL, PISA, SANI)
77	PL 68B 389	+Felicetti, Marini+ (FRAS, N.	
	OTHE	R RELATED PAPERS	
76	PL 64B 356	+Bidoli, Penso, Stella, Baldini+	(ROMA, FRAS)
75	PL 58B 481	+Bidoli, Penso, Stella+	(ROMA, FRAS)
	79 79 79 78 78 77 77 77	79 NC 49A 207 79 PL 66B 395 79 PL 66B 395 79 Batavia Conf. 506 LNC 22 305 78 PR D18 3955 77 PL 68B 393 77 PL 68B 397 77 PL 68B 389 OTHE 76 PL 64B 356	79 NC 49A 207 + Basini, Bertolucci+ + Derado, Bertand, Bisello, Bizot, Buo 79 PL 56B 395 + Derado, Bertand, Bisello, Bizot, Buo 78 LNC 22 305 + Felicetti (FRAS, N. PL 68B 393 + Dezorzi, Penso, Stella, Baldini+ 77 PL 68B 397 + Felicetti, Marini+ (FRAS, N. + Felicetti, Marin

$\overline{N}N(1100-3600)$

OMITTED FROM SUMMARY TABLE

This entry contains various high mass, unflavored structures coupled to the baryon-antibaryon system, as well as quasi-nuclear bound

NN(1100-3600) MASSES AND WIDTHS

We do not use the following data for averages, fits, limits etc.

VALUE (MeV)		DOCUMENT ID				
1100 to 3600 OUR LIMIT						
141.05 (11.10)		DOCUMENT ID		TECH	cuc	COMMENT
VALUE (MeV) 1107±4	_	DAFTARI	87	TECN DBC	<u>СНБ</u> 0	$ \begin{array}{c} \underline{COMMENT} \\ 0, \ \overline{p}n \rightarrow \end{array} $
1107 ±4		DAFTAKI	01	DBC	U	$\rho^- \pi^+ \pi^-$
$111 \pm 8 \pm 15$		DAFTARI	87	DBC	0	$0. \ \overline{p} n \rightarrow$
						$\rho^-\pi^+\pi^-$
VALUE (MeV)		DOCUMENT ID		TECN	CHG	COMMENT
1167 ±7	2	CHIBA	91	CNTR		$\overline{p}d \rightarrow \gamma X$
1191.0±9.9	2.3.4.5	CHIBA RICHTER	87	CNTR	0	$0. \ \overline{p}p \rightarrow \gamma X$
1210 ±5.0	_,,,,,,,	RICHTER	83	CNTR	0	Stopped \overline{p}
VALUE (MeV)		DOCUMENT ID		TECN	CHG	COMMENT
1325 ±5		CHIBA	91	CNTR		$\overline{\rho}d \rightarrow \gamma X$
1329.2 ± 7.6	2	CHIBA	87	CNTR	0	$0. \ \overline{p} p \rightarrow \gamma X$
VALUE (MeV)		DOCUMENT ID		TECN	CHG	COMMENT
1390.9±6.3	_ 2	CHIBA	87	CNTR	0	$0. \ \overline{p}p \rightarrow \gamma X$
1395	2,4,5,6	PAVLOPO	78	CNTR	Ü	Stopped \overline{p}
VALUE (MeV)	_	DOCUMENT ID		TECN	CHG	COMMENT
\sim 1410		BETTINI	66	DBC	0	$0. \ \overline{p} N \rightarrow 5\pi$
~ 100		BETTINI	66	DBC	0	$0. \ \overline{\rho} N \to 5\pi$
VALUE (MeV)		DOCUMENT ID		TECN	CHG	COMMENT
1468± 6	7	BRIDGES	86B	DBC	0	0. <u>\(\overline{p} \) N →</u>
						$0. \frac{2\pi^{-}\pi^{+}\pi^{0}}{pN \rightarrow}$
88 ± 18	′	BRIDGES	86B	DBC	0	$0. \overline{p} N \rightarrow$
						$2\pi^{-}\pi^{+}\pi^{0}$
VALUE (MeV)		DOCUMENT ID		TECN	CHG	COMMENT
1512 ± 7	2	CHIBA	91	CNTR	_	$\overline{p}d \rightarrow \gamma X$
1523.8± 3.6		CHIBA BRIDGES	87	CNTR DBC	0	0. p p → γX
1522 ± 7		BRIDGES	008	DBC	U	$0. \ \overline{p} N \rightarrow 2\pi^{-}\pi^{+}$
59 ±12	7	BRIDGES	86B	DBC	0	$0. \ \overline{\rho} N \rightarrow$
						$2\pi^{-}\pi^{+}$
VALUE (MeV)		DOCUMENT ID		TECN	CHG	COMMENT
1577.8± 3.4		CHIBA	87		0	$0. \ \overline{p} p \rightarrow \gamma X$
1594 ± 9	,	BRIDGES	86B	DBC	_	$0. \ \overline{p} N \rightarrow 2\pi^{-}\pi^{+}\pi^{0}$
81 ±12	7	BRIDGES	86B	DBC	-	$0. \ \frac{2\pi^{-}\pi^{+}\pi^{0}}{\overline{\rho}N} \to$
						$2\pi^{-}\pi^{+}\pi^{0}$
VALUE (MeV)	_	DOCUMENT ID		TECN	CHG	COMMENT
1633.6 ± 4.1	2	CHIBA	87	CNTR	0	$0. \ \overline{\rho} \rho \rightarrow \gamma X$
$1637.1^{+5.6}_{-7.3}$		ADIELS	84	CNTR		<i>p</i> He
VALUE (MeV)	2345	DOCUMENT ID		TECN	CHG	
1638±3.0	2,3,4,3	RICHTER	83	CNTR	0	Stopped \overline{p}
VALUE (MeV)		DOCUMENT ID		TECN	соми	1ENT
1644.0 + 5.6 - 7.3		ADIELS	84	CNTR	īРНе	
7.3		ADIECS	04	CIVII	pine	
VALUE (MeV)	_	DOCUMENT ID		TECN	COMM	MENT
1646	2,4,5,6	PAVLOPO	78	CNTR	Stopp	ped \overline{p}
VALUE (MeV)		DOCUMENT ID		TECN	соми	MENT
1687.1 + 5.0	_					12/1/
1.5	2456	ADIELS	84	CNTR	PНе	
1684	2,4,5,6	PAVLOPO	78	CNTR	Stopp	ped \overline{p}
VALUE (MeV)		DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
1693±2	2	CHIBA	91	CNTR		$\overline{p}d \rightarrow \gamma X$
1694 ± 2.0	2,3,4,5	RICHTER	83	CNTR	0	Stopped \overline{p}
141115 (141)		DOCUMENT IS		TECH	cuc	COMMENT
VALUE (MeV)	- ,	CLUDA	07			COMMENT
1713.0±2.6	-	CHIBA	87	CNTR	U	$0. \ \overline{p}p \rightarrow \ \gamma X$
VALUE (MeV)		DOCUMENT ID		TECN	CHG	COMMENT
1731.0±1.5	_ 2	CHIBA	87			0. p̄ ρ → γX
						* * * * * * * * * * * * * * * * * * * *

Meson Particle Listings $\overline{N}N(1100-3600)$

VALUE (MeV)	DOCUMENT ID	TECN	CHG	COMMENT	VALUE (MeV)	DOCUMENT ID		TECN	COM	MENT
1771 ± 1.0	2,4,5,8 RICHTER	83 CNTR	0	Stopped \overline{p}	2090±20	²⁶ KREYMER	80	STRC	13 π	$-d \rightarrow np\overline{p}\pi^-$
VALUE (MeV)	DOCUMENT ID	TECN	CHG	COMMENT	170 ± 50	²⁶ KREYMER				$-d \rightarrow np\overline{p}\pi^{-1}$
1856.6±5	BRIDGES	86D SPEC		$0. \ \overline{p}d \rightarrow \pi\pi N$	VALUE (MeV)	DOCUMENT ID		TECN	соми	MENT
20 ±5	BRIDGES			0. $\overline{p}d \rightarrow \pi\pi N$	~ 2110	27 EVANGELIST	4 79			
				·	~ 330	27 EVANGELIST				
VALUE (MeV)	DOCUMENT ID	TECN		COMMENT					,	
1873 ± 2.5	BRIDGES	86D SPEC		$0. \ \overline{p}d \rightarrow \pi\pi N$	VALUE (MeV)	DOCUMENT ID		TECN	COM	MENT
< 5	BRIDGES	86D SPEC	0	$0. \ \overline{p}d \rightarrow \pi\pi N$	2110 ± 10	²⁸ ROZANSKA			18 π	$p \rightarrow p\overline{p}n$
VALUE (MeV)	DOCUMENT ID	TECN	сомм	ENT	190 ± 10	²⁸ ROZANSKA	80	SPRK	18 π	$p \rightarrow p \overline{p} n$
1897±17	9 ABASHIAN			$p \rightarrow p3\pi$	NALUE (NA.V.)	DOCUMENT ID		TECH	cuc	COLUMENT
110±82	9 ABASHIAN	76 STRC		$p \rightarrow p3\pi$ $p \rightarrow p3\pi$	VALUE (MeV) 2141	29 DONALD	72	TECN HBC	<u>СНБ</u>	Dp S channel
1897± 1	KALOGERO			nihilation near	14	29 DONALD		HBC	0	Dp S channel
25± 6	KALOGERO	7E DDC		eshold	24	BONNEB	13	noc.	Ü	pp 5 channel
25 ± 0	KALUGERU	. 15 DBC		nihilation near eshold	VALUE (MeV)	DOCUMENT ID		TECN	COMM	MENT
VALUE (MeV)	DOCUMENT ID	TECN	СОММЕ		2180 ± 10	³⁰ ROZANSKA	80	SPRK	18 π	-ρ → p̄p̄n
~ 1920	10 EVANGELIST				270 ± 10	³⁰ ROZANSKA	80	SPRK	18 π	p → ppn
× 190	EVANGELIST									
					VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
VALUE (MeV) EV	TS DOCUMENT ID	TECN	CHG	COMMENT	2207±13	31 ALLES		HBC	0	5.7 pp
$1937.3 + 1.3 \\ - 0.7$	¹¹ FRANKLIN	87 SPEC		0.586 pp	62±52	³¹ ALLES	678	нвс	0	5.7 pp
< 3.0	¹¹ FRANKLIN	87 SPEC		0.586 pp	VALUE (MeV)	DOCUMENT ID		TECN	соми	MENT
1930 ± 2	12 ASTON	80D OMEG		0.366 ρρ γρ → ρ <u></u> ρΧ						
12 ± 7	12 ASTON	80D OMEG		$\gamma p \rightarrow p \overline{p} X$	$2210 + 79 \\ -21$					$-\rho \rightarrow K^+K^-$
	36 DAUM	80E CNTR		93 pp → p̄pX	~ 203	EVANGELIST	4 79B	OMEG	10 π	$^{-}p \rightarrow K^{+}K^{-}$
~ 6.0	DAUM	80E CNTR		93 pp → p̄pX						
1949 ±10	13 DEFOIX	80 HBC		$\overline{\rho} \rho o 5\pi$	VALUE (MeV)	DOCUMENT ID		TECN	COMM	
80 ±20	13 DEFOIX	80 HBC		$\overline{p}p \rightarrow 5\pi$	2231.9 ± 0.1	1 BARNES				$\overline{p}p \rightarrow \overline{\Lambda}\Lambda$
1939 ± 2	14 HAMILTON	80B CNTR		S channel $\overline{p}p$	0.59 ± 0.25	1 BARNES		SPEC		$\overline{p}p \rightarrow \overline{\Lambda}\Lambda$
22 ± 6	14 HAMILTON	80B CNTR		S channel pp	\sim 2229.2 \sim 1.8	CARBONELL CARBONELL				
1935.5 ± 1.0 2.8 ± 1.4	SAKAMOTO SAKAMOTO	79 HBC 79 HBC		0.37-0.73 pp 0.37-0.73 pp			93	KVUE	ρρ –	· ///
1939 ± 3	BRUCKNER	77 SPEC		0.4-0.85 p p	¹ Supersedes CARBONELL	93.				
< 4.0	BRUCKNER			0.4-0.85 p p	VALUE (MeV)	DOCUMENT ID		TECN	COMM	4FNT
1935.9± 1.0	¹⁵ CHALOUPKA	76 HBC		$\overline{ ho} ho$ total,elastic	~ 2260	32 EVANGELIST	70			
8.8^{+}_{-} 3.2	¹⁶ CHALOUPKA	76 HBC	0	pp total,elastic	~ 2260 ~ 440	32 EVANGELIST				
1942 ± 5	¹⁷ D'ANDLAU	75 HBC		0.175-0.750 pp	440	LVANGLEIS I	115	OMEG	10,10	$x p \rightarrow pp$
57.5 ± 5	18 D'ANDLAU	75 HBC		0.175-0.750 ββ 0.175-0.750 ββ	VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
	¹⁹ KALOGERO				2307± 6	ALPER	80	CNTR		62 π [−] p →
$1934.4 + 2.6 \\ - 1.4$	KALOGERO	. 75 DBC		₱ N annihilation						K+K-n
11 + 11 - 4	²⁰ KALOGERO	. 75 DBC	_	$\overline{\rho}N$ annihilation	245 ± 20	ALPER	80	CNTR	0	62 π ⁻ p →
1932 ± 2	15 CARROLL	74 CNTR		S channel $\overline{p}p \rightarrow$						K ⁺ K ⁻ n
				d	VALUE (MeV)	DOCUMENT ID		TECN	COMM	1ENT
9 + 4	¹⁶ CARROLL	74 CNTR		S channel $\overline{p}p \rightarrow$	2380 ± 10	³³ ROZANSKA	80	SPRK	18 π	p → ppn
1968	²¹ BENVENUTI	71 HBC	0	d 0.1−0.8 p p	380 ± 20	³³ ROZANSKA	80	SPRK	18 π	$p \rightarrow p \overline{p} n$
35	21 BENVENUTI	71 HBC		0.1-0.8 $\overline{p}p$						
1940 ± 8	CLINE	70 HBC		0.25-0.74 pp	VALUE (MeV)	DOCUMENT ID		TECN	COMM	
49 ± 9	CLINE	70 HBC		0.25-0.74 p	2450 ± 10	34 ROZANSKA	80			$p \rightarrow p \overline{p} n$
					280 ± 20	³⁴ ROZANSKA	80	SPRK	18 π	$\rho \rightarrow \rho \overline{\rho} n$
VALUE (MeV)	DOCUMENT ID	TECN		COMMENT		0.0004507.10		TE0		
1949±10	22 DEFOIX	80 HBC		$0.0-1.2 \ \overline{p} \rho \rightarrow 5\pi$	VALUE (MeV)	DOCUMENT ID 35 CARTER	77			COMMENT
80 ± 20	²² DEFOIX	80 HBC	0	$0.0-1.2 \ \overline{p} p \rightarrow 5\pi$	2480 ± 30		11	CNTR	U	$0.7-2.4 \overline{p}p \rightarrow \pi \pi$
VALUE (MeV)	DOCUMENT ID	сомме	MT		210 ± 25	³⁵ CARTER	77	CNTR	0	$0.7^{-2.4} \overline{p} p \rightarrow$
	23 FERRER		→ ppp							$\pi \pi$
2011 ± 7				_	VALUE (MeV)	DOCUMENT ID				COMMENT
25 + 10 - 25	FERRER	93 π ⁻ p -	→ ppp	$\pi^-\pi^0$	~ 2500	³⁶ CARTER	78B	CNTR	0	$0.7-2.4 \overline{p}p \rightarrow$
2025	GIBBARD	79 e ⁻ p -	→ e - p	$\rho \overline{ ho}$	~ 150	36 CARTER	720	CNTR	٥	K^-K^+ 0.7-2.4 $\overline{p}p \rightarrow$
< 30	GIBBARD		→ e ⁻ p		.0 150	CANTEN	100	CNIK	U	K^-K^+
2020± 3	BENKHEIRI	77 π ⁻ p -			\/ALLIE (Ma\/)	DOCUMENT ID		TECN	COM	
24 ± 12	BENKHEIRI	77 π ⁻ p -	→ ppp	π-	VALUE (MeV)					
					2710±20 170±40	ROZANSKA				p → ppn
VALUE (MeV)	DOCUMENT ID			COMMENT	170 ± 40	ROZANSKA	οU	SFKK	10 π	$p \rightarrow p \overline{p} n$
2022± 6	²⁴ AZOOZ	83 HYBR		6 p p → p n 3π	VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
14 ± 13	²⁴ AZOOZ	83 HYBR	+	6 p̄ ρ → ρπ3π	2850±5	37 BRAUN	76	DBC	_	$5.5 \overline{p}d \rightarrow N \overline{N}$
VALUE (MeV)	DOCUMENT ID	TECN	CHG	COMMENT	< 39	37 BRAUN		DBC	_	$5.5 \overline{p}d \rightarrow N\overline{N}$ $5.5 \overline{p}d \rightarrow N\overline{N}$
2023± 5	BODENKAMI				` •,	5.0.1011	. 0			pu 1010
2023 ± 5 27 ± 12	BODENKAMI			$\gamma p \rightarrow \overline{p} p p$ $\gamma p \rightarrow \overline{p} p p$	VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
	SSECTION			ir · PPP	3370±10	38 ALEXANDER	72	НВС	0	6.94 p p
VALUE (MeV)	DOCUMENT ID	TECN	CHG	COMMENT	150 ± 40	³⁸ ALEXANDER	72	HBC	0	6.94 p p
2026± 5	24 AZOOZ	83 HYBR		4 p̄ p → p̄ n3π						
20 ± 11	²⁴ AZOOZ	83 HYBR		$4 \overline{p}p \rightarrow \overline{p}n3\pi$						
VALUE (MeV)	DOCUMENT ID	TECN	CHG	COMMENT						
VALUE (NICV)										
2080 ± 10	²⁵ KREYMER	80 STRC	0	$ \begin{array}{ccc} 13 & \pi^{-} & d \rightarrow \\ & p \overline{p} & n(n) \end{array} $						

²⁵ KREYMER 80 STRC 0

 $110\pm20\,$

VALUE (MAV)

+Ishimoto+ (KEK, INUS, KYOT, TOHOK, HIRO)
+Kiu, Li
+Chu, Clement, Elinon+ (BNL, HOUS, PENN, RICE)
+Brown+ (BLSU, BNL, CASE, COLU, UMD, SYRA)
+Daftari, Kalogeropoulos+ (SYRA)
-Angelopoulos+ (ATHU, UCI, UNM, PENN, TEMP)
+Fries, Behrend, Hesse+ (KARLK, KARLE, DESY)
+Butterworth (LOIC, RHEL, SACL, SLAC, TOHOK+)

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT			
3600 ± 20	38 ALEXANDER	72	нвс	0	6.94 p p			
140 ± 20	³⁸ ALEXANDER	72	HBC	0	6.94 p p			
² Not seen by GRAF 91.								
3 Not seen by CHIBA 88, AN	GELOPOULOS 86,	DIE	LS 86.					
⁴ They looked for radiative train	nsitions to bound $p\overline{p}$	state	es, mon	-energ	getic γ rays detected			
5 Observed widths consistent	with experimental re	solut	ion.					
⁶ Not seen by ADIELS 86.								
⁷ From analysis of difference of	of π^- and π^+ spect	ra.						
⁸ Not seen by CHIBA 88, AN	GELOPOULOS 86.							
⁹ Produced backwards. ${}^{10}I(J^P) = 1(1^-)$ from a mass	s dependent partial-v	vave	analysis	taking	solution A.			
11 From reanalysis of data from	JASTRZEMBSKI	31.	•					
12 Not seen by BUSENITZ 89.								
From energy dependence of $P = +$ and $J > 1$. $a_2(1320)$	5π cross section. I^{0} $\pi \pi$ also seen.	; =	1 [—] fron	obse	rvation of ωho decay			
$14 I = 0$ favored, $J = 0$ or 1, see reactions. Not seen in $\overline{p}d$ to	en in total $\overline{p} p$ total c	oss s	section.	Primai	rily from annihilatio			
15 Narrow bump seen in total					rtain. Not seen i			
$\overline{p}p$ charge exchange by ALS section three times larger the	TON-GARNJOST	'5, C	HALOU	PKA 1	76. Integrated cros			
$\overline{p} p$ charge exchange by ALS section three times larger th	TON-GARNJOST	'5, C	HALOU	PKA 7	76. Integrated cros			
17 From energy dependence of f								
structure. 18 From energy dependence of f structure.	ar backward elastic s	catte	ring. So	me inc	lication of addition			
¹⁹ Not seen by ALBERI 79 with	comparable statist	cs.						
20 Not seen by ALBERI 79 with	n comparable statisti	cs.						
21 Seen as a bump in the $\overline{p}p$ —	$\rightarrow K_S^0 K_I^0$ cross sect	ion v	vith JPC	= 1				
²² Isospin 1 favored.	J L							
23 Not seen by AJALTOUNI 82	, ARMSTRONG 79							
²⁴ Not seen by BIONTA 80,	CARROLL 80, HAN	11LT	ON 80,	BANK	(S 81, CHUNG 8:			
BARNETT 83.								
25 Neutron spectator. See also	$n p \overline{p} \pi^-(p)$ channel	follo	wing.					
²⁶ Proton spectator. See also p	$\overline{p}n(n)$ channel above	e.						
$\frac{27}{20}I(J^P) = 1(3^-)$ from a mass	dependent partial-v	ave	analysis	taking	solution A.			
$\frac{28}{30}I(J^P) = 1(3^-)$ from amplit	ude analysis assumir	g on	e-pion e	xchang	ge.			
²⁹ Seen in final state $\omega \pi^+ \pi^-$.								
$\frac{30}{31}I(J^P) = 0(2^+)$ from amplit				xchang	ge.			
31 ALLES-BORELLI 67B see ne								
$\frac{32}{33}I(J^P) = 0(4^+)$ from a mass	dependent partial-v	ave	analysis	taking	solution A.			
$^{33}I(J^P) = 0(4^+)$ from amplit								
$\frac{34}{25}I(J_P^P) = 1(5^-)$ from amplitude analysis assuming one-pion exchange.								
$35 I(J^P) = 1(5^-)$ from amplitude analysis of $\overline{p}p \to \pi\pi$.								
$^{36}_{37}$ I=0,1 $J^P = 5^-$ from Barrel			_					
\overline{N} Decays to \overline{N} N and \overline{N} $N\pi$. N	of coon by RARNET							
³⁸ Decays to $4\pi^+4\pi^-$.	ot seen by BARNE	1 0.	٥.					

DOCUMENT ID

CHG COMMENT

NN(1100-3600) REFERENCES

BARNES	94	PL B331 203	+Birien+ (PS185 Collab.) +Protasov, Dalkarov (ISNG, LEBD) +Grigonian (WA56 Collab.)
CARBONELL	93	PL B306 407	+Protasov, Dalkarov (ISNG, LEBD)
FERRER	93	NP A558 191c	+Grigonian (WA56 Collab.)
CHIBA	91	PR D44 1933	+Grigonian (WA56 Collab.) +Fujitani+ (FUKI, KEK, SANG, OSAK, TMU)
GRAF	91	PR D44 1945	+Fero, Gee+(UCI, PENN, NMSU, KARLK, KARLE, ATHU)
BUSENITZ	89	PR D40 1	+Olszewski, Callahan+ (ILL, FNAL)
CHIBA	88	PL B202 447	+Doi (FUKI, INUS, KEK, SANG, OSAK, TMU)
CHIBA	87	PR D36 3321	+Doi+ (FUKI, INUS, KEK, SANG, OSAK, TMU)
DAFTARI	87	PRL 58 859	+Gray, Kalogeropoulos, Roy (SYRA)
FRANKLIN	87	PL B184 81	(STILL)
ADIELS	86	PL B182 405	+Backenstoss+ (STOH, BASL, LASL, THES, CERN)
ANGELOPO	86	PL B178 441	Angelopoulos+(ATHU, UCI, KARLK, KARLE, NMSU, PENN)
BRIDGES	86B	PRL 56 215	+Daftari, Kalogeropoulos, Debbe+ (SYRA, CASE)
BRIDGES	86D	PL B180 313	+Brown, Daftari+ (SYRA, BNL, CASE, UMD, COLU)
ADIELS	84	PL 138B 235	+ (BASL, KARLK, KARLE, STOH, STRB, THES)
CLOUGH	84	PL 146B 299	+Beard, Bugg+ (SURR, LOQM, ANIK, TRST, GEVA)
AZOOZ	83	PL 122B 471	+Butterworth (LOIC, RHEL, SACL, SLAC, TOHOK+)
BARNETT	83	PR D27 493	+Blockus, Burka, Chien, Christian+ (JHU)
BODENKAMP	83	PL 133B 275	+Fries, Behrend, Fenner+ (KARLK, KARLE, DESY)
RICHTER	83	PL 126B 284	+Adiels (BASL, KARLK, KARLE, STOH, STRB, THES)
AJALTOUNI	82	NP B209 301	+Bachman+ (+ CERN NEUC+)
BANKS	81	PL 100B 191	+Bachman+ (+, CERN, NEUC+) +Booth, Campbell, Armstrong+ (LIVP, CERN)
CHUNG	81	PRL 46 395	+Bensinger+ (BNL, BRAN, CINC, FSU, MASD)
JASTRZEM	81	PR D23 2784	Jastrzembski, Mandelkern+ (TEMP, UCI, UNM)
ALPER	80	PL 94B 422	+Becker+ (AMST, CERN, CRAC, MPIM, OXF+)
ASTON	80D	PL 93B 517	(BONN, CERN, EPOL, GLAS, LANC, MCHS, ORSAY+)
BIONTA	80	PRL 44 909	+Carroll, Edelstein+ (BNL, CMU, FNAL, MASD)
CARROLL	80	PRL 44 1572	+Chiang, Johnson, Cester, Webb+ (BNL, PRIN)
DAUM	80E	PL 90B 475	+Hertzberger+ (AMST, CERN, CRAC, MPIM, OXF+)
DEFOIX	80	NP B162 12	+Dobrzynski, Angelini, Bigi+ (CDEF, PISA)
HAMILTON	80	PRL 44 1179	+Pun. Trinn. Lazarus+ (LBL BNL MTHO)
HAMILTON	80B	PRL 44 1182	+Dobrzynski, Angelini, Bigi+ +Pun, Tripp, Lazarus+ +Pun, Tripp, Lazarus+ (LBL, BNL, MTHO) (LBL, BNL, MTHO)
KREYMER	80	PR D22 36	+Baggett, Fieguth+ (IND, PURD, SLAC, VAND)
ROZANSKA	80	NP B162 505	+Blum, Dietl, Grayer, Lorenz+ (MPIM, CERN)
ALBERI	79	PI 83B 247	+Alvear Castelli Poronat+ (TRST CERN IERI)

CARROLL 74 PRL 32 247 +Chiang, Kycia, Li, Mazur, Michael+ (BNL)
DONALD 73 NP B61 333 +Edwards, Gibbins, Briand, Duboc+ (LIVP, PARIS	
ALEXANDER 72 NP B45 29 +Bar-Nir, Benary, Dagan+ (TELA	
BENVENUTI 71 PRL 27 283 +Cline, Rutz, Reeder, Scherer (WISC)
CLINE 70 Preprint +English, Reeder (WISC)
ALEXANDER 72 NP B45 29 +Bar-Nir, Benary, Dagan+ (TELA BENVENUT) 71 PRL 27 283 +Cline, Rutz, Reeder, Scherer (WISC CLINE 70 Preprint +English, Reeder (WISC CLINE) (WISC CLINE) CLISC 678 NC 50A 776 Alles-Borelli, French, Frisk+ (CERN, BONN	١G
BETTINI 66 NC 42A 695 +Cresti, Limentani, Bertanza, Bigi+ (PADO, PISA	

X(1900-3600)

TANIMORI 90
LIU 87
ARMSTRONG 86C
BRIDGES 86
BRIDGES 86C
DOVER 86
ANGELOPO... 85
BODENKAMP 85
AZOOZ 84

OMITTED FROM SUMMARY TABLE THE X(1900-3600) REGION

PR D41 744 PRL 58 2288 PL B175 383 PRL 56 211 PRL 57 1534 PRL 57 1207 PL 159B 210 NP B255 717 NP B244 277

This high-mass region is covered nearly continuously with evidence for peaks of various widths and decay modes. As no satisfactory grouping into particles is yet possible, we list together in order of increasing mass all the Y=0 bumps above 1900 MeV that are coupled neither to $\overline{N}N$ nor to e^+e^- .

X(1900-3600) MASSES AND WIDTHS

We do not use the following data for averages, fits, limits, etc.

VALUE (MeV) 1900 to 3600 OUF	PLIMIT	DOCUMENT ID				
1900 10 3000 001	X CIMIT					
VALUE (MeV)		DOCUMENT ID		TECN	CHG	COMMENT
1870 ± 40		¹ ALDE	86D	GAM4	0	$100 \pi^- p \rightarrow 2\eta X$
250 ± 30		¹ ALDE	86D	GAM4	0	$100 \pi^- \rho \rightarrow 2\eta X$
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
1898 ± 18	100	THOMPSON	74	HBC	+	$13 \pi^+ \rho \rightarrow 2\rho X$
$108 + 41 \\ -27$	100	THOMPSON	74	нвс	+	13 $\pi^+ p \rightarrow 2\rho X$
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
1900 ± 40	100	BOESEBECK	68	HBC	+	$8 \pi^+ \rho \rightarrow \pi^+ \pi^0 \times$
216 ± 105	100	BOESEBECK	68	нвс	+	$ \begin{array}{c} \pi + \pi^{0} X \\ 8 \pi^{+} \rho \rightarrow \\ \pi^{+} \pi^{0} X \end{array} $
VALUE (MeV)		DOCUMENT ID		TECN	CHG	COMMENT
1929 ± 14		² FOCACCI	66	MMS		3-12 π ⁻ p
22± 2		² FOCACCI	66	MMS	-	$3-12 \pi^- \rho$
VALUE (MeV)		DOCUMENT ID		TECN	CHG	COMMENT
1970 ± 10		CHLIAPNIK	80	нвс	0	$\begin{array}{c} 32 \ K^{+} p \rightarrow \\ 2K_{S}^{0} 2\pi X \end{array}$
40 ± 20		CHLIAPNIK	80	нвс	0	$32 \begin{array}{c} K^{+} p \rightarrow \\ 2K_{S}^{0} 2\pi X \end{array}$
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
1973 ± 15	30	CASO	70	нвс	_	$11.2 \pi^{-} p \rightarrow \rho 2\pi$
80	30	CASO	70	нвс	-	$11.2 \frac{\pi}{\rho} p \rightarrow \rho 2\pi$
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMM	MENT
2070	50	TAKAHASHI	72	нвс	8 π -	$\rho \rightarrow N2\pi$
160	50	TAKAHASHI	72	нвс	$8~\pi^-$	$ ho ightarrow N2\pi$

Meson Particle Listings X(1900-3600)

VALUE (MeV)	EVTS	DOCUME		MRK3	CHG	COMMENT
~ 2104		BUGG	95	мккз		$J/\psi \rightarrow \gamma \pi^+ \pi^- \pi^+ \pi^-$
2103 ± 50	586	3 BISELLO		DM2		$J/\psi \rightarrow 4\pi\gamma$
187 ± 75	586	3 BISELLO	89B	DM2		$J/\psi ightarrow 4\pi\gamma$
2100 ± 40		4 ALDE		GAM4	0	$100 \pi^- p \rightarrow 2\eta X$
250 ± 40		⁴ ALDE	86D	GAM4	0	$100 \pi^- p \rightarrow 2\eta X$
VALUE (MeV)	EVTS	DOCUMEN	IT ID	TECN	сомм	ENT
2141 ± 12	389	GREEN	86	MPSF	400 p	A → 4KX
49 ± 28	389	GREEN	86	MPSF	400 p	$A \rightarrow 4KX$
VALUE (MeV)		DOCUME	NT ID	TECN	CHG	COMMENT
• • • We do not use t	he following	data for av				
2190 ± 10		CLAYTO	N 67	нвс	±	2.5 $\overline{p} p \rightarrow a_2$, ω
VALUE (MeV)		DOCUMEN	IT ID	TECN_	CHG	COMMENT
2195±15		² FOCACO	1 66		_	3-12 π ⁻ p
39 ± 14		² FOCACO	.1 66	MMS	_	3-12 π ⁻ ρ
VALUE (MeV)		DOCUMEN			CHG	COMMENT
2207±22		⁵ CASO ⁵ CASO	70		-	11.2 $\pi^- p$
130		CASO	70	нвс		11.2 π ⁻ p
VALUE (MeV)		DOCUMEN	IT ID	TECN	сомм	ENT
2280± 50		ATKINS	ON 85	OMEG	20-70	$\gamma p \rightarrow$
						$\pi^{+}\pi^{-}\pi^{0}$
440±110		ATKINS	ON 85	OMEG	20-70 ρω	$\begin{array}{c} \gamma \rho \rightarrow \\ , \pi^{+} \pi^{-} \pi^{0} \end{array}$
VALUE (MeV)		DOCUMEN	IT ID	TECN	CHG	COMMENT
2300 ± 100		ATKINS	ON 84F	OMEG	± 0	20–70 $\gamma p \rightarrow \rho f$
~ 250		ATKINS	ON 84F	OMEG	± 0	20-70 $\gamma p \rightarrow \rho f$
VALUE (MeV)		DOCUMEN	IT ID	TECN	CHG	COMMENT
2330±30		ATKINS				25–50 γ p →
						$\rho^{\pm} \rho^{0} \pi^{\mp}$
435±75		ATKINS	38 NC	OMEG	0	$\begin{array}{c} 25-50 \ \gamma \ \rho \rightarrow \\ \rho^{\pm} \ \rho^{0} \ \pi^{\mp} \end{array}$
VALUE (MeV)	EVTS	DOCUMEN	IT ID	TECN	CHG	COMMENT
2340 ± 20	126	6 BALTAY	75	HBC	+	$15 \pi^+ p \rightarrow p5\pi$
180 ± 60	126	⁶ BALTAY	75	HBC	+	15 $\pi^+ \rho \rightarrow \rho 5\pi$
		000000	.T. 10	T-C11	6116	COLUMENT
VALUE (MeV)		² FOCACC		TECN	CHG	COMMENT
2382±24 62± 6		² FOCACC		MMS MMS	_	3-12 π ⁻ p 3-12 π ⁻ p
02.1. 0		TOCACC	.1 00	MINIS	_	3-12 n p
VALUE (MeV)		DOCUMEN	IT ID	TECN	<u>CHG</u>	COMMENT
2500 ± 32		ANDERS	ON 69	MMS	_	16 $\pi^- p$ backward
87		ANDERS	ON 69	MMS	-	16 $\pi^- p$ backward
VALUE (MeV)	EVTS	DOCUMEN	IT ID	TECN	CHG	COMMENT
2620±20	550	BAUD	69	MMS	<u>C//G</u>	8-10 π ⁻ p
85±30	550	BAUD	69	MMS	_	8-10 π p 8-10 π p
						,
VALUE (MeV)		DOCUMEN		TECN	CHG	COMMENT
2676 ± 27		⁵ CASO	70	HBC		11.2 π ⁻ ρ
150		⁵ CASO	70	HBC		11.2 $\pi^- \rho$
VALUE (MeV)		DOCUMEN	IT ID	TECN	СОММ	ENT
2747±32		DENNE		LASS	10 π ⁺	
195±75		DENNE		LASS	10 π ⁺	

VALUE (MeV)	EVTS	DOCUMENT I		TECN	CUC	COMMENT
	640				CHG	COMMENT
2800 ± 20		BAUD	69	MMS	_	8-10 π ⁻ p
46±10	640	BAUD	69	MMS	-	8-10 π p
VALUE (MeV)	EVTS	DOCUMENT I	D	TECN	CHG	COMMENT
2820 ± 10	15	⁷ SABAU	71	HBC	+	8 π ⁺ ρ
50 ± 10	15	⁷ SABAU	71	нвс	+	8 π ⁺ p
VALUE (MeV)	EVTS	DOCUMENT I	D	TECN	CHG	COMMENT
2880 ± 20	230	BAUD	69	MMS	_	8-10 π ⁻ p
< 15	230	BAUD	69	MMS	-	8-10 π ⁻ p
VALUE (MeV)		DOCUMENT I	D	TECN	CHG	COMMENT
$3025\pm2\dot{0}$		BAUD	70	MMS	-	10.5-13 $\pi^- p$
~ 25		BAUD	70	MMS	-	10.5-13 π ⁻ p
VALUE (MeV)		DOCUMENT I	D	TECN	CHG	COMMENT
3075 ± 20		BAUD	70	MMS		10.5-13 π ⁻ p
∼ 25		BAUD	70	MMS	-	10.5-13 $\pi^- \rho$
VALUE (MeV)		DOCUMENT I	D	TECN	CHG	COMMENT
3145 ± 20		BAUD	70	MMS	-	10.5-15 π ⁻ p
< 10		BAUD	70	MMS	-	10.5-15 π ⁻ p
VALUE (MeV)		DOCUMENT I	D	TECN	CHG	COMMENT
3475 ± 20		BAUD	70	MMS	_	14-15.5 π ⁻ p
~ 30		BAUD	70	MMS	-	14-15.5 $\pi^- p$
VALUE (MeV)		DOCUMENT I	D	TECN	CHG	COMMENT
3535 ± 20		BAUD	70	MMS	_	14-15.5 $\pi^- \rho$
~ 30		BAUD	70	MMS	-	14-15.5 $\pi^- \rho$

X(1900-3600) REFERENCES

BUGG BISELLO ATKINSON ALDE GREEN ATKINSON ATKINSON DENNEY ASTON ARESTOV CHILAPNIK BALTAY B	95 89B 88 86D 86 85 83 81B 80 80 80 77 77 70 70 69 68 67 66	PL 8353 378 PR D39 701 ZPHY C38 535 PRL 56 1639 ZPHY C39 333 NP 8239 1 PR D28 2776 NP B189 205 IHEP 80-165 ZPHY C3 285 ZPHY C3	Busetto+ Axon+ (BONN, CERN, GLAS, LAI +Binon, Bricman+ (BELG, LAPP, S +Lai+ (FNAL, ARIZ, FSU, NDAM + (BONN, CERN, GLAS, LAI + (BONN, CERN, GLAS, LAI + Cranley, Firestone, Chapman+ + Bogolijubski+ Chilapnikov, Gerdyukov+ + Cautis, Cohen, Csorma, Kalelkar, Pisello+ + Cautis, Cohen, Csorma, Kalelkar, Pisello+ + Cautis, Cohen, Csorma, Kalelkar, Pisello+ + Caidos, McIlwain, Miller, Mulera+ + Kienzle, Landsberg+ + Barish+ + Uretsky + Benz+ + Conte, Tomasini+ + Collins+ + Conte, Tomasini+ + Collins+	ERP, CERN, LANL, 1, TUFTS, VAND+) NC, MCHS, IPNP+) (IOWA, MICH, JI (IOWA, MICH, JI (SERP) RP, BRUX, MONS) (COLU, BING) (COLU, BING) (PURD) (FURD) (ERP) ENN, NDAM, ANL, (BUCL, ANL) pectrometer Collab. AMB, MILA, SACL) (ENL, CERN) (LIVP, ATHU) (ERR, CERN) (LIVP, ATHU)
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- OTHER RELATED PAPERS -

ANTIPOV	72	PL 40 147	+Kienzle, Landsberg+	(SERP)
CHIKOVANI	66	PL 22 233	+Kienzle, Maglich+	(SERP)

¹ Seen in J=2 wave in one of the two ambiguous solutions.
2 Not seen by ANTIPOV 72, who performed a similar experiment at 25 and 40 GeV/c. 3 ASTON 81B sees no peak, has 850 events in Ajinenko+Barth bins. ARESTOV 80 sees no peak.
4 Seen in J=0 wave in one of the two ambiguous solutions.
5 Seen in $\rho^-\pi^+\pi^-$ (ω and η antiselected in 4π system).
6 Dominant decay into ρ^0 ρ^0 π^+ . BALTAY 78 finds confirmation in $2\pi^+\pi^-2\pi^0$ events which contain $\rho^+\rho^0$ π^0 and $2\rho^+\pi^-$.
7 Seen in $(K\overline{K}\pi\pi)$ mass distribution.

STRANGE MESONS $(S = \pm 1, C = B = 0)$

 $K^+ = u\overline{s}$, $K^0 = d\overline{s}$, $\overline{K}^0 = \overline{d}s$, $K^- = \overline{u}s$, similarly for K^* 's

 \mathcal{K}^{\pm}

$$I(J^P) = \frac{1}{2}(0^-)$$

THE CHARGED KAON MASS

(by T.G. Trippe, Lawrence Berkeley National Laboratory)

The average of the six charged kaon mass measurements which we use in the Particle Listings is

$$m_{K^{\pm}} = 493.677 \pm 0.013 \text{ MeV (S} = 2.4),$$
 (1)

where the error has been increased by the scale factor S. The large scale factor indicates a serious disagreement between different input data. The average before scaling the error is

$$m_{K^{\pm}} = 493.677 \pm 0.005 \text{ MeV}$$
 , $\chi^2 = 22.9 \text{ for 5 D.F., Prob.} = 0.04\%$, (2)

where the high χ^2 and correspondingly low χ^2 probability further quantify the disagreement.

The main disagreement is between the two most recent and precise results,

$$m_{K^{\pm}} = 493.696 \pm 0.007 \text{ MeV}$$
 DENISOV 91
 $m_{K^{\pm}} = 493.636 \pm 0.011 \text{ MeV (S} = 1.5) \text{ GALL 88}$
Average $= 493.679 \pm 0.006 \text{ MeV}$

$$\chi^2 = 21.2$$
 for 1 D.F., Prob. = 0.0004\%, (3)

both of which are measurements of x-ray energies from kaonic atoms. Comparing the average in Eq. (3) with the overall average in Eq. (2), it is clear that DENISOV 91 and GALL 88 dominate the overall average, and that their disagreement is responsible for most of the high χ^2 .

The GALL 88 measurement was made using four different kaonic atom transitions, K^- Pb (9 \rightarrow 8), K^- Pb (11 \rightarrow 10), K^- W (9 \rightarrow 8), and K^- W (11 \rightarrow 10). The m_{K^\pm} values they obtain from each of these transitions is shown in the Particle Listings and in Fig. 1. Their K^- Pb (9 \rightarrow 8) m_{K^\pm} is below and somewhat inconsistent with their other three transitions. The average of their four measurements is

$$m_{K^\pm} = 493.636 \pm 0.007$$
 ,
$$\chi^2 = 7.0 \ \mbox{for 3 D.F., Prob.} \ = 7.2\% \ . \eqno(4)$$

This is a low but acceptable χ^2 probability so, to be conservative, GALL 88 scaled up the error on their average by S=1.5 to obtain their published error ± 0.011 shown in Eq. (3) above and used in the Particle Listings average.

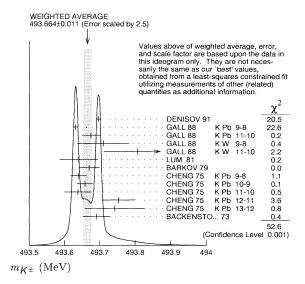


Figure 1: Ideogram of $m_{K^{\pm}}$ mass measurements. GALL 88 and CHENG 75 measurements are shown separately for each transition they measured.

The ideogram in Fig. 1 shows that the DENISOV 91 measurement and the GALL 88 K^- Pb (9 \to 8) measurement yield two well-separated peaks. One might suspect the GALL 88 K^- Pb (9 \to 8) measurement since it is responsible both for the internal inconsistency in the GALL 88 measurements and the disagreement with DENISOV 91.

To see if the disagreement could result from a systematic problem with the K^- Pb (9 \rightarrow 8) transition, we have separated the CHENG 75 data, which also used K^- Pb, into its separate transitions. Figure 1 shows that the CHENG 75 and GALL 88 K^- Pb (9 \rightarrow 8) values are consistent, suggesting the possibility of a common effect such as contaminant nuclear γ rays near the K^- Pb (9 \rightarrow 8) transition energy, although the CHENG 75 errors are too large to make a strong conclusion. The average of all 13 measurements has a χ^2 of 52.6 as shown in Fig. 1 and the first line of Table 1, yielding an unacceptable χ^2 probability of 0.00005%. The second line of Table 1 excludes both the GALL 88 and CHENG 75 measurements of the K^- Pb (9 \rightarrow 8) transition and yields a χ^2 probability of 43%. The third [fourth] line of Table 1 excludes only the GALL 88 K^- Pb (9 \rightarrow 8) [DENISOV 91] measurement and yields a χ^2 probability of 20% [8.6%]. Table 1 shows that removing both measurements of the K^- Pb (9 \rightarrow 8) transition produces the most consistent set of data, but that excluding only the GALL 88 K^- Pb (9 \rightarrow 8) transition or DENISOV 91 also produces acceptable probabilities.

Yu.M. Ivanov, representing DENISOV 91, has estimated corrections needed for the older experiments because of improved 192 Ir and 198 Au calibration γ -ray energies. He estimates

 \mathcal{K}^{\pm}

Table 1: $m_{K^{\pm}}$ averages for some combinations of Fig. 1 data.

$m_{K^{\pm}} \; (\mathrm{MeV})$	χ^2	D.F.	Prob. (9	%)	Measurements used
$\overline{493.664 \pm 0.004}$	52.6	12	0.00005	all	13 measurements
493.690 ± 0.006	10.1	10	43	no	$K^- \operatorname{Pb}(9 \rightarrow 8)$
493.687 ± 0.006	14.6	11	20	no	GALL 88 K^- Pb(9 \rightarrow 8)
493.642 ± 0.006	17.8	11	8.6	no	DENISOV 91

that CHENG 75 and BACKENSTOSS 73 m_{K^\pm} values could be raised by about 15 keV and 22 keV, respectively. With these estimated corrections, Table 1 becomes Table 2. The last line of Table 2 shows that if such corrections are assumed, then GALL 88 K^- Pb (9 \to 8) is inconsistent with the rest of the data even when DENISOV 91 is excluded. Yu.M. Ivanov warns that these are rough estimates. Accordingly, we do not use Table 2 to reject the GALL 88 K^- Pb (9 \to 8) transition, but we note that a future reanalysis of the CHENG 75 data could be useful because it might provide supporting evidence for such a rejection.

Table 2: $m_{K^{\pm}}$ averages for some combinations of Fig. 1 data after raising CHENG 75 and BACKENSTOSS 73 values by 0.015 and 0.022 MeV respectively.

$m_{K^{\pm}} \; (\mathrm{MeV})$	χ^2	D.F.	Prob. (%	6)	Measurements used
493.666 ± 0.004	53.9	12	0.00003	all	13 measurements
493.693 ± 0.006	9.0	10	53	no	$K^- \operatorname{Pb}(9 \rightarrow 8)$
493.690 ± 0.006	11.5	11	40	no	GALL 88 K^- Pb(9 \rightarrow 8)
493.645 ± 0.006	23.0	11	1.8	no	DENISOV 91

The GALL 88 measurement uses a Ge semiconductor spectrometer which has a resolution of about 1 keV, so they run the risk of some contaminant nuclear γ rays. Studies of γ rays following stopped π^- and Σ^- absorption in nucleii (unpublished) do not show any evidence for contaminants according to GALL 88 spokesperson, B.L. Roberts. The DENISOV 91 measurement uses a crystal diffraction spectrometer with a resolution of 6.3 eV for radiation at 22.1 keV to measure the 4f-3d transition in $K^{--12}{\rm C}$. The high resolution and the light nucleus reduce the probability for overlap by contaminant γ rays, compared with the measurement of GALL 88. The DENISOV 91 measurement is supported by their high-precision measurement of the 4d-2p transition energy in $\pi^{--12}{\rm C}$, which is good agreement with the calculated energy.

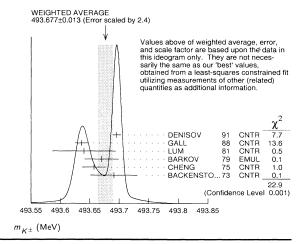
While we suspect that the GALL 88 K^- Pb (9 \rightarrow 8) measurements could be the problem, we are unable to find clear grounds for rejecting it. Therefore, we retain their measurement in the average and accept the large scale factor until further information can be obtained from new measurements and/or from reanalysis of GALL 88 and CHENG 75 data.

We thank B.L. Roberts (Boston Univ.) and Yu.M. Ivanov (Petersburg Nuclear Physics Inst.) for their extensive help in understanding this problem.

K± MASS

VALUE (MeV)	DOCUMENT ID		TECN CHG	COMMENT
493.677±0.016 OUR FIT Err	or includes scale fact	tor of	2.8.	
493.677 ± 0.013 OUR AVERAG	E Error includes sc	ale fa	ctor of 2.4. S	ee the ideogram
	below.			=
493.696±0.007	¹ DENISOV	91	CNTR -	Kaonic atoms
493.636±0.011	² GALL	88	CNTR -	Kaonic atoms
493.640 ± 0.054	LUM	81	CNTR -	Kaonic atoms
493.670 ± 0.029	BARKOV	79	EMUL ±	$e^+e^- \rightarrow$
	2			K+K-
493.657±0.020	² CHENG	75	CNTR ~	Kaonic atoms
493.691 ± 0.040	BACKENSTO	73	CNTR	Kaonic atoms
• • We do not use the follow	ving data for average	s, fit	s, limits, etc.	• • •
493.631 ± 0.007	GALL	88	CNTR -	K ⁻ Pb (9→ 8)
493.675 ± 0.026	GALL	88	CNTR -	$K^- Pb (11 \rightarrow 10)$
493.709 ± 0.073	GALL	88	CNTR -	K W (9→ 8)
493.806±0.095	GALL	88	CNTR -	K-W (11→ 10)
$493.640 \pm 0.022 \pm 0.008$	³ CHENG	75	CNTR -	K - Pb (9→ 8)
$493.658 \pm 0.019 \pm 0.012$	³ CHENG	75	CNTR -	K^- Pb $(10 \rightarrow 9)$
$493.638 \pm 0.035 \pm 0.016$	³ CHENG	75	CNTR -	K^- Pb (11 \rightarrow 10)
$493.753 \pm 0.042 \pm 0.021$	³ CHENG	75	CNTR -	K-Pb (12→ 11)
$493.742 \pm 0.081 \pm 0.027$	³ CHENG	75	CNTR -	K ⁻ Pb (13→ 12)
493.662 ± 0.19	KUNSELMAN	74	CNTR -	Kaonic atoms
493.78 ±0.17	GREINER	65	EMUL +	
493.7 ±0.3	BARKAS	63	EMUL -	
493.9 ±0.2	COHEN	57	RVUE +	

- ¹ Error increased from 0.0059 based on the error analysis in IVANOV 92.
- ² This value is the authors' combination of all of the separate transitions listed for this paper.
 ³ The CHENG 75 values for separate transitions were calculated from their Table 7 transi-
- 3 The CHENG 75 values for separate transitions were calculated from their Table 7 transition energies. The first error includes a 20% systematic error in the noncircular contaminant shift. The second error is due to a ± 5 eV uncertainty in the theoretical transition energies.



 $m_{K^+} - m_{K^-}$

Test of CPT.

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG
-0.032 ± 0.090	1.5M	⁴ FORD	72	ASPK	±
⁴ FORD 72 uses m _m	- m	$= +28 \pm 70 \text{ keV}.$			

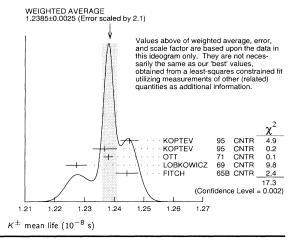
K[±] MEAN LIFE

VALUE (10 ⁻⁸ s)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
1.2386±0.0024 OU	R FIT Error i	ncludes scale fact	or of	2.0.		
1.2385±0.0025 OU	R AVERAGE	Error includes sca below.	ale fa	ctor of 2	2.1. Se	ee the ideogram
1.2451 ± 0.0030	250k	KOPTEV	95	CNTR		K at rest, U tar- get
1.2368 ± 0.0041	150k	KOPTEV	95	CNTR		K at rest, Cu tar- get
1.2380 ± 0.0016	3M	OTT	71	CNTR	+	K at rest
1.2272 ± 0.0036		LOBKOWICZ	69	CNTR	+	K in flight
1.2443 ± 0.0038		FITCH	65B	CNTR	+	K at rest

1.241	5 ± 0.0024	400k	⁵ KOPTEV	95	CNTR		K at rest
1.221	± 0.011		FORD	67	CNTR	±	
1.231	± 0.011		BOYARSKI	62	CNTR	+	
1.25	$^{+0.22}_{-0.17}$		BARKAS	61	EMUL		
1.27	$^{+0.36}_{-0.23}$	51	BHOWMIK	61	EMUL		
1.31	± 0.08	293	NORDIN	61	HBC	_	
1.24	± 0.07		NORDIN	61	RVUE	_	
1.38	± 0.24	33	FREDEN	60B	EMUL		
1.21	± 0.06		BURROWES	59	CNTR		
1.60	± 0.3	52	EISENBERG	58	EMUL		
0.95	+0.36 -0.25		ILOFF	56	EMUL		

ı

 5 KOPTEV 95 report this weighted average of their U-target and Cu-target results, where they have weighted by $1/\sigma$ rather than $1/\sigma^2.$



 $(\tau_{K^+} - \tau_{K^-}) / \tau_{average}$

This quantity is a measure of CPT invariance in weak interactions.

VALUE (%)	DOCUMENT ID	TECN
0.11 ±0.09 OUR AVERAGE	Error includes scale	factor of 1.2.
0.090 ± 0.078	LOBKOWICZ	69 CNTR
0.47 ± 0.30	FORD	67 CNTR

RARE KAON DECAYS

(by L. Littenberg, BNL and G. Valencia, Iowa State University)

- **A.** Introduction: There are several recent reviews on rare kaon decays and related topics [1–13]. The current activity in rare kaon decays can be divided roughly into four categories:
- 1. Searches for explicit violations of the Standard Model
- 2. Measurements of Standard Model parameters
- 3. Searches for ${\cal CP}$ violation
- 4. Studies of strong interactions at low energy.

The paradigm of Category 1 is the lepton flavor violating decay $K_L \to \mu e$. Category 2 includes processes such as $K^+ \to \pi^+ \nu \overline{\nu}$, which is sensitive to $|V_{td}|$. Much of the interest in Category 3 is focussed on the decays $K_L \to \pi^0 \ell \overline{\ell}$, where $\ell \equiv e, \mu, \nu$. Category 4 includes reactions like $K^+ \to \pi^+ \ell^+ \ell^-$ which constitute a testing ground for the ideas of chiral perturbation theory. Other reactions of this type are $K_L \to \pi^0 \gamma \gamma$, which also scales a CP-conserving background to CP violation in $K_L \to \pi^0 \ell^+ \ell^-$ and $K_L \to \gamma \ell^+ \ell^-$, which could possibly shed light on long distance contributions to $K_L \to \mu^+ \mu^-$.

B. Explicit violations of the Standard Model: Most of the activity here is in searches for lepton flavor violation (LFV). This is motivated by the fact that many extensions of the minimal Standard Model violate lepton flavor and by the potential to access very high scales. For example, the tree-level exchange of a LFV vector boson of mass M_X that couples to left-handed fermions with electroweak strength and without mixing angles yields $B(K_L \to \mu e) = 3.3 \times 10^{-11} (91 \text{ TeV}/M_X)^4$ [7]. This simple dimensional analysis may be used to read from Table 1 that the reaction $K_L \to \mu e$ is already probing scales of nearly 100 TeV. Table 1 summarizes the present experimental situation vis a vis LFV, along with the expected near-future progress. The decays $K_L \to \mu^\pm e^\mp$ and $K^+ \to \pi^+ e^\mp \mu^\pm$ (or $K_L \to \pi^0 e^\mp \mu^\pm$) provide complementary information on potential family number violating interactions since the former is sensitive to axial-vector (or pseudoscalar) couplings and the latter is sensitive to vector (or scalar) couplings.

Table 1: Searches for lepton flavor violation in K decay

Mode	90% CL upper limit	Exp't	Yr./Ref.	(Near-) future aim
$K^+ \to \pi^+ e \mu$	2.1E-10	BNL-777	90/14	3E-12 (BNL-865)
$K_L \rightarrow \mu e$	3.3E-11			2E-12 (BNL-871)
$K_L \! o \! \pi^0 \mu e$	3.5E-9	FNAL-799	94/16	E-11 (FNAL799II)

Another forbidden decay currently being pursued is $K^+ \to \pi^+ X^0$, where X^0 is a very light, noninteracting particle (e.g. hyperphoton, axion, familon, etc.). The published upper limit on this process [17] is 1.7×10^{-9} , but recently this has been improved to 5.2×10^{-10} [18]. Data already collected by BNL-787 are expected to yield another substantial factor in sensitivity to this process.

C. Measurements of Standard Model parameters: Until recently searches for $K^+ \to \pi^+ \nu \overline{\nu}$ have been motivated by the possibility of observing non-SM physics because the sensitivity attained was far short of the SM prediction for this decay [19] and long-distance contributions were known to be negligible [3,20]. However, BNL-787 is approaching the sensitivity at which the observation of an event could no longer be unambiguously attributed to non-SM physics. The published 90% c.l. upper limit [17] is 5.2×10^{-9} , but this has been recently improved to 2.4×10^{-9} [18], and extensive recent running with an upgraded beam and detector is expected to further improve this significantly. This reaction is now becoming interesting from the point of view of constraining SM parameters where the branching ratio is expected to be of order 10^{-10} , and can be written as [3]:

$$B(K^{+} \to \pi^{+} \nu \overline{\nu}) = \frac{\alpha^{2} B(K^{+} \to \pi^{o} e^{+} \nu)}{V_{us}^{2} 2\pi^{2} \sin^{4} \theta_{W}} \times \sum_{l=e,\mu,\tau} |V_{cs}^{*} V_{cd} X_{NL}^{\ell} + V_{ts}^{*} V_{td} X(m_{t})|^{2}$$
(1)

where $X(m_t)$ is of order 1, and X_{NL}^{ℓ} is several hundred times smaller. This form exhibits the strong dependence of this

 \mathcal{K}^{\pm}

branching ratio on $|V_{td}|$. It also makes manifest the fact that the *a priori* unknown hadronic matrix element drops out in the comparison to the very well-measured rate of K_{e3} decay. QCD corrections, which are contained in X_{NL}^{ℓ} , are relatively small and now known [21] to $\leq 10\%$. Evaluating the constants in Eq. (1) with $m_t = 175$ GeV, one can cast this result in terms of the CKM parameters A, ρ and η (see our Section on "The Cabibbo-Kobayashi-Maskawa mixing matrix") [21].

$$B(K^{+} \to \pi^{+} \nu \overline{\nu})$$

$$\approx 1.2 \times 10^{-10} A^{4} [\eta^{2} + \frac{2}{3} (\rho_{o}^{e} - \rho)^{2} + \frac{1}{3} (\rho_{o}^{\tau} - \rho)^{2}] \quad (2)$$

where $\rho_o^\ell \equiv 1 + \frac{X_{NL}^\ell}{A^2 \lambda^4 X(m_t)}$. Thus, $\mathrm{B}(K^+ \to \pi^+ \nu \overline{\nu})$ determines a circle in the ρ , η plane with center $(\rho_o,0)$; $\rho_o \equiv \frac{2}{3} \rho_o^e + \frac{1}{3} \rho_o^\tau \approx 1.4$, and radius $\approx \frac{1}{A^2} \sqrt{\frac{\mathrm{B}(K^+ \to \pi^+ \nu \overline{\nu})}{1.2 \times 10^{-10}}}$. The decay $K_L \to \mu^+ \mu^-$ also has a short distance contribu-

The decay $K_L \to \mu^+ \mu^-$ also has a short distance contribution sensitive to the CKM parameter ρ . For $m_t = 175$ GeV it is given by [21]:

$$B_{SD}(K_L \to \mu^+ \mu^-) \approx 1.9 \times 10^{-9} A^4 (\rho_o' - \rho)^2$$
 (3)

where ρ'_{o} depends on the charm quark mass and is around 1.2. This decay, however, is dominated by a long-distance contribution from a two-photon intermediate state. The absorptive (imaginary) part of the long-distance component is calculated in terms of the measured rate for $K_L \to \gamma \gamma$ to be $B_{abs}(K_L \to \gamma \gamma)$ $\mu^+\mu^-$) = $(6.8 \pm 0.3) \times 10^{-9}$; and it almost completely saturates the observed rate $B(K_L \to \mu^+ \mu^-) = (7.2 \pm 0.5) \times 10^{-9}$ listed in the current edition. The difference between the observed rate and the absorptive component can be attributed to the (coherent) sum of the short-distance amplitude and the real part of the long-distance amplitude. In order to use this mode to constrain ρ it is, therefore, necessary to know the real part of the long-distance contribution. Unlike the absorptive part, the real part of the long-distance contribution cannot be derived from the measured rate for $K_L \to \gamma \gamma$. At present, it is not possible to compute this long-distance component reliably and, therefore, it is not possible to constrain ρ from this mode. It is expected that studies of the reactions $K_L \to \ell^+\ell^-\gamma$, and $K_L \to \ell^+ \ell^- \ell'^+ \ell'^-$ for $\ell, \ell' = e$ or μ will improve our understanding of the long distance effects in $K_L \to \mu^+ \mu^-$ (the current data is parameterized in terms of α_K^* , discussed in the Form Factors section of the K_L^0 Particle Properties Listings).

D. Searches for CP violation: The mode $K_L \to \pi^0 \nu \overline{\nu}$ is dominantly CP-violating and free of hadronic uncertainties [3,22]. The Standard Model predicts a branching ratio of order 10^{-10} ; for $m_t=175$ GeV it is given approximately by [21]:

$$B(K_L \to \pi^0 \nu \overline{\nu}) \approx 5 \times 10^{-10} A^4 \eta^2 . \tag{4}$$

The current upper bound is $B(K_L \to \pi^0 \nu \overline{\nu}) \le 5.8 \times 10^{-5}$ [23] and FNAL799II (KTeV) is expected to place a bound of order 10^{-8} [24].

The decay $K_L \to \pi^0 e^+ e^-$ also has sensitivity to the product $A^4 \eta^2$. It has a direct CP-violating component that depends on the value of the top-quark mass, and that for $m_t = 175$ GeV is given by [25]:

$$B_{\rm dir}(K_L \to \pi^0 e^+ e^-) \approx 7 \times 10^{-11} A^4 \eta^2 \ .$$
 (5)

However, like $K_L \to \mu^+ \mu^-$ this mode suffers from large theoretical uncertainties due to long distance strong interaction effects. It has an indirect CP-violating component given by:

$$B_{\rm ind}(K_L \to \pi^0 e^+ e^-) = |\epsilon|^2 \frac{\tau_{K_L}}{\tau_{K_S}} B(K_S \to \pi^0 e^+ e^-) ,$$
 (6)

that has been estimated to be less than 10^{-12} [26], but that will not be known precisely until a measurement of $K_S \to \pi^0 e^+ e^-$ is available [6,27]. There is also a CP-conserving component dominated by a two-photon intermediate state that cannot be computed reliably at present. This component has an absorptive part that can be, in principle, determined from a detailed analysis of $K_L \to \pi^0 \gamma \gamma$.

An analysis of $K_L \to \pi^0 \gamma \gamma$ within chiral perturbation theory has been carried out in terms of a parameter a_V [28,29] that determines both the rate and the shape of the distribution $d\Gamma/dm_{\gamma\gamma}$. A fit to the distribution has given $-0.32 < a_V < 0.19$ [30]; a value that suggests that the absorptive part of the CP-conserving contribution to $K_L \to \pi^0 e^+ e^-$ is significantly smaller than the direct CP-violating component [30]. However, there remains some uncertainty in the interpretation of $K_L \to \pi^0 \gamma \gamma$ in terms of a_V . Analyses that go beyond chiral perturbation theory have found larger values of a_V , indicating a sizable CP-conserving component for $K_L \to \pi^0 e^+ e^-$. The real part of the CP-conserving contribution to $K_L \to \pi^0 e^+ e^-$ is also unknown.

Finally, BNL-845 observed a potential background to $K_L \to \pi^0 e^+ e^-$ from the decay $K_L \to \gamma \gamma e^+ e^-$ [31]. This was later confirmed with an order of magnitude larger sample by FNAL-799 [32], which measured additional kinematic quantities. It has been estimated that this background will enter at the level of 10^{-11} [33], comparable to the signal level. Because of this, the observation of $K_L \to \pi^0 e^+ e^-$ will depend on background subtraction with good statistics.

The current upper bound for the process $K_L \to \pi^0 e^+ e^-$ is 4.3×10^{-9} [34]. For the closely related muonic process, the upper bound is $B(K_L \to \pi^0 \mu^+ \mu^-) \leq 5.1 \times 10^{-9}$ [35]. FNAL799II expects to reach a sensitivity $\lesssim 10^{-11}$ for both reactions [36].

E. Other long distance dominated modes: The decays $K^+ \to \pi^+ \ell^+ \ell^-$ ($\ell = e$ or μ) are described by chiral perturbation theory in terms of one parameter, ω^+ [37]. This parameter determines both the rate and distribution $d\Gamma/dm_{\ell\ell}$ for these processes. A careful study of these two reactions can provide a measurement of ω^+ and a test of the chiral perturbation theory description. A simultaneous fit to the rate and spectrum of $K^+ \to \pi^+ e^+ e^-$ gives: $\omega^+ = 0.89^{+0.24}_{-0.14}$; $B(K^+ \to \pi^+ e^+ e^-) = (2.99 \pm 0.22) \times 10^{-7}$ [38]. These two results satisfy the prediction of chiral perturbation theory within

two standard deviations [6]. Improved statistics for this mode and a measurement of the mode $K^+ \to \pi^+ \mu^+ \mu^-$ are thus desired. BNL-787 has observed the process $K^+ \to \pi^+ \mu^+ \mu^-$ [39] at about the predicted level, but the result is not yet accurate enough to provide additional constraints.

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K+ DECAY MODES

 K^- modes are charge conjugates of the modes below.

	Mode	Fraction (Γ_j/Γ)	Scale factor/ Confidence level
Γ_1	$\mu^+ \nu_{\mu}$	· (63.51±0.18) %	S=1.3
Γ_2	$e^+ \nu_e$	$(1.55\pm0.07)\times10^{-5}$	5
Гз	$\pi^+\pi^0$	(21.16 ± 0.14) %	S=1.1
Γ_4	$\pi^{+}\pi^{+}\pi^{-}$	(5.59 ± 0.05) %	S=1.8
Γ_5	$\pi^{+}\pi^{0}\pi^{0}$	(1.73 ± 0.04) %	S=1.2
Γ_6	$\pi^{0} \mu^{+} \nu_{\mu}$	(3.18 ± 0.08) %	S=1.5
	Called $K_{\mu 3}^+$.		
Γ_7	$\pi^{0} e^{+} \nu_{e}$	(4.82±0.06) %	S=1.3
	Called K_{e3}^+ .		
	$\pi^0 \pi^0 e^+ \nu_e$	$(2.1 \pm 0.4) \times 10^{-5}$	5
Γ9	$\pi^{+}\pi^{-}e^{+}\nu_{e}$	$(3.91\pm0.17)\times10^{-5}$	
Γ_{10}	$\pi^{+}\pi^{-}\mu^{+}\nu_{\mu}$	$(1.4 \pm 0.9) \times 10^{-5}$	5
Γ_{11}	$\pi^0 \pi^0 \pi^0 e^+ \nu_e$	$< 3.5 \times 10^{-6}$	CL=90%
Γ_{12}	$\pi^+ \gamma \gamma$	$[a] < 1 \times 10^{-6}$	CL=90%
Γ_{13}	$\pi^+ 3\gamma$	$[a] < 1.0 \times 10^{-4}$	
Γ_{14}	$\mu^+ \nu_\mu \nu \overline{\nu}$	$< 6.0 \times 10^{-6}$	
	$e^+ \nu_e \nu \overline{\nu}$	< 6 × 10 ⁻⁵	
Γ ₁₆	$\mu^+ u_\mue^+e^-$	$(1.06\pm0.32)\times10^{-6}$	•
Γ_{17}	$e^+ u_e e^+ e^-$	$(2.1 \begin{array}{c} +2.1 \\ -1.1 \end{array}) \times 10^{-5}$,
Γ_{18}	$\mu^+ \nu_\mu \mu^+ \mu^-$	$< 4.1 \times 10^{-7}$	CL=90%
Γ ₁₉	$\mu^+ \nu_\mu \gamma$	[a,b] $(5.50\pm0.28)\times10^{-3}$	3
Γ_{20}	$\pi^+\pi^0\gamma$	[a,b] $(2.75\pm0.15)\times10^{-4}$	ļ.
Γ_{21}	$\pi^+\pi^0\gamma(DE)$	[a,c] $(1.8 \pm 0.4) \times 10^{-5}$	i
Γ_{22}	$\pi^+\pi^+\pi^-\gamma$	$[a,b]$ $(1.04 \pm 0.31) \times 10^{-4}$	ļ
Γ_{23}	$\pi^+\pi^0\pi^0\gamma$	[a,b] $(7.5 \begin{array}{c} +5.5 \\ -3.0 \end{array}) \times 10^{-6}$	5
Γ_{24}	$\pi^0 \mu^+ \nu_\mu \gamma$	$[a,b] < 6.1 \times 10^{-5}$	CL=90%
Γ ₂₅	$\pi^0 e^+ \nu_e \gamma$	[a,b] (2.62±0.20) × 10 ⁻⁴	
Γ_{26}	$\pi^0 e^+ \nu_e \gamma (SD)$	$[d] < 5.3 \times 10^{-5}$	
Γ ₂₇	$\pi^0 \pi^0 e^+ \nu_e \gamma$	< 5 × 10 ⁻⁶	

Lepton Family number (LF), Lepton number (L), $\Delta S = \Delta Q$ (SQ) violating modes, or $\Delta S = 1$ weak neutral current (S1) modes

$\begin{array}{cccccccccccccccccccccccccccccccccccc$							
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Γ ₂₈	$\pi^+\pi^+e^-\overline{\nu}_e$	SQ	<	1.2	$\times 10^{-8}$	CL=90%
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Γ_{29}	$\pi^+\pi^+\mu^-\overline{\nu}_{\mu}$	5Q	<	3.0	\times 10 ⁻⁶	CL=95%
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Γ ₃₀		S 1	(2.74 ± 0.23		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Γ_{31}	$\pi^{+}\mu^{+}\mu^{-}$	S1	<	2.3		CL=90%
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Γ ₃₂		S1	<	2.4	$\times 10^{-9}$	CL=90%
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Γ33	$\mu^- \nu e^+ e^+$	LF	<	2.0	$\times 10^{-8}$	CL=90%
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Γ ₃₄		LF	[e] <	4	$\times 10^{-3}$	CL=90%
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Γ ₃₅	$\pi^{+}\mu^{+}e^{-}$	LF	<	2.1	$\times 10^{-10}$	CL=90%
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Γ ₃₆	$\pi^{+}\mu^{-}e^{+}$	LF	<	7	× 10 ⁻⁹	CL=90%
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Γ_{37}		L	<	7	$\times 10^{-9}$	CL=90%
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Γ ₃₈	$\pi^{-}e^{+}e^{+}$	L	<	1.0	$\times 10^{-8}$	CL=90%
$\Gamma_{41} = \pi^0 e^{+} \overline{\nu}_e$ $L = [e] < 3 $	Γ39	$\pi^- \mu^+ \mu^+$	L	<	1.5		CL=90%
	Γ_{40}	$\mu^+ \overline{\nu}_e$	L	[e] <	3.3	$\times 10^{-3}$	CL=90%
$\Gamma_{42} = \pi^+ \gamma$	Γ_{41}	$\pi^0 e^+ \overline{\nu}_e$	L	[e] <	3	\times 10 ⁻³	CL=90%
	Γ_{42}	$\pi^+\gamma$					

\mathcal{K}^{\pm}

- [a] See the Particle Listings below for the energy limits used in this measure-
- [b] Most of this radiative mode, the low-momentum $\boldsymbol{\gamma}$ part, is also included in the parent mode listed without γ 's.
- [c] Direct-emission branching fraction.
- [d] Structure-dependent part.
- [e] Derived from an analysis of neutrino-oscillation experiments.

CONSTRAINED FIT INFORMATION

An overall fit to the mean life, 2 decay rate, and 20 branching ratios uses 60 measurements and one constraint to determine 8 parameters. The overall fit has a $\chi^2=78.1$ for 53 degrees of

The following off-diagonal array elements are the correlation coefficients $\langle \delta \rho_i \delta \rho_j \rangle / (\delta \rho_i \cdot \delta \rho_j)$, in percent, from the fit to parameters ρ_i , including the branching fractions, $x_i \equiv \Gamma_i/\Gamma_{\rm total}$. The fit constrains the x_i whose labels appear in this array to sum to one.

	1						
<i>x</i> ₃	-58						
x_4	-41	-12					
<i>x</i> ₅	-27	4	21				
<i>×</i> ₆	48	-17	14	2			
<i>x</i> ₇	-50	-16	34	6	39		
<i>x</i> ₈	-3	-1	2	0	2	6	
Γ	7	2	-18	4	-2	-6	0
	<i>X</i> ₁	X3	×Δ	Xs	X ₆	X7	XΩ

	Mode	Rate (10^8 s^{-1})	Scale factor
Γ_1	$\mu^+ u_{\mu}$	0.5128 ±0.0018	1.5
Γ_3	$\pi^+\pi^0$	0.1708 ±0.0012	1.1
Γ_{Δ}	$\pi^{+}\pi^{+}\pi^{-}$	0.0452 ±0.0004	1.8
Γ ₅	$\pi^{+} \pi^{0} \pi^{0}$	0.01399 ± 0.00032	1.2
Γ_6	$\pi^{0} \mu^{+} \nu_{\mu}$	0.0257 ± 0.0006	1.5
	Called $K_{\mu 3}^+$.		
Γ_7	$\pi^{0} e^{+} \nu_{e}$	0.0389 ±0.0005	1.3
	Called K_{e3}^+ .		
Γ8	$\pi^0 \pi^0 e^+ \nu_e$	$(1.69 \begin{array}{c} +0.34 \\ -0.29 \end{array}) \times 10$	o ⁻⁵

K± DECAY RATES

$\Gamma(\mu^+ u_\mu)$						Γ ₁
VALUE (10 ⁶ s ⁻¹)		DOCUMENT	ID	TECN	CHG	
51.28±0.18 OUR F	IT Error inc	udes scale fact	or of 1.5	i.		
51.2 ±0.8		FORD	67	CNTR	±	
$\Gamma(\pi^+\pi^+\pi^-)$						Γ ₄
VALUE (10 ⁶ s ⁻¹)	EVTS	DOCUMENT	ID	TECN	CHG	
4.52 ±0.04 OUR	FIT Error in	cludes scale fac	tor of 1.	.8.		
4.511 ± 0.024		⁶ FORD	70	ASPK		
• • • We do not us	se the followin	g data for aver	ages, fit	s, limits,	etc. • • •	
4.529 ± 0.032	3.2M	⁶ FORD	70	ASPK		
4.496 ± 0.030		⁶ FORD	67	CNTR	±	
⁶ First FORD 70	value is secon	FORD 70 cor	nbined v	vith FOF	RD 67.	

$(\Gamma(K^+) - \Gamma(K^-)) / \Gamma(K)$

$K^{\pm} \rightarrow \mu^{\pm} \nu_{\mu}$ RATE DIFFERENCE/AVERAGE

-0.54 ± 0.41	FORD	67	CNTR
VALUE (%)	DOCUMENT ID		TECN
Test of CPT conservation.			

$K^{\pm} \rightarrow \pi^{\pm}\pi^{+}\pi^{-}$ RATE DIFFERENCE/AVERAGE

lest of C	P conservation.					
VALUE (%)	EVTS	DOCUMENT ID		TECN	CHG	
0.07±0.12 O	UR AVERAGE					
$\boldsymbol{0.08 \pm 0.12}$		⁷ FORD	70	ASPK		
-0.50 ± 0.90		FLETCHER	67	OSPK		
• • • We do no	ot use the following	data for averag	es, fits	s, limits,	etc. •	• •
-0.02 ± 0.16		⁸ SMITH	73	ASPK	±	
0.10 ± 0.14	3.2M	⁷ FORD	70	ASPK		
0.04 ± 0.21		7 EOPD	67	CNITE		

 7 First FORD 70 value is second FORD 70 combined with FORD 67. 8 SMITH 73 value of $K^\pm\to\pi^\pm\pi^+\pi^-$ rate difference is derived from SMITH 73 value of $K^\pm\to\pi^\pm2\pi^0$ rate difference.

$K^{\pm} \rightarrow \pi^{\pm} \pi^{0} \pi^{0}$ RATE DIFFERENCE/AVERAGE

Test of CP of	onservation.				
VALUE (%)	EVTS	DOCUMENT I	D	TECN	CHG
0.0 ±0.6 OUR	AVERAGE				
0.08 ± 0.58		SMITH	73	ASPK	±
-1.1 ± 1.8	1802	HERZO	69	OSPK	

$K^{\pm} \rightarrow \pi^{\pm}\pi^{0}$ RATE DIFFERENCE/AVERAGE

	Test of <i>CPT</i>	conservation.				
VALUE	%)		DOCUMENT ID		TECN	
0.8 ± 1	.2		HERZO	69	OSPK	

$K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\gamma$ RATE DIFFERENCE/AVERAGE

Test of CP	conservation.					
VALUE (%)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
0.9 ± 3.3 OUR A	/ERAGE					
0.8 ± 5.8	2461	SMITH	76	WIRE	±	E _π 55-90 MeV
1.0 ± 4.0	4000	ABRAMS	73B	ASPK	±	Ε _π 51-100 MeV
$0.0\!\pm\!24.0$	24	EDWARDS	72	OSPK		$E_{\pi}^{''}$ 58–90 MeV

K+ BRANCHING RATIOS

$\Gamma(\mu^+ \nu_\mu)/\Gamma_{\text{total}}$							Γ_1/Γ
VALUE (units 10-2)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT	
$\textbf{63.51} \pm \textbf{0.18} \; \textbf{OUR} \; \textbf{FIT}$	Error incli	udes scale factor o	of 1.3				
63.24±0.44	62k	CHIANG	72	OSPK	+	1.84 GeV/c	κ^+
• • • We do not use t	he following	g data for average	s, fits	, limits,	etc. •	• •	
56.9 ±2.6		9 ALEXANDER	57	EMUL	+		
58.5 ±3.0		⁹ BIRGE	56	EMUL	+		

⁹ Old experiments not included in averaging.

$\Gamma(\mu^+\nu_\mu)/\Gamma(\pi^+\tau)$	$(\tau^{+}\pi^{-})$				Γ_1/Γ_4
VALUE	EVTS	DOCUMENT	ID TECN	CHG	
11.35±0.12 OUR F	IT Error inc	ludes scale facto	or of 1.8.		
• • • We do not us	se the followin	g data for avera	ges, fits, limits	, etc. • • •	
10.38 ± 0.82	427	¹⁰ YOUNG	65 EMUL	+	

 10 Deleted from overall fit because YOUNG 65 constrains his results to add up to 1. Only YOUNG 65 measured $(\mu\nu)$ directly.

 Γ_2/Γ

$\Gamma(e^+\nu_e)/\Gamma_{\rm total}$ VALUE (units 10⁻⁵) CL% EVTS DOCUMENT ID

• • • We do	not use the	following	data for averag	es, fits	s, limits,	etc. ●	•
$2.1 + 1.8 \\ -1.3$		4	BOWEN	67B	OSPK	+	
< 160.0	95		BORREANI	64	HBC	+	

$\Gamma(e^+\nu_e)/\Gamma(\mu^+\nu_\mu)$ Γ_2/Γ_1 VALUE (units 10-5)

2.45 ± 0.11 OUR A	/FRAGE				
2.51 + 0.15	404	HEINTZE	76	SPEC	+
2.37 ± 0.17	534	HEARD		SPEC	
2.42 ± 0.42	112	CLARK	72	OSPK	+
• • • We do not u	se the following	g data for averag	ges, fits	, limits,	etc. • •

 $1.8 \begin{array}{l} +0.8 \\ -0.6 \end{array}$ MACEK ASPK $1.9 \begin{array}{c} +0.7 \\ -0.5 \end{array}$ 10 BOTTERILL 67 ASPK +

$\Gamma(\pi^+\pi^0)/\Gamma_{\text{total}}$ Γ_3/Γ VALUE (units 10-2) **EVTS** DOCUMENT ID TECN CHG COMMENT

21.16±0.14 OUR FIT Error includes scale factor of 1.1. 21.18±0.28 16k CHIANG 72 OSPK + 1.84 GeV/c K+ \bullet \bullet \bullet We do not use the following data for averages, fits, limits, etc. \bullet \bullet See $\Gamma(\pi^+\pi^0)/$ 21.0 ±0.6 CALLAHAN 65 HLBC $\Gamma(\pi^+\pi^+\pi^-)$ 21.6 ± 0.6 TRILLING 65B RVUE ¹¹ ALEXANDER 23.2 ±2.2 27.7 ±2.7 57 EMUL

56 EMUL +

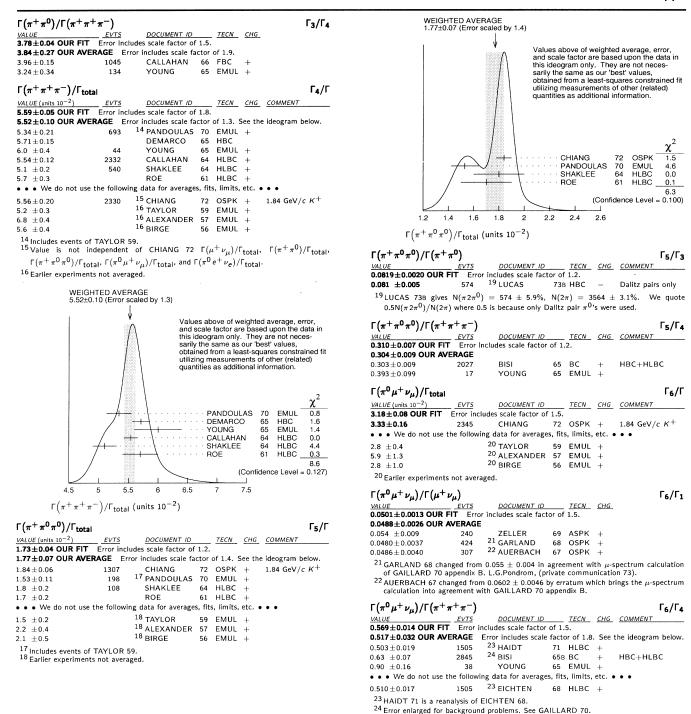
¹¹ BIRGE ¹¹ Earlier experiments not averaged.

$\Gamma \big(\pi^+ \, \pi^0\big) / \Gamma \big(\mu^+ \, \nu_\mu\big)$ Γ_3/Γ_1 VALUE EVTS DOCUMENT ID TECN CHG COMMENT 0.3331±0.0028 OUR FIT Error includes scale factor of 1.1. 0.3316±0.0032 OUR AVERAGE USHER $0.3329 \pm 0.0047 \pm 0.0010$ 45k 92 SPEC $p\overline{p}$ at rest 0.3355 ± 0.0057 12 WEISSENBE... 76 SPEC ZELLER 69 ASPK 13 AUERBACH 67 OSPK 0.305 ± 0.018 1600 0.3277 ± 0.0065 4517

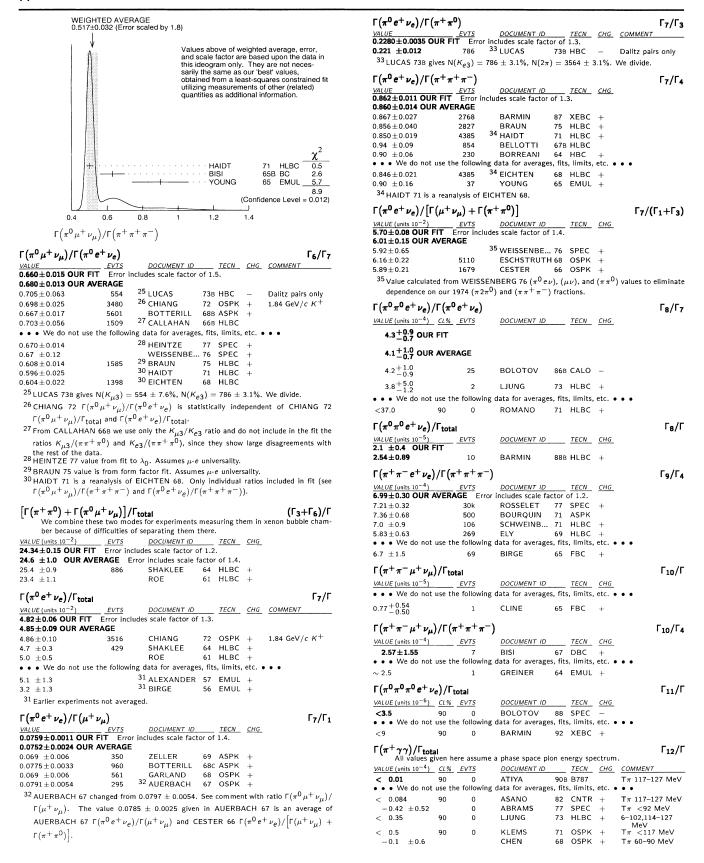
 \bullet $\,\bullet\,$ We do not use the following data for averages, fits, limits, etc. $\,\bullet\,$ $\,\bullet\,$

12 WEISSENBE... 74 STRC + $0.328\ \pm0.005$ 25k

 12 WEISSENBERG 76 revises WEISSENBERG 74. 13 AUERBACH 67 changed from 0.3253 \pm 0.0065. See comment with ratio $\Gamma(\pi^0\,\mu^+\,\nu_\mu)/$ $\Gamma(\mu^+\nu_\mu)$.



 K^{\pm}



		a phase space pion			Γ ₁₃ /Γ	$\Gamma(\pi^+\pi^+\pi^-$ VALUE (units 10 ⁻	.,,	DOCUMENT ID		TECN	CHG	Г: <u>соммент</u>
VALUE (units 10 ⁻⁴)	<u>CL%</u> 90	DOCUMENT ID	82 CNT		<u>COMMENT</u> T(π) 117–127	1.04±0.31 OU 1.10±0.48		BARMIN		VEDC		<i>5</i> () . <i>5</i> 14 1
• • • We do not use					`Me∨	1.10 ± 0.48 1.0 ± 0.4	7	STAMER		XEBC EMUL	+	$E(\gamma) > 5$ Me' $E(\gamma) > 11$ Me
<3.0	90	KLEMS	71 OSP		T(π) >117 MeV	$\Gamma(\pi^+\pi^0\pi^0\gamma$	$-)/\Gamma(\pi^{+}\pi^{0}\pi^{0})$					Γ ₂₃
$\Gamma ig(\mu^+ u_\mu u \overline{ u} ig) / \Gamma_{ m tota}$					Γ ₁₄ /Γ	VALUE (units 10		DOCUMENT ID		TECN	CHG	COMMENT
(μ νμνν)/ tota ALUE (units 10 ⁻⁶) CL		DOCUMENT ID	TECN	CHG	'14/'	$4.3^{+3.2}_{-1.7}$		BOLOTOV	85	SPEC	_	$E(\gamma) > 10 \text{ M}$
<6.0 90		36 PANG	73 CNT				\					_
³⁶ PANG 73 assume	es μ spectru	ım from $\nu ext{-} u$ interac	tion of BAF	RDIN 70		$\Gamma(\pi^0 \mu^+ u_\mu \gamma$						Γ;
$\Gamma(e^+ \nu_e \nu \overline{\nu}) / \Gamma(e^+$	+ν _ο)				Γ_{15}/Γ_{2}	VALUE (units 10 ⁻ <6.1	5) <u>CL% EVTS</u> 90 0	DOCUMENT ID	73	TECN HLBC	CHG +	$\frac{COMMENT}{E(\gamma)} > 30 \text{ Me}$
VALUE CL	EVTS	DOCUMENT ID		CHG	20, 2			230140		TIEBC		
<3.8 90	0	HEINTZE	79 SPE	2 +			$)/\Gamma(\pi^0 e^+ \nu_e)$					Γ ₂
$\Gamma(\mu^+ u_\mue^+e^-)/\Gamma$	$-(\pi^{+}\pi^{-}e$	$^{+}\nu_{e})$			Γ ₁₆ /Γ ₉	VALUE (units 10 - 0.54 ± 0.04 OU		DOCUMENT ID ror includes scale fa	ctor	TECN of 1.1.	<u>CHG</u>	COMMENT
/ALUE (units 10 ⁻³)	EVTS	DOCUMENT ID	TECN		COMMENT	0.46 ± 0.08	82	⁴⁵ BARMIN		XEBC		$E(\gamma) > 10$
27. ±8. • • • We do not use	14	37 DIAMANT			Extrapolated BR							MeV, 0.6 $\cos\theta_e \gamma$
3.3±0.9	14	³⁷ DIAMANT			m _{ee} >140	0.56 ± 0.04	192	46 BOLOTOV	86B	CALO	_	$0.9 E(\gamma) > 10 Me$
37 DIAMANT-BERG	-					0.76±0.28	13	⁴⁷ ROMANO		HLBC		$E(\gamma) > 10 \text{ Me}$
DIAMANT-BERG					to include low mass		ot use the following 82	ng data for average ⁴⁵ BARMIN			etc. •	
e pairs.						1.51 ± 0.25	82	DARWIN	aī	XEBC		$E(\gamma) > 10 \text{ Me}$ $\cos \theta_e \gamma < 0.98$
$\Gamma(e^+\nu_ee^+e^-)/\Gamma$	•	-,			Γ ₁₇ /Γ ₉	0.48 ± 0.20	16	⁴⁸ LJUNG	73	HLBC	+	$E(\gamma) > 30 \text{ Me}$
/ALUE (units 10 ⁻²)	EVTS	DOCUMENT ID	TECN			$0.22^{+0.15}_{-0.10}$		⁴⁸ LJUNG	73	HLBC	+	$E(\gamma)>$ 30 Me
0.54 ^{+0.54} -0.27	4	DIAMANT	76 SPE	+		0.53 ± 0.22		⁴⁷ ROMANO		HLBC		$E(\gamma) > 30 \text{ Me}$
$\Gamma(\mu^+ u_\mu\mu^+\mu^-)/\Gamma$	r				Γ /Γ	1.2 ±0.8		BELLOTTI		HLBC		$E(\gamma) > 30 \text{ Me}$
$(\mu^+ \nu_\mu \mu^+ \mu^-)/1$ /ALUE (units 10 ⁻⁷)	total	DOCUMENT ID	TECN	CHG	Γ ₁₈ /Γ	45 BARMIN 9	1 quotes branching	g ratio $\Gamma(K \to e\pi^0$ $\pi^+\pi^+\pi^-)$]. For	'νγ),	/F _{all} . Ti	he mea	sured normaliz
<4.1	90	ATIYA	89 B787			used $\Gamma(K \rightarrow V)$	$e\pi^{0}\nu) + \Gamma(K \rightarrow e\pi^{0}\nu)/\Gamma_{211} =$	0.0482 to calculate	the v	values di	with 6	tner experimen here.
-					- /-	$^{46}\cos\theta(e\gamma)$ b	etween 0.6 and 0.9	9.				
$-(\mu^+\nu_\mu\gamma)/\Gamma_{\rm total}$					Γ ₁₉ /Γ	47 Both ROM	ANO 71 values a	re for $\cos\theta(e\gamma)$ bet	tween	0.6 and	0.9.	Second value
/ALUE (units 10 ⁻³) 5.50±0.28 OUR AVE	EVTS ERAGE	DOCUMENT ID	TECN	<u>CHG</u>	COMMENT		ROMANO 71 for	NG 73 value. We in E_{γ} dependence.	use io	west E(y) cut	for Summary
6.6 ±1.5		38,39 DEMIDOV	90 XEB	С	$P(\mu) < 231.5$	⁴⁸ First LJUN	G 73 value is for	$\cos\theta(e\gamma)$ <0.9, see	cond	value is	for co	s $ heta(e\gamma)$ betwee
5.0 ±0.9		BARMIN	88 HLB	C +	${\sf MeV}/c$ ${\sf P}(\mu) <$		comparison with	ROMANO 71.				
		⁴⁰ AKIBA			231.5 MeV/c	$\Gamma(\pi^0 e^+ \nu_e \gamma$						Γ;
5.4 ±0.3		AKIBA	85 SPE	•	$P(\mu) < 231.5$ MeV/c		e-dependent part.	0.0000000000000000000000000000000000000		TECN	CHG	
					1416 4 / 6							
• • We do not use		ing data for average			• • •	VALUE (units 10	90	DOCUMENT ID BOLOTOV	86B	CALO	-	
3.5 ±0.8	3	39,41 DEMIDOV	90 XEB	С	$E(\gamma) > 20\;MeV$	<5.3	90		86B		-	г.
3.5 ±0.8 3.2 ±0.5			90 XEB 88 HLB	C C +	• • •	$<$ 5.3 $\Gamma(\pi^0\pi^0e^+\nu_e$	90 • γ)/Γ _{total}	BOLOTOV	86B	CALO	_	Γ ₂
3.5 ± 0.8 3.2 ± 0.5 5.8 ± 3.5 $38 P(\mu)$ cut given in	57 12 DEMIDO\	^{39,41} DEMIDOV ⁴² BARMIN WEISSENBE.	90 XEB 88 HLB 74 STR	C + C +	$E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 9 \text{ MeV}$	<5.3	90 • γ)/Γ _{total}			CALO TECN		COMMENT
3.5 ±0.8 3.2 ±0.5 5.8 ±3.5 38 P(μ) cut given in (private communi	57 12 DEMIDO\ ication).	42 BARMIN WEISSENBE. 90 paper, 235.1 M	90 XEB 88 HLB 74 STR leV/c, is a r	C + C +	$E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 9 \text{ MeV}$	<5.3 $\Gamma(\pi^{0}\pi^{0}e^{+}\nu_{0})$ VALUE (units 10 ⁻¹	90 e \(\gamma \) / \Gamma_{\text{total}} \[\frac{6}{1} \] \[\frac{CL\%}{90} \] \[0 \]	BOLOTOV		CALO TECN	_	$E_{\gamma} > 10 \text{ Me}$
3.5 \pm 0.8 3.2 \pm 0.5 5.8 \pm 3.5 38 P(μ) cut given in (private communi 39 DEMIDOV 90 que 40 Assumes μ -e univ	57 12 DEMIDON ication). iotes only in	42 BARMIN WEISSENBE. 7 90 paper, 235.1 M There bremsstrahlung d uses constraints fi	90 XEB 88 HLB 74 STR leV/c, is a r g (IB) part. rom $K \rightarrow c$	C C + C + nisprint :	$E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 9 \text{ MeV}$	<5.3 $\Gamma(\pi^{0}\pi^{0}e^{+}\nu_{0})$ $VALUE (units 10^{-1})$ <5 $\Gamma(\pi^{+}\pi^{+}e^{-1})$	90 e \(\gamma \) / \Gamma_{\text{total}} \\ \frac{6}{90} \text{CL\%} \text{EVTS}}{90} 0 \overline{\sigma_e} / \Gamma_{\text{total}} \\ \frac{1}{2} \text{Total}	BOLOTOV		CALO TECN		COMMENT
3.5 ±0.8 3.2 ±0.5 5.8 ±3.5 38 P(μ) cut given in (private communi 39 DEMIDOV 90 que 40 Assumes μ-e univ 41 Not independent	57 12 DEMIDON ication). iotes only in versality and of above D	42 BARMIN WEISSENBE. 7 90 paper, 235.1 M nner bremsstrahlung d uses constraints fi EMIDOV 90 value.	90 XEB 88 HLB 1 74 STR 1 74 STR 1 19 part. 19 com $K \rightarrow 0$ Cuts differ	C C + C + nisprint :	$E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 9 \text{ MeV}$	<5.3 $\Gamma(\pi^0 \pi^0 e^+ \nu_0)$ VALUE (units 10 ⁻¹ <5 $\Gamma(\pi^+ \pi^+ e^-)$ Test of L	90 e γ)/ Γ total $ \frac{E}{2} $ 90 $ \frac{EVTS}{90} $ 0 $ \frac{E}{2} $ $ \frac{EVTS}{90} $ 0	BOLOTOV		CALO TECN		$E_{\gamma} > 10 \text{ Me}$
3.5 ±0.8 3.2 ±0.5 5.8 ±3.5 38 P(μ) cut given in (private communi 39 DEMIDOV 90 que 40 Assumes μ-e univ 41 Not independent of 42 Not independent of	57 12 DEMIDON ication). iotes only in versality and of above D of above B	42 BARMIN WEISSENBE. 7 90 paper, 235.1 M nner bremsstrahlung d uses constraints fi EMIDOV 90 value.	90 XEB 88 HLB 1 74 STR 1 74 STR 1 19 part. 19 com $K \rightarrow 0$ Cuts differ	C C + C + nisprint :	$E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 9 \text{ MeV}$ $E(\gamma) > 9 \text{ MeV}$ according to authors	<5.3 $\Gamma(\pi^0\pi^0e^+\nu_0)$ $< \times_{ALUE \text{ (units }10^{-1})}$ < 5 $\Gamma(\pi^+\pi^+e^-)$ $= \times_{ALUE \text{ (units }10^{-1})}$ $VALUE \text{ (units }10^{-1})$	90 $\frac{e\gamma}{F_{\text{c}}} / \frac{\int \text{CL}\%}{\int 0} \frac{EVTS}{\int 0}$ 90 $\frac{EVTS}{\int 0}$ 7) / Ctotal $\frac{EVTS}{\int \frac{EVTS}{\int 0}}$	BOLOTOV DOCUMENT ID BARMIN	92	TECN TECN		$\frac{COMMENT}{E_{\gamma}} > 10 \text{ Me}$
3.5 \pm 0.8 3.2 \pm 0.5 3.8 \pm 3.5 38 P(μ) cut given in (private communi 39 DEMIDOV 90 qui 40 Assumes μ -e univ 41 Not independent 42 Not independent $(-(\pi^+\pi^0\gamma)/\Gamma_{\text{total}})$	57 12 DEMIDON ication). iotes only in versality and of above D of above B	49,41 DEMIDOV 42 BARMIN WEISSENBE. 7 90 paper, 235.1 M oner bremsstrahlung d uses constraints fi EMIDOV 90 value. ARMIN 88 value. C	90 XEB 88 HLB 1 74 STR 1 74 STR 1 19 part. 19 com $K \rightarrow 0$ Cuts differ	C C + C + nisprint :	$E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 9 \text{ MeV}$ according to authors	<5.3 $\Gamma(\pi^{0}\pi^{0}e^{+}\nu_{0})$ $VALUE (units 10^{-1} < 5)$ $\Gamma(\pi^{+}\pi^{+}e^{-})$ Test of L^{1} $VALUE (units 10^{-1} < 6)$ • • • We do not L^{1}	90 $(a \gamma)/\Gamma_{\text{total}}$ $(b) CL\% EVTS$ 90 0 $(b) \Gamma_{\text{total}}$ $(b) CV EVTS$ 0 $(c) CL\% EVTS$ 0 10 use the following 95 0	DOCUMENT ID BARMIN DOCUMENT ID data for average SCHWEINB	92 s, fits	TECN XEBC		$\frac{COMMENT}{E_{\gamma}} > 10 \text{ Me}$
1.5 \pm 0.8 1.2 \pm 0.5 1.8 \pm 3.5 1.8 \pm 3.5 1.8 \pm 9.6 1.9 Country of the private community of the private community of the private community of the private community of the private of the p	57 12 DEMIDON ication). iotes only in versality and of above D of above B	42 BARMIN WEISSENBE. 7 90 paper, 235.1 M nner bremsstrahlung d uses constraints fi EMIDOV 90 value.	90 XEB 88 HLB 1 74 STR 1 74 STR 1 19 part. 19 com $K \rightarrow 0$ Cuts differ	$\begin{array}{ccc} \mathbb{C} & + & \\ \mathbb{C} & + & \\ \mathbb{C} & + & \\ \text{nisprint} & \\ \mathbb{C} & \times & \\ \mathbb{C} &$	$E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 9 \text{ MeV}$ $E(\gamma) > 9 \text{ MeV}$ according to authors	<5.3 $\Gamma(\pi^{0}\pi^{0}e^{+}\nu_{0})$ $VALUE (units 10^{-1})$ <5 $\Gamma(\pi^{+}\pi^{+}e^{-})$ Test of L^{0} $VALUE (units 10^{-1})$ • • • We do n < 9.0 < 6.9	90 e γ)/ Γ total 6) $CL\%$ EVTS 0 $CL\%$ EVTS 0 $CL\%$ EVTS 10 tue. 7) $CL\%$ EVTS 10 tuse the followin 10 95 10 95 10 0	DOCUMENT ID BARMIN DOCUMENT ID ag data for average SCHWEINB ELY	92 s, fits 71 69	TECN XEBC		$\frac{COMMENT}{E_{\gamma}} > 10 \text{ Me}$
.5 \pm 0.8 .2 \pm 0.5 .8 \pm 3.5 38 $P(\mu)$ cut given in (private communi 39 DEMIDOV 90 que 40 Assumes μ -e univ 41 Not independent 42 Not independent $(\pi^+\pi^0\gamma)/\Gamma_{\text{total}}$	57 12 DEMIDON ication). iotes only in versality and of above D of above B	49,41 DEMIDOV 42 BARMIN WEISSENBE. 7 90 paper, 235.1 M oner bremsstrahlung d uses constraints fi EMIDOV 90 value. ARMIN 88 value. C	90 XEB: 88 HLB: $R = R + R + R + R + R + R + R + R + R + $	C + C + C + C C + C C C	$E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 9 \text{ MeV}$ according to authors	<5.3 $\Gamma(\pi^{0}\pi^{0}e^{+}\nu_{c})$ $VALUE \text{ (units 10}^{-1}\text{ <}5$ $\Gamma(\pi^{+}\pi^{+}e^{-})$ Test of L $VALUE \text{ (units 10}^{-1}\text{ • • • We do n}$ < 9.0 < 6.9 < 20.	90 27)/ Γ total 5) $CL\%$ EVTS 90 0 7-2)/ Γ total $S = \Delta Q$ rule. 7) $CL\%$ EVTS out use the followin 95 0 95 0 95	DOCUMENT ID BARMIN DOCUMENT ID ag data for average SCHWEINB ELY BIRGE	92 s, fits 71 69	TECN XEBC		$rac{COMMENT}{E_{\gamma}} > 10 ext{ Me}$
3.5 \pm 0.8 3.2 \pm 0.5 3.8 \pm 3.5 38 $P(\mu)$ cut given in (private communi 3) DEMIDOV 90 qui 40 Assumes μ -e univ 41 Not independent 42 Not independent ($-(\pi^+\pi^0\gamma)/\Gamma$ total (ALUE (units 10^{-4}) CL 2.75 \pm 0.15 OUR AV 2.71 \pm 0.45	57 12 DEMIDON ication). totes only inversality and of above D of above B WENTS WEAGE 140 2461	39,41 DEMIDOV 42 BARMIN WEISSENBE. 7 90 paper, 235.1 M mer bremsstrahlung d uses constraints fi EMIDOV 90 value. ARMIN 88 value. C DOCUMENT ID BOLOTOV SMITH	90 XEB: 88 HLB: 74 STR: leV/c, is a r g (IB) part. rom $K \rightarrow c$ Cuts differ. TECN 87 WIRI 76 WIRI 76 WIRI	C $+$ C $+$ $+$ $+$ $+$ $+$ $+$ $+$ $+$ $+$ $+$	$E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 9 \text{ MeV}$ according to authors F_{20}/Γ $\frac{COMMENT}{T\pi^{\pm} 55-90 \text{ MeV}}$ $T\pi^{\pm} 55-90 \text{ MeV}$	<5.3 $\Gamma(\pi^{0}\pi^{0}e^{+}\nu_{0})$ <5 $\Gamma(\pi^{+}\pi^{+}e^{-})$ Test of ν_{0} <9.0 <6.9 $<20.$ $\Gamma(\pi^{+}\pi^{+}e^{-})$	90 27)/ Γ total 5) $CL\%$ EVTS 90 0 7) $CL\%$ EVTS 10t use the followin 95 95 0 95 7) $(\pi^+\pi^-e^-)$	DOCUMENT ID BARMIN DOCUMENT ID ag data for average SCHWEINB ELY BIRGE	92 s, fits 71 69	TECN XEBC		$\frac{COMMENT}{E_{\gamma}} > 10 \text{ Me}$
1.5 \pm 0.8 1.2 \pm 0.5 1.8 \pm 3.5 1.8 \pm 3.5 1.8 \pm 9.6 1.9 P(μ) cut given in private communiants of the private o	57 12 DEMIDO\ ication). iotes only in versality am of above D of above B VERAGE 140 2461 2100	49,41 DEMIDOV 42 BARMIN WEISSENBE. 7 90 paper, 235.1 M nner bremsstrahust in uses constraints fi EMIDOV 90 value. ARMIN 88 value. C DOCUMENT ID BOLOTOV SMITH ABRAMS	90 XEB: 88 HLB: 74 STR: leV/c, is a r g (IB) part. rom K → c Cuts differ Cuts differ. 7ECN 87 WIRI 76 WIRI 72 ASPI	C + C + H C	$E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 9 \text{ MeV}$ according to authors F_{20}/Γ $COMMENT$ $T\pi^{-} 55-90 \text{ MeV}$ $T\pi^{+} 55-90 \text{ MeV}$ $T\pi^{+} 55-90 \text{ MeV}$	<5.3 $\Gamma(\pi^0\pi^0e^+\nu_0)$ $VALUE (units 10^{-1})$ Test of Z <td>90 27)/Γtotal 5) $CL\%$ EVTS 90 0 7-2)/Γtotal $S = \Delta Q$ rule. 7) $CL\%$ EVTS out use the followin 95 0 95 0 95</td> <td>DOCUMENT ID BARMIN DOCUMENT ID ag data for average SCHWEINB ELY BIRGE</td> <td>92 s, fits 71 69 65</td> <td>TECN XEBC</td> <td></td> <td>$rac{COMMENT}{E_{\gamma}} > 10 ext{ Me}$</td>	90 27)/ Γ total 5) $CL\%$ EVTS 90 0 7-2)/ Γ total $S = \Delta Q$ rule. 7) $CL\%$ EVTS out use the followin 95 0 95 0 95	DOCUMENT ID BARMIN DOCUMENT ID ag data for average SCHWEINB ELY BIRGE	92 s, fits 71 69 65	TECN XEBC		$rac{COMMENT}{E_{\gamma}} > 10 ext{ Me}$
1.5 \pm 0.8 2.2 \pm 0.5 8.2 \pm 0.5 8.38 $+$ 2(μ) cut given in (private communi 39 DEMIDOV 90 quad 0.40 Assumes μ - e univ 41 Not independent 42 Not independent 6.7 (π + π 0 γ)/ Γ total (ALUE (units 10 ⁻⁴) CL 2.75 \pm 0.15 OUR AN 2.71 \pm 0.45 2.87 \pm 0.32 2.71 \pm 0.19 • We do not use	57 12 DEMIDO\ ication). iotes only in versality am of above D of above B VERAGE 140 2461 2100	19,41 DEMIDOV 42 BARMIN WEISSENBE. 7 90 paper, 235.1 M mer bremsstrahus fi 10 duses constraints fi 11 EMIDOV 90 value. ARMIN 88 value. C DOCUMENT ID BOLOTOV SMITH ABRAMS ing data for average	90 XEB: 88 HLB:74 STR: leV/c, is a r (IB) part. com K Cuts differ	C $+$ C $+$ $+$ $+$ $+$ $+$ $+$ $+$ $+$ $+$ $+$	$E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 9 \text{ MeV}$ $E(\gamma) > 9 \text{ MeV}$ according to authors F_{20}/Γ $COMMENT$ $T\pi^- 55-90 \text{ MeV}$ $T\pi^+ 55-90 \text{ MeV}$ $T\pi^+ 55-90 \text{ MeV}$	<5.3 $\Gamma(\pi^0\pi^0e^+\nu_0)$ $VALUE$ (units 10 ⁻¹ <5 $\Gamma(\pi^+\pi^+e^-)$ Test of L^0 $VALUE$ (units 10 ⁻¹ • • • We do note the second of L^0 < 6.9 < 20. $\Gamma(\pi^+\pi^+e^-)$ Test of L^0 $VALUE$ (units 10 ⁻¹ < 3	90 $P_e \gamma / \Gamma_{total}$	DOCUMENT ID BARMIN DOCUMENT ID and data for average SCHWEINB ELY BIRGE Pe) DOCUMENT ID 49 BLOCH	92 s, fits 71 69 65	TECN XEBC TECN , limits, HLBC HLBC FBC TECN SPEC		$rac{COMMENT}{E_{\gamma}} > 10 ext{ Me}$
3.5 \pm 0.8 3.2 \pm 0.5 3.8 \pm 2.5 3.8 \pm 2.5 3.8 \pm 2.5 3.8 \pm 2.6 3.9 DEMIDOV 90 que 40 Assumes μ - ϵ univ 41 Not independent 42 No	57 12 DEMIDO\ ication). iotes only in versality am of above D of above B VERAGE 140 2461 2100	42 BARMIN WEISSENBE. / 90 paper, 235.1 M mer bremsstrahlung d uses constraints fi EMIDOV 90 value. ARMIN 88 value. C DOCUMENT ID BOLOTOV SMITH ABRAMS ing data for average 43 LJUNG	90 XEB: 88 HLB:74 STR: leV/c, is a right of the second K → c Cuts differ	C C C C C C C C C C	$E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 9 \text{ MeV}$ according to authors F_{20}/Γ $\frac{COMMENT}{T\pi^{-} 55-90 \text{ MeV}}$ $\frac{1}{7\pi^{+} 55-90 \text{ MeV}}$ $\frac{1}{7\pi^{+} 55-80 \text{ MeV}}$	<5.3 $\Gamma(\pi^0\pi^0e^+\nu_0)$ $VALUE$ (units 10 ⁻¹ <5 $\Gamma(\pi^+\pi^+e^-)$ Test of L^0 $VALUE$ (units 10 ⁻¹ • • • We do note the second of L^0 $VALUE$ (units 10 ⁻¹ $VALUE$ (units	90 $e \gamma$)/ Γ total $e \gamma$)/ Γ total $e \gamma$)/ Γ total $e \gamma$ / Γ total	DOCUMENT ID BARMIN DOCUMENT ID ag data for average SCHWEINB ELY BIRGE Pe) DOCUMENT ID 49 BLOCH ag data for average	92 s, fits 71 69 65	TECN XEBC TECN , limits, HLBC HLBC FBC TECN SPEC , limits,		$rac{COMMENT}{E_{\gamma}} > 10 ext{ Me}$
1.5 \pm 0.8 .2 \pm 0.5 .8 .2 \pm 0.5 .8 \pm 3.5 .38 $P(\mu)$ cut given in (private communi 3) DEMIDOV 90 qui 40 Assumes μ -e univ 41 Not independent 42 Not independent 42 Not independent 6. (π + π 0 γ)/ Γ total (ALUE (units 10 ⁻⁴) CL 2.75 \pm 0.15 OUR AV 2.71 \pm 0.45 .2.87 \pm 0.32 .2.71 \pm 0.19 • We do not use 1.5 \pm 0.6 .2.6 \pm 1.1	57 12 DEMIDO\ ication). iotes only in versality am of above D of above B VERAGE 140 2461 2100	19,41 DEMIDOV 42 BARMIN WEISSENBE. 7 90 paper, 235.1 M mer bremsstrahus fi 10 duses constraints fi 11 EMIDOV 90 value. ARMIN 88 value. C DOCUMENT ID BOLOTOV SMITH ABRAMS ing data for average	90 XEB: 88 HLB:74 STR: leV/c, is a r (IB) part. com K Cuts differ	C C C C C C C C C C	$E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 9 \text{ MeV}$ $E(\gamma) > 9 \text{ MeV}$ according to authors F_{20}/Γ $COMMENT$ $T\pi^- 55-90 \text{ MeV}$ $T\pi^+ 55-90 \text{ MeV}$ $T\pi^+ 55-90 \text{ MeV}$	<5.3 $\Gamma(\pi^0\pi^0e^+\nu_0^0\pi^0e^+\mu_0^0\pi^0e^+\nu_0^0\pi^0e^+\nu_0^0\pi^0e^+\nu_0^0\pi^0e^+\nu_0^0\pi^0e^+\nu_0^0\pi^0e^+\nu_0^0\pi^0e^+\nu_0^0\pi^0e^+\nu_0^0\pi^0e^+\nu_0^0\pi^0e^+\nu_0^0\pi^0e^+\nu_0^0e^+\nu_0^0\pi^0e^+\nu_0^0\pi^0e^+\nu_0^0\pi^0e^+\nu_0^0\pi^0e^+\nu_0^0\pi^0e^+\nu_0^0e^+\mu_0^0\pi^0e^+\nu_0^0e^+\mu_$	90 27)/ Γ total 5) $CL\%$ $EVTS$ 90 0 7e)/ Γ total $\Delta S = \Delta Q$ rule. 7) $CL\%$ $EVTS$ out use the followin 95 0 95 0 95 0 95 0 95 3 ot use the followin 95 0 3 ot use the followin 95 0 3	DOCUMENT ID BARMIN DOCUMENT ID ata for average SCHWEINB ELY BIRGE Pe DOCUMENT ID 49 BLOCH ag data for average BOURQUIN	92 s, fits 71 69 65	TECN XEBC TECN , limits, HLBC HLBC FBC TECN SPEC , limits, ASPK		$rac{COMMENT}{E_{\gamma}} > 10 ext{ Me}$
3.5 ± 0.8 3.2 ± 0.5 5.8 ± 3.5 38 P(μ) cut given in (private communi 39 DEMIDOV 90 que 40 Assumes μ-e univ 41 Not independent 42 Not independent (Γ(π+π0 γ)/Γtotal (VALUE (units 10-4) CL (2.75±0.15 OUR A) (2.71±0.45 (2.87±0.32 (2.71±0.19 • • • We do not use 1.5 + 1.1 (-0.6)	57 12 DEMIDO\ ication). iotes only in versality am of above D of above B VERAGE 140 2461 2100	42 BARMIN WEISSENBE. / 90 paper, 235.1 M mer bremsstrahlung d uses constraints fi EMIDOV 90 value. ARMIN 88 value. C DOCUMENT ID BOLOTOV SMITH ABRAMS ing data for average 43 LJUNG	90 XEB: 88 HLB:74 STR: leV/c, is a right of the second K → c Cuts differ	C C C C C C C C C C	$E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 9 \text{ MeV}$ according to authors F_{20}/Γ $\frac{COMMENT}{T\pi^{-} 55-90 \text{ MeV}}$ $\frac{1}{7\pi^{+} 55-90 \text{ MeV}}$ $\frac{1}{7\pi^{+} 55-80 \text{ MeV}}$	<5.3 $\Gamma(\pi^0\pi^0e^+\nu_{c})$ **MALUE (units 10-1 < 5) $\Gamma(\pi^+\pi^+e^-)$ Test of Δ **MALUE (units 10-1 < 9.0 < 6.9 < 20.) $\Gamma(\pi^+\pi^+e^-)$ Test of Δ **MALUE (units 10-1 < 3.0 < 4.9	90 $Pe \gamma / \Gamma_{\text{total}}$ $Pe / \Gamma_{\text{total}}$ P	DOCUMENT ID BARMIN DOCUMENT ID ag data for average SCHWEINB ELY BIRGE Pe) DOCUMENT ID 49 BLOCH ag data for average	92 s, fits 71 69 65	TECN XEBC TECN , limits, HLBC HLBC FBC TECN SPEC , limits, ASPK		$\frac{COMMENT}{E_{\gamma}} > 10 \text{ Me}$
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1.5 \pm 0.8 .2 \pm 0.5 .8 .2 \pm 0.5 .8 .2 \pm 0.5 .8 \pm 3.5 .38 $P(\mu)$ cut given in (private communi 39 DEMIDOV 90 que 40 Assumes μ - e univ 41 Not independent 42 Not independent 42 Not independent 6.7 $(\pi + \pi^0 \gamma)/\Gamma$ total (ALUE (units 10^{-4}) CL 2.75 \pm 0.15 OUR AV 2.71 \pm 0.45 .287 \pm 0.32 .2.71 \pm 0.19 • • We do not use 1.5 \pm 1.1 6.8 \pm 3.7 .2.4 \pm 0.8 <1.0 <1.9 90 .2.2 \pm 0.7 43 The LJUNG 73 va 44 MALTSEV 70 selection ($\pi + \pi^0 \gamma$ (DE))/ Γ	57 12 DEMIDON ication). Notes only in versality and of above B of	19,41 DEMIDOV 42 BARMIN WEISSENBE. 7 90 paper, 235.1 M mer bremsstrahung d uses constraints fi EMIDOV 90 value. ARMIN 88 value. C DOCUMENT ID BOLOTOV SMITH ABRAMS ing data for average 43 LJUNG 43 LJUNG 43 LJUNG 43 LJUNG EDWARDS 44 MALTSEV EMMERSON CLINE ot independent. energy to enhance	90 XEB: 88 HLB:74 STR: leV/c, is a r (IB) part. rc Cuts differ. TECN 87 WIRI 76 WIRI 72 ASPI 98, fits, limit 73 HLB: 73 HLB: 74 TLB: 75 HLB: 76 OSPI 76 OSPI 77 HLB: 78 FBC	$\begin{array}{c} \mathbb{C} & \mathbb{C} \\ \mathbb{C} & + \\ \mathbb{C} & \mathbb{C} \\ \end{array}$	$E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 9 \text{ MeV}$ according to authors $\frac{\Gamma_{20}/\Gamma}{COMMENT}$ $\frac{T\pi^{-}}{55-90} \text{ MeV}$ $\frac{T\pi^{+}}{55-90} \text{ MeV}$ $\frac{T\pi^{+}}{55-80} \text{ MeV}$	<5.3 $\Gamma(\pi^0\pi^0e^+\nu_e)$ $VALUE$ (units 10 -1 < <5 $\Gamma(\pi^+\pi^+e^-)$ Test of L^0 $VALUE$ (units 10 -1 < • • • We do not see L^0 $VALUE$ (units 10 -1 <	90 27)/ Γ total 5) $CL\%$ $EVTS$ 90 0 7e)/ Γ total $\Delta S = \Delta Q$ rule. 7) $CL\%$ $EVTS$ out use the followin 95 0 95 0 95 0 95 0 95 0 95 0 95 0 0 0 7e)/ $\Gamma(\pi^+\pi^-e^-$ 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	DOCUMENT ID BARMIN DOCUMENT ID at a for average SCHWEINB ELY BIRGE DOCUMENT ID 49 BLOCH at a for average BOURQUIN 4 at CL = 95%, w DOCUMENT ID BIRGE BIRGE Utral current. Allo	92 s, fits 71 69 65 76 s, fits 71 e con	TECN XEBC TECN , limits, HLBC HLBC FBC TECN SPEC , limits, ASPK vert.	CHG + CHG etc. • + + + + CHG etc. •	$E_{\gamma} > 10 \text{ Me}$ F_{2}
3.5 \pm 0.8 3.2 \pm 0.5 3.8 \pm 2.0.5 3.8 \pm 2.5 3.8 \pm 2.5 3.8 \pm 2.5 3.8 \pm 2.5 3.8 \pm 2.6 3.9 \pm 2.5 3.9 \pm 2.5 3.9 \pm 2.7 3.9 DEMIDOV 90 quu 40 Assumes μ -e univ 41 Not independent 42 Not i	57 12 DEMIDON ication). Notes only in versality and of above B of	42 DEMIDOV 42 BARMIN WEISSENBE. 7 90 paper, 235.1 M mer bremsstrahulen d uses constraints fi EMIDOV 90 value. ARMIN 88 value. C DOCUMENT ID BOLOTOV SMITH ABRAMS ing data for average 43 LJUNG 43 LJUNG 43 LJUNG 43 LJUNG EDWARDS 44 MALTSEV EMMERSON CLINE ot independent.	90 XEB: 88 HLB:74 STR: leV/c, is a r (IB) part. rc Cuts differ. TECN 87 WIRI 76 WIRI 72 ASPI 98, fits, limit 73 HLB: 73 HLB: 74 TLB: 75 HLB: 76 OSPI 76 OSPI 77 HLB: 78 FBC	$\begin{array}{c} \mathbb{C} & \mathbb{C} \\ \mathbb{C} & + \\ \mathbb{C} & \mathbb{C} \\ \end{array}$	$E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 9 \text{ MeV}$ according to authors F_{20}/Γ $\frac{COMMENT}{T\pi^{-55-90} \text{ MeV}}$ $\frac{1}{7\pi^{+55-90} \text{ MeV}}$	<5.3 $\Gamma(\pi^0\pi^0e^+\nu_e)$ $VALUE$ (units 10 ⁻¹ <5 $\Gamma(\pi^+\pi^+e^-)$ Test of 2 $VALUE$ (units 10 ⁻¹ • • • We do n < 9.0 < 6.9 < 20. $\Gamma(\pi^+\pi^+e^-)$ Test of 2 $VALUE$ (units 10 ⁻¹ < 3 • • • We do n < 130. 49 BLOCH 76 $\Gamma(\pi^+\pi^+\mu^-)$ Test of 2 $VALUE$ (units 10 ⁻¹ < 3.0 $\Gamma(\pi^+e^+e^-)$ Test for electrom. $VALUE$ (units 10 ⁻¹ $VALUE$ (units 10 ⁻¹ < 3.0	90 27)/ Γ total 5) $CL\%$ $EVTS$ 90 0 7e)/ Γ total $\Delta S = \Delta Q$ rule. 7) $CL\%$ $EVTS$ 10 ot use the followin 95 0 95 0 95 7e)/ $\Gamma(\pi^+\pi^-e^ \Delta S = \Delta Q$ rule. 4) $CL\%$ $EVTS$ 90 3 10 tuse the followin 95 0 quotes $3.6 \times 10^-$ 7u)/ Γ total $\Delta S = \Delta Q$ rule. 5) $CL\%$ $EVTS$ 95 0 7ftotal $\Delta S = 1$ weak ne agnetic interaction 17) $CL\%$ EVT	DOCUMENT ID BARMIN DOCUMENT ID at a for average SCHWEINB ELY BIRGE DOCUMENT ID 49 BLOCH at a for average BOURQUIN 4 at CL = 95%, w DOCUMENT ID BIRGE BIRGE Utral current. Allo	92 s, fits 71 69 65 76 s, fits 71 e con	TECN XEBC TECN , limits, HLBC HLBC FBC TECN SPEC , limits, ASPK vert.	CHG + CHG etc. • + + + + CHG etc. •	$\frac{COMMENT}{E_{\gamma}} > 10 \text{ Me}$ Γ_2
1.5 ± 0.8 1.2 ± 0.5 1.8 ± 3.5 1.8 ± 3.5 1.8 $P(\mu)$ cut given in (private communi) 1.9 DEMIDOV 90 que 1.40 Assumes μ - e univ 1.41 Not independent of 1.42 Not independent of 1.43 Pot independent of 1.44 Pot independent of 1.45 Pot indep	57 12 DEMIDON ication). Notes only in versality and of above B of	19,41 DEMIDOV 42 BARMIN WEISSENBE. 7 90 paper, 235.1 M mer bremsstrahung d uses constraints fi EMIDOV 90 value. ARMIN 88 value. C DOCUMENT ID BOLOTOV SMITH ABRAMS ing data for average 43 LJUNG 43 LJUNG 43 LJUNG 43 LJUNG EDWARDS 44 MALTSEV EMMERSON CLINE ot independent. energy to enhance	90 XEB: 88 HLB:74 STR: leV/c, is a right of the control of the	$\begin{array}{c} \mathbb{C} & \mathbb{C} \\ \mathbb{C} & + \\ \mathbb$	$E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 9 \text{ MeV}$ according to authors $\frac{\Gamma_{20}/\Gamma}{COMMENT}$ $\frac{T\pi^{-}}{55-90} \text{ MeV}$ $\frac{T\pi^{+}}{55-90} \text{ MeV}$ $\frac{T\pi^{+}}{55-80} \text{ MeV}$	<5.3 $\Gamma(\pi^0\pi^0e^+\nu_e)$ $VALUE$ (units 10 ⁻¹ <5 $\Gamma(\pi^+\pi^+e^-)$ Test of 2 $VALUE$ (units 10 ⁻¹ • • • We do n < 9.0 < 6.9 < 20. $\Gamma(\pi^+\pi^+e^-)$ Test of 2 $VALUE$ (units 10 ⁻¹ < 3 • • • We do n < 130. 49 BLOCH 76 $\Gamma(\pi^+\pi^+\mu^-)$ Test of 2 $VALUE$ (units 10 ⁻¹ < 3.0 $\Gamma(\pi^+e^+e^-)$ Test for electrom. $VALUE$ (units 10 ⁻¹ $VALUE$ (units 10 ⁻¹ < 3.0	90 27)/ Γ total 5) $CL\%$ $EVTS$ 90 0 7e)/ Γ total $\Delta S = \Delta Q$ rule. 7 $CL\%$ $EVTS$ 10 in use the following ps 0 95 0 95 6) $CL\%$ $EVTS$ 90 3 10 in use the following ps 0 10 in $EVTS$ 11 $EVTS$ 12 $EVTS$ 13 in $EVTS$ 15 $EVTS$ 16 $EVTS$ 17 $EVTS$ 18 $EVTS$ 19 $EVTS$ 19 $EVTS$ 10 $EVTS$ 10 $EVTS$ 10 $EVTS$ 10 $EVTS$ 11 $EVTS$ 12 $EVTS$ 13 $EVTS$ 15 $EVTS$ 16 $EVTS$ 17 $EVTS$ 18 $EVTS$ 18 $EVTS$ 18 $EVTS$ 19 $EVTS$ 19 $EVTS$ 19 $EVTS$ 19 $EVTS$ 10 $EVTS$ 10 $EVTS$ 10 $EVTS$ 11 $EVTS$ 12 $EVTS$ 15 $EVTS$ 16 $EVTS$ 17 $EVTS$ 18 $EVTS$ 18 $EVTS$ 19 $EVTS$ 19 $EVTS$ 19 $EVTS$ 10 $EVTS$ 10 $EVTS$ 10 $EVTS$ 10 $EVTS$ 10 $EVTS$ 10 $EVTS$ 11 $EVTS$ 12 $EVTS$ 13 $EVTS$ 15 $EVTS$ 16 $EVTS$ 16 $EVTS$ 17 $EVTS$ 18 $EVTS$ 18 $EVTS$ 19 $EVTS$ 19 $EVTS$ 19 $EVTS$ 19 $EVTS$ 20 $EVTS$ 21 $EVTS$ 22 $EVTS$ 23 $EVTS$ 24 $EVTS$ 25 $EVTS$ 26 $EVTS$ 27 $EVTS$ 28 $EVTS$ 29 $EVTS$ 29 $EVTS$ 20	DOCUMENT ID BARMIN DOCUMENT ID at a for average SCHWEINB ELY BIRGE 49 BOCUMENT ID BOCUMENT ID BOURQUIN 4 at CL = 95%, w DOCUMENT ID BIRGE utral current. Allo s. DOCUMENT 50 50 ALLIEGRO	92 s, fits 71 65 76 65 71 65	TECN XEBC TECN , limits, HLBC HLBC FBC TECN SPEC , limits, ASPK vert.	CHG + + + + + + + + + + + + ← CHG + + + + + + ← CHG + + ← CN	$E_{\gamma} > 10$ Me Γ_{z}
3.5 \pm 0.8 3.2 \pm 0.5 3.8 \pm 2.5 3.8 $+$ 2.5 3.8 $+$ 2.5 3.8 $+$ 2.5 3.8 $+$ 2.5 3.8 $+$ 2.6 3.5 3.8 $+$ 2.6 3.6 3.8 $+$ 2.6 3.7 3.8 $+$ 2.6 3.8 $+$ 2.6 3.8 $+$ 2.7 3.8 $+$ 3.7 3.8 $+$ 3.8 $+$ 3.8 $+$ 3.8 $+$ 3.8 $+$ 3.8 $+$ 3.8 $+$ 3.8 $+$ 3.8 $+$ 3.8 $+$ 3.8 $+$ 3.8 $+$ 3.8 $+$ 3.8 $+$ 3.8 $+$ 3.8 $+$ 3.8 $+$ 3.9 $+$ 3.8 $+$ 3.8 $+$ 3.9 $+$ 3.9 $+$ 4.0 $+$ 4.0 $+$ 3.8 $+$ 3.7 $+$ 3.8 $+$ 3.7 $+$ 3.8 $+$ 3.7 $+$ 3.8 $+$ 3.7 $+$ 3.8 $+$ 3.7 $+$ 3.8 $+$ 3.7 $+$ 3.8 $+$ 3.7 $+$ 3.8 $+$ 3.7 $+$ 3.8 $+$ 3.7 $+$ 3.8 $+$ 3.7 $+$ 3.8 $+$ 3.7 $+$ 3.8 $+$ 3.7 $+$ 3.8 $+$ 3.7 $+$ 3.8 $+$ 3.9 $+$ 3.8 $+$ 3.9 $+$ 3.8 $+$ 3.9 $+$ 3.9 $+$ 3.8 $+$ 3.9 $+$ 3.8 $+$ 3.9 $+$ 3.9 $+$ 3.9 $+$ 3.8 $+$ 3.9 $+$ 3.0 $+$ 3.0 $+$ 3.0 $+$ 3.0 $+$ 3.0 $+$ 3.0 $+$ 3.0 $+$ 3.0 $+$ 3.0 $+$ 3.0 $+$ 3.0 $+$ 3.0 $+$ 3	57 12 DEMIDON ication). Notes only in versality and of above B of	39,41 DEMIDOV 42 BARMIN WEISSENBE. 7 90 paper, 235.1 M mer bremsstrahing du uses constraints fi EMIDOV 90 value. ARMIN 88 value. C DOCUMENT ID BOLOTOV SMITH ABRAMS ing data for average 43 LJUNG 43 LJUNG 43 LJUNG 43 LJUNG EDWARDS 44 MALTSEV EMMERSON CLINE ot independent. F energy to enhance DOCUMENT ID	90 XEB: 88 HLB:74 STR: leV/c, is a right of the part. (IB) part76 Cuts differ	$\begin{array}{c} \mathcal{C} \\ $	$E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 9 \text{ MeV}$ according to authors F_{20}/Γ $\frac{COMMENT}{T\pi^{+} 55-90 \text{ MeV}}$ $7\pi^{+} 55-90 \text{ MeV}$ $7\pi^{+} 55-80 \text{ MeV}$	<5.3 $\Gamma(\pi^{0}\pi^{0}e^{+}\nu_{0})$ <5 $\Gamma(\pi^{+}\pi^{+}e^{-})$ Test of L^{0} <9.0 <6.9 $<20.$ $\Gamma(\pi^{+}\pi^{+}e^{-})$ Test of L^{0} <9.0 <6.9 $<20.$ $\Gamma(\pi^{+}\pi^{+}e^{-})$ Test of L^{0} <3 ••• We do note that the second of L^{0} $<130.$ $^{49} BLOCH 76$ $\Gamma(\pi^{+}\pi^{+}\mu^{-})$ Test of L^{0} L^{0} $=10.$ $VALUE (units L^{0} <3.0 \Gamma(\pi^{+}e^{+}e^{-}) Test for electrom. L^{0} VALUE (units L^{0} <2.74\pm0.23$	90 27)/ Γ total 5) $CL\%$ $EVTS$ 90 0 7e)/ Γ total $\Delta S = \Delta Q$ rule. 7) $CL\%$ $EVTS$ out use the followin 95 0 95 0 95 0 95 0 90 3 ot use the followin 95 0 quotes $3.6 \times 10^{-}$ 7 DL / Γ total $\Delta S = \Delta Q$ rule. 6) $CL\%$ $EVTS$ 0 $CL\%$ $EVTS$ 0 $CL\%$ $EVTS$ 0 7 DL / Γ total DL / Γ total DL /	DOCUMENT ID BARMIN DOCUMENT ID g data for average SCHWEINB ELY BIRGE 49 BLOCH ng data for average BOURQUIN 4 at CL = 95%, w DOCUMENT ID BIRGE utral current. Allo s.	92 s, fits 71 65 76 65 71 65	TECN SPEC, Ilmits, ASPK vert. TECN SPEC SPEC SPEC SPEC SPEC SPEC SPEC SPEC	CHG + CHG etc. • CHG etc. • CHG etc. • CHG ECC ECC ECC CHG ECC ECC ECC	COMMENT E _γ > 10 Me Γ ₂ ••• Γ ₂ irst-order weak
3.5 \pm 0.8 3.2 \pm 0.5 3.8 \pm 2.0.5 3.8 $+$ 2.5 3.8 $+$ 2.6 3.9 $+$ 2.5 3.8 $+$ 2.6 3.9 $+$ 2.7 3.9 DEMIDOV 90 quadron 40 Assumes μ - e univ 41 Not independent 42 Not independent	57 12 DEMIDON ication). Notes only in versality and of above B of	39,41 DEMIDOV 42 BARMIN WEISSENBE. / 90 paper, 235.1 M mer bremsstrahlung d uses constraints fi EMIDOV 90 value. ARMIN 88 value. C DOCUMENT ID BOLOTOV SMITH ABRAMS ing data for average 43 LJUNG 43 LJUNG 43 LJUNG 43 LJUNG 43 LJUNG 44 MALTSEV EMMERSON CLINE ot independent. + energy to enhance m+ π ⁰ γ)/Γtotal·	90 XEB: 88 HLB:74 STR: leV/c, is a right of the control of the	$\begin{array}{c} \mathbb{C} & \mathbb{C} \\ \mathbb{C} & \mathbb{C} & \mathbb{C} \\ \mathbb{C} & \mathbb{C} \\ \mathbb{C} & \mathbb{C} \\ \mathbb{C} & \mathbb{C} & \mathbb{C} \\ \mathbb{C} & \mathbb{C} \\ \mathbb{C} & \mathbb{C} & \mathbb{C} \\ \mathbb{C} & \mathbb{C} \\ \mathbb{C} & \mathbb{C} & \mathbb{C} & \mathbb{C} \\ \mathbb{C} & \mathbb{C} & $	$E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 20 \text{ MeV}$ $E(\gamma) > 9 \text{ MeV}$ according to authors F_{20}/Γ $\frac{COMMENT}{T\pi^{-55-90} \text{ MeV}}$ $\frac{1}{7\pi^{+55-90} \text{ MeV}}$ $\frac{1}{7\pi^{+55-80} \text{ MeV}}$	<5.3 $\Gamma(\pi^0\pi^0e^+\nu_{\ell})^{-1}$ <5 $\Gamma(\pi^0\pi^0e^+\nu_{\ell})^{-1}$ <5 $\Gamma(\pi^+\pi^+e^-)^{-1}$ Test of L^2 <6.9 $<20.$ $\Gamma(\pi^+\pi^+e^-)^{-1}$ Test of L^2 $<30.$ 49 BLOCH 76 $\Gamma(\pi^+\pi^+\mu^-)^{-1}$ Test of L^2 $<130.$ 49 BLOCH 76 $\Gamma(\pi^+\pi^+\mu^-)^{-1}$ Test of L^2 $<130.$ $\Gamma(\pi^+\pi^+\mu^-)^{-1}$ Test of L^2 $\sim L^2$	90 27)/ Γ total 5) $CL\%$ $EVTS$ 90 0 7e)/ Γ total $\Delta S = \Delta Q$ rule. 7) $CL\%$ $EVTS$ out use the followin 95 0 95 0 95 0 95 0 90 3 ot use the followin 95 0 quotes $3.6 \times 10^{-}$ 7 DL / Γ total $\Delta S = \Delta Q$ rule. 6) $CL\%$ $EVTS$ 0 $CL\%$ $EVTS$ 0 $CL\%$ $EVTS$ 0 7 DL / Γ total DL / Γ total DL /	DOCUMENT ID BARMIN DOCUMENT ID at a for average SCHWEINB ELY BIRGE 49 BOCUMENT ID BOCUMENT ID BOURQUIN 4 at CL = 95%, w DOCUMENT ID BIRGE utral current. Allo s. DOCUMENT 50 50 ALLIEGRO	92 s, fits 71 65 76 65 71 65	TECN , limits, HLBC HLBC FBC TECN , limits, HLBC FBC TECN SPEC , limits, ASPK vert.	CHG + CHG etc. • CHG etc. • CHG etc. • CHG ECC ECC ECC CHG ECC ECC ECC	COMMENT E _γ > 10 Me Γ ₂ ••• Γ ₂ irst-order weak

K^{\pm}

• • • We do n	ot use the followin	or data for averag	res fits li	mits etc	
< 17	90	CENCE	74		+ Three track
< 2.7	90	CENCE	74	ASPK	evts + Two track
<320	90	BEIER	72	OSPK	events \pm
< 44	90	BISI	67		+
< 8.8	90	CLINE		в FBC	+
< 24.5		1 CAMER			+
0.035 ± 0.0	92 assumes a vec 015 and a correlati assumes a vector	on coefficient of	ith a form — 0.82.	n factor g	iven by λ $=$ 0.105 \pm
tions.	$\Delta S=1$ weak neu	tral current. Allo	wed by h	igher-orde	Γ ₃₁ /Γ r electroweak interac-
VALUE (units 10		DOCUMENT ID		CN CHG	<u>:</u> _
< 2.3 • • • Wedon	90 ot use the followin	ATIYA ng data for averas		787 + mits. etc.	
<24	90	BISI		BC +	
<30	90	CAMERINI	65 F	3C +	
$(\pi^+ \nu \overline{\nu})/\Gamma_t$ Test for	$\Delta S=1$ weak neu	tral current. Allo	wed by hi	igher-orde	Γ ₃₂ /Γ r electroweak interac
tions. /ALUE (units 10 ⁻⁶	9) (18/ 51/75	DOCUMENT ID		CN CUC	COMMENT
< 2.4	9) <u>CL% EVTS</u> 90	<u>DOCUMENT ID</u> ADLER		<u>CN CHG</u> 787	COMMENT
	ot use the followin				• • •
< 7.5	90	ATIYA		787 +	T(π) 115–127 MeV
< 5.2 < 17	90 90 0	⁵² ATIYA ATIYA	93 B: 93B B:	787 + 787 +	T(π) 60-100 MeV
< 17 < 34	90 0	ATIYA		787 +	/(π) 60-100 MeV
< 140	90	ASANO	81B C		T(π) 116-127
< 940	90	⁵³ CABLE	73 CI	NTR +	MeV Τ(π) 60–105 MeV
< 560	90	⁵³ CABLE		VTR +	T(π) 60–127 MeV
<57000	90 0	⁵⁴ LJUNG ⁵³ KLEMS		LBC +	T() 117 107
< 1400	90	33 KLEMS	71 O	SPK +	T(π) 117-127 MeV
$-(\mu^- \nu e^+ e^+)$	assumes vector into $\Gamma(\pi^+\pi^-e^+)$ epton family numb	ν_e)			Γ ₃₃ /Γ ₉
VALUE (units 10 ⁻³	3) CL% EVTS	DOCUMENT ID		CN CHG	_
<0.5	90 0	55 DIAMANT		PEC +	
	-BERGER 76 quot	es this result time	es our 197	5 π π π	
$(\mu^+ u_e)/\Gamma_{ m to}$	otal n by lepton family	number conserva	tion		Γ ₃₄ /Γ
/ALUE	CL% EVTS	DOCUMENT ID		CN CHG	COMMENT
<0.004	90 0			DC 0	200 GeV K^+ nar-
		LYONS	81 HI	LBC 0	row band $ u$ beam
• • We do n	ot use the followin				beam
< 0.012	90		ges, fits, li		beam • • •
<0.012 $\Gamma(\pi^+ \mu^+ e^-)$	90	ng data for averag	ges, fits, li	mits, etc.	beam • • • Wideband ν beam
<0.012 $-(\pi^+\mu^+e^-)$ Test of le	90 /Γ _{total}	ng data for averag	ges, fits, li 82 HI	mits, etc.	beam • • • Wideband ν beam Γ_{35}/Γ
<0.012	90 // Total epton family numb 10) CL% EVTS 90 0	og data for average COOPER er conservation. DOCUMENT ID LEE	ges, fits, li 82 HI 82 EI 90 SF	mits, etc. LBC 	beam Wideband ν beam F35/Γ
<0.012 $(\pi^{+}\mu^{+}e^{-})$ Test of let (ALUE (units 10-1) < 2.1 • • • We do n	90 //r _{total} epton family numb 10) CL% EVTS 90 0 oot use the following	er conservation. DOCUMENT ID LEE g data for average	ges, fits, li 82 Hl 82 Hl 90 SF ges, fits, li	mits, etc. LBC 	beam • • • Wideband ν beam F35/Γ COMMENT
<0.012 $(\pi^{+}\mu^{+}e^{-})$ Test of let $(ALUE (units 10^{-})$ < 2.1 • • • We do n <11	90 // Total epton family numb 10) CL% EVTS 90 0 not use the followin 90 0	er conservation. DOCUMENT ID LEE g data for average CAMPAGNA	ges, fits, li 82 HI 82 FI 90 SF ges, fits, li RI 88 SF	mits, etc. LBC CON CHG PEC + mits, etc. PEC +	beam • • • Wideband ν beam Γ35/Γ • • •
<0.012 $ \begin{array}{c} (\pi^{+}\mu^{+}e^{-}) \\ \text{Test of le} \\ \text{ALUE (units 10}^{-1} \\ \text{< 2.1} \\ \text{• • We do n} \\ \text{< 11} \\ \text{< 48} $	90 // Total epton family numb 10)	cooper cooper er conservation. DOCUMENT ID LEE g data for averag CAMPAGNA DIAMANT	ges, fits, li 82 HI 82 FI 90 SF ges, fits, li RI 88 SF	mits, etc. LBC CON CHG PEC + mits, etc. PEC +	beam • • • Wideband ν beam F35/Γ COMMENT • • • In LEE 90
<0.012 $ \begin{array}{ll} $	90 // Ttotal epton family numb 10)	og data for average COOPER er conservation. DOCUMENT ID LEE g data for average CAMPAGNA DIAMANT er conservation.	90 SF (ses, fits, li RI 88 SF (ses, Fits, li RI 88 SF (ses, Fits, li RI 88 SF (ses, Fits) SF (ses, Fits)	mits, etc. LBC CHO PEC + mits, etc. PEC +	beam Wideband ν beam F35/F COMMENT In LEE 90
<0.012 $ \begin{array}{ll} $	90 // Ttotal perton family numb 10)	og data for average COOPER er conservation. DOCUMENT ID LEE g data for average CAMPAGNA DIAMANT er conservation. DOCUMENT ID	90 SF	mits, etc. LBC CECN CHG PEC + mits, etc. PEC + PEC +	beam Wideband ν beam F35/F COMMENT In LEE 90
<0.012 $ \begin{array}{l} $	90 //Ftotal epton family numb 10)	og data for average COOPER er conservation. DOCUMENT ID LEE G data for average CAMPAGNA DIAMANT er conservation. DOCUMENT ID 56 DIAMANT	90 SF (ses, fits, li RI 88 SF 76 SF 76 SF	mits, etc. LBC CCN CHO PEC + mits, etc. PEC + PEC +	beam Videband ν beam F35/ COMMENT In LEE 90 F36/
<0.012 Test of let $ALUE$ (units 10=1 < 2.11 <48 Test of let $ALUE$ (units 10=1 < 48 Test of let $ALUE$ (units 10=4 < 48 ALUE (units 10=5 < 7 • • We do ne do ne de let $ALUE$ (units 10=5 < 7 • • • We do ne de let $ALUE$ (units 10=5 < 7 • • • We do ne de let $ALUE$ (units 10=5 < 7 • • • We do ne de let $ALUE$ (units 10=5 < 7 • • • We do ne de let $ALUE$ (units 10=5 < 7 • • • We do ne de let $ALUE$ (units 10=5)	90 // Total epton family numb 10)	or conservation. DOCUMENT ID LEE CAMPAGNA DIAMANT er conservation. DOCUMENT ID 56 DIAMANT	90 SF (ses, fits, li RI 88 SF 76 SF (ses, fits, li RI 88 SF 76 SF (ses, fits, li RI 88 SF 76 SF (ses, fits, li RI 88 SF (ses,	mits, etc. LBC CHG CHG CHG CHG CHG CHG CHG C	beam Videband ν beam F35/ COMMENT In LEE 90 F36/
<0.012 Test of le Te	90 // Ttotal peton family numb 10)	or conservation. DOCUMENT ID LEE g data for average CAMPAGNA DIAMANT er conservation. DOCUMENT ID 56 DIAMANT g data for average 56 BEIER	90 SF (ses, fits, li 82 HI 82 HI 90 SF (ses, fits, li 88 SF 76 SF 76 SF (ses, fits, li 72 O:	mits, etc. LBC CECN CHG PEC + mits, etc. PEC + mits, etc. PEC + mits, etc. PEC + mits, etc.	beam Videband ν beam F35/F COMMENT In LEE 90 F36/F
<0.012 $\Gamma\left(\pi^{+}\mu^{+}e^{-}\right)$ Test of le VALUE (units 10-i < 2.1) < 4.8 $\Gamma\left(\pi^{+}\mu^{-}e^{+}\right)$ Test of le VALUE (units 10-i < 7) $\bullet \bullet \bullet \text{ We do n}$ $< 6.0 \text{ We do n}$ $< 7 \text{ We do n}$ $< 8.0 \text{ We do n}$ $< 10.0 \text$	90 // Ttotal peton family numb 10) CL% EVTS 90 0 out use the followin 90 0 // Ttotal peton family numb 2) CL% EVTS 90 0 out use the followin 90 0 out use the followin 90 out use the followin 90 int actually applies	cooper data for average COOPER er conservation. DOCUMENT ID LEE g data for average CAMPAGNA DIAMANT er conservation. DOCUMENT ID 56 DIAMANT g data for average 56 BEIER to the sum of th	90 SF (ses, fits, li 82 HI 82 HI 90 SF (ses, fits, li 88 SF 76 SF 76 SF (ses, fits, li 72 O:	mits, etc. LBC CECN CHG PEC + mits, etc. PEC + mits, etc. PEC + mits, etc. PEC + mits, etc.	beam Wideband ν beam F35/F COMMENT In LEE 90 F36/F μ^+e^+ modes.
<0.012 $\Gamma\left(\pi^{+}\mu^{+}e^{-}\right)$ Test of le $VALUE (units 10^{-1}e^{-})$ < 2.1 < 48 $\Gamma\left(\pi^{+}\mu^{-}e^{+}\right)$ Test of le $VALUE (units 10^{-1}e^{-})$ < 7 < 6 $• • • We do n$ <28 56 Measureme $\Gamma\left(\pi^{-}\mu^{+}e^{+}\right)$ Test of tr <7 $\Gamma\left(\pi^{-}\mu^{+}e^{+}\right)$ Test of tr	90 // Ttotal epton family numb 10)	cooperation. COOPER er conservation. DOCUMENT ID LEE gg data for average CAMPAGNA DIAMANT er conservation. DOCUMENT ID 56 DIAMANT gg data for average 56 BEIER to the sum of th	7E 90 SF (es, fits, li RI 88 SF 76 SF (es, fits, li 72 O e π + μ - 1	mits, etc. LBC $\frac{CCN}{DEC} = \frac{CHG}{CHG}$ $\frac{CHG}{DEC} = \frac{CHG}{CHG}$	beam Videband ν beam Γ_{35}/Γ COMMENT In LEE 90 Γ_{36}/Γ Γ_{4} Γ_{4} Γ_{4} Γ_{5} Γ_{7}/Γ
<0.012 $\Gamma\left(\pi^{+}\mu^{+}e^{-}\right)$ Test of le $VALUE (units 10^{-1}e^{-})$ < 2.1 < 48 $\Gamma\left(\pi^{+}\mu^{-}e^{+}\right)$ Test of le $VALUE (units 10^{-1}e^{-})$ < 7 < 6 $• • • We do n$ <28 56 Measureme $\Gamma\left(\pi^{-}\mu^{+}e^{+}\right)$ Test of tr <7 $\Gamma\left(\pi^{-}\mu^{+}e^{+}\right)$ Test of tr	90 // Ttotal peton family numb 10) CL% EVTS 90 0 out use the followin 90 0 // Ttotal peton family numb 2) CL% EVTS 90 0 out use the followin 90 0 out use the followin 90 out use the followin 90 int actually applies	er conservation. DOCUMENT ID LEE g data for average CAMPAGNA DIAMANT er conservation. DOCUMENT ID 56 DIAMANT g data for average 56 BEIER to the sum of th	7E 90 SF (es, fits, li RI 88 SF 76 SF (es, fits, li 72 O) e π + μ - ΓΕ	mits, etc. LBC CECN CHG PEC + mits, etc. PEC + mits, etc. PEC + mits, etc. SPK ± e+ and π	beam Wideband ν beam F35/F COMMENT In LEE 90 F36/F μ^+e^+ modes.
<0.012 - $(\pi^{+}\mu^{+}e^{-})$ Test of let ALUE (units 10-1 < 2.1 <48 - $(\pi^{+}\mu^{-}e^{+})$ Test of let ALUE (units 10-1 < 7 • • We do not <28 56 Measureme - $(\pi^{-}\mu^{+}e^{+})$ Test of tet ALUE (units 10-1 < 7 - $(\pi^{-}\mu^{+}e^{+})$ Test of tet ALUE (units 10-5 < 7	90 // Ttotal epton family numb 10) CL% EVTS 90 0 ot use the followin 90 0 // Ttotal epton family numb 2) CL% EVTS 90 0 out use the followin 90 0 // Ttotal epton family numb 90 0 ent actually applies // Ttotal otal lepton numbe 2) CL% EVTS	or data for average COOPER er conservation. DOCUMENT ID LEE or data for average CAMPAGNA DIAMANT er conservation. DOCUMENT ID 56 DIAMANT g data for average 56 BEIER to the sum of th r conservation. DOCUMENT ID 57 DIAMANT	7Ε (ses, fits, II 82 HI 82 HI 82 HI 83 Figes, fits, II 76 SFiges, fits, II 72 O: e π + μ 7	mits, etc. LBC CECN CHG PEC + mits, etc. PEC + mits, etc. PEC + mits, etc. SPK ± e+ and π	beam Wideband ν beam F35/F COMMENT In LEE 90 F36/F μ^+e^+ modes. F37/F
<0.012 - $(\pi^{+}\mu^{+}e^{-})$ Test of let for the following state of let for the following state of the following	90 // Total peton family numb 10)	or data for average COOPER er conservation. DOCUMENT ID LEE or data for average CAMPAGNA DIAMANT er conservation. DOCUMENT ID 56 DIAMANT g data for average 56 BEIER to the sum of th r conservation. DOCUMENT ID 57 DIAMANT	ges, fits, II 82 HI 82 HI 82 HI 90 SF ges, fits, II 76 SF 76 SF 77 G SF 78 Ges, fits, II 79 OSF 70 Ge π + μ - Ges 76 SF 77 G SF 78 Ges, fits, II	mits, etc. LBC CECN CHG PEC + mits, etc. PEC + mits, etc. PEC + mits, etc. SPK \pm e + and π	beam Videband ν Videban
<0.012 - $(\pi^{+}\mu^{+}e^{-})$ Test of le - $(\pi LUE (units 10^{-})e^{-})e^{-}$ - $(\pi LUE (units 10^{-})e^{-})e^{-}$ - $(\pi^{+}\mu^{-}e^{+})e^{-}$ Test of le - $(\pi^{+}\mu^{-}e^{+})e^{-}$ Test of le - $(\pi^{-}\mu^{+}e^{+})e^{-}$ Test of te - $(\pi^{-}\mu^{+}e^{-})e^{-}$ Test of te	90 // Total peton family numb 10)	er conservation. DOCUMENT ID LEE gd data for average CAMPAGNA DIAMANT er conservation. DOCUMENT ID 56 DIAMANT gd data for average 56 BEIER to the sum of th r conservation. DOCUMENT ID 57 DIAMANT gd data for average 57 BEIER	7Ε 90 SF 76 SF 72 O: e π + μ - π 76 SF 76 SF 76 SF 77	mits, etc. LBC CHG PEC + mits, etc. PEC + mits, etc. PEC + mits, etc. SPK ± e+ and π	beam Wideband ν beam F35/F COMMENT In LEE 90 F36/F μ^+e^+ modes. F37/F
<0.012 - ($\pi^+\mu^+e^-$) Test of le ALUE (units 10-1 < 2.1 < 48 - ($\pi^+\mu^-e^+$) Test of le ALUE (units 10-1 < 7 • • We do n < 28 56 Measureme - ($\pi^-\mu^+e^+$) Test of te ALUE (units 10-1 < 7 • • We do n < 28 57 Measureme 57 Measureme 57 Measureme 57 Measureme	90 // Total peton family numb 10)	er conservation. DOCUMENT ID LEE gd data for average CAMPAGNA DIAMANT er conservation. DOCUMENT ID 56 DIAMANT gd data for average 56 BEIER to the sum of th r conservation. DOCUMENT ID 57 DIAMANT gd data for average 57 BEIER	7Ε 90 SF 76 SF 72 O: e π + μ - π 76 SF 76 SF 76 SF 77	mits, etc. LBC CHG PEC + mits, etc. PEC + mits, etc. PEC + mits, etc. SPK ± e+ and π	beam Videband ν Videba
<0.012 $ \Gamma(\pi^{+}\mu^{+}e^{-}) $ Test of le $ ALUE (units 10^{-1}e^{-}) $ < 2.1 < 48 $ \Gamma(\pi^{+}\mu^{-}e^{+}) $ Test of le $ ALUE (units 10^{-1}e^{-}) $ < • • We do n <28 56 Measureme $ \Gamma(\pi^{-}\mu^{+}e^{+}) $ Test of tr $ ALUE (units 10^{-1}e^{-}) $ < • • We do n <28 57 Measureme $ \Gamma(\pi^{-}\mu^{+}e^{+}) $ Test of tr $ ALUE (units 10^{-1}e^{-}) $ < 7 • • • We do n <28 57 Measureme $ \Gamma(\pi^{+}\mu^{-}e^{+}) $ $ \Gamma(\pi^{+}\mu^{-}e^{+}) $	// Ftotal epton family numb O	conservation. Company Begins of the sum of	$\frac{7E}{90}$ $7E$	mits, etc. LBC CECN CHG PEC + mits, etc. PEC + mits, etc. PEC + mits, etc. SPK \pm e + and π PEC + mits, etc. SPK \pm e + and π	beam Videband ν
<0.012	90 // Total peton family numb 10)	er conservation. DOCUMENT ID GRADE TO BE SEE TO S	res, fits, li 82 HI 82 HI 90 SF res, fits, li 76 SF res, fits, li 72 OS e $\pi^+\mu^-$ 72 OS e $\pi^+\mu^-$ 74 Fres, fits, li 72 OS e $\pi^+\mu^-$ 75 Fres, fits, li 72 OS e $\pi^+\mu^-$	mits, etc. LBC $\frac{CCN}{PEC} + \frac{CHG}{PEC} $	beam Wideband ν beam F35/F COMMENT In LEE 90 F36/F μ^+e^+ modes. F37/F μ^+e^+ modes.
<0.012 $\Gamma\left(\pi^{+}\mu^{+}e^{-}\right)$ Test of le VALUE (units 10-15 < 2.1) <48 $\Gamma\left(\pi^{+}\mu^{-}e^{+}\right)$ Test of le VALUE (units 10-15 < 7) We do not consider the value (units 10-15 < 7) Test of the value (units 10-15 < 7) Test of the value (units 10-15 < 7) Test of the value (units 10-15 < 7) The value (units 10-15 <	90 // Ftotal epton family numb 10) CL% EVTS 90 0 out use the followin 90 0 // Ftotal epton family numb 2) CL% EVTS 90 0 out use the followin 90 out use the followin 90 out actually applies // Ftotal out lepton numbe 2) CL% EVTS out use the followin 90 er conservation. DOCUMENT ID GRADE TO BE SEE TO S	7ε, fits, li 82 HI 82 HI 90 SF 90 SF 10 SF 10 SF 10 SF 10 SF 11 SF 12 O 12 SF 12 SF 13 SF 14 SF 15 SF 16 SF 17 SF 17 SF 18 SF	mits, etc. LBC $\frac{CCN}{PEC} + \frac{CHG}{PEC} $	beam Wideband ν beam F35/F COMMENT In LEE 90 F36/F μ^+e^+ modes. F37/F μ^+e^+ modes.	

```
\Gamma(\pi^-e^+e^+)/\Gamma_{\text{total}}
                                                                                                         \Gamma_{38}/\Gamma
        Test of total lepton number conservation.
VALUE (units 10<sup>-5</sup>)
                                              DOCUMENT ID
                                                                        TECN CHG
\bullet \,\bullet\, We do not use the following data for averages, fits, limits, etc. \,\bullet\, \,\bullet\,
                                              CHANG
                                                                  68 HBC -
 \Gamma(\pi^-e^+e^+)/\Gamma(\pi^+\pi^-e^+\nu_e)  Test of total lepton number conservation.
                                                                                                        \Gamma_{38}/\Gamma_{9}
VALUE (units 10<sup>-4</sup>) CL% EVTS
                                              DOCUMENT ID
                                                                       TECN CHG
               90 0 <sup>58</sup> DIAMANT-... 76 SPEC +
 ^{58}\,\mathrm{DIAMANT\text{-}BERGER} 76 quotes this result times our 1975 BR ratio.
 \Gamma(\pi^-\mu^+\mu^+)/\Gamma_{\rm total} \\ {\rm Forbidden\ by\ total\ lepton\ number\ conservation}. 
                                                                                                         \Gamma_{39}/\Gamma

        VALUE (units 10<sup>-4</sup>)
        CL%
        DOCUMENT ID
        TECN

        <1.5</td>
        90
        59
        LITTENBERG
        92
        HBC

 ^{59} LITTENBERG 92 is from retroactive data analysis of CHANG 68 bubble chamber data.
\Gamma(\mu^+ \overline{\nu}_e) / \Gamma_{\text{total}}
      Forbidden by total lepton number conservation.
VALUE (units 10<sup>-3</sup>) CL%
                                               DOCUMENT ID
                                                                       TECN COMMENT
 <3.3
                                90
                                               COOPER
                                                                  82 HLBC Wideband \nu beam
\Gamma(\pi^0 e^+ \overline{\nu}_e)/\Gamma_{\rm total}
                                                                                                         \Gamma_{41}/\Gamma
        Forbidden by total lepton number conservation.
VALUE
                                                                       TECN__COMMENT
                 _______CL%
                                               DOCUMENT ID
                                               COOPER
                                                                   82 HLBC Wideband \nu beam
                                90
\Gamma(\pi^+\gamma)/\Gamma_{	ext{total}}
Violates angular momentum conservation. Not listed in Summary Table.
                                                                                                         \Gamma_{42}/\Gamma
\bullet \,\bullet \,\bullet We do not use the following data for averages, fits, limits, etc. \,\bullet \,\bullet
                                                                  82 CNTR +
71 OSPK +
 < 1.4
                                90
                                              ASANO
                                          60 KLEMS
 <4.0
                                90
 ^{60} Test of model of Selleri, Nuovo Cimento 60A 291 (1969).
              K+ LONGITUDINAL POLARIZATION OF EMITTED u+
```

VALUE	<u>CL%</u>	DOCUMENT ID		<u>TECN</u>	<u>CHG</u>	COMMENT	
<-0.990	90	⁶¹ AOKI	94	SPEC	+		
• • • We do not use	e the followi	ng data for average	s, fit	s, limits,	etc. •	• •	
<-0.990	90	IMAZATO	92	SPEC	+	Repl. by AOKI 94	
-0.970 ± 0.047		⁶² YAMANAKA	86	SPEC	+		
-1.0 ± 0.1		⁶² CUTTS	69	SPRK	+		
-0.96 ± 0.12		62 COOMBES	57	CNTR	+		
(1							

 61 AOKI 94 measures $\xi P_{\mu} = -0.9996 \pm 0.0030 \pm 0.0048.$ The above limit is obtained by summing the statistical and systematic errors in quadrature, normalizing to the physically significant region ($\left|\xi P_{\mu}\right|<1$) and assuming that $\xi = 1$, its maximum value. 62 Assumes $\xi = 1$.

DALITZ PLOT PARAMETERS FOR $K \to 3\pi$ DECAYS

The Dalitz plot distribution for $K^\pm \to \pi^\pm \pi^\pm \pi^\mp$, $K^\pm \to \pi^0 \pi^0 \pi^\pm$, and $K_L^0 \to \pi^+ \pi^- \pi^0$ can be parameterized by a series expansion such as that introduced by Weinberg [1]. We use the form

$$\left| M \right|^2 \propto 1 + g \frac{(s_3 - s_0)}{a m_{\pi^+}^2} + h \left[\frac{s_3 - s_0}{m_{\pi^+}^2} \right]^2 + j \frac{(s_2 - s_1)}{m_{\pi^+}^2} + ak \left[\frac{s_2 - s_1}{m_{\pi^+}^2} \right]^2 + \cdots , \tag{1}$$

where $m_{\pi^+}^2$ has been introduced to make the coefficients g, h, j, and k dimensionless, and

$$s_i = (P_K - P_i)^2 = (m_K - m_i)^2 - 2m_K T_i , i = 1, 2, 3,$$

$$s_0 = \frac{1}{3} \sum_i s_i = \frac{1}{3} (m_K^2 + m_1^2 + m_2^2 + m_3^2)$$

Here the P_i are four-vectors, m_i and T_i are the mass and kinetic energy of the i^{th} pion, and the index 3 is used for the odd pion.

The coefficient q is a measure of the slope in the variable s_3 (or T_3) of the Dalitz plot, while h and k measure the quadratic dependence on s_3 and $(s_2 - s_1)$, respectively. The coefficient j is related to the asymmetry of the plot and must be zero if CPinvariance holds. Note also that if CP is good, g, h, and k must be the same for $K^+ \to \pi^+ \pi^+ \pi^-$ as for $K^- \to \pi^- \pi^- \pi^+$.

Since different experiments use different forms for M, in order to compare the experiments we have converted to g, h, j, and k whatever coefficients have been measured. Where such conversions have been done, the measured coefficient a_u , a_t , a_u , or a_v is given in the comment at the right. For definitions of these coefficients, details of this conversion, and discussion of the data, see the April 1982 version of this note [2].

References

- 1. S. Weinberg, Phys. Rev. Lett. 4, 87 (1960).
- 2. Particle Data Group, Phys. Lett. 111B, 69 (1982).

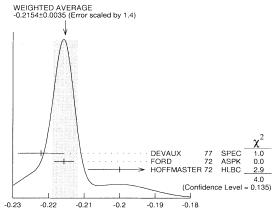
ENERGY DEPENDENCE OF K^{\pm} DALITZ PLOT

$$\begin{array}{l} |{\rm matrix\ element}|^2=1+gu+hu^2+kv^2\\ {\rm where\ }u=(s_3-s_0)\ /\ m_\pi^2\ {\rm and\ }v=(s_1-s_2)\ /\ m_\pi^2 \end{array}$$

LINEAR COEFFICIENT g_{τ^+} **FOR** $K^+ \to \pi^+ \pi^+ \pi^-$ Some experiments use Dalitz variables x and y. In the comments we give $a_y =$ coefficient of y term. See note above on "Dalitz Plot Parameters for $K \to 3\pi$ Decays." For discussion of the conversion of a_y to g, see the earlier version of the same note in the *Review* published in Physics Letters **111B** 70 (1982).

VALUE	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
-0.2154±0.0035 OU	R AVERAGE	Error includes	scale	factor of	1.4.	See the ideogram
		below.				-
-0.2221 ± 0.0065	225k	DEVAUX	77	SPEC	+	$a_V = .2814 \pm .0082$
-0.2157 ± 0.0028	750k	FORD	72	ASPK	+	$a_V = .2734 \pm .0035$
-0.200 ± 0.009	39819 6	³ HOFFMASTE	R72	HLBC	+	*
 ● ● We do not use 	the following	data for averag	es, fit	s, Iimits,	etc.	• • •
-0.196 ± 0.012	17898 6	⁴ GRAUMAN	70	HLBC	+	$a_V = 0.228 \pm 0.030$
-0.218 ± 0.016		⁵ BUTLER		HBC	+	$a_V = 0.277 \pm 0.020$
-0.22 ± 0.024	5428 65,6	⁶ ZINCHENKO	67	нвс	+	$a_y = 0.28 \pm 0.03$

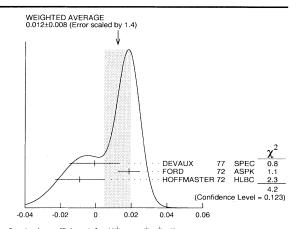
- 63 HOFFMASTER 72 includes GRAUMAN 70 data
- 64 Emulsion data added all events included by HOFFMASTER 72.
- 65 Experiments with large errors not included in average.
- 66 Also includes DBC events.



Linear energy dependence for K^+

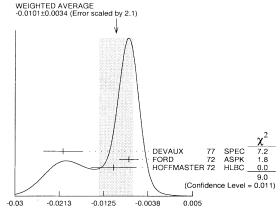
QUADRATIC COEFFICIENT h FOR $K^+ \rightarrow \pi^+\pi^+\pi^-$

VALUE	EVTS	DOCUMENT ID		TECN	CHG		
0.012 ± 0.008	OUR AVERAGE	Error includes	scale	factor of	1.4.	See th	e ideogram
		below.					
-0.0006 ± 0.0143	225k	DEVAUX	77	SPEC	+		
0.0187 ± 0.0062	750k	FORD	72	ASPK	+		
-0.009 ± 0.014	39819	HOFFMASTE	R72	HLBC	+.		



Quadratic coefficient h for K^+

QUADRATIC COL	FFICIENT A	K FOR KT -	→ π [¬]	$\pi^-\pi^-$			
VALUE	EVTS	DOCUMENT ID		TECN	CHG	_	
-0.0101±0.0034 OL	IR AVERAGE	Error includes	scale	factor o	f 2.1.	See the ide	eogram
		below.					-
-0.0205 ± 0.0039	225k	DEVAUX	77	SPEC	+		
-0.0075 ± 0.0019	750k	FORD	72	ASPK	+		
-0.0105 ± 0.0045	39819	HOFFMASTE	R72	HLRC			



Quadratic coefficient k for $K^+ \rightarrow \pi^+\pi^+\pi^-$

LINEAR COEFFICIENT g_{τ^-} **FOR** $K^- \to \pi^- \pi^- \pi^+$ Some experiments use Dalitz variables x and y. In the comments we give $a_y =$ coefficient of y term. See note above on "Dalitz Plot Parameters for $K \to 3\pi$ Decays." For discussion of the conversion of a_y to g, see the earlier version of the same note in the *Review* published in Physics Letters **111B** 70 (1982).

VALUE		EVTS		DOCUMENT ID		TECN	CHG	COMMENT	
-0.217 ±	-0.007	OUR AVERA	\GE	Error includes :	scale	factor of	f 2.5.		
$-0.2186 \pm$	0.0028	750k		FORD	72	ASPK	-	a _V =.2770 ±	.0035
$-0.193 \pm$	0.010	50919		MAST	69	HBC	-	$a_V = 0.244 \pm 0.000$	± 0.013
• • • We	do not	use the follow	ving d	ata for average	s, fits	, limits,	etc. •	• •	
-0.199 ±	0.008			LUCAS			-	a _V =0.252 ±	0.011
-0.190 ±	0.023	5778	68,69	MOSCOSO	68	HBC		$a_V = 0.242 \pm$	0.029
-0.220 ±	0.035	1347	70	FERRO-LUZZ	l 61	HBC		$a_{V} = 0.28 \pm$	0.045

 67 Quadratic dependence is required by K_L^0 experiments. For comparison we average only those K^{\pm} experiments which quote quadratic fit values.

68 Experiments with large errors not included in average.

69 Also includes DBC events. 70 No radiative corrections included.

QUADRATIC COEFFICIENT h FOR $K^- \rightarrow \pi^-$

VALUL	LVIJ	DOCUMENT	10	TECIV	CHO
0.010 ± 0.006	OUR AVERAGE				
0.0125 ± 0.0062	750k	FORD	72	ASPK	
-0.001 ± 0.012	50919	MAST	69	HBC	-

QUADRATIC COEFFICIENT k FOR $K^- \rightarrow \pi^-\pi^-\pi^+$

VALUE	EVTS	DOCUMENT ID		TECN	CHO
-0.0084 ± 0.0019 OUR	AVERAGE				
-0.0083 ± 0.0019	750k	FORD	72	ASPK	_
-0.014 ± 0.012	50919	MAST	69	HBC	

 K^{\pm}

$(\mathbf{g_{\tau^+}} - \mathbf{g_{\tau^-}}) / \mathbf{g_{\tau^-}}$	$(\mathbf{g}_{ au^+} + \mathbf{g}_{ au^-})$ lue for this qua	FOR K [±] → intity indicates	π [±] π CP viol	$+\pi^-$ ation.
VALUE (%)	EVTS	DOCUMENT I		TECN
-0.70 ± 0.53	3.2M	FORD	70	ASPK

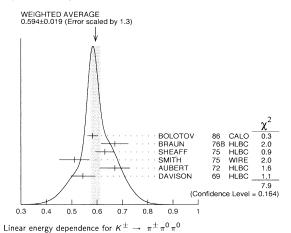
LINEAR COEFFICIENT g FOR $K^\pm \to ~\pi^\pm \pi^0 \pi^0$

Unless otherwise stated, all experiments include terms quadratic in (s_3-s_0) / $m_{\pi^+}^2$. See mini-review above.

. 3	π^+					
VALUE	<u>EVTS</u>	DOCUMENT ID		TECN	CHG	COMMENT
0.594±0.019	OUR AVERAGE	Error includes scale	factor	of 1.3.	See	the ideogram below.
0.582 ± 0.021	43k	BOLOTOV	86 (CALO	_	
0.670 ± 0.054	3263	BRAUN	76B F	HLBC	+	
0.630 ± 0.038	5635	SHEAFF	75 H	HLBC	+	
0.510 ± 0.060	27k	SMITH	75 \	WIRE	+	
0.67 ± 0.06	1365	AUBERT	72 H	HLBC	+	
0.544 ± 0.048	4048	DAVISON	69 H	HLBC	+	Also emulsion
• • • We do	not use the follow	ing data for average	s, fits,	limits,	etc.	• • •
0.806±0.220	4639	⁷¹ BERTRAND	76 E	EMUL	+	
0.484 ± 0.084	574	⁷² LUCAS	738 H	нвс	_	Dalitz pairs only
0.527 ± 0.102	198	⁷¹ PANDOULAS	70 E	EMUL	+	
0.586 ± 0.098	1874	⁷² BISI	65 H	HLBC	+	Also HBC
0.48 ±0.04	1792	⁷² KALMUS	64 H	HLBC	+	

⁷¹ Experiments with large errors not included in average.

⁷² Authors give linear fit only.



QUADRATIC COEFFICIENT h FOR $K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\pi^{0}$

See mini-reviev ALUE	v above. EVTS	DOCUMENT ID		TECN	CHG	COMMENT
0.035±0.015 OUR		DOCUMENT ID		TECIV	CHG	COMMENT
0.035 ± 0.015 OOK	AVERAGE					
0.037 ± 0.024	43k	BOLOTOV	86	CALO	-	
0.152 ± 0.082	3263	BRAUN	76B	HLBC	+	
0.041 ± 0.030	5635	SHEAFF	75	HLBC	+	
0.009 ± 0.040	27k	SMITH	75	WIRE	+	
-0.01 ±0.08	1365	AUBERT	72	HLBC	+	
0.026 ± 0.050	4048	DAVISON	69	HLBC	+	Also emulsion
• • We do not use	the followi	ng data for average	s, fits	, limits,	etc.	• •
0.164 ± 0.121	4639	⁷³ BERTRAND	76	EMUL	+	
0.018 ± 0.124	198	⁷³ PANDOULAS	70	EMUL	+	
73 Experiments with	large errors	not included in ave	erage			

$K_{\ell 3}^{\pm}$ AND $K_{\ell 3}^{0}$ FORM FACTORS

Assuming that only the vector current contributes to $K \to \pi \ell \nu$ decays, we write the matrix element as

$$M \propto f_{+}(t) \left[(P_K + P_{\pi})_{\mu} \overline{\ell} \gamma_{\mu} (1 + \gamma_5) \nu \right]$$

+ $f_{-}(t) \left[m_{\ell} \overline{\ell} (1 + \gamma_5) \nu \right] ,$ (1)

where P_K and P_{π} are the four-momenta of the K and π mesons, m_{ℓ} is the lepton mass, and f_+ and f_- are dimensionless form factors which can depend only on $t = (P_K - P_{\pi})^2$, the square of the four-momentum transfer to the leptons. If time-reversal invariance holds, f_+ and f_- are relatively real. $K_{\mu 3}$ experiments measure f_+ and f_- , while K_{e3} experiments are sensitive only

to f_+ because the small electron mass makes the f_- term negligible.

(a) $K_{\mu3}$ experiments. Analyses of $K_{\mu3}$ data frequently assume a linear dependence of f_+ and f_- on t, i.e.,

$$f_{\pm}(t) = f_{\pm}(0) \left[1 + \lambda_{\pm}(t/m_{\pi}^2) \right]$$
 (2)

Most $K_{\mu 3}$ data are adequately described by Eq. (2) for f_+ and a constant f_- (*i.e.*, $\lambda_-=0$). There are two equivalent parametrizations commonly used in these analyses:

(1) $\lambda_+, \xi(0)$ parametrization. Analyses of $K_{\mu 3}$ data often introduce the ratio of the two form factors

$$\xi(t) = f_{-}(t)/f_{+}(t)$$
.

The $K_{\mu 3}$ decay distribution is then described by the two parameters λ_+ and $\xi(0)$ (assuming time reversal invariance and $\lambda_- = 0$). These parameters can be determined by three different methods:

Method A. By studying the Dalitz plot or the pion spectrum of $K_{\mu 3}$ decay. The Dalitz plot density is (see, e.g., Chounet et al. [1]):

$$\rho(E_{\pi}, E_{\mu}) \propto f_{+}^{2}(t) \left[A + B\xi(t) + C\xi(t)^{2} \right] ,$$

where

$$\begin{split} A &= m_K \left(2 E_\mu E_\nu - m_K E_\pi' \right) + m_\mu^2 \left(\frac{1}{4} E_\pi' - E_\nu \right) \;, \\ B &= m_\mu^2 \left(E_\nu - \frac{1}{2} E_\pi' \right) \;, \\ C &= \frac{1}{4} m_\mu^2 E_\pi' \;, \\ E_\pi' &= E_\pi^{\rm max} - E_\pi = \left(m_K^2 + m_\pi^2 - m_\mu^2 \right) / 2 m_K - E_\pi \;. \end{split}$$

Here
$$E_{\pi}$$
, E_{μ} , and E_{ν} are, respectively, the pion, muon, and neutrino energies in the kaon center of mass. The density ρ is

fit to the data to determine the values of λ_+ , $\xi(0)$, and their correlation.

Method B. By measuring the $K_- a/K_-$ branching ratio

Method B. By measuring the $K_{\mu3}/K_{e3}$ branching ratio and comparing it with the theoretical ratio (see, e.g., Fearing et al. [2]) as given in terms of λ_+ and $\xi(0)$, assuming μ -e universality:

$$\begin{split} \Gamma(K_{\mu3}^{\pm})/\Gamma(K_{e3}^{\pm}) &= 0.6457 + 1.4115\lambda_{+} + 0.1264\xi(0) \\ &\quad + 0.0192\xi(0)^{2} + 0.0080\lambda_{+}\xi(0) \\ \Gamma(K_{\mu3}^{0})/\Gamma(K_{e3}^{0}) &= 0.6452 + 1.3162\lambda_{+} + 0.1264\xi(0) \\ &\quad + 0.0186\xi(0)^{2} + 0.0064\lambda_{+}\xi(0) \end{split}$$

This cannot determine λ_+ and $\xi(0)$ simultaneously but simply fixes a relationship between them.

Method C. By measuring the muon polarization in $K_{\mu 3}$ decay. In the rest frame of the K, the μ is expected to be

polarized in the direction **A** with $\mathbf{P} = \mathbf{A}/|\mathbf{A}|$, where **A** is given (Cabibbo and Maksymowicz [3]) by

$$\begin{split} \mathbf{A} &= a_1(\xi) \mathbf{p}_{\mu} \\ &- a_2(\xi) \left[\frac{\mathbf{p}_{\mu}}{m_{\mu}} \left(m_K - E_{\pi} + \frac{\mathbf{p}_{\pi} \cdot \mathbf{p}_{\mu}}{\left| \mathbf{p}_{\mu} \right|^2} (E_{\mu} - m_{\mu}) \right) + \mathbf{p}_{\pi} \right] \\ &+ m_K \mathrm{Im} \xi(t) (\mathbf{p}_{\pi} \times \mathbf{p}_{\mu}) \ .. \end{split}$$

If time-reversal invariance holds, ξ is real, and thus there is no polarization perpendicular to the K-decay plane. Polarization experiments measure the weighted average of $\xi(t)$ over the t range of the experiment, where the weighting accounts for the variation with t of the sensitivity to $\xi(t)$.

(2) λ_+, λ_0 parametrization. Most of the more recent $K_{\mu 3}$ analyses have parameterized in terms of the form factors f_{+} and f_0 which are associated with vector and scalar exchange, respectively, to the lepton pair. f_0 is related to f_+ and f_- by

$$f_0(t) = f_+(t) + \left[t/(m_K^2 - m_\pi^2)\right] f_-(t)$$
.

Here $f_0(0)$ must equal $f_+(0)$ unless $f_-(t)$ diverges at t=0. The earlier assumption that f_{+} is linear in t and f_{-} is constant leads to f_0 linear in t:

$$f_0(t) = f_0(0) \left[1 + \lambda_0(t/m_\pi^2) \right]$$
.

With the assumption that $f_0(0) = f_+(0)$, the two parametrizations, $(\lambda_+, \xi(0))$ and (λ_+, λ_0) are equivalent as long as correlation information is retained. (λ_+, λ_0) correlations tend to be less strong than $(\lambda_+, \xi(0))$ correlations.

The experimental results for $\xi(0)$ and its correlation with λ_{+} are listed in the K^{\pm} and K_{L}^{0} sections of the Particle Listings in section ξ_A , ξ_B , or ξ_C depending on whether method A, B, or C discussed above was used. The corresponding values of λ_{+} are also listed.

Because recent experiments tend to use the (λ_+, λ_0) parametrization, we include a subsection for λ_0 results. Wherever possible we have converted $\xi(0)$ results into λ_0 results and vice versa.

See the 1982 version of this note [4] for additional discussion of the $K_{\mu 3}^0$ parameters, correlations, and conversion between parametrizations, and also for a comparison of the experimental results.

(b) K_{e3} experiments. Analysis of K_{e3} data is simpler than that of $K_{\mu 3}$ because the second term of the matrix element assuming a pure vector current [Eq. (1) above] can be neglected. Here f_{+} is usually assumed to be linear in t, and the linear coefficient λ_+ of Eq. (2) is determined.

If we remove the assumption of a pure vector current, then the matrix element for the decay, in addition to the terms in Eq. (2), would contain

$$+2m_K f_S \bar{\ell}(1+\gamma_5)\nu$$

+
$$(2f_T/m_K)(P_K)_{\lambda}(P_{\pi})_{\mu} \bar{\ell} \sigma_{\lambda\mu}(1+\gamma_5)\nu ,$$

where f_S is the scalar form factor, and f_T is the tensor form factor. In the case of the K_{e3} decays where the f_- term can be neglected, experiments have yielded limits on $|f_S/f_+|$ and $|f_T/f_+|$.

References

- L.M. Chounet, J.M. Gaillard, and M.K. Gaillard, Phys. Reports 4C, 199 (1972).
- H.W. Fearing, E. Fischbach, and J. Smith, Phys. Rev. D2, 542 (1970).
- N. Cabibbo and A. Maksymowicz, Phys. Lett. 9, 352 (1964).
- Particle Data Group, Phys. Lett. 111B, 73 (1982).

KA FORM FACTORS

In the form factor comments, the following symbols are used.

f_ and f_ are form factors for the vector matrix element.

 f_{S} and f_{T} refer to the scalar and tensor term.

 $f_0 = f_+ + f_- t/(m_K^2 - m_\pi^2).$

 λ_+ , λ_- , and λ_0 are the linear expansion coefficients of f_+ , f_- , and f_0 . λ_+ refers to the $K_{\mu 3}^\pm$ value except in the K_{e3}^\pm sections.

 $d\xi(0)/d\lambda_+$ is the correlation between $\xi(0)$ and λ_+ in K_{u3}^{\pm} .

 $d\lambda_0/d\lambda_+$ is the correlation between λ_0 and λ_+ in K_{u3}^{\pm} .

t= momentum transfer to the π in units of m_π^2

DP = Dalitz plot analysis.

 $PI = \pi$ spectrum analysis.

 $MU = \mu$ spectrum analysis.

 $POL = \mu$ polarization analysis.

BR = $K_{\mu 3}^{\pm}/K_{e3}^{\pm}$ branching ratio analysis.

E = positron or electron spectrum analysis.

RC = radiative corrections

λ_{+} (LINEAR ENERGY DEPENDENCE OF f_{+} IN K_{e3}^{\pm} DECAY)

VALUE		EVTS		DOCUMENT ID		TECN	CHG	COMMENT
0.0286	5±0.0022 OUR A							
0.0284	$\pm 0.0027 \pm 0.0020$			AKIMENKO	91	SPEC		PI, no RC
0.029	± 0.004			BOLOTOV	88	SPEC		PI, no RC
0.027	± 0.008		76	BRAUN	73B	HLBC	+	DP, no RC
0.029	± 0.011	4017		CHIANG	72	OSPK	+	DP, RC neglig- ble
0.027	± 0.010	2707		STEINER	71	HLBC	+	DP, uses RC
0.045	± 0.015	1458		BOTTERILL	70	OSPK		PI, uses RC
0.08	± 0.04	960		BOTTERILL	68 C	ASPK	+	e^+ , uses RC
-0.02	+0.08 -0.12	90		EISLER	68	HLBC	+	PI, uses RC
0.045	+0.017 -0.018	854		BELLOTTI	67B	FBC	+	DP, uses RC
+0.016	± 0.016	1393		IMLAY	67	OSPK	+	DP, no RC
+0.028	+0.013 -0.014	515		KALMUS	67	FBC	+	e ⁺ , PI, no RC
-0.04	± 0.05	230		BORREANI	64	HBC	+	e^+ , no RC
-0.010	± 0.029	407		JENSEN	64	XEBC	+	PI, no RC
+0.036	±0.045	217		BROWN	62B	XEBC	+	PI, no RC
• • • V	Ve do not use the t	ollowing	dat	a for averages, t	fits,	imits, et	.c. • •	•
0.025	± 0.007		77	BRAUN	74	HLBC	+	$K_{\mu 3}/K_{e3}$ vs. t

 $^{^{74}\,\}mathrm{AKIMENKO}$ 91 state that radiative corrections would raise λ_+ by 0.0013.

 $\xi_{A}=f_{-}/f_{+}$ (determined from K_{13}^{\pm} spectra)

The parameter ξ is redundant with λ_{0} below and is not put into the Meson Summary

VALUE	$d\xi(0)/d\lambda_{\pm}$	EVTS	DOCUMENT ID		TECN	CHG	COMMENT	
-0.35 ± 0.15 O	UR EVAL	JATION	From a fit discussed	d in	note on	$K_{\ell 3}$ fo	orm factors in	
			1982 edition, PL 111B (April 1982).					
-0.27 ± 0.25	-17	3973	WHITMAN	80	SPEC	+	DP	
-0.8 ± 0.8	- 20	490		74	HLBC	+	DP	
-0.57 ± 0.24	- 9	6527	⁷⁹ MERLAN	74	ASPK	+	DP	
-0.36 ± 0.40	19	1897	⁸⁰ BRAUN		HLBC	+	DP	
-0.62 ± 0.28	- 12	4025		72	ASPK	+	PI	
$+0.45 \pm 0.28$	-15	3480	⁸² CHIANG	72	OSPK	+	DP	
-1.1 ± 0.56	- 29	3240	83 HAIDT	71	HLBC	+	DP	
-0.5 ± 0.8	- 26	2041	⁸⁴ KIJEWSKI	69	OSPK	+	PI	
$+0.72\pm0.93$	-17	444	CALLAHAN	66 B	FBC	+	PI	

 $^{^{75}}$ BOLOTOV 88 state radiative corrections of GINSBERG 67 would raise λ_+ by 0.002.

 $^{^{76}}$ BRAUN 73B states that radiative corrections of GINSBERG 67 would lower λ_+^e by 0.002 but that radiative corrections of BECHERRAWY 70 disagrees and would raise λ_{+}^{e} by

⁷⁷ BRAUN 74 is a combined $K_{\mu3}$ - K_{e3} result. It is not independent of BRAUN 73C ($K_{\mu3}$) and BRAUN 73B (K_{e3}) form factor results.

• • • We do	not use the	following	data for averages, f	its, li	mits, et	c. • •	•
-0.5 ± 0.9	none	78	EISLER	68	HLBC	+	PI, $\lambda_{+}=0$
$0.0 \begin{array}{c} +1.1 \\ -0.9 \end{array}$		2648	⁸⁵ CALLAHAN	66B	FBC	+	μ , $\lambda_{+}=0$
$+0.7 \pm 0.5$		87	GIACOMELLI	64	EMUL	+	$MU+BR,\lambda_{+}=0$
-0.08 ± 0.7			⁸⁶ JENSEN	64	XEBC	+	DP+BR
$+1.8 \pm 0.6$		76	BROWN	62B	XEBC	+	DP+BR,
							$\lambda_{+}=0$

 $^{^{78}\,\}mathrm{ARNOLD}$ 74 figure 4 was used to obtain ξ_{A} and $d\xi(0)/d\lambda_{+}.$

$\xi_B = f_-/f_+$ (determined from $K_{\mu 3}^{\pm}/K_{e 3}^{\pm}$)

The $\kappa_{\mu3}^{\pm}/\kappa_{e3}^{\pm}$ branching ratio fixes a relationship between $\xi(0)$ and λ_{+} . We quote the author's $\xi(0)$ and associated λ_{+} but do not average because the λ_{+} values differ. The fit result and scale factor given below are not obtained from these ξ_B values. Instead they are obtained directly from the fitted $K_{\mu 3}^{\pm}/K_{e3}^{\pm}$ ratio $\Gamma(\pi^0\mu^+\nu_\mu)/\Gamma(\pi^0e^+\nu_e)$, with the exception of HEINTZE 77. The parameter $\hat{\epsilon}$ is redundant with λ_0 below and is not put into the Meson Summary Table.

13 1101 P	at the the wieson su	minuty rubic.								
VALUE	EVTS	DOCUMENT ID		TECN	CHG	COMMENT				
-0.35 ± 0.15	OUR EVALUATION	From a fit discu	issed	in note	on $K_{\rho 3}$	form factors in				
		1982 edition, F	PL 11	1B (Apr	ril 1982	2).				
-0.12 ± 0.12	55k 8	⁷ HEINTZE	77	CNTR	+	$\lambda_{+} = 0.029$				
 • • We do not use the following data for averages, fits, limits, etc. 										
$0.0\ \pm0.15$	5825	CHIANG	72	OSPK	+	$\lambda_{+} = 0.03$, fig.10				
-0.81 ± 0.27		⁸ HAIDT	71	HLBC	+	λ_{+} =0.028, fig.8				
-0.35 ± 0.22	8	⁹ BOTTERILL	70	OSPK	+	$\lambda_{+} = 0.045 \pm 0.015$				
$+0.91\pm0.82$		ZELLER	69	ASPK	+	$\lambda_{+} = 0.023$				
-0.08 ± 0.15		⁹ BOTTERILL	68B	ASPK	+	$\lambda_{+} = 0.023 \pm 0.008$				
-0.60 ± 0.20	1398 8	⁸ EICHTEN	68	HLBC	+	See note				
$+1.0 \pm 0.6$	986	GARLAND	68	OSPK	+	$\lambda_{+}=0$				
$+0.75\pm0.50$	306	AUERBACH	67	OSPK	+	$\lambda_{+}=0$				
$+0.4 \pm 0.4$	636	CALLAHAN	66B	FBC	+	$\lambda_{+}=0$				
$+0.6 \pm 0.5$		BISI	65B	HBC	+	$\lambda_{+}=0$				
$+0.8\ \pm0.6$	500	CUTTS	65	OSPK	+	$\lambda_{+}=0$				
$-0.17^{+0.75}_{-0.99}$		SHAKLEE	64	XEBC	+	$\lambda_{+}=0$				

 $^{^{87}\,\}mathrm{Calculated}$ by us from λ_0 and λ_+ given below.

$\xi_C = f_-/f_+$ (determined from μ polarization in $K^\pm_{\mu 2}$) The μ polarization is a measure of $\xi(t)$. No assumptions on λ_{+-} necessary, t (weighted

by sensitivity to $\xi(t)$) should be specified. In λ_+ , $\xi(0)$ parametrization this is $\xi(0)$ for λ_+ =0. $d\xi/d\lambda=\xi t$. For radiative correction to muon polarization in $K^\pm_{\mu3}$, see GINSBERG 71. The parameter ξ is redundant with λ_0 below and is not put into the Meson Summary Table.

Meson Summa	ry Table.					
VALUE	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
-0.35±0.15 OUR E	VALUATION	From a fit discu	ssed	in note	on $K_{\ell 3}$	form factors in
		1982 edition, P	L 11	1B (Ap	ril 1982	.).
-0.25 ± 1.20	1585	⁹⁰ BRAUN	75	HLBC	+	POL, t=4.2
-0.95 ± 0.3	3133		69	OSPK	+	Total pol. $t=4.0$
-1.0 ± 0.3	6000	⁹² BETTELS	68	HLBC	+	Total pol. $t=4.9$
• • • We do not use	the followin	g data for averages	s, fits	, limits,	etc. •	• •
-0.64 ± 0.27	40k	⁹³ MERLAN	74	ASPK	+	POL, $d\xi(0)/d\lambda_+$ = +1.7
-1.4 ± 1.8	397	⁹⁴ CALLAHAN	66B	FBC	+	Total pol.
$-0.7 \begin{array}{c} +0.9 \\ -3.3 \end{array}$	2950	⁹⁴ CALLAHAN	66B	FBC	+	Long. pol.
$+1.2 \begin{array}{c} +2.4 \\ -1.8 \end{array}$	2100	⁹⁴ BORREANI	65	HLBC	+	Polarization
-4.0 to $+1.7$	500	⁹⁴ CUTTS	65	OSPK	+	Long. pol.

⁹⁰ BRAUN 75 $d\xi(0)/d\lambda_{+} = \xi t = -0.25 \times 4.2 = -1.0$.

$Im(\xi)$ in $K_{\mu 3}^{\pm}$ DECAY (from transverse μ pol.)

	ersal invariance.					
VALUE	EVTS	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
-0.017±0.025 OU	IR AVERAGE					
-0.016 ± 0.025	20M	CAMPBELL	81	CNTR	+	Pol.
$-0.3 \begin{array}{c} +0.3 \\ -0.4 \end{array}$	3133	CUTTS	69	OSPK	+	Total pol. fig.7
-0.1 ± 0.3	6000	BETTELS	68	HLBC	+	Total pol.
0.0 ± 1.0	2648	CALLAHAN	66B	FBC	+	MU
$+1.6 \pm 1.3$	397	CALLAHAN	66B	FBC	+	Total pol.
$0.5 \begin{array}{c} +1.4 \\ -0.5 \end{array}$	2950	CALLAHAN	66B	FBC	+	Long. pol.
• • • We do not u	ise the following	data for average	es, fits	, limits,	etc. •	• •
0.010 0.010	2214 95	DIATT	02	CNITE		Polarization

 $^{^{95}}$ Combined result of MORSE 80 $(\kappa^0_{\mu3})$ and CAMPBELL 81 $(\kappa^+_{\mu3})$.

λ_+ (LINEAR ENERGY DEPENDENCE OF f_+ IN $K_{\mu3}^{\pm}$ DECAY)

See also the corresponding entries and footnotes in sections ξ_A , ξ_C , and λ_0 . For radiative correction of $K_{\mu3}^{\pm}$ Dalitz plot, see GINSBERG 70 and BECHERRAWY 70.

VALUE	EVTS	DOCUMENT ID	<u>TE</u>	CN CHG	COMMENT
0.033±0.008 OUF	R EVALUATIO	N From a fit disc	cussed i	n note on <i>F</i>	$\zeta_{\ell 3}$ form factors in
		1982 edition, P	L 111B	(April 1982	2).
$+0.050\pm0.013$	3973	WHITMAN	80 SP	EC +	DP
0.025 ± 0.030	490	ARNOLD	74 HL	.BC +	DP
0.027 ± 0.019	6527	MERLAN	74 AS	PK +	DP
0.025 ± 0.017	1897	BRAUN	73C HL		DP
0.024 ± 0.019	4025	⁹⁶ ANKENBRA	72 AS	PK +	PI
-0.006 ± 0.015	3480	CHIANG	72 09	SPK +	DP
0.050 ± 0.018	3240	HAIDT	71 HL	.BC +	DP
0.009 ± 0.026	2041	KIJEWSKI	69 OS	SPK +	PI
0.0 ± 0.05	444	CALLAHAN	66B FE	BC +	PI

 $^{^{96}}$ ANKENBRANDT 72 λ_{+} from figure 3 to match $d\xi(0)/d\lambda_{+}$. Text gives 0.024 \pm 0.022.

λ_0 (LINEAR ENERGY DEPENDENCE OF f_0 IN $K_{\mu3}^\pm$ DECAY)

Wherever possible, we have converted the above values of $\xi(0)$ into values of λ_0 using the associated λ^{μ} and $dE/d\lambda$

the associa	ed X ₊ and	αξ/αλ.				
VALUE	$d\lambda_0/d\lambda_+$	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
0.004±0.007 O	UR EVALU	ATION	From a fit discussed 1982 edition, Pl			
$+0.029\pm0.011$	-0.37	3973		80 SPEC	+	DP
$+0.019\pm0.010$	+0.03	55k		77 SPEC	+	BR
$+0.008\pm0.097$	+0.92	1585	⁹⁸ BRAUN	75 HLBC	+	POL
-0.040 ± 0.040	-0.62	490		74 HLBC	+	DP
-0.019 ± 0.015	+0.27	6527	⁹⁹ MERLAN	74 ASPK	+	DP
-0.008 ± 0.020	0.53	1897		73C HLBC	+	DP
-0.026 ± 0.013	+0.03	4025		72 ASPK	+	PI
$+0.030\pm0.014$	-0.21	3480	¹⁰¹ CHIANG	72 OSPK	+	DP
-0.039 ± 0.029	-1.34	3240	¹⁰¹ HAIDT	71 HLBC	+	DP
-0.056 ± 0.024	+0.69	3133		69 OSPK	+	POL
-0.031 ± 0.045	-1.10	2041		69 OSPK	+	PI
-0.063 ± 0.024	+0.60	6000		68 HLBC	+	POL
$+0.058\pm0.036$	-0.37	444	¹⁰¹ CALLAHAN	66B FBC	+	PI
• • • We do not	use the follo	owing da	ata for averages, fits, I	imits, etc.	• • •	
-0.017 ± 0.011			¹⁰² BRAUN	74 HLBC	+	$K_{\mu 3}/K_{e3}$ vs. t

 $^{^{97}\, {\}sf HEINTZE}$ 77 uses $\lambda_+ = 0.029 \pm 0.003.~d\lambda_0/d\lambda_+$ estimated by us.

 $\begin{array}{c|c} |f_5/f_+| & \text{FOR } \mathcal{K}_{e3}^{\pm} & \text{DECAY} \\ \text{Ratio of scalar to } f_+ & \text{couplings.} \\ \hline \textit{VALUE} & \textit{CL\%} & \textit{EVTS} \\ \end{array}$ DOCUMENT ID TECN CHG COMMENT 0.084±0.023 OUR AVERAGE Error includes scale factor of 1.2. AKIMENKO 32k 91 SPEC $0.070 \pm 0.016 \pm 0.016$ 0.00 ± 0.10 $0.14 \ \, ^{+\, 0.03}_{-\, 0.04}$ 2707 STEINER 71 HLBC + • • We do not use the following data for averages, fits, limits, etc. • • •

				,	
< 0.13	90	4017	CHIANG	72 OSPK	+
< 0.23	90		BOTTERILL	68c ASPK	
< 0.18	90		BELLOTTI	67B HLBC	
< 0.30	95		KALMUS	67 HLBC	+

 $^{^{79}\,\}mathrm{MERLAN}$ 74 figure 5 was used to obtain $d\xi(0)/d\lambda_{+}$.

⁸⁰ BRAUN 73c gives $\xi(t)=-0.34\pm0.20$, $d\xi(t)/d\lambda_{+}=-14$ for $\lambda_{+}=0.027$, t=6.6. We calculate above $\xi(0)$ and $d\xi(0)/d\lambda_{+}$ for their $\lambda_{+}=0.025\pm0.017$.

⁸¹ ANKENBRANDT 72 figure 3 was used to obtain $d\xi(0)/d\lambda_{+}$.

⁸² CHIANG 72 figure 10 was used to obtain $d\xi(0)/d\lambda_+$. Fit had $\lambda_-=\lambda_+$ but would not change for $\lambda_-=0$. L.Pondrom, (private communication 74).

⁸³ HAIDT 71 table 8 (Dalitz plot analysis) gives $d\xi(0)/d\lambda_{+} = (-1.1 + 0.5)/(0.050 - 0.029)$ = -29, error raised from 0.50 to agree with $d\xi(0) = 0.20$ for fixed λ_+ .

 $^{^{84}\,\}mathrm{KIJEWSKI}$ 69 figure 17 was used to obtain $d\xi(0)/d\lambda_{+}$ and errors.

⁸⁵ CALLAHAN 66 table 1 (π analysis) gives $d\xi(0)/d\lambda_+=(0.72-0.05)/(0-0.04)=-17$, error raised from 0.80 to agree with $d\xi(0)=0.37$ for fixed λ_+ . t unknown.

⁸⁶ JENSEN 64 gives $\lambda_+^\mu=\lambda_+^e=-$ 0.020 \pm 0.027. $d\xi$ (0)/ $d\lambda_+$ unknown. Includes SHAK-LEE 64 $\xi_B(K_{\mu 3}/K_{e3}^{\top})$.

⁸⁸ EICHTEN 68 has $\lambda_+=0.023\pm0.008$, t=4, independent of λ_- . Replaced by

 $^{^{89}}$ BOTTERILL 70 is re-evaluation of BOTTERILL 68B with different λ_+ .

 $^{^{91}}$ CUTTS 69 t=4.0 was calculated from figure 8. $d\xi(0)/d\lambda_{+}=\xi t=-0.95\times 4=-3.8.$

 $^{^{92}}$ BETTELS 68 $d\xi(0)/d\lambda_{+}=\xi t=-1.0 \times 4.9=-4.9.$

⁹³ MERLAN 74 polarization result (figure 5) not possible. See discussion of polarization experiments in note on " $K_{\ell 3}$ Form Factors" in the 1982 edition of this Review [Physics Letters **111B** (1982)].

 $^{^{94}\,}t$ value not given.

 $^{^{98}\}lambda_0$ value is for $\lambda_+=0.03$ calculated by us from $\xi(0)$ and $d\xi(0)/d\lambda_+$.

 $^{^{99}}$ MERLAN 74 λ_0 and $d\lambda_0/d\lambda_+$ were calculated by us from ξ_A , λ_+^μ , and $d\xi(0)/d\lambda_+$. Their figure 6 gives $\lambda_0 = -$ 0.025 \pm 0.012 and no $d\lambda_0/d\lambda_+.$

 $^{^{100}}$ This value and error are taken from BRAUN 75 but correspond to the BRAUN 73c λ_+^μ result. $d\lambda_0/d\lambda_+$ is from BRAUN 73C $d\xi(0)/d\lambda_+$ in ξ_A above.

 $^{^{101}\,\}lambda_0$ calculated by us from $\xi(0),\,\lambda_+^\mu,$ and $d\xi(0)/d\lambda_+.$

 $^{^{102}}$ BRAUN 74 is a combined $K_{\mu3}$, K_{e3} result. It is not independent of BRAUN 73C ($K_{\mu3}$) and BRAUN 73B (K_{e3}) form factor results.

	f tensor to	f_+ couplir	ngs.	DOCUMENTS.	· D	TECH	C110	COMMENT
0.38±0.11		<u>CL% EVT</u> RAGE Er		DOCUMENT I des scale fa			CHG	COMMENT
$0.53^{+0.09}_{-0.10}$	±0.10	32	k	AKIMENKO	91	SPEC		λ_+ , f_S , f_T ,
0.07±0.37		282	7	BRAUN	75	HLBC	+	ϕ fit
$0.24 {}^{+ 0.16}_{- 0.14}$		270	7	STEINER	71	HLBC	+	λ_+ , f_S , f_T ,
	not use the	e following	data fo	r averages,	fits, limi	its, etc.		ϕ fit
0.75		90 401	7	CHIANG	72	OSPK	+	
0.58		90 90		BOTTERIL BELLOTTI		ASPK HLBC		
1.1		95		KALMUS		HLBC	+	
r/f ₊ FOR	K± DEC	CAY						
Ratio o	f tensor to	f_+ couplir		MENT ID	TECH	u		
02±0.12		<i>EVTS</i> 1585	BRAL					
ECAY FO Given in				$ ightarrow \pi^+\pi^-$ and BASILE				
ECAY FO	RM FACT				±ν			
		K [±] →	ℓ±νγ	FORM F	ACTO	RS		
For o	lefinitions o		•	F_A and vec			tor, se	e the
"Not section	e on π^\pm –	$ ightarrow$ $\ell^{\pm} u\gamma$ kaon litera	and K^\pm ature, of	$\stackrel{A}{\rightarrow} \ell^{\pm} \nu \gamma$ ten different	Form	Factors"	in the	π^{\pm}
				R AND VE	СТОР	RFORM	/ FAC	TOR FOR
$\rightarrow e \nu_e \gamma$,							
148±0.010		EVTS RAGE	DOCU	MENT ID	TECN	<u>COM</u>	MENT	••
	OOK AVE	51 ¹⁰	03 HEIN		9 SPE	с <i>к</i> –	$e\nu\gamma$	
$150 + 0.018 \\ -0.023$		51 ¹⁰	⁰⁴ HEAF	RD 7	5 SPE	с к –	ενγ	
150 ^{+ 0.018} - 0.023 ⁰³ HEINTZE	79 quotes a	51 ¹⁰ 56 ¹⁰ absolute v	⁰⁴ HEAF alue of	$F_A + F_V s$	5 SPE $\ln heta_c$. W	C K — /e use sir	$\theta_{c} = 0$	$V_{us} = 0.2205$
150 + 0.018 - 0.023 ³ HEINTZE ⁴ HEARD 7	79 quotes a 5 quotes ab	51 10 56 10 absolute v osolute val	⁰⁴ HEAF alue of <i>i</i> lue of <i>F</i>	$F_A + F_V s$ $F_A + F_V sin State $	5 SPE $\ln heta_{\mathcal{C}}$. W $\ln heta_{\mathcal{C}}$. W	C K — /e use sir e use sin	$e \nu \gamma$ $\theta_C = 0$ $\theta_C = 0$	$V_{us} = 0.2205$
150 + 0.018 - 0.023 13 HEINTZE 14 HEARD 7 4 + F _V , S	79 quotes a 5 quotes ab	51 10 56 10 absolute v osolute val	⁰⁴ HEAF alue of <i>i</i> lue of <i>F</i>	$F_A + F_V s$ $F_A + F_V sin State $	5 SPE $\ln heta_{\mathcal{C}}$. W $\ln heta_{\mathcal{C}}$. W	C K — /e use sir e use sin	$e \nu \gamma$ $\theta_C = 0$ $\theta_C = 0$	$V_{us} = 0.2205$ $V_{us} = 0.2205$ TOR FOR
$^{150}_{-0.023}^{+0.018}$ $^{13}_{-0.023}^{+0.023}$ $^{13}_{-0.023}^{+0.022}$ $^{14}_{-0.023}^{+0.022}$ $^{14}_{-0.023}^{+0.022}$ $^{14}_{-0.023}^{+0.022}$	79 quotes a 5 quotes ab	51 10 56 10 absolute v osolute val	⁰⁴ HEAF alue of <i>I</i> lue of <i>F</i>	$F_A + F_V s$ $F_A + F_V s$ $F_A + F_V s$	5 SPE $\ln heta_c$. W $\ln heta_c$.	C K — /e use sir e use sin	$egin{array}{l} e u \gamma \ & heta_{c} = 0 \ & heta_{c} = 0 \end{array}$ If FAC	$V_{us} = 0.2205$
$^{150}_{-0.023}^{+0.018}$ $^{13}_{-0.023}^{+0.023}$ $^{13}_{-0.023}^{+0.022}$ $^{14}_{-0.023}^{+0.022}$ $^{14}_{-0.023}^{+0.022}$ $^{150}_{-0.023}^{+0.018}$ $^{150}_{-0.023}^{+0.018}$	79 quotes a 5 quotes ab	51 10 56 10 absolute v v v v v v v v v v v v v v v v v v v	⁰⁴ HEAF alue of <i>I</i> lue of <i>F</i>	$F_A + F_V s$ $F_A + F_V si$ $F_A + F_V si$ $F_A + F_V si$	5 SPE $\ln heta_{\mathcal{C}}$. W $\ln heta_{\mathcal{C}}$. W	C K— /e use sin e use sin R FORM	$e \nu \gamma$ $\theta_C = 0$ $\theta_C = 0$	$V_{us} = 0.2205$
$^{150}_{-0.023}^{+0.018}$ $^{13}_{-0.023}^{+0.023}$ $^{13}_{+0.023}^{+0.012}$ $^{14}_{+0.012}^{+0.012}$ $^{150}_{-0.023}^{+0.018}$	79 quotes a 5 quotes ab SUM OF A	51 10 56 10 absolute v posolute val AXIAL-V CL% 90 10 e following	D4 HEAF alue of F lue of F lu	$F_A + F_V s$ $F_A + F_V $	$\sin \theta_{C}$. When $\sin \theta_{C}$ is $\sin \theta_{C}$. When $\cos \theta_{C}$ is $\cos \theta_{C}$ is $\cos \theta_{C}$. The $\cos \theta_{C}$ is $\cos \theta_{C}$.	Ve use sire use single use single use single use single use single use use use use use use use use use us	$\theta_{c} = 0$	$V_{us} = 0.2205$
150 $^{+0.018}_{-0.023}$ 13 HEINTZE 14 HEARD 7 14 + FV, S 15 $^{+0.018}_{-0.023}$ 16 UE 17 0.23 18 We do 1.2 to 1.	79 quotes at 5 quotes ab 5 quotes ab 5 quotes ab 7 quotes ar 7 quo	51 16 56 10 absolute v osolute val AXIAL-V CL% 90 10 e following	DA HEAR alue of F lue of F CECTOR DOCUL D5 AKIB data for DEMI	$F_A + F_V s$ $F_A + F_V $	$\sin \theta_{C}$. When $\sin \theta_{C}$ is $\sin \theta_{C}$. When $\cos \theta_{C}$ is $\cos \theta_{C}$ is $\cos \theta_{C}$. The $\cos \theta_{C}$ is $\cos \theta_{C}$.	C K— /e use sin e use sin R FORM // COM.	$\theta_{c} = 0$	$V_{us} = 0.2205$
$^{150}_{-0.023}^{+0.018}_{-0.023}^{3}$ HEINTZE $^{14}_{-0.023}^{4}$ HEARD 7 $^{14}_{-0.023}^{4}$ $^{15}_{-0.023}^{4}$ $^{15}_{-0.023}^{4}$ We do $^{-1.2}_{-0.023}$ to 1. $^{15}_{-0.023}^{5}$ AKIBA 85	79 quotes a 5 quotes abs	51 10 56 10 absolute v value v	DEMI	RD = 7. $F_A + F_V s$ $F_A + F_V $	5 SPE $\sin \theta_C$. When $\cos \theta_C$ SPE $\cos \theta_C$	Ve use sine use sine use sine C K — COM. C K — COM. C K — CC K —	$\theta_{C} = 0$ θ_{C	V _{us} = 0.2205
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150 + 0.018 13 + 0.018 13 + 0.023 14 + FV, S 14 + EARD 7 15 - 1.2 to 1. 15 5 AKIBA 85 16 OR FOR I 16 HEINTZE 17 0.49 18 19 19 19 19 19 19 19 19 19 19 19 19 19	79 quotes ab SUM OF A Y not use the 1 quotes abs DIFFEREN Λ → eν _e 79 quotes DIFFEREN Λ → μν _μ UR EVALU 66 PRL 76 6 PRL 76 7 PRL 71 3 PRL 70 3 PRL 71 3 PRL 70 3 PRL 71 3 PRL 71 3 PRL 70 5 JETPL 60 5 PRL 69 5 P	51 10 56 10 56 10 56 10 56 10 absolute valuable 90 10 following 90 solute valuable ICE OF 90 10 IFA - FV ICE OF 11 11 677 40 11 677 443 3961 1 225 6066	04 HEAF alue of - lue of F lu	RD 7. $F_A + F_V \text{ sin}$ $F_A + F_V \text$	5 SPE TECA TECA S SPE TECA TECA S SPE TECA TECA S SPE TECA S SPE TECA AND TECA AND TECA AND TECA Kawashis Kawashis Kawashis Kawashis Kawashis Lawashis	C K — (e use sir e use sin	$\begin{array}{c} \bullet e\nu\gamma \\	V _{US} = 0.2205 CTOR FOR DRM FAC- DRM FAC- DRM FAC- (PNPI) K, TOKMS) (PNPI) K, TOKMS) (PNPI) Y, TOKMS) (PNPI) INL, STON)
150 + 0.018 150 + 0.018 13 HEINTZE 14 HEARD 7 14 + FV, S 15 + μνμ 15 LUE 16 - 0.023 16 HERTER 16 - 0.023 17 HERTER 17 HERTER 18 HERTER 18 HERTER 18 HERTER 19 HERTER	79 quotes ab 5 quotes ab 5 quotes ab 7 quotes ab 8 pl 7 quotes ab 9 qu	51 10 56 10 56 10 56 10 56 10 56 10 56 10 56 10 56 10 56 10 57 20 50 10 57 20 50 10	04 HEAF alue of - lue of - l	RD 7. $F_A + F_V s$ $A + F$	5 SPE TECA	C K — (e use sire use use sire use use use use use use use use use us	$\begin{array}{l} e \nu \gamma \\	V _{uS} = 0.2205 CTOR FOR DRM FAC- DRM FAC- 787 Collab.) (PNPI) K. TOKMS) 787 Collab.) 788 Collab.) 788 Collab.) 788 Collab.) 788 Collab.) 789 Collab.) 780 Collab.) 789 Colla
A + F _V , S A + F _V , S A + F _V , S • • We do -1.2 to 1. 15 AKIBA 85 A - F _V , E OR FOR F ALUE 10.49 16 HEINTZE A - F _V , E OR FOR F ALUE 2.2 to 0.3 O 2.2 to 0.3 C2.5 to 0.3 C3.5 to 0.3 C4.6 S C5.6 S C6.7 S C6.7 S C7.7 S C	79 quotes ab 5 quotes ab 6 quotes ab 7 qu	51 10 56 10	04 HEAF alue of - ulue of - ulue of - ulue of - ECTOI DECUM 05 AKIB. data for DEMI le. AXIAL- DEMI AKIB. ETP 61 86 +Yam 1 Atiya +Chian +Chian +Chian 1 S 991. FFP 54 55 1 S 91. FFP 54 55 FFP 54 55 Vanc +Chian +C	RD 7. $F_A + F_V s$ $A + F$	5 SPE TECh	C K — '/e use sire e use sine e use sine e use sine R FORM R FORM C K — ' St, etc	$\begin{array}{c} e\nu\gamma\\ \theta_C = 1 \\ \theta_C = 1 \\ \end{array}$ $\begin{array}{c} \mu\nu\gamma\\ \theta_C = 1 \\ \end{array}$ $\begin{array}{c} \mu\nu\gamma\\ \mu\nu\gamma\\ \end{array}$ $\begin{array}{c} \mu\nu\rangle$ $\begin{array}{c$	V _{US} = 0.2205 CTOR FOR DRM FAC- DRM FAC- DRM FAC- (PNPI) K, TOKMS) R87 Collab., R

			the state of the s
LEE	90 89	PRL 64 165 PRL 63 2177	+Alliegro, Campagnari+ (BNL, FNAL, VILL, WASH, YALE) +Chiang, Frank, Haggerty, Ito, Kycia+ (BNL 787 Collab.)
ATIYA BARMIN	89	SJNP 50 421	+Barylov, Davidenko, Demidov, Dolgolenko+ (ITEP)
		Translated from	YAF 50 679.
BARMIN	88	SJNP 47 643	+Barylov, Davidenko, Demidov, Dolgolenko+ (ITEP) YAF 47 1011.
BARMIN	88B	SJNP 48 1032	+Barylov, Davidenko, Demidov, Dolgolenko+ (TEP) YAF 47 1011. +Barylov, Davidenko, Demidov, Dolgolenko+ (TEP) YAF 48 1719. +Gninenko, Dzhilkibaev, Isakov, Klubakov+ (ASCI)
		Translated from	YAF 48 1719.
BOLOTOV	88	Translated from	+Gninenko, Dzhilkibaev, Isakov, Klubakov+ (ASCI)
CAMPAGNARI	88	PRL 61 2062	+Alliegro, Chaloupka+ (BNL, FNAL, PSI, WASH, YALE) +Austin+ (BOST, MIT, WILL, CIT, CMU, WYOM)
GALL	88	PRL 60 186	+Austin+ (BOST, MIT, WILL, CIT, CMU, WYOM)
BARMIN	87	SJNP 45 62	+Barylov, Davidenko, Demidov+ (ITEP)
BOLOTOV	87	SJNP 45 1023	+Gninenko, Dzhilkibaev, Isakov, Klubakov+ (INRM)
		Translated from	YAF 45 1652.
BOLOTOV	86	SJNP 44 73 Translated from	
BOLOTOV	86B	5JNP 44 68	+Gninenko, Dzhilkibaev, Isakov+ (INRM)
YAMANAKA	86	Translated from 'PR D34 85	YAF 44 108.
Also	84	PRL 52 329	+Hayano, Taniguchi, Ishikawa+ (KEK, TOKY) Hayano, Yamanaka, Taniguchi+ (TOKY, KEK) +Ishikawa, Iwasaki+ (TOKY, TINT, TSUK, KEK)
AKIBA	85	PR D32 2911	+Ishikawa, Iwasaki+ (TOKY, TINT, TSUK, KEK)
BOLOTOV	85	JETPL 42 481 Translated from 2	+Gninenko, Dzhilkibaev, Isakov+ (INRM)
BLATT	83	PR D27 1056	+Adair, Black, Campbell+ (YALE, BNI)
ASANO	82	PL 113B 195 PL 112B 97	+Kikutani, Kurokawa, Miyachi+(KEK, TOKY, INUS, OSAK) +Guy, Michette, Tyndel, Venus (RL)
COOPER	82	PL 112B 97	+Guy, Michette, Tyndel, Venus (RL)
PDG PDG	82 82B	PL 111B	Roos, Porter, Aguilar-Benitez+ (HELS, CIT, CERN) Roos, Porter, Aguilar-Benitez+ (HELS, CIT, CERN)
ASANO	81B	PL 111B 70 PL 107B 159	Roos, Porter, Aguilar-Benitez+ (HELS, CIT, CERN) +Kikutani, Kurokawa, Miyachi+(KEK, TOKY, INUS, OSAK)
CAMPBELL	81	PRL 47 1032	+Kikutani, Kurokawa, Miyachi+(KEK, TOKY, INUS, OSAK) +Black, Blatt, Kasha, Schmidt+ (YALE, BNL)
Also	83	PR D27 1056	Blatt, Adair, Black, Campbell+ (YALE, BNL)
LUM LYONS	81 81	PR D23 2522 ZPHY C10 215	+Wiegand, Kessler, Deslattes, Seki+ (LBL, NBS+)
MORSE	80	PR D21 1750	+Albajar, Myatt (OXF) +Leipuner, Larsen, Schmidt, Blatt+ (BNL, YALE)
WHITMAN	80	PR D21 652	+Abrams, Carroll, Kycia, Li+ (ILLC, BNL, 1LL)
BARKOV	79	NP B148 53	+Vasserman, Zolotorev, Krupin+ (NOVO, KIAE)
HEINTZE	79	NP B149 365	+Heinzelmann, Igo-Kemenes+ (HEIDP, CERN)
ABRAMS DEVAUX	77 77	PR D15 22 NP B126 11	+Carroll, Kycia, Li, Michael, Mockett+ (BNL) +Bloch, Diamant-Berger, Maillard+ (SACL, GEVA)
HEINTZE	77	NP B126 11 PL 70B 482	+Heinzelmann, Igo-Kemenes+ (HEIDP CERN)
ROSSELET	77	PR D15 574	+Extermann, Fischer, Guisan+ (GEVA, SACL)
BERTRAND	76 76	NP B114 387 PL 60B 393	+Sacton+ (BRUX, KIDR, DUUC, LOUC, WARS)
BLOCH BRAUN	76B	LNC 17 521	+Bunce, Devaux, Diamant-Berger+ (GEVA, SACL) +Martyn, Erriquez+ (AACH3, BARI, BELG, CERN)
DIAMANT	76	PL 62B 485	Diamant-Berger, Bloch, Devaux+ (SACL, GEVA)
HEINTZE	76	PL 60B 302	+Heinzelmann, Igo-Kemenes, Mundhenke+ (HEIDP)
SMITH	76 76	NP B109 173 NP B115 55	+Heinzelmann, Igo-Kemenes, Mundhenke+ (HEIDP) +Booth, Renshall, Jones+ (GLAS, LIVP, OXF, RHEL) Weissenberg, Egorov, Minervina+ (ITEP, LEBD)
WEISSENBE BLOCH	75	PL 56B 201	Weissenberg, Egorov, Minervina+ (ITEP, LEBD) +Brehin, Bunce, Devaux+ (SACL, GEVA)
BRAUN	75	NP B89 210	+Cornelssen+ (AACH3 BARI BRUX CERN)
CHENG	75	NP A254 381	+Asano, Chen, Dugan, Hu, Wu+ (COLU, YALE)
HEARD HEARD	75 75B	PL 55B 324 PL 55B 327	+Heintze, Heinzelmann+ (CERN, HEIDH) +Heintze, Heinzelmann+ (CERN, HEIDH)
SHEAFF	75	PR D12 2570	+Heintze, Heinzeimaini+ (CERN, HEIDH)
SMITH	75	NP B91 45	+Booth, Renshall, Jones+ (GLAS, LIVP, OXF, RHEL)
ARNOLD	74	PR D9 1221	+ Noe, Sinciali (WICH)
BRAUN CENCE	74 74	PL 51B 393 PR D10 776	+Cornelssen, Martyn+ (AACH3, BARI, BRUX, CERN) +Harris, Jones, Morgado+ (HAWA, LBL, WISC)
Also	73	Thesis unpub.	+Harris, Jones, Morgado+ (HAWA, LBL, WISC) Clarke (WISC)
KUNSELMAN	74	PR C9 2469	Claric
		FR C9 2409	(WYOM)
MERLAN	74	PR D9 107	(ŴYOM) +Kasha, Wanderer, Adair+ (YALE, BNL, LASL)
MERLAN WEISSENBE	74 74	PR D9 107 PL 48B 474	+Kasha, Wanderer, Adair+ (YALE, BNL, LASL) Weissenberg, Egorov, Minervina+ (ITEP, LEBD)
MERLAN WEISSENBE ABRAMS	74 74 73B	PR D9 107 PL 48B 474 PRL 30 500	+Kasha, Wanderer, Adair+ (YALE, BNL, LASL) Weissenberg, Egorov, Minervina+ +Carroll Kycia, Li, Menes, Michael+ (ITEP, LEBD)
MERLAN WEISSENBE ABRAMS BACKENSTO	74 74 73B 73	PR D9 107 PL 48B 474 PRL 30 500 PL 43B 431 PRL 30 399	+Kasha, Wanderer, Adair+ (YALE, BNL, LASL) Weissenberg, Egorov, Minervina+ +Carroll Kycia, Li, Menes, Michael+ (ITEP, LEBD)
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN	74 74 73B 73 73 73B	PR D9 107 PL 48B 474 PRL 30 500 PL 43B 431 PRL 30 399 PL 47B 185	+Kasha, Wanderer, Adair+ (YALE, BNL, LASL). Weissenberg, Egorov, Minervina+ (LITEP, LEBD) +Carroll, Kycia, Li, Menes, Michael+ (BNL) Backenstoss+ (CERN, KARLK, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen (AACH3, BARI, BRUX, EERN)
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN Also	74 74 73B 73 73 73B 75	PR D9 107 PL 48B 474 PRL 30 500 PL 43B 431 PRL 30 399 PL 47B 185 NP B89 210	+Kasha, Wanderer, Adair+ (YALE, BNL, LASL). Weissenberg, Egorov, Minervina+ (TEP, LEBD) +Carroll, Kycia, Li, Menes, Michael+ (BNL) Backenstoss+ (CERN, KARLK, KARLE, HEID. STOH) +Buchholz, Mann, Parker, Roberts (PENN) +Cornelssen Braun, Cornelssen+ (AACH3, BARI, BRUX, CERN)
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN Also BRAUN	74 74 73B 73 73 73 73B 75 73C	PR D9 107 PL 48B 474 PRL 30 500 PL 43B 431 PRL 30 399 PL 47B 185 NP B89 210	+Kasha, Wanderer, Adair+ (YALE, BNL, LASL). Weissenberg, Egorov, Minervina+ (TEP, LEBD) +Carroll, Kycia, Li, Menes, Michael+ (BNL) Backenstoss+ (CERN, KARLK, KARLE, HEID. STOH) +Buchholz, Mann, Parker, Roberts (PENN) +Cornelssen Braun, Cornelssen+ (AACH3, BARI, BRUX, CERN)
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO BRAUN AISO CABLE	74 74 73B 73 73 73B 75 73C 75 73	PR D9 107 PL 48B 474 PRL 30 500 PL 43B 431 PRL 30 399 PL 47B 185 NP B89 210 PL 47B 182 NP B89 210 PR D8 3807	+Kasha, Wanderer, Adair+ (YALE, BNL, LASL). Weissenberg, Egorov, Minervina+ (TEP, LEBD) +Carroll, Kycia, Li, Menes, Michael+ Backenstoss+ (CERN, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen +Cancelssen+ +Cornelssen+ +Cornelssen+ +Cornelssen+ +Cornelssen+ +Cornelssen+ +Hilderband, Pang, Stiening +CERN, BARI, BRUX, CERN) Braun, Cornelssen+ +Hilderband, Pang, Stiening +CERN, BARI, BRUX, CERN)
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN Also BRAUN Also CABLE LJUNG	74 74 73B 73 73 73B 75 73C 75 73 73	PR D9 107 PL 48B 474 PRL 30 500 PL 43B 431 PRL 30 399 PL 47B 185 NP 889 210 PL 47B 182 NP 889 210 PR D8 3807 PR D8 1307	+Kasha, Wanderer, Adair+ (YALE, BNL, LASL). Weissenberg, Egorov, Minervina+ (TEP, LEBD) +Carroll, Kycia, Li, Menes, Michael+ Backenstoss+ (CERN, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen +Cancelssen+ +Cornelssen+ +Cornelssen+ +Cornelssen+ +Cornelssen+ +Cornelssen+ +Hilderband, Pang, Stiening +CERN, BARI, BRUX, CERN) Braun, Cornelssen+ +Hilderband, Pang, Stiening +CERN, BARI, BRUX, CERN)
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN Also BRAUN Also CABLE LJUNG Also	74 74 73B 73 73 73B 75 73C 75 73 73 73	PR D9 107 PL 48B 474 PRL 30 500 PL 43B 431 PRL 30 399 PL 47B 185 NP B89 210 PL 47B 182 NP B89 210 PR D8 3807 PR D8 1307 PRL 28 523	+Kasha, Wanderer, Adair+ (YALE, BNL, LASL) Weissenberg, Egorov, Minervina+ (UTEF, LEBD) +Carroll, Kycia, Li, Menes, Michael+ (BNL) Backenstoss+ (CERN, KARLK, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen (AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ (AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ (AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ (AACH3, BARI, BRUX, CERN) Hildebrand, Pang, Stiening +Cline Ljung (WISC)
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO BRAUN AISO CABLE LJUNG AISO AISO	74 74 73B 73 73 73B 75 73C 75 73 73	PR D9 107 PL 48B 474 PRL 30 500 PL 43B 431 PRL 30 399 PL 47B 185 NP B89 210 PR D8 3907 PR D8 1307 PR D8 1307 PR D8 1307 PRL 28 523 PRL 28 1287	+Kasha, Wanderer, Adair+ (YALE, BNL, LASL) Weissenberg, Egorov, Minervina+ (ITEF, LEBD) +Carroll, Kycia, Li, Menes, Michael+ (BNL) Backenstoss+ (CERN, KARLK, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen +Cornelssen (AACH3, BARI, BRUX, CERN) +Cornelssen (AACH3, BARI, BRUX, CERN) +Cornelssen (AACH3, BARI, BRUX, CERN) +Hildebrand, Pang, Stiening +Cline (WISC) Ljung Cline, Ljung (WISC)
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO BRAUN AISO CABLE LJUNG AISO AISO AISO AISO LUCAS	74 74 73B 73 73 73B 75 73C 75 73 73 72 72 69 73	PR D9 107 PL 48B 474 PRL 30 500 PL 43B 431 PRL 30 399 PL 47B 185 NP 889 210 PR 08 3907 PR D8 3907 PR D8 1307 PRL 28 523 PRL 28 1287 PRL 23 326 PR D8 719	+Kasha, Wanderer, Adair+ (YALE, BNL, LASL) Weissenberg, Egorov, Minervina+ (ITEF, LEBD) +Carroll, Kycia, Li, Menes, Michael+ (BNL) Backenstoss+ (CERN, KARLK, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen (AACH3, BARI, BRUX, CERN) Harun, Cornelssen+ (AACH3, BARI, BRUX, CERN) +Cornelssen (AACH3, BARI, BRUX, CERN) +Hildebrand, Pang, Stiening (EFI, LBL) +Cline (WISC) Ljung (WISC) Camerini, Ljung, Sheaff, Cline (WISC) -Taft, Willis (YALE)
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO BRAUN AISO CABLE LJUNG AISO AISO AISO LUCAS LUCAS LUCAS	74 74 73B 73 73 73B 75 73C 75 73 73 72 72 69 73 73B	PR D9 107 PL 48B 474 PRL 30 500 PL 43B 431 PRL 30 399 PL 47B 185 NP 589 210 PL 47B 185 NP 589 210 PR D8 3807 PR D8 1307 PRL 28 523 PRL 28 1287 PRL 23 326 PR D8 719 PR D8 727	+Kasha, Wanderer, Adair+ (YALE, BNL, LASL) Weissenberg, Egorov, Minervina+ (LTEP, LEBD) +Carroll, Kycia, Li, Menes, Michael+ Backenstoss+ (CERN, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen (AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ (AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ (AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ (AACH3, BARI, BRUX, CERN) Hilderbrand, Pang, Stiening +Cline Ljung Cline, Ljung Cline, Ljung Camerini, Ljung, Sheaff, Cline +Taft, Willis (YALE)
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO CABLE LJUNG AISO AISO LUCAS LUCAS LUCAS LUCAS PANG	74 74 73B 73 73 73B 75 73C 75 73 73 72 72 69 73 73B 73	PR D9 107 PL 48B 474 PRL 30 500 PL 43B 431 PRL 30 399 PL 47B 185 NP B89 210 PL 47B 182 NP B89 210 PR D8 3807 PR D8 3807 PRL 28 1287 PRL 28 523 PRL 28 1287 PRL 28 727 PR D8 719 PR D8 719 PR D8 727 PR D8 729	+Kasha, Wanderer, Adair+ (YALE, BNL, LASL) Weissenberg, Egorov, Minervina+ (LTEP, LEBD) +Carroll, Kycia, Li, Menes, Michael+ Backenstoss+ (CERN, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen (AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ (AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ (AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ (AACH3, BARI, BRUX, CERN) Hilderbrand, Pang, Stiening +Cline Ljung Cline, Ljung Cline, Ljung Camerini, Ljung, Sheaff, Cline +Taft, Willis (YALE)
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO BRAUN AISO CABLE LJUNG AISO AISO AISO LUCAS LUCAS LUCAS	74 74 73B 73 73 73B 75 73C 75 73 73 72 72 69 73 73B	PR D9 107 PL 48B 474 PR. 30 500 PL 43B 431 PR. 30 399 PL 47B 185 NP 889 210 PR D8 3807 PR D8 3807 PR D8 3807 PRI. 28 523 PRI. 28 523 PRI. 28 523 PR D8 727 PR D8 727 PR D8 719 PR D8 729 PR D8 679 PR D8 727 PR D8 68 699 PL 408 699 PL 408 699 PL 408 699	+Kasha, Wanderer, Adair+ (YALE, BNL, LASL) Weissenberg, Egorov, Minervina+ (ITEF, LEBD) +Carroll, Kycia, Li, Menes, Michael+ (BNL) Backenstoss+ (CERN, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen (AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ (AACH3, BARI, BRUX, CERN) Hildebrand, Pang, Stiening (EFI, LBL) -Cline (WISC) Ljung (WISC) Camerini, Ljung, Sheaff, Cline (WISC) -Taft, Willis (YALE) +Hildebrand, Cable, Stiening (EFI, ARIZ, LBL) Cable, Hildebrand, Pang, Stiening (EFI, ARIZ, LBL) Cable, Hildebrand, Pang, Stiening (EFI, ARIZ, LBL) Cable, Hildebrand, Pang, Stiening (EFI, LBL) Cable, Hildebrand, Pang, Stiening (EFI, LBL) Cable, Hildebrand, Pang, Stiening (EFI, LBL) Cable, Renshall, Jones+ (GLAS, LIVP, OXF, RHEL)
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO CABLE LJUNG AISO LJUNG AISO LUCAS LUCAS LUCAS PANG AISO SMITH ABRAMS	74 74 73B 73 73 73 75 73C 75 73 72 72 69 73 73B 73 72 72	PR D9 107 PL 48B 474 PRI 30 500 PL 43B 431 PRI 30 399 PL 47B 185 NP 889 210 PR 989 210 PR 182 NP 889 210 PR 183 PRI 28 1287 PRI 29 1287 PRI 29 1287 PRI 29 1287 PRI 29 1118	+Kasha, Wanderer, Adair+ (YALE, BNL, LASL) Weissenberg, Egorov, Minervina+ (LTEP, LEBD) +Carroll, Kycia, Li, Menes, Michael+ Backenstoss+ (CERN, KARLK, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen -(AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ -(AACH3, BARI, BRUX, CERN) -(Line -Ljung -(WISC) -(Cine, Ljung -(WISC) -(Camerini, Ljung, Sheaff, Cline -(WISC) -(Camerini, Ljung, Sheaff, Cline -(Taft, Willis -
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO AISO CABLE LIJUNG AISO AISO LUCAS LUCAS PANG AISO SMITH ABRAMS ANKENBRA	74 74 73B 73 73 73 75 73C 75 73 72 72 69 73 73B 73 72 72 69 73 73B 73 72 72	PR D9 107 PL 48B 474 PR. 30 500 PL 43B 431 PR. 130 399 PL 47B 185 NP 889 210 PR 186 307 PR 186 307 PR 186 307 PR 187 PR 1	+Kasha, Wanderer, Adair+ (YALE, BNL, LASL) Weissenberg, Egorov, Minervina+ (ITEF, LEBD) +Carroll, Kycia, Li, Menes, Michael+ (BNL) Backenstoss+ (CERN, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen (AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ (AACH3, BARI, BRUX, CERN) Hildebrand, Pang, Stiening (EFI, LBL) -Cline (WISC) Ljung (WISC) Camerini, Ljung, Sheaff, Cline (WISC) -Taft, Willis (YALE) +Hildebrand, Cable, Stiening (EFI, ARIZ, LBL) Cable, Hildebrand, Pang, Stiening (EFI, ARIZ, LBL) Cable, Hildebrand, Pang, Stiening (EFI, ARIZ, LBL) Cable, Hildebrand, Pang, Stiening (EFI, LBL) Cable, Renshall, Jones+ (GLAS, LIVP, OXF, RHEL) +Carroll, Kycia, Li, Menes, Michael+ (BNL) Ankenbrandt, Larsen+ (BNL), VALES, FNAL, YALES
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO BAUN AISO CABLE LJUNG AISO AISO LUCAS LUCAS PANG AISO SMITH ABRAMS ANGKENBRA AUBERT	74 74 73B 73 73 73B 75 73C 75 73 72 72 72 69 73 73B 73 73B 73 73 72 72 72 72 73 73 73 73 73 73 73 73 73 73 73 73 73	PR D9 107 PL 48B 474 PRI 30 500 PL 43B 431 PRI 30 399 PL 47B 185 NP 889 210 PR 989 210 PR 188 3807 PR D8 3807 PRI 28 1287 PRI 28 1287 PRI 28 1287 PRI 28 1287 PRI 28 1287 PR D8 1989 PL 496 411 PRI 28 1472 PRI 28 1472 PRI 28 1472 NP 869 411 PRI 29 1118 PRI 28 1472 NP 118	+Kasha, Wanderer, Adair+ (YALE, BNL, LASL) Weissenberg, Egorov, Minervina+ (ITEF, LEBD) +Carroll, Kycia, Li, Menes, Michael+ (BNL) Backenstoss+ (CERN, KARLK, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts (PENN) +Cornebsen (AACH3, BARI, BRUX, CERN) Braun, Cornebsen+ (AACH3, BARI, BRUX, CERN) Braun, Cornebsen+ (AACH3, BARI, BRUX, CERN) Braun, Cornebsen+ (AACH3, BARI, BRUX, CERN) +Cline Ljung Cline, Ljung (WISC) Camerini, Ljung, Sheaff, Cline (WISC) Camerini, Ljung, Sheaff, Cline (WISC) +Taft, Willis (YALE) +Hildebrand, Cable, Stiening (EFI, ARIZ, LBL) +Booth, Renshall, Jones+ (GLAS, LIVP, OXF, RHEL) +Carroll, Kycia, Li, Menes, Michael Ankenbrandt, Larsen+ (BNL, LASL, FNAL, YALE) +Heusse, Pascaud, Vialle+ (ORSAY, BRUX, EPOL)
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO AISO CABLE LIJUNG AISO AISO LUCAS LUCAS PANG AISO SMITH ABRAMS ANKENBRA	74 74 73B 73 73 73 75 73C 75 73 72 72 69 73 73B 73 72 72 69 73 73B 73 72 72	PR D9 107 PL 48B 474 PRI 30 500 PL 45B 431 PRI 30 599 PL 47B 185 NP B89 210 PL 47B 182 NP B89 210 PR D8 3807 PR D8 3807 PR D8 3807 PR D8 1307 PRI 28 1287 PRI 28 1287 PR D8 1989 PRI 29 104 PR D8 1989 PR D8 719 PR D9 71118 PRI 29 1118 PRI 29 1118 PRI 29 678 PR D6 1254	+Kasha, Wanderer, Adair+ (YALE, BNL, LASL) Weissenberg, Egorov, Minervina+ (ITEF, LEBD) +Carroll, Kycia, Li, Menes, Michael+ (BNL) Backenstoss+ (CERN, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen (AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ (AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ (AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ (AACH3, BARI, BRUX, CERN) Hildebrand, Pang, Stiening (EFI, LBL) +Cline (WISC) Cine, Ljung (WISC) Camerini, Ljung, Sheaff, Cline (WISC) Camerini, Ljung, Sheaff, Cline (WISC) +Taft, Willis (YALE) +Taft, Willis (YALE) -Cable, Hildebrand, Pang, Stiening (EFI, ARIZ, LBL) Cable, Hildebrand, Pang, Stiening (EFI, LBL) +Booth, Renshall, Jones+ (GLAS, LIVP, OXF, RHEL) +Carroll, Kycia, Li, Menes, Michael+ + Heusse, Pascaud, Vialle+ + Heusse, Pascaud, Vialle+ + Buchholz, Mann, Parker (PENN)
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO CABLE LJUNG AISO AISO LUCAS LUCAS PANG AISO SMITH ABRAMS AUSERT BEIER CHIANG CHARK	74 74 74 73B 73 73 75 75 73C 75 73 72 72 72 72 73 73 73 73 72 72 72 72 72 72 72 72 72 72 72 72 72	PR D9 107 PL 48B 474 PR. 30 500 PL 43B 431 PR. 30 399 PL 47B 185 NP 889 210 PL 47B 182 NP 889 210 PR 183 PR 183 PR 183 PR 183 PR 182 PR 183 PR 183 PR 184 PR 187 PR	+Kasha, Wanderer, Adair+ (YALE, BNL, LASL) Weissenberg, Egorov, Minervina+ (ITEF, LEBD) +Carroll, Kycia, Li, Menes, Michael+ (BNL) Backenstoss+ (CERN, KARLK, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts (PENN) +Cornelssen (AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ (AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ (AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ (AACH3, BARI, BRUX, CERN) Hildebrand, Pang, Stiening (EFL, LBL) -Cline (WISC) Camerini, Ljung, Sheaff, Cline (WISC) Camerini, Ljung, Sheaff, Cline (WISC) -Taft, Willis (YALE) +Taft, Willis (YALE) -Taft, Willis (YALE) -Taft, Willis (Talt) -Taft, Willis (BNL) -Taft, Willis (Talt) -Taft, Willis (Ta
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO AISO AISO AISO LUCAS LUCAS LUCAS PANG AISO SMITH ABRAMS ANGENBRA AUBERT BEIER CHIANG CLARK EDWARDS	74 74 74 73B 73 73 73C 75 73 72 72 72 72 73 73 73 72 72 72 72 72 72 72 72 72 72 72 72 72	PR D9 107 PL 48B 474 PRI 30 500 PL 45B 431 PRI 30 500 PL 47B 185 NP B89 210 PL 47B 182 NP B89 210 PR D8 3807 PR D8 3807 PR D8 1307 PRI 28 1287 PRI 28 1287 PRI 28 1287 PR D8 1989 PRI 29 107 PR D8 1989 PRI 29 107 PRI 29 10	+Kasha, Wanderer, Adair+ (YALE, BNL, LASL) Weissenberg, Egorov, Minervina+ (LTEP, LEBD) +Carroll, Kycia, Li, Menes, Michael+ Backenstoss+ (CERN, KARLK, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen -(AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ -(AACH3, BARI, BRUX, CERN) -(Line -Ljung -(WISC) -(Cline, Ljung -(WISC) -(Cline, Ljung -(WISC) -(Camerini, Ljung, Sheaff, Cline -(WISC) -(Camerini, Ljung, Sheaff, Cline -(WISC) -(Camerini, Ljung, Sheaff, Cline -(Hildebrand, Cable, Stiening -(EFI, ARIZ, LBL) -(Cable, Hildebrand, Pang, Stiening -(EFI, BRL) -(BNL) -(ARCH) -(ARC
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO CABLE LJUNG AISO AISO LUCAS LUCAS PANG SMITH ABRAMS ANKENBRA AUBERT BEIER CHIANG CLARK EDWARDS FORD	74 74 73B 73B 73 75 75 75 73C 75 73 72 72 72 72 72 72 72 72 72 72 72 72 72	PR D9 107 PL 45B 474 PRI 30 500 PL 45B 431 PRI 30 500 PL 47B 185 NP 899 210 PL 47B 185 NP 899 210 PR 108 1307 PR D8 179 PRI 28 1287 PR D8 179 PRI 29 174 PR 52 174 PR 52 174 PR 59 174 PR 59 177 PR D8 1989 PRI 29 678 PRI 29 174 PR 59 177 PR D8 1254 PRI 29 1774 PR D8 1254 PRI 29 1774 PR D8 1257	+Kasha, Wanderer, Adair+ (YALE, BNL, LASL) Weissenberg, Egorov, Minervina+ (ITEF, LEBD) +Carroll, Kycia, Li, Menes, Michael+ Backenstoss+ (CERN, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen (AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ (AACH3, BARI, BRUX, CERN) Cline Ljung Cline, Ljung Cline, Ljung Camerini, Ljung, Sheaff, Cline (WISC) Camerini, Ljung, Sheaff, Cline (WISC) Camerini, Ljung, Sheaff, Cline (WISC) Catle, Hildebrand, Pang, Stiening (EFI, ARIZ, LBL) Cable, Hildebrand, Pang, Stiening (EFI, ARIZ, LBL) Cable, Hildebrand, Pang, Stiening (EFI, ARIZ, LBL) Cable, Hildebrand, Pang, Stiening (EFI, LBL) +Carroll, Kycla, Li, Menes, Michael+ +Carroll, Kycla, Li, Menes, Michael+ +Buchhotz, Mann, Parker + (BNL) -Rosen, Shapiro, Handler, Olsen+ +Cork, Elioff, Kerth, McReynolds, Newton+ + Bier, Bertram, Herzo, Koester+ (ILL) +Prioue, Remmel, Smith, Souder (PRIN)
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO AISO AISO AISO LUCAS LUCAS LUCAS PANG AISO SMITH ABRAMS ANGENBRA AUBERT BEIER CHIANG CLARK EDWARDS	74 74 74 73 73 73 75 75 75 73 72 72 69 73 72 72 72 72 72 72 72 72 72 72 72 72 72	PR D9 107 PL 48B 474 PRI 30 500 PL 45B 431 PRI 30 500 PL 47B 185 NP B89 210 PL 47B 182 NP B89 210 PR D8 3807 PR D8 3807 PR D8 1307 PRI 28 1287 PRI 28 1287 PRI 28 1287 PR D8 1989 PRI 29 107 PR D8 1989 PRI 29 107 PRI 29 10	+Kasha, Wanderer, Adair+ (YALE, BNL, LASL) Weissenberg, Egorov, Minervina+ (LTEP, LEBD) +Carroll, Kycia, Li, Menes, Michael+ Backenstoss+ (CERN, KARLK, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen (AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ (AACH3, BARI, BRUX, CERN) (WISC) Ciline, Ljung Cline, Ljung Cline, Ljung Cline, Ljung Cline, Ljung Camernin, Ljung, Sheaff, Cline (WISC) (WISC) Camernin, Ljung (WISC)
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO BAUN AISO CABLE LJUNG AISO AISO LUCAS LUCAS PANG AISO SMITH ABRAMS ANKENBRA AUBERT BEIER CHIANG CLARK EDWARDS FORD	74 74 74 73 73 73 73 75 73 75 73 72 69 73 72 72 72 72 72 72 72 72 72 72 72 72 72	PR D9 107 PL 48B 474 PRI 30 500 PL 45B 431 PRI 30 500 PL 47B 185 NP B89 210 PR 47B 182 NP B89 210 PR 183 PRI 28 186 PR 182 PR 182 PRI 28 187 PR 18 1989 PRI 29 197 PR 18 1989 PRI 29 197 PR 18 197 PRI 29 678 PRI 29 174 PRI 29 174 PRI 29 177 PR D8 186 PRI 29 177 PR D8 186 PRI 29 1118 PRI 28 1472 PR 18 187 PR 18 18 187 PR 18 18 187 PR 18 18 18 18 18 18 18 18 18 18 18 18 18	+Kasha, Wanderer, Adair+ (YALE, BNL, LASL) Weissenberg, Egorov, Minervina+ (LTEP, LEBD) +Carroll, Kycia, Li, Menes, Michael+ Backenstoss+ (CERN, KARLK, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen (AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ (AACH3, BARI, BRUX, CERN) (WISC) Ciline, Ljung Cline, Ljung Cline, Ljung Cline, Ljung Cline, Ljung Camernin, Ljung, Sheaff, Cline (WISC) (WISC) Camernin, Ljung (WISC)
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO BAISO CABLE LJUNG AISO AISO LUCAS LUCAS PANG AISO SMITH ABRAMS ANKENBRA AUBERT BEIER CHIANG CHARA EDWARDS FORD HOFFMASTER BOURQUIN GINSBERG	74 74 74 74 74 73B 73 73 73B 75 73C 75 73 72 72 72 72 72 72 72 72 72 72 72 72 71 71	PR D9 107 PL 48B 474 PR. 30 500 PL 43B 431 PR. 30 399 PL 47B 185 NP B89 210 PR 589 210 PR 188 187 PR 188 188 187 PR 188 188 188 188 188 188 188 188 188 18	+Kasha, Wanderer, Adair+ (YALE, BNL, LASL) Weissenberg, Egorov, Minervina+ (ITEF, LEBD) +Carroll, Kycia, Li, Menes, Michael+ Backenstoss+ (CERN, KARLK, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen +Cornelssen +Cancelssen +Ciline +Taft, Willis -Canelini -Canel
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO BAUN AISO AISO AISO AISO AISO AISO AISO AISO	74 74 74 73B 73B 73B 75 73C 75 73 72 72 72 72 73 73 73 73 72 72 72 72 72 72 72 72 72 72 72 72 72	PR D9 107 PL 48B 474 PRI 30 500 PL 45B 431 PRI 30 500 PL 47B 185 NP B89 210 PR 47B 182 NP B89 210 PR 182 NP B89 210 PRI 28 1287 PR D8 1307 PR D8 1307 PRI 28 1287 PR D8 179 PRI 29 1274 PR D8 179 PRI 29 179 PR 18 179 PR 18 179 PRI 29 179 PR 18 179 PR 18 179 PRI 29 179 PR 18 18 179 PR 18 18 179 PR 18 18 179 PR 18 18 18 18 18 18 18 18 18 18 18 18 18	+Kasha, Wanderer, Adair+ (YALE, BNL, LASL) Weissenberg, Egorov, Minervina+ +Carroll, Kycia, Li, Menes, Michael+ Backenstoss+ (CERN, KARLK, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen (AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ (AACH3, BARI, BRUX, CERN) (WISC) Cline, Ljung Camernin, Ljung, Sheaff, Cline (WISC) (WISC) Camernin, Ljung, Sheaff, Cline (WISC) (
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO BAID AISO AISO AISO AISO AISO AISO AISO AISO	74 74 74 74 73B 73B 73 73B 75 73C 75 73 72 72 72 72 72 72 72 72 72 72 72 71 71 71 69 71	PR D9 107 PL 48B 474 PRI 30 500 PL 45B 431 PRI 30 500 PL 47B 185 NP B89 210 PR 47B 182 NP B89 210 PR 182 NP B89 210 PRI 28 1287 PR D8 1307 PRI 28 1287 PRI 28 1287 PR D8 179 PRI 29 1274 PR 50 411 PRI 29 1678 PR 50 411 PRI 29 1678 PR 50 411 PRI 29 1678 PRI 29 1118 PRI 28 1472 NC 12A 509 PRI 29 1274 PRI 29 1	+Kasha, Wanderer, Adair+ (YALE, BNL, LASL) Weissenberg, Egorov, Minervina+ (ITEF, LEBD) +Carroll, Kycia, Li, Menes, Michael+ Backenstoss+ (CERN, KARLK, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen (AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ (AACH3, BARI, BRUX, CERN) Celine Ljung Cline, Ljung
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO BRAUN AISO AISO AISO AISO AISO AISO AISO AISO	74 74 74 74 73B 73B 75 73C 75 73 72 72 72 72 72 72 72 72 72 72 72 72 72	PR D9 107 PL 48B 474 PRI 30 500 PL 48B 431 PRI 30 500 PL 47B 185 NP 889 210 PRI 47B 185 NP 889 210 PR 108 180 PR 108 190 PR 108 160	+Kasha, Wanderer, Adair+ (YALE, BNL, LASL) Weissenberg, Egorov, Minervinia+ (ITEP, LEBD) +Carroll, Kycia, Li, Menes, Michael+ Backenstoss+ (CERN, KARLK, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen -Carroll, ACH3, BARI, BRUX, CERN) Braun, Cornelssen+ +(AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ +(AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ +(AACH3, BARI, BRUX, CERN) +Hildebrand, Pang, Stiening -Cline -Cline -Ljung -Cline, Ljung -Camerini, Ljung, Sheaff, Cline -Taft, Willis -Taft, Willis -Hildebrand, Pang, Stiening -Camerini, Ljung, Sheaff, Cline -Hildebrand, Pang, Stiening -Booth, Renshahl, Jones-se, Michael+ -Antenbrandt, Larsen, Michael+ -Heusse, Pascaud, Vialle+ -Heusse, Pascaud, Vialle+ -Heusse, Pascaud, Vialle+ -Buchhotz, Mann, Parker -Cork, Elioff, Kerth, McReynolds, Newton+ -(BL) -Beier, Bertram, Herzo, Koester+ -(BL) -Beier, Bertram, Herzo, Koester+ -(BL) -Beier, Damant-Berger, Kunz+ -Beier, Bertram, Herzo, Koester, -(BR) -Beier, Bertram, Herzo, Kester, -(BR) -Beier, Bertram, H
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO BAID AISO AISO AISO AISO AISO AISO AISO AISO	74 74 74 74 73B 73 73 73B 75 73C 75 73 72 72 69 73 72 72 72 72 72 72 72 72 71 71 71 71 70 70 70 70	PR D9 107 PL 48B 474 PRI 30 500 PL 49B 431 PRI 30 500 PRI 49B 431 PRI 30 399 PRI 47B 185 NP 889 210 PR 989 210 PR 98 3807 PR D8 3807 PR D8 3807 PR D8 3807 PRI 28 1287 PRI 28 1287 PRI 28 1287 PRI 28 1287 PR D8 1397 PRI 28 1287 PR D8 179 PRI 29 174 PRI 29 678 PRI 29 174 PRI 29	+Kasha, Wanderer, Adair+ (YALE, BNL, LASL) Weissenberg, Egorov, Minervina+ (LTEP, LEBD) +Carroll, Kycia, Li, Menes, Michael+ Backenstoss+ (CERN, KARLK, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen -(AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ -(AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ -(AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ -(AACH3, BARI, BRUX, CERN) -Cline -Ljung -Cline -Ljung -Cline, Ljung -Cline, Ljung -Cline, Ljung -Cline, Ljung -Camernin, Ljung, Sheaff, Cline -Taft, Willis -Taft, Willis -(YALE) -Hildebrand, Cable, Stiening -Cable, Hildebrand, Pang, Stiening -Cable, Hildebrand, Stiening -Cable, Lich, CHIC, -Chilo, Lich, CHIC, -Chilo, Lich, Chilo, Lich, Lich, Chilo, Lich, Chilo, Lich, Lich, C
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO BRAUN AISO AISO AISO LUCAS LUCAS LUCAS PANG AISO SMITH ABRAMS ANKENBRA AUBERT BEIER CHIANG CLARK EDWARDS FORD CLARK BOURG AISO SMITH AISO AISO SMITH AISO AISO SMITH AISO AISO SMITH AISO AISO AISO SMITH AISO AISO AISO AISO AISO AISO AISO AISO	74 74 74 74 73B 73B 75 73C 75 73 72 72 72 72 72 72 72 72 72 72 72 72 72	PR D9 107 PL 48B 474 PRI 30 500 PL 49B 431 PRI 30 500 PL 47B 185 NP 889 210 PRI 47B 182 NP 889 210 PRI 28 182 NP 889 210 PRI 28 182 PRI 28 187 PRI 29 187	+Kasha, Wanderer, Adair+ Weissenberg, Egorov, Minervina+ +Carroll, Kycia, Li, Menes, Michael+ Backenstoss+ (CERN, KARLK, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen -Carroll, Mann, Parker, Roberts -Carroll, Mann, Parker, Roberts -Carroll, Mann, Parker, Roberts -Carroll, Gern, Mann, Parker, Roberts -Carroll, Gern, Carroll, Barl, Brux, CERN) -Carroll, Gern, Garchi, Barl, Brux, CERN) -Carroll, Gern,
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO AISO AISO AISO AISO AISO AISO AISO	74 74 74 74 73B 73B 73 73B 75 75 75 77 76 79 73 72 72 72 72 72 72 72 72 72 72 72 72 72	PR D9 107 PL 48B 474 PRI 30 500 PL 48B 474 PRI 30 500 PL 47B 185 NP 889 210 PRI 47B 185 NP 889 210 PRI 28 182 NP 889 210 PRI 28 1827 PRI 29 1828 PRI 29 1828 PRI 29 1828 PRI 29 1828 PRI 29 1838 PRI 29 1827 PRI 38B 619 PRI 36 19 PRI 36 19 PRI 36 19 PRI 24 1686 PRI 25 473 PRI 29 1838	+Kasha, Wanderer, Adair+ (YALE, BNL, LASL) Weissenberg, Egorov, Minervinia+ (ITEP, LEBD) +Carroll, Kycia, Li, Menes, Michael+ Backenstoss+ (CERN, KARLK, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen -Carroll, ACH3, BARI, BRUX, CERN) Braun, Cornelssen+ +(AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ +(AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ +(AACH3, BARI, BRUX, CERN) -Colline, Ljung -Cline, Ljung -Cline, Ljung -Cline, Ljung -Cline, Ljung -Camerini, Ljung, Sheaff, Cline -Taft, Willis -Taft, Willis -Carle, Hidebrand, Pang, Stiening -Enderini, Lyung, Sheaff, Cline -Hidebrand, Pang, Stiening -Enderini, Lyung, Sheaff, Cline -Booth, Renshal, Jones+ -Booth, Renshal, Jones+ -Carle, King, Camerini, Lyung, Sheaff, Cline -Edroll, Kycia, Li, Menes, Michaelt, -Edroll, Sheaff, Cline -Edroll, Carle, Hidebrand, Parker -Edroll, Sheaff, Cline -Edroll, Carle, Lill, -Edroll, Sheaff, Cline -Edroll, Carle, Lill, -Edroll, Kycia, Li, Menes, Michaelt -Edroll, Sheaff, Cline -Edroll, Carle, Lill, -Edroll, Sheaff, Cline -Edroll, Carle, Lill, -Edroll, Sheaff, Cline -Edroll, Cline, Lill, -Edroll, Cline, -Edroll, Cline, Lill, -Edroll, Cline, -Edroll, C
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO BRAUN AISO AISO AISO LUCAS LUCAS LUCAS PANG AISO SMITH ABRAMS ANKENBRA AUBERT BEIER CHIANG CLARK EDWARDS FORD TORD TORD TORD TORD TORD TORD TORD T	74 773B 73B 73 73B 75 73 75 75 75 77 77 77 77 77 77 77 77 77 77	PR D9 107 PL 48B 474 PRI 30 500 PL 49B 431 PRI 30 500 PRI 47B 185 NP B89 210 PRI 47B 185 NP B89 210 PRI 28 186 PRI 28 187 PRI 29 174 PRI 29 188 335 PRI 28 187 PRI 29 188 335 PRI 28 187 PRI 29 188 315 PRI 28 187 PRI 29 188 315 PRI 29 188 515 PRI 29 188 525 PL 36B 525	+Kasha, Wanderer, Adair+ Weissenberg, Egorov, Minervina+ +Carroll, Kycia, Li, Menes, Michael+ Backenstoss+ (CERN, KARLK, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen -Carroll, Marchael, Cern, Karla, Barl, Brux, Cern, Braun, Cornelssen+ -Carroll, Barl, Brux, Cern, Braun, Cornelssen+ -Ciline -Ljung -Cline -Ljung -Cline, Ljung -Cline, Ljung -Camernin, Ljung, Sheaff, Cline -Taft, Willis -Carloll, Hildebrand, Pang, Stiening -Camernin, Ljung, Sheaff, Cline -Taft, Willis -Cable, Hildebrand, Pang, Stiening -Carroll, Carloll, Carl
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO AISO AISO AISO AISO AISO AISO AISO	74 74 73B 73B 73 73B 73 73C 75 73 72 72 72 72 72 72 72 72 72 72 72 72 72	PR D9 107 PL 48B 474 PRI 30 500 PL 49B 431 PRI 30 500 PL 47B 185 NP 889 210 PRI 47B 182 NP 889 210 PRI 28 182 NP 889 210 PRI 28 182 PRI 28 182 PRI 28 182 PRI 28 187 PRI 29 174 PRI 29 186 PRI 29 186 PRI 29 187 PRI 29 186 PRI 29 186 PRI 29 187 PRI 29 187 PRI 29 186 PRI 29 187	+Kasha, Wanderer, Adair+ Weissenberg, Egorov, Minervina+ +Carroll, Kycia, Li, Menes, Michael+ Backenstoss+ (CERN, KARLK, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen -Carroll, Mann, Parker, Roberts -Cornelssen -Carroll, Bark, BRUX, CERN) -Cline -Carroll, Millis -Cable, Hildebrand, Pang, Stiening -Ceff, ARIZ, LBL -Cable, Hildebrand, Pang, Stiening -Ceff, LBL -Booth, Renshall, Jones+ -Carroll, Kycia, Li, Menes, Michaelt -Cork, Elioff, Kerth, McReynolds, Newton+ -Cork, Elioff, Kerth, McReynolds, NewtonCork, Elioff, Kerth, McReynolds, NewtonCork, Elioff, Kerth, McReynolds, NewtonCline -Cline -Clin
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO BRAUN AISO AISO AISO AISO AISO AISO AISO AISO	74 74 73B 73B 73 73B 73 73C 75 73C 75 72 72 72 72 72 72 72 72 72 72 72 72 72	PR D9 107 PL 48B 474 PRI 30 500 PL 48B 431 PRI 30 500 PL 47B 185 NP 889 210 PRI 47B 185 NP 889 210 PR D8 3007 PR D8 1307 PRI 28 1287 PRI 29 1288 PRI 29 1297 PRI 2	+Kasha, Wanderer, Adair+ Weissenberg, Egorov, Minervina+ +Carroll, Kycia, Li, Menes, Michael+ Backenstoss+ (CERN, KARLK, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen -Carroll, Mann, Parker, Roberts -Cornelssen -Carroll, Bark, BRUX, CERN) -Cline -Carroll, Millis -Cable, Hildebrand, Pang, Stiening -Ceff, ARIZ, LBL -Cable, Hildebrand, Pang, Stiening -Ceff, LBL -Booth, Renshall, Jones+ -Carroll, Kycia, Li, Menes, Michaelt -Cork, Elioff, Kerth, McReynolds, Newton+ -Cork, Elioff, Kerth, McReynolds, NewtonCork, Elioff, Kerth, McReynolds, NewtonCork, Elioff, Kerth, McReynolds, NewtonCline -Cline -Clin
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO BRAUN AISO CABLE LJUNG AISO AISO LUCAS LUCAS PANG AISO SMITH ABRAMS ANKENBRA AUBERT CHIANG CLARK EDWARDS FORD TORD TORD TORD TORD TORD TORD TORD T	74 73B 73B 73 73B 73 73B 75 75 75 75 75 75 75 72 72 72 72 72 72 72 72 72 72 72 72 72	PR D9 107 PL 48B 474 PRI 30 500 PL 49B 431 PRI 30 500 PL 47B 185 NP 889 210 PRI 47B 185 NP 889 210 PRI 28 182 NP 889 210 PRI 28 187 PRI 29 174 PRI 29 186 PRI 29 187 PRI 29 187 PRI 29 187 PRI 29 188	+Kasha, Wanderer, Adair+ Weissenberg, Egorov, Minervina+ +Carroll, Kycia, Li, Menes, Michael+ Backenstoss+ (CERN, KARLK, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen -Carroll, Mann, Parker, Roberts +Cornelssen -Carroll, Bark, BRUX, CERN) -Cornelssen -Carroll, Gard, Bark, BRUX, CERN) -Cornelssen -Carroll, Lipung -Cline, Ljung -Cline, Ljung -Camernin, Ljung, Sheaff, Cline -Taft, Willis -Cable, Hildebrand, Pang, Stiening -Carroll, Carroll,
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO AISO AISO AISO AISO AISO AISO AISO	74 74 73B 73B 73 73B 73 73C 75 73C 75 72 72 72 72 72 72 72 72 72 72 72 72 72	PR D9 107 PL 48B 474 PRI 30 500 PL 48B 474 PRI 30 500 PRI 48B 431 PRI 30 399 PRI 47B 185 NP 889 210 PRI 988 210 PR	+Kasha, Wanderer, Adair+ Weissenberg, Egorov, Minervinia+ +Carroll, Kycia, Li, Menes, Michael+ Backenstoss+ (CERN, KARLK, KARLE, HEID. STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO BRAUN AISO AISO AISO AISO AISO AISO AISO AISO	74 73B 73 73B 73 73B 75 73 75 73 75 73 72 72 72 72 72 72 72 72 72 72 72 72 72	PR D9 107 PL 48B 474 PRI 30 500 PL 48B 481 PRI 30 500 PRI 48B 481 PRI 30 399 PRI 47B 185 NP 889 210 PRI 988 1307 PRI 28 1287 PRI 28 1287 PRI 28 1287 PRI 28 1287 PRI 28 1472 PRI 29 1274 PRI 29 1275 PRI 25 1370 CERN 70-014 PR D1 1227	+Kasha, Wanderer, Adair+ Weissenberg, Egorov, Minervinia+ +Carroll, Kycia, Li, Menes, Michael+ Backenstoss+ (CERN, KARLK, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO BRAUN AISO CABLE LJUNG AISO AISO LUCAS LUCAS PANG AISO SMITH ABRAMS ANKENBRA AUBERT CHIANG CLARK EDWARDS FORD TORD TORD TORD TORD TORD TORD TORD T	74 74 73B 73 73 73 73 75 75 75 75 76 79 70 70 70 70 70 70 70 70 70 70 70 70 70	PR D9 107 PL 48B 474 PRI 30 500 PL 49B 431 PRI 30 500 PL 47B 185 NP 889 210 PRI 47B 185 NP 889 210 PRI 47B 182 NP 889 210 PRI 28 1827 PRI 29 1274 PRI 29 183 35 PRI 30 52 PRI 38 615 PRI 28 181 PRI 38 181 PRI	+Kasha, Wanderer, Adair+ Weissenberg, Egorov, Minervina+ +Carroll, Kycia, Li, Menes, Michael+ Backenstoss+ (CERN, KARLK, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen -Carroll, Mann, Parker, Roberts -Cornelssen -Carroll, Bark, Bark, BRUX, CERN) -Cornelssen -Carroll, Garloll, Bark, BRUX, CERN) -Cornelssen -Carroll, Lipung -Cline, Ljung -Cline, Ljung -Cline, Ljung -Camernin, Ljung, Sheaff, Cline -Carroll, Kyllis -Cable, Hildebrand, Pang, Stiening -Carroll, Kycia, Li, Menes, Michaelt -Carroll, Kycia, Li, Mens, Michaelt -Carroll
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO BRAUN AISO AISO AISO AISO AISO AISO AISO AISO	74 73B 73 73B 73 73B 75 73 75 73 75 73 72 72 72 72 72 72 72 72 72 72 72 72 72	PR D9 107 PL 48B 474 PRI 30 500 PL 48B 431 PRI 30 500 PRI 48B 431 PRI 30 399 PRI 47B 185 NP 889 210 PRI 988 315 PR	+Kasha, Wanderer, Adair+ Weissenberg, Egorov, Minervina+ +Carroll, Kycia, Li, Mens, Michael+ Backenstoss+ (CERN, KARLK, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen +C
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO AISO CABLE LJUNG AISO AISO LUCAS LUCAS PANG AISO SMITH BEIER CHIANG AISO CONTROL CHIANG AISO AISO AISO AISO AISO AISO AISO AISO	74 74 73B 73B 73B 73B 73B 73C 75 73 72 69 73 73 72 72 72 72 72 72 72 72 72 72 72 72 72	PR D9 107 PL 48B 474 PRI 30 500 PL 48B 431 PRI 30 500 PRI 48B 431 PRI 30 399 PRI 47B 185 NP B89 210 PRI 98B 335 PR	+Kasha, Wanderer, Adair+ (YALE, BNL, LASL) Weissenberg, Egorov, Minervinia+ (ITEF, LEBD) +Carroll, Kycia, Li, Menes, Michael+ Backenstoss+ (CERN, KARLK, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen Horrissen
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO BRAUN AISO CABLE LJUNG AISO AISO LUCAS LUCAS PANG AISO CHARK EBEIER CHARK EBEIER CHARK EDWARDS FORD AISO SMITH AISO MISSERG HAIDT AISO CLARK EDWARDS FORD CLARK EDWARDS FORD TOTHERILL FORD AISO OTT ROMANO SCHWEINB STEINER BARDIN BECHERRAWY BOTTERILL FORD GAILLARD GINSBERG GRAUMAN AISO MALTSEV PANDOULAS CUTTS	74 74 73B 73 73 73 73 73 73 73 73 72 72 72 72 72 72 72 72 72 72 72 72 72	PR D9 107 PL 48B 474 PRI 30 500 PL 48B 431 PRI 30 500 PRI 48B 431 PRI 30 399 PRI 47B 185 NP B89 210 PRI 98B 335 PR	+Kasha, Wanderer, Adair+ (YALE, BNL, LASL) Weissenberg, Egorov, Minervinia+ (ITEF, LEBD) +Carroll, Kycia, Li, Menes, Michael+ Backenstoss+ (CERN, KARLK, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen -Cornelssen -CACH3, BARI, BRUX, CERN) Braun, Cornelssen+ -CACH3, BARI, BRUX, CERN) Braun, Cornelssen+ -CACH3, BARI, BRUX, CERN) Braun, Cornelssen+ -CACH3, BARI, BRUX, CERN) -CIline -Ljung -Ciline, Ljung -Ciline, Ljung -Ciline, Ljung -Ciline, Ljung -Ciline, Ljung -Camerini, Ljung, Sheaff, Cline -Taft, Willis -Taft, Willis -Cable, Hildebrand, Pang, Stiening -Camerini, Lyung, Sheaff, Cline -Carroll, Kycia, Li, Menes, Michaelt -Carloll, Kycia, Li, Menes, Michaelt -Carloll, Kycia, Li, Menes, Michaelt -Carroll, Kycia, Li, Menes, Michaelt -Cork, Elioff, Kerth, McReynolds, Newton+ -Cork, Elioff, Kerth, Mc
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO AISO CABLE LJUNG AISO AISO LUCAS LUCAS PANG AISO AISO CONTROL CHARLE CH	74 74 73B 73B 73B 73B 73C 75 73 77 72 69 73 73 72 72 72 72 72 72 72 72 72 72 72 72 72	PR D9 107 PL 48B 474 PRI 30 500 PL 48B 474 PRI 30 500 PRI 48B 431 PRI 30 399 PRI 47B 185 NP B89 210 PRI 98B 315 PR	+Kasha, Wanderer, Adair+ Weissenberg, Egorov, Minervina+ +Carroll, Kycia, Li, Mens, Michael+ Backenstoss+ (CERN, KARLK, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen +C
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO AISO CABLE LJUNG AISO AISO LUCAS LUCAS PANG AISO SMITH BEIER CHIANG AISO COLVEAS AISO AISO AISO AISO AISO AISO AISO AI	74 73B 73 73 73 73 73 73 73 73 73 73 73 73 73	PR D9 107 PL 48B 474 PRI 30 500 PL 48B 474 PRI 30 500 PL 47B 185 NP B89 210 PRI 47B 185 NP B89 210 PRI 28 182 NP B89 210 PRI 28 182 PRI 28 187 PRI 29 197 PRI 20 1995 PRI 180 13131	+Kasha, Wanderer, Adair+ Weissenberg, Egorov, Minervina+ +Carroll, Kycia, Li, Menes, Michael+ Backenstoss+ (CERN, KARLK, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen +
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO BRAUN AISO AISO AISO AISO AISO AISO AISO AISO	74 74 73B 73 73 73 73 73 73 73 73 73 73 73 73 72 72 72 72 72 72 72 72 72 72 72 72 72	PR D9 107 PL 48B 474 PRI 30 500 PL 48B 474 PRI 30 500 PL 47B 185 NP B89 210 PRI 47B 185 NP B89 210 PRI 28 186 PRI 28 187 PRI 29 1118 PRI 29 118 PRI 29 118 PRI 29 188 PRI 28 187 PRI 29 188 PRI 28 187 PRI 29 188 PRI 29 189 PRI 29 188 PRI 29 189	+ Kasha, Wanderer, Adair+ Weissenberg, Egorov, Minervinia+ + Carroll, Kycia, Li, Menes, Michael+ Backenstoss+ (CERN, KARLK, KARLE, HEID, STOH) + Buchholz, Mann, Parker, Roberts + Cornelssen + Cornelssen + Cancelssen + Cine - Ljung - Cine, Lju
MERLAN WEISSENBE ABRAMS BACKENSTO BEIER BRAUN AISO AISO CABLE LJUNG AISO AISO LUCAS LUCAS PANG AISO SMITH BEIER CHIANG AISO COLVEAS AISO AISO AISO AISO AISO AISO AISO AI	74 73B 73 73 73 73 73 73 73 73 73 73 73 73 73	PR D9 107 PL 48B 474 PRI 30 500 PL 48B 474 PRI 30 500 PL 47B 185 NP B89 210 PRI 47B 185 NP B89 210 PRI 28 182 NP B89 210 PRI 28 182 PRI 28 187 PRI 29 197 PRI 20 1995 PRI 180 13131	+Kasha, Wanderer, Adair+ Weissenberg, Egorov, Minervina+ +Carroll, Kycia, Li, Menes, Michael+ Backenstoss+ (CERN, KARLK, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts +Cornelssen +

 K^{\pm} , K^{0} , K^{0}_{S}

LOBKOWICZ	69	PR 185 1676	+Melissinos, Nagashima, Tewksbury+ (ROCH, BNL)
Also	66	PRL 17 548	Lobkowicz, Melissinos, Nagashima+ (ROCH, BNL)
MACEK MAST	69 69	PRL 22 32 PR 183 1200	+Mann, McFarlane, Roberts+ (PENN, TEMP) +Gershwin, Alston-Garnjost, Bangerter+ (LRL)
SELLERI	69	NC 60A 291	+ definition, Alaton dampost, Dangerter+ (ENE)
ZELLER	69	PR 182 1420	+Haddock, Helland, Pahl+ (UCLA, LRL)
BETTELS Also	68 71	NC 56A 1106 PR D3 10	(AACH, BARI, BERG, CERN, EPOL, NIJM, ORSAY+) Haidt (AACH, BARI, CERN, EPOL, NIJM+)
BOTTERILL	68B	PRL 21 766	+Brown, Clegg, Corbett+ (OXF)
BOTTERILL	68C	PR 174 1661	+Brown, Clegg, Corbett+ (OXF)
BUTLER CHANG	68 68	UCRL 18420	+Bland, Goldhaber, Goldhaber, Hirata+ +Yodh, Ehrlich, Plano+ (UMD, RUTG)
CHEN	68	PRL 20 510 PRL 20 73	+Yodh, Ehrlich, Plano+ (UMD, RUTG) +Cutts, Kijewski, Stiening+ (LRL, MIT)
EICHTEN	68	PL 27B 586	(AACH, BARL CERN, EPOL, ORSAY, PADO, VALE)
EISLER	68	PR 169 1090	+Fung, Marateck, Meyer, Plano (RUTG)
ESCHSTRUTH GARLAND	68 68	PR 165 1487 PR 167 1225	+Franklin, Hughes+ (PRIN, PENN) +Tsipis, Devons, Rosen+ (COLU, RUTG, WISC)
MOSCOSO	68	Thesis	(ORSAY)
AUERBACH	67	PR 155 1505	+Dobbs, Mann+ (PENN, PRIN)
Also Erratum.	74	PR D9 3216	Auerbach
BELLOTTI	67	Heidelberg Conf.	+Pullia (MILA)
BELLOTTI	67B	NC 52A 1287 PL 20 690	+Fiorini, Pullia (MILA)
Also	66B		Bellotti, Fiorini, Pullia+ (MILA)
BISI BOTTERILL	67 67	PL 25B 572 PRL 19 982	+Cester, Chiesa, Vigone (TORI) +Brown, Corbett, Culligan+ (OXF)
Also	68	PR 171 1402	Botterill, Brown, Clegg, Corbett+ (OXF)
BOWEN	67B	PR 154 1314	+Mann, McFarlane, Hughes+ (PPA)
CLINE Proc. Inte	67B	Herceg Novi Tbl. 4 nal School on Elementary	Particle Physics
FLETCHER	67	PRL 19 98	+Beier, Edwards+ (ILL)
FORD	67	PRL 18 1214 PR 162 1570	+Lemonick, Nauenberg, Piroue (PRIN)
GINSBERG IMLAY	67 67	PR 162 1570 PR 160 1203	+Eschstruth, Franklin+ (PRIN)
KALMUS	67	PR 159 1187	+Kernan (LRL)
ZINCHENKO	67	Thesis Rutgers	(RUTG)
CALLAHAN	66 66 B	NC 44A 90	(WISC)
CALLAHAN CESTER	66B 66	PR 150 1153 PL 21 343	+Camerini+ (WISC, LRL, UCR, BARI) +Eschstruth, Oneill+ (PPA)
See footno	te 1 i	n AUERBACH 67.	
Also	67	PR 155 1505	Auerbach, Dobbs, Mann+ (PENN, PRIN)
BIRGE BISI	65 65	PR 139B 1600 NC 35 768	+Ely, Gidal, Camerini, Cline+ (LRL, WISC) +Borreani, Cester, Ferraro+ (TORI)
BISI	65B	PR 139B 1068	+Borreani, Marzari-Chiesa, Rinaudo+ (TORI)
BORREANI	65	PR 140B 1686	+Gidal, Rinaudo, Caforio+ (BARI, TORI)
CALLAHAN CAMERINI	65 65	PRL 15 129	+Cline (WISC) +Cline, Gidal, Kalmus, Kernan (WISC, LRL)
CLINE	65	NC 37 1795 PL 15 293	+Frv (WISC)
CUTTS	65	PR 138B 969	+Elioff, Stiening (LRL)
DEMARCO FITCH	65	PR 140B 1430	+Grosso, Rinaudo (TORI, CERN)
GREINER	65B 65	PR 140B 1088 ARNS 15 67	+Quarles, Wilkins (PRIN, MTHO) (LRL)
STAMER	65	PR 138B 440	+Huetter, Koller, Taylor, Grauman (STEV)
TRILLING	65B	UCRL 16473	(LRL)
YOUNG	65	965 Argonne Conference, Thesis UCRL 16362	page 5. (LRL)
Also	67	PR 156 1464	Young, Osborne, Barkas (LRL)
BORREANI	64	PL 12 123 PR 136B 1463	+Rinaudo, Werbrouck (TORI)
CALLAHAN CAMERINI	64 64	PRL 13 318	+March, Stark (WISC) +Cline, Fry, Powell (WISC, LRL)
CLINE	64	PRL 13 101	+Fry (WISC)
GIACOMELLI	64	NC 34 1134	+Monti, Quareni+ (BGNA, MUNI)
GREINER JENSEN	64 64	PRL 13 284 PR 136B 1431	+Osborne, Barkas (LRL) +Shaklee, Roe, Sinclair (MICH)
KALMUS	64	PRL 13 99	+Shaklee, Roe, Sinclair (MiCH) +Kernan, Pu, Powell, Dowd (LRL, WISC)
SHAKLEE	64	PR 136B 1423	+Jensen, Roe, Sinclair (MICH)
BARKAS	63	PRL 11 26	+Dyer, Heckman (LRL) +Loh, Niemela, Ritson (MIT)
BOYARSKI BROWN	62 62B	PR 128 2398 PRL 8 450	+Loh, Niemela, Ritson (MIT) +Kadyk, Trilling, Roe+ (LRL, MICH)
BARKAS	61	PR 124 1209	+Dyer, Mason, Norris, Nickols, Smit (LRL)
BHOWMIK	61	NC 20 857 NC 22 1087	+Jain, Mathur (DELH)
FERRO-LUZZI NORDIN	61		
ROE		PR 123 2166	+Miller, Murray, Rosenfeld+ (LRL)
	61	PR 123 2166 PRL 7 346	(LRL)
FREDEN	61 60B	PRL 7 346 PR 118 564	+Sinclair, Brown, Glaser+ (MICH, LRL) +Gilbert, White (LRL)
	61	PRL 7 346 PR 118 564 PRL 2 117	+Sinclair, Brown, Glaser+ (MICH, LRL) +Gilbert, White (MICH, LRL) +Caldwell, Frisch, Hill+ (MIT)
FREDEN BURROWES TAYLOR EISENBERG	61 60B 59 59 58	PRL 7 346 PR 118 564 PRL 2 117 PR 114 359 NC 8 663	(LRL) + Sinclair, Brown, Glaser + (MICH, LRL) + Gilbert, White (LRL) + Caldwell, Frisch, Hill+ (MIT) + Harris, Orear, Lee, Baumel (COLU) + Koch, Lohrmann, Nikolic + (BERN)
FREDEN BURROWES TAYLOR EISENBERG ALEXANDER	61 60B 59 59 58 57	PRL 7 346 PR 118 564 PRL 2 117 PR 114 359 NC 8 663 NC 6 478	(IRL) + Sinclair, Brown, Glaser+ (MICH, IRL) + Gilbert, White (IRL) + Caldwell, Frisch, Hill+ (MIT) + Harris, Orear, Lee, Baumel (COLU) + Koch, Lohrmann, Nikolic+ (BERN) + Johnston, Ocealiajeh (DUUC)
FREDEN BURROWES TAYLOR EISENBERG ALEXANDER COHEN	61 60B 59 59 58 57	PRL 7 346 PR 118 564 PRL 2 117 PR 114 359 NC 8 663 NC 6 478 Fund. Cons. Phys.	CRU + Sinclair, Brown, Glaser + (MICH, IRL) + Gilbert, White (IRL) + Caldwell, Frisch, Hill + (MIT) + Harris, Orear, Lee, Baumel (COLU) + Koch, Lohrmann, Nikolic + (BERN) + Johnston, Ocealiaigh (DUUC) + Crowe, Dumond (NAAS, LRL, CIT)
FREDEN BURROWES TAYLOR EISENBERG ALEXANDER COHEN COOMBES BIRGE	61 60B 59 59 58 57	PRL 7 346 PR 118 564 PRL 2 117 PR 114 359 NC 8 663 NC 6 478	(IRL) + Sinclair, Brown, Glaser+ (MICH, IRL) + Gilbert, White (IRL) + Caldwell, Frisch, Hill+ (MIT) + Harris, Orear, Lee, Baumel (COLU) + Koch, Lohrmann, Nikolic+ (BERN) + Johnston, Ocealiajeh (DUUC)
FREDEN BURROWES TAYLOR EISENBERG ALEXANDER COHEN COOMBES	61 60B 59 59 58 57 57	PRL 7 346 PR 118 564 PR 12 117 PR 114 359 NC 8 663 NC 6 478 Fund. Cons. Phys. PR 108 1348	+ Sinclair, Brown, Glaser+ (IRL) + Gilbert, White (MCI, IRL) + Caldwell, Frisch, Hill+ (MIT) + Harris, Orear, Lee, Baumel + Koch, Lohrmann, Nikolic+ (BERN) + Johnston, Oscalialgin (NAS, LRL, CIT) + Crow, Dumond (NAS, LRL, CIT) - Cork, Calibraith, Lambertson, Wenzel
FREDEN BURROWES TAYLOR EISENBERG ALEXANDER COHEN COOMBES BIRGE	61 60B 59 59 58 57 57 57	PRL 7 346 PR 118 564 PRL 2 117 PR 114 359 NC 8 663 NC 6 478 Fund. Cons. Phys. PR 108 1348 NC 4 834 PR 102 927	+ Sinclair, Brown, Glaser+ (RLL) + Gilbert, White (RLL) + Caldwell, Frisch, Hill+ (MT) + Harris, Orear, Lee, Baumel (COLU) + Koch, Lohrmann, Nikolic+ (BERN) - Johnston, Ocealiaigh - Crowe, Dumond (NAAS, LR., CIT) + Cork, Galibraith, Lambertson, Wenzel + Perkins, Peterson, Stork, Whitehead + Goldhaber, Lannutti, Gilbert+ (LRL)
FREDEN BURROWES TAYLOR EISENBERG ALEXANDER COHEN COOMBES BIRGE	61 60B 59 59 58 57 57 57	PRL 7 346 PR 118 564 PRL 2 117 PR 114 359 NC 8 663 NC 6 478 Fund. Cons. Phys. PR 108 1348 NC 4 834 PR 102 927	CRU Honor
FREDEN BURROWES TAYLOR EISENBERG ALEXANDER COHEN COOMBES BIRGE ILOFF	61 60B 59 59 58 57 57 57 56 56	PRL 17 346 PR 118 564 PRL 2 117 PR 114 359 NC 8 663 NC 6 478 Fund. Cons. Phys. PR 108 1348 NC 4 834 PR 102 927 OTHER	+ Sinclair, Brown, Glaser+ (RLL) + Gilbert, White (RLL) + Caldwell, Frisch, Hill+ (MT) + Harris, Orear, Lee, Baumel (COLU) + Koch, Lohrmann, Nikolic+ (BERN) - Johnston, Ocealiaigh - Crowe, Dumond (NAAS, LR., CIT) + Cork, Galibraith, Lambertson, Wenzel + Perkins, Peterson, Stork, Whitehead + Goldhaber, Lannutti, Gilbert+ (LRL)
FREDEN BURROWES TAYLOR EISENBERG ALEXANDER COHEN COOMBES BIRGE ILOFF LITTENBERG Rare and f	61 60B 59 59 58 57 57 57 56 56	PRI 7 346 PR 118 564 PRI 2 117 PR 114 359 NC 8 663 NC 6 478 Fund. Cons. Phys. PR 108 1348 NC 4 834 PR 102 927 OTHER ARNPS 43 729 Ve Kaon Decays	+ Sinciair, Brown, Glaser+ (IRL) + Gilbert, White (IRL) + Caldwell, Frisch, Hill+ (MICH, LRL) + Harris, Orear, Lee, Baumel + Koch, Lohrmann, Nikolic+ (BERN) + Johnston, Ocealiaigh + Crowe, Dumond + Crok, Galbraith, Lambertson, Wenzel + Perkins, Peterson, Stork, Whitehead + Goldhaber, Lannutti, Gilbert+ R RELATED PAPERS + Valencia (BNL, FNAL)
FREDEN BURROWES TAYLOR EISENBERG ALEXANDER COHEN COOMBES BIRGE ILOFF LITTENBERG Rare and f	61 60B 59 59 58 57 57 57 56 56	PRI 7 346 PR 118 564 PRI 2 117 PR 114 359 NC 8 663 NC 6 478 Fund. Cons. Phys. PR 108 1348 NC 4 834 PR 102 927 OTHER ARNPS 43 729 Ve Kaon Decays	+ Sinclair, Brown, Glaser+ (IRL) + Gilbert, White (IRL) + Caldwell, Frisch, Hill+ (MTC) + Harris, Orear, Lee, Baumel + Koch, Lohrmann, Nikolic+ (BERN) + Johnston, Oscaliaigh + Crowe, Dumond + Crock, Galbraith, Lambertson, Wenzel + Perkins, Peterson, Stork, Whitehead + Goldhaber, Lannutti, Gilbert+ (LRL) R RELATED PAPERS
FREDEN BURROWES TAYLOR EISENBERG ALEXANDER COHEN COOMBES BIRGE ILOFF LITTENBERG Rare and IR RITCHIE "Rare Kare	61 60B 59 59 58 57 57 57 56 56 56	PRI 7 346 PR 118 564 PRI 21 117 PR 114 359 NC 8 663 NC 6 478 Fund. Cons. Phys. PR 108 1348 NC 4 834 PR 102 927 OTHER ARNPS 43 729 ve Kaon Decays RMP 55 1149 PRPL 214 293	+ Sinclair, Brown, Glaser+ (IRL) + Gilbert, White (IRL) + Caldwell, Frisch, Hill+ (MIT) + Harris, Orear, Lee, Baumel (COLU) + Koch, Lohrmann, Nikolic+ (BERN) + Johnston, Oceallaigh (DUUC) + Crowe, Dumond (NAAS, LRL, CIT) + Crowe, Dumond + Cork, Galbraith, Lambertson, Wenzel + Perkins, Peterson, Stork, Whitehead + Goldhaber, Lannutti, Gilbert+ (LRL) RELATED PAPERS + Valencia (BNL, FNAL) + Wojcicki + Cocolicchio, Fogli, Paver (PGIA, CERN, TRSTT)
FREDEN BURROWES TAYLOR EISENBERG ALEXANDER COHEN COMBES BIRGE ILOFF LITTENBERG Rare and f RITCHIE "Rare K E BATTISTON Status and	61 60B 59 59 58 57 57 56 56 93 Radiati 93 Decays" 92 Persp	PRI 7 346 PR 118 564 PRI 2 117 PR 114 359 NC 8 663 NC 6 478 Fund. Cons. Phys. PR 108 1348 NC 4 834 PR 102 927 OTHER ARNPS 43 729 ve Kaon Decays RMP 65 1149 PRPL 214 293 sectives of K Decay Phy	+ Sinclair, Brown, Glaser+ (RLL) + Gilbert, White (RIL) + Caldwell, Frisch, Hill+ (MT) + Harris, Orear, Lee, Baumel (COLU) + Koch, Lohrmann, Nikolic+ (BERN) - Hoshnston, Ocealiaigh + Crowe, Dumond (NAAS, LRL, CIT) + Crow, Dumond (NAAS, LRL, CIT) + Crow, Calbraith, Lambertson, Wenzel + Perkins, Peterson, Stork, Whitehead + Goldhaber, Lannutti, Gilbert+ (LRL) R RELATED PAPERS + Valencia (BNL, FNAL) + Wojcicki + Cocolicchio, Fogli, Paver (PGIA, CERN, TRSTT) sics (PGIA, CERN, TRSTT)
FREDEN BURROWES TAYLOR EISENBERG ALEXANDER COHEN COOMBES BIRGE ILOFF LITTENBERG Rare and f RITCHIE "Rare KE BATTISTON Status and BRYMAN	61 60B 59 58 57 57 57 56 56 93 Radiati 93 Decays'' 92 Persp	PRI 7 346 PR 118 564 PRI 2 117 PR 114 359 NC 8 663 NC 6 478 Fund. Cons. Phys. PR 108 1348 NC 4 834 PR 102 927 OTHER ARNPS 43 729 Ve Kaon Decays RMP 65 1149 PRI 293 PRI 293 PR	+ Sinclair, Brown, Glaser+ (IRL) + Gilbert, White (IRL) + Caldwell, Frisch, Hill+ (MT) + Harris, Orear, Lee, Baumel (COLU) + Koch, Lohrmann, Nikolic+ (BERN) - Honston, Ocealiaigh + Crowe, Dumond (NAAS, LR, CIT) + Crow, Dumond (NAAS, LR, CIT) + Crow, Galbraith, Lambertson, Wenzel + Perkins, Peterson, Stork, Whitehead + Goidhaber, Lannutti, Gilbert+ (IRL) R RELATED PAPERS + Valencia (BNL, FNAL) + Wojcicki + Cocolicchio, Fogli, Paver (PGIA, CERN, TRSTT) sics (TRIU)
FREDEN BURROWES TAYLOR EISENBERG ALEXANDER COHEN COOMBES BIRGE ILOFF LITTENBERG Rare and f RITCHIE "Rare KE BATTISTON Status and BRYMAN "Rare KAG CHOUNET	61 60B 59 58 57 57 57 56 56 93 Radiati 93 Decays" 92 Persp 89 n Deca	PRI 7 346 PR 118 564 PRI 2 117 PR 114 359 NC 8 663 NC 6 478 Fund. Cons. Phys. PR 108 1348 NC 4 834 PR 102 927 OTHER ARNPS 43 729 Ve Kaon Decays RMP 65 1149 PREL 214 293 sectives of K Decay Phy LIMP A4 79 sys"	+ Sinclair, Brown, Glaser+ (IRL) + Gilbert, White (IRL) + Caldwell, Frisch, Hill+ (MT) + Harris, Orear, Lee, Baumel (COLU) + Koch, Lohrmann, Nikolic+ (BERN) - Honston, Ocealiaigh + Crowe, Dumond (NAAS, LR, CIT) + Crow, Dumond (NAAS, LR, CIT) + Crow, Galbraith, Lambertson, Wenzel + Perkins, Peterson, Stork, Whitehead + Goidhaber, Lannutti, Gilbert+ (IRL) R RELATED PAPERS + Valencia (BNL, FNAL) + Wojcicki + Cocolicchio, Fogli, Paver (PGIA, CERN, TRSTT) sics (TRIU)
FREDEN BURROWES TAYLOR EISENBERG ALEXANDER COHEN COOMBES BIRGE ILOFF LITTENBERG Rare and I RITCHIE "Rare K E BATTISTON Status and BRYMAN "Rare Kao CHOUNET FEARING	61 60B 59 58 57 57 57 56 56 56 93 Radiati 93 Decays'' 92 Persp 89 n Deca	PRI 7 346 PR 118 564 PRI 2 117 PR 114 359 NC 8 663 NC 6 478 Fund. Cons. Phys. PR 108 1348 NC 4 834 PR 102 927 OTHER ARNPS 43 729 ve Kaon Decays RMP 65 1149 PRPL 214 293 excites of K Decay Phy JMP A4 79 939° PRPL 42 199 PRPL 42 199	+ Sinclair, Brown, Glaser+ (RLL) + Gilbert, White (RLL) + Caldwell, Frisch, Hill+ (MTC) + Caldwell, Frisch, Hill+ (MTC) + Harris, Orear, Lee, Baumel (COLU) + Koch, Lohrmann, Nikolic+ (BERN) + Johnston, Ocealiaigh + Crowe, Dumond (NAAS, LRL, CI) + Crowe, Dumond (NAAS, LRL, CI) + Perkins, Peterson, Stork, Whitehead + Goldhaber, Lannutti, Gilbert+ (LRL) R RELATED PAPERS + Valencia (BNL, FNAL) + Wojcicki + Cocolicchio, Fogli, Paver (PGIA, CERN, TRSTT) sics (TRIU) + Gaillard, Gaillard (ORSAY, CERN) + HSaillard, Gaillard (ORSAY, CERN) + Glader (ORSAY, CERN) + Grider (ORSAY, CERN) - Grider (ORSA
FREDEN BURROWES TAYLOR EISENBERG ALEXANDER COHEN COOMBES BIRGE ILOFF LITTENBERG Rare and f RITCHIE "Rare Ka EATTISTON Status and BEYMAN "Rare Ka CHOUNET FEARING HAIDT	61 60B 59 58 57 57 57 56 56 56 93 Radiati 93 becays" 92 Persp n Decays" 72 70 69B	PRI 7 346 PR 118 564 PRI 21 117 PR 114 359 NC 8 663 NC 6 478 Fund. Cons. Phys. PR 108 1348 NC 4 834 PR 102 927 OTHER ARNPS 43 729 Ve Kaon Decays RMP 65 1149 PRPL 214 293 sectives of K Decay Phy LIMP A4 79 NS 49 PRPL 214 293 PRPL 214 293 PRPL 214 61 199 PR D2 542 PL 298 696	+ Sinclair, Brown, Glaser+ (IRL) + Gilbert, White + Caldwell, Frisch, Hill+ (IRL) + Caldwell, Frisch, Hill+ (MTCH, IRC) + Caldwell, Frisch, Hill+ (MTCH, IRC) + Caldwell, Frisch, Hill+ (MTCH, IRC) + Hohnston, Ocealiaigh (COLU) + Corwe, Dumond (NAAS, LRL, CIT) + Crowe, Dumond (REC) + Perkins, Peterson, Stork, Whitehead + Goldhaber, Lannutti, Gilbert+ (LRL) R RELATED PAPERS + Valencia (BNL, FNAL) + Wojcicki + Cocolicchio, Fogli, Paver (PGIA, CERN, TRSTT) sics (TRIU) + Gaillard, Gaillard (ORSAY, CERN) + Fischbach, Smith (STON, BOHR) + KACH, BARI, CERN, EPOL, NUM, ORSAY+)
FREDEN BURROWES TAYLOR EISENBERG ALEXANDER COHEN COOMBES BIRGE ILOFF LITTENBERG Rare and f RITCHIE "Rare Ka EATTISTON Status and BEYMAN "Rare Ka CHOUNET FEARING HAIDT CRONIN Rapporteur Rapporteur	61 60B 59 59 58 57 57 57 56 56 93 Radiati 93 Persys" 92 Persys 89 n Decays" 70 69B 68B 68B 68B	PRI 7 346 PRI 18 564 PRI 2 117 PRI 118 564 PRI 2 117 PRI 114 359 NC 8 663 NC 6 478 Fund. Cons. Phys. PRI 108 1348 NC 4 834 PRI 102 927 OTHER ARNPS 43 729 ve Kaon Decays RMP 65 1149 PRED 214 293 sectives of K Decay Phy LIMP A4 79 PRED 41 493 PRED 242 LIMP A4 79 PRED 41 199 PR D2 542 PL 298 696 Vienna Conf. 241	+ Sinclair, Brown, Glaser+ (IRL) + Gilbert, White + Caldwell, Frisch, Hill+ (IRL) + Caldwell, Frisch, Hill+ (MIT) + Harris, Orear, Lee, Baumel (COLU) + Koch, Lohrmann, Nikolic+ (BERN) + Johnston, Ocealiaigh (DUUC) + Crowe, Dumond + Cork, Galbraith, Lambertson, Wenzel + Perkins, Peterson, Stork, Whitehead + Goldhaber, Lannutti, Gilbert+ (IRL) RELATED PAPERS + Valencia (BNL, FNAL) + Wojcicki + Cocolicchio, Fogli, Paver (PGIA, CERN, TRSTT) sics (TRIU) + Gaillard, Gaillard (ORSAY, CERN) + Fischbach, Smith + (AACH, BARI, CERN, EPOL, NIJM, ORSAY+) (PRIN)
FREDEN BURROWES TAYLOR EISENBERG ALEXANDER COHEN COOMBES BIRGE ILOFF LITTENBERG RITCHIE BATTISTON STATUS AND STATUS AND FRANCH HADT CRONIN RAPPORTEUR RIPER RITCHIE BATTISTON STATUS AND RYMAN "Grave K.E BATTISTON TRAVE RAPPORTEUR RAPPORTEUR RAPPORTEUR RAPPORTEUR RAPPORTEUR RUILLIS	61 60B 59 59 58 57 57 57 56 56 93 Radiati 93 Decays" 92 Persp 89 90 60B 68B talk.	PRI 7 346 PR 118 564 PRI 21 117 PR 114 359 NC 8 663 NC 6 478 Fund. Cons. Phys. PR 108 1348 NC 4 834 PR 102 927 OTHER ARNPS 43 729 Ve Kaon Decays RMP 65 1149 PRPL 214 293 sectives of K Decay Phy LIMP A4 79 NS 49 PRPL 214 293 PRPL 214 293 PRPL 214 61 199 PR D2 542 PL 298 696	+ Sinclair, Brown, Glaser+ (IRL) + Gilbert, White + Caldwell, Frisch, Hill+ (IRL) + Caldwell, Frisch, Hill+ (MTCH, IRC) + Caldwell, Frisch, Hill+ (MTCH, IRC) + Caldwell, Frisch, Hill+ (MTCH, IRC) + Hohnston, Ocealiaigh (COLU) + Corwe, Dumond (NAAS, LRL, CIT) + Crowe, Dumond (REC) + Perkins, Peterson, Stork, Whitehead + Goldhaber, Lannutti, Gilbert+ (LRL) R RELATED PAPERS + Valencia (BNL, FNAL) + Wojcicki + Cocolicchio, Fogli, Paver (PGIA, CERN, TRSTT) sics (TRIU) + Gaillard, Gaillard (ORSAY, CERN) + Fischbach, Smith (STON, BOHR) + KACH, BARI, CERN, EPOL, NUM, ORSAY+)
FREDEN BURROWES TAYLOR EISENBERG ALEXANDER COHEN COOMBES BIRGE ILOFF LITTENBERG Rare and if RITCHIE K BATTISTON STATUS BATTISTON HAIDT CRONIN RAPPORTEUR WILLIS RAPPORTEUR CABIBBO	61 60B 59 59 58 57 57 57 56 56 93 Radiati 93 Decays" 92 Persp 89 90 60B 68B talk.	PRI 7 346 PR 118 564 PRI 2 117 PR 118 359 NC 8 663 NC 6 478 Fund. Cons. Phys. PR 108 1348 NC 4 834 PR 102 927 OTHEF ARNPS 43 729 ve Kaon Decays RMP 65 1149 PRPL 214 293 Very RMP 65 1149 PRPL 214 293 PRPL 4C 199 PRPL 25 42 PL 298 696 Vienna Conf. 241 Heidelberg Conf. 273 Berkeley Conf. 33	+ Sinclair, Brown, Glaser+ (IRL) + Gilbert, White (IRL) + Gilbert, White (IRL) + Caldwell, Frisch, Hill+ (MIT) + Harris, Orear, Lee, Baumel (COLU) + Koch, Lohrmann, Nikolic+ (BERN) + Johnston, Ocealiaigh + Crowe, Dumond (NAAS, LR, CIT) + Crow, Dumond (NAAS, LR, CIR) + Perkins, Peterson, Stork, Whitehead + Goldhaber, Lannutti, Gilbert+ (IRL) R RELATED PAPERS + Valencia (BNL, FNAL) + Wojcicki + Cocolicchio, Fogli, Paver (PGIA, CERN, TRSTT) sics (TRIU) + Gaillard, Gaillard (ORSAY, CERN) + Fischbach, Smith (ACH, BARI, CERN, EPOL, NIJM, ORSAY+) (PRIN) (YALE) (CERN)
FREDEN BURROWES TAYLOR EISENBERG ALEXANDER COHEN COOMBES BIRGE ILOFF LITTENBERG Rare and f RITCHIE "Rare Ka EATTISTON Status and BPYMAN "Rare Ka CHOUNET FEARING HAIDT CRONIN Rapporteur WILLIS Rapporteur CABIBBO ADAIR	61 60B 59 59 59 57 57 57 56 56 93 Radiati 93 90ecays" 92 Persp 68B 68B talk. 66 67 talk. 66 64	PRI 7 346 PR 118 564 PRI 2 117 PR 118 359 NC 8 663 NC 6 478 Fund. Cons. Phys. PR 108 1348 NC 4 834 PR 102 927 OTHER ARNPS 43 729 ve Kaon Decays RMP 65 1149 PRI 12 293 LIMP A4 79 ays" PRI 12 493 LIMP A4 79 BY RD 2 542 PL 298 696 Vienna Conf. 241 Heidelberg Conf. 273 Berkeley Conf. 33 PRI 21 12 67	+ Sinclair, Brown, Glaser+ + Gilbert, White + Caldwell, Frisch, Hill+ + Harris, Orear, Lee, Baumel + Hormann, Nikolic+ + Johnston, Ocealiaigh + Crowe, Dumond + Cork, Galbraith, Lambertson, Wenzel + Perkins, Peterson, Stork, Whitehead + Goldhaber, Lannutti, Gilbert+ R RELATED PAPERS + Valencia + Wojcicki + Cocolicchio, Fogli, Paver sics + Gaillard, Gaillard + Fischbach, Smith + (AACH, BARI, CERN, EPOL, NIJM, ORSAY+, (PRIN) (YALE) + Celipuner + Leipuner
FREDEN BURROWES TAYLOR EISENBERG ALEXANDER COHEN COOMBES BIRGE ILOFF LITTENBERG Rare and if RITCHIE BATTSTON BRYMAN BRYMAN BRYMAN CHOUNET FEARING HAIDT CRONIN Rapporteur WILLIS RAPPORTEUR CABIBBO ADAIR CABIBBO	61 60B 59 59 58 57 57 57 56 56 56 93 Radiatt 93 92 Persp n Decays" 72 70 69B 68B talk. 67 talk. 66 64 64	PRI 7 346 PR 118 564 PRI 2 117 PR 118 359 NC 8 663 NC 6 478 Fund. Cons. Phys. PR 108 1348 NC 4 834 PR 102 927 OTHEF ARNPS 43 729 Ve Kaon Decays RMP 65 1149 PRPL 214 293 Very RA 67 92 PRPL 4C 199 PRPL 214 293 Very RA 67 92 Very RA 67 93 Ver	+ Sinclair, Brown, Glaser+ (IRL) + Gilbert, White (IRL) + Gilbert, White (IRL) + Caldwell, Frisch, Hill+ (MIT) + Harris, Orear, Lee, Baumel (COLU) + Koch, Lohrmann, Nikolic+ (BERN) + Johnston, Ocealiaigh + Corwe, Dumond (NAAS, LR, CIL) + Crowe, Dumond (NAAS, LR, CIL) + Cork, Galbraith, Lambertson, Wenzel + Perkins, Peterson, Stork, Whitehead + Goidhaber, Lannutti, Gilbert+ (IRL) **RELATED PAPERS** + Valencia (BNL, FNAL) + Wojcicki + Cocolicchio, Fogli, Paver (PGIA, CERN, TRSTT) sics (TRIU) + Gaillard, Gaillard (ORSAY, CERN) + Fischbach, Smith (STON, BORN) + (AACH, BARI, CERN, EPOL, NIJM, ORSAY+) (PRIN) (YALE) + Leipuner (YALE, BNL) + Maksymowicz (CERN)
FREDEN BURROWES TAYLOR EISENBERG ALEXANDER COHEN COOMBES BIRGE ILOFF LITTENBERG Rare and f RITCHIE "Rare Ka EATTISTON Status and BPYMAN "Rare Ka CHOUNET FEARING HAIDT CRONIN Rapporteur WILLIS Rapporteur CABIBBO ADAIR	61 60B 59 59 59 57 57 57 56 56 93 Radiati 93 90ecays" 92 Persp 68B 68B talk. 66 67 talk. 66 64	PRI 7 346 PR 118 564 PRI 2 117 PR 118 359 NC 8 663 NC 6 478 Fund. Cons. Phys. PR 108 1348 NC 4 834 PR 102 927 OTHEF ARNPS 43 729 ve Kaon Decays RMP 65 1149 PRPL 214 293 vertives of K Decay Phy JIMP A4 79 ys" PRPL 4C 199 PR D2 542 PL 298 696 Vienna Conf. 241 Heidelberg Conf. 273 Berkeley Conf. 33 PL 12 67 PL 14 79 PL 14 79	+ Sinclair, Brown, Glaser+ (IRL) + Gilbert, White (IRL) + Gilbert, White (IRL) + Caldwell, Frisch, Hill+ (MIT) + Harris, Orear, Lee, Baumel (COLU) + Hohnston, Ocealiaigh + Johnston, Ocealiaigh + Crowe, Dumond (NAAS, LR, CIRL) + Crow, Dumond (NAAS, LR, CIRL) + Crow, Dumond (NAAS, LR, CIRL) + Crow, Calbraith, Lambertson, Wenzel + Perkins, Peterson, Stork, Whitehead + Goldhaber, Lannutti, Gilbert+ R RELATED PAPERS + Valencia (BNL, FNAL) + Wojcicki + Cocolicchio, Fogli, Paver (PGIA, CERN, TRSTT) sics (TRIU) + Gaiilard, Gaiilard (ORSAY, CERN, CSTON, BOH) + (AACH, BARI, CERN, EPOL, NIJM, ORSAY+) + (AACH, BARI, CERN, EPOL, NIJM, ORSAY+) + Leipuner + Maksymowicz (CERN) - Cabibbo, Maksymowicz (CERN) - Cabibbo, Maksymowicz (CERN) - Cabibbo, Maksymowicz (CERN) - CAIRL (CCIRN) - CERN (CERN) - CABICA (CERN) - CABI
FREDEN BURROWES TAYLOR EISENBERG ALEXANDER COHEN COOMBES BIRGE ILOFF LITTENBERG Rare and f RITCHIE "Rare Ka EATTISTON Status and BRYMAN "Rare Ka CHOUNET FEARING HAIDT CRONIN Rapporteur WILLIS Rapporteur CABIBBO ADAIR CABIBBO AISO AISO BIRGE	61 60B 59 59 58 57 57 57 56 56 56 93 Radiati 93 92 Persp 92 Persp 68B 68B 67 talk. 66 64 64 64 64 64 65 63	PRI 7 346 PRI 118 564 PRI 2 117 PRI 118 359 NC 8 463 NC 6 478 Fund. Cons. Phys. PRI 108 1348 NC 4 834 PRI 102 927 OTHER ARNPS 43 729 ve Kaon Decays RMP 65 1149 PRI 102 4293 sectives of K Decay Phy IJMP A4 79 PSPRI 42 199 PR D2 542 PL 298 696 Vienna Conf. 241 Heidelberg Conf. 273 Berkeley Conf. 33 PL 12 67 PL 9 352 PL 12 67 PL 9 352 PL 11 360 PL 14 72 PRI 11 35	+ Sinclair, Brown, Glaser+ (IRL) + Gilbert, White (IRL) + Gilbert, White (IRL) + Caldwell, Frisch, Hill+ (MIT) + Harris, Orear, Lee, Baumel (COLU) + Hohnston, Ocealiaigh + Johnston, Ocealiaigh + Crowe, Dumond (NAAS, LR, CIRL) + Crow, Dumond (NAAS, LR, CIRL) + Crow, Dumond (NAAS, LR, CIRL) + Crow, Calbraith, Lambertson, Wenzel + Perkins, Peterson, Stork, Whitehead + Goldhaber, Lannutti, Gilbert+ R RELATED PAPERS + Valencia (BNL, FNAL) + Wojcicki + Cocolicchio, Fogli, Paver (PGIA, CERN, TRSTT) sics (TRIU) + Gaiilard, Gaiilard (ORSAY, CERN, CSTON, BOH) + (AACH, BARI, CERN, EPOL, NIJM, ORSAY+) + (AACH, BARI, CERN, EPOL, NIJM, ORSAY+) + Leipuner + Maksymowicz (CERN) - Cabibbo, Maksymowicz (CERN) - Cabibbo, Maksymowicz (CERN) - Cabibbo, Maksymowicz (CERN) - CAIRL (CCIRN) - CERN (CERN) - CABICA (CERN) - CABI
FREDEN BURROWES TAYLOR EISENBERG ALEXANDER COHEN COOMBES BIRGE ILOFF LITTENBERG Rare and IR RITCHIE "Rare Kall Status and STATUS ON THE COMMENT OF THE COMMENT OF THE COMMENT OF THE COMMENT OF THE CABIBBO ADAIR CABIBBO ADAIR CABIBBO AISO BIRGE BLOCK	61 60B 59 59 58 57 57 57 57 56 56 56 93 Radiati 93 Perspa 89 70 68B talk. 66 67 talk. 66 64 64 64 64 65	PRI 7 346 PR 118 564 PRI 2 117 PR 118 359 NC 8 663 NC 6 478 Fund. Cons. Phys. PR 108 1348 NC 4 834 PR 102 927 OTHEF ARNPS 43 729 ve Kaon Decays RMP 65 1149 PRPL 214 293 vertives of K Decay Phy JIMP A4 79 sys" PRPL 4C 199 PR D2 542 PL 298 696 Vienna Conf. 241 Heidelberg Conf. 273 Berkeley Conf. 33 PL 12 67 PL 14 79 PL 11 360 PL 14 72 PRL 11 350 PL 11 72 PRL 11 350 PR 11 1350 PR 11 11 11 11 11 11 11 11 11 11 11 11 11	+ Sinclair, Brown, Glaser+ (IRL) + Gilbert, White (IRL) + Gilbert, White (IRL) + Caldwell, Frisch, Hill+ (MIT) + Harris, Orear, Lee, Baumel (COLU) + Koch, Lohrmann, Nikolic+ (BERN) + Johnston, Ocealiaigh + Crowe, Dumond (NAAS, LR, CIL) + Crow, Dumond (NAAS, LR, CIL) + Crow, Calbraith, Lambertson, Wenzel + Perkins, Peterson, Stork, Whitehead + Goldhaber, Lannutti, Gilbert+ (IRL) **RELATED PAPERS** + Valencia (BNL, FNAL) + Wojcicki + Cocolicchio, Fogli, Paver (PGIA, CERN, TRSTT) sics (TRIU) + Gaillard, Gaillard (ORSAY, CERN) + Fischbach, Smith (STON, BOHR) + (AACH, BARI, CERN, EPOL, NIJM, ORSAY+) + (AACH, BARI, CERN, EPOL, NIJM, ORSAY+) + Leipiuner + Maksymowicz (CERN) - Cabibbo, Maksymowicz - Cabibbo,
FREDEN BURROWES TAYLOR EISENBERG ALEXANDER COHEN COOMBES BIRGE ILOFF LITTENBERG Rare and f RITCHIE "Rare Ka EATTISTON Status and BRYMAN "Rare Ka CHOUNET FEARING HAIDT CRONIN Rapporteur WILLIS Rapporteur CABIBBO ADAIR CABIBBO AISO AISO BIRGE	61 60B 59 59 58 57 57 57 56 56 56 93 Radiati 93 ecays'' 77 69B 68B talk. 64 64 64 64 64 64 64 64 65 63 63 63	PRI 7 346 PRI 118 564 PRI 2 117 PRI 118 359 NC 8 463 NC 6 478 Fund. Cons. Phys. PRI 108 1348 NC 4 834 PRI 102 927 OTHER ARNPS 43 729 ve Kaon Decays RMP 65 1149 PRI 102 4293 sectives of K Decay Phy IJMP A4 79 PSPRI 42 199 PR D2 542 PL 298 696 Vienna Conf. 241 Heidelberg Conf. 273 Berkeley Conf. 33 PL 12 67 PL 9 352 PL 12 67 PL 9 352 PL 11 360 PL 14 72 PRI 11 35	+ Sinclair, Brown, Glaser+ (IRL) + Gilbert, White (IRL) + Gilbert, White (IRL) + Caldwell, Frisch, Hill+ (MIT) + Harris, Orear, Lee, Baumel (COLU) + Hohnston, Ocealiaigh + Johnston, Ocealiaigh + Crowe, Dumond (NAAS, LR, CIRL) + Crow, Dumond (NAAS, LR, CIRL) + Crow, Dumond (NAAS, LR, CIRL) + Crow, Calbraith, Lambertson, Wenzel + Perkins, Peterson, Stork, Whitehead + Goldhaber, Lannutti, Gilbert+ R RELATED PAPERS + Valencia (BNL, FNAL) + Wojcicki + Cocolicchio, Fogli, Paver (PGIA, CERN, TRSTT) sics (TRIU) + Gaiilard, Gaiilard (ORSAY, CERN, CSTON, BOH) + (AACH, BARI, CERN, EPOL, NIJM, ORSAY+) + (AACH, BARI, CERN, EPOL, NIJM, ORSAY+) + Leipuner + Maksymowicz (CERN) - Cabibbo, Maksymowicz (CERN) - Cabibbo, Maksymowicz (CERN) - Cabibbo, Maksymowicz (CERN) - CAIRL (CCIRN) - CERN (CERN) - CABICA (CERN) - CABI



$$I(J^P) = \frac{1}{2}(0^-)$$

KO MASS

VALUE	(MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
497.67	2±0.031 OUR FI	Т				
497.67	72±0.031 OUR A	/ERAGE				
497.66	61 ± 0.033	3713	BARKOV	87B	CMD	$e^+e^- \rightarrow \kappa_I^0 \kappa_S^0$
497.74	12±0.085	780	BARKOV	85B	CMD	$e^+e^- \rightarrow K_I^0 K_S^0$ $e^+e^- \rightarrow K_I^0 K_S^0$
• • •	We do not use th	e following d	lata for averages	, fits	, limits,	etc. • • •
497.44	±0.50		FITCH	67	OSPK	
498.9	± 0.5	4500	BALTAY			K^0 from $\overline{p}p$
497.44	± 0.33	2223	KIM	65 B	HBC	K^0 from $\overline{p}p$
498.1	± 0.4		CHRISTENS	64	OSPK	

$m_{K^0} - m_{K^\pm}$

VALUE (MeV) 3.995±0.034 OUR FIT	Error inc		of 1.1.	CHG	COMMENT
• • We do not use t	he followin	g data for average	s, fits, limits	, etc. 🛭	• •
3.95 ± 0.21	417	HILL	68B DBC	+	$K^+ d \rightarrow K^0 pp$
3.90 ±0.25	9	BURNSTEIN	65 HBC	-	
3.71 ± 0.35	7	KIM	65B HBC		$K^- p \rightarrow n \overline{K}^0$
5.4 ±1.1		CRAWFORD	59 HBC	+	
3.9 ±0.6		ROSENFELD	59 HBC	-	

$|m_{K^0} - m_{\overline{K}^0}| / m_{\text{average}}$

A test of CPT invariance.

VALUE DOCUMENT ID

$< 9 \times 10^{-19}$ OUR EVALUATION

K⁰ REFERENCES

BARKOV	87B	SJNP 46 630 Translated from	+Vasserman, Vorobev, Ivanov+	(NOVO)
BARKOV	85B	JETPL 42 138	+Blinov, Vasserman+ ZETFP 42 113.	(NOVO)
HILL	68B	PR 168 1534	+Robinson, Sakitt, Canter	(BNL, CMU)
FITCH	67	PR 164 1711	+Roth, Russ, Vernon	(PRIN)
BALTAY	66	PR 142 932	+Sandweiss, Stonehill+	(YALE, BNL)
BURNSTEIN	65	PR 138B 895	+Rubin	` (UMD)
KIM	65B	PR 140B 1334	+Kirsch, Miller	(COLU)
CHRISTENS	64	PRL 13 138	Christenson, Cronin, Fitch, Turlay	(PRIN)
CRAWFORD	59	PRL 2 112	+Cresti, Good, Stevenson, Ticho	(LRL)
ROSENFELD	59	PRL 2 110	+Solmitz, Tripp	(LRL)



$$I(J^P) = \frac{1}{2}(0^-)$$

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KO MEAN LIFE

For earlier measurements, beginning with BOLDT 58B, see our our 1986 edition, Physics Letters **170B** 130 (1986).

OUR FIT is described in the note on "CP Violation in K_L^0 Decay" in the K_I^0 Particle Listings.

VALUE (10 ⁻¹⁰ s)	EVTS	DOCUMENT ID		TECN	COMMENT
0.8927±0.0009 OL	JR FIT				
0.8932±0.0010 OL	JR AVERAC	iΕ			
$0.8941 \pm 0.0014 \pm 0$.0009	SCHWINGEN.	95	E773	Δm free, $\phi_{+-} = \phi_{SW}$
0.8929 ± 0.0016		GIBBONS	93	E731	,
0.8920 ± 0.0044	214k	GROSSMAN	87	SPEC	
0.881 ±0.009	26k	ARONSON	76	SPEC	
0.8913 ± 0.0032		¹ CARITHERS	75	SPEC	
0.8937 ± 0.0048	6M	GEWENIGER	74B	ASPK	
0.8958 ± 0.0045	50k	2 SKJEGGEST	. 72	HBC	
• • • We do not u	se the follo	wing data for averag	ges, f	its, limit	ts, etc. • • •
0.905 ±0.007		3 ARONSON	82B	SPEC	
0.867 ±0.024	2173	⁴ FACKLER	73	OSPK	
0.856 ±0.008	19994	⁵ DONALD	68B	нвс	
0.872 ± 0.009	20000	5,6 HILL	68	DBC	
0.866 ± 0.016		⁵ ALFF	66B	OSPK	
0.843 ± 0.013	5000	⁵ KIRSCH	66	HBC	

^{.843} ± 0.013 5000 First-H 66 HBC 1-CARITHERS 75 value is for $m_{\tilde{K}_L^0} - m_{\tilde{K}_S^0}$ $\Delta m = 0.5348 \pm 0.0021$. The Δm dependence of the total decay rate (inverse mean life) is $\Gamma(K_S^0) = [(1.122 \pm 0.004) + 0.16(\Delta m - 0.5348)/\Delta m] 10^{10}/s$. Value would not change significantly with our current $\Delta m = 0.5304 \pm 0.0014$. PHILL 68 has been changed by the authors from the published value (0.865 \pm 0.009) because of a correction in the shift due to η_{+-} . SKJEGGESTAD 72 and HILL 68 give detailed discussions of systematics encountered in this type of experiment. ARONSON 82 find that K_S^0 mean life may depend on the kaon energy.

- $^{
 m 4}\,{\sf FACKLER}$ 73 does not include systematic errors.
- ⁵ Pre-1971 experiments are excluded from the average because of disagreement with later more precise experiments.
- because of a correction in the shift due to η_{+-} . SKJEGGESTAD 72 and HILL 68 give detailed discussions of systematics encountered in this type of experiment.

KO DECAY MODES

	Mode	Fraction (Γ_j/Γ)	Scale factor/ Confidence level
Γ ₁	$\pi^+\pi^-$	(68.61±0.28) %	S=1.2
Γ_2	$\pi^{0} \pi^{0}$	(31.39 ± 0.28) %	S=1.2
Гз	$\pi^+\pi^-\gamma$	$[a,b]$ $(1.78\pm0.05)\times10^{-3}$	3
Γ_4	$\gamma \gamma$	$(2.4 \pm 0.9) \times 10^{-6}$	5
Γ_5	$\pi^+\pi^-\pi^0$	$(3.9 \ ^{+5.5}_{-1.9}) \times 10^{-1}$	7
Γ_6	$3\pi^{0}$	< 3.7 × 10 ⁻¹	5 CL=90%
Γ ₇	$\pi^{\pm}e^{\mp} u$	[c] $(6.70\pm0.07)\times10^{-4}$	s=1.3
Γ8	$\pi^{\pm} \mu^{\mp} \nu$	[c] $(4.69\pm0.06)\times10^{-4}$	\$ =1.2
		A C - 1 week neutral current (C1) modes	

$\Delta S = 1$ weak neutral current (S1) modes

Γ9	$\mu^+\mu^-$	51	< 3.2	$\times 10^{-7}$	CL=90%
Γ_{10}	e^+e^-	S1	< 2.8	\times 10 ⁻⁶	CL=90%
	$\pi^0 e^+ e^-$	51	< 1.1	\times 10 ⁻⁶	CL=90%

- [a] See the Particle Listings below for the energy limits used in this measure-
- [b] Most of this radiative mode, the low-momentum γ part, is also included in the parent mode listed without γ 's.
- [c] Calculated from K^0_I semileptonic rates and the K^0_S lifetime assuming ΔS

CONSTRAINED FIT INFORMATION

An overall fit to 3 branching ratios uses 17 measurements and one constraint to determine 2 parameters. The overall fit has a χ^2 = 16.5 for 16 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv$ $\Gamma_i/\Gamma_{
m total}$. The fit constrains the x_i whose labels appear in this array to sum to

$$x_2 \quad \boxed{-100}{x_1}$$

KS DECAY RATES

$\Gamma(\pi^{\pm}e^{\mp} u)$					Γ7
VALUE (10 ⁶ s ⁻¹)	DOCUMENT ID)	TECN	COMMENT	
7.50 ± 0.08 OUR EVALUATION	Error includes so	ale fac	tor of 1	.1. From κ_L^0 measure	<u>-</u> -
				$\stackrel{\cdot}{\underset{L}{\circ}} \Delta Q$ in $\stackrel{\kappa}{K^0}$ decay so $\stackrel{0}{\underset{L}{\circ}} \rightarrow \pi^{\pm} e^{\mp} \nu_e$).	that
• • We do not use the following	ng data for averag	es, fits	s, limits,	etc. • • •	
seen	BURGUN	72	нвс	$K^+ p \rightarrow K^0 p \pi^+$	
9.3 ±2.5	AUBERT	65	HLBC	$\Delta S = \Delta Q$, <i>CP</i> cons. assumed	not
$\Gamma(\pi^{\pm}\mu^{\mp} u)$					Γ8
VALUE (10 ⁶ s ⁻¹)	DOCUMENT ID				
5.25 ± 0.07 OUR EVALUATION	Error includes sc	ale fac	tor of 1	.1. From K_I^0 measure	<u>.</u> -
				ΔQ in K^0 decay so $0 \to \pi^\pm \mu^\mp u$).	that

K⁰ BRANCHING RATIOS

$\Gamma(\pi^+\pi^-)/\Gamma_{ m total}$					Γ_1/Γ
VALUE	<u>EVTS</u>	DOCUMENT ID	<u>TECN</u>	COMMENT	
0.6861 ± 0.0028 OU	R FIT Error	includes scale fact	tor of 1.2.		
0.671 ±0.010 OU	R AVERAGE				
0.670 ± 0.010	3447	⁷ DOYLE	69 HBC	$\pi^- p \rightarrow \Lambda K^0$	
0.70 ±0.08		COLUMBIA	60B HBC		
0.68 ± 0.04		CRAWFORD	598 HBC		
• • • We do not us	se the followir	ng data for average	es, fits, limits,	etc. • • •	
0.740 ±0.024		7 ANDERSON	62B HBC		

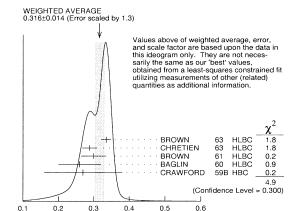
⁷ Anderson result not published, events added to Doyle sample.

$\Gamma(\pi^+\pi^-)/\Gamma(\pi^0\pi^0)$	EVTS	DOCUMENT ID		TECN	COMMENT	Γ_1/Γ_2
2.186 ± 0.028 OUR FIT			of 1		COMMENT	
2.197±0.026 OUR AVE		merades scare ractor	01 1.	۷.		
2.11 ±0.09	1315	EVERHART	76	WIRE	$\pi^- p \rightarrow \Lambda K^0$	
2.169±0.094	16k	COWELL			$\pi^- p \rightarrow \Lambda K^0$	
2.16 ±0.08	4799	HILL	73	DBC	$K^+ d \rightarrow K^0 pp$	
2.22 ±0.10	3068	⁸ ALITTI	72	HBC	$K^+ \rho \rightarrow \pi^+ \rho K$	0
2.22 ±0.08	6380	MORSE	72B	DBC	$K^+ n \rightarrow K^0 p$	
2.10 ±0.11	701	9 NAGY	72	HLBC	$K^+ n \rightarrow K^0 p$	
2.22 ±0.095	6150	¹⁰ BALTAY	71	HBC	$Kp \rightarrow K^0$ neutr	als
2.282 ± 0.043	7944	11 MOFFETT	70	OSPK	$K^+ n \rightarrow K^0 p$	
2.10 ±0.06	3700	MORFIN	69	HLBC	$K^+ n \rightarrow K^0 p$	
 ◆ ◆ We do not use th 	e follov	ving data for averages	, fits	, limits,	etc. • • •	
2.12 ±0.17	267	9 BOZOKI	69	HLBC		
2.285 ± 0.055	3016	¹¹ GOBBI	69	OSPK	$K^+ n \rightarrow K^0 p$	
⁸ The directly measur	ed quar	itity is $K_c^0 \rightarrow \pi^+\pi^-$	-/all	$\kappa^0 = 0$	0.345 ± 0.005.	
9 NAGY 72 is a final i						

The directly measured quantity is $K_S^0 \to \pi^+\pi^-/\text{all } \overline{K}^0 = 0.345 \pm 0.005$.

 $^{11}\,\mathrm{MOFFETT}$ 70 is a final result which includes GOBBI 69.

Γ(π ⁰	$\pi^0)/\Gamma_{tot}$	tal			Γ_2/Γ
VALUE	-	EVTS	DOCUMENT ID	TECN	
0.3139	± 0.0028	OUR FIT Error	includes scale fact	or of 1.2.	
0.316	±0.014	OUR AVERAGE	Error includes so below.	ale factor of 1.3.	See the ideogram
0.335	± 0.014	1066	BROWN	63 HLBC	
0.288	± 0.021	198	CHRETIEN	63 HLBC	
0.30	± 0.035		BROWN	61 HLBC	
0.26	± 0.06		BAGLIN	60 HLBC	
0.27	±0.11		CRAWFORD	59B HBC	



VALUE (units 10-3)	EVTS	DOCUMENT ID		TECN	COL	MMENT	
2.60±0.08 OUR AVI	RAGE						
2.56 ± 0.09	1286	RAMBERG	93	E731	p_{γ}	>50 MeV/c	
2.68±0.15		¹² TAUREG	76	SPEC	p_{γ}	>50 MeV/c	
2.8 ±0.6		¹³ BURGUN	73	HBC	p_{γ}	>50 MeV/c	
3.3 ±1.2	10	WEBBER	70	HBC	p_{γ}	>50 MeV/c	
no ratio given	27	BELLOTTI	66	HBC	P~	>50 MeV/c	
• • • We do not use	the follow	ing data for averag	es, fit	s, limits,	etc.		
7.10 ± 0.22	3723	RAMBERG	93	E731	p_{γ}	>20 MeV/c	
3.0 ±0.6	29	14 BOBISUT	74	HLBC		>40 MeV/c	

 $\Gamma(\pi^0\pi^0)/\Gamma_{\text{total}}$

 12 TAUREG 76 find direct emission contribution <0.06, CL = 90%. 13 BURGUN 73 estimates that direct emission contribution is 0.3 \pm 0.6. 14 BOBISUT 74 not included in average because ρ_{γ} cut differs. Estimates direct emission contribution to be 0.5 or less, CL = 95%.

 K_S^0

'ALUE (units 10 ⁻⁶)	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
2.4±0.9		35	¹⁵ BARR	95B	NA31	
• • We do not u	se the foll	owing	data for averages, fit	ts, lim	its, etc	. • • •
2.2 ± 1.1		16	¹⁶ BARR	95B	NA31	
< 13	90		BALATS	89	SPEC	
2.4 ± 1.2		19	BURKHARDT	87	NA31	
< 133	90		BARMIN	86B	XEBC	
< 200	90		VASSERMAN	86	CALO	$\phi \rightarrow K_s^0 K_l^0$
< 400	90	0	BARMIN	73B	HLBC	<i>J L</i>
< 710	90	0	¹⁷ BANNER	72B	OSPK	
< 2000	90	0	MORSE	72B	DBC	
< 2200	90	0	¹⁷ REPELLIN	71	OSPK	
<21000	90	0	¹⁷ BANNER	69	OSPK	

 15 BARR 95B quotes this as the combined BARR 95B + BURKHARDT 87 result after rescaling BURKHARDT 87 to use same branching ratios and lifetimes as BARR 95B. 16 BARR 95B result is calculated using B($K_L \rightarrow \gamma \gamma$) = (5.86 \pm 0.17) \times 10 $^{-4}$.

<490 90 ¹⁹ BARMIN 85 HLBC <850 90 METCALF 72 ASPK

18 THOMSON 94 calculates this branching ratio from their measurements $|\rho_{+-0}| = 0.035^{+}_{-0.011} \pm 0.004$ and $\phi_{\rho} = (-59 \pm 48)^{\circ}$ where $|\rho_{+-0}| e^{i\phi_{\rho}} = A(K_S^0 \to \pi^+\pi^-\pi^0, 1 + 2)/A(K_L^0 \to \pi^+\pi^-\pi^0)$.

19 BARMIN 85 assumes that CP-allowed and CP-violating amplitudes are equally suppressed.

VALUE (units 10 ⁻⁵)	CL%	DOCUMENT I	D	TECN
< 0.032	90	GJESDAL	73	ASPK
• • • We do not use	the followi	ng data for avera	ges, fits,	limits, etc. • • •
<14	90	вонм	69	OSPK
< 0.7	90	HYAMS	69B	OSPK
<22	90	²⁰ STUTZKE	69	OSPK
< 7	90	BOTT	67	OSPK
²⁰ Value calculated I	by us, using	2.3 instead of 1	event, 9	0% CL.

 $\Gamma(e^+e^-)/\Gamma_{total} \qquad \qquad \Gamma_{10}/\Gamma_{total} \qquad \Gamma_{10}/\Gamma_{total} \qquad \qquad \Gamma_{10$

VALUE (units 10	0 ⁻⁵) CL% L	EVTS	DOCUMENT ID		TECN	COMMENT
< 0.28	90	0	BLICK	94	CNTR	Hyperon facility
• • • We do	not use the	followin	g data for averag	es, fits	s, limits,	etc. • • •
< 1.0	90		BARMIN	86	XEBC	
<11	90		BITSADZE	86	CALO	
< 34	90		вонм	69	OSPK	

VALUE (units 10 ⁻⁶)	CL%	EVTS	DOCUMENT ID		TECN			
< 1.1	90	0	BARR	93B	NA31			
• • • We do not	t use the	following	data for average	es, fits	, limits,	etc.	• •	•
<45	90		GIBBONS	88	E731			

CP VIOLATION IN $K_S \rightarrow 3\pi$

(by T. Nakada, Paul Scherrer Institute and L. Wolfenstein, Carnegie-Mellon University)

The possible final states for the decay $K^0 \to \pi^+\pi^-\pi^0$ have isospin I=0, 1, 2, and 3. The I=0 and I=2 states have CP=+1 and K_S can decay into them without violating CP symmetry, but they are expected to be strongly suppressed by centrifugal barrier effects. The I=1 and I=3 states, which

have no centrifugal barrier, have CP = -1 so that the K_S decay to these requires CP violation.

In order to see CP violation in $K_S \to \pi^+\pi^-\pi^0$, it is necessary to observe the interference between K_S and K_L decay, which determines the amplitude ratio

$$\eta_{+-0} = \frac{A(K_S \to \pi^+ \pi^- \pi^0)}{A(K_L \to \pi^+ \pi^- \pi^0)}$$

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If η_{+-0} is obtained from an integration over the whole Dalitz plot, there is no contribution from the I=0 and I=2 final states and a nonzero value of η_{+-0} is entirely due to CP violation.

Only I=1 and I=3 states, which are CP=-1, are allowed for $K^0\to\pi^0\pi^0$ decays and the decay of K_S into $3\pi^0$ is an unambiguous sign of CP violation. Similarly to η_{+-0} , η_{000} is defined as

$$\eta_{000} = \frac{A(K_S \to \pi^0 \pi^0 \pi^0)}{A(K_L \to \pi^0 \pi^0 \pi^0)} \ .$$

If one assumes that CPT invariance holds and that there are no transitions to I=3 (or to nonsymmetric I=1 states), it can be shown that

$$\begin{split} \eta_{+-0} &= \eta_{000} \\ &= \epsilon + i \frac{\text{Im } a_1}{\text{Re } a_1} \ . \end{split}$$

With the Wu-Yang phase convention, a_1 is the weak decay amplitude for K^0 into I=1 final states; ϵ is determined from CP violation in $K_L \to 2\pi$ decays. The real parts of η_{+-0} and η_{000} are equal to $\mathrm{Re}(\epsilon)$. Since currently-known upper limits on $|\eta_{+-0}|$ and $|\eta_{000}|$ are much larger than $|\epsilon|$, they can be interpreted as upper limits on $\mathrm{Im}(\eta_{+-0})$ and $\mathrm{Im}(\eta_{000})$ and so as limits on the CP-violating phase of the decay amplitude a_1 .

CP-VIOLATION PARAMETERS IN KO DECAY

 $\begin{array}{l} \text{Im}(\eta_{+-0})^2 = \Gamma(\mathcal{K}_S^0 \to \pi^+\pi^-\pi^0, \textit{CP-violating}) \; / \; \Gamma(\mathcal{K}_L^0 \to \pi^+\pi^-\pi^0) \\ \textit{CPT} \; \text{assumed valid (i.e. } \; \text{Re}(\eta_{+-0}) \simeq \; 0). \end{array}$

/ALUE	CL%	<u>EVTS</u>	DOCUMENT ID		TECN	COMMENT
• • We do	not use th	e follow	ing data for average	es, fit	s, limits,	etc. • • •
< 0.23	90	601	²¹ BARMIN	85	HLBC	
<1.2	90	192	BALDO	75	HLBC	
< 0.71	90	148	MALLARY	73	OSPK	$Re(A) = -0.05 \pm 0.17$
< 0.66	90	180	JAMES	72	HBC	
<1.2	90	99	JONES	72	OSPK	
< 0.12	90	384	METCALF	72	ASPK	
<1.2	90	99	СНО	71	DBC	
<1.0	90	98	JAMES	71	HBC	Incl. in JAMES 72
<1.2	95	50	²² MEISNER	71	HBC	CL=90% not avail.
< 0.8	90	71	WEBBER	70	HBC	
< 0.45	90		BEHR	66	HLBC	
<3.8	90	18	ANDERSON	65	HBC	Incl. in WEBBER 70

 21 BARMIN 85 find Re($\eta_{+-0})=(0.05\pm0.17)$ and Im($\eta_{+-0})=(0.15\pm0.33).$ Includes events of BALDO-CEOLIN 75. These authors find Re(A) $=2.75\pm0.65$, above value at Re(A) =0.

$$\begin{array}{lll} \text{Im}(\eta_{+-0}) = \text{Im}(A(K_0^0 \to \pi^+\pi^-\pi^0, \textit{CP-violating}) / A(K_L^0 \to \pi^+\pi^-\pi^0)) \\ \frac{VALUE}{-0.015 \pm 0.017 \pm 0.025} & \frac{EVTS}{272k} & \frac{DOCUMENT ID}{203} & \frac{TECN}{SPEC} \\ \end{array}$$

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 23 ZOU 94 use theoretical constraint Re(η_{+-0}) = Re(ϵ) = 0.0016.

¹⁷ These limits are for maximum interference in K_5^0 - K_I^0 to 2γ 's.

Im(η ₀₀₀) ²	= $\Gamma(K_5^0$ -	→ 3π ⁰ id (i.e.	$\Gamma(K_L^0 \rightarrow 30)$ $\Gamma(K_L^0 \rightarrow 30)$ $\Gamma(K_L^0 \rightarrow 30)$	τ ⁰) This	limit d	determines branching ratio
)/F _{total} ab		(1000)			· ·
VALUE	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
<0.1	90	632	²⁴ BARMIN	83	HLBC	
• • • We do	not use th	e follow	ing data for averag	es, fits	, limits,	etc. • • •
< 0.28	90		²⁵ GJESDAL	74B	SPEC	Indirect meas.

74B SPEC Indirect meas. 73 HLBC BARMIN

KS REFERENCES

BARR	95B	PL B351 579	+Buchholz+ (CERN, EDIN, MANZ, LALO, PISA, SIEG) Schwingenheuer+ (EFI, CHIC, ELMT, FNAL, ILL, RUTG) +Kolosov, Kutjin, Shelikov+ (SERP, JINR)
SCHWINGEN	95	PRL 74 4376	Schwingenheuer+ (EFI, CHIC, ELMT, FNAL, ILL, RUTG)
BLICK	94	PL B334 234	+Kolosov, Kutjin, Shelikov+ (SERP, JINR)
THOMSON ZOU	94 94	PL B337 411 PL B329 519	+Zou, Beretvas, Caracappa, Devlin+ (RUTG, MINN, MICH) +Beretvas, Caracappa, Devlin+ (RUTG, MINN, MICH)
BARR	93B	PL B304 381	+Beretvas, Caracappa, Devlin+ (RUTG, MINN, MICH) +Buchholz+ (CERN, EDIN, MANZ, LALO, PISA, SIEG)
GIBBONS	93	PRL 70 1199	+Barker, Briere, Makoff+ (FNAL E731 Collab.)
RAMBERG	93	PRL 70 1199 PRL 70 2525	+Barker, Briere, Makoff+ (FNAL E731 Collab.) +Bock, Coleman, Enagonio, Hsiung+ (FNAL E731 Collab.)
BALATS	89	SJNP 49 828	
GIBBONS	88	Translated from YAF - PRL 61 2661	49 1332. +Papadimitriou+ (FNAL E731 Collab.)
BURKHARDT	87	PL B199 139	+Papadimitriou+ (FNAL E731 Collab.) + (CERN, EDIN, MANZ, LALO, PISA, SIEG)
GROSSMAN	87	PRL 59 18	+Heller, James, Shupe+ (MINN, MICH, RUTG)
BARMIN	86	SJNP 44 622	+Barylov, Davidenko, Demidov+ (ITEP)
DADMIN	86B	Translated from YAF	44 965.
BARMIN BITSADZE	86	NC 96A 159 PL 167B 138	+Barylov, Chistyakova, Chuvilo+ (ITEP, PADO) +Budagov (CMNS, SOFI, SERP, TBIL, JINR, BAKU+)
PDG	86B	PL 170B 130	Aguilar-Benitez, Porter+ (CERN, CIT+)
VASSERMAN	86	JETPL 43 588	+Golubev, Gluskin, Druzhinin+ (NOVO)
DADMIN	85	Translated from ZETF NC 85A 67	P 43 457. +Barylov, Chistyakova, Chuvilo+ (ITEP, PADO)
BARMIN Also	85B	NC 85A 67 SJNP 41 759	+Barylov, Chistyakova, Chuvilo+ (ITEP, PADO) Barmin, Barylov, Volkov+ (ITEP)
	030	Translated from YAF	41 1187.
BARMIN	83	PL 128B 129	+Barylov, Chistyakova, Chuvilo+ (ITEP, PADO)
Also	84	SJNP 39 269 Translated from YAF :	Barmin, Barylov, Golubchikov+ (ITEP, PADO)
ARONSON	82	PRL 48 1078	+Bernstein+ (BNL, CHIC, STAN, WISC)
ARONSON	82B	PRL 48 1306	+Bock, Cheng, Fischbach (BNL, CHIC, PURD)
Also	82B	PL 116B 73	Fischbach, Cheng+ (PURD, BNL, CHIC)
Also	83	PR D28 476	Aronson, Bock, Cheng+ (BNL, CHIC, PURD)
Also	83B	PR D28 495	Aronson, Bock, Cheng+ (BNL, CHIC, PURD) +McIntyre, Roehrig+ (WISC, EFI, UCSD, ILLC)
ARONSON EVERHART	76 76	NC 32A 236 PR D14 661	+McIntyre, Roehrig+ (WISC, EFI, UCSD, ILLC) +Kraus, Lande, Long, Lowenstein+ (PENN)
TAUREG	76	PL 65B 92	+Zech, Dydak, Navarria+ (HEIDH, CERN, DORT)
BALDO	75	NC 25A 688	Baldo-Ceolin Bohisut Calimani+ (PADO WISC)
CARITHERS	75	PRL 34 1244	+Modis, Nygren, Pun+ (COLU, NYU)
BOBISUT	74	LNC 11 646	+Huzita, Mattioli, Puglierin (PADO)
COWELL GEWENIGER	74 74B	PR D10 2083 PL 48B 487	+Lee-Franzini, Orcutt, Franzini+ (STON, COLU)
GEWENIGER	74B	PL 48B 487 PL 52B 119	+ Gjesdal, Presser+ (CERN, HEIDH) + Presser, Steffen+ (CERN, HEIDH)
BARMIN	73	PL 46B 465	+Cee-randm, Orbit, Planzimi+ (STON, COLO) +Gjesdal, Presser+ +Presser, Steffen+ +Barylov, Davidenko, Demidov+ (TEP)
BARMIN	73B	PL 47B 463	+Barylov, Davidenko, Delnidov+ (TTEP)
BURGUN	73	PL 46B 481	+Bertranet, Lesquoy, Muller, Pauli+ (SACL, CERN)
FACKLER GJESDAL	73 73	PRL 31 847 PL 44B 217	+Frisch, Martin, Smoot, Sompayrac (MIT) +Presser, Steffen, Steinberger+ (CERN, HEIDH)
HILL	73	PR D8 1290	+Presser, Steffen, Steinberger+ (CERN, HÈIDH) +Sakitt, Samios, Burris, Engler+ (BNL, CMU)
MALLARY	73	PR D7 1953	+Binnie, Gallivan, Gomez, Peck, Sciulli+ (CIT)
ALITTI	72	PL 39B 568	+Lesquoy, Muller (SACL)
BANNER	72B	PRL 29 237	+Cronin, Hoffman, Knapp, Shochet (PRIN)
BURGUN	72	NP B50 194	+Lesquoy, Muller, Pauli+ (SACL, CERN, OSLO) +Montanet, Paul, Saetre+ (CERN, SACL, OSLO)
JAMES JONES	72 72	NP B49 1 NC 9A 151	+Montanet, Paul, Saetre+ (CERN, SACL, OSLO) +Abashian, Graham, Mantsch, Orr, Smith+ (ILL)
METCALF	72	PL 40B 703	+Neuhofer, Niebergall+ (CERN, IPN, WIEN)
MORSE	72B	PRL 28 388	+Nauenberg, Bierman, Sager+ (COLO, PRIN, UMD)
NAGY	72	NP B47 94	+Telbisz, Vestergombi (BUDA)
Also	69	PL 30B 498	Bozoki, Fenyves, Gombosi, Nagy+ (BUDA)
SKJEGGEST			
BALTAY Also		NP B48 343	Skjeggestad, James+ (OSLO, CERN, SACL)
AISU	71	PRL 27 1678	Skjeggestad, James+ (OSLO, CERN, SACL) +Bridgewater, Cooper, Gershwin, Habibi+ (COLU)
CHO	71 71	PRL 27 1678 Thesis Nevis 187	Skjeggestad, James+ (OSLO, CERN, SACL) +Bridgewater, Cooper, Gershwin, Habibi+ (COLU) Cooper (COLU)
CHO JAMES	71	PRL 27 1678 Thesis Nevis 187 PR D3 1557	Skjeggestad, James+ (OSLO, CERN, SACL) +Bridgewater, Cooper, Gershwin, Habibi+ (COLU) Cooper (COLU) +Dralle, Canter, Engler, Fisk+ (CMU, BNL, CASE)
JAMES MEISNER	71 71 71	PRL 27 1678 Thesis Nevis 187 PR D3 1557 PL 35B 265 PR D3 59	Skjeggestad, James+ Bridgewater, Cooper, Gershwin, Habibi+ Cloud, Cooper
JAMES MEISNER REPELLIN	71 71 71 71 71 71	PRL 27 1678 Thesis Nevis 187 PR D3 1557 PL 35B 265 PR D3 59 PL 36B 603	Skjeggestad, James+ Bridgewater, Cooper, Gershwin, Habibi+ Cloud, Cooper
JAMES MEISNER REPELLIN MOFFETT	71 71 71 71 71 71 71 70	PRL 27 1678 Thesis Nevis 187 PR D3 1557 PL 35B 265 PR D3 59 PL 36B 603 BAPS 15 512	Skjeggestad, James+ Bridgewater, Cooper, Gershwin, Hablibi+ COOLU Cooper
JAMES MEISNER REPELLIN MOFFETT WEBBER	71 71 71 71 71 71 71 70 70	PRL 27 1678 Thesis Nevis 187 PR D3 1557 PL 35B 265 PR D3 59 PL 36B 603 BAPS 15 512 PR D1 1967	Skjeggestad, James+ Bridgewater, Cooper, Gershwin, Habibi+ (OLU) Cooper I-Draile, Canter, Engler, Fisk+ Hontanet, Paul, Pauli+ HMann, Hertzbach, Kofler+ HWolff, Chollet, Gaillard, Jane+ HGobbi, Green, Hakel, Rosen (ROCH) Schollt, Crawford, Alston-Garnjost (IRL)
JAMES MEISNER REPELLIN MOFFETT WEBBER Also	71 71 71 71 71 71 70 70	PRL 27 1678 Thesis Nevis 187 PR D3 1557 PL 35B 265 PR D3 59 PL 36B 603 BAPS 15 512 PR D1 1967 Thesis UCRL 19226	Skjeggestad, James+ Bridgewater, Cooper, Gershwin, Hablibi+ COUL Cooper Loralle, Canter, Engler, Fisk+ Montanet, Paul, Pauli+ Hann, HertDach, Kofler+ HWolff, Chollet, Gaillard, Jane+ Hoobbi, Green, Hakel, Rosen Hoolitz, Crawford, Alston-Garnjost Webber LEL
JAMES MEISNER REPELLIN MOFFETT WEBBER Also BANNER BOHM	71 71 71 71 71 71 70 70 69 69	PRL 27 1678 Thesis Nevis 187 PR D3 1557 PL 358 265 PR D3 59 PL 368 603 BAPS 15 512 PR D1 1967 Thesis UCRL 19226 PR 188 2033 Thesis	Skjeggestad, James+ Bridgewater, Cooper, Gershwin, Habibi+ COLU Cooper Lorale, Canter, Engler, Fisk+ Montanet, Paul, Pauli+ Hann, HertDach, Kofler+ Hann, HertDach, Kofler+ Hoolbi, Green, Hakel, Rosen Lorale, Scholer, Hakel, Rosen Hoolbi, Green, Hakel, Rosen Lorale, Crawford, Alston-Garnjost Webber LEL +Cronin, Liu, Pilcher (OSLO, CERN, SACL) (CMU, BNL, CASE) (CRN, SACL, OSLO) (MASA, BNL, YALE) (MASA, BNL, YALE) (LRL) (LRL) (LRL) (PRIN)
JAMES MEISNER REPELLIN MOFFETT WEBBER Also BANNER BOHM BOZOKI	71 71 71 71 71 71 70 70 69 69 69	PRL 27 1678 Thesis Nevis 187 PR D3 1557 PR D3 1557 PR D3 559 PL 368 603 BAPS 15 512 PR D1 1967 Thesis UCRL 19226 PR 188 2033 Thesis PL 308 498	Skjeggestad, James+ Bridgewater, Cooper, Gershwin, Habibi+ COLU) Cooper
JAMES MEISNER REPELLIN MOFFETT WEBBER Also BANNER BOHM BOZOKI DOYLE	71 71 71 71 71 71 70 70 69 69 69 69	PRL 27 1678 Thesis Newis 187 PR D3 1557 PL 358 265 PR D3 59 PL 368 603 BAPS 15 51 PR D1 1967 Thesis UCRL 19226 PR 188 2033 Thesis PL 308 498 Thesis UCRL 18139	Skjeggestad, James+ Bridgewater, Cooper, Gershwin, Hablibi+ COOLU) Cooper
JAMES MEISNER REPELLIN MOFFETT WEBBER Also BANNER BOHM BOZOKI DOYLE GOBBI	71 71 71 71 71 71 70 70 69 69 69 69 69	PRL 27 1678 Thesis Newis 187 PR D3 1557 PL 358 265 PR D3 59 PL 368 603 BAPS 15 512 PR D1 1967 Thesis UCRL 19226 PR 188 2033 Thesis UCRL 18139 PRL 22 682	Skjeggestad, James+ Bridgewater, Cooper, Gershwin, Habibi+ (OLU) Cooper I
JAMES MEISNER REPELLIN MOFFETT WEBBER Also BANNER BOHM BOZOKI DOYLE GOBBI HYAMS	71 71 71 71 71 70 70 69 69 69 69 69 69	PRL 27 1678 Thesis Nevis 187 PR D3 1557 PR D3 1557 PL 358 265 PR D3 59 PL 368 603 BAPS 15 512 PR D1 1967 Thesis UCRL 19226 PR 188 2033 Thesis PL 308 498 Thesis UCRL 18139 PRL 22 662 PR 128 521	Skjeggestad, James+ Bridgewater, Cooper, Gershwin, Hablibi+ COUL Cooper Lorale, Canter, Engler, Fisk+ Hontanet, Paul, Pauli+ Holl, Cooper, Gershwin, Hablibi+ (CMU, BNL, CASE) (CERN, SACL, OSLO) (MASA, BNL, YALE) HAnn, HertDach, Kofler+ Hoolbi, Green, Hakel, Rosen Hoolitz, Crawford, Alston-Garnjost Webber Lorale Hornitz, Crawford, Alston-Garnjost Webber Hornitz, Cr
JAMES MEISNER REPELLIN MOFFETT WEBBER Also BANNER BOHM BOZOKI DOYLE GOBBI	71 71 71 71 71 71 70 70 69 69 69 69 69	PRL 27 1678 Thesis Newis 187 PR D3 1557 PL 358 265 PR D3 59 PL 368 603 BAPS 15 512 PR D1 1967 Thesis UCRL 19226 PR 188 2033 Thesis UCRL 19226 PRL 23 682 PL 298 521 PRL 25 662 PL 298 521 PRL 22 662 PL 298 521	Skjeggestad, James+ Bridgewater, Cooper, Gershwin, Habibi+ COLU Cooper I
JAMES MEISNER REPELLIN MOFFETT WEBBER Also BANNER BOHM BOZOKI DOYLE GOBBI HYAMS MORFIN STUTZKE DONALD	71 71 71 71 71 70 70 69 69 69 69 69 69 69 69 69 69 69 69	PRL 27 1678 Thesis Nevis 187 PR D3 1557 PL 1358 265 PR D3 159 PL 368 603 BAPS 15 512 PR D1 1967 Thesis UCRL 19226 PR 188 2033 Thesis UCRL 19226 PRL 22 682 PL 298 521 PRL 23 660 PR 177 2009 PRL 177 2009 PL 177 205	Skjeggestad, James+ Bridgewater, Cooper, Gershwin, Habibi+ (OCLU) Cooper Looper Lorale, Canter, Engler, Fisk+ (CMU, BNL, CASE) Honatanet, Paul, Pauli+ (CERN, SACL, OSLO) HAnan, Hertbach, Koffer+ HAon, Hertbach, Koffer+ Hoobbi, Green, Hakel, Rosen Hobbi, Green, Hakel, Rosen Horonin, Liu, Pilicher Hernyes, Gombosi, Nagy+ Hernyes, Gombosi, Nagy+ Horen, Hakel, Moffett, Rosen+ HKoch, Potter, VonLindern, Loren+ HKoch, Potter, VonLindern, Loren+ Hooshaian, Jones, Mantsch, Orr, Smith Hedwards, Nisar+ (LLVP, CERN, IPNP, CDER)
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JAMES MEISNER REPELLIN MOFFETT WEBBER AISO BANNER BOHM BOZOKI DOYLE GOBBI HYAMS MORFIN STUTZKE DONALD HILL BOTT	71 71 71 71 71 70 70 69 69 69 69 69 69 69 69 69 69 69 69 69	PRL 27 1678 Thesis Nevis 187 PR D3 1557 PL 1358 265 PR D3 1557 PL 1368 603 BAPS 15 512 PR D1 1967 Thesis UCRL 19226 PR 188 2033 Thesis UCRL 19226 PRL 22 682 PL 298 521 PRL 22 682 PL 298 521 PRL 27 269 PRL 177 2009 PR 177 2009 PR 171 1418 PRL 124 194	Skjeggestad, James+ Bridgewater, Cooper, Gershwin, Habibi+ (COLU) Cooper Looper Lorale, Canter, Engler, Fisk+ (CMU, BNL, CASE) Hontanet, Paul, Pauli+ (CERN, SACL, OSLO) Hann, Hertbach, Kofler+ (MASA, BNL, YAL) Hootbi, Green, Hakel, Rosen (ROCH) Lobbi, Green, Hakel, Rosen (ROCH) Lorale, Crawford, Alston-Garnjost (LRL) Webber (LRL) Webber (AACH) Lorolin, Liu, Pilicher (PRIN) Lorolin, Liu, Pilicher (PRIN) Lorolin, Liu, Pilicher (ROCH) Lorolin, Lorolinder, Lorenz+ (CERN, MPIM) Lorolin, Pilicher (LOROLIN) Lorolin, Millich (LRI) Lorolin, Milli
JAMES MEISNER REPELLIN MOFFETT WEBBER AISO BANNER BOHM BOZOKI DOYLE GOBBI HYAMS MORFIN STUTZKE DONALD HILL BOTT	71 71 71 71 71 70 70 69 69 69 69 69 69 69 69 69 69 69 69 69	PRL 27 1678 Thesis Newis 187 PR D3 1557 PL 35B 265 PR D3 59 PL 36B 603 BAPS 15 512 PR D1 1967 Thesis UCRL 19226 PR 188 2033 Thesis PL 30B 498 PL 30B 499 PRL 22 682 PR 123 660 PR 127 2009 PL 27B 58 PR 177 2009 PL 27B 58 PL 1418 PL 24B 194 PL 21 595	Skjeggestad, James+ Bridgewater, Cooper, Gershwin, Hablibi+ COLU Cooper Lorale, Canter, Engler, Fisk+ Montanet, Paul, Pauli+ Wolff, Chollet, Gaillard, Jane+ Gobbi, Green, Hakel, Rosen H-Solmitz, Crawford, Alston-Garnjost Webber Lorale, Crawford, Alston-Garnjost Webber H-Cronin, Liu, Piicher H-Fenyes, Gombosi, Nagy+ H-Green, Hakel, Rosen+ H-Koch, Potter, VonLindern, Lorenz+ H-Koch, Potter, VonLindern, Lorenz+ H-Abashian, Jones, Mantsch, Orr, Smith H-Edwards, Nisar+ H-Robinson, Sakitt+ Bodenhausen, DeBouard, Cassel+ Alff-Steinberger, Heuer, Kleinknecht+ (CERN) LORD LORD LORD LORD LORD LORD LORD LORD
JAMES MEISNER REPELLIN MOFFETT WEBBER AISO BANNER BOHM BOZOKI DOYLE GOBBI HYAMS MORFIN STUTZKE DONALD HILL BOTT	71 71 71 71 71 70 70 69 69 69 69 69 69 69 69 69 69 69 69 69	PRL 27 1678 Thesis Newis 187 PR D3 1557 PL 35B 265 PR D3 59 PL 36B 603 BAPS 15 512 PR D1 1967 Thesis UCRL 19226 PR 18B 2033 Thesis PL 30B 498 PL 30B 499 PRL 22 682 PL 123 660 PR 177 2009 PL 27B 58 PR 177 2009 PL 27B 58 PL 31418 PL 24B 194 PL 21 595 PL 22 540 NC 45A 737	Skjeggestad, James+ Bridgewater, Cooper, Gershwin, Habibi+ (COLU) Cooper Looper Loraler, Engler, Fisk+ (CMU, BNL, CASE) Hontanet, Paul, Pauli+ (CERN, SACL, OSLO) Hann, Hertzbach, Kofler+ (MASA, BNL, YALE) Hollet, Gaillard, Jane+ Hoolbi, Green, Hakel, Rosen Hoolbi, Green, Hakel, Rosen Hoolbi, Green, Hakel, Rosen Hoolbi, Tengen, Hakel, Moffett, Rosen Hoolbi, Green, Hakel, Rosen Hoolbi, Green, Hakel, Rosen Hoolbi, Green, Hool
JAMES MEISNER REPELLIN MOFFETT WEBBER ALSO BANNER BOHM BOZOKI DOYLE GOBBI HYAMIN STUTZKE DONALD HILL BOTT ALFF BEHR BELLOTTI KIRSCH	71 71 71 71 71 70 69 69 69 69 69 69 69 69 69 69 69 69 69	PRL 27 1678 Thesis Newis 187 PR D3 1557 PL 1358 265 PR D3 1557 PL 1368 603 BAPS 15 512 PR D1 1967 Thesis UCRL 19226 PR 188 2033 Thesis UCRL 19226 PRL 22 682 PL 298 521 PRL 22 682 PL 298 521 PRL 23 660 PR 177 2009 PRL 177 2009 PRL 177 1009 PRL 27 1418 PRL 27	Skjeggestad, James+ Bridgewater, Cooper, Gershwin, Habibi+ (COLU) Cooper Looper Loraler, Engler, Fisk+ (CMU, BNL, CASE) Hontanet, Paul, Pauli+ (CERN, SACL, OSLO) Hann, Hertzbach, Kofler+ (MASA, BNL, YALE) Hollet, Gaillard, Jane+ Hoolbi, Green, Hakel, Rosen Hoolbi, Green, Hakel, Rosen Hoolbi, Green, Hakel, Rosen Hoolbi, Tengen, Hakel, Moffett, Rosen Hoolbi, Green, Hakel, Rosen Hoolbi, Green, Hakel, Rosen Hoolbi, Green, Hool
JAMES MEISNER REPELLIN MOFFETT WEBBER AISO BANNER BOHM BOZOKI DOVLE GOBBI HYAMS MORFIN STUTZKE DONALD HILL BOTT BEHR BELLOTTI KIRSCH ANDERSON	71 71 71 71 71 70 69 69 69 69 69 69 69 69 68 68 66 66 66 66 66 66 66 66	PRL 27 1678 Thesis Nevis 187 PR D3 1557 PL 358 265 PR D3 59 PL 368 603 BAPS 15 512 PR D1 1967 Thesis UCRL 19226 PR 188 2033 Thesis UCRL 19226 PR 188 2033 Thesis UCRL 18139 PRL 22 662 PL 298 521 PRL 23 660 PR 177 250 PR 177 359 PL 22 540 NC 45A 737 PR 147 939 PR L17 197 PR 147 197	Skjeggestad, James+ Bridgewater, Cooper, Gershwin, Habibi+ (COLU) Cooper Looper Loraler, Engler, Fisk+ (CMU, BNL, CASE) Hontanet, Paul, Pauli+ (CERN, SACL, OSLO) Hann, Hertzbach, Kofler+ (MASA, BNL, YALE) Hollet, Gaillard, Jane+ Hoolbi, Green, Hakel, Rosen Hoolbi, Green, Hakel, Rosen Hoolbi, Green, Hakel, Rosen Hoolbi, Tengen, Hakel, Moffett, Rosen Hoolbi, Green, Hakel, Rosen Hoolbi, Green, Hakel, Rosen Hoolbi, Green, Hool
JAMES MEISNER REPELLIN MOFFETT WEBBER AISO BANNER BOHM BOZOKI DOYLE GOBBI HYAMIS MORFIN STUTZKE DONALD HILL BOTT ALFF BEHR BELLOTTI KIRSCH ANDERSON AUBERT	71 71 71 71 71 70 69 69 69 69 69 69 69 69 69 68 68 68 66 66 66 66 66 66 66 65	PRL 27 1678 Thesis Newis 187 PR D3 1557 PL 1358 265 PR D3 1557 PL 1368 603 BAPS 15 512 PR D1 1967 Thesis UCRL 19226 PR 188 2033 Thesis UCRL 19226 PRL 22 682 PL 298 521 PRL 22 682 PL 298 521 PRL 22 682 PL 298 521 PRL 23 660 PR 177 2009 PRL 27 509 PRL 24 194 PL 21 595 PR 147 1418 PL 22 540 NC 45A 737 PR 147 939 PRL 14 475 PR 147 939 PRL 14 759	Skjeggestad, James+ Bridgewater, Cooper, Gershwin, Habibi+ COLU) Cooper Looper
JAMES MEISNER REPELLIN MOFFETT WEBBER AISO BANNER BOHM BOZOKI DOVLE GOBBI HYAMS MORFIN STUTZKE DONALD HILL BOTT BEHR BELLOTTI KIRSCH ANDERSON AUBERT BROWN	71 71 71 71 70 70 69 69 69 69 69 69 68 68 66 66 66 66 66 66 65 65	PRL 27 1678 Thesis Newis 187 PR D3 1557 PL 358 265 PR D3 59 PL 368 603 BAPS 15 512 PR D1 1967 Thesis UCRL 19226 PR 182 2033 Thesis UCRL 19126 PRL 22 682 PL 298 521 PRL 23 660 PR 177 2009 PRL 24 184 PRL 25 464 PRL 25 465 PR 177 2009 PRL 27 595 PR 147 399 PRL 144 475 PL 17 599 PR 130 759 PR 131 7599	Skjeggestad, James+ Bridgewater, Cooper, Gershwin, Hablib+ COLU Cooper Lorale, Canter, Engler, Fisk+ Montanet, Paul, Pauli+ Holling, Canter, Engler, Fisk+ Montanet, Paul, Pauli+ Holling, Canter, Engler, Fisk+ Hontanet, Paul, Pauli+ Holling, Canter, Engler, Fisk+ Hontanet, Paul, Pauli+ Holling, Canter, Engler, Fisk+ Hontanet, Paul, Pauli+ Holling, Canter, C
JAMES MEISNER REPELLIN MOFFETT WEBBER AISO BANNER BOHM BOZOKI DOVLE GOBBI HYAMS MORFIN STUTIZKE DONALD HILL BOTT BEHR BELLOTTI KIRSCH ANDERSON AUBERT BROWN CHRETIEN ANDERSON CHRETIEN	71 71 71 71 71 70 69 69 69 69 69 69 69 69 69 68 68 68 66 66 66 66 66 66 66 65	PRL 27 1678 Thesis Newis 187 PR D3 1557 PL 358 265 PR D3 359 PL 368 603 BAPS 15 512 PR D1 1967 Thesis UCRL 19226 PR 188 2033 Thesis UCRL 19226 PR 188 2033 Thesis PRL 23 662 PL 298 521 PRL 29 652 PL 298 521 PRL 23 660 PR 177 2009 PR 177 2009 PR 171 1418 PR 121 144 PR 12 250 PR 171 147 399 PR 131 759 PR 137 759 PR 137 759 PR 130 769 PR 131 2208 CERN Conf. 836	Skjeggestad, James+ Bridgewater, Cooper, Gershwin, Hablib+ COLU Cooper Lorale, Canter, Engler, Fisk+ Hontanet, Paul, Pauli+ Hortbach, Kofler+ Holting, Canter, Engler, Fisk+ Hontanet, Paul, Pauli+ Holting, Canter, Engler, Fisk+ Hontanet, Paul, Pauli+ Holting, Canter, Engler, Fisk+ Hontanet, Paul, Pauli+ Holting, Canter, Cante
JAMES MEISNER REPELLIN MOFFETT WEBBER AISO BANNER BOHM BOZOKI DOYLE GOBBI HYAMS MORFIN STUTZKE DONALD HILL BOTT ALFF BEHR BELLOTTI KIRSCH ANDERSON AUBERT BROWN CHRETIEN ANDERSON ANDERSON BROWN	71 71 71 71 71 70 70 69 69 69 69 69 69 69 68 68 68 66 66 66 66 66 63 63 63 63 63 63 64	PRL 27 1678 Thesis Newis 187 PR D3 1557 PL 358 265 PR D3 359 PL 368 603 BAPS 15 512 PR D1 1967 Thesis UCRL 19226 PR 188 2033 Thesis UCRL 19226 PR 188 2033 Thesis PRL 23 662 PL 298 521 PRL 29 652 PL 298 521 PRL 23 660 PR 177 2009 PR 177 2009 PR 171 1418 PR 121 144 PR 12 250 PR 171 147 399 PR 131 759 PR 137 759 PR 137 759 PR 130 769 PR 131 2208 CERN Conf. 836	Skjeggestad, James+ Bridgewater, Cooper, Gershwin, Habibi+ COLU) Cooper Ly C
JAMES MEISNER REPELLIN MOFFETT WEBBER AISO BANNER BOHM BOZOKI DOVLE GOBBI HYAMS MORFIN STUTIZKE DONALD HILL BOTT BEHR BELLOTTI KIRSCH ANDERSON AUBERT BROWN CHRETIEN ANDERSON BROWN BAGLIN	71 71 71 71 71 70 70 69 69 69 69 69 69 69 69 68 68 66 66 66 66 66 65 65 63 62 63 62 63 63 64 65 65 65 65 65 65 65 65 65 65 65 65 65	PRL 27 1678 Thesis Newis 187 PR D3 1557 PL 1358 265 PR D3 59 PL 368 603 BAPS 15 512 PR D1 1967 Thesis UCRL 19226 PR 188 2033 Thesis UCRL 19226 PR 188 2033 Thesis UCRL 18139 PRL 22 662 PL 298 521 PL 298 521 PL 277 580 PR 177 258 PR 277 158 PR 277 158 PR 277 158 PR 277 159 PR 277 59 PR 137 759 PR 147 759 PR 130 769 PR 131 2208 CERN Conf. 836 NC 19 1155 NC 181 1043	Skjeggestad, James+ Bridgewater, Cooper, Gershwin, Hablibi+ (OLU) Cooper Lorale, Canter, Engler, Fisk+ (CMU, BNL, CASE) Hontanet, Paul, Pauli+ (CERN, SACL) SLO Hann, Hertbach, Kofler+ (MASA, BNL, YALE) Hoothit, Cenen, Hakel, Rosen Loral Hontitz, Crawford, Alston-Garnjost Webber Loral (LRL) Loral Hontitz, Crawford Loral Hontitz, Crawford Loral Hontitz, Case, Loral Hontitz, Crawford Loral Hontitz, Case, Loral Hontitz, Loral Hontitz, Crawford Loral Hontitz, Case, Loral Hontitz, Lor
JAMES MEISNER REPELLIN MOFFETT WEBBER AISO BANNER BOHM BOZOKI DOYLE GOMBI HYAMS MORFIN STUTZKE DONALD HILL BOTT ALFF BEHR BELLOTTI KIRSCH ANDERSON AUBERT BROWN CHRETIEN ANDERSON BROWN	71 71 71 71 71 70 69 69 69 69 69 69 69 69 69 69 66 66 66	PRL 27 1678 Thesis Newis 187 PR D3 1557 PL 358 265 PR D3 59 PL 368 603 BAPS 15 512 PR D1 1967 Thesis UCRL 19226 PR 182 2033 Thesis UCRL 19226 PR 128 2033 Thesis PRL 22 682 PL 298 521 PRL 23 660 PR 177 2009 PRL 23 660 PR 177 1009 PRL 24 814 PL 24 144 PL 21 595 PL 248 194 PL 21 595 PL 144 475 PL 17 59 PR 147 939 PRL 147 59 PR 147 939 PRL 147 59 PR 130 769 PR 130 769 PR 130 769 PR 130 769 PR 131 1209 CERN Conf. 836 NC 19 1155 NC 181 1043 ROC 19155 NC 181 1043	Skjeggestad, James+ Bridgewater, Cooper, Gershwin, Habibi+ COLU) Cooper Ly C
JAMES MEISNER REPELLIN MOFFETT WEBBER AISO BANNER BOHM BOZOKI DOVLE GOBBI HYAMS MORFIN STUTIZKE DONALD HILL BOTT BEHR BELLOTTI KIRSCH ANDERSON AUBERT BROWN CHRETIEN ANDERSON BROWN BAGLIN	71 71 71 71 71 70 70 69 69 69 69 69 69 69 69 68 68 66 66 66 66 66 65 65 63 62 63 62 63 63 64 65 65 65 65 65 65 65 65 65 65 65 65 65	PRL 27 1678 Thesis Newis 187 PR D3 1557 PL 1358 265 PR D3 59 PL 368 603 BAPS 15 512 PR D1 1967 Thesis UCRL 19226 PR 188 2033 Thesis UCRL 19226 PR 188 2033 Thesis UCRL 18139 PRL 22 662 PL 298 521 PL 298 521 PL 277 580 PR 177 258 PR 277 158 PR 277 158 PR 277 158 PR 277 159 PR 277 59 PR 137 759 PR 147 759 PR 130 769 PR 131 2208 CERN Conf. 836 NC 19 1155 NC 181 1043	Skjeggestad, James+ Bridgewater, Cooper, Gershwin, Hablib+ COLU Cooper Looper Lorale, Canter, Engler, Fisk+ Montanet, Paul, Pauli+ Holling, Canter, Engler, Fisk+ Montanet, Paul, Pauli+ Holling, Canter, Engler, Fisk+ Hontanet, Paul, Pauli+ Holling, Canter, Engler, Fisk+ Hontanet, Paul, Pauli+ Holling, Canter,

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MULLER 60	PRL 4 418	+Birge, Fowler, Good, Piccioni+	(LRL, BNL)



$$I(J^P) = \frac{1}{2}(0^-)$$

$m_{K_I^0} - m_{K_S^0}$

For earlier measurements, beginning with GOOD 61 and FITCH 61, see our our 1986 edition, Physics Letters **170B** 132 (1986).

OUR FIT is described in the note on "CP Violation in \mathcal{K}^0_L Decay" in the \mathcal{K}^0_L Particle Listings.

Listings.			
$VALUE (10^{10} h s^{-1})$	DOCUMENT ID	TECN	COMMENT
0.5304±0.0014 OUR FIT	Γ		
0.5310±0.0019 OUR AV			
$0.5274 \pm 0.0029 \pm 0.0005$	ADLER	95 CPLR	Charge asymmetry in K_{e3}^0
$0.5297 \pm 0.0030 \pm 0.0022$			20-160 GeV K beams
0.5257 ± 0.0049	1 GIBBONS	93c E731	20-160 GeV K beams
$0.5340 \pm 0.00255 \pm 0.0015$	² GEWENIGER	74c SPEC	Gap method
$0.5334 \pm 0.0040 \ \pm 0.0015$	² GJESDAL	74 SPEC	Charge asymmetry in $K_{\ell 3}^0$
0.542 ±0.006	CULLEN	70 CNTR	
• • We do not use the	following data for a	averages, fits	, limits, etc. • • •
0.5286 ± 0.0028	3 GIBBONS	93 E731	20-160 GeV K beams
0.482 ±0.014	⁴ ARONSON		E=30-110 GeV
0.534 ±0.007	⁵ CARNEGIE	71 ASPK	Gap method
0.542 ±0.006	⁵ ARONSON	70 ASPK	Gap method
1 Fits Δm and ϕ_{+-} sim	rultaneously.		
	s have a common ointed out in WAH	łL 89.	rror due to the uncertainty in the $43.7 \pm 0.2)^{\circ}.$
⁴ ARONSON 82 find tha	at Δm may depend	d on the kaor	energy.

KO MEAN LIFE

	E (10 ⁻⁸ s)		EVTS Error inclu	DOCUMENT ID	of 1.	<u>TECN</u>
5.15	±0.04	OUR AVE	RAGE			
5.154	±0.044		0.4M	VOSBURGH	72	CNTR
5.15	± 0.14			DEVLIN	67	CNTR
• •	We do	not use the	e following o	data for averages	, fits	, limits, etc. • • •
5.0	± 0.5		e	LOWYS	67	HLBC
6.1	$+1.5 \\ -1.2$		1700	ASTBURY	65C	CNTR
5.3	± 0.6			FUJII	64	OSPK
5.1	$+2.4 \\ -1.3$		15	DARMON	62	FBC
8.1	$+3.2 \\ -2.4$		34	BARDON	58	CNTR
6 S	um of pa	artial decay	rates.			

\mathcal{K}_L^0 DECAY MODES

	Mode	Fraction (Γ_f/Γ)	Scale factor/ Confidence level
Γ_1	$3\pi^{0}$	(21.12 ±0.27)%	S=1.1
Γ_2	$\pi^{+}\pi^{-}\pi^{0}$	(12.56 ±0.20)%	S=1.7
Γ_3	$\pi^{\pm}\mu^{\mp}\nu$	[a] (27.17 ±0.25)%	S=1.1
	Called $K_{\mu 3}^0$.		
Γ_4	$\pi^-\mu^+\nu_\mu$		
Γ_5	$\pi^+\mu^-\overline{\nu}_{\mu}$		
Γ_6	$\pi^{\pm}e^{\mp} u_{e}$	[a] (38.78 ±0.27)%	S=1.1
_	Called K_{e3}^{0} .		
Γ_7	$\pi^- e^+ \nu_e$		
Γa	$\pi^+ e^- \overline{\nu}_e$		

 $^{^{24}}$ BARMIN 83 find Re($\eta_{000})=(-0.08\pm0.18)$ and Im($\eta_{000})=(-0.05\pm0.27).$ Assuming CPT invariance they obtain the limit quoted above. 25 GJESDAL 748 uses $K2\pi$, $K_{\mu3}$, and K_{e3} decay results, unitarity, and CPT. Calculates $|(\eta_{000})|=$ 0.26 \pm 0.20. We convert to upper limit.

 $^{^5}$ ARONSON 70 and CARNEGIE 71 use κ_S^0 mean life $= (0.862 \pm 0.006) \times 10^{-10}$ s. We have not attempted to adjust these values for the subsequent change in the K_S^0 mean life or in η_{+-} .

Γ_9	2γ	$(5.92 \pm 0.15) \times 10^{-4}$	
Γ_{10}	3γ	$< 2.4 \times 10^{-7}$	CL=90%
	$\pi^0 2\gamma$	[b] $(1.70 \pm 0.28) \times 10^{-6}$	
Γ_{12}	$\pi^0\pi^\pm e^\mp u$	[a] $(5.18 \pm 0.29) \times 10^{-5}$	
Γ_{13}	$(\pi \mu atom) \nu$	$(1.06 \pm 0.11) \times 10^{-7}$	
	$\pi^{\pm} e^{\mp} \nu_e \gamma$	$[a,b,c]$ (1.3 \pm 0.8) %	
Γ_{15}	$\pi^+\pi^-\gamma$	[b,c] $(4.61 \pm 0.14) \times 10^{-5}$	
Γ_{16}	$\pi^0 \pi^0 \gamma$	$< 5.6 \times 10^{-6}$	

Charge conjugation \times Parity (CP, CPV) or Lepton Family number (LF) violating modes, or $\Delta S = 1$ weak neutral current (S1) modes

Γ_{17}	$\pi^+\pi^-$	CPV	$(2.067\pm0.035)\times10^{-3}$ S	=1.1
Γ ₁₈	$\pi^{0}\pi^{0}$	CPV	$(9.36 \pm 0.20) \times 10^{-4}$	
Γ_{19}	$\mu^+\mu^-$	S1	$(7.2 \pm 0.5) \times 10^{-9}$ S	=1.4
Γ ₂₀	$\mu^+\mu^-\gamma$	S1	$(3.23 \pm 0.30) \times 10^{-7}$	
Γ_{21}	$e^{+} e^{-}$	51	$<$ 4.1 \times 10 ⁻¹¹ CL=	90%
Γ_{22}	$e^+e^-\gamma$	S1	$(9.1 \pm 0.5) \times 10^{-6}$	
Γ_{23}	$e^+e^-\gamma\gamma$	S1	[b] $(6.5 \pm 1.2) \times 10^{-7}$	
24	$\pi^{+}\pi^{-}e^{+}e^{-}$	S1	$< 2.5 \times 10^{-6} \text{ CL} =$	90%
	$\mu^{+}\mu^{-}e^{+}e^{-}$	S1	$< 4.9 \times 10^{-6} \text{ CL} =$	90%
Γ_{26}	$e^{+}e^{-}e^{+}e^{-}$	S1	[d] $(4.1 \pm 0.8) \times 10^{-8}$ S	=1.2
Γ_{27}	$\pi^{0} \mu^{+} \mu^{-}$	CP,S1		90%
Γ_{28}	$\pi^0 e^+ e^-$	CP,S1	$[e] < 4.3 \times 10^{-9} CL =$	90%
Γ_{29}	$\pi^0 \nu \overline{\nu}$	CP,S1	$(f) < 5.8 \times 10^{-5} CL =$	90%
Γ ₃₀	$e^{\pm}\mu^{\mp}$	LF	$[a] < 3.3 \times 10^{-11} CL=$	90%

- [a] The value is for the sum of the charge states of particle/antiparticle states
- [b] See the Particle Listings below for the energy limits used in this measurement.
- $\ensuremath{[c]}$ Most of this radiative mode, the low-momentum γ part, is also included in the parent mode listed without γ 's.
- [d] $m_{e^+e^-} >$ 470 MeV.
- [e] Allowed by higher-order electroweak interactions.
- [f] Violates CP in leading order. Test of direct CP violation since the indirect CP-violating and CP-conserving contributions are expected to be suppressed.

CONSTRAINED FIT INFORMATION

An overall fit to the mean life, 4 decay rate, and 12 branching ratios uses 46 measurements and one constraint to determine 8 parameters. The overall fit has a $\chi^2=41.2$ for 39 degrees of

The following off-diagonal array elements are the correlation coefficients $\langle \delta p_i \delta p_j \rangle / (\delta p_i \cdot \delta p_j)$, in percent, from the fit to parameters p_i , including the branching fractions, $x_i \equiv \Gamma_i/\Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this

	Mode	Rate (10^8 s^{-1})	Scale factor
Γ ₁	$3\pi^{0}$	0.0408 ± 0.0006	
Γ_2	$\pi^{+}\pi^{-}\pi^{0}$	0.0243 ± 0.0004	1.5
Γ3	$\pi^{\pm}\mu^{\mp}\nu$ Called $K_{\mu 3}^{0}$.	[a] 0.0525 ± 0.0007	1.1
Γ ₆	$\pi^{\pm} e^{\mp} \nu_e$ Called K_{e3}^0 .	[a] 0.0750 ± 0.0008	1.1
Γ_9	2γ	$(1.144 \pm 0.031) \times 10^{-4}$	
Γ ₁₇ Γ ₁₈	$\pi^{+}\pi^{-}$ $\pi^{0}\pi^{0}$	$(4.00 \pm 0.07) \times 10^{-4}$ $(1.81 \pm 0.04) \times 10^{-4}$	1.1

K⁰ DECAY RATES

$\Gamma(3\pi^0)$						Γ_1
VALUE (10 ⁶ s ⁻¹)	EVTS	DOCUMENT ID		TECN	COMMENT	
4.08±0.06 OUR FIT						
5.22 + 1.03	54	BEHR	66	HLBC	Assumes CP	

$\Gamma(\pi^+\pi^-\pi^0)$					Γ	2
VALUE (10 ⁶ s ⁻¹)	EVTS	DOCUMENT ID		TECN	COMMENT	
2.43±0.04 OUR FIT		des scale factor o	of 1.5.			
2.38±0.09 OUR AVE	RAGE					
$2.32^{+0.13}_{-0.15}$	192	BALDO	75	HLBC	Assumes CP	
2.35 ± 0.20	180	⁷ JAMES	72	нвс	Assumes CP	
2.71 ± 0.28	99	сно	71	DBC	Assumes CP	
2.12 ± 0.33	50	MEISNER	71	нвс	Assumes CP	
2.20 ± 0.35	53	WEBBER	70	HBC	Assumes CP	
$2.62^{+0.28}_{-0.27}$	136	BEHR	66	HLBC	Assumes CP	
 ● ● We do not use 	the followin	g data for averag	es, fits,	limits,	, etc. • • •	
2.5 ±0.3	98	⁷ JAMES	71	нвс	Assumes CP	
3.26 ± 0.77	18	ANDERSON	65	нвс		
1.4 ±0.4	14	FRANZINI		HBC		
					e and the branching rati	
$\Gamma(\pi^+\pi^-\pi^0)/$	$\Gamma(\pi^+\pi^-\pi^0)$	$\Gamma(\pi^{\pm}\mu^{\mp}\nu)$) + r(·	$\pi^{\pm} e^{\mp}$	$ u_e $. For this reason th	e
discrepancy bet	ween the Γ(-	$\pi^+\pi^-\pi^0$) meas	uremen	ts does	not affect the scale facto	r
of the overall fit	t.					
⁷ JAMES 72 is a fin	al measurer	nent and includes	JAME	S 71.		
$\Gamma(\pi^{\pm}\mu^{\mp}\nu)$					Г	2
	EVEC	DOCUMENT ID		TECN	• •	•
5.25±0.07 OUR FIT	<u>EVTS</u> Error inclu	des scale factor o	of 1 1	TECN		
• • We do not use				limits.	. etc. • • •	
		-				
$4.54 + 1.24 \\ -1.08$	19	LOWYS	67	HLBC		
$\Gamma(\pi^{\pm}e^{\mp}\nu_{e})$					Γ	_
` -,						5
VALUE (10 ⁶ s ⁻¹) 7.50±0.08 OUR FIT	EVTS	DOCUMENT ID		TECN	COMMENT	
7.7 ±0.5 OUR AVE		des scale factor c) I.I.			
7.81±0.56	620	CHAN	71	нвс		
$7.52 + 0.85 \\ -0.72$		AUBERT	65	HI DC	$\Delta S = \Delta Q.CP$ assumed	
-0.72		AUBLIN	05	HLBC	Δ3-ΔQ,CF assumed	
$\Gamma(\pi^+\pi^-\pi^0) + \Gamma(\pi^+\pi^-\pi^0)$	r± μ∓ ν) ⊣	$-\Gamma(\pi^{\pm}e^{\mp}\nu_{\bullet})$			$(\Gamma_2 + \Gamma_3 + \Gamma_6)$	١
$K_I^0 \rightarrow \text{charged}$. ((-21-31-6	′
VALUE (10 ⁶ s ⁻¹)		DOCUMENT ID		TECN		
15.18±0.14 OUR FIT				12014		
• • We do not use				limits.	, etc. • • •	
15.1 ±1.9	98	AUERBACH		OSPK		
	,,	. 10 2110/1011	000			

r(_+ _- _0)

 $\Gamma(\pi^{\pm}\mu^{\mp}\nu) + \Gamma(\pi^{\pm}e^{\mp}\nu_{e})$ $(\Gamma_3 + \Gamma_6)$ EVTS

VALUE (106 s DOCUMENT ID TECN COMMENT
 VALUE (10° 5° 1)
 EVIS
 DOCUMENT ID
 TECN

 12.75±0.12 OUR FIT
 Error includes scale factor of 1.1.

 11.9 ±0.6 OUR AVERAGE
 Error includes scale factor of 1.2.
 72 HBC $K^+p \rightarrow K^0p\pi^+$ 71 HBC $K^-p \rightarrow n\overline{K}^0$ ⁸ BURGUN 12.4 ± 0.7 410 8 WEBBER $13.1\ \pm1.3$ ^{8,9} CHO $11.6\ \pm0.9$ 393 70 DBC ⁸ FRANZINI $9.85 + 1.15 \\ -1.05$ 109 65 HBC ullet ullet We do not use the following data for averages, fits, limits, etc. ullet ullet⁸ MANN 72 HBC $K^- \rho \rightarrow n \overline{K}^0$ 8.47 ± 1.69 126 ⁹ HILL 67 DBC $K^+ n \rightarrow K^0 p$ 10.3 ±0.8 335 $^{8}_{9}\,\mathrm{Assumes}~\Delta \mathcal{S} = \Delta \mathcal{Q}$ rule. $^{9}_{9}\,\mathrm{CHO}~70$ includes events of HILL 67.

KL BRANCHING RATIOS

$\Gamma(3\pi^{\circ})/\Gamma_{\text{total}}$				Γ_1/Γ
VALUE	EVTS	DOCUMENT II		_
0.2112±0.0027 OUR	FIT Error	includes scale fa	tor of 1.1.	
0.2105 ± 0.0028	38k	¹⁰ KREUTZ	95 NA31	L
10 KREUTZ 95 meas for $\pi\mu u_{\mu}$, 2π , and			e modes. Th	hey assume PDG 1992 values

 $\Gamma(3\pi^0)/\Gamma(\pi^+\pi^-\pi^0)$ Γ_1/Γ_2
 VALUE
 EVTS
 DOCUMENT ID
 TECN

 1.68 ±0.04
 OUR FIT
 Error includes scale factor of 1.3.

 1.63 ±0.05
 OUR AVERAGE
 Error includes scale factor of 1.4.
 TECN COMMENT $1.611 \pm 0.014 \pm 0.034$ $^{11}\,\mathrm{KREUTZ}$ BUDAGOV $\begin{array}{ccc} 1.80 & \pm 0.13 \\ 2.0 & \pm 0.6 \end{array}$ 1010 ALEKSANYAN 64B FBC 188 \bullet $\,\bullet\,$ We do not use the following data for averages, fits, limits, etc. $\,\bullet\,$ $\,\bullet\,$ 883 BARMIN 728 HLBC Error statistical only 11 KREUTZ 95 excluded from fit because it is not independent of their $\Gamma(3\pi^0)/\Gamma_{ ext{total}}$

 $\Gamma\big(3\pi^0\big)/\Gamma\big(\pi^\pm\,e^\mp\,\nu_e\big)$ Γ_1/Γ_6

 VALUE
 EVTS
 DOCUMENT ID
 T

 0.545±0.009 OUR FIT
 Error includes scale factor of 1.1.
 0.545±0.004±0.009
 38k
 12 KREUTZ
 95
 N
 95 NA31

measurement, which is in the fit.

 $^{12}\,\mathrm{KREUTZ}$ 95 measurement excluded from fit because it is not independent of their $\Gamma(3\pi^0)/\Gamma_{\text{total}}$ measurement, which is in the fit.

$\frac{(\Gamma_a^+\pi^-\pi^0)}{(\Gamma_a^+\pi^-\pi^0)} + \frac{(\pi^\pm\mu^\mp\nu)}{(\pi^\pm\mu^\mp\nu)} + \frac{(\pi^\pm\epsilon^\mp\nu_e)}{(\pi^\pm\mu^+\nu)} = \frac{\Gamma_1/(\Gamma_2+\Gamma_3+\Gamma_6)}{\Gamma_2}$	$ \Gamma(\pi^{\pm}\mu^{\mp}\nu)/[\Gamma(\pi^{+}\pi^{-}\pi^{0}) + \Gamma(\pi^{\pm}\mu^{\mp}\nu) + \Gamma(\pi^{\pm}e^{\mp}\nu_{e})] \qquad \Gamma_{3}/(\Gamma_{2} + \Gamma_{3} + \Gamma_{6}) $
59±0.004 OUR FIT Error includes scale factor of 1.1.	VALUE EVTS DOCUMENT ID TECN
50±0.011 OUR AVERAGE	0.3461±0.0030 OUR FIT Error includes scale factor of 1.1. • • • We do not use the following data for averages, fits, limits, etc. • • •
51±0.014 549 BUDAGOV 68 HLBC ORSAY measur.	0.335 ± 0.055 330 ¹⁵ KULYUKINA 68 CC
77±0.021 444 BUDAGOV 68 HLBC Ecole polytec.meas	0.39 +0.08 172 ¹⁵ ASTBURY 65 CC
L +0.07 -0.06 29 KULYUKINA 68 CC	0.356 ± 0.07 251 15 LUERS 64 HBC
4 ±0.08 24 ANIKINA 64 CC	
$(\tau^+\pi^-\pi^0)/\Gamma_{ ext{total}}$	¹⁵ This mode not measured independently from $\Gamma(\pi^+\pi^-\pi^0)/[\Gamma(\pi^+\pi^-\pi^0)]$
UE DOCUMENT ID 256±0.0020 OUR FIT Error includes scale factor of 1.7.	$ \Gamma(\pi^{\pm}\mu^{\mp}\nu) + \Gamma(\pi^{\pm}e^{\mp}\nu_{e}) \Big] \text{ and } \Gamma(\pi^{\pm}e^{\mp}\nu_{e})/\Big[\Gamma(\pi^{+}\pi^{-}\pi^{0}) + \Gamma(\pi^{\pm}\mu^{\mp}\nu) - \Gamma(\pi^{\pm}e^{\mp}\nu_{e})\Big]. $
$(\pi^{+}\pi^{-}\pi^{0})/[\Gamma(\pi^{+}\pi^{-}\pi^{0})+\Gamma(\pi^{\pm}\mu^{\mp}\nu)+\Gamma(\pi^{\pm}e^{\mp}\nu_{e})]$ $\Gamma_{2}/(\Gamma_{2}+\Gamma_{3}+\Gamma_{6})$	$\Gamma(\pi^{\pm}e^{\mp}\nu_{e})/[\Gamma(\pi^{+}\pi^{-}\pi^{0})+\Gamma(\pi^{\pm}\mu^{\mp}\nu)+\Gamma(\pi^{\pm}e^{\mp}\nu_{e})] \Gamma_{6}/(\Gamma_{2}+\Gamma_{3}+\Gamma_{6})$
<u>UE EVTS DOCUMENT ID TECN COMMENT</u> 500±0.0025 OUR FIT Error includes scale factor of 1.7.	$\frac{VALUE}{VALUE} = \frac{EVTS}{VALUE} = E$
588±0.0024 OUR AVERAGE Error includes scale factor of 1.4. See the ideogram	0.4939±0.0030 OUR FIT Error includes scale factor of 1.1.
below. ± 0.003 6499 CHO 77 HBC	 • • We do not use the following data for averages, fits, limits, etc.
505 ± 0.0038 1590 ALEXANDER 738 HBC	0.498 ±0.052 500 KULYUKINA 68 CC
46 ±0.004 3200 BRANDENB 73 HBC	$0.46 \ ^{+0.08}_{-0.10}$ 202 ASTBURY 65 CC
59 ±0.010 558 EVANS 73 HLBC	0.487 \pm 0.05 153 LUERS 64 HBC
67 ±0.016 1402 KULYUKINA 68 CC 61 ±0.005 HOPKINS 67 HBC	0.46 ± 0.11 24 NYAGU 61 CC
52 ±0.015 126 HAWKINS 66 HBC	$\Gamma(\pi^{\pm}e^{\mp}\nu_{e})/[\Gamma(\pi^{\pm}\mu^{\mp}\nu)+\Gamma(\pi^{\pm}e^{\mp}\nu_{e})]$ $\Gamma_{6}/(\Gamma_{3}+\Gamma_{6})$
59 ±0.015 326 ASTBURY 65B CC	$\frac{\Gamma(\pi^{\pm}e^{+}\nu_{e})/[\Gamma(\pi^{\pm}\mu^{+}\nu) + \Gamma(\pi^{\pm}e^{+}\nu_{e})]}{\frac{VALUE}{\frac{EVTS}{}} \frac{DOCUMENT ID}{\frac{TECN}{}} \frac{TECN}{}$
78 ±0.017 566 GUIDONI 65 HBC	0.5880±0.0033 OUR FIT
• We do not use the following data for averages, fits, limits, etc. • • • • • • •	
+0.03 -0.04 66 ASTBURY 65 CC	$0.415~\pm0.120$ 320 ASTIER 61 CC
4 ± 0.004 1729 HOPKINS 65 HBC See HOPKINS 67	[=/ + + >/ + + >] /=
1 ±0.020 79 ADAIR 64 HBC	$\left[\Gamma(\pi^{\pm}\mu^{\mp}\nu) + \Gamma(\pi^{\pm}e^{\mp}\nu_{e})\right]/\Gamma_{\text{total}} \tag{\Gamma_{3}+\Gamma_{6}}$
7 +0.03	O.6596±0.0030 OUR FIT Error includes scale factor of 1.2.
	$\Gamma(2\gamma)/\Gamma_{ ext{total}}$
WEIGHTED AVERAGE 0.1588±0.0024 (Error scaled by 1.4)	VALUE (units 10 ⁻⁴) EVTS DOCUMENT ID TECN COMMENT
	5.92±0.15 OUR FIT
Values above of weighted average, error,	
Λ and scale factor are based upon the data in	4.54 \pm 0.84 16 BANNER 72B OSPK
this ideogram only. They are not necessarily the same as our 'best' values,	4.5 ± 1.0 23 ENSTROM 71 OSPK K_L^0 1.5–9 GeV/ c
obtained from a least-squares constrained fit	5.0 ±1.0 17 REPELLIN 71 OSPK
utilizing measurements of other (related) quantities as additional information.	5.5 ± 1.1 90 KUNZ 68 OSPK Norm.to 3 π (C+N) 7.4 ± 1.6 33 18 CRONIN 67 OSPK
	7.4 \pm 1.6 33 ¹⁸ CRONIN 67 OSPK 6.7 \pm 2.2 32 TODOROFF 67 OSPK Repl. CRIEGEE 66
χ^2	1.3 ±0.6
CHO 77 HBC 2.0 ALEXANDER 73B HBC 0.2	¹⁶ This value uses $(\eta_{00}/\eta_{+-})^2=1.05\pm0.14$. In general, $\Gamma(2\gamma)/\Gamma_{ ext{total}}=[(4.32\pm0.55)\pm0.14]$
── · · · · · · · · · · · · · · · · BRANDENB 73 HBC 10.2	10^{-4}] $[(\eta_{00}/\eta_{+-})^2]$.
EVANS 73 HLBC 0.0	17 Assumes regeneration amplitude in copper at 2 GeV is 22 mb. To evaluate for a give
HOPKINS 67 HBC 0.2	regeneration amplitude and error, multiply by (regeneration amplitude/22mb) 2 .
ASTRUBY 65P CC 0.0	18 CRONIN 67 replaced by KUNZ 68.
ASTBURY 65B CC 0.0 GUIDONI 65 HBC 1.3	¹⁹ CRIEGEE 66 replaced by TODOROFF 67.
14.2	
	$\Gamma(2\gamma)/\Gamma(3\pi^0)$
14.2	
0.12 0.14 0.16 0.18 0.2 0.22	$\Gamma(2\gamma)/\Gamma(3\pi^0)$ Γ_9/Γ
(Confidence Level = 0.077)	$ \Gamma(2\gamma)/\Gamma(3\pi^0) \qquad \qquad \Gamma_9/\Gamma $ $ 2.80\pm 0.08 \text{ OUR FIT} \qquad \text{EVTS} \qquad \text{DOCUMENT ID} \qquad \text{TECN} \qquad \text{COMMENT} $ $ \bullet \bullet \text{ We do not use the following data for averages, fits, limits, etc.} \bullet \bullet \bullet $ $ 2.13\pm 0.43 \qquad \qquad 28 \qquad \text{BARMIN} \qquad 71 \text{HLBC} $
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \Gamma(2\gamma)/\Gamma(3\pi^0) $
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \Gamma(2\gamma)/\Gamma(3\pi^0) $
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\Gamma(2\gamma)/\Gamma(3\pi^0)$ VALUE (units 10 ⁻³) EVTS DOCUMENT ID TECN COMMENT TO 1.1. • • • We do not use the following data for averages, fits, limits, etc. • • • 2.13 ± 0.43 28 BARMIN 71 HLBC 2.24 ± 0.28 115 BANNER 69 OSPK 2.5 ± 0.7 16 ARNOLD 68B HLBC Vacuum decay $\Gamma(2\gamma)/\Gamma(\pi^0\pi^0)$ VALUE 0.632 ± 0.009 OUR FIT 0.632 ± 0.004 ± 0.008 110 k BURKHARDT 87 NA31
$\frac{14.2}{0.12 0.14 0.16 0.18 0.2 0.22}$ $\Gamma(\pi^{+}\pi^{-}\pi^{0})/[\Gamma(\pi^{+}\pi^{-}\pi^{0}) + \Gamma(\pi^{\pm}\mu^{\mp}\nu) + \Gamma(\pi^{\pm}e^{\mp}\nu_{e})]$ $\frac{1}{\pi^{+}\pi^{-}\pi^{0}}/\Gamma(\pi^{\pm}e^{\mp}\nu_{e})$ $\frac{1}{\pi^{+}\pi^{-}\pi^{0}}/\Gamma(\pi^{+}\pi^{-}\pi^{0})$ $\frac{1}{\pi^{+}\pi^{-}\pi^{0}}/\Gamma(\pi^{-}\pi^{0})$ $\frac{1}{\pi^{+}\pi^{-}\pi^{0}}/\Gamma(\pi^{-}\pi^{-}\pi^{0})$ $\frac{1}{\pi^{+}\pi^{-}\pi^{0}}/\Gamma(\pi^{$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
$\frac{14.2}{0.12} = \frac{14.2}{0.14} = \frac{14.2}{0.16} = \frac{14.2}{0.077}$ $\frac{14.2}{0.12} = \frac{14.2}{0.14} = \frac{16}{0.18} = \frac{14.2}{0.2}$ $\frac{\Gamma(\pi^{+}\pi^{-}\pi^{0})}{\Gamma(\pi^{+}\pi^{-}\pi^{0})} + \Gamma(\pi^{\pm}\mu^{\mp}\nu) + \Gamma(\pi^{\pm}e^{\mp}\nu_{e})} = \frac{\Gamma_{2}/\Gamma_{6}}{\Gamma_{2}/\Gamma_{6}}$ $\frac{E+0.006 \text{ OUR FIT}}{E+0.003\pm0.007} = \frac{EVTS}{28k} = \frac{DOCUMENT ID}{KREUTZ} = \frac{TECN}{95 \text{ NA31}}$ $\frac{E+\pi^{\mp}\nu}{E+0.009 \text{ OUR FIT}} = \frac{EVTS}{EVTS} = \frac{DOCUMENT ID}{EVTS} = \frac{TECN}{EVTS} = \frac{COMMENT}{EVTS}$ $\frac{E+0.009 \text{ OUR FIT}}{E+0.010 \text{ OUR AVERAGE}}$ $\frac{E+0.011}{28k} = \frac{EVTS}{EVTS} = \frac{DOCUMENT ID}{EVTS} = \frac{COMMENT}{EVTS}$ $\frac{EVTS}{EVTS} = \frac{DOCUMENT ID}{EVTS} = \frac{COMMENT}{EVTS}$ $\frac{EVTS}{EVTS} = \frac{EVTS}{EVTS} = \frac$	$ \Gamma(2\gamma)/\Gamma(3\pi^0) \qquad \qquad \Gamma_9/\Gamma $ $ 280 \pm 0.08 \text{ OUR FIT} \qquad \text{EVTS} \qquad \text{DOCUMENT ID} \qquad \text{TECN} \qquad \text{COMMENT} $ $ \bullet \bullet \text{ We do not use the following data for averages, fits, limits, etc.} \bullet \bullet \bullet $ $ 2.13 \pm 0.43 \qquad 28 \qquad \text{BARMIN} \qquad 71 \qquad \text{HLBC} $ $ 2.24 \pm 0.28 \qquad 115 \qquad \text{BANNER} \qquad 69 \qquad \text{OSPK} $ $ 2.5 \pm 0.7 \qquad 16 \qquad \text{ARNOLD} \qquad 688 \qquad \text{HLBC} \qquad \text{Vacuum decay} $ $ \Gamma(2\gamma)/\Gamma(\pi^0\pi^0) \qquad \qquad \qquad \Gamma(2\gamma)/\Gamma(\pi^0\pi^0) \qquad \qquad \qquad \Gamma(2\gamma)/\Gamma(\pi^0\pi^0) \qquad \qquad \Gamma(2\gamma)/\Gamma($
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \Gamma(2\gamma)/\Gamma(3\pi^0) \qquad \qquad \Gamma_9/\Gamma $ $ 2ALUE \text{ (units }10^{-3}) \qquad EVTS \qquad DOCUMENT ID \qquad TECN \qquad COMMENT $ $ 2.80\pm0.08 \text{ OUR FIT} \qquad \text{Error includes scale factor of } 1.1. $ $ \bullet \bullet \bullet \text{ We do not use the following data for averages, fits, limits, etc.} \bullet \bullet \bullet $ $ 2.13\pm0.43 \qquad 28 \qquad \text{BARMIN} \qquad 71 \text{HLBC} $ $ 2.24\pm0.28 \qquad 115 \qquad \text{BANNER} \qquad 69 \text{OSPK} $ $ 2.5\pm0.7 \qquad 16 \qquad \text{ARNOLD} \qquad 688 \text{HLBC} \qquad \text{Vacuum decay} $ $ \Gamma(2\gamma)/\Gamma(\pi^0\pi^0) \qquad \qquad \qquad \Gamma(2\gamma)/\Gamma(\pi^0\pi^0) \qquad \qquad \Gamma_{10} $ $ \frac{EVTS}{DOCUMENT \ ID} \qquad \frac{TECN}{DOCUMENT \ ID} \qquad \frac{TECN}{DOCUMENT \ ID} $ $ \frac{TCN}{DOCUMENT \ ID} \qquad \frac{TECN}{DOCUMENT \ ID} $
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \Gamma(2\gamma)/\Gamma(3\pi^0) \qquad \qquad \Gamma_9/\Gamma $ $ 2.80\pm0.08 \text{ OUR FIT} \qquad EVTS \qquad DOCUMENT ID \qquad TECN \qquad COMMENT $ $ 2.80\pm0.08 \text{ OUR FIT} \qquad Error includes scale factor of 1.1. } $
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \Gamma(2\gamma)/\Gamma(3\pi^0) \qquad \qquad \Gamma_9/\Gamma $ $ 2.80\pm0.08 \text{ OUR FIT} \qquad EVTS \qquad DOCUMENT ID \qquad TECN \qquad COMMENT $ $ 2.80\pm0.08 \text{ OUR FIT} \qquad EVTS \qquad DOCUMENT ID \qquad TECN \qquad COMMENT $ $ 2.13\pm0.43 \qquad 28 \qquad \text{BARMIN} \qquad 71 \qquad \text{HLBC} $ $ 2.24\pm0.28 \qquad 115 \qquad \text{BANNER} \qquad 69 \qquad \text{OSPK} $ $ 2.5\pm0.7 \qquad 16 \qquad \text{ARNOLD} \qquad 688 \text{ HLBC} \qquad \text{Vacuum decay} $ $ \Gamma(2\gamma)/\Gamma(\pi^0\pi^0) \qquad \qquad \qquad \Gamma_9/\Gamma_1 $ $ \frac{VALUE}{0.632\pm0.009 \text{ OUR FIT}} \qquad \frac{EVTS}{0.632\pm0.004\pm0.008} \qquad 110k \qquad \text{BURKHARDT} \qquad 87 \text{NA31} $ $ \Gamma(3\gamma)/\Gamma_{\text{total}} \qquad \qquad \frac{VALUE}{VALUE} \qquad CL\% \qquad \frac{DOCUMENT ID}{20 \text{ BARR}} \qquad 95C \text{NA31} $ $ \Gamma(3\gamma)/\Gamma_{\text{total}} \qquad CL\% \qquad \frac{DOCUMENT ID}{20 \text{ BARR}} \qquad 95C \text{NA31} $ $ \Gamma(10/T_{\text{total}}) \qquad \frac{VALUE}{VALUE} \qquad CL\% \qquad \frac{DOCUMENT ID}{20 \text{ BARR}} \qquad 95C \text{NA31} $ $ \Gamma(10/T_{\text{total}}) \qquad \Gamma(11/T_{\text{total}}) \qquad \Gamma(11/T_{$
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$\frac{14.2}{14.2}$ 0.12 0.14 0.16 0.18 0.2 0.22 $\Gamma(\pi^{+}\pi^{-}\pi^{0})/[\Gamma(\pi^{+}\pi^{-}\pi^{0}) + \Gamma(\pi^{\pm}\mu^{\mp}\nu) + \Gamma(\pi^{\pm}e^{\mp}\nu_{e})]$ $\frac{+\pi^{-}\pi^{0}}{\pi^{0}}/\Gamma(\pi^{\pm}e^{\mp}\nu_{e})$ $\frac{EVTS}{4\pm0.006\ \text{OUR}\ \text{FIT}}$ $\frac{EVTS}{28k}$ $\frac{EVTS}{k}$ $\frac{DOCUMENT\ ID}{28k}$ $\frac{EVTS}{k}$ $\frac{DOCUMENT\ ID}{28k}$ $\frac{EVTS}{k}$ $\frac{DOCUMENT\ ID}{28k}$ $\frac{EVTS}{k}$ $\frac{EVTS}{28k}$ $\frac{EVTS}{28k$	
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14.2 (Confidence Level = 0.077) 0.12 0.14 0.16 0.18 0.2 0.22 $\Gamma(\pi^{+}\pi^{-}\pi^{0})/[\Gamma(\pi^{+}\pi^{-}\pi^{0}) + \Gamma(\pi^{\pm}\mu^{\mp}\nu) + \Gamma(\pi^{\pm}e^{\mp}\nu_{e})]$ + $\pi^{-}\pi^{0})/[\Gamma(\pi^{\pm}e^{\mp}\nu_{e})]$ + $\pi^{-}\pi^{0})/[\Gamma(\pi^{\pm}e^{\mp}\nu_{e})]$ + $\pi^{-}\pi^{0})/[\Gamma(\pi^{\pm}e^{\mp}\nu_{e})]$ - $\pi^{-}\pi^{0}$ + $\pi^{-}\pi^{0})/[\Gamma(\pi^{\pm}e^{\mp}\nu_{e})]$ - $\pi^{-}\pi^{0}$	
14.2 (Confidence Level = 0.077) 0.12 0.14 0.16 0.18 0.2 0.22 $\Gamma(\pi^{+}\pi^{-}\pi^{0})/[\Gamma(\pi^{+}\pi^{-}\pi^{0}) + \Gamma(\pi^{\pm}\mu^{\mp}\nu) + \Gamma(\pi^{\pm}e^{\mp}\nu_{e})]$ + $\pi^{-}\pi^{0})/[(\pi^{\pm}e^{\mp}\nu_{e})]$ 4±0.006 OUR FIT Error includes scale factor of 1.6. 5±0.003±0.007 28k KREUTZ 95 NA31 ± $\mu^{\mp}\nu)/[(\pi^{\pm}e^{\mp}\nu_{e})]$ Follows KREUTZ 95 NA31 $\frac{1}{2}\mu^{\pm}\nu)/[(\pi^{\pm}e^{\mp}\nu_{e})]$ Follows OUR FIT TH.0.009 OUR FIT TH.0.010 OUR AVERAGE 2±0.011 33k CHO 80 HBC 2±0.037 10k WILLIAMS 74 ASPK 1±0.044 6700 BRANDENB 73 HBC 2±0.037 10k WILLIAMS 74 HBC 1±0.044 6700 BRANDENB 73 HBC 1±0.05 770 BUDAGOV 68 HLBC 1±0.06 3548 BASILE 70 OSPK 1±0.08 3548 BASILE 70 OSPK 1±0.04 569 13 BEILLIERE 69 HLBC 3±0.030 1309 EVANS	
14.2 (Confidence Level = 0.077) 0.12 0.14 0.16 0.18 0.2 0.22 $\Gamma(\pi^{+}\pi^{-}\pi^{0})/[\Gamma(\pi^{+}\pi^{-}\pi^{0}) + \Gamma(\pi^{\pm}\mu^{\mp}\nu) + \Gamma(\pi^{\pm}e^{\mp}\nu_{e})]$ $\frac{1}{\pi^{+}\pi^{-}\pi^{0}}/\Gamma(\pi^{\pm}e^{\mp}\nu_{e})$ $\frac{1}{\pi^{+}\pi^{-}\pi^{0}}/\Gamma(\pi^{\pm}e^{\mp}\nu_{e})$ $\frac{1}{\pi^{+}\pi^{-}\pi^{0}}/\Gamma(\pi^{\pm}e^{\mp}\nu_{e})$ $\frac{1}{\pi^{+}\pi^{-}\pi^{0}}/\Gamma(\pi^{\pm}e^{\mp}\nu_{e})$ $\frac{1}{\pi^{+}\pi^{-}\pi^{0}}/\Gamma(\pi^{\pm}e^{\mp}\nu_{e})$ $\frac{1}{\pi^{+}\pi^{-}\pi^{0}}/\Gamma(\pi^{\pm}e^{\mp}\nu_{e})$ $\frac{1}{\pi^{+}\pi^{-}\pi^{0}}/\Gamma(\pi^{\pm}e^{\mp}\nu_{e})$ $\frac{1}{\pi^{+}\pi^{-}\pi^{0}}/\Gamma(\pi^{\pm}e^{\mp}\nu_{e})$ $\frac{1}{\pi^{+}\pi^{-}\pi^{0}}/\Gamma(\pi^{\pm}e^{\mp}\nu_{e})$ $\frac{1}{\pi^{+}\pi^{-}\pi^{0}}/\Gamma(\pi^{\pm}e^{\pm}\nu_{e})$ $\frac{1}{\pi^{+}\pi^{-}\pi^{0}}/\Gamma(\pi^{-}\pi^{-}\pi^{0})$ $\frac{1}{\pi^{+}\pi^{-}\pi^{0}}/\Gamma(\pi^{-}\pi^{-}\pi^{0})$ $\frac{1}{\pi^{+}\pi^{-}\pi^{0}}/\Gamma(\pi^{-}\pi^{-}\pi^{0})$ $\frac{1}{\pi^{+}\pi^{-}\pi^{0}}/\Gamma(\pi^{-}\pi^{-}\pi^{0})$ $\frac{1}{\pi^{+}\pi^{-}\pi^{0}}/\Gamma(\pi^{-}\pi^{-}\pi^{0})$ $\frac{1}{\pi^{+}\pi^{-}\pi^{0}}/\Gamma(\pi^{-}\pi^{-}\pi^{0})$ $\frac{1}{\pi^{+}\pi^{-}\pi^{0}}/\Gamma(\pi^{-}\pi^{0})$ $\frac{1}{\pi^{+}\pi^{-}\pi^{0}}/\Gamma(\pi^{-}\pi^{0})$ $\frac{1}{\pi^{+}\pi^{-}\pi^{$	

K_L^0

$\Gamma(\pi^0\pi^{\pm}e^{\mp}\nu)/\Gamma_{\text{total}}$ Γ_{12}/Γ	$\Gamma(\pi^+\pi^-)/[\Gamma(\pi^+\pi^-\pi^0)]$ Violates <i>CP</i> conservation	$)+\Gamma(\pi^{\pm}\mu^{\mp} u)+\Gamma(\pi^{\pm}e)$	$^{\mp}\nu_{e})]$ $\Gamma_{17}/(\Gamma_{2}+\Gamma_{3}+\Gamma_{6})$
<u>VALUE (units 10⁻⁵) </u>	VALUE (units 10 ⁻³) EV		TECN COMMENT
$5.16 \pm 0.20 \pm 0.22$ 729 MAKOFF 93 E731 6.2 ± 2.0 16 CARROLL 80C SPEC	2.63 ±0.04 OUR FIT • • • We do not use the fol	llowing data for averages, fits,	limits, etc. • •
• • • We do not use the following data for averages, fits, limits, etc. • • •	2.60 ±0.07 420	00 ³² MESSNER 73	ASPK $\eta_{+-} = 2.23 \pm 0.05$
<220 90 ²³ DONALDSON 74 SPEC	1.93 ±0.26		OSPK $\eta_{+-} = 1.92 \pm 0.13$
²³ DONALDSON 74 uses $K_L^0 \to \pi^+\pi^-\pi^0/(\text{all } K_L^0)$ decays $= 0.126$.	1.993 ± 0.080 2.08 ± 0.35		OSPK $\eta_{+-} = 1.95 \pm 0.04$ OSPK $\eta_{+-} = 1.99 \pm 0.16$
$\Gamma((\pi \mu atom) \nu) / \Gamma(\pi^{\pm} \mu^{\mp} \nu)$ Γ_{13} / Γ_{3}		15 33 CHRISTENS 64	OSPK $\eta_{+-} = 1.95 \pm 0.20$
VALUE (units 10 ⁻⁷) EVTS DOCUMENT ID TECN		$^+\pi^-)/\Gamma(\pi^+\pi^-\pi^0)$ MESSNI	ER 73, but with different normal-
3.90±0.39 155 ²⁴ ARONSON 86 SPEC	ization. 33 Old experiments excluded	f from fit. See subsection on η_{\perp}	+- in section on "PARAMETERS
• • • We do not use the following data for averages, fits, limits, etc. • • •		" below for average η_{+-} .	'
seen 18 COOMBES 76 WIRE	$\Gamma(\pi^0\pi^0)/\Gamma_{ m total}$		Γ ₁₈ /Γ
²⁴ ARONSON 86 quote theoretical value of $(4.31 \pm 0.08) \times 10^{-7}$.	Violates CP conservati		•
$\Gamma(\pi^{\pm}e^{\mp}\nu_{e}\gamma)/\Gamma(\pi^{\pm}e^{\mp}\nu_{e})$ Γ_{14}/Γ_{6}	VALUE (units 10 ⁻³) EV 7	TS DOCUMENT ID	TECN COMMENT
VALUE (units 10 ⁻²) EVTS DOCUMENT ID TECN COMMENT 3.3±2.0 10 PEACH 71 HLBC γ KE >15 MeV		llowing data for averages, fits,	limits, etc. • •
	2.5 ±0.8 18	34 GAILLARD 69	OSPK $\eta_{00} = 3.6 \pm 0.6$
$\Gamma(\pi^+\pi^-\gamma)/\Gamma_{\text{total}}$ For earlier limits see our 1992 edition Physical Review D45, 1 June, Part II (1992).	$1.2 \begin{array}{c} +1.5 \\ -1.2 \end{array}$	7 ³⁵ CRIEGEE 66	OSPK
VALUE (units 10 ⁻⁵) EVTS DOCUMENT ID TECN COMMENT		eriment given by FAISSNER 70	
4.61±0.14 OUR AVERAGE	³⁵ CRIEGEE 66 experiment	not designed to measure $2\pi^0$	decay mode.
4.66 \pm 0.15 3136 25 RAMBERG 93 E731 E_{γ} >20 MeV 4.41 \pm 0.32 1062 26 CARROLL 80B SPEC E_{γ} >20 MeV	$\Gamma(\pi^0\pi^0)/\Gamma(3\pi^0)$		Γ_{18}/Γ_{1}
• • • We do not use the following data for averages, fits, limits, etc. • •	Violates <i>CP</i> conservati VALUE (units 10 ⁻²) EV		TECN COMMENT
1.52 ± 0.16 516 27 CARROLL 80B SPEC E _{γ} >20 MeV		ror includes scale factor of 1.1	
2.89±0.28 546 28 CARROLL 80B SPEC	0.39 ±0.06 OUR AVERAG		UI DC
6.2 ±2.1 24 ²⁹ DONALDSON 74C SPEC			HLBC $\eta_{00} = 2.02 \pm 0.23$ HLBC $\eta_{00} = 1.9 \pm 0.5$
25 RAMBERG 93 finds that fraction of Direct Emission (DE) decays with E_{γ} >20 MeV is 0.685 \pm 0.041.		57 BANNER 69	OSPK $\eta_{00} = 2.2 \pm 0.3$
²⁶ Both components. Uses $K_L^0 \to \pi^+\pi^-\pi^0/(\text{all } K_L^0)$ decays = 0.1239.	not seen • • • We do not use the fol	BARTLETT 68 llowing data for averages, fits,	OSPK See η_{00} below
27 Internal Bremsstrahlung component only. 28 Direct γ emission component only.	1.21 ±0.30 15	50 ³⁶ REY 76	OSPK $\eta_{00} = 3.8 \pm 0.5$
29 Uses $K_L^0 \rightarrow \pi^+\pi^-\pi^0/(\text{all }K_L^0)$ decays = 0.126.	0.90 ±0.30 17	72 37 FAISSNER 70	OSPK $\eta_{00} = 3.2 \pm 0.5$
	1.31 ± 0.31 1.89 ± 0.31 1.89 ± 0.31 1.89 ± 0.31 1.89 ± 0.31	33 ³⁶ CENCE 69 09 ³⁸ CRONIN 67	OSPK $\eta_{00} = 3.7 \pm 0.5$ OSPK $\eta_{00} = 4.9 \pm 0.5$
$\Gamma(\pi^0\pi^0\gamma)/\Gamma_{\text{total}}$	1.36 ±0.18		OSPK $\eta_{00} = 3.92 \pm 0.3$
<u>VALUE (units 10^{−6}) CL% EVTS DOCUMENT ID TECN</u> < 5.6 BARR 94 NA31	36 CENCE 69 events are inc	cluded in REY 76. same 2 π^0 events as GAILLARI	D 60 F(=0=0)/F
• • • We do not use the following data for averages, fits, limits, etc. • •	38 CRONIN 67B is further a	analysis of CRONIN 67, now b	ooth withdrawn.
<230 90 0 ROBERTS 94 E799	$\Gamma(\pi^0\pi^0)/\Gamma(\pi^+\pi^-)$	·	Γ ₁₈ /Γ ₁₇
$\Gamma(\pi^+\pi^-)/\Gamma_{total}$ Γ_{17}/Γ	Violates CP conservati	ion.	. 16/ . 17
Violates CP conservation.	VALUE	DOCUMENT ID	
	0.453 ±0.006 OUR FIT		
2.067 \pm 0.035 OUR FIT Error includes scale factor of 1.1.	0.4535 ± 0.0063	³⁹ ETAFIT 96	
VALUE (units 10⁻³) DOCUMENT ID 2.067±0.035 OUR FIT Error includes scale factor of 1.1. 2.107±0.055 30 ETAFIT 96	0.4535 ± 0.0063 39 This ETAFIT value is co	omputed from fitted values of	f $ \eta_{00} / \eta_{+-} $ and the $\Gamma(K_S^0 \to K_S^0)$
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	0.4535 \pm 0.0063 39 This ETAFIT value is co $\pi^+\pi^-)/\Gamma(\kappa^0_S\to\pi^0$	omputed from fitted values of	$\lceil \eta_{00} / \eta_{+-} $ and the $\Gamma(K_S^0) ightarrow 0$ he discussion in the "Note on <i>CP</i> "
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	0.4535 \pm 0.0063 $^{39} \text{This ETAFIT value is co} \\ \pi^+\pi^-) \ / \ \Gamma(K_S^0 \to \pi^0 \\ \text{violation in } K_L^0 \text{decay."}$	omputed from fitted values of $\pi^0)$ branching fraction. See t	he discussion in the "Note on <i>CP</i>
VALUE (units 10^{-3}) 2.067 \pm 0.035 OUR FIT Error includes scale factor of 1.1. 2.107 \pm 0.055 30 ETAFIT 96 30 This ETAFIT value is computed from fitted values of $ \eta_{+-} $, the K_L^0 and K_S^0 lifetimes, and the $K_S^0 \to \pi^+\pi^-$ branching fraction. See the discussion in the "Note on CP violation in K_L^0 decay."	0.4535 \pm 0.0063 39 This ETAFIT value is co $\pi^+\pi^-$) / $\Gamma(\kappa_S^0 \to \pi^0$ violation in κ_L^0 decay." $\Gamma(\mu^+\mu^-)/[\Gamma(\pi^+\pi^-\pi^0)]$	omputed from fitted values of π^0) branching fraction. See that $\Pi = \Pi + \Gamma(\pi^\pm \mu^\mp \nu) + \Gamma(\pi^\pm e)$	the discussion in the "Note on <i>CP</i> $\left[\mp \nu_{e}\right]$ $\Gamma_{19}/(\Gamma_{2}+\Gamma_{3}+\Gamma_{6})$
VALUE (units 10^{-3}) 2.067 \pm 0.035 OUR FIT Error includes scale factor of 1.1. 2.107 \pm 0.055 30 ETAFIT 96 30 This ETAFIT value is computed from fitted values of $ \eta_{+-} $, the \mathcal{K}_L^0 and \mathcal{K}_S^0 lifetimes, and the $\mathcal{K}_S^0 \to \pi^+\pi^-$ branching fraction. See the discussion in the "Note on CP violation in \mathcal{K}_L^0 decay." $\Gamma(\pi^+\pi^-)/\Gamma(\pi^+\pi^-\pi^0)$	0.4535 \pm 0.0063 39 This ETAFIT value is complete $\pi^+\pi^-$) / $\Gamma(\mathcal{K}_S^0 \to \pi^0$ violation in \mathcal{K}_L^0 decay." $\Gamma(\mu^+\mu^-)/[\Gamma(\pi^+\pi^-\pi^0$ Test for $\Delta S=1$ weak is	omputed from fitted values of π^0) branching fraction. See t $ + \Gamma(\pi^\pm \mu^\mp \nu) + \Gamma(\pi^\pm e$ neutral current. Allowed by high	the discussion in the "Note on <i>CP</i> $\left[\frac{1}{2} \nu_e \right] \Gamma_{19} / \left(\Gamma_2 + \Gamma_3 + \Gamma_6 \right)$ gher-order electroweak interaction.
VALUE (units 10^{-3}) 2.067 \pm 0.035 OUR FIT Error includes scale factor of 1.1. 2.107 \pm 0.055 30 ETAFIT 96 30 This ETAFIT value is computed from fitted values of $ \eta_{+-} $, the K_L^0 and K_S^0 lifetimes, and the $K_S^0 \to \pi^+\pi^-$ branching fraction. See the discussion in the "Note on CP violation in K_L^0 decay."	0.4535 \pm 0.0063 39 This ETAFIT value is compared to the second of the	omputed from fitted values of π^0) branching fraction. See t $ + \Gamma(\pi^\pm \mu^\mp \nu) + \Gamma(\pi^\pm e$ neutral current. Allowed by high	the discussion in the "Note on CP $\begin{array}{ccc} & & & & & & & & & & & & & & & & & &$
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	0.4535 \pm 0.0063 39 This ETAFIT value is complete $\pi^+\pi^-$ / $\Gamma(\kappa_S^0 \to \pi^0)$ violation in κ_L^0 decay." $\Gamma(\mu^+\mu^-)/[\Gamma(\pi^+\pi^-\pi^0)$ Test for $\Delta S = 1$ weak is $\frac{VALUE (units 10^{-6})}{2}$ CL • • We do not use the follows $\Gamma(x_L^0)$ CL • 2.0 90	computed from fitted values of π^0) branching fraction. See the house of π^0 branching fraction. See the house of π^0 branching fraction from the house of π^0 branching fraction.	the discussion in the "Note on CP $\begin{array}{ccccccccccccccccccccccccccccccccccc$
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	0.4535 \pm 0.0063 39 This ETAFIT value is compared to the property of the pr	omputed from fitted values of π^0) branching fraction. See the heat of π^0 and π^0 branching fraction. See the heat of π^0 branching fraction. See the heat of π^0 branching fractions of π^0 branching fracti	the discussion in the "Note on CP Γ_{ν_e} " $\Gamma_{19}/(\Gamma_2+\Gamma_3+\Gamma_6)$ gher-order electroweak interaction. $\frac{TECN}{\Gamma_e}$ OSPK
VALUE (units 10 ⁻³) DOCUMENT ID 2.067 ± 0.035 OUR FIT Error includes scale factor of 1.1. 2.107 ± 0.055 30 ETAFIT 96 30 This ETAFIT value is computed from fitted values of $ \eta_{+-} $, the K_L^0 and K_S^0 lifetimes, and the $K_S^0 \to \pi^+\pi^-$ branching fraction. See the discussion in the "Note on <i>CP</i> violation in K_L^0 decay." $\Gamma(\pi^+\pi^-)/\Gamma(\pi^+\pi^-\pi^0)$ Violates <i>CP</i> conservation. VALUE (units 10 ⁻²) 1.645 ± 0.030 OUR FIT Error includes scale factor of 1.1. 1.64 ± 0.04 $EVTS$ DOCUMENT ID TECN COMMENT 1.645 ± 0.030 OUR FIT Terror includes scale factor of 1.1. 1.64 ± 0.04 $EVTS$ To includes scale factor of 1.1. 1.64 ± 0.04 $EVTS$ To includes scale factor of 1.1. 1.64 ± 0.04 $EVTS$ To includes scale factor of 1.1. 1.64 ± 0.04 $EVTS$ To includes scale factor of 1.1. 1.64 ± 0.04 $EVTS$ To includes scale factor of 1.1. 1.64 ± 0.04 $EVTS$ To includes scale factor of 1.1. 1.64 ± 0.05 $EVTS$ To includes scale factor of 1.1. 1.64 ± 0.05 $EVTS$ To includes scale factor of 1.1. 1.64 ± 0.05 $EVTS$ To includes scale factor of 1.1. 1.64 ± 0.05 $EVTS$ To includes scale factor of 1.1. 1.64 ± 0.05 $EVTS$ To includes scale factor of 1.1. 1.65 $EVTS$ To includes scale factor of 1.1. 1.66 ± 0.05 $EVTS$ To includes scale factor of 1.1. 1.67 $EVTS$ To includes scale factor of 1.1. 1.64 ± 0.05 $EVTS$ To includes scale factor of 1.1. 1.65 $EVTS$ To includes includes scale factor of 1.1. 1.66 $EVTS$ To includes includes scale factor of 1.1. 1.67 $EVTS$ To includes include	0.4535 \pm 0.0063 39 This ETAFIT value is complete $\pi^+\pi^-$ / $\Gamma(\kappa_S^0 \to \pi^0)$ violation in κ_L^0 decay." $\Gamma(\mu^+\mu^-)/[\Gamma(\pi^+\pi^-\pi^0)$ Test for $\Delta S = 1$ weak is $\frac{VALUE (units 10^{-6})}{2}$ CL • • We do not use the follows $\Gamma(x_L^0)$ CL • 2.0 90	omputed from fitted values of π^0) branching fraction. See the heat of π^0 and π^0 branching fraction. See the heat of π^0 branching fraction. See the heat of π^0 branching fractions of π^0 branching fracti	he discussion in the "Note on CP $(F_{\nu}e)$ $F_{\nu}e$
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	0.4535 \pm 0.0063 39 This ETAFIT value is complete $\pi^+\pi^-$) $/\Gamma(\mathcal{K}_S^0 \to \pi^0)$ violation in \mathcal{K}_L^0 decay." $\Gamma(\mu^+\mu^-)/[\Gamma(\pi^+\pi^-\pi^0)]$ Test for $\Delta S=1$ weak in $\Delta S=1$ weak in $\Delta S=1$ weak in $\Delta S=1$ when	pomputed from fitted values of π^0) branching fraction. See the house of the hou	the discussion in the "Note on CP Γ_{ν_e} " Γ_{ν_e
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	0.4535 \pm 0.0063 39 This ETAFIT value is $\cot \pi^+\pi^-$) $/ \Gamma(\kappa_S^0 \to \pi^0 \text{ violation in } \kappa_L^0 \text{ decay."}$ $\Gamma(\mu^+\mu^-)/[\Gamma(\pi^+\pi^-\pi^0 \text{ Test for } \Delta S = 1 \text{ weak i.}$ $\frac{VALUE (\text{units } 10^{-6})}{2} \qquad CL$ • • We do not use the folication of the second of the secon	omputed from fitted values of π^0) branching fraction. See the second property of π^0 branching fraction. See the second property of π^0 branching fraction. See the second property of π^0 branching fraction of π^0 branching fraction of π^0 branching fraction of π^0 branching fraction. See the second property of π^0 branching fraction of π^0 branching fraction of π^0 branching fraction. See the second property of π^0 branching fraction of π^0 branching fraction. See the second property of π^0 branching fraction of π^0 branching fraction. See the second property of π^0 branching fraction of π^0 branching fraction. See the second property of π^0 branching fraction of π^0 branching fraction. See the second property of π^0 branching fraction of π^0 branching fraction of π^0 branching fraction of π^0 branching fraction of π^0 b	he discussion in the "Note on CP \mathbb{T}_{ν_e}] $\Gamma_{19}/(\Gamma_2 + \Gamma_3 + \Gamma_6)$ gher-order electroweak interaction. $\frac{TECN}{C}$ Using the set. • • • OSPK OSPK OSPK OSPK CC Γ_{19}/Γ_{17} gher-order electroweak interaction.
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	0.4535 \pm 0.0063 39 This ETAFIT value is compared to the property of the pr	omputed from fitted values of π^0) branching fraction. See the second property of π^0 branching fraction. See the second property of π^0 branching fraction. See the second property of π^0 branching data for averages, fits, second property of π^0 branching fractions	he discussion in the "Note on CP r_{μ} " r_{ν} r_{μ} r_{ν}
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	0.4535 \pm 0.0063 39 This ETAFIT value is $\cot \pi^+\pi^-$) $/ \Gamma(\kappa_S^0 \to \pi^0 \text{ violation in } \kappa_L^0 \text{ decay."}$ $\Gamma(\mu^+\mu^-)/[\Gamma(\pi^+\pi^-\pi^0 \text{ Test for } \Delta S = 1 \text{ weak i.}$ $\frac{VALUE (\text{units } 10^{-6})}{2} \qquad CL$ • • We do not use the folication of the second of the secon	pomputed from fitted values of π^0) branching fraction. See the second probability of the probability of the second pro	he discussion in the "Note on <i>CP</i> Fue
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	0.4535 \pm 0.0063 39 This ETAFIT value is complete $\pi^+\pi^-$) / $\Gamma(K_S^0 \to \pi^0$ violation in K_S^0 decay." $\Gamma(\mu^+\mu^-)/[\Gamma(\pi^+\pi^-\pi^0$ Test for $\Delta S = 1$ weak is K_S^{ALUE} (units 10^{-6}) • • We do not use the folication of (2.2) • • We do not use the folication of (2.5) • • We do not use the folication of (2.5) • • We do not use the folication of (2.5) • • We do not use the folication of (2.5) • • We do not use the folication of (2.5) • • We do not use the folication of (2.5) • • We do not use the folication of (2.5) • • We do not use the folication of (2.5) • • We do not use the folication of (2.5) • • We do not use the folication of (2.5) • • We do not use the folication of (2.5) • • We do not use the folication of (2.5) • • We do not use the folication of (2.5) • • We do not use the folication of (2.5) • • • We do not use the folication of (2.5) • • • We do not use the folication of (2.5) • • • We do not use the folication of (2.5) • • • We do not use the folication of (2.5) • • • We do not use the folication of (2.5) • • • We do not use the folication of (2.5) • • • We do not use the folication of (2.5) • • • We do not use the folication of (2.5) • • • We do not use the folication of (2.5) • • • We do not use the folication of (2.5) • • • We do not use the folication of (2.5) • • • • We do not use the folication of (2.5) • • • • We do not use the folication of (2.5) • • • • We do not use the folication of (2.5) • • • • We do not use the folication of (2.5) • • • • We do not use the folication of (2.5) • • • • We do not use the folication of (2.5) • • • • We do not use the folication of (2.5) • • • • We do not use the folication of (2.5) • • • • • We do not use the folication of (2.5) • • • • • • • • • • • • • • • • • • •	pomputed from fitted values of π^0) branching fraction. See the set of π^0 branching fraction. See the set of π^0 branching fraction. See the set of π^0 branching fraction. Set of π^0 branching from the set of π^0 branching fractions and set of π^0 branching fractions and set of π^0 branching fractions and set of π^0 branching fractions are set of π^0 branching fractions and set of π^0 branching fractions are set of π^0 branching fractions and set of π^0 branching fractions are set of π^0 branch	he discussion in the "Note on CP Γ_{ν} $\Gamma_{19}/(\Gamma_2 + \Gamma_3 + \Gamma_6)$ $\Gamma_{19}/(\Gamma_2 + \Gamma_3 + \Gamma_6)$ Γ_{ECN}
2.067±0.035 OUR FIT Error includes scale factor of 1.1. 2.107±0.055 30 ETAFIT 96 30 This ETAFIT value is computed from fitted values of $ \eta_{+-} $, the K_L^0 and K_S^0 lifetimes, and the $K_S^0 \to \pi^+\pi^-$ branching fraction. See the discussion in the "Note on CP violation in K_L^0 decay." $\Gamma(\pi^+\pi^-)/\Gamma(\pi^+\pi^-\pi^0) \qquad \qquad \Gamma_{17}/\Gamma_2$ Violates CP conservation. **NALUE (units 10 ⁻²) **EVTS** DOCUMENT ID** TECN** COMMENT** 1.645±0.030 OUR FIT** Error includes scale factor of 1.1. 1.64±0.04 4200 MESSNER 73 ASPK $\eta_{+-} = 2.23$ $\Gamma(\pi^+\pi^-)/[\Gamma(\pi^\pm\mu^\mp\nu) + \Gamma(\pi^\pm e^\mp\nu_e)] \qquad \Gamma_{17}/(\Gamma_3+\Gamma_6)$ Violates CP conservation. **ALUE (units 10 ⁻³) **EVTS** DOCUMENT ID** TECN** COMMENT** 3.13±0.06 OUR FIT** Error includes scale factor of 1.1. 3.08±0.10 OUR AVERAGE 3.13±0.14 1687 COUPAL 85 SPEC $\eta_{+-} = 2.28 \pm 0.06$ 3.04±0.14 2703 DEVOE 77 SPEC $\eta_{+-} = 2.25 \pm 0.05$ • • • We do not use the following data for averages, fits, limits, etc. • • • 2.51±0.23 309 31 DEBOUARD 67 OSPK $\eta_{+-} = 2.00 \pm 0.09$	0.4535 \pm 0.0063 39 This ETAFIT value is complete $\pi^+\pi^-$) / $\Gamma(K_S^0 \to \pi^0$ violation in K_S^0 decay." $\Gamma(\mu^+\mu^-)/[\Gamma(\pi^+\pi^-\pi^0$ Test for $\Delta S = 1$ weak in K_S^0 when K_S^0 and K_S^0 an	omputed from fitted values of π^0) branching fraction. See the transfer of the property of	he discussion in the "Note on CP $\mathbb{P}[\nu_e]$ $\Gamma_{19}/(\Gamma_2+\Gamma_3+\Gamma_6)$ gher-order electroweak interaction. $\frac{TECN}{N}$ limits, etc. • • • OSPK OSPK OSPK CC Γ_{19}/Γ_{17} gher-order electroweak interaction. $\frac{TECN}{N}$ COMMENT of of 1.4. 95 SPEC 95 B791 limits, etc. • • •
2.067 ± 0.035 OUR FIT Error includes scale factor of 1.1. 2.107 ± 0.055 3^0 ETAFIT 9^6 3^0 This ETAFIT value is computed from fitted values of $ \eta_{+-} $, the K_L^0 and K_S^0 lifetimes, and the $K_S^0 \to \pi^+\pi^-$ branching fraction. See the discussion in the "Note on <i>CP</i> violation in K_L^0 decay." $\Gamma(\pi^+\pi^-)/\Gamma(\pi^+\pi^-\pi^0) \qquad \qquad \Gamma_{17}/\Gamma_2 \qquad \qquad \Gamma_{17}/\Gamma_2 \qquad \qquad \Gamma_{10}/\Gamma(\pi^+\pi^-)/\Gamma(\pi^+\pi^-\pi^0) \qquad \qquad \Gamma_{17}/\Gamma_2 \qquad \qquad \Gamma_{10}/\Gamma(\pi^+\pi^-)/\Gamma(\pi^+\pi^-\pi^0) \qquad \qquad \Gamma_{10}/\Gamma(\pi^+\pi^-)/\Gamma(\pi^+\pi^-\pi^0) \qquad \qquad \Gamma_{10}/\Gamma(\pi^+\pi^-)/\Gamma(\pi^+\pi^-\pi^0) \qquad \qquad \Gamma_{10}/\Gamma(\pi^+\pi^-)/\Gamma(\pi^+\pi^-\pi^0) \qquad \qquad \Gamma_{10}/\Gamma(\pi^+\pi^-)/\Gamma(\pi^+\pi^-) + \Gamma_{10}/\Gamma(\pi^+\pi^-) + \Gamma_{10}/\Gamma(\pi^-\pi^-) + \Gamma_{10}/\Gamma(\pi^-\pi^-) + \Gamma_{10}/\Gamma(\pi^-\pi^-)$	0.4535 \pm 0.0063 39 This ETAFIT value is $\cot \pi^+\pi^-)/\Gamma(K_S^0 \to \pi^0 \text{ violation in } K_L^0 \text{ decay."}$ $\Gamma(\mu^+\mu^-)/[\Gamma(\pi^+\pi^-\pi^0 \text{ Test for } \Delta S = 1 \text{ weak i} \text{ violation in } K_L^0 \text{ decay."}$ $VALUE (\text{units } 10^{-6}) \qquad CL$ • • We do not use the fole 2.0 90 < 35.0 90 < 250.0 90 < 250.0 90 < 250.0 90 (100.0) $\Gamma(\mu^+\mu^-)/\Gamma(\pi^+\pi^-)$ Test for $\Delta S = 1$ weak is $VALUE (\text{units } 10^{-6})$ $CL\%$ 3.50 \pm 0.21 OUR AVER. 3.87 \pm 0.30 3.38 \pm 0.17 • • We do not use the fole 3.9 \pm 0.3 \pm 0.1 3.45 \pm 0.18 \pm 0.13	pomputed from fitted values of π^0) branching fraction. See to π^0 branching fraction. See the π^0 branch	he discussion in the "Note on <i>CP</i> Fue
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⁴¹ AKAGI 91B give this number multiplied by the 1990 PDG average for $\Gamma(K_L^0 ightharpoonup$	$\Gamma(e^+e^-e^+e^-)/\Gamma_{\text{total}}$
$\pi^+\pi^-)/\Gamma$ (total). 42 HEINSON 91 give $\Gamma(\kappa_L^0 o \mu\mu)/\Gamma_{ m total}$. We divide out the $\Gamma(\kappa_L^0 o \pi^+\pi^-)/\Gamma_{ m total}$	Test for $\Delta S=1$ weak neutral current. Allowed by higher-order electroweak interaction. VALUE (units 10^{-8}) CL% EVTS DOCUMENT ID TECN COMMENT
PDG average which they used. 43 FUKUSHIMA 76 errors are at CL = 90%.	4.1 \pm0.8 OUR AVERAGE Error includes scale factor of 1.2. 6 \pm 2 \pm 1 18 $\frac{53}{2}$ AKAGI 95 SPEC m_{ee} >470 MeV
⁴⁴ CARITHERS 73 errors are at $CL = 68\%$, W.Carithers, (private communication 79).	10.4 ±3.7 ±1.1 8 ⁵⁴ BARR 95 NA31
45 CLARK 71 limit raised from 1.2×10^{-6} by FIELD 74 reanalysis. Not in agreement with subsequent experiments. So not averaged.	$3.96 \pm 0.78 \pm 0.32$ 27 GU 94 E799 $3.07 \pm 1.25 \pm 0.26$ 6 VAGINS 93 B845
$\Gamma(\mu^+\mu^-\gamma)/\Gamma_{ ext{total}}$ Γ_{20}/Γ	 • • We do not use the following data for averages, fits, limits, etc.
Test for $\Delta S = 1$ weak neutral current. Allowed by higher-order electroweak interaction.	7 ± 3 ± 2 6 53 AKAGI 95 SPEC m_{ee} >470 MeV 6 ± 2 ± 1 18 AKAGI 93 CNTR Sup. by AKAGI 95
VALUE (units 10 ⁻⁶) CL% EVTS DOCUMENT ID TECN	4 ±3 2 BARR 91 NA31 Sup. by BARR 95
0.323±0.023±0.019 197 SPENCER 95 E799 • • • We do not use the following data for averages, fits, limits, etc. • • •	<260 90 BALATS 83 SPEC
0.28 ±0.28 1 46 CARROLL 80D SPEC <7.81 90 47 DONALDSON 74 SPEC	53 Values are for the total branching fraction, acceptance-corrected for the $m_{\rm ee}$ cuts shown. 54 Distribution of angles between two e^+e^- pair planes favors $\mathit{CP} = -1$ for K^0_L .
46 Uses $K_L^0 \rightarrow \pi^+\pi^-\pi^0/(\text{all }K_L^0)$ decays = 0.1239.	$\Gamma(\pi^0\mu^+\mu^-)/\Gamma_{ ext{total}}$ $\Gamma_{ ext{27}}/\Gamma$
47 Uses $\mathcal{K}_{L}^{ar{0}} ightarrow \ \pi^{+} \pi^{-} \pi^{0}/(all \ \mathcal{K}_{L}^{ar{0}})$ decays $= 0.126.$	Violates $\it CP$ in leading order. Test for $\Delta \it S=1$ weak neutral current. Allowed by higher-order electroweak interaction.
$\Gamma(e^+e^-)/\Gamma_{\text{total}}$	<u>VALUE (units 10⁻⁹) CL% EVTS DOCUMENT ID TECN</u> < 5.1 90 0 HARRIS 93 E799
Test for $\Delta S = 1$ weak neutral current. Allowed by higher-order electroweak interaction. VALUE (units 10^{-10}) CL% EVTS DOCUMENT ID TECN COMMENT	 5.1 90 0 HARRIS 93 E799 • • • We do not use the following data for averages, fits, limits, etc. • • •
< 0.41 90 0 ⁴⁸ ARISAKA 93B B791	< 1200 90 0 ⁵⁵ CARROLL 80D SPEC
• • • We do not use the following data for averages, fits, limits, etc. • • •	<56600 90 ⁵⁶ DONALDSON 74 SPEC
< 1.6 90 1 AKAGI 95 SPEC < 1.6 90 1 AKAGI 91 SPEC Sup. by AKAGI 95	⁵⁵ Uses $K_L^0 \to \pi^+\pi^-\pi^0/(\text{all }K_L^0)$ decays = 0.1239. ⁵⁶ Uses $K_L^0 \to \pi^+\pi^-\pi^0/(\text{all }K_L^0)$ decays = 0.126.
< 5.6 90 INAGAKI 89 SPEC In AKAGI 91	
< 3.2 90 MATHIAZHA89 SPEC In ARISAKA 93B < 110 90 COUSINS 88 SPEC	$\Gamma(\pi^0 e^+ e^-)/\Gamma_{\text{total}}$ Violates <i>CP</i> in leading order. Direct and indirect <i>CP</i> -violating contributions are ex-
< 45 90 GREENLEE 88 SPEC Repl. by JASTRZEMB- SKI 88	pected to be comparable and to dominate the <i>CP</i> -conserving part. Test for $\Delta S=1$
< 12 90 JASTRZEM 88 SPEC	weak neutral current. Allowed by higher-order electroweak interaction. VALUE (units 10 ⁻⁹) CL% EVTS DOCUMENT ID TECN
< 15.7 90 ⁴⁹ CLARK 71 ASPK <1500 90 0 FOETH 69 ASPK	<u>VALUE (units 10⁻⁹) CL% EVTS DOCUMENT ID TECN</u> < 4.3 90 0 HARRIS 93B E799
48 ARISAKA 93B includes all events with $<$ 6 MeV radiated energy.	< 7.5 90 0 BARKER 90 E731
⁴⁹ Possible (but unknown) systematic errors. See note on CLARK 71 $\Gamma(\mu^+\mu^-)/\Gamma(\pi^+\pi^-)$ entry.	< 5.5 90 0 OHL 90 B845 • • • We do not use the following data for averages, fits, limits, etc. • • •
	< 40 90 BARR 88 NA31
$\Gamma(e^+e^-)/[\Gamma(\pi^+\pi^-\pi^0) + \Gamma(\pi^\pm\mu^\mp\nu) + \Gamma(\pi^\pm e^\mp\nu_e)] \qquad \Gamma_{21}/(\Gamma_2+\Gamma_3+\Gamma_6)$ Test for $\Delta S = 1$ weak neutral current. Allowed by higher-order electroweak interaction.	< 320 90 JASTRZEM 88 SPEC <2300 90 0 ⁵⁷ CARROLL 80D SPEC
VALUE (units 10 ⁻⁶) <u>CL%</u> <u>DOCUMENT ID</u> <u>TECN</u>	57 Uses $K_I^0 \to \pi^+\pi^-\pi^0/(\text{all } K_I^0)$ decays = 0.1239.
• • • We do not use the following data for averages, fits, limits, etc. • • • < 23.0 90 BOTT 67 OSPK	
< 23.0 90 BOTT 67 OSPN	$\Gamma(\pi^0 \nu \overline{\nu})/\Gamma_{\text{total}}$ Γ_{29}/Γ
< 200.0 90 ALFF 66B OSPK	
< 200.0 90 ALFF 66B OSPK <1000.0 ANIKINA 65 CC	Violates CP in leading order. Test of direct CP violation since the indirect CP -violating and CP -conserving contributions are expected to be suppressed. Test of $\Delta S=1$ weak
<1000.0 ANIKINA 65 CC $ \Gamma(e^+e^-\gamma)/\Gamma_{total} \qquad \qquad \Gamma_{22}/\Gamma $	Violates CP in leading order. Test of direct CP violation since the indirect CP-violating
<1000.0 ANIKINA 65 CC $ \Gamma(e^+e^-\gamma)/\Gamma_{total} $ Test for $\Delta S=1$ weak neutral current. Allowed by higher-order electroweak interaction.	Violates \overline{CP} in leading order. Test of direct CP violation since the indirect CP -violating and CP -conserving contributions are expected to be suppressed. Test of $\Delta S=1$ weak neutral current. VALUE (units 10^{-5}) \underline{CtW} \underline{EVTS} $\underline{DOCUMENT\ ID}$ \underline{TECN} \underline{CFO} \underline{CFO} \underline{CV}
<1000.0 ANIKINA 65 CC $\Gamma\left(e^{+}e^{-}\gamma\right)/\Gamma_{\text{total}} \qquad \qquad \Gamma_{22}/\Gamma$ Test for $\Delta S=1$ weak neutral current. Allowed by higher-order electroweak interaction. $\frac{VALUE \left(\text{units }10^{-6}\right)}{9.1\pm0.5 \text{ OUR AVERAGE}} \qquad \frac{DOCUMENT ID}{TECN} \qquad \frac{TECN}{TECN}$	Violates \overline{CP} in leading order. Test of direct CP violation since the indirect CP -violating and CP -conserving contributions are expected to be suppressed. Test of $\Delta S=1$ weak neutral current.
<1000.0 ANIKINA 65 CC $\Gamma(e^+e^-\gamma)/\Gamma_{total}$ Test for $\Delta S = 1$ weak neutral current. Allowed by higher-order electroweak interaction. $\frac{VALUE \text{ (units } 10^{-6})}{9.1 \pm 0.5 \text{ OUR AVERAGE}}$ 9.2 $\pm 0.5 \pm 0.5$ 1053 BARR 908 NA31	Violates \overline{CP} in leading order. Test of direct CP violation since the indirect CP -violating and CP -conserving contributions are expected to be suppressed. Test of $\Delta S=1$ weak neutral current. **VALUE (units 10^{-5})** $CL\%$ ** $EVTS$ ** $DOCUMENT ID$ ** $TECN$ ** * 5.8 90 0 WEAVER 94 E799 • • We do not use the following data for averages, fits, limits, etc. • • • • < 22 90 0 GRAHAM 92 CNTR < 760 90 58 LITTENBERG 89 RVUE
<1000.0 ANIKINA 65 CC $\Gamma(e^+e^-\gamma)/\Gamma_{total} \qquad \qquad \Gamma_{22}/\Gamma$ Test for $\Delta S = 1$ weak neutral current. Allowed by higher-order electroweak interaction. VALUE (units 10^{-6}) CL% EVTS DOCUMENT ID TECN 9.1±0.5 OUR AVERAGE 9.2±0.5±0.5 1053 BARR 908 NA31 9.1±0.4 $^{+0.6}_{-0.5}$ 919 OHL 908 B845	Violates \overline{CP} in leading order. Test of direct CP violation since the indirect CP -violating and CP -conserving contributions are expected to be suppressed. Test of $\Delta S=1$ weak neutral current. VALUE (units 10^{-5}) CL% EVTS DOCUMENT ID TECN $<$ 5.8 90 0 WEAVER 94 E799 • • We do not use the following data for averages, fits, limits, etc. • • • • < 22 90 0 GRAHAM 92 CNTR
<1000.0 ANIKINA 65 CC $\Gamma(e^+e^-\gamma)/\Gamma_{total}$ Test for $\Delta S = 1$ weak neutral current. Allowed by higher-order electroweak interaction. VALUE (units 10^{-6}) 9.1 ± 0.5 OUR AVERAGE 9.2 ± 0.5 ± 0.5 1053 BARR 908 NA31 9.1 ± 0.4 $^+0.6$ 919 OHL 908 B845 • • We do not use the following data for averages, fits, limits, etc. • •	Violates \overline{CP} in leading order. Test of direct CP violation since the indirect CP -violating and CP -conserving contributions are expected to be suppressed. Test of $\Delta S=1$ weak neutral current. **MLUE (units 10^{-5})** $CL\%$ ** $EVTS$ ** $DOCUMENT ID$ ** $TECN$ ** ** 5.8 90 0 WEAVER 94 E799 • • • We do not use the following data for averages, fits, limits, etc. • • • • • • • 22 90 0 GRAHAM 92 CNTR <760 90 58 LITTENBERG 89 RVUE **SELITTENBERG 89 is from retroactive data analysis of CRONIN 67. **T($e^{\pm}\mu^{\mp}$)/ Γ_{total}
<1000.0 ANIKINA 65 CC $\Gamma(e^+e^-\gamma)/\Gamma_{total}$ Test for $\Delta S = 1$ weak neutral current. Allowed by higher-order electroweak interaction. VALUE (units 10^{-6}) CL% EVTS 9.1 ± 0.5 OUR AVERAGE $9.2 \pm 0.5 \pm 0.5$ $9.1 \pm 0.4 + 0.6 \\ -0.5$ 919 OHL 908 B845 • • We do not use the following data for averages, fits, limits, etc. • • • 17.4 ± 8.7 4 50 CARROLL 80D SPEC 27 90 0 51 BARMIN 72 HLBC	Violates \overline{CP} in leading order. Test of direct CP violation since the indirect CP -violating and CP -conserving contributions are expected to be suppressed. Test of $\Delta S=1$ weak neutral current. VALUE (units 10^{-5}) $CL\%$ $EVTS$ $DOCUMENT ID$ $TECN$ < 5.8 90 0 WEAVER 94 E799 • • We do not use the following data for averages, fits, limits, etc. • • • • < 22 90 0 GRAHAM 92 CNTR < 760 90 58 LITTENBERG 89 RVUE 58 LITTENBERG 89 is from retroactive data analysis of CRONIN 67. $\Gamma(e^{\pm}\mu^{\mp})/\Gamma_{total}$ Γ_{30}/Γ Test of lepton family number conservation.
<1000.0 ANIKINA 65 CC $\Gamma(e^+e^-\gamma)/\Gamma_{\text{total}}$ Test for $\Delta S = 1$ weak neutral current. Allowed by higher-order electroweak interaction. $\frac{VALUE (\text{units } 10^{-6})}{9.1 \pm 0.5 \text{ OUR AVERAGE}}$ 9.2 \pm 0.5 \pm 0.5 \text{105} \text{BARR} \text{908 NA31} \\ 9.1 \pm 0.4 \bigcup 0.5 \text{919} \text{OHL} \text{908 B845} \\ • • • We do not use the following data for averages, fits, limits, etc. • • • • \text{17.4 \pm 8.7} \text{50 CARROLL} \text{800 SPEC} \\ <27 \text{90} 0 \text{51 BARMIN} 72 \text{HLBC} \\ \text{50 Uses } K_0^0 \rightarrow \pi^+ \pi^- \pi^0/(\text{all } K_0^0) \text{decays} = 0.1239. \end{arrow}	Violates \overline{CP} in leading order. Test of direct CP violation since the indirect CP -violating and CP -conserving contributions are expected to be suppressed. Test of $\Delta S=1$ weak neutral current. **MLUE (units 10^{-5})** $CL\%$ ** $EVTS$ ** $DOCUMENT ID$ ** $TECN$ ** ** 5.8 90 0 WEAVER 94 E799 • • • We do not use the following data for averages, fits, limits, etc. • • • • • • • 22 90 0 GRAHAM 92 CNTR <760 90 58 LITTENBERG 89 RVUE **SELITTENBERG 89 is from retroactive data analysis of CRONIN 67. **T($e^{\pm}\mu^{\mp}$)/ Γ_{total}
<1000.0 ANIKINA 65 CC $\Gamma(e^+e^-\gamma)/\Gamma_{total}$ Test for $\Delta S = 1$ weak neutral current. Allowed by higher-order electroweak interaction. VALUE (units 10^{-6}) CL% EVTS 9.1 ± 0.5 OUR AVERAGE $9.2 \pm 0.5 \pm 0.5$ $9.1 \pm 0.4 + 0.6 \\ -0.5$ 919 OHL 908 B845 • • We do not use the following data for averages, fits, limits, etc. • • • 17.4 ± 8.7 4 50 CARROLL 80D SPEC 27 90 0 51 BARMIN 72 HLBC	Violates CP in leading order. Test of direct CP violation since the indirect CP -violating and CP -conserving contributions are expected to be suppressed. Test of $\Delta S = 1$ weak neutral current. **MALUE (units 10^{-5})** CL% EVTS DOCUMENT ID TECN ** 5.8 90 0 WEAVER 94 E799 •• • We do not use the following data for averages, fits, limits, etc. •• • **< 22 90 0 GRAHAM 92 CNTR **< 760 90 58 LITTENBERG 89 RVUE ** **SELITTENBERG 89 is from retroactive data analysis of CRONIN 67. **T(e $^{\pm}\mu^{\mp}$)/\text{Total} **Test of lepton family number conservation.** **MALUE (units 10^{-11})** CL% EVTS DOCUMENT ID TECN COMMENT **< 3.3 90 0 59 ARISAKA 93 B791 •• • We do not use the following data for averages, fits, limits, etc. • •
<1000.0 ANIKINA 65 CC $\Gamma\left(e^{+}e^{-}\gamma\right)/\Gamma_{\text{total}}\right $ Test for $\Delta S = 1$ weak neutral current. Allowed by higher-order electroweak interaction. $VALUE(\text{units } 10^{-6})$ CL% EVTS 9.1±0.5±0.5 1053 BARR 90B NA31 9.1±0.4±0.6 919 OHL 90B B845 • • • We do not use the following data for averages, fits, limits, etc. • • • 17.4±8.7 4 50 CARROLL 80D SPEC 27 90 0 51 BARMIN 72 HLBC 50 Uses $K_L^0 \rightarrow \pi^+\pi^-\pi^0/(\text{all } K_L^0)$ decays = 0.1239. 51 Uses $K_L^0 \rightarrow 3\pi^0/\text{total} = 0.214$. $\Gamma(e^+e^-\gamma\gamma)/\Gamma_{\text{total}}$ Γ_{23}/Γ	Violates CP in leading order. Test of direct CP violation since the indirect CP -violating and CP -conserving contributions are expected to be suppressed. Test of $\Delta S = 1$ weak neutral current. **VALUE (units 10^{-5})** $CL\%$ *** $EVTS$ *** $DOCUMENT ID$ *** $TECN$ *** * • • We do not use the following data for averages, fits, limits, etc. • • • • • • • • • • • • • • • • • • •
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	Violates CP in leading order. Test of direct CP violation since the indirect CP -violating and CP -conserving contributions are expected to be suppressed. Test of $\Delta S = 1$ weak neutral current. VALUE (units 10^{-5}) $CL\%$ $EVTS$ $DOCUMENT ID$ $TECN$ < 5.8 90 0 WEAVER 94 E799 • • We do not use the following data for averages, fits, limits, etc. • • • < 22 90 0 GRAHAM 92 CNTR < 760 90 58 LITTENBERG 89 RVUE 58 LITTENBERG 89 is from retroactive data analysis of CRONIN 67. $\Gamma(e^{\pm}\mu^{\mp})/\Gamma_{total}$ Test of lepton family number conservation. $VALUE (units 10^{-11}) CL\% EVTS DOCUMENT ID TECN COMMENT < 3.3 90 0 59 ARISAKA 93 B791 • • We do not use the following data for averages, fits, limits, etc. • • < 9.4 90 0 AKAGI 95 SPEC < 3.9 90 0 O ARISAKA 93 B791 < 9.4 90 0 AKAGI 91 SPEC Sup. by AKAGI 95$
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	Violates CP in leading order. Test of direct CP violation since the indirect CP -violating and CP -conserving contributions are expected to be suppressed. Test of $\Delta S = 1$ weak neutral current. **MALUE (units 10^{-5})** $CL\%$ *** $EVTS$
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	Violates CP in leading order. Test of direct CP violation since the indirect CP -violating and CP -conserving contributions are expected to be suppressed. Test of $\Delta S = 1$ weak neutral current. **VALUE (units 10^{-5})** $CL\%$ *** $EVTS$
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	Violates CP in leading order. Test of direct CP violation since the indirect CP -violating and CP -conserving contributions are expected to be suppressed. Test of $\Delta S = 1$ weak neutral current. VALUE (units 10^{-5}) $CL\%$ $EVTS$ $DOCUMENT ID$ $TECN$ < 5.8 90 0 WEAVER 94 E799 • • We do not use the following data for averages, fits, limits, etc. • • • • < 22 90 0 GRAHAM 92 CNTR <760 90 58 LITTENBERG 89 RVUE 58 LITTENBERG 89 is from retroactive data analysis of CRONIN 67. $\Gamma(e^{\pm}\mu^{\mp})/\Gamma_{total}$ Test of lepton family number conservation. $VALUE (units 10^{-11}) CL\% EVTS DOCUMENT ID TECN COMMENT Set (100 MENT) Se$
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	Violates CP in leading order. Test of direct CP violation since the indirect CP -violating and CP -conserving contributions are expected to be suppressed. Test of $\Delta S = 1$ weak neutral current. **MALUE (units 10^{-5})** $CL\%$ *** $EVTS$
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	Violates \overline{CP} in leading order. Test of direct CP violation since the indirect CP -violating and CP -conserving contributions are expected to be suppressed. Test of $\Delta S = 1$ weak neutral current. **VALUE (units 10^{-5})** $CL\%$ *** $EVTS$ *** $DOCUMENT ID$ *** $ETP9$ *** • • We do not use the following data for averages, fits, limits, etc. • • • • • • • • • • • • • • • • • • •
	Violates CP in leading order. Test of direct CP violation since the indirect CP -violating and CP -conserving contributions are expected to be suppressed. Test of $\Delta S = 1$ weak neutral current. **VALUE (units 10^{-5})** $CL\%$ *** $EVTS$
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	Violates CP in leading order. Test of direct CP violation since the indirect CP -violating and CP -conserving contributions are expected to be suppressed. Test of $\Delta S = 1$ weak neutral current. **MLUE (units 10^{-5})** $CL\%$ *** $EVTS$ *
	Violates CP in leading order. Test of direct CP violation since the indirect CP -violating and CP -conserving contributions are expected to be suppressed. Test of $\Delta S = 1$ weak neutral current. **NALUE (units 10^{-5})** $CL\%$ *** $EVTS$
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	Violates CP in leading order. Test of direct CP violation since the indirect CP -violating and CP -conserving contributions are expected to be suppressed. Test of $\Delta S = 1$ weak neutral current. **MLUE (units 10^{-5})** $CL\%$ *** $EVTS$ *** $DOCUMENT ID$ *** **\infty\$ 5.8** 90** 0 WEAVER 94** $ET99$ ** • • • We do not use the following data for averages, fits, limits, etc. • • • • \$ < 22 90 0 GRAHAM 92 CNTR <760 90 58** LITTENBERG 89 RVUE **SELITTENBERG 89 is from retroactive data analysis of CRONIN 67.* **\begin{align*} \begin{align*}
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	Violates CP in leading order. Test of direct CP violation since the indirect CP -violating and CP -conserving contributions are expected to be suppressed. Test of $\Delta S = 1$ weak neutral current. **MALUE (units 10^{-5})** $CL\%$ *** $EVTS$ *** $DOCUMENT ID$ *** **\times \text{ 5.8}** 90 0 WEAVER 94 E799** • • • We do not use the following data for averages, fits, limits, etc. • • • • • • • • • • • • • • • • • • •
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	Violates CP in leading order. Test of direct CP violation since the indirect CP -violating and CP -conserving contributions are expected to be suppressed. Test of $\Delta S = 1$ weak neutral current. **NALUE (units 10^{-5})** $CL\%$ *** $EVTS$ *** $DOCUMENT ID$ *** **\times NE do not use the following data for averages, fits, limits, etc. • • • • • • • • • • • • • • • • • • •
$ \begin{array}{c} \text{C} & \text{COO} & \text{CO} \\ \hline \Gamma\left(e^{+}e^{-}\gamma\right)/\Gamma_{\text{total}} \\ \hline \text{Test for } \Delta S = 1 \text{ weak neutral current. Allowed by higher-order electroweak interaction.} \\ \hline \frac{VALUE (\text{units } 10^{-6})}{9.1 \pm 0.5 \text{ OUR}} & \frac{CL\%}{\text{EVTS}} & \frac{DOCUMENT ID}{DOCUMENT ID} & \frac{TECN}{TECN} \\ \hline 9.2 \pm 0.5 \pm 0.5 & 1053 & \text{BARR} & 908 \text{ NA31} \\ 9.1 \pm 0.4 \stackrel{+}{-}0.6 & 919 & \text{OHL} & 908 \text{ B845} \\ \bullet \bullet \bullet \text{ We do not use the following data for averages, fits, limits, etc.} \bullet \bullet \\ \hline 17.4 \pm 8.7 & 4 & 50 \text{ CARROLL} & 800 \text{ SPEC} \\ < 27 & 90 & 0 & 51 \text{ BARMIN} & 72 \text{ HLBC} \\ \hline 50 \text{ Uses } K_L^0 \rightarrow \pi^+\pi^-\pi^0/(\text{all } K_L^0) \text{ decays} = 0.1239.} \\ \hline 51 \text{ Uses } K_L^0 \rightarrow 3\pi^0/\text{total} = 0.214.} \\ \hline \Gamma\left(e^{+}e^{-}\gamma\gamma\right)/\Gamma_{\text{total}} \\ \hline \text{Test for } \Delta S = 1 \text{ weak neutral current. Allowed by higher-order electroweak interaction.} \\ \hline \frac{VALUE (\text{units } 10^{-7})}{6.5 \pm 1.2 \pm 0.6} & 58 \text{ NAKAYA} & 94 \text{ E799} & E_{\gamma} > 5 \text{ MeV} \\ \hline 6.6 \pm 3.2 & \text{MORSE} & 92 \text{ B845} & E_{\gamma} > 5 \text{ MeV} \\ \hline \Gamma\left(\pi^+\pi^-e^+e^-\right)/\Gamma_{\text{total}} \\ \hline \text{Test for } \Delta S = 1 \text{ weak neutral current. Allowed by higher-order electroweak interaction.} \\ \hline \frac{VALUE (\text{units } 10^{-6})}{2.2 \times 10^{-6}} & \frac{EVTS}{2.2 \times 10^{-6}} & \frac{DOCUMENT ID}{2.2 \times 10^{-6}} & \frac{TECN}{2.2 \times 10^{-6}} & \frac{CDCUMENT ID}{2.2 \times 10^{-6}} & \frac{TECN}{2.2 \times 10^{-6}} & \frac{TECN} & \frac{TECN}{2.2 \times 10^{-6}} & \frac{TECN}{2.2 \times 10^{-6}} & \frac{TECN}$	Violates CP in leading order. Test of direct CP violation since the indirect CP -violating and CP -conserving contributions are expected to be suppressed. Test of $\Delta S = 1$ weak neutral current. **MLUE (units 10^{-5})** $CL\%$ *** $EVTS$ *

ENERGY DEPENDENCE OF K_L^0 DALITZ PLOT

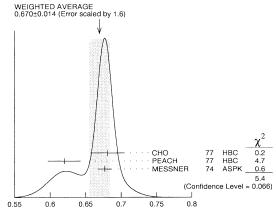
For discussion, see note on Dalitz plot parameters in the K^\pm section of the Particle Listings above. For definitions of a_V , a_t , a_t , a_u , and a_V , see the earlier version of the same note in the 1982 edition of this *Review* published in Physics Letters 111B 70 (1982).

 $|\text{matrix element}|^2 = 1 + gu + hu^2 + jv + kv^2$ where $u = (s_3 - s_0) / m_{\pi}^2$ and $v = (s_1 - s_2) / m_{\pi}^2$

LINEAR COEFFICIENT g FOR $K_I^0 \rightarrow \pi^+\pi^-\pi^0$

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.670±0.014 C	OUR AVERAGE	Error includes scale	facto	r of 1.6	See the ideogram below.
0.681 ± 0.024	6499	СНО	77	HBC	
0.620 ± 0.023	4709	PEACH	77	HBC	
0.677 ± 0.010	509k	MESSNER	74	ASPK	$a_{y} = -0.917 \pm 0.013$
• • • We do n	ot use the follo	wing data for averages	s, fits	, limits,	etc. • • •
0.69 ± 0.07	192	61 BALDO	75	HLBC	
0.590 ± 0.022	56k	61 BUCHANAN	75	SPEC	$a_{u} = -0.277 \pm 0.010$
0.619 ± 0.027	20k			ASPK	$a_t = -0.282 \pm 0.011$
0.612 ± 0.032		⁶¹ ALEXANDER		HBC	-
0.73 ± 0.04	3200	61 BRANDENB	73	HBC	
0.50 ± 0.11	180	61 JAMES	72	HBC	
0.608 ± 0.043	1486	61 KRENZ	72	HLBC	$a_t = -0.277 \pm 0.018$
0.688 ± 0.074	384	61 METCALF	72	ASPK	$a_t = -0.31 \pm 0.03$
0.650 ± 0.012	29k	⁶¹ ALBROW	70	ASPK	$a_V = -0.858 \pm 0.015$
0.593 ± 0.022	36k	61,63 BUCHANAN	70 `	SPEC	$a_{II} = -0.278 \pm 0.010$
0.664 ± 0.056	4400	⁶¹ sмiтн	70	OSPK	$a_t = -0.306 \pm 0.024$
0.400 ± 0.045	2446	⁶¹ BASILE	68B	OSPK	$a_t = -0.188 \pm 0.020$
0.649 ± 0.044	1350	⁶¹ HOPKINS	67	HBC	$a_t = -0.294 \pm 0.018$
0.428 ± 0.055	1198	61 NEFKENS	67	OSPK	$a_{II} = -0.204 \pm 0.025$
0.64 ± 0.17	280	⁶¹ ANIKINA	66	CC	$a_V = -8.2^{+0.9}_{-1.3}$
0.70 ± 0.12	126	61 HAWKINS	66	HBC	$a_V = -8.6 \pm 0.7$
0.32 ± 0.13	66	61 ASTBURY	65	CC	$a_V = -5.5 \pm 1.5$
$0.51\ \pm0.09$	310	⁶¹ ASTBURY	65B	CC	$a_V = -7.3^{+0.6}_{-0.8}$
0.55 ± 0.23	79	⁶¹ ADAIR	64	HBC	$a_V = -7.6 \pm 1.7$
$0.51\ \pm0.20$	77	⁶¹ LUERS	64	HBC	$a_V = -7.3 \pm 1.6$
61 0 1 11				10	"OUADDATIC

- 61 Quadratic dependence required by some experiments. (See sections on "QUADRATIC COEFFICIENT h" and "QUADRATIC COEFFICIENT k" below.) Correlations prevent us from averaging results of fits not including g, h, and k terms.
 62 BISI 74 value comes from quadratic fit with quad. term consistent with zero. g error is thus larger than if linear fit were used.
 63 BUCHANAN 70 result revised by BUCHANAN 75 to include radiative correlations and
- to use more reliable K_I^0 momentum spectrum of second experiment (had same beam).



Linear coeff. g for $K_L^0 \to \pi^+\pi^-\pi^0$ matrix element squared

QUADRATIC COEFFICIENT h FOR $K_I^0 \rightarrow \pi^+\pi^-\pi^0$

VALUE	EVTS	DOCUMENT ID		TECN	
0.079±0.007 OUR	AVERAGE				
0.095 ± 0.032	6499	CHO	77	HBC	
0.048 ± 0.036	4709	PEACH	77	HBC	
0.079 ± 0.007	509k	MESSNER	74	ASPK	
• • • We do not use	the followi	ng data for averag	es, fits	s, limits,	et
-0.011 ± 0.018	29k	64 ALBROW	70	ASPK	

64 ALBROW 64 SMITH 70 OSPK 0.043 ± 0.052 4400

See notes in section "LINEAR COEFFICIENT g FOR $K_I^0 \to \pi^+\pi^-\pi^0$ [MATRIX ELEMENT 2" above.

64 Quadratic coefficients h and k required by some experiments. (See section on "QUADRATIC COEFFICIENT k" below.) Correlations prevent us from averaging results of fits not including g, h, and k terms.

QUADRATIC COEFFICIENT & FOR $K_L^0 ightarrow \pi^+\pi^-\pi^0$

VALUE	EVTS	DOCUMENT ID		TECN
0.0098±0.0018 OU	RAVERAGE			
0.024 ± 0.010	6499	СНО	77	HBC
-0.008 ± 0.012	4709	PEACH	77	HBC
0.0097 ± 0.0018	509k	MESSNER	74	ASPK

LINEAR COEFFICIENT j FOR $K_L^0 \to \pi^+\pi^-\pi^0$ (*CP*-VIOLATING TERM) Listed in *CP*-violation section below.

QUADRATIC COEFFICIENT h FOR $K_L^0 \rightarrow \pi^0 \pi^0 \pi^0$

VALUE (units 10 ⁻³)	EVTS	DOCUMENT ID	TECN
-33+11+07	5.1/1	65 SOMALWAR 92	F731

 65 SOMALWAR 92 chose m_{π^+} as normalization to make it compatible with the Particle Data Group $K_L^0\to~\pi^+\pi^-\pi^0$ definitions.

KI FORM FACTORS

For discussion, see note on form factors in the \mathcal{K}^\pm section of the Particle Listings above.

In the form factor comments, the following symbols are used.

 f_{\perp} and f_{\perp} are form factors for the vector matrix element.

 f_S and f_T refer to the scalar and tensor term.

 $f_0 = f_+ + f_- t/(m_K^2 - m_\pi^2).$

 λ_+ , λ_- , and λ_0 are the linear expansion coefficients of f_+ , f_- , and f_0 .

 λ_+ refers to the $K^0_{\mu3}$ value except in the K^0_{e3} sections.

 $d\xi(0)/d\lambda_+$ is the correlation between $\xi(0)$ and λ_+ in $K^0_{\mu3}$.

 $d\lambda_0/d\lambda_+$ is the correlation between λ_0 and λ_+ in $K_{\mu3}^0$.

 $t = \text{momentum transfer to the } \pi \text{ in units of } m_{\pi}^2.$

DP = Dalitz plot analysis.

 $PI = \pi$ spectrum analysis.

 $MU = \mu$ spectrum analysis.

 $POL = \mu$ polarization analysis.

 ${\rm BR}={\it K}_{\mu 3}^0/{\it K}_{e3}^0$ branching ratio analysis.

E = positron or electron spectrum analysis.

RC = radiative corrections.

λ_+ (LINEAR ENERGY DEPENDENCE OF f_+ IN K_{e3}^0 DECAY)

For radiative correction of κ_{e3}^0 DP, see GINSBERG 67 and BECHERRAWY 70.

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.0300 ± 0.0016 OUR	AVERAGE	Error includes s	cale	factor of	1.2.
0.0306 ± 0.0034	74k	BIRULEV	81	SPEC	DP
0.025 ± 0.005	12k	⁶⁶ ENGLER	78B	HBC	DP
0.0348 ± 0.0044	18k	HILL	78	STRC	DP
0.0312 ± 0.0025	500k	GJESDAL	76	SPEC	DP
0.0270 ± 0.0028	25k	BLUMENTHAL	_75	SPEC	DP
0.044 ± 0.006	24k	BUCHANAN	75	SPEC	DP
0.040 ± 0.012	2171	WANG	74	OSPK	DP
0.045 ± 0.014	5600	ALBROW	73	ASPK	DP
0.019 ± 0.013	1871	BRANDENB	73	HBC	PI transv.
0.022 ± 0.014	1910	NEUHOFER	72	ASPK	PI
0.023 ± 0.005	42k	BISI	71	ASPK	DP
0.05 ± 0.01	16k	CHIEN	71	ASPK	DP, no RC
0.02 ± 0.013	1000	ARONSON	68	OSPK	PI
$+0.023 \pm 0.012$	4800	BASILE	68	OSPK	DP, no RC
-0.01 ± 0.02	762	FIRESTONE	67	HBC	DP, no RC
$+0.01$ ± 0.015	531	KADYK	67	HBC	e,PI, no RC
$+0.08 {}^{+0.10}_{-0.08}$	240	LOWYS	67	FBC	PI
$+0.15$ ± 0.08	577	FISHER	65	OSPK	DP, no RC
$+0.07$ ± 0.06	153	LUERS	64	HBC	DP, no RC
• • • We do not use t	he following	g data for averages	, fits	s, limits,	etc. • • •
0.029 ± 0.005	19k	⁶⁶ CHO	80	нвс	DP
0.0286 ± 0.0049	26k	BIRULEV	79	SPEC	Repl. by BIRULEV 81
0.032 ± 0.0042	48k	BIRULEV	76	SPEC	Repl. by BIRULEV 81

 66 ENGLER 788 uses an unique $K_{
m e3}$ subset of CHO 80 events and is less subject to sys-

 $\xi_{\bf a}=f_-/f_+$ (determined from $K^0_{\bf h3}$ spectra)

The parameter ξ is redundant with λ_0 below and is not put into the Meson Summary

Table.					
VALUE	$d\xi(0)/d\lambda_{\pm}$	EVTS	DOCUMENT ID	TECN	COMMENT
-0.11±0.09 OL	IR EVALUAT	ION Fr	om a fit discussed in	note on Kp	form factors in
			1982 edition, P	L 111B (Api	il 1982).
-0.10 ± 0.09	-12	150k	⁶⁷ BIRULEV	81 SPEC	DP
$+0.26 \pm 0.16$	-13	14k	⁶⁸ СНО	80 HBC	DP
$+0.13\pm0.23$	- 20	16k	68 HILL	79 STRC	DP
-0.25 ± 0.22	5.9	32k	⁶⁹ BUCHANAN	75 SPEC	DP
-0.11 ± 0.07	-17	1.6M	⁷⁰ DONALDSON	74B SPEC	DP
-1.00 ± 0.45	- 20	1385	71 PEACH	73 HLBC	DP
-1.5 ± 0.7	- 28	9086	72 ALBROW	72 ASPK	DP
$+1.2 \pm 0.8$	-18	1341	⁷³ CARPENTER	66 OSPK	DP

• • • We do not	use the follo	wing dat	a for averages, fits	, limit	ts, etc. •	• •
$+0.50 \pm 0.61$	unknown	16k	74 DALLY	72	ASPK	DP
-3.9 ± 0.4		3140	⁷⁵ BASILE	70	OSPK	DP, indep of λ_+
$-0.68 + 0.12 \\ -0.20$	-26	16k	⁷⁴ CHIEN	70	ASPK	DP

- 67 BIRULEV 81 error, $d\xi(0)/d\lambda_+$ calculated by us from λ_0 , λ_+ . $d\lambda_0/d\lambda_+=0$ used.
- ⁶⁸ HILL 79 and CHO 80 calculated by us from λ_0 , λ_+ , and $d\lambda_0/d\lambda_+$.
- 69 BUCHANAN 75 is calculated by us from λ_0 , λ_+ and $d\lambda_0/d\lambda_+$ because their appendix A value -0.20 ± 22 assumes $\xi(t)$ constant, i.e. $\lambda_-=\lambda_+$.
- 70 DONALDSON 748 gives $\xi=-0.11\pm0.02$ not including systematics. Above error and $d\xi(0)/d\lambda_+$ were calculated by us from λ_0 and λ_+ errors (which include systematics) and $d\lambda_0/d\lambda_+$.
- 71 PEACH 73 gives $\xi(0)=-0.95\pm0.45$ for $\lambda_{+}=\lambda_{-}=0.025$. The above value is for $\lambda_{-}=$ 0. K.Peach, private communication (1974).
- 72 ALBROW 72 fit has λ_- free, gets $\lambda_-=-$ 0.030 \pm 0.060 or $\Lambda=+$ 0.15 $^{+0.17}_{-0.11}$
- ⁷³ CARPENTER 66 $\xi(0)$ is for $\lambda_+=0$. $d\xi(0)/d\lambda_+$ is from figure 9.
- ⁷⁴ CHIEN 70 errors are statistical only. $d\xi(0)/d\lambda_+$ from figure 4. DALLY 72 is a reanalysis of CHIEN 70. The DALLY 72 result is not compatible with assumption $\lambda_-=0$ so not included in our fit. The nonzero λ_- value and the relatively large λ_+ value found by DALLY 72 come mainly from a single low t bin (figures 1,2). The (f_+,ξ) correlation was ignored. We estimate from figure 2 that fixing $\lambda_{-}=0$ would give $\xi(0)=-1.4\pm0.3$ and would add 10 to χ^2 . $d\xi(0)/d\lambda_+$ is not given.
- $75\,\mathrm{BASILE}$ 70 is incompatible with all other results. Authors suggest that efficiency estimates might be responsible.

$\xi_b = f_-/f_+$ (determined from $K_{\mu3}^0/K_{e3}^0$)

The $K_{\mu 3}^0/K_{e3}^0$ branching ratio fixes a relationship between $\xi(0)$ and λ_+ . We quote the author's $\xi(0)$ and associated λ_+ but do not average because the λ_+ values differ. The fit result and scale factor given below are not obtained from these ξ_b values. Instead they are obtained directly from the authors $K_{\mu3}^0/K_{e3}^0$ branching ratio via the fitted $K_{\mu 3}^0/K_{e3}^0$ ratio $(\Gamma(\pi^{\pm}\mu^{\mp}\nu)/\Gamma(\pi^{\pm}e^{\mp}\nu_e))$. The parameter ξ is redundant with λ_0 below and is not put into the Meson Summary Table.

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
-0.11±0.09 OUR	EVALUATION	From a fit discu	ssed	in note	on $K_{\ell 3}$ form factors in
		1982 edition, F			
• • • We do not u	se the following	g data for average	s, fit	s, limits,	etc. • • •
0.5 ± 0.4	6700	BRANDENB	73	HBC	BR, λ_{+} =0.019 \pm 0.013
-0.08 ± 0.25	1309	⁷⁶ EVANS	73	HLBC	BR, $\lambda_{+} = 0.02$
-0.5 ± 0.5	3548	BASILE	70	OSPK	BR, $\lambda_{+} = 0.02$
$+0.45\pm0.28$	569	BEILLIERE	69	HLBC	BR, $\lambda_{+}=0$
-0.22 ± 0.30	1309	⁷⁶ EVANS	69	HLBC	
$+0.2 \begin{array}{c} +0.8 \\ -1.2 \end{array}$		KULYUKINA	68	CC	BR, λ_{+} =0
$+1.1 \pm 1.1$	389	ADAIR	64	HBC	BR, $\lambda_{+}=0$
$+0.66^{+0.9}_{-1.3}$		LUERS	64	нвс	BR, $\lambda_{+}=0$

⁷⁶ EVANS 73 replaces EVANS 69.

 $\xi_{\bf c}=f_-/f_+$ (determined from μ polarization in $K_{\mu 3}^0$)

The μ polarization is a measure of $\xi(t)$. No assumptions on λ_{+-} necessary, t (weighted by sensitivity to $\xi(t)$) should be specified. In λ_+ , $\xi(0)$ parametrization this is $\xi(0)$ for $\lambda_{+}=0$. $d\xi/d\lambda=\xi t$. For radiative correction to μ polarization in $K_{\mu,3}^{0}$, see GINSBERG 73. The parameter ξ is redundant with λ_0 below and is not put into the Meson Summary Table.

VALUE	EVTS		TECN	
-0.11 ± 0.09	OUR EVALUATI			te on $K_{\ell 3}$ form factors in
		1982 edition, l	PL 111B (Ap	oril 1982).
$+0.178 \pm 0.105$	207k	⁷⁷ CLARK	77 SPEC	POL,
				$d\xi(0)/d\lambda_{+}=+0.68$
-0.385 ± 0.105	2.2M	⁷⁸ SANDWEISS	73 CNTR	POL, $d\xi(0)/d\lambda_{+}=-6$
$-1.81 \begin{array}{l} +0.50 \\ -0.26 \end{array}$		⁷⁹ LONGO	69 CNTR	POL, t=3.3
• • • We do no	ot use the followin	ng data for average	es, fits, limits	, etc. • • •
-1.6 ± 0.5	638	80 ABRAMS	68B OSPK	Polarization
-1.2 ± 0.5	2608	⁸⁰ AUERBACH	66B OSPK	Polarization
⁷⁷ CLARK 77	$t = +3.80, d\xi(0)$	$/d\lambda_{+} = \xi(t)t = 0$.178×3.80 =	+0.68.
	S 73 is for $\lambda_{+} =$			
			= -6.0 (tab	le 1) divided by $\xi = -1.8$
80 t value not	given	.(-,,+	- (, -, -, -, -, -, -, -, -, -, -, -, -, -,
. Jaide Hot ,	B			

$Im(\xi)$ in $K_{\mu 3}^0$ DECAY (from transverse μ pol.)

**/ µ3	•		,		
Test of 7	reversal invariance.				
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
-0.007 ± 0.026	OUR AVERAGE				
0.009 ± 0.030		MORSE	80	CNTR	Polarization
0.35 ± 0.30		CLARK	77	SPEC	POL, $t=0$
-0.085 ± 0.064	2.2M ⁸²	SANDWEISS	73	CNTR	POL, $t=0$
-0.02 ± 0.08		LONGO	69	CNTR	POL, t=3.3
-0.2 ± 0.6		ABRAMS	68B	OSPK	Polarization
• • • We do n	ot use the following o	data for average	s, fits	, limits,	etc. • • •
0.012 ± 0.026		SCHMIDT	79	CNTR	Repl. by MORSE 80

⁸¹ CLARK 77 value has additional $\xi(0)$ dependence $+0.21 \text{Re}[\xi(0)]$.

 λ_+ (LINEAR ENERGY DEPENDENCE OF f_+ IN $K_{\mu 3}^0$ DECAY)

See also the corresponding entries and notes in section " $\xi_A = f_-/f_+$ " above and section " λ_0 (LINEAR ENERGY DEPENDENCE OF f_0 IN $K_{\mu 3}^0$ DECAY)" below. For radiative correction of K_{u3}^0 Dalitz plot see GINSBERG 70 and BECHERRAWY 70.

	μ 5				
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.034 ±0.00	5 OUR EVALUATION	From a fit dis	cusse	ed in not	e on $K_{\ell 3}$ form factors in
		1982 edition, P	L 11	1B (Apr	il 1982).
0.0427 ± 0.00	44 150k	BIRULEV	81	SPEC	DP
0.028 ± 0.01	0 14k	СНО	80	HBC	DP
0.028 ± 0.01	1 16k	HILL	79	STRC	DP
0.046 ± 0.03	0 32k	BUCHANAN	75	SPEC	DP
0.030 ± 0.00	3 1.6M	DONALDSON	74B	SPEC	DP
0.085 ± 0.01	5 9086	ALBROW	72	ASPK	DP
• • • We do	not use the following o	data for averages	, fits	, limits,	etc. • • •
0.0337 ± 0.00	33 129k	DZHORD	77	SPEC	Repl. by BIRULEV 81
0.046 ± 0.00	8 82k	ALBRECHT	74	WIRE	Repl. by BIRULEV 81
0.11 ± 0.04	16k	DALLY	72	ASPK	DP
0.07 ± 0.02	16k	CHIEN	70	ASPK	Repl. by DALLY 72

 λ_0 (LINEAR ENERGY DEPENDENCE OF f_0 IN $K^0_{\mu3}$ DECAY) Wherever possible, we have converted the above values of $\xi(0)$ into values of λ_0 using the associated λ_{+}^{μ} and $d\xi(0)/d\lambda_{+}$.

	- T					
VALUE	$d\lambda_0/d\lambda_+$	EVTS	DOCUMENT ID		TECN	COMMENT
0.025 ±0.006	OUR EVALUA	ATION	From a fit discussed	l in r	note on	Ke3 form factors
			in 1982 edition			
0.0341 ± 0.0067	unknown	150k	⁸³ BIRULEV	81	SPEC	DP
$+0.050 \pm 0.008$	-0.11	14k	СНО	80	HBC	DP
$+0.039 \pm 0.010$	-0.67	16k	HILL	79	STRC	DP
$+0.047 \pm 0.009$	1.06	207k	⁸⁴ CLARK	77	SPEC	POL
$+0.025 \pm 0.019$	+0.5	32k	⁸⁵ BUCHANAN	75	SPEC	DP
$+0.019 \pm 0.004$	-0.47	1.6M	⁸⁶ DONALDSON	74B	SPEC	DP
-0.060 ± 0.038	-0.71	1385	87 PEACH	73	HLBC	DP
-0.018 ± 0.009	+0.49	2.2M	⁸⁴ SANDWEISS	73	CNTR	POL
-0.043 ± 0.052	-1.39	9086	⁸⁸ ALBROW	72	ASPK	DP
$-0.140 \begin{array}{l} +0.043 \\ -0.022 \end{array}$	+0.49		⁸⁴ LONGO	69	CNTR	POL
$+0.08$ ± 0.07	-0.54	1371	⁸⁴ CARPENTER	66	OSPK	DP
 • • We do not ι 	use the follow	ing data	for averages, fits, lir	nits,	etc. •	• •
0.041 ± 0.008		14k	⁸⁹ СНО	80	нвс	BR, $\lambda_{+} = 0.028$
$+0.0485\pm0.0076$		47k	DZHORD	77	SPEC	In BIRULEV 81
$+0.024 \pm 0.011$		82k	ALBRECHT	74	WIRE	In BIRULEV 81
$+0.06 \pm 0.03$		6700	⁹⁰ BRANDENB	73	HBC	BR,
						$\lambda_{+} = 0.019 \pm 0.013$
-0.067 ±0.227	unknown	16k	91 DALLY	72	ASPK	0.013 DP
-0.333 ± 0.034	+1.	3140	⁹² BASILE	70	OSPK	DP
83 DIDILI EV 91 «	ives d) /d)	1	S alvina an unreason	abb	narrow	arrar allinea which

- 83 BIRULEV 81 gives $d\lambda_0/d\lambda_+=-1.5$, giving an unreasonably narrow error ellipse which dominates all other results. We use $d\lambda_0/d\lambda_+=0$.
- ⁸⁴ λ_0 value is for $\lambda_+=0.03$ calculated by us from $\xi(0)$ and $d\xi(0)/d\lambda_+$.
- 85 BUCHANAN 75 value is from their appendix A and uses only $\mathit{K}_{\mu3}$ data. $\mathit{d}\lambda_0/\mathit{d}\lambda_+$ was obtained by private communication, C.Buchanan, 1976.
- 86 DONALDSON 74B $d\lambda_0/d\lambda_+$ obtained from figure 18.
- ⁸⁷ PEACH 73 assumes $\lambda_{+}=0.025$. Calculated by us from $\xi(0)$ and $d\xi(0)/d\lambda_{+}$.
- 88 ALBROW 72 λ_0 is calculated by us from $\xi_A,~\lambda_+$ and $d\xi(0)/d\lambda_+$. They give $\lambda_0=-0.043\pm0.039$ for $\lambda_-=0.$ We use our larger calculated error.
- 89 CHO 80 BR result not independent of their Dalitz plot result.
- 90 Fit for λ_0 does not include this value but instead includes the $K_{\mu3}/K_{e3}$ result from this experiment.
- experiment.

 91 DALLY 72 gives $f_0=1.20\pm0.35$, $\lambda_0=-0.080\pm0.272$, $\lambda_0'=-0.006\pm0.045$, but with a different definition of λ_0 . Our quoted λ_0 is his λ_0/f_0 . We cannot calculate true λ_0 error without his (λ_0,f_0) correlations. See also note on DALLY 72 in section ξ_A .

 92 BASILE 70 λ_0 is for $\lambda_+=0$. Calculated by us from ξ_A with $d\xi(0)/d\lambda_+=0$. BASILE 70 is incompatible with all other results. Authors suggest that efficiency estimates might be recognized.
- responsible.

$|f_{\rm S}/f_{+}|$ FOR $K_{\rm e3}^0$ DECAY Ratio of scalar to f_{+} couplings.

VALUE	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
< 0.04	68	25k	BLUMENTHA	L75	SPEC	
• • • We do	not use t	he followir	ng data for average	s, fit	s, limits,	, etc. • • •
< 0.095	95	18k	HILL	78	STRC	
< 0.07	68	48k	BIRULEV	76	SPEC	See also BIRULEV 81
< 0.19	95	5600	ALBROW	73	ASPK	
< 0.15	68		KULYUKINA	67	CC	

 $|f_T/f_+|$ FOR K_{e3}^0 DECAY Ratio of tensor to f_+ couplings.

VALUE	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
<0.23	68	25k	BLUMENTHA	L75	SPEC	
• • • We do no	t use th	ne followi	ng data for average	s, fit	s, limits,	etc. • • •
< 0.40	95	18k	HILL	78	STRC	
< 0.34	68	48k	BIRULEV	76	SPEC	See also BIRULEV 81
<1.0	95	5600	ALBROW	73	ASPK	
<1.0	68		KULYUKINA	67	CC	

 $^{^{82}}$ SANDWEISS 73 value corrected from value quoted in their paper due to new value of Re(ξ). See footnote 4 of SCHMIDT 79.

K_I^0

$\left| f_T/f_+ \right|$ FOR $K_{\mu 3}^0$ DECAY Ratio of tensor to f_+ couplings

VALUE DOCUMENT ID 0.12 ± 0.12 BIRULEV 81 SPEC

 $lpha_{K^{\bullet}}$ DECAY FORM FACTOR FOR $K_L o e^+e^-\gamma$ $\alpha_{K^{\bullet}}$ is the constant in the model of BERGSTROM 83 which measures the relative strength of the vector-vector transition $K_L \to K^* \gamma$ with $K^* \to \rho$, ω , $\phi \to \gamma^*$ and the pseudoscalar-pseudoscalar transition $K_L \to \pi$, η , $\eta' \to \gamma \gamma^*$.

<u>VALUE</u>	DOCUMENT ID	TECN
-0.28 ±0.08 OUR AVERAGE		
-0.28 ± 0.13	BARR	90B NA31
$-0.280 + 0.099 \\ -0.090$	OHL	90B B845

DECAY FORM FACTORS FOR $K_L^0 \to \pi^\pm \pi^0 \, e^\mp \nu_e$ Given in MAKOFF 93.

CP VIOLATION IN K_L^0 DECAY

(by L. Wolfenstein, Carnegie-Mellon University and T. Trippe, LBNL)

Experimentally Measured Parameters

CP violation has been observed in the semi-leptonic decays $K_L^0 \to \pi^{\mp} \ell^{\pm} \nu$ and in the nonleptonic decay $K_L^0 \to 2\pi$. The experimental numbers that have been measured are [1]

$$\delta = \frac{\Gamma(K_L^0 \to \pi^- \ell^+ \nu) - \Gamma(K_L^0 \to \pi^+ \ell^- \nu)}{\Gamma(K_L^0 \to \pi^- \ell^+ \nu) + \Gamma(K_L^0 \to \pi^+ \ell^- \nu)}$$
(1a)

$$\eta_{+-} = A(K_L^0 \to \pi^+ \pi^-)/A(K_S^0 \to \pi^+ \pi^-)$$

$$= |\eta_{+-}| e^{i\phi_{+-}}$$
(1b)

$$\eta_{00} = A(K_L^0 \to \pi^0 \pi^0) / A(K_S^0 \to \pi^0 \pi^0)$$

= $|\eta_{00}| e^{i\phi_{00}}$. (1c)

Thus there are five real numbers, three magnitudes, and two phases. We list $\delta(\mu)$ for $K_L^0 \to \pi \mu \nu$ and $\delta(e)$ for $K_L^0 \to \pi e \nu$ separately and a weighted average δ . Experimentally for the $K_L^0 \to \pi^0 \pi^0$ decay the quantities directly measured (and also of greatest theoretical interest) are $|\eta_{00}/\eta_{+-}|$ and $\phi_{00} - \phi_{+-}$.

Analysis Based on CPT Invariance [2]

CP violation can occur either in the $K^0 - \overline{K}^0$ mixing or in the decay amplitudes. Assuming CPT invariance, the CPviolation in the mixing is described by a single parameter ϵ :

$$|K_L^0\rangle = \left[(1+\epsilon) \mid K^0 \rangle - (1-\epsilon) \mid \overline{K}^0 \rangle \right]$$

$$/ \left[2(1+\mid \epsilon\mid^2) \right]^{1/2} \qquad (2a)$$

$$|K_S^0\rangle = \left[(1+\epsilon) \mid K^0 \rangle + (1-\epsilon) \mid \overline{K}^0 \rangle \right]$$

$$/ \left[2(1+\mid \epsilon\mid^2) \right]^{1/2} \qquad (2b)$$

The decay amplitudes are written

$$\langle I = 0 \mid T \mid K^0 \rangle = e^{i\delta_0} A_0 \tag{3a}$$

$$\langle I = 2 \mid T \mid K^0 \rangle = e^{i\delta_2} A_2 \tag{3b}$$

where δ_I are the $\pi\pi$ scattering phase shifts at the K^0 mass and I is the isospin of the final state. CP violation is measured by (Im $A_I/\text{Re }A_I$). One can then write

$$\eta_{+-} = \epsilon + \epsilon' \tag{4a}$$

$$\eta_{00} = \epsilon - 2\epsilon' \tag{4b}$$

where

$$\epsilon' = \frac{i}{\sqrt{2}} e^{i(\delta_2 - \delta_0)} \frac{\operatorname{Re} A_2}{\operatorname{Re} A_0} \left[\frac{\operatorname{Im} A_2}{\operatorname{Re} A_2} - \frac{\operatorname{Im} A_0}{\operatorname{Re} A_0} \right]$$
 (5)

neglecting small corrections of order ϵ' times $\operatorname{Re}(A_2/A_0)$. It is possible by a choice of phase convention to set Im A_0 or Im A_2 or $\operatorname{Im} \epsilon$ to 0, but none of these is 0 with the usual phase convention in the Standard Model. The choice Im A_0 =0 is the Wu-Yang phase convention [3].

By applying CPT invariance and unitarity it is possible to relate δ to ϵ and to determine the phases of ϵ and ϵ' . If one assumes the $\Delta S = \Delta Q$ rule (see below note on the " $\Delta S = \Delta Q$ Rule in K^0 Decay") the expression for δ becomes

$$\delta = 2 \operatorname{Re} \epsilon / (1 + |\epsilon|^2) \approx 2 \operatorname{Re} \epsilon$$
 (6)

This quantity is independent of phase convention and is seen from Eq. (2) to equal $\langle K_L^0 | K_S^0 \rangle$. The phase of ϵ is given by

$$\phi(\epsilon) \approx \tan^{-1} \frac{2(m_{K_L} - m_{K_S})}{\Gamma_{K_S} - \Gamma_{K_L}} = 43.49 \pm 0.08^{\circ}$$
 (7a)

while Eq. (5) gives

$$\phi(\epsilon') = \delta_2 - \delta_0 + \frac{\pi}{2} \approx 48 \pm 4^{\circ} . \tag{7b}$$

The approximation in Eq. (7a) depends on the assumption that direct CP violation is negligible in all K^0 decays and is expected to be good to a few tenths of a degree. Eq. (7a)is evaluated using the values of the $K_L^0 - K_S^0$ mass difference $\Delta m = (0.5304 \pm 0.0014) \times 10^{10} h s^{-1}$ and the K_S^0 mean life $\tau_s = (0.8927 \pm 0.0009) \times 10^{-10}$ s from the current edition. The value of the $\pi\pi$ phase shifts is taken from the fit given by Chell and Olsson [4]. The most important point for the analysis is that $\cos[\phi(\epsilon') - \phi(\epsilon)] \simeq 1$. The consequence of this analysis is that only two real quantities need be measured, the magnitude of ϵ and the value of (ϵ'/ϵ) including its sign. The measured quantity $|\eta_{00}/\eta_{+-}|^2$ which is very close to unity, is given to a good approximation by

$$|\eta_{00}/\eta_{+-}|^2 \approx 1 - 6\text{Re}\left(\epsilon'/\epsilon\right)$$

$$= 1 - 6(\epsilon'/\epsilon)\cos\left[\phi(\epsilon') - \phi(\epsilon)\right]. \tag{8}$$

Since the cos in Eq. (8) is expected theoretically to be very close to unity it is customary to say that $|\eta_{00}/\eta_{+-}|^2$ determines ϵ'/ϵ .

It is possible to use the values of ϕ_{+-} and $\phi_{00} - \phi_{+-}$ to set limits on CPT violation. [See Tests of Conservation Laws.]

Models

See key on page 199

In the superweak model [5] CP violation is restricted to the mass mixing so that to a high degree of accuracy one expects $\epsilon' = 0$. The phase $\phi(\epsilon)$ is given in this model exactly by Eq. (7a) so that this has sometimes been referred to as the superweak phase; however, as noted above, all CPT-invariant models give Eq. (7a) as a very good approximation. In the Standard Model CP violation is entirely due to the phase in the Cabibbo-Kobayashi-Maskawa mixing matrix [6](q.v.). Since CP violation occurs in first order in decay amplitudes and in second order in mass-matrix mixing, one expects a significant nonzero value of ϵ' . The calculation is uncertain partly because m_t and V_{td} are not well known and primarily because of the difficulty of estimating hadronic matrix elements [7]. The theoretical results for ϵ'/ϵ in the Standard Model are generally in the range from 10^{-4} to 3×10^{-3} .

Fit for ϕ_{+-} , ϕ_{00} , ϕ_{00} - ϕ_{+-} , Δm , and τ_s

The Fermilab E773 experiment has published new results on the CP-violation phases ϕ_{+-} and ϕ_{00} , the $K_L^0 - K_S^0$ mass difference Δm , and the K_S^0 mean life τ_s (Document ID in our listings: SCHWINGENHEUER 95; reference [8]). The CPLEAR experiment has published new results on ϕ_{+-} (ADLER 95B [9]) and Δm (ADLER 95 [10]).

Fermilab E773 (SCHWINGENHEUER 95 [8]) and E731 (GIBBONS 93 [11]) measure $\phi_{+-} - \phi_f$ and calculate the regeneration phase ϕ_f from the power law momentum dependence of the regeneration amplitude using analyticity and dispersion relations. In the E731 result, a systematic error of ± 0.5 degrees for departures from a pure power-law is included. For the E773 result, they modeled a variety of effects that do distort the amplitude from a pure power law and ascribed a $\pm 0.35^{\circ}$ systematic error from uncertainties in these effects. Even so, the E731 result remains valid within its quoted errors. KLEINKNECHT 94 [12] and KLEINKNECHT 95 [13] argue that these systematic errors should be around 3°, primarily because of the absence of data on the momentum dependence of the regeneration amplitude above 160 GeV/c. BRIERE 95 [14] and BRIERE 95C [15] reply that the current understanding of regeneration is sufficient to allow a precise and reliable correction for the region above 160 GeV/c. The question is one of judgement about the reliability of the assumptions used. In the absence of any contradictory evidence, we choose to accept the judgement of the E731/E773 experimenters in setting their systematic errors.

In this edition we give a joint fit to the data on ϕ_{+-} , ϕ_{00} , $\phi_{00} - \phi_{+-}$, Δm , and τ_s , including the effects of correlations. Measurements of ϕ_{+-} and ϕ_{00} are highly correlated with Δm and τ_s . The correlations are given in the footnotes of the ϕ_{+-} and ϕ_{00} data listings. In earlier editions of the Review we adjusted the experimental values of ϕ_{+-} and ϕ_{00} to account for correlations with Δm and au_s but did not include the effects of these correlations when evaluating Δm and τ_s . When a joint fit is done, the ϕ_{+-} measurements and

their correlations have a strong influence on the fitted value of Δm . This is because the CERN NA31 vacuum regeneration experiments (CAROSI 90 [16] and GEWENIGER 74B [17]), the Fermilab E773/E731 regenerator experiments (SCHWIN-GENHEUER 95 [8] and GIBBONS 93 [11]), and the CPLEAR $K^0 - \overline{K}^0$ asymmetry experiment (ADLER 95B [9]) have very different dependences of ϕ_{+-} on Δm , as can be seen in Fig. 1. The correlations move the fitted Δm lower so that the ϕ_{+-} measurements are in good agreement with each other and with ϕ (superweak).

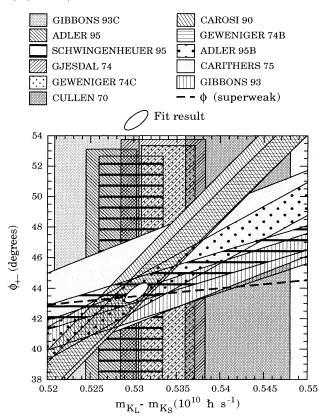


Figure 1: ϕ_{+-} vs Δm . Δm measurements appear as vertical bands spanning $\Delta m \pm 1\sigma$, some of which are cut near the top to aid the eye. The ϕ_{+-} measurements appear as diagonal bands spanning $\phi_{+-} \pm \sigma_{\phi}$. The dashed line shows ϕ (superweak). The ellipse shows the 1σ contour of the fit result. See Table 1 for data references.

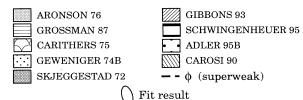
The (ϕ_{+-}, τ_s) correlations influence the τ_s fit result in a similar manner, as can be seen in Fig. 2. The influence of the ϕ_{+-} experiments is not as great on τ_s as it is on Δm because the indirect measurements of τ_s derived from the diagonal crossing bands in Fig. 2 are not as precise as the direct measurements of τ_s from E773/E731 (SCHWINGENHEUER 95 [8] and GIBBONS 93 [11]).

 K_L^0

Meson Particle Listings

Table 1: References for Fig. 1 and Fig. 2

Meas	. / Fig	. No.		
$\overline{\phi_{+-}}$	Δm	$ au_s$	PDG Document ID	Ref.
1,2			CAROSI 90	[16]
1		2	GEWENIGER 74B	[17]
1,2			ADLER 95B	[9]
1		2	CARITHERS 75	[18]
1,2	1	2	SCHWINGENHEUER 95	[8]
1,2		2	GIBBONS 93	[11]
	l		GIBBONS 93C	[19]
	l		ADLER 95	[10]
	l		GJESDAL 74	[20]
	1		GEWENIGER 74C	[21]
	1		CULLEN 70	[22]
		2	ARONSON 76	[23]
		2	GROSSMAN 87	[24]
		2	SKJEGGESTAD 72	[25]



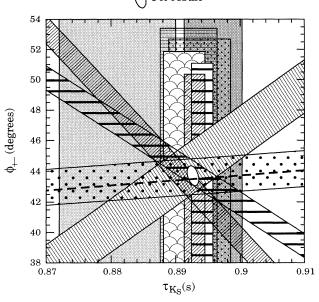


Figure 2: ϕ_{+-} vs τ_s . τ_s measurements appear as vertical bands spanning $\tau_s \pm 1\sigma$, some of which are cut near the top to aid the eye. The ϕ_{+-} measurements appear as diagonal bands spanning $\phi_{+-}\pm\sigma_{\phi}$. The dashed line shows ϕ (superweak). The ellipse shows the fit result's 1σ contour. See Table 1 for data references.

In Fig. 1 [Fig. 2] the slope of the diagonal ϕ_{+-} bands shows the $\Delta m \ [\tau_s]$ dependence; the unseen $\tau_s \ [\Delta m]$ dependent term is evaluated using the fitted τ_s [Δm]. The vertical half-width σ_{ϕ} of each band is the ϕ_{+-} error for fixed Δm $[\tau_s]$ and includes the systematic error due to the error in the fitted τ_s [Δm].

Table 2 gives the resulting fit values for the parameters and Table 3 gives the correlation matrix.

A similar analysis has been done by the CPLEAR Collaboration [26]. The small differences between their results and ours are due primarily to different treatments of τ_s . Their fit constrains τ_s to the PDG 1994 value, while our fit includes the more recent SCHWINGENHEUER 95 [8] τ measurement.

Table 2: Results of the fit for ϕ_{+-} , ϕ_{00} , $\phi_{00} - \phi_{+-}$, Δm , and τ_s . The fit has $\chi^2 = 12.0$ for 18 degrees of freedom (22 measurements -5parameters +1 constraint).

Quantity	Fit Result
φ+-	$43.7 \pm 0.6^{\circ}$
Δm	$(0.5304 \pm 0.0014) \times 10^{10} h \text{ s}^{-1}$
$ au_s$	$(0.8927 \pm 0.0009) \times 10^{-10}$ s
ϕ_{00}	$43.5 \pm 1.0^{\circ}$
$\Delta\phi$	$-0.2 \pm 0.8^{\circ}$

Table 3: Correlation matrix for the fitted parameters.

	ϕ_{+-}	Δm	$ au_s$	ϕ_{00}	$\Delta \phi$
φ ₊₋	1.00	0.71	-0.36	0.60	-0.02
Δm	0.71	1.00	-0.21	0.48	0.04
τ_s	-0.36	-0.21	1.00	-0.19	0.04
ϕ_{00}	0.60	0.48	-0.19	1.00	0.79
$\Delta \phi$	-0.02	0.04	0.04	0.79	1.00

Fit for $\epsilon'/\epsilon,\, |\eta_{+-}|,\, |\eta_{00}|,\, {
m and}\,\, {
m B}(K_L o \pi\pi)$

We list measurements of $|\eta_{+-}|$, $|\eta_{00}|$, $|\eta_{00}/\eta_{+-}|$ and ϵ'/ϵ . Independent information on $|\eta_{+-}|$ and $|\eta_{00}|$ can be obtained from measurements of the K_L^0 and K_S^0 lifetimes (τ_s) and branching ratios (B) to $\pi\pi$, using the relations

$$|\eta_{+-}| = \left[\frac{B(K_L^0 \to \pi^+ \pi^-)}{\tau(K_L^0)} \frac{\tau(K_S^0)}{B(K_S^0 \to \pi^+ \pi^-)} \right]^{1/2} , \quad (9a)$$

$$|\eta_{00}| = \left[\frac{B(K_L^0 \to \pi^0 \pi^0)}{\tau(K_L^0)} \frac{\tau(K_S^0)}{B(K_S^0 \to \pi^0 \pi^0)} \right]^{1/2} . \tag{9b}$$

For historical reasons the branching ratio fits and the CPviolation fits are done separately, but we want to include the influence of $|\eta_{+-}|$, $|\eta_{00}|$, $|\eta_{00}/\eta_{+-}|$, and ϵ'/ϵ measurements on $\mathrm{B}(K_L^0 \to \pi^+\pi^-)$ and $\mathrm{B}(K_L^0 \to \pi^0\pi^0)$ and vice versa. We approximate a global fit to all of these measurements by first performing two independent fits: 1) BRFIT, a fit to the K_L^0 branching ratios, rates, and mean life, and 2) ETAFIT, a fit to

the $|\eta_{+-}|$, $|\eta_{00}|$, $|\eta_{+-}/\eta_{00}|$, and ϵ'/ϵ measurements. The results from fit 1, along with the K_S^0 values from this edition are used to compute values of $|\eta_{+-}|$ and $|\eta_{00}|$ which are included as measurements in the $|\eta_{00}|$ and $|\eta_{+-}|$ sections with a document ID of BRFIT 96. Thus the fit values of $|\eta_{+-}|$ and $|\eta_{00}|$ given in this edition include both the direct measurements and the results from the branching ratio fit.

The process is reversed in order to include the direct $|\eta|$ measurements in the branching ratio fit. The results from fit 2 above (before including BRFIT 96 values) are used along with the K_L^0 and K_S^0 mean lives and the $K_S^0 \to \pi\pi$ branching fractions to compute the K_L^0 branching ratios $\Gamma(K_L^0 \to \pi^+\pi^-)/\Gamma({\rm total})$ and $\Gamma(K_L^0 \to \pi^0\pi^0)/\Gamma(K_L^0 \to \pi^+\pi^-)$. These branching ratio values are included as measurements in the branching ratio section with a document ID of ETAFIT 96. Thus the K_L^0 branching ratio fit values in this edition include the results of direct measurements of $|\eta_{+-}|$, $|\eta_{00}|$, $|\eta_{00}/\eta_{+-}|$, and ϵ'/ϵ . A more detailed discussion of these fits is given in the 1990 edition of this Review [27].

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CP-VIOLATION PARAMETERS IN KO DECAYS

- CHARGE ASYMMETRY IN KO DECAYS

Such asymmetry violates CP. It is related to $Re(\epsilon)$.

$\delta =$ weighted average of $\delta(\mu)$ and $\delta(e)$

DOCUMENT ID VALUE (%) EVTS DOCUMENT ID TECN COMMENT

0.327±0.012 OUR AVERAGE Includes data from the 2 datablocks that follow this one. WILLIAMS 73 ASPK $K_{\mu3}+K_{e3}$

 $\delta(\mu) = [\Gamma(\pi^-\mu^+\nu_\mu) - \Gamma(\pi^+\mu^-\overline{\nu}_\mu)]/{\sf SUM}$ Only the combined value below is put into the Meson Summary Table.

VALUE (%) EVTS DOCUMENT ID TECN.

The data in this block is included in the average printed for a previous datablock.

0.304 ± 0.025 OUR AVERAGE

GEWENIGER 74 ASPK PICCIONI 72 ASPK 0.278 ± 0.051 7.7M • • • We do not use the following data for averages, fits, limits, etc. • • • 0.60 ±0.14 0.57 ±0.17 4.1M MCCARTHY 73 CNTR 93 PACIOTTI 1 M 69 OSPK ⁹³ DORFAN 0.403 ± 0.134 1M 67 OSPK

 93 PACIOTTI 69 is a reanalysis of DORFAN 67 and is corrected for $\mu^+\mu^-$ range difference in MCCARTHY 72.

$\delta(e) = [\Gamma(\pi^- \, e^+ \, \nu_e) - \Gamma(\pi^+ \, e^- \, \overline{\nu}_e)]/\text{SUM}$

Only the combined value below is put into the Meson Summary Table.

VALUE (%)

EVTS

DOCUMENT ID

TECN

The data in this block is included in the average printed for a previous datablock.

0.333±0.014 OUR AVERAGE

 0.341 ± 0.018 GEWENIGER 74 ASPK 73 ASPK 70 CNTR 0.318 ± 0.038 40M FITCH MARX 0.346 ± 0.033 10M 94 SAAL 0.246 ± 0.059

72 ASPK 0.36 ± 0.18 600k ASHFORD 94 BENNETT 0.224 ± 0.036 10M

⁹⁴SAAL 69 is a reanalysis of BENNETT 67.

- PARAMETERS FOR $K_I^0 ightarrow 2\pi$ DECAY -

$$\begin{array}{l} \eta_{+-} = \mathsf{A}(\mathsf{K}_L^0 \to \ \pi^+ \, \pi^-) \, / \, \mathsf{A}(\mathsf{K}_S^0 \to \ \pi^+ \, \pi^-) \\ \eta_{00} = \mathsf{A}(\mathsf{K}_L^0 \to \ \pi^0 \, \pi^0) \, / \, \mathsf{A}(\mathsf{K}_S^0 \to \ \pi^0 \, \pi^0) \end{array}$$

The fitted values of $\left|\eta_{+-}\right|$ and $\left|\eta_{00}\right|$ given below are the results of a fit to $|\eta_{+-}|$, $|\eta_{00}|$, $|\eta_{00}/\eta_{+-}|$, and $\mathrm{Re}(\epsilon'/\epsilon)$. Independent information on $|\eta_{+-}|$ and $|\eta_{00}|$ can be obtained from the fitted values of the K_I^0 ightarrow $\pi\pi$ and $K_S^0 \to \pi\pi$ branching ratios and the K_L^0 and K_S^0 lifetimes. This information is included as data in the $|\eta_{+-}|$ and $|\eta_{00}|$ sections with a Document ID "BRFIT." See the "Note on CP Violation in K1 Decay"

$|\eta_{00}| = |A(K_L^0 \to 2\pi^0) / A(K_S^0 \to 2\pi^0)|$

DOCUMENT ID TECN COMMENT EVTS 2.275±0.019 OUR FIT Error includes scale factor of 1.1. 2.30 ±0.14 OUR AVERAGE ⁹⁵ BRFIT CHRISTENS... 79 ASPK 2.33 ± 0.18

 \bullet $\,\bullet\,$ We do not use the following data for averages, fits, limits, etc. $\,\bullet\,$ $\,\bullet\,$ ⁹⁶ WOLFF 71 OSPK Cu reg., 4γ 's ⁹⁶ CHOLLET 2.95 ± 0.63 70 OSPK Cu reg., 4γ 's

 95 This BRFIT value is computed from fitted values of the κ_I^0 and κ_S^0 lifetimes and branching fractions to $\pi\pi$. See the discussion in the "Note on CP violation in K_I^0

decay." 96 CHOLLET 70 gives $|\eta_{00}|=(1.23\pm0.24)\times$ (regeneration amplitude, 2 GeV/c Cu)/10000mb. WOLFF 71 gives $|\eta_{00}|=(1.13\pm0.12)\times$ (regeneration amplitude, 2 GeV/c Cu)/10000mb. We compute both $|\eta_{00}|$ values for (regeneration amplitude, 2 GeV/c Cu) = 24 \pm 2mb. This regeneration amplitude results from averaging over FAISSNER 69, extrapolated using optical-model calculations of Bohm et al., Physics Letters **27B** 594 (1968) and the data of BALATS 71. (From H. Faissner, private communication).

$|\eta_{+-}| = |A(K_L^0 \to \pi^+\pi^-) / A(K_S^0 \to \pi^+\pi^-)|$

VALUE (units 10⁻³)
2.285±0.019 OUR FIT DOCUMENT ID TECN COMMENT EVTS 2.284±0.018 OUR AVERAGE 97 BRFIT 2.271 ± 0.024 98 ADLER 958 CPLR $K^0 - \overline{K}^0$ asymmetry $2.310 \pm 0.043 \pm 0.031$ K^0 - \overline{K}^0 asymm. 105 928 SPEC $\begin{array}{cccc} 2.32 & \pm 0.14 & \pm 0.03 \\ 2.27 & \pm 0.12 & \end{array}$ ADLER CHRISTENS... 79B ASPK 2.30 ±0.035 GEWENIGER 748 ASPK • • • We do not use the following data for averages, fits, limits, etc. • • 99 COUPAL 85 SPEC P(K)=70 GeV/c 2.28 ± 0.06 100 ARONSON 2.09 ±0.02 828 SPEC E=30-110 GeV

- 97 This BRFIT value is computed from fitted values of the K_L^0 and K_S^0 lifetimes and branching fractions to $\pi\pi$. See the discussion in the "Note on CP violation in K_I^0
- ⁹⁸ ADLER 95B report $(2.312 \pm 0.043 \pm 0.030 1[\Delta m 0.5274] + 9.1[\tau_s 0.8926]) \times 10^{-3}$. We evaluate for our 1996 best values $\Delta m=(0.5304\pm0.0014)\times10^{-10}~\hbar {
 m s}^{-1}$ and $au_{
 m S}$ $= (0.8927 \pm 0.0009) \times 10^{-10} \text{ s.}$
- 99 COUPAL 85 concludes: no energy dependence of $|\eta_{+-}|$, because their value is consistent with above values which occur at lower energies. Not independent of COUPAL 85 $\Gamma(\pi^+\pi^-)/\Gamma(\pi\,\ell\,
 u)$ measurement. Enters $|\eta_{+-}|$ via BRFIT value. In editions prior to 1990, this measurement was erroneously also included in our $|\eta_{+-}|$ average and fit. We thank H. Wahl (WAHL 89) for informing us.
- $^{100} \, \mathrm{ARONSON}$ 82B find that $|\eta_{+-}|$ may depend on the kaon energy.

$|\eta_{00}/\eta_{+-}|$

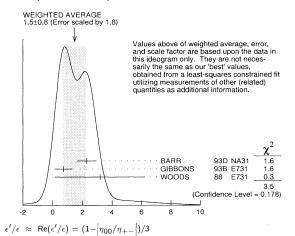
VALUE	EVTS	DOCUMENT ID	<u>TECN</u>
0.9956±0.0023 OUR FIT	Error includes	scale factor of 1	.8.
0.9930±0.0020 OUR AVE			
0.9931 ± 0.0020		⁾² BARR	93D NA31
$0.9904 \pm 0.0084 \pm 0.0036$	10	⁰³ woods	88 E731
• • • We do not use the	following data fo	or averages, fits,	limits, etc. • • •
$0.9939 \pm 0.0013 \pm 0.0015$		⁾¹ BARR	93D NA31
$0.9899 \pm 0.0020 \pm 0.0025$	10	⁾¹ BURKHARDT	88 NA31
$1.014 \pm 0.016 \pm 0.007$	3152	BERNSTEIN	85B SPEC
0.995 ±0.025	1122	BLACK	85 SPEC
1.00 ±0.09	10	⁾⁴ CHRISTENS	. 79 ASPK
1.03 ±0.07	124	BANNER	72 OSPK
1.00 ±0.06	167	HOLDER	72 ASPK

- 101 This is the square root of the ratio $\it R$ given by <code>BURKHARDT</code> 88 and <code>BARR</code> 93D.
- 102 This is the combined results from BARR 930 and BURKHARDT 88, taking into account a common systematic uncertainty of 0.0014.
- 103 We calculate $|\eta_{00}/\eta_{+-}|=1-3(\epsilon'/\epsilon)$ from WOODS 88 (ϵ'/ϵ) value.
- $^{104}\,\mathrm{Not}$ independent of $|\eta_{+-}|$ and $|\eta_{00}|$ values which are included in fit.

$\epsilon'/\epsilon \approx \operatorname{Re}(\epsilon'/\epsilon) = (1-|\eta_{00}/\eta_{+-}|)/3$

VALUE (units 10 ⁻³)	EVTS	DOCUMENT ID		TECN	COMMENT
1.5 ±0.8 OUR FIT Error	includes	scale factor of 1.8.			
1.5 ±0.8 OUR AVERAGE	Error in	cludes scale factor o	of 1.8.	See th	e ideogram below.
2.3 ±0.65	105	,106 BARR	93D	NA31	
$0.74 \pm 0.52 \pm 0.29$	>5E5	GIBBONS	93B	E731	
$3.2 \pm 2.8 \pm 1.2$		¹⁰⁵ WOODS	88	E731	
• • We do not use the follow	ving data	for averages, fits, li	imits,	etc. •	• •
2.0 ±0.7	1M	105 BARR	93D	NA31	
$-0.4 \pm 1.4 \pm 0.6$		PATTERSON	90	E731	in GIBBONS 93B
3.3 ±1.1		¹⁰⁵ BURKHARDT	88	NA31	

- $^{105}\,\mathrm{These}$ values are derived from $|\eta_{00}/\eta_{+-}|$ measurements. They enter the average in this section but enter the fit via the $|\eta_{00}/\eta_{+-}|$ section only.
- $^{106}\,\mathrm{This}$ is the combined results from BARR 93D and BURKHARDT 88, taking into account their common systematic uncertainty.



 ϕ_{+-} , PHASE of η_{+-} The dependence of the phase on Δm and τ_S is given for each experiment in the comments below, where Δm is the κ_L^0 - κ_S^0 mass difference in units $10^{10}~hs^{-1}$ and au_S is the K_S mean life in units 10^{-10} s. For the "used" data, we have evaluated these mass dependences using our 1996 values, $\Delta m = 0.5304 \pm 0.0014$, $au_S = 0.8927 \pm 0.0009$ to obtain the values quoted below. We also give the regeneration phase ϕ_f in the comments below.

OUR FIT is described in the note on "CP Violation in K_I^0 Decay" in the K_I^0 Particle

Listings.					
VALUE (°)	EVTS	DOCUMENT ID		TECN	COMMENT
43.7± 0.6 OUR FIT					
43.6± 1.2	107	ADLER	95B	CPLR	K^0 - \overline{K}^0 asymmetry
43.9± 0.8	108,109	SCHWINGEN	.95	E773	CH _{1 1} regenerator
42.9± 1.0	109,110	GIBBONS	93	E731	CH _{1,1} regenerator
44.3± 1.8	111	CAROSI	90	NA31	Vacuum regen.
44.5 ± 2.8	112	CARITHERS	75	SPEC	C regenerator
44.0 ± 1.3	113	GEWENIGER	74B	ASPK	Vacuum regen.
• • • We do not use the	e following o	lata for averages	, fits	, limits,	etc. • • •
42.3± 4.4±1.4	105 114	ADLER	92B	SPEC	$K^0 - \overline{K}^0$ asymm.
47.7± 2.0±0.9		KARLSSON		E731	,
35.3± 3.9	116	ARONSON		SPEC	
41.7± 3.5		CHRISTENS			
36.2 ± 6.1	117	CARNEGIE	72	ASPK	Cu regenerator
37 ±12	118	BALATS	71	OSPK	
40 ± 4	119	JENSEN	70	ASPK	Vacuum regen.
34 ±10	120	BENNETT	69	CNTR	Cu regenerator
44 ±12	121	вонм	69B	OSPK	Vacuum regen.
45 ± 7	122	FAISSNER	69	ASPK	Cu regenerator
51 ±11	123	BENNETT	68B	CNTR	Cu reg. uses
70 ±21	124	BOTT	67B	OSPK	C regenerator
25 ± 35	124	MISCHKE	67	OSPK	Cu regenerator
30 ±45	124	FIRESTONE	66	HBC	
45 ±50	124	FITCH	65	OCDIV	Be regenerator

- ADLER 95B report (42.7 $^{\circ}$ \pm 0.9 $^{\circ}$ \pm 0.6 $^{\circ}$ +316[Δm 0.5274] $^{\circ}$ +30[au_{s} -
- 108 SCHWINGENHEUER 95 reports $\phi_{+-} = 43.53 \pm 0.76 \, + 173 [\Delta m 0.5282] \, 275 [au_{S} 0.5282]$ 0.8926].
- 0.8926].

 109 These experiments measure $\phi_{+-} \phi_f$ and calculate the regeneration phase from the power law momentum dependence of the regeneration amplitude using analyticity and dispersion relations. SCHWINGENHEUER 95 [GIBBONS 93] includes a systematic error of 0.35° [0.5°] for uncertainties in their modeling of the regeneration amplitude. See the discussion of these systematic errors, including criticism that they could be underestimated, in the note on "C violation in K_L^0 decay."
- 110 GIBBONS 93 measures $\phi_+ \phi_f$ and calculates the regeneration phase ϕ_f from the power law momentum dependence of the regeneration amplitude using analyticity. An error of 0.6° is included for possible uncertainties in the regeneration phase. They find $\phi_{+-}=$ 42.21 \pm 0.9 +189 [Δm - 0.5257] - 460 [$\tau_{\rm S}$ - 0.8922]°, as given in SCHWINGENHEUER 95, footnote 8. GIBBONS 93 reports ϕ_{+-} (42.2 \pm 1.4)°
- $^{111} \, {\rm CAROSI} \,\, 90 \,\, \phi_{+-} = 46.9 \,\pm\, 1.4 \,\pm\, 0.7 \,\, +579 \,\, [\Delta m \,\, -0.5351] \,\, +303 \,\, [\tau_{\rm S} \,\, -0.8922]^{\circ}.$
- ¹¹²CARITHERS 75 $\phi_{+-} = (45.5 \pm 2.8) + 224 [\Delta m 0.5348]^{\circ}$. $\phi_{f} = -40.9 \pm 2.6^{\circ}$.
- ¹¹³GEWENIGER 74B $\phi_{+-} = (49.4 \pm 1.0) + 565 [\Delta m 0.540]^{\circ}$.
- 114 ADLER 92B quote separately two systematic errors: ± 0.4 from their experiment and ± 1.0 degrees due to the uncertainty in the value of Δm .
- 115 KARLSSON 90 systematic error does not include regeneration phase uncertainty.
- 116 ARONSON 82 find that ϕ_{+-} may depend on the kaon energy. 117 CARNEGIE 72 ϕ_{+-} is insensitive to $\Delta m.~\phi_f=-$ 56.2 \pm 5.2°.
- 118 BALATS 71 $\phi_{+-}^{-} = (39.0 \pm 12.0) + 198 [\Delta m 0.544]^{\circ}. \; \phi_f = -43.0 \pm 4.0^{\circ}.$
- ¹¹⁹ JENSEN 70 $\phi_{+-}^{'}=(42.4\pm4.0)+576[\Delta m-0.538]^{\circ}.$
- $^{120}\, {\tt BENNETT}$ 69 uses measurement of $(\phi_{+-})-(\phi_f)$ of ALFF-STEINBERGER 668. BEN-NETT 69 $\phi_{+-} = (34.9 \pm 10.0) + 69 [\Delta m - 0.545]^{\circ}$. $\phi_f = -49.9 \pm 5.4^{\circ}$.
- ¹²¹ BOHM 698 $\phi_{+-} = (41.0 \pm 12.0) + 479(\Delta m 0.526)^{\circ}$.
- $^{122}\,\mathrm{FAISSNER}$ 69 error enlarged to include error in regenerator phase. FAISSNER 69 ϕ_{+-} = $(49.3 \pm 7.4) + 205[\Delta m - 0.555]^{\circ}$. $\phi_f = -42.7 \pm 5.0^{\circ}$.
- 123 BENNETT 69 is a re-evaluation of BENNETT 68B.
- 124 Old experiments with large errors not included in average.

ϕ_{00} , PHASE OF η_{00}

See comment in ϕ_{+-} header above for treatment of Δm and au_{S} dependence.

OUR FIT is described in the note on "CP Violation in K_I^0 Decay" in the K_I^0 Particle

VALUE (°)	EVTS	DOCUMENT ID		TECN	COMMENT
43.5 ± 1.0 OUR FIT					
44.5 ± 2.5		¹²⁵ CAROSI	90	NA31	
• • • We do not use th	e followi	ng data for average	s, fit:	s, limits,	etc. • • •
47.4 ± 1.4 ± 0.9		¹²⁶ KARLSSON	90	E731	
55.7± 5.8		CHRISTENS			
38.0 ± 25.0	56	¹²⁷ WOLFF	71	OSPK	Cu reg., 4γ's
51.0 ± 30.0		¹²⁸ CHOLLET	70	OSPK	Cu reg., 4γ's
first quadrant preferred		GOBBI	69B	OSPK	
125 CAROSI 90 $\phi_{00}=4$	₹7.1 ± 2	$.1 \pm 1.0 + 579 \Delta m$	ı — ı	0.5351	$+252 \left[\tau_{c} - 0.8922\right]^{\circ}$
126 KARLSSON 90 syste					
127 WOLFF 71 uses rege	enerator	phase $\phi_{\mathcal{E}} = -48.2$	+ 3.	5°.	
		p +1			

 $^{128}\,\text{CHOLLET}$ 70 uses regenerator phase $\phi_f=-46.5\pm4.4^{\circ}.$

PHASE DIFFERENCE ϕ_{00} - ϕ_{+-}

OUR FIT is described in the note on "CP Violation in K_I^0 Decay" in the K_I^0 Particle

Listings.				
VALUE (°)	DOCUMENT ID	TECN	COMMENT	_
- 0.2 ± 0.8 OUR FIT				
$-$ 0.3 \pm 0.8 OUR AVERAG				
$-$ 0.30 \pm 0.88	129 SCHWINGEN	95	Combined E731, E773	
$0.2 \pm 2.6 \pm 1.2$	130 CAROSI	90 NA31		
• • • We do not use the follow	ving data for averages	, fits, limit	s, etc. • • •	
$0.62 \pm 0.71 \pm 0.75$	SCHWINGEN			
$-$ 1.6 \pm 1.2	¹³¹ GIBBONS	93 E731		
$-$ 0.3 \pm 2.4 \pm 1.2	KARLSSON			
12.6 ± 6.2	132 CHRISTENS			
7.6 ±18.0	¹³³ BARBIELLINI	73 ASPK	•	
120				

- 129 This SCHWINGENHEUER 95 values is the combined result of SCHWINGENHEUER 95 and GIBBONS 93, accounting for correlated systematic errors. 130 CAROSI 90 is excluded from the fit because it it is not independent of ϕ_{+-} and ϕ_{00}
- values. 131 GIBBONS 93 give detailed dependence of systematic error on lifetime (see the section on the K_S^0 mean life) and mass difference (see the section on $m_{K_L^0} m_{K_S^0}$).
- $^{132}\mathrm{Not}$ independent of ϕ_{+-} and ϕ_{00} values.
- 133 Independent of regenerator mechanism, $\Delta \emph{m}$, and lifetimes.

- CHARGE ASYMMETRY IN $\pi^+\pi^-\pi^0$ DECAYS -

CHARGE ASYMMETRY j FOR $K_L^0 ightarrow \pi^+\pi^-\pi^0$

Defined at beginning of section "LINEAR COEFFICIENT g FOR $\kappa_L^0 \to \pi^+\pi^-\pi^0$ above. Such asymmetry violates CP . See also note on Daltitz plot parameters in K^\pm section and note on CP violation in K^0_L decay above.

VALUE	EVTS	DOCUMENT ID		TECN	
0.0011±0.0008 OU	R AVERAGE				
0.001 ± 0.011	6499	СНО	77		
-0.001 ± 0.003	4709	PEACH	77		
0.0013 ± 0.0009	3M	SCRIBANO	70		
0.0 ± 0.017	4400	SMITH	70	OSPK	
0.001 ± 0.004	238k	BLANPIED	68		

- PARAMETERS for $K_I^0 \rightarrow \pi^+\pi^-\gamma$ DECAY -

$|\eta_{+-\gamma}| = |A(K_L^0 \to \pi^+\pi^-\gamma, CP \text{ violating})/A(K_S^0 \to \pi^+\pi^-\gamma)|$ VALUE (units 10⁻³) EVTS DOCUMENT ID TECN

2.35 ±0.07 OUF	RAVE	RAGE			
$2.359 \pm 0.062 \pm 0.0$	40	9045	MATTHEWS	95	E773
$2.15 \pm 0.26 \pm 0.2$	20	3671	RAMBERG	93B	E731
$\phi_{+-\gamma}=$ phase	of η_	⊢−γ			
VALUE (°)		EVTS	DOCUMENT ID		TECN
44 ± 4 OUR A	WER/	AGE			
43.8 ± 3.5 ± 1.9		9045	MATTHEWS	95	E773
$72\pm23\pm17$		3671	RAMBERG	93B	E731
$ \epsilon_{+-\gamma}^{\prime} /\epsilon$					
AVALUE.	C10/	EVEC	DOCUMENT ID		TECN

90 3671 ¹³⁴ RAMBERG 93B E731 134 RAMBERG 938 limit on $|\epsilon'|$ $|--\gamma|/\epsilon$ assumes than any difference between η_{+-} and $\eta_{+-\gamma}$ is due to direct CP violation.

$\Delta S = \Delta Q$ IN K^0 DECAYS

< 0.3

The relative amount of $\Delta S \neq \Delta Q$ component present is measured by the parameter x, defined as

$$x = A(\overline{K}^0 \to \pi^- \ell^+ \nu)/A(K^0 \to \pi^- \ell^+ \nu) \ .$$

We list $Re\{x\}$ and $Im\{x\}$ for K_{e3} and $K_{\mu3}$ combined.

$x = A(\overline{K}^0 \rightarrow \pi^- \ell^+ \nu)/A(K^0 \rightarrow \pi^- \ell^+ \nu) = A(\Delta S = -\Delta Q)/A(\Delta S = \Delta Q)$

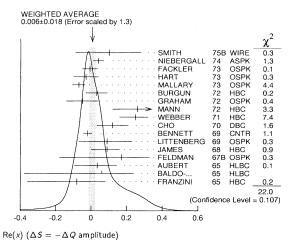
REAL PART OF	EVTS	DOCUMENT ID			COMMENT
0.006±0.018 OU	R AVERAGE	Error includes sca below.	le fa	ctor of 1	3. See the ideogram
$0.10 \begin{array}{c} +0.18 \\ -0.19 \end{array}$	79	SMITH	75 B	WIRE	$\pi^- p \rightarrow \kappa^0 \Lambda$
0.04 ± 0.03	4724	NIEBERGALL	74	ASPK	$K^+ p \rightarrow K^0 p \pi^+$
-0.008 ± 0.044	1757	FACKLER	73	OSPK	Ke3 from K ⁰
-0.03 ± 0.07	1367	HART	73	OSPK	K_{e3} from $K^0 \Lambda$
-0.070 ± 0.036	1079	MALLARY	73	OSPK	K_{e3} from $K^0\Lambda X$
0.03 ± 0.06	410	135 BURGUN	72	HBC	$K^+ p \rightarrow K^0 p \pi^+$
-0.05 ±0.09	442	¹³⁶ GRAHAM	72	OSPK	$\pi^- p \rightarrow \kappa^0 \Lambda$
$0.26 \begin{array}{c} +0.10 \\ -0.14 \end{array}$	126	MANN	72	нвс	$K^- p \rightarrow n \overline{K}^0$
$0.25 \begin{array}{c} +0.07 \\ -0.09 \end{array}$	252	WEBBER	71	нвс	$K^- p \rightarrow n \overline{K}^0$
0.12 ±0.09	215	¹³⁷ CHO	70	DBC	$K^+ d \rightarrow K^0 pp$
-0.020 ± 0.025		138 BENNETT	69	CNTR	Charge asym + Cu regen
$0.09 \begin{array}{c} +0.14 \\ -0.16 \end{array}$	686	LITTENBERG	69	OSPK	$K^+ n \rightarrow K^0 p$
$0.09 \begin{array}{c} +0.07 \\ -0.09 \end{array}$	121	JAMES	68	нвс	$\overline{p}p$
$0.17 \begin{array}{l} +0.16 \\ -0.35 \end{array}$	116	FELDMAN	67B	OSPK	$\pi^- \rho \rightarrow \kappa^0 \Lambda$
$0.035 {}^{+ 0.11}_{- 0.13}$	196	AUBERT	65	HLBC	\mathcal{K}^+ charge exchange
$0.06 \begin{array}{l} +0.18 \\ -0.44 \end{array}$	152	¹³⁹ BALDO	65	HLBC	K^+ charge exchange
$-0.08 \begin{array}{c} +0.16 \\ -0.28 \end{array}$	109	¹⁴⁰ FRANZINI	65	нвс	$\overline{p} p$
We do not us	se the followi	ng data for averages	, fits	, limits,	etc. • • •
$0.04 \begin{array}{c} +0.10 \\ -0.13 \end{array}$	100	¹³⁶ GRAHAM	72	OSPK	$K_{\mu 3}$ from $K^0 \Lambda$
-0.13 ±0.11	342	¹³⁶ MANTSCH	72	OSPK	K_{e3} from $K^0\Lambda$
$0.04 \begin{array}{l} +0.07 \\ -0.08 \end{array}$	222	¹³⁵ BURGUN	71	нвс	$K^+ \rho \rightarrow K^0 \rho \pi^+$
0.03 ± 0.03		¹³⁸ BENNETT	68	CNTR	
	335	137 HILL	67	DBC	$K^+ d \rightarrow K^0 pp$

- 136 First GRAHAM 72 value is second GRAHAM 72 value combined with MANTSCH 72.

 137 CHO 70 is analysis of unambiguous events in new data and HILL 67.

 138 BENNETT 69 is a reanalysis of BENNETT 68.

- 139 BALDO-CEOLIN 65 gives x and θ converted by us to Re(x) and Im(x).
- 140 FRANZINI 65 gives x and θ for Re(x) and Im(x). See SCHMIDT 67.



IMAGINARY PART OF x

Assumes $m_{K_i^0} - m_{K_i^0}$ positive. See Listings above.

	``L ``S			
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
-0.003 ± 0.026	OUR AVERAGE	Error includes sca	le factor of 1	.2.
$-0.10 \begin{array}{l} +0.16 \\ -0.19 \end{array}$	79	SMITH		$\pi^- \rho \rightarrow \kappa^0 \Lambda$
-0.06 ± 0.05	4724	NIEBERGALL	74 ASPK	$K^+ \rho \rightarrow K^0 \rho \pi^+$
-0.017 ± 0.060	1757	FACKLER		K_{e3} from K^0
0.09 ± 0.07	1367	HART	73 OSPK	K_{e3} from $K^0\Lambda$
$0.107 {}^{+ 0.092}_{- 0.074}$	1079	MALLARY	73 OSPK	K_{e3} from $K^0\Lambda X$
$0.07 \begin{array}{l} +0.06 \\ -0.07 \end{array}$	410	¹⁴¹ BURGUN	72 HBC	$\kappa^+ \rho \rightarrow \kappa^0 \rho \pi^+$
0.05 ± 0.13	442	¹⁴² GRAHAM	72 OSPK	$\pi^- p \rightarrow K^0 \Lambda$
$0.21 \begin{array}{c} +0.15 \\ -0.12 \end{array}$	126	MANN	72 HBC	$K^- p \rightarrow n \overline{K}^0$

0.0 ±0.08	252	WEBBER	71 HBC	
-0.08 ± 0.07	215	¹⁴³ CHO	70 DBC	$K^+ d \rightarrow K^0 pp$
$-0.11 \begin{array}{c} +0.10 \\ -0.11 \end{array}$	686	LITTENBERG	69 OSPK	$K^+ n \rightarrow K^0 p$
$+0.22 \begin{array}{c} +0.37 \\ -0.29 \end{array}$	121	JAMES	68 HBC	Īρρ
0.0 ± 0.25	116	FELDMAN	678 OSPK	$\pi^- \rho \rightarrow K^0 \Lambda$
$-0.21 \begin{array}{c} +0.11 \\ -0.15 \end{array}$	196	AUBERT	65 HLBC	\mathcal{K}^+ charge exchange
$-0.44 \begin{array}{c} +0.32 \\ -0.19 \end{array}$	152	¹⁴⁴ BALDO	65 HLBC	\mathcal{K}^+ charge exchange
$+0.24 \begin{array}{l} +0.40 \\ -0.30 \end{array}$	109	¹⁴⁵ FRANZINI	65 HBC	Pρ
\bullet \bullet We do not use	the followi	ng data for averages	, fits, limit	s, etc. • • •
$0.12 \begin{array}{c} +0.17 \\ -0.16 \end{array}$	100	¹⁴² GRAHAM	72 OSPK	$K_{\mu 3}$ from $K^0 \Lambda$
-0.04 ± 0.16	342	¹⁴² MANTSCH	72 OSPK	K_{e3} from $K^0\Lambda$
$0.12 \begin{array}{c} +0.08 \\ -0.09 \end{array}$	222	¹⁴¹ BURGUN	71 HBC	$K^+ \rho \rightarrow K^0 \rho \pi^+$
-0.20 ± 0.10	335	143 HILL	67 DBC	$K^+ d \rightarrow K^0 p p$
141 BURGUN 72 is a 1	inal result	which includes BUF	RGUN 71.	

142 First GRAHAM 72 value is second GRAHAM 72 value combined with MANTSCH 72. 143 Footnote 10 of HILL 67 should read +0.58, not -0.58 (private communication) CHO 70 is analysis of unambiguous events in new data and HILL 67. 144 BALDO-CEOLIN 65 gives x and θ converted by us to Re(x) and Im(x). 145 FOALSTHUR (5) gives +0.58 (c) +0.5

145 FRANZINI 65 gives x and θ for Re(x) and Im(x). See SCHMIDT 67.

CPT-VIOLATION PARAMETERS IN KO DECAY

If $\mathit{CP}\text{-violating}$ interactions include a T conserving part then

$$\begin{split} |\kappa_S\rangle &= [|\kappa_1\rangle + (\epsilon + \Delta)|\kappa_2\rangle]/\sqrt{1 + |\epsilon + \Delta|^2} \\ |\kappa_L\rangle &= [|\kappa_2\rangle + (\epsilon - \Delta)|\kappa_1\rangle]/\sqrt{1 + |\epsilon - \Delta|^2} \\ \text{where} \\ |\kappa_1\rangle &= [|\kappa^0\rangle + |\overline{\kappa}^0\rangle]/\sqrt{2} \\ |\kappa_2\rangle &= [|\kappa^0\rangle - |\overline{\kappa}^0\rangle]/\sqrt{2} \\ \text{and} \\ |\overline{\kappa}^0\rangle &= CP|\kappa^0\rangle. \end{split}$$

The parameter Δ specifies the $\ensuremath{\textit{CPT}}\textsc{-violating}$ part.

Estimates of Δ are given below. See also THOMSON 95 for a test of $\it CPT$ symmetry conservation in $\it K^0$ decays using the Bell-Steinberger relation.

REAL PART OF $\boldsymbol{\Delta}$

A nonzero value violates CPT invariance.

VALUE

VALUE EVTS $O.018 \pm 0.020$.018 $^{146}\,\mathrm{DEMIDOV}$ 95 reanalyzes data from HART 73 and NIEBERGALL 74. IMAGINARY PART OF Δ A nonzero value violates CPT invariance.

<u>VALUE</u> <u>EVTS</u> <u>DOCUMENT ID</u> **0.021±0.037** 6481 ¹⁴⁷ DEMIDOV 9

95 $K_{\ell 3}$ reanalysis $^{147}\,\mathrm{DEMIDOV}$ 95 reanalyzes data from HART 73 and NIEBERGALL 74.

K1 REFERENCES

ETAFIT	00	888	
ETAFIT	96	RPP	- AN - LA - A - A - A - A - A - A - A - A -
ADLER	95	PL B363 237	+Alhalel, Angelopoulos, Apostolakis+ (CPLEAR Collab.)
ADLER	95B	PL B363 243	+Alhalel, Angelopoulos, Apostolakis+ (CPLEAR Collab.)
AKAGI	95	PR D51 2061	+Fukuhisa, Hemmi+ (TOHOK, TOKY, KYOT, KEK)
BARR	95	ZPHY C65 361	+Buchholz+ (CERN, EDIN, MANZ, LALO, PISA, SIEG)
BARR	95C	PL B358 399	+Buchholz+ (CERN, EDIN, MANZ, LALO, PISA, SIEG)
DEMIDOV	95	PAN 58 968	+Gusev, Shabalin (ITEP)
From YAF			
HEINSON	95	PR D51 985	+Horvath, Knibbe, Mathiazhagan+ (BNL E791 Collab.)
KREUTZ	95	ZPHY C65 67	+Holder, Rost+ (SIEG, EDIN, MANZ, ORSAY, PISAI)
MATTHEWS	95	PRL 75 2803	+Gu, Haas, Hogan+ (RUTG, EFI, ELMT, FNAL, ILL)
SCHWINGEN	. 95	PRL 74 4376	Schwingenheuer+ (EFI, CHIC, ELMT, FNAL, ILL, RUTG)
SPENCER	95	PRL 74 3323	+ (UCLA, EFI, COLO, ELMT, FNAL, ILL, OSAK, RUTG)
THOMSON	95	PR D51 1412	+Zou (RUTG)
BARR	94	PL B328 528	+Buchholz+ (CERN, EDIN, MANZ, LALO, PISA, SIEG)
GU	94	PRL 72 3000	+ (RUTG, UCLA, EFI, COLO, ELMT, FNAL, ILL, OSAK)
NAKAYA	94	PRL 73 2169	+ (OSAK, UCLA, EFI, COLU, ELMT, FNAL, ILL, RUTG)
ROBERTS	94	PR D50 1874	+ (UCLA, EFI, COLU, ELMT, FNAL, ILL, OSAK, RUTG)
WEAVER	94	PRL 72 3758	+ (UCLA, EFI, COLU, ELMT, FNAL, ILL, OSAK, RUTG)
AKAGI	93	PR D47 R2644	+Fukuhisa, Hemmi+ (TOHOK, TOKY, KYOT, KEK)
ARISAKA	93	PRL 70 1049	+Auerbach, Axelrod, Belz, Biery+ (BNL E791 Collab.)
ARISAKA	93B	PRL 71 3910	+Auerbach, Axelrod, Belz, Biery+ (BNL E791 Collab.)
BARR	93D	PL B317 233	+Buchholz+ (CERN, EDIN, MANZ, LALO, PISA, SIEG)
GIBBONS	93	PRL 70 1199	+Barker, Briere, Makoff+ (FNAL E731 Collab.)
GIBBONS	93B	PRL 70 1203	+Barker, Briere, Makoff+ (FNAL E731 Collab.)
GIBBONS	93C	Thesis RX-1487	(CHIC)
HARRIS	93	PRL 71 3914	+Briere, Cheu, Makoff, McFarland+ (FNAL E799 Collab.)
HARRIS	93B	PRL 71 3918	+Briere, Cheu, Makoff, McFarlane+ (FNAL E799 Collab.)
MAKOFF	93	PRL 70 1591	+Barker, Briere, Gibbons+ (FNAL E731 Collab.)
Also	95	PRL 75 2069 (erratum	
RAMBERG	93	PRL 70 2525	+Bock, Coleman, Enagonio, Hsiung+ (FNAL E731 Collab.)
RAMBERG	93B	PRL 70 2529	+Bock, Coleman, Enagonio, Hsiung+ (FNAL E731 Collab.)
VAGINS	93	PRL 71 35	+Adair, Greenlee, Kasha, Mannelli+ (BNL E845 Collab.)
ADLER	92B	PL B286 180	+Alhalel, Angelopoulos, Apostolakis+ (CPLEAR Collab.)
Also	92	SJNP 55 840	Adler, Alhalel, Angelopoulos+ (CPLEAR Collab.)
BARR	92	PL B284 440	+Buchholz+ (CERN, EDIN, MANZ, LALO, PISA, SIEG)
GRAHAM	92	PL B295 169	+Barker, Briere, Gibbons, Makoff+ (FNAL E731 Collab.)
MORSE	92	PR D45 36	+Leipuner, Larsen, Jastrzembski+ (BNL, YALE, VASS)
PDG	92		II Hikasa, Barnett, Stone+ (KEK, LBL, BOST+)
SOMALWAR	92	PRL 68 2580	+Barker, Briere, Gibbons+ (FNAL E731 Collab.)
	91	PRL 68 2580 PRL 67 2614	
AKAGI			
AKAGI	91B	PRL 67 2618	+Fukuhisa, Hemmi+ (TOHOK, TOKY, KYOT, KEK)

HEINSON 91	PL B259 389	+Carosi+ (CERN, EDIN, MANZ, LALO, PISA, SIEG) + (UCI, UCLA, LANL, PENN, STAN, TEMP, TEXA+)
PAPADIMITR 91 BARKER 90	PR D44 R1 PR D44 R573 PR D41 3546	Papadimitriou, Barker, Briere+ (FNAL E/31 Collab.)
Also 88 BARR 90B	PRL 61 2661 PL B240 283	+Briere, Gibbons, Makoff+ (FNAL E731 Collab.) Gibbons, Papadimitriou+ (FNAL E731 Collab.) +Carosi+ (CERN, EDIN, MANZ, LALO, PISA, SIEG)
BARR 90C CAROSI 90	PL B242 523 PL B237 303	+Carosi+ +Clarke+ (CERN, EDIN, MANZ, LALO, PISA, SIEG) (CERN, EDIN, MANZ, LALO, PISA, SIEG)
KARLSSON 90 OHL 90	PRL 64 2976 PRL 64 2755	+Gollin, Okamitsu, Tschirhart, Barker+(FNAL E731 Collab.) +Adair, Greenlee, Kasha, Mannelli+ (BNL E845 Collab.)
OHL 90B PATTERSON 90	PRL 65 1407 PRL 64 1491	+Adair, Greenlee, Kasha, Mannelli+ (BNL E845 Collab.) +Barker+ (FNAL E731 Collab.)
INAGAKI 89 LITTENBERG 89	PR D40 1712 PR D39 3322	+Kobayashi, Sato, Shinkawa+ (KEK, TOKY, KYOT) (BNL)
MATHIAZHA 89 MATHIAZHA 89B PAPADIMITR 89	PRL 63 2181 PRL 63 2185 PRL 63 28	Mathiazhagan+ (UCI, UCLA, LANL, PENN, STÀN+) Mathiazhagan+ (UCI, UCLA, LANL, PENN, STAN+) Papadimitriou, Gibbons, Patterson+ (FNAL E731 Collab.)
SCHAFFNER 89 WAHL 89	PR D39 990	+Greenlee, Kasha, Mannelli, Ohl+ (YALE, BNL)
BARR 88 BURKHARDT 88	PL B214 303 PL B206 169	+Clarke+ (CERN, EDIN, MANZ, LALO, PISA, SIEG) +Clarke+ (CERN, EDIN, MANZ, LALO, PISA, SIEG) +Konigsberg+ (UCLA, LASL, PENN, STAN, TEMP, WILL)
COUSINS 88 GREENLEE 88	PR D38 2914 PRL 60 893	+Kasha, Mannelli, Mannelli+ (YALE, BNL)
JASTRZEM 88 WOODS 88 BURKHARDT 87	PRL 61 2300 PRL 60 1695	Jastrzembski, Larsen, Leipuner, Morse+ (BNL, YALE) +Nishikawa, Patterson, Wah, Winstein+(FNAL E731 Collab.)
BURKHARDT 87 ARONSON 86 Also 82	PL B199 139 PR D33 3180 PRL 48 1078	+ (CERN, EDIN, MANZ, LALO, PISA, SIEG) +Bernstein, Bock+ (BNL, CHIC, STAN, WISC) Aronson, Bernstein+ (BNL, CHIC, STAN, WISC)
PDG 86C BERNSTEIN 85B	PL 170B 132 PRL 54 1631	Aguilar-Benitez, Porter+ (CERN, CIT+)
BLACK 85 COUPAL 85	PRL 54 1628 PRL 55 566	+Bock, Carlsmith, Coupal+ (CHIC, SACL) +Blatt, Campbell, Kasha, Mannelli+ +Bernstein, Bock, Carlsmith+ (CHIC, SACL)
BALATS 83	SJNP 38 556 Translated from YAF 3	+Berezin, Bogdanov, Vishnevsky+ (ITEP) 3 927.
BERGSTROM 83 ARONSON 82 ARONSON 82B	PL 131B 229 PRL 48 1078 PRL 48 1306	+Masso, Singer +Bernstein+ (BNL, CHIC, STAN, WISC) +Bock, Cheng, Fischbach (BNL, CHIC, PURD)
Also 82B Also 83	PL 116B 73 PR D28 476	Fischbach, Cheng+ (PURD, BNL, CHIC)
Also 83B PDG 82B	PR D28 495 PL 111B 70	Aronson, Bock, Cheng+ (BNL, CHIC, PURD) Aronson, Bock, Cheng+ (BNL, CHIC, PURD) Roos, Porter, Aguilar-Benitez+ (HELS, CIT, CERN)
BIRULEV 81 Also 80	NP B182 1 SJNP 31 622	+Dzhordzhadze, Genchev, Grigalashvili+ (JINR) Birulev, Vestergombi, Genchev+ (JINR)
CARROLL 80B	Translated from YAF 3 PRL 44 529	1 1204. +Chiang, Kycia, Li, Littenberg, Marx+ (BNL, ROCH)
CARROLL 80C CARROLL 80D CHO 80	PL 96B 407 PRL 44 525	+Chiang, Kycia, Li, Littenberg, Marx+ (BNL, ROCH)
CHO 80 MORSE 80 BIRULEV 79	PR D22 2688 PR D21 1750 SJNP 29 778	+Derrick, Miller, Schlereth, Engler+ +Leipuner, Larsen, Schmidt, Blatt+ +Vestergombi, Gvakhariya, Genchev+ (JINR)
CHRISTENS 79	Translated from YAF 2' PRL 43 1209	9 1516. Christenson, Goldman, Hummel, Roth+ (NYU)
CHRISTENS 79B HILL 79	PRL 43 1212 NP B153 39	Christenson, Goldman, Hummel, Roth+ (NYU) +Sakitt, Snape, Stevens+ (BNL, SLAC, SBER)
SCHMIDT 79 SHOCHET 79	PRL 43 556 PR D19 1965	+Blatt, Campbell, Grannan+ (YALE, BNL) +Linsay, Grosso-Pilcher, Frisch+ (EFI, ANL)
Also 77 ENGLER 78B	PRL 39 59 PR D18 623	Shochet, Linsay, Grosso-Pilcher+ (EFI, ANL) +Keyes, Kraemer, Tanaka, Cho+ (CMU, ANL)
HILL 78 CHO 77	PL 73B 483 PR D15 587	+Sakitt, Snape, Stevens+ +Derrick, Lissauer, Miller, Engler+ (ANL, CMU)
CLARK 77 Also 75 DEVOE 77	PR D15 553 Thesis LBL-4275 PR D16 565	+Field, Holley, Johnson, Kerth, Sah, Shen (LBL) Shen +Cronin, Frisch, Grosso-Pilcher+ (EFI, ANL)
DZHORD 77	SJNP 26 478 Translated from YAF 2	Dzhordzhadze, Kekelidze, Krivokhizhin+ (JINR) 6 910.
PEACH 77 BIRULEV 76	NP B127 399	+Cameron+ (BGNA, EDIN, GLAS, PISA, RHEL)
	SJNP 24 178	+Vestergombi, Vovenko, Votruba+ (JINR)
COOMBES 76 DONALDSON 76	Translated from YAF 2- PRL 37 249	4 340. +Flexer, Hall, Kennelly, Kirkby+ (STAN, NYU)
COOMBES 76 DONALDSON 76 Also 74 FUKUSHIMA 76	Translated from YAF 2-	4 340. +Flexer, Hall, Kennelly, Kirkby+ (STAN, NYU) +Hitlin, Kennelly, Kirkby, Liu+ (SLAC) Donaldson (SLAC)
DONALDSON 76 Also 74 FUKUSHIMA 76 GJESDAL 76 REY 76	Translated from YAF 2- PRL 37 249 PR D14 2839 Thesis SLAC-0184 PRL 36 348 NP B109 118 PR D13 1161	4 340. + Flexer, Hall, Kennelly, Kirkby+ (STAN, NYU) + Hitlin, Kennelly, Kirkby, Liu+ (SLAC) Donaldson (SLAC) + Jensen, Surko, Thaler+ (PRIN, MASA) + Kamae, Presser, Steffen+ (CERN, HEIDH) + Cence, Jones, Parker+ (NDAM, HAWA, LBL)
DONALDSON 76 Also 74 FUKUSHIMA 76 GJESDAL 76 REY 76 Also 69 BALDO 75	Translated from YAF 2- PRL 37 249 PR D14 2839 Thesis SLAC-0184 PRL 36 348 NP B109 118 PR D13 1161 PRL 22 1210 NC 25A 688	4 340. +Flexer, Hall, Kennelly, Kirkby+ +Hittin, Kennelly, Kirkby, Liu+ Donaldson Donaldson (Flox, Marchaeler) - Hamae, Preser, Steffen+ - Ceren, Jones, Parker+ - Cence, Parker+
DONALDSON 76 Also 74 FUKUSHIMA 76 GJESDAL 76 REY 76 Also 69 BALDO 75 BLUMENTHAL 75 BUCHANAN 75	Translated from YAF 2- PRL 37 249 PR D14 2839 Thesis SLAC-0184 PRL 36 388 NP B109 118 PR D13 1161 PRL 22 1210 NC 25A 688 PRL 34 164 PR D11 457	4 340. +Flexer, Hall, Kennelly, Kirkby+ +Hittin, Kennelly, Kirkby, Liu+ Donaldson Donaldson (Flox, Marchaeler) - Hamae, Preser, Steffen+ - Ceren, Jones, Parker+ - Cence, Parker+
DONALDSON 76 Also 74 FUKUSHIMA 76 GJESDAL 76 REY 76 Also 69 BALDO 75 BLUMENTHAL 75 BUCHANAN 75 CARITHERS 75 SMITH 758	Translated from YAF 2- PRL 37 249 PR D14 2839 Thesis SLAC-0184 PRL 36 348 NP B109 118 NP B109 118 NC 25A 668 PRL 34 164 PR D11 457 PRL 34 1244 Thesis UCSD unpub.	4 340. + Flexer, Hall, Kennelly, Kirkby+
DONALDSON 76 Also 74 FUKUSHIMA 76 GJESDAL 76 REY 76 Also 69 BALDO 75 BLUMENTHAL 75 BUCHANAN 75 CARITHERS 75 SMITH 758 ALBRECHT 74 BISI 74	Translated from YAF 2: PRI. 37 249 PR D14 2839 PR D13 1151 PRI. 22 1210 PRI. 22 1210 PRI. 24 164 PR D13 1151 PR D13 1151 PR D13 1154 PR D13 1154 PR D14 164 PR D15 PR D1 165	4 340. + Flexer, Hall, Kennelly, Kirkby+
DONALDSON 76 Also 74 FUKUSHIMA 76 GJESDAL 76 REY 16 Also 69 BALDO 75 BLUMENTHAL 75 BUCHANAN 75 CARITHERS 75 ALBRECHT 74 DONALDSON 74 Also 76	Translated from YAF 2: PRI. 37 249 PR D14 2839 PR D18 PR D13 1151 PRI. 22 1210 PRI. 25 4 688 PRI. 34 164 PR D14 1457 PRI. 34 1244 PRI. 25 PR D11 457 PRI. 34 1244 PRI. 25 PRI. 36 125 PRI.	4 340. 4 340. 4 Flexer, Hall, Kennelly, Kirkby+ 4 Hittin, Kennelly, Kirkby, Liu+ Donaldson 5 LAC Donaldson CERN, Hellow (PRN, MASA) (HAWA, LRI) (PADO, WISC) (PADO, WISC) (PENN, CHIC, TEMP) (PADO, WISC) (LOU, NYU) (COLU, NYU)
DONALDSON 76 FUKUSHIMA 76 FUKUSHIMA 76 FUKUSHIMA 76 FUKUSHIMA 75 FUKUSHIMA 75 FUKUSHIMA 75 FUKUSHIMA 76 FUKUSHIMA 76 FUKUSHIMA 78 FUKUSHIMA 78 FUKUSHIMA 78 78 78 78 78 78 78 7	Translated from YAF 2: PRI. 37 249 PR D14 2839 PR D14 284 164 PR D15 285 PR D15 285 PR D17 285 PR D18 2839 PR D18 2839 PR D19 2990 PR D18 2839 PR D19 2990 PR D18 337 PR D14 2839 PR D19 2990 PRI. 31 337	4 340. 4 340. 4 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
DONALDSON 76 FURUSHIMA 76 FURUSHIMA 76 FURUSHIMA 76 FURUSHIMA 76 FURUSHIMA 76 FURUSHIMA 75 FURUSHIMA 75 FURUSHIMA 76 FURU	Translated from YAF 2-PRI. 37 249 PR D14 2839 PR D19 118 PR D13 1161 PRI. 22 1210 NC 25A 688 PRI. 34 164 PR D11 457 PRI. 34 1244 Thesis UCSD unpub. PI. 48B 393 PI. 50B 504 Thesis SLAC-014 PR D14 2839 PR D2 9960 PRI. 31 337 PRI. 33 554 Thesis SLAC-0184 PR D14 2839	4 340. 4 340. 4 540. 4 Flexer, Hall, Kennelly, Kirkby + Hitlin, Kennelly, Kirkby, Liu + (SLAC) Donaldson (SLAC) Donaldson, Hitlin, Kennelly, Kirkby, Liu + (SLAC) Colonaldson, Hitlin, Kennelly, Kirkby, Liu + (SLAC) Colonaldson, Hitlin, Kennelly, Kirkby, Liu + (SLAC) Donaldson, Hitlin, Kennelly, Kirkby, Liu + (SLAC)
DONALDSON 76 FIELD 74 74 74 75 76 76 76 76 76 76 76	Translated from YAF 2-PRI. 37 249 PR D14 2839 PR D14 2839 PR D14 2839 PR D14 2839 PR D18 3 348 PR D18 118 PR D13 1161 PRI. 22 1210 NC 25A 688 PRI. 34 164 PR D11 457 PRI. 34 1244 Thesis UCSD unpub. PI. 488 393 PL 50B 504 Thesis SLAC-014 PR D14 2839 PR D2 9260 PRI. 31 337 PRI. 33 554 Thesis SLAC-0184 PR D14 2839 SLAC-PUB-1498 unpub PI. 4239 SLAC-PUB-1498 unpub	4 340. 4 340. 4 340. 4 Heixer, Hall, Kennelly, Kirkby, Liu+ Conaldson Cence, Jones, Parker+ Cence, Jones, Peterson, Stenger+ Baido-Ceolin, Bobisut, Calimani+ Frankel, Nagy+ Drickey, Pepper, Rudnick+ Hodds, Nygren, Pun+ Columber, Peterson (JINR, BERL, BUDA, PRAG, SERP, SOFT) Ferrero (JINR, BERL, BUDA, PRAG, SERP, SOFT) Ferrere (SLAC, UCSC) Donaldson, Hitlin, Kennelly, Kirkby, Liu+ Fytyberger, Hitlin, Liu+ Donaldson, Hitlin, Kennelly, Kirkby, Liu+ CILAC, UCSC, Donaldson, Hitlin, Kennelly, Kirkby, Liu+ CILAC, UCSC, Donaldson, Hitlin, Kennelly, Kirkby, Liu+ (SLAC, UCSC, SLAC, JUSC) Donaldson, Hitlin, Kennelly, Kirkby, Liu+ (SLAC, UCSC, SLAC, JUSC) Donaldson, Hitlin, Kennelly, Kirkby, Liu+ (SLAC, UCSC, SLAC, JUSC) CILAC, UCSC, SLAC, JUSC, SLAC, J
DONALDSON 76 FIELD 74 76 76 76 76 76 76 76	Translated from YAF 2-PRI. 37 249 PR D14 2839 PR D14 2839 PR D14 2839 PR D14 2839 PR D18 3 348 PR D18 118 PR D13 1161 PRI. 22 1210 NC 25A 688 PRI. 34 164 PR D11 457 PRI. 34 1244 Thesis UCSD unpub. PI. 488 393 PL 50B 504 Thesis SLAC-0184 PR D14 2839 PR D9 2960 PRI. 31 337 PR D9 2960 PRI. 31 337 PR D14 2839 SLAC-PUB-1498 unpub PR D14 2839 SLAC-PUB-1498 unpub PI. 488 483 Thesis CERN Int. 74-4 PI. 488 487 Thesis SLAC-1184 Thesis SL	4 340. 4 340. 4 340. 4 Heixer, Hall, Kennelly, Kirkby + Heixer, Hall, Kennelly, Kirkby, Liu + (SLAC) Donaldson 5 Cence, Jones, Parker + (CERN, HEID) 6 Cence, Jones, Peterson, Stenger + Baido-Ceolin, Bobisut, Calimani + Frankel, Nagy + Horickey, Pepper, Rudnick + (PADO, WISC) 6 Link Berll, Budba, Paragon, Pun + (COLU, NY, COLU, NY, NY, COLU, NY, NY, COLU, NY, NY, COLU, NY, NY, NY, NY, NY, NY, NY, NY, NY, NY
DONALDSON 76 FIELD 74 76 76 76 76 76 76 76	Translated from YAF 2-PRL 37 249 PR D14 2839 PR D19 118 PR D13 1161 PRL 22 1210 NC 25A 688 PRL 34 164 PR D11 457 PRL 34 1244 Thesis UCSD unpub. PL 48B 393 PL 50B 504 Thesis SLAC-0184 PR D14 2839 PR D9 2960 PRL 31 337 PR D9 2960 PRL 31 337 PR D14 2839 SLAC-PUB-1498 unpub PL 48B 483 Thesis CERN Int. 74-4 PL 489 37 PL 489 A39 Thesis CERN Int. 74-4 PL 489 L489 A39 Thesis CERN Int. 74-4 PL 489 B119 PL 48B 483 Thesis CERN Int. 74-4 PL 52B 119 PL 52B 119	4 340. 4 340. 4 340. 4 Heixer, Hall, Kennelly, Kirkby, Liu+ Conaldson Cenec, Jones, Parker+ Cenec, Jones, Peterson, Stenger+ Baido-Ceolin, Bobisut, Calimani+ Frankel, Nagy+ Drickey, Pepper, Rudnick+ Hodds, Nygren, Pun+ Coll, Nagy- Hoddson, Hitlin, Kennelly, Kirkby, Liu+ Fryberger, Hitlin, Liu+ Fryberger, Hitlin, Liu+ Hitlin, Kennelly, Kirkby, Liu+ Conaldson, Hitlin, Kennelly, Kirkby, Liu+ Hitlin, Kennelly, Kirkby, Liu+ Conaldson, Hitlin, Kennelly, Kirkby, Liu+ Conaldson Conaldson, Hitlin, Kennelly, Kirkby, Liu+ Conaldson Co
DONALDSON 76 FIELD 74 76 76 76 76 76 76 76	Translated from YAF 2-PRL 37 249 PR D14 2839 PR D18 31 161 PR D13 1161 PR D13 1161 PR D13 1161 PR D13 1164 PR D11 457 PRL 34 1247 PRL 34 1257 PRL 35 1547 PRL 36 1257 PRL 37 157 PRL 37 157 PRL 38 158 PR D9 1258 PR	4 340. 4 340. 4 340. 4 Heixer, Hall, Kennelly, Kirkby, Liu+ Conaldson Cence, Jones, Parker+ Cence, Jones, Peterson, Stenger+ Baido-Ceolin, Bobisut, Calimani+ Frankel, Magy + Drickey, Pepper, Rudnick+ Hodds, Nygren, Pun+ Coll, Donaldson, Hitlin, Kennelly, Kirkby, Liu+ Fryberger, Hitlin, Liu+ Hitlin, Kennelly, Kirkby, Liu+ Conaldson, Hitlin, Kennelly, Kirkby, Liu+ Hitlin, Kennelly, Kirkby, Liu+ Cislac, USCS Donaldson, Hitlin, Kennelly, Kirkby, Liu+ Glack, USCS Conaldson, Hitlin, Kennelly, Kirkby, Liu+ Glack, USCS Glack, USCS Conaldson, Hitlin, Kennelly, Kirkby, Liu+ Glack, USCS Glack Glac
DONALDSON 76 FURUSHIMA 76 FURUSHIMA 76 FURUSHIMA 76 FURUSHIMA 76 FURUSHIMA 75 FURUSHIMA 75 FURUSHIMA 75 FURUSHIMA 76 FURU	Translated from YAF 2-PRI. 37 249 PR D14 2839 PR D19 118 PR D13 1161 PRI. 22 1210 NC 25A 688 PRI. 34 164 PR D11 457 PRI. 34 1244 Thesis UCSD unpub. PI. 488 393 PI. 50B 504 Thesis SLAC-0184 PR D14 2839 PR D9 2960 PRI. 31 337 PRI. 33 554 Thesis SLAC-0184 PR D14 2839 SLAC-PUB-1498 unpub PI. 33 554 Thesis SLAC-0184 PR D14 2839 SLAC-PUB-1498 unpub PI. 488 483 Thesis CERN Int. 74-4 PI. 458 B119 PI. 488 487 PI. 52B 119 PI. 489 103 PRI. 33 1458 PI. 498 103 PRI. 33 1458 PI. 498 103	4 340. 4 340. 4 340. 4 Heiter, Hall, Kennelly, Kirkby, Liu+
DONALDSON 76 FILD 74 FILD 76	Translated from YAF 2-PRI. 37 249 PR D14 2839 PR D19 118 PR D13 1161 PRI. 22 1210 NC 25A 688 PRI. 34 164 PR D11 457 PRI. 34 1244 Thesis UCSD unpub. PI. 488 393 PI. 508 504 Thesis SLAC-014 PR D14 2839 PR D19 2960 PRI. 31 337 PRI. 33 554 Thesis SLAC-0184 PR D14 2839 SLAC-PUB-1498 unpub PI. 488 483 Thesis CERN Int. 74-4 PI. 488 487 PI. 488 487 PI. 488 487 PI. 488 487 PI. 488 193 Thesis CERN Int. 74-4 PI. 488 487 PI. 488 193 PI. 488 193 PRI. 33 1458 PI. 498 103 PRI. 33 1458 PI. 498 103 PRI. 33 1458 PI. 33 340 PRI. 33 340 PRI. 33 340 PRI. 33 340 PRI. 53 3 240 PRI. 53 22	4 340. 4 340. 4 340. 4 Heixer, Hall, Kennelly, Kirkby, Liu+ Conaldson Cenec, Jones, Parker+ Cenec, Jones, Peterson, Stenger+ Baido-Ceolin, Bobisut, Calimani+ Prankel, Nagy+ Drickey, Pepper, Rudnick+ Hodds, Nygren, Pun+ Coll, Nagy+
DONALDSON 76 FURUSHIMA 76 FURUSHIMA 76 FURUSHIMA 76 FURUSHIMA 76 FURUSHIMA 75 FURUSHIMA 75 FURUSHIMA 75 FURUSHIMA 76 FURU	Translated from YAF 2-PRI. 37 249 PR D14 2839 PR D13 1161 PR D13 1164 PR D11 457 PRI. 34 164 PR D11 457 PRI. 34 164 PR D14 2839 PL 50B 504 PR D14 2839 PR D3 390 PR D3 300	4 340. 4 340. 4 340. 4 Heixer, Hall, Kennelly, Kirkby + Hitlin, Kennelly, Kirkby, Liu+ (SLAC) Donaldson 5 Cence, Jones, Patrker+ (CERN, HEIDH) 4 Cence, Jones, Peterson, Stenger+ (Baddo-Ceolin, Bobisut, Calimani+ (PADO, WISC) 4 Frankel, Nagy+ (PENN, CHIC, LINE) 4 Hodis, Nygren, Pun+ (CULA, SLAC, JINU) 4 Hodis, Nygren, Pun+ (CULA, SLAC, JINU) 5 Conaldson, Hitlin, Kennelly, Kirkby, Liu+ (SLAC, LISC) 5 Children, Fryberger, Hitlin, Liu+ (SLAC, LISC) 6 Children, Fryberger, Hitlin, Liu+ (SLAC, LISC) 6 Children, Fryberger, Hitlin, Liu+ (SLAC, LISC) 6 Children, Fryberger, Hitlin, Liu+ (SLAC, LISC) 7 Conaldson, Hitlin, Kennelly, Kirkby, Liu+ (SLAC, LISC) 7 Conaldson, Hitlin, Kennelly, Kirkby, Liu+ (SLAC, LISC) 8 Challen, Fryberger, Hitlin, Liu+ (SLAC, LISC) 9 CHALLEN, Liuh 1 CERN, HEIDH 1 CHALLEN, LIUH 1 CH
DONALDSON 74	Translated from YAF 2-PRI. 37 249 PR D14 2839 PR D18 3 348 PR D13 1161 PRI. 22 1210 NC 25A 688 PRI. 34 164 PR D11 457 PRI. 34 1244 Thesis UCSD unpub. PI. 488 393 PL 508 504 Thesis SLAC-014 PR D14 2839 PR D2 2960 PRI. 31 337 PRI. 33 554 Thesis SLAC-0184 PR D14 2839 SLAC-PUB-1498 unpub PI. 488 PR D14 2839 SLAC-PUB-1498 unpub PI. 488 PI. 528 PI. 99 PI. 33 240 PRI. 33 1458 PI. 498 PI. 33 340 PRI. 33 1458 PI. 498 PI. 586 PI. 596 PI. 596 PI. 597 PI. 598 PI	4 340. 4 340. 4 340. 4 Heixer, Hall, Kennelly, Kirkby, Liu+
DONALDSON 74	Translated from YAF 2-PRI. 37 249 PR D14 2839 PR D13 1161 PRI. 22 1210 NC 25A 688 PRI. 34 164 PR D11 457 PRI. 34 1244 Thesis UCSD unpub. PI. 48B 393 PL 50B 504 Thesis SLAC-0184 PR D14 2839 PR D3 2960 PRI. 31 337 PRI. 33 524 Thesis SLAC-184 PR D14 2839 SLAC-PUB-1499 unpub PI. 33 547 PR D14 2839 Thesis CERN Int. 74-4 PL 52B 119 PL 48B 487 PL 48B 487 PL 48B 119 PL 48B 487 PL 52B 119 PL 48B 539 PR D3 1978 PRI. 31 1025 PRI. 30 1336 PRI. 30 1336 PRI. 30 1336 PRI. 31 1025 PRI. 30 1336 PRI. 30 1336 PRI. 30 1336	4 340. 4 340. 4 340. 4 Heiter, Hall, Kennelly, Kirkby, Liu+ (SLAC) Donaldson Kamae, Presser, Steffen+ (CERN, HEIDH) Ferrero Gondon, Bobisut, Calimani+ Frankel, Nagy+ Horkey, Pepper, Rudnick+ Horkey, Pepper, Rudnick+ Horkey, Pepper, Rudnick+ Fryberger, Hitlin, Liu+ Fryberger, Hitlin, Liu+ Fryberger, Hitlin, Liu+ Hitlin, Kennelly, Kirkby, Liu+ Glesdal, Presser, Steffen+ Luth Glesdal, Presser, Steffen+ Glesdal, Presser, Kamae, Cantellon, Glesdal,
DONALDSON 74	Translated from YAF 2-PRI. 37 249 PR D14 2839 PR D13 1161 PRI. 22 1210 NC 25A 688 PRI. 34 164 PR D11 457 PRI. 34 1244 Thesis UCSD unpub. PI. 48B 393 PL 50B 504 Thesis SLAC-0184 PR D14 2839 PR D39 2950 PRI. 31 357 PRI. 33 554 PR D14 2839 SLAC-PRI. 38 554 PR D14 2839 SLAC-PRI. 38 554 PR D14 2839 PR D39 285 SLAC-PRI. 38 554 PR D14 2839 PR D39 285 SLAC-PRI. 38 554 PR D14 2839 PR D39 295 PR D39 295 PR D39 295 PR D39 295 PR D39 540 PRI. 33 1458 PRI. 39 103 PRI. 39 540 PRI. 38 22 PRI. 38 103 PRI. 39 540 PRI. 39 540 PRI. 39 540 PRI. 39 103 PR	4 340. 4 340. 4 340. 4 Heiter, Hall, Kennelly, Kirkby, Liu+ Conaldson Cenec, Jones, Parker+ Cence, Jones, Peterson, Stenger+ Baido-Ceolin, Bobisut, Calimani+ Frankel, Nagy+ Horkey, Pepper, Rudnick+ Horkey, Pepper, Rudnick+ Coll, Nygren, Pun+ Coll, Richer, Coll, Richer, Coll, Richer, Coll, C
DONALDSON 74	Translated from YAF 2-PRI. 37 249 PR D14 2839 PR D13 1161 PRI. 22 1210 NC 25A 688 PRI. 34 164 PR D11 457 PRI. 34 1244 Thesis UCSD unpub. PI. 48B 393 PI. 50B 504 Thesis SLAC-0184 PR D14 2839 PR D3 2950 PRI. 31 357 PRI. 35 55A Thesis SLAC-0184 PR D14 2839 PR D3 2950 PRI. 31 357 PRI. 35 55A Thesis SLAC-0184 PR D14 2839 PRI. 38 55B PI. 49B 487 PRI. 38 158 PI. 49B 193 PI. 52B 108 PI. 52B 108 PI. 52B 108 PI. 52B 113 PRI. 33 1458 PI. 49B 103 PRI. 33 1458 PI. 49B 103 PRI. 33 1458 PI. 52B 108 PI. 52B 108 PI. 52B 108 PI. 52B 103 PI. 52B 103 PRI. 33 1458 PRI. 33 1458 PRI. 33 1458 PRI. 33 1458 PRI. 39 103 PRI. 39 540 PRI. 39 540 PRI. 39 540 PRI. 39 103 PRI. 39 103 PRI. 39 103 PRI. 30 1336 PRI. 30 1336 PRI. 30 1336 PRI. 30 1336 PRI. 31 1025 PRI. 31 1025 PRI. 31 1025 PRI. 31 1025 PRI. 31 11524 PRI. 31 1524 PRI. 548 PRI. 548 PRI. 31 1524 PRI. 548 PRI. 54	4 340. 4 340. 4 340. 4 Heixer, Hall, Kennelly, Kirkby + Hitlin, Kennelly, Kirkby, Liu + (SLAC) Donaldson, Feterson, Stenger + Baido-Ceolin, Bobistt, Calimani + Frankel, Mag, Horrowski, Perser, Steffen + (NDAM, HAWA, LBL) Baido-Ceolin, Bobistt, Calimani + Prankel, Mag, Horrowski, Mag, Horrowsk
DONALDSON 74	Translated from YAF 2-PRI. 37 249 PR D14 2839 PR D13 1161 PRI. 22 1210 NC 25A 688 PRI. 33 164 PR D13 1161 PRI. 34 1244 PR D11 457 PRI. 34 1244 PR D11 457 PRI. 34 1254 PR D14 2839 PR D9 2960 PRI. 31 337 PR D9 2960 PRI. 31 337 PRI. 35 544 PR D14 2839 SIAC-PUB-1498 unpub PI. 488 483 Thesis CERN Int. 74-4 PR D14 2839 SIAC-PUB-1498 unpub PI. 488 483 PR D14 2839 SIAC-PUB-1498 unpub PI. 488 483 PR D14 2839 PR D14 2839 PR D14 488 483 PR D14 2839 PR D14 2839 PR D14 488 483 PR D14 2839 PR D14 488 483 PR D14 288 103 PR D14 288 103 PR D15 288 113 PRI. 33 1458 PI. 498 103 PRI. 33 1458 PI. 498 103 PRI. 33 1458 PI. 498 103 PRI. 33 1458 PRI. 31 1025 PRI. 31 1027 PRI. 31 1347 PRI. 31 1524 PRI.	4 340. 4 340. 4 340. 4 Heiter, Hall, Kennelly, Kirkby, Liu+ (SLAC) Donaldson 5 Hesser, Surko, Thaler+ 4 Cence, Jones, Parker+ Cence, Jones, Peterson, Stenger+ Baido-Ceolin, Bobisut, Calimani+ Frankel, Nagy+ Drickey, Pepper, Rudnick+ Hodds, Nygren, Pun+ Condidation 6 JINR, BERL, BUDA. PRAG, SERP, SOFT, Ferrero Coll, Nyster, Punk, Liu+ Fryberger, Hitlin, Liu+ Fryberger, Hitlin, Liu+ Hitlin, Kennelly, Kirkby, Liu+ Cisca, Donaldson, Fryberger, Hitlin, Liu+ Cisca, Donaldson, Hitlin, Kennelly, Kirkby, Liu+ Fryberger, Hitlin, Liu+ Cisca, USSC Donaldson, Hitlin, Kennelly, Kirkby, Liu+ Fryberger, Hitlin, Liu+ Cisca, USSC Donaldson, Hitlin, Kennelly, Kirkby, Liu+ Fryberger, Hitlin, Liu+ Cisca, USSC Donaldson, Hitlin, Kennelly, Kirkby, Liu+ Cisca, Presser, Hitlin, Kennelly, Kirkby, Liu+ Ciscal, Presser, Steffen+ Ciscal, Presser, Steffen+ Ciscal, Presser, Karnae, Steffen+ Ciscal, Presser,
DONALDSON 74 FURUSHIMA 76 FURUSHIMA 76 FURUSHIMA 76 FURUSHIMA 76 FURUSHIMA 75 FURUSHIMA 75 FURUSHIMA 75 FURUSHIMA 76 FURU	Translated from YAF 2-PRI. 37 249 PR D14 2839 PR D13 1161 PRI. 22 1210 NC 25A 688 PRI. 34 164 PR D11 457 PRI. 34 164 PR D11 457 PRI. 34 1244 Thesis UCSD unpub. PI. 488 393 PL 508 504 Thesis SLAC-014 PR D14 2839 PR D2 9260 PRI. 31 337 PRI. 33 554 Thesis SLAC-0184 PR D14 2839 SLAC-PUB-1498 unpub PI. 33 554 Thesis SLAC-0184 PR D14 2839 SLAC-PUB-1498 unpub PI. 33 547 PR D1 488 487 PR D14 2839 SLAC-PUB-1498 unpub PI. 488 487 PI. 528 113 PRI. 33 1458 PI. 498 103 PRI. 33 1458 PI. 498 103 PRI. 33 1458 PI. 498 103 PRI. 31 1025 PRI. 31 1027 PRI. 31 524 PRI. 31 687 PRI. 32 51214	4 340. 4 340. 4 340. 4 Heiter, Hall, Kennelly, Kirkby + Hitlin, Kennelly, Kirkby + Liu + CSLAC, Donaldson, Feterson, Stenger + Baido-Ceolin, Bobisut, Calimani + Frankel, Magy + Horkey, Pepper, Rudinck + Collub, Magy + Horkey, Pepper, Rudinck + Collub, Magy + Horkey, Pepper, Rudinck + Collub, Magy + Col
DONALDSON 76 FURUARION 76 FURU	Translated from YAF 2 PRI. 37 249 PR D14 2839 PR D15 285 PR D16 285 PR D17 285 PR D17 285 PR D18 285 PR D18 285 PR D19 285	4 340. 4 340. 4 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
DONALDSON 74	Translated from YAF 2-PRI. 37 249 PR D14 2839 PR D13 1161 PR D13 1164 PR D14 1274 PR D14 2839 PR D9 2960 PR D14 2839 PR D9 2960 PR D14 2839 PR D14 2839 PR D17 287 PR D18 137 PR D18 137 PR D18 1498 PR D18 1498 PR D18 1498 PR D18 158 PR D18 158 PR D18 158 PR D18 158 PR D18 159 PR D18 103 PR D3 103 PR D9 540 PR D18 103 PR D3 1078 PR D7 367 PR D3 1174 PR D1 1572	4 340. 4 340. 4 340. 4 Helixer, Hall, Kennelly, Kirkby, Liu+
DONALDSON 74	Translated from YAF 2-PRI. 37 249 PR D14 2839 PR D34 284 PR D34 284 PR D35 284 PR D35 285 PR D37 285 PR D37 285 PR D37 285 PR D37 285 PR D3 137 PR D57 285 PR D3 137 PR D57 285 PR D57	4 340. 4 340. 4 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1

ALBROW 72 ASHFORD 72	NP B44 1 PL 38B 47	+Aston, Barber, Bird, Ellison+ +Brown, Masek, Maung, Miller, Ruderman+	(UCSD)	KUNZ BENNETT	68 67	Thesis PU-68-46 PRL 19 993	+Nygren, Saal, Steinberger+ (COLU)
BANNER 72	PRL 28 1597	+Cronin, Hoffman, Knapp, Shochet	(PRIN)	BOTT	67	PL 24B 194	Bott-Bodenhausen, DeBouard, Cassel+ (CERN)
BANNER 721 BARMIN 72	3 PRL 29 237 SJNP 15 636	+Cronin, Hoffman, Knapp, Shochet +Davidenko, Demidov, Dolgolenko+	(PRIN) (ITEP)	BOTT Also	67B 66B	PL 24B 438 PL 20 212	Bott-Bodenhausen, Debouard, Dekkers+ (CERN) Bott-Bodenhausen, Debouard, Cassel+ (CERN)
	Translated from YAF 1	.5 1149.		Also	66	PL 23 277	Bott-Bodenhausen, DeBouard, Cassel+ (CERN)
BARMIN 721	3 SJNP 15 638 Translated from YAF 1	+Barylov, Davidenko, Demidov+ .5 1152.	(ITEP)	CRONIN Also	67 68	PRL 18 25 Thesis unpub.	+Kunz, Risk, Wheeler (PRIN) Wheeler (PRIN)
BURGUN 72 CARNEGIE 72	NP B50 194 PR D6 2335	+Lesquoy, Muller, Pauli+ (SACL, CERN,	OSLO) (PRIN)	CRONIN	67B	Princeton 11/67	+Kunz, Risk, Wheeler (PRIN)
CARNEGIE 72 DALLY 72	PL 41B 647	+Cester, Fitch, Strovink, Sulak +Innocenti, Seppi+ (SLAC, JHU,		DEBOUARD	67	NC 52A 662 PL 15 58	+Dekkers, Jordan, Mermod+ (CERN) DeBouard, Dekkers, Scharff+ (CERN, ORSAY, MPIM)
Also 70	PL 33B 627	Chien, Cox. Ettlinger+ (JHU, SLAC,	UCLA)	Also DEVLIN	65 67	PRL 18 54	DeBouard, Dekkers, Scharff+ (CERN, ORSAY, MPIM) +Solomon, Shepard, Beall+ (PRIN, UMD)
Also 71 GRAHAM 72	PL 35B 261 NC 9A 166	Chien, Cox, Ettlinger+ (JHU, SLAC, +Abashian, Jones, Mantsch, Orr+ (ILL,	NEAS)	Also	68	PR 169 1045	Sayer, Beall, Devlin, Shephard+ (UMD, PPA, PRIN)
HOLDER 72	PL 40B 141	+Radermacher, Staude+ (AACH, CERN	, TORI)	DORFAN FELDMAN	67 67B	PRL 19 987 PR 155 1611	+Enstrom, Raymond, Schwartz+ (SLAC, LRL) +Frankel, Highland, Sloan (PENN)
JAMES 72 KRENZ 72	NP B49 1 LNC 4 213	+Montanet, Paul, Saetre+ (CERN, SACL, +Hopkins, Evans, Muir, Peach (AACH, CERN	OSLO)	FIRESTONE	67	PRL 18 176	+Kim, Lach, Sandweiss+ (YALE, BNL)
MANN 72	PR D6 137	+Kofler, Meisner, Hertzbach+ (MASA, BNL	, YALE)	FITCH GINSBERG	67 67	PR 164 1711 PR 162 1570	+Roth, Russ, Vernon (PRIN) (MASB)
MANTSCH 72	NC 9A 160		NEAS)	HAWKINS	67	PR 156 1444	`(YALE)
MCCARTHY 72 METCALF 72	PL 42B 291 PL 40B 703	+Brewer, Budnitz, Entis, Graven+ +Neuhofer, Niebergall+ (CERN, IPN,	(LBL) WIEN)	HILL HOPKINS	67 67	PRL 19 668 PRL 19 185	+Luers, Robinson, Sakitt+ (BNL, CMU)
NEUHOFER 72	PL 41B 642	+Niebergall, Regler, Stier+ (CERN, ORSAY	, VIEN)	KADYK	67	PRL 19 185 PRL 19 597	+Bacon, Eisler (BNL) +Chan, Drijard, Oren, Sheldon (LRL)
PICCIONI 72 Also 74	PRL 29 1412 PR D9 2939	+Coombes, Donaldson, Dorfan, Fryberger+ Piccioni, Donaldson+ (SLAC, UCSC,	(SLAC)	KULYUKINA	67	Preprint	+Mestvirishvili, Nyagu+ (JINR)
VOSBURGH 72	PR D6 1834	+Devlin, Esterling, Goz, Bryman+ (RUTG,	MASA)	LOWYS MISCHKE	67 67	PL 24B 75 PRL 18 138	+Aubert, Chounet, Pascaud+ (EPOL, ORSAY) +Abashian, Abrams+ (ILL)
Also 71 BALATS 71	PRL 26 866 SJNP 13 53	Vosburgh, Devlin, Esterling, Goz+ +Berezin, Vishnevsky, Galanina+	MASA) (ITEP)	NEFKENS	67	PR 157 1233	+Abashian, Abrams, Carpenter, Fisher+ (ILL)
	Translated from YAF I	3 93.	(ITEP)	SCHMIDT TODOROFF	67 67	Thesis Nevis 160 Thesis	(COLU)
BARMIN 71 BISI 71	PL 35B 604 PL 36B 533	+Barylov, Veselovsky, Davidenko+ +Darriulat, Ferrero, Rubbia+ (AACH, CERN		ALFF	66B	PL 21 595	Alff-Steinberger, Heuer, Kleinknecht+ (CERN)
BURGUN 71	LNC 2 1169	+Lesquoy, Muller, Pauli+ (SACL, CERN,	OSLO)	ANIKINA	66	SJNP 2 339 Translated from YAF 2	+Vardenga, Zhuravleva+ (JINR) 471.
CARNEGIE 71 CHAN 71	PR D4 I Thesis LBL-350	+Cester, Fitch, Strovink, Sulak	(PRIN) (LBL)	AUERBACH	66B	PRL 17 980	+Mann, McFarlane, Sciulli (PENN)
CHIEN 71	PL 35B 261	+Cox, Ettlinger+ (JHU, SLAC,	UCLA)	BASILE BEHR	66 66	Balaton Conf. PL 22 540	+Cronin, Thevenet+ (SACL) +Brisson, Petiau+ (EPOL, MILA, PADO, ORSAY)
Also 72 CHO 71	PL 41B 647 PR D3 1557	Dally, Innocenti, Seppi+ (SLAC, JHU, +Dralle, Canter, Engler, Fisk+ (CMU, BNL,	UCLA)	BOTT	66	PL 23 277	Bott-Bodenhausen, DeBouard, Cassel+ (CERN)
CLARK 71	PRL 26 1667	+Elioff, Field, Frisch, Johnson, Kerth+	(LRL)	CARPENTER CRIEGEE	66 66	PR 142 871 PRL 17 150	+Abashian, Abrams, Fisher (ILL) +Fox, Frauenfelder, Hanson, Moscat+ (ILL)
Also 70 Also 71	Thesis UCRL 19709 Thesis UCRL 20264	Johnson Frisch	(LRL) (LRL)	FIRESTONE	66	PRL 16 556	+Kim, Lach, Sandweiss+ (YALE, BNL)
Also 74	SLAC-PUB-1498 unput	. Field	(SLAC)	HAWKINS Also	66 67	PL 21 238 PR 156 1444	(YALE) Hawkins (YALE)
ENSTROM 71	PR D4 2629	+Akavia, Coombes, Dorfan+ (SLAC,	STAN) (STAN)	ANDERSON	65	PRL 14 475	+Crawford, Golden, Stern, Binford+ (LRL, WISC)
Also 70 JAMES 71	Thesis SLAC-0125 PL 35B 265	+Montanet, Paul, Pauli+ (CERN, SACL,	OSLO)	ANIKINA ASTBURY	65 65	JINR P 2488 PL 16 80	+Vardenga, Zhuravleva, Kotlya+ (JINR) +Finocchiaro, Beusch+ (CERN, ZURI)
MEISNER 71	PR D3 59	+Mann, Hertzbach, Kofler+ (MASA, BNL	, YALE)	ASTBURY	65	HPA 39 523	+Finocchiaro, Beusch+ (CERN, ZURI) Pepin
PEACH 71 REPELLIN 71	PL 35B 351 PL 36B 603	+Evans, Muir, Budagov, Hopkins+ (EDIN, +Wolff, Chollet, Gaillard, Jane+ (ORSAY,	CERN)	ASTBURY	65B	PL 18 175	+Michelini, Beusch+ (CERN, ZURI)
WEBBER 71	PR D3 64	+Solmitz, Crawford, Alston-Garnjost	(LRL)	ASTBURY AUBERT	65C 65	PL 18 178 PL 17 59	+Michelini, Beusch+ (CERN, ZURI) +Behr, Canavan, Chounet+ (EPOL, ORSAY)
Also 68 Also 69	PRL 21 498 Thesis UCRL 19226	Webber, Solmitz, Crawford, Alston-Garnjost Webber	(LRL) (LRL)	Also	67	PL 24B 75	Lowys, Aubert, Chounet, Pascaud+ (EPOL, ORSAY)
WOLFF 71	PL 36B 517	+Chollet, Repellin, Gaillard+ (ORSAY,		BALDO FISHER	65 65	NC 38 684 ANL 7130 83	Baldo-Ceolin, Calimani, Ciampolillo+ (PADO) +Abashian, Abrams, Carpenter+ (ILL)
ALBROW 70	PL 33B 516	+Aston, Barber, Bird, Ellison+ (MCHS,	DARE)	FITCH	65	PRL 15 73	+Roth, Russ, Vernon (PRIN)
ARONSON 70 BARMIN 70	PRL 25 1057 PL 33B 377	+Ehrlich, Hofer, Jensen+ (EFI, ILLC +Barylov, Borisov, Bysheva+ (ITEF	, SLAC) P, JINR)	FRANZINI GALBRAITH	65 65	PR 140B 127 PRL 14 383	+Kirsch, Plano+ (COLU, RUTG) +Manning, Jones+ (AERE, BRIS, RHEL)
BASILE 70	PR D2 78	+Cronin, Thevent, Turlay, Zylberajch+	(SACL)	GUIDONI	65	Argonne Conf. 49	+Barnes, Foelsche, Ferbel, Firestone+ (BNL, YALE)
BECHERRAWY 70 BUCHANAN 70	PR D1 1452 PL 33B 623	+Drickey, Rudnick, Shepard+ (SLAC, JHU,	(ROCH) UCLA)	HOPKINS	65	Argonne Conf. 67	+Bacon, Eisler (VAND, RUTG)
Also 71	Private Comm.	Cox	· ·	ADAIR ALEKSANYAN	64 64B	PL 12 67 Dubna Conf. 2 102	+Leipuner (YALE, BNL) +Alikhanyan, Vartazaryan+ (YERE)
BUDAGOV 70 Also 688	PR D2 815 3 PL 28B 215	+Cundy, Myatt, Nezrick+ (CERN, ORSAY, Budagov, Cundy, Myatt+ (CERN, ORSAY,	EPOL)	Also	64	JETP 19 1019	Aleksanyan+ (LEBD, MPEI, YERE)
CHIEN 70	PL 33B 627	+Cox, Ettlinger+ (JHU, SLAC,		ANIKINA	64	JETP 19 42	46 1504. +Zhuravleva+ (GEOR, JINR)
Also 71 CHO 70	Private Comm. PR D1 3031	Cox +Dralle, Canter, Engler, Fisk+ (CMU, BNL,	CACE)	CHRISTENS	64	Translated from ZETF - PRL 13 138	46 59. Christenson, Cronin, Fitch, Turlay (PRIN)
Also 67	PRL 19 668	Hill, Luers, Robinson, Sakitt+ (BNL	, CMU)	FUJII	64	Dubna Conf. 2 146	+Jovanovich, Turkot+ (BNL, UMD, MIT)
CHOLLET 70	PL 31B 658	+Gaillard, Jane, Ratcliffe, Repellin+	(CERN)	LUERS DARMON	64 62	PR 133B 1276 PL 3 57	+Mittra, Willis, Yamamoto (BNL)
CULLEN 70 DARRIULAT 70	PL 32B 523 PL 33B 249	+Darriulat, Deutsch, Foeth+ +Ferrero, Grosso, Holder+ (AACH, CERN		ASTIER	61	Aix Conf. 1 227	+Rousset, Six +Blaskovic, Rivet, Siaud+ (EPOL)
FAISSNER 70	NC 70A 57	+Reithler, Thome, Gaillard+ (AACH3, CERN,	RHEL)	FITCH	61	NC 22 1160	+Piroue, Perkins (PRIN, LASL)
GINSBERG 70 JENSEN 70	PR D1 229 Thesis		(HAIF) (EFI)	GOOD NYAGU	61 61	PR 124 1223 PRL 6 552	+Matsen, Muller, Piccioni+ +Okonov, Petrov, Rosanova, Rusakov (JINR)
Also 69	PRL 23 615		FI, ILL)	Also	61B	JETP 13 1138	Nyagu, Okonov, Petrov, Rozanova+ (JINR)
MARX 70 Also 708	PL 32B 219 3 Thesis Nevis 179	+Nygren, Peoples+ (COLU, HARV, Marx	CERN) (COLU)	BARDON	58	Translated from ZETF - ANP 5 156	40 1618. +Lande, Lederman (COLU, BNL)
SCRIBANO 70	PL 32B 224	+Mannelli, Pierazzini, Marx+ (PISA, COLU,	`HARV)				(,
SMITH 70 WEBBER 70	PL 32B 133 PR D1 1967), BNL)			OTHER	RELATED PAPERS
WEBBER 70 Also 69	Thesis UCRL 19226	+Solmitz, Crawford, Alston-Garnjost Webber	(LRL) (LRL)			DD 040 1150	(1460)
BANNER 69	PR 188 2033	+Cronin, Liu, Pilcher	(PRIN)	HAYAKAWA "Searching	93 for 7	PR D48 1150 CP , CPT , $\Delta S = \Delta Q$	+Sanda (NAGO) Rule Violations in the Neutral K Meson System: A Guide"
Also 68 Also 68	PRL 21 1103 PRL 21 1107	Banner, Cronin, Liu, Pilcher Cronin, Liu, Pilcher	(PRIN) (PRIN)	LITTENBERG	93	ARNPS 43 729	+Valencia (BNL, FNAL)
BEILLIERE 69	PL 30B 202	+Boutang, Limon	(EPOL)	RITCHIE	93	ive Kaon Decays RMP 65 1149	+Wojcicki
BENNETT 69 BOHM 698	PL 29B 317 3 NP B9 605		Ĵ, BNL) (CERN)	"Rare K [WINSTEIN	Decays'	RMP 65 1113	+Wolfenstein
Also 68	PL 27B 321	Bohm, Darriulat, Grosso, Kaftanov	(CERN)			Direct CP Violation"	+-vvoirenstein
CENCE 69 EVANS 69	PRL 22 1210 PRL 23 427	+Jones, Peterson, Stenger+ (HAW)	A, LRL) CERN)	BATTISTON	92	PRPL 214 293 sectives of K Decay Phys	+Cocolicchio, Fogli, Paver (PGIA, CERN, TRSTT)
FAISSNER 69	PL 30B 204	+Foeth, Staude, Tittel+ (AACH3, CERN	, TORI)	DIB	92	PR D46 2265	+Peccei (UCLA)
FOETH 69	PL 30B 282	+Holder, Radermacher+ (AACH, CERN		Tests of C	PT co	onservation in the neutral	kaon system.
GAILLARD 69 Also 67	NC 59A 453 PRL 18 20	+Galbraith, Hussri, Jane+ (CERN, RHEL, Gaillard, Krienen, Galbraith+ (CERN, RHEL,	AACH)	KLEINKNECHT New Resul	ts on	CNPP 20 281 CP Violation in Decays of	of Neutral K Mesons. (MANZ)
GOBBI 698	3 PRL 22 685	+Green, Hakel, Moffett, Rosen, Goz+ (ROCH,	RUTG)	KLEINKNECHT	Γ90	ZPHY C46 S57	(MANZ)
LITTENBERG 69 LONGO 69	PRL 22 654 PR 181 1808	+Field, Piccioni, Mehlhop+ +Young, Helland (MICH,	UCLA)	PEACH BRYMAN	90 89	JPG 16 131 IJMP A4 79	(EDIN) (TRIU)
PACIOTTI 69	Thesis UCRL 19446		(LRL)	"Rare Kao	n Dec	ays"	
SAAL 69 ABRAMS 68E	Thesis PR 176 1603	+Abashian, Mischke, Nefkens, Smith+	(COLU) (ILL)	KLEINKNECHT GINSBERG	Γ76 73	ARNS 26 1 PR D8 3887	+Smith (MIT, STON)
ARNOLD 68E	B PL 28B 56	+Budagov, Cundy, Aubert+ (CERN,	ORŠAY)	GINSBERG	70	PR D1 229	(HAIF)
ARONSON 68 Also 69	PRL 20 287 PR 175 1708	+Chen Aronson, Chen	(PRIN) (PRIN)	HEUSSE CRONIN	70 68C	LNC 3 449 Vienna Conf. 281	+Aubert, Pascaud, Vialle (ORSAY) (PRIN)
BARTLETT 68	PRL 21 558	+Carnegie, Fitch+	(PRIN)	RUBBIA	67	PL 24B 531	+Steinberger (CERN, COLU)
BASILE 68	PL 26B 542	+Cronin, Thevenet, Turlay+	(SACL)	Also	66C	PL 23 167	Rubbia, Steinberger (CERN, COLU)
BASILE 688 BENNETT 68	B PL 28B 58 PL 27B 244	+Cronin, Thevenet, Turlay, Zylberajch+ +Nygren, Steinberger+ (COLU,	(SACL) CERN)	Also Also	66C 66B	PL 20 207 PL 21 595	Alff-Steinberger, Heuer, Kleinknecht+ (CERN) Alff-Steinberger, Heuer, Kleinknecht+ (CERN)
BENNETT 688	3 PL 27B 248	+Nygren, Steinberger+ (COLU,	CERN)	AUERBACH	66	PR 149 1052	+Dobbs, Lande, Mann, Sciulli+ (PENN)
BLANPIED 68 BOHM 68E	PRL 21 1650 3 PL 27B 594	+Levit, Engels+ (CASE, HARV,	MCGI)	Also FIRESTONE	65 66B	PRL 14 192 PRL 17 116	Auerbach, Lande, Mann, Sciulli, Uto+ (PENN) +Kim, Lach, Sandweiss+ (YALE, BNL)
BUDAGOV 68	NC 57A 182	+Burmeister, Cundy+ (CERN, ORSAY	, IPNP)	BEHR	65	Argonne Conf. 59	+Brisson, Bellotti+ (EPOL, MILA, PADO)
Also 68E JAMES 68	B PL 28B 215 NP B8 365	Budagov, Cundy, Myatt+ (CERN, ORSAY, +Briand (IPNP.	EPOL) CERN)	MESTVIRISH TRILLING	. 65 65B	JINR P 2449 UCRL 16473	Mestvirishvili, Nyagu, Petrov, Rusakov+ (JINR) (LRL)
Also 68	PRL 21 257	Helland, Longo, Young (UCLA,	MICH)	Updated fr	rom 19	965 Argonne Conference,	page 115.
KULYUKINA 68	JETP 26 20 Translated from ZETF	+ Mestvirishvili, Nyagu+ 53 29.	(JINR)	JOVANOV	63	BNL Conf. 42	Jovanovich, Fischer, Burris+ (BNL, UMD)

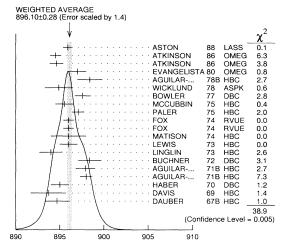
K*(892)

 $K^*(892)$

$$I(J^P) = \frac{1}{2}(1^-)$$

K*(892) MASS

	RGED ONL	.Y					
	(MeV)	EVTS	DOCUMENT ID		TECN		COMMENT
	±0.24 OUR		Error includes s			1.1.	0
890.4	$\pm 0.2 \pm 0.5$	79709± 801	¹ BIRD	89	LASS	_	11 $K^- \rho \rightarrow \overline{K}^0 \pi^- \rho$
892.6	± 0.5	5840	BAUBILLIER	84B	нвс	-	$\begin{array}{c} 8.25 \ K^- \ p \rightarrow \\ \overline{K}^0 \ \pi^- \ p \end{array}$
888	±3		NAPIER	84	SPEC	+	$200 \pi^- \rho \rightarrow 2K_S^0 X$
891	±1		NAPIER	84	SPEC	_	$200 \pi^- p \rightarrow 2K_5^0 X$
891.7	+2.1	3700	BARTH	83	нвс	+	$70 K^{+} p \rightarrow K^{0} \pi^{+} X$
891	±1	4100	TOAFF	81	нвс	_	$6.5 \ K^- p \rightarrow \overline{K}{}^0 \pi^- p$
892.8			AJINENKO	80	HBC	+	32 $K^+ p \rightarrow K^0 \pi^+ X$
890.7	± 0.9	1800	AGUILAR	78 B	нвс	±	$0.76 \ \overline{p} \ p \rightarrow \\ \kappa^{\mp} \ \kappa^{0}_{S} \ \pi^{\pm}$
886.6	+2.4	1225	BALAND	78	нвс	±	$12 \overline{\rho} \rho \rightarrow (K \pi)^{\pm} X$
891.7		6706	COOPER	78	HBC	±	$0.76 \overline{p} p \rightarrow (K \pi)^{\pm} X$
891.9			² PALER	75	нвс	_	14.3 $K^- p \to (K \pi)^-$
892.2	±1.5	4404	AGUILAR	71B	нвс	_	X 3.9,4.6 $K^- p \rightarrow$
891	± 2	1000	CRENNELL	69D	DBC	_	$(K\pi)^{-} p$ 3.9 $K^{-} N \rightarrow K^{0} \pi^{-} X$
894	±1.0	2886	3 FRIEDMAN	69	нвс	_	$2.1 \stackrel{K^0\pi^-\chi}{K^-\rho} \rightarrow \overline{K}^0\pi^-\rho$
892	±2	728	FRIEDMAN	69	НВС	-	$ \begin{array}{ccc} 2.45 & K^{-} & p \rightarrow \\ \overline{K}^{0} & \pi^{-} & p \end{array} $
892	±1.0	3229	FRIEDMAN	69	нвс	_	$2.6 \overset{\kappa^-\pi}{\kappa^-} \overset{p}{\rho} \to \overline{\kappa}^0 \pi^- \rho$
892	±1.6	1027	FRIEDMAN	69	HBC	_	$2.7 \ K^- p \rightarrow \overline{K}^0 \pi^- p$
890	± 3.0	720	BARLOW	67	HBC	±	1.2 p p →
889	±3.0	600	BARLOW	67	нвс	±	$(K^0\pi)^{\pm}K^{\mp}$ 1.2 $\overline{p}p \rightarrow$
							$(\kappa^0\pi)^{\pm}\kappa\pi$
891	± 2.3		³ DEBAERE	67B	HBC	+	$3.5 K^+ p \rightarrow K^0 \pi^+ p$
891.0	± 1.2	1700	4 WOJCICKI	64	HBC	-	$1.7 K^- p \rightarrow \overline{K}{}^0 \pi^- p$
	We do not u	se the follow	ving data for ave	rages	, fits, lir	nits, e	tc. • • •
890.0	±2.3	800 3,	⁴ CLELAND	82	SPEC	+	30 $K^+ p \rightarrow K_S^0 \pi^+ p$
896.0			4 CLELAND	82	SPEC	+	50 $K^+p \rightarrow K_0^0 \pi^+p$
893	±1		4 CLELAND	82	SPEC		$50 K^+ p \rightarrow K_0^0 \pi^- p$
				81		-	$50 K^{\pm} p \rightarrow K_{S}^{\pi} p$ $50 K^{\pm} p \rightarrow K^{\pm} \pi^{0} p$
896.0		380 187	DELFOSSE	81	SPEC SPEC	+	$50 K^{\pm} p \rightarrow K^{\pm} \pi^{0} p$ $50 K^{\pm} p \rightarrow K^{\pm} \pi^{0} p$
886.0 894.2			DELFOSSE 3 CLARK	73	HBC	_	$3.13 K^- p \rightarrow K^- \pi^- p$
094.2	±2.0					_	$\overline{K}^0\pi^-\rho$
894.3			4 CLARK	73	HBC	-	3.3 $K^- p \rightarrow \overline{K}^0 \pi^- p$
888	±2.5		3 DEWIT	68	HBC	-	$3 K^- n \rightarrow \overline{K}^0 \pi^- n$
892.0	±2.6	341	³ SCHWEING	68	НВС	-	$5.5 K^- p \rightarrow \overline{K}{}^0 \pi^- p$
	TRAL ONL	Y EVTS	DOCUMENT ID		TECN	CHG	COMMENT
	(MeV) 0±0.28 OUR			cale			COMMENT See the ideogram below.
	±0.5 ±0.2	AVENAGE	ASTON	88	LASS	0	$11 K^- p \rightarrow K^- \pi^+ n$
	±0.63	25k	2 ATKINSON	86	OMEG	U	20-70 γp
	3±0.76		2 ATKINSON	86	OMEG		20-70 γp
897	± 1	28k	EVANGELISTA	80	OMEG	0	$ \begin{array}{c} 10 \ \pi^{-} \rho \rightarrow \\ K^{+} \pi^{-} (\Lambda, \Sigma) \end{array} $
898.4	± 1.4	1180	AGUILAR	78в	нвс	0	$0.76 \overline{p} p \rightarrow K^{\mp} K_{S}^{0} \pi^{\pm}$
894.9	±1.6		WICKLUND	78	ASPK	0	3,4,6 $K^{\pm}N \rightarrow (K\pi)^0 N$
897.6	± 0.9		BOWLER	77	DBC	0	$5.4 \frac{K^+ d}{K^+ \pi^- pp}$
895.5	±1.0	3600	MCCUBBIN	75	нвс	0	$3.6 K^- p \rightarrow K^- \pi^+ n$
897.1			² PALER	75	нвс	0	$14.3 K^{-} \rho \rightarrow (K\pi)^{0}$
896.0	± 0.6	10k	FOX	74	RVUE	0	$2 \stackrel{\frown}{K^-} p \rightarrow \stackrel{\frown}{K^-} \pi^+ n$
896.0			FOX	74		0	$2 K^+ n \rightarrow K^+ \pi^- p$
896	± 2		⁵ MATISON	74	HBC	0	12 $K^+p \rightarrow K^+\pi^-\Delta$
896	± 1	3186	LEWIS	73	нвс	0	$\begin{array}{c} 2.1-2.7 \ K^+ \ \rho \rightarrow \\ K\pi\pi\rho \end{array}$
894.0	±1.3		LINGLIN	73	нвс	0	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$
898.4			3 BUCHNER	72	DBC	0	4.6 $K^{+} n \rightarrow K^{+} \pi^{-} p$
897.9			3 AGUILAR		НВС	0	3.9,4.6 $K^- p \rightarrow K^- \pi^+ n$
898.0	±0.7		³ AGUILAR		нвс	0	3.9,4.6 $K^- p \rightarrow K^- \pi^+ \pi^- p$
895	± 1		⁴ HABER	70	DBC	0	$3 K^- N \rightarrow K^- \pi^+ X$
893.7	±2.0	10k	DAVIS	69	HBC	0	12 K ⁺ p →
894.7	±1.4	1040	3 DAUBER	67B	нвс	0	$K^{+}\pi^{-}\pi^{+}\rho$ 2.0 $K^{-}\rho \rightarrow$
							$\kappa^-\pi^+\pi^-\rho$
• • •		se the follow 5900	ving data for ave				
900.7			BARTH	83	HBC	0	$70 K^+ p \rightarrow K^+ \pi^- X$



 $K^*(892)^0$ mass (MeV)

- ¹ From a partial wave amplitude analysis.
- Inclusive reaction. Complicated background and phase-space effects. 3 Mass errors enlarged by us to Γ/\sqrt{N} . See note.
- ⁴ Number of events in peak reevaluated by us.
- ⁵ From pole extrapolation.

$K^*(892)$ MASSES AND MASS DIFFERENCES

Unrealistically small errors have been reported by some experiments. We use simple "realistic" tests for the minimum errors on the determination of a mass and width from a sample of N events:

$$\delta_{\min}(m) = \frac{\Gamma}{\sqrt{N}}, \quad \delta_{\min}(\Gamma) = 4\frac{\Gamma}{\sqrt{N}} \; .$$

We consistently increase unrealistic errors before averaging. For a detailed discussion, see the 1971 edition of this Note.

$m_{K^{\bullet}(892)^{0}} - m_{K^{\bullet}(892)^{\pm}}$						
VALUE (MeV) 6.7±1.2 OUR AVE	EVTS RAGE	DOCUMENT ID	TECN	<u>CHG</u>	COMMENT	
7.7 ± 1.7	2980	AGUILAR	78B HBC	±0	$0.76 \overline{p} \rho \rightarrow \\ \kappa^{\mp} \kappa^{0}_{5} \pi^{\pm}$	
5.7 ± 1.7	7338	AGUILAR	718 HBC	-0	3.9,4.6 K p	
6.3 ± 4.1	283	⁶ BARASH	67B HBC		0.0 p p	
⁶ Number of events in peak reevaluated by us.						

K*(892) RANGE PARAMETER

All from partial wave amplitude analyses.

VALUE (GeV-1)	DOCUMENT ID		TECN	CHG	COMMENT
12.1 ± 3.2 ± 3.0	BIRD	89	LASS	_	11 $K^- p \rightarrow \overline{K}{}^0 \pi^- p$
3.4 ± 0.7	ASTON	88	LASS	0	11 $K^- \rho \rightarrow K^- \pi^+ n$

K*(892) WIDTH

CHARGED OI	EVTS	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
49.8±0.8 OUR I	FIT					
49.8±0.8 OUR	AVERAGE					
$45.2 \pm 1 \pm 2$	79709± 801	⁷ BIRD	89	LASS		11 $K^- \rho \rightarrow \overline{K}^0 \pi^- \rho$
49 ±2	5840	BAUBILLIER	84B	нвс	-	$8.25 \begin{array}{c} K^- p \rightarrow \\ \overline{K}^0 \pi^- p \end{array}$
56 ±4		NAPIER	84	SPEC		$200 \pi^{-} p \rightarrow 2K_{5}^{0} X$
51 ±2	4100	TOAFF	81	HBC	-	6.5 $K^- \rho \rightarrow \overline{K}^0 \pi^- \rho$
50.5 ± 5.6		AJINENKO	80	HBC	+	$32 K^+ p \rightarrow K^0 \pi^+ X$
45.8 ± 3.6	1800	AGUILAR	78B	HBC	±	0.76 p p →
52.0 ± 2.5	6706	8 COOPER	78	нвс	±	$K^{\mp} K_{S}^{0} \pi^{\pm}$ $0.76 \overline{p}p \rightarrow (K\pi)^{\pm} X$
					11:	
52.1 ± 2.2	9000	⁹ PALER	75	нвс	****	$\begin{array}{c} 14.3 \ K^- p \rightarrow (K\pi)^- \\ X \end{array}$

						
46.3±6.7	765	8 CLARK	73	нвс	_	3.13 K ⁻ p →
48.2±5.7	1150	8,10 CLARK	73	нвс	_	$\overline{K}^0 \pi^- \rho$ 3.3 $K^- \rho \to \overline{K}^0 \pi^- \rho$
54.3±3.3	4404	8 AGUILAR		нвс	_	3.9,4.6 $K^-p \rightarrow$
		_				$(K\pi)^-p$
53 ±4.0	2886	⁸ FRIEDMAN	69	нвс		$2.1 \ K^- p \rightarrow \ \overline{K}{}^0 \pi^- p$
49 ±7.3	728	⁸ FRIEDMAN	69	нвс	-	$\begin{array}{c} 2.45 \ K^{-} \ \rho \rightarrow \\ \overline{K}^{0} \ \pi^{-} \ \rho \end{array}$
46 ±3.2	3229	⁸ FRIEDMAN	69	нвс	_	$2.6 \text{ K}^{-} \text{p} \rightarrow \overline{\text{K}}^{0} \pi^{-} \text{p}$
49 ±6.1	1027	⁸ FRIEDMAN	69	нвс	_	$2.7 K^- \rho \rightarrow \overline{K}^0 \pi^- \rho$
46 ±5	1700	8,10 WOJCICKI	64	нвс	-	1.7 $K^- \rho \rightarrow \overline{K}^0 \pi^- \rho$
• • • We do not ι	ise the 1	following data for ave	rages	s, fits, lir	nits, e	
42.8 ± 7.1	3700	BARTH	83	нвс	+	70 $K^+ p \rightarrow K^0 \pi^+ X$
64.0 ± 9.2	800	8,10 CLELAND	82	SPEC	+	$30 K^+ p \rightarrow K_S^0 \pi^+ p$
62.0 ± 4.4	3200	8,10 CLELAND	82	SPEC	+	$50 K^+ p \rightarrow K_S^{0} \pi^+ p$
55 ±4	3600	8,10 CLELAND	82	SPEC	-	$50 K^+ p \rightarrow K_S^0 \pi^- p$
62.6 ± 3.8	380	DELFOSSE	81	SPEC	+	$50 \ K^{\pm} p \rightarrow K^{\pm} \pi^{0} p$
50.5 ± 3.9	187	DELFOSSE	81	SPEC	_	$50 \ K^{\pm} p \rightarrow K^{\pm} \pi^{0} p$
NEUTRAL ONL	Y					
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
50.5 ± 0.6 OUR FIT 50.5 ± 0.6 OUR AV		r includes scale factor Error includes scale			1	
50.8±0.8±0.9		ASTON	88	LASS	0	11 $K^- p \rightarrow K^- \pi^+ n$
46.5±4.3	5900	BARTH	83	HBC	0	$70 K^+ p \rightarrow K^+ \pi^- X$
54 ±2	28k	EVANGELISTA	80	OMEG	0	$ \begin{array}{c} 10 \ \pi^{-} \rho \rightarrow \\ K^{+} \pi^{-} (\Lambda, \Sigma) \end{array} $
45.9±4.8	1180	AGUILAR	78 B	нвс	0	$0.76 \overline{p}p \rightarrow K^{\mp} K_S^0 \pi^{\pm}$
51.2±1.7		WICKLUND	78	ASPK	0	3,4,6 $K^{\pm}N \rightarrow (K\pi)^0 N$
48.9±2.5		BOWLER	77	DBC	0	$5.4 \begin{array}{c} K^+ d \rightarrow \\ K^+ \pi^- \rho \rho \end{array}$
48 +3	3600	MCCUBBIN	75	нвс	0	3.6 $K^- \rho \rightarrow K^- \pi^+ n$
50.6±2.5	22k	⁹ PALER	75	нвс	0	${\overset{14.3}{\times}}^{K^-} p \rightarrow (K\pi)^0$
47 ±2	10k	FOX	74	RVUE	0	$2 \hat{K}^- p \rightarrow K^- \pi^+ n$
51 ±2		FOX	74	RVUE	0	$2 K^+ n \rightarrow K^+ \pi^- p$
46.0±3.3	3186	⁸ LEWIS	73	HBC	0	$\begin{array}{c} 2.1-2.7 \ K^+ \rho \rightarrow \\ K\pi\pi\rho \end{array}$
51.4±5.0	1700	⁸ BUCHNER	72	DBC	0	$4.6 K^{+} n \rightarrow K^{+} \pi^{-} p$
55.8 ^{+4.2} -3.4	2934	8 AGUILAR	71B	нвс	0	3.9,4.6 K ⁻ p →
-3.4						$K^-\pi^+n$
48.5±2.7	5362	AGUILAR	71B	нвс	0	3.9,4.6 $K^- p \rightarrow K^- \pi^+ \pi^- p$
54.0 ± 3.3	4300	8,10 HABER	70	DBC	0	$3 K^- N \rightarrow K^- \pi^+ X$
53.2±2.1	10k	⁸ DAVIS	69	нвс	0	12 $K^+ p \rightarrow$
44 ±5.5	1040	⁸ DAUBER	67 B	нвс	0	$K^{+}\pi^{-}\pi^{+}\rho$ $2.0 K^{-}\rho \rightarrow$
7 From a partial s						$K^-\pi^+\pi^-\rho$

- 7 From a partial wave amplitude analysis. 8 Width errors enlarged by us to $4\times \Gamma/\sqrt{N};$ see note. 9 Inclusive reaction. Complicated background and phase-space effects. 10 Number of events in peak reevaluated by us.

K*(892) DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Confidence level
Γ1	Κπ	~ 100	%
Γ_2		(99.899±0.009)	%
Γ_3	$(\kappa\pi)^0$	(99.770±0.020)	%
Γ_4	$K^0\gamma$	(2.30 ± 0.20)	$\times 10^{-3}$
Γ_5	$K^{\pm}\gamma$	(1.01 ± 0.09)	$\times 10^{-3}$
Γ ₆	Κππ	< 7	× 10 ⁻⁴ 95%

CONSTRAINED FIT INFORMATION

An overall fit to the total width and a partial width uses 18 measurements and one constraint to determine 3 parameters. The overall fit has a $\chi^2=15.2$ for 16 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\left\langle \delta p_i \delta p_j \right\rangle / \left(\delta p_i \cdot \delta p_j \right)$, in percent, from the fit to parameters p_i , including the branching fractions, $x_i \equiv \Gamma_i / \Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to one.

$$x_5$$
 -100 17 -17 x_2 x_5

	Mode	Rate (MeV)
Γ ₂ Γ ₅	$(\kappa\pi)^{\pm}$ $\kappa^{\pm}\gamma$	$\begin{array}{cc} 49.8 & \pm 0.8 \\ 0.050 \pm 0.005 \end{array}$

CONSTRAINED FIT INFORMATION

An overall fit to the total width and a partial width uses 18 measurements and one constraint to determine 3 parameters. The overall fit has a $\chi^2=18.4$ for 16 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\left\langle \delta p_i \delta p_j \right\rangle / (\delta p_i \cdot \delta p_j)$, in percent, from the fit to parameters p_i , including the branching fractions, $x_i \equiv \Gamma_i/\Gamma_{\rm total}$. The fit constrains the x_i whose labels appear in this array to sum to one.

	Mode	Rate (MeV)	Scale factor
Γ ₃	$(K\pi)^0$	50.4 ±0.6	1.1
Γ_4	$\kappa^0\gamma$	0.117 ± 0.010	

K*(892) PARTIAL WIDTHS

$\Gamma(K^0\gamma)$									Γ4
	<u>VTS</u>	DOCUME	NT IE		TECN	CHG	COMMEN	T	
116 ±10 OUR FIT 116.5± 9.9	584	CARLS	AIT LI	. 06	SPEC	0	νO Λ .	$\kappa_{\rm S}^0\pi^0{\rm A}$	
	504	CARLS		00	SEEC	U	~L~ →	ΛS ^{π-} Α	
$\Gamma(K^{\pm}\gamma)$									Γ ₅
VALUE (keV)	DOCU	MENT ID		TECN	CHG	COMM	ENT		
50± 5 OUR FIT 50± 5 OUR AVERAG	E								
48±11	BERG	3	83	SPEC		156 K	- A → 7	\overline{K}_{π} A	
$51\pm$ 5	CHA	NDLEE	83	SPEC	+	200 K	+ A → /	ΚπΑ	

	,	(*(892) BRAN	CHII	NG RAT	TIOS		
$\Gamma(K^0\gamma)/\Gamma_{\text{tota}}$	ı						Γ4/Γ
VALUE (units 10-3		OCUMENT ID	TEC	N CHG	CON	IMENT	
2.30±0.20 OUR	FIT						
 ● ● We do no 	t use the fo	llowing data for a	verag	es, fits,	limits,	etc. • • •	
1.5 ±0.7	C	ARITHERS 75B	CNT	TR 0	8-1	5 <i>K</i> ⁰ A	
$\Gamma(K^{\pm}\gamma)/\Gamma_{\text{tota}}$	nl						Γ_5/Γ
VALUE (units 10 ⁻³		DOCUMENT ID		TECN	CHG	COMMENT	
1.01 ± 0.09 Ol							
• • • We do no	t use the fo	llowing data for a	verag	es, fits,	limits,	etc. • • •	
<1.6	95	BEMPORAD	73	CNTR	+	10-16 K ⁺ A	
$\Gamma(K\pi\pi)/\Gamma(I$	$(\pi)^{\pm}$						Γ_6/Γ_2
VALUE	CL%	DOCUMENT ID		TECN	CHG	COMMENT	
<0.0007	95	JONGEJANS	78	нвс		$4 K^- p \rightarrow p \overline{l}$	$\sqrt{60} 2\pi$
 • • We do no 	t use the fo	llowing data for a	verag	es, fits,	limits,	etc. • • •	
< 0.002		WOJCICKI	64	HBC	_	$1.7 K^- \rho \rightarrow 7$	K ⁰ π- n

K*(892) REFERENCES

BIRD	89	SLAC-332	(SLAC)
ASTON	88	NP B296 493	+Awaji, Bienz, Bird+ (SLAC, NAGO, CINC, INUS)
ATKINSON	86	ZPHY C30 521	 (BONN, CERN, GLAS, LANC, MCHS, CURIN+)
CARLSMITH	86	PRL 56 18	+Bernstein, Peyaud, Turlay (EFI, SACL)
BAUBILLIER	84B	ZPHY C26 37	+ (BIRM, CERN, GLAS, MICH, CURIN)
NAPIER	84	PL 149B 514	+Chen+ (TUFTS, ARIZ, FNAL, FLOR, NDAM+)
BARTH	83	NP B223 296	+Drevermann+ (BRUX, CERN, GENO, MONS+)
BERG	83	Thesis UMI 83-21652	(ROCH)
CHANDLEE	83	PRL 51 168	+Berg, Cihangir, Collick+ (ROCH, FNAL, MINN)
CLELAND	82	NP B208 189	+Delfosse, Dorsaz, Gloor (DURH, GEVA, LAUS, PITT)
DELFOSSE	81	NP B183 349	+Guisan, Martin, Muhlemann, Weill+ (GEVA, LAUS)
TOAFF	81	PR D23 1500	+Musgrave, Ammar, Davis, Ecklund+ (ANL, KANS)
AJINENKO	80	ZPHY C5 177	+Barth, Dujardin+ (SERP, BRUX, MONS, SACL)
EVANGELISTA	80	NP B165 383	+ (BARI, BONN, CERN, DARE, GLAS, LIVP+)
AGUILAR	78B	NP B141 101	Aguilar-Benitez+ (MADR, TATA, CERN+)
BALAND	78	NP B140 220	+Grard+ (MONS, BELG, CERN, LOIC, LALO)
COOPER	78	NP B136 365	+Gurtu+ (TATA, CERN, CDEF+)
JONGEJANS	78	NP B139 383	+Cerrada+ (ZEEM, CERN, NIJM, OXF)
WICKLUND	78	PR D17 1197	+Ayres, Diebold, Greene, Kramer, Pawlicki (ANL)
BOWLER	77	NP B126 31	
CARITHERS	75B	PRL 35 349	+Dainton, Drake, Williams (OXF) +Muhlemann, Underwood+ (ROCH, MCGI)
MCCUBBIN	75	NP B86 13	+Lyons (OXF)
PALER	75	NP B96 1	+Tovey, Shah, Spiro+ (RHEL, SACL, ÈPOL)
FOX	74	NP B80 403	+Griss (CIT)
MATISON	74	PR D9 1872	+Galtieri, Alston-Garnjost, Flatte, Friedman+ (LBL)
BEMPORAD	73	NP B51 1	+Beusch, Freudenreich+ (CERN, ETH, LOIC)
CLARK	73	NP B54 432	+Lyons, Radojicic (OXF)
LEWIS	73	NP B60 283	+Allen, Jacobs+ (LOWC, LOIC, CDEF)
LINGLIN	73	NP B55 408	(CERN)
BUCHNER	72	NP B45 333	+Dehm, Charriere, Cornet+ (MPIM, CERN, BRUX)
AGUILAR	71B	PR D4 2583	Aguilar-Benitez, Eisner, Kinson (BNL)
HABER	70	NP B17 289	+Shapira, Alexander+ (REHO, SACL, BGNA, EPOL)
CRENNELL	69D	PRL 22 487	+Karshon, Lai, O'Neall, Scarr (BNL)
DAVIS	69	PRL 23 1071	+Derenzo, Flatte, Garnjost, Lynch, Solmitz (LRL)
FRIEDMAN	69	Thesis UCRL 18860	(LRL)
DEWIT	68	Thesis	(ÁNIK)
SCHWEING	68	PR 166 1317	Schweingruber, Derrick, Fields+ (ANL, NWES)
BARASH	67B	PR 156 1399	+Kirsch, Miller, Tan (COLU)
	67	NC 50A 701	+Lillestol, Montanet+ (CERN, CDEF, IRAD, LIVP)
	67B	PR 153 1403	+Schlein, Slater, Ticho (UCLA)
	67B	NC 51A 401	+Goldschmidt-Clermont, Henri+ (BRUX, CERN)
WOJCICKI	64	PR 135B 484	(LRL)

 $K^*(892)$, $K_1(1270)$

OTHER RELATED PAPERS	K ₁ (1270) DECAY MODES
KAMAL 92 PL B284 421 +Xu (ALBE) NAPIER 84 PL 149B 514 +Chen+ (TUFTS, ARIZ, FNAL, FLOR, NDAM+)	Mode Fraction (Γ_j/Γ)
CLELAND 82 NP B208 189 + Deffosse, Dorsaz, Gloor (DURH, GEVA, LAUS, PITT) ALEXANDER 62 PRL 8 447 + Kalbfleisch, Miller, Smith (LRL) ALSTON 628 CERN Conf. 291 + Ticho, Wojcicki+ (LRL)	Γ_1 $K\rho$ (42 ±6)%
ARMENTEROS 62C CERN Conf. 295 +Astrer, Montanet+ (CERN, CDEF)	$\Gamma_2 = K_0^*(1430)\pi$ (28 ±4)%
COLLEY 62B CERN Conf. 315 +Gelfand+ (COLU, RUTG) ALSTON 61 PRL 6 300 +Alvarez, Eberhard, Good+ (LRL)	$\Gamma_3 = K^*(892)\pi$ (16 ±5)%
	Γ_4 $K\omega$ (11.0±2.0) % Γ_5 $K f_0$ (1370) (3.0±2.0) %
$K_1(1270)$ $I(J^P) = \frac{1}{2}(1^+)$	
	K ₁ (1270) PARTIAL WIDTHS
K ₁ (1270) MASS	$\Gamma(K ho)$ VALUE (MeV) DOCUMENT ID TECN CHG COMMENT
VALUE (MeV) DOCUMENT ID	◆ ◆ We do not use the following data for averages, fits, limits, etc. ◆ ◆
1273±7 OUR AVERAGE Includes data from the 2 datablocks that follow this one.	57 \pm 5 MAZZUCATO 79 HBC + 4.2 $K^-p \rightarrow \Xi^-(K\pi\pi)^+$ 75 \pm 6 CARNEGIE 778 ASPK \pm 13 $K^\pm p \rightarrow (K\pi\pi)^\pm p$
PRODUCED BY K-, BACKWARD SCATTERING, HYPERON EXCHANGE	
VALUE (MeV) EVTS DOCUMENT ID TECN CHG COMMENT The data in this block is included in the average printed for a previous datablock.	$\Gamma(K_0^*(1430)\pi)$ VALUE (MeV) DOCUMENT ID TECN CHG COMMENT
1275 ± 10 700 GAVILLET 78 HBC + 4.2 $K^-p \rightarrow$	◆ ◆ We do not use the following data for averages, fits, limits, etc. ◆ ◆
$\Xi^{-}(K\pi\pi)^{+}$	26±6 CARNEGIE 778 ASPK ± 13 $K^{\pm}p \rightarrow (K\pi\pi)^{\pm}p$
PRODUCED BY K BEAMS VALUE (MeV) DOCUMENT ID TECN CHG COMMENT	$\Gamma(K^*(892)\pi)$
The data in this block is included in the average printed for a previous datablock.	VALUE (MeV) DOCUMENT ID TECN CHG COMMENT • • • We do not use the following data for averages, fits, limits, etc. • •
1270 ± 10 DAUM 81C CNTR - 63 $K^- p \rightarrow K^- 2\pi p$	14±11 MAZZUCATO 79 HBC + 4.2 $K^-p \rightarrow \Xi^-(K\pi\pi)^+$
• • • We do not use the following data for averages, fits, limits, etc. • • •	2± 2 CARNEGIE 778 ASPK ± $13 K^{\pm} p \rightarrow (K\pi\pi)^{\pm} p$
\sim 1276 1 TORNQVIST 82B RVUE \sim 1300 VERGEEST 79 HBC $-$ 4.2 $K^{-}p \rightarrow (\overline{K}\pi\pi)^{-}p$	$\Gamma(K\omega)$
1289±25 2 CARNEGIE 77 ASPK ± $13 K^{\pm} p \rightarrow (K \pi \pi)^{\pm} p$	VALUE (MeV) DOCUMENT ID TECN CHG COMMENT
~ 1300 BRANDENB 76 ASPK \pm 13 $K^{\pm}p \rightarrow (K\pi\pi)^{\pm}p$	◆ ◆ We do not use the following data for averages, fits, limits, etc. ◆ ◆
\sim 1270 OTTER 76 HBC $-$ 10,14,16 $K^- p ightarrow (\overline{K} \pi \pi)^- p$	4±4 MAZZUCATO 79 HBC + 4.2 $K^- p \rightarrow \Xi^- (K \pi \pi)^+$
1260 DAVIS 72 HBC + 12 $K^+ p$	24±3 CARNEGIE 77B ASPK ± 13 $K^{\pm} p \rightarrow (K\pi\pi)^{\pm} p$
1234±12 FIRESTONE 728 DBC + 12 K ⁺ d	$\Gamma(Kf_0(1370))$
1 From a unitarized quark-model calculation. 2 From a model-dependent fit with Gaussian background to BRANDENBURG 76 data.	VALUE (MeV) DOCUMENT ID TECN CHG COMMENT
PRODUCED BY BEAMS OTHER THAN K MESONS	• • • We do not use the following data for averages, fits, limits, etc. • • • $22\pm5 \qquad \qquad CARNEGIE \qquad 778 \; ASPK \; \pm \qquad 13 \; K^{\pm} p \to (\kappa \pi \pi)^{\pm} p$
VALUE (MeV) EVTS DOCUMENT ID TECN CHG COMMENT	22 \pm 5 CARNEGIE 778 ASPK \pm 13 $K^{\pm} \rho \rightarrow (K\pi\pi)^{\pm} \rho$
• • • We do not use the following data for averages, fits, limits, etc. • • •	K_1 (1270) BRANCHING RATIOS
1294 \pm 10 310 RODEBACK 81 HBC 4 $\pi^-p \rightarrow \Lambda K 2\pi$ 1300 40 CRENNELL 72 HBC 0 4.5 $\pi^-p \rightarrow \Lambda K 2\pi$	$\Gamma(K ho)/\Gamma_{ m total}$
$^{1242}_{-10}^{+9}$ 3 ASTIER 69 HBC 0 $\overline{p}p$	VALUE DOCUMENT ID TECN COMMENT
1300 45 CRENNELL 67 HBC 0 6 $\pi^- \rho \rightarrow \Lambda K 2\pi$	0.42 \pm 0.06 5 DAUM 81C CNTR 63 $K^- \rho \to K^- 2\pi \rho$
3 This was called the $^{\prime}$ meson.	• • • We do not use the following data for averages, fits, limits, etc. • •
K ₁ (1270) WIDTH	dominant RODEBACK 81 HBC $4 \pi^- p \rightarrow \Lambda K 2\pi$
N1(1270) WIDTH	$\Gamma(K_0^*(1430)\pi)/\Gamma_{\text{total}}$
VALUE (MeV) DOCUMENT ID	VALUE DOCUMENT ID TECN COMMENT
OO LOO OUR ESTIMATE. This is only an educated access the every given is larger than	0.28+0.04 5 DAUM 81C CNTR 63 $K^- p \rightarrow K^- 2\pi p$
90±20 OUR ESTIMATE This is only an educated guess; the error given is larger than the error on the average of the published values.	0.28±0.04 5 DAUM 81c CNTR 63 K ⁻ p → K ⁻ 2π p
the error on the average of the published values.	$\Gamma(K^*(892)\pi)/\Gamma_{\text{total}}$
the error on the average of the published values. 87 ± 7 OUR AVERAGE Includes data from the 2 datablocks that follow this one. PRODUCED BY K-, BACKWARD SCATTERING, HYPERON EXCHANGE	
the error on the average of the published values. 87 ± 7 OUR AVERAGE Includes data from the 2 datablocks that follow this one.	$\frac{\Gamma(K^*(892)\pi)/\Gamma_{total}}{VALUE} \underbrace{\begin{array}{cccc} DOCUMENT & ID & IECN & COMMENT \\ \hline 0.16\pm0.05 & 5 & DAUM & 81c & CNTR & 63 & K^- p> & K^- 2\pi p \end{array}}$
the error on the average of the published values. 87 ± 7 OUR AVERAGE Includes data from the 2 datablocks that follow this one. PRODUCED BY K ⁻ , BACKWARD SCATTERING, HYPERON EXCHANGE VALUE (MeV) EVTS DOCUMENT ID TECN CHG COMMENT The data in this block is included in the average printed for a previous datablock.	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
the error on the average of the published values. 87 \pm 7 OUR AVERAGE Includes data from the 2 datablocks that follow this one. PRODUCED BY K-, BACKWARD SCATTERING, HYPERON EXCHANGE VALUE (MeV) EVTS DOCUMENT ID TECN CHG COMMENT The data in this block is included in the average printed for a previous datablock. T5 \pm 15 700 GAVILLET 78 HBC + 4.2 K- ρ \rightarrow $\Xi^- K \pi \pi$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
the error on the average of the published values. 87 ± 7 OUR AVERAGE Includes data from the 2 datablocks that follow this one. PRODUCED BY K⁻, BACKWARD SCATTERING, HYPERON EXCHANGE VALUE (MeV) EVTS DOCUMENT ID TECN CHG COMMENT The data in this block is included in the average printed for a previous datablock. 75 ± 15 700 GAVILLET 78 HBC + 4.2 K⁻ p →	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
the error on the average of the published values. 87 \pm 7 OUR AVERAGE Includes data from the 2 datablocks that follow this one. PRODUCED BY K^- , BACKWARD SCATTERING, HYPERON EXCHANGE VALUE (MeV) EVTS DOCUMENT ID TECN CHG COMMENT The data in this block is included in the average printed for a previous datablock. 75 \pm 15 700 GAVILLET 78 HBC + 4.2 $K^- p \rightarrow \Xi^- K \pi \pi$ PRODUCED BY K BEAMS	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
the error on the average of the published values. 87 \pm 7 OUR AVERAGE Includes data from the 2 datablocks that follow this one. PRODUCED BY K^- , BACKWARD SCATTERING, HYPERON EXCHANGE VALUE (MeV) EVTS DOCUMENT ID TECN CHG COMMENT The data in this block is included in the average printed for a previous datablock. 75 \pm 15 700 GAVILLET 78 HBC + 4.2 $K^ p \rightarrow$ $E^- K \pi \pi$ PRODUCED BY $E^- K = E^- K \pi \pi$ PRODUCED BY $E^- K = E^- K \pi \pi$ PRODUCED BY $E^- K = E^- K \pi \pi$ The data in this block is included in the average printed for a previous datablock. 90 \pm 8 DAUM 81C CNTR - 63 $E^- K = E^- K = E$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
the error on the average of the published values. 87 \pm 7 OUR AVERAGE Includes data from the 2 datablocks that follow this one. PRODUCED BY K^- , BACKWARD SCATTERING, HYPERON EXCHANGE VALUE (MeV) EVTS DOCUMENT ID TECN CHG COMMENT The data in this block is included in the average printed for a previous datablock. 75 \pm 15 700 GAVILLET 78 HBC $+$ 4.2 $K^-p \rightarrow E^- K \pi \pi$ PRODUCED BY K BEAMS VALUE (MeV) DOCUMENT ID TECN CHG COMMENT The data in this block is included in the average printed for a previous datablock. 90 \pm 8 DAUM 81C CNTR $-$ 63 $K^-p \rightarrow K^-2\pi p$ \bullet \bullet \bullet We do not use the following data for averages, fits, limits, etc. \bullet \bullet	$\Gamma(K^*(892)\pi)/\Gamma_{total} \qquad \qquad \Gamma_{3}/\Gamma_{total} \qquad \qquad \Gamma_{4}/\Gamma_{total} \qquad$
the error on the average of the published values. R7 ± 7 OUR AVERAGE Includes data from the 2 datablocks that follow this one. RRODUCED BY K^- , BACKWARD SCATTERING, HYPERON EXCHANGE VALUE (MeV) EVTS DOCUMENT ID TECN CHG COMMENT. The data in this block is included in the average printed for a previous datablock. R75±15 700 GAVILLET 78 HBC + 4.2 $K^- \rho \rightarrow E^- K \pi \pi$ PRODUCED BY K BEAMS VALUE (MeV) DOCUMENT ID TECN CHG COMMENT. The data in this block is included in the average printed for a previous datablock. 90± 8 DAUM 81c CNTR - 63 $K^- \rho \rightarrow K^- 2\pi \rho$ • • • We do not use the following data for averages, fits, limits, etc. • • • 150 VERGEEST 79 HBC - 4.2 $K^- \rho \rightarrow (\overline{K}\pi\pi)^- \rho$	$ \Gamma(K^*(892)\pi)/\Gamma_{total} $
the error on the average of the published values. 87 \pm 7 OUR AVERAGE Includes data from the 2 datablocks that follow this one. PRODUCED BY K^- , BACKWARD SCATTERING, HYPERON EXCHANGE VALUE (MeV) EVTS DOCUMENT ID TECN CHG COMMENT The data in this block is included in the average printed for a previous datablock. 75 \pm 15 700 GAVILLET 78 HBC + 4.2 $K^-p \rightarrow E^-K\pi\pi$ PRODUCED BY K BEAMS VALUE (MeV) DOCUMENT ID TECN CHG COMMENT The data in this block is included in the average printed for a previous datablock. 90 \pm 8 DAUM 81c CNTR - 63 $K^-p \rightarrow K^-2\pi p$ • • • We do not use the following data for averages, fits, limits, etc. • • • VERGEEST 79 HBC - 4.2 $K^-p \rightarrow (K^-\pi\pi)^-p$ 150 \pm 71 4 CARNEGIE 77 ASPK \pm 13 $K^\pm p \rightarrow (K^-\pi\pi)^\pm p$ BRANDENB 76 ASPK \pm 13 $K^\pm p \rightarrow (K^-\pi\pi)^\pm p$	$ \Gamma(K^*(892)\pi)/\Gamma_{total} $
the error on the average of the published values. 87 \pm 7 OUR AVERAGE Includes data from the 2 datablocks that follow this one. PRODUCED BY K^- , BACKWARD SCATTERING, HYPERON EXCHANGE VALUE (MeV) EVTS DOCUMENT ID TECN CHG COMMENT The data in this block is included in the average printed for a previous datablock. 75 \pm 15 700 GAVILLET 78 HBC + 4.2 $K^-p \rightarrow E^- K \pi \pi$ PRODUCED BY K BEAMS VALUE (MeV) DOCUMENT ID TECN CHG COMMENT The data in this block is included in the average printed for a previous datablock. 90 \pm 8 DAUM 81C CNTR - 63 $K^-p \rightarrow K^-2\pi p$ • • • We do not use the following data for averages, fits, limits, etc. • • • 150 VERGEEST 79 HBC - 4.2 $K^-p \rightarrow (K^-\pi\pi)^-p$ 150 \pm 71 4 CARNEGIE 77 ASPK \pm 13 $K^\pm p \rightarrow (K^-\pi\pi)^\pm p$ 200 BRANDENB 76 ASPK \pm 13 $K^\pm p \rightarrow (K^-\pi\pi)^\pm p$ 120 DAVIS 72 HBC + 12 K^+p	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
the error on the average of the published values. Included data from the 2 datablocks that follow this one. PRODUCED BY K^- , BACKWARD SCATTERING, HYPERON EXCHANGE VALUE (MeV) EVTS DOCUMENT ID TECN CHG COMMENT The data in this block is included in the average printed for a previous datablock. 75±15 700 GAVILLET 78 HBC + 4.2 $K^- p \rightarrow E^- K \pi \pi$ PRODUCED BY K BEAMS VALUE (MeV) DOCUMENT ID TECN CHG COMMENT The data in this block is included in the average printed for a previous datablock. 90±8 DAUM 81C CNTR - 63 $K^- p \rightarrow K^- 2\pi p$ • • • We do not use the following data for averages, fits, limits, etc. • • • • • • • • • • • • • • • • • • •	$ \Gamma(K^*(892)\pi)/\Gamma_{total} $
the error on the average of the published values. 87 \pm 7 OUR AVERAGE Includes data from the 2 datablocks that follow this one. PRODUCED BY K^- , BACKWARD SCATTERING, HYPERON EXCHANGE VALUE (MeV) EVTS DOCUMENT ID TECN CHG COMMENT The data in this block is included in the average printed for a previous datablock. 75 \pm 15 700 GAVILLET 78 HBC + 4.2 $K^-p \rightarrow E^- K \pi \pi$ PRODUCED BY K BEAMS VALUE (MeV) DOCUMENT ID TECN CHG COMMENT The data in this block is included in the average printed for a previous datablock. 90 \pm 8 DAUM 81C CNTR - 63 $K^-p \rightarrow K^-2\pi p$ • • • We do not use the following data for averages, fits, limits, etc. • • • 150 VERGEEST 79 HBC - 4.2 $K^-p \rightarrow (K^-\pi\pi)^-p$ 150 \pm 71 4 CARNEGIE 77 ASPK \pm 13 $K^\pm p \rightarrow (K^-\pi\pi)^\pm p$ 200 BRANDENB 76 ASPK \pm 13 $K^\pm p \rightarrow (K^-\pi\pi)^\pm p$ 120 DAVIS 72 HBC + 12 K^+p	$ \Gamma(K^*(892)\pi)/\Gamma_{total} $

310 RODEBACK 81 HBC $4\pi^-p \rightarrow \Lambda K2\pi$ 40 CRENNELL 72 HBC 0 $4.5 \pi^-p \rightarrow \Lambda K2\pi$ ASTIER 69 HBC 0 $\overline{p}p$ 45 CRENNELL 67 HBC 0 $6 \pi^-p \rightarrow \Lambda K2\pi$

K₁(1270) REFERENCES

TORNQVIST DAUM RODEBACK MAZZUCATO VERGEEST	81 79 79	NP B203 268 NP B187 1 ZPHY C9 9 NP B156 532 NP B158 265	+Hertzberger+ (AMST, CERN, CRAC, MPIM, OXF+) +Sjøgren+ (CERN, CDEF, MADR, STOH) +Pennington+ (CERN, ZEEM, NIJM, OXF) +Jongejans, Dionisi+ (NIJM, AMST, CERN, OXF)
GAVILLET	78	PL 76B 517	+Diaz, Dionisi+ (AMST, CERN, NIJM, OXF) JP
CARNEGIE	77	NP B127 509	+Cashmore, Davier, Dunwoodie, Lasinski+ (SLAC)
CARNEGIE	77B	Pl. 68B 287	+Cashmore, Dunwoodie, Lasinski+ (SLAC)
BRANDENB	76	PRL 26 703	Brandenburg, Carnegie, Cashmore+ (SLAC) JP
OTTER	76	NP B106 77	+ (AACH3, BERL, CERN, LOIC, VIEN, EPOL+) JP
CRENNELL	72	PR D6 1220	+Gordon, Lai, Scarr (BNL)
DAVIS	72	PR D5 2688	+Alston-Garnjost, Barbaro, Flatte, Friedman, Lynch+ (LBL)
FIRESTONE	72B	PR D5 505	+Goldhaber, Lissauer, Trilling (LBL)
ASTIER	69	NP B10 65	+Marechal, Montanet+ (CDEF, CERN, IPNP, LIVP) IJP
CRENNELL	67	PRL 19 44	+Kalbfleisch, Lai, Scarr, Schumann (BNL) I

OTHER RELATED PAPERS

SUZUKI	93	PR D47 1252		(LBL)
BAUBILLIER	82B	NP B202 21	+ (BIRM, CERN, GLAS	, MSU, CÙRIN)
FERNANDEZ	82	ZPHY C16 95	+Aguilar-Benitez+ (MADR, CERN,	CDEF, STOH) JE
GAVILLET	82	ZPHY C16 119		PADO, ROMA)
SHEN	66	PRL 17 726	+Butterworth, Fu, Goldhaber, Trilling	(LRL)
Also	66	Private Comm.	Goldhaber	(LRL)
ALMEIDA	65	PL 16 184	+Atherton, Byer, Dornan, Forson+	(CAVE)
ARMENTEROS		PL 9 207	+Edwards, D'Andlau+	(CERN, CDEF)
Also	66	PR 145 1095	Barash, Kirsch, Miller, Tan	(COLU)
ARMENTEROS		Dubna Conf. 1 577	+Edwards, D'Andlau+	(CERN, CDEF)
Also	64C	Dubna Conf. 1 617	Armenteros	

$K_1(1400)$

$$I(J^P) = \frac{1}{2}(1^+)$$

K1(1400) MASS

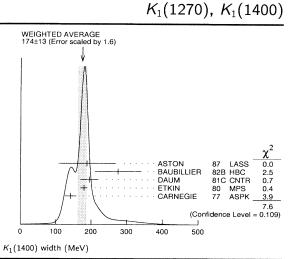
	VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
	1402± 7 OUR AVE	RAGE				
	$1373 \pm 14 \pm 18$	$^{ m 1}$ ASTON	87	LASS	0	$11 K^- \rho \rightarrow \overline{K}^0 \pi^+ \pi^- n$
	1392 ± 18	BAUBILLIER	82B	HBC	0	8.25 $K^- p \rightarrow K_S^0 \pi^+ \pi^- n$
	1410 ± 25	DAUM	81C	CNTR	_	$63 K^- p \rightarrow K^- 2\pi p$
	1415 ± 15	ETKIN	80	MPS	0	$6 K^- p \rightarrow \overline{K}^0 \pi^+ \pi^- n$
	1404 ± 10	² CARNEGIE	77	ASPK	\pm	$13 K^{\pm} \rho \rightarrow (K \pi \pi)^{\pm} \rho$
	• • • We do not use t	he following data	for a	verages,	fits, li	mits, etc. • •
,	~ 1350	³ TORNQVIST	828	RVUE		
,	~ 1400	VERGEEST	79	HBC	_	$4.2 K^- p \rightarrow (\overline{K} \pi \pi)^- p$
,	~ 1400	BRANDENB	76	ASPK	±	4.2 $K^- p \rightarrow (\overline{K} \pi \pi)^- p$ 13 $K^{\pm} p \rightarrow (K \pi \pi)^{\pm} p$
	1420	DAVIS	72	HBC	+	12 K ⁺ p
	1368 ± 18	FIRESTONE	72B	DBC	+	12 K ⁺ d
	1					

 $^{^1\,\}mathrm{From}$ partial-wave analysis of $\mathrm{K}^0\,\pi^+\,\pi^-$ system.

K1(1400) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
174±13 OUR AVERA	GE Error includ	tes s	cale fact	or of 1	.6. See the ideogram below.
$188 \pm 54 \pm 60$	⁴ ASTON	87	LASS	0	$11 K^- p \rightarrow \overline{K}^0 \pi^+ \pi^- n$
276 ± 65	BAUBILLIER	82B	HBC	0	8.25 $K^- p \rightarrow K_S^0 \pi^+ \pi^- n$
195 ± 25	DAUM	810	CNTR	_	63 $K^- p \rightarrow K^- 2\pi p$
180 ± 10			MPS		$6 K^- p \rightarrow \overline{K}^0 \pi^+ \pi^- n$
142±16	CARNEGIE	77	ASPK	\pm	$13 K^{\pm} p \rightarrow (K \pi \pi)^{\pm} p$
• • • We do not use the	e following data t	for a	verages,	fits, lir	mits, etc. • • •
~ 200	VERGEEST	79	нвс	_	4.2 $K^- p \rightarrow (\overline{K} \pi \pi)^- p$
~ 160	BRANDENB	76	ASPK	±	$13 K^{\pm} \rho \rightarrow (K\pi\pi)^{\pm} \rho$
80	DAVIS	72	HBC	+	12 K+p
241 ± 30	FIRESTONE	728	DBC	+	12 K+d
4	0 1				

 $^{^4}$ From partial-wave analysis of $K^0\,\pi^+\,\pi^-$ system. 5 From a model-dependent fit with Gaussian background to BRANDENBURG 76 data.



$K_1(1400)$	DECAY	MODES
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	Mode	Fraction (Γ_i/Γ)	
Γ ₂ Γ ₃ Γ ₄	Κ*(892)π Κρ Κ f ₀ (1370) Κω	(94 ±6) % (3.0±3.0) % (2.0±2.0) % (1.0±1.0) %	
Γ_5	$K_0^*(1430)\pi$		

K1(1400) PARTIAL WIDTHS

Γ(<i>K</i> *(892)π)						Γ_1
VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT	
117±10	CARNEGIE	77	ASPK	\pm	13 $K^{\pm} \rho \rightarrow (K\pi\pi)^{\pm} \rho$	
$\Gamma(K\rho)$						Γ2
VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT	
2 ±1	CARNEGIE	77	ASPK	\pm	13 $K^{\pm} \rho \rightarrow (K \pi \pi)^{\pm} \rho$	
$\Gamma(K\omega)$						Γ4
VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT	
23±12	CARNEGIE	77	ASPK	±	$13 K^{\pm} p \rightarrow (K\pi\pi)^{\pm} p$	

K1(1400) BRANCHING RATIOS

Γ(<i>K*</i> (892)π)/Γ	totai			Γ_1/Γ
VALUE		D TECN		
0.94±0.06	⁶ DAUM	81C CNTR	$63~\textrm{K}^-\rho \to~\textrm{K}^-2\pi\rho$	
$\Gamma(K\rho)/\Gamma_{\text{total}}$				Γ2/Γ
VALUE		D TECN		
0.03 ±0.03	o DAUM	81c CNTR	63 $K^- p \rightarrow K^- 2\pi p$	
$\Gamma(Kf_0(1370))/\Gamma$	total			Г ₃ /Г
VALUE	DOCUMENT I			
0.02 ±0.02	6 DAUM	81c CNTR	$63~K^-~\rho~\rightarrow~K^-~2\pi~\rho$	
$\Gamma(K\omega)/\Gamma_{total}$				Γ_4/Γ
VALUE	DOCUMENT I	D TECN	COMMENT	
0.01 ±0.01	⁶ DAUM	81C CNTR	$63~K^-~p~\rightarrow~K^-~2\pi~p$	
$\Gamma(K_0^*(1430)\pi)/1$	total			r _s /r
VALUE		D <u>TECN</u>		
not seen	6 DAUM	81C CNTR	63 $K^- \rho \rightarrow K^- 2\pi \rho$	
D-wave/S-wave	RATIO FOR K1	(1400) → K	*(892) <i>π</i>	
VALUE	DOCUMENT IL	<u>TECN</u>	COMMENT	
	,			

81c CNTR 63 $K^- p \rightarrow K^- 2\pi p$

6 DAUM

 6 Average from low and high t data.

0.04 ±0.01

² From a model-dependent fit with Gaussian background to BRANDENBURG 76 data.

³ From a unitarized quark-model calculation.

$K_1(1400)$, $K^*(1410)$, $K_0^*(1430)$, $K_2^*(1430)$

K₁(1400) REFERENCES

ASTON	87		+Awaji, D'Amore+ (SLAC, NAGO, CINC, INUS)
BAUBILLIER	82B	NP B202 21	+ (BIRM, CERN, GLAS, MSU, CURIN)
TORNQVIST	82B	NP B203 268	(HELS)
DAUM	81 C	NP B187 1	+Hertzberger+ (AMST, CERN, CRAC, MPIM, OXF+)
ETKIN	80	PR D22 42	+Foley, Lindenbaum, Kramer+ (BNL, CUNY) JP
VERGEEST	79	NP B158 265	+Jongejans, Dionisi+ (NIJM, AMST, CERN, OXF)
CARNEGIE	77	NP B127 509	+Cashmore, Davier, Dunwoodie, Lasinski+ (SLAC)
BRANDENB	76	PRL 26 703	Brandenburg, Carnegie, Cashmore+ (SLAC) JP
DAVIS	72	PR D5 2688	+Alston-Garnjost, Barbaro, Flatte, Friedman, Lynch+ (LBL)
FIRESTONE	72B	PR D5 505	+Goldhaber, Lissauer, Trilling (LBL)

- OTHER RELATED PAPERS -

	93	PR D47 1252		(LBL)
FERNANDEZ :	82	ZPHY C16 95	+Aguilar-Benitez+ (MADR, CERN,	
SHEN	66	PRL 17 726	+Butterworth, Fu, Goldhaber, Trilling	(LRL)
Also	66	Private Comm.	Goldhaber	(LRL)
ALMEIDA	65	PL 16 184	+Atherton, Byer, Dornan, Forson+	(CAVE)
ARMENTEROS	64	PL 9 207	+Edwards, D'Andlau+	(CERN, CDEF)
Also	66	PR 145 1095	Barash, Kirsch, Miller, Tan	(COLU)
ARMENTEROS	64B	Dubna Conf. 1 577	+Edwards, D'Andlau+	(CERN, CDEF)
Also	64C	Dubna Conf. 1 617	Armenteros	

 $K^*(1410)$

$$I(J^P) = \frac{1}{2}(1^-)$$

K*(1410) MASS

VALUE (MeV)	DOCUMENT ID	TE	CN CHG	COMMENT
1412±12 OUR AVE	RAGE Error includ			
1367±54	BIRD			11 $K^- \rho \rightarrow \overline{K}{}^0 \pi^- \rho$
$1380 \pm 21 \pm 19$	ASTON	88 LA	.SS 0	$11 K^- \rho \rightarrow K^- \pi^+ n$
1420 ± 7 ± 10	ASTON	87 LA	SS 0	11 $K^- \rho \rightarrow \overline{K}^0 \pi^+ \pi^- n$
• • • We do not use	the following data	for avera	ages, fits,	limits, etc. • • •
1474 ± 25	BAUBILLIER	828 HE	3C 0	8.25 $K^- p \rightarrow \overline{K}^0 2\pi n$
1500 ± 30	ETKIN	80 MI	PS 0	$6 K^- p \rightarrow \overline{K}^0 \pi^+ \pi^- n$

K*(1410) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
227± 22 OUR AVERA					
114 ± 101	BIRD	89	LASS	-	11 $K^- \rho \rightarrow \overline{K}^0 \pi^- \rho$
176 ± 52 ± 22					$11 K^- p \rightarrow K^- \pi^+ n$
240 ± 18 ± 12	ASTON	87	LASS	0	11 $K^- \rho \rightarrow \overline{K}^0 \pi^+ \pi^- n$
• • • We do not use t	he following data	for a	verages,	fits, li	imits, etc. • • •
275 ± 65	BAUBILLIER				8.25 $K^- \rho \rightarrow \overline{K}^0 2\pi n$
$\textbf{500} \pm \textbf{100}$	ETKIN	80	MPS	0	$6 K^- \rho \rightarrow \overline{K}^0 \pi^+ \pi^- n$

K*(1410) DECAY MODES

	Mode	Fraction (Γ _i /Γ)	Confidence level	
Γ ₁	K*(892)π	> 40 %	95%	
Γ_2	$K\pi$	(6.6 ± 1.3) %		
Γ_3	$K\rho$	< 7 %	95%	

K*(1410) BRANCHING RATIOS

$\Gamma(K\rho)/\Gamma(K^*(8))$	92)π)						Γ_3/Γ_1
VALUE	CL%	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT	
< 0.17	95	ASTON	84	LASS	0	11 $K^-p \rightarrow$	$\overline{K}^0 2\pi n$
$\Gamma(K\pi)/\Gamma(K^*(8))$	92)π)	ı					Γ_2/Γ_1
VALUE	CL%	DOCUMENT ID		TECN	CHG	COMMENT	
< 0.16	95	ASTON	84	LASS	0	11 $K^-p \rightarrow$	$\overline{K}^0 2\pi n$
$\Gamma(K\pi)/\Gamma_{\text{total}}$							Γ_2/Γ
VALUE		DOCUMENT ID	TECI	V CHG		IMENT	
$0.066 \pm 0.010 \pm 0.0$	80	ASTON 88	LAS	S 0	11 F	<-p → K-	π^+ n

K*(1410) REFERENCES

BIRD	89	SLAC-332		(SLAC)
ASTON	88	NP B296 493	+Awaji, Bienz, Bird+	(SLAC, NAGO, CINC, INUS)
ASTON	87	NP B292 693	+Awaji, D'Amore+	(SLAC, NAGO, CINC, INUS)
ASTON	84	PL 149B 258	+Carnegie, Dunwoodie+	(SLAC, CARL, OTTA) JP
BAUBILLIER	82B	NP B202 21	+ (BIRM,	CERN, GLAS, MSU, CURIN)
ETKIN	80	PR D22 42	+Foley, Lindenbaum, Kramer+	(BNL, CUNY) JP

 $K_0^*(1430)$

$$I(J^P) = \frac{1}{2}(0^+)$$

See our minireview in the 1994 edition and in this edition under the

K*(1430) MASS

VALUE (MeV)	DOCUMENT ID	TECNCHG	COMMENT
1429 ±4±5	¹ ASTON 8	8 LASS 0	11 $K^- \rho \rightarrow K^- \pi^+ n$
• • • We do not use	the following data for	r averages, fits, I	imits, etc. • • •
\sim 1450	² TORNQVIST 9	6 RVUE	$\pi\pi \to \pi\pi$, K \overline{K} , K π
~ 1430	BAUBILLIER 8		8.25 $K^- p \rightarrow \overline{K}^0 \pi^- p$
~ 1425	3,4 ESTABROOKS 7	8 ASPK	13 $K^{\pm} p \rightarrow K^{\pm} \pi^{\pm} (n, \Delta)$
\sim 1450.0	MARTIN 7	8 SPEC	$10 K^{\pm} p \rightarrow K_{S}^{0} \pi p$
_			9

 1 Uses a model for the background, without this background they get a mass 1340 MeV, where the phase shift passes 90°. 2 T-matrix pole.

ı

- 3 Mass defined by pole position. 4 From elastic $K\pi$ partial-wave analysis.

K*(1430) WIDTH

VALUE (MeV)	DOCUMENT ID	TECN	CHG	COMMENT
287±10±21	ASTON 88	LASS	0	11 $K^- \rho \rightarrow K^- \pi^+ n$
• • • We do not use	the following data for	averages,	fits, li	imits, etc. • • •
\sim 320	⁵ TORNQVIST 96	RVUE		$\pi\pi \to \pi\pi$, $K\overline{K}$, $K\pi$
~ 200	BAUBILLIER 84			
200 to 300	⁶ ESTABROOKS 78	ASPK		13 $K^{\pm} p \rightarrow K^{\pm} \pi^{\pm} (n, \Delta)$
⁵ T-matrix pole.				
	artial-wave analysis.			
	,			

K*(1430) DECAY MODES

	Mode	Fraction (Γ_{j}/Γ)
Γ ₁	Κπ	(93±10) %

K*(1430) BRANCHING RATIOS

$\Gamma(K\pi)/\Gamma_{\text{total}}$						Γ_1/Γ
VALUE	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT	
$0.93 \pm 0.04 \pm 0.09$	ASTON	88	LASS	0	$11 K^- \rho \rightarrow K^- \pi^+ n$	

K*(1430) REFERENCES

TORNQVIST	96	PRL 76 1575	+Roos (HELS)	
ASTON	88	NP B296 493	+Awaji, Bienz, Bird+ (SLAC, NAGO, CINC, INUS)	
BAUBILLIER	84B	ZPHY C26 37	+ (BIRM, CERN, GLAS, MICH, CURIN)	
ESTABROOKS	78	NP B133 490	+Carnegie+ (MCGI, CARL, DURH, SLAC)	
MARTIN	78	NP B134 392	+Shimada, Baldi, Bohringer+ (DURH, GEVA)	
			= '	

OTHER RELATED PAPERS

TORNQVIST GOLDBERG	69	PRL 49 624 PL 30B 434	+Huffer, Laloum+	(SABRE Collab.)
SCHLEIN	69	Argonne Conf. 446	+Chien, Malamud, Mellema, Schlein+	(UCLA)
TRIPPE	68	PL 28B 203		(UCLA)



$$I(J^P) = \frac{1}{2}(2^+)$$

We consider that phase-shift analyses provide more reliable determi-

K*(1430) MASS

CHARGED ONLY, WITH FINAL STATE $K\pi$

VALUE (M	eV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
1425.4±	1.3 OUR	AVERAGE	Error includes so	cale	factor of		
$1423.4\pm$	2 ±3	24809± 820	¹ BIRD	89	LASS	-	11 $K^- \rho \rightarrow \overline{K}^0 \pi^- \rho$
$1420\pm$	4	1587	BAUBILLIER	84B	HBC	-	8.25 K ⁻ p →
							$\overline{K}^0\pi^-\rho$
$1436~\pm$	5.5	400	^{2,3} CLELAND	82	SPEC	+	30 $K^+ p \rightarrow K_S^0 \pi^+ p$
1430 ±	3.2	1500	^{2,3} CLELAND	82	SPEC	+	$50 K^+ \rho \rightarrow K_S^0 \pi^+ \rho$
1430 \pm	3.2	1200	^{2,3} CLELAND	82	SPEC	_	$50 K^+ p \rightarrow K_S^0 \pi^- p$
1423 ±	5	935	TOAFF	81	HBC	-	6.5 $K^- p \to \overline{K}^0 \pi^- p$
$1428.0\pm$	4.6		⁴ MARTIN	78	SPEC	+	$10 K^{\pm} \rho \rightarrow K_S^0 \pi \rho$
$1428.0\pm$	4.6		⁴ MARTIN	78	SPEC	+	$10 K^{\pm} \rho \rightarrow K_S^0 \pi \rho$

1423.8 ± 4.6		⁴ MARTIN	78	SPEC	-	$10 K^{\pm} p \rightarrow K_{5}^{0} \pi p$
1420.0 ± 3.1	1400	AGUILAR	71B	HBC	_	3.9,4.6 K ⁻ p
1425 ± 8.0	225	^{2,3} BARNHAM	7 10	HBC	+	$K^+ \rho \rightarrow K^0 \pi^+ \rho$
1416 ± 10	220	CRENNELL	69D	DBC	-	$3.9\frac{K^-}{K^0}\frac{N}{\pi^-}\frac{N}{N}$
1414 ±13.0	60	² LIND	69	нвс	+	$9 K^+ p \rightarrow K^0 \pi^+ p$
1427 ± 12	63	² SCHWEING	68	HBC		$5.5 K^- p \rightarrow \overline{K} \pi N$
1423 ±11.0	39	² BASSANO	67	HBC	_	$4.6-5.0 \ K^- p \rightarrow$
						$\overline{\mathcal{K}}^0\pi^-\rho$
NEUTRAL ON	_Y					
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
1432.4± 1.3 OUF						
$1431.2 \pm 1.8 \pm 0.$	7	⁵ ASTON	88	LASS	0	11 $K^- p \rightarrow K^- \pi^+ n$
1434 \pm 4 \pm 6		⁵ ASTON	87	LASS	0	11 $K^- \rho \rightarrow$
1433 ± 6 ±10		⁵ ASTON	84R	LASS	0	$\frac{\overline{K}^0\pi^+\pi^-}{11\ K^-\rho\to \overline{K}^02\pi n}$
1471 ±12		5 BAUBILLIER		HBC	0	8.25 $K^-p \rightarrow$
1411 111		B/10B/EE/E/1	020		Ü	$NK_{S}^{0}\pi\pi$
1428 ± 3		⁵ ASTON	81C	LASS	0	$11 K^- p \rightarrow K^- \pi^+ n$
1434 ± 2		⁵ ESTABROOKS	78	ASPK	0	13 $K^{\pm}p \rightarrow pK\pi$
1440 ±10		⁵ BOWLER	77	DBC	0	$5.5 K^+ d \rightarrow K\pi pp$
• • • We do not	use the fo	llowing data for ave	rages	, fits, li	nits, e	tc. • • •
1420 ± 7	300	HENDRICK	76	DBC		8.25 $K^+ N \rightarrow K^+ \pi N$
1421.6 ± 4.2	800	MCCUBBIN	75	нвс	0	$3.6 K^- p \rightarrow K^- \pi^+ I$
1420.1 ± 4.3		⁶ LINGLIN	73	HBC	0	2-13 $K^+ \rho \rightarrow$
1419.1± 3.7	1800	AGUILAR	71B	нвс	0	$K^{+}\pi^{-}X$ 3.9,4.6 $K^{-}p$
1416 ± 6	600	CORDS	71	DBC	0	$9 K^+ n \rightarrow K^+ \pi^- p$
1421.1± 2.6	2200	DAVIS	69	нвс	0	12 $K^+p \rightarrow K^+\pi^-X$
1 From a partial		nlitudo analysis				•

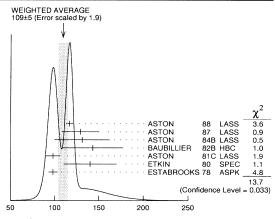
- $^{1}\,\mathrm{From}$ a partial wave amplitude analysis.
- ² Errors enlarged by us to Γ/\sqrt{N} ; see the note with the $K^*(892)$ mass.
- 3 Number of events in peak re-evaluated by us. 4 Systematic error added by us. 5 From phase shift or partial-wave analysis.

- ⁶ From pole extrapolation, using world K^+p data summary tape.

K*(1430) WIDTH

CHARGED ONLY, WITH FINAL STATE $K\pi$ VALUE (MeV) EVTS DOCUMENT ID TECN CHG COMMENT 98.4 ± 2.3 OUR AVERAGE 98.4 ± 24 809 ± 7 BIRD 89 LASS - 11 $K^-p \to \overline{K}^0\pi^-$ 109 ± 22 400 8.9 CLELAND 82 SPEC + 30 $K^+p \to K^0_0\pi^-$ 124 ± 12.8 1500 8.9 CLELAND 82 SPEC + 50 $K^+p \to K^0_0\pi^+$ 113 ± 12.8 1200 8.9 CLELAND 82 SPEC - 50 $K^+p \to K^0_0\pi^-$ 85 ± 16 935 TOAFF 81 HBC - 6.5 $K^-p \to K^0_0\pi^-$ 96.5 ± 3.8 MARTIN 78 SPEC + 10 $K^\pm p \to K^0_0\pi^-$								
98.4 ± 2.4 OUR AVERAGE 98 ± 4 ± 4 24809 ± 7 BIRD 89 LASS - 11 $K^-p \rightarrow \overline{K}^0\pi^-$ 109 ±22 400 8,9 CLELAND 82 SPEC + 30 $K^+p \rightarrow K^0_0\pi^+$ 124 ±12.8 1500 8,9 CLELAND 82 SPEC + 50 $K^+p \rightarrow K^0_0\pi^+$ 113 ±12.8 1200 8,9 CLELAND 82 SPEC - 50 $K^+p \rightarrow K^0_0\pi^+$ 85 ±16 935 TOAFF 81 HBC - 6.5 $K^-p \rightarrow K^0_0\pi^-$								
$\begin{array}{cccccccccccccccccccccccccccccccccccc$								
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$								
109 ±22 400 8.9 CLELAND 82 SPEC + 30 $K^+p \rightarrow K_0^0\pi^+$ 124 ±12.8 1500 8.9 CLELAND 82 SPEC + 50 $K^+p \rightarrow K_0^0\pi^+$ 113 ±12.8 1200 8.9 CLELAND 82 SPEC - 50 $K^+p \rightarrow K_0^0\pi^-$ 85 ±16 935 TOAFF 81 HBC - 6.5 $K^-p \rightarrow K_0^0\pi^-$	p							
85 ± 16 935 TOAFF 81 HBC $-$ 6.5 $K^- p \rightarrow \overline{K}^{0} \pi^-$	p							
85 ± 16 935 TOAFF 81 HBC $-$ 6.5 $K^- p \rightarrow \overline{K}^{0} \pi^-$	· p							
85 ± 16 935 TOAFF 81 HBC $-$ 6.5 $K^- p \rightarrow \overline{K}^{0} \pi^-$	· p							
96.5 \pm 3.8 MARTIN 78 SPEC $+$ 10 $K^{\pm} \rho \rightarrow K_{c}^{0} \pi \rho$	- p							
	,							
96.5 ± 3.8 MARTIN 78 SPEC + $10 K^{\pm} p \rightarrow K^{0}_{5} \pi p$ 97.7 ± 4.0 MARTIN 78 SPEC - $10 K^{\pm} p \rightarrow K^{0}_{5} \pi p$								
94.7 ^{+15.1} _{-12.5} 1400 AGUILAR 71B HBC - 3.9,4.6 K ⁻ p								
NEUTRAL ONLY								
VALUE (MeV) EVTS DOCUMENT ID TECN CHG COMMENT								

NE	JTRA	L ONLY					
	JE (MeV)		DOCUMENT ID		TECN	CHG	COMMENT
109	± 5	OUR AVERAGE		ale fa	actor of	1.9. S	ee the ideogram below.
116.	5 ± 3.6	± 1.7	¹⁰ ASTON	88	LASS	0	11 $K^-p \rightarrow K^-\pi^+n$
129	± 15	± 15	¹⁰ ASTON	87	LASS	0	11 $K^-p \rightarrow$
			10				$\overline{K}^0\pi^+\pi^-\underline{n}$
131	± 24	±20	10 ASTON		LASS	0	$11 K^- p \rightarrow \overline{K}^0 2\pi n$
143	± 34		¹⁰ BAUBILLIER	82B	HBC	0	8.25 K ⁻ p →
							$NK_S^0\pi\pi$
98	± 8		¹⁰ ASTON	81c	LASS	0	$11 \ K^-p \rightarrow K^-\pi^+ n$
140	± 30		¹⁰ ETKIN	80	SPEC	0	6 K p →
							$\overline{K}^0\pi^+\pi^-n$
	± 5		10 ESTABROOKS			-	13 $K^{\pm} \rho \rightarrow \rho K \pi$
• •	• We c	to not use the foll	owing data for aver	ages	, fits, lir	nits, et	ic. • • •
125	±29	300	8 HENDRICK	76	DBC		8.25 K ⁺ N →
							$K^+\pi N$
116		800	MCCUBBIN	75	нвс	0	3.6 $K^-p \rightarrow K^-\pi^+n$
61	± 14		¹¹ LINGLIN	73	нвс	0	$2-13 K^+ \rho \rightarrow$
	1.10.3						$K^+\pi^-X$
116.	$6^{+10.3}_{-15.5}$	1800	AGUILAR	718	нвс	0	3.9,4.6 K ⁻ p
144	±24.0	600	⁸ CORDS	71	DBC	0	$9 K^+ n \rightarrow K^+ \pi^- \rho$
101	± 10	2200	DAVIS	69	нвс	0	12 $K^+p \rightarrow$
							$\kappa^+\pi^-\pi^+\rho$



 $K_2^*(1430)^0$ width (MeV)

- ⁷ From a partial wave amplitude analysis.
- ⁸ Errors enlarged by us to $4\Gamma/\sqrt{N}$; see the note with the $K^*(892)$ mass.
- ⁹ Number of events in peak re-evaluated by us.
- 10 From phase shift or partial-wave analysis.

 11 From pole extrapolation, using world K^+p data summary tape.

K2(1430) DECAY MODES

	Mode	Fraction $(\Gamma_{\hat{I}}/\Gamma)$	Scale factor/ Confidence level
Γ_1	Κπ	(49.7±1.2) %	
Γ_2	$K^*(892)\pi$	(25.2±1.7) %	
Γ_3	$K^*(892)\pi\pi$	(13.0±2.3) %	
Γ ₄	$K\rho$	(8.8 ± 0.8) %	S=1.2
Γ ₅	$K\omega$	(2.9±0.8) %	
Γ_6	$K^+\gamma$	$(2.4\pm0.5)\times10^{-3}$	
Γ ₇	$K\eta$	$(1.4^{+2.8}_{-0.9}) \times 10^{-3}$	S=1.1
Γ ₈	$K \omega \pi$	$< 7.2 \times 10^{-4}$	CL=95%
Γ9	$K^0\gamma$	< 9 × 10 ⁻⁴	CL=90%

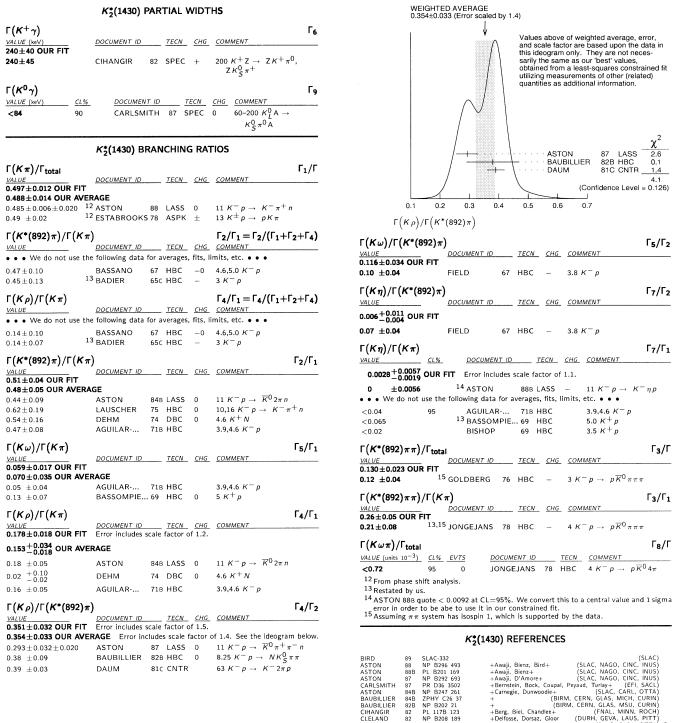
CONSTRAINED FIT INFORMATION

An overall fit to the total width, a partial width, and 10 branching ratios uses 28 measurements and one constraint to determine 8 parameters. The overall fit has a $\chi^2=19.5$ for 21 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\left\langle \delta \rho_i \delta \rho_j \right\rangle / (\delta \rho_i \cdot \delta \rho_j) \text{, in percent, from the fit to parameters } \rho_i \text{, including the branch-}$ ing fractions, $x_i \equiv \Gamma_i/\Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to one.

	Mode	Rate (MeV)	Scale factor
Г	Κπ	48.9 ±1.7	
Γ_2	$K^*(892)\pi$	24.8 ±1.7	
Γ3	$K^*(892)\pi\pi$	12.8 ±2.3	
Γ4	$K\rho$	8.7 ±0.8	1.2
Γ_5	$K\omega$	2.9 ±0.8	
Γ_6	$K^+\gamma$	$\textbf{0.24} \pm \textbf{0.04}$	
Γ ₇	$K\eta$	$0.14 \begin{array}{l} + 0.28 \\ - 0.09 \end{array}$	1.1

$K_2^*(1430)$



BIRD	89	SLAC-332	(SLAC)
ASTON	88	NP B296 493	+Awaji, Bienz, Bird+ (SLAC, NAGO, CINC, INUS)
ASTON	88B	PL B201 169	+Awaji, Bienz+ (SLAC, NAGO, CINC, INUS)
ASTON	87	NP B292 693	+Awaji, D'Amore+ (SLAC, NAGO, CINC, INUS)
CARLSMITH	87	PR D36 3502	+Bernstein, Bock, Coupal, Peyaud, Turlay+ (EFI, SACL)
ASTON	84B	NP B247 261	+Carnegie, Dunwoodie+ (SLAC, CARL, OTTA)
BAUBILLIER	84B	ZPHY C26 37	+ (BIRM, CERN, GLAS, MICH, CURIN)
BAUBILLIER	82B	NP B202 21	+ (BIRM, CERN, GLAS, MSU, CURIN)
CIHANGIR	82	PL 117B 123	+Berg, Biel, Chandlee+ (FNAL, MINN, ROCH)
CLELAND	82	NP B208 189	+Delfosse, Dorsaz, Gloor (DURH, GEVA, LAUS, PITT)
ASTON	81C	PL 106B 235	+Carnegie, Dunwoodie+ (SLAC, CARL, OTTA) JF
DAUM	81 C	NP B187 1	+Hertzberger+ (AMST, CERN, CRAC, MPIM, OXF+)
TOAFF	81	PR D23 1500	+Musgrave, Ammar, Davis, Ecklund+ (ANL, KANS)
ETKIN	80	PR D22 42	+Foley, Lindenbaum, Kramer+ (BNL, CUNY) JF
ESTABROOKS	78	NP B133 490	+Carnegie+ (MCGI, CARL, DURH, SLAC)
Also	78B	PR D17 658	Estabrooks, Carnegie+ (MCGI, CARL, DURH+)
JONGEJANS	78	NP B139 383	+Cerrada+ (ZEEM, CERN, NIJM, OXF)
MARTIN		NP B134 392	+Shimada, Baldi, Bohringer+ (DURH, GEVA)
BOWLER	77	NP B126 31	+Dainton, Drake, Williams (OXF)

82B HBC

81C CNTR

 Γ_5/Γ_2

 Γ_7/Γ_2

 Γ_7/Γ_1

 Γ_3/Γ

 Γ_3/Γ_1

 Γ_8/Γ

GOLDBERG HENDRICK LAUSCHER MCCUBBIN DEHM LINGLIN AGUILAR BARNHAM CORDS BASSOMPIE BISHOP CRENNELL DAVIS LIND SCHWEING AISO BASSANO FIELD BADIER	76 75 75 74 73 71B 71C 71 69 69 69 69 69 67 67 67 67	LNC 17 253 NP B112 189 NP B86 189 NP B86 187 NP B75 47 NP B75 408 NP B25 408 NP B28 171 PR D4 1974 NP B13 189 NP B9 403 PRL 22 487 PRL 22 487 PRL 23 1071 PR 104 11 PR 166 1317 Thesis PRL 19 968 PL 24 8 638 PL 24 8 638	+ Otter, Wiczorek+ (ABCLV Collab.) JP Lyons (OXF) +Goebel, Wittek+ (MPIM, BRUX, MONS, CERN) (CERN) Aguilar-Benitez, Eisner, Kinson (BNL) +Colley, Jobes, Griffiths, Hughes+ (PURD, UCD, IUPU) Bassompierre+ (PURD, UCD, IUPU) Bassompierre+ (WISC) +Goshaw, Erwin, Walker (RISC) +Karshon, Lai, O'Neall, Scarr (BNL) +Derenzo, Flatte, Garnjost, Lynch, Solmitz (LRL) +Alexander, Firstene, Fu, Goldhaber (LRL)
			OTHER RELATED PAPERS ———
ATKINSON BAUBILLIER CHUNG FOCARDI HAQUE HARDY	86 82B 65 65 65 65	ZPHY C30 52 NP B202 21 PRL 15 325 PL 16 351 PL 14 338 PRL 14 401	21 + (BONN, CERN, GLAS, LANC, MCHS, CURIN+) + (BIRM, CERN, GLAS, MSU, CURIN) +Dahl, Hardy, Hess, Jacobs, Kirz (LRL) +Ranzi, Serra+ (BGNA, SACL) Hague+ +Chung, Dahl, Hess, Kirz, Miller (LRL)
K(14	60)	$I(J^P) = \frac{1}{2}(0^-)$
OMITTED Ob:	FR serve	OM SUM	MARY TABLE partial-wave analysis. Not seen by VERGEEST 79.
			K(1460) MASS
VALUE (MeV)			CUMENT ID TECN CHG COMMENT
\sim 1460 \sim 1400		DAI 1 BR/	owing data for averages, fits, limits, etc. $ullet$ $ullet$ $ullet$ $ullet$ 81c CNTR $-$ 63 $K^-p o K^-2\pi p$ ANDENB 76B ASPK \pm 13 $K^\pm p o K\pi\pi N$ 370). Decay into $K^*(892)\pi$ seen.
			K(1460) WIDTH
<i>VALUE</i> (MeV)	not		CUMENT ID TECN CHG COMMENT
~ 250		DAU 2 BRA	owing data for averages, fits, limits, etc. $ullet$ $ullet$ $ullet$ $ullet$ 81C CNTR $-$ 63 $K^-p \to K^-2\pi p$ ANDENB 76B ASPK \pm 13 $K^\pm p \to K\pi\pi N$ 370). Decay into $K^*(892)\pi$ seen.
\sim 250		DAU 2 BRA	UM 81C CNTR $-$ 63 $K^-p \rightarrow K^-2\pi p$ ANDENB 76B ASPK \pm 13 $K^{\pm}p \rightarrow K\pi\pi N$
\sim 250	main	DAU 2 BRA	UM 81C CNTR $-$ 63 $K^-p \rightarrow K^-2\pi p$ ANDENB 768 ASPK \pm 13 $K^{\pm}p \rightarrow K\pi\pi N$ 370). Decay into $K^*(892)\pi$ seen.
~ 250 $^{2} \text{ Coupled}$ $\qquad \qquad $	main : :	DAI 2 BR $^{\prime}$ By to $^{\prime}$ $^{\prime}$ $^{\prime}$ $^{\prime}$ $^{\prime}$	UM 81C CNTR $-$ 63 $K^-p \rightarrow K^-2\pi p$ ANDENB 768 ASPK \pm 13 $K^{\pm}p \rightarrow K\pi\pi N$ 370). Decay into $K^*(892)\pi$ seen.
\sim 250 ² Coupled Mode $\Gamma_1 \qquad K^*(8)$ $\Gamma_2 \qquad K \rho$	main : :	DAU 2 BRA 4 ly to $Kf_0(13)$ π	UM 81C CNTR $-$ 63 $K^-p \rightarrow K^-2\pi p$ ANDENB 768 ASPK \pm 13 $K^{\pm}p \rightarrow K\pi\pi N$ 370). Decay into $K^*(892)\pi$ seen.
~ 250 2 Coupled Mode $\Gamma_1 K^*(8)$ $\Gamma_2 K \rho$ $\Gamma_3 K_0^*(1)$ $\Gamma(K^*(892))$	main 392)	DAI 2 BRA 19 to $K f_0(13)$	UM 81C CNTR $-$ 63 $K^-p \rightarrow K^-2\pi p$ ANDENB 768 ASPK \pm 13 $K^{\pm}p \rightarrow K\pi\pi N$ 370). Decay into $K^*(892)\pi$ seen. $K(1460) \ DECAY \ MODES$
$\begin{array}{c} \sim 250 \\ 2 \text{Coupled} \end{array}$	main 2.8892). 1430 π)	DAI $_2$ BR $_4$ BR $_5$ BY to $_6$ $_6$ $_1$ $_2$ $_3$ $_4$ $_4$ $_5$ $_6$ $_7$ $_8$ $_8$ $_8$ $_8$ $_8$ $_8$ $_8$ $_8$	UM 81C CNTR $-$ 63 $K^-p \rightarrow K^-2\pi p$ ANDENB 768 ASPK \pm 13 $K^{\pm}p \rightarrow K\pi\pi N$ 370). Decay into $K^*(892)\pi$ seen. K(1460) DECAY MODES
$\begin{array}{c} \sim 250 \\ 2 \text{ Coupled} \end{array}$ $\begin{array}{c} \text{Mode} \\ -1 & K^*(8) \\ 2 & K \rho \\ -3 & K_0^*(1) \end{array}$ $\begin{array}{c} -(K^*(892)) \\ \text{MALUE (MeV)} \\ \bullet \bullet \text{ We do} \end{array}$	main 2.8892). 1430 π)	DAI $_2$ BR $_4$ BR $_5$ BY to $_6$ $_6$ $_1$ $_2$ $_3$ $_4$ $_4$ $_5$ $_6$ $_7$ $_8$ $_8$ $_8$ $_8$ $_8$ $_8$ $_8$ $_8$	UM 81C CNTR $-$ 63 $K^-p \rightarrow K^-2\pi p$ ANDENB 768 ASPK \pm 13 $K^{\pm}p \rightarrow K\pi\pi N$ 370). Decay into $K^*(892)\pi$ seen. K(1460) DECAY MODES K(1460) PARTIAL WIDTHS Towns of the following data for averages, fits, limits, etc. • • •
Mode $ \begin{array}{ccc} & & & & \\ & & $	main 2.8892). 1430 π)	DAI $_2$ BR $_4$ BY to $_6$ $_1$ $_2$ DAI use the folice DAI	UM 81c CNTR $-$ 63 $K^-p \rightarrow K^-2\pi p$ ANDENB 768 ASPK \pm 13 $K^{\pm}p \rightarrow K\pi\pi N$ 370). Decay into $K^*(892)\pi$ seen. K(1460) DECAY MODES K(1460) PARTIAL WIDTHS Tecn Comment owing data for averages, fits, limits, etc. • • • • • • • • • • • • • • • • • • •
~ 250 $^{2} \text{ Coupled}$	main 8892) 1430 π) not	DAI $_2$ BR $_4$ BY to $_6$ $_1$ $_2$ BR $_4$ $_3$ $_4$ $_4$ $_4$ $_5$ $_4$ $_5$ $_4$ $_5$ $_5$ $_6$ $_7$ $_8$ $_8$ $_7$ use the folic DAI $_8$	UM 81c CNTR $-$ 63 $K^-p \rightarrow K^-2\pi p$ ANDENB 768 ASPK \pm 13 $K^{\pm}p \rightarrow K\pi\pi N$ 370). Decay into $K^*(892)\pi$ seen. K(1460) DECAY MODES K(1460) PARTIAL WIDTHS TECN COMMENT Owing data for averages, fits, limits, etc. • • • • UM 81c CNTR 63 $K^-p \rightarrow K^-2\pi p$
Mode Mode Γ_1 $K^*(8)$ Γ_2 K_ρ Γ_3 $K_0^*(1)$ $\Gamma(K^*(892))$ $VALUE (MeV)$	main 8892) 1430 π) not	DAI $_2$ BR $_4$ BY to $_6$ $_1$ $_2$ BR $_4$ $_3$ $_4$ $_4$ $_4$ $_5$ $_4$ $_5$ $_4$ $_5$ $_5$ $_6$ $_7$ $_8$ $_8$ $_7$ use the folic DAI $_8$	UM 81C CNTR $-$ 63 $K^-p \rightarrow K^-2\pi p$ ANDENB 768 ASPK \pm 13 $K^{\pm}p \rightarrow K\pi\pi N$ 370). Decay into $K^*(892)\pi$ seen. K(1460) DECAY MODES K(1460) PARTIAL WIDTHS CUMENT ID TECN COMMENT owing data for averages, fits, limits, etc. • • • UM 81C CNTR 63 $K^-p \rightarrow K^-2\pi p$ CUMENT ID TECN COMMENT owing data for averages, fits, limits, etc. • • •
~ 250 $^{2} \text{Coupled}$ Mode $\Gamma_{1} K^{*}(\mathbf{E})$ $\Gamma_{2} K \rho$ $\Gamma_{3} K_{0}^{*}(\mathbf{I})$ $\Gamma(K^{*}(892))$ $VALUE (MeV)$ • • • We do ~ 109 $\Gamma(K \rho)$ $VALUE (MeV)$ • • • We do ~ 34 $\Gamma(K_{0}^{*}(1430))$	main $\frac{1}{2}$	DAL 2 BR $^{\prime\prime}$ BR $^{\prime\prime}$ by to $^{\prime\prime}$ $^{\prime\prime}$ $^{\prime\prime}$ $^{\prime\prime}$ $^{\prime\prime}$ use the folic DAL DAL DAL	UM 81c CNTR $-$ 63 $K^-p \rightarrow K^-2\pi p$ ANDENB 768 ASPK \pm 13 $K^{\pm}p \rightarrow K\pi\pi N$ 370). Decay into $K^*(892)\pi$ seen. K(1460) DECAY MODES K(1460) PARTIAL WIDTHS TECN COMMENT OWING data for averages, fits, limits, etc. • • • UM 81c CNTR 63 $K^-p \rightarrow K^-2\pi p$ TOWING data for averages, fits, limits, etc. • • • UM 81c CNTR 63 $K^-p \rightarrow K^-2\pi p$ TOWING data for averages, fits, limits, etc. • • • UM 81c CNTR 63 $K^-p \rightarrow K^-2\pi p$
~ 250 $^{2} \text{Coupled}$	main $\frac{1}{392}$ $\frac{\pi}{1430}$ $\frac{\pi}{1430}$ $\frac{\pi}{1430}$ $\frac{\pi}{1430}$ $\frac{\pi}{1430}$	DAI 2 BR/	UM 81c CNTR $-$ 63 $K^-p \rightarrow K^-2\pi p$ ANDENB 768 ASPK \pm 13 $K^{\pm}p \rightarrow K\pi\pi N$ 370). Decay into $K^*(892)\pi$ seen. K(1460) DECAY MODES K(1460) PARTIAL WIDTHS TECN COMMENT Owing data for averages, fits, limits, etc. • • • UM 81c CNTR 63 $K^-p \rightarrow K^-2\pi p$ TOWING data for averages, fits, limits, etc. • • • UM 81c CNTR 63 $K^-p \rightarrow K^-2\pi p$ TOWING data for averages, fits, limits, etc. • • • UM 81c CNTR 63 $K^-p \rightarrow K^-2\pi p$
Mode $ \Gamma_{1} K^{*}(\mathbb{E}) $ $ \Gamma_{2} K \rho $ $ \Gamma_{3} K_{0}^{*}(\mathbb{I}) $ $ \Gamma(K^{*}(892) $ $ VALUE (MeV) $ • • • We do $ \sim 109 $ $ \Gamma(K \rho) $ $ VALUE (MeV) $ • • • We do $ \sim 34 $ $ \Gamma(K_{0}^{*}(1430) $ $ VALUE (MeV) $ $ VALUE (MeV) $	main $\frac{1}{392}$ $\frac{\pi}{1430}$ $\frac{\pi}{1430}$ $\frac{\pi}{1430}$ $\frac{\pi}{1430}$ $\frac{\pi}{1430}$	DAI 2 BR/	UM 81c CNTR $-$ 63 $K^-p \rightarrow K^-2\pi p$ ANDENB 768 ASPK \pm 13 $K^{\pm}p \rightarrow K\pi\pi N$ 370). Decay into $K^*(892)\pi$ seen. K(1460) DECAY MODES K(1460) PARTIAL WIDTHS CUMENT ID TECN COMMENT Owing data for averages, fits, limits, etc. • • • UM 81c CNTR 63 $K^-p \rightarrow K^-2\pi p$ CUMENT ID TECN COMMENT Owing data for averages, fits, limits, etc. • • • UM 81c CNTR 63 $K^-p \rightarrow K^-2\pi p$ CUMENT ID TECN COMMENT OWING data for averages, fits, limits, etc. • • • UM 81c CNTR 63 $K^-p \rightarrow K^-2\pi p$
~ 250 $^{2} \text{Coupled}$	main $\frac{1}{392}$ π π not 0 not	DAI $_2$ BR/ $_3$ BR/ $_4$ BR/ $_5$ BR/	UM 81c CNTR $-$ 63 $K^-p \rightarrow K^-2\pi p$ ANDENB 768 ASPK \pm 13 $K^{\pm}p \rightarrow K\pi\pi N$ 370). Decay into $K^*(892)\pi$ seen. K(1460) DECAY MODES K(1460) PARTIAL WIDTHS TECN COMMENT Owing data for averages, fits, limits, etc. • • • UM 81c CNTR 63 $K^-p \rightarrow K^-2\pi p$ TOWING data for averages, fits, limits, etc. • • • UM 81c CNTR 63 $K^-p \rightarrow K^-2\pi p$ TOWING B1c CNTR 63 $K^-p \rightarrow K^-2\pi p$ TOWING data for averages, fits, limits, etc. • • • UM 81c CNTR 63 $K^-p \rightarrow K^-2\pi p$ TOWING data for averages, fits, limits, etc. • • • UM 81c CNTR 63 $K^-p \rightarrow K^-2\pi p$ TOWING data for averages, fits, limits, etc. • • •
~ 250 $^{2} \text{Coupled}$	main $\frac{1}{100}$	DAI $_2$ BR/ $_3$ BR/ $_4$ BR/ $_5$ BR/	UM 81c CNTR $-$ 63 $K^-p \rightarrow K^-2\pi p$ ANDENB 768 ASPK \pm 13 $K^{\pm}p \rightarrow K\pi\pi N$ 370). Decay into $K^*(892)\pi$ seen. K(1460) DECAY MODES K(1460) PARTIAL WIDTHS TECN COMMENT Owing data for averages, fits, limits, etc. • • • UM 81c CNTR 63 $K^-p \rightarrow K^-2\pi p$ TOWING data for averages, fits, limits, etc. • • • UM 81c CNTR 63 $K^-p \rightarrow K^-2\pi p$ TOWING data for averages, fits, limits, etc. • • • UM 81c CNTR 63 $K^-p \rightarrow K^-2\pi p$ TOWING data for averages, fits, limits, etc. • • • UM 81c CNTR 63 $K^-p \rightarrow K^-2\pi p$ TOWING data for averages, fits, limits, etc. • • • UM 81c CNTR 63 $K^-p \rightarrow K^-2\pi p$ K(1460) REFERENCES +Hertzberger+ (AMST, CERN, CRAC, MPIM, OXF+)
~ 250 $^{2} \text{Coupled}$	main $\frac{1}{100}$	DAI $_2$ BR/ $_3$ by to $_4$ $_6$ (13) $_4$ $_7$ $_6$ $_7$ $_8$ $_7$ $_8$ $_8$ $_8$ $_9$ $_9$ $_9$ $_9$ $_9$ $_9$ $_9$ $_9$	UM 81c CNTR $-$ 63 $K^-p \rightarrow K^-2\pi p$ ANDENB 768 ASPK \pm 13 $K^{\pm}p \rightarrow K\pi\pi N$ 370). Decay into $K^*(892)\pi$ seen. K(1460) DECAY MODES K(1460) PARTIAL WIDTHS CUMENT ID TECN COMMENT Owing data for averages, fits, limits, etc. • • • UM 81c CNTR 63 $K^-p \rightarrow K^-2\pi p$ CUMENT ID TECN COMMENT Owing data for averages, fits, limits, etc. • • • UM 81c CNTR 63 $K^-p \rightarrow K^-2\pi p$ CUMENT ID TECN COMMENT Owing data for averages, fits, limits, etc. • • • UM 81c CNTR 63 $K^-p \rightarrow K^-2\pi p$ CUMENT ID TECN COMMENT Owing data for averages, fits, limits, etc. • • • UM 81c CNTR 63 $K^-p \rightarrow K^-2\pi p$ K(1460) REFERENCES + Hertzberger+ + Jongejans, Dionisi+ (MIJM, AMST, CERN, CRAC, MPIM, OXF+) + Jongejans, Dionisi+ (MIJM, AMST, CERN, CRAC, MPIM, OXF+)

$K_2(1580)$

$$I(J^P) = \frac{1}{2}(2^-)$$

OMITTED FROM SUMMARY TABLE

Seen in partial-wave analysis of the $K^-\pi^+\pi^-$ system. Needs confirmation.

K2(1580) MASS

VALUE (MeV) DOCUMENT ID CHG COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • ~ 1580 OTTER 10,14,16 K⁻ p

K₂(1580) WIDTH

DOCUMENT ID CHG COMMENT VALUE (MeV) \bullet $\,\bullet\,$ We do not use the following data for averages, fits, limits, etc. $\,\bullet\,$ $\,\bullet\,$ $\sim 110\,$ 79 – 10,14,16 K⁻ p

K2(1580) DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ	K*(892)π	seen
Γ_2	$K_2^*(1430)\pi$	possibly seen

K2(1580) BRANCHING RATIOS

$\Gamma(K^*(892)\pi)/\Gamma_{\text{total}}$						Γ_1/Γ
VALUE	DOCUMENT ID		TECN	CHG	COMMENT	
seen	OTTER	79	HBC	_	10,14,16 K^-p	
$\Gamma(K_2^*(1430)\pi)/\Gamma_{\text{total}}$	ai					Γ_2/Γ
VALUE	DOCUMENT ID		TECN	CHG	COMMENT	
possibly seen	OTTER	79	HBC	_	10,14,16 K ⁻ p	

K2(1580) REFERENCES

79 NP B147 1 +Rudolph+ OTTER (AACH3, BERL, CERN, LOIC, WIEN) JP



$$I(J^P) = \frac{1}{2}(1^+)$$

OMITTED FROM SUMMARY TABLE

This entry contains various peaks in strange meson systems ($K^+\phi$, $K\pi\pi$) reported in partial-wave analysis in the 1600–1900 mass re-

K1(1650) MASS

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
1650±50	FRAME	86	OMEG	+	13 $K^+ p \rightarrow \phi K^+ p$
 • • We do not use the 	following data	for a	verages,	fits, li	mits, etc. • • •
\sim 1840	ARMSTRONG	83	OMEG	_	$18.5 K^- p \rightarrow 3Kp$
\sim 1800	DAUM	81C	CNTR	***	$63~K^-~p~\rightarrow~K^-~2\pi~p$

K1(1650) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT	
150 ± 50	FRAME	86	OMEG	+	13 $K^+ \rho \rightarrow \phi K^+ \rho$	
• • • We do not use the	following data	for a	verages,	fits, li	mits, etc. • • •	
~ 250	DAUM	81C	CNTR	-	$63~K^-~p~\rightarrow~K^-~2\pi~p$	

K1(1650) DECAY MODES

Mode				
Κππ Κφ				

K₁(1650) REFERENCES

FRAME	86	NP	B276	667	+Hughes, Lynch,	Minto, McFadzean+	(GLAS)
ARMSTRONG	83	NP	B221	1	+	(BARI, BIRM, CERN, MILA,	CURIN+)
DAUM	81C	NP	B187	1	+Hertzberger+	(AMST, CERN, CRAC, MPIN	1, OXF+)

 $K^*(1680), K_2(1770)$



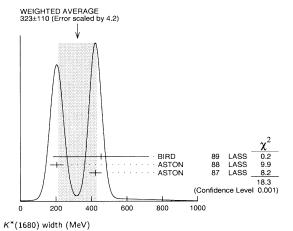
$$I(J^P) = \frac{1}{2}(1^-)$$

K*(1680) MASS

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
1714 ± 20 OUR AVER					
1678 ± 64					11 $K^- \rho \rightarrow \overline{K}{}^0 \pi^- \rho$
$1677 \pm 10 \pm 32$	ASTON	88	LASS	0	11 $K^-p \rightarrow K^-\pi^+n$
$1735 \pm 10 \pm 20$	ASTON	87	LASS	0	11 K ⁻ p $\rightarrow \overline{K}^0 \pi^+ \pi^- n$
• • • We do not use the	following data	for a	verages,	fits, li	mits, etc. • • •
$^{1800\pm70}_{\sim1650}$	ETKIN ESTABROOKS		MPS ASPK		$ \begin{array}{ccc} 6 & K^{-} p \rightarrow \overline{K}^{0} \pi^{+} \pi^{-} n \\ 13 & K^{\pm} p \rightarrow K^{\pm} \pi^{\pm} n \end{array} $

K*(1680) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
323±110 OUR AVERAG	E Error include	s sca	ale facto	r of 4.2	2. See the ideogram below.
454 ± 270					11 $K^- \rho \rightarrow \overline{K}{}^0 \pi^- \rho$
205± 16±34					$11 K^- \rho \rightarrow K^- \pi^+ n$
423± 18±30	ASTON	87	LASS	0	11 $K^- p \rightarrow \overline{K}^0 \pi^+ \pi^- n$
• • • We do not use the	following data f	or a	verages,	fits, lir	nits, etc. • • •
170± 30			MPS	0	$6 K^- p \rightarrow \overline{K}^0 \pi^+ \pi^- n$
250 to 300	ESTABROOKS	78	ASPK.	0	13 $K^{\pm} p \rightarrow K^{\pm} \pi^{\pm} n$



K*(1680) DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ ₁	Κπ	(38.7 ± 2.5) %
Γ_2	$K\rho$	$(31.4^{+4.7}_{-2.1})$ %
Γ_3	$K^*(892)\pi$	$(29.9^{+2.2}_{-4.7})\%$

CONSTRAINED FIT INFORMATION

An overall fit to 4 branching ratios uses 4 measurements and one constraint to determine 3 parameters. The overall fit has a $\chi^2=2.9$ for 2 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\left\langle \delta x_i \delta x_j \right\rangle / (\delta x_i \cdot \delta x_j),$ in percent, from the fit to the branching fractions, $x_i \equiv \Gamma_i / \Gamma_{\rm total}.$ The fit constrains the x_i whose labels appear in this array to sum to one.

$$\begin{array}{c|cccc}
x_2 & -36 \\
x_3 & -39 & -72 \\
\hline
& x_1 & x_2
\end{array}$$

K*(1680) BRANCHING RATIOS

$\Gamma(K\pi)/\Gamma_{\text{total}}$						Γ_1/Γ
VALUE	DOCUMENT ID		TECN	CHG	COMMENT	
0.387±0.026 OUR FIT						
$0.388 \pm 0.014 \pm 0.022$	ASTON	88	LASS	0	11 $K^-p \rightarrow K^-$	π^+ n

$\Gamma(K\pi)/\Gamma(K^*(892)\pi)$)					Γ_1/Γ_3
VALUE	DOCUMENT ID		TECN	CHG	COMMENT	
$1.30^{+0.23}_{-0.14}$ OUR FIT						
2.8 ±1.1	ASTON	84	LASS	0	11 $K^- p \rightarrow \overline{K}^0 2\pi n$	
$\Gamma(K\rho)/\Gamma(K\pi)$						Γ_2/Γ_1
VALUE	DOCUMENT ID		TECN	CHG	COMMENT	
$0.81^{+0.14}_{-0.09}$ OUR FIT						
1.2 ±0.4	ASTON	84	LASS	0	11 $K^- p \rightarrow \overline{K}^0 2\pi n$	
$\Gamma(K\rho)/\Gamma(K^*(892)\pi)$						Γ_2/Γ_3
VALUE	DOCUMENT ID		TECN	CHG	COMMENT	
$^{1.05}^{+0.27}_{-0.11}$ OUR FIT						
$0.97 \pm 0.09 {+0.30 \atop -0.10}$	ASTON	87	LASS	0	11 $K^- \rho \rightarrow \overline{K}^0 \pi^+ \pi$	n

K*(1680) REFERENCES

BIRD	89	SLAC-332		(SLAC)
ASTON	88	NP B296 493	+Awaji, Bienz, Bird+	(SLAC, NAGO, CINC, INUS)
ASTON	87	NP B292 693	+Awaji, D'Amore+	(SLAC, NAGO, CINC, INUS)
ASTON	84	PL 149B 258	+Carnegie, Dunwoodie+	(SLAC, CARL, OTTA) JP
ETKIN	80	PR D22 42	+Foley, Lindenbaum, Kramer-	
ESTABROOKS	78	NP B133 490	+Carnegie+	(MCGI, CARL, DURH, SLAC) JP



VALUE (MeV) EVTS

$$I(J^P) = \frac{1}{2}(2^-)$$

THE $K_2(1770)$ AND THE $K_2(1820)$

A partial-wave analysis of the $K^-\omega$ system based on about 100,000 $K^-p \to K^-\omega p$ events (ASTON 93) gives evidence for two $q\bar{q}$ D-wave states near 1.8 GeV. A previous analysis based on about 200,000 diffractively produced $K^-p \to K^-\pi^+\pi^-p$ events (DAUM 81) gave evidence for two $J^P=2^-$ states in this region, with masses \sim 1780 MeV and \sim 1840 MeV and widths \sim 200 MeV, in good agreement with the results of ASTON 93. In contrast, the masses obtained using a single resonance do not agree well: ASTON 93 obtains 1728 \pm 7 MeV, while DAUM 81 estimates \sim 1820 MeV. We conclude that there are indeed two K_2 resonances here.

We list under the $K_2(1770)$ other measurements that do not resolve the two-resonance structure of the enhancement.

K2(1770) MASS

DOCUMENT ID TECN CHG COMMENT

	1773± 8		¹ ASTON	93	LASS		$11K^- \rho \rightarrow K^- \omega \rho$
^	1780		² DAUM	81 C	CNTR	_	$63~K^-~p~\rightarrow~K^-~2\pi~p$
•	• • We do not use	the follo	wing data for aver	rages	, fits, lin	nits, et	tc. • • •
	1810 ± 20		FRAME	86	OMEG	+	13 $K^+ p \rightarrow \phi K^+ p$
^	1730		ARMSTRONG	83	OMEG	_	$18.5~K^-p \rightarrow ~3Kp$
	1710±15	60	CHUNG	74	HBC	-	$7.3 K^- p \rightarrow K^- \omega p$
	1767± 6		BLIEDEN	72	MMS	-	11-16 K ⁻ p
	1730 ± 20	306	³ FIRESTONE	72B	DBC	+	12 K ⁺ d
	1765 ± 40		⁴ COLLEY	71	HBC	+	$10 K^+ \rho \rightarrow K 2\pi N$
	1740		DENEGRI	71	DBC	-	$12.6 \ K^- d \rightarrow \overline{K} 2\pi d$
	1745 ± 20		AGUILAR	70c	HBC	-	4.6 K ⁻ p
	1780 ± 15		BARTSCH	70C	HBC	_	10.1 K p
	1760 ± 15		LUDLAM	70	HBC	-	12.6 K ⁻ p
	1						

- $^1\,\mathrm{From}$ a partial wave analysis of the $K^-\,\omega$ system.
- 2 From a partial wave analysis of the $K^-2\pi$ system. 3 Produced in conjunction with excited deuteron.
- ⁴ Systematic errors added correspond to spread of different fits.

K2(1770) WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
186±14		⁵ ASTON		LASS		$\frac{11K^-p \to K^-\omega p}{}$
~ 210		⁶ DAUM	81c	CNTR	_	$63~K^-p \rightarrow ~K^-2\pi p$
• • • We do not	use the follo	wing data for ave	rages	, fits, lir	nits, e	tc. • • •
140 ± 40		FRAME	86	OMEG	+	13 $K^+p \rightarrow \phi K^+p$
~ 220		ARMSTRONG	83	OMEG	-	$18.5 K^- p \rightarrow 3K p$
110 ± 50	60	CHUNG	74	HBC	-	$7.3 K^- p \rightarrow K^- \omega p$
100 ± 26		BLIEDEN	72	MMS	_	11-16 K ⁻ p
210 ± 30	306	⁷ FIRESTONE	72B	DBC	+	12 K ⁺ d
90±70		⁸ COLLEY	71	HBC	+	$10 K^+ p \rightarrow K 2\pi N$
130		DENEGRI	71	DBC	-	12.6 $K^-d \rightarrow \overline{K} 2\pi d$
100 ± 50		AGUILAR	70c	HBC	_	4.6 K ⁻ p
138 ± 40		BARTSCH	70c	HBC		10.1 K ⁻ p
$50 + 40 \\ -20$		LUDLAM	70	НВС	-	12.6 K ⁻ p

- 5 From a partial wave analysis of the $K^-\,\omega$ system. 6 From a partial wave analysis of the $K^-\,2\pi$ system.

- 7 Produced in conjunction with excited deuteron.
 8 Systematic errors added correspond to spread of different fits.

K2(1770) DECAY MODES

	Mode	Fraction (Γ_i/Γ)	
1	Κππ		
2	$K_2^*(1430)\pi$	dominant	
3	$K^*(892)\pi$	seen	
4	$K f_2(1270)$	seen	
5	$K\phi$	seen	
ó	$K\omega$	seen	

K2(1770) BRANCHING RATIOS

For discussion of the experimental evidence on other decay modes, see HUGHES 71, SLATTERY 71, EISNER 74.

$\Gamma(K_2^*(1430)\pi)/\Gamma(K\pi\pi)$ $(K_2^*(1430) \to K\pi)$

 Γ_2/Γ_1

DOCUMENT ID	TECN CH	IG COMMENT
ise the following data	for averages, fits	, limits, etc. • • •
DAUM	81c CNTR	$63 K^- p \rightarrow K^- 2\pi p$
⁹ FIRESTONE	72B DBC +	12 K ⁺ d
COLLEY	71 HBC	10 K ⁺ p
AGUILAR	70c HBC -	4.6 K ⁻ p
BARTSCH	70c HBC	10.1 K - p
BARBARO	69 HBC +	12.0 K ⁺ p
	DAUM DAUM FIRESTONE COLLEY AGUILAR BARTSCH	use the following data for averages, fits DAUM 81C CNTR FIRESTONE 728 DBC + COLLEY 71 HBC AGUILAR 70C HBC -

•		⁹ Produced	in	conjunction	with	excited	deuteron.
---	--	-----------------------	----	-------------	------	---------	-----------

Г(K*(89	2)π)/Γ	(Κππ)

 Γ_3/Γ_1

$\Gamma(Kf_2(1270))/\Gamma(K\pi$	π)			Γ_4/Γ_1
~ 0.23	DAUM	81C CNTR	$63~K^-~p~\rightarrow~K^-~2\pi~p$	
ullet $ullet$ We do not use the	following data	for averages,	fits, limits, etc. • • •	
VALUE	DOCUMENT ID		COMMENT	

$\Gamma(K f_2(1270))/\Gamma(K\pi\pi)$ $(f_2(1270) \rightarrow \pi\pi)$ DOCUMENT ID TECN COMMENT

		•	do	not	use	the	following	data	for	averages,	fits,	limits,	etc	. •	• •	•
~	0.	74					DAUM		81	c CNTR	63	К ⁻ р -	→ <i>i</i>	K-	2π	p

$\Gamma(K\phi)/\Gamma_{\text{total}}$	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT	Γ ₅ /Γ
seen	ARMSTRONG 8	83	OMEG	-	18.5 $K^- p \rightarrow K^- \phi N$	
$\Gamma(K\omega)/\Gamma_{\text{total}}$						Г6/Г
VALUE	DOCUMENT ID		TECN	CHG	COMMENT	
seen	OTTER 8	81	нвс	±	8.25,10,16 K [±] p	
seen	CHUNG 7	74	нвс		$7.3 K^- p \rightarrow K^- \omega p$	

K₂(1770) REFERENCES

ASTON	93	PL B308 186	+Bienz, Bird+ (SLAC, NAGO, CINC, INUS)	
FRAME	86	NP B276 667	+Hughes, Lynch, Minto, McFadzean+ (GLAS)	,
ARMSTRONG	83	NP B221 1	+ (BARI, BIRM, CERN, MILA, CURIN+)	
DAUM	81 C	NP B187 1	+Hertzberger+ (AMST, CERN, CRAC, MPIM, OXF+)	
OTTER	81	NP B181 1	(AACH3, BERL, LOIC, VIEN, BIRM, BELG, CERN+)	
CHUNG	74	PL 51B 413	+Eisner, Protopopescu, Samios, Strand (BNL)	
EISNER	74	Boston Conf. 140	(BNL)	
BLIEDEN	72	PL 39B 668	+Finocchiaro, Bowen, Earles+ (STON, NEAS)	
FIRESTONE	72B	PR D5 505	+Goldhaber, Lissauer, Trilling (LBL)	
COLLEY	71	NP B26 71	+ Jobes, Kenyon, Pathak, Hughes+ (BIRM, GLAS)	
DENEGRI	71	NP B28 13	+Antich, Callahan, Carson, Chien, Cox+ (JHU)	JP
HUGHES	71	Bologna Conf. 29:	(ĠLAS)	
SLATTERY	71	UR-875-332	(ROCH)	
AGUILAR	70C	PRL 25 54	Aguilar-Benitez, Barnes, Bassano, Chung+ (BNL)	
BARTSCH	70C	PL 33B 186	+Deutschmann+ (AACH, BERL, CERN, LOIC, VIEN)	
LUDLAM	70	PR D2 1234	+Sandweiss, Slaughter (YALE)	
BARRARO.	60	DDI 22 1207	Barbaro Galtieri Davis Flatte I (1911)	

OTHER RELATED PAPERS -

BERLINGHIERI 67	PRL 18 1087	+Farber, Ferbel, Forman	(ROCH)
CARMONY 67	PRL 18 615	+Hendricks, Lander	(UCSD)
JOBES 67	PL 26B 49	+Bassompierre, DeBaere+	(BIRM, CERN, BRUX)
BARTSCH 66	PL 22 357	+Deutschmann+	(AACH, BERL, CERN+)

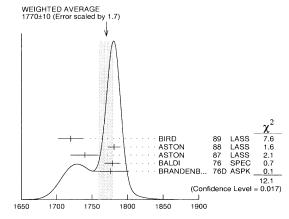
 $K_3^*(1780)$

 $I(J^P) = \frac{1}{2}(3^-)$

K*(1780) MASS

VALUE (MeV)	EVTS	DOCUMENT ID	TECN CHG	COMMENT
1770±10 OUR A	VERAGE	Error includes scale fact	or of 1.7. See	the ideogram below.
$1720 \pm 10 \pm 15$	6111		LASS	11 $K^- \rho \rightarrow \overline{K}^0 \pi^- \rho$
$1781 \pm 8 \pm 4$		² ASTON 88	LASS 0	11 $K^- p \rightarrow K^- \pi^+ n$
$1740 \pm 14 \pm 15$		² ASTON 87	LASS 0	11 K ⁻ p →
		2		$\overline{K}^0\pi^+\pi^-\eta_0$
1779 ± 11			SPEC +	$10 K^+ p \rightarrow K^0 \pi^+ p$
1776 ± 26		⁴ BRANDENB 76D	ASPK 0	13 $K^{\pm} p \rightarrow K^{\pm} \pi^{\mp} N$
• • • We do not	use the fo	llowing data for averages	, fits, limits, e	tc. • • •
1749 ± 10		ASTON 88B	LASS -	11 $K^- p \rightarrow K^- \eta p$
1780 ± 9	300	BAUBILLIER 84B	HBC -	8.25 $K^-p \rightarrow$
				$\overline{\kappa}^0 \pi^- \rho$
1790 ± 15		BAUBILLIER 82B	HBC 0	8.25 $K^-p \rightarrow$
				$K_S^0 2\pi N$
1784 ± 9	2060	CLELAND 82	SPEC ±	$50 \ K^{+} p \rightarrow K_{S}^{0} \pi^{\pm} p$
1786 ± 15		⁵ ASTON 81D	LASS 0	$11 K^- \rho \rightarrow K^- \pi^+ n$
1762± 9	190	TOAFF 81	HBC -	$6.5 K^- p \rightarrow \overline{K}{}^0 \pi^- p$
1850 ± 50		ETKIN 80	MPS 0	$6 K^- \rho \rightarrow \overline{K}{}^0 \pi^+ \pi^-$
1812 ± 28		BEUSCH 78	OMEG	10 $K^-p \rightarrow$
				$\overline{K}^0\pi^+\pi^-n$
1786± 8		CHUNG 78	MPS 0	$6 K^- p \rightarrow K^- \pi^+ n$

- $^{1}_{\circ}$ From a partial wave amplitude analysis.
- From a fit to Y_6^2 moment. $J^P = 3^-$ found.
- 4 Confirmed by phase shift analysis of ESTABROOKS 78, yields $J^P=3^-$. 5 From a fit to the Y^0_6 moment.



 $K_3^*(1780)$ mass (MeV)

K*(1780) WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
164±17 OUR	AVERAGE	Error includes sca	le fa	ctor of 1	.1.	
$187 \pm 31 \pm 20$	6111	⁶ BIRD	89	LASS		11 $K^- p \rightarrow \overline{K}^0 \pi^- p$
$203 \pm 30 \pm 8$		⁷ ASTON	88	LASS	0	11 $K^-p \rightarrow K^-\pi^+n$
$171 \pm 42 \pm 20$		⁷ ASTON	87	LASS	0	
		_				$\frac{\overline{K}^0\pi^+\pi^-}{10}\frac{\pi^+\pi^-}{K^0\pi^+\rho}$
135 ± 22		⁸ BALDI	76	SPEC	+	$10 K^+ p \rightarrow K^0 \pi^+ p$
• • • We do not	use the foll	lowing data for ave	rage	, fits, li	mits, e	tc. • • •
193 + 51		ASTON	000	LASS		11 K= a K=a
$\frac{193}{-37}$		ASTON	888	LASS		11 $K^- p \rightarrow K^- \eta p$
99 ± 30	300	BAUBILLIER	84B	HBC	-	8.25 K ⁻ p →
						$\overline{\kappa}{}^0\pi^-\rho$
\sim 130		BAUBILLIER	82B	HBC	0	8.25 $K^-p \rightarrow$
						$K_{S}^{0} 2\pi N$
191 ± 24	2060	CLELAND	82	SPEC	\pm	$50 K^{+} p \rightarrow K_{5}^{0} \pi^{\pm} p$
225 ± 60		9 ASTON	810	LASS	0	11 $K^- p \rightarrow K^- \pi^+ n$

$K_3^*(1780), K_2(1820)$

~ 80	190	TOAFF	81	нвс		6.5 $K^-p \rightarrow \overline{K}^0\pi^-p$
240 ± 50		ETKIN	80	MPS	0	$6 K^- p \rightarrow \overline{K}^0 \pi^+ \pi^-$
181 ± 44		¹⁰ BEUSCH	78	OMEG		10 $K^-p \rightarrow$
						$\overline{K}^0 \pi^+ \pi^- n$
96 ± 31		CHUNG	78	MPS	0	$6 K^- p \rightarrow K^- \pi^+ n$
270 ± 70		¹¹ BRANDENB	76D	ASPK	0	13 $K^{\pm} p \rightarrow K^{\pm} \pi^{\mp} N$

K*(1780) DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Scale factor/ Confidence level
Γ_1	Kρ	(45 ±4)%	S=1.4
Γ_2	$K^*(892)\pi$	(27.3±3.2) %	S=1.5
Γ_3	$K\pi$	(19.3±1.0) %	
Γ_4	$K\eta$	(8.0 ± 1.5) %	S=1.4
Γ ₅	$K_2^*(1430)\pi$	< 21 %	CL=95%

CONSTRAINED FIT INFORMATION

An overall fit to 4 branching ratios uses 5 measurements and one constraint to determine 4 parameters. The overall fit has a χ^2 = 2.2 for 2 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\left\langle \delta x_i \delta x_j \right\rangle / (\delta x_i \cdot \delta x_j),$ in percent, from the fit to the branching fractions, $x_i \equiv \Gamma_i / \Gamma_{\rm total}.$ The fit constrains the x_i whose labels appear in this array to sum to

K*(1780) BRANCHING RATIOS

		3(178U) BF					
$\Gamma(K\rho)/\Gamma(K^*(89))$	$2)\pi)$						Γ_1/Γ_1
VALUE	<u>D</u> (CUMENT ID		TECN	CHG	COMMENT	
1.66 ± 0.31 OUR FI	F Erro	includes sca	le fa	ctor of 1			
$1.52 \pm 0.21 \pm 0.10$	A	STON	87	LASS	0	11 $K^- \rho \rightarrow \overline{K}^0 \pi^+ \tau$	$\tau^- n$
Γ (K*(892) π)/Γ((κπ)						Γ_2/Γ_1
VALUE		CUMENT ID		TECN	CHG	COMMENT	
1.42 ± 0.19 OUR FI	F Erro	includes sca	le fa	ctor of 1	.4.		
1.09±0.26	A:	STON	84B	LASS	0	11 $K^- \rho \rightarrow \overline{K}^0 2\pi n$	
$\Gamma(K\pi)/\Gamma_{total}$							Γ ₃ /
VALUE	DO	CUMENT ID		TECN	CHG	COMMENT	
0.193±0.010 OUR	FIT						
0.188±0.010 OUR	AVERAC	Ε					
$0.187 \pm 0.008 \pm 0.009$	8 A:	STON	88	LASS	0	11 $K^- p \rightarrow K^- \pi^+$	n
0.19 ±0.02	ES	STABROOKS	78	ASPK	0	13 $K^{\pm} p \rightarrow K \pi N$	
$\Gamma(K\eta)/\Gamma(K\pi)$							Γ4/Γ
VALUE	Do	CUMENT ID		TECN	CHG	COMMENT	
0.41 ± 0.07 OUR F	IT Err	or includes sc	ale f	actor of	1.5.		
0.41 ± 0.050	12 BI	RD	89	LASS	-	11 $K^- \rho \rightarrow \overline{K}^0 \pi^- \rho$	9
• • • We do not us	se the fo	llowing data	for a	verages,	fits, li	imits, etc. • • •	
0.50 ± 0.18	A	STON	88B	LASS		$11~K^-\rho \to~K^-\eta\rho$	
12 This result supe	rsedes A	STON 88B.					
$\Gamma(K_2^*(1430)\pi)/\Gamma$	(K*(8	92)π)					Γ ₅ /Γ
VALUE	CL%	DOCUMEN	T ID		ECN	CHG COMMENT	
<0.78	95	ASTON		87 L	ASS	0 11 $K^-p \rightarrow$	
						$\overline{K}^0\pi^+\pi^-n$	

K*(1780) REFERENCES

BIRD	89	SLAC-332	(SLAC)
ASTON	88	NP B296 493	+Awaji, Bienz, Bird+ (SLAC, NAGO, CINC, INUS)
ASTON	88B	PL B201 169	+Awaji, Bienz+ (SLAC, NAGO, CINC, INUS) JP
ASTON	87	NP B292 693	+Awaji, D'Amore+ (SLAC, NAGO, CINC, INUS)
ASTON	84B	NP B247 261	+Carnegie, Dunwoodie+ (SLAC, CARL, OTTA)
BAUBILLIER	84B	ZPHY C26 37	+ (BIRM, CERN, GLAS, MICH, CURIN)
BAUBILLIER	82B	NP B202 21	+ (BIRM, CERN, GLAS, MSU, CURIN)
CLELAND	82	NP B208 189	+Delfosse, Dorsaz, Gloor (DURH, GEVA, LAUS, PITT)
ASTON	81D	PL 99B 502	+Dunwoodie, Durkin, Fieguth+ (SLAC, CARL, OTTA) JP
TOAFF	81	PR D23 1500	+Musgrave, Ammar, Davis, Ecklund+ (ANL, KANS)
ETKIN	80	PR D22 42	+Foley, Lindenbaum, Kramer+ (BNL, CUNY) JP
BEUSCH	78	PL 74B 282	+Birman, Konigs, Otter+ (CERN, AACH3, ETH) JP
CHUNG	78	PRL 40 355	+Etkin+ (BNL, BRAN, CUNY, MASA, PENN) JP
ESTABROOKS	78	NP B133 490	+Carnegie+ (MCGI, CARL, DURH, SLAC) JP
Also	78B	PR D17 658	Estabrooks, Carnegie+ (MCGI, CARL, DURH+)
BALDI	76		+Boehringer, Dorsaz, Hungerbuhler+ (GEVA) JP
BRANDENB	76D	PL 60B 478	Brandenburg, Carnegie, Cashmore+ (SLAC) JP

OTHER RELATED PAPERS -

AGUILAR	73	PRL 30 672	Aguilar-Benitez, Chung, Eisner+	(BNL)
WALUCH	73	PR D8 2837	+Flatte, Friedman	(LBL)
CARMONY	71	PRL 27 1160	+Cords, Clopp, Erwin, Meiere+ (PURD, U	CD, IÙPU)
FIRESTONE	71	PL 36B 513	+Goldhaber, Lissauer, Trilling	(LBL)



$$I(J^P) = \frac{1}{2}(2^-)$$

Observed by ASTON 93 from a partial wave analysis of the $K^-\,\omega$ system. See mini-review under $K_2(1770)$. Needs confirmation.

K2(1820) MASS

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
1816±13	1 ASTON	93 LASS	$11K^-p \rightarrow K^-\omega p$
~ 1840	² DAUM	81C CNTR	$63 K^- p \rightarrow K^- 2\pi p$

 $^{^1\,\}mathrm{Fron}$ a partial wave analysis of the $K^-\,\omega$ system.

K2(1820) WIDTH

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
276±35	³ ASTON	93 LASS	$11K^-p \rightarrow K^-\omega p$
~ 230	4 DALIM	81C CNTR	$63 K^{-} D \rightarrow K^{-} 2\pi D$

 $^{^3}$ Fron a partial wave analysis of the $\mathcal{K}^-\,\omega$ system.

K2(1820) DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ ₁	$K\phi$	possibly seen
Γ_2	Κππ	
Γ_3	$K_2^*(1430)\pi$	seen
Γ_4	$K^{*}(892)\pi$	seen
Γ_5	$K f_2(1270)$	seen
Γ_6	$K\omega$	seen

K2(1820) BRANCHING RATIOS

$\Gamma(K_2^*(1430)\pi)/\Gamma(K\pi\pi)$					Γ_3/Γ_2
VALUE	DOCUMENT ID		TECN	COMMENT	
• • • We do not use the following	data for average	s, fits	, limits,	etc. • • •	
~ 0.77	DAUM	810	CNTR	$63K^-p \rightarrow$	$\overline{K} 2\pi p$
$\Gamma(K^*(892)\pi)/\Gamma(K\pi\pi)$					Γ_4/Γ_2
VALUE	DOCUMENT ID		TECN	COMMENT	
	data for average	s, fits	, limits,	etc. • • •	
~ 0.05	DAUM	810	CNTR	$63K^-p \rightarrow$	$\overline{K} 2\pi p$
$\Gamma(K f_2(1270))/\Gamma(K\pi\pi)$					Γ_5/Γ_2
VALUE	DOCUMENT ID		TECN	COMMENT	
• • • We do not use the following	data for average	s, fits	, limits,	etc. • • •	
~ 0.18	DAUM	81C	CNTR	$63K^-p \rightarrow$	$\overline{K} 2\pi p$

K2(1820) REFERENCES

ASTON	PL B308 186	+Bienz, Bird+	(SLAC, NAGO, CINC, INUS)
DAUM	NP B187 1	+Hertzberger+	(AMST, CERN, CRAC, MPIM, OXF+)

⁶ From a partial wave amplitude analysis. 7 From energy-independent partial-wave analysis. 8 From a fit to Y_2^2 moment. $J^P=3^-$ found. 9 From a fit to Y_2^0 moment.

 $^{^{10}}$ Errors enlarged by us to 4F/ \sqrt{N} ; see the note with the $K^*(892)$ mass. 11 ESTABROOKS 78 find that BRANDENBURG 76D data are consistent with 175 MeV width. Not averaged.

 $^{^2\,\}mathrm{From}$ a partial wave analysis of the $K^-\,2\pi$ system.

 $^{^4\,\}mathrm{From}$ a partial wave analysis of the $K^-\,2\pi$ system.

K(1830)

$$I(J^P) = \frac{1}{2}(0^-)$$

OMITTED FROM SUMMARY TABLE

Seen in partial-wave analysis of ${\it K}^-\,\phi$ system. Needs confirmation.

K	(1830)	MASS
---	--------	------

VALUE (MeV)	DOCUMENT ID	TECN	CHG	COMMENT
• • • We do not use the	e following data for a	verages,	fits, li	mits, etc. • • •
~ 1830	ARMSTRONG 83	OMEG	_	$18.5~\textrm{K}^-\rho \rightarrow~3\textrm{K}\rho$

K(1830) WIDTH

VALUE (MeV)	DOCUMENT ID	TECN	CHG	COMMENT
• • • We do not use the	e following data for a	verages,	fits, li	mits, etc. • • •
~ 250	ARMSTRONG 83	OMEG	_	$18.5~K^-~p~\rightarrow~3K~p$

K(1830) DECAY MODES

Mode $K\phi$

K(1830) REFERENCES

ARMSTRONG 83 NP B221 1

(BARI, BIRM, CERN, MILA, CURIN+) JP



$$I(J^P) = \frac{1}{2}(0^+)$$

OMITTED FROM SUMMARY TABLE

Seen in partial-wave analysis of the $K^-\pi^+$ system. Needs confir-

K*(1950) MASS

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
1945±10±20	¹ ASTON	88	LASS	0	$11 K^- \rho \rightarrow K^- \pi^+ n$
¹ We take the central	value of the two	solu	tions and	the la	arger error given.

K*(1950) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
201±34±79	² ASTON	88	LASS	0	11 $K^- p \rightarrow K^- \pi^+ n$

 $^{2}\,\mathrm{We}$ take the central value of the two solutions and the larger error given.

K*(1950) DECAY MODES

	Mode	Fraction (Γ_I/Γ)
Γ ₁	Κπ	(52±14) %

K*(1950) BRANCHING RATIOS

$\Gamma(K\pi)/\Gamma_{\text{total}}$				Γ_1/Γ
VALUE	DOCUMENT ID	<u>TE</u>	CN CHG	COMMENT
$0.52 \pm 0.08 \pm 0.12$	³ ASTON	88 LA	ASS 0	11 $K^- \rho \rightarrow K^- \pi^+ n$
2				

 $^{3}\hspace{-0.05cm}$ We take the central value of the two solutions and the larger error given.

K*(1950) REFERENCES

+Awaji, Bienz, Bird+ (SLAC, NAGO, CINC, INUS) ASTON 88 NP B296 493

 $K_2^*(1980)$

$$I(J^P) = \frac{1}{2}(2^+)$$

TED FROM SUMMARY TABLE

Needs confirmation.

$K_2^*(1980)$	MASS
---------------	------

VALUE (MeV) 1975±22 OUR A	EVTS ERAGE	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
1978 ± 40	241 ± 47	BIRD	89	LASS	-	11 $K^- \rho \rightarrow \overline{K}{}^0 \pi^- \rho$
1973 \pm 8 \pm 25	7.	ASTON	87	LASS	0	$\begin{array}{c} 11 \ K^- p \rightarrow \\ \overline{K}^0 \pi^+ \pi^- n \end{array}$

K*(1980) WIDTH

VALUE (MeV)	EVTS	DOCUMENT I	D	TECN	CHG	COMMENT
373±33±60		ASTON	87	LASS	0	$\begin{array}{c} 11 \ K^- p \rightarrow \\ \overline{K}^0 \pi^+ \pi^- p \end{array}$
• • • We do r	not use the follo	wing data for a				
398 ± 47	241±	BIRD	89	LASS	-	11 $K^- p \rightarrow \overline{K}^0 \pi^- p$

K*(1980) DECAY MODES

	Mode		
Г1	K*(892)π		
Γ_2^-	$K\rho$		

K₂*(1980) BRANCHING RATIOS

$\Gamma(K\rho)/\Gamma(K^*(892)\pi)$)					12/11
VALUE,	DOCUMENT ID		TECN		COMMENT	
1.49±0.24±0.09	ASTON	87	LASS	0	11 $K^- p \rightarrow \overline{K}^0 \pi^+ \pi$	r n

K*(1980) REFERENCES

BIRD ASTON	SLAC-332 NP B292 693	+Awaji, D'Amore+	(SLAC, NAGO, CINC	(SLAC) , INUS)

 $K_4^*(2045)$

$$I(J^P) = \frac{1}{2}(4^+)$$

K*(2045) MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
2045± 9 OUR A	VERAGE	Error includes sca	le fa	ctor of 1	.1.	
2062± 14±13		$^{ m 1}$ ASTON	86	LASS	0	
2039 ± 10	400	^{2,3} CLELAND	82	SPEC	±	$50 K^+ p \rightarrow K_S^0 \pi^{\pm} p$
$2070 {}^{+ 100}_{- 40}$		⁴ ASTON	810	LASS	0	11 $K^- p \rightarrow K^- \pi^+ n$
2045 ± 9 OUR AVERAGE Error includes scale factor of 1.1. 2062 ± 14 ± 13 1 ASTON 86 LASS 0 11 $K^-p \rightarrow K^-\pi^+n$ 2039 ± 10 400 2.3 CLELAND 82 SPEC ± 50 $K^+p \rightarrow K_S^0\pi^\pm p$ 2070 ± 100 4 ASTON 81c LASS 0 11 $K^-p \rightarrow K^-\pi^+n$ • • We do not use the following data for averages, fits, limits, etc. • • 2079 ± 7 431 TORRES 86 MPSF 400 $pA \rightarrow 4KX$ 2088 ± 20 650 BAUBILLIER 82 HBC - 8.25 $K^-p \rightarrow K_S^0\pi^-p$						
2079± 7	431	TORRES	86	MPSF		400 pA → 4KX
2088± 20	650	BAUBILLIER	82	HBC	-	
2115 ± 46	488	CARMONY	77	нвс	0	$9 K^+ d \rightarrow K^+ \pi' s X$
1 From a fit to al	ll momen	ts.				

⁴ From energy-independent partial-wave analysis.

K*(2045) WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
198± 30 OUR A	VERAGE					
$221 \pm 48 \pm 27$		⁵ ASTON	86	LASS	0	$11 K^- p \rightarrow K^- \pi^+ n$
189± 35	400	^{6,7} CLELAND	82	SPEC	±	$50 K^+ p \rightarrow K_S^0 \pi^{\pm} p$
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$						
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$						
$170 + 100 \\ -50$	650	BAUBILLIER	82	нвс	-	
$240 + 500 \\ -100$		⁸ ASTON	8 1C	LASS	0	11 $K^- p \rightarrow K^- \pi^+ n$
300 ± 200		CARMONY	77	нвс	0	$9 K^+ d \rightarrow K^+ \pi' s X$

² From a fit to 8 moments.
³ Number of events evaluated by us.

⁵ From a fit to all moments. ⁶ From a fit to 8 moments. ⁷ Number of events evaluated by us. ⁸ From energy-independent partial-wave analysis.

 $K_4^*(2045)$, $K_2(2250)$, $K_3(2320)$, $K_5^*(2380)$

K*(2045) DECAY MODES

	Mode	Fraction (Γ_j/Γ)	
Γ,	Κπ	(9.9±1.2) %	
Γ_2	$K^*(892)\pi\pi$	(9 ±5)%	
Γ_3	$K^*(892)\pi\pi\pi$	(7 ±5)%	
Γ4	$\rho K \pi$	(5.7±3.2) %	
Γ ₅	$\omega K \pi$	(5.0±3.0) %	
Γ ₆	$\phi K \pi$	(2.8 ± 1.4) %	
Γ ₇	φK*(892)	(1.4 ± 0.7) %	

K*(2045) BRANCHING RATIOS

$\Gamma(K\pi)/\Gamma_{\text{total}}$					Γ_1/Γ
VALUE	DOCUMENT ID		TECN	CHG	COMMENT
0.099±0.012	ASTON	88	LASS	0	11 $K^- p \rightarrow K^- \pi^+ n$
$\Gamma(K^*(892)\pi\pi)/\Gamma($	Κ π)				Γ_2/Γ_1
VALUE	DOCUMENT ID		TECN	CHG	COMMENT
0.89±0.53	BAUBILLIER	82	нвс	-	$8.25 \ K^- p \rightarrow p K_S^0 3\pi$
$\Gamma(K^*(892)\pi\pi\pi)/\Gamma$	(Κπ)				Γ_3/Γ_1
VALUE	DOCUMENT ID		TECN	CHG	COMMENT
0.75±0.49	BAUBILLIER	82	нвс	_	$8.25 \ K^- p \rightarrow p K_S^0 3\pi$
$\Gamma(\rho K\pi)/\Gamma(K\pi)$					Γ_4/Γ_1
VALUE	DOCUMENT ID		TECN	CHG	COMMENT
0.58±0.32	BAUBILLIER	82	нвс		$8.25 \ K^- p \rightarrow p K_S^0 3\pi$
$\Gamma(\omega K\pi)/\Gamma(K\pi)$					Γ_5/Γ_1
VALUE	DOCUMENT ID		TECN	CHG	COMMENT
0.50±0.30	BAUBILLIER	82	нвс	-	$8.25 \ K^- p \rightarrow p K_S^0 3\pi$
$\Gamma(\phi K \pi)/\Gamma_{\text{total}}$					Γ ₆ /Γ
VALUE	DOCUMENT ID		TECN	COM	
0.028±0.014	⁹ TORRES	86	MPSF	400 p	oA → 4KX
9 Error dotorminatio	n ic model depend	ont			

⁹ Error determination is model dependent.

$\Gamma(\phi K^*(892))/\Gamma_{to}$	otal				Γ_7/Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
0.014 ± 0.007	¹⁰ TORRES	86	MPSF	400 pA → 4KX	

K*(2045) REFERENCES

CARMON TO THE DIG 1231 TELOPPE, EMILES, MICHEL, TELOP	ASTON ASTON TORRES BAUBILLIER CLELAND ASTON CARMONY		NP 8296 493 PL B180 308 PR 34 707 PL 118B 447 NP B208 189 PL 106B 235 PR D16 1251	+Awaji, D'Amore+ (SLAC, +Lai+ (VPI, ARIZ, FNAL, FS +Burns+ (BIRM, CERN, +Delfosse, Dorsaz, Gloor (DURH,	GLAS, MSU, CURIN)
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- OTHER RELATED PAPERS -

	01112		
BROMBERG 80	NP B292 693	+Awaji, D'Amore+	(SLAC, NAGO, CINC, INUS)
	PR D22 1513	+Haggerty, Abrams, Dzierba	(CIT, FNAL, ILLC, IND)
	PRL 27 1160	+Cords, Clopp, Erwin, Meiere	+ (PURD, UCD, IUPU)



$$I(J^P) = \frac{1}{2}(2^-)$$

OMITTED FROM SUMMARY TABLE

This entry contains various peaks in strange meson systems reported in the 2150–2260 MeV region, as well as enhancements seen in the antihyperon-nucleon system, either in the mass spectra or in the J^P = 2 wave.

K2(2250) MASS

VALUE (MeV)	EVTS	DOCUMENT ID TECN CHG COMMENT	
2247±17 OUR A	VERAGE		
2200 ± 40		¹ ARMSTRONG 83c OMEG – 18 $K^-p \rightarrow \Lambda \bar{p}$	
2235 ± 50		¹ BAUBILLIER 81 HBC - $8 K^- \rho \rightarrow \Lambda \overline{\rho}$	X
2260 ± 20		¹ CLELAND 81 SPEC \pm 50 $K^+p \rightarrow \Lambda_{\overline{p}}$	ōΧ
• • • We do not	use the follo	owing data for averages, fits, limits, etc. • •	
2147± 4	37	CHLIAPNIK 79 HBC + 32 $K^+ \rho \rightarrow \overline{\Lambda} \rho$	Х
2240 ± 20	20	LISSAUER 70 HBC 9 K ⁺ p	
$^{1}J^{P}=2^{-}$ fro	m moments	analysis.	

K₂(2250) WIDTH

VALUE (MeV)		DOCUMENT ID		TECN	CHG	COMMENT	
180±30 OUR /	AVERAGE						
150 ± 30						18 $K^- p \rightarrow \Lambda \overline{p} X$	
210 ± 30		² CLELAND	81	SPEC	±	$50 K^+ p \rightarrow \Lambda \overline{p} X$	
• • • We do not	use the follo	owing data for ave	rages	, fits, lir	nits, et	tc. • • •	
~ 200		² BAUBILLIER	81	нвс	_	$8 K^- p \rightarrow \Lambda \overline{p} X$	
~ 40	37	CHLIAPNIK	79	HBC	+	32 $K^{+} p \rightarrow \overline{\Lambda} p X$	
80 ± 20	20	LISSAUER				9 K ⁺ p	
$^2J^P=2^-$ from moments analysis.							

K2(2250) DECAY MODES

	Mode			
Γ_1	$K\pi\pi$			
Γ_2	pΛ			

K₂(2250) REFERENCES

ARMSTRONG	83C	NP B227 365	+ (BARI, BIRM	. CERN. MILA. CURIN+)
BAUBILLIER		NP B183 1		RN. GLAS, MSU, CURIN) JP
CLELAND	81	NP B184 1	+Nef, Martin+ (PI	TT, GEVA, LAUS, DURH) JP
CHLIAPNIK	79	NP B158 253	Chliapnikov, Gerdyukov+	(CERN, BELG, MONS)
LISSAUER	70	NP B18 491	+Alexander, Firestone, Goldhaber	(LBL)

- OTHER RELATED PAPERS -

ALEXANDER 68B PRL 20 755 +Firestone, Goldhaber, Shen (LRL)



$$I(J^P) = \frac{1}{2}(3^+)$$

OMITTED FROM SUMMARY TABLE Seen in the $J^P=3^+$ wave of the

 $=3^+$ wave of the antihyperon-nucleon system. Needs confirmation.

K₃(2320) MASS

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT	
2324 ± 24 OUR AVERAG	jE					
2330 ± 40	¹ ARMSTRONG	83C	OMEG	_	18 $K^-p \rightarrow$	ΛpX
2320 ± 30	¹ CLELAND	81	SPEC	±	50 $K^+p \rightarrow$	ΛPX
1 /P - 3+ from mon	nents analysis					

K₃(2320) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT	
150±30	² ARMSTRONG	830	OMEG	_	18 $K^- p \rightarrow \Lambda \overline{p} X$	
ullet $ullet$ We do not	use the following data	for a	verages,	fits, li	mits, etc. • • •	
\sim 250	² CLELAND	81	SPEC	±	$50~K^+\rho\to~\Lambda \overline{\rho} X$	
$^{2}J^{P}=3^{+}$ from	m moments analysis.					

K₃(2320) DECAY MODES

	Mode	
Γ ₁	pΛ	

K₃(2320) REFERENCES

ARMSTRONG 83C NP B227 365 CLELAND 81 NP B184 1 (BARI, BIRM, CERN, MILA, CURIN+) (PITT, GEVA, LAUS, DURH) +Nef, Martin+



$$I(J^P) = \frac{1}{2}(5^-)$$

OMITTED FROM SUMMARY TABLE

Needs confirmation.

K*(2380) MASS

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
2382±14±19	¹ ASTON	86	LASS	0	11 $K^- p \rightarrow K^- \pi^+ n$
1 From a fit to all t	the moments				

	K*(2	380) WID	ГН		
VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT	
178±37±32	² ASTON	86	LASS	0	11 $K^- \rho \rightarrow K^- \pi^+ n$	
² From a fit to a	II the moments.					
	K ₅ *(2380)) DE	CAY N	IODE	:S	
Mode			F	raction	$\Gamma(\Gamma_i/\Gamma)$	
Γ ₁ Κπ		(6.1±1.2) %				
	<i>K</i> *(2380) B	RAN	ICHING	G RAT	ΓIOS	
$\Gamma(K\pi)/\Gamma_{\text{total}}$					Γ ₁ /Γ	
' (^ //)/ total			TECN	CHG	COMMENT	
VALUE VALUE	DOCUMENT ID					

$K_4(2500$))

ASTON ASTON

$$I(J^P) = \frac{1}{2}(4^-)$$

(SLAC, NAGO, CINC, INUS) (SLAC, NAGO, CINC, INUS)

OMITTED FROM SUMMARY TABLE

88 NP B296 493 86 PL B180 308

Needs confirmation.

K4(2500) MASS

+Awaji, Bienz, Bird+ +Awaji, D'Amore+

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
2490±20	1 CLELAND	81	SPEC	±	50 $K^+ p \rightarrow \Lambda \overline{p}$
$^{1}J^{P}=4^{-}$ from m	noments analysis.				

K4(2500) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT	
• • • We do not use t	he following data f	for a	verages,	fits, li	mits, etc. • • •	
\sim 250	² CLELAND	81	SPEC	±	50 $K^+ \rho \rightarrow \Lambda \overline{\rho}$	
$^2J^P=4^-$ from mo	ments analysis.					

K4(2500) DECAY MODES

	Mode	
Γ_1	pΛ	

K₄(2500) REFERENCES

+Nef, Martin+ CLELAND 81 NP B184 1 (PITT, GEVA, LAUS, DURH)



$$I^{G}(J^{PC}) = ?^{?}(?^{??})$$

OMITTED FROM SUMMARY TABLE

Narrow peak observed in several ($\Lambda \overline{p}$ + pions) and ($\overline{\Lambda} p$ + pions) states in Σ^- Be reactions by BOURQUIN 86 and in np and nA reactions by ALEEV 93. Not seen by BOEHNLEIN 91. If due to strong decays, this state has exotic quantum numbers (B=0, Q=+1, S=-1for $\Lambda \overline{p} \pi^+ \pi^+$ and $I \geq 3/2$ for $\Lambda \overline{p} \pi^-$). See also under non- $q \overline{q}$ candidates. Needs confirmation.

K(3100) MASS DOCUMENT ID

VALUE (MeV) ≈ 3100 OUR ESTIMATE	DOCUMENT ID		
3-BODY DECAYS VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
3054±11 OUR AVERAGE			
3060 ± 7 ± 20	¹ ALEEV 9	3 BIS2	$K(3100) \rightarrow \Lambda \overline{p} \pi^+$
3056 ± 7±20	¹ ALEEV 9	3 BIS2	$K(3100) \rightarrow \overline{\Lambda} p \pi^-$
3055 ± 8 ± 20	¹ ALEEV 9	3 BIS2	$K(3100) \rightarrow \Lambda \overline{p} \pi^-$
3045± 8±20	¹ ALEEV 9	3 BIS2	$K(3100) \rightarrow \overline{\Lambda} \rho \pi^+$
¹ Supersedes ALEEV 90.			

4-BODY DECAYS VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
3059±11 OUR AVERAGE	DOCUMENT ID		1ECIV	COMMENT
3067+ 6+20	1 ALFEV	93	BIS2	$K(3100) \rightarrow \Lambda \overline{p} \pi^+ \pi^+$
3060 ± 8±20	1 ALEEV	93	BIS2	$K(3100) \rightarrow \Lambda \overline{p} \pi^+ \pi^-$
3055 ± 7±20	1 ALEEV	93	BIS2	$K(3100) \rightarrow \overline{\Lambda} p \pi^- \pi^-$
3052± 8±20	1 ALEEV	93	BIS2	$K(3100) \rightarrow \overline{\Lambda} p \pi^- \pi^+$
• • We do not use the follo	wing data for average	es, fit	s, limits	, etc. • • •
3105±30	BOURQUIN	86	SPEC	$K(3100) \rightarrow \Lambda \overline{p} \pi^+ \pi^+$
3115±30	BOURQUIN	86	SPEC	$K(3100) \rightarrow \Lambda \overline{p} \pi^+ \pi^-$
5-BODY DECAYS				
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
• • We do not use the follo	wing data for average	s, fit	s, limits,	, etc. • • •
3095 ± 30	BOURQUIN	86	SPEC	$K(3100) \rightarrow \Lambda \overline{\rho} \pi^+ \pi^+ \pi^-$

K(3100) WIDTH

VALUE (MeV)	DOCUMENT	ID	TECN	COMMENT
• • • We do not use the	following data for avera	ages, fit	s, limits	, etc. • • •
42±16	² ALEEV	93	BIS2	$K(3100) \rightarrow \Lambda \overline{p} \pi^{+}$
36 ± 15	² ALEEV	93	BIS2	$K(3100) \rightarrow \overline{\Lambda} p \pi^-$
50±18	² ALEEV	93	BIS2	$K(3100) \rightarrow \Lambda \overline{p} \pi^{-}$
30±15	² ALEEV	93	BIS2	$K(3100) \rightarrow \overline{\Lambda} p \pi^+$

Supersedes ALEEV 9	0.				
4-BODY DECAYS VALUE (MeV)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the	following	data for average	s, fits	s, limits,	etc. • • •
22± 8		² ALEEV	93	BIS2	$K(3100) \rightarrow \Lambda \overline{p} \pi^+ \pi^+$
28 ± 12		² ALEEV	93	BIS2	$K(3100) \rightarrow \Lambda \overline{p} \pi^+ \pi^-$
32 ± 15		² ALEEV	93	BIS2	$K(3100) \rightarrow \overline{\Lambda} \rho \pi^- \pi^-$
30 ± 15		² ALEEV	93	BIS2	$K(3100) \rightarrow \overline{\Lambda} \rho \pi^- \pi^+$
<30	90	BOURQUIN	86	SPEC	$K(3100) \rightarrow \Lambda \overline{p} \pi^+ \pi^+$
<80	90	BOURQUIN	86	SPEC	$K(3100) \rightarrow \Lambda \overline{p} \pi^+ \pi^-$
5-BODY DECAYS					
VALUE (MeV)	CL%	DOCUMENT ID		TECN	COMMENT
• • We do not use the	following	data for average	s, fits	s, limits,	etc. • • •
<30	90	BOURQUIN	86	SPEC	$K(3100) \rightarrow \Lambda \overline{p} \pi^+ \pi^+ \pi^-$

K(3100) DECAY MODES

	Mode
Γ ₁	$K(3100)^0 \rightarrow \Lambda \overline{p} \pi^+$
Γ_2	$K(3100)^{} \rightarrow \Lambda \overline{p} \pi^{-}$
Гз	$K(3100)^- \rightarrow \Lambda \overline{p} \pi^+ \pi^-$
	$K(3100)^+ \rightarrow \Lambda \overline{p} \pi^+ \pi^+$
	$K(3100)^0 \rightarrow \Lambda \overline{p} \pi^+ \pi^+ \pi^-$
Γ ₆	$K(3100)^0 \rightarrow \Sigma(1385)^+ \overline{\rho}$

Γ(Σ(1385)+7	\bar{p})/ $\Gamma(\Lambda \bar{p}\pi^+)$					Γ_6/Γ_1
VALUE	CL%	DOCUMENT ID		TECN	COMMENT	
< 0.04	90	ALEEV	93	BIS2	$\begin{array}{c} K(3100)^{0} \rightarrow \\ \Sigma(1385)^{+} \overline{p} \end{array}$	

K(3100) REFERENCES

ALEEV	93	PAN 56 1358 Translated from YAF		(BIS-2 Collab.)
BOEHNLEIN ALEEV BOURQUIN	90		+Chung+ +Arefiev, Balandin+	(FLOR, BNL, IND, RICE, MASD) (BIS-2 Collab.) I, RAL, HE:DP, LAUS, BRIS, CERN)

Meson Particle Listings D MESONS

CHARMED MESONS $(C = \pm 1)$

 $D^+=c\overline{d}$, $D^0=c\overline{u}$, $\overline{D}{}^0=\overline{c}\,u$, $D^-=\overline{c}\,d$, similarly for D^* 's

NOTE ON D MESONS

(by P.R. Burchat, Stanford University)

The new experimental results on charm meson decays reported in this edition are predominantly from CLEO II at the e^+e^- storage ring CESR and from fixed-target experiments, especially photoproduction experiment E687 at Fermilab. The first results from the BES experiment, operating at an e^+e^- center-of-mass energy of 4.0 GeV, also appear in this edition. BES has measured the branching fractions for the purely leptonic decay $D_s^+ \to \mu^+\nu_\mu$ and for $D_s^+ \to \phi\pi^+$, albeit with large statistical uncertainties.

Semileptonic decays

For a detailed discussion of experimental measurements and theoretical predictions for leptonic and semileptonic decays of both charm and bottom hadrons, see the recent review by J.D. Richman and P.R. Burchat [1]. Also see the "Note on Semileptonic Decays of D and B Mesons, Part I," by R.J. Morrison and J.D. Richman, in our 1994 edition [2].

In this edition, we have added to the Particle Listings the measurements of the form-factor ratios for $D^+ \to \overline{K}^{*0} \ell^+ \nu_{\ell}$ and $D_s^+ \to \phi \ell^+ \nu_\ell$. The form factors $A_1(q^2)$, $A_2(q^2)$, and $V(q^2)$ are defined in the "Note on Semileptonic Decays of B Mesons" in the B-meson Particle Listings. The ratios $A_2(0)/A_1(0)$ and $V(0)/A_1(0)$ have been measured by Fermilab fixed-target experiments E691, E687, and E653 for the mode $D^+ \to \overline{K}^{*0} \ell^+ \nu_{\ell}$, and by E687, E653, and CLEO for the mode $D_s^+ \to \phi \ell^+ \nu_{\ell}$. For each semileptonic mode, the averages of the measured form-factor ratios can be combined with the measured decay rate to extract the values of the form factors themselves [3]. The results are $A_1(0) = 0.55 \pm 0.03$, $A_2(0) = 0.40 \pm 0.08$, and $V(0) = 1.0 \pm 0.2 \text{ for } D^+ \to \overline{K}^{*0} \ell^+ \nu_{\ell} \text{ and } A_1(0) = 0.62 \pm 0.06,$ $A_2(0) = 1.0 \pm 0.3$, and $V(0) = 0.9 \pm 0.3$ for $D_s^+ \to \phi \ell^+ \nu_{\ell}$. The measured decay rate for $D \to \overline{K}\ell^+\nu_{\ell}$ can be used to extract the single vector form factor $f_{+}(0)$. The result is $f_{+}(0) = 0.74 \pm 0.03$. Recent quark-model predictions are in good agreement with the D measurements. Lattice gauge calculations are in good agreement with the vector form factors but predict axial form factors that are somewhat higher than the measured values.

Measurements of the ratio $\Gamma(D \to \overline{K}^* \ell^+ \nu_\ell)/\Gamma(D \to \overline{K} \ell^+ \nu_\ell)$ confirm the initial experimental result that the ratio is only a little over one half, whereas initial theoretical expectations were that it would be about one. By taking into account effects originally ignored, such as relativistic corrections, theorists have managed to accommodate the observed ratio of rates in quark-model calculations. Lattice gauge calculations are also in reasonable agreement with the measured ratio. In contrast to

semileptonic B decays, no evidence for higher-mass resonances or nonresonant final states has been observed in semileptonic D decays.

Although the experimental results are statistically limited, the semileptonic decays $D_s^+ \to \phi \ell^+ \nu_\ell$ and $D_s^+ \to (\eta \text{ or } \eta') \ell^+ \nu_\ell$ appear to follow the pattern of D decays, both in terms of form-factor ratios and of the relative decay rates to vector and pseudoscalar mesons.

Searches for D^0 - \overline{D}^0 mixing

There have been a number of papers published recently concerning both the sensitivity of $D^0\overline{D}{}^0$ mixing to new physics and the validity of various assumptions made in existing searches [4]. We have reorganized the mixing limits in the Listings and have added more detailed comments regarding the assumptions made in various searches.

Absolute branching fractions for D_s^+

Two model-independent measurements of the absolute branching fraction for $D_s^+ \to \phi \pi^+$, from BES and CLEO, appear in this edition. All previous measurements depended on theoretical models or on estimates of D_s^+ production cross sections. We no longer use these older results when calculating the average and fit values for $B(D_s^+ \to \phi \pi^+)$. The BES collaboration (BAI 95C) uses $e^+e^- \rightarrow D_s^+D_s^-$ events in which one or both of the D_s^{\pm} decays are reconstructed to obtain a measurement of the $D_s^+ \to \phi \pi^+$ branching fraction without assumptions on the cross section for D_s^{\pm} production. However, with only two events in which both D_s^{\pm} decays are reconstructed, the result, $B(D_s^+ \to \phi \pi^+) = (3.9^{+5.1+1.8}_{-1.9-1.1})\%$, has a very large statistical uncertainty. For their new measurement, the CLEO collaboration (ARTUSO 96) measures the branching ratio B($D_s^+ \to \phi \pi^+$)/B($D^0 \to K^- \pi^+$) = 0.92 ± 0.20 ± 0.11 by partially reconstructing the decay $\overline{B}^0 \to D^{*+}D_s^{*-}$. They then use their measured value of $B(D^0 \to K^-\pi^+)$ to determine $B(D_s^+ \to \phi \pi^+) = (3.59 \pm 0.77 \pm 0.48)\%.$

In the past, we of necessity relied heavily on estimates of $\mathrm{B}(D_s^+ \to \phi \pi^+)$ based on measurements of $\Gamma(D_s^+ \to$ $\phi \ell^+ \nu_\ell / \Gamma(D_s^+ \to \phi \pi^+)$, combined with theoretical predictions for $F = \Gamma(D_s^+ \to \phi \ell^+ \nu_\ell) / \Gamma(D^+ \to \overline{K}^{*0} \ell^+ \nu_\ell)$ and measurements of $B(D^+ \to \overline{K}^{*0}\ell^+\nu_\ell)$ and the relative D_s^+ and D^+ lifetimes. Although we include the measured values of $\Gamma(D_s^+ \to \infty)$ $\phi \ell^+ \nu_\ell / \Gamma(D_s^+ \to \phi \pi^+)$ in the Listings, we no longer use the individual estimates of $B(D_s^+ \to \phi \pi^+)$ since they are each based on different (and sometimes obsolete) estimates of the measured and theoretical correction factors. Here we apply the current best estimates of the correction factors to the current world average, $\Gamma(D_s^+ \to \phi \ell^+ \nu_\ell)/\Gamma(D_s^+ \to \phi \pi^+) = 0.54 \pm 0.05$. When we use the world averages $B(D^+ \to \overline{K}^{*0} \ell^+ \nu_{\ell}) = (4.8 \pm 0.4)\%$ and $\tau(D_s^+)/\tau(D^+) = 0.442 \pm 0.017$, we calculate $B(D_s^+ \to \phi \pi^+)$ to be $(3.9 \pm 0.5)\% \cdot F$. Theoretical estimates for F are near 1.0 with a theoretical uncertainty conservatively estimated to be about 25%. Therefore, this estimate for $B(D_s^+ \to \phi \pi^+)$ is in good agreement with the two new model-independent measurements.

D^+ and D_s^+ decay constants

For the leptonic decays $D^+ \to \ell^+ \nu_\ell$ and $D_s^+ \to \ell^+ \nu_\ell$ only one parameter for each, called the decay constant, is required to describe the nonperturbative physics. (See also the "Note on Pseudoscalar-Meson Decay Constants" in the π^{\pm} Particle Listings.) Decay constants are also used to describe other processes, such as $D^0\overline{D}{}^0$ and $B^0\overline{B}{}^0$ mixing, and hence are quite important. Unfortunately, leptonic decays of heavy mesons have small branching fractions and are difficult to reconstruct. However, observations of leptonic D_s^+ decays have now been published by WA75 (AOKI 93), CLEO II (ACOSTA 94), and BES (BAI 95). The systematic and statistical uncertainties on the D_s^+ decay constant are still large. The branching fractions for leptonic B decays are expected to be so small that observation will not be experimentally feasible for some time. Therefore, as the errors on the D_s^+ decay constant decrease with larger data samples, we would benefit from more theoretical work relating the B decay constant to the more easily measured D^+ and D_s^+ decay constants.

References

- 1. J.D. Richman and P.R. Burchat, Rev. Mod. Phys. 67, 893 (1995).
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- 4. G. Blaylock, A. Seiden, Y. Nir, Phys. Lett. B355, 555
 - L. Wolfenstein, Phys. Rev. Lett. 75, 2460 (1995);
 - J.L. Hewett, presented at LAFEX International School on High-Energy Physics, (Feb. 6-22, 1995), hep-ph/9505246, SLAC Report No. SLAC-PUB-95-6821;
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$$I(J^P) = \frac{1}{2}(0^-)$$

${\it D}^{\pm}$ MASS

The fit includes D^{\pm} , D^{0} , D_{ϵ}^{\pm} , $D^{*\pm}$, D^{*0} , and $D_{\epsilon}^{*\pm}$ mass and mass

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
1869.3± 0.5 OUR FIT	Error inc	ludes scale factor	of 1.1	ι.	
1869.4± 0.5 OUR AVE	RAGE				
$1870.0 \pm\ 0.5 \pm 1.0$	317	BARLAG	9 0c	ACCM	π^- Cu 230 GeV
1863 ± 4		DERRICK	84	HRS	e^+e^- 29 GeV
1869.4± 0.6		¹ TRILLING	81	RVUE	$e^{+}e^{-}$ 3.77 GeV
• • We do not use the	e following	g data for averages	s, fits	, limits,	etc. • • •
1875 ±10	9	ADAMOVICH	87	EMUL	Photoproduction
1860 ±16	6				Photoproduction
1868.4 ± 0.5					e ⁺ e ⁻ 3.77 GeV
1874 ± 5		GOLDHABER			D^0 , D^+ recoil spectra
1868.3 ± 0.9		¹ PERUZZI			e ⁺ e ⁻ 3.77 GeV
1874 ±11		PICCOLO			e ⁺ e ⁻ 4.03, 4.41 GeV
1876 ±15	50	PERUZZI	76	MRK1	$K^{\mp}\pi^{\pm}\pi^{\pm}$

 $^{^1}$ PERUZZI 77 and SCHINDLER 81 errors do not include the 0.13% uncertainty in the absolute SPEAR energy calibration. TRILLING 81 uses the high precision $J/\psi(1S)$ and $\psi(2S)$ measurements of ZHOLENTZ 80 to determine this uncertainty and combines the PERUZZI 77 and SCHINDLER 81 results to obtain the value quoted.

D± MEAN LIFE

Measurements with an error $>0.1\times10^{-12}$ s are omitted from the average, and those with an error $>0.2\times10^{-12}$ s have been omitted from the

VALUE (10 ⁻¹² s)	EVTS	DOCUMENT ID	TECN	COMMENT
1.057±0.015 OUR AV	ERAGE			
$1.048 \pm 0.015 \pm 0.011$	9k	FRABETTI	94D E687	$D^+ \rightarrow K^- \pi^+ \pi^+$
$1.075\pm0.040\pm0.018$	2455	FRABETTI	91 E687	
				$\gamma, \stackrel{K^-\pi^+\pi^+}{D^+} \stackrel{\pi^+\pi^+}{\to} K^-\pi^+\pi^+$
$1.03 \pm 0.08 \pm 0.06$	200	ALVAREZ	90 NA14	γ , $D^+ \rightarrow K^-\pi^+\pi^+$
$1.05 \begin{array}{l} +0.077 \\ -0.072 \end{array}$	317	² BARLAG	90c ACCM	π^- Cu 230 GeV
$1.05 \pm 0.08 \pm 0.07$	363	ALBRECHT	88I ARG	e ⁺ e ⁻ 10 GeV
$1.090\pm0.030\pm0.025$	2992	RAAB	88 E691	Photoproduction
• • • We do not use	the follow	ing data for average	es, fits, limit	s, etc. • • •
$1.12 \begin{array}{c} +0.14 \\ -0.11 \end{array}$	149	AGUILAR	87D HYBR	$\pi^- ho$ and $ ho ho$
$1.09 \begin{array}{c} +0.19 \\ -0.15 \end{array}$	59	BARLAG	87B ACCM	K^- and π^- 200 GeV
$1.14 \pm 0.16 \pm 0.07$	247	CSORNA	87 CLEO	e^+e^- 10 GeV
1.09 ± 0.14	74	³ PALKA	87B SILI	π Be 200 GeV
$0.86 \ \pm 0.13 \ ^{+0.07}_{-0.03}$	48	ABE	86 HYBR	γρ 20 GeV

² BARLAG 90C estimates the systematic error to be negligible.

D+ DECAY MODES

 D^- modes are charge conjugates of the modes below

	3 33		C1- f+/
	Mode	Fraction (Γ_i/Γ)	Scale factor/ Confidence level
	inclusiv	ve modes	
Γ1	e ⁺ anything	(17.2 ±1.9) %	
Γ2	K ⁻ anything	(24.2 ±2.8)%	S=1.4
Γ3	\overline{K}^0 anything $+ K^0$ anything	(59 ±7)%	
Γ₄	K ⁺ anything	(5.8 ±1.4)%	
Γ ₅	η anything	[a] < 13 %	CL=90%
Γ ₆	μ^+ anything		
Γ ₇	$\mu^+\mu^-$ anything		
	Leptonic and se	mileptonic modes	
Γ8	$\mu^+ \nu_{\mu}$	< 7.2 × 1	10 ⁻⁴ CL=90%
Г9	$\overline{K}^0 \ell^+ \nu_\ell$	[b] (6.7 ±0.8)%	
Γ ₁₀	$\overline{K}^0 e^+ \nu_e$	$(6.6 \pm 0.9)\%$	
Γ11	$\overline{K}{}^0\mu^+ u_\mu$	$(7.0 \begin{array}{c} +3.0 \\ -2.0 \end{array})\%$	
Γ ₁₂	$K^-\pi^+e^+\nu_e$	(4.2 +0.9) %	
Γ ₁₃	K*(892)0 e+,,	(3.2 ±0.33) %	
' 13	$\overline{K}^*(892)^0 e^+ \nu_e \times B(\overline{K}^{*0} \to K^- \pi^+)$	(3.2 ±0.33) /6	
Γ ₁₄	$K^-\pi^+e^+\nu_e$ nonresonant	< 7 × 1	10 ⁻³ CL=90%
Γ ₁₅	$K^-\pi^+\mu^+\nu_\mu$	(3.2 ±0.4) %	S=1.1
. 15	In the fit as $\frac{2}{3}\Gamma_{27} + \Gamma_{17}$, where		
Γ ₁₆	$\overline{K}^*(892)^0 \mu^+ \nu_{\mu}$	(3.0 ±0.4) %	
. 10	$\times \ B(\overline{K}^{*0} \to K^-\pi^+)$	(5.5 ± 5.1) //	
Γ ₁₇	$\kappa^-\pi^+\mu^+\nu_\mu$ nonresonant	(2.7 ±1.1)×1	10-3
Γ ₁₈	$\overline{K}^0 \pi^+ \pi^- e^+ \nu_e$	(2.1 ±1.1) ~ .	
Γ ₁₉	$K^-\pi^+\pi^0e^+\nu_e$		
Γ ₂₀	$(\overline{K}^*(892)\pi)^0 e^+ \nu_e$	< 1.2 %	CL=90%
Γ ₂₁	$(\overline{K}\pi\pi)^0 e^+ \nu_e \text{ non-} \overline{K}^*(892)$		10 ⁻³ CL=90%
Γ ₂₂	$K^{-}\pi^{+}\pi^{0}\mu^{+}\nu_{\mu}$		10 ⁻³ CL=90%
Γ ₂₃	$\pi^0 \ell^+ \nu_\ell$	[c] (5.7 ±2.2)×1	
Γ ₂₄	$\pi^+\pi^-e^+\nu_e$	[6] (5.7 ±2.2) × 1	10
	Fractions of some of the following appeared above as submodes of par		
Γ_{25}	\overline{K}^* (892) ⁰ $\ell^+ \nu_\ell$	[b] (4.8 \pm 0.4) %	
Γ ₂₆	$\overline{K}^*(892)^0 e^+ \nu_e$	(4.8 \pm 0.5) %	
Γ ₂₇	$\overline{K}^*(892)^0 \mu^+ \nu_{\mu}$	(4.5 \pm 0.6) %	S=1.1
Γ ₂₈	$ ho^0e^+ u_e$		10 ⁻³ CL=90%
Γ ₂₉	$ ho^0 \mu^+ u_\mu$	$(2.0 \ ^{+1.5}_{-1.3}) \times 1$	10-3
Γ ₃₀	$\phi e^+ u_e$	< 2.09 %	CL=90%
Γ_{31}	$\phi \mu^+ \nu_{\mu}$	< 3.72 %	CL=90%
Γ_{32}	$\eta'(958) \mu^+ \nu_{\mu}$	< 9 × 1	10 ⁻³ CL=90%

³ PALKA 87B observes this in $D^+ \to \overline{K}^*(892) e \nu$.

```
Hadronic modes with a \overline{K} or \overline{K}K\overline{K}
                                                                                                                                                                                    K^*(892)^-\pi^+\pi^+3-body
                                                                                                                                                                   Γ<sub>84</sub>
                                                                                                                                                                                                                                                         (2.1 \pm 0.9)\%
            \overline{K}{}^0\pi^+
 \Gamma_{33}
                                                                                      ( 2.74 \pm 0.29) %
                                                                                                                                                                            K^- \rho^+ \pi^+ total
                                                                                                                                                                   Γ<sub>85</sub>
                                                                                                                                                                                                                                                         (3.1 \pm 1.1)\%
            K^-\pi^+\pi^+
                                                                                                                                                                             K^{-}\rho^{+}\pi^{+}3-body

K^{0}\rho^{0}\pi^{+}total
 Γ<sub>34</sub>
                                                                              [d] (9.1 \pm 0.6)\%
                                                                                                                                                                   Γ<sub>86</sub>
                                                                                                                                                                                                                                                         ( 1.1 \pm 0.4 ) %
                 \overline{K}^*(892)^0\pi^+
                                                                                      (1.28\pm0.13)\%
 Γ35
                                                                                                                                                                                                                                                         ( 4.2 \pm 0.9 ) %
                                                                                                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                   Γ<sub>87</sub>
                      \times B(\overline{K}^{*0} \rightarrow K^{-}\pi^{+})
                                                                                                                                                                                   \overline{K}^0 \rho^0 \pi^+ 3-body
                                                                                                                                                                                                                                                        (5 \pm 5 ) \times 10^{-3}
                                                                                                                                                                   Γ<sub>88</sub>

\overline{K}^{0} f_{0}(980) \pi^{+}

\overline{K}^{*}(892)^{0} \pi^{+} \pi^{+} \pi^{-}

\overline{K}^{*}(892)^{0} \rho^{0} \pi^{+}

                 \overline{K}_{0}^{*}(1430)^{0}\pi^{+}
\Gamma_{36}
                                                                                      (2.3 \pm 0.3)\%
                                                                                                                                                                   Γ89
                                                                                                                                                                                                                                                                                                     CL=90%
                 \times \ \mathsf{B}(\overline{K}_0^*(1430)^0 \to K^-\pi^+)
\overline{K}^*(1680)^0\pi^+
                                                                                                                                                                                                                                                        ( 1.02±0.27) %
                                                                                                                                                                   \Gamma_{90}
 Γ37
                                                                                      (3.7 \pm 0.8) \times 10^{-3}
                                                                                                                                                                   \Gamma_{91}
                                                                                                                                                                                                                                                        (7.7 \pm 3.3) \times 10^{-3}
                      \times B(\overline{K}^*(1680)<sup>0</sup> \rightarrow K^-\pi^+)
                                                                                                                                                                                                                              Pionic modes
\Gamma_{38}
                 K^-\pi^+\pi^+ nonresonant
                                                                                       (8.6 \pm 0.9)\%
                                                                                                                                                                              \pi^+\pi^0
                                                                                                                                                                   \Gamma_{92}
                                                                                                                                                                                                                                                       (2.5 \pm 0.7) \times 10^{-3}
           \overline{K}^0\pi^+\pi^0
 Γ39
                                                                             [d] (9.7 \pm 3.0)\%
                                                                                                                                       S-1 1
                                                                                                                                                                   \Gamma_{93} \quad \pi^{+}\pi^{+}\pi^{-}
\Gamma_{94} \quad \rho^{0}\pi^{+}
                                                                                                                                                                                                                                                        ( 3.2~\pm0.6 ) \times\,10^{-3}
                \frac{\ddot{\kappa}^0}{K^0} \rho^+
Γ<sub>40</sub>
                                                                                       (6.6 \pm 2.5)\%
                                                                                                                                                                                                                                                      < 1.4 \times 10^{-3}
                                                                                                                                                                   \Gamma_{94}
                                                                                                                                                                                                                                                                                                    CL=90%
                 \overline{K}^*(892)^0\pi^+
                                                                                       ( 6.4~\pm0.6 ) \times\,10^{-3}
 \Gamma_{41}
                                                                                                                                                                                 \pi^+\pi^+\pi^- nonresonant
                                                                                                                                                                   \Gamma_{95}
                                                                                                                                                                                                                                                       (2.5 \pm 0.7) \times 10^{-3}
                     \times B(\overline{K}^{*0} \rightarrow \overline{K}^{0}\pi^{0})
                                                                                                                                                                   \Gamma_{96} = \pi^{+} \pi^{+} \pi^{-} \pi^{0}
                                                                                                                                                                                                                                                        (1.9 \begin{array}{c} +1.5 \\ -1.2 \end{array}) \%
                 \overline{K}{}^0\pi^+\dot{\pi}^0 nonresonant
 \Gamma_{42}
                                                                                      ( 1.3 \pm 1.1 ) %

\frac{-\pi^{+}\pi^{+}\pi^{0}}{\overline{K}^{*}(892)^{0}}\rho^{+} \text{ total}

\times B(\overline{K}^{*0} \to K^{-}\pi^{+})

                                                                                                                                                                                  \eta \pi^+ \times B(\eta \rightarrow \pi^+ \pi^- \pi^0)
\Gamma_{43}
                                                                             [d] (6.4 ±1.1)%
                                                                                                                                                                   \Gamma_{97}
                                                                                                                                                                                                                                                       ( 1.8 \pm 0.6 ) \times 10^{-3}
                                                                                                                                                                                \omega \pi^+ \times B(\omega \to \pi^+ \pi^- \pi^0)
                                                                                                                                                                                                                                                      < 6 × 10<sup>-3</sup>
                                                                                      (1.4 \pm 0.9)\%
\Gamma_{44}
                                                                                                                                                                   Γ<sub>98</sub>
                                                                                                                                                                                                                                                                                                    C1 = 90\%
                                                                                                                                                                   \Gamma_{99} = \pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}
                                                                                                                                                                                                                                                        ( 1.0 ^{+0.8}_{-0.7} ) \times 10^{-3}
                 \overline{K}_{1}(1400)^{0}\pi^{+}
\Gamma_{45}
                                                                                      (2.2 \pm 0.6)\%
                     \stackrel{\frown}{\times} B(\stackrel{\frown}{K}_1(1400)^0 \rightarrow K^-\pi^+\pi^0)
                                                                                                                                                                   \Gamma_{100} \pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0}
                                                                                                                                                                                                                                                        (2.9 \begin{array}{c} +2.9 \\ -2.0 \end{array}) \times 10^{-3}
                 K^-\rho^+\pi^+total

K^-\rho^+\pi^+3-body
\Gamma_{46}
                                                                                       (3.1 \pm 1.1)\%
\Gamma_{47}
                                                                                       ( 1.1~\pm0.4 ) %
                                                                                                                                                                                  Fractions of some of the following modes with resonances have already
                K \cap \pi^{+}3-body

\overline{K}^{*}(892)^{0}\pi^{+}\pi^{0} total

\times B(\overline{K}^{*0} \to K^{-}\pi^{+})

\overline{K}^{*}(892)^{0}\pi^{+}\pi^{0}3-body

\times B(\overline{K}^{*0} \to K^{-}\pi^{+})
\Gamma_{48}
                                                                                      (4.5 \pm 0.9)\%
                                                                                                                                                                                 appeared above as submodes of particular charged-particle modes.
                                                                                                                                                                   \begin{array}{ccc} \Gamma_{101} & \eta \, \pi^+ \\ \Gamma_{102} & \rho^0 \, \pi^+ \end{array}
                                                                                                                                                                                                                                                       (7.5 \pm 2.5) \times 10^{-3}
\Gamma_{49}
                                                                                      (2.8 \pm 0.9)\%
                                                                                                                                                                                                                                                                               \times 10^{-3}
                                                                                                                                                                                                                                                     < 1.4
                                                                                                                                                                                                                                                                                                    CL=90%
                                                                                                                                                                   \Gamma_{103} \omega \pi^+
                                                                                                                                                                                                                                                                               × 10<sup>-3</sup>
                                                                                                                                                                                                                                                     < 7
                                                                                                                                                                                                                                                                                                    CL=90%
                 K^*(892)^-\pi^+\pi^+ 3-body
× B(K^{*-} \rightarrow K^-\pi^0)
\Gamma_{50}
                                                                                                                                                                   \Gamma_{104} \ \eta \rho^+
                                                                                      (7 \pm 3) \times 10^{-3}
                                                                                                                                                                                                                                                      < 1.2
                                                                                                                                                                                                                                                                               %
                                                                                                                                                                                                                                                                                                    CL=90%
                                                                                                                                                                   \Gamma_{105} \eta'(958)\pi^{+}
                                                                                                                                                                                                                                                                               \times 10<sup>-3</sup>
                                                                                                                                                                                                                                                      < 9
                                                                                                                                                                                                                                                                                                    CL=90%
                 K^-\pi^+\pi^+\pi^0 nonresonant
\Gamma_{51}
                                                                                                                                                                   \Gamma_{106} \eta'(958) \rho^{+}
                                                                             [e] (1.2 \pm 0.6)\%
                                                                                                                                                                                                                                                                                                    CL=90%
            \overline{K}{}^0\pi^+\pi^+\pi^-
 \Gamma_{52}
                                                                             [d]
                                                                                      (7.0 \pm 1.0)\%
                                                                                                                                                                                                            Hadronic modes with a K\overline{K} pair
                \overline{K}{}^0\,a_1(1260)^+
\Gamma_{53}
                                                                                       ( 4.0 \pm 0.9 ) %
                                                                                                                                                                   \Gamma_{107} K^+ \overline{K}{}^0
                     \times B(a_1(1260)^+ \to \pi^+\pi^+\pi^-)
                                                                                                                                                                                                                                                      (7.2 \pm 1.2) \times 10^{-3}
                                                                                                                                                                   \Gamma_{108}^{-108} K^{+}K^{-}\pi^{+}
                                                                                                                                                                                                                                               [d] ( 8.9 \pm 0.8 ) \times 10^{-3}
\Gamma_{54}
                 \overline{K}_1(1400)^0 \pi^+
                                                                                      (2.2 \pm 0.6)\%
                      \times B(\overline{K}_1(1400)^0 \rightarrow \overline{K}^0\pi^+\pi^-)
                                                                                                                                                                                                                                                        ( 3.0~\pm 0.3 ) \times\,10^{-3}
                                                                                                                                                                                \phi \pi^+ \times B(\phi \rightarrow K^+ K^-)
                                                                                                                                                                   \Gamma_{109}
                                                                                                                                                                                  K^+ \overline{K}^* (892)^0 \times B(\overline{K}^{*0} \to K^- \pi^+)
                                                                                                                                                                                                                                                        ( 2.8~\pm0.4 ) \times\,10^{-3}
                K^*(892)^-\pi^+\pi^+3-body

\times B(K^{*-} \rightarrow \overline{K^0}\pi^-)

\overline{K^0}\rho^0\pi^+total
                                                                                                                                                                   \Gamma_{110}
\Gamma_{55}
                                                                                      ( 1.4 \pm 0.6 ) %
                                                                                                                                                                                   K^+K^-\pi^+ nonresonant
Γ<sub>56</sub>
                                                                                                                                                                                                                                                        (4.6 \pm 0.9) \times 10^{-3}
                                                                                      (4.2 \pm 0.9)\%
                                                                                                                                                                   \Gamma_{112} K^0\overline{K}^0\pi^+
                     \dot{\overline{K}}^0 \rho^0 \pi^+ 3-body
                                                                                      ( 5 \pm 5 ) \times 10^{-3}
\Gamma_{57}
                                                                                                                                                                                  K^*(892)^+ \overline{K}{}^0
                 \overline{K}^0\pi^+\pi^+\pi^- nonresonant
                                                                                      (8 \pm 4) \times 10^{-3}
                                                                                                                                                                                                                                                        ( 2.0\ \pm0.9 ) %
                                                                                                                                                                   \Gamma_{113}
Γ<sub>58</sub>
                                                                                                                                                                                       \times B(K^{*+} \rightarrow K^0 \pi^+)
            K^-\pi^+\pi^+\pi^+\pi^-
                                                                                      ( 8.2 \pm 1.4 ) \times 10^{-3}
\Gamma_{59}
                                                                                                                                                                   \Gamma_{114} \quad K^{+} K^{-} \pi^{+} \pi^{0}
                \overline{K}^*(892)^0\pi^+\pi^+\pi^-
                                                                                      ( 6.8 \pm 1.8 ) \times 10^{-3}
Γ<sub>60</sub>
                                                                                                                                                                                \phi \pi^+ \pi^0 \times B(\phi \rightarrow K^+ K^-)
                     \times B(\overline{K}^{*0} \rightarrow K^{-}\pi^{+})
                                                                                                                                                                   Γ<sub>115</sub>
                                                                                                                                                                                                                                                       (1.1 \pm 0.5)\%

\begin{array}{ccc}
\stackrel{\times}{\overline{K}} * (892)^0 \rho^0 \pi^+ \\
\times \mathsf{B}(\overline{K}^{*0} \to K^- \pi^+)
\end{array}

                                                                                                                                                                                     \phi \rho^+ \times B(\phi \to K^+ K^-)
                                                                                                                                                                   Γ<sub>116</sub>
                                                                                                                                                                                                                                                      < 7 \times 10^{-3}
                                                                                                                                                                                                                                                                                                    CL=90%
\Gamma_{61}
                                                                                      (5.1 \pm 2.2) \times 10^{-3}
                                                                                                                                                                                 K^+K^-\pi^+\pi^0 non-\phi
                                                                                                                                                                                                                                                      (1.5 \begin{array}{c} +0.7 \\ -0.6 \end{array})\%
                                                                                                                                                                   \Gamma_{117}
           \mathit{K}^-\,\pi^+\,\pi^+\,\pi^0\,\pi^0
                                                                                                                                                                   \Gamma_{118} K^+\overline{K}{}^0\pi^+\pi^-
                                                                                      ( 2.2 \begin{tabular}{c} +5.0 \\ -0.9 \end{tabular} ) %
\Gamma_{62}
                                                                                                                                                                                                                                                     < 2
                                                                                                                                                                                                                                                                                                    CL=90%
                                                                                                                                                                   \Gamma_{119}^{110} \ K^0 K^- \pi^+ \pi^+
                                                                                                                                                                                                                                                       (1.0 \pm 0.6)\%
           \overline{K}{}^0\pi^+\pi^+\pi^-\pi^0
                                                                                      ( 5.4 \begin{array}{c} +3.0 \\ -1.4 \end{array} ) %
\Gamma_{63}
                                                                                                                                                                                  K^*(892)^+\overline{K}^*(892)^0
                                                                                                                                                                   \Gamma_{120}
                                                                                                                                                                                                                                                       ( 1.2 \pm 0.5 ) %
                                                                                                                                                                                       \times B^2(K^* \to K\pi^+)
           \overline{K}{}^0\pi^+\pi^+\pi^+\pi^-\pi^-
\Gamma_{64}
                                                                                      (8 \pm 7) \times 10^{-4}

\Gamma_{121} \xrightarrow{K^0 K^- \pi^+ \pi^+ \text{non-} K^{*+} \overline{K}^{*0}} 
\Gamma_{122} \xrightarrow{K^+ K^- \pi^+ \pi^+ \pi^-} 

            K^-\pi^+\pi^+\pi^+\pi^-\pi^0
                                                                                      ( 2.0 \pm 1.8 ) \times 10^{-3}
\Gamma_{65}
                                                                                                                                                                                                                                                                               \times 10<sup>-3</sup>
                                                                                                                                                                                                                                                                                                    CL=90%
           \overline{K}{}^{0}\,\overline{K}{}^{0}\,K^{+}
\Gamma_{66}
                                                                                      (1.8 \pm 0.8)\%
                                                                                                                                                                                  \phi \pi^{+} \pi^{+} \pi^{-}
                                                                                                                                                                                                                                                                               \times 10^{-3}
                                                                                                                                                                   \Gamma_{123}
                                                                                                                                                                                                                                                     < 1
                                                                                                                                                                                                                                                                                                    CL=90%
                                                                                                                                                                                       \times B(\phi \rightarrow K^+K^-)
              Fractions of some of the following modes with resonances have already
              appeared above as submodes of particular charged-particle modes.
                                                                                                                                                                                   K^+K^-\pi^+\pi^+\pi^- nonresonant
                                                                                                                                                                   \Gamma_{124}
                                                                                                                                                                                                                                                     < 3
                                                                                                                                                                                                                                                                                                    CL=90%
            \overline{K}^0 \rho^+
                                                                                     ( 6.6 ±2.5 ) %
           \frac{K}{K^0} a_1(1260)^+
\frac{K}{K^0} a_2(1320)^+
                                                                                      ( 8.1 \pm 1.7 ) %
Γ<sub>68</sub>
                                                                                                                                                                                 Fractions of the following modes with resonances have already appeared
                                                                                                       \times 10<sup>-3</sup>
                                                                                   < 3
                                                                                                                                  CL=90%
                                                                                                                                                                                  above as submodes of particular charged-particle modes.
\Gamma_{69}
Γ70
            \overline{K}^*(892)^0 \pi^+
                                                                                     (1.92 \pm 0.19)\%
                                                                                                                                                                   \Gamma_{125} \phi\pi^+
                                                                                                                                                                                                                                                       ( 6.1 \pm 0.6 ) \times 10^{-3}
           \frac{K^*(892)^o \pi}{K^*(892)^0 \rho^+ \text{total}}
\frac{K^*(892)^0 \rho^+ S\text{-wave}}{K^*(892)^0 \rho^+ P\text{-wave}}
\Gamma_{71}
                                                                                                                                                                   \Gamma_{126} \phi \pi^+ \pi^0
                                                                                      ( 2.1 \pm1.4 )%
                                                                                                                                                                                                                                                       (2.3 \pm 1.0)\%
                                                                                                                                                                               \phi \rho^+
 Γ72
                                                                             [e] (1.7 \pm 1.6)\%
                                                                                                                                                                   \Gamma_{127}
                                                                                                                                                                                                                                                     < 1.5
                                                                                                                                                                                                                                                                               %
                                                                                                                                                                                                                                                                                                    CL=90%
                                                                                                                                                                  \Gamma_{128} \phi_{\pi}^{+} \pi^{+} \pi^{-} \Gamma_{129} K^{+} \overline{K}^{*} (892)^{0}
                                                                                   < 1 \times 10^{-3}
\Gamma_{73}
                                                                                                                                  CL=90%
                                                                                                                                                                                                                                                                               \times 10^{-3}
                                                                                                                                                                                                                                                     < 2
                                                                                                                                                                                                                                                                                                    CL=90%
                \frac{K}{K}*(892)<sup>0</sup> \rho+ D-wave \frac{K}{K}*(892)<sup>0</sup> \rho+ D-wave longitudi-
                                                                                    (10 \pm 7) \times 10^{-3}
                                                                                                                                                                                                                                                       ( 4.2 \pm 0.5 ) \times\,10^{-3}
\Gamma_{74}
                                                                                                           × 10<sup>-3</sup>
                                                                                                                                                                   \Gamma_{130} \quad K^*(892)^{+} \frac{-7}{K}{}^{0}
Γ<sub>75</sub>
                                                                                   < 7
                                                                                                                                  CL=90%
                                                                                                                                                                                                                                                       ( 3.0 \pm 1.4 ) %
                                                                                                                                                                   \Gamma_{131} K^*(892)^+ \overline{K}^*(892)^0
                                                                                                                                                                                                                                                       ( 2.6 \pm 1.1 ) %
           \overline{K}_{1}(1270)^{0}\pi^{+}
Γ<sub>76</sub>
                                                                                                                                  CL=90%
           \overline{K}_1(1400)^0 \pi^+
                                                                                                                                                                                                    Doubly Cabibbo suppressed (DC) modes,
                                                                                    (5.0 \pm 1.3)\%
\Gamma_{77}
           \overline{K}^*(1410)^0 \pi^+
                                                                                   < 7 \times 10<sup>-3</sup>
                                                                                                                                                                                                \Delta C = 1 weak neutral current (C1) modes, or
Γ<sub>78</sub>
                                                                                                                                  CL=90%
           K_0^*(1410)^n \pi^+

K_0^*(1430)^0 \pi^+

K^*(1680)^0 \pi^+

K^*(892)^0 \pi^+ \pi^0 \text{ total}
                                                                                                                                                                            Lepton Family number (LF) or Lepton number (L) violating modes
                                                                                    (3.7 \pm 0.4)\%
\Gamma_{79}
                                                                                                                                                                  \Gamma_{132} \quad \stackrel{\cdot}{K^{+}} \pi^{+} \pi^{-} \Gamma_{133} \quad \stackrel{\cdot}{K^{+}} \rho^{0}
                                                                                                                                                                                                                                 DC
                                                                                                                                                                                                                                                     ( 6.5 \pm 2.6 ) \times 10^{-4}
                                                                                      ( 1.45 \pm 0.31) %
Γ<sub>80</sub>
                                                                                                                                                                                                                                                                            × 10<sup>-4</sup>
                                                                                                                                                                                                                                   DC
                                                                                                                                                                                                                                                    < 6
                                                                                      (6.7 \pm 1.4)\%
                                                                                                                                                                  \Gamma_{133}
                                                                                                                                                                                                                                                                                                    CL=90%
Γ<sub>81</sub>
           K^*(892)^0 \pi^+ \pi^0 3-body

K^*(892)^- \pi^+ \pi^+ total
                                                                                                                                                                                  K^*(892)^0\pi^+
                                                                                                                                                                                                                                                                              × 10<sup>-4</sup>
                                                                                                                                                                                                                                                    < 1.9
\Gamma_{82}
                                                                                     (4.2 \pm 1.4)\%
                                                                                                                                                                  Γ<sub>134</sub>
                                                                                                                                                                                                                                  DC
                                                                                                                                                                                                                                                                                                    CL=90%
                                                                                                                                                                  \Gamma_{135} \quad K^+ K^+ K^-
                                                                                                                                                                                                                                                                               \times 10<sup>-4</sup>
                                                                                                                                                                                                                                   DC
                                                                                                                                                                                                                                                     < 1.5
                                                                                                                                                                                                                                                                                                    CL=90%
```

Γ ₁₃₆	ϕK^+	DC	<	1.3	× 10 ⁻⁴	CL=90%
Γ_{137}	$\pi^{+} e^{+} e^{-}$	C1	<	6.6	× 10 ⁻⁵	CL=90%
Γ_{138}	$\pi^{+}\mu^{+}\mu^{-}$	C1	<	1.8	× 10 ⁻⁵	CL=90%
Γ_{139}	$\rho^{+} \mu^{+} \mu^{-}$	C1	<	5.6	× 10 ⁻⁴	CL=90%
Γ_{140}	$K^{+}e^{+}e^{-}$		[f] <	4.8	\times 10 ⁻³	CL=90%
Γ_{141}	$K^{+}\mu^{+}\mu^{-}$		[f] <	3.2	× 10 ⁻⁴	CL=90%
Γ_{142}	$\pi^+ e^{\pm} \mu^{\mp}$	LF	[g] <	3.8	\times 10 ⁻³	CL=90%
Γ_{143}	$\pi^+e^+\mu^-$	LF	<	3.3	\times 10 ⁻³	CL=90%
	$\pi^{+} e^{-} \mu^{+}$	LF	<	3.3	\times 10 ⁻³	CL=90%
Γ ₁₄₅	$K^+e^+\mu^-$	LF	<	3.4	\times 10 ⁻³	CL=90%
Γ ₁₄₆		LF	<	3.4	$\times 10^{-3}$	CL=90%
Γ ₁₄₇	$\pi^{-}e^{+}e^{+}$	L	<	4.8	$\times 10^{-3}$	CL=90%
Γ ₁₄₈	$\pi^{-}\mu^{+}\mu^{+}$	L.	<	2.2	× 10 ⁻⁴	CL=90%
Γ ₁₄₉	$\pi^{-}e^{+}\mu^{+}$	L	<	3.7	× 10 ⁻³	CL=90%
	$\rho^{-}\mu^{+}\mu^{+}$	L	<	5.6	× 10 ⁻⁴	CL=90%
Γ ₁₅₁	$K^-e^+e^+$	L	<	9.1	× 10 ⁻³	CL=90%
	$K^- \mu^+ \mu^+$	L	<	3.2	× 10 ⁻⁴	CL=90%
Γ ₁₅₃	$K^{-}e^{+}\mu^{+}$	L	<	4.0	× 10 ⁻³	CL=90%
Γ ₁₅₄	$K^*(892)^- \mu^+ \mu^+$	L	<	8.5	× 10 ⁻⁴	CL=90%

 Γ_{155} A dummy mode used by the fit.

- (36 ± 5) %
- [a] This is a weighted average of D^\pm (44%) and D^0 (56%) branching fractions. See " D^+ and $D^0 \to (\eta \, \text{anything}) / (\text{total } D^+ \, \text{and } D^0)$ " under " D^+ Branching Ratios" in these Particle Listings.
- [b] This value averages the e^+ and μ^+ branching fractions, after making a small phase-space adjustment to the μ^+ fraction to be able to use it as an e^+ fraction; hence our ℓ^+ is really an e^+ .
- [c] ℓ indicates e or μ mode, not sum over modes.
- [d] The branching fractions for this mode may differ from the sum of the submodes that contribute to it, due to interference effects. See the relevant papers.
- [e] The two experiments determining this ratio are in serious disagreement. See the Particle Listings.
- [f] This mode is not a useful test for a $\Delta C=1$ weak neutral current because both quarks must change flavor in this decay.
- $[g] \ \mbox{The value}$ is for the sum of the charge states of particle/antiparticle states indicated.

CONSTRAINED FIT INFORMATION

An overall fit to 23 branching ratios uses 37 measurements and one constraint to determine 14 parameters. The overall fit has a $\chi^2=13.8$ for 24 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\left\langle \delta x_i \delta x_j \right\rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv \Gamma_i / \Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to

	1									
×12	4									
×17	4	2								
^X 26	15	29	8							
×27	12	7	31	26						
<i>×</i> 33	41	6	5	20	16					
×34	27	17	14	57	45	35				
<i>x</i> 39	0	0	0	0	0	0	0			
×43	6	4	3	13	10	8	23	0		
×52	8	5	4	17	14	10	30	0	18	
×70	18	11	9	37	30	23	65	0	15	20
×77	4	3	2	9	7	5	15	0	31	37
×84	2	1	1	5	4	3	9	0	29	13
<i>x</i> ₁₅₅	-33	-27	-12	-40	-33	-29	-52	-60	-46	-45
	<i>x</i> ₁₀	<i>x</i> ₁₂	<i>×</i> 17	^X 26	×27	<i>x</i> 33	×34	×39	×43	<i>x</i> ₅₂
×77	10									
×84	6	12								
x ₁₅₅	-36	-47	-33							
	×70	×77	×84							

D+ BRANCHING RATIOS

See the "Note on D Mesons" above. Some now-obsolete measurements have been omitted from these Listings.

— Inclusive modes ——

$\Gamma(e^+ \text{ anything})/\Gamma_{to}$	tal			Γ_1/Γ
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.172±0.019 OUR AV	ERAGE			
$0.20 \begin{array}{c} +0.09 \\ -0.07 \end{array}$		AGUILAR	87E HYBR	πp, pp 360, 400 GeV
$0.170 \pm 0.019 \pm 0.007$	158	BALTRUSAIT	85B MRK3	s e ⁺ e [−] 3.77 GeV
0.168 ± 0.064	23	SCHINDLER	81 MRK2	e ⁺ e ⁻ 3.771 GeV
• • • We do not use t	he followin	ig data for average	es, fits, limits	, etc. • • •
0.220 + 0.044		BACINO	80 DLCO	$e^{+}e^{-}$ 3.77 GeV

D^+ and $D^0 \rightarrow (e^+$ anything) / (total D^+ and D^0)

If measured at the $\psi(3770)$, this quantity is a weighted average of D^+ (44%) and D^0 (56%) branching fractions. Only experiments at $E_{\rm CM}=3.77$ GeV are included in the average here.

VALUE EVTS	DOCUMENT ID TECN COMMENT
0.110 ± 0.011 OUR AVERAGE	Error includes scale factor of 1.1.
0.117±0.011 295	BALTRUSAIT85B MRK3 e^+e^- 3.77 GeV
0.10 ± 0.032	4 SCHINDLER 81 MRK2 e^+e^- 3.771 GeV
0.072 ± 0.028	FELLER 78 MRK1 e^+e^- 3.772 GeV
• • We do not use the follow	wing data for averages, fits, limits, etc. • •
$0.134 \pm 0.015 \pm 0.010$	⁵ ABE 93E VNS e^+e^- 58 GeV
$0.098 \pm 0.009 ^{+0.006}_{-0.005}$ 240	6 ALBRECHT 92F ARG e^+e^-pprox 10 GeV
$0.096 \pm 0.007 \pm 0.015$	⁷ ONG 88 MRK2 e^+e^- 29 GeV
$0.116^{+0.011}_{-0.009}$	⁷ PAL 86 DLCO e ⁺ e ⁻ 29 GeV
$0.091 \pm 0.009 \pm 0.013$	7 AIHARA 85 TPC e^+e^- 29 GeV
$0.092 \pm 0.022 \pm 0.040$	7 ALTHOFF 84J TASS e^+e^- 34.6 GeV
0.091 ± 0.013	⁷ KOOP 84 DLCO See PAL 86
0.08 ± 0.015	⁸ BACINO 79 DLCO e^+e^- 3.772 GeV

⁴ Isolates ${\it D}^+$ and ${\it D}^0 \rightarrow {\it e}^+ \, {\it X}$ and weights for relative production (44%–56%).

5 ABE 93E also measures forward-backward asymmetries and fragmentation functions for c and b quarks.

c and D quants.

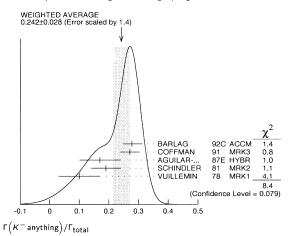
6 ALBRECHT 92F uses the excess of right-sign over wrong-sign leptons in a sample of events tagged by fully reconstructed $D^*(2010)^+ \rightarrow D^0 \pi^+$ decays.

⁷Average BR for charm $\rightarrow e^+$ X. Unlike at $E_{\rm cm}=3.77$ GeV, the admixture of charmed

mesons is unknown. ⁸ Not independent of BACINO 80 measurements of $\Gamma(e^+ \text{ anything})/\Gamma_{\text{total}}$ for the D^+ and D^0 separately.

$\Gamma(K^- \text{ anything})/\Gamma_t$	otal				Γ ₂ /Γ
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.242 ± 0.028 OUR AV	ERAGE	Error includes scale	facto	r of 1.4	. See the ideogram below.
$0.278 {}^{+ 0.036}_{- 0.031}$		⁹ BARLAG	9 2C	АССМ	π^- Cu 230 GeV
$0.271 \pm 0.023 \pm 0.024$		COFFMAN	91	MRK3	$e^{+}e^{-}$ 3.77 GeV
0.17 ± 0.07		AGUILAR	87E	HYBR	πp, pp 360, 400 GeV
0.19 ±0.05	26	SCHINDLER	81	MRK2	e ⁺ e ⁻ 3.771 GeV
0.10 ±0.07	3	VUILLEMIN	78	MRK1	e ⁺ e ⁻ 3.772 GeV
• • • We do not use t	the follov	ving data for average	s, fits	, limits,	etc. • • •
$0.16 \begin{array}{l} +0.08 \\ -0.07 \end{array}$		AGUILAR	86B	HYBR	See AGUILAR- BENITEZ 87E

⁹BARLAG 92C computes the branching fraction using topological normalization.



$\Gamma(K^0 \text{ anything}) + \Gamma(K^0 \text{ anything})]/\Gamma_{\text{total}}$ Γ_3/Γ	$\Gamma(\overline{K^0}e^+\nu_e)/\Gamma_{\text{total}}$ VALUE FYTS DOCUMENT ID TECH COMMENT
ALUE EVTS DOCUMENT ID TECN COMMENT	VALUE EVTS DOCUMENT ID TECN COMMENT 0.066±0.009 OUR FIT
$612 \pm 0.065 \pm 0.043$ COFFMAN 91 MRK3 e^+e^- 3.77 GeV	$0.06 + 0.022 \pm 0.007$ 13 BAI 91 MRK3 $e^+e^- \approx 3.77 \text{ GeV}$
52 ± 0.18 15 SCHINDLER 81 MRK2 e^+e^- 3.771 GeV	-0.013 -0.013
39 ± 0.29 3 VUILLEMIN 78 MRK1 e^+e^- 3.772 GeV	$\Gamma(\overline{K}^0 e^+ \nu_e) / \Gamma(\overline{K}^0 \pi^+)$ Γ_{10} / Γ_3
$(K^+$ anything $)/\Gamma_{\text{total}}$ Γ_4/Γ	VALUE EVTS DOCUMENT ID TECN COMMENT
UE EVTS DOCUMENT ID TECN COMMENT	2.39 ± 0.33 OUR FIT 2.60 ± 0.35 ± 0.26 186 ¹⁷ BEAN 93C CLEO $e^+e^- \approx \Upsilon(4S)$
58±0.014 OUR AVERAGE 55±0.013±0.009 COFFMAN 91 MRK3 e ⁺ e ⁻ 3.77 GeV	, ,
	17 BEAN 93C uses $\overline{K}^0\mu^+\nu_\mu$ as well as $\overline{K}^0e^+\nu_e$ events and makes a small phase-spa
$_{-0.05}^{+0.06}$ AGUILAR 87E HYBR $\pi p, pp$ 360, 400 GeV	adjustment to the number of the μ^+ events to use them as e^+ events.
06 ± 0.04 12 SCHINDLER 81 MRK2 e^+e^- 3.771 GeV 06 ± 0.06 2 VUILLEMIN 78 MRK1 e^+e^- 3.772 GeV	$\Gamma(\overline{K}^0 e^+ \nu_e) / \Gamma(K^- \pi^+ \pi^+)$ Γ_{10} / Γ_3
	VALUE DOCUMENT ID TECN COMMENT
$^+$ and $D^0 o (\eta \text{ anything}) / (\text{total } D^+ \text{ and } D^0)$	0.72±0.10 OUR FIT 0.66±0.09±0.14 ANJOS 91C E691 γ Be 80–240 GeV
If measured at the $\psi(3770)$, this quantity is a weighted average of D^+ (44%) and D^0	·
(56%) branching fractions. Only the experiment at $E_{cm} = 3.77$ GeV is used. ALUE DOCUMENT ID TECN COMMENT	$\Gamma(\overline{K}^0\mu^+ u_\mu)/\Gamma_{ ext{total}}$ Γ_{11}
0.13 PARTRIDGE 81 CBAL e ⁺ e ⁻ 3.77 GeV	VALUE EVTS DOCUMENT ID TECN COMMENT
 ◆ We do not use the following data for averages, fits, limits, etc. 	0.07 $^{+0.028}_{-0.016}$ $^{\pm}$ 0.012 14 BAI 91 MRK3 $e^+e^-\approx 3.77 \text{ GeV}$
10 BRANDELIK 79 DASP e^+e^- 4.03 GeV	
¹⁰ The BRANDELIK 79 result is based on the absence of an η signal at $E_{\rm Cm}=4.03$ GeV. PARTRIDGE 81 observes a substantially higher η cross section at 4.03 GeV.	$\Gamma(\overline{K}^0\mu^+\nu_\mu)/\Gamma(\mu^+$ anything) Γ_{11}/Γ
PARTRIDGE 81 observes a substantially higher η cross section at 4.03 GeV.	VALUE EVTS DOCUMENT ID COMMENT
$(c/\overline{c} \rightarrow \mu^+ \text{ anything})/\Gamma(c/\overline{c} \rightarrow \text{ anything})$	• • • We do not use the following data for averages, fits, limits, etc. • •
This is the average branching ratio for charm $ ightarrow \ \mu^+ X$. The mixture of charmed	0.76 ± 0.06 84 18 AOKI 88 π^- emulsion
particles is unknown and may actually contain states other than <i>D</i> mesons. ALUE	18 From topological branching ratios in emulsion with an identified muon.
	$\Gamma(K^-\pi^+e^+\nu_e)/\Gamma_{\text{total}}$ Γ_{12}
081 ^{+0.010} _{-0.009} OUR AVERAGE	VALUE CL% EVTS DOCUMENT ID TECN COMMENT
$0.0086\pm0.017^{+0.008}_{-0.007}$ 69 11 ALBRECHT 92F ARG e^+e^-pprox 10 GeV	0.042 ^{+0.009} OUR FIT
$0.78 \pm 0.009 \pm 0.012$ ONG 88 MRK2 e^+e^- 29 GeV	
078 \pm 0.015 \pm 0.02 BARTEL 87 JADE $e^{+}e^{-}$ 34.6 GeV	$0.035 ^{+0.012}_{-0.007} \pm 0.004$ 14 ¹⁹ BAI 91 MRK3 $e^+e^- \approx 3.77$
$0.012^{+0.02}_{-0.01}$ ALTHOFF 84G TASS e^+e^- 34.5 GeV	 ◆ We do not use the following data for averages, fits, limits, etc.
• We do not use the following data for averages, fits, limits, etc. • • •	<0.057 90 ²⁰ AGUILAR 87F HYBR πρ, ρρ 360, 400
.089±0.018±0.025 BARTEL 85J JADE See BARTEL 87	$$^{19}\rm BAI~91$$ finds that a fraction $0.79^{+}_{-}0.15^{+}0.09$ of combined D^{+} and D^{0} decays
ALBRECHT 92F uses the excess of right-sign over wrong-sign leptons in a sample of	
events tagged by fully reconstructed $D^*(2010)^+ \rightarrow D^0 \pi^+$ decays.	$\overline{K}\pi e^+\nu_e$ (24 events) are $\overline{K}^*(892)e^+\nu_e$.
cremes ragged by rany recommendation = ()	
$(c/\overline{c} \rightarrow e^+e^- \text{ anything})/\Gamma(c/\overline{c} \rightarrow \text{ anything})$	²⁰ AGUILAR-BENITEZ 87F computes the branching fraction using topological normalization.
$(c/\overline{c} \rightarrow e^+e^-$ anything)/ $\Gamma(c/\overline{c} \rightarrow \text{anything})$	 20 AGUILAR-BENITEZ 87F computes the branching fraction using topological normalization. Γ(K*(892)⁰ ℓ⁺ν_ℓ)/Γ_{total}
$f(c/\overline{c} \rightarrow e^+e^-\text{anything})/\Gamma(c/\overline{c} \rightarrow \text{anything})$ ALUE CL% EVTS DOCUMENT ID TECH COMMENT • • We do not use the following data for averages, fits, limits, etc. • • •	²⁰ AGUILAR-BENITEZ 87F computes the branching fraction using topological normalization. $\Gamma(\overline{K}^*(892)^0 \ell^+ \nu_\ell) / \Gamma_{\text{total}}$ We average our $\overline{K}^{*0} e^+ \nu_e$ and $\overline{K}^{*0} \mu^+ \nu_\mu$ branching fractions, after multiplying t
$(c/\overline{c} \rightarrow e^+e^-\text{anything})/\Gamma(c/\overline{c} \rightarrow \text{anything})$ ALUE CLY EVTS DOCUMENT ID TECN COMMENT • • We do not use the following data for averages, fits, limits, etc. • • • • • • • • • • • • • • • • • • •	²⁰ AGUILAR-BENITEZ 87F computes the branching fraction using topological normalization. $\Gamma(\overline{K}^*(892)^0 \ell^+ \nu_\ell) / \Gamma_{\text{total}}$ We average our $\overline{K}^{*0} e^+ \nu_e$ and $\overline{K}^{*0} \mu^+ \nu_\mu$ branching fractions, after multiplying the latter by a phase-space factor of 1.05 to be able to use it with the $\overline{K}^{*0} e^+ \nu_e$ fractions.
$(c/\overline{c} \rightarrow e^+e^-\text{anything})/\Gamma(c/\overline{c} \rightarrow \text{anything})$ ALUE CL% EVTS DOCUMENT ID TECN COMMENT • • We do not use the following data for averages, fits, limits, etc. • • • • • • • • • • • • • • • • • • •	²⁰ AGUILAR-BENITEZ 87F computes the branching fraction using topological normalition. $\Gamma(\overline{K}^*(892)^0 \ell^+ \nu_\ell) / \Gamma_{\text{total}}$ $\Gamma_{\text{25}},$ We average our $\overline{K}^{*0} e^+ \nu_e$ and $\overline{K}^{*0} \mu^+ \nu_\mu$ branching fractions, after multiplying to
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	20 AGUILAR-BENITEZ 87F computes the branching fraction using topological normalization. $\Gamma(\overline{K}^*(892)^0 \ell^+ \nu_\ell) / \Gamma_{\text{total}} \qquad \qquad \Gamma_{25},$ We average our $\overline{K}^{*0} e^+ \nu_e$ and $\overline{K}^{*0} \mu^+ \nu_\mu$ branching fractions, after multiplying to latter by a phase-space factor of 1.05 to be able to use it with the $\overline{K}^{*0} e^+ \nu_e$ fraction. Hence our ℓ^+ here is really an e^+ . NALUE DOCUMENT ID COMMENT
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	20 AGUILAR-BENITEZ 87F computes the branching fraction using topological normalization. $\Gamma(\overline{K}^*(892)^0 \ell^+ \nu_\ell) / \Gamma_{\text{total}} \qquad \qquad \Gamma_{25/}$ We average our $\overline{K}^{*0} e^+ \nu_e$ and $\overline{K}^{*0} \mu^+ \nu_\mu$ branching fractions, after multiplying to latter by a phase-space factor of 1.05 to be able to use it with the $\overline{K}^{*0} e^+ \nu_e$ fraction. Hence our ℓ^+ here is really an e^+ . NALUE DOCUMENT ID COMMENT.
	20 AGUILAR-BENITEZ 87F computes the branching fraction using topological normalization. $\Gamma(\overline{K}^*(892)^0 \ell^+ \nu_\ell) / \Gamma_{\text{total}} \qquad \qquad \Gamma_{25/}$ We average our $\overline{K}^{*0} e^+ \nu_e$ and $\overline{K}^{*0} \mu^+ \nu_\mu$ branching fractions, after multiplying to latter by a phase-space factor of 1.05 to be able to use it with the $\overline{K}^{*0} e^+ \nu_e$ fraction. Hence our ℓ^+ here is really an e^+ . NALUE DOCUMENT ID COMMENT
$(c/\overline{c} \rightarrow e^+e^-\text{anything})/\Gamma(c/\overline{c} \rightarrow \text{anything})$ ALUE CL% EVTS DOCUMENT ID TECN COMMENT • We do not use the following data for averages, fits, limits, etc. • • • (2.2 × 10 ⁻³ 90 0.1 12 HAAS 88 CLEO e^+e^- 10 GeV 12 The normalization uses a continuum charm production estimate. $(c/\overline{c} \rightarrow e^+\mu^-\text{anything})/\Gamma(c/\overline{c} \rightarrow \text{anything})$ ALUE CL% EVTS DOCUMENT ID TECN COMMENT • We do not use the following data for averages, fits, limits, etc. • • • • • • • • • • • • • • • • • • •	20 AGUILAR-BENITEZ 87F computes the branching fraction using topological normalization. $\Gamma(\overline{K}^*(892)^0\ell^+\nu_\ell)/\Gamma_{total} \qquad \qquad \Gamma_{25/}$ We average our $\overline{\kappa}^{*0}$ $e^+\nu_e$ and $\overline{\kappa}^{*0}$ $\mu^+\nu_\mu$ branching fractions, after multiplying to latter by a phase-space factor of 1.05 to be able to use it with the $\overline{\kappa}^{*0}$ $e^+\nu_e$ fraction. Hence our ℓ^+ here is really an e^+ . $\frac{NALUE}{0.048\pm0.004} \frac{DOCUMENT\ ID}{0.048\pm0.005} \frac{COMMENT}{0.047\pm0.006} \frac{Our\ \Gamma(\overline{\kappa}^{*0}$ $e^+\nu_e)/\Gamma_{total}}{0.047\pm0.006} \frac{96}{0.047\pm0.006} \frac{Our\ \Gamma(\overline{\kappa}^{*0}$ $e^+\nu_e)/\Gamma_{total}}{0.047\pm0.006} \frac{1.05\times our\ \Gamma(\overline{\kappa}^{*0}$ $e^+\nu_\mu)/\Gamma_{total}}{0.047\pm0.006}$
$(c/\overline{c} \rightarrow e^+e^-\text{anything})/\Gamma(c/\overline{c} \rightarrow \text{anything})$ ALUE CL% EVTS DOCUMENT ID • We do not use the following data for averages, fits, limits, etc. (2.2×10^{-3}) 90 0.1 (2.2×10^{-3}) 90 0.2 (2.2×10^{-3}) 10 TECN COMMENT • We do not use the following data for averages, fits, limits, etc. 3.7 × 10 ⁻³ 90 0.2 (2.2×10^{-3}) 90 0.2 (2.2×10^{-3}) 13 The normalization uses a continuum charm production estimate.	20 AGUILAR-BENITEZ 87F computes the branching fraction using topological normalization. $\Gamma(\overline{K}^*(892)^0 \ell^+ \nu_\ell)/\Gamma_{\text{total}} \qquad \qquad \Gamma_{25/K}$ We average our $\overline{K}^{*0} e^+ \nu_e$ and $\overline{K}^{*0} \mu^+ \nu_\mu$ branching fractions, after multiplying to latter by a phase-space factor of 1.05 to be able to use it with the $\overline{K}^{*0} e^+ \nu_e$ fraction. Hence our ℓ^+ here is really an e^+ . $\frac{NALUE}{0.048 \pm 0.004} \frac{DOCUMENT ID}{0.048 \pm 0.005} \frac{COMMENT}{0.047 \pm 0.006} \frac{96}{0.047 \pm 0.006} \frac{96}{$
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$c/\overline{c} \rightarrow e^+e^-$ anything)/ $\Gamma(c/\overline{c} \rightarrow \text{anything})$ LUE CLY EVTS DOCUMENT ID TECN COMMENT • • We do not use the following data for averages, fits, limits, etc. • • • 2.2 × 10 ⁻³ 90 0.1 12 HAAS 88 CLEO e^+e^- 10 GeV The normalization uses a continuum charm production estimate. $c/\overline{c} \rightarrow e^+\mu^-$ anything)/ $\Gamma(c/\overline{c} \rightarrow \text{anything})$ LUE CLY EVTS DOCUMENT ID TECN COMMENT • • We do not use the following data for averages, fits, limits, etc. • • • 3.7 × 10 ⁻³ 90 0.2 13 HAAS 88 CLEO e^+e^- 10 GeV The normalization uses a continuum charm production estimate. $c/\overline{c} \rightarrow \mu^+\mu^-$ anything)/ $\Gamma(c/\overline{c} \rightarrow \text{anything})$ LUE CLY EVTS DOCUMENT ID TECN COMMENT • • We do not use the following data for averages, fits, limits, etc. • • • 0.018 90 0.3 14 HAAS 88 CLEO e^+e^- 10 GeV 0.019 95 0.3 15 ALTHOFF 84G TASS e^+e^- 34.5 GeV	20 AGUILAR-BENITEZ 87F computes the branching fraction using topological normalition. $\Gamma(\overline{K^*(892)^0}\ell^+\nu_\ell)/\Gamma_{total} \qquad \qquad \Gamma_{25}$ We average our $K^{*0}e^+\nu_e$ and $\overline{K^{*0}}\mu^+\nu_\mu$ branching fractions, after multiplying a latter by a phase-space factor of 1.05 to be able to use it with the $\overline{K^{*0}}e^+\nu_e$ fractional latter by a phase-space factor of 1.05 to be able to use it with the $\overline{K^{*0}}e^+\nu_e$ fractional latter by a phase-space factor of 1.05 to be able to use it with the $\overline{K^{*0}}e^+\nu_e$ fractional latter by a phase-space factor of 1.05 to be able to use it with the $\overline{K^{*0}}e^+\nu_e$ fractional latter by a phase-space factor of 1.05 to be able to use it with the $\overline{K^{*0}}e^+\nu_e$ fractional latter by a phase-space factor of 1.05 to be able to use it with the $\overline{K^{*0}}e^+\nu_e$ fractional latter by a phase-space factor of 1.05 to be able to use it with the $\overline{K^{*0}}e^+\nu_e$ fractional latter by a phase-space factor of 1.05 to be able to use it with the $\overline{K^{*0}}e^+\nu_e$ fractional latter by a phase-space factor of 1.05 to be able to use it with the $\overline{K^{*0}}e^+\nu_e$ fractional latter by a phase-space factor of 1.05 to be able to use it with the $\overline{K^{*0}}e^+\nu_e$ fractional latter by a phase-space factor of 1.05 to be able to use it with the $\overline{K^{*0}}e^+\nu_e$ fractional latter by a phase-space factor of 1.05 to be able to use it with the $\overline{K^{*0}}e^+\nu_e$ fractional latter by a phase-space factor of 1.05 to be able to use it with the $\overline{K^{*0}}e^+\nu_e$ fractional latter by a phase-space factor of 1.05 to be able to use it with the $\overline{K^{*0}}e^+\nu_e$ fractional latter by a phase-space factor of 1.05 to be able to use it with the $\overline{K^{*0}}e^+\nu_e$ fractional latter by a phase-space factor of 1.05 to be able to use it with the $\overline{K^{*0}}e^+\nu_e$ fractional latter by a phase-space factor of 1.05 to be able to use it with the $\overline{K^{*0}}e^+\nu_e$ fractional latter by a phase-space factor of 1.05 to be able to use it with the $\overline{K^{*0}}e^+\nu_e$ fractional latter by a phase-space factor of 1.05 to be able to use
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$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c} 20 \text{ AGUILAR-BENITEZ 87F computes the branching fraction using topological normalization.} \\ \hline \Gamma(\overline{K^*(892)^0}\ell^+\nu_\ell)/\Gamma_{\text{total}} & \Gamma_{25/K} \\ \hline \text{We average our } \overline{K^{*0}}e^+\nu_e \text{ and } \overline{K^{*0}}\mu^+\nu_\mu \text{ branching fractions, after multiplying tall latter by a phase-space factor of 1.05 to be able to use it with the } \overline{K^{*0}}e^+\nu_e \text{ fraction hence our } \ell^+ \text{ here is really an } e^+. \\ \hline \text{MALUE} & DOCUMENT ID & COMMENT \\ \hline 0.048 \pm 0.004 \text{ OUR AVERAGE} \\ 0.048 \pm 0.005 & \text{PDG} & 96 \text{ Our } \Gamma(\overline{K^{*0}}e^+\nu_e)/\Gamma_{\text{total}} \\ 0.048 \pm 0.006 & \text{PDG} & 96 \text{ 1.05} \times \text{ our } \Gamma(\overline{K^{*0}}\mu^+\nu_\mu)/\Gamma_{\text{total}} \\ 0.047 \pm 0.006 & \text{PDG} & 96 \text{ 1.05} \times \text{ our } \Gamma(\overline{K^{*0}}\mu^+\nu_\mu)/\Gamma_{\text{total}} \\ 0.047 \pm 0.006 & \text{PDG} & 96 \text{ 1.05} \times \text{ our } \Gamma(\overline{K^{*0}}\mu^+\nu_\mu)/\Gamma_{\text{total}} \\ 0.047 \pm 0.006 & \text{PDG} & 96 \text{ 1.05} \times \text{ our } \Gamma(\overline{K^{*0}}\mu^+\nu_\mu)/\Gamma_{\text{total}} \\ 0.047 \pm 0.006 & \text{PDG} & 96 \text{ 1.05} \times \text{ our } \Gamma(\overline{K^{*0}}\mu^+\nu_\mu)/\Gamma_{\text{total}} \\ 0.047 \pm 0.006 & \text{PDG} & 96 \text{ 1.05} \times \text{ our } \Gamma(\overline{K^{*0}}\mu^+\nu_\mu)/\Gamma_{\text{total}} \\ \text{Unseen decay modes of the } \overline{K^{*}}(892)^0 \text{ are included.} \\ \hline NALUE & EVTS & DOCUMENT ID & TECN & COMMENT \\ \hline 0.53 \pm 0.05 \text{ OUR FIT} & DOCUMENT ID & TECN & COMMENT \\ \hline 0.53 \pm 0.05 \text{ OUR AYERAGE} & DOCUMENT ID & TECN & COMMENT \\ \hline 0.62 \pm 0.15 \pm 0.09 & 35 & \text{ADAMOVICH 91 OMEG } \pi^- 340 \text{ GeV} \\ \hline 0.55 \pm 0.08 \pm 0.10 & 880 & \text{ALBRECHT 91 ARG } e^+e^-\approx \Upsilon(45) \\ \hline 0.62 \pm 0.15 \pm 0.09 & 35 & \text{ADAMOVICH 91 OMEG } \pi^- 340 \text{ GeV} \\ \hline 0.54 \pm 0.05 \text{ OUR AYERAGE} & \text{ANJOS} & 898 \text{ E691 Photoproduction} \\ \hline 21 \text{ BEAN 93c uses } \overline{K^{*0}}\mu^+\nu_\mu \text{ as well as } \overline{K^{*0}}e^+\nu_e \text{ events and makes a small phase-spaladjustment to the number of the } \mu^+ \text{ events to use them as } e^+ \text{ events.} \\ \hline \Gamma(K^-\pi^+e^+\nu_e \text{ nonresonant})/\Gamma_{\text{total}} & \underline{\Gamma_{14}}\mu^+\mu^-\mu^-\mu^-\mu^-\mu^-\mu^-\mu^-\mu^-\mu^-\mu^-\mu^-\mu^-\mu^-\mu$
	$ \begin{array}{c} 20 \text{ AGUILAR-BENITEZ 87F computes the branching fraction using topological normalition.} \\ \hline \Gamma(\overline{K}^*(892)^0 \ell^+ \nu_\ell) / \Gamma_{\text{total}} \\ \hline We average our $\overline{K}^{*0} \mathrm{e}^+ \nu_e$ and $\overline{K}^{*0} \mu^+ \nu_\mu$ branching fractions, after multiplying total latter by a phase-space factor of 1.05 to be able to use it with the $\overline{K}^{*0} \mathrm{e}^+ \nu_e$ fraction. Hence our ℓ^+ here is really an e^+. \\ \hline Hence our ℓ^+ here is really an e^+ here is really and $e^+$$
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$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c} 20 \text{ AGUILAR-BENITEZ 87F computes the branching fraction using topological normalition.} \\ \hline \Gamma(\overline{K^*(892)^0}\ell^+\nu_\ell)/\Gamma_{\text{total}} & \Gamma_{25} \\ \hline We average our $K^{*0}\mathrm{e}^+\nu_e$ and $K^{*0}\mu^+\nu_\mu$ branching fractions, after multiplying I latter by a phase-space factor of 1.05 to be able to use it with the $\overline{K^{*0}}\mathrm{e}^+\nu_e$ fraction. Hence our ℓ^+ here is really an e^+. \\ \hline MALUE & DOCUMENT ID & COMMENT \\ \hline 0.048 \pm 0.004 \mathrm{OUR}\mathrm{AVERAGE} \\ 0.048 \pm 0.005 \mathrm{PDG} & 96 \mathrm{Our}\Gamma(\overline{K^{*0}}\mathrm{e}^+\nu_e)/\Gamma_{\mathrm{total}} \\ 0.048 \pm 0.006 \mathrm{PDG} & 96 1.05 \times \mathrm{our}\Gamma(\overline{K^{*0}}\mathrm{e}^+\nu_e)/\Gamma_{\mathrm{total}} \\ 0.047 \pm 0.006 \mathrm{PDG} & 96 1.05 \times \mathrm{our}\Gamma(\overline{K^{*0}}\mathrm{e}^+\nu_e)/\Gamma_{\mathrm{total}} \\ 0.047 \pm 0.006 \mathrm{PDG} & 96 1.05 \times \mathrm{our}\Gamma(\overline{K^{*0}}\mathrm{e}^+\nu_e)/\Gamma_{\mathrm{total}} \\ 0.047 \pm 0.006 \mathrm{PDG} & 96 1.05 \times \mathrm{our}\Gamma(\overline{K^{*0}}\mathrm{e}^+\nu_e)/\Gamma_{\mathrm{total}} \\ 0.047 \pm 0.006 \mathrm{PDG} & 96 1.05 \times \mathrm{our}\Gamma(\overline{K^{*0}}\mathrm{e}^+\nu_e)/\Gamma_{\mathrm{total}} \\ 0.047 \pm 0.006 \mathrm{PDG} & 96 1.05 \times \mathrm{our}\Gamma(\overline{K^{*0}}\mathrm{e}^+\nu_e)/\Gamma_{\mathrm{total}} \\ 1.16 \pm 0.21 \mathrm{OUR}\mathrm{FIT} \\ 1.0 \pm 0.3 35 \mathrm{ADAMOVICH} 91 \mathrm{OMEG}\pi^- 340 \mathrm{GeV} \\ \Gamma(\overline{K^{*}}(892)^0\mathrm{e}^+\nu_e)/\Gamma(K^-\pi^+\pi^+) \Gamma_{20} \mathrm{COMMENT} \\ 1.0 \pm 0.3 35 \mathrm{ADAMOVICH} 91 \mathrm{OMEG}\pi^- 340 \mathrm{GeV} \\ \Gamma(\overline{K^{*}}(892)^0\mathrm{e}^+\nu_e)/\Gamma(K^-\pi^+\pi^+) \Gamma_{20} \mathrm{COMMENT} \\ 1.0 \pm 0.3 0.50 \mathrm{OUR}\mathrm{FIT} \\ 0.53 \pm 0.05 \mathrm{OUR}\mathrm{AVERAGE} \\ 0.67 \pm 0.09 \pm 0.07 710 21 \mathrm{BEAN} 93c \mathrm{CLEO}\mathrm{e}^+\mathrm{e}^-\approx \Upsilon(45) \\ 0.62 \pm 0.15 \pm 0.09 35 \mathrm{ADAMOVICH} 91 \mathrm{OMEG}\pi^- 340 \mathrm{GeV} \\ 0.55 \pm 0.08 \pm 0.10 880 \mathrm{ALBRECHT} 91 \mathrm{ARG}\mathrm{e}^+\mathrm{e}^-\approx 10.4 \mathrm{GeV} \\ 0.49 \pm 0.04 \pm 0.05 \mathrm{ANJOS} 898 \mathrm{E691} \mathrm{Photoproduction} \\ 21 \mathrm{BEAN} $

	$(\mu^+ u_\mu) / \Gamma_{\text{total}}$				Г ₃₁ /Г
Unseen decay modes of the K*(892) ⁰ are included. <u>VALUE</u> <u>EVTS</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> <u>VALUE</u> <u>VALUE</u>	Decay modes of the ϕ r Output Decay modes of the ϕ r CL%			COMMENT	
0.045 ±0.006 OUR FIT Error includes scale factor of 1.1.	0372 90	BAI	91 MRK3	$e^+e^-\approx 3.77$	GeV
0.0325±0.0071±0.0075 224 ²³ KODAMA 92c E653 π^- emulsion 600 GeV ²³ KODAMA 92c measures $\Gamma(D^+ \to \overline{K}^{*0} \mu^+ \nu_\mu)/\Gamma(D^0 \to K^- \mu^+ \nu_\mu) = 0.43 \pm 0.09 \pm$	$(958) \mu^+ \nu_\mu) / \Gamma(\overline{K}^*)$ Decay modes of the η'				Γ_{32}/Γ_{27}
0.09 and then uses $\Gamma(D^0 \to K^- \mu^+ \nu_\mu) = (7.0 \pm 0.7) \times 10^{10} \mathrm{s}^{-1}$ to get the quoted			TECN		
branching fraction. See also the footnote to KODAMA 92c in the next data block.	20 90	KODAMA	938 E653	π^- emulsion 6	00 GeV
$\Gamma(\overline{K}^*(892)^0 \mu^+ \nu_{\mu}) / \Gamma(K^- \pi^+ \pi^+)$ $\Gamma_{27} / \Gamma_{34}$	Hadi	onic modes with a	K or KK	<u>r</u>	
Unseen decay modes of the $\overline{K}^*(892)^0$ are included. VALUE	$(70\pi^+)/\Gamma_{\text{total}}$				Г ₃₃ /Г
0.49 ± 0.06 OUR FIT Error includes scale factor of 1.1.	IE EVTS	DOCUMENT ID	TECN	COMMENT	. 33/.
	74±0.0029 OUR FIT 2 ±0.004 OUR AVERA	GF.			
24	$2 \pm 0.005 \pm 0.002$ 161	ADLER		$e^{+}e^{-}$ 3.77 Ge	٠V
то по то	3 ±0.009 36			$e^{+}e^{-}$ 3.771 (
$\kappa = \mu \cdot \nu_{i,i}$ events, as reported in the preceding data block.	3 ±0.013 17			e ⁺ e ⁻ 3.77 Ge	
	SCHINDLER 81 (MARK- be 0.14 ± 0.03 nb, We use				
VALUE DOCUMENT ID TECN COMMENT	PERUZZI 77 (MARK-1)	measures $\sigma(e^+e^- \rightarrow AABK 3.(ABK 5)$	$\psi(3770)$	× branching frac	tion to be
0.003±0.029 OUR FIT	0.14 ± 0.05 nb. We use th	ie MARK-3 (ADLER	88C) value of	$\sigma = 4.2 \pm 0.6$	± 0.3 np.
· ·	$(\kappa^0\pi^+)/\Gamma(\kappa^-\pi^+\pi^+)$				Γ_{33}/Γ_{34}
$\Gamma(\overline{K^0}\pi^+\pi^-e^+\nu_e)/\Gamma_{ ext{total}}$ $\Gamma_{ ext{18}}/\Gamma$ $\frac{VALU}{0.300}$	2±0.031 OUR FIT	S <u>DOCUMENT IE</u>	TECN_	COMMENT	
VALUE EVEC DOCUMENT ID TECH COMMENT	4±0.030±0.031 26	4 ANJOS	90c E69 1	Photoproduct	ion
=(::	$(-\pi^+\pi^+)/\Gamma_{total}$				Г ₃₄ /Г
2.022 _ 0.006 ± 0.004 1 AdditAt 07 111 BK 7p, pp 300, 400 dev	IE EVTS	DOCUMENT ID	TECN	COMMENT	- 547
	1 ± 0.006 OUR FIT 1 ± 0.007 OUR AVERAGE				
0.00	$3 \pm 0.006 \pm 0.008$ 1502	22	94 CLEO	$e^+e^-pprox \gamma$ (4)	5)
VALUE FUTC DOCUMENT ID TECH COMMENT	1±0.013±0.004 1164			e ⁺ e ⁻ 3.77 Ge	
0.09	1 ± 0.019 239 6 ± 0.020 85	³³ SCHINDLER ³⁴ PERUZZI		$e^{+}e^{-}$ 3.771 Ge $e^{+}e^{-}$ 3.77 Ge	
	We do not use the follo				•
0.04	$4^{+0.015}_{-0.014}$	35 BARLAG	92c ACCM	π ⁻ Cu 230 Ge	V
	$3 + 0.028 \pm 0.011$ 8	35 AGUILAR	87F HYBR	πp, pp 360, 4	00 GeV
-/-T	BALEST 94 measures the	ratio of $D^+ \rightarrow K^-$	$\pi^+\pi^+$ and	$D^0 \rightarrow \kappa^-\pi^+$	branching
Unseen decay modes of the $\overline{K}^*(892)$ are included.	ractions to be 2.35 \pm 0.1	6 ± 0.16 and uses th			
	$K^-\pi^+$ fraction (AKERIB SCHINDLER 81 (MARK-:		→ 1/2(3770)) × branching	raction to
· L	be 0.38 \pm 0.05 nb. We use	the MARK-3 (ADLE	R 88c) value	of $\sigma = 4.2 \pm 0.6$	\pm 0.3 nb.
	PERUZZI 77 (MARK-1) $_{ m 0.36~\pm~0.06}$ nb. We use th				
<0.009 90 ANIOS 92 F691 Photograduction 35 /	AGUILAR-BENITEZ 87F a				
	cal normalization.				
$ \Gamma(K^-\pi^+\pi^0\mu^+\nu_\mu)/\Gamma(K^-\pi^+\mu^+\nu_\mu) \qquad \qquad \Gamma_{22}/\Gamma_{15} = \Gamma_{22}/(\Gamma_{17} + \frac{2}{3}\Gamma_{27}) $ $ VALUE \qquad \qquad CL\% \qquad DOCUMENT ID \qquad TECN \qquad COMMENT $	$(892)^0 \pi^+) / \Gamma (K^- \pi)$				Γ_{70}/Γ_{34}
<0.042 90 FRABETTI 93E E687 γ Be $\overline{E}_{\gamma} \approx 200$ GeV	Unseen decay modes of E			COMMENT	
0.3	212±0.016 OUR FIT		1207	COMMENT	
	210±0.015 OUR AVERA 206±0.009±0.014	FRABETTI	94G E687	γ Be, $\overline{E}_{\gamma} \approx$ 220) GeV
27	255±0.014±0.050	ANJOS	93 E691	γ Be 90–260 G	
	21 ±0.06 ±0.06	ALVAREZ	91B NA14	Photoproduction	
	20 ± 0.02 ± 0.11 • We do not use the follo	ADLER wing data for average		e ⁺ e [−] 3.77 Ge	V
	- 110 00 1101 000 1110 10110			e ⁺ e ⁻ 3.771 G	
$I I \pi ' \pi C' \nu_{el} / I \text{ total}$ (0.0	053 90	SCHINDLER			eV
$\Gamma(\pi^+\pi^-e^+\nu_e)/\Gamma_{ ext{total}}$ $\Gamma_{ ext{24}}/\Gamma$ <0.0					
VALUE CL% DOCUMENT ID TECN COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • • □ (K	$(5.00)^{-1} \pi^{+})/\Gamma(K^{-1})$	$(\tau^{+}\pi^{+})$			e∨ Г ₇₉ /Г ₃₄
VALUE CL% DOCUMENT ID TECN COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • • <0.057	$\Gamma_0^{ar{r}}(1430)^0\pi^+)/\Gamma(K^-\pi)$ Unseen decay modes of	$(\pi^+\pi^+)$ the $\overline{K}_0^*(1430)^0$ are in	cluded.	COMMENT	
VALUE • • • We do not use the following data for averages, fits, limits, etc. • • • • 0.057 90 28 AGUILAR-BENITEZ 87F computes the branching fraction using topological normalization VALUE 10 COMMENT 1 FECN COMMENT	$\frac{7}{0}(1430)^0\pi^+)/\Gamma(K^-\pi^-)$ Unseen decay modes of $\frac{7}{0}$ ±0.04 OUR AVERAGE	$(\pi^+\pi^+)$ the $\overline{K}_0^*(1430)^0$ are in	cluded. <u>TECN</u>	COMMENT	Γ ₇₉ /Γ ₃₄
VALUE CL% DOCUMENT ID TECN COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • <0.057 90 28 AGUILAR 87F HYBR πp, pp 360, 400 GeV 28 AGUILAR-BENITEZ 87F computes the branching fraction using topological normalization. VALUE OASI O.458	$f_0^*(1430)^0 \pi^+)/\Gamma(K^-)$ Unseen decay modes of f_0^* ± 0.04 OUR AVERAGE f_0^*	$\pi^+\pi^+)$ the $\overline{K}_0^*(1430)^0$ are in DOCUMENT ID	ocluded. <i>TECN</i> 94G E687	γ Be, $\overline{E}_{\gamma} pprox 220$	Γ ₇₉ /Γ ₃₄
VALUE CL% DOCUMENT ID TECN COMMENT • • We do not use the following data for averages, fits, limits, etc. • • • < 0.057 90 28 AGUILAR 87F HYBR πp , pp 360, 400 GeV 28 AGUILAR-BENITEZ 87F computes the branching fraction using topological normalization. $\Gamma(\rho^0 e^+ \nu_e)/\Gamma_{\text{total}}$ VALUE O COMMENT ID TECN COMMENT O 400	$r_0^{\sigma}(1430)^0 \pi^+)/\Gamma(K^- \pi^-)$ Unseen decay modes of E = ±0.04 OUR AVERAGE 8±0.035±0.094 0±0.031±0.027	$r^+\pi^+$) the $\overline{K}_0^*(1430)^0$ are in $\frac{DOCUMENT ID}{FRABETTI}$ ANJOS	cluded. <u>TECN</u>		Γ ₇₉ /Γ ₃₄
VALUE CL% DOCUMENT ID TECN COMMENT • • We do not use the following data for averages, fits, limits, etc. • • • < 0.057 90 28 AGUILAR 87F HYBR πp , pp 360, 400 GeV 28 AGUILAR-BENITEZ 87F computes the branching fraction using topological normalization. $\Gamma(\rho^0 e^+ \nu_e)/\Gamma_{\text{total}}$ VALUE O COMMENT ID TECN COMMENT O 400	$F_0^*(1430)^0 \pi^+)/\Gamma(K^- \pi^-)$ Unseen decay modes of E ± 0.04 OUR AVERAGE 0.035 ± 0.094 0.031 ± 0.027 $F_0^*(1680)^0 \pi^+)/\Gamma(K^- \pi^-)$	$r^+\pi^+$) the $\overline{K}^*_0(1430)^0$ are in $DOCUMENT ID$ FRABETTI ANJOS $r^+\pi^+$)	94G E687 93 E691	γ Be, $\overline{E}_{\gamma} pprox 220$	Γ ₇₉ /Γ ₃₄
VALUE CL% DOCUMENT ID TECN COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • • < 0.057 90 28 AGUILAR 87F HYBR πp , pp 360, 400 GeV 28 AGUILAR-BENITEZ 87F computes the branching fraction using topological normalization. $\Gamma(\rho^0 e^+ \nu_e)/\Gamma_{total}$ VALUE CL% DOCUMENT ID TECN COMMENT < 0.400 $\Gamma(R^0 e^+ \nu_e)/\Gamma_{total}$ VALUE CL% DOCUMENT ID TECN COMMENT < 0.400 $\Gamma(R^0 e^+ \nu_e)/\Gamma_{total}$ VALUE CL% DOCUMENT ID TECN COMMENT < 0.400 $\Gamma(R^0 e^+ \nu_e)/\Gamma_{total}$ VALUE CL% DOCUMENT ID TECN COMMENT $\Gamma(R^0 e^+ \nu_e)/\Gamma_{total}$ VALUE CL% DOCUMENT ID TECN COMMENT $\Gamma(R^0 e^+ \nu_e)/\Gamma_{total}$ VALUE CL% DOCUMENT ID TECN COMMENT $\Gamma(R^0 e^+ \nu_e)/\Gamma_{total}$ VALUE CL% DOCUMENT ID TECN COMMENT $\Gamma(R^0 e^+ \nu_e)/\Gamma_{total}$ VALUE CL% DOCUMENT ID TECN COMMENT $\Gamma(R^0 e^+ \nu_e)/\Gamma_{total}$ VALUE CL% DOCUMENT ID TECN COMMENT $\Gamma(R^0 e^+ \nu_e)/\Gamma_{total}$ VALUE CL% DOCUMENT ID TECN COMMENT $\Gamma(R^0 e^+ \nu_e)/\Gamma_{total}$ VALUE CL% DOCUMENT ID TECN COMMENT $\Gamma(R^0 e^+ \nu_e)/\Gamma_{total}$ VALUE CL% DOCUMENT ID TECN COMMENT $\Gamma(R^0 e^+ \nu_e)/\Gamma_{total}$ VALUE CL% DOCUMENT ID TECN COMMENT $\Gamma(R^0 e^+ \nu_e)/\Gamma_{total}$ VALUE CL% DOCUMENT ID TECN COMMENT $\Gamma(R^0 e^+ \nu_e)/\Gamma_{total}$ VALUE CL% DOCUMENT ID TECN COMMENT $\Gamma(R^0 e^+ \nu_e)/\Gamma_{total}$ VALUE CL% DOCUMENT ID TECN COMMENT $\Gamma(R^0 e^+ \nu_e)/\Gamma_{total}$ VALUE CL% DOCUMENT ID TECN COMMENT $\Gamma(R^0 e^+ \nu_e)/\Gamma_{total}$ VALUE CL% DOCUMENT ID TECN COMMENT $\Gamma(R^0 e^+ \nu_e)/\Gamma_{total}$ VALUE CL% DOCUMENT ID TECN COMMENT $\Gamma(R^0 e^+ \nu_e)/\Gamma_{total}$ VALUE CL% DOCUMENT ID TECN COMMENT $\Gamma(R^0 e^+ \nu_e)/\Gamma_{total}$ VALUE CL% DOCUMENT ID TECN COMMENT $\Gamma(R^0 e^+ \nu_e)/\Gamma_{total}$ VALUE CL% DOCUMENT ID TECN COMMENT $\Gamma(R^0 e^+ \nu_e)/\Gamma_{total}$ VALUE CL% DOCUMENT ID TECN COMMENT $\Gamma(R^0 e^+ \nu_e)/\Gamma_{total}$ VALUE CL% DOCUMENT ID TECN COMMENT $\Gamma(R^0 e^+ \nu_e)/\Gamma_{total}$ VALUE CL% DOCUMENT ID TECN COMMENT $\Gamma(R^0 e^+ \nu_e)/\Gamma_{total}$ VALUE CL% DOCUMENT ID TECN COMMENT $\Gamma(R^0 e^+ \nu_e)/\Gamma_{total}$ VALUE CL% DOCUMENT ID TECN COMMENT $\Gamma(R^0 e^+ \nu_e)/\Gamma_{total}$ VALUE CL% DOCUMENT I	$E_0^{\text{Fe}}(1430)^0\pi^+)/\Gamma(K^-\pi^-)$ Unseen decay modes of E ± 0.04 OUR AVERAGE E	$(\tau^+\pi^+)$ the $\overline{K}_0^*(1430)^0$ are in DOCUMENT ID FRABETTI ANJOS $(\tau^+\pi^+)$ the $\overline{K}^*(1680)^0$ are in	94G E687 93 E691	γ Be, $\overline{E}_{\gamma} \approx 220$ γ Be 90–260 G	Γ ₇₉ /Γ ₃₄
VALUE CL% DOCUMENT ID TECN COMMENT TECN TECN TECN COMMENT TECN TECN TECN TECN TECN TECN TECN T	$F_0^*(1430)^0\pi^+)/\Gamma(K^-\pi^-)$ Unseen decay modes of F_0^* ± 0.04 OUR AVERAGE 0.035 ± 0.094 0.031 ± 0.027 $F_0^*(1680)^0\pi^+)/\Gamma(K^-\pi^-)$ Unseen decay modes of F_0^* 0.032 OUR AVERAGE	$\mathbf{r}^+\boldsymbol{\pi}^+$) the $\overline{K}_0^*(1430)^0$ are in DOCUMENT ID FRABETTI ANJOS $\mathbf{r}^+\boldsymbol{\pi}^+$) the $\overline{K}^*(1680)^0$ are in DOCUMENT ID Error includes scale	946 E687 93 E691 cluded. <u>TECN</u>	γ Be, $\overline{E}_{\gamma} \approx$ 220 γ Be 90–260 Gr	Γ ₇₉ /Γ ₃₄ ο GeV εν Γ ₈₀ /Γ ₃₄
VALUE CL% DOCUMENT ID TECN COMMENT •• We do not use the following data for averages, fits, limits, etc. •• < 0.057 90 28 AGUILAR 87F HYBR πp , $p p$ 360, 400 GeV 28 AGUILAR-BENITEZ 87F computes the branching fraction using topological normalization. $\Gamma(\rho^0 e^+ \nu_e)/\Gamma_{\text{total}} \qquad \Gamma_{28}/\Gamma$ $VALUE \qquad CL\% \qquad DOCUMENT ID \qquad TECN \qquad COMMENT$ $< 0.0037 \qquad 90 \qquad BAI \qquad 91 \qquad MRK3 e^+ e^- \approx 3.77 \text{ GeV}$ $\Gamma(\rho^0 \mu^+ \nu_\mu)/\Gamma(\overline{K}^*(892)^0 \mu^+ \nu_\mu) \qquad \Gamma_{29}/\Gamma_{27} \qquad VALUE \qquad EVTS \qquad DOCUMENT ID \qquad TECN \qquad COMMENT$ $0.166 \qquad 0.182 \qquad 0.0031 0.001 $	F ₀ (1430) ⁰ π ⁺)/ Γ (K ⁻ α) Unseen decay modes of E \pm 0.04 OUR AVERAGE 0 \pm 0.035 \pm 0.094 0 \pm 0.027 F*(1680) ⁰ π ⁺)/ Γ (K ⁻ α) Unseen decay modes of E 0 \pm 0.032 OUR AVERAGE 0 \pm 0.023 \pm 0.028	$r^+\pi^+$) the $\overline{K}^*_0(1430)^0$ are in DOCUMENT ID FRABETTI ANJOS $r^+\pi^+$) the $\overline{K}^*(1680)^0$ are in DOCUMENT ID Error includes scale FRABETTI	94G E687 93 E691 cluded. TECN factor of 1.1	γ Be, $\overline{E}_{\gamma} \approx 220$ γ Be 90–260 Gr	Γ ₇₉ /Γ ₃₄ O GeV F ₈₀ /Γ ₃₄
VALUE	r_0^* (1430) 0 π $^+$)/Γ(K^- α Unseen decay modes of E ±0.04 OUR AVERAGE 3±0.035±0.094 0±0.031±0.027 r_0^* (1680) 0 π $^+$)/Γ(K^- α Unseen decay modes of E 0±0.032 OUR AVERAGE 2±0.023±0.028 3±0.015±0.050	$\mathbf{r}^+\boldsymbol{\pi}^+$) the $\overline{K}_0^*(1430)^0$ are in DOCUMENT ID FRABETTI ANJOS $\mathbf{r}^+\boldsymbol{\pi}^+$) the $\overline{K}^*(1680)^0$ are in DOCUMENT ID Error includes scale FRABETTI ANJOS	946 E687 93 E691 cluded. <u>TECN</u>	γ Be, $\overline{E}_{\gamma} \approx$ 220 γ Be 90–260 Gr	Γ ₇₉ /Γ ₃₄ O GeV F ₈₀ /Γ ₃₄
VALUE • • We do not use the following data for averages, fits, limits, etc. • • • < 0.057 90 28 AGUILAR 87F HYBR πp , $p p$ 360, 400 GeV 28 AGUILAR-BENITEZ 87F computes the branching fraction using topological normalization. 0.451 $\Gamma(\rho^0 e^+ \nu_e)/\Gamma_{total}$ V_{ALUE} V_{AUB}	F ₀ (1430) ⁰ π^+)/ Γ (K^- 2 Unseen decay modes of E ±0.04 OUR AVERAGE B±0.035±0.094 0±0.031±0.027 F*(1680) ⁰ π^+)/ Γ (K^- 2 Unseen decay modes of E 0±0.032 OUR AVERAGE 2±0.023±0.028 B±0.015±0.050	$r^+\pi^+$) the $\overline{K}_0^*(1430)^0$ are in DOCUMENT ID FRABETTI ANJOS $r^+\pi^+$) the $\overline{K}^*(1680)^0$ are in DOCUMENT ID Error includes scale FRABETTI ANJOS $r^+\pi^+$)	946 E687 93 E691 cluded. <u>TECN</u> factor of 1.1 946 E687 93 E691	γ Be, $\overline{E}_{\gamma} \approx 22$ l γ Be 90–260 Gr	Γ ₇₉ /Γ ₃₄ O GeV F ₈₀ /Γ ₃₄
VALUE • • We do not use the following data for averages, fits, limits, etc. • • • • • We do not use the following data for averages, fits, limits, etc. • • • • 0.057 90 28 AGUILAR 87F HYBR πρ, ρρ 360, 400 GeV 28 AGUILAR-BENITEZ 87F computes the branching fraction using topological normalization. Γ(ρ ⁰ e + ν _e)/Γtotal ΔΑΙUΕ C0.0037 90 BAI 91 MRK3 $e^+e^- \approx 3.77$ GeV Γ(ρ ⁰ μ + ν _μ)/Γ(\overline{K} *(892) ⁰ μ + ν _μ) Γ29/Γ27 ΔΑΙUE EVTS DOCUMENT ID TECN COMMENT O.166 0.182 0.044 + 0.031 ± 0.014 4 29 KODAMA 93C E653 π = emulsion 600 GeV 0.113 Γ(Κ ΔΑΙUE O this KODAMA 93C result is based on a final signal of 4.0 + 2.8 ± 1.3 events; the estimates of backgrounds that affect this number are somewhat model dependent.	F ₀ (1430) ⁰ π ⁺)/ Γ (K ⁻ α) Unseen decay modes of E \pm 0.04 OUR AVERAGE $3\pm$ 0.035 \pm 0.094 \pm 0.031 \pm 0.027 F*(1680) ⁰ π ⁺)/ Γ (K ⁻ α) Unseen decay modes of E $0\pm$ 0.032 OUR AVERAGE $0\pm$ 0.023 \pm 0.028 $0\pm$ 0.015 \pm 0.050 F ⁻ π ⁺ π ⁺ nonresonant E	$\mathbf{r}^+\boldsymbol{\pi}^+$) the $\overline{K}_0^*(1430)^0$ are in DOCUMENT ID FRABETTI ANJOS $\mathbf{r}^+\boldsymbol{\pi}^+$) the $\overline{K}^*(1680)^0$ are in DOCUMENT ID Error includes scale FRABETTI ANJOS	94G E687 93 E691 cluded. TECN factor of 1.1	γ Be, $\overline{E}_{\gamma} \approx 220$ γ Be 90–260 Gr	Γ ₇₉ / Γ ₃₄ O GeV O G
$VALUE$ • • We do not use the following data for averages, fits, limits, etc. • • • < 0.057 90 28 AGUILAR 87F HYBR πρ, ρρ 360, 400 GeV 28 AGUILAR-BENITEZ 87F computes the branching fraction using topological normalization. $\Gamma(\rho^0 e^+ \nu_e)/\Gamma_{\text{total}}$ $VALUE$ < 0.0037 90 BAI 91 MRK3 $e^+ e^- \approx 3.77 \text{ GeV}$ $VALUE$ < 0.0037 $VALUE$ $= EVTS$ $= DOCUMENT ID$ $= TECN$ $= COMMENT$ $= TECN$ $= $	F ₀ (1430) ⁰ π^+)/ Γ (K^- 2 Unseen decay modes of E ±0.04 OUR AVERAGE B±0.035±0.094 0±0.031±0.027 F*(1680) ⁰ π^+)/ Γ (K^- 2 Unseen decay modes of E 0±0.032 OUR AVERAGE 2±0.023±0.028 B±0.015±0.050	$r^+\pi^+$) the $\overline{K}_0^*(1430)^0$ are in DOCUMENT ID FRABETTI ANJOS $r^+\pi^+$) the $\overline{K}^*(1680)^0$ are in DOCUMENT ID Error includes scale FRABETTI ANJOS $r^+\pi^+$)	946 E687 93 E691 Cluded. TECN Factor of 1.1 946 E687 93 E691	γ Be, $\overline{E}_{\gamma} \approx 22$ l γ Be 90–260 Gr	GeV PO GeV PO GeV PO GeV PO GeV PO GeV
value c.6.% DOCUMENT ID TECN COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • • < 0.0.57 90 28 AGUILAR 87F HYBR πρ. ρρ 360, 400 GeV 28 AGUILAR-BENITEZ 87F computes the branching fraction using topological normalization. $\Gamma(\rho^0 e^+ \nu_e)/\Gamma_{\text{total}}$ $\frac{VALUE}{VAUB}$ $\frac{CL\%}{VAUB}$ $\frac{CL\%}{VAUB}$ $\frac{DOCUMENT ID}{VAUB}$ $\frac{TECN}{VAUB}$ $\frac{COMMENT}{VAUB}$ $\frac{COMMENT}{VAUB}$ $\frac{CL\%}{VAUB}$ $\frac{DOCUMENT ID}{VAUB}$ $\frac{TECN}{VAUB}$ $\frac{COMMENT}{VAUB}$	$F_0^*(1430)^0 \pi^+)/\Gamma(K^- \pi^-)$ Unseen decay modes of E ± 0.04 OUR AVERAGE $\pm 0.035 \pm 0.094$ $\pm 0.031 \pm 0.027$ $F^*(1680)^0 \pi^+)/\Gamma(K^- \pi^-)$ Unseen decay modes of E 0 ± 0.032 OUR AVERAGE ± 0.028 $3 \pm 0.015 \pm 0.050$ $E^- \pi^+ \pi^+$ nonresonant E ± 0.07 OUR AVERAGE	$\mathbf{r}^+ \boldsymbol{\pi}^+$) the $\overline{K}_0^* (1430)^0$ are in DOCUMENT ID FRABETTI ANJOS $\mathbf{r}^+ \boldsymbol{\pi}^+$) Error includes scale FRABETTI ANJOS)/ $\Gamma(K^- \boldsymbol{\pi}^+ \boldsymbol{\pi}^+)$ DOCUMENT ID	946 E687 93 E691 cluded. TECN factor of 1.1 946 E687 93 E691 7ECN 946 E687 93 E691	γ Be, $\overline{E}_{\gamma} \approx 22$ l γ Be 90–260 Gr $\frac{COMMENT}{\gamma}$ Be, $\overline{E}_{\gamma} \approx 22$ l γ Be 90–260 Gr $\frac{COMMENT}{\gamma}$	GeV 2) GeV 2) GeV 2) GeV 2) GeV 2) GeV 2) GeV

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0.07 \pm 0.030 OUR FIT Error includes scale factor of 1.1. 0.107 \pm 0.029 OUR AVERAGE 0.102 \pm 0.025 \pm 0.016 159 ADLER 88C MRK3 e^+e^- 3.77 GeV 0.19 \pm 0.12 10 36 SCHINDLER 81 MRK2 e^+e^- 3.77 GeV 0.19 \pm 0.12 10 36 SCHINDLER 81 MRK2 e^+e^- 3.77 GeV 0.19 \pm 0.12 10 36 SCHINDLER 81 MRK2 e^+e^- 3.77 GeV 0.19 \pm 0.12 10 36 SCHINDLER 81 MRK2 e^+e^- 3.77 GeV 0.19 \pm 0.12 10 36 SCHINDLER 81 MRK2 e^+e^- 3.77 GeV 0.19 \pm 0.12 10 36 SCHINDLER 81 MRK2 e^+e^- 3.77 GeV 0.19 \pm 0.10 \pm 0.19 \pm 0.19 \pm 0.19 \pm 0.10 \pm 0.19 \pm 0.10 \pm 0.19 \pm 0.19 \pm 0.19 \pm 0.10 \pm 0.19 \pm 0.1	Γ43
0.102 \pm 0.025 \pm 0.016 159 ADLER 88C MRK3 e^+e^- 3.77 GeV 0.19 \pm 0.12 10 36 SCHINDLER 81 MRK2 e^+e^- 3.77 GeV 0.19 \pm 0.12 10 36 SCHINDLER 81 MRK2 e^+e^- 3.77 GeV 36 SCHINDLER 81 (MARK-2) measures $\sigma(e^+e^-) + \psi(3770)$) × branching fraction to be 0.78 \pm 0.48 nb. We use the MARK-3 (ADLER 88C) value of $\sigma=4.2\pm0.6\pm0.3$ nb. $\Gamma(K^0\rho^+)/\Gamma(K^0\pi^+\pi^0)$ $\Gamma(K^0\rho^+)/\Gamma(K^0\rho^+)/\Gamma(K^0\rho^+)/\Gamma(K^0\rho^+)$ $\Gamma(K^0\rho^+)/\Gamma(K^0\rho^+)/\Gamma(K^0\rho^+)/\Gamma(K^0\rho^+)/\Gamma(K^0\rho^+)$ $\Gamma(K^0\rho^+)/\Gamma(K^0$	
36 SCHINDLER 81 (MARK-2) measures $\sigma(e^+e^- \to \psi(3770))$ × branching fraction to be 0.78 ± 0.48 nb. We use the MARK-3 (ADLER 88c) value of $\sigma = 4.2 \pm 0.6 \pm 0.3$ nb. $\Gamma(K^0 \rho^+)/\Gamma(K^0 \pi^+ \pi^0)$ $VALUE$ $0.68 \pm 0.08 \pm 0.12$ $0.68 \pm 0.08 \pm 0.12$ 0.12 0.12 0.12 0.20 ± 0.06 0.20 ± 0.06 $0.13 \pm 0.07 \pm 0.08$ $0.13 \pm $	
$ \frac{VALUE}{C(K^*(892)^0 \pi^+)} / \Gamma(\overline{K^0 \pi^+ \pi^0}) $ Unseen decay modes of the $\overline{K}^*(892)^0$ are included. $ \frac{VALUE}{O.20\pm 0.06} OUR FIT $ 0.57 ± 0.18 ± 0.18 $ \frac{DOCUMENT ID}{ADLER} = \frac{DOCUMENT ID}{ADLER} = \frac{TECN}{NRK3} e^+e^- 3.77 \text{ GeV} $ $ \frac{VALUE}{O.20\pm 0.06} OUR FIT $ 0.57 ± 0.18 ± 0.18 $ \frac{DOCUMENT ID}{ADLER} = \frac{DOCUMENT ID}{NRK3} = \frac{TECN}{NRK3} e^+e^- 3.77 \text{ GeV} $ $ \frac{VALUE}{NRK3} = \frac{COMMENT}{NRK3} e^+e^- 3.77 \text{ GeV} $ $ \frac{VALUE}{NRK3} = \frac{COMMENT}{NRK3} e^+e^- 3.77 \text{ GeV} $ $ \frac{VALUE}{NRK3} = \frac{COMMENT}{NRK3} e^+e^- 3.77 \text{ GeV} $ $ \frac{VALUE}{NRK3} = \frac{COMMENT}{NRK3} e^+e^- 3.77 \text{ GeV} $ $ \frac{VALUE}{NRK3} = \frac{COMMENT}{NRK3} e^+e^- 3.77 \text{ GeV} $ $ \frac{VALUE}{NRK3} = \frac{COMMENT}{NRK3} e^+e^- 3.77 \text{ GeV} $ $ \frac{VALUE}{NRK3} = \frac{COMMENT}{NRK3} e^+e^- 3.77 \text{ GeV} $ $ \frac{VALUE}{NRK3} = \frac{COMMENT}{NRK3} e^+e^- 3.77 \text{ GeV} $ $ \frac{VALUE}{NRK3} = \frac{COMMENT}{NRK3} e^+e^- 3.77 \text{ GeV} $ $ \frac{VALUE}{NRK3} = \frac{COMMENT}{NRK3} e^+e^- 3.77 \text{ GeV} $ $ \frac{VALUE}{NRK3} = \frac{COMMENT}{NRK3} e^+e^- 3.77 \text{ GeV} $ $ \frac{VALUE}{NRK3} = \frac{COMMENT}{NRK3} e^+e^- 3.77 \text{ GeV} $ $ \frac{VALUE}{NRK3} = \frac{COMMENT}{NRK3} e^+e^- 3.77 \text{ GeV} $ $ \frac{VALUE}{NRK3} = \frac{COMMENT}{NRK3} e^+e^- 3.77 \text{ GeV} $ $ \frac{VALUE}{NRK3} = \frac{COMMENT}{NRK3} e^+e^- 3.77 \text{ GeV} $ $ \frac{VALUE}{NRK3} = \frac{COMMENT}{NRK3} e^+e^- 3.77 \text{ GeV} $ $ \frac{VALUE}{NRK3} = \frac{COMMENT}{NRK3} e^+e^- 3.77 \text{ GeV} $ $ \frac{VALUE}{NRK3} = \frac{COMMENT}{NRK3} e^+e^- 3.77 \text{ GeV} $ $ \frac{VALUE}{NRK3} = \frac{COMMENT}{NRK3} e^+e^- 3.77 \text{ GeV} $ $ \frac{VALUE}{NRK3} = \frac{COMMENT}{NRK3} e^+e^- 3.77 \text{ GeV} $ $ \frac{VALUE}{NRK3} = \frac{COMMENT}{NRK3} e^+e^- 3.77 \text{ GeV} $ $ \frac{VALUE}{NRK3} = \frac{COMMENT}{NRK3} e^+e^- 3.77 \text{ GeV} $ $ \frac{VALUE}{NRK3} = \frac{COMMENT}{NRK3} e^+e^- 3.77 \text{ GeV} $ $ \frac{VALUE}{NRK3} = \frac{COMMENT}{NRK3} e^+e^- 3.77 \text{ GeV} $ $ \frac{VALUE}{NRK3} = \frac{COMMENT}{NRK3} e^+e^- 3.77 \text{ GeV} $ $ \frac{VALUE}{NRK3} = \frac{COMMENT}{NRK3} e^+e^- 3.77 \text{ GeV} $ $ \frac{VALUE}{NRK3} = \frac{COMMENT}{NRK3} e^+e^- 3.77 \text{ GeV} $ $ \frac{VALUE}{NRK3} = \frac{COMMENT}{NRK3} e^+e^- 3.77 \text{ GeV} $ $ \frac{VALUE}{NRK3} = \frac{COMMENT}{NRK$	Jouy
$\Gamma(\overline{K}^*(892)^0\pi^+)/\Gamma(\overline{K}^0\pi^+\pi^0)$ Unseen decay modes of the $\overline{K}^*(892)^0$ are included. Unseen decay	
Unseen decay modes of the $\overline{K}^*(892)^0$ are included. Unseen decay modes of the $\overline{K}^*(892)^0$ are incl	ı ₂ /Γ
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	-,
0.57 \pm 0.18 \pm 0.18 ADLER 87 MRK3 e^+e^- 3.77 GeV 38 See, however, the next entry: ANJOS 92c sees a large signal in this channel. $\Gamma(\overline{K^0\pi^+\pi^0} \text{ nonresonant})/\Gamma(\overline{K^0\pi^+\pi^0}) = \frac{\Gamma_{42}/\Gamma_{39}}{\rho_{OCUMENT ID}} = \frac{\Gamma_{42}/\Gamma_{42}}{\rho_{OCUMENT ID}} = \frac{\Gamma_{42}/\Gamma_{42}}{\rho_{OCUMENT ID}} = \frac{\Gamma_{43}/\Gamma_{42}/\Gamma_{42}}{\rho_{OCUMENT ID}} = \frac{\Gamma_{43}/\Gamma_{42}/\Gamma_{42}/\Gamma_{42}}{\rho_{OCUMENT ID}} = \frac{\Gamma_{43}/\Gamma_{42}/\Gamma_{42}/\Gamma_{42}}{\rho_{OCUMENT ID}} = \frac{\Gamma_{43}/\Gamma_{42}/\Gamma_{42}/\Gamma_{42}}{\rho_{OCUMENT ID}} = \frac{\Gamma_{43}/\Gamma_{42}/\Gamma_{42}/\Gamma_{42}}{\rho_{OCUMENT ID}} = \frac{\Gamma_{43}/\Gamma_{42}/\Gamma_{42}/\Gamma_{42}/\Gamma_{42}}{\rho_{OCUMENT ID}} = \frac{\Gamma_{43}/\Gamma_{42}/\Gamma_{42}/\Gamma_{42}/\Gamma_{42}/\Gamma_{42}}{\rho_{OCUMENT ID}} = \frac{\Gamma_{43}/\Gamma_{42}/\Gamma_{42}/\Gamma_{42}/\Gamma_{42}/\Gamma_{42}/\Gamma_{42}/\Gamma_{42}/\Gamma_{42}/\Gamma_{42}/\Gamma_{42}/\Gamma_{42}/\Gamma_{42}/\Gamma_{42}/\Gamma_{42}/\Gamma_{42}/\Gamma_{42}/\Gamma_{42}/\Gamma_{42}/\Gamma_{42}$	
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	
$\frac{VALUE}{\Gamma(K^-\pi^+\pi^+\pi^0)/\Gamma_{total}} \frac{DOCUMENT ID}{\Gamma_{43}/\Gamma} \frac{TECN}{O.66\pm 0.09\pm 0.17} \frac{DOCUMENT ID}{ANJOS} \frac{TECN}{92C} \frac{COMMENT}{PR} \frac{VALUE}{PR} \frac{DOCUMENT ID}{PR} \frac{TECN}{PR} \frac{COMMENT}{PR} \frac{TECN}{PR} $	Γ ₄₃
VALUE EVTS DOCUMENT ID TECH COMMENT	
A	Γ43
0.058±0.012±0.012 142 COFFMAN 928 MRK3 e ⁺ e ⁻ 3.77 GeV Unseen decay modes of the K*(892) ⁻ are included. • • • We do not use the following data for averages, fits, limits, etc. • • • VALUE DOCUMENT ID TECN COMMENT	
0.034 $^{+0.056}_{-0.070}$ 37 BARLAG 92C ACCM π^- Cu 230 GeV 0.32 $^{\pm0.14}$ OUR FIT Error includes scale factor of 1.1. 0.24 $^{\pm0.09}$ ANJOS 92C E691 $_{\gamma}$ Be 90–260 GeV	
$0.022^{+0.047}_{-0.006} \pm 0.004$ 1 37 AGUILAR 87F HYBR πp , ρp 360, 400 GeV $\Gamma(K^-\pi^+\pi^+\pi^0 \text{ nonresonant})/\Gamma_{\text{total}}$	1/Г
0.063 $^{+0.014}_{-0.013} \pm 0.012$ 175 BALTRUSAIT86E MRK3 See COFFMAN 92B <u>VALUE CL% DOCUMENT ID TECN COMMENT</u> • • • We do not use the following data for averages, fits, limits, etc. • • •	—
37 AGUILAR-BENITEZ 87F and BARLAG 92C compute the branching fraction by topological normalization. 40 0.002 90 39 ANJOS 92C E691 γ Be 90–260 GeV	
$\Gamma(K^-\pi^+\pi^+\pi^0)/\Gamma(K^-\pi^+\pi^+)$ Γ_{43}/Γ_{34} Γ_{43}/Γ_{34} Γ_{43}/Γ_{34} Γ_{43}/Γ_{34} Γ_{43}/Γ_{34} Γ_{43}/Γ_{34} Γ_{43}/Γ_{34} $\Gamma_{43}/\Gamma_{43}/\Gamma_{44}/\Gamma_{44}$ $\Gamma_{43}/\Gamma_{44}/\Gamma_$; see
$\frac{\text{VALUE}}{\text{0.71} \pm \text{0.12 OUR FIT}} \frac{\text{EVTS}}{\text{0.71} \pm \text{0.12 OUR FIT}} \frac{\text{DOCUMENT ID}}{\text{TECN}} \frac{\text{COMMENT}}{\text{TECN}} \frac{\text{COMMENT}}{\text{COMMENT}} \Gamma(K^-\pi^+\pi^+\pi^0 \text{ nonresonant})/\Gamma(K^-\pi^+\pi^+\pi^0)$	Γ43
0.76 \pm 0.11 \pm 0.12 91 ANJOS 92 C E691 γ Be 90–260 GeV VALUE DOCUMENT ID TECN COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • • 0.184 \pm 0.070 \pm 0.050 COFFMAN 92B MRK3 e^+e^- 3.77 GeV	
0.69±0.10±0.16 ANJOS 89E E691 See ANJOS 92C	
0.57 + 0.65 1 AGUILAR 83B HYBR π^-p , 360 GeV $\sqrt{K^0}\pi^+\pi^+\pi^-)/\Gamma_{\text{total}}$ Γ_{52}	₂ /Γ
$\Gamma(\overline{K}^*(892)^0 \rho^+ \text{total})/\Gamma(K^- \pi^+ \pi^+ \pi^0)$ Γ ₇₁ /Γ ₄₃ 0.070 ± 0.010 OUR FIT 0.071 ± 0.016 OUR AVERAGE 0.066 ± 0.015 ± 0.005 168 ADLER 88C MRK3 $e^+ e^-$ 3.77 GeV	
0.33±0.165±0.12 ANJOS 92C E691 γBe 90−260 GeV • • • We do not use the following data for averages, fits, limits, etc. • • •	
$\Gamma(\overline{K}^*(892)^0 \rho^+ S\text{-wave})/\Gamma(K^-\pi^+\pi^+\pi^0)$ Γ_{72}/Γ_{43} 0.042 + 0.019 41 BARLAG 92C ACCM π^- Cu 230 GeV Unseen decay modes of the $\overline{K}^*(892)^0$ are included. The two experiments disagree	
severely here.	
0.26 \pm0.25 OUR AVERAGE Error includes scale factor of 3.1. be 0.51 \pm 0.08 nb. We use the MARK-3 (ADLER 88C) value of $\sigma = 4.2 \pm 0.6 \pm 0.3$	3 nb.
0.15 \pm 0.075 \pm 0.045 ANJOS 92C E691 γ Be 90–260 GeV 41 AGUILAR-BENITEZ 87F and BARLAG 92C compute the branching fraction by topo 0.833 \pm 0.116 \pm 0.165 COFFMAN 92B MRK3 e^+e^- 3.77 GeV ical normalization.	-logد
$\Gamma(\overline{K}^*(892)^0 \rho^+ P ext{-wave})/\Gamma_{ ext{total}}$ Γ_{73}/Γ $\Gamma(\overline{K}^0 \pi^+ \pi^+ \pi^-)/\Gamma(K^- \pi^+ \pi^+)$ Γ_{52}/Γ_{13}	Γ ₃₄
Unseen decay modes of the $\overline{K}^*(892)^0$ are included. 0.78 ± 0.10 QUP ETT. 0.78 ± 0.10 QUP ETT.	
VALUE CL% DOCUMENT ID TECN COMMENT COMMENT COMMENT <0.001	
• • • We do not use the following data for averages, fits, limits, etc. • • • $\Gamma(\overline{K}^0 a_1(1260)^+)/\Gamma(\overline{K}^0 \pi^+ \pi^+ \pi^-)$	Γ ₅₂
<0.005 90 COFFMAN 928 MRK3 e^+e^- 3.77 GeV Unseen decay modes of the $a_1(1260)^+$ are included. F(V*1002)0 a+ D units) /F(V=-+++0) FECT COMMENT 10 TECT C	
$1(h^2(692)^2)^2$ D-wave)/ $1(h^2(\pi^2)^2)^2$ 1.15 ±0.19 OUR AVERAGE Error includes scale factor of 1.1.	
<u>VALUE</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> 1.078±0.114±0.140 COFFMAN 928 MRK3 e ⁺ e ⁻ 3.77 GeV	
0.15±0.09±0.045 ANJOS 92C E691 γBe 90-260 GeV □ (\$\frac{1}{1}\text{CON}(0) + \text{Durant location line}(1) \(\frac{1}{1}\text{CON}(0) \\ \frac{1}\text{CON}(0) \\ \frac{1}CO	٦/و
Unseen decay modes of the $a_2(1320)^+$ are included.	•/
<u>VALUE</u> <u>CL% DOCUMENT ID</u> <u>TECN COMMENT</u> C0.003 90 ANIOS 92C E691 7Be 90-260 GeV	
<0.007 90 COFFMAN 92B MRK3 e ⁺ e [−] 3.77 GeV • • • We do not use the following data for averages, fits, limits, etc. • •	
$\Gamma(\overline{K}_1(1400)^0\pi^+)/\Gamma(K^-\pi^+\pi^+\pi^0)$	
VALUE DOCUMENTID TECH COMMENT	6/F
0.77 \pm 0.20 OUR FIT Unseen decay modes of the $\overline{K}_1(1270)^0$ are included. 0.907 \pm 0.218 \pm 0.180 COFFMAN 92B MRK3 e^+e^- 3.77 GeV VALUE CL% DOCUMENT ID TECN COMMENT	
$\frac{<0.007}{\Gamma(K^-\rho^+\pi^+\text{total})/\Gamma(K^-\pi^+\pi^+\pi^0)}$ $\frac{<0.007}{\Gamma_{85}/\Gamma_{43}}$ 0.007 90 ANJOS 92C E691 γ Be 90–260 GeV \bullet • • We do not use the following data for averages, fits, limits, etc. • • •	
This includes $K^*(892)^0 \rho^+$, etc. The next entry gives the specifically 3-body fraction. <0.011 90 COFFMAN 92B MRK3 e^+e^- 3.77 GeV	
VALUE DOCUMENT ID TECN COMMENT 0.48±0.13±0.09 ANJOS 92 E E691 γ Be 90-260 GeV	

					_
$\Gamma(\overline{K}_1(1400)^0\pi^+)/\Gamma_{\text{tota}}$ Unseen decay modes	$oldsymbol{I}$ of the $\overline{K}_1(1400)^0$ are $oldsymbol{I}$	included.	Γ ₇₇₇ /Γ	VALUE EVTS DOCUMENT ID TECN COMMENT	62/I
VALUE CL	.% DOCUMENT ID	TECN	COMMENT	0.022 $^{+0.047}_{-0.008}$ $^{+0.004}$ 1 44 AGUILAR 87F HYBR $\pi \rho$, $\rho \rho$ 360, 400 G	eV
• • • We do not use the fo < 0.009 90			, etc. • • • γ Be 90–260 GeV	• • • We do not use the following data for averages, fits, limits, etc. • • •	
⁴² ANJOS 92C sees no e				$<$ 0.015 44 BARLAG 92C ACCM π^- Cu 230 GeV	
	, whereas COFFMAN		$ \overline{K}_1(1400)^0 \pi^+ $ branching	TAGUILAK-BENITEZ 87F and BARLAG 92C compute the branching fraction by to ical normalization.	polog
$\Gamma(\overline{K}_1(1400)^0\pi^+)/\Gamma(\overline{K}^0)$	$0\pi^{+}\pi^{+}\pi^{-})$		Γ ₇₇ /Γ ₅₂		63/1
Unseen decay modes o	of the $\overline{K}_1(1400)^0$ are in DOCUMENT ID		COMMENT	<u>VALUEEVTS</u> <u>DOCUMENT ID</u> <u>TECN COMMENT</u> 0.054_0.014 OUR AVERAGE	
0.70 ±0.17 OUR FIT			COMMENT	0.099 + 0.036 $0.099 + 0.070$ $0.090 + 0.070$ $0.090 + 0.070$ $0.090 + 0.070$ $0.090 + 0.070$ $0.090 + 0.090$	
0.623±0.106±0.180	COFFMAN	928 MRK3	e ⁺ e ⁻ 3.77 GeV	10.050	- \ /
$\Gamma(\overline{K}^*(1410)^0\pi^+)/\Gamma_{total}$			Г ₇₈ /Г		
Unseen decay modes of VALUE	of the $\overline{K}^*(1410)^0$ are i % DOCUMENT ID		COMMENT	45 AGUILAR-BENITEZ 87F and BARLAG 92C compute the branching fraction by topical normalization.	polog
<0.007 90			e ⁺ e ⁻ 3.77 GeV	· $\Gamma(\overline{\mathcal{K}}^0\pi^+\pi^+\pi^+\pi^-\pi^-)/\Gamma_{ ext{total}}$ Γ	64/1
$\Gamma(K^*(892)^-\pi^+\pi^+\text{total})$	ı <i>\ /┌<i>(</i>द्वि° "+ "+ "− \</i>		Γ ₈₃ /Γ ₅₂	NALUE DOCUMENT IS TECH CONTINUE	64/'
	of the <i>K</i> *(892) — are ii	ncluded.	183/152	0.0008 \pm 0.0007 46 BARLAG 92C ACCM π^- Cu 230 GeV	
VALUE EV	TS DOCUMENT ID	TECN	COMMENT	⁴⁶ BARLAG 92C computes the branching fraction using topological normalization.	
• • We do not use the fo	-			$\Gamma(K^-\pi^+\pi^+\pi^-\pi^0)/\Gamma_{\text{total}}$	65/F
	14 ALEEV	94 BIS2	nN 20−70 GeV	<u>VALUE</u> <u>DOCUMENT ID</u> <u>TECN COMMENT</u> 0.0020±0.0018 47 BARLAG 92C ACCM π Cu 230 GeV	
$\Gamma(K^*(892)^-\pi^+\pi^+3$ -bo			Γ ₈₄ /Γ	0.0020 \pm 0.0018 47 BARLAG 92C ACCM π^- Cu 230 GeV 47 BARLAG 92C computes the branching fraction using topological normalization.	
Unseen decay modes of VALUE	• •		COMMENT	= (30 30 ss) \ (m/ss=-1-1)	
0.021 ±0.009 OUR FIT				$\Gamma(\overline{K^0}\overline{K^0}K^+)/\Gamma(K^-\pi^+\pi^+)$ Γ_{66}	/Γ ₃₄
• • We do not use the following the following the following that the following the following the following that the following the followi	-			0.20±0.09 OUR AVERAGE Error includes scale factor of 2.4.	
< 0.013	COFFMAN	92B MRK3	e ⁺ e ⁻ 3.77 GeV	$0.14 \pm 0.04 \pm 0.02$ 39 ALBRECHT 941 ARG $e^+e^- \approx 10 \text{ GeV}$	
$\Gamma(K^*(892)^-\pi^+\pi^+3$ -bo	$dy)/\Gamma(\overline{K}^0\pi^+\pi^+\pi^-)$	⁻)	Γ_{84}/Γ_{52}	0.34 \pm 0.07 70 AMMAR 91 CLEO $e^{+}e^{-}\approx$ 10.5 GeV	′
	of the $K^*(892)^-$ are in			Pionic modes ———	
<i>VALUE</i> 0.29±0.13 OUR FIT Error			COMMENT	$\Gamma(\pi^+\pi^0)/\Gamma(K^-\pi^+\pi^+)$	/Γ ₃₄
$0.50 \pm 0.09 \pm 0.21$	ANJOS		$\gamma\mathrm{Be}$ 90–260 GeV	VALUE EVTS DOCUMENT ID TECN COMMENT	,
$\Gamma(\overline{K}^0 \rho^0 \pi^+ \text{total}) / \Gamma(\overline{K}^0)$	$\pi^{+}\pi^{+}\pi^{-}$		Γ_{87}/Γ_{52}	0.028 \pm 0.006 \pm 0.005 34 SELEN 93 CLEO $e^+e^-\approx \Upsilon(4S)$	
		entries gives ti	ne specifically 3-body reac-	$\Gamma(\pi^+\pi^+\pi^-)/\Gamma(K^-\pi^+\pi^+)$	/Γ ₃₄
tion.				VALUE EVTS DOCUMENT ID TECN COMMENT	
0.60±0.10±0.17 90		92c E691	<u>COMMENT</u> γ Be 90–260 GeV	0.035±0.006 OUR AVERAGE 0.032±0.011±0.003 20 ADAMOVICH 93 WA82 π ⁻ 340 GeV	
$\Gamma(\overline{K}^0 ho^0\pi^+$ 3-body $)/\Gamma_{ m tot}$			·	$0.035\pm0.007\pm0.003$ ANJOS 89 E691 Photoproduction	
VALUE CL		TECN	F ₈₈ /F	$0.042 \pm 0.016 \pm 0.010$ 57 BALTRUSAIT85E MRK3 e^+e^- 3.77 GeV	
• • We do not use the fol				$\Gamma(ho^0\pi^+)/\Gamma(K^-\pi^+\pi^+)$	/Γ ₃₄
< 0.004 90	COFFMAN	92B MRK3	$e^{+}e^{-}$ 3.77 GeV	VALUE CL% DOCUMENT ID TECN COMMENT	
$-(\overline{K}^0 \rho^0 \pi^+ \text{3-body})/\Gamma(\overline{K}^0 \rho^0 \pi^+ \text{3-body})$	$(0_{\pi^{+}\pi^{+}\pi^{-}})$		Γ ₈₈ /Γ ₅₂	<0.015 90 ANJOS 89 E691 Photoproduction	
/ALUE		TECN	COMMENT		/Γ ₃₄
0.07±0.04±0.06	ANJOS	92C E691	γ Be 90–260 GeV	VALUE DOCUMENT ID TECN COMMENT 0.027±0.007±0.002 ANJOS 89 E691 Photoproduction	
$-(\overline{K}^0 f_0(980)\pi^+)/\Gamma_{\text{total}}$			Γ ₈₉ /Γ		
ALUE CLS	M DOCUMENT ID	TECN	COMMENT	, , , , , , , , , , , , , , , , , , ,	₉₆ /Г
<0.005 90	ANJOS	92C E691	γBe 90–260 GeV	VALUE DOCUMENT ID TECN COMMENT	
$-(\overline{K}^0\pi^+\pi^+\pi^-$ nonreson	$(\kappa^0\pi^+\pi^+\pi^+)$	π ⁻)	Γ_{58}/Γ_{52}	0.019+0.015 -0.012 48 BARLAG 92C ACCM π ⁻ Cu 230 GeV	
ALUE OUR AVERAGE		TECN	COMMENT	⁴⁸ BARLAG 92C computes the branching fraction using topological normalization.	
0.12±0.06 OUR AVERAGE 0.10±0.04 ±0.06	ANJOS	92c E691	γ Be 90-260 GeV	$\Gamma(\pi^+\pi^+\pi^-\pi^0)/\Gamma(K^-\pi^+\pi^+)$	/Γ ₃₄
$0.17 \pm 0.056 \pm 0.100$	COFFMAN		e ⁺ e ⁻ 3.77 GeV	VALUE CL% DOCUMENT ID TECN COMMENT	
$\Gamma(K^-\pi^+\pi^+\pi^+\pi^-)/\Gamma_{to}$	stal		Γ ₅₉ /Γ	• • • We do not use the following data for averages, fits, limits, etc. • • • < 0.4 90 ANJOS 89€ E691 Photoproduction	
ALUE		TECN	COMMENT	-/ 12 1-4 12 12	
• We do not use the following the follo	lowing data for average	es, fits, limits,	etc. • • •	$\Gamma(\eta\pi^+)/\Gamma(K^-\pi^+\pi^+)$ Unseen decay modes of the η are included.	/Γ ₃₄
$0.0037 + 0.0012 \\ -0.0010$	⁴³ BARLAG	92c ACCM	π^- Cu 230 GeV	Unseen decay modes of the η are included. <u>VALUE CL% EVTS DOCUMENT ID TECN COMMENT</u>	
⁴³ BARLAG 92C computes t	the branching fraction	using topologi	cal normalization.	0.083±0.023±0.014 99 DAOUDI 92 CLEO $e^+e^- \approx 10.000$	5
$(K^{-}\pi^{+}\pi^{+}\pi^{+}\pi^{-})/\Gamma(E^{-}\pi^{+}\pi^{+}\pi^{-})$			Γ ₅₉ /Γ ₃₄	GeV • • • We do not use the following data for averages, fits, limits, etc. • •	
ALUE EVT	,	TECN	COMMENT 159/134	<0.12 90 ANJOS 89E E691 Photoproduct	ion
.09 ±0.01 ±0.01	_	90D E691	Photoproduction	$\Gamma(\omega\pi^+)/\Gamma(K^-\pi^+\pi^+)$	/F24
$(\overline{K}^*(892)^0\pi^+\pi^+\pi^-)/1$	$\Gamma(K^-\pi^+\pi^+\pi^+\pi^-$)	Γ ₉₀ /Γ ₅₉	Unseen decay modes of the ω are included.	- 34
Unseen decay modes of	` .	,	190/159	<u>VALUE CL% DOCUMENT ID TECN COMMENT</u> <0.08 90 ANJOS 89E E691 Photoproduction	
ALUE	DOCUMENT ID	TECN_	COMMENT	·	
.25±0.12±0.23	ANJOS	90D E691	Photoproduction		9/F
$(\overline{K}^*(892)^0 \rho^0 \pi^+)/\Gamma(\overline{K}^*)$			Γ ₉₁ /Γ ₉₀	<u>VALUE</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u>	
ALUE TELO17L010	DOCUMENT ID	TECN_	COMMENT	0.0010 ⁺ 0.0008 49 BARLAG 92C ACCM π ⁻ Cu 230 GeV	
0.75±0.17±0.19	ANJOS	90D E691	Photoproduction	$^{ m 49}$ BARLAG 92C computes the branching fraction using topological normalization.	

$\frac{1}{\Gamma(\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-})/\Gamma(K^{-}\pi^{+}\pi^{+})}$	$\Gamma(\phi \rho^+)/\Gamma(K^-\pi^+\pi^+)$
<u>VALUE</u> <u>CL%</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> • • • We do not use the following data for averages, fits, limits, etc. • • •	Unseen decay modes of the ϕ are included. VALUE CL% DOCUMENT ID TECN COMMENT
<0.019 90 ANJOS 89 E691 Photoproduction	<0.16 90 DAOUDI 92 CLEO $e^{+}e^{-} \approx 10.5 \text{ GeV}$
$\Gamma(\eta ho^+)/\Gamma(K^-\pi^+\pi^+)$ Unseen decay modes of the η are included.	$\Gamma(K^+K^-\pi^+\pi^0$ non- $\phi)/\Gamma_{ ext{total}}$ $\Gamma_{117}/\Gamma_{ ext{VALUE}}$ DOCUMENT ID TECN COMMENT
VALUE CL% DOCUMENT ID TECN COMMENT $<$ 0.13 90 DAOUDI 92 CLEO $e^+e^-\approx 10.5 \text{ GeV}$	0.015 $^{+0.007}_{-0.006}$ 53 BARLAG 92C ACCM π^- Cu 230 GeV
$\Gamma(\pi^+\pi^+\pi^+\pi^-\pi^-\pi^0)/\Gamma_{\text{total}}$ Γ_{100}/Γ	$^{53}\mathrm{BARLAG}$ 92C computes the branching fraction using topological normalization.
VALUE DOCUMENT ID TECN COMMENT	$\Gamma(K^+K^-\pi^+\pi^0\operatorname{non-}\phi)/\Gamma(K^-\pi^+\pi^+)$ Γ_{117}/Γ_{34}
0.0029 $^{+0.0029}_{-0.0020}$ 50 BARLAG 92C ACCM π^{-} Cu 230 GeV	<u>VALUE</u> <u>CL%</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> • • • • We do not use the following data for averages, fits, limits, etc. • • •
$^{50}\mathrm{BARLAG}$ 92C computes the branching fraction using topological normalization.	<0.25 90 ANJOS 89E E691 Photoproduction
$\Gamma(\eta'(958)\pi^+)/\Gamma(K^-\pi^+\pi^+)$ Γ_{105}/Γ_{34}	$\Gamma(K^+\overline{K}^0\pi^+\pi^-)/\Gamma_{\text{total}}$ Γ_{118}/Γ
Unseen decay modes of the $\eta'(958)$ are included. VALUE	VALUE CL% DOCUMENT ID TECN COMMENT
<0.1 90 DAOUDI 92 CLEO $e^+e^-\approx 10.5 \text{ GeV}$	<0.02 90 ALBRECHT 92B ARG $e^+e^- \simeq 10.4 \text{ GeV}$
 <0.1 90 ALVAREZ 91 NA14 Photoproduction • • We do not use the following data for averages, fits, limits, etc. • • • 	$\Gamma(K^0K^-\pi^+\pi^+)/\Gamma_{\text{total}}$ Γ_{119}/Γ
<0.13 90 ANJOS 918 E691 γ Be, $\overline{E}_{\gamma} \approx 145$ GeV	VALUEDOCUMENT IDTECNCOMMENT $0.01 \pm 0.005 \pm 0.003$ ALBRECHT928 ARG $e^+e^- \simeq 10.4 \text{ GeV}$
$\Gamma(\eta'(958)\rho^{+})/\Gamma(K^{-}\pi^{+}\pi^{+})$ Γ_{106}/Γ_{34}	• • • We do not use the following data for averages, fits, limits, etc. • •
Unseen decay modes of the $\eta'(958)$ are included.	<0.003 54 BARLAG 92C ACCM π^- Cu 230 GeV
VALUE CL% DOCUMENT ID TECN COMMENT	$^{54}\mathrm{BARLAG}$ 92C computes the branching fraction using topological normalization.
<0.17 90 DAOUDI 92 CLEO $e^+e^-\approx 10.5 \text{ GeV}$	$\Gamma(K^*(892)^+\overline{K}^*(892)^0)/\Gamma_{\text{total}}$ Γ_{131}/Γ
Hadronic modes with a KK pair	Unseen decay modes of the $K^*(892)$'s are included. VALUE DOCUMENT ID TECN COMMENT
$\Gamma(K^+\overline{K^0})/\Gamma(\overline{K^0}\pi^+)$ VALUE EVTS DOCUMENT ID TECN COMMENT	0.026±0.008±0.007 ALBRECHT 92B ARG $e^+e^- \simeq 10.4 \text{ GeV}$
0.263±0.035 OUR AVERAGE	$\Gamma(K^0K^-\pi^+\pi^+\text{non-}K^{*+}\overline{K}^{*0})/\Gamma_{ ext{total}}$ Γ_{121}/Γ
0.25 \pm 0.04 \pm 0.02 129 FRABETTI 95 E687 γ Be $\overline{E}_{\gamma} \approx$ 200 GeV 0.271 \pm 0.065 \pm 0.039 69 ANJOS 90C E691 γ Be	VALUE CL% DOCUMENT ID TECN COMMENT
$0.317 \pm 0.086 \pm 0.048$ 31 BALTRUSAIT85E MRK3 e^+e^- 3.77 GeV	<0.0079 90 ALBRECHT 92B ARG $e^+e^- \simeq 10.4 \text{ GeV}$
0.25 ± 0.15 6 SCHINDLER 81 MRK2 e^+e^- 3.771 GeV	$\Gamma(\phi\pi^+\pi^+\pi^-)/\Gamma_{\text{total}}$ Γ_{128}/Γ
$\Gamma(K^+K^-\pi^+)/\Gamma(K^-\pi^+\pi^+)$ Γ_{108}/Γ_{34}	Unseen decay modes of the ϕ are included. VALUE CLM EVTS DOCUMENT ID TECN COMMENT
<u>VALUE</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> 0.0976±0.0042±0.0046 FRABETTI 958 E687 Dalitz plot analysis	<0.002 90 0 ANJOS 88 E691 Photoproduction
$\Gamma(\phi\pi^+)/\Gamma(K^-\pi^+\pi^+)$ Γ_{125}/Γ_{34}	$\Gamma(\phi\pi^+\pi^+\pi^-)/\Gamma(\kappa^-\pi^+\pi^+)$ Γ_{128}/Γ_{34}
Unseen decay modes of the ϕ are included.	Unseen decay modes of the φ are included. VALUE CL% DOCUMENT ID TECN COMMENT
VALUE EVTS DOCUMENT ID TECN COMMENT 0.068±0.005 OUR AVERAGE	
$0.058 \pm 0.006 \pm 0.006$ FRABETTI 958 E687 Dalitz plot analysis $0.062 \pm 0.017 \pm 0.006$ 19 ADAMOVICH 93 WA82 π^- 340 GeV	< 0.031 90 ALVAREZ 90C NA14 Photoproduction
$0.052 \pm 0.017 \pm 0.005$ 128 DAOUDI 92 CLEO $e^+e^- \approx 10.5 \text{ GeV}$	$\Gamma(\phi\pi^+\pi^+\pi^-)/\Gamma(\phi\pi^+)$ $\Gamma_{128}/\Gamma_{125}$
0.098±0.032±0.014 12 ALVAREZ 90C NA14 Photoproduction 0.071±0.008±0.007 84 ANJOS 88 E691 Photoproduction	<u>VALUE</u> <u>CL%</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> • • • • We do not use the following data for averages, fits, limits, etc. • • •
$0.084 \pm 0.021 \pm 0.011$ 21 BALTRUSAIT85E MRK3 e^+e^- 3.77 GeV	$<$ 0.6 90 FRABETTI 92 E687 γ Be
$\Gamma(K^{+}\overline{K}^{*}(892)^{0})/\Gamma(K^{-}\pi^{+}\pi^{+})$ Γ_{129}/Γ_{34}	$\Gamma(K^+K^-\pi^+\pi^+\pi^-\text{nonresonant})/\Gamma_{\text{total}}$ Γ_{124}/Γ
Unseen decay modes of the $\overline{K}^*(892)^0$ are included.	VALUE CL% EVTS DOCUMENT ID TECN COMMENT
VALUE EVTS DOCUMENT ID TECN COMMENT 0.047±0.005 OUR AVERAGE Error includes scale factor of 1.2.	<0.03 90 12 ANJOS 88 E691 Photoproduction
$0.044 \pm 0.003 \pm 0.004$ $0.058 \pm 0.009 \pm 0.006$ 73 ANJOS 88 E691 Photoproduction	Rare or forbidden modes
$0.048\pm0.021\pm0.011$ 14 BALTRUSAIT85E MRK3 e^+e^- 3.77 GeV	$\Gamma(K^+\pi^+\pi^-)/\Gamma(K^-\pi^+\pi^+)$ Γ_{132}/Γ_{34}
⁵¹ See FRABETTI 95B for evidence also of $\overline{K}_0^*(1430)K^+$ in the $D^+ \to K^+K^-\pi^+$ Dalitz	A doubly Cabibbo-suppressed decay with no simple spectator process possible.
plot.	VALUEEVTSDOCUMENT IDTECNCOMMENT0.0072±0.0023±0.001721FRABETTI95ε E687 γ Be, \overline{E}_{γ} = 220 GeV
$\Gamma(K^+K^-\pi^+ \text{ nonresonant})/\Gamma(K^-\pi^+\pi^+)$ VALUE EVTS DOCUMENT ID TECN COMMENT COMMENT	$\Gamma(K^+\rho^0)/\Gamma(K^-\pi^+\pi^+)$ Γ_{133}/Γ_{34}
0.050±0.009 OUR AVERAGE	A doubly Cabibbo-suppressed decay with no simple spectator process possible.
0.049±0.008±0.006 95 ANJOS 88 E691 Photoproduction 0.059±0.026±0.009 37 BALTRUSAIT85E MRK3 e ⁺ e ⁻ 3.77 GeV	VALUECL%DOCUMENT IDTECNCOMMENT<0.0067
$\Gamma(K^*(892)^+\overline{K}^0)/\Gamma(\overline{K}^0\pi^+)$ Γ_{130}/Γ_{33}	
Unseen decay modes of the $K^*(892)^+$ are included.	$\Gamma(K^*(892)^0\pi^+)/\Gamma(K^-\pi^+\pi^+)$ A doubly Cabibbo-suppressed decay with no simple spectator process possible. Unseen
VALUEEVTSDOCUMENT IDTECNCOMMENT $1.1 \pm 0.3 \pm 0.4$ 67FRABETTI95E687 γ Be $\overline{E}_{\gamma} \approx 200$ GeV	decay modes of the $K^st(892)^0$ are included.
	VALUECL%DOCUMENT IDTECNCOMMENT $<$ 0.002190FRABETTI95E E687 γ Be, \overline{E}_{γ} = 220 GeV
$\Gamma(\phi\pi^+\pi^0)/\Gamma_{ ext{total}}$ Unseen decay modes of the ϕ are included.	
VALUE DOCUMENT ID TECN COMMENT	$\Gamma(K^+K^+K^-)/\Gamma(K^-\pi^+\pi^+)$ A doubly Cabibbo-suppressed decay with no simple spectator process possible.
0.023 \pm 0.010 52 BARLAG 92C ACCM π^- Cu 230 GeV 52 BARLAG 92C computes the branching fraction using topological normalization.	VALUE CL% EVTS DOCUMENT ID TECN COMMENT
and the second s	<0.0016 90 ⁵⁵ FRABETTI 95F E687 γ Be, $\overline{E}_{\gamma} \approx 220$ GeV
$\Gamma(\phi\pi^+\pi^0)/\Gamma(K^-\pi^+\pi^+)$ Unseen decay modes of the ϕ are included.	 ◆ • We do not use the following data for averages, fits, limits, etc.
<u>VALUE</u> <u>CL%</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> • • • We do not use the following data for averages, fits, limits, etc. • •	0.057 \pm 0.020 \pm 0.007 13 ADAMOVICH 93 WA82 π^- 340 GeV 55 Using the $\phi\pi^+$ mode to normalize, FRABETTI 95F gets $\Gamma(K^+K^+K^-)/\Gamma(\phi\pi^+)<$
< 0.58 90 ALVAREZ 90C NA14 Photoproduction	0.025.
<0.28 90 ANJOS 89E E691 Photoproduction	

Γ(φ Κ ⁺)/Γ(φ A doubly 0		suppressed	decay with no si	im ple	spectat	or process possil	136/ Г 125	
<i>VALUE</i> <0.021		CL% <u>EVTS</u> 90	DOCUME: FRABET		95F E	$\frac{COMMEN}{COMMEN}$	<u>r</u> ≈ 220	ı
• • • We do no	t use the	following o	data for average	s. fits	. limits.	GeV etc.		
0.058 + 0.032		4		-,		E691 γ Be, \overline{E}_{γ}	= 145	
56 The evidence	of ANJ	OS 92D is a	small excess of	ever	nts (4.5	GeV +2.4 -2.0).		
$\Gamma(\pi^+e^+e^-)/$	Γ _{total}						Γ ₁₃₇ /Γ	
interaction			DOCUMENT ID			higher-order el	ectroweak	
<6.6 × 10 ⁻⁵	90		AITALA	96	E791	π^- N 500 GeV	***************************************	ı
• • • We do no $<2.5 \times 10^{-3}$		following o						
$< 2.5 \times 10^{-3}$ $< 2.6 \times 10^{-3}$	90 90	39 57	WEIR HAAS			e ⁺ e ⁻ 29 GeV e ⁺ e ⁻ 10 GeV		
		re normaliz				$K^-\pi^+\pi^+$, an	d <i>D</i> *+ →	
$\Gamma(\pi^+\mu^+\mu^-)$	/Γ _{total}		neutral current	. AI	lowed by	/ higher-order el	Γ ₁₃₈ /Γ ectroweak	
interaction VALUE			DOCUMENT ID		-	_		
$< 1.8 \times 10^{-5}$	90		AITALA	96	E791	π^- N 500 GeV		I
• • • We do no								
$<2.2 \times 10^{-4}$ $<5.9 \times 10^{-3}$	90 90	0	KODAMA WEIR	95 908		π^- emulsion 60 e^+e^- 29 GeV	00 GeV	ı
$< 2.9 \times 10^{-3}$	90	36 ⁵⁸	HAAS			e ⁺ e ⁻ 10 GeV		
58 The branchin 0 $^{+}$ using			ted to $D^0 \to K^-$	π+	, D ⁺ →	$K^-\pi^+\pi^+$, an	d <i>D</i> *+ →	
$\Gamma(\rho^+\mu^+\mu^-)/A$ test for	Γ _{total} the Δ <i>C</i>	= 1 weak	neutral current	. AI	lowed by	/ higher-order el	Γ ₁₃₉ /Γ ectroweak	
interaction VALUE	s. <u>CL%</u>	EVTS	DOCUMENT ID		TECN	COMMENT		
<5.6 × 10 ⁻⁴	90	0	KODAMA	95	E653	π^- emulsion 60	00 GeV	ı
Γ(K+e+e-)/		C. A.	DOCUMENT IS		T-61		Γ_{140}/Γ	
<4.8 × 10 ⁻³		<u>CL%</u> 90	WEIR			e ⁺ e ⁻ 29 GeV		
$\Gamma(K^+\mu^+\mu^-)$	/Γ _{total}	FVTS	DOCUMENT ID		TECN	COMMENT	Γ_{141}/Γ	
<3.2 × 10 ⁻⁴	90	0	KODAMA		E653		00 GeV	ı
• • • We do not $<9.2 \times 10^{-3}$	t use the	following o	lata for averages WEIR			etc. • • • e^+e^- 29 GeV		
$\Gamma(\pi^+ e^{\pm} \mu^{\mp})/$	Feetal						Γ ₁₄₂ /Γ	
A test of le	epton-fan		r conservation.				. 142/	
<3.8 × 10 ⁻³	<u>CL%</u> 90'		DOCUMENT ID			e ⁺ e ⁻ 10 GeV		
59 The branchin	g ratios a	re normaliz					d <i>D</i> *+ →	
$D^0\pi^+$ using		88C.						
$\Gamma(\pi^+e^+\mu^-)/$ A test of le	l total epton-fan	nily-numbe	r conservation.				Γ_{143}/Γ	
VALUE <3.3 × 10 ^{−3}		<u>CL%</u> 90	DOCUMENT ID			COMMENT e+e- 29 GeV		
$\Gamma(\pi^+e^-\mu^+)/$		50	W LIIV	905	WIKKZ	e e 23 GeV	Γ/Γ	
A test of le	' total epton-fan		r conservation.				Γ_{144}/Γ	
<3.3 × 10 ^{−3}		<u>CL%</u> 90	DOCUMENT ID WEIR			e+e- 29 GeV		
$\Gamma(K^+e^+\mu^-)$	Γ _{total}						Γ ₁₄₅ /Γ	
VALUE	epton-fan		r conservation. DOCUMENT ID		TECN	COMMENT		
$< 3.4 \times 10^{-3}$		90	WEIR	90B	MRK2	e ⁺ e ⁻ 29 GeV		
Γ (K⁺ e⁻ μ⁺) / A test of le	epton-fam	nily-numbe	r conservation.				Γ_{146}/Γ	
<3.4 × 10 ⁻³		<u>CL%</u> 90	DOCUMENT ID WEIR					
<3.4 × 10 ° Γ(π ⁻ e ⁺ e ⁺)/Ι		<i>7.</i> 0	VY LIIX	208	WINNZ	c - e - 29 GeV	Γ ₁₄₇ /Γ	
A test of le	total epton-nur		rvation. DOCUMENT ID		TECN	COMMENT	. 14(),	
<4.8 × 10 ⁻³		90	WEIR			e ⁺ e ⁻ 29 GeV		

$(\pi^-\mu^+\mu^+)$ / A test of le	• total epton-n	umber con					Γ ₁₄₈ /Ι
ALUE	CL%		DOCUMENT ID			COMMENT	
<2.2 × 10 ⁻⁴	90	0	KODAMA		E653	π emulsion 6	00 GeV
• • We do no	90	e ronowing					
$<6.8 \times 10^{-3}$	90		WEIR	908	MKK2	e ⁺ e ⁻ 29 GeV	
$(\pi^-e^+\mu^+)/$ A test of le	Γ _{total} epton-n	umber con	servation.				Γ ₁₄₉ /Ι
ALUE		CL%	DOCUMENT ID			COMMENT	
<3.7 × 10 ⁻³		90	WEIR	90B	MRK2	e ⁺ e ⁻ 29 GeV	
$(\rho^-\mu^+\mu^+)/A$	F _{total}	umber con	servation.				Γ ₁₅₀ /Ι
ALUE	CL%	<u>EVTS</u>	DOCUMENT ID		TECN	COMMENT	
<5.6 × 10 ⁻⁴	90	0	KODAMA	95	E653	π^- emulsion 6	00 GeV
(K -e+e+)/ A test of le	Γ _{total} epton-ni	umber con	servation.				Γ ₁₅₁ /Ι
ALUE		CL%	DOCUMENT ID			COMMENT	
<9.1 × 10 ⁻³		90	WEIR	90B	MRK2	e ⁺ e ⁻ 29 GeV	
$(K^-\mu^+\mu^+)$	/Γ _{total}	umber con	servation.				Γ ₁₅₂ /Ι
ALUE	CL%	<u>EVTS</u>	DOCUMENT ID		TECN	COMMENT	
<3.2 × 10 ⁻⁴	90	0	KODAMA		E653		00 GeV
• • We do not		e following					
<4.3 × 10 ⁻³	90		WEIR	90B	MRK2	e ⁺ e ⁻ 29 GeV	
$(K^-e^+\mu^+)/$ A test of le		umber cons	servation.				Γ ₁₅₃ /Ι
ALUE		CL%	DOCUMENT ID			COMMENT	
$<4.0 \times 10^{-3}$		90	WEIR	90B	MRK2	e ⁺ e 29 GeV	
(K*(892) - μ A test of le	+ μ+), epton-ni	/Γ _{total} umber cons	servation.				Γ ₁₅₄ /Γ
ALUE	CL%	EVTS	DOCUMENT ID		TECN	COMMENT	
<8.5 × 10 ⁻⁴	90	0	KODAMA	95	E653	π^- emulsion 60	00 GeV
$A_{CP}(K^+K^-\pi)$ This is the the sum of	±) in	D [±] → /	n D^+ and D^-	partial	widths	METRIES for these modes	divided by
ALUE - 0.031 ± 0.068	60	EDARETT	ID TECN	_ <u>COM</u>	MENI 14 < A ~	P < +0.081 (90	% CL)
						$\rho < \pm 0.061 (90)$ $K^{-}\pi^{+}\pi^{+})$, th	
			of events observ				ic ratio 0
						•	
This is the the sum of ALUE -0.12±0.13	different the wid 61 941 meas	ice between Iths. DOCUMENT FRABETT Sures N(D	n D^+ and D^- 10 TECN 1 941 E687 $+ \rightarrow K^+ \overline{K}^* (8)$	partial <u>СОМ</u> – 0.: 92) ⁰)/	widths for $MENT$ $33 < A_C$ $N(D^+)$	for these modes $\rho < +0.094 (90)$ $\rightarrow K^- \pi^+ \pi^+)$	% CL)
$A_{CP}(K^{\pm}K^{*0})$ This is the the sum of ALUE -0.12±0.13 61 FRABETTI 9 of (efficiency- $A_{CP}(\phi\pi^{\pm})$ in	different the wide of the wide	ice between this. DOCUMENT FRABETT sures N(D ⁻ ed) numbe φπ [±] ice between this. DOCUMENT	n D^+ and D^- 10 TECN 1 941 E687 $+ \to K^+ \overline{K}^* (8)$ rs of events obs 1 D^+ and D^- 10 TECN	partial COM 0.: 92) ⁰)/ erved, partial COM	widths to the second s	for these modes of $P < +0.094$ (90 $\rightarrow K^-\pi^+\pi^+$) illarly for the D^- for these modes of	% CL) the ratio divided by
ACP($K^{\pm}K^{*0}$) This is the the sum of the sum of 0.12 \pm 0.13 61 FRABETTI 9 of (efficiency-ACP($\phi\pi^{\pm}$) in This is the the sum of 0.066 \pm 0.086	different the wide the wide of the wide o	ce between this. DOCUMENT FRABETT sures $N(D^-)$ ed) numbe $\phi \pi^{\pm}$ ce between this. DOCUMENT FRABETT	n D^+ and D^- 10 15687 1 941 E687 1 D^+ D^+ D^+ D^- 10 1687 10 17 D^+ D^- 11 1687	partial	widths to the widths of the w	for these modes $\rho < +0.094$ (90 $\rightarrow K^-\pi^+\pi^+$) liarly for the D^-	% CL) the ratio divided by

D^{\pm} PRODUCTION CROSS SECTION AT $\psi(3770)$

A compilation of the cross sections for the direct production of D^\pm mesons at or near the $\psi(3770)$ peak in e^+e^- production.

VALUE (nanobarns)	DOCUMENT ID	TECN	COMMENT
• • • We do not use the	following data for average	s, fits, limits	, etc. • • •
$4.2 \pm 0.6 \pm 0.3$			3 e ⁺ e [−] 3.768 GeV
5.5 ±1.0	⁶⁴ PARTRIDGE	84 CBAL	e ⁺ e ⁻ 3.771 GeV
$6.00 \pm 0.72 \pm 1.02$			e ⁺ e [−] 3.771 GeV
9.1 ±2.0	⁶⁶ PERUZZI	77 MRK1	. e ⁺ e ⁻ 3.774 GeV

 ⁶³ This measurement compares events with one detected D to those with two detected D mesons, to determine the the absolute cross section. ADLER 88c measure the ratio of cross sections (neutral to charged) to be 1.36 ± 0.23 ± 0.14. This measurement does not include the decays of the ψ(3770) not associated with charmed particle production.
 64 This measurement comes from a scan of the ψ(3770) resonance and a fit to the cross section. PARTRIDGE 84 measures 6.4 ± 1.15 nb for the cross section. We take the phase space division of neutral and charged D mesons in ψ(3770) decay to be 1.33, and we assume that the ψ(3770) is an isosinglet to evaluate the cross sections. The noncharm decays (e.g. radiative) of the ψ(3770) are included in this measurement and may amount to a few percent correction.

 D^{\pm} , D^{0}

65 This measurement comes from a scan of the $\psi(3770)$ resonance and a fit to the cross section. SCHINDLER 80 assume the phase space division of neutral and charged D mesons in $\psi(3770)$ decay to be 1.33, and that the $\psi(3770)$ is an isosinglet. The noncharm decays (e.g. radiative) of the $\psi(3770)$ are included in this measurement and may amount to a few percent correction.
66 This measurement comes from a scan of the $\psi(3770)$ resonance and a fit to the cross section. The phase space division of neutral and charged D mesons in $\psi(3770)$ decay is taken to be 1.33, and $\psi(3770)$ is assumed to be an isosinglet. The noncharm decays (e.g. radiative) of the $\psi(3770)$ are included in this measurement and may amount to a few percent correction. We exclude this measurement from the average because of uncertainties in the contamination from τ lepton pairs. Also see RAPIDIS 77.

$D^+ ightarrow \overline{K}^*(892)^0 \ell^+ \nu_\ell$ FORM FACTORS

$r_2 \equiv A_2(0)/A_1(0) \text{ in } D^+ o \ \overline{K}^*(892)^0 \ell^+ \nu_\ell$ TECN__COMMENT DOCUMENT ID 0.73±0.15 OUR AVERAGE $^{67}\, {\rm FRABETTI}$ $\,$ 93E E687 $\,$ 220 GeV $\gamma \, {\rm Be}$ 874 $0.78 \pm 0.18 \pm 0.10$ $0.82^{+0.22}_{-0.23}\pm0.11$ 305 67 KODAMA 92 E653 600 GeV π^- N 0.0 ±0.5 ±0.2 183 68 ANJOS 90E E691 γ Be 90-260 GeV 67 FRABETTI 93E and KODAMA 92 use ${\it D}^{+} \rightarrow ~\overline{\it K}^{*}(892)^{0}\,\mu^{+}\,\nu_{\mu}$ decays. ⁶⁸ ANJOS 90E uses $D^+ ightarrow \ \overline{{\it K}}^*(892)^0 \, e^+ \, e_\mu$ decays.

$r_{\nu} \equiv V(0)/A_1(0) \text{ in } D^+ \rightarrow \overline{K}^*(892)^0 \ell^+ \nu_{\ell}$

		. , .							
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT					
1.90±0.25 OUR AVE	RAGE								
$1.74 \pm 0.27 \pm 0.28$	874	⁶⁹ FRABETTI	93E E687	220 GeV γ Be					
$2.00^{+0.34}_{-0.32}\pm0.16$	305	⁶⁹ KODAMA	92 E653	600 GeV π^- N					
$2.0 \pm 0.6 \pm 0.3$	183	⁷⁰ ANJOS	90E E691	γ Be 90-260 GeV					
69 FRABETTI 93E and KODAMA 92 use $D^+ ightarrow \overline{K}^*$ (892) $^0 \mu^+ u_{\mu}$ decays.									
70 ANJOS 90E uses I	$0^+ \rightarrow \overline{K}$	*(892) ⁰ e ⁺ e deci	avs.	,					

Γ_L/Γ_T in $D^+ \rightarrow \overline{K}^*(892)^0 \ell^+ \nu_\ell$

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
1.23 ± 0.13 OUR AVERA	GE				
$1.20 \pm 0.13 \pm 0.13$	874		93E	E687	220 GeV γ Be
$1.18 \pm 0.18 \pm 0.08$	305	⁷¹ KODAMA	92	E653	600 GeV π^- N
$1.8 \ ^{+ 0.6}_{- 0.4} \ \pm 0.3$	183	⁷² ANJOS	90E	E691	γ Be 90–260 GeV

 71 FRABETTI 93E and KODAMA 92 use $D^+
ightarrow \overline{K}^*(892)^0 \, \mu^+ \, \nu_\mu$ decays. Γ_L/Γ_T is evaluated for a lepton mass of zero. 72 ANJOS 90E uses $D^+ \rightarrow \overline{K}^*(892)^0 \, e^+ \, e_\mu$ decays.

Γ_+/Γ_- in $D^+ \rightarrow \overline{K}^*(892)^0 \ell^+ \nu_\ell$

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.16±0.04 OUR AVE	RAGE				
$0.16 \pm 0.05 \pm 0.02$	305	⁷³ KODAMA	92	E653	600 GeV π^- N
$0.15^{+0.07}_{-0.05}\pm0.03$	183	⁷⁴ ANJOS	90E	E691	γ Be 90-260 GeV

 $^{73}\,\rm KODAMA$ 92 uses $D^+\to~\overline{K}^*(892)^0\mu^+\nu_{\mu}$ decays. Γ_+/Γ_- is evaluated for a lepton 74 Mass of zero. 74 ANJOS 90E uses $D^+ \to \overline{K}^*(892)^0 \, e^+ \, e_\mu$ decays.

D± REFERENCES

AITALA	96	PRL 76 364	+Amato, Anjos+	(FNAL E791	Collab.)
PDG	96	PR D54 1			
FRABETTI	95	PL B346 199	+Cheung, Cumalat+	(FNAL E687	Collab.)
FRABETTI	95B	PL B351 591	+Cheung, Cumalat+	(FNAL E687	
FRABETTI	95E	PL B359 403	+Cheung, Cumalat+	(FNAL E687	
FRABETTI	95F	PL B363 259	+Cheung, Cumalat+	(FNAL E687	
KODAMA	95	PL B345 85	+Ushida, Mokhtarani+	(FNAL E653	
ALBRECHT	941	ZPHY C64 375	+Hamacher, Hofmann+	(ARGUS	
ALEEV	94	PAN 57 1370	+Balandin+	(Serpukhov BIS-2	
ALLEV	54	Translated from YF 57	1443.	(Serpukilov DIS-2	Collab.)
BALEST	94	PRL 72 2328	+Cho, Daoudi, Ford+	(CLEO	Collab.)
FRABETTI	94 D	PL B323 459	+Cheung, Cumalat+	(FNAL E687	Collab.)
FRABETTI	94G	PL B331 217	+Cheung, Cumalat+	(FNAL E687	Collab.)
FRABETTI	941	PR D50 R2953	+Cheung, Cumalat+	(FNAL E687	
ABE	93E	PL B313 288	+Amako, Arai, Arima, Asano+	(VENUS	
ADAMOVICH	93	PL B305 177	+Alexandrov, Antinori+	(CERN WA82	
AKERIB	93	PRL 71 3070	+Barish, Chadha, Chan+		Collab.)
ALAM	93	PRL 71 1311	+Kim, Nemati, O'Neill+		Collab.)
ANJOS	93	PR D48 56	+Appel, Bean, Bracker+	(FNAL E691	
BEAN	93C	PL B317 647	+Gronberg, Kutschke, Menary+		Collab.)
FRABETTI	93E	PL B307 262	+Grim, Paolone, Yager+	(FNAL E687	
KODAMA	93B	PL B313 260	+Ushida, Mokhtarani+	(FNAL E653	
KODAMA	93C	PL B316 455	+Ushida, Mokhtarani+	(FNAL E653	
SELEN	93	PRL 71 1973	+Sadoff, Ammar, Ball+		Collab.)
ALBRECHT	92B	ZPHY C53 361	+Ehrlichmann, Hamacher, Kruege		
ALBRECHT	92F	PL B278 202	+Ehrlichmann, Hamacher+	(ARGUS	
ANJOS	92	PR D45 R2177	+Appel, Bean, Bracker+	(FNAL E691	
ANJOS	92C	PR D46 1941	+Appel, Bean, Bracker+	(FNAL E691	
ANJOS	92D	PRL 69 2892	+Appel, Bean, Bediaga+	(FNAL E691	
BARLAG	92C	ZPHY C55 383		(ACCMOR	
	90D		+Becker, Bozek, Boehringer+		
Also	90D 92B	ZPHY C48 29	Barlag, Becker, Boehringer, Bos		
COFFMAN		PR D45 2196	+DeJongh, Dubois, Eigen+	(Mark III	
DAOUDI	92	PR D45 3965	+Ford, Johnson, Lingel+		Collab.)
FRABETTI	92	PL B281 167	+Bogart, Cheung, Culy+	(FNAL E687	
KODAMA	92	PL B274 246	+Ushida, Mokhtarani+	(FNAL E653	
KODAMA	92C	PL B286 187	+Ushida, Mokhtarani+	(FNAL E653	
ADAMOVICH	91	PL B268 142	+Alexandrov, Antinori, Barberis+		Collab.)
ALBRECHT	91	PL B255 634	+Ehrlichmann, Hamacher, Kruege		
ALVAREZ	91	PL B255 639	+Barate, Bloch, Bonamy+	(CERN NA14/2	
ALVAREZ	91B	ZPHY C50 11	+Barate, Bloch, Bonamy+	(CERN NA14/2	
AMMAR	91	PR D44 3383	+Baringer, Coppage, Davis+		Collab.)
ANJOS	91B	PR D43 R2063	+Appel, Bean, Bracker+	(FNAL E691	
ANJOS	91C	PRL 67 1507	+Appel, Bean, Bracker+	(FNAL-TPS	
BAI	91	PRL 66 1011	+Bolton, Brown, Bunnell+	(Mark III	Collab.)

COFFMAN	91	PL B263 135	+DeJongh, Dubois, Eigen, Hitlin+ (Mark III								
FRABETTI	91	PL B263 584	+Bogart, Cheung, Culy+ (FNAL E687								
ALVAREZ	90	ZPHY C47 539	+Barate, Bloch, Bonamy+ (CERN NA14/2								
ALVAREZ ANJOS	90C 90C	PL B246 261 PR D41 2705	+Barate, Bloch, Bonamy+ (CERN NA14/2								
ANJOS	90C	PR D41 2705 PR D42 2414	+Appel, Bean+ (FNAL E691 +Appel, Bean, Bracker+ (FNAL E691								
ANJOS	90E	PRL 65 2630	+Appel, Bean, Bracker+ (FNAL E691 +Appel, Bean, Bracker+ (FNAL E691								
BARLAG	90C	ZPHY C46 563	+Becker, Boehringer, Bosman+ (ACCMOR								
VEIR	90B	PR D41 1384	+Klein, Abrams, Adolphsen, Akerlof+ (Mark II								
NJOS	89	PRL 62 125	+Appel, Bean, Bracker+ (FNAL E691								
NJOS	89B	PRL 62 722	+Appel, Bean, Bracker+ (FNAL E691	Collab.)							
NJOS	89E	PL B223 267	+Appel, Bean, Bracker+ (FNAL E691								
ADLER	88B	PRL 60 1375	+Becker, Blaylock+ (Mark III								
ADLER	88C	PRL 60 89	+Becker, Blaylock+ (Mark III								
ALBRECHT	881	PL B210 267	+Boeckmann, Glaeser+ (ARGUS								
ANJOS	88	PRL 60 897	+Appel+ (FNAL E691								
AOKI	88	PL B209 113		Collab.)							
HAAS	88	PRL 60 1614		Collab.)							
ONG	88	PRL 60 2587	+Weir, Abrams, Amidei+ (Mark II								
RAAB	88	PR D37 2391	+Anjos, Appel, Bracker+ (FNAL E691								
ADAMOVICH	87	EPL 4 887	+Alexandrov, Bolta+ (Photon Emulsion	Collab.)							
ADLER	87	PL B196 107	+Becker, Blaylock, Bolton+ (Mark III								
AGUILAR	87D	PL B193 140	Aguilar-Benitez, Allison+ (LEBC-EHS								
Also	88B	ZPHY C40 321	Aguilar-Benitez, Allison, Bailly+ (LEBC-EHS								
GUILAR	87E	ZPHY C36 551	Aguilar-Benitez, Allison+ (LEBC-EHS								
Also	88B	ZPHY C40 321	Aguilar-Benitez, Allison, Bailly+ (LEBC-EHS								
GUILAR	87F	ZPHY C36 559	Aguilar-Benitez, Allison+ (LEBC-EHS								
Also	88	ZPHY C38 520		7							
BARLAG	87B	ZPHY C37 17	+Becker, Boehringer, Bosman+ (ACCMOR	Collab.)							
BARTEL	87	ZPHY C33 339		Collab.)							
SORNA	87	PL B191 318		Collab.)							
ALKA	87B	ZPHY C35 151	+Bailey, Becker+ (ACCMOR								
ABE	86	PR D33 1	+ (SLAC Hybrid Facility Photon	Collab.)							
AGUILAR	86B	ZPHY C31 491	Aguilar-Benitez, Allison+ (LEBC-EHS								
BALTRUSAIT	86E	PRL 56 2140	Baltrusaitis, Becker, Blaylock, Brown+ (Mark III								
PAL	86	PR D33 2708	+Atwood, Barish, Bonneaud+ (DELCO								
AIHARA	85	ZPHY C27 39		Collab.)							
BALTRUSAIT	85B	PRL 54 1976	Baltrusaitis, Becker, Blaylock, Brown+ (Mark III								
BALTRUSAIT	85E	PRL 55 150	Baltrusaitis, Becker, Blaylock, Brown+ (Mark III	Collab.)							
BARTEL	85J	PL 163B 277		Collab.)							
ADAMOVICH	84	PL 140B 119	+Alexandrov, Bolta, Bravo+ (CERN WA58								
ALTHOFF	84 G	ZPHY C22 219	+Braunschweig, Kirschfink+ (TASSO								
ALTHOFF	84 J	PL 146B 443	+Branschweig, Kirschfink+ (TASSO								
DERRICK	84	PRL 53 1971		Collab.)							
(OOP	84	PRL 52 970	+Sakuda, Atwood, Baillon+ (DELCO								
PARTRIDGE	84	Thesis CALT-68									
AGUILAR	83B	PL 123B 98	Aguilar-Benitez, Allison+ (LEBC-EHS								
UBERT	83	NP B213 31		Collab.)							
PARTRIDGE	81	PRL 47 760	+Peck, Porter, Gu+ (Crystal Ball								
CHINDLER	81	PR D24 78	+Alam, Boyarski, Breidenbach+ (Mark II								
FRILLING	81	PRPL 75 57		L, UCB)							
BACINO	80	PRL 45 329	+Ferguson+ (DELCO								
CHINDLER	80	PR D21 2716	+Siegrist, Alam, Boyarski+ (Mark II								
HOLENTZ	80	PL 96B 214		(NOVO)							
Also	81	SJNP 34 814	Zholentz, Kurdadze, Lelchuk+	(NOVO)							
	70	Translated from	YAF 34 1471.	C-11-1-3							
BACINO	79	PRL 43 1073	+Ferguson, Nodulman+ (DELCO								
BRANDELIK	79	PL 80B 412		Collab.)							
ELLER	78	PRL 40 274	+Litke, Madaras, Ronan+ (Mark I								
/UILLEMIN	78	PRL 41 1149	+Feldman, Feller+ (Mark I								
SOLDHABER	77	PL 69B 503	+Wiss, Abrams, Alam+ (Mark I								
PERUZZI	77	PRL 39 1301		Collab.)							
PICCOLO	77	PL 70B 260		Collab.)							
	77	PRL 39 526		Collab.)							
		PRL 37 569	+Piccolo, Feldman, Nguyen, Wiss+ (Mark I	Collab.)							
	76	1 KE 31 307	OTHER RELATED PAPERS								
	76		THER RELATED PAPERS								
PERUZZI		o		STANI							
RAPIDIS PERUZZI RICHMAN ROSNER	76 95 95			STAN) (CHIC)							

+Delongh Dubois Figen Hitlin+

(Mark III Collab.)



COFFMAN 91 PI R263 135

 $I(J^P) = \frac{1}{2}(0^-)$

D0 MASS

The fit includes D^{\pm} , D^{0} , D_{s}^{\pm} , $D^{*\pm}$, D^{*0} , and $D_{s}^{*\pm}$ mass and mass difference measurements.

VALUE (MeV)	EVTS	DOCUMENT ID	TEC	NCOMMENT
1864.5± 0.5 OUR FIT	Error inc	ludes scale factor	of 1.1.	
1864.1 ± 1.0 OUR AVE	RAGE			
$1864.6 \pm 0.3 \pm 1.0$	641	BARLAG	90c AC	CM π Cu 230 GeV
1852 ± 7	16	ADAMOVICH	87 EM	UL Photoproduction
1861 ± 4		DERRICK	84 HR	6 e ⁺ e− 29 GeV
• • • We do not use the	e following	g data for average	s, fits, lim	its, etc. • • •
1856 ±36	22	ADAMOVICH	848 EM	UL Photoproduction
1847 ± 7	1	FIORINO	81 EM	UL $\gamma N ightarrow \overline{D}{}^0 +$
1863.8± 0.5		¹ SCHINDLER	81 MR	K2 e ⁺ e ⁻ 3.77 GeV
1864.7 ± 0.6		¹ TRILLING	81 RV	JE $e^{+}e^{-}$ 3.77 GeV
1863.0 ± 2.5	238	ASTON	80E OM	EG $\gamma p \rightarrow \overline{D}^0$
1860 ± 2	143	² AVERY	80 SPE	$C \gamma N \rightarrow D^{*+}$
1869 ± 4	35	² AVERY		$C \gamma N \rightarrow D^{*+}$
1854 ± 6	94	² ATIYA		$EC \gamma N \rightarrow D^0 \overline{D}{}^0$
1850 ±15	64	BALTAY	78C HB	$C \nu N \rightarrow K^0 \pi \pi$
1863 ± 3		GOLDHABER	77 MR	K1 D^0 , D^+ recoil spectra
1863.3± 0.9		¹ PERUZZI	77 MR	K1 e ⁺ e ⁻ 3.77 GeV
1868 ±11		PICCOLO	77 MR	K1 e ⁺ e ⁻ 4.03, 4.41 GeV
1865 ±15	234	GOLDHABER	76 MR	K1 $K\pi$ and $K3\pi$

 1 PERUZZI 77 and SCHINDLER 81 errors do not include the 0.13% uncertainty in the absolute SPEAR energy calibration. TRILLING 81 uses the high precision $J/\psi(1.5)$ and $\psi(2.5)$ measurements of ZHOLENTZ 80 to determine this uncertainty and combines the PERUZZI 77 and SCHINDLER 81 results to obtain the value quoted. TRILLING 81 enters the fit in the D^\pm mass, and PERUZZI 77 and SCHINDLER 81 enter in the $m_{D^\pm}-m_{D^0}$, below.

² Error does not include possible systematic mass scale shift, estimated to be less than 5

$|m_{D_1^0} - m_{D_2^0}|$

The D_1^0 and D_2^0 are the mass eigenstates of the D^0 meson.

VALUE (10 ¹⁰	$h s^{-1}$	CL%	DOCUMENT ID	TECN	COMMENT	
< 21		90	3,4 ANJOS	88c E691	Photoproduction	
• • • We	do not us	se the follo	wing data for average	s, fits, limits	s, etc. • • •	
< 40		90	3 ALBRECHT	87K ARG	e^+e^- 10 GeV	
< 24		90			π^- W 225 GeV	
<106		90	^{3,6} ҮАМАМОТО	85 DLCC	e ⁺ e ⁻ 29 GeV	
< 99		90	⁵ BODEK	82 SPEC	π^- , $ ho$ Fe $ ightarrow$ D^0	
3 Limit	inferred	from the	$D^0-\overline{D}^0$ mixing r	atio $\Gamma(K^+)$	π^- or $K^+\pi^-\pi^+\pi^-$	(vi

- This interior in the $D^{-}D^{-}$ inixing ratio $I(K \pi^{-} \sigma^{-} K \pi^{-} \pi^{+} \pi^{+} \pi^{-})$ near the end of the D^{0} Listings.

 4 Calculated by us using $\Delta m = (2r/(1-r))^{1/2}\hbar/4.15 \times 10^{-13} \text{ s}$, where r is the $D^{0}-\overline{D}^{0}$ mixing ratio. See the data on $r \equiv \Gamma(K + \pi^{-} \sigma^{-} K \pi^{-} \pi^{+} \pi^{-} (\text{via } \overline{D}^{0}))/\Gamma(K \pi^{-} \pi^{+} \sigma^{-} \pi^{-} \pi^{ \begin{array}{l} {\cal K}^-\pi^+\pi^+\pi^-) \text{ near the end of the } D^0 \text{ Listings.} \\ {}^5\text{Limit inferred from the } D^0 \text{-} \overline{D}^0 \text{ mixing ratio } \Gamma(\mu^- \text{anything (via } \overline{D}^0))/\Gamma(\mu^+ \text{anything)} \end{array}$
- near the end of the D^0 Listings. 6 YAMAMOTO 85 gives $\Delta m/\Gamma < 0.44$. We use $\Gamma = \hbar/4.15 \times 10^{-13}$ s.

$m_{D^\pm}-m_{D^0}$

The fit includes D^\pm , D^0 , D^\pm_s , $D^{*\pm}$, D^{*0} , and $D^{*\pm}_s$ mass and mass difference measurements.

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
4.78±0.10 OUR FIT					
4.74±0.28 OUR AVERAGE					
4.7 ±0.3	⁷ SCHINDLER	81	MRK2	e ⁺ e 3.77 GeV	
5.0 ±0.8	⁷ PERUZZI	77	MRK1	$e^{+}e^{-}$ 3.77 GeV	
⁷ See the footnote on TRILLING	81 in the D^0 and	D±	section	s on the mass.	

${\it D}^{\rm 0}$ MEAN LIFE

Measurements with an error $>0.05\times10^{-12}$ s are omitted from the average, and those with an error $>0.1\times10^{-12}$ s or that have been superseded by later results have been removed from the Listings.

VALUE (10 ⁻¹² s)	EVTS	DOCUMENT ID		TECN	COMMENT
0.415±0.004 OUR A	VERAGE				
$0.413 \pm 0.004 \pm 0.003$	16k	FRABETTI	94D	E687	$K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$
$0.424 \pm 0.011 \pm 0.007$	5118	FRABETTI	91	E687	$K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$
$0.417 \pm 0.018 \pm 0.015$	890	ALVAREZ	90	NA14	$K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$
$0.388^{+0.023}_{-0.021}$	641	BARLAG	9 0c	ACCM	π^- Cu 230 GeV
$0.48 \pm 0.04 \pm 0.03$	776	ALBRECHT	881	ARG	e ⁺ e ⁻ 10 GeV
$0.422 \pm 0.008 \pm 0.010$	4212	RAAB	88	E691	Photoproduction
0.42 ± 0.05	90	BARLAG	87B	ACCM	K^- and π^- 200 GeV
 ● ● We do not use 	the following	ng data for avera	ges,	fits, limi	ts, etc. • • •
$0.34 \ ^{+ 0.06}_{- 0.05} \ \pm 0.03$	58	AMENDOLIA	88	SPEC	Photoproduction
$0.46 \begin{array}{l} +0.06 \\ -0.05 \end{array}$	145	AGUILAR	87 D	HYBR	$\pi^- ho$ and $ ho ho$
$0.50 \pm 0.07 \pm 0.04$	317	CSORNA	87	CLEO	e^+e^- 10 GeV
$0.61 \pm 0.09 \pm 0.03$	50	ABE	86	HYBR	γ p 20 GeV
$0.47 {}^{+ 0.09}_{- 0.08} \pm 0.05$	74	GLADNEY	86	MRK2	e^+e^- 29 GeV
$0.43 \begin{array}{l} +0.07 & +0.01 \\ -0.05 & -0.02 \end{array}$	58	USHIDA	86в	EMUL	u wideband
$0.37 \begin{array}{c} +0.10 \\ -0.07 \end{array}$	26	BAILEY	85	SILI	π^- Be 200 GeV
⁸ BARLAG 90C esti	mate system	natic error to be	negli	gible.	

$|\Gamma_{D_1^0} - \Gamma_{D_2^0}|/\Gamma_{D^0}$ MEAN LIFE DIFFERENCE/AVERAGE

The D_1^0 and D_2^0 are the mass eigenstates of the D^0 meson.

<u>VALUE</u> <0.17	<u>CL%</u> 90 9,	DOCUMENT II ANJOS		COMMENT Photoproduction
• • • We do no	ot use the following	data for avera	ges, fits, limits	, etc. • • •
< 0.21	90	¹¹ LOUIS	86 SPEC	π^- W 225 GeV
< 0.8	90	9 YAMAMOTO	O 85 DLCO	e^+e^- 29 GeV
< 0.55	90	^{l 1} BODEK	82 SPEC	π^- , pFe $\rightarrow D^0$
9 This limit i	s inferred from the	0.70 mivir	ng ratio F(K+	π^- or $K^+\pi^-\pi^+\pi^-$ (v

- This limit is inferred from the D^0 - D^0 mixing ratio $\Gamma(K^+\pi^-)$ or D^0)/ $\Gamma(K^-\pi^+)$ or $K^-\pi^+\pi^+\pi^-$) near the end of the D^0 Listings.
- 10 Calculated by us using $\Delta\Gamma/\Gamma = [8r/(1+r)]^{1/2}$, where r is the $D^0-\overline{D}^0$ mixing ratio. See the data on $r \equiv \Gamma(K^+\pi^- \text{ or } K^+\pi^-\pi^+\pi^- (\text{via }\overline{D}^0))/\Gamma(K^-\pi^+ \text{ or } K^-\pi^+\pi^+\pi^-)$
- near the end of the D^0 Listings. 11 Limit inferred from the D^0 - \overline{D}^0 mixing ratio $\Gamma(\mu^-$ anything (via \overline{D}^0))/ $\Gamma(\mu^+$ anything) near the end of the D^0 Listings.

D⁰ DECAY MODES

	\overline{D}^{U} modes are charge conjugates of			Scale factor/
	Mode		Fraction (Γ_i/Γ)	Confidence level
	Inclusiv	e mod	les	
Г1	e ⁺ anything		(7.7 ±1.2)%	S=1.1
Γ ₂	μ^+ anything	[a]	(6.8 ±1.0)%	
	K ⁻ anything		(53 ±4)%	
4	\overline{K}^0 anything $+ K^0$ anything		(42 ±5)%	
5	K^+ anything			
-			$(3.4 \begin{array}{c} +0.6 \\ -0.4 \end{array})$ %	0
6	η anything	[<i>b</i>]	< 13 %	CL=90%
	Semilepto			
7	$K^-\ell^+ u_\ell$	[c]	$(3.48\pm0.16)\%$	
В	$K^-e^+\nu_e$		$(3.64\pm0.20)\%$	
•	$K^-\mu^+ u_\mu^-$		(3.23±0.19) %	•
10	$K^-\pi^0e^+ u_e$		$(1.6 \begin{array}{c} +1.3 \\ -0.5 \end{array})$ %	b
1	$\overline{K}{}^0\pi^-e^+ u_e$		$(2.8 \begin{array}{c} +1.7 \\ -0.9 \end{array}) \%$	
2	$\overline{K}^*(892)^- e^+ \nu_e$		(1.34±0.22) %	
	$\overline{K}^*(892)^- e^+ \nu_e \times B(K^{*-} \to \overline{K}^0 \pi^-)$		` ,	
13	$K^*(892)^-\ell^+\nu_\ell$			
14	$K^{-}\pi^{0}(\pi^{0})e^{+}\nu_{e}$			
15	$\overline{K}^0 \pi^- (\pi^0) e^+ \nu_e$			
16				
١7	$K^-\pi^+\pi^-\mu^+ u_{\mu}$		< 1.2 ×	10 ⁻³ CL=90%
18	$(\overline{K}^*(892)\pi)^{-}\mu^{+}\nu_{\mu}$		< 1.4 ×	10^{-3} CL=90%
19	$\pi^- e^+ \nu_e$		$(3.8 \begin{array}{c} +1.2 \\ -1.0 \end{array}) \times$	10-3
0	A fraction of the following resonance a submode of a charged-particle mo $K^*(892)^- e^+ \nu_e$ Hadronic modes we have the fraction of the following resonance as the fraction of the fraction	de.	(2.01±0.33) %	
1	$K^-\pi^+$	with a		
2	$\frac{\kappa}{K}$ 0 π 0		(3.83±0.12) %	
	$\frac{\kappa}{\kappa^0} \frac{\pi}{\pi^+} \pi^-$	[4]	(2.11±0.21) %	
3	$\frac{\pi}{K^0} \rho^0$	[d]	(5.4 ±0.4)%	
4	$\frac{K}{K^0} f_0(980)$		(1.20±0.17) %	
5	$\times B(f_0 \rightarrow \pi^+\pi^-)$		(3.0 \pm 0.8) \times	10 5
_	$\overline{K}^0 f_2(1270)$		(2.3 ±0.9)×	10-3
6			(2.3 ±0.9) x	10 -
7	$\frac{\times B(f_2 \rightarrow \pi^+ \pi^-)}{\overline{K}^0 f_0(1370)}$		(4 2 - 1 1 2)	10-3
1	$\times B(f_0 \rightarrow \pi^+\pi^-)$		(4.3 ±1.3)×	10
8	$K^*(892)^-\pi^+$		(3.3 ±0.3) %	
8	$\times \ B(K^{*-} \to \overline{K}{}^{0}\pi^{-})$		(3.3 ± 0.3) /6	
9	$K_0^*(1430)^-\pi^+$		(6.4 ±1.6)×	10-3
9		. \	(0.4 ±1.0) x	10
	$\times B(K_0^*(1430)^- \to \overline{K}^0 \pi^-$)		
0	$\overline{K}^0\pi^+\pi^-$ nonresonant		$(1.46\pm0.24)\%$	
1	$K^-\pi^+\pi^0$	[d]	$(13.9 \pm 0.9)\%$	S=1.3
2	$K^-\rho^+$		(10.8 ±1.0) %	
3	$K^*(892)^-\pi^+$		(1.7 ±0.2) %	
	$\times B(K^{*-} \rightarrow K^-\pi^0)$			
4	$\overline{K}^*(892)^0\pi^0$		(2.1 ± 0.3) %	
	$\times B(\overline{K}^{*0} \to K^-\pi^+)$			2
5	$K^-\pi^+\pi^0$ nonresonant		(6.9 \pm 2.5) \times	10-3
6	$K^0 \pi^0 \pi^0$			
7	$\overline{K}^*(892)^0\pi^0$		(1.0 \pm 0.2)%	
	$\times B(\overline{K}^{*0} \to \overline{K}^0\pi^0)$			2
8	$\overline{K}{}^0\pi^0\pi^0$ nonresonant		(7.8 \pm 2.0) \times	10-3
9	$K^-\pi^+\pi^+\pi^-$	[d]	(7.5 \pm 0.4) %	S=1.1
0	$K^-\pi^+\rho^0$ total		(6.3 ± 0.4) %	2
1	$K^-\pi^+\rho^0$ 3-body		(4.7 \pm 2.1) \times	
40	$\overline{K}^*(892)^0 a^0$		(98 +22) >	10-3

 $\overline{K}^*(892)^0 \rho^0 \times B(\overline{K}^{*0} \to K^- \pi^+)$

 $\begin{array}{ll} & \text{n} & \text{a}_1(1260)^+ \\ & \times & \text{B}(a_1(1260)^+ \to \pi^+\pi^+\pi^-) \\ & \overline{K}^*(892)^0 \, \pi^+\pi^- \, \text{total} \\ & \times & \text{B}(\overline{K}^{*0} \to K^-\pi^+) \\ & \overline{K}^*(892)^0 \, \pi^+\pi^- \, \text{3-body} \\ & \times & \text{B}(\overline{K}^{*0} \to K^-\pi^+) \end{array}$

 $K^-a_1(1260)^+$

 Γ_{42}

 Γ_{43}

 Γ_{45}

(9.8 ± 2.2) $\times 10^{-3}$

($3.6~\pm0.6$) %

(1.5 \pm 0.4) %

(9.5 ± 2.1) $\times 10^{-3}$

 D^0

```
\Gamma_{102} \quad \overline{K}_1(1400)^0 \pi^0
\Gamma_{103} \quad K^*(1410)^- \pi^+
\Gamma_{46}
                        K_1(1270)^-\pi^+
                                                                                                              [e] (3.6 \pm 1.0) \times 10^{-3}
                                                                                                                                                                                                                                                                                                                                                                                                                                   CL=90%
                \begin{array}{c} \times \ \mathsf{B}(K_1(1270)^- \to K^-\pi^+\pi^-) \\ K^-\pi^+\pi^+\pi^- \text{ nonresonant} \\ \overline{K}^0\pi^+\pi^-\pi^0 \end{array}
                                                                                                                                                                                                                                                                                                                                                               < 1.2
                                                                                                                                                                                                                                                                                                                                                                                                                                   CL=90%
                                                                                                                                                                                                                                         \Gamma_{104} \quad K_0^*(1430)^- \pi^+
                                                                                                                           (1.75 \pm 0.25)\%
                                                                                                                                                                                                                                                                                                                                                               (1.04\pm0.26)\%
                                                                                                                                                                                                                                        < 8 × 10<sup>-3</sup>
Γ<sub>48</sub>
                                                                                                              [d] (10.0 \pm 1.2)%
                                                                                                                                                                                                                                                                                                                                                                                                                                   CL=90%
                     \begin{array}{l} ({}^{\mathsf{C}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{\mathsf{T}}{}^{
                                                                                                                           ( 1.6 \pm 0.3 ) \times\,10^{-3}
                                                                                                                                                                                                                                                                                                                                                                                                 \times 10^{-3}
\Gamma_{49}
                                                                                                                                                                                                                                                                                                                                                              < 4
                                                                                                                                                                                                                                                                                                                                                                                                                                   CL=90%
                                                                                                                           ( 1.9\ \pm0.4 )%
 Γ<sub>50</sub>
                                                                                                                                                                                                                                                                                                                                                               (1.8 \pm 0.9)\%
                                                                                                                           (4.0 \pm 1.6)\%
 \Gamma_{51}
                                                                                                                                                                                                                                                                                                                                                               ( 1.9 \pm0.5 )%

\Gamma_{109} \quad K^{-}\pi^{+}\omega 

\Gamma_{110} \quad \overline{K}^{*}(892)^{0}\omega 

\Gamma_{111} \quad K^{-}\pi^{+}\eta'(958)

                                                                                                                                                                                                                                                                                                                                                                  (3.0 \pm 0.6)\%
                                                                                                                          ( 4.9 \pm 1.1 ) \times 10^{-3}
\Gamma_{52}
                                                                                                                                                                                                                                                                                                                                                                 (1.1 \pm 0.4)\%
            \begin{array}{c} K_{1}(1270)^{-}\,\pi^{+} & , \\ \times \, \mathsf{B}(K_{1}(1270)^{-} \to \overline{K}^{0}\,\pi^{-}\,\pi^{0}) \\ \overline{K}^{*}(892)^{0}\,\pi^{+}\,\pi^{-}\,3\text{-body} & (4.7\,\pm 1.1\,)\,\times 10^{-3} \\ \times \, \mathsf{B}(\overline{K}^{*}0 \to \overline{K}^{0}\,\pi^{0}) \\ \overline{K}^{0}\,\pi^{+}\,\pi^{-}\,\pi^{0}\,\text{nonresonant} & (2.1\,\pm 2.1\,)\,\% \\ K^{-}\,\pi^{+}\,\pi^{0}\,\pi^{0} & (15\,\pm 5\,)\,\% \\ K^{-}\,\pi^{+}\,\pi^{+}\,\pi^{-}\,\pi^{0} & (4.0\,\pm 0.4\,)\,\% \\ \overline{K}^{*}(892)^{0}\,\pi^{+}\,\pi^{-}\,\pi^{0} & (1.2\,\pm 0.6\,)\,\% \\ \times \, \mathsf{B}(\overline{K}^{*}0 \to K^{-}\,\pi^{+}) \\ \overline{K}^{*}(892)^{0}\,\eta & \end{array}
                                                                                                                                                                                                                                                                                                                                                                 (7.0 \pm 1.8) \times 10^{-3}
                                                                                                                                                                                                                                         \Gamma_{112}^{111} \quad \overline{K}^*(892)^0 \, \eta'(958)
Γ<sub>53</sub>
                                                                                                                                                                                                                                                                                                                                                               < 1.1 \times 10^{-3}
                                                                                                                                                                                                                                                                                                                              Pionic modes
                                                                                                                                                                                                                                         \Gamma_{113} \pi^{+}\pi^{-}
                                                                                                                                                                                                                                                                                                                                                                  (1.52\pm0.11)\times10^{-3}
                                                                                                                                                                                                                                         \Gamma_{114} \quad \pi^0 \pi^0
\Gamma_{115} \quad \pi^+ \pi^- \pi^0
                                                                                                                                                                                                                                                                                                                                                                   ( 8.4 \pm 2.2 ) \times 10^{-4}
\Gamma_{55}
                                                                                                                                                                                                                                                                                                                                                                   (1.6 \pm 1.1)\%
                                                                                                                                                                                                                                                                                                                                                                                                                                         S=2.7
Γ<sub>56</sub>
                                                                                                                                                                                                                                         \Gamma_{116}^{116} \pi^{+}\pi^{+}\pi^{-}\pi^{-}
                                                                                                                                                                                                                                                                                                                                                                   (7.4 \pm 0.6) \times 10^{-3}
 \Gamma_{57}
                                                                                                                                                                                                                                         \Gamma_{117}^{117} \pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0}
                                                                                                                                                                                                                                                                                                                                                                   (1.9 \pm 0.4)\%
 Γ<sub>58</sub>
                                                                                                                                                                                                                                         \Gamma_{118} \pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{-}\pi^{-}
                                                                                                                                                                                                                                                                                                                                                                   (4.0 \pm 3.0) \times 10^{-4}

\frac{\widetilde{K}^*(892)^0 \eta}{\times B(\overline{K}^{*0} \to K^- \pi^+)}

\Gamma_{59}
                                                                                                                                                                                                                                                                                                     Hadronic modes with a K\overline{K} pair
                                                                                                                                                                                                                                         \Gamma_{119} K^+K^-
                                                                                                                                                                                                                                                                                                                                                                 (4.33\pm0.27)\times10^{-3}
                                    \times B(\eta \rightarrow \pi^{+}\pi^{-}\pi^{0})'
                                                                                                                                                                                                                                         \Gamma_{120} K^0\overline{K}^0
                                                                                                                                                                                                                                                                                                                                                                   ( 1.3 \pm 0.4 ) \times 10^{-3}
                        K^-\pi^+\omega \times B(\omega \to \pi^+\pi^-\pi^0)
                                                                                                                                                                                                                                         Γ<sub>60</sub>
                                                                                                                          (2.7 \pm 0.5)\%
                                                                                                                                                                                                                                                                                                                                                                 ( 6.4 \pm 1.0 ) \times 10^{-3}
                                                                                                                                                                                                                                                                                                                                                                                                                                         S=1.1

\overline{K}^*(892)^0 \omega \times B(\overline{K}^{*0} \to K^- \pi^+)

                                                                                                                          (7 \pm 3) \times 10^{-3}
                                                                                                                                                                                                                                                              \overline{K}^*(892)^0 K^0
 \Gamma_{61}
                                                                                                                                                                                                                                                                                                                                                                < 1.1 × 10<sup>-3</sup>
                                                                                                                                                                                                                                         \Gamma_{122}
                                                                                                                                                                                                                                                                                                                                                                                                                                   CL=90%
                                                                                                                                                                                                                                                                \times B(\overline{K}^{*0} \to K^{-}\pi^{+})

\times B(\overline{K}^{*0} \to K^{-}\pi^{+})

\times (892)^{+}K^{-}

\times B(K^{*+} \to K^{0}\pi^{+})
                                    \times B(\omega \rightarrow \pi^{+}\pi^{-}\pi^{0})
                                                                                                                                                                                                                                                                                                                                                                 (2.3 \pm 0.5) \times 10^{-3}
                                                                                                                                                                                                                                         Γ<sub>123</sub>
\Gamma_{62}
                 \overline{K}^{0}\pi^{+}\pi^{+}\pi^{-}\pi^{-}
                                                                                                                           (5.8 \pm 1.6) \times 10^{-3}
                 \overline{K}{}^0\pi^+\pi^-\pi^0\pi^0(\pi^0)
                                                                                                                           (10.6 \ ^{+7.3}_{-3.0}) \%
\Gamma_{63}
                                                                                                                                                                                                                                                                 K^0K^-\pi^+ nonresonant
                                                                                                                                                                                                                                         \Gamma_{124}
                                                                                                                                                                                                                                                                                                                                                                 (2.3 \pm 2.3) \times 10^{-3}
                                                                                                                                                                                                                                         \Gamma_{125}^{127} \ \overline{K}^0 K^+ \pi^-
                                                                                                                                                                                                                                                                                                                                                                 ( 4.9 \pm 1.0 ) \times 10^{-3}
\Gamma_{64}
                 \overline{K}{}^0 K^+ K^-
                                                                                                                            (9.3 \pm 1.0) \times 10^{-3}
                                                                                                                                                                                                                                                              K^*(892)^0 \overline{K}{}^0
              In the fit as \frac{1}{2}\Gamma_{76} + \Gamma_{66}, where \frac{1}{2}\Gamma_{76} = \Gamma_{65}.

\overline{K}^0 \phi \times B(\phi \to K^+K^-) (4.2 ±0.5 )×10<sup>-3</sup>
                                                                                                                                                                                                                                                                                                                                                                                                                                   CL=90%
                                                                                                                                                                                                                                                                                                                                                                                                  \times 10^{-4}
                                                                                                                                                                                                                                                                                                                                                               < 5
                                                                                                                                                                                                                                         Γ<sub>126</sub>
                                                                                                                                                                                                                                                                      \times B(K^{*0} \rightarrow K^{+}\pi^{-})
                                                                                                                                                                                                                                                                K^*(892)^-K^+ \times B(K^{*-} \to \overline{K}^0\pi^-)
                                                                                                                                                                                                                                                                                                                                                                  ( 1.2 \pm 0.7 ) \times 10^{-3}
                                                                                                                                                                                                                                         \Gamma_{127}
                        \overline{K}^0K^+K^- non-\phi
                                                                                                                           (5.0 \pm 0.8) \times 10^{-3}
 Γ<sub>66</sub>
               K_{S}^{0}K_{S}^{0}K_{S}^{0}
                                                                                                                          ( 9.7 \pm 2.3 ) \times 10^{-4}
 \Gamma_{67}
                 K^{+}K^{-}K^{-}\pi^{+}
                                                                                                                          ( 2.1 \pm 0.5 ) \times 10^{-4}
                                                                                                                                                                                                                                                              \overline{K}^0 K^+ \pi^- nonresonant
                                                                                                                                                                                                                                                                                                                                                                 (3.8 \begin{array}{c} +2.3 \\ -1.9 \end{array}) \times 10^{-3}
                                                                                                                                                                                                                                         \Gamma_{128}
 Γ<sub>68</sub>
                K^+K^-\overline{K}{}^0\pi^0
                                                                                                                                                                                                                                         \Gamma_{129} K^+ K^- \pi^+ \pi^-
                                                                                                                                                                                                                                                                                                                                                       [f] (2.58\pm0.28)\times10^{-3}
                                                                                                                          (7.2 \ ^{+4.8}_{-3.5}) \times 10^{-3}
 Γ<sub>69</sub>
                                                                                                                                                                                                                                                              \phi \pi^{+} \pi^{-} \times \mathsf{B}(\phi \to K^{+} K^{-})\phi \rho^{0} \times \mathsf{B}(\phi \to K^{+} K^{-})
                                                                                                                                                                                                                                                                                                                                                                 ( 5.3 \pm 1.4 ) \times 10^{-4}
                                                                                                                                                                                                                                         Γ<sub>130</sub>
                                                                                                                                                                                                                                                                                                                                                                   ( 5.3 \pm 1.4 ) \times 10^{-4}
                                                                                                                                                                                                                                          Γ<sub>131</sub>
                      Fractions of many of the following modes with resonances have already
                                                                                                                                                                                                                                                                 K^+K^-\rho^0 3-body
                                                                                                                                                                                                                                                                                                                                                                   ( 9.0 \pm 2.3 ) \times 10^{-4}
                                                                                                                                                                                                                                          \Gamma_{132}
                      appeared above as submodes of particular charged-particle modes. (Modes
                                                                                                                                                                                                                                                                K^*(892)^0 K^- \pi^+ \times B(K^{*0} \to K^+ \pi^-)
                                                                                                                                                                                                                                                                                                                                                                   (2.1 \pm 0.9) \times 10^{-3}
                                                                                                                                                                                                                                          \Gamma_{133}
                      for which there are only upper limits and \overline{K}^*(892) 
ho submodes only appear
                      below.)
                                                                                                                                                                                                                                                                \overline{K}^*(892)^0 K^+ \pi^- \times B(\overline{K}^{*0} \to K^- \pi^+)
               \frac{\overline{K}^{0} \eta}{\overline{K}^{0} \rho^{0}}
\frac{K^{-} \rho^{+}}{\overline{K}^{0} \omega}
                                                                                                                                                                                                                                                                                                                                                                  (1.1 \pm 0.8) \times 10^{-3}
                                                                                                                          (7.0 \pm 1.0) \times 10^{-3}
 Γ70
                                                                                                                           (1.20 \pm 0.17)\%
 Γ71
                                                                                                                                                                                                                                                                K^*(892)^0 \overline{K}^*(892)^0 \times B^2(K^{*0} \to K^+\pi^-)
                                                                                                                                                                                                                                                                                                                                                                  (6 \pm 2 ) \times 10<sup>-4</sup>
 Γ<sub>72</sub>
                                                                                                                                                                                                 S=1.2
                                                                                                                           (10.8 \pm 1.0)\%
                                                                                                                          ( 2.1 ±0.4 ) %
Γ<sub>73</sub>

\Gamma_{136} \xrightarrow{K^+K^-\pi^+\pi^- \text{ non-} \phi} K^+K^-\pi^+\pi^- \text{ non-resonant}

\Gamma_{138} \xrightarrow{K^0\overline{K}^0\pi^+\pi^-} K^0\overline{K}^0\pi^+\pi^-

                 \overline{K}^0 \eta'(958)
                                                                                                                                                                                                                                                                                                                                                                  ( 1.7 \pm 0.5 ) \times\,10^{-3}
                                                                                                                          ( 1.70±0.26) %
 \Gamma_{74}
                                                                                                                                                                                                                                                                                                                                                                                                  × 10<sup>-4</sup>
                 \overline{K}^{0} f_{0}(980)
                                                                                                                                                                                                                                                                                                                                                                 < 8
                                                                                                                                                                                                                                                                                                                                                                                                                                   CL=90%
\Gamma_{75}
                                                                                                                         (5.7 \pm 1.6) \times 10^{-3}
                                                                                                                                                                                                                                                                                                                                                                 ( 6.8 \pm 2.7 ) \times 10 ^{-3}
                \overline{K}^0 \phi
                                                                                                                         ( 8.5 \pm 1.0 ) \times 10^{-3}
 Γ<sub>76</sub>
                                                                                                                                                                                                                                          \Gamma_{139} K^+ K^- \pi^+ \pi^- \pi^0
                \frac{K^-a_1(1260)^+}{K^0a_1(1260)^0}
                                                                                                                                                                                                                                                                                                                                                                   (3.1 \pm 2.0) \times 10^{-3}
                                                                                                                         (7.3 \pm 1.1)\%
Γ<sub>77</sub>
                                                                                                                                                                                          CL=90%
                                                                                                                      < 1.9 %
 Γ<sub>78</sub>
                 \overline{K}^0 f_2(1270)
                                                                                                                      ( 4.1 \pm 1.5 ) \times 10<sup>-3</sup>
                                                                                                                                                                                                                                                              Fractions of most of the following modes with resonances have already
                                                                                                                         (6.9 \pm 2.1) \times 10^{-3}
                                                                                                                                                                                                                                                              appeared above as submodes of particular charged-particle modes.
                 \overline{K}^0 f_0(1370)
 Γ<sub>80</sub>
                                                                                                                                                                                                                                          \Gamma_{140} \ \overline{K}^*(892)^0 K^0
                                                                                                                        < 2 × 10<sup>-3</sup>
                                                                                                                                                                                                                                                                                                                                                             < 1.6 \times 10^{-3}
                 K = a_2(1320)^+
                                                                                                                                                                                           CL=90%
                                                                                                                                                                                                                                                                                                                                                                                                                                   CL=90%
 Γ<sub>81</sub>
                                                                                                                                                                                                                                          Γ<sub>141</sub> K*(892)+K-
                                                                                                                                                                                                                                                                                                                                                               ( 3.5 \pm 0.8 ) \times\,10^{-3}
                 \frac{K^*(892)^-\pi^+}{K^*(892)^0\pi^0}
\Gamma_{82}
                                                                                                                         (5.0 ±0.4)%
                                                                                                                                                                                                S=1.2
                                                                                                                                                                                                                                          \Gamma_{142} \quad K^*(892)^0 \overline{K}^0
                                                                                                                                                                                                                                                                                                                                                               < 8 × 10<sup>-4</sup>
                                                                                                                                                                                                                                                                                                                                                                                                                                   CL=90%
                                                                                                                        (3.1 \pm 0.4)\%
 Γ<sub>83</sub>
                                                                                                                                                                                                                                          \Gamma_{143} \quad K^*(892)^- K^+ \\ \Gamma_{144} \quad \phi \pi^0
                                                                                                                                                                                                                                                                                                                                                               ( 1.8 \pm1.0 ) \times 10<sup>-3</sup>
                 \overline{K}^*(892)^0 \pi^+ \pi^- \text{total}
                                                                                                                         ( 2.3 ±0.5 ) %
                       \overline{K}^*(892)^0 \pi^+ \pi^- 3-body
                                                                                                                                                                                                                                                                                                                                                                < 1.4 \times 10^{-3}
                                                                                                                                                                                                                                                                                                                                                                                                                                   CL=90%
                                                                                                                          (1.42 \pm 0.32)\%
 Γ85
                 K^-\pi^+\rho^0 total K^-\pi^+\rho^0 3-body
                                                                                                                                                                                                                                          \Gamma_{145} \phi \eta
                                                                                                                                                                                                                                                                                                                                                              < 2.8
                                                                                                                                                                                                                                                                                                                                                                                                  \times 10^{-3}
                                                                                                                                                                                                                                                                                                                                                                                                                                   CL=90%
\Gamma_{86}
                                                                                                                          ( 6.3 \pm 0.4 ) %
                                                                                                                                                                                                                                                                                                                                                                                                \times 10<sup>-3</sup>
                                                                                                                            ( 4.7 \pm 2.1 ) \times 10^{-3}
                                                                                                                                                                                                                                                                                                                                                              < 2.1
                                                                                                                                                                                                                                                                                                                                                                                                                                   CL=90%
                                                                                                                                                                                                                                          \Gamma_{146} \phi \omega
 Γ<sub>87</sub>
                                                                                                                                                                                                                                         \Gamma_{147} \phi \pi^{+} \pi^{-}
\Gamma_{148} \phi \rho^{0}
                        \overline{K}^*(892)^0 \rho^0
                                                                                                                                                                                                                                                                                                                                                               (1.07\pm0.29)\times10^{-3}
                                                                                                                            ( 1.47±0.33) %
 \Gamma_{88}
                               \overline{K}^*(892)^0 \rho^0 transverse
                                                                                                                                                                                                                                                                                                                                                                   ( 1.07 \pm 0.29) \times 10^{-3}
                                                                                                                            ( 1.5 \pm 0.5 ) %
 Γ89
                              K^*(892)^0 \rho^0 S-wave K^*(892)^0 \rho^0 S-wave long. K^*(892)^0 \rho^0 P-wave
                                                                                                                                                                                                                                                                 \phi \pi^+ \pi^- 3-body
                                                                                                                                                                                                                                                                                                                                                                                                                                   CL=90%
 \Gamma_{90}
                                                                                                                          (2.8 \pm 0.6)\%
                                                                                                                                                                                                                                          \Gamma_{149}
                                                                                                                                                                                                                                                                                                                                                                < 5
                                                                                                                                                                                                                                           \Gamma_{150} K^*(892)^0 K^- \pi^+ + \text{c.c.}
                                                                                                                       < 3 × 10<sup>-3</sup> < 3 × 10<sup>-3</sup>
 \Gamma_{91}
                                                                                                                                                                                           CL=90%
                                                                                                                                                                                                                                                             K^*(892)^0 K^- \pi^+

K^*(892)^0 K^+ \pi^-
                                                                                                                                                                                                                                                                                                                                                                 (3.2 \pm 1.3) \times 10^{-3}
                                                                                                                                                                                           CL=90%
                                                                                                                                                                                                                                          \Gamma_{151}
 \Gamma_{92}
                                                                                                                                                                                                                                                                                                                                                                  ( 1.7 \pm 1.2 ) \times 10^{-3}
                               \overline{K}^*(892)^0 \rho^0 D-wave
                                                                                                                                                                                                                                          \Gamma_{152}
 \Gamma_{93}
                                                                                                                          ( 1.9 \pm 0.6 ) %
                                                                                                                                                                                                                                                             K^*(892)^0 \overline{K}^*(892)^0
                                                                                                                                                                                                                                                                                                                                                                  ( 1.4 \pm 0.5 ) \times 10<sup>-3</sup>
                K*(892) - ρ+
                                                                                                                          (6.0 ±2.4)%
 \Gamma_{94}
                     K^*(892)^- \rho^+ longitudinal K^*(892)^- \rho^+ transverse K^*(892)^- \rho^+ P-wave
                                                                                                                         ( 2.9 ±1.2 ) %
                                                                                                                         (3.2 \pm 1.8)\%
                                                                                                                        < 1.5
                                                                                                                       CL=90%
             K^{-}\pi^{+}f_{0}(980)
                                                                                                                                                                                           CL=90%
                                                                                                                      < 1.1
 \Gamma_{98}
                       \overline{K}^*(892)^0 f_0(980)
                                                                                                                                                                                           CL=90%
 \Gamma_{100} K_1(1270)^- \pi^+
                                                                                                                [e] ( 1.06±0.29) %
 \Gamma_{101} \quad K_1(1400) = \pi^+
                                                                                                                        < 1.2
                                                                                                                                                                                           CL=90%
```

Doubly Cabibbo suppressed (DC) modes, $\Delta C=2$ forbidden via mixing (C2M) modes, $\Delta C=1$ weak neutral current (C1) modes, or Lepton Family number (LF) violating modes

Γ_{154}	$K^+\pi^-$	DC	(2.9 ±1.4	$) \times 10^{-4}$	
Γ_{155}	$K^+\pi^-$ (via $\overline{D}{}^0$)	C2M		1.9	$\times 10^{-4}$	CL=90%
Γ ₁₅₆		DC	<	1.4	$\times 10^{-3}$	CL=90%
	$K^+\pi^-\pi^+\pi^-$ (via \overline{D}^0)	C2M	<	4	× 10 ⁻⁴	CL=90%
Γ ₁₅₈	μ^- anything (via \overline{D}^0)	C2M	<	4	$\times 10^{-4}$	CL=90%
Γ ₁₅₉	e+ e-	CI	<	1.3	$\times 10^{-5}$	CL=90%
Γ ₁₆₀	$\mu^+\mu^-$	C1	<	7.6	$\times 10^{-6}$	CL=90%
Γ ₁₆₁	$\pi^0 e^+ e^-$	C1	<	4.5	\times 10 ⁻⁵	CL=90%
Γ ₁₆₂	$\pi^0\mu^+\mu^-$	C1	<	1.8	× 10 ⁻⁴	CL=90%
Γ_{163}	$\eta e^+ e^-$	C1	<	1.1	× 10 ⁻⁴	CL=90%
Γ ₁₆₄	$\eta \mu^+ \mu^-$	C1	<	5.3	× 10 ⁻⁴	CL=90%
Γ165	$\rho^0 e^+ e^-$	C1	<	1.0	$\times 10^{-4}$	CL=90%
Γ_{166}	$\rho^0 \mu^+ \mu^-$	C1	<	2.3	\times 10 ⁻⁴	CL=90%
Γ ₁₆₇		C1	<	1.8	× 10 ⁻⁴	CL=90%
Γ ₁₆₈	$\omega \mu^+ \mu^-$	C1	<	8.3	× 10 ⁻⁴	CL=90%
Γ_{169}	$\phi e^+ e^-$	C1	<	5.2	$\times 10^{-5}$	CL=90%
Γ_{170}	$\phi \mu^+ \mu^-$	C1	<	4.1	× 10 ⁻⁴	CL=90%
Γ_{171}	$\overline{K}{}^0e^+e^-$		[g] <	1.1	$\times 10^{-4}$	CL=90%
Γ_{172}	$\overline{\mathcal{K}}^0 \mu^+ \mu^-$		[g] <	2.6	\times 10 ⁻⁴	CL=90%
Γ173	$\overline{K}^*(892)^0 e^+ e^-$		[g] <	1.4	$\times 10^{-4}$	CL=90%
Γ ₁₇₄	$\overline{K}^*(892)^0 \mu^+ \mu^-$		[g] <		$\times 10^{-3}$	CL=90%
Γ_{175}	$\pi^{+}\pi^{-}\pi^{0}\mu^{+}\mu^{-}$	C1	<	8.1	$\times 10^{-4}$	CL=90%
Γ_{176}	$\mu^{\pm} e^{\mp}$	LF	[h] <	1.9	\times 10 ⁻⁵	CL=90%
Γ ₁₇₇	$\pi^0 e^{\pm} \mu^{\mp}$	LF	[h] <	8.6	$\times 10^{-5}$	CL=90%
Γ_{178}	$\eta e^{\pm} \mu^{\mp}$	LF	[h] <	1.0	\times 10 ⁻⁴	CL=90%
Γ ₁₇₉	$\rho^0 e^{\pm} \mu^{\mp}$	LF	[h] <	4.9	$\times 10^{-5}$	CL=90%
Γ_{180}	$\omega e^{\pm} \mu^{\mp}$	LF	[h] <	1.2	\times 10 ⁻⁴	CL=90%
Γ ₁₈₁	$\phi e^{\pm} \mu^{\mp}$	LF	[h] <	3.4	$\times 10^{-5}$	CL=90%
Γ_{182}	$\overline{K}{}^0 e^{\pm} \mu^{\mp}$	LF	[h] <	1.0	× 10 ⁻⁴	CL=90%
Γ_{183}	$\overline{K}^*(892)^0 e^{\pm} \mu^{\mp}$	LF	[h] <	1.0	$\times 10^{-4}$	CL=90%

 $\Gamma_{184}~$ A dummy mode used by the fit.

S=

[a] This value is calculated from the ratio $\Gamma(K^-\,\mu^+\,\nu_\mu)/\Gamma(\mu^+\,{\rm anything})$ in these Particle Listings.

 $(23.8 \pm 3.5)\%$

- [b] This is a weighted average of D^\pm (44%) and D^0 (56%) branching fractions. See " D^+ and $D^0 \to (\eta \, \text{anything}) / (\text{total } D^+ \, \text{and } D^0)$ " under " D^+ Branching Ratios" in these Particle Listings.
- [c] This value averages the e^+ and μ^+ branching fractions, after making a small phase-space adjustment to the μ^+ fraction to be able to use it as an e^+ fraction; hence our ℓ^+ is really an e^+ .
- [d] The branching fractions for this mode may differ from the sum of the submodes that contribute to it, due to interference effects. See the relevant papers.
- $[\emph{e}]$ The two experiments determining this ratio are in serious disagreement. See the Particle Listings.
- [f] The experiments on the division of this charge mode amongst its submodes disagree, and the submode branching fractions here add up to considerably more than the charged-mode fraction.
- [g] This mode is not a useful test for a $\Delta C=1$ weak neutral current because both quarks must change flavor in this decay.
- [h] The value is for the sum of the charge states of particle/antiparticle states indicated.

CONSTRAINED FIT INFORMATION

An overall fit to 49 branching ratios uses 114 measurements and one constraint to determine 27 parameters. The overall fit has a $\chi^2=60.3$ for 88 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\left\langle \delta x_i \delta x_j \right\rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv \Gamma_i / \Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to

<i>X</i> 9	33									
<i>x</i> ₁₉	10	3								
x ₂₀	10	5	1							
<i>x</i> ₂₁	59	56	6	9						
<i>x</i> ₂₂	8	6	1	24	11					
<i>x</i> ₂₃	10	8	1	36	14	66				
<i>x</i> ₃₁	19	17	2	8	31	18	19			
<i>x</i> 39	21	20	2	3	36	4	6	11		
x ₄₈	5	4	1	18	8	34	51	10	4	
×57	14	13	1	2	23	3	4	7	34	2
×66	5	4	0	16	7	30	46	9	3	23
×70	5	4	1	17	7	58	47	11	3	24
x ₇₃	4	3	0	13	5	24	37	7	3	43
^X 76	6	5	1	22	9	40	60	12	4	30
<i>x</i> ₈₂	9	7	1	31	13	56	84	20	5	43
<i>x</i> 83	9	8	1	7	15	25	19	44	5	10
× ₈₅	5	4	0	1	8	1	1	2	22	1
X89	3	3	0	2	5	3	5	2	12	9
x ₁₀₀	3	2	0	7	4	13	20	4	4	40
<i>x</i> ₁₀₈	5	5	1	2	9	4	5	24	3	2
×119	31	29	3	5	52	6	8	16	19	4
x ₁₂₀	3	3	0	6	5	12	17	4	2	9
x ₁₂₁	6	5	1	14	9	26	39	9	3	20
<i>X</i> 125	5	4	0	11	8	20	30	7	3	15
<i>x</i> ₁₄₁	3	2	0	11	4	20	30	6	2	15
X ₁₈₄	-29	-26	-6	-36	-40	-55	-72	-54	-31	-69
	<i>x</i> ₈	<i>X</i> 9	<i>×</i> 19	x ₂₀	<i>x</i> ₂₁	<i>x</i> ₂₂	x ₂₃	×31	<i>x</i> 39	×48
^X 66	2	20								
×70	2	22	17							
X73	1	17	17	22						
×76	2	7 39	28 40	22 31						
x ₈₂	3	9	15	7	50 12	18				
x ₈₃	7	1	1	1	1	1	1			
X ₈₅	4	2	2	4	3	4	1	3		
X ₈₉	2	9	10	17	12	17	4	1	4	
× ₁₀₀ × ₁₀₈	2	2	3	2	3	5	10	1	1	1
× ₁₁₉	12	4	4	3	5	7	8	4	2	2
× ₁₂₀	1	8	8	6	10	15	4	0	1	4
× ₁₂₀	2	18	19	15	24	33	8	1	2	8
X ₁₂₅	2	14	14	11	18	25	6	1	2	6
×141	1	14	14	11	18	26	6	0	2	6
×141 ×184	-25	-34	-39	-45	-44	-66	-41	-16	-24	-35
^184	×57		× ₇₀							
	^57	×66	^/0	×73	×76	x ₈₂	×83	^X 85	×89	× ₁₀₀
×119	5									
x ₁₂₀	1	7								
x ₁₂₁	2	5	7							
× ₁₂₅	2	4	5	12						
×141	1	2	5	12	9					
x ₁₈₄	-26	-22	15	-32	-25	-24				
	× ₁₀₈	x ₁₁₉	x ₁₂₀	x ₁₂₁	x ₁₂₅	×141				

D⁰ BRANCHING RATIOS

See the "Note on D Mesons" in the D^{\pm} Listings.

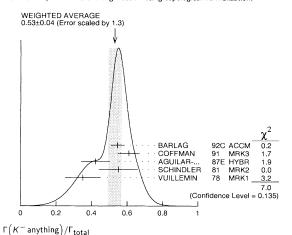
Some older now obsolete results have been omitted from these Listings.

-- Inclusive modes -

Γ(e ⁺ anything)/Γ _{total}				Γ_1/Γ
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.077±0.012 OUR AVERAGE	E Error in	cludes scale factor of	of 1.1.	
0.15 ±0.05				πp, pp 360, 400 GeV
$0.075 \pm 0.011 \pm 0.004$	137	BALTRUSAIT	85B MRK3	e ⁺ e ⁻ 3.77 GeV
0.055 ± 0.037	12	SCHINDLER	81 MRK2	e ⁺ e ⁻ 3.771 GeV

$\Gamma(K^- \text{ anything})/\Gamma$	total			Γ 3/Γ
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.53 ±0.04 OUR A	VERAGE	Error includes scale	factor of 1.3	. See the ideogram below.
$0.546^{+0.039}_{-0.038}$		¹² BARLAG	92c ACCM	π^- Cu 230 GeV
$0.609 \pm 0.032 \pm 0.052$		COFFMAN	91 MRK3	e ⁺ e ⁻ 3.77 GeV
0.42 ± 0.08		AGUILAR	87E HYBR	πp, pp 360, 400 GeV
0.55 ± 0.11	121	SCHINDLER	81 MRK2	e ⁺ e ⁻ 3.771 GeV
0.35 ±0.10	19	VUILLEMIN	78 MRK1	e ⁺ e ⁻ 3.772 GeV

 $^{^{\}rm 12}\,{\rm BARLAG}$ 92c computes the branching fraction using topological normalization.



$\left[\Gamma(\overline{K}^0 \text{ anything}) + \Gamma(K^0 \text{ anything})\right]/\Gamma_{\text{total}}$							
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT		
0.42 ±0.05 OUR AV	/ERAGE						
$0.455 \pm 0.050 \pm 0.032$		COFFMAN	91	MRK3	$e^{+}e^{-}$ 3.77 GeV		
0.29 ± 0.11	13	SCHINDLER	81	MRK2	e ⁺ e ⁻ 3.771 GeV		
0.57 ±0.26	6	VUILLEMIN	78	MRK1	$e^{+}e^{-}$ 3.772 GeV		
$\Gamma(K^+ \text{ anything})/\Gamma_0$	total					Γ ₅ /Γ	
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT		
0.034+0.006 OUR AV	/ERAGE						
$0.034 ^{+ 0.007}_{- 0.005}$		¹³ BARLAG	920	ACCM	π^- Cu 230 GeV		
$0.028 \pm 0.009 \pm 0.004$		COFFMAN	91	MRK3	$e^{+}e^{-}$ 3.77 GeV		
$0.03 \begin{array}{c} +0.05 \\ -0.02 \end{array}$		AGUILAR	87E	HYBR	πρ, ρρ 360, 400 C	GeV	
0.08 ± 0.03	25	SCHINDLER	81	MRK2	$e^{+}e^{-}$ 3.771 GeV		
13 BARLAG 92c com	putes the b	oranching fraction u	sing	topologi	cal normalization.		

Semileptonic modes

1 (N	ℓ ' ν_ℓ)/ total	17/1
	We average our ${\it K}^- e^+ \nu_e$ and ${\it K}^- \mu^+ \nu_\mu$ branching fractions, after	multiplying the
	latter by a phase-space factor of 1.03 to be able to use it with the ${\cal K}^-$	$e^+ \nu_e$ fraction.

Hence our ℓ^+ here is really an e^+ DOCUMENT ID COMMENT

0.0349±0.0016 OUR AVERAGE						
0.0364 ± 0.0020	PDG	96	Our F	$(K^- e^+ \nu_e)/\Gamma_{\text{total}}$		
0.0333 ± 0.0020	PDG	96	1.03 ×	$(K^-e^+ u_e)/\Gamma_{ m total}$ our $\Gamma(K^-\mu^+ u_\mu)/\Gamma_{ m total}$	_{Ttotal}	
$\Gamma(K^-e^+ u_e)/\Gamma_{ m total}$					Γ_8/Γ	
VALUE EVTS	DOCUMENT ID		TECN	COMMENT		
0.0364 ± 0.0020 OUR FIT Error	includes scale fac-	tor of	1.1.			
0.034 ±0.005 ±0.004 55	ADLER	89	MRK3	$e^{+}e^{-}$ 3.77 GeV		

K ⁻ e ⁺ ν _e)/Γ(K ⁻	EVTS	DOCUMENT ID	TECN	COMMENT	Γ ₈ /Γ ₂₁
5 ±0.04 OUR FIT	-				
5 ±0.04 OUR AV	ERAGE				
$78 \pm 0.027 \pm 0.044$	2510	¹⁴ BEAN	93C CLEO	$e^+e^- \approx$	$\Upsilon(45)$
0 ±0.06 ±0.06	584	¹⁵ CRAWFORD	91B CLEO	$e^+e^-\approx$	10.5 GeV
$1 \pm 0.07 \pm 0.11$	250	¹⁶ ANJOS	89F E691	Photoproc	luction
4 BEAN 93C uses K°	$-\mu^+\nu_{\mu}$:	as well as $\mathit{K}^-\mathit{e}^+\mathit{v}_e$	events and	makes a sm	all phase-space
adjustment to the	number o	f the μ^+ events to	use them as	e ⁺ events.	A pole mass of
$2.00\pm0.12\pm0.18$	GeV/c^2	is obtained from th	e a^2 depende	ence of the	decav rate.
CRAWFORD 91B L	ses K – e	$+\nu_{\alpha}$ and $K^{-}\mu^{+}\nu$	candidates	to measure	a pole mass of
CRAWFORD 91B L	ses K ⁻ e	$^+ u_e$ and $\kappa^-\mu^+ u_e$	$_{\mu}$ candidates	to measure	a

-0.2 -0.2	
¹⁶ ANJOS 89F measures a pole mass of $2.1^{+0.4}_{-0.2} \pm 0.2$ GeV/ c^2 from the q^2 dependence	
of the decay rate.	

$\Gamma(K^-\mu^+\nu_\mu)/\Gamma(K^-$	$^{-}\pi^{+})$			Γ_9/Γ_{21}
VALUE		DOCUMENT ID	TECN	COMMENT
0.84 ±0.04 OUR FIT	-			
0.84 ±0.04 OUR AV	ERAGE			
$0.852 \pm 0.034 \pm 0.028$	1897	¹⁷ FRABETTI	95G E687	γ Be \overline{E}_{γ} $=$ 220 GeV
$0.82\ \pm0.13\ \pm0.13$	338	¹⁸ FRABETTI	931 E687	$\gamma \operatorname{Be} \overline{E}_{\gamma}' = 221 \operatorname{GeV}$
$0.79\ \pm0.08\ \pm0.09$	231	¹⁹ CRAWFORD	91B CLEO	$e^+e^-pprox 10.5$ GeV
				$0) = -1.3^{+3.6}_{-3.4} \pm 0.6$, and
	4	. + 0 11 + 0 07	· .	2

measures a pole mass of $1.87^{+0.11}_{-0.08}^{+0.11}_{-0.06}^{+0.07}$ GeV/ c^2 from the q^2 dependence of the decay 18 FRABETTI 931 measures a pole mass of $2.1^{+0.7}_{-0.3}^{+0.7}$ GeV/c² from the $\it q^2$ dependence of the decay rate.

 $^{19} \, {\sf CRAWFORD}$ 91B measures a pole mass of 2.00 \pm 0.12 \pm 0.18 ${\sf GeV}/c^2$ from the $\it q^2$ dependence of the decay rate.

$\Gamma(K^-\mu^+\nu_\mu)/\Gamma(\mu^+$	anythin	g)				Γ_9/Γ_2
VALUE	EVTS	DOCUMENT	ID	TECN	COMMENT	
$0.472 \pm 0.051 \pm 0.040$	232	KODAMA	94	E653	π^- emulsion	600 GeV
• • • We do not use the	ne followi	ng data for aver	ages, fits	s, limits,	etc. • • •	
$0.32\ \pm0.05\ \pm0.05$	124	KODAMA	91	EMUL	<i>p</i> A 800 GeV	
$\Gamma(K^-\pi^0e^+ u_e)/\Gamma_{ m tot}$	tal					Γ ₁₀ /Γ
VALUE	EVTS	DOCUMENT	ID	TECN	COMMENT	
$0.016^{+0.013}_{-0.005}\pm0.002$	4	²⁰ BAI	91	MRK3	$e^+e^-\approx 3.5$	77 GeV

 $^{20}\,\mathrm{BAI}$ 91 finds that a fraction $0.79^{+0.15}_{-0.17}^{+0.09}_{-0.03}$ of combined D^{+} and D^{0} decays to $\overline{K}\pi\,e^+\,\nu_e$ (24 events) are $\overline{K}^*(892)e^+\,\nu_e$. BAI 91 uses 56 $K^-\,e^+\,\nu_e$ events to measure a pole mass of 1.8 \pm 0.3 \pm 0.2 GeV/ c^2 from the q^2 dependence of the decay rate.

$\Gamma(\overline{K}^0\pi^-e^+\nu_e)/\Gamma_{to}$	tal					Γ ₁₁ /Γ
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT	
$0.028^{+0.017}_{-0.008} \pm 0.003$	6	²¹ BAI	91	MRK3	e^+e^-pprox 3.77 Ge	eV

 $^{21}\,\mathrm{BAI}$ 91 finds that a fraction $0.79^{+0.15}_{-0.17}^{+0.09}_{-0.03}$ of combined D^{+} and D^{0} decays to $\overline{K}\pi e^+\nu_e$ (24 events) are $\overline{K}^*(892)e^+\nu_e$.

$\Gamma(K^*(892)^-e^+\nu_e)/\Gamma(K^-e^+)$ Unseen decay modes of the	-,	-144		Γ ₂₀ /Γ ₈
VALUE 0.55±0.09 OUR FIT	DOCUMENT ID		COMMENT	
0.51±0.18±0.06	CRAWFORD	91B CLEO	$e^+e^-\approx$	10.5 GeV
$\Gamma(K^*(892)^-e^+\nu_e)/\Gamma(\overline{K}^0\pi^+$	π^{-}			Γ_{20}/Γ_{23}
Unseen decay modes of the	$\overline{K}^*(892)^-$ are inc	cluded.		
VALUE EVTS	DOCUMENT ID	TECN	COMMENT	
0.37±0.06 OUR FIT				

152 ²² BEAN $0.38 \pm 0.06 \pm 0.03$ 93C CLEO $e^+e^-pprox \Upsilon(4S)$ ²² BEAN 93C uses $K^{*-}\mu^+\nu_\mu$ as well as $K^{*-}e^+\nu_e$ events and makes a small phase-space adjustment to the number of the μ^+ events to use them as e^+ events.

 $\Gamma\big(K^*(892)^-\,\ell^+\,\nu_\ell\big)/\Gamma\big(\overline{K}{}^0\,\pi^+\,\pi^-\big)$ This an average of the $K^*(892)^-\,{
m e}^+\,{
u_{
m e}}$ and $K^*(892)^-\,{\mu}^+\,{
u_{\mu}}$ ratios. Unseen decay modes of the $K^*(892)^-$ are included.

<u>EVTS</u> DOCUMENT ID TECN COMMENT \bullet $\,\bullet\,$ We do not use the following data for averages, fits, limits, etc. $\,\bullet\,$ $\,\bullet\,$

137 23 ALEXANDER 908 CLEO e^+e^- 10.5–11 GeV $0.24 \pm 0.07 \pm 0.06$ 23 ALEXANDER 90B cannot exclude extra π^0 's in the final state. See nearby data blocks for more detailed results.

 $\Gamma \big(\textit{K}^- \pi^0 (\pi^0) \, \mathrm{e}^+ \nu_e \big) / \Gamma_{\mathsf{total}}$ Γ_{14}/Γ DOCUMENT ID TECN COMMENT VALUE EVTS • • • We do not use the following data for averages, fits, limits, etc. • • $0.023^{\,+\,0.050}_{\,-\,0.006}\,\pm\,0.001$ 1 ²⁴ AGUILAR-... 87F HYBR πρ, ρρ 360, 400 GeV

 $^{^{24}}$ AGUILAR-BENITEZ 87F computes the branching fraction using topological normalization. Does not distinguish presence of a second π^0 .

ı

$\Gamma(\overline{K^0}\pi^-(\pi^0)e^+ u_e)/\Gamma_{ ext{total}}$ VALUEEVTS DOCUMENT IDTECNCOMMENT	$\Gamma(\overline{K}^0\pi^+\pi^-)/\Gamma_{\text{total}}$	EVTS DOCUMENT ID	Γ ₂₃ /Γ
• • • We do not use the following data for averages, fits, limits, etc. • •		r includes scale factor of 1.2.	TECN COMMENT
$0.079^{+0.069}_{-0.023}\pm0.005$ 3 ²⁵ AGUILAR 87F HYBR πp , pp 360, 400 GeV	0.055 ±0.005 OUR AVERAGE		
	$0.0503 \pm 0.0039 \pm 0.0049$ $0.064 \pm 0.005 \pm 0.010$		ARG $e^+e^- \approx \Upsilon(4S)$ MRK3 e^+e^- 3.77 GeV
25 AGUILAR-BENITEZ 87F computes the branching fraction using topological normalization. Does not distinguish presence of a second $\pi^0.$	0.052 ± 0.016 0.079 ± 0.023	32 37 SCHINDLER 81	MRK2 e^+e^- 3.771 GeV MRK1 e^+e^- 3.77 GeV
$\Gamma(\overline{K}^*(892)^0\pi^-e^+\nu_e)/\Gamma(K^*(892)^-e^+\nu_e)$ Γ_{16}/Γ_{20}	36 See the footnote on the Al		
Unseen decay modes of the $\overline{K}^*(892)^0$ are included.	method used.		
ALUE CL% DOCUMENT ID TECN COMMENT	37 SCHINDLER 81 (MARK-2) he 0.30 ± 0.08 nb. We use the	measures $\sigma(e^+e^- \rightarrow \psi(377)$ ne MARK-3 (ADLER 88C) valu	0)) \times branching fraction to
• • We do not use the following data for averages, fits, limits, etc. • •	³⁸ PERUZZI 77 (MARK-1) me	asures $\sigma(e^+e^- \rightarrow \psi(3770))$	× branching fraction to be
<0.64 90 26 CRAWFORD 91B CLEO $e^+e^- \approx 10.5$ GeV	0.46 \pm 0.12 nb. We use the	MARK-3 (ADLER 88c) value o	of $\sigma=$ 5.8 \pm 0.5 \pm 0.6 nb.
²⁶ The limit on $(\overline{K}^*(892)\pi)^- \ \mu^+ u_\mu$ below is much stronger.	$\Gamma(\overline{K}{}^0\pi^+\pi^-)/\Gamma(K^-\pi^+)$		Γ_{23}/Γ_{21}
$(K^-\pi^+\pi^-\mu^+\nu_\mu)/\Gamma(K^-\mu^+\nu_\mu)$	VALUE EVTS	DOCUMENT ID TECN	COMMENT
ALUE CL% DOCUMENT ID TECN COMMENT	1.41±0.11 OUR FIT Error incl 1.65±0.17 OUR AVERAGE	udes scale factor of 1.2.	
<0.037 90 ΚΟDAMA 938 Ε653 π emulsion 600 GeV	1.61±0.10±0.15 856	FRABETTI 94J E687	γ Be \overline{E}_{γ} =220 GeV
	1.7 ±0.8 35		$\gamma N \to D^{*+}$
$((\overline{K}^*(892)\pi)^-\mu^+\nu_\mu)/\Gamma(K^-\mu^+\nu_\mu)$ Γ_{18}/Γ_9 ALUE CL% DOCUMENT ID TECN COMMENT	2.8 ±1.0 116	PICCOLO 77 MRK	1 e ⁺ e ⁻ 4.03, 4.41 GeV
ALUE CL% DOCUMENT ID TECN COMMENT <0.043	$\Gamma(\overline{K}^0 \rho^0) / \Gamma(\overline{K}^0 \pi^+ \pi^-)$		Γ., /Γ.,
²⁷ KODAMA 93B searched in $K^-\pi^+\pi^-\mu^+\nu_{\mu^+}$ but the limit includes other $(\overline{K}^*(892)\pi)^-$	VALUE	DOCUMENT ID TECN	Γ ₂₄ /Γ ₂₃
charge states.	0.223±0.027 OUR AVERAGE	Error includes scale factor of 1	
(a+ \ /F	$0.350 \pm 0.028 \pm 0.067$	FRABETTI 94G E687	γ Be, $\overline{\it E}_{\gamma} pprox$ 220 GeV
$(\pi^-e^+ u_e)/\Gamma_{ ext{total}}$ $\Gamma_{ ext{19}}/\Gamma$	$0.227 \pm 0.032 \pm 0.009$ $0.215 \pm 0.051 \pm 0.037$	ALBRECHT 93D ARG	$e^{+}e^{-}\approx 10 \text{ GeV}$
	$0.215 \pm 0.051 \pm 0.037$ $0.20 \pm 0.06 \pm 0.03$	ANJOS 93 E691 FRABETTI 928 E687	γ Be 90–260 GeV γ Be $\overline{E}_{\gamma} =$ 221 GeV
0038 ^{+0.0012} _{-0.0010} OUR FIT	0.12 ±0.01 ±0.07		$e^{+}e^{-}$ 3.77 GeV
0039+0.0023 -0.0011±0.0004 7 ²⁸ ADLER 89 MRK3 e ⁺ e ⁻ 3.77 GeV			
	$\Gamma(K^0f_0(980))/\Gamma(K^0\pi^+\pi^-)$ Unseen decay modes of the		Γ ₇₅ /Γ ₂₃
This result of ADLER 89 gives $ \frac{V_{Cd}}{V_{Cs}} \cdot \frac{f_{K}^{+}(0)}{f_{K}^{+}(0)} ^2 = 0.057 + 0.038 \pm 0.005$.	VALUE	DOCUMENT ID TECN	COMMENT
1	0.105±0.029 OUR AVERAGE		
$(\pi^- e^+ \nu_e) / \Gamma(K^- e^+ \nu_e)$ Γ_{19} / Γ_8	$0.131 \pm 0.031 \pm 0.034$	FRABETTI 94G E687	γ Be, $\overline{E}_{\gamma} pprox$ 220 GeV
LUE EVTS DOCUMENT ID TECN COMMENT	$0.088 \pm 0.035 \pm 0.012$	ALBRECHT 93D ARG	e^+e^-pprox 10 GeV
105 ^{+0.033} OUR FIT	$\Gamma(\overline{K}^0 f_2(1270))/\Gamma(\overline{K}^0 \pi^+ \pi^-$	-) '	Γ_{79}/Γ_{23}
103±0.039±0.013 87 ²⁹ BUTLER 95 CLEO < 0.156 (90% CL)	Unseen decay modes of the		. 19/ . 23
45 (-)	VALUE	DOCUMENT ID TECN	COMMENT
BUTLER 95 has 87 \pm 33 $\pi^ e^+\nu_e$ events. The result gives $ rac{V_{Cd}}{V_{cs}}\cdotrac{f_+^n(0)}{f_+^K(0)} ^2=0.052\pm$	0.076±0.028 OUR AVERAGE 0.065±0.025±0.030	FRABETTI 94G E687	γ Be, $\overline{E}_{\gamma} pprox$ 220 GeV
0.020 ± 0.007 .	$0.088 \pm 0.037 \pm 0.014$	ALBRECHT 93D ARG	$e^+e^-\approx 10 \text{ GeV}$
——— Hadronic modes with a \overline{K} or $\overline{K}K\overline{K}$ ———			
$(K^-\pi^+)/\Gamma_{\text{total}}$ Γ_{21}/Γ	$\Gamma(\overline{K}^0 f_0(1370))/\Gamma(\overline{K}^0 \pi^+ \pi^-)$ Unseen decay modes of the		Γ ₈₀ /Γ ₂₃
(K ⁻ π ⁺)/I total	VALUE VALUE	DOCUMENT ID TECN	COMMENT
0383±0.0012 OUR FIT	0.13 ±0.04 OUR AVERAGE		
0386±0.0014 OUR AVERAGE	$0.123 \pm 0.035 \pm 0.049$	FRABETTI 94G E687	γ Be, $\overline{E}_{\gamma} pprox$ 220 GeV
30 ALBRECHT 94 ARG $e^+e^- \approx \gamma(45)$ 0341 $\pm 0.0012 \pm 0.0028$ 1173 31 ALBRECHT 94F ARG $e^+e^- \approx \gamma(45)$	$0.131 \pm 0.045 \pm 0.021$	ALBRECHT 93D ARG	e^+e^-pprox 10 GeV
0341 \pm 0.0012 \pm 0.0028 1173 31 ALBRECHT 94F ARG $e^+e^- \approx \Upsilon(4S)$ 0391 \pm 0.0008 \pm 0.0017 4208 31,32 AKERIB 93 CLEO $e^+e^- \approx \Upsilon(4S)$	$\Gamma(K^*(892)^-\pi^+)/\Gamma(\overline{K}^0\pi^+\pi^+)$	r ⁻)	Γ_{82}/Γ_{23}
0362±0.0034±0.0044 31 DECAMP 91J ALEP From Z decays	Unseen decay modes of the		02, 20
045 $\pm 0.008 \pm 0.005$ 56 31 ABACHI 88 HRS e^+e^- 29 GeV	VALUE EVTS		COMMENT
042 ±0.004 ±0.004 930 ADLER 88C MRK3 e ⁺ e ⁻ 3.77 GeV 041 ±0.006 263 ³³ SCHINDLER 81 MRK2 e ⁺ e ⁻ 3.771 GeV	0.93 ±0.04 OUR FIT Error in 0.96 ±0.04 OUR AVERAGE	cludes scale factor of 1.1.	
34 ±0.000 34 PERUZZI 77 MRK1 e^+e^- 3.77 GeV	$0.938 \pm 0.054 \pm 0.038$	FRABETTI 94G E687	γ Be, $\overline{E}_{\gamma} pprox$ 220 GeV
OALBRECHT 94 uses D^0 mesons from $\overline{B}{}^0 \to D^{*+} \ell^- \overline{\nu}_\ell$ decays. This is a different set	$1.08 \pm 0.063 \pm 0.045$	ALBRECHT 93D ARG	$e^+e^-\stackrel{\gamma}{pprox}$ 10 GeV
of events than used by ALBRECHT 94F.	$0.720\pm0.145\pm0.185$		γ Be 90-260 GeV
¹¹ ABACHI 88, DECAMP 91J, AKERIB 93, and ALBRECHT 94F use $D^*(2010)^+ \rightarrow 0$	0.96 ±0.12 ±0.075		γ Be $\overline{E}_{\gamma} = 221$ GeV
$D^0\pi^+$ decays. The π^+ is both slow and of low p_T with respect to the event thrust	0.84 ±0.06 ±0.08		3 e ⁺ e [−] 3.77 GeV
axis ($\approx D^{*+}$ direction). The excess number of such π^+ 's over background gives the number of $D^*(2010)^+ \to D^0 \pi^+$ events, and the fraction with $D^0 \to K^- \pi^+$ gives	$1.05 \begin{array}{c} +0.23 \\ -0.26 \end{array} \begin{array}{c} +0.07 \\ -0.09 \end{array} \hspace{1cm} 25$	SCHINDLER 81 MRK2	? e ⁺ e [−] 3.771 GeV
the $D^0 \rightarrow K^-\pi^+$ branching fraction.	$\Gamma(K_0^*(1430)^-\pi^+)/\Gamma(\overline{K}^0\pi^+$	π ⁻)	r/r.
2 Radiative corrections increase this AKERIR 93 value to 0.0395 ± 0.0008 ± 0.0017	Unseen decay modes of the	$\overline{K}^*(1430)^-$ are included	Γ_{104}/Γ_{23}
³ SCHINDLER 81 (MARK-2) measures $\sigma(e^+e^- \rightarrow \psi(3770)) \times$ branching fraction to	VALUE	DOCUMENT ID TECN	COMMENT
be 0.24 \pm 0.02 nb. We use the MARK-3 (ADLER 88c) value of $\sigma=5.8\pm0.5\pm0.6$ nb. ⁴ PERUZZI 77 (MARK-1) measures $\sigma(e^+e^-\to\psi(3770))\times$ branching fraction to be	0.19 ±0.05 OUR AVERAGE		
0.25 ± 0.05 nb. We use the MARK-3 (ADLER 88C) value of $\sigma = 5.8 \pm 0.5 \pm 0.6$ nb.	$0.176 \pm 0.044 \pm 0.047$	FRABETTI 94G E687	γ Be, $\overline{E}_{\gamma} pprox$ 220 GeV
₩ 0_0\/r(₩+\	$0.208 \pm 0.055 \pm 0.034$	ALBRECHT 93D ARG	e^+e^-pprox 10 GeV
	$\Gamma(K_2^*(1430)^-\pi^+)/\Gamma(\overline{K}{}^0\pi^+$	π^{-}	Γ_{105}/Γ_{23}
. /: \ /		•	• 105/ • 23
LUE EVTS DOCUMENT ID TECN COMMENT 15±0.06 OUR FIT Error includes scale factor of 1.1.	Unseen decay modes of the	,,	
LUE EVTS DOCUMENT ID TECN COMMENT 15±0.06 OUR FIT Error includes scale factor of 1.1.	Unseen decay modes of the	DOCUMENT ID TECN	COMMENT
LUE EVTS DOCUMENT ID TECN COMMENT 15±0.06 OUR FIT Error includes scale factor of 1.1. 1.1. 16±0.23±0.22 119 ANJOS 928 E691 γ Be 80–240 GeV		DOCUMENT ID TECN ALBRECHT 93D ARG	$e^+e^-\approx 10 \text{ GeV}$
LUE	<u>VALUE</u> <u>CL%</u> <0.15 90	ALBRECHT 93D ARG	$e^+e^ \approx$ 10 GeV
LUE	$\frac{VALUE}{< 0.15}$ 90 $\Gamma(\overline{K^0}\pi^+\pi^- \text{ nonresonant})/\Gamma$	ALBRECHT 93D ARG $(\overline{K}{}^0\pi^+\pi^-)$	$e^+e^ \approx 10$ GeV Γ_{30}/Γ_{23}
LUEEVTSDOCUMENT IDTECNCOMMENT	<u>VALUE</u> <u>CL%</u> <0.15 90	ALBRECHT 93D ARG	$e^+e^ \approx$ 10 GeV
$\frac{EVTS}{55\pm0.06 \text{ OUR FIT}} \frac{EVTS}{EVTS} \frac{DOCUMENT ID}{ANJOS} \frac{TECN}{928 \text{ E691}} \frac{COMMENT}{\gamma \text{ Be } 80-240 \text{ GeV}}$ $\frac{(K^0\pi^0)}{\Gamma(K^0\pi^+\pi^-)} \frac{\Gamma_{22}/\Gamma_{23}}{EVTS} \frac{DOCUMENT ID}{B90\pm0.031 \text{ OUR FIT}} \frac{TECN}{TECN} \frac{COMMENT}{TECN}$ 378 ± 0.033 OUR AVERAGE $\frac{EVTS}{EVTS} \frac{DOCUMENT ID}{EVTS} \frac{EVTS}{EVTS} \frac{DOCUMENT ID}{EVTS} \frac{EVTS}{EVTS} \frac{EVTS}{EV$	$\frac{CL\%}{\sqrt{0.15}}$ 90 Γ($\overline{K}^0\pi^+\pi^-$ nonresonant)/Γ $\frac{\Delta LUE}{\sqrt{0.27}}$ ±0.04 OUR AVERAGE 0.263±0.024±0.041	ALBRECHT 93D ARG $(\overline{K}{}^0\pi^+\pi^-)$	$e^+e^ \approx 10$ GeV Γ_{30}/Γ_{23}
ALUE EVTS DOCUMENT ID TECN COMMENT 55±0.06 OUR FIT Error includes scale factor of 1.1. 36±0.23±0.22 119 ANJOS 928 E691 γ Be 80–240 GeV ($\overline{K^0}\pi^0$)/ $\Gamma(\overline{K^0}\pi^+\pi^-)$ EVTS DOCUMENT ID TECN COMMENT 3790±0.031 OUR FIT 378±0.033 OUR AVERAGE	$\begin{array}{c c} \underline{VALUE} & \underline{CL\%} \\ \hline < 0.15 & 90 \\ \hline \Gamma \left(\overline{K^0} \pi^+ \pi^- \text{ nonresonant} \right) / \Gamma \\ \underline{VALUE} \\ \hline 0.27 \pm 0.04 & \text{OUR AVERAGE} \\ \end{array}$	ALBRECHT 93D ARG $(\overline{K^0}\pi^+\pi^-)$ DOCUMENT ID ANJOS 93 E691 FRABETTI 92B E687	$e^+e^-\approx 10 \text{ GeV}$ Γ_{30}/Γ_{23} COMMENT

 D^0

$\Gamma(K^-\pi^+\pi^0)/\Gamma_{\text{total}}$					Γ ₃₁ /Γ
	E <i>VTS</i> Error inclu	DOCUMENT ID des scale factor	of 1.3.	COMMENT	
0.131 ± 0.016 OUR AVER	AGE				
$0.133 \pm 0.012 \pm 0.013$ 0.117 ± 0.043	931 37 ³⁹	ADLER SCHINDLER		e ⁺ e ⁻ 3.77 Ge ⁻ e ⁺ e ⁻ 3.771 G	
³⁹ SCHINDLER 81 (MA be 0.68 ± 0.23 nb. We	RK-2) mea	sures $\sigma(e^+e^-)$	$ ightarrow \psi(3770)$ R 88C) value	of $\sigma=$ 5.8 \pm 0.5	raction to \pm 0.6 nb.
$\Gamma(K^-\pi^+\pi^0)/\Gamma(K^-\pi^0)$	·+)				Γ_{31}/Γ_{21}
3.62 ± 0.24 OUR FIT Er	<i>EVTS</i> ror include:	DOCUMENT ID s scale factor of		COMMENT	
3.47±0.30 OUR AVERAG				See the ideogram	•
$3.81 \pm 0.07 \pm 0.26$ $3.04 \pm 0.16 \pm 0.34$	10k 931 40	BARISH ALBRECHT	96 CLEO 92P ARG	$e^+e^-\approx \Upsilon(4)$ $e^+e^-\approx 10 \text{ G}$, -
$4.0 \pm 0.9 \pm 1.0$	69	ALVAREZ	91B NA14	Photoproductio	n
2.8 ±0.14±0.52 4.2 ±1.4	1050 41	KINOSHITA SUMMERS	91 CLEO 84 E691	$e^+e^- \sim 10.7$ Photoproduction	
⁴⁰ This value is calculate	d from nu		of ALBREC		
WEIGHTE 3.47±0.30					
Í	\downarrow				
	<u></u>	and s this i sarily obtai	scale factor a deogram only / the same as ined from a le	reighted average, re based upon the . They are not no our 'best' values ast-squares cons	e data in eces- trained fit
	ا ل	utilizi	ing measuren	nents of other (rel ional information.	ated)
					2
			5451611	00 0150	χ^2
	/		BARISH ALBRECH		1.3
		 	· · ALVAREZ		
	/	1	··SUMMER	IS 84 E691	<u>0.3</u> 4.9
				(Confidence Leve	
0 :	2 4	1 6	8	 10	
$\Gamma(\kappa^-\pi^+\pi^0)$	/Γ(<i>K</i> - π	+)			
$\Gamma(K^-\rho^+)/\Gamma(K^-\pi^+)$	`				Γ ₃₂ /Γ ₃₁
0.78 ±0.05 OUR AVER	EVTS	DOCUMENT ID	TECN	COMMENT	
$0.765 \pm 0.041 \pm 0.054$	AGL	FRABETTI	94G E687	γ Be, $\overline{E}_{\gamma} pprox 220$) GeV
0.647 ± 0.039 ± 0.150		ANJOS	93 E691	γ Be 90-260 G	
0.81 ±0.03 ±0.06 • • • We do not use the	following	ADLER data for average		e ⁺ e ⁻ 3.77 G∈ , etc. • • •	: v
$0.31 \begin{array}{c} +0.20 \\ -0.14 \end{array}$	13	SUMMERS	84 E691	Photoproduction	on
$0.85 \begin{array}{l} +0.11 & +0.09 \\ -0.15 & -0.10 \end{array}$	31	SCHINDLER	81 MRK2	e^+e^- 3.771 C	ieV
Γ(K*(892) ⁻ π ⁺)/Γ(I	√-π+π ⁰)			Γ ₈₂ /Γ ₃₁
Unseen decay mode		*(892) are in			
VALUE 0.362±0.035 OUR FIT	Error inclu	DOCUMENT ID Ides scale factor	of 1.3.	COMMENT	
0.28 ±0.04 OUR AVER	AGE	CDADETTI	046 5697	Po E 0/22	0.00/
$0.444 \pm 0.084 \pm 0.147$ $0.252 \pm 0.033 \pm 0.035$		FRABETTI ANJOS	946 E691	γ Be, $\overline{E}_{\gamma} \approx 22$ γ Be 90–260 G	
0.36 ±0.06 ±0.09		ADLER		e ⁺ e ⁻ 3.77 Ge	
$\Gamma(\overline{K}^*(892)^0\pi^0)/\Gamma(K$	$-\pi^{+}\pi^{0}$				Γ_{83}/Γ_{31}
Unseen decay mod	es of the $\overline{\mathcal{K}}$	892) ⁰ are inc <u>DOCUMENT ID</u>	luded.	COMMENT	
0.227±0.027 OUR FIT 0.221±0.029 OUR AVER	RAGE	DOCOMENT 1B	TECIV	COMMENT	
$0.248 \pm 0.047 \pm 0.023$		FRABETTI		γ Be, $\overline{E}_{\gamma} \approx 22$	
$\begin{array}{ccc} 0.213 \pm 0.027 \pm 0.035 \\ 0.20 \ \pm 0.03 \ \pm 0.05 \end{array}$		ANJOS ADLER	93 E691 87 MRK3	γ Be 90–260 G e^+e^- 3.77 Ge	
$\Gamma(K^-\pi^+\pi^0$ nonresor					Γ_{35}/Γ_{31}
VALUE 0.049±0.018 OUR AVER	<i>EVTS</i> R AGE Err	DOCUMENT ID or includes scale			
$0.101 \pm 0.033 \pm 0.040$		FRABETTI	94G E687	γ Be, $\overline{E}_{\gamma} pprox$ 22	
$0.036 \pm 0.004 \pm 0.018$		ANJOS ADLER	93 E691 87 MRK3	γ Be 90–260 G $e^{+}e^{-}$ 3.77 Ge	
0.09 ±0.02 ±0.04 • • • We do not use the	following				- V
$0.51\ \pm0.22$	21	SUMMERS	84 E691	Photoproducti	on

```
\Gamma(\overline{K}^*(892)^0\pi^0)/\Gamma(\overline{K}^0\pi^0)
                                                                                                                                \Gamma_{83}/\Gamma_{22}
        Unseen decay modes of the \overline{\mathcal{K}}^*(892)^0 are included.
VALUE EVTS DOCUMENT ID TECN COMMENT

1.49±0.23 OUR FIT Error includes scale factor of 1.1.
1.65^{+0.39}_{-0.31}\pm0.20
                                                          PROCARIO 938 CLEO \overline{K}^0\pi^0\pi^0 Dalitz plot
\Gamma(\overline{K}_{2}^{*}(1430)^{0}\pi^{0})/\Gamma(\overline{K}^{*}(892)^{0}\pi^{0})
                                                                                                                              \Gamma_{106}/\Gamma_{83}
         Unseen decay modes of the \overline{\mathcal{K}}_2^*(1430)^0 and \overline{\mathcal{K}}^*(892)^0 are included.
                                                           DOCUMENT ID TECN COMMENT
                                                           PROCARIO 93B CLEO \overline{K}^0 \pi^0 \pi^0 Dalitz plot
\Gamma(\overline{K}^0\pi^0\pi^0 \text{ nonresonant})/\Gamma(\overline{K}^0\pi^0)
                                                                                                                                 \Gamma_{38}/\Gamma_{22}
                                  EVTS

    DOCUMENT ID
    TECN
    COMMENT

    PROCARIO
    938 CLEO
    \overline{K}^0 \pi^0 \pi^0 Dalitz plot

VALUE
0.37±0.08±0.04
                                           76
\Gamma(K^-\pi^+\pi^+\pi^-)/\Gamma_{\rm total}
<u>VALUE</u> <u>EVTS</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u>
0.075 ± 0.004 OUR FIT Error includes scale factor of 1.1.
0.075 \pm0.006 OUR AVERAGE Error includes scale factor of 1.3. See the ideogram below. 
0.079 \pm0.015 \pm0.009 41 ALBRECHT 94 ARG e^+e^-\approx \Upsilon(45)
                                                                <sup>42</sup> ALBRECHT
                                                                                              94F ARG e^+e^- \approx \Upsilon(4S)
0.0680 \pm 0.0027 \pm 0.0057
                                                  1430
                                                                                              88C MRK3 e<sup>+</sup>e<sup>-</sup> 3.77 GeV
0.091\ \pm0.008\ \pm0.008
                                                   992
                                                                     ADLER
                                                               43 SCHINDLER 81 MRK2 e<sup>+</sup> e<sup>-</sup> 3.771 GeV
0.117 \pm 0.025
                                                               44 PERUZZI 77 MRK1 e<sup>+</sup>e<sup>-</sup> 3.77 GeV
0.062 \pm 0.019
                                                     44
  <sup>41</sup> ALBRECHT 94 uses D^0 mesons from \overline B{}^0 \to D^{*+} \ell^- \overline \nu_\ell decays. This is a different set
      of events than used by ALBRECHT 94F.
  <sup>42</sup> See the footnote on the ALBRECHT 94F measurement of \Gamma(K^-\pi^+)/\Gamma_{\text{total}} for the
 **See the footnote on the ALBRECHT 94F measurement of 1(K-\pi^+)/1_{\text{total}} for the method used. 43 SCHINDLER 81 (MARK-2) measures \sigma(e^+e^- \to \psi(3770)) \times branching fraction to be 0.68 \pm 0.11 nb. We use the MARK-3 (ADLER 88C) value of \sigma=5.8\pm0.5\pm0.6 nb. 44 PERUZZI 77 (MARK-1) measures \sigma(e^+e^- \to \psi(3770)) \times branching fraction to be 0.36 \pm 0.10 nb. We use the MARK-3 (ADLER 88C) value of \sigma=5.8\pm0.5\pm0.6 nb.
                        WEIGHTED AVERAGE
0.075±0.006 (Error scaled by 1.3)
                                                                          Values above of weighted average, error, and scale factor are based upon the data in this ideogram only. They are not necessarily the same as our 'best' values, obtained from a least-squares constrained fit utilizing measurements of other (related) quantities as additional information.
                                                                                                               94 ARG
94F ARG
88C MRK3
81 MRK2
                                                                                        ALBRECHT
                                                                                        ALBRECHT
ADLER
                                                                                        SCHINDLER
                                                                                                                        MRK1_
                                                                                        PERUZZI
                                                                                                       (Confidence Level = 0.160)
                                                                                       0.2
                                                                                                       0.25
                                     0.05
                                                                      0.15
                \Gamma(\kappa^-\pi^+\pi^+\pi^-)/\Gamma_{\text{total}}
 \Gamma(K^-\pi^+\pi^+\pi^-)/\Gamma(K^-\pi^+)
                                                                                                                                 \Gamma_{39}/\Gamma_{21}
1.97±0.10 OUR FIT
                                                            DOCUMENT ID TECN COMMENT
                                     EVTS
 2.01 \pm 0.13 OUR AVERAGE
                                                                                     92C E691 γ Be 90-260 GeV
 1.7 \pm 0.2 \pm 0.2
                                        1745
                                                            ANJOS
 1.90 \pm 0.25 \pm 0.20
                                                            ALVAREZ
                                                                                     91B NA14 Photoproduction
                                          337
                                                            BORTOLETTO88 CLEO e^+e^- 10.55 GeV
 2.12 \pm 0.16 \pm 0.09
                                                                                    86 ACCM \pi^- Be fixed target 85F ARG e^+e^- 10 GeV 83B SPEC \pi^- Be \to D^0
 2.0 ± 0.9
                                                            BAILEY
                                                            ALBRECHT
2.17 \pm 0.28 \pm 0.23
                                                            BAILEY
 2.0 \pm 1.0
                                            10
                                                                                    77 MRK1 e<sup>+</sup>e<sup>-</sup> 4.03, 4.41 GeV
                                                            PICCOLO
                                          214
 2.2 \pm 0.8
 \Gamma(K^-\pi^+\rho^0 \text{total})/\Gamma(K^-\pi^+\pi^+\pi^-)
          This includes K^- a<sub>1</sub>(1260)<sup>+</sup>, K^*(892)<sup>0</sup> \rho^0, etc. The next entry gives the specifically 39-body fraction. We rely on the MARK III and E691 full amplitude analyses of the K^-\pi^+\pi^+\pi^- channel for values of the resonant substructure.
 0.835 ± 0.035 OUR AVERAGE
 0.80 \pm 0.03 \pm 0.05
 0.855 \pm 0.032 \pm 0.030
                                                            COFFMAN
                                                                                   92B MRK3 e^{+}e^{-} 3.77 GeV
 \bullet \,\bullet \,\bullet We do not use the following data for averages, fits, limits, etc. \,\bullet \,\bullet
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ALVAREZ

0.98 ±0.12 ±0.10

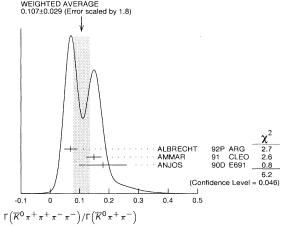
91B NA14 Photoproduction

				ses of the $K^-\pi^+\pi^+$				
928 WKK3 e e			-	COMMENT) TECN	DOCUMENT ID	EVTS	VALUE D.063±0.028 OUR A
				γ Be 90–260 GeV	92c E691	ANJOS	WEINAGE	$0.05 \pm 0.03 \pm 0.02$
						COFFMAN		$0.084 \pm 0.022 \pm 0.04$
	DOCUMENT ID		VALUE					• • • We do not use $0.77 \pm 0.06 \pm 0.06$
92C E691 γ Be 9	ANJOS	⊦0.03	0.30±0.0					0.77 ±0.06 ±0.06 0.85 +0.11 -0.22
)	$\Gamma(K^-\pi^+\pi^+\pi^-)$	$0^{0}\pi^{+}\pi^{-}$ 3-body)	Γ <i>(K</i> *(8					
		en decay modes of the	Un <u>VALUE</u>	annot determine what fr	.VAREZ 91B ca			tion of this is K^-
			\	Γ ₈₈ /Γ		$^{-}\pi^{-})$	$-(K^-\pi^+\pi^+)$	$\Gamma(\overline{K}^*(892)^0 \rho^0)/\Gamma$
		±0.045	0.165±0.					
		f ₀ (980))/Γ _{total}	- Γ(<i>K</i> -π				<u>EVTS</u>	VALUE
TECN COMM	DOCUMENT ID	<u>CL%</u>	VALUE				the following	0.195±0.03±0.03 • • • We do not use
92C E691 γ Be 9	SOLNA	90	<0.011			ALVAREZ		0.34 ±0.09±0.09
π-)	t)/ $\Gamma(K^-\pi^+\pi^+)$	$\pi^+\pi^-$ nonresonan	Γ(K -π			BAILEY	5	0.75 ±0.3
,	DOCUMENT ID		VALUE	e^+e^- 4.03, 4.41 GeV	77 MRK1	PICCOLO	20	$0.15 \begin{array}{c} +0.16 \\ -0.15 \end{array}$
02c E601 - Po 0	ANIOS				- \	(v- + + -		F (77*(000)0 0
				1 89/1				
				COMMENT			modes of the	Unseen decay m VALUE
Tron com	DOCUMENT ID							0.20 ±0.07 OUR FI
IECN COMMI	DUCUMENT ID			e ⁺ e ⁻ 3.77 GeV	92B MRK3	COFFMAN		0.213±0.024±0.075
	COFFMAN	2±0.025 140	0.103±0.	Γ ₉₀ /Γ				
s, fits, limits, etc. •	-						modes of the	
92C ACCM π^- Cu	⁴⁶ BARLAG	2 3	0.134^{+0}_{-0}					VALUE 0.375±0.045±0.06
sing topological nor	branching fraction ι			γ Be 90-260 GeV	92C E691			
			•	Г91				
TECN COMM		7)/ I (N 7 7 7		5011115UT		, ,		
		OUR FIT						VALUE <0.003
000 400 .+	47 ALBBECUT				720 1111113			
				Г92				$\Gamma(\overline{K}^*(892)^0 \rho^0 P_{-W})$
	KINOSHITA			COMMENT				Unseen decay m VALUE
of ALBRECHT 92P	numbers in Table 1	ue is calculated from	47 This v			COFFMAN	90	<0.003
		·(K- \pi +)	$\Gamma(\overline{K}^0n)$	etc. • • •	ges, fits, limits,	data for averag	the following	• • • We do not use
		n decay modes of the	Uns	γ Be 90–260 GeV	92C E691	ANJOS	90	< 0.009
				Γ ₉₃ /Γ		$^{-}\pi^{+}\pi^{+}\pi^{-}$	wave)/Γ(<i>K</i>	Γ <i>(K</i> *(892) ⁰ ρ ⁰ <i>D</i> -ν
			• • • • •	30,	ıcluded.			
89D ARG e'e	ALBRECHI							VALUE
		$(\overline{K}^0\pi^0)$	$\Gamma(\overline{K}^0\eta)$	γ Be 90–260 GeV	92C E691	ANJOS		$0.255 \pm 0.045 \pm 0.06$
TECN COMM				Г99			(0)	$\Gamma(\overline{K}^*(892)^0 f_0(980)$
7207 000000	BOCOMENT ID							
93B CLEO $\eta \rightarrow \gamma$	PROCARIO	E0.03 225	0.32±0.0					VALUE <0.007
		$(K^0\pi^+\pi^-)$	$\Gamma(\overline{K}^0\eta)$	γ Be 90-260 GeV	920. 6691			
	e η are included.	n decay modes of the	line	Г ₇₇ /Г		r ⁺ π ⁻)	$/\Gamma(K^-\pi^+\tau)$	$\Gamma(K^-a_1(1260)^+)/$
TECN COMME	DOCUMENT ID	7 OUR FIT	0.130±0.	COMMENT	ncluded.	a ₁ (1260) ⁺ are in	nodes of the	
938 CLEO $\eta \rightarrow \tau$	PROCARIO			COMMENT		DOCUMENT ID	VERAGE	VALUE 0.97 ±0.14 OUR AV
		·(K- \pi +)	r(k 0,)			ANJOS		0.94 ±0.13 ±0.20
	e ω are included.	n decay modes of the	Uns	e + e = 3.77 GeV	928 MRK3	COFFMAN		$0.984 \pm 0.048 \pm 0.16$
TECN COMME	DOCUMENT ID		VALUE	Γ _{81,}			$/\Gamma_{\text{total}}$	$\Gamma(K^{-}a_{2}(1320)^{+})$
89D ARG e+e-	ALBRECHT							
_								<i>∨ALUE</i> <0.002
	a are included							•
TECN COMME	DOCUMENT ID	EVTS	VALUE			COFFMAN	90	<0.006
ctor of 1.1	ror includes scale fo	DUR FIT DUR AVERAGE Err		F /F		-+\	/[(K+	F(K.(1270)= -+)
	48 ALBRECHT			Γ ₁₀₀ /Γ two experiments disagr	included The	•		$\Gamma(K_1(1270)^-\pi^+)$
92P ARG e+e-	KINOSHITA		0.54 ± 0.1	cybernienta disagi		1(***10) ale		considerably her
	KINOSHITA							
91 CLEO e^+e^-		ue is calculated from		COMMENT	TECN	DOCUMENT ID	CL%	VALUE
91 CLEO e^+e^-		ue is calculated from	48 This v				FIT	0.14 ±0.04 OUR
91 CLEO e^+e^- of ALBRECHT 92P	numbers in Table 1 ω are included.		⁴⁸ This ν Γ(Κ⁰ ω) Uns	e ⁺ e ⁻ 3.77 GeV	92B MRK3	COFFMAN	FIT B8	0.14 ±0.04 OUR 0.194±0.056±0.08
91 CLEO e^+e^-	numbers in Table 1	ue is calculated from $-(K^0\pi^+\pi^-\pi^0)$ n decay modes of the	⁴⁸ This ν Γ (Κ⁰ ω) Uns <u>VALUE</u>	e ⁺ e ⁻ 3.77 GeV	928 MRK3 ges, fits, limits,	COFFMAN	FIT B8	0.14 ±0.04 OUR
91 CLEO e^+e^- of ALBRECHT 92P	numbers in Table 1 ω are included.	ue is calculated from $-(\overline{K^0}_{\pi}^{+}_{\pi}^{-}_{\pi}^{0})$ n decay modes of the OUR FIT	⁴⁸ This ν Γ (Κ⁰ ω) Uns <u>VALUE</u>	e ⁺ e [−] 3.77 GeV etc. • • •	928 MRK3 ges, fits, limits,	COFFMAN data for averag	FIT B8 the following 90	VALUE 0.14 ±0.04 OUR 0.194±0.056±0.08 • • • We do not use
	TECN COMMENT	COFFMAN 92B MRK3 e^+e^- ($K^-\pi^+\pi^+\pi^-$) , etc. The next entry gives the specificall e $K^*(892)^0$ are included. DOCUMENT ID TECN COMMENT ID TECN COMMEN	$ \frac{c1\%}{90} \frac{DOCUMENT ID}{COFFMAN} \frac{TECN}{928} \frac{COMME}{e^+e^-} $ $ \frac{92}{92} \frac{n}{m} + \pi - \text{total} / \Gamma (K^-\pi^+\pi^+\pi^-) $ is includes $\overline{K}^*(892)^0 \rho^0$, etc. The next entry gives the specificall is seen decay modes of the $\overline{K}^*(892)^0$ are included. $ \frac{DOCUMENT ID}{DOCUMENT ID} \frac{TECN}{\gamma \text{ Be 90}} \frac{COMME}{\gamma \text{ Be 90}} $ $ \frac{92}{90} \frac{n}{m} + \pi - 3 - \text{body} / \Gamma (K^-\pi^+\pi^+\pi^-) $ is seen decay modes of the $\overline{K}^*(892)^0$ are included. $ \frac{DOCUMENT ID}{\rho \text{ OUR FIT}} \frac{TECN}{\rho \text{ COMMENT}} \frac{COMMENT}{\rho \text{ DOCUMENT ID}} \frac{TECN}{\gamma \text{ Be 90}} \frac{COMMENT}{\gamma \text{ Be 90}} $ $ \frac{4}{90} \frac{1}{\gamma \text{ Be 90}} \frac{1}{\gamma Be $	This includes K^* (992) 0 π^+ and the property of the	See of the $K = \pi^+ \pi^+ \pi^-$ COMMENT OR 90-260 GeV et et et a. 3.77 GeV Photoproduction et et a. 4.3, 4.41 GeV Janob determine what fraction in the MARK III and file or values of the resonant of the	mpBitude analyses of the $K^-\pi^+\pi^+\pi^-$ 12. E691 γ Re 90-260 GeV 2320 MRK3 e^+e^- 3.77 GeV 2320 MRK3 e^+e^-	Military Decomposition Decomposition	MARK III and East full amplitude analyses of the K**π*π**π**π** COMMENT COMMENT

 D^0

$\Gamma(\overline{K}^0\eta'(958))/\Gamma(\overline{K}^0\eta'(958))$		$\eta'(958)$ are inclu		Γ ₇₄ /Γ ₂ ;
VALUE 0.32±0.04 OUR AVE	EVTS	DOCUMENT ID		COMMENT
$0.31 \pm 0.02 \pm 0.04$	594	PROCARIO 49 ALBRECHT	93B CLEO	$\eta' \rightarrow \eta \pi^+ \pi^-, \rho^0 \gamma$
$0.37 \pm 0.13 \pm 0.06$ 49 This value is calcu	18 Ilated from			
-(K*(892) ⁻ ρ ⁺)/Γ				Г94/Г4
		π ') : K*(892) — are in	cluded.	1 94/1 4
0.606±0.188±0.126		DOCUMENT ID		<u>COMMENT</u> • e ⁺ e [−] 3.77 GeV
-(K*(892)-ρ+lon	oitudinal)		.0)	Γ ₉₅ /Γ ₄₁
		$K^*(892)^-$ are in	cluded.	,
ALUE 0.290±0.111		DOCUMENT ID		<i>COMMENT</i> • e ⁺ e [−] 3.77 GeV
	navorco) /			
		K*(892) = are in		Γ ₉₆ /Γ ₄₁
/ALUE		DOCUMENT ID	TECN	COMMENT
).317±0.180			92B MRK3	e ⁺ e ⁻ 3.77 GeV
$\Gamma(K^*(892)^- \rho^+ P_{-1})$ Unseen decay m		o tal : <i>K</i> *(892) [—] are in	cluded.	Г ₉₇ /I
/ALUE	<u>CL%</u>	DOCUMENT ID	TECN	
<0.015 50 Obtained using ot	90 her K *(892			e ⁺ e ⁻ 3.77 GeV
			na isospin rei	
$\Gamma(\overline{K}^*(892)^0 ho^0$ $\Gamma(\overline{K}^*(892)^0)$		$(K^{\circ}\pi^{+}\pi^{-}\pi^{\circ})$ $\overline{K}^{*}(892)^{0}$ are inc	cluded.	Γ ₈₉ /Γ ₄₁
ALUE 0.15 ±0.06 OUR FI		DOCUMENT ID		COMMENT
0.126±0.111	•	COFFMAN	92B MRK3	e ⁺ e [−] 3.77 GeV
$(K^0 a_1(1260)^0)/($	total			Γ ₇₈ /Ι
Unseen decay m	odes of the	$a_1(1260)^0$ are in	cluded.	
ALUE	CL%	DOCUMENT ID	TECN	
<0.019	90		928 MKK3	e ⁺ e ⁻ 3.77 GeV
$(K_1(1270)^-\pi^+)$			ncluded	Γ ₁₀₀ /Γ ₄
ALUE		K ₁ (1270) are i DOCUMENT ID		COMMENT
0.106±0.028 OUR FI	Т			e ⁺ e [−] 3.77 GeV
	_	COLLINAN	ASO IMINAS	
$(\overline{K}_{1}(1400)^{0}\pi^{0})/V$	total	DOCUMENT ID	TECN	Γ ₁₀₂ /Ι
<0.037	90			e ⁺ e ⁻ 3.77 GeV
$(K^*(892)^0\pi^+\pi^-$	3-body)/	$\Gamma(\overline{K}^0\pi^+\pi^-\pi^0)$)	Γ ₈₅ /Γ ₄ ,
Unseen decay m	odes of the	\overline{K}^* (892) 0 are inc	cluded.	
/ALUE).14 ±0.04 OUR FI	T Error in	DOCUMENT ID cludes scale factor	r of 1.1.	
0.191±0.105		COFFMAN	928 MRK3	e ⁺ e [−] 3.77 GeV
$-(\overline{\mathcal{K}}{}^0\pi^+\pi^-\pi^0$ non	resonant)			Γ ₅₅ /Γ ₄
ALUE 147+0 150		DOCUMENT ID		<i>COMMENT</i> • e ⁺ e [−] 3.77 GeV
0.210±0.147±0.150		COLLINAN	740 IVINA3	
Γ (Κ⁻ π⁺ π⁰ π⁰)/ Γ	total EVTS	DOCUMENT_ID	TECN	Г ₅₆ /I
	24	⁵¹ ADLER	88c MRK3	e ⁺ e [−] 3.77 GeV
		or data for average	es, fits, limits	
• • We do not use	the followin	-	00- 4	
• • We do not use 0.177 ± 0.029		⁵² BARLAG		T π Cu 230 GeV
• • We do not use 0.177 ± 0.029 $0.209 + 0.074 \pm 0.012$	9	⁵² BARLAG ⁵² AGUILAR	87F HYBR	πp, pp 360, 400 GeV
• • • We do not use 0.177 ± 0.029 $0.209 \stackrel{+}{-}0.074 \pm 0.012$ 0.514 ± 0.012 0.012 0.012 0.012 0.012 0.012 0.012 0.012 0.012	9 an absolute $K^+\pi^-$ in EZ 87F and don. They d	52 BARLAG 52 AGUILAR normalization me pure $D\overline{D}$ events. BARLAG 92C con	87F HYBR thod finding t npute the bra	
• • We do not use 0.177 \pm 0.029 0.209 $^+$ 0.074 \pm 0.012 51 ADLER 88c uses a detected \overline{D}^0 \rightarrow 52 AGUILAR-BENITI logical normalization included in the $-(K^-\pi^+\pi^+\pi^-\pi^0)$	9 an absolute $K^+\pi^-$ in EZ 87F and ion. They deaverage.	52 BARLAG 52 AGUILAR normalization me pure $D\overline{D}$ events. BARLAG 92C con o not distinguish	87F HYBR thod finding t npute the bra the presence	this decay channel opposit enching fraction using topo of a third π^0 , and thus ar
• • We do not use 0.177 ± 0.029 $0.209\pm0.074\pm0.012$ $0.209\pm0.043\pm0.012$ $0.209\pm0.043\pm0.012$ $0.209\pm0.043\pm0.012$ $0.209\pm0.043\pm0.012$ 0.209 ± 0.043 $0.209\pm0.$	9 an absolute $K^+\pi^-$ in EZ 87F and ion. They deaverage.	52 BARLAG 52 AGUILAR normalization me pure $D\overline{D}$ events. BARLAG 92C con o not distinguish	87F HYBR thod finding t npute the bra the presence	this decay channel opposit enching fraction using topo of a third π^0 , and thus ar
• • We do not use 0.177 \pm 0.029 \pm 0.074 \pm 0.012 51 ADLER 88c uses a detected $\overline{D}^0 \rightarrow 52$ AGUILAR-BENITI logical normalization tincluded in the $-(K^-\pi^+\pi^+\pi^-\pi^0)$ ALUE 1.06 \pm 0.10 OUR FIT 0.98 \pm 0.11 \pm 0.11	9 an absolute $K^+\pi^-$ in EZ 87F and ion. They de average. 9)/ $\Gamma(K^-\pi^-)$	52 BARLAG 52 AGUILAR normalization me pure DD events. BARLAG 92C con o not distinguish r+) DOCUMENT ID 53 ALBRECHT	87F HYBR thod finding to npute the bra the presence TECN 92P ARG	$\pi p, pp$ 360, 400 GeV this decay channel opposit unching fraction using topo of a third π^0 , and thus ar $\frac{\Gamma_{57}/\Gamma_2}{e^+e^-} \approx 10 \text{ GeV}$
• • We do not use 0.177 ± 0.029 $0.209+0.074\pm0.012$ $0.209+0.074\pm0.012$ $0.209+0.074\pm0.012$ $0.209+0.074$ a detected $\overline{D}{}^{0}$ $0.209+0.074$ logical normalization included in the $-(K-\pi+\pi+\pi-\pi^{0})$ 0.06 ± 0.10 OUR FIT $0.98\pm0.11\pm0.11$ $0.98\pm0.11\pm0.11$	an absolute $K^+\pi^-$ in EZ 87F and ion. They de average. K^0 / $\Gamma(K^-\pi^-)$ 225 ulated from	52 BARLAG 52 AGUILAR normalization me pure $D\overline{D}$ events. BARLAG 92C con o not distinguish r+) DOCUMENT ID 53 ALBRECHT numbers in Table	87F HYBR thod finding to npute the bra the presence TECN 92P ARG	$\pi p, pp$ 360, 400 GeV this decay channel opposit unching fraction using topo of a third π^0 , and thus ar $\frac{\Gamma_{57}/\Gamma_2}{e^+e^-} \approx 10 \text{ GeV}$
• • We do not use 0.177 ± 0.029 $0.209+0.074\pm0.012$ $0.209+0.074\pm0.012$ $0.209+0.074\pm0.012$ $0.209+0.074\pm0.012$ $0.209+0.074\pm0.012$ $0.209+0.$	an absolute $K^+\pi^-$ in EZ 87F and ion. They de average. 2) $/\Gamma(K^-\pi^-) = \frac{EVTS}{225}$ ulated from 2) $/\Gamma(K^-\pi^-) = \frac{EVTS}{25}$	52 BARLAG 52 AGUILAR normalization me pure DD events. BARLAG 92C con o not distinguish r+) DOCUMENT ID 53 ALBRECHT numbers in Table r+π+π-)	87F HYBR thod finding to npute the bra the presence TECN 92P ARG 1 of ALBREC	this decay channel opposite this decay channel opposite this decay channel opposite this decay channel opposite the following fraction using topo of a third π^0 , and thus are $\frac{\Gamma_{57}/\Gamma_2}{e^+e^-} \approx 10 \text{ GeV}$ CHT 92P. Γ_{57}/Γ_3
• • We do not use 0.177 \pm 0.029 0.209 $^+$ 0.074 \pm 0.012 51 ADLER 88c uses a detected $\overline{D}^0 \rightarrow 52$ AGUILAR-BENITI logical normalization included in the $-(K^-\pi^+\pi^+\pi^-\pi^0)$ ALUE 1.08 \pm 0.11 \pm 0.11 53 This value is calcular to $-(K^-\pi^+\pi^+\pi^-\pi^0)$ ALUE $-(K^-\pi^+\pi^+\pi^-\pi^0)$ ALUE $-(K^-\pi^+\pi^+\pi^-\pi^0)$ ALUE	an absolute $K^+\pi^-$ in EZ 87F and ion. They de average. K^0 / $\Gamma(K^-\pi^-)$ 225 ulated from	52 BARLAG 52 AGUILAR normalization me pure $D\overline{D}$ events. BARLAG 92C con o not distinguish r+) DOCUMENT ID 53 ALBRECHT numbers in Table	87F HYBR thod finding to npute the bra the presence TECN 92P ARG 1 of ALBREC	this decay channel opposite this decay channel opposite this decay channel opposite this decay channel opposite the following fraction using topo of a third π^0 , and thus are $\frac{\Gamma_{57}/\Gamma_2}{e^+e^-} \approx 10 \text{ GeV}$ CHT 92P. Γ_{57}/Γ_3
• • We do not use 0.177 ± 0.029 $0.209+0.074\pm0.012$ 51 ADLER 88c uses a detected $\overline{D}^0 \rightarrow 52$ AGUILAR-BENITI logical normalization included in the $-(K-\pi+\pi+\pi-\pi^0)$ 0.06 ± 0.10 OUR FIT $0.08\pm0.11\pm0.11$	9 an absolute $K^+\pi^-$ in EZ 87F and ion. They de average. 2)// $\Gamma(K^-\pi^-)$ 225 ulated from 2)/ $\Gamma(K^-\pi^-)$ EVTS RAGE	52 BARLAG 52 AGUILAR normalization me pure $D\overline{D}$ events. BARLAG 92C con o not distinguish in pocument id 53 ALBRECHT numbers in Table r+ π + π - pocument id pocument id	87F HYBR thod finding to mpute the bra the presence TECN 92P ARG 1 of ALBREC	this decay channel opposite this decay channel opposite this decay channel opposite the decay channel opposite the decay control of a third π^0 , and thus are $\frac{\Gamma_{57}/\Gamma_2}{e^+e^-} \approx 10 \text{ GeV}$ CHT 92P. $\frac{\Gamma_{57}/\Gamma_3}{COMMENT}$
0.177 \pm 0.029 0.209 $^+$ 0.074 $^+$ 0.012 51 ADLER 88c uses a detected $\overline{D}^0 \rightarrow$ 52 AGUILAR-BENITI logical normalization included in the control of t	9 an absolute $K^+\pi^-$ in EZ 87F and ion. They d e average. 2)/ $\Gamma(K^-\pi^-)$ 225 ulated from 2)/ $\Gamma(K^-\pi^-)$	52 BARLAG 52 AGUILAR normalization me pure DD events. BARLAG 92C con o not distinguish r+) DOCUMENT ID 53 ALBRECHT numbers in Table r+π+π-)	87F HYBR thod finding to npute the bra the presence TECN 92P ARG 1 of ALBREC	this decay channel opposite this decay channel opposite this decay channel opposite the decay channel opposite the decay control of a third π^0 , and thus are $\frac{\Gamma_{57}/\Gamma_2}{e^+e^-} \approx 10 \text{ GeV}$ CHT 92P. $\frac{\Gamma_{57}/\Gamma_3}{COMMENT}$

$\Gamma(\overline{K}^*(892)^0\pi^+\pi^-)$				í	107/F ₅
	odes of the	e \overline{K}^* (892) 0 are in			
VALUE 0.45±0.15±0.15		DOCUMENT ID	90D E691	COMMENT Photoproduction	n .
	- L\	7.11500	700 2071		
$\Gamma(\overline{K}^*(892)^0\eta)/\Gamma(F$		- T/* (202)		'	108/F ₂
VALUE		e K*(892) ⁰ and η <u>DOCUMENT ID</u>		COMMENT	
0.49±0.12 OUR FIT					
0.58±0.19 ^{+0.24} -0.28	46	KINOSHITA	91 CLEO	$e^+ e^- \sim 10.7 \text{ C}$	SeV
$\overline{(K^*(892)^0\eta)}/\Gamma(F$	$(-\pi^{+}\pi^{0}$)		ı	108/F ₃
		$e^{\overline{K}*}(892)^0$ and η	are included.		100, 0
VALUE 0.134±0.034 OUR FIT	<u>EVTS</u>	DOCUMENT ID	TECN	COMMENT	
0.13 ±0.02 ±0.03	214	PROCARIO	93B CLEO	$\overline{K}^{*0}\eta \rightarrow K^{-}$	$\pi^+/\gamma\gamma$
$\Gamma(K^-\pi^+\omega)/\Gamma(K^-$	-+1				109/F2
		e ω are included.			109/12
ALUE	EVTS	DOCUMENT ID		COMMENT	
0.78±0.12±0.10	99	⁵⁴ ALBRECHT		$e^+e^-\approx 10 \text{ G}$	SeV
⁵⁴ This value is calcul	ated from	numbers in Table	.1 of ALBREC	HT 92P.	
$\Gamma(\overline{K}^*(892)^0\omega)/\Gamma(I$					110/F ₂
,		$e \overline{K}^* (892)^0$ and ω			
ALUE 0.28±0.11±0.04	<u>EVTS</u>	55 ALBRECHT	92P ARG		
55 This value is calcul					JC V
					- /-
$\Gamma(\overline{K}^*(892)^0\omega)/\Gamma(\overline{I})$		' π π σ) e K * (892) ⁰ and ω			110/F ₅
VALUE		DOCUMENT ID			
• • We do not use t		ng data for averag			
< 0.44	90	⁵⁶ ANJOS		Photoproduction	
56 Recovered from th malization consiste	e publishe	d limit, $\Gamma(\overline{K}^*(892))$	$(2)^0 \omega)/\Gamma_{\text{total}}$	in order to mak	e our nor
					- /-
$\Gamma(K^-\pi^+\eta'(958))/$			4.4	ı	- ₁₁₁ /Γ ₃
VALUE	EVTS	e $\eta'(958)$ are inclu DOCUMENT ID	TECN_	COMMENT	
	286			$\eta' \rightarrow \eta \pi^+ \pi^-$	0
$0.093 \pm 0.014 \pm 0.019$		ritocattio	936 CLEO		$\rho^{0}\gamma$
			936 CLEO		
Γ(Κ *(892) ⁰ η′(958)))/Γ(<i>K</i> -	$\pi^+\eta'(958))$, ρ ^υ γ ₁₁₂ /Γ _{11:}
Γ (K*(892)⁰ η'(958) Unseen decay m))/Γ(<i>K</i> -	$\pi^+ \eta' (958)$ e $\overline{K}^* (892)^0$ are in <u>DOCUMENT ID</u>	cluded.		
Γ (Κ*(892)⁰ η'(958) Unseen decay m <u>VALUE</u>))/ Г(<i>K</i> [—] odes of the	$\pi^+\eta'(958))$ e $\overline{K}^*(892)^0$ are in	cluded.		
T (K* (892) ⁰ η' (958) Unseen decay m- VALUE <0.15))/ Г(<i>K</i> ⁻ odes of the <u>CL%</u> 90	$\pi^+\eta'(958)$) $\overline{K}^*(892)^0$ are in DOCUMENT ID PROCARIO	cluded.		
T(\overline{K}^{*} (892) 0 η' (958) Unseen decay mixelue <0.15 T(\overline{K}^{0} $\pi^{+}\pi^{+}\pi^{-}\pi^{-}$ VALUE))/Γ(<i>K</i> ⁻ odes of the <u>CL%</u> 90)/Γ(<i>K</i> ⁰ π	$\pi^+ \eta'(958)$) $= \overline{K}^*(892)^0$ are in $= \frac{DOCUMENT ID}{PROCARIO}$ $= \pi^+ \pi^-$	ocluded. TECN 93B CLEO	Γ:	₁₁₂ /Γ ₁₁ Γ ₆₂ /Γ ₂ :
$\Gamma(\overline{K}^{*}(892)^{0} \eta'(958)^{*})$ Unseen decay module <0.15 $\Gamma(\overline{K}^{0} \pi^{+} \pi^{+} \pi^{-} \pi^{-})$ VALUE $<0.107 \pm 0.029$ OUR AV)/ $\Gamma(K^-)$ odes of the $\frac{CL\%}{90}$)/ $\Gamma(\overline{K}^0\pi$ $\frac{EVTS}{ERAGE}$	$\pi^+\eta'(958)$) $e^-K^*(892)^0$ are in <u>DOCUMENT ID</u> PROCARIO $r^+\pi^-$) <u>DOCUMENT ID</u> Error includes scal	93B CLEO TECN TE	COMMENT 3. See the ideogr	Γ ₆₂ /Γ ₂
T $(K^{\circ}(892)^{0} \eta'(958)^{\circ})$ Unseen decay module <0.15 T $(K^{0} \pi^{+} \pi^{+} \pi^{-} \pi^{-})$ VALUE 0.107 ±0.029 OUR AV 0.07 ±0.02 ±0.01))/Γ(<i>K</i> ⁻ odes of the <u>CL%</u> 90)/Γ(<i>K</i> ⁰ π	π ⁺ η'(958)) e K* (892) ⁰ are in <u>DOCUMENT ID</u> PROCARIO r+π ⁻) <u>DOCUMENT ID</u> Error includes scal 57 ALBRECHT	93B CLEO TECN TECN TECN TECN Refactor of 1.8 92P ARG	$\frac{COMMENT}{e^+e^-} pprox 10 ext{ C}$	Γ ₆₂ /Γ ₂ am below
T $(K^*(892)^0 \eta'(958))$ Unseen decay m VALUE <0.15 T $(K^0 \pi^+ \pi^+ \pi^- \pi^-)$ VALUE 0.107 ±0.029 OUR AV 0.07 ±0.02 ±0.01 0.149 ±0.026)/Γ(<i>K</i> ⁻ odes of the <u>CL%</u> 90)/Γ(<i>K</i> ⁰ π <u>EVTS</u> ERAGE 11	$\pi^+\eta'(958)$) $e^-K^*(892)^0$ are in <u>DOCUMENT ID</u> PROCARIO $r^+\pi^-$) <u>DOCUMENT ID</u> Error includes scal	93B CLEO TECN TECN TECN TECN Refactor of 1.8 92P ARG	$\frac{COMMENT}{8}.$ See the ideogr $e^+e^-\approx 10$ C $e^+e^-\approx 10.5$	Γ ₆₂ /Γ ₂ : am below GeV GeV
T $(K^*(892)^0 \eta'(958))$ Unseen decay m VALUE <0.15 T $(K^0 \pi^+ \pi^+ \pi^- \pi^-)$ VALUE 0.107 ±0.029 OUR AV 0.07 ±0.02 ±0.01 0.149 ±0.026)/Γ(K ⁻ odes of the	π ⁺ η'(958)) E [*] (892) ⁰ are in DOCUMENT ID PROCARIO F ⁺ π ⁻) DOCUMENT ID Error includes scal 57 ALBRECHT AMMAR ANJOS	938 CLEO 7 TECN 938 CLEO 7 TECN 92P ARG 91 CLEO 90D E691	$\begin{array}{c} \textbf{COMMENT} \\ \textbf{3. See the ideogr} \\ e^+e^- \approx 10.5 \\ e^+e^- \approx 10.5 \\ \textbf{Photoproduction} \end{array}$	Γ ₆₂ /Γ ₂ : am below GeV
T(\overline{K}^* (892) 0 η' (958) Unseen decay m. ALUE <0.15 T(\overline{K}^0 $\pi^+\pi^+\pi^-\pi^-$) ALUE 0.17 ±0.029 OUR AV 0.149 ±0.026 0.18 ±0.07 ±0.04 57 This value is calcul)/Γ(K ⁻ odes of the	π ⁺ η'(958)) E K*(892) ⁰ are in DOCUMENT ID PROCARIO F+π ⁻) DOCUMENT ID Error includes scal 57 ALBRECHT AMMAR ANJOS numbers in Table	938 CLEO 7 TECN 938 CLEO 7 TECN 92P ARG 91 CLEO 90D E691	$\begin{array}{c} \textbf{COMMENT} \\ \textbf{3. See the ideogr} \\ e^+e^- \approx 10.5 \\ e^+e^- \approx 10.5 \\ \textbf{Photoproduction} \end{array}$	Γ ₆₂ /Γ ₂ : am below GeV
T (\overline{K}^* (892) 0 η' (958) Unseen decay m. ALUE <0.15 T (\overline{K}^0 $\pi^+\pi^+\pi^-\pi^-$) ALUE 0.107 ±0.029 OUR AV 0.17 ±0.026 0.18 ±0.07 ±0.04 57 This value is calculated.	odes of the <u>CL%</u> 90)/Γ(K ⁰ m <u>EVTS</u> 11 56 6 lated from	π ⁺ η'(958)) E K*(892) ⁰ are in DOCUMENT ID PROCARIO F+π ⁻) DOCUMENT ID Error includes scal 57 ALBRECHT AMMAR ANJOS numbers in Table	938 CLEO 7 TECN 938 CLEO 7 TECN 92P ARG 91 CLEO 90D E691	$\begin{array}{c} \textbf{COMMENT} \\ \textbf{3. See the ideogr} \\ e^+e^- \approx 10.5 \\ e^+e^- \approx 10.5 \\ \textbf{Photoproduction} \end{array}$	Γ ₆₂ /Γ ₂ : am below GeV GeV
T(\overline{K}^* (892) 0 η' (958) Unseen decay m. ALUE <0.15 T(\overline{K}^0 $\pi^+\pi^+\pi^-\pi^-$) ALUE 0.107 ±0.029 OUR AV 0.17 ±0.026 0.18 ±0.07 ±0.04 57 This value is calcul	odes of the <u>CL%</u> 90)/Γ(K ⁰ m <u>EVTS</u> 11 56 6 lated from	π+η'(958)) E **(892) ⁰ are in DOCUMENT ID PROCARIO F+π-) DOCUMENT ID DOCUM	938 CLEO 7 TECN 938 CLEO 7 TECN 92P ARG 91 CLEO 90D E691	$COMMENT$ 3. See the ideogr $e^+e^-\approx 10.5$ $e^+e^-\approx 10.5$ Photoproduction	Γ ₆₂ /Γ ₂ : am below GeV GeV
VALUE <0.15 $\Gamma(\overline{K^0}\pi^+\pi^+\pi^-\pi^-)$ VALUE 0.107 ±0.029 OUR AV 0.07 ±0.02 ±0.01 0.149 ±0.026 0.18 ±0.07 ±0.04 57 This value is calcul	odes of the <u>CL%</u> 90)/Γ(K ⁰ m <u>EVTS</u> 11 56 6 lated from	π+η'(958)) E **(892) ⁰ are in DOCUMENT ID PROCARIO F+π-) DOCUMENT ID DOCUM	938 CLEO 7 TECN 938 CLEO 7 TECN 92P ARG 91 CLEO 90D E691	$COMMENT$ 3. See the ideogr $e^+e^-\approx 10.5$ $e^+e^-\approx 10.5$ Photoproduction	Γ ₆₂ /Γ ₂ : am below GeV GeV



 $^{^{58}}$ AGUILAR-BENITEZ 87F computes the branching fraction using topological normalization, and does not distinguish the presence of a third $\pi^0.$

$\Gamma(\overline{K}^0K^+K^-)/\Gamma(\overline{K}^0\pi^+\pi^-)$ VALUE EVTS	Γ ₆₄ /Γ ₂₃	$_{0} = (\Gamma_{66} + \frac{1}{2}\Gamma_{76})/\Gamma_{23}$ OMMENT	$\Gamma(\pi^+\pi^+\pi^-\pi^-\pi^0)/\Gamma_{\text{total}}$	<u>D</u> 0	CUMENT ID	TECN	СОММЕ		Γ ₁₁₇ /Γ
0.172±0.014 OUR FIT 0.178±0.019 OUR AVERAGE			0.0192 ^{+0.0041} -0.0038	63 _{BA}	RLAG	92c ACC	Λ π Cu	230 GeV	
0.20 ±0.05 ±0.04 47	FRABETTI 92B E687 γ	Be \overline{E}_{γ} = 221 GeV	63 BARLAG 92C computes the	branchir	ng fraction us	ing topolo	gical norm	alization.	
0.170±0.022 136	AMMAR 91 CLEO e	+ e − ≈ 10.5 GeV	F(+ + +)/F						- /-
0.24 ±0.08		$^+e^-$ near $\Upsilon(4S)$	$\Gamma(\pi^+\pi^+\pi^+\pi^-\pi^-\pi^-)/\Gamma_{\rm t}$		CUMENT ID	TECH	cours		Γ ₁₁₈ /Γ
0.185±0.055 52	ALBRECHT 858 ARG e	+ e− 10 GeV	VALUE		CUMENT ID		COMME		
r (720 +) /r (720 -+)		Γ ₇₆ /Γ ₂₃	0.0004±0.0003		RLAG	92c ACC			
$\Gamma(\overline{K^0}\phi)/\Gamma(\overline{K^0}\pi^+\pi^-)$ Unseen decay modes of the	d are included	176/123	⁶⁴ BARLAG 92C computes the	e branchir	ng fraction us	ing topolo	gical norm	alization.	
VALUEEVTS		OMMENT	Had	ronic m	odes with a	KK pa	ir	_	
0.158±0.016 OUR FIT									
0.156±0.017 OUR AVERAGE			$\Gamma(K^+K^-)/\Gamma(K^-\pi^+)$					Г1	19/F ₂₁
$0.13 \pm 0.06 \pm 0.02$ 13		Be \overline{E}_{γ} = 221 GeV		EVTS	DOCUMEN	T ID	TECN C	OMMENT	
0.163±0.023 63		$+e^- \approx 10.5 \text{ GeV}$	0.113±0.006 OUR FIT						
0.155±0.033 56		+ e ⁻ 10 GeV	0.113±0.006 OUR AVERAGE		ED + D E T	T I 040	F407	D. 7	220
0.14 ±0.05 29		$^+e^-$ near \varUpsilon (45)	$0.109 \pm 0.007 \pm 0.009$	581	FRABET	11 940	E687 ~	$_{\gamma}$ Be $\overline{\mathcal{E}}_{\gamma}$ $=$ GeV	220
 • • We do not use the following 	g data for averages, fits, limits, etc	c. • • •	$0.107 \pm 0.029 \pm 0.015$	103	ADAMO	/ICH 92	OMEG 1		eV
0.186±0.052 26	ALBRECHT 858 ARG Se	ee ALBRECHT 87E	$0.138 \pm 0.027 \pm 0.010$	155	FRABET			Be	
- (30) (4) (4)	<u> </u>	F /F	0.16 ±0.05	34	ALVARE	Z 918	NA14	hotoprod	luction
$\Gamma(\overline{K}{}^0 K^+ K^-$ non- $\phi)/\Gamma(\overline{K}{}^0 \pi$		Γ ₆₆ /Γ ₂₃	$0.107 \pm 0.010 \pm 0.009$	193	ANJOS	910	E691 F	hotoprod	luction
VALUE EVTS	DOCUMENT ID TECN CO	OMMENT	$0.10\ \pm0.02\ \pm0.01$	131	ALBREC			e+ e− ≈	
0.093±0.014 OUR FIT			$0.117 \pm 0.010 \pm 0.007$	249	ALEXAN	DER 90	CLEO	e ⁺ e ⁻ 10.	.5-11
0.088±0.019 OUR AVERAGE	FRABETTI 92β E687 γ	Be \overline{E}_{γ} = 221 GeV	$0.122 \pm 0.018 \pm 0.012$	118	RAITDII	SAIT85E	MRK3	GeV -+e= 3.7	77 Ge\/
0.11 ±0.04 ±0.03 20		$+e^-$ 10 GeV	$0.122 \pm 0.018 \pm 0.012$ 0.113 ± 0.030	110	ABRAMS		MRK2		
0.084 ± 0.020	ALBRECHT 87E ARG e	10 GeV	5.115.10.055		, , SKAWIS	. , , , ,			
$\Gamma(K_S^0 K_S^0 K_S^0) / \Gamma(\overline{K}^0 \pi^+ \pi^-)$		Γ_{67}/Γ_{23}	$\Gamma(K^+K^-)/\Gamma(\pi^+\pi^-)$					Γ ₁₁	9/۲ ₁₁₃
VALUE EVTS	DOCUMENT ID TECN CO	OMMENT	The unused results h	here are	redundant	with Γ	(K^+K^-)	$/\Gamma(K^{-}\pi^{-})$	+) and
0.018±0.004 OUR AVERAGE	DOCOMENT ID		$\Gamma(\pi^+\pi^-)/\Gamma(K^-\pi^+)$ m	easureme	ents by the sa	me experi	ments.	, `	,
0.035 ± 0.012 ± 0.006 10	FRABETTI 94J E687 γ	Be \overline{E}_{γ} =220 GeV	VALUE EVTS		CUMENT ID			NT	
0.016±0.005 22	AMMAR 91 CLEO e	.+e ⁻ ≈ 10.5 GeV	• • We do not use the follow	ving data	for averages	, fits, limit	s, etc. •	• •	
0.017±0.007±0.005 5	ALBRECHT 90c ARG e	$^{+}e^{-}\approx$ 10 GeV	$2.53 \pm 0.46 \pm 0.19$		RABETTI	94c E687		,= 220 G	ieV
					DAMOVICH				
$\Gamma(K^+K^-K^-\pi^+)/\Gamma(K^-\pi^+)$	$\pi^{+}\pi^{-}$)	Γ ₆₈ /Γ ₃₉	$2.23 \pm 0.81 \pm 0.46$ $1.95 \pm 0.34 \pm 0.22$		NJOS	91D E691		roduction	
ALUE EV	TS DOCUMENT ID TEC		2.5 ±0.7		BRECHT.	90c ARG		≈ 10 Ge	
0.0028±0.0007±0.0001	20 FRABETTI 95C E68		2.35 ± 0.7 $2.35 \pm 0.37 \pm 0.28$ 110		EXANDER			10.5-11	
		GeV	2.55 ± 0.57 ± 0.20	,,_	2701112211				
									· / [
$r(K+K-\overline{K}0\pi^0)/\Gamma$		Γεο/Γ	$\Gamma(K^0\overline{K}^0)/\Gamma(\overline{K}^0\pi^+\pi^-)$					Γı	23 י/20
$\Gamma(K^+K^-\overline{K}^0\pi^0)/\Gamma_{total}$	DOCUMENT ID TECH CO	Γ ₆₉ /Γ	$\Gamma(K^0\overline{K}^0)/\Gamma(\overline{K}^0\pi^+\pi^-)$		OCUMENT ID	<u>TECI</u>	v <u>COMM</u>		120/ 123
VALUE	DOCUMENT ID TECN CO	OMMENT	VALUE EVTS	<u>D</u>	OCUMENT ID	<u>TECI</u>	V COMM		120/ 723
VALUE				<u>D</u>	OCUMENT ID	TECI	V <u>COMM</u>		23
0.0072 + 0.0048 0.0072 - 0.0035	59 BARLAG 92C ACCM π	Cu 230 GeV	0.023 + 0.008 OUR FIT	<u>D</u>	OCUMENT ID	<u>TECI</u>	N <u>COMM</u>		120/ 123
0.0072 + 0.0048 0.0072 - 0.0035		Cu 230 GeV	0.023 + 0.008 OUR FIT 0.025 + 0.010 OUR AVERAGE					ENT	
0.0072+0.0048 0.0072+0.0035	59 BARLAG 92C ACCM π	Cu 230 GeV	$\frac{VALUE}{0.023 + 0.008} \frac{EVTS}{0.007}$ OUR FIT $\frac{0.025 + 0.010}{0.008}$ OUR AVERAGE $0.039 \pm 0.013 \pm 0.013$	FI	RABETTI	94J E68	7 γBe \overline{l}	$arepsilon_{\gamma}=$ 220 G	5eV
0.0072 + 0.0048 0.0072 + 0.0035 59 BARLAG 92C computes the bi	59 BARLAG 92C ACCM π	COMMENT — Cu 230 GeV Il normalization.	$\frac{VALUE}{0.023 + 0.008} \frac{EVTS}{0.007}$ OUR FIT $\frac{0.025 + 0.010}{0.008}$ OUR AVERAGE $0.039 \pm 0.013 \pm 0.013$	FI		94J E68	7 γBe \overline{l}	$arepsilon_{\gamma}=$ 220 G	5eV
$ \frac{1}{1} \frac{1} \frac$	59 BARLAG 92C ACCM π ranching fraction using topological — Pionic modes	COMMENT Cu 230 GeV Il normalization. \[\begin{align*} \Gamma_{113}/\Gamma_2 & \\ \Gamma_2 &	$\begin{array}{c} \underline{\text{VALUE}} & \underline{\text{EVTS}} \\ \textbf{0.023} + \textbf{0.008} \\ \textbf{0.007} & \textbf{OUR FIT} \\ \textbf{0.025} + \textbf{0.010} & \textbf{OUR AVERAGE} \\ \textbf{0.039} \pm \textbf{0.013} \pm \textbf{0.013} & \textbf{20} \\ \textbf{0.021} + \textbf{0.011} \\ \textbf{-0.008} \pm \textbf{0.002} & \textbf{5} \\ \end{array}$	FI	RABETTI	94J E68	7 γBe \overline{l}	$arepsilon_{\gamma}=$ 220 G	5eV
$VALUE$ 0.0072 $^+$ 0.0048 0.0072 $^+$ 0.0035 59 BARLAG 92C computes the binomial of the properties	59 BARLAG 92C ACCM π ranching fraction using topological — Pionic modes	COMMENT — Cu 230 GeV Il normalization.	$\begin{array}{c} \underline{\text{VALUE}} & \underline{\text{EVTS}} \\ \textbf{0.023} + \textbf{0.008} \\ \textbf{0.007} & \textbf{OUR FIT} \\ \textbf{0.025} + \textbf{0.010} & \textbf{OUR AVERAGE} \\ \textbf{0.039} \pm \textbf{0.013} \pm \textbf{0.013} & \textbf{20} \\ \textbf{0.021} + \textbf{0.011} \\ \textbf{-0.008} \pm \textbf{0.002} & \textbf{5} \\ \end{array}$	FI	RABETTI	94J E68	7 γBe \overline{l}	$\tilde{\gamma}_{\gamma} = 220 \text{ G}$ $10.5 - 11$	GeV
$\frac{ALUE}{0.0072 - 0.0048}$ 59 BARLAG 92C computes the binomial $\frac{1}{2}$	BARLAG 92C ACCM π ranching fraction using topological Pionic modes DOCUMENT ID TEC	COMMENT Cu 230 GeV Inormalization. F113/F21 CN COMMENT	$\frac{VALUE}{0.023 + 0.008} \frac{EVTS}{0.007}$ OUR FIT $\frac{0.025 + 0.010}{0.008}$ OUR AVERAGE $0.039 \pm 0.013 \pm 0.013$	F A	RABETTI	94J E68	7 γ Be \overline{t} Ο e^+e^-	Εητ ε _γ =220 G 10.5-11	GeV
$ \frac{\sqrt{4LUE}}{0.0072 + 0.0048} $ $ \frac{59}{BARLAG} $ $ \frac{59}{BARLAG} $ $ \frac{7}{(\pi^+\pi^-)/\Gamma(K^-\pi^+)} $ $ \frac{EL}{0.0396 \pm 0.0027} $ OUR AVERAGE	59 BARLAG 92C ACCM π ranching fraction using topological — Pionic modes	COMMENT Cu 230 GeV Inormalization. F113/F21 CN COMMENT	$\begin{array}{c} \underline{VALUE} & \underline{EVTS} \\ 0.023 + 0.008 \\ 0.027 + 0.008 \\ 0.008 & \mathbf{OUR} \ \mathbf{FIT} \\ \\ 0.025 + 0.010 \\ 0.013 + 0.013 \\ 0.039 + 0.013 + 0.013 \\ 0.021 + 0.011 \\ 0.001 + 0.002$	F A	RABETTI LEXANDER	94J E68 90 CLE	7 γ Be \overline{t} Ο e^+e^-	Εητ ε _γ =220 G 10.5-11	GeV
$ \frac{VALUE}{0.0072 + 0.0048} $ $ \frac{59}{9} BARLAG 92C computes the bi}{0.0072 + 0.0035} $ $ \frac{\Gamma(\pi^+\pi^-)/\Gamma(K^-\pi^+)}{VALUE} $ $\frac{EV}{0.0396 \pm 0.0027 OUR AVERAGE}$ $\frac{EV}{0.0043 \pm 0.007 \pm 0.003}$	59 BARLAG 92C ACCM π ranching fraction using topological Pionic modes 775 DOCUMENT ID TEC 777 FRABETTI 94C E68 227 SELEN 93 CLE	TOMMENT Cu 230 GeV In normalization. F113/F21 CN COMMENT $7 \text{ Be } \overline{E}_{\gamma} = 220$ 6 GeV EO $e^+e^-\approx \gamma(45)$	$\begin{array}{c} \underline{VALUE} & \underline{EVTS} \\ \textbf{0.023} & + \textbf{0.008} \\ \textbf{0.023} & + \textbf{0.008} \\ \textbf{0.008} & \textbf{OUR FIT} \\ \\ \textbf{0.025} & + \textbf{0.010} \\ \textbf{0.039} & \pm \textbf{0.013} \\ \textbf{0.039} & \pm \textbf{0.013} \\ \textbf{0.021} & + \textbf{0.011} \\ \textbf{0.001} & \pm \textbf{0.002} \\ \\ \textbf{0.021} & + \textbf{0.011} \\ \textbf{0.001} & \pm \textbf{0.002} \\ \\ \textbf{0.021} & + \textbf{0.011} \\ \textbf{0.002} & \pm \textbf{0.002} \\ \\ \textbf{0.021} & + \textbf{0.002} \\ \textbf{0.003} & \pm \textbf{0.002} \\ \\ \textbf{0.003} & \pm \textbf{0.002} \\ \\ \textbf{0.003} & \pm \textbf{0.002} \\ \\ \textbf{0.003} & \pm \textbf{0.003} \\ \\ \textbf{0.003}$	FI A	RABETTI LEXANDER OCUMENT ID	94J E68' 90 CLE	7 γBe E Ο e ⁺ e ⁻	ΕΝΤ ε _γ =220 G 10.5-11 Γ ₁₂	GeV
$VALUE$ 0.0072 $^{+}$ 0.0048 59 BARLAG 92C computes the bin $\Gamma(\pi^{+}\pi^{-})/\Gamma(K^{-}\pi^{+})$ $VALUE$ 0.00396 \pm 0.0027 OUR AVERAGE 0.043 \pm 0.007 \pm 0.003 1 0.0348 \pm 0.0030 \pm 0.0023 2 0.048 \pm 0.003 \pm 0.008	59 BARLAG 92C ACCM π ranching fraction using topological Pionic modes 77 FRABETTI 94C E68 227 SELEN 93 CLE 51 ADAMOVICH 92 OM	FOMMENT C U 230 GeV II normalization. F113/F21 CN COMMENT 87 γ Be \overline{E}_{γ} = 220 GeV EO $e^+e^- \approx \Upsilon(45)$ MEG π^- 340 GeV	$\begin{array}{c} \underline{VALUE} & \underline{EVTS} \\ 0.023 + 0.008 \\ 0.027 + 0.008 \\ 0.008 & \mathbf{OUR} \ \mathbf{FIT} \\ \\ 0.025 + 0.010 \\ 0.013 + 0.013 \\ 0.039 + 0.013 + 0.013 \\ 0.021 + 0.011 \\ 0.001 + 0.002$	FI A	RABETTI LEXANDER	94J E68 90 CLE	7 γBe E Ο e ⁺ e ⁻	ΕΝΤ ε _γ =220 G 10.5-11 Γ ₁₂	GeV
$\Gamma(\pi^+\pi^-)/\Gamma(K^-\pi^+)$ 0.0036 SPBARLAG 92C computes the bias of the property o	59 BARLAG 92C ACCM π ranching fraction using topological Pionic modes 77 FRABETTI 94C E66 127 SELEN 93 CLE 127 SELEN 93 CLE 128 ADAMOVICH 92 OM 120 ANJOS 91D E69	TOMMENT C Cu 230 GeV Il normalization. F113/F21 CN COMMENT 87 γ Be \overline{E}_{γ} = 220 GeV EO $e^+e^-\approx \gamma(45)$ MEG π^- 340 GeV 91 Photoproduction	$\begin{array}{c} \underline{VALUE} & \underline{EVTS} \\ \textbf{0.023} & + \textbf{0.008} \\ \textbf{0.023} & + \textbf{0.008} \\ \textbf{0.008} & \textbf{OUR FIT} \\ \\ \textbf{0.025} & + \textbf{0.010} \\ \textbf{0.039} & \pm \textbf{0.013} \\ \textbf{0.039} & \pm \textbf{0.013} \\ \textbf{0.021} & + \textbf{0.011} \\ \textbf{0.001} & \pm \textbf{0.002} \\ \\ \textbf{0.021} & + \textbf{0.011} \\ \textbf{0.001} & \pm \textbf{0.002} \\ \\ \textbf{0.021} & + \textbf{0.011} \\ \textbf{0.002} & \pm \textbf{0.002} \\ \\ \textbf{0.021} & + \textbf{0.002} \\ \textbf{0.003} & \pm \textbf{0.002} \\ \\ \textbf{0.003} & \pm \textbf{0.002} \\ \\ \textbf{0.003} & \pm \textbf{0.002} \\ \\ \textbf{0.003} & \pm \textbf{0.003} \\ \\ \textbf{0.003}$	FI A DO	RABETTI LEXANDER DOLUMENT ID	94J E68' 90 CLE <u>TECN</u> 88 SPEC	7 γ Be \overline{t} O e^+e^-	$\tilde{\epsilon}_{\gamma}$ =220 G \cdot 10.5–11 Γ_{12}	GeV
$\frac{ALUE}{0.0072}$ + 0.0048 $\frac{59}{0.0035}$ 59 BARLAG 92c computes the binomial of the bino	59 BARLAG 92C ACCM π ranching fraction using topological — Pionic modes 77	Tomment Cu 230 GeV In normalization. F113/F21 CN COMMENT 87 γ Be $\overline{E}_{\gamma} = 220$ GeV EO $e^+e^- \approx \gamma(45)$ AEG $\pi^- 340$ GeV 11 Photoproduction GG $e^+e^- \approx 10$ GeV	$\begin{array}{c} \underline{VALUE} & \underline{EVTS} \\ 0.023 + 0.008 \\ 0.008 & \text{OUR FIT} \\ \hline \\ 0.025 + 0.010 \\ 0.008 & \text{OUR AVERAGE} \\ 0.039 \pm 0.013 \pm 0.013 & 20 \\ 0.021 + 0.011 \\ 0.008 \pm 0.002 & 5 \\ \hline \\ \Gamma(K^0\overline{K^0})/\Gamma(K^+K^-) \\ \underline{VALUE} & \underline{EVTS} \\ 0.29 + 0.09 \\ -0.08 & \text{OUR FIT} \\ 0.24 \pm 0.16 & 4 \\ 65 & \text{Includes a correction comm} \\ \hline \end{array}$	FI A DO	RABETTI LEXANDER DOLUMENT ID	94J E68' 90 CLE <u>TECN</u> 88 SPEC	7 γ Be \overline{t} O e^+e^-	$\bar{\epsilon}_{\gamma}$ =220 G · 10.5-11 $\bar{\Gamma}_{12}$ NT 800 GeV	GeV GeV 20/Γ11
$\frac{VALUE}{0.0072 - 0.0035}$ $\frac{59}{9}$ BARLAG 92c computes the binomial by $\frac{1}{2}$ BARLAG 92c computes the bin	59 BARLAG 92C ACCM π ranching fraction using topological Pionic modes 77 FRABETTI 94C E66 127 SELEN 93 CLE 127 SELEN 93 CLE 128 ADAMOVICH 92 OM 120 ANJOS 91D E69	TOMMENT C Cu 230 GeV In normalization. F113/F21 CN COMMENT 87 γ Be $\overline{E}_{\gamma} = 220$ GeV EO $e^+e^- \approx \gamma(45)$ MEG π^- 340 GeV 91 Photoproduction 16 $e^+e^- \approx 10$ GeV EO $e^+e^- \approx 10$ GeV EO $e^+e^- \approx 10$ GeV	$\begin{array}{c} \underline{VALUE} & \underline{EVTS} \\ \textbf{0.023} + \textbf{0.008} \\ \textbf{0.023} + \textbf{0.008} \\ \textbf{0.008} & \textbf{OUR FIT} \\ \textbf{0.025} + \textbf{0.010} \\ \textbf{0.025} + \textbf{0.010} \\ \textbf{0.039} \pm \textbf{0.013} \pm \textbf{0.013} & 20 \\ \textbf{0.021} + \textbf{0.011} \pm \textbf{0.002} & 5 \\ \hline \Gamma(\textbf{K}^0 \overline{\textbf{K}^0}) / \Gamma(\textbf{K}^+ \textbf{K}^-) \\ \underline{VALUE} & \underline{EVTS} \\ \textbf{0.29} + \textbf{0.09} \\ \textbf{0.08} & \textbf{OUR FIT} \\ \textbf{0.24} \pm \textbf{0.16} & 4 \\ \textbf{65} & \textbf{Includes a correction comm} \\ \hline \Gamma(\textbf{K}^0 \mathbf{K}^- \boldsymbol{\pi}^+) / \Gamma(\textbf{K}^- \boldsymbol{\pi}^+) \end{array}$	FI A <u>DO</u> 65 CU nunicated	RABETTI LEXANDER DOUMENT ID JMALAT to us by the	94J E68 90 CLE TECN 88 SPEC authors of	7 γBe \bar{t} O e^+e^- COMME COMME	$\bar{\epsilon}_{\gamma}$ =220 G· 10.5-11 $\bar{\Gamma}_{12}$ 800 GeV AT 88.	5eV GeV 20∕Γ110
$\frac{ALUE}{0.0072}$ + 0.0048	59 BARLAG 92C ACCM π ranching fraction using topological — Pionic modes 77	Tomment Cu 230 GeV In normalization. F113/F21 CN COMMENT 87 γ Be \overline{E}_{γ} = 220 GeV EO $e^+e^-\approx 7(45)$ AEG π^- 340 GeV 19 Photoproduction 19 $e^+e^-\approx 10$ GeV EO $e^+e^-=10.5-11$ GeV	$\begin{array}{ll} \underline{VALUE} & \underline{EVTS} \\ 0.023 + 0.008 \\ 0.008 & \text{OUR FIT} \\ \hline \\ 0.025 + 0.010 \\ 0.010 & \text{OUR AVERAGE} \\ 0.039 \pm 0.013 \pm 0.013 & 20 \\ 0.021 + 0.018 \\ -0.008 \pm 0.002 & 5 \\ \hline \\ \Gamma(K^0\overline{K^0})/\Gamma(K^+K^-) \\ \underline{VALUE} & \underline{EVTS} \\ 0.29 + 0.09 \\ -0.08 & \text{OUR FIT} \\ 0.24 \pm 0.16 & 4 \\ 65 & \text{Includes a correction comm} \\ \hline \\ \Gamma(K^0K^-\pi^+)/\Gamma(K^-\pi^+) \\ \underline{VALUE} & \underline{VALUE} \\ \hline \end{array}$	FI A DO 65 Ct nunicated	RABETTI LEXANDER COUMENT ID JMALAT to us by the	94J E68' 90 CLE <u>TECN</u> 88 SPEC authors of	7 γBe \bar{t} O e^+e^- COMME COMME	$\bar{\epsilon}_{\gamma}$ =220 G· 10.5-11 $\bar{\Gamma}_{12}$ 800 GeV AT 88.	5eV GeV 20∕Γ11
$VALUE$ 0.0072 $^{+}$ 0.0048 59 BARLAG 92C computes the binomial by the binomial	59 BARLAG 92C ACCM π ranching fraction using topological — Pionic modes 77 FRABETTI 94C E68 127 SELEN 93 CLE 127 SELEN 93 CLE 128 ADAMOVICH 92 OM 129 ANJOS 91D E68 130 ALBRECHT 90C AR 110 ALEXANDER 90 CLE 139 BALTRUSAIT85E MR	Tomment Cu 230 GeV In normalization. F113/F21 CN COMMENT 87 γ Be \overline{E}_{γ} = 220 GeV EO $e^+e^-\approx 7(45)$ AEG π^- 340 GeV 19 Photoproduction 19 $e^+e^-\approx 10$ GeV EO $e^+e^-=10.5-11$ GeV	$\begin{array}{c} \underline{VALUE} & \underline{EVTS} \\ \textbf{0.023} & + \textbf{0.008} \\ \textbf{0.023} & + \textbf{0.008} \\ \textbf{0.007} & \textbf{OUR FIT} \\ \textbf{0.025} & + \textbf{0.010} \\ \textbf{0.039} & + \textbf{0.013} \\ \textbf{0.039} & + \textbf{0.013} \\ \textbf{0.021} & + \textbf{0.011} \\ \textbf{0.001} & + \textbf{0.002} \\ \textbf{0.001} & + \textbf{0.002} \\ \textbf{5} \\ \hline & \Gamma(\textbf{K}^{\textbf{0}} \overline{\textbf{K}^{\textbf{0}}}) / \Gamma(\textbf{K}^{+} \textbf{K}^{-}) \\ \underline{VALUE} & \underline{EVTS} \\ \textbf{0.29} & + \textbf{0.03} \\ \textbf{0.09} & \textbf{OUR FIT} \\ \textbf{0.24} & + \textbf{0.16} \\ \textbf{4} \\ \textbf{65} & \textbf{Includes a correction comm} \\ & \Gamma(\textbf{K}^{\textbf{0}} \textbf{K}^{-} \pi^{+}) / \Gamma(\textbf{K}^{-} \pi^{+}) \\ \underline{VALUE} & \underline{\textbf{0.167} \pm \textbf{0.026}} & \textbf{OUR FIT} \\ \hline & \textbf{0.167} & \pm \textbf{0.026} & \textbf{OUR FIT} \\ \hline & \textbf{0.167} & \pm \textbf{0.026} & \textbf{OUR FIT} \\ \hline & \textbf{Error} \\ \hline \end{array}$	FI A DC 65 CU nunicated includes	RABETTI LEXANDER DOLUMENT ID JMALAT to us by the DOLUMENT ID Scale factor	94J E68' 90 CLE TECN 88 SPEC authors of 1.1.	7 γBe \overline{t} O e ⁺ e ⁻ COMME COMME COMME	$\tilde{\epsilon}_{\gamma}$ =220 G· 10.5–11 Γ_{12} 800 GeV	GeV GeV 20/「119
$\frac{\sqrt{2}LUE}{0.0072 - 0.0035}$ 59 BARLAG 92C computes the binomial by $\frac{\sqrt{2}LUE}{\sqrt{2}}$	59 BARLAG 92¢ ACCM π ranching fraction using topological — Pionic modes 77	Tomment C Cu 230 GeV In normalization. F113/F21 CN COMMENT 87 γ Be \overline{E}_{γ} = 220 GeV EO $e^+e^-\approx \Upsilon(4S)$ MEG π^- 340 GeV 91 Photoproduction G $e^+e^-\approx 10$ GeV EO $e^+e^-\approx 10$ GeV EO $e^+e^-\approx 10$ GeV RX3 $e^+e^-\approx 3.77$ GeV RX2 $e^+e^-\approx 3.77$ GeV	$\begin{array}{c} \underline{VALUE} \\ \hline 0.023 + 0.008 \\ 0.023 + 0.008 \\ 0.008 \\ \hline 0.009 + 0.010 \\ 0.025 + 0.010 \\ 0.039 \pm 0.013 \pm 0.013 \\ 0.021 + 0.011 \\ 0.002 \pm 0.002 \\ \hline \\ \Gamma(K^0\overline{K^0})/\Gamma(K^+K^-) \\ \underline{VALUE} \\ \hline 0.29 + 0.09 \\ -0.08 \\ \hline 0.08 + 0.09 \\ 0.08 \\ \hline OK - \pi^+)/\Gamma(K^-\pi^+) \\ \underline{VALUE} \\ \hline 0.167 \pm 0.026 \\ \hline OUR FIT \\ \hline 0.167 \pm 0.026 \\ \hline OUR FIT \\ \hline 0.167 \pm 0.026 \\ \hline OUR FIT \\ \hline 0.167 \pm 0.026 \\ \hline OUR FIT \\ \hline 0.167 \pm 0.026 \\ \hline OUR FIT \\ \hline 0.167 \pm 0.026 \\ \hline OUR FIT \\ \hline OUR FUT \\ \hline OUR FIT \\ \hline OUR FUT $	FI A A DOC 65 CU nunicated includes 66 AN	RABETTI LEXANDER DOLUMENT ID JMALAT to us by the DOLUMENT ID Scale factor NJOS	94J E68' 90 CLE TECN 88 SPEC authors of 1.1. 91 E691	7 γBe \(\bar{e}\) O \(e^+e^-\) COMME COMME COMME γ Be 80	$F_{\gamma} = 220 \text{ G}$ $F_{10.5-11}$ F_{12} F_{13} F_{14} F_{15} $F_{$	5eV GeV 20/Γ119
$\frac{\sqrt{2}LUE}{0.0072 - 0.0035}$ 59 BARLAG 92C computes the binomial by $\frac{\sqrt{2}LUE}{\sqrt{2}}$	59 BARLAG 92C ACCM π ranching fraction using topological Pionic modes	Tomment C Cu 230 GeV In normalization. F113/F21 CN COMMENT 87 γ Be \overline{E}_{γ} = 220 GeV EO $e^+e^-\approx \gamma(45)$ AEG π^- 340 GeV 91 Photoproduction 19 $e^+e^-\approx 10$ GeV EO $e^+e^-= 10.5-11$ GeV RK3 $e^+e^-= 3.77$ GeV RK2 $e^+e^-= 3.77$ GeV F114/F21	$\begin{array}{c} \underline{VALUE} & \underline{EVTS} \\ \textbf{0.023} & + \textbf{0.008} \\ \textbf{0.023} & + \textbf{0.008} \\ \textbf{0.007} & \textbf{OUR FIT} \\ \textbf{0.025} & + \textbf{0.010} \\ \textbf{0.039} & + \textbf{0.013} \\ \textbf{0.039} & + \textbf{0.013} \\ \textbf{0.021} & + \textbf{0.011} \\ \textbf{0.001} & + \textbf{0.002} \\ \textbf{0.001} & + \textbf{0.002} \\ \textbf{5} \\ \hline & \Gamma(\textbf{K}^{\textbf{0}} \overline{\textbf{K}^{\textbf{0}}}) / \Gamma(\textbf{K}^{+} \textbf{K}^{-}) \\ \underline{VALUE} & \underline{EVTS} \\ \textbf{0.29} & + \textbf{0.03} \\ \textbf{0.09} & \textbf{OUR FIT} \\ \textbf{0.24} & + \textbf{0.16} \\ \textbf{4} \\ \textbf{65} & \textbf{Includes a correction comm} \\ & \Gamma(\textbf{K}^{\textbf{0}} \textbf{K}^{-} \pi^{+}) / \Gamma(\textbf{K}^{-} \pi^{+}) \\ \underline{VALUE} & \underline{\textbf{0.167} \pm \textbf{0.026}} & \textbf{OUR FIT} \\ \hline & \textbf{0.167} & \pm \textbf{0.026} & \textbf{OUR FIT} \\ \hline & \textbf{0.167} & \pm \textbf{0.026} & \textbf{OUR FIT} \\ \hline & \textbf{Error} \\ \hline \end{array}$	FI A A DOC 65 CU nunicated includes 66 AN	RABETTI LEXANDER DOLUMENT ID JMALAT to us by the DOLUMENT ID Scale factor NJOS	94J E68' 90 CLE TECN 88 SPEC authors of 1.1. 91 E691	7 γBe \(\bar{e}\) O \(e^+e^-\) COMME COMME COMME γ Be 80	$F_{\gamma} = 220 \text{ G}$ $F_{10.5-11}$ F_{12} F_{13} F_{14} F_{15} $F_{$	5eV GeV 20/Γ119
$\frac{\sqrt{2}LUE}{0.0072 - 0.0035}$ 59 BARLAG 92C computes the binomial by $\frac{\sqrt{2}LUE}{\sqrt{2}}$	59 BARLAG 92C ACCM π ranching fraction using topological — Pionic modes 77 FRABETTI 94C E68 127 SELEN 93 CLE 151 ADAMOVICH 92 OM 20 ANJOS 91D E66 157 ALBRECHT 90C AR 110 ALEXANDER 90 CLE 139 BALTRUSAIT85E MR ABRAMS 79D MR	Γ_{113}/Γ_{21} COMMENT 7 113/Γ21 EN COMMENT 87 γ Be \overline{E}_{γ} = 220 GeV EO $e^+e^-\approx \gamma(45)$ MEG π^- 340 GeV 91 Photoproduction Ge $e^+e^-\approx 10$ GeV EO $e^+e^-\approx 10$ GeV EO $e^+e^-\approx 10$ GeV RK2 e^+e^- 3.77 GeV RK2 e^+e^- 3.77 GeV Γ_{114}/Γ_{21}	$\begin{array}{c} \underline{VALUE} \\ \hline 0.023 + 0.008 \\ 0.023 + 0.008 \\ 0.008 \\ 0.009 \\ 0.009 \\ 0.013 \pm 0.013 \\ 0.021 + 0.011 \\ 0.001 \pm 0.002 \\ 0.001 \pm 0.002 \\ 0.001 + 0.011 \\ 0.002 \\ 0.001 \\ 0.002 \\ 0.$	FI A A DC 65 CU nunicated DC includes 66 AN of column	RABETTI LEXANDER DOLUMENT ID JMALAT to us by the DOLUMENT ID Scale factor NJOS	94J E68' 90 CLE TECN 88 SPEC authors of 1.1. 91 E691	7 γBe \(\bar{e}\) O \(e^+e^-\) COMME COMME COMME γ Be 80	$\bar{\epsilon}_{\gamma}$ =220 G $^{\circ}$ 10.5–11 $^{\circ}$ 12 $^{\circ}$ 800 GeV $^{\circ}$ XT 88. $^{\circ}$ 10–240 GeV $^{\circ}$ 1 be omitty	5eV GeV 20/Γ119 121/Γ2
$\frac{(\kappa L U E)}{(\kappa L U E)}$ 0.0072 $\frac{+0.0048}{-0.0035}$ 59 BARLAG 92C computes the bracket by $\frac{(\kappa L U E)}{(\kappa L U E)}$ 2.00396 ± 0.0027 OUR AVERAGE 0.043 ± 0.007 ± 0.003 1 0.0348 $\pm 0.0030 \pm 0.0023$ 2 0.048 $\pm 0.0030 \pm 0.008$ 1 0.055 ± 0.008 0.005 ± 0.008 0.055 ± 0.008 0.005 ± 0.005 1 0.040 ± 0.007 ± 0.006 0.050 ± 0.007 ± 0.006 0.033 ± 0.010 ± 0.006 0.033 ± 0.015	59 BARLAG 92C ACCM π ranching fraction using topological — Pionic modes 77 FRABETTI 94C E68 127 SELEN 93 CLE 151 ADAMOVICH 92 OM 20 ANJOS 91D E66 157 ALBRECHT 90C AR 110 ALEXANDER 90 CLE 139 BALTRUSAIT85E MR ABRAMS 79D MR	Tomment C Cu 230 GeV In normalization. F113/F21 CN COMMENT 87 γ Be \overline{E}_{γ} = 220 GeV EO $e^+e^-\approx \gamma(45)$ AEG π^- 340 GeV 91 Photoproduction 19 $e^+e^-\approx 10$ GeV EO $e^+e^-= 10.5-11$ GeV RK3 $e^+e^-= 3.77$ GeV RK2 $e^+e^-= 3.77$ GeV F114/F21	$\begin{array}{c} \underline{VALUE} & \underline{EVTS} \\ \textbf{0.023} + \textbf{0.008} & \textbf{OUR FIT} \\ \textbf{0.025} + \textbf{0.010} & \textbf{OUR AVERAGE} \\ \textbf{0.039} \pm \textbf{0.013} \pm \textbf{0.013} & \textbf{20} \\ \textbf{0.021} + \textbf{0.013} \pm \textbf{0.002} & \textbf{5} \\ \hline \Gamma(\textbf{K}^{\textbf{0}} \overline{\textbf{K}^{\textbf{0}}}) / \Gamma(\textbf{K}^{\textbf{+}} \textbf{K}^{\textbf{-}}) \\ \underline{VALUE} & \underline{EVTS} \\ \textbf{0.29} + \textbf{0.03} & \textbf{OUR FIT} \\ \textbf{0.24} \pm \textbf{0.16} & \textbf{4} \\ \textbf{65} & \text{Includes a correction comm} \\ \Gamma(\textbf{K}^{\textbf{0}} \textbf{K}^{\textbf{-}} \textbf{\pi}^{\textbf{+}}) / \Gamma(\textbf{K}^{\textbf{-}} \textbf{\pi}^{\textbf{+}}) \\ \underline{VALUE} & \textbf{0.167} \pm \textbf{0.026} & \textbf{OUR FIT} \\ \textbf{0.167} \pm \textbf{0.026} & \textbf{OUR FIT} \\ \textbf{0.167} \pm \textbf{0.006} \\ \textbf{66} & \text{The factor 100 at the top of } \\ \Gamma(\textbf{K}^{\textbf{0}} \textbf{K}^{\textbf{-}} \textbf{\pi}^{\textbf{+}}) / \Gamma(\overline{\textbf{K}^{\textbf{0}}} \textbf{\pi}^{\textbf{+}} \textbf{\pi}^{\textbf{-}}) \\ \Gamma(\textbf{K}^{\textbf{0}} \textbf{K}^{\textbf{-}} \textbf{\pi}^{\textbf{+}}) / \Gamma(\overline{\textbf{K}^{\textbf{0}}} \textbf{\pi}^{\textbf{+}} \textbf{\pi}^{\textbf{-}}) \end{array}$	65 CL nunicated includes 66 AN of column	RABETTI LEXANDER DOCUMENT ID JMALAT to us by the DOCUMENT ID scale factor NJOS n2 of Table I	94J E68' 90 CLE TECN 88 SPEC authors of TECN 91 E691 of ANJOS	7 γ Be $\overline{\ell}$ O e^+e^- COMME n N O- F CUMALA γ Be 86 91 should	$\tilde{\epsilon}_{\gamma}$ =220 G \cdot 10.5-11 \cdot 112 \cdot 12 \cdot 13 \cdot 15 \cdot 15 \cdot 16 \cdot 17 \cdot 17 \cdot 18 \cdot 17 \cdot 17 \cdot 17 \cdot 18 \cdot 17 \cdot 17 \cdot 18 \cdot 19	5eV GeV 20/Γ11: 121/Γ2:
$VALUE$ 0.0072 $^+$ 0.0048 0.0072 $^+$ 0.0035 59 BARLAG 92c computes the binomial of the properties o	59 BARLAG 92C ACCM π ranching fraction using topological — Pionic modes 77 FRABETTI 94C E68 127 SELEN 93 CLE 151 ADAMOVICH 92 OM 20 ANJOS 91D E66 157 ALBRECHT 90C AR 110 ALEXANDER 90 CLE 139 BALTRUSAIT85E MR ABRAMS 79D MR	Tomment To Cu 230 GeV In normalization. F113/F21 CN COMMENT 87 γ Be \overline{E}_{γ} = 220 GeV EO $e^+e^-\approx \gamma(4S)$ AEG π^- 340 GeV 19 Photoproduction 19 $e^+e^-\approx 10$ GeV EO e^+e^- 10.5–11 GeV RK3 e^+e^- 3.77 GeV RK3 e^+e^- 3.77 GeV F114/F21 F114/F21 F114/F21 F114/F21	$\begin{array}{c} \underline{VALUE} \\ \hline 0.023 + 0.008 \\ 0.023 + 0.008 \\ 0.008 \\ 0.009 \\ 0.009 \\ 0.013 \pm 0.013 \\ 0.021 + 0.011 \\ 0.001 \pm 0.002 \\ 0.001 \pm 0.002 \\ 0.001 + 0.011 \\ 0.002 \\ 0.001 \\ 0.002 \\ 0.$	65 CUnunicated includes 66 An of column	RABETTI LEXANDER DOLUMENT ID SCALE FACTOR DOLUMENT ID SCALE FACTOR DOLUMENT ID DOLUMENT ID	94J E68' 90 CLE TECN 88 SPEC authors of 1.1. 91 E691 of ANJOS	7 γBe \(\bar{e}\) O \(e^+e^-\) COMME COMME COMME γ Be 80	$\tilde{\epsilon}_{\gamma}$ =220 G \cdot 10.5-11 \cdot 112 \cdot 12 \cdot 13 \cdot 15 \cdot 15 \cdot 16 \cdot 17 \cdot 17 \cdot 18 \cdot 17 \cdot 17 \cdot 17 \cdot 18 \cdot 17 \cdot 17 \cdot 18 \cdot 19	5eV GeV 20/Γ11: 121/Γ2:
20.0072 $^{+}$ 0.0048 59 BARLAG 92c computes the binomial of the properties of the	59 BARLAG 92C ACCM π ranching fraction using topological — Pionic modes 775	Tomment To Cu 230 GeV In normalization. Fig. 7 Be $\overline{E}_{\gamma} = 220$ GeV EO $e^+e^- \approx \Upsilon(45)$ HEG π^- 340 GeV 19 Photoproduction 19 $e^+e^- \approx 10$ GeV EO e^+e^- 10.5–11 GeV RK3 e^+e^- 3.77 GeV RK2 e^+e^- 3.77 GeV Fig. 7 GeV	$\begin{array}{c} \underline{VALUE} & \underline{EVTS} \\ 0.023 + 0.008 \\ 0.008 & \text{OUR FIT} \\ \hline 0.025 + 0.010 \\ 0.008 & \text{OUR AVERAGE} \\ 0.039 \pm 0.013 \pm 0.013 & 20 \\ 0.021 + 0.013 \\ 0.008 \pm 0.002 & 5 \\ \hline \Gamma(K^0\overline{K^0})/\Gamma(K^+K^-) \\ \underline{VALUE} & \underline{EVTS} \\ 0.29 + 0.09 \\ -0.08 & \text{OUR FIT} \\ 0.24 \pm 0.16 & 4 \\ 65 & \text{Includes a correction comm} \\ \hline \Gamma(K^0K^-\pi^+)/\Gamma(K^-\pi^+) \\ \underline{VALUE} \\ \hline 0.167 \pm 0.026 & \text{OUR FIT} \\ 0.16 \pm 0.06 \\ 66 & \text{The factor 100 at the top C} \\ \hline \Gamma(K^0K^-\pi^+)/\Gamma(\overline{K^0}\pi^+\pi^-) \\ \underline{VALUE} & \underline{EVTS} \\ \hline C(K^0K^-\pi^+)/\Gamma(\overline{K^0}\pi^+\pi^-) \\ \underline{VALUE} & \underline{EVTS} \\ \underline{EVTS} \\ \hline \end{array}$	65 CL nunicated includes 66 AN of column	RABETTI LEXANDER DOLUMENT ID JMALAT to us by the scale factor NJOS 12 of Table I	94J E68' 90 CLE TECN 88 SPEC authors of TECN 91 E691 of ANJOS	7 YBe \overline{t} O e ⁺ e ⁻ COMME TOUMALA YBE 80 91 should	$\tilde{\epsilon}_{\gamma}$ =220 G \cdot 10.5-11 \cdot 112 \cdot 12 \cdot 13 \cdot 15 \cdot 15 \cdot 16 \cdot 17 \cdot 17 \cdot 18 \cdot 17 \cdot 17 \cdot 17 \cdot 18 \cdot 17 \cdot 17 \cdot 18 \cdot 19	GeV GeV 20/Γ11 121/Γ2
2.0072 $^{+}$ 0.0048 2.0072 $^{+}$ 0.0035 59 BARLAG 92C computes the branch of the second of the s	59 BARLAG 92C ACCM # Franching fraction using topological Pionic modes TS DOCUMENT ID TECN 77 FRABETTI 94C E68 127 SELEN 93 CLE 127 SELEN 93 CLE 128 ADAMOVICH 92 OM 129 ANJOS 91D E66 130 ALBRECHT 90C AR 131 ALBRANDER 90 CLE 132 BALTRUSAIT85E MR 133 BALTRUSAIT85E MR 134 ABRAMS 79D MR DOCUMENT ID TECN CLE 135 SELEN 93 CLEO e	Γ_{113}/Γ_{21} COMMENT For County 230 GeV In normalization. Fig. 13/Γ21 COMMENT 87 γ Be $\overline{E}_{\gamma} = 220$ GeV EO $e^+e^- \approx \Upsilon(45)$ AEG π^- 340 GeV 91 Photoproduction Ge $e^+e^- \approx 10$ GeV EO e^+e^- 10.5–11 GeV RK2 e^+e^- 3.77 GeV RK2 e^+e^- 3.77 GeV Fig. 114/Γ21 COMMENT Fig. 115/Γ	$\begin{array}{c} \underline{VALUE} & \underline{EVTS} \\ 0.023 + 0.008 \\ 0.008 & \text{OUR FIT} \\ \hline \\ 0.025 + 0.018 \\ 0.008 & \text{OUR AVERAGE} \\ 0.039 \pm 0.013 \pm 0.013 & 20 \\ 0.021 + 0.018 \\ -0.008 \pm 0.002 & 5 \\ \hline \\ \Gamma(K^0\overline{K^0})/\Gamma(K^+K^-) \\ \underline{VALUE} & \underline{EVTS} \\ 0.29 + 0.09 \\ -0.08 & \text{OUR FIT} \\ 0.24 \pm 0.16 & 4 \\ 65 & \text{Includes a correction comm} \\ \hline \\ \Gamma(K^0K^-\pi^+)/\Gamma(K^-\pi^+) \\ \underline{VALUE} \\ 0.167 \pm 0.026 & \text{OUR FIT} \\ \hline 0.16 & \pm 0.06 \\ 66 & \text{The factor 100 at the top of} \\ \hline \\ \Gamma(K^0K^-\pi^+)/\Gamma(\overline{K^0}\pi^+\pi^-) \\ \underline{VALUE} \\ 0.119 \pm 0.018 & \text{OUR FIT} \\ \underline{EVTS} \\$	65 CU nunicated includes 66 AN of column	RABETTI LEXANDER DOLUMENT ID JMALAT to us by the scale factor NJOS 12 of Table I	94J E68' 90 CLE TECN 88 SPEC authors of TECN 91 E691 of ANJOS	7 γ Be \overline{k} O e^+e^- COMME nNO^- CUMALA γ Be 88 91 should	$rac{1}{2} \gamma = 220 \text{ G}$ $rac{1}{2} 0.5 - 11$ ra	GeV GeV 121/\(\Gamma_2\)
20.0072 $^{+}$ 0.0048 59 BARLAG 92c computes the bias of the properties of the pro	59 BARLAG 92C ACCM π ranching fraction using topological Pionic modes 77 FRABETTI 94C E68 127 SELEN 93 CLE 151 ADAMOVICH 92 OM 120 ANJOS 91D E66 157 ALBRECHT 90 CLE 158 ABRAMS 79D MR 159 BALTRUSAIT85E MR 159 ABRAMS 79D MR 150 ABRAMS 79D MR	Γ_{113}/Γ_{21} COMMENT 7	$\begin{array}{c} \underline{VALUE} & \underline{EVTS} \\ 0.023 + 0.008 & \text{OUR FIT} \\ 0.025 + 0.010 & \text{OUR AVERAGE} \\ 0.039 \pm 0.013 \pm 0.013 & 20 \\ 0.021 + 0.011 \pm 0.002 & 5 \\ \hline \Gamma(K^0\overline{K}^0)/\Gamma(K^+K^-) & \underline{EVTS} \\ 0.29 + 0.09 & \text{OUR FIT} \\ 0.29 + 0.08 & \text{OUR FIT} \\ 0.24 \pm 0.16 & 4 \\ 65 & \text{Includes a correction comm} \\ \hline \Gamma(K^0K^-\pi^+)/\Gamma(K^-\pi^+) & \underline{VALUE} \\ 0.167 \pm 0.026 & \text{OUR FIT} & \text{Error} \\ 0.16 & \pm 0.06 & 66 & \text{The factor 100 at the top of} \\ \hline \Gamma(K^0K^-\pi^+)/\Gamma(\overline{K}^0\pi^+\pi^-) & \underline{EVTS} \\ 0.119 \pm 0.018 & \text{OUR FIT} & \underline{EVTS} \\ 0.119 \pm 0.018 & \text{OUR FIT} & \underline{EVTS} \\ 0.119 \pm 0.021 & \text{OUR AVERAGE} \\ \end{array}$	65 CL nunicated includes 66 AN of column	RABETTI LEXANDER DOCUMENT ID SCALE FACTOR SCALE FACTOR DOCUMENT ID SCALE FACTOR COLUMENT ID SCALE FACTOR COLUMENT ID SCALE FACTOR COLUMENT ID COLUMENT	94.J E68' 90 CLE TECN 88 SPEC authors of 1.1. 91 E691 of ANJOS TECN TECN TECN TECN TECN TECN TECN TEC	7 γ Be $\overline{\ell}$ O e^+e^- COMME COMME γ Be 80 91 should COMME 3. ρ	$\tilde{\Gamma}_{\gamma}$ =220 G Γ_{γ} =220 G Γ_{γ} =220 G Γ_{γ} =220 G Γ_{γ} =240 GeV	GeV GeV 220/Γ111 121/Γ2:
$VALUE$ 0.0072 $^{+}$ 0.0048 59 BARLAG 92c computes the binomial by the properties of the properties	59 BARLAG 92C ACCM π ranching fraction using topological Pionic modes 77 FRABETTI 94C E68 127 SELEN 93 CLE 151 ADAMOVICH 92 OM 120 ANJOS 91D E66 157 ALBRECHT 90 CLE 158 ABRAMS 79D MR 159 BALTRUSAIT85E MR 159 ABRAMS 79D MR 150 ABRAMS 79D MR	Γ_{113}/Γ_{21} COMMENT For County 230 GeV In normalization. Fig. 13/Γ21 COMMENT 87 γ Be $\overline{E}_{\gamma} = 220$ GeV EO $e^+e^- \approx \Upsilon(45)$ AEG π^- 340 GeV 91 Photoproduction Ge $e^+e^- \approx 10$ GeV EO e^+e^- 10.5–11 GeV RK2 e^+e^- 3.77 GeV RK2 e^+e^- 3.77 GeV Fig. 114/Γ21 COMMENT Fig. 115/Γ	$\begin{array}{c} \underline{VALUE} \\ 0.023 + 0.008 \\ 0.003 + 0.008 \\ 0.008 \\ 0.009 + 0.010 \\ 0.025 + 0.010 \\ 0.039 \pm 0.013 \pm 0.013 \\ 0.021 + 0.011 \\ 0.001 \pm 0.002 \\ 0.001 + 0.011 \\ 0.001 \pm 0.002 \\ 0.001 + 0.001 \\ 0.001 \pm 0.002 \\ 0.001 + 0.001 \\ 0.001 \pm 0.002 \\ 0.001 + 0.001 \\ 0.001 + 0.00$	65 CU nunicated includes 66 AN of column	RABETTI LEXANDER DOUMENT ID SCALE Factor NJOS 12 of Table I DOUMENT ID SCALE Factor Scale factor Scale factor Scale factor Cludes Scale MMAR	94J E68' 90 CLE TECN 88 SPEC authors of 1.1. 91 E691 of ANJOS 1.1. factor of 1 1.1 factor of 1 1.1 91 CLEC	7 γ Be $\overline{\ell}$ O e^+e^- COMME COMME γ Be 80 91 should COMME 3. ρ	$\tilde{\epsilon}_{\gamma}$ =220 G $^{\circ}$ 10.5-11 $^{\circ}$ 12 $^{\circ}$ 800 GeV $^{\circ}$ XT 88. $^{\circ}$ 10-240 GeV $^{\circ}$ 1 be omitted $^{\circ}$ \approx 10.5 G \approx 10 GeV	GeV GeV 121/\(\Gamma_2\)
$(R_{1} + R_{1} + R_{2}) = \frac{1}{10000000000000000000000000000000000$	59 BARLAG 92C ACCM π ranching fraction using topological Pionic modes 77 FRABETTI 94C E68 127 SELEN 93 CLE 151 ADAMOVICH 92 OM 120 ANJOS 91D E66 157 ALBRECHT 90 CLE 158 ABRAMS 79D MR 159 BALTRUSAIT85E MR 159 ABRAMS 79D MR 150 ABRAMS 79D MR	Tomment To Cu 230 GeV Il normalization. Fig. 13/F21 CN COMMENT 87 γ Be $\overline{E}_{\gamma} = 220$ GeV EQ $e^+e^- \approx \gamma(4S)$ AEG π^- 340 GeV 91 Photoproduction Ge $e^+e^- \approx 10$ GeV EQ e^+e^- 10.5-11 GeV RK3 e^+e^- 3.77 GeV RK2 e^+e^- 3.77 GeV Til4/F21 COMMENT $e^+e^- \approx \gamma(4S)$ Fig. 115/F COMMENT To Cu 230 GeV	$\begin{array}{c} \underline{VALUE} \\ 0.023 + 0.008 \\ 0.008 \\ 0.008 \\ 0.008 \\ 0.008 \\ 0.008 \\ 0.013 \pm 0.013 \\ 0.021 + 0.013 \\ 0.021 + 0.013 \\ 0.001 \pm 0.002 \\ 0.001 \pm 0.002 \\ 0.008 \\ 0.009 \\ 0.00$	65 CL nunicated includes 66 AN of column	RABETTI LEXANDER DOCUMENT ID SCALE FACTOR DOCUMENT ID SCALE FACTOR SCALE FACTOR SCALE FACTOR MAR BRECHT	94J E68' 90 CLE TECN 88 SPEC authors of 1.1. 91 E691 of ANJOS TECN 71 TECN 72 TECN 73 TECN 74 TECN 75 1.1. 76 T.1. 76 T.1. 77 TECN 78	7 γ Be $\overline{\ell}$ O e^+e^- COMME COMME γ Be 80 91 should COMME 3. ρ	$\tilde{\epsilon}_{\gamma}$ =220 G $^{\circ}$ 10.5-11 $^{\circ}$ 12 $^{\circ}$ 800 GeV $^{\circ}$ XT 88. $^{\circ}$ 10-240 GeV $^{\circ}$ 1 be omitted $^{\circ}$ \approx 10.5 G \approx 10 GeV	GeV GeV 121/\(\Gamma_2\)
20.0072 $^{+}$ 0.0048 59 BARLAG 92c computes the bias of the properties of the pro	59 BARLAG 92C ACCM π ranching fraction using topological — Pionic modes 77 FRABETTI 94C E68 127 SELEN 93 CLE 127 SELEN 93 CLE 128 ADAMOVICH 92 OM 129 ANJOS 91D E69 139 BALTRUSAIT85E MR 139 ABRAMS 79D MR 139 BALTRUSAIT85E MR 140 ABRAMS 79D MR 150 ABRAMS 79D	Tomment To Cu 230 GeV In normalization. Fig. 7 Be $\overline{E}_{\gamma} = 220$ GeV EO $e^+e^- \approx \Upsilon(4S)$ AEG $\pi^- 340$ GeV Photoproduction EG $e^+e^- \approx 10$ GeV EO $e^+e^- \approx 10$ GeV EO $e^+e^- \approx 10$ GeV EO $e^+e^- \approx 10$ GeV EXAS $e^+e^- \approx 10$ GeV FILA $e^+e^- \approx 10$ GeV	$\begin{array}{c} \underline{VALUE} \\ 0.023 + 0.008 \\ 0.003 + 0.008 \\ 0.008 \\ 0.009 + 0.010 \\ 0.025 + 0.010 \\ 0.039 \pm 0.013 \pm 0.013 \\ 0.021 + 0.011 \\ 0.001 \pm 0.002 \\ 0.001 + 0.011 \\ 0.001 \pm 0.002 \\ 0.001 + 0.001 \\ 0.001 \pm 0.002 \\ 0.001 + 0.001 \\ 0.001 \pm 0.002 \\ 0.001 + 0.001 \\ 0.001 + 0.00$	$\frac{DC}{65}$ Cununicated includes $\frac{DC}{66}$ Anof column $\frac{DC}{66}$ Error in All	RABETTI LEXANDER DOUMENT ID JMALAT to us by the scale factor NJOS n2 of Table I DOUMENT ID scale factor rolludes scale MMAR BRECHT	94.J E68: 90 CLE TECN 88 SPEC authors of 1.1. 91 E691 of ANJOS TECN TECN 1 TECN 1 TECN 1 TECN 1 TECN 1 TECN 2 TECN 2 TECN 2 TECN 2 TECN 3 TECN 4 TECN 4 TECN 5 TECN 5 TECN 6 TECN	7 γ Be $\overline{\ell}$ O e^+e^- COMME COMME COMME γ Be 80 91 should COMME COMME γ Be	F_{γ} = 220 G F_{γ} = 220	GeV GeV 1121/Γ2:
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20.0072 $^{+}$ 0.0048 59 BARLAG 92C computes the bias of the properties of the pro	59 BARLAG 92C ACCM π ranching fraction using topological Pionic modes 77 FRABETTI 94C E68 27 SELEN 93 CLE 51 ADAMOVICH 92 OM ANJOS 91D E69 57 ALBRECHT 90C AR ABRAMS 79D MR DOCUMENT ID TECN C Error includes scale factor of 2.7. 60 BARLAG 92C ACCM π 61 BALTRUSAIT85E MRK3 e ranching fraction using topological range party explain the unexpected vents are consistent with ρ0 π0. POCUMENT ID TECN C Error includes scale factor of 2.7. 61 BALTRUSAIT85E MRK3 e ranching fraction using topological range party explain the unexpected vents are consistent with ρ0 π0. FRABETTI 95C E687 ADAMOVICH 92 OMEG	Tomment To Cu 230 GeV In normalization. Fig. 21 To Comment T	0.023 $^{+0.008}_{-0.007}$ OUR FIT 0.025 $^{+0.010}_{-0.008}$ OUR AVERAGE 0.039 $^{+0.013}_{-0.008}$ ± 0.002 5 Γ($K^{0}\overline{K}^{0}$)/Γ($K^{+}K^{-}$) VALUE 0.29 $^{+0.09}_{-0.08}$ OUR FIT 0.24 $^{+0.01}_{-0.08}$ OUR FIT 0.24 $^{+0.09}_{-0.08}$ OUR FIT 0.167 $^{+0.09}_{-0.08}$ OUR FIT Error 0.167 $^{+0.09}_{-0.08}$ OUR FIT Error 0.16 $^{+0.06}_{-0.08}$ OUR FIT Error 0.16 $^{+0.06}_{-0.08}$ EVTS 0.119 $^{+0.09}_{-0.08}$ OUR FIT Error 0.119 $^{+0.026}_{-0.08}$ OUR FIT Error 0.119 $^{+0.021}_{-0.018}$ OUR FIT Error 0.119 $^{+0.021}_{-0.018}$ OUR AVERAGE 0.108 $^{+0.019}_{-0.019}$ 61 0.16 $^{+0.03}_{-0.019}$ 61 0.16 $^{+0.03}_{-0.019}$ 61 0.16 $^{+0.03}_{-0.019}$ 61 0.17 $^{+0.03}_{-0.019}$ 61 0.18 $^{+0.09}_{-0.019}$ 61 0.19 $^{+0.09}_{-0.019}$ 61 0.19 $^{+0.09}_{-0.019}$ 61 0.19 $^{+0.09}_{-0.019}$ 77 Unseen decay modes of t VALUE • • • We do not use the follow 0.00 $^{+0.03}_{-0.00}$ 67 The factor 100 at the top of $^{+0.03}_{-0.00}$ 67 The factor 100 at the top of $^{+0.03}_{-0.00}$ 100 at the top of $^{+0.03}_{-0.00}$ 67 The factor 100 at the top of $^{+0.03}_{-0.00}$ 100 at the top of $^{+0.03}_{-0.00}$ 67 The factor 100 at the top of $^{+0.03}_{-0.00}$ 67 The factor 100 at the top of $^{+0.03}_{-0.00}$ 67 The factor 100 at the top of $^{+0.03}_{-0.00}$ 67 The factor 100 at the top of $^{+0.03}_{-0.00}$ 67 The factor 100 at the top of $^{+0.03}_{-0.00}$ 67 The factor 100 at the top of $^{+0.03}_{-0.00}$ 67 The factor 100 at the top of $^{+0.03}_{-0.00}$ 67 The factor 100 at the top of $^{+0.03}_{-0.00}$ 67 The factor 100 at the top of $^{+0.03}_{-0.00}$ 100 at the top of $^{+0.03}_{-0.$	$\frac{DC}{65}$ CL nunicated $\frac{DC}{66}$ An of column Al. $\frac{DC}{K}$ wing data $\frac{DC}{67}$ An of column $\frac{DC}{67}$ wing data $\frac{DC}{67}$ wing the $\frac{DC}{67}$ of the $\frac{DC}{67}$ the $\frac{DC}{67}$ of the DC	RABETTI LEXANDER DOLUMENT ID SUMALAT To us by the DOLUMENT ID SCALE factor SUJOS 12 of Table I DOLUMENT ID SCALE FACTOR SCALE SPECHT SPECH	94J E68' 90 CLE TECN 88 SPEC authors of 1.1. 91 E691 of ANJOS TECN 1 TECN 90 ARG 1 TECN 2 TECN 2 TECN 2 TECN 2 TECN 3 TECN 3 TECN 3 TECN 3 TECN 4 TECN 5 TECN 6 TECN	7 γ Be $\overline{\ell}$ O e^+e^- COMME n N O- CUMALA γ Be 80 91 should n So $e^+e^ e^+e^ n$ So $e^+e^ $	Fig. 10.5 of r_1 and r_2 of r_3 of r_4 of r_4 of r_5	GeV 220/Γ111 / Ced
20.0072 $^{+}$ 0.0048 0.0072 $^{+}$ 0.0035 59 BARLAG 92c computes the binomial of the following of the fol	SP BARLAG 92C ACCM π ranching fraction using topological Pionic modes	TII3/ Γ_{21} CN 230 GeV In normalization. F113/ Γ_{21} CN COMMENT 87 γ Be $\overline{E}_{\gamma} = 220$ GeV EO $e^+e^- \approx \gamma(4S)$ AEG π^- 340 GeV 19 Photoproduction 10 $e^+e^- \approx 10$ GeV EO e^+e^- 10.5–11 GeV RK3 e^+e^- 3.77 GeV TI14/ Γ_{21} COMMENT F- Cu 230 GeV The Comment Provided The C	0.023 $+ 0.008$ OUR FIT 0.025 $+ 0.010$ OUR AVERAGE 0.039 $\pm 0.013 \pm 0.013$ 20 0.021 $+ 0.011$ ± 0.002 5 $\Gamma(K^0K^0)/\Gamma(K^+K^-)$ MALUE 0.29 $+ 0.03$ OUR FIT 0.24 ± 0.16 4 65 Includes a correction comm $\Gamma(K^0K^-\pi^+)/\Gamma(K^-\pi^+)$ MALUE 0.167 ± 0.026 OUR FIT Error 0.16 ± 0.06 66 The factor 100 at the top of ± 0.06 1.19 ± 0.018 OUR FIT Error 0.19 ± 0.018 OUR FIT Error 0.19 ± 0.021 OUR AVERAGE 0.108 ± 0.019 0.16 ± 0.03 0.17 $+ 0.03$ 0.18 ± 0.019 0.19 $+ 0.03$ 0.19 $+ 0.03$ 0.10 $+ 0.03$ 0.10 $+ 0.03$ 0.10 $+ 0.03$ 67 The factor 100 at the top of ± 0.03 67 The factor 100 at the top of ± 0.03 10 ± 0.03 67 The factor 100 at the top of ± 0.03 10 ± 0.03 11 ± 0.03 12 ± 0.03 13 ± 0.03 14 ± 0.03 15 ± 0.03 16 ± 0.03 17 ± 0.03 17 ± 0.03 18 ± 0.03 19 ± 0.03 10 ± 0.03 10 ± 0.03 10 ± 0.03 11 ± 0.03 12 ± 0.03 13 ± 0.03 14 ± 0.03 15 ± 0.03 16 ± 0.03 17 ± 0.03 18 ± 0.03 19 ± 0.03 10 ± 0.03 11 ± 0.03 12 ± 0.03 13 ± 0.03 14 ± 0.03 15 ± 0.03 16 ± 0.03 17 ± 0.03 18 ± 0.03 19 ± 0.03 10 $\pm 0.$	$\frac{DC}{65}$ CL nunicated $\frac{DC}{66}$ includes $\frac{DC}{66}$ includes $\frac{DC}{66}$ includes $\frac{DC}{66}$ wing data $\frac{DC}{67}$ wing data $\frac{DC}{67}$ the $\frac{DC}{67}$ includes $\frac{DC}{67}$ wing $\frac{DC}{67}$ includes $\frac{DC}{67}$ wing $\frac{DC}{67}$ includes $\frac{DC}{67}$ wing $\frac{DC}{67}$ includes $\frac{DC}{67}$ wing $\frac{DC}{67}$ includes \frac	RABETTI LEXANDER DOLUMENT ID SCALE FACTOR	94J E68' 90 CLE TECN 88 SPEC authors of 1.1. 91 E691 of ANJOS TECN 1 TECN	7 γ Be \overline{k} O e^+e^- COMME i	F_{γ} = 220 G F_{γ} = 220 G F_{γ} = 220 G F_{γ} = 220 GeV F_{γ} = 300 GeV F_{γ}	GeV GeV 121/\(\Gamma_2\) Ged. GeV V ted.
2.0072 $+$ 0.0048 0.0072 $+$ 0.0048 59 BARLAG 92c computes the binder of the binde	59 BARLAG 92C ACCM π ranching fraction using topological — Pionic modes 775	The comment of the c	0.023 $+ 0.008$ OUR FIT 0.025 $+ 0.010$ OUR AVERAGE 0.039 $\pm 0.013 \pm 0.013$ 20 0.021 $+ 0.011 \pm 0.002$ 5 $\Gamma(K^0\overline{K}^0)/\Gamma(K^+K^-)$ MALUE 0.29 $+ 0.09$ OUR FIT 0.24 ± 0.16 4 65 Includes a correction comm $\Gamma(K^0K^-\pi^+)/\Gamma(K^-\pi^+)$ MALUE 0.167 ± 0.026 OUR FIT Error 0.16 ± 0.06 66 The factor 100 at the top of the factor 100 at th	$\frac{DC}{65}$ CUnunicated includes 66 AN of column AL H) the \overline{K}^* (8 $\frac{DC}{65}$ wing data 67 AN of column π π π the \overline{K}^* (8 $\frac{DC}{65}$ AN π π π π π π	RABETTI LEXANDER DOLUMENT ID SCALE FACTOR	94J E68' 90 CLE TECN 88 SPEC authors of 1.1. 91 E691 of ANJOS TECN 1 TECN 1 TECN 1 TECN 1 TECN 1 TECN 1 TECN 2 TECN 2 TECN 3 TECN 3 TECN 4 TECN 4 TECN 4 TECN 5 TECN 5 TECN 6 TECN 6 TECN 6 TECN 6 TECN 6 TECN 7	7 γ Be \overline{k} O e^+e^- COMME γ Be 80 91 should γ Be 81 91 should γ Be 81 91 should	F_{γ} = 220 G F_{γ}	GeV GeV 121/\(\Gamma_2\) Ged. 121/\(\Gamma_2\) GeV V ted.
24.00 $\frac{1}{2}$.0072 $\frac{1}{2}$.0048 $\frac{1}{2}$.0072 $\frac{1}{2}$.0035 $\frac{1}{2}$.0072 $\frac{1}{2}$.0035 $\frac{1}{2}$.0036 $\frac{1}{2}$.0036 $\frac{1}{2}$.0036 $\frac{1}{2}$.00396 $\frac{1}{2}$.0037 $\frac{1}{2}$.0038 $\frac{1}{2}$.0039 $\frac{1}{2}$.0039 $\frac{1}{2}$.0030 $\frac{1}{2}$.0030 $\frac{1}{2}$.0048 $\frac{1}{2}$.0030 $\frac{1}{2}$.005 $\frac{1}{2}$.005 $\frac{1}{2}$.006 $\frac{1}{2}$.005 $\frac{1}{2}$.006 $\frac{1}{2}$.007 $\frac{1}{2}$.006 $\frac{1}{2}$.007 $\frac{1}{2}$.006 $\frac{1}{2}$.007 $\frac{1}{2}$.006 $\frac{1}{2}$.007 $\frac{1}{2}$.007 $\frac{1}{2}$.007 $\frac{1}{2}$.008 $\frac{1}{2}$.009 $\frac{1}{2}$	59 BARLAG 92C ACCM π ranching fraction using topological — Pionic modes 77 FRABETTI 94C E68 77 FRABETTI 94C E68 78 SELEN 93 CLE 10 ADAMOVICH 92 OM 20 ANJOS 91D E66 11 ADAMOVICH 92 OM 21 ALEXANDER 90 CLE 239 BALTRUSAIT85E MR ABRAMS 79D MR 10 ALEXANDER 90 CLE 24 SELEN 93 CLEO e 15 ALBRECHT 90C AR 25 ALBRECHT 90C AR 26 BALTRUSAIT85E MR ABRAMS 79D MR 16 BALTRUSAIT85E MR 26 BALTRUSAIT85E MR 27 CLEO e 17 CLEO CLEO 28 CLEO e 18 ALTRUSAIT85E MR 29 CACCM π 20 BARLAG 92C ACCM π 21 BALTRUSAIT85E MR 21 BALTRUSAIT85E MR 21 BALTRUSAIT85E MR 22 CACCM π 25 CLEO e 26 BARLAG 92C ACCM π 26 BARLAG 92C ACCM π 26 BARLAG 92C ACCM π 27 CLEO CLEO 28 CACCM π 29 CACCM π 29 CACCM π 29 CACCM π 20 CLEO CLEO 29 CACCM π 20 CLEO CLEO 20	The comment of the c	0.023 $+ 0.008$ OUR FIT 0.025 $+ 0.010$ OUR AVERAGE 0.039 $\pm 0.013 \pm 0.013$ 20 0.021 $+ 0.011$ ± 0.002 5 $\Gamma(K^0K^0)/\Gamma(K^+K^-)$ MALUE 0.29 $+ 0.03$ OUR FIT 0.24 ± 0.16 4 65 Includes a correction comm $\Gamma(K^0K^-\pi^+)/\Gamma(K^-\pi^+)$ MALUE 0.167 ± 0.026 OUR FIT Error 0.16 ± 0.06 66 The factor 100 at the top of ± 0.06 1.19 ± 0.018 OUR FIT Error 0.19 ± 0.018 OUR FIT Error 0.19 ± 0.021 OUR AVERAGE 0.108 ± 0.019 0.16 ± 0.03 0.17 $+ 0.03$ 0.18 ± 0.019 0.19 $+ 0.03$ 0.19 $+ 0.03$ 0.10 $+ 0.03$ 0.10 $+ 0.03$ 0.10 $+ 0.03$ 67 The factor 100 at the top of ± 0.03 67 The factor 100 at the top of ± 0.03 10 ± 0.03 67 The factor 100 at the top of ± 0.03 10 ± 0.03 11 ± 0.03 12 ± 0.03 13 ± 0.03 14 ± 0.03 15 ± 0.03 16 ± 0.03 17 ± 0.03 17 ± 0.03 18 ± 0.03 19 ± 0.03 10 ± 0.03 10 ± 0.03 10 ± 0.03 11 ± 0.03 12 ± 0.03 13 ± 0.03 14 ± 0.03 15 ± 0.03 16 ± 0.03 17 ± 0.03 18 ± 0.03 19 ± 0.03 10 ± 0.03 11 ± 0.03 12 ± 0.03 13 ± 0.03 14 ± 0.03 15 ± 0.03 16 ± 0.03 17 ± 0.03 18 ± 0.03 19 ± 0.03 10 $\pm 0.$	$\frac{DC}{65}$ CUnunicated includes 66 AN of column AL H) the \overline{K}^* (8 $\frac{DC}{65}$ wing data 67 AN of column π π π the \overline{K}^* (8 $\frac{DC}{65}$ AN π π π π π π	RABETTI LEXANDER DOLUMENT ID SCALE FACTOR	94J E68' 90 CLE TECN 88 SPEC authors of 1.1. 91 E691 of ANJOS TECN 1 TECN 1 TECN 1 TECN 1 TECN 1 TECN 1 TECN 2 TECN 2 TECN 3 TECN 3 TECN 4 TECN 4 TECN 4 TECN 5 TECN 5 TECN 6 TECN 6 TECN 6 TECN 6 TECN 6 TECN 7	7 γ Be \overline{k} O e^+e^- COMME $nN = 0$ COMME γ Be 80 91 should $n = 0$	F_{γ} = 220 G F_{γ}	GeV 20/\(\Gamma_{11}\)/\(\Gamma_{22}\)/\(\Gamm

 D^0

$\Gamma(K^*(892)^+K^-)/\Gamma(K^-\pi^+)$ Γ_{141}/Γ_{21} Unseen decay modes of the $K^*(892)^+$ are included.	$\Gamma(\phi\pi^+\pi^-)/\Gamma(K^-\pi^+\pi^+\pi^-)$
0.090±0.020 OUR FIT	VALUE EVTS DOCUMENT ID TECN COMMENT 0.014 ±0.004 OUR AVERAGE Error includes scale factor of 1.5. See the ideogram
0.16 +0.08 68 ANJOS 91 E691 γ Be 80-240 GeV	below. 0.011 ± 0.003 FRABETTI 95C E687 γ Be, $\overline{E}_{\gamma} \approx$ 200 GeV
68 The factor 100 at the top of column 2 of Table I of ANJOS 91 should be omitted.	0.020 \pm 0.006 \pm 0.005 28 ALBRECHT 94 ARG $e^+e^-\stackrel{*}{\approx}$ 10 GeV 0.024 \pm 0.006 34 ⁷⁴ AMMAR 91 CLEO $e^+e^-\approx$ 10.5 GeV
$\Gamma(K^*(892)^+K^-)/\Gamma(\overline{K^0}\pi^+\pi^-)$ Unseen decay modes of the $K^*(892)^+$ are included.	 • • We do not use the following data for averages, fits, limits, etc.
VALUE EVTS DOCUMENT ID TECN COMMENT 0.064 ± 0.014 OUR FIT Error includes scale factor of 1.1.	0.0076 + 0.0066 3 ANJOS 91 E691 γBe 80-240 GeV
0.058±0.014 OUR AVERAGE	74 AMMAR 91 measures $\phi \rho^0$, but notes that $\phi \rho^0$ dominates $\phi \pi^+ \pi^-$. We put the measurement here to keep from having more $\phi \rho^0$ than $\phi \pi^+ \pi^-$.
0.064 \pm 0.018 23 AMMAR 91 CLEO $e^+e^-\approx 10.5 \text{ GeV}$ 0.05 \pm 0.02 \pm 0.01 15 ALBRECHT 90C ARG $e^+e^-\approx 10 \text{ GeV}$	WEIGHTED AVERAGE
$\Gamma(K^0 K^- \pi^+ \text{nonresonant})/\Gamma(K^- \pi^+)$ Γ_{124}/Γ_{21}	0.014±0.004 (Error scaled by 1.5)
VALUE DOCUMENT ID TECN COMMENT 0.06±0.06 69 ANJOS 91 E691 γ Be 80-240 GeV	
$^{69}\mathrm{The}$ factor 100 at the top of column 2 of Table I of ANJOS 91 should be omitted.	
$\Gamma(\overline{K}^0 K^+ \pi^-)/\Gamma(K^- \pi^+)$ Γ_{125}/Γ_{21}	
VALUE DOCUMENT ID TECN COMMENT 0.129±0.025 OUR FIT	
0.10 \pm 0.05 70 ANJOS 91 E691 γ Be 80–240 GeV	
⁷⁰ The factor 100 at the top of column 2 of Table I of ANJOS 91 should be omitted.	
$\Gamma(\overline{K}^0K^+\pi^-)/\Gamma(\overline{K}^0\pi^+\pi^-)$ VALUE EVTS DOCUMENT ID TECN COMMENT	\downarrow
0.091±0.018 OUR FIT	FRABETTI 95C E687 1.2
	ALBRECHT 94I ARG 0.5
$\Gamma(K^*(892)^0\overline{K^0})/\Gamma(K^-\pi^+)$ Γ_{142}/Γ_{21} Unseen decay modes of the $K^*(892)^0$ are included.	4.4 (Confidence Level = 0.113)
VALUE DOCUMENT ID TECN COMMENT	0 0.01 0.02 0.03 0.04 0.05 0.06
• • • We do not use the following data for averages, fits, limits, etc. • • • 0.00 + 0.04 71 ANJOS 91 E691 7Be 80–240 GeV	$\Gamma\left(\phi\pi^{+}\pi^{-}\right)/\Gamma\left(K^{-}\pi^{+}\pi^{+}\pi^{-}\right)$
$0.00^{+0.04}_{-0.00}$ 71 ANJOS 91 E691 γ Be 80–240 GeV 71 The factor 100 at the top of column 2 of Table I of ANJOS 91 should be omitted.	$\Gamma(\phi \rho^0)/\Gamma(K^-\pi^+\pi^+\pi^-)$ Γ_{148}/Γ_{39}
	Unseen decay modes of the ϕ are included. Everyone (through 1995) agrees that $\phi \rho^0$
$\Gamma(K^*(892)^0\overline{K^0})/\Gamma(\overline{K^0}\pi^+\pi^-)$ Γ_{142}/Γ_{23} Unseen decay modes of the $K^*(892)^0$ are included.	dominates $\phi\pi^+\pi^-$, so for now we equate the two branching fractions. VALUE
VALUE CL% DOCUMENT ID TECN COMMENT	• • • We do not use the following data for averages, fits, limits, etc. • • •
<0.015 90 AMMAR 91 CLEO $e^+e^- \approx 10.5 \text{ GeV}$	0.005 ± 0.003 FRABETTI 95C E687 γ Be, $\overline{E}_{\gamma}\approx 200$ GeV $0.020\pm0.006\pm0.005$ 28 ALBRECHT 94I ARG $e^+e^-\approx 10$ GeV
$\Gamma(K^*(892)^-K^+)/\Gamma(K^-\pi^+)$ Γ_{143}/Γ_{21}	$\Gamma(\phi\pi^+\pi^-3\text{-body})/\Gamma(K^-\pi^+\pi^+\pi^-)$ Γ_{149}/Γ_{39}
Unseen decay modes of the $K^*(892)^-$ are included. VALUE DOCUMENT ID TECN COMMENT	VALUE CL% DOCUMENT ID TECN COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •	<0.006 90 FRABETTI 95c E687 γ Be, $\overline{E}_{\gamma} \approx$ 200 GeV
$0.00^{+0.03}_{-0.00}$ 72 ANJOS 91 E691 γ Be 80–240 GeV	$\Gamma(K^+K^-\rho^0$ 3-body)/ $\Gamma(K^-\pi^+\pi^+\pi^-)$ Γ_{132}/Γ_{39}
72 The factor 100 at the top of column 2 of Table I of ANJOS 91 should be omitted.	VALUEDOCUMENT IDTECNCOMMENT 0.012 ± 0.003 FRABETTI95C E687 γ Be, $\overline{E}_{\gamma} \approx 200$ GeV
$\Gamma(K^*(892)^-K^+)/\Gamma(\overline{K^0}\pi^+\pi^-)$ Γ_{143}/Γ_{23} Unseen decay modes of the $K^*(892)^-$ are included.	$\Gamma(K^*(892)^0 K^- \pi^+ + \text{c.c.})/\Gamma(K^- \pi^+ \pi^+ \pi^-)$ Γ_{150}/Γ_{39}
VALUE EVTS DOCUMENT ID TECN COMMENT	Unseen decay modes of the $K^*(892)^0$ are included.
0.034±0.019 12 AMMAR 91 CLEO $e^+e^-\approx 10.5 \text{ GeV}$	<u>VALUE</u> <u>CL%</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> • • • We do not use the following data for averages, fits, limits, etc. • • •
$\Gamma(\overline{K}^0K^+\pi^-\text{nonresonant})/\Gamma(K^-\pi^+)$ Γ_{128}/Γ_{21}	<0.017 90 75 FRABETTI 95C E687 γ Be, $\overline{E}_{\gamma} \approx$ 200 GeV
VALUE DOCUMENT ID TECN COMMENT 0.10 - 0.05 73 ANJOS 91 E691 γ Be 80-240 GeV	$0.010^{+0.016}_{-0.010}$ ANJOS 91 E691 γ Be 80–240 GeV
73 The factor 100 at the top of column 2 of Table I of ANJOS 91 should be omitted.	75 This FRABETTI 95C upper limit is in conflict with values in the next two data blocks.
	$\Gamma(K^*(892)^0K^-\pi^+)/\Gamma(K^-\pi^+\pi^+\pi^-)$ Γ_{151}/Γ_{39}
$\Gamma(\phi\pi^0)/\Gamma_{ ext{total}}$ $\Gamma_{ ext{144}}/\Gamma$	The $K^{*0}K^-\pi^+$ and $\overline{K}^{*0}K^+\pi^-$ modes are distinguished by the charge of the pion in $D^*(2010)^\pm o D^0\pi^\pm$ decays. Unseen decay modes of the $K^*(892)^0$ are included.
<0.0014 90 ALBRECHT 941 ARG $e^+e^- \approx 10 \text{ GeV}$	VALUEEVTSDOCUMENT IDTECNCOMMENT $0.043\pm0.014\pm0.009$ 55ALBRECHT94IARG $e^+e^-\approx 10$ GeV
$\Gamma(\phi\eta)/\Gamma_{ m total}$ $\Gamma_{ m 145}/\Gamma$	$\Gamma(\overline{K}^*(892)^0K^+\pi^-)/\Gamma(K^-\pi^+\pi^+\pi^-)$ Γ_{152}/Γ_{39}
VALUE CL% DOCUMENT ID TECN COMMENT <0.0028 90 ALBRECHT 94I ARG $e^+e^-\approx 10 \text{ GeV}$	The $K^{*0}K^-\pi^+$ and $\overline{K}^{*0}K^+\pi^-$ modes are distinguished by the charge of the pion
-	in $D^*(2010)^\pm o D^0\pi^\pm$ decays. Unseen decay modes of the $\overline{K}^*(892)^0$ are included. VALUE
$\Gamma(\phi\omega)/\Gamma_{ ext{total}}$ $\Gamma_{ ext{146}}/\Gamma$	0.023 \pm 0.013 \pm 0.009 30 ALBRECHT 941 ARG $e^+e^- \approx 10 \; \text{GeV}$
<0.0021 90 ALBRECHT 941 ARG $e^+e^-\approx 10 \text{ GeV}$	= (15 (202)() (F(15 + 1 - 1)
	$\Gamma(K^*(892)^0\overline{K}^*(892)^0)/\Gamma(K^-\pi^+\pi^+\pi^-)$ Γ_{153}/Γ_{39}
$\Gamma(K^+K^-\pi^+\pi^-)/\Gamma(K^-\pi^+\pi^+\pi^-)$ Γ_{129}/Γ_{39}	Unseen decay modes of the $K^*(892)^0$ and $\overline{K}^*(892)^0$ are included.
$\Gamma(K^+K^-\pi^+\pi^-)/\Gamma(K^-\pi^+\pi^+\pi^-)$ Γ_{129}/Γ_{39} $VALUE$ $EVTS$ $O.0342\pm0.0033$ OUR AVERAGE	Unseen decay modes of the $K^*(892)^0$ and $\overline{K}^*(892)^0$ are included. VALUE CL% EVTS DOCUMENT ID TECN COMMENT 0.018 \pm 0.007 OUR AVERAGE Error includes scale factor of 1.2.
$\Gamma(K^+K^-\pi^+\pi^-)/\Gamma(K^-\pi^+\pi^+\pi^-)$ Γ_{129}/Γ_{39} $VALUE$ $EVTS$ $DOCUMENT ID$ $TECN$ $COMMENT$ 0.0342 ± 0.0033 OUR AVERAGE $0.035 \pm 0.004 \pm 0.002$ 244 FRABETTI 95C E687 γBe, $\overline{E}_{\gamma} \approx 200$ GeV	Unseen decay modes of the $K^*(892)^0$ and $\overline{K}^*(892)^0$ are included. **NALUE** CLS** EVTS** DOCUMENT ID TECN COMMENT** 0.018±0.007 OUR AVERAGE Error includes scale factor of 1.2. 0.016±0.006 FRABETTI 95C E687 γ Be, $\overline{E}_{\gamma} \approx$ 200 GeV
$\Gamma(K^+K^-\pi^+\pi^-)/\Gamma(K^-\pi^+\pi^+\pi^-)$ Γ_{129}/Γ_{39} $VALUE$ $EVTS$ $O.0342\pm0.0033$ OUR AVERAGE	Unseen decay modes of the $K^*(892)^0$ and $\overline{K}^*(892)^0$ are included. VALUE CL% EVTS DOCUMENT ID TECN COMMENT 0.018 \pm 0.007 OUR AVERAGE Error includes scale factor of 1.2.
$\Gamma(K^+K^-\pi^+\pi^-)/\Gamma(K^-\pi^+\pi^+\pi^-)$ Γ_{129}/Γ_{39} $\Gamma_{30342\pm0.0033}$ OUR AVERAGE 0.035 ±0.004 ±0.002 244 FRABETTI 95C E687 γ Be, $\overline{E}_{\gamma}\approx$ 200 GeV 0.041 ±0.007 ±0.005 114 ALBRECHT 94I ARG $e^+e^-\approx$ 10 GeV	Unseen decay modes of the $K^*(892)^0$ and $\overline{K}^*(892)^0$ are included. NALUE CL% EVTS DOCUMENT ID TECN COMMENT 0.018 \pm 0.007 QUR AVERAGE 0.016 \pm 0.006 FRABETTI 95c E687 γ Be, $\overline{E}_{\gamma} \approx$ 200 GeV 0.036 \pm 0.016 11 ANJOS 91 E691 γ Be 80–240 GeV

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				465
		Meson	Parti	cle Listings
				•
-				D^0
		$\Gamma(K^-\pi^+\pi^+\pi^-)$		Γ ₁₅₇ /Γ ₃₉
	0 - \overline{D}^{0} mixing I $^{\circ}$	imit. <u>DOCUMENT ID</u>	TECN	COMMENT
<0.005	90 0±4	87 ANJOS	88C E691	Photoproduction
87 ANJOS 88C us	es decay-time	information to distin	guish doubly	Cabibbo-suppressed (DCS)
decays from E) ^U -D ^U mixing ng amplitudes	 However, the resu When interference 	it assumes i	no interference between the the limit degrades to 0.007.
Combined wit	h results on F	$(\pm \pi^{\mp}$, the limit is,	assuming n	o interference, 0.0037. See
also the data	on $ m_{D_1^0} - n $	$\sigma_{D_2^0}^{-1}$ and on $ \Gamma_{D_1^0}^{-1} $	$-\Gamma_{D_2^0} /\Gamma$ ne	ar the beginning of the D^0
Listings.	•	-		
$\Gamma(\mu^-$ anything (Γ ₁₅₈ /Γ ₂
		limit. See the som $\tau^-\pi^+\pi^-$ (via \overline{D}^0).		r limits above from $D^0 \rightarrow$
VALUE VALUE	CL%	DOCUMENT ID		COMMENT
<0.0056	90	LOUIS	86 SPEC	
		ing data for average		
<0.012 <0.044	90 90	BENVENUTI BODEK	85 CNTF 82 SPEC	μ C, 200 GeV π^- , ρ Fe $\rightarrow D^0$
				·
$\Gamma(e^+e^-)/\Gamma_{\text{tota}}$	$\int_{0}^{\infty} dt = \int_{0}^{\infty} dt = \int_{0$	eak neutral current.	Allowed by	F ₁₅₉ /F first-order weak interaction
combined w	ith electroma	gnetic interaction.		
<1.3 × 10 ⁻⁵	<u>CL% EVTS</u> 90 0	DOCUMENT ID		COMMENT
		ing data for average		$e^+e^-pprox \ \varUpsilon(4S)$
$< 1.3 \times 10^{-4}$	90	ADLER		3 e ⁺ e [−] 3.77 GeV
$< 1.7 \times 10^{-4}$	90 7	ALBRECHT	88G ARG	e ⁺ e ⁻ 10 GeV
<2.2 × 10 ⁻⁴	90 8	HAAS	88 CLEO	e ⁺ e ⁻ 10 GeV
$\Gamma(\mu^+\mu^-)/\Gamma_{\text{tot}}$	al			Γ ₁₆₀ /Γ
		eak neutral current. gnetic interaction.	Allowed by	first-order weak interaction
VALUE	CL% EVTS	DOCUMENT ID		COMMENT
<7.6 × 10 ⁻⁶	90 0	ADAMOVICH ing data for average		
$< 3.4 \times 10^{-5}$	90 1	FREYBERGER		
$< 4.4 \times 10^{-5}$	90 0	KODAMA	95 E653	π^- emulsion 600 GeV
$<3.1 \times 10^{-5}$	90	88 MISHRA	94 E789	-4.1 ± 4.8 events
$<7.0 \times 10^{-5}$ $<1.1 \times 10^{-5}$	90 3 90	ALBRECHT LOUIS	88G ARG 86 SPEC	e ⁺ e ⁻ 10 GeV π ⁻ W 225 GeV
$< 3.4 \times 10^{-4}$	90	AUBERT	85 EMC	Deep inelast. $\mu^- N$
				the PDG." For an alternate
	-	0×10^{-6} at 90% co	nfidence leve	el, see the paper.
$\Gamma(\pi^0 e^+ e^-)/\Gamma_1$	total			Γ ₁₆₁ /Γ
A test for t interactions		weak neutral current	t. Allowed	by higher-order electroweak
VALUE	CL% EVTS	DOCUMENT ID		COMMENT
<4.5 × 10 ⁻⁵	90 0	FREYBERGER	R 96 CLEO	$e^+e^-\approx \Upsilon(4S)$
$\Gamma(\pi^0\mu^+\mu^-)/\Gamma$	total	noutral current Al	lowed by big	Γ_{162}/Γ her-order electroweak inter-
actions.	ie AC1 wear			
<1.8 × 10 ⁻⁴	CL% EVTS	DOCUMENT ID KODAMA		
	90 2 use the follow	ing data for average		
$< 5.4 \times 10^{-4}$	90 3	FREYBERGER	R 96 CLEO	$e^+e^-pprox \Upsilon(45)$
$\Gamma(\eta e^+ e^-)/\Gamma_{to}$				Γ /Γ
A test for t	tal :he $\Delta C = 1$ \	weak neutral current	t. Allowed	Γ163/Γ by higher-order electroweak
interactions				
	<u>CL% EVTS</u> 90 0			$e^+e^-\approx \Upsilon(4S)$
$\Gamma(\eta \mu^+ \mu^-)/\Gamma_{to}$ A test for t	Stall the $\Delta C = 1$ v	weak neutral current	t. Allowed	Γ164/Γ by higher-order electroweak
interactions				
<5.3 × 10 ⁻⁴	<u>CL% EVTS</u> 90 0			$e^+e^-\approx \Upsilon(4S)$

interactions. VALUE | CL% | EVTS | DOCUMENT ID | TECN | COMMENT
 \bullet \bullet We do not use the following data for averages, fits, limits, etc. \bullet \bullet $< 4.5 \times 10^{-4}$ 90 2 HAAS 88 CLEO e^+e^- 10 GeV 89 This FREYBERGER 96 limit is obtained using a phase-space model. The limit changes to $<1.8\times10^{-4}$ using a photon pole amplitude model.

0.0017±0.0005	7	BARI	.AG 920	ACCM	π Cu :	230 GeV
77 BARLAG 92C comput	tes the brai	nching	fraction using	topologic	al norm	alization.
$\Gamma(K^+K^-\pi^+\pi^-$ nonre	esonant)	/F(K-	$-\pi^{+}\pi^{+}\pi^{-}$			Γ ₁₃₇ /Γ ₃₉
VALUE	CL%	•	•	TECN	COMMEN	
<0.011	90			E687		$_{\gamma} \approx$ 200 GeV
 • • We do not use the 	following	data fo	r averages, fits	, limits,	etc. • •	•
$0.001 {}^{+ 0.011}_{- 0.001}$		ANJO	OS 91	E691	γ Be 80-	-240 GeV
Γ (Κ⁰Κ̄⁰π+π −)/Γ (Κ	$(70 \pi^{+} \pi^{-})$)	DOCUMENT ID	r	ECN C	Γ ₁₃₈ /Γ ₂₃
0.126±0.038±0.030	25	5	ALBRECHT	941 A		⁺ e [−] ≈ 10 GeV
$\Gamma(K^+K^-\pi^+\pi^-\pi^0)$	Γ _{total}					Γ ₁₃₉ /Γ
VALUE					COMMEN	
0.0031±0.0020		BARI			π ⁻ Cu	
⁷⁸ BARLAG 92C comput	tes the brai	nching	fraction using	topologi	al norm	alization.
	Rare	or fo	rbidden mod	les		
-/14+ -\ /-/14- +\						F /F
$\Gamma(\pmb{K}^+\pi^-)/\Gamma(\pmb{K}^-\pi^+)$ The $D^0 o K^+\pi^-$		doubly	Cabibbo suppr	ressed		Γ_{154}/Γ_{21}
VALUE	CL% E		DOCUMENT		TECN	COMMENT
0.0077±0.0025±0.002	25	19	⁷⁹ CINABRO	94	CLEO	$e^+e^-\approx$
• • We do not use the	following	data fo	r averages fits	limits	etc • •	Υ(4S)
< 0.011	90	autu 10	79 AMMAR	91	CLEO	$e^+e^-\approx 10.5$
			80 ANJOS			GeV
<0.015	90 1:	± 6			E691	Photoproduc- tion
< 0.014	90		81 ALBRECH		ARG	$e^{+}e^{-}$ 10 GeV
<0.04	90		⁸¹ ABACHI ⁸² BAILEY		HRS	e ⁺ e ⁻ 29 GeV
<0.07	90	0	oz BAILEY	86	ACCM	π Be fixed target
< 0.11	90	2	⁸¹ ALBRECH		ARG	e ⁺ e ⁻ 10 GeV
< 0.081	90	81	,83 YAMAMO		DLCO	e ⁺ e ⁻ 29 GeV
<0.23	90		,83 ALTHOFF	848	TASS	e ⁺ e ⁻ 34.4 GeV
< 0.11	90		,83 AVERY	80	SPEC	$\gamma N \rightarrow D^{*+}$
< 0.16	90		,83 FELDMAN		MRK1	e ⁺ e ⁻ 4 GeV
<0.18	90		,83 GOLDHAE			e ⁺ e ⁻ 4 GeV
⁷⁹ These experiments of D^0 - \overline{D}^0 mixing. 80 ANJOS 88c uses decaded as from D^0 - \overline{D}^0 mixing amp 81 In these measurementell whether D^0 or a double Cabibbo suppress Results as 6 searches from $\Gamma(D^0 - K^+\pi^-)$ 83. The results are givenicantly for our denomination of $\Gamma(K^+\pi^-)$ (via \overline{D}^0) / Γ This is a D^0 - \overline{D}^0 m	y-time infomixing. Ho solitudes. We ts, the characteristic for the characteristic for the characteristic for events where $\kappa + \pi - 3$ as $\Gamma(\kappa + \pi)$ in a to $\kappa + \pi$.	rmation owever, then interpreted for the mixing with an $\pi^+\pi^-$	the result asserference is all the pion in D^* one of the means for the decay. oppositely chair or D^* of D^* or	doubly Coumes no owed, the $\pm \rightarrow ($ suremen rged eK	Cabibbo-s interfere e limit de D^0 or \overline{D} ts can dis pair. Th $K^-\pi^+$	suppressed (DCS) ence between the egrades to 0.049. 10) π^{\pm} is used to stinguish between the limit is actually $\pi^{+}\pi^{-}$).
	EVTS	DOCU	MENT ID	TECN	COMMEN	IT
VALUE CL%	1 ± 4 8	4 ANJO	OS 880	E691	Photopr	oduction
	y-time info mixing. Ho ditudes. W s on $K^\pm\pi^{\pm}$	owever, hen int $\mp \pi + \pi$	the result ass erference is all the limit is,	owed, th assumir	e limit d Ig no inte	egrades to 0.019 erference, 0.0037
<0.005 84 ANJOS 88C uses decadecays from D^0 - D^0 DCS and mixing amp Combined with results See also the data on D^0 Listings. $\Gamma(K^+\pi^-\pi^+\pi^-)/\Gamma(I^0)$	y-time info mixing. Ho olitudes. W s on $K^{\pm}\pi^{\pm}$ $ m_{D_1^0} - n$	owever, hen int $\mp \pi + \pi$ $n_{D_2^0} _{a}$	the result ass erference is all the limit is,	owed, th assumir	e limit d Ig no inte	egrades to 0.019 erference, 0.0037
<0.005 84 ANJOS 88c uses decadecays from $D^0 - \overline{D}^0$ DCS and mixing amp Combined with results See also the data on D^0 Listings. $\Gamma(K^+\pi^-\pi^+\pi^-)/\Gamma(L^0)$ Doubly Cabibbo su	y-time info mixing. Ho olitudes. W s on $K^{\pm}\pi^{\pm}$ $ m_{D_1^0} - n$ $K^-\pi^+\pi^+$ ppressed.	owever, hen into $\mp \pi^+ \pi^ D_2^{0 }$	the result asserference is all $-$, the limit is, nd on $ \Gamma_{D_1^0} $	owed, the assuming $\Gamma_{D_2^0}^{- \Gamma }$	e limit d ig no inte near the	egrades to 0.019 erference, 0.0037 beginning of the Γ_{156}/Γ_{39}
<0.005 84 ANJOS 88C uses decadecays from D^0 - D^0 DCS and mixing amp Combined with results See also the data on D^0 Listings. $\Gamma(K^+\pi^-\pi^+\pi^-)/\Gamma(I^0)$	y-time info mixing. He dilitudes. We son $K^{\pm}\pi^{-1}$ M^{-1} ppressed. M^{-1}	owever, hen into $\mp \pi^+ \pi^ D_2^{0 }$	the result asserference is all. $\bar{}$, the limit is, nd on $ \Gamma_{D_1^0} $	owed, the assuming $\Gamma_{D_2^0} /\Gamma$	e limit d ng no inte near the COMMEN	egrades to 0.019 erference, 0.0037 beginning of the Γ_{156}/Γ_{39}

 85 AMMAR 91 cannot distinguish between doubly Cabibbo-suppressed decay and D^0 - \overline{D}^0 86 ANJOS 88C uses decay-time information to distinguish doubly Cabibbo-suppressed (DCS) decays from D^0 - \overline{D}^0 mixing. However, the result assumes no interference between the DCS and mixing amplitudes. When interference is allowed, the limit degrades to 0.033.

$\Gamma(\rho^0 \mu^+ \mu^-)/\Gamma_{\text{total}}$ A test for the $\Delta C = 1$ weak neutral current. Allowed by higher-order electroweak	$\Gamma(\pi^0 e^{\pm} \mu^{\mp})/\Gamma_{\text{total}}$ Γ_{177}/Γ
interactions.	A test of lepton family number conservation. The value is for the sum of the two charge states.
VALUE CL% EVTS DOCUMENT ID TECN COMMENT	VALUE CL% EVTS DOCUMENT ID TECN COMMENT
$< 2.3 \times 10^{-4}$ 90 0 KODAMA 95 E653 π^- emulsion 600 GeV	<8.6 × 10 ⁻⁵ 90 2 FREYBERGER 96 CLEO $e^+e^-\approx \Upsilon(4S)$
• • We do not use the following data for averages, fits, limits, etc. • • •	` /
$<$ 4.9 $ imes$ 10 $^{-4}$ 90 1 90 FREYBERGER 96 CLEO $e^+e^-pprox \Upsilon$ (45)	$\Gamma(\eta e^{\pm} \mu^{\mp}) / \Gamma_{ ext{total}}$ $\Gamma_{ ext{178}} / \Gamma$
$< 8.1 \times 10^{-4}$ 90 5 HAAS 88 CLEO $e^{+}e^{-}$ 10 GeV	A test of lepton family number conservation. The value is for the sum of the two
⁹⁰ This FREYBERGER 96 limit is obtained using a phase-space model. The limit changes	charge states. VALUE CL% EVTS DOCUMENT ID TECN COMMENT
to $< 4.5 \times 10^{-4}$ using a photon pole amplitude model.	VALUE CL% EVTS DOCUMENT ID TECN COMMENT $< 1.0 \times 10^{-4}$ 90 0 FREYBERGER 96 CLEO $e^+e^- \approx \Upsilon(4S)$
$\Gamma(\omegae^+e^-)/\Gamma_{ m total}$ $\Gamma_{ m 167}/\Gamma$	CI.UX IU 90 0 PRETBERGER 96 CLEO e e 8 7 (45)
A test for the $\Delta C = 1$ weak neutral current. Allowed by higher-order electroweak	$\Gamma(ho^0 e^{\pm} \mu^{\mp}) / \Gamma_{ ext{total}}$ Γ_{179} / Γ
interactions.	A test of lepton family number conservation. The value is for the sum of the two
VALUE CL% EVTS DOCUMENT ID TECN COMMENT	charge states.
<1.8 x 10 ⁻⁴ 90 1 91 FREYBERGER 96 CLEO $e^+e^- \approx \Upsilon(4S)$	VALUE CL% EVTS DOCUMENT ID TECN COMMENT
91 This FREYBERGER 96 limit is obtained using a phase-space model. The limit changes	<4.9 $ imes$ 10 ⁻⁵ 90 0 ⁹⁸ FREYBERGER 96 CLEO $e^+e^-pprox \varUpsilon(4S)$
to $<$ 2.7 $ imes$ 10^{-4} using a photon pole amplitude model.	⁹⁸ This FREYBERGER 96 limit is obtained using a phase-space model. The limit changes
$\Gamma(\omega \mu^+ \mu^-)/\Gamma_{\text{total}}$ Γ_{168}/Γ	to $< 5.0 \times 10^{-5}$ using a photon pole amplitude model.
A test for the $\Delta C = 1$ weak neutral current. Allowed by higher-order electroweak	r(-+ T)/r
interactions.	$\Gamma(\omega e^{\pm} \mu^{\mp})/\Gamma_{\text{total}}$ Γ_{180}/Γ
VALUE CL% EVTS DOCUMENT ID TECN COMMENT	A test of lepton family number conservation. The value is for the sum of the two charge states.
<8.3 x 10 ⁻⁴ 90 0 92 FREYBERGER 96 CLEO $e^+e^- \approx \Upsilon(4S)$	VALUECL% EVTS DOCUMENT ID TECN COMMENT
⁹² This FREYBERGER 96 limit is obtained using a phase-space model. The limit changes	<1.2 x 10 ⁻⁴ 90 0 99 FREYBERGER 96 CLEO $e^+e^- \approx \Upsilon(45)$
to $< 6.5 \times 10^{-4}$ using a photon pole amplitude model.	
[(+++\/F	⁹⁹ This FREYBERGER 96 limit is obtained using a phase-space model. The same limit is obtained using a photon pole amplitude model.
$\Gamma(\phi e^+e^-)/\Gamma_{\text{total}}$ A test for the $\Delta C=1$ weak neutral current. Allowed by higher-order electroweak	•
A test for the $\Delta C = 1$ weak neutral current. Allowed by higher-order electroweak interactions.	$\Gamma(\phi e^{\pm} \mu^{\mp}) / \Gamma_{ ext{total}}$ $\Gamma_{ ext{181}} / \Gamma$
VALUE CL% EVTS DOCUMENT ID TECN COMMENT	A test of lepton family number conservation. The value is for the sum of the two
<5.2 x 10 ⁻⁵ 90 2 ⁹³ FREYBERGER 96 CLEO $e^+e^- \approx \Upsilon(4S)$	charge states.
93 This FREYBERGER 96 limit is obtained using a phase-space model. The limit changes	VALUE CL% EVTS DOCUMENT ID TECN COMMENT
to $< 7.6 \times 10^{-5}$ using a photon pole amplitude model.	<3.4 x 10 ⁻⁵ 90 0 100 FREYBERGER 96 CLEO $e^+e^-\approx \Upsilon(4S)$
	100 This FREYBERGER 96 limit is obtained using a phase-space model. The limit changes
$\Gamma(\phi \mu^+ \mu^-)/\Gamma_{ ext{total}}$ A test for the $\Delta C=1$ weak neutral current. Allowed by higher-order electroweak	to $<$ 3.3 $ imes$ 10 $^{-5}$ using a photon pole amplitude model.
interactions.	$\Gamma(\overline{K}^0 e^{\pm} \mu^{\mp})/\Gamma_{\text{total}}$ Γ_{182}/Γ
VALUE CL% EVTS DOCUMENT ID TECN COMMENT	$\Gamma(K^0e^+\mu^+)/\Gamma_{\text{total}}$ Γ_{182}/Γ A test of lepton family number conservation. The value is for the sum of the two
<4.1 x 10⁻⁴ 90 0 94 FREYBERGER 96 CLEO $e^+e^- \approx r(45)$	charge states.
94 This FREYBERGER 96 limit is obtained using a phase-space model. The limit changes	VALUE CL% EVTS DOCUMENT ID TECN COMMENT
to $< 2.4 \times 10^{-4}$ using a photon pole amplitude model.	$<1.0 \times 10^{-4}$ 90 0 FREYBERGER 96 CLEO $e^+e^- \approx \Upsilon(4S)$
•	
$\Gamma(\overline{K}^0 e^+ e^-)/\Gamma_{\text{total}}$ Γ_{171}/Γ	$\Gamma(\overline{K}^*(892)^0 e^{\pm} \mu^{\mp})/\Gamma_{\text{total}}$ Γ_{183}/Γ
Allowed by first-order weak interaction combined with electromagnetic interaction. VALUE CL% EVTS DOCUMENT ID TECN COMMENT	A test of lepton family number conservation. The value is for the sum of the two
$<1.1 \times 10^{-4}$ 90 0 FREYBERGER 96 CLEO $e^+e^-\approx \Upsilon(4S)$	charge states.
• • • We do not use the following data for averages, fits, limits, etc. • • •	VALUE CL% EVTS DOCUMENT ID TECN COMMENT
	<1.0 x 10 ⁻⁴ 90 0 101 FREYBERGER 96 CLEO $e^+e^-\approx \Upsilon(4S)$
$<1.7 \times 10^{-3}$ 90 ADLER 89C MRK3 $e^{+}e^{-}$ 3.77 GeV	101 This FREYBERGER 96 limit is obtained using a phase-space model. The same limit is
$\Gamma(\overline{K}^0\mu^+\mu^-)/\Gamma_{total}$ Γ_{172}/Γ	obtained using a photon pole amplitude model.
Allowed by first-order weak interaction combined with electromagnetic interaction.	OO COMMON ATTING DECOMPOSED AND ALTERNATION
VALUE CL% EVTS DOCUMENT ID TECN COMMENT	D ⁰ CP-VIOLATING DECAY-RATE ASYMMETRIES
<2.6 × 10 ⁻⁴ 90 2 KODAMA 95 E653 π^- emulsion 600 GeV	$A_{CP}(K^+K^-)$ in D^0 , $\overline{D}{}^0 \rightarrow K^+K^-$
• • • We do not use the following data for averages, fits, limits, etc. • • •	This is the difference between D^0 and \overline{D}^0 partial widths for these modes divided by
$<$ 6.7 \times 10 ⁻⁴ 90 1 FREYBERGER 96 CLEO $e^+e^-\approx~ \varUpsilon(45)$	the sum of the widths.
$\Gamma(\overline{K}^*(892)^0 e^+ e^-)/\Gamma_{\text{total}}$ Γ_{173}/Γ	VALUE DOCUMENT ID TECN COMMENT
Allowed by first-order weak interaction combined with electromagnetic interaction.	0.06 ±0.05 OUR AVERAGE
VALUE CL% EVTS DOCUMENT ID TECN COMMENT	$+0.080\pm0.061$ BARTELT 95 CLEO $-0.022 < A_{CP} < +0.18 (90\%CL)$ $+0.024\pm0.084$ 102 FRABETTI 94I E687 $-0.11 < A_{CP} < +0.16 (90\% CL)$
<1.4 x 10 ⁻⁴ 90 1 95 FREYBERGER 96 CLEO $e^+e^- \approx \Upsilon(4S)$	<u>-</u>
95 This FREYBERGER 96 limit is obtained using a phase-space model. The limit changes	¹⁰² FRABETTI 941 measures $N(D^0 \to K^+K^-)/N(D^0 \to K^-\pi^+)$, the ratio of (efficiency-
to $< 2.0 \times 10^{-4}$ using a photon pole amplitude model.	corrected) numbers of events observed, and similarly for the $\overline{D}{}^0.$
• ' ' '	$A_{CP}(K_S^0\phi)$ in D^0 , $\overline{D}{}^0 \rightarrow K_S^0\phi$
$\Gamma(\overline{K}^*(892)^0 \mu^+ \mu^-)/\Gamma_{\text{total}}$ Γ_{174}/Γ	
Allowed by first-order weak interaction combined with electromagnetic interaction. VALUECL%_EVTSDOCUMENT IDTECNCOMMENT	This is the difference between D^0 and $\overline{D}{}^0$ partial widths for these modes divided by the sum of the widths.
	value <u>Document id</u> <u>TECN COMMENT</u>
•	-0.028±0.094 BARTELT 95 CLEO -0.182 <a<sub>CP < +0.126 (90%CL)</a<sub>
⁹⁶ This FREYBERGER 96 limit is obtained using a phase-space model. The limit changes	
to $< 1.0 \times 10^{-3}$ using a photon pole amplitude model.	$A_{CP}(K^0_S\pi^0)$ in D^0 , $\overline{D}{}^0 o K^0_S\pi^0$
$\Gamma(\pi^+\pi^-\pi^0\mu^+\mu^-)/\Gamma_{ ext{total}}$ Γ_{175}/Γ	This is the difference between D^0 and \overline{D}^0 partial widths for these modes divided by
A test for the $\Delta C=1$ weak neutral current. Allowed by higher-order electroweak inter-	the sum of the widths.
actions. VALUE CL% EVTS DOCUMENT ID TECN COMMENT	VALUE DOCUMENT ID TECN COMMENT
	-0.018±0.030 BARTELT 95 CLEO -0.067 <a<sub>CP < +0.031 (90%CL)</a<sub>
<8.1 x 10⁻⁴ 90 1 KODAMA 95 E653 π^- emulsion 600 GeV	-0
$\Gamma(\mu^{\pm} e^{\mp})/\Gamma_{ ext{total}}$ Γ_{176}/Γ	D^0 PRODUCTION CROSS SECTION AT $\psi(3770)$
A test of lepton family number conservation.	A compilation of the cross sections for the direct production of D^0 mesons
VALUE CL% EVTS DOCUMENT ID TECN COMMENT	at or near the $\psi(3770)$ peak in e^+e^- production.
< 1.9 x 10 ⁻⁵ 90 2 FREYBERGER 96 CLEO $e^+e^-\approx \Upsilon(4S)$	
• • • We do not use the following data for averages, fits, limits, etc. • •	VALUE (nanobarns) DOCUMENT ID TECN COMMENT
$< 1.0 \times 10^{-4}$ 90 4 ALBRECHT 88G ARG $e^{+}e^{-}$ 10 GeV	• • • We do not use the following data for averages, fits, limits, etc. • • •
$< 2.7 \times 10^{-4}$ 90 9 HAAS 88 CLEO $e^{+}e^{-}$ 10 GeV	
$< 1.2 \times 10^{-4}$ 90 BECKER 87C MRK3 $e^{+}e^{-}$ 3.77 GeV	5.8 \pm 0.5 \pm 0.6 103 ADLER 88C MRK3 e^+e^- 3.768 GeV 7.3 \pm 1.3 104 PARTRIDGE 84 CBAL e^+e^- 3.771 GeV
$< 9 \times 10^{-4}$ 90 PALKA 87 SILI 200 GeV πp	7.3 ± 1.3 10^{-9} PARTRIDGE 84 CBAL e e 3.771 GeV 10^{-9} SCHINDLER 80 MRK2 e^+e^- 3.771 GeV
$<21 \times 10^{-4}$ 90 0 97 RILES 87 MRK2 $e^{+}e^{-}$ 29 GeV	$\frac{300 \pm 0.93 \pm 1.21}{11.5 \pm 2.5}$ $\frac{300 \pm 0.93 \pm 1.21}{106 \text{ PERUZZI}}$ 77 MRK1 e^+e^- 3.774 GeV
97 RILES 87 assumes B($D ightarrow~K\pi)=3.0\%$ and has production model dependency.	TENGLES TO WHITE C C STITE OUV

- 103 This measurement compares events with one detected D to those with two detected D mesons, to determine the the absolute cross section. ADLER 88c find the ratio of cross sections (neutral to charged) to be $1.36 \pm 0.23 \pm 0.14$. 104 This measurement comes from a scan of the $\psi(3770)$ resonance and a fit to the cross section. PARTRIDGE 84 measures 6.4 ± 1.15 nb for the cross section. We take the phase space division of neutral and charged D mesons in $\psi(3770)$ decay to be 1.33, and we assume that the $\psi(3770)$ is an isosinglet to evaluate the cross sections. The noncharm decays (e.g. radiative) of the $\psi(3770)$ are included in this measurement and may amount to a few percent correction.
- may amount to a tew percent correction.

 105 This measurement comes from a scan of the $\psi(3770)$ resonance and a fit to the cross section. SCHINDLER 80 assume the phase space division of neutral and charged D mesons in $\psi(3770)$ decay to be 1.33, and that the $\psi(3770)$ is an isosinglet. The noncharm decays (e.g. radiative) of the $\psi(3770)$ are included in this measurement and may amount to a few percent correction.
- to a few percent correction.
 106 This measurement comes from a scan of the $\psi(3770)$ resonance and a fit to the cross section. The phase space division of neutral and charged D mesons in $\psi(3770)$ decay is taken to be 1.33, and $\psi(3770)$ is assumed to be an isosinglet. The noncharm decays (e.g. radiative) of the $\psi(3770)$ are included in this measurement and may amount to a few percent correction. We exclude this measurement from the average because of uncertainties in the contamination from τ lepton pairs. Also see RAPIDIS 77.

D⁰ REFERENCES

D- REFERENCES						
BARISH	96	PL B373 334	+Chadha, Chan, Eigen+	(CLEO	Collab.)	
FREYBERGER PDG	96 96	PRL 76 3065	+Gibaut, Kinoshita+	(CLEO	Collab.)	
ADAMOVICH	95	PR D54 1 PL B353 563	+Adinolfi, Alexandrov+	(CERN BEATRICE	Collab.)	
BARTELT	95	PR D52 4860	+Csorna, Egyed, Jain+	(CLEO	Collab.)	
BUTLER FRABETTI	95 95C	PR D52 2656 PL B354 486	+Fu, Nemati, Ross, Skubic+ +Cheung, Cumalat+	(CLEO (FNAL E687	Collab.)	
FRABETTI	95G	PL B364 127	+Cheung, Cumalat+	(FNAL E687	Collab.)	
KODAMA	95	PL B345 85 PL B324 249	+Cheung, Cumalat+ +Ushida, Mokhtarani+	(FNAL E653 (ARGUS	Collab.)	
ALBRECHT ALBRECHT	94 94F	PL B324 249 PL B340 125	+Ehrlichmann, Hamacher+ +Hamacher, Hofmann+	(ARGUS	Collab.)	
ALBRECHT	941	7 PHY C64 375	+Hamacher, Hofmann+	(ARGUS	Collab.)	
CINABRO	94 94C	PRL 72 1406	+Henderson, Liu, Saulnier+	(CLEO	Collab.)	
FRABETTI	94C	PL B321 295 PL B323 459	+Cheung, Cumalat+ +Cheung, Cumalat+	(FNAL E687 (FNAL E687	Collab.)	
FRABETTI	94G	PL B331 217	+Cheung, Cumalat+ +Cheung, Cumalat+	(FNAL E687	Collab.)	
FRABETTI FRABETTI	941 94 J	PR D50 R2953	+Cheung, Cumalat+ +Cheung, Cumalat+ +Ushida, Mokhtarani+ +Brown, Cooper+ +Barish, Chadha, Chan+	(FNAL E687 (FNAL E687	Collab.)	
KODAMA	94	PL B340 254 PL B336 605	+Ushida, Mokhtarani+	(FNAL E653	Collab.)	
MISHRA	94	PR D50 R9	+Brown, Cooper+	(FNAL E789	Collab.)	
AKERIB ALBRECHT	93 93D	PRL 71 3070 PL B308 435	+Barish, Chadha, Chan+ +Ehrlichmann, Hamacher+	(ARGUS	Collab.)	
ANJOS	93	PR D48 56	Annel Rean Brackers			
BEAN FRABETTI	93C 93I	PL B317 647	+Gronberg, Kutschke, Menary+ +Bogart, Cheung, Culy+ +Ushida, Mokhtarani+	(CLEO (FNAL E687 (FNAL E653	Collab.)	
KODAMA	93B	PL B315 203 PL B313 260	+Ushida, Mokhtarani+	(FNAL E653	Collab.)	
PROCARIO	93B	PR D48 4007	+Yang, Akerib, Barish+ +Sadoff, Ammar, Ball+	(CIEO	Collab.)	
SELEN ADAMOVICH	93 92	PRL 71 1973 PL B280 163	+Sadoff, Ammar, Ball+	(CLEO (CERN WA82	Collab.)	
ALBRECHT	92P	ZPHY C56 7	+Alexandrov, Antinori+ +Cronstroem, Ehrlichmann+	(ARGUS	Collab.)	
ANJOS	92B	PR D46 R1	+Appel, Bean, Bracker+	(FNAL E691	Collab.)	
ANJOS BARLAG	92C 92C	PR D46 1941	+Appel, Bean, Bracker+	(FNAL E691 (ACCMOR	Collab.)	
Also	90D	ZPHY C55 383 ZPHY C48 29	+Becker, Bozek, Boehringer+ Barlag, Becker, Boehringer, Bo	sman+ (ACCMOR	Collab.)	
COFFMAN	92B	PR D45 2196	+DeJongh, Dubois, Eigen+	(Mark III	Collab.)	
Also FRABETTI	90 92	PRL 64 2615 PL B281 167	Adler, Blaylock, Bolton+	(Mark III (FNAL E687	Collab.)	
FRABETTI	92B	PL B286 195	+Bogart, Cheung, Culy+ +Bogart, Cheung, Culy+	(FNAL E687	Collab.)	
ALVAREZ	91B	ZPHY C50 11		(CÈRN NA14/2 (CLEO	Collab.)	
AMMAR ANJOS	91 91	PR D44 3383 PR D43 R635	+Barate, Bloch, Bonamy+ +Baringer, Coppage, Davis+ +Appel, Bean, Bracker+	(CLEO (FNAL-TPS	Collab.)	
ANJOS	91D	PR D44 R3371	+Appel, Bean, Bracker+ +Appel, Bean, Bracker+	(FNAL-TPS	Collab.)	
BAI	91	PRI 66 1011	+Bolton, Brown, Bunnell+	(Mark III	Collab.)	
COFFMAN CRAWFORD	91 91B	PL B263 135 PR D44 3394	+DeJongh, Dubois, Eigen, Hitlin +Fulton, Gan, Jensen+	+ (Mark III	Collab.)	
DECAMP	91 J	PL B266 218 PL B263 584	+Deschizeaux Gov Lees+	(ALEPH	Collab.)	
FRABETTI	91	PL B263 584 PR D43 2836	+Bogart, Cheung, Culy+ +Pipkin, Procario, Wilson+	(FNAL E687	Collab.)	
KINOSHITA KODAMA	91 91	PR D43 2836 PRL 66 1819	+Ushida, Mokhtarani, Paolone+	(CLEO (FNAL E653	Collab.)	
ALBRECHT	90C	ZPHY C46 9	+Glaeser, Harder, Krueger+ +Artuso, Bebek, Berkelman+	(ARGUS	Collab.)	
ALEXANDER ALEXANDER	90 90B	PRL 65 1184	+Artuso, Bebek, Berkelman+		Collab.)	
ALVAREZ	900	PRL 65 1531 ZPHY C47 539	+Artuso, Bebek, Berkelman+ +Barate, Bloch, Bonamy+	(CERN NA14/2	Collab.)	
ANJOS	90D	PR D42 2414	+Appel, Bean, Bracker+	(FNAL E691	Collab.)	
BARLAG ADLER	90C 89	ZPHY C46 563 PRL 62 1821	+Becker, Boehringer, Bosman+ +Becker, Blaylock, Bolton+	(ACCMOR (Mark III	Collab.)	
ADLER	89C	PR D40 906	+Bai, Becker, Blaylock, Bolton+	(Mark III	Collab.)	
ALBRECHT	89D	7PHY C43 181	+Bai, Becker, Blaylock, Bolton+ +Boeckmann, Glaeser, Harder+ +Appel, Bean, Bracker, Browder	(ARGUS	Collab.)	
ANJOS ABACHI	89F 88	PRL 62 1587 PL B205 411	+Appel, Bean, Bracker, Browder	+ (FNAL E691	Collab.)	
ADLER	88	PL B205 411 PR D37 2023	+Akeriof, Baringer+ +Becker, Blaylock+	(Mark III	Collab.)	
ADLER	88C	PRI 60 89	+Becker, Blaylock+	(Mark III	Collab.)	
ALBRECHT ALBRECHT	88G 88I	PL B209 380 PL B210 267	+Boeckmann, Glaeser+ +Boeckmann, Glaeser+	(ARGUS (ARGUS	Collab.)	
AMENDOLIA	88	EPL 5 407 PRL 60 1239 PR D37 1719	+Bagliesi, Batignani+	(NA1	Collab.)	
ANJOS	88C	PRL 60 1239	+Appel+	(NA1 (FNAL E691 Moneti+ (CLEO	Collab.)	
BORTOLETTO Also	89D	PR D37 1719 PR D39 1471 erratum	+Goldberg, Horwitz, Mestayer, N	noneti+ (CLEO	Collab.)	
CUMALAT	88	Pl B210 253	+Shipbaugh, Binkley+ +Hempstead, Jensen+	(E-400	Collab.)	
HAAS RAAB	88 88	PRL 60 1614 PR D37 2391	+Hempstead, Jensen+	(CLEO (FNAL E691	Collab.)	
ADAMOVICH	87	EPL 4 887	+Anjos, Appel, Bracker+ +Alexandrov, Bolta+	(Photon Emulsion	Collab)	
ADLER	87	PL B196 107	+Becker, Blaylock, Bolton+	(Mark III	Collab.)	
	87D 88B	PL B193 140 7PHY C40 321	Aguilar-Benitez, Allison+ Aguilar-Benitez, Allison, Bailly+	(LEBC-EHS	Collab.)	
AGUILAR	87E	ZPHY C40 321 ZPHY C36 551 ZPHY C40 321 ZPHY C36 559	Aguilar-Benitez, Allison+	(LEBC-EHS	Collab.)	
Also	88B	ZPHY C40 321	Aguilar-Benitez, Allison, Bailly+ Aguilar-Benitez, Allison+	LEBC-EHS (LEBC-EHS	Collab.)	
AGUILAR Also	87F 88	ZPHY C38 520 erratum	Aguilar-Benitez, Allison+	(LEBC-ERS	Collab.)	
ALBRECHT	87E	ZPHY C38 520 erratum ZPHY C33 359	+Binder, Boeckmann, Glaser+	(ARGUS	Collab.)	
ALBRECHT BARLAG	87K 87B	PL B199 447 ZPHY C37 17	+Andam, Binder, Boeckmann+ +Becker, Boehringer, Bosman+	(ARGUS (ACCMOR	Collab.)	
BECKER	87C	PL B193 147	+Blaylock, Bolton, Brown+	(Mark III	Collab.)	
Also	87D	PL B198 590 erratum PL B191 318	Becker, Blaylock, Bolton+	(Mark III (Mark III	Collab.)	
CSORNA PALKA	87 87	PL B189 238	+Mestayer, Panvini, Word+ +Bailey, Becker, Belau+	(CLEO (ACCMOR	Collab \	
RILES	87	PR D35 2914 PL B182 101	+Dorfan, Abrams, Amidei+ +Akerlof, Baringer, Ballam+	(Mark II (HRS	Collab.)	
ABACHI	86D 86	PL B182 101	+Akerlof, Baringer, Ballam+	(HRS orid Facility Photon	Collab.)	
ABE	00	PR D33 1	+ (SLAC Hyb	nia raciity Proton	Conab.)	

BAILEY	86	ZPHY C30 51	+Belau, Boehringer, Bosman+ (ACCMOR Colli	ah \
BEBEK	86	PRL 56 1893	+Berkelman, Blucher, Cassel+ (CLEO Colli	
GLADNEY	86	PR D34 2601	+Jaros, Ong, Barklow+ (Mark II Colli	
LOUIS	86	PRL 56 1027	+Adolphsen, Alexander+ (PRIN, CHIC, I	
USHIDA	86B	PRL 56 1771	+Kondo+ (AICH, FNAL, KOBE, SEOU, MCG	
ALBRECHT	85B	PL 158B 525	+Binder, Harder, Philipp+ (ARGUS Colla	
ALBRECHT	85F	PL 150B 235	+Binder, Harder, Philipp+ (ARGUS Colla	
AUBERT	85	PL 155B 461	+Bassompierre, Becks, Benchouk+ (EMC Colla	
BAILEY	85	ZPHY C28 357	+Belau, Boehringer, Bosman+ (ABCCMR Colla	
BALTRUSAIT.	85B	PRL 54 1976	Baltrusaitis, Becker, Blaylock, Brown+ (Mark III Colla	
BALTRUSAIT.		PRL 55 150	Baltrusaitis, Becker, Blaylock, Brown+ (Mark III Colla	
BENVENUTI	85	PL 158B 531	+Bollini, Bruni, Camporesi+ (BCDMS Colla	
YAMAMOTO	85	PRL 54 522	+Yamamoto, Atwood, Baillon+ (DELCO Colla	
ADAMOVICH	84B	PL 140B 123	+Alexandrov, Bravo+ (CERN WA58 Colla	ıb.)
ALTHOFF	84B	PL 138B 317	+Braunschweig, Kirschfink+ (TASSO Colla	ıb.)
DERRICK	84	PRL 53 1971	+Fernandez, Fries, Hyman+ (HRS Colla	ıb.)
PARTRIDGE	84	Thesis CALT-68-1150	(Crystal Ball Colla	
SUMMERS	84	PRL 52 410	 + (UCSB, CARL, COLO, FNAL, TNTO, OKLA, CNF 	
BAILEY	83B	PL 132B 237	+Bardsley, Becker, Blanar+ (ACCMOR Colla	
BODEK	82	PL 113B 82	+Breedon+ (ROCH, CIT, CHIC, FNAL, STA	
FIORINO	81	LNC 30 166	 + (Photon-Emulsion and Omega-Photon Colla 	b.)
SCHINDLER	81	PR D24 78	+Alam, Boyarski, Breidenbach+ (Mark II Colla	
TRILLING	81	PRPL 75 57	(LBL, UC	
ASTON	80E	PL 94B 113	 + (BONN, CERN, EPOL, GLAS, LANC, MCHS 	
AVERY	80	PRL 44 1309	+Wiss, Butler, Gladding+ (ILL, FNAL, COI	
SCHINDLER	80	PR D21 2716	+Siegrist, Alam, Boyarski+ (Mark II Colla	
ZHOLENTZ	80	PL 96B 214	+Kurdadze, Lelchuk, Mishnev+ (NOV	
Also	81	SJNP 34 814	Zholentz, Kurdadze, Lelchuk+ (NOV	(0)
1001110	200	Translated from YAF 3		
ABRAMS	79D	PRL 43 481	+Alam, Blocker, Boyarski+ (Mark II Colla	
ATIYA	79	PRL 43 414	+Holmes, Knapp, Lee+ (COLU, ILL, FN/	
BALTAY	78C	PRL 41 73	+Caroumbalis, French, Hibbs, Hylton+ (COLU, BI	
VUILLEMIN	78	PRL 41 1149	+Feldman, Feller+ (Mark I Colla	
FELDMAN	77B	PRL 38 1313	+Peruzzi, Piccolo, Abrams, Alam+ (Mark I Colla	
GOLDHABER	77	PL 69B 503	+Wiss, Abrams, Alam+ (Mark I Colla	
PERUZZI	77	PRL 39 1301	+Piccolo, Feldman+ (Mark I Colla	
PICCOLO	77	PL 70B 260	+Peruzzi, Luth, Nguyen, Wiss, Abrams+ (Mark I Colla	
RAPIDIS	77	PRL 39 526	+Gobbi, Luke, Barbaro-Galtieri+ (Mark I Colla	
GOLDHABER	76	PRL 37 255	+Pierre, Abrams, Alam+ (Mark I Colla	b.)

OTHER RELATED PAPERS

RICHMAN ROSNER (UCSB, STAN) (CHIC)



 $I(J^P) = \frac{1}{2}(1^-)$ I, J, P need confirmation.

J consistent with 1, value 0 ruled out (NGUYEN 77).

D*(2007)0 MASS

The fit includes D^{\pm} , D^{0} , D_{s}^{\pm} , $D^{*\pm}$, D^{*0} , and $D_{s}^{*\pm}$ mass and mass

 VALUE (MeV)
 DOCUMENT ID
 TECN
 COMMENT

 2006.7 ± 0.5 OUR FIT
 Error includes scale factor of 1.1.
 TECN
 COMMENT
 \bullet \bullet \bullet We do not use the following data for averages, fits, limits, etc. \bullet \bullet 1 GOLDHABER 77 MRK1 $e^{+}e^{-}$ ¹ From simultaneous fit to $D^*(2010)^+$, $D^*(2007)^0$, D^+ , and D^0 .

$m_{D^*(2007)^0} - m_{D^0}$

The fit includes D^{\pm} , D^{0} , D_{s}^{\pm} , $D^{*\pm}$, D^{*0} , and $D_{s}^{*\pm}$ mass and mass difference measurements.

AUTOF (INICA)	LVIJ	DOCUMENT ID TECH COMMENT
142.12±0.07 OUR FIT	Ī	
142.12±0.07 OUR AV	ERAGE	
$142.2 \pm 0.3 \pm 0.2$	145	ALBRECHT 95F ARG $e^+e^- \rightarrow \text{hadrons}$
$142.12 \pm 0.05 \pm 0.05$	1176	BORTOLETTO928 CLE2 $e^+e^- \rightarrow \text{hadrons}$
• • • We do not use	he followin	g data for averages, fits, limits, etc. • •
142.2 ±2.0		SADROZINSKI 80 CBAL $D^{*0} ightarrow D^0 \pi^0$
142.7 ± 1.7		2 GOLDHABER 77 MRK1 e^+e^-
² From simultaneous	fit to D*($(2010)^+$, $(2007)^0$, $(2007)^0$, $(2007)^0$, and $(2007)^0$.

D*(2007)0 WIDTH

VALUE (MeV)	CL%	DOCUMENT ID	TECN	COMMENT
<2.1	90	³ ABACHI	88B HRS	$D^{*0} \rightarrow D^{+}\pi^{-}$
• • • We do not use the	e following	data for average	s, fits, limits,	etc. • • •
<5		GOLDHABER	76B MRK1	$e^+e^- \rightarrow D^*D^*$
³ Assuming $m_{D^{*0}} = 2$	2007.2 ± 2	$1.1 \text{ MeV}/c^2$.		

D*(2007)0 DECAY MODES

 $\overline{\it D}^*(2007)^0$ modes are charge conjugates of modes below.

	Mode	Fraction (Γ_i/Γ)
Γ ₁	$D^{0} \pi^{0}$	(61.9±2.9) %
Γ ₂	$D^{0} \gamma$	(38.1±2.9) %

$D^*(2007)^0$, $D^*(2010)^{\pm}$

CONSTRAINED FIT INFORMATION

An overall fit to a branching ratio uses 3 measurements and one constraint to determine 2 parameters. The overall fit has a χ^2 = 0.5 for 2 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\left\langle \delta x_i \delta x_j \right\rangle / (\delta x_i \cdot \delta x_j),$ in percent, from the fit to the branching fractions, $x_i \equiv$ $\Gamma_i/\Gamma_{
m total}$. The fit constrains the x_i whose labels appear in this array to sum to

$$x_2 \quad \boxed{-100}{x_1}$$

D*(2007)0 BRANCHING RATIOS

Γ_1/Γ						$\Gamma(D^0\pi^0)/\Gamma_{ m total}$	
	COMMENT	TECN		DOCUMENT ID	EVTS	VALUE	
						0.619±0.029 OUR FIT	
	etc. • • •	, limits,	s, fits	data for averages	ne following o	• • • We do not use t	
hadrons	$e^+e^- \rightarrow$	ARG	95F	ALBRECHT	858	$0.596 \pm 0.035 \pm 0.028$	
hadrons	$e^+e^- \rightarrow$	CLE2	92	BUTLER	1097	$0.636 \pm 0.023 \pm 0.033$	
Γ_2/Γ						$\Gamma(D^0\gamma)/\Gamma_{\text{total}}$	
	COMMENT	TECN		DOCUMENT ID	EVTS	VALUE	
						0.381 ± 0.029 OUR FIT	
					RAGE	0.381 ± 0.029 OUR AVI	
				ALBRECHT	456	$0.404 \pm 0.035 \pm 0.028$	
hadrons	$e^+e^- \rightarrow$	CLE2	92	BUTLER	621	$0.364 \pm 0.023 \pm 0.033$	
	e^+e^-	MRK3	88D	ADLER		$0.37 \pm 0.08 \pm 0.08$	
	etc. • • •	, limits,	s, fits	data for average	ne following	• • • We do not use t	
[⊢] e ⁻	29 GeV e+	HRS	87	LOW		0.47 ±0.23	
drons	e^+e^- , ha	JADE	85G	BARTEL		0.53 ±0.13	
	e^+e^-	MRK2	82	COLES		0.47 ± 0.12	
	e^+e^-	MRK1	77	GOLDHABER		0.45 ± 0.15	
						4	

⁴ The BUTLER 92 branching ratios are not independent, they have been constrained by the authors to sum to 100%.

D*(2007)0 REFERENCES

ALBRECHT 95F	ZPHY C66 63	+Ehrlichmann+	(ARGUS Collab.)
BORTOLETTO 92B	PRL 69 2046	+Brown, Dominick+	(CLEO Collab.)
BUTLER 92	PRL 69 2041	+Fu, Kalbfleish+	(CLEO Collab.)
ABACHI 88B	PL B212 533	+Akerlof+ (ANL, If	ND, MICH, PURD, LBL)
ADLER 88D	PL B208 152	+Becker+	(Mark III Collab.)
LOW 87	PL B183 232	+Abachi, Akerlof, Baringer+	(HRS Collab.)
BARTEL 85G	PL 161B 197	+Dietrich, Ambrus+	(JADE Collab.)
COLES 82	PR D26 2190	+Abrams, Blocker, Blondel+	(LBL, SLAC)
SADROZINSKI 80	Madison Conf. 681	+ (PRIN, CI	T, HARV, SLAC, STAN)
GOLDHABER 77	PL 69B 503	+Wiss, Abrams, Alam+	(Mark I Collab.)
NGUYEN 77	PRL 39 262	+Wiss, Abrams, Alam, Boyarski+	` (LBL, SLAC) J
GOLDHABER 76B	SLAC Conf. 379		(LBL, SLAC)
Available as I BI	-5534		, , ,

- OTHER RELATED PAPERS -

KAMAL	92	PI B284 421	+X11	(ALBE)
			170	
TRILLING	81	PRPL 75 57		(LBL, UCB)
FELDMAN	77C	Banff Sum. Inst. 75		(SLAC)
GOLDHABER	76	PRL 37 255	+Pierre, Abrams, Alam+	(Mark I Collab.)



$$I(J^P) = \frac{1}{2}(1^-)$$

I, J, P need confirmation.

$D^*(2010)^{\pm}$ MASS

The fit includes D^{\pm} , D^{0} , D_{ϵ}^{\pm} , $D^{*\pm}$, D^{*0} , and $D_{\epsilon}^{*\pm}$ mass and mass difference measurements.

VALUE (MeV)	DOCUMENT ID	TECN	CHG	COMMENT
2010.0±0.5 OUR FIT Error inc				
• • We do not use the following	ng data for averages, fit	s, limits,	etc. •	• •
2008 ±3	¹ GOLDHABER 77			
2008.6 ± 1.0	² PERUZZI 77	MRK1	±	e^+e^-

From simultaneous fit to $D^*(2010)^+$, $D^*(2007)^0$, D^+ , and D^0 ; not independent of FELDMAN 778 mass difference below. PERUZZI 77 mass not independent of FELDMAN 778 mass difference below and PERUZZI 77 D^0 mass value.

$m_{D^{*}(2010)^{+}} - m_{D^{+}}$

The fit includes D^\pm , D^0 , D_s^\pm , $D^{*\pm}$, D^{*0} , and $D_s^{*\pm}$ mass and mass difference measurements.

VALUE (MeV)	EVTS	DOCUMENT ID TECN	COMMENT
140.64±0.09 OUR FIT			
$140.64 \pm 0.08 \pm 0.06$	620	BORTOLETTO92B CLE2	$e^+e^- \rightarrow hadrons$

$m_{D^*(2010)^+} - m_{D^0}$

The fit includes D^\pm , D^0 , D_s^\pm , $D^{*\pm}$, D^{*0} , and $D_s^{*\pm}$ mass and mass difference measurements.

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
145.42±0.05 OUR	FIT				
145.42±0.04 OUR	AVERAGE				
$145.39 \pm 0.06 \pm 0.03$		BARLAG	92B	ACCM	π^- 230 GeV
$145.40 \pm 0.05 \pm 0.10$		ABACHI		HRS	
$145.46 \pm 0.07 \pm 0.03$		ALBRECHT			$D^{*\pm} \rightarrow D^0 \pi^+$
145.8 ± 1.5	16	AHLEN			$D^{*+} \rightarrow D^0 \pi^+$
145.1 ± 1.8	12	BAILEY			$D^{*\pm} \rightarrow D^0 \pi^{\pm}$
145.5 ± 0.3	28	BAILEY	83	SPEC	$D^{*\pm} \rightarrow D^0 \pi^{\pm}$
145.1 ± 0.5	14	BAILEY	83	SPEC	
145.5 ± 0.5	14	YELTON	82	MRK2	$29~e^+~e^-~\rightarrow~K^-~\pi^+$
145.5 ± 0.3	60	FITCH	81	SPEC	π ⁻ A
145.2 ± 0.6	2	BLIETSCHAU	79	BEBC	νρ
145.3 ± 0.5	30	FELDMAN	77B	MRK1	$D^{*+} \rightarrow D^0 \pi^+$
• • • We do not use	the following	g data for averages	, fits	, limits,	etc. • • •
145.4 ±0.2	48	3 DERRICK	95	ZEUS	$D^{*\pm} \rightarrow D^0 \pi^{\pm}$
145.5 ±0.2	115	3 ALEXANDER	91B	OPAL	$D^{*\pm} \rightarrow D^0 \pi^{\pm}$
145.30 ± 0.06		3 DECAMP	9 1J	ALEP	$D^{*\pm} \rightarrow D^0 \pi^{\pm}$
~ 145.5		AVERY	80	SPEC	γ A
3 Systematic error no	ot evaluated	_			

$m_{D^{\bullet}(2010)^{+}} - m_{D^{\bullet}(2007)^{0}}$

VALUE (MeV)	DOCUMENT ID	TECN COMMENT
• • • We do not use the follow	owing data for averages, fit	s, limits, etc. • • •
26110	4 DEDUZZI - 22	MDK1 at a=

 $^{^4}$ Not independent of FELDMAN 77B mass difference above, PERUZZI 77 D^0 mass, and GOLDHABER 77 D*(2007)0 mass.

D*(2010)* WIDTH

VALUE (MeV)	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
<0.131	90	110	BARLAG	928 ACC	Λ π ⁻ 230 GeV
• • • We do	not use the	following	ng data for average	s, fits, limit	s, etc. • • •
<1.1	90		ABACHI	88B HRS	$D^{*\pm} \rightarrow D^0 \pi^{\pm}$
<2.2			YELTON	82 MRK	$e^{+}e^{-} \rightarrow K^{-}\pi^{+}\pi^{-}$
< 2.0	90	30	FELDMAN	778 MRK	$1 D^{*+} \rightarrow D^0 \pi^+$

$D^*(2010)^{\pm}$ DECAY MODES

 $D^*(2010)^-$ modes are charge conjugates of the modes below.

	Mode	Fraction $(\Gamma_{\hat{I}}/\Gamma)$
$\overline{\Gamma_1}$	$D^0 \pi^+$	(68.3±1.4) %
Γ_2	$D^+\pi^0$	(30.6±2.5) %
Γ_3	$D^+\gamma$	$(1.1^{+2.1}_{-0.7})\%$

CONSTRAINED FIT INFORMATION

An overall fit to 2 branching ratios uses 3 measurements and one constraint to determine 3 parameters. The overall fit has a χ^2 = 0.0 for 1 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\left<\delta x_i \delta x_j \right>/(\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv$ $\Gamma_i/\Gamma_{ ext{total}}$. The fit constrains the x_i whose labels appear in this array to sum to

$$\begin{array}{c|cccc} x_2 & -55 & \\ x_3 & 0 & -83 \\ \hline & x_1 & x_2 \end{array}$$

ı

D*(2010)+ BRANCHING RATIOS

$\Gamma(D^0\pi^+)/\Gamma_{\text{total}}$				Γ_1/Γ
VALUE	DOCUMENT ID	<u>TECN</u>	COMMENT	
0.683±0.014 OUR FIT 0.683±0.014 OUR AVERAGE				
$0.688 \pm 0.024 \pm 0.013$	ALBRECHT	95F ARG	$e^+e^- \rightarrow$	hadrons
$0.681 \pm 0.010 \pm 0.013$	⁷ BUTLER	92 CLE2	$e^+e^- \rightarrow$	hadrons
• • We do not use the following	ng data for average	s, fits, limit	s, etc. • • •	
$0.57 \pm 0.04 \pm 0.04$	ADLER	88D MRK	3 e ⁺ e ⁻	
0.44 ±0.10	COLES			
0.6 ±0.15	⁵ GOLDHABER	77 MRK	1 e ⁺ e ⁻	
r				

I

⁵ Assuming that isospin is conserved in the decay.

$\Gamma(D^+\pi^0)/\Gamma_{ m total}$					Γ_2/Γ
ALUE .306±0.025 OUR I	<u>EVTS</u>	DOCUMENT ID	<u>TECN</u>	COMMENT	
• We do not us		g data for average	es, fits, limits	, etc. • • •	
$0.312 \pm 0.011 \pm 0.008$		ALBRECHT		$e^+e^- \rightarrow h$	
$0.308 \pm 0.004 \pm 0.008$	3 410	7 BUTLER		$e^+e^- \rightarrow h$	adrons
0.26 ±0.02 ±0.02 0.34 ±0.07		ADLER COLES	88D MRK3 82 MRK2		
$(D^+\gamma)/\Gamma_{\text{total}}$					Г ₃ /Г
ALUE TITOLIA	CL%	EVTS DOCU	IMENT ID	TECN COM	-,
0.011 + 0.021 OU	R FIT				
0.011±0.014±0.6	016	12 ⁷ BUT	LER 92		e ⁻ →
• • We do not us	e the followin	g data for average	s, fits, limits	etc. • • •	nadrons
<0.052	90	ALBI	RECHT 95		e [—] → nadrons
0.17 ±0.05 ±0.0	05	ADLI ⁶ COLI		D MRK3 e ⁺	e —
0.22 ±0.12 ⁶ Not independent	of r(D0 +			MRK2 e ⁺	
7 The BUTLER 9					
the authors to si					
	D *	(2010) [±] REFEI	RENCES		
	PHY C66 63	+Ehrlichmann+		(ARGU	JS Collab.)
ARLAG 92B PL	B349 225 B278 480	+Krakauer, et al +Becker, Bozek-	+	(ZEL (ACCMC	JS Collab.) JR Collab.)
ORTOLETTO 92B PF UTLER 92 PF	RL 69 2046 RL 69 2041	+Brown, Domini +Fu, Kalbfleish+	ck+	(CLE	O Collab.)
LEXANDER 91B PL	B262 341 B266 218	+Allison, Allport +Deschizeaux, G	, Anderson, Arc	elli+ (OPA	AL Collab.) 'H Collab.)
BACHI 88B PL	B212 533	+Akerlof+ +Becker+	(ANL	, IND, MICH, PL	JRD, LBL) III Collab.)
LBRECHT 85F PL	B208 152 150B 235	+Binder, Harder,	Philipp+	(ARGL	JS Collab.)
AILEY 83 PL	RL 51 1147 . 132B 230	+Akerlof+ +Bardsley+	(AMST, BR	LBL, MICH, PUF IS, CERN, CRAC	, MPIM+)
FITON 82 PE	R D26 2190 RL 49 430	+Abrams, Block +Feldman, Goldi	er, Blondel+ naber+	(SLAC, LBL, UC	BL, SLAC) B, HARV)
TCH 81 PF VERY 80 PF	RL 46 761 RL 44 1309	+Devaux, Cavag +Wiss, Butler, C	lia, May+ Gladding+	(SLAC, LBL, UC (PRIN, SACL, TO (ILL, FNA	ORI, BNL) AL. COLU)
LIETSCHAU 79 PL	86B 108 RL 38 1313	+ +Peruzzi, Piccole	(AACH3, E	ONN, CERN, MI	PIM, OXF) I Collab.)
OLDHABER 77 .PL	69B 503 RL 39 1301	+Wiss, Abrams, +Piccolo, Feldm	Alam+	(Mark	I Collab.)
		IER RELATED		(14101 K	i conab.)
MAL 92 PL	. B284 421	+Xu	PAPER3		(ALDE)
THOFF 83C PL	126B 493 RL 49 610	+Fischer, Burkha	ardt+	(TASS H, RUTG, SYRA	(ALBE) O Collab.)
RILLING 81 PF	RPL 75 57 RL 37 569	+ Piccolo, Feldm		(L	BL, UCB)
(0221 70 F1	(L 37 309	+r iccolo, relalii.	an, ivguyen, vvis	ist (iviain	T Conab.)
D (2420)	0	I(J ^F	$rac{1}{2}(1^{+})$	-)	
$D_1(2420)$		I, J,	P need o	confirmation	
Seen in D	$^*(2010)^+\pi^-$	$J^P = 1^+ \text{ acc}$	ording to AL	BRECHT 89	н.
		D ₁ (2420) ⁰ M	ASS		
	E1 (TA)			60141/51/7	
LUE (MeV) 22.2±1.8 OUR A	<u>EVTS</u> VERAGE Er	ror includes scale			
$21 \begin{array}{c} +1 \\ -2 \end{array} \pm 2$	286	AVERY	94C CLE2	$e^+e^- \rightarrow L$	»+π-X
422 ±2 ±2	51	FRABETTI	94B E687	$\gamma \mathrm{Be} o D^*$	
2428 ±3 ±2	279	AVERY	90 CLEO		
414 ±2 ±5 428 ±8 ±5	171 171	ALBRECHT ANJOS	89н ARG 89с TPS	$e^+e^- \rightarrow D$ $\gamma N \rightarrow D^{*+}$	
				,	
		D ₁ (2420) ⁰ WII	DTH		
LUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT	
3.9 + 4.6 OUR AV	ERAGE				
+ 6 - 5 ± 3	286	AVERY	94c CLE2	$e^+e^- \rightarrow L$)*+π-X
5 ± 8 ± 4	51	FRABETTI	94B E687	γ Be → D*	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	279	AVERY	90 CLEO	$e^+e^- \rightarrow L$	
$\pm 6 + \frac{10}{5}$	171	ALBRECHT	89H ARG	$e^+e^- ightarrow {\it L}$	
- 5					

 \bullet \bullet We do not use the following data for averages, fits, limits, etc. \bullet \bullet

$D_1(2420)^0$ DECAY MODES $\overline{\it D}_{1}(2420)^{0}$ modes are charge conjugates of modes below. $D^*(2010)^+\pi^-$ D+`π⁻ not seen D1(2420)0 BRANCHING RATIOS 2010) $^+\pi^-$)/ Γ_{total} Γ_1/Γ TECN COMMENT DOCUMENT ID 90 CLEO $e^{+}e^{-} \rightarrow D^{*+}\pi^{-}X$ 89H ARG $e^{+}e^{-} \rightarrow D^{*}\pi^{-}X$ AVERY ALBRECHT $\gamma N \rightarrow D^{*+}\pi^{-}X$ ANJOS 89c TPS $\pi^{-})/\Gamma(D^{*}(2010)^{+}\pi^{-})$ Γ_2/Γ_1 DOCUMENT ID TECN COMMENT CL% 90 CLEO $e^+e^- \rightarrow D^+\pi^- X$ AVERY 90 D₁(2420)⁰ REFERENCES 94C PL B331 236 94B PRL 72 324 90 PR D41 774 89H PL B232 398 89C PRL 62 1717 +Freyberger, Rodriguez+ +Cheung, Cumalat+ +Besson +Glaser, Harder+ +Appel+ (CLEO Collab.) (FNAL E687 Collab.) (CLEO Collab.) (ARGUS Collab.) JP (FNAL E691 Collab.) $I(J^P) = \frac{1}{2}(?^?)$ $(2420)^{\pm}$ I needs confirmation. FED FROM SUMMARY TABLE Seen in $D^*(2007)^0\pi^+$. $J^P=0^+$ ruled out. $D_1(2420)^{\pm}$ MASS EVTS DOCUMENT ID TECN COMMENT GOUR AVERAGE Error includes scale factor of 2.0. ± 2 146 BERGFELD 94B CLE2 $e^+e^- \rightarrow D^{*0}\pi^+ X$ $\gamma N \rightarrow D^0 \pi^+ X^0$ ANJOS 89c TPS ±5 190 $m_{D_1^*(2420)^{\pm}} - m_{D_1^*(2420)^0}$ DOCUMENT ID ∕leV) TECN COMMENT BERGFELD 948 CLE2 $e^+e^- \rightarrow \text{hadrons}$ $D_1(2420)^{\pm}$ WIDTH MeV) OUR AVERAGE EVTS DOCUMENT ID TECN COMMENT BERGFELD 94B CLE2 $e^+e^- \rightarrow D^{*0}\pi^+X$ ±4 146 <u>+</u>8 89C TPS $\gamma N \rightarrow D^0 \pi^+ X^0$ $D_1(2420)^{\pm}$ DECAY MODES $D_1^*(2420)^-$ modes are charge conjugates of modes below. Fraction (Γ_i/Γ) Mode $D^*(2007)^0 \pi^+$ $D^0 \pi^+$ not seen D1(2420) BRANCHING RATIOS 2007) $^0\pi^+)/\Gamma_{ m total}$ Γ_1/Γ DOCUMENT ID TECN COMMENT 89C TPS $\gamma N \rightarrow D^0 \pi^+ X^0$ Γ_2/Γ_1 $^{+})/\Gamma(D^{*}(2007)^{0}\pi^{+})$ CL% DOCUMENT ID TECN COMMENT We do not use the following data for averages, fits, limits, etc. • • < 0.18 BERGFELD 94B CLE2 $e^+e^- \rightarrow \text{hadrons}$ D₁(2420)[±] REFERENCES

+Eisenstein, Gollin+ +Appel+ (CLEO Collab.) (FNAL E691 Collab.)

BERGFELD ANJOS 94B PL B340 194 89C PRL 62 1717

 $D_2^*(2460)^0$, $D_2^*(2460)^+$

$D_2^*(2460)^0$

$$I(J^P) = \frac{1}{2}(2^+)$$

 $J^P = 2^+$ assignment strongly favored (ALBRECHT 89B).

D*(2460)0 MASS

VALUE	(MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
2458.9	±2.	OUR	AVERAGE Error	includes scale	factor	of 1.2.	
2465	± 3	± 3	486	AVERY	94C	CLE2	$e^+e^- \rightarrow D^+\pi^-X$
2453	± 3	± 2	128	FRABETTI	94B	E687	$\gamma \text{Be} \rightarrow D^+ \pi^- X$
2461	± 3	± 1	440	AVERY	90	CLEO	$e^+e^- \rightarrow D^{*+}\pi^-X$
2455	± 3	± 5	337	ALBRECHT	89B	ARG	$e^+e^- \rightarrow D^+\pi^-X$
2459	± 3	±2	153	ANJOS	89C	TPS	$\gamma N \rightarrow D^{+}\pi^{-}X$
	We	do not	use the following o	lata for averag	es, fits	, limits,	etc. • • •
2466	±7		1	ASRATYAN	95	BEBC	$\begin{array}{ccc} 53,40 \ \nu(\overline{\nu}) \rightarrow & p + X, \\ d + X \end{array}$

$D_2^*(2460)^0$ WIDTH

VALUE (MeV) 23 + 5 OUR AVERAGE	EVTS	DOCUMENT ID	TECN	COMMENT
28 ⁺ ₇ ± 6	486	AVERY	94c CLE2	$e^+e^- \rightarrow D^+\pi^-X$
$25\pm10\pm~5$	128	FRABETTI	94B E687	$\gamma\mathrm{Be} \to D^+\pi^-\mathrm{X}$
20^{+9+9}_{-12-10}	440	AVERY	90 CLEO	$e^+e^- \rightarrow D^{*+}\pi^-X$
$15 + 13 + 5 \\ -10 - 10$	337	ALBRECHT	89B ARG	$e^+e^- \rightarrow D^+\pi^- X$
$20\pm10\pm5$	153	ANJOS	89C TPS	$\gamma N \rightarrow D^+ \pi^- X$

D*(2460)0 DECAY MODES

 $\overline{\it D}_{2}^{*}(2460)^{0}$ modes are charge conjugates of modes below.

	Mode	Fraction (Γ_i/Γ)
Γ ₁ Γ ₂	$D^+\pi^- \ D^*(2010)^+\pi^-$	seen seen

D₂*(2460)⁰ BRANCHING RATIOS

$\Gamma(D^+\pi^-)/\Gamma_{total}$			Γ_1/Γ
VALUE EVTS	DOCUMENT ID	TECN	COMMENT
seen 337	ALBRECHT	89B ARG	$e^+e^- \rightarrow D^+\pi^-X$
seen	ANJOS	89c TPS	$\gamma N \rightarrow D^+ \pi^- X$
$\Gamma(D^*(2010)^+\pi^-)/\Gamma_{total}$			Γ_2/Γ
VALUE	DOCUMENT ID	TECN	COMMENT
seen	AVERY	90 CLEO	$e^+e^- \rightarrow D^{*+}\pi^-X$
seen	ALBRECHT	89H ARG	$e^+e^- \rightarrow D^*\pi^-X$
$\Gamma(D^{+}\pi^{-})/\Gamma(D^{*}(2010)^{+}\pi^{-})$			Γ_1/Γ_2
VALUE	DOCUMENT ID	TECN	COMMENT
2.3±0.6 OUR AVERAGE			
$2.2 \pm 0.7 \pm 0.6$	AVERY	94C CLE2	$e^+e^- \rightarrow D^{*+}\pi^- X$
2.3 ± 0.8	AVERY	90 CLEO	e+ e-
$3.0 \pm 1.1 \pm 1.5$	ALBRECHT	89н ARG	$e^+e^- \rightarrow D^*\pi^-X$

D₂*(2460)⁰ REFERENCES

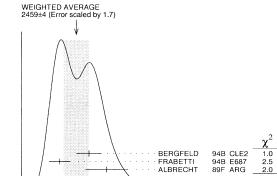
ASRATYAN	95	ZPHY C68 43	 + (BIRM, BELG, CERN 	, SERP, ITEP, MPIM, RAL)
AVERY	94 C	PL B331 236	+Freyberger, Rodriguez+	(CLEO Collab.)
FRABETTI	94 B	PRL 72 324	+Cheung, Cumalat+	(FNAL E687 Collab.)
AVERY	90	PR D41 774	+Besson	(CLEO Collab.)
ALBRECHT	89B	PL B221 422	+Boeckmann+	(ARGUS Collab.) JP
ALBRECHT	89H	PL B232 398	+Glaser, Harder+	(ARGUS Collab.) JP
ANJOS	89C	PRL 62 1717	+Appel+	(FNAL E691 Collab.)

 $D_2^*(2460)^{\pm}$

 $I(J^P) = \frac{1}{2}(2^+)$

$D_2^*(2460)^{\pm}$ MASS

	VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
:	2459±4 OUR AVERAGE	Error inc	ludes scale facto	r of 1.7. See	the ideogram below.
:	2463±3±3	310	BERGFELD		$e^+e^- \rightarrow D^0\pi^+X$
:	2453±3±2	185	FRABETTI		$\gamma \text{ Be} \rightarrow D^0 \pi^+ X$
- :	2469±4±6		ALBRECHT	89F ARG	$e^+e^- \rightarrow D^0\pi^+X$



(Confidence Level

2440 2450 2460 $D_2^*(2460)^{\pm}$ mass (MeV)

$m_{D_2^*(2460)^{\pm}} - m_{D_2^*(2460)^0}$

2480

2470

VALUE	(MeV)	DOCUMENT ID	TECN	COMMENT
0.	9±3.	3 OUR AVERAGE	Error includes scale fa	ctor of 1.1.	
- 2	± 4	±4	BERGFELD	94B CLE2	$e^+e^- \rightarrow \text{hadrons}$
0	± 4		FRABETTI	94B E687	$\gamma \text{Be} \rightarrow D\pi X$
14	± 5	±8	ALBRECHT	89F ARG	$e^+e^- \rightarrow D^0\pi^+X$

$D_2^*(2460)^{\pm}$ WIDTH

VALUE (MeV) 25 + 8 OUR AVER	EVTS PAGE	DOCUMENT ID	TECN	COMMENT
27 + 11 ± 5	310	BERGFELD	, 10 CLLL	$e^+e^- \rightarrow D^0\pi^+X$
$23\pm~9\pm5$	185	FRABETTI	94B E687	$\gamma \text{ Be} \rightarrow D^0 \pi^+ X$

$D_2^*(2460)^{\pm}$ DECAY MODES

 $D_2^*(2460)^-$ modes are charge conjugates of modes below.

	Mode	Fraction (Γ_i/Γ)
Γ1	$D^0 \pi^+$	seen
Γ_2	$D^{*0}\pi^{+}$	seen

D*(2460)* BRANCHING RATIOS

$\Gamma(D^0\pi^+)/\Gamma_{total}$				Γ_1/Γ
VALUE	DOCUMENT ID	TECN	COMMENT	
seen	ALBRECHT	89F ARG	$e^+e^ \rightarrow$	$D^0 \pi^+ X$
$\Gamma(D^0\pi^+)/\Gamma(D^{*0}\pi^+)$				Γ_1/Γ_2
VALUE	DOCUMENT ID	TECN	COMMENT	
$1.9 \pm 1.1 \pm 0.3$	BERGFELD	94B CLE2	$e^+e^- \rightarrow$	hadrons

D*(2460)* REFERENCES

CHARMED, STRANGE MESONS $(C = S = \pm 1)$

 $D_s^+ = c\overline{s}$, $D_s^- = \overline{c}s$, similarly for D_s^* 's

D_s^\pm was F^\pm

$$I(J^P) = 0(0^-)$$

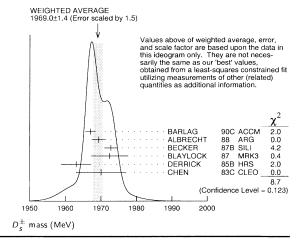
The angular distributions of the decays of the ϕ and $\overline{K}^*(892)^0$ in the $\phi\pi^+$ and $K^+\overline{K}^*(892)^0$ modes strongly indicate that the spin is zero. The parity given is that expected of a $c\,\overline{s}$ ground state.

D_s^{\pm} MASS

The fit includes D^\pm , D^0 , D_s^\pm , $D^{*\pm}$, D^{*0} , and $D_s^{*\pm}$ mass and mass difference measurements. Measurements of the D_s^\pm mass with an error greater than 10 MeV are omitted from the fit and average. A number of early measurements have been omitted altogether.

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
1968.5± 0.6 OUR FIT	Error includes	s scale factor of 1	.1.	
1969.0 ± 1.4 OUR AVE	RAGE Error i	ncludes scale fact	or of 1.5. Se	e the ideogram below.
1967.0 ± 1.0 ± 1.0	54	BARLAG	90c ACCM	π^- Cu 230 GeV
1969.3± 1.4± 1.4		ALBRECHT	88 ARG	e ⁺ e ⁻ 9.4-10.6 GeV
1972.7± 1.5± 1.0	21	BECKER	87B SILI	200 GeV π,K,p
1972.4± 3.7± 3.7	27	BLAYLOCK	87 MRK3	e^+e^- 4.14 GeV
1963 \pm 3 \pm 3	30	DERRICK	85B HRS	e^+e^- 29 GeV
1970 \pm 5 \pm 5	104	CHEN	83C CLEO	$e^{+}e^{-}$ 10.5 GeV
• • • We do not use the	following dat	a for averages, fit	s, limits, etc.	• • •
1968.3± 0.7± 0.7	290	¹ ANJOS	88 E691	Photoproduction
1980 ±15	6	USHIDA	86 EMUL	u wideband
1973.6 ± 2.6 ± 3.0	163	ALBRECHT	85D ARG	e^+e^- 10 GeV
1948 ±28 ±10	65	AIHARA	84D TPC	e^+e^- 29 GeV
1975 \pm 9 \pm 10	49	ALTHOFF	84 TASS	$e^{+}e^{-}$ 14–25 GeV
1975 ± 4	3	BAILEY	84 ACCM	hadron $^+$ Be $ ightarrow$ $\phi\pi^+$ X

 1 ANJOS 88 enters the fit via $m_{D_{\varsigma}^{\pm}}-m_{D^{\pm}}$ (see below).



$m_{D_s^\pm} - m_{D^\pm}$

The fit includes D^\pm , D^0 , D_s^\pm , $D^{*\pm}$, D^{*0} , and $D_s^{*\pm}$ mass and mass difference measurements.

VALUE (MeV)	EVTS	DOCUMENT	ID	TECN	COMMENT	
99.2±0.5 OUR FIT	Error include	s scale factor	of 1.1.			
99.2±0.5 OUR AVER	RAGE					
$99.5 \pm 0.6 \pm 0.3$		BROWN	94	CLEO	$e^+e^-pprox \varUpsilon$ (45)	
98.5 ± 1.5	555	CHEN	89	CLEO	$e^{+}e^{-}$ 10.5 GeV	
99.0 ± 0.8	290	ANJOS	88	E691	Photoproduction	

Ds MEAN LIFE

Measurements with an error greater than $0.2 \times 10^{-12} \, \text{s}$ are omitted from the average.

VALUE (10 ⁻¹² s)	EVTS	DOCUMENT ID		TECN	COMMENT
0.467±0.017 OUR AV	ERAGE				
$0.475 \pm 0.020 \pm 0.007$	900	FRABETTI	93F	E687	γ Be, $D_{\mathcal{S}}^+ o \phi \pi^+$
$0.33 \ ^{+ 0.12}_{- 0.08} \ \pm 0.03$	15	ALVAREZ	90	NA14	γ , $D_s^+ \rightarrow \phi \pi^+$
$0.469^{+0.102}_{-0.086}$	54	² BARLAG	90c	ACCM	π^- Cu 230 GeV
$0.50\ \pm0.06\ \pm0.03$	104	FRABETTI	90	E687	γ Be, $\phi\pi^+$
$0.56 \ ^{+0.13}_{-0.12} \ \pm 0.08$	144	ALBRECHT	881	ARG	e^+e^- 10 GeV
$0.47\ \pm0.04\ \pm0.02$	228	RAAB	88	E691	Photoproduction
$0.33 \begin{array}{l} +0.10 \\ -0.06 \end{array}$	21	³ BECKER	87B	SILI	200 GeV π , K , p
$0.26 \begin{array}{c} +0.16 \\ -0.09 \end{array}$	6	USHIDA	86	EMUL	u wideband
• • • We do not use t	he followir	g data for averages	, fits	, limits,	etc. • • •
$0.31 \ ^{+0.24}_{-0.20} \ \pm 0.05$	18	AVERILL	89	HRS	e^+e^- 29 GeV
$0.48 \ ^{+ 0.06}_{- 0.05} \ \pm 0.02$	99	SOLNA	87B	E691	See RAAB 88
$0.57 \ ^{+ 0.36}_{- 0.26} \ \pm 0.09$	9	BRAUNSCH	87	TASS	$e^{+}e^{-}$ 35-44 GeV
$0.47\ \pm0.22\ \pm0.05$	141	CSORNA	87	CLEO	e^+e^- 10 GeV
$0.35 \ ^{+0.24}_{-0.18} \ \pm 0.09$	17	JUNG	86	HRS	See AVERILL 89
$0.32 \begin{array}{l} +0.30 \\ -0.13 \end{array}$	3	BAILEY	84	АССМ	hadron $^+$ Be $ ightarrow \phi \pi^+ X$
$0.19 \begin{array}{l} +0.13 \\ -0.07 \end{array}$	4	USHIDA	83	EMUL	See USHIDA 86
² BARLAG 90c estim ³ BECKER 878 estim					

D DECAY MODES

Branching fractions for modes with a resonance in the final state include all the decay modes of the resonance. D_S^- modes are charge conjugates of the modes below

	Mode	Fraction (Γ_i/Γ)	Confidence level
	Inclusive	modes	
Γ ₁	\mathcal{K}^- anything	$(13 \begin{array}{c} +14 \\ -12 \end{array}) \%$	
2	$\overline{\mathcal{K}}^0$ anything $+$ \mathcal{K}^0 anything	(39 ±28) %	
3	\mathcal{K}^+ anything	$(20 \ ^{+18}_{-14})\%$	
4	non- $K\overline{K}$ anything	(64 ±17)%	
5	e ⁺ anything	< 20 %	90%
	Leptonic and sen	nileptonic modes	
6	$\mu^+ u_\mu$	(9 ± 4)×10	0-3
7	$\phi \ell^+ \nu_\ell$	[a] (1.9 ± 0.5) %	
8	$\eta \ell^+ \nu_\ell + \eta'(958) \ell^+ \nu_\ell$	$(3.3 \pm 1.0)\%$	
9	$\eta \ell^+ \nu_{\ell}$	(2.5 ± 0.7) %	2
LO	$\eta'(958)\ell^+ u_\ell$	(8.7 ± 3.4) × 10	₀ -3
	Hadronic modes with a KF	$\overline{\zeta}$ pair (including from	$a \phi$)
11	$K^+\overline{K}^0$	(3.6 ± 1.1) %	
12	$K^+K^-\pi^+$	[b] (4.6 ± 1.2) %	
13	$\phi\pi^+\ K^+\overline{K}^*$ (892) 0	(3.6 ± 0.9) %	
14 15	$f_0(980)\pi^+$	$(3.4 \pm 0.9) \%$ $(1.1 \pm 0.4) \%$	
15 16	$K^{+}\overline{K}_{0}^{*}(1430)^{0}$	$(7 \pm 4) \times 10$	₁ -3
17	$f_J(1710)\pi^+ \to K^+K^-\pi^+$	[c] $(1.5\pm 2.0) \times 10$	
. 8	$K^+K^-\pi^+$ nonresonant	(9 ± 4)×10	
9		, ,	
20		(4.3 ± 1.4) %	
21	$K^{+}K^{-}\pi^{+}\pi^{0}$		
22	$\phi \pi^+ \pi^0 \phi \rho^+$	(9 ± 5)%	
23	+ Do + +	(6.7± 2.3) % < 2.6 %	90%
24 25	$\phi \pi^+ \pi^0$ 3-body $K^+ K^- \pi^+ \pi^0$ non- ϕ	< 9 %	90%
25 26	$K^{+}\overline{K}^{0}\pi^{+}\pi^{-}$	< 2.8 %	90%
2 0 27	$\kappa^0 \kappa^- \pi^+ \pi^+$	(4.3± 1.5) %	
28	$K^*(892)^+\overline{K}^*(892)^0$	(5.8 ± 2.5) %	
29	$K^0K^-\pi^+\pi^+$ non- $K^{*+}\overline{K}^{*0}$	< 2.9 %	90%
30	$K^{+}K^{-}\pi^{+}\pi^{+}\pi^{-}$		
		/ 10 0 () 0/	

 $(3.0^{+}_{-2.0})\%$ $(3.0^{+}_{-2.0})\times10^{-3}$

 $\phi \pi^{+} \pi^{+} \pi^{-}$

 $K^+K^-\pi^+\pi^+\pi^-$ non- ϕ

 Γ_{31}

 D_s^{\pm}

Other hadronic modes (0, 1, or 3 K's)								
Γ ₃₃	$\pi^{+}\pi^{+}\pi^{-}$		(1.4± 0.	4) %				
Γ ₃₄	$ ho^{0}\pi^{+}$		< 2.9	× 10 ⁻³	90%			
Γ ₃₅	$f_0(980)\pi^+$		(1.2± 0.	5) %				
Γ ₃₆	$\pi^+\pi^+\pi^-$ nonresonant		(1.0 ± 0.	4) %				
Γ ₃₇	$\pi^{+} \pi^{+} \pi^{-} \pi^{0}$		< 12	%	90%			
Γ ₃₈	$\eta\pi^+$		(2.0± 0.	6) %				
Γ ₃₉	$\omega \pi^+$		< 1.8	%	90%			
Γ_{40}	$\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}$		(3.0 + 4.	$_{0}^{0}) \times 10^{-3}$				
Γ_{41}	$\pi^{+} \pi^{+} \pi^{-} \pi^{0} \pi^{0}$							
Γ_{42}	$\eta \rho^+$		(10.3± 3.	2) %				
Γ_{43}	$\eta\pi^+\pi^0$ 3-body		< 3.0	%	90%			
Γ_{44}	$\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0}$		(4.9± 3.	2) %				
Γ_{45}	$\eta'(958)\pi^{+}$		(4.9± 1.	8) %				
Γ_{46}	$\pi^{+} \pi^{+} \pi^{+} \pi^{-} \pi^{-} \pi^{0} \pi^{0}$							
Γ_{47}	$\eta'(958)\rho^{+}$		(12 ± 4)) %				
Γ ₄₈	$\eta'(958)\pi^{+}\pi^{0}$ 3-body		< 3.1	%	90%			
Γ_{49}	$K^0\pi^+$		< 8		90%			
30	$K^+\pi^+\pi^-$		(1.0± 0.					
Γ_{51}	$K^+ \rho^0$		< 2.9		90%			
	$K^*(892)^0 \pi^+$		(6.5± 2.	8) × 10 ⁻³				
. 55	K+K+K-		< 6		90%			
Γ_{54}	ϕK^+		< 5	× 10 ⁻⁴	90%			
	$\Delta C = 1$ weak ne	utral c	urrent (C1) mo	des, or				
	Lepton num	ber (L)) violating mode	es				
Γ ₅₅	$\pi^{+} \mu^{+} \mu^{-}$		[d] < 4.3	× 10 ⁻⁴	90%			
Γ ₅₆	$K^+\mu^+\mu^-$	C1	< 5.9	× 10 ⁻⁴	90%			
Γ ₅₇	$K^*(892)^+ \mu^+ \mu^-$	C1	< 1.4	× 10 ⁻³	90%			
Γ ₅₈	$\pi^-\mu^+\mu^+$	L	< 4.3	\times 10 ⁻⁴	90%			
	$K^-\mu^+\mu^+$	L	< 5.9	\times 10 ⁻⁴	90%			
Γ ₆₀	$K^*(892)^- \mu^+ \mu^+$	L	< 1.4	× 10 ⁻³	90%			

[a] For now, we average together measurements of the $\phi\,e^+\,\nu_e$ and $\phi\,\mu^+\,\nu_\mu$ branching fractions. This is the $\it average$, not the $\it sum$.

 $(82 \pm 4)\%$

 Γ_{61} . A dummy mode used by the fit.

- [b] The branching fractions for this mode may differ from the sum of the submodes that contribute to it, due to interference effects. See the relevant papers.
- [c] This value includes only K^+K^- decays of the $f_J(1710)$, because branching fractions of this resonance are not known.
- [d] This mode is not a useful test for a ΔC =1 weak neutral current because both quarks must change flavor in this decay.

CONSTRAINED FIT INFORMATION

An overall fit to 10 branching ratios uses 18 measurements and one constraint to determine 8 parameters. The overall fit has a $\chi^2=8.3$ for 11 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\left\langle \delta \kappa_i \delta \kappa_j \right\rangle / \left(\delta \kappa_i \cdot \delta \kappa_j \right)$, in percent, from the fit to the branching fractions, $\kappa_i \equiv \Gamma_i / \Gamma_{\text{total}}$. The fit constrains the κ_i whose labels appear in this array to sum to one

	l						
<i>X</i> 9	87						
x_{10}	67	57					
x_{12}	84	73	56				
<i>x</i> ₁₃	92	80	61	91			
×14	86	74	57	92	93		
×35	55	48	37	55	60	56	
<i>x</i> ₆₁	-94	-86	-67	-95	97	95	-65
	× ₇	<i>x</i> ₉	<i>x</i> ₁₀	x_{12}	<i>x</i> ₁₃	<i>x</i> ₁₄	×35

D+ BRANCHING RATIOS

A few older, now obsolete results have been omitted. They may be found in earlier editions.

	 Inclusive mod 	ies ·		_	
$\Gamma(K^- \text{ anything})/\Gamma_{\text{total}}$					Γ_1/Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
$0.13^{+0.14}_{-0.12} \pm 0.02$	COFFMAN	91	MRK3	e ⁺ e ⁻ 4.14 GeV	

	(<i>K</i> 0 anyt	:hing)]/F _{total}				Γ ₂ /Ι
VALUE		DOCUMENT ID			COMMENT	
$0.39^{igoplus 0.28}_{-0.27} \pm 0.04$		COFFMAN	91	MRK3	e ⁺ e ⁻ 4.14 GeV	/
$\Gamma(K^+ \text{ anything})/\Gamma_{\text{tot}}$	al l					Г3/
VALUE		DOCUMENT ID		TECN	COMMENT	. 3/
$0.20^{f +0.18}_{-0.13}{\pm 0.04}$		COFFMAN	91	MRK3	e ⁺ e ⁻ 4.14 GeV	,
$\Gamma(non\text{-}\kappa\overline{\mathcal{K}}anything)$	/ C *****					Γ4/
VALUE	/ · total	DOCUMENT ID		TECN	COMMENT	• 4/
0.64±0.17±0.03		⁴ COFFMAN	91		e ⁺ e ⁻ 4.14 GeV	/
4 COFFMAN 91 uses the $K\overline{K}$ fraction. This and/or non-spectator	number ir	measurements of nplies that a larg	the k	aon cont ction of	tent to determine D_S^+ decays invol	this nor ve η , η
$\Gamma(e^+ \text{ anything}) / \Gamma_{\text{tota}}$	ıl					Γ ₅ /
VALUE	CL%	DOCUMENT ID				
<0.20 ⁵ Expressed as a value,	90	⁵ BAI			e ⁺ e ⁻ 4.14 Ge\	
$\Gamma(\mu^+\nu_\mu)/\Gamma_{\text{total}}$ See the "Note on <u>VALUE</u>	EVTS	DOCUMENT	ID	<u>TECI</u>	V COMMENT	Γ 6/ the π [±]
• • We do not use the						
$0.015 ^{+0.013}_{-0.006} {}^{+0.003}_{-0.002}$		⁶ BAI	ç	95 BES	$e^+e^- \rightarrow D$	$_{s}^{+}D_{s}^{-}$
$0.004 + 0.0018 + 0.002 \\ -0.0014 - 0.001$	9 8	⁷ AOKI	ç	93 WA7	75 π^- emulsion	350 Ge
< 0.03	0	⁸ AUBERT	8	3 SPE	C μ ⁺ Fe, 250 G	ieV
⁶ BAI 95 uses one act	ual D_s^+ –	$\rightarrow \mu^+ \nu_{\mu}$ event to	ogeth	er with	two $D_s^+ \rightarrow \tau^+ \iota$	√ even
⁷ AOKI 93 assumes the	e ratio of	MeV. production cross s	sectio	ns of the	$e D_s^+$ and D^0 is 0).27. Th
value of $\Gamma(\mu^+\nu_\mu)/\Gamma$ MeV.	e ratio of total ^{give}	production cross s s a pseudoscalar (decay	constar	it $f_{D_s} = (232 \pm$	45 ± 52
value of $\Gamma(\mu^+\nu_\mu)/\Gamma$ MeV. 8 AUBERT 83 assume	e ratio of total ^{give}	production cross s s a pseudoscalar (decay	constar	it $f_{D_s} = (232 \pm$	45 ± 52
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value of $\Gamma(\mu^+\nu_\mu)/\Gamma$ MeV. 8 AUBERT 83 assume $\Gamma(\mu^+\nu_\mu)/\Gamma(\phi\pi^+)$ See the "Note on VALUE	e ratio of total give that the <i>L</i> Pseudosca <u>EVTS</u>	production cross s s a pseudoscalar o D_S^{\pm} production rat alar-Meson Decay	decay te is 2	constar 20% of to stants" in	at $f_{D_S} = (232 \pm 600)$ otal charm product the Listings for $\frac{COMMENT}{COMMENT}$	45 \pm 52 tion rate Γ_6/Γ_1 the π^{\pm}
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value of $\Gamma(\mu^+\nu_\mu)/\Gamma$ MeV. 8 AUBERT 83 assume $\Gamma(\mu^+\nu_\mu)/\Gamma(\phi\pi^+)$ See the "Note on VALUE 0.245 ± 0.052 ± 0.074	e ratio of total give that the L Pseudosca $EVTS$ 39 $f_{D_S} = (3)$	production cross s s a pseudoscalar of D_s^{\pm} production rat alar-Meson Decay <u>DOCUMENT ID</u> 9 ACOSTA 344 \pm 37 \pm 52 \pm	te is 2 Cons	constar 20% of to stants" in TECN CLEO	at $f_{D_S} = (232 \pm 0.00)$ of the Listings for $\frac{COMMENT}{e^+e^-} \approx \Upsilon(4.5)$	45 \pm 52 tion rat $\frac{\Gamma_6/\Gamma_1}{\text{the }\pi^{\pm}}$
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 14 BRANDENBURG 95 uses both e^+ and μ^+ events and makes a phase-space adjustment

to use the μ^+ events as e^+ events.

 D_s^{\pm}

$(\eta'(958)\ell^+\nu_\ell)/\Gamma(\phi\ell^+\nu_\ell)$ Unseen decay modes of the resonances are included.	Γ_{10}/Γ_{7}	$\Gamma(K^+\overline{K}^*(892)^0)/\Gamma(K^+K)$ Unseen decay modes of t		ied.		Γ_{14}/Γ_{1}
<u>ALUE</u> <u>CL% EVTS</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>C</u> 0.44±0.13 OUR FIT	OMMENT	VALUE	DOCUMENT ID	TECN_	COMMENT	
• • ₩ do not use the following data for averages, fits, limits, etc. •		0.74 ±0.08 OUR FIT 0.717±0.069±0.060	FRABETTI 9	58 E687	Dalitz plot an	nalysis
	emulsion 600 GeV	$\Gamma(K^+\overline{K}^*(892)^0)/\Gamma(\phi\pi^+)$ Unseen decay modes of t	he resonances are inclu	ded.		Γ_{14}/Γ_{1}
15 BRANDENBURG 95 uses both e^+ and μ^+ events and makes a phas to use the μ^+ events as e^+ events. 16 KODAMA 938 uses μ^+ events.	e-space adjustment	VALUE EVTS 0.93±0.09 OUR FIT 0.95±0.10 OUR AVERAGE	DOCUMENT ID		COMMENT	
·	(F . F . \ /F	$0.85 \pm 0.34 \pm 0.20$ 9		OC NA14	Photoproduct e^+e^- 4.14 (
Unseen decay modes of the resonances are included.	$r = (\Gamma_9 + \Gamma_{10})/\Gamma_7$	$0.84 \pm 0.30 \pm 0.22$ $1.05 \pm 0.17 \pm 0.12$	CHEN 8	9 CLEO	e ⁺ e ⁻ 10 Ge	eV
ALUE EVTS DOCUMENT ID TECN COMM. 72±0.23 OUR FIT	ENT	$0.87 \pm 0.13 \pm 0.05$ 117 1.44 ± 0.37 87		8 E691 7F ARG	Photoproduct e ⁺ e ⁻ 10 Ge	
9 \pm 1.6 13 17 KODAMA 93 E653 π^- er \bullet \bullet We do not use the following data for averages, fits, limits, etc. \bullet	• •	$\Gamma(f_0(980)\pi^+)/\Gamma(K^+K^-\pi)$ Unseen decay modes of t				Γ ₃₅ /Γ
.67 \pm 0.17 \pm 0.17 18 BRANDENB 95 CLEO $e^+e^ ^{17}$ KODAMA 93 uses μ^+ events.	au pprox au(45)	VALUE	DOCUMENT ID	TECN_	COMMENT	
18 This BRANDENBURG 95 data is redundant with data in previous bl	locks.	0.25±0.09 OUR FIT 1.00±0.32±0.24	FRABETTI 9	58 E687	Dalitz plot an	nalysis
——— Hadronic modes with a $K\overline{K}$ pair. ——	***********	$\Gamma(f_J(1710)\pi^+ \to K^+K^-)$	π^+)/ $\Gamma(K^+K^-\pi^+)$			Γ ₁₇ /Γ
$\Gamma(K^+\overline{K}{}^0)/\Gamma(\phi\pi^+)$	Γ_{11}/Γ_{13}	This includes only K^+K	decays of the $f_J(17)$	10), becaı	use branching ra	
ALUE <u>EVTS</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMM</u>	•	resonance are not known. <u>VALUE</u>	DOCUMENT ID	TECN	COMMENT	
.01 \pm 0.16 OUR AVERAGE .15 \pm 0.31 \pm 0.19 68 ANJOS 90C E691 γ Be		$0.034 \pm 0.023 \pm 0.035$		5B E687	Dalitz plot an	ıalysis
.92 \pm 0.32 \pm 0.20 ADLER 898 MRK3 e^+e^- .99 \pm 0.17 \pm 0.10 CHEN 89 CLEO e^+e^-		$\Gamma(K^+\overline{K}_0^*(1430)^0)/\Gamma(K^+\overline{K}_0^*)$ Unseen decay modes of t	$(-\pi^+)$ he $\overline{\kappa}_0^*$ (1430) 0 are inclu	ded.		Γ ₁₆ /Γ
$(\phi\pi^+)/\Gamma_{ m total}$	Γ ₁₃ /Γ	VALUE 0.150±0.052±0.052	DOCUMENT ID	<u>TECN</u> 5B E687	COMMENT Dalitz plot an	alveie
For the first time, we have model-independent measurements of this and so we no longer use the earlier, model-dependent results. See				35 E007	Danitz piot an	
Mesons" in the D^+ Listings for a discussion. 4LUE CL% EVTS DOCUMENT ID TECN COLUMENT ID TECN	OMMENT	$\Gamma(K^+K^-\pi^+\text{nonresonant})$ VALUE EVTS	/I (φπ') <u>DOCUMENT ID</u>	TECN	COMMENT	Γ ₁₈ /Γ
0.036 ±0.009 OUR FIT 0.036 ±0.009 OUR AVERAGE		0.25±0.07±0.05 48	ANJOS 8	8 E691	Photoproduct	ion
$0.0359 \pm 0.0077 \pm 0.0048$ 19 ARTUSO 96 CLEO e^{-1}	$^+e^-$ at $\Upsilon(4S)$	$\Gamma(K^*(892)^+\overline{K}{}^0)/\Gamma(\phi\pi^+)$				Γ_{20}/Γ
-0.019 -0.011	+ e− 4.03 GeV	Unseen decay modes of t VALUE	he resonances are include DOCUMENT ID		COMMENT	4
• • We do not use the following data for averages, fits, limits, etc. • $0.051 \pm 0.004 \pm 0.008$ 21 BUTLER 94 CLEO e^{-}		$1.20\pm0.21\pm0.13$	CHEN 8	9 CLEO	e ⁺ e ⁻ 10 Ge	V
<0.048 90 MUHEIM 94	$^+e^-\approx \Upsilon(4S)$	$\Gamma(K^*(892)^+\overline{K}^0)/\Gamma(K^+\overline{K}^0)$	⁰)			Γ ₂₀ /Γ
0.046 ±0.015 22 MUHEIM 94 0.031 ±0.009 22 MUHEIM 94		Unseen decay modes of t	he K*(892) ⁺ are included DOCUMENT ID		COMMENT	
0.031 \pm 0.009 \pm 0.006 21 FRABETTI 93G E687 γ	Be \overline{E}_{γ} $=$ 220 GeV	• • • We do not use the follow				
	$^+e^-pprox$ 10.4 GeV $^+e^-$ 4.14 GeV	<0.9 90	FRABETTI 9	5 E687	γ Be $\overline{E}_{\gamma} pprox 20$	00 GeV
0.031 $\pm 0.006 {}^{+0.011}_{-0.009}$ 21 ALEXANDER 908 CLEO $ e^{-0.001}_{-0.009}$	+ e ⁻ 10.5-11 GeV	$\Gamma(\phi\pi^+\pi^0)/\Gamma(\phi\pi^+)$				Γ_{22}/Γ
	hotoproduction Be, $\overline{E}_{\gamma}~pprox~145$ GeV	<u>VALUE</u> <u>CL%</u> <u>EVTS</u> 2.4±1.0±0.5 11 • • • We do not use the follow		9E E691	Photoproduct	:ion
0.02 ±0.01 405 24 CHEN 89 CLEO e	+ e ⁻ 10 GeV	<2.6 90	-	0c NA14		ion
0.033 \pm 0.011 30 ²⁴ DERRICK 85B HRS e^-	+ e ⁻ 35-44 GeV + e ⁻ 29 GeV	$\Gamma(\phi ho^+)/\Gamma(\phi\pi^+)$				Γ ₂₃ /Γ
¹⁹ ARTUSO 96 uses partially reconstructed $\overline{B}^0 \to D^{*+}D_s^{*-}$ decay independent value for $\Gamma(D_s^- \to \phi\pi^-)/\Gamma(D^0 \to K^-\pi^+)$ of 0.92 ±	s to get a model-	<u>VALUE</u> <u>EVTS</u> 1.86±0.26^{+0.29} 253	DOCUMENT ID AVERY 9	TECN	$e^+e^- \simeq 10.$	
²⁰ BAI 95C uses $e^+e^- o D_s^+D_s^-$ events in which one or both of the L	D_s^\pm are observed to	1.86 \pm 0.26 \pm 0.23 253 $\Gamma(\phi \pi^{+} \pi^{0} \text{ 3-body}) / \Gamma(\phi \pi^{+}$		2 CLEO	e e 🖭 10.	.s Geν Γ ₂₄ /Γ
obtain the first model-independent measurement of the $D_s^+ \to \phi \pi^+$ without assumptions about $\sigma(D_s^\pm)$. However, with only two "doubly-t		VALUE CL%	DOCUMENT ID	TECN		
statistical error is too large for the result to be competitive with indir ADLER 90B used the same method to set a limit.	rect measurements.	<0.71 90		2 CLEO	$e^+e^-\approx 10.$.5 GeV
²¹ BUTLER 94, FRABETTI 93G, ALBRECHT 91, ALEXANDER 90B	and ANJOS 90B	$\Gamma(K^+K^-\pi^+\pi^0 \text{ non-}\phi)/\Gamma($		TECN	COMMENT	Γ ₂₅ /Γ
measure the ratio $\Gamma(D_s^+ \to \phi \ell^+ \nu_\ell)/\Gamma(D_s^+ \to \phi \pi^+)$, where ℓ = then use a theoretical calculation of the ratio of widths $\Gamma(D_s^+ \to \phi \pi^+)$		<u>VALUE</u> <u>CL%</u> <2.4 90	25 ANJOS 8	<u>TECN</u> 9E E691	<u>COMMENT</u> Photoproduct	ion
$\overline{K}^{*0} \ell^+ \nu$). Not everyone uses the same value for this ratio.		$^{25}\mathrm{Total}$ minus ϕ component.			•	
22 The two MUHEIM 94 values here are model-dependent calculations data sets. The first uses measurements of the $D_2^*(2460)^0$ and $D_{51}(2460)^0$:536) ⁺ , the second	$\Gamma(K^+\overline{K}{}^0\pi^+\pi^-)/\Gamma(\phi\pi^+)$	DOCUMENT ID	TECN	COMMENT	Γ ₂₆ /Γ
uses <i>B</i> -decay factorization and $\Gamma(D_s^+ \to \mu^+ \nu_\mu)/\Gamma(D_s^+ \to \phi \ell^+ \nu_\ell)$.		<u>VALUE</u> <u>CL%</u> <0.77 90		2B ARG	$e^+e^-\simeq 10.$.4 GeV
using the semileptonic width of $D_s^+ o \phi \ell^+ \nu_\ell$ is not independent of here. Note also the upper limit, based on the sum of established D_s^+		$\Gamma(K^0K^-\pi^+\pi^+)/\Gamma(\phi\pi^+)$				Γ ₂₇ /Γ
Refer Note also the upper limit, based on the sum of established D_s^2 ALVAREZ 90c relies on the Lund model to estimate the ratio of D_s^+ to		VALUE	DOCUMENT ID	<u>TECN</u>	COMMENT	
24 Values based on crude estimates of the D_s^{\pm} production level. DERR statistical only.	ICK 85B errors are	1.2 \pm 0.2 \pm 0.2 $\Gamma(K^*(892)^+\overline{K}^*(892)^0)/\Gamma($		2B ARG	$e^+e^-\simeq 10.$.4 GeV Γ₂₈/ Γ
statistical only.			he resonances are includ	led.		,
$(\phi\pi^+)/\Gamma(K^+K^-\pi^+)$	Γ_{13}/Γ_{12}	VALUE	DOCUMENT ID	TECN		
			DOCUMENT ID ALBRECHT 9:	TECN 2B ARG	$\frac{COMMENT}{e^+e^-} \simeq 10.$.4 GeV

 D_s^{\pm}

$\Gamma(\phi\pi^+\pi^+\pi^-)/\Gamma(\phi\pi^+)$		Γ ₃₁ /Γ ₁₃	$\Gamma(\eta'(958)\pi^+)/\Gamma(\eta'(958)\pi^+)$				Γ ₄₅ /Γ ₁₃
<u>VALUE</u> <u>CL%</u> <u>EVTS</u> 0.51±0.12 OUR AVERAGE	DOCUMENT ID TECN COM	MENT	Unseen decay n	nodes of the resor 	nances are included DOCUMENT ID		COMMENT
0.58±0.21±0.10 21	FRABETTI 92 E687 γBe	e					e the ideogram below.
$0.42 \pm 0.13 \pm 0.07$ 19	· ·	otoproduction	$1.20\pm0.15\pm0.11$	281	ALEXANDER	92 CLEO	$\eta' \rightarrow \eta \pi^+ \pi^-$,
$1.11 \pm 0.37 \pm 0.28$ 62		e ⁻ 10 GeV	.15				$ ho^0 \gamma$
• • We do not use the following data for	•		$2.5 \pm 1.0 \begin{array}{c} +1.5 \\ -0.4 \end{array}$	22	ALVAREZ	91 NA14	Photoproduction
<0.24 90	ALVAREZ 90c NA14 Pho	otoproduction	$2.5 \pm 0.5 \pm 0.3$	215	ALBRECHT	90D ARG	e^+e^-pprox 10.4 GeV
$\Gamma(K^+K^-\pi^+\pi^+\pi^-$ non- $\phi)/\Gamma_{\text{total}}$		Γ ₃₂ /Γ	• • We do not use	•	•		
	MENT ID TECN COMMENT	. 32/ .	<1.3	90	ANJOS	91B E691	γ Be, $\overline{E}_{\gamma}~pprox~145$ GeV
0.003 +0.003 -0.002 BARLA	AG 92¢ ACCM π ⁻ 230 Ge ^v	v					GC V
-0.002	720 ACCIII N 230 GC	•		HTED AVERAGE 4 (Error scaled by	2 1)		
$\Gamma(K^+K^-\pi^+\pi^+\pi^-\text{non-}\phi)/\Gamma(\phi\pi^+)$		Γ_{32}/Γ_{13}	1.720.		/		
• • • • • • • • • • • • • • • • • • • •	MENT ID TECN COMMENT			٧			
ullet $ullet$ We do not use the following data for	averages, fits, limits, etc. • •			Λ			
<0.32 90 10 ANJOS	S 88 E691 Photoprodu	ction					
Other hadronic mo	odes (0, 1, or 3 K's)						
	5des (6) 1) 61 6 11 5)						
$\Gamma(\pi^+\pi^+\pi^-)/\Gamma(\phi\pi^+)$		Γ_{33}/Γ_{13}					
	MENT ID TECN COMMENT						
0.39±0.08 OUR AVERAGE 0.33±0.10±0.04 29 ADAM	IOVICH 93 WA82 π ⁻ 340 Ge ^v						
0.44±0.10±0.04 ANJOS							2
							<u> </u>
$\Gamma(ho^0\pi^+)/\Gamma(\phi\pi^+)$		Γ_{34}/Γ_{13}		1+1		LEXANDER	92 CLEO 0.7 91 NA14 1.1
<u>VALUE</u> <u>CL%</u> <u>DOCUM</u> <0.08 90 ANJOS		ction		1		LVAREZ LBRECHT	91 NA14 1.1 90D ARG <u>3.9</u>
• • We do not use the following data for	· ·	Ction		1 _	_		5.7
<0.22 90 ALBRE		GeV		/		(Cor	fidence Level = 0.058)
4 15 - 4			0	1 2	3 4	5 6	
$\Gamma(f_0(980)\pi^+)/\Gamma(\phi\pi^+)$	a and to decide d	Γ_{35}/Γ_{13}	$\Gamma(n'(958))$	$\pi^+)/\Gamma(\phi\pi^+)$			
Unseen decay modes of the resonances			1 (1) (330)	")/·(Ψ")			
0.32±0.10 OUR FIT			$\Gamma(\eta'(958)\rho^+)/\Gamma(q$				Γ_{47}/Γ_{13}
0.28±0.10±0.03 ANJOS	S 89 E691 Photoprodu	ction	Unseen decay n		nances are included OCUMENT ID	i. <u>TECN</u> <u>CO</u>	MMENT
$\Gamma(\pi^+\pi^+\pi^- \text{ nonresonant})/\Gamma(\phi\pi^+)$		Γ_{36}/Γ_{13}					
	MENT ID TECN COMMENT	- 30/ - 13	$3.44\pm0.62^{+0.44}_{-0.46}$	68 A	VERY 92	CLEO η'	$\rightarrow \eta \pi^+ \pi^-$
0.29±0.09±0.03 ANJOS	S 89 E691 Photoprodu	ction	$\Gamma(\eta'(958)\pi^{+}\pi^{0}3-$	body)/ $\Gamma(\phi\pi^+)$	١		Γ_{48}/Γ_{13}
$\Gamma(\pi^+\pi^+\pi^-\pi^0)/\Gamma(\phi\pi^+)$		Γ /Γ	Unseen decay n	nodes of the resor	nances are included	i.	. 46/ . 13
, , , , ,	IENT ID TECN COMMENT	Γ_{37}/Γ_{13}	VALUE		OCUMENT ID	TECN CO	
<3.3 90 ANJOS		ction	<0.85	90 D	AOUDI 92	CLEO e	$e^- \approx 10.5 \text{ GeV}$
-(1) (-(1)	·		$\Gamma(K^0\pi^+)/\Gamma(\phi\pi^+)$)			Γ_{49}/Γ_{13}
$\Gamma(\eta \pi^+)/\Gamma(\phi \pi^+)$ Unseen decay modes of the resonances	s are included	Γ ₃₈ /Γ ₁₃	VALUE	CL% D	OCUMENT ID	TECN CO	
	DCUMENT ID TECN COMME	NT	<0.21	90 A	DLER 89B	MRK3 e ⁺	e 4.14 GeV
0.54±0.09±0.06 165 AL	LEXANDER 92 CLEO $\eta ightarrow \gamma$	γ,	$\Gamma(K^0\pi^+)/\Gamma(K^+\overline{I})$	₹⁰)			Γ_{49}/Γ_{11}
• • We do not use the following data for	π^+	$\pi^-\pi^0$	VALUE	•	OCUMENT ID	TECN CO	MMENT
		roduction	• • We do not use	-	_		
			< 0.53	90 F	RABETTI 95	E687 γ B	se $\overline{E}_{\gamma}pprox$ 200 GeV
$\Gamma(\omega\pi^+)/\Gamma(\phi\pi^+)$	and the dead of the dead	Γ_{39}/Γ_{13}	$\Gamma(K^+\pi^+\pi^-)/\Gamma(d)$	<i>5</i> π ⁺)			Γ_{50}/Γ_{13}
Unseen decay modes of the resonances VALUE			VALUE	•	OCUMENT ID	TECN CO	MMENT
<0.5 90 ANJOS		ction	$0.28 \pm 0.06 \pm 0.05$	85 F	RABETTI 95E	Ε687 γΕ	Se, $\overline{E}_{\gamma} =$ 220 GeV
	,		r(k+ -0) /r/+ +	1			*
$\Gamma(\pi^+\pi^+\pi^+\pi^-\pi^-)/\Gamma_{\text{total}}$	CALL ID TEST COLUMN	Γ ₄₀ /Γ	$\Gamma(K^+\rho^0)/\Gamma(\phi\pi^+)$,	OCUMENT ID	TECN CO	Γ ₅₁ /Γ ₁₃
	TECN COMMENT		<u>VALUE</u> <0.08				Se, \overline{E}_{γ} = 220 GeV
0.003 +0.004 -0.003 BARLA	AG 92C ACCM π ⁻ 230 Ge ⁴	V					,
$\Gamma(\pi^+\pi^+\pi^+\pi^-\pi^-)/\Gamma(\phi\pi^+)$		Γ.o./Γ.o	Γ(K*(892) ⁰ π ⁺)/Γ Unseen decay n	$\Gamma(\phi\pi^+)$	annee en te-to-t		Γ_{52}/Γ_{13}
· · · · · · · · · · · · · · · · · · ·	IENT ID TECN COMMENT	Γ_{40}/Γ_{13}	Unseen decay n VALUE	nodes of the resor 	nances are included OCUMENT ID	1. <u>TECN CO</u>	MMENT
• • We do not use the following data for			0.18±0.05±0.04				se, \overline{E}_{γ} = 220 GeV
<0.29 90 ANJOS		ction	F/1/4 1/4 1/-1 /-/				,
			Γ(K+K+K-)/Γ(• •	OCUMENT ID	TECN CO	Γ ₅₃ /Γ ₁₃
$\Gamma(\eta \rho^+)/\Gamma(\phi \pi^+)$	s are included	Γ_{42}/Γ_{13}	<u>∨ALUE</u> <0.016			<u>TECN</u> <u>CO</u> E687 γ B	Se, $\overline{E}_{\gamma} \approx 220 \text{ GeV}$
Unseen decay modes of the resonances <u>VALUE</u> <u>EVTS</u> <u>DOCUM</u>	S are included. <u>IENT ID TECN COMMENT</u>						,
2.86±0.38 ⁺ 0.36 217 AVERY		$+\pi^{-}\pi^{0}$	$\Gamma(\phi K^+)/\Gamma(\phi \pi^+)$				Γ_{54}/Γ_{13}
	1/1/11		VALUE		OCUMENT ID	TECN CO	
$\Gamma(\eta\pi^+\pi^0$ 3-body $)/\Gamma(\phi\pi^+)$		Γ_{43}/Γ_{13}	<0.013				se, $\overline{E}_{\gamma} \approx $ 220 GeV
Unseen decay modes of the resonances			• • • We do not use				
VALUE CL% DOCUM		0 F Go)/	< 0.071				se, $\overline{\mathcal{E}}_{oldsymbol{\gamma}}=$ 145 GeV
<0.82 90 DAOUI	DI 92 CLEO $e^+e^- \approx 1$	iu.s Gev	_	Rare o	r forbidden mod	les	
$\Gamma(\pi^+\pi^+\pi^+\pi^-\pi^-\pi^0)/\Gamma_{ ext{total}}$		Γ_{44}/Γ	$\Gamma(\pi^+\mu^+\mu^-)/\Gamma_{ m tot}$:al			Γ ₅₅ /Γ
	MENT ID TECN COMMENT		This mode is no	ot a useful test for	ra $\Delta C=1$ weak no	eutral curren	t because both quarks
0.049+0.033 -0.030 BARLA	AG 92C ACCM π^- 230 GeV	V		avor in this decay. <u>EVTS</u> <u>De</u>	OCUMENT ID	TECN CO	MMENT
			<4.3 × 10 ⁻⁴ 90				emulsion 600 GeV

actions. /ALUE	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
<5.9 × 10 ⁻⁴	90	0	KODAMA	95	E653	π^- emulsion 600 GeV
	the Δ <i>C</i> =	∕Γ _{total} =1 weak	neutral current. All	lowed	by high	Γ ₅₇ / ner-order electroweak inte
actions. ALUE	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
<1.4 × 10 ⁻³	90	0	KODAMA	95	E653	π^- emulsion 600 GeV
$(\pi^-\mu^+\mu^+)$ A test of	/Γ _{total}	ımber c	onservation.			Γ ₅₈ /
'ALUE	<u>CL%</u>	EVTS	DOCUMENT ID		TECN	COMMENT
<4.3 × 10 ⁻⁴	90	0	KODAMA	95	E653	π^- emulsion 600 GeV
	epton-nu		onservation.			Γ ₅₉ /
<5.9 × 10 ⁻⁴	<u>CL%</u> . 90	0 0	DOCUMENT ID KODAMA	95	TECN E653	π^- emulsion 600 GeV
(K*(892) ⁻ μ	+ u+)					Г ₆₀ /
A test of l	epton-nu	mber c	onservation.			
<1.4 × 10 ⁻³	<u>CL%</u> . 90	<u>EV15</u>	DOCUMENT ID KODAMA	95	TECN E653	π^- emulsion 600 GeV
ALUE		D + -				COMMENT
ALUE		D + -	$\phi \ell^+ \nu_\ell$	170		
ALUE .6±0.4 OUR A		D + -	• φℓ+ν _ℓ DOCUMENT ID 26 AVERY			COMMENT
ALUE .6±0.4 OUR AN .4±0.5±0.3 .1±0.8±0.1		D+ EVTS 308 90	b φℓ ⁺ ν _ℓ DOCUMENT ID 26 AVERY 27 FRABETTI	94B 94F	TECN CLEO E687	e^+e^- 10 GeV $_{\gamma}$ Be, $\overline{E}_{\gamma}=$ 220 GeV
6±0.4 OUR AV. $.4\pm0.5\pm0.3$ $.1\pm0.8\pm0.1$ $.1_{-0.5}^{+0.6}\pm0.2$	VERAGE	D+ EVTS 308 90 19	DOCUMENT ID 26 AVERY 27 FRABETTI 27 KODAMA	94B 94F	TECN CLEO	COMMENT
ALUE .6±0.4 OUR AV .4±0.5±0.3 .1±0.8±0.1 .1 $^{+0.6}_{-0.5}$ ±0.2 26 AVERY 94B	VERAGE	D ⁺ _s − EVTS 308 90 19 → φ	DOCUMENT ID 26 AVERY 27 FRABETTI 27 KODAMA	94B 94F 93	TECN CLEO E687 E653	$\frac{COMMENT}{e^+e^- \ 10 \ \text{GeV}}$ $\gamma \text{Be}, \ \overline{E}_{\gamma} = 220 \ \text{GeV}$ 600 GeV $\pi^- N$
ALUE .6±0.4 OUR A .4±0.5±0.3 .1±0.8±0.1 .1±0.6±0.2 26 AVERY 94B 27 FRABETTI 9 V = V(0)/A1	USES D_s^+	$ \begin{array}{c} D_s^+ - \\ \hline EVTS} \\ \vdots \\ 308 \\ 90 \\ 19 \\ \rightarrow \phi_s \\ KODAN $	• $\phi \ell^+ \nu_\ell$ DOCUMENT ID 26 AVERY 27 FRABETTI 27 KODAMA $e^+ \nu_e$ decays. MA 93 use $D_5^+ \rightarrow Q$ $\phi \ell^+ \nu_\ell$	94Β 94F 93	$ extit{TECN}$ CLEO E687 E653 $ extit{} u_{\mu}$ deca	$\begin{array}{l} {\it COMMENT} \\ e^+ e^- 10 {\rm GeV} \\ \gamma {\rm Be}, \overline{E}_{\gamma} = 220 {\rm GeV} \\ 600 {\rm GeV} \pi^- N \end{array}$ ys.
ALUE .6±0.4 OUR A .4±0.5±0.3 .1±0.8±0.1 .1±0.6±0.2 .26 AVERY 94B .27 FRABETTI 9 $v \equiv V(0)/A_1$ ALUE	uses D_s^+ and D_s^+	$D_s^+ - \frac{EVTS}{308}$ $\begin{array}{c} 308 \\ 90 \\ 19 \end{array}$ $\rightarrow \phi \downarrow $	$\begin{array}{l} \bullet $	94Β 94F 93	$ extit{TECN}$ CLEO E687 E653 $ extit{} u_{\mu}$ deca	$\begin{array}{c} \underline{\textit{COMMENT}} \\ e^+ e^- 10 \text{GeV} \\ \gamma \text{Be}, \overline{E}_{\gamma} = 220 \text{GeV} \\ 600 \text{GeV} \pi^- N \end{array}$
ALUE A. $0.4 \times 0.4 \times 0$	uses D_s^+ and D_s^+	$D_s^+ - \frac{EVTS}{308}$ $\begin{array}{c} 308 \\ 90 \\ 19 \end{array}$ $\rightarrow \phi \downarrow $	+ $\phi \ell^+ \nu_\ell$ DOCUMENT ID 26 AVERY 27 FRABETTI 27 KODAMA $e^+ \nu_e$ decays. MA 93 use $D_s^+ \rightarrow Q_s^+$ $\phi \ell^+ \nu_\ell$ DOCUMENT ID 28 AVERY 29 FRABETTI	94B 94F 93 9μ+	$ extit{TECN}$ CLEO E687 E653 $ extit{} u_{\mu}$ deca	$\begin{array}{l} {\it COMMENT} \\ e^+ e^- 10 {\rm GeV} \\ \gamma {\rm Be}, \overline{E}_{\gamma} = 220 {\rm GeV} \\ 600 {\rm GeV} \pi^- N \end{array}$ ys.
ALUE ALUE VALUE ALUE	uses D_s^+ and D_s^+	D_s^+ — EVTS 308 90 19 ϕ KODAN D_s^+ \to EVTS 308	+ $\phi \ell^+ \nu_\ell$ DOCUMENT ID 26 AVERY 27 FRABETTI 27 KODAMA $e^+ \nu_e$ decays. MA 93 use $D_S^+ \rightarrow Q$ $\phi \ell^+ \nu_\ell$ DOCUMENT ID 28 AVERY	948 94F 93 94β 94F	CLEO E687 E653 ν_{μ} deca	$\begin{array}{c} \underline{COMMENT} \\ e^+ e^- 10 \mathrm{GeV} \\ \gamma \mathrm{Be}, \overline{E}_{\gamma} = 220 \mathrm{GeV} \\ 600 \mathrm{GeV} \pi^- N \end{array}$ ys. $\underline{COMMENT} \\ e^+ e^- 10 \mathrm{GeV} \end{array}$
$V_{V} \equiv V(0)/A_{1}$ V_{ALUE} V_{ALU	USES D_s^+ and D_s^+ (0) in D_s^- USES D_s^+	$ \begin{array}{c} D_{\bullet}^{+} - \\ EVTS \\ \vdots \\ 308 \\ 90 \\ 19 \\ \rightarrow \phi \\ KODAN $ $ \begin{array}{c} O_{\bullet}^{+} \rightarrow \\ EVTS \\ \vdots \\ 308 \\ 90 \\ 19 \\ \rightarrow \phi \\ \bullet \end{array} $	$\phi \ell^+ \nu_\ell$ DOCUMENT ID 26 AVERY 27 FRABETTI 27 KODAMA $e^+ \nu_e$ decays. MA 93 use $D_s^+ \rightarrow Q_s$ $\phi \ell^+ \nu_\ell$ DOCUMENT ID 28 AVERY 29 FRABETTI 29 KODAMA	948 94F 93 94β 94β 94β 93	TECN CLEO E687 E653 ν _μ deca TECN CLEO E687 E653	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \ 10 \ \mathrm{GeV} \\ \gamma \ \mathrm{Be}, \ \overline{E}_{\gamma} = 220 \ \mathrm{GeV} \\ 600 \ \mathrm{GeV} \ \pi^- \ N \\ \\ \mathrm{sys}. \\ \\ \underline{COMMENT} \\ e^+e^- \ 10 \ \mathrm{GeV} \\ \gamma \ \mathrm{Be}, \ \overline{E}_{\gamma} = 220 \ \mathrm{GeV} \\ 600 \ \mathrm{GeV} \ \pi^- \ N \\ \end{array}$
ALUE 18-0.4 OUR AI 1.1+0.6 ± 0.3 1.1±0.8 ± 0.1 1.1+0.6 ± 0.2 26 AVERY 94B 27 FRABETTI 9 10 $=$ V(0)/A1 11 ALUE 1.5±0.5 OUR AI 1.9±0.6 ± 0.3 1.8±0.9±0.2 1.3±1.1 ± 0.4 28 AVERY 948 948	USES D_s^+ and $ $ (0) in L VERAGE USES D_s^+ and $ $	$D_s^+ \rightarrow \phi$ SODAN SODAN	• $\phi \ell^+ \nu_\ell$ DOCUMENT ID 26 AVERY 27 FRABETTI 27 KODAMA $e^+ \nu_e$ decays. MA 93 use $D_s^+ \rightarrow Q_s^+$ $\phi \ell^+ \nu_\ell$ DOCUMENT ID 28 AVERY 29 FRABETTI 29 KODAMA $e^+ \nu_e$ decays.	948 94F 93 94β 94β 94β 93	TECN CLEO E687 E653 ν _μ deca TECN CLEO E687 E653	$\begin{array}{c} \underline{COMMENT} \\ e^+ e^- 10 \mathrm{GeV} \\ \gamma \mathrm{Be}, \overline{E}_{\gamma} = 220 \mathrm{GeV} \\ 600 \mathrm{GeV} \pi^- N \end{array}$ ys. $\begin{array}{c} \underline{COMMENT} \\ e^+ e^- 10 \mathrm{GeV} \\ \gamma \mathrm{Be}, \overline{E}_{\gamma} = 220 \mathrm{GeV} \\ 600 \mathrm{GeV} \pi^- N \end{array}$
ALUE 14.04 OUR AI A+0.5±0.3 A+0.8±0.1 A+0.6±0.2 AVERY 94B AVERY 94B AUE 5.±0.5 OUR AI AUE 3.±0.9±0.2 AUE 3.±0.9±0.2 3.±0.9±0.2 3.±0.9±0.2 3.±0.9±0.2 3.±0.9±0.2 3.±0.9±0.2 3.±0.9±0.2 4.5±0.5±0.5 AUE 4.5±0.5±0.5 AUE 5.±0.5 AUE 5.±0.5 AUE 6.±0.7 AUE 6	uses D_s^+ and D_s^+ uses D_s^+ and D_s^+ uses D_s^+ and D_s^+ and D_s^+ and D_s^+ and D_s^+	$\begin{array}{c} D_{\boldsymbol{s}}^{+} - \\ \underline{EVTS} \\ \vdots \\ 308 \\ 90 \\ 19 \\ \rightarrow \phi + \\ \underline{KODAN} \\ SODAN \\ 0 \\ 19 \\ \rightarrow \phi + \\ \underline{VTS} \\ \vdots \\ \vdots \\ \Delta ODAN \\ \bot \\ \underline{EVTS} \\ \vdots \\ \Delta ODAN \\ \underline{EVTS} \\ \underline{EVTS} \\ \underline{CVTS} \\ CVTS$	• $\phi \ell^+ \nu_\ell$ DOCUMENT ID 26 AVERY 27 FRABETTI 27 KODAMA $e^+ \nu_e$ decays. MA 93 use $D_s^+ \rightarrow Q_s^+$ $\phi \ell^+ \nu_\ell$ DOCUMENT ID 28 AVERY 29 FRABETTI 29 KODAMA $e^+ \nu_e$ decays.	94B 94F 93 94B 94F 93	CLEO E687 E653 ν_{μ} deca TECN CLEO E687 E653 ν_{μ} deca	$\frac{COMMENT}{e^+e^- \ 10 \ \text{GeV}} \\ \gamma \text{Be}, \overline{E}_{\gamma} = 220 \ \text{GeV} \\ 600 \ \text{GeV} \ \pi^- N \\ \text{sys}. \\ \\ \frac{COMMENT}{e^+e^- \ 10 \ \text{GeV}} \\ \gamma \text{Be}, \overline{E}_{\gamma} = 220 \ \text{GeV} \\ 600 \ \text{GeV} \ \pi^- N \\ \text{ys}. \\ \\ \text{ys}. \\ \\ \frac{E}{N} = \frac{10 \ \text{GeV}}{N} \\ \text{geV} = 10$
ALUE 1.5±0.4 OUR A' .4±0.5±0.3 .1±0.8±0.1 .1±0.6±0.2 26 AVERY 94B 27 FRABETTI 9 .5±0.5 OUR A' .8±0.9±0.4 .3±0.1 .9±0.6±0.3 .3±0.9±0.4 .28 AVERY 94B .29 FRABETTI 9 .27 In D_s^+ .410.2 .410.3 .410	uses D_s^+ and D_s^+ uses D_s^+ and D_s^+ uses D_s^+ and D_s^+ and D_s^+ and D_s^+ and D_s^+	$\begin{array}{c} D_{+}^{+} - \\ \hline EVTS \\ \hline \vdots \\ \hline 308 \\ 90 \\ \hline 19 \\ \hline \rightarrow \phi \\ \hline KODAN \\ \hline 19 \\ \hline \rightarrow \phi \\ \hline CVTS \\ \hline \vdots \\ \hline 308 \\ 90 \\ \hline 19 \\ \hline \rightarrow \phi \\ \hline CVTS \\ \hline \vdots \\ \hline 308 \\ \hline 308 \\ \hline 90 \\ \hline 19 \\ \hline \rightarrow \phi \\ \hline CVTS \\ \hline \vdots \\ \hline 308 $	$\phi \ell^+ \nu_\ell$ DOCUMENT ID 26 AVERY 27 FRABETTI 27 KODAMA $e^+ \nu_e$ decays. MA 93 use $D_s^+ \rightarrow Q_s$ $\phi \ell^+ \nu_\ell$ DOCUMENT ID 28 AVERY 29 FRABETTI 29 KODAMA $e^+ \nu_e$ decays. MA 93 use $D_s^+ \rightarrow Q_s$ $e^+ \nu_e$ decays. MA 93 use $D_s^+ \rightarrow Q_s$ $e^+ \nu_e$ decays. MA 93 use $D_s^+ \rightarrow Q_s$	948 947 93 94β 94β 94β 93 94β 94β	$\frac{TECN}{CLEO}$ CLEO CLEO E687 E653 $\frac{TECN}{CLEO}$ CLEO E687 CLEO CLEO CLEO CLEO CLEO CLEO CLEO CLEO	$\frac{COMMENT}{e^+e^- \ 10 \ \text{GeV}}{\gamma \ \text{Be}, \ \overline{E}_{\gamma} = 220 \ \text{GeV}}$ 600 GeV $\pi^- N$ bys. $\frac{COMMENT}{600 \ \text{GeV}}{\pi^- N}$ ys. $\frac{COMMENT}{\pi^- N}$ ys. $\frac{COMMENT}{\pi^- N}$ compared to $\frac{1}{N} = \frac{1}{N} = \frac{1}{N$
ALUE	USES D_s^+ 0 0 0 0 0 0 0 0 0 0	$D_{+}^{+} - \frac{EVTS}{308}$ 308 90 19 $\rightarrow \phi$ $KODAN$ $D_{+}^{+} \rightarrow \frac{\phi}{2}$ $AODAN$ AOD	ϕ $\ell^+ \nu_\ell$ DOCUMENT ID 26 AVERY 27 FRABETTI 27 KODAMA $e^+ \nu_e$ decays. MA 93 use $D_s^+ \rightarrow Q_s$ ϕ $\ell^+ \nu_\ell$ DOCUMENT ID 28 AVERY 29 FRABETTI 29 KODAMA $e^+ \nu_e$ decays. MA 93 use $D_s^+ \rightarrow Q_s$ DOCUMENT ID 30 AVERY 31 FRABETTI	948 94F 93 94F 94F 93 94β 94F	CLEO CLEO E687 μ_{μ} deca	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \ 10 \ \mathrm{GeV} \\ \gamma \ \mathrm{Be}, \ \overline{E}_{\gamma} = 220 \ \mathrm{GeV} \\ 600 \ \mathrm{GeV} \ \pi^- \ N \\ \\ \mathrm{Sys}. \\ \\ \underline{COMMENT} \\ e^+e^- \ 10 \ \mathrm{GeV} \\ \gamma \ \mathrm{Be}, \ \overline{E}_{\gamma} = 220 \ \mathrm{GeV} \\ 600 \ \mathrm{GeV} \ \pi^- \ N \\ \\ \mathrm{ys}. \\ \\ \underline{COMMENT} \\ e^+e^- \ 10 \ \mathrm{GeV} \\ \gamma \ \mathrm{Be}, \ \overline{E}_{\gamma} = 220 \ \mathrm{GeV} \\ \end{array}$
ALUE 1. $+0.4$ OUR A' 1. $+0.5\pm0.3$ 1. $+0.6\pm0.2$ 26 AVERY 94B 27 FRABETTI 9 28 EV (0) / A ₁ (ALUE 1. $+0.5\pm0.5$ 28 AVERY 94B 29 FRABETTI 9 27 FRABETTI 9 28 AVERY 94B 29 FRABETTI 9 20 FRABETTI 9 20 FRABETTI 9 21 (L/ Γ_T in D_s^+ 22 (L/ Γ_T in D_s^+ 23 (L/ Γ_T in D_s^+ 24 (L/ Γ_T in D_s^+ 25 (L/ Γ_T in D_s^+ 26 (L/ Γ_T in D_s^+ 27 (L/ Γ_T in D_s^+ 28 (L/ Γ_T in D_s^+ 29 (L/ Γ_T in D_s^+ 21 (L/ Γ_T in D_s^+ 21 (L/ Γ_T in D_s^+ 22 (L/ Γ_T in D_s^+ 24 (L/ Γ_T in D_s^+ 24 (L/ Γ_T in D_s^+ 24 (L/ Γ_T in D_s^+ 25 (L/ Γ_T in D_s^+ 26 (L/ Γ_T in D_s^+ 27 (L/ Γ_T in D_s^+ 28 (L/ Γ_T in D_s^+ 29 (L/ Γ_T in D_s^+ 21 (L/ Γ_T in D_s^+ 21 (L/ Γ_T in D_s^+ 22 (L/ Γ_T in D_s^+ 24 (L/ Γ_T in D_s^+ 24 (L/ Γ_T in D_s^+ 25 (L/ Γ_T in D_s^+ 26 (L/ Γ_T in D_s^+ 27 (L/ Γ_T in D_s^+ 28 (L/ Γ_T in D_s^+	USES D_s^+ 04F and 1 (0) in L VERAGE USES D_s^+ 04F and 1 AVERAGE	D _s + − EVTS 308 90 19 → \$\phi\$ EVTS 308 90 19 → \$\phi\$ EVTS 308 90 19 → \$\phi\$ (CODAN 4 EVTS 308 90 19	$+$ $\psi \ell^+ \nu_\ell$ DOCUMENT ID 26 AVERY 27 FRABETTI 27 KODAMA $e^+ \nu_e$ decays. MA 93 use $D_S^+ \rightarrow Q_S^+ \rightarrow Q_S^- \rightarrow Q$	948 947 93 94β 94β 94β 93 94β 94β	CLEO CLEO E687 μ_{μ} deca	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \ 10 \ \mathrm{GeV} \\ \gamma \mathrm{Be}, \ \overline{E}_{\gamma} = 220 \ \mathrm{GeV} \\ 600 \ \mathrm{GeV} \ \pi^- N \\ \\ \mathrm{sys}. \\ \\ \underline{COMMENT} \\ e^+e^- \ 10 \ \mathrm{GeV} \\ \gamma \mathrm{Be}, \ \overline{E}_{\gamma} = 220 \ \mathrm{GeV} \\ 600 \ \mathrm{GeV} \ \pi^- N \\ \\ \mathrm{ys}. \\ \\ \underline{COMMENT} \\ e^+e^- \ 10 \ \mathrm{GeV} \\ \end{array}$

BAI 95 PRL 74 4599 +Bardon, Blum, Breakstone+ (BES Collab.) BRANDENB 95 PRL 75 3804 Brandenburg, Cinabro, Liu+ (CLC Collab.) FRABETTI 95 PL B364 199 +Cheung, Cumalat+ (FNAL E687 Collab.) FRABETTI 95 PL B351 591 +Cheung, Cumalat+ (FNAL E687 Collab.) FRABETTI 95 PL B353 259 +Cheung, Cumalat+ (FNAL E687 Collab.) FRABETTI 95 PL B363 259 +Cheung, Cumalat+ (FNAL E687 Collab.) ACOSTA 94 PR D49 5690 +Athanas, Masek, Paar+ (FNAL E687 Collab.) ACOSTA 94 PR D49 5690 +Athanas, Masek, Paar+ (CLEO Collab.) BROWN 94 PR D50 1884 +Fast, McIlwain, Miao+ (CLEO Collab.) BROWN 94 PR D50 1884 +Fast, McIlwain, Miao+ (CLEO Collab.) BROWN 94 PR D43 7867 +Freyberger, Rodriguez+ (CLEO Collab.) BROWN 94 PR D43 7867 +Freyberger, Rodriguez+ (CLEO Collab.) BROWN 94 PR D43 3767 +Freyberger, Rodriguez+ (CLEO Collab.) BROWN 94 PR D43 3767 +Freyberger, Rodriguez+ (CLEO Collab.) BROWN 94 PR D43 3767 +Freyberger, Rodriguez+ (CLEO Collab.) BROWN 94 PR D43 3767 +Freyberger, Rodriguez+ (CLEO Collab.) BROWN 94 PR D43 3767 +Cheung, Cumalat+ (FNAL E687 Collab.) BROWN 95 PL B305 1377 +Alexandrov, Antinori+ (CERN WAS Collab.) BROWN 95 PR D43 3767 +Baroni, Bisi, Bresilm+ (FNAL E687 Collab.) BROWN 95 PR D43 3767 +Baroni, Bisi, Bresilm+ (FNAL E687 Collab.) BROWN 95 PR D43 3767 +Baroni, Bisi, Bresilm+ (FNAL E687 Collab.) BROWN 95 PR D45 3965 +Bortichmann, Hamacher, Krueger+ (ARCUS Collab.) ALBRECHT 92 PR D45 3965 +Bortichmann, Hamacher, Krueger+ (ARCUS Collab.) ALBRECHT 92 PR D45 3965 +Freyberger, Rodriguez, Petron+ (CLEO Collab.) Brown PR D45 3965 +Freyberger, Rodriguez, Petron+ (CLEO Collab.) Brown PR D45 3965 +Freyberger, Rodriguez, Petron+ (CLEO Collab.) Brown PR D45 3965 +Freyberger, Rodriguez, Petron+ (CLEO Collab.) Brown PR D45 3965 +Freyberger, Rodriguez, Petron+ (CLEO Collab.) Brown PL B255 639 +PR D43 87063	ARTUSO	96	PL B378 364	+Efimov, Gao, Goldberg+	(CLEO	Collab)
BANDENBLANDERS 95						
BRANDENB 95 PRL 175 3804 Brandenburg, Cinabro, Liu+ (CLEC Collab.) FRABETTI 95 PL B346 199 +Cheung, Cumalat+ (FNAL E687 Collab.) FRABETTI 95 PL B351 591 +Cheung, Cumalat+ (FNAL E687 Collab.) FRABETTI 95 PL B359 403 +Cheung, Cumalat+ (FNAL E687 Collab.) KODAMA 95 PL B345 85 +Cheung, Cumalat+ (FNAL E687 Collab.) ACOSTA 94 PR D49 5690 +Athanas, Masek, Paar+ (CLEC Collab.) AVERY 94 PL B337 405 +Freyberger, Rodriguer+ (CLEC Collab.) BROWN 94 PR D50 1884 +Fast, McIlwain, Miao+ (CLEC Collab.) BUTLER 94 PL B322 4255 +Fu, Kalbifisch, Ross+ (CLEC Collab.) FRABETTI 94 PL B328 187 +Cheung, Cumalat+ (FNAL E687 Collab.) MUHEIM 94 PR B313 253 +Cheung, Cumalat+ (FNAL E687 Collab.) FRABETTI 95 PR P1 318 +Baroni, Bis, Bresilm+ (ERN WAS2 Collab.) FRABETTI 97						
FRABETTI 95						
FRABETTI 95E PL B351 591						
FRABETTI 95F PL B359 403						
FRABETTI 95F PL B363 259						
ACOSTA 94 PR D49 5590						
ACOSTA						
AVERY 948 PL B337 405						
BROWN 94						
BUTLER	AVERY	94B	PL B337 405	+Freyberger, Rodriguez+	(CLEO	Collab.)
FRABETTI						
MUHEIM 94 PR D49 3767 Stone CSYRA ADAMOVICH 93 PL B305 177 Alexandrov, Antinori+ (CERN WA82 Collab.) AOKI 93 PTP 89 131 Baroni, Bisi, Bresilin+ (CERN WA75 Collab.) FRABETTI 935 PRL 171 827 Cheung, Cumalat, Dallapiccola+ (FNAL E687 Collab.) FRABETTI 936 PL B313 253 Cheung, Cumalat+ (FNAL E687 Collab.) KODAMA 93 PL B313 260 Cheung, Cumalat+ (FNAL E637 Collab.) KODAMA 93 PL B313 260 Cheung, Cumalat+ (FNAL E637 Collab.) FNAL E637 Collab.) FNAL E638 Collab.) Collab. Cheung, Cumalat+ (FNAL E637 Collab.) Cheung	BUTLER	94	PL B324 255	+Fu, Kalbfleisch, Ross+	(CLEO	Collab.)
ADAMOVICH 93	FRABETTI	94F	PL B328 187	+Cheung, Cumalat+	(FNAL E687	Collab.)
AOKI 93	MUHEIM	94	PR D49 3767	+Stone		(SYRA)
FRABETTI 93F PR. 71 827	ADAMOVICH	93	PL B305 177	+Alexandrov, Antinori+	(CERN WA82	Collab.)
FRABETTI 936 PL 8313 253	AOKI	93	PTP 89 131	+Baroni, Bisi, Breslin+	(CERN WA75	Collab.)
KODAMA 93	FRABETTI		PRL 71 827	+Cheung, Cumalat, Dallapiccola+	(FNAL E687	Collab.)
KODAMA	FRABETTI	93G	PL B313 253	+Cheung, Cumalat+	(FNAL E687	Collab.)
ALBRECHT 92B ZPHY C53 361 +Enrifchmann, Hamacher, Krueger+ (ARGUS Collab.) (CLEO Collab.) ALEXANDER 92 PRL 69 2892 +Bebels, Berkelman, Beson (CLEO Collab.) (CLEO Collab.) AVERY 92 PRL 68 1279 +Appel, Bean, Bediaga+ (FNAL E91 (CleD Collab.) Also 905 ZPHY C53 383 +Becker, Borek, Boehringer+ (ACCMOR Collab.) Also 900 ZPHY C42 29 PR D45 3965 +Ford, Johnson, Lingel+ (ACCMOR Collab.) FRABETTI 92 PL B235 634 +Emritchmann, Hamacher, Krueger+ (ARGUS Collab.) ALVAREZ 91 PL B255 639 +Emritchmann, Hamacher, Krueger+ (ARGUS Collab.) ANJOS 918 PR D43 R2063 +Speck, Boehringer+ (ARGUS Collab.) COFFMAN 91 PL B256 135 +Appel, Bean, Bracker+ (FNAL E91 Collab.) + Poptinger +Appel, Bean, Bracker+ (FNAL E91 Collab.) +Appel, Bean, Bracker+ (FNAL E91 Collab.)	KODAMA	93	PL B309 483	+Ushida, Mokhtarani+	(FNAL E653	Collab.)
ALEXANDER 92 PRL 68 1275 + Bebek, Berkelman, Besson++ (CLEO Collab, Collab, AVERY ANJOS 92D PRL 69 2892 + Appel, Bean, Bediaga+ (FNAL E69) Collab, AVERY 92 PRL 68 1279 + Freyberger, Rodriguez, Yelton+ (CLEO Collab, BARLAG AVERTY 48 - Pecker, Bozek, Boehringer+ (CLEO Collab, Barlag, Becker, Bozek, Boehringer, Bosman+ (ACCMOR Collab, Barlag, Becker, Boehringer, Bosman+ (ACCMOR Collab, Barlag, Barlag, Becker, Boehr	KODAMA	93B	PL B313 260	+Ushida, Mokhtarani+	(FNAL E653	Collab.)
ANJOS 92D PRI. 69 2892	ALBRECHT	92B	ZPHY C53 361	+Ehrlichmann, Hamacher, Krueger+	(ARGUS	Collab.)
AVERY 92 PRI. 68 1279 + Freyberger, Rodriguez, Velton+ (CLEO Collab.) BARLAG 902 ZPHY C55 383 + Becker, Bozek, Boehringer+ (ACCMOR Collab.) Also 900 ZPHY C48 29 Barlag, Becker, Boehringer, Bosman+ (ACCMOR Collab.) DAOUDI 92 PR D45 3965 + Ford, Johnson, Lingel+ (CLEO Collab.) FRABETTI 92 PL B251 167 + Bogart, Cheung, Culy+ (FNAL E667 Collab.) ALWAREZ 91 PL B255 634 + Ehrlichmann, Hamacher, Krueger+ (ARGUS Collab.) ALVAREZ 91 PL B255 639 + Barate, Bloch, Bonamy+ (CERN NA14/2 Collab.) ANJOS 91 PL B263 135 + Appel, Bean, Bracker+ (FNAL E691 Collab.) OFFMAN 91 PL B263 135 + Delongh, Dubois, Eigen, Hitlin+ (Mark III) Collab.)	ALEXANDER	92	PRL 68 1275	+Bebek, Berkelman, Besson+	(CLEO	Collab.)
BARLAG 92C ZPHY CSS 333 +Becker, Bozek, Böehringer+ (ACCMOR Collab.) Also 90D ZPHY C48 29 PL BASTAG ACCMOR Collab.) FRABETTI 92 PL B281 167 Hord, Johnson, Lingel+ (CLEO Collab.) FRABECHT 91 PL B255 634 +Bogart, Cheung, Culy+ (FNAL E687 Collab.) ALVAREZ 91 PL B255 634 +Ehrlichmann, Hamacher, Krueger+ (ARGUS Collab.) ANJOS 918 PR D43 R2063 +Sarate, Bloch, Bonamy+ (CERN NA14/2 Collab.) OFFMAN 91 PL B263 135 +DeJongh, Dubois, Eigen, Hitlin+ (Mark III) Collab.)	ANJOS	92D	PRL 69 2892	+Appel, Bean, Bediaga+	(FNAL E691	Collab.)
Also 90D ZPHY C48 29 Barlag, Becker, Boehringer, Bosman+ (ACCMOR Collab.)	AVERY	92	PRL 68 1279	+Freyberger, Rodriguez, Yelton+	(CLEO	Collab.)
DAOUDI 92 PR D45 3965 +Ford, Johnson, Lingel+ (CLEO Collab.) FRABETTI 92 PL B281 167 +Bogart, Cheung, Culy+ (FNAL E687 Collab.) ALBRECHT 91 PL B255 634 +Ehrlichmann, Hamacher, Krueger+ (ARGUS Collab.) ALVAREZ 91 PL B255 639 +Barate, Bloch, Bonamy+ (CERN NA14/2 Collab.) ANJOS 91B PR D43 R2063 +Appel, Bean, Bracker+ (FNAL E691 Collab.) COFFMAN 91 PL B263 135 +DeJongh, Dubois, Eigen, Hitlin+ (Mark IIII Collab.)	BARLAG	92C	ZPHY C55 383	+Becker, Bozek, Boehringer+	(ACCMOR	Collab.)
FRABETTI 92 Pl. B281 167 + Bogart, Cheung, Cúly+ (FNAL E687 Collab.) ALBRECHT 91 Pl. B255 634 + Ehrlichmann, Hamacher, Krueger+ (ARGUS Collab.) ALVAREZ 91 Pl. B255 639 + Barate, Bloch, Bonamy+ (CERN NA14/2 Collab.) ANJOS 918 PR D43 78063 + Appel, Bean, Bracker+ (FNAL E691 Collab.) COFFMAN 91 Pl. B263 135 + Delongh, Dubois, Eigen, Hitlin+ (Mark IIII Collab.)	Also	90D	ZPHY C48 29	Barlag, Becker, Boehringer, Bosma	n+ (ACCMOR	Collab.)
ALBRECHT 91 PL 8255 634 +Ehrlichmann, Hamacher, Krueger+ (ARGUS Collab.) ALVAREZ 91 PL 8255 639 +Barate, Bloch, Bonamy+ (CERN NA14/2 Collab.) ANJOS 918 PR 043 R2063 +Appel, Bean, Bracker+ (FNAL E691 Collab.) COFFMAN 91 PL 8263 135 +DeJongh, Dubois, Eigen, Hitlin+ (Mark III) Collab.)	DAOUDI	92	PR D45 3965	+Ford, Johnson, Lingel+	(CLEO	Collab.)
ALBRECHT 91 PL 8255 634 +Ehrlichmann, Hamacher, Krueger+ (ARGUS Collab.) ALVAREZ 91 PL 8255 639 +Barate, Bloch, Bonamy+ (CERN NA14/2 Collab.) ANJOS 918 PR 043 R2063 +Appel, Bean, Bracker+ (FNAL E691 Collab.) COFFMAN 91 PL 8263 135 +DeJongh, Dubois, Eigen, Hitlin+ (Mark III) Collab.)	FRABETTI	92	PL B281 167	+Bogart, Cheung, Culy+	(FNAL E687	Collab.)
ALVAREZ 91 PL 8255 639 +Barate, Bloch, Bonamy+ (CERN NA14/2 Collab.) ANJOS 91B PR D43 R2063 +Appel, Bean, Bracker+ (FNAL E691 Collab.) COFFMAN 91 PL 8263 135 +DeJongh, Dubois, Eigen, Hitlin+ (Mark IIII Collab.)	ALBRECHT	91	PL B255 634			
COFFMAN 91 PL B263 135 +DeJongh, Dubois, Eigen, Hitlin+ (Mark III Collab.)	ALVAREZ	91	PL B255 639			
COFFMAN 91 PL B263 135 +DeJongh, Dubois, Eigen, Hitlin+ (Mark III Collab.)	ANJOS	91B	PR D43 R2063			
		91				
ADLER 90B PRL 64 169 +Bai, Blaylock, Bolton+ (Mark III Collab.)	ADLER	90B	PRI 64 169	+Bai, Blaylock, Bolton+		
ALBRECHT 90D PL B245 315 +Ehrlichmann, Glaeser, Harder+ (ARGUS Collab.)		90D	PL B245 315			

ALEX.	ANDER	90B	PRL 65 1531	+Artuso, Bebek, Berkelman+	(CLEO	Collab.)
ALVA	REZ	90	ZPHY C47 539	+Barate, Bloch, Bonamy+	(CERN NA14/2	
ALVA	REZ	90C	PL B246 261	+Barate, Bloch, Bonamy+	(CERN NA14/2	Collab.)
ANJO	S	90B	PRL 64 2885	+Appel, Bean, Bracker+	` (FNAL E691	
ANJO	S	90C	PR D41 2705	+Appel, Bean+	(FNAL E691	Collab.)
BAI		90	PRL 65 686	+Blaylock, Bolton, Brient+	(Mark III	Collab.)
BARL	AG	90C	ZPHY C46 563	+Becker, Boehringer, Bosman+	(ÀCCMOR	
FRAB	ETTI	90	PL B251 639	+Bogart, Cheung, Coteus+	(FNAL E687	Collab.)
ADLE	R	89B	PRL 63 1211	+Bai, Becker, Blaylock, Bolton+	(Mark III	
A	lso	89D	PRL 63 2858 erratum			,
ANJO	S	89	PRL 62 125	+Appel, Bean, Bracker+	(FNAL E691	Collab.)
ANJO	S	89E	PL B223 267	+Appel, Bean, Bracker+	(FNAL E691	Collab.)
AVER	LL	89	PR D39 123	+Blockus, Brabson+		Collab.)
CHEN		89	PL B226 192	+McIlwain, Miller, Ng, Shibata+	(ČLEO	Collab.)
ALBR	ECHT	88	PL B207 349	+Binder, Boeckmann+	(ARGUS	
ALBR	ECHT	881	PL B210 267	+Boeckmann, Glaeser+	(ARGUS	Collab.)
ANJO	S	88	PRL 60 897	+Appel+	(FNAL E691	Collab.)
RAAB		88	PR D37 2391	+Anjos, Appel, Bracker+	(FNAL E691	Collab.)
ALBR	ECHT	87F	PL B179 398	+Binder, Boeckmann, Glaeser+	` (ARGUS	
ALBR	ECHT	87G	PL B195 102	+Andam, Binder, Boeckmann+	(ARGUS	Collab.)
ANJO	S	87B	PRL 58 1818	+Appel, Bracker, Browder+	(FNAL E691	Collab.)
BECK	ER	87B	PL B184 277	+Boehringer, Bosman+	(NA11 and NA32	Collab.)
BLAY	OCK	87	PRL 58 2171	+Bolton, Brown, Bunnell+	(Mark III	Collab.)
BRAU	NSCH	87	ZPHY C35 317	Braunschweig, Gerhards+	(TASSO	Collab.)
CSOR	NA	87	PL B191 318	+Mestayer, Panvini, Word+		Collab.)
JUNG		86	PRL 56 1775	+Abachi+	(HRS	Collab.)
USHIE		86	PRL 56 1767	+Kondo, Tasaka, Park+	(FNAL E531	Collab.)
ALBRI	ECHT	85D	PL 153B 343	+Drescher, Binder, Drews+	(ARGUS	Collab.)
DERR		85B	PRL 54 2568	+Fernandez, Fries, Hyman+	(HRS	Collab.)
AIHAF		84D	PRL 53 2465	+Alston-Garnjost, Badtke, Bakken-		Collab.)
ALTH		84	PL 136B 130	+Braunschweig, Kirschfink+	(TASSO	
BAILE		84	PL 139B 320	+Belau, Bohringer, Bosman+	(ACCMOR	
AUBE	RT	83	NP B213 31	+Bassompierre, Becks, Best+		Collab.)
CHEN		83C	PRL 51 634	+Alam, Giles, Kagan+		Collab.)
USHIE)A	83	PRL 51 2362	+Kondo, Fujioka, Fukushima+	(FNAL E653	Collab.)

- OTHER RELATED PAPERS -

95 RMP 67 893

(UCSB, STAN)



$$I(J^P) = ?(??)$$

$D_s^{*\pm}$ MASS

The fit includes D^\pm , D^0 , D_s^\pm , $D^{*\pm}$, D^{*0} , and $D_s^{*\pm}$ mass and mass difference measurements.

 $^1\,\mathrm{Assuming}~D_{\,\mathbf{S}}^{\,\pm}\,\,\mathrm{mass} = 1968.7\,\pm\,0.9\,\,\mathrm{MeV}.$

$m_{D_s^{*\pm}} - m_{D_s^{\pm}}$

The fit includes D^\pm , D^0 , D_s^\pm , $D^{*\pm}$, D^{*0} , and $D_s^{*\pm}$ mass and mass difference measurements.

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
143.8 ± 0.4 OUR	FIT				
143.9 ± 0.4 OUR	AVERAGE				
$143.76 \pm\ 0.39 \pm 0.40$		GRONBERG	95	CLE2	e^+e^-
$144.22 \pm\ 0.47 \pm 0.37$		BROWN			
$142.5 \ \pm \ 0.8 \ \pm 1.5$		² ALBRECHT	88	ARG	$e^+e^- \rightarrow D_s^{\pm} \gamma X$
139.5 \pm 8.3 \pm 9.7	60	AIHARA	84D	TPC	$e^+e^- ightarrow hadrons$
 ● ● We do not use 	the followin	g data for average	s, fits	, limits,	etc. • • •
143.0 ±18.0	8	ASRATYAN	85	HLBC	FNAL 15-ft, ν-2H
110 ± 46		BRANDELIK	79	DASP	$e^+e^- \rightarrow D_e^{\pm} \gamma X$
					3

 $^2\,\mbox{Result}$ includes data of ALBRECHT 84B.

D*± WIDTH

VALUE (MeV)	CL%	DOCUMENT ID		TECN	COMMENT
< 1.9	90	GRONBERG	95	CLE2	e^+e^-
< 4.5	90	ALBRECHT	88	ARG	$E_{cm}^{ee} = 10.2 \text{ GeV}$
• • • We do not u	se the followin	g data for average	es, fits	s, limits,	etc. • • •
< 4.9	90	BROWN	94	CLE2	e+e-
<22	90	BLAYLOCK	87	MRK3	$e^+e^- \rightarrow D_s^{\pm} \gamma X$

D*+ DECAY MODES

 D_s^{*-} modes are charge conjugates of the modes below.

	Mode	Fraction (Γ_j/Γ)
Γ ₁	$D_s^+ \gamma$	seen
Γ_2	$D_s^+ \pi^0$	seen

 $D_s^{*\pm}$, $D_{s1}(2536)^{\pm}$, $D_{sJ}(2573)^{\pm}$

D*+ BRANCHING RATIOS

$\Gamma(D_s^+\gamma)/\Gamma_{\text{total}}$					Γ_1/Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
dominant OUR ESTIMATE					
• • We do not use the follow	wing data for average	s, fits	, limits	etc. • • •	
seen	ASRATYAN	91		$\overline{ u}_{\mu}$ Ne	
seen	ALBRECHT	88	ARG	$e^+e^- \rightarrow$	$D_s^{\pm} \gamma X$
seen	AIHARA	84D			•
seen	ALBRECHT	84B			
seen	BRANDELIK	79			
$\Gamma(D_s^+\pi^0)/\Gamma(D_s^+\gamma)$					Γ_2/Γ_1
VALUE	DOCUMENT ID		TECN	COMMENT	
$0.062^{\begin{subarray}{c} +0.020 \\ -0.018 \end{subarray}} \pm 0.022$	GRONBERG	95	CLE2	e^+e^-	

D_s^{±±} REFERENCES

GRONBERG BROWN ASRATYAN ALBRECHT BLAYLOCK ASRATYAN	95 94 91 88 87 85	PRL 75 3232 PR D50 1884 PL B257 525 PL B207 349 PRL 58 2171 PL 156B 441	+Korte, Kutschke+ +Fast, McIlwain, Miao+ +Marage+(1TEP, BELG, SACL, SERP, +Binder, Boeckmann+ +Bolton, Brown, Bunnell+ +Fedotov, Ammosov, Burtovoy+	(CLEO Collab.) (CLEO Collab.) CRAC, BARI, CERN) (ARGUS Collab.) (Mark III Collab.) (ITEP, SERP)
	85 84D	PL 156B 441 PRL 53 2465		(ITEP, SERP) (TPC Collab.)
ALBRECHT BRANDELIK	84B 79	PL 146B 111 PL 80B 412	+Drescher, Heller+ +Braunschweig, Martyn, Sander+	(ARGUS Collab.) (DASP Collab.)

OTHER RELATED PAPERS ----

KAMAL	92	PL B284 421	+Xu	(ALBE)
BRANDELIK	78C	PL 76B 361	+Cords+	(DASP Collab.)
BRANDELIK	77B	PL 70B 132	+Braunschweig, Martyn, Sander+	(DASP Collab.)

$D_{s1}(2536)^{\pm}$

$$I(J^P) = 0(1^+)$$

I, J, P need confirmation.

Seen in $D^*(2010)^+ K^0$. Not seen in $D^+ K^0$ or $D^0 K^+$. $J^P=1^+$ assignment strongly favored.

$D_{s1}(2536)^{\pm}$ MASS

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
2535.35 ± 0.34 OUR	AVERAGE			
2534.2 ± 1.2	9	ASRATYAN	94 BEBC	$\stackrel{\nu N \rightarrow}{D^*} \stackrel{\kappa^0 X, D^{*0}}{K^{\pm} X}$
$2535 \pm \ 0.6 \ \pm 1$	75	FRABETTI	94B E687	$\gamma \text{Be} \rightarrow D^{*+} K^0 X$.
2535.3 \pm 0.2 \pm 0.5	134	ALEXANDER	93 CLE2	$e^+e^- \rightarrow D^{*0}K^+X$
$2534.8 \ \pm \ 0.6 \ \pm 0.6$	44	ALEXANDER	93 CLE2	$e^+e^- \rightarrow D^{*+}K^0X$
$2535.2 \ \pm \ 0.5 \ \pm 1.5$	28	ALBRECHT	92R ARG	$0.4 e^{+}e^{-} \rightarrow 0.4 K^{+}X$
2536.6 \pm 0.7 \pm 0.4		AVERY	90 CLEO	$D^{*0}K^+X$ $e^+e^- \rightarrow D^{*+}K^0X$
2535.9 \pm 0.6 \pm 2.0		ALBRECHT	89E ARG	$D_{c1}^* \rightarrow D^*(2010)K^0$
• • • We do not use	the following	data for averages	s, fits, limits	, etc. • • •
2535 ±28		¹ ASRATYAN	88 HLBC	$\nu N \rightarrow D_S \gamma \gamma X$
1 Not seen in $D^{*}K$.				

$m_{D_{s1}(2536)^{\pm}} - m_{D_{s}^{*}(2111)}$

	D ₅₁ (2000)	,	
VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
424±28	ASRATYAN 88	HLBC	$D_s^{*\pm}\gamma$

$D_{s1}(2536)^{\pm}$ WIDTH

VALUE (MeV)	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
<2.3	90		ALEXANDER	93	CLEO	$e^{+}e^{-} \rightarrow D^{*0}K^{+}X$
• • • We do n	ot use the	following	data for average	s, fits,	, limits,	etc. • • •
<3.2	90	75	FRABETTI	94B	E687	$\gamma \text{Be} \rightarrow D^{*+} \kappa^0 X$,
						$D^{*0}K^+X$
<3.9	90		ALBRECHT	92R	ARG	$0.4 e^{+}e^{-} \rightarrow D^{*0}K^{+}X$
< 5.44	90		AVERY	90	CLEO	$e^+e^- \rightarrow D^{*+} K^0 X$
<4.6	90		ALBRECHT	89E	ARG	$D_{s1}^* \rightarrow D^*(2010)K^0$

$D_{s1}(2536)^+$ DECAY MODES

 $D_{s1}(2536)^-$ modes are charge conjugates of the modes below.

	Mode	Fraction (Γ_i/Γ)	
Γ_1	D*(2010)+ K ⁰	seen	_
Γ_2	D*(2007) ⁰ K+	seen	
Γ_3	D^+K^0	not seen	
Γ_4	$D^0 K^+$	not seen	
Γ ₅	$D_s^{*+}\gamma$	possibly seen	

D_{s1}(2536)+ BRANCHING RATIOS

$\Gamma(D^+K^0)/\Gamma(D^*(2))$	(010)+ K ⁰)				Γ_3/Γ_1
VALUE	CL%_	DOCUMENT ID		TECN	COMMENT
<0.40	90	ALEXANDER	93	CLEO	$e^+e^- \rightarrow D^{*+}K^0X$
< 0.43	90	ALBRECHT	89E	ARG	$D_{s1}^* \to D^*(2010) K^0$
$\Gamma(D_s^{*+}\gamma)/\Gamma_{\text{total}}$					Γ ₅ /Γ
VALUE		DOCUMENT ID		TECN	COMMENT
possibly seen		ASRATYAN	88	HLBC	$\nu N \rightarrow D_S \gamma \gamma X$
$\Gamma(D^0K^+)/\Gamma(D^*(2))$	2007) ⁰ K ⁺)				Γ_4/Γ_2
VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.12	90	ALEXANDER	93	CLEO	$e^+e^- \rightarrow D^{*0}K^+X$
$\Gamma(D_s^{*+}\gamma)/\Gamma(D^*(2))$	007) ⁰ K ⁺)				Γ ₅ /Γ ₂
VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.42	90	ALEXANDER	93	CLEO	$e^+e^- \rightarrow D^{*0}K^+X$
	D-1(536)± REEF	REN	CES	

$D_{s1}(2536)^{\pm}$ REFERENCES

ASRATYAN FRABETTI ALEXANDER ALBRECHT AVERY ALBRECHT	93 92R 90 89E	ZPHY C 61 563 PRL 72 324 PL B303 377 PL B297 425 PR D41 774 PL B230 162	+Cheung, Cumalat+ +Bebek+ +Ehrlichmann+ +Besson +Glaser, Harder+	LG, CERN, SERP, ITEP, RAL) (FNAL E687 Collab.) (CLEO Collab.) (ARGUS Collab.) (CLEO Collab.) (ARGUS Collab.)
ASRATYAN	88 88	ZPHY C40 483	+Glaser, Harder+ +Fedotov+	(ITEP, SERP)

$D_{sJ}(2573)^{\pm}$

$$I(J^P) = ?(??)$$

I

 J^P is natural, width and decay modes consistent with 2^+ .

$D_{sJ}(2573)^{\pm}$ MASS

VALUE (MeV) 2573.5±1.7 OUR A	EVTS VERAGE	DOCUMENT ID		TECN	CHG	COMMENT
2574.5±3.3±1.6		ALBRECHT	96	ARG		$e^+e^- \rightarrow D^0 K^+ X$
$2573.2^{+1.7}_{-1.6} \pm 0.9$	217	KUBOTA	94	CLE2	+	$e^+e^-{\sim}~$ 10.5 GeV

$D_{sJ}(2573)^{\pm}$ WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
15 +5 OUR AV	ERAGE					
$10.4 \pm 8.3 \pm 3.0$		ALBRECHT	96	ARG		$e^+e^- \rightarrow D^0 K^+ X$
$16 \begin{array}{c} +5 \\ -4 \end{array} \pm 3$	217	KUBOTA	94	CLE2	+	$e^+e^-{\sim}~$ 10.5 GeV

$D_{sJ}(2573)^+$ DECAY MODES

 $D_{sJ}({\it 2573})^-$ modes are charge conjugates of the modes below.

	Mode	Fraction (Γ_i/Γ)
1 2	D ⁰ K ⁺ D*(2007) ⁰ K ⁺	seen seen

$D_{sJ}(2573)^+$ BRANCHING RATIOS

$\Gamma(D^0K^+)/\Gamma_{\text{total}}$						Γ_1/Γ	
VALUE	EVTS	DOCUMENT ID		TECN	CHG	COMMENT	
seen	217	KUBOTA	94	CLE2	\pm	$e^+e^-{\sim}~10.5~{\rm GeV}$	
$\Gamma(D^*(2007)^0 K^+)/\Gamma(D^0 K^+)$ Γ_2/Γ_1							
VALUE	CL%	DOCUMENT ID		TECN	CHG	COMMENT	
<0.33	90	KUBOTA	94	CLE2	+	$e^+e^-{\sim}$ 10.5 GeV	

$D_{sJ}(2573)^{\pm}$ REFERENCES

ALBRECHT	96	ZPHY C69 405	+Hamacher, Hofmann+	(ARGUS Collab.)
KUBOTA	94	PRL 72 1972	+Lattery, Nelson, Patton+	(CLEO Collab.)

BOTTOM MESONS $(B = \pm 1)$

 $B^+ = u\overline{b}$, $B^0 = d\overline{b}$, $\overline{B}^0 = \overline{d}b$, $B^- = \overline{u}b$, similarly for B^* 's

B-particle organization

Many measurements of B decays involve admixtures of B hadrons. Previously we arbitrarily included such admixtures in the B^\pm section, but because of their importance we have created two new sections: ${}^*B^\pm/B^0$ Admixture" for $\Upsilon(4S)$ results and ${}^*B^\pm/B^0/B_S^0/b$ -baryon Admixture" for results at higher energies. Most inclusive decay branching fractions are found in the Admixture sections. $B^0 \cdot \overline{B}^0$ mixing data are found in the B^0 section, while $B_s^0 \cdot \overline{B}_s^0$ mixing data and $B \cdot \overline{B}$ mixing data for a B^0/B_s^0 admixture are found in the B^0 section. CP-violation data are found in the B^0 section. B^0 -baryons are found near the end of the Baryon section.

The organization of the B sections is now as follows, where bullets indicate particle sections and brackets indicate reviews.

```
[Production and Decay of b-flavored Hadrons]
         [Semileptonic Decays of B Mesons]

    B<sup>±</sup>

             mass
             mean life
             branching fractions
             mass
             mean life
             branching fractions
             polarization in B^0 decay
             B^0 - \overline{B}^0 mixing
             [B^0 - \overline{B}{}^0 Mixing and CP Violation in B Decay]
              CP violation

    B<sup>±</sup> B<sup>0</sup> Admixture

             branching fractions
         • B^{\pm}/B^{0}/B_{s}^{0}/b-baryon Admixture
             mean life
             production fractions
             branching fractions
             mass

 B<sup>*</sup><sub>J</sub>(5732)

             mass
             width

    B<sub>s</sub><sup>0</sup>

             mass
             mean life
             branching fractions
             polarizaton in B_s^0 decay
             B_c^0 - \overline{B}_c^0 mixing
             B-\overline{B} mixing (admixture of B^0, B_c^0)

    B<sub>s</sub>*

             mass
         • B_{sJ}^*(5850)
             mass
             width
At end of Baryon Listings:

    Λ<sub>b</sub>

             mass
             mean life
             branching fractions
         • Ξ<sub>b</sub>,Ξ<sub>b</sub>
```

mean life

PRODUCTION AND DECAY OF b-FLAVORED HADRONS

K. Honscheid, Ohio State University, Columbus

In the two years since the last edition of this review our understanding of the physics of B mesons and b-flavored baryons has significantly improved. 1995 was another record setting year for the CLEO experiment as well as the Cornell e^+e^- storage ring (CESR) which reached an instantaneous luminosity of 3.3×10^{32} cm⁻²s⁻¹. More than 4 fb⁻¹ have been logged by the CLEO Collaboration. At CERN, the Z program has been completed and each of the four LEP experiments has recorded data samples containing about 3 million Z decays, corresponding to approximately 0.7×10^6 produced $b\bar{b}$ quark pairs. The FNAL $p\overline{p}$ collider run continued throughout most of 1995 and the CDF and DØ experiments have collected close to 100 pb⁻¹ of new data. SLD has begun to contribute to Bphysics. Using the excellent resolution of their vertex detector they have obtained precise measurements of B-meson lifetimes. New results in this edition include:

- The first observation of exclusive semileptonic $b \to u$ transitions
- The determination of the decay rate for inclusive $b \to s \gamma$ transitions.
- Updated lifetimes and masses for *b*-flavored hadrons.
- Improved measurements of $B^0 \overline{B}^0$ and $B_s^0 \overline{B}_s^0$ oscillations
- A new set of inclusive branching ratios for B mesons.
- Updated limits on rare B decays including new results on $b \rightarrow s$ gluon.

Weak decays of heavy quarks test the Standard Model and can be used to determine its parameters, in particular the weak-mixing angles of the Cabibbo-Kobayashi-Maskawa matrix. Experiments with B mesons may lead to the first precise determination of the fourth CKM parameter, the complex phase. While the underlying decay of the heavy quark is governed by the weak interaction, it is the strong force that is responsible for the formation of the hadrons that are observed by experimenters. Hence, in order to extract the Standard Model parameters from the experimental data, an understanding of the interplay of the weak and strong interaction is needed.

Production and spectroscopy

Elementary particles are characterized by their masses, lifetimes, and internal quantum numbers. The bound states with a b quark and a \overline{u} or \overline{d} antiquark are referred to as the B_d $(\overline{B^0})$ and the B_u (B^-) mesons, respectively. The first radial excitation is called the B^* meson. B^{**} is the generic name for the four orbitally excited (L=1) B meson states that correspond to the P-wave mesons in the charm system, D^{**} .

Experimental studies of b decay are performed at the $\Upsilon(4S)$ resonance near the production threshold as well as at higher energies in proton-antiproton collisions and Z decays. For quantitative analyses of B decays the initial composition of the data sample must be known. At the threshold experiments this is

b-flavored hadrons

determined by the ratio of charged to neutral decays of the $\Upsilon(4S)$. This ratio is denoted

$$\frac{f_{+}}{f_{0}} = \frac{\Upsilon(4S) \to B^{+}B^{-}}{\Upsilon(4S) \to B^{0}\overline{B}^{0}} \tag{1}$$

The $\Upsilon(4S)$ resonance decays only to $B^0\overline{B}^0$ and B^+B^- pairs, while heavier states such as B_s or B_c are not accessible. The current experimental limit for non- $B\overline{B}$ decays of the $\Upsilon(4S)$ is less than 4% at the 95% confidence level [1]. CLEO has measured the production ratio using semileptonic B decays and found [2]

$$\frac{f_{+}}{f_{0}} = 1.13 \pm 0.14 \pm 0.13 \pm 0.06 \tag{2}$$

where the last error is due to the uncertainties in the ratio of B^0 and B^+ lifetimes. This is consistent with equal production of B^+B^- and $B^0\overline{B}^0$ pairs and unless explicitly stated otherwise we will assume $f_+/f_0=1$. This assumption is further supported by the near equality of the B^+ and B^0 masses.

At high energy collider experiments the b quarks hadronize as B_d , B_u , B_s , and B_c mesons or as baryons containing b quarks. The composition of the initial sample is not very precisely known although over the last year significant improvements have been achieved. Several methods have been developed to determine f_{B_s} and f_{Λ_b} , the fractions of B_s mesons, and b-flavored baryons produced in $Z \to b\bar{b}$ decays. ALEPH use their measurement of the product branching fraction, $f_{B_s} \times B(\overline{B}_s^0 \to D_s^+ \ell^- \overline{\nu}_\ell$ anything) = $0.82 \pm 0.09^{+0.13}_{-0.14}\%$ [3]. Under the assumption of equal semileptonic partial widths for b-flavored hadrons results from the $\Upsilon(4S)$ experiments can be used to obtain an estimate for $B(\overline{B}_s^0 \to D_s^+ \ell^- \overline{\nu}_\ell)$. Using these results ALEPH [4] extract the fraction of b quarks that hadronize to B_s mesons to[†]

$$f_{B_8} = 11.1_{-2.6}^{+2.5}\% \tag{3}$$

A similar procedure is followed to obtain an estimate for the fraction of b baryons [5]:

$$f_{A_h} = 13.2 \pm 2.4 \pm 3.3\% \tag{4}$$

An alternative methods to determine f_{B_s} starts with the time integrated mixing parameter

$$\overline{\chi} = f_{B_o} \chi_s + f_{B^0} \chi_d \tag{5}$$

Assuming $\chi_s=0.5$ and using the measured value for χ_d the fraction of B_s mesons can be extracted [6]

$$f_{B_8} = 11.3^{+2.5}_{-2.6}\% (6)$$

Averaging the two measurements of f_{B_s} with correlated systematics taken into account yields

$$\langle f_{B_s} \rangle = 11.2^{+1.8}_{-1.9}\%$$
 (7)

Assuming that $f_{B^0}=f_{B^+}$ and $f_{B^0}+f_{B^+}+f_{B_s}+f_{A_b}=1$ we obtain the results listed in Table 1.

Table 1: Fractions of weakly decaying b-hadron species in $Z \to b\bar{b}$ decay.

b-hadron	Fraction [%]
B^+ B^0 B_s Λ_b	37.8 ± 2.2 37.8 ± 2.2 $11.2^{+1.8}_{-1.9}$ 13.2 ± 4.1

To date, the existence of four b-flavored mesons $(B^-, \overline{B}^0, B^*, B_s)$ has been established. The LEP experiments have provided evidence for excited B^{**} and B_s^{**} states. The B_c is still not observed. The A_b baryon has been exclusively reconstructed by CDF and the LEP experiments. First indications of Σ_b and Ξ_b production have been presented by the LEP collaborations [7]. DELPHI has measured the $\Sigma_b^* - \Sigma_b$ hyperfine splitting to 56 ± 16 MeV [8].

Lifetimes

The lifetime of a b-flavored hadron is given by its hadronic and semileptonic decay rates

$$\frac{1}{\tau_B} = \Gamma_{\text{tot}} = \Gamma_{\text{hadronic}} + \Gamma_{\text{semileptonic}} \tag{8}$$

In the naive spectator model the heavy quark can decay only via the external spectator mechanism and thus the lifetimes of all mesons and baryons containing b quarks would be equal. Nonspectator effects such as the interference between contributing amplitudes modify this simple picture and give rise to a lifetimes hierarchy for b-flavored hadrons similar to the charm sector. However, since the lifetime differences are expected to scale as $1/m_Q^2$, where m_Q is the mass of the heavy quark, the variation in the b system should be significantly smaller, of order 10% or less [9]. For the b system we expect

$$\tau(B^{-}) \geq \tau(\overline{B}^{0}) \approx \tau(B_{s}) > \tau(\Lambda_{b}^{0}) \tag{9}$$

Measurements of lifetimes for the various b-flavored hadrons thus provide a means to determine the importance of nonspectator mechanisms in the b sector.

The experimental errors on individual B-lifetime measurements are approaching the 5-10% level. However, in order to reach the precision necessary to test theoretical predictions, the results from different experiments need to be averaged. Using the conventional approach of weighting the measurements according to their error does not take into account the underlying exponential lifetime distribution. If a measurement fluctuates low then its weight in the average will increase, leading to a bias towards low values. Combining lifetime measurements correctly is a difficult task that requires detailed knowledge of common systematic uncertainties and correlations between the results from different experiments. The average lifetimes for b-flavored hadrons given in this edition have been determined by L. Di Ciaccio (DELPHI) and the LEP B Lifetimes Working Group. Among other things, they considered uncertainties in the composition of the b sample and background, correlation

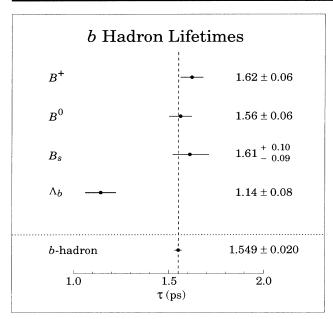


Figure 1: Summary of lifetime measurements for individual b hadrons and for the b-hadron admixture at high energy (LEP and CDF).

in the b momentum estimation and common errors in b and c branching fractions. A detailed description of their procedures and the treatment of correlated and uncorrelated errors can be found in [10]. The experimental papers used in this calculation are given in the Particle Listing sections on b-flavored mesons and baryons. A summary of the average b-hadron lifetimes is shown in Fig. 1. The pattern of measured lifetimes follows the theoretical expectations outlined above and nonspectator effects are observed to be small. However, the Λ_b baryon lifetime is unexpectedly short. As has been noted by several authors, the observed value of the Λ_b lifetime is quite difficult to accommodate theoretically [11,12].

Semileptonic decays and mixing

Measurements of semileptonic B decays are important for the determination of the weak couplings $|V_{cb}|$ and $|V_{ub}|$ and test our understanding of the dynamics of heavy quark decay. A measurement technique using events with two leptons was introduced by the ARGUS experiment [13] which significantly reduces the model dependence associated with the subtraction of the $b \to c \to \ell$ cascade component. A high momentum lepton is selected $(p_{\ell} > 1.4 \text{ GeV})$ which tags a $b\bar{b}$ event. This primary lepton is then combined with an additional lepton candidate which has a momentum above 0.5 GeV. In the absence of mixing, if the second lepton has a charge opposite to the tagging lepton it is a primary lepton from the b decay, while if the second lepton has the same sign as the tag it is a cascade lepton. Models of semileptonic B decay are only needed for

the small extrapolation to zero lepton momentum. Using this method, CLEO II finds

$$B_{sl} = (10.49 \pm 0.17 \pm 0.43)\% \tag{10}$$

consistent with the conventional single lepton analysis.

Assuming the semileptonic decay width is the same for all b-flavored hadrons, the semileptonic branching ratio should be slightly different at LEP since other b particles are produced:

$$B_{sl}(\Upsilon(4S)) = \frac{\Gamma_{sl}}{\Gamma_{tot}} = \Gamma_{sl} \times \frac{(\tau_{B^+} + \tau_{B^0})}{2}$$
 (11)

while

$$B_{\rm sl}(Z) = \Gamma_{\rm sl} \times \tau_b \tag{12}$$

Using the world averages for the B lifetimes and the CLEO semileptonic branching fraction this gives

$$B_{\rm sl}(Z) = \frac{2\tau_b}{(\tau_{B^+} + \tau_{B^0})} \times B_{\rm sl}(\Upsilon(4S)) = 10.2 \pm 0.4\%$$
 (13)

Note that the contribution of other hadrons reduces the expected average semileptonic branching fraction at the Z. This is below the experimental average from LEP, $B_{\rm sl}(Z)=10.9\pm0.1\pm0.3$, but the errors are still too large to draw any conclusions.

It is interesting to compare the inclusive semileptonic branching fraction to the sum of branching fractions for exclusive modes. CLEO and the LEP collaborations have updated their measurements of $B(B \to D\ell\nu_{\ell})$ and $B(B \to D^*\ell\nu_{\ell})$. Including the recent observations of $B \to D^{**}(2420)\ell\nu_{\ell}$ and $B \to D^{**}(2460)$ by OPAL and ALEPH the sum of exclusive semileptonic branching fractions amounts to $8.81 \pm 0.1\%$. The remaining decays may correspond to $B \to D^{**}\ell\nu_{\ell}$ where D^{**} denotes a p-wave charmed meson with a large width (e.g. the very broad but as of now unobserved $1^3P_1(2490)$ and $1^3P_0(2440)$ states). It is also possible that the other missing decays are $B \to D\pi \ell^- \nu_\ell$ where the $D\pi$ system is nonresonant or originates from the decay of a broad excited charm meson. These possibilities are difficult to check experimentally. It is also conceivable that the difference between the sum of the exclusive modes and the inclusive semileptonic rate is due to a systematic error in the D meson absolute branching fraction scale.

The ALEPH, DELPHI, OPAL, and CDF experiments have performed explicit measurements of $\operatorname{Prob}(B^0 \to \overline{B^0})$ as a function of time to obtain the parameter $x_d = \Delta m_d/\Gamma$ [6]. The initial state b quark flavor is tagged either using leptons or jet charge, while the flavor of the final state b quark is tagged using either $\overline{B}_d \to D^{*+}\ell^-X$, $\overline{B}_d \to D^{*+}X$, or $\overline{B}_d \to \ell^-X$. If the final state is not fully reconstructed, as is the case for the analyses using dileptons, then the decay time must be determined using a topological vertexing technique where the lepton from the B decay and the other tracks in the same jet hemisphere are combined. The boost is determined using the observed energy, missing momentum and a correction factor determined from a Monte Carlo simulation. Averaging these results gives $\Delta m_d = 0.458 \pm 0.020 \, \mathrm{ps}^{-1}$ which is statistically superior to

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the results obtained from time integrated measurements by experiments at the $\Upsilon(4S)$.

The measurement of the mixing parameter $x_s = \Delta m_s/\Gamma$ for the B_s meson combined with the results on $B^0-\overline{B}^0$ oscillations allows the determination of the ratio of the CKM matrix elements $|V_{td}|^2/|V_{ts}|^2$ with significantly reduced theoretical uncertainties. Experimentally the measurement of x_s is a challenge. For large values, as expected for the B_s meson, time integrated measurements of B_s mixing become insensitive to x_s and one must make time dependent measurements in order to extract this parameter. These are very difficult because of the rapid oscillation rate of the B_s meson. Using an event sample with a lepton and a tag based on a jet charge technique where each track is weighted by its rapidity, ALEPH has searched for a high frequency component in their fit to the proper time distribution. They find $\Delta m_s > 6 \text{ ps}^{-1}$ or $x_s > 8.8$ at the 95% confidence level [6].

Hadronic decays

CLEO has presented a set of new measurements of inclusive B-meson decay rates that can be used to test the parton level expectation that most B decays proceed via a $b \to c$ transition. If we neglect the small contributions from $b \to u$ and penguin transitions, we expect about 1.15 charm quarks to be produced per B decay. The additional 15% is due to the fact that the virtual W forms a $s\bar{c}$ quark pair with a probability of approximately 0.15. This expectation can be verified experimentally by adding all inclusive $b \to c$ branching fractions. Using the world averages for the $b \to c$ branching fractions we find [14]:

Charm yield = B(
$$B \to D^0 X$$
) + B($B \to D^+ X$) + B($B \to D_s X$)
+ B($B \to A_c X$) + B($B \to \Xi_c^+ X$) + B($B \to \Xi_c^0 X$)
+ 2 × B($B \to \psi X$) + 2 × B($B \to \psi' X$)
+ 2 × B($B \to \chi_{c1} X$) + 2 × B($B \to \chi_{c2} X$)
+ 2 × B($B \to \eta_c X$ (incl. other $c\bar{c}$))
= 1.15 ± 0.05 (14)

The factor of 2 which multiplies $B(B \to c\bar{c}X)$ accounts for the two charm quarks produced in $b \to c\bar{c}s$ transitions. Wherever possible the branching fractions for direct production are used. The contribution of $B \to \eta_c X$ and other charmonia is generously taken to be at the CLEO 90% confidence level upper limit $B(B \to \eta_c X) < 0.90\%$.

Another interesting quantity is the fraction of B decays in which two charm quarks are produced. In a parton level calculation, Palmer and Stech [15] find that $B(B \to X_{c\overline{c}}) = 19 \pm 1\%$ where the theoretical error is the uncertainty due to

the choice of quark masses. This can be compared to the sum of the experimental measurements [14]

$$B(B \to X_{c\overline{c}}) = B(B \to D_s X) + B(B \to \psi X) + B(B \to \psi' X)$$

$$+ B(B \to \chi_{c1} X) + B(B \to \chi_{c2} X) + B(B \to \Xi_c X)$$

$$+ B(B \to \eta_c X \text{ (incl. other } \overline{c}))$$

$$= (15.8 \pm 2.8)\%$$
(15)

where the direct $B \to \psi$ and $B \to \chi_{c1}$ branching fraction have been used. The contribution from $B \to \Xi_c^0 X$ is reduced by 1/3 to take into account the fraction that is not produced by the $b \to c \bar{c} s$ subprocess but by $b \to c \bar{u} d + s \bar{s}$ quark popping.

A possible contribution of $B \to D\overline{D}KX$ decays, which corresponds to the quark level process $b \to c\overline{c}s$ with popping of a light quark pair, is not included in the sum calculated above. Buchalla, Dunietz, and Yamamoto have recently suggested that the latter mechanism may be significant [16]. This possibility leads to wrong sign $D\text{-}\ell$ correlations and is currently under investigation at CLEO. Preliminary results [17] indicate a significant branching fraction on the order of 10% for $B \to \overline{D}_{\text{upper vertex}} X$.

The charm yield per B-meson decay is related to an intriguing puzzle in B physics: the experimental value for the semileptonic branching ratio of B mesons is significantly below the theoretical lower bound B > 12.5% from QCD calculations within the parton model [18]. An enhanced hadronic decay rate would resolve this discrepancy and several explanations have been proposed. The theoretically preferred solution calls for an enhancement of the $b \to c\bar{c}s$ channel [19]. Increasing the $b \to c\bar{c}s$ component, however, would increase the average number of c quarks produced per b-quark decay and lead to another interesting problem: the predicted number of charm quarks per b decay would rise to 1.3 while the current experimental value for this number is 1.15 ± 0.05 . Moreover, as noted above, $B(B \to X_{c\bar{c}}) = 15.8 \pm 2.8$ is far below the required 30%. A systematic study of inclusive hadronic B decays to mesons and baryons and more precise measurements of charm meson branching fractions will be required to resolve this problem.

Measurements of exclusive hadronic B decays have reached sufficient precision to challenge our understanding of the dynamics of these decays. The factorization hypothesis has been experimentally confirmed for decays with large energy release. By comparing hadronic B^- and \overline{B}^0 decays, the relative contributions from external and internal spectator decays have been disentangled. For all decay modes studied the B^- branching ratio was found to be larger than the corresponding \overline{B}^0 branching ratio indicating constructive interference between the external and internal spectator amplitudes. This came as a surprise since destructive interference was observed in hadronic charm decay. However, the B^- modes analyzed so far comprise only a small fraction of the total hadronic rate. Further experimental study is required to determine at what level constructive interference is present in the remainder of hadronic B^- decays.

Rare decays

All B meson decays that do not occur through the usual $b \to c$ transition are known as rare B decays. The simplest diagram for a rare B decay is obtained by replacing the $b \to c$ transition by a CKM suppressed $b \to u$ transition. These decays probe the small CKM matrix element V_{ub} , the magnitude of which sets bounds on the combination $\rho^2 + \eta^2$ in the Wolfenstein parameterization of the CKM matrix. So far the only measurement of the magnitude of V_{ub} has been obtained from measurements of inclusive semileptonic B decays [20]. Last year CLEO reported the observation of exclusive semileptonic transitions. Using their large data sample and employing the excellent hermiticity of the CLEO II detector they were able to measure (using the BSW model) $B(B^0 \to \pi^- \ell^+ \nu_\ell) = (1.63 \pm 0.46 \pm 0.34) \times 10^{-4}$ and $B(B^0 \to \rho^- \ell^+ \nu_\ell) = (3.88 \pm 0.54 \pm 0.34) \times 10^{-4}$ [21].

While the errors are still large these results are an important step towards establishing a reliable value of $|V_{uh}|$.

Exclusive hadronic $b \to u$ transitions still await experimental discovery. CLEO sees a significant signal in the combined $B^0 \to \pi^+\pi^-$, $K^+\pi^-$ channels but detector resolution and statistics are not sufficient to separate the two modes.

The observation of the decay $B \to K^*(892)\gamma$, reported in 1993 by the CLEO II experiment, provided first evidence for the 1-loop penguin diagram [22]. The observed branching fractions were used to constrain a large class of Standard Model extensions [23]. However, due to the uncertainties in the hadronization, only the inclusive $b \to s\gamma$ rate can be reliably compared with theoretical calculations. This rate can be measured from the endpoint of the inclusive photon spectrum in B decay. CLEO found $B(b \to s\gamma) = (2.32 \pm 0.54 \pm 0.35) \times 10^{-4}$.

A larger total rate is expected for gluonic penguins, the counterpart of $b \to s \gamma$ with the photon replaced by a gluon. However, it is a major experimental challenge to measure the inclusive $b \to s g$ rate, where the virtual gluon hadronizes as a $q \bar{q}$ pair. Since the coupling of gluons to quark-antiquark pairs is flavor independent, it is expected that except for modifications due to phase space $b \to s \bar{s} s$ will be comparable to $b \to s \bar{u} u$, $b \to s \bar{d} d$. A recent CLEO search revealed no signal for exclusive $b \to s \bar{s} s$ decays such as $\bar{B} \to \phi K^{(*)}$ nor did they find an excess in the endpoint of the ϕ momentum spectrum for inclusive $B \to \phi$ transitions.

Outlook

With the end of the Fermilab collider run and the change of the LEP beam energies CLEO and SLD will be the only collider experiments in the next few years to collect data. While this might slow down the current rate of rapid progress in our understanding of heavy flavor physics there are still many answers hidden in the large data samples collected by CDF and the LEP collaborations. This combined with the ever-growing CLEO data sample will provide many new insights into all aspects of B physics.

The one exception is a measurement of the complex phase in CKM matrix. Data samples at least one order of magnitude

larger than those available at present are needed to observe CP asymmetries in the B-meson system and to perform one of the most fundamental consistency check of the Standard Model. This is the justification for the construction of high luminosity e^+e^- storage rings (PEP II/BaBar, CESR III/CLEO III, TRISTAN II/BELLE) as well as a dedicated fixed target experiment at the HERA ring at DESY. Hadron collider experiments dedicated to the study of CP violation have also been proposed at Fermilab and at CERN.

Notes and References

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SEMILEPTONIC DECAYS OF B MESONS

(by J.D. Richman, University of California, Santa Barbara)

In this section, we discuss some of the key questions related to semileptonic decays of B mesons: the inclusive semileptonic branching fraction, the determination of $|V_{cb}|$ and $|V_{ub}|$ from inclusive and exclusive measurements, recent progress in exclusive semileptonic decays, and form factor measurements and tests of heavy-quark effective theory. We emphasize the uncertainties that arise in extracting $|V_{cb}|$ and $|V_{ub}|$ from data. Further discussions of these and related issues are given in the references [1,2,3]. Before addressing the experimental progress, we review the formalism of form factors for both D and B exclusive semileptonic decays. Measurements of form factors in semileptonic D decays are included in the D meson Particle Listings.

Form-factor formalism for exclusive semileptonic decays

The amplitude for an exclusive semileptonic process can be constructed from the available four-vectors in the decay and from form factors, which are Lorentz invariant functions of q^2 , the square of the mass of the virtual W. Because these functions describe the effect of strong interactions, nonperturbative techniques such as lattice QCD are needed to calculate them. Form factors are generally largest at the maximum value of q^2 , where the daughter meson has the smallest recoil velocity and the overlap between the parent- and daughter-meson wave functions is largest. Studies of form factors in D semileptonic decays have focused on the modes $D \to \overline{K}\ell^+\nu_{\ell}$ and $D \to \overline{K}^*\ell^+\nu_{\ell}$, which dominate the inclusive semileptonic rate. In B decays, the analogous modes, $B \to \overline{D}\ell^+\nu_{\ell}$ and $B \to \overline{D}^*\ell^+\nu_{\ell}$, account for about two-thirds of the inclusive semileptonic rate. The decay $B \to \overline{D}\ell^+\nu_{\ell}$ has a large background from $B \to \overline{D}^* \ell^+ \nu_{\ell}$, so in B decays, form factor measurements have focused mainly on $B \to \overline{D}^* \ell^+ \nu_{\ell}$. In this section, we discuss the formalism used in form-factor measurements for the decays $P \to P'\ell\nu_{\ell}$, where P and P' are pseudoscalar mesons, and $P \to V \ell \nu_{\ell}$, where V is a vector meson.

The differential decay rate for $P(Q\overline{q}) \to P'(q'\overline{q}) \ell \nu_{\ell}$ is

$$\frac{d\Gamma}{da^2} = \frac{G_F^2 |V_{q'Q}|^2 k_{P'}^3 |f_+(q^2)|^2}{24\pi^3} \ . \tag{1}$$

Here G_F is the Fermi decay constant, $V_{q'Q}$ is the relevant CKM matrix element, $k_{P'}$ is the momentum of P' in the rest frame of the parent meson, and $f_+(q^2)$ is a vector form factor. (Eq. (1) assumes massless charged leptons, which is almost exact for electrons and a very good approximation for muons, but it is not correct for τ 's.) The dominant q^2 dependence comes from the p-wave factor $k_{P'}^3$, which can be written in terms of q^2 and the particle masses. This factor increases the rate at low q^2 , which is opposite to the q^2 dependence of the form factor f_+ .

The exclusive decay rate for $P \to V \ell \nu_{\ell}$ can be expressed in terms of three q^2 -dependent helicity amplitudes, $H_{\pm}(q^2)$ and $H_0(q^2)$, where the subscripts indicate the helicity of either the virtual W or the vector meson. The rate is given by

$$\begin{split} \frac{d\Gamma}{dq^2\,d\cos\theta_\ell\,d\cos_V\,d\chi} &= \frac{3G_F^2|V_{q'Q}|^2\,k_V\,q^2}{8(4\pi)^4M^2} \\ \left\{ [(1+\eta\cos\theta_\ell)^2|H_+(q^2)|^2 + (1-\eta\cos\theta_\ell)^2|H_-(q^2)|^2]\sin^2\theta_V \right. \\ &+ 4\sin^2\theta_\ell\cos^2\theta_V|H_0(q^2)|^2 \\ &- 2\sin^2\theta_\ell\sin^2\theta_V\cos(2\chi)H_+(q^2)H_-(q^2) \\ &- 4\eta\sin\theta_\ell(1+\eta\cos\theta_\ell)\sin\theta_V\cos\theta_V\cos\chi\,H_+(q^2)H_0(q^2) \\ &+ 4\eta\sin\theta_\ell(1-\eta\cos\theta_\ell)\sin\theta_V\cos\theta_V\cos\chi\,H_-(q^2)H_0(q^2) \right\} \,. \end{split}$$

Here M is the mass of the parent meson, k_V is the momentum of the vector meson and is a function of q^2 , and the factor $\eta{=}{+}1$ ($\eta=-1$) applies to B (D) decays. The angles θ_ℓ , θ_V , and χ are defined in Fig. 1. The helicity amplitudes H_\pm and H_0 can be expressed in terms of two axial-vector form factors, $A_1(q^2)$ and $A_2(q^2)$, and a vector form factor $V(q^2)$:

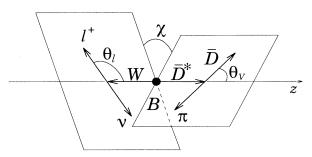


Figure 1: Definition of the angles θ_ℓ , θ_V , and χ . The decay $B \to \overline{D}^*\ell^+\nu_\ell$ is used as an example. The polar angles θ_ℓ and θ_V are defined in the rest frames of the virtual W and the \overline{D}^* , respectively, and χ is the azimuthal angle between the projections of the lepton and the \overline{D} momentum vectors in the plane perpendicular to z.

$$H_{\pm}(q^2) = (M+m)A_1(q^2) \mp \frac{2M \, k_V}{(M+m)} V(q^2)$$

$$H_0(q^2) = \frac{1}{2m\sqrt{q^2}} \Big[(M^2 - m^2 - q^2)(M+m)A_1(q^2) - \frac{4M^2 \, k_V^2}{(M+m)} A_2(q^2) \Big] , \qquad (3)$$

where m is the mass of the daughter meson. The form factors f_+ , A_1 , A_2 , and V are dimensionless.

The V-A coupling results in a larger amplitude to produce a negative-helicity vector meson in $c\overline{q}$ or $b\overline{q}$ decay than one of positive helicity: $|H_{-}| > |H_{+}|$. This difference produces a forward-backward asymmetry for the charged lepton in the virtual-W rest frame, since the net angular momentum along the decay axis of the initial heavy meson must be zero. For $D(c\overline{q})$ decays, a positively charged (right-handed) lepton is produced in association with a left-handed daughter s or dquark, resulting in a softer energy spectrum for the charged lepton than for the neutrino after boosting the lepton energy into the D rest frame. (A similar argument shows that the shape of the spectrum is the same for a \overline{D} decay.) For $\overline{B}(b\overline{q})$ decays, a negatively charged (left-handed) lepton is produced in association with a left-handed daughter quark, giving a harder energy spectrum for the charged lepton than for the neutrino in the B rest frame. In $P \to P'\ell\nu_{\ell}$ decays, there is no asymmetry, since the P' meson can only have helicity zero. Thus, the effect of V-A is to soften the inclusive lepton spectrum in D decays and to harden it in B decays. It is useful to define rates for decays into specific helicity states:

$$\Gamma_i = \frac{G_F^2 |V_{q'Q}|^2}{96\pi^3} \int dq^2 \ k_V \frac{q^2}{M^2} |H_i(q^2)|^2 \ . \tag{4}$$

Experiments extract various ratios of these rates, including Γ_+/Γ_- , $\Gamma_L/\Gamma_T = \Gamma_0/(\Gamma_- + \Gamma_+)$, the lepton forward-backward asymmetry $A_{FB} = (3\eta/4)(\Gamma_- - \Gamma_+)/\Gamma$, and the polarization parameter $\alpha = 2\Gamma_0/(\Gamma_+ + \Gamma_-) - 1$. Because the form factor A_1 appears in all three helicity amplitudes, the ratios of form factors V/A_1 and A_2/A_1 , can be obtained by fitting the measured shape of the distribution of variables q^2 , θ_ℓ , θ_V , and χ . The actual values of the form factors can be extracted from these form-factor ratios and the measured total decay rate.

The inclusive semileptonic branching fraction

The b-hadron inclusive semileptonic branching fraction, \mathcal{B}_{SL} , has been measured both at the $\Upsilon(4S)$, where the b hadrons are a mixture of B^+ and B^0 mesons, and at the Z, where B_s mesons and b baryons are produced as well. Here \mathcal{B}_{SL} is the branching fraction to either electrons or muons, not their sum. Semileptonic decays to τ leptons are suppressed by phase space and have been observed, within large errors, at the expected level [4,5]. Measurements of \mathcal{B}_{SL} are given in Table 1 for single-lepton measurements at the $\Upsilon(4S)$, in Table 2 for the LEP experiments, and in Table 3 for dilepton measurements at the $\Upsilon(4S)$.

Table 2: Measurements from LEP experiments of the inclusive b-hadron semileptonic branching fraction, $\mathrm{B}(X_{\overline{b}} \to X \ell^+ \nu_\ell)$, where X_b is a hadron containing a b-quark. At the Z, the population of b hadrons includes not only B^0 and B^+ mesons, but also a small fraction of B_s mesons and b baryons. The three errors are statistical, systematic, and the uncertainty due to model dependence.

Expt.	Ref.	$\mathrm{B}(X_{\overline{b}} \to X \ell^+ \nu_{\ell})\%$
ALEPH	[11]	$11.39 \pm 0.33 \pm 0.33 \pm 0.26$
DELPHI	[12]	$11.06 \pm 0.39 \pm 0.12 \pm 0.19$
L3 (prelim.)	[13]	$11.73 \pm 0.48 \pm 0.28 \pm 0.31$
OPAL	[14]	$10.5 \pm 0.6 \pm 0.4 \pm 0.3$
LEP Avg.		11.2 ± 0.4

Table 3: Measurements from CLEO and ARGUS experiments of the inclusive *B*-meson semileptonic branching fraction, using the dilepton method, which reduces the model dependence of the result.

Expt.	Ref.	$\mathcal{B}(B \to X \ell^+ \nu_{\ell})\%$
ARGUS CLEO II	[15] [16]	$9.6 \pm 0.5 \pm 0.4$ $10.49 \pm 0.17 \pm 0.43$
Average		10.19 ± 0.37

Table 1: Measurements of the inclusive semileptonic branching fraction (%), $\mathcal{B}_{SL} = \mathrm{B}(B \to X \ell^+ \nu_\ell)$, averaged over the B mesons produced at the $\Upsilon(4S)$ (B^+ and B^0). These results are based on analyses of the inclusive single-lepton spectrum. Results are given separately for each of the models used to extract \mathcal{B}_{SL} . In the ARGUS measurement, the first error combines both statistical and systematic uncertainties; the second error in the ARGUS ACCMM value is due to the extra free parameters present in this model. The fit of the CLEO data using the unmodified ISGW model is poor, so the results from that fit are less reliable. The table also gives the CLEO inclusive branching fraction to charm final states ($X_{\overline{c}}$) only, which is extracted from the same fit. (Sources of error in these measurements are discussed in the text.)

Expt. (1ℓ method)	ACCMM	ISGW	ISGW**		
ARGUS [6]	$10.2 \pm 0.5 \pm 0.2$	9.8 ± 0.5			
CRYSTAL BALL [7]	$12.0 \pm 0.5 \pm 0.7$	$11.9 \pm 0.4 \pm 0.7$			
CUSB-II [8]	$10.0 \pm 0.4 \pm 0.3$	$10.0 \pm 0.4 \pm 0.3$			
CLEO-I [9]	$10.5 \pm 0.2 \pm 0.4$	$9.9 \pm 0.1 \pm 0.4$	$11.2 \pm 0.3 \pm 0.4$		
CLEO-II (prelim.) [10]	$10.65 \pm 0.05 \pm 0.33$	$10.42 \pm 0.05 \pm 0.33$	$10.98 \pm 0.10 \pm 0.33$		
Average	10.51 ± 0.21	10.22 ± 0.20	11.05 ± 0.28		
CLEO-II (prelim.) [10] $B \to X_{\overline{c}} \ell^+ \nu_{\ell}$	$10.48 \pm 0.07 \pm 0.33$	$10.41 \pm 0.07 \pm 0.33$	$10.87 \pm 0.10 \pm 0.33$		

Meson Particle Listings Semileptonic Decays of B's

The challenge for inclusive measurements is to determine what part of the observed lepton momentum spectrum is due to leptons from b-hadron decay (primary leptons) and what part is due to leptons from charm decay (secondary leptons) or to other sources (misidentified hadrons, photon conversions, $J/\psi(1S)$ decays, etc.). The standard technique is to fit the observed lepton momentum spectrum to a sum of the shapes expected for primary and secondary decays, after subtracting out backgrounds from other sources. Thus, a large part of the effort (and uncertainty) in the analysis is in the determination of these shapes.

Experiments at the $\Upsilon(4S)$ (ARGUS and CLEO) use theoretical models to describe the primary lepton spectrum. Some of these models have free parameters that are determined from the fit. The ACCMM model [17], for example, is based on an inclusive calculation of b-quark decay, and it has parameters corresponding to the c-quark mass and the Fermi momentum of the spectator quark, among others. A commonly used exclusive model is ISGW [18], in which the dominant contributions to the primary spectrum are from $B \to \overline{D}\ell^+\nu_{\ell}$ and $B \to \overline{D}^*\ell^+\nu_{\ell}$, with some $B \to \overline{D}^{**}\ell^+\nu_{\ell}$. Here, D^{**} refers to a mixture of p-wave and radially excited charm mesons. CLEO finds [9,10] that the amount of $B \to \overline{D}^{**} \ell^+ \nu_{\ell}$ in this model is too low to adequately describe the lepton momentum spectrum, so a modified version of the ISGW model, ISGW**, has been created. In ISGW**, the D^{**} fraction is allowed to vary, but the D^* -to-D ratio is fixed at the value (2.3) predicted by ISGW. The fit to the CLEO data using ISGW** is significantly better than that using ISGW.

The shape used to describe the secondary lepton spectrum in these fits, although somewhat more complicated to obtain, is based on data. The DELCO charm-decay lepton spectrum [19] is fit to a theoretical model (ACCMM) and then boosted according to the inclusive D-meson momentum spectrum measured at the $\Upsilon(4S)$. Future measurements should be able to use a charm lepton spectrum obtained by summing the spectra for the known exclusive charm semileptonic modes, which account for most of the inclusive rate.

LEP experiments (ALEPH, DELPHI, L3, and OPAL) measure \mathcal{B}_{SL} by fitting the spectra of p and p_T (the momentum transverse to the jet axis) in single lepton and dilepton events. The shape of the primary spectrum is taken from CLEO or ARGUS, so that model-related uncertainties in these experiments are propagated into the LEP results.

The extraction of the B semileptonic branching fraction from the momentum spectrum of single leptons, therefore, relies on models. In CLEO, which currently has the largest data sample, the spread of values obtained using different models is comparable to the experimental errors. The dominant experimental errors are due to tracking and lepton identification uncertainties.

The ARGUS collaboration [15] has introduced a second method, using dilepton events, that substantially reduces the need for models. One lepton (the "tagging lepton") is required to have high momentum and is thus nearly always primary.

The analysis then examines the momentum spectrum of the second lepton in the event. By requiring that both leptons be in the same hemisphere, events in which the two leptons come from the decay chain of a single B meson (produced nearly at rest at the $\Upsilon(4S)$) are effectively removed. Thus, (1) the tagging lepton is primary, and (2) the leptons are from different B mesons. Then, unless mixing occurs, a lepton whose charge is opposite to that of the tagging lepton must be primary, while one with the same charge as the tagging lepton must be secondary. One corrects for mixing by using the known mixing probability. The relative charges of the two leptons, therefore, can be used to separate the primary and secondary spectra of the second lepton. There is a lower momentum cutoff due to experimental acceptance, however, and a small extrapolation, based on models, is required to obtain the total semileptonic rate. The ARGUS and CLEO measurements based on this technique are listed in Table 3. This method also very much reduces the sensitivity to any possible non- $B\overline{B}$ decays of the $\Upsilon(4S)$, which are assumed to be negligible in the single-lepton method.

The values of \mathcal{B}_{SL} given in Table 1, Table 2, Table 3 are lower than most of the theoretical predictions, which give [20] $\mathcal{B}_{SL} \geq 12.5\%$. Such calculations, however, are difficult partly because they must determine the total hadronic rate, which has uncertainties associated with both perturbative and nonperturbative QCD effects. In particular, enhancements to the $b \to c\bar{c}s$ rate have been discussed as a possible explanation for the low value of \mathcal{B}_{SL} . For example, a recent analysis by Bagan, et al. [21] predicts values of \mathcal{B}_{SL} in the range 11% to 12% (with large uncertainties), as well as a somewhat larger average number, n_c , of charm quarks per decay than is found by experiment [1]. The problem of \mathcal{B}_{SL} is perhaps best rephrased as the joint problem of understanding \mathcal{B}_{SL} and n_c .

The semileptonic branching fraction can be used to calculate $|V_{cb}|$ using $\mathcal{B}_{SL} = \gamma_{\text{thy}} |V_{cb}|^2 \tau_B$, where γ_{thy} is a constant predicted by theory and τ_B is the appropriate B-hadron lifetime. Whereas the model dependence in the determination of \mathcal{B}_{SL} is associated with the predicted shapes of momentum spectra, the extraction of $|V_{cb}|$ is also sensitive to the uncertainty in $\gamma_{\rm thy}$. It is difficult to assign errors to rate predictions based on quarkmodel calculations. Quite often, a nominal theoretical error of 20% in the rate is assumed, leading to a 10% theoretical error on $|V_{cb}|$. For example, the value of $|V_{cb}|$ using the ACCMM model and the average of all experiments performing a single-lepton analysis at the $\Upsilon(4S)$ is $|V_{cb}| = 0.041 \pm 0.001 \text{ (expt)} \pm 0.004 \text{ (thy)}$ (assuming the value $\tau_B = 1.55 \pm 0.06$ ps used in Sec. 11, "The Cabibbo-Kobayashi-Maskawa Mixing Matrix"). However, some of the calculations based on heavy-quark expansions suggest that this theoretical uncertainty may be overestimated by a factor of two. HQET-based calculations have been presented by Shifman et al. [22], Luke and Savage [23], and Ball et al. [24]; this subject is controversial and is reviewed by Richman and Burchat [1], who assign a theoretical uncertainty of ± 0.003 .

The lepton endpoint region and determination of $|V_{ub}|$

The determination of $|V_{ub}|$ is one of the most important and challenging measurements in B physics. For $|V_{ub}/V_{cb}| \approx 0.1$, the rate for $B \to X_{\overline{u}}\ell^+\nu_\ell$, where $X_{\overline{u}}$ is a charmless hadronic system, is expected to be only about 1% of the inclusive semileptonic rate. By working in the region at and beyond the lepton-momentum-spectrum endpoint for $B \to X_{\overline{c}}\ell^+\nu_\ell$ processes, however, one gains enormously in sensitivity to $B \to X_{\overline{u}}\ell^+\nu_\ell$ decays.

Although the advantages of working in this endpoint region $(2.3 < p_{\ell} < 2.6 \text{ GeV/}c)$ are decisive, there are also disadvantages. A major difficulty is the need to convert the measured rate for this tiny portion of phase space into a value of $|V_{ub}|$. This calculation can be performed using either inclusive or exclusive models, but both have substantial uncertainties in predicting the rate in the endpoint region. Inclusive models are expected to be fairly reliable, if one considers a large enough part of phase space, but they may not be reliable in the endpoint region, which some theorists argue [18] is dominated by a small set of exclusive channels $(B \to \rho \ell^+ \nu_\ell, B^+ \to \omega \ell^+ \nu_\ell,$ and $B \to \pi \ell^+ \nu_{\ell}$). Alternatively, exclusive models can be used to predict the sum of contributions of individual modes in this region. However, large uncertainties exist in the calculations of the rates for exclusive modes, and some of the observed rate may be due to nonresonant final states [25]. The exclusive calculations here are more difficult than those for $B \to X_{\overline{c}} \ell^+ \nu_{\ell}$: because the u-quark mass is small, the kinematic configuration in which the final-state hadron has zero recoil velocity does not provide a reliable place to normalize the form factors, as it does in $b \to c$ decays. Furthermore, the range of recoil velocities available to the light final-state mesons in a $B \to X_{\overline{u}} \ell^+ \nu_{\ell}$ transition is much larger than for the charm mesons in a $B \to X_{\overline{c}} \ell^+ \nu_{\ell}$ decay. One therefore expects a much larger variation in the form factors. As a result, measurements of $|V_{ub}|$ are currently quite model dependent, and there is substantial variation among values obtained using different models.

The analysis of the endpoint region, although an "inclusive" measurement, is quite different from the measurement of \mathcal{B}_{SL} described in the previous section: at the $\Upsilon(4S)$, nonresonant (continuum) processes produce high-momentum leptons that constitute an enormous background (relative to a $B \to X_{\overline{u}} \ell^+ \nu_\ell$ signal) unless suppressed by kinematic cuts. The signal efficiency of these cuts is model dependent, unlike the very loose cuts used in the analysis of the inclusive lepton spectrum. In particular, the efficiency depends on the q^2 distribution of the signal events, so the value obtained for the rate in the endpoint region depends on the shape assumed for this distribution. The most important sensitivity to models, however, arises when one converts the rate to $|V_{ub}|$.

Table 4 lists the measurements of $|V_{ub}/V_{cb}|$ from CLEO and ARGUS. The CLEO-II studies, which are based on about five times as much data as either the original ARGUS or the CLEO-I analyses, yield values of $|V_{ub}/V_{cb}|$ significantly lower than the earlier measurements.

Table 4: Measurements of $|V_{ub}/V_{cb}|$ using the inclusive rate in the endpoint region. The ARGUS and CLEO-I results are each based on about 200,000 $b\bar{b}$ events, and the CLEO-II results are based on about 955,000 $b\bar{b}$ events.

Model	ARGUS	CLEO-I	CLEO-II
	[26]	[27]	[28]
ACCMM ISGW			0.076 ± 0.008 0.101 ± 0.010

Progress on exclusive semileptonic decays

In the past year, substantial progress has been made in understanding the exclusive semileptonic decays of B mesons. In particular, the observation of $B \to \pi \ell^+ \nu_\ell$ and $B \to \rho \ell^+ \nu_\ell$ by CLEO represents a milestone for these studies. In this section, we give an overview of the exclusive modes, focusing primarily on recent progress.

Measurements of exclusive semileptonic decays of B mesons are less precise and less complete than those for D mesons. Unlike D decays, where $D \to K\ell^+\nu_{\ell}$ and $D \to K^*\ell^+\nu_{\ell}$ come close to saturating the Cabibbo-favored rate, the analogous modes $B \to \overline{D}\ell^+\nu_{\ell}$ and $B \to \overline{D}^*\ell^+\nu_{\ell}$ account for only 60% to 70% of the rate for $b \rightarrow c\ell\nu_{\ell}$. The only well-measured semileptonic decay is $B \to \overline{D}^* \ell^+ \nu_{\ell}$, which has the largest branching fraction of all B decays, accounting for about 45% of the semileptonic rate. Recently, there has been some progress in improving the measurement for $B \to \overline{D}\ell^+\nu_{\ell}$ [29], which has a large background due to feed down from $B \to \overline{D}^* \ell^+ \nu_{\ell}$. Another contrast with D semileptonic decays is that the ratio of $B \to \overline{D}^* \ell^+ \nu_{\ell}$ to $B \to \overline{D} \ell^+ \nu_{\ell}$ is about 2.3, whereas in D decays the analogous vector-to-pseudoscalar ratio is about 0.6. LEP experiments [30,31] have made significant progress in observing the decays $B \to \overline{D}_1 \ell^+ \nu_{\ell}$ and $B \to \overline{D}_2^* \ell^+ \nu_{\ell}$, where the use of high-precision vertex detectors has proved to be a powerful technique for reducing combinatorial background.

The most significant recent development has been the observation [32] of exclusive charmless semileptonic decays, which should eventually lead to better determinations of $|V_{ub}|$. For these decays, unlike $B \to X_{\overline{c}} \ell^+ \nu_{\ell}$, model predictions [18] indicate that the rate should be distributed over many exclusive channels, with no dominant modes. The decays with the largest expected branching fractions are $B^0 \to \rho^- \ell^+ \nu_\ell$, $B^+ \to \rho^0 \ell^+ \nu_\ell$, and $B^+ \to \omega \ell^+ \nu_{\ell}$, which in the quark model are predicted to occur in the ratio 2:1:1. The branching fractions for $B^0 \to \pi^- \ell^+ \nu_{\ell}$ and $B^+ \to \pi^0 \ell^+ \nu_\ell$ are expected to be roughly one-third to onehalf of those for the corresponding decays to ρ mesons. For reasons that are largely independent of models, the lepton spectra for the decays to vector mesons are expected to be harder than those for the decays to pseudoscalars. CLEO has now obtained preliminary branching fractions for $B \to \pi \ell^+ \nu_{\ell}$ and $B \to \rho \ell^+ \nu_{\ell}$, which are listed in Table 5. These branching fractions are consistent with predictions based on models, assuming the value of $|V_{ub}|$ obtained from the analysis of the lepton spectrum endpoint.

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Table 5: Preliminary CLEO II branching fractions for exclusive B semileptonic decays to final states without charm. These results assume efficiencies obtained from the ISGW model [18]; if the WSB model [33] is used, the branching fractions are somewhat higher. The first error is statistical and the second systematic. The third error on the $B^0 \to \rho^- \ell^+ \nu_\ell$ branching fraction is due to a possible non-resonant $\pi\pi$ contribution.

Mode	Ref.	Branching fraction
$B^0 \to \rho^- \ell^+ \nu_\ell$ $B^0 \to \pi^- \ell^+ \nu_\ell$	[32] [32]	$(2.28 \pm 0.36 \pm 0.59^{+0.00}_{-0.46}) \times 10^{-4}$ $(1.34 \pm 0.35 \pm 0.28) \times 10^{-4}$

Measurement of $|V_{cb}|$ from $B \to \overline{D}^* \ell^+ \nu_{\ell}$

Three types of measurements can be used to determine $|V_{cb}|$: (1) the inclusive semileptonic rate (discussed above), (2) the rates for $B \to \overline{D}\ell^+\nu_\ell$ or $B \to \overline{D}^*\ell^+\nu_\ell$, and (3) the partial rate for $B \to \overline{D}^*\ell^+\nu_\ell$ for the region of phase space in which the D^* recoils slowly. The $B \to \overline{D}^*\ell^+\nu_\ell$ mode is especially well suited to measuring $|V_{cb}|$. With HQET, the rate for this process can be accurately predicted (as a function of $|V_{cb}|^2$) for the kinematic configuration in which the D^* is produced at rest (with the lepton and neutrino back to back in the B rest frame). This configuration occurs when $q^2 = q^2_{\rm max} = (m_B - m_{D^*})^2$. The light constituents of the initial B meson are then essentially undisturbed by the $B \to X_{\overline{c}}\ell^+\nu_\ell$ transition, at least in the limit where the b and c quark masses are taken to be very large compared with $\Lambda_{\rm QCD}$.

In this heavy-quark symmetry (HQS) limit, all of the $B \to \overline{D}^*\ell^+\nu_\ell$ form factors are related to a single form factor, the Isgur-Wise function, which depends only on the relative four-velocities of the initial and final hadrons: $\xi = \xi(v_B \cdot v_{D^*})$. Note that $v_B \cdot v_{D^*} = \gamma_{D^*}$, where the relativistic factor γ_{D^*} is measured in the B-meson rest frame. The quantity $v \cdot v'$, where v is the initial and v' is the final meson four-velocity, is often called w or y in the literature. It is linearly related to q^2 by

$$w = v \cdot v' = \frac{M^2 + m^2 - q^2}{2Mm} \,, \tag{5}$$

where M and m are the masses of the parent and daughter mesons.

At zero recoil $(w=1 \text{ or } q^2=q_{\max}^2)$, the normalization of ξ is known in the HQS limit, $\xi(1)=1$, which means that the decay rate in this configuration can be accurately predicted as a function of $|V_{cb}|^2$. Corrections to this picture arise from hard-gluon corrections and because the masses of the b and c quarks are not truly infinite. However, the HQS-limit prediction for $B\to \overline{D}^*\ell^+\nu_\ell$ is partly protected by Luke's theorem [34], which states that at zero recoil there are no leading order $(1/m_Q)$ nonperturbative corrections at w=1, where m_Q is the mass of a heavy quark (c or b). As a consequence, the leading nonperturbative corrections to the zero-recoil decayrate prediction arise at order $1/m_Q^2$. The calculation of these corrections, which introduces some model dependence, has been

the subject of many investigations. The results are generally expressed in terms of a function $\mathcal{F}(w)$ that can be derived from the form factors and which determines the differential rate through [35]

$$\frac{1}{\tau_B} \cdot \frac{dB(B^0 \to D^{*-}\ell^+\nu_\ell)}{dw} = \frac{G_F^2}{48\pi^3} m_{D^*}^3 (m_B - m_{D^*})^2
\times \sqrt{w^2 - 1} (w+1)^2 \left[1 + \frac{4w}{w+1} \frac{1 - 2wr + r^2}{(1-r)^2} \right]
\times |V_{cb}|^2 \mathcal{F}(w)^2,$$
(6)

where $r=m_{D^*}/m_B$. The rate at zero recoil is determined by $\mathcal{F}(1)$, which is predicted to be in the range 0.89 to 0.96 [36,37,22]. These predictions can be used to determine $|V_{cb}|$ from the measured rate at zero recoil. Strictly speaking, there is no phase space for this configuration, so in practice one has to measure the rate in a small region near w=1.

Current experiments have difficulty in measuring the rate in this region due to limited statistics. The rate at zero recoil is therefore obtained by measuring the rate as a function of w and then extrapolating to w=1. This procedure introduces some model dependence because HQET does not predict the w dependence of the form factors, which involves nonperturbative QCD physics. (Several groups are using lattice QCD and QCD sum rules to predict the w dependence and are beginning to obtain interesting results [38,3].) Because the w range is small, however, the form factors are expected to have only modest variation, which is approximately linear. CLEO, ARGUS, ALEPH, and DELPHI use a variety of functional forms to parametrize the w dependence. The different extrapolations to w=1 lead to a range of values for $|V_{cb}|$. This method leads to $|V_{cb}|=0.041\pm0.003\pm0.002$, as discussed in Sec. 11, "The Cabibbo-Kobayashi-Maskawi Mixing Matrix." Thus, the inclusive and zero-recoil methods agree well. It should be noted that $|V_{cb}|$ can also be obtained from the total rates for $B \to \overline{D}\ell^+\nu_{\ell}$ and $B \to \overline{D}^* \ell^+ \nu_{\ell}$. These values tend to be somewhat lower [1]. However, the theoretical predictions for the full decay rate are expected to be less reliable than those for the zero-recoil configuration of $B \to \overline{D}^* \ell^+ \nu_{\ell}$, since the form factors must be known over the full q^2 range.

Form factor measurements

Both CLEO and ARGUS have used measurements of kinematic distributions to obtain information on the form factors for $B \to \overline{D}^* \ell^+ \nu_\ell$. In contrast to D-meson semileptonic decays, however, one expects the predictions of heavy quark effective theory to be applicable to $B \to X_{\overline{c}} \ell^+ \nu_\ell$. Here, both the initial-and final-state quarks are heavy compared with the typical hadronic scale set by $\Lambda_{\rm QCD}$.

The differential decay rate for $\overline{B}^0 \to D^{*+}\ell^+\nu_\ell$, $D^{*+} \to D^0\pi^+$ can be expressed in terms of three form factors $A_1(q^2)$, $A_2(q^2)$, and $V(q^2)$, as discussed at the beginning of this article.

In the heavy-quark symmetry limit, the form factors are related to the Isgur-Wise function ξ :

$$V(q^{2}) = A_{2}(q^{2}) = \frac{A_{1}(q^{2})}{\left[1 - \frac{q^{2}}{(m_{B} + m_{D^{*}})^{2}}\right]}$$
$$= \frac{(m_{B} + m_{D^{*}})}{2\sqrt{m_{B}m_{D^{*}}}} \xi(w) . \tag{7}$$

This limit motivates the choice of form factor ratios [3]

$$R_{1} \equiv \left[1 - \frac{q^{2}}{(m_{B} + m_{D^{*}})^{2}}\right] \frac{V(q^{2})}{A_{1}(q^{2})}$$

$$R_{2} \equiv \left[1 - \frac{q^{2}}{(m_{B} + m_{D^{*}})^{2}}\right] \frac{A_{2}(q^{2})}{A_{1}(q^{2})}, \tag{8}$$

which are predicted to be unity, independent of w, in the heavy-quark symmetry limit. For finite heavy-quark masses, R_1 and R_2 are expected to have a mild dependence on w. Note that these quantities differ from the traditional form-factor ratios $(A_2/A_1 \text{ and } V/A_1)$ used to describe charm semileptonic decays, where heavy-quark symmetry is not expected to be a good approximation. To consider departures from the heavy-quark symmetry limit but still express the form factors in a manner that makes this limit transparent, one can use

$$A_{1}(q^{2}) = \frac{m_{B} + m_{D^{*}}}{2\sqrt{m_{B}m_{D^{*}}}} \left[1 - \frac{q^{2}}{(m_{B} + m_{D^{*}})^{2}} \right] h_{A_{1}}(w) ,$$

$$A_{2}(q^{2}) = \frac{m_{B} + m_{D^{*}}}{2\sqrt{m_{B}m_{D^{*}}}} R_{2}(w) h_{A_{1}}(w) ,$$

$$V(q^{2}) = \frac{m_{B} + m_{D^{*}}}{2\sqrt{m_{B}m_{D^{*}}}} R_{1}(w) h_{A_{1}}(w) ,$$
(9)

where $h_{A_1}(w) \to \xi(w)$ in the heavy-quark symmetry limit. Departures from this limit produce two effects: deviations of $R_1(1)$ and $R_2(1)$ from unity and a slight variation of R_1 and R_2 with w.

To measure the form factors, CLEO has performed [39] a four-dimensional fit, including correlations, to the kinematic variables q^2 , $\cos\theta_\ell$, $\cos\theta_V$, and χ . (The angles are defined at the beginning of this article.) In this fit, R_1 and R_2 were assumed to be constant, while h_{A_1} was assumed to have a linear dependence on w, with slope $\rho_{A_1}^2$: $h_{A_1}(w) = h_{A_1}(1)(1-\rho_{A_1}^2(w-1))$. The preliminary fit results are

$$R_1 = 1.18 \pm 0.30 \pm 0.12$$
,
$$R_2 = 0.71 \pm 0.22 \pm 0.07$$
,
$$\rho_{A_1}^2 = 0.91 \pm 0.15 \pm 0.06$$
. (10)

The values of R_1 and R_2 are in good agreement with predictions based on HQET with corrections [3,40]. The results for R_1 and R_2 are rather insensitive both to the form assumed for $h_{A_1}(w)$ and to the mild w dependence of R_1 and R_2 suggested by these theoretical calculations. However, the value of $\rho_{A_1}^2$ is sensitive to the form of h_{A_1} . Functions with curvature, such as exponentials or pole forms, give somewhat larger values of $\rho_{A_1}^2$.

Earlier results obtained by CLEO [41,42] and ARGUS [43] obtained A_{FB} , the lepton forward-backward asymmetry, and A_{pol} , the D^* polarization, each integrated over phase space. These results are consistent with the new result discussed above [1] but have lower precision.

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$$I(J^P) = \frac{1}{2}(0^-)$$

Quantum numbers not measured. Values shown are quark-model

See also the B^\pm/B^0 ADMIXTURE and $B^\pm/B^0/B_s^0/b$ -baryon AD-MIXTURE sections.

B± MASS

The fit uses m_{B^+} , $(m_{B^0}-m_{B^+})$, m_{B^0} , and $(m_{B^0}-(m_{B^+}+m_{B^0})/2)$ to determine m_{B^+} , m_{B^0} , $m_{B^0_2}$, and the mass differences.

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT	
5278.9±1.8 OUR FI	Т				
5278.9±1.5 OUR AV	/ERAGE				
$5279.1 \pm 1.7 \pm 1.4$	147	¹ ABE	96B CDF	$p\overline{p}$ at 1.8 TeV	
$5278.8 \pm 0.54 \pm 2.0$	362	² ALAM		$e^+e^- \rightarrow \Upsilon(4S)$	
$5278.3 \pm 0.4 \pm 2.0$		² BORTOLETT	092 CLEO	$e^+e^- \rightarrow \Upsilon(4S)$	
$5280.5 \pm 1.0 \pm 2.0$		^{2,3} ALBRECHT	90J ARG	$e^+e^- \rightarrow \Upsilon(4S)$	
$5278.6 \pm 0.8 \pm 2.0$		² BEBEK	87 CLEO	$e^+e^- ightarrow \gamma$ (45)	
• • • We do not use	the followin	ng data for average	s, fits, limits	, etc. • • •	
$5275.8 \pm 1.3 \pm 3.0$	32	ALBRECHT	87c ARG	$e^+e^- \rightarrow \Upsilon(4S)$	
$5278.2 \pm 1.8 \pm 3.0$	12	⁴ ALBRECHT	87D ARG	$e^+e^- \rightarrow \Upsilon(4S)$	
1	L 14		- 4 A D E OC		

- ¹ Excluded from fit because it is not independent of ABE 96B B_s^0 mass and B_s^0 -B mass difference. 2 These experiments all report a common systematic error 2.0 MeV. We have artificially
- increased the systematic error to allow the experiments to be treated as independent measurements in our average. See "Treatment of Errors" section of the Introductory Text. These experiments actually measure the difference between half of $E_{\rm CM}$ and the
- 3 ALBRECHT 90J assumes 10580 for $\varUpsilon(4S)$ mass. Supersedes ALBRECHT 87C and
- Found using fully reconstructed decays with $J/\psi(1S)$. ALBRECHT 87D assume $m_{\varUpsilon(4S)}$ = 10577 MeV.

B[±] MEAN LIFE

See $B^{\pm}/B^0/B_s^0/b$ -baryon ADMIXTURE section for data on B-hadron mean life averaged over species of bottom particles.

"OUR EVALUATION" is an average of the data listed below performed by the LEP B Lifetimes Working Group as described in our review "Production and Decay of b-flavored Hadrons" in the B^\pm Section of the Listings. The averaging procedure takes into account correlations between the measurements and asymmetric lifetime errors.

				a asymmetric metime errors.
VALUE (10 ⁻¹² s)	EVTS	DOCUMENT ID	TECN	COMMENT
1.62±0.06 OUR EVA	LUATION			
$1.56 \pm 0.13 \pm 0.06$		⁵ ABE	96c CDF	$p\overline{p}$ at 1.8 TeV
$1.58 \pm 0.09 \pm 0.04$		⁵ BUSKULIC	96G ALEF	$e^+e^- \rightarrow Z$
$1.58 ^{+0.21}_{-0.18} ^{+0.04}_{-0.03}$	94	⁶ BUSKULIC	96G ALEF	$e^+e^- \rightarrow Z$
$1.61 \pm 0.16 \pm 0.12$		^{5,7} ABREU	95Q DLPI	$+ e^+e^- \rightarrow Z$
$1.72 \pm 0.08 \pm 0.06$		⁸ ADAM	95 DLPI	$+ e^+e^- \rightarrow Z$
$1.52 \pm 0.14 \pm 0.09$		⁵ AKERS	95T OPA	$_{-}$ $e^{+}e^{-} \rightarrow Z$
$1.61 \pm 0.16 \pm 0.05$	148	⁶ ABE	94D CDF	pp̄ at 1.8 TeV
• • • We do not use	the follow	ing data for averag	ges, fits, lim	its, etc. • • •
$1.58 \pm 0.09 \pm 0.03$		⁹ BUSKULIC	96G ALEF	$e^+e^- \rightarrow Z$
1.70 ± 0.09		¹⁰ ADAM	95 DLPI	$+ e^+e^- \rightarrow Z$
$1.30^{+0.33}_{-0.29}\pm0.16$	92	⁵ ABREU	930 DLPI	H Sup. by ABREU 95Q
$1.56 \pm 0.19 \pm 0.13$	134	⁸ ABREU	93G DLP	H Sup. by ADAM 95
$1.51 {}^{+ 0.30 + 0.12}_{- 0.28 - 0.14}$	59	⁵ ACTON	93c OPA	Sup. by AKERS 95T
$1.47 ^{+ 0.22 + 0.15}_{- 0.19 - 0.14}$	77	⁵ BUSKULIC	93D ALEF	Sup. by BUSKULIC 96G

⁵ Data analyzed using $D/D^*\ell X$ event vertices.

- 6 Measured mean life using fully reconstructed decays. 7 ABREU 95Q assumes B($B^0 \rightarrow D^{**-}\ell^+\nu_\ell$) = 3.2 \pm 1.7%.
- ⁸ Data analyzed using vertex-charge technique to tag B charge.
- 9 Combined result of $D/D^*\ell X$ analysis and fully reconstructed B analysis. 10 Combined ABREU 950 and ADAM 95 result.

B+ DECAY MODES

 B^- modes are charge conjugates of the modes below. Modes which do not identify the charge state of the B are listed in the B^\pm/B^0 ADMIXTURE

The branching fractions listed below assume 50% $B^0 \, \overline{B}{}^0$ and 50% $B^+ \, B^$ production at the $\Upsilon(4S)$. We have attempted to bring older measurements up to date by rescaling their assumed $\Upsilon(4S)$ production ratio to 50:50 and their assumed $D,D_{\rm S},D^*$, and ψ branching ratios to current values whenever this would affect our averages and best limits significantly.

Indentation is used to indicate a subchannel of a previous reaction. All resonant subchannels have been corrected for resonance branching fractions to the final state so the sum of the subchannel branching fractions can exceed that of the final state.

Scale factor/

Mode	Fraction (Γ_i/Γ)	Confidence level
Semileptonic and	l leptonic modes	
	•	
$\overline{D}^0 \ell^+ \nu_{\ell}$	[a] (1.6 ±0.7) %	
$\overline{D}^*(2007)^0 \ell^+ \nu_{\ell}$	[a] (5.3 ±0.8)%	
$\pi^0 e^+ \nu_e$	< 2.2 ×	10 ⁻³ CL=90%
$\omega \ell^+ \nu_\ell$	[a] < 2.1 ×	10 ⁻⁴ CL=90%
$\omega \mu^+ \nu_\mu$		
$\rho^0 \ell^+ \nu_\ell$	[a] < 2.1 ×	10 ⁻⁴ CL=90%
$e^+ \nu_e$	< 1.5 ×	10 ⁻⁵ CL=90%
$\mu^+ u_{\mu}$	< 2.1 ×	10 ⁻⁵ CL=90%
$ au^+ u_ au$	< 1.8 ×	10 ⁻³ CL=90%
D, D*, or	D _s modes	
$\overline{D}{}^0\pi^+$	(5.3 ±0.5)×	10-3
$\overline{D}{}^0 \rho^+$	(1.34±0.18) %	0
$\overline{D}^{0}\pi^{+}\pi^{+}\pi^{-}$	(1.1 ±0.4) %	, 0
$\overline{D}{}^0\pi^+\pi^+\pi^-$ nonresonant	(5 ±4)×	10-3
	(4.2 \pm 3.0) \times	10-3
$\overline{D}{}^{0}a_{1}(1260)^{+}$	(5 ±4)×	10-3
$D^*(2010)^-\pi^+\pi^+$	(2.1 \pm 0.6) \times	10-3
	< 1.4 ×	10 ⁻³ CL=90%
$D^*(2007)^0\pi^+$		
$D^*(2007)^0 \rho^+$		
$D^*(2007)^0 \pi^+ \pi^+ \pi^-$		
$D^*(2007)^0 a_1(1260)^+$, ,	
$D^*(2010)^-\pi^+\pi^+\pi^0$,	
$D_1^*(2420)^{\circ} \rho^{+}$	< 1.4 ×	10 ⁻³ CL=90%
$D_2^*(2460)^{\circ}\pi^+$	< 1.3 ×	10 ⁻³ CL=90%
	Semileptonic and $\begin{array}{c} \ell^+\nu_\ell \text{ anything }\\ \overline{D^0}\ell^+\nu_\ell \\ \overline{D^*}(2007)^0\ell^+\nu_\ell \\ \pi^0e^+\nu_e \\ \omega\ell^+\nu_\ell \\ \omega\mu^+\nu_\mu \\ \rho^0\ell^+\nu_\ell \\ e^+\nu_e \\ \mu^+\nu_\mu \\ \tau^+\nu_\tau \end{array}$ $D,D^*,\text{or}\overline{\overline{D}^0}\pi^+ \\ \overline{D^0}\rho^+ \\ \overline{D^0}\pi^+\pi^+\pi^- \end{array}$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$

$\overline{}$	_

Γ ₂₈	$\overline{D}_{2}^{*}(2460)^{0} \rho^{+}$	< 4.7 × 10	-3 CL=90%	$\Gamma_{96} = \pi^{+}\pi^{-}\pi^{+}\pi^{0}$		< 4.0	× 10 ⁻³	CL=90%
Γ ₂₉	$\overline{D}^{0}D_{s}^{+}$	(1.7 \pm 0.6) %		$\Gamma_{97}^{90} \rho^+ \rho^0$		< 1.0	× 10 ⁻³	CL=90%
Γ ₃₀	$\overline{D}{}^0 D_s^{*+}$	$(1.2 \pm 1.0)\%$		$\Gamma_{98} = a_1(1260)^+ \pi^0$		< 1.7	× 10 ⁻³	CL=90%
Γ ₃₁	$\overline{D}^*(2007)^0 D_s^+$	(10 ±7) × 10	-3	$a_1(1260)^0 \pi^+$		< 9.0	× 10 ⁻⁴	CL=90%
Γ ₃₂	$\overline{D}^*(2007)^0 D_s^{*+}$	(2.3 ±1.4) %		$\Gamma_{100} \qquad \omega \pi^+$		< 4.0	× 10 ⁻⁴	CL=90%
Γ ₃₃	$D_s^+\pi^0$	< 2.0 × 10	-4 CL=90%	$\Gamma_{101}^{101} \eta \pi^{+}$		< 7.0	× 10 ⁻⁴	CL=90%
Γ ₃₄	$D_{s}^{*+}\pi^{0}$	< 3.3 × 10		$\Gamma_{102} \pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}$ $\Gamma_{103} \rho^{0} a_{1} (1260)^{+}$		< 8.6	$\times 10^{-4} \times 10^{-4}$	CL=90%
Γ ₃₅	$D_s^+ \eta$	< 5 × 10				< 6.2 < 7.2	× 10 · · · × 10 · · ·	CL=90% CL=90%
Γ ₃₆	$D_s^{*+}\eta$	< 8 × 10		$\Gamma_{104} ho^0 a_2 (1320)^+ \ \Gamma_{105} ho^+ \pi^+ \pi^+ \pi^+ \pi^- \pi^- \pi^0$		< 6.3	× 10 × 10 ⁻³	CL=90%
	$D_s^+ \rho^0$	< 4 × 10°		Γ_{106} $a_1(1260)^+$ $a_1(1260)^0$)	< 1.3	%	CL=90%
Γ ₃₇	$D_s \rho$			106 01(1200) 01(1200)			. **	CL-3070
Γ ₃₈	$D_s^{*+} \rho^0$			_	Baryon me			
Γ ₃₉	$D_s^+\omega$			$\Gamma_{107} p \overline{p} \pi^+$		< 1.6	× 10 ⁻⁴	CL=90%
Γ ₄₀	$D_s^{*+}\omega$	< 7 × 10		$\Gamma_{108} p \overline{p} \pi^+ \pi^+ \pi^-$		< 5.2	× 10 ⁻⁴	CL=90%
Γ ₄₁	$D_s^+ a_1 (1260)^0$	< 2.2 × 10		$\Gamma_{109} p\overline{\Lambda}$		< 6	× 10 ⁻⁵	CL=90%
Γ ₄₂	$D_s^{*+} a_1 (1260)^0$	< 1.6 × 10		$\Gamma_{110} \underline{p} \overline{\Lambda} \pi^+ \pi^-$		< 2.0	$\times 10^{-4} \times 10^{-4}$	CL=90%
Γ_{43}	$D_s^+\phi$	< 3.2 × 10		$\Gamma_{111} \overline{\Delta}{}^{0} p$		< 3.8 < 1.5	× 10 · · · × 10 · · · × 10 · · ·	CL=90% CL=90%
Γ ₄₄	$D_{s}^{*+} \phi$	< 4 × 10		$\Gamma_{112} \Delta^{++} \overline{p}$		< 1.5	X 10	CL=90%
Γ_{45}	$D_s^+ \overline{K}^0$	< 1.1 × 10	-3 CL=90%	Lepton Family number (L	F) or Lepton	number (L)	violating mo	des, or
Γ_{46}	$D_s^{*+}\overline{K}^0$	< 1.1 × 10	-3 CL=90%		ak neutral cu	ırrent (<i>B1</i>) n		
Γ_{47}	$D_s^+ \overline{K}^* (892)^0$	< 5 × 10	-4 CL=90%	$\Gamma_{113} \pi^{+} e^{+} e^{-}$	B1	< 3.9	× 10 ⁻³	CL=90%
Γ ₄₈	$D_{s}^{*+} \overline{K}^{*} (892)^{0}$	< 4 × 10	-4 CL=90%	$\Gamma_{114} \pi^{+} \mu^{+} \mu^{-}$	B1	< 9.1	× 10 ⁻³	CL=90%
Γ ₄₉	$D_s^- \pi^+ \dot{K}^+$	< 8 × 10°		$\Gamma_{115} K^{+} e^{+} e^{-}$	B1			
Γ ₅₀	$D_s^{*-}\pi^+K^+$	< 1.2 × 10		$\Gamma_{116} K^{+} \mu^{+} \mu^{-}$	B1	< 1.7	× 10 ⁻⁴	CL=90%
	$D_s^- \pi^+ K^*(892)^+$	< 6 × 10		$\Gamma_{117} K^*(892)^+ e^+ e^-$	B1	< 6.9	× 10 ⁻⁴	CL=90%
Γ ₅₁	$D_s^{*-}\pi^+K^*(892)^+$	< 8 × 10		$\Gamma_{118} K^*(892)^+ \mu^+ \mu^-$	B1	< 1.2	× 10 ⁻³	CL=90%
Γ ₅₂	$D_s = \pi \cdot K (892)$	< 8 × 10	- CL=90%	$\Gamma_{119} \pi^{+} e^{+} \mu^{-}$	LF	< 6.4	× 10 ⁻³	CL=90%
		nium modes	•	$\Gamma_{120} \pi^{+} e^{-} \mu^{+}$	LF	< 6.4	× 10 ⁻³	CL=90%
Γ ₅₃	$J/\psi(1S)K^+$	$(1.01\pm0.14)\times10^{-1}$		$\Gamma_{121} K^+ e^+ \mu^-$	LF LF	< 6.4	× 10 ⁻³	CL=90%
Γ ₅₄	$J/\psi(1S) K^{+} \pi^{+} \pi^{-}$	$(1.4 \pm 0.6) \times 10^{-1}$		Γ_{122}^{-1} $K^{+}e^{-}\mu^{+}$ Γ_{123} $\pi^{-}e^{+}e^{+}$	LF L	< 6.4 < 3.9	$^{\times 10^{-3}}_{\times 10^{-3}}$	CL=90% CL=90%
Γ ₅₅	$J/\psi(1S) K^*(892)^+$	$(1.7 \pm 0.5) \times 10^{-1}$		$\Gamma_{124}^{123} \pi^{-} \mu^{+} \mu^{+}$	L	< 9.1	× 10 -3	CL=90%
Γ ₅₆	$J/\psi(1S)\pi^{-}$	$(4.4 \pm 2.4) \times 10^{-1}$		$\Gamma_{125}^{124} \pi^{-} e^{+} \mu^{+}$	L	< 6.4	× 10 ⁻³	CL=90%
Γ ₅₇	$\psi(25)K^{+}$	(6.9 ±3.1) × 10		$\Gamma_{126}^{125} K^{-}e^{+}e^{+}$	L	< 3.9	× 10 ⁻³	CL=90%
Γ ₅₈	$\psi(2S) K^*(892)^+$	< 3.0 × 10		$\Gamma_{127}^{126} K^{-} \mu^{+} \mu^{+}$	Ĺ	< 9.1	× 10 ⁻³	CL=90%
Γ ₅₉	$\psi(2S) K^*(892)^+ \pi^+ \pi^- \chi_{c1}(1P) K^+$	$(1.9 \pm 1.2) \times 10^{-2}$ $(1.0 \pm 0.4) \times 10^{-2}$		$\Gamma_{128}^{127} K^{-} e^{+} \mu^{+}$	L	< 6.4	× 10 ⁻³	CL=90%
Γ ₆₀	$\chi_{c1}(1P)K^*(892)^+$	< 2.1 × 10°		120				
Γ ₆₁			CL 90 /6	[a] ℓ indicates e or μ mode	e, not sum ov	er modes.		
Γ ₆₂	$\kappa^0\pi^+$	<pre> modes</pre>	-5 CL=90%	R+	BRANCHING	G PATIOS		
Γ ₆₃	$K^+\pi^0$	< 1.4 × 10	-5 CL=90%		DIVALCE	d IIAI IOS		
Γ ₆₄	$K^*(892)^0 \pi^+$	< 4.1 × 10		$\Gamma(\ell^+ u_\ell$ anything $)/\Gamma_{ ext{total}}$				Γ_1/Γ
Γ_{65}	$K^*(892)^+\pi^0$	< 9.9 × 10		VALUE	DOCUMENT I		COMMENT	
Γ_{66}	$K^+\pi^-\pi^+$ (no charm)	< 1.9 × 10		$0.101 \pm 0.018 \pm 0.015$	ATHANAS	94 CLE2	$e^+e^- \rightarrow \gamma$	(45)
Γ ₆₇	$K_1(1400)^0\pi^+$	< 2.6 × 10		$\lceil (\overline{D}{}^0 \ell^+ u_\ell) / \lceil_{total} \rceil$				Γ_2/Γ
Γ ₆₈	$K_{2}^{*}(1430)^{0}\pi^{+}$	< 6.8 × 10		$\ell = e$ or μ , not sum over e :	and μ modes.			12/1
Γ ₆₉	$\kappa^+ \rho^0$	< 1.9 × 10		VALUE	DOCUMENT I		COMMENT	
Γ ₇₀	$K^0 \stackrel{\cdot}{\rho}^+$	< 4.8 × 10		$0.016 \pm 0.006 \pm 0.003$	11 FULTON	91 CLEO	$e^+e^- \rightarrow \gamma$	(45)
Γ ₇₁	$K^*(892)^+\pi^+\pi^-$	< 1.1 × 10		¹¹ FULTON 91 assumes equal pro	oduction of B^{0}	$\overline{B}{}^0$ and B^+B^-	at the $\Upsilon(4S)$	
Γ ₇₂	$K^*(892)^+ \rho^0$	< 9.0 × 10		$\Gamma(\overline{D}^*(2007)^0\ell^+ u_\ell)/\Gamma_{total}$				Γ_3/Γ
Γ ₇₃	$K_1(1400)^{+} \rho^{0} \ K_2^*(1430)^{+} \rho^{0}$	< 7.8 × 10 ⁻¹ < 1.5 × 10 ⁻¹		$\ell = e \text{ or } \mu$, not sum over e :	and μ modes.			13/1
Γ ₇₄	$K_2(1430)^+ \rho^-$ $K^+ K^- K^+$			VALUE EVTS		NT ID TE	CN COMMENT	
Γ ₇₅			-4 CL=90%				Fo + -	20(+0)
				0.053 ±0.008 OUR AVERAGE	12			71/151
Г ₇₆	$K^+\phi$	< 1.2 × 10	⁻⁵ CL=90%	$0.0513 \pm 0.0054 \pm 0.0064$ 302	12 BARISH			
Γ ₇₇	Κ ⁺ φ Κ*(892) ⁺ Κ ⁺ Κ ⁻	< 1.2 × 10 ⁻¹ < 1.6 × 10 ⁻¹	-5 CL=90% -3 CL=90%	$0.0513 \pm 0.0054 \pm 0.0064$ 302 $0.066 \pm 0.016 \pm 0.015$	¹³ ALBREC	CHT 92c AR	$e^+e^- \rightarrow$	
Γ ₇₇ Γ ₇₈	${\overset{{\cal K}^+}{\kappa^*}}(892)^+{\overset{{\cal K}^+}{\kappa^-}}{\overset{{\cal K}^*}{\kappa^*}}(892)^+{\overset{{\cal C}^-}{\phi}}$	$< 1.2 \times 10^{-}$ $< 1.6 \times 10^{-}$ $< 7.0 \times 10^{-}$	-5 CL=90% -3 CL=90% -5 CL=90%	$0.0513 \pm 0.0054 \pm 0.0064$ 302 $0.066 \pm 0.016 \pm 0.015$ • • • We do not use the following	¹³ ALBREC g data for avera	CHT 92C AR	G $e^+e^- \rightarrow$, etc. • • •	Υ(45)
Γ ₇₇ Γ ₇₈ Γ ₇₉	$K^+ \phi$ $K^*(892)^+ K^+ K^ K^*(892)^+ \phi$ $K_1(1400)^+ \phi$	$ \begin{array}{cccc} < & 1.2 & \times & 10^{-} \\ < & 1.6 & \times & 10^{-} \\ < & 7.0 & \times & 10^{-} \\ < & 1.1 & \times & 10^{-} \end{array} $	-5 CL=90% -3 CL=90% -5 CL=90% -3 CL=90%	$0.0513\pm0.0054\pm0.0064$ 302 $0.066\pm0.016\pm0.015$ • • • We do not use the following seen 398	¹³ ALBREC g data for avera ¹⁴ SANGHI	CHT 92C AR ages, fits, limits ERA 93 CL	G $e^+e^- \rightarrow$, etc. • • • E2 $e^+e^- \rightarrow$	γ(45) γ(45)
Γ ₇₇ Γ ₇₈ Γ ₇₉ Γ ₈₀	$K^{+}\phi$ $K^{*}(892)^{+}K^{+}K^{-}$ $K^{*}(892)^{+}\phi$ $K_{1}(1400)^{+}\phi$ $K_{2}^{*}(1430)^{+}\phi$	$ \begin{array}{ccccc} < & 1.2 & & \times 10^{\circ} \\ < & 1.6 & & \times 10^{\circ} \\ < & 7.0 & & \times 10^{\circ} \\ < & 1.1 & & \times 10^{\circ} \\ < & 3.4 & & \times 10^{\circ} \end{array} $	-5 CL=90% -3 CL=90% -5 CL=90% -3 CL=90% -3 CL=90%	$0.0513\pm0.0054\pm0.0064$ 302 $0.066\pm0.016\pm0.015$ • • • We do not use the following seen 398 $0.041\pm0.008 {}^{+0.008}_{-0.009}$	¹³ ALBREC g data for avera ¹⁴ SANGHI ¹⁵ FULTON	CHT 92C AR nges, fits, limits ERA 93 CL N 91 CL	$e^+e^- \rightarrow e^+e^- \rightarrow e^-e^- ^- \rightarrow e^-e^- $	$\Upsilon(4S)$ $\Upsilon(4S)$ $\Upsilon(4S)$
Γ ₇₇ Γ ₇₈ Γ ₇₉ Γ ₈₀ Γ ₈₁	$K^+\phi$ $K^*(892)^+K^+K^ K^*(892)^+\phi$ $K_1(1400)^+\phi$ $K_2^*(1430)^+\phi$ $K^+f_0(980)$	< 1.2	-5 CL=90% -3 CL=90% -5 CL=90% -3 CL=90% -3 CL=90% -5 CL=90%	$0.0513\pm0.0054\pm0.0064$ 302 $0.066\pm0.016\pm0.015$ • • • We do not use the following seen 398 $0.041\pm0.008 +0.008 -0.009$ $0.070\pm0.018\pm0.014$	13 ALBREC 3 data for avera 14 SANGHI 15 FULTON 16 ANTRE	CHT 92C AR gges, fits, limits ERA 93 CL N 91 CL ASYAN 90B CB	eG $e^+e^- \rightarrow$ etc. • • • E2 $e^+e^- \rightarrow$ EO $e^+e^- \rightarrow$	$\Upsilon(4S)$ $\Upsilon(4S)$ $\Upsilon(4S)$ $\Upsilon(4S)$
Γ ₇₇ Γ ₇₈ Γ ₇₉ Γ ₈₀ Γ ₈₁ Γ ₈₂	$K^+\phi$ $K^*(892)^+ K^+K^ K^*(892)^+\phi$ $K_1(1400)^+\phi$ $K_2^*(1430)^+\phi$ $K^*f_0(980)$ $K^*(892)^+\gamma$	< 1.2	-5 CL=90% -3 CL=90% -5 CL=90% -3 CL=90% -3 CL=90% -5 CL=90%	0.0513 \pm 0.0054 \pm 0.0064 302 0.066 \pm 0.015 \bullet • • We do not use the following seen 398 0.041 \pm 0.008 \pm 0.009 0.070 \pm 0.018 \pm 0.014 \pm 0.014 \pm 0.014 \pm 0.015	13 ALBREC 3 data for avera 14 SANGHI 15 FULTON 16 ANTRE	CHT 92C AR gges, fits, limits ERA 93 CL N 91 CL ASYAN 90B CB	eG $e^+e^- \rightarrow$ etc. • • • E2 $e^+e^- \rightarrow$ EO $e^+e^- \rightarrow$	$\Upsilon(4S)$ $\Upsilon(4S)$ $\Upsilon(4S)$ $\Upsilon(4S)$
Γ ₇₇ Γ ₇₈ Γ ₇₉ Γ ₈₀ Γ ₈₁ Γ ₈₂ Γ ₈₃	$K^+\phi$ $K^*(892)^+K^+K^ K^*(892)^+\phi$ $K_1(1400)^+\phi$ $K_2^*(1430)^+\phi$ $K^+f_0(980)$	< 1.2	-5 CL=90% -3 CL=90% -5 CL=90% -3 CL=90% -3 CL=90% -5 CL=90% -5 CL=90%	0.0513 \pm 0.0054 \pm 0.0064 302 0.066 \pm 0.016 \pm 0.015 • • • We do not use the following seen 398 0.041 \pm 0.008 \pm 0.009 0.070 \pm 0.018 \pm 0.014 \pm 12 BARISH 95 use B($D^0 \rightarrow K^-$ = (63.6 \pm 2.3 \pm 3.3)%.	13 ALBREC data for avera 14 SANGHI 15 FULTON 16 ANTRE 17 17 18 18 18 19 $^{$	EHT 92c AR ages, fits, limits ERA 93 CL N 91 CL ASYAN 908 CB ± 0.08 ± 0.17	eG $e^+e^- \rightarrow$ etc. • • • E2 $e^+e^- \rightarrow$ EO $e^+e^- \rightarrow$ AL $e^+e^- \rightarrow$ 1% and B(D^{*0}	$ \begin{array}{c} \Upsilon(4S) \\ \Upsilon(4S) \\ \Upsilon(4S) \\ \Upsilon(4S) \\ \Upsilon(4S) \\ \rightarrow D^0 \pi^0 \end{array} $
Γ ₇₇ Γ ₇₈ Γ ₇₉ Γ ₈₀ Γ ₈₁ Γ ₈₂ Γ ₈₃ Γ ₈₄	$K^+\phi$ $K^*(892)^+K^+K^ K^*(892)^+\phi$ $K_1(1400)^+\phi$ $K_2^*(1430)^+\phi$ $K^+f_0(980)$ $K^*(892)^+\gamma$ $K_1(1270)^+\gamma$ $K_1(1400)^+\gamma$	< 1.2	-5 CL=90% -3 CL=90% -5 CL=90% -3 CL=90% -5 CL=90% -5 CL=90% -5 CL=90%	0.0513 \pm 0.0054 \pm 0.0064 302 0.066 \pm 0.016 \pm 0.015 • • • We do not use the following seen 398 0.041 \pm 0.008 $+$ 0.009 0.070 \pm 0.018 \pm 0.014 12 BARISH 95 use B($D^0 \rightarrow K^-$ = (63.6 \pm 2.3 \pm 3.3)%. 13 ALBRECHT 92c reports 0.058	13 ALBREC 3 data for avera 14 SANGHI 15 FULTON 16 ANTREA π^+) = (3.91 $\pm 0.014 \pm 0.013$	EHT 92C AR leges, fits, limits ERA 93 CL N 91 CL ASYAN 90B CB \pm 0.08 \pm 0.17%	and B(D^{*0}) and B(D^{*0}) ing the method	$ \begin{array}{c} \Upsilon(4S) \\ \Upsilon(4S) \\ \Upsilon(4S) \\ \Upsilon(4S) \\ & $
Γ ₇₇ Γ ₇₈ Γ ₇₉ Γ ₈₀ Γ ₈₁ Γ ₈₂ Γ ₈₃ Γ ₈₄ Γ ₈₅	$K^+\phi$ $K^*(892)^+K^+K^ K^*(892)^+\phi$ $K_1(1400)^+\phi$ $K_2^*(1430)^+\phi$ $K^+f_0(980)$ $K^*(892)^+\gamma$ $K_1(1270)^+\gamma$	< 1.2	-5 CL=90% -3 CL=90% -5 CL=90% -3 CL=90% -5 CL=90% -5 CL=90% -5 CL=90% -6 CL=90% -7 CL=90% -7 CL=90%	0.0513±0.0054±0.0064 302 0.066 ±0.016 ±0.015 • • • We do not use the following seen 398 0.041 ±0.008 $^{+0.008}_{-0.009}$ 0.070 ±0.018 ±0.014 12 BARISH 95 use B($D^0 \rightarrow K^-$ = (63.6 ± 2.3 ± 3.3)%.	13 ALBREC 3 data for avera 14 SANGHI 15 FULTON 16 ANTREA π^+) = (3.91 $\pm 0.014 \pm 0.013$ 2d PDG 94 B(D	EHT 92C AR leges, fits, limits ERA 93 CL N 91 CL ASYAN 90B CB \pm 0.08 \pm 0.17%	and B(D^{*0}) and B(D^{*0}) ing the method	$ \begin{array}{c} \Upsilon(4S) \\ \Upsilon(4S) \\ \Upsilon(4S) \\ \Upsilon(4S) \\ & $
Γ ₇₇ Γ ₇₈ Γ ₇₉ Γ ₈₀ Γ ₈₁ Γ ₈₂ Γ ₈₃ Γ ₈₄ Γ ₈₅ Γ ₈₆	$K^+\phi$ $K^*(892)^+K^+K^ K^*(892)^+\phi$ $K_1(1400)^+\phi$ $K_2^*(1430)^+\phi$ $K^+f_0(980)$ $K^*(892)^+\gamma$ $K_1(1270)^+\gamma$ $K_1(1400)^+\gamma$ $K_2^*(1430)^+\gamma$ $K^*(1680)^+\gamma$	< 1.2	-5 CL=90% -3 CL=90% -5 CL=90% -3 CL=90% -5 CL=90% -3 CL=90% -5 CL=90% -5 CL=90% -3 CL=90% -3 CL=90% -3 CL=90%	0.0513 \pm 0.0054 \pm 0.0064 302 0.066 \pm 0.015 • • • We do not use the following seen 398 0.041 \pm 0.008 \pm 0.009 0.070 \pm 0.018 \pm 0.014 \pm 0.018 \pm 0.014 \pm 0.018 \pm 0.014 \pm 0.018 \pm 0.014 \pm 0.018 \pm 0.015 \pm 0.015 \pm 0.015 \pm 0.015 \pm 0.018 \pm 0.019 0.058 \pm 0.058 \pm 0.058 \pm 0.059 \pm 0.	13 ALBREG g data for avera 14 SANGHI 15 FULTON 16 ANTREA π^+) = (3.91 $\pm 0.014 \pm 0.013$ ed PDG 94 B(D $\Upsilon(45)$.	EHT 92C AR 1ges, fits, limits ERA 93 CL N 91 CL ASYAN 90B CB \pm 0.08 \pm 0.17 B. We rescale us $0.00 \rightarrow K^-\pi^+$).	eG $e^+e^- \rightarrow$ etc. • • • E2 $e^+e^- \rightarrow$ E0 $e^+e^- \rightarrow$ AL $e^+e^- \rightarrow$ 9% and B(D^{*0} ing the method Assumes equa	$\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$ $\to D^0 \pi^0$) described in a production
Γ ₇₇ Γ ₇₈ Γ ₇₉ Γ ₈₀ Γ ₈₁ Γ ₈₂ Γ ₈₃ Γ ₈₄ Γ ₈₅ Γ ₈₆ Γ ₈₇	$K^+\phi$ $K^*(892)^+ K^+K^ K^*(892)^+\phi$ $K_1(1400)^+\phi$ $K_2^*(1430)^+\phi$ $K^*(980)$ $K^*(892)^+\gamma$ $K_1(1270)^+\gamma$ $K_1(1400)^+\gamma$ $K_2^*(1430)^+\gamma$ $K_2^*(1430)^+\gamma$ $K_3^*(1780)^+\gamma$	< 1.2	-5 CL=90% -3 CL=90% -5 CL=90% -3 CL=90% -3 CL=90% -5 CL=90% -5 CL=90% -5 CL=90% -3 CL=90% -3 CL=90% -3 CL=90% -3 CL=90%	0.0513 \pm 0.0054 \pm 0.0064 0.066 \pm 0.015 • • • We do not use the following seen 398 0.041 \pm 0.008 \pm 0.009 0.070 \pm 0.018 \pm 0.014 12 BARISH 95 use B($D^0 \rightarrow K^-$ = (63.6 \pm 2.3 \pm 3.3)%. 13 ALBRECHT 92C reports 0.058: STONE 94 but with the update of $B^0 \overline{B}^0$ and $B^+ B^-$ at the 7 14 Combining $\overline{D}^{*0} \ell^+ \nu_\ell$ and \overline{D}^{*+} decay angular distributions to decay angular distributions decay angular decay angu	13 ALBREC $_{9}$ data for avera 14 SANGHI 15 FULTON 16 ANTRE/ $^{-}\pi^+)=(3.91\pm0.014\pm0.013\pm000000000000000000000000000000000$	CHT 92c AR 1985, fits, limits ERA 93 CL N 91 CL ASYAN 90B CB \pm 0.08 \pm 0.17) S. We rescale us $10^{-0} \rightarrow K^{}\pi^{+}$). HERA 93 test $3/4*(\Gamma^{-}-\Gamma^{+})$	eG $e^+e^- \rightarrow$ etc. • • • E2 $e^+e^- \rightarrow$ EO $e^+e^- \rightarrow$ AL $e^+e^- \rightarrow$ % and B(D^{*0} ing the method Assumes equal V-A structure $1/F = 0.14 \pm 0$	$\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$ $\to D^0\pi^0$) described in I production and fit the
Γ ₇₇ Γ ₇₈ Γ ₇₉ Γ ₈₀ Γ ₈₁ Γ ₈₂ Γ ₈₃ Γ ₈₄ Γ ₈₅ Γ ₈₆	$K^+\phi$ $K^*(892)^+K^+K^ K^*(892)^+\phi$ $K_1(1400)^+\phi$ $K_2^*(1430)^+\phi$ $K^+f_0(980)$ $K^*(892)^+\gamma$ $K_1(1270)^+\gamma$ $K_1(1400)^+\gamma$ $K_2^*(1430)^+\gamma$ $K^*(1680)^+\gamma$ $K_3^*(1780)^+\gamma$ $K_4^*(2045)^+\gamma$	< 1.2	-5 CL=90% -3 CL=90% -5 CL=90% -3 CL=90% -5 CL=90% -3 CL=90% -5 CL=90% -5 CL=90% -3 CL=90% -3 CL=90% -3 CL=90% -3 CL=90%	0.0513 \pm 0.0054 \pm 0.0064 0.066 \pm 0.015 • • • We do not use the following seen 398 0.041 \pm 0.008 \pm 0.009 0.070 \pm 0.018 \pm 0.014 12 BARISH 95 use B($D^0 \rightarrow K^-$ = (63.6 \pm 2.3 \pm 3.3)%. 13 ALBRECHT 92C reports 0.058: STONE 94 but with the update of $B^0 \overline{B}^0$ and $B^+ B^-$ at the 14 Combining $\overline{D}^{+0} \ell^+ \nu_\ell$ and \overline{D}^{++} decay angular distributions to a Assuming a value of V_{CD} , they	13 ALBREC g data for avera 14 SANGHI 15 FULTON 16 ANTREA π^+) = (3.91 \pm 0.014 \pm 0.013 ed PDG 94 B(D Γ (45). $-\ell^+\nu_\ell$ SANGI obtain A_{FB} = y measure V , A	CHT 92c AR 1985, fits, limits ERA 93 CL N 91 CL ASYAN 90B CB \pm 0.08 \pm 0.17%, We rescale us 10 $_{\odot}$ $_{\odot}$ $_{\sim}$ $^{-\pi}$ $^{+}$). HERA 93 test 3 /4+(Γ - $^{-}$ Γ + $^{+}$ 1, and 4 2, the	eG $e^+e^- \rightarrow$, etc. • • • E2 $e^+e^- \rightarrow$ EO $e^+e^- \rightarrow$ AL $e^+e^- \rightarrow$ % and B(D^{*0} ing the method Assumes equa V-A structure $1/F = 0.14 \pm 0$ three form fac	$\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$ $\to D^0\pi^0$) described in I production and fit the
Γ ₇₇ Γ ₇₈ Γ ₇₉ Γ ₈₀ Γ ₈₁ Γ ₈₂ Γ ₈₃ Γ ₈₄ Γ ₈₅ Γ ₈₆ Γ ₈₇ Γ ₈₈	$K^+\phi$ $K^*(892)^+ K^+K^ K^*(892)^+ \phi$ $K_1(1400)^+ \phi$ $K_2^*(1430)^+ \phi$ $K^+f_0(980)$ $K^*(892)^+ \gamma$ $K_1(1270)^+ \gamma$ $K_1(1400)^+ \gamma$ $K_2^*(1430)^+ \gamma$ $K^*(1680)^+ \gamma$ $K_3^*(1780)^+ \gamma$ $K_4^*(2045)^+ \gamma$ Light unflavon	< 1.2	-5 CL=90% -3 CL=90% -5 CL=90% -3 CL=90% -5 CL=90% -3 CL=90% -5 CL=90% -5 CL=90% -3 CL=90% -3 CL=90% -3 CL=90% -3 CL=90% -3 CL=90%	0.0513 \pm 0.0054 \pm 0.0064 0.066 \pm 0.015 • • • We do not use the following seen 398 0.041 \pm 0.008 \pm 0.009 0.070 \pm 0.018 \pm 0.014 12 BARISH 95 use B($D^0 \rightarrow K^ =$ (63.6 \pm 2.3 \pm 3.3)%. 13 ALBRECHT 92c reports 0.058: STONE 94 but with the update of $B^0 \overline{B}^0$ and $B^+ B^-$ at the 14 Combining $\overline{D}^{*0} \ell^+ \nu_\ell$ and \overline{D}^{**} decay angular distributions to a Assuming a value of V_{cb} , they $D^* \ell \nu_\ell$ decay, where results are	13 ALBREC g data for avera 14 SANGHI 15 FULTON 16 ANTRE/ $^{-}$ $\pi^+) = (3.91$ $\pm 0.014 \pm 0.013$ $\pm 0.014 \pm 0.013$ $\pm 0.014 \pm 0.013$ $\pm 0.014 \pm 0.013$ ± 0.014 ± 0.014 SANGI Obtain $^{-}$ $A_{FB} = 0.014$ we slightly dependently $^{-}$ 4e slightly dependently $^{-}$ 40 ± 0.014 \pm	CHT 92c AR 1ges, fits, limits ERA 93 CL N 91 CL ASYAN 90B CB \pm 0.08 \pm 0.17 S, We rescale us $0^0 \rightarrow K^-\pi^+$). HERA 93 test 3/4*($\Gamma^ \Gamma^+$ \pm 1, and A_2 , the dident on model	eG $e^+e^- \rightarrow$ etc. • • • E2 $e^+e^- \rightarrow$ E0 $e^+e^- \rightarrow$ AL $e^+e^- \rightarrow$ % and B(D^{*0} ing the method Assumes equa V-A structure V-A structure V-A structure in the form factor assumptions.	$\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$ $\to D^0 \pi^0$) described in I production and fit the 0.06 \pm 0.03. ctors for the
Γ ₇₇ Γ ₇₈ Γ ₇₉ Γ ₈₀ Γ ₈₁ Γ ₈₂ Γ ₈₃ Γ ₈₄ Γ ₈₅ Γ ₈₆ Γ ₈₇ Γ ₈₈	$\begin{array}{c} K^{+}\phi \\ K^{*}(892)^{+} K^{+} K^{-} \\ K^{*}(892)^{+} \phi \\ K_{1}(1400)^{+} \phi \\ K_{2}^{*}(1430)^{+} \phi \\ K^{*}(1270)^{+} \gamma \\ K_{1}(1270)^{+} \gamma \\ K_{1}(1270)^{+} \gamma \\ K_{2}(1430)^{+} \gamma \\ K^{*}_{2}(1430)^{+} \gamma \\ K^{*}_{3}(1780)^{+} \gamma \\ K^{*}_{4}(2045)^{+} \gamma \\ \end{array}$	<pre>< 1.2</pre>	-5 CL=90% -3 CL=90% -5 CL=90% -3 CL=90% -3 CL=90% -5 CL=90% -5 CL=90% -5 CL=90% -3 CL=90%	0.0513 \pm 0.0054 \pm 0.0064 0.066 \pm 0.015 • • • We do not use the following seen 398 0.041 \pm 0.008 $_{-}^{+}$ 0.009 0.070 \pm 0.018 \pm 0.014 12 BARISH 95 use B($D^0 \rightarrow K^-$ = (63.6 \pm 2.3 \pm 3.3)%. 13 ALBRECHT 92c reports 0.058. STONE 94 but with the update of $B^0 \overline{B^0}$ and $B^+ B^-$ at the 14 Combining $\overline{D}^{*0} \ell^+ \nu_\ell$ and \overline{D}^{*+} decay angular distributions to a Assuming a value of V_{CD} , they $D^* \ell^+ \nu_\ell$ decay, where results are 15 Assumes equal production of B^0	13 ALBREC g data for avera 14 SANGHI 15 FULTON 16 ANTRE/ $^{-}\pi^+)=(3.91\pm0.014\pm0.013$ dd PDG 94 B(D $^{-}$ T(45). $^{-}\ell^+\nu_\ell$ SANGI obtain $^{-}$ F ₀ = $^{-}$ y measure $^{-}$ V, $^{-}$ g and $^{-}$ B $^{-}$ and $^{-}$ B $^{-}$ on $^{-}$ B $^{-}$ O $^{-$	CHT 92c AR 1ges, fits, limits ERA 93 CL N 91 CL ASYAN 90B CB \pm 0.08 \pm 0.17 S, We rescale us $0^0 \rightarrow K^-\pi^+$). HERA 93 test 3/4*($\Gamma^ \Gamma^+$ \pm 1, and A_2 , the dident on model	eG $e^+e^- \rightarrow$ etc. • • • E2 $e^+e^- \rightarrow$ E0 $e^+e^- \rightarrow$ AL $e^+e^- \rightarrow$ % and B(D^{*0} ing the method Assumes equa V-A structure V-A structure V-A structure in the form factor assumptions.	$\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$ $\to D^0 \pi^0$) described in I production and fit the 0.06 \pm 0.03. ctors for the
Γ ₇₇ Γ ₇₈ Γ ₇₉ Γ ₈₀ Γ ₈₁ Γ ₈₂ Γ ₈₃ Γ ₈₄ Γ ₈₅ Γ ₈₆ Γ ₈₇ Γ ₈₈	$\begin{array}{c} K^{+}\phi \\ K^{*}(892)^{+} K^{+} K^{-} \\ K^{*}(892)^{+}\phi \\ K_{1}(1400)^{+}\phi \\ K_{2}^{*}(1430)^{+}\phi \\ K^{+}f_{0}(980) \\ K^{*}(892)^{+}\gamma \\ K_{1}(1270)^{+}\gamma \\ K_{1}(1400)^{+}\gamma \\ K_{2}^{*}(1430)^{+}\gamma \\ K_{3}^{*}(1780)^{+}\gamma \\ K_{3}^{*}(1780)^{+}\gamma \\ K_{4}^{*}(2045)^{+}\gamma \\ \end{array}$ Light unflavor	< 1.2	-5 CL=90% -3 CL=90% -5 CL=90% -3 CL=90% -5 CL=90% -5 CL=90% -5 CL=90% -6 CL=90% -7 CL=90%	0.0513 \pm 0.0054 \pm 0.0064 0.066 \pm 0.015 • • • We do not use the following seen 398 0.041 \pm 0.008 $+$ 0.009 0.070 \pm 0.018 \pm 0.019 12 BARISH 95 use B($D^0 \rightarrow K^-$ = (63.6 \pm 2.3 \pm 3.3)%. 13 ALBRECHT 92C reports 0.058: STONE 94 but with the update of $B^0 B^0$ and $B^+ B^-$ at the 14 Combining $\overline{D}^{*0} \ell^+ \nu_\ell$ and \overline{D}^{*} decay angular distributions to a Assuming a value of V_{cb} , they $D^* \ell \nu_\ell$ decay, where results are 15 Assumes equal production of E^0 by branching ratio assumption	13 ALBRECG data for avera 14 SANGHI 15 FULTON 16 ANTRE/ τ^+) = (3.91 \pm 0.014 \pm 0.013 \pm 0 PDG 94 B(D T (45). $ \ell^+\nu_\ell$ SANGI obtain $A_{FB}=$ y measure V , A e slightly depension 90 B 0 and B^+ 1 ins.	CHT 92c AR 1ges, fits, limits ERA 93 CL N 91 CL ASYAN 90B CB \pm 0.08 \pm 0.17] I. We rescale us $0 \rightarrow K^-\pi^+$). HERA 93 test $3/4*(\Gamma^-\Gamma^+$ 1_1 , and A_2 , the ident on model B^- at the $\Upsilon(4)$	eG $e^+e^- \rightarrow$ etc. • • • E2 $e^+e^- \rightarrow$ EO $e^+e^- \rightarrow$ AL $e^+e^- \rightarrow$ % and B(D^{*0} ing the method Assumes equa V-A structure)/ $\Gamma = 0.14 \pm 0$ three form far assumptions. S). Uncorrecte	$\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$ $\to D^0 \pi^0$) described in I production and fit the 0.06 \pm 0.03. ctors for the
Γ ₇₇ Γ ₇₈ Γ ₇₉ Γ ₈₀ Γ ₈₁ Γ ₈₂ Γ ₈₃ Γ ₈₄ Γ ₈₅ Γ ₈₆ Γ ₈₇ Γ ₈₈ Γ ₈₉ Γ ₉₀ Γ ₉₁	$\begin{array}{c} K^{+}\phi \\ K^{*}(892)^{+} K^{+} K^{-} \\ K^{*}(892)^{+}\phi \\ K_{1}(1400)^{+}\phi \\ K_{2}^{*}(1430)^{+}\phi \\ K^{*}(6980) \\ K^{*}(892)^{+}\gamma \\ K_{1}(1270)^{+}\gamma \\ K_{1}(1400)^{+}\gamma \\ K_{2}^{*}(1430)^{+}\gamma \\ K_{3}^{*}(1780)^{+}\gamma \\ K_{3}^{*}(1780)^{+}\gamma \\ K_{4}^{*}(2045)^{+}\gamma \\ \end{array}$	< 1.2	-5 CL=90% -3 CL=90% -3 CL=90% -3 CL=90% -5 CL=90% -5 CL=90% -5 CL=90% -3 CL=90% -3 CL=90% -3 CL=90% -3 CL=90% -3 CL=90% -5 CL=90% -5 CL=90%	0.0513 \pm 0.0054 \pm 0.0064 0.066 \pm 0.015 • • • We do not use the following seen 398 0.041 \pm 0.008 \pm 0.009 0.070 \pm 0.018 \pm 0.014 12 BARISH 95 use B($D^0 \rightarrow K^-$ = (63.6 \pm 2.3 \pm 3.3)%. 13 ALBRECHT 92C reports 0.058: STONE 94 but with the update of $B^0 B^0$ and $B^+ B^-$ at the 14 Combining $\overline{D}^{*0} \ell^+ \nu_\ell$ and \overline{D}^{**} decay angular distributions to a Assuming a value of V_{cb} , they $D^{**} \ell \nu_\ell$ decay, where results are 15 Assumes equal production of E^0 branching ratio assumption 16 ANTREASYAN 90B is average	13 ALBRECG data for avera 14 SANGHI 15 FULTON 16 ANTRE/ τ^+) = (3.91 \pm 0.014 \pm 0.013 \pm 0 PDG 94 B(D T (45). $ \ell^+\nu_\ell$ SANGI obtain $A_{FB}=$ y measure V , A e slightly depension 90 B 0 and B^+ 1 ins.	CHT 92c AR 1ges, fits, limits ERA 93 CL N 91 CL ASYAN 90B CB \pm 0.08 \pm 0.17] I. We rescale us $0 \rightarrow K^-\pi^+$). HERA 93 test $3/4*(\Gamma^-\Gamma^+$ 1_1 , and A_2 , the ident on model B^- at the $\Upsilon(4)$	eG $e^+e^- \rightarrow$ etc. • • • E2 $e^+e^- \rightarrow$ EO $e^+e^- \rightarrow$ AL $e^+e^- \rightarrow$ % and B(D^{*0} ing the method Assumes equa V-A structure)/ $\Gamma = 0.14 \pm 0$ three form far assumptions. S). Uncorrecte	$\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$ $\to D^0\pi^0$) described in I production and fit the 0.06 \pm 0.03. etcrs for the d for D and
F ₇₇ F ₇₈ F ₇₉ F ₈₀ F ₈₁ F ₈₂ F ₈₃ F ₈₄ F ₈₅ F ₈₆ F ₈₇ F ₈₈ F ₉₀ F ₉₁ F ₉₂	$K^+\phi$ $K^*(892)^+K^+K^ K^*(892)^+\phi$ $K_1(1400)^+\phi$ $K_2(1430)^+\phi$ $K_2^*(1430)^+\phi$ $K^*(992)^+\gamma$ $K_1(1270)^+\gamma$ $K_1(1400)^+\gamma$ $K_2^*(1430)^+\gamma$ $K_2^*(1430)^+\gamma$ $K_3^*(1780)^+\gamma$ $K_4^*(1680)^+\gamma$ $K_4^*(2045)^+\gamma$ Light unflavor $\pi^+\pi^0$ $\pi^+\pi^ \pi^+\pi^ \rho^0\pi^+$ $\pi^+f_0(980)$	< 1.2	-5 CL=90% -3 CL=90% -5 CL=90% -3 CL=90% -5 CL=90% -5 CL=90% -5 CL=90% -6 CL=90% -3 CL=90% -3 CL=90% -3 CL=90% -3 CL=90% -4 CL=90% -4 CL=90% -4 CL=90%	0.0513 \pm 0.0054 \pm 0.0064 0.066 \pm 0.015 ••• We do not use the following seen 398 0.041 \pm 0.008 $+$ 0.008 0.070 \pm 0.018 \pm 0.014 12 BARISH 95 use B($D^0 \rightarrow K^-$ = (63.6 \pm 2.3 \pm 3.3)%. 13 ALBRECHT 92C reports 0.058: STONE 94 but with the update of $B^0 B^0$ and $B^+ B^-$ at the 14 Combining $\overline{D}^{*0} \ell^+ \nu_\ell$ and \overline{D}^{**} decay angular distributions to a Assuming a value of V_{cb} , they $D^* \ell \nu_\ell$ decay, where results are 15 Assumes equal production of E D^* branching ratio assumption 16 ANTREASYAN 90B is average $\Gamma(\pi^0 e^+ \nu_e)/\Gamma_{\text{total}}$	13 ALBRECG data for avera 14 SANGHI 15 FULTON 16 ANTRE/ π^+) = (3.91 \pm 0.014 \pm 0.013 \pm 0.014 \pm 0.015 \pm 0.014 \pm 0.015 \pm 0.014 \pm 0.015 \pm 0.014 \pm 0.015 \pm 0.015 \pm 0.016 \pm 0.017 \pm 0	CHT 92c AR 1ges, fits, limits ERA 93 CL N 91 CL ASYAN 90B CB \pm 0.08 \pm 0.17). We rescale us $10^{\circ} \rightarrow K^{-}\pi^{+}$). HERA 93 test $3/4*(\Gamma^{-}-\Gamma^{+}$ 1, and A_{2} , the ident on model B^{-} at the $\Upsilon(4)$ *(2010) charge	eG $e^+e^- \rightarrow$ etc. • • • E2 $e^+e^- \rightarrow$ E0 $e^+e^- \rightarrow$ AL $e^+e^- \rightarrow$ % and B(D^{*0} ing the method Assumes equa V-A structure)/ $\Gamma = 0.14 \pm 0$ three form far assumptions. S). Uncorrecte	$\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$ $\to D^0 \pi^0$) described in I production and fit the 0.06 \pm 0.03. ctors for the
F ₇₇ F ₇₈ F ₇₉ F ₈₀ F ₈₁ F ₈₂ F ₈₃ F ₈₄ F ₈₅ F ₈₆ F ₈₇ F ₈₈ F ₈₉ F ₉₀ F ₉₁	$\begin{array}{c} K^{+}\phi \\ K^{*}(892)^{+} K^{+} K^{-} \\ K^{*}(892)^{+}\phi \\ K_{1}(1400)^{+}\phi \\ K_{2}^{*}(1430)^{+}\phi \\ K^{*}(6980) \\ K^{*}(892)^{+}\gamma \\ K_{1}(1270)^{+}\gamma \\ K_{1}(1400)^{+}\gamma \\ K_{2}^{*}(1430)^{+}\gamma \\ K_{3}^{*}(1780)^{+}\gamma \\ K_{3}^{*}(1780)^{+}\gamma \\ K_{4}^{*}(2045)^{+}\gamma \\ \end{array}$	< 1.2	-5 CL=90% -3 CL=90% -3 CL=90% -3 CL=90% -5 CL=90% -5 CL=90% -5 CL=90% -5 CL=90% -3 CL=90% -3 CL=90% -3 CL=90% -4 CL=90% -4 CL=90% -4 CL=90% -4 CL=90%	0.0513 \pm 0.0054 \pm 0.0064 0.066 \pm 0.015 • • • We do not use the following seen 398 0.041 \pm 0.008 \pm 0.009 0.070 \pm 0.018 \pm 0.014 12 BARISH 95 use B($D^0 \rightarrow K^-$ = (63.6 \pm 2.3 \pm 3.3)%. 13 ALBRECHT 92C reports 0.058: STONE 94 but with the update of $B^0 B^0$ and $B^+ B^-$ at the 14 Combining $\overline{D}^{*0} \ell^+ \nu_\ell$ and \overline{D}^{**} decay angular distributions to a Assuming a value of V_{cb} , they $D^{**} \ell \nu_\ell$ decay, where results are 15 Assumes equal production of E^0 branching ratio assumption 16 ANTREASYAN 90B is average	13 ALBRECG data for avera 14 SANGHI 15 FULTON 16 ANTRE. π^+) = (3.91 \pm 0.014 \pm 0.013 \pm 0.014 \pm 0.015 \pm 0.016 \pm 0.017 \pm 0.018 \pm 0.018 \pm 0.019 \pm	CHT 92c AR 1ges, fits, limits ERA 93 CL N 91 CL ASYAN 90B CB \pm 0.08 \pm 0.17). We rescale us $10^{\circ} \rightarrow K^{-}\pi^{+}$). HERA 93 test $3/4*(\Gamma^{-}-\Gamma^{+}$ 1, and A_{2} , the ident on model B^{-} at the $\Upsilon(4)$ *(2010) charge	G $e^+e^- \rightarrow$ etc. $\bullet \bullet \bullet$ E2 $e^+e^- \rightarrow$ E0 $e^+e^- \rightarrow$ E0 $e^+e^- \rightarrow$ % and B(D^{*0} ing the method Assumes equa V-A structure V-A structure V-A structure V-A structure three form far assumptions. S). Uncorrecte states.	$\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$ $\to D^0 \pi^0$) described in I production and fit the 0.06 \pm 0.03. ctors for the d for D and

 B^{\pm}

$\Gamma(\omega \ell^+ \nu_\ell)/\Gamma_{\text{total}}$ $\ell = e \text{ or } \mu, \text{ not } t$	sum over e	and μ modes.			Γ ₅ /Γ	$\Gamma(\overline{D}{}^0\pi^+\pi^+\pi^-$ nonresona	DOCUMENT	ID TE	ECN COMME	ENT	Γ ₁₄ /
VALUE	<u>CL%</u> 90	DOCUMENT ID 17 BEAN		COMMENT		$0.0051 \pm 0.0034 \pm 0.0023$	³⁰ BORTOLE				5)
<2.1 × 10 ⁻⁴ 17 BEAN 93B limit se	et using ISG	W Model. Using	isospin and th		l to combine	30 BORTOLETTO 92 assur Mark III branching fractio		on of B ⁺ a	and B^0 at th	e Υ(4 <i>S</i>) a	and us
$\Gamma(\rho^0 \ell^+ \nu_\ell)$ and $\Gamma(90\%$ CL for $B^+ \rightarrow 0\%$	$\omega \ell^+ \nu_{\ell}$. T	he range corresp	onds to the IS	GW, WSB, and		$\Gamma(\overline{D}{}^0\pi^+ ho^0)/\Gamma_{ ext{total}}$	DOCUMENT	/D T/	ECNCOMME	ENT.	Γ ₁₅
An upper limit on	$ V_{ub}/V_{cb} $	< 0.8-0.13 at 90	0% CL is deriv	ed as well.		0.0042±0.0023±0.0020	31 BORTOLE				5)
$(\omega \mu^+ \nu_\mu) / \Gamma_{\text{total}}$		DOCUMENT ID	D TECN		Γ ₆ /Γ	31 BORTOLETTO 92 assur Mark III branching fractio	nes equal production				
• We do not use teen		g data for averag		, etc. • • •		$\Gamma(\overline{D}^0 a_1(1260)^+)/\Gamma_{\text{total}}$					Γ ₁₆
¹⁸ In ALBRECHT 910 transition.				g evidence for	the $b \rightarrow u$	VALUE 0.0045±0.0019±0.0031	32 BORTOLE		E <u>CN COMME</u> LEO e ⁺ e ⁻		5)
$(ho^0 \ell^+ u_\ell) / \Gamma_{ m total}$					Γ ₇ /Γ	32 BORTOLETTO 92 assur Mark III branching fractio		on of \mathcal{B}^+ a	and B^0 at th	e Υ(4 <i>S</i>) a	and i
$\ell = e$ or μ_r not :	sum over e	and μ modes. <u>DOCUMENT ID</u>	TECN	COMMENT		$\Gamma(D^*(2010)^-\pi^+\pi^+)/\Gamma_{\rm t}$	otal				Γ17
<2.1 × 10 ⁻⁴		¹⁹ BEAN		e ⁺ e ⁻ → 1	r(45)	VALUE C	L% EVTS D	OCUMENT ID	<u>TECN</u>	COMME	NT
19 BEAN 938 limit se Γ $(\omega^0\ell^+\nu_\ell)$ and Γ						0.0021±0.0006 OUR AVE	14 33 A	LAM	94 CLE2	e+ e− Υ(%	
at 90% CL for B+ models. An upper	$\rightarrow \rho^0 \ell^+$	$ u_\ell$. The range of	corresponds to	the ISGW, W	/SB, and KS	$0.0026 \pm 0.0014 \pm 0.0007$	11 34 A	LBRECHT	90J ARG	e+ e- γ(4.	-
$(e^+ \nu_e)/\Gamma_{\rm total}$	1 . 1	2D. CDI			Γ_8/Γ	$0.0024 {}^{+0.0017}_{-0.0016} {}^{+0.0010}_{-0.0006}$		EBEK		e ⁺ e ⁻ γ(4.	
1.5 × 10 ⁻⁵	<u>CL%</u> 90	DOCUMENT ID		$e^+e^- \rightarrow$	r(4S)	• • • We do not use the foll < 0.004			imits, etc. ● TO92 CLEO		→
$(\mu^+ u_\mu)/\Gamma_{ m total}$				- •	٦ (٩٥) ٦ ₉ /٢	0.005 ±0.002 ±0.003		LBRECHT		e^+e^-	S) →
4LUE <2.1 × 10 ⁻⁵	<u>CL%</u> 90	<u>DOCUMENT ID</u> ARTUSO		$e^+e^- \rightarrow $	r(4S)	³³ ALAM 94 assume equal I					CLE
$(au^+ u_ au)/\Gamma_{ m total}$					Γ ₁₀ /Γ	$B(D^*(2010)^+ \to D^0 \pi^+ K^- \pi^+ \pi^0)/B(D^0 \to K^- K^- K^- K^- K^- K^- K^- K^- K^- K^-$) and absolute B(D $^-\pi^+$) and B(D 0 $^-$	$0^0 \rightarrow K^-\pi$ $\rightarrow K^-\pi^+ \tau$	π^+ and the P $\pi^+\pi^-$)/B(D	DG 1992 I $^0 \rightarrow K^-$	$\frac{B(D^0)}{\pi^+}$
ALUE	CL%	DOCUMENT ID	TECN_	COMMENT		34 Assumes equal production fractions for the D.	of \mathcal{B}^+ and \mathcal{B}^0 at	the $\Upsilon(45)$	and uses the	Mark III b	ranc
<1.8 × 10 ⁻³		²⁰ BUSKULIC	95 ALEP	$e^+e^- \rightarrow Z$	z I	35 BEBEK 87 value has bee	en updated in BER	KELMAN 9	91 to use sar	ne assump	ption
We do not use to	the following	g data for averag	ges, fits, limits	. etc. • • •							
					_	noted for BORTOLETTO		1			
$<1.04 \times 10^{-2}$		21 ALBRECHT	95D ARG	$e^+e^- \rightarrow $		³⁶ BORTOLETTO 92 assur	nes equal production				
$<1.04 \times 10^{-2}$ $<2.2 \times 10^{-3}$	90	ARTUSO	95D ARG 95 CLE2	$e^+e^- \rightarrow e^+e^- \rightarrow e^-e^- ^- \rightarrow e^-e^- ^- \rightarrow e^-e^- \rightarrow e^-e$	r(45)	³⁶ BORTOLETTO 92 assur Mark III branching fractio	nes equal productions for the D and D	*(2010). T	he authors als	so find the	prod
$<1.04 \times 10^{-2}$ $<2.2 \times 10^{-3}$ 20 BUSKULIC 95 use	90 es same miss	ARTUSO sing-energy techr	95D ARG 95 CLE2 nique as in \overline{b} –	$e^+e^- \rightarrow e^+e^- \rightarrow e^-e^- ^- \rightarrow e^-e^- ^- \rightarrow e^-e^- \rightarrow e^-e$	r(45)	³⁶ BORTOLETTO 92 assur Mark III branching fractio branching fraction into D	mes equal productions for the D and D ** π followed by D *	*(2010). T ** → D*(2	he authors als $2010)\pi$ to be	so find the	prod
$<$ 1.04 \times 10 ⁻² $<$ 2.2 \times 10 ⁻³ ²⁰ BUSKULIC 95 use restricted to endpo	90 es same miss oint region o	ARTUSO sing-energy techr of missing-energy	95D ARG 95 CLE2 nique as in \overline{b} - distribution.	$e^+e^- \rightarrow e^+e^- \rightarrow e^+e^- \rightarrow e^+\nu_{ au} X$, b	r(45)	36 BORTOLETTO 92 assur Mark III branching fractio branching fraction into <i>D</i> 0.0003 where <i>D**</i> repres	nes equal productions for the D and D ** π followed by D 3 ents all orbitally exc	*(2010). The state of P and P and P are stated P mass P and P are state of P are state of P and P are state of P are state of P and P are state of P are state of P and P are state of P are state of P and P are	he authors als $2010)\pi$ to be sons.	so find the 0.0014 + 0	proc 0.000 0.000
$<1.04 \times 10^{-2}$ $<2.2 \times 10^{-3}$ 20 BUSKULIC 95 use restricted to endpo 21 ALBRECHT 950 u	90 es same miss oint region o	ARTUSO sing-energy techr of missing-energy	95D ARG 95 CLE2 nique as in \overline{b} - distribution.	$e^+e^- \rightarrow e^+e^- \rightarrow e^+e^- \rightarrow e^+\nu_{ au} X$, b	r(45) ut analysis is	36 BORTOLETTO 92 assur Mark III branching fractio branching fraction into D 0.0003 where D** repress 37 ALBRECHT 87c use PI B(T'(45) — B+B-) =	nes equal productions for the D and D^* ** π followed by D^3 ents all orbitally exc DG 86 branching	*(2010). The second P^* $P^$	he authors also $2010)\pi$ to be sons. D and $D^*(2)$	so find the 0.0014 $^{+0}_{-0}$	proc 0.000 0.000 assi
$<1.04 \times 10^{-2}$ $<2.2 \times 10^{-3}$ 20 BUSKULIC 95 use restricted to endpo 21 ALBRECHT 950 u	90 es same miss oint region o	ARTUSO sing-energy techr of missing-energy	95D ARG 95 CLE2 nique as in \overline{b} - distribution. 8 B decay as ta	$e^+e^- \rightarrow e^+e^- \rightarrow e^+e^- \rightarrow e^+\nu_{ au} X$, b	$r(4s)$ ut analysis is Γ_{11}/Γ	36 BORTOLETTO 92 assur Mark III branching fraction branching fraction into D 0.0003 where D^{**} repressible Table 18 ($\Upsilon(4S) \rightarrow B^+B^-$) = BRECHT 90J.	nes equal productions for the D and D^* ** π followed by D^3 ents all orbitally exc DG 86 branching	*(2010). The second P^* $P^$	he authors also $2010)\pi$ to be sons. D and $D^*(2)$	so find the 0.0014 $^{+0}_{-0}$	e proc 0.000 0.000 assu d by
$<1.04 \times 10^{-2}$ $<2.2 \times 10^{-3}$ 20 BUSKULIC 95 use restricted to endpo 21 ALBRECHT 95D u $<(0.0053\pm0.0005)$ OUR 10	90 es same missoint region duse full recon	ARTUSO sing-energy techn of missing-energy nstruction of one	95D ARG 95 CLE2 Inique as in \overline{b} - distribution. 8 B decay as ta	$\begin{array}{ccc} e^{+} e^{-} & \rightarrow & \\ e^{+} e^{-} & \rightarrow & \\ \rightarrow & \tau^{+} \nu_{\tau} X, \text{ b} \\ \end{array}$	r(45) ut analysis is F ₁₁ /F	36 BORTOLETTO 92 assur Mark III branching fraction branching fraction into D 0.0003 where D^{**} repressive the same of t	nes equal productions for the D and D *** π followed by D * ents all orbitally excDG 86 branching: 55% and B(Υ (45)	*(2010). To the second	he authors als $2010)\pi$ to be sons. D and $D^*(2^{00})=45\%$.	so find the $0.0014 + 0.0014 = 0.0014$	assi d by
<1.04 × 10 ⁻² <2.2 × 10 ⁻³ ²⁰ BUSKULIC 95 use restricted to endpo ²¹ (D̄0 π ⁺)/Γ _{total} ΔLUE .0053±0.0005 OUR Δ	90 es same missoint region of use full recon EVTS AVERAGE 05 304	ARTUSO sing-energy techn of missing-energy nstruction of one DOCUMEN 22 ALAM	95D ARG 95 CLE2 nique as in \overline{b} - distribution. 8 B decay as to \overline{b}	$e^{+}e^{-} \rightarrow e^{+}e^{-} \rightarrow \tau^{+}\nu_{\tau}X$, beg.	$r(4s)$ ut analysis is Γ_{11}/Γ T T T T T T T	36 BORTOLETTO 92 assur Mark III branching fraction branching fraction into D 0.0003 where D^{**} repressible for the series of the series $B(\Upsilon(4S) \rightarrow B^+B^-) = BRECHT$ 90J. $\Gamma(D^-\pi^+\pi^+)/\Gamma_{total}$ WALUE	mes equal productions for the D and D ** π followed by D ' ents all orbitally exclose 0.5 and $0.$	*(2010). To the second	he authors also $2010)\pi$ to be sons. D and $D^*(2^{0})=45\%$. Since T in D and T in T in T	so find the 0.0014^{+0}_{-0} 0.0014^{+0}_{-0} 0.0010) and Supersedec	assi d by
(21.04 × 10 ⁻² (2.2 × 10 ⁻³) 20 BUSKULIC 95 use restricted to endpo 21 ALBRECHT 950 u (700 m ⁺)/Ftotal ALUE (10055±0.0005 OUR ALUE) (10055±0.0004±0.0006 (10050±0.0007±0.0006)	90 es same miss bint region c use full recor EVTS AVERAGE 05 304 06 54	ARTUSO sing-energy techr of missing-energy nstruction of one DOCUMEN 22 ALAM 23 BORTOL	95D ARG 95 CLE2 nique as in \overline{b} - distribution. a B decay as to \overline{b}	$\begin{array}{ccc} e^+e^- & \rightarrow & \\ e^+e^- & \rightarrow & \\ \rightarrow & \tau^+\nu_{\tau} X, \text{ b} \\ & & \text{ag.} \\ & & & \\ & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & $	$r(45)$ ut analysis is $rac{\Gamma_{11}/\Gamma}{\tau}$ $\rightarrow r(45)$ $\rightarrow r(45)$	36 BORTOLETTO 92 assur Mark III branching fraction branching fraction into D 0.0003 where D^{**} repressive the strength of the strength	mes equal productions for the D and D ** π followed by D ents all orbitally exe DG 86 branching : 55% and B(Υ(45) - CL% EVTS 90 3	*(2010). TI ** $\rightarrow D^*$ (2 cited D mes ratios for B^0 B^0 DOCUMEN B ALAM	he authors all 2010) π to be sons. D and $D^*(2^{10}) = 45\%$. $\frac{T}{10}$ $\frac{T}{94}$ CI	so find the $0.0014 + 0.0014 $	assid by F ₁₈ MMEN
<1.04 × 10 ⁻² <2.2 × 10 ⁻³ ²⁰ BUSKULIC 95 use restricted to endpo ²¹ ALBRECHT 95D u (D ⁰ π ⁺)/Γtotal ΔLUE .0053±0.0005 OUR / .0055±0.0004±0.000 .0050±0.0007±0.000 .0054-0.0018+0.001	90 es same miss oint region c use full recon EVTS AVERAGE 05 304 06 54 112 14	ARTUSO sing-energy techn of missing-energy nstruction of one DOCUMEN 22 ALAM 23 BORTOL 24 BEBEK	95D ARG 95 CLE2 nique as in \overline{b} - distribution. 8 B decay as to (T ID TE) 94 CL ETTO92 CL 87 CL	$\begin{array}{cccc} e^+e^- & \rightarrow & \\ e^+e^- & \rightarrow & \\ e^+e^- & \rightarrow & \\ \end{array}$ $\begin{array}{cccc} \tau^+\nu_{\tau}X, \ b \\ \\ \begin{array}{ccccc} & commen \\ \\ \end{array}$ $\begin{array}{ccccc} commen \\ \\ \end{array}$ $\begin{array}{ccccc} commen \\ \\ \end{array}$ $\begin{array}{ccccc} commen \\ \\ \end{array}$ $\begin{array}{cccccc} commen \\ \\ \end{array}$ $\begin{array}{cccccc} commen \\ \\ \end{array}$ $\begin{array}{cccccc} commen \\ \\ \end{array}$ $\begin{array}{cccccccccc} commen \\ \\ \end{array}$ $\begin{array}{cccccccccccccccccccccccccccccccccccc$	$r(45)$ ut analysis is $rac{\Gamma_{11}/\Gamma}{\tau}$ $\rightarrow r(45)$ $\rightarrow r(45)$	36 BORTOLETTO 92 assur Mark III branching fraction branching fraction into D 0.0003 where D^{**} repressible for the series of the series $B(\Upsilon(4S) \rightarrow B^+B^-) = BRECHT$ 90J. $\Gamma(D^-\pi^+\pi^+)/\Gamma_{total}$ WALUE	mes equal productions for the D and D when T and T ments all orbitally executed by D^{t} or D^{t} and	*(2010). TI ** $\rightarrow D^*$ (2 cited D mes ratios for B^0 B^0 DOCUMEN BALAM rages, fits, li	he authors also to be sons. D and $D^*(2^{-1}) = 45\%$. Since $\frac{T \cdot ID}{94} = \frac{T \cdot ID}{100} = \frac{T \cdot ID}{1000} = \frac{T \cdot ID}{1000} = \frac{T \cdot ID}{1000} = \frac{T \cdot ID}{10000} = \frac{T \cdot ID}{1000000000000000000000000000000000000$	so find the $0.0014 \stackrel{+}{-} 0$	assid by F18 MMEN e (4.5)
<1.04 × 10 ⁻² <2.2 × 10 ⁻³ ²⁰ BUSKULIC 95 use restricted to endpo ²¹ ALBRECHT 95D u (D0 π+)/Ftotal (ALUE .0063±0.0005 OUR A .0050±0.0007±0.000 .0050±0.0007±0.000 .0054-0.0015-0.000 • We do not use 1	90 es same missoint region of use full reconsesses full r	ARTUSO sing-energy techn of missing-energy nstruction of one DOCUMEN 22 ALAM 23 BORTOL 24 BEBEK g data for average	95D ARG 95 CLE2 nique as in \overline{b} - distribution. 8 decay as to 17 ID TEI STORY 94 CL STORY 87 CL ges, fits, limits	$\begin{array}{cccc} e^+e^- & \rightarrow & \\ e^+e^- & \rightarrow & \\ & \rightarrow & \tau^+\nu_{\tau} X, \text{ b} \\ & & \text{ag.} \\ & & \text{CN} & \underline{\text{COMMEN}} \\ & & \text{E2} & e^+e^- & \\ & & \text{EO} & e^+e^- & \\ & & \text{EO} & e^+e^- & \\ & & \text{, etc.} & \bullet & \bullet \\ \end{array}$	$r(45)$ ut analysis is $rac{\Gamma_{11}/\Gamma}{\tau}$ $rac{\tau}{\tau}$ $rac{\tau}{\tau}$ $rac{\tau}{\tau}$ $rac{\tau}{\tau}$ $rac{\tau}{\tau}$ $rac{\tau}{\tau}$ $rac{\tau}{\tau}$	36 BORTOLETTO 92 assur Mark III branching fraction branching fraction into D 0.0003 where D^{**} repressive the strength of the strength	mes equal productions for the D and D when T and T ments all orbitally executed by D^{t} or D^{t} and	*(2010). TI ** $\rightarrow D^*$ (2 cited D mes ratios for B^0 B^0 DOCUMEN BALAM rages, fits, li	he authors all 2010) π to be sons. D and $D^*(2^{10}) = 45\%$. $\frac{T}{10}$ $\frac{T}{94}$ CI	so find the $0.0014 + 0.0014 + 0.0014 + 0.0014 + 0.0014 + 0.0014$ Superseded LE2 $e^+e^+e^-$	assid by F18 MMEN e T(45
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$<1.04 \times 10^{-2}$ $<2.2 \times 10^{-3}$ 20 BUSKULIC 95 use restricted to endpo 21 ALBRECHT 95D u $(D^0\pi^+)/\Gamma$ total 20 ALBRECHT 95D u $(D^0\pi^+)/\Gamma$ ALBRECHT 95D u $(D^0\pi^+)/\Gamma$ ALBRECHT 95D u $(D^0\pi^+)/\Gamma$ ALBRECHT 95D u $(D^0\pi^+)/\Gamma$ total 20 ALBRECHT 85K 87 value 1 0.013 $\pm 0.0018 \pm 0.001$	es same missiont region cuse full recoil region cuse full recoil see full recoil region cuse full recoil region cuse full recoil region cuse full recoil re	ARTUSO sing-energy technif missing-energy processing and processi	95D ARG 95 CLE2 195 CLE2 196 distribution. 19 B decay as ta 17 ID TEC 18 CLETTO92 CL 187 CL 187 CL 188 AB at the 19 B($D^0 \rightarrow K^-$ 184 CL 185 Super State of the second of	$e^+e^- \rightarrow e^+e^- \rightarrow e^+e^- \rightarrow e^+e^- \rightarrow e^+e^- \rightarrow e^+e^- \rightarrow e^+e^- \rightarrow e^-e^- \rightarrow e^-e^- \rightarrow e^-e^- \rightarrow e^-e^- \rightarrow e^-e^- \rightarrow e^-e^- \rightarrow e^-e^-e^- \rightarrow e^-e^- ^- \rightarrow e^-e^- ^- \rightarrow e^-e^- ^- \rightarrow e^-e^- ^- \rightarrow e^-e^- ^- \rightarrow e^-e^- ^- \rightarrow e^-e^- ^- \rightarrow e^-e^- ^- \rightarrow e^-e^- ^- \rightarrow e^-e^- $	$r(45)$ ut analysis is $r(45)$ ut analysis is $r(11/\Gamma)$ r $r(45)$ $r(45)$ $r(45)$ $r(45)$ $r(45)$ $r(45)$ $r(45)$ $r(45)$ Help cled II $r(45)$	36 BORTOLETTO 92 assur Mark III branching fraction branching fraction into D 0.0003 where D^{**} represents 77 ALBRECHT 87c use PIB($T(45) \rightarrow B^+B^-$) = BRECHT 901. $\Gamma(D^-\pi^+\pi^+)/\Gamma_{total}$ 20.0014 • • • We do not use the foll 0.007 0.0025 0.007 0.0025 0.007 0.0028 38 ALAM 94 assume equal 0.007 BORTOLETTO 92 assur Mark III branching fraction followed by 0.007 0.005 0.007 0.005 0.007 0.005 0.007 0.005 0.007 0.005 0.007 0.005 0.007 0.005 0.007 0.005 0.007 0.005 0.007 0.005 0.007 0.007 0.007 0.007 0.007 0.007 0.007 0.0018 0.0016 0.0016 $0.0040 \pm 0.0014 \pm 0.0012$ • • • We do not use the foll $0.0040 \pm 0.0014 \pm 0.0012$	nes equal productions for the D and D with π followed by D^{*} ents all orbitally excludes D and D or D or D and D or	*(2010). TI ** $\rightarrow D^*(2)$ Eited D mes ratios for artisos $B^0 B^0 B^0$ BALAM **ages, fits, li **go BEBEK** and B^0 at the artisos $B^0 B^0$ at the artisos $B^0 B^0$. B **ENT ID **GOUNDENT OF ARTISOS FOR	he authors also 2010) π to be sons. D and $D^*(2^{00}) = 45\%$.	so find the $0.0014 + 0.0014 + 0.0014 + 0.0014 + 0.0014 + 0.0010$ and Superseded Supersed Supersed Supersed Supersed Supersed Superseded Superseded Super	e prod 0.0000 assu assu Fig MMEN T(45) And (45) C(45)
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$<1.04 \times 10^{-2}$ $<2.2 \times 10^{-3}$ 20 BUSKULIC 95 use restricted to endpo 21 ALBRECHT 95D u 7	es same missiont region cuse full recoil see	ARTUSO sing-energy technif missing-energy properties of the single-energy posturation of one and the properties of the	95D ARG 95 CLE2 195 CLE2 196 distribution. 19 B decay as ta 19 4 CL 197 CL 197 CL 198 GEN 199 AR 19	$\begin{array}{c} e^+e^- \rightarrow \\ e^-e^- \rightarrow \\ e^-e$	$\begin{array}{c} r(4s) \\ \text{ut analysis is} \\ \hline \Gamma_{11}/\Gamma \\ \hline \tau \\ \hline \\ \rightarrow r(4s) \\ \text{is the CLEO III} \\ \rightarrow \kappa^-\pi^+) \\ \text{IIII branching sumptions as} \\ \text{BRECHT 90J.} \\ \hline \Gamma_{12}/\Gamma \\ \hline \tau \\ \rightarrow r(4s) \\ \text{is the CLEO II} \\ \rightarrow r(4s) \\ \rightarrow r(4s$	36 BORTOLETTO 92 assur Mark III branching fraction into D 0.0003 where D^{**} representations of the second state of the	nes equal productions for the D and D ** π followed by D° ents all orbitally excloses 86 branching: 55% and B(Υ (45) $\frac{EVTS}{90}$ 3 owing data for average 90 \$\text{1}\$ 4 production of B^+ ; $\frac{EVTS}{90}$ EVT	*(2010). TI ** $\rightarrow D^*(2i)$ *(2010). TI ** $\rightarrow D^*(2i)$ *(2010). TI ** $\rightarrow D^*(2i)$ *(3) $\rightarrow B^0\overline{B}$ *(3) $\rightarrow B^0\overline{B}$ *(3) $\rightarrow B^0\overline{B}$ *(4) $\rightarrow B^0\overline{B}$ *(5) $\rightarrow B^0\overline{B}$ *(5) $\rightarrow B^0\overline{B}$ *(6) $\rightarrow B^0\overline{B}$ *(7) $\rightarrow B^0\overline{B}$ *(8) $\rightarrow B^0\overline{B}$ *(9) $\rightarrow B^0\overline{B}$ *(9) $\rightarrow B^0\overline{B}$ *(10) $\rightarrow B^0\overline{B}$ *(11) $\rightarrow B^0\overline{B}$ *(12) $\rightarrow B^0\overline{B}$ *(13) $\rightarrow B^0\overline{B}$ *(14) $\rightarrow B^0\overline{B}$ *(15) $\rightarrow B^0\overline{B}$ *(16) $\rightarrow B^0\overline{B}$ *(17) $\rightarrow B^0\overline{B}$ *(18) $\rightarrow B^0\overline{B}$ *(19) $\rightarrow B^0\overline$	he authors also 2010) π to be sons. D and $D^*(2^{0}) = 45\%$. Similarly, etc. D are and D at the D and D at the D and D at the D and D and D are and into D and D are and D are and D are an D are an D and D are an D are an D are an D and D are an	so find the $0.0014 + 0.0014 + 0.0014 + 0.0014 + 0.0014 + 0.0010$ and Superseded Superseded LEO e^+ (e^+) and use the e^+ (e^+) and e^- (e^+) and e^- (e^-) and e^-) and e^- (e^-) and e^- (e^-) and e^-) and e^- (e^-) and e^-) and e^- (e^-) and e^-	process proc
$<1.04 \times 10^{-2}$ $<2.2 \times 10^{-3}$ $<2.0 \text{ BUSKULIC 95 use}$ restricted to endpo 2 2 ALBRECHT 950 uP 2 3	## 190 ## 200 ##	ARTUSO sing-energy technif missing-energy properties of the single-energy posturation of one and the properties of the	95D ARG 95 CLE2 195 CLE2 196 distribution. 19 B decay as ta 19 4 CL 197 CL 197 CL 198 GEN 199 AR 19	$\begin{array}{c} e^+e^- \rightarrow \\ e^-e^- \rightarrow \\ e^-e$	$r(45)$ ut analysis is $r(11/\Gamma)$ $r(45)$ $r(45)$ $r(45)$ $r(45)$ $r(45)$ $r(45)$ $r(45)$ $the CLEO III r(45) r(45$	36 BORTOLETTO 92 assur Mark III branching fraction branching fraction into D 0.0003 where D^{**} represents 37 ALBRECHT 87c use PI B($T(45) \rightarrow B^+B^-$) = BRECHT 901. $\Gamma(D^-\pi^+\pi^+)/\Gamma_{\text{total}}$ 20.0014 •• • We do not use the foll $0.0025 + 0.0023 - 0.0008$ 38 ALAM 94 assume equal $0.0025 + 0.0023 - 0.0008$ 38 ALAM 94 assume equal $0.0025 + 0.0023 - 0.0008$ 39 BORTOLETTO 92 assur Mark III branching fraction followed by $D_0^*(2340) \rightarrow D_0^*(2340) \rightarrow D_0^*(2400) \rightarrow D_0^*(2400) \rightarrow D_0^*(2400) \rightarrow D_0^*(2000) \rightarrow D_0^$	nes equal productions for the D and D with π followed by D^{*} ents all orbitally excloded 86 branching: 55% and B($T(4S)$) and $T(4S)$ owing data for average $T(4S)$ owing data for average $T(4S)$ decays 43% to	*(2010). TI ** $\rightarrow D^*(2)$ Eited D mes ratios for a ratios B^0 B ALAM rages, fits, li B^0 B BBEK and B^0 at the ratio B^0 at B^0 EIT B^0 EIT B^0 CICHT 90. Grages, fits, li B^0 CICHT 90. Grages, fits, li B^0 CICHT 90. B^0 EIT B^0 EIT B^0 CICHT 90. B^0 EIT	he authors also 2010) π to be sons. D and $D^*(2^{0}) = 45\%$. Solution D and $D^*(2^{0}) = 45\%$. Solution D and $D^*(2^{0}) = 45\%$. Solution D and	so find the $0.0014+0.$	Γ_{19} assistant Γ_{19} and Γ_{19} are Γ_{19} and Γ_{19} and Γ_{19} and Γ_{19} are Γ_{19} and Γ_{19} and Γ_{19} are Γ_{19} and Γ_{19} are Γ_{19} and Γ_{19} and Γ_{19} are Γ_{19} are Γ_{19} and Γ_{19} are Γ_{19} are Γ_{19} and Γ_{19} are Γ_{19} are Γ_{19} and Γ_{19} are Γ_{19} and Γ_{19} are Γ_{19} and Γ_{19} are Γ_{19} and Γ_{19} are Γ_{19} are Γ_{19} and Γ_{19} are Γ_{19} are Γ_{19} are Γ_{19} are Γ_{19} and Γ_{19} are
<1.04 × 10 ⁻² <2.2 × 10 ⁻³ ²⁰ BUSKULIC 95 use restricted to endpo 21 ALBRECHT 95D u (D07 π+)/Γtotal (ALUE 1.0053±0.0005 OUR 0 0.0055±0.0007±0.000 0.0055±0.0007±0.000 0.0055±0.0007±0.000 0.0050±0.0007±0.000 0.0050±0.0005±0.000 0.0050±0.0005±0.000 0.0050±0.0005±0.000 0.0050±0.0005±0.000 0.0050±0.0005±0.000 0.0019±0.0010±0.000 0.0019±0.0010±0.000 0.0019±0.0010±0.000 0.0019±0.0010±0.000 0.0019±0.0010±0.000 0.0019±0.0010±0.000 0.0010±0.000	## 190 ## 200 ##	ARTUSO sing-energy technism in missing-energy technism in missing-energy missing-energy missing-energy instruction of one 22 ALAM 23 BORTOL 24 BEBEK g data for average 23 ALBRECI 25 ALBRECI 25 ALBRECI 26 ALBRECI 27 ALBRECI 28 ALBRECI 29 ALBRECI 29 ALBRECI 20 ALAM 20 ALBRECI 20 ALAM 21 ALBRECI 21 ALAM 22 ALBRECI 23 ALBRECI 24 ALAM 26 ALAM 27 ALBRECI 28 ALBRECI 28 ALBRECI 29 ALBRECI 29 ALBRECI 20 ALBRECI 20 ALBRECI 20 ALBRECI 21 ALBRECI 22 ALBRECI 23 ALBRECI 24 ALBRECI 25 ALBRECI 26 ALBRECI 27 ALBRECI 28 ALBRECI 28 ALBRECI 29 ALBRECI 20 ALBRECI 20 ALBRECI 20 ALBRECI 21 ALBRECI 22 ALBRECI 23 ALBRECI 24 ALBRECI 25 ALBRECI 26 ALBRECI 27 ALBRECI 28 ALBRECI 28 ALBRECI 29 ALBRECI 20 ALBRECI 21 ALBRECI 22 ALAM 23 ALBRECI 25 ALBRECI 26 ALAM 27 ALBRECI 26 ALAM 27 ALBRECI 27 ALBRECI 28 ALBRECI 28 ALBRECI 28 ALBRECI 28 ALBRECI 29 ALBRECI 20 ALBRECI 21 ALBRECI 22 ALAM 23 ALBRECI 24 ALBRECI 25 ALBRECI 26 ALAM 27 ALBRECI 26 ALAM 27 ALBRECI 27 ALBRECI 28 ALBRECI 29 ALBRECI 20 ALBR	95D ARG 95 CLE2 195 CLE2 196 STEP 197 CLE3 198 DECAY AS TAIL 197 CL 87 CL 87 CL 198 SEP 199 AR HT 190 AR 1	$e^+e^- \rightarrow e^+e^- \rightarrow e^+e^- \rightarrow e^+e^- \rightarrow e^+e^- \rightarrow e^+e^- \rightarrow e^+e^- \rightarrow e^-e^- \rightarrow e^-e^- \rightarrow e^-e^- \rightarrow e^-e^- \rightarrow e^-e^- \rightarrow e^-e^- \rightarrow e^-e^-e^- \rightarrow e^-e^- ^- \rightarrow e^-e^- \rightarrow e^-e^- \rightarrow e^-e^-e^- \rightarrow e^-e^-e^- \rightarrow e^-e^-e^-e^-e^-e^-e^-e^-e^-e^-e^-e^-e^-e$	$\begin{array}{c} r(4s) \\ \text{ut analysis is} \\ \hline \Gamma_{11}/\Gamma \\ \hline \tau \\ \hline \\ \rightarrow r(4s) \\ \text{is the CLEO III} \\ \rightarrow \kappa^-\pi^+) \\ \text{IIII branching sumptions as} \\ \text{BRECHT 90J.} \\ \hline \Gamma_{12}/\Gamma \\ \hline \tau \\ \rightarrow r(4s) \\ \text{is the CLEO II} \\ \rightarrow r(4s) \\ \rightarrow r(4s$	36 BORTOLETTO 92 assur Mark III branching fraction branching fraction into D 0.0003 where D^{**} represe 37 ALBRECHT 87c use PI B($\Gamma(4S) \rightarrow B^+B^-$) = BRECHT 90.1 F($D^-\pi^+\pi^+$)/ Γ total VALUE <0.0014 • • • We do not use the foll <0.007 0.0025 $^+$ 0.0041 $^+$ 0.0024 $^-$ 0.0023 $^-$ 0.0008 38 ALAM 94 assume equal $^-$ 18 BORTOLETTO 92 assur Mark III branching fraction followed by D^* (2340) $^-$ 19 D^* 2(2460) $^-$ 10 D^* 15 $^-$ 10 D^* 16 $^-$ 11 D^* 16 D^* 16 D^* 17 D^* 17 D^* 18 BEBEK 87 assumed. F(\overline{D}^* (2007) $^0\pi^+$)/ Γ total VALUE D^* 19 D^* 10 D^* 10 D^* 10 D^* 2 D^* 10 D^* 10 D^* 2 D^* 3 D^* 40 D^* 4	nes equal productions for the D and D with π followed by D^{*} ents all orbitally excludes D and D owing data for average D owing data for average D owing data for average D owing data for average D owing data D owing data D owing data for average D owing data for a D	*(2010). TI ** $\rightarrow D^*(2)$ Eited D mes ratios for a ratios B^0 B ALAM rages, fits, li B^0 B BBEK and B^0 at the ratio B^0 at B^0 EIT B^0 EIT B^0 CICHT 90. Grages, fits, li B^0 CICHT 90. Grages, fits, li B^0 CICHT 90. B^0 EIT B^0 EIT B^0 CICHT 90. B^0 EIT	he authors also 2010) π to be sons. D and $D^*(2^{0}) = 45\%$. Solution D and $D^*(2^{0}) = 45\%$. Solution D and $D^*(2^{0}) = 45\%$. Solution D and	so find the $0.0014+0.$	Γ_{19} assistant Γ_{19} and Γ_{19} are Γ_{19} and Γ_{19} and Γ_{19} and Γ_{19} are Γ_{19} and Γ_{19} and Γ_{19} are Γ_{19} and Γ_{19} are Γ_{19} and Γ_{19} and Γ_{19} are Γ_{19} are Γ_{19} and Γ_{19} are Γ_{19} are Γ_{19} and Γ_{19} are Γ_{19} are Γ_{19} and Γ_{19} are Γ_{19} and Γ_{19} are Γ_{19} and Γ_{19} are Γ_{19} and Γ_{19} are Γ_{19} are Γ_{19} and Γ_{19} are Γ_{19} are Γ_{19} are Γ_{19} are Γ_{19} and Γ_{19} are
$<1.04 \times 10^{-2}$ $<2.2 \times 10^{-3}$ $<2.0 \text{ BUSKULIC 95 use}$ restricted to endpo 2 2 ALBRECHT 950 uP 2 3	90 es same mission tegion cuse full recoil see full recoil se	ARTUSO sing-energy technif missing-energy properties of the single-energy posturation of one and the properties of the	95D ARG 95 CLE2 nique as in \overline{b} distribution. B decay as to distribution. B decay as to distribution. 94 CL ETTO92 CL 87 CL ges, fits, limits HT 90J AR HT 88K AR d B^0 at the 7 π^+). 18 CL HT 90J AR ELMAN 91 to distribution of the dis	$e^+e^- \rightarrow e^+e^- \rightarrow e^-e^- ^- \rightarrow e^-e^- $	$\begin{array}{c} r(4s) \\ \text{ut analysis is} \\ \hline \Gamma_{11}/\Gamma \\ \hline \tau \\ \hline \\ \rightarrow r(4s) \\ \text{is the CLEO III} \\ \rightarrow \kappa^-\pi^+) \\ \text{III branching sumptions as} \\ \text{BRECHT 90J.} \\ \hline \Gamma_{12}/\Gamma \\ \hline \tau \\ \rightarrow r(4s) \\ \rightarrow r(4s) \\ \rightarrow r(4s) \\ \text{is the CLEO III} \\ \rightarrow r(4s) \\ \rightarrow r(4s) \\ \text{is the CLEO III} \\ \rightarrow r(4s) \\ \rightarrow r(4$	36 BORTOLETTO 92 assur Mark III branching fraction branching fraction into D 0.0003 where D^{**} represents 37 ALBRECHT 87c use PI B($T(45) \rightarrow B^+B^-$) = BRECHT 901. $\Gamma(D^-\pi^+\pi^+)/\Gamma_{\text{total}}$ 20.0014 •• • We do not use the foll $0.0025 + 0.0023 - 0.0008$ 38 ALAM 94 assume equal $0.0025 + 0.0023 - 0.0008$ 38 ALAM 94 assume equal $0.0025 + 0.0023 - 0.0008$ 39 BORTOLETTO 92 assur Mark III branching fraction followed by $D_0^*(2340) \rightarrow D_0^*(2340) \rightarrow D_0^*(2400) \rightarrow D_0^*(2400) \rightarrow D_0^*(2400) \rightarrow D_0^*(2000) \rightarrow D_0^$	nes equal productions for the D and D with T followed by D^{*} ents all orbitally exclosed 86 branching: 55% and B(T (45) T for T	*(2010). TI ** $\rightarrow D^*(2010)$. TI ** $\rightarrow D^*(2010)$. The state of D mes ratios for a ratio B^0 at the state of B^0 at the ratio B^0 and B^0 at the ratio B^0 and B^0 at the ratio B^0 at the ratio B^0 and B^0 at the ratio B^0 and B^0 and B^0 at the ratio B^0 and B^0 and B^0 at the ratio B^0 and B^0 and	he authors also 2010) π to be sons. D and $D^*(2^{*0}) = 45\%$. $S^{*0} $	so find the $0.0014+0.0014+0.0014+0.0014+0.0014+0.0014+0.001010$ and Supersedect $\frac{ECN}{ECN}$ COM. LE2 e^+ e^+ $e^ e^	proposed pr

Γ(D *(2007) ⁰ ρ ⁺)/r _{total}				Γ_{20}/Γ
VALUE 0.0155±0.0031 O	JR AVERAGE	DOCUMENT I	<u>TECN</u>	COMMENT	
$0.0168 \pm 0.0021 \pm 0$ $0.010 \pm 0.006 \pm 0$		44 ALAM 45 ALBRECHT	94 CLE2 90J ARG	$e^+e^- \rightarrow \gamma$ $e^+e^- \rightarrow \gamma$	` '
44 ALAM 94 assu	me equal production	on of B^+ and B	0 at the Υ (45) and use the	CLEO II
B(D*(2007)0	$ ightarrow D^0 \pi^0$) and abs $D^0 ightarrow K^- \pi^+$) as	solute B($D^0 \rightarrow$	$K^-\pi^+$) and t	ne PDG 1992 I	$B(D^0 \rightarrow$
$K^-\pi^+\pi^0)/B($	$(D^0 \rightarrow K^-\pi^+)$ and π^0 contribution (nd B($D^0 \rightarrow K^-$ under the ρ^+ is	π™π™π™)/B negligible.	$(D^0 \rightarrow K^-\pi)$	⊤). The
⁴⁵ Assumes equal	production of B^+	$^{ ext{-}}$ and $B^{ ext{O}}$ at the	r(4S) and u	ses Mark III b	ranching
	e <i>D</i> and <i>D*</i> (2010)	•			- /-
Γ(D *(2007) ⁰ π ⁺ VALUE	π'π)/ total	DOCUMENT I	<u>TECN</u>	COMMENT	Γ ₂₁ /Γ
0.0094±0.0020±0	.0017 48 46	,47 ALAM	94 CLE2	$e^+e^- \rightarrow \gamma$. ,
$B(D^*(2007)^0 + K^-\pi^+\pi^0)/B(47$ The three pion	me equal production $D^0 \pi^0$) and absolute $D^0 \to K^- \pi^+$) and absolute $K^0 \to K^- \pi^+$ and $K^0 \to K^- \pi^+$ are $K^0 \to K^- \pi^+$.	solute B($D^0 \rightarrow K$) and B($D^0 \rightarrow K$) to be between 1.	$(K^-\pi^+)$ and the $(K^-\pi^+\pi^+\pi^-)/(\pi^+\pi^-)$	The PDG 1992 \mathbb{R} $\mathbb{R}(D^0 \rightarrow \mathcal{K}^-)$ consistent with	$B(D^0 ightarrow \pi^+)$. th an a_1
Γ(D *(2007) ⁰ a ₁	(1260) ⁺)/Γ _{total}				Γ ₂₂ /Γ
VALUE 0.0188±0.0040±0	10.10	DOCUMENT ID			;; (i)
48 ALAM 94 valu observation tha	ie is twice their F it the three pions a	$(\overline{D}^*(2007)^0\pi^+)$ are dominantly in	$\pi^+\pi^-)/\Gamma_{ m total}$ n the $a_1(1260)$	value based mass range 1.	on their 0 to 1.6
$B(D^*(2007)^0$	me equal production $D^0\pi^0$ and absolute $D^0 o K^-\pi^+$)	solute B($D^0 \rightarrow$	$K^-\pi^+$) and the	ne PDG 1992 E	$3(D^0 \rightarrow$
Γ(D*(2010) ⁻ π ⁻	$^+\pi^+\pi^0)/\Gamma_{ m total}$				Γ_{23}/Γ
<i>VALUE</i> 0.0150±0.0070 ±0	.0003 26	DOCUMENT II	90J ARG	$\frac{COMMENT}{e^+e^- \rightarrow \gamma}$	(45)
	ise the following d	ata for averages,	fits, limits, etc		(43)
0.043 ±0.013 ±0		⁵¹ ALBRECHT		$e^+e^- \rightarrow \gamma$	
0.06. We resca	U reports 0.018 ± 0 le to our best value	0.007 ± 0.005 for B($D^*(2010)^+$	$\rightarrow D^0 \pi^+) =$	$\rightarrow D^{0}\pi^{+}) =$ (68.3 ± 1.4)	= 0.57 ± × 10 ⁻² .
Our first error	is their experimen best value. Assum	t's error and ou	second error	is the systema	tic error
uses Mark III bi	anching fractions	for the D .			
	7C use PDG 86 $B^+B^-) = 55\%$ and				
Γ(<i>D</i> *(2010) ⁻ π ⁻¹					Γ ₂₄ /Γ
<i>∨ALUE</i> <0.01		DOCUMENT ID ALBRECHT		$e^- \rightarrow \Upsilon(4S)$:)
52 Assumes equal	production of B^+ e D and D^* (2010)	and B^0 at the		,	′
$\Gamma(\overline{D}_{1}^{*}(2420)^{0}\pi^{+}$)/F _{total}				Γ ₂₅ /Γ
<u>VALUE</u> 0.0015±0.0006 OL	EVTS	DOCUMENT II		COMMENT	
$0.0011 \pm 0.0005 \pm 0$.0002 8	⁵³ ALAM	94 CLE2		(45)
0.0025 ± 0.0007 ± 0	.0006 me equal productio	⁵⁴ ALBRECHT			(4 <i>5</i>)
$B(D^*(2010)^+$	$\rightarrow D^0 \pi^+$) and ab	solute B($D^0 \rightarrow$	$K^-\pi^+$) and t	he PDG 1992 B	$3(D^0 \rightarrow$
$K^-\pi^+\pi^0)/B($	$D^0 ightarrow K^-\pi^+$) and D assume equal p	d assuming $B(D)$	$(2420)^0 \rightarrow D$	* $(2010)^{+}\pi^{-}$)	= 67%.
CLEO II B(D*	$(2010)^+ \rightarrow D^0 \pi$	⁺) assuming B	$(D_1(2420)^0 -$	$D^*(2010)^+$	$\pi^-) =$
67%.					
$\Gamma(\overline{D}_1^*(2420)^0 \rho^+$		DOCUMENT ID	TECN CO	MACNE	Γ_{26}/Γ
VALUE <0.0014		DOCUMENT ID ALAM)
55 ALAM 94 assu	me equal production	on of B^+ and B	0 at the $\Upsilon(4S)$) and use the	CLEO II
Β(<i>D</i> *(2010) ⁺ Γ ($\rightarrow D^0 \pi^+$) assum	ing B(<i>D</i> ₁ (2420)	$J \rightarrow D^*(2010)$	$(10^{+}\pi^{-}) = 67\%$	₆ . Г ₂₇ /Г
VALUE	CL%	DOCUMENT ID	TECN CO	MMENT	. 21/'
<0.0013 • • • We do not u	90 56	ALAM 9	94 CLE2 e^+	$e^- \rightarrow \gamma (4S)$)
<0.0028				$e^- \rightarrow \Upsilon(4S)$)
<0.0023	90 58	ALBRECHT 9	94D ARG e ⁺	$e^- \rightarrow \Upsilon(45)$	j l
56 ALAM 94 assur	me equal production $\pi^+\pi^+$) and B(D_2^*) and use the	Mark III
B($D^+ \rightarrow K^-$	me equal production $\pi^+\pi^+$), the CLE	on of B^+ and B	0 at the Υ (4 S) and use the and $B(D_2^*(24))$	Mark III 60) ⁰ →
D*(2010) ⁺ π ⁻ 58 ALBRECHT 94) = 20%. D assume equal p	roduction of R+	and B^0 at the	ie $\Upsilon(4S)$ and	use the
CLEO II B(D*($(2010)^+ \rightarrow D^0 \pi^+$) and B(D*2(24	$50)^0 \rightarrow D^*(20)$	$(10)^{+}\pi^{-}) =$	30%.
		_			

$\Gamma(\overline{D}_2^*(2460)^0 \rho^+)$	<u>CL%</u>			ECN COMME	
<0.0047 <0.005	90 90	⁵⁹ ALAM ⁶⁰ ALAM	94 C 94 C	LE2 e ⁺ e ⁻ LE2 e ⁺ e ⁻	$\rightarrow \Upsilon(4S)$ $\rightarrow \Upsilon(4S)$
⁵⁹ ALAM 94 assume	e equal pro $+\pi^+$) and	duction of B^+ an $B(D_2^*(2460)^0 \rightarrow$	d B ⁰ at	the $\Upsilon(4S)$ an	
60 ALAM 94 assume	e equal pro $^+\pi^+$), the	duction of B^+ an CLEO II B(D^* (20	d B^0 at	the $\Upsilon(4S)$ an	d use the Mark $B(D_2^*(2460)^0)$
$\Gamma(\overline{D}{}^0D_s^+)/\Gamma_{\text{total}}$					Γ ₂₉
0.017±0.006 OUR A 0.018±0.009±0.004	VERAGE	61 ALBRECHT 62 BORTOLET		RG e^+e^-	
$0.016 \pm 0.007 \pm 0.004$	5				
62 BORTOLETTO 9	t value B(<i>E</i> and our se 90 <i>D</i> ⁰ brar 0 reports 0	$O_s^+ o \phi \pi^+) = (3)$ scond error is the specified ratios, e.g.,	3.6 ± 0.9) ystematic $B(D^0 \rightarrow 0)$	0×10^{-2} . Out error from us $K^-\pi^+) = 0.02$.	r first error is thing our best val 3.71 \pm 0.25%. We rescale to ϵ
error and our seco	ond error is	the systematic em	ror from ι	using our best	value.
$\Gamma(\overline{D}^0 D_s^{*+})/\Gamma_{\text{total}}$		DOCUMENT IE	<u> </u>	ECN COMME	Г ₃₀
0.012±0.009±0.003		⁶³ ALBRECHT	92G A		$\rightarrow \gamma(45)$
63 ALBRECHT 92G	reports 0.0	016 ± 0.012 ± 0.0	003 for B	$(D_s^+ \rightarrow \phi \pi$	⁺) = 0.027. ¹
rescale to our bes experiment's error Assumes PDG 19	t value B(<i>E</i> and our se 90 <i>D</i> ⁰ bran	$Q_s^+ \rightarrow \phi \pi^+) = (3)$ cond error is the synching ratios, e.g.,	3.6 ± 0.9) ystematic $B(D^0 \rightarrow$	$(\times 10^{-2}) \times 10^{-2}$. Ou error from us $(K^-\pi^+) = 0$	r first error is thing our best val $3.71\pm0.25\%$.
$\Gamma(\overline{D}^*(2007)^0 D_s^+)$	/Γ _{total}	DOCUMENT ID) <u>T</u>	ECN COMME	Γ ₃₁
		64 ALBRECHT	92G A		$\rightarrow \Upsilon(4S)$
$0.010\pm0.007\pm0.002$					
64 ALBRECHT 92G	reports 0.0	013 ± 0.009 ± 0.0	002 for B	$(D_s^+ \rightarrow \phi \pi$	+) = 0.027. \
64 ALBRECHT 92G rescale to our best	t value B(<i>E</i>		002 for B 3.6 ± 0.9	$(D_s^+ \rightarrow \phi \pi) \times 10^{-2}$. Our	+) = 0.027. Ver first error is the
64 ALBRECHT 926 rescale to our besi experiment's error Assumes PDG 19 $_{3.71}\pm0.25\%$ and $\Gamma(\overline{D}^*(2007)^0D_s^{*+})$	t value B($\it L$) and our se 90 $\it D^0$ and 1 B($\it D^*$ (200	$013 \pm 0.009 \pm 0.00$ $O_s^+ \to \phi \pi^+) = (300000000000000000000000000000000000$	002 for B 3.6 ± 0.9 ystematic ching ration $= 55 \pm 69$	$(D_s^+ \rightarrow \phi \pi) \times 10^{-2}$. Ou error from us os, e.g., B(D%.	$^{+}$) = 0.027. Ye first error is the sing our best val $^{0} \rightarrow \kappa^{-}\pi^{+}$)
64 ALBRECHT 92G rescale to our best experiment's error Assumes PDG 19 3.71 ± 0.25% and	t value B($\it L$) and our se 90 $\it D^0$ and 1 B($\it D^*$ (200	$0.03 \pm 0.009 \pm 0.00$ $0.05 + 0.009 \pm 0.009$ $0.05 + 0.009 \pm 0.009$ 0.05 + 0.009 0.05 + 0.009 0.	002 for B 3.6 ± 0.9) ystematic ching rati $= 55 \pm 69$	$(D_s^+ \rightarrow \phi \pi) \times 10^{-2}$. Our error from us os, e.g., B(D).	$^{+}$) = 0.027. Ye first error is the sing our best val $^{0} \rightarrow \kappa^{-}\pi^{+}$)
64 ALBRECHT 92G rescale to our best experiment's error Assumes PDG 19 3.71 ± 0.25% and \(\bar{D}^*(2007)^0 D_5^* + \bar{VALUE} \)	t value B(L) and our se 90 D^0 and B(D^* (200) $/\Gamma_{total}$	$0.03 \pm 0.009 \pm 0.009$ 0.09 + 0.009 + 0.009 0.000 + 0.009 + 0.009 0.000 + 0.009 + 0.009 0.000 + 0.009 + 0.009 0.000 + 0.009	002 for B 3.6 ± 0.9) ystematic ching ration 5.5 ± 6.9 0.5 ± 0.9 0.5 ± 0.9 0.5 ± 0.9	$(D_s^+ \rightarrow \phi \pi) \times 10^{-2}$. Ou error from us os, e.g., B(D%.	$^{+}$) = 0.027. The first error is the fing our best value 0 $^{-}$ $^{-$
64 ALBRECHT 92G rescale to our best experiment's error Assumes PDG 19 3.71 ± 0.25% and Γ(D*(2007) ⁰ D _s *+ VALUE 0.023±0.013±0.006 65 ALBRECHT 92G rescale to our best experiment's error	t value $B(L)$ and our se $90 \ D^0$ and $B(D^*(200))$ / Γ_{total} reports 0.0 t value $B(L)$ and our se	$0.03 \pm 0.009 \pm 0.009$ 0.09 + 0.009 + 0.009 0.000 + 0.009 + 0.009 0.000 + 0.009 + 0.009 0.000 + 0.009 + 0.009 0.000 + 0.009	002 for B 3.6 ± 0.9) ystematic ching ration $= 55 \pm 6$ 9 $\frac{7.0}{926}$ A $= 2.005$ for B $= 3.6 \pm 0.9$) ystematic	$ \begin{array}{ccc} (D_s^+ \rightarrow & \phi \pi \\ > \times 10^{-2}. & \text{Ou} \\ \text{error from us} \\ \text{os, e.g., B}(D) \\ \%. \\ \end{array} $	$+$) = 0.027. If irst error is the sing our best value $0 \rightarrow \kappa - \pi + 1$. Figure $0 \rightarrow \kappa - \pi + 1$. Figure $0 \rightarrow \kappa - \pi + 1$. If irst error is the notion of the single our best value $0 \rightarrow \kappa - 1$. If irst error is the notion of the single our best value $0 \rightarrow \kappa - 1$.
64 ALBRECHT 92G rescale to our best experiment's error Assumes PDG 19 $3.71 \pm 0.25\%$ and $\Gamma(\overline{D}^*(2007)^0 D_s^{*+})$ WALUE 0.003 $\pm 0.013 \pm 0.006$ 65 ALBRECHT 92G rescale to our best experiment's error Assumes PDG 19 $3.71 \pm 0.25\%$ and $\Gamma(D_s^+\pi^0)/\Gamma_{total}$	t value B(L and our segon D^0 and B(D^* (200) D^0 and B(D^* (200) D^0 reports 0.0 t value B(L and our segon D^0 and B(D^* (200)	$0.13 \pm 0.009 \pm 0.0$ $0.5^+ \rightarrow \phi \pi^+) = (3 \pm 0.009 \pm 0.0)$ $0.5^+ \rightarrow \phi \pi^+) = (3 \pm 0.009 \pm 0.0)$ $0.7^+ (2007)^0$ brand $0.7^+ (2007)^0 \rightarrow D^0 \pi^0) = (3 \pm 0.016 \pm 0.0)$ $0.7^+ \rightarrow \phi \pi^+) = (3 \pm 0.009 \pm 0.0)$ $0.7^+ (2007)^0$ brand $0.7^+ (2007)^0 \rightarrow D^0 \pi^0) = (3 \pm 0.009 \pm 0.0)$	002 for B 3.6 ± 0.9) systematic ching ration $= 55 \pm 69$ 0.05 for B 0.05 f	$(D_s^+ \rightarrow \phi \pi) \times 10^{-2}$. Ou error from us os, e.g., B(D%. ECN COMME RG $e^+e^ (D_s^+ \rightarrow \phi \pi) \times 10^{-2}$. Our error from us os, e.g., B(D%.	$^{+}$) = 0.027. If irst error is the sing our best value 0 $\rightarrow K^{-}\pi^{+}$) Factor $^{+}$ $\rightarrow \Upsilon(4S)$ $^{+}$ $^{+}$ $^{+}$ $^{+}$ $^{+}$ $^{+}$ $^{+}$ $^{-}$ $^{-}$ $^{-}$ $^{-}$ $^{+}$ $^{-}$
64 ALBRECHT 92G rescale to our best experiment's error Assumes PDG 19 3.71 ± 0.25% and F (\$\overline{D}^*(2007)^0 D_s^*+' \\ VALUE 0.023±0.013±0.006 65 ALBRECHT 92G rescale to our best experiment's error Assumes PDG 19 3.71 ± 0.25% and	t value $B(L)$ and our se $90 \ D^0$ and $B(D^*(200))$ / Γ_{total} reports 0.0 t value $B(L)$ and our se	$013 \pm 0.009 \pm 0.0$ 0.009 ± 0.0	002 for B 3.6 ± 0.9) ystematic ching ration 0.5 ± 6.9 0.5 ± 6.9 0.5 ± 6.9 0.5 ± 6.9 ystematic ching ration 0.5 ± 6.9 ystematic ching ration 0.5 ± 6.9 0.5 ± 6.9	$(D_s^+ o \phi \pi) \times 10^{-2}$. Ou error from us os, e.g., B(D %. ECN COMME RG e^+e^- ($D_s^+ o \phi \pi$) $\times 10^{-2}$. Our error from us os, e.g., B(D %.	$^{+}$) = 0.027. If first error is the fing our best value 0 $\rightarrow \kappa^{-}\pi^{+}$) Factor $^{+}$ $^{-}$ $^$
64 ALBRECHT 92G rescale to our best experiment's error Assumes PDG 19 3.71 ± 0.25% and Γ(Φ*(2007) ⁰ D**) VALUE 0.023±0.013±0.006 65 ALBRECHT 92G rescale to our best experiment's error Assumes PDG 19 3.71 ± 0.25% and Γ(D**, π ⁰)/Γtotal VALUE <0.00020	t value B(L and our se 90 D^0 and B(D^* (200))/ Γ total reports 0.0 t value B(L and our se 90 D^0 and B(D^* (200) and B(L^* (200) and B(L^* (200) and B(L^* (200) L^* (200) L^* (200) and B(L^* ($013 \pm 0.009 \pm 0.0$ 0.009 ± 0.0	0.02 for B 0.02 for B 0.0	$\begin{array}{ccc} (D_{5}^{+} \rightarrow & \phi \pi \\ \times 10^{-2}. & \text{Ou} \\ \text{error from us} \\ \text{os, e.g., B}(D \\ \%. \\ \\ \frac{\text{ECN}}{\text{COMME}} & \frac{\text{COMME}}{\text{RG}} \\ \text{e}^{+} e^{-} \\ \text{e}^{+} \times 10^{-2}. & \text{Ou} \\ \text{error from us} \\ \text{os, e.g., B}(D \\ \%. \\ \\ \frac{\text{ECN}}{\text{COMME}} & \frac{\text{COMME}}{\text{CM}} \\ \text{e}^{+} e^{-} \\ \text{e}^{+} e^{-} \\ \end{array}$	$^+$) = 0.027. If first error is the fing our best value $^0 \to K^-\pi^+$) Factor $^+$ $^+$ $^+$ $^+$ $^+$ $^+$ $^+$ $^ ^+$ $^+$ $^+$ $^+$ $^+$ $^ ^+$ $^+$ $^+$ $^+$ $^+$ $^+$ $^+$ $^+$
64 ALBRECHT 92G rescale to our best experiment's error Assumes PDG 19 $3.71 \pm 0.25\%$ and $\Gamma(\overline{D^*}(2007)^0 D_s^{*+})$ VALUE 0.003 $\pm 0.013 \pm 0.006$ 65 ALBRECHT 92G rescale to our best experiment's error Assumes PDG 19 $3.71 \pm 0.25\%$ and $\Gamma(D_s^+\pi^0)/\Gamma_{\text{total}}$ VALUE	t value $B(L)$ and our se $90 D^0$ and $10 D^0$	$0.13 \pm 0.009 \pm 0.0$ $0.5^+_5 \rightarrow \phi \pi^+) = (3000 \pm 0.0)$ $0.5^+_5 \rightarrow \phi \pi^+) = (3000 \pm 0.0)$ $0.5^+_5 \rightarrow 0.0$ $0.5^+_5 \rightarrow 0.0$	0.02 for B 0.02 for B 0.0	$\begin{array}{ccc} (D_{5}^{+} \rightarrow & \phi \pi \\ \times 10^{-2}. & \text{Ou} \\ \text{error from us} \\ \text{os, e.g., B}(D \\ \%. \\ \\ \frac{\text{ECN}}{\text{COMME}} & \frac{\text{COMME}}{\text{RG}} \\ \text{e}^{+} e^{-} \\ \text{e}^{+} \times 10^{-2}. & \text{Ou} \\ \text{error from us} \\ \text{os, e.g., B}(D \\ \%. \\ \\ \frac{\text{ECN}}{\text{COMME}} & \frac{\text{COMME}}{\text{CM}} \\ \text{e}^{+} e^{-} \\ \text{e}^{+} e^{-} \\ \end{array}$	$^+$) = 0.027. Yr first error is thing our best val 0 $^ ^ ^+$) F32. Wr $^ ^ ^+$) First error is thing our best val 0 $^ ^ ^+$ $^ ^ ^+$ $^ ^ ^ ^ ^ ^ ^ ^-$
64 ALBRECHT 92G rescale to our best experiment's error Assumes PDG 19 $3.71 \pm 0.25\%$ and $\Gamma(D^*(2007)^0D_s^{++})$ WALUE $0.023 \pm 0.013 \pm 0.006$ 65 ALBRECHT 92G rescale to our best experiment's error Assumes PDG 19 $3.71 \pm 0.25\%$ and $\Gamma(D_s^+\pi^0)/\Gamma_{\text{total}}$ VALUE <0.00020 66 ALEXANDER 93E our best value B($\Gamma(D_s^+\pi^0) + \Gamma(D_s^0)$	t value B(L and our se $90~D^0$ and $1~B(D^*(200))$ //ftotal reports 0.0 t value B(L and our se $90~D^0$ and $1~B(D^*(200))$ $\frac{CL\%}{90}$ $\frac{CL\%}{90}$ $\frac{CL\%}{90}$ $\frac{CL\%}{90}$ $\frac{CL\%}{90}$ $\frac{CL\%}{90}$ $\frac{CL\%}{90}$ $\frac{CL\%}{90}$ $\frac{CL\%}{90}$	$0.13 \pm 0.009 \pm 0.0$ $0.5^+ \rightarrow \phi \pi^+) = (3 \pm 0.009 \pm 0.0)$ $0.5^+ \rightarrow \phi \pi^+) = (3 \pm 0.009 \pm 0.009)$ $0.009 \rightarrow 0.009 \pm 0.009$ $0.009 \rightarrow 0.009 \rightarrow 0.009$	consider B and B	$\begin{array}{ll} (D_{s}^{+}\rightarrow\phi\pi\\)\times10^{-2}. \ \ \mathrm{Ou} \\ \mathrm{error} \ \mathrm{from} \ \mathrm{us} \\ \mathrm{os, e.g., B}(D) \\ \mathrm{error} \ \mathrm{from} \ \mathrm{us} \\ \mathrm{os, e.g., B}(D) \\ \mathrm{error} \ \mathrm{from} \ \mathrm{us} \\ \mathrm{error} \ \mathrm{from} \ \mathrm{us} \\ \mathrm{os, e.g., B}(D) \\ \mathrm{error} \ \mathrm{from} \ \mathrm{us} \\ \mathrm{os, e.g., B}(D) \\ \mathrm{error} \ \mathrm{from} \ \mathrm{us} \\ \mathrm{os, e.g., B}(D) \\ \mathrm{error} \ \mathrm{from} \ \mathrm{us} \\ \mathrm{error} \ \mathrm{from} \ \mathrm{us} \\ \mathrm{os, e.g., B}(D) \\ \mathrm{error} \ \mathrm{from} \ \mathrm{us} \\ \mathrm{error} \ \mathrm{from} \ \mathrm{us} \\ \mathrm{os, e.g., B}(D) \\ \mathrm{error} \ \mathrm{error} \ \mathrm{from} \ \mathrm{us} \\ \mathrm{error} \ \mathrm{error} \ \mathrm{error} \ \mathrm{error} \\ \mathrm{error} \ \mathrm{error} \ \mathrm{error} \ \mathrm{error} \ \mathrm{error} \\ \mathrm{error} \ $	$+$) = 0.027. If irst error is the sing our best value $0 \rightarrow K^-\pi^+$) Factor $K^-\pi^+$
64 ALBRECHT 92G rescale to our best experiment's error Assumes PDG 19 $3.71 \pm 0.25\%$ and $\Gamma(\overline{D}^*(2007)^0 D_s^{*+}; VALUE 0.023 \pm 0.013 \pm 0.006$ 65 ALBRECHT 92G rescale to our best experiment's error Assumes PDG 19 $3.71 \pm 0.25\%$ and $\Gamma(D_s^+\pi^0)/\Gamma_{\text{total}}$ VALUE < 0.00020 66 ALEXANDER 93E our best value B($\Gamma(D_s^+\pi^0)+\Gamma(D_s^+\pi^0)$	t value $B(L)$ and our set 0.00 0	$0.13 \pm 0.009 \pm 0.0$ $0.13 \pm 0.016 \pm 0.016$ $0.13 \pm 0.016 \pm 0.016$ $0.13 \pm 0.016 \pm 0.016$ $0.13 \pm 0.016 \pm$	consider B and B	$(D_s^+ o \phi \pi) \times 10^{-2}$. Ou error from us os, e.g., B(D %. ECN COMME RG e^+e^- ($D_s^+ o \phi \pi) \times 10^{-2}$. Our error from us os, e.g., B(D %.	$+$) = 0.027. Yr first error is thing our best val $0 o K^-\pi^+$) Fa2. NT $+$) = 0.027. Yr first error is thing our best val $0 o K^-\pi^+$) Fa3. NT $+$ 7(45) $+$ 7(45) $+$ 733. Wr rescale
64 ALBRECHT 92G rescale to our best experiment's error Assumes PDG 19 $3.71 \pm 0.25\%$ and $\Gamma(D^*(2007)^0 D_s^{*+})$ VALUE 0.023 \pm 0.013 \pm 0.006 65 ALBRECHT 92G rescale to our best experiment's error Assumes PDG 19 $3.71 \pm 0.25\%$ and $\Gamma(D_s^+\pi^0)/\Gamma_{\text{total}}$ VALUE $<$ 0.00020 66 ALEXANDER 93E our best value B($\Gamma(D_s^+\pi^0)+\Gamma(D_s^+\pi^0)$	t value B(L and our se 90 D^0 and 10 B(D^* (200))/ Γ total reports 0.0. t value B(L and our se 90 D^0 and 10 B(D^* (200) B reports $<$ 0 0 0 and 10 B(0 0 0 0 0 0 0 0 0 0	$0.13 \pm 0.009 \pm 0.0$ $conderor$ is the system $D^*(2007)^0$ brain $D^*(2007)^0$ brain $D^*(2007)^0 \rightarrow D^0 \pi^0) = 0$ $\frac{DOCUMENT ID}{65 \text{ ALBRECHT}}$ 0.016 ± 0.0 $0.05 + 0.0$ $0.05 + 0.$	002 for B 3.6 ± 0.9) ystematic ching ration $= 55 \pm 69$ 0.05 0.05 0.05 0.05 0.05 for B 0.05 fo	$\begin{array}{ll} (D_{s}^{+} \rightarrow \phi\pi \\ \times 10^{-2}. \ \mathrm{Ou} \\ \mathrm{error \ from \ us} \\ \mathrm{os, \ e.g., \ B}(D \\ \%. \\ \\ \frac{\mathrm{ECN}}{\mathrm{COMME}} \\ \mathrm{COMME} \\ \mathrm{RG} \\ e^{+}e^{-} \\ \mathrm{COMME} \\ $	$+$) = 0.027. If first error is the fing our best value $0 \to K^-\pi^+$) Factor $0 \to K^-\pi^+$ $+$) = 0.027. If $0 \to K^-\pi^+$ Factor $0 \to K^-\pi^+$ Factor $0 \to K^-\pi^+$
64 ALBRECHT 92G rescale to our best experiment's error Assumes PDG 19 $3.71 \pm 0.25\%$ and $\Gamma(\overline{D}^*(2007)^0 D_s^{*+}; VALUE 0.023 \pm 0.013 \pm 0.006$ 65 ALBRECHT 92G rescale to our best experiment's error Assumes PDG 19 $3.71 \pm 0.25\%$ and $\Gamma(D_s^+\pi^0)/\Gamma_{\text{total}}$ VALUE < 0.00020 66 ALEXANDER 93E our best value B($\Gamma(D_s^+\pi^0)+\Gamma(D_s^+\pi^0)$	t value B(L and our se 90 D^0 and 10 B(D^* (200))/ Γ total reports 0.0. t value B(L and our se 90 D^0 and 10 B(D^* (200) 0 0 0 0 0 0 0 0 0 0	$0.13 \pm 0.009 \pm 0.0$ $0.13 \pm 0.016 \pm 0.016$ $0.13 \pm 0.016 \pm 0.016$ $0.13 \pm 0.016 \pm 0.016$ 0.13 ± 0.016	002 for B 3.6 ± 0.9) ystematic ching ration $= 55 \pm 69$ 0.05 0.05 0.05 0.05 0.05 for B 0.05 fo	$\begin{array}{ll} (D_{s}^{+} \rightarrow \phi\pi \\ \times 10^{-2}. \ \mathrm{Ou} \\ \mathrm{error \ from \ us} \\ \mathrm{os, \ e.g., \ B}(D \\ \%. \\ \\ \frac{\mathrm{ECN}}{\mathrm{COMME}} \\ \mathrm{COMME} \\ \mathrm{RG} \\ e^{+}e^{-} \\ \mathrm{COMME} \\ $	$+$) = 0.027. Yr first error is thing our best val $0 o K^-\pi^+$) Fa2. NT $+$) = 0.027. Yr first error is thing our best val $0 o K^-\pi^+$) Fa3. NT $+$ $+$ $+$ $+$ $+$ $+$ $+$ $+$
64 ALBRECHT 92G rescale to our best experiment's error Assumes PDG 19 $3.71 \pm 0.25\%$ and $\Gamma(D^*(2007)^0D_s^{++})$ $VALUE$ 0.023 $\pm 0.013 \pm 0.006$ 65 ALBRECHT 92G rescale to our best experiment's error Assumes PDG 19 $3.71 \pm 0.25\%$ and $\Gamma(D_s^+\pi^0)/\Gamma_{\rm total}$ $VALUE$ < 0.00020 66 ALEXANDER 93E our best value B($I_s^ I_s^ I_s$	t value B(L and our se $90~D^0$ and $18~D^+$ (200) / Γ total reports 0.0 value B(L and our se $90~D^0$ and $18~D^+$ (200) 10^{-1} (10^{-1} (10^{-1}) 10^{-1} ($0.13 \pm 0.009 \pm 0.0$, $0.13 \pm 0.016 \pm 0.016$, $0.13 \pm 0.016 \pm 0.016$, 0.13 ± 0.016 ,	002 for B 3.6 ± 0.9) ystematic ching ratio = 55 ± 6 9 11 0 926 A 005 for B 3.6 ± 0.9) ystematic ching ratio = 55 ± 6 9 11 0	$\begin{array}{ll} (D_{5}^{+}\rightarrow\phi\pi\\ \times 10^{-2}. \ \mathrm{Ou} \\ \mathrm{error from us} \\ \mathrm{os, e.g., B}(D) \\ \mathrm{6.} \\ \\ \frac{\mathrm{ECN}}{\mathrm{COMME}} \\ \mathrm{RG} \\ \mathrm{e^{+}e^{-}} \\ \mathrm{e^{+}} \\ \mathrm{e^{+}} \\ \mathrm{e^{+}} \\ \mathrm{e^{+}} \\ \mathrm{e^{-}} \\ \mathrm{e^{+}} \\ \mathrm{e^{-}} \\ \mathrm$	$+$) = 0.027. Yr first error is thing our best val $0 o K^-\pi^+$) Fa2. Wr $\to \Upsilon(4S)$ $+$) = 0.027. Yr first error is thing our best val $0 o K^-\pi^+$) Fa3. Wr $\to \Upsilon(4S)$ 37. We rescale ($\Gamma_{33}+\Gamma_{34}$), Wr $\to \Upsilon(4S)$ We rescale to G
64 ALBRECHT 92G rescale to our best experiment's error Assumes PDG 19 3.71 \pm 0.25% and $\Gamma(\bar{D}^*(2007)^0 D_s^{*+})^{*}$ VALUE 0.023 \pm 0.013 \pm 0.006 65 ALBRECHT 92G rescale to our best experiment's error Assumes PDG 19 3.71 \pm 0.25% and $\Gamma(D_s^+\pi^0)/\Gamma_{\text{total}}$ VALUE <0.00020 66 ALEXANDER 93E our best value B($(D_s^+\pi^0)/\Gamma_{\text{total}}$ VALUE <0.0007 67 ALBRECHT 93E rest value B($(D_s^+\pi^0)/\Gamma_{\text{total}}$ value B($(D_s^+\pi^0)/\Gamma_{\text{total}}$ VALUE $(D_s^+\pi^0)/\Gamma_{\text{total}}$ VALUE $(D_s^+\pi^0)/\Gamma_{\text{total}}$	t value $B(L)$ and our se 90 D^0 and 10 $B(D^*(200))$ / Γ total reports 0.0 ; 10 10 10 10 10 10 10 10	$0.13 \pm 0.009 \pm 0.0$, $0.13 \pm 0.016 \pm 0.016$, $0.13 \pm 0.016 \pm 0.016$, 0.13 ± 0.016 ,	002 for B 3.6 ± 0.9) ystematic ching ratio = 55 ± 6 9 11 0 926 A 005 for B 3.6 ± 0.9) ystematic ching ratio = 55 ± 6 9 11 0	$\begin{array}{ll} (D_{5}^{+}\rightarrow\phi\pi\\ \times 10^{-2}. \ \mathrm{Ou} \\ \mathrm{error from us} \\ \mathrm{os, e.g., B}(D) \\ \mathrm{6.} \\ \\ \frac{\mathrm{ECN}}{\mathrm{COMME}} \\ \mathrm{RG} \\ \mathrm{e^{+}e^{-}} \\ \mathrm{e^{+}} \\ \mathrm{e^{+}} \\ \mathrm{e^{+}} \\ \mathrm{e^{+}} \\ \mathrm{e^{-}} \\ \mathrm{e^{+}} \\ \mathrm{e^{-}} \\ \mathrm$	$+$) = 0.027. Yr first error is thing our best val $0 o K^-\pi^+$) Fa2. Wr $\to \Upsilon(4S)$ $+$) = 0.027. Yr first error is thing our best val $0 o K^-\pi^+$) Fa3. Wr $\to \Upsilon(4S)$ 37. We rescale ($\Gamma_{33}+\Gamma_{34}$), Wr $\to \Upsilon(4S)$ We rescale to G
64 ALBRECHT 92G rescale to our best experiment's error Assumes PDG 19 $3.71 \pm 0.25\%$ and $\Gamma(\overline{D^*}(2007)^0 D_s^{*+})^{*+}$ VALUE 0.023 \pm 0.013 \pm 0.006 65 ALBRECHT 92G rescale to our best experiment's error Assumes PDG 19 $3.71 \pm 0.25\%$ and $\Gamma(D_s^+\pi^0)/\Gamma_{total}$ VALUE <0.00020 66 ALEXANDER 93E our best value B(L_s^+) (L_s^-) L_s^- (L_s^-) $L_$	t value B(L and our se $90~D^0$ and $10~D^0$	$0.13 \pm 0.009 \pm 0.0$, $c_{s} \rightarrow \phi \pi^{+}) = (3 + 0.009 \pm 0.0)$, $c_{s} \rightarrow \phi \pi^{+}) = (3 + 0.009 \pm 0.0)$, $c_{s} \rightarrow \phi \pi^{+}) = (3 + 0.009 \pm 0.0)$, $c_{s} \rightarrow \phi \pi^{-}) = (3 + 0.016 \pm 0.0)$, $c_{s} \rightarrow \phi \pi^{+}) = (3 + 0.016 \pm 0.0)$, $c_{s} \rightarrow \phi \pi^{+}) = (3 + 0.016 \pm 0.0)$, $c_{s} \rightarrow \phi \pi^{+}) = (3 + 0.016 \pm 0.0)$, $c_{s} \rightarrow \phi \pi^{+}) = (3 + 0.016 \pm 0.0)$, $c_{s} \rightarrow \phi \pi^{+}) = (3 + 0.016 \pm 0.0)$, $c_{s} \rightarrow \phi \pi^{+}) = (3 + 0.016 \pm 0.0)$, $c_{s} \rightarrow \phi \pi^{+}) = (3 + 0.009 \pm 0.009 $	consider B and B	$\begin{array}{ll} (D_{5}^{+} \rightarrow \phi\pi \\ \times 10^{-2}. \ \mathrm{Ou} \\ \mathrm{error \ from \ us} \\ \mathrm{os, \ e.g., \ B}(D \\ \mathrm{c.} \end{array}$	$+$) = 0.027. Yr first error is thing our best val $0 o K^-\pi^+$) Fa2. NT $+$) = 0.027. Yr first error is thing our best val $0 o K^-\pi^+$) Fa3. NT $+$ $+$ $+$ $+$ $+$ $+$ $+$ $+$
64 ALBRECHT 92G rescale to our best experiment's error Assumes PDG 19 3.71 \pm 0.25% and $\Gamma(\bar{D}^*(2007)^0 D_s^{*+})^{*}$ VALUE 0.023 \pm 0.013 \pm 0.006 65 ALBRECHT 92G rescale to our best experiment's error Assumes PDG 19 3.71 \pm 0.25% and $\Gamma(D_s^+\pi^0)/\Gamma_{\text{total}}$ VALUE <0.00020 66 ALEXANDER 93E our best value B($(D_s^+\pi^0)/\Gamma_{\text{total}}$ VALUE <0.0007 67 ALBRECHT 93E rest value B($(D_s^+\pi^0)/\Gamma_{\text{total}}$ value B($(D_s^+\pi^0)/\Gamma_{\text{total}}$ VALUE $(D_s^+\pi^0)/\Gamma_{\text{total}}$ VALUE $(D_s^+\pi^0)/\Gamma_{\text{total}}$	t value B(L and our se 90 D^0 and 16 B(D^* (200))/ Γ total reports 0.0. t value B(L and our se 90 D^0 and 16 B(D^* (200) B reports < 0.0 $C = \frac{CL \%}{90}$ $C = \frac{CL \%}{90}$ reports < 0.0 $C = \frac{CL \%}{90}$	$0.13 \pm 0.009 \pm 0.0$ $0.13 \pm 0.016 \pm 0.0$ $0.13 \pm $	consider B and B	$\begin{array}{ll} (D_{5}^{+} \rightarrow \phi\pi \\ \times 10^{-2}. \ \mathrm{Ou} \\ \mathrm{error \ from \ us} \\ \mathrm{os, \ e.g., \ B}(D \\ \mathrm{c.} \end{array}$	$+$) = 0.027. If first error is the fing our best value $0 \to K^-\pi^+$) Factor $0 \to K^-\pi^+$ $0 \to K^-\pi^+$ $0 \to K^-\pi^+$ $0 \to K^-\pi^+$ Factor $0 \to K^-\pi^+$ Factor $0 \to K^-\pi^+$ $0 \to K^-\pi^+$ $0 \to K^-\pi^+$ We rescale to $0 \to K^-\pi^+$
64 ALBRECHT 92G rescale to our best experiment's error Assumes PDG 19 $3.71 \pm 0.25\%$ and $\Gamma(D^*(2007)^0D_s^*+\frac{1}{2})$ $0.023 \pm 0.013 \pm 0.006$ 65 ALBRECHT 92G rescale to our best experiment's error Assumes PDG 19 $3.71 \pm 0.25\%$ and $\Gamma(D_s^+\pi^0)/\Gamma$ total $\frac{VALUE}{VALUE}$ <0.00020 66 ALEXANDER 93E our best value B($\Gamma(D_s^+\pi^0)+\Gamma(D_s^+\pi^0)/\Gamma$ $\Gamma(D_s^+\pi^0)/\Gamma$ total $\frac{VALUE}{VALUE}$ <0.0007 67 ALBRECHT 93E $\Gamma(D_s^+\pi^0)/\Gamma$ total $\frac{VALUE}{VALUE}$ <0.0003 68 ALEXANDER 93E our best value B($\Gamma(D_s^+\pi^0)/\Gamma$ $\Gamma(D_s$	t value $B(D)$ and our set $\theta(D)$ and our set $\theta(D)$ $\theta(D$	$0.13 \pm 0.009 \pm 0.0$, $cond = 0.009 \pm 0.009$, $cond = 0.009$, $cond = 0.009 \pm 0.009$, $cond = 0.009$, $cond$	consider B and B	$\begin{array}{ll} (D_{s}^{+} \rightarrow \phi\pi \\ \times 10^{-2}. \ \mathrm{Ou} \\ \mathrm{error} \ \mathrm{from} \ \mathrm{us} \\ \mathrm{os, e.g., B}(D \\ \mathrm{c.} \end{array}$	$+$) = 0.027. Yr first error is the ing our best val $0 o K^-\pi^+$) Fa2. NT $+$) = 0.027. Yr first error is the ing our best val $0 o K^-\pi^+$) Fa3. NT $+$ $+$ $+$ $+$ $+$ $+$ $+$ $+$
64 ALBRECHT 92G rescale to our best experiment's error Assumes PDG 19 $3.71 \pm 0.25\%$ and $\Gamma(D^*(2007)^0D_s^{*+})$ VALUE 0.023 \pm 0.013 \pm 0.006 65 ALBRECHT 92G rescale to our best experiment's error Assumes PDG 19 $3.71 \pm 0.25\%$ and $\Gamma(D_s^+\pi^0)/\Gamma$ total VALUE <0.00020 66 ALEXANDER 93E our best value B($(D_s^+\pi^0)/\Gamma$ 100 $(D_s^+\pi^0)/\Gamma$ 10 $(D_s^+\pi^0)/\Gamma$ 10 $(D_s^+\pi^0)/\Gamma$ 10 $(D_s^+\pi^0)/\Gamma$ 11 $(D_s^+$	t value B(L and our se 90 D^0 and 16 B(D^* (200))/ Γ total reports 0.0. t value B(L and our se 90 D^0 and 16 B(D^* (200) B reports < 0.0 $C = \frac{CL \%}{90}$ $C = \frac{CL \%}{90}$ reports < 0.0 $C = \frac{CL \%}{90}$	$0.13 \pm 0.009 \pm 0.0$ $0.13 \pm 0.016 \pm 0.0$ $0.13 \pm $	consider B and B	$\begin{array}{ll} (D_{s}^{+} \rightarrow \phi\pi \\ \times 10^{-2}. \ \mathrm{Ou} \\ \mathrm{error} \ \mathrm{from} \ \mathrm{us} \\ \mathrm{os, e.g., B}(D \\ \mathrm{c.} \end{array}$	$+$) = 0.027. Vr first error is thing our best valid $0 \to K^-\pi^+$) Fa2, NT $+$) = 0.027. Vr first error is thing our best valid $0 \to K^-\pi^+$) Fa33, NT $+$ $+$ $+$ $+$ $+$ $+$ $+$ $+$ $+$ $+$

 B^{\pm}

$\Gamma(D_s^{*+}\eta)/\Gamma_{\text{total}}$ Γ_{36}/Γ	$\Gamma(D_s^{*+}\phi)/\Gamma_{\text{total}}$ Γ_{44}/Γ
VALUE CL% DOCUMENT ID TECN COMMENT	VALUE CL% DOCUMENT ID TECN COMMENT
<0.0008 90 70 ALEXANDER 93B CLE2 $e^+e^- \rightarrow \Upsilon(4S)$	<0.0004 90 83 ALEXANDER 93B CLE2 $e^+e^- \rightarrow \Upsilon(45)$
⁷⁰ ALEXANDER 93B reports $<$ 7.5 \times 10 ⁻⁴ for B($D_s^+ \rightarrow \phi \pi^+$) = 0.037. We rescale to	• • • We do not use the following data for averages, fits, limits, etc. • • •
our best value B($D_s^+ o \phi \pi^+$) = 0.036.	<0.0016 90 84 ALBRECHT 93E ARG $e^+e^- \rightarrow \Upsilon(4S)$
$\Gamma(D_s^+ \rho^0)/\Gamma_{\text{total}}$ Γ_{37}/Γ	⁸³ ALEXANDER 93B reports $< 4.2 \times 10^{-4}$ for B($D_s^+ \rightarrow \phi \pi^+$) = 0.037. We rescale to
VALUE CL% DOCUMENT ID TECN COMMENT COMMENT	our best value B($D_s^+ \rightarrow \phi \pi^+$) = 0.036.
<0.0004 90 71 ALEXANDER 93B CLE2 $e^+e^- \rightarrow \Upsilon(4S)$	⁸⁴ ALBRECHT 93E reports $< 2.1 \times 10^{-3}$ for B($D_s^+ \rightarrow \phi \pi^+$) = 0.027. We rescale to our
71 ALEXANDER 93B reports $<$ 3.7 $ imes$ 10 $^{-4}$ for B($D_s^+ o \phi \pi^+$) = 0.037. We rescale to	best value B($D_{\mathcal{S}}^+ o \phi \pi^+) = 0.036$.
our best value B($D_s^+ \rightarrow \phi \pi^+$) = 0.036.	$\Gamma(D_s^+ \overline{K}^0)/\Gamma_{\text{total}}$ Γ_{45}/Γ
, and the second	VALUE CLY DOCUMENT ID TECH COMMENT
$\left[\Gamma(D_s^+\rho^0) + \Gamma(D_s^+\overline{K}^*(892)^0)\right]/\Gamma_{\text{total}} \qquad (\Gamma_{37} + \Gamma_{47})/\Gamma$	<0.0011 $\begin{array}{cccccccccccccccccccccccccccccccccccc$
VALUE CL% DOCUMENT ID TECN COMMENT 72 ALBRECHT 93E ARG $e^+e^- \rightarrow \Upsilon(4S)$	 • • We do not use the following data for averages, fits, limits, etc.
<0.0025 90 ⁷² ALBRECHT 93E ARG $e^+e^- \rightarrow \Upsilon(4S)$	<0.0019 90 86 ALBRECHT 93E ARG $e^+e^- ightarrow \Upsilon(4S)$
⁷² ALBRECHT 93E reports $< 3.4 \times 10^{-3}$ for B($D_S^+ o \phi \pi^+$) = 0.027. We rescale to our	85 ALEXANDER 93B reports $< 10.3 imes 10^{-4}$ for B $(D_S^+ o \phi \pi^+) = 0.037$. We rescale to
best value B($D_{\mathcal{S}}^+ ightarrow \phi \pi^+) = 0.036$.	our best value B($D_{S}^{+} ightarrow \phi \pi^{+}) = 0.036$.
Γ(D*± 20)/Γ	86 ALBRECHT 93E reports $<$ 2.5 $ imes$ 10^{-3} for B($D_s^+ ightarrow \phi \pi^+$) = 0.027. We rescale to our
$\Gamma(D_s^{*+} ho^0)/\Gamma_{ ext{total}}$ Γ_{38}/Γ VALUE CL% DOCUMENT ID TECN COMMENT	best value B($D_s^+ o \phi \pi^+$) = 0.036.
VALUECL%DOCUMENT IDTECNCOMMENT<0.0005	
73 ALEXANDER 93B reports $< 4.8 \times 10^{-4}$ for B($D_s^+ \rightarrow \phi \pi^+$) = 0.037. We rescale to	$\Gamma(D_s^{*+}\overline{K}^0)/\Gamma_{\text{total}}$ Γ_{46}/Γ
our best value B($D_s^+ o \phi \pi^+$) = 0.037. We rescale to	$\frac{VALUE}{}$ CL% DOCUMENT ID TECN COMMENT <0.0011 90 87 ALEXANDER 938 CLE2 e^+e^- → $\Upsilon(4S)$
out best value of $\nu_{\rm S} \rightarrow \psi \pi^+ j = 0.030$.	<0.0011 90 ⁸⁷ ALEXANDER 93B CLE2 $e^+e^- \rightarrow \Upsilon(4S)$ • • • We do not use the following data for averages, fits, limits, etc. • • •
$\left[\Gamma(D_s^{*+}\rho^0) + \Gamma(D_s^{*+}\overline{K}^*(892)^0)\right]/\Gamma_{total} \qquad (\Gamma_{38}+\Gamma_{48})/\Gamma$	\sim 0.0023
VALUECL%DOCUMENT IDTECNCOMMENT<0.0015	
	⁸⁷ ALEXANDER 93B reports $< 10.9 \times 10^{-4}$ for B $(D_s^+ \rightarrow \phi \pi^+) = 0.037$. We rescale to
74 ALBRECHT 93E reports $<$ 2.0 \times 10 $^{-3}$ for B($D_s^+ o \phi \pi^+$) = 0.027. We rescale to our	our best value B($D_S^+ \rightarrow \phi \pi^+$) = 0.036.
best value B($D_s^+ o \phi \pi^+$) = 0.036.	⁸⁸ ALBRECHT 93E reports $< 3.1 imes 10^{-3}$ for B($D_s^+ o \phi \pi^+$) = 0.027. We rescale to our
-	best value B($D_s^+ \rightarrow \phi \pi^+$) = 0.036.
$\Gamma(D_s^+\omega)/\Gamma_{\text{total}}$ Γ_{39}/Γ	$\Gamma(D_s^+\overline{K}^*(892)^0)/\Gamma_{\text{total}}$ Γ_{47}/Γ
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	VALUE CL% DOCUMENT ID TECH COMMENT
<0.0005 90 ⁷⁵ ALEXANDER 938 CLE2 $e^+e^- \rightarrow \Upsilon(45)$ • • • We do not use the following data for averages, fits, limits, etc. • • •	VALUECL%DOCUMENT IDTECNCOMMENT<0.0005
<0.0025 90 76 ALBRECHT 93E ARG $e^+e^- \rightarrow \Upsilon(4S)$	89 ALEXANDER 93B reports $<$ 4.4 $ imes$ 10 $^{-4}$ for B($D_S^+ o \phi \pi^+$) = 0.037. We rescale to
	our best value B($D_S^+ o \phi \pi^+$) = 0.036.
⁷⁵ ALEXANDER 93B reports $< 4.8 \times 10^{-4}$ for B($D_s^+ \rightarrow \phi \pi^+$) = 0.037. We rescale to	
our best value B($D_s^+ \rightarrow \phi \pi^+$) = 0.036.	$\Gamma(D_s^{*+}\overline{K}^*(892)^0)/\Gamma_{\text{total}}$ Γ_{48}/Γ
⁷⁶ ALBRECHT 93E reports $< 3.4 \times 10^{-3}$ for B($D_s^+ \rightarrow \phi \pi^+$) = 0.027. We rescale to our	$\frac{VALUE}{}$ CL% DOCUMENT ID TECN COMMENT <0.0004 90 90 ALEXANDER 93B CLE2 e^+e^- → $\Upsilon(4S)$
best value B($D_{\mathcal{S}}^+ o \phi \pi^+$) = 0.036.	
$\Gamma(D_s^{*+}\omega)/\Gamma_{\text{total}}$ Γ_{40}/Γ	90 ALEXANDER 93B reports $<$ 4.3 \times 10 $^{-4}$ for B($D_s^+ o \phi \pi^+$) = 0.037. We rescale to
VALUE CL% DOCUMENT ID TECN COMMENT	our best value B $(D_S^+ o\phi\pi^+)=0.036.$
<0.0007 90 77 ALEXANDER 938 CLE2 $e^+e^- \rightarrow \Upsilon(4S)$	$\Gamma(D_s^-\pi^+K^+)/\Gamma_{\text{total}}$ Γ_{49}/Γ
 • • We do not use the following data for averages, fits, limits, etc. 	VALUE CI% DOCUMENT ID TECH COMMENT
<0.0014 90 78 ALBRECHT 93E ARG $e^+e^- ightarrow \varUpsilon(4S)$	$\frac{VALUE}{0.0008}$ $\frac{CL\%}{90}$ $\frac{DOCUMENT ID}{4}$ $\frac{TECN}{0.0008}$ $\frac{COMMENT}{91}$ ALBRECHT 93E ARG $e^+e^- \rightarrow \Upsilon(4S)$
77 ALEXANDER 93B reports $< 6.8 imes 10^{-4}$ for B($D_S^+ o \phi \pi^+$) $= 0.037$. We rescale to	91 ALBRECHT 93E reports $< 1.1 \times 10^{-3}$ for B($D_s^+ o \phi \pi^+$) = 0.027. We rescale to our
our best value B($D_{\mathbf{S}}^+ o \phi \pi^+$) = 0.036.	best value B($D_s^+ o \phi \pi^+$) = 0.036.
⁷⁸ ALBRECHT 93E reports $< 1.9 \times 10^{-3}$ for B($D_S^+ o \phi \pi^+$) = 0.027. We rescale to our	best value $B(D_S \to \phi \pi^+) = 0.036$.
best value B($D_{\rm s}^+ o \phi \pi^+$) = 0.036.	$\Gamma(D_s^{*-}\pi^+K^+)/\Gamma_{\text{total}}$ Γ_{50}/Γ
	VALUE CL% DOCUMENT ID TECN COMMENT
$\Gamma(D_s^+ a_1(1260)^0)/\Gamma_{\text{total}}$ Γ_{41}/Γ	<0.0012 90 ⁹² ALBRECHT 93E ARG $e^+e^- ightarrow \varUpsilon(4S)$
VALUE CL% DOCUMENT ID TECN COMMENT	92 ALBRECHT 93E reports $<$ 1.6 $ imes$ 10 $^{-3}$ for B($D_S^+ ightarrow \phi \pi^+$) = 0.027. We rescale to our
<0.0022 90 79 ALBRECHT 93E ARG $e^+e^- \rightarrow \Upsilon(4S)$	best value B($D_s^+ \rightarrow \phi \pi^+$) = 0.036.
⁷⁹ ALBRECHT 93E reports $< 3.0 \times 10^{-3}$ for B($D_s^+ \rightarrow \phi \pi^+$) = 0.027. We rescale to our	-
best value B($D_s^+ o \phi \pi^+$) = 0.036.	$\Gamma(D_s^- \pi^+ K^*(892)^+)/\Gamma_{\text{total}}$ Γ_{51}/Γ
Γ(D*+ a (1960)0) /Γ	VALUE CL% DOCUMENT ID TECN COMMENT <0.006 90 93 ALBRECHT 93E ARG $e^+e^- \rightarrow \Upsilon(4S)$
$\Gamma(D_s^{++}a_1(1260)^0)/\Gamma_{total}$ VALUE CL% DOCUMENT ID TECN COMMENT	
VALUECL%DOCUMENT IDTECNCOMMENT<0.0016	⁹³ ALBRECHT 93E reports $< 8.6 \times 10^{-3}$ for B($D_s^+ o \phi \pi^+$) = 0.027. We rescale to our
	best value B($D_s^+ \rightarrow \phi \pi^+$) = 0.036.
OU ALBRECHT 935 reports $\angle 2.2 \times 10^{-3}$ for $R(D^{+} \rightarrow A_{m}^{+}) = 0.027$ M/a rescale to our	$\Gamma(D_s^{*-}\pi^+K^*(892)^+)/\Gamma_{total}$ Γ_{52}/Γ
80 ALBRECHT 93E reports $< 2.2 \times 10^{-3}$ for B($D_s^+ \rightarrow \phi \pi^+$) = 0.027. We rescale to our best value B($D_s^+ \rightarrow \phi \pi^+$) = 0.036	· \ - c · · · · \ \ \ \ \ / · · · rotal
⁸⁰ ALBRECHT 93E reports $< 2.2 \times 10^{-3}$ for B $(D_s^+ \to \phi \pi^+) = 0.027$. We rescale to our best value B $(D_s^+ \to \phi \pi^+) = 0.036$.	VALUE CL% DOCUMENT ID TECN COMMENT
best value B($D_s^+ o \phi \pi^+$) = 0.036.	VALUE CL% DOCUMENT ID TECN COMMENT <0.008 90 94 ALBRECHT 93E ARG $e^+e^- \rightarrow T(4S)$
best value B($D_s^+ o \phi \pi^+$) = 0.036. $ \Gamma \Big(D_s^+ \phi \Big) / \Gamma_{\text{total}} $	$\frac{VALUE}{0.008}$ $\frac{CL\%}{90}$ $\frac{DOCUMENT\ ID}{4}$ $\frac{TECN}{2}$ $\frac{COMMENT}{9}$ $\frac{COMMENT}{4}$ $\frac{COMENT}{4}$ $\frac{COMENT}{4}$ $\frac{COMMENT}{4}$ $\frac{COMENT}{4}$ $\frac{COMENT}{4}$ $\frac{COMMENT}{4}$ $\frac{COMENT}{4}$
best value $B(D_S^+ \to \phi \pi^+) = 0.036$. $ \Gamma(D_S^+ \phi)/\Gamma_{\text{total}} $ $ \frac{VALUE}{\sqrt{0.00032}} \qquad \frac{CL\%}{90} \qquad \frac{DOCUMENT\ ID}{81\ ALEXANDER} \qquad \frac{TECN}{93B\ CLE2} \qquad \frac{COMMENT}{e^+e^- \to T(4S)} $	VALUECL%DOCUMENT IDTECNCOMMENT<0.008
best value $B(D_S^+ \to \phi \pi^+) = 0.036$. $ \Gamma(D_S^+ \phi)/\Gamma_{total} $ $ VALUE $	VALUE CL% DOCUMENT ID TECN COMMENT 90 94 ALBRECHT 93E ARG $e^+e^- \rightarrow \Upsilon(4S)$ 94 ALBRECHT 93E reports $< 1.1 \times 10^{-2}$ for B($D_s^+ \rightarrow \phi \pi^+$) = 0.027. We rescale to our best value B($D_s^+ \rightarrow \phi \pi^+$) = 0.036.
best value $B(D_S^+ \to \phi \pi^+) = 0.036$. $ \Gamma(D_S^+ \phi)/\Gamma_{total} $	VALUECL%DOCUMENT IDTECNCOMMENT<0.008
best value $B(D_S^+ \to \phi \pi^+) = 0.036$. $ \Gamma(D_S^+ \phi)/\Gamma_{total} $	VALUE CL% DOCUMENT ID TECN COMMENT 0 SEARG 0 0 0 0 0 0 0 0 0 0
best value $B(D_S^+ \to \phi \pi^+) = 0.036$.	VALUE CLY DOCUMENT ID TECN COMMENT
best value $B(D_S^+ \to \phi \pi^+) = 0.036$. $ \Gamma(D_S^+ \phi)/\Gamma_{total} $	VALUE CL% DOCUMENT ID TECN COMMENT 0 SEARG 0 0 0 0 0 0 0 0 0 0

• • • We do not use the following data for averages, fits, limits, etc. • •	$\Gamma(\psi(2S)K^*(892)^+\pi^+\pi^-)/\Gamma_{ ext{total}}$ Γ_{59}/Γ VALUE EVTS DOCUMENT ID TECN COMMENT
22 \pm 10 \pm 2 BUSKULIC 92G ALEP $e^+e^- \rightarrow Z$ 7 \pm 4 3 98 ALBRECHT 870 ARG $e^+e^- \rightarrow T(4S)$ 10 \pm 7 \pm 2 3 99 BEBEK 87 CLEO $e^+e^- \rightarrow T(4S)$	0.0019±0.0011±0.0004 3 111 ALBRECHT 901 ARG $e^+e^- \rightarrow \Upsilon(4S)$ 111 Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.
9 \pm 5 3 100 ALAM 86 CLEO $e^+e^- \rightarrow \Upsilon(4S)$ 95 Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.	$\Gamma(\chi_{c1}(1P)K^+)/\Gamma_{total}$ Γ_{60}/Γ
96 BORTOLETTO 92 reports 8 \pm 2 \pm 2 for B $(J/\psi(1S) ightarrow e^+e^-) = 0.069 \pm 0.009$. We	VALUE <u>EVTS</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u>
rescale to our best value $B(J/\psi(1S) \rightarrow e^+e^-) = (6.02 \pm 0.19) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.	0.0010 \pm 0.0004 OUR AVERAGE 0.00097 \pm 0.00040 \pm 0.00009 6 112 ALAM 94 CLE2 $e^+e^- \rightarrow \Upsilon(4S)$ 0.0019 \pm 0.0013 \pm 0.0006 113 ALBRECHT 92E ARG $e^+e^- \rightarrow \Upsilon(4S)$
⁹⁷ ALBRECHT 90J reports $7\pm 3\pm 1$ for B $(J/\psi(1S)\to e^+e^-)=0.069\pm0.009$. We rescale to our best value B $(J/\psi(1S)\to e^+e^-)=(6.02\pm0.19)\times10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using	¹¹² Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$. ¹¹³ ALBRECHT 92E assumes no $\chi_{c2}(1P)$ production and B($\Upsilon(4S) \rightarrow B^+B^-$) = 50%.
our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$. 98 ALBRECHT 870 assume $B^+B^-/B^0\overline{B}^0$ ratio is 55/45. Superseded by ALBRECHT 90J.	$\Gamma(\chi_{c1}(1P)K^*(892)^+)/\Gamma_{total}$ VALUE CL% DOCUMENT ID TECN COMMENT
99 BEBEK 87 value has been updated in BERKELMAN 91 to use same assumptions as noted for BORTOLETTO 92. 100 ALAM 86 assumes B^{\pm}/B^0 ratio is 60/40.	CO.0021 90 114 ALAM 94 CLE2 $e^+e^- \rightarrow r(4S)$ 114 Assumes equal production of B^+ and B^0 at the $r(4S)$.
$\Gamma(J/\psi(1S)K^+\pi^+\pi^-)/\Gamma_{\text{total}}$ Γ_{54}/Γ	$\Gamma(\kappa^0\pi^+)/\Gamma_{\text{total}}$ Γ_{62}/Γ
<u>VALUE</u> <u>CL% EVTS</u> <u>DOCUMENT ID</u> <u>TECN COMMENT</u> 0.0014 ±0.0006 OUR AVERAGE	VALUE CL% DOCUMENT ID TECN COMMENT
$0.00137\pm0.00081\pm0.00004$ 101 BORTOLETTO92 CLEO $e^+e^- ightarrow ag{7(45)}$	<4.8 x 10^{-5} 90 ASNER 96 CLE2 $e^+e^- \rightarrow \Upsilon(4S)$ ••• We do not use the following data for averages, fits, limits, etc. •••
$0.00137\pm0.00090\pm0.00004$ 6 102 ALBRECHT 87D ARG $e^+e^-\to \gamma$	$<$ 1.9 \times 10 $^{-4}$ 90 ALBRECHT 91B ARG $e^+e^- ightarrow \Upsilon$ (4S)
 ◆ We do not use the following data for averages, fits, limits, etc. 	$<1.0 \times 10^{-4}$ 90 115 AVERY 89B CLEO $e^+e^- \to \Upsilon(4S)$ $<6.8 \times 10^{-4}$ 90 AVERY 87 CLEO $e^+e^- \to \Upsilon(4S)$
<0.0018 90 103 ALBRECHT 90J ARG $e^+e^- \rightarrow \Upsilon(4S)$	115 AVERY 89B reports $< 9 \times 10^{-5}$ assuming the $\Upsilon(4S)$ decays 43% to $B^0 \overline{B}{}^0$. We rescale
$101 {\sf BORTOLETTO}$ 92 reports 0.0012 \pm 0.0006 \pm 0.0004 for B($J/\psi(1S) \to e^+e^-) =$	to 50%.
0.069 ± 0.009 . We rescale to our best value B($J/\psi(1S) \rightarrow e^+e^-$) = (6.02 \pm 0.19) \times 10 ⁻² . Our first error is their experiment's error and our second error is the systematic	$\Gamma(K^+\pi^0)/\Gamma_{\text{total}}$
error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.	VALUE CL% DOCUMENT ID TECN COMMENT $<1.4 \times 10^{-5}$ 90 ASNER 96 CLE2 $e^+e^- \rightarrow \Upsilon(4S)$
102 ALBRECHT 87D reports 0.0012 ± 0.0008 for B($J/\psi(1S) \rightarrow e^+e^-$) = 0.069 ± 0.009 . We rescale to our best value B($J/\psi(1S) \rightarrow e^+e^-$) = $(6.02 \pm 0.19) \times 10^{-2}$. Our first	
error is their experiment's error and our second error is the systematic error from using	$\Gamma(K^*(892)^0\pi^+)/\Gamma_{\text{total}}$ VALUE CLY DOCUMENT ID TECH COMMENT
our best value. They actually report 0.0011 ± 0.0007 assuming $B^+B^-/B^0\overline{B}^0$ ratio is 55/45. We rescale to 50/50. Analysis explicitly removes $B^+ \to \psi(2S)K^+$.	VALUE CL% DOCUMENT ID TECN COMMENT $<4.1 \times 10^{-5}$ 90 ASNER 96 CLE2 $e^+e^- \rightarrow \Upsilon(4S)$
103 ALBRECHT 90J reports $<$ 0.0016 for B $(J/\psi(1S) ightarrow e^+e^-) = 0.069$. We rescale to	 • • We do not use the following data for averages, fits, limits, etc.
our best value B $(J/\psi(1S) \rightarrow e^+e^-) = 0.0602$. Assumes equal production of B^+ and	$<4.8 \times 10^{-4}$ 90 116 ABREU 95N DLPH $e^+e^- \rightarrow Z$
B^0 at the $\Upsilon(4S)$.	$<1.7 \times 10^{-4}$ 90 ALBRECHT 91B ARG $e^+e^- \rightarrow \Upsilon(4S)$ $<1.5 \times 10^{-4}$ 90 117 AVERY 89B CLEO $e^+e^- \rightarrow \Upsilon(4S)$
$\Gamma(J/\psi(1S)K^*(892)^+)/\Gamma_{\text{total}}$ Γ_{55}/Γ	$<2.6 \times 10^{-4}$ 90 AVERY 87 CLEO $e^{+}e^{-} \rightarrow r(4S)$
For polarization information see the Listings at the end of the " ${\cal B}^0$ Branching Ratios" section.	116 Assumes a B^0 , B^- production fraction of 0.39 and a B_S production fraction of 0.12.
VALUE EVTS DOCUMENT ID TECN COMMENT 0.0017 ±0.0005 OUR AVERAGE	117 AVERY 89B reports $<1.3\times10^{-4}$ assuming the $\varUpsilon(4S)$ decays 43% to $B^0\overline{B}{}^0$. We rescale to 50%.
$0.00178 \pm 0.00051 \pm 0.00023$ 13 ¹⁰⁴ ALAM 94 CLE2 $e^+e^- \rightarrow \Upsilon(4S)$	
0.00149 \pm 0.00107 \pm 0.00005	$\Gamma(K^*(892)^+\pi^0)/\Gamma_{\text{total}}$ $\Gamma_{65}/\Gamma_{\text{VALUE}}$ $\Gamma_{65}/\Gamma_{\text{COMMENT}}$
104 Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.	<9.9 x 10⁻⁵ 90 ASNER 96 CLE2 e^+e^- → $\Upsilon(4S)$
¹⁰⁵ BORTOLETTO 92 reports 0.0013 ± 0.0009 ± 0.0003 for B($J/\psi(1S) \rightarrow e^+e^-$) =	$\Gamma(K^+\pi^-\pi^+ \text{(no charm)})/\Gamma_{\text{total}}$ Γ_{66}/Γ
0.069 ± 0.009 . We rescale to our best value B($J/\psi(1S) \rightarrow e^+e^-$) = (6.02 \pm 0.19) \times 10 ⁻² . Our first error is their experiment's error and our second error is the systematic	VALUE CL% DOCUMENT ID TECN COMMENT
error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.	<1.9 × 10 ⁻⁴ 90 ¹¹⁸ AVERY 89B CLEO $e^+e^- \rightarrow \Upsilon(45)$ • • • We do not use the following data for averages, fits, limits, etc. • • •
106 ALBRECHT 901 reports $0.0016 \pm 0.0011 \pm 0.0003$ for $B(J/\psi(1S) \rightarrow e^+e^-) = 0.069 \pm 0.009$. We rescale to our best value $B(J/\psi(1S) \rightarrow e^+e^-) = (6.02 \pm 0.19) \times 10^{-2}$.	$<4.0 \times 10^{-4}$ 90 119 ABREU 95N DLPH $e^+e^- \rightarrow Z$
Our first error is their experiment's error and our second error is the systematic error	$<3.3 \times 10^{-4}$ 90 ALBRECHT 91E ARG $e^+e^- \rightarrow \Upsilon(45)$
from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.	118 AVERY 898 reports $< 1.7 \times 10^{-4}$ assuming the $\Upsilon(4S)$ decays 43% to $B^0 \overline{B}{}^0$. We
$\Gamma(J/\psi(1S)\pi^-)/\Gamma(J/\psi(1S)K^+)$ Γ_{56}/Γ_{53}	rescale to 50%. 119 Assumes a 90 , $^{8-}$ production fraction of 0.39 and a 8 production fraction of 0.12.
VALUE EVTS DOCUMENT ID TECN COMMENT 0.043 \pm 0.023 5 107 ALEXANDER 95 CLE2 $e^+e^- \rightarrow \Upsilon(4S)$	-(
107 Assumes equal production of B^+B^- and $B^0\overline{B}{}^0$ on $\varUpsilon(4S)$.	$\Gamma(K_1(1400)^{\nu}\pi^{+})/\Gamma_{total}$ VALUE CL% DOCUMENT ID TECN COMMENT
$\Gamma(\psi(2S)K^+)/\Gamma_{ ext{total}}$ Γ_{57}/Γ	<2.6 x 10 ⁻³ 90 ALBRECHT 91B ARG $e^+e^- \rightarrow \Upsilon(4S)$
VALUE (units 10-4) CL% EVTS DOCUMENT ID TECN COMMENT	$\Gamma(K_2^*(1430)^0\pi^+)/\Gamma_{\text{total}}$ Γ_{68}/Γ
6.9± 3.1 OUR AVERAGE Error includes scale factor of 1.3. 6.1± 2.3 ± 0.9 7 108 ALAM 94 CLE2 $e^+e^ \rightarrow$	VALUE CL% DOCUMENT ID TECN COMMENT
$\Upsilon(4S)$	<6.8 x 10 ⁻⁴ 90 ALBRECHT 91B ARG $e^+e^- \rightarrow \Upsilon(4S)$
18 \pm 8 \pm 4 5 108 ALBRECHT 90J ARG $e^+e^- ightarrow$ \varUpsilon (4 5)	$\Gamma(K^+ ho^0)/\Gamma_{total}$
• • • We do not use the following data for averages, fits, limits, etc. • •	VALUE CL% DOCUMENT ID TECN COMMENT
< 5 90 108 BORTOLETTO92 CLEO $e^+e^- \rightarrow \gamma(45)$	<1.9 x 10 ⁻⁵ 90 ASNER 96 CLE2 $e^+e^- \rightarrow \Upsilon(4S)$ • • • We do not use the following data for averages, fits, limits, etc. • • •
22 \pm 17 3 109 ALBRECHT 87D ARG $e^+e^- \rightarrow \\ \varUpsilon(4S)$	$<1.9 \times 10^{-4}$ 90 ¹²⁰ ABREU 95N DLPH $e^+e^- \rightarrow Z$
¹⁰⁸ Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.	$<1.8 \times 10^{-4}$ 90 ALBRECHT 91B ARG $e^+e^- \rightarrow \Upsilon(45)$
109 ALBRECHT 87D assume $B^+B^-/B^0\overline{B}^0$ ratio is 55/45. Superseded by ALBRECHT 90J.	$<8 \times 10^{-5}$ 90 121 AVERY 898 CLEO $e^+e^- \rightarrow \Upsilon(4S)$ $<2.6 \times 10^{-4}$ 90 AVERY 87 CLEO $e^+e^- \rightarrow \Upsilon(4S)$
$\Gamma(\psi(2S)K^*(892)^+)/\Gamma_{\text{total}}$ Γ_{58}/Γ	120 Assumes a B^0 , B^- production fraction of 0.39 and a B_S production fraction of 0.12.
VALUE CL% DOCUMENT ID TECN COMMENT	121 AVERY 89B reports $< 7 \times 10^{-5}$ assuming the $\Upsilon(4S)$ decays 43% to $B^0 \overline{B}{}^0$. We rescale
<0.0030 90 110 ALAM 94 CLE2 $e^+e^- \rightarrow \Upsilon(4S)$ • • • We do not use the following data for averages, fits, limits, etc. • • •	to 50%.
<0.0035 90 110 BORTOLETTO92 CLEO $e^+e^- \rightarrow \Upsilon(4S)$	$\Gamma(K^0 ho^+)/\Gamma_{ ext{total}}$ Γ_{70}/Γ
<0.0049 90 110 ALBRECHT 90J ARG $e^+e^- ightarrow \Upsilon(45)$	VALUE CL% DOCUMENT ID TECN COMMENT
¹¹⁰ Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.	<4.8 x 10⁻⁵ 90 ASNER 96 CLE2 e^+e^- → $\Upsilon(4S)$

 B^{\pm}

	·-)/F _{total}			Γ ₇₁ /Γ	$\Gamma(K_1(1400)^+\gamma)/$					Γ ₈₄ /
<1.1 × 10 ⁻³	<u>CL%</u> 90	DOCUMENT ID ALBRECHT 91E	E ARG $e^+e^- \rightarrow 1$		<u>∨ALUE</u> <0.0022	<u>CL%</u> 90	DOCUMENT ID 130 ALBRECHT		$e^+e^- \rightarrow \gamma$	(45)
<1.1 x 10 - Γ(K*(892)+ ρ ⁰)/Ι		ALBRECH 316	EARG EVE - 7	г (43) Г <mark>72</mark> /Г	130 ALBRECHT 890				,	` '
(N (USZ) P)/	' total	DOCUMENT ID	TECN COMMENT	. 72/ .	rescale to 50%.					
<9.0 × 10 ⁻⁴	90	ALBRECHT 918	B ARG $e^+e^- \rightarrow 7$	r(4S)	$\Gamma(K_2^*(1430)^+\gamma)/$	Γ _{total}				Γ ₈₅ /
$(K_1(1400)^+ \rho^0)$	/Γ			Γ ₇₃ /Γ	<u>∨ALUE</u> <0.0014	<u>CL%</u> 90	DOCUMENT ID 131 ALBRECHT		$e^+e^- \rightarrow \gamma$	(45)
ALUE	/ ' total 	DOCUMENT ID	TECN COMMENT	173/1	131 ALBRECHT 896					` '
<7.8 × 10 ⁻⁴	90	ALBRECHT 916	B ARG $e^+e^- \rightarrow 7$	r(45)	rescale to 50%.	reports	0.0015 assuming t	10 7 (45) det	cuys 4570 to B	, , , , , , , , , , , , , , , , , , ,
$(K_2^*(1430)^+ \rho^0)$	/F _{total}	DOCUMENT ID	TECN COMMENT	Γ ₇₄ /Γ	$\Gamma(K^*(1680)^+\gamma)/V$	Γ _{total}	DOCUMENT ID	TECN_	COMMENT	Γ ₈₆ /
<1.5 × 10 ⁻³	90		BARG $e^+e^- \rightarrow 7$	r(45)	<0.0019	90	132 ALBRECHT	89G ARG	$e^+e^- \rightarrow \gamma$	(45)
(K+K-K+)/[total			Γ ₇₅ /Γ	¹³² ALBRECHT 890 rescale to 50%.	reports <	0.0017 assuming t	he $\Upsilon(4S)$ dec	cays 45% to B	3 ⁰ B ⁰ . ∨
ALUE	<u>CL%</u>	DOCUMENT ID 122 ABREU 950	TECN COMMENT N DLPH $e^+e^- \rightarrow Z$		$\Gamma(K_3^*(1780)^+\gamma)/$	Ttotal				Γ ₈₇
<3.1 × 10 ⁻⁴		ig data for averages, fit			VALUE	CL%	DOCUMENT ID	TECN	COMMENT	
$< 3.5 \times 10^{-4}$	90	-	E ARG $e^+e^- \rightarrow 1$	r(45)	<0.0055	90	¹³³ ALBRECHT	89G ARG	$e^+e^- \rightarrow \Upsilon$	(45)
			a $B_{\mathcal{S}}$ production fraction	. ,	¹³³ ALBRECHT 896 to 50%.	reports < 0	.005 assuming the 1	^(4 <i>S</i>) decays 4	45% to $B^0 \overline{B}{}^0$.	We resca
$\Gamma(K^+\phi)/\Gamma_{\text{total}}$	CL%	DOCUMENT ID	TECNCOMMENT_	Γ ₇₆ /Γ	Γ(K *(2045)+γ)/					Γ ₈₈ /
<1.2 × 10 ⁻⁵	90		CLE2 $e^+e^- \rightarrow 1$	r(4S)	<u>VALUE</u> <0.0099	<u>CL%</u> 90	DOCUMENT ID 134 ALBRECHT	89G ARG	$e^+e^- \rightarrow \gamma$	(45)
	e the followin	g data for averages, fit			134 ALBRECHT 890 rescale to 50%.				,	` '
$<1.8 \times 10^{-4}$	90	ALBRECHT 918	BARG $e^+e^- \rightarrow 1$	Υ(4S)						г.
<9 × 10 ⁻⁵			B CLEO $e^+e^- \rightarrow 1$		$\Gamma(\pi^+\pi^0)/\Gamma_{\text{total}}$	CL%	DOCUMENT ID	TECN	COMMENT	Г89/
$<2.1 \times 10^{-4}$	90 D= anadustia		CLEO $e^+e^- \rightarrow 1$ a B_S production fraction		<1.7 × 10 ⁻⁵	90	ASNER		$e^+e^- \rightarrow \gamma$	(45)
			a B_s production fraction B_s by decays 43% to B_s		• • • We do not us	e the follow	ing data for average			,
to 50%.	115 (0 × 10	assuming the 7 (15)	, decays 10 % to 5	,	$< 2.4 \times 10^{-4}$	90	135 ALBRECHT			
(K*(892)+K+	K-)/[Γ ₇₇ /Γ	$< 2.3 \times 10^{-3}$	90	136 BEBEK		$e^+e^- \rightarrow \gamma$. ,
ALUE	<u>CL%</u>	DOCUMENT ID	TECN COMMENT	. , , , , .	135 ALBRECHT 90B 136 BEBEK 87 assur				d B^+B^- at γ	r(4 <i>S</i>).
<1.6 × 10 ⁻³	90	ALBRECHT 918	E ARG $e^+e^- \rightarrow 1$	r(45)		,	5) decays 43% to B	- Б		
-(Κ* (892) ⁺ φ)/Γ				Γ ₇₈ /Γ	$\Gamma(\pi^+\pi^+\pi^-)/\Gamma_{to}$					Γ ₉₀ /
(Λ (U32) Ψ)/·	CL%	DOCUMENT ID	TECN COMMENT	. 76/	<u>∨ALUE</u> <1.9 × 10 ⁻⁴	<u>CL%</u> 90	DOCUMENT ID. 137 BORTOLETT			(46)
<7.0 × 10 ⁻⁵	90	ASNER 96	CLE2 $e^+e^- \rightarrow 7$	r(4S)	• • • We do not us					(43)
• • We do not us $<1.3 \times 10^{-3}$	e the followin 90	ng data for averages, flt ALBRECHT 918	ts, limits, etc. \bullet \bullet B ARG $e^+e^- \rightarrow 7$	r(45)	$< 2.2 \times 10^{-4}$	90	¹³⁸ ABREU	95N DLPH	$e^+e^- \rightarrow Z$	(46)
					$<4.5 \times 10^{-4}$ ¹³⁷ BORTOLETTO	90	139 ALBRECHT			
$(K_1(1400)^+\phi)/$		DOCUMENT ID	TECH COMMENT	Γ ₇₉ /Γ	We rescale to 50	10/2		- '		
<1.1 × 10 ⁻³	<u>CL%</u> 90				138 Assumes a B ⁰ , I	B ⁻ product	ion fraction of 0.39	and a B _S pro-	duction fraction	n of 0.12
C1.1 X 10	70	DOCUMENT ID ALBRECHT 91	B ARG $e^+e^- \rightarrow 0$	Υ(4 <i>S</i>)	139 ALBRECHT 90B	3 limit assun	nes equal production	າ of $B^0\overline B{}^0$ an	id B^+B^- at γ	r(45).
				Υ(45) Г <mark>80</mark> /Г		3 limit assun	nes equal production	of $B^0\overline B{}^0$ an	nd B ⁺ B [−] at 7	r(45).
$(K_2^*(1430)^+ \phi)/$ VALUE			B ARG $e^+e^- o ag{TECN}$	Г ₈₀ /Г	$\Gamma(ho^0\pi^+)/\Gamma_{ m total}$	3 limit assun <u>CL% _EVTS</u>	nes equal production DOCUMENT ID		nd B^+B^- at γ	r(45).
$(K_2^*(1430)^+\phi)/ALUE$	/F _{total}	ALBRECHT 91:	B ARG $e^+e^- \rightarrow 7$	Г ₈₀ /Г	$\frac{\Gamma(\rho^0 \pi^+)/\Gamma_{\text{total}}}{\stackrel{VALUE}{< 4.3 \times 10^{-5}}} \stackrel{C}{=}$	<u>EVTS</u> 0	<u>DOCUMENT ID</u> ASNER	96 CLE2	and B^+B^- at γ $\frac{COMMENT}{e^+e^- \rightarrow \gamma}$	r(45). Г 91,
$(K_2^*(1430)^+ \phi)/$ $< 3.4 \times 10^{-3}$	/F _{total}	ALBRECHT 91:	B ARG $e^+e^- \rightarrow 7$	Γ ₈₀ /Γ	$\Gamma(\rho^0 \pi^+)/\Gamma_{\text{total}}$ $\frac{VALUE}{<4.3 \times 10^{-5}}$ 9 • • • We do not us	<u>EVTS</u> 10 se the follow	DOCUMENT ID ASNER ing data for average	TECN 96 CLE2 es, fits, limits,	and B^+B^- at γ $\frac{COMMENT}{e^+e^- \rightarrow \gamma}$ etc. • •	r(45). Г91/
$\frac{\Gamma(K_2^*(1430)^+\phi)}{\Gamma(K_2^*(1430)^+\phi)}$ <3.4 × 10 ⁻³ $\frac{\Gamma(K^+f_0(980))}{\Gamma(K_2^*(1430)^+\phi)}$	/r _{total}	ALBRECHT 911 DOCUMENT ID ALBRECHT 911 DOCUMENT ID	B ARG $e^+e^- \rightarrow 7$	Г ₈₀ /Г	$\frac{\Gamma(\rho^0 \pi^+)/\Gamma_{\text{total}}}{\stackrel{VALUE}{< 4.3 \times 10^{-5}}} \stackrel{C}{\stackrel{9}{=}}$ • • • We do not us $\stackrel{< 2.6 \times 10^{-4}}{{=}} 9$	CL% <u>EVTS</u> 10 se the follow	DOCUMENT ID ASNER ing data for average	TECN 96 CLE2 es, fits, limits, 95N DLPH	$\begin{array}{c} COMMENT \\ e^{+}e^{-} \rightarrow \Upsilon \\ etc. \bullet \bullet \\ e^{+}e^{-} \rightarrow Z \end{array}$	(45). Fg1 (45)
$\frac{\Gamma(K_2^*(1430)^+\phi)}{(K_2UE)}$ $<3.4 \times 10^{-3}$ $\frac{\Gamma(K^+f_0(980))}{(K^+UE)}$ $<8 \times 10^{-5}$	/rtotal	ALBRECHT 911 DOCUMENT ID ALBRECHT 911 DOCUMENT ID 125 AVERY 891	B ARG $e^+e^- \rightarrow 0$ TECN COMMENT B ARG $e^+e^- \rightarrow 0$ TECN COMMENT B CLEO $e^+e^- \rightarrow 0$	Γ ₈₀ /Γ (45) Γ ₈₁ /Γ (45)	$\Gamma(\rho^0 \pi^+)/\Gamma_{\text{total}}$ $\times ALUE$ $< 4.3 \times 10^{-5}$ 9 • • • We do not us $< 2.6 \times 10^{-4}$ 9 $< 1.5 \times 10^{-4}$ 9	CL% <u>EVTS</u> 10 se the follow 10	DOCUMENT ID ASNER ing data for average	96 CLE2 es, fits, limits, 95N DLPH 90B ARG	and B^+B^- at γ $\frac{COMMENT}{e^+e^- \to \gamma}$ etc. $\bullet \bullet \bullet$ $e^+e^- \to Z$ $e^+e^- \to \gamma$	(45). Fg1, (45)
$(K_2^*(1430)^+\phi)/K_{ALUE}$ $<3.4 \times 10^{-3}$ $(K^+f_0(980))/F_{ALUE}$ $<8 \times 10^{-5}$ 25 AVERY 898 repo	/rtotal	ALBRECHT 911 DOCUMENT ID ALBRECHT 911 DOCUMENT ID 125 AVERY 891	B ARG $e^+e^- \rightarrow \Omega$ TECN COMMENT B ARG $e^+e^- \rightarrow \Omega$ TECN COMMENT	Γ ₈₀ /Γ (45) Γ ₈₁ /Γ (45)	$\Gamma(\rho^0 \pi^+)/\Gamma_{\text{total}}$ $\sim 4.3 \times 10^{-5}$ • • • We do not us $\sim 2.6 \times 10^{-4}$ $\sim 1.5 \times 10^{-4}$ $\sim 1.7 \times 10^{-4}$ $\sim 1.7 \times 10^{-4}$	CL% <u>EVTS</u> 10 se the follow	DOCUMENT ID ASNER ing data for average 140 ABREU 141 ALBRECHT	96 CLE2 es, fits, limits, 95N DLPH 90B ARG 089 CLEO 87 CLEO	$\begin{array}{c} \text{COMMENT} \\ e^+e^- \rightarrow & \Upsilon \\ \text{etc.} \bullet \bullet \\ e^+e^- \rightarrow & \Upsilon \\ \end{array}$	(45) (45) (45) (45) (45) (45)
$\frac{\Gamma(K_2^*(1430)^+\phi)}{(5.4 \times 10^{-3})}$ $\frac{\Gamma(K^+f_0(980))}{(5.4 \times 10^{-5})}$	/rtotal	ALBRECHT 911 DOCUMENT ID ALBRECHT 911 DOCUMENT ID 125 AVERY 891	B ARG $e^+e^- \rightarrow 0$ TECN COMMENT B ARG $e^+e^- \rightarrow 0$ TECN COMMENT B CLEO $e^+e^- \rightarrow 0$	Γ ₈₀ /Γ (45) Γ ₈₁ /Γ (45)	$\Gamma(\rho^0 \pi^+)/\Gamma_{\text{total}}$ $\times 4.0E$ $< 4.3 \times 10^{-5}$ $= 0.0$ $< 0.5 \times 10^{-4}$ $< 0.5 \times 10^{-4}$ $< 0.5 \times 10^{-4}$ $< 0.7 \times 10^{-4}$ $< 0.7 \times 10^{-4}$ $< 0.3 \times 10^{-4}$	EVTS 10 10 10 10 10 10 10 10 10 10 10 10 10	DOCUMENT ID ASNER ing data for average 140 ABREU 141 ALBRECHT 142 BORTOLETT 142 BEBEK GILES	96 CLE2 es, fits, limits, 95N DLPH 90B ARG 089 CLEO 87 CLEO 84 CLEO	$\begin{array}{c} \text{COMMENT} \\ e^+e^- \rightarrow \Upsilon \\ \text{etc.} \bullet \bullet \bullet \\ e^+e^- \rightarrow \Upsilon \\ \text{Repl. by BEB} \end{array}$	(45) (45) (45) (45) (45) (45) (45) (45)
(K*(1430)+ φ)/ ΔΑΙ UE <3.4 × 10 ⁻³ -(K+ f ₀ (980))/Γ ₁ ΔΑΙ UE <8 × 10 ⁻⁵ 25 AVERY 898 reports 50%.	CL% 90 total	ALBRECHT 911 DOCUMENT ID ALBRECHT 911 DOCUMENT ID 125 AVERY 891	B ARG $e^+e^- \rightarrow 0$ TECN COMMENT B ARG $e^+e^- \rightarrow 0$ TECN COMMENT B CLEO $e^+e^- \rightarrow 0$	Γ ₈₀ /Γ (45) Γ ₈₁ /Γ (45)	$\Gamma(\rho^0 \pi^+)/\Gamma_{\text{total}}$ VALUE $< 4.3 \times 10^{-5}$ • • • We do not us $< 2.6 \times 10^{-4}$ $< 1.5 \times 10^{-4}$ $< 1.7 \times 10^{-4}$ $< 2.3 \times 10^{-4}$ $< 6 \times 10^{-4}$ 9 140 Assumes a B^0 , $A = 10^{-4}$	EVTS 10 10 10 10 10 10 10 10 10 1	DOCUMENT ID ASNER ing data for average 140 ABREU 141 ALBRECHT 142 BORTOLETT 142 BEBEK GILES ion fraction of 0.39	96 CLE2 es, fits, limits, 95N DLPH 908 ARG 089 CLE0 87 CLE0 84 CLEO and a Bc pro	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \Upsilon \\ \text{etc.} \bullet \bullet \bullet \\ e^+e^- \rightarrow \Upsilon \\ e^+e^- \rightarrow \Upsilon \\ e^+e^- \rightarrow \Upsilon \\ \text{re} + e^- \rightarrow \Upsilon \\ \text{re} + e^- \rightarrow \Upsilon \\ \text{Repl.} \text{ by BEB} \\ \text{subdition fraction} \end{array}$	(45) (45) (45) (45) (45) (45) (45) (45)
(K*(1430)+ φ)/ ΔΑΙ UE <3.4 × 10-3 (K+ fo(980))/Γο ΔΑΙ UE <8 × 10-5 25 ΑΝΕΚΥ 898 reports 50%. (K*(892)+γ)/Γο	/ Total	ALBRECHT 911 DOCUMENT ID ALBRECHT 911 DOCUMENT ID 125 AVERY 891 5 assuming the \(\gamma(4S)\)	B ARG $e^+e^- \rightarrow \Omega$ TECN COMMENT B ARG $e^+e^- \rightarrow \Omega$ TECN COMMENT B CLEO $e^+e^- \rightarrow \Omega$ Oddown to B Ω Odd	Γ_{80}/Γ $\Gamma_{(4S)}$ Γ_{81}/Γ $\Gamma_{(4S)}$	$\Gamma(\rho^0 \pi^+)/\Gamma_{\text{total}}$ $\times 4.0E$ $< 4.3 \times 10^{-5}$ $= 0.0$ $< 0.5 \times 10^{-4}$ $< 0.5 \times 10^{-4}$ $< 0.5 \times 10^{-4}$ $< 0.7 \times 10^{-4}$ $< 0.7 \times 10^{-4}$ $< 0.3 \times 10^{-4}$	CL% EVTS 10 10 10 10 10 10 10 10 10 10 10 10 10	DOCUMENT ID ASNER ing data for average 140 ABREU 141 ALBRECHT 142 BORTOLETT 142 BEBEK GILES ion fraction of 0.39 nes equal production	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \Upsilon \\ \text{etc.} \bullet \bullet \bullet \\ e^+e^- \rightarrow \Upsilon \\ \text{ete} \rightarrow \nabla \\ e^+e^- \rightarrow \Upsilon \\ e^+e^- \rightarrow \Upsilon \\ \text{ete} \rightarrow \nabla \\ \text{ete} \rightarrow$	(45) (45) (45) (45) (45) (45) (45) (45)
$\frac{1}{2} \left(\frac{K_{2}^{*}(1430)^{+} \phi}{6} \right) / \frac{1}{2} $ $\frac{1}{2} \frac{K_{2}^{*}(1430)^{+} \phi}{6} = \frac{1}{2}	$ \frac{\sqrt{\Gamma_{\text{total}}}}{90} $ $ \frac{CL\%}{90} $ $ \text{orts} < 7 \times 10^{-1} $ $ \frac{CL\%}{10^{-5}} $	ALBRECHT 911 DOCUMENT ID ALBRECHT 911 DOCUMENT ID 125 AVERY 891 5 assuming the $\Upsilon(4S)$ EVTS DOCUMENT 5 126 AMMAR	B ARG $e^+e^- \rightarrow 0$ TECN COMMENT B ARG $e^+e^- \rightarrow 0$ TECN COMMENT B CLEO $e^+e^- \rightarrow 0$ G decays 43% to $B^0\overline{B}^0$	Γ_{80}/Γ $\Gamma_{(4S)}$ Γ_{81}/Γ $\Gamma_{(4S)}$	$\Gamma(\rho^0 \pi^+)/\Gamma_{\text{total}}$ VALUE $< 4.3 \times 10^{-5}$ • • • We do not us $< 2.6 \times 10^{-4}$ $< 1.5 \times 10^{-4}$ $< 1.7 \times 10^{-4}$ $< 2.3 \times 10^{-4}$ $< 6 \times 10^{-4}$ 9 140 Assumes a B^0 , 141 ALBRECHT 906	EVTS 10 10 10 10 10 10 10 10 10 1	DOCUMENT ID ASNER ing data for average 140 ABREU 141 ALBRECHT 142 BORTOLETT 142 BEBEK GILES ion fraction of 0.39 nes equal production ecays 43% to BOB	96 CLE2 es, fits, limits, 95N DLPH 908 ARG 1089 CLE0 87 CLEO and a B_5 pro n of $B^0 \overline{B}^0$ and 0. We rescale	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \Upsilon \\ \text{etc.} \bullet \bullet \bullet \\ e^+e^- \rightarrow \Upsilon \\ \text{etc.} \bullet \bullet \bullet \\ e^+e^- \rightarrow \Upsilon \\ e^+e^- \rightarrow \Upsilon \\ e^+e^- \rightarrow \Upsilon \\ e^+e^- \rightarrow \Upsilon \\ \text{etc.} \bullet \bullet \bullet \bullet \bullet \\ \text{etc.} \bullet \bullet \bullet \bullet \\ \text{etc.} \bullet \bullet \bullet \bullet \\ \text{etc.} \bullet \bullet \bullet \\ \text{etc.} \bullet \bullet \bullet \bullet \\ \text{etc.} \bullet \bullet \bullet \\ \text{etc.} \bullet \bullet \bullet \bullet \\ \text{etc.} \bullet \bullet \\ \text{etc.} \bullet \bullet \bullet \\ \text{etc.} \bullet \bullet \bullet \\ \text{etc.} \bullet \bullet \bullet \\ \text{etc.} $	(45) (45) (45) (45) (45) (45) (45) (45)
$(K_{\star}^{*}(1430)^{+}\phi)/K_{\star}^{ALUE}$ $<3.4 \times 10^{-3}$ $(K^{+}f_{0}(980))/F_{\star}^{ALUE}$ $<8 \times 10^{-5}$ <25 AVERY 898 reports 50%. $-(K^{*}(892)^{+}\gamma)/F_{\star}^{ALUE}$ $(5.7 \pm 3.1 \pm 1.1) \times 6 \bullet \text{ We do not us}$	$ \frac{\sqrt{\Gamma_{\text{total}}}}{90} $ $ \frac{CL\%}{90} $ $ \text{orts} < 7 \times 10^{-1} $ $ \frac{CL\%}{10^{-5}} $	ALBRECHT 911 DOCUMENT ID ALBRECHT 911 DOCUMENT ID 125 AVERY 891 5 assuming the $\Upsilon(4S)$ EVTS DOCUMENT	B ARG $e^+e^- \rightarrow 0$ TECN COMMENT B ARG $e^+e^- \rightarrow 0$ TECN COMMENT B CLEO $e^+e^- \rightarrow 0$ Godecays 43% to $B^0\overline{B}^0$ TID TECN COM 93 CLE2 e^+e^- Tits, limits, etc. • • •	Γ_{80}/Γ $\Gamma_{(4S)}$ Γ_{81}/Γ $\Gamma_{(4S)}$	$\Gamma(\rho^0 \pi^+)/\Gamma_{\text{total}}$ $\sim 4.3 \times 10^{-5}$ • • • • We do not us $\sim 2.6 \times 10^{-4}$ $\sim 1.5 \times 10^{-4}$ $\sim 1.7 \times 10^{-4}$	10 EVTS 10 EVT	DOCUMENT ID ASNER ing data for average 140 ABREU 141 ALBRECHT 142 BORTOLETT 142 BEBEK GILES ion fraction of 0.39 nes equal production ecays 43% to B ⁰ B ⁰ DOCUMENT ID	$\frac{TECN}{96}$ CLE2 es, fits, limits, 95N DLPH 908 ARG O89 CLEO 87 CLEO and a B_S pro of $B^0 \overline{B}^0$ and $\frac{1}{2} B^0$ We rescale	$\begin{array}{c} \operatorname{COMMENT} \\ e^+e^- \to \Upsilon \\ \operatorname{etc.} \bullet \bullet \bullet \\ e^+e^- \to \Upsilon \\ \operatorname{ete.} \bullet \bullet \to \Upsilon \\ \operatorname{ete.} \bullet \to \Upsilon \\ \operatorname{ete.} \to \Upsilon \\ \operatorname{dete.} \to \Upsilon \\ dete$	(45) (45) (45) (45) (45) (45) (45) (45)
$\frac{\Gamma(K_2^*(1430)^+\phi)}{ALUE} \times \frac{3.4 \times 10^{-3}}{6(K^+f_0(980))} / \Gamma_0$ $\frac{ALUE}{68 \times 10^{-5}} \times \frac{25}{6} \text{ AVERY 89B report 50\%}.$ $\frac{\Gamma(K^*(892)^+\gamma)}{6(5.7 \pm 3.1 \pm 1.1)} \times \frac{3.4}{6} \times \frac$	$\frac{CL\%}{90}$ total $\frac{CL\%}{90}$ orts < 7 × 10 ⁻¹ total $\frac{CL\%}{10^{-5}}$ se the following	ALBRECHT 911 DOCUMENT ID ALBRECHT 911 DOCUMENT ID 125 AVERY 891 5 assuming the $\Upsilon(4S)$ EVTS DOCUMENT 5 126 AMMAR ng data for averages, fill	B ARG $e^+e^- \rightarrow 0$ TECN COMMENT B ARG $e^+e^- \rightarrow 0$ TECN COMMENT B CLEO $e^+e^- \rightarrow 0$ Godecays 43% to $B^0\overline{B}^0$ TID TECN COM 93 CLE2 e^+e^+ its, limits, etc. • • • HT 89G ARG e^+	Γ_{80}/Γ $\Gamma_{(4S)}$ Γ_{81}/Γ $\Gamma_{(4S)}$ Γ_{82}/Γ $\Gamma_{(4S)}$ $\Gamma_{(4S)}$ $\Gamma_{(4S)}$ $\Gamma_{(4S)}$ $\Gamma_{(4S)}$	$\Gamma(\rho^0 \pi^+)/\Gamma_{\text{total}}$ AUUE $< 4.3 \times 10^{-5}$ • • • We do not us $< 2.6 \times 10^{-4}$ $< 1.5 \times 10^{-4}$ $< 1.7 \times 10^{-4}$ $< 2.3 \times 10^{-4}$ $< 6 \times 10^{-4}$ 9 140 Assumes a B^0 , 141 ALBRECHT 90e 142 Papers assume t $\Gamma(\pi^+ f_0(980))/\Gamma_t$ AUUE $< 1.4 \times 10^{-4}$ 143 BORTOLETTO	ELY EVTS 10 10 10 10 10 10 10 10 10 1	DOCUMENT ID ASNER Ing data for average 140 ABREU 141 ALBRECHT 142 BORTOLETT 142 BEBEK GILES ion fraction of 0.39 nes equal production ecays 43% to B ⁰ B ⁰ DOCUMENT ID 143 BORTOLETT	96 CLE2 es, fits, limits, 95N DLPH 908 ARG O89 CLEO 87 CLEO and a B_S pro on of $B^0 \overline{B}^0$ and o. We rescale $\frac{TECN}{TECN}$	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \Upsilon $	(45) (45) (45) (45) (45) (45) (45) (45) (45) (45) (45) (45)
$\frac{\Gamma(K_2^*(1430)^+\phi)}{(ALUE)} = \frac{(K^*f_0(980))}{\Gamma(K^*f_0(980))} = \frac{(K^*f_0(980))}{\Gamma(K^*f_0(892)^+\gamma)} = \frac{(K^*(892)^+\gamma)}{(5.7\pm 3.1\pm 1.1)} = \frac{(K^*(892)^+\gamma)}{(5.5\pm 3.1\pm 1.1)} = \frac{(5.5\pm 3.1\pm 1.1)}{(5.5\pm 3.1\pm 1.1)} = (5.5$	$\sqrt{\Gamma_{\text{total}}}$ $\frac{CL\%}{90}$ $\frac{CL\%}{90}$ $\frac{CL\%}{90}$ $\frac{CL\%}{10^{-5}}$ $\frac{CL\%}{10^{-5}}$ se the followin 10^{-4} 90	ALBRECHT 91a DOCUMENT ID ALBRECHT 91a DOCUMENT ID 125 AVERY 89a 5 assuming the $\Upsilon(4S)$ EVTS DOCUMENT 5 126 AMMAR 127 ALBRECH	B ARG $e^+e^- \rightarrow 0$ TECN COMMENT B ARG $e^+e^- \rightarrow 0$ TECN COMMENT B CLEO $e^+e^- \rightarrow 0$ G decays 43% to $B^0\overline{B}^0$ TECN COM 93 CLE2 e^+e^- Airs, limits, etc. • • • HT 89G ARG e^+e^- 89B CLEO e^+e^+	Γ_{80}/Γ $\Gamma_{(45)}$ Γ_{81}/Γ $\Gamma_{(45)}$	$\Gamma(\rho^0 \pi^+)/\Gamma_{\text{total}}$ ALUE <4.3 × 10 ⁻⁵ • • • We do not us <2.6 × 10 ⁻⁴ <1.5 × 10 ⁻⁴ 9 <1.7 × 10 ⁻⁴ 9 <2.3 × 10 ⁻⁴ 9 46 × 10 ⁻⁴ 9 140 Assumes a B^0 , 141 ALBRECHT 90e 142 Papers assume t $\Gamma(\pi^+f_0(980))/\Gamma_{\text{total}}$ ALUE <1.4 × 10 ⁻⁴ 143 BORTOLETTO We rescale to 50	ELY EVTS 10 10 10 10 10 10 10 10 10 1	DOCUMENT ID ASNER Ing data for average 140 ABREU 141 ALBRECHT 142 BORTOLETT 142 BEBEK GILES ion fraction of 0.39 nes equal production ecays 43% to B ⁰ B ⁰ DOCUMENT ID 143 BORTOLETT	96 CLE2 es, fits, limits, 95N DLPH 908 ARG O89 CLEO 87 CLEO and a B_S pro on of $B^0 \overline{B}^0$ and o. We rescale $\frac{TECN}{TECN}$	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \Upsilon $	(45). (45) (45) (45) (45) (45) (45) (45) (47) (47) (47) (47) (48) (48) (48)
$F(K_2^*(1430)^+\phi)/F_{ALUE}$ $(3.4 \times 10^{-3})^+$ $F(K^+f_0(980))/F_{ALUE}$ $(48 \times 10^{-5})^+$ (5.25 AVERY 89B reports 50%. $F(K^*(892)^+\gamma)/F_{ALUE}$ $(5.7 \pm 3.1 \pm 1.1) \times 10^+$ $(5.5 \times 10^+)^+$ $(5.5 \times 10^+)^+$ $(5.5 \times 10^+)^+$ $(5.5 \times 10^+)^+$ $(5.5 \times 10^+)^+$	7 total $\frac{CL\%}{90}$ $\frac{CL\%}{90}$ $\frac{CL\%}{90}$ orts $< 7 \times 10^{-7}$ $\frac{CL\%}{10^{-5}}$ se the followin 10^{-4} $\frac{90}{10^{-4}}$ $\frac{90}{10^{-3}}$ $\frac{90}{90}$	ALBRECHT 91a DOCUMENT ID ALBRECHT 91a DOCUMENT ID 125 AVERY 89a 5 assuming the 7(45) EVTS DOCUMENT 5 126 AMMAR and data for averages, fit 127 ALBRECH 128 AVERY AVERY	B ARG $e^+e^- \rightarrow 0$ TECN COMMENT B ARG $e^+e^- \rightarrow 0$ TECN COMMENT B CLEO $e^+e^- \rightarrow 0$ Godecays 43% to $B^0\overline{B}^0$ TID TECN COM 93 CLE2 e^+e^- its, limits, etc. • • • HT 89G ARG e^+ 89B CLEO e^+e^-	Γ_{80}/Γ $T(4S)$ Γ_{81}/Γ $T(4S)$ T_{82}/Γ T_{82}/Γ T_{82}/Γ T_{83}/Γ T_{83}/Γ T_{84}/Γ	$\Gamma(\rho^0 \pi^+)/\Gamma_{\text{total}}$ ALUE <4.3 × 10 ⁻⁵ • • • We do not us <2.6 × 10 ⁻⁴ <1.5 × 10 ⁻⁴ 9 <1.7 × 10 ⁻⁴ 9 <2.3 × 10 ⁻⁴ 9 46 × 10 ⁻⁴ 9 140 Assumes a B^0 , 141 ALBRECHT 90e 142 Papers assume t $\Gamma(\pi^+f_0(980))/\Gamma_t$ ALUE <1.4 × 10 ⁻⁴ 143 BORTOLETTO We rescale to 50 $\Gamma(\pi^+f_2(1270))/\Gamma_t$	1.1% EVTS 10 10 10 10 10 10 10 10 10 10 10 10 10	DOCUMENT ID ASNER ing data for average 140 ABREU 141 ALBRECHT 142 BORTOLETT 142 BEBEK GILES ion fraction of 0.39 nes equal production ecays 43% to B ⁰ B DOCUMENT ID 143 BORTOLETT < 1.2 × 10 ⁻⁴ assu	96 CLE2 es, fits, limits, 95N DLPH 90B ARG 089 CLEO 87 CLEO and a B_5 pro n of B^0 \overline{B}^0 and B_5 we rescale \overline{B}^0 \overline	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \Upsilon \\ to 50\%. \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \Upsilon \\$	(45). (45) (45) (45) (45) (45) (45) (45) (47) (47) (47) (47) (48) (48) (48)
$(K_{\bullet}^{*}(1430)^{+}\phi)/ALUE$ $(3.4 \times 10^{-3})^{-1}(K^{+}f_{0}(980))/\Gamma_{0}$ $(2.4 \times 10^{-5})^{-1}(K^{*}(892)^{+}\gamma)/\Gamma_{0}$ $(3.4 \times 10^{-5})^{-1}(K^{*}(892)^{+}\gamma)/\Gamma_{0}$ $(3.4 \times 10^{-5})^{-1}(6.7 \times 10^{-5})^{-1}(6.7 \times 10^{-5})^{-1}$ $(3.7 \times 10^{-5})^{-1}(6.7 \times 10^{-5})^{-1}$	/\tilde{\text{Ftotal}} \\ \text{ \frac{CL\%}{90}} \\ \text{ total} \\ \text{ \frac{CL\%}{90}} \\ \text{ pot st } < 7 \times 10^{-5} \end{align*} \text{ total} \\ \text{ \frac{CL\%}{10^{-5}}} \\ \text{ total} \\ \text{ 10^{-4}} \\ \text{ 10^{-4}} \\ \text{ 90} \\ \text{ 10^{-4}} \\ \text{ 90} \\ \text{ 10^{-3}} \\ \text{ 90} \\ \text{ 10^{-4}} \\ \text{ 90} \\ \text{ 10^{-3}} \\ \text{ 90} \\ \text{ 10^{-4}} \\ \text{ 90} \\ \text{ 10^{-3}} \\ \text{ 90} \\ \text{ 10^{-4}} \\ \text{ 90} \\ \text{ 10^{-3}} \\ \	ALBRECHT 91 DOCUMENT ID ALBRECHT 91 ALBRECHT 91 125 AVERY 89 5 assuming the T(4S) EVTS DOCUMENT 5 126 AMMAR 127 ALBRECH 128 AVERY AVERY AVERY 2.3 events above backg 5% to B ⁰ B ⁰ .	B ARG $e^+e^- \rightarrow 0$ TECN COMMENT B ARG $e^+e^- \rightarrow 0$ TECN COMMENT B CLEO $e^+e^- \rightarrow 0$ Godecays 43% to $B^0\overline{B}^0$ TID TECN COM 93 CLE2 e^+e^- its, limits, etc. • • • HT 89G ARG e^+ 89B CLEO e^+e^-	Γ_{80}/Γ $\Gamma_{(45)}$ Γ_{81}/Γ $\Gamma_{(45)}$	$\Gamma(\rho^0 \pi^+)/\Gamma_{\text{total}}$ 24.3 × 10 ⁻⁵ 9 • • • We do not us 2.6 × 10 ⁻⁴ 9 <1.5 × 10 ⁻⁴ 9 <1.7 × 10 ⁻⁴ 9 <2.3 × 10 ⁻⁴ 9 140 Assumes a B^0 , 141 ALBRECHT 908 142 Papers assume t $\Gamma(\pi^+ f_0(980))/\Gamma_t$ 21.4 × 10 ⁻⁴ 143 BORTOLETTO We rescale to 50 $\Gamma(\pi^+ f_2(1270))/\Gamma_t$ 24.4 × 10 ⁻⁴	2.5% EVTS 100 100 100 100 100 100 100 1	DOCUMENT ID ASNER 140 ABREU 141 ALBRECHT 142 BORTOLETT 142 BEBEK GILES ion fraction of 0.39 nes equal production ecays 43% to B ⁰ B ⁰ DOCUMENT ID 143 BORTOLETT < 1.2 × 10 ⁻⁴ assu DOCUMENT ID 144 BORTOLETT	7ECN 96 CLE2 95, fits, limits, 95N DLPH 908 ARG 089 CLE0 87 CLE0 84 CLE0 84 CLE0 0 60 60 60 60 60 60 60 60 60 60 60 60 60	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \Upsilon \\ \underline{COMMENT} $	(45). (45) (45) (45) (45) (45) (45) (45) (45)
$(K_{2}^{*}(1430)^{+}\phi)/MLUE$ $<3.4 \times 10^{-3}$ $(K_{1}^{*}(980))/\Gamma_{1}^{*}MLUE$ $<8 \times 10^{-5}$ 25 AVERY 89B report to 50%. $(K^{*}(892)^{+}\gamma)/\Gamma_{2}^{*}MLUE}$ $(5.7 \pm 3.1 \pm 1.1) \times 10^{-3}$ $<5.5 \times 10^{-5}$ $<1.8 \times 10^{-5}$	$\frac{CL\%}{90}$ total $\frac{CL\%}{90}$ orts < 7 × 10 ⁻¹ total $\frac{CL\%}{10^{-5}}$ se the followin 10 ⁻⁴ 90 10 ⁻³ 90 1	ALBRECHT 91 DOCUMENT ID ALBRECHT 91 ALBRECHT 91 125 AVERY 89 5 assuming the T(4S) EVTS DOCUMENT 5 126 AMMAR 127 ALBRECH 128 AVERY AVERY AVERY 2.3 events above backg 5% to B ⁰ B ⁰ .	B ARG $e^+e^- \rightarrow 0$ TECN COMMENT B ARG $e^+e^- \rightarrow 0$ TECN COMMENT B CLEO $e^+e^- \rightarrow 0$ Godecays 43% to $B^0\overline{B}^0$ TID TECN COM 93 CLE2 e^+e^- its, limits, etc. • • • HT 89G ARG e^+ 89B CLEO e^+e^-	Γ_{80}/Γ $\Gamma_{(4S)}$ Γ_{81}/Γ $\Gamma_{(4S)}$ 0. We rescale Γ_{82}/Γ $\Gamma_{(4S)}$ $\Gamma_{(4S)}$ $\Gamma_{(4S)}$ $\Gamma_{(4S)}$ $\Gamma_{(4S)}$ $\Gamma_{(4S)}$	$\Gamma(\rho^0 \pi^+)/\Gamma_{\text{total}}$ AUUE <4.3 × 10 ⁻⁵ 9 • • • We do not us <2.6 × 10 ⁻⁴ 9 <1.5 × 10 ⁻⁴ 9 <1.7 × 10 ⁻⁴ 9 <2.3 × 10 ⁻⁴ 9 140 Assumes a B^0 , 141 ALBRECHT 90e 142 Papers assume t $\Gamma(\pi^+ f_0(980))/\Gamma_t$ AUUE $\Gamma(\pi^+ f_2(1270))/\Gamma_t$ VALUE $\Gamma(\pi^+ f_2(1270))/\Gamma_t$ VALUE	1.5 EVTS 10 10 10 10 10 10 10 10 10 10 10 10 10	DOCUMENT ID ASNER 140 ABREU 141 ALBRECHT 142 BORTOLETT 142 BEBEK GILES ion fraction of 0.39 nes equal production ecays 43% to B ⁰ B ⁰ DOCUMENT ID 143 BORTOLETT < 1.2 × 10 ⁻⁴ assu DOCUMENT ID 144 BORTOLETT	7ECN 96 CLE2 95, fits, limits, 95N DLPH 908 ARG 089 CLE0 87 CLE0 84 CLE0 84 CLE0 0 60 60 60 60 60 60 60 60 60 60 60 60 60	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \Upsilon \\ \underline{COMMENT} $	(45). (45). (45). (45). (45). (45). (45). (45). (45). (45). (45). (45). (45).
$\Gamma(K_2^*(1430)^+\phi)/K_{ALUE}$ $<3.4 \times 10^{-3}$ $\Gamma(K^+f_0(980))/\Gamma_{ALUE}$ $<8 \times 10^{-5}$ 12^5 AVERY 89B report to 50%. $\Gamma(K^*(892)^+\gamma)/\Gamma_{ALUE}$ $(5.7 \pm 3.1 \pm 1.1) \times 10^{-3}$ $<5.5 \times 10^{-5}$ $<1.8 \times 10^{-5}$ $<1.5 \times 1$	$\frac{CL\%}{90}$ total $\frac{CL\%}{90}$ orts < 7×10^{-5} total $\frac{CL\%}{10^{-5}}$ se the followin 10^{-4} 90 10^{-4} 90 10^{-3} 90 erved 4.1 ± 2 45) decays 43 45) decays 43	ALBRECHT 911 DOCUMENT ID ALBRECHT 911 125 AVERY 891 15 126 AMMAR 127 ALBRECH 128 AVERY AVERY AVERY AVERY 2.3 events above backg 5% to $B^0 \overline{B}^0$. 3% to $B^0 \overline{B}^0$.	B ARG $e^+e^- \rightarrow 0$ TECN COMMENT B ARG $e^+e^- \rightarrow 0$ TECN COMMENT B CLEO $e^+e^- \rightarrow 0$ G decays 43% to $B^0\overline{B}^0$ TID TECN COM 93 CLE2 e^+e^+ its, limits, etc. • • HT 89G ARG e^+e^+ 89B CLEO e^+e^+ 87 CLEO e^+e^+ ground.	Γ_{80}/Γ $\Gamma_{(45)}$ Γ_{81}/Γ $\Gamma_{(45)}$	$\Gamma(\rho^0 \pi^+)/\Gamma_{\text{total}}$ $^{24.3}$ × 10 ⁻⁵ 9 • • • • We do not us $^{2.6}$ × 10 ⁻⁴ 9 $^{2.5}$ × 10 ⁻⁴ 9 $^{2.3}$ × 10 ⁻⁴ 9 $^{2.3}$ × 10 ⁻⁴ 9 $^{2.3}$ × 10 ⁻⁴ 9 $^{3.4}$ Assumes a $^{6.7}$ × 11 41 ALBRECHT 906 42 Papers assume t 41 Γ(π ⁺ f ₀ (980))/Γ _t $^{24.4}$ × 10 ⁻⁴ $^{34.3}$ BORTOLETTO We rescale to 50 $^{44.4}$ BORTOLETTO We rescale to 50	1.1% EVTS 100 100 100 100 100 100 100 100 100 10	DOCUMENT ID ASNER 140 ABREU 141 ALBRECHT 142 BORTOLETT 142 BEBEK GILES ion fraction of 0.39 nes equal production ecays 43% to B ⁰ B ⁰ DOCUMENT ID 143 BORTOLETT < 1.2 × 10 ⁻⁴ assu DOCUMENT ID 144 BORTOLETT	7ECN 96 CLE2 95, fits, limits, 95N DLPH 908 ARG 089 CLE0 87 CLE0 84 CLE0 84 CLE0 0 60 60 60 60 60 60 60 60 60 60 60 60 60	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \Upsilon \\ \underline{COMMENT} $	(45). (45). (45). (45). (45). (45). (45). (45). (47). (45). (45). (45). (45). (45). (45). (45). (45). (45). (45). (45). (45).
$\Gamma(K_2^*(1430)^+\phi)/K_{ALUE}$ $<3.4 \times 10^{-3}$ $\Gamma(K^+f_0(980))/\Gamma_{CALUE}$ $<8 \times 10^{-5}$ 12^5 AVERY 89B report to 50%. $\Gamma(K^*(892)^+\gamma)/\Gamma_{CALUE}$ $(5.7 \pm 3.1 \pm 1.1) \times 10^{-3}$ $<5.5 \times 10^{-5}$ $<1.8 \times 10^{-5}$	$\frac{CL\%}{90}$ total $\frac{CL\%}{90}$ orts < 7 × 10 ⁻¹ total $\frac{CL\%}{10^{-5}}$ se the followin 10 ⁻⁴ 90 10 ⁻⁴ 90 10 ⁻³ 90 erved 4.1 ± 2 45) decays 4:45) decays 4:7 Total $\frac{CL\%}{10^{-5}}$	ALBRECHT 911 DOCUMENT ID ALBRECHT 911 DOCUMENT ID 125 AVERY 891 5 126 AMMAR 127 ALBRECH 128 AVERY AVERY AVERY 2.3 events above backg 5% to \$B^0\$ \$\overline{B}^0\$. DOCUMENT ID	B ARG $e^+e^- \rightarrow 0$ TECN COMMENT B ARG $e^+e^- \rightarrow 0$ TECN COMMENT B CLEO $e^+e^- \rightarrow 0$ Godecays 43% to $B^0\overline{B}^0$ TID TECN COM 93 CLE2 e^+e^- its, limits, etc. • • • HT 89G ARG e^+ 89B CLEO e^+e^-	Γ_{80}/Γ Γ_{61}/Γ Γ_{61}/Γ Γ_{62}/Γ Γ_{62}/Γ Γ_{62}/Γ Γ_{63}/Γ Γ_{63}/Γ Γ_{63}/Γ	Γ(ρ^0 π ⁺)/Γ _{total} 24.3 × 10 ⁻⁵ 9 • • • • We do not us 2.6 × 10 ⁻⁴ 9 <1.5 × 10 ⁻⁴ 9 <1.7 × 10 ⁻⁴ 9 <2.3 × 10 ⁻⁴ 9 <6 × 10 ⁻⁴ 9 140 Assumes a B^0 , 141 ALBRECHT 906 142 Papers assume t Γ(π^+ f_0 (980))/Γ _t 21.4 × 10 ⁻⁴ 143 BORTOLETTO We rescale to 50 Γ(π^+ f_2 (1270))/Γ 24.4 × 10 ⁻⁴ 144 BORTOLETTO	1.1% EVTS 100 100 100 100 100 100 100 100 100 10	DOCUMENT ID ASNER 140 ABREU 141 ALBRECHT 142 BORTOLETT 142 BEBEK GILES ion fraction of 0.39 nes equal production ecays 43% to B ⁰ B ⁰ DOCUMENT ID 143 BORTOLETT < 1.2 × 10 ⁻⁴ assu DOCUMENT ID 144 BORTOLETT	96 CLE2 es, fits, limits, 95N DLPH 908 ARG O89 CLEO 87 CLEO and a B_s pro on of $B^0 \overline{B}^0$ and 0. We rescale $\frac{TECN}{TO89} \text{ CLEO}$ ming the $\Upsilon(4)$	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \Upsilon \\ \underline{COMMENT} $	(45). (45). (45). (45). (45). (45). (45). (45). (45). (45). (45). (45). (45).

					Г ₉₅ /Г	Γ(<i>p̄p̄</i> π ⁺ π ⁺ 1	$r^-)/\Gamma_{total}$				Γ ₁₀₈ /
<u>VALUE</u> <7.7 × 10 ^{−5}	<u>CL%</u> 90	DOCUMENT ID		$e^+e^- \rightarrow$	T(4C)	VALUE <5.2 × 10 ^{−4}		DOCUMENT IE 163 ALBRECHT		COMMENT	
• • We do not use the					7 (43)	-		4.7 × 10 ⁻⁴ assumi			
$< 5.5 \times 10^{-4}$	90	¹⁴⁶ ALBRECHT	90B ARG	$e^+e^ \rightarrow$	Υ(4S)	rescale to 5		4.7 × 10 - assumi	ng the 7 (45)	decays 45% 1	to B° B°. V
¹⁴⁶ ALBRECHT 90B lin	nit assum	es equal productio	on of $B^0\overline B{}^0$ as	nd B^+B^- a	t Υ(45).	$\Gamma(p\overline{\Lambda})/\Gamma_{\text{total}}$					-
$\Gamma(\pi^+\pi^-\pi^+\pi^0)/\Gamma_{to}$					Г ₉₆ /Г	' (P^\)/' total	CL%	DOCUMENT IE	TECN	COMMENT	Γ ₁₀₉ /
VALUE	CL%_	DOCUMENT ID	TECN	COMMENT	. 96/	<6 × 10 ⁻⁵	90	164 AVERY		$e^+e^- \rightarrow$	Υ(4S)
$<4.0 \times 10^{-3}$	90	147 ALBRECHT		$e^+e^- \rightarrow$	Υ(4S)	• • • We do n	ot use the follo	wing data for averag			. ()
¹⁴⁷ ALBRECHT 90B lim	nit assum	es equal productio	on of $B^0\overline{B}{}^0$ ar	nd B^+B^- a	t γ(4 <i>S</i>).	$< 9.3 \times 10^{-5}$	90	¹⁶⁵ ALBRECHT			
$\Gamma(ho^+ ho^0)/\Gamma_{ m total}$					Γ ₉₇ /Γ	164 AVERY 898	s reports $< 5 imes 1$	10^{-5} assuming the	Υ (4 S) decays	s 43% to $B^0\overline{B}$	⁰ . We resca
VALUE	CL%	DOCUMENT ID		COMMENT		165 ALBRECH	Γ 88F reports <	8.5×10^{-5} assuming	ng the $\Upsilon(4S)$	decays 45% t	to <i>B⁰ B</i> ⁰ . V
$<1.0 \times 10^{-3}$		¹⁴⁸ ALBRECHT				rescale to 5	0%.		- , ,	,	
¹⁴⁸ ALBRECHT 90B lim	nit assum	es equal productio	on of $B^0\overline B{}^0$ ar	nd B^+B^- at	t Υ(45).	$\Gamma(\rho \overline{\Lambda} \pi^+ \pi^-)$	/Γ _{total}				Γ110/
$\Gamma(a_1(1260)^+\pi^0)/\Gamma_{t_1}$	otal				Г98/Г	VALUE	CL%	DOCUMENT ID	TECN	COMMENT	
VALUE	CL%		<u>TECN</u>			<2.0 × 10 ⁻⁴	90	166 ALBRECHT			
<1.7 × 10 ⁻³		¹⁴⁹ ALBRECHT				166 ALBRECHT rescale to 5	「88F reports <	1.8×10^{-4} assuming	ng the $\Upsilon(4S)$	decays 45% t	to $B^0\overline{B}{}^0$. W
¹⁴⁹ ALBRECHT 90B lim		es equal productio	n of $B^0\overline{B}{}^0$ ar	nd B^+B^- at	$t \ \Upsilon(4S)$.						
$\Gamma(a_1(1260)^0\pi^+)/\Gamma_{ m to}$	otal				7/وو۲	$\Gamma(\overline{\Delta}^0 p)/\Gamma_{\text{tot}}$					Γ ₁₁₁ /
VALUE	CL%	DOCUMENT ID		COMMENT		<u>VALUE</u> <3.8 × 10 ^{−4}	<u>CL%</u> 90	DOCUMENT ID 167 BORTOLETT			2(45)
<9.0 × 10 ⁻⁴		150 ALBRECHT				•		$< 3.3 \times 10^{-4}$ assu			
150 ALBRECHT 908 lim	nit assum	es equal productio	n of B [∪] B̄ [∪] ar	nd <i>B</i> + <i>B</i> - at	r(45).	We rescale	to 50%.	. < 3.3 × 10 . assr	ming the /(45) decays 43	2 ⁄0 to B, B,
$\Gamma(\omega\pi^+)/\Gamma_{total}$					Γ ₁₀₀ /Γ	$\Gamma(\Delta^{++}\overline{p})/\Gamma_{t}$					Γ ₁₁₂ /
VALUE	<u>CL%</u>	DOCUMENT ID				VALUE	cotal <u>CL%</u>	DOCUMENT ID	TECN	COMMENT	' 112/
<4.0 × 10⁻⁴ ¹⁵¹ ALBRECHT 908 lim		151 ALBRECHT				$<1.5 \times 10^{-4}$	90	168 BORTOLETT			Υ(4S)
	nit assumi	es equal productio	n of Bo Bo an	nd B^+B^- at	7(45).			$< 1.3 \times 10^{-4} \text{ assu}$	iming the $\gamma($	4 <i>S</i>) decays 43	3% to B ⁰ B
$\Gamma(\eta\pi^+)/\Gamma_{total}$					Γ_{101}/Γ	We rescale t	to 50%.				
√ALUE <7.0 × 10 ⁻⁴	CL%		TECN_			$\Gamma(\pi^+e^+e^-)$					Γ ₁₁₃ /
<7.0 x 10		152 ALBRECHT				Test for Z	$\Delta B = 1$ weak n	eutral current. Allow	wed by higher	r-order electro	weak intera
		s equal production	n or B°B° an	id B 'B at	1 (45).	VALUE	CL%	DOCUMENT ID	TECN	COMMENT	
$\Gamma(\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-})$	/Γ _{total}				Γ_{102}/Γ	< 0.0039	90	¹⁶⁹ WEIR	908 MRK2	e ⁺ e ⁻ 29 G	GeV
/ALUE <8.6 × 10 ^{−4}	<u>CL%</u> 90	DOCUMENT ID 153 ALBRECHT	TECN			¹⁶⁹ WEIR 90в а	ssumes B+ pro	duction cross sectio	n from LUNE	Э.	
						=(± ± _\	-				
$\Gamma(ho^0 a_1(1260)^+)/\Gamma_{ m to}$						tions.	$\Delta B = 1$ weak n	eutral current. Allov			F₁₁₄/ weak interac
- (ρ ⁰ a ₁ (1260)+)/Γ _{to} _{ALUE}	otal 	s equal production <u>DOCUMENT ID</u>	n of $B^0\overline{B}{}^0$ an	d B ⁺ B ⁻ at	τ(45). Γ ₁₀₃ /Γ	Test for Z tions. <u>VALUE</u>	$\Delta B = 1$ weak n	DOCUMENT ID	TECN	COMMENT	weak interac
$\frac{\Gamma(\rho^0 a_1(1260)^+)/\Gamma_{to}}{\langle 6.2 \times 10^{-4} \rangle}$ • • • We do not use the	otal <u>CL%</u> 90 e followin	DOCUMENT ID STATES BORTOLETT G data for average	n of $B^0\overline{B}^0$ an $TECN$ TO89 CLEO es, fits, limits,	od B^+B^- at $\frac{COMMENT}{e^+e^-} \rightarrow$ etc. \bullet \bullet	$r(4S)$. r_{103}/r $r_{(4S)}$	Test for Z tions. <u>VALUE</u> <0.0091	$\Delta B = 1$ weak n $ \frac{CL\%}{90}$		7ECN 908 MRK2	<u>СОММЕНТ</u> e ⁺ e ⁻ 29 G	weak interac
$\Gamma(\rho^0 a_1(1260)^+)/\Gamma_{to}$ $<6.2 \times 10^{-4}$ • • • We do not use th $<6.0 \times 10^{-4}$	otal <u>CL%</u> 90 e followin	s equal production DOCUMENT ID 154 BORTOLETT g data for average 155 ALBRECHT	n of $B^0 \overline{B}{}^0$ and $TECN$ TO89 CLEO es, fits, limits, 908 ARG	$\begin{array}{c} COMMENT \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \end{array}$	r(4S). $r(4S)$ $r(4S)$	Test for 2 tions. VALUE <0.0091 170 WEIR 90B a $\Gamma(K^+e^+e^-)$	$\Delta B = 1$ weak n $\frac{CL\%}{90}$ ssumes B^+ pro	DOCUMENT ID 170 WEIR eduction cross section	TECN 908 MRK2 n from LUND	<u>COMMENT</u> e e ⁺ e ⁻ 29 G	SeV
$(\rho^0 a_1(1260)^+)/\Gamma_{to}$ (ALUE) (6.2×10^{-4}) (6.0×10^{-4}) (6.0×10^{-4}) (3.2×10^{-3})	otal <u>CL%</u> 90 e followin 90 90	DOCUMENT ID L54 BORTOLETT g data for average L55 ALBRECHT L54 BEBEK	n of $B^0\overline{B}^0$ an $\frac{TECN}{COS9}$ CLEO es, fits, limits, 90B ARG 87 CLEO	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \\ \text{etc.} \bullet \bullet \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \end{array}$	$\frac{r(4s)}{r(4s)}$ $\frac{r_{103}/\Gamma}{r(4s)}$ $\frac{r(4s)}{r(4s)}$	Test for Z tions. <u>VALUE</u> <0.0091 170 WEIR 90B a $\Gamma(K^+e^+e^-)$ Test for Z	$\Delta B = 1$ weak n $\frac{CL\%}{90}$ ssumes B^+ pro	DOCUMENT ID 170 WEIR	TECN 908 MRK2 n from LUND	<u>COMMENT</u> e e ⁺ e ⁻ 29 G	weak intera
$(\rho^0 a_1(1260)^+)/\Gamma_{to}$ (ALUE) (6.2 × 10 ⁻⁴ $< 6.0 \times 10^{-4}$ $< 6.0 \times 10^{-4}$ $< 3.2 \times 10^{-3}$ (54 BORTOLETTO 89	otal CL% 90 e followin 90 90 reports <	s equal production DOCUMENT ID 54 BORTOLETT g data for average 55 ALBRECHT 54 BEBEK 5.4 × 10 ⁻⁴ assu	n of $B^0\overline{B}^0$ an $\frac{TECN}{COS9}$ CLEO es, fits, limits, 90B ARG 87 CLEO ming the $\Upsilon(4)$	$\begin{array}{c} COMMENT \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \end{array}$	r(4s). $r(4s)$ $r(4s)$ $r(4s)$ $r(4s)$ $r(4s)$ $r(4s)$ $r(4s)$ $r(4s)$ $r(4s)$	Test for 2 tions. VALUE <0.0091 170 WEIR 90B a $\Gamma(K^+e^+e^-)$	$\Delta B = 1$ weak n $\frac{CL\%}{90}$ ssumes B^+ pro	DOCUMENT ID 170 WEIR eduction cross section	TECN 90B MRK2 n from LUNE	COMMENT e^+e^- 29 G e^-	weak intera
$-(\rho^0 a_1(1260)^+)/\Gamma_{to}$ $ALUE$ <6.2 × 10 ⁻⁴ •• We do not use th <6.0 × 10 ⁻⁴ <3.2 × 10 ⁻³ 554 BORTOLETTO 89 i We rescale to 50%. 55 ALBRECHT 908 lim	otal CL% 90 e followin 90 90 reports <	s equal production DOCUMENT ID 54 BORTOLETT g data for average 55 ALBRECHT 54 BEBEK 5.4 × 10 ⁻⁴ assu	n of $B^0\overline{B}^0$ an $\frac{TECN}{COS9}$ CLEO es, fits, limits, 90B ARG 87 CLEO ming the $\Upsilon(4)$	$\begin{array}{c} COMMENT \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \end{array}$	r(4s). $r(4s)$ $r(4s)$ $r(4s)$ $r(4s)$ $r(4s)$ $r(4s)$ $r(4s)$ $r(4s)$ $r(4s)$	Test for Δ tions. <u>VALUE</u> <0.0091 170 WEIR 90B a Γ(K+e+e-) Test for Δ tions. <u>VALUE</u>	$\Delta B = 1$ weak n $\frac{CL\%}{90}$ ssumes B^+ pro $\frac{\Gamma}{\Delta B} = 1$ weak n $\frac{CL\%}{2}$	DOCUMENT ID 170 WEIR adduction cross section eutral current. Allow	TECN 90B MRK2 n from LUNE wed by higher	COMMENT e^+e^- 29 G Conder electron $COMMENT$	weak interactions
$(\rho^0 a_1(1260)^+)/\Gamma_{to}$ (ALUE) (6.2 × 10 ⁻⁴ $< 6.0 \times 10^{-4}$ $< 6.0 \times 10^{-4}$ $< 3.2 \times 10^{-3}$ (54 BORTOLETTO 89	otal CL% 90 e followin 90 90 reports <	s equal production DOCUMENT ID 54 BORTOLETT g data for average 55 ALBRECHT 54 BEBEK 5.4 × 10 ⁻⁴ assu	n of $B^0 \overline B^0$ an $\frac{TECN}{CO89}$ CLEO es, fits, limits, 908 ARG 87 CLEO ming the $\Upsilon(4$ n of $B^0 \overline B^0$ an	$\begin{array}{c} \text{dd } B^+B^- \text{ at} \\ \hline \\ \frac{COMMENT}{e^+e^-} \\ e^+e^- \\ e^+e^- \\ \Rightarrow \\ S) \text{ decays } 43 \\ \text{d} B^+B^- \text{ at} \\ \end{array}$	r(4s). $r(4s)$ $r(4s)$ $r(4s)$ $r(4s)$ $r(4s)$ $r(4s)$ $r(4s)$ $r(4s)$ $r(4s)$	Test for Z tions. VALUE <0.0091 170 WEIR 90B a \(\begin{align*} align	$\Delta B = 1$ weak n $CL\%$ 90 ssumes B^+ pro // Ctotal $\Delta B = 1$ weak n $CL\%$ ot use the follow	DOCUMENT ID 170 WEIR oduction cross sectio eutral current. Allow DOCUMENT ID ving data for average 171 ALBRECHT	908 MRK2 n from LUNE wed by higher TECN es, fits, limits,	comment e^+e^- 29 G corrected electron COMMENT , etc. • • • • • • • • • • • • • • • • • • •	weak interactions $\Gamma_{115}/\Gamma_{115}$ weak interaction $\Gamma_{115}/\Gamma_{115}$
$\Gamma(\rho^0 a_1(1260)^+)/\Gamma_{to}$ (ALUE) (6.2 × 10 ⁻⁴ • • We do not use th constant to the cons	otal CL%90 e followin9090 reports < it assume	DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID	n of $B^0 \overline{B}^0$ an \underline{TECN} TO89 CLEO es, fits, limits, 908 ARG 87 CLEO ming the $\Upsilon(4$ n of $B^0 \overline{B}^0$ an \underline{TECN}	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ S) \text{ decays 43} \\ d \ B^+B^- \text{ at} \end{array}$	τ(45). Γ ₁₀₃ /Γ τ(45) τ(45) τ(45) γ(45) γ(45) γ(45) γ(45) Γ(45). Γ ₁₀₄ /Γ	Test for Δ tions. **Example 1.70 WEIR 90B a $\Gamma(K^+e^+e^-)$ Test for Δ tions. **ALUE** • • • We do not $< 9.9 \times 10^{-5} < 6.8 \times 10^{-3}$	$\Delta B = 1$ weak n $\frac{CL\%}{90}$ ssumes B^+ pro $\frac{\Gamma}{L}$ total $B = 1$ weak n $\frac{CL\%}{L}$ to use the follow 90	DOCUMENT ID 170 WEIR oduction cross sectio eutral current. Allow DOCUMENT ID ving data for average 171 ALBRECHT 172 WEIR	908 MRK2 n from LUND wed by higher TECN es, fits, limits, 91E ARG 908 MRK2	COMMENT $e^{+}e^{-} eq 9 ext{ G}$ conder electron $COMMENT$ $e^{+}e^{-} eq 9 ext{ G}$	F115/weak interactions of the service of the servic
$\Gamma(\rho^0 a_1(1260)^+)/\Gamma_{to}$ (ALUE) <6.2 × 10 ⁻⁴ • • We do not use th <6.0 × 10 ⁻⁴ ·3.2 × 10 ⁻³ SW rescale to 50%. 50 × 10 × 10 × 10 × 10 × 10 × 10 × 10 ×	otal - CL% 90 e followin 90 90 reports < it assume ttal - CL% 90	s equal production DOCUMENT ID 1.54 BORTOLETT g data for average 1.55 ALBRECHT 1.54 BEBEK 5.4 × 10 ⁻⁴ assur s equal production DOCUMENT ID 56 BORTOLETT	n of $B^0 \overline{B}^0$ an $\frac{TECN}{CO89}$ CLEO es, fits, limits, 908 ARG 87 CLEO ming the $\Upsilon(4$ n of $B^0 \overline{B}^0$ an $\frac{TECN}{CO89}$ CLEO	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \longrightarrow \\ e^+e^- \longrightarrow \\ e^+e^- \longrightarrow \\ S) \text{ decays 43} \\ d \ B^+B^- \text{ at} \\ \\ \underline{COMMENT} \\ e^+e^- \longrightarrow \\ \end{array}$	τ(45). Γ ₁₀₃ /Γ τ(45) τ(45) τ(45) γ(45) γ(45) γ(45) γ(45) Γ(45). Γ ₁₀₄ /Γ	Test for Z tions. VALUE <0.0091 170 WEIR 90B a \(\begin{align*} align	$\Delta B = 1$ weak n $CL\%$ 90 ssumes B^+ pro // Ctotal $\Delta B = 1$ weak n $CL\%$ ot use the follow	DOCUMENT ID 170 WEIR oduction cross section eutral current. Allow DOCUMENT ID ving data for average 171 ALBRECHT 172 WEIR 173 AVERY	908 MRK2 n from LUNE wed by higher TECN es, fits, limits, 91E ARG 908 MRK2 898 CLEO	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \ 29 \ G \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	weak interactions of the second secon
$-(\rho^0 a_1(1260)^+)/\Gamma_{to}$ (ALUE) (6.2 × 10 ⁻⁴ • • • We do not use th (6.0 × 10 ⁻⁴ × 3.2 × 10 ⁻³ 54 BORTOLETTO 89 α We rescale to 50%. 54 BORTOLETTO 90 lim $-(\rho^0 a_2(1320)^+)/\Gamma_{to}$ (ALUE) (7.2 × 10 ⁻⁴ • • We do not use the	otal CL% 90 90 90 reports < it assume tal CL% 90 e followin	DOCUMENT ID 54 BORTOLETT g data for average 155 ALBRECHT 154 BEBEK 5.4 × 10 ⁻⁴ assur s equal production DOCUMENT ID 56 BORTOLETT g data for average	n of $B^0 \overline{B}^0$ an $\frac{TECN}{CO89}$ CLEO es, fits, limits, 908 ARG 87 CLEO ming the $\Upsilon(4$ n of $B^0 \overline{B}^0$ an $\frac{TECN}{CO89}$ CLEO es, fits, limits,	$\begin{array}{c} \text{COMMENT} \\ e^+e^- \rightarrow \\ \text{etc.} \bullet \bullet \\ e^+e^- \rightarrow \\ \text{S) decays 43} \\ \text{d } B^+B^- \text{ at} \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	$\Upsilon(45)$. Γ_{103}/Γ $\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$. $\Upsilon(45)$. Γ_{104}/Γ $\Upsilon(45)$	Test for Δ tions. VALUE <0.0091 170 WEIR 90B a Γ(K+e+e-) Test for Δ tions. VALUE • • • We do not <9.9 × 10-5 <6.8 × 10-3 <6 × 10-5 <2.5 × 10-4	$\Delta B = 1$ weak n $\frac{CL\%}{90}$ ssumes B^+ pro $/\Gamma$ total $\Delta B = 1$ weak n $\frac{CL\%}{90}$ to use the follow 90 90 90 90	DOCUMENT ID 170 WEIR oduction cross sectio eutral current. Allov DOCUMENT ID ving data for average 171 ALBRECHT 172 WEIR 173 AVERY 174 AVERY	908 MRK2 n from LUNE wed by higher Es, fits, limits, 91E ARG 908 MRK2 89B CLEO 87 CLEO	COMMENT $e^{+}e^{-} 29 G$ condend electron $COMMENT$ $e^{+}e^{-} 29 G$ $e^{+}e^{-} 29 G$ $e^{+}e^{-} 39 G$ $e^{+}e^{-} 39 G$ $e^{+}e^{-} 39 G$ $e^{+}e^{-} 39 G$	weak intera- Fulfy weak intera- r(4s) ieV r(4s) r(4s)
$\Gamma(\rho^0 a_1(1260)^+)/\Gamma_{to}$ (ALUE) (6.2 × 10 ⁻⁴ • • • We do not use the (6.0 × 10 ⁻⁴ s.) = 0.0 × 10 ⁻³ 54 BORTOLETTO 89 in We rescale to 50%. 55 ALBRECHT 90B lim $\Gamma(\rho^0 a_2(1320)^+)/\Gamma_{to}$ (ALUE) (7.2 × 10 ⁻⁴ • • We do not use the (2.6 × 10 ⁻³)	potal - CL% 90 90 90 reports < it assume tal - CL% 90 e followin	DOCUMENT ID 154 BORTOLETT g data for average 155 ALBRECHT 154 BEBEK 5.4 × 10 ⁻⁴ assu s equal production DOCUMENT ID 156 BORTOLETT g data for average 157 BEBEK	n of $B^0 \overline{B}^0$ an $\frac{TECN}{0.000}$ CLEO es, fits, limits, 908 ARG 87 CLEO ming the $\Upsilon(4$ n of $B^0 \overline{B}^0$ an $\frac{TECN}{0.000}$ COS es, fits, limits, 87 CLEO	$\begin{array}{c} \text{COMMENT} \\ e^+e^- \rightarrow \\ e^$	r(45). $r(45)$ $r(45)$ $r(45)$ $r(45)$ $r(45)$ $r(45)$ $r(45)$. $r(45)$. $r(45)$ $r(45)$ $r(45)$	Test for Z tions. **XALUE** **C0.0091* 170 WEIR 90B a F(K+e+e-) Test for Z tions. **XALUE** • • • We do not <9.9 × 10-5 <6.8 × 10-3 <6 × 10-5 <2.5 × 10-4 171 ALBRECHT rescale to 56	$\Delta B = 1$ weak n $\frac{CL\%}{90}$ ssumes B^+ pro // total $\Delta B = 1$ weak n $\frac{CL\%}{90}$ to use the follow 90 90 90 91E reports < 19%	DOCUMENT ID 170 WEIR oduction cross sectio eutral current. Allow DOCUMENT ID 171 ALBRECHT 172 WEIR 173 AVERY 174 AVERY 9.0 × 10 ⁻⁵ assumin	908 MRK2 n from LUNE wed by higher TECN es, fits, limits, 91E ARG 908 MRK2 898 CLEO 87 CLEO g the \(\gamma(45) \)	COMMENT $e^+e^- 29 G$ corder electron $COMMENT$ $e^+e^- 29 G$ $e^+e^- 39 G$ $e^+e^- 40 G$ $e^+e^- 30 G$ $e^+e^- 40 G$ $e^+e^- 30 G$ $e^+e^- 40 G$ $e^+e^- 4$	F(45) T(45) T(45) T(45)
$(\rho^0 a_1(1260)^+)/\Gamma_{to}$ (ALUE) (6.2 × 10 ⁻⁴ • • We do not use th (6.0 × 10 ⁻⁴ 5.3.2 × 10 ⁻³ 54 BORTOLETTO 89 in ($(\rho^0 a_2(1320)^+)/\Gamma_{to}$ (ALUE) (7.2 × 10 ⁻⁴ • • We do not use the (2.6 × 10 ⁻³ 55 BORTOLETTO 89 in	otal	DOCUMENT ID 154 BORTOLETT g data for average 155 ALBRECHT 154 BEBEK 15.4 × 10-4 assur s equal production DOCUMENT ID 156 BORTOLETT g data for average 157 BEBEK 16.3 × 10-4 assur	TECN TO BO \overline{B}^0 and TECN TO BO ARG BY CLEO TO BO ARG TO BO \overline{B}^0 and TECN TO BO CLEO TO BO TECN TO BO CLEO TO BO	$\begin{array}{c} \text{COMMENT} \\ e^+e^- \rightarrow \\ \text{etc.} \bullet \bullet \\ e^+e^- \rightarrow \\ \text{S) decays 43} \\ \text{d } B^+B^- \text{ at} \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	r(45). $r(45)$ $r(45)$ $r(45)$ $r(45)$ $r(45)$ $r(45)$ $r(45)$. $r(45)$	Test for Δ tions. **Example 1.70 WEIR 90B a $\Gamma(K^+e^+e^-)$ Test for Δ tions. **AULE** • • • We do not $<9.9 \times 10^{-5}$ $<6.8 \times 10^{-3}$ $<6 \times 10^{-3}$ $<6 \times 10^{-5}$ $<2.5 \times 10^{-4}$ 171 ALBRECHT rescale to 50. 172 WEIR 90B a 173 AVERY 89B	$\Delta B = 1$ weak n $\frac{CL\%}{90}$ ssumes B^+ pro $\frac{\Gamma}{\Gamma}$ total $\Delta B = 1$ weak n $\frac{CL\%}{90}$ bt use the follow 90 90 90 90 91E reports < $\frac{CL\%}{90}$ %.	DOCUMENT ID 170 WEIR oduction cross sectio eutral current. Allov DOCUMENT ID ving data for average 171 ALBRECHT 172 WEIR 173 AVERY 174 AVERY 9.0 × 10 ⁻⁵ assumin duction cross section	908 MRK2 n from LUND wed by higher FECN es, fits, limits, 91E ARG 908 MRK2 898 CLEO 87 CLEO g the $\Upsilon(4S)$	COMMENT $e^+e^- 29 G$ COMMENT $e^+e^- = 0$	Fig. (45) $r(45)$ $r(45)$ $r(45)$ $r(45)$ $r(45)$ $r(5)$ $r(45)$ $r(5)$ $r(5)$ $r(5)$ $r(5)$ $r(5)$ $r(5)$ $r(5)$ $r(5)$ $r(5)$
$-(\rho^0 a_1(1260)^+)/\Gamma_{to}$ (ALUE) $<6.2 \times 10^{-4}$ • • We do not use th $<6.0 \times 10^{-4}$ $<3.2 \times 10^{-3}$ $<3.2 \times 10^{-3}$ <56 BORTOLETTO 89 in $-(\rho^0 a_2(1320)^+)/\Gamma_{to}$ (ALUE) $<7.2 \times 10^{-4}$ • • We do not use the $<2.6 \times 10^{-3}$ <6 BORTOLETTO 89 in	otal	DOCUMENT ID 154 BORTOLETT g data for average 155 ALBRECHT 154 BEBEK 15.4 × 10-4 assur s equal production DOCUMENT ID 156 BORTOLETT g data for average 157 BEBEK 16.3 × 10-4 assur	TECN TO BO \overline{B}^0 and TECN TO BO ARG BY CLEO TO BO ARG TO BO \overline{B}^0 and TECN TO BO CLEO TO BO TECN TO BO CLEO TO BO	$\begin{array}{c} \text{COMMENT} \\ e^+e^- \rightarrow \\ \text{etc.} \bullet \bullet \\ e^+e^- \rightarrow \\ \text{S) decays 43} \\ \text{d } B^+B^- \text{ at} \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	r(45). $r(45)$ $r(45)$ $r(45)$ $r(45)$ $r(45)$ $r(45)$ $r(45)$. $r(45)$	Test for ∠ tions. VALUE <0.0091 170 WEIR 90B a \(\begin{align*} \begin{align*} \cdot	$\Delta B = 1$ weak n $\frac{CL\%}{90}$ ssumes B^+ pro $\frac{CL\%}{100}$ to use the follow 90 90 90 91E reports < $\frac{CL\%}{100}$ ssumes $\frac{CL\%}{100}$ reports < $\frac{CL\%}{100}$	DOCUMENT ID 170 WEIR oduction cross sectio eutral current. Allov DOCUMENT ID 171 ALBRECHT 172 WEIR 173 AVERY 174 AVERY 9.0 × 10 ⁻⁵ assumin duction cross sectio 0 ⁻⁵ assuming the 7	908 MRK2 n from LUND wed by higher FECN es, fits, limits, 918 MRK2 898 CLEO 87 CLEO 87 CLEO g the $\Upsilon(4S)$ n from LUND $\Upsilon(4S)$ decays	COMMENT $e^+e^- 29 \text{ G}$ comment $e^+e^- 39 \text{ G}$ $e^-e^- 39 $	Fig. (45) r (47) r (47) r (47) r (48) r (47) r (48)
$(\rho^0 a_1(1260)^+)/\Gamma_{to}$ (ALUE) <6.2 × 10 ⁻⁴ • • We do not use the <6.0 × 10 ⁻⁴ <3.2 × 10 ⁻³ 54 BORTOLETTO 89 in We rescale to 50%. 55 ALBRECHT 90B lim $(\rho^0 a_2(1320)^+)/\Gamma_{to}$ (ALUE) <7.2 × 10 ⁻⁴ • • We do not use the <2.6 × 10 ⁻³ 56 BORTOLETTO 89 in September 50%. 59 BEBEK 87 reports < to 50%.	Ottal	Sequal production DOCUMENT ID 1.54 BORTOLETT 54 BEBEK 5.4 × 10 ⁻⁴ assumes equal production DOCUMENT ID 56 BORTOLETT data for average 57 BEBEK 6.3 × 10 ⁻⁴ assuming the 7	TECN TO BO \overline{B}^0 and TECN TO BO ARG BY CLEO TO BO ARG TO BO \overline{B}^0 and TECN TO BO CLEO TO BO TECN TO BO CLEO TO BO	$\begin{array}{c} \text{COMMENT} \\ e^+e^- \rightarrow \\ \text{etc.} \bullet \bullet \\ e^+e^- \rightarrow \\ \text{S) decays 43} \\ \text{d } B^+B^- \text{ at} \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	r(45). $r(45)$ $r(45)$ $r(45)$ $r(45)$ $r(45)$ % to $r(45)$ % to $r(45)$	Test for ∠ tions. VALUE <0.0091 170 WEIR 90B a \(\begin{align*} \begin{align*} \cdot	$\Delta B = 1$ weak n $\frac{CL\%}{90}$ ssumes B^+ pro $\frac{CL\%}{100}$ to use the follow 90 90 90 91E reports < $\frac{CL\%}{100}$ ssumes $\frac{CL\%}{100}$ reports < $\frac{CL\%}{100}$	DOCUMENT ID 170 WEIR oduction cross sectio eutral current. Allov DOCUMENT ID ving data for average 171 ALBRECHT 172 WEIR 173 AVERY 174 AVERY 9.0 × 10 ⁻⁵ assumin duction cross section	908 MRK2 n from LUND wed by higher FECN es, fits, limits, 918 MRK2 898 CLEO 87 CLEO 87 CLEO g the $\Upsilon(4S)$ n from LUND $\Upsilon(4S)$ decays	COMMENT $e^+e^- 29 \text{ G}$ comment $e^+e^- 29 \text{ G}$ comment $e^+e^- 39 \text{ G}$ $e^-e^- 39 \text{ G}$ e^-e	Fig. (45) $r(45)$
$(\rho^0 a_1(1260)^+)/\Gamma_{to}$ ALLUE <6.2 × 10 ⁻⁴ • • We do not use the control of the control	Ottal	Sequal production DOCUMENT ID 1.54 BORTOLETT 54 BEBEK 5.4 × 10 ⁻⁴ assumes equal production DOCUMENT ID 56 BORTOLETT data for average 57 BEBEK 6.3 × 10 ⁻⁴ assuming the 7	n of $B^0 \overline{B}^0$ an $\frac{TECN}{CO89}$ CLEO es, fits, limits, 908 ARG 87 CLEO ming the $\Upsilon(4$ n of $B^0 \overline{B}^0$ an $\frac{TECN}{CO89}$ CLEO es, fits, limits, 87 CLEO ming the $\Upsilon(4.5)$ decays 4	$\begin{array}{c} \text{COMMENT} \\ e^+e^- \rightarrow \\ \text{etc.} \bullet \bullet \\ e^+e^- \rightarrow \\ \text{S) decays 43} \\ \text{d } B^+B^- \text{ at} \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	r(45). $r(45)$ $r(45)$ $r(45)$ $r(45)$ $r(45)$ $r(45)$ $r(45)$. $r(45)$	Test for Z tions. **XALUE** **C.0.091* 170 WEIR 90B a **If (K+e+e-) Test for Z tions. **MEUE** • • • We do not < 9.9 × 10-5 < 6.8 × 10-3 < 6 × 10-5 < 2.5 × 10-4 171 ALBRECHT rescale to 50 172 WEIR 90B a 173 AVERY 89B to 50%. 174 AVERY 87 re to 50%.	$\Delta B = 1$ weak n $\frac{CL\%}{90}$ ssumes B^+ pro $\frac{\Gamma}{\Gamma}$ total $\Delta B = 1$ weak n $\frac{CL\%}{90}$ ot use the follow 90 90 90 90 91E reports $< 5 \times 1$ eports $< 5 \times 1$ eports $< 2.1 \times 1$	DOCUMENT ID 170 WEIR oduction cross sectio eutral current. Allov DOCUMENT ID 171 ALBRECHT 172 WEIR 173 AVERY 174 AVERY 9.0 × 10 ⁻⁵ assumin duction cross sectio 0 ⁻⁵ assuming the 7	908 MRK2 n from LUND wed by higher FECN es, fits, limits, 918 MRK2 898 CLEO 87 CLEO 87 CLEO g the $\Upsilon(4S)$ n from LUND $\Upsilon(4S)$ decays	COMMENT $e^+e^- 29 \text{ G}$ comment $e^+e^- 29 \text{ G}$ comment $e^+e^- 39 \text{ G}$ $e^-e^- 39 \text{ G}$ e^-e	weak interactions of the following series of the foll
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$(\rho^0 a_1(1260)^+)/\Gamma_{to}$ ALLUE <6.2 × 10 ⁻⁴ • • We do not use the control of the control	btal	s equal production DOCUMENT ID 1.54 BORTOLETT G.55 ALBRECHT 5.4 × 10 ⁻⁴ assuit s equal production DOCUMENT ID 56 BORTOLETT GATA SSUIT 3 assuming the 7 DOCUMENT ID 58 ALBRECHT s equal production	n of $B^0 \overline{B}^0$ an $\frac{TECN}{COS}$ CLEO es, fits, limits, 908 ARG 87 CLEO ming the $\Upsilon(4)$ n of $B^0 \overline{B}^0$ an $\frac{TECN}{COS}$ CLEO es, fits, limits, 87 CLEO ming the $\Upsilon(4)$ decays 4 $\frac{TECN}{COS}$ 908 ARG	$\begin{array}{c} \text{COMMENT} \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ \text{S}) \text{ decays 43} \\ \text{d } B^+B^- \text{ at} \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	$T(45)$. T_{103}/Γ $T(45)$	Test for ∠ tions. VALUE <0.0091 170 WEIR 90B a \(\begin{align*} \begin{align*} \pm	$\Delta B = 1$ weak n $\frac{CL\%}{90}$ ssumes B^+ pro $\frac{\Gamma}{\Gamma}$ total $\Delta B = 1$ weak n $\frac{CL\%}{90}$ bt use the follow 90 90 90 91E reports $< \frac{SL\%}{90}$ %.	DOCUMENT ID 170 WEIR reduction cross section DOCUMENT ID 171 ALBRECHT 172 WEIR 173 AVERY 174 AVERY 175 AVERY 176 Assuming the 7 177 O-4 assuming the 7 DOCUMENT ID	908 MRK2 n from LUND es, fits, limits, 91E ARG 908 MRK2 898 CLEO 87 CLEO g the $\Upsilon(4S)$ decays $\Upsilon(4S)$ decays	COMMENT $e^+e^- 29 G$ comment $e^+e^- 29 G$ comment $e^+e^ 29 G$ comment $e^+e^ 29 G$ comment $e^+e^ 30 G$ comment $e^+e^ 30 G$ comment $e^+e^ 30 G$ comment	weak interactions of the property of the prop
$(\rho^0 a_1(1260)^+)/\Gamma_{to}$ (ALUE) (6.2 × 10 ⁻⁴ • • We do not use the constant of the cons	btal	s equal production DOCUMENT ID 1.54 BORTOLETT G.55 ALBRECHT 5.4 × 10 ⁻⁴ assuit s equal production DOCUMENT ID 56 BORTOLETT GATA SSUIT 3 assuming the 7 DOCUMENT ID 58 ALBRECHT s equal production	n of $B^0 \overline{B}^0$ and $TECN$ O89 CLEO es, fits, limits, 908 ARG and $B^0 \overline{B}^0$ and $TECN$ O89 CLEO es, fits, limits, 87 CLEO es, fits, limits, 87 CLEO ming the $T(4.5)$ decays 4	$\begin{array}{c} \text{COMMENT} \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ \text{S}) \text{ decays 43} \\ \text{d } B^+B^- \text{ at} \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	r(4s). $r(4s)$	Test for Δ tions. **Example 1.70 WEIR 90B a $\Gamma(K^+e^+e^-)$ Test for Δ tions. **ALUE* ••• We do not $< 9.9 \times 10^{-5} < 6.8 \times 10^{-3} < 6 \times 10^{-5} < 2.5 \times 10^{-4}$ 171 ALBRECHT rescale to 50. 172 WEIR 90B a 173 AVERY 89B to 50%. $\Gamma(K^+\mu^+\mu^-)$ Test for Δ tions. **Example 1.70 Year 1	$\Delta B = 1$ weak n $\frac{CL\%}{90}$ ssumes B^+ produced by $B = 1$ weak not see the follow $\frac{CL\%}{90}$ of the second $\frac{90}{90}$ $\frac{90}{90}$ $\frac{91}{90}$ reports $< 1 \times 1 $	DOCUMENT ID 170 WEIR oduction cross section EUTRAL ERECHT 172 WEIR 173 AVERY 174 AVERY 9.0 × 10 ⁻⁵ assuming duction cross section 0 ⁻⁵ assuming the 7 0 ⁻⁴ assuming the 7	908 MRK2 n from LUND wed by higher FECN s, fits, limits, 91E ARG 908 MRK2 898 CLEO g the \(7(4S) \) decays \(7(4S) \) decays \(7(4S) \) decays wed by higher FECN 898 CLEO	COMMENT $e^+e^- 29 G$ comment $e^+e^- 29 G$ comment $e^+e^- \rightarrow e^+e^- 29 G$ comment $e^+e^- \rightarrow e^+e^- \rightarrow e^-e^- ^- \rightarrow e^-e^- \rightarrow e^-e^- \rightarrow e^-e^- \rightarrow e^-e^- \rightarrow e^-e^- \rightarrow e^-e^- \rightarrow e^-e^$	weak interactions of the second of the seco
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Test of lepton for $ALUE$ 0.0064 184 WEIR 90B assume $\Gamma(\pi^-e^+e^+)/\Gamma_{tota}$ Test of total lepton for $ALUE$ 0.0039 185 WEIR 90B assume $\Gamma(\pi^-\mu^+\mu^+)/\Gamma_{tota}$ Test of total lepton for $ALUE$ 0.0091 186 WEIR 90B assume $\Gamma(\pi^-e^+\mu^+)/\Gamma_{tota}$ Test of total lepton for $ALUE$ Test of total lepton for $ALUE$	amily num	DOCUMENT II	908 M lion from I	MRK2 LUND. MRK2 LUND. MRK2 LUND.	e^+e^- 29 Gr $\frac{COMMENT}{e^+e^-}$ 29 Gr $\frac{COMMENT}{e^+e^-}$ 29 Gr	Γ ₁₂₃ /I eV Γ ₁₂₄ /I eV
Test of lepton for the property of the proper	amily num	DOCUMENT II 184 WEIR duction cross section DOCUMENT II 185 WEIR duction cross section DOCUMENT II 186 WEIR duction cross section DOCUMENT II 187 WEIR	908 M	MRK2 LUND. MRK2 LUND. MRK2 LUND.	$e^{+}e^{-}$ 29 G COMMENT $e^{+}e^{-}$ 29 G COMMENT $e^{+}e^{-}$ 29 G COMMENT $e^{+}e^{-}$ 29 G	Γ ₁₂₃ /I eV Γ ₁₂₄ /I eV Γ ₁₂₅ /I
Test of lepton for the property of the proper	amily num	DOCUMENT II 184 WEIR duction cross section DOCUMENT II 185 WEIR duction cross section DOCUMENT II 186 WEIR duction cross section DOCUMENT II 187 WEIR	908 M	MRK2 LUND. MRK2 LUND. MRK2 LUND.	$e^{+}e^{-}$ 29 G COMMENT $e^{+}e^{-}$ 29 G COMMENT $e^{+}e^{-}$ 29 G COMMENT $e^{+}e^{-}$ 29 G	Γ ₁₂₃ /I eV Γ ₁₂₄ /I eV Γ ₁₂₅ /I
Test of lepton for the property of the proper	amily num	DOCUMENT II 184 WEIR duction cross section DOCUMENT II 185 WEIR duction cross section DOCUMENT II 186 WEIR duction cross section DOCUMENT II 187 WEIR duction cross section DOCUMENT II 187 WEIR duction cross section	908 M	MRK2 LUND. MRK2 LUND. MRK2 LUND.	$e^{+}e^{-}$ 29 G COMMENT $e^{+}e^{-}$ 29 G COMMENT $e^{+}e^{-}$ 29 G COMMENT $e^{+}e^{-}$ 29 G	Γ ₁₂₃ /Ι eV Γ ₁₂₄ /Ι eV Γ ₁₂₅ /Ι
Test of lepton for the property of the proper	amily num	DOCUMENT II 184 WEIR duction cross section DOCUMENT II 185 WEIR duction cross section DOCUMENT II 186 WEIR duction cross section DOCUMENT II 187 WEIR duction cross section	90B M lion from I 90B M lion f	MRK2 LUND. MRK2 LUND. MRK2 LUND. MRK2 LUND.	$e^{+}e^{-}$ 29 G $\frac{COMMENT}{e^{+}e^{-}}$ 29 G $\frac{COMMENT}{e^{+}e^{-}}$ 29 G $\frac{COMMENT}{e^{+}e^{-}}$ 29 G	Γ ₁₂₃ /Ι eV Γ ₁₂₄ /Ι eV Γ ₁₂₅ /Ι
Test of lepton for the property of the proper	amily num	DOCUMENT II 184 WEIR duction cross section DOCUMENT II 185 WEIR duction cross section DOCUMENT II 186 WEIR duction cross section DOCUMENT II 187 WEIR duction cross section	908 M ion from I	MRK2 LUND. MRK2 LUND. MRK2 LUND. MRK2 LUND. MRK2 LUND.	$e^{+}e^{-}$ 29 G $\frac{COMMENT}{e^{+}e^{-}}$ 29 G $\frac{COMMENT}{e^{+}e^{-}}$ 29 G $\frac{COMMENT}{e^{+}e^{-}}$ 29 G	Γ ₁₂₃ /I eV Γ ₁₂₄ /I eV Γ ₁₂₅ /I eV
Test of lepton for the property of the proper	amily num	DOCUMENT II DOCUM	908 M ion from I	MRK2 LUND. TECN MRK2 LUND. MRK2 LUND. TECN MRK2 LUND.	$e^{+}e^{-}$ 29 Gr	Γ ₁₂₃ /I eV Γ ₁₂₄ /I eV Γ ₁₂₅ /I eV
Test of lepton for the property of the proper	amily num	DOCUMENT II 184 WEIR duction cross section. DOCUMENT II 185 WEIR duction cross section. DOCUMENT II 186 WEIR duction cross section. DOCUMENT II 187 WEIR duction cross section. DOCUMENT II 188 WEIR duction cross section. DOCUMENT II 188 WEIR duction cross section.	908 M ion from I	MRK2 LUND. TECN MRK2 LUND. MRK2 LUND. TECN MRK2 LUND.	$e^{+}e^{-}$ 29 Gr	F ₁₂₃ /lev F ₁₂₄ /lev F ₁₂₅ /lev F ₁₂₆ /lev
Test of lepton for the property of the proper	amily num	DOCUMENT II 184 WEIR duction cross section DOCUMENT II 185 WEIR duction cross section DOCUMENT II 186 WEIR duction cross section DOCUMENT II 187 WEIR duction cross section DOCUMENT II 187 WEIR duction cross section DOCUMENT II 188 WEIR	908 M ion from I	MRK2 LUND. FECN MRK2 LUND. MRK2 LUND. MRK2 LUND. MRK2 LUND.	$e^{+}e^{-}$ 29 G $\frac{COMMENT}{e^{+}e^{-}}$ 29 G $\frac{COMMENT}{e^{+}e^{-}}$ 29 G $\frac{COMMENT}{e^{+}e^{-}}$ 29 G	F ₁₂₃ /lev F ₁₂₄ /lev F ₁₂₅ /lev F ₁₂₆ /lev F ₁₂₆ /lev
Test of lepton for the property of the proper	amily num	DOCUMENT II 184 WEIR duction cross section DOCUMENT II 185 WEIR duction cross section DOCUMENT II 186 WEIR duction cross section DOCUMENT II 187 WEIR duction cross section DOCUMENT II 188 WEIR duction cross section DOCUMENT II 188 WEIR duction cross section DOCUMENT II 188 WEIR duction cross section DOCUMENT II DO	908 M ion from I	MRK2 LUND. FEEN MRK2 LUND. MRK2 LUND. MRK2 LUND. MRK2 LUND. MRK2 LUND.	$e^{+}e^{-}$ 29 G $\frac{COMMENT}{e^{+}e^{-}}$ 29 G $\frac{COMMENT}{e^{+}e^{-}}$ 29 G $\frac{COMMENT}{e^{+}e^{-}}$ 29 G	Γ ₁₂₃ /I eV Γ ₁₂₄ /I eV Γ ₁₂₅ /I eV Γ ₁₂₇ /I
Test of lepton for the property of the proper	amily num	DOCUMENT II 184 WEIR duction cross section DOCUMENT II 185 WEIR duction cross section DOCUMENT II 186 WEIR duction cross section DOCUMENT II 187 WEIR duction cross section DOCUMENT II 188 WEIR duction cross section DOCUMENT II 189 WEIR	908 M ion from I	MRK2 LUND. FEEN MRK2 LUND. FEEN MRK2 LUND. LUND. FEEN MRK2 LUND.	$e^{+}e^{-}$ 29 G COMMENT $e^{+}e^{-}$ 29 G COMMENT $e^{+}e^{-}$ 29 G COMMENT $e^{+}e^{-}$ 29 G	Γ ₁₂₃ /I eV Γ ₁₂₄ /I eV Γ ₁₂₅ /I eV Γ ₁₂₇ /I
Test of lepton for Laboratory Test of lepton for Laboratory ($\pi^-e^+e^+$)/ Γ_{tota} Test of total lepta ($\pi^-\mu^+\mu^+$)/ Γ_{tota} Test of total lepta ($\pi^-\mu^+\mu^+$)/ Γ_{tota} Test of total lepta ($\pi^-\mu^+\mu^+$)/ Γ_{tota} Test of total lepta ($\pi^-e^+\mu^+$)/ Γ_{tota} Test of total lepta ($\pi^-e^+e^+$)/ Γ_{tota} Test of Γe^+e^+)/ Γe^+e^+	amily num	DOCUMENT II 184 WEIR duction cross section DOCUMENT II 185 WEIR duction cross section DOCUMENT II 186 WEIR duction cross section DOCUMENT II 187 WEIR duction cross section DOCUMENT II 188 WEIR duction cross section DOCUMENT II 189 WEIR	908 M ion from I	MRK2 LUND. FEEN MRK2 LUND. FEEN MRK2 LUND. LUND. FEEN MRK2 LUND.	$e^{+}e^{-}$ 29 G COMMENT $e^{+}e^{-}$ 29 G COMMENT $e^{+}e^{-}$ 29 G COMMENT $e^{+}e^{-}$ 29 G	Γ ₁₂₃ /I eV Γ ₁₂₄ /I eV Γ ₁₂₅ /I eV Γ ₁₂₇ /I
Test of lepton for the property of the proper	amily num	DOCUMENT II 184 WEIR duction cross section DOCUMENT II 185 WEIR duction cross section DOCUMENT II 186 WEIR duction cross section DOCUMENT II 187 WEIR duction cross section DOCUMENT II 188 WEIR duction cross section DOCUMENT II 188 WEIR duction cross section DOCUMENT II 189 WEIR	908 M ion from I	MRK2 LUND. FECN MRK2 LUND. MRK2 LUND. MRK2 LUND. MRK2 LUND. FECN MRK2 LUND.	$e^{+}e^{-}$ 29 G $\frac{COMMENT}{e^{+}e^{-}}$ 29 G $\frac{COMMENT}{e^{+}e^{-}}$ 29 G $\frac{COMMENT}{e^{+}e^{-}}$ 29 G $\frac{COMMENT}{e^{+}e^{-}}$ 29 G	Γ ₁₂₃ /I eV Γ ₁₂₄ /I eV Γ ₁₂₅ /I eV Γ ₁₂₅ /I eV Γ ₁₂₆ /I
Test of lepton for the property of the proper	amily num	DOCUMENT II 184 WEIR duction cross section DOCUMENT II 185 WEIR duction cross section DOCUMENT II 186 WEIR duction cross section DOCUMENT II 187 WEIR duction cross section DOCUMENT II 188 WEIR duction cross section DOCUMENT II 189 WEIR	908 M ion from I 908 M	MRK2 LUND. FECN MRK2 LUND. FECN MRK2 LUND. FECN MRK2 LUND. FECN MRK2 LUND.	$e^{+}e^{-}$ 29 G $\frac{COMMENT}{e^{+}e^{-}}$ 29 G $\frac{COMMENT}{e^{+}e^{-}}$ 29 G $\frac{COMMENT}{e^{+}e^{-}}$ 29 G $\frac{COMMENT}{e^{+}e^{-}}$ 29 G	F ₁₂₃ /lev F ₁₂₄ /lev F ₁₂₅ /lev F ₁₂₆ /lev F ₁₂₇ /lev F ₁₂₈ /

B[±] REFERENCES

ABE ABE	96B 96C	PR D53 3496 PRL (to be publ.)	+Albrow, Amendolia, Amidei+ +Akimoto, Akopian, Albrow+	(CDF Collab.) (CDF Collab.)
ASNER	96	TOM/PUB/3492	Athones Blice Browns	(CLEO C-11-1-)
BUSKULIC	96G	PR D53 1039 ZPHY C (submitted)	+Athanas, Bliss, Brower+ +De Bonis, Decamp, Ghez+	(CLEO Collab.) (ALEPH Collab.)
CERN-PPE		ZENT C (Submitted)	+De Bollis, Decamp, Gnez+	(ALEPH CONAD.)
ABREU	95N	PL B357 255	+Adam, Adye, Agasi+	(DELPHI Collab.)
ABREU	95Q	ZPHY C68 13	+Adam, Adye, Agasi+	(DELPHI Collab.)
ADAM	95	ZPHY C68 363	+Adye, Agasi, Ajinenko+	(DELPHI Collab.)
AKERS	95T	ZPHY C67 379	+Alexander, Allison, Ametewee+	(OPAL Collab.)
ALBRECHT	95D	PL B353 554	+Hamacher, Hofmann, Kirchoff+	(ARGUS Collab.)
ALEXANDER	95	PL B341 435	+Bebek, Berkelman, Bloom+	(CLEO Collab.)
Also	95C		Alexander, Bebek, Berkelman, Bloom+	(CLEO Collab.)
ARTUSO	95	PRL 75 785	+Gao, Goldberg, He+	(CLEO Collab.)
BARISH	95	PR D51 1014	+Chadha, Chan, Cowen+	(CLEO Collab.)
BUSKULIC	95	PL B343 444	+Casper, De Bonis, Decamp, Ghez, Goy+	(ALEPH Collab.)
ABE	94D	PRL 72 3456	+Albrow, Amidei, Anway-Wiese, Apollinari	(CDF Collab.)
ALAM	94	PR D50 43	+Kim, Nemati, O'Neill, Severini+	(CLEO Collab.)
ALBRECHT	94D	PL B335 526	+Hamacher, Hofmann, Kirchhoff, Mankel+	
ATHANAS	94	PRL 73 3503	+Brower, Masek, Paar, Gronberg+	(CLEO Collab.)
Also	95		Athanas, Brower, Masek, Paar+	(CLEO Collab.)
PDG	94	PR D50 1173	Montanet+ (CERN, LE	L, BOST, IFIC+)
STONE	94	HEPSY 93-11		
ABREU	93D	ZPHY C57 181	+Adam, Adye, Agasi, Alekseev+	(DELPHI Collab.)
ABREU	93G	PL B312 253	+Adam, Adye, Agasi, Ajinenko+	(DELPHI Collab.)
ACTON	93C	PL B307 247	+Alexander, Allison, Allport, Anderson+	(OPAL Collab.)
ALBRECHT	93E 93B	ZPHY C60 11	+Ehrlichmann, Hamacher, Hofmann+	(ARGUS Collab.)
ALEXANDER AMMAR	936	PL B319 365 PRL 71 674	+Bebek, Berkelman, Bloom, Browder+ +Ball, Baringer, Coppage, Copty+	(CLEO Collab.) (CLEO Collab.)
BEAN	93B	PRL 70 2681	+Gronberg, Kutschke, Menary, Morrison+	(CLEO Collab.)
BUSKULIC	93D	PL B307 194	+Decamp, Goy, Lees, Minard+	(ALEPH Collab.)
Also	94H	PL B325 537 (errata)	+Decamp, Goy, Lees, Millard+	(ALLI II Collab.)
SANGHERA	93	PR D47 791	+Skwarnicki, Stroynowski, Artuso, Goldber,	g+(CLEO Collab.)
ALBRECHT	92C	PL B275 195	+Ehrlichmann, Hamacher, Krueger, Nau+	
ALBRECHT	92E	PL B277 209	+Ehrlichmann, Hamacher, Krueger, Nau+	
ALBRECHT	92G	ZPHY C54 1	+Ehrlichmann, Hamacher, Krueger, Nau+	
BORTOLETTO	92	PR D45 21	+Brown, Dominick, McIlwain+	(CLEO Collab.)
BUSKULIC	92G	PL B295 396	+Decamp, Goy, Lees, Minard+	(ALEPH Collab.)
ALBRECHT	91B	PL B254 288	+Glaeser, Harder, Krueger, Nippe+	(ARGUS Collab.)
ALBRECHT	91C	PL B255 297	+Ehrlichmann, Glaeser, Harder, Krueger+	(ARGUS Collab.)
ALBRECHT	91E	PL B262 148	+Glaeser, Harder, Krueger, Nippe+	(ARGUS Collab.)
BERKELMAN	91	ARNPS 41 1	+Stone	(CORN, SYRA)
"Decays of FULTON	91	PR D43 651	+Jensen, Johnson, Kagan, Kass+	(CLEO Collab.)
ALBRECHT	90B	PL B241 278	+Glaeser, Harder, Krueger, Nilsson+	(ARGUS Collab.)
ALBRECHT	90J	ZPHY C48 543	+Ehrlichmann, Harder, Krueger+	(ARGUS Collab.)
ANTREASYAN	90B	ZPHY C48 553		ystal Ball Collab.)
BORTOLETTO		PRL 64 2117	+Goldberg, Horwitz, Jain, Mestayer+	(CLEO Collab.)
Also	92	PR D45 21	Bortoletto, Brown, Dominick, McIlwain+	(CLEO Collab.)
WEIR	90B	PR D41 1384	+Klein, Abrams, Adolphsen, Akerlof+	(Mark II Collab.)
ALBRECHT	89G	PL B229 304	+Glaeser, Harder, Krueger+	(ARGUS Collab.)
AVERY	89B	PL B223 470	+Besson, Garren, Yelton+	(CLEO Collab.)
BEBEK	89	PRL 62 8	+Berkelman, Blucher+	(CLEO Collab.)
BORTOLETTO		PRL 62 2436	+Goldberg, Horwitz, Mestayer+	(CLEO Collab.)
ALBRECHT	88F	PL B209 119	+Boeckmann, Glaeser+	(ARGUS Collab.)
ALBRECHT	88K	PL B215 424	+Boeckmann, Glaeser+	(ARGUS Collab.)
ALBRECHT	87C 87D	PL B185 218	+Binder, Boeckmann, Glaser+	(ARGUS Collab.)
ALBRECHT		PL B199 451	+Andam, Binder, Boeckmann+	(ARGUS Collab.) (CLEO Collab.)
AVERY BEBEK	87 87	PL B183 429 PR D36 1289	+Besson, Bowcock, Giles+ +Berkelman, Blucher, Cassel+	(CLEO Collab.)
ALAM	86	PR D36 1209 PR D34 3279	+Katayama, Kim, Sun+	(CLEO Collab.)
PDG	86	PL 170B	Aguilar-Benitez, Porter+	(CERN, CIT+)
GILES	84	PR D30 2279	+Hassard, Hempstead, Kinoshita+	(CLEO Collab.)
				,

- OTHER RELATED PAPERS -

BERKELMAN 91 ARNPS 41 1 +Stone (CORN, SYRA)

"Decays of B Mesons"
MILLER 90 MPL A5 2683

"Recent Results in B Physics"
SCHINDLER 88 High Energy Electron-Positron Physics 234
Editors: A. Ali and P. Soeding, World Scientific, Singapore
SCHUBERT 87 HEP-HD/987-7
EPS Conference - Uppsala, Proc., Vol. 2, p. 791



$$I(J^P) = \frac{1}{2}(0^-)$$

Quantum numbers not measured. Values shown are quark-model predictions.

See also the B^\pm/B^0 ADMIXTURE and $B^\pm/B^0/B_s^0/b$ -baryon ADMIXTURE sections

See the Notes "Experimental Highlights of B Meson Production and Decay" and "Semileptonic Decays of B Mesons" at the beginning of the B^\pm Particle Listings and the Note on " B^0 – \overline{B}^0 Mixing and CP Violation in B Decay" near the end of the B^0 Particle Listings.

BO MASS

The fit uses m_{B^+} , $(m_{B^0}-m_{B^+})$, $m_{B^0_s}$, and $(m_{B^0_s}-(m_{B^+}+m_{B^0})/2)$ to determine m_{B^+} , m_{B^0} , $m_{B^0_s}$, and the mass differences. m_{B^0} data are excluded from the fit because they are not independent.

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
5279.2±1.8 OUR FI	Т				
5279.8±1.6 OUR AV	/ERAGE				
$5281.3 \pm 2.2 \pm 1.4$	51	¹ ABE	96B	CDF	$p\overline{p}$ at 1.8 TeV
$5279.2 \pm 0.54 \pm 2.0$	340	² ALAM	94	CLE2	$e^+ e^- ightarrow \gamma(4S)$
$5278.0 \pm 0.4 \pm 2.0$		² BORTOLETT	O92	CLEO	$e^+e^- \rightarrow \Upsilon(45)$
5279.6 ± 0.7 ± 2.0	40	^{2,3} ALBRECHT	90 J	ARG	$e^+e^- \rightarrow \Upsilon(45)$
$5280.6 \pm 0.8 \pm 2.0$		² BEBEK	87	CLEO	$e^+ e^- ightarrow ~ \varUpsilon(4S)$
M/o do not uso	Aho fallou	ing data for average	o fito	limite	ata

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ALBRECHT 87C ARG e^+e^- \rightarrow \varUpsilon(4S) 4 ALBRECHT 87D ARG e^+e^- \rightarrow \varUpsilon(4S)
5279.5 ± 1.6 ± 3.0
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- 1 Excluded from fit because it is not independent of ABE 96B B_s^0 mass and B_s^0 -B mass
- difference. 2 These experiments all report a common systematic error 2.0 MeV. We have artificially the experiments to be treated as independent increased the systematic error to allow the experiments to be treated as independent measurements in our average. See "Treatment of Errors" section of the Introductory Text. These experiments actually measure the difference between half of $E_{\rm Cm}$ and the
- 3 ALBRECHT 90J assumes 10580 for \varUpsilon (45) mass. Supersedes ALBRECHT 87C and
- ALBRECHT 87D. AFFICIAL FOR THE PROPERTY ALBRECHT 87D assume $m_{\Upsilon(4S)} = 10^{-10}$ 10577 MeV.

$m_{B^0} - m_{B^+}$

The mass difference measurements are not independent of the B^\pm and B^0 mass measurement by the same experimenters. The fit uses $m_{B^+},$ $(m_{B^0}-m_{B^+}),$ $m_{B^0_{\varsigma}}$ and $(m_{B^0_{\varsigma}}-(m_{B^+}+m_{B^0})/2)$ to determine m_{B^+} , m_{B^0} , m_{B^0} , and the mass differences.

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
0.35±0.29 OUR FIT Error	includes scale factor o	f 1.1.	
0.34±0.32 OUR AVERAGE	Error includes scale fa	actor of 1.2.	
$0.41 \pm 0.25 \pm 0.19$			$e^+e^- \rightarrow \Upsilon(4S)$
$-0.4 \pm 0.6 \pm 0.5$	BORTOLETTO	92 CLEO	$e^+e^- \rightarrow \Upsilon(45)$
$-0.9 \pm 1.2 \pm 0.5$			$e^+e^- \rightarrow \Upsilon(45)$
$2.0 \pm 1.1 \pm 0.3$	⁵ BEBEK	87 CLEO	$e^+e^- ightarrow \gamma(45)$
⁵ BEBEK 87 actually measi mass, so the $m_{R0} - m_{R1}$	ure the difference betw	een half of	$E_{\rm cm}$ and the B^\pm or B^0
mass, so the $m_{D0} - m_{D+}$. is more accurate. Ass	ume $m_{\Upsilon(A)}$	$c_1 = 10580 \text{ MeV}.$

$m_{B_{II}^0} - m_{B_I^0}$

See the B^0 - \overline{B}^0 MIXING section near the end of these B^0 Listings.

B⁰ MEAN LIFE

See $B^{\pm}/B^0/B_s^0/b$ -baryon ADMIXTURE section for data on B-hadron mean life averaged over species of bottom particles.

"OUR EVALUATION" is an average of the data listed below performed by the LEP B Lifetimes Working Group as described in our review "Production and Decay of b-flavored Hadrons" in the B^\pm Section of the Listings. The averaging procedure takes into account correlations between the measurements and asymmetric lifetime errors.

VALUE (10 ⁻¹² s)	EVTS	DOCUMENT ID	TEC	N COMMENT
1.56±0.06 OUR E		DOCUMENTID		COMMENT
	VALUATION	⁶ ABE	060 60	1 0 T-1/
$1.54 \pm 0.08 \pm 0.06$				pp at 1.8 TeV
$1.61 \pm 0.07 \pm 0.04$		⁶ BUSKULIC	96G AL	$P e^+e^- \rightarrow Z$
$1.25^{+0.15}_{-0.13}\pm0.05$	121	⁷ BUSKULIC	96G ALI	$e^+e^- \rightarrow Z$
$1.49 {}^{+ 0.17 + 0.08}_{- 0.15 - 0.06}$		⁸ BU S KULIC	96G ALI	$e^+e^- \rightarrow Z$
$1.61^{+0.14}_{-0.13}{\pm}0.08$	1	^{6,9} ABREU	95Q DLI	PH $e^+e^- \rightarrow Z$
$1.63 \pm 0.14 \pm 0.13$		¹⁰ ADAM	95 DLI	$^{\circ}$ H $e^{+}e^{-} \rightarrow Z$
$1.53 \pm 0.12 \pm 0.08$	6	¹¹ AKERS	95T OP	AL $e^+e^- \rightarrow Z$
$1.57 \pm 0.18 \pm 0.08$	121	⁷ ABE	94D CD	- p p̄ at 1.8 TeV
• • • We do not a	use the following	g data for average	s, fits, lim	its, etc. • • •
1.55 ± 0.06 ± 0.03		12 BUSKULIC	96C AL	$e^+e^- \rightarrow Z$
1.62±0.12		13 ADAM	95 DLI	
		_	95 DEI	H e e → Z
$1.17^{+0.29}_{-0.23}\pm0.16$	96	⁶ ABREU	93D DLI	PH Sup. by ABREU 95Q
$1.55 \pm 0.25 \pm 0.18$	76	¹⁰ ABREU	93G DLI	PH Sup. by ADAM 95
$1.51^{+0.24}_{-0.23}^{+0.12}_{-0.14}$	78	⁶ ACTON	93C OP	AL Sup. by AKERS 95T
$1.52 {}^{+ 0.20 + 0.07}_{- 0.18 - 0.13}$	77	⁶ BUSKULIC	93D AL	P Sup. by BUSKULIC 96G
$1.20 {}^{+ 0.52 + 0.16}_{- 0.36 - 0.14}$	15	¹⁴ WAGNER	90 MR	K2 <i>Ec</i> m = 29 GeV
$0.82^{+0.57}_{-0.37}{\pm}0.27$		¹⁵ AVERILL	89 HR	6

- $^6_-$ Data analyzed using $D/D^*\ell X$ event vertices.
- 7 Measured mean life using fully reconstructed decays.
- 8 Measured mean life using partially reconstructed $D^*-\pi^+ X$ vertices. 9 ABREU 95Q assumes B($B^0 \to D^{**-}\ell^+\nu_\ell$) = 3.2 \pm 1.7%.

- 10 Data analyzed using vertex-charge technique to tag B charge. 11 AKERS 95T assumes B($B^0 \rightarrow D_S^{(*)}D^0(*)) = 5.0 \pm 0.9\%$ to find B^+/B^0 yield.
- 11 AKERS 95T assumes B($B^0 \to D_5^{(*)}D^0(*)$) = 5.0 ± 0.9% to find B^+/B^0 yield. 12 Combined result of $D/D^*\ell \times$ analysis, fully reconstructed B analysis, and partially reconstruced $D^{*-}\pi^+ \times$ analysis. 13 Combined ABREU 95Q and ADAM 95 result. 14 WAGNER 90 tagged B^0 mesons by their decays into $D^{*-}e^+\nu$ and $D^{*-}\mu^+\nu$ where the D^{*-} is tagged by its decay into $\pi^-\overline{D}^0$. 15 AVERILL 89 is an estimate of the B^0 mean lifetime assuming that $B^0 \to D^{*+} + X$ always

MEAN LIFE RATIO τ_{B^+}/τ_{B^0}

au_{B^+}/ au_{B^0} (average of direct and inferred)

VALUE DOCUMENT ID

1.02 ± 0.05 OUR AVERAGE Includes data from the 2 datablocks that follow this one.

 au_{B^+}/ au_{B^0} (direct measurements) "OUR EVALUATION" is an average of the data listed below performed by the LEP B Lifetimes Working Group as described in our review "Production and Decay of b-flavored Hadrons" in the B^\pm Section of the Listings. The averaging procedure takes into account correlations between the measurements and asymmetric lifetime errors.

<u>VALUE</u> <u>EVTS</u> <u>DOCUMENT ID</u> <u>TECN COMMENT</u>
The data in this block is included in the average printed for a previous datablock.

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1.03±0.06 OUR EVALUATION
                                          16 ABE
                                                                 96C CDF p\overline{p} at 1.8 TeV
96G ALEP e^+e^- \rightarrow Z
1.01 \pm 0.11 \pm 0.02
0.98 \pm 0.08 \pm 0.03
                                          <sup>16</sup> BUSKULIC
1.27 ^{\,+\, 0.23 \,+\, 0.03}_{\,-\, 0.19 \,-\, 0.02}
                                          <sup>17</sup> BUSKULIC
                                                                 96G ALEP e^+e^- \rightarrow Z
1.00 \,{}^{+\, 0.17}_{-\, 0.15} \,{\pm}\, 0.10
                                      16,18 ABREU
                                                                 95Q DLPH e^+e^- \rightarrow Z
                                          <sup>19</sup> ADAM
1.06^{\,+\,0.13}_{\,-\,0.10}\,{\pm}\,0.10
                                                                 95 DLPH e^+e^- \rightarrow Z
0.99 \pm 0.14 ^{+0.05}_{-0.04}
                                      16,20 AKERS
                                                                 95T OPAL e^+e^- \rightarrow Z
                                        <sup>17</sup> ABE
                                                                 94D CDF pp at 1.8 TeV
1.02 \pm 0.16 \pm 0.05
                                269
<sup>21</sup> BUSKULIC
1.03 \pm 0.08 \pm 0.02
                                                                 96G ALEP e^+e^- \rightarrow Z
1.11^{\,+\,0.51}_{\,-\,0.39}\,{\pm}\,0.11
                                          <sup>16</sup> ABREU
                                                                 93D DLPH Sup. by ABREU 95Q
1.01 \, {}^{+\, 0.29}_{-\, 0.22} \, {\pm}\, 0.12
                                          <sup>19</sup> ABREU
                                253
                                                                 93G DLPH Sup. by ADAM 95
1.0 \ ^{+0.33}_{-0.25}\!\pm\!0.08
                                             ACTON
                                                                 93C OPAL Sup. by AKERS 95T
                                130
0.96^{\,+\,0.19}_{\,-\,0.15}^{\,+\,0.18}_{\,-\,0.12}
                                        <sup>16</sup> BUSKULIC
                                154
                                                                 93D ALEP Sup. by BUSKULIC 96G
```

- ¹⁶ Data analyzed using $D/D^*\ell X$ vertices.
- 17 Measurement using fully reconstructed decays. 18 ABREU 95Q assumes B($B^0 \rightarrow D^{**-}\ell^+\nu_\ell$) = 3.2 \pm 1.7%.
- ¹⁹ Data analyzed using vertex-charge technique to tag B charge. ²⁰ AKERS 95T assumes $B(B^0 \to D_S^{(*)}D^{0(*)}) = 5.0 \pm 0.9\%$ to find B^+/B^0 yield.
- ²¹ Combined result of $D/D^*\ell X$ analysis and fully reconstructed B analysis.

 τ_{B^+}/τ_{B^0} (inferred from branching fractions)

These measurements are inferred from the branching fractions for semileptonic decay or other spectator-dominated decays by assuming that the rates for such decays are equal for B^0 and B^+ . We do not use measurements which assume equal production of B^0 and B^+ because of the large uncertainty in the production ratio.

<u>VALUE</u> <u>CL% EVTS</u> <u>DOCUMENT ID</u> <u>TECN COMMENT</u>
The data in this block is included in the average printed for a previous datablock. 22 ATHANAC

$0.93 \pm 0.18 \pm 0.12$	22	ATHANAS	94 CLE2	$e^+e^- \rightarrow$	7(45)
 ● ● We do not 	use the following of	lata for averages	, fits, limits,	etc. • • •	
$0.91 \pm 0.27 \pm 0.21$		ALBRECHT	92C ARG	$e^+e^- \rightarrow$	$\Upsilon(45)$
1.0 ±0.4			92G ARG	$e^+e^- \rightarrow$	$\Upsilon(45)$
$0.89 \pm 0.19 \pm 0.13$			91 CLEO	$e^+e^- \rightarrow$	$\Upsilon(4S)$
$1.00 \pm 0.23 \pm 0.14$			89L ARG		
0.49 to 2.3	90 25	BEAN	87B CLEO	$e^+e^- \rightarrow$	$\Upsilon(45)$

- 22 ATHANAS 94 uses events tagged by fully reconstructed B^- decays and partially or fully reconstructed B^0 decays.
- ²³ Assumes equal production of B^0 and B^+ .

Mode

- ²⁴ ALBRECHT 92G data analyzed using $B \to D_S \overline{D}$, $D_S \overline{D}^*$, $D_S^* \overline{D}$, $D_S^* \overline{D}^*$ events.
- 25 BEAN 87B assume the fraction of $B^0\overline{B}^0$ events at the $\Upsilon(4S)$ is 0.41.

B⁰ DECAY MODES

 $\overline{\it B}{}^{0}$ modes are charge conjugates of the modes below. Reactions indicate the weak decay vertex and do not include mixing. Modes which do not identify the charge state of the B are listed in the B^\pm/B^0 ADMIXTURE

The branching fractions listed below assume 50% $B^0\,\overline{B}{}^0$ and 50% $B^+\,B^$ production at the $\Upsilon(4S)$. We have attempted to bring older measurements up to date by rescaling their assumed $\Upsilon(4S)$ production ratio to 50:50 and their assumed $D,\ D_s,\ D^*$, and ψ branching ratios to current values whenever this would affect our averages and best limits significantly.

Indentation is used to indicate a subchannel of a previous reaction. All resonant subchannels have been corrected for resonance branching fractions to the final state so the sum of the subchannel branching fractions can exceed that of the final state.

Fraction (Γ_i/Γ) Confidence level

Semileptonic and leptonic modes

	Schnicpto	me and reptome modes	
Γ_1	$\ell^+ u_\ell$ anything	[a] (10.3 \pm 1.0)%	
Γ_2	$D^-\ell^+ u_\ell$	[a] (1.9 \pm 0.5) %	
Γ3	$D^*(2010)^-\ell^+ u_\ell$	[a] (4.56±0.27) %	
Γ_4	$ ho^-\ell^+ u_\ell$	$[a] < 4.1 \times 10^{-}$	4 CL=90%
Γ_5	$\pi^{-} \mu^{+} \nu_{}$		

 B^0

Γ ₆ Γ ₇ Γ ₈	D, D*, or L	D- modes								
Γ ₇		- S C - C - C - C - C - C - C - C -			Γ ₇₄	$K^*(892)^0 \rho^0$		< 4.6	× 10 ⁻⁴	CL=90%
	$D^-\pi^+$	(3.0 ± 0.4)			Γ ₇₅	$K^*(892)^0 f_0(980)$		< 1.7	× 10 ⁻⁴	CL=90%
۲8	$\underline{D}^- \rho^+$	(7.8 ± 1.4)			Γ ₇₆	$K_1(1400)^+\pi^-$		< 1.1	× 10 ⁻³	CL=90%
	$\overline{D}{}^0\pi^+\pi^-$		× 10 ⁻³	CL=90%	Г ₇₇	$K^-a_1(1260)^+$	[[b] < 3.9	× 10 ⁻⁴	CL=90%
Γ9	$D^*(2010)^-\pi^+$	(2.6 ± 0.4)				$K^*(892)^0 K^+ K^-$		< 6.1	× 10 ⁻⁴	CL=90%
Γ ₁₀	$D^-\pi^+\pi^+\pi^-$	(8.0 ±2.5)			Γ ₇₉	$K^*(892)^0 \phi$		< 4.3	× 10 ⁻⁵	CL=90%
Γ ₁₁	$(D^-\pi^+\pi^+\pi^-)$ nonresonant	(3.9 ±1.9)			Γ ₈₀	$K_1(1400)^0 \rho^0$		< 3.0	$\times 10^{-3}$	CL=90%
Γ ₁₂	$D^-\pi^+\rho^0$	(1.1 ±1.0)			Γ ₈₁	$K_1(1400)^0 \phi$		< 5.0	× 10 ⁻³	CL=90%
Γ ₁₃	$D^-a_1(1260)^+$	(6.0 ±3.3)			_	$K_2^*(1430)^0 \rho^0$		< 1.1	× 10 ³	CL=90%
Γ ₁₄	$D^*(2010)^-\pi^+\pi^0$	(1.5 ±0.5)				$K_2^*(1430)^0 \phi$		< 1.4	× 10 ⁻³	CL=90%
Γ ₁₅	$D^*(2010)^- \rho^+$	(7.3 ± 1.5)				$K^*(892)^0 \gamma$			9) $\times 10^{-5}$	
Γ ₁₆	$D^*(2010)^-\pi^+\pi^+\pi^-$	(7.6 ±1.7)		S=1.3		$K_1(1270)^0 \gamma$		< 7.0	$\times 10^{-3}$	CL=90%
Γ ₁₇	$(D^*(2010)^-\pi^+\pi^+\pi^-)$ non-	(0.0 ± 2.5)	× 10 ⁻³			$K_1(1400)^0 \gamma$		< 4.3	× 10 ⁻³	CL=90%
г	resonant $D^*(2010)^-\pi^+ ho^0$	(5.7 ±3.1)	3			$K_2^*(1430)^0 \gamma$		< 4.0	× 10 ⁻⁴	CL=90%
Γ ₁₈		(1.30±0.27)				$K^*(1680)^0 \gamma$		< 2.0	× 10 ⁻³	CL=90%
Γ ₁₉	$D^*(2010)^- a_1(1260)^+ $ $D^*(2010)^- \pi^+ \pi^+ \pi^- \pi^0$	(3.4 ± 1.8)			Γ ₈₉	$K_3^*(1780)^0 \gamma$		< 1.0	%	CL=90%
Γ ₂₀	$\overline{D}_{2}^{*}(2460)^{-}\pi^{+}$		× 10 ⁻³	CL=90%	Γ ₉₀	$K_4^*(2045)^0 \gamma$		< 4.3	× 10 ⁻³	CL=90%
Γ ₂₁			× 10 ⁻³		Γ_{91}	$\phi\phi$		< 3.9	\times 10 ⁻⁵	CL=90%
Γ ₂₂	$\overline{D}_{2}^{*}(2460)^{-}\rho^{+}$			CL=90%		Light v	inflavored m	eson modes		
Γ ₂₃	$D^-D_s^+$, ,	× 10 ⁻³		Γ ₉₂	$\pi^{+}\pi^{-}$		< 2.0	× 10 ⁻⁵	CL=90%
Γ ₂₄	$D^*(2010)^-D_s^+$	(1.2 ± 0.6)				$\pi^{0}\pi^{0}$		< 9.1	\times 10 ⁻⁶	CL=90%
Γ ₂₅	$D^{-}D_{s}^{*+}$	(2.0 ± 1.5)	%			$\eta \pi^0$		< 2.5	× 10 ⁻⁴	CL=90%
Γ_{26}	$D^*(2010)^- D_s^{*+}$	(1.9 ± 1.2)	%		_*.	$\eta\eta$		< 4.1	× 10 ⁻⁴	CL=90%
Γ ₂₇	$D_s^+\pi^-$	< 2.8	\times 10 ⁻⁴	CL=90%	Γ ₉₆	$\pi^{+}\pi^{-}\pi^{0}$		< 7.2	× 10 ⁻⁴	CL=90%
Γ ₂₈	$D_{s}^{*+}\pi^{-}$		× 10 ⁻⁴	CL=90%	Γ ₉₇	$\rho^0\pi^0$		< 2.4	× 10 ⁻⁵	CL=90%
Γ ₂₉	$D_s^+ \rho^-$		× 10 ⁻⁴	CL=90%	Γ ₉₈	$\rho^{\mp}\pi^{\pm}$	ſ	c] < 8.8	× 10 ⁻⁵	CL=90%
_	5 * ±		× 10 × 10 -4	CL=90%		$\pi^{+}\pi^{-}\pi^{+}\pi^{-}$	į,	< 2.8	× 10 ⁻⁴	CL=90%
F ₃₀	$D_s^{*+}\rho^-$				Γ ₁₀₀	$\rho^0 \rho^0$		< 2.8	× 10 ⁻⁴	CL=90%
Г31	$D_s^+ a_1(1260)^-$		× 10 ⁻³	CL=90%	Γ ₁₀₁	$a_1(1260)^{\mp}\pi^{\pm}$	ſ	c] < 4.9	\times 10 ⁻⁴	CL=90%
Γ ₃₂	$D_s^{*+} a_1(1260)^-$		× 10 ⁻³	CL=90%	Γ ₁₀₂	$a_2(1320)^{\mp}\pi^{\pm}$		c] < 3.0	× 10 ⁻⁴	CL=90%
Γ_{33}	$D_s^- K^+$		× 10 ⁻⁴	CL=90%	Γ ₁₀₂	$\pi^{+}\pi^{-}\pi^{0}\pi^{0}$		< 3.1	$\times 10^{-3}$	CL=90%
Γ ₃₄	$D_{s}^{*-}K^{+}$	< 1.7	$\times 10^{-4}$	CL=90%	Γ ₁₀₄	$\rho^+ \rho^-$		< 2.2	× 10 ⁻³	CL=90%
Γ ₃₅	$D_{s}^{-}K^{*}(892)^{+}$	< 9.9	$\times 10^{-4}$	CL=90%	Γ ₁₀₅	$a_1(1260)^0 \pi^0$		< 1.1	\times 10 ⁻³	CL=90%
Γ ₃₆	$D_{s}^{*-} K^{*}(892)^{+}$		\times 10 ⁻³	CL=90%	Γ ₁₀₆	$\omega \pi^0$		< 4.6	× 10 ⁻⁴	CL=90%
Γ ₃₇	$D_s^-\pi^+K^0$		$\times 10^{-3}$	CL=90%	Γ ₁₀₇	$\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0}$		< 9.0	$\times 10^{-3}$	CL=90%
-			× 10 ⁻³	CL=90%	Γ ₁₀₈	$a_1(1260)^+ \rho^-$		< 3.4	\times 10 ⁻³	CL=90%
Γ ₃₈	$D_s^{*-}\pi^+ K^0$				Γ ₁₀₉	$a_1(1260)^0 \rho^0$		< 2.4	\times 10 ⁻³	CL=90%
Γ ₃₉	$D_s^- \pi^+ K^*(892)^0$		× 10 ⁻³	CL=90%	Γ110	$\pi^{+}\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{-}\pi^{-}$		< 3.0	\times 10 ⁻³	CL=90%
Γ ₄₀	$D_{s}^{*-}\pi^{+}K^{*}(892)^{0}$		× 10 ⁻³	CL=90%	Γ ₁₁₁	$a_1(1260)^+ a_1(1260)^-$		< 2.8	$\times 10^{-3}$	CL=90%
Γ_{41}	\overline{D}^{0} π^{0}		$\times 10^{-4}$	CL=90%	Γ112	$\pi^{+}\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{-}\pi^{0}$		< 1.1	%	CL=90%
Γ ₄₂	$\overline{D}_{0}^{0} \rho^{0}$		× 10 ⁻⁴	CL=90%	***		Baryon mo	des		
Γ ₄₃	$\frac{\overline{D}^0}{\overline{D}^0}\eta$		× 10 ⁻⁴	CL=90%	Γ ₁₁₃	n n		< 3.4	× 10 ⁻⁵	CL=90%
Γ44	$\frac{\overline{D}^0}{\overline{D}^0}\eta'$	< 8.6	× 10 ⁻⁴	CL=90%		$\rho \overline{\rho} \pi^+ \pi^-$		< 2.5	× 10 ⁻⁴	CL=90%
Γ ₄₅	$\overline{D}^0 \omega$		× 10 ⁻⁴	CL=90%		$p \Lambda \pi^-$		< 1.8	× 10 ⁻⁴	CL=90%
Γ ₄₆	$\overline{D}^*(2007)^0\pi^0$	< 9.7	× 10 ⁻⁴	CL=90%	Γ. 115	$\Delta^0 \overline{\Delta}{}^0$		< 1.5	× 10 ⁻³	CL=90%
Γ47	$\overline{D}^*(2007)^0 \rho^0$	< 1.17	× 10 ⁻³	CL=90%	Γ116	$\Delta^{++}\Delta^{}$		< 1.1	× 10 ⁻⁴	CL=90%
Γ ₄₈	$\overline{D}^*(2007)^0 \eta$		× 10 ⁻⁴	CL=90%	Γ117	$\frac{\Sigma}{\Sigma_c} - \Delta^{++}$		< 1.2	× 10 ⁻³	CL=90%
Γ ₄₉	$D^*(2007)^0 \eta'$	< 2.7	$\times 10^{-3}$	CL=90%	'118					CL3070
Γ ₅₀	$\overline{D}^*(2007)^0 \omega$	< 2.1	\times 10 ⁻³	CL=90%		Lepton Family r	• •			
	Charmoniu	m modes			_	$\Delta B = 1$ wea				a
Γ_{51}	$J/\psi(1S)K^0$	(7.5 ±2.1)	\times 10 ⁻⁴		119		B1	< 3.9	× 10 ⁻⁵	CL=90%
	$J/\psi(1S)K^+\pi^-$	(1.1 ±0.6)			Γ ₁₂₀		B1	< 5.9	× 10 ⁻⁶	CL=90%
Γ ₅₃	$J/\psi(1S) K^*(892)^0$	(1.58±0.27)			121	$K^0 e^+ e^-$	B1	< 5.9	× 10 ⁻⁶	CL=90%
Γ ₅₄	$J/\psi(1S)\pi^{0}$	< 6.9	\times 10 ⁻³	CL=90%	122	ν e · e ν 0+−	B1	< 3.0	$\times 10^{-4} \times 10^{-4}$	CL=90%
Γ ₅₅	$\psi(2S)K^{0}$	< 8	\times 10 ⁻⁴	CL=90%	123	$K^0 \mu^+ \mu^- K^* (892)^0 e^+ e^-$	B1 B1	< 3.6	× 10 ⁻⁴ × 10 ⁻⁴	CL=90% CL=90%
Γ ₅₆	$\psi(25)K^{+}\pi^{-}$	< 1	$\times 10^{-3}$	CL=90%	124	K*(892)° e' e		< 2.9		
Γ ₅₇	$\psi(2S)K^*(892)^0$	(1.4 ±0.9)			125	$K^*(892)^0 \mu^+ \mu^-$	B1	< 2.3	$\times 10^{-5} \times 10^{-6}$	CL=90%
Γ ₅₈	$\chi_{c1}(1P)K^{0}$	< 2.7	\times 10 ⁻³	CL=90%	126	$e^{\pm}\mu^{\mp}$		c] < 5.9	× 10 ° × 10 −4	CL=90%
Γ ₅₉	$\chi_{c1}(1P)K^*(892)^0$	< 2.1	$\times 10^{-3}$	CL=90%	l 127	$e^{\pm}\tau^{\mp}$		c] < 5.3 c] < 8.3	× 10 ⁴ × 10 ⁻⁴	CL=90% CL=90%
0,					128	$\mu^{\pm} \tau^{\mp}$	LF [c] < 8.3	× 10 ·	CL=90%
_	K or K*		5	GL 000/	[a]	ℓ indicates e or μ mode,	not sum ov	er modes.		
F ₆₀	$K^+\pi^-$	< 1.7	× 10 ⁻⁵	CL=90%		B^0 and B^0_s contributions			on weighted	average of
Γ ₆₁	$K^0\pi^0$	< 4.0	× 10 ⁻⁵	CL=90%		the two decay rates.	or separat	.ca. chine is		
Γ ₆₂	K+ K-	< 4	× 10 ⁻⁶	CL=90%		,	of the chare-	ctator of na-	ticle/antina-	ticle states
Γ ₆₃	$K^{+}\rho^{-}$	< 3.5	× 10 ⁻⁵	CL=90%		The value is for the sum of indicated	or the charge	states or par	ncie/antipar	ticle states
Γ ₆₄	$K^0 \pi^+ \pi^-$	- 20	10-5	CI 000/		indicated.				
Γ ₆₅	$K^{0} \rho^{0}$	< 3.9	× 10 ⁻⁵	CL=90%		<i>B</i> ⁰ F	BRANCHING	RATIOS		
F ₆₆	$K^0 f_0(980)$	< 3.6	× 10 ⁻⁴	CL=90%		For branching ratios in wh			ng R is not de	ter-
Γ ₆₇	K*(892)+π ⁻ κ*(892)0π0	< 7.2	× 10 ⁻⁵	CL=90%		mined, see the B^{\pm} section	circ cirarge	. Jc uccayll	uc	
Γ ₆₈	$K^*(892)^0 \pi^0$	< 2.8	× 10 ⁻⁵	CL=90%						
Γ ₆₉	$K_2^*(1430)^+\pi^-$	< 2.6	× 10 ⁻³	CL=90%		$ u_\ell$ anything)/ $\Gamma_{ ext{total}}$				Γ_1/Γ
Γ ₇₀	$K^{0}K^{+}K^{-}$	< 1.3	× 10 ⁻³	CL=90%	VALUE 0.103 4	±0.010 OUR AVERAGE	DOCUMENT I	D TECN	COMMENT	
Γ ₇₁	$\overset{\mathcal{K}^0}{\kappa^-} \overset{\phi}{\pi^+} \overset{\pi^+}{\pi^-}$	< 8.8	$\times 10^{-5} \times 10^{-4}$	CL=90%		±0.010 OUR AVERAGE	ALBRECHT	94 ARG	$e^+e^- \rightarrow 7$	r(45)
Γ_{72}	$K = \pi + \pi$	[b] < 2.1		CL=90%		±0.011±0.013	ATHANAS		e+e- → 1	
Γ_{73}	$\alpha : 18971 \pi : \pi$	< 1.4	$\times 10^{-3}$	CL=90%		± 0.030 ± 0.009		N 92 CLEO		

$\Gamma(D^-\ell^+\nu_\ell)/\Gamma_{\text{total}}$ ℓ denotes e or μ , not th	e sum.					Γ ₂ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT		
0.019±0.005 OUR AVERAGE						
$0.018 \pm 0.006 \pm 0.003$	²⁶ FULTON	91	CLEO	$e^+e^- \rightarrow$	r(45)	
$0.020 \pm 0.007 \pm 0.006$	²⁷ ALBRECHT	89.1	ARG	$e^+e^- \rightarrow$	$\Upsilon(45)$	

 26 FULTON 91 assumes assuming equal production of B^0 and B^+ at the $\varUpsilon(4S)$ and uses Mark III D and D* branching ratios.

 27 ALBRECHT 89J reports 0.018 \pm 0.006 \pm 0.005. We rescale using the method described in STONE 94 but with the updated PDG 94 B($D^0 \rightarrow K^-\pi^+$).

$\Gamma(D^*(2010)^-\ell^+\nu_\ell)/\Gamma_1$	total		Γ_3/Γ
VALUE	EVTS	DOCUMENT ID TECN COMMENT	
0.0456±0.0027 OUR AVE	RAGE		
$0.0449 \pm 0.0032 \pm 0.0039$	376	²⁸ BARISH 95 CLE2 $e^+e^- \rightarrow 7$	^(45)
$0.0518 \pm 0.0030 \pm 0.0062$	410	29 BUSKULIC 95N ALEP $e^+e^- \rightarrow \bar{z}$	
$0.045 \pm 0.003 \pm 0.004$		30 ALBRECHT 94 ARG $e^+e^- \rightarrow 7$	^(4 <i>5</i>)
$0.047 \pm 0.005 \pm 0.005$	235	31 ALBRECHT 93 ARG $e^+e^- \rightarrow 1$	^(45)
$0.040 \pm 0.004 \pm 0.006$		32 BORTOLETTO89B CLEO $e^+e^- \rightarrow 1$	^(45)
• • • We do not use the f	ollowing	data for averages, fits, limits, etc. • •	
seen	398	33 SANGHERA 93 CLE2 $e^+e^- \rightarrow 7$	^(4 <i>5</i>)
0.070 ±0.018 ±0.014		34 ANTREASYAN 90B CBAL $e^+e^- \rightarrow 1$	^(4 <i>5</i>)
		³⁵ ALBRECHT 89C ARG $e^+e^- \rightarrow 1$	^(4 <i>5</i>)
0.060 ±0.010 ±0.014		36 ALBRECHT 89J ARG $e^+e^- \rightarrow 1$	^(4 <i>S</i>)

47 37 ALBRECHT 87J ARG $e^+e^- \rightarrow \Upsilon(4S)$ $0.070 \pm 0.012 \pm 0.019$ ²⁸ BARISH 95 use B($D^0 \to K^- \pi^+$) = (3.91 ± 0.08 ± 0.17)% and B($D^{*+} \to D^0 \pi^+$) $(68.1 \pm 1.0 \pm 1.3)\%$.

²⁹ BUSKULIC 95N assumes fraction (B^+) = fraction (B^0) = 38.2 \pm 1.3 \pm 2.2% and au_{B^0} $= 1.58 \pm 0.06$ ps. $\Gamma(D^{*-}\ell^+\nu_\ell)/{
m total} = [5.18 - 0.13({
m fraction}(B^0) - 38.2) - 1.5(au_{B^0} - 1.5)$

³⁰ ALBRECHT 94 assumes B($D^{*+} \rightarrow D^0 \pi^+$) = 68.1 \pm 1.0 \pm 1.3%. Uses partial reconstruction of D^{*+} and is independent of D^{0} branching ratios.

 $31\,\text{ALBRECHT}$ 93 reports 0.052 \pm 0.005 \pm 0.006. We rescale using the method described in STONE 94 but with the updated PDG 94 B($D^0\to K^-\pi^+$). We have taken their average e and μ value. They also obtain $\alpha=2*\Gamma^0/(\Gamma^-+\Gamma^+)-1=1.1\pm0.4\pm0.2$, $A_{AF}=3/4*(\Gamma^--\Gamma^+)/\Gamma=0.2\pm0.08\pm0.06$ and a value of $|V_{Cb}|=0.036$ depending on model assumptions.

depending on model assumptions. 32 We have taken average of the the BORTOLETTO 89B values for electrons and muons, 0.046 \pm 0.005 \pm 0.007. We rescale using the method described in STONE 94 but with the updated PDG 94 B($D^0 \rightarrow K^-\pi^+$). The measurement suggests a D^* polarization parameter value $\alpha=0.65\pm0.66\pm0.25$. 33 Combining $\overline{D}^{*0}\ell^+\nu_\ell$ and $\overline{D}^{*-}\ell^+\nu_\ell$ SANGHERA 93 test V-A structure and fit the

decay angular distributions to obtain $A_{FB}=3/4*(\Gamma^--\Gamma^+)/\Gamma=0.14\pm0.06\pm0.03$. Assuming a value of V_{Cb} , they measure V, A_1 , and A_2 , the three form factors for the $D^*\ell\nu_\ell$ decay, where results are slightly dependent on model assumptions.

 34 ANTREASYAN 90B is average over B and $\overline{D}^*(2010)$ charge states.

 35 The measurement of ALBRECHT 89C suggests a D^* polarization γ_L/γ_T of 0.85 \pm 0.45.

36 ALBRECHT 89) is ALBRECHT 87J value rescaled using B($D^*(2010)^- \rightarrow D^0\pi^-$) = 0.57 \pm 0.04 \pm 0.04. Superseded by ALBRECHT 93.

 37 ALBRECHT 87J assume μ -e universality, the B($\Upsilon(4S) \rightarrow B^0 \overline{B}{}^0) = 0.45$, the B($D^0 \rightarrow B^0 \overline{B}{}^0$) $K^-\pi^+)=(0.042\pm0.004\pm0.004)$, and the B($D^*(2010)^-\to D^0\pi^-)=0.49\pm0.08$. Superseded by ALBRECHT 89J.

$\Gamma(\rho^-\ell^+\nu_\ell)/\Gamma_{\rm total}$ $\ell=e$ or μ , not sum over e and μ modes. <u>CL%</u> 90 DOCUMENT ID TECN COMMENT 38 BEAN 93B CLE2 $e^+e^- \rightarrow \Upsilon(4S)$

38 BEAN 93B limit set using ISGW Model. Using isospin and the quark model to combine FOR AN 93B limit set using is say Model. Using isospin and the quark moder to Combine $(\rho^0\ell^+\ell_\ell)$ and $\Gamma(\omega\ell^+\nu_\ell)$ with this result, they obtain a limit $<(1.6{-}2.7)\times 10^{-4}$ at 90% CL for $B^+\to (\omega\sigma r\ \rho^0)\ell^+\nu_\ell$. The range corresponds to the ISGW, WSB, and KS models. An upper limit on $|V_{ub}/V_{cb}|<0.8{-}0.13$ at 90% CL is derived as well.

$\Gamma(\pi^-\mu^+\nu_\mu)/\Gamma_{\text{total}}$		Γ_5/Γ
VALUE	DOCUMENT ID TECN	
• • • We do not use t	he following data for averages, fits, limits, etc. • • •	
seen	39 ALBRECHT 91C ARG	

 39 In ALBRECHT 91C, one event is fully reconstructed providing evidence for the $b \rightarrow u$

$\Gamma(D^-\pi^+)/\Gamma_{\text{total}}$						Γ_6/Γ
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT	
0.0030±0.0004 OUR AVE	RAGE					
$0.0029 \pm 0.0004 \pm 0.0002$	81	⁴⁰ ALAM	94	CLE2	$e^+e^- \rightarrow$	$\Upsilon(4S)$
$0.0027 \pm 0.0006 \pm 0.0005$		⁴¹ BORTOLETT	O92	CLEO	$e^+e^- \rightarrow$	$\Upsilon(4S)$
$0.0048 \pm 0.0011 \pm 0.0011$	22	⁴² ALBRECHT	90 J	ARG	$e^+e^- \rightarrow$	$\Upsilon(45)$
$0.0051 \!+\! 0.0028 \!+\! 0.0013 \\ -0.0025 \!-\! 0.0012$	4	⁴³ BEBEK	87	CLEO	$e^+e^- \to$	Y(45)
• • • We do not use the f	ollowing	data for averages, fi	ts, lir	nits, etc	. • • •	

7 42 ALBRECHT 88K ARG $e^+e^-
ightarrow \varUpsilon(4S)$ ⁴⁰ ALAM 94 reports [B($B^0 \to D^-\pi^+$) × B($D^+ \to K^-\pi^+\pi^+$)] = 0.000265 ± 0.000032 ± 0.000023. We divide by our best value B($D^+ \to K^-\pi^+\pi^+$) = $(9.1\pm0.6)\times10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B+ and B^0 at the $\Upsilon(45)$.

 41 BORTOLETTO 92 assumes equal production of B^+ and B^0 at the $\varUpsilon(45)$ and uses Mark III branching fractions for the D. 42 ALBRECHT 88k assumes $B^0\,\overline{B}^0.B^+B^-$ production ratio is 45:55. Superseded by ALBRECHT 90J which assumes 50:50. 43 BEBEK 87 value has been updated in BERKELMAN 91 to use same assumptions as

noted for BORTOLETTO 92.

$\Gamma(D^-\rho^+)/\Gamma_{\text{total}}$					Γ_7/Γ
VALUE	EVTS	DOCUMENT ID	TECI	COMMENT	
0.0078±0.0014 OUR AVE	RAGE				
$0.0078 \pm 0.0013 \pm 0.0005$	79	⁴⁴ ALAM			
$0.009 \pm 0.005 \pm 0.003$	9	⁴⁵ ALBRECHT	90J ARG	$e^+e^- \rightarrow$	Y(45)
• • • We do not use the f	ollowing	data for averages, fi	ts, limits,	etc. • • •	
$0.022 \pm 0.012 \pm 0.009$	6	⁴⁵ ALBRECHT	88K ARG	$e^+e^- \rightarrow$	$\Upsilon(4S)$
44 ALAM 94 reports [B($B^0 \rightarrow$	$D^-\rho^+) \times B(D^+$	\rightarrow κ^-	$\pi^+\pi^+)] = 0$.000704 ±
0.000096 ± 0.000070	We d	ivide by our best	value B(I	$\rho^+ \rightarrow \kappa^-$	$\pi^{+}\pi^{+}) =$
$(9.1 \pm 0.6) \times 10^{-2}$.	Our first	error is their exper	iment's er	ror and our se	econd error
is the systematic error	from usin	g our best value. As	sumes equ	al production	of B^+ and

 45 ALBRECHT 88K assumes $B^0\overline{B}^0.8^+B^-$ production ratio is 45:55. Superseded by ALBRECHT 901 which assumes 50:50.

$\Gamma(\overline{D}{}^{0}\pi^{+}\pi$	-)/Γ _{total}						Γ_8/Γ
VALUE	CL% EVTS	DOCUMENT ID		TECN	COMMENT		
< 0.0016	90	⁴⁶ ALAM	94	CLE2	$e^+e^- \rightarrow$	$\Upsilon(4S)$	
• • • We do	not use the follo	wing data for averag	es, fits	, limits,	etc. • • •		
< 0.007	90	47 BORTOLET					
< 0.034	90	⁴⁸ BEBEK	87	CLEO	$e^+e^- \rightarrow$	T(45)	
0.07 ±0	.05 5	⁴⁹ BEHRENDS	83	CLEO	$e^+e^- \rightarrow$	$\Upsilon(4S)$	
46 Accumac	agual production	of R+ and R0 at th	a ~(1	S۱			

 47 BORTOLETTO 92 assumes equal production of B^+ and B^0 at the $\Upsilon(45)$ and uses Mark III branching fractions for the D. The product branching fraction into $D_0^*(2340)\pi$ followed by $D_0^*(2340) \rightarrow D^0 \pi$ is < 0.0001 at 90% CL and into $D_2^*(2460)$ followed by $D_2^*(2460) \rightarrow D^0 \pi$ is < 0.0004 at 90% CL.

 48 BEBEK 87 assume the $\Upsilon(45)$ decays 43% to $B^0\overline{B}^0$. We rescale to 50%. B($D^0\to K^-\pi^+)=(4.2\pm0.4\pm0.4)\%$ and B($D^0\to K^-\pi^+\pi^+\pi^-)=(9.1\pm0.8\pm0.8)\%$

were used. 49 Corrected by us using assumptions: B($D^0 \rightarrow K^-\pi^+$) = (0.042 ± 0.006) and B($T(45) \rightarrow B^0\overline{B}^0$) = 50%. The product branching ratio is B($B^0 \rightarrow \overline{D}^0\pi^+\pi^-$)B($\overline{D}^0 \rightarrow K^+\pi^-$) = (0.39 ± 0.26) × 10⁻².

F(D*(2010)= -+) /F

I (D. (2010)	π ' $)$ / total					19/1
VALUE		EVTS	DOCUMENT ID	TECN_	COMMENT	
0.0026 ±0.0004	OUR AVE	RAGE				
0.0026 ±0.0003	±0.0004	82	⁵⁰ ALAM	94 CLE2	$e^+e^- \rightarrow$	$\Upsilon(4S)$
0.0033 ±0.0010	±0.0001		⁵¹ BORTOLETTO	O92 CLEO	$e^+e^- \rightarrow$	$\Upsilon(4S)$
0.00234 ± 0.0008	37 ± 0.00005	12	⁵² ALBRECHT	90J ARG	$e^+e^- \rightarrow$	$\Upsilon(45)$
$0.00234 + 0.0014 \\ -0.0010$	$\frac{18}{9} \pm 0.00005$	5	53 BEBEK	87 CLEO	$e^+e^- \to$	Y(45)
• • • We do no	t use the foll	lowing	data for averages, fi	ts, limits, etc	. • • •	
0.010 ±0.004	±0.001	8	⁵⁴ AKERS	94J OPAL	$e^+e^- \rightarrow$	Z
0.0027 ±0.0014	±0.0010	5	⁵⁵ ALBRECHT	87c ARG	$e^+e^ \rightarrow$	$\Upsilon(45)$
0.0035 ±0.002	± 0.002		⁵⁶ ALBRECHT	86F ARG	$e^+e^ \rightarrow$	$\Upsilon(45)$
0.017 ±0.005	± 0.005	41	⁵⁷ GILES	84 CLEO	$e^+e^- \rightarrow$	Y(45)
50						(1.50.11

 50 ALAM 94 assume equal production of B^+ and B^0 at the \varUpsilon (45) and use the CLEO II

ALAM 94 assume equal production of B and B^o at the I (45) and use the CLEO II $B(D^*(2010)^+ \to D^0\pi^+)$ and absolute $B(D^0 \to K^-\pi^+)$ and the PDG 1992 $B(D^0 \to K^-\pi^+\pi^+\pi^0)/B(D^0 \to K^-\pi^+)$ and $B(D^0 \to K^-\pi^+\pi^+\pi^-)/B(D^0 \to K^-\pi^+)$. 51 BORTOLETTO 92 reports 0.0040 \pm 0.0010 \pm 0.0007 for $B(D^*(2010)^+ \to D^0\pi^+) = 0.57 \pm 0.06$. We rescale to our best value $B(D^*(2010)^+ \to D^0\pi^+) = (68.3 \pm 1.4) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error using our best value. error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(45)$ and uses Mark III branching fractions for the D.

⁵² ALBRECHT 90J reports 0.0028 \pm 0.0009 \pm 0.0006 for B(D^* (2010) $^+$ \rightarrow $D^0\pi^+$) = 0.57 ± 0.06 . We rescale to our best value B($D^*(2010)^+ \rightarrow D^0 \pi^+$) = (68.3 ± 1.4) × 10⁻². Our first error is their experiment's error and our second error is the systematic

and uses Mark III branching fractions for the D.

53 BEBEK 87 reports 0.0028 + 0.0015 + 0.0012 + 0.0015 for B($D^*(2010)^+ \rightarrow D^0 \pi^+$) = 0.57 ± 0.0012 for B($D^*(2010)^+ \rightarrow D^0 \pi^+$) = 0.57 ± 0.0012 for B($D^*(2010)^+ \rightarrow D^0 \pi^+$) = $0.68.3 \pm 1.4$) × 10^{-2} . O.U.B. (we restate to our best value $B(D(2010)^{3-2} - D(R^2)) = (80.3 \pm 1.4) \times 10$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Updated in BERKELMAN 91 to use same assumptions as noted for BORTOLETTO 92 and ALBRECHT 901. 5^4 Assumes $B(Z \to b\bar{b}) = 0.217$ and 38% B_d production fraction.

$\Gamma(D^-\pi^+\pi^+\pi^-)/\Gamma_{total}$				Γ_{10}/Γ
VALUE	DOCUMENT ID	TECN	COMMENT	
0.0080 + 0.0021 + 0.0014	58 BORTOLETTO92	CLEO	e+e- →	T(45)

 58 BORTOLETTO 92 assumes equal production of B^+ and B^0 at the $\varUpsilon(45)$ and uses Mark III branching fractions for the D.

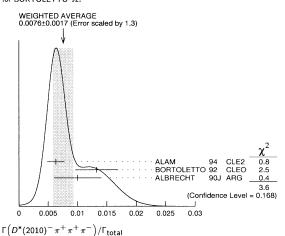
 B^0

2.0.039 \pm 0.0014 \pm 0.0013 2.0.039 \pm 0.0014 \pm 0.0013 59 BORTOLETTO 92 assumes Mark III branching fractions for the following fractions for t	equal produc	LETTO92 CI		$e^- \rightarrow \gamma$	
Mark III branching fractions from $\Gamma(D^-\pi^+\rho^0)/\Gamma_{\rm total}$ (ALUE 0.0011 \pm 0.0009 \pm 0.0004 60 BORTOLETTO 92 assumes Mark III branching fractions from the second of th	or the <i>D</i> . DOCUMEN	ction of \mathcal{B}^+ a	nd B^0 at	t the $\Upsilon(4.5)$	S) and uses
$\Gamma(D^-\pi^+\rho^0)/\Gamma_{ m total}$ $O(D^+\pi^+\rho^0)/\Gamma_{ m total}$ $O(D(D^+\mu^0))$ $O(D(D^+\mu$	DOCUMEN				., una uses
0.0011±0.0009±0.0004 60 BORTOLETTO 92 assumes Mark III branching fractions f		NT ID TO	CN_ CO		Γ ₁₂ /Γ
60 BORTOLETTO 92 assumes Mark III branching fractions f				$e^- \rightarrow \gamma$	(45)
		ction of \mathcal{B}^+ a	nd B^0 a	t the $\Upsilon(45)$	3) and uses
					Γ ₁₃ /Γ
VALUE 0.0060 ± 0.0022 ± 0.0024	61 BORTOL	NT ID TE		mment e → Υ	(45)
61 BORTOLETTO 92 assumes Mark III branching fractions t	equal produc				` '
$\Gamma(D^*(2010)^-\pi^+\pi^0)/\Gamma_{\text{total}}$	s pocu	IMENT ID	TECN	COMMENT	Γ ₁₄ /Γ
0.0150±0.0051±0.0003 5			ARG	$e^+e^- \rightarrow$	Υ(4S)
• We do not use the following					
0.015 \pm 0.008 \pm 0.008 62 ALBRECHT 90J reports 0.01 0.06. We rescale to our best Our first error is their exper from using our best value. A uses Mark III branching fract 63 ALBRECHT 87C use PDG B($\Upsilon(4S) \rightarrow B^+B^-$) = 55	value B(D*(2 iment's error ssumes equal ions for the D 86 branching	0.005 for B(D^* 2010) ⁺ $\rightarrow D$ and our second production of D . g. ratios.	$^0\pi^+)=$ nd error i $^+$ and $^-$	(68.3 ± 1.6) s the system B^0 at the $D^*(2010)$	$(-1) = 0.57 \pm 0.40 \times 10^{-2}$, ematic error $(-1) = 0.57 \pm 0.00$
BRECHT 90J.	70 and D(1(43) → 0 0) = 43/	o. Superse	dea by AL-
$\Gamma(D^*(2010)^- ho^+)/\Gamma_{ ext{total}}$					Γ ₁₅ /Γ
VALUE		JMENT ID		COMMENT	
$0.0159 \pm 0.0112 \pm 0.0003$	9 ⁶⁷ ALBF	TOLETTO92 RECHT 90J	CLEO	$e^+e^- \rightarrow e^+e^- \rightarrow e^+e^- \rightarrow \bullet \bullet \bullet \bullet$	
$0.081 \pm 0.029 \begin{array}{c} +0.059 \\ -0.024 \end{array}$	9 ⁶⁸ CHE	N 85	CLEO	$e^+e^ \rightarrow$	T(45)
64 ALAM 94 assume equal proc $B(D^*(2010)^+ \rightarrow D^0\pi^+)$ at $K^-\pi^+\pi^0)/B(D^0 \rightarrow K^-\pi^+)$ 65 This decay is nearly comple expected from the factoriza contribution under the ρ^+ is 66 BORTOLETTO 92 reports 0.57 ± 0.06. We rescale to 0.10 ⁻² . Our first error is their error from using our best valuand uses Mark III branching 167 ALBRECHT 901 reports 0.00 0.06. We rescale to our best Our first error is their exper from using our best value. A uses Mark III branching fract 68 Uses $B(D^* \rightarrow D^0\pi^+) = 0.0$ on D branching ratios.	nd absolute B($^+$) and B(D^0) tely longituding tion hypothes less than 9% 0.019 \pm 0.008 urr best value rexperiment's us. Assumes e reactions for tif 7 \pm 0.003 \pm 0 value B(D^* ($^+$) criment's essumes equal lons for the D 6 \pm 0.15 and E	$(D^0 \rightarrow K^-\pi)$ $C^0 \rightarrow K^-\pi^+\pi$ nally polarized sis (ROSNER at 90% CL. 8 ± 0.011 for B(D^* (2010) ⁺ se error and oue equal production be D . 0.003 for B(D^* 2010) ⁺ $\rightarrow D$ and our secon production of D .	$^+$) and the $^+$ and the $^+$ $^ ^ ^ ^ ^ ^ ^ ^-$	the PDG 19° $B(D^0 \rightarrow B^0)$ $B(D^0 \rightarrow$	92 ${\rm B}(D^0 \to {\rm K}^-\pi^+)$. \pm 5)%, as an $\pi^+\pi^0$ \pm 5)%, as an $\pi^+\pi^0$ \pm 3.3 \pm 1.4) \times 5 eystematic the ${\rm T}(4S)$ \pm 10 \pm 2.5 ematic error ${\rm T}(4S)$ and not depend not depend
$\Gamma(D^*(2010)^-\pi^+\pi^+\pi^-)/\Gamma$					Γ ₁₆ /Γ
0.0076±0.0017 OUR AVERAG		DOCUMENT ID	tor of 1.3	3. See the	<u>м£N I</u> ideogram
$0.0063 \pm 0.0010 \pm 0.0011$	49 69,70	below. ALAM	94 CI		e →
$0.0133 \pm 0.0036 \pm 0.0003$	71	BORTOLETT	ΓO92 CI	1 LEO e+e	r(4 <i>5</i>) e →
0.0100±0.0040±0.0002		ALBRECHT	90J A	. 1	r(45)
• • We do not use the following	ng data for a	verages, fits, li		1 . • • •	r(4 <i>S</i>)
$0.033 \pm 0.009 \pm 0.016$		ALBRECHT	87C A	RG e ⁺ ຄຸ້າ	e ⁻ → r(4S) e ⁻ → r(4S)
<0.042 90		BEBEK		LEO e+e	; — → r(4 <i>S</i>)
69 ALAM 94 assume equal prov B(D^* (2010) $^+ \rightarrow D^0\pi^+$) a $K^-\pi^+\pi^0$)/B($D^0 \rightarrow K^-\pi^0$ 70 The three pion mass is requiremeson. (If this channel is d that for $\overline{D}^{*-}\pi^+\pi^+\pi^-$.)	nd absolute Bi ·+) and B(D ^C ired to be bet	$(D^0 ightarrow K^- \pi^0 $ $0 ightarrow K^- \pi^+ \tau^0$ tween 1.0 and	+) and t τ+π-)/! 1.6 GeV) and use the PDG 19 $B(D^0 \rightarrow 0)$ consistent	the CLEO I' 92 B($D^0 \rightarrow K^-\pi^+$). with an a_1

 10^{-2} . Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D. ⁷² ALBRECHT 90J reports $0.012 \pm 0.003 \pm 0.004$ for B($D^*(2010)^+ \rightarrow D^0 \pi^+$) = 0.57 ± 0.004 0.06. We rescale to our best value B($D^*(2010)^+ \rightarrow D^0\pi^+$) = (68.3 \pm 1.4) \times 10⁻². Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D.

73 ALBRECHT 87c use PDG 86 branching ratios for D and $D^*(2010)$ and assume B($\Upsilon(4S) \to B^+B^-$) = 55% and B($\Upsilon(4S) \to B^0B^0$) = 45%. Superseded by AL-BRECHT 90J.

74 BEBEK 87 value has been updated in BERKELMAN 91 to use same assumptions as noted for BORTOLETTO 92.



$$\begin{array}{c|ccccc} \Gamma((D^{+}(2010)^{-}\pi^{+}\pi^{+}\pi^{-}) & \text{nonresonant})/\Gamma_{\text{total}} & & & & \Gamma_{17}/\Gamma_{\text{total}} \\ \hline \nu_{AUE} & DOCUMENT ID & TECN & COMMENT & & & \\ \hline 0.0000 \pm 0.0019 \pm 0.0016 & & & 75 \text{ BORTOLETTO92} & \text{CLEO} & e^{+}e^{-} \rightarrow & \Upsilon(4S) \\ \hline \end{array}$$

 75 BORTOLETTO 92 assumes equal production of B^+ and B^0 at the $\varUpsilon(4S)$ and uses Mark III branching fractions for the D and $D^*(2010)$.

$$\frac{\Gamma(D^*(2010)^-\pi^+\rho^0)/\Gamma_{total}}{VALUE} \xrightarrow{DOCUMENT\ ID} \frac{TECN}{TECN} \xrightarrow{COMMENT} \frac{\Gamma_{18}/\Gamma_{total}}{\Gamma_{0.0057\pm0.0031\pm0.0001}}$$

 76 BORTOLETTO 92 reports 0.0068 \pm 0.0032 \pm 0.0021 for B(D^* (2010) $^+ \rightarrow D^0 \pi^+$) = 0.57 \pm 0.06. We rescale to our best value B($D^*(2010)^+ \rightarrow D^0 \pi^+$) = (68.3 \pm 1.4) \times 10^{-2} . Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(45)$ and uses Mark III branching fractions for the D.

77 ALAM 94 value is twice their $\Gamma(D^*(2010)^-\pi^+\pi^+\pi^-)/\Gamma_{\text{total}}$ value based on their observation that the three pions are dominantly in the $a_1(1260)$ mass range 1.0 to 1.6

 78 ALAM 94 assume equal production of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO II

⁷⁹BORTOLETTO 92 reports 0.018 \pm 0.006 \pm 0.006 for B(D*(2010)⁺ \rightarrow D⁰ π ⁺) = 0.57 \pm 0.06. We rescale to our best value B($D^*(2010)^+ \rightarrow D^0 \pi^+$) = (68.3 \pm 1.4) \times 10⁻². Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(45)$ and uses Mark III branching fractions for the D.

⁸⁰ ALBRECHT 90J reports $0.041 \pm 0.015 \pm 0.016$ for B($D^*(2010)^+ \rightarrow D^0 \pi^+$) = 0.57 ± 0.016 0.06. We rescale to our best value $B(D^*(2010)^+ \to D^0\pi^+) = 0.57 \pm 0.06$. We rescale to our best value $B(D^*(2010)^+ \to D^0\pi^+) = (68.3 \pm 1.4) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D.

 81 ALAM 94 assumes equal production of B^+ and B^0 at the \varUpsilon (4S) and use the CLEO II absolute B($D^0 \to K^-\pi^+$) and B($D_2^*(2460)^+ \to D^0\pi^+$) = 30%.

	$ ho^+)/\Gamma_{total}$			Γ ₂₂ /Γ
VALUE <0.0049	<u>CL%</u> 90	B2 ALAM 94	$\begin{array}{ccc} \underline{TECN} & \underline{COMMENT} \\ \text{CLE2} & e^+e^- \rightarrow \end{array}$	
		uction of B^+ and B^0 a		
absolute B($\kappa^0 \to \kappa^- \pi^+$) a	and B($D_2^*(2460)^+ \to 1$	$D^0\pi^+) = 30\%.$	ise the CLLO
$\Gamma(D^-D_s^+)/\Gamma_t$			TECH	Γ ₂₃ /Ι
<i>VALUE</i> 0.007±0.004 Ol	JR AVERAGE		TECN COMME	
$0.013 \pm 0.011 \pm 0$		83 ALBRECHT	92G ARG e+e-	$\rightarrow \gamma(4S)$
0.007 ± 0.004 ± 0			92 CLEO e ⁺ e ⁻	$\rightarrow \Upsilon(45)$
• • • • vve do no 0.012±0.007	t use the followin	g data for averages, fits 85 BORTOLETTO		~ ~(4S)
	-	$.7 \pm 0.013 \pm 0.006$ for		
rescale to ou experiment's	best value $B(D_s^2)$	$f^+ \pm 0.013 \pm 0.006$ for $f^+ \to \phi \pi^+) = (3.6 \pm 0.006)$ ond error is the systema ching ratios, e.g., B(D^+	$1.9) \times 10^{-2}$. Our fire this error from using	rst error is thei our best value
		$0080 \pm 0.0045 \pm 0.003$		
0.011. We re error is their our best valu branching fra	escale to our best experiment's erro e. Assumes equal ctions for the D.	value B($D_s^+ o \phi \pi^+$) or and our second error production of B^+ and	$)=(3.6\pm0.9) imes1$ is the systematic e B^0 at the $\varUpsilon(4S)$ ar	.0 ^{—2} . Our firs rror from usin nd uses Mark I
		,		
Γ(D*(2010) [—] VALUE 0.012±0.006 OL	EVTS	DOCUMENT ID	TECN COMMENT	Γ ₂₄ /Ι
$0.010 \pm 0.008 \pm 0$		86 ALBRECHT 92G	ARG $e^+e^- \rightarrow$	$\Upsilon(4S)$
0.013±0.008±0		87 BORTOLETTO92		r(45)
• • • vve do no 0.024±0.014	t use the followin	g data for averages, fits 88 BORTOLETTO90		20(4.6)
		$.4 \pm 0.010 \pm 0.003$ for		
OO ALBRECH I	92G reports 0.01	$\phi_{5}^{+} \rightarrow \phi \pi^{+} = (3.6 \pm 0.003)$	$B(D_s \rightarrow \phi \pi^+)$	= 0.027. W
Assumes PD	error and our sec G 1990 <i>D</i> ⁺ and	$D^*(2010)^+$ branching	ratios, e.g., $B(D^0)$	our best value
- 55 ± 4%	$^{\prime}$ 6, B(D^+ → K^-	$\pi^+\pi^+) = 7.1 \pm 1.0\%$	6, and B(<i>D</i> *(2010)	$^+ \rightarrow D^0 \pi^+$
$= 55 \pm 4\%$. 87 BORTOLET	TO 92 reports 0.0	0.00000000000000000000000000000000000	6, and B(D^* (2010) $ ext{B}(D^+_{\mathcal{S}} o \phi \pi^+) =$	$^{+} \rightarrow D^{0} \pi^{+}$ 0.030 ± 0.011
= 55 ± 4%. 87 BORTOLET We rescale to is their expenses to value. A branching fra	TO 92 reports 0.0 o our best value riment's error and Assumes equal proctions for the D	$0.016 \pm 0.009 \pm 0.006$ for $B(D_s^+ \rightarrow \phi \pi^+) = (3$ d our second error is the oduction of B^+ and B^+ and $D^*(2010)$.	6, and B($D^*(2010)$) B($D_s^+ o \phi \pi^+$) = .6 \pm 0.9) $ imes$ 10 ⁻² . The systematic error 0 at the $\Upsilon(4S)$ and	$^+$ $^ ^ ^ ^0$ $^ ^+$ $^-$ 0.030 \pm 0.011 Our first error from using ou d uses Mark II
= 55 ± 4%. 87 BORTOLET We rescale to is their expenses to value. A branching franching franc	TO 92 reports 0.0 pour best value riment's error and Assumes equal proctions for the D TO 90 assume B	$0.016 \pm 0.009 \pm 0.006$ for $0.006 + 0.006$ f	6, and B($D^*(2010)$) B($D_s^+ o \phi \pi^+$) = .6 \pm 0.9) $ imes$ 10 ⁻² . The systematic error 0 at the $\Upsilon(4S)$ and	$^{+} \rightarrow D^{0} \pi^{+}$ 0.030 ± 0.011 Our first error from using oud uses Mark II TOLETTO 92
= 55 \pm 4%. 87 BORTOLET We rescale to is their expenses to alue. A branching frame BORTOLET $\Gamma(D^{-}D_{5}^{*+})/\Gamma$	TO 92 reports 0.0 pour best value riment's error and Assumes equal proctions for the D TO 90 assume B	$016 \pm 0.009 \pm 0.006$ for $B(D_S^+ \rightarrow \phi \pi^+) = (3 \text{ d our second error is the oduction of } B^+ \text{ and } B$ and $D^*(2010)$. $(D_S^- \rightarrow \phi \pi^+) = 2\%$. S	6, and $B(D^*(2010))$ $B(D_S^+ o \phi \pi^+) = 0.6 \pm 0.9) \times 10^{-2}$. Let systematic error 0 at the $\Upsilon(4S)$ and superseded by BOR	$^{+} \rightarrow D^{0}\pi^{+}$ 0.030 ± 0.011 Our first error from using oud uses Mark II TOLETTO 92
= 55 \pm 4%. 87 BORTOLET We rescale to is their expension to the second to be the second to the s	TO 92 reports 0.0 or our best value riment's error and assumes equal proctions for the D TO 90 assume Bitotal	$016 \pm 0.009 \pm 0.006$ for $B(D_S^+ \rightarrow \phi \pi^+) = (3$ d our second error is the oduction of B^+ and B and $D^*(2010)$. $(D_S \rightarrow \phi \pi^+) = 2\%$. So $\frac{DOCUMENT\ ID}{89\ ALBRECHT} = 926$	6, and B(D^* (2010) B($D_S^+ \to \phi \pi^+$) = 6.6 \pm 0.9) \times 10 ⁻² . Le systematic error 0 at the T (45) and Superseded by BOR TECN COMMENT ARG $e^+e^- \to$	$+ \rightarrow D^0 \pi^+$ 0.030 ± 0.011 Our first error from using ou d uses Mark II TOLETTO 92 \[\begin{align*} \Gamma_{25}/I & & & & & & & & & & & & & & & & & & &
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= 55 ± 4%. 87 BORTOLET We rescale to is their expeint their experiment experiment their ex	TO 92 reports 0.02 to our best value riment's error and assumes equal proctions for the D TO 90 assume By total	$\begin{array}{l} \text{D16} \pm 0.009 \pm 0.006 \text{ for} \\ \text{B}(D_s^+ \to \phi \pi^+) = (3 \\ \text{d our second error is the oduction of } B^+ \text{ and } B \\ \text{and } D^*(2010). \\ (D_s \to \phi \pi^+) = 2\%. \\ \text{S} \\ \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & $	6, and $B(D^*(2010)$ $B(D_S^+ \to \phi \pi^+) = 6.6 \pm 0.9) \times 10^{-2}$. In the proof of at the $T(4S)$ and superseded by BOR $\frac{TECN}{ARG} = \frac{COMMENT}{ARG} + C$	$+ \rightarrow D^0 \pi^+$ 0.030 ± 0.011 Our first error from using out of uses Mark II TOLETTO 92 \[\begin{align*} \b
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= 55 \pm 4%. 87 BORTOLET We rescale to is their expenses value. λ branching fra 88 BORTOLET $\Gamma(D^-D_s^*+)/\Gamma_{VALUE}$ 0.020 \pm 0.014 \pm 0 89 ALBRECHT rescale to ou experiment's Assumes PD $\Gamma(D^*(2010)^-VALUE(units 10^{-2})$ 4.15 \pm 1.11 \pm 1.02 90 BORTOLET best value BG error and our $\Gamma(D^*(2010)^-VALUE(units 10^{-2})$ 4.15 \pm 1.11 \pm 0.01 \pm 0 91 ALBRECHT rescale to our experiment's Assumes PD 3.71 \pm 0.25% \pm 55 \pm 4%. $\Gamma(D_s^*\pi^-)/\Gamma_{tc}$	TO 92 reports 0.02 to our best value riment's error and assumes equal proctions for the D TO 90 assume Bi total 1.005 92G reports 0.02 to best value B(D_s^{-1} error and our sec G 1990 D^+ brane D_s^{+}) + $\Gamma(D^*(D_s^{+})$ + $\Gamma(D^*(D_s^{+}))$ / $\Gamma(D_s^{+})$ + $\Gamma(D_s^{+})$ = second error is to D_s^{+}) / $\Gamma(D_s^{+})$ + $\Gamma(D_s^{+})$ = second error is to D_s^{+}) / $\Gamma(D_s^{+})$ + $\Gamma(D_s^{+})$ = second error is to D_s^{+}) - $\Gamma(D_s^{+})$ + $\Gamma(D_s^{+})$ + $\Gamma(D_s^{+})$ + $\Gamma(D_s^{+})$ + $\Gamma(D_s^{+})$ + $\Gamma(D_s^{+})$ - $\Gamma(D_s^{+})$ +	$(16 \pm 0.009 \pm 0.006 \text{ for } B(D_s^+ \rightarrow \phi \pi^+) = (3 \text{ do our second error is the oduction of } B^+ \text{ and } B$ and $D^*(2010)$. $(D_S \rightarrow \phi \pi^+) = 2\%$. So $DCUMENT\ ID$ $(D_S \rightarrow \phi \pi^+) = 2\%$. So $DCUMENT\ ID$ $(D_S \rightarrow \phi \pi^+) = (3.6 \pm 0.007 \text{ for } 0.009 fo$	6, and $B(D^*(2010)$ $B(D_s^+ \to \phi \pi^+) = 6.6 \pm 0.9) \times 10^{-2}$. In systematic error of at the $\Upsilon(4S)$ and superseded by BOR $\frac{TECN}{ARG} = \frac{COMMENT}{ARG} + e^+ e^- \to \frac{B(D_s^+ \to \phi \pi^+)}{ARG} = \frac{COMMENT}{ARG} + \frac{COMMENT}{AR$	$+ \rightarrow D^0 \pi^+$ 0.030 ± 0.011 Our first error from using out duses Mark II TOLETTO 92 \[\begin{align*} \tau(45) & = 0.027. \text{ W} \\ \text{st error is their our best value} & = 7.7 \pm 1.0\%. \\ \begin{align*} \tau(45) & = \text{rescale to out it experiment'} \\ \text{tue.} & = 0.027. \text{ W} \\ \text{st error is their our best value} & st error is
= 55 ± 4%. 87 BORTOLET We rescale to is their experiments and our full to 100	TO 92 reports 0.02 to our best value riment's error and assumes equal proctions for the D TO 90 assume Bi stotal 1.005 92G reports 0.02 to best value B(D_s^2 error and our sec G 1990 D^+ brane D_s^2 by D_s^2 for example D_s^2 for e	$016 \pm 0.009 \pm 0.006$ for $B(D_s^+ \rightarrow \phi \pi^+) = (3$ d our second error is the oduction of B^+ and B and $D^*(2010)$. $(D_S \rightarrow \phi \pi^+) = 2\%$. S $\frac{DOCUMENT\ ID}{89\ ALBRECHT} 92G$ $67\ \pm 0.017 \pm 0.009$ for $\frac{1}{5} \rightarrow \phi \pi^+) = (3.6 \pm 0.017 \pm 0.009)$ for $\frac{1}{5} \rightarrow \phi \pi^+) = (3.6 \pm 0.017 \pm 0.009)$ for $\frac{1}{5} \rightarrow \phi \pi^+) = (3.6 \pm 0.017 \pm 0.009)$ BORTOLETTO90 $\frac{DOCUMENT\ ID}{90\ BORTOLETTO90}$ $\frac{5}{5} \pm 2.0\ for\ B(D_s^+ \rightarrow e (3.6 \pm 0.9) \times 10^{-2})$ (he systematic error from $\frac{DOCUMENT\ ID}{91\ ALBRECHT} 92G$ $\frac{1}{5} \rightarrow \phi \pi^+) = (3.6 \pm 0.006\ for \frac{1}{5} \rightarrow \phi \pi^+) = (3.6 \pm 0.014 \pm 0.006\ for \frac{1}{5} \rightarrow \phi \pi^+) = (3.6 \pm 0.006\ for \frac{1}{5} \rightarrow 0$	6, and $B(D^*(2010)$ $B(D_S^+ \to \phi \pi^+) = 0.6 \pm 0.9) \times 10^{-2}$. We systematic error of at the $T(4S)$ and superseded by BOR $\frac{TECN}{ARG} = \frac{COMMENT}{e} + e - \frac{1}{e} + \frac{1}{e} + \frac{1}{e} = \frac{1}{e} + \frac{1}{e} = \frac{1}{e} + \frac{1}{e} = \frac{1}$	$+ \rightarrow D^0 \pi^+$ 0.030 ± 0.011 Our first error from using out duses Mark II TOLETTO 92 \[\begin{align*} \tau(45) & = 0.027. \text{ W} \\ \text{st error is their our best value} & = 7.7 \pm 1.0\%. \\ \begin{align*} \tau(45) & = \text{rescale to out it experiment'} \\ \text{tue.} & = 0.027. \text{ W} \\ \text{st error is their our best value} & st error is
= 55 ± 4%. 87 BORTOLET We rescale to is their expeints to steel to out the steel th	TO 92 reports 0.02 to our best value riment's error and assumes equal protions for the D TO 90 assume By total	$016 \pm 0.009 \pm 0.006$ for $B(D_s^+ \rightarrow \phi \pi^+) = (3.6 \pm 0.001)$ d our second error is the oduction of B^+ and B and $D^*(2010)$. $(D_S \rightarrow \phi \pi^+) = 2\%$. S $\frac{DOCUMENT\ ID}{89\ ALBRECHT} 92G$ $27 \pm 0.017 \pm 0.009$ for $\frac{1}{7} \rightarrow \phi \pi^+) = (3.6 \pm 0.001)$ for odd error is the systemaching ratios, e.g., $B(D^+)$ for $\frac{1}{7} \rightarrow \phi \pi^+$ for $\frac{1}{7} \rightarrow \frac{1}{7} \rightarrow \frac{1}{7}$ for $\frac{1}{7} \rightarrow \frac{1}{7} \rightarrow \frac{1}{7$	6, and $B(D^*(2010)$ $B(D_S^+ \to \phi \pi^+) = 0.6 \pm 0.9) \times 10^{-2}$. We systematic error of at the $T(4S)$ and superseded by BOR TECN COMMENT ARG $e^+e^- \to 0.9 \times 10^{-2}$. Our fits error from using tic error from using our best value of $T(S) = 0.9 \times 10^{-2}$. We consider the number of $T(S) = 0.9 \times 10^{-2}$. We consider the number of $T(S) = 0.9 \times 10^{-2}$. We consider the number of $T(S) = 0.9 \times 10^{-2}$. We consider the number of $T(S) = 0.9 \times 10^{-2}$. Our fitting artis, e.g., $T(S) = 0.9 \times 10^{-2}$. Our fitting ratios, e.g., $T(S) = 0.9 \times 10^{-2}$. Our fitting ratios, e.g., $T(S) = 0.9 \times 10^{-2}$. Our fitting ratios, e.g., $T(S) = 0.9 \times 10^{-2}$. And $T(S) = 0.9 \times 10^{-2}$. Ilimits, etc. • • • • • • • • • • • • • • • • • • •	$+ \rightarrow D^0 \pi^+$ 0.030 ± 0.011 Our first error from using our duses Mark III TOLETTO 92 \[\begin{align*} \Gamma_5 / I & \\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \
= $55 \pm 4\%$. 87 BORTOLET We rescale to is their expenses to value. λ branching fra 88 BORTOLET $\Gamma(D^-D_s^{*+})/\Gamma_{VALUE}$ 0.020 \pm 0.014 \pm 0 89 ALBRECHT rescale to ou experiment's Assumes PD $\Gamma(D^*(2010)^-VALUE(units 10^{-2})$ 4.15 \pm 1.11 \pm 1.02 90 BORTOLET best value Bigerror and our $\Gamma(D^*(2010)^-VALUE(0.01) \pm 0.01$ 91 ALBRECHT rescale to our experiment's Assumes PD 3.71 \pm 0.25% \pm 55 \pm 4%. $\Gamma(D_s^+\pi^-)/\Gamma_{tc}$ VALUE <0.00028 • • We do no <0.0013 92 ALEXANDER	TO 92 reports 0.02 to our best value riment's error and assumes equal protions for the D TO 90 assume By total	$016 \pm 0.009 \pm 0.006$ for $B(D_s^+ \rightarrow \phi \pi^+) = (3.6 \pm 0.001)$. So $D_s^+ \rightarrow 0.006$ for $B(D_s^+ \rightarrow 0.001)$ for $B(D_$	6, and $B(D^*(2010)$ $B(D_S^+ \to \phi \pi^+) = 0.6 \pm 0.9) \times 10^{-2}$. We systematic error of at the $T(4S)$ and superseded by BOR TECN COMMENT ARG $e^+e^- \to 0.9 \times 10^{-2}$. Our fits error from using tic error from using our best value of $T(S) = 0.9 \times 10^{-2}$. We consider the number of $T(S) = 0.9 \times 10^{-2}$. We consider the number of $T(S) = 0.9 \times 10^{-2}$. We consider the number of $T(S) = 0.9 \times 10^{-2}$. We consider the number of $T(S) = 0.9 \times 10^{-2}$. Our fitting artis, e.g., $T(S) = 0.9 \times 10^{-2}$. Our fitting ratios, e.g., $T(S) = 0.9 \times 10^{-2}$. Our fitting ratios, e.g., $T(S) = 0.9 \times 10^{-2}$. Our fitting ratios, e.g., $T(S) = 0.9 \times 10^{-2}$. And $T(S) = 0.9 \times 10^{-2}$. Ilimits, etc. • • • • • • • • • • • • • • • • • • •	$+ \rightarrow D^0 \pi^+$ 0.030 ± 0.011 Our first error from using out of uses Mark I TOLETTO 92 \[\begin{align*} \tau_{25}/\limet_{1} & Total

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\Gamma(D_s^{*+}\pi^-)/\Gamma_{\text{total}}
                                                                                     \Gamma_{28}/\Gamma
                       VALUE
 ^{94} ALEXANDER 93B reports < 4.4 \times 10^{-4} for B(D_s^+ 	o \phi \pi^+) = 0.037. We rescale to
   our best value B(D_c^+ \rightarrow \phi \pi^+) = 0.036.
\left[\Gamma(D_s^+\pi^-)+\Gamma(D_s^-K^+)\right]/\Gamma_{\text{total}}
             ^{95} ALBRECHT 93E reports < 1.7 \times 10 ^{-3} for B(D_S^+ 
ightarrow \phi \pi^+) = 0.027. We rescale to our
   best value B(D_s^+ \rightarrow \phi \pi^+) = 0.036.
\left[\Gamma(D_s^{*+}\pi^-) + \Gamma(D_s^{*-}K^+)\right]/\Gamma_{\text{total}}
VALUECL%DOCUMENT IDTECNCOMMENT<0.0009</td>9096 ALBRECHT93E ARGe^+e^- \rightarrow r(4S)
 ^{96} ALBRECHT 93E reports < 1.2 	imes 10^{-3} for B(D_s^+ 	o \phi \pi^+) = 0.027. We rescale to our
   best value B(D_c^+ \rightarrow \phi \pi^+) = 0.036.
\Gamma(D_s^+ \rho^-)/\Gamma_{\text{total}}
                                                                                     \Gamma_{29}/\Gamma
                       \frac{\text{CL\%}}{90} \frac{\text{DOCUMENT ID}}{97} \frac{\text{TECN}}{\text{ALEXANDER}} \frac{\text{COMMENT}}{938} CLE2 e^+e^- \rightarrow
VALUE
<0.0016 90 98 ALBRECHT 93E ARG e^+e^- \rightarrow \Upsilon(4S)
 ^{97} ALEXANDER 93B reports < 6.6 \times 10 ^{-4} for B(D _{s}^{+} \rightarrow ~\phi\pi^{+}) = 0.037. We rescale to
   our best value B(D_c^+ \rightarrow \phi \pi^+) = 0.036.
 <sup>98</sup> ALBRECHT 93E reports < 2.2 \times 10^{-3} for B(D_c^+ \to \phi \pi^+) = 0.027. We rescale to our
   best value B(D_s^+ \rightarrow \phi \pi^+) = 0.036.
\Gamma(D_s^{*+}\rho^-)/\Gamma_{\text{total}}
                                                                                     \Gamma_{30}/\Gamma
                       VALUE
<0.0019 90 100 ALBRECHT 93E ARG e^+e^- \rightarrow \Upsilon(4S)
 ^{99} ALEXANDER 93B reports < 7.4 	imes 10^{-4} for B(D_s^+ 	o \phi \pi^+) = 0.037. We rescale to
    our best value B(D_c^+ \rightarrow \phi \pi^+) = 0.036.
^{100} ALBRECHT 93E reports < 2.5 \times 10^{-3} for B(D_c^+ \rightarrow \phi \pi^+) = 0.027. We rescale to our
   best value B(D_c^+ \rightarrow \phi \pi^+) = 0.036.
\Gamma(D_s^+ a_1(1260)^-)/\Gamma_{\text{total}}
                                                                                     \Gamma_{31}/\Gamma
value <u>CL%</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u>
<0.0026 90 <sup>101</sup> ALBRECHT 93E ARG e^+e^- \rightarrow r(4S)
^{101} ALBRECHT 93E reports < 3.5 	imes 10^{-3} for B(D_s^+ 	o \phi \pi^+) = 0.027. We rescale to our
   best value B(D_c^+ \rightarrow \phi \pi^+) = 0.036.
\Gamma(D_s^{*+}a_1(1260)^-)/\Gamma_{\text{total}}
                                                                                     \Gamma_{32}/\Gamma
           VALUE
<0.0022
^{102}ALBRECHT 93E reports < 2.9 \times 10^{-3} for B(D_c^+ \to \phi \pi^+) = 0.027. We rescale to our
   best value B(D_e^+ \rightarrow \phi \pi^+) = 0.036.
\Gamma(D_s^-K^+)/\Gamma_{\text{total}}
                                                                                     \Gamma_{33}/\Gamma
90 104 BORTOLETTO90 CLEO e^+e^- \rightarrow \Upsilon(4S)
^{103} ALEXANDER 93B reports < 2.3 \times 10^{-4} for B(D_c^+ 	o \phi \pi^+) = 0.037. We rescale to
   our best value B(D_s^+ \rightarrow \phi \pi^+) = 0.036.
<sup>104</sup>BORTOLETTO 90 assume B(D_S \rightarrow \phi \pi^+) = 2%.
\Gamma(D_s^{*-}K^+)/\Gamma_{\text{total}}
                                                                                     \Gamma_{34}/\Gamma
            VALUE
< 0.00017
^{105} ALEXANDER 93B reports < 1.7 \times 10^{-4} for B(D_c^+ \rightarrow \phi \pi^+) = 0.037. We rescale to
   our best value B(D_c^+ \rightarrow \phi \pi^+) = 0.036.
\Gamma(D_s^-K^*(892)^+)/\Gamma_{total}
                                                                                     \Gamma_{35}/\Gamma
90 107 ALBRECHT 93E ARG e^+e^- \rightarrow \Upsilon(4S)
^{106}ALEXANDER 93B reports < 9.7 \times 10^{-4} for B(D_s^+ 	o \phi \pi^+) = 0.037. We rescale to
   our best value B(D_s^+ \rightarrow \phi \pi^+) = 0.036.
^{107} ALBRECHT 93E reports <4.6\times10^{-3} for B(D _{\rm S}^{+}~\rightarrow~\phi\pi^{+})= 0.027. We rescale to our
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best value B($D_c^+ \rightarrow \phi \pi^+$) = 0.036.

 B^0

VALUE	Total F36/F
<0.0011	90 108 ALEXANDER 93B CLE2 $e^+e^- \rightarrow \Upsilon(4S)$
< 0.004	e following data for averages, fits, limits, etc. \bullet \bullet \bullet 90 109 ALBRECHT 93E ARG $e^+e^- o au(4S)$
	eports $< 11.0 \times 10^{-4}$ for B($D_s^+ o \phi \pi^+$) = 0.037. We rescale to
	$^+\rightarrow\phi\pi^+)=0.036.$
	orts $<$ 5.8 $ imes$ 10 $^{-3}$ for B($D_s^+ o \phi \pi^+$) $=$ 0.027. We rescale to ou
best value B($D_s^+ o$	
$-(D_s^-\pi^+K^0)/\Gamma_{\text{total}}$	Γ ₃₇ /Γ
	CL% DOCUMENT ID TECN COMMENT
<0.005	90 110 ALBRECHT 93E ARG $e^+e^- \rightarrow \Upsilon(4S)$
	orts $< 7.3 imes 10^{-3}$ for B($D_s^+ o \phi \pi^+$) = 0.027. We rescale to ou
best value B($D_s^+ \rightarrow$	$\phi\pi^{\pm})=0.036.$
$\Gamma(D_s^{*-}\pi^+K^0)/\Gamma_{\text{tota}}$	_{ιΙ} Γ ₃₈ /Γ
ALUE	CL% DOCUMENT ID TECN COMMENT
<0.0031	90 111 ALBRECHT 93E ARG $e^+e^- \rightarrow \Upsilon(4S)$
best value $B(D_s^+ \rightarrow$	ports $<$ 4.2 $ imes$ 10^{-3} for B($D_S^+ o \phi \pi^+$) = 0.027. We rescale to ou
$\Gamma(D_s^-\pi^+K^*(892)^0)$	/F _{total} F ₃₉ /F
<i>∨ALUE</i> <0.004	$\begin{array}{c ccccc} \underline{CL\%} & \underline{DOCUMENT\ ID} & \underline{TECN} & \underline{COMMENT} \\ 90 & ^{112} \text{ALBRECHT} & 93E & \text{ARG} & e^+e^- \rightarrow \varUpsilon(4S) \end{array}$
	forts $< 5.0 imes 10^{-3}$ for B $(D_{ m S}^+ o ~\phi \pi^+) =$ 0.027. We rescale to ou
best value B($D_s^+ \rightarrow$	
Γ(D*-π+K*(892) ⁰	
VALUE	// total
<0.0020	90 113 ALBRECHT 93E ARG $e^+e^- ightarrow \gamma(45)$
^{L13} ALBRECHT 93E rep	forts $<$ 2.7 $ imes$ 10^{-3} for B($D_s^+ ightarrow \phi \pi^+$) $=$ 0.027. We rescale to ou
best value B($D_s^+ \rightarrow$	$\phi \pi^+) = 0.036.$
$\Gamma(\overline{D}{}^0\pi^0)/\Gamma_{total}$	Γ ₄₁ /Γ
VALUE // total	CL% DOCUMENT ID TECN COMMENT
<u>√ALUE</u> <0.00048	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
<u>VALUE</u> <0.00048 114 ALAM 94 assume e	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
VALUE <0.00048 114 ALAM 94 assume earlier absolute $B(D^0 \rightarrow K)$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
VALUE <0.00048 114 ALAM 94 assume early absolute $B(D^0 \to K^-\pi)$ $\Gamma(\overline{D}^0 \rho^0)/\Gamma_{\text{total}}$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
VALUE <0.00048 114 ALAM 94 assume et absolute $B(D^0 \rightarrow K - \pi)$ $\Gamma(\overline{D}^0 \rho^0) / \Gamma \text{total}$ VALUE C.5%	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
value <0.00048 114 ALAM 94 assume et absolute $B(D^0 \rightarrow K \pi \pi)$ $\Gamma(\overline{D}^0 \rho^0)/\Gamma$ total value <0.00055 90	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
value <0.00048 114 ALAM 94 assume et absolute $B(D^0 \rightarrow K \pi)$ and $B(D^0 \rightarrow K \pi)$ $\Gamma(\overline{D}^0 \rho^0)/\Gamma$ total value <0.00055 90	Qual production of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO I (τ, π^+) and the PDG 1992 $B(D^0 \to K^-\pi^+\pi^0)/B(D^0 \to K^-\pi^+)$. Parameter $B(D^0 \to K^-\pi^+)$.
<10.00048 114 ALAM 94 assume et absolute $B(D^0 \to K - \pi)$ ($D^0 \to 0$) / Γ (Dalum) ($D^0 \to 0$) / Γ (Clin) ($D^0 \to 0$) / Γ ($D^0 \to 0$) / Γ ($D^0 \to 0$) ($D^0 \to 0$) • • • We do not use the 0.0006 ($D^0 \to 0.0006$ ($D^0 \to 0.0006$ ($D^0 \to 0.0006$) ($D^0 \to 0.0006$ ($D^0 \to 0.0006$) ($D^0 \to 0.0006$) ($D^0 \to 0.0006$ ($D^0 \to 0.0006$) ($D^0 \to 0.0006$) 	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
VALUE <0.00048 $114 \text{ ALAM 94 assume e}$ $absolute B(D^0 \rightarrow K and B(D^0 \rightarrow K \pi \Gamma(\overline{D}^0 \rho^0)/\Gamma \text{ total} VALUE \qquad CL\% <0.00055 90 •• We do not use the <0.0006 90 <0.0007 90 115 ALAM 94 assume ee.$	Qual production of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO I $\Gamma(4S)$ and the PDG 1992 $\Gamma(4S)$ and $\Gamma(4S)$ and use the CLEO I $\Gamma(4S)$ and the PDG 1992 $\Gamma(4S)$ and $\Gamma(4S)$ are following data for averages, fits, limits, etc. \bullet \bullet 116 BORTOLETTO92 CLEO $\Gamma(4S)$ and use the CLEO I qual production of $\Gamma(4S)$ and use the CLEO I $\Gamma(4S)$ and $\Gamma(4S)$ and use the CLEO I $\Gamma(4S)$ and $\Gamma(4S$
VALUE <0.00048 114 ALAM 94 assume et absolute $B(D^0 \rightarrow K - \pi)$ $\Gamma(\overline{D^0} \rho^0)/\Gamma \text{total}$ VALUE <0.00055 90 • • • We do not use the condition of the con	qual production of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO I $(-\pi^+)$ and the PDG 1992 $B(D^0 \to K^-\pi^+)$. Fig. 115 ALAM 94 CLE2 $e^+e^- \to \Upsilon(4S)$ and use the CLEO I $(-\pi^+)$ and the PDG 1992 $B(D^0 \to K^-\pi^+\pi^0)/B(D^0 \to K^-\pi^+)$. Fig. 115 ALAM 94 CLE2 $e^+e^- \to \Upsilon(4S)$ are following data for averages, fits, limits, etc. • • • 116 BORTOLETTO92 CLEO $e^+e^- \to \Upsilon(4S)$ and 117 ALBRECHT 88K ARG $e^+e^- \to \Upsilon(4S)$ qual production of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO I $(-\pi^+)$ and the PDG 1992 $B(D^0 \to K^-\pi^+\pi^0)/B(D^0 \to K^-\pi^+)$.
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VALUE <.0.00048 114 ALAM 94 assume exabsolute $B(D^0 \rightarrow K - \pi)$ $\Gamma(\overline{D^0} \rho^0)/\Gamma$ total VALUE <.0.00055 • • • We do not use the constant of the constant	gual production of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO I $\Upsilon(-\pi^+)$ and the PDG 1992 B($D^0 \to K^-\pi^+$). Fully production of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO I $\Upsilon(-\pi^+)$ and the PDG 1992 B($D^0 \to K^-\pi^+\pi^0$)/B($D^0 \to K^-\pi^+$). Fully DOCUMENT ID TECN COMMENT 115 ALAM 94 CLE2 $e^+e^- \to \Upsilon(4S)$ are following data for averages, fits, limits, etc. ••• 116 BORTOLETTO92 CLEO $e^+e^- \to \Upsilon(4S)$ and use the CLEO I $\Upsilon(-\pi^+)$ and the PDG 1992 B($D^0 \to K^-\pi^+\pi^0$)/B($D^0 \to K^-\pi^+$). Fully ALBRECHT 88K ARG $e^+e^- \to \Upsilon(4S)$ and use the CLEO I $\Upsilon(-\pi^+)$ and the PDG 1992 B($D^0 \to K^-\pi^+\pi^0$)/B($D^0 \to K^-\pi^+\pi^0$). Fully Bortouction of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO I $\Upsilon(-\pi^+)$ and the PDG 1992 B($D^0 \to K^-\pi^+\pi^0$)/B($D^0 \to K^-\pi^0$). Fully Bortouction of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO I $\Upsilon(-\pi^+)$ and the PDG 1992 B($D^0 \to K^-\pi^+\pi^0$)/B($D^0 \to K^-\pi^+\pi^0$)/B($D^0 \to K^-\pi^0$). Fully Bortouction of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO I $\Upsilon(-\pi^+)$ and the PDG 1992 B($D^0 \to K^-\pi^+\pi^0$)/B($D^0 \to K^-\pi^+\pi^0$). Fully Bortouction of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO I $\Upsilon(-\pi^+)$ and the PDG 1992 B($D^0 \to K^-\pi^+\pi^0$)/B($D^0 \to K^-\pi^+\pi^0$)/B($D^0 \to K^-\pi^0$). Fully Bortouction of B^+ and B^0 at the $\Upsilon(-4S)$ and use the CLEO I $\Upsilon(-\pi^+)$ and the PDG 1992 B($D^0 \to K^-\pi^+\pi^0$)/B($D^0 \to K^-\pi^+\pi^0$)/B($D^0 \to K^-\pi^0$).

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\Gamma(\overline{D}^*(2007)^0\pi^0)/\Gamma_{\text{total}}
                                                                                                              \Gamma_{46}/\Gamma
                                                DOCUMENT ID TECN COMMENT
VALUE
                                CL%
                                 90 121 ALAM 94 CLE2 e^+e^- \rightarrow \Upsilon(4S)
 < 0.00097
^{121} ALAM 94 assume equal production of B^+ and B^0 at the \Upsilon(4S) and use the CLEO II
     {\rm B}(D^*(2007)^0 \to D^0\pi^0) and absolute {\rm B}(D^0 \to K^-\pi^+) and the PDG 1992 {\rm B}(D^0
     K^-\pi^+\pi^0)/B(D^0\to K^-\pi^+) and B(D^0\to K^-\pi^+\pi^+\pi^-)/B(D^0\to K^-\pi^+).
\Gamma(\overline{D}^*(2007)^0 \rho^0)/\Gamma_{\text{total}}
               <0.00117
^{122}ALAM 94 assume equal production of B^+ and B^0 at the arphi(4S) and use the CLEO II
     B(D^*(2007)^0 \rightarrow D^0\pi^0) and absolute B(D^0 \rightarrow K^-\pi^+) and the PDG 1992 B(D^0 \rightarrow K^-\pi^+\pi^0)/B(D^0 \rightarrow K^-\pi^+) and B(D^0 \rightarrow K^-\pi^+\pi^0)/B(D^0 \rightarrow K^-\pi^+).
\Gamma(\overline{D}^*(2007)^0\eta)/\Gamma_{\text{total}}
                                                                                                              \Gamma_{48}/\Gamma
                              <u>CL%</u> <u>DUCC...</u>
on 123 ALAM
                                                DOCUMENT ID TECN COMMENT
VALUE
                                                                     94 CLE2 e^+e^- \rightarrow \Upsilon(4S)
 < 0.00069
^{123}ALAM 94 assume equal production of B^+ and B^0 at the \varUpsilon(45) and use the CLEO II
     B(D^*(2007)D^0 \to D^0 \pi^0) and absolute B(D^0 \to K^- \pi^+) and the PDG 1992 B(D^0 \to K^- \pi^+ \pi^0)/B(D^0 \to K^- \pi^+) and B(D^0 \to K^- \pi^+ \pi^0)/B(D^0 \to K^- \pi^+).
\Gamma(\overline{D}^*(2007)^0 \eta')/\Gamma_{\text{total}}
                            ^{124}ALAM 94 assume equal production of B^+ and B^0 at the \varUpsilon(45) and use the CLEO II
     Action 94 assume equal production of B . And B is at the (+5) and use the CECO in B(D^4 \subset N^2)^0 \to D^0 \pi^0) and absolute B(D^0 \to K^- \pi^+) and the PDG 1992 B(D^0 \to K^- \pi^+ \pi^0)/B(D^0 \to K^- \pi^+) and B(D^0 \to K^- \pi^+ \pi^0)/B(D^0 \to K^- \pi^+).
\Gamma(\overline{D}^*(2007)^0\omega)/\Gamma_{\text{total}}
                                                                                                               \Gamma_{50}/\Gamma
                               CL%
VALUE
                                                DOCUMENT ID TECN COMMENT
                                         125 ALAM
                                                                     94 CLE2 e^+e^- \rightarrow \Upsilon(4S)
 < 0.0021
                                 90
^{125}ALAM 94 assume equal production of B^+ and B^0 at the arphi(4S) and use the CLEO II
     ALAM 94 assume equal production of B. And B at the \Gamma(4S) and use the CLEO \Pi B(D^*(2007)^0 \to D^0\pi^0) and absolute B(D^0 \to K^-\pi^+) and the PDG 1992 B(D^0 \to K^-\pi^+\pi^+) and B(D^0 \to K^-\pi^+\pi^+\pi^-)/B(D^0 \to K^-\pi^+).
\Gamma(J/\psi(1S)K^0)/\Gamma_{\text{total}}
                                                                                                              \Gamma_{51}/\Gamma
                                     CL% EVTS
VALUE (units 10-4)
                                                         DOCUMENT ID TECN COMMENT
     7.5 ±2.1 OUR AVERAGE
                                                10 126 ALAM
     7.5 \ \pm 2.4 \ \pm 0.8
                                                                                  94 CLE2 e+e
                                                       126 BORTOLETTO92 CLEO e^+e^- \rightarrow \gamma(4S)
     6.87 \pm 4.03 \pm 0.22
                                                 2 127 ALBRECHT 90J ARG
    9.2 \pm 7.1 \pm 0.3
\bullet \bullet \bullet We do not use the following data for averages, fits, limits, etc. \bullet \bullet
                                                         ALAM
^{126} BORTOLETTO 92 reports 6 \pm 3 \pm 2 for B(J/\psi(15) \rightarrow~e^+\,e^-)= 0.069 \pm 0.009. We
     rescale to our best value B(J/\psi(1S) \rightarrow e^+e^-) = (6.02 \pm 0.19) \times 10^{-2}. Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the \Upsilon(4S).
127 ALBRECHT 90J reports 8 \pm 6 \pm 2 for B(J/\psi(1S) \rightarrow e^+e^-) = 0.069 \pm 0.009. We
     rescale to our best value B(J/\psi(15) \rightarrow e^+e^-) = (6.02 \pm 0.19) \times 10^{-2}. Our first error is their experiment's error and our second error is the systematic error from using
     our best value. Assumes equal production of B^+ and B^0 at the \Upsilon(4S).
\Gamma(J/\psi(1S)K^+\pi^-)/\Gamma_{
m total}
                                                                                                              \Gamma_{52}/\Gamma
                                    CL% EVTS
                                                             DOCUMENT ID
                                                                                     TECN COMMENT
                                                       ^{128} BORTOLETTO92 CLEO e^+e^-
   0.00115±0.00055±0.00004
• • • We do not use the following data for averages, fits, limits, etc. • •
                                                       ^{129}\, {\sf ALBRECHT} 87D ARG e^+
 < 0.0013
                                                                                 84 CLEO e^+e^- \rightarrow \Upsilon(4S)
 < 0.0063
                                                             GILES
 ^{128}BORTOLETTO 92 reports 0.0010 \pm 0.0004 \pm 0.0003 for B(J/\psi(1S) \rightarrow e^+e^-) =
     0.069 \pm 0.009. We rescale to our best value B(J/\psi(1S) \rightarrow e^+e^-) = (6.02 \pm 0.19) \times
      10<sup>-2</sup>. Our first error is their experiment's error and our second error is the systematic
error from using our best value. Assumes equal production of B^+ and B^0 at the \Upsilon(4S). 129 ALBRECHT 87D assume B^+B^-/B^0\,\overline{B}^0 ratio is 55/45. K\pi system is specifically selected as nonresonant.
\Gamma(J/\psi(1S)K^*(892)^0)/\Gamma_{\text{total}}
                                                      DOCUMENT ID TECN COMMENT
0.00158±0.00027 OUR AVERAGE
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130 ALAM

133 BEBEK

94 CLE2 $e^+e^- \rightarrow \Upsilon(4S)$

87 CLEO $e^+e^- \rightarrow \Upsilon(4S)$

131 BORTOLETTO92 CLEO $e^+e^- \rightarrow r(45)$ 132 ALBRECHT 90J ARG $e^+e^- \rightarrow r(45)$

 $0.00169 \pm 0.00031 \pm 0.00018$ 29

 $0.00126 \pm 0.00065 \pm 0.00004$ $0.00126 \pm 0.00059 \pm 0.00004$

 $0.0040 \pm 0.0018 \pm 0.0001$

a a a We do not	use the follow	ing data for average	s fits limits et		
• • • • • • • • • • • • • • • • • • •	use the follow	134 ALBRECH		$e^+e^- \rightarrow \Upsilon(4S)$	ı
0.0040 ±0.0030		135 ALBAJAR	91E UA1	$E_{\rm cm}^{p\overline{p}}$ = 630 GeV	•
0.0033 ±0.0018		5 136 ALBRECH		$e^+e^- \rightarrow \Upsilon(4S)$	
$0.0041\ \pm0.0018$		5 ¹³⁷ ALAM	86 CLEO	. ,	
130 The neutral a	nd charged B	events together are	predominantly	longitudinally polarized,	
				ction using HQET, 0.73 * decay is dominated by	
				and B^0 at the $\Upsilon(4S)$.	
¹³¹ BORTOLETT	O 92 reports	$0.0011 \pm 0.0005 \pm$	0.0003 for B(J	$I/\psi(1S) \rightarrow e^+e^-) =$	
				$e^{-}) = (6.02 \pm 0.19) \times$	
				derror is the systematic $^{+}$ and B^{0} at the $\Upsilon(4S)$.	
				$) \rightarrow e^{+}e^{-}) = 0.069 \pm$	
0.009. We res	scale to our be	st value B $(J/\psi(1S)$	$\rightarrow e^+e^-) =$	$(6.02 \pm 0.19) \times 10^{-2}$.	
		riment's error and o Assumes equal produ		is the systematic error of B^0 at the $\Upsilon(45)$	
133 BEBEK 87 rep	orts 0.0035 ± 0	0.0016 ± 0.0003 for E	$B(J/\psi(1S) \rightarrow e$	$^{+}e^{-}) = 0.069 \pm 0.009.$	
We rescale to	our best value	$B(J/\psi(1S) \rightarrow e^{+}$	$e^{-}) = (6.02 \pm$	$0.19) \times 10^{-2}$. Our first	
error is their e	experiment's er . Updated in f	ror and our second BORTOLETTO 92 t	error is the syst o use the same	ematic error from using assumptions.	
134 ALBRECHT 9	4G measures th	e polarization in the	vector-vector de	cay to be predominantly	1
longitudinal, F	$T/\Gamma = 0.03 \pm$	0.16 ± 0.15 making	the neutral deca	ay a <i>CP</i> eigenstate when	ļ
the K*0 decay			of 269/		ı
136 ALBRECHT 8	7D assume R+	production fraction $R = /R 0 \overline{R} 0$ ratio is	01 30%. 55/45 Superce	ded by ALBRECHT 90J.	
				of the decay $B^+ \rightarrow$	
		nas been retracted ir		,	
$\Gamma(J/\psi(1S)\pi^0)$	/Caasal			Γ ₅₄ /Γ	
VALUE	CL% EVTS	DOCUMENT ID	TECN C		
<6.9 × 10 ⁻³	90 1	138 ALEXANDER		$+e^- \rightarrow \gamma(45)$	1
138 Assumes equal	l production of	B^+B^- and $B^0\overline{B}^0$	on $\Upsilon(4S)$.		1
$\Gamma(\psi(2S)K^0)/\Gamma$				Γ/Γ	•
VALUE	total CL%_	DOCUMENT ID	TECN C	Γ ₅₅ /Γ	
<0.0008	90	139 ALAM		$+e^- \rightarrow \gamma(45)$	
	use the followi	ing data for averages		` '	
< 0.0015	90	139 BORTOLETTO	092 CLEO <i>e</i>	$^+e^- ightarrow \gamma$ (4S)	
< 0.0028	90	139 ALBRECHT		$^+e^- \rightarrow ~ \gamma (4S)$	
139 Assumes equal	I production of	$^{\mathrm{F}}B^{+}$ and B^{0} at the	$\Upsilon(45)$.		
$\Gamma(\psi(2S)K^+\pi^-$					
$I(\Psi(ZJ)) \cap A$)/F _{total}			Γ ₅₆ /Γ	
VALUE N)/F _{total}	DOCUMENT ID	TECN C	Г ₅₆ /Г	
<i>VALUE</i> <0.001	<u>CL%</u> 90	¹⁴⁰ ALBRECHT	90J ARG <i>е</i>		
<i>VALUE</i> <0.001	<u>CL%</u> 90		90J ARG <i>е</i>	OMMENT	
<i>VALUE</i> <0.001	CL% 90 I production of	¹⁴⁰ ALBRECHT	90J ARG <i>е</i>	OMMENT	
VALUE <0.001 140 Assumes equal Γ(ψ(25) Κ*(89) VALUE	$\frac{CL\%}{90}$ I production of 2)0/ Γ_{total}	140 ALBRECHT 6 6 6 and 6 at the 6	90J ARG e^{i} $\Upsilon(4S)$.	$ ho_{DMMENT}$ $+ e^- o r(4S)$ $ ho_{57}/\Gamma$ $ ho_{COMMENT}$	
$\frac{VALUE}{<0.001}$ 140 Assumes equal $\Gamma(\psi(2S)K^*(89))$ $\frac{VALUE}{0.0014\pm0.0008}$	$\frac{CL\%}{90}$ I production of 2)0 / Γ_{total} $\frac{CL\%}{\pm 0.0004}$	140 ALBRECHT 6 6 6 and 6 at the 6 141 BORTOLET	90J ARG e^{i} $\Upsilon(4S)$. D TO92 CLEO	$\begin{array}{c} \underline{\text{COMMENT}} \\ + e^- \rightarrow r(4S) \end{array}$ $\begin{array}{c} \underline{\text{Γ_{57}/Γ}} \\ \underline{\text{$COMMENT$}} \\ e^+ e^- \rightarrow r(4S) \end{array}$	
$\frac{VALUE}{<0.001}$ 140 Assumes equal $\Gamma(\psi(2S)K^*(89))$ $\frac{VALUE}{0.0014\pm0.0008}$ • • • We do not	$\frac{CL\%}{90}$ I production of $\frac{2}{0}$ $\frac{CL\%}{1}$ $\frac{CL\%}{1}$ $\frac{CL\%}{1}$ $\frac{CL\%}{1}$ use the following $\frac{CL\%}{1}$	140 ALBRECHT 6 8 and 80 at the 141 BORTOLET 141 BORTOLET 141 g data for averages	90J ARG e^{-t} $\Upsilon(4S)$. D TECN TO92 CLEO s, fits, limits, etc.	$ \begin{array}{c} \underline{OMMENT} \\ + e^{-} \rightarrow \Upsilon(4S) \end{array} $ $ \begin{array}{c} \Gamma_{57}/\Gamma \\ \underline{COMMENT} \\ e^{+} e^{-} \rightarrow \Upsilon(4S) \end{array} $ $ \begin{array}{c} COMMENT \\ COMMENT \\ COMMENT \end{array} $	
$ \frac{\text{VALUE}}{\text{<0.001}} $ 140 Assumes equal $ \Gamma(\psi(2S)K^{*}(89) $ $ \frac{\text{VALUE}}{\text{0.0014±0.0008}} $ • • • We do not <0.0019	$\frac{CL\%}{90}$ I production of 2)0 / Γ_{total} $\frac{CL\%}{\pm 0.0004}$	140 ALBRECHT F B + and B 0 at the DOCUMENT II 141 BORTOLET ng data for averages 141 ALAM	90J ARG e^{i} $\Upsilon(4S)$. D TECN TO92 CLEO 5, fits, limits, et 94 CLE2	$ \begin{array}{c} \frac{COMMENT}{+e^{-} \rightarrow r(4S)} \\ \hline & \Gamma_{57}/\Gamma \\ \frac{COMMENT}{e^{+}e^{-} \rightarrow r(4S)} \\ c. \bullet \bullet \bullet \\ e^{+}e^{-} \rightarrow r(4S) \end{array} $	
$\frac{VALUE}{< 0.001}$ 140 Assumes equal Γ (ψ(25) K*(89) VALUE 0.0014±0.0008 • • • We do not <0.0019 <0.0023	$\frac{CL\%}{90}$ I production of $\frac{2}{0}$ $\frac{CL\%}{\pm 0.0004}$ use the following $\frac{90}{90}$	140 ALBRECHT B + and B 0 at the DOCUMENT II 141 BORTOLET ng data for averages 141 ALAM 141 ALBRECHT	90J ARG e^{i} $\Upsilon(4S)$. D TECN TO92 CLEO 5, fits, limits, etc. 94 CLE2 90J ARG	$ \begin{array}{c} \underline{OMMENT} \\ + e^{-} \rightarrow \Upsilon(4S) \end{array} $ $ \begin{array}{c} \Gamma_{57}/\Gamma \\ \underline{COMMENT} \\ e^{+} e^{-} \rightarrow \Upsilon(4S) \end{array} $ $ \begin{array}{c} COMMENT \\ COMMENT \\ COMMENT \end{array} $	
<u>VALUE</u> <0.001 140 Assumes equal Γ(ψ(2S) Κ*(89: VALUE 0.0014±0.0008 • • We do not <0.0019 <0.0023 141 Assumes equal	$\frac{c \ell \%}{90}$ production of 2)0)/ Γ total $\frac{c \ell \%}{4}$ ± 0.0004 use the following 90 90 production of	140 ALBRECHT F B + and B 0 at the DOCUMENT II 141 BORTOLET ng data for averages 141 ALAM	90J ARG e^{i} $\Upsilon(4S)$. D TECN TO92 CLEO 5, fits, limits, etc. 94 CLE2 90J ARG	$\begin{array}{c} \underline{OMMENT} \\ +e^- \rightarrow r(4S) \\ \hline \\ \underline{COMMENT} \\ e^+e^- \rightarrow r(4S) \\ \mathbf{c. \bullet \bullet} \\ e^+e^- \rightarrow r(4S) \\ e^+e^- \rightarrow r(4S) \\ e^+e^- \rightarrow r(4S) \\ \end{array}$	
$VALUE$ <0.001 140 Assumes equal $\Gamma(\psi(2S)K^*(89)$ VALUE 0.0014±0.0008 • • We do not <0.0019 <0.0023 141 Assumes equal $\Gamma(\chi_{c1}(1P)K^0)$	CL% 90 I production of 2)0)/Ftotal ±0.0004 use the followi 90 90 I production of /Ftotal	140 ALBRECHT 6 6 $^{+}$ and 60 at the $^{-}$ 141 BORTOLET ng data for averages 141 ALAM 141 ALBRECHT 6 6 6 6 at the	90J ARG $e^{-\frac{1}{2}}$ r	$ \begin{array}{c} \hline COMMENT \\ +e^{-} \rightarrow \Upsilon(4S) \end{array} $ $ \begin{array}{c} \Gamma_{57}/\Gamma \\ e^{+}e^{-} \rightarrow \Upsilon(4S) \end{array} $ $ \begin{array}{c} comment \\ e^{+}e^{-} \rightarrow \Upsilon(4S) \end{array} $ $ \begin{array}{c} e^{+}e^{-} \rightarrow \Upsilon(4S) \end{array} $ $ \begin{array}{c} e^{+}e^{-} \rightarrow \Upsilon(4S) \end{array} $ $ \begin{array}{c} F_{58}/\Gamma \end{array} $	
$VALUE$ <0.001 140 Assumes equal $\Gamma(\psi(2S)K^*(89)VALUE$ 0.0014±0.0008 • • We do not <0.0019 <0.0023 141 Assumes equal $\Gamma(\chi_{c1}(1P)K^0)VALUE$ VALUE		140 ALBRECHT (B+ and B ⁰ at the DOCUMENT II 141 BORTOLET 141 ALAM 141 ALBRECHT (B+ and B ⁰ at the	90J ARG <i>e T</i> (45). TO92 CLEO 5, fits, limits, et 94 CLE2 90J ARG <i>T</i> (45).	$ \begin{array}{c} \hline \text{COMMENT} \\ +e^{-} \rightarrow r(4S) \end{array} $ $ \begin{array}{c} \hline \Gamma_{57}/\Gamma \\ e^{+}e^{-} \rightarrow r(4S) \end{array} $ $ \begin{array}{c} \bullet \bullet \bullet \bullet \\ e^{+}e^{-} \rightarrow r(4S) \end{array} $ $ \begin{array}{c} \bullet $	
$\frac{VALUE}{<0.001}$ 140 Assumes equal Γ (ψ(2S) K*(89) VALUE 0.0014±0.0008 • • • We do not <0.0019 <0.0023 141 Assumes equal Γ (χ _{c1} (1P) K ⁰) VALUE <0.0027	20% 90 I production of 22)0)/Ftotal 20.0004 use the following 90 90 I production of 7Ftotal 20.0004	140 ALBRECHT (B+ and B ⁰ at the DOCUMENT II 141 BORTOLET 141 ALAM 141 ALBRECHT (B+ and B ⁰ at the DOCUMENT ID	90J ARG e T(45). 7 (45). 7 (45). 7 (45). 7 (45). 7 (45). 94 CLE2 90J ARG 7 (45).	$ \frac{COMMENT}{+e^{-} \rightarrow \Upsilon(4S)} $ $ \frac{COMMENT}{e^{+}e^{-} \rightarrow \Upsilon(4S)} $ $ e^{+}e^{-} \rightarrow \Upsilon(4S) $ $ e^{+}e^{-} \rightarrow \Upsilon(4S) $ $ e^{+}e^{-} \rightarrow \Upsilon(4S) $ $ \frac{\Gamma_{58}/\Gamma}{COMMENT} $ $ +e^{-} \rightarrow \Upsilon(4S) $	
$VALUE$ <0.001 140 Assumes equal Γ (ψ(25) K^* (89) $VALUE$ 0.0014±0.0008 • • We do not <0.0019 <0.0023 141 Assumes equal Γ (X_{c1} (1 P) K^0) $VALUE$ <0.0027		140 ALBRECHT f B+ and B ⁰ at the DOCUMENT II 141 BORTOLET ng data for averages 141 ALAM 141 ALBRECHT f B+ and B ⁰ at the DOCUMENT ID 142 ALAM equal production of	90J ARG e T(45). 7 (45). 7 (45). 7 (45). 7 (45). 7 (45). 94 CLE2 90J ARG 7 (45).	$ \begin{array}{c} \hline \text{COMMENT} \\ +e^{-} \rightarrow \Upsilon(4S) \end{array} $ $ \begin{array}{c} \Gamma_{57}/\Gamma \\ e^{+}e^{-} \rightarrow \Upsilon(4S) \end{array} $ $ \begin{array}{c} e^{+}e^{-} \rightarrow \Upsilon(4S) \\ e^{+}e^{-} \rightarrow \Upsilon(4S) \end{array} $ $ \begin{array}{c} e^{+}e^{-} \rightarrow \Upsilon(4S) \\ e^{+}e^{-} \rightarrow \Upsilon(4S) \end{array} $ $ \begin{array}{c} \Gamma_{58}/\Gamma \\ \hline \text{COMMENT} \\ +e^{-} \rightarrow \Upsilon(4S) \end{array} $ the $\Upsilon(4S)$.	
$VALUE$ <0.001 140 Assumes equal Γ (ψ(25) K*(89) VALUE 0.0014±0.0008 • • We do not <0.0019 <0.0023 141 Assumes equal Γ ($X_{c1}(1P)$ K°0) VALUE <0.0027 142 BORTOLETT: Γ ($X_{c1}(1P)$ K*(ξ	$\frac{CL\%}{90}$ I production of $\frac{2}{0}$)/ Γ total $\frac{CL\%}{90}$ $\frac{90}{90}$ I production of $\frac{CL\%}{90}$ O 92 assumes $\frac{CL\%}{90}$	140 ALBRECHT (B+ and B ⁰ at the DOCUMENT II 141 BORTOLET 141 ALAM 141 ALBRECHT (B+ and B ⁰ at the DOCUMENT ID 142 ALAM equal production of	90J ARG e $T(4S)$. TO92 CLEO 5, fits, limits, et 94 CLE2 90J ARG $T(4S)$. TECN 26 $TECN$ 27 $TECN$ 28 $TECN$ 29 $TECN$ 30 $TECN$ 30 $TECN$ 31 $TECN$ 32 $TECN$ 34 $TECN$ 35 $TECN$ 36 $TECN$ 36 $TECN$ 37 $TECN$ 37 $TECN$ 38	$\begin{array}{c} \frac{COMMENT}{+e^{-}\rightarrow \ \Upsilon(4S)} \\ \\ \hline & \Gamma_{57}/\Gamma \\ \hline \frac{COMMENT}{e^{+}e^{-}\rightarrow \ \Upsilon(4S)} \\ \hline \vdots & \bullet \bullet \bullet \\ e^{+}e^{-}\rightarrow \ \Upsilon(4S) \\ e^{+}e^{-}\rightarrow \ \Upsilon(4S) \\ \hline \\ \frac{COMMENT}{+e^{-}\rightarrow \ \Upsilon(4S)} \\ \\ \hline \text{the } \Upsilon(4S). \\ \hline \\ \hline \Gamma_{59}/\Gamma \\ \hline \end{array}$	
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$ \begin{array}{l} \underline{\text{VALUE}} \\ < 0.001 \\ 140 \text{ Assumes equal} \\ \hline \Gamma(\psi(2S)K^*(89) \\ \underline{\text{VALUE}} \\ 0.0014 \pm 0.0008 \\ \bullet \bullet \text{ we do not} \\ < 0.0019 \\ < 0.0023 \\ 141 \text{ Assumes equal} \\ \hline \Gamma(\chi_{c1}(1P)K^0) \\ \underline{\text{VALUE}} \\ < 0.0027 \\ 142 \text{ BORTOLETT} \\ \hline \Gamma(\chi_{c1}(1P)K^*(6) \\ \underline{\text{VALUE}} \\ < 0.0021 \\ 143 \text{ BORTOLETT}. \end{array} $	CL% 90 I production of 2)0)/\(\text{Ftotal}\) \[\frac{CL\%}{90}\] \[\frac{CL\%}{90}\] I production of \(\frac{CL\%}{90}\) O 92 assumes \[\frac{CL\%}{90}\] O 92 assumes	140 ALBRECHT (B+ and B ⁰ at the DOCUMENT II 141 BORTOLET ng data for averages 141 ALAM 141 ALBRECHT (B+ and B ⁰ at the DOCUMENT ID DOCUMENT ID	90J ARG <i>e T</i> (45). 7 (45). 7 (45). 7 (45). 7 (45). 7 (45). 7 (45). 7 (45). 7 (45). 7 (45). 7 (45). 7 (45). 7 (45).	$\begin{array}{c} \frac{COMMENT}{+e^{-} \rightarrow r(4S)} \\ \\ \hline & \Gamma_{57}/\Gamma \\ \hline \frac{COMMENT}{e^{+}e^{-} \rightarrow r(4S)} \\ c. \bullet \bullet \bullet \\ e^{+}e^{-} \rightarrow r(4S) \\ e^{+}e^{-} \rightarrow r(4S) \\ \hline \\ \frac{COMMENT}{+e^{-} \rightarrow r(4S)} \\ \\ \text{the } r(4S). \\ \hline \\ \frac{COMMENT}{+e^{-} \rightarrow r(4S)} \\ \\ \text{the } r(4S). \\ \hline \\ \frac{COMMENT}{+e^{-} \rightarrow r(4S)} \\ \\ \text{the } r(4S). \\ \hline \end{array}$	
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$VALUE$ <0.001 140 Assumes equal $\Gamma(\psi(2S)K^*(89)$ $VALUE$ 0.0014±0.0008 • • We do not <0.0023 141 Assumes equal $\Gamma(X_{C1}(1P)K^0)$ $VALUE$ <0.0027 142 BORTOLETT $\Gamma(X_{C1}(1P)K^*(89)$ $VALUE$ <0.0021 <p>143 BORTOLETT $\Gamma(K^+\pi^-)/\Gamma_{tot}$ $VALUE$ <0.0021 <p>143 BORTOLETT $\Gamma(K^+\pi^-)/\Gamma_{tot}$ $VALUE$ <0.0021 </p> <0.0021 </p> 143 BORTOLETT $\Gamma(K^+\pi^-)/\Gamma_{tot}$ $VALUE$ <0.0021 <1.7 × 10−5 • • We do not <9 × 10−5 <2.6 × 10−5 <2.6 × 10−5 <2.6 × 10−5 <3.2 × 10−4 144 Assumes a B ⁰ Contributions	CL% 90 I production of 2)0)/Ftotal	140 ALBRECHT 18 + and 80 at the DOCUMENT II 141 BORTOLET 141 ALBRECHT 141 ALBRECHT 142 ALAM 141 ALBRECHT 142 ALAM equal production of 1 143 ALAM equal production of DOCUMENT ID ASNER ng data for averages 144 ABREU 145 AKERS 144 ABREU 145 AKERS 144 ABREU 145 AKERS 146 BATTLE ALBRECHT 147 AVERY AVERY AVERY AVERY Ion fraction of 0.39 80 decays cannot to BOCUMENT ID ASNER ALBRECHT ALBRECHT ALBRECHT ALBRECHT AVERY	90J ARG <i>e</i> T(45). TO92 CLEO 5, fits, limits, et 94 CLE2 <i>e</i> 95 ARG 96 CLE2 <i>e</i> 5, fits, limits, et 95N DLPH <i>e</i> 91L OPAL <i>e</i>	$\begin{array}{c} \frac{COMMENT}{+e^- \rightarrow r(4S)} \\ \\ \hline $	
$VALUE$ <0.001 140 Assumes equal $\Gamma(\psi(2S)K^*(89)$ $VALUE$ 0.0014±0.0008 • • We do not <0.0019 <0.0023 141 Assumes equal $\Gamma(\chi_{c1}(1P)K^0)$ $VALUE$ <0.0027 142 BORTOLETT $\Gamma(\chi_{c1}(1P)K^*(60)$ $VALUE$ <1.7 × 10−5 • • We do not <9 × 10−5 <2.6 × 10−5 <3.2 × 10−4 144 Assumes a B^0 Contributions weighted avera weighted avera	CL% 90 I production of 2)0)/Ftotal	140 ALBRECHT 18 + and B ⁰ at the DOCUMENT II 141 BORTOLET 141 ALAM 141 ALBRECHT 18 + and B ⁰ at the DOCUMENT ID 142 ALAM equal production of DOCUMENT ID 143 ALAM equal production of DOCUMENT ID 144 ABREU 145 AKERS 146 BATTLE ALBRECHT 147 AVERY AVERY ION rates for the two in rates for the	90J ARG e T(45). 1002 CLEO 5, fits, limits, etc 94 CLE2 e 96 CLE2 e 97 CLE0 e 98 DLPH e 991 ARG e 918 ARG e 87 CLEO e 87 CLEO e 87 CLEO e 87 CLEO e 88 prode eseparated. L	OMMENT $+e^{-} \rightarrow r(4S)$ $rac{COMMENT}{e^{+}e^{-} \rightarrow r(4S)}$ $e^{+}e^{-} \rightarrow r(4S)$ $e^{+}e^{-} \rightarrow r(4S)$ $e^{+}e^{-} \rightarrow r(4S)$ $e^{+}e^{-} \rightarrow r(4S)$ $he \rightarrow r(4S)$ $rac{COMMENT}{fe^{-} \rightarrow r(4S)}$ $the rac{T}{fe^{-} \rightarrow r(4S)}$ t	
$VALUE$ CO.001 140 Assumes equal Γ (ψ(2S) K* (89) VALUE 0.0014±0.0008 • • We do not <0.0019 <0.0023 141 Assumes equal Γ ($X_{c1}(1P)$ K°) VALUE CO.0027 142 BORTOLETT Γ ($X_{c1}(1P)$ K* (6) VALUE CO.0021 143 BORTOLETT Γ ($X_{c1}(1P)$ K* (6) VALUE CO.0021 143 BORTOLETT Γ ($X_{c1}(1P)$ K* (6) VALUE CO.0021 144 BORTOLETT • • We do not <9 × 10 − 5 <2.6 × 10 − 5 <2.6 × 10 − 5 <3.1 × 10 − 5 <3.2 × 10 − 4 144 Assumes a B ⁰ Contributions weighted avera 145 Assumes B(Z	CL% 90 I production of 2)0)/Ftotal	140 ALBRECHT **F* B* and **B* at the **DOCUMENT II 141 BORTOLLET **Ing data for averages 141 ALAM 141 ALBRECHT **F* B* and *B* D **Ing DOCUMENT ID 142 ALAM equal production of **Ing DOCUMENT ID 143 ALAM equal production of **DOCUMENT ID ASNER **Ing data for averages 144 ABREU 145 AKERS 146 BATTLE ALBRECHT 147 AVERY AVERY ion fraction of 0.39 **B* decays cannot t y rates for the two 17 and *B* B* G* (B* G*)* fra trand *B* G	90J ARG <i>e T</i> (45). TO92 CLEO TO92 CLEO TO94 CLE2 90J ARG T(45). TECN CLE2 94 CLE2 <i>e</i> B+ and B ⁰ at TECN CLE2 96 CLE2 <i>e</i> Hand B ⁰ at TECN CLE2 97 ARG TECN CLE2 98 CLE2 99 ARG TECN CLE2 99 ARG TECN CLE2 99 ARG TECN CLE2 99 ARG 10 A	$\begin{array}{c} \frac{COMMENT}{+e^- \rightarrow r(4S)} \\ \\ \hline \\ \frac{COMMENT}{e^+e^- \rightarrow r(4S)} \\ \\ \frac{e^+e^- \rightarrow r(4S)}{e^+e^- \rightarrow r(4S)} \\ \\ \frac{e^+e^- \rightarrow r(4S)}{e^+e^- \rightarrow r(4S)} \\ \\ \frac{COMMENT}{+e^- \rightarrow r(4S)} \\ \\ \frac{COMMENT}{+e^$	
$VALUE$ CO.001 140 Assumes equal Γ (ψ(2S) K* (89) VALUE 0.0014±0.0008 • • We do not <0.0019 <0.0023 141 Assumes equal Γ ($X_{c1}(1P)$ K°) VALUE CO.0027 142 BORTOLETT Γ ($X_{c1}(1P)$ K* (6) VALUE CO.0021 143 BORTOLETT Γ ($X_{c1}(1P)$ K* (6) VALUE CO.0021 143 BORTOLETT Γ ($X_{c1}(1P)$ K* (6) VALUE CO.0021 144 BORTOLETT • • We do not <9 × 10 − 5 <2.6 × 10 − 5 <2.6 × 10 − 5 <3.1 × 10 − 5 <3.2 × 10 − 4 144 Assumes a B ⁰ Contributions weighted avera 145 Assumes B(Z	CL% 90 I production of 2)0)/Ftotal	140 ALBRECHT **B* + and *B*0 at the **DOCUMENT II 141 BORTOLET Ing data for averages 141 ALAM 141 ALBRECHT **B* + and *B*0 at the **DOCUMENT ID 142 ALAM equal production of **DOCUMENT ID 143 ALAM equal production of **DOCUMENT ID ASNER Ing data for averages 144 ABREU 145 AKERS 146 BATTLE ALBRECHT 147 AVERY AVERY AVERY ion fraction of 0.39 **B*0 decays cannot by rates for the two related to the two relat	90J ARG <i>e T</i> (45). TO92 CLEO TO92 CLEO TO94 CLE2 90J ARG T(45). TECN CLE2 94 CLE2 <i>e</i> B+ and B ⁰ at TECN CLE2 96 CLE2 <i>e</i> Hand B ⁰ at TECN CLE2 97 ARG TECN CLE2 98 CLE2 99 ARG TECN CLE2 99 ARG TECN CLE2 99 ARG TECN CLE2 99 ARG 10 A	$\begin{array}{c} \frac{COMMENT}{+e^- \rightarrow r(4S)} \\ \\ \hline \\ \frac{COMMENT}{e^+e^- \rightarrow r(4S)} \\ \\ \frac{e^+e^- \rightarrow r(4S)}{e^+e^- \rightarrow r(4S)} \\ \\ \frac{e^+e^- \rightarrow r(4S)}{e^+e^- \rightarrow r(4S)} \\ \\ \frac{COMMENT}{+e^- \rightarrow r(4S)} \\ \\ \frac{COMMENT}{+e^$	

$\Gamma(K^0\pi^0)/\Gamma_{\text{total}}$	CLAY	500111				Γ ₆₁ /
^{∕ALUE} <4.0 × 10 ^{−5}	<u>CL%</u> 90	DOCUMENT ID ASNER		TECN CLE2	$e^+e^- \rightarrow$	Υ(45)
$[\Gamma(K^+\pi^-)+\Gamma(\pi^+\pi^-)]$	-11/r.					`
ALUE	')]/' tol	DOCUMENT	ID	TECI		(Г ₆₀ +Г ₉₂)/ ∾т
$1.8^{+0.6}_{-0.5}^{+0.3}_{-0.4}) \times 10^{-5}$	17.2	ASNER	96	CLE	2 e ⁺ e ⁻	→ Υ(45)
• We do not use th		data for average	s, fits,	limits,	etc. • • •	
$2.4^{+0.8}_{-0.7}\pm0.2)\times10^{-5}$		¹⁴⁸ BATTLE		CLE		$\rightarrow \gamma(45)$
⁴⁸ BATTLE 93 assume	s equal prod	duction of $B^0\overline{B}^0$	and <i>E</i>	3+ B-	at $\Upsilon(4S)$.	
$(K^+K^-)/\Gamma_{\text{total}}$						Γ ₆₂ /
<0.4 × 10 ⁻⁵	<u>CL%</u> 90	DOCUMENT ID ASNER		CLE2	$e^+e^- \rightarrow$	Υ(4S)
We do not use th	e following	data for average	s, fits,	limits,	etc. • • •	` '
$< 1.2 \times 10^{-4}$ $< 0.7 \times 10^{-5}$		⁹ ABREU ⁰ BATTLE	95N E		$e^+e^- \rightarrow e^+e^- \rightarrow$	
49 Assumes a <i>B</i> ⁰ , <i>B</i> ⁻						
Contributions from	\mathcal{B}^0 and \mathcal{B}^0_s	decays cannot	be sep	arated	. Limits ar	e given for th
weighted average of 50 BATTLE 93 assumes	the decay r	ates for the two	neutrai	I B me	esons.	
$(K^+ \rho^-)/\Gamma_{\text{total}}$				_	(()	Γ ₆₃ /
ALUE	CL%	DOCUMENT ID	1	TECN	COMMENT	' 63/
<3.5 × 10 ⁻⁵	90	ASNER	96 C	CLE2	$e^+e^- \rightarrow$	Y (45)
$(K^0\pi^+\pi^-)/\Gamma_{\text{total}}$						Γ ₆₄ /
ALUE	CL%	DOCUMENT ID		Imite	COMMENT	
 • We do not use the <4.4 × 10⁻⁴ 	90	ALBRECHT	91E A		etc. • • • • • • • • • • • • • • • • • • •	Υ(45)
$(K^0 \rho^0)/\Gamma_{\text{total}}$. ,
(\rac{\rac{\rac{\rac{\rac{\rac{\rac{	CL%	DOCUMENT ID	7	TECN	COMMENT	Γ ₆₅ /
<3.9 × 10 ⁻⁵	90	ASNER	96 C	CLE2	$e^+e^ \rightarrow$	Υ(4S)
• • We do not use the 3.2×10^{-4}	e following 90	data for average ALBRECHT			etc. • • • $e^+e^- \rightarrow$	Υ(4S)
(3.2×10^{-4}) (5.0×10^{-4})		1 AVERY	91B A		$e^+e^- \rightarrow e^+e^- \rightarrow$	1 (45) Υ(45)
< 0.064	90 15	² AVERY	87 C		$e^+e^- \rightarrow$	r(45)
51 AVERY 89B reports	< 5.8 × 1	0^{-4} assuming t	he Υ (4	4 <i>S</i>) de	cays 43% t	to $B^0\overline{B}^0$. W
52 rescale to 50%. 52 AVERY 87 reports <	. 0.00 2000			- 400/	to 00 00	M/o roccolo t
F00/	. U.UO assu	ming the $\Upsilon(4S)$	decays	5 40%	10 B- B	vve rescale t
50%.	. U.UO assu	ming the $\Upsilon(4S)$	decays	S 40%	10 B - B	
^{50%.} (Κ⁰ f₀(980))/Γ_{total}						Γ ₆₆ /
50%. (<i>Κ⁰ f</i> ₀ (980))/Γ _{total}	CL%	DOCUMENT ID AVERY		ECN		Γ ₆₆ /
50%. (K ⁰ f ₀ (980))/\(\Gamma_{\text{total}}\) (3.6 \times 10^{-4} 63 AVERY 89B reports	<u>CL%</u> 90 15	DOCUMENT ID 3 AVERY	<u>I</u> 89B C	<i>ECN</i>	$\frac{\textit{COMMENT}}{e^+e^-} \rightarrow$	Γ ₆₆ /
50%. (K ⁰ f ₀ (980))/Γ _{total} Δ <i>LUE</i> (3.6 × 10 ⁻⁴ 53 AVERY 89B reports rescale to 50%.	- <u>CL%</u> 90 15 < 4.2 × 1	DOCUMENT ID 3 AVERY	<u>I</u> 89B C	<i>ECN</i>	$\frac{\textit{COMMENT}}{e^+e^-} \rightarrow$	$r_{66}/r_{66}/r_{66}$ To $B^0\overline{B}^0$. We
50%. $(K^0 f_0(980))/\Gamma_{\text{total}}$ 4LUE 33.6 × 10 ⁻⁴ 53 AVERY 89B reports rescale to 50%. $(K^*(892)^+\pi^-)/\Gamma_{\text{total}}$	201% 90 15 < 4.2 × 10	DOCUMENT ID 3 AVERY 0 ⁻⁴ assuming t	<u>7</u> 89B C he	CLEO 15) de	$\frac{COMMENT}{e^+e^-} \rightarrow ecays 43\% t$	$r_{66}/r_{66}/r_{66}$ To $B^0\overline{B}^0$. We
50%. (K ⁰ f ₀ (980))/Γ _{total} ALUE 3.6 × 10 ⁻⁴ 53 AVERY 89B reports rescale to 50%. (K*(892)+π-)/Γ _{total}	- <u>CL%</u> 90 15 < 4.2 × 1	DOCUMENT ID 3 AVERY		<i>ECN</i>	$\frac{\textit{COMMENT}}{e^+e^-} \rightarrow$	Γ ₆₆ /
50%. $(K^0 f_0(980))/\Gamma_{\text{total}}$ 4LUE 3.6 × 10 ⁻⁴ 53 AVERY 89B reports rescale to 50%. $(K^*(892)^+\pi^-)/\Gamma_{\text{total}}$ 4LUE 57.2 × 10 ⁻⁵ • • We do not use the	$-\frac{CL\%}{90}$ 15 < 4.2 × 10 0 tal - $\frac{CL\%}{90}$ 90 e following	DOCUMENT ID AVERY 0-4 assuming t DOCUMENT ID ASNER data for average	7 89β C he Υ(4 96 C s, fits,	CLEO CLEO CLEO CLEO CLE2 limits,	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \\ \text{cays 43\% t} \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ \text{etc.} \bullet \bullet \\ \end{array}$	$\frac{r(4S)}{r(4S)} \approx B^0 \overline{B}^0. \text{ w}$ $\frac{r_{67}}{r_{(4S)}}$
50%. $(K^0 f_0(980))/\Gamma_{\text{total}}$ 44.UE 43.6 × 10 ⁻⁴ 453 AVERY 89B reports rescale to 50%. $(K^*(892)^+\pi^-)/\Gamma_{\text{total}}$ 44.UE 7.7.2 × 10 ⁻⁵ • We do not use the 46.2 × 10 ⁻⁴	$-\frac{CL\%}{90}$ 15 < 4.2 × 10 otal - $\frac{CL\%}{90}$ 90 e following 90	DOCUMENT ID 3 AVERY 0 - 4 assuming t DOCUMENT ID ASNER data for average ALBRECHT	7 898 Che \(\gamma \)	CLEO CLEO CLEO CLE2 Ilmits,	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \\ \text{cays 43\% t} \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ \text{etc.} \bullet \bullet \\ e^+e^- \rightarrow \\ \end{array}$	$\frac{r_{66}/r_{(45)}}{r_{(45)}} \approx 8^0 \overline{B}^0. \text{ w}$ $\frac{r_{67}/r_{(45)}}{r_{(45)}}$
50%. $(K^0 f_0(980))/\Gamma_{\text{total}}$ 4. UE (3.6×10^{-4}) (3.6×10^{-4}) (3.6×10^{-4}) (5.6×10^{-4}) (5.6×10^{-5}) • We do not use the (6.2×10^{-4}) (3.8×10^{-4}) (5.6×10^{-4})	- CL% 90 15 < 4.2 × 1 - CL% 90 e following 90 90 90 15 90 15	DOCUMENT ID 3 AVERY 0 - 4 assuming t DOCUMENT ID ASNER data for average data for AVERY 4 AVERY 5 AVERY	898 C he Υ (4 96 C s, fits, 918 A 898 C 87 C	EECN CLEO 45) de CLE2 limits, ARG CLEO	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \\ \text{cays 43\% t} \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ \text{etc.} \bullet \bullet \\ e^+e^- \rightarrow \\ \end{array}$	r(4S) $r(4S)$ $r(4S)$ $r(4S)$ $r(4S)$ $r(4S)$ $r(4S)$ $r(4S)$
50%. $(K^0f_0(980))/\Gamma_{\text{total}}$ ALUE 3.3.6 × 10 ⁻⁴ 33 AVERY 89B reports rescale to 50%. $(K^*(892)^+\pi^-)/\Gamma_{\text{total}}$ ALUE 5.7.2 × 10 ⁻⁵ • • We do not use the 6.6.2 × 10 ⁻⁴ 3.8.8 × 10 ⁻⁴ 5.6.6 × 10 ⁻⁴ 44 AVERY 89B reports	$\begin{array}{ccc} \frac{CL\%}{90} & 15 \\ < 4.2 \times 1 \\ \\ \text{otal} & \\ \frac{CL\%}{90} & \\ \text{e following} & \\ 90 & 15 \\ 90 & 15 \\ < 4.4 \times 1 \\ \end{array}$	DOCUMENT ID 3 AVERY 0-4 assuming t DOCUMENT ID ASNER data for average ALBRECHT 4 AVERY 5 AVERY 0-4 assuming t	7 89B C he Υ (4 96 C s, fits, 91B A 89B C 87 C	ECN_CLEO LE2 limits, ARG CLEO CLEO	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \\ \text{cays 43\% t} \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ \text{etc.} \bullet \bullet \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ \text{cays 43\% t} \\ \end{array}$	$\Gamma_{66}/$ $r(45)$ $\circ B^0 \overline{B}^0$. W $\Gamma_{67}/$ $r(45)$ $r(45)$ $r(45)$ $r(45)$ $r(45)$ $r(45)$ $\circ B^0 \overline{B}^0$. W
50%. $(K^0 f_0(980))/\Gamma_{total}$ ALUE (3.6×10^{-4}) (3.6×10^{-4}) (3.6×10^{-4}) $(5.6 \times $	$\begin{array}{ccc} \frac{CL\%}{90} & 15 \\ < 4.2 \times 1 \\ \\ \text{otal} & \\ \frac{CL\%}{90} & \\ \text{e following} & \\ 90 & 15 \\ 90 & 15 \\ < 4.4 \times 1 \\ \end{array}$	DOCUMENT ID 3 AVERY 0-4 assuming t DOCUMENT ID ASNER data for average ALBRECHT 4 AVERY 5 AVERY 0-4 assuming t	7 89B C he Υ (4 96 C s, fits, 91B A 89B C 87 C	ECN_CLEO LE2 limits, ARG CLEO CLEO	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \\ \text{cays 43\% t} \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ \text{etc.} \bullet \bullet \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ \text{cays 43\% t} \\ \end{array}$	$\Gamma_{66}/$ $r(45)$ $\circ B^0 \overline{B}^0$. W $\Gamma_{67}/$ $r(45)$ $r(45)$ $r(45)$ $r(45)$ $r(45)$ $r(45)$ $\circ B^0 \overline{B}^0$. W
50%. $(K^0 f_0(980))/\Gamma_{total}$ 44. UE (3.6 × 10 ⁻⁴ 53. AVERY 89B reports rescale to 50%. $(K^*(892)^+\pi^-)/\Gamma_{total}$ 44. UE (7.2 × 10 ⁻⁵ • We do not use the 66.2 × 10 ⁻⁴ 5.6 × 10 ⁻⁴ 5.6 × 10 ⁻⁴ 5.5 × 10 ⁻⁴ 5.5 AVERY 89B reports to 50%. E^{54} 5.5 AVERY 87 reports < to 50%.	20 15 2 4.2 × 10 10 11 11 11 11 11 11 11 11 11 11 11	DOCUMENT ID 3 AVERY 0-4 assuming t DOCUMENT ID ASNER data for average ALBRECHT 4 AVERY 5 AVERY 0-4 assuming t	7 89B C he Υ (4 96 C s, fits, 91B A 89B C 87 C	ECN_CLEO LE2 limits, ARG CLEO CLEO	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \\ \text{cays 43\% t} \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ \text{etc.} \bullet \bullet \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ \text{cays 43\% t} \\ \end{array}$	$\Gamma_{66}/$ $T(4S)$ to $B^0\overline{B}^0$. W $\Gamma_{67}/$ $T(4S)$
50%. $(K^0 f_0(980))/\Gamma_{\text{total}}$ 4. UE (3.6×10^{-4}) (3.6×10^{-4}) (3.6×10^{-4}) (3.6×10^{-4}) (5.6×10^{-5}) (4.0×10^{-5}) (5.6×10^{-4}) $(5.$	20 15 2 4.2 × 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	DOCUMENT ID 3 AVERY 0-4 assuming th DOCUMENT ID ASNER data for average ALBRECHT 4 AVERY 5 AVERY 0-4 assuming the T	96 Cs, fits, 918 A 898 C 87 C he γ(4)	CLEO CLE2 limits, ARG CLEO CLEO CLEO CLEO CLEO CLEO CLEO CLEO	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \\ \mathrm{ccays} \ 43\% \ \mathrm{t} \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ \mathrm{etc.} \bullet \bullet \bullet \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ \mathrm{cays} \ 43\% \ \mathrm{t} \\ \mathrm{10\% \ to} \ B^0 \overline{I} \\ \end{array}$	$r_{66}/r_{(45)}$ $r_{(45)}$ $r_{67}/r_{(45)}$ $r_{(45)}$ $r_{(45)}$ $r_{(45)}$ $r_{(45)}$ $r_{(45)}$ $r_{(45)}$ $r_{(45)}$
50%. $(K^0f_0(980))/\Gamma_{\text{total}}$ 44.UE 33.4 × 10 ⁻⁴ 33 AVERY 89B reports rescale to 50%. $(K^*(892)^+\pi^-)/\Gamma_{\text{total}}$ 44.UE 7.2 × 10 ⁻⁵ • We do not use the 6.2 × 10 ⁻⁴ 3.8 × 10 ⁻⁴ 5.6 × 10 ⁻⁴ 5.6 × 10 ⁻⁴ 5.6 × 10 ⁻⁵ 5.6 × 10 ⁻⁵ 6.7 × 10 ⁻⁵ 6.8 × 10 ⁻⁶ 6.9	20 15 2 4.2 × 10 10 11 11 11 11 11 11 11 11 11 11 11	DOCUMENT ID 3 AVERY 0-4 assuming t DOCUMENT ID ASNER data for average ALBRECHT 4 AVERY 5 AVERY 0-4 assuming t	898 C 687 C 645) de	ECN_CLEO LE2 limits, ARG CLEO CLEO	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \\ \text{cays 43\% t} \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ \text{etc.} \bullet \bullet \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ \text{cays 43\% t} \\ \end{array}$	$r(4s)$ to $B^0 \overline{B}^0$. W $r(4s)$
50%. (K ⁰ f ₀ (980))/Γ _{total} ALUE 3.3.6 × 10 ⁻⁴ 33 AVERY 89B reports rescale to 50%. (K*(892)+π-)/Γ _{tot} ALUE 5.6 × 10 ⁻⁴ 3.8 × 10 ⁻⁴ 5.6 × 10 ⁻⁴ 4.3.8 × 10 ⁻⁴ 5.5 × 10 ⁻⁴ 5.5 × 10 ⁻⁴ 5.6 × 10 ⁻⁴ 5.7 × 10 ⁻⁴ 5.8 × 10 ⁻⁴ 5.9 × 10 ⁻⁴ 5.9 × 10 ⁻⁴ 5.9 × 10 ⁻⁴ 5.0	$\begin{array}{c} \frac{CL\%}{90} & 15 \\ < 4.2 \times 1 \\ \end{array}$ example 1 cti cti s s s s s s s s s s	DOCUMENT ID 3 AVERY 0-4 assuming t DOCUMENT ID ASNER data for average ALBRECHT 4 AVERY 5 AVERY 0-4 assuming t assuming the T	898 C 687 C 645) de	CLEO CLEO CLEO CLEO CLEO CLEO CLEO CLEO	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \\ \mathrm{ccays} \ 43\% \ \mathrm{t} \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ \mathrm{ccays} \ 43\% \ \mathrm{t} \\ 10\% \ \mathrm{to} \ B^0 \overline{I} \\ \\ \underline{COMMENT} \\ \\ \underline{COMMENT} \\ \end{array}$	r(4s) $r(4s)$
50%. $(K^0 f_0(980))/\Gamma_{\text{total}}$ 44.UE 33.6 × 10 ⁻⁴ 53 AVERY 89B reports rescale to 50%. $(K^*(892)^+\pi^-)/\Gamma_{\text{total}}$ 44.UE 77.2 × 10 ⁻⁵ • We do not use the 6.2 × 10 ⁻⁴ 43.8 × 10 ⁻⁴ 45.6 × 10 ⁻⁴ 54 AVERY 89B reports rescale to 50%. $(K^*(892)^0\pi^0)/\Gamma_{\text{total}}$ 4.UE (K*(892) $^0\pi^0$)/ Γ_{total} 4.UE 12.2.8 × 10 ⁻⁵ $(K^*_2(1430)^+\pi^-)/\Gamma_{\text{total}}$	$\begin{array}{c} \frac{CL\%}{90} & 15 \\ < 4.2 \times 1 \\ \end{array}$ example 1 cti cti s s s s s s s s s s	DOCUMENT ID 3 AVERY 0-4 assuming t DOCUMENT ID ASNER data for average ALBRECHT 4 AVERY 5 AVERY 0-4 assuming t assuming the T		CLEO CLEO CLEO CLEO CLEO CLEO CLEO CLEO	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \\ \mathrm{ccays} \ 43\% \ \mathrm{t} \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ \mathrm{ccays} \ 43\% \ \mathrm{t} \\ 10\% \ \mathrm{to} \ B^0 \overline{I} \\ \\ \underline{COMMENT} \\ \\ \underline{COMMENT} \\ \end{array}$	$r(4s)$ to $B^0 \overline{B}^0$. W $r(4s)$
50%. $(K^0 f_0(980))/\Gamma_{\text{total}}$ 44.UE 33.6 × 10 ⁻⁴ 53 AVERY 89B reports rescale to 50%. $(K^*(892)^+\pi^-)/\Gamma_{\text{total}}$ 44.UE 77.2 × 10 ⁻⁵ • We do not use the 6.2 × 10 ⁻⁴ 43.8 × 10 ⁻⁴ 45.6 × 10 ⁻⁴ 54 AVERY 89B reports rescale to 50%. $(K^*(892)^0\pi^0)/\Gamma_{\text{total}}$ 4.UE (K*(892) $^0\pi^0$)/ Γ_{total} 4.UE 12.2.8 × 10 ⁻⁵ $(K^*_2(1430)^+\pi^-)/\Gamma_{\text{total}}$	$\begin{array}{c} \frac{CL\%}{90} & 15 \\ < 4.2 \times 1 \\ \end{array}$ that $\begin{array}{c} \frac{CL\%}{90} & 90 \\ = \text{following} \\ 90 & 15 \\ 90 & 15 \\ \\ 7 \times 10^{-4} \\ \end{array}$ al $\begin{array}{c} \frac{CL\%}{90} & 90 \\ = \frac{CL\%}{90} &$	DOCUMENT ID 3 AVERY 0 - 4 assuming t DOCUMENT ID ASNER data for average ALBRECHT 4 AVERY 5 AVERY 0 - 4 assuming t assuming the T DOCUMENT ID ASNER		CLEO CLEO CLEO CLEO CLEO CLEO CLEO CLEO	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \\ \mathrm{ccays} \ 43\% \ \mathrm{t} \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ \mathrm{ccays} \ 43\% \ \mathrm{t} \\ 10\% \ \mathrm{to} \ B^0 \overline{I} \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ COMMEN$	$r(4s)$ to $s^0 \overline{s}^0$. W $r(4s)$
50%. $(K^0 f_0(980))/\Gamma_{\text{total}}$ 44.UE 33.6 × 10 ⁻⁴ 53 AVERY 89B reports rescale to 50%. $(K^*(892)^+\pi^-)/\Gamma_{\text{total}}$ 44.UE 7.7.2 × 10 ⁻⁵ • We do not use the 4.3.8 × 10 ⁻⁴ 4.3.8 × 10 ⁻⁴ 4.5.6 × 10 ⁻⁴ 5.6 AVERY 89B reports rescale to 50%. $(K^*(892)^0\pi^0)/\Gamma_{\text{total}}$ 4.UE (2.8 × 10 ⁻⁵ $(K^*(892)^0\pi^0)/\Gamma_{\text{total}}$ 4.UE (2.8 × 10 ⁻⁵ $(K^*(1430)^+\pi^-)/\Gamma_{\text{total}}$ 4.UE (2.6 × 10 ⁻³	$\begin{array}{c} \frac{CL\%}{90} & 15 \\ < 4.2 \times 1 \\ \end{array}$ etal. $\begin{array}{c} \frac{CL\%}{90} \\ 90 & 15 \\ 90 & 15 \\ 90 & 15 \\ < 4.4 \times 10 \\ 7 \times 10^{-4} \\ \end{array}$ al. $\begin{array}{c} \frac{CL\%}{90} \\ 90 & 15 \\ \end{array}$ betal. $\begin{array}{c} \frac{CL\%}{90} \\ 0 & 10 \\ \end{array}$	DOCUMENT ID 3 AVERY 0 - 4 assuming t DOCUMENT ID ASNER data for average ALBRECHT 4 AVERY 5 AVERY 0 - 4 assuming t assuming the T DOCUMENT ID ASNER		CLEO CLEO CLEO CLEO CLEO CLEO CLEO CLEO	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \\ \mathrm{ccays} \ 43\% \ \mathrm{t} \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ \mathrm{ccays} \ 43\% \ \mathrm{t} \\ 10\% \ \mathrm{to} \ B^0 \overline{I} \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ \underline{COMMENT} \\ \\ \\ \underline{COMMENT} \\ \\ COMM$	$r(4s)$ to $s^0 \overline{s}^0$. W $r(4s)$
50%. $(K^0 f_0(980))/\Gamma_{\text{total}}$ ALUE 33 AVERY 89B reports rescale to 50%. $(K^*(892)^+\pi^-)/\Gamma_{\text{total}}$ ALUE 7.7.2 × 10 ⁻⁵ • We do not use the 6.2 × 10 ⁻⁴ 43.8 × 10 ⁻⁴ 5.6 × 10 ⁻⁴ 5.4 AVERY 89B reports rescale to 50%. $(K^*(892)^0\pi^0)/\Gamma_{\text{total}}$ ALUE $(K^*(892)^0\pi^0)/\Gamma_{\text{total}}$ $(K^*(892)^0\pi^0)/\Gamma_{\text{total}}$ $(K^*(892)^0\pi^0)/\Gamma_{\text{total}}$ $(K^*(892)^0\pi^0)/\Gamma_{\text{total}}$ $(K^*(892)^0\pi^0)/\Gamma_{\text{total}}$	$\begin{array}{c} \frac{CL\%}{90} & 15 \\ < 4.2 \times 1 \\ \end{array}$ otal $\begin{array}{c} \frac{CL\%}{90} \\ 90 & 15 \\ 90 & 15 \\ < 4.4 \times 1 \\ 7 \times 10 - 4 \\ \end{array}$ al $\begin{array}{c} \frac{CL\%}{90} \\ 90 & 15 \\ < 4.4 \times 1 \\ \end{array}$ otal $\begin{array}{c} \frac{CL\%}{90} \\ \frac{CL\%}{90} \\ \end{array}$	DOCUMENT ID 3 AVERY 0 — 4 assuming t DOCUMENT ID ASNER data for average ALBRECHT 4 AVERY 5 AVERY 0 — 4 assuming the 7 DOCUMENT ID ASNER DOCUMENT ID ALBRECHT ALBRECHT DOCUMENT ID ALBRECHT DOCUMENT ID ALBRECHT DOCUMENT ID		CLEO LEO LEO LEO LEO LEO LEO LEO LEO LEO	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \\ \mathrm{ccays} \ 43\% \ \mathrm{t} \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ \mathrm{ccays} \ 43\% \ \mathrm{t} \\ 10\% \ \mathrm{to} \ B^0 \overline{I} \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ \\ \underline{COMMENT}	Γ_{66}/Γ_{1} Γ_{1} Γ_{1} Γ_{1} Γ_{1} Γ_{2} Γ_{1} Γ_{2} Γ_{3} Γ_{4} Γ_{4} Γ_{4} Γ_{5} Γ_{5} Γ_{68}/Γ_{5} Γ_{69}/Γ_{5} Γ_{50}/Γ_{50}
50%. $(K^0 f_0(980))/\Gamma_{\text{total}}$ 44.UE 33.6 × 10 ⁻⁴ 53 AVERY 89B reports rescale to 50%. $(K^*(892)^+\pi^-)/\Gamma_{\text{total}}$ 44.UE 77.2 × 10 ⁻⁵ • We do not use the 6.2 × 10 ⁻⁴ 43.8 × 10 ⁻⁴ 45.6 × 10 ⁻⁴ 54.AVERY 89B reports 57 rescale to 50%. $(K^*(892)^0\pi^0)/\Gamma_{\text{total}}$ 4.UE 22.8 × 10 ⁻⁵ $(K^*(892)^0\pi^0)/\Gamma_{\text{total}}$ 4.UE 22.6 × 10 ⁻³ $(K^0K^+K^-)/\Gamma_{\text{total}}$ 4.UE 21.3 × 10 ⁻³	$\begin{array}{c} \frac{CL\%}{90} & 15 \\ < 4.2 \times 1 \\ \end{array}$ example of the second of the	DOCUMENT ID 3 AVERY 0 - 4 assuming t DOCUMENT ID ASNER data for average ALBRECHT 4 AVERY 5 AVERY 0 - 4 assuming the T DOCUMENT ID ASNER DOCUMENT ID ALBRECHT		CLEO LEO LEO LEO LEO LEO LEO LEO LEO LEO	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \\ \mathrm{ccays} \ 43\% \ \mathrm{t} \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ \mathrm{ccays} \ 43\% \ \mathrm{t} \\ 10\% \ \mathrm{to} \ B^0 \overline{I} \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ \\ \underline{COMMENT}	$r(4s)$ to $B^0\overline{B^0}$. W $r(4s)$
50%. $(K^0 f_0(980))/\Gamma_{\text{total}}$ 44.UE 33.6 × 10 ⁻⁴ 53 AVERY 89B reports rescale to 50%. $(K^*(892)^+\pi^-)/\Gamma_{\text{total}}$ 44.UE 77.2 × 10 ⁻⁵ • We do not use the 6.2 × 10 ⁻⁴ 43.8 × 10 ⁻⁴ 45.6 × 10 ⁻⁴ 55.6 AVERY 89B reports 55 AVERY 87 reports < to 50%. $(K^*(892)^0\pi^0)/\Gamma_{\text{total}}$ 44.UE 22.8 × 10 ⁻⁵ $(K^*(1430)^+\pi^-)/\Gamma_{\text{total}}$ 46.6 × 10 ⁻³ $(K^0K^+K^-)/\Gamma_{\text{total}}$ 47.1.3 × 10 ⁻³ $(K^0\phi)/\Gamma_{\text{total}}$	$\begin{array}{c} \frac{CL\%}{90} & 15 \\ < 4.2 \times 1 \\ \end{array}$ ortal $\begin{array}{c} \frac{CL\%}{90} \\ 90 & 15 \\ 90 & 15 \\ < 4.4 \times 1 \\ 7 \times 10^{-4} \\ \end{array}$ al $\begin{array}{c} \frac{CL\%}{90} \\ 90 \\ \end{array}$ total $\begin{array}{c} \frac{CL\%}{90} \\ 90 \\ \end{array}$ or $\begin{array}{c} \frac{CL\%}{90} \\ 90 \\ \end{array}$	DOCUMENT ID 3 AVERY 0 — 4 assuming t DOCUMENT ID ASNER data for average ALBRECHT 4 AVERY 5 AVERY 0 — 4 assuming the 7 DOCUMENT ID ASNER DOCUMENT ID ALBRECHT DOCUMENT ID ALBRECHT DOCUMENT ID ALBRECHT		CLEO LLEO LLEO LLEO LLEO LLEO LLEO LLEO	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \\ \mathrm{ccays} \ 43\% \ \mathrm{t} \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ \mathrm{ccays} \ 43\% \ \mathrm{t} \\ 10\% \ \mathrm{to} \ B^0 \overline{I} \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ \\ \underline{COMMENT} \\ e^+e^- $	Γ_{66}/Γ_{1} Γ_{1} Γ_{1} Γ_{1} Γ_{1} Γ_{2} Γ_{1} Γ_{2} Γ_{3} Γ_{4} Γ_{4} Γ_{4} Γ_{5} Γ_{5} Γ_{68}/Γ_{5} Γ_{69}/Γ_{5} Γ_{50}/Γ_{50}
50%. $(K^0 f_0(980))/\Gamma_{\text{total}}$ ALUE $(3.6 \times 10^{-4} \times 10^{-4})$ $(3.6 \times 10^{-4} \times 10^{-4})$ $(4.6 \times 10^{-4} \times 10^{-4})$ ALUE $(7.2 \times 10^{-5} \times 10^{-4} \times 10^{-4})$ $(5.6 \times 10^{-4} \times 10^{-4} \times 10^{-4} \times 10^{-4})$ $(5.6 \times 10^{-4} \times 10^{-4} \times 10^{-4} \times 10^{-4})$ $(6.2 \times 10^{-4} \times 10^{-4} \times 10^{-4})$ $(6.3 \times 10^{-5} \times 10^{-5} \times 10^{-5})$ $(6.3 \times 10^{-5} \times 10^{-5})$ $(6.3 \times 10^{-5} \times 10^{-5} \times 10^{-5})$ $(6$	$\begin{array}{c} \frac{CL\%}{90} & 15 \\ < 4.2 \times 1 \\ \\ \frac{CL\%}{90} & \\ 0 & \\ \frac{CL\%}{90} & \\ 90 & 15 \\ 90 & 15 \\ < 4.4 \times 1 \\ 7 \times 10^{-4} \\ \\ \frac{CL\%}{90} & \\ \\ $	DOCUMENT ID 3 AVERY 0 — 4 assuming t DOCUMENT ID ASNER data for average ALBRECHT 4 AVERY 5 AVERY 0 — 4 assuming the 7 DOCUMENT ID ASNER DOCUMENT ID ALBRECHT		CLEO AS) de EECN LLE2 ASS) de EECN LLE2 ARG LLE2 ARG LLE2 ARG LLE2 ARG ARG	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \\ \mathrm{ccays} \ 43\% \ \mathrm{t} \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ \mathrm{ccays} \ 43\% \ \mathrm{t} \\ 10\% \ \mathrm{to} \ B^0 \overline{I} \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ \underline{COMMENT} \\ \\$	$\Gamma_{66}/\Gamma_{(45)}$ $r_{(45)}$
50%. $(K^0 f_0(980))/\Gamma_{\text{total}}$ 44.UE 53 AVERY 89B reports rescale to 50%. $(K^*(892)^+\pi^-)/\Gamma_{\text{total}}$ 43.8 × 10 ⁻⁴ 53.8 × 10 ⁻⁴ 53.8 × 10 ⁻⁴ 54.0 × 10 ⁻⁴ 55.6 × 10 ⁻⁴ 55.6 × 10 ⁻⁴ 55.6 AVERY 89B reports rescale to 50%. $(K^*(892)^0\pi^0)/\Gamma_{\text{total}}$ 40.E $(K^*(892)^0\pi^0)/\Gamma_{\text{total}}$ 40.E $(K^0K^+K^-)/\Gamma_{\text{total}}$ 40.E $(K^0K^+K^-)/\Gamma_{\text{total}}$ 40.E $(K^0K^-K^-)/\Gamma_{\text{total}}$ 40.E $(K^0K^-K^-K^-)/\Gamma_{\text{total}}$	$\begin{array}{c} \frac{CL\%}{90} & 15 \\ < 4.2 \times 1 \\ \end{array}$ stal $\begin{array}{c} \frac{CL\%}{90} \\ 90 & 15 \\ 90 & 15 \\ 90 & 15 \\ < 4.4 \times 1 \\ 7 \times 10^{-4} \\ \end{array}$ al $\begin{array}{c} \frac{CL\%}{90} \\ 90 \\ \end{array}$ stotal $\begin{array}{c} \frac{CL\%}{90} \\ 90 \\ \end{array}$ stotal $\begin{array}{c} \frac{CL\%}{90} \\ 90 \\ \end{array}$	DOCUMENT ID ASNER DOCUMENT ID ASNER ASNER ALBRECHT AVERY DOCUMENT ID ASNER DOCUMENT ID ASNER DOCUMENT ID ALBRECHT ALBRECHT DOCUMENT ID ALBRECHT DOCUMENT ID ALBRECHT DOCUMENT ID ASNER		CLE2 CLE2 CLEO 45) de CLE2 Climits, ARG CLEO 45) de ccays 4 CLE2 CLE2 CLE2 CLE2 CLEC CLEC CLEC CLEC	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \\ cays \ 43\% \ t \\ \hline \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ cays \ 43\% \ t \\ 10\% \ to \ B^0 \ \overline{t} \\ \hline \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ \underline{COMMENT} \\ e^+$	$r(4s)$ to $s^0 \overline{s}^0$. W $r(4s)$
50%. $(K^0 f_0(980))/\Gamma_{\text{total}}$ 44.UE 33.6 × 10 ⁻⁴ 53 AVERY 89B reports rescale to 50%. $(K^*(892)^+\pi^-)/\Gamma_{\text{total}}$ 44.UE 77.2 × 10 ⁻⁵ • We do not use the 6.2 × 10 ⁻⁴ 43.8 × 10 ⁻⁴ 45.6 × 10 ⁻⁴ 45.6 × 10 ⁻⁴ 55 AVERY 89B reports to 50%. $(K^*(892)^0\pi^0)/\Gamma_{\text{total}}$ 44.UE 22.8 × 10 ⁻⁵ $(K^*_2(1430)^+\pi^-)/\Gamma_{\text{total}}$ 44.UE 21.3 × 10 ⁻³ $(K^0 K^+ K^-)/\Gamma_{\text{total}}$ 44.UE 21.3 × 10 ⁻³ $(K^0 \phi)/\Gamma_{\text{total}}$ 44.UE 21.8 × 10 ⁻⁵ • We do not use the 6.7.2 × 10 ⁻⁴	$\begin{array}{c} \frac{CL\%}{90} & 15 \\ < 4.2 \times 1 \\ \end{array}$ otal $\begin{array}{c} \frac{CL\%}{90} \\ 90 & 15 \\ 90 & 15 \\ 90 & 15 \\ < 4.4 \times 1 \\ 7 \times 10 - 4 \\ \end{array}$ al $\begin{array}{c} \frac{CL\%}{90} \\ 90 & \\ \end{array}$ total $\begin{array}{c} \frac{CL\%}{90} \\ 90 & \\ \end{array}$ c $\begin{array}{c} \frac{CL\%}{90} \\ 90 & \\ \end{array}$ o $\begin{array}{c} \frac{CL\%}{90} \\ 90 & \\ \end{array}$ e $\begin{array}{c} \frac{CL\%}{90} \\ 90 & \\ \end{array}$ e $\begin{array}{c} \frac{CL\%}{90} \\ 90 & \\ \end{array}$ o $\begin{array}{c} \frac{CL\%}{90} \\ 90 & \\ \end{array}$	DOCUMENT ID ASNER data for average ALBRECHT ASNER AVERY ALBRECHT AVERY DO-4 assuming the T DOCUMENT ID ASNER DOCUMENT ID ALBRECHT ALBRECHT DOCUMENT ID ALBRECHT DOCUMENT ID ALBRECHT DOCUMENT ID ALBRECHT DOCUMENT ID ALBRECHT ASNER data for average ALBRECHT		CLEO LLEO LLEO LLEO LLEO LLEO LLEO LLEO	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \\ \mathrm{ccays} \ 43\% \ \mathrm{t} \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ \mathrm{ccays} \ 43\% \ \mathrm{t} \\ 10\% \ \mathrm{to} \ B^0 \overline{I} \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ \\ \underline{COMMENT} \\ e^+e^- $	r(4s) $r(4s)$
50%. (K^0 f ₀ (980))/ Γ total ALUE (3.6 × 10 ⁻⁴ 53 AVERY 89B reports rescale to 50%. (K^* (892)+ π -)/ Γ total ALUE (7.2 × 10 ⁻⁵ • We do not use the (5.2 × 10 ⁻⁴ (3.8 × 10 ⁻⁴ (5.6 × 10 ⁻⁴ 54 AVERY 89B reports rescale to 50%.	CL% 90 15	DOCUMENT ID ASNER DOCUMENT ID ASSUMING t ASVERY DOCUMENT ID ASSUMING t ASVERY DOCUMENT ID ASNER DOCUMENT ID ASNER DOCUMENT ID ALBRECHT DOCUMENT ID ALBRECHT DOCUMENT ID ALBRECHT DOCUMENT ID ASNER		CLEO CLEO AS) de CLEO CLEO CLEO CLEO CLEO CLEO CLEO CLEO	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \\ cays \ 43\% \ t \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ e^+e^- \rightarrow \\ cays \ 43\% \ t \\ 10\% \ to \ B^0 \ \overline{I} \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ \\ COMMENT$	Γ_{66}/Γ_{14} Γ_{14}

Γ (Κ -π+π+π-)/Γ	total	DOCUMENT ID TECN CO.	Г ₇₂ /Г _{ммент}	Γ(<i>K</i> ₁ (1270) ⁰ γ)/Γ _{total}	DOCUMENT ID	TECN	COMMENT	Γ ₈₅ /Ι
<2.1 × 10 ⁻⁴		158 ABREU 95N DLPH e+	•	<0.0070	90	167 ALBRECHT	89G ARG	$e^+e^- \rightarrow \gamma$	r(45)
		on fraction of 0.39 and a B_S produ		167 ALBRECHT	89G reports <	0.0078 assuming th	e $\Upsilon(4S)$ de		
Contributions from	B^0 and B	$s^0_{m s}$ decays cannot be separated. Li	mits are given for the	rescale to 50	%.			-	
		rates for the two neutral B meson	s.	$\Gamma(K_1(1400)^0\gamma$)/r _{total}				Γ ₈₆ /
$(K^*(892)^0\pi^+\pi^-)$	$/\Gamma_{total}$		Γ ₇₃ /Γ	VALUE	CL%	DOCUMENT ID	TECN	COMMENT	
ALUE	CL%_		MMENT	<0.0043	90		89G ARG	$e^+e^- \rightarrow \gamma$	` '
<1.4 × 10 ⁻³	90	ALBRECHT 91E ARG e+	$e^- \rightarrow \Upsilon(45)$	¹⁶⁸ ALBRECHT rescale to 50°	89G reports <	0.0048 assuming th	e $\Upsilon(4S)$ de	cays 45% to	$B^0\overline{B}^0$. W
$(K^*(892)^0 \rho^0)/\Gamma_{to}$	otal		Γ ₇₄ /Γ						
ALUE	CL%		MMENT	Γ(K ₂ *(1430) ⁰ γ	-				Γ ₈₇ /
<4.6 × 10 ⁻⁴	90		$e^- \rightarrow \gamma(4S)$	VALUE <4.0 × 10 ⁻⁴	<u>CL%</u>	DOCUMENT ID	TECN		
$< 5.8 \times 10^{-4}$		g data for averages, fits, limits, etc. 159 AVERY 89B CLEO e^+			90	169 ALBRECHT	89G ARG	$e^+e^- \rightarrow \gamma$, ,
$< 9.6 \times 10^{-4}$		160 AVERY 87 CLEO e+		rescale to 50°		4.4×10^{-4} assuming	the T(45)	decays 45% to	<i>B⁰B⁰</i> . W
		10^{-4} assuming the $\Upsilon(4S)$ decays	` '	F(1/#/1/00)0	\ /=				- /
rescale to 50%		$^{-3}$ assuming the $\varUpsilon(4S)$ decays 40%		Γ(Κ* (1680) ⁰ ງ	/)/	DOCUMENT ID	TECN	COMMENT	Γ ₈₈ /
to 50%.	< 1.2 × 10	assuming the 7 (43) decays 40%	to B - B We rescale	<0.0020	90	170 ALBRECHT	89G ARG	$e^+e^- \rightarrow \gamma$	r(45)
(K*(892) ⁰ f ₀ (980)	١/٣		Γ ₇₅ /Γ			< 0.0022 assuming th			. ,
(N (092) 10(900)	// total 	DOCUMENT IDTECNCO		rescale to 50°		COULT DISTINING LI	c 7 (+3) dc	cays 4570 to	<i>D D</i> . •••
<1.7 × 10 ⁻⁴		161 AVERY 898 CLEO e^+		Γ(K ₃ *(1780) ⁰ γ	/) /F				Г89/
		10^{-4} assuming the $\Upsilon(4S)$ decays	, ,	VALUE	CL%	DOCUMENT ID	TECN	COMMENT	' 89/
rescale to 50%.		, , ,		<0.010	90	171 ALBRECHT	89G ARG		r(45)
$(K_1(1400)^+\pi^-)/$	Γ _{total}		Γ ₇₆ /Γ		89G reports <	0.011 assuming the $ au$	(45) decays	45% to $B^0\overline{B}{}^0$. We resca
ALUE	CL%		MMENT	to 50%.		-			
<1.1 × 10 ⁻³	90	ALBRECHT 91B ARG e ⁺	$e^- \rightarrow \Upsilon(4S)$	Γ(Κ *(2045) ⁰ γ	/)/F _{total}				Γ ₉₀ /
$(K^-a_1(1260)^+)/$	[total		Γ ₇₇ /Γ	VALUE	CL%_	DOCUMENT ID	TECN	COMMENT	
ALUE	CL%	DOCUMENT ID TECN CO.		<0.0043	90	¹⁷² ALBRECHT	89G ARG	$e^+e^- \rightarrow \gamma$	r(45)
(3.9 × 10 ⁻⁴	90	162 ABREU 95N DLPH e+	$e^- \rightarrow Z$			0.0048 assuming th	e γ(4 <i>S</i>) de	cays 45% to	$B^0 \overline{B}^0$. V
⁶² Assumes a B ⁰ , B ⁻	_ producti	on fraction of 0.39 and a $B_{\rm S}$ produ	ction fraction of 0.12.	rescale to 50°	%.				
Contributions from	B^0 and B	$3_{ m c}^0$ decays cannot be separated. Li	mits are given for the	$\Gamma(\phi\phi)/\Gamma_{ m total}$					Г91/
		rates for the two neutral B meson	s.	VALUE	CL%	DOCUMENT ID	TECN	COMMENT	
(K*(892)0 K+K-	$)/\Gamma_{total}$		Γ ₇₈ /Γ	<3.9 × 10 ⁻⁵	90	ASNER	96 CLE2	$e^+e^- \rightarrow \gamma$	r(45)
ALUE	CL%	DOCUMENT ID TECN CO.	MMENT	$\Gamma(\pi^+\pi^-)/\Gamma_{\rm tot}$	tal .				Γ ₉₂ /
<6.1 × 10 ⁻⁴	90	ALBRECHT 91E ARG e ⁺	$e^- \rightarrow \Upsilon(4S)$	VALUE	<u>CL%EVTS</u>	DOCUMENT ID	TECN	COMMENT	. 92/
$(K^*(892)^0 \phi) / \Gamma_{\text{tot}}$	-ni		Γ ₇₉ /Γ	<2.0 × 10 ⁻⁵	90	ASNER	96 CLE2	$e^+e^- \rightarrow \gamma$	r(45)
ALUE	CL%_	DOCUMENT ID TECN CO.	MMENT	• • • We do not	t use the follow	ving data for averages	, fits, limits,	etc. • • •	
<4.3 × 10 ⁻⁵	90	ASNER 96 CLE2 e ⁺		$< 5.5 \times 10^{-5}$	90	173 ABREU	95N DLPH		
	he followin	g data for averages, fits, limits, etc.		$<4.7 \times 10^{-5}$	90	¹⁷⁴ AKERS ¹⁷⁵ BATTLE	94L OPAL	$e^+e^- \rightarrow Z$	
$< 3.2 \times 10^{-4}$	90		$e^- \rightarrow \gamma(4S)$	$<2.9 \times 10^{-5}$ $<1.3 \times 10^{-4}$	90 90	175 ALBRECHT	93 CLE2 90B ARG		r(45) r(45)
$<3.8 \times 10^{-4}$ $<3.8 \times 10^{-4}$		163 AVERY 89B CLEO e^+		$< 7.7 \times 10^{-5}$	90	¹⁷⁶ BORTOLETTO			r(45)
		10^{-4} assuming the $\Upsilon(4S)$ decays	* *	$< 2.6 \times 10^{-4}$	90	¹⁷⁶ BEBEK	87 CLEO		r(45)
rescale to EO%		- , , .		<5 × 10 ⁻⁴	90 4	GILES		$e^+e^- \rightarrow \gamma$	
to 50%.	$< 4.7 \times 10^{\circ}$	$^{-4}$ assuming the $ \varUpsilon (4S)$ decays 40%	to $B^{0}\overline{B}^{0}$. We rescale	173 Assumes a B	0 , $^{-}$ produc	tion fraction of 0.39 a	nd a B_S pro	duction fraction	on of 0.12.
			_ ,_	174 Assumes B(Z	$(a \rightarrow bb) = 0$	217 and B_d^0 (B_s^0) fra	ction 39.5%	(12%).	
$(K_1(1400)^0 \rho^0)/\Gamma_0$			Γ ₈₀ /Γ			of $B^0 \overline{B}{}^0$ and $B^+ B^-$		+- FO9/	
<3.0 × 10 ⁻³	<u>CL%</u>		$e^- \rightarrow \Upsilon(4S)$			decays 43% to $B^0\overline{B}^0$. vve rescale	ιυ 5U%.	
	90	ALBRECHT 91B ARG e ⁺	c → 1(45)	$\Gamma(\pi^0\pi^0)/\Gamma_{ m tota}$	al				Γ ₉₃ /
$(K_1(1400)^0 \phi)/\Gamma_{tc}$	otal		Г ₈₁ /Г	VALUE	<u>CL%</u>	DOCUMENT ID		COMMENT	
ALUE	CL%		MMENT	<0.91 × 10 ⁻⁵	90 tuse the follow	ASNER		$e^+e^- \rightarrow \gamma$	r(45)
<5.0 × 10 ⁻³	90	ALBRECHT 91B ARG e+	$e^- \rightarrow \Upsilon(4S)$		use the follow	ving data for averages ¹⁷⁷ ACCIARRI		$e^+e^- \rightarrow Z$	7
$(K_2^*(1430)^0 \rho^0)/\Gamma$	total		Γ ₈₂ /Γ	<6.0 × 10 ⁻⁵			95H L3		1
ALUE	CL%	DOCUMENT ID TECN CO	MMENT	*** ACCIARRI 95	он assumes f _B	$_0 = 39.5 \pm 4.0$ and f	$B_s = 12.0 \pm$	3.U%.	
<1.1 × 10 ⁻³	90	ALBRECHT 918 ARG e^{\pm}	$e^- \rightarrow \Upsilon(4S)$	$\Gamma(\eta \pi^0)/\Gamma_{\text{total}}$					Г94/
$(K_2^*(1430)^0 \phi)/\Gamma_{\rm to}$	-4-1		Г ₈₃ /Г	VALUE	CL%	DOCUMENT ID	TECN	COMMENT	· 74 /
(**2(***30) Ψ)/ to ALUE	otal <u>CL%_</u>	DOCUMENT ID TECN CO.	I 83/I MMENT	<2.5 × 10 ⁻⁴	90	178 ACCIARRI	95H L3	$e^+e^- \rightarrow Z$?
<1.4 × 10 ⁻³	90		$e^- \rightarrow \Upsilon(4S)$	• • • We do not	t use the follow	ving data for averages	., fits, limits,	etc. • • •	
				$< 1.8 \times 10^{-3}$	90	¹⁷⁹ ALBRECHT	90в ARG		r(45)
$(K^*(892)^0\gamma)/\Gamma_{\text{tot}}$			Γ ₈₄ /Γ	¹⁷⁸ ACCIARRI 9	5н assumes f _R	$_0=39.5\pm4.0$ and t	B _s = 12.0 ±	3.0%.	
ALUE (units 10 ⁻⁵)	CL%		CN COMMENT			mes equal production			$\Upsilon(4S)$.
$4.0 \pm 1.7 \pm 0.8$		8 ¹⁶⁵ AMMAR 93 CL	E2 $e^+e^- \rightarrow \Upsilon(4S)$						
• • We do not use t	he followin	g data for averages, fits, limits, etc.		$\Gamma(\eta\eta)/\Gamma_{\text{total}}$	CL%	DOCUMENT IS	TECN	COMMENT	Γ ₉₅ /
< 42	90	ALBRECHT 89G AR		<4.1 × 10 ⁻⁴	90	180 ACCIARRI	95H L3	e ⁺ e ⁻ → Z	7
			$\Upsilon(4S)$			$_0=39.5\pm4.0$ and f			
< 24	90	166 AVERY 898 CL	EO $e^+e^- \rightarrow \Upsilon(4S)$			U 39.3 ± 4.0 and 7	Rs - 12.0 ±	_ J.U /Q.	
		AVERY 87 CL	EO $e^+e^- \rightarrow$	$\Gamma(\pi^+\pi^-\pi^0)/\Gamma$	T _{total}				Γ ₉₆ /
<210	90	AVENT 87 CE							
<210		.8 events above background.	$\Upsilon(4S)$	VALUE	CL%	DOCUMENT ID 181 ALBRECHT	TECN	COMMENT	

			Г ₉₇ /Г	, -,	. ,,				Γ ₁₀₉ /
<2.4 × 10 ⁻⁵	CL% DOCUMENT ID 90 ASNER	96 CLE2 e ⁺ e ⁻		<u>VALUE</u> <2.4 × 10 ^{−3}	<u>CL%</u> 90	DOCUMENT ID		COMMENT	T(45)
	e following data for average			-		nes equal production			` '
$<4.0 \times 10^{-4}$	90 ¹⁸² ALBRECHT						i Oi B B ai	iu b b a	` ,
	it assumes equal production				$\pi^-\pi^-\pi^-)/\Gamma_{tc}$				Γ ₁₁₀ /
			`	VALUE		DOCUMENT ID		COMMENT	
$\Gamma(ho^{\mp}\pi^{\pm})/\Gamma_{total}$			Г98/Г		90	¹⁹⁹ ALBRECHT			` '
√ALUE <8.8 × 10^{−5}	CL%DOCUMENT I			- ¹⁹⁹ ALBRECH	T 90B limit assun	nes equal production	of $B^{U}\overline{B}^{U}$ ar	nd B^+B^- a	t Υ(45).
	90 ASNER e following data for average	96 CLE2 e ⁺		Γ(a ₁ (1260) ⁺	a ₁ (1260) ⁻)/F	total			Γ111/
$< 5.2 \times 10^{-4}$	90 ¹⁸³ ALBRECHT			VALUE		DOCUMENT ID	TECN	COMMENT	
$<5.2 \times 10^{-3}$	90 184 BEBEK	87 CLEO e+		<2.8 × 10 ⁻³	90	200 BORTOLETT	O89 CLEO	$e^+e^- \rightarrow$	$\Upsilon(4S)$
	it assumes equal production		` '		not use the follow	ing data for average			
	6.1×10^{-3} assuming the γ			$<6.0 \times 10^{-3}$	90	²⁰¹ ALBRECHT			,
to 50%.	_	` ,		²⁰⁰ BORTOLE	TTO 89 reports	$< 3.2 imes 10^{-3}$ assur	ning the Υ (4	(S) decays 4	3% to B ⁰ B
$\Gamma(\pi^+\pi^-\pi^+\pi^-)/\Gamma_{to}$	tal		٦/وو٦	. We rescale 201 ALBRECH	to 50%. T 908 limit assun	nes equal production	of $B^0 \overline{B}{}^0$ ar	nd B^+B^- a	t Y(45).
ALUE	CL% DOCUMENT ID	TECNCOMN							
<2.8 × 10 ⁻⁴	90 ¹⁸⁵ ABREU	95N DLPH e+e	→ Z		$\pi^-\pi^-\pi^-\pi^0)/$				Γ ₁₁₂ /
• • We do not use the	e following data for average	s, fits, limits, etc. •	• •	VALUE	<u>CL%</u>	202 ALDDESUE		COMMENT_	20(1.0)
$<6.7 \times 10^{-4}$	90 ¹⁸⁶ ALBRECHT	90в ARG e ⁺ e	$^- \rightarrow \Upsilon(45)$	<1.1 × 10 ⁻²	90	²⁰² ALBRECHT			
185 Assumes a B ⁰ , B ⁻	production fraction of 0.39	and a B _s production	n fraction of 0.12.	202 ALBRECH	T 90B limit assun	nes equal production	of B ^U B ^U ar	$10^{+}B^{-}$ a	t $\Upsilon(4S)$.
	it assumes equal production			$\Gamma(p\overline{p})/\Gamma_{\text{total}}$	1				Γ ₁₁₃ /
r/-0-0\/r			r/r	VALUE		DOCUMENT ID	TECN	COMMENT	
Γ(ρ ⁰ ρ ⁰)/Γ _{total}	CL% DOCUMENT ID	TECN_ COMN	Γ ₁₀₀ /Γ	<3.4 × 10 °	90	²⁰³ BORTOLETT			$\Upsilon(45)$
<2.8 × 10 ⁻⁴		90B ARG e ⁺ e ⁻			not use the follow	ing data for average	s, fits, limits,	etc. • • •	
4-10 11 -0	e following data for average			$< 3.5 \times 10^{-4}$	90	204 ABREU		$e^+e^- \rightarrow$	
<2.9 × 10 ⁻⁴	90 188 BORTOLETTO			$<1.2 \times 10^{-4}$ $<1.7 \times 10^{-4}$	90 90	²⁰⁵ ALBRECHT ²⁰³ BEBEK	88F ARG		
$<4.3 \times 10^{-4}$	90 ¹⁸⁸ BEBEK	87 CLEO e ⁺ e ⁻		•				e+e- →	1 (45)
187 ALBRECHT 908 lim	it assumes equal production	of $B^0 \overline{B}{}^0$ and B^+	B^- at $\Upsilon(4S)$.	204 Assumes a	mes the 7 (45) d	ecays 43% to $B^0\overline{B}^0$. We rescale	to 50%.	tion of 0 12
188 Paper assumes the $ \gamma$	\cap (4 S) decays 43% to $B^0\overline{B}{}^0$). We rescale to 50%	%.			1.3×10^{-4} assuming			
$\pi^{\pm}(a_1(1260)^{\mp}\pi^{\pm})/\Gamma_{tc}$			Γ ₁₀₁ /Γ	receals to I		10 8338111116	5 the 1 (43)	accays 4570	
(B1(1200) · N)/ · Y	Otal CL% DOCUMENT ID	TECN COMM		$\Gamma(\rho \overline{\rho} \pi^+ \pi^-)$	/r				Γ114
<4.9 × 10 ⁻⁴	90 189 BORTOLETT			, ,					' 114/
•	e following data for average			VALUE (units 10	*) <u>CL%</u> 90	DOCUMENT ID 206 BEBEK		COMMENT	20(4.5)
$<6.3 \times 10^{-4}$	90 190 ALBRECHT	90в ARG e+e-	$\rightarrow \gamma(45)$	<2.5		ing data for average		e ⁺ e ⁻ →	1 (45)
		87 CLEO e+e-			iot use the follow	ing data for average	5, 1115, 11111115,	CLC. U U	
$<1.0 \times 10^{-3}$	90 ¹⁸⁹ BEBEK	87 CLEO 6.6	$^{-} \rightarrow T(45)$		00	207 ADDELL	OF IL DI DII	-+	7
	90 103 BEBEK $(4S)$ decays 43% to $B^0\overline{B}{}^0$		• •	< 9.5	90	²⁰⁷ ABREU ²⁰⁸ ALBRECHT		$e^+e^- \rightarrow e^+e^- \rightarrow$	
189 Paper assumes the $ au$. We rescale to 509	%.	<9.5 5.4 ± 1.8 ± 2.	0	²⁰⁸ ALBRECHT	88F ARG	$e^+e^-\rightarrow$	T(45)
189 Paper assumes the 7	$\Gamma(4S)$ decays 43% to $B^0\overline{B}{}^0$. We rescale to 509	%. B^- at $\Upsilon(4S)$.	<9.5 5.4±1.8±2. 206 BEBEK 89	0 reports $< 2.9 \times 1$	208 ALBRECHT $^{0-4}$ assuming the γ	88F ARG (4 <i>5</i>) decays	$e^+e^- \rightarrow$ 43% to $B^0\overline{B}$	\varUpsilon (4 S) $ar{s}^0$. We resca
189 Paper assumes the $ \gamma _{190}$ ALBRECHT 908 limi $ \Gamma ig(a_2 (1320)^{\mp} \pi^{\pm} ig) / \Gamma_{ m to} $	$C(4S)$ decays 43% to $B^0\overline{B}^0$ it assumes equal production	0 . We rescale to 50% of $^{0}B^{0}$ and $^{+}$	%. B ⁻ at Υ(45). Γ₁₀₂/ Γ	<9.5 5.4±1.8±2. ²⁰⁶ BEBEK 89 to 50%. ²⁰⁷ Assumes a	0 reports $< 2.9 \times 1$ B^0 , B^- product	208 ALBRECHT $^{0-4}$ assuming the 7 ion fraction of 0.39	88F ARG $(4S)$ decays and a B_S pro	$e^+e^- \rightarrow$ 43% to $B^0\overline{B}$ duction frac	Υ (4 S) $ olimits^0$. We resca
189 Paper assumes the 7 190 ALBRECHT 90B limi $\Gamma(a_2(1320)^{\mp}\pi^{\pm})/\Gamma_{to}$	$\Gamma(4S)$ decays 43% to $B^0\overline{B}^0$ it assumes equal production otal $\Gamma(4S)$	We rescale to 50% of $B^0 \overline{B}{}^0$ and B^+	%. B ⁻ at Υ(4 <i>S</i>). Γ₁₀₂/Γ	<9.5 5.4±1.8±2. 206 BEBEK 89 to 50%. 207 Assumes a 208 ALBRECH	oreports $< 2.9 \times 1$ B^0 , B^- product T 88F reports 6.0	208 ALBRECHT $^{0-4}$ assuming the γ	88F ARG $(4S)$ decays and a B_S pro	$e^+e^- \rightarrow$ 43% to $B^0\overline{B}$ duction frac	Υ (4 S) $ olimits^0$. We resca
189 Paper assumes the 7 190 ALBRECHT 908 limit $\Gamma(a_2(1320)^{\mp}\pi^{\pm})/\Gamma_{tc}$ 184 189	$\Gamma(4S)$ decays 43% to $B^0\overline{B}^0$ it assumes equal production otal $\frac{CL\%}{L}$	O. We rescale to 50% of $B^0 \overline{B}^0$ and B^+ TECN COMM O89 CLEO $e^+ e^-$	K_0 . B^- at $\Upsilon(4S)$. Γ_{102}/Γ_0 Γ_{102}/Γ_0 $\Gamma_0 \to \Gamma(4S)$	<9.5 5.4±1.8±2. 206 BBBEK 89 to 50%. 207 Assumes a 208 ALBRECH We rescale	oreports $< 2.9 \times 1$ B^0 , B^- product 88F reports 6.0 to 50%.	208 ALBRECHT $^{0-4}$ assuming the 7 ion fraction of 0.39	88F ARG $(4S)$ decays and a B_S pro	$e^+e^- \rightarrow$ 43% to $B^0\overline{B}$ duction frac	Υ (45) \overline{S}^0 . We rescation of 0.12. 5% to \overline{B}^0
189 Paper assumes the γ ALBRECHT 90B limin $\Gamma(a_2(1320)^{\mp}\pi^{\pm})/\Gamma_{tc}$ 189 ALUE	$\Gamma(4S)$ decays 43% to $B^0\overline{B}^0$ it assumes equal production obtai $\frac{C_1N}{90}$ $\frac{DOCUMENT\ ID}{191}$ BORTOLETTO	O. We rescale to 50% of $B^0 \overline{B}^0$ and B^+ TECN COMM O89 CLEO $e^+ e^-$	K_0 . B^- at $\Upsilon(4S)$. Γ_{102}/Γ_0 Γ_{102}/Γ_0 Γ_{102}/Γ_0 Γ_{103}/Γ_0	<9.5 5.4±1.8±2. 206 BEBEK 89 to 50%. 207 Assumes a 208 ALBRECH We rescale \(\begin{align*} \be	oreports $< 2.9 \times 1$ B^0 , B^- product 88F reports 6.0 to 50%.	208 ALBRECHT 0^{-4} assuming the γ ion fraction of 0.39 $0 \pm 2.0 \pm 2.2$ assum	88F ARG $\Gamma(4S)$ decays and a B_S proning the $\varUpsilon(4$	$e^+e^- \rightarrow$ 43% to $B^0\overline{E}$ duction frac S) decays 4	Υ (4 <i>S</i>) $ar{s}^0$. We rescation of 0.12. 5% to $ar{B}^0$ $ar{B}$
189 Paper assumes the γ 190 ALBRECHT 908 limi $\Gamma\left(a_{2}(1320)^{\mp}\pi^{\pm}\right)/\Gamma_{tc}$ $\frac{VALUE}{<3.0\times10^{-4}}$ • • • We do not use the $<1.4\times10^{-3}$	$\Gamma(4S)$ decays 43% to $B^0\overline{B}^0$ it assumes equal production obtai $\frac{CL\%}{90}$ $\frac{DOCUMENT\ ID}{191}$ BORTOLETT(e following data for average	We rescale to 50% of $B^0 \overline{B}^0$ and B^+ TECN COMM O89 CLEO e^+e^- s, fits, limits, etc. •	$K_{0}^{\prime\prime}$, $K_{0}^{\prime\prime}$ at $r(45)$. Γ_{102}/Γ Γ_{02}/Γ Γ_{03}/Γ Γ_{045}/Γ Γ_{045}/Γ	<9.5 5.4±1.8±2. 206 BEBEK 89 to 50%. 207 Assumes a 208 ALBRECH' We rescale Γ(ρΛπ-)/Γ	0 reports $< 2.9 \times 1$ B^0 , B^- product T 88F reports 6.0 to 50%.	208 ALBRECHT 0^{-4} assuming the γ ion fraction of 0.39 $0 \pm 2.0 \pm 2.2$ assum	88F ARG $\Gamma(4S)$ decays and a B_S prohing the $\Upsilon(4)$	$e^+e^- \rightarrow$ 43% to $B^0\overline{E}$ duction frac S) decays 4	$\Upsilon(4S)$ \overline{S}^0 . We rescation of 0.12. \overline{S}^0 to \overline{S}^0 \overline{S}^0
189 Paper assumes the γ 190 ALBRECHT 908 limi $ \left(\frac{1}{42} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tt} $ $ \frac{1}{42} (1320)^{\mp} \pi^{\pm} $ $ \frac{1}{42} (1320)^{\mp} $	$\Gamma(4S)$ decays 43% to $B^0\overline{B}^0$ it assumes equal production obtai $\frac{CL\%}{90}$ $\frac{DOCUMENT\ ID}{191}$ BORTOLETTO e following data for average $\frac{191}{191}$ BEBEK $\Gamma(4S)$ decays 43% to $B^0\overline{B}^0$	We rescale to 50% of $B^0 \overline{B}^0$ and B^+ TECN COMM O89 CLEO e^+e^- s, fits, limits, etc. •	B^- at $\Upsilon(4S)$. Figure 102/F $\frac{(ENT)}{}$ \rightarrow $\Upsilon(4S)$ \bullet \rightarrow $\Upsilon(4S)$	<9.5 5.4 \pm 1.8 \pm 2. 206 BEBEK 89 to 50%. 207 Assumes a 208 ALBRECH We rescale $\Gamma(p \overline{\Lambda} \pi^-)/\Gamma_{MAUE}$ <1.8 \times 10 ⁻⁴	0 reports $< 2.9 \times 1$ B^0 , B^- product T 88F reports 6.0 to 50%.	208 ALBRECHT 0^{-4} assuming the γ ion fraction of 0.39 $0 \pm 2.0 \pm 2.2$ assum	88F ARG (45) decays and a B_5 prohing the $\Upsilon(4)$ $\frac{TECN}{88F}$ ARG	$e^+e^- \rightarrow$ 43% to $B^0\overline{E}$ duction frac S) decays 4 $\frac{COMMENT}{e^+e^- \rightarrow}$	$\Upsilon(4S)$ \overline{S}^0 . We rescation of 0.12. \overline{S}^0 % to \overline{B}^0 \overline{B}^0 Γ_{115}
189 Paper assumes the γ 190 ALBRECHT 90B limit $\Gamma(a_2(1320)^{\mp}\pi^{\pm})/\Gamma_{tot}$ $< 3.0 \times 10^{-4}$ $= 0$ We do not use the $< 1.4 \times 10^{-3}$ $= 0$ 191 Paper assumes the γ $= 0$	r(45) decays 43% to $B^0\overline{B}^0$ it assumes equal production obtai $\frac{CL\%}{90}$ $\frac{DOCUMENT\ ID}{191}$ BORTOLETTO e following data for average $\frac{191}{191}$ BEBEK r(45) decays 43% to $B^0\overline{B}^0$	0. We rescale to 50% of $B^0 \overline{B}^0$ and B^+ TECN COMM O89 CLEO e^+e^- 87 CLEO e^+e^- 0. We rescale to 50%	%. B ⁻ at $\Upsilon(4S)$. F ₁₀₂ / Γ $\xrightarrow{\text{MENT}}$ $\xrightarrow{\bullet}$ $\Upsilon(4S)$ $\xrightarrow{\bullet}$ $\Upsilon(4S)$ $\xrightarrow{\bullet}$ $\Upsilon(4S)$ $\xrightarrow{\bullet}$ $\Upsilon(4S)$	<9.5 5.4±1.8±2. 206 BEBEK 89 to 50%. 207 Assumes a 208 ALBRECH' We rescale Γ (ρ Āπ -)/Γ, VALUE <1.8 × 10-4 209 ALBRECH'	0 reports $< 2.9 \times 1$ B^0 , B^- product T 88F reports 6.0 to 50%. total $\frac{CL\%}{90}$ T 88F reports < 2	208 ALBRECHT 0^{-4} assuming the γ ion fraction of 0.39 $0 \pm 2.0 \pm 2.2$ assum	88F ARG (45) decays and a B_5 prohing the $\Upsilon(4)$ $\frac{TECN}{88F}$ ARG	$e^+e^- \rightarrow$ 43% to $B^0\overline{E}$ duction frac S) decays 4 $\frac{COMMENT}{e^+e^- \rightarrow}$	$\Upsilon(4S)$ \overline{S}^0 . We rescation of 0.12. \overline{S}^0 % to \overline{B}^0 \overline{B}^0 Γ_{115}
189 Paper assumes the γ 190 ALBRECHT 908 limi $ \left(\frac{a_2(1320)^{\mp} \pi^{\pm}}{A} \right) / \Gamma_{tot} $ $ \begin{array}{c} (A_2(1320)^{\mp} \pi^{\pm}) / \Gamma_{tot} \\ \hline < 3.0 \times 10^{-4} \\ \hline > \bullet \bullet \text{ We do not use the} \\ < 1.4 \times 10^{-3} \\ \hline 1.91 \text{ Paper assumes the } \gamma \\ \hline \left(\pi^{+} \pi^{-} \pi^{0} \pi^{0} \right) / \Gamma_{\text{total}} \\ \hline < ALUE \\ \end{array} $	r(45) decays 43% to $B^0\overline{B}^0$ it assumes equal production obtal CLS $DOCUMENT ID$	0. We rescale to 50% of $B^0 \overline{B}^0$ and B^+ TECN COMM O89 CLEO e^+e^- s, fits, limits, etc. • 87 CLEO e^+e^- 0. We rescale to 50%	%. B at $\Upsilon(4S)$. Figs.	<9.5 5.4±1.8±2. 206 BEBKR 89 to 50%. 207 Assumes a 208 ALBRECH' We rescale Γ(pĀπ^-)/Γ VALUE <1.8 × 10 ⁻⁴ 209 ALBRECH' rescale to 5	0 reports $< 2.9 \times 1$ B^0 , B^- product T 88F reports 6.0 to 50%. total $\frac{CL\%}{90}$ T 88F reports < 2.0 $CL\%$	208 ALBRECHT 0^{-4} assuming the γ ion fraction of 0.39 $0 \pm 2.0 \pm 2.2$ assum	88F ARG (45) decays and a B_5 prohing the $\Upsilon(4)$ $\frac{TECN}{88F}$ ARG	$e^+e^- \rightarrow$ 43% to $B^0\overline{E}$ duction frac S) decays 4 $\frac{COMMENT}{e^+e^- \rightarrow}$	$\Upsilon(4S)$ \overline{S}^0 . We rescation of 0.12.5% to $B^0\overline{B}$ $\Gamma_{115}/\Gamma_{115}/\Gamma_{115}$
189 Paper assumes the γ 190 ALBRECHT 90B limin $\Gamma(a_2(1320)^{\mp}\pi^{\pm})/\Gamma_{tc}$ $<3.0 \times 10^{-4}$ \bullet \bullet We do not use the $<1.4 \times 10^{-3}$ 191 Paper assumes the γ $\Gamma(\pi^{+}\pi^{-}\pi^{0}\pi^{0})/\Gamma_{total}$ $<3.1 \times 10^{-3}$	r(45) decays 43% to $B^0\overline{B}^0$ it assumes equal production obtal C_{10}	0. We rescale to 50% of $B^0 \overline{B}^0$ and B^+ TECN COMM O89 CLEO e^+e^- s, fits, limits, etc. • 87 CLEO e^+e^- 0. We rescale to 50% TECN COMM 908 ARG e^+e^-	%. B at $\Upsilon(4S)$. Figs.	< 9.5 5.4 ± 1.8 ± 2. 206 BEBEK 89 to 50%. 207 Assumes a 208 ALBRECH' We rescale Γ(ρ̄Λπ)/Γ VALUE < 1.8 × 10-4 209 ALBRECH' rescale to 5 Γ(Δ ⁰ Δ̄ ⁰)/Γ	0 reports $< 2.9 \times 1$ B^0 , B^- product T 88F reports 6.0 to 50%. total $\frac{CL\%}{90}$ T 88F reports $< 2.00\%$. total	208 ALBRECHT 0^{-4} assuming the 7 ion fraction of 0.39 $0 \pm 2.0 \pm 2.2$ assum $0 \pm 2.0 \pm 2.2$ assum 0 ± 2.0 ALBRECHT	88F ARG $\Gamma(4S)$ decays and a B_S proping the $\Upsilon(4)$ $\frac{TECN}{88F}$ ARG $\Gamma(4S)$	$e^+e^- \rightarrow$ 43% to $B^0\overline{E}$ duction frac S) decays 4 $\frac{COMMENT}{e^+e^- \rightarrow}$ decays 45%	$\Upsilon(4S)$ \overline{S}^0 . We rescation of 0.12.5% to $B^0\overline{B}$ $\Gamma_{115}/\Gamma_{115}/\Gamma_{115}$
189 Paper assumes the γ 190 ALBRECHT 908 limi $ \left(\frac{1}{42} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{42} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{42} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{42} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{42} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{42} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{42} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm} \right) / \Gamma_{tot} $ $ \left(\frac{1}{422} (1320)^{\mp} \pi^{\pm$	r(45) decays 43% to $B^0\overline{B}^0$ it assumes equal production obtal CLS $DOCUMENT ID$	0. We rescale to 50% of $B^0 \overline{B}^0$ and B^+ TECN COMM O89 CLEO e^+e^- s, fits, limits, etc. • 87 CLEO e^+e^- 0. We rescale to 50% TECN COMM 908 ARG e^+e^-	%. B at $\Upsilon(4S)$. Figs.	<9.5 5.4±1.8±2. 206 BBERK 89 to 50%. 207 Assumes a 208 ALBRECH We rescale Γ(ρΛπ−)/Γ, Δ1.8 × 10−4 209 ALBRECH rescale to 5 Γ(Δ0 Δ0)/Γ, ΔΔ1.0E	0 reports $< 2.9 \times 1$ B^0 , B^- product T 88F reports 6.0 to 50%. total $\frac{cL\%}{90}$ T 88F reports $< 2.50\%$.	208 ALBRECHT 0^{-4} assuming the γ ion fraction of 0.39 $0 \pm 2.0 \pm 2.2$ assum $0 \pm 2.0 \pm 2.2$ 0 ± 2.2	88F ARG $\Gamma(4S)$ decays and a B_S prohing the $\Upsilon(4S)$ 88F ARG g the $\Upsilon(4S)$ g	$e^+e^- \rightarrow$ 43% to $B^0\overline{E}$ duction frac S) decays 4 $\frac{COMMENT}{e^+e^- \rightarrow}$ decays 45%	$\Upsilon(4S)$ \overline{S}^0 . We rescation of 0.12. 5% to \overline{B}^0 \overline{B}^0 \overline{B}^0 \overline{B}^0 \overline{B}^0 . V
189 Paper assumes the γ 90 ALBRECHT 908 limi	r(45) decays 43% to $B^0\overline{B}^0$ it assumes equal production obtal C_{10}	0. We rescale to 50% of $B^0 \overline{B}^0$ and B^+ TECN COMM O89 CLEO e^+e^- s, fits, limits, etc. • 87 CLEO e^+e^- 0. We rescale to 50% TECN COMM 908 ARG e^+e^-	%. B at $\Upsilon(4S)$. Figs.	< 9.5 5.4±1.8±2. 206 BBEBEK 89 to 50%. 207 Assumes a 208 ALBRECH We rescale Γ (ρΛπ -)/Γ MLUE < 1.8 × 10 - 4 209 ALBRECH rescale to 5 Γ (Δ ⁰ Δ̄ ⁰)/Γ MLUE < 0.0015	0 reports $< 2.9 \times 1$ B^0 , B^- product T 88F reports 6.0 to 50%. total $\frac{CL\%}{90}$ T 88F reports < 2 50%. total $\frac{CL\%}{90}$ 90	208 ALBRECHT 0^{-4} assuming the γ ion fraction of 0.39 $0 \pm 2.0 \pm 2.2$ assum ng $0 \pm 2.0 \pm 2.2$ assuming $0 \pm 2.0 \pm 2.2$ 0 ± 2.2 assuming $0 \pm 2.0 \pm 2.2$ 0 ± 2	88F ARG $\Gamma(4S)$ decays and a B_S prohing the $\Upsilon(4S)$ 88F ARG $\Gamma(4S)$	$e^+e^- \rightarrow$ 43% to $B^0\overline{E}$ duction frac S) decays 4 $COMMENT$ $e^+e^- \rightarrow$ $COMMENT$ $e^+e^- \rightarrow$	r(45) r0. We rescation of 0.12. 5% to r 0. r 115/ r(45) r116/ r(45)
1.89 Paper assumes the 7^{190} ALBRECHT 908 limit $\Gamma\left(a_2(1320)^{\mp}\pi^{\pm}\right)/\Gamma_{tot}$ (ALUE) $< 3.0 \times 10^{-4}$ $< 1.4 \times 10^{-3}$ 1.91 Paper assumes the $7^{1}(\pi^{+}\pi^{-}\pi^{0}\pi^{0})/\Gamma_{tot}$ (ALUE) $< 3.1 \times 10^{-3}$ 1.92 ALBRECHT 908 limit $= (\rho^{+}\rho^{-})/\Gamma_{total}$ (ALUE) $= (\rho^{+}\rho^{-})/\Gamma_{total}$ (ALUE)	r(45) decays 43% to $B^0\overline{B}^0$ it assumes equal production obtai $\frac{CL\%}{90}$ 191 BORTOLETTIC following data for average 90 191 BEBEK r(45) decays 43% to $B^0\overline{B}^0$ al $\frac{CL\%}{90}$ 192 ALBRECHT it assumes equal production $\frac{CL\%}{90}$ DOCUMENT ID	0. We rescale to 50% of $B^0 \overline{B}^0$ and B^+ TECN COMM OB9 CLEO e^+e^- 87 CLEO e^+e^- 9. We rescale to 50% TECN COMM 90B ARG e^+e^- of $B^0 \overline{B}^0$ and B^+	B^- at $\Upsilon(4S)$. Fig. Γ 102/ Γ MENT $\longrightarrow \Upsilon(4S)$ \bullet \bullet $\longrightarrow \Upsilon(4S)$ $- \longrightarrow \Upsilon(4S)$ $- \longrightarrow \Upsilon(4S)$ B^- at $\Upsilon(4S)$. Fig. Γ Γ MENT Γ Γ Γ Γ Γ Γ Γ Γ	< 9.5 5.4±1.8±2. 206 BEBEK 89 to 50%. 207 Assumes a 208 ALBRECH We rescale Γ (ρΛπ)/Γ MLUE < 1.8 x 10-4 209 ALBRECH rescale to 5 Γ (Δ ⁰ Δ ⁰)/Γ MALUE < 0.0015 210 BORTOLE	0 reports $< 2.9 \times 1$ B^0 , B^- product T 88F reports 6.0 to 50%. total $\frac{CL\%}{90}$ T 88F reports < 2 50%. total $\frac{CL\%}{90}$ 90	208 ALBRECHT 0^{-4} assuming the γ ion fraction of 0.39 $0 \pm 2.0 \pm 2.2$ assum $0 \pm 2.0 \pm 2.2$ 0 ± 2.2	88F ARG $\Gamma(4S)$ decays and a B_S prohing the $\Upsilon(4S)$ 88F ARG $\Gamma(4S)$	$e^+e^- \rightarrow$ 43% to $B^0\overline{E}$ duction frac S) decays 4 $COMMENT$ $e^+e^- \rightarrow$ $COMMENT$ $e^+e^- \rightarrow$	$r(45)$ g^0 . We rescation of 0.12.5% to g^0
189 Paper assumes the 7 190 ALBRECHT 908 limi $\Gamma\left(a_2(1320)^{\mp}\pi^{\pm}\right)/\Gamma_{tt}$ $(ALUE)$ $<3.0 \times 10^{-4}$ •• We do not use the (2.4×10^{-3}) 191 Paper assumes the (2.4×10^{-3}) 192 ALBRECHT 908 limi (2.4×10^{-3}) 192 ALBRECHT 908 limi (2.4×10^{-3}) 193 ALBRECHT 908 limi (2.4×10^{-3}) 194 ALBRECHT 908 limi (2.4×10^{-3}) 195 ALBRECHT 908 limi (2.4×10^{-3}) 196 ALBRECHT 908 limi (2.4×10^{-3}) 197 ALBRECHT 908 limi (2.4×10^{-3}) 198 ALBRECHT 908 limi (2.4×10^{-3}) 199 ALBRECHT 908 limi	$\Gamma(4S)$ decays 43% to $B^0\overline{B}^0$ it assumes equal production obtain the sum of the sum	0. We rescale to 50% of $B^0 \overline{B}^0$ and B^+ TECN COMM OB9 CLEO e^+e^- 87 CLEO e^+e^- 9. We rescale to 50% TECN COMM 90B ARG e^+e^- of $B^0 \overline{B}^0$ and B^+ TECN COMM 90B ARG e^+e^-	%. B^- at $\Upsilon(4S)$. Figure 102/ Γ $0.04/\Gamma$ $0.04/\Gamma$ Figure 103/ Γ $0.04/\Gamma$ Figure 104/ Γ $0.04/\Gamma$ Figure 104/ Γ $0.04/\Gamma$ $0.04/\Gamma$ $0.04/\Gamma$ $0.04/\Gamma$ $0.04/\Gamma$ $0.04/\Gamma$ $0.04/\Gamma$ $0.04/\Gamma$	< 9.5 5.4±1.8±2. 206 BEBEK 89 to 50%. 207 Assumes a 208 ALBRECH We rescale Γ (ρΛπ)/Γ MLUE <1.8 × 10-4 209 ALBRECH rescale to 5 Γ (Δ ⁰ Δ̄ ⁰)/Γ MLUE <0.0015 210 BORTOLE to 50%.	0 reports $< 2.9 \times 1$ B^0 , B^- product T 88F reports 6.0 to 50%. total $CL\%$ 90 T 88F reports < 2 50%. total $CL\%$ 90 T 70 89 reports < 2	208 ALBRECHT 0^{-4} assuming the γ ion fraction of 0.39 $0 \pm 2.0 \pm 2.2$ assum ng $0 \pm 2.0 \pm 2.2$ assuming $0 \pm 2.0 \pm 2.2$ 0 ± 2.2 assuming $0 \pm 2.0 \pm 2.2$ 0 ± 2	88F ARG $\Gamma(4S)$ decays and a B_S prohing the $\Upsilon(4S)$ 88F ARG $\Gamma(4S)$	$e^+e^- \rightarrow$ 43% to $B^0\overline{E}$ duction frac S) decays 4 $COMMENT$ $e^+e^- \rightarrow$ $COMMENT$ $e^+e^- \rightarrow$	$\Upsilon(45)$ $\Upsilon(45)$ We rescation of 0.12.55% to $B^0\overline{B}$ $\Gamma_{115/}$ $\Upsilon(45)$ to $B^0\overline{B}^0$. V $\Gamma_{116/}$ $\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$
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189 Paper assumes the γ 190 ALBRECHT 908 limit $\Gamma\left(a_2(1320)^{\mp}\pi^{\pm}\right)/\Gamma_{tot}$ \sqrt{ALUE} $<3.0 \times 10^{-4}$ \bullet • • • We do not use the γ 191 Paper assumes the γ 191 Paper assumes the γ 192 ALBRECHT 908 limit $\Gamma\left(\rho^{+}\rho^{-}\right)/\Gamma_{total}$ \sqrt{ALUE} $<2.2 \times 10^{-3}$ 193 ALBRECHT 908 limit \sqrt{ALUE}	r(45) decays 43% to $B^0\overline{B}^0$ it assumes equal production obtain the same equal production of the sa	0. We rescale to 50% of $B^0 \overline{B}^0$ and B^+ TECN COMM OB9 CLEO e^+e^- 87 CLEO e^+e^- 9. We rescale to 50% TECN COMM 90B ARG e^+e^- of $B^0 \overline{B}^0$ and B^+ TECN COMM 90B ARG e^+e^-	K_{0} at $Y(4S)$. Figure 102/F Figure 103/F Figure 1	< 9.5 5.4 ± 1.8 ± 2. 206 BEBER 89 to 50%. 207 Assumes a 208 ALBRECH' We rescale Γ(ρ/Λπ)/Γ VALUE < 1.8 × 10-4 209 ALBRECH rescale to 5 Γ(Δ0/Λ0)/Γ VALUE < 0.0015 210 BORTOLE to 50%. Γ(Δ++ Δ VALUE	0 reports < 2.9 × 1 B ⁰ , B ⁻ product T 88F reports 6.0 to 50%. total CL% 90 T 88F reports < 2 50%. total CL% 90 TTO 89 reports <	208 ALBRECHT 0^{-4} assuming the 7 ion fraction of 0.39 $0 \pm 2.0 \pm 2.2$ assum $0 \pm 2.0 \pm 2.2$ assum $0 \pm 2.0 \pm 2.2$ assum $0 \pm 2.0 \pm 2.2$ assuming $0 \pm 2.0 \pm 2.2$ assuming $0 \pm 2.0 \pm 2.0$ BORTOLETTIC 0.0018 assuming 0 ± 2.0 BORTOLETTIC	88F ARG $\Gamma(4S)$ decays and a B_S prohing the $\Upsilon(4)$ 88F ARG $\Gamma(4S)$	$e^+e^- \rightarrow$ 43% to $B^0\overline{E}$ duction frac 5) decays 4 $\frac{COMMENT}{e^+e^- \rightarrow}$ decays 45% $\frac{COMMENT}{e^+e^- \rightarrow}$ 43% to $B^0\overline{E}$	$\Upsilon(45)$ \S^0 . We rescation of 0.12.55% to $B^0\overline{B}^0$. V $\Upsilon(45)$
189 Paper assumes the γ 190 ALBRECHT 90B limit $\Gamma\left(a_2(1320)^{\mp}\pi^{\pm}\right)/\Gamma_{tot}$ $< 3.0 \times 10^{-4}$ $< \cdot $	r(45) decays 43% to $B^0\overline{B}^0$ it assumes equal production obtain the same of the same o	0. We rescale to 50% of $B^0 \overline{B}^0$ and B^+ TECN COMM OB9 CLEO e^+e^- 87 CLEO e^+e^- . We rescale to 50% TECN COMM 90B ARG e^+e^- of $B^0 \overline{B}^0$ and B^+ of $B^0 \overline{B}^0$ and B^+	%. B^- at $\Upsilon(4S)$. F102/ Γ MENT $\rightarrow \Upsilon(4S)$ • • $\rightarrow \Upsilon(4S)$ %. F103/ Γ $\rightarrow \Upsilon(4S)$ F104/ Γ $\rightarrow \Upsilon(4S)$ $\rightarrow \Upsilon(4S)$ $\rightarrow \Upsilon(4S)$ $\rightarrow \Upsilon(4S)$ $\rightarrow \Upsilon(4S)$ $\rightarrow \Upsilon(4S)$	<9.5 5.4 \pm 1.8 \pm 2. 206 BBEKR 89 to 50%. 207 ASSUMES a 208 ALBRECH' We rescale $\Gamma(p \overline{\Lambda} \pi^{-})/\Gamma_{VALUE}$ <1.8 \times 10-4 209 ALBRECH' rescale to 5 $\Gamma(\Delta^{0} \overline{\Delta^{0}})/\Gamma_{VALUE}$ <0.0015 210 BORTOLE to 50%. $\Gamma(\Delta^{+} + \Delta^{-})$ WALUE <1.1 \times 10-4	0 reports $< 2.9 \times 1$ B^0 , B^- product T 88F reports 6.0 to 50%. total $\frac{CL\%}{90}$ T 88F reports $< 2.50\%$. total $\frac{CL\%}{90}$ TTO 89 reports $< \frac{CL\%}{90}$ TTO 89 reports $< \frac{CL\%}{90}$ TO 89 reports $< \frac{CL\%}{90}$ TO 90 $= \frac{CL\%}{90}$	208 ALBRECHT 0^{-4} assuming the 7 ion fraction of 0.39 $0 \pm 2.0 \pm 2.2$ assum ng $0 \pm 2.0 \pm 2.2$ BORTOLETTIC $0 \pm 2.0 \pm 2.2$ 0 ± 2.0 BORTOLETTIC 0	88F ARG $^{\circ}(4S)$ decays and a B_s prohing the $^{\circ}(4S)$ 88F ARG $^{\circ}$ the $^{\circ}(4S)$ $^{\circ}$ D89 CLEO $^{\circ}$ CLEO $^{\circ}$ CS99 CLEO	$e^+e^- \rightarrow$ 43% to $B^0\overline{E}$ duction frac S) decays 4 $\frac{COMMENT}{e^+e^- \rightarrow}$ decays 45% $\frac{COMMENT}{e^+e^- \rightarrow}$ 43% to $B^0\overline{E}$ $\frac{COMMENT}{e^+e^- \rightarrow}$	$\Upsilon(45)$ $\Upsilon(45)$ We rescation of 0.12.55% to $B^0\overline{B}$ $\Gamma_{115/}$ $\Upsilon(45)$ to $B^0\overline{B}^0$. V $\Gamma_{116/}$ $\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$
189 Paper assumes the 7 190 ALBRECHT 908 limi $\Gamma\left(a_2(1320)^{\mp}\pi^{\pm}\right)/\Gamma_{tt}$ $(ALUE)$ $<3.0 \times 10^{-4}$ •• We do not use the 7 (1.4 \times 10^{-3}) 191 Paper assumes the 7 $\Gamma\left(\pi^{+}\pi^{-}\pi^{0}\pi^{0}\right)/\Gamma_{tota}$ $ALUE$ $<3.1 \times 10^{-3}$ 192 ALBRECHT 908 limi $\Gamma\left(\rho^{+}\rho^{-}\right)/\Gamma_{total}$ $ALUE$ $<2.2 \times 10^{-3}$ 193 ALBRECHT 908 limi $\Gamma\left(a_1(1260)^{0}\pi^{0}\right)/\Gamma_{total}$ $ALUE$ $=(a_1(1260)^{0}\pi^{0})/\Gamma_{total}$ $ALUE$	r(45) decays 43% to $B^0\overline{B}^0$ it assumes equal production obtain the same of the same o	0. We rescale to 50% of $B^0 \overline{B}^0$ and B^+ TECN COMM OB9 CLEO e^+e^- s, fits, limits, etc. 87 CLEO e^+e^- 7. We rescale to 50% TECN COMM 90B ARG e^+e^- of $B^0 \overline{B}^0$ and B^+ TECN COMM 90B ARG e^+e^- of $B^0 \overline{B}^0$ and B^+	76. B at $\Upsilon(45)$. Figure 102/F Figure 103/F Figure 103	< 9.5 5.4±1.8±2. 206 BBERK 89 to 50%. 207 Assumes a 208 ALBRECH* We rescale Γ (ρ Λπ -) / Γ, VALUE < 1.8 × 10 - 4 209 ALBRECH* rescale to 5 Γ (Δ0 Δ0) / Γ, VALUE < 0.0015 210 BORTOLE to 50%. Γ (Δ+ Δ -) VALUE < 1.1 × 10 - 4 211 BORTOLE 21.1 × 10 - 4 211 BORTOLE	0 reports < 2.9 × 1 B ⁰ , B ⁻ product T 88F reports 6.0 to 50%. total CL% 90 T 88F reports < 2 50%. total CL% 90 TTO 89 reports <	208 ALBRECHT 0^{-4} assuming the 7 ion fraction of 0.39 $0 \pm 2.0 \pm 2.2$ assum $0 \pm 2.0 \pm 2.2$ assum $0 \pm 2.0 \pm 2.2$ assum $0 \pm 2.0 \pm 2.2$ assuming $0 \pm 2.0 \pm 2.2$ assuming $0 \pm 2.0 \pm 2.0$ BORTOLETTIC 0.0018 assuming 0 ± 2.0 BORTOLETTIC	88F ARG $^{\circ}(4S)$ decays and a B_s prohing the $^{\circ}(4S)$ 88F ARG $^{\circ}$ the $^{\circ}(4S)$ $^{\circ}$ D89 CLEO $^{\circ}$ CLEO $^{\circ}$ CS99 CLEO	$e^+e^- \rightarrow$ 43% to $B^0\overline{E}$ duction frac S) decays 4 $\frac{COMMENT}{e^+e^- \rightarrow}$ decays 45% $\frac{COMMENT}{e^+e^- \rightarrow}$ 43% to $B^0\overline{E}$ $\frac{COMMENT}{e^+e^- \rightarrow}$	$\Upsilon(45)$ $\Upsilon(45)$ We rescation of 0.12.55% to $B^0\overline{B}$ $\Gamma_{115/}$ $\Upsilon(45)$ to $B^0\overline{B}^0$. V $\Gamma_{116/}$ $\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$ $\Upsilon(45)$
189 Paper assumes the 7 L90 ALBRECHT 90B limit $\Gamma(a_2(1320)^{\mp}\pi^{\pm})/\Gamma_{tot}$ $VALUE$ $<3.0 \times 10^{-4}$ \bullet \bullet \bullet We do not use the $<1.4 \times 10^{-3}$ 191 Paper assumes the 7 $\Gamma(\pi^{+}\pi^{-}\pi^{0}\pi^{0})/\Gamma_{tota}$ $VALUE$ $<3.1 \times 10^{-3}$ 192 ALBRECHT 90B limit $\Gamma(\rho^{+}\rho^{-})/\Gamma_{tota}$ $VALUE$ $<2.2 \times 10^{-3}$ 193 ALBRECHT 90B limit $\Gamma(a_1(1260)^{0}\pi^{0})/\Gamma_{tota}$ $VALUE$ $<1.1 \times 10^{-3}$	$\Gamma(4S)$ decays 43% to $B^0\overline{B}^0$ it assumes equal production obtain the sum of the sum	0. We rescale to 50% of $B^0\overline{B}^0$ and B^+ TECN COMM OB9 CLEO e^+e^- 87 CLEO e^+e^- 9. We rescale to 50% TECN COMM 90B ARG e^+e^- of $B^0\overline{B}^0$ and B^+ TECN COMM 90B ARG e^+e^- of $B^0\overline{B}^0$ and B^+ TECN COMM 90B ARG e^+e^- of $B^0\overline{B}^0$ and B^+	$ B^{-} \text{ at } \Upsilon(4S). $ $ \Gamma_{102}/\Gamma $ $ \bullet \bullet $ $ \bullet $ $ \bullet \bullet $ $ \bullet $	<9.5 5.4 \pm 1.8 \pm 2. 206 BBERK 89 to 50%. 207 Assumes a 208 ALBRECH We rescale $\Gamma(\rho \overline{\Lambda} \pi^{-})/\Gamma_{VALUE}$ <1.8 \pm 10-4 209 ALBRECH rescale to 5 $\Gamma(\Delta^{0} \overline{\Delta^{0}})/\Gamma_{VALUE}$ <0.0015 210 BORTOLE to 50%. $\Gamma(\Delta^{+} + \Delta^{-})$ VALUE <1.1 \pm 10-4 211 BORTOLE rescale to 5	0 reports < 2.9 × 1 B ⁰ , B ⁻ product T 88F reports 6.0 to 50%. total CL% 90 T 88F reports < 2 50%. total CL% 90 TTO 89 reports < CL% 90 TTO 89 reports	208 ALBRECHT 0^{-4} assuming the 7 ion fraction of 0.39 $0 \pm 2.0 \pm 2.2$ assum ng $0 \pm 2.0 \pm 2.2$ BORTOLETTIC $0 \pm 2.0 \pm 2.2$ 0 ± 2.0 BORTOLETTIC 0	88F ARG $^{\circ}(4S)$ decays and a B_s prohing the $^{\circ}(4S)$ 88F ARG $^{\circ}$ the $^{\circ}(4S)$ $^{\circ}$ D89 CLEO $^{\circ}$ CLEO $^{\circ}$ CS99 CLEO	$e^+e^- \rightarrow$ 43% to $B^0\overline{E}$ duction frac S) decays 4 $\frac{COMMENT}{e^+e^- \rightarrow}$ decays 45% $\frac{COMMENT}{e^+e^- \rightarrow}$ 43% to $B^0\overline{E}$ $\frac{COMMENT}{e^+e^- \rightarrow}$	r(45) $r(45)$
189 Paper assumes the 7 190 ALBRECHT 908 limit $\Gamma(a_2(1320)^{\mp}\pi^{\pm})/\Gamma_{tot}$ $VALUE$ $<3.0 \times 10^{-4}$ \bullet • • • We do not use the 7 191 Paper assumes the 7 $\Gamma(\pi^{+}\pi^{-}\pi^{0}\pi^{0})/\Gamma_{tot}$ $VALUE$ $<3.1 \times 10^{-3}$ 192 ALBRECHT 908 limit $\Gamma(\rho^{+}\rho^{-})/\Gamma_{total}$ $VALUE$ $<2.2 \times 10^{-3}$ 193 ALBRECHT 908 limit $\Gamma(a_1(1260)^{0}\pi^{0})/\Gamma_{tot}$ $VALUE$ $<1.1 \times 10^{-3}$ 194 ALBRECHT 908 limit $\Gamma(a_1(1260)^{0}\pi^{0})/\Gamma_{tot}$ $VALUE$ $<1.1 \times 10^{-3}$ 194 ALBRECHT 908 limit $\Gamma(a_1(1260)^{0}\pi^{0})/\Gamma_{tot}$	The contraction of the contract	0. We rescale to 50% of $B^0\overline{B}^0$ and B^+ TECN COMM OB9 CLEO e^+e^- 87 CLEO e^+e^- 9. We rescale to 50% TECN COMM 90B ARG e^+e^- of $B^0\overline{B}^0$ and B^+ TECN COMM 90B ARG e^+e^- of $B^0\overline{B}^0$ and B^+ TECN COMM 90B ARG e^+e^- of $B^0\overline{B}^0$ and B^+	$B^{-} \text{ at } \Upsilon(4S).$ $F = \frac{102}{\Gamma}$ $MENT \longrightarrow \Upsilon(4S)$ $\bullet \bullet$ $\bullet \bullet$ $- \to \Upsilon(4S)$ $- \to \Upsilon(4S)$ $B^{-} \to \Upsilon(4S).$ $F = \frac{104}{\Gamma}$ $- \to \Upsilon(4S).$ $F = \frac{104}{\Gamma}$ $- \to \Upsilon(4S).$ $F = \frac{105}{\Gamma}$ $- \to \Upsilon(4S).$ $F = \frac{105}{\Gamma}$ $- \to \Upsilon(4S).$ $B^{-} \to \Upsilon(4S).$	<9.5 5.4 \pm 1.8 \pm 2. 206 BBERK 89 to 50%. 207 Assumes a 208 ALBRECH We rescale $\Gamma(\rho \overline{\Lambda} \pi^{-})/\Gamma_{,}$ VALUE <1.8 \times 10-4 209 ALBRECH rescale to 5 $\Gamma(\Delta^{0} \overline{\Delta^{0}})/\Gamma_{,}$ VALUE <0.0015 210 BORTOLE to 50%. $\Gamma(\Delta^{+} + \Delta^{-})$ VALUE <1.1 \times 10-4 211 BORTOLE rescale to 5 $\Gamma(\overline{\Sigma_{c}} - \Delta^{+})$	0 reports < 2.9 × 1 B ⁰ , B ⁻ product T 88F reports 6.0 to 50%. total CL% 90 T 88F reports < 2 50%. total CL% 90 TTO 89 reports < CL% 90 TTO 89 reports 50%.	208 ALBRECHT 0^{-4} assuming the 7 ion fraction of 0.39 $0 \pm 2.0 \pm 2.2$ assum $0 \pm 2.0 \pm 2.2$ ALBRECHT $0 \pm 2.0 \pm 2.0$ BORTOLETTIC $0 \pm 2.0 \pm 2.0$ BORTOLETTIC 0 ± 2.0 BO	88F ARG $\Gamma(45)$ decays and a B_5 proping the $\Upsilon(4)$ 88F ARG g the $\Upsilon(45)$ 0099 CLEO $\Gamma(45)$ decays $\frac{TECN}{TECN}$ 089 CLEO ching $\Upsilon(45)$ c	$e^+e^- \rightarrow$ 43% to $B^0\overline{E}$ duction frac S) decays 4 $\frac{COMMENT}{e^+e^- \rightarrow}$ decays 45% $\frac{COMMENT}{e^+e^- \rightarrow}$ 43% to $B^0\overline{E}$ $\frac{COMMENT}{e^+e^- \rightarrow}$ decays 43% to	$\Upsilon(4S)$ \S^0 . We rescation of 0.12. \S^0 to $B^0 \overline{B}$ Γ $\Upsilon(4S)$ $\Upsilon(4S)$ \S^0 . We rescation of Ξ^0 .
189 Paper assumes the γ 190 ALBRECHT 90B limit $\Gamma\left(a_2(1320)^{\mp}\pi^{\pm}\right)/\Gamma_{tot}$ $VALUE$ $<3.0\times10^{-4}$ \bullet \bullet \bullet We do not use the \sim 1.4 \times 10 ⁻³ 191 Paper assumes the \sim 17 $(\pi^{+}\pi^{-}\pi^{0}\pi^{0})/\Gamma_{total}$ $VALUE$ $<3.1\times10^{-3}$ 192 ALBRECHT 90B limit $\Gamma\left(\rho^{+}\rho^{-}\right)/\Gamma_{total}$ $VALUE$ $<2.2\times10^{-3}$ 193 ALBRECHT 90B limit $\Gamma\left(a_1(1260)^{0}\pi^{0}\right)/\Gamma_{total}$ $VALUE$ $<1.1\times10^{-3}$ 194 ALBRECHT 90B limit $\Gamma\left(\omega\pi^{0}\right)/\Gamma_{total}$ $VALUE$ $<1.1\times10^{-3}$ 194 ALBRECHT 90B limit $\Gamma\left(\omega\pi^{0}\right)/\Gamma_{total}$	r(45) decays 43% to $B^0\overline{B}^0$ it assumes equal production total $\frac{CL\%}{90}$ 191 BORTOLETT: e following data for average 90 191 BEBEK r(45) decays 43% to $B^0\overline{B}^0$ al $\frac{CL\%}{90}$ 192 ALBRECHT it assumes equal production $\frac{CL\%}{90}$ 193 ALBRECHT it assumes equal production $\frac{CL\%}{90}$ 194 ALBRECHT it assumes equal production $\frac{CL\%}{90}$ 195 ALBRECHT it assumes equal production $\frac{CL\%}{90}$ 196 ALBRECHT it assumes equal production $\frac{CL\%}{90}$ 197 ALBRECHT it assumes equal production $\frac{CL\%}{90}$ 198 ALBRECHT it assumes equal production $\frac{CL\%}{90}$ 199 ALBRECHT it assumes equal production	0. We rescale to 50% of $B^0 \overline{B}^0$ and B^+ TECN COMM OB9 CLEO e^+e^- 87 CLEO e^+e^- 9. We rescale to 50% TECN COMM 90B ARG e^+e^- of $B^0 \overline{B}^0$ and B^+ TECN COMM 90B ARG e^+e^- of $B^0 \overline{B}^0$ and B^+ TECN COMM 90B ARG e^+e^- of $B^0 \overline{B}^0$ and B^+ TECN COMM 90B ARG e^+e^- of $B^0 \overline{B}^0$ and B^+	$B^{-} \text{ at } \Upsilon(4S).$ $F = \frac{102}{\Gamma}$ $MENT \longrightarrow \Upsilon(4S)$ $\bullet \bullet$ $\bullet \longrightarrow \Upsilon(4S)$ $\%.$ $F = \frac{103}{\Gamma}$ $A = \frac{103}{\Gamma}$ $A = \frac{104}{\Gamma}$	<9.5 5.4 \pm 1.8 \pm 2. 206 BBERK 89 to 50%. 207 Assumes a 208 ALBRECH We rescale $\Gamma(\rho \overline{\Lambda} \pi^{-})/\Gamma_{,}$ VALUE <1.8 \times 10-4 209 ALBRECH rescale to 5 $\Gamma(\Delta^{0} \overline{\Delta^{0}})/\Gamma_{,}$ VALUE <0.0015 210 BORTOLE to 50%. $\Gamma(\Delta^{+} + \Delta^{-})$ VALUE <1.1 \times 10-4 211 BORTOLE rescale to 5 $\Gamma(\overline{\Sigma}_{c} - \Delta^{+})$ VALUE	0 reports < 2.9 × 1 B ⁰ , B ⁻ product T 88F reports 6.0 to 50%. total CL% 90 T 88F reports < 2 10%. total CL% 90 TTO 89 reports < 7)/\(\begin{align*} \text{Total} & \text{CL%} & \text{90} & \text{TTO 89 reports} & \text{10} & \te	208 ALBRECHT 0 - 4 assuming the 7 ion fraction of 0.39 0 ± 2.0 ± 2.2 assum POCUMENT ID 209 ALBRECHT 2.0 × 10 - 4 assuming POCUMENT ID 210 BORTOLETTIC 0.0018 assuming 7 POCUMENT ID 211 BORTOLETTIC < 1.3 × 10 - 4 assuming POCUMENT ID 213 BORTOLETTIC < 1.3 × 10 - 4 assuming POCUMENT ID DOCUMENT ID	88F ARG $\Gamma(4S) \text{ decays}$ and a B_S proping the $\Upsilon(4S)$ 88F ARG $TECN$	$e^+e^- \rightarrow$ 43% to $B^0\overline{E}$ duction frac S) decays 4 $\frac{COMMENT}{e^+e^- \rightarrow}$ decays 45% $\frac{COMMENT}{e^+e^- \rightarrow}$ 43% to $B^0\overline{E}$ $\frac{COMMENT}{e^+e^- \rightarrow}$	r(4S) $r(4S)$
189 Paper assumes the 7 190 ALBRECHT 908 limit $= (a_2(1320)^{\mp}\pi^{\pm})/\Gamma_{tot}$ $= (a_2(1320)^{\mp}\pi^{\pm})/\Gamma_{tot}$ $= (a_2(1320)^{\mp}\pi^{\pm})/\Gamma_{tot}$ $= (a_2(1320)^{\mp}\pi^{\pm})/\Gamma_{tot}$ $= (a_1(1260)^{\mp}\pi^{\pm})/\Gamma_{tot}$ $= (a_1(1260)^{\mp}\pi^{\pm})/\Gamma_{tot}$ $= (a_1(1260)^{\mp}\pi^{\pm})/\Gamma_{tot}$ $= (a_1(1260)^{\pm}\pi^{\pm})/\Gamma_{tot}$ $= (a_1(1260)^{\pm}\pi$	T(45) decays 43% to $B^0\overline{B}^0$ it assumes equal production obtai CL% DOCUMENT ID 90 191 BORTOLETTO 191 BEBEK T(45) decays 43% to $B^0\overline{B}^0$ al CL% DOCUMENT ID 90 192 ALBRECHT it assumes equal production CL% DOCUMENT ID 90 193 ALBRECHT it assumes equal production tai CL% DOCUMENT ID 90 194 ALBRECHT it assumes equal production tai CL% DOCUMENT ID 90 194 ALBRECHT it assumes equal production	2). We rescale to 50% of $B^0\overline{B}^0$ and B^+ TECN COMM OB9 CLEO e^+e^- 87 CLEO e^+e^- 9. We rescale to 50% TECN COMM 908 ARG e^+e^- 10 of $B^0\overline{B}^0$ and B^+ 11 TECN COMM 908 ARG e^+e^- 10 of $B^0\overline{B}^0$ and B^+ 12 TECN COMM 908 ARG e^+e^- 10 of $B^0\overline{B}^0$ and B^+ 11 TECN COMM 908 ARG e^+e^- 10 of $B^0\overline{B}^0$ and B^+ 12 TECN COMM 13 TECN COMM 14 TECN COMM	$ \begin{array}{ccc} K_{B} & \text{at } \Upsilon(4S). \\ & & \Gamma_{102}/\Gamma \\ & & \Gamma_{102}/\Gamma \\ & & \bullet	< 9.5 $5.4 \pm 1.8 \pm 2.$ 206 BBEK 89 $to 50\%.$ 207 Assumes a 208 ALBRECH' We rescale $\Gamma(p \overline{\Lambda} \pi^{-})/\Gamma_{VALUE}$ <1.8 × 10 ⁻⁴ $^{209} \text{ ALBRECH'}$ rescale to 5 $\Gamma(\Delta^{0} \overline{\Delta^{0}})/\Gamma_{VALUE}$ <0.0015 $^{210} \text{ BORTOLE}$ to 50%. $\Gamma(\Delta^{+} + \Delta^{-} - VALUE)$ <1.1 × 10 ⁻⁴ $^{211} \text{ BORTOLE}$ rescale to 5 $\Gamma(\overline{\Sigma}_{C} - \Delta^{+} + VALUE)$ <0.0012	0 reports < 2.9 × 1 B ⁰ , B ⁻ product T 88F reports 6.0 to 50%. total CL% 90 T 88F reports < 2 10%. T 88F reports < 2 10%. T 88F reports < 2 10%. TTO 89 reports < 10%. 10	208 ALBRECHT 0-4 assuming the 7 ion fraction of 0.39 0 ± 2.0 ± 2.2 assum DOCUMENT ID 209 ALBRECHT 2.0 × 10-4 assuming DOCUMENT ID 210 BORTOLETTO C 0.0018 assuming 7 211 BORTOLETTO C 1.3 × 10-4 assuming 212 PROCARIO	88F ARG $\Gamma(45)$ decays and a B_5 prohing the $\Upsilon(4)$ 88F ARG $\Gamma(45)$ 88F ARG $\Gamma(45)$ $\Gamma(45)$ $\Gamma(45)$ decays $\Gamma(45)$ decays $\Gamma(45)$	$e^+e^- \rightarrow$ 43% to $B^0\overline{E}$ duction frac S) decays 4 COMMENT $e^+e^- \rightarrow$ decays 45% COMMENT $e^+e^- \rightarrow$ 43% to $B^0\overline{E}$ COMMENT $e^+e^- \rightarrow$	$\Upsilon(45)$ 80. We rescation of 0.12.55% to $B^0 \overline{B}^0$ 7(45) to $B^0 \overline{B}^0$. V Γ 116/ Γ 45) we rescation of 0.15% to Γ 117/ Γ 45) to Γ 118/ Γ 45) Γ 118/ Γ 45)
189 Paper assumes the 7 190 ALBRECHT 908 limit $\Gamma(a_2(1320)^{\mp}\pi^{\pm})/\Gamma_{tot}$ $\times 1.0 \times 1.0^{-4}$ $\times 1.0 \times 1.0^{-3}$ $\times 1.0 \times 1.0^{-3}$ $\times 1.0 \times 1.0^{-3}$ $\times 1.0 \times 1.0^{-3}$ $\times 1.0 \times 1.0 \times 1.0^{-3}$ $\times 1.0 \times 1.0 \times 1.0 \times 1.0^{-3}$ $\times 1.0 \times 1.0 $	C(45) decays 43% to $B^0\overline{B}^0$ it assumes equal production obtai CL% DOCUMENT ID 90 191 BORTOLETTO 191 BEBEK C(45) decays 43% to $B^0\overline{B}^0$ al CL% DOCUMENT ID 90 192 ALBRECHT it assumes equal production CL% DOCUMENT ID 90 193 ALBRECHT it assumes equal production tai CL% DOCUMENT ID 90 194 ALBRECHT it assumes equal production tai CL% DOCUMENT ID 90 195 ALBRECHT it assumes equal production	2). We rescale to 50% of $B^0 \overline{B}^0$ and B^+ TECN COMM 089 CLEO e^+e^- 87 CLEO e^+e^- 90 BARG e^+e^- 10 $B^0 \overline{B}^0$ and B^+ TECN COMM 90B ARG e^+e^- 10 $B^0 \overline{B}^0$ and B^+ 11 TECN COMM 90B ARG e^+e^- 10 $B^0 \overline{B}^0$ and B^+ 12 TECN COMM 90B ARG e^+e^- 10 $B^0 \overline{B}^0$ and B^+ 11 TECN COMM 90B ARG e^+e^- 10 $B^0 \overline{B}^0$ and B^+ 12 TECN COMM 90B ARG e^+e^-	$ B^{-} \text{ at } \Upsilon(4S). $ $ \Gamma_{102}/\Gamma $ $ \downarrow \bullet \bullet $ $ - \rightarrow \Upsilon(4S) $ $ \downarrow \bullet $ $ - \rightarrow \Upsilon(4S) $ $ \downarrow \bullet $ $ \bullet \bullet $ $ - \rightarrow \Upsilon(4S) $ $ \downarrow \bullet $ $ \bullet \bullet $	< 9.5 5.4±1.8±2. 206 BEBK 89 to 50%. 207 Assumes a 208 ALBRECH' We rescale Γ(ρ̄/Λπ)/Γ VALUE <1.8 × 10-4 209 ALBRECH rescale to 5 Γ(Δ0 Δ0)/Γ VALUE <0.0015 210 BORTOLE to 50%. Γ(Δ++ Δ	0 reports < 2.9 × 1 B ⁰ , B ⁻ product T 88F reports 6.0 to 50%. total CL% 90 T 88F reports < 2 50%. total CL% 90 TTO 89 reports < C)//Ftotal CL% 90 TTO 89 reports 50%.	208 ALBRECHT 0^{-4} assuming the 7 ion fraction of 0.39 $0 \pm 2.0 \pm 2.2$ assum $0 \pm 2.0 \pm 2.2$ assuming the $0 \pm 2.0 \pm 2.2$ assuming $0 \pm 2.0 \pm 2.2$ assuming $0 \pm 2.0 \pm 2.2$ BOCUMENT $0 \pm 2.0 \pm 2.2$ BORTOLETTS $0 \pm $	88F ARG $\Gamma(45)$ decays and a B_5 prohing the $\Upsilon(4)$ 88F ARG $\Gamma(45)$ 88F ARG $\Gamma(45)$ $\Gamma(45)$ $\Gamma(45)$ decays $\Gamma(45)$ decays $\Gamma(45)$	$e^+e^- \rightarrow$ 43% to $B^0\overline{E}$ duction frac S) decays 4 COMMENT $e^+e^- \rightarrow$ decays 45% COMMENT $e^+e^- \rightarrow$ 43% to $B^0\overline{E}$ COMMENT $e^+e^- \rightarrow$	r(4S) $r(4S)$
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189 Paper assumes the 7 190 ALBRECHT 908 limit $\Gamma(a_2(1320)^{\mp}\pi^{\pm})/\Gamma_{tc}$ 23.0 × 10 ⁻⁴ • • • • We do not use the 2.1.4 × 10 ⁻³ 1.91 Paper assumes the 7 $\Gamma(\pi^{+}\pi^{-}\pi^{0}\pi^{0})/\Gamma_{tota}$ 2.2 × 10 ⁻³ 1.92 ALBRECHT 908 limit $\Gamma(\rho^{+}\rho^{-})/\Gamma_{tota}$ 2.2 × 10 ⁻³ 1.93 ALBRECHT 908 limit $\Gamma(\alpha_1(1260)^{0}\pi^{0})/\Gamma_{tota}$ 2.1.4 × 10 ⁻³ 1.94 ALBRECHT 908 limit $\Gamma(\omega\pi^{0})/\Gamma_{tota}$ 2.1.4 × 10 ⁻³ 1.95 ALBRECHT 908 limit $\Gamma(\omega\pi^{0})/\Gamma_{tota}$ 2.4.6 × 10 ⁻⁴ 1.95 ALBRECHT 908 limit $\Gamma(\omega\pi^{0})/\Gamma_{tota}$ 2.4.6 × 10 ⁻⁴ 1.95 ALBRECHT 908 limit $\Gamma(\omega\pi^{0})/\Gamma_{tota}$ 2.4.6 × 10 ⁻⁴ 1.95 ALBRECHT 908 limit $\Gamma(\omega\pi^{0})/\Gamma_{tota}$ 2.1.4 × 10 ⁻³ 1.95 ALBRECHT 908 limit $\Gamma(\omega\pi^{0})/\Gamma_{tota}$ 2.1.4 × 10 ⁻⁴ 1.95 ALBRECHT 908 limit $\Gamma(\omega\pi^{0})/\Gamma_{tota}$	C(45) decays 43% to $B^0\overline{B}^0$ it assumes equal production obtai 191 BORTOLETTO 191 BORTOLETTO 191 BEBEK	2). We rescale to 50% of $B^0 \overline{B}^0$ and B^+ TECN COMM 089 CLEO e^+e^- 87 CLEO e^+e^- 90 BARG e^+e^- 10 $B^0 \overline{B}^0$ and B^+ TECN COMM 90B ARG e^+e^- 10 $B^0 \overline{B}^0$ and B^+ 11 TECN COMM 90B ARG e^+e^- 10 $B^0 \overline{B}^0$ and B^+ 12 TECN COMM 90B ARG e^+e^- 10 $B^0 \overline{B}^0$ and B^+ 11 TECN COMM 90B ARG e^+e^- 10 $B^0 \overline{B}^0$ and B^+ 12 TECN COMM 90B ARG e^+e^-	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	< 9.5 $5.4 \pm 1.8 \pm 2.206$ BBEK 89 $5.0 \pm 0.50\%$. 207 Assumes a 208 ALBRECH We rescale $\Gamma(p \overline{\Lambda} \pi^{-})/\Gamma_{VALUE}$ < 1.8 × 10-4 209 ALBRECH rescale to 5 $\Gamma(\Delta^{0} \overline{\Delta^{0}})/\Gamma_{VALUE}$ < 0.0015 210 BORTOLE to 50%. $\Gamma(\Delta^{+} + \Delta^{-} - \frac{VALUE}{211}$ < 1.1 × 10-4 211 BORTOLE rescale to 5 $\Gamma(\overline{\Sigma}_{C} - \Delta^{+} + \frac{VALUE}{212}$ < 0.0012 212 PROCARIO best value $\Gamma(\gamma \gamma)/\Gamma_{total}$	0 reports $< 2.9 \times 1$ B^0 , B^- product T 88F reports 6.0 to 50%. total $\frac{CL\%}{90}$ T 88F reports < 2 50%. total $\frac{CL\%}{90}$ TTO 89 reports < 2 $\frac{CL\%}{90}$ TTO 89 reports < 2 $\frac{CL\%}{90}$ $\frac{CL\%}{90}$ $\frac{CL\%}{90}$ 0 TO 89 reports < 2 $\frac{CL\%}{90}$ $\frac{CL\%}{90}$ 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	208 ALBRECHT 0^{-4} assuming the 7 ion fraction of 0.39 $0 \pm 2.0 \pm 2.2$ assum $0 \pm 2.0 \pm 2.2$ assuming the $0 \pm 2.0 \pm 2.2$ assuming $0 \pm 2.0 \pm 2.2$ assuming $0 \pm 2.0 \pm 2.2$ BORTOLETTIC 0 ± 2.2 PROCARIO $0 \pm$	88F ARG $\Gamma(4S)$ decays and a B_S prohing the $\Upsilon(4S)$ 0 88F ARG 0 88F ARG 0 88F ARG 0 89 CLEO 0 80 CLEO 0 90 CLEO	$e^+e^- \rightarrow$ 43% to $B^0\overline{E}$ duction frac S) decays 4 COMMENT $e^+e^- \rightarrow$ decays 45% COMMENT $e^+e^- \rightarrow$ 43% to $B^0\overline{E}$ COMMENT $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ 0.043. We	$\Upsilon(45)$ $\Upsilon(45)$ (70.00)
189 Paper assumes the 7 190 ALBRECHT 908 limin $\Gamma(a_2(1320)^{\mp}\pi^{\pm})/\Gamma_{tot}$ $VALUE$ $<3.0 \times 10^{-4}$ \bullet • • • We do not use the $<1.4 \times 10^{-3}$ 191 Paper assumes the $?$ $\Gamma(\pi^{+}\pi^{-}\pi^{0}\pi^{0})/\Gamma_{tot}$ $VALUE$ $<3.1 \times 10^{-3}$ 192 ALBRECHT 908 limin $\Gamma(\rho^{+}\rho^{-})/\Gamma_{total}$ $VALUE$ $<2.2 \times 10^{-3}$ 193 ALBRECHT 908 limin $\Gamma(a_1(1260)^{0}\pi^{0})/\Gamma_{tot}$ $VALUE$ $<1.1 \times 10^{-3}$ 194 ALBRECHT 908 limin $\Gamma(\omega\pi^{0})/\Gamma_{total}$ $VALUE$ $<1.5 \times 10^{-3}$ 195 ALBRECHT 908 limin $\Gamma(\omega\pi^{0})/\Gamma_{total}$ $VALUE$ $<4.6 \times 10^{-4}$ 195 ALBRECHT 908 limin $\Gamma(\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0})/\Gamma_{total}$ $VALUE$ $<4.6 \times 10^{-4}$ 195 ALBRECHT 908 limin $\Gamma(\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0})/\Gamma_{total}$ $VALUE$ $<4.6 \times 10^{-4}$ 195 ALBRECHT 908 limin $\Gamma(\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0})/\Gamma_{total}$ $VALUE$ $<9.0 \times 10^{-3}$	C(45) decays 43% to $B^0\overline{B}^0$ it assumes equal production obtains the sequence of the sequen	0. We rescale to 50% of $B^0 \overline{B}^0$ and B^+ TECN COMM OB9 CLEO e^+e^- 87 CLEO e^+e^- 1. We rescale to 50% TECN COMM 90B ARG e^+e^- of $B^0 \overline{B}^0$ and B^+ TECN COMM 90B ARG e^+e^- of $B^0 \overline{B}^0$ and B^+ TECN COMM 90B ARG e^+e^- of $B^0 \overline{B}^0$ and B^+ TECN COMM 90B ARG e^+e^- of $B^0 \overline{B}^0$ and B^+ TECN COMM 90B ARG e^+e^- of $B^0 \overline{B}^0$ and B^+ TECN COMM 90B ARG e^+e^-	$B^- \text{ at } \Upsilon(4S).$ $F = \frac{102}{\Gamma}$ $MENT \longrightarrow \Upsilon(4S)$ $\bullet \bullet$ $\bullet \bullet$ $- \to \Upsilon(4S)$ $- \to \Upsilon(4S)$ $B^- \Rightarrow \Upsilon(4S).$ $F = \frac{104}{\Gamma}$ $- \to \Upsilon(4S).$ $F = \frac{104}{\Gamma}$ $- \to \Upsilon(4S).$ $F = \frac{105}{\Gamma}$ $- \to \Upsilon(4S).$ $F = \frac{105}{\Gamma}$ $- \to \Upsilon(4S).$ $F = \frac{106}{\Gamma}$ $- \to \Upsilon(4S).$ $\Gamma = \frac{107}{\Gamma}$ $- \to \Upsilon(4S).$	< 9.5 $5.4 \pm 1.8 \pm 2.206$ BBEK 89 $5.0 \pm 0.50\%$. 207 Assumes a 208 ALBRECH We rescale $\Gamma(p \overline{\Lambda} \pi^{-})/\Gamma_{VALUE}$ < 1.8 × 10-4 209 ALBRECH rescale to 5 $\Gamma(\Delta^{0} \overline{\Delta^{0}})/\Gamma_{VALUE}$ < 0.0015 210 BORTOLE to 50%. $\Gamma(\Delta^{+} + \Delta^{-} - \frac{VALUE}{211}$ < 1.1 × 10-4 211 BORTOLE rescale to 5 $\Gamma(\overline{\Sigma}_{C} - \Delta^{+} + \frac{VALUE}{212}$ < 0.0012 212 PROCARIO best value $\Gamma(\gamma \gamma)/\Gamma_{total}$	0 reports $< 2.9 \times 1$ B^0 , B^- product T 88F reports 6.0 to 50%. total $\frac{CL\%}{90}$ T 88F reports < 2 50%. total $\frac{CL\%}{90}$ TTO 89 reports < 2 $\frac{CL\%}{90}$ TTO 89 reports < 2 $\frac{CL\%}{90}$ $\frac{CL\%}{90}$ $\frac{CL\%}{90}$ 0 TO 89 reports < 2 $\frac{CL\%}{90}$ $\frac{CL\%}{90}$ 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	208 ALBRECHT 0^{-4} assuming the 7 ion fraction of 0.39 $0 \pm 2.0 \pm 2.2$ assum $0 \pm 2.0 \pm 2.2$ assuming the $0 \pm 2.0 \pm 2.2$ assuming $0 \pm 2.0 \pm 2.2$ assuming $0 \pm 2.0 \pm 2.2$ BOCUMENT $0 \pm 2.0 \pm 2.2$ BORTOLETTS $0 \pm $	88F ARG $\Gamma(4S)$ decays and a B_S prohing the $\Upsilon(4S)$ $\Gamma(4S)$	$e^+e^- \rightarrow$ 43% to $B^0\overline{E}$ duction frac S) decays 4 $\frac{COMMENT}{e^+e^- \rightarrow}$ 43% to $B^0\overline{E}$ $\frac{COMMENT}{e^+e^- \rightarrow}$ decays 43% to $\frac{COMMENT}{e^+e^- \rightarrow}$ $\frac{COMMENT}{e^+e^- \rightarrow}$ 0.043. We	r(45) $r(45)$
189 Paper assumes the 7 190 ALBRECHT 908 limin $\Gamma(a_2(1320)^{\mp}\pi^{\pm})/\Gamma_{tot}$ $VALUE$ $<3.0 \times 10^{-4}$ \bullet • • • We do not use the $<1.4 \times 10^{-3}$ 191 Paper assumes the $?$ $\Gamma(\pi^{+}\pi^{-}\pi^{0}\pi^{0})/\Gamma_{tot}$ $VALUE$ $<3.1 \times 10^{-3}$ 192 ALBRECHT 908 limin $\Gamma(\rho^{+}\rho^{-})/\Gamma_{total}$ $VALUE$ $<2.2 \times 10^{-3}$ 193 ALBRECHT 908 limin $\Gamma(a_1(1260)^{0}\pi^{0})/\Gamma_{tot}$ $VALUE$ $<1.1 \times 10^{-3}$ 194 ALBRECHT 908 limin $\Gamma(\omega\pi^{0})/\Gamma_{total}$ $VALUE$ $<1.5 \times 10^{-3}$ 195 ALBRECHT 908 limin $\Gamma(\omega\pi^{0})/\Gamma_{total}$ $VALUE$ $<4.6 \times 10^{-4}$ 195 ALBRECHT 908 limin $\Gamma(\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0})/\Gamma_{total}$ $VALUE$ $<4.6 \times 10^{-4}$ 195 ALBRECHT 908 limin $\Gamma(\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0})/\Gamma_{total}$ $VALUE$ $<4.6 \times 10^{-4}$ 195 ALBRECHT 908 limin $\Gamma(\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0})/\Gamma_{total}$ $VALUE$ $<9.0 \times 10^{-3}$	C(45) decays 43% to $B^0\overline{B}^0$ it assumes equal production obtains the sequence of the sequen	0. We rescale to 50% of $B^0 \overline{B}^0$ and B^+ TECN COMM OB9 CLEO e^+e^- 87 CLEO e^+e^- 1. We rescale to 50% TECN COMM 90B ARG e^+e^- of $B^0 \overline{B}^0$ and B^+ TECN COMM 90B ARG e^+e^- of $B^0 \overline{B}^0$ and B^+ TECN COMM 90B ARG e^+e^- of $B^0 \overline{B}^0$ and B^+ TECN COMM 90B ARG e^+e^- of $B^0 \overline{B}^0$ and B^+ TECN COMM 90B ARG e^+e^- of $B^0 \overline{B}^0$ and B^+ TECN COMM 90B ARG e^+e^-	$B^- \text{ at } \Upsilon(4S).$ $F = \frac{102}{\Gamma}$ $MENT \longrightarrow \Upsilon(4S)$ $\bullet \bullet$ $\bullet \bullet$ $- \to \Upsilon(4S)$ $- \to \Upsilon(4S)$ $B^- \Rightarrow \Upsilon(4S).$ $F = \frac{104}{\Gamma}$ $- \to \Upsilon(4S).$ $F = \frac{104}{\Gamma}$ $- \to \Upsilon(4S).$ $F = \frac{105}{\Gamma}$ $- \to \Upsilon(4S).$ $F = \frac{105}{\Gamma}$ $- \to \Upsilon(4S).$ $F = \frac{106}{\Gamma}$ $- \to \Upsilon(4S).$ $\Gamma = \frac{107}{\Gamma}$ $- \to \Upsilon(4S).$	<9.5 5.4±1.8±2. 206 BBEK 89 to 50%. 207 ASSUMES a 208 ALBRECH We rescale \(\big(\bar{P} \bar{A} \bar{\pi} \right) \bar{F} \\ \text{VALUE} \\ <0.0015 210 BORTOLE to 50%. \(\bar{A} \bar{\pi} \bar{A} \bar{\pi} \\ \text{VALUE} \\ <1.1 \times 10^{-4} 211 BORTOLE rescale to 5 \(\bar{F} \bar{A} \bar{\pi} \\ \text{VALUE} \\ <1.1 \times 10^{-4} 211 BORTOLE rescale to 5 \(\bar{F} \bar{\pi} \bar{\pi} \bar{\pi} \\ \text{VALUE} \\ <1.1 \times 10^{-4} 211 BORTOLE rescale to 5 \(\bar{F} \bar{\pi} \bar{\pi} \bar{\pi} \\ \text{VALUE} \\ <0.0012 212 PROCARIO best value \(\bar{F} \bar{\pi} \bar{\pi} \bar{\pi} \\ Total tors tors tors tors tors tors tors tors	0 reports < 2.9 × 1 B^0 , B^- product T 88F reports 6.0 to 50%. total CL% 90 T 88F reports < 2 50%. total CL% 90 TTO 89 reports < TTO	208 ALBRECHT 0^{-4} assuming the 7 ion fraction of 0.39 $0 \pm 2.0 \pm 2.2$ assum $\frac{DOCUMENT\ ID}{209}$ 209 ALBRECHT 0.0×10^{-4} assuming $\frac{DOCUMENT\ ID}{200}$ 210 BORTOLETTIC 0.0018 assuming 7 $\frac{DOCUMENT\ ID}{211}$ 211 BORTOLETTIC 0.018 assuming 7 $\frac{DOCUMENT\ ID}{212}$ 212 PROCARIO 0012 for $B(\Lambda_C^+ \to +^+) = 0.044$. utral current. Allow	88F ARG	$e^+e^- \rightarrow$ 43% to $B^0\overline{E}$ duction frac S) decays 4 COMMENT $e^+e^- \rightarrow$ decays 45% COMMENT $e^+e^- \rightarrow$ 43% to $B^0\overline{E}$ COMMENT $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ 0.043. We COMMENT $e^+e^- \rightarrow$ 0.043. We	$\Upsilon(45)$ \mathfrak{F}^0 . We rescale tion of 0.12.5% to $B^0\overline{B}^0$ Γ 115/ $\Upsilon(45)$ \mathfrak{F}^0 Γ 116/ Γ 17/ Γ 17/ Γ 17/ Γ 18/ Γ 118/ Γ 119/ Γ 1
189 Paper assumes the 7 190 ALBRECHT 908 limin $\Gamma(a_2(1320)^{\mp}\pi^{\pm})/\Gamma_{tot}$ (2.1320) $\Gamma(a_2(1320)^{\mp}\pi^{\pm})/\Gamma_{tot}$ (3.0 × 10 ⁻⁴ • • • • We do not use the 7 191 Paper assumes the 7 $\Gamma(\pi^{+}\pi^{-}\pi^{0}\pi^{0})/\Gamma_{tot}$ (3.1 × 10 ⁻³ 192 ALBRECHT 908 limin $\Gamma(\rho^{+}\rho^{-})/\Gamma_{total}$ (2.2 × 10 ⁻³ 193 ALBRECHT 908 limin $\Gamma(a_1(1260)^{0}\pi^{0})/\Gamma_{tot}$ (3.1 × 10 ⁻³ 194 ALBRECHT 908 limin $\Gamma(\omega\pi^{0})/\Gamma_{tot}$ (4.1 × 10 ⁻³ 195 ALBRECHT 908 limin $\Gamma(\omega\pi^{0})/\Gamma_{total}$ (4.6 × 10 ⁻⁴ 195 ALBRECHT 908 limin $\Gamma(\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0})/\Gamma_{total}$ (9.0 × 10 ⁻³ 196 ALBRECHT 908 limin $\Gamma(\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0})/\Gamma_{total}$ (9.0 × 10 ⁻³ 196 ALBRECHT 908 limin 196	C(45) decays 43% to $B^0\overline{B}^0$ it assumes equal production 191 BORTOLETTIC following data for average 90 191 BEBEK C(45) decays 43% to $B^0\overline{B}^0$ all compared to the following data for average 90 192 ALBRECHT in assumes equal production CL% DOCUMENT ID 193 ALBRECHT it assumes equal production CL% DOCUMENT ID 194 ALBRECHT it assumes equal production CL% DOCUMENT ID 195 ALBRECHT it assumes equal production CL% DOCUMENT ID 195 ALBRECHT it assumes equal production CL% DOCUMENT ID 195 ALBRECHT it assumes equal production CL% DOCUMENT ID 195 ALBRECHT it assumes equal production CL% DOCUMENT ID 196 ALBRECHT it assumes equal production	0. We rescale to 50% of $B^0 \overline{B}^0$ and B^+ TECN COMM OB9 CLEO e^+e^- 87 CLEO e^+e^- 1. We rescale to 50% TECN COMM 90B ARG e^+e^- of $B^0 \overline{B}^0$ and B^+ TECN COMM 90B ARG e^+e^- of $B^0 \overline{B}^0$ and B^+ TECN COMM 90B ARG e^+e^- of $B^0 \overline{B}^0$ and B^+ TECN COMM 90B ARG e^+e^- of $B^0 \overline{B}^0$ and B^+ TECN COMM 90B ARG e^+e^- of $B^0 \overline{B}^0$ and B^+ TECN COMM 90B ARG e^+e^-	$B^{-} \text{ at } \Upsilon(4S).$ $F = T \text{ 102}/\Gamma$ $F = T \text{ 103}/\Gamma$ $F = T \text{ 103}/\Gamma$ $F = T \text{ 104}/\Gamma$ $F = T \text{ 104}/\Gamma$ $F = T \text{ 105}/\Gamma$ $F = T \text{ 105}/\Gamma$ $F = T \text{ 106}/\Gamma$ $F = T$	<9.5 5.4±1.8±2. 206 BBEKR 89 to 50%. 207 Assumes a 208 ALBRECH' We rescale Γ(ρ/π -)/Γ VALUE <1.8 × 10-4 209 ALBRECH rescale to 5 Γ(Δ0 Δ0)/Γ VALUE <0.0015 210 BORTOLE to 50%. Γ(Δ++ Δ VALUE <1.1 × 10-4 211 BORTOLE rescale to 5 Γ(Σ- Δ++ VALUE <0.0012 212 PROCARIO best value Γ(γγ)/Γtotal Test for tions. VALUE <3.9 × 10-5	0 reports < 2.9 × 1 B^0 , B^- product T 88F reports 6.0 to 50%. total CL% 90 T 88F reports < 2 50%. total CL% 90 TTO 89 reports < TTO	208 ALBRECHT 0^{-4} assuming the 7° ion fraction of 0.39 $0 \pm 2.0 \pm 2.2$ assum $0 \pm 2.0 \pm 2.2$ assuming the $0 \pm 2.0 \pm 2.2$ assuming $0 \pm 2.0 \pm 2.2$ assuming $0 \pm 2.0 \pm 2.2$ assuming $0 \pm 2.0 \pm 2.2$ BORTOLETTIC 0 ± 2.2 BORTOLE	88F ARG $\Gamma(4S)$ decays and a B_S prohing the $\Upsilon(4S)$ $\Gamma(4S)$	$e^+e^- \rightarrow$ 43% to $B^0\overline{E}$ duction frac S) decays 4 $\frac{COMMENT}{e^+e^- \rightarrow}$ decays 45% $\frac{COMMENT}{e^+e^- \rightarrow}$ 43% to $B^0\overline{E}$ $\frac{COMMENT}{e^+e^- \rightarrow}$ decays 43% to 60% $\frac{COMMENT}{e^+e^- \rightarrow}$ 0.043. We order electrons	$\Upsilon(45)$ \mathfrak{F}^0 . We rescale tion of 0.12.5% to $B^0\overline{B}^0$ Γ 115/ $\Upsilon(45)$ \mathfrak{F}^0 Γ 116/ Γ 17/ Γ 17/ Γ 17/ Γ 18/ Γ 118/ Γ 119/ Γ 1
89 Paper assumes the 7 90 ALBRECHT 908 limit (a ₂ (1320) $^{+}\pi^{\pm}$)/ $^{-}$ tu (ALUE) (3.0 × 10 $^{-4}$) • • We do not use the (3.1 × 10 $^{-3}$) Paper assumes the 7 ($\pi^{+}\pi^{-}\pi^{0}\pi^{0}$)/ $^{-}$ total (ALUE) (3.1 × 10 $^{-3}$) Paper assumes the 7 (a ₁ (1260) $^{-}$ 0)/ $^{-}$ total (2.2 × 10 $^{-3}$) 93 ALBRECHT 908 limit (a ₁ (1260) $^{-}$ 0 $^{-}$ 0)/ $^{-}$ total (2.1 × 10 $^{-3}$) 94 ALBRECHT 908 limit (a ₁ (1260) $^{-}$ 0)/ $^{-}$ total (2.4 × 10 $^{-4}$ 95 ALBRECHT 908 limit (4.6 × 10 $^{-4}$ 95 ALBRECHT 908 limit (7.7 × 10 $^{-4}$ 10)/ $^{-4}$ 104 (1260) (12 $^{-4}$ 10)/ $^{-4}$ 104 (1260) (12 $^{-4}$ 10)/ $^{-4}$ 104 (12 $^{-4}$ 10)/ $^{-4}$ 104 (12 $^{-4}$ 10)/ $^{-4}$ 104 (12 $^{-4}$ 10)/ $^{-4}$ 104 (12 $^{-4}$ 10)/ $^{-4}$ 104 (12 $^{-4}$ 10)/ $^{-4}$ 104 (12 $^{-4}$ 10)/ $^{-4}$ 104 (12 $^{-4}$ 10)/ $^{-4}$ 104 (13 $^{-4}$ 10)/ $^{-4}$ 104 (13 $^{-4}$ 10)/ $^{-4}$ 104 (13 $^{-4}$ 10)/ $^{-4}$ 104 (13 $^{-4}$ 10)/ $^{-4}$ 104 (13 $^{-4}$ 10)/ $^{-4}$ 104 (13 $^{-4}$ 10)/ $^{-4}$ 104 (13 $^{-4}$ 10)/ $^{-4}$ 104 (13 $^{-4}$ 10)/ $^{-4}$ 104 (13 $^{-4}$ 10)/ $^{-4}$ 104 (13 $^{-4}$ 10)/ $^{-4}$ 104 (13 $^{-4}$ 10)/ $^{-4}$ 104 (13 $^{-4}$ 10)/ $^{-4}$ 104 (13 $^{-4}$ 10)/ $^{-4}$ 104 (13 $^{-4}$ 10)/ $^{-4}$ 104 (13 $^{-4}$ 10)/ $^{-4}$ 104 (13 $^{-4}$ 10)/ $^{-4}$ 104 (13 $^{-4}$ 104 (13 $^{-4}$ 105)/ $^{-4}$ 104 (13 $^{-4}$ 106)/ $^{-4}$ 106 (13 $^{-4}$ 106)/ $^{-4}$ 10	C(45) decays 43% to $B^0\overline{B}^0$ it assumes equal production 191 BORTOLETTIC following data for average 90 191 BEBEK C(45) decays 43% to $B^0\overline{B}^0$ all compared to the following data for average 90 192 ALBRECHT in assumes equal production CL% DOCUMENT ID 193 ALBRECHT it assumes equal production CL% DOCUMENT ID 194 ALBRECHT it assumes equal production CL% DOCUMENT ID 195 ALBRECHT it assumes equal production CL% DOCUMENT ID 195 ALBRECHT it assumes equal production CL% DOCUMENT ID 195 ALBRECHT it assumes equal production CL% DOCUMENT ID 195 ALBRECHT it assumes equal production CL% DOCUMENT ID 196 ALBRECHT it assumes equal production	0. We rescale to 50% of $B^0 \overline{B}^0$ and B^+ TECN COMM OB9 CLEO e^+e^- 87 CLEO e^+e^- 1. We rescale to 50% TECN COMM 90B ARG e^+e^- of $B^0 \overline{B}^0$ and B^+ TECN COMM 90B ARG e^+e^- of $B^0 \overline{B}^0$ and B^+ TECN COMM 90B ARG e^+e^- of $B^0 \overline{B}^0$ and B^+ TECN COMM 90B ARG e^+e^- of $B^0 \overline{B}^0$ and B^+ TECN COMM 90B ARG e^+e^- of $B^0 \overline{B}^0$ and B^+ TECN COMM 90B ARG e^+e^-	$B^- \text{ at } \Upsilon(4S).$ $F = \frac{102}{\Gamma}$ $F = \frac{102}{\Gamma}$ $F = \frac{103}{\Gamma}$ $F = \frac{103}{\Gamma}$ $F = \frac{104}{\Gamma}$ $F = \frac{106}{\Gamma}$ $F = \frac{106}{\Gamma}$ $F = \frac{107}{\Gamma}$ $F = \frac{108}{\Gamma}$	<9.5 5.4±1.8±2. 206 BBEKR 89 to 50%. 207 Assumes a 208 ALBRECH' We rescale Γ(ρ/π -)/Γ VALUE <1.8 × 10-4 209 ALBRECH rescale to 5 Γ(Δ0 Δ0)/Γ VALUE <0.0015 210 BORTOLE to 50%. Γ(Δ++ Δ VALUE <1.1 × 10-4 211 BORTOLE rescale to 5 Γ(Σ- Δ++ VALUE <0.0012 212 PROCARIO best value Γ(γγ)/Γtotal Test for tions. VALUE <3.9 × 10-5	0 reports < 2.9 × 1 B^0 , B^- product T 88F reports 6.0 to 50%. total CL% 90 T 88F reports < 2 50%. total CL% 90 TTO 89 reports < TTO	208 ALBRECHT 0^{-4} assuming the 7 ion fraction of 0.39 $0 \pm 2.0 \pm 2.2$ assum $\frac{DOCUMENT\ ID}{209}$ 209 ALBRECHT 0.0×10^{-4} assuming $\frac{DOCUMENT\ ID}{200}$ 210 BORTOLETTIC 0.0018 assuming 7 $\frac{DOCUMENT\ ID}{211}$ 211 BORTOLETTIC 0.018 assuming 7 $\frac{DOCUMENT\ ID}{212}$ 212 PROCARIO 0012 for $B(\Lambda_C^+ \to +^+) = 0.044$. utral current. Allow	88F ARG $\Gamma(4S)$ decays and a B_S prohing the $\Upsilon(4S)$ $\Gamma(4S)$	$e^+e^- \rightarrow$ 43% to $B^0\overline{E}$ duction frac S) decays 4 $\frac{COMMENT}{e^+e^- \rightarrow}$ decays 45% $\frac{COMMENT}{e^+e^- \rightarrow}$ 43% to $B^0\overline{E}$ $\frac{COMMENT}{e^+e^- \rightarrow}$ decays 43% to 60% $\frac{COMMENT}{e^+e^- \rightarrow}$ 0.043. We order electrons	$\Upsilon(45)$ \S^0 . We resc. tion of 0.12 5% to $B^0\overline{B}$ Γ 115, Γ (45) to $B^0\overline{B}^0$. V Γ 116, Γ (45) Γ (47) Γ (47) Γ (48) rescale to Γ (118, Γ (48) rescale to Γ (119) Γ (49) weak interactions of Γ (119)

¹⁹⁷ ALBRECHT 90B limit assumes equal production of $B^0 \overline{B}{}^0$ and $B^+ B^-$ at $\Upsilon(4S)$.

225 Paper assumes the $\Upsilon(4S)$ decays 43% to $B^0\overline{B}^0$. We rescale to 50%. 226 ALBRECHT 87D reports $<5\times10^{-5}$ assuming the $\Upsilon(4S)$ decays 45% to $B^0\overline{B}^0$. We rescale to 50%. 227 AVERY 87 reports $<9\times10^{-5}$ assuming the $\Upsilon(4S)$ decays 40% to $B^0\overline{B}^0$. We rescale to 50%.

 B^0

	weak neutr	al current. Allov	ved by higher	Γ_{120}/Γ order electroweak interac-	$\Gamma(e^{\pm} au^{\mp})/\Gamma_{ ext{total}}$ Test of lepton fa					Γ ₁₂₇ /Γ
tions. VALUE	CL%_	DOCUMENT ID	TECN	COMMENT	VALUE	<u>CL%</u>	DOCUMENT ID		COMMENT	
<5.9 × 10 ⁻⁶	90	AMMAR		$e^+e^- \rightarrow \Upsilon(4S)$	<5.3 × 10 ⁻⁴	90	AMMAR	94 CLE2	$e^+e^- \rightarrow$	$\Upsilon(45)$
• • • We do not use the	he following	data for average			$\Gamma(\mu^{\pm} au^{\mp})/\Gamma_{total}$					Γ ₁₂₈ /Γ
$< 2.6 \times 10^{-5}$		⁴ AVERY	89B CLEO	$e^+e^- \rightarrow \Upsilon(4S)$	Test of lepton fa					120,
$< 7.6 \times 10^{-5}$		⁵ ALBRECHT	87D ARG	$e^+e^- \rightarrow \Upsilon(4S)$	VALUE	CL%	DOCUMENT ID		COMMENT	
$<6.4 \times 10^{-5}$		6 AVERY		$e^+e^- \rightarrow \Upsilon(4S)$	<8.3 × 10 ⁻⁴	90	AMMAR	94 CLE2	$e^+e^- \rightarrow$	$\Upsilon(45)$
<3 × 10 ⁻⁴	90	GILES		Repl. by AVERY 87		201	DIZATION IN A	0 55644		
to 50%		-	. , ,	43% to $B^0\overline{B}^0$. We rescale		POL	ARIZATION IN E	DECAY		
²¹⁵ ALBRECHT 87D re	ports < 8.5	$ imes$ 10 $^{-5}$ assumin	g the $\Upsilon(4S)$	decays 45% to $B^0\overline{B}{}^0$. We	Γ_L/Γ in $B^0 \rightarrow J/r$	$\psi(15)K^*$	(892) ⁰			
rescale to 50%. 216 AVERY 87 reports to 50%.	$< 8 \times 10^{-5}$	assuming the γ	'(4 <i>5</i>) decays 4	10% to $B^0\overline{B}^0$. We rescale		CP eigens	tate with $CP = -1$	[+1].		K*(892) ⁰
	weak neutr	al current. Allov	ved by higher-	$ ho_{121}$ /Γ -order electroweak interac-	0.76±0.07 OUR AVER	65	ABE	95z CDF	Pp at 1.8 T	ГеV
tions. <u>VALUE</u>	CL%	DOCUMENT ID	TECN	COMMENT	$0.80\pm0.08\pm0.05$		²²⁸ ALAM	94 CLE2		
<5.9 × 10 ⁻⁶	90	AMMAR		$e^+e^- \rightarrow \Upsilon(4S)$	$0.97 \pm 0.16 \pm 0.15$			94G ARG	$e^+e^ \rightarrow$	$\Upsilon(4S)$
• • • We do not use the					²²⁸ Averaged over an a	admi×ture	of B^0 and B^+ deca	ys.		
$< 8.3 \times 10^{-6}$	90 21	.7 ALBAJAR	91c UA1	$E_{cm}^{p\overline{p}} = 630 \; GeV$	Γ_I/Γ in $B^0 \to D^*$	ρ ⁺				
$<1.2 \times 10^{-5}$		8 ALBAJAR	91c UA1	$E_{\rm cm}^{p\bar{p}} = 630 \text{ GeV}$	VALUE	EVTS	DOCUMENT ID	TECN	COMMENT	
$<4.3 \times 10^{-5}$		9 AVERY		$e^+e^- \rightarrow \Upsilon(4S)$	$0.93 \pm 0.05 \pm 0.05$	76	ALAM	94 CLE2	$e^+e^ \rightarrow$	$\Upsilon(4S)$
$<4.5 \times 10^{-5}$		O ALBRECHT	87D ARG	$e^+e^- \rightarrow \gamma(4S)$						
$< 7.7 \times 10^{-5}$		¹ AVERY	87 CLEO	$e^+e^- \rightarrow \Upsilon(4S)$			B^0 - $\overline{B}{}^0$ MIXIN	G		
<2 × 10 ⁻⁴	90	GILES	84 CLEO	Repl. by AVERY 87	For a discussion	on of BO-F	mixing see the no	te on "R ⁰ -R	0 Mixing an	d CP
$^{217}B^0$ and _s are not	separated.	_			Violation in E			te on B B	mixing un	u c/
²¹⁸ Obtained from unse	parated B ⁰	and B_s^0 measure	ement by assu	ming a $B^0:B^0_s$ ratio 2:1.	•					
	$< 5 \times 10^{-3}$	assuming the γ	^(4 <i>S</i>) decays 4	43% to $B^0 \overline{B}{}^0$. We rescale	X _d	vine naran	neter is the the pro	hability (inte		Alma Land
to 50%. 220 ALBRECHT 87D re	ports < 5 ×	10^{-5} assuming	the $\Upsilon(4S)$ d	lecays 45% to $B^0\overline{B}^0$. We	produced B ⁰ (or	(\overline{B}^0) deca	ys as a \overline{B}^0 (or B^0).	e.g. for incl	egrated over usive lepton	decays
rescale to 50%				10% to $B^0\overline{B}^0$. We rescale			$(via \ \overline{B}^0))/\Gamma(B^0 \rightarrow$		auto topcon	acca, c
to 50%.	< 9 × 10 ³	assuming the T	(45) decays 4	10% to B ^o B ^o . We rescale			$(\text{via } B^0))/\Gamma(\overline{B}^0 \rightarrow$			
					Where experime	nts have m	easured the parame		$-\chi$), we have	e converted to
$\Gamma(K^0 e^+ e^-)/\Gamma_{\text{total}}$		al aa. Alla		Γ ₁₂₂ /Γ	χ . Mixing violat	es the ΔB	\neq 2 rule.			
tions.	weak neutr	il current. Allow	rea by nigner-	order electroweak interac-	Note that the me	easuremen	t of x at energies hig	her than the	$\Upsilon(4S)$ have	not separated
VALUE	CL%	DOCUMENT ID		COMMENT			oscripts indicate B ⁰	$(\overline{b}d)$ or $B_s^0(\overline{b})$	(s). They are	e listed in the
<3.0 × 10 ⁻⁴	90	ALBRECHT		$e^+e^- \rightarrow \Upsilon(45)$	B_s^0 - \overline{B}_s^0 MIXING	section.				
• • We do not use th					The experiments	s at Υ(4.5)	make an assumption	n about the	$B^0 \overline{B}^0$ fracti	ion and about
$< 5.2 \times 10^{-4}$		² AVERY		$e^+e^- \rightarrow \Upsilon(45)$			semileptonic branc			
to 50%.	< 6.5 × 10 ⁻¹	assuming the 7	(45) decays	40% to $B^0 \overline{B}{}^0$. We rescale	OUR EVALUAT	ION includ	les x_d calculated from	om ∧ <i>m</i> ai	nd #- ^-	
							a carearatea iri	2 B ⁰ u.	· · · · · · · · · · · · · · · · · · ·	
$\Gamma(K^0\mu^+\mu^-)/\Gamma_{\text{total}}$	wask saute	al current Allow	uad bu blabas	Γ ₁₂₃ /Γ order electroweak interac-	<u>VALUE</u> 0.175±0.016 OUR I	CL%	DOCUMENT ID	TECN	COMMENT	<u> </u>
tions.	weak neutra	il current. Allow	rea by nigner-	order electroweak interac-	0.156±0.024 OUR		ON			
VALUE	<u>CL%</u>	DOCUMENT ID		COMMENT	0.16 ±0.04 ±0.04		²²⁹ ALBRECHT	94 ARG	$e^{+}e^{-}$ $-$	→ Υ(4S)
<3.6 × 10 ⁻⁴	90 22	3 AVERY	87 CLEO	$e^+e^- ightarrow \gamma(4S)$	$0.149 \pm 0.023 \pm 0.022$	2	220			
						_	230 BARTELT	93 CLE2		→ Υ(4S)
• • We do not use the	he following				0.171 ± 0.048		²³¹ ALBRECHT	92L ARG	$e^+e^ -$	→ Υ(45) → Υ(45)
$< 5.2 \times 10^{-4}$	he following 90	ALBRECHT	91E ARG	$e^+e^- \rightarrow \Upsilon(4S)$	 ◆ ◆ We do not use to 		²³¹ ALBRECHT ng data for averages	92L ARG , fits, limits,	e ⁺ e [−] − etc. • • •	· r(45)
$<$ 5.2 \times 10 ⁻⁴ 223 AVERY 87 reports $<$	he following 90	ALBRECHT	91E ARG		• • • We do not use to 0.24 ±0.12		²³¹ ALBRECHT ng data for averages ²³² ELSEN	92L ARG , fits, limits, 90 JADE	e ⁺ e ⁻ - etc. • • • e ⁺ e ⁻ 39	→
$ <5.2\times10^{-4} $ 223 AVERY 87 reports < to 50%.	he following 90 $< 4.5 \times 10^{-4}$	ALBRECHT	91E ARG	$e^+e^- \rightarrow \Upsilon(4S)$	 ◆ ◆ We do not use to 		231 ALBRECHT ng data for averages ²³² ELSEN ARTUSO	92L ARG , fits, limits, 90 JADE	e ⁺ e [−] − etc. • • •	→ \(\hat{\chi} \) \(
<5.2 × 10 ⁻⁴ ²²³ AVERY 87 reports < to 50%. Γ (Κ*(892) ⁰ e ⁺ e ⁻)	he following $90 < 4.5 \times 10^{-4}$	ALBRECHT 4 assuming the γ	91E ARG ((4 <i>5</i>) decays 4	$e^+e^- ightarrow \Upsilon(45)$ 40% to $B^0\overline{B}{}^0$. We rescale Γ_{124}/Γ	• • • We do not use to 0.24 ± 0.12 $0.158 + 0.052 - 0.059$ 0.17 ± 0.05	the followin	231 ALBRECHT ng data for averages 232 ELSEN ARTUSO 233 ALBRECHT	92L ARG , fits, limits, 90 JADE 89 CLEC 871 ARG	$e^{+}e^{-}$ - etc. • • • • • $e^{+}e^{-}$ 39 • $e^{+}e^{-}$ - $e^{+}e^{-}$	7(45) 5-44 GeV $7(45)$ $7(45)$
<5.2 × 10 ⁻⁴ 223 AVERY 87 reports < to 50%. $\Gamma(K^*(892)^0 e^+ e^-)$ Test for $\Delta B = 1$	he following $90 < 4.5 \times 10^{-4}$	ALBRECHT 4 assuming the γ	91E ARG ((4 <i>5</i>) decays 4	$e^+e^- ightarrow\varUpsilon(45)$ 40% to $B^0\overline B{}^0$. We rescale	• • • We do not use to 0.24 ± 0.12 0.158 -0.052 0.17 ± 0.05 0.17 ± 0.05	the followin	231 ALBRECHT ng data for averages 232 ELSEN ARTUSO 233 ALBRECHT 234 BEAN	92L ARG , fits, limits, 90 JADE 89 CLEC 871 ARG 87B CLEC	e^+e^- etc. • • • e^+e^- 39 $e^+e^ e^+e^ e^+e^ e^+e^-$	7(45) 5-44 GeV $7(45)$ $7(45)$ $7(45)$
<5.2 × 10 ⁻⁴ ²²³ AVERY 87 reports < to 50%. Γ (Κ*(892) ⁰ e ⁺ e ⁻)	he following $90 < 4.5 \times 10^{-4}$	ALBRECHT 4 assuming the γ	91E ARG ((4 <i>5</i>) decays 4	$e^+e^- ightarrow \Upsilon(45)$ 40% to $B^0\overline{B}{}^0$. We rescale Γ_{124}/Γ	• • • We do not use to 0.24 ± 0.12 $0.158 + 0.052$ 0.059 0.17 ± 0.05 < 0.19 < 0.27	the following th	231 ALBRECHT ng data for averages 232 ELSEN ARTUSO 233 ALBRECHT 234 BEAN 235 AVERY	92L ARG , fits, limits, 90 JADE 89 CLEC 87I ARG 87B CLEC 84 CLEC	$e^{+}e^{-}$ - etc. • • • • $e^{+}e^{-}$ - 38 $e^{+}e^{-}$ - $e^{+}e^{-}$	7(45) 5-44 GeV $7(45)$ $7(45)$ $7(45)$ $7(45)$ $7(45)$
$<5.2 \times 10^{-4}$ ²²³ AVERY 87 reports < to 50%. $\Gamma(K^*(892)^0 e^+ e^-)$ Test for $\Delta B = 1$ tions.	90 < 4.5 × 10 ⁻² /Γ _{total} weak neutra	ALBRECHT 4 assuming the γ	91E ARG (45) decays 4	$e^+e^- ightarrow \varUpsilon(4S)$ 40% to $B^0\overline B{}^0$. We rescale $$\Gamma_{124}/\Gamma$$ order electroweak interac-	• • • We do not use to 0.24 ±0.12 0.158+0.059 0.17 ±0.05 <0.19 <0.27 229 ALBRECHT 94 rep	90 90 90 poorts <i>r</i> =0.1	231 ALBRECHT ng data for averages 232 ELSEN ARTUSO 233 ALBRECHT 234 BEAN 235 AVERY 94 \pm 0.062 \pm 0.054.	92L ARG , fits, limits, 90 JADE 89 CLEC 87I ARG 87B CLEC 84 CLEC	$e^{+}e^{-}$ - etc. • • • • $e^{+}e^{-}$ - 38 $e^{+}e^{-}$ - $e^{+}e^{-}$	7(45) 5-44 GeV $7(45)$ $7(45)$ $7(45)$ $7(45)$ $7(45)$
$<5.2 \times 10^{-4}$ 223 AVERY 87 reports $<$ to 50%. $\Gamma (K^*(892)^0 e^+ e^-)_{I}$ Test for $\Delta B = 1$ tions. MALUE $<2.9 \times 10^{-4}$	he following 90 < 4.5 × 10 ⁻² // Total weak neutro 90	ALBRECHT 4 assuming the γ al current. Allow DOCUMENT ID	91E ARG (45) decays 4 ved by higher- TECN	$e^+e^- ou ag{45}$ 40% to $B^0\overline{B}^0$. We rescale Γ_{124}/Γ order electroweak interac- $COMMENT$ $e^+e^- ou ag{45}$	• • • We do not use to 0.24 ±0.12 0.158+0.059 0.17 ±0.05 <0.19 <0.27 229 ALBRECHT 94 reptaged events (leptaged events (leptag	the following 90 90 90 90 $90 + ports r = 0.1 90 + pools +$	231 ALBRECHT ng data for averages 232 ELSEN ARTUSO 233 ALBRECHT 234 BEAN 235 AVERY 94 ± 0.062 ± 0.054. from D*).	92L ARG , fits, limits, 90 JADE 89 CLEC 87I ARG 87B CLEC 84 CLEC	$e^{+}e^{-}$ - etc. • • • • • • • • • • • • • • • • • • •	7(45) 5-44 GeV $7(45)$ $7(45)$ $7(45)$ $7(45)$ $7(45)$ 10 10 10 10 10 10 10 10
<5.2 \times 10 ⁻⁴ 223 AVERY 87 reports < to 50%. $\Gamma\left(K^{\bullet}(892)^{0} e^{+} e^{-}\right)_{\text{Test for } \Delta B = 1}$ tions. $\frac{VALUE}{<2.9 \times 10^{-4}}$ $\Gamma\left(K^{\bullet}(892)^{0} \mu^{+} \mu^{-}\right)_{\text{Test } \Delta B = 1}$	he following 90 $< 4.5 \times 10^{-4}$ / Γ total weak neutral $\frac{CL\%}{90}$	ALBRECHT 4 assuming the 7 al current. Allow DOCUMENT ID ALBRECHT	91E ARG (45) decays 4 ved by higher- TECN 91E ARG	$e^+e^- o au(4S)$ 40% to $B^0 \overline B{}^0$. We rescale Γ_{124}/Γ order electroweak interac- $\frac{COMMENT}{e^+e^- o au(4S)}$ Γ_{125}/Γ	• • • We do not use to 0.24 ±0.12 0.158+0.052 0.158 ±0.059 0.17 ±0.05 <0.19 <0.27 229 ALBRECHT 94 reg tagged events (lept 230 BARTELT 93 anal	90 90 90 ports <i>r</i> =0.1 ton + pion lysis perfor	231 ALBRECHT ng data for averages 232 ELSEN ARTUSO 233 ALBRECHT 234 BEAN 235 AVERY 94 ± 0.062 ± 0.054. from D*), med using tagged of	92L ARG , fits, limits, 90 JADE 89 CLEC 87I ARG 87B CLEC 84 CLEC We convert	$e^{+}e^{-}$ - etc. • • • • • • • • • • • • • • • • • • •	7(45) 5-44 GeV $7(45)$ $7(45)$ $7(45)$ $7(45)$ $7(45)$ 10 10 10 10 10 10 10 10
<5.2 × 10 ⁻⁴ 223 AVERY 87 reports < to 50%. $\Gamma(K^*(892)^0 e^+ e^-)_{,}$ Test for $\Delta B = 1$ tions. **MALUE** <2.9 × 10 ⁻⁴ $\Gamma(K^*(892)^0 \mu^+ \mu^-)_{,}$ MALUE** **MALUE** **M	he following 90 $< 4.5 \times 10^{-4}$ // total weak neutron 90 // Total 90 // Total $CL\%$	ALBRECHT assuming the 7 al current. Allow DOCUMENT ID ALBRECHT DOCUMENT ID	91E ARG (45) decays 4 ved by higher- 1ECN 91E ARG	$e^+e^- ightarrow \Upsilon(45)$ 40% to $B^0 \overline{B}{}^0$. We rescale Γ_{124}/Γ order electroweak interac- $COMMENT$ $e^+e^- ightarrow \Upsilon(45)$ Γ_{125}/Γ $COMMENT$	• • • We do not use to 0.24 ±0.12 0.158+0.052 0.158 ±0.059 0.17 ±0.05 <0.19 <0.27 229 ALBRECHT 94 reg tagged events (lept 230 BARTELT 93 anal dilepton events the	90 90 90 oorts <i>r</i> =0.1 ton + pion lysis perfor	231 ALBRECHT ng data for averages 232 ELSEN ARTUSO 233 ALBRECHT 234 BEAN 235 AVERY 94 ± 0.062 ± 0.054. from D*). med using tagged 4.157 ± 0.016 ± 0.02	92L ARG, fits, limits, 90 JADE 89 CLEC 871 ARG 87B CLEC 84 CLEC We convert events (lepto 3 g).	e^+e^- - etc. • • • e^+e^- 38 e^+e^- - e^+e^- - e^+e^- - e^+e^- - etc. e^-	→ Y(45) 5-44 GeV → Y(45) → Y(45) → Y(45) → Y(45) → P(45) →
<5.2 × 10 ⁻⁴ 223 AVERY 87 reports < to 50%. $\Gamma(K^*(892)^0 e^+ e^-)_{, \text{ tions.}}$ Test for $\Delta B = 1$ tions. **MALUE** <2.9 × 10 ⁻⁴ $\Gamma(K^*(892)^0 \mu^+ \mu^-)_{, \text{ MALUE}}$ <2.3 × 10 ⁻⁵	he following 90 $< 4.5 \times 10^{-4}$ // total weak neutron 90 // total 90 // total 22 90 22	ALBRECHT 4 assuming the 7 al current. Allow DOCUMENT ID ALBRECHT DOCUMENT ID 4 ALBAJAR	91E ARG (45) decays 4 ved by higher- 1ECN 91E ARG 1ECN 91C UA1 .	$e^+e^- o \Upsilon(45)$ 40% to $B^0 \overline{B}{}^0$. We rescale Γ_{124}/Γ order electroweak interac- $\underline{COMMENT}$ $e^+e^- o \Upsilon(45)$ Γ_{125}/Γ $\underline{COMMENT}$ $E^{D\bar{D}}_{cm} = 630 \; \text{GeV}$	• • • We do not use to 0.24 ±0.12 0.158+0.052 0.159 +0.059 0.17 ±0.05 <0.19 <0.27 229 ALBRECHT 94 reptagged events (lept 230 BARTELT 93 and dilepton events the 231 ALBRECHT 92L is	90 90 90 ports r=0.1 ton + pion lysis perfor by obtain 0 a combine	231 ALBRECHT ng data for averages 232 ELSEN ARTUSO 233 ALBRECHT 234 BEAN 235 AVERY 94 ± 0.062 ± 0.054. from D*). med using tagged 4.157 ± 0.016 ± 0.02	92L ARG, fits, limits, 90 JADE 89 CLEC 87I ARG 87B CLEC We convert events (lepto 3 steps of the step of the s	e^+e^- etc. \bullet \bullet \bullet e^+e^- 39 $e^+e^ e^+e^ $	• Y(45) 5-44 GeV • Y(45) • Y(45) • Y(45) • Y(45) • Y(45) • parison. Uses • D*). Using
<5.2 \times 10 ⁻⁴ 223 AVERY 87 reports < to 50%. $\Gamma\left(K^{\bullet}(892)^{0} e^{+} e^{-}\right)_{I}$ Test for $\Delta B = 1$ tions. VALUE $<2.9 \times 10^{-4}$ $\Gamma\left(K^{\bullet}(892)^{0} \mu^{+} \mu^{-}\right)_{I}$ VALUE $<2.3 \times 10^{-5}$ • • • We do not use the	he following 90 $< 4.5 \times 10^{-4}$ // total weak neutr: 90 // total $= \frac{CL\%}{90}$ // total $= \frac{CL\%}{90}$ 90 22 he following	ALBRECHT al current. Allow DOCUMENT ID ALBRECHT DOCUMENT ID 4 ALBAJAR data for average	91E ARG r(45) decays 4 ved by higher- rECN 91E ARG rECN 91C UA1 es, fits, limits,	$e^+e^- ightarrow \Upsilon(45)$ 40% to $B^0 \overline{B}{}^0$. We rescale Γ_{124}/Γ order electroweak interac- $\underline{COMMENT}$ $e^+e^- ightarrow \Upsilon(45)$ Γ_{125}/Γ $\underline{COMMENT}$ $E_{\rm Cm}^{DD} = 630 \; {\rm GeV}$ etc. • • •	• • • We do not use to 0.24 ±0.12 0.158+0.052 0.158+0.059 0.17 ±0.05 <0.19 <0.27 229 ALBRECHT 94 reptagged events (leptagged events (leptagged events the 231 ALBRECHT 921 is It uses all previous BRECHT 87i. A va	90 90 90 90 poorts r=0.1 ton + pion lysis perfor y obtain 0 a combine ARGUS d	231 ALBRECHT ng data for averages 232 ELSEN ARTUSO 233 ALBRECHT 234 BEAN 235 AVERY $94\pm0.662\pm0.054$. from D^*). med using tagged 4 . $157\pm0.016\pm0.03$ d measurement empta in addition to 150 . 1	92L ARG, fits, limits, 90 JADE 89 CLEC 871 ARG 878 CLEC We convert vents (lepto 33. Sloying severa ew data and citty measure trues of the several seve	e^+e^- etc. • • • • • • • • • • • • • • • • • • •	T(4S) $T(4S)$ $T(4S$
<5.2 × 10 ⁻⁴ 223 AVERY 87 reports < to 50%. $\Gamma(K^{\bullet}(892)^{0} e^{+} e^{-})_{\mu}$ Test for $\Delta B = 1$ tions. $VALUE$ <2.9 × 10 ⁻⁴ $\Gamma(K^{\bullet}(892)^{0} \mu^{+} \mu^{-})_{\mu}$ $VALUE$ <2.3 × 10 ⁻⁵ • • We do not use the <3.4 × 10 ⁻⁴	he following 90 $< 4.5 \times 10^{-4}$ // Ttotal weak neutr: $\frac{CL\%}{90}$ // Ttotal $\frac{CL\%}{90}$ 22 he following 90	ALBRECHT al current. Allow DOCUMENT ID ALBRECHT DOCUMENT ID 4 ALBAJAR data for average ALBRECHT	91E ARG (45) decays of the second sec	$e^+e^- o \Upsilon(45)$ 40% to $B^0 \overline{B}{}^0$. We rescale Γ_{124}/Γ order electroweak interac- $\underline{COMMENT}$ $e^+e^- o \Upsilon(45)$ Γ_{125}/Γ $\underline{COMMENT}$ $E^{D\bar{D}}_{cm} = 630 \; \text{GeV}$	• • • We do not use to 0.24 ±0.12 0.158+0.059 0.17 ±0.05 0.17 ±0.05 0.27 229 ALBRECHT 94 reptagged events (leptagged events the 231 ALBRECHT 92 list uses all previous BRECHT 871. Ave to measure x = ΔΛ to measu	90 90 90 oorts r =0.1 ton + pion lysis perfor y obtain 0 a combine ARGUS d silue of r = M/Γ = 0.7:	231 ALBRECHT ng data for averages 232 ELSEN ARTUSO 233 ALBRECHT 234 BEAN 235 AVERY $94\pm0.062\pm0.054$. from D^*), med using tagged a .157 $\pm0.016\pm0.03$ d measurement or a 20.6 $\pm7.0\%$ is for the B_d a 20.15 or the a 30 a 40 a 50 a	92L ARG, fits, limits, 90 JADE 89 CLEC 871 ARG 878 CLEC We convert vents (lepto 33. Sloying severa ew data and citty measure trues of the several seve	e^+e^- etc. • • • • • • • • • • • • • • • • • • •	T(4S) $T(4S)$ $T(4S$
<5.2 \times 10 ⁻⁴ 223 AVERY 87 reports < to 50%. $\Gamma\left(K^{\bullet}(892)^{0} e^{+} e^{-}\right)_{I}$ Test for $\Delta B = 1$ tions. VALUE $<2.9 \times 10^{-4}$ $\Gamma\left(K^{\bullet}(892)^{0} \mu^{+} \mu^{-}\right)_{I}$ VALUE $<2.3 \times 10^{-5}$ • • • We do not use the	he following 90 $< 4.5 \times 10^{-4}$ // Ttotal weak neutr: $\frac{CL\%}{90}$ // Ttotal $\frac{CL\%}{90}$ 22 he following 90	ALBRECHT al current. Allow DOCUMENT ID ALBRECHT DOCUMENT ID 4 ALBAJAR data for average ALBRECHT	91E ARG (45) decays of the second sec	$e^+e^- ightarrow \Upsilon(45)$ 40% to $B^0 \overline{B}{}^0$. We rescale Γ_{124}/Γ order electroweak interac- $\underline{COMMENT}$ $e^+e^- ightarrow \Upsilon(45)$ Γ_{125}/Γ $\underline{COMMENT}$ $E_{\rm Cm}^{DD} = 630 \; {\rm GeV}$ etc. • • •	• • • We do not use to 0.24 ± 0.12 $0.158 + 0.059$ 0.17 ± 0.05 0.17 ± 0.05 0.19 0.27 0.27 0.29 ALBRECHT 94 reputaged events (lept 230 BARTELT 93 anal dilepton events the 231 ALBRECHT 92 List uses all previous BRECHT 871. A vent of measure $x = \Delta M$ and uses $\tau = \Delta M$	90 90 90 90 90 boots $r=0.1$ ton + pion lysis perfor ey obtain 0 a combine ARGUS d alue of $r=0$ $M/\Gamma=0.7$ $M/\Gamma=0.7$	231 ALBRECHT ng data for averages 232 ELSEN ARTUSO 233 ALBRECHT 234 BEAN 235 AVERY $94\pm0.062\pm0.054$. from D^*). med using tagged $0.157\pm0.016\pm0.03$ dd measurement emplata in addition to $0.06\pm7.0\%$ is directly $0.06\pm7.0\%$ in $0.06\pm7.0\%$ is directly $0.06\pm7.0\%$ in $0.06\pm7.0\%$	92L ARG, fits, limits, 90 JADE 89 CLEC 871 ARG 87B CLEC 84 CLEC We convert events (lepto 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3	e^+e^- etc. • • • • • • • • • • • • • • • • • • •	T(4S) $T(4S)$ $T(4S$
<5.2 \times 10 ⁻⁴ 223 AVERY 87 reports < to 50%. $\Gamma(K^{\bullet}(892)^{0} e^{+} e^{-})_{I}$ Test for $\Delta B = 1$ tions. VALUE <2.9 \times 10 ⁻⁴ $\Gamma(K^{\bullet}(892)^{0} \mu^{+} \mu^{-})_{I}$ VALUE <2.3 \times 10 ⁻⁵ • • • We do not use the <3.4 \times 10 ⁻⁴ 224 ALBAJAR 91C assu	he following 90 $< 4.5 \times 10^{-4}$ // Ttotal weak neutr: $\frac{CL\%}{90}$ // Ttotal $\frac{CL\%}{90}$ 22 he following 90	ALBRECHT al current. Allow DOCUMENT ID ALBRECHT DOCUMENT ID 4 ALBAJAR data for average ALBRECHT	91E ARG (45) decays of the second sec	$e^+e^- o \Upsilon(4S)$ 40% to $B^0 \overline B^0$. We rescale Γ_{124}/Γ order electroweak interac- $COMMENT$ $e^+e^- o \Upsilon(4S)$ Γ_{125}/Γ $COMMENT$ $E^{DB}_{cm} = 630 \text{ GeV}$ etc. • • • $e^+e^- o \Upsilon(4S)$	• • • We do not use to 0.24 ± 0.12 $0.158 + 0.059 \pm 0.059$ 0.17 ± 0.05 < 0.19 < 0.27 < 229 ALBRECHT 94 reptagged events (leptagged events) (leptagged events) and dilepton events the 231 ALBRECHT 92L is to measure $x = \Delta h$ and uses $x = 4 \pm 0.05 \pm 0.05$ $x = 4 \pm 0.$	the following 90 90 oorts r =0.1 ton $+$ pion lysis perfor y obtain 0 a combine $ARGUS$ dalue of r = M/Γ = 0.7: 0 = (0.95 see a com	231 ALBRECHT ng data for averages 232 ELSEN ARTUSO 233 ALBRECHT 234 BEAN 235 AVERY 94 \pm 0.062 \pm 0.054. from D^*). med using tagged α .157 \pm 0.016 \pm 0.02 d measurement em lata in addition to r 20.6 \pm 7.0% is dire 2 \pm 0.15 for the B_d \pm 0.14) $(f_+ - /f_0)$. bination of B_g and	92L ARG, fits, limits, 90 JADE 89 CLEC 87 ARG 87B CLEC 84 CLEC We convert events (lepto 3). Significant sew data and city measure meson. Assu B _d mesons.	e^+e^- - etc. • • • E^- etc. • • • E^- etc. E^- etc. E^- or E^- etc. E^- or E	7(4S) $7(4S)$ $7(4S)$ $7(4S)$ $7(4S)$ $7(4S)$ $7(4S)$ $7(4S)$ $7(4S)$ 10 10 10 10 10 10 10 10
<5.2 × 10 ⁻⁴ 223 AVERY 87 reports < to 50%. $\Gamma(K^{\bullet}(892)^{0} e^{+} e^{-})_{\mu}$ Test for $\Delta B = 1$ tions. $VALUE$ <2.9 × 10 ⁻⁴ $\Gamma(K^{\bullet}(892)^{0} \mu^{+} \mu^{-})_{\mu}$ $VALUE$ <2.3 × 10 ⁻⁵ • • We do not use the <3.4 × 10 ⁻⁴	he following 90 < 4.5 × 10 ⁻⁴ // total weak neutri	ALBRECHT al current. Allow DOCUMENT ID ALBRECHT DOCUMENT ID 4 ALBAJAR data for average ALBRECHT \$\overline{D}\$ quarks give \$B\$	91E ARG (45) decays of the second sec	$e^+e^- ightarrow \Upsilon(45)$ 40% to $B^0 \overline{B}{}^0$. We rescale Γ_{124}/Γ order electroweak interac- $\underline{COMMENT}$ $e^+e^- ightarrow \Upsilon(45)$ Γ_{125}/Γ $\underline{COMMENT}$ $E_{\rm Cm}^{DD} = 630 \; {\rm GeV}$ etc. • • •	• • • We do not use to 0.24 ± 0.12 0.158 ± 0.059 0.17 ± 0.05 0.17 ± 0.05 0.17 ± 0.05 0.19 ± 0.27 0.27 0.29 ALBRECHT 94 reptagged events (leptagged events) (leptagged events) 0.21 ALBRECHT 92 and dilepton events that 0.21 ALBRECHT 91. A vento measure 0.21 and uses 0.21 Albrecht 871. A vento measure 0.21 Albrecht 871. B vento measure 0.21 Albrecht 871. A vento measure 0.21 A vento measure	the following the following specific property of t	231 ALBRECHT ng data for averages 232 ELSEN ARTUSO 233 ALBRECHT 234 BEAN 235 AVERY $94\pm0.062\pm0.054$. from D^*), med using tagged a . $157\pm0.016_{-0.02}^{+0.03}$ dimeasurement emplata in addition to a	92L ARG, fits, limits, 90 JADE 89 CLEC 871 ARG 87B CLEC 84 CLEC We convert events (lepto 33 events) subjuing several ew data and extly measure meson. Assu 8d mesons. e-sign dilepto Measures r=	e^+e^- - etc. • • • E^- etc E^- et	T(4S) $T(4S)$ $T(4S$
<5.2 × 10 ⁻⁴ 223 AVERY 87 reports < to 50%. $\Gamma(K^*(892)^0 e^+ e^-)_{,Test}$ for $\Delta B = 1$ tions. **MALUE* <2.9 × 10 ⁻⁴ $\Gamma(K^*(892)^0 \mu^+ \mu^-)_{,Test}$ **MALUE* <2.3 × 10 ⁻⁵ •• We do not use the <3.4 × 10 ⁻⁴ 224 ALBAJAR 91C assu $\Gamma(e^{\pm} \mu^{\mp})/\Gamma_{total}$ Test of lepton fan MALUE*	he following 90 < 4.5 × 10 ⁻⁴ // total weak neutri	ALBRECHT al current. Allow DOCUMENT ID ALBRECHT DOCUMENT ID 4 ALBAJAR data for average ALBRECHT \$\overline{D}\$ quarks give \$B\$	91E ARG r(45) decays 4 ved by higher	$e^+e^- o \Upsilon(4S)$ 40% to $B^0 \overline B^0$. We rescale Γ_{124}/Γ order electroweak interac- $COMMENT$ $e^+e^- o \Upsilon(4S)$ Γ_{125}/Γ $COMMENT$ $E^{DB}_{cm} = 630 \text{ GeV}$ etc. • • • $e^+e^- o \Upsilon(4S)$	• • • We do not use to 0.24 ± 0.12 0.158+0.052 0.158+0.059 0.17 ± 0.05 <0.19 <0.27 229 ALBRECHT 94 reptagged events (lept 230 BARTELT 93 anal dilepton events the 231 ALBRECHT 92 List uses all previous BRECHT 871. A veto measure x = ΔΛ and uses τ p± / TB 232 These experiments 233 ALBRECHT 871 is plus leptons, and c to X for compariso	the following the following specific probability of the following spe	231 ALBRECHT ng data for averages 232 ELSEN ARTUSO 233 ALBRECHT 234 BEAN 235 AVERY 94 \pm 0.062 \pm 0.054. from D^*). med using tagged 4.157 \pm 0.016 \pm 0.02 d measurement emptata in addition to to 2.0.6 \pm 7.0% is directly 1.15 for the B_d \pm 0.14) $(f_+ - /f_0)$. bination of B_s and neasurement with like constructed event. ded by ALBRECHT	92L ARG, fits, limits, 90 JADE 89 CLEC 81 ARG 87B CLEC 84 CLEC We convert events (lepto 33 cloying severa ew data and cuty measure meson. Assu 8d mesons. e-sign dilepto Measures r= 92L.	e^+e^- - etc. • • • E^- etc E^- et	T(4S) $T(4S)$ $T(4S$
<5.2 × 10 ⁻⁴ 223 AVERY 87 reports < to 50%. $\Gamma(K^*(892)^0 e^+ e^-)_{,Test for \Delta B = 1}$ tions. **MALUE* <2.9 × 10 ⁻⁴ $\Gamma(K^*(892)^0 \mu^+ \mu^-)_{,Test for \Delta B = 1}$ **ALUE* <2.3 × 10 ⁻⁵ •• We do not use the <3.4 × 10 ⁻⁴ 224 ALBAJAR 91C assu $\Gamma(e^{\pm} \mu^{\mp})/\Gamma_{total}$ Test of lepton fanting the state of 10 septon fanting the state of 10	he following 90 $< 4.5 \times 10^{-4}$ Total weak neutring 10 $< \frac{Ct\%}{90}$ 90 $< 2t\%$ he following 90 mmes 36% of milly number $< \frac{Ct\%}{90}$ 90 $< t\%$	ALBRECHT al current. Allow DOCUMENT ID ALBRECHT DOCUMENT ID ALBAJAR data for average ALBRECHT D quarks give B' conservation. DOCUMENT ID AMMAR	91E ARG r(4S) decays 4 ved by higher- rECN 91E ARG 91C UA1 . es, fits, limits, 91E ARG 0 mesons.	$e^+e^- o \Upsilon(45)$ 40% to $B^0 \overline{B}^0$. We rescale Γ_{124}/Γ order electroweak interac- $COMMENT$ $e^+e^- o \Upsilon(45)$ $COMMENT$ $E_{Cm}^{DD} = 630 \text{ GeV}$ etc. • • • $e^+e^- o \Upsilon(45)$ Γ_{126}/Γ $COMMENT$ $E^{DD} = F_{Cm}$ $E^{DD} = F_{Cm}$ $E^{DD} = F_{Cm}$ $E^{DD} = F_{Cm}$	• • • We do not use to 0.24 ±0.12 0.158+0.059 0.17 ±0.059 0.17 ±0.05 <0.19 <0.27 229 ALBRECHT 94 reptagged events (lept 230 BARTELT 93 anal dilepton events the 231 ALBRECHT 92L is to use all previous BRECHT 871. A vato measure x = ΔΛ and uses τ B±/τ B 232 These experiments plus leptons, and cto X for compariso 234 BEAN 878 measure 234 BEAN 878 measure x = ΔΛ and uses τ B±/τ B 235 ALBRECHT 871 is plus leptons, and cto X for compariso 234 BEAN 878 measure 234 BEAN 878 measure x = ΔΛ and uses x B±/τ B 235 ALBRECHT 871 is plus leptons, and cto X BEAN 878 measure x = ΔΛ and x = ΔΛ	the following the following specific properties are specific properties of the following specific properties of the follo	231 ALBRECHT ng data for averages 232 ELSEN ARTUSO 233 ALBRECHT 234 BEAN 235 AVERY 94 \pm 0.062 \pm 0.054. from D^*), med using tagged 4.157 \pm 0.016 \pm 0.02 at measurement emptata in addition to t 20.6 \pm 0.7% is dirt 2 \pm 0.15 for the B_d \pm 0.14) $(f_+ - /f_0)$. denote the sum of t	92L ARG, fits, limits, 90 JADE 89 CLEC 87 ARG 87B CLEC 84 CLEC We convert events (lepto 33 decity measure meson. Assu 8d mesons. e-sign dilepto Measures r= 92L X.	e^+e^- - etc. • • • E^- etc E^- et	T(4S) $T(4S)$ $T(4S$
<5.2 × 10 ⁻⁴ 223 AVERY 87 reports < to 50%. $\Gamma(K^{\bullet}(892)^{0} e^{+} e^{-})_{\Lambda}$ Test for $\Delta B = 1$ titlons. VALUE <2.9 × 10 ⁻⁴ $\Gamma(K^{\bullet}(892)^{0} \mu^{+} \mu^{-})_{\Lambda}$ VALUE <2.3 × 10 ⁻⁵ •• We do not use the <3.4 × 10 ⁻⁴ 224 ALBAJAR 91C assure $\Gamma(e^{\pm} \mu^{\mp})_{\Lambda}$ Test of lepton fand VALUE <5.9 × 10 ⁻⁶ •• We do not use the control of the value of	he following 90 $< 4.5 \times 10^{-4}$ // total weak neutring: $\frac{ct\%}{90}$ // total $\frac{ct\%}{90}$ 22 he following 90 with sample in the sample	ALBRECHT 4 assuming the 7 al current. Allow DOCUMENT ID ALBRECHT DOCUMENT ID 4 ALBAJAR data for average ALBRECHT D quarks give B' conservation. DOCUMENT ID AMMAR data for average	91E ARG r(45) decays 4 ved by higher- rECN 91E ARG 91C UA1 . es, fits, limits, 91E ARG 0 mesons. rECN 94 CLE2 es, fits, limits, limits,	$e^+e^- o au(45)$ 40% to $B^0 \overline{B}^0$. We rescale Γ_{124}/Γ order electroweak interac- $COMMENT$ $e^+e^- o au(45)$ Γ_{125}/Γ $COMMENT$ $E^{D\bar{D}}_{Cm} = 630 \text{ GeV}$ etc. • • • $e^+e^- o au(45)$ Γ_{126}/Γ $COMMENT$ $e^+e^- o au(45)$	• • • We do not use to 0.24 ± 0.12 0.158+0.052 0.158+0.059 0.17 ± 0.05 0.17 ± 0.05 0.27 229 ALBRECHT 94 represents (lepth 230 BARTELT 93 and dilepton events the 231 ALBRECHT 92L is to 123 to	the following the following specific to the	231 ALBRECHT ng data for averages 232 ELSEN ARTUSO 233 ALBRECHT 234 BEAN 235 AVERY 94 \pm 0.662 \pm 0.054. from D^*). med using tagged 6.157 \pm 0.016 \pm 0.02 d measurement empta in addition to t 0.20 d measurement with like 2 \pm 0.14) $(f_+ - /f_0)$. bination of B_s and neasurement with like constructed event. ded by ALBRECHT 24; we converted to Limit assumes semilit exists. The limit exists. The limit exists. The limit exists.	92L ARG, fits, limits, 90 JADE 89 CLEC 84 CLEC 84 CLEC We convert events (lepto 3 cloying severae we data and cuty measure meson. Assu 8d mesons. e-sign dilepto Measures r= 92L. X. eptonic BR ft was correct to the several	e^+e^- = etc. • • • • E = e^+e^- 3: e^+e^- — —	7(4S) $7(4S)$ $7(4S)$ $7(4S)$ $7(4S)$ $7(4S)$ $7(4S)$ $7(4S)$ $7(4S)$ 10 10 10 10 10 10 10 10
<5.2 × 10 ⁻⁴ 223 AVERY 87 reports < to 50%. $\Gamma\left(K^{\bullet}(892)^{0} e^{+} e^{-}\right)_{Test} \text{ for } \Delta B = 1$ $tions.$ $VALUE$ <2.9 × 10 ⁻⁴ $\Gamma\left(K^{\bullet}(892)^{0} \mu^{+} \mu^{-}\right)_{VALUE}$ <2.3 × 10 ⁻⁵ • • We do not use the <3.4 × 10 ⁻⁴ 224 ALBA JAR 91C assure $\Gamma\left(e^{\pm} \mu^{\mp}\right)/\Gamma_{total}$ $Test of lepton fant VALUE$ <5.9 × 10 ⁻⁶ • • We do not use the <3.4 × 10 ⁻⁵	he following 90 < 4.5 × 10 ⁻⁴ // total weak neutri ct//s 90 // total - ct//s 90 22 he following 90 mms 36% of mily number - ct//s 90 100 100 100 100 100 100 100 100 100	ALBRECHT 4 assuming the 7 al current. Allow DOCUMENT ID ALBRECHT DOCUMENT ID 4 ALBAJAR data for average ALBRECHT D quarks give B' conservation. DOCUMENT ID AMMAR data for average 5 AVERY	91E ARG r(45) decays 4 ved by higher- 1ECN 91E ARG 91C UA1 . 2s, fits, limits, 91E ARG 0 mesons. 1ECN 94 CLE2 2s, fits, limits, 89B CLEO	$e^+e^- \rightarrow \Upsilon(4S)$ 40% to $B^0\overline{B}^0$. We rescale Γ_{124}/Γ order electroweak interac- $COMMENT$ $e^+e^- \rightarrow \Upsilon(4S)$ $e^+e^- \rightarrow \Upsilon(4S)$	• • • We do not use to 0.24 ± 0.12 0.158+0.052 0.158+0.059 0.17 ± 0.05 0.17 ± 0.05 0.27 229 ALBRECHT 94 represents (lepth 230 BARTELT 93 and dilepton events the 231 ALBRECHT 92L is to 123 to	the following the following specific to the	231 ALBRECHT ng data for averages 232 ELSEN ARTUSO 233 ALBRECHT 234 BEAN 235 AVERY 94 \pm 0.062 \pm 0.054. from D^* 1. med using tagged α 1.157 \pm 0.016 \pm 0.02 d measurement emp atta in addition to r 20.6 \pm 7.0% is dire \pm 0.15 for the B_d \pm 0.14) $(f_t - f_0)$. bination of B_s and neasurement with like constructed by ALBRECHT 24; we converted to limit assumes semilim	92L ARG, fits, limits, 90 JADE 89 CLEC 84 CLEC 84 CLEC We convert events (lepto 3 cloying severae we data and cuty measure meson. Assu 8d mesons. e-sign dilepto Measures r= 92L. X. eptonic BR ft was correct to the several	e^+e^- = etc. • • • • E = e^+e^- 3: e^+e^- — —	7(4S) $7(4S)$ $7(4S)$ $7(4S)$ $7(4S)$ $7(4S)$ $7(4S)$ $7(4S)$ $7(4S)$ 10 10 10 10 10 10 10 10
<5.2 × 10 ⁻⁴ 223 AVERY 87 reports < to 50%. $\Gamma\left(K^*(892)^0 e^+ e^-\right)_{L}$ Test for $\Delta B = 1$ tions. **MALUE* <2.9 × 10 ⁻⁴ $\Gamma\left(K^*(892)^0 \mu^+ \mu^-\right)_{L}$ **MALUE* <2.3 × 10 ⁻⁵ •• We do not use the continuous of the c	he following 90 < 4.5 × 10 ⁻⁴ // Lotal weak neutri CL% 90 // Lotal - CL% 90 22 he following 90 mmes 36% of mily number - CL% 90 he following 90 22 90 22	ALBRECHT al current. Allow DOCUMENT ID ALBRECHT ALBAJAR data for average ALBRECHT quarks give B' conservation. DOCUMENT ID AMMAR AMMAR 5 AVERY 6 ALBRECHT	91E ARG r(45) decays 4 ved by higher- TECN 91E ARG 91C UA1 . es, fits, limits, 91E ARG mesons. 7ECN 94 CLE2 es, fits, limits, 89B CLEO 87D ARG	$e^+e^- \rightarrow \Upsilon(4S)$ 40% to $B^0\overline{B}^0$. We rescale Γ_{124}/Γ order electroweak interac- $COMMENT$ $e^+e^- \rightarrow \Upsilon(4S)$ $E^{p\overline{p}}_{cm} = 630 \text{ GeV}$ etc. • • • $e^+e^- \rightarrow \Upsilon(4S)$ Γ_{126}/Γ $COMMENT$ $e^+e^- \rightarrow \Upsilon(4S)$ etc. • • • $e^+e^- \rightarrow \Upsilon(4S)$ etc. • • • $e^+e^- \rightarrow \Upsilon(4S)$ $e^+e^- \rightarrow \Upsilon(4S)$ $e^+e^- \rightarrow \Upsilon(4S)$	• • • We do not use to 0.24 ± 0.12 0.158+0.052 0.158+0.059 0.17 ± 0.05 0.17 ± 0.05 0.27 229 ALBRECHT 94 represents (lepth 230 BARTELT 93 and dilepton events the 231 ALBRECHT 92L is to 123 to	the following the following specific to the	231 ALBRECHT ng data for averages 232 ELSEN ARTUSO 233 ALBRECHT 234 BEAN 235 AVERY 94 \pm 0.662 \pm 0.054. from D^*). med using tagged 6.157 \pm 0.016 \pm 0.02 d measurement empta in addition to t 0.20 d measurement with like 2 \pm 0.14) $(f_+ - /f_0)$. bination of B_s and neasurement with like constructed event. ded by ALBRECHT 24; we converted to Limit assumes semilit exists. The limit exists. The limit exists. The limit exists.	92L ARG, fits, limits, 90 JADE 89 CLEC 84 CLEC 84 CLEC We convert events (lepto 3 cloying severae we data and cuty measure meson. Assu 8d mesons. e-sign dilepto Measures r= 92L. X. eptonic BR ft was correct to the several	e^+e^- = etc. • • • • E = e^+e^- 3: e^+e^- — —	7(4S) $7(4S)$ $7(4S)$ $7(4S)$ $7(4S)$ $7(4S)$ $7(4S)$ $7(4S)$ $7(4S)$ 10 10 10 10 10 10 10 10
<5.2 × 10 ⁻⁴ 223 AVERY 87 reports < to 50%. $\Gamma\left(K^{\bullet}(892)^{0} e^{+} e^{-}\right)_{Test} \text{ for } \Delta B = 1$ $tions.$ $VALUE$ <2.9 × 10 ⁻⁴ $\Gamma\left(K^{\bullet}(892)^{0} \mu^{+} \mu^{-}\right)_{VALUE}$ <2.3 × 10 ⁻⁵ • • We do not use the <3.4 × 10 ⁻⁴ 224 ALBA JAR 91C assure $\Gamma\left(e^{\pm} \mu^{\mp}\right)/\Gamma_{total}$ $Test of lepton fant VALUE$ <5.9 × 10 ⁻⁶ • • We do not use the <3.4 × 10 ⁻⁵	he following 90 < 4.5 × 10 ⁻⁴ // Lotal weak neutri CL% 90 // Lotal - CL% 90 22 he following 90 mmes 36% of mily number - CL% 90 he following 90 22 90 22	ALBRECHT 4 assuming the 7 al current. Allow DOCUMENT ID ALBRECHT DOCUMENT ID 4 ALBAJAR data for average ALBRECHT D quarks give B' conservation. DOCUMENT ID AMMAR data for average 5 AVERY	91E ARG r(45) decays 4 ved by higher- rECN 91E ARG 91C UA1 . es, fits, limits, 91E ARG 0 mesons. 7ECN 94 CLE2 es, fits, limits, 89B CLEO 87D ARG 87 CLEO	$e^+e^- \rightarrow \Upsilon(4S)$ 40% to $B^0\overline{B}^0$. We rescale Γ_{124}/Γ order electroweak interac- $COMMENT$ $e^+e^- \rightarrow \Upsilon(4S)$ $e^+e^- \rightarrow \Upsilon(4S)$	• • • We do not use to 0.24 ± 0.12 0.158+0.052 0.158+0.059 0.17 ± 0.05 0.17 ± 0.05 0.27 229 ALBRECHT 94 represents (lepth 230 BARTELT 93 and dilepton events the 231 ALBRECHT 92L is to 123 to	the following the following specific to the	231 ALBRECHT ng data for averages 232 ELSEN ARTUSO 233 ALBRECHT 234 BEAN 235 AVERY 94 \pm 0.662 \pm 0.054. from D^*). med using tagged 6.157 \pm 0.016 \pm 0.02 d measurement empta in addition to t 0.20 d measurement with like 2 \pm 0.14) $(f_+ - /f_0)$. bination of B_s and neasurement with like constructed event. ded by ALBRECHT 24; we converted to Limit assumes semilit exists. The limit exists. The limit exists. The limit exists.	92L ARG, fits, limits, 90 JADE 89 CLEC 84 CLEC 84 CLEC We convert events (lepto 3 cloying severae we data and cuty measure meson. Assu 8d mesons. e-sign dilepto Measures r= 92L. X. eptonic BR ft was correct to the several	e^+e^- = etc. • • • • E = e^+e^- 3: e^+e^- — —	T(4S) $T(4S)$ $T(4S$

$\Delta m_{B^0} = m_{B^0_H} - m_{B^0_L}$

 Δm_{B^0} is the $B^0 {-} \overline{B}^0$ oscillation frequency in time-dependent mixing experiments. OUR EVALUATION includes Δm_{B^0} calculated from χ_d and au_{B^0} .

$VALUE (10^{12} h s^{-1})$	EVTS DOCUMENT	ID TECN	COMMENT	
0.474±0.031 OUR EVAL	.UATION			
0.50 ±0.04 OUR AVER				
0.496 ± 0.046	²³⁶ AKERS		$e^+e^- \rightarrow Z$	
$0.50 \pm 0.12 \pm 0.06$	²³⁷ ABREU	94M DLPH	$e^+e^- \rightarrow Z$	
$0.50 \begin{array}{l} +0.07 & +0.11 \\ -0.06 & -0.10 \end{array}$	²³⁸ BUSKULIO	94B ALEP	$e^+e^- \rightarrow Z$	
$0.52 \begin{array}{c} +0.10 \\ -0.11 \end{array} \begin{array}{c} +0.04 \\ -0.03 \end{array}$	²³⁹ BUSKULIO	93K ALEP	$e^+e^- \rightarrow Z$	
• • • We do not use the	following data for ave	rages, fits, limits,	etc. • • •	
$0.462 + 0.040 + 0.052 \\ -0.053 - 0.035$	²³⁸ AKERS	95J OPAL	$e^+e^- \rightarrow Z$	
$0.508 \pm 0.075 \pm 0.025$	²⁴⁰ AKERS	94c OPAL	$e^+e^- \rightarrow Z$	
$0.57 \pm 0.11 \pm 0.02$	153 ²³⁹ AKERS	94H OPAL	$e^+e^- \rightarrow Z$	
236 This AKERS 95J value measurement, and di tematic errors.	ue combines the jet ch lepton measurement fro			
237 ABREU 94M uses D*	± and hemisphere cha	rges.		
238 Uses dileptons.	,	-		
239 Uses D* Hepton cor	relations.			
240	· -			

 240 AKERS 94C uses $D^{*\pm}\ell^{\mp}$ events and jet charge.

 $\mathbf{x_d} = \Delta m_{B^0} / \Gamma_{B^0}$ This section combines results from the previous two sections.

Time integrated mixing measurements of X determine this quantity directly via

$$\frac{\Delta m_{B^0}}{\Gamma_{B^0}} = \left(\frac{\chi}{0.5 - \chi}\right)^{1/2}$$

while time-dependent mixing measurements determine $\Delta m_{B^0} = m_{B^0_L} - m_{B^0_L}$ which are combined with τ_{B^0} to give

$$\frac{\Delta m_{B^0}}{\Gamma_{B^0}} = \frac{(m_{B^0_H} - m_{B^0_L})^{\tau_{B^0}}}{\hbar} \; .$$

The averaging takes into account the common systematic errors on the LEP experiments due to τ_{D0} .

VALUE	DOCUMENT ID	TECN	COMMENT	
0.73±0.05 OUR AVERAGE				
$0.77 \pm 0.07 \pm 0.03$	²⁴¹ AKERS	95J OPAL	$e^+e^- \rightarrow Z$	
$0.78 \pm 0.21 \pm 0.03$	²⁴¹ ABREU	94M DLPH	$e^+e^- \rightarrow Z$	
0.69 ± 0.18	²⁴² ALBRECHT	94 ARG	$e^+e^- \rightarrow \Upsilon(45)$	
$0.78^{+0.20}_{-0.18}\pm0.03$	²⁴¹ BUSKULIC	94B ALEP	$e^+e^- \rightarrow Z$	
0.65 ± 0.10	²⁴² BARTELT	93 CLE2	$e^+e^- \rightarrow \Upsilon(4S)$	
$0.81^{+0.17}_{-0.18}\!\pm\!0.03$	²⁴¹ BUSKULIC	93K ALEP	$e^+e^- \rightarrow Z$	
0.72 ± 0.15	242 ALBRECHT	92L ARG	$e^+e^- \rightarrow \Upsilon(4S)$	

²⁴¹ Value is their Δm_{B0} measurement combined with $\tau_{B0}=(1.56\pm0.06)$ ps, the average from this edition. The systematic error on τ_{B} and is common to experiments bearing this footnote. The averaging takes this into account.

$B^0-\overline{B}{}^0$ MIXING AND CP VIOLATION IN B DECAY (by H. Quinn, SLAC)

The neutral B meson system is like the neutral kaon system, in that two CP-conjugate states exist. For early work on CPviolation in the B system see Ref. 1. The mass eigenstates are not CP eigenstates, but are mixtures of the two CP-conjugate quark states, the mixing being due to box diagrams, shown in Figure 1. The two mass eigenstates can be written

$$|B_L\rangle = p|B^0\rangle + q|\overline{B}^0\rangle$$
,
 $|B_H\rangle = p|B^0\rangle - q|\overline{B}^0\rangle$. (1)

Here H and L stand for Heavy and Light, respectively.

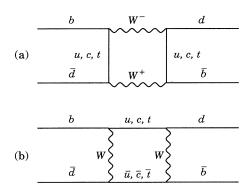


Figure 1: Mixing Diagrams.

Whereas in the kaon case the lifetimes of the two eigenstates are significantly different and the difference in masses between them is small, in the B system it is the mass differences that dominate the physics, and the two states have nearly equal predicted widths (and thus lifetimes).

$$\Gamma = (\Gamma_H + \Gamma_L)/2 , \ \Delta \Gamma = \Gamma_H - \Gamma_L .$$
 (2)

The difference between the widths of the two eigenstates is produced by the contributions from channels to which both B^0 and \overline{B}^0 can decay. These have branching ratios of $\mathcal{O}(10^{-3})$ [2]. Furthermore there are contributions of both signs to the difference, so there is no reason that the net effect should be much larger than the individual terms. Conservatively, one expects $\Delta\Gamma/\Gamma < 10^{-2}$. Experimentally no effect of a difference in lifetimes has been observed. In what follows, we neglect any effects from $\Delta\Gamma$, except where explicitly stated. We define also

$$M \equiv (M_H + M_L)/2 , \quad \Delta M \equiv M_H - M_L .$$
 (3)

²⁴² Derived from time-integrated mixing parameter χ .

The proper time evolution of an initially (t=0) pure B^0 or $\overline{B}{}^0$ is given by

$$\begin{split} |B^0_{\rm phys}(t)\rangle &= \\ &\exp(-\Gamma t/2) \exp(-iMt) \\ &\quad \times \{\cos(\Delta M t/2) |B^0\rangle + i(q/p) \sin(\Delta M t/2) |\overline{B}^0\rangle \} \ , \\ |\overline{B}^0_{\rm phys}(t)\rangle &= \\ &\exp(-\Gamma t/2) \exp(-iMt) \\ &\quad \times \{i(p/q) \sin(\Delta M t/2) |B^0\rangle + \cos(\Delta M t/2) |\overline{B}^0\rangle \} \ . \ (4) \end{split}$$

The probability that an initial B^0 ($\overline{B}{}^0$) decays as a $\overline{B}{}^0$ (B^0) is thus

$$P(t) = \frac{1}{2}e^{-\Gamma t}(1 - \cos(\Delta M t)) \tag{5}$$

where we have used |p/q| = 1 which is true when we neglect the effects of $\Delta\Gamma$. Time-dependent mixing measurements are now being done; earlier experiments measured only the timeintegrated mixing, which is parameterized by a parameter \mathcal{X}_d for B_d (i.e., B^0) and \mathcal{X}_s for B_s (i.e., B_s^0). The quantity \mathcal{X} measures the total probability that a created B^0 decays as a \overline{B}^0 ; it is given by

$$\chi_q = \int_0^\infty P_q(t)dt = \frac{x_q^2}{2(1+x_q^2)} ,$$
 (6)

where q=d,s and $x_q=\frac{\Delta M_q}{\Gamma_q}$, the ratio of the $B_q^0-\overline{B}_q^0$ oscillation frequency to the decay rate. The value of x_d is about 0.7, not very different from the similar quantity for the K^0 which is 0.48. The value of x_s is expected to be much larger, so that the quantity χ_s will be close to its upper limit of 0.5. This means that one cannot determine x_s accurately by measuring χ_s . It will require excellent time resolution to resolve the time-dependent mixing of the B_s^0 system, and thereby determine $\Delta M_{B_s^0}$ [3].

In the B^0 – \overline{B}^0 mixing section of the B^0 Particle Listings, we list the χ_d measurements, most of which come from $\Upsilon(4S)$ data, and the Δm_{B^0} measurements, which come from Z data. We average these sections separately, but then include the results from both sections in "OUR EVALUATION" of χ_s and $\Delta M_{B_s^0}$. We convert both of these sets of measurements and list them in the x_d section. The x_d values obtained from Δm_{B^0} measurements have a common systematic error due to the error on τ_{B^0} . The averaging takes this common systematic error into account.

In the B_s^0 – \overline{B}_s^0 mixing section of the B_s^0 Particle Listings, we give measurements of χ_B , the mixing parameter for a high-energy admixture of b-hadrons

$$\chi_B = f_d \frac{\mathcal{B}_d}{\langle \mathcal{B} \rangle} \chi_d + f_s \frac{\mathcal{B}_s}{\langle \mathcal{B} \rangle} \chi_s . \tag{7}$$

Here f_d and f_s are the fractions of b hadrons that are produced as B^0 and B_s^0 mesons respectively, and \mathcal{B}_d , \mathcal{B}_s , and $\langle \mathcal{B} \rangle$ are branching fractions for B_d , B_s , and the b-hadron admixture

respectively decaying to the observed mode. If we assume that $\chi_s = 0.5$ and $\mathcal{B}_d/\langle \mathcal{B} \rangle = \mathcal{B}_s/\langle \mathcal{B} \rangle = 1$, Eq. (7) can be used to determine f_s as discussed in the note on "Production and Decay of b-Flavored Hadrons."

$CP\ violation\ in\ B\ decays-Standard\ Model\ predictions$:

There are three symmetries of the strong interactions that are not conserved in weak processes. These are the symmetries C, charge conjugation, which relates particle to antiparticle, P, parity, which relates a left-handed particle to a similar righthanded one, and T, time-reversal invariance, which relates a process or state to the time-reversed process or state. In all field theories the product of these three operations, CPT, is an exact symmetry of the equations of motion. All weak decays violate P and C, and a very small part of the weak decays also violate the product CP (and thus T). In the Standard Model this CP violation occurs because there is a single phase that remains in the Cabibbo-Kobayashi-Maskawa (CKM) matrix after all possible field redefinitions that can remove such phases have been made. In a minimal two-generation Standard Model no such phase occurs. The presence of CP-violating effects in K decays was interpreted by Kobayashi and Maskawa in 1973 to suggest a third quark generation. Other extensions beyond the minimal Standard Model, such as theories with additional Higgs multiplets, give further ways to introduce CP violation into the theory. Hence it is of great interest to study whether the pattern of CP-violating effects that can be observed in B decays follows the predictions of the minimal Standard Model, or instead requires the introduction of beyond Standard Model effects. In what follows we first discuss the predictions of the minimal Standard Model. Cosmologists attempting to understand the process by which the matter-antimatter asymmetry of the universe arose suggest that additional sources of CP violation may be needed to give the observed baryon to photon ratio of the universe [4]. Many models which go beyond the Standard Model indeed introduce such possibilities; a few of these are discussed in the final section of this review.

The CKM matrix is the matrix of weak couplings in the three generation Standard Model, expressed in the basis of quark mass eigenstates. This matrix, which must be unitary if the three generations are the complete theory, is discussed in some detail in a separate article in this *Review*. Here we need only remind ourselves of some notation that is commonly used in this context. The matrix can be written

$$V = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$
(8)

$$\simeq \begin{pmatrix} 1 - \lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1 - \lambda^2/2 & A\lambda^2 \\ A\lambda^3(1 - \rho - i\eta) & -A\lambda^2 & 1 \end{pmatrix} + O(\lambda^4) \ .$$

The second expression here is a parameterization due to Wolfenstein [5] with $\lambda = \sin(\theta_{\text{Cabibbo}})$, which is frequently used in discussing CP-violating effects. It is given here up to terms

of order λ^3 , since higher order terms in λ are negligible in most situations. For a way to include higher order terms see Ref. 6. The unitarity triangle is a simple geometrical representation of a relationship which results from the unitarity of the three-generation CKM matrix V:

$$V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0 (9)$$

(In fact there are nine such relationships given by the unitarity of the CKM matrix, but only three are independent conditions and of those the other two will be more difficult to test because they have one term that is of order λ^2 relative to the others.) The three complex quantities $V_{id}V_{ib}^*$ form a triangle in the complex plane. The three angles of this triangle are labeled

$$\alpha \equiv \arg\left(-\frac{V_{td}V_{tb}^*}{V_{ud}V_{ub}^*}\right) , \quad \beta \equiv \arg\left(-\frac{V_{cd}V_{cb}^*}{V_{td}V_{tb}^*}\right) ,$$

$$\gamma \equiv \arg\left(-\frac{V_{ud}V_{ub}^*}{V_{cd}V_{vb}^*}\right) . \tag{10}$$

In terms of the Wolfenstein parameters we can also write

$$\tan(\alpha) = \frac{\eta}{(\eta^2 - \rho(1 - \rho))} , \quad \tan(\beta) = \frac{\eta}{(1 - \rho)} ,$$

$$\tan(\gamma) = \frac{\eta}{\rho} . \tag{11}$$

Notice that the sign as well the magnitude of these angles is meaningful and can be measured.

Figure 2 shows the unitarity triangle, as it is usually drawn, rescaled by $V_{cd}V_{cb}^*$. This makes the base of the triangle real and of unit length and the apex of the triangle is then the point (ρ, η) in the complex plane. A major aim of CP-violation studies of B decays is to make enough independent measurements of the sides and angles that this triangle is overdetermined and thus to check the validity of the Standard Model. Already a number of constraints can be made on the basis of present data on x_d , V_{ub}/V_{cb} , and ϵ in K decays. These constraints have been discussed in many places in the literature; for a recent summary see Ref. 7. Their exact form depends on the mass of the top quark and on the range of values allowed for the B_K parameter in K decays and the parameter combination $B_B f_B^2$ in B decays.

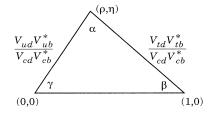


Figure 2: The (rescaled) Unitarity Triangle.

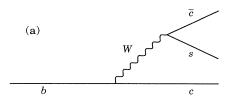
The CKM phases, that is the phases in decay amplitudes which arise because of the phase in the CKM matrix, are often called weak phases, in contrast to the phases which arise from final state rescattering effects, which are referred to as strong phases. When one compares the amplitude for decay to a CP eigenstate to that for the related CP conjugate process, the weak phase ϕ_i of each contribution changes sign, while the strong phase δ_i is unchanged:

$$\mathcal{A} = \Sigma_i \mathcal{A}_i e^{i(\delta_i + \phi_i)} , \overline{\mathcal{A}} = \Sigma_i \mathcal{A}_i e^{i(\delta_i - \phi_i)} . \tag{12}$$

Direct CP violation is a difference in the direct decay rate between $B \to f$ and $\overline{B} \to \overline{f}$ without any contribution from mixing effects. This requires $|\mathcal{A}| \neq |\overline{\mathcal{A}}|$, which occurs only if there is more than one term in the sum Eq. (12), and only if the two terms have both different weak phases and different strong phases. A nonzero result for Re ϵ' in K decay is a direct CP-violation effect. Direct CP violation can occur both in charged channels and in neutral channels.

In the Standard Model direct CP violation occurs when there are two sets of diagrams with different weak phases that contribute to the same decay. There are two major classes of diagrams that contribute to weak decays, tree diagrams and penguin diagrams, examples of which are shown in Figure 3. Tree diagrams are those in which the W does not reconnect to the quark line from which it was emitted. Penguin diagrams are loop diagrams in which the W is reabsorbed on the same quark line, producing a net change of flavor, and a gluon, photon or Z is emitted from the loop. There may be several different tree diagrams for a given process, namely emission from the heavy quark line accompanied by W decay, W exchange between the initial valence quarks, and/or valence quark-antiquark annihilation to produce the W. However all such contributions which enter a given transition do so with the same CKM (weak) phase. Thus, in the Standard Model, direct CP violation occurs because of interference between tree diagrams and penguin diagrams when these have different weak phases, or, in channels where there are no tree contributions, it can also arise because of different weak phases of different penguin contributions. This latter can be a significant effect for $b \rightarrow s\overline{s}d$ decays, as is discussed below.

To calculate the size of expected CP-violation effects one begins from the relevant quark decay diagrams. In general weak-decay amplitudes for b quarks can be divided into two factors: a CKM factor given by the CKM-matrix elements that enter at each W vertex, and a Feynman amplitude from evaluating the diagram. In addition to the suppression from being loop diagrams, penguin diagrams for B decay require the emission of a hard gluon (or photon) from the loop to account for the mass difference between the b quark and the s or d quark produced when the W is reabsorbed. The Feynman amplitude of the penguin diagram is thus suppressed relative to tree diagrams by a factor of order $\alpha_s(m_b)/4\pi$. It is difficult to make firm predictions based on this argument for the strength of the CP-violating effects in exclusive charged B-decay channels



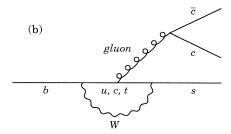


Figure 3: Quark level processes for $b \to c\overline{c}s$: (a) Tree diagram; (b) Penguin diagram. In the case of elelectroweak penguin contributions, the *gluon* is replaced by a Z or a γ .

because the relationship between the free-quark decay diagrams and the exclusive meson-decay amplitudes is model dependent. Furthermore one cannot reliably predict the strong phases that contribute to the asymmetry.

There are additional CP-violating effects in neutral B decays which arise from interference between the two paths to a given final state f

$$B \to f \text{ or } B \to \overline{B} \to f$$

This CP violation in the interference between the mixed and unmixed decay paths is sometimes called CP violation due to interference between mixing and decay. It is similar to the effect measured by the parameter Im ϵ in K decay. The interference between the two contributions can produce rate differences between the decay and its CP conjugate. These effects are of particular interest because they do not depend upon strong phases and hence the measured asymmetries can be directly related to the CKM phases. In some channels there can be direct CP violation in addition to this effect. In such channels the relationship between the measured asymmetry and the CKM parameters is more complicated. We will briefly discuss techniques to separate such contributions later in this review.

A third type of CP violation, referred to as indirect CP violation, or CP violation in the mixing, would arise from any difference in the widths $\Delta\Gamma$ of the two mass eigenstates, or more precisely from complex mixing effects that would also give a nonvanishing lifetime difference for the two B mass eigenstates. Such effects are expected to be tiny in the B_d system. For B_s a small difference in the widths is possible, due to the fact that a number of the simplest two-body channels contribute only to a single CP. The difference in widths could be as much as 20% of the total width in the B_s system [8]. In the particular case

of semileptonic decays there are no penguin diagram contributions, and hence, in the approximations used throughout the discussion above, the CP-conjugate decay rates are equal. An indirect CP-violating asymmetry would be seen as an charge asymmetry in the same-sign dilepton events produced via mixing from an incoherent state that initially contains a $B^0\overline{B}^0$ pair. This asymmetry vanishes with $\Delta\Gamma$; it is expected to be no larger than 1% in B_d decays. [9].

A simple way to distinguish the three types of CP violation is to note that direct CP violation occurs when $|\overline{\mathcal{A}}/\mathcal{A}| \neq 1$, indirect CP violation requires $|q/p| \neq 1$, but CP violation due the interference between direct decay and decay after mixing can occur when both quantities have unit absolute value; it requires only that their product have a nonzero weak phase [10].

Neutral B decays to CP eigenstates: The decays of neutral B's into CP eigenstates is of particular interest because many of these decays allow clean theoretical interpretation in terms of the parameters of the Standard Model [11]. We denote such a state by f_{CP} , for example $f_{CP} = J/\psi(1S)K_S$ or $f_{CP} = \pi\pi$, and define the amplitudes

$$\mathcal{A}_{f_{CP}} \equiv \langle f_{CP} | B^0 \rangle, \quad \overline{\mathcal{A}}_{f_{CP}} \equiv \langle f_{CP} | \overline{B}^0 \rangle$$
 (13)

For convenience let us introduce the quantity r_{fGP}

$$r_{f_{CP}} \equiv \frac{q}{p} \frac{\overline{A_{f_{CP}}}}{A_{f_{CP}}} \ . \tag{14}$$

In the limit of no CP violation, $r_{fCP}=\pm 1$, where the sign is given by the CP eigenvalue of the particular state f_{CP} . (Note that in the literature the quantity r_{fCP} is frequently denoted by λ , but we have chosen to avoid this notation as it introduces a confusion with the $\lambda=\sin(\theta_{\rm Cabibbo})$ in the Wolfenstein parameterization of the CKM matrix.)

The time-dependent rates for initially pure B^0 or $\overline{B}{}^0$ states to decay into a final state f_{CP} at time t is then given by:

$$\langle f_{CP}|B^{0}_{\rm phys}(t)\rangle =$$

$$\mathcal{A}_{f_{CP}} \exp(-\Gamma t/2) \exp(-iMt)$$

$$\times \left[\cos(\Delta Mt/2) + ir_{f_{CP}} \sin(\Delta Mt/2)\right] ,$$

$$\langle f_{CP}|\overline{B}^{0}_{\rm phys}(t)\rangle =$$

$$\mathcal{A}_{f_{CP}} \exp(-\Gamma t/2) \exp(-iMt)(p/q)$$

$$\times \left[i\sin(\Delta Mt/2) + r_{f_{CP}} \cos(\Delta Mt/2)\right] . \tag{15}$$
Thus

$$\begin{split} \Gamma(B_{\rm phys}^0(t) &\to f_{CP}) = \\ |\mathcal{A}_{f_{CP}}|^2 e^{-\Gamma t} \bigg[\frac{1 + |r_{f_{CP}}|^2}{2} + \frac{1 - |r_{f_{CP}}|^2}{2} \end{split}$$

$$\times \cos(\Delta Mt) - \operatorname{Im} r_{f_{CP}} \sin(\Delta Mt) \bigg],$$

$$B^0$$

$$\Gamma(\overline{B}_{\text{phys}}^{0}(t) \to f_{CP}) =$$

$$|\mathcal{A}_{f_{CP}}|^{2} e^{-\Gamma t} \left[\frac{1 + |r_{f_{CP}}|^{2}}{2} - \frac{1 - |r_{f_{CP}}|^{2}}{2} \right] \times \cos(\Delta M t) + \operatorname{Im} r_{f_{CP}} \sin(\Delta M t) . \tag{16}$$

The time-dependent CP asymmetry is

$$a_{f_{CP}}(t) \equiv \frac{\Gamma(B_{\text{phys}}^{0}(t) \to f_{CP}) - \Gamma(\overline{B}_{\text{phys}}^{0}(t) \to f_{CP})}{\Gamma(B_{\text{phys}}^{0}(t) \to f_{CP}) + \Gamma(\overline{B}_{\text{phys}}^{0}(t) \to f_{CP})}$$
(17)

$$a_{f_{CP}}(t) = \frac{(1 - |r_{f_{CP}}|^2)\cos(\Delta M t) - 2\text{Im}\ (r_{f_{CP}})\sin(\Delta M t)}{1 + |r_{f_{CP}}|^2}.(18)$$

When the small difference in width of the two B_d states is ignored we can write

$$(q/p)_{B_d} = \frac{(V_{tb}^* V_{td})}{(V_{tb} V_{td}^*)} , (19)$$

and thus

$$q/p = e^{-2i\phi_M} (20)$$

where $2\phi_M$ denotes the CKM phase of the $B-\overline{B}$ mixing diagram. Further, when there is no direct CP violation in a channel, that is when all amplitudes that contribute have the same CKM decay-phase, ϕ_D , then $|\mathcal{A}_{f_{CP}}/\overline{\mathcal{A}_{f_{CP}}}|=1$. In that case $r_{f_{CP}}$ depends on CKM-matrix parameters only, without hadronic uncertainties, and can be written $r_{f_{CP}}=\pm e^{-2i(\phi_D+\phi_M)}$. Then Eq. (18) simplifies to

$$a_{f_{CP}}(t) = \mp \operatorname{Im} (r_{f_{CP}}) \sin(\Delta M t)$$

= $\pm \sin(2(\phi_M + \phi_D)) \sin(\Delta M t)$. (21)

where the overall sign is given by the CP eigenvalue, ± 1 , of the final state f_{CP} . The mixing phase ϕ_M and the decay phase ϕ_D are each convention dependent, that is their value can be changed by redefining the phases of some of the quark fields. However $\operatorname{Im}\ r_{f_{CP}}$ depends on convention-independent combinations of CKM parameters only, and thus from Eq. (21) one can directly relate the measured CP-violating asymmetry to the phase of particular combination of CKM-matrix elements in the Standard Model.

In an e^+e^- B collider running at the $\Upsilon(4S)$ resonance, the initial B system is produced in a definite CP-eigenstate state which evolves coherently and thus remains $B^0\overline{B}{}^0$ until such time as one of the particles decays. The time evolution of the second particle to decay thus begins at the time of the first decay. Events where one B decays to a flavor-tagging mode while the other decays to a CP-study mode can be used to reconstruct the dependence of the asymmetry on the time between the tagging decay and the CP-study mode decay. The tagging decay may be later, in which case the event is assigned a negative time. Note that the measurement of time dependence is essential at such a machine since, in the interesting cases where Eq. (21) applies, the time-integrated CP asymmetry vanishes.

Hadron machines on the other hand produce uncorrelated B and \overline{B} mesons. In that case the time in the above equations is the time between production and decay, which is always positive, so time-integrated asymmetries do not vanish. Both the tagging particle and the particle decaying to the CP-study mode evolve through mixing, beginning from the time of production. Such machines produce many more B's than will an e^+e^- B factory but the necessity of triggering selections to isolate B events reduces the effective signal somewhat. In addition there are significant backgrounds to contend with in purely hadronic channels, so those channels with leptonic signatures are more readily studied in this environment. The results from the two types of machines will have many complementary features.

Extracting CKM parameters from measured asymmetries: In order to relate the measured asymmetries to the CKM-matrix parameters one looks at the CKM elements that appear in the relevant decay amplitudes and in the mixing diagrams. If the final state of the decay includes a K_S , an additional contribution from the K-mixing phase must be included in relating the measured asymmetry to the CKM parameters.

Table 1 gives the CKM factors for the various b-quark decay channels. For penguin diagrams the table gives the CKM factor of the dominant contributions. Unitarity of the CKM matrix is used to re-express the three different up-type quark loop contributions as a sum of two terms, one of which dominates the contribution. In the case of $b \to d$ processes the subdominant term is suppressed by a term which vanishes with the difference between charm and up quark masses. In the case of $b \to s$ decays the subdominant penguin amplitudes are suppressed by two powers of λ relative to the dominant term given here.

The columns labeled "Sample B_d Modes" and "Sample B_s Modes" list some of the simplest CP-study modes for each case. (These are either CP eigenstates, or modes from which CP-eigenstate contributions can be isolated, for example by angular analysis.) The columns labeled "Angle" show the particular combination of CKM phases $\phi_M + \phi_D$ that is measured by the CP-violating asymmetry in these decays, given as an angle of the unitarity triangle. For most channels the measured asymmetry in a time-dependent measurement is $\pm \sin(2(\phi_M + \phi_D))\sin(\Delta Mt)$. For a time-integrated measurement (uncorrelated production) the asymmetry is $\pm (x_q/(1+x_q^2))\sin(2(\phi_M+\phi_D))$. The sign is given by the CP eigenvalue of the particular final state studied. (The exception to these statements is the channel DK discussed below.)

In obtaining the results given in the table several simplifying approximations have been used. Terms of higher order in $\lambda =$ $\sin(\theta_{\text{Cabibbo}})$ have been dropped. Penguin diagrams that occur at the same order of λ as the corresponding tree diagrams are neglected in stating the relationship of the asymmetry to angles in the unitarity triangle. The comments below the table state

 B^0

where these assumptions are used. Even with these assumptions there are cases where the tree and penguin diagrams are expected to give comparable contributions with different CKM phases. For these decays, as with other direct CP-violating processes, there is no simple relationship between the measured asymmetry and a CKM phase, and thus no entry in the "Angle" columns in Table 1.

The mode $D^0K^*(892)$ is listed even though it is not a CP eigenstate because it has been shown that an analysis of this mode can be used to extract the angle γ [12]. The same type of analysis can also be applied to charged B decays [13]. However the relationship between the decay asymmetry and the angle is not as simple as Eq. (21) in this case. The result will require accurate measurements of a number of branching ratios.

In the case of the $b \to u\overline{u}d + d\overline{d}d$, the penguin contributions occur at the same order in λ as the tree diagrams and are thus are expected to be small compared to them because of the $\alpha(m_b)/\pi$ suppression factor. The result given in Table 1 makes this approximation. If however this expectation proves false, so that the contribu-

tions are comparable, one still may be able to extract a measurement of $\sin(2\alpha)$ from the $\pi^+\pi^-$ asymmetry. This is achieved by measuring the rates in several isospin-related channels and using a multiparameter fit to separate tree and penguin contributions to the amplitudes [14]. The impact of electroweak penguins. which will not be removed by this analysis [15] is quite small in this channel. [16] The isospin analysis will require measuring the decay rate for channel $\pi^0\pi^0$, which will be a challenge. For the $\rho\pi$ decays, if penguins are not negligible, the restrictions due to isospin can again be used to make a multiparameter fit to the ρ -regions of the Dalitz plot for $\pi^+\pi^-\pi^0$ distribution [17]. The interference between different ρ -charge channels is significant and may provide sufficient information to allow the separation of tree and penguin effects and thus extraction of the parameter α . Such analyses at the very least can be used to test whether the penguin contributions are indeed small enough to be neglected in the determination of α .

In the case $b \to s\overline{s}d$ there are no tree graph contributions. The phase of the dominant penguin contribution is such that, combined with mixing effects, it gives a zero asymmetry for

Table 1.	R decay	modes for	CP studies	

Quark Process	Tree CKM	Leading Penguin CKM	Sample B_d Modes	B_d Angle	Sample B_s Modes	B_s Angle	Comments
$b \to c\overline{c}s$	$V_{cb}V_{cs}^* = A\lambda^2$	$V_{cb}V_{cs}^* = A\lambda^2$	$J/\psi(1S)K_S$	β	$J/\psi(1S)\eta', D_s\overline{D}_s$	0	(a)
$b \to s\overline{s}s$	0	$V_{cb}V_{cs}^* = A\lambda^2$	ϕK_S	β	$\phi\eta^{\prime}$	0	(b)
$b \to u \overline{u} s$	$V_{ub}V_{us}^* = A\lambda^4(\rho - i\eta)$	$V_{cb}V_{cs}^* = A\lambda^2$	$K_S\pi^0, K_S ho^0$	_	$\phi\pi^0, K^+K^-$	_	(c)
$b \to d\overline{d}s$	0	$V_{cb}V_{cs}^* = A\lambda^2$	$K_S\pi^0,K_S ho^0$	_	$\phi\pi^0, K_S\overline{K}_S$	_	(c)
$b \rightarrow c\overline{c}d$	$V_{cb}V_{cd}^* = -A\lambda^3$	$V_{tb}V_{td}^* = A\lambda^3(1 - \rho + i\eta)$	$D^+D^-, J/\psi(1S)\pi^0, D^0\overline{D}^0(\dagger)$	β	$J/\psi(1S)K_S$	0	(d)
$b \to s\overline{s}d$	0	$V_{tb}V_{td}^* = A\lambda^3(1 - \rho + i\eta)$	$\phi\pi^0, K_S\overline{K}_S$	<u>-</u>	ϕK_S	β	(c)
$b \to u\overline{u}d$ $b \to d\overline{d}d$	$V_{ub}V_{ud}^* = A\lambda^3(\rho - i\eta)$	$V_{tb}V_{td}^* = A\lambda^3(1 - \rho + i\eta)$	$\pi\pi,\pi ho,\pi a_1$	α	$\pi^0 K_S, ho^0 K_S$	γ	(e)
$b \to c\overline{u}s$ $b \to u\overline{c}s$	$V_{cb}V_{us}^* = A\lambda^3$ $V_{ub}V_{cs}^* = A\lambda^3(\rho - i\eta)$	0	$D_{CP}^{0}K^{*}(892)$	γ	$D^0_{CP} \phi$	_	(f),(g)
$b \to c\overline{u}d$ $b \to u\overline{c}d$	$\begin{split} V_{cb}V_{cd}^* &= A\lambda^2 \\ V_{ub}V_{cd}^* &= A\lambda^4(\rho - i\eta) \end{split}$	0	$D^0_{CP}\pi^0, D^0_{CP} ho^0$	_	$D^0_{CP}K_S$	_	(g)

⁽a) Tree and penguin contribute with same weak phase.

⁽b) Penguin only, rare decays.

⁽c) Tree and penguin compete. Isospin analysis may allow extraction of α , β , for B_d channels, γ , 0 for B_s , where these angles come from tree and penguin contributions respectively. $K_S\overline{K}_S$ penguin only, except 0 asymmetry.

⁽d) Ignoring penguin relative to tree.

 $[\]left(e\right)$ Ignoring penguin relative to tree, or using isospin analysis.

⁽f) Self-tagging $K^*(892)$ decay modes can give γ when data from $B_d \to D^0_{CP}$, i.e. decays to CP eigenstates, and D^0 - or \overline{D}^0 -identified modes are combined. Similar results for charged $B \to DK$.

⁽g) Asymmetry in $D^0_{CP}\pi$, $D^0_{CP}K_S$, etc. modes is difficult to relate to CKM angles.

^(†) $D^0\overline{D}^0$ from rescattering only, rate expected to be small.

 B_d decays and an asymmetry proportional to β for B_s decays. However, Gérard and Hou [18] have pointed out that the sub-dominant penguin terms, proportional to $V_{ub}V_{ud}^*$ can give significant direct CP-violation asymmetries for such channels. Fleischer [19] has estimated that this asymmetry is possibly as large as 50%. While the sub-dominant term in this case would vanish if the masses of the up quark and the charm quark were equal, these estimates, based on the actual quark mass values and operator matrix elements estimated using models, cannot be excluded. Thus, contrary to some comments in the literature, observation of CP-violating asymmetries in channels such as $B_d \to \phi \pi^0$ or $K^0 \overline{K}{}^0$ would not necessarily require beyond-Standard-Model effects to explain them. The B_s decays $b \to c\overline{c}s$ and $b \to s\overline{s}s$ are not affected by this argument. In the first of these the tree terms dominate and the dominant penguin contributions have the same weak phase as those, so the doubly Cabibbo-suppressed sub-dominant penguin contributions are truly negligible. Even in the second case, where there are no tree contributions, the sub-dominant penguin terms are again doubly Cabibbo-suppressed $(V_{ub}V_{us}^*$ compared to $V_{cb}V_{cs}^*)$ and thus the possible Standard Model asymmetry is less than a few

There are some common decay channels of the B^0 and $\overline{B}{}^0$ which are not CP eigenstates. For example the channel $J/\psi(1S)K^*(892)$ where the $K^*(892) \to K_S\pi^0$, the final state is not a CP eigenstate because both even and odd relative angular momenta between the $J/\psi(1S)$ and the $K^*(892)$ are allowed. If there is sufficient data one can use angular analysis to separate the different CP final states and measure the asymmetry in each [21]. The same applies in many quasi-two-body decays, such as other vector-vector channels, or those with higher-spin particles in final states. The branching ratio to these channels can be significantly larger than the CP-eigenstate (vector-scalar or scalar-scalar) channels with the same quark content. Such angular analyses may therefore be important in achieving accurate values for the parameters α and β .

Additional ways to extract CKM parameters by relationships between rates for channels such as $\pi\pi$, πK that can be extracted using SU(3) invariance have received considerable recent attention in the literature. [20] While these relationships will be interesting to investigate, the uncertainties introduced by SU(3) corrections may be significant. The review by Buras cited above gives a good summary of these ideas.

Beyond-Standard-Model effects: The predictions given above are all for the Standard Model. Models beyond the Standard Model may introduce additional contributions to the mixing amplitudes and thereby destroy the relationships given here; in addition they may introduce further direct CP violation.

One model often used as a "straw man" in evaluating the potential of experimental tests of Standard Model predictions is the superweak model, which was one of the earliest proposals for the mechanism of CP violation; in fact it predates the

Standard Model [22]. In the modernized version of this model it is assumed that the CKM matrix is real and that all CPviolating effects arise from a contribution to the mixing that comes from beyond the Standard Model. In this case all the CP-eigenstate channels for B decay would have the same CPviolating asymmetry (up to a sign which differs for CP-odd and CP-even channels) [23]. This applies even to those channels predicted to have zero asymmetry in the Standard Model, as well as those for which the Standard Model prediction is complicated by the competition between tree and penguin contributions. Observation of significantly different asymmetries in any two neutral B decay CP-eigenstate channels would rule out such a model. In addition the observation of any asymmetry in a charged B decay or in a neutral B decay to a flavor-tagging final state would be evidence for direct CP violation [24] and would exclude the superweak model.

Many other models for the physics beyond the Standard Model have been discussed in the literature [25]. The most common additional CP-violating effect is a new contribution to the mixing process, due for example to charged Higgs contributions. The appearance of such contributions in K mixing is already severely restricted by the neutral-K mass difference. However this does not rule out additional contributions to B mixing that would destroy the relationship between the mixing phase ϕ_M and the CKM-matrix elements. This in turn would lead to violations of the predictions given in Table 1 which are based on this relationship. Models with additional (exotic or fourth generation) quarks would remove the constraints of the three-generation mixing matrix and hence lead to the failure of Eq. (9) and would allow new contributions to $B^0 - \overline{B}{}^0$ mixing and hence lead to the failure of Eq. (19) [26]. Any observed deviations from the relationships predicted by the Standard Model will provide a window on the nature of physics beyond the Standard Model.

While the discussion above stresses those channels in which there is a simple relationship between an observed asymmetry and the parameters of the CKM matrix in the Standard Model, this does not mean that other channels are entirely without interest. To date CP violation has only been observed in the neutral K system. Any observation of CP violation in B decays would be exciting. The Standard Model prediction is that direct *CP*-violating asymmetries are likely to be at most a few percent, so large effects in these channels would suggest beyond Standard Model effects. On the other hand, even within the Standard Model the asymmetries due to the interference between decays with and without mixing in the neutral B system can be quite large; current constraints do not rule out cases where Im $(r_{f_{CP}})$ is 1. It is likely that study of the many common decay channels of the B^0 and the \overline{B}^0 will greatly expand our understanding of the sources of CP violation.

B^0

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CP VIOLATION PARAMETERS

$|\text{Re}(\epsilon_{B^0})|$

CP Impurity in B_d^0 system. It is obtained from $a_{\ell\ell}$, the charge asymmetry in like-sign dilepton events at the $\Upsilon(4S)$.

$$\text{Re}(\epsilon_{B^0}) \simeq \frac{1}{4} a_{\ell\ell} = \frac{1}{4} \frac{N(\ell^+\ell^+) - N(\ell^-\ell^-)}{N(\ell^+\ell^+) + N(\ell^-\ell^-)}$$

VALUE DOCUMENT ID TECN COMMENT 243 BARTELT < 0.045 93 CLE2 $e^+e^- \rightarrow \Upsilon(45)$

 $^{243} \, \mathrm{BARTELT}$ 93 finds $a_{\ell \, \ell} = \mathrm{0.033}$ which yields the above $\mathrm{Re}(\epsilon_{B^0})$. = 0.031 \pm 0.096 \pm 0.032 which corresponds to $|a_{\ell\ell}| <$ 0.18,

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PDG	Also BUSKULIC	95 94B	PRL 74 3090 (erratum)	+De Bonis Decamo Ghez Gov Lees+	(ALEPH Collab.)
PROCARIO 94 PRL 73 1306 +Balest, Cho, Daoudi, Ford+ C(LEO Collab.) STONE 94 HEPPY 93-11 +Adam, Adye, Agasi, Aleksee+ (DELPHI Collab.) ABREU 930 PL 8312 253 +Adam, Adye, Agasi, Aljnenko+ (DELPHI Collab.) ACTON 930 PL 8307 247 +Alexander, Allison, Allport, Anderson+ (DRL PHI Collab.) ALBRECHT 932 PNP (C57 531 +Adam, Adye, Agasi, Aljnenko+ (DELPHI Collab.) ALBRECHT 932 PNP (C57 531 +Adam, Adye, Agasi, Aljnenko+ (DELPHI Collab.) ALBRECHT 932 PNR (T1 1680 +Ehrlichmann, Hamacher, Hofmann+ (ARGUS Collab.) ALEXANDER 3819 365 +Ball, Baringer, Coppage, Copty+ (CLEO Collab.) AMMAR 93 PRL 71 1680 +Escheinma, Bloom, Browder (CLEO Collab.) ABATTEL 93 PRL 71 1892 +Ernst, Kroha, Kwon, Roberts+ (CLEO Collab.) Also PNR P	PDG	94	PR D50 1173	Montanet+ (CERN, LE	L, BOST, IFIC+)
ABREU 930 ZPHY (S7 181 +Adam, Adye, Agasi, Alekseev+ (DELPHI Collab.) ABREU 936 PL B307 247 +Adam, Adye, Agasi, Aljinenko+ (DELPHI Collab.) ALBRECHT 93 PHV (S7 53) +Adam, Adye, Agasi, Aljinenko+ (DELPHI Collab.) ALBRECHT 93 PRL 71 160 +Ehrlichmann, Hamacher, Hofmann+ (ARGUS Collab.) ALBREAN 93 PRL 17 160 +Ball Baringer, Coppage, Copty+ (CLCO Collab.) AMMAR 93 PRL 17 1922 +Ernst, Kroha, Kwon, Roberts+ (CLCO Collab.) BATTLE 93 PRL 17 1922 +Ernst, Kroha, Kwon, Roberts+ (CLCO Collab.) BASNULIC 930 PR D307 194 +Decamp, Goy, Lees, Minard+ (ALEPH Collab.) ALBRECHT 90 PR D47 791 +Swarnicki, Stroynowski, Artuso, Goldberg+(CLEC Collab.) ALBRECHT 91 PR D47 791 +Swarnicki, Stroynowski, Artuso, Goldberg+(CLEC Collab.) ALBRECHT 91 PR D45 212 +Kinicoshita, Pipkin, Procario+ (ARGUS Collab.) ALBRECHT 91 PR D45 212 <td></td> <td>94</td> <td>PRL 73 1306</td> <td>+Balest, Cho, Daoudi, Ford+</td> <td>(CLEO Collab.)</td>		94	PRL 73 1306	+Balest, Cho, Daoudi, Ford+	(CLEO Collab.)
ACTON 93C PL B307 247 ALBRECHT 93 ZPHY (57 53) ALBRECHT 93 ZPHY (57 61 11 ALEXANDER 93B PL B319 365 AMMAR 93 PRL 71 674 BARTELT 93 PRL 71 1680 BATTILE 93 PRL 71 1680 BATTILE 93 PRL 71 1680 BATTILE 93 PRL 71 1892 BEAN 93B PRL 72 2681 BUSKULIC 93D PL B307 194 Also 94H PL B325 537 BUSKULIC 93K PL B313 498 ASSANGHERA 93 PR D4 791 ALBRECHT 92C PR B275 195 LABRECHT 92C PL B275 195 LABRECHT 92C PR D45 21 BUSKULIC 92B PR D45 21 HENDERSON 92 PR D45 21 HENDERSON 93 RABHECHT 91E PL B252 188 ALBRECHT 91E PL B254 288 LABAJAR 91C PL B255 297 ALBRECHT 91E PL B254 288 HERCHT 91E PL B254 288 HERCHT 91E PL B254 218 HERCHT 91E PL B254 218 HERCHT 91C PL B255 297 ALBRECHT 91C PL B252 293 ALBRECHT 91C PL B252 294 ALBRECHT 91C PL B252 294 ALBRECHT 91C PL B252 297 ALBRECHT 91C PL B252 294 ALBRECHT 91C PL B252 297 ALBRECHT 91C PL B252 298 ALBRECHT 91C PL B252 297 ALBRECHT 91C PL B25			ZPHY C57 181	+Adam, Adve, Agasi, Alekseev+	(DELPHI Collab.)
ALBRECHT 93E / PFHY C60 11 ALEXANDER 93B PL 131 935 AMMAR 93 PRL 71 674 +Belek, Berkelman, Bloom, Browder (CLEO Collab.) BATTLE 93 PRL 71 1690 BATTLE 93 PRL 71 1690 BATTLE 93 PRL 71 17 1690 BATTLE 93 PRL 71 3922 +Ernst, Kroha, Kwon, Roberts+ CLEO Collab.) BUSKULIC 93D PL B307 194 Also 94H PL B325 537 BUSKULIC 93K PL B313 495 BUSKULIC 93K PL B313 496 BUSKULIC 93K PL B313 497 ALBRECHT 97C PL B275 195 ALBRECHT 97C PL B275 195 ALBRECHT 97C PL B275 195 HENDERSON 92 PR D45 2212 HENDERSON 93 PR D46 251 ALBRECHT 91C PL B256 163 ALBRECHT 91C PL B256 2163 ALBRECHT 91C PL B256 2164 ALBRECHT 91C PL B256 2164 ALBRECHT 91C PL B256 297 ALBRECHT 91C PL B256 2164 ALBRECHT 91C PL B256 297 A	ABREU	93G	PL B312 253	+Adam, Adye, Agasi, Ajinenko+	(DELPHI Collab.)
ALBRECHT 93E / PFHY C60 11 ALEXANDER 93B PL 131 935 AMMAR 93 PRL 71 674 +Belek, Berkelman, Bloom, Browder (CLEO Collab.) BATTLE 93 PRL 71 1690 BATTLE 93 PRL 71 1690 BATTLE 93 PRL 71 17 1690 BATTLE 93 PRL 71 3922 +Ernst, Kroha, Kwon, Roberts+ CLEO Collab.) BUSKULIC 93D PL B307 194 Also 94H PL B325 537 BUSKULIC 93K PL B313 495 BUSKULIC 93K PL B313 496 BUSKULIC 93K PL B313 497 ALBRECHT 97C PL B275 195 ALBRECHT 97C PL B275 195 ALBRECHT 97C PL B275 195 HENDERSON 92 PR D45 2212 HENDERSON 93 PR D46 251 ALBRECHT 91C PL B256 163 ALBRECHT 91C PL B256 2163 ALBRECHT 91C PL B256 2164 ALBRECHT 91C PL B256 2164 ALBRECHT 91C PL B256 297 ALBRECHT 91C PL B256 2164 ALBRECHT 91C PL B256 297 A	ACTON		PL B307 247		(OPAL Collab.)
ALEXANDER 938 PL B319 365 + bebek, Berkelman, Bloom, Browder+ (CLEO Collab.) BARTELT 93 PRL 71 1674 + Ball, Barriger, Coppage, Copty+ (CLEO Collab.) BARTELT 93 PRL 71 1680 + Csorna, Egyed, Jain, Sheldon+ (CLEO Collab.) BATTLE 93 PRL 70 2681 + Csorna, Egyed, Jain, Sheldon+ (CLEO Collab.) BEAN 938 PRL 70 2681 + Cronberg, Kutschke, Menary, Morrison+ (CLEO Collab.) BUSKULLC 93D PL B307 194 + Cronberg, Kutschke, Menary, Morrison+ (ALEPH Collab.) Also 94H PL B325 537 (errata) BUSKULLC 93K PL B313 498 + Decamp, Goy, Less, Minard+ (ALEPH Collab.) ALBRECHT 92C PL B275 195 + Skwanicki, Stroynowski, Artuso, Goldberg+(CLEO Collab.) ALBRECHT 92C PL B275 195 + Ehnichmann, Hamacher, Krueger, Nau+ (ARGUS Collab.) ALBRECHT 92L PHY CS5 357 + Ehnichmann, Hamacher, Krueger, Nau+ (ARGUS Collab.) ALBRECHT 91L PL B273 540 + Ehnichmann, Hamacher, Krueger, Nau+ (ARGUS Collab.) ALBRECHT 91L PL B273 540 + Ph. Berwin, Allkofer, Ankovisk, Appimon+ (LIEO Collab.) ALBRECHT 91L PL B255 297 + Ehnichmann, Glasers, Harder, Krueger+ (ARGUS Collab.) ALBRECHT 91L PL B255 297 + Ehnichmann, Glasers, Harder, Krueger, Mijope+ (ARGUS Collab.) ALBRECHT 91L PL B255 297 + Ehnichmann, Glasers, Harder, Krueger, Nijope+ (ARGUS Collab.) ALBRECHT 91L PL B255 297 + Ehnichmann, Glasers, Harder, Krueger, Nijope+ (ARGUS Collab.) ALBRECHT 91L PL B262 148 + Glaser, Harder, Krueger, Nijope+ (ARGUS Collab.) ALBRECHT 91L PL B262 148 + Glaser, Harder, Krueger, Nijope+ (ARGUS Collab.) ALBRECHT 91L PL B262 148 + Glaser, Harder, Krueger, Nijope+ (ARGUS Collab.) ALBRECHT 91L PL B262 148 + Glaser, Harder, Krueger, Nijope+ (ARGUS Collab.) ALBRECHT 91L PL B262 148 + Glaser, Harder, Krueger, Nijope+ (ARGUS Collab.) ALBRECHT 91L PL B262 148 + Glaser, Harder, Krueger, Nijope+ (ARGUS Collab.) ALBRECHT 91L PL B262 148 + Glaser, Harder, Krueger, Nijope+ (ARGUS Collab.) ALBRECHT 91L PL B262 148 + Glaser, Harder, Krueger, Nijope+ (ARGUS Collab.) ALBRECHT 89C PL B291 121 + Harder, Margus, Nijope+ (ARGUS Collab.) ALBRECHT 89C PL B291 121 + Harder, Margus, Nijope+ (ARGUS Collab.) ALBRECHT	ALBRECHT	93E	ZPHY C60 11	+Ehrlichmann, Hamacher, Hofmann+	(ARGUS Collab.)
BUSKULIC SSK Pl. B313 498	ALEXANDER	93B	PL B319 365		(CLEO Collab.)
BUSKULIC SSK Pl. B313 498	BARTELT		PRL 71 1680	+Csorna, Egved, Jain, Sheldon+	(CLEO Collab.)
BUSKULIC SSK Pl. B313 498	BATTLE		PRL 71 3922	+Ernst, Kroha, Kwon, Roberts+	(CLEO Collab)
BUSKULIC SSK Pl. B313 498			PRL 70 2681 PL R307 194	+Gronberg, Kutschke, Menary, Morrison+	(CLEO Collab.)
BUSKULIC 93K P. B313 498 +De Bonis, Decamp, Ghez, Goy+ (ALEPH Collab.) SANGHERA 93 PR D47 791 +Skwaricki, Stroynowski, Artuso, Goldberg+(CLEO Collab.) +Skwaricki, Stroynowski, Artuso, Goldberg-(Collab.) +Skwaricki, Stroynowski, Artuso, Goldberg-(Collab.) +Skwaricki, Stroynowski, Artuso, Goldberg-(Clean Collab.) +Skwaricki, Artuso, Goldberg-(Cl	Also	94H	PL B325 537 (errata)		
ALBRECHT 92C PH 9275 195 ALBRECHT 92C ZPHY C54 1 ALBRECHT 92C ZPHY C54 1 ALBRECHT 92C ZPHY C55 357 BORTOLETTO 92 PR D45 2212 HENDERSON 92 PR D45 2212 HENDERSON 92 PR D45 2212 HENDERSON 92 PR D45 2212 HENDERSON 93 PR D45 2212 HENDERSON 94 PR D45 2212 HENDERSON 95 PR D45 2212 HENDERSON 95 PR D45 2212 HENDERSON 96 PR D45 2212 HENDERSON 97 PR D45 2212 HENDERSON 97 PR D45 2212 HENDERSON 97 PR D45 2212 HENDERSON 98 PR D45 2212 HENDERSON 99 PR D45 2212 HENDERSON 90 PR D45 2212 HENDERSON 90 PR D45 2212 HENDERSON 91 PR D46 2216 HENDERSON 91 PR D46 397 PR D47 3732 WAGNER 90 PR D42 3732 WAGNER 90 PR D43 3732 WAGNER 90 PR D42 3732 WAGNER 90 PR D43 3732 HHishaw. Ong, Snyder+ ALBRECHT 897 Hishshaw. ARGUS Collab.) ALBRECHT 897 PR D33 123 BBIOCKUS, Brabson+ Hishshaw. Ong, Snyder+ ALBRECHT 897 HISHShaw. ARGUS Collab. ALBRECHT 897 PR D33 123 BBIOCKUS, Brabson+ HISHShaw. ARGUS Collab. ALBRECHT 897 PR D33 123 BBIOCKUS, Brabson+ HISHSHAW. ARGUS Collab. ALBRECHT 897 PR D33 123 BBIOCKUS, Brabson+ HISHSHAW. ARGUS Collab. ALBRECHT 897 PR D33 124 HISHSHAW. ARGUS Co	BUSKULIC	93K	PL B313 498	+De Bonis, Decamp, Ghez, Goy+	(ALEPH Collab.)
ALBRECHT 92C ZPHY C54 1 ALBRECHT 92L ZPHY C55 37 BORTOLETTO 92 PR D45 212 HENDERSON 92 PR D45 2212 HENDERSON 91 PR D45 2215 HABIAGR 91C PL B262 168 ALBRECHT 91C PL B255 297 HABIOWA, Allkofer, Ankoviak, Apsimon+ UALI Collab. ALBRECHT 91C PL B255 297 HENDERSON 81 MENORS FULTON 91 PR D45 651 HESRELMAN 91 "Decays of 8 Mesons" FULTON 91 PR D43 651 HABIAGRECHT 905 PL B262 148 HERRELMAN 908 PR D42 1732 ALBRECHT 907 PRL 64 2117 HOSPIN 91 PR D45 651 HABIAGRECHT 909 PR D47 3732 WAGNER 90 PR D42 3732 WAGNER 80 PL B229 304 HABBECHT 897 PL B229 315 HABIAGRECHT 898 PL B223 340 HABBECHT 898 PL B223 470 HABIAGRECHT 899 PR D42 3732 WAGNER 89 PR D42 3732 WAFRIEN 899 PR D42 3732 WAGNER 89 PR D42 3732 HABIAGRECHT 897 PL B229 315 HABIAGRECHT 897 PL B229 315 HABIAGRECHT 897 PL B229 315 HABIAGRECHT 897 PL B229 316 HABIAGRECHT 897 PL B229 3175 HABIAGRECHT 897 PL B229 3175 HABIAGRECHT 897 PR D42 3245 HABIAGRECHT 897 PL B229 3175 HABI		93 92C	PL B275 195	+Ehrlichmann, Hamacher, Krueger, Nau+	(ARGUS Collab.)
BORTOLETTO 92	ALBRECHT	92G	ZPHY C54 1	+Ehrlichmann, Hamacher, Krueger, Nau+	(ARGUS Collab.)
KRAMER 92 Pl. B279 181 +Palmer (HAMB, OSU)			ZPHY C55 357 PR D45 21	+Ehrlichmann, Hamacher, Krueger, Nau+	(ARGUS Collab.)
KRAMER 92 Pl. B279 181 +Palmer HAMB, OSU ALBAJAR 91C Pl. B262 163 +Albrow, Allkofer, Ankoviak, Apsimon+ (UA1 Collab.) ALBAJAR 91E Pl. B273 540 +Albrow, Allkofer, Ankoviak, Apsimon+ (UA1 Collab.) ALBRECHT 91C Pl. B255 297 +Ehrlichmann, Glaeser, Harder, Krueger, Nippe+ (ARGUS Collab.) ALBRECHT 91C Pl. B255 297 +Ehrlichmann, Glaeser, Harder, Krueger+ (ARGUS Collab.) ARNPS 11 *Stone (CORN. SYRA) *Stone BMesors* FULTON 91 PR D43 651 +Jensen, Johnson, Kagan, Kass+ (CLEO Collab.) ALBRECHT 901 PR D43 651 +Jensen, Johnson, Kagan, Kass+ (CLEO Collab.) ALBRECHT 901 PR D43 651 +Jensen, Johnson, Kagan, Kass+ (CLEO Collab.) ANTREASANA 908 PR D43 732 +Golder, Horwitz, Jain, Mestayer+ (CLEO Collab.) ARTHOLOGY ARGUS Collab.) ALBRECHT 907 PRL 64 2117 +Goldberg, Horwitz, Jain, Mestayer+ (CLEO Collab.) ALBRECHT 890 PL B229 304 +Jensen, Johnson, Ambrus, Barlow, Bartel+ (JADE Collab.) ALBRECHT 890 PL B229 304 +Jensen, Johnson, Marger, Harder, Krueger, Harder, Krueger+ (ARGUS Collab.) ALBRECHT 890 PL B229 304 +Jensen, Johnson, Kagan, Kass+ (CLEO Collab.) ALBRECHT 890 PL B229 304 +Jensen, Johnson, Marger, Harder+ (ARGUS Collab.) ALBRECHT 891 PL B229 304 +Jensen, Johnson, Marger, Harder+ (ARGUS Collab.) ALBRECHT 891 PL B229 304 +Jensen, Johnson, Marger, Harder+ (ARGUS Collab.) AVERNY 898 PL B223 540 +Jensen, Johnson, Marger, Harder+ (ARGUS Collab.) AVERNY 899 PL B223 540 +Jensen, Johnson, Marger, Harder+ (ARGUS Collab.) ALBRECHT 887 PL B209 119 +Jensen, Johnson, Marger, Harder+ (ARGUS Collab.) ALBRECHT 887 PL B209 119 +Jensen, Johnson, Marger, Harder+ (ARGUS Collab.) ALBRECHT 887 PL B209 119 +Jensen, Johnson, Marger, Harder+ (ARGUS Collab.) ALBRECHT 887 PL B209 119 +Jensen, Johnson, Marger, Harder+ (ARGUS Collab.) ALBRECHT 877 PL B183 49 +Jensen, John			PR D45 2212	+Kinoshita, Pipkin, Procario+	(CLEO Collab.)
ALBRECHT 91C PL B255 297			PL B279 181	+Palmer	(HAMB, OSU)
ALBRECHT 91C PL B255 297	ALBAJAR		PL B273 540	+Albrow, Allkofer, Ankoviak+	(UA1 Collab.)
## Serrect Ser	ALBRECHT		PL B254 288	+Glaeser, Harder, Krueger, Nippe+	(ARGUS Collab.)
## Serrect Ser	ALBRECHT	91 F	PL B255 297 PL B262 148	+Glaeser, Harder, Krueger, Nippe+	(ARGUS Collab.)
TULTON 91 PR D43 637 ALBRECHT 90B PL B241 278 ALBRECHT 901 ZPHY (48 533 ANTREASYAN 90B ZPHY (48 535) BORTOLETTO 90 PRL 64 2117 ELSEN 90 ZPHY (48 6349 ROSNER 90 PR D42 3732 WAGNER 90 PR D42 3732 Hisshaw, Ong, Snyder+ (Mark II Collab.) ALBRECHT 387 PL B229 304 ALBRECHT 387 PL B229 304 ALBRECHT 891 PL B229 3154 AVERIL 89 PR D33 233 BEDEK 87 BEDEK 87 BORTOLETTO 89 PR L 62 283 BEDEK 87 PR L 63 1667 Goldber, Horwitz, Mestayer+ (CLEO Collab.) ALBRECHT 888 PL B23 470 BEBEK 87 ALBRECHT 887 PL B33 1667 Goldber, Horwitz, Mestayer+ (CLEO Collab.) ALBRECHT 887 ALBRECHT 889 PR L 63 1667 Goldber, Horwitz, Mestayer+ (CLEO Collab.) ALBRECHT 887 ALBRECHT 887 PR L 63 1667 Goldberg, Horwitz, Mestayer+ (CLEO Collab.) ALBRECHT 887 ALBRECHT 887 PR L 63 1667 Goldberg, Horwitz, Mestayer+ (CLEO Collab.) ALBRECHT 887 ALBRECHT 887 PR L 63 1667 Goldberg, Horwitz, Mestayer+ (CLEO Collab.) ALBRECHT 887 ALBRECHT 887 PR L 63 1667 Goldberg, Horwitz, Mestayer+ (CLEO Collab.) ALBRECHT 887 PR L 63 1667 Goldberg, Horwitz, Mestayer+ (CLEO Collab.) ALBRECHT 887 PL B183 149 Boeks, Bandonn, Glaser+ (ARGUS Collab.) ALBRECHT 870 PL B183 149 Boeks, Bandonn, Glaser+ (ARGUS Collab.) ALBRECHT 871 PL B183 149 Hoeks, Bander, Buckmann+ (ARGUS Collab.) ALBRECHT 871 PL B183 499 Hoeks, Broden, Blucher, Cassel+ (CLEO Collab.) ALBRECHT 871 PL B183 499 Hesson, Blucher, Cassel+ (CLEO Collab.) BEBEK 87 PR D30 1299 Herkelman, Blucher, Cassel+ (CLEO Collab.) BEBEK 87 PR D30 1299 Herkelman, Blucher, Cassel+ (CLEO Collab.) CHEO Collab. HAAS 88 PR D30 1299 Herkelman, Blucher, Cassel+ (CLEO Collab.) CHEO Collab. Herkelman, Bluc	BERKELMAN	91	ARNPS 41 1	+Stone	(CORN, SYRA)
ALBRECHT 901 ZPHY (48 543	"Decays of FULTON	1 <i>B</i> M	esons" PR D43 651	+Jensen, Johnson, Kagan, Kass+	
BORTOLETTO 90	ALBRECHT			+Glaeser, Harder, Krueger, Nilsson+	(ARGUS Collab.)
BORTOLETTO 90			ZPHY C48 543	+Ehrlichmann, Harder, Krueger+	(ARGUS Collab.)
ROSNER 90 PR D42 3732 Hinshaw, Ong, Snyder+ (Mark II Collab.) WAGNER 80 Pl. B219 121 +Boeckmannn, Glaeser, Harder+ (ARGUS Collab.) ALBRECHT 890 Pl. B229 304 +Glaeser, Harder, Krueger+ (ARGUS Collab.) ALBRECHT 891 Pl. B229 175 +Glaser, Harder, Harder, Krueger, Nippe, Oest+ (ARGUS Collab.) ALBRECHT 891 Pl. B232 554 +Glaeser, Harder, Krueger, Nippe, Oest+ (ARGUS Collab.) AVERIUS 89 PR D39 123 +Bebek, Berkelman, Blucher+ (CLEO Collab.) AVERY 89 PR L62 283 +Bebek, Brabson+ (CLEO Collab.) BORTOLETTO 89 PR L62 84 +Goldberg, Horwitz, Mestayer+ (CLEO Collab.) BORTOLETTO 89 PR L62 166 1667 +Goldberg, Horwitz, Mestayer+ (CLEO Collab.) ALBRECHT 88F P. B209 119 +Boeckmann, Glaeser+ (ARGUS Collab.) ALBRECHT 87C P. B185 218 +Binder, Boeckmann, Glaeser+ (ARGUS Collab.) ALBRECHT 87D P. B185 218 +Binder, Boeckmann, Glaeser+ (ARGUS Col	BORTOLETTO	90	PRL 64 2117	+Goldberg, Horwitz, Jain, Mestayer+	(CLEO Collab.)
WAGNER 90	ELSEN	90	ZPHY C46 349	+Allison, Ambrus, Barlow, Bartel+	(JADE Collab.)
ALBRECHT 896 PL B229 304 + Glasser, Harder, Krueger+ (ARGUS Collab.) ALBRECHT 891 PL B229 175 + Glasser, Harder+ (ARGUS Collab.) ALBRECHT 891 PL B229 154 + Glasser, Harder+, Krueger, Nippe, Oest+ (ARGUS Collab.) AVERIL 89 PRL 62 2233 + Blockus, Brabson+ (HRS Collab.) AVERY 898 PL B223 470 + Blockus, Brabson+ (HRS Collab.) BEBEK 89 PRL 62 8 + Berkelman, Blucher+ (CLEO Collab.) BORTOLETTO 899 PRL 62 2436 + Goldberg, Horwitz, Mestayer+ (CLEO Collab.) ALBRECHT 88F PL B209 119 + Bockmann, Glaseer+ (ARGUS Collab.) ALBRECHT 87C PL B185 218 + Binder, Bockmann, Glaseer+ (ARGUS Collab.) ALBRECHT 87D PL B199 451 + Andam, Binder, Bockmann+ (ARGUS Collab.) ALBRECHT 87D PL B199 451 + Andam, Binder, Bockmann+ (ARGUS Collab.)	WAGNER	90	PRL 64 1095	+Hinshaw, Ong, Snyder+	(Mark II Collab.)
ALBRECHT 891 PL B229 175 +Glaser, Harder + Harder, Krueger, Nippe, Oest + (ARGUS Collab.) (ARGUS Collab.) ALBRECHT 89 PR D232 554 +Glaser, Harder, Krueger, Nippe, Oest + (CLEO Collab.) (ARGUS Collab.) AVERIUL 89 PR D39 123 +Bebek, Berkelman, Blucher + (CLEO Collab.) (HRS Collab.) AVERY 898 PR D823 470 +Besson, Garren, Velton + (CLEO Collab.) (CLEO Collab.) BEBEK 89 PRL 62 88 +Berkelman, Blucher + (CLEO Collab.) (CLEO Collab.) BORTOLETTO 89 PRL 63 1667 +Goldberg, Horwitz, Mestayer + (CLEO Collab.) (CLEO Collab.) ALBRECHT 88F PL B209 119 +Boeckmann, Glaser + (ARGUS Collab.) (ARGUS Collab.) ALBRECHT 87C PL B185 218 +Bioder, Boeckmann, Glaser + (ARGUS Collab.) (ARGUS Collab.) ALBRECHT 87D PL B199 451 +Andam, Binder, Boeckmann + (ARGUS Collab.) ALBRECHT 87D PL B183 429 +Andam, Binder, Boeckmann + (ARGUS Collab.) ALBRECHT 87D PL B183 429 +Besson, Bowcock, Giles + (CLEO Collab.) AVERY 87 PL B183 429	ALBRECHT		PL B219 121	+Boeckmannn, Glaeser, Harder+	(ARGUS Collab.)
ALBRECHT 89, Pl. B232 554 + Glaser, Harder, Krueger, Nippe, Oest+ (ARGUS Collab.) AVERIL 89 PR D39 123 + Blockus, Brabson+ (CLEO Collab.) AVERY 898 PL B233 470 + Besex, Garren, Yelton+ (CLEO Collab.) BORTOLETTO 899 PRL 62 8 + Berkelman, Blucher+ (CLEO Collab.) BORTOLETTO 899 PRL 63 1667 + Goldberg, Horwitz, Mestayer+ (CLEO Collab.) ALBRECHT 88F PL B209 119 + Boeckmann, Glasere+ (ARGUS Collab.) ALBRECHT 87C PL B185 218 + Boeckmann, Glasere+ (ARGUS Collab.) ALBRECHT 87C PL B185 218 + Andam, Binder, Boeckmann+ (ARGUS Collab.) ALBRECHT 871 PL B199 451 + Andam, Binder, Boeckmann+ (ARGUS Collab.) ALBRECHT 871 PL B199 451 + Andam, Binder, Boeckmann+ (ARGUS Collab.) ALBRECHT 871 PL B192 245 + Andam, Binder, Boeckmann+ (ARGUS Collab.) ALBRECHT 871 PL B193 452 + Andam, Binder, Boeckmann+ (ARGUS Collab.) ALBRECHT 871 PL B193 452 + Andam, Binder, Boeckmann+ (ARGUS Collab.) ALBRECHT 871 PL B193 452 + Andam, Binder, Boeckmann+ (ARGUS Collab.) ALBRECHT 871 PL B193 452 + Andam, Binder, Boeckmann+ (ARGUS Collab.) ALBRECHT 871 PL B193 452 + Andam, Binder, Boeckmann+ (ARGUS Collab.) ALBRECHT 871 PL B193 452 + Andam, Binder, Boeckmann+ (ARGUS Collab.) ALBRECHT 871 PL B193 452 + Andam, Binder, Boeckmann+ (ARGUS Collab.) ALBRECHT 871 PL B193 452 + Andam, Binder, Boeckmann+ (ARGUS Collab.) ALBRECHT 871 PL B193 452 + Andam, Binder, Boeckmann+ (ARGUS Collab.) ALBRECHT 871 PL B193 452 + Andam, Binder, Boeckmann+ (ARGUS Collab.) ALBRECHT 872 PR B181 459 + Besson, Bowcock, Engler+ (CLEO Collab.) ALBRECHT 866 PL B182 95 + Hölnder, Boeckmann, Glaser+ (CLEO Collab.) ALBRECHT 867 PL B182 95 + Hölnder, Boeckmann, Glaser+ (CLEO Collab.) ALBRECHT 867 PL B182 95 + Hölnder, Boeckmann, Glaser+ (CLEO Collab.) ALBRECHT 867 PL B182 95 + Hölnder, Boeckmann, Glaser+ (CLEO Collab.) ALBRECHT 867 PL B182 95 + Hölnder, Boeckmann, Glaser+ (CLEO Collab.) ALBRECHT 867 PL B182 95 + Hölnder, Boeckmann, Glaser+ (CLEO Collab.) ALBRECHT 867 PL B182 95 + Hölnder, Boeckmann, Glaser+ (CLEO Collab.) ALBRECHT 868 PL B182 95 + Hölnder, Boeckmann, Glaser+ (CLEO C	ALBRECHT		PL B229 304 PL B229 175	+Glaser Harder+	(ARGUS Collab.)
AVERIL 89 PR D39 123 +Blockus, Brabson+ (HRS Collab.) AVERY 898 PL B223 470 +Beson, Garren, Velton+ (CLEO Collab.) BEBEK 89 PR L 62 8 +Berkelman, Blucher+ (CLEO Collab.) BORTOLETTO 89 PR L 62 2436 +Goldberg, Horwitz, Mestayer+ (CLEO Collab.) ALBRECHT 88F PL B209 119 +Boeckmann, Glaser+ (ARGUS Collab.) ALBRECHT 87C PL B185 218 +Bloder, Boeckmann, Glaser+ (ARGUS Collab.) ALBRECHT 87D PL B199 451 +Andam, Binder, Boeckmann+ (ARGUS Collab.) ALBRECHT 87D PL B192 245 +Andam, Binder, Boeckmann+ (ARGUS Collab.) ALBRECHT 87J PL B183 429 +Besson, Bowcock, Giles+ (CLEO Collab.) ALBRECHT 87D PL B183 429 +Besson, Bowcock, Giles+ (CLEO Collab.) ALBRECHT 87D PR D36 1289 +Berkelman, Blucher, Cassel+ (CLEO Collab.) ALBRECHT	ALBRECHT	89L	PL B232 554	+Glaeser, Harder, Krueger, Nippe, Oest+	(ARGUS Collab.)
AVERY 898 Pl. B223 470 + Besson, Garren, Yelton+ (CLEO Collab.) BEBEK 89 PRL 62 8 + Berkelman, Blucher+ (CLEO Collab.) BORTOLETTO 89 PRL 62 2436 + Goldberg, Horwitz, Mestayer+ (CLEO Collab.) BORTOLETTO 89 PRL 63 1667 + Goldberg, Horwitz, Mestayer+ (CLEO Collab.) ALBRECHT 88F PL B209 119 + Boeckmann, Glaeser+ (ARGUS Collab.) ALBRECHT 87C PL B185 218 + Boeckmann, Glaeser+ (ARGUS Collab.) ALBRECHT 87D PL B185 218 + Binder, Boeckmann, Glaser+ (ARGUS Collab.) ALBRECHT 87D PL B199 451 + Andam, Binder, Boeckmann+ (ARGUS Collab.) ALBRECHT 87D PL B192 425 + Andam, Binder, Boeckmann+ (ARGUS Collab.) ALBRECHT 87D PL B183 429 + Besson, Bowcock, Giles+ (CLEO Collab.) AVERY 87D PL B183 429 + Besson, Bowcock, Giles+ (CLEO Collab.) ALBRECHT 86D PR D34 3279 + Bridner, Brock, Brock, Engler+ (CLEO Collab.) ALBRECHT </td <td></td> <td></td> <td>PRL 62 2233</td> <td>+Bebek, Berkelman, Blucher+</td> <td>(CLEO Collab.)</td>			PRL 62 2233	+Bebek, Berkelman, Blucher+	(CLEO Collab.)
BEBEK 89 PRL 62 8 + Berkelman, Blucher + (CLEO Collab.) BORTOLETTO 89 PRL 62 2436 + Goldberg, Horwitz, Mestayer + (CLEO Collab.) BORTOLETTO 89PRL 63 1667 + Goldberg, Horwitz, Mestayer + (CLEO Collab.) ALBRECHT 88F PL B209 119 + Boeckmann, Glaeser + (ARGUS Collab.) ALBRECHT 87C PL B185 218 + Benekmann, Glaeser + (ARGUS Collab.) ALBRECHT 87D PL B195 2245 + Andam, Binder, Boeckmann + (ARGUS Collab.) ALBRECHT 871 PL B197 452 + Andam, Binder, Boeckmann + (ARGUS Collab.) AVERY 87 PL B183 429 + Besson, Bowcock, Giles + (CLEO Collab.) ALBRECHT 87D PL B198 451 + Bobbink, Brock, Engler + (CLEO Collab.) AVERY 87 PL B183 429 + Besson, Bowcock, Giles + (CLEO Collab.) ALBRECHT 87D PL B183 429 + Besson, Brock, Engler + (CLEO Collab.) ALBRECH 87 PR D36 1289 + Berkelman, Blucher, Cassel + (CLEO Collab.) ALBRECH 86 PL D30 3279 + Katayama, Kim, Sun + (CLEO Collab.) ALBRECH			PL B223 470	+Besson, Garren, Yelton+	(CLEO Collab.)
BORTOLETTO 898 PRL 63 1667			PRL 62 8	+Berkelman, Blucher+	(CLEO Collab.)
ALBRECHT 88K Pl. B215 424 +Boeckmann, Glaser+ (ARGUS Collab.) ALBRECHT 87D Pl. B185 218 +Binder, Boeckmann, Glaser+ (ARGUS Collab.) ALBRECHT 87D Pl. B199 451 +Andam, Binder, Boeckmann+ (ARGUS Collab.) ALBRECHT 87D Pl. B192 245 +Andam, Binder, Boeckmann+ (ARGUS Collab.) AVERY 87 Pl. B183 429 +Beson, Bowcock, Glies+ (CLEO Collab.) AVERY 87 PR D38 1239 +Berkelman, Binder, Cassel+ (CLEO Collab.) ALAM 86 PR D34 3279 +Katayama, Kim, Sun+ (CLEO Collab.) ALBRECHT 86F PL B182 95 +Binder, Boeckmann, Glaser+ (ARGUS Collab.) ALBRECHT 86F PL B182 95 +Binder, Boeckmann, Glaser+ (CLEO Collab.) CHA 86P PL D33 2396 +Goldberg, Horwitz, Jawahery+ (CLEO Collab.) CHA 86P PL B15 1309 +Bebek, Berkelman, Cassel+ (CLEO Collab.) CHA 85 PRL B5 13109 +Bebek, Berkelman, Cassel+ (CLEO Collab.)	BORTOLETTO) 89) 89R	PRI 62 2436 PRI 63 1667	+Goldberg, Horwitz, Mestayer+ +Goldberg, Horwitz, Mestayer+	(CLEO Collab.)
ALBRECHT 88K Pl. B215 424 +Boeckmann, Glaseser+ (ARGUS Collab.) ALBRECHT 87C Pl. B185 218 +Binder, Boeckmann, Glaser+ (ARGUS Collab.) ALBRECHT 87D Pl. B199 451 +Andam, Binder, Boeckmann+ (ARGUS Collab.) ALBRECHT 87D Pl. B192 245 +Andam, Binder, Boeckmann+ (ARGUS Collab.) AVERY 87 Pl. B183 429 +Beson, Bowcock, Giles+ (CLEO Collab.) BEBK 87B PR D36 1289 +Berkelman, Blucher, Cassel+ (CLEO Collab.) ALAMM 86 PR D34 3279 +Katayama, Kim, Sun+ (CLEO Collab.) ALBRECHT 86F PL B182 95 +Binder, Boeckmann, Glaser+ (ARGUS Collab.) PDG 86 PL 1708 Aguilar-Bentiez, Potter (CERO Collab.) CHEN 85 PR D31 2386 +Goldberg, Horwitz, Jawahery+ (CLEO Collab.) CHAN 85 PR L55 1248 +Hempstead, Jensen, Kagan+ (CLEO Collab.) GILES 84 PR D30 2279 +Hassard, Hempstead, Kimoshita+ (CLEO Collab.)	ALBRECHT	88F	PL B209 119	+Boeckmann, Glaeser+	(ARGUS Collab.)
ALBRECHT 87D PL B199 451 +Andam, Binder, Boeckmann+ (ARGUS Collab.) ALBRECHT 871 PL B192 245 +Andam, Binder, Boeckmann+ (ARGUS Collab.) ALBRECHT 871 PL B197 452 +Andam, Binder, Boeckmann+ (ARGUS Collab.) AVERY 87 PL B183 +9 Beson, Bowcock, Engler+ (CLEO Collab.) BEBEK 7 PR D36 1289 +Berkelman, Blucher, Cassel+ (CLEO Collab.) ALAM 86 PR D34 3279 +Katayama, Kim, Sun+ (CLEO Collab.) ALBRECHT 86F PL B182 95 +Binder, Boeckmann, Glaser+ (ARGUS Collab.) PDG 86 PL 1708 Aguilar-Bentiez, Porter+ (CERO Collab.) CHAN 85 PRL D31 2386 +Goldberg, Horwitz, Jawahery+ (CLEO Collab.) HAAS 85 PRL D5 1249 +Benebek, Berkelman, Cassel+ (CLEO Collab.) GILES 84 PR D30 2279 +Bassard, Hempstead, Minoshita+ (CLEO Collab.)		88K	PL B215 424 PL B185 218		
ALBRECHT 87J PL B197 452 +Andam, Binder, Boeckmann+ (ARGUS Collab.) AVERY 87 PL B183 429 +Besson, Bowcock, Engler+ (CLEO Collab.) BEBAN 87 PR L 58 183 +Bobbink, Brock, Engler+ (CLEO Collab.) BEBEK 87 PR D36 1229 +Berkelman, Blucher, Cassel+ (CLEO Collab.) ALBRECHT 86 PR D34 3279 +Katayama, Kim, Sun+ (CLEO Collab.) ALBRECHT 86 PL B182 95 +Binder, Boeckmann, Glaser+ (ARGUS Collab.) CHEN 87 PR D31 3366 +Goldberg, Horwitz, Jawahery+ (CLEO Collab.) HAAS 87 PR D31 3309 +Bebek, Berkelman, Cassel+ (CLEO Collab.) GILES 84 PR D30 2279 +Hassard, Hempstead, Minoshita+ (CLEO Collab.)	ALBRECHT	87D	PL B199 451	+Andam, Binder, Boeckmann+	(ARGUS Collab.)
BEAN 87B PRL 59 183 +Bobbink. Brock, Engler+ (CLEO Collab.) BEBEK 87 PR D36 1289 +Berkelman, Blucher, Cassel+ (CLEO Collab.) ALAM 86 PR D34 3279 +Katayama, Kim, Sun+ (CLEO Collab.) ALBRECHT 86F PL B182 95 +Sinder, Boeckmann, Glaser+ (ARGUS Collab.) PDG 86 PL 170B Aguilar-Benitez, Porter+ (CERN, CIT+) CHEN 85 PR D31 2396 +Goldberg, Horwitz, Jawahery+ (CLEO Collab.) HAAS 85 PRL 55 1248 +Hempstead, Jensen, Kagan+ (CLEO Collab.) AVERY 84 PRL D30 2279 +Bassard, Hempstead, Kinoshita+ (CLEO Collab.)	ALBRECHT		PL B192 245 PL B197 452	+Andam, Binder, Boeckmann+	(ARGUS Collab.)
BEAN 87B PRL 59 183 +Bobbink. Brock, Engler+ (CLEO Collab.) BEBEK 87 PR D36 1289 +Berkelman, Blucher, Cassel+ (CLEO Collab.) ALAM 86 PR D34 3279 +Katayama, Kim, Sun+ (CLEO Collab.) ALBRECHT 86F PL B182 95 +Sinder, Boeckmann, Glaser+ (ARGUS Collab.) PDG 86 PL 170B Aguilar-Benitez, Porter+ (CERN, CIT+) CHEN 85 PR D31 2396 +Goldberg, Horwitz, Jawahery+ (CLEO Collab.) HAAS 85 PRL 55 1248 +Hempstead, Jensen, Kagan+ (CLEO Collab.) AVERY 84 PRL D30 2279 +Bassard, Hempstead, Kinoshita+ (CLEO Collab.)	AVERY	87	PL B183 429	+Besson, Bowcock, Giles+	(CLEO Collab.)
ALAM 86 PR D34 3279 + Katayama, Kim, Sun+ (CLEO Collab.) ALBRECHT 86F PL B182 95 + Sinder, Boeckmann, Glaser+ (ARGUS Collab.) PDG 86 PL 170B Aguilar-Benitez, Porter+ (CERN, CIT+) CHEN 85 PR D31 2386 + Goldberg, Horwitz, Jawahery+ (CLEO Collab.) HAAS 85 PRL 55 1248 + Hempstead, Jensen, Kagan+ (CLEO Collab.) AVERY 84 PRL 53 1309 + Bebek, Berkelman, Cassel+ (CLEO Collab.) GILES 84 PR D30 2279 + Hassard, Hempstead, Kinoshita+ (CLEO Collab.)	BEAN	87B	PRL 58 183	+Bobbink, Brock, Engler+	(CLEO Collab.)
PDG 86 PL 170B Aguilar-Benitez, Porter+ (CERN, CIT+) CHEN 85 PR D31 2386 +Goldberg, Horwitz, Jawahery+ (CLEO Collab.) HAAS 85 PRL 55 1248 +Hempstead, Jensen, Kagan+ (CLEO Collab.) AVERY 84 PRL 53 1309 +Bebek, Berkelman, Cassel+ (CLEO Collab.) GILES 84 PR D30 2279 +Hassard, Hempstead, Kinoshita+ (CLEO Collab.)	ALAM	86	PR D34 3279	+Katayama, Kim, Sun+	(CLEO Collab.)
CHEN 85 PR D31 2386 +Goldberg, Horwitz, Jawahery+ (CLEO Collab.) HAAS 85 PRL 55 1248 +Hempstead, Jensen, Kagan+ (CLEO Collab.) AVERY 84 PRL 53 1309 +Bebek, Berkelman, Cassel+ (CLEO Collab.) GILES 84 PR D30 2279 +Hassard, Hempstead, Kinoshita+ (CLEO Collab.)		86F	PL B182 95	+Binder, Boeckmann, Glaser+	(ARGUS Collab.)
GILES 84 PR D30 2279 +Hassard, Hempstead, Kinoshita+ (CLEO Collab.)			PR D31 2386	+Goldberg, Horwitz, Jawahery+	(CLEO Collab.)
GILES 84 PR D30 2279 +Hassard, Hempstead, Kinoshita+ (CLEO Collab.)	HAAS	85	PRL 55 1248	+Hempstead, Jensen, Kagan+	(CLEO Collab.)
BEHRENDS 83 PRL 50 881 + Chadwick, Chauveau, Ganci+ (CLEO Collab.)	GILES		PR D30 2279	+Hassard, Hempstead, Kinoshita+	(CLEO Collab.)
			PRL 50 881	+Chadwick, Chauveau, Ganci+	(CLEO Collab.)

OTHER	R RELATED PAPERS	
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SCHINDLER 88 High Energy Electron-P	ositron Physics 234	(SLAC)
Editors: A. Ali and P. Soeding, World S SCHUBERT 87 IHEP-HD/87-7		(HEIDH)

B^{\pm}/B^{0} ADMIXTURE

B DECAY MODES

The branching fraction measurements are for an admixture of B mesons at the $\Upsilon(4S)$. The values quoted assume that B($\Upsilon(4S) \rightarrow B\overline{B}$) = 100%.

For inclusive branching fractions, e.g., $B \to D^\pm$ anything, the treatment of multiple D's in the final state must be defined. One possiblity would be to count the number of events with one-or-more D's and divide by the total number of B's. Another possibility would be to count the total number of D's and divide by the total number of B's, which is the definition of average multiplicity. The two definitions are identical when only one of the specified particles is allowed in the final state. Even though the "one-or-more' definition seems sensible, for practical reasons inclusive branching fractions are almost always measured using the multiplicity definition. For heavy final state particles, authors call their results inclusive branching fractions while for light particles some authors call their results multiplicities. In the ${\it B}$ sections, we list all results as inclusive branching fractions, adopting a multiplicity definition. This means that inclusive branching fractions can exceed 100% and that inclusive partial widths can exceed total widths, just as inclusive cross sections can exceed total cross sections.

 $\overline{\mathcal{B}}$ modes are charge conjugates of the modes below. Reactions indicate

	Mode	Fraction (Γ_i/Γ)	Confidence level
	Semileptonic and	l leptonic modes	
Γ_1	$e^+ u_e$ anything	[a] (10.4 ±0.4) %	S=1.3
Γ_2	$\overline{p}e^+ u_e$ anything	< 1.6 ×	10 ⁻³ CL=90%
Γ_3	$\mu^+ u_\mu$ anything	[a] (10.3 ± 0.5) %	
Γ_4	$\ell^+ u_\ell$ anything	[a,b] (10.43 ± 0.24) %	
Γ ₅	$D^-\ell^+ u_\ell$ anything	[b] (2.7 ±0.8)%	
Γ_6	$\overline{D}{}^0\ell^+ u_\ell$ anything	[b] (7.0 ±1.4)%	
Γ_7	$D^{*-}\ell^+ u_\ell$ anything		
Γ ₈	$D^{*0}\ell^+ u_\ell$ anything		
Γ_9	$\overline{D}^{**}\ell^+ u_\ell$	[b,c] (2.7 \pm 0.7)%	
Γ_{10}	$\overline{D}(1)(2420)^0\ell^+\nu_\ell$ anything	seen	
Γ_{11}	\overline{D} (2)*(2460) 0 ℓ^+ $ u_\ell$ anything	not seen	
Γ_{12}	$D^{*-}\pi^+\ell^+ u_\ell$ anything	$(1.00\pm0.34)\%$	
Γ_{13}	$D_s^-\ell^+ u_\ell$ anything	$[b] < 9 \times 3$	10 ⁻³ CL=90%
Γ_{14}	$D_s^-\ell^+ u_\ell K^+$ anything	$[b] < 6 \times 1$	10 ^{−3} CL=90%
Γ_{15}	$D_s^-\ell^+ u_\ell K^0$ anything	[b] < 9 ×	10 ⁻³ CL=90%
Γ_{16}	$\ell^+ u_\ell^-$ noncharmed	[b]	
Γ ₁₇	$\mathit{K}^{+}\ell^{+} u_{\ell}$ anything	[b] (6.0 \pm 0.5) %	
Γ_{18}	$K^-\ell^+ u_\ell$ anything	[b] (10 ±4)×	10-3
Γ_{19}	${\mathcal K}^0 / \overline{\mathcal K}{}^0 \ell^+ u_\ell$ anything	[b] (4.4 ± 0.5)%	
	<i>D</i> , <i>D</i> *, or	D _s modes	
Γ_{20}	D^{\pm} anything	(24.2 ±3.3) %	
Γ21	D^0/\overline{D}^0 anything	(58 ±5)%	S=1.1
Γ ₂₂	$D^*(2010)^{\pm}$ anything	(23.1 \pm 3.3) %	S=1.1

$D^{*}(2010)\gamma$	<
$D_s^+\pi^-$, $D_s^{*+}\pi^-$, $D_s^+\rho^-$,	[d] <
$D_s^{*+} \rho^-$, $D_s^+ \pi^0$, $D_s^{*+} \pi^0$,	
$D_{s}^{+}\eta$, $D_{s}^{*+}\eta$, $D_{s}^{+}\rho^{0}$,	
$D_s^{*+} \rho^0$, $D_s^+ \omega$, $D_s^{*+} \omega$	
Charmon	nium mode
L/ab(1S) anything	- (

 Γ_{23} D_s^{\pm} anything

 $\Gamma_{25} D^*(2010) \gamma$

 D_sD , D_s^*D , D_sD^* , or $D_s^*D^*$

27	$J/\psi(15)$ anything	(1.14 ±	0.06) %	
Γ ₂₈	$J/\psi(1S)$ (direct) anything	(8.0 ±	$0.8) \times 10^{-3}$	
Γ_{29}	$\psi(2S)$ anything	(3.5 ±	$0.5) \times 10^{-3}$	
Γ ₃₀	$\chi_{c1}(1P)$ anything	(4.2 ±	$0.7) \times 10^{-3}$	
Γ ₃₁	$\chi_{c1}(1P)$ (direct) anything	(3.7 ±	$0.7) \times 10^{-3}$	
Γ_{32}	$\chi_{c2}(1P)$ anything	<	3.8	$\times 10^{-3}$	CL=90%
Γ33	$\eta_c(1S)$ anything	<	9	$\times 10^{-3}$	CL=90%

[d] (8.6 ±1.6)%

[d] (4.9 ± 1.1)%

< 1.1

[d] < 5

 $\times 10^{-3}$

 $\times 10^{-4}$

CL=90%

	K	or <i>K</i> *	mor	ies				
Γ ₃₄	K^{\pm} anything		[d]		78.9	±2.5) %	
Γ ₃₅	K ⁺ anything			(66	± 5) %	
Γ ₃₆	K^- anything			(13	\pm 4) %	
Γ ₃₇	$\mathcal{K}^0 / \overline{\mathcal{K}}{}^0$ anything		[d]	(64	± 4) %	
Γ ₃₈	$K^*(892)^{\pm}$ anything			(18	± 6) %	
Γ ₃₉	$K^*(892)^0 / \overline{K}^*(892)^0$ anythin	ıg	[d]	(14.6	± 2.6) %	
Γ ₄₀	$K^*(892)\gamma$							
Γ ₄₁	$K_1(1400)\gamma$			<	4.1		× 10	
Γ ₄₂	$K_2^*(1430)\gamma$			<	8.3		× 10 ⁻	
Γ ₄₃	$K_2(1770)\gamma$			<	1.2		× 10 ⁻	
Γ44	$K_3^*(1780)\gamma$			<	3.0		× 10 ⁻	
Γ ₄₅	$K_4^*(2045)\gamma$			<			× 10	
Γ ₄₆	$\overline{b} \rightarrow \overline{s} \gamma$			(2.3	± 0.7) × 10 ⁻	- 4
Γ ₄₇	$b \rightarrow \overline{s}$ gluon							
	Light unfla	vored	mes	on	mod	es		
Γ ₄₈	π^\pm anything		[d,e]	(359	±7) %	
Γ_{49}	$ ho^0$ anything			(21	± 5) %	
Γ ₅₀	ω anything			<	81		%	CL=90%
Γ ₅₁	ϕ anything			(3.5	±0.7) %	S=1.
	Ва	ryon	mode	es				
Γ_{52}	charmed-baryon anything	-		(6.4	±1.1) %	
Γ ₅₃	$\overline{\Sigma}_c^{}$ anything			į.) × 10 ⁻	-3
Γ ₅₄	$\overline{\Sigma}_{a}^{c}$ anything			<	1.1		%	CL=90%
Γ ₅₅	$\overline{\Sigma}_{c}^{c}$ anything $\overline{\Sigma}_{c}^{0}$ anything			(5.2	±2.5) × 10 ⁻	-3
Γ ₅₆	$\overline{\Sigma}_{c}^{0} N(N = p \text{ or } n)$			<`	1.7		× 10 ⁻	
Γ ₅₇	p/\overline{p} anything		[d]	(±0.4) %	
Γ ₅₈	p/\overline{p} (direct) anything		[d]	(±0.5	,	
Γ ₅₉	Λ/Λ anything		[d]	(±0.5	,	
Γ ₆₀	$\Xi^{-}/\overline{\Xi}^{+}$ anything		[d]	() × 10 ⁻	-3
Γ ₆₁	baryons anything		. ,	ì		±0.6		
Γ ₆₂	p panything			ì		7±0.2		
Γ ₆₃	$\Lambda \overline{p} / \overline{\Lambda} p$ anything		[d]	ì		±0.4		
Γ ₆₄	$\Lambda \overline{\Lambda}$ anything			<	5		× 10 ⁻	·3 CL=90%
	$\Delta B = 1$ weak ne	utral	curre	ent	(B1) mor	les	
Γ ₆₅	e^+e^- anything	B1		<	2.4	,	× 10 ⁻	-3 CL=90%
Γ ₆₆	$\mu^+\mu^-$ anything	B1		<	2.4		× 10-	
[a]	These values are model deper in the B^+ Particle Listings.	enden	t. Se	e '	Note	on S	emilept	tonic Decays
[b]	ℓ indicates e or μ mode, not	sum	over	mo	odes.			
[c]	D^{**} stands for the sum of t $D(2^{1}S_{0})$, and $D(2^{1}S_{1})$ reson			1),	D(1	${}^{3}P_{0}),$	D(1 ³ P	$(1), D(1^3P_2)$
[d]	The value is for the sum of the indicated.			ate	s of	partic	le/antip	article state
[e]	Inclusive branching fractions greater than 100%.	have	e a n	nul	tiplic	ity de	finition	and can b

- greater than 100%.

B^{\pm}/B^{0} ADMIXTURE BRANCHING RATIOS

 $\Gamma(\ell^+\nu_\ell \, \text{anything})/\Gamma_{\text{total}}$ These branching fraction values are model dependent. See the note on "Semileptonic Decays of $\mathcal B$ Mesons at the beginning of the $\mathcal B^+$ Particle Listings.

VALUE	DOCUMENT ID TECN COMMENT	
0.1043±0.0024 OUR AVERAGE	Includes data from the 2 datablocks that follow this	
0.108 ±0.002 ±0.0056	one. 1 HENDERSON 92 CLEO $e^+e^- ightarrow \varUpsilon(45)$	

 1 HENDERSON 92 measurement employs e and $\mu. \,$ The systematic error contains 0.004 in quadrature from model dependence. The authors average a variation of the Isgur, Scora, Grinstein, and Wise model with that of the Altarelli-Cabibbo-Corbò-Maiani-Martinelli model for semileptonic decays to correct the acceptance.

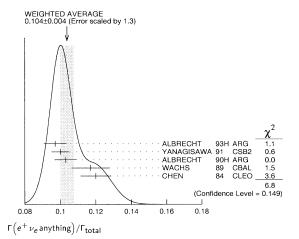
 $\Gamma(e^+
u_e$ anything)/ Γ_{total} These branching fraction values are model dependent. See the note on "Semileptonic" Decays of B Mesons at the beginning of the B^+ Particle Listings.

<u>VALUE</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u>
The data in this block is included in the average printed for a previous datablock.

```
0.104 \pm 0.004 OUR AVERAGE Error includes scale factor of 1.3. See the ideogram below.
                                                      ^2 ALBRECHT \, 93H ARG \, e^+ e^- \rightarrow \, \varUpsilon(4S) ^3 YANAGISAWA 91 CSB2 \, e^+ e^- \rightarrow \, \varUpsilon(4S) ^4 ALBRECHT \, 90H ARG \, e^+ e^- \rightarrow \, \varUpsilon(4S)
0.097 \pm 0.005 \pm 0.004
0.100 \pm 0.004 \pm 0.003
0.103 \pm 0.006 \pm 0.002
                                                                                89 CBAL Direct e at \Upsilon(4S)
84 CLEO Direct e at \Upsilon(4S)
0.117 \pm 0.004 \pm 0.010
0.120 \pm 0.007 \pm 0.005
                                                        CHEN
\bullet \,\bullet \,\bullet We do not use the following data for averages, fits, limits, etc. \,\bullet \,\bullet
                                                      ^6 KLOPFEN... 83B CUSB Direct e at \varUpsilon(4S)
0.132 \pm 0.008 \pm 0.014
```

Meson Particle Listings B^{\pm}/B^{0} ADMIXTURE

- 2 ALBRECHT 93H analysis performed using tagged semileptonic decays of the ${\it B.}$ This technique is almost model independent for the lepton branching ratio.
- a YANAGISAWA 91 also measures an average semileptonic branching ratio at the $\Upsilon(5.5)$ of 9.6–10.5% depending on assumptions about the relative production of different B
- ⁴ ALBRECHT 90H uses the model of ALTARELLI 82 to correct over all lepton momenta. 0.099 ± 0.006 is obtained using ISGUR 89B.
- 5.039 \pm 0.000 is obtained above p(e)=2.4 GeV, WACHS 89 determine $\sigma(B\to e\nu {\rm up})/\sigma(B\to e\nu {\rm charm})<0.065$ at 90% CL.
- ⁶ Ratio $\sigma(b \rightarrow e \nu \text{up})/\sigma(b \rightarrow e \nu \text{charm}) < 0.055 \text{ at CL} = 90\%.$



 $\Gamma(\mu^+\nu_\mu \text{ anything})/\Gamma_{\text{total}}$ These branching fraction values are model dependent. See the note on "Semileptonic Decays of B Mesons at the beginning of the B^+ Particle Listings.

DOCUMENT ID TECN COMMENT VALUE DOCUMENT ID TECN COMMENT

The data in this block is included in the average printed for a previous datablock.

0.103±0.005 OUR AVERAGE

$0.100 \pm 0.006 \pm 0.002$	' ALBRECHT	90H ARG	$e^+e^- \rightarrow \Upsilon(4S)$
$0.108 \pm 0.006 \pm 0.01$	CHEN	84 CLEO	Direct μ at $\Upsilon(4S)$
$0.112 \pm 0.009 \pm 0.01$	LEVMAN	84 CUSB	Direct μ at $\Upsilon(4S)$

 7 ALBRECHT 90H uses the model of ALTARELLI 82 to correct over all lepton momenta. 0.097 ± 0.006 is obtained using ISGUR 89B

$\Gamma(\overline{\rho}_{e} + \mu_{e}) / \Gamma_{e}$

$\Gamma(\overline{p}e^+\nu_e \text{ anything})$	$/\Gamma_{total}$				Г	2/Γ
VALUE	CL%	DOCUMENT ID	TECN	COMMENT		
< 0.0016	90	ALBRECHT	90н ARG	$e^+e^- \rightarrow$	$\Upsilon(4S)$	

Γ_5/Γ_4 $\Gamma(D^-\ell^+\nu_\ell \text{ anything})/\Gamma(\ell^+\nu_\ell \text{ anything})$

VALUE	DOCUMENT ID	TECN	COMMENT
$0.26 \pm 0.07 \pm 0.04$	8 FULTON 91	CLEO	$e^+e^- \rightarrow \Upsilon(4S)$

⁸ FULTON 91 uses B($D^+ \rightarrow K^- \pi^+ \pi^+$) = (9.1 ± 1.3 ± 0.4)% as measured by MARK III.

$\Gamma(\overline{D}^0 \ell^+ \nu_\ell \text{ anything}) / \Gamma(\ell^+ \nu_\ell \text{ anything})$ Γ_6/Γ_4 $\ell = e \text{ or } \mu.$

VALUE DOCUMENT ID TECN COMMENT 9 FULTON $0.67 \pm 0.09 \pm 0.10$ 91 CLEO $e^+e^- \rightarrow \Upsilon(4S)$

⁹ FULTON 91 uses B($D^0 \rightarrow K^-\pi^+$) = (4.2 \pm 0.4 \pm 0.4)% as measured by MARK III.

$\Gamma(D^{*-}\ell^+\nu_{\ell} \text{ anything})/\Gamma_{\text{total}}$ VALUE (units 10-2) DOCUMENT ID TECN COMMENT

¹⁰ BARISH 95 CLE2 $e^+e^- \rightarrow \Upsilon(4S)$ $0.6 \pm 0.3 \pm 0.1$

¹⁰ BARISH 95 use B($D^0 \to K^-\pi^+$) = (3.91 \pm 0.08 \pm 0.17)% and B($D^{*+} \to D^0\pi^+$) $= (68.1 \pm 1.0 \pm 1.3)\%.$

$\Gamma(D^{*0}\ell^+\nu_\ell \text{ anything})/\Gamma_{\text{total}}$ Γ_8/Γ

VALUE (units 10 ⁻²)	DOCUMENT ID	TECI	V COMMENT	
• • • We do not use the follow	wing data for averag	es, fits, lim	its, etc. • • •	
$0.6 \pm 0.6 \pm 0.1$	¹¹ BARISH	95 CLE	$e^+e^- \rightarrow$	r(45)
¹¹ BARISH 95 use B($D^0 \rightarrow$				$\rightarrow D^0 \pi^+) =$
$(68.1 \pm 1.0 \pm 1.3)\%$, B(D	$*^0 \rightarrow D^0 \pi^0$) = (63)	3.6 ± 2.3 ±	3.3)%.	

 $\Gamma(\overline{D}^{**}\ell^+\nu_\ell)/\Gamma_{\mathsf{total}}$

٦/و٦

 D^{**} stands for the sum of the $D(1 \, ^1P_1)$, $D(1 \, ^3P_0)$, $D(1 \, ^3P_1)$, $D(1 \, ^3P_2)$, $D(2 \, ^1S_0)$, and $D(2^{1}S_{1})$ resonances. $\ell=e$ or μ , not sum over e and μ modes.

CL% EVTS DOCUMENT ID TECN COMMENT 12 ALBRECHT 93 ARG $e^+e^- \rightarrow \gamma(4S)$ 0.027±0.005±0.005 63

• • • We do not use the following data for averages, fits, limits, etc. • • 95

¹³ BARISH

 12 ALBRECHT 93 assumes the GISW model to correct for unseen modes. Using the BHKT model, the result becomes 0.023 \pm 0.006 \pm 0.004. Assumes B($D^*+\to D^0\pi^+$) = 68.1%, B($D^0\to K^-\pi^+$) = 3.65%, B($D^0\to K^-\pi^+\pi^-\pi^+$) = 7.5%. We have taken their average e and μ value. 13 BARISH 95 use B($D^0\to K^-\pi^+$) = (3.91 \pm 0.08 \pm 0.17)%, assume all nonresonant

channels are zero, and use GISW model for relative abundances of D^{**} states.

$\Gamma(\overline{D}(1)(2420)^0\ell^+\nu_\ell$ anything)/ Γ_{total} Γ_{10}/Γ VALUE DOCUMENT ID TECN COMMENT 14 BUSKULIC 958 ALEP $e^+e^- \rightarrow Z$

 $^{14}\, {\rm BUSKULIC}$ 95B reports $f_B \times {\rm B}(B \to \overline{D}_1 (2420)^0 \, \ell^+ \, \nu_\ell \, {\rm anything}) \times {\rm B}(\overline{D}_1 (2420)^0 \to 0)$ $\overline{D}^*(2010)^-\pi^+) = (2.04 \pm 0.58 \pm 0.34)10^{-3}$, where f_B is the production fraction for a single B charge state.

$\Gamma(\overline{D}(2)^*(2460)^0\ell^+\nu_\ell$ anything)/ $\Gamma_{\rm total}$ Γ_{11}/Γ $15 \, { m BUSKULIC}$ 958 ALEP $e^+e^- ightarrow Z$

 $^{15}\, {\rm BUSKULIC}$ 95B reports $f_B \times {\rm B}(B \to \overline D_2^*(2460)^0 \, \ell^+ \nu_\ell \, {\rm anything}) \times {\rm B}(\overline D_2^*(2460)^0 \to \overline D_2^*(2460)^0 \, \ell^+ \, \nu_\ell \, {\rm anything}) \times {\rm B}(\overline D_2^*(2460)^0 \to \overline D_2^*(2460)^0 \, \ell^+ \, \nu_\ell \, {\rm anything}) \times {\rm B}(\overline D_2^*(2460)^0 \to \overline D_2^*(2460)^0 \, \ell^+ \, \nu_\ell \, {\rm anything}) \times {\rm B}(\overline D_2^*(2460)^0 \to \overline D_2^*(2460)^0 \, \ell^+ \, \nu_\ell \, {\rm anything}) \times {\rm B}(\overline D_2^*(2460)^0 \to \overline D_2^*(2460)^0 \, \ell^+ \, \nu_\ell \, {\rm anything}) \times {\rm B}(\overline D_2^*(2460)^0 \to \overline D_2^*(2460)^0 \, \ell^+ \, \nu_\ell \, {\rm anything}) \times {\rm B}(\overline D_2^*(2460)^0 \to \overline D_2^*(2460)^0 \, \ell^+ \, \nu_\ell \, {\rm anything}) \times {\rm B}(\overline D_2^*(2460)^0 \to \overline D_2^*(2460)^0 \, \ell^+ \, \nu_\ell \, {\rm anything}) \times {\rm B}(\overline D_2^*(2460)^0 \to \overline D_2^*(2460)^0 \, \ell^+ \, \nu_\ell \, {\rm anything}) \times {\rm B}(\overline D_2^*(2460)^0 \to \overline D_2^*(2460)^0 \, \ell^+ \, \nu_\ell \, {\rm anything})$ $\overline{D}^*(2010)^-\pi^+) \le 0.81 \times 10^{-3}$ at CL=95%, where f_B is the production fraction for a single B charge state

$\Gamma \big(D^{*-} \pi^+ \ell^+ \nu_\ell \, \text{anything} \big) / \Gamma_{\text{total}}$ Includes resonant and nonresonant contributions. Γ_{12}/Γ VALUE (units 10⁻³) DOCUMENT ID TECN COMMENT

16 BUSKULIC 95B ALEP $e^+e^- \rightarrow Z$ 16 BUSKULIC 95B reports $f_B imes {
m B}(B o \overline{D}^*(2010)^- \pi^+ \ell^+
u_\ell$ anything) $= (3.7 \pm 1.0 \pm$

0.7)10 $^{-3}$. Above value assumes $f_B=$ 0.37 \pm 0.03. $\Gamma(D_s^-\ell^+\nu_\ell \text{ anything})/\Gamma_{\text{total}}$ Γ_{13}/Γ CL% DOCUMENT ID TECN COMMENT VALUE

 $^{-17}$ ALBRECHT 93E ARG $e^+e^- \rightarrow \Upsilon(4S)$ 17 ALBRECHT 93E reports < 0.012 for B($D_s^+
ightarrow \phi \pi^+$) = 0.027. We rescale to our best value B($D_{s}^{+} \rightarrow \phi \pi^{+}$) = 0.036.

$\Gamma(D_{\epsilon}^{-}\ell^{+}\nu_{\ell}K^{+}\text{anything})/\Gamma_{\text{total}}$ Γ_{14}/Γ DOCUMENT ID TECN COMMENT VALUE CL%

18 ALBRECHT 93E ARG $e^+e^- \rightarrow \Upsilon(4S)$ ¹⁸ ALBRECHT 93E reports < 0.008 for B($D_c^+ \rightarrow \phi \pi^+$) = 0.027. We rescale to our best value B($D_c^+ \to \phi \pi^+$) = 0.036.

 $\Gamma(D_s^-\ell^+\nu_\ell K^0 \text{ anything})/\Gamma_{\text{total}}$ Γ_{15}/Γ

 19 ALBRECHT 93E reports < 0.012 for B($D_s^+
ightarrow \phi \pi^+$) = 0.027. We rescale to our best value B($D_{c}^{+} \rightarrow \phi \pi^{+}$) = 0.036.

$\Gamma(\ell^+\nu_\ell \text{ noncharmed})/\Gamma(\ell^+\nu_\ell \text{ anything})$

 Γ_7/Γ

ı

90

90

 ℓ denotes e or μ , not the sum. These experiments measure this ratio in very limited momentum intervals.

VALUE CL% EVIS	DOCUMENT ID	TECN_	COMMENT	
	²⁰ ALBRECHT	94c ARG	$e^+e^- \rightarrow$	$\gamma(45)$
107	²¹ BARTELT	93B CLE2	$e^+e^ \rightarrow$	$\Upsilon(4S)$
77		91c ARG		
76	²³ FULTON	90 CLEO	$e^+e^ \rightarrow$	$\Upsilon(4S)$
• • • We do not use the followi	ng data for average	es, fits, limits,	etc. • • •	
	24			

24 ALBRECHT 90 ARG $e^+e^- \rightarrow \Upsilon(45)$ ²⁵ BEHRENDS 87 CLEO $e^+e^- \rightarrow \Upsilon(4S)$ < 0.04 90 < 0.04

84 CLEO Direct e at $\Upsilon(4S)$ KLOPFEN... 83B CUSB Direct e at $\Upsilon(4S)$ < 0.055

²⁰ ALBRECHT 94c find $\Gamma(b \rightarrow c)/\Gamma(b \rightarrow all) = 0.99 \pm 0.02 \pm 0.04$.

21 BARTELT 938 (CLEO II) measures an excess of $107 \pm 15 \pm 11$ leptons in the lepton momentum interval 2.3-2.6 GeV/c which is attributed to $b \rightarrow u\ell\nu_\ell$. This corresponds to a model-dependent partial branching ratio ΔB_{BB} between $(1.15\pm0.16\pm0.15)\times10^{-4}$, as evaluated using the KS model (KOERNER 88), and $(1.54\pm0.22\pm0.20)\times10^{-4}$

as evaluated using the KS model (NOEKNER 88), and $(1.54 \pm 0.22 \pm 0.20) \times 10^{-1}$ using the ACCMM model (ARTUSO 93). The corresponding values of $|V_{ub}|/|V_{cb}|$ are 0.056 ± 0.006 and 0.076 ± 0.008 , respectively. ²²ALBRECHT 91c result supersedes ALBRECHT 90. Two events are fully reconstructed providing evidence for the $b \rightarrow u$ transition. Using the model of ALTARELLI 82, they obtain $|V_{ub}/V_{cb}| = 0.11 \pm 0.012$ from 77 leptons in the 2.3-2.6 GeV momentum range.

23 FULTON 90 observe 76 ± 20 excess e and μ (lepton) events in the 2.3-2.8 GeV momentum range. p=2.4-2.6 GeV signaling the presence of the $b\to u$ transition. The average branching ratio, $(1.8\pm0.4\pm0.3)\times10^{-4}$, corresponds to a model-dependent measurement of approximately $|V_{ub}/V_{cb}|=0.1$ using $B(b\to c\ell\nu)=10.2\pm0.2\pm0.7\%$.

24 ALBRECHT 90 observes 41 interval p = 2.3–2.6 GeV signorrespond to a model-deper 25 The quoted possible limits r model or momentum range calculated. This correspondite technique employed is more do not provide a numerical in the provide and the prov	gnaling the presence and ent measurement ange from 0.018 to is chosen. We select to a limit on $ V_U $ robust than their presence.	of the $b \rightarrow$ of $ V_{ub}/V_{c} $ 0.04 for the the most condition to the the most condition to the evidence of $ V_{cb} < 1$	$\begin{array}{c} u \text{ transitio} \\ b = 0.10 \pm \\ \text{ratio, dependent on the length} \end{array}$	n. The events 0.01. Iding on which imit they have	; !
$\Gamma(K^+\ell^+\nu_\ell \text{ anything})/\Gamma(\ell^+\ell^+\nu_\ell \text{ denotes } e \text{ or } \mu, \text{ not the } \ell^+\ell^+\nu_\ell \text{ anything})$	ν _ε anything)			Γ_{17}/Γ_{4}	
0.58 ±0.05 OUR AVERAGE	DOCUMENT ID	TECN	COMMENT		
0.594±0.021±0.056	ALBRECHT	94c ARG	$e^+e^- \rightarrow$	Υ(45)	ı
0.54 ±0.07 ±0.06	²⁶ ALAM	87B CLEO			•
²⁶ ALAM 87B measurement reli	ies on lepton-kaon o	orrelations.			
$\Gamma(K^-\ell^+\nu_\ell \text{ anything})/\Gamma(\ell^+\ell^+\nu_\ell \text{ denotes } e \text{ or } \mu_\ell \text{ not the } e$				Γ ₁₈ /Γ ₄	
VALUE	DOCUMENT ID	TECN	COMMENT	· · · · · · · · · · · · · · · · · · ·	
0.092±0.035 OUR AVERAGE	AL DESCUE		4 -	22(+2)	
$0.086 \pm 0.011 \pm 0.044$ $0.10 \pm 0.05 \pm 0.02$	ALBRECHT ²⁷ ALAM	94c ARG 87B CLEO	$e^+e^- \rightarrow e^+e^- \rightarrow$,
27 ALAM 87B measurement reli			e·e →	1 (43)	
		orrelations.		- /-	
$\Gamma(K^0/\overline{K}^0\ell^+\nu_\ell \text{ anything})/\Gamma$				Γ_{19}/Γ_{4}	
ℓ denotes e or μ , not the v	DOCUMENT ID	and K State	es. COMMENT		
0.42 ±0.05 OUR AVERAGE					_
$0.452 \pm 0.038 \pm 0.056$	28 ALBRECHT				ı
0.39 ±0.06 ±0.04	²⁹ ALAM		$e^+e^- \rightarrow$	T(45)	
28 ALBRECHT 94c assume a A			κ_{S}^{0} .		ı
²⁹ ALAM 87B measurement reli	es on lepton-kaon c	orrelations.			
$\Gamma(c/\overline{c})/\Gamma_{\text{total}}$					
VALUE	DOCUMENT ID				
• • We do not use the following	-				
$0.98 \pm 0.16 \pm 0.12$	30 ALAM		$e^+e^- \rightarrow$	` ,	
30 From the difference between lepton-kaon correlations. It thus removed it from the ave	does not consider t				
$\Gamma(D^{\pm}$ anything $)/\Gamma_{ ext{total}}$				Γ ₂₀ /Γ	
VALUE EVTS	DOCUMENT ID	TECN	COMMENT	207	
0.242±0.033 OUR AVERAGE	31		4		
$0.25 \pm 0.04 \pm 0.02$	31 BORTOLETT			` ,	
$0.23 \pm 0.05 \begin{array}{l} +0.01 \\ -0.02 \end{array}$	32 ALBRECHT	91H ARG	$e^+e^ \rightarrow$	T(45)	•
• • We do not use the following					
$0.21 \pm 0.05 \pm 0.01$ 20k	33 BORTOLETT	O87 CLEO	Sup. by BO LETTO	ORTO- 92	ı
31 BORTOLETTO 92 reports [E	$B(B o D^{\pm} ext{ anything})$	$(x) \times B(D^+ -$			1
0.0030 \pm 0.0018. We divide					•
10 ⁻² . Our first error is thei	r experiment's error	and our sec	ond error is	the systematic	
error from using our best val 32 ALBRECHT 91H reports [B(ue. B> D± anything)	v R(D±	K++	/1 — 0 0200 ±	
0.0027 ± 0.0040 . We divide	by our best value B	$\chi D^+ \rightarrow K^-$	$-\pi^{+}\pi^{+}) =$	$(9.1 \pm 0.6) \times$	ı
10^{-2} . Our first error is their	r experiment's error				
error from using our best val	ue.				
33 BORTOLETTO 87 reports [E					ı
0.004 ± 0.002 . We divide by	our pest value B(DT	$\rightarrow K \pi^{+}$	π ') = (9.1:	$\pm 0.6) \times 10^{-2}$.	

VALUE EVTS DOCUMENT ID TECN COMMENT 0.58 ± 0.05 OUR AVERAGE Error includes scale factor of 1.1. 0.61 ± 0.05 ± 0.02 34 BORTOLETTO92 CLEO $e^+e^- → T(45)$ 0.51 ± 0.08 ± 0.02 35 ALBRECHT 91 H ARG $e^+e^- → T(45)$ • • • We do not use the following data for averages, fits, limits, etc. • • • 0.55 ± 0.07 ± 0.02 21k 36 BORTOLETTO87 CLEO $e^+e^- → T(45)$ 0.63 ± 0.19 ± 0.02 37 GREEN 83 CLEO Repl. by BORTOLETTO 87 LETTO 87 34 BORTOLETTO 92 reports [B(B → D ⁰ /D ⁰ anything) × B(D ⁰ → K ⁻ π ⁺)] = 0.0012 ± 0.0014. We divide by our best value B(D ⁰ → K ⁻ π ⁺) = (3.83 ± 0.12)	Γ_{21}/Γ
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	
• • • We do not use the following data for averages, fits, limits, etc. • • • 0.55 \pm 0.07 \pm 0.02	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$;)
0.63 \pm 0.19 \pm 0.02 37 GREEN 83 CLEO Repl. by BORTO LETTO 87 34 BORTOLETTO 92 reports $[B(B \to D^0/\overline{D}^0 {\rm anything}) \times B(D^0 \to K^-\pi^+)] =$	
0.63 \pm 0.19 \pm 0.02 37 GREEN 83 CLEO Repl. by BORTOLETTO 87 LETTO 87 34 BORTOLETTO 92 reports [B($B \rightarrow D^0/\overline{D}^0$ anything) \times B($D^0 \rightarrow K^-\pi^+$)] =	5)
³⁴ BORTOLETTO 92 reports $[B(B \to D^0/\overline{D}^0 \text{ anything}) \times B(D^0 \to K^-\pi^+)] = 0.0012 \pm 0.0014$. We divide by our best value $B(D^0 \to K^-\pi^+) = (3.83 \pm 0.12)$	
0.0012 ± 0.0014 . We divide by our best value B($D^0 \rightarrow K^-\pi^+$) = (3.83 ± 0.12)	0.02 3 3±
	$\times 10^{-2}$.
Our first error is their experiment's error and our second error is the systematic e	
using our best value. ³⁵ ALBRECHT 91H reports $[B(B \to D^0/\overline{D}^0 \text{ anything}) \times B(D^0 \to K^-\pi^+)] = 0$	

0.0015 ± 0.0025. We divide by our best value $B(D^0 \to K^-\pi^+) = (3.83 \pm 0.12) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

36 BORTOLETTO 87 reports $[B(B \to D^0/\overline{D}^0 \text{ anything}) \times B(D^0 \to K^-\pi^+)] = 0.0210 \pm 10.0015 \pm 0.0021$. We divide by our best value $B(D^0 \to K^-\pi^+) = (3.83 \pm 0.12) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

37 GREEN 83 reports $[B(B \to D^0/\overline{D}^0]$ anything) \times $B(D^0 \to K^-\pi^+)] = 0.024 \pm 0.006 \pm 0.004$. We divide by our best value $B(D^0 \to K^-\pi^+) = (3.83 \pm 0.12) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

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B^{\pm}/B^{\circ} ADMIX TURE
\Gamma(D^{*}(2010)^{\pm} \text{anything})/\Gamma_{\text{total}} \qquad \qquad \Gamma_{22}/\Gamma_{\text{converse}}
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VALUE	EVIS	DOCUMENT ID TECH COMMENT	
0.231 ±0.033 OUR AVE	RAGE	Error includes scale factor of 1.1.	
$0.209 \pm 0.035 \pm 0.004$		³⁸ BORTOLETTO92 CLEO $e^+e^- \rightarrow \Upsilon(4S)$	
$0.28 \pm 0.05 \pm 0.01$		³⁹ ALBRECHT 91H ARG $e^+e^- \rightarrow \Upsilon(4S)$	
• • • We do not use t	he follow	ving data for averages, fits, limits, etc. • • •	
$0.22 \ \pm 0.04 \ ^{+0.07}_{-0.04}$	5200	40 BORTOLETTO87 CLEO $e^+e^- ightarrow$ \varUpsilon (45)	
$0.27\ \pm0.06\ ^{+0.08}_{-0.06}$	510	41 CSORNA 85 CLEO Repl. by BORTO-	

 38 BORTOLETTO 92 reports 0.25 \pm 0.03 \pm 0.04 for B($D^*(2010)^+ \rightarrow D^0\pi^+) = 0.57 \pm$ 0.06. We rescale to our best value B($D^*(2010)^+ \rightarrow D^0\pi^+) = (68.3 \pm 1.4) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. They also use the Mark III B($D^0 \rightarrow K^-\pi^+)$ branching fraction.

using our best value. They also use the mark III $B(D^+ \to K^-\pi^+)$ braintining naction, 39 ALBRECHT 91H reports $0.348 \pm 0.060 \pm 0.035$ for $B(D^*(2010)^+ \to D^0\pi^+) = 0.55 \pm 0.04$. We rescale to our best value $B(D^*(2010)^+ \to D^0\pi^+) = (68.3 \pm 1.4) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Uses the PDG 90 $B(D^0 \to K^-\pi^+) = 0.0371 \pm 0.0025$.

⁴⁰BORTOLETTO 87 uses old MARK III (BALTRUSAITIS 86E) branching ratios $B(D^0 \to K^-\pi^+) = 0.056 \pm 0.004 \pm 0.003$ and also assumes $B(D^*(2010)^+ \to D^0\pi^+) = 0.60^{+0.08}_{-0.15}$. The product branching ratio for $B(B \to D^*(2010)^+)$ $B(D^*(2010)^+ \to D^0\pi^+)$ is 0.13 \pm 0.02 \pm 0.012. Superseded by BORTOLETTO 92.

 41 V – A momentum spectrum used to extrapolate below p=1 GeV. We correct the value assuming B($D^0\to K^-\pi^+$) = 0.042 ± 0.006 and B($D^{*+}\to D^0\pi^+$) = 0.6 $^{+0.08}_{-0.15}$. The product branching fraction is B($B\to D^{*+}$ X)·B($D^{*+}\to \pi^+D^0$)·B($D^0\to K^-\pi^+$) = (68 ± 15 ± 9) × 10 $^{-4}$.

$\Gamma(D_s^{\pm} \text{ anything})/\Gamma_{to}$	tal					Γ ₂₃ /Γ
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT	
0.086±0.016 OUR AVI	RAGE					
$0.081 \pm 0.014 ^{+ 0.019}_{- 0.020}$		⁴² ALBRECHT	92 G	ARG	$e^+e^- \to$	Y(45)
$0.085 \pm 0.013 ^{+ 0.020}_{- 0.021}$	257	43 BORTOLETT	TO90	CLEO	$e^+e^- \to$	Y(45)
$0.105 \pm 0.028 {}^{\displaystyle +0.025}_{\displaystyle -0.026}$		⁴⁴ HAAS	86	CLEO	$e^+e^-\rightarrow$	$\Upsilon(4S)$
• • • We do not use t	he followii	ng data for averag	es, fits	, limits,	etc. • • •	
$0.116 \pm 0.030 \pm 0.028$		⁴⁵ ALBRECHT	87H	ARG	$e^+e^-\rightarrow$	Y(45)

 42 ALBRECHT 92G reports [B(B \rightarrow D_s^{\pm} anything) \times B(D_s^{+} \rightarrow $\phi\pi^{+})] = 0.00292 \pm 0.00039 \pm 0.00031$. We divide by our best value B(D_s^{+} \rightarrow $\phi\pi^{+}) = (3.6 \pm 0.9) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

 43 BORTOLETTO 90 reports [B($B\to D_s^\pm$ anything) \times B($D_s^+\to \phi\pi^+)]=0.00306\pm0.00047.$ We divide by our best value B($D_s^+\to \phi\pi^+)=(3.6\pm0.9)\times10^{-2}.$ Our first error is their experiment's error and our second error is the systematic error from using our best value.

our best value. 44 HAAS 86 reports $[B(B \to D_s^{\pm} \text{ anything}) \times B(D_s^{+} \to \phi \pi^{+})] = 0.0038 \pm 0.0010$. We divide by our best value $B(D_s^{+} \to \phi \pi^{+}) = (3.6 \pm 0.9) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. 64 \pm 22% decays are 2-body.

 45 ALBRECHT 87H reports $[\dot{B}(B\to D_s^\pm {\rm anything})\times B(D_s^+\to \phi\pi^+)]=0.0042\pm0.0009\pm0.0006.$ We divide by our best value $B(D_s^+\to \phi\pi^+)=(3.6\pm0.9)\times10^{-2}.$ Our first error is their experiment's error and our second error is the systematic error from using our best value. 46 \pm 16% of $B\to D_s$ X decays are 2-body. Superseded by ALBRECHT 926.

$\Gamma(D_s D, D_s^* D, D_s D^*, \text{ or } D_s^* D^*) / \Gamma(D_s^{\pm} \text{ anything})$ $\Gamma_{24} / \Gamma_{23}$

$\Gamma(D^*(2010)\gamma)/\Gamma_{\text{total}}$		Γ ₂₅ /Γ
0.56 ± 0.10	BORTOLETTO90 CLEO	
0.57±0.08 OUR AVERAGE 0.58±0.07±0.09	ALBRECHT 92G ARG	$e^+e^- \rightarrow \gamma(45)$
VALUE VALUE	DOCUMENT ID TECN	COMMENT

 46 LESIAK 92 set a limit on the inclusive process B($b\to s\gamma)<2.8\times 10^{-3}$ at 90% CL for the range of masses of 892–2045 MeV, independent of assumptions about s-quark hadronization.

$$\begin{array}{l} \Gamma(D_s^+\pi^-,\,D_s^+\pi^-,\,D_s^+\rho^-,\,D_s^{*+}\rho^-,\,D_s^+\pi^0,\,D_s^{*+}\pi^0,\,D_s^+\eta,\,D_s^{*+}\eta,\,D_s^+\rho^0,\\ D_s^{*+}\rho^0,\,D_s^+\omega,\,D_s^{*+}\omega)/\Gamma_{\rm total} \end{array}$$

 47 ALEXANDER 93B reports $<4.8\times10^{-4}$ for B($D_S^+\to\phi\pi^+)=0.037.$ We rescale to our best value B($D_S^+\to\phi\pi^+)=0.036.$ This branching ratio limit provides a model-dependent upper limit $|V_{u,b}|/|V_{c,b}|<0.16$ at CL=90%.

Meson Particle Listings B^{\pm}/B^{0} ADMIXTURE

$\Gamma(J/\psi(1S))$ anything $/\Gamma$	total		Γ ₂₇ ,
VALUE (units 10 ⁻²) EV7		TECN	COMMENT
L.14±0.06 OUR AVERAGE	40	95B CLE2	$e^+e^- \rightarrow \gamma(45)$
1.28±0.44±0.04 2	40		$e^+e^- \rightarrow \gamma(45)$
.23±0.27±0.04 12	F0	87D ARG	$e^+e^- \rightarrow \Upsilon(4S)$
.34±0.24±0.04 5	2 ⁵¹ ALAM	86 CLEO	$e^+e^- \rightarrow \Upsilon(4S)$
	llowing data for average	s, fits, limits	i, etc. • • •
1.4 +0.6	7 ⁵² ALBRECHT	85H ARG	$e^+e^- \rightarrow \Upsilon(4S)$
	6 ⁵³ HAAS	85 CLEO	Repl. by ALAM 86
48 BALEST 958 reports 1.1	$12 \pm 0.04 \pm 0.06$ for B(J	$/\psi(1S) \rightarrow \epsilon$	$e^+e^-) = 0.0599 \pm 0.003$
We rescale to our best first error is their experi	value B $(J/\psi(1S) \rightarrow \epsilon$ iment's error and our sentence $J/\psi(1S) \rightarrow \epsilon$	e^+e^-) = (6) cond error is e^+e^- and	$5.02\pm0.19) imes10^{-2}$. Os the systematic error from $1\mu^+\mu^-$ and use PDG 19
error is their experiment our best value. 50 ALBRECHT 87D reports We rescale to our best v	alue B $(J/\psi(1S) ightarrow e^+$'s error and our second : 1.07 \pm 0.16 \pm 0.22 for E alue B $(J/\psi(1S) ightarrow e^+$	$e^-)=(6.02)$ error is the $G(J/\psi(1S)-e^-)=(6.02)$	$(2 \pm 0.19) \times 10^{-2}$. Our fi systematic error from usi $e^+e^- = 0.069 \pm 0.069 \pm 0.000 \pm 0.0000 \pm 0.0000 \pm 0.0000 \pm 0.00000 \pm 0.0000 \pm 0.0000 \pm 0.0000 \pm 0.00000 \pm 0.0000 \pm 0.0000 \pm 0.000$
our best value. ALBREO 0.0081 \pm 0.0023. 51 ALAM 86 reports 1.09 \pm	CHT 87D find the branch \pm 0.16 \pm 0.21 for B (J/ψ)	ing ratio for $(1S) ightarrow \mu^+$	
rescale to our best valuerror is their experiment our best value. 52 Statistical and systemat a CL = 90% limit of 0.0	's error and our second ic errors were added in q	error is the uadrature. <i>A</i>	\pm 0.19) \times 10 ⁻² . Our fi systematic error from usi ALBRECHT 85H also rep
53 Dimuon and dielectron of $\Gamma(J/\psi(1S))$ (direct) anyt	events used.		Γ ₂₈
/ALUE	DOCUMENT ID	TECN	
0.0080±0.0008	⁵⁴ BALEST	95B CLE2	$e^+e^- ightarrow \varUpsilon(4S)$
branching ratio contains through $\psi(2S) \rightarrow J/\psi$	$f(1S) ightarrow e^+e^-$ and J/ψ J/ψ $(1S)$ mesons directly $f(1S)$, $\chi_{C1}(1P) ightarrow J/\psi$ ates, BALEST 95B corre	$\mu(1S) \rightarrow \mu^+$ from B dec $\mu(1S)$, or χ_{C}	$^-\mu^-$. The $B\to J/\psi(1S)$ mess cays and also from feeddo $_2(1P)\to J/\psi(1S)$. Using the down and finds the B
$\Gamma(\psi(2S)$ anything $)/\Gamma_{ ext{tot}}$	al EVTS DOCUMENT	ID TE	CN_COMMENT
0.0035±0.0005 OUR AVER	AGE		COMMENT.
0.0034±0.0004±0.0003	240 ⁵⁵ BALEST	958 CL T 87D AF	
	ℓ^-) = 0.30 \pm 0.05 \pm	ode branchi 0.04 and B	, ,
$\Gamma(x_{c1}(1P))$ anything $\Gamma(x_{c1}(1P))$	total		Г ₃₀
VALUE 0.0042±0.0007 OUR AVER	EVTS DOCUMENT	ID TE	CN COMMENT
0.0040±0.0006±0.0004	112 ⁵⁶ BALEST	95B CL	.E2 $e^+e^- \rightarrow \Upsilon(4S)$
$0.0105 \pm 0.0035 \pm 0.0025$	⁵⁷ ALBRECH	T 92E AF	$rac{e^+e^-}{\rightarrow} r(4S)$
56 BALEST 95B assume B(value. Fit to ψ -photon i component. 57 ALBRECHT 92E assume	nvariant mass distribution	on allows for	1.6) \times 10 $^{-2}$, the PDG 19 a $\chi_{c1}(1P)$ and a $\chi_{c2}(1$
$\Gamma(\chi_{c1}(1P))$ (direct) anyt	hing)/Ctotal		Г31
VALUE	DOCUMENT ID	TECN	
0.0037±0.0007	⁵⁸ BALEST	95B CLE2	$e^+ e^- ightarrow ~ \varUpsilon(4S)$
58 BALEST 958 assume PE and $\mu^+\mu^-$ modes. The directly from B decays the measured inclusive r $X_{c1}(1P)$ (direct) X brane	ie $B ightarrow \chi_{C1}(1P) X$ bra and also from feeddown ates, BALEST 95B corre	nching ratio	reconstructed in the e^+e^- contains $\chi_{c1}(1P)$ mess $(2S) \to \chi_{c1}(1P)\gamma$. Us seeddown and finds the B
$\Gamma(\chi_{c2}(1P)$ anything)/ Γ_{VALUE}	TS DOCUMENT ID	TECN	Г 32 соммент
•••••	35 ⁵⁹ BALEST	95B CLE2	$e^+ e^- \rightarrow \Upsilon(45)$
59 BALEST 958 assume B(value. $J/\psi(1S)$ mesons 1994 branching fractions to B($B \rightarrow \chi_{\rm C2}(1P){\rm X})$	are reconstructed in the are used. If interpreted	e e^+e^- an as signal, th	$1.1) imes 10^{-2}$, the PDG 19 d $\mu^+\mu^-$ modes, and Ple 35 \pm 13 events correspo
$\Gamma(\eta_c(1S))$ anything $\Gamma(\eta_c(1S))$		_	Γ ₃₃
	DOCUMENT ID 60 BALEST		
<0.009 90			$e^+e^- \rightarrow \Upsilon(4S)$
60 BALEST 95B assume PI are reconstructed in $J/\tau < m_{\eta_{\mathcal{C}}}(1S) <$ 3010 MeV	$b(1S) \rightarrow e^+e^- \text{ and } J$		ing ratios. $J/\psi(1S)$ meson $\mu^+\mu^-$. Search region 29

$\Gamma(K^{\pm}$ anything $)/\Gamma_{ ext{total}}$						Г _{34.}
VALUE 0.789±0.025 OUR AVERAC	;F	DOCUMENT ID		TECN	COMMENT	
0.82 ±0.01 ±0.05		ALBRECHT	940	ARG	$e^+e^ \rightarrow$	Υ(4S)
$0.775 \pm 0.015 \pm 0.025$	61	ALBRECHT		ARG	$e^+e^- \rightarrow$	$\Upsilon(45)$
0.85 ±0.07 ±0.09		ALAM		CLEO		$\Upsilon(45)$
• • We do not use the fo	-	-				***
seen seen		BRODY GIANNINI	82 82	CLEO	$e^+e^- \rightarrow e^+e^- \rightarrow$	Υ(45) Υ(45)
⁶¹ ALBRECHT 931 value is						
K^- anything ALBRECH 62 Assuming $\Upsilon(4S) \rightarrow B \overline{I}$ (the second error is sys leads to a value for $(b\text{-}q$ 63 GIANNINI 82 at CESR-0 than 0.82 \pm 0.10 below	B, a tota tematic) µark → CUSB ob	I of 3.38 ± 0.34 In the context c -quark)/(b -quark) $\pm 0.38 \pm 0.38$	kt of uark -).35 <i>k</i>	the star → all) < ⁰ per h	ndard B -dec of $1.09 \pm 0.$ ladronic ever	ay model, t 33 ± 0.13 . It much hig
$\Gamma(K^+$ anything) $/\Gamma_{total}$						Γ ₃₅
VALUE	6/	DOCUMENT ID		TECN		20(1.0)
0.66 ±0.05 • • • We do not use the fo		ALBRECHT		ARG Limits	e ⁺ e ⁻ →	<i>T</i> (4 <i>S</i>)
$0.620 \pm 0.013 \pm 0.038$		ALBRECHT		ARG	e+ e- →	Y(45)
0.620 ± 0.013 ± 0.038 0.66 ± 0.05 ± 0.07		ALAM		CLEO	$e^+e^- \rightarrow$	$\Upsilon(4S)$ $\Upsilon(4S)$
64 Measurement relies on le not include mixing of the a mixing parameter r of	neutral $(18.1~\pm$	B meson. Mixir 4.3)%.	ng effe	ects wer	e corrected f	or by assum
65 Measurement relies on I of the neutral B meson.	epton-ka	on correlations.	. It ir	cludes	production t	hrough mix
$\Gamma(K^-$ anything)/ Γ_{total}						Г ₃₆
VALUE		DOCUMENT ID		TECN		
0.13 ±0.04 • • • We do not use the fo		ALBRECHT		ARG	$e^+e^- \rightarrow$	Y(45)
\bullet • We do not use the io		ata for average ALBRECHT		ARG	$e^+e^- \rightarrow$	2(45)
0.165 ± 0.011 ± 0.036 0.19 ± 0.05 ± 0.02		ALAM		CLEO	e · e → e + e - →	Υ(45) Υ(45)
66 Measurement relies on le						. ,
not include mixing of the a mixing parameter r of 67 Measurement relies on 1 of the neutral B meson.	(18.1 \pm	4.3)%.				
$\Gamma(K^0/\overline{K}^0)$ anything $)/\Gamma_{ m to}$	otal					Γ ₃₇
VALUE		DOCUMENT ID		TECN	COMMENT	
0.64 ±0.04 OUR AVERAC		ALBRECHT	940	ARG	p+p	Y(45)
0.642 ± 0.04 OUR AVERAC 0.642 ± 0.010 ± 0.042 0.63 ± 0.06 ± 0.06		ALBRECHT ALAM		ARG CLEO	$e^+e^- \rightarrow e^+e^- \rightarrow$	
0.642±0.010±0.042 0.63 ±0.06 ±0.06	68	ALAM	87B	CLEO	$e^+e^- \rightarrow$	
0.642±0.010±0.042 0.63 ±0.06 ±0.06 68 ALBRECHT 94C assume	68 e a <i>K</i> ⁰ /7	ALAM	87B	CLEO	$e^+e^- \rightarrow$	r(45)
0.642±0.010±0.042 0.63 ±0.06 ±0.06 68 ALBRECHT 94C assum (K*(892) [±] anything)/	68 e a <i>K</i> ⁰ /7	ALAM	87B twice	CLEO that of	$e^+e^- \rightarrow \kappa_S^0$.	
0.642±0.010±0.042 0.63 ±0.06 ±0.06 68 ALBRECHT 94C assum Γ(K*(892)±anything)/ WALUE	68 e a <i>K</i> ⁰ /7	ALAM Omultiplicity DOCUMENT ID	87B twice	CLEO that of	$e^+e^- \rightarrow K_S^0$.	τ(45) Γ ₃₈
0.642±0.010±0.042 0.63 ±0.06 ±0.06 68 ALBRECHT 94c assum \(\Gamma(K^*(892)^\pm\) anything\)/ \(\text{VALUE}\) 0.182±0.054±0.024	68 e a K ⁰ /i <mark>F_{total}</mark>	ALAM Omultiplicity DOCUMENT ID ALBRECHT	87B twice	CLEO that of	$e^+e^- \rightarrow K_S^0$.	γ(45) Γ ₃₈ γ(45)
$0.642 \pm 0.010 \pm 0.042$ $0.63 \pm 0.06 \pm 0.06$ 68 ALBRECHT 94c assuming/ VALUE VALUE $0.182 \pm 0.054 \pm 0.024$ $\Gamma (K^*(892)^0 / \overline{K}^*(892)^0$	68 e a K ⁰ /i <mark>F_{total}</mark>	ALAM O multiplicity DOCUMENT ID ALBRECHT S)/Ftotal	87B twice	CLEO that of TECN ARG	$e^+e^- \rightarrow \kappa_S^0$. COMMENT $e^+e^- \rightarrow$	τ(45) Γ ₃₈
$0.642 \pm 0.010 \pm 0.042$ $0.63 \pm 0.06 \pm 0.06$ 68 ALBRECHT 94c assuming/ $\Gamma (K^*(892)^{\pm} \text{ anything})/$ VALUE $0.182 \pm 0.054 \pm 0.024$ $\Gamma (K^*(892)^0 / \overline{K}^*(892)^0$ VALUE	68 e a K ⁰ /i <mark>F_{total}</mark>	ALAM DOCUMENT ID ALBRECHT S)/Ftotal DOCUMENT ID	87B twice	CLEO that of TECN ARG	$e^+e^- \rightarrow K_S^0$. COMMENT $e^+e^- \rightarrow COMMENT$	τ(45) Γ ₃₈ τ(45)
$0.642 \pm 0.010 \pm 0.042$ $0.63 \pm 0.06 \pm 0.06$ 68 ALBRECHT 94c assuming/ $\Gamma (K^*(892)^{\pm} \text{ anything})/$ VALUE $0.182 \pm 0.054 \pm 0.024$ $\Gamma (K^*(892)^0 / \overline{K}^*(892)^0$ VALUE	68 e a K ⁰ /i <mark>F_{total}</mark>	ALAM O multiplicity DOCUMENT ID ALBRECHT S)/Ftotal	87B twice	CLEO that of TECN ARG	$e^+e^- \rightarrow \kappa_S^0$. COMMENT $e^+e^- \rightarrow$	γ(45) Γ ₃₈ γ(45)
$0.642\pm0.010\pm0.042$ $0.63\pm0.06\pm0.06$ 68 ALBRECHT 94c assum: $\Gamma\left(K^*(892)^{\pm} \text{ anything}\right)/VALUE}$ $0.182\pm0.054\pm0.024$ $\Gamma\left(K^*(892)^0 / \overline{K}^*(892)^0 / $	68 e a K ⁰ /i <mark>F_{total}</mark>	ALAM DOCUMENT ID ALBRECHT S)/Ftotal DOCUMENT ID	87B twice	CLEO that of TECN ARG	$e^+e^- \rightarrow K_S^0$. COMMENT $e^+e^- \rightarrow COMMENT$	τ(45) Γ ₃₈ τ(45)
$0.642 \pm 0.010 \pm 0.042$ $0.63 \pm 0.06 \pm 0.06$ $68 \text{ ALBRECHT 94c assuming}$ $\Gamma (K^*(892)^{\pm} \text{ anything}) / VALUE$ $0.182 \pm 0.054 \pm 0.024$ $\Gamma (K^*(892)^0 / \overline{K}^*(892)^0 / $	68 e a K ⁰ //	ALAM To multiplicity DOCUMENT ID ALBRECHT BOCUMENT ID ALBRECHT ALBRECHT DOCUMENT ID	87B twice 94J 94J	CLEO that of TECN ARG TECN ARG	$e^+e^- \rightarrow K_S^0$. COMMENT $e^+e^- \rightarrow COMMENT$ $e^+e^- \rightarrow COMMENT$	τ(4s) Γ ₃₈ τ(4s) Γ ₃₉ τ(4s)
$0.642 \pm 0.010 \pm 0.042$ $0.63 \pm 0.06 \pm 0.06$ 68 ALBRECHT 94c assuming / ($K^*(892)^{\pm}$ anything) / ($K^*(892)^{\pm}$ anything) / ($K^*(892)^{0}$ / $K^*(892)^{0}$	68 e a K ⁰ /7	ALAM multiplicity DOCUMENT ID ALBRECHT MOCUMENT ID ALBRECHT DOCUMENT ID data for average	87B twice 94J 94J	CLEO that of TECN ARG TECN ARG	$e^+e^- \rightarrow K_S^0$. COMMENT $e^+e^- \rightarrow COMMENT$ $e^+e^- \rightarrow COMMENT$ etc. • •	τ(4s) Γ38 τ(4s) Γ39 τ(4s) Γ40
$0.642 \pm 0.010 \pm 0.042$ $0.63 \pm 0.06 \pm 0.06$ $68 \text{ ALBRECHT 94C assuming}$ $\Gamma(K^*(892)^{\pm} \text{ anything})/VALUE}$ $0.182 \pm 0.054 \pm 0.024$ $\Gamma(K^*(892)^0/\overline{K}^*(892)^0$ $0.146 \pm 0.016 \pm 0.020$ $\Gamma(K^*(892)^\gamma)/\Gamma_{\text{total}}$ $VALUE$ $0.140 \pm 0.016 \pm 0.020$	68 K ⁰ /7 Ftotal anythin illowing 6	ALAM multiplicity DOCUMENT ID ALBRECHT B)/Ftotal DOCUMENT ID ALBRECHT DOCUMENT ID data for average	94J 94J 94J	TECN ARG TECN ARG TECN ARG TECN ARG TECN GRANT COMMENTS	$\begin{array}{c} e^+e^- \rightarrow \\ \kappa_S^0. \\ \hline \\ \frac{COMMENT}{e^+e^-} \rightarrow \\ \hline \end{array}$	τ(4s) Γ38 τ(4s) Γ39 τ(4s) Γ40
$0.642 \pm 0.010 \pm 0.042$ $0.63 \pm 0.06 \pm 0.06$ 68 ALBRECHT 94c assuming // (K*(892) \pm anything) // (ALUE) $0.182 \pm 0.054 \pm 0.024$ Γ (K*(892) 0 / \overline{K} *(892) 0 / $$	68 69 69	ALAM **Property of the control of t	87B twice 94J 94J es, fits 92 88H	TECN ARG TECN ARG TECN ARG TECN ARG TECN CBAL ARG	$\begin{array}{c} e^+e^-\rightarrow\\ {\cal K}_S^0.\\ \\ \hline {\it COMMENT}\\ e^+e^-\rightarrow\\ \\ \hline {\it COMMENT}\\ e^+e^-\rightarrow\\ \\ \hline {\it comment}\\ e^+e^-\rightarrow\\ \\ e^+e^-\rightarrow\\ \\ \hline {\it e}^+e^-\rightarrow\\ \\ \hline {\it e}^+e^-\rightarrow$	7(45) F38 7(45) F39 7(45) F40 7(45) 7(45)
$0.642\pm0.010\pm0.042$ $0.63\pm0.06\pm0.06$ 68 ALBRECHT 94c assum: $\Gamma(K^*(892)^{\pm} \text{ anything})/V_{LOLUE}$ $0.182\pm0.054\pm0.024$ $\Gamma(K^*(892)^0/\overline{K}$	68 Anythin Solution in the interest of the second	ALAM OCUMENT ID ALBRECHT DOCUMENT ID ALBRECHT DOCUMENT ID DALBRECHT DOCUMENT ID DALBRECHT DALBRECHT LESIAK ALBRECHT Clusive process	94J 94J 98H 92 88H 8(b -	CLEO that of $\frac{TECN}{ARG}$ ARG $\frac{TECN}{ARG}$, limits, CBAL ARG $\rightarrow s\gamma$)	$\begin{array}{c} e^+e^- \rightarrow \\ \kappa_S^0. \\ \\ \hline \\ \frac{COMMENT}{e^+e^-} \rightarrow \\ \\ \hline \\ \frac{COMMENT}{e^+e^-} \rightarrow \\ \\ \hline \\ \frac{COMMENT}{e^+e^-} \rightarrow \\ \\ \frac{e^+e^-}{e^-} \rightarrow \\ \\ < 2.8 \times 10 \\ \end{array}$	7(45) F38 7(45) F40 7(45) 7(45) 7(45) -3 at 90%
$0.642 \pm 0.010 \pm 0.042$ $0.63 \pm 0.06 \pm 0.06$ $68 \text{ ALBRECHT 94c assuming}/\text{CK*(892)}^{\pm} \text{ anything}/\text{CK*(892)}^{\pm}$ $0.182 \pm 0.054 \pm 0.024$ $\Gamma(K^*(892)^0 / \overline{K}^*(892)^0$ $VALUE$ $0.146 \pm 0.016 \pm 0.020$ $\Gamma(K^*(892)\gamma) / \Gamma_{\text{total}}$ $VALUE$ $0.146 \pm 0.016 \pm 0.020$ $\Gamma(K^*(892)\gamma) / \Gamma_{\text{total}}$ $VALUE$ $0.146 \pm 0.016 \pm 0.020$ $\Gamma(K^*(892)\gamma) / \Gamma_{\text{total}}$ $VALUE$ $0.146 \pm 0.016 \pm 0.020$ $\Gamma(K^*(892)\gamma) / \Gamma_{\text{total}}$ $VALUE$ 0.166 ± 0.020 0.166 ± 0.02	e a K^0/\tilde{l} Ftotal anythin 30 illowing (control of 892-	ALAM To multiplicity DOCUMENT ID ALBRECHT ALBRECHT DOCUMENT ID ALBRECHT DOCUMENT ID ALBRECHT ALBRECHT CLESIAK ALBRECHT Clusive process 2045 MeV, indi	94J 94J 94B 92 88H B(<i>b</i>	CLEO that of $\frac{TECN}{ARG}$ ARG $\frac{TECN}{ARG}$, limits, CBAL ARG $\Rightarrow s\gamma$) ent of z	$\begin{array}{l} e^+e^-\rightarrow \\ K_S^0. \\ \\ \underline{COMMENT}\\ e^+e^-\rightarrow \\ \\ \underline{COMMENT}\\ e^+e^-\rightarrow \\ \underline{COMMENT}\\ e^+e^-\rightarrow \\ e^+e^-\rightarrow \\ < 2.8\times 10^\circ \\ \\ \end{array}$	7(45) F38 7(45) F40 7(45) 7(45) 7(45) -3 at 90%
$0.642 \pm 0.010 \pm 0.042$ $0.63 \pm 0.06 \pm 0.06$ $68 \text{ ALBRECHT 94c assuming}$ Γ (K^* (892) $^{\pm}$ anything)/ VALUE $0.182 \pm 0.054 \pm 0.024$ Γ (K^* (892) 0 / \overline{K}^* (892) 0 VALUE $0.146 \pm 0.016 \pm 0.020$ Γ (K^* (892) $^{\gamma}$)/ Γ total VALUE $0.146 \pm 0.016 \pm 0.020$ Γ (K^* (892) $^{\gamma}$)/ Γ total $0.146 \pm 0.016 \pm 0.020$ Γ (K^* (892) γ)/ Γ total $0.146 \pm 0.016 \pm 0.020$ $0.166 \pm 0.016 \pm 0.020$ $0.166 \pm 0.016 \pm 0.020$ $0.166 \pm 0.016 \pm 0.020$ 0.167 ± 0.016 0.16	Ftotal anythin illowing 6 on the in of 892-	ALAM DOCUMENT ID DOCUMENT ID ALBRECHT DOCUMENT ID DALBRECHT DOCUMENT ID DALBRECHT DOCUMENT ID DOCUMENT ID DOCUMENT ID	94J 94J 94B 92 88H 8(<i>b</i> -eepend	cLEO that of $\frac{TECN}{ARG}$ ARG $\frac{TECN}{ARG}$ So, limits, $\frac{TECN}{ARG}$ ARG $\frac{TECN}{ARG}$ ent of $\frac{TECN}{ARG}$	$\begin{array}{c} e^+e^-\rightarrow\\ K_S^0.\\ \hline\\ \underline{COMMENT}\\ e^+e^-\rightarrow\\ \hline\\ \underline{COMMENT}\\ e^+e^-\rightarrow\\ \hline\\ \underline{COMMENT}\\ e^+e^-\rightarrow\\ e^+e^-\rightarrow\\ e^+e^-\rightarrow\\ e^+e^-\rightarrow\\ e^+e^-\rightarrow\\ e^-e^-\rightarrow\\ e^-e^-e^-\rightarrow\\ e^-e^-e^-\rightarrow\\ e^-e^-e^-\rightarrow\\ e^-e^-e^-\rightarrow\\ e^-e^-e^-\rightarrow\\ e^-e^-e^-e^-\rightarrow\\ e^-e^-e^-e^-e^-e^-\rightarrow\\ e^-e^-e^-e^-e^-e^-e^-e^-e^-e^-$	T(45) F38 T(45) F40 T(45) T(45) T(45) T(45) -3 at 90% about s-qu
0.642 ± 0.010 ± 0.042 0.63 ± 0.06 ± 0.06 68 ALBRECHT 94c assuming Γ (K^* (892) ± anything) / WALUE 0.182 ± 0.054 ± 0.024 Γ (K^* (892) 0 / \overline{K}^* (892) 0 VALUE 0.146 ± 0.016 ± 0.020 Γ (K^* (892) γ) / Γ total WALUE 0 • • • We do not use the for for the range of masses hadronization. Γ (K_1 (1400) γ) / Γ total WALUE <<.1.1 × 10 ⁻⁴ 90	68 E a K ⁰ /7 Ttotal anythin % dillowing (c) on the in of 892-	ALAM **DOCUMENT ID** ALBRECHT **BOCUMENT ID** ALBRECHT **DOCUMENT ID** DOCUMENT ID** Data for average **D LESIAK ALBRECHT clusive process 2045 MeV, indi- **DOCUMENT ID** ALBRECHT	94J 94J 94J 98H 88H 88H	cLEO that of $\frac{TECN}{ARG}$ ARG $\frac{TECN}{ARG}$, limits, CBAL ARG $\Rightarrow s\gamma$) ent of a	$\begin{array}{c} e^+e^- \to \\ \kappa_S^0. \\ \\ \hline \\ \frac{COMMENT}{e^+e^-} \to \\ \\ \hline \\ \frac{COMMENT}{e^+e^-} \to \\ \\ \hline \\ \frac{COMMENT}{e^+e^-} \to \\ \\ \frac{e^+e^-}{e^-} \to \\ \\ \hline \\ \frac{e^+e^-}{e^+e^-} \to \\ \\ \frac{e^+e^-}{e^+e^-} \to \\ \\ \frac{e^+e^-}{e^+e^-} \to \\ \\ \frac{e^+e^-}{e^-} \to \\ \\ \frac{e^-e^-}{e^-} \to $	T(45) F38 T(45) F40 T(45) T(45) T(45) T(45) -3 at 90% about s-qu
$0.642 \pm 0.010 \pm 0.042$ $0.63 \pm 0.06 \pm 0.06$ $68 \text{ ALBRECHT 94c assume}$ $\Gamma(K^*(892)^{\pm} \text{ anything})/VALUE}$ $0.182 \pm 0.054 \pm 0.024$ $\Gamma(K^*(892)^0/\overline{K}$	68 Frotal manythin Sullowing 69 30 31 31 31 31 31 31 31 31 31	ALAM **DOCUMENT ID** ALBRECHT **BOCUMENT ID** ALBRECHT **DOCUMENT ID** data for average **D LESIAK ALBRECHT clusive process 2045 MeV, inde **DOCUMENT ID** ALBRECHT **DOCUMENT ID** ALBRECHT Clusive process ALBRECHT **DOCUMENT ID** ALBRECHT **DOCUMENT ID** ALBRECHT **DOCUMENT ID** ALBRECHT	94J 94J 94J 94S 94S 88H 8(b) epend	CLEO that of that of $\frac{TECN}{ARG}$ ARG $\frac{TECN}{ARG}$, limits, $\frac{TECN}{ARG}$ ARG $\frac{TECN}{ARG}$ ARG $\frac{TECN}{ARG}$ ARG $\frac{TECN}{ARG}$ ARG $\frac{TECN}{ARG}$	$\begin{array}{c} e^+e^- \rightarrow \\ \kappa_S^0. \\ \\ \hline \\ \frac{COMMENT}{e^+e^-} \rightarrow \\ \\ \hline \\ \frac{COMMENT}{e^+e^-} \rightarrow \\ \\ \frac{e^+e^-}{e^+e^-} \rightarrow \\ \\ < 2.8 \times 10 \\ \\ \\ \frac{COMMENT}{e^+e^-} \rightarrow \\ \\ < 2.8 \times 10 \\ \\ \\ \\ \frac{COMMENT}{e^+e^-} \rightarrow \\ \\ < 2.8 \times 10 \\ \\ \\ \\ \frac{COMMENT}{e^+e^-} \rightarrow \\ \\ \\ \\ \\ \frac{e^+e^-}{e^-} \rightarrow \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ $	$\Upsilon(45)$ Γ_{38} $\Upsilon(45)$ Γ_{39} $\Upsilon(45)$ Γ_{40} Γ_{45} Γ_{45} Γ_{45} Γ_{45} Γ_{45} Γ_{45} Γ_{45}
$0.642 \pm 0.010 \pm 0.042$ $0.63 \pm 0.06 \pm 0.06$ $68 \text{ ALBRECHT 94c assume}$ $\Gamma(K^*(892)^{\pm} \text{ anything})/VALUE}$ $0.182 \pm 0.054 \pm 0.024$ $\Gamma(K^*(892)^0/\overline{K}$	68 Frank ⁰ /7 Fotal — anythin — % fillowing 69 on the in of 892 y on the in of 892	ALAM **To multiplicity **DOCUMENT ID ALBRECHT **DOCUMENT ID ALBRECHT **DOCUMENT ID Jata for average **LESIAK ALBRECHT clusive process 2045 MeV, indi **DOCUMENT ID ALBRECHT	94J 94J 94J 94B 88H 8(b) epend	CLEO that of TECN ARG TECN ARG TECN Sylvient of a TECN ARG	$\begin{array}{c} e^+e^- \rightarrow \\ \kappa_S^0. \\ \\ \hline \\ \frac{COMMENT}{e^+e^-} \rightarrow \\ \\ \hline \\ \frac{COMMENT}{e^+e^-} \rightarrow \\ \\ \frac{COMMENT}{e^+e^-} \rightarrow \\ \\ < 2.8 \times 10^\circ \\ \\ \frac{COMMENT}{e^+e^-} \rightarrow \\ \\ < 2.8 \times 10^\circ \\ \\ \\ \frac{COMMENT}{e^+e^-} \rightarrow \\ \\ < 2.8 \times 10^\circ \\ \\ \\ \frac{COMMENT}{e^+e^-} \rightarrow \\ \\ < 2.8 \times 10^\circ \\ \\ \\ \\ \frac{COMMENT}{e^+e^-} \rightarrow \\ \\ < 2.8 \times 10^\circ \\ \\ \\ \\ \\ \frac{COMMENT}{e^+e^-} \rightarrow \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ $	T(45) F38 T(45) F40 T(45) T(45) T(45) T41 T(45) T(45) T(45) T(45)
$0.642 \pm 0.010 \pm 0.042$ $0.63 \pm 0.06 \pm 0.06$ $68 \text{ ALBRECHT 94c assuming}$ $\Gamma(K^*(892)^{\pm} \text{ anything})/VALUE}$ $0.182 \pm 0.054 \pm 0.024$ $\Gamma(K^*(892)^0/\overline{K}^*(892)^0/K^{\pm}($	68 Frank ⁰ /7 Fotal — anythin — % fillowing 69 on the in of 892 y on the in of 892	ALAM **To multiplicity **DOCUMENT ID ALBRECHT **DOCUMENT ID ALBRECHT **DOCUMENT ID Jata for average **LESIAK ALBRECHT clusive process 2045 MeV, indi **DOCUMENT ID ALBRECHT	94J 94J 94J 94B 88H 8(b) epend	CLEO that of TECN ARG TECN ARG TECN Sylvient of a TECN ARG	$\begin{array}{c} e^+e^- \rightarrow \\ \kappa_S^0. \\ \\ \hline \\ \frac{COMMENT}{e^+e^-} \rightarrow \\ \\ \hline \\ \frac{COMMENT}{e^+e^-} \rightarrow \\ \\ \frac{COMMENT}{e^+e^-} \rightarrow \\ \\ < 2.8 \times 10^\circ \\ \\ \frac{COMMENT}{e^+e^-} \rightarrow \\ \\ < 2.8 \times 10^\circ \\ \\ \\ \frac{COMMENT}{e^+e^-} \rightarrow \\ \\ < 2.8 \times 10^\circ \\ \\ \\ \frac{COMMENT}{e^+e^-} \rightarrow \\ \\ < 2.8 \times 10^\circ \\ \\ \\ \\ \frac{COMMENT}{e^+e^-} \rightarrow \\ \\ < 2.8 \times 10^\circ \\ \\ \\ \\ \\ \frac{COMMENT}{e^+e^-} \rightarrow \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ $	T(45) F38 T(45) F40 T(45) T(45) T(45) T41 T(45) T(45) T(45) T(45)
$0.642 \pm 0.010 \pm 0.042$ $0.63 \pm 0.06 \pm 0.06$ 68 ALBRECHT 94c assuming Γ (K^* (892) $^{\pm}$ anything)/ NALUE $0.182 \pm 0.054 \pm 0.024$ Γ (K^* (892) 0 / \overline{K}^* (892) 0 NALUE $0.146 \pm 0.016 \pm 0.020$ Γ (K^* (892) $^{\gamma}$)/ Γ total value • • • We do not use the form of the range of masses hadronization. Γ (K_1 (1400) $^{\gamma}$)/ Γ total value $= 0.016 \pm 0.016 \pm 0.020$ $= $	68 68 68 68 68 69 69 69 69 69	ALAM DOCUMENT ID ALBRECHT DOCUMENT ID ALBRECHT DOCUMENT ID DALBRECHT DOCUMENT ID DALBRECHT LISIVE process 2045 MeV, indid DOCUMENT ID ALBRECHT DALBRECHT DALBRECH	94J 94J 94J 94J 988H 88H 86,6 92 88H 892	CLEO that of that of that of that of that of that of ARG ARG ARG TECN ARG TECN ARG \rightarrow S γ) ent of z TECN ARG \rightarrow S γ) ent of z TECN ARG \rightarrow S γ) and γ TECN ARG γ TECN TECN TECN TECN TECN TECN THAT γ TECN TECN TECN TECN TECN TECN TECN TECN	$\begin{array}{c} e^+e^- \to \\ \kappa_S^0. \\ \hline \\ \frac{COMMENT}{e^+e^-} \to \\ \hline \\ \frac{COMMENT}{e^+e^-} \to \\ \hline \\ \frac{COMMENT}{e^+e^-} \to \\ \hline \\ \frac{e^+e^- \to e^+e^- \to e^+e^-}{e^+e^-} \to \\ \hline \\ \frac{COMMENT}{e^+e^-} \to \\ \frac{e^+e^- \to e^+e^-}{e^+e^-} \to \\ \hline \\ \frac{e^+e^- \to e^-}{e^+e^-} \to \\ \hline \\ \frac{e^+e^- \to e^-}{e^-e^-} \to \\ \hline \\ \frac{e^+e^- \to e^-}{e^-e^-} \to \\ \hline \\ \frac{e^+e^- \to e^-}{e^-e^-} \to \\ \hline \\ \frac{e^+e^- \to e^-}{e^-} \to \\ \hline \\ \frac{e^-e^-}{e^-} \to e^- \to e^-$	T(45) F38 T(45) F40 T(45) T(45) T(45) -3 at 90% about s-qu F41 T(45)
$0.642 \pm 0.010 \pm 0.042$ $0.63 \pm 0.06 \pm 0.06$ $68 \text{ ALBRECHT 94c assuming}$ Γ (K^* (892) $^{\pm}$ anything)/ NALUE 0.182 ± 0.054 ± 0.024 Γ (K^* (892) 0 / \overline{K}^* (892) 0 NALUE 0.146 ± 0.016 ± 0.020 Γ (K^* (892) $^{\gamma}$)/ Γ total NALUE 0.15 × 10 $^{-3}$ 90 (2.4 × 10 $^{-4}$ 99 69 LESIAK 92 set a limit of for the range of masses hadronization. Γ (K_1 (1400) γ)/ Γ total NALUE 0.16 × 10 $^{-3}$ 90 70 LESIAK 92 set a limit of for the range of masses hadronization. Γ (K_1 (1400) Y)/ Γ total NALUE (1.6 × 10 $^{-3}$ 90 70 LESIAK 92 set a limit of for the range of masses hadronization. Γ (K_2 (1430) Y)/ Γ total NALUE (8.3 × 10 $^{-4}$ 90	68 68 68 68 68 69 69 69 69 69	DOCUMENT ID ALBRECHT DOCUMENT ID ALBRECHT DOCUMENT ID DALBRECHT DOCUMENT ID DALBRECHT DALBRECHT Clusive process 2045 MeV, indi DOCUMENT ID ALBRECHT DALBRECHT DAL	94J 94J 94J 94J 988H 88H 86,6 92 88H 892	CLEO that of that of that of ARG ARG ARG TECN ARG CBAL ARG ARG ARG ARG ARG $\rightarrow s\gamma$) ent of \vec{c} thinks, it is a similar that of the ARG	$\begin{array}{c} e^+e^- \to \\ \kappa_S^0. \\ \hline \\ \frac{COMMENT}{e^+e^-} \to \\ \hline \\ \frac{COMMENT}{e^+e^-} \to \\ \hline \\ \frac{COMMENT}{e^+e^-} \to \\ \hline \\ \frac{e^+e^- \to }{e^+e^-} \to \\ \hline \\ \frac{e^+e^- \to }{e^+e^-} \to \\ \hline \\ \frac{COMMENT}{e^+e^-} \to \\ \\ \frac{e^+e^- \to }{e^+e^-} \to \\ \\ \frac{e^+e^- \to }{e^-} \to \\ \\ \frac{e^-e^- \to }{e^-} \to \\ \\ \frac{e^+e^- \to }{e^-} \to \\ \\ \frac{e^-e^- \to }{e^-} \to \\$	T(45) T38 T(45) T(45) T(45) T(45) T(45) -3 at 90% about s-qu T(45) T(45) T(45) T(45) T(45) T(45) T(45)
$0.642 \pm 0.010 \pm 0.042$ $0.63 \pm 0.06 \pm 0.06$ $68 \text{ ALBRECHT 94c assuming}$ $\Gamma(K^*(892)^{\pm} \text{ anything})/V_{NALUE}$ $0.182 \pm 0.054 \pm 0.024$ $\Gamma(K^*(892)^0 / \overline{K}^*(892)^0$ V_{NALUE} $0.146 \pm 0.016 \pm 0.020$ $\Gamma(K^*(892) \gamma)/\Gamma_{\text{total}}$ V_{NALUE} $0.166 \pm 0.016 \pm 0.020$ $\Gamma(K^*(892) \gamma)/\Gamma_{\text{total}}$ V_{NALUE} $0.166 \pm 0.016 \pm 0.020$ $\Gamma(K^*(892) \gamma)/\Gamma_{\text{total}}$ V_{NALUE} $0.166 \pm 0.016 \pm 0.020$ $0.166 \pm$	68 Pea x 60/7 Fotal manythin % Illowing (1) illowing (7) illowing (8) for the in of 892-	ALAM **DOCUMENT ID** ALBRECHT **DOCUMENT ID** ALBRECHT **DOCUMENT ID** DALBRECHT **DOCUMENT ID** ALBRECHT Clusive process 2045 MeV, inde **DOCUMENT ID** ALBRECHT data for average **DESIAK Clusive process 2045 MeV, inde **DOCUMENT ID** ALBRECHT data for average **DESIAK Clusive process 2045 MeV, inde **DOCUMENT ID** ALBRECHT ALBRECHT **DOCUMENT ID** ALBRECHT	94J 94J 94J 94J 88H 8(b - 88H 892 88(b - 92) 88H 88H	CLEO that of that of that of that of that of ARG ARG TECN ARG TECN ARG TECN ARG $\rightarrow s\gamma$) ent of a ARG $\rightarrow s\gamma$) ent of a TECN ARG ARG ARG ARG ARG ARG ARG ARG	$\begin{array}{c} e^+e^- \to \\ \kappa_S^0. \\ \\ \hline \\ \frac{COMMENT}{e^+e^-} \to \\ \\ \hline \\ \frac{COMMENT}{e^+e^-} \to \\ \\ \frac{COMMENT}{e^+e^-} \to \\ \\ \frac{e^+e^-}{e^-} \to \\ \\ \frac{e^+e^-}{e^+e^-} \to \\ \\ \frac{e^+e^-}{e^+e^-} \to \\ \\ \frac{e^+e^-}{e^+e^-} \to \\ \\ \frac{e^+e^-}{e^+e^-} \to \\ \\ \frac{e^+e^-}{e^-} \to \\ \\ \frac{e^-e^-}{e^-} \to \\ \\ $	T(45) F38 T(45) F40 T(45) T(45) T(45) -3 at 90% about s-qu F41 T(45)
$0.642 \pm 0.010 \pm 0.042$ $0.63 \pm 0.06 \pm 0.06$ $68 \text{ ALBRECHT 94c assuming}$ Γ (K^* (892) $^{\pm}$ anything)/ WALUE $0.182 \pm 0.054 \pm 0.024$ Γ (K^* (892) 0 / \overline{K}^* (892) 0 VALUE $0.146 \pm 0.016 \pm 0.020$ Γ (K^* (892) $^{\gamma}$)/ Γ total WALUE $0.146 \pm 0.016 \pm 0.020$ Γ (K^* (892) $^{\gamma}$)/ Γ total Governormal of the range of masses hadronization. Γ (K_1 (1400) γ)/ Γ total WALUE $0.16 \pm 0.016 \pm 0.020$ $0.$	68 Fe a K ⁰ /7 Ftotal Manythin % Millowing (69) Millowing (70) Millowing	ALAM DOCUMENT ID ALBRECHT DOCUMENT ID ALBRECHT DOCUMENT ID DALBRECHT DOCUMENT ID DALBRECHT LISIVE process 2045 MeV, indid DOCUMENT ID ALBRECHT DALBRECHT DALBRECH	94J 94J 94J 94J 988H 88H 88H	CLEO that of that of that of that of that of ARG ARG TECN ARG TECN ARG TECN ARG $\rightarrow s\gamma$) ent of a ARG $\rightarrow s\gamma$) ent of a TECN ARG ARG ARG ARG ARG ARG ARG ARG	$\begin{array}{c} e^+e^- \to \\ \kappa_S^0. \\ \hline \\ \frac{COMMENT}{e^+e^-} \to \\ \hline \\ \frac{COMMENT}{e^+e^-} \to \\ \hline \\ \frac{COMMENT}{e^+e^-} \to \\ \hline \\ \frac{e^+e^-}{e^+e^-} \to \\ \hline \\ \frac{e^+e^-}{e^+e^-} \to \\ \end{array}$	T(45) F38 T(45) F40 T(45) T(45) T(45) -3 at 90% about s-qu F41 T(45)

Meson Particle Listings B^{\pm}/B^0 ADMIXTURE

$\Gamma(K_3^*(1780)\gamma)/\Gamma_{\text{total}}$ Γ_{44}/Γ	$\Gamma(\overline{\Sigma}_c^0 N(N=p \text{ or } n))/\Gamma_{\text{total}}$ Γ_{56}/Γ
VALUE CL% DOCUMENT ID TECN COMMENT $<3.0 \times 10^{-3}$ 90 ALBRECHT 88H ARG $e^+e^- \rightarrow \Upsilon(4S)$	VALUE CL% DOCUMENT ID TECN COMMENT <0.0017 90 81 PROCARIO 94 CLE2 $e^+e^- \rightarrow \Upsilon(4S)$
$\Gamma(K_4^*(2045)\gamma)/\Gamma_{\text{total}}$ Γ_{45}/Γ	⁸¹ PROCARIO 94 reports $<$ 0.0017 for B($\Lambda_C^+ o pK^-\pi^+$) = 0.043. We rescale to our
VALUE CL% DOCUMENT ID TECN COMMENT	best value B($\Lambda_c^+ \rightarrow p K^- \pi^+$) = 0.044.
<.1.0 x 10 ⁻³ 90 72 LESIAK 92 CBAL $e^+e^- \rightarrow r(45)$ 73 TRANSPORTED TO THE PROPERTY OF TH	$\Gamma(p/\overline{p}_{anything})/\Gamma_{total}$ Γ_{57}/Γ
72 LESIAK 92 set a limit on the inclusive process B(b $\rightarrow s\gamma) < 2.8 \times 10^{-3}$ at 90% CL for the range of masses of 892–2045 MeV, independent of assumptions about s -quark hadronization.	Includes p and p̄ from Λ and Ā decay. VALUE EVTS DOCUMENT ID TECN COMMENT 0.080±0.004 OUR AVERAGE
$\Gamma(\overline{b} \to \overline{s}\gamma)/\Gamma_{\text{total}}$ Γ_{46}/Γ	$0.080\pm0.005\pm0.005$ ALBRECHT 931 ARG $e^+e^- ightarrow ~ \Upsilon(4S)$
VALUE DOCUMENT ID TECN COMMENT	$0.080 \pm 0.005 \pm 0.003$ CRAWFORD 92 CLEO $e^+e^- \rightarrow \Upsilon(4S)$
$(2.32\pm0.57\pm0.35)\times10^{-4}$ ALAM 95 CLE2 $e^+e^-\to \Upsilon(4S)$	$0.082\pm0.005^{+0.013}_{-0.010}$ 2163 ⁸² ALBRECHT 89K ARG $e^+e^- \rightarrow \gamma$ (45) ••• We do not use the following data for averages, fits, limits, etc. •••
$\Gamma(\overline{b} \to \overline{s} gluon)/\Gamma_{total}$ VALUE EVTS DOCUMENT ID TECN COMMENT	>0.021 83 ALAM 83B CLEO $e^+e^- ightarrow \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •	82 ALBRECHT 89K include direct and nondirect protons. 83 ALAM 83B reported their result as $>$ 0.036 \pm 0.006 \pm 0.009. Data are consistent with
<0.08 2 73 ALBRECHT 95D ARG $e^+e^- ightarrow \varUpsilon(4S)$	equal yields of p and \overline{p} . Using assumed yields below cut, $B(B \to p + X) = 0.03$ not
73 ALBRECHT 95D use full reconstruction of one B decay as tag. Two candidate events	including protons from A decays.
for charmless B decay can be interpreted as either $b \to s$ gluon or $b \to u$ transition. If interpreted as $b \to s$ gluon they find a branching ratio of ~ 0.026 or the upper limit	Γ(p/p̄(direct) anything)/Γ _{total} Γ ₅₈ /Γ VALUE EVTS DOCUMENT ID TECN COMMENT
quoted above. Result is highly model dependent.	0.055±0.005 OUR AVERAGE
$\Gamma(\pi^{\pm} \text{anything})/\Gamma_{\text{total}}$ Γ_{48}/Γ	$0.055\pm0.005\pm0.0035$ ALBRECHT 93I ARG $e^+e^- ightarrow \varUpsilon(4S)$ $0.056\pm0.006\pm0.005$ CRAWFORD 92 CLEO $e^+e^- ightarrow \varUpsilon(4S)$
<u>VALUE</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> 3.585 \pm 0.025 \pm 0.070	0.055 ± 0.016 1220 ⁸⁴ ALBRECHT 89K ARG $e^+e^- ightarrow \varUpsilon(4S)$
74 ALBRECHT 93 excludes π^{\pm} from $\kappa_0^{\rm C}$ and Λ decays. If included, they find 4.105 \pm	84 ALBRECHT 89K subtract contribution of Λ decay from the inclusive proton yield.
0.025 ± 0.080 .	$\Gamma(\Lambda/\overline{\Lambda}_{anything})/\Gamma_{total}$ Γ_{59}/Γ
$\Gamma(\rho^0 \text{ anything})/\Gamma_{\text{total}}$ Γ_{49}/Γ	VALUE EVTS DOCUMENT ID TECN COMMENT 0.040±0.005 OUR AVERAGE
VALUE DOCUMENT ID TECN COMMENT	$0.038\pm0.004\pm0.006$ 2998 CRAWFORD 92 CLEO $e^+e^- ightarrow arphi(45)$
0.208 \pm 0.042 \pm 0.032 ALBRECHT 94J ARG $e^+e^- \rightarrow \Upsilon(4S)$	$0.042\pm0.005\pm0.006$ 943 ALBRECHT 89K ARG $e^+e^- \rightarrow \Upsilon(4S)$
$\Gamma(\omega \text{ anything})/\Gamma_{\text{total}}$ Γ_{50}/Γ	85 ALAM 83B CLEO $e^+e^- o au(45)$
VALUE CL% DOCUMENT ID TECN COMMENT	$85\mathrm{ALAM}$ 83B reported their result as $> 0.022\pm0.007\pm0.004$. Values are for
<0.81 90 ALBRECHT 94J ARG $e^+e^- oup \Upsilon(4S)$	$(B(\Lambda X)+B(\overline{\Lambda}X))/2$. Data are consistent with equal yields of p and \overline{p} . Using assumed yields below cut, $B(B\to\Lambda X)=0.03$.
$\Gamma(\phi \text{ anything})/\Gamma_{\text{total}}$ Γ_{51}/Γ	
<u>VALUE</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> 0.035 ±0.007 OUR AVERAGE Error includes scale factor of 1.8.	Γ(Ξ ⁻ /Ξ̄ ⁺ anything)/Γ _{total} Γ ₆₀ /Γ VALUE EVTS DOCUMENT ID TECN COMMENT
$0.0390\pm0.0030\pm0.0035$ ALBRECHT 94J ARG $e^+e^- ightarrow \varUpsilon$ (45)	0.0027±0.0006 OUR AVERAGE
0.023 \pm 0.006 \pm 0.005 BORTOLETTO86 CLEO $e^+e^- \rightarrow \Upsilon(4S)$	$0.0027\pm0.0005\pm0.0004$ 147 CRAWFORD 92 CLEO $e^+e^- ightarrow \varUpsilon(4S)$ 0.0028 ± 0.0014 54 ALBRECHT 89K ARG $e^+e^- ightarrow \varUpsilon(4S)$
Γ (charmed-baryon anything)/ Γ total Γ 52/ Γ	-/·
VALUECL%DOCUMENT IDTECNCOMMENT0.064 \pm 0.008 \pm 0.00875 CRAWFORD92 CLEO $e^+e^- \rightarrow \Upsilon(4S)$	(baryons anything)/F _{total}
0.064±0.008±0.008 One of CRAWFORD 92 CLEO $e^+e^- \rightarrow \Upsilon(4S)$ One of We do not use the following data for averages, fits, limits, etc.	0.068 \pm 0.005 \pm 0.003 86 ALBRECHT 920 ARG $e^+e^- \rightarrow r(4S)$
0.14 \pm 0.09 76 ALBRECHT 88E ARG $e^+e^- \rightarrow \Upsilon(4S)$	• • • We do not use the following data for averages, fits, limits, etc. • • • 0.076 ± 0.014 87 ALBRECHT 89K ARG $e^+e^- \rightarrow \Upsilon(45)$
<0.112 90 ⁷⁷ ALAM 87 CLEO $e^+e^- \rightarrow \Upsilon(4S)$	86 ALBRECHT 920 result is from simultaneous analysis of ρ and Λ yields, $\rho \overline{\rho}$ and $\Lambda \overline{\rho}$ corre-
⁷⁵ CRAWFORD 92 result derived from lepton baryon correlations. Assumes all charmed baryons in B^0 and B^{\pm} decay are Λ_c .	lations, and various lepton-baryon and lepton-baryon-antibaryon correlations. SupersedesALBRECHT 89k.
⁷⁶ ALBRECHT 88E measured B($B \rightarrow A_c^+ X$)·B($A_c^+ \rightarrow \rho K^- \pi^+$) = (0.30 ± 0.12 ± 0.06)%	87 ALBRECHT 89K obtain this result by adding their their measurements (5.5 \pm 1.6)% for
and used B($\Lambda_{C}^{+} ightarrow ho K^{-} \pi^{+})$ $=$ (2.2 ± 1.0)% from ABRAMS 80 to obtain above number.	direct protons and $(4.2\pm0.5\pm0.6)\%$ for inclusive \varLambda production. They then assume $(5.5\pm1.6)\%$ for neutron production and add it in also. Since each B decay has two
77 Assuming all baryons result from charmed baryons, ALAM 86 conclude the branching fraction is 7.4 \pm 2.9%. The limit given above is model independent.	baryons, they divide by 2 to obtain (7.6 \pm 1.4)%.
	$\Gamma(p\overline{p}anything)/\Gamma_{total}$ Γ_{62}/Γ
$\Gamma(\overline{\mathcal{L}_c}^-$ anything)/ $\Gamma_{ ext{total}}$ $\Gamma_{ ext{53}}/\Gamma$ VALUE EVTS DOCUMENT ID TECN COMMENT	Includes <i>p</i> and \overline{p} from Λ and $\overline{\Lambda}$ decay. <u>VALUE</u> <u>EVTS</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u>
0.0048 \pm 0.0024 \pm 0.0006 77 78 PROCARIO 94 CLE2 $e^+e^- \rightarrow \Upsilon(45)$	0.0247±0.0023 OUR AVERAGE
⁷⁸ PROCARIO 94 reports [B($B \rightarrow \overline{\Sigma}_C^{}$ anything) \times B($\Lambda_C^+ \rightarrow pK^-\pi^+$)] = 0.00021 ±	0.024 ± 0.001 ± 0.004 CRAWFORD 92 CLEO $e^+e^- \rightarrow \Upsilon(4S)$ 0.025 ± 0.002 ± 0.002 918 ALBRECHT 89K ARG $e^+e^- \rightarrow \Upsilon(4S)$
0.00008 \pm 0.00007. We divide by our best value B($\Lambda_C^+ \to pK^-\pi^+$) = (4.4 \pm 0.6) \times	
10^{-2} . Our first error is their experiment's error and our second error is the systematic	Includes p and \overline{p} from Λ and $\overline{\Lambda}$ decay.
error from using our best value.	VALUE DOCUMENT ID TECN COMMENT
$\Gamma(\Sigma_c^- \text{anything})/\Gamma_{\text{total}}$ Γ_{54}/Γ	• • • We do not use the following data for averages, fits, limits, etc. • • • $0.30\pm0.02\pm0.05$ 88 CRAWFORD 92 CLEO $e^+e^-\to \Upsilon(4S)$
value <u>cl%</u> <u>document id</u> <u>tecn</u> <u>comment</u> $<$ c. comment $<$ c. comment $<$ c. comment $>$ c. comment $>$ c. c. comment $>$ c. c. c. c. c. c. c. c.	⁸⁸ CRAWFORD 92 value is not independent of their $\Gamma(p\overline{p}$ anything)/ Γ_{total} value.
⁷⁹ PROCARIO 94 reports $[B(B \to \overline{\Sigma}_c^- \text{ anything}) \times B(\Lambda_c^+ \to pK^-\pi^+)] = < 0.00048.$	
We divide by our best value $B(\Lambda_c^+ \to pK^-\pi^+) = 0.044$.	Includes p and \overline{p} from Λ and $\overline{\Lambda}$ decay.
	<u>VALUE</u> <u>EVTS</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> 0.025±0.004 OUR AVERAGE
- (==0	
$\Gamma(\overline{\Sigma}_{c}^{0} \text{ anything})/\Gamma_{\text{total}}$ Γ_{55}/Γ	$0.029\pm0.005\pm0.005$ CRAWFORD 92 CLEO $e^+e^- ightarrow \varUpsilon(4S)$
- (=1)	$\begin{array}{ccccccc} 0.029\pm0.005\pm0.005 & \text{CRAWFORD} & 92 & \text{CLEO} & e^+e^- \rightarrow & \varUpsilon(4S) \\ 0.023\pm0.004\pm0.003 & 165 & \text{ALBRECHT} & 89\text{K} & \text{ARG} & e^+e^- \rightarrow & \varUpsilon(4S) \end{array}$
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$0.023\pm0.004\pm0.003$ 165 ALBRECHT 89K ARG $e^+e^- \rightarrow \Upsilon(4S)$ $\Gamma(\Lambda \overline{\rho}/\overline{\Lambda} \rho \text{anything})/\Gamma(\Lambda/\overline{\Lambda} \text{anything})$ Γ_{63}/Γ_{59}
T($\overline{\Sigma}_c^0$ anything)/ Γ_{total} VALUE EVTS DOCUMENT ID RECTOR SO PROCARIO 94 reports [B($B \rightarrow \overline{\Sigma}_c^0$ anything) \times B($\Lambda_c^+ \rightarrow pK^-\pi^+$)] = 0.00023 \pm 0.00008 \pm 0.00007. We divide by our best value B($\Lambda_c^+ \rightarrow pK^-\pi^+$) = (4.4 \pm 0.6) \times	0.023 \pm 0.004 \pm 0.003 165 ALBRECHT 89K ARG $e^+e^- \rightarrow r\dot{(}4S\dot{)}$ $\Gamma(\Lambda \overline{\rho}/\overline{\Lambda} \rho \text{anything})/\Gamma(\Lambda/\overline{\Lambda} \text{anything})$ Includes ρ and $\overline{\rho}$ from Λ and $\overline{\Lambda}$ decay.
T($\overline{\Sigma}_{c}^{0}$ anything)/ Γ_{total} Let Σ DOCUMENT ID ROPROCARIO 94 reports [B($B \rightarrow \overline{\Sigma}_{c}^{0}$ anything) \times B($\Lambda_{c}^{+} \rightarrow pK^{-}\pi^{+}$)] = 0.00023 \pm 0.00008 \pm 0.00007. We divide by our best value B($\Lambda_{c}^{+} \rightarrow pK^{-}\pi^{+}$)] = 4.4 \pm 0.6) \times 10 ⁻² . Our first error is their experiment's error and our second error is the systematic	$0.023\pm0.004\pm0.003$ 165 ALBRECHT 89K ARG $e^+e^- \rightarrow \Upsilon(4S)$ $\Gamma(\Lambda \overline{\rho}/\overline{\Lambda} \rho \text{anything})/\Gamma(\Lambda/\overline{\Lambda} \text{anything})$ Γ_{63}/Γ_{59}
T($\overline{\Sigma}_c^0$ anything)/ Γ_{total} VALUE EVTS DOCUMENT ID RECTOR SO PROCARIO 94 reports [B($B \rightarrow \overline{\Sigma}_c^0$ anything) \times B($\Lambda_c^+ \rightarrow pK^-\pi^+$)] = 0.00023 \pm 0.00008 \pm 0.00007. We divide by our best value B($\Lambda_c^+ \rightarrow pK^-\pi^+$) = (4.4 \pm 0.6) \times	0.023±0.004±0.003 165 ALBRECHT 89K ARG $e^+e^- \rightarrow \Upsilon(4S)$ $\Gamma(\Lambda \overline{\rho}/\overline{\Lambda} \rho \text{anything})/\Gamma(\Lambda/\overline{\Lambda} \text{anything}) \qquad \qquad \Gamma_{63}/\Gamma_{59}$ Includes ρ and $\overline{\rho}$ from Λ and $\overline{\Lambda}$ decay. VALUE DOCUMENT ID TECN COMMENT

B^{\pm}/B^{0} ADMIXTURE, $B^{\pm}/B^{0}/B_{s}^{0}/b$ -baryon ADMIXTURE

$\Gamma(\Lambda \overline{\Lambda} anythin$							Γ ₆₄ ,	1
VALUE	<u>CL%</u>	EVTS	DOCUMENT ID					_
<0.005	90		CRAWFORD				$\Upsilon(4S)$	
• • • We do n	ot use the	following	ng data for averag					
< 0.0088	90	12	ALBRECHT	89K	ARG	$e^+e^- \rightarrow$	Υ(45)	
$\Gamma(\Lambda \overline{\Lambda} anythin$	ıg)/Γ(<i>Λ</i> ,	∕⊼anyt	hing)				Γ ₆₄ /Γ	Ε
			DOCUMENT ID					_
• • • We do n	ot use the	following	ng data for averag	es, fits	, limits,	etc. • • •		
< 0.13		90	⁹⁰ CRAWFORD	92	CLEO	e^+e^-	$\Upsilon(45)$	
⁹⁰ CRAWFOR	D 92 valu	e is not	independent of th	eir Γ(,	17anyth	$_{ m ting})/\Gamma_{ m total}$	value.	
		eak neu	tral current. <u>DOCUMENT ID</u>		TECN	COMMENT	Γ ₆₅ ,	/
			ng data for averag					-
< 0.05		90	BEBEK	81	CLEO	$e^+e^- \rightarrow$	Y(45)	
		eak neu	tral current. DOCUMENT ID		<u>TECN</u>	COMMENT	Г ₆₆	/
• • • We do n	ot use the	following	ng data for averag	es, fit	, limits,	etc. • • •		
< 0.017		90	CHADWICK	81	CLEO	$e^+e^- \to$	$\Upsilon(4S)$	
[Γ(e ⁺ e ⁻ any Test for .	$\Delta B = 1 \text{ w}$	/eak neu	μ anything)]/ tral current. DOCUMENT ID			· ·	Γ ₆₅ +Γ ₆₆)	/
<0.0024			91 BEAN					
	ot use the		ng data for averag				, (45)	
< 0.0062			92 AVERY				EAN 87	
	enarts [()		$(e^+e^-)/2$ and					
			semileptonic dec				5-2.9.	
	E	3±/B0	ADMIXTURE	REFE	RENC	ES		_

ALAM			
	95	PRL 74 2885	+Kim, Ling, Mahmood+ (CLEO Collab.)
ALBRECHT	95D	PL B353 554	+Hamacher, Hofmann, Kirchoff+ (ARGUS Collab.)
BALEST	95B	PR D52 2661	+Cho, Ford, Johnson+ (CLEO Collab.)
BARISH	95	PR D51 1014	+Chadha, Chan, Cowen+ (CLEO Collab.)
BUSKULIC	95B	PL B345 103	+Casper, De Bonis, Decamp+ (ALEPH Collab.)
ALBRECHT	94 C	ZPHY C62 371	+Ehrlichmann, Hamacher, Hofmann+ (ARGUS Collab.)
ALBRECHT	94J	ZPHY C61 1	+Ehrlichmann, Hamacher, Hofmann+ (ARGUS Collab.)
PROCARIO	94	PRL 73 1306	+Balest, Cho, Daoudi, Ford+ (CLEO Collab.)
ALBRECHT	93	ZPHY C57 533	+Ehrlichmann, Hamacher, Hofmann+ (ARGUS Collab.)
		ZPHY C60 11	
ALBRECHT	93E		+Ehrlichmann, Hamacher, Hofmann+ (ARGUS Collab.)
ALBRECHT	93H	PL B318 397	+Ehrlichmann, Hamacher, Hofmann+ (ARGUS Collab.)
ALBRECHT	931	ZPHY C58 191	+Cronstroem, Ehrlichmann, Hamacher+ (ARGUS Collab.)
ALEXANDER	93B	PL B319 365	+Bebek, Berkelman, Bloom, Browder+ (CLEO Collab.)
ARTUSO	93	PL B311 307	(SYRA)
BARTELT	93B	PRL 71 4111	+Csorna, Egyed, Jain, Akerib+ (CLEO Collab.)
ALBRECHT	92E	PL B277 209	+Ehrlichmann, Hamacher, Krueger, Nau+ (ARGUS Collab.)
ALBRECHT	92G	ZPHY C54 1	+Ehrlichmann, Hamacher, Krueger, Nau+ (ARGUS Collab.)
ALBRECHT	920	ZPHY C56 1	+Cronstroem, Ehrlichmann+ (ARGUS Collab.)
BORTOLETTO	92	PR D45 21	+Brown, Dominick, McIlwain+ (CLEO Collab.)
CRAWFORD	92	PR D45 752	+Fulton, Jensen, Johnson+ (CLEO Collab.)
HENDERSON	92	PR D45 2212	+Kinoshita, Pipkin, Procario+ (CLEO Collab.)
LESIAK	92	ZPHY C55 33	+Antreasyan, Bartels, Besset, Bieler+ (Crystal Ball Collab.)
ALBRECHT	91C	PL B255 297	+Ehrlichmann, Glaeser, Harder, Krueger+ (ARGUS Collab.)
ALBRECHT	91H	ZPHY C52 353	
FULTON	91	PR D43 651	+ Jensen, Johnson, Kagan, Kass+ (CLEO Collab.)
YANAGISAWA	91	PRL 66 2436	+Heintz, Lee-Franzini, Lovelock, Narain+ (CUSB II Collab.)
ALBRECHT	90	PL B234 409	+Glaeser, Harder, Krueger+ (ARGUS Collab.)
ALBRECHT	90H	PL B249 359	+Ehrlichmann, Glaeser, Harder, Krueger+ (Argus Collab.)
BORTOLETTO		PRL 64 2117	+Goldberg, Horwitz, Jain, Mestayer+ (CLEO Collab.)
Also	92	PR D45 21	Bortoletto, Brown, Dominick, McIlwain+ (CLEO Collab.)
FULTON	90	PRL 64 16	+Hempstead, Jensen, Johnson+ (CLEO Collab.)
MASCHMANN	90	ZPHY C46 555	+Antreasyan, Bartels, Besset+ (Crystal Ball Collab.)
PDG	90	PL B239	Hernandez, Stone, Porter+ (IFIC, BOST, CIT+)
ALBRECHT	89K	ZPHY C42 519	+Boeckmann, Glaeser, Harder+ (ARGUS Collab.)
ISGUR	89B	PR D39 799	+Scora, Grinstein, Wise (TNTO, CIT)
WACHS	89	ZPHY C42 33	+Antreasyan, Bartels, Bieler+ (Crystal Ball Collab.)
ALBRECHT	88E	PL B210 263	+Boeckmann, Glaeser+ (ARGUS Collab.)
ALBRECHT	88H	PL B210 258	+Boeckmann, Glaeser+ (ARGUS Collab.)
KOERNER	88	ZPHY C38 511	+Schuler (MANZ, DESY)
			Tacilitei (MANZ, DEST)
			LKitukama Kim Liu (CLEO Collab.)
ALAM	87	PRL 59 22	+Kitukama, Kim, Li+ (CLEO Collab.)
ALAM	87B	PRL 58 1814	+Katayama, Kim, Sun+ (CLEO Collab.)
ALAM ALBRECHT	87B 87D	PRL 58 1814 PL B199 451	+Katayama, Kim, Sun+ (CLEO Collab.) +Andam, Binder, Boeckmann+ (ARGUS Collab.)
ALAM ALBRECHT ALBRECHT	87B 87D 87H	PRL 58 1814 PL B199 451 PL B187 425	+Katayama, Kim, Sun+ (CLEO Collab.) +Andam, Binder, Boeckmann+ (ARGUS Collab.) +Binder, Boeckmann, Glaser+ (ARGUS Collab.)
ALAM ALBRECHT ALBRECHT BEAN	87B 87D 87H 87	PRL 58 1814 PL B199 451 PL B187 425 PR D35 3533	+Katayama, Kim, Sun+ (CLEO Collab.) +Andam, Binder, Boeckmann+ (ARGUS Collab.) +Binder, Boeckmann, Glaser+ (ARGUS Collab.) +Bobbink, Brock, Engler+ (CLEO Collab.)
ALAM ALBRECHT ALBRECHT BEAN BEHRENDS	87B 87D 87H 87 87	PRL 58 1814 PL B199 451 PL B187 425 PR D35 3533 PRL 59 407	+Katayama, Kim, Sun+ (CLEO Collab.) +Andam, Binder, Boeckmann+ (ARGUS Collab.) +Binder, Boeckmann, Glaser+ (ARGUS Collab.) +Bobbink, Brock, Engler+ (CLEO Collab.) +Morrow, Guida, Guida+ (CLEO Collab.)
ALAM ALBRECHT ALBRECHT BEAN BEHRENDS BORTOLETTO	87B 87D 87H 87 87 87	PRL 58 1814 PL B199 451 PL B187 425 PR D35 3533 PRL 59 407 PR D35 19	+Katayama, Kim, Sun+ (CLEO Collab.) +Andam, Binder, Boeckmann+ (ARGUS Collab.) +Binder, Boeckmann, Glaser+ (ARGUS Collab.) +Bobbink, Brock, Engler+ (CLEO Collab.) +Morrow, Guida, Guida+ (CLEO Collab.) +Chen, Garren, Goldberg+ (CLEO Collab.)
ALAM ALBRECHT ALBRECHT BEAN BEHRENDS BORTOLETTO ALAM	87B 87D 87H 87 87 87 87	PRL 58 1814 PL B199 451 PL B187 425 PR D35 3533 PRL 59 407 PR D35 19 PR D34 3279	+Katayama, Kim, Sun+ (CLEO Collab.) +Andam, Binder, Boeckmann+ (ARGUS Collab.) +Binder, Boeckmann, Glaser+ (ARGUS Collab.) +Bobbink, Brock, Engler+ (CLEO Collab.) +Morrow, Guida, Guida+ (CLEO Collab.) +Chen, Garren, Goldberg+ (CLEO Collab.) +Katayama, Kim, Sun+ (CLEO Collab.)
ALAM ALBRECHT ALBRECHT BEAN BEHRENDS BORTOLETTO ALAM BALTRUSAIT	87B 87D 87H 87 87 87 86 . 86E	PRL 58 1814 PL 8199 451 PL 8187 425 PR D35 3533 PRL 59 407 PR D35 19 PR D34 3279 PRL 56 2140	+ Katayama, Kim, Sun+ (CLEO Collab.) + Andam, Binder, Boeckmann+ (ARGUS Collab.) + Binder, Boeckmann, Glaser+ (ARGUS Collab.) + Bobbink, Brock, Engler+ (CLEO Collab.) + Morrow, Guida, Guida+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Katayama, Kim, Sun+ Baltrusslits, Becker, Blaylock, Brown+ (Mark IIII Collab.)
ALAM ALBRECHT ALBRECHT BEAN BEHRENDS BORTOLETTO ALAM	87B 87D 87H 87 87 87 86 . 86E	PRL 58 1814 PL B199 451 PL B187 425 PR D35 3533 PRL 59 407 PR D35 19 PR D34 3279 PRL 56 2140 PRL 56 800	+ Katayama, Kim, Sun+ (CLEO Collab.) + Andam, Binder, Boeckmann+ (ARGUS Collab.) + Binder, Boeckmann, Glaser+ (ARGUS Collab.) + Bobbink, Brock, Engler+ (CLEO Collab.) + Morrow, Guida, Guida+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) Baltrusaitis, Becker, Blaylock, Brown+ (Mark III Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.)
ALAM ALBRECHT ALBRECHT BEAN BEHRENDS BORTOLETTO ALAM BALTRUSAIT BORTOLETTO HAAS	87B 87D 87H 87 87 87 86 . 86E	PRL 58 1814 PL 8199 451 PL 8187 425 PR D35 3533 PRL 59 407 PR D35 19 PR D34 3279 PRL 56 2140 PRL 56 800 PRL 56 2781	+ Katayama, Kim, Sun+ (CLEO Collab.) + Andam, Binder, Boeckmann+ (ARGUS Collab.) + Binder, Boeckmann, Glaser+ (ARGUS Collab.) + Bobbink, Brock, Engler+ (CLEO Collab.) + Morrow, Guida, Guida+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Katayama, Kim, Sun+ Baltrusslits, Becker, Blaylock, Brown+ (Mark IIII Collab.)
ALAM ALBRECHT ALBRECHT BEAN BEHRENDS BORTOLETTO ALAM BALTRUSAIT. BORTOLETTO	87B 87D 87H 87 87 87 86 . 86E	PRL 58 1814 PL B199 451 PL B187 425 PR D35 3533 PRL 59 407 PR D35 19 PR D34 3279 PRL 56 2140 PRL 56 800	+ Katayama, Kim, Sun+ (CLEO Collab.) + Andam, Binder, Boeckmann+ (ARGUS Collab.) + Binder, Boeckmann, Glaser+ (ARGUS Collab.) + Bobbink, Brock, Engler+ (CLEO Collab.) + Horrow, Guida, Guida+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) Baltrusaitis, Becker, Blaylock, Brown+ (Mark III Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.)
ALAM ALBRECHT ALBRECHT BEAN BEHRENDS BORTOLETTO ALAM BALTRUSAIT BORTOLETTO HAAS	87B 87D 87H 87 87 86 . 86E . 86E	PRL 58 1814 PL 8199 451 PL 8187 425 PR D35 3533 PRL 59 407 PR D35 19 PR D34 3279 PRL 56 2140 PRL 56 800 PRL 56 2781	+ Katayama, Kim, Sun+ (CLEO Collab.) + Andam, Binder, Boeckmann+ (ARGUS Collab.) + Bilder, Boeckmann, Glaser+ (ARGUS Collab.) + Bobbink, Brock, Engler+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Katayama, Kim, Sun+ (CLEO Collab.) + Baltrusalitis, Becker, Blaylock, Brown+ (Mark III Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Hempstead, Jensen, Kagan+ (CLEO Collab.)
ALAM ALBRECHT BEAN BEHRENDS BORTOLETTC ALAM BALTRUSAIT. BORTOLETTC HAAS ALBRECHT	87B 87D 87H 87 87 86 . 86E 86 . 86E	PRL 58 1814 PL B199 451 PL B187 425 PR D35 3533 PRL 59 407 PR D35 19 PR D34 3279 PRL 56 2140 PRL 56 800 PRL 56 2781 PL 162B 395	+ Katayama, Kim, Sun+ (CLEO Collab.) + Andam, Binder, Boeckmann+ (ARGUS Collab.) + Bilder, Boeckmann, Glaser+ (ARGUS Collab.) + Bobbink, Brock, Engler+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Katayama, Kim, Sun+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Hempstead, Jensen, Kagan+ (CLEO Collab.) + Bilder, Harder+ (ARGUS Collab.) + Garren, Mestayer, Panvini+ (CLEO Collab.)
ALAM ALBRECHT BEAN BEHRENDS BORTOLETTC ALAM BALTRUSAIT. BORTOLETTC HAAS ALBRECHT CSORNA HAAS	87B 87D 87H 87 87 86 . 86E . 86 86 86 85H 85	PRL 58 1814 PL 8199 451 PL 8187 425 PR 035 3533 PRL 59 407 PR D35 19 PR D34 3279 PRL 56 800 PRL 56 2040 PRL 56 20781 PL 1628 395 PRL 54 1894 PRL 55 1248	+ Katayama, Kim, Sun+ (CLEO Collab.) + Andam, Binder, Boeckmann+ (ARGUS Collab.) + Binder, Boeckmann, Glaser+ (ARGUS Collab.) + Bobbink, Brock, Engler+ (CLEO Collab.) + Horrow, Guida, Guida+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) Baltrusaitis, Becker, Blaylock, Brown+ (Mark III Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Hempstead, Jensen, Kagan+ (CLEO Collab.) + Garren, Mestayer, Parwini+ (CLEO Collab.) + Hempstead, Jensen, Kagan+ (CLEO Collab.)
ALAM ALBRECHT ALBRECHT BEAN BEHRENDS BORTOLETTC ALAM BALTRUSAIT. BORTOLETTC HAAS ALBRECHT CSORNA HAAS AVERY	87B 87D 87H 87 87 86 . 86E 86 86 85H 85 85	PRL 58 1814 PL 8199 451 PL 8197 425 PR 035 3533 PRL 59 407 PR 034 3279 PRL 56 2140 PRL 56 2240 PRL 56 2781 PL 162B 395 PRL 55 1248 PRL 55 1248 PRL 55 1248	+ Katayama, Kim, Sun+ (CLEO Collab.) + Andam, Binder, Boeckmann+ (ARGUS Collab.) + Bilnder, Boeckmann, Glaser+ (ARGUS Collab.) + Bobbink, Brock, Engler+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Katayama, Kim, Sun+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Hempstead, Jensen, Kagan+ (CLEO Collab.) + Bilder, Harder+ (ARGUS Collab.) + Garren, Mestayer, Panvini+ (CLEO Collab.) + Hempstead, Jensen, Kagan+ (CLEO Collab.) + Bebek, Berkelman, Cassel+ (CLEO Collab.)
ALAM ALBRECHT ALBRECHT BEAN BEHRENDS BORTOLETTC ALAM BALTRUSAIT BORTOLETTC HAAS ALBRECHT CSORNA HAAS AVERY CHEN	87B 87D 87H 87 87 86 . 86E 86 85H 85 85 84 84	PRL 58 1814 PL 8199 451 PL 8187 425 PR D35 3533 PRL 59 407 PR D34 3279 PRL 56 2140 PRL 56 800 PRL 56 2781 PL 162B 395 PRL 54 1894 PRL 55 1248 PRL 53 1309 PRL 55 1084	+ Katayama, Kim, Sun+ (CLEO Collab.) + Andam, Binder, Boeckmann+ (ARGUS Collab.) + Binder, Boeckmann, Glaser+ (ARGUS Collab.) + Bobbink, Brock, Engler+ (CLEO Collab.) + Horrow, Guida, Guida+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Katayama, Kim, Sun+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Hempstead, Jensen, Kagan+ (CLEO Collab.) + Baltrusaitis, Becker, Baynoin+ (CLEO Collab.) + Binder, Harder+ (CLEO Collab.) + Bebek, Berkelman, Cassel+ (CLEO Collab.)
ALAM ALBRECHT ALBRECHT BEAN BEHRENDS BORTOLETTC ALAM BORTOLETTC HAAS ALBRECHT CSORNA HAAS AVERY CHEN LEVMAN	87B 87D 87H 87 87 86 . 86E . 86 85H 85 84 84	PRL 58 1814 PL 8199 451 PL 8187 425 PR 035 3533 PRL 59 407 PR D35 19 PR 034 3279 PRL 56 2140 PRL 56 22140 PRL 56 2781 PL 1628 395 PRL 54 1894 PRL 55 1248 PRL 55 1248 PRL 52 1089 PRL 52 1089	+ Katayama, Kim, Sun+ (CLEO Collab.) + Andam, Binder, Boeckmann+ (ARGUS Collab.) + Bilnder, Boeckmann, Glaser+ (ARGUS Collab.) + Bobbink, Brock, Engler+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Katayama, Kim, Sun+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Hempstead, Jensen, Kagan+ (CLEO Collab.) + Bilder, Harder+ (ARGUS Collab.) + Garren, Mestayer, Panvini+ (CLEO Collab.) + Hempstead, Jensen, Kagan+ (CLEO Collab.) + Bebek, Berkelman, Cassel+ (CLEO Collab.) + Goldberg, Horwitz, Jawahery+ (CLEO Collab.) + Sreedhar, Han, Imilay+ (CLEO Collab.)
ALAM ALBRECHT ALBRECHT BEAN BEHRENDS BORTOLETTC ALAM BALTRUSAIT. BORTOLETTC HAAS ALBRECHT CSORNA HAAS AVERY CHEN LEVMAN ALAM	87B 87D 87H 87 87 86 . 86E . 86E 86 85 H 85 84 84 84 84 83B	PRL 58 1814 PL 8199 451 PL 8187 425 PR 035 3533 PRL 59 407 PR 035 19 PR 034 3279 PRL 56 2140 PRL 56 2781 PL 162B 395 PRL 54 1894 PRL 53 1309 PRL 53 1309 PRL 53 1309 PRL 54 1894 PRL 51 1143	+ Katayama, Kim, Sun+ (CLEO Collab.) + Andam, Binder, Boeckmann+ (ARGUS Collab.) + Binder, Boeckmann, Glaser+ (ARGUS Collab.) + Bobbink, Brock, Engler+ (CLEO Collab.) + Morrow, Guida, Guida+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Katayama, Kim, Sun+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Hempstead, Jensen, Kagan+ (CLEO Collab.) + Binder, Harder+ (ARGUS Collab.) + Hempstead, Jensen, Kagan+ (CLEO Collab.) + Bebek, Berkelman, Cassel+ (CLEO Collab.) + Goldberg, Horwitz, Jawahery+ (CLEO Collab.) + Sreedhar, Han, Imlay+ (CUSB Collab.) + Sreedhar, Han, Imlay+ (CUSB Collab.)
ALAM ALBRECHT ALBRECHT BEAN BEHRENDS BORTOLETTC ALAM BALTRUSAIT. BORTOLETTC HAAS ALBRECHT CSORNA HAAS AVERY CHEN LEVMAN ALAM GREEN	87B 87D 87H 87 87 86 86E 86 86 85H 85 85 84 84 83B 83	PRL 58 1814 PL 8199 451 PL 8198 452 PR 035 3533 PRL 59 407 PR 034 3279 PRL 56 2140 PRL 56 800 PRL 56 2781 PL 16278 395 PRL 55 1248 PRL 55 1248 PRL 55 1248 PRL 52 1084 PRL 52 1084 PRL 51 1143 PRL 51 1143	+ Katayama, Kim, Sun+ (CLEO Collab.) + Andam, Binder, Boeckmann+ (ARGUS Collab.) + Bilnder, Boeckmann, Glaser+ (ARGUS Collab.) + Bobbink, Brock, Engler+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Katayama, Kim, Sun+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Hempstead, Jensen, Kagan+ (CLEO Collab.) + Bilder, Harder+ (ARGUS Collab.) + Garren, Mestayer, Panvini+ (CLEO Collab.) + Hempstead, Jensen, Kagan+ (CLEO Collab.) + Goldberg, Horwitz, Jawahery+ (CLEO Collab.) + Goldberg, Horwitz, Jawahery+ (CLEO Collab.) + Sreedhar, Han, Imilay+ (CUSG Collab.) + Csorna, Garren, Mestayer+ (CLEO Collab.) + Hicks, Sannes, Skubic+ (CLEO Collab.)
ALAM ALBRECHT ALBRECHT BEAN BEHRENDS BORTOLETTC ALAM BALTRUSAIT. BORTOLETTC HAAS ALBRECHT CSORNA HAAS AVERY CHEN LEVMAN ALAM GREEN KLOPFEN	87B 87D 87H 87 87 86 86 86 86 85H 85 85 84 84 84 83B 83B	PRL 58 1814 PL 8199 451 PL 8198 452 PR 025 3333 PRL 59 407 PR D25 19 PR D24 3279 PRL 56 2140 PRL 56 2781 PRL 56 2781 PRL 52 3159 PRL 52 1248 PRL 53 1309 PRL 55 1248 PRL 53 1309 PRL 51 1148 271 PRL 51 1347 PL 1318 444	+ Katayama, Kim, Sun+ (CLEO Collab.) + Andam, Binder, Boeckmann+ (ARGUS Collab.) + Binder, Boeckmann, Glaser+ (ARGUS Collab.) + Bobbink, Brock, Engler+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Katayama, Kim, Sun+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Hempstead, Jensen, Kagan+ (CLEO Collab.) + Baltrusaitis, Becker, Baylock, Brown+ (CLEO Collab.) + Binder, Harder+ (CLEO Collab.) + Bebek, Berkelman, Cassel+ (CLEO Collab.) + Goldberg, Horwitz, Jawahery+ (CLEO Collab.) + Sreedhar, Han, Imlay+ (CUSB Collab.) + Scorna, Garren, Mestayer+ + Hicks, Sannes, Skubic+ (CLEO Collab.)
ALAM ALBRECHT ALBRECHT BEAN BEHRENDS BORTOLETTC ALAM BALTRUSAIT. HAAS ALBRECHT CSORNA HAAS AVERY CHEN LEVMAN ALAM GREEN KLOPFEN ALTARELLI	87B 87D 87H 87 86 86 86 86 85H 85 84 84 84 84 84 83 83 83 83 83 82	PRL 58 1814 PL 8199 451 PL 8187 425 PR 035 5333 PRL 59 407 PR D35 19 PR D34 3279 PRL 56 204 PRL 56 800 PRL 56 2781 PL 1628 395 PRL 52 1084 PRL 55 1248 PRL 52 1084 PRL 51 1143 PRL 51 1143	+ Katayama, Kim, Sun+ (CLEO Collab.) + Andam, Binder, Boeckmann+ (ARGUS Collab.) + Bilnder, Boeckmann, Glaser+ (ARGUS Collab.) + Bobbink, Brock, Engler+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Hempstead, Jenen, Kagan+ (CLEO Collab.) + Bilder, Harder+ (ARGUS Collab.) + Bartusation, Mestayer, Panvini+ (CLEO Collab.) + Hempstead, Jensen, Kagan+ (CLEO Collab.) + Goldberg, Horwitz, Jawahery+ (CLEO Collab.) + Goldberg, Horwitz, Jawahery+ (CLEO Collab.) + Goldberg, Horwitz, Jawahery+ (CLEO Collab.) + Sreedhar, Han, Imilay+ (CUSB Collab.) + Csorna, Garren, Mestayer+ (CLEO Collab.) + Hicks, Sannes, Skubic+ (CLEO Collab.) Klopfenstein, Horstkotte+ + Cabibbo, Corbo, Maini, Martinelli (ROMA, NIFN, FRAS)
ALAM ALBRECHT ALBRECHT BEAN BEHRENDS BORTOLETTC ALAM BALTRUSAIT. ALBRECHT CSORNA HAAS AVERY CHEN LEVMAN ALAM GREEN KLOPFEN ALTRELLI BRODY	87B 87D 87H 87 87 86 86 86 86 85 85 84 84 84 84 83B 83B 83B 83B 83B 83B	PRL 58 1814 PL 8199 451 PL 8199 451 PL 8187 425 PR 025 3333 PRL 59 407 PR 125 19 PR 125 19 PRL 56 2140 PRL 56 2781 PRL 56 2781 PRL 52 1248 PRL 53 1309 PRL 55 1248 PRL 53 1309 PRL 51 1347 PL 1308 444 NP 8208 365 PRL 131 347 PL 1308 444 NP 8208 365	+ Katayama, Kim, Sun+ (CLEO Collab.) + Andam, Binder, Boeckmann+ (ARGUS Collab.) + Binder, Boeckmann, Glaser+ (ARGUS Collab.) + Bobbink, Brock, Engler+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Katayama, Kim, Sun+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Hempstead, Jensen, Kagan+ (CLEO Collab.) + Binder, Harder+ (CLEO Collab.) + Bebek, Berkelman, Cassel+ (CLEO Collab.) + Goldberg, Horwitz, Jawahery+ (CLEO Collab.) + Sreedhar, Han, Imlay+ (CLEO Collab.) + Scorna, Garren, Mestayer+ (CLEO Collab.) + Klopfenstein, Horstkotte+ (CLEO Collab.)
ALAM ALBRECHT ALBRECHT BEAN BEHRENDS BORTOLETTC ALAM BALTRUSAIT. BORTOLETTC HAAS ALBRECHT CSORNA HAAS AVERY CHEN LEVMAN ALAM GREEN KLOPFEN ALTARELLI BRODY GJANNINI	87B 87D 87H 87 87 86 86 86 85 85 85 84 84 84 83 83 83 83 83 83 83 82 82	PRL 58 1814 PL 8199 451 PL 8187 425 PR 138 785 5333 PRL 59 407 PR 138 199 PR 138 199 PRL 56 2140 PRL 56 800 PRL 56 2781 PL 1628 395 PRL 52 1084 PRL 55 1248 PRL 55 1248 PRL 51 1143 PRL 51	+ Katayama, Kim, Sun+ (CLEO Collab.) + Andam, Binder, Boeckmann+ (ARGUS Collab.) + Bilnder, Boeckmann, Glaser+ (ARGUS Collab.) + Bobbink, Brock, Engler+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Hempstead, Jenen, Kagan+ (CLEO Collab.) + Goldberg, Horwitz, Jawahery+ (CLEO Collab.) + Goldberg, Horwitz, Jawahery+ (CLEO Collab.) + Grodhard, Han, Imilay+ (CUSB Collab.) + Kiopfenstein, Horstkotte+ (CLEO Collab.) Klopfenstein, Horstkotte+ (CLEO Collab.) + Cabbo, Corbo, Maini, Martinelli (ROMA, INFR.), FAAS + Chen, Goldberg, Horwitz+ (CLEO Collab.)
ALAM ALBRECHT ALBRECHT BEAN BEHRENDS BORTOLETTC ALAM BORTOLETTC HAAS ALBRECHT CSORNA HAAS AVERY CHEN LEVMAN ALAM GREEN KLOPFEN ALTRELLI BRODY GJANNINI BRODY GJANNINI BEBEK	87B 87D 87H 87 87 86 . 86E 86 86 85 85 84 84 84 83 83 83 83 83 83 83 83 83 83 83 83 83	PRL 58 1814 PL 8199 451 PL 8199 451 PL 8187 425 PR 035 3333 PRL 59 407 PR D35 19 PR D35 19 PR D36 2140 PRL 56 200 PRL 56 2781 PRL 56 2781 PRL 57 189 PRL 5	+ Katayama, Kim, Sun+ (CLEO Collab.) + Andam, Binder, Boeckmann+ (ARGUS Collab.) + Bilnder, Boeckmann, Glaser+ (ARGUS Collab.) + Bobbink, Brock, Engler+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Katayama, Kim, Sun+ (CLEO Collab.) + Katayama, Kim, Sun+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Hempstead, Jensen, Kagan+ (CLEO Collab.) + Binder, Harder+ (ARGUS Collab.) + Bebek, Berkelman, Cassel+ (CLEO Collab.) + Bebek, Berkelman, Cassel+ (CLEO Collab.) + Goldberg, Horwitz, Jawahery+ (CLEO Collab.) + Sorona, Garren, Mestayer+ (CLEO Collab.) + Klopfenstein, Horstoknown, Mestayer+ (CLEO Collab.) + Cabibbo, Coobo, Maini, Martinelli (ROMA, INFN, FRAS) + Chen, Goldberg, Horwitz+ (CUSB Collab.) + Cabibbo, Coldberg, Horwitz+ (CUSB Collab.)
ALAM ALBRECHT ALBRECHT BEAN BEHRENDS BORTOLETTC ALAM BALTRUSAIT. BORTOLETTC HAAS ALBRECHT CSORNA HAAS AVERY CHEN LEVMAN ALAM GREEN KLOPFEN ALTARELLI BRODY GJANNINI	87B 87D 87H 87 87 86 86 86 85 85 85 84 84 84 83 83 83 83 83 83 83 82 82	PRL 58 1814 PL 8199 451 PL 8187 425 PR 138 785 5333 PRL 59 407 PR 138 199 PR 138 199 PRL 56 2140 PRL 56 800 PRL 56 2781 PL 1628 395 PRL 52 1084 PRL 55 1248 PRL 55 1248 PRL 51 1143 PRL 51	+ Katayama, Kim, Sun+ (CLEO Collab.) + Andam, Binder, Boeckmann+ (ARGUS Collab.) + Bilnder, Boeckmann, Glaser+ (ARGUS Collab.) + Bobbink, Brock, Engler+ (CLEO Collab.) + Chen, Garren, Goldberg+ (CLEO Collab.) + Hempstead, Jenen, Kagan+ (CLEO Collab.) + Goldberg, Horwitz, Jawahery+ (CLEO Collab.) + Goldberg, Horwitz, Jawahery+ (CLEO Collab.) + Grodhard, Han, Imilay+ (CUSB Collab.) + Kiopfenstein, Horstkotte+ (CLEO Collab.) Klopfenstein, Horstkotte+ (CLEO Collab.) + Cabbo, Corbo, Maini, Martinelli (ROMA, INFR.), FAAS + Chen, Goldberg, Horwitz+ (CLEO Collab.)

$B^{\pm}/B^{0}/B_{s}^{0}/b$ -baryon ADMIXTURE

$B^{\pm}/B^{0}/B_{s}^{0}/b$ -baryon ADMIXTURE MEAN LIFE

These measurements of the B mean life are averages over bottom particles produced, weighted by their semileptonic branching ratios, unless otherwise stated. Only the measurements at high energy are averaged since it is expected that the admixtures of b hadrons from Z decay and 1.8 TeV $\rho \, \overline{\rho}$ collisions should should not differ significantly.

"OUR EVALUATION" is an average of the data listed below performed by the LEP B Lifetimes Working Group as described in our review "Production and Decay of b-flavored Hadrons" in the B^\pm Section of the Listings. The averaging procedure takes into account correlations between the measurements and asymmetric lifetime errors.

VALUE (10 ⁻¹² s)	EVTS	DOCUMENT ID	TECN	COMMENT
1.549±0.020 OUR E			12014	COMMENT.
$1.582 \pm 0.011 \pm 0.027$		¹ ABREU	96E DLPH	$e^+e^- \rightarrow Z$
$1.533 \pm 0.013 \pm 0.022$	19.8k	² BUSKULIC	96F ALEP	$e^+e^- \rightarrow Z$
$1.564 \pm 0.030 \pm 0.036$		³ ABE,K	95B SLD	$e^+e^- \rightarrow Z$
$1.542 \pm 0.021 \pm 0.045$		⁴ ABREU	94L DLPH	$e^+e^- \rightarrow Z$
$1.46 \pm 0.06 \pm 0.06$	5344	⁵ ABE	93J CDF	$p\overline{p}$ at 1.8 TeV
$1.523 \pm 0.034 \pm 0.038$	5372	⁶ ACTON	93L OPAL	
$1.535 \pm 0.035 \pm 0.028$	7357	⁶ ADRIANI	93K L3	$e^+e^- \rightarrow Z$
$1.511 \pm 0.022 \pm 0.078$		⁷ BUSKULIC	930 ALEP	
• • • We do not use	the follo			
$1.575 \pm 0.010 \pm 0.026$		⁸ ABREU	96E DLPH	$e^+e^- \rightarrow Z$
$1.50 \ ^{+0.24}_{-0.21} \ \pm 0.03$		⁹ ABREU	94P DLPH	$e^+e^- \rightarrow Z$
$1.23 \ ^{+0.14}_{-0.13} \ \pm 0.15$	188	¹⁰ ABREU	93D DLPH	Sup. by ABREU 94L
$1.49 \ \pm 0.11 \ \pm 0.12$	253	¹¹ ABREU	93G DLPH	Sup. by ABREU 94L
$1.51 \ ^{+0.16}_{-0.14} \ \pm 0.11$	130	¹² ACTON	93C OPAL	$e^+e^- \rightarrow Z$
1.28 ±0.10		¹³ ABREU	92 DLPH	Sup. by ABREU 94L
$1.37 \pm 0.07 \pm 0.06$	1354	¹⁴ ACTON	92 OPAL	Sup. by ACTON 93L
$1.49 \pm 0.03 \pm 0.06$		¹⁵ BUSKULIC	92F ALEP	Sup. by BUSKULIC 96F
$1.35 \ ^{+ 0.19}_{- 0.17} \ \pm 0.05$		¹⁶ BUSKULIC	92G ALEP	$e^+ e^- \rightarrow Z$
$1.32 \pm 0.08 \pm 0.09$	1386	¹⁷ ADEVA	91H L3	Sup. by ADRIANI 93K
$1.32 \ ^{+ 0.31}_{- 0.25} \ \pm 0.15$	37	¹⁸ ALEXANDER	91G OPAL	$e^+e^- \rightarrow Z$
$1.29 \pm 0.06 \pm 0.10$	2973	¹⁹ DECAMP	91c ALEP	Sup. by BUSKULIC 92F
$1.36 \begin{array}{l} +0.25 \\ -0.23 \end{array}$		²⁰ HAGEMANN	90 JADE	E ^{ee} _{cm} = 35 GeV
1.13 ±0.15		²¹ LYONS	90 RVUE	
$1.35 \pm 0.10 \pm 0.24$		BRAUNSCH	89B TASS	Ecm = 35 GeV
$0.98 \pm 0.12 \pm 0.13$		ONG	89 MRK2	E ^{ee} _{Cm} = 29 GeV
$1.17 \begin{array}{c} +0.27 \\ -0.22 \end{array} \begin{array}{c} +0.17 \\ -0.16 \end{array}$		KLEM	88 DLCO	E ^{ee} cm = 29 GeV
$1.29 \pm 0.20 \pm 0.21$		²² ASH	87 MAC	E ^{ee} _{cm} = 29 GeV
$1.02 \begin{array}{c} +0.42 \\ -0.39 \end{array}$	301	²³ BROM	87 HRS	E ^{ee} _{Cm} = 29 GeV
¹ Uses inclusively re	econstruct	ed secondary vertic	es.	

- Uses inclusively reconstructed secondary vertices.
 BUSKULIC 96F analyzed using 3D impact parameter.
- 3 ABE, K 95B uses an inclusive topological technique. ABREU 94L uses charged particle impact parameters. Their result from inclusively reconstructed secondary vertices is superseded by ABREU 96E. 5 ABE 93J analyzed using $J/\psi(1S) \rightarrow \mu\mu$ vertices.
- ACTON 931 and ADRIANI 934 analyzed using lepton (e and μ) impact parameter at Z. 7 BUSKULIC 930 analyzed using dipole method.
- $^\prime$ BUSKULIC 930 analyzed using dipole method. 8 Combines ABREU 96E secondary vertex result with ABREU 94L impact parameter result. 9 From proper time distribution of $b \rightarrow J/\psi(15)$ anything. 10 ABREU 93D data analyzed using $D/D^*\ell$ anything event vertices. 11 ABREU 93C data analyzed using charged and neutral vertices.

- 12 ACTON 93c analysed using D/D^+ (anything event vertices.)
 13 ABREU 92 is combined result of muon and hadron impact parameter analyses. Hadron tracks gave $(12.7 \pm 0.4 \pm 1.2) \times 10^{-13}$ s for an admixture of B species weighted by production fraction and mean charge multiplicity, while muon tracks gave $(13.0\pm 1.0\pm 0.8)\times$ $10^{-13}\,\mathrm{s}$ for an admixture weighted by production fraction and semileptonic branching
- $14\frac{\text{Taction.}}{\text{ACTON}}$ 92 is combined result of muon and electron impact parameter analyses. 15 BUSKULIC 92F uses the lepton impact parameter distribution for data from the 1991
- 16 Fun.

 16 BUSKULIC 92G use $J/\psi(1S)$ tags to measure the average b lifetime. This is comparable to other methods only if the $J/\psi(1S)$ branching fractions of the different b-flavored hadrons are in the same ratio.

 17 hadrons are in the same ratio.

 18 listing $2\pi \to e^+ X$ or $\mu^+ X$, ADEVA 91H determined the average lifetime for an admixture of B hadrons from the impact parameter distribution of the lepton.
- of B nations from the impact parameter distribution of the exponential B using $Z \to J/\psi(1S)X, J/\psi(1S) \to \ell^+\ell^-$, ALEXANDER 91G determined the average lifetime for an admixture of B hadrons from the decay point of the $J/\psi(1S)$.
- 21 LYONS 90 combine the results of the B lifetime measuresments of ONG 89, BRAUN-SCHWEIG 898, KLEM 88, and ASH 87, and JADE data by private communication. They use statistical techniques which include variation of the error with the mean life. and possible correlations between the systematic errors. This result is not independent of the measured results used in our average.

 22 We have combined an overall scale error of 15% in quadrature with the systematic error
- of \pm 0.7 to obtain \pm 2.1 systematic error. ²³ Statistical and systematic errors were combined by BROM 87.

CHARGED b-HADRON ADMIXTURE MEAN LIFE

VALUE (10 ⁻¹² s)	DOCUMENT IL)	TECN	COMMENT
$1.72 \pm 0.08 \pm 0.06$	²⁴ ADAM	95	DLPH	$e^+e^- \rightarrow Z$
²⁴ ADAM 95 data analyzed us	sing vertex-charge t	echniq	ue to tag	g <i>b</i> -hadron charge.

NEUTRAL b-HADRON ADMIXTURE MEAN LIFE

VALUE (10 ⁻¹² s)	DOCUMENT ID		TECN	COMMENT	
1.58±0.11±0.09	25 ADAM	95	DLPH	$e^+e^- \rightarrow$	Z
.25 ADAM 95 data analyzed usi	ng vertex-charge te	chniq	ue to tag	b-hadron o	harge.

MEAN LIFE RATIO $au_{ ext{charged }b- ext{hadron}}/ au_{ ext{neutral }b- ext{hadron}}$

VALUE	DOCUMENT ID	TECN	COMMENT	_
$1.09^{+0.11}_{-0.10}\pm0.08$	²⁶ ADAM	95 DLPH	$e^+e^- \rightarrow Z$	ı

$^{26}\,\mathrm{ADAM}$ 95 data analyzed using vertex-charge technique to tag b-hadron charge.

b PRODUCTION FRACTIONS AND DECAY MODES

The branching fraction measurements are for an admixture of B mesons and baryons at energies above the $\Upsilon(4S)$. Only the highest energy results (LEP, Tevatron, $Sp\overline{p}S$) are used in the branching fraction averages. The production fractions give our best current estimate of the admixture at

For inclusive branching fractions, e.g., $B \to D^\pm$ anything, the treatment of multiple D's in the final state must be defined. One possibilty would be to count the number of events with one-or-more D's and divide by the total number of B's. Another possibility would be to count the total number of D's and divide by the total number of B's, which is the definition of average multiplicity. The two definitions are identical when only one of the specified particles is allowed in the final state. Even though the "one-or-more" definition seems sensible, for practical reasons inclusive branching fractions are almost always measured using the multiplicity definition. For heavy final state particles, authors call their results inclusive branching fractions while for light particles some authors call their results multiplicities. In the B sections, we list all results as inclusive branching fractions, adopting a multiplicity definition. This means that inclusive branching fractions can exceed 100% and that inclusive partial widths can exceed total widths, just as inclusive cross sections can exceed total cross sections.

The modes below are listed for a \overline{b} initial state. b modes are their charge conjugates. Reactions indicate the weak decay vertex and do not include

Mode Fraction (Γ_i/Γ)

PRODUCTION FRACTIONS

The production fractions for weakly decaying b-hadrons at the Z have been calculated from the best values of mean lives, mixing parameters, and branching fractions in this edition by O. Hayes (CERN) and M. Jimack (U. Birmingham) as described in the note "Production and Decay of b-Flavored Hadrons" in the B^\pm Particle Listings. Values assume

$$\begin{array}{ll} B(\overline{b} \to B^+) = B(\overline{b} \to B^0) \\ B(\overline{b} \to B^+) + B(\overline{b} \to B^0) + B(\overline{b} \to B^0_S) + B(b \to \Lambda_b) = 100 \text{ \%}. \end{array}$$

The notation for production fractions varies in the literature (f_{B^0}, f(b \rightarrow $\overline{B}{}^0$), Br($b \to \overline{B}{}^0$)). We use our own branching fraction notation here, $B(\overline{b} \rightarrow B^0).$

	$\overline{\underline{b}} \rightarrow B^+$	(37.8 ± 2.2) %
Γ_2	$\overline{b} \rightarrow B^0$	(37.8 ± 2.2) %
Γ3	$\overline{b} \rightarrow B_s^0$	(11.2 + 1.8 - 1.9)%
Ги	$b \rightarrow \Lambda_b$	(132 + 41)%

DECAY MODES

Camellantania and lantania was de-

	Semileptonic and	i iepto	nic modes
Γ ₅	$\overline{b} ightarrow e^+ u_e$ anything	[a]	(11.1 ± 1.0) %
Γ_6	$\overline{b} ightarrow \ \mu^+ u_{\mu}$ anything	[a]	(10.7 \pm 0.7) %
Γ_7	$\overline{b} ightarrow \ell^+ u_\ell$ anything	[a,b]	(11.13 ± 0.29) %
Γ8	$\overline{b} ightarrow D^- \ell^+ u_\ell$ anything	[b]	(2.01 ± 0.29) %
Γ_9	$\overline{b} ightarrow \; \overline{D}{}^0 \ell^+ u_\ell$ anything	[b]	$(6.6 \pm 0.6)\%$
Γ_{10}	$\overline{b} ightarrow \ D^{*-} \ell^+ u_\ell$ anything	[b]	(2.76 ± 0.29) %
Γ_{11}	$\overline{b} ightarrow \; \overline{D}^0_i \ell^+ u_\ell$ anything	[b,c]	seen
Γ_{12}	$\overline{b} ightarrow D_i^- \ell^+ u_\ell$ anything	[b,c]	seen
Γ_{13}	$\overline{b} ightarrow \ \overline{D}_2^* (2460)^0 \ell^+ u_\ell {\sf any}$ -		seen
	thing		
Γ_{14}	$\overline{b} ightarrow ~D_2^*(2460)^-\ell^+ u_\ell$ any-		seen
	thing		
Γ_{15}	$\overline{b} ightarrow ~ au^+ u_ au$ anything		(2.7 ± 0.4)%
Γ_{16}	$\overline{b} \rightarrow \overline{b} \rightarrow \overline{c} \rightarrow \ell^- \overline{\nu}_\ell$ anything	[b]	$(7.9 \pm 0.8)\%$

$\overline{b} \rightarrow J/\psi(1S)$ anything Γ_{17} $1.16 \pm 0.10) \%$ $\overline{b} ightarrow \psi(2S)$ anything ($4.8~\pm~2.4$) $\times\,10^{-3}$ $\overline{b} \rightarrow \chi_{c1}(1P)$ anything (1.8 ± 0.5)% K or K* modes $\frac{\overline{b}}{\overline{b}} \rightarrow \overline{s}\gamma$ $\underline{b} \rightarrow K^{\pm} \text{ anything }$ $\times 10^{-3}$ 1.2 90% (88 ±19)% $\frac{\overline{b}}{\overline{b}} \rightarrow K_S^0$ anything (29.0 ± 2.9) % Baryon modes Γ_{23} $\overline{b} \rightarrow p/\overline{p}$ anything $(14 \pm 6)\%$ $\overline{b} \rightarrow \Lambda/\overline{\Lambda}$ anything $(5.9 \pm 1.1)\%$ Other modes $\overline{b} \rightarrow \text{charged anything}$ [d] (584 ±40)%

Charmonium modes

$\Delta B=1$ weak neutral current (B1) modes

1 26	$b \rightarrow$	e⊤e⁻anything	B1				
Γ_{27}	$\overline{b} \rightarrow$	$\mu^+\mu^-$ anything	B1	<	5.0	× 10 ⁻⁵	90%
Γ ₂₈	$\overline{b} \rightarrow$	$ u \overline{ u}$ anything	B1	<	3.9	× 10 ⁻⁴	

- [a] These values are model dependent. See 'Note on Semileptonic Decays' in the B⁺ Particle Listings.
- [b] ℓ indicates e or μ mode, not sum over modes.
- [c] D_i represents an unresolved mixture of pseudoscalar and tensor D^{**} (Pwave) states.
- [d] Inclusive branching fractions have a multiplicity definition and can be greater than 100%.

B±/B⁰/B_s0/b-baryon ADMIXTURE BRANCHING RATIOS

 $\Gamma(\ell^+ \nu_\ell \text{ anything})/\Gamma_{\text{total}}$ These branching fraction values are model dependent. See the note on "Semileptonic of the ℓ^+ Posticle Listings Decays of D and B Mesons, Part II" at the beginning of the B^+ Particle Listings.

VALUE	DOCUMENT ID	TECN	COMMENT	
0.1113±0.0029 OUR AVERAGE	Includes data from	n the 2 data	blocks that follow t	his
	one.			
$0.1106 \pm 0.0039 \pm 0.0022$	²⁷ ABREU	95D DLPH	$e^+e^- \rightarrow Z$	
$0.114 \pm 0.003 \pm 0.004$	²⁸ BUSKULIC	94G ALEP	$e^+e^- \rightarrow Z$	
27				

- 27 ABREU 95D give systematic errors ± 0.0019 (model) and 0.0012 (R_{c}). We combine
- these in quadrature. 28 BUSKULIC 94G uses e and μ events. This value is from a global fit to the lepton ρ and $\rho_{\mathcal{T}}$ (relative to jet) spectra which also determines the b and c production fractions, the fragmentation functions, and the forward-backward asymmetries. This branching ratio depends primarily on the ratio of dileptons to single leptons at high $\rho_{\mathcal{T}}$, but the lower $\rho_{\mathcal{T}}$ portion of the lepton spectrum is included in the global fit to reduce the model dependence. The model dependence is ± 0.0026 and is included in the systematic error.

$\Gamma(e^+\nu_e \text{ anything})/\Gamma_{\text{total}}$

These branching fraction values are model dependent. See the note on "Semileptonic Decays of D and B Mesons, Part II" at the beginning of the B^+ Particle Listings.

026 DI DII +++-

<u>VALUE</u> <u>EVTS</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u>
The data in this block is included in the average printed for a previous datablock. 0.111 ± 0.010 OUR AVERAGE

$0.107 \pm 0.015 \pm 0.00$	07 260	-, ABKEO	93C DLPH	$e \mid e \rightarrow Z$
$0.109^{+0.014}_{-0.013}\pm0.00$	055 2719	³⁰ AKERS	938 OPAL	$e^+ e^- \rightarrow Z$
$0.138 \pm 0.032 \pm 0.00$	08	³¹ ADEVA	91c L3	$e^+e^- \rightarrow Z$
• • • We do not ι	use the followin	ng data for averag	es, fits, limits,	etc. • • •
$0.086 \pm 0.027 \pm 0.00$	08	32 ABE	93E VNS	$E_{cm}^{ee} = 58 \; GeV$
$0.111 \pm 0.028 \pm 0.02$	26	BEHREND	90D CELL	$E_{cm}^{ee} = 43 \; GeV$
$0.150 \pm 0.011 \pm 0.02$	22	BEHREND	90D CELL	E_{cm}^{ee} = 35 GeV
$0.112 \pm 0.009 \pm 0.03$	11	ONG	88 MRK2	$E_{CM}^{\mathit{ee}} = 29 \; GeV$
$0.149 ^{+ 0.022}_{- 0.019}$		PAL	86 DLCO	$E_{cm}^{\mathit{ee}} = 29 \; GeV$
$0.110 \pm 0.018 \pm 0.03$	10	AIHARA	85 TPC	E_{cm}^{ee} = 29 GeV
$0.111 \pm 0.034 \pm 0.04$	40	ALTHOFF	84J TASS	$E_{cm}^{ee} = 34.6 \text{ GeV}$
0.146 ± 0.028		KOOP	84 DLCO	Repl. by PAL 86
$0.116 \pm 0.021 \pm 0.01$	17	NELSON	83 MRK2	$F_{\rm em}^{ee} = 29 \text{ GeV}$

29 ADDELL

- Ečm $^{29} {\sf ABREU}$ 93C event count includes ee events. Combining $ee,~\mu\mu,$ and $e\mu$ events, they
- obtain 0.100 \pm 0.007 \pm 0.007. 30 AKERS 93B analysis performed using single and dilepton events.
- 30 AKERS 93B analysis performed using single and dilepton events.
 31 ADEVA 91c measure the average B(b → eX) branching ratio using single and double tagged b enhanced Z events. Combining e and μ results, they obtain 0.113 ± 0.010 ± 0.006. Constraining the initial number of b quarks by the Standard Model prediction (378 ± 3 MeV) for the decay of the Z into b̄D, the electron result gives 0.112 ± 0.004 ± 0.008. They obtain 0.119 ± 0.003 ± 0.006 when e and μ results are combined. Used to measure the b̄D width itself, this electron result gives 370 ± 12 ± 24 MeV and combined with the muon result gives 385 ± 7 ± 22 MeV.
 32 ADE 0.22 experiment also measures forward-backward asymmetries and fragmentation.
- 32 ABE 93E experiment also measures forward-backward asymmetries and fragmentation functions for b and c.

$B^{\pm}/B^0/B_s^0/b$ -baryon ADMIXTURE

95 ALEP $e^+e^- \rightarrow Z$ 94c L3 $e^+e^- \rightarrow Z$ 198es, fits, limits, etc. • • • 93B ALEP Repl. by BUSKULIC 95 10 at the Z , but species are not separated. 10 TECN COMMENT 95D DLPH $e^+e^- \rightarrow Z$ 946 ALEP $e^+e^- \rightarrow Z$
93B ALEP Repl. by BUSKULIC 95. at the Z , but species are not separated.
at the Z , but species are not separated.
at the Z , but species are not separated.
$\Gamma_{16}/$
$\frac{D}{D} \qquad \frac{TECN}{COMMENT}$ 95D DLPH $e^+e^- \rightarrow Z$
950 DLPH $e^+e^- \rightarrow Z$
94G ALEP $e^+e^- \rightarrow Z$
(model) and 0.0032 (R_C). We combi
same global fit as their $\Gamma(\overline{b} \rightarrow \ell^+ \nu_{\ell})$
value is from the same global fit as the
ratue is from the same global nt as the
F
F ₁₇ /
NI ID TECN COMMENT
94P DLPH $e^+e^- \rightarrow Z$
NI 93J L3 $e^+e^- o Z$ ILIC 92G ALEP $e^+e^- o Z$
ges, fits, limits, etc. • •
NI 92 L3 $e^+e^- \rightarrow Z$
EUZZI 83 MRK2 E ^{ee} _{CM} = 29 GeV
m b decays at the Z. Uses $J/\psi(1S)$
$b\overline{b}/\Gamma_{hadron}=0.22$. om b decays at the Z . Uses $J/\psi(1S)$ -
It for B($Z ightarrow J/\psi(1S)$ X) = (4.1 \pm 0.7 dron contribution to $J/\psi(1S)$ productio
Γ ₁₈ /
94P DLPH $e^+e^- \rightarrow Z$
els. Assumes $\Gamma(Z \to b\overline{b})/\Gamma_{\text{hadron}} = 0.22$ Γ_{19}/Γ_{19} D
94P DLPH $e^+e^- \rightarrow Z$
93J L3 $e^+e^- \rightarrow Z$
m b decays at the Z. Uses $\chi_{c1}(1P)$. Assumes no $\chi_{c2}(1P)$ and $\Gamma(Z)$ d assumes χ_{c1} come from b decays at
) Γ ₁₉ /Γ ₁
D TECN COMMENT
ges, fits, limits, etc. $ullet$ $ullet$ $e^+e^- o Z$
93J L3 $e^+e^- \rightarrow Z$
ematics cancel.
ematics cancel. Г 20/
Practics cancel. F20/ D TECN COMMENT
ematics cancel. $$\Gamma_{20}/$$ $$D = TECN = COMMENT$$ $$93L L3 = e^+e^- \rightarrow Z$$
rematics cancel.
Prematics cancel. $\Gamma_{20}/\Gamma_{$
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
ematics cancel.
ematics cancel.
Prematics cancel.
ematics cancel.
Prematics cancel.

Γ(charged anythi	ng)/i total					25/1
VALUE		DOCUMENT ID				
5.84±0.04±0.38		ABREU	95C	DLPH	$e^+e^- \rightarrow Z$	
$\Gamma(\mu^+\mu^-$ anything Test for $\Delta B = 0$		tral current.				Γ ₂₇ /Ι
VALUE	CL%	DOCUMENT ID		TECN	COMMENT	
<5.0 × 10 ⁻⁵	90	ALBAJAR	910	UA1	$E_{\rm cm}^{p\overline{p}} = 630 \text{ GeV}$	
• • We do not us	se the followin	ng data for averag	es, fits	, limits,	etc. • • •	
< 0.02	95	ALTHOFF	84G	TASS	Eee = 34.5 GeV	
		ADEVA	83	MRKJ	$E_{cm}^{ee} = 30-38 \text{ Ge}$	V
< 0.007	95	ADEVA				
<0.007	95	BARTEL	83B	JADE	Eee = 33-37 Ge	٧
<0.007 $\Gamma(e^+e^- \text{ anythin} \\ \text{Test for } \Delta B = 0$	$_{95}$ $g) + \Gamma(\mu^+)$	BARTEL μ^- anything)]/	838 F _{total}	JADE	$E_{\rm CM}^{ee} = 33-37 \text{ Ge}$	٧
<0.007 $\Gamma(e^+e^-\text{ anythin}$ Test for $\Delta B = \frac{ALUE}{ALUE}$	95 g) + Γ(μ + μ = 1 weak neut	BARTEL # anything)]/ tral current. DOCUMENT ID	838 F _{total}	JADE <u>TECN</u>	E ^{ee} _{cm} = 33-37 Ge (Γ ₂₆ +	٧
<0.007 $[\Gamma(e^+e^-\text{ anythin} \text{ Test for } \Delta B = \frac{ALUE}{2}$	95 g) + Γ(μ + μ = 1 weak neut	BARTEL	83B F _{total} es, fits	JADE TECN i, limits,	E ^{ee} _{cm} = 33-37 Ge (Γ ₂₆ +	٧
VALUE • • • We do not us <0.008	95 g) + Γ(μ+) = 1 weak neut	BARTEL	R3B Ttotal es, fits 83	JADE <u>TECN</u> 5, limits, MRK2	$E_{\text{cm}}^{ee} = 33-37 \text{ Ge}$ $(\Gamma_{26} + \frac{COMMENT}{\text{etc.} \bullet \bullet \bullet}$ $E_{\text{cm}}^{ee} = 29 \text{ GeV}$	∨ Γ ₂₇)/
(0.007) $ \begin{bmatrix} \Gamma(e^+e^- \text{ anythin}) \\ \text{Test for } \Delta B = 0 \\ \text{ALUE} \end{bmatrix} $ • • • We do not us (0.008) $ \frac{\Gamma(\nu \text{ anything})}{\text{Test for } \Delta B = 0 \\ \text{ALUE} $	95 g) + Γ(μ+) = 1 weak neut	BARTEL	F _{total}	JADE TECN i, limits, MRK2	$E_{\text{cm}}^{\text{ge}} = 33-37 \text{ Ge}$ $(\Gamma_{26} + \frac{COMMENT}{\text{etc.} \bullet \bullet \bullet}$ $E_{\text{cm}}^{\text{ge}} = 29 \text{ GeV}$ $COMMENT$	∨ Γ ₂₇)/
(0.007) $ \begin{bmatrix} \Gamma(e^+e^- \text{ anythin}) \\ \text{Test for } \Delta B = 0 \\ \text{ALUE} \end{bmatrix} $ • • • We do not us (0.008) $ \frac{\Gamma(\nu \text{ anything})}{\text{Test for } \Delta B = 0 \\ \text{ALUE} $	95 g) + Γ(μ+) = 1 weak neut	BARTEL	F _{total}	JADE TECN i, limits, MRK2	$E_{\text{cm}}^{\text{ge}} = 33-37 \text{ Ge}$ $(\Gamma_{26} + \frac{COMMENT}{\text{etc.} \bullet \bullet \bullet}$ $E_{\text{cm}}^{\text{ge}} = 29 \text{ GeV}$ $COMMENT$	٧
<0.007 $ \Gamma(e^+e^-\text{ anythin } \text{ Test for } \Delta B = \frac{ALUE}{2} $ • • We do not us <0.008 $ (\nu \overline{\nu} \text{ anything})/\Gamma $	g) + Γ(μ ⁺) 1 weak neur Ct% 10 total 1 weak neur	BARTEL	Ftotal es, fits	JADE TECN MRK2 TECN RVUE	$E_{\rm cm}^{ee} = 33-37 { m Ge}$ $ (\Gamma_{26} + \frac{COMMENT}{{ m etc.} \bullet \bullet \bullet} $ $ E_{\rm cm}^{ee} = 29 { m GeV} $ $ \frac{COMMENT}{{ m e}^+ { m e}^- \to Z} $	∨ Γ ₂₇)/ Γ ₂₈ /

$B^{\pm}/B^{0}/B_{s}^{0}/b$ -baryon ADMIXTURE REFERENCES

ABREU	96E	PL B377 195	+Adam, Adye, Agasi+	(DELPHI Collab.)
BUSKULIC	96F	PL B369 151	+Casper, De Bonis, Decamp+	(ALEPH Collab.)
GROSSMAN	96	NP B465 369	+Ligeti, Nardi	(REHO, CIT)
ABE.K	95B	PRL 75 3624	Abe, Abt, Ahn, Akagi+	(SLD Collab.)
ABREU	95C	PL B347 447	+Adam, Adye, Agasi+	(DELPHI Collab.)
ABREU	95D	ZPHY C66 323	+Adam, Adye, Agasi+	(DELPHI Collab.)
ADAM	95	ZPHY C68 363	+Adye, Agasi, Ajinenko+	(DELPHI Collab.)
AKERS	95Q	ZPHY C67 57	+Alexander, Allison, Ametewee	
BUSKULIC	95	PL B343 444	+Casper, De Bonis, Decamp, C	
ABREU	94L	ZPHY C63 3	+Adam, Adye, Agasi, Aleksan+	
ABREU	94P	PL B341 109	+Adam, Adye, Agasi, Ajinenko-	
ACCIARRI	94C	PL B332 201	+Adam, Adriani, Aguilar-Benite	
BUSKULIC	94G	ZPHY C62 179	+Casper, De Bonis, Decamp, C	
ABE	93E	PL B313 288	+Amako, Arai, Arima, Asano+	(VENUS Collab.)
ABE	93 J	PRL 71 3421	+Albrow, Amidei, Anway-Wiese	+ (CDF Collab.)
ABREU	93C	PL B301 145	+Adam, Adye, Agasi, Aleksan+	(DELPHI Collab.)
ABREU	93D	ZPHY C57 181	+Adam, Adye, Agasi, Alekseev-	+ (DELPHI Collab.)
ABREU	93G	PL B312 253	+Adam, Adye, Agasi, Ajinenko-	
ACTON	93C	PL B307 247	+Alexander, Allison, Allport, Ar	
ACTON	93L	ZPHY C60 217	+Akers, Alexander, Allison, And	
ADRIANI	93 J	PL B317 467	+Aguilar-Benitez, Ahlen, Alcara	
ADRIANI	93K	PL B317 474	+Aguilar-Benitez, Ahlen, Alcare	
ADRIANI	931	PL B317 637	+Aguilar-Benitez, Ahlen, Alcara	
AKERS	93B	ZPHY C60 199	+Alexander, Allison, Anderson,	
	93B	PL B298 479		
BUSKULIC			+Decamp, Goy, Lees, Minard+	(ALEPH Collab.)
BUSKULIC	930	PL B314 459	+De Bonis, Decamp, Ghez, Go	
ABREU	92	ZPHY C53 567	+Adam, Adami, Adye+	(DELPHI Collab.)
ACTON	92	PL B274 513	+Alexander, Allison, Allport, Ar	
ADRIANI	92	PL B288 412	+Aguilar-Benitez, Ahlen, Akbari	
BUSKULIC	92F	PL B295 174	+Decamp, Goy, Lees, Minard+	(ALEPH Collab.)
BUSKULIC	92G	PL B295 396	+Decamp, Goy, Lees, Minard+	(ALEPH Collab.)
ADEVA	91C	PL B261 177	+Adriani, Aguilar-Benitez, Akba	ri+ (L3 Collab.)
ADEVA	91H	PL B270 111	+Adrani, Aguilar-Benitez, Akbar	i, Alcaraz+ (L3 Collab.)
ALBAJAR	91 C	PL B262 163	+Albrow, Allkofer, Ankoviak, A	psimon+ (UA1 Collab.)
ALEXANDER	91 G	PL B266 485	+Allison, Allport+	(ÒPAL Collab.)
DECAMP	91C	PL B257 492	+Deschizeaux, Goy, Lees, Minar	
BEHREND	90D	ZPHY C47 333	+Criegee, Field, Franke, Jung+	(CELLO Collab.)
HAGEMANN	90	ZPHY C48 401	+Ramcke, Allison, Ambrus, Bar	
LYONS	90	PR D41 982	+Martin, Saxon	(OXF, BRIS, RAL)
BRAUNSCH	89B	ZPHY C44 1	Braunschweig, Gerhards, Kirsc	
ONG	89	PRL 62 1236	+Jaros, Abrams, Amidei, Baden	
KLEM	88	PR D37 41	+Atwood, Barish+	
	88			(DELCO Collab.)
ONG		PRL 60 2587	+Weir, Abrams, Amidei+	(Mark II Collab.)
ASH	87	PRL 58 640	+Band, Bloom, Bosman+	(MAC Collab.)
BARTEL	87	ZPHY C33 339	+Becker, Felst, Haidt+	(JADE Collab.)
BROM	87	PL B195 301	+Abachi, Akerlof, Baringer+	(HRS Collab.)
PAL	86	PR D33 2708	+Atwood, Barish, Bonneaud+	(DELCO Collab.)
AIHARA	85	ZPHY C27 39	+Alston-Garnjost, Badtke, Bakk	
BARTEL	85 J	PL 163B 277	+Becker, Cords, Felst+	(JADE Collab.)
ALTHOFF	84G	ZPHY C22 219	+Braunschweig, Kirschfink+	(TASSO Collab.)
ALTHOFF	84 J	PL 146B 443	+Branschweig, Kirschfink+	(TASSO Collab.)
KOOP	84	PRL 52 970	+Sakuda, Atwood, Baillon+	(DELCO Collab.)
ADEVA	83	PRL 50 799	+Barber, Becker, Berdugo+	(Mark-J Collab.)
ADEVA	83B	PRL 51 443	+Barber, Becker, Berdugo+	(Mark-J Collab.)
BARTEL	83B	PL 132B 241	+Becker, Bowdery, Cords+	(JADE Collab.)
FERNANDEZ	83D	PRL 50 2054	+Ford, Read, Smith+	(MAC Collab.)
MATTEUZZI	83	PL 129B 141	+Abrams, Amidei, Blocker+	(Mark II Collab.)
NELSON	83	PRL 50 1542	+Blondel, Trilling, Abrams+	(Mark II Collab.)
THE ESTIMATE	-53	1 N.C 30 1342	rolonder, rinning, Abrams+	(IMAIN II COIIAD.)



$$I(J^P) = \frac{1}{2}(1^-)$$

I, J, P need confirmation. Quantum numbers shown are quarkmodel predictions.

B* MASS

From mass difference below and the average of our B masses $(m_{B^{\pm}} + m_{B^0})/2$.

VALUE (MeV) 5324.8±1.8 OUR FIT

DOCUMENT ID

		m _{B*} - m _E	3		
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
45.7±0.4 OUR FIT					
45.7±0.4 OUR AVE	RAGE				
$45.3 \pm 0.35 \pm 0.87$	4227	¹ BUSKULIC	96D	ALEP	Eee = 88-94 GeV
45.5±0.3 ±0.8		¹ ABREU	95R	DLPH	E ^{ee} _{cm} = 88–94 GeV
46.3±1.9	1378	¹ ACCIARRI	95B	L3	Eee = 88-94 GeV
46.4±0.3 ±0.8		² AKERIB	91	CLE2	$e^+e^- \rightarrow \gamma X$
45.6 ± 0.8					$e^+e^- \rightarrow \gamma X, \gamma \ell X$
45.4 ± 1.0		³ LEE-FRANZIN	1190	CSB2	$e^+e^- \rightarrow \gamma(5S)$
 • • We do not use 	the followi	ng data for average	s, fits	, limits,	etc. • • •
52 ±2 ±4	1400	⁴ HAN	85	CUSB	$e^+e^- \rightarrow \gamma e X$
					·

VALUE (MeV)

<6

 $1_{\,U,\ d,\ S}$ flavor averaged. 2 These papers report E_{γ} in the B^* center of mass. The $m_{B^*}-m_B$ is 0.2 MeV higher.

 B_s B_s separate the above value.

⁴ HAN 85 is for $E_{\rm cm}=$ 10.6–11.2 GeV, giving an admixture of B^0 , B^+ , and $B_{\rm S}$.

$|(m_{B^{*+}}-m_{B^+})-(m_{B^{*0}}-m_{B^0})|$ DOCUMENT ID TECN COMMENT CL%

ABREU 95R DLPH $E_{ m CM}^{\it ee}=$ 88–94 GeV

B* DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ ₁	Вγ	dominant

B* REFERENCES

BUSKULIC	96D	ZPHY C69 393	+Casper, De Bonis, Decamp+	(ALEPH	Collab.)
ABREU	95R	ZPHY C68 353	+Adam, Adye, Agasi+	(DELPHI	Collab.)
ACCIARRI	95B	PL B345 589	+Adam, Adriani, Aguilar-Benitez+	(L3	Collab.)
AKERIB	91	PRL 67 1692	+Barish, Cown, Eigen, Stroynowski+	(CLÈO	Collab.)
WU	91	PL B273 177		(CUSB II	
EE-FRANZINI	90	PRL 65 2947	+Heintz, Lovelock, Narain, Schamberger+	(CUSB II	Collab.)
HAN	85	PRL 55 36	+Klopfenstein, Mageras+ (COLU, LS	Ü, MPIM,	STON)

 B^* , $B_J^*(5732)$

$B_J^*(5732)$

$$I(J^P) = ?(?^?)$$

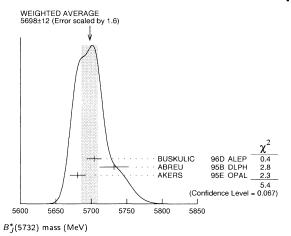
I, J, P need confirmation.

OMITTED FROM SUMMARY TABLE

Signal can be interpreted as stemming from several narrow and broad resonances. Needs confirmation.

B*_J(5732) MASS

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
5698±12 OUR A	VERAGE Error	includes scale fac	tor of 1.6. S	ee the ideogram below.
5704 ± 4 ± 10	1944	¹ BUSKULIC	96D ALEP	Ecm= 88-94 GeV
$5732 \pm 5 \pm 20$	2157	ABREU	95B DLPH	Ecm= 88-94 GeV
5681 ± 11	1738	AKERS	95E OPAL	Ecm= 88-94 GeV
1 Using $m_{B\pi}$ –	$-m_B = 424 \pm 4$	± 10 MeV.		



$B_J^*(5732)$ WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
128±18 OUR AV	ERAGE			
145 ± 28	2157	ABREU	95B DLPH	Ecm = 88-94 GeV
116 ± 24	1738	AKERS	95E OPAL	Ecm = 88-94 GeV

$B_J^*(5732)$ DECAY MODES

	Mode	Fraction (Γ_j/Γ)				
Γ ₁	$B^*\pi + B\pi$	dominant				
B*(5732) REFERENCES						

+Casper, De Bonis, Decamp+

(ALEPH Collab.) (DELPHI Collab.) (OPAL Collab.)

96D ZPHY C69 393 95B PL B345 598 95E ZPHY C66 19

BOTTOM, STRANGE MESONS $(B = \pm 1, S = \mp 1)$

 $B_s^0 = s\overline{b}, \overline{B}_s^0 = \overline{s}b,$ similarly for B_s^* 's

 B_s^0

$$I(J^P) = 0(0^-)$$

I, J, P need confirmation. Quantum numbers shown are quarkmodel predictions.

BO MASS

The fit uses m_{B^+} , $(m_{B^0} - m_{B^+})$, $m_{B^0_c}$, and $(m_{B^0_c} - (m_{B^+} + m_{B^0})/2)$ to determine m_{B^+} , m_{B^0} , $m_{B_c^0}$, and the mass differences.

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
5369.3 ± 2.0 OUR FIT				
5369.6 ± 2.4 OUR AVE	RAGE			
$5369.9 \pm\ 2.3 \pm 1.3$	32	¹ ABE	96B CDF	$p\overline{p}$ at 1.8 TeV
5374 ±16 ±2	3	ABREU	94D DLPH	$e^+e^- \rightarrow Z$
5359 ±19 ±7	1	¹ AKERS	94J OPAL	$e^+e^- \rightarrow Z$
5368.6 ± 5.6 ± 1.5	2	BUSKULIC	93G ALEP	$e^+e^- \rightarrow Z$
• • We do not use the	e following	data for averages,	fits, limits, et	C. • • •
5370 ±40	6	² AKERS	94J OPAL	$e^+e^- \rightarrow Z$
$5383.3 \pm 4.5 \pm 5.0$	14	ABE	93F CDF	Repl by ABE 96B
1 From the decay B_{s} -	$\rightarrow J/\psi(1S)$	ϕ .		
1 From the decay B_{s} - 2 From the decay B_{s} -	$\rightarrow D_c^- \pi^+$			

$m_{B_s^0} - m_B$

 m_B is the average of our B masses $(m_{B^\pm}+m_{B^0})/2$. The fits uses m_{B^+} , $(m_{B^0}-m_{B^+})$, $m_{B^0_s}$, and $m_{B^0_s}-m_B$ to determine m_{B^+} , m_{B^0} , $m_{B^0_s}$ and the mass differences.

	CL%	DOCUMENT ID		TECN	COMMENT	
90.2±2.2 OUR FIT 89.7±2.7±1.2		ABE	96B	CDF	p p at 1.8	TeV
• • We do not use the	following d	ata for averages	, fits	limits,	etc. • • •	
80 to 130	68	LEE-FRANZINI	90	CSB2	$e^+e^- \rightarrow$	$\Upsilon(5S)$

$m_{B_{\xi H}^0} - m_{B_{\xi I}^0}$

See the $B_s^0 - \overline{B}_s^0$ MIXING section near the end of these B_s^0 Listings.

BO MEAN LIFE

"OUR EVALUATION" is an average of the data listed below performed by the LEP ${\cal B}$ Lifetimes Working Group as described in our review "Production and Decay of b-flavored Hadrons" in the ${\cal B}^\pm$ Section of the Listings. The averaging procedure takes

VALUE (10 ⁻¹² s)	EVTS	DOCUMENT ID	TECN	COMMENT
$1.61^{+0.10}_{-0.09}$ our eva	LUATION			
$1.56 + 0.29 + 0.08 \\ -0.26 - 0.07$		³ ABREU	96F DLPH	$e^+e^- \rightarrow Z$
$1.65^{+0.34}_{-0.31}\pm0.12$		⁴ ABREU	96F DLPH	$e^+ e^- \rightarrow Z$
$1.76 \pm 0.20 {}^{+ 0.15}_{- 0.10}$		⁵ ABREU	96F DLPH	$e^+e^- \rightarrow Z$
$1.60 \pm 0.26 ^{+0.13}_{-0.15}$		⁶ ABREU	96F DLPH	$e^+e^- \rightarrow Z$
$1.61 + 0.30 + 0.18 \\ -0.29 - 0.16$	90	⁴ BUSKULIC	96E ALEP	$e^+e^- \rightarrow Z$
$1.42^{+0.27}_{-0.23}\pm0.11$	76	³ ABE	95R CDF	$p\overline{p}$ at 1.8 TeV
$1.74^{+1.08}_{-0.69}\pm0.07$	8	⁷ ABE	95R CDF	$p\overline{p}$ at 1.8 TeV
$1.54^{+0.25}_{-0.21}\pm0.06$	79	³ AKERS	95G OPAL	$e^+e^- \rightarrow Z$
$1.59^{+0.17}_{-0.15}\pm0.03$	134	³ BUSKULIC	950 ALEP	$e^+e^- \rightarrow Z$
 We do not use 	the following	ng data for averag	es, fits, limits	, etc. • • •
1.67 ± 0.14		⁸ ABREU	96F DLPH	$e^+e^- \rightarrow Z$
0.96 ± 0.37	41	⁹ ABREU	94E DLPH	Sup. by ABREU 96F
$1.92^{+0.45}_{-0.35}\pm0.04$	31	³ BUSKULIC	94c ALEP	Sup. by BUSKULIC 950
$1.13^{+0.35}_{-0.26} \pm 0.09$	22	³ ACTON	93H OPAL	Sup. by AKERS 95G

 $^{^3}$ Measured using $D_s^-\ell^+$ vertices.

BO DECAY MODES

These branching fractions all scale with $B(\overline{b} \rightarrow B_s^0)$, the LEP B_s^0 production fraction. The first four were evaluated using $B(\overline{b} \rightarrow B_S^0) =$ $(11.2 + 1.8 \atop -1.9)\%$ and the rest assume B($\overline{b} \rightarrow B_5^0$) = 12%.

The branching fraction B($B_s^0 o D_s^- \ell^+
u_\ell$ anything) is not a pure measurement since the measured product branching fraction $B(\overline{b} \rightarrow B_s^0) \times$ ${\sf B}(B_s^0 \to D_s^-\ell^+\nu_\ell$ anything) was used to determine ${\sf B}(\overline{b} \to B_s^0)$, as described in the note on "Production and Decay of *b*-Flavored Hadrons."

	Mode	Fraction (Γ_i/Γ_i)	-) Con	fidence level
Γ_1	D_s^- anything	(87 ±31) %	
Γ_2	$D_s^-\ell^+ u_\ell$ anything	[a] (7.6 ± 2.	4) %	
Γ_3	$D_s^- \pi^+$	< 12	%	
Γ_4	$J/\psi(1S)\phi$	< 6	\times 10 ⁻³	
Γ_5	$\psi(2S)\phi$	seen		
Γ ₆	$\pi^{\circ}\pi^{\circ}$	< 2.1	\times 10 ⁻⁴	90%
Γ ₅ Γ ₆ Γ ₇	$\eta \pi^0$	< 1.0	\times 10 ⁻³	90%
Γ8	$\eta \eta$	< 1.5	\times 10 ⁻³	90%
Γ_9	$\pi^+ K^-$	< 2.6	\times 10 ⁻⁴	90%
Γ ₁₀	K ⁺ K ⁻	< 1.4	\times 10 ⁻⁴	90%
	$\Delta B = 1$ weak neutral	current (<i>B1</i>) mo	odes	
Γ_{11}	$\gamma\gamma$ B1	< 1.48	× 10 ⁻⁴	90%

[a] Not a pure measurement. See note at head of B_s^0 Decay Modes.

BO BRANCHING RATIOS

 $\Gamma(D_s^- \text{ anything})/\Gamma_{\text{total}}$ Γ_1/Γ

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.87±0.31 OUR AVE	RAGE			
$0.76 \pm 0.23 \pm 0.23$	90	¹⁰ BUSKULIC	96E ALEP	$e^+e^- o Z$
$1.46 \pm 0.54 \pm 0.44$	147	¹¹ ACTON	92N OPAL	$e^+e^- \rightarrow Z$

¹⁰ BUSKULIC 96E separate $c\bar{c}$ and $b\bar{b}$ sources of D_s^+ mesons using a lifetime tag, subtract generic $\overline{b} \to W^+ \to D_s^+$ events, and obtain $B(\overline{b} \to B_s^0) \times B(B_s^0 \to D_s^-$ anything) = 0.088 ± 0.020 ± 0.020 assuming B($D_S \rightarrow \phi \pi$) = (3.5 ± 0.4) × 10⁻² and PDG 1994 values for the relative partial widths to other D_S channels. We evaluate using our current values B($\overline{b} \to B_S^0$) = 0.112 $^{+0.018}_{-0.019}$ and B($D_S \to \phi \pi$) = 0.036 \pm 0.009. Our first error is their experiment's and our second error is that due to B($\overline{b} \to B_S^0$) and B($D_S \to \phi \pi$).

 11 ACTON 92N assume that excess of 147 \pm 48 D_S^0 events over that expected from B^0 , B^+ , and $c\overline{c}$ is all from B_s^0 decay. The product branching fraction is measured to be $\mathsf{B}(\overline{b}\to \ B_s^0)\mathsf{B}(B_s^0\to \ D_s^- \text{ anything})\times \mathsf{B}(D_s^-\to \ \phi\pi^-) = (5.9\pm 1.9\pm 1.1)\times 10^{-3}.$ We evaluate using our current values $B(\overline{b}\to B_S^0)=0.112^{+0.018}_{-0.019}$ and $B(D_S\to\phi\pi)=0.036\pm0.009$. Our first error is their experiment's and our second error is that due to $B(\overline{b} \to B_S^0)$ and $B(D_S \to \phi \pi)$.

 $\Gamma(D_s^-\ell^+\nu_\ell \text{anything})/\Gamma_{\text{total}}$ The values and averages in this section serve only to show what values result if one assumes our $B(\bar{b} \to B_s^0)$. They cannot be thought of as measurements since the

underlying product branching fractions were also used to determinine $B(\overline{b}\to B_s^0)$ as described in the note on "Production and Decay of b-Flavored Hadrons."

	VALUE	EV15	DOCUMENT ID		COMMENI		
	0.076±0.024 OUR AVE	RAGE					
	$0.071^{+0.011}_{-0.012}\pm0.021$	134	¹² BUSKULIC	950 ALEP	$e^+ e^- \rightarrow Z$		
	$0.14 \pm 0.06 \pm 0.04$				$e^+ e^- \rightarrow Z$		
	$0.097 \pm 0.034 \pm 0.029$	18	¹⁴ ACTON	92N OPAL	$e^+e^- \rightarrow Z$		
	$0.13 \pm 0.04 \pm 0.04$	27	¹⁵ BUSKULIC	92E ALEP	$e^+e^-\toZ$		
	12 0 1 10 1 1 1 1 0 0 0 0 0					5/7	

 12 BUSKULIC 950 use $D_{_{f S}}\ell$ correlations. The measured product branching ratio is B(\overline{b} ightarrow B_s) × B($B_s \rightarrow D_s^- \ell^+ \nu_\ell$ anything) = (0.82 \pm 0.09 $^+$ 0.13)% assuming B($D_s \rightarrow \phi \pi$) = (3.5 \pm 0.4) × 10 $^-$ 2 and PDG 1994 values for the relative partial widths to the six other D_s channels used in this analysis. Combined with results from $\Upsilon(4S)$ experiments this can be used to extract B($\overline{E}_s \rightarrow D_s$) (10.0 \pm 0.2 \pm 2.5 \pm 3.5 his can be used to extract B($\overline{b} \rightarrow B_S$) = (11.0 \pm 1.2 $^{+2.5}_{-2.6}$)%. We evaluate using our current values B($\overline{b} \to B_S^0$) = 0.112 $^{+0.018}_{-0.019}$ and B($D_S \to \phi\pi$) = 0.036 \pm 0.009. Our first error is their experiment's and our second error is that due to $B(\overline{b} \to B_s^0)$ and

 13 ABREU 92M measured muons only and obtained product branching ratio B(Z
ightarrow bor $\overline{b}) \times \mathsf{B}(\overline{b} \to B_{\mathsf{S}}) \times \mathsf{B}(B_{\mathsf{S}} \to D_{\mathsf{S}} \mu^+ \nu_{\mu} \, \mathsf{anything}) \times \mathsf{B}(D_{\mathsf{S}} \to \phi \pi) = (18 \pm 8) \times 10^{-5}.$ We evaluate using our current values $B(\overline{b} \to B_S^0) = 0.112 {+0.018 \atop -0.019}$ and $B(D_S \to \phi\pi)$ = 0.036 ± 0.009. Our first error is their experiment's and our second error is that due to $B(\overline{b} \to B_S^0)$ and $B(D_S \to \phi\pi)$. We use $B(Z \to bor \overline{b}) = 2B(Z \to b\overline{b}) = 2B(Z \to b\overline{b})$ $2\times(0.1546\pm0.0014)$.

^{*}Measured using D_S to retrices.

5 Measured using $\phi \ell$ vertices.

5 Measured using $\phi \ell$ vertices.

6 Measured using inclusive D_S vertices.

7 Exclusive reconstruction of $B_S \rightarrow \psi \phi$.

8 Combined result for the four ABREU 96F methods.

9 ABREU 94E uses the flight-distance distribution of D_S vertices, ϕ -lepton vertices, and D_{-H} vertices. $D_{S}\mu$ vertices.

 R^0

B_s^0					
$\begin{array}{lll} \times \mathrm{B}(D_S^- \to \phi \pi^- \\ \mathrm{B}(\overline{b} \to B_S^0) = 0 \\ \mathrm{their} \ \mathrm{experiment's} \\ \mathrm{15} \ \mathrm{BUSKULIC} \ \mathrm{92E} \ \mathrm{is} \\ \mathrm{2.7} \pm 0.7\% \ \mathrm{for} \ \mathrm{the} \\ \mathrm{measured} \ \mathrm{to} \ \mathrm{be} \ \mathrm{B} \\ \mathrm{We} \ \mathrm{evaluate} \ \mathrm{using} \\ \mathrm{=} \ 0.036 \pm 0.009. \\ \mathrm{to} \ \mathrm{B}(\overline{b} \to B_S^0) \ \mathrm{ar} \end{array}$	measured is $)=(3.9\pm0.014)$ and our semeasured is $\phi\pi^+$ brain $(\overline{b}\to B_S^0)$ our current Our first e	s measured to be B $1.1\pm0.8)\times10^{-4}$ $_{9}^{B}$ and B(D_{S} $ ightarrow$ ϕ cond error is that ϕ	$(\overline{b} \rightarrow B_s^0)$ B(.4. We evaluar) π) = 0.036 sinue to B($\overline{b} \rightarrow B_s^0$) and K^* (89 are average pro ν_ℓ anything) S_s^0 = 0.112 $\frac{1}{2}$ ment's and oil	$B_s^0 \rightarrow D_s^- \ell$ the using our \pm 0.009. On θ_s^0 and θ_s^0	$+$ ν_{ℓ} anything) current values are first error is $8(D_S \rightarrow \phi \pi)$. Into the value in the value of the v
$\Gamma(D_s^-\pi^+)/\Gamma_{\text{total}}$	EVTS	DOCUMENT ID	TECN	COMMENT	Γ ₃ /Γ
<0.12	6	¹⁶ AKERS	94J OPAL	e^+e^-	z
• • We do not use	the followir				
seen	1	BUSKULIC	93G ALEP		
$f(\overline{b} \rightarrow B_{S}^{0}) \cdot B(B_{S}^{0})$ $B(\overline{b} \rightarrow B_{S}^{0}) = 0.$	$\rightarrow D_s^- \pi^-$	and measures the $^+$) $<~1.3\%$ at CL	limit on the period of the per	product brar divide by ou	nching fraction r current value
$\Gamma(J/\psi(1S)\phi)/\Gamma_{tot}$	al				Γ_4/Γ
VALUE	EVTS	DOCUMENT ID			
<0.006 • • • We do not use	1 the followin	¹⁷ AKERS		$e^+e^- \rightarrow$	Z
seen	14	¹⁸ ABE	93F CDF	$p\overline{p}$ at 1.8	TeV/
seen	1		92N OPAL		
value B($\overline{b} \rightarrow B_s^0$) 18 ABE 93F measured 19 In ACTON 92N a	$ ightarrow J/\psi(1-1)$ = 0.112. dusing J/ψ imit on the	$(S)\phi)< 7 imes 10^{-4}$ $\phi(1S) ightarrow \mu^+\mu^-$ a	at CL = 90% and $\phi \rightarrow K^+$ g fraction is n	. We divide	by our current
$\Gamma(\psi(2S)\phi)/\Gamma_{\text{total}}$					Γ_5/Γ
VALUE Seen		DOCUMENT ID BUSKULIC	93G ALEP	$e^+e^- \rightarrow$	7
$\Gamma(\pi^0\pi^0)/\Gamma_{ ext{total}}$	1	BOSKOLIC	930 ALEF	€. €	- Γ ₆ /Γ
VALUE	CL%	DOCUMENT ID	TECN	COMMENT	
<2.1 × 10 ⁻⁴	90	²⁰ ACCIARRI	95H L3	e ⁺ e [−] →	Z
²⁰ ACCIARRI 95H ass	sumes f _{B0}	$=$ 39.5 \pm 4.0 and	$f_{B_s} = 12.0 \pm$	3.0%.	_ I
$\Gamma(\eta \pi^0)/\Gamma_{\text{total}}$	C1 W	DOCUMENT ID	TECN	COMMENT	Γ ₇ /Γ
<1.0 × 10 ⁻³	<u>CL%</u> 90	21 ACCIARRI	95H L3	$e^+e^- \rightarrow$	Z
²¹ ACCIARRI 95H ass					
	Б-		25		- /-
$\Gamma(\eta\eta)/\Gamma_{\text{total}}$	C1.0/	DOCUMENT ID	TECH	COLUMENT	Г8/Г
VALUE <1.5 × 10 ⁻³	<u>CL%</u> 90	22 ACCIARRI	95H L3	$e^+e^- \rightarrow$	7
²² ACCIARRI 95H ass					i
$\Gamma(\pi^+ K^-)/\Gamma_{total}$					- ۲ ₉ /۲
VALUE	CL%_	23 AKERS			
$<2.6 \times 10^{-4}$ ²³ Assumes B($Z \rightarrow$	90 $b\overline{b}) = 0.21$		94L OPAL action 39.5%		2 I
		0 3			- /-
$\Gamma(K^+K^-)/\Gamma_{\text{total}}$	CLW	DOCUMENT ID	TECN	COMMENT	Γ ₁₀ /Γ
<1.4 × 10 ⁻⁴	<u>CL%</u> 90	DOCUMENT ID 24 AKERS	94L OPAL	e ⁺ e ⁻ →	z
²⁴ Assumes B($Z \rightarrow$					i
	1 weak neu	itral current. Allow	ed by higher-	order electr	Γ ₁₁ /Γ oweak interac-
tions. VALUE	CL%	DOCUMENT ID	TECN	COMMENT	
<14.8 × 10 ⁻⁵	90	²⁵ ACCIARRI	95ı L3	$e^+e^-\rightarrow$	Z

POLARIZATION IN BO DECAY

 $^{25}\,\mathrm{ACCIARRI}$ 951 assumes $f_{B^0}=$ 39.5 \pm 4.0 and $f_{B_8}=$ 12.0 \pm 3.0%.

Γ_L/Γ in $B_s^0 \rightarrow$	$J/\psi(1S)\phi$			
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
$0.56 \!\pm\! 0.21 \! \substack{+0.02 \\ -0.04}$	19	ABE	95Z CDF	$p\overline{p}$ at 1.8 TeV

$B_s^0 - \overline{B}_s^0$ MIXING

For a discussion of B^0_s - \overline{B}^0_s mixing see the note on " B^0 - \overline{B}^0 Mixing and CPViolation in B Decay" in the B^0 Particle Listings above.

This $B^0_s {\overline B}^0_s$ mixing parameter measures the probability (integrated over time) that a produced B_s^0 (\overline{B}_s^0) decays as a \overline{B}_s^0 (B_s^0). It cannot exceed 0.50. Mixing violates

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
>0.49	95	²⁶ BUSKULIC	95J ALEP	$e^+e^- \rightarrow Z$
• • • We do not use the	following	g data for averages	, fits, limits,	etc. • • •
0.74 ± 0.27	95	²⁷ ABREU	94F RVUE	$e^+e^- \rightarrow Z$
$0.43^{+0.26}_{-0.17}$		²⁸ ACCIARRI	94D RVUE	
0.46 ± 0.21			92c RVUE	Sup. by ACCIARRI 94D
0.53 ± 0.15		³⁰ ALBAJAR	91D RVUE	

 $^{26}\, \rm BUSKULIC$ 95J is their $\Delta m_{B_{\varsigma}^0}$ measurement combined with $\tau_{B_{\varsigma}^0}=1.61\, \rm ps,~our~central$ value. Assumes $f_S = 11.2\%$.

value. Assumes 15 = 11.27.

27 From a combination of DELPHI (ABREU 94F), CLEO (ARTUSO 89), and ARGUS (ALBRECHT 92L). Estimated from ABREU 94F figure 7.

(ALBRECHT 921). Estimated from ABREU 94F figure 7.
28 Uses BARTELT 93 to remove B_d mixing contribution and assuming $f_d=0.375\pm0.05$ and $f_s=0.15\pm0.05$.
29 From combination of L3 (ADEVA 92C), CLEO (ARTUSO 89), and ARGUS (ALBRECHT 921). Corresponding limit is >0.16 at 90%CL.
30 From combination of UA1 (ALBAJAR 910), CLEO (BEAN 87B), ARGUS (ALBRECHT 87I), ALEPH (DECAMP 91), and L3 (ADEVA 90P). Corresponding limits are >0.23 at 95% CL and >0.27 at 90% CL.

χ_{B} at high energy

This is a B- \bar{B} mixing measurement for an admixture of B^0 and B^0_s at high energy, $\chi_B=f_d\chi_d+f_s\chi_s$

 $^{\chi}B=^{I}d^{\chi}d+^{I}s^{\Lambda}s$ where f_d and f_s are the production fractions of B_d^0 and B_s^0 mesons relative to all b-flavored hadrons. Only the measurements at the Z and higher energy $p\bar{p}$ are averaged. TECN COMMENT $\begin{array}{c|c} \underline{\textit{VALUE}} & \underline{\textit{CL\%}} & \underline{\textit{EVTS}} \\ \hline \textbf{0.126} \!\pm\! 0.008 \ \textbf{OUR AVERAGE} \end{array}$ DOCUMENT ID

0.000				
$0.121 \pm 0.016 \pm 0.006$		31 ABREU	94J DLPH	$e^+e^- \rightarrow Z$
$0.123 \pm 0.012 \pm 0.008$		ACCIARRI	94D L3	$e^+e^- \rightarrow Z$
$0.114 \pm 0.014 \pm 0.008$		³² BUSKULIC	94G ALEP	$e^+e^- \rightarrow Z$
$0.143^{+0.022}_{-0.021} \pm 0.007$		³³ AKERS	93B OPAL	$e^+e^- ightarrow ~Z$
0.129 ± 0.022		³⁴ BUSKULIC	92B ALEP	$e^+ e^- \rightarrow Z$
$0.176 \pm 0.031 \pm 0.032$	1112	³⁵ ABE	91G CDF	p p 1.8 TeV
$0.148 \pm 0.029 \pm 0.017$		³⁶ ALBAJAR	91D UA1	p p̄ 630 GeV
ullet $ullet$ We do not use the	following data	for averages, fits, lin	nits, etc. • •	
$0.144 \pm 0.014 ^{+\ 0.017}_{-\ 0.011}$		³⁷ ABREU	94F DLPH	Sup. by
0.131 ± 0.014		³⁸ ABREU	94J DLPH	$e^+\stackrel{ABREU}{e^-} \rightarrow Z$
$0.157 \pm 0.020 \pm 0.032$		³⁹ ALBAJAR	94 UA1	$\sqrt{s} = 630 \text{ GeV}$
$0.121 ^{+ 0.044}_{- 0.040} \!\pm\! 0.017$	1665	⁴⁰ ABREU	93c DLPH	Sup. by ABREU 94J
$0.145^{+0.041}_{-0.035}\pm0.018$		⁴¹ ACTON	92c OPAL	$e^+e^- \rightarrow Z$
$0.121 \pm 0.017 \pm 0.006$		⁴² ADEVA	92C L3	Sup. by AC- CIARRI 94D
$0.132 \pm 0.22 ^{+ 0.015}_{- 0.012}$	823	⁴³ DECAMP	91 ALEP	$e^+e^- \to Z$
$0.178^{+0.049}_{-0.040}\!\pm\!0.020$		⁴⁴ ADEVA	90P L3	$e^+e^- \to Z$
$0.17 \begin{array}{l} +0.15 \\ -0.08 \end{array}$		^{45,46} WEIR	90 MRK2	e^+e^- 29 GeV
$0.21 \begin{array}{c} +0.29 \\ -0.15 \end{array}$		⁴⁵ BAND	88 MAC	$E_{ m cm}^{\it ee}=$ 29 GeV
>0.02	90	⁴⁵ BAND	88 MAC	$E_{cm}^{ee} = 29 \text{ GeV}$
0.121 ± 0.047		^{45,47} ALBAJAR	87C UA1	Repl. by AL-

45,48 SCHAAD 31 This ABREU 94J result is from 5182 $\ell\ell$ and 279 $\Lambda\ell$ events. The systematic error includes

85 MRK2 $E_{\rm cm}^{ee} = 29 \, {\rm GeV}$

0.004 for model dependence. ³² BUSKULIC 94G data analyzed using $e\,e,\,e\,\mu$, and $\mu\mu$ events.

90

33 AKERs 938 analysis performed using ete, e.μ., and μμ events.

34 BUSKULIC 94g data analysis performed using dilepton events.

35 ABE 91G measurement of X is done with e.μ and ee events.

36 ALBAJAR 91D measurement of X is done with dimuons.

37 ABREU 94F uses the average electric charge sum of the jets recoiling against a b-quark jet tagged by a high p_T muon. The result is for X̄ = f_QX_Q+0.9f_XX_S.

38 This ABREU 94 result combines $\ell\ell$, $\Lambda\ell$, and jet-charge ℓ (ABREU 94F) analyses. It is for $\overline{X} = f_d X_d + 0.96 f_s X_s$.

40 ABREU 93c data analyzed using $e\,e,\,e\,\mu$, and $\mu\mu$ events. 41 ACTON 92c uses electrons and muons. Superseded by AKERS 93B.

 42 ADEVA 92c uses electrons and muons. 43 DECAMP 91 done with opposite and like-sign dileptons. Superseded by BUSKULIC 92B. 44 ADEVA 90P measurement uses $ee,~\mu\mu,~$ and $e\mu$ events from 118k events at the Z. Superseded by ADEVA 92c.

Superseded by ADEVA 92c. 45 These experiments are not in the average because the combination of B_S and B_d mesons which they see could differ from those at higher energy. 46 The WEIR 90 measurement supersedes the limit obtained in SCHAAD 85. The 90% CL are 0.06 and 0.38. 47 ALBAJAR 87c measured $X=(\overline{B}^0\to B^0\to \mu^+ X)$ divided by the average production weighted semileptonic branching fraction for B hadrons at 546 and 630 GeV. 48 Limit is average probability for hadron containing B quark to produce a positive lepton.

$$\begin{split} \Delta m_{B_s^0} &= m_{B_{sH}^0} - m_{B_{sL}^0} \\ & \Delta m_{B_s^0} \text{ is a measure of the } B_s^0 \text{-} \overline{B}_s^0 \text{ oscillation frequency in time-dependent mixing} \end{split}$$

$VALUE (10^{12} h s^{-1})$	CL%	DOCUMENT ID	TECN	COMMENT	
>5.9	95	49 BUSKULIC 95	J ALEP	$e^+e^- \rightarrow Z$	
• • • We do not use the	ne follow	ing data for averages, f	its, limits,	etc. • • •	
>2.2	95			$e^+e^- \rightarrow Z$	
>1.8	95	50 BUSKULIC 94	B ALEP	$e^+e^- \rightarrow Z$	

 $^{49}\, {\rm BUSKULIC}$ 95J determine $\Delta m_{B_{-}^0}$ from time dependence of B mixing using a jet charge technique to tag initial quark state and a lepton tag to determine flavor of the decaying b quark. They find $\Delta m_g > 5.6$ [> 6.1] \hbar ps⁻¹ when $f_s = 10\%$ [12%]. We interpolate to our central value $f_s = 11.2\%$. 50 Uses dileptons.

$x_s = \Delta m_{B_c^0} / \Gamma_{B_s^0}$

This section combines the results from the previous two sections.

Time integrated mixing measurement of X determine this quantity directly via

$$\frac{\Delta m_{B_s^0}}{\Gamma_{B_s^0}} = \left(\frac{\chi}{0.5 - \chi}\right)^{1/2}$$

while time-dependent mixing measurements determine $\Delta m_{B_{\S}^0} = m_{B_{\S L}^0} - m_{B_{\S L}^0}$ which

$$\frac{\Delta m_{B_s^0}}{\Gamma_{B^0}} = \frac{(m_{B_s^0 H}^0 - m_{B_{sL}^0}) \ \tau_{B_s^0}}{\hbar}$$

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
>9.5	95	⁵¹ BUSKULIC	95J ALEP	$e^+e^- \rightarrow Z$

⁵¹ BUSKULIC 95J is their $\Delta m_{B_2^0}$ measurement combined with $au_{B_2^0}=1.61$ ps, our central value. Assumes $f_S = 11.2\%$.

BO REFERENCES

ABE	96B	PR D53 3496	+Albrow, Amendolia, Amidei+	(CDF	Collab.)
ABREU	96F	ZPHY C (submitted)	+Adam, Adye, Agasi+	(DELPHI	Collab.)
CERN-PPE	/96-32				
BUSKULIC	96E	ZPHY C69 585	+Casper, De Bonis, Decamp+	(ALEPH	Collab.)
ABE	95R	PRL 74 4988	+Albrow, Amendolia, Amidei+	(CDF	Collab.)
ABE	95 Z	PRL 75 3068	+Albrow, Amendolia, Amidei+	(CDF	Collab.)
ACCIARRI	95H	PL B363 127	+Adam, Adriani, Aguilar-Benitez+	(L3	Collab.)
ACCIARRI	951	PL B363 137	+Adam, Adriani, Aguilar-Benitez+	(L3	Collab.)
AKERS	95G	PL B350 273	+Alexander, Allison, Ametewee+	(OPAL	Collab.)
AKERS	95 J	ZPHY C66 555	+Alexander, Allison, Ametewee+	(OPAL	Collab.)
BUSKULIC	95 J	PL B356 409	+Casper, De Bonis, Decamp+	(ALEPH	Collab.)
BUSKULIC	950	PL B361 221	+Casper, De Bonis, Decamp+	(ALEPH	Collab.)
ABREU	94D	PL B324 500	+Adam, Adye, Agasi, Aleksan+	(DELPHI	Collab.)
ABREU	94E	ZPHY C61 407	+Adam, Adye, Agasi, Aleksan+	(DELPHI	Collab.)
Also	92M	PL B289 199	Abreu, Adam, Adye, Agasi, Alekseev+	(DELPHI	Collab.)
ABREU	94F	PL B322 459	+Adam, Adye, Agasi, Ajinenko+	(DELPHI	Collab.)
ABREU	94 J	PL B332 488	+Adam, Adye, Agasi, Ajinenko+	(DELPHI	Collab.)
ACCIARRI	94 D	PL B335 542	+Adam, Adriani, Aguilar-Benitez, Ahlen+	(L3	Collab.)
AKERS	94 J	PL B337 196	+Alexander, Allison, Anderson, Arcelli+	(OPAL	Collab.)
AKERS	94L	PL B337 393	+Alexander, Allison, Anderson, Arcelli+	(OPAL	Collab.)
ALBAJAR	94	ZPHY C61 41	+Ankoviak, Bartha, Bezaguet, Boehrer+	(UA1	Collab.)
BUSKULIC	94B	PL B322 441	+De Bonis, Decamp, Ghez, Goy, Lees+	(ALEPH	Collab.)
BUSKULIC	94C	PL B322 275	+De Bonis, Decamp, Ghez, Goy, Lees+	(ALEPH	Collab.)
BUSKULIC	94G	ZPHY C62 179	+Casper, De Bonis, Decamp, Ghez+	(ALEPH	Collab.)
ABE .	93F	PRL 71 1685	+Albrow, Amidei, Anway-Wiese+	CDF	Collab.)
ABREU	93C	PL B301 145	+Adam, Adye, Agasi, Aleksan+	(DELPHI	Collab.)
ACTON	93H	PL B312 501	+Akers, Alexander, Allison, Anderson+	OPAL	Collab.)
AKERS	93B	ZPHY C60 199	+Alexander, Allison, Anderson, Arcelli+	(OPAL	Collab.)
BARTELT	93	PRL 71 1680	+Csorna, Egyed, Jain, Sheldon+	(CLEO	Collab.)
BUSKULIC	93G	PL B311 425	+De Bonis, Decamp, Ghez, Goy, Lees+	(ALEPH	Collab.)
ABREU	92M	PL B289 199	+Adam, Adye, Agasi, Alekseev+	(DELPHI	Collab.)
ACTON	92C	PL B276 379	+Alexander, Allison, Allport, Anderson+	(OPAL	Collab.)
ACTON	92N	PL B295 357	+Alexander, Allison, Allport, Anderson+		Collab.)
ADEVA	92C	PL B288 395	+Adriani, Aguilar-Benitez, Ahlen+		Collab.)
ALBRECHT	92L	ZPHY C55 357	+Ehrlichmann, Hamacher, Krueger, Nau+	(ARGUS	
BUSKULIC	92B	PL B284 177	+Decamp, Goy, Lees, Minard+	(ALEPH	
BUSKULIC	92E	PL B294 145	+Decamp, Goy, Lees, Minard+	(ALEPH	Collab.)
ABE	91 G	PRL 67 3351	+Amidei, Apollinari, Atac, Auchincloss+		Collab.)
ALBAJAR	91 D	PL B262 171	+Albrow, Allkofer, Ankoviak, Apsimon+	(UA1	Collab.)
DECAMP	91	PL B258 236	+Deschizeaux, Goy, Lees, Minard+	(ALEPH	Collab.)
ADEVA	90P	PL B252 703	+Adriani, Aguilar-Benitez, Akbari, Alcaraz-		Collab.)
LEE-FRANZINI	90	PRL 65 2947	+Heintz, Lovelock, Narain, Schamberger+	(CUSB II	Collab.)
WEIR	90	PL B240 289	+Abrams, Adolphsen, Alexander, Alvarez+	(Mark II	Collab.)
ARTUSO	89	PRL 62 2233	+Bebek, Berkelman, Blucher+		Collab.)
BAND	88	PL B200 221	+Camporesi, Chadwick+		Collab.)
ALBAJAR	87C	PL B186 247	+Albrow, Allkofer, Arnison+		Collab.)
ALBRECHT	871	PL B192 245	+Andam, Binder, Boeckmann+	(ARGUS	
BEAN	87B	PRL 58 183	+Bobbink, Brock, Engler+		Collab.)
SCHAAD	85	PL 160B 188	+Nelson, Abrams, Amidei+	(Mark II	Collab.)

- OTHER RELATED PAPERS

93 JPG 19 1069 +London "Prospects for measuring the $B_s^0 - \overline{B}_s^0$ mixing ratio x_s " (DESY, MONT)



$$I(J^P) = ?(??)$$

I, J, P need confirmation.

OMITTED FROM SUMMARY TABLE Needs confirmation.

B* MASS

From mass difference below and the B_s^0 mass.

VALUE (MeV)
5416.3±3.3 OUR FIT

DOCUMENT ID

 $m_{B_{\bullet}^{\bullet}}-m_{B_{\bullet}}$

VALUE (MeV) 47.0±2.6 OUR FIT DOCUMENT ID TECN COMMENT

 1 LEE-FRANZINI90 CSB2 $e^{+}e^{-} \rightarrow \Upsilon(5S)$ 1 LEE-FRANZINI 90 measure 46.7 \pm 0.4 \pm 0.2 MeV for an admixture of B^0 , B^+ , and $B_{\rm S}$. They use the shape of the photon line to separate the above value for $B_{\rm S}$.

 $\left|\left(m_{B_{\epsilon}^*}-m_{B_{\epsilon}}\right)-\left(m_{B^*}-m_{B}\right)\right|$

 DOCUMENT ID
 TECN
 COMMENT

 ABREU
 95R DLPH
 Eem = 88-94 GeV
 VALUE (MeV) CL% <6

B* DECAY MODES

Mode Fraction (Γ_i/Γ) Γ_1 $B_s \gamma$ dominant

B* REFERENCES

ABREU 95R ZPHY C68 353 LEE-FRANZINI 90 PRL 65 2947

+Adam, Adye, Agasi+ +Heintz, Lovelock, Narain, Schamberger+(CUSB II Collab.)

 $B_{sJ}^*(5850)$

AKERS

$$I(J^P) = ?(?^?)$$

I, J, P need confirmation.

OMITTED FROM SUMMARY TABLE

Signal can be interpreted as coming from $\overline{b}s$ states. Needs confir-

$B_{s,l}^{*}(5850)$ MASS

VALUE (MeV) DOCUMENT ID TECN COMMENT **EVTS** 95E OPAL $E_{
m cm}^{\it ee}=$ 88–94 GeV 5853±15 141 AKERS

$B_{sJ}^{*}(5850)$ WIDTH

DOCUMENT ID TECN COMMENT VALUE (MeV) EVTS AKERS 95E OPAL $E_{
m cm}^{\it ee}=$ 88–94 GeV 47±22 141

B_{sJ}^* (5850) REFERENCES

95E ZPHY C66 19

+Alexander, Allison+

(OPAL Collab.)

Charmonium, $\eta_c(1S)$

 $\eta_c(1S)$

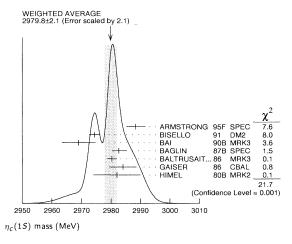
$$I^{G}(J^{PC}) = 0^{+}(0^{-}+)$$

$\eta_c(1S)$ MASS

VALUE (MeV)		DOCUMENT ID		COMMENT
2979.8± 2.1 OUR AV	ERAGE E	rror includes scale fa	ctor of 2.1.	See the ideogram below
2988.3 ⁺ 3.3 - 3.1		ARMSTRONG 9	5F SPEC	$\overline{p}p \rightarrow \gamma\gamma$
2974.4± 1.9		¹ BISELLO	1 DM2	$J/\psi \rightarrow \eta_C \gamma$
2969 \pm 4 \pm 4	80	BAI 9	0в MRK3	$J/\psi \rightarrow$
				$\gamma K^+ K^- K^+ K^-$
2982.6 ⁺ 2.7 - 2.3	12	BAGLIN 8	7B SPEC	$\overline{\rho} \rho \rightarrow \gamma \gamma$
2980.2± 1.6		¹ BALTRUSAIT £	6 MRK3	$J/\psi \rightarrow \eta_C \gamma$
2984 \pm 2.3 \pm 4.0		GAISER 8	6 CBAL	$J/\psi \rightarrow \gamma X, \psi(2S) \rightarrow$
2002 0	10	² HIMEL 8	OB MRK2	γX
2982 ± 8				
• • We do not use t	ne tollowin	g data for averages,	rits, iimits,	etc. • • •
2956 ±12 ±12		BAI 9	0в MRK3	$J/\psi \rightarrow$
				$\gamma K^+ K^- K_5^0 K_1^0$
2976 ± 8		3 BALTRUSAIT	4 MRK3	$J/\psi \rightarrow 2\phi\gamma$
2980 ± 9		² PARTRIDGE 8	80B CBAL	e+ e-
1 Average of several	decay mod	00		

 $[\]frac{1}{2}$ Average of several decay modes. $\frac{2}{2}$ Mass adjusted by us to correspond to $J/\psi(1{\it S})$ mass =3097 MeV.

 $^{^3\}eta_C \rightarrow \ \phi\phi.$

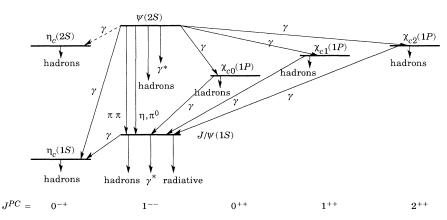


EVTS	DOCUMENT ID			
			<u>TECN</u>	COMMENT
ERAGE				
	ARMSTRONG	95F	SPEC	$\overline{\rho} \rho o \gamma \gamma$
12	BAGLIN	87B	SPEC	$\overline{p} p \rightarrow \gamma \gamma$
23	⁴ BALTRUSAIT.	.86	MRK3	$J/\psi \rightarrow \gamma \rho \overline{\rho}$
	GAISER	86	CBAL	$J/\psi \rightarrow \gamma X, \psi(2S) \rightarrow \gamma X$
he followin	g data for averages	, fits	, limits,	
18	HIMEL	80B	MRK2	e^+e^-
	PARTRIDGE	80B	CBAL	e+ e-
	23 he followin 18	12 BAGLIN 23 ⁴ BALTRUSAIT. GAISER he following data for averages 18 HIMEL PARTRIDGE	12 BAGLIN 87B 23 ⁴ BALTRUSAIT86 GAISER 86 he following data for averages, fits 18 HIMEL 80B PARTRIDGE 80B	23 ⁴ BALTRUSAIT86 MRK3 GAISER 86 CBAL he following data for averages, fits, limits,

$\eta_c(1S)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ_i)) Confidence	e level
	Decays involving	hadronic resonances	3	
Γ_1	$\eta'(958)\pi\pi$	(4.1 ± 1.7)	%	
Γ_2	ho ho	(2.6 ± 0.9)	%	
	$K^*(892)^0 K^- \pi^+ + \text{c.c.}$	(2.0 ± 0.7) 9	%	
Γ_4	$K^*(892)\overline{K}^*(892)$	(8.5 ±3.1)	× 10 ⁻³	
Γ_5	$\phi \phi$	(7.1 ± 2.8)	× 10 ⁻³	
Γ_6	$a_0(980)\pi$	< 2	%	90%
	$a_2(1320)\pi$	< 2	%	90%
Γ8	$K^*(892)\overline{K} + \text{c.c.}$	< 1.28	%	90%
Γ9	$f_2(1270)\eta$	< 1.1		90%
Γ_{10}	$\omega \omega$	< 3.1	× 10 ⁻³	90%
	Decays into	stable hadrons		
Γ_{11}	$K\overline{K}\pi$	(5.5 ±1.7)	%	
Γ_{12}	$\eta \pi \pi$	(4.9 ±1.8)	%	
Γ_{13}	$\pi^+\pi^-K^+K^-$	$(2.0 \begin{array}{c} +0.7 \\ -0.6 \end{array})$	%	
Γ_{14}	$2(K^{+}K^{-})$	(2.1 ± 1.2) 9	V ₆	
	$2(\pi^{+}\pi^{-})'$	(1.2 ±0.4)		
Γ ₁₆	$p\overline{\overline{p}}$	(1.2 ±0.4)	× 10 ⁻³	
	$K\overline{K}\eta$	< 3.1	%	90%
Γ ₁₈	$\pi^+\pi^- p \overline{p}$	< 1.2	%	90%
Γ_{19}	$\Lambda \overline{\Lambda}$	< 2	$\times 10^{-3}$	90%
	Radia	tive decays		
Γ_{20}	$\gamma \gamma$	(3.0 ±1.2)	× 10 ⁻⁴	

THE CHARMONIUM SYSTEM



The current state of knowledge of the charmonium system and transitions, as interpreted by the charmonium model. Uncertain states and transitions are indicated by dashed lines. The notation γ^* refers to decay processes involving intermediate virtual photons, including decays to e^+e^- and $\mu^+\mu^-$.

 $\eta_c(1S)$

	$\eta_c($	15) PARTIAL	WIDTHS			$\Gamma(a_2(1320)\pi)/\Gamma_{to}$	otal <u>CL%</u>	DOCUMENT ID	TECN	COMMENT	Γ ₇ /
$(\gamma\gamma)$				-cu comutat	Γ ₂₀	<0.02	90	7 BALTRUSAIT86			
	CL% EVT	DOCUMEN	<u> 110 11</u>	COMMENT		$\Gamma(f_2(1270)\eta)/\Gamma_{to}$	tal				/و۲
7.5 + 1.6 OUR AV	ERAGE					VALUE	CL%	DOCUMENT ID		COMMENT	
6.7^{+}_{-} $\begin{array}{c} 2.4 \\ 1.7 \\ \end{array} \pm 2.3$				PEC $\overline{p}p \rightarrow \gamma\gamma$		<0.011	90	⁷ BALTRUSAIT86	MRK3	$J/\psi \rightarrow \eta_C \gamma$	
11.3 ± 4.2 8.0 ± 2.3 ± 2.4	17	ALBRECI ADRIANI			e+e-n.	$\Gamma(\omega\omega)/\Gamma_{ ext{total}}$					Γ ₁₀ /
$5.9^{+}_{-1.8}^{2.1}\pm 1.9$	1.	CHEN		LEO $e^+e^- \rightarrow$		<u>VALUE</u> <0.0031	<u>CL%</u> 90	DOCUMENT ID 7 BALTRUSAIT86		COMMENT	
6.4 + 5.0 6.4 - 3.4		AIHARA		PC e ⁺ e ⁻ →				ng data for averages, fit			
3.4 – 3.4 28 ±15		5 BERGER		LUT $\gamma\gamma o K\overline{K}$		< 0.0063		⁷ BISELLO 91	DM2	$J/\psi ightarrow \gamma \omega \omega$	
• We do not use	the following					$\Gamma(K\overline{K}\pi)/\Gamma_{ ext{total}}$					Γ ₁₁ /
(11	90	BLINOV	86 M	D1 e ⁺ e ⁻ →	e+ e- X	VALUE 0.055 ±0.017 O	CL%			TECN COMM	ENT
⁵ Re-evaluated by A	IHARA 880).				0.055 ±0.008 O		SE `_ J			
	ης	(1 5) Γ(i)Γ(γγ)	/Γ(total)			$0.0690 \pm 0.0142 \pm 0$	0.0132	33 ⁷ BISELLO	91	DM2 J/ψ -	→ (+ κ - π
$\Gamma(K\overline{K}\pi) \times \Gamma(\gamma\gamma)$. , , , , , , , ,		r	Γ ₁₁ Γ ₂₀ /Γ	0.0543±0.0094±0	0.0094	68 ⁷ BISELLO	91	DM2 J/ψ -	→.
	// total CL% EVT:	DOCUMEN	T ID TI	ECN COMMENT	11. 20/.			or 79 DAL TRUE	AIT OC		$(\pm \pi^{\mp} K)$
0.94±0.18 OUR AV	/ERAGE	6.4.5556		nc	+ ر_0 ≖	0.048 ±0.011 0.161 ±0.092		95 ^{7,9} BALTRUS ¹⁰ HIMEL		MRK3 J/ψ - MRK2 $\psi(2S)$	
0.84 ± 0.21 $1.06 \pm 0.41 \pm 0.27$	1:	⁶ ALBRECI BRAUNS		RG $\gamma\gamma ightarrow~K^\pm$ ASS $\gamma\gamma ightarrow~K\overline{K}$		0.161 +0.092 -0.073	the follows	TO HIMEL ng data for averages, fit			η_{c}
$1.5 \begin{array}{l} +0.60 \\ -0.45 \end{array} \pm 0.3$	1.	_		LUT $\gamma\gamma \rightarrow K\overline{K}$		< 0.107	90			cBAL J/ψ -	$\rightarrow \eta_{c} \gamma$
● • We do not use							- •			-/ +	-
<0.63	95	6 BEHREN		ELL $\gamma\gamma ightarrow \kappa_{S}^{0}$ ASS $\gamma\gamma ightarrow \kappa_{S}^{0}$	$6\kappa^{\pm}\pi^{\mp}$	$\Gamma(\eta\pi\pi)/\Gamma_{\text{total}}$	EVTS	DOCUMENT ID	TECN	COMMENT	Γ ₁₂ ,
<4.4	95	ALTHOF	F 858 T	ASS $\gamma \gamma \rightarrow K \overline{K}$	\overline{K}_{π}	0.049±0.018 OUR E	VALUATIO				
$^{6}\kappa^{\pm}\kappa^{0}_{S}\pi^{\mp}$ correct	ted to $K\overline{K}$	π by factor 3.				0.047±0.015 OUR A 0.054±0.020	VERAGE 75	7 BALTRUSAIT86	MRK3	$J/\psi \rightarrow n_c \gamma$	
	- /1	S) BRANCHIN	IC DATIOS			$0.037 \pm 0.013 \pm 0.020$		⁷ PARTRIDGE 80			$\pi^-\gamma$
		•		1		$\Gamma(\pi^+\pi^-K^+K^-)$	/F _{total}				Γ ₁₃
-		HADRONIC D	ECAYS —			VALUE	EVTS	DOCUMENT ID	TECN	COMMENT	
$(\eta'(958)\pi\pi)/\Gamma_{tot}$	tal				Γ_1/Γ	0.020 +0.007 OUR A	WERAGE				
NLUE 041±0.017	<u>EVTS</u> 14	7 DALTBUSAN		$\frac{COMMENT}{3 J/\psi \rightarrow \eta_C \gamma}$		0.021 ± 0.007	110	⁷ BALTRUSAIT86	MRK3	$J/\psi \to ~\eta_C \gamma$	
.U41±0.U17											
		BALINOSAI		3 3/4 . 1/6 /		$0.014 + 0.022 \\ -0.009$		¹⁰ HIMEL 80	B MRK2	$\psi(2S) \rightarrow \eta_C$	γ
$(\rho \rho)/\Gamma_{\text{total}}$				3 3/4 . 1161	Γ ₂ /Γ			¹⁰ HIMEL 80	B MRK2	$\psi(2S) \rightarrow \eta_C$	
ALUE (units 10 ⁻³)	CL% EVT.	S <u>DOCUMEN</u>	IT ID TI	ECN COMMENT	Γ ₂ /Γ	$\Gammaig(2(\pi^+\pi^-)ig)/\Gamma_{ m tot}$					Γ ₁₅ ,
	CL% EVT.	S <u>DOCUMEN</u>	IT ID TI stematicerrors	ECN COMMENT s as correlated.)		$\Gamma(2(\pi^+\pi^-))/\Gamma_{tot}$ $VALUE$ 0.012 ±0.004 OUF	EVALUATI	<u>/TS DOCUMENT ID</u> ION		$\psi(2S) ightarrow \eta_C$	Γ ₁₅ ,
ALUE (units 10 ⁻³) 26 ± 9 OUR E 25 ± 8 OUR A 26.0± 2.4±8.8	<u>CL% EVT.</u> EVALUATION EVERAGE	<u>DOCUMEN</u> ON (Treating system) On The system of the syst	TID TISTEMATICE TO THE TITLE TO	ECN COMMENT s as correlated.) M2 $J/\psi \rightarrow \gamma \mu$	ρ0ρ0	$\Gamma(2(\pi^{+}\pi^{-}))/\Gamma_{tol}$ 0.012 ± 0.004 OUR 0.0120 ± 0.0031 OUR	EVALUATI R AVERAGE	<u>/TS DOCUMENT IC</u> ION	<u> </u>	ECN <u>COMMEN</u>	Γ ₁₅ ,
26 ± 9 OUR E 25 ± 8 OUR A 26.0 ± 2.4 ± 8.8 23.6 ± 10.6 ± 8.2	CL% EVT. EVALUATION EVERAGE 11:	DOCUMEN ON (Treating system) 7 BISELLO 7 BISELLO	of ID The stematic errors of 1 D 91 D 91 D	ECN COMMENT s as correlated.) M2 $J/\psi \rightarrow \gamma \mu$ M2 $J/\psi \rightarrow \gamma \mu$	ρ0ρ0	$\Gamma(2(\pi^{+}\pi^{-}))/\Gamma_{tot}$ $\frac{VALUE}{0.012 \pm 0.004}$ QUF 0.0120 ± 0.0031 QUF $0.0105 \pm 0.0017 \pm 0.0$	R EVALUATI R AVERAGE 034 1	ON DOCUMENT ID	91 D	ECN COMMEN M2 $J/\psi \rightarrow \gamma 2\pi^{+}$	Γ ₁₅ ,
26 \pm 9 OUR E 25 \pm 8 OUR A 26.0 \pm 2.4 \pm 8.8 23.6 \pm 10.6 \pm 8.2 • • We do not use	CL% EVT. EVALUATION EVERAGE 11:	DOCUMENT OF THE PROPERTY OF TH	stematicerrors 91 D 91 D ges, fits, limit	ECN COMMENT s as correlated.) M2 $J/\psi \rightarrow \gamma \mu$ M2 $J/\psi \rightarrow \gamma \mu$	ρ ⁰ ρ ⁰ ρ ⁰	$\Gamma(2(\pi^{+}\pi^{-}))/\Gamma_{tot}$ VALUE 0.012 ±0.004 OUF 0.0120±0.0031 OUF 0.0105±0.0017±0.00 0.013 ±0.006	R EVALUATI R AVERAGE 034 1	DOCUMENT IS 37 PBISELLO 25 PBALTRUSAI	91 D	M2 $J/\psi ightarrow \gamma 2\pi^+$	Γ_{15} , τ $2\pi^{-}$ $\eta_{C}\gamma$
26 \pm 9 OUR E 25 \pm 8 OUR A 26.0 \pm 2.4 \pm 8.8 23.6 \pm 10.6 \pm 8.2 • • We do not use	CL% EVT. EVALUATION EVERAGE 11: 3: the followin	DOCUMEN Treating system Treating syste	stematicerrors 91 D 91 D ges, fits, limit	ECN COMMENT s as correlated.) M2 $J/\psi \rightarrow \gamma \mu$ M2 $J/\psi \rightarrow \gamma \mu$ s, etc. • •	ρ ⁰ ρ ⁰ ρ ρ ⁺ ρ ⁻	$\Gamma(2(\pi^{+}\pi^{-}))/\Gamma_{tot}$ $\frac{VALUE}{0.012 \pm 0.004}$ QUF 0.0120 ± 0.0031 QUF $0.0105 \pm 0.0017 \pm 0.0$	R EVALUATI R AVERAGE 034 1	ON DOCUMENT ID	91 D	ECN COMMEN M2 $J/\psi \rightarrow \gamma 2\pi^{+}$	Γ_{15} , τ $2\pi^{-}$ $\eta_{C}\gamma$
ALUE (units 10^{-3}) 26 ± 9 OUR E 25 ± 8 OUR A 26.0 ± 2.4 ± 8.8 23.6 ± 10.6 ± 8.2 • • We do not use (140 (K*(892) ⁰ K ⁻ π ⁺	CL% EVT. EVALUATION EVERAGE 11: 3: the followin 90 -+ c.c.)/I	DOCUMEN Treating system Treating syste	stematicerrors 91 D 91 D 92 Ses, fits, limit	EEC. COMMENT S as correlated.) M2 $J/\psi \rightarrow \gamma \mu$ M2 $J/\psi \rightarrow \gamma \mu$ S, etc. • • • IRK3 $J/\psi \rightarrow \eta_C$	ρ ⁰ ρ ⁰ ρ ⁰	$\Gamma(2(\pi^{+}\pi^{-}))/\Gamma_{tot}$ VALUE 0.012 ±0.004 OUF 0.0120±0.0031 OUF 0.0105±0.0017±0.00 0.013 ±0.006	R EVALUATI R AVERAGE 034 1	DOCUMENT IS 37 PBISELLO 25 PBALTRUSAI	91 D	M2 $J/\psi ightarrow \gamma 2\pi^+$	Γ_{15} , τ $2\pi^{-}$ $\eta_{C}\gamma$ $\rightarrow \eta_{C}\gamma$
ALUE (units 10^{-3}) 26 ± 9 OUR E 25 ± 8 OUR A 26.0 ± 2.4 ± 8.8 23.6 ± 10.6 ± 8.2 • • We do not use (K*(892)^0 K - π + ALUE	CL% EVT. EVALUATION EVERAGE 11: 3: the followin	5 DOCUMEN Treating system 3 7 BISELLO 2 7 BISELLO 3 data for average 7 BALTRU total DOCUMENT IL	of ID Tistematicerrors 91 D 91 D 92 Ses, fits, limit SAIT86 M	ECN COMMENT s as correlated.) M2 $J/\psi \rightarrow \gamma \mu$ M2 $J/\psi \rightarrow \gamma \mu$ s, etc. • •	ρ ⁰ ρ ⁰ ρ ρ ⁺ ρ ⁻	$\Gamma(2(\pi^{+}\pi^{-}))/\Gamma_{tot}$ $VALUE$ 0.012 ±0.004 OUF 0.0120±0.0031 OUF 0.0105±0.0017±0.00 0.013 ±0.006 0.020 +0.015 -0.010 $\Gamma(2(K^{+}K^{-}))/\Gamma_{tot}$ $VALUE$	R EVALUATI R AVERAGE 034 1	ON DOCUMENT IE 37 BISELLO 25 FBALTRUSAI 10 HIMEL	91 D T86 N 80B N	M2 $J/\psi ightarrow \gamma 2\pi^+$ IRK3 $J/\psi ightarrow$ IRK2 $\psi(25)-$	$\Gamma_{15,\gamma}$ τ
ALUE (units 10^{-3}) 26 \pm 9 OUR E 25 \pm 8 OUR A 26.0 \pm 2.4 \pm 8.8 23.6 \pm 10.6 \pm 8.2 • • We do not use (140 (K*(892)^0 K^- π + ALUE 02 \pm 0.007	CL% EVT. EVALUATION WERAGE 11: 3: the followin 90 -+ c.c.)/I EVTS 63	5 DOCUMEN Treating system 3 7 BISELLO 2 7 BISELLO 3 data for average 7 BALTRU total DOCUMENT IL	of ID Tistematicerrors 91 D 91 D 92 Ses, fits, limit SAIT86 M	ECN <u>COMMENT</u> s as correlated.) M2 $J/\psi \rightarrow \gamma_{I}$ M2 $J/\psi \rightarrow \gamma_{I}$ s, etc. • • RK3 $J/\psi \rightarrow \eta_{C}$	ρ ⁰ ρ ⁰ ρ ρ ⁺ ρ ⁻ ε ^γ	$\Gamma(2(\pi^{+}\pi^{-}))/\Gamma_{tot}$ $VALUE$ 0.012 ±0.004 OUR 0.0120±0.0031 OUF 0.0105±0.0017±0.0 0.013 ±0.006 0.020 +0.015 $\Gamma(2(K^{+}K^{-}))/\Gamma_{tot}$	R EVALUATI R AVERAGE 034 1	ON DOCUMENT IE 37 BISELLO 25 FBALTRUSAI 10 HIMEL	91 D T86 N 80B N	ECN COMMEN M2 $J/\psi ightharpoonup \gamma 2\pi^+$ IRK3 $J/\psi ightharpoonup 1$ IRK2 $\psi(25)$ —	Γ_{15} τ
$\begin{array}{lll} & \begin{array}{lllllllllllllllllllllllllllllllllll$	$\frac{CL\%}{EVT}$ EVT. $\frac{EVT}{EVALUATIC}$ 11: 3: the following 90 $\frac{EVT}{63}$ $\frac{EVTS}{63}$	ON (Treating system) The property of the prop	stematicerrors 91 D 91 D ges, fits, limit SAIT86 M T86 MRK	ECN COMMENT s as correlated.) M2 $J/\psi \rightarrow \gamma_{I}$ M2 $J/\psi \rightarrow \gamma_{I}$ S, etc. • • • RK3 $J/\psi \rightarrow \eta_{C}$	ρ ⁰ ρ ⁰ ρ ρ ⁺ ρ ⁻	$\Gamma(2(\pi^{+}\pi^{-}))/\Gamma_{tot}$ $VALUE$ 0.012 ±0.004 OUF 0.0120±0.0031 OUF 0.0105±0.0017±0.00 0.013 ±0.006 0.020 +0.015 -0.010 $\Gamma(2(K^{+}K^{-}))/\Gamma_{tot}$ $VALUE$	R EVALUATI R AVERAGE 034 1	ON DOCUMENT IE 37 BISELLO 25 FBALTRUSAI 10 HIMEL	91 D T86 N 80B N	M2 $J/\psi ightarrow \gamma 2\pi^+$ IRK3 $J/\psi ightarrow$ IRK2 $\psi(25)-$	$ \begin{array}{c} \Gamma_{15}, \\ \tau \\ \end{array} $ $ \begin{array}{c} -2\pi^{-} \\ \eta_{c}\gamma \\ $
26 \pm 9 OUR E 25 \pm 8 OUR A 26.0 \pm 2.4 \pm 8.8 23.6 \pm 10.6 \pm 8.2 • • We do not use (140 ($K^*(892)^0K^-\pi^+$ 44.UE 02 \pm 0.007 ($K^*(892)\overline{K}^*(892)$	CL% EVTS STALUATIC WERAGE 11: 3: the followin 90 -+ c.c.)/I EVTS 63))// total EVTS	S DOCUMENT IE	stematicerrors 91 D 91 D 93 D 94 SAIT86 M 95 TECN	ECN COMMENT s as correlated.) M2 $J/\psi \rightarrow \gamma_{\mu}$ s, etc. • • RK3 $J/\psi \rightarrow \eta_{C}$ COMMENT COMMENT	ρ ⁰ ρ ⁰ ρ ρ ⁺ ρ ⁻ ε ^γ	$ \begin{array}{c} \Gamma \left(2(\pi^{+}\pi^{-}) \right) / \Gamma_{\text{tot}} \\ \frac{VALUE}{0.012 \pm 0.004} \text{OUF} \\ 0.012 \pm 0.004 \text{OUF} \\ 0.0120 \pm 0.0031 \text{OUF} \\ 0.0105 \pm 0.0017 \pm 0.00 \\ 0.020 + 0.015 \\ -0.010 \\ \end{array} $ $ \begin{array}{c} \Gamma \left(2(K^{+}K^{-}) \right) / \Gamma_{\text{tot}} \\ \frac{VALUE}{0.021 \pm 0.010 \pm 0.006} \\ \Gamma \left(p\overline{p} \right) / \Gamma_{\text{total}} \\ \frac{VALUE}{0.001} \left(\frac{VALUE}{0.001} \right) - \frac{VALUE}{0.001} $	R EVALUATI R AVERAGE 034 1 otal	ON DOCUMENT IE 37 BISELLO 25 FBALTRUSAI 10 HIMEL	91 D T86 N 80B N	M2 $J/\psi ightarrow \gamma 2\pi^+$ IRK3 $J/\psi ightarrow$ IRK2 $\psi(25)-$	$ \begin{array}{c} \Gamma_{15}, \\ \tau \\ \end{array} $ $ \begin{array}{c} -2\pi^{-} \\ \eta_{c}\gamma \\ $
$\begin{array}{lll} \frac{MUE \text{ (units }10^{-3})}{26 \pm 9} & \text{OUR E} \\ 25 \pm 8 & \text{OUR A} \\ 26.0 \pm 2.4 \pm 8.8 \\ 23.6 \pm 10.6 \pm 8.2 \\ \bullet & \text{We do not use} \\ 140 \\ (K^*(892)^0 K^- \pi^+ \\ \frac{MUE}{2} \\ 02 \pm 0.007 \\ (K^*(892) \overline{K}^*(892) \\ \frac{MUE \text{ (units }10^{-4})}{6 \pm 31 \text{ OUR AVERAG}} \end{array}$	CL% EVTS STALUATIC WERAGE 11: 3: the followin 90 -+ c.c.)/I EVTS 63))// total EVTS	ON (Treating system) The property of the prop	stematicerrors 91 D 91 D 93 D 94 SAIT86 M 95 TECN	ECN COMMENT s as correlated.) M2 $J/\psi \rightarrow \gamma_{I}$ M2 $J/\psi \rightarrow \gamma_{I}$ S, etc. • • IRK3 $J/\psi \rightarrow \eta_{C}$ COMMENT $= \frac{COMMENT}{e^{+}e^{-}}$	ρ ⁰ ρ ⁰ ρ ⁺ ρ ⁻ c ^γ Γ ₃ /Γ	$ \begin{split} & \Gamma \big(2 \big(\pi^+ \pi^- \big) \big) / \Gamma_{\text{tot}} \\ & \frac{VALUE}{0.012 \pm 0.004} \text{OUF} \\ & 0.012 \pm 0.004 \text{OUF} \\ & 0.0120 \pm 0.0031 \text{OUF} \\ & 0.0105 \pm 0.0017 \pm 0.00 \\ & 0.013 \pm 0.006 \\ & 0.020 + 0.015 \\ & \Gamma \big(2 \big(K^+ K^- \big) \big) / \Gamma_{\text{tot}} \\ & \frac{VALUE}{0.021 \pm 0.010 \pm 0.006} \\ & \Gamma \big(p \overline{p} \big) / \Gamma_{\text{total}} \\ & \frac{VALUE \left(\text{units } 10^{-4} \right)}{12 \pm 4 \text{OUR AVERA}} \end{split} $	E EVALUATION OF THE PROPERTY O	ON DOCUMENT ID 37 PBISELLO 25 PBALTRUSAL 10 HIMEL DOCUMENT ID ALBRECHT 94	91 D T86 N 80B N TECN H ARG	M2 $J/\psi \rightarrow \gamma 2\pi^+$ IRK3 $J/\psi \rightarrow 1$ IRK2 $\psi(25) - \frac{COMMENT}{\gamma \gamma \rightarrow K^+ K}$	$ \begin{array}{c} \Gamma_{15}, \\ \tau \\ \end{array} $ $ \begin{array}{c} -2\pi^{-} \\ \eta_{c}\gamma \\ $
26 \pm 9 OUR E 25 \pm 8 OUR E 25 \pm 8 OUR E 26.0 \pm 2.4 \pm 8.8 23.6 \pm 10.6 \pm 8.2 • • We do not use 140 ($K^{\bullet}(892)^{0}K^{-}\pi^{+}$ 12UE 102 \pm 0.007 ($K^{\bullet}(892)\overline{K}^{\bullet}(892)$ 12UE (units 10 ⁻⁴) \pm 31 OUR AVERAGE 1 \pm 28 \pm 27	CL% EVT. EVT. VERAGE 11: 3: 1the followin 90 -+ c.c.)/I - EVTS 63))/\Gamma_total EVTS 65	DOCUMENT ILE DOCUMENT ILE DOCUMENT ILE DOCUMENT ILE BISSELLO BISSELLO DOCUMENT ILE BISSELLO BISSELLO	stematicerrors 91 D 91 D 91 D 91 D TECN 91 D TECN 91 DM2	ECN COMMENT s as correlated.) M2 $J/\psi \rightarrow \gamma_{\mu}$ s, etc. • • RK3 $J/\psi \rightarrow \eta_{C}$ COMMENT COMMENT	ρ ⁰ ρ ⁰ ρ ⁺ ρ ⁻ c ^γ Γ ₃ /Γ	$ \begin{split} & \Gamma \big(2 \big(\pi^+ \pi^- \big) \big) / \Gamma_{\text{tot}} \\ & \underbrace{^{NALUE}}_{0.012 \ \pm 0.004} \ \text{OUF} \\ & 0.012 \ \pm 0.0031 \ \text{OUF} \\ & 0.0105 \ \pm 0.0017 \ \pm 0.006 \\ & 0.013 \ \pm 0.006 \\ & 0.020 \ + 0.015 \\ & -0.010 \\ \\ & \Gamma \big(2 \big(K^+ K^- \big) \big) / \Gamma_{\text{tot}} \\ & \underbrace{^{NALUE}}_{NALUE} \\ & 0.021 \ \pm 0.010 \ \pm 0.006 \\ & \Gamma \big(p \overline{p} \big) / \Gamma_{\text{total}} \\ & \underbrace{^{NALUE}_{\text{(units } 10^{-4})}}_{12 \ \pm 4} \ \text{OUR AVERA} \\ & 10 \ \pm \ 3 \ \pm 4 \\ & 11 \ \pm \ 6 \end{split} $	R EVALUATI R AVERAGE 034 1 otal	77 BISELLO 25 7 BALTRUSAI 10 HIMEL DOCUMENT ID ALBRECHT 94 DOCUMENT ID 7 BISELLO 91 7 BALTRUSAIT86	91 DT86 M 80B M H ARG	ECN COMMEN M2 $J/\psi \rightarrow \gamma 2\pi^{+}$ RK3 $J/\psi \rightarrow \gamma \pi^{+}$ RK2 $\psi(25) - \gamma \pi^{-}$ COMMENT $\gamma \gamma \rightarrow K^{+}K$ COMMENT $J/\psi \rightarrow \gamma p \overline{p}$	$ \begin{array}{c} \Gamma_{15}, \\ \tau \\ \end{array} $ $ \begin{array}{c} -2\pi^{-} \\ \eta_{c}\gamma \\ $
$\begin{array}{lll} & \text{AUE (units 10^{-3})} \\ & 26 & \pm 9 & \text{OUR E} \\ & 25 & \pm 8 & \text{OUR A} \\ & 26.0 \pm 2.4 \pm 8.8 \\ & 23.6 \pm 10.6 \pm 8.2 \\ & \bullet \text{ We do not use} \\ & (140) \\ & \left(K^{\bullet}(892)^{0} K^{-} \pi^{+} \right. \\ & \left. 4UE \\ & 02 & \pm 0.007 \\ & \left(K^{\bullet}(892) \overline{K}^{\bullet}(892) \overline{K}^{\bullet}(892$	CL% EVT. EVALUATION WERAGE 11: 3: 3: the followin 90 -+ c.c.)/I	DOCUMENT ILE DOCUMENT ILE DOCUMENT ILE DOCUMENT ILE BISSELLO BISSELLO DOCUMENT ILE BISSELLO BISSELLO	stematicerrors 91 D 91 D 91 D 91 D TECN 91 D TECN 91 DM2	ECN COMMENT s as correlated.) M2 $J/\psi \rightarrow \gamma_{\mu}$ s, etc. • • RK3 $J/\psi \rightarrow \eta_{c}$ $J/\psi \rightarrow \eta_{c}$ $J/\psi \rightarrow \eta_{c}$ COMMENT $J/\psi \rightarrow \eta_{c}$ $J/\psi \rightarrow \eta_{c}$	ρ ⁰ ρ ⁰ ρ ⁺ ρ ⁻ c ^γ Γ ₄ /Γ	$ \begin{split} &\Gamma\big(2(\pi^+\pi^-)\big)/\Gamma_{\text{tot}} \\ &\frac{VALUE}{0.012 \pm 0.004} \text{OUR} \\ &0.012 \pm 0.0031 \text{OUR} \\ &0.0120 \pm 0.0031 \text{OUR} \\ &0.0105 \pm 0.0017 \pm 0.00 \\ &0.013 \pm 0.006 \\ &0.020 + 0.015 \\ &0.020 + 0.015 \\ &\Gamma\big(2(K^+K^-)\big)/\Gamma_{\text{tot}} \\ &\frac{VALUE}{0.021 \pm 0.010 \pm 0.006} \\ &\Gamma\big(p\overline{p}\big)/\Gamma_{\text{total}} \\ &\frac{VALUE}{12 \pm 4 \text{OUR} \text{AVERA}} \\ &10 \pm 3 \pm 4 \end{split} $	E EVALUATION OF THE PROPERTY O	77 BISELLO 25 7 BALTRUSAI 10 HIMEL DOCUMENT ID ALBRECHT 94 DOCUMENT ID 7 BISELLO 91 7 BALTRUSAIT86	91 DT86 M 808 M H ARG DM2 MRK3	ECN COMMEN M2 $J/\psi \rightarrow \gamma 2\pi^{+}$ RK3 $J/\psi \rightarrow \gamma \pi^{+}$ RK2 $\psi(25) - \gamma \pi^{-}$ COMMENT $\gamma \gamma \rightarrow K^{+}K$ COMMENT $J/\psi \rightarrow \gamma p \overline{p}$	$ \begin{array}{c} \Gamma_{15} \\ \tau \\ \end{array} $ $ \begin{array}{c} $
26.0 \pm 9 OUR E 25 \pm 8 OUR A 26.0 \pm 2.4 \pm 8.8 23.6 \pm 10.6 \pm 8.2 • • We do not use (140) ($K^*(892)^0K^-\pi^+$ 4LUE .02 \pm 0.007 ($K^*(892)\overline{K}^*(892)$ ALUE (units 10 ⁻⁴) 5 \pm 31 OUR AVERAG 2 \pm 28 \pm 27 0. \pm 50 ($K^*(892)\overline{K}$ + c.c.	CL% EVT. EVALUATION WERAGE 11: 3: 3: the followin 90 -+ c.c.)/I	DOCUMENT ILE DOCUMENT ILE DOCUMENT ILE DOCUMENT ILE BISSELLO BISSELLO DOCUMENT ILE BISSELLO BISSELLO	stematicerrors 91 D 91 D ges, fits, limit SAIT86 M T86 MRK D TECN 91 DM2 T86 MRK	ECN COMMENT 5 as correlated.) M2 $J/\psi \rightarrow \gamma_{H}$ 5, etc. • • RK3 $J/\psi \rightarrow \eta_{C}$ COMMENT $e^{+}e^{-} \rightarrow \gamma_{K} + K - \pi$ 3 $J/\psi \rightarrow \eta_{C}\gamma$	ρ ⁰ ρ ⁰ ρ ¹ ε ^γ Γ ₃ /Γ Γ ₄ /Γ	$ \begin{split} & \Gamma \big(2 \big(\pi^+ \pi^- \big) \big) / \Gamma_{\text{tot}} \\ & \frac{VALUE}{O.012 \pm 0.004} \text{OUF} \\ & 0.012 \pm 0.004 \text{OUF} \\ & 0.0120 \pm 0.0031 \text{OUF} \\ & 0.0105 \pm 0.0017 \pm 0.00 \\ & 0.013 \pm 0.006 \\ & 0.020 + 0.015 \\ \hline & \Gamma \big(2 \big(K^+ K^- \big) \big) / \Gamma_{\text{tot}} \\ & \frac{VALUE}{VALUE} \\ & 0.021 \pm 0.010 \pm 0.006 \\ \hline & \Gamma \big(p \overline{p} \big) / \Gamma_{\text{total}} \\ & \frac{VALUE \left(\text{units } 10^{-4} \right)}{12 \pm 4 \text{OUR AVERA}} \\ & 10 \pm 3 \pm 4 \\ & 11 \pm 6 \\ & 29 {}^{+29}_{-15} \end{split} $	E EVALUATION OF THE PROPERTY O	77 BISELLO 25 7 BALTRUSAI 10 HIMEL DOCUMENT ID ALBRECHT 94 DOCUMENT ID 7 BISELLO 91 7 BALTRUSAIT86	91 DT86 M 808 M H ARG DM2 MRK3	M2 $J/\psi \rightarrow \gamma 2\pi^+$ IRK3 $J/\psi \rightarrow 1$ IRK2 $\psi(2S) \rightarrow 1$ $COMMENT$ $J/\psi \rightarrow \gamma p \overline{p}$ $J/\psi \rightarrow \eta_C \gamma$	Γ_{15} , τ
ALUE (units 10^{-3}) 26 ± 9 OUR E 25 ± 8 OUR A 26.0± 2.4±8.8 23.6±10.6±8.2 • • We do not use (140 (K*(892)^0 K^- π + ALUE .02 ±0.007 (K*(892)\overline{K}*(892) ALUE (units 10^{-4}) 5±31 OUR AVERAG 2±28±27 0±50 (K*(892)\overline{K}+ c.c. ALUE	CL% EVT. EVALUATION WERAGE 11: 3: the followin 90 -+ c.c.)// EVTS 63))// total EVTS 14 9 -)// total	S DOCUMENT IL DOCUMENT IL DOCUMENT IL BISELLO DOCUMENT IL DOCUMENT IL DOCUMENT IL BISELLO DOCUMENT IL DOCUMENT IL DOCUMENT IL DOCUMENT IL BISELLO	91 D 10 10 10 10 10 10 10 10 10 10 10 10 10	ECN COMMENT 5 as correlated.) M2 $J/\psi \rightarrow \gamma_{\mu}$ 5, etc. • • RK3 $J/\psi \rightarrow \eta_{c}$ COMMENT $V_{c} = V_{c} + V_{c}$ $V_{c} = V_{c} + V_{c}$ $V_{c} = V_{c} + V_{c}$ COMMENT $V_{c} = V_{c} + V_{c}$	$ \frac{\rho^0 \rho^0}{\rho^+ \rho^-} $ $ \frac{\Gamma_3}{\Gamma} $ $ \frac{\Gamma_4}{\Gamma} $ $ \frac{\Gamma_8}{\kappa^{\pm} \pi^{\mp}} $	$ \begin{array}{l} \Gamma(2(\pi^{+}\pi^{-}))/\Gamma_{\rm tot} \\ \frac{VALUE}{O.012 \pm 0.004} {\rm OUF} \\ 0.012 \pm 0.004 {\rm OUF} \\ 0.0120 \pm 0.0031 {\rm OUF} \\ 0.0105 \pm 0.0017 \pm 0.00 \\ 0.0105 \pm 0.0017 \pm 0.00 \\ 0.020 + 0.015 \\ -0.010 \\ \hline \Gamma(2(K^{+}K^{-}))/\Gamma_{\rm tot} \\ \frac{VALUE}{VALUE} \\ 0.021 \pm 0.010 \pm 0.006 \\ \hline \Gamma(p\overline{p})/\Gamma_{\rm total} \\ \frac{VALUE}{VALUE} {\rm OUR} {\rm AVERA} \\ 10 \pm 3 \pm 4 \\ 11 \pm 6 \\ 29 ^{+29}_{-15} \\ \hline \Gamma(K\overline{K}\eta)/\Gamma_{\rm total} \\ \end{array} $	EVALUATION REPORT OF THE PROPERTY OF THE PROPE	77 BISELLO 25 7 BALTRUSAI 10 HIMEL DOCUMENT ID ALBRECHT 94 DOCUMENT ID 7 BISELLO 91 7 BALTRUSAIT86	91 DT86 M 808 M - TECN H ARG - TECN DM2 MRK3 B MRK2	M2 $J/\psi \rightarrow \gamma 2\pi^+$ IRK3 $J/\psi \rightarrow 1$ IRK2 $\psi(2S) \rightarrow 1$ $COMMENT$ $J/\psi \rightarrow \gamma p \overline{p}$ $J/\psi \rightarrow \eta_C \gamma$	Γ_{15} , τ
26.0 ± 9 OUR E 25 ± 8 OUR A 26.0 ± 2.4 ± 8.8 23.6 ± 10.6 ± 8.2 • We do not use <140 $(K^*(892)^0K^-\pi^+$ ALUE (units 10 ⁻⁴) 5 ± 31 OUR AVERAGE 2 ± 28 ± 27 0 ± 50 $(K^*(892)\overline{K}^+$ c.c. ALUE (0.0128	CL% EVT. EVALUATION WERAGE 11: 3: 3: the followin 90 -+ c.c.)/I EVTS 63 3))// total EVTS 14 9 -)// total CL%	DOCUMENT ID	91 D 91 D 91 D 91 D 91 D 70 FECN 91 D 71 FECN 91 DM2 71 FECN 91 DM2 71 FECN 91 DM2 71 FECN 71	ECN COMMENT s as correlated.) M2 $J/\psi \rightarrow \gamma_{H}$ s, etc. • • RK3 $J/\psi \rightarrow \eta_{C}$ COMMENT $J/\psi \rightarrow \eta_{C}$	$ \frac{\rho^0 \rho^0}{\rho^+ \rho^-} $ $ \frac{\Gamma_3}{\Gamma} $ $ \frac{\Gamma_4}{\Gamma} $ $ \frac{\Gamma_8}{\kappa^{\pm} \pi^{\mp}} $	$ \begin{split} & \Gamma \big(2 \big(\pi^+ \pi^- \big) \big) / \Gamma_{\text{tot}} \\ & \frac{VALUE}{O.012 \pm 0.004} \text{OUF} \\ & 0.012 \pm 0.004 \text{OUF} \\ & 0.0120 \pm 0.0031 \text{OUF} \\ & 0.0105 \pm 0.0017 \pm 0.00 \\ & 0.013 \pm 0.006 \\ & 0.020 + 0.015 \\ \hline & \Gamma \big(2 \big(K^+ K^- \big) \big) / \Gamma_{\text{tot}} \\ & \frac{VALUE}{VALUE} \\ & 0.021 \pm 0.010 \pm 0.006 \\ \hline & \Gamma \big(p \overline{p} \big) / \Gamma_{\text{total}} \\ & \frac{VALUE \left(\text{units } 10^{-4} \right)}{12 \pm 4 \text{OUR AVERA}} \\ & 10 \pm 3 \pm 4 \\ & 11 \pm 6 \\ & 29 {}^{+29}_{-15} \end{split} $	E EVALUATION OF THE PROPERTY O	ON DOCUMENT ID 37 PBISELLO 25 PBALTRUSAI 10 HIMEL DOCUMENT ID ALBRECHT 94 DOCUMENT ID 7 BISELLO 91 7 BALTRUSAIT86 10 HIMEL 80	91 C T86 M 808 M H ARG TECN DM2 MRK3 B MRK2	$\begin{array}{lll} \text{EEN} & \text{COMMEN} \\ \text{M2} & J/\psi \rightarrow \\ & \gamma 2\pi^{+} \\ \text{IRK3} & J/\psi \rightarrow \\ \text{IRK2} & \psi(25) - \\ & \\ \hline & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\$	Γ_{15} , τ
26 \pm 9 OUR E 25 \pm 8 OUR A 26.0 \pm 2.4 \pm 8.8 23.6 \pm 10.6 \pm 8.2 • • We do not use <140 • (K*(892) ⁰ K ⁻ π ⁺ **ALUE* **.02 \pm 0.007 **I(K*(892) K*(892) K	2018 EVT. VALUATION VERAGE 11: 32: 1the followin 90 -+ c.c.)/I	S DOCUMENT IL DOCUMENT IL DOCUMENT IL BISELLO DOCUMENT IL DOCUMENT IL DOCUMENT IL BISELLO DOCUMENT IL DOCUMENT IL DOCUMENT IL DOCUMENT IL BISELLO	91 D 10 10 10 10 10 10 10 10 10 10 10 10 10	ECN COMMENT 5 as correlated.) M2 $J/\psi \rightarrow \gamma_{\mu}$ 5, etc. • • RK3 $J/\psi \rightarrow \eta_{c}$ COMMENT $V_{c} = V_{c} + V_{c}$ $V_{c} = V_{c} + V_{c}$ $V_{c} = V_{c} + V_{c}$ COMMENT $V_{c} = V_{c} + V_{c}$	$ \frac{\rho^0 \rho^0}{\rho^+ \rho^-} $ $ \frac{\Gamma_3}{\Gamma} $ $ \frac{\Gamma_4}{\Gamma} $ $ \frac{\Gamma_8}{\kappa^{\pm} \pi^{\mp}} $	$ \begin{split} & \Gamma \big(2 \big(\pi^+ \pi^- \big) \big) / \Gamma_{\text{tot}} \\ & \frac{VALUE}{O.012 \pm 0.004} \text{OUF} \\ & 0.012 \pm 0.004 \text{OUF} \\ & 0.0120 \pm 0.0031 \text{OUF} \\ & 0.0105 \pm 0.0017 \pm 0.00 \\ & 0.0105 \pm 0.0017 \pm 0.00 \\ & 0.020 + 0.015 \\ & -0.010 \\ & \Gamma \big(2 \big(K^+ K^- \big) \big) / \Gamma_{\text{tot}} \\ & \frac{VALUE}{VALUE} \\ & 0.021 \pm 0.010 \pm 0.006 \\ & \Gamma \big(p \overline{p} \big) / \Gamma_{\text{total}} \\ & \frac{VALUE}{11 \pm 6} \\ & 29 ^{+29}_{-15} \\ & \Gamma \big(K \overline{K} \eta \big) / \Gamma_{\text{total}} \\ & \frac{VALUE}{VALUE} \\ & < 0.031 \\ \end{split} $	EVALUATI R EVALUATI R AVERAGE 034 1 Detai EVTS GE 18 23 CL% 90	77 BISELLO 25 7 BALTRUSAI 10 HIMEL DOCUMENT ID ALBRECHT 94 DOCUMENT ID 7 BISELLO 91 7 BALTRUSAIT86 10 HIMEL 80	91 C T86 M 808 M H ARG TECN DM2 MRK3 B MRK2	$\begin{array}{lll} \text{EEN} & \text{COMMEN} \\ \text{M2} & J/\psi \rightarrow \\ & \gamma 2\pi^{+} \\ \text{IRK3} & J/\psi \rightarrow \\ \text{IRK2} & \psi(25) - \\ & \\ \hline & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\$	Γ _{15,} τ -2π- η _c γ Γ _{14,} - κ+ κ Γ _{16,} γ
26 ± 9 OUR E 25 ± 8 OUR A 26.0± 2.4±8.8	2018 EVT. VALUATION VERAGE 11: 32: 1the followin 90 -+ c.c.)/I	S DOCUMENT IL DOCUMENT IL DOCUMENT IL BISELLO DOCUMENT IL DOCUMENT IL DOCUMENT IL BISELLO DOCUMENT IL DOCUMENT IL DOCUMENT IL DOCUMENT IL BISELLO	91 D 10 10 10 10 10 10 10 10 10 10 10 10 10	ECN COMMENT 5 as correlated.) M2 $J/\psi \rightarrow \gamma_{\mu}$ 5, etc. • • RK3 $J/\psi \rightarrow \eta_{c}$ COMMENT $V_{c} = V_{c} + V_{c}$ $V_{c} = V_{c} + V_{c}$ $V_{c} = V_{c} + V_{c}$ COMMENT $V_{c} = V_{c} + V_{c}$	Γ_{3}/Γ Γ_{4}/Γ Γ_{8}/Γ Γ_{6}/Γ Γ_{7}/Γ	$ \begin{split} & \Gamma \big(2 \big(\pi^+ \pi^- \big) \big) / \Gamma_{\text{tot}} \\ & \underbrace{_{VALUE}} \\ & 0.012 \pm 0.004 \text{OUR} \\ & 0.0120 \pm 0.0031 \text{OUF} \\ & 0.0105 \pm 0.0017 \pm 0.00 \\ & 0.013 \pm 0.006 \\ & 0.020 + 0.015 \\ & 0.020 + 0.015 \\ & \underbrace{_{VALUE}} \\ & 0.021 \pm 0.010 \pm 0.006 \\ & \Gamma \big(p\overline{p} \big) / \Gamma_{\text{total}} \\ & \underbrace{_{VALUE}} \\ & \underbrace{_{VALUE}} \\ & 12 \pm 4 \text{OUR AVERA} \\ & 10 \pm 3 \pm 4 \\ & 11 \pm 6 \\ & 29 ^{+29}_{-15} \\ & \Gamma \big(\mathcal{K} \mathcal{K} \eta \big) / \Gamma_{\text{total}} \\ & \underbrace{_{VALUE}} \\ & _$	EVALUATI R EVALUATI R AVERAGE 034 1 Detai EVTS GE 18 23 CL% 90	77 BISELLO 25 7 BALTRUSAI 10 HIMEL DOCUMENT ID ALBRECHT 94 DOCUMENT ID 7 BISELLO 91 7 BALTRUSAIT86 10 HIMEL 80	91 DT86 M 808 M - TECN H ARG DM2 MRK3 B MRK2	$\begin{array}{lll} \text{EEN} & \text{COMMEN} \\ \text{M2} & J/\psi \rightarrow \\ & \gamma 2\pi^{+} \\ \text{IRK3} & J/\psi \rightarrow \\ \text{IRK2} & \psi(25) - \\ & \\ \hline & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\$	$ \begin{array}{c} \Gamma_{15,\gamma} \\ \tau \\ \end{array} $ $ \begin{array}{c} $
26. \pm 9 OUR E 25 \pm 8 OUR A 26.0 \pm 2.4 \pm 8.8 OUR A 26.0 \pm 2.4 \pm 8.8 23.6 \pm 10.6 \pm 8.2 • We do not use (140 (K*(892)°K* π +4.02 \pm 0.007 (K*(892) \overline{K} *(892) \overline{K} *(892) \overline{K} *(892) \overline{K} +c.c. 4.02 \pm 0.0128 (0.0132 ($\phi \phi$)/ Γ total ALUE (units 10 ⁻⁴) 1±28 OUR EVALUA	CL% EVT. EVALUATION (CL% EVT. EVALUATION (CL% EVT. (CL% 90	DOCUMENT IL	91 D 10 10 10 10 10 10 10 10 10 10 10 10 10	ECN COMMENT s as correlated.) M2 $J/\psi \rightarrow \gamma_{\ell}$ s, etc. • • RK3 $J/\psi \rightarrow \eta_{c}$ $J/\psi \rightarrow \eta_{c}$ COMMENT $e^{+}e^{-} \rightarrow \gamma_{c} \gamma$ $J/\psi \rightarrow \eta_{c} \gamma$ COMMENT $J/\psi \rightarrow \gamma_{c} \gamma$ COMMENT $J/\psi \rightarrow \gamma_{c} \gamma$	Γ_{3}/Γ Γ_{4}/Γ Γ_{8}/Γ Γ_{6}/Γ Γ_{7}/Γ	$ \begin{split} & \Gamma \big(2 \big(\pi^+ \pi^- \big) \big) / \Gamma_{\text{tot}} \\ & \underbrace{_{VALUE}} \\ & 0.012 \pm 0.004 \text{OUR} \\ & 0.0120 \pm 0.0031 \text{OUR} \\ & 0.0105 \pm 0.0017 \pm 0.00 \\ & 0.013 \pm 0.006 \\ & 0.020 + 0.015 \\ & \underbrace{_{VALUE}} \\ & 0.021 \pm 0.010 \pm 0.006 \\ & \Gamma \big(p\overline{p} \big) / \Gamma_{\text{total}} \\ & \underbrace{_{VALUE}} \\ & \underbrace{_{VALUE}} \\ & 12 \pm 4 \text{OUR AVERA} \\ & 10 \pm 3 \pm 4 \\ & 11 \pm 6 \\ & 29 \stackrel{+29}{-15} \\ & \Gamma \big(\mathcal{K} \mathcal{K} \eta \big) / \Gamma_{\text{total}} \\ & \underbrace{_{VALUE}} \\ & < 0.031 \\ & \Gamma \big(\pi^+ \pi^- p\overline{p} \big) / \Gamma_{\text{tot}} \\ & \end{split} $	EVALUATI R EVALUATI R AVERAGE 034 1 Obtai EVTS 18 23 90 tail	TS DOCUMENT ID 37 PARTRUSAI 37 PARTRUSAI 10 HIMEL DOCUMENT ID ALBRECHT 94 DOCUMENT ID 7 BISELLO 91 7 BALTRUSAIT86 DOCUMENT ID 7 BALTRUSAIT86 DOCUMENT ID 7 BALTRUSAIT86	91 DT86 N 80B N H ARG TECN DM2 MRK3 B MRK2 TECN MRK3	$\begin{array}{lll} \text{EEN} & \underline{\text{COMMEN}} \\ & \gamma	Γ_{15} , τ Γ_{16} , Γ_{16} , Γ_{16} , Γ_{17} , Γ_{18} ,
ALUE (units 10^{-3}) 26 \pm 9 OUR E 25 \pm 8 OUR A 26.0 \pm 2.4 \pm 8.8 23.6 \pm 10.6 \pm 8.2 • We do not use (140) (K*(892) ⁰ K ⁻ π ⁺ ALUE 02 \pm 0.007 (K*(892) \overline{K} *(892 ALUE (units 10^{-4}) 5 \pm 31 OUR AVERAG 2 \pm 28 \pm 27 0 \pm 50 (K*(892) \overline{K} + c.c. ALUE (0.0138 (0.0132 ($\phi \phi$)/ Γ total ALUE (units 10^{-4}) 1 \pm 28 OUR EVALUA 1 \pm 20 UR AVERAG	CL% EVT. EVALUATION (CL% EVT. EVALUATION (CL% EVT. (CL% 90	DOCUMENT IL	91 D 10 10 10 10 10 10 10 10 10 10 10 10 10	SECN COMMENT So as correlated.) M2 $J/\psi \rightarrow \gamma_{H}$ M2 $J/\psi \rightarrow \gamma_{H}$ M3 $J/\psi \rightarrow \eta_{C}$ M6 SIRK3 $J/\psi \rightarrow \eta_{C}$ COMMENT $e^{+}e^{-} \rightarrow \gamma_{K} + K^{-}\pi$ 3 $J/\psi \rightarrow \eta_{C}\gamma$ COMMENT $J/\psi \rightarrow \gamma_{C} K^{0}$ $J/\psi \rightarrow \gamma_{C} K^{0}$ COMMENT $J/\psi \rightarrow \gamma_{C} K^{0}$ $J/\psi \rightarrow \gamma_{C} K^{0}$ $J/\psi \rightarrow \gamma_{C} K^{0}$ COMMENT Trelated.)	Γ_{3}/Γ Γ_{4}/Γ Γ_{8}/Γ Γ_{6}/Γ Γ_{7}/Γ	$ \begin{split} & \Gamma \left(2(\pi^+\pi^-) \right) / \Gamma_{\text{tot}} \\ & \frac{VALUE}{0.012 \pm 0.004} \text{OUR} \\ & 0.012 \pm 0.0031 \text{OUF} \\ & 0.0120 \pm 0.0031 \text{OUF} \\ & 0.0105 \pm 0.0017 \pm 0.00 \\ & 0.013 \pm 0.006 \\ & 0.020 + 0.015 \\ \hline & \Gamma \left(2(K^+K^-) \right) / \Gamma_{\text{tot}} \\ & \frac{VALUE}{0.021 \pm 0.010 \pm 0.006} \\ & \Gamma \left(p\overline{p} \right) / \Gamma_{\text{total}} \\ & \frac{VALUE}{12 \pm 4 \text{OUR} \text{AVERA}} \\ & 10 \pm 3 \pm 4 \\ & 11 \pm 6 \\ & 29 \stackrel{+}{-}15 \\ \hline & \Gamma \left(K \overline{K} \eta \right) / \Gamma_{\text{total}} \\ & \frac{VALUE}{4 \text{OUS}} \\ & < 0.031 \\ \hline & \Gamma \left(\pi^+\pi^-p\overline{p} \right) / \Gamma_{\text{total}} \\ & < 0.012 \\ \end{split} $	E EVALUATI R EVALUATI R AVERAGE 034 1 obtai 18 23 CL% 90 tai CL%	TS DOCUMENT ID 37 PARTRUSAI 37 PARTRUSAI 10 HIMEL DOCUMENT ID ALBRECHT 94 DOCUMENT ID 7 BISELLO 91 7 BALTRUSAIT86 DOCUMENT ID 7 BALTRUSAIT86 DOCUMENT ID 7 BALTRUSAIT86	91 DT86 N 80B N H ARG TECN DM2 MRK3 B MRK2 TECN MRK3	EECN COMMEN M2 $J/\psi \rightarrow \gamma 2\pi^+$ RK3 $J/\psi \rightarrow 1$ RK2 $\psi(25) - 1$ COMMENT $J/\psi \rightarrow \gamma p \overline{p}$ $J/\psi \rightarrow \eta_C \gamma$ $\psi(25) \rightarrow \eta_C \gamma$ COMMENT $J/\psi \rightarrow \eta_C \gamma$	Γ ₁₅ , τ -2π ⁻ η _c γ Γ ₁₄ , - κ ⁺ κ Γ ₁₆ , γ Γ ₁₈ , γ
MUE (units 10 ⁻³) 26 ± 9 OUR E 25 ± 8 OUR A 26.0± 2.4±8.8 23.6±10.6±8.2 • • We do not use (140 (K*(892) 0 K $^{-}$ π $^{+}$ HUE 02 ±0.007 (K*(892) $^{\overline{K}}$ *(892) ±531 OUR AVERAG ±28±27 0±50 (K*(892) $^{\overline{K}}$ + c.c. HUE 0.0128 0.0132 ($\phi \phi$)/ $^{\Gamma}$ total H±28 OUR EVALUA ±22 OUR AVERAG ±18±24	CL% EVT. EVALUATION CL% EVT. CL% EVT. CL% EVT. CL% EVT. CL% CL% CL% CL% CL% CL% CL% CL	Total DOCUMENT IL	91 D TECN 91 DM2	ECN COMMENT 5 as correlated.) M2 $J/\psi \rightarrow \gamma_H$ M2 $J/\psi \rightarrow \gamma_H$ S, etc. • • • IRK3 $J/\psi \rightarrow \eta_C \gamma$ COMMENT $e^+e^- \rightarrow \gamma_K + K^-\pi$ 3 $J/\psi \rightarrow \gamma_C \gamma$ COMMENT $J/\psi \rightarrow \gamma_K + K^0$ COMMENT $J/\psi \rightarrow \gamma_K + K^0$ COMMENT Trelated.)	$ \rho^{0}\rho^{0} $ $ \rho^{+}\rho^{-} $ $ \Gamma_{3}/\Gamma $ $ \Gamma_{4}/\Gamma $ $ \Gamma_{8}/\Gamma $ $ \frac{\kappa^{\pm}\pi^{\mp}}{\kappa^{-}\pi^{0}} $ $ \Gamma_{5}/\Gamma $	$ \begin{split} & \Gamma \left(2(\pi^{+}\pi^{-}) \right) / \Gamma_{\text{tot}} \\ & \frac{VALUE}{0.012 \pm 0.004} \text{OUF} \\ & 0.012 \pm 0.0031 \text{OUF} \\ & 0.0105 \pm 0.0017 \pm 0.00 \\ & 0.013 \pm 0.006 \\ & 0.020 + 0.015 \\ & 0.020 + 0.015 \\ & - 0.010 \\ \end{split} $ $ & \Gamma \left(2(K^{+}K^{-}) \right) / \Gamma_{\text{tot}} \\ & \frac{VALUE}{0.021 \pm 0.010 \pm 0.006} \\ & \Gamma \left(p\overline{p} \right) / \Gamma_{\text{total}} \\ & \frac{VALUE}{11 \pm 6} \\ & 29 \stackrel{+}{-} 29 \\ & \Gamma \left(K \overline{K} \eta \right) / \Gamma_{\text{total}} \\ & \frac{VALUE}{0.010 \pm 0.006} \\ & \Gamma \left(K \overline{K} \eta \right) / \Gamma_{\text{total}} \\ & \frac{VALUE}{0.0031} \\ & \Gamma \left(K \overline{K} \eta \right) / \Gamma_{\text{total}} \\ & \frac{VALUE}{0.0031} \\ & \Gamma \left(\pi^{+}\pi^{-}p\overline{p} \right) / \Gamma_{\text{total}} \\ & \frac{VALUE}{0.0031} \\ & \Gamma \left(\pi^{+}\pi^{-}p\overline{p} \right) / \Gamma_{\text{total}} \\ & \frac{VALUE}{0.0031} \\ & \Gamma \left(\pi^{+}\pi^{-}p\overline{p} \right) / \Gamma_{\text{total}} \\ & \frac{VALUE}{0.0031} \\ & \Gamma \left(\pi^{+}\pi^{-}p\overline{p} \right) / \Gamma_{\text{total}} \\ & \frac{VALUE}{0.0031} \\ & \Gamma \left(\pi^{+}\pi^{-}p\overline{p} \right) / \Gamma_{\text{total}} \\ & \frac{VALUE}{0.0031} \\ & \frac{VALUE}{$	E EVALUATI R EVALUATI R AVERAGE 034 1 obtai 18 23 CL% 90 tai CL%	TS DOCUMENT ID 37 PARTRUSAI 37 PARTRUSAI 10 HIMEL DOCUMENT ID ALBRECHT 94 DOCUMENT ID 7 BISELLO 91 7 BALTRUSAIT86 DOCUMENT ID 7 BALTRUSAIT86 DOCUMENT ID 7 BALTRUSAIT86	91 DT86 N 80B N H ARG TECN DM2 MRK3 B MRK2 TECN MRK3	EECN COMMEN M2 $J/\psi \rightarrow \gamma 2\pi^+$ RK3 $J/\psi \rightarrow 1$ RK2 $\psi(25) - 1$ COMMENT $J/\psi \rightarrow \gamma p \overline{p}$ $J/\psi \rightarrow \eta_C \gamma$ $\psi(25) \rightarrow \eta_C \gamma$ COMMENT $J/\psi \rightarrow \eta_C \gamma$	Γ ₁₅ , τ -2π ⁻ η _c γ Γ ₁₄ , - κ ⁺ κ Γ ₁₆ , γ Γ ₁₈ , γ
MUE (units 10 ⁻³) 26 ± 9 OUR E 25 ± 8 OUR A 26.0± 2.4±8.8 23.6±10.6±8.2 • • We do not use (140 (K*(892) 0 K $^{-}$ π $^{+}$ HUE 02 ±0.007 (K*(892) $^{\overline{K}}$ *(892) ±531 OUR AVERAG ±28±27 0±50 (K*(892) $^{\overline{K}}$ + c.c. HUE 0.0128 0.0132 ($\phi \phi$)/ $^{\Gamma}$ total H±28 OUR EVALUA ±22 OUR AVERAG ±18±24	CL% EVT. EVALUATION CL% EVT. CL% EVT. CL% EVT. CL% EVT. CL% CL% CL% CL% CL% CL% CL% CL	DOCUMENT IC BISELLO T BISELLO T BALTRUSAI T BISELLO T BALTRUSAI DOCUMENT IC BISELLO T BALTRUSAI	91 D 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	ECN COMMENT s as correlated.) M2 $J/\psi \rightarrow \gamma_{K}$ M2 $J/\psi \rightarrow \gamma_{K}$ M3 $J/\psi \rightarrow \eta_{C}$ ERK3 $J/\psi \rightarrow \eta_{C}$ COMMENT $e^{+}e^{-} \rightarrow \gamma_{K} + K - \pi$ 3 $J/\psi \rightarrow \gamma_{K}$ COMMENT $J/\psi \rightarrow \gamma_{K}$ COMMENT $J/\psi \rightarrow \gamma_{K}$ COMMENT $J/\psi \rightarrow \gamma_{K}$ Trrelated.) 3 $J/\psi \rightarrow \gamma_{K} + K - K$	ρ ⁰ ρ ⁰ ρ ⁺ ρ ⁻ c γ Γ ₃ /Γ Γ ₄ /Γ + π ⁻ Γ ₈ /Γ Κ [±] π [∓] κ ⁻ π ⁰ Γ ₅ /Γ	$ \begin{split} & \Gamma\left(2(\pi^{+}\pi^{-})\right)/\Gamma_{\text{tot}} \\ & \frac{VALUE}{0.012 \pm 0.004} \text{OUR} \\ & 0.0120 \pm 0.0031 \text{OUF} \\ & 0.0105 \pm 0.0017 \pm 0.00 \\ & 0.013 \pm 0.006 \\ & 0.020 \pm 0.015 \\ & 0.020 \pm 0.015 \\ & 0.021 \pm 0.015 \\ \hline & \Gamma\left(2(K^{+}K^{-})\right)/\Gamma_{\text{tot}} \\ & \frac{VALUE}{0.021 \pm 0.010 \pm 0.006} \\ & \Gamma\left(p\overline{p}\right)/\Gamma_{\text{total}} \\ & \frac{VALUE}{12 \pm 4 \text{OUR} \text{AVERA}} \\ & 10 \pm 3 \pm 4 \\ & 11 \pm 6 \\ & 29 \pm 29 \\ & -15 \\ \hline & \Gamma\left(K\overline{K}\eta\right)/\Gamma_{\text{total}} \\ & \frac{VALUE}{0.031} \\ & \frac{VALUE}{0.031} \\ & \Gamma\left(\pi^{+}\pi^{-}p\overline{p}\right)/\Gamma_{\text{tot}} \\ & \frac{VALUE}{0.031} \\ & \Gamma\left(\pi^{+}\pi^{-}p\overline{p}\right)/\Gamma_{\text{total}} \\ & \frac{VALUE}{0.012} \\ & = 0.012 \\ \hline & \Gamma\left(\Lambda\overline{A}\right)/\Gamma_{\text{total}} \end{split} $	EVALUATI R EVALUATI R AVERAGE 034 1 Obtai 18 23 CL% 90 tai CL% 90	TS DOCUMENT IE 37 PISELLO 25 PALTRUSAI' 10 HIMEL DOCUMENT ID ALBRECHT 94 DOCUMENT ID 7 BISELLO 91 7 BALTRUSAIT86 10 HIMEL 80 DOCUMENT ID 7 BALTRUSAIT86 DOCUMENT ID HIMEL 80 DOCUMENT ID HIMEL 80	91 C T86 M 80B M H ARG DM2 MRK3 B MRK2 TECN MRK3	$\begin{array}{lll} \text{EEN} & \text{COMMEN} \\ \text{M2} & J/\psi \rightarrow \\ & \gamma 2\pi^{+} \\ \text{IRK3} & J/\psi \rightarrow \\ \text{IRK2} & \psi(25) - \\ \\ & \frac{\text{COMMENT}}{\gamma \gamma \rightarrow K^{+}K} \\ & \frac{\text{COMMENT}}{J/\psi \rightarrow \gamma_{C}\gamma} \\ & \psi(25) \rightarrow \eta_{C} \\ \\ & \frac{\text{COMMENT}}{J/\psi \rightarrow \eta_{C}\gamma} \\ & \frac{\text{COMMENT}}{\psi(25) \rightarrow \eta_{C}} \\ \end{array}$	Γ ₁₅ τ -2π - η _c γ τ η _c γ Γ 14 - κ + κ Γ 16 γ Γ 17
MUE (units 10 ⁻³) 26 ± 9 OUR E 25 ± 8 OUR A 26.0± 2.4±8.8 23.6±10.6±8.2 • We do not use (140) (K*(892) ⁰ K*-π+ MUE 002 ±0.007 (K*(892) [∞] K*(892) 3±31 OUR AVERAG 2±28±27 0±50 (K*(892) [∞] K+ c.c. MUE (units 10 ⁻⁴) 1±28 OUR EVALUA 1±22 OUR EVALUA 1±24 OUR EVALUA 1±25 OUR EVALUA 1±25 OUR EVALUA 1±26 OUR EVALUA 1±27 OUR EVALUA 1±28 O	20 EVTS 11: 20 SEVTS 13: 20 SEVTS 14 90 14 90 15: 20 SEVTS 16: 30 SEVTS 17: 30 SEVTS 18: 40 SEVTS 40	DOCUMENT IC BISELLO T BISELLO T BALTRUSAL TOTAL DOCUMENT IC BISELLO T BALTRUSAL	91 D 10 10 10 10 10 10 10 10 10 10 10 10 10	ECN COMMENT s as correlated.) M2 $J/\psi \rightarrow \gamma_{K}$ M2 $J/\psi \rightarrow \gamma_{K}$ M3 $J/\psi \rightarrow \eta_{C}$ ERK3 $J/\psi \rightarrow \eta_{C}$ COMMENT $V_{K} = V_{K} + V_{K} + V_{K}$ COMMENT $V_{K} = V_{K} + V_{K} + V_{K}$ COMMENT $V_{K} = V_{K} + V_{K} + V_{K}$ COMMENT Trelated.) 3 $J/\psi \rightarrow \gamma_{K} + V_{K} + V_{K}$ $V_{K} = V_{K} + V_{K} + V_{K} + V_{K}$ $V_{K} = V_{K} + V_{K} + V_{K} + V_{K}$	ρ ⁰ ρ ⁰ ρ ⁺ ρ ⁻ c γ Γ ₃ /Γ Γ ₄ /Γ + π ⁻ Γ ₈ /Γ Κ [±] π [∓] κ ⁻ π ⁰ Γ ₅ /Γ	$ \begin{split} & \Gamma\left(2(\pi^{+}\pi^{-})\right)/\Gamma_{\text{tot}} \\ & \frac{VALUE}{VALUE} \\ & 0.012 \pm 0.004 \text{OUF} \\ & 0.0120 \pm 0.0031 \text{OUF} \\ & 0.0105 \pm 0.0017 \pm 0.00 \\ & 0.013 \pm 0.006 \\ & 0.020 + 0.015 \\ & - 0.010 \\ & \Gamma\left(2(K^{+}K^{-})\right)/\Gamma_{\text{tot}} \\ & \frac{VALUE}{VALUE} \\ & 0.021 \pm 0.010 \pm 0.006 \\ & \Gamma\left(p\overline{p}\right)/\Gamma_{\text{total}} \\ & \frac{VALUE}{VALUE} \left(\text{units } 10^{-4}\right) \\ & 12 \pm 4 \text{OUR AVERA} \\ & 10 \pm 3 \pm 4 \\ & 11 \pm 6 \\ & 29 \stackrel{+}{-}29 \\ & \Gamma\left(K\overline{K}\eta\right)/\Gamma_{\text{total}} \\ & \frac{VALUE}{VALUE} \\ & < 0.031 \\ & \Gamma\left(\pi^{+}\pi^{-}p\overline{p}\right)/\Gamma_{\text{tot}} \\ & \frac{VALUE}{VALUE} \\ & < 0.012 \\ & \Gamma\left(\Lambda\overline{A}\right)/\Gamma_{\text{total}} \\ & \frac{VALUE}{VALUE} \\ & < 0.002 \\ \end{split} $	E EVALUATI R AVERAGE 034 1 obtai 6 EVTS 18 23 6 6 6 6 6 6 6 7 90 6 6 6 6 7 90 6 6 6 7 90	### DOCUMENT ID 10 DOCUMENT ID	91 D T86 N 80B N H ARG DM2 MRK3 B MRK2 TECN MRK3 TECN B MRK2	$\begin{array}{lll} \text{EEN} & \text{COMMEN} \\ \text{M2} & J/\psi \rightarrow \\ & \gamma 2\pi^{+} \\ \text{IRK3} & J/\psi \rightarrow \\ \text{IRK2} & \psi(25) - \\ \\ & \text{COMMENT} \\ & J/\psi \rightarrow \gamma_{P} \overline{p} \\ & J/\psi \rightarrow \eta_{C} \gamma \\ & \psi(25) \rightarrow \eta_{C} \\ \\ & \text{COMMENT} \\ & J/\psi \rightarrow \eta_{C} \gamma \\ & \psi(25) \rightarrow \eta_{C} \\ \\ & \text{COMMENT} \\ & \psi(25) \rightarrow \eta_{C} \\ \\ & \text{COMMENT} \\ & \psi(25) \rightarrow \eta_{C} \\ \\ & \text{COMMENT} \\ & \psi(25) \rightarrow \eta_{C} \\ \\ & \text{COMMENT} \\ & \psi(25) \rightarrow \eta_{C} \\ \\ & \text{COMMENT} \\ & \psi(25) \rightarrow \eta_{C} \\ \\ & \text{COMMENT} \\ \\ & \text{COMMENT} \\ & \text{COMMENT} \\ & \text{COMMENT} \\ \\ & \text{COMMENT} \\ & \text{COMMENT} \\ \\ \\ \\ & \text{COMMENT} \\ \\ \\ \\ & \text{COMMENT} \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	Γ ₁₅ -2π ⁻ η _c γ η _c γ Γ ₁₄ -κ+κ Γ ₁₆ γ Γ ₁₇ Γ ₁₈ γ Γ ₁₉
MUE (units 10 ⁻³) 26 ± 9 OUR E 25 ± 8 OUR A 26.0± 2.4±8.8 23.6±10.6±8.2 • We do not use (140) (K*(892) $^{\circ}$ K- π + MUE 002 ±0.007 (K*(892) $^{\circ}$ K*(892) E±31 OUR AVERAG 2±28±27 0±50 (K*(892) $^{\circ}$ K+ c.c. MUE (0.0128 (0.0132 ($\phi \phi$)/ $^{\circ}$ total MUE (units 10 ⁻⁴) ±±28 OUR EVALUA ±±22 OUR AVERAG ±±18±24 • • We do not use	20 EVTS 11: 20 SEVTS 13: 20 SEVTS 14 90 14 90 15: 20 SEVTS 16: 30 SEVTS 17: 30 SEVTS 18: 40 SEVTS 40	DOCUMENT IC BISELLO T BISELLO T BALTRUSAL TOTAL DOCUMENT IC BISELLO T BALTRUSAL	91 D 10 10 10 10 10 10 10 10 10 10 10 10 10	ECN COMMENT 5 as correlated.) M2 $J/\psi \rightarrow \gamma_{K}$ M2 $J/\psi \rightarrow \gamma_{K}$ M3 $J/\psi \rightarrow \gamma_{K}$ S, etc. • • • IRK3 $J/\psi \rightarrow \eta_{C}$ COMMENT $e^{+}e^{-} \rightarrow \gamma_{K} + K^{-}\pi$ 3 $J/\psi \rightarrow \gamma_{K} + K^{-}\pi$ COMMENT Trelated.) 3 $J/\psi \rightarrow \gamma_{K} + K^{-}K$ S, etc. • • $J/\psi \rightarrow \gamma_{K} + K^{-}K$ S, etc. • • $J/\psi \rightarrow \gamma_{K} + K^{-}K$ S, etc. • •	$ \rho^{0}\rho^{0} $ $ \rho^{+}\rho^{-} $ $ \epsilon^{\gamma} $ $ \Gamma_{3}/\Gamma $ $ \Gamma_{4}/\Gamma $ $ + \pi^{-} $ $ \Gamma_{5}/\Gamma $ $ \epsilon^{+}\kappa^{-} $ $ \epsilon^{0}\kappa^{0}\kappa^{0} $ $ \epsilon^{0}\kappa^{0}\kappa^{0} $	$ \begin{split} & \Gamma\left(2(\pi^{+}\pi^{-})\right)/\Gamma_{\text{tot}} \\ & \frac{VALUE}{VALUE} \\ & 0.012 \pm 0.004 \text{OUF} \\ & 0.0120 \pm 0.0031 \text{OUF} \\ & 0.0105 \pm 0.0017 \pm 0.00 \\ & 0.013 \pm 0.006 \\ & 0.020 \pm 0.015 \\ & -0.010 \\ & \Gamma\left(2(K^{+}K^{-})\right)/\Gamma_{\text{tot}} \\ & \frac{VALUE}{VALUE} \\ & 0.021 \pm 0.010 \pm 0.006 \\ & \Gamma\left(p\overline{p}\right)/\Gamma_{\text{total}} \\ & \frac{VALUE}{VALUE} \left(\text{units } 10^{-4}\right) \\ & 12 \pm 4 \text{OUR AVERA} \\ & 10 \pm 3 \pm 4 \\ & 11 \pm 6 \\ & 29 \pm 29 \\ & -15 \\ & \Gamma\left(K\overline{K}\eta\right)/\Gamma_{\text{total}} \\ & \frac{VALUE}{VALUE} \\ & < 0.031 \\ & \Gamma\left(\pi^{+}\pi^{-}p\overline{p}\right)/\Gamma_{\text{tot}} \\ & \frac{VALUE}{VALUE} \\ & < 0.012 \\ & \Gamma\left(\Lambda\overline{A}\right)/\Gamma_{\text{total}} \\ & \frac{VALUE}{VALUE} \\ & < 0.012 \\ & \Gamma\left(\Lambda\overline{A}\right)/\Gamma_{\text{total}} \\ & \frac{VALUE}{VALUE} \\ & < 0.012 \\ & \Gamma\left(\Lambda\overline{A}\right)/\Gamma_{\text{total}} \\ & \frac{VALUE}{VALUE} \\ & < 0.012 \\ & \Gamma\left(\Lambda\overline{A}\right)/\Gamma_{\text{total}} \\ & \frac{VALUE}{VALUE} \\ & < 0.012 \\ & \Gamma\left(\Lambda\overline{A}\right)/\Gamma_{\text{total}} \\ & \frac{VALUE}{VALUE} \\ & < 0.012 \\ & \Gamma\left(\Lambda\overline{A}\right)/\Gamma_{\text{total}} \\ & \frac{VALUE}{VALUE} \\ & < 0.012 \\ & \Gamma\left(\Lambda\overline{A}\right)/\Gamma_{\text{total}} \\ & \frac{VALUE}{VALUE} \\ & < 0.012 \\ & \Gamma\left(\Lambda\overline{A}\right)/\Gamma_{\text{total}} \\ & \frac{VALUE}{VALUE} \\ & < 0.012 \\ & \Gamma\left(\Lambda\overline{A}\right)/\Gamma_{\text{total}} \\ & \frac{VALUE}{VALUE} \\ & < 0.012 \\ & \Gamma\left(\Lambda\overline{A}\right)/\Gamma_{\text{total}} \\ & \frac{VALUE}{VALUE} \\ & < 0.012 \\ & \Gamma\left(\Lambda\overline{A}\right)/\Gamma_{\text{total}} \\ & \frac{VALUE}{VALUE} \\ & < 0.012 \\ & \Gamma\left(\Lambda\overline{A}\right)/\Gamma_{\text{total}} \\ & \frac{VALUE}{VALUE} \\ & < 0.012 \\ & < 0.012 \\ & < 0.012 \\ & < 0.012 \\ & < 0.012 \\ & < 0.012 \\ & < 0.012 \\ & < 0.012 \\ & < 0.012 \\ & < 0.012 \\ & < 0.012 \\ & < 0.012 \\ & < 0.012 \\ & < 0.012 \\ & < 0.012 \\ & < 0.012 \\ & < 0.012 \\ & < 0.012 \\ & < 0.$	E EVALUATI R AVERAGE 034 1 obtai 6 EVTS 18 23 6 6 6 6 6 6 6 7 90 6 6 6 6 7 90 6 6 6 7 90	### DOCUMENT ID 10 DOCUMENT ID	91 D T86 N 80B N H ARG DM2 MRK3 B MRK2 TECN MRK3 TECN B MRK2	$\begin{array}{lll} \text{EEN} & \text{COMMEN} \\ \text{M2} & J/\psi \rightarrow \\ & \gamma 2\pi^{+} \\ \text{IRK3} & J/\psi \rightarrow \\ \text{IRK2} & \psi(25) - \\ \\ & \text{COMMENT} \\ & J/\psi \rightarrow \gamma_{P} \overline{p} \\ & J/\psi \rightarrow \eta_{C} \gamma \\ & \psi(25) \rightarrow \eta_{C} \\ \\ & \text{COMMENT} \\ & J/\psi \rightarrow \eta_{C} \gamma \\ & \psi(25) \rightarrow \eta_{C} \\ \\ & \text{COMMENT} \\ & \psi(25) \rightarrow \eta_{C} \\ \\ & \text{COMMENT} \\ & \psi(25) \rightarrow \eta_{C} \\ \\ & \text{COMMENT} \\ & \psi(25) \rightarrow \eta_{C} \\ \\ & \text{COMMENT} \\ & \psi(25) \rightarrow \eta_{C} \\ \\ & \text{COMMENT} \\ & \psi(25) \rightarrow \eta_{C} \\ \\ & \text{COMMENT} \\ \\ & \text{COMMENT} \\ & \text{COMMENT} \\ & \text{COMMENT} \\ \\ & \text{COMMENT} \\ & \text{COMMENT} \\ \\ \\ \\ & \text{COMMENT} \\ \\ \\ \\ & \text{COMMENT} \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	Γ ₁₅ , τ -2π ⁻ η _c γ τ η _c γ Γ ₁₄ , - κ+ κ Γ ₁₆ , γ Γ ₁₇ , γ Γ ₁₈ , γ
ALUE (units 10^{-3}) 26 \pm 9 OUR E 25 \pm 8 OUR A 26.0 \pm 2.4 \pm 8.8 23.6 \pm 10.6 \pm 8.2 • We do not use (140) (K*(892) ⁰ K ⁻ π ⁺ 4LUE (02 \pm 0.007 (K*(892) K*(892) E \pm 31 OUR AVERAGE 2 \pm 28 \pm 27 D \pm 50 (K*(892) K+ c.c. 4LUE (0.0128 (0.0128 (0.0132 ($\phi \phi$) / Γ total 4LUE (units 10^{-4}) 1 \pm 22 OUR AVERAGE 4 \pm 18 \pm 24 7 \pm 21 \pm 24 • We do not use 1 \pm 7 \pm 10	CL% EVT. EVALUATION 11: 3: the followin 90 -+ c.c.)/	Total DOCUMENT IL	91 DM2	ECN COMMENT s as correlated.) M2 $J/\psi \rightarrow \gamma_K$ M2 $J/\psi \rightarrow \gamma_K$ M3 $J/\psi \rightarrow \gamma_C$ S, etc. • • IRK3 $J/\psi \rightarrow \eta_C$ COMMENT $e^+e^- \rightarrow \gamma_K + K^-\pi$ 3 $J/\psi \rightarrow \gamma_C \gamma$ COMMENT $J/\psi \rightarrow \gamma_C \gamma$ COMMENT Trelated.) 3 $J/\psi \rightarrow \gamma_C \gamma$ $\gamma_C \rightarrow \gamma_C \rightarrow \gamma_C \gamma_C$ COMMENT $\gamma_C \rightarrow \gamma_C \gamma_C \rightarrow \gamma_C \gamma_C \gamma_C \gamma_C \gamma_C \gamma_C \gamma_C \gamma_C \gamma_C \gamma_C$	$ \rho^{0}\rho^{0} $ $ \rho^{+}\rho^{-} $ $ \epsilon^{\gamma} $ $ \Gamma_{3}/\Gamma $ $ \Gamma_{4}/\Gamma $ $ + \pi^{-} $ $ \Gamma_{5}/\Gamma $ $ \epsilon^{+}\kappa^{-} $ $ \epsilon^{0}\kappa^{0}\kappa^{0} $ $ \epsilon^{0}\kappa^{0}\kappa^{0} $	$\Gamma\left(2(\pi^{+}\pi^{-})\right)/\Gamma_{\text{tot}}$ $\frac{VALUE}{VALUE}$ 0.012 ±0.004 OUF 0.0120±0.0031 OUF 0.0105±0.0017±0.0 0.013 ±0.006 0.020 +0.015 -0.010 $\Gamma\left(2(K^{+}K^{-})\right)/\Gamma_{\text{tot}}$ $\frac{VALUE}{VALUE}$ 0.021±0.010±0.006 $\Gamma\left(p\overline{p}\right)/\Gamma_{\text{total}}$ $\frac{VALUE}{VALUE}$ 12±4 OUR AVERA 10±3±4 11±6 29-29 -15 $\Gamma\left(K\overline{K}\eta\right)/\Gamma_{\text{total}}$ $\frac{VALUE}{VALUE}$ <0.031 $\Gamma\left(\pi^{+}\pi^{-}p\overline{p}\right)/\Gamma_{\text{tot}}$ $\frac{VALUE}{VALUE}$ <0.012 $\Gamma\left(\Lambda\overline{A}\right)/\Gamma_{\text{total}}$ $\frac{VALUE}{VALUE}$ <0.002 $\Gamma\left(\Gamma^{+}\Gamma\right)/\Gamma_{\text{total}}$ $\frac{VALUE}{VALUE}$ <0.002 $\Gamma\left(\Gamma^{+}\Gamma\right)/\Gamma_{\text{total}}$ $\frac{VALUE}{VALUE}$ <0.002	E EVALUATI R AVERAGE 034 1 obtai 6 EVTS 18 23 6 6 6 6 6 6 6 7 90 6 6 6 6 7 90 6 6 6 7 90	### DOCUMENT ID 10 DOCUMENT ID	91 D T86 N 808 N TECN H ARG DM2 MRK3 B MRK2 TECN MRK3 TECN MRK3 TECN DM2 TECN DM2 TECN DM2	EECN COMMENT M2 $J/\psi \rightarrow \gamma 2\pi^{+}$ IRK3 $J/\psi \rightarrow \gamma 2\pi^{+}$ IRK2 $\psi(25) \rightarrow \gamma \gamma \gamma \rightarrow \gamma \gamma \gamma \rightarrow \gamma \gamma \gamma \rightarrow \gamma	Γ _{15,7} -2π -η _c γ - η _c γ - κ+ κ - Γ _{16,7} Γ _{18,7} Γ _{18,7} Γ _{18,7} Γ ₁₆ Γ ₅ / Γ ₁₆
$\begin{array}{lll} & \begin{array}{lll} & \end{array} \end{array} \end{array} \end{array} \end{array} \end{array}$	CL% EVT.	S DOCUMENT IL T BISELLO T BISELLO B ALTRUSAI DOCUMENT IL BISELLO BISE	91 D 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	ECN COMMENT s as correlated.) M2 $J/\psi \rightarrow \gamma_K$ M2 $J/\psi \rightarrow \gamma_K$ S, etc. • • IRK3 $J/\psi \rightarrow \eta_C \gamma$ COMMENT $V_{C} = V_{C}	$\rho^{0}\rho^{0}$ $\rho^{+}\rho^{-}$ Γ_{3}/Γ Γ_{4}/Γ Γ_{5}/Γ Γ_{5}/Γ Γ_{5}/Γ	$ \Gamma\left(2(\pi^{+}\pi^{-})\right)/\Gamma_{\text{tot}} $ $ \frac{VALUE}{0.012 \pm 0.004} \text{ OUR} $ $ 0.012 \pm 0.0031 \text{ OUF} $ $ 0.0105 \pm 0.0017 \pm 0.00 $ $ 0.013 \pm 0.006 $ $ 0.020 + 0.015 $ $ 0.020 + 0.015 $ $ \Gamma\left(2(K^{+}K^{-})\right)/\Gamma_{\text{tot}} $ $ \frac{VALUE}{0.021 \pm 0.010 \pm 0.006} $ $ \Gamma\left(p\overline{p}\right)/\Gamma_{\text{total}} $ $ \frac{VALUE}{12 \pm 4 \text{ OUR AVERA}} $ $ 10 \pm 3 \pm 4 $ $ 11 \pm 6 $ $ 29 + 29 $ $ -15 $ $ \Gamma\left(K^{-}K^{-}\eta\right)/\Gamma_{\text{total}} $ $ \frac{VALUE}{0.0031} $ $ \Gamma\left(\pi^{+}\pi^{-}p\overline{p}\right)/\Gamma_{\text{total}} $ $ \frac{VALUE}{0.0012} $ $ C0.012 $ $ \Gamma\left(\Lambda^{-}\Lambda\right)/\Gamma_{\text{total}} $ $ \frac{VALUE}{0.002} $ $ \Gamma_{1}\Gamma_{1}/\Gamma_{2}^{2} \text{ total in } p\overline{p} $ $ \frac{VALUE}{0.003} $	EVALUATI R EVALUATI R AVERAGE 034 1 Detai 034 1 044 1 054 1 054 1 054 1 054 1 054 1 056 1 057 1 057 1 058 1	77 BISELLO 25 7 BALTRUSAI 10 HIMEL DOCUMENT ID ALBRECHT 94 DOCUMENT ID 7 BISELLO 91 7 BALTRUSAIT86 10 HIMEL 80 DOCUMENT ID 7 BALTRUSAIT86 DOCUMENT ID HIMEL 80 7 BALTRUSAIT86 DOCUMENT ID HIMEL 80 DOCUMENT ID HIMEL 80 POCUMENT ID BALTRUSAIT86 DOCUMENT ID BALTRUSAIT86 DOCUMENT ID BALTRUSAIT86 BOCUMENT ID BALTRUSAIT86 DOCUMENT ID BALTRUSAIT86 BOCUMENT ID BALTRUSAIT86	91 C T86 N 80B N H ARG DM2 MRK3 B MRK2 - TECN MRK3 B MRK2 - TECN DM2 TECN DM2 TECN S TECN DM2	$\begin{array}{ccc} ECN & COMMEN \\ M2 & J/\psi \rightarrow \\ & \gamma 2\pi^{+} \\ IRK3 & J/\psi \rightarrow \\ IRK2 & \psi(2S) \rightarrow \\ \hline & COMMENT \\ & J/\psi \rightarrow \gamma p\overline{p} \\ & J/\psi \rightarrow \eta_{C} \gamma \\ & \psi(2S) \rightarrow \eta_{C} \\ \hline & COMMENT \\ & J/\psi \rightarrow \eta_{C} \gamma \\ \hline & COMMENT \\ & J/\psi \rightarrow \eta_{C} \gamma \\ \hline & COMMENT \\ & \psi(2S) \rightarrow \eta_{C} \\ \hline & V(2S) \rightarrow \eta_{C} \\ $	Γ _{15,7} - 2π - η _c γ
NUE (units 10^{-3}) 26 \pm 9 OUR E 25 \pm 8 OUR A 26.0 \pm 2.4 \pm 8.8 23.6 \pm 10.6 \pm 8.2 • We do not use (140) (K*(892) ⁰ K ⁻ π ⁺ 14.UE 02 \pm 0.007 (K*(892) K*(892) (K*(892) K*(892) (K*(892) K*+ c.c. 14.UE 0.0128 10.0128 10.0128 10.0132 ($\phi \phi$) / Γ total 14.UE (units 10^{-4}) 14.UE 20 UR EVALUA 14.22 OUR AVERAG 14.18 \pm 24 7.21 \pm 24 • We do not use 12.7 \pm 7.2 \pm 10	CL% EVT. EVALUATION 11: 3: the followin 90 -+ c.c.)/	Total DOCUMENT IL	91 D 2 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	ECN COMMENT s as correlated.) M2 $J/\psi \rightarrow \gamma_K$ M2 $J/\psi \rightarrow \gamma_K$ M3 $J/\psi \rightarrow \gamma_C$ S, etc. • • IRK3 $J/\psi \rightarrow \eta_C$ COMMENT $e^+e^- \rightarrow \gamma_K + K^-\pi$ 3 $J/\psi \rightarrow \gamma_C \gamma$ COMMENT $J/\psi \rightarrow \gamma_C \gamma$ COMMENT Trelated.) 3 $J/\psi \rightarrow \gamma_C \gamma$ $\gamma_C \rightarrow \gamma_C \rightarrow \gamma_C \gamma_C$ COMMENT $\gamma_C \rightarrow \gamma_C \gamma_C \rightarrow \gamma_C \gamma_C \gamma_C \gamma_C \gamma_C \gamma_C \gamma_C \gamma_C \gamma_C \gamma_C$	$\rho^{0}\rho^{0}$ $\rho^{+}\rho^{-}$ Γ_{3}/Γ Γ_{4}/Γ Γ_{5}/Γ Γ_{5}/Γ Γ_{5}/Γ		E EVALUATI R EVALUATI R AVERAGE 034 1 Detai 18 23 23 490 41 24 90 41 51 61 61 61 61 61 61 61 61 6	### DOCUMENT ID 10 DOCUMENT ID	91 D T86 M 808 M H ARG DM2 MRK3 B MRK2 - TECN MRK3 - TECN DM2 TECN DM2 TECN SPEC	M2 $J/\psi \rightarrow \gamma 2\pi^{+}$ IRK3 $J/\psi \rightarrow \gamma 1\pi$ IRK2 $\psi(25) - \gamma 1\pi$ $\psi(25) \rightarrow \psi(25) \rightarrow \psi($	Γ 15, τ T T T T T T T

$\eta_c(1S)$, $J/\psi(1S)$

RADIATIVE DECAYS		Decays involving	hadronic i	resonances	
	ر ۲ ₅	$\rho\pi$		$1.28 \pm 0.10)$ %	
	' 6	$\rho^0 \pi^0$,	4.2 ± 0.5) $\times 10^{-3}$	
VALUE (units 10 ⁻⁴) CL% DOCUMENT ID TECN COMMENT 3.0 ±1.2 OUR AVERAGE	- <u>Γ</u> ₇	$a_2(1320) \rho$		1.09±0.22) %	
$2.80^{+0.67}_{-0.58}\pm 1.0$ ARMSTRONG 95F SPEC $\overline{p}p \rightarrow \gamma\gamma$	L ⁸	$\omega \pi^{+} \pi^{+} \pi^{-} \pi^{-}$		$8.5 \pm 3.4 \times 10^{-3}$	
	•	$\omega \pi^{+} \pi^{-}$ $K^{*}(892)^{0} \overline{K}_{2}^{*}(1430)^{0} + \text{c.c.}$		7.2 ± 1.0) $\times 10^{-3}$ 6.7 ± 2.6) $\times 10^{-3}$	
6 $^{+4}_{-3}$ ± 4 BAGLIN 878 SPEC $\overline{p}p \rightarrow \gamma\gamma$	Γ ₁₀ Γ ₁₁	$\omega K^*(892) K_2(1430) + c.c.$		$5.3 \pm 2.0 \times 10^{-3}$	
• • We do not use the following data for averages, fits, limits, etc. • •	Γ ₁₂	$\omega f_{5}(1270)$		$4.3 \pm 0.6 \times 10^{-3}$	
< 9 90 $\frac{7}{11}$ BISELLO 91 DM2 $J/\psi \rightarrow \gamma\gamma\gamma$	Γ ₁₃	$K^{+}\overline{K}^{*}(892)^{-} + \text{c.c.}$		$5.0 \pm 0.4 \times 10^{-3}$	
<18 90 11 BLOOM 83 CBAL $J/\psi \rightarrow \eta_{C} \gamma$	Γ ₁₄	$K^0 \overline{K}^* (892)^0 + \text{c.c.}$		$4.2 \pm 0.4 \times 10^{-3}$	
¹¹ Using B($J/\psi(1S) \to \gamma \eta_C(1S)$) = 0.0127 ± 0.0036.	Γ ₁₅	$\omega \pi^0 \pi^0$		$3.4 \pm 0.8 \times 10^{-3}$	
$\Gamma_I \Gamma_f / \Gamma_{\text{total}}^2 \text{ in } p \overline{p} \to \eta_c(1S) \to \gamma \gamma$ $\Gamma_{16} \Gamma_{20} / \Gamma_{16} \Gamma_{1$	2 Γ ₁₆	$b_1(1235)^{\pm}\pi^{\mp}$		3.0 ± 0.5) $\times 10^{-3}$	
VALUE (units 10 ⁻⁶) EVTS DOCUMENT ID TECN COMMENT	Γ ₁₇	$\omega K^{\pm} K_{S}^{0} \pi^{\mp}$		$3.0 \pm 0.7 \times 10^{-3}$	
0.36 +0.08 OUR AVERAGE Error includes scale factor of 1.1.		$b_1(1235)^0 \pi^0$		$2.3 \pm 0.6 \times 10^{-3}$	
	Γ ₁₉	$\phi K^*(892)\overline{K} + \text{c.c.}$ $\omega K\overline{K}$		$2.04 \pm 0.28) \times 10^{-3}$ $1.9 \pm 0.4) \times 10^{-3}$	
$0.336 ^{+ 0.080}_{- 0.070}$ ARMSTRONG 95F SPEC $ \overline{p} p o \gamma \gamma$	Γ ₂₀	$\omega K K$ $\omega f_I(1710) \rightarrow \omega K \overline{K}$		$4.8 \pm 1.1 \times 10^{-4}$	
0.68 $^{+0.42}_{-0.31}$ 12 BAGLIN 87B SPEC $\overline{p} p ightarrow \gamma \gamma$	Γ ₂₂	$\phi_2(\pi^+\pi^-)$		$1.60\pm0.32)\times10^{-3}$	
	- Γ ₂₃	$\Delta(1232)^{++} \overline{p}\pi^{-}$		$1.6 \pm 0.5 \times 10^{-3}$	
$\eta_{c}(1S)$ REFERENCES	Γ ₂₄	$\omega \dot{\eta}$	($1.58\pm0.16)\times10^{-3}$	
(411) 5500 0510 1101 11150	Γ ₂₅	$\phi K \overline{K}$	($1.48\pm0.22)\times10^{-3}$	
ARMSTRONG 95F PR D52 4839 +Bettoni+ (FNAL, FERR, GENO, UCI, NWES+) ALBRECHT 94H PL B338 390 +Hamacher, Hofmann+ (ARGUS Collab.)	Γ ₂₆	$\phi f_J(1710) \rightarrow \phi K \overline{K}$		$3.6 \pm 0.6 \times 10^{-4}$	
ADRIANI 93N PL B318 575 + Aguilar-Benitez, Ahlen+ (L3 Collab.) BISELLO 91 NP B350 1 + Busetto+ (DM2 Collab.)	Γ ₂₇	$p\overline{p}\omega$,	$1.30\pm0.25)\times10^{-3}$	S=1.3
BAI 90B PRL 65 1309 +Blaylock+ (Mark III Collab.) CHEN 90B PL B243 169 +McIlwain+ (CLEO Collab.)	Γ ₂₈	$\Delta(1232)^{++} \overline{\Delta}(1232)^{}$		1.10 ± 0.29) × 10^{-3}	
BAGLIN 89 PL B231 557 +Baird, Bassompierre (R704 Collab.)	Γ ₂₉	$\Sigma (1385)^{-} \overline{\Sigma} (1385)^{+} $ (or c.c.) $p \overline{p} \eta' (958)$		$1.03\pm0.13) \times 10^{-3}$ 9 ±4) \times 10 ⁻⁴	S=1.7
BRAUNSCH 89 ZPHY C41 533 Braunschweig, Bock+ (TASSO Collab.)	Г ₃₀ Г ₃₁		,	9 ± 4) \times 10 ⁻⁴ 8 ± 4) \times 10 ⁻⁴	S=1.7 S=2.7
AIHARA 88D PRL 60 2355 + Alston-Garnjost+ (TPC Collab.) BAGLIN 87B PL B187 191 + Baird, Bassompierre, Borreani+ (R704 Collab.)	Γ ₃₂			$8.0 \pm 1.2 \times 10^{-4}$	32.1
BALTRUSAIT 86 PR D33 629 Baltrusaitis, Coffman, Hauser+ (Mark III Collab.) BERGER 86 PL 167B 120 +Genzel, Lackas, Pielorz+ (PLUTO Collab.)	. 32 Г ₃₃			$7.2 \pm 0.9 \times 10^{-4}$	
BLINOV 86 +Blinov, Bondar, Bukin+ (NOVO) Proc. XXIII Int. HEP Conf., Berkeley, CA (1986); World Scientific, Singapore, 1987, ed. S.C. Loken	Γ ₃₄			$6.8 \pm 2.4 \times 10^{-4}$	
GAISER 86 PR D34 711 +Bloom, Bulos, Godfrey+ (Crystal Ball Collab.) ALTHOFF 85B ZPHY C29 189 +Braunschweig, Kirschfink+ (TASSO Collab.)	Г ₃₅	$\phi \eta$	(6.5 ± 0.7) $\times 10^{-4}$	
BALTRUSAIT 84 PRL 52 2126 Baltrusaitis+ (CIT, UCSC, ILL, SLAC, WASH) JP BLOOM 83 ARNS 33 143 +Peck (SLAC, CIT)	· Γ ₃₆	<u>=(1530)</u> − = +		5.9 ± 1.5) $\times 10^{-4}$	
HIMEL 80B PRL 45 1146 +Trilling, Abrams, Alam+ (SLAC, LBL, UCB)	_ ₃₇	$p K^{-} \overline{\Sigma} (1385)^{0}$		$5.1 \pm 3.2 \times 10^{-4}$	
PARTRIDGE 80B PRL 45 1150 +Peck+ (CIT, HARV, PRIN, STAN, SLAC)	Γ ₃₈	$\omega \pi^0$		4.2 ± 0.6) $\times 10^{-4}$ 3.3 ± 0.4) $\times 10^{-4}$	S=1.4
OTHER RELATED PAPERS	Г ₃₉ Г ₄₀	$\phi \eta'(958) \ \phi f_0(980)$		$3.2 \pm 0.9 \times 10^{-4}$	S=1.9
ARMSTRONG 89 PL B221 216 +Benayoun+(CERN, CDEF, BIRM, BARI, ATHU, CURIN+)	Γ ₄₁			$3.2 \pm 1.4 \times 10^{-4}$	0-1.7
BLOOM 79 Fermilab Symp. 92 (CIT, HARV, PRIN, SLAC, STAN)	_ Γ ₄₂	· · · · · · · · · · · · · · · · · · ·		$3.1 \pm 0.5 \times 10^{-4}$	
	 Г ₄₃		(2.6 ± 0.5) $\times 10^{-4}$	S=1.1
$J/\psi(1S)$ $I^{G}(J^{PC}) = 0^{-(1-1)}$	Γ ₄₄	$ ho\eta$		$1.93\pm0.23)\times10^{-4}$	
3/4(20)	Γ ₄₅	5.2		$1.67 \pm 0.25) \times 10^{-4}$	
	_ Г ₄₆			1.4 ± 0.5) $\times 10^{-4}$ 1.05 ± 0.18) $\times 10^{-4}$	
$J/\psi(1S)$ MASS	Γ ₄₇ Γ ₄₈			4.5 ± 1.5) $\times 10^{-5}$	
VALUE (MeV) EVTS DOCUMENT ID TECN COMMENT	_ Γ ₄₉		[a] <		CL=90%
3096.88±0.04 OUR AVERAGE	Γ ₅₀	$K\overline{K}_{2}^{*}(1430) + \text{c.c.}$	<	4.0×10^{-3}	CL=90%
3096.87 \pm 0.03 \pm 0.03 ARMSTRONG 93B SPEC $\bar{p}p \rightarrow e^+e^-$ 3096.95 \pm 0.1 \pm 0.3 193 BAGLIN 87 SPEC $\bar{p}p \rightarrow e^+e^-$ X	Γ ₅₁		<	2.9×10^{-3}	CL=90%
3096.95 \pm 0.1 \pm 0.3 193 BAGLIN 87 SPEC $\overline{p}p \rightarrow e^+e^-X$ 3098.4 \pm 2.0 38k LEMOIGNE 82 GOLI 190 GeV π^- Be $\rightarrow 2\mu$	Γ ₅₂			5 × 10 ⁻⁴	CL=90%
3096.93 ± 0.09 502 ZHOLENTZ 80 REDE e^+e^-	53	•		3.7×10^{-4}	CL=90%
3097.0 ± 1 BRANDELIK 79C DASP e^+e^-	Γ ₅₄			3.1×10^{-4} 2.5×10^{-4}	CL=90% CL=90%
1 From a simultaneous fit to e^+e^- , $\mu^+\mu^-$ and hadronic channels assuming $\Gamma(e^+e^-$	-) Γ ₅₅ Γ ₅₆			2.5 × 10 × 10 × 10 × 10 × 10 × 10 × 10 × 1	CL=90%
$=\Gamma(\mu^+\mu^-).$	<u> </u>	— (Table 10 T		2 × 10 ⁻⁴	CL=90%
$J/\psi(1S)$ WIDTH	_			1 × 10 ⁻⁴	CL=90%
<i>3/ψ</i> (13) W ID1H	Γ ₅₉	à — , ·		9×10^{-5}	CL=90%
VALUE (keV) DOCUMENT ID TECN COMMENT	F ₆₀		<	6.8×10^{-6}	CL=90%
87 ± 5 OUR AVERAGE 84.4± 8.9 BAI 95B BES e ⁺ e		Decays into	stable ha	drons	
84.4 \pm 8.9 BAI 958 BES e^+e^- 99 \pm 12 \pm 6 ARMSTRONG 938 SPEC $\overline{p}p \rightarrow e^+e^-$	Γ ₆₁			3.37 ± 0.26) %	
$85.5 + 6.1 \\ -5.8 $ 2 HSUEH 92 RVUE See γ mini-review	Γ ₆₂			2.9 ±0.6)%	
	Γ ₆₃	$\pi^{+}\pi^{-}\pi^{0}$		1.50±0.20) %	
² Using data from COFFMAN 92, BALDINI-CELIO 75, BOYARSKI 75, ESPOSITO 75 BRANDELIK 79c.	' 64	$\pi^{+}\pi^{-}\pi^{0}K^{+}K^{-}$		1.20±0.30) %	
	— Г ₆₅			$(9.0 \pm 3.0) \times 10^{-3}$ $(7.2 \pm 2.3) \times 10^{-3}$	
	Γ ₆₆			$(6.1 \pm 1.0) \times 10^{-3}$	
$J/\psi(1S)$ DECAY MODES	Г		,		S=1.3
Scale facto		1	i	$6.0 \pm 0.5 \times 10^{-3}$	
Mode Fraction $(\Gamma_{\hat{l}}/\Gamma)$ Scale facto	^{'/} _{'el} Γ ₆₈	$p\overline{p}\pi^+\pi^-$		$(6.0 \pm 0.5) \times 10^{-3}$ $(4.0 \pm 1.0) \times 10^{-3}$	5=1.5
Mode Fraction (Γ_I/Γ) Scale facto Confidence lev	^{r/} _{el} Γ ₆₈ 	$egin{array}{l} ho\overline{ ho}\pi^+\pi^-\ 2(\pi^+\pi^-)\ 3(\pi^+\pi^-) \end{array}$	($4.0 \pm 1.0 \times 10^{-3}$ $4.0 \pm 2.0 \times 10^{-3}$	3=1.3
$\begin{tabular}{ c c c c c c c c c c c c c c c c c c c$	^{г/} rel Г ₆₈ Г ₇₀ Г ₇₁	$rac{ ho\overline{ ho}\pi^{+}\pi^{-}}{2(\pi^{+}\pi^{-})} \ rac{3(\pi^{+}\pi^{-})}{n\overline{n}\pi^{+}\pi^{-}}$	(($(4.0 \pm 1.0) \times 10^{-3}$ $(4.0 \pm 2.0) \times 10^{-3}$ $(4 \pm 4) \times 10^{-3}$	3=1.3
$\begin{tabular}{ c c c c c c c c c c c c c c c c c c c$	Γ/el Γ ₆₈ Γ ₆₉ Γ ₇₀ Γ ₇₁ Γ ₇₂	$egin{array}{l} ho\overline{p}\pi^+\pi^-\ 2(\pi^+\pi^-)\ 3(\pi^+\pi^-)\ n\overline{n}\pi^+\pi^-\ \end{array}$	((($(4.0 \pm 1.0) \times 10^{-3}$ $(4.0 \pm 2.0) \times 10^{-3}$ $(4 \pm 4) \times 10^{-3}$ $(3.8 \pm 0.5) \times 10^{-3}$	3=1.3
$\begin{tabular}{ c c c c c c c c c c c c c c c c c c c$	^{г/} rel Г ₆₈ Г ₇₀ Г ₇₁	$ \rho \overline{p} \pi^+ \pi^- \\ 2(\pi^+ \pi^-) \\ 3(\pi^+ \pi^-) \\ n \overline{n} \pi^+ \pi^- \\ \Sigma \overline{\Sigma} \\ 2(\pi^+ \pi^-) K^+ K^- $	($(4.0 \pm 1.0) \times 10^{-3}$ $(4.0 \pm 2.0) \times 10^{-3}$ $(4 \pm 4) \times 10^{-3}$	S=1.9

 Γ_2/Γ

 $\frac{DOCUMENT\ ID}{8\ BOYARSKI}$ 75 MRK1 e^+e^-

Meson Particle Listings

 $J/\psi(1S)$

$p\overline{p}\eta$ (2.09±0.18) × 10 ⁻³ $\Gamma(e^+e^-)$	Гз
$p \bar{n} \pi^-$ (2.00 ± 0.10) × 10 ⁻³ <u>VALUE (keV)</u>	DOCUMENT ID TECN COMMENT
$n\overline{n}$ (1.9 ±0.5)×10 ⁻³ 5.26±0.37 OUF	R EVALUATION
$\equiv \overline{\equiv}$ (1.8 ± 0.4) \times 10 ⁻³ S=1.8	ot use the following data for averages, fits, limits, etc. • • •
$\Lambda \overline{\Lambda}$ (1.35±0.14) × 10 ⁻³ S=1.2 5.14±0.39	BAI 958 BES e^+e^-
$p\overline{p}\pi^0$ (1.09±0.09) × 10 ⁻³ 5.36 ^{+0.29}	4 HSUEH 92 RVUE See γ mini-review
$\Lambda \overline{\Sigma}^- \pi^+ \text{ (or c.c.)}$ [a] $(1.06 \pm 0.12) \times 10^{-3}$ 4.72 ± 0.35	ALEXANDER 89 RVUE See Υ mini-review
$pK^{-}\overline{\Lambda}$ (8.9 ±1.6) × 10 ⁻⁴ 4.4 ±0.6	⁴ BRANDELIK 79C DASP e ⁺ e ⁻
$2(K^+K^-)$ (7.0 ±3.0) × 10 ⁻⁴ 4.6 ±0.8	⁵ BALDINI 75 FRAG e^+e^-
$pK^{-}\overline{\Sigma}^{0}$ (2.9 ±0.8) × 10 ⁻⁴ 4.8 ±0.6	BOYARSKI 75 MRK1 e ⁺ e ⁻
$K^{+}K^{-}$ (2.37±0.31) × 10 ⁻⁴ 4.6 ±1.0	ESPOSITO 75B FRAM e^+e^-
	ultaneous fit to e^+e^- , $\mu^+\mu^-$, and hadronic channels assuming $\Gamma(e^+e^-)$
$\pi^{+}\pi^{-}$ (1.47±0.23) × 10 ⁻⁴ $= \Gamma(\mu^{+}\mu^{-})$	
	qual partial widths for e^+e^- and $\mu^+\mu^-$.
4 = 1 	-
$\kappa^0 \kappa^0$	Γ4
	DOCUMENT ID TECN COMMENT
···	ot use the following data for averages, fits, limits, etc. • • •
$\gamma \eta_c(1S)$ (1.3 ±0.4)% 5.13±0.52	BAI 95B BES e^+e^-
$\gamma \pi^{+} \pi^{-} 2\pi^{0}$ (8.3 ±3.1) × 10 ⁻³ 4.8 ±0.6	BOYARSKI 75 MRK1 e ⁺ e ⁻
$\gamma \eta \pi \pi$ (6.1 ±1.0) × 10 ⁻³ 5 ±1	ESPOSITO 75B FRAM e^+e^-
$\gamma \eta (1440) \rightarrow \gamma K \overline{K} \pi \qquad [c] (9.1 \pm 1.8) \times 10^{-4}$	Γ ₁₁₅
$\gamma \eta(1440) \rightarrow \gamma \gamma \rho^0$ (6.4 ±1.4) × 10 ⁻⁵ VALUE (eV)	CL% DOCUMENT ID TECN COMMENT
$\gamma \rho \rho \qquad (4.5 \pm 0.8) \times 10^{-3} $	90 BRANDELIK 79C DASP e ⁺ e ⁻
$\gamma \eta'(958)$ (4.31±0.30) × 10 ⁻³	90 BRANDELIK 190 DASF 6 6
$\gamma 2\pi^{+} 2\pi^{-}$ (2.8 ±0.5) × 10 ⁻³ S=1.9	(/ (6.6) E())=(± -) (E() + 1)
$_0 \gamma f_4(2050)$ (2.7 ±0.7) × 10 ⁻³	$J/\psi(1S)$ $\Gamma(i)\Gamma(e^+e^-)/\Gamma(ext{total})$
$1 \gamma \omega \omega$ (1.59±0.33)×10 ⁻³ This co	ombination of a partial width with the partial width into e^+e^-
	th the total width is obtained from the integrated cross section into
$_3 \gamma f_2(1270)$ (1.38±0.14)×10 ⁻³ channe	e l $_{ m I}$ in the e^+e^- annihilation.
$A \sim f_1(1710) \rightarrow \gamma K\overline{K}$ $(9.7 + 1.2) \times 10^{-4}$	
$_{5}^{+}$ $\gamma\eta$ (8.6 ±0.8) \times 10 ⁻⁴	$\langle \Gamma(e^+e^-)/\Gamma_{\text{total}} $ $\Gamma_1\Gamma_3/\Gamma_1$
$_{6}$ $\gamma f_{1}(1420) \rightarrow \gamma K \overline{K} \pi$ (8.3 ±1.5) × 10 ⁻⁴ $\frac{VALUE(\text{keV})}{}$	DOCUMENT ID TECN COMMENT
$7 \gamma f_1(1285)$ (6.5 ±1.0) × 10 ⁻⁴ • • • We do not	ot use the following data for averages, fits, limits, etc. • • •
$_{8} \gamma f_{2}'(1525)$ (6.3 ±1.0) × 10 ⁻⁴ 4 ±0.8	⁷ BALDINI 75 FRAG e^+e^-
$9 \ \gamma \phi \phi$ (4.0 ±1.2)×10 ⁻⁴ S=2.1 3.9±0.8	⁷ ESPOSITO 75B FRAM e^+e^-
1 11± 1 4	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	$\Gamma(e^+e^-)/\Gamma_{\text{total}}$ $\Gamma_3\Gamma_3/\Gamma$
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	DOCUMENT ID TECN COMMENT
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	ot use the following data for averages, fits, limits, etc. • • •
$\frac{3}{4} \gamma p \overline{p} \pi^{+} \pi^{-}$ < 7.9 × 10 ⁻⁴ CL=90% 0.35±0.02	BRANDELIK 79C DASP e ⁺ e ⁻
$\frac{4}{5} \gamma \gamma$ < 5 × 10 ⁻⁴ CL=90% 0.32±0.07	⁷ BALDINI 75 FRAG e ⁺ e ⁻
0.34 ± 0.14	BEMPORAD 75 FRAB e ⁺ e ⁻
0.34±0.09	⁷ ESPOSITO 75B FRAM e^+e^-
7 3 γ < 5.5 × 10 5 CL=90% 0.36±0.10 8 $\gamma f_0(2200)$	⁷ FORD 75 SPEC e^+e^-
$g \gamma_{0}(2220)$ $ \Gamma(\mu^{+}\mu^{-}) \times $	$\Gamma(e^+e^-)/\Gamma_{\text{total}}$ $\Gamma_4\Gamma_3/\Gamma$
	DOCUMENT ID TECH COMMENT
	ot use the following data for averages, fits, limits, etc. • •
a) The value is for the sum of the charge states of particle/antiparticle states 0.31 ± 0.09	BEMPORAD 75 FRAB e ⁺ e ⁻ DASP 75 DASP e ⁺ e ⁻
a) The value is for the sum of the charge states of particle/antiparticle states 0.51 ± 0.09 indicated. 0.38 ± 0.05	DASP 75 DASP e ⁺ e ⁻ 7 ESPOSITO 75B FRAM e ⁺ e ⁻
0.46 0.10	7 LIBERMAN 75 SPEC e ⁺ e ⁻
b] includes $pp\pi^+\pi^-\gamma$ and excludes $pp\eta$, $pp\omega$, $pp\eta$.	
c] See the "Note on the $\eta(1440)$ " in the $\eta(1440)$ Particle Listings. $\Gamma(p\overline{p}) \times \Gamma(e^{-p})$	$e^+e^-)/\Gamma_{ ext{total}}$ $\Gamma_{75}\Gamma_3/\Gamma_3$
VALUE (keV)	DOCUMENT ID TECN COMMENT
$J/\psi(1S)$ PARTIAL WIDTHS 9.7 \pm 1.7	6 ARMSTRONG 93B SPEC $\overline{p}p \rightarrow e^+e^-$
6 Using F	$_{\rm I} = 85.5 ^{+6.1}_{-5.8} {\rm MeV}.$
.1	
	dant with branching ratios or partial widths above.
JE (keV) DOCUMENT ID TECN COMMENT 7 Data redund	
UE (keV) DOCUMENT ID TECN COMMENT TECN COMMENT TO Data redund TECN COMMENT To Data redund	I/M(1C) PRANCHING PATIOS
• We do not use the following data for averages, fits, limits, etc. • • • \pm 8.1 BAI 95B BES e^+e^-	$J/\psi(15)$ Branching ratios
• We do not use the following data for averages, fits, limits, etc. • • • $ \pm 8.1 \qquad \text{BAL } \qquad 958 \text{ BES} \qquad e^+e^- \\ \pm 24 \qquad \qquad \text{BALDINI} \qquad 75 \text{ FRAG } e^+e^- $	
UE (keV)DOCUMENT IDTECNCOMMENT7 Data redund• We do not use the following data for averages, fits, limits, etc. • • • \pm 8.1BAI95B BES $e^+e^ \pm$ 24BALDINI 75FRAG $e^+e^ \pm$ 14BOYARSKI75 MRKI e^+e^- For the	e first four branching ratios, see also the partial widths, and (partial
UE (keV)DOCUMENT IDTECNCOMMENT7 Data redund• We do not use the following data for averages, fits, limits, etc. • • • \pm 8.1BAI95B BES $e^+e^ \pm$ 24BALDINI 75FRAG $e^+e^ \pm$ 14BOYARSKI75 MRKI e^+e^- For the	
• We do not use the following data for averages, fits, limits, etc. • • • $ \pm 8.1 \qquad \text{BAI} \qquad 958 \text{ BES} \qquad e^+e^- \\ \pm 24 \qquad \text{BALDINI} \qquad 75 \text{ FRAG} \qquad e^+e^- \\ \pm 14 \qquad \text{BOYARSKI} \qquad 75 \text{ MRK1} \qquad e^+e^- \qquad \text{For the} \\ \pm 25 \qquad \text{ESPOSITO} \qquad 758 \text{ FRAM} \qquad e^+e^- \qquad \text{widths} $	e first four branching ratios, see also the partial widths, and (partial) \times $\Gamma(e^+e^-)/\Gamma_{total}$ above.
$\frac{JE(\text{keV})}{}$ DOCUMENT ID TECN COMMENT 7 Data redund • We do not use the following data for averages, fits, limits, etc. • • • ± 8.1 BAI 958 BES e^+e^- ± 24 BALDINI 75 FRAG e^+e^- ± 14 BOYARSKI 75 MRK1 e^+e^- For the ± 25 ESPOSITO 758 FRAM e^+e^- widths) Fruitualγ → hadrons) F2 Γ(hadrons)/Γ	e first four branching ratios, see also the partial widths, and (partial) $\times \Gamma(e^+e^-)/\Gamma_{ m total}$ above.
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	the first four branching ratios, see also the partial widths, and (partial $) \times \Gamma(e^+e^-)/\Gamma_{total}$ above. Total
$\frac{JE(\text{keV})}{}$ DOCUMENT ID TECN COMMENT 7 Data redund • We do not use the following data for averages, fits, limits, etc. • • • ± 8.1 BAI 958 BES e^+e^- ± 24 BALDINI 75 FRAG e^+e^- ± 14 BOYARSKI 75 MRK1 e^+e^- For the ± 25 ESPOSITO 758 FRAM e^+e^- widths) Fruitualγ → hadrons) F2 Γ(hadrons)/Γ	the first four branching ratios, see also the partial widths, and (partial $) \times \Gamma(e^+e^-)/\Gamma_{\rm total}$ above.

 $\frac{\Gamma(\text{virtual}\gamma \rightarrow \text{hadrons})/\Gamma_{\text{total}}}{\text{0.17 } \pm 0.02}$

 $^8\,\text{Included}$ in $\Gamma \big(\text{hadrons}\big)/\Gamma_{\mbox{total}}.$

$J/\psi(1S)$

Γ ₁₃ /				$+ c.c.)/\Gamma_{total}$	Γ(<i>K</i> + K *(892)−⊣	Г ₃ /Г		$(e^+e^-)/\Gamma_{\text{total}}$
· ·	COMMENT	TECN	CUMENT ID	EVTS VERAGE	VALUE (units 10 ⁻³) 5.0 ±0.4 OUR AVE	COMMENT	DOCUMENT ID TECN	0602±0.0019 OUR AVERAGE
5	$J/\psi ightarrow { m hadron}$	DM2	USSET 90	2285	4.57±0.17±0.70	e ⁺ e ⁻	BAI 958 BES	0609±0.0033
	$J/\psi \to K^{\pm}K^{0}$ $K^{+}K^{-}\pi^{0}$				$5.26 \pm 0.13 \pm 0.53$	$\psi(2S) \rightarrow J/\psi \pi^+ \pi^ e^+ e^-$	COFFMAN 92 MRK3 BOYARSKI 75 MRK1	0592±0.0015±0.0020 069 ±0.009
•	etc. • • •					Г ₄ /Г		$(\mu^+\mu^-)/\Gamma_{\text{total}}$
	$J/\psi \rightarrow K^+K^-$			24	2.6 ±0.6	COMMENT	DOCUMENT ID TECN	UE
π^+	$J/\psi \rightarrow K^{\pm}K_{5}^{0}$			48	3.2 ±0.6			601±0.0019 OUR AVERAGE
	$J/\psi \to K^{\pm}X$	DASP	AUNSCH 76	39	4.1 ± 1.2	e+ e-	BAI 958 BES	0608±0.0033
Γ ₁₄ /				+ c.c.) / Ftotal	Γ(<i>Κ</i> ⁰ <i>K</i> *(892) ⁰ +	$\psi(2S) \rightarrow J/\psi \pi^+ \pi^-$		$0.590 \pm 0.0015 \pm 0.0019$
14/	COMMENT	TECN	CUMENT ID	EVTS	VALUE (units 10 ⁻³)	e+ e-	BOYARSKI 75 MRK1	069 ±0.009
	COMMENT	72014	COMENTIB		4.2 ±0.4 OUR AVE	Γ_3/Γ_4		$(e^+e^-)/\Gamma(\mu^+\mu^-)$
5	$J/\psi ightarrow { m hadron}$	DM2	USSET 90	1192	$3.96 \pm 0.15 \pm 0.60$	COMMENT	DOCUMENT ID TECN	LUE
π [∓]	$J/\psi \rightarrow K^{\pm}K_{\pm}^{0}$				$4.33 \pm 0.12 \pm 0.45$			We do not use the following
			-	se the following o	 ● ● We do not use 	e+ e-	BAI 958 BES	0±0.07
π^{\mp}	$J/\psi \rightarrow K^{\pm}K_{3}^{0}$	MRK1	NNUCCI 77	45	2.7 ± 0.6	e+ e-	BOYARSKI 75 MRK1	00±0.05
/-			902))	\ /F/W+Te	Γ(<i>Κ</i> ⁰ <i>K</i> *(892) ⁰ +		ESPOSITO 758 FRAM	01 ± 0.15
14/F ₁	COMMENT	TECN		F C.C.)/1 (N · N	VALUE	e ⁺ e ⁻	FORD 75 SPEC	3 ± 0.10
	$J/\psi \rightarrow$				0.82±0.05±0.09		ADRONIC DECAYS	на
c.c.	$K\overline{K}^*(892) +$	WINNS	TIMAN 00		0.0110.0310.07		IDITOTIC DECITO	
	(5,2) 1				=/ 0 0\·-	Γ₅/Γ		$(ho\pi)/\Gamma_{ m total}$
Γ ₁₅ /				ıl	$\Gamma(\omega\pi^0\pi^0)/\Gamma_{ m total}$	COMMENT	DOCUMENT ID TEC	LUE EVTS
	COMMENT	TECN	CUMENT ID	EVTS	VALUE (units 10 ⁻³)	3 e ⁺ e ⁻	COFFMAN 88 MR	0128±0.0010 OUR AVERAGE 0142±0.0001±0.0019
$3\pi^{0}$	$J/\psi \rightarrow \pi^+\pi^-$	DM2	IGUSTIN 89	509	$3.4 \pm 0.3 \pm 0.7$	2 e ⁺ e ⁻		013 ±0.003 150
Γ ₁₆ /)/Fac	$\Gamma(b_1(1235)^{\pm}\pi^{\mp})$		ALEXANDER 78 PL	016 ±0.004 183
16/	COMMENT	TECH	CUMENT ID	•		e+e-	BRANDELIK 78B DA	0133±0.0021
	COMMENT	TECN	COMENTID	GE EVTS	VALUE (units 10 ⁻⁴) 30±5 OUR AVERAGE	R e + e -		010 ±0.002 543
$-)_{\pi}^{0}$	$J/\psi \rightarrow 2(\pi^{+}\pi^{-})$	DM2	IGUSTIN 89	4600	31±6	1 e ⁺ e ⁻	JEAN-MARIE 76 MR	013 ±0.003 153
,			IRMESTER 77D	87	29±7	Γ ₆ /Γ ₅		$(ho^0\pi^0)/\Gamma(ho\pi)$
				-	=/ ··+··0 =\ /-	'6/'5	DOCUMENT ID TECN	LUE
Γ ₁₇ /					$\Gamma(\omega K^{\pm} K_S^0 \pi^{\mp})/\Gamma$		COFFMAN 88 MRK3	328±0.005±0.027
	COMMENT		CUMENT ID	EVTS	VALUE (units 10 ⁻⁴)			We do not use the following
ons	$e^+e^- \rightarrow hadr$	MRK3	CKER 87	$^{879\pm}_{41}$	$29.5 \pm 1.4 \pm 7.0$	+ e-	SCHARRE 798 MRK1	36 ±0.03
						e+ e	ALEXANDER 78 PLUT	85 ±0.08
Γ ₁₈ /				/Γ _{total}	$\Gamma(b_1(1235)^0\pi^0)/$		BRANDELIK 78B DASP	32 ±0.08
	COMMENT	TECN	CUMENT ID	EVTS	VALUE (units 10 ⁻⁴)		BARTEL 76 CNTR	39 ±0.11
	e^+e^-	DM2	IGUSTIN 89	229	23±3±5	e+e-	JEAN-MARIE 76 MRK1	37 ±0.09
Γ19/				- c c) / [$\Gamma(\phi K^*(892)\overline{K} + c$	Γ_7/Γ		$(a_2(1320)\rho)/\Gamma_{\text{total}}$
. 19/	COMMENT	TECN	CUMENT ID	EVTS	VALUE (units 10 ⁻⁴)	COMMENT	DOCUMENT ID TECN	LUE (units 10 ⁻³) EVTS
	COMMENT	TECH	COMENTID		20.4±2.8 OUR AVE			.9±2.2 OUR AVERAGE
5	$J/\psi ightarrow { m hadron}$	DM2	LVARD 88		20.7±2.4±3.0	$I/\psi \rightarrow \rho^0 \rho^{\pm} \pi^{\mp}$	AUGUSTIN 89 DM2	.7±0.7±2.5 7584
ons	$e^+e^- ightarrow hadr$	MRK3	CKER 87	155±	20 ± 3 ± 3	$e^+e^- \to 2(\pi^+\pi^-)\pi^0$	VANNUCCI 77 MRK1	3.4 ± 4.5 36
				20		Г ₈ /Г		$(\omega\pi^+\pi^+\pi^-\pi^-)/\Gamma_{ ext{total}}$
$\Gamma_{20}/$					$\Gamma(\omega K \overline{K})/\Gamma_{\text{total}}$		DOCUMENT ID TOO	• • • • • • • • • • • • • • • • • • • •
	COMMENT	TECN	CUMENT ID	EVTS	VALUE (units 10-4)	COMMENT		ALUE (units 10 ⁻⁴) EVTS
					19 ± 4 OUR AVE	$e^+e^- \to 3(\pi^+\pi^-)\pi^0$	VANNUCCI 77 MRK1	5 ±34 140
š	$J/\psi \rightarrow \text{hadron}$				19.8 ± 2.1 ± 3.9	٦/و٢		$(\omega \pi^+ \pi^-)/\Gamma_{ ext{total}}$
	e e e -	MRK1		22	16 ±10	COMMENT	DOCUMENT ID TECN	LUE (units 10 ⁻³) EVTS
			branching ratios.		10 Addition of ω K^+			2±1.0 OUR AVERAGE
Γ ₂₁ /				$\omega K \overline{K})/\Gamma_{\text{total}}$	$\Gamma(\omega f_J(1710) \rightarrow \omega$	$J/\psi \rightarrow 2(\pi^+\pi^-)\pi^0$	AUGUSTIN 89 DM2	0±1.6 18058
/	COMMENT	TECN	CUMENT ID	,, total	VALUE (units 10 ⁻⁴)		BURMESTER 77D PLUT	3 ± 1.6 215
	$J/\psi \rightarrow \text{hadron}$			11,12	4.8±1.1±0.3	$e^+e^- \to 2(\pi^+\pi^-)\pi^0$	VANNUCCI 77 MRK1	3±1.9 348
	, ,				¹¹ Includes unknowr	Γ_9/Γ_{61}		$(\omega \pi^{+} \pi^{-}) / \Gamma(2(\pi^{+} \pi^{-}) \pi^{0})$
	ranching ratios				¹² Addition of $f_I(17)$	OMMENT '9/'61	DOCUMENT ID TECN_	UE
				·	3.			We do not use the following
$\Gamma_{22}/$				total	$\Gamma(\phi 2(\pi^+\pi^-))/\Gamma_{\rm t}$		9 JEAN-MARIE 76 MRK1	
	COMMENT	TECN	CUMENT ID		VALUE (units 10 ⁻⁴)			9 Final state $(\pi^+\pi^-)\pi^0$ under th
		DM2	LVARD 88		$16.0 \pm 1.0 \pm 3.0$	II U.		• •
5	$J/\psi ightarrow { m hadron}$			π=\ /r	$\Gamma(\Delta(1232)^{++}\overline{p}\pi$	Γ ₁₀ /Γ	/Γ _{total}	$(K^*(892)^0\overline{K}_2^*(1430)^0 + \text{c.c.})$
	$J/\psi ightarrow $ hadron			" //ˈtotai	VALUE (units 10 ⁻³)	COMMENT	DOCUMENT ID TECN	LUE (units 10 ⁻⁴) EVTS
		TE 011	SUMMENT ID	• •				
	COMMENT		CUMENT ID	EVTS		+ e- →	VANNUCCI 77 MRK1	±26 40
	COMMENT	TECN MRK2		• •	1.58±0.23±0.40		***************************************	±26 40
Γ ₂₃ /	COMMENT			EVTS		$e^+e^{\pi^+\pi^-K^+K^-}$	***************************************	
Γ ₂₃ /	COMMENT e+e-	MRK2		EVTS	1.58±0.23±0.40	e ⁺ e ⁻ → κ ⁺ κ ⁻ Γ ₁₁ /Γ	VANNUCCI 77 MRK1	$\omega K^*(892)\overline{K} + \text{c.c.})/\Gamma_{\text{total}}$
Γ ₂₃ /	COMMENT e+e- COMMENT	MRK2	CUMENT ID		$1.58\pm0.23\pm0.40$ $\Gamma(\omega\eta)/\Gamma_{ ext{total}}$	$e^+e^{\pi^+\pi^-K^+K^-}$ Γ_{11}/Γ	VANNUCCI 77 MRK1	$\omega K^*(892)\overline{K} + \text{c.c.})/\Gamma_{\text{total}}$ LUE (units 10^{-4}) EVTS
Γ ₂₃ /	$COMMENT$ $e^+e^ COMMENT$ $J/\psi ightarrow hadron$	MRK2 TECN DM2	CUMENT ID USSET 90		1.58 \pm 0.23 \pm 0.40 $\Gamma(\omega\eta)/\Gamma_{\rm total}$ VALUE (units 10^{-3}) 1.58 \pm 0.16 OUR AVI 1.43 \pm 0.10 \pm 0.21	e ⁺ e ⁻ → κ ⁺ κ ⁻ Γ ₁₁ /Γ	VANNUCCI 77 MRK1	$\omega K^*(892)\overline{K} + \text{c.c.})/\Gamma_{\text{total}}$ UE (units 10^{-4}) $EVTS$
Γ ₂₃ /	COMMENT e+e- COMMENT	MRK2 TECN DM2	CUMENT ID USSET 90	332 EVTS EVTS VERAGE	1.58 \pm 0.23 \pm 0.40 $\Gamma(\omega \eta)/\Gamma_{\text{total}}$ VALUE (units 10 ⁻³) 1.58 \pm 0.16 OUR AVI	$\begin{array}{ccc} e^+e^- & \rightarrow \\ \pi^+\pi^-K^+K^- & & \\ \hline \Gamma_{11}/\Gamma & & \\ \hline COMMENT & \\ e^+e^- & \rightarrow & \text{hadrons} \end{array}$	VANNUCCI 77 MRK1	$\omega K^*(892)\overline{K} + \text{c.c.})/\Gamma_{\text{total}}$ $UE \text{ (units } 10^{-4})$ $\pm 14 \pm 14$ $EVTS$ 530 ± 140
Γ ₂₃ /	$COMMENT$ $e^+e^ COMMENT$ $J/\psi ightarrow hadron$	MRK2 TECN DM2	CUMENT ID USSET 90	332 EVTS EVTS VERAGE	1.58 \pm 0.23 \pm 0.40 $\Gamma(\omega\eta)/\Gamma_{\text{total}}$ VALUE (units 10 ⁻³) 1.58 \pm 0.16 OUR AVI 1.43 \pm 0.10 \pm 0.21 1.71 \pm 0.08 \pm 0.20	$\begin{array}{ccc} + e^{-} \xrightarrow{\rightarrow} & & & \\ \pi^{+} \pi^{-} K^{+} K^{-} & & & \\ & & & & & \\ \hline & & & & & \\ \hline & & & &$	DOCUMENT ID TECN BECKER 87 MRK3	$\omega K^*(892)\overline{K} + \text{c.c.})/\Gamma_{\text{total}}$ $\frac{\omega EVTS}{530 \pm 140}$ $\omega f_2(1270))/\Gamma_{\text{total}}$
Γ ₂₃ /	$\begin{array}{c} \underline{COMMENT} \\ e^+ e^- \end{array}$ $\begin{array}{c} \underline{COMMENT} \\ J/\psi \rightarrow \text{ hadron} \\ e^+ e^- \rightarrow 3\pi \eta \end{array}$	MRK2 TECN DM2 MRK3	CUMENT ID USSET 90 DEFMAN 88	332 EVTS VERAGE 378	1.58 \pm 0.23 \pm 0.40 $\Gamma(\omega\eta)/\Gamma_{\text{total}}$ VALUE (units 10 ⁻³) 1.58 \pm 0.16 OUR AVI 1.43 \pm 0.10 \pm 0.21 1.71 \pm 0.08 \pm 0.20 $\Gamma(\phi K \overline{K})/\Gamma_{\text{total}}$	$\begin{array}{ccc} e^+e^- & \rightarrow \\ \pi^+\pi^-K^+K^- & & \\ \hline \Gamma_{11}/\Gamma & & \\ \hline COMMENT & \\ e^+e^- & \rightarrow & \text{hadrons} \end{array}$	VANNUCCI 77 MRK1	$\frac{E \times (892)\overline{K} + \text{c.c.})/\Gamma_{\text{total}}}{E \times (892)\overline{K} + \text{c.c.}}$ $\frac{E \times TS}{530 \pm 140}$ $\frac{E \times TS}{140}$
Γ ₂₃ /	$COMMENT$ $e^+e^ COMMENT$ $J/\psi ightarrow hadron$	MRK2 TECN DM2	CUMENT ID USSET 90	EVTS 332 VERAGE 378	1.58 \pm 0.23 \pm 0.40 $\Gamma(\omega \eta)/\Gamma_{\text{total}}$ VALUE (units 10 ⁻³) 1.58 \pm 0.16 OUR AVI 1.43 \pm 0.10 \pm 0.21 1.71 \pm 0.08 \pm 0.20 $\Gamma(\phi K K)/\Gamma_{\text{total}}$ VALUE (units 10 ⁻⁴)	$\begin{array}{ccc} + e^{-} & \rightarrow \\ \pi^{+} \pi^{-} K^{+} K^{-} \end{array}$ $\begin{array}{c} \Gamma_{11}/\Gamma \\ \hline \text{COMMENT} \\ e^{+} e^{-} & \rightarrow \text{ hadrons} \end{array}$ $\begin{array}{c} \Gamma_{12}/\Gamma \\ \hline \text{COMMENT} \end{array}$	DOCUMENT ID TECN DOCUMENT ID TECN DOCUMENT ID TECN	$\omega K^*(892)\overline{K} + \text{c.c.})/\Gamma_{\text{total}}$ $UE \text{ (units } 10^{-4})$ $\pm 14 \pm 14$ 530 ± 140 $\omega f_2(1270))/\Gamma_{\text{total}}$ $UE \text{ (units } 10^{-3})$ $EVTS$ ± 140 $EVTS$ $EVTS$ $EVTS$ $EVTS$ $EVTS$ $EVTS$
Γ ₂₃ / Γ ₂₄ /	$\begin{array}{c} \underline{COMMENT} \\ e^+ e^- \end{array}$ $\begin{array}{c} \underline{COMMENT} \\ J/\psi \rightarrow \text{ hadron} \\ e^+ e^- \rightarrow 3\pi \eta \end{array}$	TECN DM2 MRK3	COMENT ID USSET 90 DEFMAN 88	EVTS 332 EVTS VERAGE 378 EVTS ERAGE	1.58 \pm 0.23 \pm 0.40 $\Gamma(\omega\eta)/\Gamma_{\text{total}}$ VALUE (units 10 ⁻³) 1.58 \pm 0.16 OUR AVI 1.43 \pm 0.10 \pm 0.21 1.71 \pm 0.08 \pm 0.20 $\Gamma(\phi K \overline{K})/\Gamma_{\text{total}}$	$\begin{array}{ccc} + e^{-} & \rightarrow \\ \pi^{+} \pi^{-} K^{+} K^{-} \end{array}$ $\begin{array}{c} \Gamma_{11} / \Gamma \\ \hline COMMENT \\ + e^{-} & \rightarrow \text{ hadrons} \end{array}$ $\begin{array}{c} \Gamma_{12} / \Gamma \\ \hline COMMENT \\ + e^{-} \end{array}$	DOCUMENT ID TECN BECKER 87 MRK3	$\frac{E_{UE \text{ (units } 10^{-4})}}{140}$ $\frac{EVTS}{140}$ $\frac{EVTS}{1400}$ $\frac{EVTS}{1400}$ $\frac{EVTS}{14000}$ $\frac{EVTS}{140000}$ $\frac{EVTS}{14000000000000000000000000000000000000$
Γ ₂₃ / Γ ₂₄ /	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \end{array}$ $\begin{array}{c} \underline{COMMENT} \\ J/\psi \rightarrow \text{ hadron} \\ e^+e^- \rightarrow 3\pi\eta \\ \\ \underline{COMMENT} \\ J/\psi \rightarrow \text{ hadron} \end{array}$	TECN DM2 MRK3	COMENT ID USSET 90 DEFMAN 88 COMENT ID LVARD 88	EVTS 332 EVTS VERAGE 378 EVTS ERAGE	1.58 \pm 0.23 \pm 0.40 $\Gamma(\omega\eta)/\Gamma_{\text{total}}$ 1.58 \pm 0.16 OUR AVI 1.43 \pm 0.10 \pm 0.21 1.71 \pm 0.08 \pm 0.20 $\Gamma(\phi K \overline{K})/\Gamma_{\text{total}}$ 1.4.8 \pm 2.2 OUR AVEI 1.8.2.2 OUR AVEI	$\begin{array}{ccc} + e^{-} & \rightarrow \\ \pi^{+} \pi^{-} K^{+} K^{-} \end{array}$ $\begin{array}{c} \Gamma_{11}/\Gamma \\ \hline COMMENT \\ + e^{-} & \rightarrow \text{ hadrons} \end{array}$ $\begin{array}{c} \Gamma_{12}/\Gamma \\ \hline COMMENT \\ + e^{-} \\ + e^{-} \end{array}$	DOCUMENT ID TECN BECKER 87 MRK3 DOCUMENT ID TECN AUGUSTIN 89 DM2 BURMESTER 770 PLUT	$\frac{(\omega K^*(892) \overline{K} + \text{c.c.}) / \Gamma_{\text{total}}}{8 \pm 14 \pm 14} = \frac{EVTS}{140}$ $\frac{EVTS}{140}$ $(\omega f_2(1270)) / \Gamma_{\text{total}}$ $\frac{EVTS}{140}$ $\frac{EVTS}{140}$ $\frac{EVTS}{140}$ $\frac{EVTS}{3 \pm 0.6 \text{ OUR AVERAGE}}$ $3 \pm 0.2 \pm 0.6 = 5860$

$\Gamma(\phi f_J(1710) \rightarrow \phi K \overline{K})/\Gamma_{\text{tot}}$ VALUE (units 10 ⁻⁴)		Γ ₂₆							Г39/Г
	,15 FALVARD 88 DM2	$\frac{COMMENT}{J/\psi \rightarrow \text{hadrons}}$	VALUE (units 10 ⁻³) 0.33 ±0.04 OUI		EVTS DOCE	UMENT	r ID	TECN C	COMMENT
¹⁴ Including interference with f_2'		$J/\psi \rightarrow \text{flations}$	0.41 ±0.03 ±0.0		167 JOU	SSET	90	DM2 .	$J/\psi \rightarrow$
15 Includes unknown branching f	raction $f_J(1710) \rightarrow K\overline{K}$.		$0.308 \pm 0.034 \pm 0.0$	36	COF	FMAN	V 88	MRK3 6	hadrons e+e- →
$\Gamma(p\overline{p}\omega)/\Gamma_{\text{total}}$	3 . ,	-	• • • We do not us	e the followin	a data for average	oc fita	e limite	etc e e	$\kappa^+ \kappa^- \eta'$
VALUE (units 10 ⁻³) EVTS	DOCUMENT ID TECN	Г ₂₇ соммент	<1.3	90		NUCC		MRK1 6	ر -م+ء
1.30±0.25 OUR AVERAGE Err		COMMENT			*/		-, ,,	WINNE	
$1.10 \pm 0.17 \pm 0.18$ 486	EATON 84 MRK2		$\Gamma(\phi f_0(980))/\Gamma_{\text{tot}}$						Γ ₄₀ /Γ
1.6 ±0.3 77	PERUZZI 78 MRK1	e+ e-	<u>VALUE</u> (units 10 ⁻⁴) 3.2±0.9 OUR AVER	AGE Error	DOCUMENT ID		1 9	COMMENT	
$\Gamma(\Delta(1232)^{++}\overline{\Delta}(1232)^{})/$	Γ _{total}	Γ ₂₈		NGE ENO	¹⁸ FALVARD		DM2	$J/\psi ightarrow h$	adrons
VALUE (units 10 ⁻³) EVTS	DOCUMENT ID TECN	COMMENT	2.6±0.6	50	¹⁸ GIDAL	81	MRK2	$J/\psi \rightarrow$	
1.10±0.09±0.28 233	EATON 84 MRK2	e+e-	¹⁸ Assuming B(f_0 (9	80) → ππ)	- 0.78			K+ K-	- K+ K-
$\Gamma(\Sigma(1385)^{-}\overline{\Sigma}(1385)^{+})$ (or c.	c.))/F _{total}	Γ ₂₉	/r		_ 5.761				
VALUE (units 10 ⁻³) EVTS	•		(=(1930)===)/						Γ ₄₁ /Γ
1.03±0.13 OUR AVERAGE			VALUE (units 10 ⁻³) 0.32±0.12±0.07	EVTS	DOCUMENT ID		TECN DM2	COMMENT e+e	
$1.00 \pm 0.04 \pm 0.21$ 631 ± 25			0.32±0.12±0.07	24 ± 9	HENRARD	87	DIVIZ	e · e	
$1.19 \pm 0.04 \pm 0.25$ 754 ± 27	HENRARD 87 DN	$12 e^+e^- \rightarrow \Sigma^{*+}$	$\Gamma(\Sigma(1385)^{-}\overline{\Sigma}^{+}($	or c.c.)) / [-	otal				Γ ₄₂ /Γ
$0.86 \pm 0.18 \pm 0.22$ 56		RK2 $e^+e^- \rightarrow \Sigma^{*-}$	VALUE (units 10 ⁻³)	EVTS	DOCUMENT ID		TECN	COMMENT	- 44/1
1.03±0.24±0.25 68	EATON 84 MF	RK2 $e^+e^- \rightarrow \Sigma^{*+}$	0.31±0.05 OUR AV	RAGE					
$\Gamma(p\overline{p}\eta'(958))/\Gamma_{\text{total}}$		Г ₃₀		74 ± 8	HENRARD		DM2	e ⁺ e ⁻ →	
VALUE (units 10 ⁻³) EVTS		COMMENT	0.34±0.04±0.07	77 ±	HENRARD	87	DM2	$e^+e^- \rightarrow$	Σ^{*+}
0.9 ±0.4 OUR AVERAGE Erro 0.68±0.23±0.17 19	or includes scale factor of 1.7. EATON 84 MRK2	e+e-	$0.29 \pm 0.11 \pm 0.10$	26	EATON			$e^+e^- \rightarrow$	
1.8 ±0.6 19	PERUZZI 78 MRK1		$0.31 \pm 0.11 \pm 0.11$	28	EATON	84	MRK2	e ⁺ e ⁻ →	Σ^{*+}
T(+ f) (1E0E) \ /T		-	$\Gamma(\phi f_1(1285))/\Gamma_{to}$	tal					Γ ₄₃ /Γ
$\Gamma(\phi f_2'(1525))/\Gamma_{\text{total}}$ VALUE (units 10 ⁻⁴) EVTS	DOCUMENT ID TECN	Г31	VALUE (units 10 1)	EVTS	DOCUMENT ID			COMMENT	
8 ±4 OUR AVERAGE Error		COMMENT	2.6±0.5 OUR AVER 3.2±0.6±0.4	AGE Error i	includes scale fact JOUSSET			$J/\psi \rightarrow \phi$	o/ + ->
	17 FALVARD 88 DM2	$J/\psi ightarrow { m hadrons}$	$2.1 \pm 0.5 \pm 0.4$	25	19 JOUSSET			$J/\psi \rightarrow \phi$ $J/\psi \rightarrow \phi$	
4.8±1.8 46	¹⁶ GIDAL 81 MRK2	$J/\psi \rightarrow K^+K^-K^+K^-$	● ● We do not use						•
		V . V V . V							
16 Re-evaluated using B(f_2' (1525	$) \rightarrow KK) = 0.713.$		$0.6 \pm 0.2 \pm 0.1$	16 ±	BECKER	87	MRK3	$J/\psi \rightarrow \phi$	$K\overline{K}\pi$
16 Re-evaluated using B(f'_2 (1525) 17 Including interference with f_J ($) \rightarrow KK) = 0.713.$ 1710).			6					
17 Including interference with f_J	$) \rightarrow KK) = 0.713.$ 1710).	F	¹⁹ We attrribute to bution at 1297 M	6 the f ₁ (1285)					
Γ^{17} Including interference with $f_{f}(\Gamma^{0})$	1710).	Γ ₃₂	¹⁹ We attrribute to bution at 1297 M	6 the f ₁ (1285)					ant mass distri-
17 Including interference with $f_f((\phi \pi^+ \pi^-) / \Gamma_{\text{total}})$ VALUE (units $^{10^{-3}})$ 0.80 ± 0.12 OUR AVERAGE) \rightarrow KK) = 0.713. 1710). DOCUMENT ID TECN	Γ ₃₂	/F $\frac{\int^{(\rho\eta)/\Gamma_{\text{total}}}}{\int^{(\rho\eta)/\Gamma_{\text{total}}}}$	6 the f ₁ (1285) lev.		ed in t			
17 Including interference with $f_J($ $\Gamma(\phi\pi^+\pi^-)/\Gamma_{ ext{total}}$ $VALUE (units 10^{-3}) EVTS 0.80\pm0.12 OUR AVERAGE 0.78\pm0.03\pm0.12$	1710). DOCUMENT ID TECN	$J/\psi ightarrow ext{hadrons}$	/\(\Gamma_{\text{pitton}}\) /\(\Gamma_{\text{pitton}}\) /\(\Gamma_{\text{pitton}}\) /\(\Gamma_{\text{total}}\) /\(\Gamma_{	the $f_1(1285)$ lev. $EVTS$ VERAGE	the signal observe	ed in t	the π^+ τ	π ⁻ η invaria	F44/F
17 Including interference with $f_J($ $\Gamma(\phi\pi^+\pi^-)/\Gamma_{ ext{total}}$ $VALUE$ (units 10^{-3}) EVTS 0.80 ± 0.12 OUR AVERAGE $0.78\pm0.03\pm0.12$ 23	DOCUMENT ID TECN	$J/\psi ightarrow ext{hadrons}$	/F $\frac{\int^{(\rho\eta)/\Gamma_{\text{total}}}}{\int^{(\rho\eta)/\Gamma_{\text{total}}}}$	6 the f ₁ (1285) lev.	the signal observe	ed in t	the π ⁺ τ <u>TECN</u> DM2	$\pi^-\eta$ invaria	Γ44/Γ adrons
17 Including interference with $f_J($ $\Gamma(\phi\pi^+\pi^-)/\Gamma_{ ext{total}}$ $VALUE$ (units 10^{-3}) $EVTS$ 0.80 ± 0.12 OUR AVERAGE $0.78\pm0.03\pm0.12$ 2.1 ±0.9 23 $\Gamma(\phi K^\pm K_S^0\pi^\mp)/\Gamma_{ ext{total}}$	1710). DOCUMENT ID TECN	$J/\psi ightarrow ext{hadrons}$	/F $\frac{19}{\text{We attrribute to}}$ bution at 1297 M $\Gamma(\rho\eta)/\Gamma_{\text{total}}$ $\frac{\text{VALUE (units 10}^{-3})}{0.193\pm0.023 \text{ OUR A}}$ $\frac{0.194\pm0.017\pm0.029}{0.193\pm0.013\pm0.029}$	6 the f ₁ (1285) lev. EVTS VERAGE 299	the signal observed DOCUMENT ID	ed in t	the π ⁺ τ <u>TECN</u> DM2	$\pi^-\eta$ invaria $\frac{COMMENT}{J/\psi ightarrow$ has	Γ_{44}/Γ_{-} adrons $\pi^+\pi^-\eta$
17 Including interference with $f_{J}($ $\Gamma(\phi\pi^{+}\pi^{-})/\Gamma_{\text{total}}$ $VALUE$ (units 10^{-3}) EVTS 0.80 ± 0.12 OUR AVERAGE $0.78\pm0.03\pm0.12$ 2.1 ± 0.9 23 $\Gamma(\phi\kappa^{\pm}\kappa^{0}_{S}\pi^{\mp})/\Gamma_{\text{total}}$ $VALUE$ (units 10^{-4}) EVTS	1710). DOCUMENT ID TECN	$SOMMENT$ $J/\psi \rightarrow \text{hadrons}$ e^+e^-	/F ρ /	6 the f ₁ (1285) ev. EVTS VERAGE299	DOCUMENT ID JOUSSET COFFMAN	90 88	the π ⁺ τ <u>TECN</u> DM2 MRK3	$T = \eta$ invaria $T = \eta$ invaria $T = 0$ invaria $T = 0$ invaria $T = 0$ invariants $T = $	Γ44/Γ adrons
17 Including interference with $f_J(\phi\pi^+\pi^-)/\Gamma_{ ext{total}}$ $VALUE$ (units 10^{-3}) EVTS 0.80 ± 0.12 OUR AVERAGE $0.78\pm0.03\pm0.12$ 2.1 ± 0.9 23 $\Gamma(\phi K^{\pm}K_S^0\pi^{\mp})/\Gamma_{ ext{total}}$ $VALUE$ (units 10^{-4}) EVTS 7.2 ± 0.9 OUR AVERAGE	DOCUMENT ID TECN FALVARD 88 DM2 FELDMAN 77 MRK1 DOCUMENT ID TECN	$J/\psi \rightarrow \text{hadrons}$ $e^+e^ \Gamma_{33}$	/F $\frac{19}{\text{We attrribute to}}$ bution at 1297 M $\Gamma(\rho\eta)/\Gamma_{\text{total}}$ $\frac{\text{VALUE (units 10}^{-3})}{0.193\pm0.023 \text{ OUR A}}$ $\frac{0.194\pm0.017\pm0.029}{0.193\pm0.013\pm0.029}$	6 the f ₁ (1285) lev. EVTS VERAGE 299	the signal observed DOCUMENT ID	90 88	the π ⁺ τ <u>TECN</u> DM2	$\pi^-\eta$ invaria $\frac{COMMENT}{J/\psi ightarrow$ has	Γ_{44}/Γ_{-} adrons $\pi^+\pi^-\eta$
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17 Including interference with $f_{J}(\[\Gamma(\phi\pi^{+}\pi^{-})/\Gamma_{\text{total}} \] \]$ $VALUE (units 10^{-3}) \] EVTS$ 0.80 ± 0.03 ± 0.12 2.1 ± 0.9 23 $\Gamma(\phi K^{\pm} K_{S}^{0}\pi^{\mp})/\Gamma_{\text{total}} \]$ $VALUE (units 10^{-4}) \] EVTS$ 7.2 ± 0.9 OUR AVERAGE 7.4 ± 0.9 ± 1.1 7 ± 0.6 ± 1.0 163 ± 15 $\Gamma(\omega f_{1}(1420))/\Gamma_{\text{total}} \]$ $VALUE (units 10^{-4}) \] EVTS$ 6.8 + 1.9 ± 1.7 111 + 31 1126 $\Gamma(\phi \eta)/\Gamma_{\text{total}} \]$ $VALUE (units 10^{-3}) \] EVTS$ 0.65 ± 0.07 OUR AVERAGE 0.64 ± 0.04 ± 0.11 346 0.661 ± 0.045 ± 0.078	DOCUMENT ID TECN FALVARD 88 DM2 FELDMAN 77 MRK1 DOCUMENT ID TECN FALVARD 88 DM2 BECKER 87 MRK3 DOCUMENT ID TECN BECKER 87 MRK3 DOCUMENT ID TECN JOUSSET 90 DM2	$\begin{array}{c} \underline{COMMENT} \\ J/\psi \ \rightarrow \ \text{hadrons} \\ e^+e^- \\ \hline \\ J/\psi \ \rightarrow \ \text{hadrons} \\ e^+e^- \ \rightarrow \ \text{hadrons} \\ \hline \\ \underline{COMMENT} \\ e^+e^- \ \rightarrow \ \text{hadrons} \\ \hline \\ \underline{COMMENT} \\ e^+e^- \ \rightarrow \ \text{hadrons} \\ \hline \\ COMMENT \\ \\ COMMENT \\ \hline \\ COMMENT \\ COMME$	19 We attribute to button at 1297 Metable function at 1297 Metable	6 the $f_1(1285)$ EVTS VERAGE 299 al EVTS VERAGE 6 $f_1(1285)$ $f_1(1285)$	DOCUMENT ID JOUSSET COFFMAN DOCUMENT ID JOUSSET COFFMAN DOCUMENT ID 20 AUGUSTIN = 0.78. DOCUMENT ID JOUSSET	90 88 90 88	TECN DM2 MRK3 TECN DM2 MRK3 TECN DM2 TECN DM2	$\begin{array}{c} \sigma & \text{π-η invaria} \\ \frac{COMMENT}{J/\psi} & \to \text{ his} \\ e^+ e^- & \to \\ \frac{COMMENT}{J/\psi} & \to \text{ his} \\ \frac{COMMENT}{J/\psi} & \to \text{ 2} \end{array}$	adrons $\pi^+\pi^-\eta$ Γ_{45}/Γ adrons $3\pi\eta'$ Γ_{46}/Γ $(\pi^+\pi^-)\pi^0$ Γ_{47}/Γ adrons
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17 Including interference with $f_{J}(\[\Gamma(\phi\pi^{+}\pi^{-})/\Gamma_{total} \] \]$ $VALUE (units 10^{-3})$ $VALUE (units 10^{-3})$ $VALUE (units 10^{-3})$ $VALUE (units 10^{-4})$ $VALUE (units 10^{-3})$	DOCUMENT ID TECN	$\begin{array}{c} \underline{COMMENT} \\ J/\psi \rightarrow \text{ hadrons} \\ e^+e^- \\ \hline \\ J/\psi \rightarrow \text{ hadrons} \\ e^+e^- \rightarrow \text{ hadrons} \\ \hline \\ \underline{COMMENT} \\ e^+e^- \rightarrow \text{ hadrons} \\ \hline \\ J/\psi \rightarrow \text{ hadrons} \\ \hline \\ J/\psi \rightarrow \text{ hadrons} \\ e^+e^- \rightarrow K^+K^-\eta \\ \hline \\ \hline \\ COMMENT \\ \hline \\ \hline \\ GOMMENT \\ \\ GOMMENT \\ \hline \\ GOMMENT \\ GOMMENT \\ \hline \\ GOMMENT \\$	19 We attribute to button at 1297 Metallic main state Met	6 the $f_1(1285)$ EVTS VERAGE 299 al EVTS VERAGE 6 al $EVTS$	DOCUMENT ID JOUSSET COFFMAN DOCUMENT ID JOUSSET COFFMAN DOCUMENT ID 20 AUGUSTIN = 0.78. DOCUMENT ID JOUSSET	90 88 90 88	TECN DM2 MRK3 TECN DM2 MRK3 TECN DM2 TECN DM2	$\begin{array}{c} \sigma & \text{π-η invaria} \\ \frac{COMMENT}{J/\psi} & \to \text{ his} \\ e^+ e^- & \to \\ \frac{COMMENT}{J/\psi} & \to \text{ his} \\ \frac{COMMENT}{J/\psi} & \to \text{ 2} \end{array}$	adrons $\pi^+\pi^-\eta$ Γ_{45}/Γ adrons $3\pi\eta'$ Γ_{46}/Γ $(\pi^+\pi^-)\pi^0$ Γ_{47}/Γ adrons
17 Including interference with $f_{J}(\[\Gamma(\phi\pi^{+}\pi^{-})/\Gamma_{total} \] \]$ $VALUE (units 10^{-3})$ $VALUE (units 10^{-3})$ $VALUE (units 10^{-3})$ $VALUE (units 10^{-4})$ $VALUE (units 10^{-3})$	DOCUMENT ID TECN	$\begin{array}{c} \underline{COMMENT} \\ J/\psi \to \text{ hadrons} \\ e^+e^- \\ \hline & \Gamma_{33}, \\ \underline{COMMENT} \\ J/\psi \to \text{ hadrons} \\ e^+e^- \to \text{ hadrons} \\ \hline & \Gamma_{34}, \\ \underline{COMMENT} \\ e^+e^- \to \text{ hadrons} \\ \hline & \Gamma_{35}, \\ \underline{COMMENT} \\ J/\psi \to \text{ hadrons} \\ e^+e^- \to K^+K^-\eta \\ \hline & \Gamma_{36}, \end{array}$	19 We attribute to bution at 1297 Metable funds 10-3	6 the $f_1(1285)$ EVTS VERAGE 299 al EVTS VERAGE 6 al $EVTS$	DOCUMENT ID JOUSSET COFFMAN DOCUMENT ID JOUSSET COFFMAN DOCUMENT ID 20 AUGUSTIN = 0.78. DOCUMENT ID JOUSSET	90 88 90 88	TECN DM2 MRK3 TECN DM2 MRK3 TECN DM2 MRK3 TECN DM2 MRK3	$\begin{array}{c} \sigma & \text{π-η invaria} \\ \frac{COMMENT}{J/\psi} & \to \text{ his} \\ e^+ e^- & \to \\ \frac{COMMENT}{J/\psi} & \to \text{ his} \\ \frac{COMMENT}{J/\psi} & \to \text{ 2} \end{array}$	ant mass distri-
17 Including interference with $f_{f}(x)$ Including int	DOCUMENT ID TECN	$\begin{array}{c} \underline{COMMENT} \\ J/\psi \rightarrow \text{ hadrons} \\ e^+e^- \\ \hline \\ J/\psi \rightarrow \text{ hadrons} \\ e^+e^- \rightarrow \text{ hadrons} \\ \hline \\ COMMENT \\ e^+e^- \rightarrow \text{ hadrons} \\ \hline \\ COMMENT \\ J/\psi \rightarrow \text{ hadrons} \\ e^+e^- \rightarrow K^+K^-\eta \\ \hline \\ COMMENT \\ e^+e^- \rightarrow K^+K^-\eta \\ \hline \\ COMMENT \\ e^+e^- \end{array}$	19 We attrribute to button at 1297 M	6 the $f_1(1285)$ EVTS VERAGE 299 al EVTS VERAGE 6 al $EVTS$	DOCUMENT ID JOUSSET COFFMAN DOCUMENT ID JOUSSET COFFMAN DOCUMENT ID 20 AUGUSTIN = 0.78. DOCUMENT ID JOUSSET COFFMAN	90 88 90 88 89	TECN DM2 MRK3 TECN DM2 MRK3 TECN DM2 MRK3 TECN DM2 TECN DM2 TECN TECN TECN TECN TECN TECN TECN TECN	$\begin{array}{c} \pi^- \eta \text{ invaria} \\ \hline \Delta D = 0 \\ \hline \Delta$	ant mass distri-
17 Including interference with $f_{f}(\zeta)$ $\Gamma(\phi\pi^{+}\pi^{-})/\Gamma_{\text{total}}$ $VALUE$ (units 10^{-3}) $EVTS$ 0.80 ± 0.12 $O.78\pm0.03\pm0.12$ $O.78\pm0.03\pm0.12$ $O.78\pm0.03\pm0.12$ $O.78\pm0.03\pm0.12$ $O.78\pm0.03\pm0.12$ $O.78\pm0.03\pm0.12$ $O.78\pm0.03\pm0.12$ $O.78\pm0.03\pm0.12$ $O.78\pm0.03\pm0.12$ $O.79\pm0.03\pm0.12$ $O.79\pm0.03\pm0.03\pm0.12$ $O.79\pm0.03\pm0.03\pm0.12$ $O.79\pm0.03\pm0.03\pm0.12$ $O.79\pm0.03\pm0.03\pm0.03$ $O.79\pm0.03\pm0.03\pm0.03$ $O.79\pm0.03\pm0.03\pm0.03$ $O.79\pm0.03\pm0.03\pm0.03$ $O.79\pm0.03\pm0.03\pm0.03$ $O.79\pm0.03\pm0.03\pm0.03$ $O.79\pm0.03\pm0.03\pm0.03$ $O.79\pm0.03\pm0.03\pm0.03$ $O.79\pm0.03\pm0.03\pm0.03$ $O.79\pm0.03\pm0.03$ $O.79\pm0.03$ $O.7$	DOCUMENT ID TECN	$\begin{array}{c} \underline{COMMENT} \\ J/\psi \rightarrow \text{ hadrons} \\ e^+e^- \\ \hline \\ J/\psi \rightarrow \text{ hadrons} \\ e^+e^- \rightarrow \text{ hadrons} \\ \hline \\ \underline{COMMENT} \\ e^+e^- \rightarrow \text{ hadrons} \\ \hline \\ J/\psi \rightarrow \text{ hadrons} \\ e^+e^- \rightarrow K^+K^-\eta \\ \hline \\ \underline{COMMENT} \\ e^+e^- \rightarrow K^+K^-\eta \\ \hline \\ \underline{COMMENT} \\ e^+e^- \\ \hline \end{array}$	/F /F $\Gamma(\rho\eta)/\Gamma_{\text{total}}$ // $\Gamma(\rho\eta)/\Gamma_{\text{total}}$	the $f_1(1285)$ lev. EVTS VERAGE 299 SI EVTS VERAGE 6 SO) $\rightarrow \pi\pi$: I EVTS VERAGE 19	DOCUMENT ID JOUSSET COFFMAN DOCUMENT ID JOUSSET COFFMAN DOCUMENT ID 20 AUGUSTIN = 0.78. DOCUMENT ID JOUSSET COFFMAN	90 88 90 88 89	TECN DM2 MRK3 TECN DM2 MRK3 TECN DM2 MRK3 TECN DM2 TECN DM2 TECN TECN TECN TECN TECN TECN TECN TECN	$\begin{array}{c} \pi^- \eta \text{ invaria} \\ \frac{COMMENT}{J/\psi \to \text{ h:}} \\ e^+ e^- \to \\ \frac{COMMENT}{J/\psi \to \text{ h:}} \\ \frac{e^+ e^- \to \\ \frac{COMMENT}{J/\psi \to \text{ 2}(} \\ \frac{COMMENT}{J/\psi \to \pi} \end{array}$	ant mass distri-
	DOCUMENT ID TECN	$\begin{array}{c} \underline{COMMENT} \\ J/\psi \longrightarrow \text{hadrons} \\ e^+e^- \\ \hline \\ & \Gamma_{33}, \\ \underline{COMMENT} \\ \\ J/\psi \longrightarrow \text{hadrons} \\ e^+e^- \longrightarrow \text{hadrons} \\ \hline \\ & \Gamma_{34}, \\ \underline{COMMENT} \\ e^+e^- \longrightarrow \text{hadrons} \\ e^+e^- \longrightarrow K^+K^-\eta \\ \hline \\ & \Gamma_{36}, \\ \underline{COMMENT} \\ e^+e^- \\ \hline \\ & \Gamma_{37}, \\ \underline{COMMENT} \\ \end{array}$	/F // // // // // // // // //	the $f_1(1285)$ lev. EVTS VERAGE 299 al EVTS VERAGE 6 al $g_{00} \rightarrow \pi \pi \gamma = 0$ VERAGE 19	DOCUMENT ID JOUSSET COFFMAN DOCUMENT ID JOUSSET COFFMAN DOCUMENT ID 20 AUGUSTIN = 0.78. DOCUMENT ID JOUSSET COFFMAN DOCUMENT ID JOUSSET COFFMAN	90 88 90 88 89	TECN DM2 MRK3 TECN DM2 MRK3 TECN DM2 MRK3 TECN DM2 MRK3 TECN DM2 TECN DM2 TECN DM2 TECN DM2 TECN DM2	$\begin{array}{c} \sigma = \eta \text{ invaria} \\ \frac{COMMENT}{J/\psi \to \text{ h: }} \\ e^+e^- \to \\ \frac{COMMENT}{J/\psi \to \text{ h: }} \\ \frac{e^+e^- \to \\ \frac{COMMENT}{J/\psi \to \text{ 2}(} \\ \frac{COMMENT}{J/\psi \to \text{ n: }} \\ \frac{J/\psi \to \text{ h: }}{J/\psi \to \text{ n: }} \\ \frac{COMMENT}{J/\psi \to \text{ h: }} \\ $	ant mass distri-
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17 Including interference with $f_{f}(x)$ Including int	DOCUMENT ID TECN	$\begin{array}{c} \underline{COMMENT} \\ J/\psi \rightarrow \text{ hadrons} \\ e^+e^- \\ \hline \\ J/\psi \rightarrow \text{ hadrons} \\ e^+e^- \rightarrow \text{ hadrons} \\ \hline \\ COMMENT \\ e^+e^- \rightarrow \text{ hadrons} \\ \hline \\ COMMENT \\ J/\psi \rightarrow \text{ hadrons} \\ e^+e^- \rightarrow K^+K^-\eta \\ \hline \\ COMMENT \\ e^+e^- \\ \hline \\ COMMENT \\ e^+e^- \\ \hline \\ GOMMENT \\ e^+e^- \\ \\ GOMMENT \\ \\ GOMMENT \\ FOOM \\ FOOM \\ FOOM \\ FOOM \\ FOOM \\ FOOM \\ F$	/F Position at 1297 M Pos	the $f_1(1285)$ Lev. EVTS VERAGE 299 al EVTS VERAGE 6 al EVTS VERAGE 19 Total $CL\%$ 90	DOCUMENT ID JOUSSET COFFMAN DOCUMENT ID JOUSSET COFFMAN DOCUMENT ID 20 AUGUSTIN = 0.78. DOCUMENT ID JOUSSET COFFMAN DOCUMENT ID JOUSSET COFFMAN	90 88 90 88 89	TECN DM2 MRK3 TECN DM2 MRK3 TECN DM2 MRK3 TECN DM2 TECN DM2 TECN DM2 TECN DM2 TECN DM2	$\begin{array}{c} \pi^- \eta \text{ invaria} \\ \frac{COMMENT}{J/\psi \to \text{ h: }} \\ e^+ e^- \to \\ \frac{COMMENT}{J/\psi \to \text{ h: }} \\ \frac{e^+ e^- \to \\ \frac{COMMENT}{J/\psi \to \text{ 2}} \\ \frac{COMMENT}{J/\psi \to \text{ n: }} \\ \frac{J/\psi \to \text{ h: }}{J/\psi \to \text{ n: }} \\ \frac{COMMENT}{J/\psi \to \text{ h: }} \\ \frac$	ant mass distri-
17 Including interference with $f_{f}(x)$ Including int	DOCUMENT ID TECN	$\begin{array}{l} \underline{COMMENT} \\ J/\psi \longrightarrow \text{hadrons} \\ e^+e^- \\ \hline \\ & \Gamma_{33}, \\ \underline{COMMENT} \\ \\ J/\psi \longrightarrow \text{hadrons} \\ e^+e^- \longrightarrow \text{hadrons} \\ \hline \\ & \Gamma_{34}, \\ \underline{COMMENT} \\ e^+e^- \longrightarrow \text{hadrons} \\ e^+e^- \longrightarrow K^+K^-\eta \\ \hline \\ & \Gamma_{36}, \\ \underline{COMMENT} \\ e^+e^- \\ \hline \\ & \Gamma_{37}, \\ \underline{COMMENT} \\ e^+e^- \\ \hline \\ & \Gamma_{38}, \\ \underline{COMMENT} \\ \end{array}$	/F // // // // // // // // //	the $f_1(1285)$ Lev. EVTS VERAGE 299 al EVTS VERAGE 6 al $EVTS$ VERAGE 19 Crustian $f_1(1285)$ $f_1(1285)$ $f_2(1285)$ $f_3(1285)$ $f_4(1285)$	DOCUMENT ID JOUSSET COFFMAN DOCUMENT ID JOUSSET COFFMAN DOCUMENT ID 20 AUGUSTIN = 0.78. DOCUMENT ID JOUSSET COFFMAN DOCUMENT ID FALVARD DOCUMENT ID BRAUNSCH	90 88 90 88 89 90 88	TECN DM2 MRK3 TECN DM2 MRK3 TECN DM2 MRK3 TECN DM2	$\begin{array}{l} \pi^- \eta \text{ invaria} \\ \hline \Delta D = 0 \\ \hline \Delta$	ant mass distri-
17 Including interference with $f_{f}(x)$ Including int	DOCUMENT ID TECN	$\begin{array}{l} \underline{COMMENT} \\ J/\psi \longrightarrow \text{hadrons} \\ e^+e^- \\ \hline \\ & \Gamma_{33}, \\ \underline{COMMENT} \\ \\ J/\psi \longrightarrow \text{hadrons} \\ e^+e^- \longrightarrow \text{hadrons} \\ \hline \\ & \Gamma_{34}, \\ \underline{COMMENT} \\ e^+e^- \longrightarrow \text{hadrons} \\ e^+e^- \longrightarrow K^+K^-\eta \\ \hline \\ & \Gamma_{36}, \\ \underline{COMMENT} \\ e^+e^- \\ \hline \\ & \Gamma_{37}, \\ \underline{COMMENT} \\ e^+e^- \\ \hline \\ & \Gamma_{38}, \\ \underline{COMMENT} \\ \end{array}$	/F // $(\rho \eta)/\Gamma_{\text{total}}$	the $f_1(1285)$ Lev. EVTS VERAGE 299 al EVTS VERAGE 6 al EVTS VERAGE 19 Total $CL\%$ 90	DOCUMENT ID JOUSSET COFFMAN DOCUMENT ID JOUSSET COFFMAN DOCUMENT ID 20 AUGUSTIN = 0.78. DOCUMENT ID JOUSSET COFFMAN DOCUMENT ID JOUSSET COFFMAN	90 88 90 88 89 90 88	TECN DM2 MRK3 TECN DM2 MRK3 TECN DM2 MRK3 TECN DM2	$\begin{array}{c} \pi^- \eta \text{ invaria} \\ \frac{COMMENT}{J/\psi \to \text{ h: }} \\ e^+ e^- \to \\ \frac{COMMENT}{J/\psi \to \text{ h: }} \\ \frac{e^+ e^- \to \\ \frac{COMMENT}{J/\psi \to \text{ 2}} \\ \frac{COMMENT}{J/\psi \to \text{ n: }} \\ \frac{J/\psi \to \text{ h: }}{J/\psi \to \text{ n: }} \\ \frac{COMMENT}{J/\psi \to \text{ h: }} \\ \frac$	ant mass distri-

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	25 126 EVTS AGE Error 1435 48 533 FED AVERAI (Error scaled) 2)/\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\	DOCUMENT ID includes scale fac EATON BESCH PERUZZI GE iby 1.3)	77 MRK1 TECN tor of 1.3. 84 MRK2 81 BONA 78 MRK1 BESCH PERUZZ 8	84 MF 81 BC 78 MF (Confidence Le 10	$\frac{\chi^2}{\Gamma_{68}/\Gamma_{69}/\Gamma_{70}/\Gamma_{69}}$ in below. $\frac{\chi^2}{\Gamma_{69}/\Gamma_{70}/\Gamma_{69}}$
$(p\overline{p}\pi^{+}\pi^{-})/\Gamma_{\text{total}}$ $\frac{ALUE(\text{units }10^{-3})}{10}$ $\frac{0}{2}$ $\frac{1}{2}$	126	DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID JEAN-MARIE	77 MRK1 TECN tor of 1.3. 84 MRK2 81 BONA 78 MRK1 BESCH PERUZZ 8	e+e-	${}^{0.5}_{S}K^{\pm}\pi^{\mp}$ ${}^{68/}$ Rim below. ${}^{1.0}_{S}K^{2}$
$(p\overline{p}\pi^{+}\pi^{-})/\Gamma_{\text{total}}$ $ALUE \text{ (units } 10^{-3})$ $0 \pm 0.5 \text{ OUR AVER}$ $46 \pm 0.17 \pm 0.43$ 8 ± 1.6 5 ± 0.6 WEIGHT 6.0 ± 0.5 ($\Gamma(p\overline{p}\pi^{+}\pi^{-})/\Gamma_{\text{total}}$ $ALUE \text{ (units } 10^{-4})$ 0 ± 20 $\Gamma(n\overline{n}\pi^{+}\pi^{-})/\Gamma_{\text{total}}$ $ALUE \text{ (units } 10^{-3})$	2 EVTS AGE Error 1435 48 533 IED AVERAI (Error scaled) 2 2 // Ttotal (L.) EVTS 76 EVTS 32	DOCUMENT ID Includes scale face EATON BESCH PERUZZI GE In by 1.3) DOCUMENT ID JEAN-MARIE	EATON BESCH PERUZZ TECN TO MRK1	See the ideograph of th	F68/ am below. $\frac{\chi^2}{1.0}$ IK2 1.0 NA 1.9 IK1 0.7 3.6 evel = 0.16
ALUE (units 10^{-3}) 0 ± 0.5 OUR AVERY 46 ± 0.17 ± 0.43 8 ± 1.6 5 ± 0.6 WEIGHT 6.0±0.5 ($\Gamma(p\overline{p}\pi^{+}\pi^{-})/\Gamma \text{total}$ ALUE (units 10^{-4}) 0±20 $\Gamma(n\overline{n}\pi^{+}\pi^{-})/\Gamma \text{total}$ ALUE (units 10^{-3})	EVTS AGE Error 1435 48 533 IED AVERAI (Error scaled) 2)// total (L EVTS 76 EVTS 32	includes scale face EATON BESCH PERUZZI GE 1 by 1.3) Jean-Marie Document ID JEAN-MARIE	EATON BESCH PERUZZ	See the ideogra e+e- e+e- e+e- e+e- 10 84 MF BC 78 MF (Confidence Le 10 10 COMMENT e+e-	$\frac{\chi^2}{1.0}$ NA 1.9 kK1 0.7 3.6 evel = 0.16
0 ±0.5 OUR AVERA 46 ±0.17 ±0.43 8 ±1.6 5 ±0.6 WEIGHT 6.0±0.5 (AGE	includes scale face EATON BESCH PERUZZI GE 1 by 1.3) Jean-Marie Document ID JEAN-MARIE	EATON BESCH PERUZZ	See the ideogra e+e- e+e- e+e- e+e- 10 84 MF BC 78 MF (Confidence Le 10 10 COMMENT e+e-	$\frac{\chi^2}{1.0}$ IK2 1.0 NA 1.9 IK1 0.7 3.6 evel = 0.167
46 \pm 0.17 \pm 0.43 8 \pm 1.6 5 \pm 0.6 WEIGHT 6.0 \pm 0.5 ($\Gamma(p\overline{p}\pi^{+}\pi^{-})$ $\Gamma(2(\pi^{+}\pi^{-}))/\Gamma_{\text{total}}$ ALUE (units 10 ⁻⁴) 0 \pm 20 $\Gamma(n\overline{n}\pi^{+}\pi^{-})/\Gamma_{\text{total}}$ ALUE (units 10 ⁻³)	1435 48 533 IED AVERAI (Error scaled) 2 2 // Ttotal (L EVTS 76 EVTS 32	EATON BESCH PERUZZI GE d by 1.3) A A A B B B B B B B B B B	84 MRK2 81 BONA 78 MRK1 BESCH PERUZZ 8	84 MF 81 BC 78 MF (Confidence Le 10	$\frac{\chi^2}{1.0}$ IK2 1.0 NA 1.9 IK1 0.7 3.6 evel = 0.16
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$(2(\pi^{+}\pi^{-}))/\Gamma_{\text{total}}$ $(2(\pi^{+}\pi^{-}))/\Gamma_{\text{total}}$ $(3(\pi^{+}\pi^{-}))/\Gamma_{\text{total}}$ $(4UE)$ (0 ± 20) $(6\pi\pi^{+}\pi^{-})/\Gamma_{\text{total}}$ $(4UE)$	EVTS 32	DOCUMENT ID DOCUMENT ID DOCUMENT ID	<u>TECN</u> 76 MRK1	COMMENT COMMENT	Γ ₆₉ /
$(2(\pi^{+}\pi^{-}))/\Gamma_{\text{total}}$ $(2(\pi^{+}\pi^{-}))/\Gamma_{\text{total}}$ $(3(\pi^{+}\pi^{-}))/\Gamma_{\text{total}}$ $(4UE)$ (0 ± 20) $(6\pi\pi^{+}\pi^{-})/\Gamma_{\text{total}}$ $(4UE)$	EVTS 32	DOCUMENT ID DOCUMENT ID DOCUMENT ID	<u>TECN</u> 76 MRK1	COMMENT e+e-	Γ ₇₀ ,
$(2(\pi^{+}\pi^{-}))/\Gamma_{\text{total}}$ $(2(\pi^{+}\pi^{-}))/\Gamma_{\text{total}}$ $(3(\pi^{+}\pi^{-}))/\Gamma_{\text{total}}$ $(4UE)$ (0 ± 20) $(6\pi\pi^{+}\pi^{-})/\Gamma_{\text{total}}$ $(4UE)$	EVTS 32 EVTS 32	DOCUMENT ID JEAN-MARIE DOCUMENT ID	76 MRK1	e ⁺ e ⁻	Γ _{70/}
$(2(\pi^{+}\pi^{-}))/\Gamma_{\text{total}}$ $(2(\pi^{+}\pi^{-}))/\Gamma_{\text{total}}$ $(3(\pi^{+}\pi^{-}))/\Gamma_{\text{total}}$ $(4UE)$ (0 ± 20) $(6\pi\pi^{+}\pi^{-})/\Gamma_{\text{total}}$ $(4UE)$	EVTS 32 EVTS 32	DOCUMENT ID JEAN-MARIE DOCUMENT ID	76 MRK1	e ⁺ e ⁻	Γ ₇₀ /
ALUE $(3(\pi^+\pi^-))/\Gamma_{\text{total}}$ $(3(\pi^+\pi^-))/\Gamma_{\text{total}}$ $(3(\pi^+\pi^-))/\Gamma_{\text{total}}$ $(3(\pi^+\pi^-))/\Gamma_{\text{total}}$ $(3(\pi^+\pi^-))/\Gamma_{\text{total}}$ $(3(\pi^+\pi^-))/\Gamma_{\text{total}}$ $(3(\pi^+\pi^-))/\Gamma_{\text{total}}$ $(3(\pi^+\pi^-))/\Gamma_{\text{total}}$	EVTS 76 EVTS 32 EVTS	JEAN-MARIE	76 MRK1	e ⁺ e ⁻	Γ ₇₀ /
$\frac{(3(\pi^+\pi^-))/\Gamma_{\text{total}}}{(3(\pi^+\pi^-))/\Gamma_{\text{total}}}$ $\frac{ALUE (\text{units }10^{-4})}{0\pm 20}$ $\frac{(n\bar{n}\pi^+\pi^-)/\Gamma_{\text{total}}}{(ALUE (\text{units }10^{-3})}$	76 EVTS 32 EVTS	JEAN-MARIE	76 MRK1	e ⁺ e ⁻	
$(3(\pi^+\pi^-))/\Gamma_{\text{total}}$ $(3(\pi^+\pi^-))/\Gamma_{\text{total}}$ $(3(\pi^+\pi^-))/\Gamma_{\text{total}}$ $(3(\pi^+\pi^-))/\Gamma_{\text{total}}$ $(3(\pi^+\pi^-))/\Gamma_{\text{total}}$ $(3(\pi^+\pi^-))/\Gamma_{\text{total}}$ $(3(\pi^+\pi^-))/\Gamma_{\text{total}}$	32 EVTS	DOCUMENT ID	TECN	COMMENT	
ALUE (units 10^{-4}) 0 ± 20 $\Gamma(n\bar{n}\pi^+\pi^-)/\Gamma_{\text{total}}$ ALUE (units 10^{-3})	32 EVTS				
0±20 $\Gamma(n\overline{n}\pi^+\pi^-)/\Gamma_{ ext{total}}$ ALUE (units 10^{-3})	32 <u>EVTS</u>				r
$(n\overline{n}\pi^+\pi^-)/\Gamma_{\text{total}}$ (ALUE (units 10 ⁻³)	<u>EVTS</u>	32/114 11//11/12	70 1111111		-
ALUE (units 10 ⁻³)	EVTS				
		0.0000000000000000000000000000000000000	TECH	COLUENT	Γ ₇₁ /
8+36	5	DOCUMENT ID BESCH	81 BONA	COMMENT e+e-	
		BESCIT	01 50,0		-
$(\Sigma \overline{\Sigma})/\Gamma_{\text{total}}$					Γ ₇₂ /
ALUE (units 10 ⁻³) .8 ±0.5 OUR AVER	RAGE	DOCUMENT	ID TE	CN COMMEN	·
.18±0.12±0.69	$884\pm$	PALLIN	87 D	M2 e^+e^-	
.74±0.48±0.75	30 90	EATON		RK2 e ⁺ e ⁻ -	
.2 ±7.8	3	BESCH PERUZZI		DNA e ⁺ e ⁻ - RK1 e ⁺ e ⁻ -	
.9 ±1.2	52	PERUZZI	78 IVI	KVI 6.6	
$(2(\pi^{+}\pi^{-})K^{+}K^{-})$	·)/F _{total}				Γ ₇₃ /
ALUE (units 10 ⁻⁴)	EVTS	DOCUMENT ID VANNUCCI	77 MRK1	COMMENT	
1±13	30	VAINIVUCCI	// WIRK	ı e e	
$\Gamma(p\overline{p}\pi^+\pi^-\pi^0)/\Gamma_{\rm to}$					Γ74/
			TECN	COMMENT	
			ctor of 1.9.		
	364	EATON			
.6 ±0.6	39	PERUZZI	78 MRK	l e'e	
$\Gamma(p\overline{p})/\Gamma_{total}$					Γ _{75/}
	EVTS	DOCUMENT ID	TECN	COMMENT	
	RAGE 48	ANTONELLI	93 SPEC	e^+e^-	
		PALLIN	87 DM2	e^+e^-	
	1420	EATON			
	133	BESCH			
1.5 ±0.4					
2.5 ±0.4 2.0 ±0.5	331	²³ PERUZZI			
2.5 ±0.4 2.0 ±0.5		_			
2.5 ±0.4 2.0 ±0.5 2.2 ±0.2		_			
1 1 1 2 2 2	Including $\rho \overline{\rho} \pi^+$ VALUE (units 10^{-3}) 2.3 ± 0.9 OUR AVEF 3.36 $\pm 0.65 \pm 0.28$ 1.6 ± 0.6 $\Gamma(\rho \overline{\rho})/\Gamma_{\text{total}}$ VALUE (units 10^{-3}) 2.14 ± 0.10 OUR AVEF 2.0 ± 0.3 1.91 $\pm 0.04 \pm 0.30$ 2.16 $\pm 0.07 \pm 0.15$ 2.5 ± 0.4	Including $ρ\bar{p}π^+π^-γ$ and expected in the state of t	Including $p\bar{p}\pi^+\pi^-\gamma$ and excluding $ω$, $η$, $η'$ 2.3 ±0.9 OUR AVERAGE Error includes scale falsa.36 ±0.65 ±0.28 364 EATON 1.6 ±0.6 39 PERUZZI	Including $p\bar{p}\pi^+\pi^-\gamma$ and excluding ω , η , η' VALUE (units 10^{-3}) EVTS DOCUMENT 10^{-} TECN 2.3 ±0.9 OUR AVERAGE Error includes scale factor of 1.9. 3.36±0.65±0.28 364 EATON 84 MRK: 1.6 ±0.6 39 PERUZZI 78 MRK: VALUE (units 10^{-3}) EVTS DOCUMENT $1D$ TECN 2.14±0.10 OUR AVERAGE 2.0 ±0.3 48 ANTONELLI 93 SPEC 1.91±0.04±0.30 PALLIN 87 DM2 2.16±0.07±0.15 1420 EATON 84 MRK: 2.5 ±0.4 133 BRANDELIK 790 DASE 2.0 ±0.5 BESCH 78 BONV. 2.2 ±0.2 331 PERUZZI 78 MRK:	Including $p\bar{p}\pi^+\pi^-\gamma$ and excluding $ω, η, η'$ VALUE (units 10^{-3}) EVTS DOCUMENT $1D$ 3.36 ± 0.65 ± 0.28 3.64 1.6 ± 0.6 3.79 PERUZZI 78 MRK1 e^+e^- F($p\bar{p}$)/Ftotal VALUE (units 10^{-3}) EVTS DOCUMENT $1D$ TECN MRK1 $e^+e^ e^+e^ e^+e^ e^+e^ e^+e^ e^+e^ e^+e^ e^+e^-$ DOCUMENT $1D$ TECN COMMENT TECN COMMENT TECN COMMENT $e^+e^ e^+e^ $

Meson Particle Listings $J/\psi(1S)$

VALUE 0.051±0.02					Γ ₇₅ /Γ ₄	$\Gamma(pK^{-}\overline{\Lambda})/\Gamma_{\text{total}}$						Γ ₈₃ /Γ
	EVTS	24 WIIK	75 PLUT	COMMENT		VALUE (units 10 ⁻³)	EVTS	DOCUMENT ID			COMMENT	
.051 ± 0.02 24 Assuming angular	20		75 PLUI	e e		$0.89 \pm 0.07 \pm 0.14$	307	EATON	84	MRK2	e+ e-	
	distribution	(1+cos-θ).				$\Gamma(2(K^+K^-))/\Gamma_{\text{total}}$						Γ ₈₄ /Ι
$(p\overline{p}\eta)/\Gamma_{\text{total}}$					Г ₇₆ /Г	VALUE (units 10 ⁻⁴)		DOCUMENT ID			COMMENT	
ALUE (units 10 ⁻³) .09±0.18 OUR AVER	EVTS RAGE	DOCUMENT ID	TECN	COMMENT		7 ±3		VANNUCCI	77	MRK1	e+ e-	
.03±0.13±0.15	826	EATON	84 MRK2			$\Gamma(hoK^-\overline{\Sigma}^0)/\Gamma_{ m total}$						Γ ₈₅ /Ι
5 ±1.2		BRANDELIK	79c DASP			VALUE (units 10 ⁻³)	EVTS	DOCUMENT ID			COMMENT	
3 ±0.4	197	PERUZZI	78 MRK1	e + e -		$0.29 \pm 0.06 \pm 0.05$	90	EATON	84	MRK2	e^+e^-	
$(p \overline{n} \pi^-) / \Gamma_{\text{total}}$					Γ ₇₇ /Γ	$\Gamma(K^+K^-)/\Gamma_{\text{total}}$						Γ ₈₆ /Γ
4 <i>LUE</i> (units 10 ⁻³)	EVTS	DOCUMENT ID	TECN	COMMENT		VALUE (units 10 ⁻⁴)	EVTS	DOCUMENT ID		TECN	COMMENT	
.00±0.10 OUR AVER 02±0.07±0.16	1288	EATON	OA MARKO	$e^+e^- \rightarrow p\pi$	_	2.37±0.31 OUR AVERA 2.39±0.24±0.22	107	BALTRUSAIT	055	MDICO	.+	
93±0.07±0.16	1191	EATON		$e^+e^- \rightarrow \overline{p}\pi$		2.39±0.24±0.22 2.2 ±0.9	6	BRANDELIK				
7 ±0.7	32	BESCH		$e^+e^- \rightarrow p\pi$		$\Gamma(\Lambda\overline{\Lambda}\pi^0)/\Gamma_{ m total}$						F /
6 ±1.2 16±0.29	5 194	BESCH PERUZZI		$e^+e^- \rightarrow \overline{\rho}\pi$ $e^+e^- \rightarrow \rho\pi$		VALUE (units 10 ⁻³)	FLOTO	DOCUMENT ID		TECH	COLUMENT	Γ ₈₇ /Γ
04±0.27	204	PERUZZI		$e^+e^- \rightarrow \overline{p}\pi$			19 ±	DOCUMENT ID HENRARD	87	TECN DM2	e+e-	
				•		0.22 ± 0.03 ± 0.03	4	HENKARD	07	DIVIZ	e · e	
(ΞΞ)/Γ _{total}					Γ ₇₉ /Γ	$\Gamma(\pi^+\pi^-)/\Gamma_{ m total}$						Γ ₈₈ /Γ
4 <i>LUE</i> (units 10 ⁻³) .8 ±0.4 OUR AVEF	RAGE Fre	DOCUMENT or includes scale fa		CN <u>COMMENT</u> See the ideogram	n below.	VALUE (units 10-4)	EVTS	DOCUMENT ID		TECN	COMMENT	
.40±0.12±0.24	132±			12 $e^+e^- \rightarrow$		1.47±0.23 OUR AVERA		DALTOUG		MOVE	.+	
.28±0.16±0.40	11 194			RK2 e ⁺ e ⁻ →	z- <u>z</u> +	$1.58 \pm 0.20 \pm 0.15$ 1.0 ± 0.5	84 5	BALTRUSAIT BRANDELIK				
2 ±0.8	71	PERUZZI		RK1 e ⁺ e ⁻		1.6 ±1.6	1	VANNUCCI		MRK1		
14/5/01	ITED AVES	ACE				$\Gamma(K_S^0 K_L^0)/\Gamma_{\text{total}}$						Г89/Г
	ITED AVER					VALUE (units 10 ⁻⁴)	EVTS	DOCUMENT ID		TECN	COMMENT	. 64/ ,
	Ţ					1.08±0.14 OUR AVERA	MGE					
	Λ,					$1.18 \pm 0.12 \pm 0.18$	74	JOUSSET BALTRUSAIT		DM2	$J/\psi \rightarrow \text{hadrons}$	
	/ \					1.01 ± 0.16 ± 0.09	74	BALIRUSAII	850	WIKKS	e · e	
						$\Gamma(\Lambda \overline{\Sigma} + \text{c.c.})/\Gamma_{\text{total}}$						Γ ₉₀ /1
						VALUE (units 10 ⁻³)	CL%	DOCUMENT ID			COMMENT	
						<0.15	90	PERUZZI	78	MRK1	$e^+e^- \rightarrow \Lambda X$	
						$\Gamma(K_S^0 K_S^0)/\Gamma_{\text{total}}$						Γ ₉₁ /Γ
						VALUE (units 10 ⁻⁴)	CL%	DOCUMENT ID			COMMENT	
	1							²⁵ BALTRUSAIT				
1		$\overline{}$			2	<0.052	90	DALIKUSAII	85c	MRK3	e+ e-	
					x ²	<0.052 ²⁵ Forbidden by <i>CP</i> .	90	BALIKUSAII	85C	мккз	e+ e-	
	<u> </u>		· HENRARI					RADIATIVE DE			e ⁺ e ⁻	
	<u> </u>	1	HENRARI EATON PERUZZI	84 MRK	2 1.4 1 <u>3.2</u>	²⁵ Forbidden by <i>CP</i> .					e+ e- 	Γ ₉₂ /Γ
	-+ -	+	· · EATON · · PERUZZI	84 MRK 78 MRK	2 1.4 1 3.2 6.5	25 Forbidden by <i>CP</i> . $\Gamma(\gamma\eta_c(15))/\Gamma_{ ext{total}}$ VALUE		RADIATIVE DE	CAYS		COMMENT	Г ₉₂ /Г
	<u> </u>	+	EATON PERUZZI	84 MRK 78 MRK (Confidence Leve	2 1.4 1 3.2 6.5	²⁵ Forbidden by <i>CP</i> . $\Gamma(\gamma \eta_c(15))/\Gamma_{\text{total}}$ VALUE 0.0127 \pm 0.0036	<u>EVTS</u>	RADIATIVE DE	CAYS	TECN_CBAL	$\frac{\textit{COMMENT}}{J/\psi \rightarrow \gamma X}$	Γ ₉₂ /Γ
0		3 4	· · EATON · · PERUZZI	84 MRK 78 MRK	2 1.4 1 3.2 6.5	25 Forbidden by <i>CP</i> . $\Gamma(\gamma \eta_c(1S))/\Gamma_{\text{total}}$ $VALUE$ 0.0127 \pm 0.0036 • • • We do not use the	<i>EVTS</i> e followi	RADIATIVE DE DOCUMENT ID GAISER ing data for average	CAYS	TECN CBAL limits,	$\frac{COMMENT}{J/\psi \rightarrow \gamma X}$ etc. • • •	Г92/Г
	_		EATON PERUZZI	84 MRK 78 MRK (Confidence Leve	2 1.4 1 3.2 6.5	25 Forbidden by <i>CP</i> . $\Gamma(\gamma \eta_c(15))/\Gamma_{\text{total}}$ $VALUE$ 0.0127 \pm 0.0036 • • • We do not use the seen	<i>_EVTS</i> e followi 16	RADIATIVE DE	CAYS	TECN CBAL limits,	$\frac{COMMENT}{J/\psi \rightarrow \gamma X}$ etc. • • •	-
` ′	_		EATON PERUZZI	84 MRK 78 MRK (Confidence Leve	$ \begin{array}{c} 2 & 1.4 \\ 1 & 3.2 \\ \hline 6.5 \\ \text{el} = 0.039) \end{array} $	25 Forbidden by <i>CP</i> . $\Gamma(\gamma \eta_c(15))/\Gamma_{\text{total}}$ $VALUE$ 0.0127±0.0036 • • • We do not use the seen $\Gamma(\gamma \pi^+ \pi^- 2\pi^0)/\Gamma_{\text{total}}$	<i>_EVTS</i> e followi 16	RADIATIVE DE DOCUMENT ID GAISER ing data for average BALTRUSAIT	86 s, fits,84	TECN CBAL limits, MRK3	$\begin{array}{c} \underline{COMMENT} \\ J/\psi \to \gamma \\ \text{etc.} \bullet \bullet \bullet \\ J/\psi \to 2\phi \\ \gamma \end{array}$	-
$(n\overline{n})/\Gamma_{\text{total}}$	otal (units	10^{-3})	PERUZZI	84 MRK 78 MRK (Confidence Leve	2 1.4 1 3.2 6.5	25 Forbidden by <i>CP</i> . $\Gamma(\gamma \eta_c(1S))/\Gamma_{\text{total}}$ $VALUE$ 0.0127 \pm 0.0036 • • • We do not use the seen $\Gamma(\gamma \pi^+ \pi^- 2\pi^0)/\Gamma_{\text{total}}$ $VALUE \text{ (units } 10^{-3}\text{)}$	<i>_EVTS</i> e followi 16	RADIATIVE DE DOCUMENT ID GAISER ing data for average BALTRUSAIT DOCUMENT ID	86 s, fits,84	TECN_CBAL limits, MRK3	$\begin{array}{c} \underline{COMMENT} \\ J/\psi \to \gamma \mathrm{X} \\ \mathrm{etc.} \bullet \bullet \bullet \\ J/\psi \to 2\phi \gamma \\ \\ \underline{COMMENT} \end{array}$	-
(<i>n π</i>)/Γ _{total}	otal (units		EATON PERUZZI	84 MRK 78 MRK (Confidence Leve	$ \begin{array}{c} 2 & 1.4 \\ 1 & 3.2 \\ \hline 6.5 \\ \text{el} = 0.039) \end{array} $	Forbidden by CP. $\Gamma(\gamma \eta_c(1S))/\Gamma_{\text{total}}$ $VALUE$ 0.0127±0.0036 • • • We do not use the seen $\Gamma(\gamma \pi^+ \pi^- 2\pi^0)/\Gamma_{\text{total}}$ $VALUE \text{ (units } 10^{-3}\text{)}$ 8.3±0.2±3.1	_EVTS e followi 16	RADIATIVE DE DOCUMENT ID GAISER ing data for average BALTRUSAIT	86 s, fits,84	TECN_CBAL limits, MRK3	$\begin{array}{c} \underline{COMMENT} \\ J/\psi \to \gamma \mathrm{X} \\ \mathrm{etc.} \bullet \bullet \bullet \\ J/\psi \to 2\phi \gamma \\ \\ \underline{COMMENT} \end{array}$	-
(n\overline{n})/\Gamma_{\text{total}} \[\lambda_{LUE (units 10^{-2})} \] \[\delta_{\text{0.05}} \text{OUR AV} \] \[\delta_{0.055} \]	otal (units	10 ⁻³) DOCUMENT ID ANTONELLI	5 TECN 93 SPEC	84 MRK 78 MRK (Confidence Leve 6 COMMENT e+e-	$ \begin{array}{c} 2 & 1.4 \\ 1 & 3.2 \\ \hline 6.5 \\ \text{el} = 0.039) \end{array} $	Forbidden by CP. $\Gamma(\gamma \eta_c(1S))/\Gamma_{\text{total}}$ $VALUE$ 0.0127±0.0036 • • • We do not use the seen $\Gamma(\gamma \pi^+ \pi^- 2\pi^0)/\Gamma_{\text{total}}$ $VALUE(\text{units } 10^{-3})$ 8.3±0.2±3.1 $^{26} 4\pi \text{ mass less than } 2.0$	_EVTS e followi 16	RADIATIVE DE DOCUMENT ID GAISER ing data for average BALTRUSAIT DOCUMENT ID	86 s, fits,84	TECN_CBAL limits, MRK3	$\begin{array}{c} \underline{COMMENT} \\ J/\psi \to \gamma \mathrm{X} \\ \mathrm{etc.} \bullet \bullet \bullet \\ J/\psi \to 2\phi \gamma \\ \\ \underline{COMMENT} \end{array}$	Г93/Г
(n\overline{n})/\Gamma_{\text{total}} 4LUE (units 10^{-2}) 19 \(\pm 0.05\) OUR AV 190 \(\pm 0.055\)	otal (units	10 ⁻³)	5 EATON PERUZZI	84 MRK 78 MRK (Confidence Leve 6 COMMENT e+e-	$ \begin{array}{c} 2 & 1.4 \\ 1 & 3.2 \\ \hline 6.5 \\ \text{el} = 0.039) \end{array} $	25 Forbidden by CP. $\Gamma(\gamma \eta_c(1S))/\Gamma_{\text{total}}$ $VALUE$ 0.0127 \pm 0.0036 • • • We do not use the seen $\Gamma(\gamma \pi^+ \pi^- 2\pi^0)/\Gamma_{\text{total}}$ $VALUE \text{ (units } 10^{-3}\text{)}$ 8.3 \pm 0.2 \pm 3.1 26 4 π mass less than 2.0 $\Gamma(\gamma \eta \pi \pi)/\Gamma_{\text{total}}$	_EVTS e followi 16	PADIATIVE DE DOCUMENT ID GAISER ing data for average BALTRUSAIT DOCUMENT ID 26 BALTRUSAIT	86 s, fits,84	TECN CBAL limits, MRK3 TECN MRK3	$\begin{array}{c} \underline{COMMENT} \\ J/\psi \to \gamma \\ X \text{ etc.} \bullet \bullet \\ J/\psi \to 2\phi \\ \gamma \\ \underline{COMMENT} \\ J/\psi \to 4\pi \\ \gamma \end{array}$	-
(n\overline{n})/\Gamma_{\text{total}} \(\ldots \overline{n}\)/\(\text{Total} \) 19 \(\pm 0.05\) OUR AV 190 \(\pm 0.055\) 18 \(\pm 0.09\)	otal (units	10 ⁻³) DOCUMENT ID ANTONELLI	5 TECN 93 SPEC	84 MRK 78 MRK (Confidence Leve 6 COMMENT e+e-	$ \begin{array}{c} 2 & 1.4 \\ 1 & 3.2 \\ \hline 6.5 \\ \text{el} = 0.039) \end{array} $	Forbidden by CP. $\Gamma(\gamma \eta_c(1S))/\Gamma_{\text{total}}$ $VALUE$ 0.0127±0.0036 • • • We do not use the seen $\Gamma(\gamma \pi^+ \pi^- 2\pi^0)/\Gamma_{\text{total}}$ $VALUE(\text{units } 10^{-3})$ 8.3±0.2±3.1 $^{26} 4\pi \text{ mass less than } 2.0$	EVTS e followi 16 al	PACUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID	86 s, fits,84	TECN CBAL limits, MRK3 TECN MRK3	$\begin{array}{c} \underline{COMMENT} \\ J/\psi \to \gamma \mathrm{X} \\ \mathrm{etc.} \bullet \bullet \bullet \\ J/\psi \to 2\phi \gamma \\ \\ \underline{COMMENT} \end{array}$	Г93/Г
$(n\overline{n})/\Gamma_{\text{total}}$ ALUE (units 10^{-2}) 19 ± 0.05 OUR AV 190±0.055 18 ± 0.09 $(\Lambda\overline{\Lambda})/\Gamma_{\text{total}}$	otal (units	10 ⁻³) DOCUMENT ID ANTONELLI	5 TECN 93 SPEC	84 MRK 78 MRK (Confidence Leve 6 COMMENT e+e-	2 1.4 1.3.2 6.5 el = 0.039)	25 Forbidden by <i>CP</i> . $\Gamma(\gamma \eta_c(1S))/\Gamma_{\text{total}}$ $VALUE$ 0.0127 \pm 0.0036 • • • We do not use the seen $\Gamma(\gamma \pi^+ \pi^- 2\pi^0)/\Gamma_{\text{total}}$ $VALUE \text{ (units } 10^{-3}\text{)}$ 8.3 \pm 0.2 \pm 3.1 26 4 π mass less than 2.0 $\Gamma(\gamma \eta \pi \pi)/\Gamma_{\text{total}}$ $VALUE \text{ (units } 10^{-3}\text{)}$ 6.1 \pm 1.0 OUR AVERAG 5.85 \pm 0.3 \pm 1.05	EVTS e followi 16 al	PACUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID 26 BALTRUSAIT	86 s, fits, 84	TECN CBAL limits, MRK3 TECN MRK3	$\begin{array}{c} \underline{COMMENT} \\ J/\psi \to \gamma X \\ \text{etc.} \bullet \bullet \bullet \\ J/\psi \to 2\phi \gamma \\ \\ \underline{COMMENT} \\ J/\psi \to 4\pi \gamma \\ \\ \underline{COMMENT} \\ J/\psi \to \eta \pi^+ \pi^- \end{array}$	Г ₉₃ /Г
$(n\overline{n})/\Gamma_{\text{total}}$	EVTS LEVTS 40 EVTS ADDRESS EVTS RAGE EVTS	DOCUMENT ID ANTONELLI BESCH DOCUMENT ID or includes scale far	PERUZZI 5 TECN 93 SPEC 78 BONA TECN T	84 MRK 78 MRK (Confidence Leve 6 COMMENT e+e- e+e- COMMENT	2 1.4 1.3.2 6.5 el = 0.039)	25 Forbidden by <i>CP</i> . $\Gamma(\gamma \eta_{C}(1S))/\Gamma_{\text{total}}$ VALUE 0.0127±0.0036 • • • We do not use the seen $\Gamma(\gamma \pi^{+}\pi^{-}2\pi^{0})/\Gamma_{\text{total}}$ VALUE (units 10 ⁻³) 8.3±0.2±3.1 26 4π mass less than 2.0 $\Gamma(\gamma \eta \pi \pi)/\Gamma_{\text{total}}$ VALUE (units 10 ⁻³) 6.1 ±1.0 OUR AVERAG 5.88±0.3±1.05 7.8 ±1.2±2.4	_EVTS e followi 16 al 0 GeV.	PACUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID 26 BALTRUSAIT DOCUMENT ID 27 EDWARDS 27 EDWARDS	86 s, fits, 84	TECN CBAL limits, MRK3 TECN MRK3	$\begin{array}{c} \underline{COMMENT} \\ J/\psi \longrightarrow \gamma \times \\ \text{etc.} \bullet \bullet \bullet \\ J/\psi \longrightarrow 2\phi \gamma \\ \underline{COMMENT} \\ J/\psi \longrightarrow 4\pi \gamma \\ \underline{COMMENT} \\ \underline{COMMENT} \end{array}$	Г ₉₃ /Г
$(n\overline{n})/\Gamma_{\text{total}}$ $(M\overline{n})/\Gamma_{\text{total}}$ $MUE \text{ (units } 10^{-2})$ 19 ± 0.05 OUR AV 190 ± 0.055 18 ± 0.09 $(M\overline{M})/\Gamma_{\text{total}}$ $MUE \text{ (units } 10^{-3})$ 35 ± 0.14 OUR AVER $38 \pm 0.05 \pm 0.20$	EVTS ERAGE 40 EVTS RAGE Erro	DOCUMENT ID ANTONELLI BESCH DOCUMENT ID or includes scale far PALLIN	SPEC 78 BONA TECN TECN TECN TECN TECN TO 1.2. TECN T	84 MRK 78 MRK (Confidence Level) 6 $COMMENT$ $e^+e^ e^+e^-$ $COMMENT$ e^+e^-	2 1.4 1.3.2 6.5 el = 0.039)	$\Gamma(\gamma \eta_c(1S))/\Gamma_{\text{total}}$ $VALUE$ 0.0127±0.0036 • • • We do not use the seen $\Gamma(\gamma \pi^+ \pi^- 2\pi^0)/\Gamma_{\text{total}}$ $VALUE$ (units 10^{-3}) 8.3±0.2±3.1 26 4π mass less than 2.0 $\Gamma(\gamma \eta \pi \pi)/\Gamma_{\text{total}}$ $VALUE$ (units 10^{-3}) 6.1 ±1.0 OUR AVERAG 5.88±0.3±1.05 7.8 ±1.2±2.4 27 Broad enhancement a	EVTS e followi 16 al 0 GeV.	PACUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID POCUMENT ID 27 EDWARDS 27 EDWARDS MeV.	86 s, fits, 84	TECN CBAL limits, MRK3 TECN MRK3	$\begin{array}{c} \underline{COMMENT} \\ J/\psi \to \gamma X \\ \text{etc.} \bullet \bullet \bullet \\ J/\psi \to 2\phi \gamma \\ \\ \underline{COMMENT} \\ J/\psi \to 4\pi \gamma \\ \\ \underline{COMMENT} \\ J/\psi \to \eta \pi^+ \pi^- \end{array}$	Γ ₉₃ /Ι
$(n\overline{n})/\Gamma_{\text{total}}$ $(n\overline{n})/\Gamma_{\text{total}}$ $(nUE (units 10^{-2})$ 19 ± 0.05 OUR AV 190 ± 0.055 18 ± 0.09 $(A\overline{A})/\Gamma_{\text{total}}$ $1.0UE (units 10^{-3})$ 35 ± 0.14 OUR AVER $38 \pm 0.05 \pm 0.20$ $58 \pm 0.08 \pm 0.19$	EVTS LEVTS 40 EVTS ADDRESS EVTS RAGE EVTS	DOCUMENT ID ANTONELLI BESCH DOCUMENT ID or includes scale far	PERUZZI 5 TECN 93 SPEC 78 BONA TECN T	84 MRK 87 MRK (Confidence Level) 6 $COMMENT$ $e^+e^ e^+e^ COMMENT$ $e^+e^ e^+e^-$	2 1.4 1.3.2 6.5 el = 0.039)	$\Gamma(\gamma \eta_c(1S))/\Gamma_{\text{total}}$ $VALUE$ 0.0127±0.0036 • • • We do not use the seen $\Gamma(\gamma \pi^+ \pi^- 2\pi^0)/\Gamma_{\text{total}}$ $VALUE$ (units 10 ⁻³) 8.3±0.2±3.1 26 4 π mass less than 2.0 $\Gamma(\gamma \eta \pi \pi)/\Gamma_{\text{total}}$ $VALUE$ (units 10 ⁻³) 6.1±1.0 OUR AVERAG 5.85±0.3±1.05 7.8±1.2±2.4 27 Broad enhancement at $\Gamma(\gamma \eta (1440) \rightarrow \gamma KK)$	EVTS e followi 16 al 0 GeV.	PACUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID POCUMENT ID 27 EDWARDS 27 EDWARDS MeV.	86 s, fits, 84	TECN CBAL limits, MRK3 TECN MRK3	$\begin{array}{c} \underline{COMMENT} \\ J/\psi \to \gamma X \\ \text{etc.} \bullet \bullet \bullet \\ J/\psi \to 2\phi \gamma \\ \\ \underline{COMMENT} \\ J/\psi \to 4\pi \gamma \\ \\ \underline{COMMENT} \\ J/\psi \to \eta \pi^+ \pi^- \end{array}$	Г ₉₃ /Г
(\$\bar{n}\$)\$/\(\bar{\text{total}}\) \(\bar{\text{LUE}}\)\(\bar{\text{total}}\) \(\bar{\text{LUE}}\)\(\text{total}\) \(\bar{\text{19}}\)\(\text{0.05}\) \(\bar{\text{0.05}}\) \(\bar{\text{1}}\)\(\bar{\text{total}}\) \(\bar{\text{LUE}}\)\(\text{(units } 10^{-3}\) \(\bar{\text{35}}\)\(\text{1.4}\) \(\text{OUR AVER}\) \(\bar{\text{38}}\)\(\text{0.05}\)\(\text{0.08}\) \(\text{0.08}\)\(\text{0.08}\) \(\text{0.14}\) \(\text{0.14}\) \(\text{0.05}\)\(\text{0.20}\) \(\text{5}\)\(\text{1.6}\)	EVTS FERAGE 40 EVTS RAGE ETTS RAGE ETTS 1847 365	DOCUMENT ID ANTONELLI BESCH DOCUMENT ID or includes scale far PALLIN EATON	5 TECN 93 SPEC 78 BONA TECN TECN 101 102 103 104 105 105 105 105 105 105 105	84 MRK 78 MRK (Confidence Level) 6 $ \frac{COMMENT}{e^+e^-} $ $ e^+e^- $	2 1.4 1.3.2 6.5 el = 0.039)	25 Forbidden by <i>CP</i> . $\Gamma(\gamma \eta_{c}(1S))/\Gamma_{total}$ $VALUE$ 0.0127±0.0036 • • • We do not use the seen $\Gamma(\gamma \pi^{+}\pi^{-}2\pi^{0})/\Gamma_{total}$ $VALUE (units 10^{-3})$ 8.3±0.2±3.1 26 4π mass less than 2.0 $\Gamma(\gamma \eta \pi \pi)/\Gamma_{total}$ $VALUE (units 10^{-3})$ 6.1 ±1.0 OUR AVERAG 5.85 ±0.3±1.05 7.8 ±1.2±2.4 27 Broad enhancement at a result of the second of the seco	_EVTS e following 16 al 0 GeV. GE at 1700 ₹π)/Γt	PACUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID POCUMENT ID 27 EDWARDS 27 EDWARDS MeV.	86 86, s, fits, 84 868	TECN CBAL limits, MRK3 TECN MRK3	$\begin{array}{c} \underline{COMMENT} \\ J/\psi \to \gamma X \\ \text{etc.} \bullet \bullet \bullet \\ J/\psi \to 2\phi \gamma \\ \\ \underline{COMMENT} \\ J/\psi \to 4\pi \gamma \\ \\ \underline{COMMENT} \\ J/\psi \to \eta \pi^+ \pi^- \end{array}$	Г ₉₃ /Г
$(n\overline{n})/\Gamma_{\text{total}}$	EVTS FERAGE 40 EVTS RAGE Error 1847 365 5	DOCUMENT ID ANTONELLI BESCH DOCUMENT ID or includes scale far PALLIN EATON BESCH	93 SPEC 78 BONA TECN TECN TECN TECN TECN TO ME	84 MRK 78 MRK (Confidence Level) 6 $ \frac{COMMENT}{e^+e^-} $ $ e^+e^- $	2 1.4 1 3.2 6.5 el = 0.039)	$\Gamma(\gamma \eta_c(1S))/\Gamma_{\text{total}}$ $VALUE$ 0.0127±0.0036 • • • We do not use the seen $\Gamma(\gamma \pi^+ \pi^- 2\pi^0)/\Gamma_{\text{total}}$ $VALUE$ (units 10 ⁻³) 8.3±0.2±3.1 26 4 π mass less than 2.0 $\Gamma(\gamma \eta \pi \pi)/\Gamma_{\text{total}}$ $VALUE$ (units 10 ⁻³) 6.1±1.0 OUR AVERAG 5.85±0.3±1.05 7.8±1.2±2.4 27 Broad enhancement at $\Gamma(\gamma \eta (1440) \rightarrow \gamma KK)$	EVTS e followi 16 al 0 GeV. GE at 1700 ₹π)/Γto	PADIATIVE DE DOCUMENT ID ACTION OF THE PROPERTY OF THE PROPE	86 86, s, fits,84 868	TECN CBAL Imits, MRK3 TECN MRK3 TECN CBAL CBAL CBAL	$\begin{array}{c} \underline{COMMENT} \\ J/\psi \to \gamma \\ \text{etc.} \bullet \bullet \bullet \\ J/\psi \to 2\phi \\ \gamma \\ \underline{COMMENT} \\ J/\psi \to 4\pi \\ \gamma \\ \underline{COMMENT} \\ J/\psi \to \eta \\ \pi^+ \\ \pi^- \\ J/\psi \to \eta \\ 2\pi^0 \end{array}$	Г ₉₃ /Г
$(n\overline{n})/\Gamma_{\text{total}}$ $\frac{LUE \text{ (units }10^{-2})}{19 \pm 0.05}$ OUR AV 190 ± 0.055 (18 ± 0.09 (AA)/ Γ_{total} $\frac{LUE \text{ (units }10^{-3})}{35 \pm 0.14}$ OUR AVER $38 \pm 0.05 \pm 0.20$ $58 \pm 0.08 \pm 0.19$ 6 ± 1.6 1 ± 0.2 ($p\overline{p}\pi^0$)/ Γ_{total}	EVTS 40 EVTS 40 EVTS 40 EVTS 40 1847 365 5 196	DOCUMENT ID ANTONELLI BESCH DOCUMENT ID or includes scale factoric pallin EATON BESCH PERUZZI	5 TECN 93 SPEC 78 BONA TECN 200 TECN 201 TECN 202 TECN 203 TECN 204 MRK2 205 MRK2 206 MRK1 207 MRK1	84 MRK 78 MRK (Confidence Leve 6 COMMENT e+e- e+e- e+e- e+e- e+e- e+e- e+e- e+	2 1.4 1.3.2 6.5 el = 0.039)	25 Forbidden by CP . $\Gamma(\gamma \eta_c(15))/\Gamma_{\text{total}}$ $VALUE$ 0.0127 \pm 0.0036 • • • We do not use the seen $\Gamma(\gamma \pi^+ \pi^- 2\pi^0)/\Gamma_{\text{total}}$ $VALUE \text{ (units } 10^{-3})$ 8.3 \pm 0.2 \pm 3.1 26 4π mass less than 2.0 $\Gamma(\gamma \eta \pi \pi)/\Gamma_{\text{total}}$ $VALUE \text{ (units } 10^{-3})$ 6.1 \pm 1.0 OUR AVERAG 5.85 \pm 0.3 \pm 1.05 7.8 \pm 1.2 \pm 2.4 27 Broad enhancement a $\Gamma(\gamma \eta(1440) \rightarrow \gamma KK)$ $VALUE \text{ (units } 10^{-3})$ 0.91 \pm 0.18 OUR AVERAG 0.83 \pm 0.13 \pm 0.13		PADIATIVE DE DOCUMENT ID GAISER ING data for average BALTRUSAIT DOCUMENT ID ACCUMENT ID	86 86, s, fits,84 868	TECN CBAL limits, MRK3 TECN MRK3 TECN CBAL CBAL CBAL CBAL CBAL DM2	$\begin{array}{c} \underline{COMMENT} \\ J/\psi \to \gamma \\ \text{etc.} \bullet \bullet \\ J/\psi \to 2\phi \\ \gamma \\ \hline\\ \underline{COMMENT} \\ J/\psi \to 4\pi \\ \gamma \\ \hline\\ \underline{COMMENT} \\ J/\psi \to \eta \\ \pi^+ \\ \pi^- \\ J/\psi \to \eta \\ 2\pi^0 \\ \hline\\ \underline{COMMENT} \\ COMMENT \\ COMMENT \\ \hline\\ \underline{COMMENT} \\ COMMENT	Г ₉₃ /Г Г ₉₄ /Г
$(n\overline{n})/\Gamma_{\text{total}}$ $(100)/\Gamma_{\text{total}}$	EVTS EVTS EVTS A0 EVTS RAGE Erro 1847 365 196	DOCUMENT ID ANTONELLI BESCH DOCUMENT ID or includes scale far PALLIN EATON BESCH PERUZZI DOCUMENT ID	93 SPEC 78 BONA TECN	84 MRK 78 MRK (Confidence Leve 6 COMMENT e+e- e+e- e+e- e+e- e+e- e+e- e+e- e+	2 1.4 1 3.2 6.5 el = 0.039)	25 Forbidden by <i>CP</i> . $\Gamma(\gamma \eta_c(1S))/\Gamma_{\text{total}}$ $VALUE$ 0.0127±0.0036 • • • We do not use the seen $\Gamma(\gamma \pi^+ \pi^- 2\pi^0)/\Gamma_{\text{total}}$ $VALUE \text{ (units } 10^{-3}\text{)}$ 8.3±0.2±3.1 $^{26} 4\pi \text{ mass less than } 2.0$ $\Gamma(\gamma \eta \pi \pi)/\Gamma_{\text{total}}$ $VALUE \text{ (units } 10^{-3}\text{)}$ 6.1 ±1.0 OUR AVERAG 5.85±0.3±1.05 7.8 ±1.2±2.4 $^{27} \text{ Broad enhancement a}$ $\Gamma(\gamma \eta (1440) \rightarrow \gamma K \overline{K})$ $VALUE \text{ (units } 10^{-3}\text{)}$ 0.91±0.18 OUR AVERAG	EVTS e following 16 al 0 GeV. $(\vec{\tau}, \vec{\tau})/\Gamma_{t}$ 2 2 2 e following	RADIATIVE DE DOCUMENT ID GAISER ing data for average BALTRUSAIT 26 BALTRUSAIT DOCUMENT ID 27 EDWARDS 27 EDWARDS MeV. Otal DOCUMENT ID BALTRUSAIT ADOCUMENT ID BALTRUSAIT BOCUMENT ID BALTRUSAIT ADOCUMENT ID BALTRUSAIT BALTRUSAIT BALTRUSAIT ADOCUMENT ID BALTRUSAIT BALTRUSAI	86 s, fits, 84 868 838 838	TECN CBAL limits, MRK3 TECN MRK3 TECN CBAL CBAL CBAL TECN DM2 MRK3	$\begin{array}{c} \underline{COMMENT} \\ J/\psi \to \gamma \times \\ \text{etc.} \bullet \bullet \bullet \\ J/\psi \to 2\phi \gamma \\ \\ \underline{COMMENT} \\ J/\psi \to 4\pi \gamma \\ \\ \underline{COMMENT} \\ J/\psi \to \eta 2\pi^0 \\ \\ \underline{COMMENT} \\ J/\psi \to \gamma K\overline{K}\pi \\ J/\psi \to \gamma K_S^0 K^{\pm} \end{array}$	Г ₉₃ /Г Г ₉₄ /Г
$(n\overline{n})/\Gamma_{\text{total}}$ $10E(\text{units }10^{-2})$ 19 ± 0.05 OUR AV 190 ± 0.055 18 ± 0.09 $(A\overline{A})/\Gamma_{\text{total}}$ $10E(\text{units }10^{-3})$ 35 ± 0.14 OUR AVER $38\pm 0.05\pm 0.20$ $58\pm 0.08\pm 0.19$ 5 ± 1.6 1 ± 0.2 $(p\overline{p}\pi^0)/\Gamma_{\text{total}}$ $10E(\text{units }10^{-3})$ 99 ± 0.09 OUR AVER $13\pm 0.09\pm 0.09$	EVTS EVTS EVTS A0 EVTS RAGE Erro 1847 365 196	DOCUMENT ID ANTONELLI BESCH DOCUMENT ID or includes scale far PALLIN EATON BESCH PERUZZI DOCUMENT ID EATON	5 TECN 93 SPEC 78 BONA TECN 24 MRK2 84 MRK1 TECN 84 MRK2	84 MRK 87 MRK (Confidence Level) 6 COMMENT e+e- e+e- e+e- e+e- e+e- e+e- e+e- e+	2 1.4 1 3.2 6.5 el = 0.039)	25 Forbidden by <i>CP</i> . $\Gamma(\gamma \eta_c(1S))/\Gamma_{total}$ $VALUE$ 0.0127±0.0036 • • • We do not use the seen $\Gamma(\gamma \pi^+ \pi^- 2\pi^0)/\Gamma_{total}$ $VALUE$ (units 10^{-3}) 8.3±0.2±3.1 26 4π mass less than 2.0 $\Gamma(\gamma \eta \pi \pi)/\Gamma_{total}$ $VALUE$ (units 10^{-3}) 6.1 ±1.0 OUR AVERAG 5.85 ± 0.3 ± 1.05 7.8 ±1.2 ± 2.4 27 Broad enhancement at a constant of the second of the	EVTS e following 16 al 0 GeV. $(\vec{\tau}, \vec{\tau})/\Gamma_{t}$ 2 2 2 e following	PADIATIVE DE DOCUMENT ID GAISER ing data for average BALTRUSAIT DOCUMENT ID 26 BALTRUSAIT DOCUMENT ID 27 EDWARDS 27 EDWARDS 27 EDWARDS MeV. DOCUMENT ID BALTRUSAIT BALTRUSAIT ADOCUMENT ID BALTRUSAIT BOCUMENT ID BOCUMENT ID BALTRUSAIT BALTRUSAIT ADOCUMENT ID BALTRUSAIT BALTRUSAI	86 86 838 838 92 90c s, fits, 92	TECN CBAL limits, MRK3 TECN MRK3 TECN DM2 DM2 MRK3 limits, DM2	$\begin{array}{c} \underline{COMMENT} \\ J/\psi \to \gamma \times \\ \text{etc.} \bullet \bullet \\ J/\psi \to 2\phi \gamma \\ \\ \underline{COMMENT} \\ J/\psi \to 4\pi \gamma \\ \\ \underline{COMMENT} \\ J/\psi \to \eta \pi^+ \pi^- \\ J/\psi \to \gamma \pi^0 \\ \\ \underline{COMMENT} \\ J/\psi \to \gamma K\overline{K}\pi \\ J/\psi \to \gamma K\overline{K}\pi \\ J/\psi \to \gamma K\overline{K}\pi \\ \\ J/\psi \to \gamma K\overline{K}\pi \\ \\ J/\psi \to \gamma K\overline{K}\pi \\ \\ \end{bmatrix}$	Г ₉₃ /Г Г ₉₄ /Г
$(n\overline{n})/\Gamma_{\text{total}}$	EVTS ERAGE 40 EVTS RAGE EVTS 1847 365 196 EVTS 186E 685	DOCUMENT ID ANTONELLI BESCH DOCUMENT ID or includes scale far PALLIN EATON BESCH PERUZZI DOCUMENT ID EATON BRANDELIK	5 TECN 93 SPEC 78 BONA TECN 76 MRK2 81 BONA 78 MRK1 TECN 84 MRK2 79 DASP	84 MRK 878 MRK (Confidence Level) 6 COMMENT $e^+e^ e^+e^ $	2 1.4 1 3.2 6.5 el = 0.039)	25 Forbidden by <i>CP</i> . $\Gamma(\gamma \eta_c(1S))/\Gamma_{\text{total}}$ $VALUE$ 0.0127±0.0036 • • • We do not use the seen $\Gamma(\gamma \pi^+ \pi^- 2\pi^0)/\Gamma_{\text{total}}$ $VALUE$ (units 10^{-3}) 8.3±0.2±3.1 26 4π mass less than 2.0 $\Gamma(\gamma \eta \pi \pi)/\Gamma_{\text{total}}$ $VALUE$ (units 10^{-3}) 6.1 ±1.0 OUR AVERAG 5.85±0.3±1.05 7.8 ±1.2±2.4 27 Broad enhancement at $\Gamma(\gamma \eta(1440) \rightarrow \gamma K \overline{K})$ $VALUE$ (units 10^{-3}) 0.91±0.18 OUR AVERAG 0.83±0.13±0.18 1.03+0.21±0.26 -0.18-0.19 • • We do not use the $1.78\pm0.21\pm0.33$ 3.8 ±0.3 ±0.6	EVTS e followin 16 al 0 GeV. 3E 2 2 2 2 e followin 2	PADIATIVE DE DOCUMENT ID GAISER ing data for average BALTRUSAIT 26 BALTRUSAIT DOCUMENT ID 27 EDWARDS 27 EDWARDS MeV. DOCUMENT ID BALTRUSAIT BALTRUSAIT AUGUSTIN 8,30 BAI ng data for average 8,31 AUGUSTIN 28 AUGUSTIN	86 86, s, fits,84 868 838 838 92 90c 92 90 92 90 92	TECN CBAL Ilmits, MRK3 TECN MRK3 CBAL CBAL CBAL MRK3 IDM2 MRK3 IJMM2 DM2 DM2 DM2	$\begin{array}{c} \underline{COMMENT} \\ J/\psi \to \gamma X \\ \mathrm{etc.} \bullet \bullet \\ J/\psi \to 2\phi \gamma \\ \\ \underline{COMMENT} \\ J/\psi \to 4\pi \gamma \\ \\ \underline{COMMENT} \\ J/\psi \to \eta \pi^+ \pi^- \\ J/\psi \to \eta 2\pi^0 \\ \\ \underline{COMMENT} \\ J/\psi \to \gamma K\overline{K}\pi \end{array}$	Γ ₉₃ /Γ Γ ₉₄ /Γ - - - - - - - - - - - - - - - - - - -
$(n\overline{n})/\Gamma_{\text{total}}$	EVTS ERAGE 40 EVTS RAGE EVTS 1847 365 196 EVTS RAGE 685 109	DOCUMENT ID ANTONELLI BESCH DOCUMENT ID or includes scale far PALLIN EATON BESCH PERUZZI DOCUMENT ID EATON	5 TECN 93 SPEC 78 BONA TECN 24 MRK2 84 MRK1 TECN 84 MRK2	84 MRK 878 MRK (Confidence Level) 6 COMMENT $e^+e^ e^+e^ $	2 1.4 1 3.2 6.5 el = 0.039)	25 Forbidden by <i>CP</i> . $\Gamma(\gamma \eta_{C}(1S))/\Gamma_{\text{total}}$ $VALUE$ 0.0127±0.0036 • • • We do not use the seen $\Gamma(\gamma \pi^{+}\pi^{-}2\pi^{0})/\Gamma_{\text{total}}$ $VALUE \text{ (units } 10^{-3})$ 8.3±0.2±3.1 $264\pi \text{ mass less than } 2.0$ $\Gamma(\gamma \eta \pi \pi)/\Gamma_{\text{total}}$ $VALUE \text{ (units } 10^{-3})$ 6.1 ±1.0 OUR AVERAG 5.85 ±0.3±1.05 7.8 ±1.2±2.4 $27 \text{ Broad enhancement } a$ $\Gamma(\gamma \eta (1440) \rightarrow \gamma K\overline{K})$ $VALUE \text{ (units } 10^{-3})$ 0.91±0.18 OUR AVERAG 0.83±0.13±0.18 $1.03^{-0.18} = 0.19$ • • We do not use the 1.78±0.21±0.33 3.8 ±0.3 ±0.6 0.66+0.17+0.24 0.66-0.15	EVTS e followin 16 al 0 GeV. 3E 2 2 2 2 e followin 2	PADIATIVE DE DOCUMENT ID GAISER ing data for average BALTRUSAIT DOCUMENT ID 26 BALTRUSAIT DOCUMENT ID 27 EDWARDS 727 EDWARDS MeV. Otal DOCUMENT ID 8,29 AUGUSTIN 8,30 BAI 8,31 AUGUSTIN 28 AUGUSTIN 29 AUGUSTIN 20 AUGUSTI	86 86 85, fits,84 868 838 838 92 90 90, fits, 92 90 90, 90, 90	TECN CBAL Limits, MRK3 TECN MRK3 TECN CBAL CBAL TECN DM2 MRK3 JIMM2 DM2 MRK3 MRK3 MRK3 MM2 MRK3	$\begin{array}{c} \underline{COMMENT} \\ J/\psi \to \gamma \mathbf{X} \\ \mathrm{etc.} \bullet \bullet \bullet \\ J/\psi \to 2\phi \gamma \\ \\ \underline{COMMENT} \\ J/\psi \to 4\pi \gamma \\ \\ \underline{COMMENT} \\ J/\psi \to \eta \pi^+ \pi^- \\ J/\psi \to \eta 2\pi^0 \\ \\ \underline{COMMENT} \\ J/\psi \to \gamma K\overline{K}\pi \\ J/\psi $	Γ ₉₃ /Γ Γ ₉₄ /Γ - - - - - - - - - - - - - - - - - - -
$(n\overline{n})/\Gamma_{\text{total}}$ $(4LUE (\text{units } 10^{-2})$ $19 \pm 0.05 \text{ OUR AV}$ 190 ± 0.055 18 ± 0.09 $(\Lambda\overline{\Lambda})/\Gamma_{\text{total}}$ $4LUE (\text{units } 10^{-3})$ $38 \pm 0.05 \pm 0.20$ $58 \pm 0.08 \pm 0.19$ 6 ± 1.6 1 ± 0.2 $(P\overline{p}\pi^0)/\Gamma_{\text{total}}$ $4LUE (\text{units } 10^{-3})$ $109 \pm 0.09 \text{ OUR AVER}$ $13 \pm 0.09 \pm 0.09$ 4 ± 0.4 100 ± 0.15 $(\Lambda \overline{\Sigma}^- \pi^+ (\text{or c.c.}))$	EVTS RAGE = Fro 1847 365 5 196 EVTS RAGE = Fro 1847 365 5 196 EVTS RAGE = 685 109)/Ftotal	DOCUMENT ID ANTONELLI BESCH DOCUMENT ID or includes scale far PALLIN EATON BESCH PERUZZI DOCUMENT ID EATON BRANDELIK PERUZZI	5 TECN 93 SPEC 78 BONA TECN 24 MRK2 81 BONA 78 MRK1 TECN 84 MRK2 79 DASP 78 MRK1	84 MRK 87 MRK (Confidence Level 6 COMMENT e+e- e+e- e+e- e+e- e+e- e+e- e+e- e+	2 1.4 1 3.2 6.5 el = 0.039)	25 Forbidden by <i>CP</i> . $\Gamma(\gamma \eta_c(1S))/\Gamma_{total}$ $\frac{VALUE}{0.0127\pm0.0036} \bullet \bullet \bullet \bullet \text{ We do not use the seen}$ $\Gamma(\gamma \pi^+\pi^-2\pi^0)/\Gamma_{total}$ $\frac{VALUE}{VALUE} \text{ (units } 10^{-3})$ 8.3±0.2±3.1 26 4 π mass less than 2.0 $\Gamma(\gamma \eta \pi \pi)/\Gamma_{total}$ $\frac{VALUE}{VALUE} \text{ (units } 10^{-3})$ 6.1 ±1.0 OUR AVERAG 5.85 ±0.3±1.05 7.8 ±1.2±2.4 27 Broad enhancement at a constant and a	EVTS e followin 16 al 0 GeV. 3E 2 2 2 2 e followin 2	PADIATIVE DE DOCUMENT ID GAISER ing data for average BALTRUSAIT DOCUMENT ID 26 BALTRUSAIT DOCUMENT ID 27 EDWARDS 27 EDWARDS MeV. Otal DOCUMENT ID 8,29 AUGUSTIN 8,30 BAI ng data for average 8,31 AUGUSTIN 28 AUGUSTIN 8,32 BAI 28 WISNIEWSKI	86 s, fits,84868 838 838 92 90c s, fits, 92 90 90c 87	TECN CBAL Limits, MRK3 TECN MRK3 TECN CBAL CBAL DM2 MRK3 Iimits, DM2 MRK3 MRK3 MRK3	$\begin{array}{c} \underline{COMMENT} \\ J/\psi \to \gamma \times \\ \text{etc.} \bullet \bullet \bullet \\ J/\psi \to 2\phi \gamma \\ \\ \underline{COMMENT} \\ J/\psi \to 4\pi \gamma \\ \\ \underline{COMMENT} \\ J/\psi \to \eta \pi^+ \pi^- \\ J/\psi \to \eta 2\pi^0 \\ \\ \underline{COMMENT} \\ J/\psi \to \gamma K\overline{K}\pi \\ J/\psi \to	Γ ₉₃ /Γ Γ ₉₄ /Γ
$(n\overline{n})/\Gamma_{\text{total}}$	EVTS RAGE ETTS 1847 365 5 196 EVTS RAGE ETTS 196 EVTS RAGE 685 109)// Total EVTS EVTS	DOCUMENT ID ANTONELLI BESCH DOCUMENT ID or includes scale far PALLIN EATON BESCH PERUZZI DOCUMENT ID EATON BRANDELIK	5 TECN 93 SPEC 78 BONA TECN 24 MRK2 81 BONA 78 MRK1 TECN 84 MRK2 79 DASP 78 MRK1	84 MRK 87 MRK (Confidence Level 6 COMMENT e+e- e+e- e+e- e+e- e+e- e+e- e+e- e+	2 1.4 1 3.2 6.5 el = 0.039)	25 Forbidden by <i>CP</i> . $\Gamma(\gamma \eta_{C}(1S))/\Gamma_{\text{total}}$ $VALUE$ 0.0127±0.0036 • • • We do not use the seen $\Gamma(\gamma \pi^{+}\pi^{-}2\pi^{0})/\Gamma_{\text{total}}$ $VALUE \text{ (units } 10^{-3})$ 8.3±0.2±3.1 $264\pi \text{ mass less than } 2.0$ $\Gamma(\gamma \eta \pi \pi)/\Gamma_{\text{total}}$ $VALUE \text{ (units } 10^{-3})$ 6.1 ±1.0 OUR AVERAG 5.85 ±0.3±1.05 7.8 ±1.2±2.4 $27 \text{ Broad enhancement } a$ $\Gamma(\gamma \eta (1440) \rightarrow \gamma K\overline{K})$ $VALUE \text{ (units } 10^{-3})$ 0.91±0.18 OUR AVERAG 0.83±0.13±0.18 $1.03^{-0.18} = 0.19$ • • We do not use the 1.78±0.21±0.33 3.8 ±0.3 ±0.6 0.66+0.17+0.24 0.66-0.15	EVTS e followin 16 al 0 GeV. at 1700 2 2 2 2 2 e followin 2	PADIATIVE DE DOCUMENT ID GAISER ing data for average BALTRUSAIT DOCUMENT ID 26 BALTRUSAIT DOCUMENT ID 27 EDWARDS 727 EDWARDS MeV. Otal DOCUMENT ID 8,29 AUGUSTIN 8,30 BAI 8,31 AUGUSTIN 28 AUGUSTIN 29 AUGUSTIN 20 AUGUSTI	86 s., fits,84868 838 838 92 90c s, fits, 92 90 90c 87 82E	TECN CBAL Limits, MRK3 TECN MRK3 TECN CBAL CBAL DM2 MRK3 Iimits, DM2 MRK3 MRK3 MRK3	$\begin{array}{c} \underline{COMMENT} \\ J/\psi \to \gamma \times \\ \text{etc.} \bullet \bullet \\ J/\psi \to 2\phi \gamma \\ \\ \underline{COMMENT} \\ J/\psi \to 4\pi \gamma \\ \\ \underline{COMMENT} \\ J/\psi \to \eta \pi^+ \pi^- \\ J/\psi \to \eta 2\pi^0 \\ \\ \underline{COMMENT} \\ J/\psi \to \gamma K\overline{K}\pi \\ J/\psi \to \kappa K\overline{K}\pi \\ J/\psi \to K\overline{K}\pi \\ K$	Γ ₉₃ /Γ Γ ₉₄ /Γ
$(n\overline{n})/\Gamma_{\text{total}}$	EVTS RAGE ETTS 1847 365 5 196 EVTS RAGE ETTS 196 EVTS RAGE 685 109)// Total EVTS EVTS	DOCUMENT ID ANTONELLI BESCH DOCUMENT ID or includes scale far PALLIN EATON BESCH PERUZZI DOCUMENT ID EATON BRANDELIK PERUZZI	5 TECN 93 SPEC 78 BONA TECN 24 MRK2 81 BONA 78 MRK1 TECN 84 MRK2 79 DASP 78 MRK1	84 MRK 78 MRK (Confidence Leve 6 COMMENT e+e- e+e- e+e- e+e- e+e- e+e- e+e- e+	2 1.4 3.2 6.5 el = 0.039) \[\begin{align*} \begin{align*} \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	25 Forbidden by <i>CP</i> . $\Gamma(\gamma \eta_c(1S))/\Gamma_{total}$ NALUE 0.0127±0.0036 • • • We do not use the seen $\Gamma(\gamma \pi^+ \pi^- 2\pi^0)/\Gamma_{total}$ NALUE (units 10 ⁻³) 8.3±0.2±3.1 26 4π mass less than 2.0 $\Gamma(\gamma \eta \pi \pi)/\Gamma_{total}$ NALUE (units 10 ⁻³) 6.1 ±1.0 OUR AVERAG 5.85±0.3±1.05 7.8 ±1.2±2.4 27 Broad enhancement at a T (γη(1440) $\rightarrow \gamma K K$ NALUE (units 10 ⁻³) 0.91±0.18 OUR AVERAG 0.83±0.13±0.18 1.03+0.21+0.26 1.03+0.21+0.26 0.66+0.17+0.24 0.18 0.21+0.33 3.8 ±0.3 ±0.6 0.66+0.17+0.24 0.16-0.15 6.3 ±1.4 4.0 ±0.7 ±1.0 4.3 ±1.7 28 Includes unknown bra	EVTS e following 16 al 0 GeV. GE 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	PADIATIVE DE DOCUMENT ID GAISER ing data for average BALTRUSAIT DOCUMENT ID 26 BALTRUSAIT 27 EDWARDS 27 EDWARDS MeV. DOCUMENT ID 28 AUGUSTIN 8,30 BAI ng data for average 8,31 AUGUSTIN 28 AUGUSTIN 8,32 BAI 28 WISNIEWSKI 28 EDWARDS 8,33 SCHARRE fraction n(1440)	86 86, s, fits, 84 868 838 92 90c s, fits, 92 90 90c 87 82E 80	TECN CBAL Limits, MRK3 TECN MRK3 TECN CBAL CBAL DM2 MRK3 Jimits, DM2 DM2 MRK3 MRK3 MRK3 MRK3 MRK3 MRK3	$\begin{array}{c} \underline{COMMENT} \\ J/\psi \to \gamma \times \\ \text{etc.} \bullet \bullet \\ J/\psi \to 2\phi \gamma \\ \\ \underline{COMMENT} \\ J/\psi \to 4\pi \gamma \\ \\ \underline{COMMENT} \\ J/\psi \to \eta \pi^+ \pi^- \\ J/\psi \to \eta 2\pi^0 \\ \\ \underline{COMMENT} \\ J/\psi \to \gamma K\overline{K}\pi \\ J/\psi \to \kappa K\overline{K}\pi \\ J/\psi \to K\overline{K}\pi \\ K$	Γ ₉₃ /Γ Γ ₉₄ /Γ
$(n\overline{n})/\Gamma_{\text{total}}$	EVTS RAGE ETTS 1847 365 5 196 EVTS RAGE ETTS RAGE 685 109 // Total EVTS RAGE 225± 155	DOCUMENT ID ANTONELLI BESCH DOCUMENT ID Includes scale far PALLIN EATON BESCH PERUZZI DOCUMENT ID EATON BRANDELIK PERUZZI DOCUMENT HENRARD	## FECH 15 15 15 15 15 15 15 1	84 MRK 78 MRK (Confidence Level 6 $ \frac{COMMENT}{e^+e^-} $ $ e^+e^- $ $ e^-e^- $ $ e^+e^- $ $ e^-e^- $ $ e^-e^$	2 1.4 1 3.2 6.5 el = 0.039) Γ ₇₈ /Γ Γ ₈₀ /Γ Γ ₈₂ /Γ ΛΣ+π-	25 Forbidden by <i>CP</i> . $\Gamma(\gamma \eta_c(15))/\Gamma_{\text{total}}$ VALUE 0.0127±0.0036 • • • We do not use the seen $\Gamma(\gamma \pi^+ \pi^- 2\pi^0)/\Gamma_{\text{total}}$ VALUE (units 10 ⁻³) 8.3±0.2±3.1 26 4 π mass less than 2.0 $\Gamma(\gamma \eta \pi \pi)/\Gamma_{\text{total}}$ VALUE (units 10 ⁻³) 6.1 ±1.0 OUR AVERAG 5.85±0.3±1.05 7.8 ±1.2±2.4 27 Broad enhancement at 1.2 × 1.2 × 1.2 × 1.2 × 1.2 × 1.2 × 1.2 × 1.2 × 1.3 × 1.3 × 1.3 × 1.3 × 1.3 × 1.3 × 1.3 × 1.3 × 1.3 × 1.3 × 1.3 × 1.3 × 1.3 × 1.3 × 1.3 × 1.3 × 1.3 × 1.4 × 1.5		PADIATIVE DE DOCUMENT ID GAISER ing data for average BALTRUSAIT DOCUMENT ID 26 BALTRUSAIT 27 EDWARDS 27 EDWARDS MeV. DOCUMENT ID 28 AUGUSTIN 8,30 BAI ng data for average 8,31 AUGUSTIN 28 AUGUSTIN 8,32 BAI 28 WISNIEWSKI 28 EDWARDS 8,33 SCHARRE fraction n(1440)	86 86, s, fits, 84 868 838 92 90c s, fits, 92 90 90c 87 82E 80	TECN CBAL Limits, MRK3 TECN MRK3 TECN CBAL CBAL DM2 MRK3 Jimits, DM2 DM2 MRK3 MRK3 MRK3 MRK3 MRK3 MRK3	$\begin{array}{c} \underline{COMMENT} \\ J/\psi \to \gamma \times \\ \text{etc.} \bullet \bullet \\ J/\psi \to 2\phi \gamma \\ \\ \underline{COMMENT} \\ J/\psi \to 4\pi \gamma \\ \\ \underline{COMMENT} \\ J/\psi \to \eta \pi^+ \pi^- \\ J/\psi \to \eta 2\pi^0 \\ \\ \underline{COMMENT} \\ J/\psi \to \gamma K\overline{K}\pi \\ J/\psi \to \kappa K\overline{K}\pi \\ J/\psi \to K\overline{K}\pi \\ K$	Γ ₉₃ /Γ Γ ₉₄ /Γ
$(n \overline{n})/\Gamma_{\text{total}}$ $ALUE (\text{units } 10^{-2})$ $.19 \pm 0.05 \text{ OUR AV}$ $.190 \pm 0.055 \text{ OUR AV}$ $.190 \pm 0.055$ $.18 \pm 0.09$ $(A\overline{A})/\Gamma_{\text{total}}$ $ALUE (\text{units } 10^{-3})$ $.35 \pm 0.14 \text{ OUR AVER}$ $.35 \pm 0.14 \text{ OUR AVER}$ $.35 \pm 0.05 \pm 0.20$ $.58 \pm 0.08 \pm 0.19$ $.6 \pm 1.6$ $.1 \pm 0.2$ $(P\overline{p}\pi^0)/\Gamma_{\text{total}}$ $ALUE (\text{units } 10^{-3})$ $.09 \pm 0.09 \text{ OUR AVER}$ $.13 \pm 0.09 \pm 0.09$ $.4 \pm 0.4$ $.00 \pm 0.15$ $(A\overline{\Sigma} - \pi^+ (\text{or c.c.}))$ $.06 \pm 0.12 \text{ OUR AVER}$ $.90 \pm 0.06 \pm 0.16$ $.11 \pm 0.06 \pm 0.20$	EVTS RAGE ETTS 1847 365 5 196 EVTS RAGE ETTS 1865 109 / T total EVTS RAGE 225± 15 342± 188	DOCUMENT ID ANTONELLI BESCH DOCUMENT ID OF INCIDIES SCALE FAPALLIN EATON BESCH PERUZZI DOCUMENT ID EATON BRANDELIK PERUZZI DOCUMENT HENRARD HENRARD	## FECN TECN 10 10 10 10 10 10 10 1	84 MRK 78 MRK (Confidence Level 6 $ \begin{array}{cccc} \hline COMMENT \\ e^+e^-\\ e^+e^- \end{array} $ $ \begin{array}{ccccc} e^+e^-\\ e^-\\ e^-\\ e^-e^-\\ e^-\\ e^-\\ e^-\\ e^$	2 1.4 1 3.2 6.5 $el = 0.039$) Γ_{78}/Γ Γ_{80}/Γ Γ_{81}/Γ Γ_{82}/Γ $\Lambda \Sigma + \pi^ \Lambda \Sigma^- \pi^+$	25 Forbidden by <i>CP</i> . Γ($\gamma\eta_c(15)$)/ Γ_{total} NALUE 0.0127±0.0036 • • • We do not use the seen Γ($\gamma\pi^+\pi^-2\pi^0$)/ Γ_{total} NALUE (units 10^{-3}) 8.3±0.2±3.1 26 4π mass less than 2.0 Γ($\gamma\eta\pi\pi$)/ Γ_{total} NALUE (units 10^{-3}) 6.1 ±1.0 OUR AVERAG 5.85±0.3±1.05 7.8 ±1.2±2.4 27 Broad enhancement at a recommend π and	EVTS e followin 16 al 0 GeV. SE 2 2 e followin 2 2 2 annching 392) K 0 0 al state.	PRADIATIVE DE DOCUMENT ID GAISER ing data for average BALTRUSAIT DOCUMENT ID 26 BALTRUSAIT POCUMENT ID 27 EDWARDS 27 EDWARDS MeV. DOCUMENT ID BALTRUSAIT AUGUSTIN 8,30 BAI ng data for average 8,31 AUGUSTIN 28 AUGUSTIN 28 AUGUSTIN 28 AUGUSTIN 28 AUGUSTIN 8,32 BAI 28 WISNIEWSKI 28 EDWARDS 8,33 SCHARRE fraction $\eta(1440) \rightarrow -$ + partial wave.	86 86, s, fits, 84 868 838 92 90c s, fits, 92 90 90c 87 82E 80	TECN CBAL Limits, MRK3 TECN MRK3 TECN CBAL CBAL DM2 MRK3 Jimits, DM2 DM2 MRK3 MRK3 MRK3 MRK3 MRK3 MRK3	$\begin{array}{c} \underline{COMMENT} \\ J/\psi \to \gamma \times \\ \text{etc.} \bullet \bullet \\ J/\psi \to 2\phi \gamma \\ \\ \underline{COMMENT} \\ J/\psi \to 4\pi \gamma \\ \\ \underline{COMMENT} \\ J/\psi \to \eta \pi^+ \pi^- \\ J/\psi \to \eta 2\pi^0 \\ \\ \underline{COMMENT} \\ J/\psi \to \gamma K\overline{K}\pi \\ J/\psi \to K\overline{K}\pi \\ K\overline{K}\pi \\ J/\psi \to K\overline{K}\pi \\ J/\psi \to K\overline{K}\pi \\ J/\psi \to K\overline{K}\pi \\	Γ ₉₃ /Γ Γ ₉₄ /Γ - - - - - - - - - - - - - - - - - - -
$\Gamma(\overline{P})/\Gamma_{total}$		DOCUMENT ID ANTONELLI BESCH DOCUMENT ID Includes scale far PALLIN EATON BESCH PERUZZI DOCUMENT ID EATON BRANDELIK PERUZZI DOCUMENT HENRARD	5 TECN 93 SPEC 78 BONA TECN 26 TECN 27 TECN 28 MRK2 38 MRK1 TECN 84 MRK2 79 DASP 78 MRK1 10 TECN 87 DM 88 MRK1	84 MRK 78 MRK (Confidence Level 6 $ \frac{COMMENT}{e^+e^-} $ $ e^+e^- $ $ e^-e^- $ $ e^+e^- $ $ e^-e^- $ $ e^-e^$	2 1.4 1 3.2 6.5 $ S = 0.039$) $ S = 0.039$ $ S = 0.039$ $ S = 0.039$	25 Forbidden by <i>CP</i> . $\Gamma(\gamma \eta_c(15))/\Gamma_{\text{total}}$ VALUE 0.0127±0.0036 • • • We do not use the seen $\Gamma(\gamma \pi^+ \pi^- 2\pi^0)/\Gamma_{\text{total}}$ VALUE (units 10 ⁻³) 8.3±0.2±3.1 26 4 π mass less than 2.0 $\Gamma(\gamma \eta \pi \pi)/\Gamma_{\text{total}}$ VALUE (units 10 ⁻³) 6.1 ±1.0 OUR AVERAG 5.85±0.3±1.05 7.8 ±1.2±2.4 27 Broad enhancement at 1.2 × 1.2 × 1.2 × 1.2 × 1.2 × 1.2 × 1.2 × 1.2 × 1.3 × 1.3 × 1.3 × 1.3 × 1.3 × 1.3 × 1.3 × 1.3 × 1.3 × 1.3 × 1.3 × 1.3 × 1.3 × 1.3 × 1.3 × 1.3 × 1.3 × 1.4 × 1.5	EVTS e followin 16 al 0 GeV. 3E 2 2 2 2 2 2 2 2 3 anching gap (a) state. 80) n 0 -	PRADIATIVE DE DOCUMENT ID GAISER ing data for average BALTRUSAIT DOCUMENT ID 26 BALTRUSAIT POCUMENT ID 27 EDWARDS 27 EDWARDS MeV. DOCUMENT ID BALTRUSAIT AUGUSTIN 8,30 BAI ng data for average 8,31 AUGUSTIN 28 AUGUSTIN 28 AUGUSTIN 28 AUGUSTIN 28 AUGUSTIN 8,32 BAI 28 WISNIEWSKI 28 EDWARDS 8,33 SCHARRE fraction $\eta(1440) \rightarrow -$ + partial wave.	86 86, s, fits, 84 868 838 92 90c s, fits, 92 90 90c 87 82E 80	TECN CBAL Limits, MRK3 TECN MRK3 TECN CBAL CBAL DM2 MRK3 Jimits, DM2 DM2 MRK3 MRK3 MRK3 MRK3 MRK3 MRK3	$\begin{array}{c} \underline{COMMENT} \\ J/\psi \to \gamma \times \\ \text{etc.} \bullet \bullet \\ J/\psi \to 2\phi \gamma \\ \\ \underline{COMMENT} \\ J/\psi \to 4\pi \gamma \\ \\ \underline{COMMENT} \\ J/\psi \to \eta \pi^+ \pi^- \\ J/\psi \to \eta 2\pi^0 \\ \\ \underline{COMMENT} \\ J/\psi \to \gamma K\overline{K}\pi \\ J/\psi \to K\overline{K}\pi \\ K\overline{K}\pi \\ J/\psi \to K\overline{K}\pi \\ J/\psi \to K\overline{K}\pi \\ J/\psi \to K\overline{K}\pi \\	Γ ₉₃ / Γ ₉₄ / Γ ₉₅ / ± _π ∓

$J/\psi(1\mathcal{S})$

$(\gamma \eta (1440) \rightarrow \gamma \gamma \rho^0) / \Gamma_{\text{tot}}$		$\Gamma(\gamma\eta(1440) \to \gamma\rho^0\rho^0)/\Gamma_{\text{total}}$ Γ_{102}/Γ
ALUE (units 10 ⁻⁵)	DOCUMENT ID TECN COMMENT 34 COFFMAN 90 MRK3 $J/\psi \rightarrow \gamma\gamma\pi^{+}\pi^{-}$	VALUE (units 10 ⁻³) 1.7 ±0.4 OUR AVERAGE Error includes scale factor of 1.3.
. 4±1.2±0.7 ³⁴ Includes unknown branching	** **	2.1 \pm 0.4 BUGG 95 MRK3 $J/\psi \rightarrow \gamma \pi^+ \pi^- \pi^+ \pi^-$
	$\eta(1440) \rightarrow \gamma \rho^{-1}$	1.36 ± 0.38 43,44 BISELLO 89B DM2 $J/\psi \rightarrow 4\pi\gamma$
$\Gamma(\gamma ho ho)/\Gamma_{total}$	Γ ₉₇ /Γ	43 Estimated by us from various fits.
ALUE (units 10 ⁻³) CL%	DOCUMENT ID TECN COMMENT	44 Includes unknown branching fraction to $ ho^0 ho^0$.
4.5 ± 0.8 OUR AVERAGE 4.7 ±0.3 ±0.9	35 BALTRUSAIT868 MRK3 $J/\psi ightarrow 4\pi\gamma$	$\Gamma(\gamma f_2(1270))/\Gamma_{\text{total}}$ $\Gamma_{103}/\Gamma_{\text{total}}$
3.75 ± 1.05 ± 1.20	36 BURKE 82 MRK2 $J/\psi \rightarrow 4\pi\gamma$	VALUE (units 10 ⁻³) EVTS DOCUMENT ID TECN CHG COMMENT
	ring data for averages, fits, limits, etc. • • •	1.38 \pm 0.14 OUR AVERAGE 1.33 \pm 0.05 \pm 0.20 45 AUGUSTIN 87 DM2 $J/\psi \rightarrow \gamma \pi^+ \pi^-$
(0.09 90	37 BISELLO 89B $J/\psi ightarrow 4\pi\gamma$	1.36 \pm 0.09 \pm 0.23 45 BALTRUSAIT87 MRK3 $J/\psi ightarrow \gamma \pi^+ \pi^-$
85 $^{4\pi}$ mass less than 2.0 GeV.	$2\rho^0$ corrected to 2ρ by factor of 3.	1.48 \pm 0.25 \pm 0.30 178 EDWARDS 82B CBAL $e^{+}e^{-} \rightarrow 2\pi^{0}\gamma$
7 $^{4}\pi$ mass in the range 2.0–25	5 GeV.	2.0 \pm 0.7 35 ALEXANDER 78 PLUT 0 e^+e^- 1.2 \pm 0.6 30 ⁴⁶ BRANDELIK 78B DASP $e^+e^- \rightarrow$
$(\gamma \eta'(958))/\Gamma_{total}$	Г ₉₈ /Г	$\frac{1.2 \pm 0.0}{\pi} + \frac{1}{\pi} - \frac{1}{\gamma}$
LUE (units 10 ⁻³) EVTS	DOCUMENT ID TECN COMMENT	⁴⁵ Estimated using B($f_2(1270) \rightarrow \pi\pi$)=0.843 \pm 0.012. The errors do not contain th uncertainty in the $f_2(1270)$ decay.
1±0.30 OUR AVERAGE		46 Restated by us to take account of spread of E1, M2, E3 transitions.
$0\pm0.14\pm0.53$	BOLTON 92B MRK3 $J/\psi \rightarrow \gamma \pi^+ \pi^- \eta, \eta \rightarrow$	-4 -4 · 4 · -
$30 \pm 0.31 \pm 0.71$	BOLTON 92B MRK3 $J/\psi \stackrel{\uparrow}{\rightarrow} \gamma \pi^+ \pi^- \eta$, $\eta \rightarrow$	· · · · · · · · · · · · · · · · · · ·
04±0.16±0.85 622	$\pi^+\pi^-\pi^0$ AUGUSTIN 90 DM2 $J/\psi o\gamma\eta\pi^+\pi^-$	<u>VALUE (units 10⁻⁴) CL% DOCUMENT ID TECN COMMENT</u> 9.7±1.2 OUR AVERAGE
$39 \pm 0.09 \pm 0.66$ 2420	AUGUSTIN 90 DM2 $J/\psi o \gamma \eta \pi^+ \pi^-$ AUGUSTIN 90 DM2 $J/\psi o \gamma \gamma \pi^+ \pi^-$	9.2 \pm 1.4 \pm 1.4 47 AUGUSTIN 88 DM2 $J/\psi ightarrow \gamma K^+K^-$
±0.3 ±0.6	BLOOM 83 CBAL $e^+e^- \rightarrow 3\gamma +$	10.4 \pm 1.2 \pm 1.6 47 AUGUSTIN 88 DM2 $J/\psi \rightarrow \gamma K_S^0 K_S^0$
We do not use the follow	hadrons γ ring data for averages, fits, limits, etc. $ullet$ $ullet$	$9.6\pm1.2\pm1.8$ 47 BALTRUSAIT87 MRK3 $J/\psi \rightarrow \gamma K^+K^-$
± 1.1 6	BRANDELIK 79C DASP $e^+e^- \rightarrow 3\gamma$	• • • We do not use the following data for averages, fits, limits, etc. • • • < 0.8 90 48 BISELLO 898 $J/\psi \rightarrow 4\pi\gamma$
3 ±1.3	³⁸ SCHARRE 79B MRK1 $e^+e^- \rightarrow \gamma X$	1.6 \pm 0.4 \pm 0.3 1.6 \pm 0.4 \pm 0.4 1.6
±0.7	SCHARRE 798 MRK1 $e^+e^- \rightarrow 2\pi 2\gamma$	3.8 \pm 1.6 50 EDWARDS 82D CBAL $e^+e^- ightarrow \eta\eta\gamma$
8 ± 0.7 57	BARTEL 76 CNTR $e^+e^- \rightarrow 2\gamma \rho$	⁴⁷ Includes unknown branching fraction to K^+K^- or $K^0_SK^0_S$. We have multiplied K^+K^-
8 From the inclusive γ decay :	spectrum.	measurement by 2, and $K^0_S K^0_S$ by 4 to obtain $K\overline{K}$ result.
$(\gamma 2\pi^+ 2\pi^-)/\Gamma_{total}$	Г99/Г	48 Includes unknown branching fraction to $ ho^0 ho^0$. 49 Includes unknown branching fraction to $\pi^+\pi^-$.
UE (units 10 ⁻³)	DOCUMENT ID TECN COMMENT	To includes unknown branching fraction to $\pi^+\pi^-$. 50 Includes unknown branching fraction to $\eta\eta$.
±0.5 OUR AVERAGE E 2±0.14±0.73	rror includes scale factor of 1.9. See the ideogram below. 39 BISELLO 89B DM2 $J/\psi ightarrow 4\pi \gamma$	
2±0.14±0.73 8±0.13±0.35	40 BISELLO 89B DM2 $J/\psi o 4\pi\gamma$	$\Gamma(\gamma\eta)/\Gamma_{\text{total}}$ $\Gamma_{105}/\Gamma_{105}$
$5\pm0.08\pm0.45$	40 BALTRUSAIT868 MRK3 $J/\psi ightarrow 4\pi\gamma$	VALUE (units 10 ⁻³) EVTS DOCUMENT ID TECN COMMENT 0.86±0.08 OUR AVERAGE
$5 \pm 0.45 \pm 1.20$	⁴¹ BURKE 82 MRK2 e^+e^-	$0.88 \pm 0.08 \pm 0.11$ BLOOM 83 CBAL e^+e^-
$^{9}4\pi$ mass less than 3.0 GeV. $^{9}4\pi$ mass less than 2.0 GeV.		0.82 ± 0.10 BRANDELIK 79C DASP e^+e^-
4π mass less than 2.5 GeV.		1.3 \pm 0.4 21 BARTEL 77 CNTR e^+e^-
WEIGHTED AVE	RAGE	$\Gamma(\gamma f_1(1420) \to \gamma K \overline{K} \pi) / \Gamma_{\text{total}}$ $\Gamma_{106} / \Gamma_{\text{total}}$
2.8±0.5 (Error sc		VALUE (units 10 ⁻³) DOCUMENT ID TECN COMMENT
,		0.83 \pm 0.15 OUR AVERAGE 0.76 \pm 0.15 \pm 0.21 51,52 AUGUSTIN 92 DM2 $J/\psi \rightarrow \gamma K \overline{K} \pi$
\ \ \		0.87 \pm 0.14 \pm 0.11 \pm 0.87 \pm 0.87 \pm 0.11 \pm 0.87 \pm 0.81 \pm 0.
		⁵¹ Included unknown branching fraction $f_1(1420) \to K\overline{K}\pi$. ⁵² From fit to the $K^*(892)K$ 1 $^+$ + partial wave.
1 1 5		
	\	$\Gamma(\gamma f_1(1285))/\Gamma_{\text{total}}$ $\Gamma_{107}/\Gamma_{\text{total}}$
		VALUE (units 10 ⁻³) DOCUMENT ID TECN COMMENT 0.65 ±0.10 OUR AVERAGE
		$0.625 \pm 0.063 \pm 0.103$ 53 BOLTON 92 MRK3 $J/\psi \to \gamma f_1(1285)$
	<u> x</u> ²	0.70 \pm 0.08 \pm 0.16 54 BOLTON 928 MRK3 $J/\psi \rightarrow \gamma \eta \pi^+ \pi^-$
	BISELLO 89B DM2 4.2 BISELLO 89B DM2 3.7	⁵³ Obtained summing the sequential decay channels $R(I/h) = of(1385) f(1385) = of(144 + 0.39 + 0.37) \times 10^{-4}$
-	- ··· \···· BALTRUSAIT 86B MRK3 0.3	$B(J/\psi \to \gamma f_1(1285), f_1(1285) \to \pi\pi\pi\pi) = (1.44 \pm 0.39 \pm 0.27) \times 10^{-4};$ $B(J/\psi \to \gamma f_1(1285), f_1(1285) \to \delta\pi, \delta \to \eta\pi) = (3.90 \pm 0.42 \pm 0.87) \times 10^{-4};$
	BURKE 82 MRK2 2.5 10.8	$B(J/\psi \to \gamma f_1(1285), f_1(1285) \to \delta \pi, \delta \to K\overline{K}) = (0.66 \pm 0.26 \pm 0.29) \times 10^{-4};$
	(Confidence Level = 0.013)	$B(J/\psi \to \gamma f_1(1285), f_1(1285) \to \gamma \rho^0) = (0.25 \pm 0.07 \pm 0.03) \times 10^{-4}.$
0 2	4 6 8 10	⁵⁴ Using B($f_1(1285) \rightarrow a_0(980)\pi$) = 0.37, and including unknown branching ratio for
		$a_0(980) \rightarrow \eta \pi$.
$\Gamma(\gamma 2\pi^+ 2\pi^-)/\Gamma_{\text{tot}}$	al (units 10 ⁻³)	$\Gamma(\gamma f_2'(1525))/\Gamma_{\text{total}}$ $\Gamma_{108}/\Gamma_{\text{total}}$
$\gamma f_4(2050))/\Gamma_{\text{total}}$	Γ ₁₀₀ /Γ	VALUE (units 10 ⁻³) CL% EVTS DOCUMENT ID TECN COMMENT
7/4(2050))// total .UE (units 10 ⁻³)	DOCUMENT ID TECN COMMENT	0.63 \pm 0.10 OUR AVERAGE $0.70\pm0.17\pm0.11$ 55 AUGUSTIN 88 DM2 $J/\psi \rightarrow$
'±0.5±0.5	42 BALTRUSAIT87 MRK3 $J/\psi \rightarrow \gamma \pi^+ \pi^-$	$\gamma K^+ K^-$
	$f_4(2050) \rightarrow \pi \pi / \text{ total} = 0.167.$	$0.56\pm0.06\pm0.11$ S AUGUSTIN 88 DM2 $J/\psi \rightarrow$
		$\gamma {\cal K}_{S}^{0} {\cal K}_{S}^{0} = 0.84 \pm 0.20 \pm 0.17$ 55 BALTRUSAIT87 MRK3 $J/\psi \rightarrow$
γωω)/Γ _{total}	Γ ₁₀₁ /Γ	$0.84 \pm 0.20 \pm 0.17$ SS BALTRUSAIT87 MRK3 $J/\psi ightarrow \gamma K^+ K^-$
.UE (units 10 ⁻³) EV	TS DOCUMENT ID TECN COMMENT	 ● We do not use the following data for averages, fits, limits, etc.
	$0\pm$ BISELLO 87 SPEC e^+e^- , hadrons γ	0.25 \pm 0.14 55 FRANKLIN 83B MRK2 $J/\psi \rightarrow \gamma K\overline{K}$
9±0.33 OUR AVERAGE		<0.34 90 4 56 BRANDELIK 79c DASP $e^+e^- \rightarrow$
9±0.33 OUR AVERAGE 1±0.2 ±0.42 120	17	$\begin{array}{cccccccccccccccccccccccccccccccccccc$
9±0.33 OUR AVERAGE 1±0.2 ±0.42 120		$\begin{array}{cccccccccccccccccccccccccccccccccccc$
9±0.33 OUR AVERAGE 1±0.2 ±0.42 120	17	$\pi^+\pi^-\gamma$

 $\Gamma(3\gamma)/\Gamma_{\text{total}}$

VALUE (units 10⁻³)

 $J/\psi(1S)$

$\Gamma(\gamma\phi\phi)/\Gamma_{\text{total}}$ VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT	Γ ₁₀₉ /Γ	$\Gamma(\gamma f_0(2200))/\Gamma_{\text{total}}$ VALUE (units 10^{-4})
4.0±1.2 OUR AVERA		includes scale fac	tor of :	2.1. Se	e the ideogram be	elow.	• • We do not use the following the fol
$7.5 \pm 0.6 \pm 1.2$	168	BAI ⁵⁷ BISELLO			$J/\psi \rightarrow \gamma 4K$		1.5
$3.4 \pm 0.8 \pm 0.6$	33 ± 7	3, BISELLO	90	DM2	$J/\psi \rightarrow \gamma K^+ K^- K_s^0$) K0	63 Includes unknown branchi
3.1 ± 0.7 ± 0.4		⁵⁷ BISELLO	86 B	DM2	$J/\psi ightarrow$, _	
					7 K+ K- K-	+ K-	$\Gamma(\gamma f_J(2220))/\Gamma_{\text{total}}$
$^{57}\phi\phi$ mass less than	2.9 GeV, η	η_C excluded.					VALUE (units 10 ⁻⁵) EVT
WEIGH	TED AVER	AGE					• • We do not use the following the fol
4.0±1.2	(Error scale	ed by 2.1)					< 2.3 95 < 1.6 95
1	V						$12.4^{+6.4}_{-5.2}\pm 2.8$ 23
	Λ						
							$8.4^{+3.4}_{-2.8}\pm 1.6$ 93
							⁶⁴ Includes unknown branchi
1 1							$\Gamma(\gamma f_0(1370))/\Gamma_{\text{total}}$
							VALUE (units 10 ⁻⁴) EVTS
1 /							3.38±0.33±0.64
							• • We do not use the following the fol
						γ^2	7.0 ±0.6 ±1.1 261
	1 -	+	в	AI.	90B MRK3		65 Includes unknown branchi
-	<u> </u>			SELLO SELLO	90 DM2	0.3 1.2	$\Gamma(\gamma f_0(1500))/\Gamma_{ m total}$
	' V		D1.			8.4	VALUE (units 10 ⁻⁴)
			1		(Confidence Leve	I = 0.015)	8.2±1.5
0	5	10	15		20		66 Including unknown branch
$\Gamma(\gamma\phi\phi)/\Gamma_{t}$	otal (units	s 10 ⁻⁴)					
$\Gamma(\gamma p \overline{p})/\Gamma_{\text{total}}$						Γ ₁₁₀ /Γ	BAI 95B PL B355 374
VALUE (units 10 ⁻³)	CL%	EVTS DOCI	JMENT	ID	TECN COMME		BUGG 95 PL B353 378 ANTONELLI 93 PL B301 317
0.38±0.07±0.07		49 EAT			MRK2 e+e-		ARMSTRONG 93B PR D47 772 AUGUSTIN 92 PR D46 1951
• • • We do not use t	he followin	ng data for averag	es, fits	, limits,	, etc. • • •		BOLTON 92 PL B278 495 BOLTON 92B PRL 69 1328
< 0.11	90	PER	UZZI	78	MRK1 e ⁺ e ⁻		COFFMAN 92 PRL 68 282 HSUEH 92 PR D45 R218
$\Gamma(\gamma\eta(2225))/\Gamma_{\text{total}}$						Γ_{111}/Γ	AUGUSTIN 90 PR D42 10 BAI 90B PRL 65 1309
VALUE (units 10 ⁻³)		DOCUMENT ID		TECN	COMMENT		BAI 90C PRL 65 2507 BISELLO 90 PL B241 617
0.29±0.06 OUR AVER	AGE	⁵⁸ BAI	000	MDIZ	$J/\psi ightarrow 0$		COFFMAN 90 PR D41 1410 JOUSSET 90 PR D41 1389
$.33 \pm 0.08 \pm 0.05$		BAI	908	IVIKKS	$\gamma K^+ K^- K^+$	+κ-	ALEXANDER 89 NP B320 45 AUGUSTIN 89 NP B320 1
$0.27 \pm 0.06 \pm 0.06$		⁵⁸ BAI	90B	MRK3	$ \gamma K^{+} K^{-} K^{+} $ $ J/\psi \to \gamma K^{+} K^{-} K^{0} $		BISELLO 89B PR D39 701 AUGUSTIN 88 PRL 60 2238
					$\gamma K^+ K^- K_2^0$	$\frac{1}{5}\kappa_{L}^{0}$	COFFMAN 88 PR D38 2695 FALVARD 88 PR D38 2706
$0.24^{+0.15}_{-0.10}$	59	^{0,60} BISELLO	8 9 B	DM2	$J/\psi ightarrow 4\pi \gamma$		AUGUSTIN 87 ZPHY C36 36 BAGLIN 87 NP B286 592
⁵⁸ Includes unknown b	ranching f	raction to $\phi\phi$.					BALTRUSAIT 87 PR D35 2077
⁵⁹ Estimated by us fro	m various	fits.					BECKER 87 PRL 59 186 BISELLO 87 PL B192 239
60 Includes unknown t							HENRARD 87 NP B292 670 PALLIN 87 NP B292 653
$\Gamma(\gamma\eta(1760) o \gamma ho^0$	$\rho^0)/\Gamma_{\rm tot}$					Γ_{112}/Γ	WISNIEWSKI 87 Hadron 87 Co BALTRUSAIT 86B PR D33 1222
VALUE (units 10 ⁻³)		DOCUMENT ID			COMMENT		BALTRUSAIT 86D PRL 56 107 BISELLO 86B PL B179 294
0.13±0.09		,62 BISELLO	89B	DM2	$J/\psi \rightarrow 4\pi \gamma$		GAISER 86 PR D34 711 BALTRUSAIT 85C PRL 55 1723
62 Includes unknown t							BALTRUSAIT 85D PR D32 566 BALTRUSAIT 84 PRL 52 2126
						- /-	EATON 84 PR D29 804 BLOOM 83 ARNS 33 143
$\Gamma(\gamma \pi^0)/\Gamma_{\text{total}}$	F1.07.5					Γ ₁₁₃ /Γ	EDWARDS 83B PRL 51 859 EINSWEILER 83 Brighton Conf
VALUE (units 10 ⁻³) D.039±0.013 OUR AV	ERAGE	DOCUMENT ID		TECN	COMMENT		FRANKLIN 83 PRL 51 963 FRANKLIN 83B Thesis SLAC-0
$0.036 \pm 0.011 \pm 0.007$		вьоом	83	CBAL	e^+e^-		BURKE 82 PRL 49 632 EDWARDS 82B PR D25 3065
0.073 ± 0.047	10	BRANDELIK	79 C	DASP	e+ e-		EDWARDS 82D PRL 48 458 Also 83 ARNS 33 143
$\Gamma(\gamma ho \overline{ ho} \pi^+ \pi^-)/\Gamma_{ m tot}$	al					Γ ₁₁₄ /Γ	EDWARDS 82E PRL 49 259 LEMOIGNE 82 PL 113B 509
VALUE (units 10 ⁻³)	CL%	DOCUMENT ID		TECN	COMMENT	1171	BESCH 81 ZPHY C8 1 GIDAL 81 PL 107B 153
<0.79	90	EATON			e+ e-	7.41	PARTRIDGE 80 PRL 44 712 SCHARRE 80 PL 97B 329
$\Gamma(\gamma\gamma)/\Gamma_{\text{total}}$						Γ ₁₁₅ /Γ	ZHOLENTZ 80 PL 96B 214 Also 81 SJNP 34 814
VALUE (units 10 ⁻³)	CL%	DOCUMENT ID		TECN	COMMENT	. 119/ ,	Translated from BRANDELIK 79C ZPHY C1 233
<0.5	90	BARTEL			e+e-		SCHARRE 79B SLAC-PUB-23: Also 79 LBL-9502
						r/r	ALEXANDER 78 PL 72B 493 BESCH 78 PL 78B 347
$\Gamma(\gamma \Lambda \overline{\Lambda})/\Gamma_{\text{total}}$	CLEV	DOCUMENT 'S		TECN	COMMENT	Γ ₁₁₆ /Γ	BRANDELIK 78B PL 74B 292 PERUZZI 78 PR D17 2901
VALUE (units 10 ⁻³) <0.13	<u>CL%</u>	DOCUMENT ID HENRARD		TECN DM2	e+e-		BARTEL 77 PL 66B 489 BURMESTER 77D PL 72B 135
~0.13	90	HENNAND	01	DIVIZ	C . C		FELDMAN 77 PRPL 33C 28

 Γ_{117}/Γ

 $\frac{\textit{DOCUMENT ID}}{\textit{PARTRIDGE}}$ 80 CBAL e^+e^-

Γ(γ <i>f</i> ₀ (2200))/Γ _{tot} ,	al				Γ ₁₁₈ /Γ
VALUE (units 10 ⁻⁴)		DOCUMENT ID		TECN	COMMENT
• • • We do not use	the follow				
1.5		⁶³ AUGUSTIN	88	DM2	$J/\psi \rightarrow \gamma K_S^0 K_S^0$
63 Includes unknown	branching	fraction to $K^0_S K^0_S$			0 0
$\Gamma(\gamma f_J(2220))/\Gamma_{\text{tot}}$	al				Γ ₁₁₉ /Γ
VALUE (units 10 ⁻⁵)	EVTS	DOCUMENT ID		TECN	COMMENT
• • We do not use	the followi	ing data for average	s, fits	, limits,	etc. • • •
< 2.3	95	64 AUGUSTIN	88	DM2	$J/\psi \rightarrow \gamma K^+ K^-$
< 1.6	95	⁶⁴ AUGUSTIN	88	DM2	$J/\psi \rightarrow \gamma K_S^0 K_S^0$
V 1.0				MADICA	$J/\psi \rightarrow \gamma K_S^0 K_S^0$
$12.4^{+6.4}_{-5.2}\pm 2.8$	23	64 BALTRUSAIT	86 D	MRK3	$J/\psi \rightarrow \gamma \kappa_{\tilde{S}} \kappa_{\tilde{S}}$
	23 93				$J/\psi \to \gamma \kappa_{\tilde{S}} \kappa_{\tilde{S}}$ $J/\psi \to \gamma K^+ K^-$
$12.4^{+6.4}_{-5.2}\pm 2.8$	93	⁶⁴ BALTRUSAIT	.86 D	MRK3	
$12.4^{+6.4}_{-5.2}\pm 2.8$ $8.4^{+3.4}_{-2.8}\pm 1.6$ 64 Includes unknown	93 branching	⁶⁴ BALTRUSAIT	.86 D	MRK3	
$12.4^{+6.4}_{-5.2} \pm 2.8$ $8.4^{+3.4}_{-2.8} \pm 1.6$	93 branching	⁶⁴ BALTRUSAIT	86D or <i>K</i>	MRK3 5 K 5.	$J/\psi \rightarrow \gamma K^+ K^-$
12.4 $^{+6.4}_{-5.2}$ ±2.8 8.4 $^{+3.4}_{-2.8}$ ±1.6 64 Includes unknown $\Gamma(\gamma f_0(1370))/\Gamma_{\text{total}}$ VALUE (units 10 ⁻⁴)	93 branching	64 BALTRUSAIT fraction to K^+K^-	86D or <i>K</i>	MRK3 O K O. TECN	$J/\psi \rightarrow \gamma K^+ K^-$
$12.4^{+6.4}_{-5.2} \pm 2.8$ $8.4^{+3.4}_{-2.8} \pm 1.6$ 64 Includes unknown $\Gamma(\gamma f_0(1370))/\Gamma_{\text{total}}$	93 branching i EVTS	64 BALTRUSAIT fraction to K^+K^- DOCUMENT ID 65 BOLTON	86D or <i>K</i> 92B	MRK3 -0 K0	$J/\psi \rightarrow \gamma K^+ K^-$ $\frac{\Gamma_{120}/\Gamma}{J/\psi \rightarrow \gamma \eta \pi^+ \pi^-}$
12.4 $^{+6.4}_{-5.2}$ ±2.8 8.4 $^{+3.4}_{-2.8}$ ±1.6 64 Includes unknown $\Gamma(\gamma f_0(1370))/\Gamma_{\text{total}}$ $VALUE$ (units 10^{-4}) 3.38±0.33±0.64	93 branching i EVTS	64 BALTRUSAIT fraction to K+K- DOCUMENT ID 65 BOLTON ing data for average	86D or <i>K</i> 92B	MRK3 O KO. TECN MRK3 Imits,	$J/\psi \rightarrow \gamma K^+ K^-$ $\frac{\Gamma_{120}/\Gamma}{J/\psi \rightarrow \gamma \eta \pi^+ \pi^-}$
12.4 $^{+6.4}_{-5.2}$ ±2.8 8.4 $^{+3.4}_{-2.8}$ ±1.6 64 Includes unknown $\Gamma(\gamma f_0(1370))/\Gamma_{\text{total}}$ VALUE (units 10 ⁻⁴) 3.38±0.33±0.64 • • We do not use	93 branching il EVTS the following	64 BALTRUSAIT fraction to K+K- DOCUMENT ID 65 BOLTON ing data for average 65 AUGUSTIN	86D or <i>K</i> 92B ss, fits	MRK3 O KO. TECN MRK3 Imits,	$J/\psi \rightarrow \gamma K^{+} K^{-}$ $\frac{\Gamma_{120}/\Gamma}{J/\psi \rightarrow \gamma \eta \pi^{+} \pi^{-}}$ etc. • • •
12.4 $^{+6.4}_{-5.2}$ ±2.8 8.4 $^{+2.8}_{-2.8}$ ±1.6 64 Includes unknown $\Gamma(\gamma f_0(1370))/\Gamma_{\text{tot}}$ WALUE (units 10 ⁻⁴) 3.33±0.33±0.64 • • We do not use 7.0 ±0.6 ±1.1	93 branching il EVTS the following 261 branching	64 BALTRUSAIT fraction to K+K- DOCUMENT ID 65 BOLTON ing data for average 65 AUGUSTIN	86D or <i>K</i> 92B ss, fits	MRK3 O KO. TECN MRK3 Imits,	$J/\psi \rightarrow \gamma K^{+} K^{-}$ $\frac{\Gamma_{120}/\Gamma}{J/\psi \rightarrow \gamma \eta \pi^{+} \pi^{-}}$ etc. • • •
12.4 $^{+6.4}_{-5.2}$ ±2.8 8.4 $^{+3.4}_{-2.8}$ ±1.6 64 Includes unknown $\Gamma(\gamma f_0(1370))/\Gamma_{total}$ $VALUE (units 10^{-4})$ 3.38±0.33±0.64 • • • We do not use 7.0 ±0.6 ±1.1 65 Includes unknown	93 branching al EVTS the followi 261 branching	64 BALTRUSAIT fraction to K^+K^- $\frac{DOCUMENT\ ID}{65}$ BOLTON ing data for average 65 AUGUSTIN fraction to $\eta\pi^+\pi^-$ $\frac{DOCUMENT\ ID}{DOCUMENT\ ID}$	928 s, fits	MRK3 OS KOS. TECN MRK3 i, limits, DM2	$J/\psi \rightarrow \gamma K^+ K^-$ $\frac{\Gamma_{120}/\Gamma}{J/\psi \rightarrow \gamma \eta \pi^+ \pi^-}$ etc. • • $J/\psi \rightarrow \gamma \eta \pi^+ \pi^-$ Γ_{121}/Γ COMMENT
12.4 $^{+6.4}_{-5.2}$ ±2.8 8.4 $^{+3.4}_{-2.8}$ ±1.6 64 Includes unknown $\Gamma(\gamma f_0(1370))/\Gamma_{\text{tota}}$ $VALUE$ (units 10^{-4}) 3.38±0.33±0.64 • • • We do not use 7.0 ±0.6 ±1.1 65 Includes unknown $\Gamma(\gamma f_0(1500))/\Gamma_{\text{tota}}$	93 branching al EVTS the followi 261 branching	64 BALTRUSAIT fraction to K^+K^- $\frac{DOCUMENT\ ID}{65}$ BOLTON ing data for average 65 AUGUSTIN fraction to $\eta\pi^+\pi^-$ $\frac{DOCUMENT\ ID}{DOCUMENT\ ID}$	928 s, fits	MRK3 OS KOS. TECN MRK3 i, limits, DM2	$J/\psi \rightarrow \gamma K^{+} K^{-}$ Γ_{120}/Γ $\frac{COMMENT}{J/\psi \rightarrow \gamma \eta \pi^{+} \pi^{-}}$ etc. • • • $J/\psi \rightarrow \gamma \eta \pi^{+} \pi^{-}$ Γ_{121}/Γ

$J/\psi(1S)$ REFERENCES

		-/ 1	(,
BAI	95B	PL B355 374	+Chen, Chen+ (BES Collab.)
BUGG	95	PL B353 378	+Scott, Zoli+ (LOQM, PNPI, WASH)
ANTONELLI	93	PL B301 317	+Baldini+ (FENICE Collab.)
ARMSTRONG	93B	PR D47 772	+Bettoni, Bharadwaj+ (FNAL E760 Collab.)
AUGUSTIN BOLTON	92	PR D46 1951 PL B278 495	+Cosme (DM2 Collab.) +Brown, Bunnell+ (Mark III Collab.)
BOLTON	92 92B	PRL 69 1328	+Brown, Bunnell+ (Mark III Collab.)
COFFMAN	92	PRL 68 282	+DeJongh, Dubois, Hitlin+ (Mark III Collab.)
HSUEH	92	PR D45 R2181	+Palestini (FNAL, TORI)
AUGUSTIN	90	PR D42 10	+Cosme+ (DM2 Collab.)
BAI	90B	PRL 65 1309	+Blaylock+ (Mark III Collab.)
BAI	90C	PRL 65 2507	+Blaylock+ (Mark III Collab.)
COFFMAN	90 90	PL B241 617 PR D41 1410	+Busetto+ (DM2 Collab.) +De Jongh+ (Mark III Collab.)
JOUSSET	90	PR D41 1410 PR D41 1389	+De Jongh+ (Mark III Collab.) +Ajaltouni+ (DM2 Collab.)
ALEXANDER	89	NP B320 45	+Bonvicini, Drell, Frey, Luth (LBL, MICH, SLAC)
AUGUSTIN	89	NP B320 1	+Cosme (DM2 Collab.)
BISELLO	89B	PR D39 701	Busetto+ (DM2 Collab.)
AUGUSTIN	88	PRL 60 2238	+Calcaterra+ (DM2 Collab.)
COFFMAN	88	PR D38 2695	+Dubois, Eigen, Hauser+ (Mark III Collab.)
FALVARD	88	PR D38 2706	+Ajaltouni+ (CLER, FRAS, LALO, PADO)
AUGUSTIN BAGLIN	87 87	ZPHY C36 369 NP B286 592	+Cosme+ (LALO, CLER, FRAS, PADO) + (LAPP, CERN, GENO, LYON, OSLO, ROMA+)
BALTRUSAIT		PR D35 2077	+ (LAPP, CERN, GENO, LYON, OSLO, ROMA+) Baltrusaitis, Coffman, Dubois+ (Mark III Collab.)
BECKER	87	PRL 59 186	+Blaylock, Bolton, Brown+ (Mark III Collab.)
BISELLO	87	PL B192 239	+Ajaltouni, Baldini+ (PADO, CLER, FRAS, LALO)
HENRARD	87	NP B292 670	+Ajaltouni, et al (CLER, FRAS, LALO, PADO)
PALLIN	87	NP B292 653	+Ajaltouni+ (CLER, FRAS, LALO, PADO)
WISNIEWSKI	87	Hadron 87 Conf.	(Mark III Collab.)
BALTRUSAIT BALTRUSAIT		PR D33 1222 PRL 56 107	Baltrusaitis, Coffman, Hauser+ (Mark III Collab.)
BISELLO	86B	PL B179 294	Baltrusaitis (CIT, UCSC, ILL, SLAC, WASH) +Busetto, Castro, Limentani+ (DM2 Collab.)
GAISER	86	PR D34 711	+Bloom, Bulos, Godfrey+ (Crystal Ball Collab.)
BALTRUSAIT		PRL 55 1723	+Bloom, Bulos, Godfrey+ (Crystal Ball Collab.) Baltrusaitis, (CIT, UCSC, ILL, SLAC, WASH) Baltrusaitis, Coffman+ (CIT, UCSC, ILL, SLAC, WASH) Baltrusaitis+ (CIT, UCSC, ILL, SLAC, WASH)
BALTRUSAIT		PR D32 566	Baltrusaitis, Coffman+ (CIT, UCSC, ILL, SLAC, WASH)
BALTRUSAIT		PRL 52 2126	Baltrusaitis+ (CIT, UCSC, ILL, SLAC, WASH)
EATON	84	PR D29 804	+Goldhaber, Abrams, Alam, Boyarski+ (LBL, SLAC)
BLOOM EDWARDS	83 83B	ARNS 33 143 PRL 51 859	+Peck (SLAC, CIT) +Partridge, Peck+ (CIT, HARV, PRIN, STAN, SLAC)
EINSWEILER	83	Brighton Conf. 348	(Mark III Collab.)
FRANKLIN	83	PRL 51 963	+Franklin, Feldman, Abrams, Alam+ (LBL, SLAC)
FRANKLIN	83B	Thesis SLAC-0254	(STAN)
BURKE	82	PRL 49 632	+Trilling, Abrams, Alam, Blocker+ (LBL, SLAC)
EDWARDS	82B	PR D25 3065	+Partridge, Peck+ (CIT, HARV, PRIN, STAN, SLAC)
EDWARDS	82D 83	PRL 48 458 ARNS 33 143	+Partridge, Peck+ (CIT, HARV, PRIN, STAN, SLAC)
Also EDWARDS	82E	PRL 49 259	Bloom, Peck (SLAC, CIT) +Partridge, Peck+ (CIT, HARV, PRIN, STAN, SLAC)
LEMOIGNE	82	PL 113B 509	+Barate, Astbury+ (SACL, LOIC, SHMP, IND)
BESCH	81	ZPHY C8 1	+Eisermann, Lohr, Kowalski+ (BONN, DESY, MANZ)
GIDAL	81	PL 107B 153	+Goldhaber, Guy, Millikan, Abrams+ (SLAC, LBL)
PARTRIDGE	80	PRL 44 712	+Peck+ (CIT, HARV, PRIN, SLAC, STAN)
SCHARRE	80	PL 97B 329	+Trilling, Abrams, Alam, Blocker+ (SLAC, LBL)
ZHOLENTZ Also	80 81	PL 96B 214 SJNP 34 814	+Kurdadze, Lelchuk, Mishnev+ (NOVO) Zholentz, Kurdadze, Lelchuk+ (NOVO)
Also	01	Translated from YAF	34 1471.
BRANDELIK	79C	ZPHY C1 233	+Cords+ (DASP Collab.)
SCHARRE	79B	SLAC-PUB-2321	(SLAC, LBL) Abrams, Alam, Blocker, Boyarski+ (SLAC, LBL)
Also ALEXANDER	79 78	LBL-9502 PL 72B 493	Abrams, Alam, Blocker, Boyarski+ (SLAC, LBL)
BESCH	78	PL 72B 493 PL 78B 347	+Criegee+ (DESY, HAMB, SIEG, WUPP) +Eisermann, Kowalski, Eyss+ (BONN, DESY, MANZ)
BRANDELIK	78B	PL 74B 292	+Eisermann, Kowalski, Eyss+ (BONN, DESY, MANZ) +Cords+ (DASP Collab.)
PERUZZI	78	PR D17 2901	+Piccolo, Alam, Boyarski, Goldhaber+ (SLAC, LBL)
BARTEL	77	PL 66B 489	+Duinker, Olsson, Heintze+ (DESY, HEIDP)
BURMESTER	77D	PL 72B 135	+Criegee+ (DESY, HAMB, SIEG, WUPP)
FELDMAN	77	PRPL 33C 285	+Perl (LBL, SLAC) +Abrams, Alam, Boyarski+ (SLAC, LBL)
VANNUCCI BARTEL	77 76	PR D15 1814 PL 64B 483	+Abrams, Alam, Boyarski+ (SLAC, LBL) +Duinker, Olsson, Steffen, Heintze+ (DESY, HEIDP)
BRAUNSCH	76	PL 63B 487	Braunschweig+ (DASP Collab.)
JEAN-MARIE	76	PRL 36 291	+Abrams, Boyarski, Breidenbach+ (SLAC, LBL) IG
BALDINI	75	PL 58B 471	Baldini-Celio, Bozzo, Capon+ (FRAS, ROMA)
BEMPORAD	75	Stanford Symp. 113	(PISA, FRAS)
BOYARSKI	75	PRL 34 1357	+Breidenbach, Bulos, Feldman+ (SLAC, LBL) JPC

 $J/\psi(1S)$, $\chi_{c0}(1P)$

DASP 75 PL 56B 491 Braunschweig, Konigs+ (DASP Collab.)	$\Gamma(\pi^+\pi^-K^+K^-)/\Gamma_{\text{total}}$	Γ ₂ /Γ
ESPOSITO 75B LNC 14 73 +Bartoli, Biselio+ (FRAS, NAPL, PADO, ROMA) FORD 75 PRI 34 604 +Beron, Hilger, Hofstadter+ (SLAC, PENN) LIBERMAN 75 Stanford Symp. 55 WIIK 75 Stanford Symp. 69 (DESY)	VALUE 0.030±0.007	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
OTHER RELATED PAPERS	$\Gamma(ho^0\pi^+\pi^-)/\Gamma_{ m total}$	Г ₃ /Г
BAGLIN 85 SLAC Summer Inst. 609 (LAPP, CERN, GENO, LYON, OSLO, ROMA+)	VALUE 0.016±0.005	$\frac{DOCUMENT\ ID}{5}$ TANENBAUM 78 MRK1 $\psi(2S) ightarrow \gamma \chi_{CD}$
LEE 85 SLAC 282 (SLAC) BARATE 83 PL 121B 449 +Bareyre, Bonamy+ (SACL, LOIC, SHMP, IND)		
ABRAMS 74 PRL 33 1453 + Briggs, Augustin, Boyarski+ (LBL, SLAC) ASH 74 LNC 11 705 + Zorn, Bartoli+ (FRAS, UMD, NAPL, PADO, ROMA)	$\Gamma(3(\pi^+\pi^-))/\Gamma_{\text{total}}$	DOCUMENT ID TECN COMMENT
AUBERT 74 PRL 33 1404 + Becker, Biggs, Burger, Chen, Everhart (MIT, BNL) AUGUSTIN 74 PRL 33 1406 + Boyarski, Abrams, Briggs+ (SLAC, LBL) BACCI 74 PRL 33 1408 + Bartoli, Barbarino, Barbeillini+ (FRAS)	0.015±0.005	⁵ TANENBAUM 78 MRK1 $\psi(2S) \rightarrow \gamma \chi_{c0}$
Also 74B PRL 33 1649 Bacci BALDINI 74 LNC 11 711 Baldini-Celio, Bacci+ (FRAS, ROMA)	$\Gamma(K^{+}\overline{K}^{*}(892)^{0}\pi^{-}+\text{c.c.})/$	Γ _{total} Γ ₅ /Γ
BARBIELLINI 74 LNC 11 718 +Bemporad+ (FRAS, NAPL, PISA, ROMA) BRAUNSCH 74 PL 53B 393 Braunschweig+ (DASP Collab.)	VALUE	DOCUMENT ID TECN COMMENT
CHRISTENS 70 PRL 25 1523 Christenson, Hicks, Lederman+ (COLU, BNL, CERN)	0.012±0.004	⁵ TANENBAUM 78 MRK1 $\psi(2S) \rightarrow \gamma \chi_{c0}$
6. 86	$\Gamma(\pi^+\pi^-)/\Gamma_{ m total}$	Γ ₆ /Γ
$\chi_{c0}(1P)$ $I^{G}(J^{PC}) = 0^{+}(0^{+})$	VALUE (units 10 ⁻⁴) 75±21 OUR AVERAGE	DOCUMENT ID TECN COMMENT
	70 ± 30	5 BRANDELIK 798 DASP $\psi(2S) \rightarrow \gamma^{\chi}{}_{c0}$
$x_{c0}(1P)$ MASS	80±30	5 TANENBAUM 78 MRK1 $\psi(2S) \rightarrow \gamma \chi_{c0}$
VALUE (MeV) EVTS DOCUMENT ID TECN COMMENT	$\Gamma(K^+K^-)/\Gamma_{\text{total}}$	Γ ₇ /Γ
3415.1± 1.0 OUR AVERAGE	VALUE (units 10 ⁻⁴) 71±24 OUR AVERAGE	DOCUMENT ID TECN COMMENT
3417.8 \pm 0.4 \pm 4	60±30	⁵ BRANDELIK 79B DASP $\psi(2S) \rightarrow \gamma \chi_{CO}$
3422 ± 10 2 BARTEL 78B CNTR $e^+e^- o J/\psi 2\gamma$	90±40	⁵ TANENBAUM 78 MRK1 $\psi(25) ightarrow \gamma \chi_{C0}^{c0}$
3416 \pm 3 \pm 4	$\Gamma(\pi^+\pi^- ho\overline{ ho})/\Gamma_{ m total}$	Г _в /Г
• • • We do not use the following data for averages, fits, limits, etc. • • •	VALUE 0.005 ±0.002	$\frac{DOCUMENT\ ID}{5}$ TANENBAUM 78 MRK1 $\psi(2S) ightarrow \gamma \chi_{c0}$
3407 \pm 8 2 ⁴ WIIK 75 DASP $e^+e^- \rightarrow J/\psi 2\gamma$		
1 Using mass of $\psi(2S)=3686.0$ MeV. 2 Mass value shifted by us by amount appropriate for $\psi(2S)$ mass $=3686$ MeV and	$\Gamma(\pi^0\pi^0)/\Gamma_{\text{total}}$ VALUE (units 10^{-3})	Γ ₉ /Γ DOCUMENT ID TECN COMMENT
$J/\psi(1S)$ mass $=3097$ MeV.	3.1±0.4±0.5	6 LEE 85 CBAL $\psi' \rightarrow$ photons
³ Systematic error added linearly by us. ⁴ Only two events; this mass apparently never published.	$\Gamma(\eta\eta)/\Gamma_{total}$	Γ ₁₀ /Γ
	VALUE (units 10 ⁻³)	DOCUMENT ID TECN COMMENT
$x_{c0}(1P)$ WIDTH	2.5±0.8±0.8	6 LEE 85 CBAL ψ' \rightarrow photons
VALUE (MeV) DOCUMENT ID TECN COMMENT	$\Gamma(\rho \overline{\rho})/\Gamma_{\text{total}}$	Γ ₁₁ /Γ
13.5±3.3±4.2 GAISER 86 CBAL $\psi(2s) \to \gamma X, \gamma \pi^0 \pi^0$	VALUE (units 10 ⁻⁴)	DOCUMENT ID TECN COMMENT
$\chi_{c0}(1P)$ DECAY MODES	<9.0 90	5 BRANDELIK 798 DASP $\psi(2S) ightarrow \gamma \chi_{c0}$
ACO(11) DEGAT MODES	⁵ Calculated using B($\psi(2S) \rightarrow$ tainty in the $\psi(2S)$ decay.	$\gamma \chi_{c0}(1P))=$ 0.094; the errors do not contain the uncer-
Mode Fraction (Γ_i/Γ) Confidence level	6 Calculated using B $(\psi(2S)$ $-$	$\gamma \chi_{c0}(1P)) = 0.093 \pm 0.008.$
Hadronic decays		RADIATIVE DECAYS
$\Gamma_1 = 2(\pi^+\pi^-)$ (3.7 ± 0.7) % $\Gamma_2 = \pi^+\pi^-K^+K^-$ (3.0 ± 0.7) %	$\Gamma(\gamma J/\psi(1S))/\Gamma_{total}$	Γ ₁₂ /Γ
$\Gamma_2 = \pi^+ \pi^- K^+ K^-$ (3.0 ± 0.7) % $\Gamma_3 = \rho^0 \pi^+ \pi^-$ (1.6 ± 0.5) %	VALUE (units 10 ⁻⁴)	DOCUMENT ID TECN COMMENT
$\Gamma_4 = 3(\pi^+\pi^-)$ (1.5±0.5) %	66± 18 OUR AVERAGE 60± 18	GAISER 86 CBAL $\psi(2S) \rightarrow \gamma \chi_{CD}$
$\Gamma_5 K^+ \overline{K}^* (892)^0 \pi^- + \text{c.c.} $ (1.2±0.4) % $\Gamma_6 \pi^+ \pi^- (7.5 \pm 2.1) \times 10^{-3}$	320 ± 210	⁷ BRANDELIK 79B DASP $\psi(2S) \rightarrow \gamma \chi_{c0}$
$\Gamma_6 \qquad \pi^+ \pi^- \qquad (7.5 \pm 2.1) \times 10^{-3}$ $\Gamma_7 \qquad K^+ K^- \qquad (7.1 \pm 2.4) \times 10^{-3}$	150 ± 100 210 ± 210	7 BARTEL 78B CNTR $\psi(2S) ightarrow \gamma \chi_{C0}^{2}$ 7 TANENBAUM 78 MRK1 $\psi(2S) ightarrow \gamma \chi_{C0}^{2}$
$\Gamma_8 = \pi^+ \pi^- p \overline{p}$ (5.0±2.0) × 10 ⁻³		
$\Gamma_9 = \pi^0 \pi^0$ $(3.1 \pm 0.6) \times 10^{-3}$ $\Gamma_{10} = \eta \eta$ $(2.5 \pm 1.1) \times 10^{-3}$	$\Gamma(\gamma\gamma)/\Gamma_{\text{total}}$ VALUE (units 10^{-4}) CL%	Γ ₁₃ /Γ DOCUMENT ID TECN COMMENT
$\Gamma_{10} \eta \eta$ $(2.5 \pm 1.1) \times 10^{-3}$ $\Gamma_{11} p \overline{p}$ $(2.5 \pm 1.1) \times 10^{-4}$ 90%	VALUE (units 10 ⁻⁴) CL% 4.0±2.0±1.1	6 LEE 85 CBAL $\psi' \rightarrow$ photons
Radiative decays		ng data for averages, fits, limits, etc. • •
$\Gamma_{12} \gamma J/\psi(1S)$ (6.6 ± 1.8) × 10 ⁻³	<15 90	⁷ YAMADA 77 DASP $e^+e^- \rightarrow 3\gamma$
$\Gamma_{13} \gamma \gamma \qquad (4.0 \pm 2.3) \times 10^{-4}$	tainty in the $\psi(2S)$ decay.	$\gamma \chi_{c0}(1P)) = 0.094$; the errors do not contain the uncer-
$\chi_{c0}(1P)$ PARTIAL WIDTHS		(1D) DECEDENCES
		C _{CO} (1P) REFERENCES
$\Gamma(\gamma\gamma)$ Γ_{13} VALUE (keV) CL% DOCUMENT ID TECN COMMENT	CHEN 90B PL B243 169 AIHARA 88D PRL 60 2355	+Mcliwain+ (CLEO Collab.) +Alston-Garnjost+ (TPC Collab.)
< 6.2 95 CHEN 908 CLEO $e^+e^- \to e^+e^- \chi_{CO}$		
	GAISER 86 PR D34 711 LEE 85 SLAC 282	+Bloom, Bulos, Godfrey+ (Crystal Ball Collab.) (SLAC)
4.0 \pm 2.8 LEE 85 CBAL $\psi' o ext{ photons}$	GAISER 86 PR D34 711 LEE 85 SLAC 282 BRANDELIK 79B NP B160 426 HIMEL 79 Thesis SLAC-022:	(SLAC) +Cords+ (DASP Collab.) (SLAC)
	GAISER 86 PR D34 711 LEE 85 SLAC 282 BRANDELIK 79B NP B160 426 HIMEL 79 Thesis SLAC-022: Also 82 Private Comm. BARTEL 78B PL 79B 492	(SLAC) +Cords+ (DASP Collab.) } (SLAC) Trilling (BL. UCB) +Dittmann, Duinker, Olsson, O'Neill+ (DESY, HEIDP)
4.0±2.8 LEE 85 CBAL ψ' → photons • • • We do not use the following data for averages, fits, limits, etc. • • • <17 95 AIHARA 88D TPC e^+e^- → e^+e^- X	GAISER 86 PR D34 711 LEE 85 SLAC 282 BRANDELIK 798 NP B160 426 HIMEL 79 Thesis SLAC-022: Also 82 Private Comm. BARTEL 788 PL 798 492 TANENBAUM 78 PR D17 1731 Also 82 Private Comm. BIDDICK 77 PRL 38 1324	CSLAC (SLAC (SLAC Collab.)
4.0 \pm 2.8 LEE 85 CBAL $\psi' \to \text{photons}$ • • • We do not use the following data for averages, fits, limits, etc. • • •	GAISER 86 PR D34 711 LEE 85 SLAC 282 BRANDELIK 79B NP B160 426 HIMEL 79 Thesis SLAC-022: Also 82 Private Comm. BARTEL 78B PL 79B 492 TANENBAUM 78 PR D17 1731 Also 82 Private Comm.	(SLAC) +Cords+ (DASP Collab.) Trilling (SLAC) +Dittmann, Duinker, Olsson, O'Neill+ (DESY, HEIDP) +Alam, Boyarski+ (SLAC, LBL) Trilling +Burnett+ (UCSD, UMD, PAVI, PRIN, SLAC, STAN) 59
4.0±2.8 LEE 85 CBAL ψ' → photons • • • We do not use the following data for averages, fits, limits, etc. • • • <17 95 AIHARA 88D TPC e^+e^- → e^+e^- X	GAISER 86 PR D34 711 LEE 85 LAC 282 BRANDELIK 79 The B160 426 HIMEL 79 Thesis SLAC-022: Also 82 Private Comm. BARTEL 78 PR D17 1731 Also 82 Private Comm. BIDDICK 77 PRL 38 1324 YAMADA 77 Hamburg Conf. Wilk 75 Stanford Symp.	(SLAC) +Cords+ (DASP Collab.) Trilling (SLAC) +Dittmann, Duinker, Olsson, O'Neill+ (DESY, HEIDP) +Alam, Boyarski+ (SLAC, LBL) Trilling +Burnett+ (UCSD, UMD, PAVI, PRIN, SLAC, STAN) 59
4.0 ± 2.8 LEE 85 CBAL $\psi' \rightarrow$ photons • • • We do not use the following data for averages, fits, limits, etc. • • • <17 95 AIHARA 880 TPC $e^+e^- \rightarrow e^+e^- \times$ $ x_{c0}(1P) \text{ BRANCHING RATIOS} $ $ \qquad	GAISER 86 PR D34 711 LEE 85 LAC 282 BRANDELIK 799 NP B160 426 HIMEL 79 Thesis SLAC-0222 Also 82 Private Comm. BARTEL 788 PL 798 492 TANEMBAUM 78 PR D17 1731 Also 82 Private Comm. BIDDICK 77 PRL 38 1324 YAMADA 77 Hamburg Conf. VIIIK 75 Stanford Symp. 1 OREGLIA 82 PR D25 2259	+Cords+
4.0 ± 2.8 LEE 85 CBAL $\psi' \rightarrow \text{photons}$ • • • We do not use the following data for averages, fits, limits, etc. • • • <17 95 AIHARA 88D TPC $e^+e^- \rightarrow e^+e^- \times$ $ \frac{\chi_{c0}(1P) \text{ BRANCHING RATIOS}}{\text{HADRONIC DECAYS}} $ $ \frac{\Gamma(2(\pi^+\pi^-))/\Gamma_{\text{total}}}{\frac{VALUE}{\sqrt{ALUE}}} \frac{\Gamma_1/\Gamma}{\frac{TECN}{\sqrt{COMMENT}}} $	GAISER 86 PR D34 711 LEE 85 LAC 282 BRANDELIK 797 PN P B160 426 HIMEL 79 Thesis SLAC-022 Also 82 Private Comm. BARTEL 78 PR D17 1731 Also 82 Private Comm. BIDDICK 77 PRL 38 1324 YAMADA 77 HAMDA 77 WIIK 75 Stanford Symp. 1 OREGLIA 82 PR D25 2259 FELDMAN 755 PRL 35 1189 OREGLIA 85 PR D25 2259 FELDMAN 755 PRL 35 1189	+Cords + (SLAC)
4.0 ± 2.8 LEE 85 CBAL $\psi' \rightarrow$ photons • • • We do not use the following data for averages, fits, limits, etc. • • • <17 95 AIHARA 880 TPC $e^+e^- \rightarrow e^+e^- \times$ $ x_{c0}(1P) \text{ BRANCHING RATIOS} $ $$	GAISER 86 PR D34 711 LEE 85 LAC 282 BRANDELIK 79 PN B160 426 HIMEL 79 PN B160 426 Also 82 Private Comm. BIDDICK 77 PRL 38 1324 VAMADA 77 PRL 38 1324 VAMADA 77 Hamburg Conf. OREGLIA 82 PR D25 2259 FELDMAN 758 PRL 35 821	(SLAC) +Cords+ (DASP Collab.) Trilling +Dittmann, Duinker, Olsson, O'Neill+ (DESY, HEIDP) +Alam, Boyarski+ (SLAC, LBL, Trilling +Burnett+ (UCSD, UMD, PAVI, PRIN, SLAC, STAN) HER RELATED PAPERS +Partridge+ +Jean-Marie, Sadoulet, Vannucci+ (LBL, SLAC)

 $\chi_{c1}(1P)$

$I^{G}(J^{PC})$	=	0+(1	++)
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		X _{c1} (1P) MAS	S		
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
3510.53 ± 0.12 OUR A	/ERAGE				
$3510.53 \pm 0.04 \pm 0.12$	513	ARMSTRONG			$\overline{p}p \rightarrow e^+e^-\gamma$
$3511.3 \pm 0.4 \pm 0.4$	30	BAGLIN	86B	SPEC	$\overline{p}p \rightarrow e^+e^-X$
$3512.3 \pm 0.3 \pm 4.0$		¹ GAISER	86	CBAL	$\psi(2S) \rightarrow \gamma X$
3507.4 ± 1.7	91	2 LEMOIGNE	82	GOLI	190 GeV π^- Be $\rightarrow \gamma 2\mu$
3510.4 ± 0.6		OREGLIA	82	CBAL	$e^+e^- \rightarrow J/\psi 2\gamma$
3510.1 ± 1.1	254	³ HIMEL	80	MRK2	$e^+e^- \rightarrow J/\psi 2\gamma$
3509 ±11	21	BRANDELIK	79B	DASP	$e^+e^- \rightarrow J/\psi 2\gamma$
3507 ± 3		³ BARTEL	78B	CNTR	$e^+e^- \rightarrow J/\psi 2\gamma$
3505.0 ± 4 ±4		3,4 TANENBAUM	78	MRK1	e+ e-
3513 ± 7	367	3 BIDDICK	77	CNTR	$\psi(2S) \rightarrow \gamma X$
• • • We do not use th	e follow	ing data for averages	, fits	, limits,	etc. • • •
3510 ±20		BARTEL	76B	CNTR	$e^+e^- \rightarrow J/\psi 2\gamma$
3500 ±10	40	TANENBAUM	75	MRK1	Hadrons γ
3507 ± 7	7	WIIK	75	DASP	$e^+e^- o J/\psi 2\gamma$

 1 Using mass of $\psi(2S)=3686.0$ MeV.

Mode

- $^2J/\psi(1S)$ mass constrained to 3097 MeV.
- 3 Mass value shifted by us by amount appropriate for $\psi(2S)$ mass = 3686 MeV and $J/\psi(1S)$ mass = 3097 MeV.
- ⁴ From a simultaneous fit to radiative and hadronic decay channels.

$\chi_{c1}(1P)$ WIDTH

VALUE (MeV)	CL% EVTS	DOCUMENT ID	TECN	COMMENT
0.88±0.11±0.08	513	ARMSTRONG 92	SPEC	$\overline{p}p \rightarrow e^+e^-\gamma$
• • • We do not use th	e following data fo	r averages, fits, limits	, etc. •	• •
<1.3	95	BAGLIN 868	SPEC	$\overline{p}p \rightarrow e^+e^-X$
<3.8	90	GAISER 86	CBAL	$\psi(25) \rightarrow \gamma X$

$\chi_{c1}(1P)$ DECAY MODES

Fraction (Γ_i/Γ)

		Hadronic decays
Γ_1	$3(\pi^{+}\pi^{-})$	(2.2±0.8) %
Γ_2	$2(\pi^{+}\pi^{-})$	(1.6±0.5) %
Γ_3	$\pi^{+}\pi^{-}K^{+}K^{-}$	$(9 \pm 4) \times 10^{-3}$
	$ ho^0 \pi^+ \pi^-$	$(3.9\pm3.5)\times10^{-3}$
Γ_5	$K^{+}\overline{K}^{*}(892)^{0}\pi^{-}$ + c.c.	$(3.2\pm2.1)\times10^{-3}$
Γ_6	$\pi^+\pi^-p\overline{p}$	$(1.4\pm0.9)\times10^{-3}$
Γ_7	$\rho \overline{p}$	$(8.6\pm1.2)\times10^{-5}$
Γ8	$\pi^{+}\pi^{-} + K^{+}K^{-}$	$< 2.1 \times 10^{-3}$

Radiative decays

Γ9	$\gammaJ/\psi(1S)$	(27.3±1.6) %
Γ_{10}	$\gamma \gamma$	

$\chi_{c1}(1P)$ PARTIAL WIDTHS

$\Gamma(\rho \overline{\rho})$					Γ,
VALUE (eV)	EVTS	DOCUMENT ID	TECN	COMMENT	
74± 9 OUR AVERAG	3E				
76±10±5	513	⁵ ARMSTRONG 92	SPEC	$\overline{p}p \rightarrow e^+e^-\gamma$	
$69^{+16}_{-13}\pm 4$		⁵ BAGLIN 868	SPEC	$\overline{p} p \rightarrow e^+ e^- X$	
_					

 5 Restated by us using B(X $_{\rm C1}(1P)\to J/\psi(1S)\gamma)$ B($J/\psi(1S)\to e^+e^-)=0.0171\pm0.0011$.

$\chi_{c1}(1P)$ BRANCHING RATIOS

--- HADRONIC DECAYS -

$\Gamma(3(\pi^+\pi^-))/\Gamma_{\text{total}}$				Γ_1/Γ
VALUE	DOCUMENT ID	TECN	COMMENT	
0.022 ± 0.008	⁷ TANENBAUM 78	MRK1	$\psi(2S) \to \ \gamma \chi_{c1}$	
$\Gamma(2(\pi^+\pi^-))/\Gamma_{\text{total}}$				Γ_2/Γ
VALUE	DOCUMENT ID	TECN	COMMENT	
0.016±0.005	7 TANENBAUM 78	MRK1	$\psi(25) \rightarrow \gamma^{\chi}_{c1}$	
$\Gamma(\pi^+\pi^-K^+K^-)/\Gamma_{\text{total}}$				Γ_3/Γ
VALUE (units 10 ⁻⁴)	DOCUMENT ID	TECN	COMMENT	
00.1.40	7 TANENBALIM 78	MDV1	4/(25) Y	

$\Gamma(\rho^0\pi^+\pi^-)/\Gamma_{\text{total}}$					T4/F
VALUE (units 10-4)		DOCUMENT ID	TECN	COMMENT	
39±35		⁷ TANENBAUM 78	MRK1	$\psi(2S) \rightarrow \gamma \chi_{c1}$	
$\Gamma(K^{+}\overline{K}^{*}(892)^{0}\pi^{-}$	+ c.c.)/i	- total			Γ ₅ /Γ
VALUE (units 10-4)		DOCUMENT ID	TECN	COMMENT	
32±21		⁷ TANENBAUM 78	MRK1	$\psi(2S) \rightarrow \gamma \chi_{c1}$	
$\Gamma(\pi^+\pi^-p\overline{p})/\Gamma_{\text{total}}$	l				Γ ₆ /Γ
VALUE (units 10 ⁻⁴)		DOCUMENT ID	TECN	COMMENT	
14±9		⁷ TANENBAUM 78	MRK1	$\psi(2S) \rightarrow \gamma \chi_{c1}$	
$\Gamma(p\overline{p})/\Gamma_{\text{total}}$					Γ7/Γ
VALUE (units 10-4) CL%	EVTS	DOCUMENT ID	TECN	COMMENT	
0.86±0.12	513	6 ARMSTRONG 92	SPEC	$\overline{p}p \rightarrow e^+e^-\gamma$	
• • • We do not use t	he followir	ng data for averages, fit	s, limits,	etc. • • •	
> 0.54 95		BAGLIN 868	SPEC	$\overline{p}p \rightarrow e^+e^-X$	
<12.0 90		7 BRANDELIK 79E	DASP	$\psi(25) \rightarrow \gamma \chi_{C1}$	
⁶ Restated by us usin 0.0011.		$(1P) \rightarrow J/\psi(1S)\gamma)B($.0171 ±
$[\Gamma(\pi^+\pi^-) + \Gamma(K^+)]$	κ-)]/r	total			Г8/Г
VALUE (units 10 ⁻⁴)	CL%	DOCUMENT ID	TECN	COMMENT	
<21		⁷ FELDMAN 77	MRK1	$\psi(2S) \rightarrow \gamma \chi_{C1}$	
• • We do not use t	he followir	ig data for averages, fit	s, limits,	etc. • • •	
<38	90	⁷ BRANDELIK 798	DASP	$\psi(25) \rightarrow \gamma \chi_{c1}$	
⁷ Estimated using B uncertainty in the a	$(\psi(2S) \rightarrow \psi(2S) decay$	$\gamma \chi_{c1}(1P)) = 0.087$. The	errors do not con	tain the

- RADIATIVE DECAYS -

$\Gamma(\gamma J/\psi(1S))/\Gamma_{\text{total}}$						٦٩/٢
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT	
0.273±0.016 OUR AVER	RAGE					
0.284 ± 0.021		GAISER	86	CBAL	$\psi(2S) \rightarrow \gamma X$	
0.274 ± 0.046	943	⁸ OREGLIA			$\psi(2S) \rightarrow \gamma^{\chi}_{c1}$	
0.28 ±0.07					$\psi(2S) \rightarrow \gamma \chi_{c1}$	
0.19 ±0.05		⁸ BRANDELIK	79B	DASP	$\psi(2S) \rightarrow \gamma \chi_{c1}$	
0.29 ±0.05		⁸ BARTEL	78B	CNTR	$\psi(25) \rightarrow \gamma \chi_{c1}$	
0.28 ±0.09		⁸ TANENBAUM	78	MRK1	$\psi(2S) \rightarrow \gamma \chi_{c1}$	
• • We do not use the	following	data for averages	, fits	, limits,	etc. • • •	
0.57 ±0.17		⁸ BIDDICK	77	CNTR	$\psi(2S) \rightarrow \gamma X$	
$\Gamma(\gamma\gamma)/\Gamma_{\text{total}}$						Γ ₁₀ /Γ
	CL%	DOCUMENT ID		TECN	COMMENT	
• • • We do not use the	following	data for averages	, fits	, limits,	etc. • • •	
< 0.0015	90	8 YAMADA	77	DASP	$e^+e^- ightarrow 3\gamma$	
8 Estimated using B(ψ uncertainty in the ψ ((2 <i>5</i>) → 2 <i>5</i>) decay	$\gamma^{\chi}_{c1}(1P)) = 0$.087	. The	errors do not con	tain the

$\chi_{c1}(1P)$ REFERENCES

ARMSTRONG	92	NP B373 35	+Bettoni+ (FNAL, FERR, GE	NO. UCI. NWES+)
Also	92B	PRL 68 1468	Armstrong, Bettoni+(FNAL, FERR, GE	
BAGLIN	86B	PL B172 455	(LAPP, CERN, GENO, LYON	
GAISER	86	PR D34 711	+Bloom, Bulos, Godfrey+ (4	
LEMOIGNE	82	PL 113B 509	+Barate, Astbury+ (SACL,	
OREGLIA	82	PR D25 2259	+Partridge+ (SLAC, CIT, H.	ARV. PRIN. STAN)
Also	82B	Private Comm.	Oreglia	(EFI)
HIMEL	80	PRL 44 920	+Abrams, Alam, Blocker+	(LBL, SÌAC)
Also	82	Private Comm.	Trilling	(LBL, UCB)
BRANDELIK	79B	NP B160 426	+Cords+	(DASP Collab.)
BARTEL	78B	PL 79B 492	+Dittmann, Duinker, Olsson, O'Neill+	(DESY, HEIDP)
TANENBAUM	78	PR D17 1731	+Alam, Boyarski+	(SLAC, LBL)
Also	82	Private Comm.	Trilling	(LBL, UCB)
BIDDICK	77	PRL 38 1324	+Burnett+ (UCSD, UMD, PAVI, P	RIN, SLAC, STAN)
FELDMAN	77	PRPL 33C 285	+Perl	(LBL, SLAC)
YAMADA	77	Hamburg Conf. 69		(DASP Collab.)
BARTEL	76B	Tbilisi Conf. N75	+Duinker, Olsson, Heintze+	(DESY, HEIDP)
TANENBAUM	75	PRL 35 1323	+Whitaker, Abrams+	(LBL, SLAC)
WIIK	75	Stanford Symp. 69		(DESY)
		AT115	D DEL ATED DADEDO	

- OTHER RELATED PAPERS -

BARATE BRAUNSCH	83 75B	PL 121B 449 PL 57B 407	+Bareyre, Bonamy+ Braunschweig, Konigs+	(SACL, LOIC, SHMP, IND) (DASP Collab.)
FELDMAN	75	Stanford Symp. 39		` (SLAC)
HEINTZE	75	Stanford Symp. 97		(ĤEIDP)
SIMPSON	75	PRL 35 699	+Beron, Ford, Hilger, Hofstadte	r+ (STAN, PENN)

 $h_c(1P)$, $\chi_{c2}(1P)$

 $I^{G}(J^{PC}) = ?^{?}(?^{??})$

OMITTED FROM SUMMARY TABLE Needs confirmation.

$h_c(1P)$	MASS
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VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
3526.14	±0.24 OUR AVE	RAGE				
3526.20	$0 \pm 0.15 \pm 0.20$	59	ARMSTRONG	92D	SPEC	$\overline{p} p \rightarrow J/\psi \pi^0$
3525.4	$\pm 0.8 \pm 0.4$	5	BAGLIN	86	SPEC	$\overline{\rho} \rho o J/\psi X$
• • • '	We do not use the	following o	data for averages	, fits	, limits,	etc. • • •
3527	± 8	42	ANTONIAZZI	94	E705	300 π^{\pm} , $\rho \text{Li} \rightarrow$
						$J/\psi \pi^0 X$

$h_c(1P)$ WIDTH

VALUE (MeV)	CL% I	VTS	DOCUMENT ID	TECN	COMMENT
<1.1	90	59	ARMSTRONG 92D	SPEC	$\overline{\rho} \rho \rightarrow J/\psi \pi^0$

$h_c(1P)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)	
Γ_1	$J/\psi(1S)\pi^0$	seen	
Γ_2	$J/\psi(1S)\pi\pi$	not seen	
Γ_3	p p		

$\Gamma(J/\psi(1S)\pi\pi)/\Gamma(J/\psi(1S)\pi^0)$

$\Gamma(J/\psi(1S)\pi\pi)/\Gamma(J/\psi(1S)\pi\pi)$	$\psi(1S)\pi^0$)			Γ_2/Γ_1
VALUE	CL%	DOCUMENT ID	TECN	COMMENT	
< 0.18	90	ARMSTRONG 92D	SPEC	$\overline{p} p \rightarrow J/\psi \pi^0$	

$h_c(1P)$ REFERENCES

ANTONIAZZI	94	PR D50 4258	+Arenton+	(E705 Collab.)
ARMSTRONG	92D	PRL 69 2337	+Bettoni+	(FNAL, FERR, GENO, UCI, PENN, TORI)
BAGLIN	86	PL B171 135	+Baird+	(LAPP, CERN, TORI, STRB, OSLO, ROMA+)

$\chi_{c2}(1P)$

$$I^{G}(J^{PC}) = 0^{+}(2^{+})$$

$x_{c2}(1P)$ MASS

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
3556.17± 0.13 OUR AV	/ERAGE			
$3556.15 \pm\ 0.07 \pm 0.12$	585	ARMSTRONG	92 SPEC	$\overline{p}p \rightarrow e^+e^-\gamma$
$3556.9 \pm 0.4 \pm 0.5$	50	BAGLIN	86B SPEC	$\overline{p}p \rightarrow e^+e^-X$
3557.8 \pm 0.2 \pm 4		¹ GAISER	86 CBAL	$\psi(25) \rightarrow \gamma X$
3553.4 ± 2.2	66	² LEMOIGNE	82 GOLI	190 GeV π^- Be $\rightarrow \gamma 2\mu$
3555.9 ± 0.7		³ OREGLIA	82 CBAL	$e^+e^- \rightarrow J/\psi 2\gamma$
3557 ± 1.5	69	⁴ HIMEL	80 MRK2	$e^+e^- \rightarrow J/\psi 2\gamma$
3551 ±11	15	BRANDELIK	79B DASP	$e^+e^- \rightarrow J/\psi 2\gamma$
3553 ± 4		⁴ BARTEL	78B CNTR	$e^+e^- o J/\psi 2\gamma$
3553 ± 4 ±4		^{4,5} TANENBAUM	78 MRK1	e ⁺ e ⁻
3563 ± 7	360	⁴ BIDDICK	77 CNTR	$e^+e^- \rightarrow \gamma X$
• • • We do not use the	e followir	ng data for averages	s, fits, limits	, etc. • • •
3550 ±10		TRILLING	76 MRK1	$e^+e^- ightarrow hadrons \gamma$
3543 ±10	4	WHITAKER	76 MRK1	$e^+e^- \rightarrow J/\psi 2\gamma$

- 1 Using mass of $\psi(2S)=3686.0$ MeV. 2 $J/\psi(1S)$ mass constrained to 3097 MeV. 3 Assuming $\psi(2S)$ mass =3686 MeV and $J/\psi(1S)$ mass =3097 MeV. 4 Mass value shifted by us by amount appropriate for $\psi(2S)$ mass =3686 MeV and $J/\psi(1S)$ mass =3097 MeV. 4
- From a simultaneous fit to radiative and hadronic decay channels.

$x_{c2}(1P)$ WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
2.00±0.18 OUR AV	RAGE				
$1.98 \pm 0.17 \pm 0.07$	585	ARMSTRONG	92	SPEC	$\overline{p} p \rightarrow e^+ e^- \gamma$
$2.6 \begin{array}{c} +1.4 \\ -1.0 \end{array}$	50	BAGLIN	86 B	SPEC	$\overline{p} p \rightarrow e^+ e^- X$
$2.8 \begin{array}{c} +2.1 \\ -2.0 \end{array}$		⁶ GAISER	86	CBAL	$\psi(2S) \rightarrow \gamma X$

⁶ Errors correspond to 90% confidence level; authors give only width range.

$\chi_{c2}(1P)$ DECAY MODES

	Mode	Fraction (Γ_j/Γ)	Confidence level				
	Hadronic decays						
Γ_1	$2(\pi^{+}\pi^{-})$	(2.2 ±0.5) %					
Γ_2	$\pi^{+}\pi^{-}K^{+}K^{-}$	(1.9 ±0.5)%					
	$3(\pi^{+}\pi^{-})$	(1.2 ±0.8) %					
	$ ho^0\pi^+\pi^-$	(7 ±4)×10	-3				
	$K^{+}\overline{K}^{*}(892)^{0}\pi^{-}+\text{c.c.}$	(4.8 \pm 2.8) $ imes$ 10	-3				
	$\pi^+\pi^-\rho\overline{\rho}$	(3.3 ± 1.3) \times 10					
	$\pi^+\pi^-$	(1.9 ± 1.0) \times 10					
	K+K-	(1.5 ± 1.1) \times 10					
Γ9	$p \overline{p} \\ \pi^0 \pi^0$	$(10.0 \pm 1.0) \times 10$					
10	$\pi^0\pi^0$	$(1.10\pm0.28)\times10$					
	$\eta\eta$	(8 ±5)×10	-4				
Γ ₁₂	$J/\psi(1S)\pi^{+}\pi^{-}\pi^{0}$	< 1.5 %	90%				
	Radiative decays						
Γ_{13}	$\gamma J/\psi(1S)$	(13.5 \pm 1.1) %					
Γ_{14}	$\gamma\gamma$	(1.6 ± 0.5) $ imes$ 10	-4				

$\chi_{c2}(1P)$ PARTIAL WIDTHS

$\Gamma(p\overline{p})$			و۲
VALUE (eV)	EVTS	DOCUMENT ID TECN COMMENT	
206 ± 22 OUR AVE	RAGE		
$197 \pm 18 \pm 16$	585	⁷ ARMSTRONG 92 SPEC $\overline{p}p \rightarrow e^+e^-$	- γ
$252^{+55}_{-48}\pm21$		⁷ BAGLIN 86B SPEC $\overline{p}p \rightarrow e^+e^-$	- x

⁷Restated by us using B($\chi_{c2}(1P) \rightarrow J/\psi(1S)\gamma$)B($J/\psi(1S) \rightarrow e^+e^-$) = 0.0085 \pm

ALUE (keV)	CL%	DOCUMENT ID		TECN	COMMENT
0.37 ±0.17 OU	R AVERAGE	Error includes sca	le fac	tor of 1	9.
1.08 ±0.30 ±0.3	26	DOMINICK	94	CLE2	$e^+e^- \rightarrow e^+e^- \chi_{c2}$
$0.321 \pm 0.078 \pm 0.00$	054	⁸ ARMSTRONG	93	SPEC	$\overline{p}p \rightarrow \gamma\gamma$
$3.4 \pm 1.7 \pm 0.9$	-	BAUER	93	TPC	$e^+e^- \rightarrow e^+e^-\chi_{c2}$
$2.9 \begin{array}{cc} +1.3 \\ -1.0 \end{array} \pm 1.$	7	BAGLIN	87в	SPEC	$\overline{p} p \rightarrow \gamma \gamma$
• • We do not us	se the followin	g data for averages	, fits	, limits,	etc. • • •
(4.2	95	UEHARA	91	VNS	$e^+e^- \rightarrow e^+e^-\chi_{c2}$
(1.0	95	CHEN	90B	CLEO	$e^+e^- \rightarrow e^+e^-\chi_{c2}$
(4.2	95	AIHARA	88D	TPC	$e^+e^- \rightarrow e^+e^- \times$
(1.6	90	YAMADA	77	DASP	$e^+e^- o 3\gamma$

$x_{c2}(1P)$ BRANCHING RATIOS

- HADRONIC DECAYS -

	misitoriic secri	_		
$\Gamma(2(\pi^+\pi^-))/\Gamma_{\text{total}}$	DOCUMENT ID			Γ ₁ /Γ
0.022 ± 0.005	¹⁰ TANENBAUM 78	MRK1	$\psi(2S) \rightarrow \gamma \chi_{C2}$	
$\Gamma(\pi^+\pi^-K^+K^-)/\Gamma_{\text{total}}$	DOCUMENT ID	TECH	COLUMNIA	Γ2/Γ
	10 TANENBAUM 78			
0.019±0.005	13 TANENBAUM 78	MKKI	$\psi(25) \rightarrow \gamma \chi_{C2}$	
$\Gamma(3(\pi^+\pi^-))/\Gamma_{\text{total}}$	DOCUMENT ID	TECH	COLUMENT	Γ_3/Γ
VALUE	DOCUMENT ID			
0.012±0.008	¹⁰ TANENBAUM 78	MRK1	$\psi(25) \rightarrow \gamma \chi_{c2}$	
$\Gamma(ho^0\pi^+\pi^-)/\Gamma_{ m total}$				Γ_4/Γ
VALUE (units 10 ⁻⁴)	DOCUMENT ID			
68±40	¹⁰ TANENBAUM 78	MRK1	$\psi(2S) \rightarrow \gamma \chi_{C2}$	
$\Gamma(K^{+}\overline{K}^{*}(892)^{0}\pi^{-} + \text{c.c.})/$	Γ _{total}			Γ ₅ /Γ
VALUE (units 10 ⁻⁴)	DOCUMENT ID	TECN	COMMENT	
	10			

48±28

10 TANENBAUM 78 MRK1 $\psi(2S)
ightarrow \gamma^{\chi}{}_{c2}$

81 SLAC Summer Inst. 3554Edwards+ (SLAC, CIT, HARV, PRIN, STAN, SLAC)
788 PL 79B 492 +Dittmann, Duinker, Olsson, O'Neill+ (DESY, HEIDP)

$\Gamma(\pi^+\pi^-p\overline{p})/\Gamma_{\text{total}}$		Г ₆ /Г	Y	c2(1P) REFERENCES
VALUE (units 10 ⁻⁴)	DOCUMENT ID TECN COMMENT	. 0/		,
33±13	10 TANENBAUM 78 MRK1 $\psi(2S) \rightarrow \gamma^{\chi}_{C2}$		DOMINICK 94 PR D50 4265 ARMSTRONG 93 PRL 70 2988	+Sanghera+ (CLEO Collab.) +Bettoni, Bharadwaj+ (FNAL E760 Collab.)
=(+ -\/=	, , , , , , , , , , , , , , , , , , , ,		BAUER 93 PL B302 345 ARMSTRONG 92 NP B373 35	+Belcinski+ (TPC Collab.) +Bettoni+ (FNAL, FERR, GENO, UCI, NWES+)
$\Gamma(\pi^+\pi^-)/\Gamma_{\text{total}}$		Γ_7/Γ	Also 92B PRL 68 1468 UEHARA 91 PL B266 188	Armstrong, Bettoni+(FNAL, FERR, GENO, UCI, NWES+)
VALUE (units 10 ⁻³) EVTS	DOCUMENT ID TECN COMMENT		CHEN 90B PL B243 169	+Abe+ (VENUS Collab.) +Mcllwain+ (CLEO Collab.)
1.9±1.0 4	10 BRANDELIK 790 DASP $\psi(25) ightarrow \gamma \chi_{c2}$		AIHARA 88D PRL 60 2355 BAGLIN 87B PL B187 191	+Alston-Garnjost+ (TPC Collab.) +Baird, Bassompierre, Borreani+ (R704 Collab.)
$\left[\Gamma(\pi^+\pi^-) + \Gamma(K^+K^-)\right]$	/Γ _{total} (Γ ₇ -	-Γ ₈)/Γ	BAGLIN 86B PL B172 455 GAISER 86 PR D34 711	(LAPP, CERN, GENO, LYON, OSLO, ROMA+) +Bloom, Bulos, Godfrey+ (Crystal Ball Collab.)
VALUE (units 10 ⁻⁴)	DOCUMENT ID TECN COMMENT	0,,	LEE 85 SLAC 282 LEMOIGNE 82 PL 113B 509	(SLAC)
24±10	10 TANENBAUM 78 MRK1 $\psi(2S) ightarrow \gamma \chi_{C2}$		OREGLIA 82 PR D25 2259 Also 82B Private Comm.	+Barate, Astbury+ (SACL, LOIC, SHMP, IND) +Partridge+ (SLAC, CIT, HARV, PRIN, STAN) Oreglia (EFI)
F(V+V-)/F		F /F	BARATE 81 PR D24 2994	+Astbury+ (SACL, LOIC, SHMP, CERN, ÎND)
$\Gamma(K^+K^-)/\Gamma_{\text{total}}$	DOCUMENT ID	Г ₈ /Г	HIMEL 80 PRL 44 920 Also 82 Private Comm.	+Abrams, Alam, Blocker+ (LBL, SLAC) Trilling (LBL, UCB)
$\frac{VALUE \text{ (units } 10^{-3})}{1.5 \pm 1.1}$ EVTS	$\begin{array}{c ccccc} \underline{DOCUMENT\ ID} & \underline{TECN} & \underline{COMMENT} \\ \hline 10 \ BRANDELIK & 79C \ DASP & \psi(2S) \rightarrow & \gamma \chi_{C2} \\ \end{array}$		BRANDELIK 79B NP B160 426 BRANDELIK 79C ZPHY C1 233	+Cords+ (DASP Collab.) +Cords+ (DASP Collab.)
	DIVIDEFILITY FOR DASE $\psi(zs) \rightarrow \gamma \chi_{c2}$		BARTEL 78B PL 79B 492 SPITZER 78 Kyoto Sum. Inst.	+Dittmann, Duinker, Olsson, O'Neill+ (DESY, HEIDP) 47 (HAMB)
$\Gamma(p\overline{p})/\Gamma_{\text{total}}$		۲۹/۲	TANENBAUM 78 PR D17 1731 Also 82 Private Comm.	+Alam, Boyarski+ (SLAC, LBL) Trilling (LBL, UCB)
VALUE (units 10 ⁻⁴) CL%	EVTS DOCUMENT ID TECN COMMENT		BIDDICK 77 PRL 38 1324 YAMADA 77 Hamburg Conf. 69	+Burnett+ (UCSD, UMD, PAVI, PRIN, SLAC, STAN)
1.00±0.10 OUR AVERAGE 1.00±0.11	585 9 ARMSTRONG 92 SPEC $\overline{p}p \rightarrow e^{+}$	- e- ~	TRILLING 76 Stanford Symp. 43 WHITAKER 76 PRL 37 1596	(LBL) +Tanenbaum, Abrams, Alam+ (SLAC, LBL)
$0.97^{+0.44}_{-0.28} \pm 0.08$	BAGLIN 86B SPEC $\overline{p}p \rightarrow e^{-1}$	•		
	wing data for averages, fits, limits, etc. \bullet \bullet		—— отн	HER RELATED PAPERS ———
< 9.5 vve do not use the follow	wing data for averages, fits, limits, etc. $ullet$ $ullet$ $ullet$ BRANDELIK 79B DASP $\psi(2S) ightarrow$	~ Y -	BARATE 83 PL 121B 449 FELDMAN 75B PRL 35 821	+Bareyre, Bonamy+ (SACL, LOIC, SHMP, IND) +Jean-Marie, Sadoulet, Vannucci+ (LBL, SLAC)
	$_{2}(1P) \rightarrow J/\psi(1S)\gamma)$ B $(J/\psi(1S) \rightarrow e^{+}e^{-}) = 0.$		Also 75C PRL 35 1189	+ Jean-Marie, Sadouiet, Vannucci+ (LBL, SLAC) Feldman
0.0007.	$2(11) \rightarrow 3/\psi(13)\gamma D(3/\psi(13) \rightarrow e \cdot e) = 0.$	UU05 I	Erratum. TANENBAUM 75 PRL 35 1323	+Whitaker, Abrams+ (LBL, SLAC)
$\Gamma_I \Gamma_f / \Gamma_{\text{total}}^2 \text{ in } p \overline{p} \rightarrow \chi_{c2} (1)$	$P) \rightarrow \gamma \gamma$ Γ_{9}	- ₁₄ /Γ ²		C - PC - 2 - 2 - 2 - 1
VALUE (units 10 ⁻⁷) EVTS	DOCUMENT ID TECN COMMENT		$\eta_c(2S)$	$I^{G}(J^{PC}) = ?^{?}(?^{?+})$
	ving data for averages, fits, limits, etc. • •			
$0.160 \pm 0.039 \pm 0.016$	ARMSTRONG 93 SPEC $\overline{p}p \rightarrow \gamma\gamma$		OMITTED FROM SUMMA	RY TABLE
$0.99 \begin{array}{l} +0.46 \\ -0.35 \end{array}$	¹¹ BAGLIN 878 SPEC $\overline{p}p \rightarrow \gamma\gamma$		Needs confirmation.	
$\Gamma(\pi^0\pi^0)/\Gamma_{\text{total}}$		Γ ₁₀ /Γ		$\eta_c(2S)$ MASS
VALUE (units 10 ⁻³)	DOCUMENT ID TECN COMMENT		VALUE (MeV)	DOCUMENT ID TECN COMMENT
$1.1 \pm 0.2 \pm 0.2$	12 LEE 85 CBAL $\psi' ightarrow$ photons		3594±5	¹ EDWARDS 82C CBAL $e^+e^- \rightarrow \gamma X$
$\Gamma(\eta\eta)/\Gamma_{\text{total}}$		Γ ₁₁ /Γ	1 Assuming mass of $\psi(2S)=36$	*
' (''') / ' total VALUE (units 10 ⁻⁴)	DOCUMENT ID TECN COMMENT	. 11/ .		
7.9±4.1±2.4	12 LEE 85 CBAL $\psi' \rightarrow \text{photons}$			$\eta_c(2S)$ WIDTH
			VALUE (MeV) CL%	DOCUMENT ID TECN COMMENT
$\Gamma(J/\psi(1S)\pi^+\pi^-\pi^0)/\Gamma_{\text{tot}}$		Γ_{12}/Γ		g data for averages, fits, limits, etc. • •
<u>VALUE</u> <u>CL%</u> <0.015 90	DOCUMENT ID TECN COMMENT		<8.0 95	EDWARDS 82C CBAL $e^+e^- \rightarrow \gamma X$
CO.012 80	BARATE 81 SPEC 190 GeV π^- Be = $2\pi 2\mu$	→	_0.0	ESTATION OF COME EVE - 1/V
10 Estimated using B $(\psi(2S)$ -	$\gamma \chi_{\mathcal{C}2}(1P)) = 0.078$; the errors do not contain the	uncer-	η_c	(2S) DECAY MODES
tainty in the $\psi(2S)$ decay. 11 Assuming isotropic $\chi_{C2}(1F)$) - ~ distribution			•
			Mode	Fraction (Γ_i/Γ)
oo .coa.c .o co.culated				Traction (T ₁ /T)
	using B($\psi(2S) \to \gamma \chi_{C2}(1P)$) = 0.078 \pm 0.008.		Γ_1 hadrons	seen
			Γ_1 hadrons Γ_2 $\gamma\gamma$	
	using $B(\psi(2S) \to \gamma \chi_{C2}(1P)) = 0.078 \pm 0.008$. RADIATIVE DECAYS ———	Г ₁₃ /Г	$\frac{\Gamma_2}{\Gamma_2}$ $\gamma\gamma$	seen
$\Gamma(\gamma J/\psi(1S))/\Gamma_{\text{total}}$ VALUE EVTS	using $B(\psi(2S) \to \gamma \chi_{C2}(1P)) = 0.078 \pm 0.008$. RADIATIVE DECAYS ———	Γ ₁₃ /Γ	$\frac{\Gamma_2}{\Gamma_2}$ $\gamma\gamma$	
$\Gamma(\gamma J/\psi(1S))/\Gamma_{ ext{total}}$ $VALUE$ 0.135 \pm 0.011 OUR AVERAGE	using $B(\psi(2S) \to \gamma \chi_{c2}(1P)) = 0.078 \pm 0.008$. RADIATIVE DECAYS —	Γ ₁₃ /Γ	$\frac{\Gamma_2 - \gamma \gamma}{\eta_c(29)}$	Seen S) BRANCHING RATIOS
$\Gamma(\gamma J/\psi(1S))/\Gamma_{\text{total}}$ $VALUE$ 0.135±0.011 OUR AVERAGE 0.124±0.015	using $B(\psi(2S) \to \gamma X_{C2}(1P)) = 0.078 \pm 0.008$. RADIATIVE DECAYS DOCUMENT ID TECN COMMENT GAISER 86 CBAL $\psi(2S) \to \gamma X$	Г ₁₃ /Г	$\frac{\Gamma_2}{\Gamma_2}$ $\gamma\gamma$	seen 5) BRANCHING RATIOS Γ ₁ /Γ DOCUMENT ID TECN COMMENT
$\Gamma(\gamma J/\psi(1S))/\Gamma_{\text{total}}$ NALUE 0.135±0.011 OUR AVERAGE 0.124±0.015 0.162±0.028 479	using $B(\psi(2S) \to \gamma \chi_{c2}(1P)) = 0.078 \pm 0.008$. RADIATIVE DECAYS DOCUMENT ID GAISER 6 CBAL $\psi(2S) \to \gamma X$ 13 OREGLIA 82 CBAL $\psi(2S) \to \gamma X$ 13 HIMEL 80 MRK2 $\psi(2S) \to \gamma \chi_{c2}$	Г ₁₃ /Г	$rac{\Gamma_2}{\Gamma_2} rac{\gamma \gamma}{\eta_c$ (25 $\Gamma(ext{hadrons})/\Gamma_{ ext{total}}$	seen 5) BRANCHING RATIOS Γ ₁ /Γ
$\Gamma(\gamma J/\psi(1S))/\Gamma_{total}$ $VALUE$ 0.135±0.011 OUR AVERAGE 0.124±0.015 0.162±0.028 0.14 ±0.04 0.18 ±0.05	using $B(\psi(2S) \to \gamma \chi_{c2}(1P)) = 0.078 \pm 0.008$. RADIATIVE DECAYS DOCUMENT ID TECN COMMENT GAISER 6 CBAL $\psi(2S) \to \gamma \chi$ 13 OREGLIA 82 CBAL $\psi(2S) \to \gamma \chi_{c2}$ 13 HIMEL 80 MRK2 $\psi(2S) \to \gamma \chi_{c2}$ 13 BRANDELIK 798 DASP $\psi(2S) \to \gamma \chi_{c2}$	Г13/Г	$\Gamma_2 \qquad \gamma \gamma \qquad \qquad \eta_c (25) = \Gamma (hadrons) / \Gamma_{total} = \frac{VALUE}{seen}$	seen S) BRANCHING RATIOS $\frac{DOCUMENT\ ID}{EDWARDS} \frac{TECN}{82C\ CBAL} \frac{COMMENT}{e^+e^- \to \gamma X}$
Γ(γ J/ψ(1S))/Γ _{total} LVALUE 0.135±0.011 OUR AVERAGE 0.124±0.015 0.162±0.028 0.14 ±0.04 0.18 ±0.05 0.13 ±0.03	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Γ ₁₃ /Γ	Γ_2 $\gamma\gamma$ η_c (2.5 Γ (hadrons)/ Γ total ΔUUE seen $\Gamma(\gamma\gamma)/\Gamma$ total	seen S) BRANCHING RATIOS $\frac{DOCUMENT\ ID}{EDWARDS} \frac{TECN}{82C\ CBAL} \frac{COMMENT}{e^+e^- \to \gamma X}$ Γ_2/Γ
$\Gamma(\gamma J/\psi(1S))/\Gamma_{total}$ VALUE 0.135±0.011 OUR AVERAGE 0.124±0.015 0.162±0.028 479 0.14 ±0.04 0.18 ±0.05 0.13 ±0.03 0.11 +0.13 -0.07	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	Г ₁₃ /Г	$\Gamma_2 \qquad \gamma \gamma \qquad \qquad \eta_c (25) = \Gamma (hadrons) / \Gamma_{total} = \frac{VALUE}{seen}$	seen S) BRANCHING RATIOS $\frac{DOCUMENT\ ID}{EDWARDS} \frac{TECN}{82C\ CBAL} \frac{COMMENT}{e^+e^- \to \gamma X}$ Γ_2/Γ
Γ(γ J/ψ(1S))/Γ _{total} LVALUE D.135±0.011 OUR AVERAGE D.124±0.015 D.162±0.028 D.14 ±0.04 D.18 ±0.05 D.13 ±0.03 D.11 ±0.13 D.11 ±0.13 D.11 ±0.13 D.11 ±0.13 D.11 ±0.13 D.11 ±0.13 D.11 ±0.07 D.13 ±0.08	using $B(\psi(2S) \to \gamma \chi_{c2}(1P)) = 0.078 \pm 0.008$. RADIATIVE DECAYS ————————————————————————————————————	Г ₁₃ /Г	Γ_2 $\gamma\gamma$ $\eta_c(25)$ $\Gamma(\text{hadrons})/\Gamma_{\text{total}}$ $VALUE$ seen $\Gamma(\gamma\gamma)/\Gamma_{\text{total}}$ $VALUE$ $CL\%$	Seen Seen Seen Seen Seen Seen Seen Seen
Γ(γ J/ψ(1S))/Γ _{total} LEVTS D.135±0.011 OUR AVERAGE D.124±0.015 D.16±0.028 D.14±0.04 D.18±0.05 D.13±0.03 D.11±0.13 D.007 D.13±0.08 D • • We do not use the follow	using $B(\psi(2S) \to \gamma \chi_{c2}(1P)) = 0.078 \pm 0.008$. RADIATIVE DECAYS DOCUMENT ID GAISER 66 CBAL $\psi(2S) \to \gamma \chi_{c2}$ 13 OREGLIA 13 BRANDELIK 13 BRANDELIK 19B DASP $\psi(2S) \to \gamma \chi_{c2}$ 13 BRANDELIK 19B DASP $\psi(2S) \to \gamma \chi_{c2}$ 13 BRANDELIX 13 BRANDELIX 14 PROBLEM TO THE PROBLEM T	Γ ₁₃ /Γ		Seen Seen Seen Seen Seen Seen Seen Seen
$\Gamma(\gamma J/\psi(15))/\Gamma_{\text{total}}$ LALUE D.135±0.011 OUR AVERAGE D.124±0.015 D.162±0.028 D.14±0.04 D.18±0.05 D.13±0.03 D.11±0.13 D.13±0.08 • • • We do not use the follow 0.28±0.13	using $B(\psi(2S) \to \gamma \chi_{c2}(1P)) = 0.078 \pm 0.008$. RADIATIVE DECAYS $\frac{DOCUMENT\ ID}{}$ TECN GAISER 6 CBAL $\psi(2S) \to \gamma \chi_{c2}$ 13 OREGLIA 13 HIMEL 80 MRK2 $\psi(2S) \to \gamma \chi_{c2}$ 13 BRANDELIK 79B DASP $\psi(2S) \to \gamma \chi_{c2}$ 13 BRANDELIK 79B CNTR $\psi(2S) \to \gamma \chi_{c2}$ 13 SPITZER 78 PLUT $\psi(2S) \to \gamma \chi_{c2}$ 13 TANENBAUM 78 MRK1 $\psi(2S) \to \gamma \chi_{c2}$ 14 TANENBAUM 78 MRK1 $\psi(2S) \to \gamma \chi_{c2}$ 15 BIDDICK 77 CNTR $\psi(2S) \to \gamma \chi_{c2}$		$\frac{\Gamma_2}{\eta_c(25)} \frac{\gamma\gamma}{\eta_c(25)}$ $\frac{\Gamma(\text{hadrons})/\Gamma_{\text{total}}}{\text{seen}}$ $\frac{\Gamma(\gamma\gamma)/\Gamma_{\text{total}}}{\sqrt{ALUE}}$ $\frac{VALUE}{<0.01}$ 90	Seen 5) BRANCHING RATIOS $ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
$\Gamma(\gamma J/\psi(1S))/\Gamma_{\text{total}}$ NALUE 0.135±0.011 OUR AVERAGE 0.124±0.015 0.162±0.028 0.14±0.04 0.18±0.05 0.13±0.03 0.11±0.03 0.11±0.03 0.13±0.08 • • • We do not use the follow 0.28±0.13	using $B(\psi(2S) \to \gamma \chi_{c2}(1P)) = 0.078 \pm 0.008$. RADIATIVE DECAYS DOCUMENT ID GAISER 66 CBAL $\psi(2S) \to \gamma \chi_{c2}$ 13 OREGLIA 13 BRANDELIK 13 BRANDELIK 19B DASP $\psi(2S) \to \gamma \chi_{c2}$ 13 BRANDELIK 19B DASP $\psi(2S) \to \gamma \chi_{c2}$ 13 BRANDELIX 13 BRANDELIX 14 PROBLEM TO THE PROBLEM T		$ \begin{array}{c c} \Gamma_2 & \gamma \gamma \\ \hline & \eta_c(2.5) \\ \hline \Gamma(\text{hadrons})/\Gamma_{\text{total}} \\ \hline & \text{seen} \\ \hline \Gamma(\gamma \gamma)/\Gamma_{\text{total}} \\ \hline & \text{value} \\ \hline < 0.01 & 90 \\ \hline & \eta_c(2.5) \\ \hline & \text{seen} \\ \hline & \Gamma(\gamma \gamma)/\Gamma_{\text{total}} \\ \hline & \text{seen} \\ \hline & $	Seen Seen Seen Seen Seen Seen Seen Seen
$ \begin{array}{lll} & & & & & & & & & & & & & & & & \\ & & & & & & & & & & & & & \\ \hline \textbf{0.135} \pm \textbf{0.011} & \textbf{OUR} & \textbf{AVERAGE} \\ \textbf{0.124} \pm \textbf{0.015} & \textbf{0.162} \pm \textbf{0.028} & \textbf{479} \\ \textbf{0.162} \pm \textbf{0.028} & \textbf{479} \\ \textbf{0.18} & \pm \textbf{0.04} & \textbf{0.13} & \pm \textbf{0.03} \\ \textbf{0.13} & \pm \textbf{0.03} & \textbf{0.01} & -\textbf{0.07} \\ \textbf{0.13} & \pm \textbf{0.03} & \textbf{0.01} & -\textbf{0.07} \\ \textbf{0.13} & \pm \textbf{0.08} & \textbf{\bullet} & \textbf{\bullet} & \textbf{We do not use the follow} \\ \textbf{0.28} & \pm \textbf{0.13} & \textbf{13} & \textbf{Estimated using B} (\psi(2S) - \textbf{0.13}) \end{array} $	using $B(\psi(2S) \to \gamma \chi_{c2}(1P)) = 0.078 \pm 0.008$. RADIATIVE DECAYS DOCUMENT ID GAISER 86 CBAL $\psi(2S) \to \gamma \chi_{c2}$ 13 OREGLIA 82 CBAL $\psi(2S) \to \gamma \chi_{c2}$ 13 BRANDELIK 798 DASP $\psi(2S) \to \gamma \chi_{c2}$ 13 BRANDELIK 798 CNTR $\psi(2S) \to \gamma \chi_{c2}$ 13 SPITZER 78 PLUT $\psi(2S) \to \gamma \chi_{c2}$ 13 TANENBAUM 78 MRK1 $\psi(2S) \to \gamma \chi_{c2}$ 13 TANENBAUM 78 MRK1 $\psi(2S) \to \gamma \chi_{c2}$ 13 BIDDICK 77 CNTR $\psi(2S) \to \gamma \chi_{c2}$ 13 BIDDICK 77 CNTR $\psi(2S) \to \gamma \chi_{c2}$		$ \begin{array}{c c} \Gamma_2 & \gamma \gamma \\ \hline & \eta_c(2.5) \\ \hline \Gamma(\text{hadrons})/\Gamma_{\text{total}} \\ \hline & \text{seen} \\ \hline \Gamma(\gamma \gamma)/\Gamma_{\text{total}} \\ \hline & \text{value} \\ \hline < 0.01 & 90 \\ \hline & \eta_c(2.5) \\ \hline & \text{seen} \\ \hline & \Gamma(\gamma \gamma)/\Gamma_{\text{total}} \\ \hline & \text{seen} \\ \hline & $	Seen 5) BRANCHING RATIOS $ \begin{array}{cccccccccccccccccccccccccccccccccc$

OREGLIA PORTER BARTEL

 $\frac{DOCUMENT\ ID}{14}$ ARMSTRONG 93 SPEC $\overline{p}\,p \to \gamma\gamma$

 $\frac{VALUE \text{ (units } 10^{-4})}{1.60\pm0.39\pm0.23}$

 $^{14}\, \text{Using B}(\chi_{\it C2}(1P) \to \ \, p\, \overline{p}) = (1.00\, \pm \, 0.23) \times 10^{-4}.$

 $\psi(2S)$

ψ (2 <i>S</i>)

$I^{G}(J^{PC})$	=	$0^{-}(1$)
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$\psi(2S)$ MASS

VALUE (MeV)	EVTS	DOCUMENT ID TECN COMMENT	
3686.00±0.09 OUR	VERAGE		
$3686.02 \pm 0.09 \pm 0.27$		ARMSTRONG 93B SPEC $\overline{p}p \rightarrow e^+e^-$	
3686.00 ± 0.10	413	ZHOLENTZ 80 OLYA e^+e^-	
• • • We do not use	the following	data for averages, fits, limits, etc. • • •	
3683 ±5	77	ANTONIAZZI 94 E705 300 π^{\pm} , $ ho$ Li $ ightarrow$	
		$J/\psi \pi^+ \pi^- X$	

$m_{\psi(2S)}-m_{J/\psi(1S)}$

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
589.07±0.13 OUR AVERAGE				
589.7 ±1.2	LEMOIGNE	82	GOLI	190 GeV π^- Be $\rightarrow 2\mu$
589.07 ± 0.13	¹ ZHOLENTZ	80	OLYA	e^+e^-
588.7 ±0.8	LUTH	75	MRK1	

 $^{^{1}\,\}mathrm{Redundant}$ with data in mass above.

Mode

$\psi(2S)$ WIDTH

VALUE (keV)	DOCUMENT ID TECN	COMMENT
277±31 OUR AVERAGE	Error includes scale factor of 1.1.	
$306 \pm 36 \pm 16$ 243 \pm 43	ARMSTRONG 93B SPEC ² PDG 92 RVUE	• •

 $^{^2}$ Uses $\Gamma(e\,e)$ from ALEXANDER 89 and B(e\,e) = (88 \pm 13) \times 10 $^{-4}$ from FELDMAN 77.

$\psi(2S)$ DECAY MODES

Fraction (Γ_j/Γ)

Γ ₁	hadrons	(98.10±0.30) %
Γ2	virtual $\gamma \rightarrow hadrons$	(2.9 ±0.4) %
	e ⁺ e ⁻	$(8.8 \pm 1.3) \times 10^{-3}$
Γ ₄	$\mu^+ \mu^-$	$(7.7 \pm 1.7) \times 10^{-3}$
	Decays into	$J/\psi(1S)$ and anything
Γ_5	$J/\psi(1S)$ anything	(57 ±4)%
	$J/\psi(1S)$ neutrals	(23.2 \pm 2.6) %
	$J/\psi(1S)\pi^+\pi^-$	(32.4 ±2.6) %
Γ8	$J/\psi(1S) \pi^0 \pi^0$	$(18.4 \pm 2.7)\%$
	$J/\psi(1S)\eta$	(2.7 ±0.4) % S=1.7
Γ_{10}	$J/\psi(1S)\pi^0$	$(9.7 \pm 2.1) \times 10^{-4}$
	Ha	adronic decays

Γ11	$3(\pi^+\pi^-)\pi^0$	$(3.5 \pm 1.6) \times 10^{-3}$
Γ12	$2(\pi^{+}\pi^{-})\pi^{0}$	$(3.1 \pm 0.7) \times 10^{-3}$
	$\pi^{+}\pi^{-}K^{+}K^{-}$	$(1.6 \pm 0.4) \times 10^{-3}$
Γ ₁₄	$\pi^+\pi^-p\overline{p}$	$(8.0 \pm 2.0) \times 10^{-4}$

' 14	n n pp	(8.0 ±2.0) x 10
Γ_{15}	$K^{+}\overline{K}^{*}(892)^{0}\pi^{-}+\text{c.c.}$	$(6.7 \pm 2.5) \times 10^{-4}$
	$2(\pi^{+}\pi^{-})$	$(4.5 \pm 1.0) \times 10^{-4}$
Γ_{17}	$\rho^0 \pi^+ \pi^-$	$(4.2 \pm 1.5) \times 10^{-4}$
Γ ₁₈	$\overline{p} p$	$(1.9 \pm 0.5) \times 10^{-4}$
	$3(\pi^{+}\pi^{-})$	$(1.5 \pm 1.0) \times 10^{-4}$
Γ ₂₀	$\overline{p} p \pi^0$	$(1.4 \pm 0.5) \times 10^{-4}$
Γ21	K+K-	$(1.0 \pm 0.7) \times 10^{-4}$
Γ22	$\pi^{+}\pi^{-}\pi^{0}$	$(9 \pm 5) \times 10^{-5}$
Γ23	$\pi^+\pi^-$	$(8 \pm 5) \times 10^{-5}$
Γ ₂₄	$\Lambda \overline{\Lambda}$	$< 4 \times 10^{-4} \text{ CL} = 90\%$
Γ ₂₅	<u>=-</u> <u>=</u> +	$< 2 \times 10^{-4} \text{ CL} = 90\%$
Γ ₂₆	$\rho\pi$	$< 8.3 \times 10^{-5} \text{ CL} = 90\%$
Γ ₂₇	$K^{+}K^{-}\pi^{0}$	$< 2.96 \times 10^{-5} \text{ CL} = 90\%$
Γ ₂₈	$K^{+}\overline{K}^{*}(892)^{-}+\text{ c.c.}$	$< 5.4 \times 10^{-5}$ CL=90%

		Radiative	decay
	(- m)		

		Radiative decays			
Γ29	$\gamma \chi_{c0}(1P)$	(9.3	±0.8) %	
Γ_{30}	$\gamma \chi_{c1}(1P)$	(8.7	±0.8) %	
Γ ₃₁	$\gamma \chi_{c2}(1P)$	(7.8	\pm 0.8) %	
Γ ₃₂	$\gamma \eta_c(1S)$	(2.8	± 0.6) $\times 10^{-3}$	
Γ33	$\gamma \eta_c(2S)$				
Γ ₃₄	$\gamma \pi^0$	<	5.4	\times 10 ⁻³	CL=95%
Γ ₃₅	$\gamma \eta'(958)$	<	1.1	× 10 ⁻³	CL=90%
Γ ₃₆	$\gamma \eta$				
Γ ₃₇	$\gamma \gamma$	<	1.6	× 10 ⁻⁴	CL=90%
Γ ₃₈	$\gamma \eta (1440) \rightarrow \gamma K \overline{K} \pi$	<	1.2	× 10 ⁻⁴	CL=90%

Mode needed for fitting purposes

 Γ_{39} 1. – other fit modes

CONSTRAINED FIT INFORMATION

An overall fit to 7 branching ratios uses 13 measurements and one constraint to determine 6 parameters. The overall fit has a χ^2 = $6.9 \ \text{for 8 degrees of freedom}\,.$

The following off-diagonal array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv$ $\Gamma_i/\Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to

<i>x</i> ₈	35				
<i>x</i> 9	0	-11			
<i>x</i> ₃₀	1	-7	0		
<i>x</i> ₃₁	0	-3	0	0	
X39	-80	-78	-4	-14	-16
	<i>x</i> ₇	<i>x</i> ₈	<i>×</i> 9	×30	<i>x</i> ₃₁

F(hadrons)

<43

Scale factor/

Confidence level

$\psi(2S)$ PARTIAL WIDTHS

i (ilaulolis)						' 1
VALUE (keV)		DOCUMENT ID		TECN	COMMENT	
• • • We do not use	the followin	g data for average	s, fit	s, limits,	etc. • • •	
224 ± 56		LUTH	75	MRK1	e^+e^-	
$\Gamma(e^+e^-)$						Гз
VALUE (keV)		DOCUMENT ID		TECN	COMMENT	
2.14 ± 0.21		ALEXANDER	89	RVUE	See γ mini-review	,
 ● ● We do not use 	the followin	g data for average	s, fit	s, limits,	etc. • • •	
2.0 ±0.3		BRANDELIK	790	DASP	e+ e-	
2.1 ±0.3		³ LUTH	75	MRK1	e+ e-	
³ From a simultane $= \Gamma(\mu^+\mu^-)$.	ous fit to e	e^- , $\mu^+\mu^-$, and	l had	ronic cha	annels assuming Γ(e ⁺ e ⁻)
$\Gamma(\gamma\gamma)$						Γ37
VALUE (eV)	CL%	DOCUMENT ID		TECN	COMMENT	

$\psi(2S) \Gamma(i)\Gamma(e^+e^-)/\Gamma(total)$

BRANDELIK 79C DASP e+e-

This combination of a partial width with the partial width into e^+e^- and with the total width is obtained from the integrated cross section into channel $_{\rm l}$ in the e^+e^- annihilation. We list only data that have not been used to determine the partial width $\Gamma({\rm l})$ or the branching ratio $\Gamma({\rm l})/{\rm total}.$

$\Gamma(\text{hadrons}) \times \Gamma(e^+e^-)/\Gamma_{\text{total}}$	ŀ			$\Gamma_1\Gamma_3/\Gamma$
VALUE (keV)	DOCUMENT ID	TECN	COMMENT	
• • • We do not use the following of	data for averages, fit	s, limits,	etc. • • •	
2.2 ± 0.4	ABRAMS 75	MRK1	e^+e^-	

$\psi(2S)$ BRANCHING RATIOS

$\Gamma(\text{hadrons})/\Gamma_{\text{total}}$					Γ_1/Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
0.981 ±0.003	⁴ LUTH	75	MRK1	e+ e-	
$\Gamma(\text{virtual}\gamma \rightarrow \text{hadrons})/\Gamma_{\text{total}}$					Γ_2/Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
0.029 ± 0.004	⁵ LUTH	75	MRK1	e^+e^-	
$\Gamma(e^+e^-)/\Gamma_{\text{total}}$					Г ₃ /Г
VALUE (units 10 ⁻⁴)	DOCUMENT ID		TECN	COMMENT	
88±13	6 FELDMAN	77	RVUE	e+ e-	
$\Gamma(\mu^+\mu^-)/\Gamma_{\text{total}}$					Γ_4/Γ
VALUE (units 10-4)	DOCUMENT ID		TECN	COMMENT	
77±17			SPEC	e+e-	
$\Gamma(\mu^+\mu^-)/\Gamma(e^+e^-)$					Γ_4/Γ_3
VALUE	DOCUMENT ID		TECN	COMMENT	
• • • We do not use the following	data for average	es, fit	s, limits,	etc. • • •	
0.89 ± 0.16	BOYARSKI	750	MRK1	e+ e-	

 $^{^4}$ Includes cascade decay into $J/\psi(1S)$. ⁵ Included in $\Gamma(hadrons)/\Gamma_{total}$.

From an overall fit assuming equal partial widths for e^+e^- and $\mu^+\mu^-$. For a measurement of the ratio see the entry $\Gamma(\mu^+\mu^-)/\Gamma(e^+e^-)$ below. Includes LUTH 75, HILGER 75, BURMESTER 77. Restated by us using $B(\psi(2S) \to J/\psi(1S)$ anything) = 0.55.

 ψ (2S)

DECAYS I	NTO $J/\psi(1S)$ AND ANYTHING ———	$\Gammaigl(J/\psi(1S)\pi^0igr)/\Gamma_{total}$		Γ ₁₀ /
$\Gamma(J/\psi(1S))$ anything $\Gamma(J/\psi(1S))$	$\Gamma_5/\Gamma = (\Gamma_7 + \Gamma_8 + \Gamma_9 + 0.273\Gamma_{30} + 0.135\Gamma_{31})/\Gamma$	VALUE (units 10 ⁻⁴) 9.7±2.1 OUR AVERAGE	EVTS DOCUMENT ID TECH	COMMENT
<u>/ALUE</u> 0.57±0.04 OUR FIT 0.55±0.07 OUR AVERAGE	DOCUMENT ID TECN COMMENT	15 ±6 9 ±2 ±1		$(2 e^+e^-)$ $U \psi(2S) \rightarrow U \psi(2S) \rightarrow U \psi(2S) \rightarrow U \psi(2S) \rightarrow U \psi(2S)$
.51±0.12 .57±0.08	BRANDELIK 79C DASP $e^+e^- \rightarrow \mu^+\mu^- X$ ABRAMS 75B MRK1 $e^+e^- \rightarrow \mu^+\mu^- X$	⁸ The ABRAMS 75B measure	ment of Γ_6/Γ_5 and the TANENBAUM ANENBAUM 76 result is used in the	
$(J/\psi(1S)$ neutrals $)/\Gamma_{ ext{total}}$, i	more accurate corrections fo 9 Not independent of the TAN	r angular distributions. IENBAUM 76 result for Γ_6/Γ_7 .	rit because it includ
ALUE	$\Gamma = (0.9761\Gamma_8 + 0.708\Gamma_9 + 0.273\Gamma_{30} + 0.135\Gamma_{31})/\Gamma$ DOCUMENT ID	10 Ignoring the $J/\psi(1S)\eta$ and 11 Low statistics data removed		
.232±0.026 OUR FIT			HADRONIC DECAYS ———	
$(J/\psi(1S))$ neutrals $)/\Gamma(J/\psi)$ $0.708\Gamma_9+0.273\Gamma_{30}+0.135\Gamma_{30}$ ALUE	$(\Gamma_1)/(\Gamma_7+\Gamma_8+\Gamma_9+0.273\Gamma_{30}+0.135\Gamma_{31})$	$\Gamma(3(\pi^+\pi^-)\pi^0)/\Gamma_{ m total}$		Γ ₁₁ /
.409±0.026 OUR FIT		$\frac{VALUE \text{ (units } 10^{-4})}{35 \pm 16} \qquad \frac{EVTS}{6}$	FRANKLIN 83 MRK2 e ⁺	
 We do not use the following 44 ±0.03 	ng data for averages, fits, limits, etc. $ullet$ $ulle$			
	- 7 7	$\Gamma(2(\pi^+\pi^-)\pi^0)/\Gamma_{\text{total}}$ VALUE (units 10 ⁻⁴) EVTS	DOCUMENT ID TECN CON	Γ ₁₂ /
$(J/\psi(1S) \text{ neutrals})/\Gamma(J/\psi)$	$(15)\pi^{+}\pi^{-})$ 7 = $(0.9761\Gamma_{8}+0.708\Gamma_{9}+0.273\Gamma_{30}+0.135\Gamma_{31})/\Gamma_{7}$	31± 7 OUR AVERAGE		
4LUE	DOCUMENT ID TECN COMMENT	30 ± 8 42 35 ± 15	FRANKLIN 83 MRK2 e ⁺ o ABRAMS 75 MRK1 e ⁺	
72±0.08 OUR FIT 73±0.09	8 TANENBAUM 76 MRK1 e+e-	$\Gamma(\pi^+\pi^-K^+K^-)/\Gamma_{\text{total}}$		Γ ₁₃ /
$\left(J/\psi(1S)\pi^+\pi^- ight)/\Gamma_{total}$	Γ ₇ /Γ	VALUE (units 10 ⁻⁴)	DOCUMENT ID TECH CON	
324±0.026 OUR FIT	DOCUMENT ID TECN COMMENT	16±4	12 TANENBAUM 78 MRK1 e+	
332±0.033 OUR AVERAGE		$\Gamma(\pi^+\pi^-p\overline{p})/\Gamma_{\text{total}}$		Γ ₁₄ /
32 ±0.04 36 ±0.06	ABRAMS 75B MRK1 $e^+e^- \rightarrow J/\psi \pi^+\pi^-$ WIIK 75 DASP $e^+e^- \rightarrow J/\psi \pi^+\pi^-$	VALUE (units 10 ⁻⁴) 8 ±2	12 TANENBAUM 78 MRK1 e+	
$\left(J/\psi(1S)\pi^0\pi^0 ight)/\Gamma_{total}$	F ₈ /F	$\Gamma(K^+\overline{K}^*(892)^0\pi^-+\text{c.c.})/$		Γ ₁₅ /
84±0.027 OUR FIT		VALUE (units 10 ⁻⁴) 6.7±2.5	TANENBAUM 78 MRK1 e+	
18 ±0.06	WIIK 75 DASP $e^+e^- \rightarrow J/\psi 2\pi^0$		TAIVEIVEACIN TO WIRKI C C	
$\left(J/\psi(1S)\pi^0\pi^0\right)/\Gamma\left(J/\psi(1S)\right)$	· · · · · · · · · · · · · · · · · · ·	$\Gamma(2(\pi^+\pi^-))/\Gamma_{\text{total}}$ VALUE (units 10^{-4})	DOCUMENT ID TECN COM	Γ ₁₆ /
10E 57±0.08 OUR FIT	DOCUMENT ID TECN COMMENT	4.5±1.0	TANENBAUM 78 MRK1 e ⁺ e	
	ng data for averages, fits, limits, etc. • •			
53±0.06 64±0.15	⁹ TANENBAUM 76 MRK1 e ⁺ e ⁻ ¹⁰ HILGER 75 SPEC e ⁺ e ⁻	$\Gamma(\rho^0\pi^+\pi^-)/\Gamma_{\text{total}}$ VALUE (units 10 ⁻⁴)	DOCUMENT ID TECN COM	Γ ₁₇ /
		4.2±1.5	TANENBAUM 78 MRK1 e+	
$(J/\psi(1S)\eta)/\Gamma_{total}$	Γρ/Γ EVTS DOCUMENT ID TECN COMMENT	$\Gamma(\overline{p}p)/\Gamma_{total}$		Γ ₁₈ /
27 ±0.004 OUR FIT Error	includes scale factor of 1.7. Error includes scale factor of 1.6. See the ideogram	<u>VALUE (units 10⁴)</u> <u>EVTS</u> 1.9±0.5 OUR AVERAGE	DOCUMENT ID TECN COM	' 18/
025 ±0.006	below. 166 HIMEL 80 MRK2 e^+e^-	1.4 ± 0.8 4	BRANDELIK 790 DASP e^+e^-	
0218±0.0014±0.0035	386 OREGLIA 80 CBAL $e^+e^- \rightarrow$	2.3±0.7	FELDMAN 77 MRK1 e ⁺ e	-
036 ±0.005	164 BARTEL 78B CNTR e^+e^-	$\Gamma(3(\pi^+\pi^-))/\Gamma_{ ext{total}}$		Γ ₁₉ /
	g data for averages, fits, limits, etc. • •	VALUE (units 10 ⁻⁴)	DOCUMENT ID TECN COM	
35 ±0.009	17 11 BRANDELIK 798 DASP $e^+e^- \rightarrow J/\psi 2\gamma$	1.5±1.0	12 TANENBAUM 78 MRK1 e+e	
43 ±0.008	44 11 TANENBAUM 76 MRK1 e^+e^-	$\Gamma(\overline{ ho} ho\pi^0)/\Gamma_{ m total}$		Γ ₂₀ /
WEIGHTED AVER		VALUE (units 10 ⁻⁴) EVTS	DOCUMENT ID TECN COM FRANKLIN 83 MRK2 e ⁺ e	
0.027±0.004 (Error	scaled by 1.6)	1.4±0.5	FRANKLIN 83 MRK2 e + e	
	Values above of weighted average, error,	$\Gamma(K^+K^-)/\Gamma_{\text{total}}$		Γ ₂₁ /
/	and scale factor are based upon the data in this ideogram only. They are not neces-	<u>VALUE (units 10⁻⁴) CL%</u> 1.0±0.7		
1	sarily the same as our 'best' values, obtained from a least-squares constrained fit		ng data for averages, fits, limits, etc.	
1 1	utilizing measurements of other (related) guantities as additional information.	<0.5 90	FELDMAN 77 MRK1 e ⁺ e	·-
		-4 1 3 4-		Γ ₂₃ /
	de l'acceptance de desire l'acceptance de l'ac	$\Gamma(\pi^+\pi^-)/\Gamma_{\text{total}}$		
	qualities de decisional monitation.	$\Gamma(\pi^+\pi^-)/\Gamma_{\text{total}}$ VALUE (units 10^{-4}) CL%	DOCUMENT ID TECN COM	
		VALUE (units 10 ⁻⁴) CL% 0.8±0.5	BRANDELIK 79C DASP e+e	MENT -
	√2 ²	VALUE (units 10 ⁻⁴) CL% 0.8±0.5 • • • We do not use the following	BRANDELIK 79C DASP e^+e^- ong data for averages, fits, limits, etc.	MENT ;- • • •
	$\begin{array}{cccccccccccccccccccccccccccccccccccc$		BRANDELIK 79C DASP e+e	MENT • • •
	+ · · · · · · · · · · · · · · · · · · ·	$ \begin{array}{ccc} & & & & & & & & & & & & \\ \hline \textbf{0.8 \pm 0.5} & & & \bullet & \bullet & \text{We do not use the followis} \\ & & & & \bullet & \text{Ve do not use the followis} \\ & & & & & & & & \\ \hline \textbf{C}(\textbf{\pi}^+ \textbf{\pi}^- \textbf{\pi}^0) / \Gamma_{\textbf{total}} \\ \end{array} $	BRANDELIK 79C DASP $e^+\epsilon$ or additional properties of the BRANDELIK 79C DASP $e^+\epsilon$ or additional properties of the BRANDELIK $e^+\epsilon$	<u>MENT</u> Γ ₂₂ /Ι
	HIMEL 80 MRK2 0.1 OREGLIA 80 CBAL 1.6 BARTEL 78B CNTR 3.6 5.2	VALUE (units 10 ⁻⁴) CL% 0.8±0.5 • • • We do not use the following constant of the follow	BRANDELIK 79C DASP e+eng data for averages, fits, limits, etc. FELDMAN 77 MRK1 e+e	MENT • • • • - □ F ₂₂ /
	HIMEL 80 MRK2 0.1 OREGLIA 80 CBAL 1.6 BARTEL 78B CNTR 3.6 5.2 (Confidence Level = 0.073)	$ \begin{array}{ccc} & & & & & & & & & & & & \\ \hline \textbf{0.8 \pm 0.5} & \bullet & \bullet & & & & & & \\ \bullet & \bullet & & & & & &$	BRANDELIK 79C DASP $e^+\epsilon$ or additional properties of the BRANDELIK 79C DASP $e^+\epsilon$ or additional properties of the BRANDELIK $e^+\epsilon$	<u>MENT</u> • • • • • Γ ₂₂ / <u>MENT</u> → hadrons
$0 0.01 0.0$ $\Gamma(J/\psi(1S)\eta)/\Gamma_{\text{total}}$	HIMEL 80 MRK2 0.1 OREGLIA 80 CBAL 1.6 BARTEL 78B CNTR 3.6 5.2 (Confidence Level = 0.073)	VALUE (units 10 ⁻⁴) CL% 0.8±0.5 • • • We do not use the following constant of the follow	BRANDELIK 79C DASP e+eng data for averages, fits, limits, etc. FELDMAN 77 MRK1 e+e	MENT F ₂₂ / MENT → hadrons F ₂₄ /

 $\psi(2S), \psi(3770)$

(<i>Ξ</i> − Ξ +)/Γ _{total}						Γ ₂₅ /Γ
4LUE (units 10 ⁻⁴)	CL%	DOCUMENT ID	77	TECN	e+e-	
(2	90	FELDMAN	77	MRK1	e · e	
$(\rho\pi)/\Gamma_{total}$						Γ ₂₆ /Γ
ALUE (units 10 ⁻⁴) CL% C 0.83 90		DOCUMENT ID FRANKLIN	83		COMMENT	
We do not use the						
10 90		BARTEL	76		e^+e^-	
(10 90		¹³ ABRAMS	75	MRK1	e+ e-	
$(K^+K^-\pi^0)/\Gamma_{\text{total}}$						Γ ₂₇ /Γ
ALUE (units 10 ⁻⁵) CL%	EVTS	DOCUMENT ID			COMMENT	
(2.96 90	1	FRANKLIN	83	MRK2	e ⁺ e ⁻ →	hadrons
$(K^{+}\overline{K}^{*}(892)^{-}+c.6$	c.)/Γ _{tot}	al				Γ ₂₈ /Γ
ALUE (units 10 ⁻⁵)	CL%	DOCUMENT ID			COMMENT	
(5.4	90	FRANKLIN	83	MRK2	e ⁺ e ⁻ →	hadrons
12 Assuming entirely str 13 Final state $ ho^0 \pi^0$.	ong deca	y.				
i mai state p n .	_					
	— н	ADIATIVE DE	CAY	5		
$(\gamma \chi_{c0}(1P))/\Gamma_{total}$						Γ ₂₉ /Γ
4LUE (units 10 ⁻²) .3±0.8 OUR AVERAGE	=	DOCUMENT ID		TECN	COMMENT	
9±0.5±0.8	-	¹⁴ GAISER	86	CBAL		
2±2.3		¹⁴ BIDDICK	77		e^+e^-	γX
5±2.6		¹⁴ WHITAKER	76	MRK1	e ⁻ e ⁻	
$(\gamma \chi_{c1}(1P))/\Gamma_{total}$						Γ₃₀/ Γ
ALUE (units 10 ⁻²) .7±0.8 OUR FIT		DOCUMENT ID		TECN	COMMENT	
.7±0.8 OUR AVERAGE	Ē					
0±0.5±0.7		15 GAISER	86	CBAL		
1 ± 1.9		¹⁶ BIDDICK	77	CNTR	e ⁺ e ⁻ →	γX
$(\gamma \chi_{c2}(1P))/\Gamma_{total}$						Γ_{31}/Γ
4LUE (units 10 ⁻²)		DOCUMENT ID		TECN	COMMENT	
.8±0.8 OUR FIT .8±0.8 OUR AVERAGE	E					
$0 \pm 0.5 \pm 0.7$		17 GAISER	86	CBAL		
.0 ± 2.0		¹⁶ BIDDICK	77	CNTR	$e^+e^- \rightarrow$	γX
$(\gamma \eta_c(1S))/\Gamma_{total}$						Γ ₃₂ /Γ
ALUE (units 10 ⁻²)		DOCUMENT ID			COMMENT	
.28±0.06		GAISER	86	CBAL	e ⁺ e ⁻ →	γX
$(\gamma \eta_c(25))/\Gamma_{\text{total}}$						Г ₃₃ /Г
	CL%	DOCUMENT ID			COMMENT	
We do not use the						
2 to 1.3	95	EDWARDS	820	CBAL	e ⁺ e [−] →	γΧ
$(\gamma\pi^0)/\Gamma_{ m total}$						Γ ₃₄ /Γ
ALUE (units 10 ⁻⁴)	CL%	DOCUMENT ID			COMMENT	
 54 • We do not use the 	95 e followin	¹⁸ LIBERMAN g data for averag		SPEC s. limits.	e ⁺ e	
100	90	g data for averag WIIK		DASP		
						- 1-
$(\gamma \eta'(958))/\Gamma_{\text{total}}$	CLAY	DOCUMENT :-		TECH	course-	Γ ₃₅ /Γ
4LUE (units 10 ⁻²)	90	DOCUMENT ID 19 BARTEL	76	TECN CNTR	COMMENT	- 1000,
• We do not use the						
<0.6	90	²⁰ BRAUNSCH	. 77	DASP	e+ e-	
$(\gamma \eta)/\Gamma_{\text{total}}$						Γ ₃₆ /Γ
4LUE (units 10 ⁻²)	CL%	DOCUMENT ID		TECN	COMMENT	- 30, -
• • We do not use the	e followin					
<0.02	90	YAMADA	77	DASP	$e^+e^ \rightarrow$	3γ
$(\gamma \eta(1440) \rightarrow \gamma K \overline{K})$	$(\pi)/\Gamma_{to}$	tal				Γ ₃₈ /Γ
	CL%	DOCUMENT ID		TECN	COMMENT	
4LUE (units 10 ⁻³)	90	21 SCHARRE	80		e+ e-	
4LUE (units 10 ⁻³) < 0.12						
<0.12 14 Angular distribution						
<0.12 14 Angular distribution 15 Angular distribution	(1-0.189)	$\cos^2\theta$) assumed.				
C0.12 ¹⁴ Angular distribution ¹⁵ Angular distribution ¹⁶ Valid for isotropic dis ¹⁷ Angular distribution	(1-0.189 stribution (1-0.052	$\cos^2 \theta$) assumed of the photon. $\cos^2 \theta$) assumed				
<0.12 14 Angular distribution 15 Angular distribution	(1-0.189) stribution (1-0.052) $B(\psi(2S))$	$\cos^2\theta$) assumed of the photon. $\cos^2\theta$) assumed $\rightarrow \mu^+\mu^-$) = 0	0.0077			

$\psi(2S)$ REFERENCES

ANTONIAZZI	94	PR D50 4258	+Arenton+	(E705 Collab.)	
ARMSTRONG	93B	PR D47 772	+Bettoni, Bharadwaj+	(FNAL E760 Collab.)	
PDG	92	PR D45, 1 June, Part		(KEK, LBL, BOST+)	
ALEXANDER	89	NP B320 45	+Bonvicini, Drell, Frey, Luth		
GAISER	86	PR D34 711	+Bloom, Bulos, Godfrey+	(Crystal Ball Collab.)	
FRANKLIN	83	PRL 51 963	+Franklin, Feldman, Abrams, Alam+		
EDWARDS	82C	PRL 48 70	+Partridge, Peck+ (CIT, HARV,		
LEMOIGNE	82	PL 113B 509	+Barate, Astbury+ (SAC		
HIMEL	80	PRL 44 920	+Abrams, Alam, Blocker+		
OREGLIA	80	PRL 45 959		HARV, PRIN, STAN)	
SCHARRE	80	PL 97B 329	+Trilling, Abrams, Alam, Blocker+		
ZHOLENTZ	80	PL 96B 214	+Kurdadze, Lelchuk, Mishnev+	(NOVO)	
Also	81	SJNP 34 814	Zholentz, Kurdadze, Lelchuk+	(NOVO)	
		Translated from YAF 3		(,	
BRANDELIK	79B	NP B160 426	+Cords+	(DASP Collab.)	
BRANDELIK	79C	ZPHY C1 233	+Cords+	(DASP Collab.)	
BARTEL	78B	PL 79B 492	+Dittmann, Duinker, Olsson, O'Neill+	(DESY, HEIDP)	
TANENBAUM	78	PR D17 1731	+Alam, Boyarski+	(SLAC, LBL)	
BIDDICK	77	PRL 38 1324	+Burnett+ (UCSD, UMD, PAVI,	, PRIN, SLAC, STAN)	
BRAUNSCH	77	PL 67B 249	Braunschweig+	(DASP Collab.)	
BURMESTER	77	PL 66B 395	+Criegee+ (DESY,	HAMB, SIEG, WUPP)	
FELDMAN	77	PRPL 33C 285	+Perl	(LBL, SLAC)	
YAMADA	77	Hamburg Conf. 69		(DASP Collab.)	
BARTEL	76	PL 64B 483	+Duinker, Olsson, Steffen, Heintze+	(DESY, HEIDP)	
TANENBAUM	76	PRL 36 402	+Abrams, Boyarski, Bulos+	(SLAC, LBL)	IG
WHITAKER	76	PRL 37 1596	+Tanenbaum, Abrams, Alam+	(SLAC, LBL)	
ABRAMS	75	Stanford Symp. 25		(LBL)	
ABRAMS	75B	PRL 34 1181	+Briggs, Chinowsky, Friedberg+	(LBL, SLAC)	
BOYARSKI	75C	Palermo Conf. 54	+Breidenbach, Bulos, Abrams, Briggs-		
HILGER	75	PRL 35 625	+Beron, Ford, Hofstadter, Howell+	(STAN, PENN)	
LIBERMAN	75		,,	(STAN)	
LUTH	75	PRL 35 1124	+Boyarski, Lynch, Breidenbach+	(SLAC, LBL)	JPC
WIIK	75	Stanford Symp. 69		(DESY)	

- OTHER RELATED PAPERS -

LEE	85	SLAC 282		(SLAC)
BARATE	83	PL 121B 449	+Bareyre, Bonamy+ (SAC	CL, LOIC, SHMP, IND)
FRANKLIN	83B	Thesis SLAC-0254		(STAN)
AUBERT	75B	PRL 33 1624	+Becker, Biggs, Burger, Glenn+	(MIT, BNL)
BRAUNSCH	75B	PL 57B 407	Braunschweig, Konigs+	(DASP Collab.)
CAMERINI	75	PRL 35 483	+Learned, Prepost, Ash, Anderson+	(WISC, SLAC)
FELDMAN	75B	PRL 35 821	+Jean-Marie, Sadoulet, Vannucci+	(LBL, SLAC)
GRECO	75	PL 56B 367	+Pancheri-Srivastava, Srivastava	(FRAS)
JACKSON	75	NIM 128 13	+Scharre	(LBL)
SIMPSON	75	PRL 35 699	+Beron, Ford, Hilger, Hofstadter+	(STAN, PENN)
ABRAMS	74	PRL 33 1453	+Briggs, Augustin, Boyarski+	(LBL, SLAC)



$$I^{G}(J^{PC}) = ?^{?}(1^{--})$$

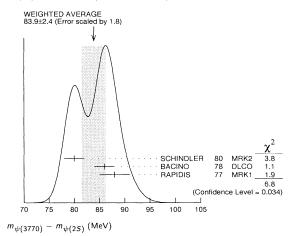
ψ (3770) MASS

 $^{1}\,\mathrm{Errors}$ include systematic common to all experiments.

$m_{\psi(3770)} - m_{\psi(2S)}$

VAL	UE (MeV)	DOCUMENT ID		TECN	COMMENT
83.9	±2.4 OUR AVERAGE	Error includes scale fact	or of	1.8. See	the ideogram below.
80	± 2	SCHINDLER	80	MRK2	e+ e-
86	± 2	² BACINO	78	DLCO	e+ e-
88	± 3	RAPIDIS	77	MRK1	e+ e-

 $^2\,\mathrm{SPEAR}~\psi(2S)$ mass subtracted (see SCHINDLER 80).



ψ (3770) WIDTH	$\psi(4$	040) PARTIAL WIDTHS
DOCUMENT ID TECN COMMENT	Γ(e ⁺ e ⁻)	Γ,
ludes scale factor of 1.1.	VALUE (keV)	DOCUMENT ID TECN COMMENT
SCHINDLER 80 MRK2 e ⁺ e ⁻	0.75±0.15	BRANDELIK 78c DASP e ⁺ e ⁻
BACINO 78 DLCO e ⁺ e ⁻	ψ(404	10) BRANCHING RATIOS
RAPIDIS // MRK1 e' e	• •	•
ψ (3770) DECAY MODES	•	Γ ₁ /Γ
Frankley (F. /F)		g data for averages, fits, limits, etc. • •
· · · · · · · · · · · · · · · · · · ·	~ 1.0	FELDMAN 77 MRK1 e ⁺ e ⁻
_	. F(D0万0) /F(D*(2007)0万0。	LCC) [-/[.
(1.12±0.17) \(\tau \)	VALUE (2001) D	Fc.c.) F ₂ /F:
(3770) PARTIAL WIDTHS	0.05 ±0.03	1 GOLDHABER 77 MRK1 $e^{+}e^{-}$
Гэ	1 Phase-space factor (p^3) explic	citly removed.
DOCUMENT ID TECN COMMENT	$\Gamma(D^*(2007)^0 \overline{D}^*(2007)^0)/\Gamma($	$(D^*(2007)^0\overline{D}^0 + \text{c.c.})$ Γ_4/Γ_3
r includes scale factor of 1.2.	VALUE	DOCUMENT ID TECN COMMENT
SCHINDLER 80 MRK2 e^+e^-		² GOLDHABER 77 MRK1 e ⁺ e ⁻
BACINO 78 DLCO e^+e^-	² Phase-space factor (p ³) explic	citly removed.
	ψ	(4040) REFERENCES
	·	` '
Delow.	Also 79C ZPHY C1 233	Brandelik, Cords+ (DASP Collab.)
3770) BRANCHING RATIOS	GOLDHABER 77 PL 69B 503	+Perl (LBL, SLAC) +Wiss, Abrams, Alam+ (Mark I Collab.)
Г./Г	отн	IER RELATED PAPERS
DOCUMENT ID TECN COMMENT	HEIKKILA 84 PR D29 110	+Tornqvist, Ono (HELS, AACHT)
PERUZZI 77 MRK1 $e^+e^- \rightarrow D\overline{D}$	ONO 84 ZPHY C26 307 SIEGRIST 82 PR D26 969	(ORSAY) +Schwitters, Alam, Chinowsky+ (SLAC, LBL)
Гэ/Г	AUGUSTIN 75 PRL 34 764 BACCI 75 PL 58B 481	+Boyarski, Abrams, Briggs+ (SLAC, LBL) +Bidoli, Penso, Stella+ (ROMA, FRAS)
DOCUMENT ID TECN COMMENT	BOYARSKI 75B PRL 34 762 ESPOSITO 75 PL 58B 478	+Breidenbach, Abrams, Briggs+ (SLAC, LBL) +Felicetti, Peruzzi+ (FRAS, NAPL, PADO, ROMA)
ocludes scale factor of 1.2.		
RAPIDIS 77 MRK1 e ⁺ e ⁻	a/\(\d160\)	$I^{G}(J^{PC}) = ?^{?}(1^{-})$
ψ (3770) REFERENCES	$\varphi(4100)$	(-) (-)
+Siegrist, Alam, Bovarski+ (Mark II Collab.)		
+Baumgarten, Birkwood+ (SLAC, UCLA, UCI)		ψ (4160) MASS
+Gobbi, Luke, Barbaro-Galtieri+ (Mark Collab.)	VALUE (MeV)	DOCUMENT ID TECN COMMENT
	4159±20	BRANDELIK 78C DASP e ⁺ e ⁻
$I^{G}(J^{PC}) = ?^{?}(1^{-})$	4159±20 ————————————————————————————————————	
$I^{G}(J^{PC}) = ?^{?}(1^{-})$	4159±20	BRANDELIK 78C DASP $e^+e^ \psi$ (4160) WIDTH
	VALUE (MeV)	ψ(4160) WIDTH DOCUMENT ID TECN COMMENT
$I^{G}(J^{PC}) = ?^{?}(1^{-})$ ψ (4040) MASS		ψ (4160) WIDTH
ψ(4040) MASS DOCUMENT ID TECN COMMENT	<u>VALUE (MeV)</u> 78±20	ψ(4160) WIDTH DOCUMENT ID TECN COMMENT BRANDELIK 78c DASP e ⁺ e ⁻
ψ(4040) MASS	<u>VALUE (MeV)</u> 78±20	ψ(4160) WIDTH DOCUMENT ID TECN COMMENT
ψ (4040) MASS DOCUMENT ID TECN COMMENT BRANDELIK 78C DASP \dot{e}^+e^-	<u>VALUE (MeV)</u> 78±20 ψ(. Mode	ψ(4160) WIDTH DOCUMENT ID TECN COMMENT BRANDELIK 78c DASP e ⁺ e ⁻
ψ (4040) MASS DOCUMENT ID TECN COMMENT BRANDELIK 78C DASP $\dot{e}^+e^ \psi$ (4040) WIDTH	<u>VALUE (MeV)</u> 78±20 ψ(.	ψ(4160) WIDTH DOCUMENT ID TECN COMMENT BRANDELIK 78C DASP e ⁺ e ⁻ 4160) DECAY MODES
ψ(4040) MASS DOCUMENT ID TECN COMMENT BRANDELIK 78C DASP e+e- ψ(4040) WIDTH DOCUMENT ID TECN COMMENT	$VALUE (MeV)$ 78±20 $\psi(e^{-1})$ Mode $\Gamma_1 = e^+ e^-$	ψ (4160) WIDTH $\underline{pOCUMENT\ ID}$ \underline{TECN} $COMMENT$ $BRANDELIK$ $78c$ $DASP$ e^+e^- 4160) DECAY MODES Fraction (Γ_j/Γ) $(10\pm 4)\times 10^{-6}$
ψ (4040) MASS DOCUMENT ID TECN COMMENT BRANDELIK 78C DASP $\dot{e}^+e^ \psi$ (4040) WIDTH	78 \pm 20 $\psi(\cdot)$ Mode $\Gamma_1 e^+ e^-$ $\psi(4)$	ψ (4160) WIDTH DOCUMENT ID TECN COMMENT BRANDELIK 78C DASP e^+e^- 4160) DECAY MODES Fraction $(\Gamma_{\bar{I}}/\Gamma)$
ψ(4040) MASS DOCUMENT ID TECN COMMENT BRANDELIK 78C DASP e+e- ψ(4040) WIDTH DOCUMENT ID TECN COMMENT	$\frac{VALUE \text{ (MeV)}}{78\pm20}$ $\frac{\psi(4)}{\Gamma_1 e^+e^-}$ $\psi(4)$ $\Gamma(e^+e^-)$	ψ (4160) WIDTH $\frac{DOCUMENT\ ID}{BRANDELIK}$ $\frac{TECN}{78C}$ $\frac{COMMENT}{e^+e^-}$ 4160) DECAY MODES Fraction (Γ_j/Γ) $(10\pm 4)\times 10^{-6}$ L60) PARTIAL WIDTHS
ψ(4040) MASS DOCUMENT ID TECN COMMENT BRANDELIK 78C DASP e+e- ψ(4040) WIDTH DOCUMENT ID TECN COMMENT BRANDELIK 78C DASP e+e- ψ(4040) DECAY MODES	VALUE (MeV) 78±20 ψ Mode $\Gamma_1 e^+ e^ \psi$ ψ ψ ψ ψ ψ ψ	ψ (4160) WIDTH DOCUMENT ID TECN COMMENT BRANDELIK 78c DASP e^+e^- 4160) DECAY MODES Fraction (Γ_i/Γ) $(10\pm4)\times10^{-6}$ 160) PARTIAL WIDTHS DOCUMENT ID TECN COMMENT
ψ (4040) MASS DOCUMENT ID TECN COMMENT BRANDELIK 78C DASP $\dot{e}^+e^ \psi$ (4040) WIDTH DOCUMENT ID TECN COMMENT BRANDELIK 78C DASP $e^+e^ \psi$ (4040) DECAY MODES Fraction (Γ_i/Γ)	$\frac{VALUE \text{ (MeV)}}{78\pm20}$ $\frac{\psi(4)}{\Gamma_1 e^+e^-}$ $\psi(4)$ $\Gamma(e^+e^-)$	ψ (4160) WIDTH $\frac{DOCUMENT\ ID}{BRANDELIK}$ $78C\ DASP\ e^{+}e^{-}$ 4160) DECAY MODES Fraction (Γ_{j}/Γ) $(10\pm4)\times10^{-6}$ L60) PARTIAL WIDTHS
ψ (4040) MASS DOCUMENT ID TECN COMMENT BRANDELIK 78C DASP $\dot{e}^+e^ \psi$ (4040) WIDTH DOCUMENT ID TECN COMMENT BRANDELIK 78C DASP $e^+e^ \psi$ (4040) DECAY MODES Fraction (Γ_I/Γ) $(1.4 \pm 0.4) \times 10^{-5}$	$VALUE (MeV)$ 78 ± 20 $\psi(4)$ $Mode$ $\Gamma_1 e^+e^-$ $\psi(4)$ $\Gamma(e^+e^-)$ $VALUE (keV)$ 0.77 ± 0.23	ψ (4160) WIDTH $\underline{pOCUMENT\ ID}$ \underline{TECN} $COMMENT$
ψ (4040) MASS DOCUMENT ID TECN COMMENT BRANDELIK 78C DASP $\dot{e}^+e^ \psi$ (4040) WIDTH DOCUMENT ID TECN COMMENT BRANDELIK 78C DASP $e^+e^ \psi$ (4040) DECAY MODES Fraction (Γ_I/Γ) $(1.4\pm0.4)\times10^{-5}$ seen	$VALUE (MeV)$ 78 ± 20 $\psi(4)$ $Mode$ $\Gamma_1 e^+e^ \psi(4)$ $\Gamma(e^+e^-)$ $VALUE (keV)$ 0.77 ± 0.23	ψ(4160) WIDTH
ψ (4040) MASS DOCUMENT ID TECN COMMENT BRANDELIK 78C DASP $\dot{e}^+e^ \psi$ (4040) WIDTH DOCUMENT ID TECN COMMENT BRANDELIK 78C DASP $e^+e^ \psi$ (4040) DECAY MODES Fraction (Γ_I/Γ) $(1.4 \pm 0.4) \times 10^{-5}$	$VALUE (MeV)$ 78 ± 20 $\psi(e)$ Mode $\Gamma_1 e^+e^ \psi(4)$ $\Gamma(e^+e^-)$ $VALUE (keV)$ 0.77±0.23 ψ BRANDELIK 78C PL 76B 361	$ψ$ (4160) WIDTH $DOCUMENT ID DOS Fraction (Γi/Γ)$ (10±4) × 10 ⁻⁶ 160) PARTIAL WIDTHS $DOCUMENT ID TECN COMMENT DOCUMENT ID TECN E+e^-$ (4160) REFERENCES $+ Cords+ (DASP Collab.)$
ψ (4040) MASS DOCUMENT ID TECN COMMENT BRANDELIK 78C DASP $e^+e^ \psi$ (4040) WIDTH DOCUMENT ID TECN COMMENT BRANDELIK 78C DASP $e^+e^ \psi$ (4040) DECAY MODES Fraction (Γ_I/Γ) $(1.4 \pm 0.4) \times 10^{-5}$ seen seen	$VALUE (MeV)$ 78 ± 20 $\psi(e)$ Mode $\Gamma_1 e^+e^ \psi(4)$ $\Gamma(e^+e^-)$ $VALUE (keV)$ 0.77±0.23 ψ BRANDELIK 78C PL 76B 361	$ψ$ (4160) WIDTH $pOCUMENT\ ID$ $POCUMENT\ $
	Rudes scale factor of 1.1. SCHINDLER 80 MRK2 e^+e^- BACINO 78 DLCO e^+e^- RAPIDIS 77 MRK1 e^+e^- P(3770) DECAY MODES Fraction (i^{I}/Γ) Scale factor dominant $(1.12\pm0.17)\times10^{-5}$ 1.2 (3770) PARTIAL WIDTHS TECN COMMENT ID TECN COMMENT includes scale factor of 1.2. Error includes scale factor of 1.2. SCHINDLER 80 MRK2 e^+e^- BACINO 78 DLCO e^+e^- wing data for averages, fits, limits, etc. • • • • 3 RAPIDIS 77 MRK1 e^+e^- below. TOOLUMENT ID TECN COMMENT includes to a comparation of the comparation	Indes scale factor of 1.1. SCHINDLER 80 MRK2 e^+e^- BACINO 78 DLCO e^+e^- RAPIDIS 77 MRK1 $e^+e^ \psi(3770)$ DECAY MODES Fraction (Γ_I/Γ) Scale factor dominant $(1.12\pm0.17)\times10^{-5}$ 1.2 GAMENT ID TECN COMMENT ID Includes scale factor of 1.2. SCHINDLER 80 MRK2 e^+e^- BACINO 78 DLCO e^+e^- Wing data for averages, fits, limits, etc. • • • • • • We do not use the following a RAPIDIS 77 MRK1 e^+e^- Declow. Fig. 1770) BRANCHING RATIOS F1/ Γ DOCUMENT ID TECN COMMENT ID TECN SCHINDLER 80 MRK2 e^+e^- BACINO 78 DLCO e^+e^- Wing data for averages, fits, limits, etc. • • • • • • • • • • • • • • • • • • •

 ψ (4415)

2/	(4415)	$I^{G}(J^{PC}) = ?$?(1)			$\psi(441$	5) PARTIAL	WIDTHS		
Ψ	(4413)			Γ(e ⁺ e ⁻) VALUE (keV)			DOCUMENT ID	TECN	COMMEN	,,,
		ψ (4415) MASS		0.47±0.10	OUR	AVERAGE	DOCUMENT 1D	- ILCN	COMMEN	
		, ,		0.49 ± 0.13			BRANDELIK	78C DASP		
	E (MeV)	DOCUMENT ID TECN	COMMENT	0.44 ± 0.14			SIEGRIST	76 MRK1	e+e-	
	15± 6 OUR AVERAGE 17±10	BRANDELIK 78C DASP	e+e-			J/441E	DDANCUIA	C DATIOC		
	14± 7	SIEGRIST 76 MRK1				Ψ(4415)) BRANCHIN	IG KATIOS		
• • •	We do not use the fol	lowing data for averages, fits, limits		Γ(hadrons	s)/[total				Γ ₁ /
~ 44	00	KNIES 77 PLUT	$e^+e^- \rightarrow \mu^+\mu^-$	VALUE			DOCUMENT ID			
				dominant			SIEGRIST	76 MRK1	e^+e^-	
		ψ (4415) WIDTH					-			***************************************
						$\psi(4$	415) REFER	ENCES		
	E (MeV) 15 OUR AVERAGE Er	ror includes scale factor of 1.8.	COMMENT	BRANDELIK	780	PL 76B 361	+Cords+			(DASP Collab.)
66±		BRANDELIK 78C DASP	a+ a-	KNIES	77	Hamburg Symp. 93			(F	PLUTO Collab.)
33 ±		SIEGRIST 76 MRK1		SIEGRIST	76	PRL 36 700	+Abrams, Boyar	ski, Breidenbach	+	(LBL, SLAC)
		SIZGRIST TO MINITE				OTHE	R RELATED	PAPERS -		
		ψ (4415) DECAY MODES		BURMESTER LUTH	77 77	PL 66B 395 PL 70B 120	+Criegee+ +Pierre, Abrams			, SIEG, WUPP) (LBL, SLAC)
	Mode	Fraction (F ₁	/r)							
Γ1	hadrons	dominant								
Γ ₂	e+ e-	(1.1±0.4) ×	10-5							
2		(

Γ2

 Γ_1/Γ

Meson Particle Listings Bottomonium

bb MESONS

WIDTH DETERMINATIONS OF THE Υ STATES

As is the case for the $J/\psi(1S)$ and $\psi(2S)$, the full widths of the $b\overline{b}$ states $\Upsilon(1S)$, $\Upsilon(2S)$, and $\Upsilon(3S)$ are not directly measurable, since they are much narrower than the energy resolution of the e^+e^- storage rings where these states are produced. The common indirect method to determine Γ starts from

$$\Gamma = \Gamma_{\ell\ell}/B_{\ell\ell} \ , \tag{1}$$

where $\Gamma_{\ell\ell}$ is one leptonic partial width and $B_{\ell\ell}$ is the corresponding branching fraction ($\ell=e, \mu, \text{ or } \tau$). One then assumes e- μ - τ universality and uses

$$\Gamma_{\ell\ell} = \Gamma_{ee}$$

$$B_{\ell\ell} = \text{average of } B_{ee}, \ B_{\mu\mu}, \ \text{and } B_{\tau\tau} \ .$$
 (2)

The electronic partial width Γ_{ee} is also not directly measurable at e^+e^- storage rings, only in the combination $\Gamma_{ee}\Gamma_{\rm had}/\Gamma$, where $\Gamma_{\rm had}$ is the hadronic partial width and

$$\Gamma_{\text{had}} + 3\Gamma_{ee} = \Gamma \ . \tag{3}$$

This combination is obtained experimentally from the energy-integrated hadronic cross section

$$\int \sigma(e^+e^- \to \Upsilon \to \text{hadrons})dE$$

resonanc

$$=\frac{6\pi^2}{M^2}\frac{\Gamma_{ee}\Gamma_{\rm had}}{\Gamma}C_r = \frac{6\pi^2}{M^2}\frac{\Gamma_{ee}^{(0)}\Gamma_{\rm had}}{\Gamma}C_r^{(0)} , \qquad (4)$$

where M is the Υ mass, and C_r and $C_r^{(0)}$ are radiative correction factors. C_r is used for obtaining Γ_{ee} as defined in Eq. (1), and contains corrections from all orders of QED for describing $(b\bar{b}) \to e^+e^-$. The lowest order QED value $\Gamma_{ee}^{(0)}$, relevant for comparison with potential-model calculations, is defined by the lowest order QED graph (Born term) alone, and is about 7% lower than Γ_{ee} .

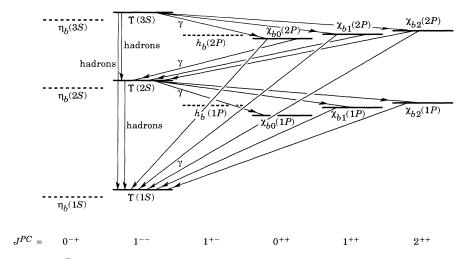
THE BOTTOMONIUM SYSTEM

Υ (11020)

Υ (10860)

 $\Upsilon(4S)$

 $B\overline{B}$ threshold



The level scheme of the $b\bar{b}$ states showing experimentally established states with solid lines. Singlet states are called η_b and h_b , triplet states Υ and χ_{bJ} . In parentheses it is sufficient to give the radial quantum number and the orbital angular momentum to specify the states with all their quantum numbers. E.g., $h_b(2P)$ means 2^1P_1 with n=2, L=1, S=0, J=1, PC=+-. If found, D-wave states would be called $\eta_b(nD)$ and $\Upsilon_J(nD)$, with J=1,2,3 and $n=1,2,3,4,\cdots$. For the χ_b states, the spins of only the $\chi_{b2}(1P)$ and $\chi_{b1}(1P)$ have been experimentally established. The spins of the other χ_b are given as the preferred values, based on the quarkonium models. The figure also shows the observed hadronic and radiative transitions.

Bottomonium, $\Upsilon(1S)$

The Listings give experimental results on B_{ee} , $B_{\mu\mu}$, $B_{\tau\tau}$, and $\Gamma_{ee}\Gamma_{\rm had}/\Gamma$. The entries of the last quantity have been re-evaluated consistently using the correction procedure of KURAEV 85.The partial width Γ_{ee} is obtained from the average values for $\Gamma_{ee}\Gamma_{\rm had}/\Gamma$ and $B_{\ell\ell}$ using

$$\Gamma_{ee} = \frac{\Gamma_{ee}\Gamma_{had}}{\Gamma(1 - 3B_{\ell\ell})} \ . \tag{5}$$

The total width Γ is then obtained from Eq. (1). We do not list Γ_{ee} and Γ values of individual experiments. The Γ_{ee} values in the Meson Summary Table are also those defined in Eq. (1).



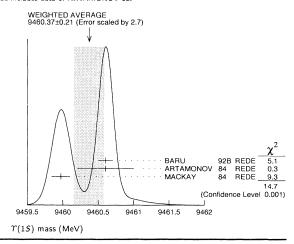
$$I^{G}(J^{PC}) = 0^{-}(1^{-})$$

$\Upsilon(1S)$ MASS

VALUE (MeV)	DOCUMENT ID	TECN COMMENT
9460.37±0.21 OUR AVERAGE	Error includes scal below.	e factor of 2.7. See the ideogram
$9460.60\pm0.09\pm0.05$	¹ BARU	928 REDE $e^+e^- \rightarrow \text{hadrons}$
9460.6 ±0.4	² ARTAMONOV	84 REDE $e^+e^- \rightarrow \text{hadrons}$
$9459.97 \pm 0.11 \pm 0.07$	MACKAY	84 REDE $e^+e^- \rightarrow \text{hadrons}$
• • • We do not use the follow	ing data for average	s, fits, limits, etc. • • •
$9460.59 \!\pm\! 0.12$	BARU	86 REDE $e^+e^- \rightarrow \text{hadrons}$

¹ Superseding BARU 86.

² Value includes data of ARTAMONOV 82.



r(1s) WIDTH

VALUE (keV)	DOCUMENT ID
52.5±1.8 OUR EVALUATION	See Υ mini-review.

$\Upsilon(1S)$ DECAY MOD	ΞÇ

	Mode	Fraction (Γ_i/Γ)	Scale factor/ Confidence level
Γ_1	$\tau^+\tau^-$	(2.67+0.14) %	
Γ ₂ Γ ₃	$e^{+}e^{-}\ \mu^{+}\mu^{-}$	(2.52±0.17) %	
Γ_3	$\mu^+\mu^-$	(2.48 ± 0.07) %	S=1.1
	. Ha	adronic decays	
Γ_4	$J/\psi(1S)$ anything	(1.1 ±0.4) × 10	-3
Γ_5	$ ho\pi$	< 2 × 10	-4 CL=90%
Γ ₅ Γ ₆ Γ ₇	$\pi^+\pi^-$	< 5 × 10	-4 CL=90%
Γ_7	K ⁺ K ⁻	< 5 × 10	-4 CL=90%
Г ₈ Г9	$p\overline{p}$ $D^*(2010)^\pm$ anything	< 5 × 10	4 CL=90%

	Radiative de	ays		
Γ_{10}		(7.0 ±1.	$5) \times 10^{-4}$	
	$\gamma 3h^+3h^-$		$0) \times 10^{-4}$	
Γ_{12}	γ 4 h^+ 4 h^-	$(7.4 \pm 3.$	5) $\times 10^{-4}$	
	$\gamma\pi^+\pi^-K^+K^-$	$(2.9 \pm 0.$	9) $\times 10^{-4}$	
	$\gamma 2\pi^+ 2\pi^-$	$(2.5 \pm 0.$	9) $\times 10^{-4}$	
	$\gamma 3\pi^+ 3\pi^-$	$(2.5 \pm 1.$	$2) \times 10^{-4}$	
	$\gamma 2\pi^{+}2\pi^{-}K^{+}K^{-}$	$(2.4 \pm 1.$	$2) \times 10^{-4}$	
	$\gamma \pi^+ \pi^- \rho \overline{\rho}$	$(1.5 \pm 0.$	6) \times 10 ⁻⁴	
	$\gamma 2\pi^+ 2\pi^- \rho \overline{\rho}$	(4 ± 6)) × 10 ⁻⁵	
	$\gamma 2K^+2K^-$	$(2.0 \pm 2.$	0) $\times 10^{-5}$	
Γ ₂₀	$\gamma \eta'(958)$	< 1.3	\times 10 ⁻³	CL=90%
	$\gamma\eta$	< 3.5	× 10 ⁻⁴	CL=90%
	$\gamma f_2'(1525)$	< 1.4	× 10 ⁻⁴	CL=90%
	$\gamma f_2(1270)$	< 1.3	$\times 10^{-4}$	CL=90%
	$\gamma \eta (1440)$	< 8.2	$\times 10^{-5}$	CL=90%
	$\gamma f_J(1710) \rightarrow \gamma K \overline{K}$	< 2.6	× 10 ⁻⁴	CL=90%
	$\gamma f_0(2200) \rightarrow \gamma K^+ K^-$	< 2	× 10 ⁻⁴	CL=90%
	$\gamma f_J(2220) \rightarrow \gamma K^+ K^-$	< 1.5	× 10 ⁻⁵	CL=90%
	$\gamma \eta(2225) \rightarrow \gamma \phi \phi$	< 3	\times 10 ⁻³	CL=90%
Γ_{29}	γ^{X}	< 3	\times 10 ⁻⁵	CL=90%
_	X = pseudoscalar with m < 7.2 GeV		2	
Γ ₃₀	$\frac{\gamma X \overline{X}}{\overline{X}}$	< 1	× 10 ⁻³	CL=90%
	XX = vectors with m < 3.1 GeV			

$\Upsilon(1S) \Gamma(i)\Gamma(e^+e^-)/\Gamma(total)$

$\Gamma(e^+e^-) \times \Gamma(\mu^+\mu^-)/\Gamma_{ m total}$	I				$\Gamma_2\Gamma_3/\Gamma$
VALUE (eV)	DOCUMENT ID		TECN	COMMENT	
31.2±1.6±1.7	KOBEL	92	CBAL	$e^+e^- \rightarrow$	$\mu^+\mu^-$
$\Gamma(\text{hadrons}) \times \Gamma(e^+e^-)/\Gamma_{\text{tot}}$	al				$\Gamma_0\Gamma_2/\Gamma$
VALUE (keV)	DOCUMENT ID		TECN	COMMENT	
1.216±0.027 OUR AVERAGE					
$1.187 \pm 0.023 \pm 0.031$				$e^+e^- \rightarrow$	
$1.23 \pm 0.02 \pm 0.05$	3 JAKUBOWSKI	88	CBAL	$e^+e^- \rightarrow$	hadrons
1.37 ±0.06 ±0.09	⁴ GILES	84B	CLEO	$e^+e^- \rightarrow$	hadrons
$1.23 \pm 0.08 \pm 0.04$	⁴ ALBRECHT				
$1.13 \pm 0.07 \pm 0.11$	4 NICZYPORUK				
1.09 ±0.25	⁴ BOCK	80	CNTR	$e^+e^- \rightarrow$	hadrons
1.35 ±0.14	⁵ BERGER	79	PLUT	$e^+e^- \rightarrow$	hadrons
ullet $ullet$ We do not use the following	data for averages	, fits	, limits,	etc. • • •	
$1.17 \pm 0.06 \pm 0.10$	⁴ TUTS	83	CUSB	$e^+e^- \rightarrow$	hadrons
 Radiative corrections evaluated Radiative corrections reevaluate Radiative corrections reevaluate 	ed by BUCHMUE	LLEF	R 88 follo	owing KUR $\beta(\mu\mu)=0.0$	AEV 85. 026.

$\Upsilon(1S)$ PARTIAL WIDTHS

Γ(e + e-)				Γ_2
VALUE (keV)	DOCUMENT ID	TECN	COMMENT	
1.32±0.04±0.03	6 ALBRECHT 95	E ARG	$e^+e^- \rightarrow hadrons$	
6 Applying the formula of	Kuraey and Fadin			

$\Upsilon(1S)$ BRANCHING RATIOS

$\Gamma(\tau^+\tau^-)/\Gamma_{\text{total}}$	VTS L	DOCUMENT ID	TECN	COMMENT	Γ_1/Γ
0.0267 ^{+0.0014} _{-0.0016} OUR AVERAG		Jocometer 15	<u> </u>	COMMENT	
$0.0261 \pm 0.0012 + 0.0009$	25k (CINABRO 94	B CLE2	$e^+e^- \rightarrow$	τ ⁺ τ ⁻
0.027 ±0.004 ±0.002	7 /	ALBRECHT 85	c ARG	T(25) →	
0.034 ±0.004 ±0.004	. (GILES 83	S CLEO	$e^{+}e^{-}\rightarrow$	$\tau^+\tau^-$ $\tau^+\tau^-$
⁷ Using B($\Upsilon(1S) \rightarrow ee$) =	B(γ(15) -	$\rightarrow \mu\mu) = 0.0256$; not use	d for width	evaluations.
$\Gamma(\mu^+\mu^-)/\Gamma_{ m total}$					Г3/Г
VALUE	EVTS	DOCUMENT ID	TE	CN COMM	ENT
0.0248±0.0007 OUR AVERAG	GE Error it	ncludes scale fact	or of 1.1.		
$0.0212 \pm 0.0020 \pm 0.0010$		⁸ BARU	92 M	D1 e ⁺ e ⁻	
$0.0231 \pm 0.0012 \pm 0.0010$		⁸ KOBEL	92 CE	BAL e^+e^-	μ ,,=
$0.0252 \pm 0.0007 \pm 0.0007$		CHEN	89B CL	EO $e^{+\stackrel{\prime}{e}_{+}}$	
$0.0261 \pm 0.0009 \pm 0.0011$		KAARSBERG	89 CS	B2 e ⁺ e ⁻	μ \rightarrow μ
$0.0230\!\pm\!0.0025\!\pm\!0.0013$	86	ALBRECHT	87 AF	r r r r	
$0.029 \pm 0.003 \pm 0.002$	864	BESSON	84 CL	EO $\Upsilon(25)$	$\pi^-\mu^+\mu^-$

Meson Particle Listings $\Upsilon(1S)$

0.027 ±0.003 ±0.003	ANDREWS 83	CLEO e^+e^-	Г	$(\gamma 2\pi^+ 2\pi^- K^+ K^-)$	-)/F _{total}				Γ ₁₆ /Γ
0.032 ±0.013 ±0.003	ALBRECHT 82	DASP $e^+e^- \rightarrow$		LUE (units 10 ⁻⁴)	EVTS	DOCUMENT ID	TECI	V COMMENT	. 10,
0.032 ±0.013 ±0.003 0.038 ±0.015 ±0.002	NICZYPORUK 82	$\mu^+\mu^-$	2.	4±0.9±0.8	18 ± 7	FULTON	90B CLE	$o e^+e^- \rightarrow$	hadrons
		$\mu^+\mu^-$	Г	$(\gamma 2\pi^+ 2\pi^- p \overline{p})/\Gamma$	total				Γ ₁₈ /Γ
$0.014 \begin{array}{l} +0.034 \\ -0.014 \end{array}$	BOCK 80	CNTR $e^+e^{\mu^+\mu^-}$		LUE (units 10 ⁻⁴)	EVTS	DOCUMENT ID	TECI	V COMMENT	. 18/.
0.022 ±0.020	BERGER 79	PLUT $e^+e^- \rightarrow u^+u^-$		4±0.4±0.4	7 ± 6	FULTON	90B CLE	$o e^+e^- \rightarrow$	hadrons
• • We do not use the following data	for averages, fits, limits,	etc. • • •	Г	$(\gamma 2h^+2h^-)/\Gamma_{ m tota}$	d				Γ ₁₀ /Γ
0.027 ±0.003 ±0.003	TUTS 83	CUSB $e^+e^{\mu^+\mu^-}$		LUE (units 10 ⁻⁴)	EVTS	DOCUMENT ID	TEC	COMMENT	10,
⁸ Taking into account interference betw	ween the resonance and		7.0	0±1.1±1.0	80 ±	FULTON	90B CLE	O e ⁺ e ⁻ →	hadrons
$\Gamma(e^+e^-)/\Gamma_{\text{total}}$			Γ ₂ /Γ Γ	$(\gamma 3h^+3h^-)/\Gamma_{ m tota}$					r/r
VALUE EVTS	DOCUMENT ID	TECN COMMENT		(7511 · 511)/ · tota LUE (units 10 ⁻⁴)	EVTS	DOCUMENT ID	TEC	COMMENT	Γ ₁₁ /Γ
0.0252±0.0017 OUR AVERAGE 0.0242±0.0014±0.0014 307	ALBRECHT 87	ARG $\gamma(2S) \rightarrow$	-	4±1.5±1.3	39 ±	FULTON	90B CLE		hadrons
0.028 ±0.003 ±0.002 826		CLEO $r(2S) \rightarrow r$			11				
		$\pi^+\pi^-\epsilon$	e e	$(\gamma 4h^+4h^-)/\Gamma_{ m tota}$					Γ_{12}/Γ
0.051 ±0.030	BERGER 80C	PLUT $e^+e^- \rightarrow e^+e^-$		LUE (units 10 ⁻⁴) 4±2.5±2.5	36 ±	DOCUMENT ID FULTON	908 CLE		hadrons
$\Gamma(J/\psi(1S)$ anything) $/\Gamma_{ ext{total}}$			Γ ₄ /Γ	¥±2.5±2.5	12	TOLTON	905 CLE	0 6.6 -	Haurons
	CUMENT ID TECN	COMMENT	Г.	$(ho\pi)/\Gamma_{total}$					Γ ₅ /Γ
	BRECHT 92J ARG	$e^+e^- \rightarrow e^+e^-$	X, <u>VA</u>	LUE (units 10 ⁻⁴)	CL%	DOCUMENT ID	TECM		
1.1 ±0.4±0.2 ⁹ FUI	LTON 89 CLEO			2 • • We do not use t	90	FULTON	90B	$r(15) \rightarrow$	$\rho^0 \pi^0$
• • We do not use the following data			_	• • vve do not use t	ne following	BLINOV	s, 11ts, 11m1 90 MD1		°0 =0
	SCHMANN 90 CBAL	$e^+e^- ightarrow hadrons$		21	90	NICZYPORUK			
<20 90 NIC ⁹ Using B($(J/\psi) \rightarrow \mu^{+}\mu^{-}$) = (6.9 ±	ZYPORUK 83 LENA		Г	(<i>D</i> *(2010) [±] anyth	inσ) /Γ				٦/و٦
	E 0.9)%.		L/A	LUE (units 10 ⁻³)	<u>CL%</u>	DOCUMENT ID	TECN	COMMENT	. 9/.
$\Gamma(\pi^+\pi^-)/\Gamma_{\text{total}}$			10/1	19		3 ALBRECHT	92J ARG		$D^0\pi^{\pm}X$
<u>VALUE (units 10^{−4})</u> <u>CL%</u> <u>DOC</u> <5 90 BAI	<u>CUMENT ID</u> <u>TECN</u> RU 92 MD1	$rac{COMMENT}{r(1S) \rightarrow \pi^+\pi^-}$	1	3 For $x_p > 0.2$.					
	NO 92 WIDT	7 (15) → N · N	. г	$(\gamma\eta(1440))/\Gamma_{ m total}$					Γ ₂₄ /Γ
$\Gamma(K^+K^-)/\Gamma_{\text{total}}$									
			17/1	LUE (units 10 ⁻⁵)	CL%	DOCUMENT ID	TECN		
VALUE (units 10 ⁻⁴) CL% DOC	CUMENT ID TECN	COMMENT T(15) K+ K-			CL%	4 FULTON	908 CLE		$\gamma K^+ \pi^{\mp} K_S^0$
<u>VALUE (units 10⁻⁴) CL% DOC</u> <5 90 BAI		$\gamma(15) \rightarrow K^+K^-$		LUE (units 10 ⁻⁵)	<u>CL%</u> 90 1	⁴ FULTON	90B CLE	$rac{7}{(15)} \rightarrow$	γ K ⁺ π [∓] K ⁰ _S
$\frac{VALUE (units 10^{-4})}{<5}$ $\frac{CL\%}{90}$ BAI $\Gamma(\rho \overline{\rho})/\Gamma_{\text{total}}$	RU 92 MD1	$r_{(1S)} \rightarrow \kappa^+ \kappa^-$	Γ _B /Γ	LUE (units 10 ⁻⁵) 8.2 4 Includes unknown b	<u>CL%</u> 90 1	⁴ FULTON	90B CLE	$rac{7}{(15)} \rightarrow$	
\(\text{VALUE}\) (units 10 ⁻⁴) \(\text{CL\%}\) \(\text{DOC}\) <\(5\) 90 \(\text{BAI}\) \(\text{\sigma}\) \(\text{\sigma}\) \(\text{Total}\) \(\text{VALUE}\) (units 10 ⁻⁴) \(\text{CL\%}\) \(\text{DOC}\)	RU 92 MD1	$\Upsilon(1S) \rightarrow K^+ K^-$	Γ ₈ /Γ Γ(8.2 4 Includes unknown t $(\gamma \eta'(958))/\Gamma_{ ext{total}}$	CL% 90 1 pranching rat	4 FULTON io of $\eta(1440) ightarrow$	908 CLE Κ [±] π [∓] Ι	$ \frac{1}{0} \overline{r(1s)} \rightarrow 0 $ $ \frac{1}{0} \overline{r(1s)} \rightarrow 0 $	$\gamma \kappa^+ \pi^\mp \kappa_S^0$
\(\text{VALUE}\(\text{units}\)\(\text{10}^{-4}\)\\ <\(5\)\\ 90\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\	RU 92 MD1	$r_{(1S)} \rightarrow \kappa^+ \kappa^-$	-	LUE (units 10 ⁻⁵) 8.2 4 Includes unknown b	<u>CL%</u> 90 1	⁴ FULTON	90B CLE Κ [±] π [∓] μ	$ \frac{1}{0} \overline{r(1s)} \rightarrow 0 $ $ \frac{1}{0} \overline{r(1s)} \rightarrow 0 $	Γ ₂₀ /Γ
$VALUE$ (units 10^{-4}) $CL\%$ DOC $<$ 5 90 BAI $\Gamma(p\overline{p})/\Gamma_{total}$ $VALUE$ (units 10^{-4}) $CL\%$ 90 10 BAI 10 Supersedes BARU 92 in this node.	RU 92 MD1	$\frac{r(1S) \to K^+ K^-}{r(1S) \to \rho \overline{\rho}}$	Γ ₈ /Γ Γ(8.2 4 Includes unknown the $(\gamma \eta'(958))/\Gamma_{\text{total}}$ LUE (units 10^{-3}) 1.3	CL% 90 1 pranching rat	4 FULTON io of $\eta(1440) \rightarrow$ $DOCUMENT ID$	90B CLE Κ [±] π [∓] μ	$\begin{array}{c} $	Γ ₂₀ /Γ
$VALUE$ (units 10^{-4}) $CL\%$ DOC $<$ 5 90 BAI $\Gamma(p\overline{p})/\Gamma_{total}$ $VALUE$ (units 10^{-4}) $CL\%$ 90 10 BAI 10 Supersedes BARU 92 in this node.	RU 92 MD1	$\frac{r(1S) \to K^+ K^-}{r(1S) \to \rho \overline{\rho}}$	Γ ₈ /Γ Γ(8.2 4 Includes unknown to $(\gamma \eta'(958))/\Gamma_{\text{total}}$ 1.3 $(\gamma \eta)/\Gamma_{\text{total}}$	CL% 90 1 pranching rat 	4 FULTON io of η(1440) → $^{-1}$ DOCUMENT ID SCHMITT	908 CLE κ [±] π [∓] μ <u>TECN</u> 88 CBA	$ \begin{array}{c} \hline $	Γ ₂₀ /Γ
VALUE (units 10^{-4}) CL% DOC 5 90 BAI F($p\bar{p}$)/Ftotal VALUE (units 10^{-4}) CL% P0 BAI 10 Supersedes BARU 92 in this node. F(γX)/Ftotal (X = pseudoscalar with m< 7.2 Gr VALUE (units 10^{-5}) CL% DOC VALUE (units 10^{-5}) CL% DOC	RU 92 MD1	$T(1S) \rightarrow K^+K^ COMMENT$ $T(1S) \rightarrow \rho \bar{\rho}$ $COMMENT$	Γ ₈ /Γ Γ(29/Γ Γ(4/2))	8.2 4 Includes unknown the $(\gamma \eta'(958))/\Gamma_{\text{total}}$ LUE (units 10^{-3}) 1.3	CL% 90 1 pranching rat	4 FULTON io of $\eta(1440) \rightarrow$ $DOCUMENT ID$	908 CLE κ±π∓μ <u>TECN</u> 88 CBA	$ \begin{array}{c} \hline $	Γ ₂₀ /Γ γ× Γ ₂₁ /Γ
VALUE (units 10^{-4}) CL% DOC $<$ 5 90 BAI $\Gamma(p\overline{p})/\Gamma_{\text{total}}$ VALUE (units 10^{-4}) CL% DOC $<$ 5 90 10 BAI 10 Supersedes BARU 92 in this node. $\Gamma(\gamma X)/\Gamma_{\text{total}}$ (X = pseudoscalar with $m < 7.2$ Gr VALUE (units 10^{-5}) CL% DOC $<$ 3 90 11 BAI	RU 92 MD1	$ \begin{array}{ccc} \hline \gamma(1S) \to & K^+ K^- \\ \hline \underline{COMMENT} \\ \gamma(1S) \to & p\overline{p} \end{array} $	Γ ₈ /Γ Γ(Γ ₂₉ /Γ Γ(8.2 4 Includes unknown to $(\gamma \eta'(958))/\Gamma_{\text{total}}$ LUE (units 10^{-3}) 1.3 $(\gamma \eta)/\Gamma_{\text{total}}$ LUE (units 10^{-4}) 3.5	$\frac{CL\%}{90} = 1$ oranching rat $\frac{CL\%}{90}$ $\frac{CL\%}{90}$	4 FULTON io of $η(1440) \rightarrow$ $^{OCUMENT\ ID}$ SCHMITT $^{OCUMENT\ ID}$	908 CLE κ±π∓μ <u>TECN</u> 88 CBA	$\begin{array}{c} 0 & r(1s) \rightarrow \\ \zeta_{S}^{0}. \end{array}$ $\begin{array}{c} COMMENT \\ T(1s) \rightarrow \end{array}$ $\begin{array}{c} COMMENT \\ COMMENT \end{array}$	Γ ₂₀ /Γ γ× Γ ₂₁ /Γ
VALUE (units 10^{-4}) CL% DOC <5	RU 92 MD1	$T(1S) \rightarrow K^+K^ COMMENT$ $T(1S) \rightarrow \rho \bar{\rho}$ $COMMENT$	Γ ₈ /Γ Γ(Γ ₂₉ /Γ Γ(Γ ₂₉ /Γ Γ(Γ ₄ Γ ₂₉ /Γ Γ(Γ ₄ Γ ₄ Γ ₇ Γ ₇ Γ ₇	8.2 4 Includes unknown to $(\gamma \eta'(958))/\Gamma_{\text{total}}$ 1.3 $(\gamma \eta)/\Gamma_{\text{total}}$ LUE (units 10^{-3}) 1.4 $(\gamma \eta)/\Gamma_{\text{total}}$ LUE (units 10^{-4})	$\frac{CL\%}{90} = 1$ oranching rat $\frac{CL\%}{90}$ $\frac{CL\%}{90}$	4 FULTON io of $η(1440) \rightarrow$ $^{OCUMENT\ ID}$ SCHMITT $^{OCUMENT\ ID}$	908 CLE κ±π∓μ <u>TECN</u> 88 CBA	$ \begin{array}{c} O \\ \hline \Gamma(1S) \rightarrow \\ C	Γ ₂₀ /Γ γ× Γ ₂₁ /Γ
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VALUE (units 10^{-4}) CL% DOC S 90 BAI $\Gamma(p\overline{p})/\Gamma_{total}$ VALUE (units 10^{-4}) CL% DOC S 90 10 BAI 10 Supersedes BARU 92 in this node. $\Gamma(\gamma X)/\Gamma_{total}$ (X = pseudoscalar with m< 7.2 Gr VALUE (units 10^{-5}) CL% DOC 3 90 11 BAI 11 For a noninteracting pseudoscalar X or $\Gamma(\gamma X\overline{X})/\Gamma_{total}$ (X \overline{X} = vectors with m< 3.1 GeV)	RU 92 MD1	$\begin{array}{cccc} \hline \Upsilon(1S) \to & K^+K^- \\ \hline $	Γ ₈ /Γ Γ(₂₉ /Γ Γ(₄ Γ ₂₉ /Γ Γ(₄ Γ ₂₉ /Γ Γ(₄ Γ ₄ Γ ₄ Γ ₄ Γ ₄ Γ ₄ Γ ₅₀ /Γ Γ(₄ Γ ₅₀ /Γ Γ ₆	8.2 4 Includes unknown to $(\gamma \eta'(958))/\Gamma$ total LUE (units 10^{-3}) 3.3 $(\gamma \eta)/\Gamma$ total LUE (units 10^{-4}) 3.5 $(\gamma f'_2(1525))/\Gamma$ total LUE (units 10^{-5}) 1.4 • • We do not use to (10^{-5})	CL% 90 1 pranching rat CL% 90 CL% 90 all CL% 90 1 he following	4 FULTON io of η(1440) → DOCUMENT ID SCHMITT DOCUMENT ID SCHMITT DOCUMENT ID 5 FULTON data for average:	908 CLE K±π∓ μ TECN 88 CBA TECN 908 CLE 5, fits, limi	$\begin{array}{c} O & T(1S) \rightarrow \\ C_S^0 & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & $	Γ_{20}/Γ $\gamma \times$ Γ_{21}/Γ $\gamma \times$ Γ_{22}/Γ $\gamma \kappa^{+} \kappa^{-}$
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VALUE (units 10^{-4}) CL% DOC <5	RU 92 MD1 CUMENT ID TECN RU 96 MD1 eV) TECN LEST 95 CLEO with mass < 7.2 GeV. CUMENT ID TECN LEST 95 CLEO	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Γ ₈ /Γ Γ ₈ /Γ Γ ₈ /Γ Γ ₉ /Γ Γ ₉ /Γ Γ ₉ /Γ Γ ₁ /Γ Γ Γ ₁ /Γ Γ Γ Γ Γ Γ Γ Γ Γ Γ	8.2 4 Includes unknown to $(\gamma \eta'(958))/\Gamma$ total LUE (units 10^{-3}) 1.3 $(\gamma \eta)/\Gamma$ total LUE (units 10^{-4}) 3.5 $(\gamma \eta'_2(1525))/\Gamma$ total LUE (units 10^{-5}) 14 • • We do not use to 19.4 5 Assuming $B(f'_2(1525))/\Gamma$ total LUE (units 10^{-5})	oranching rational properties of the following $\frac{CL\%}{90}$ $\frac{CL\%}{9$	4 FULTON io of η(1440) → DOCUMENT ID SCHMITT DOCUMENT ID SCHMITT DOCUMENT ID 5 FULTON data for average: 5 ALBRECHT = 0.71.	908 CLE K±π∓μ TECN 88 CBA TECN 908 CLE 5, fits, limi 89 ARG	$\begin{array}{c} O & \overline{T(1S)} \rightarrow \\ O & \overline{C(1S)} \rightarrow \\ \hline C & \underline{COMMENT} \\ C & \underline{COMMENT} \\ C & \underline{COMMENT} \\ C & \underline{COMMENT} \\ O & \underline{T(1S)} \rightarrow \\ \text{ts, etc.} \bullet \bullet \bullet \\ & \underline{T(1S)} \rightarrow \\ \end{array}$	Γ_{20}/Γ $\gamma \times$ Γ_{21}/Γ $\gamma \times$ Γ_{22}/Γ $\gamma \kappa^{+} \kappa^{-}$
VALUE (units 10^{-4}) CL% DOC $<$ 5 90 BAI $\Gamma(\rho \overline{\rho})/\Gamma_{\text{total}}$ VALUE (units 10^{-4}) CL% 90 10 BAI 10 Supersedes BARU 92 in this node. $\Gamma(\gamma X)/\Gamma_{\text{total}}$ (X = pseudoscalar with $m < 7.2$ Gr $<$ 3 90 11 BAI 11 For a noninteracting pseudoscalar X or $\Gamma(\gamma X \overline{X})/\Gamma_{\text{total}}$ (X \overline{X} = vectors with $m < 3.1$ GeV) VALUE (units 10^{-3}) CL% DOC $<$ 1 90 12 BAI 12 For a noninteracting vector X with $m < 1.2$ For a noninteracting vector X with $m < 1.2$ For a noninteracting vector X with $m < 1.2$ For a noninteracting vector X with $m < 1.2$ For a noninteracting vector X with $m < 1.2$ For a noninteracting vector X with $m < 1.2$ For a noninteracting vector X with $m < 1.2$ For a noninteracting vector X with $m < 1.2$ For a noninteracting vector X with $m < 1.2$ For a noninteracting vector X with $m < 1.2$ For a noninteracting vector X with $m < 1.2$ For a noninteracting vector X with $m < 1.2$ For a noninteracting vector X with $m < 1.2$ For a noninteracting vector X with $m < 1.2$ For a noninteracting vector X with $m < 1.2$ For a noninteracting vector X with $m < 1.2$ For a noninteracting vector X with $m < 1.2$ For a noninteracting vector X with $m < 1.2$ For a noninteracting vector X with $m < 1.2$ For a noninteracting vector $m < 1.2$ For a noninteracting vector $m < 1.2$ For $m <$	### RU 92 MD1 ### MD	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Γ ₈ /Γ Γ ₀ Γ ₀ Γ ₁₄ /Γ	8.2 4 Includes unknown to $(\gamma \eta'(958))/\Gamma$ total LUE (units 10^{-3}) 3.5 $(\gamma \eta)/\Gamma$ total LUE (units 10^{-4}) 3.5 $(\gamma \eta'/(1525))/\Gamma$ total LUE (units 10^{-4}) 4.0 • • We do not use to 19.4 • • We do not use to 19.4 • $(\gamma f)/(1710) \rightarrow \gamma K$ LUE (units 10^{-4})	$ \frac{CL\%}{90} = 1 $ oranching rat $ \frac{CL\%}{90} = \frac{CL\%}{90} $ al $ \frac{CL\%}{90} = 1 $ the following $ \frac{CL\%}{90} = 1 $ $ \frac{CL\%}{7} = \frac{CL\%}{7} $ $ \frac{CL\%}{7} = \frac{CL\%}{7} $ $ \frac{CL\%}{7} = \frac{CL\%}{7} $	4 FULTON io of η(1440) → DOCUMENT ID SCHMITT DOCUMENT ID 5 FULTON data for average: 5 ALBRECHT = 0.71.	908 CLE κ±π∓ρ 88 CBA 37 CBA 88 CBA 7 C CBA 908 CLE 5, fits, limi 89 ARG	$\begin{array}{c} O & T(1S) \rightarrow \\ C_S^0 & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & $	Γ_{20}/Γ $\gamma \times$ Γ_{21}/Γ $\gamma \times$ Γ_{22}/Γ $\gamma K^{+}K^{-}$ $\gamma K^{+}K^{-}$ Γ_{25}/Γ
VALUE (units 10^{-4}) CL% DOC 5 90 BAI F($p\bar{p}$)/Ftotal VALUE (units 10^{-4}) CL% 90 10 BAI 10 Supersedes BARU 92 in this node. F(γX)/Ftotal (X = pseudoscalar with m< 7.2 Gr (X = pseudoscalar with m< 7.2 Gr 11 For a noninteracting pseudoscalar X or F($\gamma X\bar{X}$)/Ftotal (X = vectors with m< 3.1 GeV) VALUE (units 10^{-3}) CL% 20 21 POO 21 BAI 12 For a noninteracting vector X with m F($\gamma 2\pi^+ 2\pi^-$)/Ftotal VALUE (units 10^{-4}) EVTS DOC 10 DOC 10 DOC 11 DOC 12 DOC 12 DOC 13 DOC 14 DOC 15 DOC 16 DOC 17 DOC 17 DOC 18 DOC 19 DOC 10 DOC	RU 92 MD1 CUMENT ID TECN RU 96 MD1 eV) CUMENT ID TECN LEST 95 CLEO with mass < 7.2 GeV. CUMENT ID TECN LEST 95 CLEO ass < 3.1 GeV.	$\begin{array}{c} T(1S) \rightarrow & K^{+}K^{-} \\ \hline \\ COMMENT \\ T(1S) \rightarrow & \rho \overline{\rho} \end{array}$	Γ ₈ /Γ Γ(ΥΑ ΥΑ ΥΑ Γ(Γ(8.2 4 Includes unknown to $(\gamma \gamma' (958))/\Gamma$ total LUE (units 10^{-5}) 3.5 $(\gamma \gamma')/\Gamma$ total LUE (units 10^{-4}) 4.0 • • We do not use to 19.4 5 Assuming $B(f_2'(152))/\Gamma$ total $(\gamma f_1(1710) \rightarrow \gamma K)$ LUE (units 10^{-4}) 5 Assuming $B(f_2'(152))/\Gamma$	$ \frac{CL\%}{90} \qquad 1 $ oranching rat $ \frac{CL\%}{90} \qquad 90 $ $ \frac{CL\%}{90} \qquad 1 $ the following $ \frac{CL\%}{90} \qquad 1 $	4 FULTON io of η(1440) → DOCUMENT ID SCHMITT DOCUMENT ID 5 FULTON data for average: 5 ALBRECHT = 0.71. DOCUMENT ID 6 ALBRECHT	908 CLE K±π∓μ 7ECN 88 CBA 7ECN 908 CLE 5, fits, limi 89 ARG	$\begin{array}{c} O & T(1S) \rightarrow \\ C_S^0 & \\ \hline \\ C_S^0 & \\ C_S^0 & \\ \hline \\ C_S^0 & \\ C_S^0 & \\ \hline \\ C_S^0 & \\ C_S^0 & \\ \hline \\ C_S^0 & \\ C_S^0 & \\ \hline \\ C_S^0 & \\ C$	Γ_{20}/Γ $\gamma \times$ Γ_{21}/Γ $\gamma \times$ Γ_{22}/Γ $\gamma K^{+}K^{-}$ $\gamma K^{+}K^{-}$ Γ_{25}/Γ
VALUE (units 10^{-4}) CL% DOC 5 90 BAI F($p\bar{p}$)/ Γ total VALUE (units 10^{-4}) CL% 90 10 BAI 10 Supersedes BARU 92 in this node. F(γX)/ Γ total (X = pseudoscalar with m< 7.2 Gr VALUE (units 10^{-5}) CL% DOC 3 90 11 BAI 11 For a noninteracting pseudoscalar X or $(x\bar{X})$ / Γ total (X = vectors with m< 3.1 GeV) VALUE (units 10^{-3}) CL% 12 BAI 12 For a noninteracting vector X with m F($\gamma 2\pi^+ 2\pi^-$)/ Γ total VALUE (units 10^{-4}) EVTS DOC 2.5 ± 0.7 ± 0.5	RU 92 MD1 CUMENT ID TECN RU 96 MD1 eV) CUMENT ID TECN LEST 95 CLEO with mass < 7.2 GeV. CUMENT ID TECN LEST 95 CLEO ass < 3.1 GeV.	$\begin{array}{c} T(1S) \rightarrow & K^+K^- \\ \hline COMMENT \\ T(1S) \rightarrow & p\overline{p} \\ \hline \\ \hline COMMENT \\ e^+e^- \rightarrow & \gamma + X \\ \hline \\ \hline COMMENT \\ e^+e^- \rightarrow & \gamma + X \\ \hline \\ \hline COMMENT \\ e^+e^- \rightarrow & hadrons \\ \hline \end{array}$	Γ ₈ /Γ Γ ₈ /Γ Γ ₁ Γ ₂₉ /Γ Γ Γ Γ Γ Γ Γ Γ Γ Γ Γ Γ Γ Γ Γ Γ Γ Γ Γ	8.2 4 Includes unknown to $(\gamma \eta'(958))/\Gamma$ total LUE (units 10^{-3}) 3.5 $(\gamma \eta)/\Gamma$ total LUE (units 10^{-4}) 3.5 $(\gamma \eta'/(1525))/\Gamma$ total LUE (units 10^{-4}) 4.0 • • We do not use to 19.4 • • We do not use to 19.4 • $(\gamma f)/(1710) \rightarrow \gamma K$ LUE (units 10^{-4})	$\frac{CL\%}{90} \qquad 1$ oranching rat $\frac{CL\%}{90}$ $\frac{CL\%}{90}$ al $\frac{CL\%}{90} \qquad 1$ the following $\frac{CL\%}{90} \qquad K\overline{K}$ $\frac{CK}{F}/\Gamma_{total}$ $\frac{CL\%}{90} \qquad 1$ the following	4 FULTON io of η(1440) → DOCUMENT ID SCHMITT DOCUMENT ID 5 FULTON data for average: 5 ALBRECHT = 0.71. DOCUMENT ID 6 ALBRECHT	908 CLE K±π∓μ TECN 88 CBA TECN 908 CLE 5, fits, limi 89 ARG 5, fits, limi 908 CLE	$\begin{array}{c} O & \overline{T(1S)} \rightarrow \\ O & \overline{C(1S)} \rightarrow \\$	Γ_{20}/Γ γX Γ_{21}/Γ γX Γ_{22}/Γ $\gamma K^{+}K^{-}$ Γ_{25}/Γ $\gamma K^{+}K^{-}$ $\gamma K^{+}K^{-}$
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VALUE (units 10^{-4}) CL% DOC 5 90 BAI F($p\bar{p}$)/Ftotal VALUE (units 10^{-4}) CL% 90 10 BAI 10 Supersedes BARU 92 in this node. F(γX)/Ftotal (X = pseudoscalar with m< 7.2 Gr VALUE (units 10^{-5}) CL% DOC 3 90 11 BAI 11 For a noninteracting pseudoscalar X or F($\gamma X\bar{X}$)/Ftotal (X \overline{X} = vectors with m< 3.1 GeV) VALUE (units 10^{-3}) CL% DOC 12 BAI 12 For a noninteracting vector X with m F($\gamma 2\pi^+ 2\pi^-$)/Ftotal VALUE (units 10^{-4}) EVTS DOC T($\gamma \pi^+ \pi^- K^+ K^-$)/Ftotal VALUE (units 10^{-4}) EVTS DOC T($\gamma \pi^+ \pi^- K^+ K^-$)/Ftotal	RU 92 MD1	$\begin{array}{cccc} T(1S) \rightarrow & K^+K^- \\ \hline COMMENT & & & & \\ \hline COMMENT & & & \\ \hline \end{array}$	Γ ₈ /Γ Γ ₈ /Γ Γ ₈ /Γ Γ ₁ Γ ₂₉ /Γ Γ Γ Γ Γ Γ Γ Γ Γ Γ Γ Γ Γ Γ Γ Γ Γ Γ Γ	8.2 4 Includes unknown to $(\gamma \eta'(958))/\Gamma$ total $(\gamma \eta'(958))/\Gamma$ total $(\gamma \eta)/\Gamma$ total $(\gamma \eta)$	$ \frac{c t \%}{90} \qquad 1 $ oranching rat $ \frac{c t \%}{90} $ $ \frac{c t \%}{90} $ al $ \frac{c t \%}{90} \qquad 1 $ the following $ \frac{g_0}{90} \qquad 1 $ $ \frac{c t \%}{F}/F_{total} $ $ \frac{c t \%}{90} \qquad 1 $ the following $ \frac{g_0}{90} \qquad 1 $ the following $ \frac{g_0}{90} \qquad 1 $ $ \frac{g_0}{90} \qquad 1 $ $ \frac{g_0}{90} \qquad 1 $	4 FULTON io of η(1440) → DOCUMENT ID SCHMITT DOCUMENT ID 5 FULTON data for average: 5 ALBRECHT = 0.71. DOCUMENT ID 6 ALBRECHT data for average: 6 FULTON 6 FULTON 7 ALBRECHT	908 CLE **ECA** **RECA** **RECA** **RECA** **RECA** **RECA** **RECA** **RECA** **RECA** **PECA** **PECA*	$\begin{array}{c} O & T(1S) \rightarrow \\ C_S^0 \\ \vdots \\ C_S^1 \\ C_S^1 \\ \vdots \\ C_S^1 \\ C$	
VALUE (units 10^{-4}) CL% DOC	RU 92 MD1	$\begin{array}{c} T(1S) \rightarrow K^+K^- \\ \hline \\ COMMENT \\ T(1S) \rightarrow p\overline{p} \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow \gamma + X \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow \gamma + X \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \end{array}$	Γ ₁₃ /Γ Γ Γ Γ Γ Γ Γ Γ Γ Γ Γ Γ Γ	## LUE (units 10^{-5}) ## R.2 # Includes unknown to the form of the control	$\frac{CL\%}{90}$ 1 pranching rat $\frac{CL\%}{90}$ $\frac{CL\%}{90}$ $\frac{CL\%}{90}$ 1 the following $\frac{CL\%}{90}$ 1 $\frac{CL\%}{90}$ 1 $\frac{CL\%}{90}$ 1	4 FULTON io of η(1440) → DOCUMENT ID SCHMITT DOCUMENT ID 5 FULTON data for average: 5 ALBRECHT = 0.71. DOCUMENT ID 6 ALBRECHT data for average: 6 FULTON 6 FULTON 7 ALBRECHT 8 SCHMITT	908 CLE K±π∓μ TECN 88 CBA TECN 89 ARG 5, fits, limi 908 CLE 908 CLE 908 CLE	$\begin{array}{c} O & T(1S) \rightarrow \\ C_S^0 \\ \vdots \\ C_S^1 \\ C_S^1 \\ \vdots \\ C_S^1 \\ C$	
VALUE (units 10^{-4}) CL% DOC 5 90 BAI F($p\bar{p}$)/ Γ total VALUE (units 10^{-4}) CL% 90 10 BAI 10 Supersedes BARU 92 in this node. F(γX)/ Γ total (X = pseudoscalar with $m < 7.2$ Gr VALUE (units 10^{-5}) CL% 90 11 BAI 11 For a noninteracting pseudoscalar X or F($\gamma X\bar{X}$)/ Γ total (X \overline{X} = vectors with $m < 3.1$ GeV) VALUE (units 10^{-3}) CL% 12 BAI 12 For a noninteracting vector X with m F($\gamma 2\pi^{+}2\pi^{-}$)/ Γ total VALUE (units 10^{-4}) EVTS T($\gamma \pi^{+}\pi^{-}K^{+}K^{-}$)/ Γ total VALUE (units 10^{-4}) EVTS DOC 2.9±0.7±0.6 29 ± FUL 8	RU 92 MD1	$\begin{array}{c} T(1S) \rightarrow K^+K^- \\ \hline \\ COMMENT \\ T(1S) \rightarrow \rho \overline{\rho} \\ \hline \\ COMMENT \\ e^+e^- \rightarrow \gamma + X \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \end{array}$	Γ ₈ /Γ Γ ₈ /Γ Γ ₈ /Γ Γ ₈ /Γ Γ ₉ /Γ	8.2 4 Includes unknown to $(\gamma \eta'(958))/\Gamma$ total UUE (units 10^{-3}) 1.3 $(\gamma \eta)/\Gamma$ total UUE (units 10^{-4}) 3.5 $(\gamma f_2'(1525))/\Gamma$ total UUE (units 10^{-4}) 1.9 4 • We do not use to 10^{-4}) 2.6 • We do not use to 10^{-4}) 2.6 • We do not use to 10^{-4}) 2.6 • We do not use to 10^{-4}) 2.6 6.6 Assuming 10^{-4}) 8 24 6.6 6.7 6.7 6.7 6.7 6.7 6.7 6.	$ \frac{c t \%}{90} \qquad 1 $ oranching rat $ \frac{c t \%}{90} $ $ \frac{c t \%}{90} $ $ \frac{c t \%}{90} $ $ \frac{c t \%}{90} \qquad 1 $ the following $ \frac{c t \%}{90} \qquad 1 $ the following $ \frac{c t \%}{90} \qquad 1 $ the following $ \frac{c t \%}{90} \qquad 1 $ $ \frac{c t \%}{10} \qquad 1 $ $ c $	4 FULTON io of η(1440) → DOCUMENT ID SCHMITT DOCUMENT ID SCHMITT DOCUMENT ID 5 FULTON data for average: 5 ALBRECHT = 0.71. DOCUMENT ID 6 ALBRECHT data for average: 6 FULTON 7 ALBRECHT 8 SCHMITT = 0.38. = 0.04.	908 CLE **ECA** **RECA** **RECA** **RECA** **RECA** **RECA** **RECA** **RECA** **RECA** **PECA** **PECA*	$\begin{array}{c} O & T(1S) \rightarrow \\ C_S^0 \\ \vdots \\ C_S^1 \\ C_S^1 \\ \vdots \\ C_S^1 \\ C$	
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VALUE (units 10^{-4}) CL% DOC $<$ 5 $>$ 5 $>$ 90 $>$ 6 $<$ 5 $>$ 90 $>$ 8 $<$ 7 $(p \overline{p}) / \Gamma_{\text{total}}$ VALUE (units 10^{-4}) $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0 $<$ 0	RU 92 MD1	$\begin{array}{c} T(1S) \rightarrow K^+K^- \\ \hline COMMENT \\ T(1S) \rightarrow p\overline{p} \\ \hline \\ \hline COMMENT \\ e^+e^- \rightarrow \gamma + X \\ \hline \\ \hline COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ \hline COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ \hline \\ \hline COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ $	Γ ₈ /Γ Γ ₈ /Γ Γ ₈ /Γ Γ ₉ /Γ Γ ₁₃ /Γ Γ ₁₃ /Γ Γ ₁ /Γ Γ ₁₇ /Γ Γ ₁ /Γ Γ ₁₉ /Γ Γ ₁ /Γ Γ ₁₉ /Γ	## LUE (units 10 ⁻⁵) 8.2 4 Includes unknown to the following the following that the following the follow	$\frac{c t \%}{90} \qquad 1$ oranching rational production of the following sign of the follo	4 FULTON io of η(1440) → DOCUMENT ID SCHMITT DOCUMENT ID 5 FULTON data for average: 5 ALBRECHT ata for average: 6 FULTON 6 FULTON 7 ALBRECHT 8 SCHMITT = 0.38. = 0.04. = 0.18. DOCUMENT ID 9 ALBRECHT data for average: 9 ALBRECHT ata for average: 10 FULTON 11 FULTON 12 FULTON 13 FULTON 14 FULTON 15 FULTON 16 FULTON 17 ALBRECHT 18 SCHMITT 19 O.38.	908 CLE K±π∓μ TECN 88 CBA TECN 908 CLE 5, fits, limi 89 ARG TECN 89 ARG 7ECN 89 ARG TECN 89 ARG TECN 89 ARG TECN 89 ARG 7ECN 89 ARG	$\begin{array}{c} O & T(1S) \rightarrow \\ COS & \\ \hline COMMENT \\ COMME$	Γ ₂₀ /Γ γ [×] Γ ₂₁ /Γ γ [×] Γ ₂₂ /Γ γ ^{κ+} κ ⁻ γ ^{κ+} κ ⁻ γ ^{κ+} κ ⁻ γ ^{κ+} κ ⁻ γ ^κ ⁰ κ ⁰ _γ κ ⁰ _γ κ ⁰ _γ γ ⁺ π ⁻ Γ ₂₃ /Γ
VALUE (units 10^{-4}) CL% DOC <5 90 BAI $\Gamma(p\overline{p})/\Gamma$ total VALUE (units 10^{-4}) CL% 90 10 BAI $VALUE$ (units 10^{-5}) CL% DOC <3 90 11 BAI $VALUE$ (units 10^{-5}) CL% DOC <3 90 12 BAI $VALUE$ (units 10^{-5}) CL% DOC <1 90 12 BAI $VALUE$ (units 10^{-3}) CL% DOC <1 90 12 BAI $VALUE$ (units 10^{-3}) CL% DOC <1 POC <1 POC $VALUE$ (units 10^{-4}) EVTS $VALUE$ (units 10^{-4}	RU 92 MD1	$\begin{array}{c} T(1S) \rightarrow K^+K^- \\ \hline \\ COMMENT \\ T(1S) \rightarrow p\overline{p} \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow \gamma + X \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ CO$	Γ ₈ /Γ Γ ₈ /Γ Γ ₈ /Γ Γ ₉ /Γ Γ ₁₃ /Γ Γ ₁₃ /Γ Γ ₁ /Γ Γ Γ Γ Γ Γ Γ Γ Γ Γ	2.02 (units 10^{-5}) 8.2 4 Includes unknown to $(\gamma \gamma' (958)) / \Gamma$ total 2.02 (units 10^{-3}) 1.3 $(\gamma \gamma) / \Gamma$ total 2.02 (units 10^{-4}) 3.5 $(\gamma f'_2(1525)) / \Gamma$ total 3.5 $(\gamma f'_2(1525)) / \Gamma$ total 4 • • We do not use to 10^{-5} 1.4 • • We do not use to 10^{-5} 2.6 • • We do not use to 10^{-5} 3.7 Assuming 10^{-5} 3.8 Assuming 10^{-5} 3.9 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	$\frac{c t \%}{90} \qquad 1$ oranching rational production of the following sign of the follo	4 FULTON io of η(1440) → DOCUMENT ID SCHMITT DOCUMENT ID SCHMITT 5 FULTON data for average: 5 ALBRECHT ata for average: 6 FULTON 6 FULTON 7 ALBRECHT 8 SCHMITT = 0.38. = 0.04. = 0.18.	908 CLE K±π∓μ TECN 88 CBA TECN 908 CLE 5, fits, limi 908 CLE 89 ARG 89 ARG 89 ARG 7 TECN 89 ARG 89 ARG 89 ARG 89 ARG 89 ARG 89 ARG	$\begin{array}{c} O & T(1S) \rightarrow \\ COS & \\ C$	
VALUE (units 10^{-4}) CL% DOC <5 90 BAI $\Gamma(\rho \overline{\rho})/\Gamma_{\text{total}}$ VALUE (units 10^{-4}) CL% 90 BAI 10 Supersedes BARU 92 in this node. $\Gamma(\gamma X)/\Gamma_{\text{total}}$ (X = pseudoscalar with $m < 7.2$ Gr VALUE (units 10^{-5}) CL% DOC <3 90 11 BAI 11 For a noninteracting pseudoscalar X in 10^{-5} CL% DOC $\langle X = V = V = V = V = V = V = V = V = V =$	RU 92 MD1	$\begin{array}{c} T(1S) \rightarrow K^+K^- \\ \hline \\ COMMENT \\ T(1S) \rightarrow p\overline{p} \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow \gamma + X \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ \hline \\ COMMENT \\ e^+e^- \rightarrow hadrons \\ CO$	Γ ₈ /Γ Γ ₈ /Γ Γ ₈ /Γ Γ ₈ /Γ Γ ₉ /Γ Γ ₉ /Γ Γ ₁₃ /Γ	2.02 (units 10^{-5}) 8.2 4 Includes unknown to $(\gamma \gamma' (958)) / \Gamma$ total 2.02 (units 10^{-3}) 1.3 $(\gamma \gamma) / \Gamma$ total 2.02 (units 10^{-4}) 3.5 $(\gamma f'_2(1525)) / \Gamma$ total 3.5 $(\gamma f'_2(1525)) / \Gamma$ total 4 • • We do not use to 10^{-5} 1.4 • • We do not use to 10^{-5} 2.6 • • We do not use to 10^{-5} 3.7 Assuming 10^{-5} 3.8 Assuming 10^{-5} 3.9 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	$ \frac{c t \%}{90} \qquad 1 $ oranching rat $ \frac{c t \%}{90} $ al $ \frac{c t \%}{90} $ 1 the following $ \frac{90}{90} \qquad 1 $ 1 the following $ \frac{6 t \%}{90} \qquad 1 $ 1 the following $ \frac{6 t \%}{90} \qquad 1 $ 1 the following $ \frac{6 t \%}{90} \qquad 1 $ 1 the following $ \frac{90}{90} \qquad 1 $ 1 the following $ \frac{90}{90} \qquad 1 $ 1 the following $ \frac{6 t \%}{90} \qquad 1 $ 1 the following $ \frac{6 t \%}{90} \qquad 1 $ 1 the following $ \frac{6 t \%}{90} \qquad 1 $ 1 the following $ \frac{6 t \%}{90} \qquad 1 $ 1 The following $ \frac{6 t \%}{90} \qquad 1 $ 1 The following $ \frac{6 t \%}{90} \qquad 1 $ 1 The following $ \frac{6 t \%}{90} \qquad 1 $ 1 The following $ \frac{6 t \%}{90} \qquad 1 $ 1 The following $ \frac{6 t \%}{90} \qquad 1 $ 1 The following $ \frac{6 t \%}{90} \qquad 1 $ 1 The following $ \frac{6 t \%}{90} \qquad 1 $ 1 The following $ \frac{6 t \%}{90} \qquad 1 $ 1 The following	4 FULTON io of η(1440) → DOCUMENT ID SCHMITT DOCUMENT ID 5 FULTON data for averages 5 ALBRECHT = 0.71. DOCUMENT ID 6 ALBRECHT data for averages 6 FULTON 6 FULTON 7 ALBRECHT 8 SCHMITT = 0.38. = 0.04. = 0.18. DOCUMENT ID 9 ALBRECHT data for averages 9 FULTON 5 FULTON 5 FULTON 7 ALBRECHT 8 SCHMITT - 0.38 0.04 0.18.	908 CLE K±π∓μ TECN 88 CBA TECN 908 CLE 5, fits, limi 908 CLE 89 ARG 89 ARG 89 ARG 7 TECN 89 ARG 89 ARG 89 ARG 89 ARG 89 ARG 89 ARG	$\begin{array}{c} O & T(1S) \rightarrow \\ C_{S}^{O} & \\ \hline COMMENT \\ C_{S}^{O} & \\ \hline COMMENT \\ C_{S}^{O} & \\ \hline C_{S}$	

 $\Upsilon(1S)$, $\chi_{b0}(1P)$, $\chi_{b1}(1P)$

$\Gamma(\gamma f_J(2220) \rightarrow \gamma$	$K^+K^-)$	/Γ _{total}				Γ_{27}/Γ
VALUE (units 10 ⁻⁵)	CL%	DOCUMENT ID		TECN	COMMENT	
< 1.5	90	²⁰ FULTON	90B	CLEO	$\gamma(15) \rightarrow \gamma K$	+ K-
	the follow	ing data for average	s, fits	, limits,	etc. • • •	
< 2.9	90	²⁰ ALBRECHT	89	ARG	$\Upsilon(1S) \rightarrow \gamma K$	+ K-
<20	90	²⁰ BARU	89	MD1	$\gamma(15) \rightarrow \gamma K$	+ K-
²⁰ Including unknow	n branchin	g ratio of $f_J(2220)$	→ K	+ K		
$\Gamma(\gamma\eta(2225) \rightarrow \gamma \phi$	φφ)/Γ _{tota}	ıl				Γ ₂₈ /Γ
VALUE	CL%	DOCUMENT ID		TECN	COMMENT	
<0.003	90	²¹ BARU	89	MD1	$\Upsilon(1S) \rightarrow$	
					~K+K-K	+ 1/-
					111 11 11	' A
²¹ Assuming that th	e η(2225)	decays only into $\phi\phi$			/	' N
						Γ ₂₆ /Γ
$\Gamma(\gamma f_0(2200) \rightarrow \gamma$				TECN	COMMENT	
²¹ Assuming that th $\Gamma(\gamma f_0(2200) \rightarrow \gamma)$ VALUE <0.0002	K+K-),	/F _{total}				Γ ₂₆ /Γ

$\Upsilon(1S)$ REFERENCES	71	15)	RE	FEI	RE	NC	ES
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BARU	96	PRPL 267 71	+Blinov, Blinov, Bondar+	(NOVO)
ALBRECHT	95E	ZPHY C65 619	+Hamacher+	(ARGUS Collab.)
BALEST	95	PR D51 2053	+Cho, Ford, Johnson+	(CLEO Collab.)
CINABRO	94B	PL B340 129	+Liu, Saulnier, Wilson+	(CLEO Collab.)
ALBRECHT	92.1	ZPHY C55 25	+Ehrlichmann, Hamacher+	(ARGUS Collab.)
BARU	92	ZPHY C54 229	+Beilin, Blinov+	(NOVO)
BARU	92B	ZPHY C56 547	+Blinov, Blinov, Bondar+	(NOVO)
KOBEL	92	ZPHY C53 193	+Antreasyan, Bartels, Besset+	(Crystal Ball Collab.)
BLINOV	90	PL B245 311	+Bondar+	(NOVO)
FULTON	90B	PR D41 1401	+Hemostead+	(CLEO Collab.)
MASCHMANN		ZPHY C46 555	+Antreasyan, Bartels, Besset+	(Crystal Ball Collab.)
ALBRECHT	89	ZPHY C42 349	+Boeckmann, Glaeser, Harder+	(ARGUS Collab.)
ALEXANDER	89	NP B320 45	+Bonvicini, Drell, Frey, Luth	(LBL, MICH, SLAC)
BARU	89	7PHY C42 505	+Beilin, Blinov, Blinov+	(NOVO)
CHEN	89B	PR D39 3528	+McIlwain, Miller+	(CLEO Collab.)
FULTON	89	PL B224 445	+Haas, Hempstead+	(CLEO Collab.)
KAARSBERG	89	PRL 62 2077	+Heintz+	(CUSB Collab.)
BUCHMUEL		HE e ⁺ e ⁻ Physics 412	Buchmueller, Cooper	(HANN, DESY, MIT)
		ind P. Soeding, World S		(6
JAKUBOWSKI		ZPHY C40 49	+Antreasyan, Bartels+	(Crystal Ball Collab.) IGJP0
SCHMITT	88	ZPHY C40 199	+Antreasyan+	(Crystal Ball Collab.)
ALBRECHT	87	ZPHY C35 283	+Binder, Boeckmann, Glaeser+	(ARGUS Collab.)
BARU	86	ZPHY C30 551	+Blinov, Bondar, Bukin+	(NOVO)
ALBRECHT	85C	PL 154B 452	+Drescher, Heller+	(ARGUS Collab.)
KURAEV	85	SJNP 41 466	+Fadin	(NOVO)
		Translated from YAF 4:		
ARTAMONOV		PL 137B 272	+Baru, Blinov, Bondar+	(NOVO)
BESSON	84	PR D30 1433	+Green, Hicks, Namjoshi, Sannes+	(CLEO Collab.)
GILES	84B	PR D29 1285	+Hassard, Hempstead, Kinoshita+	(CLEO Collab.)
MACKAY	84	PR D29 2483	+Hasard, Giles, Hempstead+	(CUSB Collab.)
ANDREWS	83	PRL 50 807	+Avery, Berkelman, Cassel+	(CLEO Collab.)
GILES	83	PRL 50 877	 + (HARV, OSU, ROCH, F 	
NICZYPORUK		ZPHY C17 197	+ Jakubowski, Zeludziewicz+	(LENA Collab.)
TUTS	83	Cornell Conf. 284		(CUSB Collab.)
ALBRECHT	82	PL 116B 383		HEIDH, LUND, ITEP)
ARTAMONOV		PL 118B 225	+Baru, Blinov, Bondar, Bukin, Grosh	
NICZYPORUK		ZPHY C15 299	+Folger, Bienlein+	(LENA Collab.)
BERGER	80C	PL 93B 497	+Lackas, Raupach+	(PLUTO Collab.)
BOCK	80	ZPHY C6 125		MPIM, DESY, HAMB)
BERGER	79	ZPHY C1 343	+Alexander+	(PLUTO Collab.)

- OTHER RELATED PAPERS ----

COOPER	86	Berkeley Conf. 67	(MIT)
KOENIGS	86	DESY 86/136	Koenigsmann (DESY)
ALBRECHT	84	PL 134B 137	+Drescher, Heller+ (ARGUS Collab.)
ARTAMONOV	84	PL 137B 272	+Baru, Blinov, Bondar+ (NOVO)
ARTAMONOV	82	PL 118B 225	+Baru, Blinov, Bondar, Bukin, Groshev+ (NOVO)
BERGER	78	PL 76B 243	+Alexander, Daum+ (PLUTO Collab.)
BIENLEIN	78	PL 78B 360	+Glawe, Bock, Blanar+ (DESY, HAMB, HEIDP, MPIM)
DARDEN	78	PL 76B 246	+Hofmann, Schubert+ (DESY, DORT, HEIDH, LUND)
GARELICK	78	PR D18 945	+Gauthier, Hicks, Oliver+ (NEAS, WASH, TUFTS)
KAPLAN	78	PRL 40 435	+Appel, Herb, Hom+ (STON, FNAL, COLU)
YOH	78	PRL 41 684	+Herb, Hom, Lederman+ (COLU, FNAL, STON)
COBB	77	PL 72B 273	+lwata, Fabjan+ (BNL, CERN, SYRA, YALE)
HERB	77	PRL 39 252	+Hom, Lederman, Appel, Ito+ (COLU, FNAL, STON)
INNES	77	PRL 39 1240	+Appel, Brown, Herb, Hom+ (COLU, FNAL, STON)



$$J^{G}(J^{PC}) = 0^{+}(0^{+})$$

J needs confirmation.

Observed in radiative decay of the $\Upsilon(25)$, therefore C=+. Branching ratio requires E1 transition, M1 is strongly disfavored, therefore P=+.

$\chi_{b0}(1P)$ MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
9859.8±1.3 OUR AVERAGE					
$9860.0 \pm 0.5 \pm 1.4$	¹ ALBRECHT		ARG	$\Upsilon(2S) \rightarrow$	$conv.\gamma X$
$9858.3 \pm 1.6 \pm 2.7$	¹ NERNST	85 (CBAL	$\Upsilon(2S) \rightarrow$	γX
9864.1±7 ±1	¹ HAAS	84 (CLEO	$\Upsilon(2S) \rightarrow$	$conv.\gamma X$
• • • We do not use the fol	lowing data for average	s, fits,	limits,	etc. • • •	
$9872.8 \pm 0.7 \pm 5.0$	¹ KLOPFEN	83 (CUSB	$\Upsilon(25) \rightarrow$	γX
¹ From γ energy below, as	suming $\Upsilon(2S)$ mass =	10023.	.4 MeV		

γ ENERGY IN $\varUpsilon(2S)$ DECAY

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT		
162.3±1.3 OUR AVERAGE						
$162.1 \pm 0.5 \pm 1.4$	ALBRECHT	85E	ARG	$\Upsilon(2S) \rightarrow$	$conv.\gamma X$	
$163.8 \pm 1.6 \pm 2.7$	NERNST	85	CBAL	$\Upsilon(2S) \rightarrow$	γX	
$158.0 \pm 7 \pm 1$	HAAS	84	CLEO	$\Upsilon(2S) \rightarrow$	$conv.\gamma X$	
 ◆ • We do not use the following data for averages, fits, limits, etc. • • 						
$149.4 \pm 0.7 \pm 5.0$	KLOPFEN	83	CUSB	$\Upsilon(2S) \rightarrow$	γX	

$x_{b0}(1P)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Confidence leve
Γ ₁	$\gamma \Upsilon(1S)$	<6 %	90%

$x_{b0}(1P)$ BRANCHING RATIOS

$\Gamma(\gamma \Upsilon(1S))/\Gamma_{total}$						Γ_1/Γ
VALUE	CL%	DOCUMENT ID		TECN	COMMENT	
<0.06	90	WALK	86	CBAL	$\Upsilon(25) \rightarrow$	$\gamma \gamma \ell^{+} \ell^{-}$
< 0.11	90	PAUSS	83	CUSB	$\Upsilon(25) \rightarrow$	$\gamma \gamma \ell^+ \ell^-$

$\chi_{b0}(1P)$ REFERENCES

WALK ALBRECHT NERNST HAAS KLOPFEN	85E 85 84 83	PRL 51 160	+Zschorsch+ +Drescher, Heller+ +Antreasyan, Aschman+ +Jensen, Kagan, Kass, Behrends+ Klopfenstein, Horstkotte+	(Crystal Ball Collab.) (ARGUS Collab.) (Crystal Ball Collab.) (CLEO Collab.) (CUSB Collab.)
PAUSS	83	PL 130B 439	+Dietl, Eigen+ (MPIM, COLU,	CORN, LSU, STON)



$$J^{G}(J^{PC}) = 0^{+}(1^{+})$$

J needs confirmation.

Observed in radiative decay of the $\Upsilon(2S)$, therefore C=+. Branching ratio requires E1 transition, M1 is strongly disfavored, therefore P=+. J=1 from SKWARNICKI 87.

$x_{b1}(1P)$ MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
9891.9±0.7 OUR AVERAGE				
9890.8±0.9±1.3	¹ WALK	86	CBAL	$\Upsilon(2S) \rightarrow \gamma \gamma \ell^+ \ell^-$
9890.8±0.3±1.1	1 ALBRECHT	85E	ARG	$\Upsilon(2S) \rightarrow \text{conv.} \gamma X$
9892.0±0.8±2.4	$^{ m 1}$ NERNST	85	CBAL	$\Upsilon(2S) \rightarrow \gamma X$
9893.6±0.8±1.0	¹ HAAS	84	CLEO	$\Upsilon(2S) \rightarrow \text{conv.} \gamma X$
9894.4±0.4±3.0	1 KLOPFEN	83	CUSB	$\Upsilon(2S) \rightarrow \gamma X$
9892 ±3	¹ PAUSS	83	CUSB	$\gamma(25) \rightarrow \gamma \gamma \ell^{+} \ell^{-}$

γ ENERGY IN $\Upsilon(2S)$ DECAY

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
130.6±0.7 OUR AVERAGE				
$131.7 \pm 0.9 \pm 1.3$	WALK	86	CBAL	$\Upsilon(2S) \rightarrow \gamma \gamma \ell^+ \ell^-$
$131.7 \pm 0.3 \pm 1.1$	ALBRECHT	85E	ARG	$\Upsilon(2S) \rightarrow \text{conv.} \gamma X$
$130.6 \pm 0.8 \pm 2.4$	NERNST	85	CBAL	$\Upsilon(2S) \rightarrow \gamma X$
129 ±0.8±1	HAAS	84	CLEO	$\Upsilon(25) \rightarrow \text{conv.} \gamma X$
$128.1 \pm 0.4 \pm 3.0$	KLOPFEN	83	CUSB	$\Upsilon(2S) \rightarrow \gamma X$
130.6 ± 3.0	PAUSS	83	CUSB	$\Upsilon(2S) \rightarrow \gamma \gamma \ell^+ \ell^-$

$\chi_{b1}(1P)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ_1	γ Υ(15)	(35 ± 8) %

$x_{b1}(1P)$ BRANCHING RATIOS

				Γ ₁ /Ι
DOCUMENT ID		TECN	COMMENT	
WALK	86	CBAL	$\Upsilon(2S) \rightarrow$	$\gamma\gamma\ell^+\ell^-$
KLOPFEN	83	CUSB	$\Upsilon(2S) \rightarrow$	$\gamma\gamma\ell^+\ell^-$
	WALK	WALK 86	WALK 86 CBAL	DOCUMENT IDTECNCOMMENTWALK86CBAL $\Upsilon(25) \rightarrow$ KLOPFEN83CUSB $\Upsilon(25) \rightarrow$

$x_{b1}(1P)$ REFERENCES

SKWARNICKI	87	PRL 58 972	+Antreasyan, Besset+	(Crystal Ball Collab.) J
WALK	86	PR D34 2611	+Zschorsch+	(Crystal Ball Collab.)
ALBRECHT	85E	PL 160B 331	+Drescher, Heller+	(ARGUS Collab.)
NERNST	85	PRL 54 2195	+Antreasyan, Aschman+	(Crystal Ball Collab.)
HAAS	84	PRL 52 799	+Jensen, Kagan, Kass, Behrends+	(CLEO Collab.)
KLOPFEN	83	PRL 51 160	Klopfenstein, Horstkotte+	(CUSB Collab.)
PAUSS	83	PL 130B 439	+Dietl, Eigen+ (MPIM, COLU	, CORN, LSU, STON)

$\chi_{b2}(1P)$

$$I^G(J^{PC}) = 0^+(2^{++})$$

J needs confirmation.

Observed in radiative decay of the $\Upsilon(2S)$, therefore C=+. Branching ratio requires E1 transition, M1 is strongly disfavored, therefore P=+. J=2 from SKWARNICKI 87.

$\chi_{b2}(1P)$ MASS

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
9913.2±0.6 OUR AVERAGE			
$9915.8 \pm 1.1 \pm 1.3$	¹ WALK	86 CBAL	$\Upsilon(2S) \rightarrow \gamma \gamma \ell^+ \ell^-$
$9912.2 \pm 0.3 \pm 0.9$	1 ALBRECHT	85E ARG	$\Upsilon(2S) \rightarrow \text{conv.} \gamma X$
$9912.4 \pm 0.8 \pm 2.2$	1 NERNST	85 CBAL	$\Upsilon(2S) \rightarrow \gamma X$
$9913.3 \pm 0.7 \pm 1.0$	1 HAAS	84 CLEC	$\Upsilon(2S) \rightarrow conv. \gamma X$
$9914.6 \pm 0.3 \pm 2.0$	¹ KLOPFEN	83 CUSE	$\Upsilon(2S) ightarrow \gamma X$
9914 ±4	¹ PAUSS	83 CUSE	$\gamma(2S) \rightarrow \gamma \gamma \ell^+ \ell^-$

 $^1\,{\sf From}\,\,\gamma$ energy below, assuming $\varUpsilon(2S)$ mass = 10023.4 MeV.

γ ENERGY IN $\Upsilon(2S)$ DECAY

VALUE (MeV) 109.6±0.6 OUR AVERAGE	DOCUMENT ID		TECN	COMMENT
$107.0 \pm 1.1 \pm 1.3$ $110.6 \pm 0.3 \pm 0.9$ $110.4 \pm 0.8 \pm 2.2$ $109.5 \pm 0.7 \pm 1.0$ $108.2 \pm 0.3 \pm 2.0$	WALK ALBRECHT NERNST HAAS KLOPFEN	85E 85 84 83	ARG CBAL CLEO CUSB	$\begin{array}{ll} \Upsilon(2S) \to & \gamma \gamma \ell^+ \ell^- \\ \Upsilon(2S) \to & conv. \gamma X \\ \Upsilon(2S) \to & \gamma X \\ \Upsilon(2S) \to & conv. \gamma X \\ \Upsilon(2S) \to & conv. \gamma X \\ \Upsilon(2S) \to & \gamma X \end{array}$
108.8 ± 4.0	PAUSS	83	CUSB	$\Upsilon(2S) \rightarrow \gamma \gamma \ell^+ \ell^-$

$x_{b2}(1P)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ1	$\gamma \Upsilon(1S)$	(22±4) %

$x_{b2}(1P)$ BRANCHING RATIOS

$\Gamma(\gamma \Upsilon(1S))/\Gamma_{total}$					Γ_1/Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
0.22±0.04 OUR AVERAGE					
$0.27 \pm 0.06 \pm 0.06$	WALK	86	CBAL	$\Upsilon(2S) \rightarrow$	$\gamma \gamma \ell^+ \ell^-$
0.20 ± 0.05	KLOPFEN	83	CUSB	Y(25) →	$\gamma\gamma\ell^+\ell^-$

$\chi_{b2}(1P)$ REFERENCES

SKWARNICKI	87	PRL 58 972	+Antreasyan, Besset+		(Crystal Ball	Collab.) J
WALK	86	PR D34 2611	+Zschorsch+		(Crystal Ball	Collab.)
ALBRECHT	85E	PL 160B 331	+Drescher, Heller+		(ARGUS	Collab.)
NERNST	85	PRL 54 2195	+Antreasyan, Aschman	+	(Crystal Ball	Collab.)
HAAS	84	PRL 52 799	+Jensen, Kagan, Kass,	Behrends+	(CLEO	Collab.)
KLOPFEN	83	PRL 51 160	Klopfenstein, Horstko			Collab.)
PAUSS	83	PL 130B 439	+Dietl, Eigen+	(MPIM, COLU,	CORN, LSU,	STON)

$\Upsilon(2S)$

$$I^{G}(J^{PC}) = 0^{-}(1^{-})$$

T(25)	MASS
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VALUE (GeV)	DOCUMENT ID		TECN	COMMENT
10.02330 ± 0.00031 OUR A	/ERAGE			
10.0236 ±0.0005	¹ BARU	86B	REDE	$e^+e^- ightarrow hadrons$
10.0231 ±0.0004	BARBER	84	REDE	$e^+e^- ightarrow hadrons$
¹ Reanalysis of ARTAMO	NOV 84.			

$\Upsilon(2S)$ WIDTH

T(2S) DECAY MODES

	Mode	Fraction (Γ_i/Γ) Co	nfidence level
$\overline{\Gamma_1}$	$\Upsilon(1S)\pi^+\pi^-$	(18.5 ±0.8) %	
Γ_2	$\Upsilon(1S)\pi^0\pi^0$	$(8.8 \pm 1.1)\%$	
Γ_3	$\tau^+\tau^-$	$(1.7 \pm 1.6)\%$	
Γ_4	$\mu^+\mu^-$	(1.31±0.21) %	
Γ_5	e^+e^-	seen	
Γ_6	$\Upsilon(1S)\pi^0$	< 8 × 10 ⁻³	90%
Γ_7	$\Upsilon(1S)\eta$	$< 2 \times 10^{-3}$	90%
Γ8	$J/\psi(1S)$ anything	< 6 × 10 ⁻³	90%
		Radiative decays	
Γ9	$\gamma \chi_{b1}(1P)$	(6.7 ±0.9) %	
Γ_{10}	$\gamma \chi_{b2}(1P)$	(6.6 ± 0.9) %	
Γ_{11}	$\gamma \chi_{b0}(1P)$	$(4.3 \pm 1.0)\%$	
Γ_{12}	$\gamma f_J(1710)$	$< 5.9 \times 10^{-4}$	90%
Γ_{13}	$\gamma f_2'(1525)$	$< 5.3 \times 10^{-4}$	90%
Γ_{14}	$\gamma f_2(1270)$	$< 2.41 \times 10^{-4}$	90%
	$\gamma f_J(2220)$		

$\Upsilon(2S) \Gamma(i)\Gamma(e^+e^-)/\Gamma(total)$

$\Gamma(e^+e^-) \times \Gamma(\mu^+\mu^-)/\Gamma_{\text{total}}$ VALUE (eV)	DOCUMENT ID		TECN	COMMENT	- "
6.5±1.5±1.0	KOBEL	92	CBAL	$e^+e^-\rightarrow$	$\mu^+\mu^-$
$\Gamma(\text{hadrons}) \times \Gamma(e^+e^-)/\Gamma_{\text{tota}}$	al				$\Gamma_0\Gamma_5/\Gamma$
VALUE (keV)	DOCUMENT ID		TECN	COMMENT	
0.553±0.023 OUR AVERAGE					
$0.552 \pm 0.031 \pm 0.017$	² BARU	96	MD1	$e^+e^- \rightarrow$	hadrons
0.54 ±0.04 ±0.02	² JAKUBOWSKI	88	CBAL	$e^+e^- \rightarrow$	hadrons
0.58 ±0.03 ±0.04	³ GILES	84B	CLEO	$e^+e^- \rightarrow$	hadrons
0.60 ±0.12 ±0.07	³ ALBRECHT	82	DASP	$e^+e^- \rightarrow$	hadrons
$0.54 \pm 0.07 ^{+0.09}_{-0.05}$	³ NICZYPORUK	81C	LENA	$e^+e^-\rightarrow$	hadrons
0.41 ±0.18	³ воск	80	CNTR	$e^+e^- \rightarrow$	hadrons
• • • We do not use the following	data for averages	, fits	, limits,	etc. • • •	
0.59 +0.03 +0.05	³ TUTS	83	CUSB	e^+e^-	hadrons

 2 Radiative corrections evaluated following KURAEV 85. 3 Radiative corrections reevaluated by BUCHMUELLER 88 following KURAEV 85.

$\Upsilon(2S)$ PARTIAL WIDTHS

Γ(e ⁺ e ⁻)				Γ ₅
VALUE (keV)	DOCUMENT ID	TECN	COMMENT	
0.52 ±0.03 OUR ESTIMATE				
$0.52 \pm 0.03 \pm 0.01$	⁴ ALBRECHT	95E ARG	$e^+e^- ightarrow hadrons$	
⁴ Applying the formula of Kurae	v and Fadin.			

$\Upsilon(2S)$ BRANCHING RATIOS

 Γ_8/Γ

 $\Gamma(J/\psi(1S))$ anything $\Gamma(J/\psi(1S))$

VALUE	CL%	DOCUMENT ID	TE	CN_CC	DMMENT
<0.006	90	MASCHMANN 90	СВ	AL e [⊣]	$^+e^- ightarrow $ hadrons
$\Gamma(\Upsilon(1S)\pi^+\pi^-)/\Gamma_{tc}$	otal				Γ ₁ /Γ
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.185 ± 0.008 OUR AVE	RAGE				
$0.181 \pm 0.005 \pm 0.010$	11.6k	ALBRECHT	87	ARG	$e^+e^+ \xrightarrow{-} \dots$
0.169 ± 0.040		GELPHMAN	85	CBAL	$e^+e^- \xrightarrow{\pi^+\pi^-} MM$ $e^+e^- \xrightarrow{\pi^+\pi^-}$
$0.191 \pm 0.012 \pm 0.006$		BESSON	84	CLEO	$\pi^+\pi^-$ MM
0.189 ± 0.026		FONSECA	84	CUSB	e+e- →
0.21 ± 0.07	7	NICZYPORUK	81B	LENA	$e^+e^- \rightarrow -$

 $\Upsilon(2S)$, $\chi_{b0}(2P)$

$\Gamma(\Upsilon(1S)\pi^0\pi^0)/\Gamma_{\rm tot}$						Γ_2/Γ
VALUE 0.088±0.011 OUR AVE	EVTS RAGE	DOCUMENT ID		TECN	COMMENT	
$0.095 \pm 0.019 \pm 0.019$	25	ALBRECHT	87	ARG	$e^+e^- \rightarrow$	$\pi^{0}\pi^{0}\ell^{+}\ell^{-}$
0.080 ± 0.015		GELPHMAN	85	CBAL		$\ell^{+}\ell^{-}\pi^{0}\pi^{0}$
0.103±0.023		FONSECA	84	CUSB		$\ell^{+}\ell^{-}\pi^{0}\pi^{0}$
$\Gamma(\tau^+\tau^-)/\Gamma_{\text{total}}$			-			Г ₃ /Г
VALUE		DOCUMENT ID		TECN	COMMENT	
$0.017 \pm 0.015 \pm 0.006$		HAAS	84B	CLEO	e ⁺ e ⁻ →	$\tau^+\tau^-$
$\Gamma(\mu^+\mu^-)/\Gamma_{\text{total}}$	C(A)	Documen	VT (0			Γ ₄ /Γ
VALUE 0.0131±0.0021 OUR	CL%	_ <u>DOCUME</u>	VI ID	1	TECN COM	MENI
0.0131 ± 0.0021 GON $0.0122\pm0.0028\pm0.00$		⁵ KOBEL		92 (CBAL e+e	$- \rightarrow \mu^{+}\mu^{-}$
$0.0122 \pm 0.0025 \pm 0.00$ $0.0138 \pm 0.0025 \pm 0.00$		KAARSE	RERG			$- \rightarrow \mu^{+}\mu^{-}$
0.009 ±0.006 ±0.00		6 ALBREC		85 A	ARG e+e	$- \rightarrow \mu^+\mu^-$
0.018 ±0.008 ±0.00		HAAS			CLEO e+e	$- \rightarrow \mu^+ \mu^-$
• • • We do not use the	e following	data for average	s, fits	s, limits,	etc. • • •	
< 0.038	90	NICZYP				$- \rightarrow \mu^+ \mu^-$
⁵ Taking into account						F F
⁶ Re-evaluated using B				ice and	continuum.	
$\Gamma(\Upsilon(1S)\pi^0)/\Gamma_{total}$						Γ_6/Γ
VALUE	CL%	DOCUMENT ID				-1
<0.008	90	LURZ	87	CBAL	e ⁺ e ⁻ →	$\ell^+\ell^-\gamma\gamma$
$\Gamma(\Upsilon(1S)\eta)/\Gamma_{\text{total}}$						Γ_7/Γ
VALUE	CL%	DOCUMENT ID		TECN	COMMENT	. ,,.
<0.002	90	FONSECA	84	CUSB		
• • We do not use the					, etc. • • •	
< 0.005	90	ALBRECHT	87	ARG		
					$e^+e^- \rightarrow e^+e^- \rightarrow e^+e^- \rightarrow$	ℓ ⁺ ,ℓ ⁻ ΜΜ
< 0.007	90	LURZ	87	CBAL	$e^+e^- \rightarrow 3\pi^0$)	$\ell^+\ell^-(\gamma\gamma,$
< 0.010	90	BESSON	84	CLEO	,	
$\Gamma(\gamma \chi_{b1}(1P))/\Gamma_{\text{total}}$						Γ_{9}/Γ
VALUE	DACE	DOCUMENT ID		TECN	COMMENT	
0.067±0.009 OUR AVE	KAGE	ALDDECUT	05-	ARG	$e^+e^- \rightarrow$	
$0.091 \pm 0.018 \pm 0.022$		ALBRECHT	85	CBAL		
$0.065 \pm 0.007 \pm 0.012$		NERNST HAAS	84	CLEO		
$0.080 \pm 0.017 \pm 0.016$ 0.059 ± 0.014		KLOPFEN	83	CUSB	e+e- →	
$\Gamma(\gamma \chi_{b2}(1P))/\Gamma_{total}$						Γ ₁₀ /Γ
VALUE		DOCUMENT ID		TECN	COMMENT	
0.066±0.009 OUR AVE	RAGE				-1	
$0.098 \pm 0.021 \pm 0.024$		ALBRECHT		ARG	e ⁺ e ⁻ →	
$0.058 \pm 0.007 \pm 0.010$		NERNST	85	CBAL		
$0.102 \pm 0.018 \pm 0.021$		HAAS	84	CLEO		
0.061±0.014		KLOPFEN	83	CUSB	e ⁺ e ⁻ →	
$\Gamma(\gamma \chi_{b0}(1P))/\Gamma_{total}$		DOCUMENT ID		TECN	COMMENT	Γ_{11}/Γ
0.043±0.010 OUR AVE	RAGE	DOCUMENT ID		12214	COMMINICIAL	
$0.064 \pm 0.014 \pm 0.016$		ALBRECHT	85E	ARG	$e^+e^- \rightarrow$	γ conv. X
$0.036 \pm 0.008 \pm 0.009$		NERNST		CBAL	$e^+e^- \rightarrow$	γX
$0.044 \pm 0.023 \pm 0.009$		HAAS		CLEO		
• • • We do not use the	e following	data for average				
0.035 ± 0.014		KLOPFEN				γX
$\Gamma(\gamma f_J(1710))/\Gamma_{total}$						Γ_{12}/Γ
VALUE (units 10 ⁻⁵)	CL%	DOCUMENT ID		TECN	COMMENT	
<59	20	ALDINECTT	0,	,,,,,	. (23)	γ K ⁺ K
• • We do not use the						
< 5.9 7 Re-evaluated assumi		⁸ ALBRECHT 10) $\rightarrow K^+K^-$			7 (25) →	γπ τ π
⁸ Includes unknown br						
$\Gamma(\gamma f_2'(1525))/\Gamma_{\text{total}}$						Γ_{13}/Γ
VALUE (units 10 ⁻⁵)	CL%	DOCUMENT ID ALBRECHT		TECN	COMMENT	
<53 9 Re-evaluated assumi					γ(2S) →	γ K ⁺ K ⁻
- ne-evaluated assumi	iig D(12(15	20) → NK) =	U.71	•		
$\Gamma(\gamma f_2(1270))/\Gamma_{\text{total}}$						Γ_{14}/Γ
VALUE (units 10 ⁻⁵) <24.1	CL%	DOCUMENT ID		TECN	COMMENT	
<24.1	90 1	O ALBRECHT	89	ARG	γ(25) →	$\gamma \pi^+ \pi^-$
¹⁰ Using B($f_2(1270) \rightarrow$. ,	
5 (2()	,					

$\Gamma(\gamma f_J(2220))/\Gamma_{tot}$	al				Γ_{15}/Γ
VALUE (units 10 ⁻⁵)	CL%	DOCUMENT ID	TECN	COMMENT	
• • • We do not use	the following	ng data for averages	s, fits, limit	s, etc. • • •	
<6.8	90	¹¹ ALBRECHT	89 ARG	$\Upsilon(2S) \rightarrow$	$\gamma K^+ K^-$
¹¹ Includes unknown	branching i	ratio of $f_J(2220) \rightarrow$	· κ+κ		

$\Upsilon(2S)$ REFERENCES

BARU	96	PRPL 267 71	+Blinov, Blinov, Bondar+		(NOVO)
ALBRECHT	95E	ZPHY C65 619	+Hamacher+	(ARGUS	Collab.)
KOBEL	92	ZPHY C53 193	+Antreasyan, Bartels, Besset+	(Crystal Ball	Collab.)
MASCHMANN	90	ZPHY C46 555	+Antreasyan, Bartels, Besset+	(Crystal Ball	
ALBRECHT	89	ZPHY C42 349	+Boeckmann, Glaeser, Harder+	(ARGUS	Collab.)
KAARSBERG	89	PRL 62 2077	+Heintz+	`(CUSB	Collab.)
BUCHMUEL		HE e+e- Physics 412	Buchmueller, Cooper	(HANN, DES	
Editors: A.	. Ali a	nd P. Soeding, World So	cientific, Singapore		
JAKUBOWSKI	88	ZPHY C40 49	+Antreasyan, Bartels+	(Crystal Ball	Collab.) IGJPO
ALBRECHT	87	ZPHY C35 283	+Binder, Boeckmann, Glaeser+	(ARGUS	Collab.)
LURZ	87	ZPHY C36 383	+Antreasyan, Besset+	(Crystal Ball	Collab.)
BARU	86B	ZPHY C32 622	+Blinov, Bondar, Bukin+		(NOVO)
ALBRECHT	85	ZPHY C28 45	+Dreschell, Heller+	(ARGUS	Collab.)
ALBRECHT	85E	PL 160B 331	+Drescher, Heller+	(ARGUS	Collab.)
GELPHMAN	85	PR D11 2893	+Lurz, Antreasyan+	(Crystal Ball	Collab.)
KURAEV	85	SJNP 41 466	+Fadin		(NOVO)
		Translated from YAF 41			
NERNST	85	PRL 54 2195	+Antreasyan, Aschman+	(Crystal Ball	
ARTAMONOV	84	PL 137B 272	+Baru, Blinov, Bondar+		(NOVO)
BARBER	84	PL 135B 498	 + (DESY, ARGUS Collab 		Collab.)
BESSON	84	PR D30 1433	+Green, Hicks, Namjoshi, Sannes+		Collab.)
FONSECA	84	NP B242 31	+Mageras, Son, Dietl, Eigen+	(CUSB	Collab.)
GILES	84B	PR D29 1285	+Hassard, Hempstead, Kinoshita+	(CLEO	Collab.)
HAAS	84	PRL 52 799	+Jensen, Kagan, Kass, Behrends+	(CLEO	Collab.)
HAAS	84B	PR D30 1996	+Jensen, Kagan, Kass, Behrends+	(CLEO	Collab.)
KLOPFEN	83	PRL 51 160	Klopfenstein, Horstkotte+	(CUSB	Collab.)
TUTS	83	Cornell Conf. 284		(CUSB	Collab.)
ALBRECHT	82	PL 116B 383	+Hofmann+ (DESY, DORT,	HEIDH, LUNE), ITEP)
NICZYPORUK	81B	PL 100B 95	+Chen, Folger, Lurz+		Collab.)
NICZYPORUK	81C	PL 99B 169	+Chen, Vogel, Wegener+	(LENA	Collab.)
BOCK	80	ZPHY C6 125		MPIM, DESY,	

- OTHER RELATED PAPERS ---

ALEXANDER	89	NP B320 45	+Bonvicini, Drell, Frey, Luth	(LBL, MICH, SLAC)
COOPER	86	Berkeley Conf. 67		(MIT)
WALK	86	PR D34 2611	+Zschorsch+	(Crystal Ball Collab.)
ALBRECHT	84	PL 134B 137	+Drescher, Heller+	(ARGUS Collab.)
ARTAMONOV	84	PL 137B 272	+Baru, Blinov, Bondar+	(NOVO)
ANDREWS	83	PRL 50 807	+Avery, Berkelman, Cassel+	(CLEO Collab.)
GREEN	82	PRL 49 617	+Sannes, Skubic, Snyder+	(CLEO Collab.)
BIENLEIN	78	PL 78B 360	+Glawe, Bock, Blanar+ (DESY	, HAMB, HEIDP, MPIM)
DARDEN	78	PL 76B 246	+Hofmann, Schubert+ (DESY	, DORT, HEIDH, LUND)
KAPLAN	78	PRL 40 435	+Appel, Herb, Hom+	(STON, FNAL, COLU)
YOH	78	PRL 41 684	+Herb, Hom, Lederman+	(COLU, FNAL, STON)
COBB	77	PL 72B 273	+Iwata, Fabian+ (BN	NL. CERN. SYRA. YALE)
HERB	77	PRL 39 252	+Hom, Lederman, Appel, Ito+	(COLU, FNAL, STON)
INNES	77	PRL 39 1240	+Appel, Brown, Herb, Hom+	(COLU, FNAL, STON)



$$I^G(J^{PC}) = 0^+(0^{++})$$

J needs confirmation.

Observed in radiative decay of the $\Upsilon(3S)$, therefore C=+. Branching ratio requires E1 transition, M1 is strongly disfavored, therefore

$\chi_{b0}(2P)$ MASS

VALUE (GeV)	DOCUMENT ID		TECN	COMMENT
10.2321 ±0.0006 OUR AVERAGE				
$10.2312 \pm 0.0008 \pm 0.0012$	$^{ m 1}$ HEINTZ	92	CSB2	$e^+e^- \rightarrow \gamma \times , \ell^+\ell^- \gamma \gamma$
10.2323 ± 0.0007	² MORRISON	91	CLE2	$e^+e^- \rightarrow \gamma X$

γ ENERGY IN \varUpsilon (35) DECAY

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT	
122.8±0.5 OUR AV	ERAGE Err	or includes scale f	actor	of 1.1.		
123.0 ± 0.8	4959	³ HEINTZ	92	CSB2	$e^+e^- \rightarrow$	γX
124.6 ± 1.4	17	⁴ HEINTZ	92	CSB2	$e^+e^- \rightarrow$	$\ell^+\ell^-\gamma\gamma$
$122.3 \pm 0.3 \pm 0.6$	9903	MORRISON	91	CLE2	$e^+e^- \rightarrow$	γX
2						

$\chi_{b0}(2P)$ DECAY MODES

Mode	Fraction (Γ_i/Γ)
γ Υ(25) γ Υ(15)	(4.6 ± 2.1) % (9 ±6) × 10 ⁻³

¹ From the average photon energy for inclusive and exclusive events and assuming $\varUpsilon(3S)$ mass $=10355.3\pm0.5$ MeV. Supersedes HEINTZ 91 and NARAIN 91. 2 From Υ energy below assuming $\varUpsilon(3S)$ mass $=10355.3\pm0.5$ MeV. The error on the $\varUpsilon(3S)$ mass is not included in the individual measurements. It is included in the final average.

 $^{^3}$ A systematic uncertainty on the energy scale of 0.9% not included. Supersedes NARAIN 91. 4 A systematic uncertainty on the energy scale of 0.9% not included. Supersedes HEINTZ 91.

$\chi_{b0}(2P)$ BRANCHING RATIOS

$\Gamma(\gamma \Upsilon(2S))/\Gamma_{\text{total}}$					Γ_1/Γ
VALUE	CL%	DOCUMENT ID	TECN	COMMENT	
< 0.089	90	5 CRAWFORD	92B CLE2	$e^+e^- \rightarrow \ell^+$	$\ell^-\gamma\gamma$
$0.046 \pm 0.020 \pm 0.007$		6 HEINTZ	92 CSB2	$e^+e^- \rightarrow \ell^+$	$\ell^-\gamma\gamma$
⁵ Using B($\Upsilon(2S) \rightarrow \mu$					(\(\cap (2S) →
$\mu^{+}\mu^{-}) < 1.19 \times 1$					
⁶ Using B($\Upsilon(2S) \rightarrow$	$\mu^{+}\mu^{-}$)	$= (1.44 \pm 0.10)\%$	B($\Upsilon(3S)$	$\rightarrow \gamma \chi_{b0}(2P)$	$=$ (6.0 \pm
0.4 ± 0.6)% and ass	uming e	universality. Supe	rsedes HFIN	T7 91.	

$\Gamma(\gamma \Upsilon(1S)) / \Gamma_{total}$					Γ_2/Γ
VALUE	CL%	DOCUMENT ID	TECN	COMMENT	
< 0.025	90	⁷ CRAWFORD 928	CLE2	$e^+e^- \rightarrow$	$\ell^+\ell^-\gamma\gamma$
$0.009 \pm 0.006 \pm 0.001$		⁸ HEINTZ 92	CSB2	$e^+e^- \rightarrow$	$\ell^+\ell^-\gamma\gamma$
_					

 7 Using B(7 (15) → 4 $^{+}$ $^{-}$) = (2.57 ± 0.07)%, B(7 (35) → 7 7 7 (15))×2 B(7 (15) → 4 $^{+}$ 4 $^{-}$) < 0.63 × 10⁻⁴, and B(7 (35) → 7 8 10 (2P) 7) = 0.049.

 $\mu = \mu + \lambda = 0.33 \times 10^{-1} \times 10^{-$

$\chi_{b0}(2P)$ REFERENCES

CRAWFORD HEINTZ	92	PL B294 13 PR D46 192	8 +Lee, Franzini+	(CLEO Collab.) (CUSB II Collab.)
HEINTZ	91	PRL 66 156	+Schmidt+	(CUSB Collab.)
MORRISON	91	PRL 67 169		(CLEO Collab.)
NARAIN	91	PRL 66 311		(CUSB Collab.)

- OTHER RELATED PAPERS -

TUTS	83	Cornell Conf. 28	4	(CUSB Collab.)
EIGEN	82	PRL 49 1616	+Bohringer, Herb+	(CUSB Collab.)
HAN	82	PRI 49 1612	⊥Horstkotte Imlav⊥	(CUSB Collab)



$$I^G(J^{PC}) = 0^+(1^{++})$$

J needs confirmation.

Observed in radiative decay of the $\Upsilon(3S)$, therefore C=+. Branching ratio requires E1 transition, M1 is strongly disfavored, therefore

$\chi_{b1}(2P)$ MASS

VALUE (GeV)	DOCUMENT ID		TECN	COMMENT	
10.2552±0.0005 OUR AVERAGE					
$10.2547 \pm 0.0004 \pm 0.0010$	¹ HEINTZ	92	CSB2	$e^+e^- \rightarrow$	$\gamma X, \ell^+ \ell^- \gamma \gamma$
10 2553 ± 0 0005	² MORRISON	91	CLE2	e+e	~ X

 1 From the average photon energy for inclusive and exclusive events and assuming $\varUpsilon(3S)$ mass = 10355.3 \pm 0.5 MeV. Supersedes HEINTZ 91 and NARAIN 91. 2 From γ energy below assuming $\varUpsilon(3S)$ mass = 10355.3 \pm 0.5 MeV. The error on the $\varUpsilon(3S)$ mass is not included in the individual measurements. It is included in the final

$m\chi_{b1(2P)} - m\chi_{b0(2P)}$

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
$23.5 \pm 0.7 \pm 0.7$	³ HEINTZ	92	CSB2	$e^+e^- \rightarrow$	$\gamma \times , \ell^+ \ell^- \gamma \gamma$

³ From the average photon energy for inclusive and exclusive events. Supersedes NARAIN 91.

γ ENERGY IN $\Upsilon(3S)$ DECAY

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
99.90±0.26 OUR A	VERAGE			
99 ±1	169	CRAWFORD	92B CLE2	$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$
100.1 ±0.4	11147	⁴ HEINTZ	92 CSB2	$e^+e^- \rightarrow \gamma X$
100.2 ±0.5	223	⁵ HEINTZ	92 CSB2	$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$
99.5 ±0.1 ±0.5	25759	MORRISON	91 CLE2	$e^+e^- \rightarrow \gamma X$

⁴ A systematic uncertainty on the energy scale of 0.9% not included. Supersedes

A systematic uncertainty on the energy scale of 0.9% not included. HEINTZ 91.

X_{b1}(2P) DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Scale factor
Γ ₁	γ Υ(2S)	(21 ±4)%	1.5
Γ_2	$\gamma \Upsilon(15)$	(8.5 ± 1.3) %	1.3

$\chi_{b1}(2P)$ BRANCHING RATIOS

$\Gamma(\gamma T(25))/\Gamma_{\text{total}}$				Γ_1/Γ
VALUE	DOCUMENT ID	TECN	COMMENT	
0.21 ±0.04 OUR AVERAGE	Error includes scale	factor of 1.5		
$0.356 \pm 0.042 \pm 0.092$	⁶ CRAWFORD	92B CLE2	$e^+e^- \rightarrow$	$\ell^+\ell^-\gamma\gamma$
$0.199 \pm 0.020 \pm 0.022$	⁷ HEINTZ	92 CSB2	$e^+e^- \rightarrow$	$\ell^+\ell^-\gamma\gamma$
6 Using B($\Upsilon(2S) \to \mu^+ \mu^-$) $\mu^+ \mu^-$) = (10.23±1.20±1	$= (1.37 \pm 0.26)\%$, E .26) $\times 10^{-4}$, and B(γ	$3(\Upsilon(3S) \rightarrow \gamma \chi_{L}^{2}$	$(\gamma \Upsilon(2S)) \times 2$ (2P)) = 0.	2 B($^{(25)}$ \rightarrow $^{105}_{-0.002}^{+0.003}$ \pm
$^{0.013.}$ 7 Using B($\gamma(2S) ightarrow \mu^+ \mu^-$ 0.5 \pm 0.5)% and assuming	$e\mu$ universality. Supe	, B(Υ (3 S) $-$ ersedes HEIN $^{\circ}$	$\gamma^{\chi}{}_{b1}$ (2 P FZ 91.)) = (11.5 ±

 $\Gamma(\gamma \Upsilon(1S))/\Gamma_{\text{total}}$ Γ_2/Γ DOCUMENT ID TECN COMMENT

0.085 \pm 0.013 OUR AVERAGE Error includes scale factor of 1.3. 8 CRAWFORD 928 CLE2 $e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$ 9 HEINTZ 92 CSB2 $e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$ $0.080 \pm 0.009 \pm 0.007$

⁸ Using B($\Upsilon(1S) \rightarrow \mu^+\mu^-$) = (2.57 ± 0.07)%, B($\Upsilon(3S) \rightarrow \gamma\gamma \Upsilon(1S)$)×2 B($\Upsilon(1S)$ $\mu^{+}\mu^{-}) = (6.47 \pm 1.12 \pm 0.82) \times 10^{-4} \text{ and B}(\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P)) = 0.105 ^{+0.003}_{-0.002} \pm 0.003$

9 Using B($\Upsilon(1S) \rightarrow \mu^+\mu^-$)=(2.57 ± 0.07)%, B($\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P)$) = (11.5 ± 0.5 ± 0.5)% and assuming $e\mu$ universality. Supersedes HEINTZ 91.

$\chi_{b1}(2P)$ REFERENCES

CRAWFORD		PL B294 139	+Fulton	(CLEO Collab.)
HEINTZ	92	PR D46 1928	+Lee, Franzini+	(CUSB II Collab.)
HEINTZ	91	PRL 66 1563	+Kaarsberg+	(CUSB Collab.)
MORRISON	91	PRL 67 1696	+Schmidt+	(CLEO Collab.)
NARAIN	91	PRL 66 3113	+Lovelock+	(CUSB Collab.)

OTHER RELATED PAPERS -

TUTS	83	Cornell Conf. 284		(CUSB Collab.)
EIGEN	82	PRL 49 1616	+Bohringer, Herb+	(CUSB Collab.)
HAN	82	PRL 49 1612	+Horstkotte, Imlay+	(CUSB Collab.)



$$I^G(J^{PC}) = 0^+(2^{++})$$

J needs confirmation.

Observed in radiative decay of the $\Upsilon(3S)$, therefore C=+. Branching ratio requires E1 transition, M1 is strongly disfavored, therefore

$\chi_{b2}(2P)$ MASS

VALUE (GeV)	DOCUMENT ID		TECN	COMMENT	
10.2685 ± 0.0004 OUR AVERAG	E				
$10.2681 \pm 0.0004 \pm 0.0010$	¹ HEINTZ	92	CSB2	$e^+e^- \rightarrow$	$\gamma \times$, $\ell^+ \ell^- \gamma \gamma$
10.2685 ± 0.0004	² MORRISON	91	CLE2	$e^+e^- \rightarrow$	γX

 1 From the average photon energy for inclusive and exclusive events and assuming $\varUpsilon(35)$ mass = 10355.3 \pm 0.5 MeV. Supersedes HEINTZ 91 and NARAIN 91.

² From γ energy below, assuming $\Upsilon(3S)$ mass = 10355.3 \pm 0.5 MeV. The error on the $\Upsilon(3S)$ mass is not included in the individual measurements. It is included in the final

$m\chi_{b2}(2P) - m\chi_{b1}(2P)$

	COMMENT
13.5±0.4±0.5	$e^+e^- \rightarrow \gamma X$, $\ell^+\ell^- \gamma \gamma$

³ From the average photon energy for inclusive and exclusive events. Supersedes NARAIN 91.

γ ENERGY IN $\Upsilon(3S)$ DECAY

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
86.64 ± 0.23 OUR AVE	RAGE			
86 ±1	101	CRAWFORD	92B CLE2	$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$
86.7 ±0.4	10319	⁴ HEINTZ	92 CSB2	$e^+e^- ightarrow ho \chi X$
86.9 ±0.4	157	⁵ HEINTZ		$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$
$86.4 \pm 0.1 \pm 0.4$	30741	MORRISON	91 CLE2	$e^+e^- \rightarrow \gamma X$

⁴ A systematic uncertainty on the energy scale of 0.9% not included. Supersedes NARAIN 91.
5 A systematic uncertainty on the energy scale of 0.9% not included. Supersedes

A systematic uncertainty on the energy scale of 0.9% not included. Supersedes HEINTZ 91.

$\chi_{b2}(2P)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ ₁	γ Γ(25)	(16.2 ± 2.4) %
Γ ₂	γ Γ(15)	(7.1 ± 1.0) %

 $\chi_{b2}(2P), \Upsilon(3S)$

$\chi_{b2}(2P)$ BRANCHING RATIOS

$\Gamma(\gamma \Upsilon(2S))/\Gamma_{\text{total}}$				Γ_1/Γ
VALUE	DOCUMENT ID	TECN	COMMENT	
0.162 ± 0.024 OUR AVERAGE				
$0.135 \pm 0.025 \pm 0.035$	⁶ CRAWFORD			
$0.173 \pm 0.021 \pm 0.019$	⁷ HEINTZ	92 CSB2	$e^+e^- \rightarrow \ell^+$	$\ell^-\gamma\gamma$
6 Using B($\Upsilon(2S) \rightarrow \mu^+\mu^-$) $\mu^+\mu^-$) = (4.98 ± 0.94 ± 0. 0.017. 7 Using B($\Upsilon(2S) \rightarrow \mu^+\mu^-$ 0.5 ± 0.4)% and assuming	62) $ imes$ 10 $^{-4}$, and B(γ	$\gamma(35) \rightarrow \gamma \chi$	$b_2(2P)) = 0.13$	5 ± 0.003 ±

$\Gamma(\gamma \Upsilon(1S))/\Gamma_{total}$					Γ_2/Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
0.071 ± 0.010 OUR AVERAGE					
$0.072 \pm 0.014 \pm 0.013$	⁸ CRAWFORD	92B	CLE2	$e^+e^- \rightarrow$	$\ell^+\ell^-\gamma\gamma$
$0.070 \pm 0.010 \pm 0.006$	⁹ HEINTZ	92	CSB2	$e^+e^- \rightarrow$	$\ell^+\ell^-\gamma\gamma$
⁸ Using B($\Upsilon(1S) \rightarrow \mu^+ \mu^-$) =	(2.57 + 0.07)%	B(T(3	35) →	$\gamma \gamma \Upsilon(25)) \times$	2 B(γ(15) →

^o Using B(Υ(1S) → $\mu^+\mu^-$) = (2.57 ± 0.07)%, B(Υ(3S) → $\gamma\gamma$ Υ(2S))×2 B(Υ(1S) → $\mu^+\mu^-$) = (5.03 ± 0.94 ± 0.63) × 10⁻⁴, and B(Υ(3S) → $\gamma\chi_{b2}(2P)$) = 0.135 ± 0.003 ± 0.017.

⁹ Using B(Υ(1S) → $\mu^+\mu^-$) = (2.57 ± 0.07)%, B(Υ(3S) → $\gamma\chi_{b2}(2P)$) = (11.1 ± 0.5 ± 0.4)% and assuming $e\mu$ universality. Supersedes HEINTZ 91.

$\chi_{b2}(2P)$ REFERENCES

CRAWFORD	92B	PL B294 139	+Fulton	(CLEO Collab.)
HEINTZ	92	PR D46 1928	+Lee, Franzini+	(CÚSB II Collab.)
HEINTZ	91	PRL 66 1563	+Kaarsberg+	(CUSB Collab.)
MORRISON	91	PRL 67 1696	+Schmidt+	(CLEO Collab.)
NARAIN	91	PRL 66 3113	+Lovelock+	(CUSB Collab.)

- OTHER RELATED PAPERS -

TUTS	83	Cornell Conf. 284		(CUSB Collab.)
EIGEN	82	PRL 49 1616	+Bohringer, Herb+	(CUSB Collab.)
HAN	82	PRL 49 1612	+Horstkotte, Imlay+	(CUSB Collab.)

$\Upsilon(3S)$

$$I^{G}(J^{PC}) = 0^{-}(1^{-})$$

7(35) MASS

VALUE (GeV)	DOCUMENT ID	TECN	COMMENT
10.3553±0.0005	¹ BARU	86B REDE	$e^+e^- \rightarrow hadrons$

¹ Reanalysis of ARTAMONOV 84.

r(3s) WIDTH

$\tau(3S)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Scale factor
Γ ₁	$\Upsilon(2S)$ anything	(10.6 ±0.8)%	
Γ_2	$\Upsilon(2S)\pi^+\pi^-$	$(2.8 \pm 0.6)\%$	2.2
Γ_3	$\Upsilon(2S)\pi^0\pi^0$	(2.00±0.32) %	
Γ_4	$\Upsilon(2S)\gamma\gamma$	(5.0 ±0.7) %	
Γ_5	$\Upsilon(1S)\pi^+\pi^-$	(4.48±0.21) %	
Γ_6	$\Upsilon(1S)\pi^0\pi^0$	(2.06±0.28) %	
Γ_7	$\Upsilon(1S)\eta$		
Γ ₈	$\mu^+\mu^-$	(1.81 ± 0.17) %	
Γ9	$e^+ e^-$	seen	
		Radiative decays	
Γ_{10}	$\gamma \chi_{b2}(2P)$	$(11.4 \pm 0.8)\%$	1.3
	$\gamma \chi_{b1}(2P)$	$(11.3 \pm 0.6)\%$	
Γ_{12}	$\gamma \chi_{b0}(2P)$	(5.4 ±0.6)%	1.1

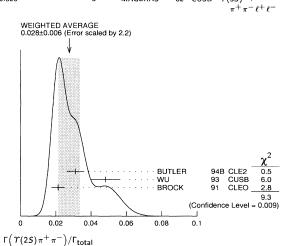
$\Upsilon(3S) \Gamma(i)\Gamma(e^+e^-)/\Gamma(\text{total})$

$\Gamma(\text{hadrons}) \times \Gamma(e^+e^-)/\Gamma_{\text{total}}$						
VALUE (keV)	DOCUMENT ID		TECN	COMMENT		
$0.45 \pm 0.03 \pm 0.03$	² GILES	84B	CLEO	$e^+e^- \rightarrow$	hadrons	
• • • We do not use the fol	lowing data for average	es, fits	, limits,	etc. • • •		
$0.39 \pm 0.02 \pm 0.03$	² TUTS	83	CUSB	$e^+e^-\to$	hadrons	
² Radiative corrections ree	valuated by BUCHMUE	ELLER	88 follo	owing KURA	AEV 85.	

au(3s) Branching ratios

$\Gamma(\Upsilon(2S))$ anyt	thing)/ Γ_{total}					Γ ₁ /Γ
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT	
0.106 ± 0.008	OUR AVERAG	E				
0.1023 ± 0.0105	4625	3,4,5 BUTLER	94B	CLE2	$e^+e^- \rightarrow$	$\ell^+\ell^- \times$
0.111 ± 0.012	4891	^{4,5,6} BROCK	91	CLEO	$e^+e^- \rightarrow \pi^+\pi^-$	
					π'π ε	:' ε

$\Gamma(\Upsilon(2S)\pi^+\pi^-)/\Gamma_{ ext{total}}$					Γ ₂ /Γ			
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT			
0.028 ±0.006 OUR AVERAGE	E Erro	r includes scale fact	or of	2.2. See	the ideogram			
		below.			_			
0.0312 ± 0.0049	980	3,7 BUTLER	94B	CLE2	$ \begin{array}{c} e^+e^- \to \\ \pi^+\pi^-\ell^+\ell^-\\ \Upsilon(3S) \to \end{array} $			
		۵			$\pi^{+}\pi^{-}\ell^{+}\ell^{-}$			
$0.0482 \pm 0.0065 \pm 0.0053$	138	6 MU	93	CUSB	$\Upsilon(35) \rightarrow$			
0.0213 ± 0.0038	974	⁶ BROCK	91	CLEO	$e^+e^-\rightarrow$			
0.0213 \pm 0.0038 974 6 BROCK 91 CLEO $e^+e^- \rightarrow \pi^+\pi^-\chi$, $\pi^+\pi^-\chi$, $\pi^+\pi^-\chi$, $\pi^+\pi^-\chi$, $\pi^+\pi^-\chi$, $\pi^+\pi^-\chi$.								
	•	•						
0.031 ± 0.020	5	MAGERAS	82	CUSB	$\Upsilon(3S) \rightarrow$			



$\Gamma(\Upsilon(2S)\pi^0\pi^0)/\Gamma_{\text{tot}}$		00	CUMENT ID		TECN	сомм	- NT	Г3/Г
0.0200±0.0032 OUR A	_ <u>EVTS</u> /ERAG		COMENTID		TECIV	COMIN	CIV I	
0.0216±0.0039		7,8 _{BU}	TLER	94B	CLE2	e^+e^-	· → ℓ+ℓ-	$\pi^{0}\pi^{0}$
0.017 ±0.005 ±0.002	10	9 HE	INTZ		CSB2		$\rightarrow \ell^+\ell^-$	
$\Gamma(\Upsilon(2S)\gamma\gamma)/\Gamma_{\text{total}}$		DO	CUMENT ID		TECN	сомм	FNT	Γ ₄ /Γ
0.0502±0.0069			TLER		CLE2		→ ℓ ⁺ ℓ [−]	2γ
$\Gamma(\Upsilon(1S)\pi^+\pi^-)/\Gamma_{to}$	otal	EVTS	DOCUM	AFNT I	D	TECN	COMMENT	Γ ₅ /Γ
0.0448±0.0021 OUR A	/ERAG					74017	<u>oomman, </u>	
0.0452 ± 0.0035		11830	⁴ BUTL	ER	94B	CLE2	$e^+e^{\pi^+\pi^-}$	X,
0.0446±0.0034±0.0050		451	⁴ wu		93	CUSB	$\gamma^{\pi^+\pi^-}_{(3S)}$	
0.0446 ± 0.0030		11221	⁴ BROC	ĸ	91	CLEO	$e^{+} \begin{array}{c} \pi^{+} \pi^{-} \\ e^{-} \end{array} \xrightarrow{\pi^{+} \pi^{-}} \\ \pi^{+} \pi^{-} \end{array}$	Χ,
• • • We do not use th	e follov	wing data	for averag	es, fits	, limits	, etc. •	π'π	ε · ε
0.049 ±0.010		22	GREE	N	82	CLEO	γ(3 <i>S</i>) →	
0.039 ±0.013		26	MAGE	RAS	82	CUSB	$\gamma^{\pi^+\pi^-}_{(3S)} \xrightarrow[\pi^+\pi^-]{}$	
$\Gamma(\Upsilon(1S)\pi^0\pi^0)/\Gamma_{\text{tot}}$			CUMENT ID		TECH	601414		Γ ₆ /Γ
VALUE 0.0206±0.0028 OUR AV	<u>EVTS</u> /FRAG		COMENTIO		TECN	сомм	ENI	
0.0199±0.0034	56		TLER	94B	CLE2	e+ e-	→ ℓ+ℓ-	$\pi^{0}\pi^{0}$
0.022 ±0.004 ±0.003	33	¹⁰ HE		92	CSB2	e+ e-	$\rightarrow \ell^+\ell^-$	$\pi^0\pi^0$
$\Gamma(\Upsilon(1S)\eta)/\Gamma_{\text{total}}$								Γ ₇ /Γ
VALUE	CL%	DO	CUMENT ID		TECN	COMM	ENT	
<0.0022	90	BR	оск	91	CLEO	$e^+e^{\pi^+}$	$\pi^{-}\pi^{0}\ell^{+}\ell$	-

$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\Gamma(\mu^+\mu^-)/\Gamma_{ ext{total}}$						Γ ₈ /Ι
0.0202±0.0019±0.0033	VALUE		DOCUMENT ID		TECN	COMMENT	
0.0173±0.0015±0.0011 KAARSBERG 89 CSB2 $e^+e^- \rightarrow \mu^+\mu^-$ 0.033±0.013±0.007 1096 ANDREWS 83 CLEO $e^+e^- \rightarrow \mu^+\mu^-$ 0.033±0.013±0.007 1096 ANDREWS 83 CLEO $e^+e^- \rightarrow \mu^+\mu^-$ 100/10/10/10/10/10/10/10/10/10/10/10/10/	0.0202±0.0019±0.0033)E	CHEN	8 9 B	CLEO		
	$0.0173 \pm 0.0015 \pm 0.0011$		KAARSBERG	89	CSB2		
$ \begin{array}{c} \frac{VALUE}{VALUE} & \frac{EVTS}{Error} \frac{DOCUMENT\ ID}{Includes\ scale\ factor\ of\ 1.3}. \\ 0.111\pm 0.008\ OUR\ AVERAGE \\ 0.113\pm 0.005\pm 0.004 \\ 0.135\pm 0.003\pm 0.017 \\ 30741 & MORRISON \ 91 \ CLE2 \ e^+e^- \to \gamma \\ 10.15\pm 0.005\pm 0.005 \\ 0.115\pm 0.005\pm 0.005 \\ 0.115\pm 0.005\pm 0.005 \\ 0.105\pm 0.003\pm 0.013 \\ 0.105\pm 0.003\pm 0.013 \\ 0.105\pm 0.0005 \\ 0.115\pm 0.1055 \\ 0.115\pm 0.1055 \\ 0.115\pm 0.1055 \\ 0.115\pm 0.1155	0.033 ±0.013 ±0.007	1096	ANDREWS	83	CLEO	$e^{+}\stackrel{\mu}{e^{-}}\stackrel{\mu}{\underset{\mu^{+}}{\rightarrow}}\stackrel{\mu}{\underset{\mu^{-}}{\rightarrow}}$	
2.114±0.008 OUR AVERAGE Error includes scale factor of 1.3. 2.111±0.005±0.004 10319 11 HEINTZ 92 CSB2 $e^+e^- \rightarrow \gamma$ X 2.135±0.003±0.017 30741 MORRISON 91 CLE2 $e^+e^- \rightarrow \gamma$ X $\Gamma(\chi \chi_b(2P))/\Gamma_{total} \frac{EVTS}{DOCUMENT\ ID} \frac{TECN}{TECN} \frac{COMMENT}{TECN} \frac{T1}{TECN} \frac{T1}{TECN} $	$\Gamma(\gamma \chi_{b2}(2P))/\Gamma_{\text{total}}$						Γ10/
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	VALUE	EVTS	DOCUMENT ID		TECN	COMMENT	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.114±0.008 OUR AVERAGE			of 1.3	3.		
	$0.111 \pm 0.005 \pm 0.004$	10319	HEINTZ	92			γ
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$0.135 \pm 0.003 \pm 0.017$	30741	MORRISON	91	CLE2	$e^+e^- \rightarrow$	γX
$\begin{array}{llll} \textbf{0.113} \pm 0.006 \ \textbf{OUR AVERAGE} \\ \textbf{0.115} \pm 0.005 \pm 0.005 & 11147 & 11 \ \textbf{HEINTZ} & 92 \ \textbf{CSB2} & e^+e^- \rightarrow \gamma \\ \textbf{0.105} \pm 0.003 \pm 0.013 & 25759 & \textbf{MORRISON} & 91 \ \textbf{CLE2} & e^+e^- \rightarrow \gamma \\ \textbf{X} \\ \textbf{D.054} \pm 0.003 \pm 0.013 & 25759 & \textbf{MORRISON} & 91 \ \textbf{CLE2} & e^+e^- \rightarrow \gamma \\ \textbf{X} \\ \textbf{VALUE} & & & & & & & & & & & & & & & & & & &$	$\Gamma(\gamma \chi_{b1}(2P))/\Gamma_{\text{total}}$	mi ama	205144547 12		* ====		Γ ₁₁ /Ι
$\begin{array}{llllllllllllllllllllllllllllllllllll$		EVIS	DOCUMENT ID		TECN	COMMENT	
$\Gamma(\chi_{D0}(2P))/\Gamma_{\text{total}} \qquad $	0.115±0.005±0.005	11147 11	L HEINTZ	92	CSB2	$e^+e^- \rightarrow$	γ
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$0.105^{+0.003}_{-0.002} \pm 0.013$	25759	MORRISON	91	CLE2		
24.006 OUR AVERAGE EVTS DOCUMENT ID TECN COMMENT 10.006 ±0.004 ±0.006 The control of the contr	$\Gamma(\gamma \chi_{to}(2P))/\Gamma_{total}$					I	Γ ₁₂ /[
$\begin{array}{lll} 0.060\pm 0.004\pm 0.006 & 4959 & ^{11}\ \text{HEINTZ} & 92\ \text{CSB2} & e^+e^-\to \gamma \\ 0.049 + 0.003 & 9903 & \text{MORRISON} & 91\ \text{CLE2} & e^+e^-\to \gamma \text{X} \\ \hline & 3\ \text{Using B}(\varUpsilon(2S)\to \varUpsilon(1S)\gamma\gamma) = (0.038\pm 0.007)\%, \text{ and B}(\varUpsilon(2S)\to \varUpsilon(1S)\pi^0\pi^0) = \\ (1/2)B(\varUpsilon(2S)\to \varUpsilon(1S)\pi^+\pi^-). & \\ 4\ \text{Using B}(\varUpsilon(2S)\to \varUpsilon(1S)\pi^+\pi^-) = (2.48\pm 0.06)\%. & \text{With the assumption of } e\mu \text{ universality} \\ 5\ \text{Using B}(\varUpsilon(2S)\to \mu^+\mu^-) = (1.31\pm 0.21)\%, B(\varUpsilon(2S)\to \varUpsilon(1S)\gamma\gamma)\times 2B(\varUpsilon(1S)-\mu^+\mu^-) = (0.188\pm 0.035)\%, \text{ and B}(\varUpsilon(2S)\to \varUpsilon(1S)\pi^0\pi^0)\times 2B(\varUpsilon(1S)\to \mu^+\mu^-) = (0.436\pm 0.035)\%. & \text{With the assumption of } e\mu \text{ universality}. \\ 7\ \text{From the exclusive mode.} & B(\varUpsilon(2S)\to \mu^+\mu^-) = (1.31\pm 0.21)\% \text{ and assuming } e\mu \text{ universality}. \\ 9\ \text{B}(\varUpsilon(2S)\to \mu^+\mu^-) = (1.44\pm 0.10)\% \text{ and assuming } e\mu \text{ universality}. & \text{Supersede HEINTZ 91.} \\ 10\ \text{Using B}(\varUpsilon(1S)\to \mu^+\mu^-) = (2.57\pm 0.07)\% \text{ and assuming } e\mu \text{ universality}. & \text{Supersede HEINTZ 91.} \\ \end{array}$	VALUE	EVTS	DOCUMENT ID		TECN		
$\begin{array}{lll} 0.049 + 0.003 \pm 0.006 & 9903 & \text{MORRISON} & 91 & \text{CLE2} & e^+e^- \to \gamma \text{X} \\ 3 & \text{Using B}(\gamma(2S) \to \gamma(1S)\gamma\gamma) = (0.038 \pm 0.007)\%, \text{ and B}(\gamma(2S) \to \gamma(1S)\pi^0\pi^0) = \\ (1/2)\text{B}(\gamma(2S) \to \gamma(1S)\pi^+\pi^-). & \text{Using B}(\gamma(1S) \to \mu^+\mu^-) = (2.48 \pm 0.06)\%. & \text{With the assumption of } e_\mu \text{ universality} \\ 5 & \text{Using B}(\gamma(2S) \to \gamma(1S)\pi^+\pi^-) = (18.5 \pm 0.8)\%. & \text{Using B}(\gamma(2S) \to \gamma(1S)\pi^0\pi^0) \times 2\text{B}(\gamma(1S) \to \mu^+\mu^-) = (1.31 \pm 0.21)\%, & \text{B}(\gamma(2S) \to \gamma(1S)\gamma\gamma) \times 2\text{B}(\gamma(1S) \to \mu^+\mu^-) = (0.436 \pm 0.056)\%. & \text{With the assumption of } e_\mu \text{ universality}. & \text{Prom the exclusive mode.} \\ & \text{B}(\gamma(2S) \to \mu^+\mu^-) = (1.31 \pm 0.21)\% \text{ and assuming } e_\mu \text{ universality}. & \text{P}(\gamma(2S) \to \gamma(1S)) \to \mu^+\mu^-) \\ & \text{P}(\gamma(2S) \to \mu^+\mu^-) = (1.44 \pm 0.10)\% \text{ and assuming } e_\mu \text{ universality}. & \text{Supersede HEINTZ 91.} & \text{Supersede } \mu \text{ HEINTZ 91}. & \text{Supersede } \mu $	0.054±0.006 OUR AVERAGE	Error includ	des scale factor	of 1.1			
³ Using B($\Upsilon(2S) \to \Upsilon(1S) \gamma \gamma$) = (0.038 ± 0.007)%, and B($\Upsilon(2S) \to \Upsilon(1S) \pi^0 \pi^0$) = (1/2)B($\Upsilon(2S) \to \Upsilon(1S) \pi^+ \pi^-$). ⁴ Using B($\Upsilon(1S) \to \mu^+ \mu^-$) = (2.48 ± 0.06)%. With the assumption of $e\mu$ universality 5 Using B($\Upsilon(2S) \to \Upsilon(1S) \pi^+ \pi^-$) = (18.5 ± 0.8)%. ⁶ Using B($\Upsilon(2S) \to \mu^+ \mu^-$) = (1.31 ± 0.21)%, B($\Upsilon(2S) \to \Upsilon(1S) \gamma \gamma$)×2B($\Upsilon(1S) \to \mu^+ \mu^-$) = (0.436 ± 0.035)%, and B($\Upsilon(2S) \to \Upsilon(1S) \pi^0 \pi^0$)×2B($\Upsilon(1S) \to \mu^+ \mu^-$ = (0.436 ± 0.056)%. With the assumption of $e\mu$ universality. ⁷ From the exclusive mode. ⁸ B($\Upsilon(2S) \to \mu^+ \mu^-$) = (1.31 ± 0.21)% and assuming $e\mu$ universality. ⁹ B($\Upsilon(2S) \to \mu^+ \mu^-$) = (1.44 ± 0.10)% and assuming $e\mu$ universality. Supersede HEINTZ 91.	$0.060 \pm 0.004 \pm 0.006$	4959 11	HEINTZ	92	CSB2	$e^+e^- \rightarrow$	γ
(1/2)B($\Upsilon(2S) \to \Upsilon(1S)\pi^+\pi^-$). 4 Using B($\Upsilon(1S) \to \mu^+\mu^-$) = (2.48 ± 0.06)%. With the assumption of $e\mu$ universality 5 Using B($\Upsilon(2S) \to \pi(1S)\pi^+\pi^-$) = (18.5 ± 0.8)%. 6 Using B($\Upsilon(2S) \to \mu^+\mu^-$) = (1.31 ± 0.21)%, B($\Upsilon(2S) \to \Upsilon(1S)\gamma\gamma$)×2B($\Upsilon(1S) \to \mu^+\mu^-$) = (0.436 ± 0.035)%, and B($\Upsilon(2S) \to \Upsilon(1S)\pi^0\pi^0$)×2B($\Upsilon(1S) \to \mu^+\mu^-$ = (0.436 ± 0.056)%. With the assumption of $e\mu$ universality. 7 From the exclusive mode. 8 B($\Upsilon(2S) \to \mu^+\mu^-$) = (1.31 ± 0.21)% and assuming $e\mu$ universality. 9 B($\Upsilon(2S) \to \mu^+\mu^-$) = (1.44 ± 0.10)% and assuming $e\mu$ universality. Supersede HEINTZ 91.	$0.049^{+0.003}_{-0.004} \pm 0.006$	9903	MORRISON	91	CLE2	$e^+e^-\to$	γΧ
⁴ Using B(γ(15) → $\mu^+\mu^-$) = (2.48 ± 0.06)%. With the assumption of $e\mu$ universality ⁵ Using B(γ(2S) → γ(15) π ⁺ π ⁻) = (18.5 ± 0.8)%. ⁶ Using B(γ(2S) → $\mu^+\mu^-$) = (1.31 ± 0.21)%, B(γ(2S) → γ(1S) γγ)×2B(γ(1S) − $\mu^+\mu^-$) = (0.188 ± 0.035)%, and B(γ(2S) → γ(1S) π ⁰ π ⁰)×2B(γ(1S) → $\mu^+\mu^-$ = (0.436 ± 0.056)%. With the assumption of $e\mu$ universality. ⁷ From the exclusive mode. ⁸ B(γ(2S) → $\mu^+\mu^-$) = (1.31 ± 0.21)% and assuming $e\mu$ universality. ⁹ B(γ(2S) → $\mu^+\mu^-$) = (1.44 ± 0.10)% and assuming $e\mu$ universality. Supersede HEINTZ 91. ¹⁰ Using B(γ(1S) → $\mu^+\mu^-$) = (2.57 ± 0.07)% and assuming $e\mu$ universality. Supersede HEINTZ 91.	³ Using B($\Upsilon(2S) \rightarrow \Upsilon(1S)$	$(\gamma \gamma) = (0.038)$	3 ± 0.007)%, an	d B(r(25) -	$\rightarrow r(15)\pi^0$	$\pi^{0}) =$
5 Using B($\Upsilon(2S) \to \Upsilon(1S)\pi^+\pi^-$) = (18.5 ± 0.8)%. 6 Using B($\Upsilon(2S) \to \mu^+\mu^-$) = (1.31 ± 0.21)%, B($\Upsilon(2S) \to \Upsilon(1S)\gamma\gamma$)×2B($\Upsilon(1S) \to \mu^+\mu^-$) = (0.188 ± 0.035)%, and B($\Upsilon(2S) \to \Upsilon(1S)\pi^0\pi^0$)×2B($\Upsilon(1S) \to \mu^+\mu^-$ = (0.436 ± 0.056)%. With the assumption of e_μ universality. 7 From the exclusive mode. 8 B($\Upsilon(2S) \to \mu^+\mu^-$) = (1.31 ± 0.21)% and assuming e_μ universality. 9 B($\Upsilon(2S) \to \mu^+\mu^-$) = (1.44 ± 0.10)% and assuming e_μ universality. Supersede HEINTZ 91. 10 Using B($\Upsilon(1S) \to \mu^+\mu^-$) = (2.57 ± 0.07)% and assuming e_μ universality. Supersede HEINTZ 91.	$(1/2)B(\Upsilon(2S) \rightarrow \Upsilon(1S))$	$\tau^{+}\pi^{-}$).	•				
6 Using B(γ(25) → μ ⁺ μ ⁻) = (1.31 ±0.21)%, B(γ(25) → γ(15)γγ)×2B(γ(15) − μ ⁺ μ ⁻) = (0.188 ± 0.035)%, and B(γ(25) → γ(15)π ⁰ π ⁰)×2B(γ(15) → μ ⁺ μ ⁻ = (0.436 ± 0.056)%. With the assumption of $e\mu$ universality. 7 From the exclusive mode. 8 B(γ(25) → μ ⁺ μ ⁻) = (1.31 ± 0.21)% and assuming $e\mu$ universality. 9 B(γ(25) → μ ⁺ μ ⁻) = (1.44 ± 0.10)% and assuming $e\mu$ universality. Supersede HEINTZ 91. 10 Using B(γ(15) → μ ⁺ μ ⁻) = (2.57 ± 0.07)% and assuming $e\mu$ universality. Supersede HEINTZ 91.	⁴ Using B($\Upsilon(1S) \rightarrow \mu^+\mu^-$	$) = (2.48 \pm 0.000)$	0.06)%. With th	e ass	um ptior	n of $e\mu$ unive	rsality
$\mu^+\mu^-)=(0.188\pm0.035)\%$, and B($\Upsilon(2S)\to\Upsilon(1S)\pi^0\pi^0)\times 2B(\Upsilon(1S)\to\mu^+\mu^-=(0.436\pm0.056)\%$. With the assumption of $e\mu$ universality. From the exclusive mode. B($\Pi(\gamma(2S)\to\mu^+\mu^-)=(1.31\pm0.21)\%$) and assuming $e\mu$ universality. B($\Pi(\gamma(2S)\to\mu^+\mu^-)=(1.44\pm0.10)\%$) and assuming $e\mu$ universality. Supersede HEINTZ 91. 10 Using B($\Pi(1S)\to\mu^+\mu^-)=(2.57\pm0.07)\%$ and assuming $e\mu$ universality. Supersede HEINTZ 91.	⁵ Using B($\Upsilon(2S) \rightarrow \Upsilon(1S)$	$(\pi^{+}\pi^{-}) = ($	$18.5 \pm 0.8)\%$.				•
$\mu^+\mu^-$) = (0.188 ± 0.035)%, and B($\Upsilon(2S) \rightarrow \Upsilon(1S)\pi^0\pi^0$)×2B($\Upsilon(1S) \rightarrow \mu^+\mu^-$ = (0.436 ± 0.056)%. With the assumption of $e\mu$ universality. From the exclusive mode. B($\Upsilon(2S) \rightarrow \mu^+\mu^-$) = (1.31 ± 0.21)% and assuming $e\mu$ universality. B($\Upsilon(2S) \rightarrow \mu^+\mu^-$) = (1.44 ± 0.10)% and assuming $e\mu$ universality. Supersede HEINTZ 91. 10 Using B($\Upsilon(1S) \rightarrow \mu^+\mu^-$) = (2.57 ± 0.07)% and assuming $e\mu$ universality. Supersede HEINTZ 91.	6 Using B($\Upsilon(2S) \rightarrow \mu^+\mu^-$	$) = (1.31 \pm 0.00)$	$(0.21)\%$, $B(\Upsilon(25)$	() →	$\Upsilon(15)$	$\gamma\gamma)\times 2B(\Upsilon($	15) –
= (0.436 \pm 0.056)%. With the assumption of $e\mu$ universality. ⁷ From the exclusive mode. ⁸ B($\Upsilon(2S) \rightarrow \mu^+\mu^-$) = (1.31 \pm 0.21)% and assuming $e\mu$ universality. ⁹ B($\Upsilon(2S) \rightarrow \mu^+\mu^-$) = (1.44 \pm 0.10)% and assuming $e\mu$ universality. Supersede HEINTZ 91. ¹⁰ Using B($\Upsilon(1S) \rightarrow \mu^+\mu^-$) = (2.57 \pm 0.07)% and assuming $e\mu$ universality. Supersede HEINTZ 91.							
8 B($\Upsilon(2S) \rightarrow \mu^+\mu^-)=(1.31\pm0.21)\%$ and assuming $e\mu$ universality. 9 B($\Upsilon(2S) \rightarrow \mu^+\mu^-)=(1.44\pm0.10)\%$ and assuming $e\mu$ universality. Supersede HEINTZ 91. 1 Using B($\Upsilon(1S) \rightarrow \mu^+\mu^-)=(2.57\pm0.07)\%$ and assuming $e\mu$ universality. Supersede HEINTZ 91.	$= (0.436 \pm 0.056)\%$. With	the accumn	tion of eu unive	rsalit	y. `	, , ,	,
9 B($\Upsilon(2S) \to \mu^+\mu^-$) = (1.44 \pm 0.10)% and assuming e μ universality. Supersede HEINTZ 91. 10 Using B($\Upsilon(1S) \to \mu^+\mu^-$) = (2.57 \pm 0.07)% and assuming e μ universality. Supersede HEINTZ 91.		the assump					
HĖINTZ 91. ¹⁰ Using B($\gamma(1S) \rightarrow \mu^+\mu^-$) = (2.57 \pm 0.07)% and assuming $e\mu$ universality. Supersede HEINTZ 91.							
¹⁰ Using B($\Upsilon(1S) \rightarrow \mu^+ \mu^-$) = (2.57 \pm 0.07)% and assuming $e \mu$ universality. Supersede HEINTZ 91.	$^{8}B(\Upsilon(2S) \rightarrow \mu^{+}\mu^{-}) = (1$	1.31 ± 0.21)9	% and assuming				
HEINTZ 91.	${}^{8}B(\Upsilon(2S) \to \mu^{+}\mu^{-}) = (1)^{9}B(\Upsilon(2S) \to \mu^{+}\mu^{-}) = (1)^{10}$	1.31 ± 0.21)9	% and assuming				ersede
11 Supersedes NARAIN 91.	8 B($\Upsilon(2S) \to \mu^{+}\mu^{-}$) = (1 9 B($\Upsilon(2S) \to \mu^{+}\mu^{-}$) = HEINTZ 91.	1.31 ± 0.21)9 (1.44 ± 0.10	% and assuming i)% and assumi	ng e	μ unive	rsality. Supe	
	${}^{8} B(\Upsilon(2S) \to \mu^{+} \mu^{-}) = (1)^{9} B(\Upsilon(2S) \to \mu^{+} \mu^{-}) = HEINTZ 91.$ ${}^{10} Using B(\Upsilon(1S) \to \mu^{+} \mu^{-}) + HEINTZ 91.$	1.31 ± 0.21)9 (1.44 ± 0.10	% and assuming i)% and assumi	ng e	μ unive	rsality. Supe	

au(3S) REFERENCES

BUTLER	94B	PR D49 40	+Fu, Kalbfleisch, Lambrecht+	(CLEO Collab.)				
WU	93	PL B301 307	+Franzini, Kanekal+	(CUSB Collab.)				
HEINTZ	92	PR D46 1928	+Lee, Franzini+	(CÙSB II Collab.)				
BROCK	91	PR D43 1448	+Ferguson+	(CLEO Collab.)				
HEINTZ	91	PRL 66 1563	+Kaarsberg+	(CUSB Collab.)				
MORRISON	91	PRL 67 1696	+Schmidt+	(CLEO Collab.)				
NARAIN	91	PRL 66 3113	+Lovelock+	(CUSB Collab.)				
CHEN	89B	PR D39 3528	+McIlwain, Miller+	(CLEO Collab.)				
KAARSBERG	89	PRL 62 2077	+Heintz+	(CUSB Collab.)				
BUCHMUEL	88	HE e ⁺ e ⁻ Physics 41:	2 Buchmueller, Cooper	(HANN, DESY, MIT)				
Editors: A	. Ali a	and P. Soeding, World S		,				
BARU	86B	ZPHY C32 622	+Blinov, Bondar, Bukin+	(NOVO)				
KURAEV	85	SJNP 41 466	+Fadin	(NOVO)				
		Translated from YAF 4						
ARTAMONOV	84	PL 137B 272	+Baru, Blinov, Bondar+	(NOVO)				
GILES	84B	PR D29 1285	+Hassard, Hempstead, Kinoshita+	(CLEO Collab.)				
ANDREWS	83	PRL 50 807	+Avery, Berkelman, Cassel+	(CLEO Collab.)				
TUTS	83	Cornell Conf. 284		(CUSB Collab.)				
GREEN	82	PRL 49 617	+Sannes, Skubic, Snyder+	(CLEO Collab.)				
MAGERAS	82	PL 118B 453	+Herb, Imlay+ (COLU, CORI	N, LSU, MPIM, STON)				
	OTHER RELATED PAPERS							
ALEXANDER	89	NP B320 45	+Bonvicini, Drell, Frey, Luth	(LBL, MICH, SLAC)				

ALEXANDER	89	NP B320 45	+Bonvicini, Drell, Frey, Luth	(LBL, MICH, SLAC)
ARTAMONOV	84	PL 137B 272	+Baru, Blinov, Bondar+	(NOVO)
GILES	84B	PR D29 1285	+Hassard, Hempstead, Kinoshita+	(CLEO Collab.)
HAN	82	PRL 49 1612	+Horstkotte, Imlay+	(CUSB Collab.)
PETERSON	82	PL 114B 277	+Giannini, Lee-Franzini+	(CUSB Collab.)
KAPLAN	78	PRL 40 435	+Appel, Herb, Hom+	(STON, FNAL, COLU)
YOH	78	PRL 41 684	+Herb, Hom, Lederman+	(COLU, FNAL, STON)
COBB	77	PL 72B 273	+Iwata, Fabjan+ (BNI	, CERN, SYRA, YALE)
HERB	77	PRL 39 252	+Hom, Lederman, Appel, Ito+	(COLU, FNAL, STON)
INNES	77	PRL 39 1240	+Appel, Brown, Herb, Hom+	(COLU, FNAL, STON)

 $\Upsilon(4S)$ or $\Upsilon(10580)$

 $I^{G}(J^{PC}) = ?^{?}(1^{-})$

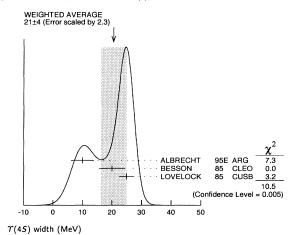
7(45) MASS

VALUE (GeV)	DOCUMENT ID		TECN	COMMENT		
10.5800±0.0035	¹ BEBEK	87	CLEO	$e^+e^- \rightarrow$	hadrons	
	ing data for average	es, fits	, limits,	etc. • • •		
10.5774 ± 0.0010	² LOVELOCK	85	CUSB	$e^+e^- \rightarrow$	hadrons	
¹ Reanalysis of BESSON 85.						

Υ (4S) WIDTH

VALUE (MeV)	DOCUMENT ID	TECNCOMMENT
21 ±4 OUR AVERAGE	Error includes scale factor of	2.3. See the ideogram below.
10.0 ± 2.8 ± 2.7	³ ALBRECHT 95E	ARG $e^+e^- \rightarrow hadrons$
20 ±2 ±4	BESSON 85	CLEO $e^+e^- \rightarrow \text{hadrons}$
25 ±2.5	LOVELOCK 85	CUSB $e^+e^- \rightarrow hadrons$

³Using LEYAOUANC 77 parametrization of $\Gamma(s)$.



T(45) DECAY MODES

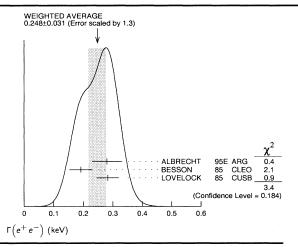
	Mode	Fraction (F	Confidence level	
Γ1	ВB	domina		
Γ_2	$e^+ e^-$	(2.8±0.		
Гз	J/ψ (3097) anything	(2.2±0.	$7) \times 10^{-3}$	
Γ_4	D^{*+} anything $+$ c.c.	< 7.4	%	90%
Γ_5	ϕ anything	< 2.3	$\times 10^{-3}$	90%
Γ_6	$\varUpsilon(1S)$ anything	< 4	\times 10 ⁻³	90%
Γ ₇	non- $B\overline{B}$	< 4	%	95%

au(45) PARTIAL WIDTHS

Γ(e ⁺ e ⁻)			l	Γ2
VALUE (keV)	DOCUMENT ID	TECN	COMMENT	
0.248 ± 0.031 OUR AVERAGE	Error includes scale	factor of 1.3.	See the ideogram belo	w.
0.28 ±0.05 ±0.01	4 ALBRECHT	95E ARG	$e^+e^- \rightarrow hadrons$	
$0.192 \pm 0.007 \pm 0.038$			$e^+e^- \rightarrow \text{hadrons}$	
0.283 ± 0.037	LOVELOCK	85 CUSB	$e^+e^- ightarrow hadrons$	
⁴ Using LEYAOUANC 77 par	ametrization of $\Gamma(s)$.			

² No systematic error given.

 $\Upsilon(4S), \Upsilon(10860), \Upsilon(11020)$



au(4 s) branching ratios										
Γ(e ⁺ e ⁻)/		al							ļ	Γ 2/Γ
VALUE (units 10					DOCUMENT ID		TECN	COMMENT		
2.77±0.50±					ALBRECHT		ARG	$e^+e^- \rightarrow$	hadrons	
⁵ Using LE	⁵ Using LEYAOUANC 77 parametrization of $\Gamma(s)$.									
Γ(J/ψ(309	7)a	nything)/r _{tota}	ı	DOCUMENT ID		TEC.		1	Г ₃ /Г
VALUE					DOCUMENT ID		TECN	e+e-		
0.0022±0.00	JU6±	0.0004			ALEXANDER	90C	CLEO	e ' e		
[\(\(D^{*+} \) an	ythi	ng) + [, ,,	/۲					1	Γ ₄ /Γ
VALUE			CL%		DOCUMENT ID		TECN	COMMENT		
<0.074			90	C	ALEXANDER	90c	CLEO	e^+e^-		
6 For $x >$	0.47	3.								
Γ(φanythir	ng)/	r _{total}							_	Γ ₅ /Γ
VALUE			CL%	-	DOCUMENT ID		TECN	COMMENT		
<0.0023			90	′	ALEXANDER	9 0C	CLEO	e^+e^-		
7 For $x >$	0.52									
Γ(<i>Υ</i> (1 <i>S</i>)a	nyth	ing)/Γ							1	Γ ₆ /Γ
VALUE			CL%		DOCUMENT ID		TECN	COMMENT		
<0.004			90		ALEXANDER	90c	CLEO	e+ e-		
Γ(non-BB)/г	total							I	Γ ₇ /Γ
VALUE			CL%		DOCUMENT ID		TECN	COMMENT		
<0.04			95		BARISH	96B	CLEO	e ⁺ e ⁻		
T(4S) REFERENCES										
BARISH ALBRECHT ALEXANDER BEBEK BESSON LOVELOCK LEYAOUANC	96B 95E 90C 87 85 85 77	PRL 76 ZPHY C PRL 64 PR D36 PRL 54 PRL 54 PL B71	65 619 2226 1289 381 377		+Chadha, Chan, +Hamacher+ +Artuso+ +Berkelman, Blu +Green, Namjosh +Horstkotte, Klo +Oliver, Pene, R	cher, (ni, San pfenste	nes+	(AF (C (C	CLEO Collai RGUS Collai CLEO Collai CLEO Collai CLEO Collai CUSB Collai (ORSA	b.) b.) b.) b.) b.)
			- OTH	łΕ	R RELATED	PAP	ERS -			
HENDERSON ANDREWS FINOCCHI	92 80B 80	PR D45 PRL 45 PRL 45	219		+Kinoshita, Pipki +Berkelman, Cab Finocchiaro, Gia	enda,	Cassel+) (i	LEO Collai LEO Collai USB Collai	b.)

$\Upsilon(10860)$

$I^{G}(J^{PC}) = ??(1--)$

7(10860) MASS

DOCUMENT ID
 VALUE (GeV)
 DOCUMENT ID
 TECN
 COMMENT

 10.865±0.008 OUR AVERAGE
 Error includes scale factor of 1.1.
 $10.868 \pm 0.006 \pm 0.005$ BESSON 85 CLEO $e^+e^- \rightarrow \text{hadrons}$ 85 CUSB $e^+e^- \rightarrow \text{hadrons}$ 10.845 ± 0.020

Υ (10860) WIDTH

VALUE (MeV)
110±13 OUR AVERAGE DOCUMENT ID TECN COMMENT 85 CLEO $e^+e^- \rightarrow \text{hadrons}$ 85 CUSB $e^+e^- \rightarrow \text{hadrons}$ $112 \pm 17 \pm 23$ BESSON $110\pm15\,$ LOVELOCK

au(10860) DECAY MODES

Mode Fraction (Γ_i/Γ) $e^+e^ (2.8\pm0.7)\times10^{-6}$

au(10860) PARTIAL WIDTHS

 $\Gamma(e^+e^-)$ Γ_1 VALUE (keV)
 VALUE (keV)
 DOCUMENT ID
 TECN

 0.31 ±0.07
 OUR AVERAGE
 Error includes scale factor of 1.3.
 TECN COMMENT 85 CLEO $e^+e^- \rightarrow \text{hadrons}$ 85 CUSB $e^+e^- \rightarrow \text{hadrons}$ $0.22 \pm 0.05 \pm 0.07$ BESSON 0.365 ± 0.070 LOVELOCK

T(10860) REFERENCES

+Green, Namjoshi, Sannes+ +Horstkotte, Klopfenstein+ 85 PRL 54 381 85 PRL 54 377 (CLEO Collab.) (CUSB Collab.)

$\Upsilon(11020)$

$I^{G}(J^{PC}) = ?^{?}(1^{-})$

T(11020) MASS

VALUE (GeV)
11.019±0.008 OUR AVERAGE DOCUMENT ID TECN COMMENT 85 CLEO $e^+e^- \rightarrow \text{hadrons}$ 85 CUSB $e^+e^- \rightarrow \text{hadrons}$ $11.019\!\pm\!0.005\!\pm\!0.007$ BESSON 11.020 ± 0.030

Υ (11020) WIDTH

VALUE (MeV)
79±16 OUR AVERAGE DOCUMENT ID TECN COMMENT 85 CLEO $e^+e^- \rightarrow \text{hadrons}$ 85 CUSB $e^+e^- \rightarrow \text{hadrons}$ 61±13±22 BESSON 90 ± 20 LOVELOCK

au(11020) DECAY MODES

Fraction (Γ_i/Γ) Mode Γ_1 $e^+e^ (1.6\pm0.5)\times10^{-6}$

au(11020) PARTIAL WIDTHS

 $\Gamma(e^+e^-)$ Γ_1 VALUE (keV) TECN COMMENT DOCUMENT ID 0.130 ± 0.030 OUR AVERAGE 85 CLEO $e^+e^- \rightarrow \text{hadrons}$ 85 CUSB $e^+e^- \rightarrow \text{hadrons}$ $0.095 \pm 0.03 \ \pm 0.035$ BESSON 0.156 ± 0.040 LOVELOCK

au(11020) REFERENCES

BESSON LOVELOCK +Green, Namjoshi, Sannes+ +Horstkotte, Klopfenstein+ (CLEO Collab.) (CUSB Collab.) 85 PRL 54 381 85 PRL 54 377

Meson Particle Listings Non- $q\overline{q}$ Candidates

NON-qq CANDIDATES

We include here mini-reviews and reference lists on gluonium and other non- $q\overline{q}$ candidates. See also $N\overline{N}(1100\text{--}3600)$ for possible bound states.

$NON-q\overline{q}$ MESONS

The existence of gluon self coupling in QCD suggests that gluonia (or glueballs) and hybrids $(q\overline{q}g)$ might exist. Another possible kind of non- $q\overline{q}$ mesons is multiquark states. For detailed reviews, see HEUSCH 86, CLOSE 87, TOKI 88, and BURNETT 90. Among the signatures naively expected for glueballs are (i) no place in $q\overline{q}$ nonets, (ii) flavor-singlet couplings, (iii) enhanced production in gluon-rich channels such as $J/\psi(1S)$ decay, and (iv) reduced $\gamma\gamma$ coupling. However, mixing effects with $q\overline{q}$ states, and other dynamical effects such as form factors, may obscure these simple signatures. If mixing is large, only the finding of more states than are predicted by the $q\overline{q}$ quark model remains as a clear signal for non-exotic non- $q\overline{q}$ states.

Lattice gauge theory calculations in the quenched approximation (without quark loops) predict the lightest glueball to be a scalar with a mass of typically 1550 ± 95 MeV (BALI 93). The same calculations find a tensor glueball mass of 2270 ± 100 MeV, and glueballs with other spin-parities are predicted to be still heavier. A more recent lattice calculation (SEXTON 95) predicts a slightly higher mass, 1740 ± 71 MeV. Including dynamical quarks will, however, change the predicted masses.

Hybrid mesons are $q\overline{q}$ states combined with a gluonic excitation (BARNES 82, CHANOWITZ 83, ISGUR 85, CLOSE 95). Hybrids span flavor nonets, may have exotic (non- $q\overline{q}$) quantum numbers (a $J^{PC}=1^{-+}$ state is expected in all models), and are predicted to have characteristic decay modes (LEYAOUANC 85, CLOSE 95). The masses of the lightest hybrids are typically predicted to be in the range 1500 to 2000 MeV. Charm hybrids ($c\overline{c}g$) are attractive experimentally since they may appear as supernumerary states in the predictable charmonium spectrum. The $\psi(4040)$ and $\psi(4160)$ are possibly mixtures of $c\overline{c}$ and $c\overline{c}g$ states (CLOSE 96).

The third class of non- $q\bar{q}$ states, the multiquark states, can be either baglike or clusters of mesons (VOLOSHIN 76, JAFFE 77, GUTBROD 79). A subclass of the latter are the deuteronlike meson-meson bound states, or deusons, where the long-range pion exchange is the major source of binding (TORNQVIST 91 and 94, ERICSON 93, MANOHAR 93). Many of the best non- $q\overline{q}$ candidates discussed below lie close to important thresholds, which suggests that they might be bound states of a meson pair. Examples include the $f_0(980)$ and $a_0(980)$ (close to the $K\overline{K}$ threshold), the $f_1(1420)$ (above the $K\overline{K}^*$ threshold, thus not a bound state but perhaps a threshold enhancement), the $f_0(1500)$ and $f_2(1520)$ ($\omega\omega$ and $\rho\rho$), the $f_J(1710)$ $(K^*\overline{K}^*)$, and the $\psi(4040)$ $(D^*\overline{D}^*)$. Many suggestions for such mesonium candidates, involving both light and heavy quarks and binding mechanisms, have appeared (WEINSTEIN 90, DOVER 91, BARNES 92, DOOLEY 92).

The candidates we discuss below are chosen because they are difficult to interpret as conventional $q\overline{q}$ states. We do not see it as our task to discuss theoretical interpretations of the candidates, but merely to catalogue the observations of possible relevance.

Scalar mesons: There are four known isoscalars with $J^{PC}=0^{++}$: the $f_0(400-1200)$, a very broad structure around 800 MeV, the $f_0(980)$, the $f_0(1370)$, and the $f_0(1500)$; the spin of another established isoscalar, the $f_J(1710)$, may be 0 or 2. In the quark model, one expects two 1^3P_0 states and one $2^3P_0(u\overline{u}+d\overline{d})$ -like state below 1.8 GeV. Thus, there are too many scalars to find a place in the quark model.

However, for scalar resonances, naive quark model expectations, in particular ideal mixing, could be strongly broken by the opening of inelastic thresholds. Thus, the physical scalar $q\bar{q}$ spectrum may be very much distorted from naive expectations. For a detailed discussion of this sector, see our Note under the $f_0(1370)$.

In this edition, we have merged the $f_0(1590)$ observed in π^-p interactions at high energies with the $f_0(1525)$ observed in $\overline{p}p$ annihilations, under the new name $f_0(1500)$. The $\pi\pi$ and $\eta\eta$ S-waves have a T-matrix pole at $m-i\Gamma/2\sim 1500-i60$ MeV, which corresponds to the physical mass and width (AMSLER 95B, AMSLER 95C), while a simple Breit-Wigner description gives a slightly higher mass and width (AMSLER 92, ALDE 88). For consistency, we average the mass and width determined by the T-matrix poles. A coupled-channel analysis taking unitarity constraints into account has been performed in $\overline{p}p$ (AMSLER 95D) but not in π^-p . Thus, we do not view the apparent discrepancies in the decay branching ratios to $\pi^0\pi^0$, $\eta\eta$, and $\eta\eta'$ between the $\overline{p}p$ and π^-p experiments to be serious.

In the model of $\Lambda MSLER$ 95E and $\Lambda MSLER$ 96, the (nearly ideally mixed) ground state scalar $q\overline{q}$ nonet consists of the $a_0(1450)$, the $K_0^*(1430)$, the $f_0(1370)$, and the still missing isoscalar $s\overline{s}$ state, which cannot be the $f_0(1500)$ due to its comparatively narrow width and low $K\overline{K}$ decay branching ratio. The $f_0(1500)$ is interpreted as a scalar glueball mixed with the two nearby $q\overline{q}$ isoscalars.

The $f_J(1710)$ (whose spin is uncertain) has been seen mainly in the gluon-rich $J/\psi(1S)$ radiative decay, where it is copiously produced. Before 1991, the spin of the $f_J(1710)$ was believed to be 2, and the subsequent spin-0 determination in $J/\psi(1S)$ radiative decay (CHEN 91) has not been confirmed. In central production, the WA76 experiment (ARMSTRONG 89D) on 300 GeV/c pp interactions sees a structure at the same mass, but favors spin 2. The $f_J(1710)$ has not been seen in hadronic production $(K^-p\to K\overline{K}A)$ (ASTON 88D), nor in $\gamma\gamma$ fusion. The ratio of the branching fractions in $J/\psi(1S)\to \omega f_J$ and $J/\psi(1S)\to \phi f_J$ suggests that nonstrange and strange components are both important in this state. Its mass and width are consistent with the prediction for the ground-state glueball, according to the most recent lattice gauge calculations (SEXTON 95), if one assumes that the spin is indeed zero.

Meson Particle Listings Non- $q\bar{q}$ Candidates

Pseudoscalar mesons: The established isoscalars with $J^{PC} = 0^{-+}$ are the η , the $\eta'(958)$, the $\eta(1295)$, and the $\eta(1440)$ [which may be two pseudoscalar resonances, an $\eta(1410)$ and an $\eta(1490)$; see the Note under the $\eta(1440)$]. In the $q\bar{q}$ model, one expects two 1^1S_0 and two 2^1S_0 pseudoscalars between 500 and

Identifying the $\eta(1280)$ with the 2^1S_0 $(u\overline{u}+d\overline{d})$ state is natural, but it is more problematic to identify one of the two peaks in the $\eta(1440)$ region with the 2^1S_0 $s\overline{s}$ state. The $\eta(1440)$ is observed in $s\overline{s}$ -depleted reactions like $\pi^-p \to \eta\pi\pi n$ (ANDO 86), $p\overline{p}$ annihilation (BAILLON 67, AMSLER 95F, BERTIN 95), and $\pi^-p \to a_0(980)\pi p$ (CHUNG 85, BIRMAN 88), and is not seen in the $s\overline{s}$ -enriched channels like $K^-p \to K^*(892)\overline{K}A$ (ASTON 87). The fact that ANDO 86 sees the $\eta(1440)$ and $\eta(1280)$ with similar intensities argues that these states are of a similar nature, e.g., radial excitations of the η and $\eta'(958)$. However, as there are suggestions that the $\eta(1440)$ is in fact two η 's, the situation remains confused.

The $\pi(1770)$ (BERDNIKOV 94, AMELIN 95B) has a surprisingly narrow width (if interpreted as the second radial excitation of the π), a large coupling to $K\overline{K}$, and decays to a pair of mesons, one with $\ell(q\overline{q}) = 0$, the other with $\ell(q\overline{q}) = 1$. This is the signature expected for a hybrid meson (CLOSE 95).

Axial-vector mesons: The $q\overline{q}$ model predicts a nonet that includes two isoscalar 1^3P_1 states with masses below about 1.6 GeV. Three such 1^{++} states are known, the $f_1(1285)$, the $f_1(1420)$, and the $f_1(1530)$, which suggests that one of these is a non- $q\overline{q}$ meson. The $f_1(1420)$ is the most likely candidate: see CALDWELL 90 and the Note under the $f_1(1420)$. The proximity of the $K\overline{K}^*$ threshold suggests this may be a dominantly $K\overline{K}^*$ mesonium resonance or a threshold enhancement (LONGACRE 90, TORNOVIST 91).

Tensor mesons: The two $1^{3}P_{2}$ $q\overline{q}$ states are very likely the well-known $f_{2}(1270)$ and $f'_{2}(1525)$. There are several other states, which have been suggested as $J^{PC} = 2^{++}$ non- $q\overline{q}$ candidates: the $f_{2}(1430)$, $f_{2}(1520)$, $f_{J}(1710)$, $f_{2}(1810)$, $f_{2}(2010)$, $f_{2}(2150)$, $f_{2}(2300)$, and $f_{2}(2340)$.

The $f_2(1520)$ is observed by the ASTERIX Collaboration (MAY 89) in $p\overline{p}$ P-wave annihilation in the $\pi^+\pi^-\pi^0$ channel and by the Crystal Barrel Collaboration (ANISOVICH 94, AMSLER 95B) in $3\pi^0$, close to the $\rho\rho$ and $\omega\omega$ thresholds. It has no place in a $q\overline{q}$ scheme, since all nearby $q\overline{q}$ states are already accounted for. Similarly, the $f_J(1710)$ could be composed of $K^*\overline{K}^*$ and $\omega\phi$ (DOOLEY 92), since it lies close to these thresholds.

Of the heavier states, the $f_2(1810)$ is likely to be the 2^3P_2 , and among those above 2 GeV one expects the 2^3P_2 $s\bar{s}$, 1^3F_2 $s\bar{s}$, and 3^2P_2 $s\bar{s}$, but a gluonium interpretation of one of the four states is not excluded. These three f_2 resonances have been observed in the OZI-rule forbidden process $\pi p \to \phi \phi n$ (ETKIN 88), which has been claimed as favoring the gluonium interpretation.

A similar $\phi\phi$ mass spectrum is seen by ARMSTRONG 89B in the \varOmega spectrometer. The DM2 and MARK-III collaborations see threshold $\phi\phi$ production, but favor $J^P=0^-$, not $_{2}^+$

In $\gamma\gamma\to 4\pi$ near the $\rho\rho$ threshold, TASSO (BRANDE-LIK 80B, ALTHOFF 82), MARK2 (BURKE 81), CELLO (BEHREND 84E), PLUTO (BERGER 88B), SLAC TPC (AIHARA 88), and ARGUS (ALBRECHT 91F) observe a resonance-like structure. This is dominated by $\rho^0\rho^0$, and the cross section peaks a little above the $f_2(1520)$. This process has not been explained by models in which only conventional resonances dominate. The fact that the $\gamma\gamma\to\rho^+\rho^-$ is small (ALBRECHT 91F quotes 1/4 for the $\rho^+\rho^-/\rho^0\rho^0$ ratio) requires both isospin 0 and 2 for the $\rho\rho$ system. A resonance interpretation in terms of $q^2\bar{q}^2$ states thus requires the presence of a flavor exotic I=2 resonance (ACHASOV 82, 87, 90). The 2++ partial wave is found to dominate the $\rho\rho$ structure (BERGER 88B, ALBRECHT 91F), with some 0++ at the lowenergy end, while $J^P=0^-$ and 2- contribute very little.

In $\gamma\gamma \to \omega\rho$ and $\phi\rho$, there are also broad enhancements that peak near 1.7 GeV. The dominant partial wave is 2^{++} in $\omega\rho$, while 2^{-+} is favored in $\phi\rho$ (ALBRECHT 94Z).

Other exotic or non- $q\overline{q}$ candidates: An isovector $\phi\pi^0$ resonance at 1480 MeV has been reported by BITYUKOV 87 in $\pi^-p \to \phi\pi^0n$ (listed under the $\rho(1450)$). Preliminary indications favor the nonexotic $J^{PC}=1^{--}$, but the large OZI-rule violating branching ratio $\phi\pi:\omega\pi$ seems peculiar for a $(u\overline{u}-d\overline{d})$ I=1 $q\overline{q}$ object. However, ACHASOV 88 shows that the threshold effect from the two-step process $\rho(1600) \to K\overline{K}^* \to \pi\phi$ can violate the rule, especially near threshold. No sign of this candidate is seen in $\pi\omega$ (FUKUI 91). In addition, the small coupling to the photon makes an identification with the $\rho(1450)$ difficult (CLEGG 88). More recently DONNACHIE 93, analyzing e^+e^- -annihilation and diffractive-photoproduction data, suggests there may be 4-quark states near 1100 and 1300 MeV.

Another exotic candidate is the $\hat{\rho}(1405)$ (ALDE 88B, IDDIR 88), seen in the GAMS experiment under the $a_2(1320)$ in $\pi^-p \to \eta \pi^0 n$ with the exotic quantum numbers $J^{PC} = 1^{-+}$. The analysis of ALDE 88B has, however, been questioned by PROKOSHKIN 95B, 95C. Although the forward-backward asymmetry demands an $\eta \pi$ P-wave, it may be due to a nonresonant amplitude. The Crystal Barrel Collaboration has reported results on the corresponding P-wave in $\eta \pi$ seen in $p\bar{p} \to \eta \pi \pi$; they see a much broader effect, which can be explained as nonresonant or as a resonance with $\Gamma \approx 600$ MeV (AMSLER 94D). AOYAGI 93 also notes the $\eta \pi$ P-wave, but its interpretation is unclear

Another possible 1⁻⁺ candidate is the isosinglet X(1910) (ALDE 89), which seems to decay to $\eta\eta'$ but not to $\pi^0\pi^0$ or $\eta\eta$ (ALDE 89). An enhancement with quantum numbers 1⁻⁺, decaying to $f_1(1285)$, has also been reported around 1900 MeV (LEE 94).

Meson Particle Listings Non- $q\overline{q}$ Candidates

A narrow resonance, listed under the $K_J(3100)$, has been reported at about 3100 MeV (BOURQUIN 86, ALEEV 93) in several $A\overline{p}$ +pions and $\overline{A}p$ +pions states. The observation of the doubly-charged states $A\overline{p}\pi^-$ and $\overline{A}p\pi^+$ implies, assuming the decay is strong, I=3/2, clearly not a $q\overline{q}$ state. In addition, a narrow peak is observed at about 3250 MeV, listed under the X(3250), in the hidden strangeness combinations containing a baryon-antibaryon pair (ALEEV 93). However, all these observations need confirmation.

Non- $q\overline{q}$ Candidates

OMITTED FROM SUMMARY TABLE

NON-qq CANDIDATES REFERENCES

AMSLER 96	PR D53 295	+Close	(ZURI, RAL)
CLOSE 96	PL B366 323	+Page	(RAL)
AMELIN 95B	PL B356 595	+Berdnikov, Bityukov+	(SERP, TBIL)
AMSLER 95B	PL B342 433	+Armstrong, Brose+	(Crystal Barrel Collab.)
AMSLER 95C	PL B353 571	+Armstrong, Hackman+	(Crystal Barrel Collab.)
AMSLER 95D	PL B355 425	+Armstrong, Spanier+	(Crystal Barrel Collab.)
AMSLER 95E	PL B353 385	+Close	(ZURI, RAL)
AMSLER 95F	PL B358 389	+Armstrong, Urner+	(Crystal Barrel Collab.)
BERTIN 95	PI B361 187	+Bruschi+	(OBELIX Collab.)
CLOSE 95	NP B443 233	+Page	(RAL)
PROKOSHKIN 95B	PAN 58 606	+Sadovski	(SERP)
TROROSTIKIN 33B	Translated from YAF		(SERF)
PROKOSHKIN 95C	PAN 58 853	+Sadovski	(SERP)
	Translated from YAF	58 921	(32111)
SEXTON 95	PRL 75 4563	+Vaccarino, Weingarten+	(IBM)
ALBRECHT 94Z	PL B332 451	+Ehrlichmann+	(ARGUS Collab.)
AMSLER 94D	PL B333 277	+Anisovich, Spanier+	(Crystal Barrel Collab.)
ANISOVICH 94	PL B323 233	+Armstrong+	(Crystal Barrel Collab.)
BERDNIKOV 94	PL B337 219	+Bityukov+	(SERP, TBIL)
LEE 94	PL B323 227		D. KYUN, MASD, RICE)
TORNOVIST 94	ZPHY C61 525	Tornquist	(HELS)
ALEEV 93	PAN 56 1358	+Balandin+	(BIS-2 Collab.)
	Translated from YAF		(5.5 2 55.135.)
AOYAGI 93	PL B314 246	+Fukui, Hasegawa+	(BKEI Collab.)
BALI 93	PL B309 378	+Schilling, Hulsebo, Irving, Micha-	
DONNACHIE 93	ZP C60 187	+Kalashnikova, Clegg	(BNL)
ERICSON 93	PL B309 426	+ Karl	(ČERN)
			(/

MANOHAR	93	NP B399 17	+Wise (MIT)
AMSLER	92	PL B291 347	+Wise (MIT) +Augustin, Baker+ (Crystal Barrel Collab.)
BARNES	92	PR D46 131	
DOOLEY	92	PL B275 478	
ALBRECHT	91F	ZPHY C50 1	
CHEN	91	Hadron 91 Conf.	+Appuan, Paulini, Funk+ (ARGUS Collab.)
SLAC-PUB		Hadron 91 Com.	(Mark III Collab.)
DOVER	91	PR C43 379	+Gutsche, Faessler (BNL)
FUKUI	91	PL B257 241	
	91		+Horikawa+ (SUGI, NAGO, KEK, KYOT, MIYA)
TORNQVIST		PRL 67 556	(HELS)
ACHASOV	90	TF 20 (178)	+Shestakov (NOVM)
BREAKSTONE		ZPHY C48 569	+ (ISU, BGNA, CERN, DORT, HEIDH, WARS)
BURNETT	90	ARNPS 46 332	+Sharpe (RAL)
CALDWELL	90	Hadron 89 Conf. p 12	7 (UCSB)
LONGACRE	90	PR D42 874	(BNL)
WEINSTEIN	90	PR D41 2236	+lsgur (TNTO)
ALDE	89	PL B216 447	+Binon, Bricman, Donskov+ (SERP, BELG, LANL, LAPP)
ARMSTRONG	89B	PL B221 221	+Benayoun+(CERN, CDEF, BIRM, BARI, ATHU, CURIN+)
ARMSTRONG	89D	PL B227 186	+Benayoun (ATHU, BARI, BIRM, CERN, CDEF)
MAY	89	PL B225 450	+Duch, Heel+ (ASTERIX Collab.)
ACHASOV	88	PL B207 199	+Kozhevnikov (NOVM)
AIHARA	88	PR D37 28	+Alston, Avery, Barbaro-Galtieri+ (TPC-2γ Collab.)
ALDE	88	PL B201 160	+Bellazzini, Binon+ (SERP, BELG, LANL, LAPP, PISA)
ALDE	88B	PL B205 397	+Binon, Boutemeur+ (SERP, BELG, LANL, LAPP)
ASTON	88D	NP B301 525	+Awaji, Bienz+ (SLAC, NAGO, CINC, INUS)
BERGER	88B	ZPHY C38 521	+Klovning, Burger+ (PLUTO Collab.)
BIRMAN	88	PRL 61 1557	
CLEGG	88	ZPHY C40 313	
ETKIN	88		+Donnachie (MCHS, LANC)
		PL B201 568	+Foley, Lindenbaum+ (BNL, CUNY)
IDDIR	88	PL B205 564	+Le Yaouanc, Ono+ (ORSAY, TOKY)
TOKI	88	AIP Conf.	(SLAC)
ACHASOV	87	ZPHY C36 161	+Karnakov, Shestakov (NOVM)
ASTON	87	NP B292 693	+Awaji, D'Amore+ (SLAC, NAGO, CINC, INUS)
BITYUKOV	87	PL B188 383	+Dzhelyadin, Dorofeev, Golovkin+ (SERP)
CLOSE	87	RPP 51 833	(RHEL)
ANDO	86	PRL 57 1296	+lmai+ (KEK, KYOT, NIRS, SAGA, INUS, TSUK+)
BOURQUIN	86	PL B172 113	+Brown+ (GEVA, RAL, HEIDP, LAUS, BRIS, CERN)
HEUSCH	86	Seewinkel Symposium o	n Multiparticle Dynamics (SLAC)
CHUNG	85	PRL 55 779	+Fernow, Boehnlein+ (BNL, FLOR, IND, MASD)
ISGUR	85	PRL 54 869	+Kokorski, Patou (TNTO)
LEYAOUANC	85	ZPHY C28 309	+Olivek, Pene, Raynal, Ono (ORSAY)
BEHREND	84E	ZPHY C21 205	+Achenberg, Deboer+ (CELLO Collab.)
BINON	83	NC 78A 313	+Donskov, Duteil+ (BELG, LAPP, SERP, CERN)
WEINSTEIN	83B	PR D27 588	+isgur (TNTO)
AIHARA	82	PR D37 28	+Alston, Avery, Barbaro-Galtieri+ (TPC Collab.)
ALTHOFF	82	ZPHY C16 13	
	82		
BARNES BURKE	81	PL B116 365 PL B103 153	+Close (RHEL)
			+Abrams, Alam, BLocher+ (Mark II Collab.)
BRANDELIK	80B		+Boerner, Burkhard+ (TASSO Collab.)
GUTBROD	79		+Kramer, Rumpf (DESY)
JAFFE	77	PR D15 267,281	(MIT)
VOLOSHIN	76	JETPL 23 333	+Okun (ÎTEP)
DAULON		Translated from ZETFP	
BAILLON	67	NC 50A 393	+Edwards, D'Andlau, Astier+ (CERN, CDEF, IRAD)
ACHASOV	82	PL B108 134	+Devyanin, Shestakov (NOVM)

N BARYONS $(S=0, I=1/2)$	
p	561
$\stackrel{\cdot}{n}$	567
N resonances	575
Δ BARYONS $(S=0,I=3/2)$	
	600
Δ resonances	600
Λ BARYONS $(S=-1,I=0)$	
$oldsymbol{\Lambda}$	619
arLambda resonances	622
Σ BARYONS $(S=-1,I=1)$	
Σ^+	636
Σ^0	638
Σ^-	639
Σ resonances	641
	011
Ξ BARYONS $(S=-2,I=1/2)$	
$arepsilon^0$	660
$\underline{\underline{e}}^-$	661
Ξ resonances	664
Ω BARYONS $(S=-3,I=0)$	
$arOmega^-$	671
Ω resonances	672
CHARMED BARYONS $(C = +1)$	
	673
$arLambda_c^+$	673 677
Λ_c^+	677
A_c^+	677 678
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A_c^+	677 678 678 679 679 680 681 683 684
A_c^+	677 678 678 679 679 680 681 683 684
A_c^+ $A_c(2593)^+$ $A_c(2625)^+$ $\Sigma_c(2455)$ $\Sigma_c(2530)$ Ξ_c^+ Ξ_c^0 Ξ_c^0 $\Xi_c(2645)$ Ω_c^0 BOTTOM (BEAUTY) BARYON ($B=-1$) A_b^0 Ξ_b^0 , Ξ_b^- Notes in the Baryon Listings Baryon Decay Parameters N and Δ Resonances	677 678 678 679 679 680 681 683 684
$\begin{array}{c} A_c^+ \\ A_c(2593)^+ \\ A_c(2625)^+ \\ \varSigma_c(2455) \\ \varSigma_c(2530) \\ \Xi_c^+ \\ \Xi_c^0 \\ \Xi_c(2645) \\ \varOmega_c^0 \\ \end{array}$ $\begin{array}{c} BOTTOM \ (BEAUTY) \ BARYON \ (B=-1) \\ A_b^0 \\ \Xi_b^0, \ \Xi_b^- \\ \end{array}$ $\begin{array}{c} Notes \ in \ the \ Baryon \ Listings \\ Baryon \ Decay \ Parameters \\ N \ and \ \Delta \ Resonances \\ Baryon \ Magnetic \ Moments \\ \Lambda \ and \ \Sigma \ Resonances \\ \end{array}$	677 678 678 679 679 680 681 681 683 684
A_c^+ $A_c(2593)^+$ $A_c(2625)^+$ $\Sigma_c(2455)$ $\Sigma_c(2530)$ Ξ_c^+ Ξ_c^0 Ξ_c^0 $\Xi_c(2645)$ Ω_c^0 BOTTOM (BEAUTY) BARYON ($B=-1$) A_b^0 Ξ_b^0 , Ξ_b^- Notes in the Baryon Listings Baryon Decay Parameters N and Δ Resonances Baryon Magnetic Moments Λ and Σ Resonances The $\Lambda(1405)$ The $\Sigma(1670)$ Region	677 678 678 679 679 680 681 683 684 568 571 619 622
A_c^+ $A_c(2593)^+$ $A_c(2625)^+$ $\Sigma_c(2455)$ $\Sigma_c(2530)$ Ξ_c^+ Ξ_c^0 Ξ_c^0 $\Xi_c(2645)$ Ω_c^0 BOTTOM (BEAUTY) BARYON ($B=-1$) A_b^0 Ξ_b^0 , Ξ_b^- Notes in the Baryon Listings Baryon Decay Parameters N and Δ Resonances Baryon Magnetic Moments A and Σ Resonances The $\Lambda(1405)$	677 678 678 679 679 680 681 681 683 684 568 571 619 622 623

N BARYONS (S=0, I=1/2)

 $p, N^{+} = uud; n, N^{0} = udd$

 $I(J^P) = \frac{1}{2}(\frac{1}{2})$ Status: ***

The mass is known much more precisely in u (atomic mass units) than in MeV; see the footnote. The conversion from u to MeV, 1 u = 931.49432 ± 0.00028 MeV, involves the relatively poorly known electronic

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
938.27231±0.00028	¹ COHEN	87	RVUE	1986 CODATA value
• • • We do not use the following	data for average	s, fit	s, limits,	etc. • • •
938.2796 ±0.0027	COHEN	73	RVUE	1973 CODATA value
¹ The mass is known much more	precisely in u: n	7 = 1	.007276	470 ± 0.000000012 u.

P MASS

See, however, the next entry in the Listings, which establishes the \overline{p} mass much more precisely.

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following	data for averages	, fits	s, limits,	etc. • • •
938.30 ±0.13	ROBERTS	78	CNTR	
938.229 ± 0.049	ROBERSON	77	CNTR	
938.179 ± 0.058	HU	75	CNTR	Exotic atoms
938.3 ±0.5	BAMBERGER	70	CNTR	

\bar{p}/p CHARGE-TO-MASS RATIO, $\left|\frac{q_{\bar{p}}}{m_{\bar{p}}}\right|/\left(\frac{q_{\bar{p}}}{m_{\bar{p}}}\right)$

A test of CPT invariance. Listed here are measurements involving the inertial masses. For a discussion of what may be inferred about the ratio of \overline{p} and p gravitational masses, see ERICSON 90; they obtain an upper bound of 10^{-6} – 10^{-7} for violation of the equivalence principle for \overline{p} 's.

VALUE	DOCUMENT ID	TECN	COMMENT
$1.0000000015 \pm 0.0000000011$	² GABRIELSE 9	5 TRAP	Penning trap
	g data for averages,	fits, limits,	etc. • • •
1.000000023 ±0.000000042	³ GABRIELSE 9	0 TRAP	Penning trap
² Equation (2) of GABRIELS (G. Gabrielse, private commun		$M(\overline{p})/M(p)$	o) = 0.999 999 99 <u>8</u> 5 (11)

 3 GABRIELSE 90 also measures $m_{\overline p}/m_{e^-}=1836.152660\pm0.000083$ and $m_p/m_{e^-}=1836.152680\pm0.000088$. Both are completely consistent with the 1986 CODATA COHEN 87) value for m_p/m_e of 1836.152701 \pm 0.000037. We use the CODATA values of the masses (they come from an overall fit to a variety of data on the fundamental constants) and don't try to take into account more recent measurements involving the masses.

$(\left|\frac{q_{\overline{p}}}{m_{\overline{p}}}\right| - \frac{q_{\overline{p}}}{m_{\overline{p}}}) / \left|\frac{q}{m}\right|_{\text{average}}$

A test of CPT invariance. Taken from the \overline{p}/p charge-to-mass ratio,

VALUE DOCUMENT ID $(1.5\pm1.1)\times10^{-9}$ OUR EVALUATION

$|q_p + q_{\overline{p}}|/e$

A test of *CPT* invariance. Note that the \overline{p}/p charge-to-mass ratio, given above, is much better determined. See also a similar test involving the

VALUE DOCUMENT ID <2 × 10⁻⁵ ⁴ HUGHES 92 RVUE

⁴ HUGHES 92 uses recent measurements of Rydberg-energy and cyclotron-frequency ratios.

$|q_p + q_e|/e$

See DYLLA 73 for a summary of experiments on the neutrality of matter. See also "n CHARGE" in the neutron Listings.

DOCUMENT ID COMMENT 73 Neutrality of SF₆ ⁵ DYLLA ◆ • We do not use the following data for averages, fits, limits, etc. $< 0.8 \times 10^{-21}$ MARINELLI 84 Magnetic levitation ⁵ Assumes that $q_n=q_p\!+\!q_e$

ρ MAGNETIC MOMENT

See the "Note on Baryon Magnetic Moments" in the A Listings.

VALUE (µN)		DOCUMENT ID		TECN	COMMENT	
2.79284738	6±0.00000063	COHEN	87	RVUE	1986 CODATA value	
2.7928456	±0.0000011	COHEN	73	RVUE	1973 CODATA value	

P MAGNETIC MOMENT

A few early results have been omitted.

VALUE (μ _N)	DOCUMENT ID		TECN	COMMENT
-2.800 ±0.008 OUR AVERAGE				
-2.8005 ± 0.0090	KREISSL	88	CNTR	\overline{p} ²⁰⁸ Pb 11 \rightarrow 10 X-ray
-2.817 ± 0.048	ROBERTS	78	CNTR	
-2.791 ± 0.021	HU	75	CNTR	Exotic atoms

$(\mu_p - |\mu_{\overline{p}}|) / |\mu_{\text{average}}|$

A test of CPT invariance. Calculated from the p and \overline{p} magnetic moments, above.

DOCUMENT ID

$(-2.6\pm2.9)\times10^{-3}$ OUR EVALUATION

ı

p ELECTRIC DIPOLE MOMENT

A nonzero value is forbidden by both T invariance and P invariance.

VALUE (10 ⁻²³ ecm)	EVTS	DOCUMENT ID		TECN	COMMENT
- 3.7± 6.3		сно	89	NMR	TI F molecules
- 3.7± 6.3 CHO • • • We do not use the following data for aver < 400 DZUBA 130 ± 200 6 WILKENIN 900 ± 1400 7 WILKENIN 7 WILKENIN		g data for average	es, fit	s, limits,	etc. • • •
< 400		DZUBA	85	THEO	Uses ¹²⁹ Xe moment
130 ± 200		6 WILKENING	84		
900 ±1400		7 WILKENING	84		
700 000		LIABBICON		4400	Address described to the control of

 $^{700 \}pm 900$ HARRISON 69 MBR Molecular beam $^{6}\,\text{This}$ WILKENING 84 value includes a finite-size effect and a magnetic effect.

p ELECTRIC POLARIZABILITY Top

VALUE (10 ⁻⁴ fm ³)	DOCUMENT ID		TECN	COMMENT
12.1 ±0.8 ±0.5	⁸ MACGIBBON	95	RVUE	global average
• • We do not use the follow	wing data for average	s, fits	s, limits,	etc. • • •
12.5 ± 0.6 ± 0.9	MACGIBBON	95	CNTR	γp Compton scattering
$9.8 \pm 0.4 \pm 1.1$	HALLIN	93	CNTR	γp Compton scattering
$10.62 + 1.25 + 1.07 \\ -1.19 - 1.03$	ZIEGER			γp Compton scattering
$10.9 \pm 2.2 \pm 1.3$	⁹ FEDERSPIEL	91	CNTR	γp Compton scattering
8 MACCIDBON OF sombine	the results of ZIECE	D 00	FFDF	DEDIEL Of and their aum

⁸ MACGIBBON 95 combine the results of ZIEGER 92, FEDERSPIEL 91, and their own experiment to get a "global average" in which model errors and systematic errors are treated in a consistent way. See MACGIBBON 95 for a discussion.

⁹ FEDERSPIEL 91 obtains for the (static) electric polarizability α_p , defined in terms of the

ρ MAGNETIC POLARIZABILITY $\overline{\beta}_{\rho}$

The electric and magnetic polarizabilities are subject to a dispersion sumrule constraint $\overline{\alpha}+\overline{\beta}=(14.2\pm0.5)\times10^{-4}~{\rm fm^3}$. Errors here are anticorrelated with those on $\overleftarrow{\alpha}_{\pmb{p}}$ due to this constraint.

VALUE (10 ⁻⁴ fm ³)	DOCUMENT ID		TECN	COMMENT
2.1 ±0.8 ±0.5	¹⁰ MACGIBBON	95	RVUE	global average
• • We do not use the following the fol	owing data for averages	s, fits	, limits,	etc. • • •
$1.7 \pm 0.6 \pm 0.9$	MACGIBBON	95	CNTR	γp Compton scattering
$4.4 \pm 0.4 \pm 1.1$	HALLIN	93	CNTR	γp Compton scattering
$3.58 + 1.19 + 1.03 \\ -1.25 - 1.07$	ZIEGER	92	CNTR	γp Compton scattering
$3.3 \pm 2.2 \pm 1.3$	FEDERSPIEL	91	CNTR	γp Compton scattering
10				

10 MACGIBBON 95 combine the results of ZIEGER 92, FEDERSPIEL 91, and their own experiment to get a "global average" in which model errors and systematic errors are treated in a consistent way. See MACGIBBON 95 for a discussion.

⁷ This WILKENING 84 value is more cautious than the other and excludes the finite-size effect, which relies on uncertain nuclear integrals.

induced electric dipole moment by ${\bf D}=4\pi\epsilon_0\alpha_p{\bf E}$, the value $(7.0\pm2.2\pm1.3)\times10^{-4}~{\rm fm}^3$.

Baryon Particle Listings

n

p MEAN LIFE

A test of baryon conservation. See the "p Partial Mean Lives" section below for limits that depend on decay modes. p= proton, n= bound neutron.

	u u,			
(years)	PARTICLE	DOCUMENT IL	2	TECN
>1.6 × 10 ²⁵	p, n	^{11,12} EVANS	77	
• • • We do not	use the followi	ng data for averages,	fits, lin	nits, etc. • • •
$>3 \times 10^{23}$	p	12 DIX	70	CNTR
$>3 \times 10^{23}$	p, n	12,13 FLEROV	58	
11 Mean lifetime 12 Converted to 13 Mean lifetime	mean life by div	viding half-life by In(2	2) = 0.6	593.

MEAN LIFE

The best limit by far, that of GOLDEN 79, relies, however, on a number of astrophysical assumptions. The other limits come from direct observations of stored antiprotons. See also " \overline{p} Partial Mean Lives" after "p Partial Mean Lives," below.

LIMIT (years)	CL% E	VTS	DOCUMENT ID		TECN	COMMENT
	the fol	owing dat	a for averages,	fits, li	mits, et	c. • • •
>0.28			GABRIELSE	90	TRAP	Penning trap
>0.08	90	1	BELL	79	CNTR	Storage ring
$>1 \times 10^{7}$			GOLDEN	79	SPEC	\overline{p}/p , cosmic rays
$> 3.7 \times 10^{-3}$			BREGMAN	78	CNTR	Storage ring

p DECAY MODES

Below, for N decays, p and n distinguish proton and neutron partial lifetimes. See also the "Note on Nucleon Decay" in our 1994 edition (Phys. Rev. **D50**, 1673) for a short review.

The "partial mean life" limits tabulated here are the limits on τ/B_I , where τ is the total mean life and B_I is the branching fraction for the mode in question.

	Mode		Partial mean life (10 ³⁰ years)	Confidence level
		Antilepton +	meson	
$ au_1$	$N \rightarrow e^+ \pi$	•	> 130 (n), > 550 (p)	90%
τ_2	$N \rightarrow \mu^+ \pi$		> 100 (n), > 270 (p)	90%
τ_3	$N \rightarrow \nu \pi$		> 100 (n), > 25 (p)	90%
τ_4	$p \rightarrow e^+ \eta$		> 140	90%
τ_5	$p \rightarrow \mu^+ \eta$		> 69	90%
τ_6	$n \rightarrow \nu \eta$		> 54	90%
$ au_7$	$N \rightarrow e^+ \rho$		> 58 (n), > 75 (p)	90%
$ au_8$	$N \rightarrow \mu^+ \rho$		> 23 (n), > 110 (p)	90%
τ_9	$N \rightarrow \nu \rho$		> 19 (n), > 27 (p)	90%
τ_{10}	$p \rightarrow e^+ \omega$		> 45	90%
τ_{11}	$p \rightarrow \mu^+ \omega$		> 57	90%
τ_{12}	$n \rightarrow \nu \omega$		> 43	90%
τ_{13}	$N \rightarrow e^+ K$		> 1.3 (n), > 150 (p)	90%
τ_{14}	$p ightarrow e^+ K_S^0$		> 76	90%
$ au_{15}$	$p \rightarrow e^+ K_I^{0}$		> 44	90%
τ_{16}	$N \rightarrow \mu^+ K$		> 1.1 (n), > 120 (p)	90%
τ_{17}	$p \rightarrow \mu^+ K_S^0$		> 64	90%
τ_{18}	$p \rightarrow \mu^+ K_I^0$		> 44	90%
τ_{19}	$N \rightarrow \nu K$		> 86 (n), > 100 (p)	90%
τ_{20}	$p \to e^+ K^* (892)^0$		> 52	90%
τ_{21}	$N \rightarrow \nu K^*(892)$		> 22 (n), > 20 (p)	90%
		Antilepton + I	nesons	
τ_{22}	$\rho \rightarrow e^+\pi^+\pi^-$		> 21	90%
τ_{23}	$p \rightarrow e^+ \pi^0 \pi^0$		> 38	90%
T24	$n \rightarrow e^+\pi^-\pi^0$		> 32	90%
τ_{25}	$p \rightarrow \mu^+ \pi^+ \pi^-$		> 17	90%
τ_{26}	$p \rightarrow \mu^+ \pi^0 \pi^0$		> 33	90%
τ_{27}	$n \rightarrow \mu^+ \pi^- \pi^0$		> 33	90%
τ_{28}	$n \rightarrow e^+ K^0 \pi^-$		> 18	90%
		Lepton + m	eson	
τ_{29}	$n \rightarrow e^- \pi^+$	Lepton , m	> 65	90%
τ ₃₀	$n \rightarrow \mu^- \pi^+$		> 49	90%
τ_{31}	$n \rightarrow e^- \rho^+$		> 62	90%
τ_{32}	$n \rightarrow \mu^- \rho^+$		> 7	90%
τ_{33}	$n \rightarrow e^- K^+$		> 32	90%
τ_{34}	$n \rightarrow \mu^- K^+$		> 57	90%
J-7.	•			

	Lepto	n + mesons	
$ au_{35}$	$p \rightarrow e^- \pi^+ \pi^+$	> 30	90%
$ au_{36}$	$n \rightarrow e^- \pi^+ \pi^0$	> 29	90%
$ au_{37}$	$p \rightarrow \mu^- \pi^+ \pi^+$	> 17	90%
τ_{38}	$n \rightarrow \mu^- \pi^+ \pi^0$	> 34	90%
τ_{39}	$p \rightarrow e^- \pi^+ K^+$	> 20	90%
T40	$ ho ightarrow \ \mu^- \pi^+ K^+$	> 5	90%
	Antilepto	on + photon(s)	
τ_{41}	$p \rightarrow e^+ \gamma$	> 460	90%
	$p \rightarrow \mu^+ \gamma$	> 380	90%
τ_{43}	$n \rightarrow \nu \gamma$	> 24	90%
τ_{44}	$p \rightarrow e^{+} \gamma \gamma$	> 100	90%
	Thr	ee leptons	
τ_{45}	$p \rightarrow e^+e^+e^-$	> 510	90%
T46	$p \rightarrow e^+ \mu^+ \mu^-$	> 81	90%
τ_{47}	$p \rightarrow e^+ \nu \nu$	> 11	90%
τ_{48}	$n \rightarrow e^+e^-\nu$	> 74	90%
	$n \rightarrow \mu^+ e^- \nu$	> 47	90%
τ_{50}	$n \rightarrow \mu^+ \mu^- \nu$	> 42	90%
τ_{51}	$p \rightarrow \mu^+ e^+ e^-$	> 91	90%
$ au_{52}$	$p \rightarrow \mu^+ \mu^+ \mu^-$	> 190	90%
τ_{53}	$p \rightarrow \mu^+ \nu \nu$	> 21	90%
τ_{54}	$p \rightarrow e^- \mu^+ \mu^+$	> 6	90%
τ_{55}	$n \rightarrow 3\nu$	> 0.0005	90%
	Inclu	sive modes	
τ_{56}	$N \rightarrow e^+$ anything	> 0.6 (n, p)	90%
τ_{57}	$N ightarrow \mu^+$ anything	> 12 (n, p)	90%
τ_{58}	$N \rightarrow \nu$ anything		
τ_{59}	$N ightarrow e^+ \pi^0$ anything	> 0.6 (n, p)	90%
τ_{60}	$N \rightarrow 2$ bodies, ν -free		
	$\Delta B = 2$	linucleon modes	
	The following are lifetime limits	ner iron nucleus	

The following are lifetime limits per iron nucleus.

⁷ 61	$pp \rightarrow \pi^+\pi^+$	> 0.7	90%
⁷ 62	$pn \rightarrow \pi^+\pi^0$	> 2	90%
T ₆₃	$nn \rightarrow \pi^+\pi^-$	> 0.7	90%
⁷ 64	$nn \rightarrow \pi^0 \pi^0$	> 3.4	90%
⁷ 65	$pp \rightarrow e^+e^+$	> 5.8	90%
⁷ 66	$pp \rightarrow e^+ \mu^+$	> 3.6	90%
⁷ 67	$pp \rightarrow \mu^+ \mu^+$	> 1.7	90%
⁷ 68	$pn \rightarrow e^+ \overline{\nu}$	> 2.8	90%
⁷ 69	$pn \rightarrow \mu^{+}\overline{\nu}$	> 1.6	90%
770	$nn \rightarrow \nu_e \overline{\nu}_e$	> 0.000012	90%
771	$n n \rightarrow \nu_{\mu} \overline{\nu}_{\mu}$	> 0.000006	90%

P DECAY MODES

	Mode	(years)	Confidence level
τ_{72}	$\overline{p} \rightarrow e^- \gamma$	> 1848	95%
τ_{73}	$\overline{ ho} ightarrow e^- \pi^0$	> 554	95%
τ_{74}	$\overline{p} \rightarrow e^- \eta$	> 171	95%
τ_{75}	$\overline{p} \rightarrow e^- K_S^0$	> 29	95%
	$\overline{p} \rightarrow e^- K_L^{\overline{0}}$	> 9	95%

p PARTIAL MEAN LIVES

The "partial mean life" limits tabulated here are the limits on τ/B_j , where τ is the total mean life for the proton and B_j is the branching fraction for the mode in question.

Decaying particle: p= proton, n= bound neutron. The same event may appear under more than one partial decay mode. Background estimates may be accurate to a factor of two.

$\tau(N \rightarrow e^{+}$	$^{\perp}\pi)$					$ au_1$
LIMIT (10 ³⁰ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID	TECN
>550	P	90	0	0.7	¹⁴ BECKER-SZ 90	IMB3
>130	n	90	0	<0.2	HIRATA 890	KAMI

● ● We 70	do not use th	e follow 90	-	a for averages, 0.5	fits, limits, etc. • • • BERGER		FREJ	τ(p → μ'							
70	p n	90	0	0.5 ≤ 0.1	BERGER		FREJ	(10 ³⁰ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
260	P	90	0	<0.04	HIRATA		KAMI	>69	P	90	1		HIRATA		C KAMI
310	P	90		0.6	SEIDEL	88	IMB	• • • We	do not use th	e followin	g dat	a for averages,	fits, limits, etc. • • •		
100	n	90		1.6	SEIDEL	88	IMB	>26	p	90	1	0.8	BERGER	91	FREJ
1.3	n	90	0		BARTELT	87	SOUD	> 1.3	p	90		0.7	PHILLIPS	89	HPW
1.3	P	90	0		BARTELT	87	SOUD	>34	p	90		1.5	SEIDEL	88	IMB
250	P	90		0.3	HAINES	86	IMB	>46	p	90		6	HAINES	86	IMB
31	n	90 90	8	9	HAINES	86	IMB	>26	P	90	1		ARISAKA	85	KAMI
64	P	90	0	<0.4 <0.7	ARISAKA	85	KAMI	>17	p (free)	90		6	BLEWITT	85	
26 82	n n (fron)				ARISAKA	85	KAMI	>46	p	90	7	8	BLEWITT	85	IMB
250	p (free)	90 90		0.2	BLEWITT BLEWITT	85 ee	IMB	~(n	۵)						
25	p n	90	4	4	PARK	85 85	IMB IMB	$\tau(n \rightarrow \nu)$	1)						
15	p, n	90	0	7	BATTISTONI	84	NUSX	LIMIT (10 ³⁰ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
0.5	p,	90	-	0.3	15 BARTELT	83	SOUD	>54	n	90		0.9		904	KAMI
0.5	n	90		0.3	15 BARTELT	83	SOUD						HIRATA fits, limits, etc. • • •		. KAWII
5.8	p	90	2	0.0	16 KRISHNA		KOLR								
5.8	'n	90	2		16 KRISHNA		KOLR	>29	n	90		0.9	BERGER	89	FREJ
0.1	n-	90			¹⁷ GURR	67	CNTR	>16	n	90			SEIDEL	88	IMB
			rocult is	ncludes data fro				>25	n	90	7	6	HAINES	86	IMB
limit	ased on zero	events	result ii	iciuues uata iro	JIII SEIDEL 88.			>30	n	90	0	0.4	KAJITA	86	KAMI
'We ha	e calculated	90% CL	limit fr	om 1 confined	event.			>18	n	90	4	3	PARK	85	IMB
We ha	ve converted I	nalf-life 1	0 90%	CL mean life.				> 0.6	n	90	2		²² CHERRY	81	ном
								²² We hav	e converted 2	possible	event	s to 90% CL lir	nit.		
$V \rightarrow \mu$,						$ au_2$	$\tau(N \rightarrow e^{i}$							
⁰ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	LIMIT	•						
00	n	90	0	<0.2	HIRATA	89c	KAMI	(10 ³⁰ years)	PARTICLE		EVTS	BKGD EST	DOCUMENT ID		TECN
70	P	90		0.5	SEIDEL		IMB	>75	P	90			HIRATA		KAMI
• We	do not use th	e followi	ng data	for averages,	fits, limits, etc. • • •			>58	n	90		1.9	HIRATA	890	KAM
31	p ·	90		0.2	BERGER	91	FREJ	• • • We o	io not use the	e followin	g dat	a for averages, f	fits, limits, etc. • • •		
5	n	90		1.0	BERGER		FREJ	>29	p	90	0	2.2	BERGER	91	FREJ
0	p	90		< 0.07	HIRATA		KAMI	>41	n	90		1.4	BERGER	91	FREJ
3	n	90	-	0.5	SEIDEL	88	IMB	>38	n	90	2	4.1	SEIDEL	88	IMB
6	P	90	2		HAINES	86	IMB	> 1.2	p	90	0		BARTELT	87	SOU
3	n	90		7	HAINES	86	IMB	> 1.5	n .	90	0		BARTELT	87	SOUI
16	p	90		<0.7	ARISAKA	85	KAMI	>17	p	90	7	7	HAINES	86	IMB
20	'n	90		<0.4	ARISAKA	85	KAMI	>14	'n	90	9	4	HAINES	86	IMB
59	p (free)	90		0.2	BLEWITT	85	IMB	>12	p	90	0	<1.2	ARISAKA	85	KAM
00	p (ivee)	90		0.4	BLEWITT	85	IMB	> 6	n	90	2	<1	ARISAKA	85	KAMI
38	n	90		4	PARK	85	IMB	> 6.7	p (free)	90	6	6	BLEWITT	85	IMB
10	 р, п	90	ō	•	BATTISTONI	84	NUSX	>17	p	90	7	7	BLEWITT	85	IMB
1.3	p, n	90	0		ALEKSEEV	81	BAKS	>12	n	90	4	2	PARK	85	IMB
	•							> 0.6	n	90	1	0.3	23 BARTELT	83	SOUD
$V \rightarrow \nu$	π)						$ au_3$	> 0.5	p	90	1	0.3	²³ BARTELT	83	SOUD
T	•						-	> 9.8	p	90	1		²⁴ KRISHNA	82	KOLR
years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	> 0.8	p	90	2		²⁵ CHERRY	81	ном
25	P	90	32	32.8	HIRATA	89 C	KAMI	23 Limit ba	sed on zero e	events.					
00	n	90		3	HIRATA	89C	KAMI	²⁴ We have	e calculated 9	10% CL II	mit fr	om 0 confined o	events.		
					fits, limits, etc. • • •					possible	event	s to 90% CL lin	nit.		
13	n	90		1.2	BERGER	89	FREJ	$\tau(N \rightarrow \mu)$	⁺ ρ)						
0	P	90	11		BERGER	89	FREJ	LIMIT	• ,						
6 2	n	90	73		HAINES	86	IMB	(10 ³⁰ years)	PARTICLE	CL% I	EVTS	BKGD EST	DOCUMENT ID		TECN
2 D	p	90	16		KAJITA	86	KAMI	>110	P	90	0	1.7	HIRATA	890	KAM
7	n n	90 90		1 19	KAJITA	86 ee	KAMI	> 23	n	90	1	1.8	HIRATA	890	KAM
	n n	90	28 0	13	PARK BATTISTONI	85 84	IMB NUSX	• • • We d	lo not use the	following	g data	a for averages, f	its, limits, etc. 🔸 🔸		
7 <u>2</u>	n p	90 90			BATTISTONI	84 84	NUSX	> 12	p	90	0	0.5	BERGER	91	FREJ
2 5.8	•	90 90	≤ 3 1		18 KRISHNA		KOLR	> 22	n	90		1.1	BERGER		FREJ
).3	p p	90	2		19 CHERRY	81	HOME	> 4.3	p	90		0.7	PHILLIPS		HPW
).3).1	-	90 90	2		²⁰ GURR			> 30	p	90		0.5	SEIDEL	88	IMB
	p					07	CNTR	> 11	n	90		1.1	SEIDEL	88	IMB
/e hav	e calculated	90% CL	limit fro	om 1 confined	event.			> 16	D D	90		4.5	HAINES	86	IMB
e nav	e converted 2	possible	events	s to 90% CL lin	nit.			> 7	n	90		5	HAINES	86	IMB
e nav	e converted h	iait-iife t	U 9U%	CL mean life.				> 12	p	90		<0.7	ARISAKA	85	KAM
→ e ⁻	[⊢] n)						<i>T</i> 4	> 5	n	90		<1.2	ARISAKA	85	KAM
	-1)						-4	> 5.5	p (free)	90		5	BLEWITT	85	IMB
years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	> 16	P	90		5	BLEWITT		IMB
)	P	90		<0.04	HIRATA	89C	KAMI	> 9	'n	90	1		PARK	85	IMB
We			ng data	for averages, f	its, limits, etc. • •			$\tau(N \to \nu)$	o)						
ŀ	p	90	0		BERGER	91	FREJ		7						
)	p	90	0	0.6	SEIDEL	88	IMB	LIMIT (10 ³⁰ years)	PARTICLE	CL% E	VTS	BKGD EST	DOCUMENT ID		TECN
)	ρ	90	5	3.3	HAINES	86	IMB	>27	P	90		1.5	HIRATA	890	KAM
4	p	90		< 0.8	ARISAKA	85	KAMI	>19	n	90		0.5	SEIDEL		IMB
+	p (free)	90	5	6.5	BLEWITT	85	IMB						its, limits, etc. • •	-00	.IVI D
1	P (mee)														
4 4 D	p	90	5 2	4.7	BLEWITT ²¹ CHERRY	85	IMB	• • • • • • • • • • • • • • • • • • •	o not use the	. TOHOWINE	, aute	. Tor averages, n	its, illinits, etc. • • •		

Baryon Particle Listings

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24	n	90 90	4 0	2.4 0.9	BERGER BERGER	89 89	FREJ FREJ	$\tau(N \to \mu)$	+ <i>K</i>)						$ au_1$
13	p n	90	4	3.6	HIRATA		KAMI	LIMIT (10 ³⁰ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
.3	D D	90		1.1	SEIDEL	88	IMB	>120	P	90	1	0.4	HIRATA	800	KAMI
8	p	90	6	5	HAINES	86	IMB	> 1.1	'n	90	ō	0.4	BARTELT		SOUD
2	n	90	15	-	HAINES	86	IMB					a for averages, fi	its, limits, etc. • • •	01	3000
1	p	90		1	KAJITA	86	KAMI	> 54	p	90	0		BERGER	91	FREJ
4	n	90	2	2	KAJITA	86	KAMI	> 3.0	p	90		0.7	PHILLIPS	89	HPW
4.1	p (free)	90	6	7	BLEWITT	85	IMB	> 19	p	90		2.5	SEIDEL	88	IMB
8.4	p	90	6	5	BLEWITT	85	IMB	> 1.5	P	90	0	2.0	31 BARTELT	87	SOUD
2	n	90	7	3	PARK	85	IMB	> 40	p	90	7	6	HAINES	86	IMB
0.9	p	90	2		²⁶ CHERRY	81	HOME	> 19	p	90			ARISAKA	85	KAMI
0.6	n	90	2		²⁶ CHERRY	81	HOME	> 6.7	p (free)	90	11		BLEWITT	85	IMB
We hav	e converted 2	nossihl	e event	ts to 90% CL I	limit			> 40	p	90	7		BLEWITT	85	IMB
		p = ====						> 6	p	90	1		BATTISTONI		NUSX
$p \rightarrow e^{+}$	⊦ω)						$ au_{10}$	> 0.6	p	90	0		32 BARTELT	83	SOUD
IT 10 years)	•							> 0.4	n	90	0		32 BARTELT	83	SOUD
O years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	> 5.8	p	90	2		³³ KRISHNA	82	KOLR
5	P	90	2	1.45	HIRATA	890	KAMI	> 2.0	p	90	0		CHERRY	81	HOME
• We d	do not use the	followi	ng dat	a for averages,	fits, limits, etc. • •			> 0.2	n	90			³⁴ GURR	67	CNTR
	p	90	0	1.1	BERGER	91	FREJ	31 BARTE	LT 87 limit a	nnlies to	n	$\mu + \kappa_0$			
7 5	p	90		1.0	SEIDEL	88	IMB	32 Limit h	sed on zero e	Mente		rs.			
1.5	p	90	0	1.0	BARTELT	87	SOUD	33 We have	calculated 9	0% CL II	imit fr	om 1 confined e	event.		
7.	p D	90		5.3	HAINES	86	IMB	34 We have	e converted h	alf-life to	90%	CL mean life.			
5	p	90	1	<1.4	ARISAKA	85	KAMI								
2	p (free)	90	6	7.5	BLEWITT	85	IMB	$\tau(p \rightarrow \mu^{+}$	^s)						τ
7	p (nee)	90		5.7	BLEWITT	85	IMB	LIMIT (10 ³⁰ years)	DADTICIT	C19/	EVTC	PVCD CCT	DOCUMENT I		TECH
.6	p p	90	1	0.3	27 BARTELT		SOUD		PARTICLE			BKGD EST	DOCUMENT ID		TECN
.8	p	90	1	5.5	28 KRISHNA	82	KOLR	>64	P	90	0	1.2	BERGER	91	FREJ
2.8	D	90	2		29 CHERRY		HOME	$\tau(p \rightarrow \mu^{+}$	- K 9)						-
	•		-					LILIT	·· <i>L</i>)						τ
.iiiiit Di Ne hav	ased on zero e	nwents.	limit f	rom 0 confined	Levents			(10 ³⁰ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
Ne hav	e converted 2	possibl	e event	s to 90% CL I	imit.			>44	P	90	0	≤ 0.1	BERGER	91	FREJ
			_,		**				-		٠		DEMOER	,,	
$ ightarrow \mu^+$	+ω)						$ au_{11}$	$\tau(N \rightarrow \nu)$	K) -						τ
									,						
years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	LIMIT (10 ³⁰ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
7	P	90	2	1.9	HIRATA	890	KAMI	>100	P	90	9	7.3	HIRATA	890	KAMI
• We d	do not use the	followi	ng data	a for averages,	fits, limits, etc			> 86	n	90	0	2.4	HIRATA	890	KAMI
	p	90		1.0	BERGER	Q1	FREJ	 ● ● We d 	o not use the	followin	g data	for averages, fi	ts, limits, etc. • • •		
1.4	p	90		0.7	PHILLIPS		HPW	> 15	n	90	1	1.8	BERGER	89	FREJ
)	D	90		1.3	SEIDEL	88	IMB	> 15	p	90		1.8	BERGER	89	FREJ
3	p	90	2		HAINES	86	IMB	> 0.28	p	90		0.7	PHILLIPS	89	HPW
.5	ρ (free)	90		8.7	BLEWITT		IMB	> 0.3	p	90	0		BARTELT	87	SOUD
	p (nee)	90		7	BLEWITT		IMB	> 0.75	n	90	0		35 BARTELT	87	SOUD
	P	90	U	•	BLLWIII	65	IIVID	> 10	p	90		5	HAINES	86	IMB
$\rightarrow \nu a$	a)						$ au_{12}$	> 15	n	90		5	HAINES	86	IMB
	-,						.12	> 28	p	90	3	3	KAJITA	86	KAMI
years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN .	> 32	n	90	0	1.4	KAJITA	86	KAMI
3	n	90		2.7	HIRATA	890	KAMI	> 1.8	p (free)	90		11	BLEWITT	85	IMB
					fits, limits, etc. • •	5,0		> 9.6	p	90		5	BLEWITT	85	IMB
						00	EDE	> 10	n	90	2	2	PARK	85	IMB
	n	90		0.7	BERGER	89	FREJ	> 5	n	90	0		BATTISTONI	84	NUSX
	n	90		1.3	SEIDEL	88	IMB	> 2	ρ	90	0		BATTISTONI	84	NUSX
	n .	90		6	HAINES	86	IMB	> 0.3	n	90	0		³⁶ BARTELT	83	SOUD
	n	90		2	KAJITA	86	KAMI	> 0.1	p	90	0		³⁶ BARTELT	83	SOUD
.0	n	90	1	2	PARK 30 CHERRY	85	IMB	> 5.8	p	90	1		³⁷ KRISHNA	82	KOLR
	n	90	2		30 CHERRY	81	HOME	> 0.3	n	90	2		38 CHERRY	81	HOME
∕e hav	e converted 2	possibl	e event	s to 90% CL I	imit.			35 BARTE	LT 87 limit a	pplies to	$n \rightarrow$	νK_{S}^{0} .			
							-	36 Limitha	sed on zero e	wente		9			
l → e	· ^)						<i>T</i> 13	3/ M/a haw	a calculated Q	∩% CI II	mit fr	om 1 confined e	vent.		
years)	PARTICLE	C19/	EVITO	BKCD EST	DOCUMENT IN		TECN	30 We have	converted 2	possible	events	s to 90% CL lim	iit.		
		CL%		BKGD EST	DOCUMENT ID		TECN		K*(892)0)						_
0	P	90	0	<0.27	HIRATA		KAMI	•	W (032)						7
1.3	<i>n</i>	90	0		ALEKSEEV	81	BAKS	LIMIT (10 ³⁰ years)	PARTICI F	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
 We c 	o not use the	tollowi	ng data	a tor averages,	fits, limits, etc. • •					90				900	
	ρ	90	0		BERGER	91	FREJ	>52	p o not use the			1.55	HIRATA	89C	KAMI
	P	90	0	1.8	SEIDEL	88	IMB						ts, limits, etc. • •	0-	ED5.
0	-	90		4.5	HAINES	86	IMB	>10	p	90		0.8	BERGER		FREJ
7	p		0	< 0.8	ARISAKA		KAMI	>10	p	90	1	<1	ARISAKA	85	KAMI
0 7 7 8	p p	90		8.5	BLEWITT		IMB	$\tau(N \rightarrow \nu)$	K*(892))						τ
7 8 4	p	90				~=	IMB	LIMIT	())						- 12
0 7 8 4 7	p p	90 90	5	4	BLEWITT										TECN
0 7 8 4 7	p p p (free)	90			BLEWITT ALEKSEEV		BAKS		PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		
0 7 8 4 7 1.3	p p p (free) p	90 90	5				BAKS	(10 ³⁰ years)				BKGD EST	DOCUMENT ID	89	FREI
0 7 8 4 7 1.3	p p p (free) p	90 90	5					(10 ³⁰ years) > 22	n	90	0	2.1	BERGER		FREJ
0 7 8 4 7 1.3 → e ⁺	p p p (free) p p	90 90 90	5 0	4	ALEKSEEV		714	(10 ³⁰ years) >22 >20	n P	90 90	0 5	2.1 2.1	BERGER HIRATA		FREJ KAMI
0 7 8 4 7 1.3 → e ⁺	p p p (free) p	90 90 90	5 0	4 BKGD EST	ALEKSEEV DOCUMENT ID	81	T14	(10 ³⁰ years) >22 >20 • • • We d	n p o not use the	90 90 followin	0 5 g data	2.1 2.1 for averages, fi	BERGER HIRATA ts, limits, etc. • • •	89 C	KAMI
0 7 8 4 7 1.3 → e ⁺	p p p (free) p p	90 90 90	5 0	4	ALEKSEEV	81	714	(10 ³⁰ years) >22 >20 • • • We d >17	n p o not use the	90 90 followin 90	0 5 g data 0	2.1 2.1 for averages, fi 2.4	BERGER HIRATA ts, limits, etc. • • • BERGER	89C 89	KAMI FREJ
77 8 4 77 1.3 — e ⁺	p p (free) p p FARTICLE p	90 90 90	5 0	4 BKGD EST	ALEKSEEV DOCUMENT ID	81	T14	(10 ³⁰ years) >22 >20 • • • We d >17 >21	n p o not use the	90 90 followin 90 90	0 5 g data 0 4	2.1 2.1 for averages, fi 2.4 2.4	BERGER HIRATA ts, limits, etc. • • • BERGER HIRATA	89C 89 89C	KAMI FREJ KAMI
0 7 8 4 7 1.3 → e ⁺	p p (free) p p FARTICLE p	90 90 90	5 0	4 BKGD EST	ALEKSEEV DOCUMENT ID	81	T14	(10 ³⁰ years) > 22 > 20 • • • We d >17 >21 >10	p o not use the p n p	90 90 followin 90 90 90	0 5 g data 0 4 7	2.1 2.1 a for averages, fi 2.4 2.4 6	BERGER HIRATA ts, limits, etc. • • • BERGER HIRATA HAINES	89C 89 89C 86	FREJ KAMI IMB
$ \begin{array}{c} 0 \\ 7 \\ 8 \\ 4 \\ 7 \\ 1.3 \\ \rightarrow e^{+} \\ \underline{\qquad} \\ years) \end{array} $	P (free) P P P P P P P P P P P P P P P P P P P	90 90 90 90	5 0 <i>EVTS</i> 0	### BKGD EST 0.5	ALEKSEEV DOCUMENT ID BERGER	81	### T14 TECN	(10 ³⁰ years) >22 >20 • • • We d >17 >21 >10 > 5	p o not use the p n p n	90 90 followin 90 90 90	0 5 g data 0 4 7 8	2.1 2.1 for averages, fi 2.4 2.4 6 7	BERGER HIRATA ts, limits, etc. • • • BERGER HIRATA HAINES HAINES	890 890 86 86	FREJ KAMI IMB IMB
$ \begin{array}{c} 0 \\ 7 \\ 8 \\ 4 \\ 7 \\ 1.3 \\ \rightarrow e^{+} \\ \underline{\qquad} \\ years) \end{array} $	p p (free) p p FARTICLE p	90 90 90	5 0 <i>EVTS</i> 0	4 BKGD EST	ALEKSEEV DOCUMENT ID	81	T14 TECN FREJ	(10 ³⁰ years) >22 >20 • • • We d >17 >21 >10 > 5 > 8	p o not use the p n p n p n p p	90 90 followin 90 90 90 90	0 5 g data 0 4 7 8 3	2.1 2.1 for averages, fi 2.4 2.4 6 7	BERGER HIRATA ts, limits, etc. • • • BERGER HIRATA HAINES HAINES KAJITA	890 890 860 86	FREJ KAMI IMB IMB KAMI
$ \begin{array}{c} 0 \\ 7 \\ 8 \\ 4 \\ 7 \\ 1.3 \\ \rightarrow e^{+} \\ years \end{array} $	P (free) P P P P P P P P P P P P P P P P P P P	90 90 90 90	5 0 <i>EVTS</i> 0	### BKGD EST 0.5	ALEKSEEV DOCUMENT ID BERGER	91	### T14 TECN	(10 ³⁰ years) >22 >20 • • • We d >17 >21 >10 > 5 >8 > 6	n p o not use the p n p n p	90 90 followin 90 90 90 90 90	0 5 g data 0 4 7 8 3 2	2.1 2.1 of or averages, fi 2.4 6 6 7 2 1.6	BERGER HIRATA ts, limits, etc. • • • BERGER HIRATA HAINES HAINES KAJITA KAJITA	89C 89 89C 86 86 86 86	FREJ KAMI IMB IMB KAMI KAMI
$ \begin{array}{c} 0 \\ 7 \\ 8 \\ 4 \\ 7 \\ 1.3 \\ \rightarrow e^{+} \\ years \end{array} $	P p (free) p p (free) p p PARTICLE P P KUL) PARTICLE	90 90 90 CL% 90	5 0 <i>EVTS</i> 0	BKGD EST 0.5 BKGD EST	DOCUMENT ID	91	### ### ### ### ### ### ### ### ### ##	(10 ³⁰ years) > 22 >20 • • • We d >17 >21 >10 > 5 > 8 > 6 > 5.8	n p o not use the p n p n p n p n p n p n p n p free)	90 90 followin 90 90 90 90 90 90	0 5 g data 0 4 7 8 3 2	2.1 2.1 for averages, fi 2.4 2.4 6 7 2 1.6 16	BERGER HIRATA ts, limits, etc. • • • BERGER HIRATA HAINES HAINES KAJITA KAJITA BLEWITT	890 890 86 86 86 86 85	FREJ KAMI IMB IMB KAMI KAMI IMB
0 7 8 4 7 1.3 → e ⁺	P p (free) p p (free) p p PARTICLE P P KUL) PARTICLE	90 90 90 CL% 90	5 0 <i>EVTS</i> 0	BKGD EST 0.5 BKGD EST	DOCUMENT ID	91	### ### ### ### ### ### ### ### ### ##	(10 ³⁰ years) >22 >20 • • • We d >17 >21 >10 > 5 >8 > 6	n p o not use the p n p n p	90 90 followin 90 90 90 90 90	0 5 g data 0 4 7 8 3 2	2.1 2.1 if or averages, fi 2.4 2.4 6 7 2 1.6 1.6 16	BERGER HIRATA ts, limits, etc. • • • BERGER HIRATA HAINES HAINES KAJITA KAJITA	89C 89C 86 86 86 86 85 85	FREJ KAMI IMB IMB KAMI KAMI

³⁹We have converted 1 possible event to 90% CL limit.

	1 1														
LIMIT.	$^{+}\pi^{+}\pi^{-})$						T22	$\tau(p \rightarrow e^{-})$	•						<i>T</i> 35
	PARTICLE			BKGD EST	DOCUMENT ID		TECN		PARTICLE	CL%	EVTS		DOCUMENT ID		TECN
>21	P	90	0	2.2	BERGER	91	FREJ	>30	p do not use th	90 na fallou	ing da		BERGER its, limits, etc. • • •		B FREJ
$\tau(p \rightarrow e$	$^{+}\pi^{0}\pi^{0}$						<i>T</i> 23	> 2.0	p	90		0.7	PHILLIPS		HPW
LIMIT	PARTICLE	CL%	EVTC	BKGD EST	DOCUMENT ID		TECN			,,,	·	0.7	r milling	09	111.44
>38	P	90		0.5	BERGER	91	FREJ	$\tau(n \rightarrow e^{-})$							<i>T</i> 36
-	•		_					LIMIT (10 ³⁰ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
$\tau(n \to e$							T24	>29	n	90		0.78	BERGER	916	B FREJ
(10 ³⁰ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	$\tau(p \to \mu)$	+-+)						~-
>32	n	90	1	0.8	BERGER	91	FREJ	LIMIT	•						<i>T</i> 37
$\tau(p \rightarrow p)$	$^{+}\pi^{+}\pi^{-})$						$ au_{25}$	(10 ³⁰ years)				BKGD EST	DOCUMENT ID		TECN
LIMIT	•							>17	p do not use th	90 ne follow		1.72 ta for averages fi	BERGER ts, limits, etc. • • •		3 FREJ
(10 ³⁰ years)	PARTICLE	<u>CL%</u> _		BKGD EST	DOCUMENT ID		TECN	> 7.8	p	90		0.7	PHILLIPS		HPW
	p do not use the		1 g dat	a for averages, fits,	BERGER limits, etc. • •		FREJ		•						
> 3.3	р	90		0.7	PHILLIPS		HPW	$\tau(n \to \mu)$	-π ⁻ π ⁰)						<i>T</i> 38
,	± 0 0/							<i>LIMIT</i> (10 ³⁰ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
$\tau(p \to \mu)$	$\pi^{0}\pi^{0}$						<i>T</i> 26	>34	n	90	0	0.78	BERGER	918	FREJ
LIMIT (10 ³⁰ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	$\tau(p \rightarrow e^{-}$	$-\pi^{+}K^{+}$						<i>7</i> 39
>33	P	90	1	0.9	BERGER	91	FREJ	LIMIT	,						
$\tau(n \rightarrow \mu$	$+\pi^{-}\pi^{0}$						<i>T</i> 27	(10 ³⁰ years)				<u>BKGD EST</u> 2.50	DOCUMENT ID BERGER		FREJ
LIMIT	•							•	P	90	3	2.50	BERGER	918	3 FKEJ
(10 ³⁰ years)	PARTICLE	<u>CL%</u> _		BKGD EST 1.1	DOCUMENT ID		TECN FREJ	$\tau(p \rightarrow \mu^{-})$							$ au_{40}$
		90	U	1.1	BERGER	91	FKEJ	LIMIT (10 ³⁰ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
$\tau(n \rightarrow e$							$ au_{28}$	>5	P	90		0.78	BERGER	91B	FREJ
(10 ³⁰ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	$\tau(p \rightarrow e^{+}$	۱						
>18	n	90		0.2	BERGER	91	FREJ	LIMIT	'7)						$ au_{41}$
$\tau(n \rightarrow e$	+1							(10 ³⁰ years)	PARTICLE	CL%	EVTS		DOCUMENT ID		TECN
							<i>T</i> 29	>460 • • • We o	p do not use th	90 e follow		0.6	SEIDEL ts, limits, etc. • • •	88	IMB
LIMIT (10 ³⁰ years)				BKGD EST	DOCUMENT ID		TECN	>133	p	90		.a ioi averages, ii 0.3	BERGER	Ω1	FREJ
>65 • • • We	n do not uso the	90 followin		1.6 a for averages, fits, I	SEIDEL		IMB	>360	p	90		0.3	HAINES	86	IMB
>55	n	90		1.09	BERGER		FREJ	> 87	p (free)	90			BLEWITT	85	IMB
>16	n	90	9		HAINES		IMB	>360 > 0.1	p p	90 90	U	0.2	BLEWITT ⁴⁰ GURR	85 67	IMB CNTR
>25	n	90	2	4	PARK	85	IMB				to 90%	CL mean life.			
$\tau(n \to \mu$	$-\pi^{+}$)						730								_
LIMIT	•							$ au(extbf{ extit{p}} ightarrow extbf{\mu}^{ ext{ iny LIMIT}}$	' אי						T42
(10 ³⁰ years)	PARTICLE	<u>CL%</u>		BKGD EST 0.5	DOCUMENT ID SEIDEL	88	TECN IMB	(10 ³⁰ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
				o.s a for averages, fits, I		•	IIVID	>380	p	90 o followi			SEIDEL	88	IMB
>33	n	90	0	1.40	BERGER	91B	FREJ	>155	p	90			ts, limits, etc. • • • BERGER	91	FREJ
> 2.7	n	90		0.7	PHILLIPS		HPW	> 97	p	90			HAINES	86	IMB
>25 >27	n n	90 90	7 2		HAINES PARK		IMB IMB	> 61	p (free)	90		0.2	BLEWITT		IMB
,								>280 > 0.3	р р	90 90	0	0.6	BLEWITT ⁴¹ GURR	85 67	IMB CNTR
$\tau(n \rightarrow e^{-})$	-ρ⊤)						<i>T</i> 31			nalf-life t	to 90%	CL mean life.		-	
(10 ³⁰ years)	PARTICLE	CL% I	EVTS	BKGD EST	DOCUMENT ID		TECN								
>62	<i>n</i>	90		4.1	SEIDEL		IMB	$ au(extbf{ extit{H}} o au)$	")						<i>T</i> 43
				for averages, fits, li			II.AD	(10 ³⁰ years)	PARTICLE	<u>CL%</u>		BKGD EST	DOCUMENT ID		TECN
>12 >12	n n	90 90	13 5		HAINES PARK		IMB IMB	>24	n to not use th	90 e followi		6.86 a for averages fit	BERGER s, limits, etc. • • •	91B	FREJ
			-		** *	-		> 9	n not use th	90 g	ng dat. 73		HAINES	86	IMB
$\tau(n \to \mu)$	$ ho^{ op})$						τ_{32}	>11	n	90	28		PARK		IMB
(10 ³⁰ years)	PARTICLE	CL% L	EVTS	BKGD EST	DOCUMENT ID		TECN	$\tau(p \rightarrow e^+$	-~~)						_
>7	n	90		1.1	SEIDEL	88	IMB		(דד						T44
				for averages, fits, li				LIMIT (10 ³⁰ years)	PARTICLE	CL%		BKGD EST	DOCUMENT ID		TECN
>2.6 >9	n n	90 90	0 7	0.7	PHILLIPS HAINES		HPW IMB	>100	P	90	1	0.8	BERGER	91	FREJ
>9	n	90	2		PARK		IMB	$\tau(ho ightarrow e^+$	e+e-)						T45
$\tau(n \rightarrow e^{-}$	- K +1						e	<i>LIMIT</i> (10 ³⁰ years)	PARTICLE	CL%	EV/TC	BKGD EST	DOCUMENT ID		
LIMIT	,						⁷ 33	>510	PARTICLE	90		0.3	HAINES	86	TECN IMB
(10 ³⁰ years)	PARTICLE			BKGD EST	DOCUMENT ID		TECN						s, limits, etc. • •		=
>32	n do not use the	90 following		2.96 for averages, fits, li	BERGER		FREJ	>147	P	90		0.1	BERGER		FREJ
> 0.23	n	90		0.7	PHILLIPS		HPW	> 89 >510	p (free)	90 90		0.5 0.7	BLEWITT BLEWITT		IMB IMB
					,cii 3	3,	• •		•	90	U		DEENALL	65	CIVIL
$\tau(n \to \mu^-)$	(K+)						734	$\tau(p \rightarrow e^+$							$ au_{46}$
(10 ³⁰ years)	PARTICLE	CL% E	VTS	BKGD EST	DOCUMENT ID		TECN	L <i>IMIT</i> (10 ³⁰ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
>57	n	90		2.18	BERGER		FREJ	>81	P	90	0	0.16	BERGER	91	FREJ
				for averages, fits, li			LIBIG:						s, limits, etc. • •		
> 4.7	n	90	U	0.7	PHILLIPS	89	HPW	> 5.0	p	90	0	0.7	PHILLIPS	89	HPW

Baryon Particle Listings

p

$(p \rightarrow e^+)$						T47	$\tau(N \to e)$	†π ^υ anyth	ning)			
MIT 0 ³⁰ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID	TECN	LIMIT (10 ³⁰ years)	PARTICLE	CL% E	VTS BKGD EST	DOCUMEN	T ID TECH
11	P	90	11	6.08	BERGER	91B FREJ	>0.6	p, n	90	0	LEARNEI	D 79 RVI
(n → e ⁺	-e-ν)					T48	$\tau(N \rightarrow 2$	bodies, ν -	·free)			
AIT 1 ³⁰ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID	TECN	LIMIT (10 ³⁰ years)	PARTICLE	CL% E	VTS BKGD EST	DOCUMEN	T ID TECI
74	n	90	0	-	BERGER	91B FREJ	• • • We	do not use	the following	data for averages, fi	ts, limits, etc. •	• •
					its, limits, etc. • • •		>1.3	p, n	90	0	ALEKSEE	EV 81 BAH
45 26	n n	90 90		5	HAINES PARK	86 IMB 85 IMB	$\tau(pp \rightarrow c$	-+-+1				
		90	•	3	TAKK	05 IIVID						
$(n \to \mu^+$	[⊢] e [−] ν)					<i>T</i> 49			TS BKGD ES			COMMENT
017 30 years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID	TECN	>0.7	90	4 2.34	BERGER	918 FREJ	au per iron nu
47	n	90	0	< 0.1	BERGER	91B FREJ	$\tau(pn \rightarrow r)$	$(\pi^{+}\pi^{0})$				
$(n \rightarrow \mu^{+}$	+ u- v)					τ ₅₀	LIMIT (10 ³⁰ years)	CI 9/ 51/	TS BKGD ES	T DOCUMENT	ID TECN	COMMENT
WIT	-						>2.0	90	0 0.31	BERGER		τ per iron nu
	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID	TECN				DENTOLIN	715	, po
42 • • We d	n do not use the	90 follow		1.4 a for averages, t	BERGER fits, limits, etc. • • •	91B FREJ	$\tau(nn \rightarrow n)$					
5.1	n	90		0.7	PHILLIPS	89 HPW	<i>LIMIT</i> (10 ³⁰ years)	CL% EV	TS BKGD ES	T DOCUMENT	ID TECN	COMMENT
16	n	90	14		HAINES	86 IMB	>0.7	90	4 2.18	BERGER	918 FREJ	au per iron nu
19	n	90	4	7	PARK	85 IMB	$\tau(nn \rightarrow 1)$	_0_0\				
$(p \rightarrow \mu^{+})$	+ e+ e-)					τ ₅₁	LIMIT	. ^ /				
NT.	•	CIN	FLATO	DVCD FCT	DOCUMENT :		LIMIT (10 ³⁰ years)		TS BKGD ES			COMMENT
91	PARTICLE P	<u>CL%</u> 90	EVTS 0	BKGD EST ≤ 0.1	DOCUMENT ID BERGER	91 FREJ	>3.4	90	0 0.78	BERGER	91B FREJ	au per iron nu
	•	,,,	J	3 4.2	DEMOEN	22 INCJ	au(pp ightarrow 0	e ⁺ e ⁺)				
	$^{+}\mu^{+}\mu^{-})$					τ ₅₂	LIMIT	•	TO 0110-		(D	CO1
11T 30 years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID	TECN	(10 ³⁰ years) > 5.8	CL% EV	TS BKGD ES:	T <u>DOCUMENT</u> BERGER	91B FREJ	COMMENT τ per iron nu
190	P	90	1		HAINES	86 IMB			0 (0.1	BENGER	ATP LKET	7 per fron na
	do not use the	follow	ing dat	a for averages, i	fits, limits, etc. • • •		$\tau(pp \rightarrow 0)$	e+μ+)				
119	p	90		0.2	BERGER	91 FREJ	LIMIT (10 ³⁰ years)	CL% EV	TS BKGD ES	T DOCUMENT	ID TECN	COMMENT
10.5 44	ρ ρ (free)	90 90		0.7 0.7	PHILLIPS BLEWITT	89 HPW 85 IMB	>3.6	90	0 <0.1	BERGER	91B FREJ	
190	p (IICC)	90	1		BLEWITT	85 IMB				o Erro Err	715	, po
2.1	p	90	1			82 NUSX	$\tau(pp \rightarrow p)$	$\mu^{+} \mu^{+})$				
² We hav	e converted 1	possib	le even	t to 90% CL lim	it.		LIMIT (10 ³⁰ years)	CL% EV	TS BKGD ES	T DOCUMENT	ID TECN	COMMENT
(p → μ ⁺	+νν)					753	>1.7	90	0 0.62	BERGER	918 FREJ	τ per iron nu
AIT .	·						-/	-+-\				
•21	PARTICLE P	<u>CL%</u> 90		BKGD EST 11.23	DOCUMENT ID BERGER	91B FREJ	τ(pn → 0	υ)				
	-		•	11.20	BENGEN	715 (1123	(10 ³⁰ years)		TS BKGD ES	T DOCUMENT		COMMENT
	$-\mu^{+}\mu^{+})$					754	>2.8	90	5 9.67	BERGER	91B FREJ	au per iron nu
017 30 years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID	TECN	$\tau(pn \rightarrow p)$	4 + 2)				
6.0	P	90	0	0.7	PHILLIPS	89 HPW	LIMIT	•				
(n → 3v	۸						(10 ³⁰ years)		TS BKGD ES			COMMENT
AIT	<i>'</i>)					7 ₅₅	>1.6	90	4 4.37	BERGER	91B FREJ	au per iron nu
~~~~	PARTICLE	CL%		BKGD EST	DOCUMENT ID	TECN	$\tau(nn \rightarrow i$	$v_e \overline{v}_e$				
0.00049	<b>n</b>	90	2		⁴³ SUZUKI	93B KAMI	LIMIT (10 ³⁰ years)	CL% EV	TS BKGD ES	T DOCUMENT	ID TECN	COMMENT
					fits, limits, etc. • • • ⁴⁴ BERGER	91B FREJ	>0.000012		5 9.7	BERGER		τ per iron nu
0.00003		90 90		6.1 11.2	44 BERGER	918 FREJ			5 5	DENGEN	715 T NES	, per 11011 114
	n	90	0	11.2	LEARNED	79 RVUE	$\tau(nn \rightarrow 1)$	$ u_{\mu} \overline{ u}_{\mu}$				
³ The SU	IZUKI 93B lim	it appl	ies to a	ny of $\nu_e \nu_e \overline{\nu}_e$ ,	$\nu_{\mu}  \nu_{\mu}  \overline{\nu}_{\mu}$ , or $\nu_{\tau}  \nu_{\tau}  \overline{\nu}_{\tau}$		LIMIT (10 ³⁰ years)	CL% EV	TS BKGD ES	T DOCUMENT	ID TECN	COMMENT
⁴ The firs	t BERGER 9	LB limit	is for	$n \rightarrow \nu_e \nu_e \overline{\nu}_e$ ,	the second is for $n \rightarrow$	$\nu_{\mu}\nu_{\mu}\overline{\nu}_{\mu}$ .	>0.000006		4 4.4	BERGER		τ per iron nu
A1	+ 46:											<u> </u>
	+anything)					756			<b>₽</b> P/	ARTIAL MEAN L	IVES	
AIT 30 years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID	TECN	т	ne "partial i	nean life" lim	nits tabulated here ar	e the limits on 7	-/B:, where
0.6	<b>p</b> , n	90			⁴⁵ LEARNED	79 RVUE	$\overline{ au}$	is the total	mean life for	the antiproton and l		
⁵ The ele	ctron may be	primar	y or sec	ondary.			fo	r the mode	in question.			
N → μ	+anything)					757	$\tau(\overline{p} \rightarrow e^{-})$	~)				
UT	,						VALUE (years	.,	CL%	DOCUMENT ID	TECN COMI	MENT
	PARTICLE	CL%	_EVTS	BKGD EST	46,47 CHERRY	TECN NOME	>1848		95		CALO 8.9 C	
<b>L2</b> • • We o	<b>p, n</b> do not use the	90 follow		a for averages	fits, limits, etc. • • •	81 HOME	_/= ·-	٥١سـ -				
1.8	p, n	90		2.0.08031	47 COWSIK	80 CNTR	$\tau(\overline{p} \to e^{-})$	•	· (10/	DOCUMENT ID	TECN COM	MENT
6	p, n	90			⁴⁷ LEARNED	79 RVUE	VALUE (years		<u>CL%</u> 95		CALO 8.9 C	
We hav	e converted 2	possib	le even	ts to 90% CL lir	nit.		<b>/334</b>		,,,	GLEN 92	CALO 0.7 C	, c p ucani
The mu	ion may be pi	imary o	or secon	ndary.			$\tau(\overline{p} \rightarrow e^{-}$	.,				
N→ν	anything)					7 ₅₈	VALUE (years	)	<u>CL%</u>	DOCUMENT ID		MENT
	hing $=\pi, \rho$ ,	K, etc.				- 30	>171		95	GEER 94	CALO 8.9 0	$\widetilde{GeV}/c\;\overline{p}\;beam$
							<b>/</b>	0\				
UT.	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID	TECN	$\tau(\overline{D} \rightarrow P)$	- K21				
1/T 30 years)	PARTICLE do not use the	CL% follow		BKGD EST a for averages,	DOCUMENT ID fits, limits, etc. • • •	<u>TECN</u>	$ au(\overline{p}  o e^{-})$ VALUE (years		CL%_	DOCUMENT ID	TECN COMI	WENT

$ au(\overline{p}  ightarrow e^- K_L^0)$						776
VALUE (years)	CL%	DOCUMENT ID		TECN	COMMENT	
>9	95	GEER	94	CALO	8.9 GeV/c ₱ beam	

#### p REFERENCES

GABRIELSE	95	PRL 74 3544	+Phillips, Quint+ (	(HARV, MANZ, SEOUL)
MACGIBBON	95	PR C52 2097	+Garino, Lucas, Nathan+	(ILL, SASK, INRM)
GEER	94	PRL 72 1596	+Marriner, Rav+	(FNAL, UCLA, PSU)
HALLIN	93	PR C48 1497	+Amendt, Bergstrom+	(SASK, BOST, ILL)
SUZUKI	.93B	PL B311 357		(KAMIOKANDE Collab.)
HUGHES	92	PRL 69 578	+Deutch	
				(LANL, AARH)
ZIEGER	92	PL B278 34	+Van de Vyver, Christmann, DeGra	
Also	92B		) Zieger,, Van den Abeele, Ziegle	
BERGER	91	ZPHY C50 385	+Froehlich, Moench, Nisius+	(FREJUS Collab.)
BERGER	91B	PL B269 227	+Froehlich, Moench, Nisius+	(FREJUS Collab.)
FEDERSPIEL	91	PRL 67 1511	+Eisenstein, Lucas, MacGibbon+	(ILL)
BECKER-SZ	90	PR D42 2974	Becker-Szendy, Bratton, Cady, Cas	
ERICSON	90	EPL 11 295	+Richter	(CERN, DARM)
GABRIELSE	90	PRL 65 1317		RV, MANZ, WASH, IBS)
BERGER	89	NP B313 509	+Froehlich, Moench+	(FREJUS Collab.)
CHO	89	PRL 63 2559	+Sangster, Hinds	(YALE)
HIRATA	89C	PL B220 308	+Kajita, Kifune, Kihara+	(Kamiokande Collab.)
PHILLIPS	89	PL B224 348	+Matthews, Aprile, Cline+	(HPW Collab.)
KREISSL	88	ZPHY C37 557	+Hancock, Koch, Koehler, Poth+	(CERN PS176 Collab.)
SEIDEL	88	PRL 61 2522	+Bionta, Blewitt, Bratton+	(IMB Collab.)
BARTELT	87	PR D36 1990	+Courant, Heller+	(Soudan Collab.)
Also	89	PR D40 1701 erratum	Bartelt, Courant, Heller+	(Soudan Collab.)
COHEN	87	RMP 59 1121	+ Taylor	` (RISC, NBS)
HAINES	86	PRL 57 1986	+Bionta, Blewitt, Bratton, Casper+	
KAJITA	86	JPSJ 55 711	+Arisaka, Koshiba, Nakahata+	(Kamiokande Collab.)
ARISAKA	85	JPSJ 54 3213	+Kajita, Koshiba, Nakahata+	(Kamiokande Collab.)
BLEWITT	85	PRL 55 2114	+LoSecco, Bionta, Bratton+	(IMB Collab.)
DZUBA	85	PL 154B 93	+Flambaum, Silvestrov	(NOVO)
PARK	85	PRL 54 22	+Blewitt, Cortez, Foster+	(IMB Collab.)
BATTISTONI	84	PL 133B 454	+Bellotti, Bologna, Campana+	(NUSEX Collab.)
MARINELLI	84	PL 137B 439	+Morpurgo	(GENO)
WILKENING	84	PR A29 425	+Ramsey, Larson	(HARV, VIRG)
BARTELT	83	PRL 50 651	+Courant, Heller, Joyce, Marshak+	(MINN, ANL)
BATTISTONI	82	PL 118B 461	+Bellotti, Bologna, Campana+	(NUSEX Collab.)
KRISHNA	82	PL 115B 349	Krishnaswamy, Menon+	(TATA, OSKC, INUS)
ALEKSEEV	81	JETPL 33 651	+Bakatanov, Butkevich, Voevodskii+	(PNPI)
		Translated from ZETFP		
CHERRY	81	PRL 47 1507	+Deakyne, Lande, Lee, Steinberg+	(PENN, BNL)
COWSIK	80	PR D22 2204	+Narasimhan	(TATA)
BELL	79	PL 86B 215	+Calvetti, Carron, Chaney, Cittolin+	(CERN)
GOLDEN	79	PRL 43 1196	+Horan, Mauger, Badhwar, Lacy+	(NASA, PSLL)
LEARNED	79	PRL 43 907	+Reines, Soni	` (uci)
BREGMAN	78	PL 78B 174	+Calvetti, Carron, Cittolin, Hauer, H	
ROBERTS	78	PR D17 358	rearrest, carron, cuttom, mann,	(WILL, RHEL)
EVANS	77	Science 197 989	+Steinberg	(BNL, PENN)
ROBERSON	77	PR C16 1945		CIT, CMU, VPI, WILL)
HU	75	NP A254 403	+Asano, Chen, Cheng, Dugan+	(COLU, YALE)
COHEN	73	JPCRD 2 663		
			+Taylor	(RISC, NBS)
DYLLA	73	PR A7 1224	+King	(MIT)
BAMBERGER	70	PL 33B 233	+Lynen, Piekarz+	(MPIH, CERN, KARL)
DIX	70	Thesis Case		(CASE)
HARRISON	69	PRL 22 1263	+Sandars, Wright	(OXF)
GURR	67	PR 158 1321	+Kropp, Reines, Meyer	(CASE, WITW)
FLEROV	58	DOKL 3 79	+Klochkov, Skobkin, Terentev	(ASCI)

$$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$$
 Status: ***

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We have omitted some results that have been superseded by later experiments. See our earlier editions.

#### n MASS

The mass is known much more precisely in u (atomic mass units) than in MeV; see the footnotes. The conversion from u to MeV, 1 u =931.49432±0.00028 MeV, involves the relatively poorly known electronic charge. The DIFILIPPO 94 value, in u, is by far the best, but when converted to MeV differs only negligibly from the 1986 CODATA value, which, for consistency, we stick with.

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
939.56563±0.00028	1 COHEN	87	RVUE	1986 CODATA value
• • • We do not use the fol	lowing data for average	s, fit	s, limits,	etc. • • •
$939.56565 \pm 0.00028$	² DIFILIPPO	94		Penning trap
$939.56564 \pm 0.00028$	3,4 GREENE	86	SPEC	$np \rightarrow d\gamma$
939.5731 ±0.0027	⁴ COHEN	73	RVUE	1973 CODATA value

- 1  The mass is known much more precisely in u:  $m=1.008664904\pm0.000000014$  u.
- The mass is known much more precisely in u:  $m=1.0086649235\pm0.000000023$  u. We use the conversion factor given above to get the mass in MeV.
- 3 The mass is known much more precisely in u:  $m=1.008664919\pm0.000000014$  u.  4  These determinations are not independent of the  $m_n-m_p$  measurements below.

#### 77 MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
939.485±0.051	59	⁵ CRESTI	86	HBC	$\overline{D} p \rightarrow \overline{n} n$

 $^{5}\,\text{This}$  is a corrected result (see the erratum). The error is statistical. The maximum systematic error is 0.029 MeV.

#### $(m_n - m_{\overline{n}}) / m_{\text{average}}$

A test of CPT invariance. Calculated from the n and  $\overline{n}$  masses, above.

DOCUMENT ID  $(9\pm5) \times 10^{-5}$  OUR EVALUATION

#### $m_n - m_p$

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
1.293318 ±0.000009	⁶ COHEN	87	RVUE	1986 CODATA value	
• • We do not use the follow	wing data for average	es, fits	, limits,	etc. • • •	
$1.2933328 \pm 0.0000072$	GREENE	86	SPEC	$np \rightarrow d\gamma$	
$1.293429 \pm 0.000036$	COHEN	73	RVUE	1973 CODATA value	
6 Calculated by us from the	COUEN 97 ratio m	/m -	- 1 0013	279404 ± 0 000000000	١.

#### n MEAN LIFE

u,  $m_n - m_p = 0.001388434 \pm 0.000000009$  u.

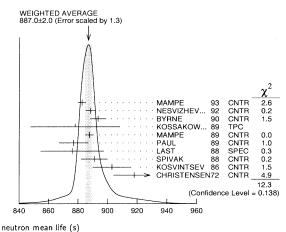
We now compile only direct measurements of the lifetime, not those inferred from decay correlation measurements. (Limits on lifetimes for bound neutrons are given in the section "p PARTIAL MEAN LIVES.")

For a review, see EROZOLIMSKII 89 and papers that follow it in an issue of NIM devoted to the "Proceedings of the International Workshop on Fundamental Physics with Slow Neutrons" (Grenoble 1989). For later reviews and/or commentary, see FREEDMAN 90, SCHRECKENBACH 92, and PENDLEBURY 93.

VALUE (s)	DOCUMENT ID TECN COMMENT	
	ERAGE Error includes scale factor of 1.	3. See the ideogram below.
882.6 ± 2.7	7 MAMPE 93 CNTR Gravitatio	nal trap
888.4± 3.1± 1.1	NESVIZHEV 92 CNTR Gravitatio	nal trap
893.6± 3.8± 3.7	BYRNE 90 CNTR Penning t	rap
878 $\pm 27$ $\pm 14$	KOSSAKOW 89 TPC Pulsed be	am
887.6 ± 3.0	MAMPE 89 CNTR Gravitatio	nal trap
877 ±10	PAUL 89 CNTR Storage ri	ng
876 ±10 ±19	LAST 88 SPEC Pulsed be	am
891 ± 9	SPIVAK 88 CNTR Beam	
903 ±13	KOSVINTSEV 86 CNTR Gravitatio	nal trap
918 ±14	CHRISTENSEN72 CNTR	
• • • We do not use	the following data for averages, fits, limi	ts, etc. • • •
888.4± 2.9	ALFIMENKOV 90 CNTR See NESV	/IZHEVSKII 92
937 ±18	⁸ BYRNE 80 CNTR	
875 ±95	KOSVINTSEV 80 CNTR	
881 ± 8	BONDAREN 78 CNTR See SPIVA	4K 88
7 IGNATOVICH 95	calls into question some of the correctio	ns and averaging procedures

used by MAMPE 93. If MAMPE 93 is removed from the data averaged here, our new average is 889.2  $\pm$  2.2 s, with a scale factor of 1.1.

⁸ This measurement has been withdrawn (J. Byrne, private communication, 1990).



#### n MAGNETIC MOMENT

0.000037 (the 1986 CODATA value from COHEN 87).

VALUE (μ _N )	DOCUMENT II	D .	TECN	COMMENT
$-1.91304275\pm0.00000045$	COHEN	87	RVUE	1986 CODATA value
• • We do not use the follow	ing data for avera	ges, fit	s, limits,	etc. • • •
$-1.91304277 \pm 0.00000048$	⁹ GREENE	82	MRS	
⁹ GREENE 82 measures the magnetons. The value above				

#### n ELECTRIC DIPOLE MOMENT

A nonzero value is forbidden by both *T* invariance and *P* invariance. A number of early results have been omitted. See RAMSEY 90 and GOLLIB 46 for review.

VALUE (10 ⁻²⁵ ecm)	CL%	DOCUMENT ID		TECN	COMMENT
< 1.1	95	ALTAREV	92	MRS	$(+0.26 \pm 0.42 \pm 0.16) \times 10^{-25}$
• • • We do not	use the follo	wing data for av	erag	es, fits, I	imits, etc. • • •
< 1.2	95	SMITH	90	MRS	$d = (-0.3 \pm 0.5) \times 10^{-25}$
< 2.6	95	ALTAREV	86	MRS	$d = (-1.4 \pm 0.6) \times 10^{-25}$
$0.3 \pm 4.8$		PENDLEBURY	84	MRS	Ultracold neutrons
< 6	90	ALTAREV	81	MRS	$d = (2.1 \pm 2.4) \times 10^{-25}$
<16	90	ALTAREV	79	MRS	$d = (4.0 \pm 7.5) \times 10^{-25}$

#### n ELECTRIC POLARIZABILITY $\alpha_n$

Following is the electric polarizability  $\alpha_n$  defined in terms of the induced electric dipole moment by  ${\bf D}=4\pi\epsilon_0\alpha_n{\bf E}$ . For a review, see SCHMIED-MAYER 89.

VALUE (10 ⁻³ fm ³ )	DOCUMENT ID	TECN	COMMENT
0.98+0.19 OUR AVERAGE	Error includes scale fac	ctor of 1.1.	
0.0 ±0.5	¹⁰ KOESTER	95 CNTR	n Pb, n Bi transmission
$1.20 \pm 0.15 \pm 0.20$	SCHMIEDM	91 CNTR	n Pb transmission
$1.07 + 0.33 \\ -1.07$	ROSE	90B CNTR	$\gamma d \rightarrow \gamma n p$
0.8 ±1.0	KOESTER	88 CNTR	n Pb, n Bi transmission
1.2 ±1.0	SCHMIEDM	88 CNTR	n Pb, n C transmission
• • We do not use the following the fol	owing data for averages	, fits, limits,	etc. • • •
$1.17 + 0.43 \\ -1.17$	ROSE	90 CNTR	See ROSE 90B

 10  KOESTER 95 uses natural Pb and the isotopes 208, 207, and 206. See this paper for a discussion of methods used by various groups to extract  $\alpha_{n}$  from data.

#### n CHARGE

See also " $|q_{p}+q_{e}|/e$ " in the proton Listings.

VALUE (10 ⁻²¹ e)	DOCUMENT ID	TECN	COMMENT
$-0.4\pm1.1$	¹¹ BAUMANN 88	3	Cold n deflection
• • We do not use the follow	wing data for averages, f	its, limits,	etc. • • •
-15 ±22	¹² GAEHLER 82	2 CNTR	Reactor neutrons
11 The BAUMANN 88 error	±1.1 gives the 68% CL II	imits abou	ut the the value -0.4.
12 The GAEHLER 82 error $\pm$	22 gives the 90% CL lim	its about	the the value $-15$ .

#### LIMIT ON NT OSCILLATIONS

#### Mean Time for $n\overline{n}$ Transition in Vacuum

A test of  $\Delta B{=}2$  baryon number nonconservation. MOHAPATRA 80 and MOHAPATRA 80 discuss the theoretical motivations for looking for  $n\overline{n}$  oscillations. DOVER 83 and DOVER 85 give phenomenological analyses. The best limits come from looking for the decay of neutrons bound in nuclei. However, these analyses require model-dependent corrections for nuclear effects. See KABIR 83, DOVER 89, and ALBERICO 91 for discussions. Direct searches for  $n \rightarrow \overline{n}$  transitions using reactor neutrons are cleaner but give somewhat poorer limits. We include limits for both free and bound neutrons in the Summary Table.

VALUE (s)	CL%	DOCUMENT ID		TECN	COMMENT	
>1.2 × 10 ⁸	90	BERGER	90	FREJ	n bound in iron	
>1.2 × 10 ⁸	90	TAKITA	86	CNTR	Kamiokande	
• • • We do not	use the followin	g data for average	es, fits	s, limits,	etc. • • •	
$> 8.6 \times 10^{7}$	90	BALDO	94	CNTR	Reactor neutrons	ı
$>1 \times 10^{7}$	90	BALDO	90	CNTR	See BALDO-CEOLIN 94	-
$>$ 4.9 $\times$ 10 ⁵	90	BRESSI	90	CNTR	Reactor neutrons	
$>$ 4.7 $\times$ 10 ⁵	90	BRESSI	89	CNTR	See BRESSI 90	
$>1 \times 10^{6}$	90	FIDECARO	85	CNTR	Reactor neutrons	
$> 8.8 \times 10^{7}$	90	PARK	85B	CNTR		
$>3 \times 10^{7}$		BATTISTONI	84	NUSX		
$> 2.7 \times 10^{7} - 1.1 \times$	108	JONES	84	CNTR		
$>$ 2 $\times 10^{7}$		CHERRY	83	CNTR		

#### n DECAY MODES

	Mode	Fraction $(\Gamma_i/\Gamma)$	Confidence level
Γ ₁ Γ ₂	$pe^-\overline{ u}_e$ hydrogen-atom $\overline{ u}_e$	100 %	
	Charge conser	vation (Q) violating mode	
Γ3	$p \nu_e \overline{\nu}_e$	$Q < 9 \times 10^{-24}$	90%

#### n BRANCHING RATIOS

Γ(hydrogen-atom	$\overline{\nu}_e)/\Gamma_{\text{total}}$			$\Gamma_2/\Gamma$
VALUE	CL%	DOCUMENT	D TECN	
• • • We do not us	e the followi	ng data for aver	ges, fits, limits, etc. • •	•
$< 3 \times 10^{-2}$	95	¹³ GREEN	90 RVUE	
¹³ GREEN 90 infers	that $ au(hydr$	$v_e$	$3 \times 10^4$ s by comparing	g neutron lifetime

 13  GREEN 90 infers that  $\tau({\rm hydrogen\text{-}atom}\,\overline{\nu_e})>3\times 10^4\,{\rm s}$  by comparing neutron lifetime measurements made in storage experiments with those made in  $\beta\text{-}decay$  experiments. However, the result depends sensitively on the lifetime measurements, and does not of course take into account more recent measurements of same.

 $\Gamma(p\nu_e\overline{\nu}_e)/\Gamma_{total}$  Forbidden by charge conservation.  $\Gamma_3/\Gamma$ VALUE <9 × 10⁻²⁴ ullet ullet We do not use the following data for averages, fits, limits, etc. ullet ullet $<\!9.7\times 10^{-18}$ 83 CNTR  $^{113}\mathrm{Cd} \rightarrow ~^{113}m\mathrm{In\,neut}.$ ROY 90  $< 7.9 \times 10^{-21}$ VAIDYA CNTR  87 Rb  $\rightarrow$   $^{87}m$ Srneut.  $<3 \times 10^{-19}$ NORMAN CNTR  $^{87}\text{Rb} \rightarrow ^{87}m\text{Srneut}.$ 

#### NOTE ON BARYON DECAY PARAMETERS

(by E.D. Commins, University of California, Berkeley)

#### Baryon semileptonic decays

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The typical spin-1/2 baryon semileptonic decay is described by a matrix element, the hadronic part of which may be written as:

$$\overline{B}_f \left[ f_1(q^2) \gamma_\lambda + i \ f_2(q^2) \sigma_{\lambda\mu} q^\mu + g_1(q^2) \gamma_\lambda \gamma_5 + g_3(q^2) \gamma_5 q_\lambda \right] B_i .$$

Here  $B_i$  and  $\overline{B}_f$  are spinors describing the initial and final baryons, and  $q=p_i-p_f$ , while the terms in  $f_1$ ,  $f_2$ ,  $g_1$ , and  $g_3$  account for vector, induced tensor ("weak magnetism"), axial vector, and induced pseudoscalar contributions [1]. Second-class current contributions are ignored here. In the limit of zero momentum transfer,  $f_1$  reduces to the vector coupling constant  $g_V$ , and  $g_1$  reduces to the axial-vector coupling constant  $g_A$ . The latter coefficients are related by Cabibbo's theory [2], generalized to six quarks (and three mixing angles) by Kobayashi and Maskawa [3]. The  $g_3$  term is negligible for transitions in which an  $e^\pm$  is emitted, and gives a very small correction, which can be estimated by PCAC [4], for  $\mu^\pm$  modes. Recoil effects include weak magnetism, and are taken into account adequately by considering terms of first order in

$$\delta = \frac{m_i - m_f}{m_i + m_f}$$

where  $m_i$  and  $m_f$  are the masses of the initial and final baryons.

The experimental quantities of interest are the total decay rate, the lepton-neutrino angular correlation, the asymmetry coefficients in the decay of a polarized initial baryon, and the polarization of the decay baryon in its own rest frame for an unpolarized initial baryon. Formulae for these quantities are derived by standard means [5] and are analogous to formulae for nuclear beta decay [6]. We use the notation of Ref. 6 in the Listings for neutron beta decay. For comparison with experiments at higher  $q^2$ , it is necessary to modify the form factors at  $q^2 = 0$  by a "dipole"  $q^2$  dependence, and for high-precision comparisons to apply appropriate radiative corrections [7].

The ratio  $g_A/g_V$  may be written as

$$g_A/g_V = |g_A/g_V| e^{i\phi_{AV}}$$
.

n

The presence of a "triple correlation" term in the transition probability, proportional to  $\text{Im}(g_A/g_V)$  and of the form

$$\boldsymbol{\sigma}_i \cdot (\mathbf{p}_\ell \times \mathbf{p}_\nu)$$

for initial baryon polarization or

$$\sigma_f \cdot (\mathbf{p}_\ell \times \mathbf{p}_\nu)$$

for final baryon polarization, would indicate failure of time-reversal invariance. The phase angle  $\phi$  has been measured precisely only in neutron decay (and in ¹⁹Ne nuclear beta decay), and the results are consistent with T invariance.

#### Hyperon nonleptonic decays

The amplitude for a spin-1/2 hyperon decaying into a spin-1/2 baryon and a spin-0 meson may be written in the form

$$M = G_F m_{\pi}^2 \cdot \overline{B}_f (A - B\gamma_5) B_i ,$$

where A and B are constants [1]. The transition rate is proportional to

$$R = 1 + \gamma \widehat{\omega}_f \cdot \widehat{\omega}_i + (1 - \gamma)(\widehat{\omega}_f \cdot \widehat{\mathbf{n}})(\widehat{\omega}_i \cdot \widehat{\mathbf{n}}) + \alpha(\widehat{\omega}_f \cdot \widehat{\mathbf{n}} + \widehat{\omega}_i \cdot \widehat{\mathbf{n}}) + \beta \widehat{\mathbf{n}} \cdot (\widehat{\omega}_f \times \widehat{\omega}_i) ,$$

where  $\widehat{\mathbf{n}}$  is a unit vector in the direction of the final baryon momentum, and  $\widehat{\boldsymbol{\omega}}_i$  and  $\widehat{\boldsymbol{\omega}}_f$  are unit vectors in the directions of the initial and final baryon spins. (The sign of the last term in the above equation was incorrect in our 1988 and 1990 editions.) The parameters  $\alpha$ ,  $\beta$ , and  $\gamma$  are defined as

$$\begin{split} \alpha &= 2\operatorname{Re}(s^*p)/(\,|\,s\,|^2 + \,|\,p\,|^2) \ , \\ \beta &= 2\operatorname{Im}(s^*p)/(\,|\,s\,|^2 + \,|\,p\,|^2) \ , \\ \gamma &= (\,|\,s\,|^2 - \,|\,p\,|^2)/(\,|\,s\,|^2 + \,|\,p\,|^2) \ , \end{split}$$

where s=A and  $p=|\mathbf{p}_f|B/(E_f+m_f)$ ; here  $E_f$  and  $\mathbf{p}_f$  are the energy and momentum of the final baryon. The parameters  $\alpha$ ,  $\beta$ , and  $\gamma$  satisfy

$$\alpha^2 + \beta^2 + \gamma^2 = 1.$$

If the hyperon polarization is  $\mathbf{P}_Y$ , the polarization  $\mathbf{P}_B$  of the decay baryons is

$$\mathbf{P}_B = \frac{(\alpha + \mathbf{P}_Y \cdot \widehat{\mathbf{n}}) \widehat{\mathbf{n}} + \beta (\mathbf{P}_Y \times \widehat{\mathbf{n}}) + \gamma \widehat{\mathbf{n}} \times (\mathbf{P}_Y \times \widehat{\mathbf{n}})}{1 + \alpha \mathbf{P}_Y \cdot \widehat{\mathbf{n}}}$$

Here  $\mathbf{P}_B$  is defined in the rest system of the baryon, obtained by a Lorentz transformation along  $\hat{\mathbf{n}}$  from the hyperon rest frame, in which  $\hat{\mathbf{n}}$  and  $\mathbf{P}_Y$  are defined.

An additional useful parameter  $\phi$  is defined by

$$\beta = (1 - \alpha^2)^{1/2} \sin \phi .$$

In the Listings, we compile  $\alpha$  and  $\phi$  for each decay, since these quantities are most closely related to experiment and are essentially uncorrelated. When necessary, we have changed the signs of reported values to agree with our sign conventions.

In the Baryon Summary Table, we give  $\alpha$ ,  $\phi$ , and  $\Delta$  (defined below) with errors, and also give the value of  $\gamma$  without error.

Time-reversal invariance requires, in the absence of final-state interactions, that s and p be relatively real, and therefore that  $\beta=0$ . However, for the decays discussed here, the final-state interaction is strong. Thus

$$s = |s| e^{i\delta_s}$$
 and  $p = |p| e^{i\delta_p}$ ,

where  $\delta_s$  and  $\delta_p$  are the pion-baryon s- and p-wave strong interaction phase shifts. We then have

$$\beta = \frac{-2|s||p|}{|s|^2 + |p|^2} \sin(\delta_s - \delta_p).$$

One also defines  $\Delta = -\tan^{-1}(\beta/\alpha)$ . If T invariance holds,  $\Delta = \delta_s - \delta_p$ . For  $\Lambda \to p\pi^-$  decay, the value of  $\Delta$  may be compared with the s- and p-wave phase shifts in low-energy  $\pi^-p$  scattering, and the results are consistent with T invariance.

#### Radiative hyperon decays

For the radiative decay of a polarized spin-1/2 hyperon,  $B_i \to B_f \gamma$ , the angular distribution of the direction  $\hat{p}$  of the final spin-1/2 baryon in the hyperon rest frame is

$$\frac{d\Gamma_{\gamma}}{d\Omega} = \frac{\Gamma_{\gamma}}{4\pi} \left( 1 + \alpha_{\gamma} \widehat{p} \cdot \mathbf{P}_{i} \right) ,$$

where  $\mathbf{P}_i$  is the hyperon polarization and the asymmetry parameter  $\alpha_{\gamma}$  is

$$\alpha_{\gamma} = \frac{2\text{Re}\left[g_1'(0)f_M^*(0)\right]}{|g_1'(0)|^2 + |f_M(0)|^2}$$

Here  $f_M=\frac{(m_i-m_f)}{(m_i+m_f)}\left[(m_i+m_f)f_2'-f_1'\right]$ , where  $f_1'(q^2)$ ,  $f_2'(q^2)$ , and  $g_1'(q^2)$  are the  $\Delta Q=0$  analogs of the  $|\Delta Q|=1$  form factors defined above.

#### References

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- 2. N. Cabibbo, Phys. Rev. Lett. 10, 531 (1963).
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- M.L. Goldberger and S.B. Treiman, Phys. Rev. 111, 354 (1958).
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- Y. Yokoo, S. Suzuki, and M. Morita, Prog. Theor. Phys. 50, 1894 (1973).

#### $n \rightarrow \rho e^- \nu$ DECAY PARAMETERS

See the above "Note on Baryon Decay Parameters." For discussions of recent results, see the references cited at the beginning of the section on the neutron mean life. For discussions of the values of the weak coupling constants  $g_A$  and  $g_V$  obtained using the neutron and asymmetry parameter A, comparisons with other methods of obtaining these constants, and implications for particle physics and for astrophysics, see DUBBERS 91 and WOOLCOCK 91. For tests of the  $V\!-\!A$  theory of neutron decay, see EROZOLIMSKII 91B.

#### BA / BV

VALUE	DOCUMENT ID TECN COMMENT
-1.2601 ±0.0025 OUR AV	ERAGE Error includes scale factor of 1.1.
$-1.266 \pm 0.004$	SCHRECK 95 TPC e mom-n spin corr.
$-1.2544 \pm 0.0036$	EROZOLIM 91 CNTR e mom-n spin corr.
$-1.262 \pm 0.005$	BOPP 86 SPEC e mom-n spin corr.
$-1.261 \pm 0.012$	14 EROZOLIM 79 CNTR e mom-n spin corr.
$-1.259 \pm 0.017$	14 STRATOWA 78 CNTR proton recoil spectrum
$-1.258 \pm 0.015$	15 KROHN 75 CNTR e mom-n spin corr.
<ul> <li>• • We do not use the f</li> </ul>	ollowing data for averages, fits, limits, etc. • • •
$-1.226 \pm 0.042$	MOSTOVOY 83 RVUE
-1.263 ±0.015	EROZOLIM 77 CNTR See EROZOLIMSKII 79
-1.250 ±0.036	¹⁴ DOBROZE 75 CNTR See STRATOWA 78
-1.263 ±0.016	16 KROPF 74 RVUE n decay alone
$-1.250 \pm 0.009$	16 KROPF 74 RVUE $n$ decay + nuclear ft
14 These experiments mea	sure the absolute value of $g_{\mathcal{A}}/g_{\mathcal{V}}$ only.

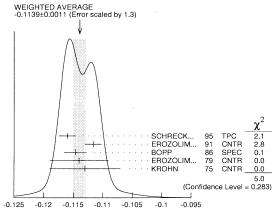
¹⁵ KROHN 75 includes events of CHRISTENSEN 70. 16 KROPF 74 reviews all data through 1972.

#### $\beta$ ASYMMETRY PARAMETER A

This is the neutron-spin electron-momentum correlation coefficient. Unless otherwise noted, the values are corrected for radiative effects and weak magnetism.

noted, the values are corrected	u for radiative e	necus	and wea	k magnetism.
VALUE	DOCUMENT ID		TECN	COMMENT
-0.1139±0.0011 OUR AVERAGE	Error includes below.	scale	factor of	1.3. See the ideogram
$-0.1160\pm0.0009\pm0.0011$	SCHRECK	95	TPC	e mom-n spin corr.
$-0.1116 \pm 0.0014$	EROZOLIM	91	CNTR	
$-0.1146 \pm 0.0019$	BOPP	86	SPEC	
$-0.114 \pm 0.005$	⁷ EROZOLIM	79	CNTR	
$-0.113 \pm 0.006$	⁷ KROHN	75	CNTR	

 17  These results are not corrected for radiative effects and weak magnetism, but the corrections are small compared to the errors.



 $\beta$  ASYMMETRY PARAMETER A

#### $\overline{\nu}$ ASYMMETRY PARAMETER B

This is the neutron-spin antineutrino-momentum correlation coefficient.

VALUE	DOCUMENT ID	TEC	NCOMMENT
0.990 ±0.008 OUR AVER			
0.9894±0.0083	KUZNETSOV	95 CN	TR Cold polarized neutrons
0.995 ±0.034	CHRISTENSEN	170 CN	TR
1.00 ±0.05	EROZOLIM	70c CN	TR
e-⊽ ANGULAR CORREI	ATION COFFEICIE	NT a	
VALUE			N COMMENT
-0.102 ±0.005 OUR AVE	RAGE		
0.1017   0.0051	STDATOMA	78 CN	TR Proton recoil spectrum
$-0.1017 \pm 0.0051$	SINAIOWA	10 CIV	IN FIOLON recon spectrum

## $\phi_{AV}$ , PHASE OF $g_A$ RELATIVE TO $g_V$ Time reversal invariance requires this to be 0 or 180°.

VALUE (°)	DOCUMENT ID		TECN	COMMENT
180.07±0.18 OUR EVALUATION		Kano		puantity $D$ given in the $g_A/g_V$ in $\sin\phi_{AV}=$
180.09±0.18 OUR AVERAGE				
$179.71 \pm 0.39$	EROZOLIM	78	CNTR	Polarized neutrons
$180.35 \pm 0.43$	EROZOLIM	74	CNTR	Polarized neutrons
$180.14 \pm 0.22$	STEINBERG	74	CNTR	Polarized neutrons
• • • We do not use the following	data for average	s, fit	s, limits,	etc. • • •
181.1 ±1.3	^{l8} KROPF	74	RVUE	n decay

¹⁸ KROPF 74 reviews all data through 1972.

#### TRIPLE CORRELATION COEFFICIENT D

These are measurements of the component of n spin perpendicular to the decay plane in  $\beta$  decay. Should be zero if T invariance is not violated.

VALUE			DOCUMENT II		TECN	COMMENT	
(-0.5 ±	1.4	) × 10 ⁻³	OUR AVERAGE				
+ 0.0022	±0.0030	)				Polarized neutrons	
- 0.0027	£0.0050	)	¹⁹ EROZOLIM.	74	CNTR	Polarized neutrons	
- 0.0011	±0.0017	7	STEINBERG	74	CNTR	Polarized neutrons	

¹⁹ EROZOLIMSKII 78 says asymmetric proton losses and nonuniform beam polarization may give a systematic error up to 0.003, thus increasing the EROZOLIMSKII 74 error to 0.005. STEINBERG 74 and STEINBERG 76 estimate these systematic errors to be insignificant in their experiment.

#### n REFERENCES

We have omitted some papers that have been superseded by later experiments. See our earlier editions.

IGNATOVICH	95	JETPL 62 1	(JINR)
		Translated from ZETFP	62 3.
KOESTER	95	PR C51 3363	+Waschkowski, Mitsyna+ (MUNT, JINR, LATV)
KUZNETSOV	95	PRL 75 794	+Serebrov, Stepanenko+ (PNPI, KIAE, HARV, NIST)
SCHRECK	95	PL B349 427	Schreckenbach, Liaud+ (MUNT, ILLG, LAPP)
BALDO	94	ZPHY C63 409	Baldo-Ceolin, Benetti+ (HEID, ILLG, PADO, PAVI)
DIFILIPPO	94	PRL 73 1481	+Natarajan, Boyce, Pritchard (MIT)
Also	93	PRL 71 1998	Natarajan, Boyce, DiFilippo, Pritchard (MIT)
GOLUB	94	PRPL 237C 1	+Lamoreaux (HAHN, WASH)
MAMPE	93	JETPL 57 82	+Bondarenko, Morozov+ (KIAE)
		Translated from ZETFP	57 77.
PENDLEBURY	93	ARNPS 43 687	(ILLG)
ALTAREV	92	PL B276 242	+Borisov, Borovikova, Ivanov+ (PNPI)
NESVIZHEV	92	JETP 75 405	Nesvizhevskii, Serebrov, Tal'daev+ (PNPI, JINR)
		Translated from ZETF 1	102 740.
SCHRECK	92	JPG 18 1	Schreckenbach, Mampe (ILLG)
ALBERICO	91	NP A523 488	+de Pace, Pignone (TORI)
DUBBERS	91	NP A527 239c	(ILLG)
Also	90	EPL 11 195	Dubbers, Mampe, Doehner (ILLG, HEID)
EROZOLIM	91	PL B263 33	Erozolimskii, Kuznetsov, Stepanenko, Kuida+ (PNPI, KIAE)
Also	90	SJNP 52 999	Erozolimskii, Kuznetsov, Stepanenko, Kuida+ (PNPI, KIAE)
		Translated from YAF 52	1583.
EROZOLIM	91B	SJNP 53 260	Erozolimskii, Mostovoi (KIAE)
CCULATERA		Translated from YAF 53	
SCHMIEDM	91	PRL 66 1015	Schmiedmayer, Riehs, Harvey, Hill (TUW, ORNL)
WOOLCOCK	91	MPL A6 2579	(CANB)
ALFIMENKOV	90	JETPL 52 373 Translated from ZETFP	+Varlamov, Vasil'ev, Gudkov+ (PNPI, JINR)
BALDO	90		
BERGER	90	PL B236 95 PL B240 237	Baldo-Ceolin, Benetti, Bitter+ (PADO, PAVI, HEIDP, ILLG)
BRESSI	90	NC 103A 731	+Froehlich, Moench, Nisius+ (FREJUS Collab.)
BYRNE	90	PRL 65 289	+Calligarich, Cambiaghi+ (PAVI, ROMA, MILA)
FREEDMAN	90	CNPP 19 209	+Dawber, Spain, Williams+ (SUSS, NBS, SCOT, CBNM)
GREEN	90	JPG 16 L75	+Thompson (ANL)
		ARNPS 40 1	
RAMSEY ROSE	90 90	PL B234 460	(HARV)
ROSE	90B	NP A514 621	+Zurmuehl, Rullhusen, Ludwig+ (GOET, MPCM, MANZ)
SMITH	908	PL B234 191	+Zurmuehl, Rullhusen, Ludwig+ (GOET, MPCM)
BRESSI	89	ZPHY C43 175	+Crampin+ (SUSS, RAL, HARV, WASH, ILLG, MUNT)
			+Calligarich, Cambiaghi+ (INFN, MILA, PAVI, ROMA)
DOVER	89	NIM A284 13	+Gal, Richard (BNL, HEBR, ISNG)
EROZOLIM	89	NIM A284 89	Erozolimskii (PNPI)
KOSSAKOW		NP A503 473	Kossakowski, Grivot+ (LAPP, SAVO, ISNG, ILLG)
MAMPE	89	PRL 63 593	+Ageron, Bates, Pendlebury, Steyerl (ILLG, RISL, SUSS, URI)
MOHAPATRA	89	NIM A284 1	(UMD)
PAUL	89	ZPHY C45 25	+Anton, Paul, Paul, Mampe (BONN, WUPP, MPIH, ILLG)
SCHMIEDM	89	NIM A284 137	Schmiedmayer, Rauch, Riehs (WIEN)
BAUMANN	88	PR D37 3107	+Gaehler, Kalus, Mampe (BAYR, MUNI, ILLG)
KOESTER	88	ZPHY A329 229	+Waschkowski, Meier (MUNI, MUNT)
LAST	88	PRL 60 995	+Arnold, Doehner, Dubbers+ (HEIDP, ILLG, ANL)
SCHMIEDM	88	PRL 61 1065	Schmiedmayer, Rauch, Riehs (TUW)
Also	88B	PRL 61 2509 erratum	Schmiedmayer, Rauch, Riehs (TUW)
SPIVAK	88	JETP 67 1735	(KIAE)
COHEN	87	Translated from ZETF 9 RMP 59 1121	
ALTAREV	86	JETPL 44 460	+Taylor (RISC, NBS) +Borisov, Borovikova, Brandin, Egorov+ (PNPI)
ALIMILEV	00	Translated from ZETFP	44 360
BOPP	86	PRL 56 919	+Dubbers, Hornig, Klemt, Last+ (HEIDP, ANL, ILLG)
Also	88	ZPHY C37 179	Klemt, Bopp, Hornig, Last+ (HEIDP, ANL, ILLG)
CRESTI	86	PL B177 206	+Pasquali, Peruzzo, Pinori, Sartori (PADO)
Also	88	PL B200 587 erratum	Cresti, Pasquali, Peruzzo, Pinori, Sartori (PADO)
GREENE	86	PRL 56 819	+Kessler, Deslattes, Boerner (NBS, ILLG)
KOSVINTSEV	86	JETPL 44 571	+Morozov, Terekhov (KIAE)
		Translated from ZETFP	44 444.
TAKITA	86	PR D34 902	+Arisaka, Kajita, Kifune+ (KEK, TOKY+)
DOVER	85	PR C31 1423	+Gal, Richard (BNL)
FIDECARO	85	PL 156B 122	+Lanceri+ (CERN, ILLG, PADO, RAL, SUSS)
PARK	85B	NP B252 261	+Blewitt, Cortez, Foster+ (IMB Collab.)
BATTISTONI	84	PL 133B 454	+Bellotti, Bologna, Campana+ (NUSEX Collab.)
JONES	84	PRL 52 720	+Bionta, Blewitt, Bratton+ (IMB Collab.)
PENDLEBURY	84	PL 136B 327	+Smith, Golub, Byrne+ (SUSS, HARV, RAL, ILLG)
CHERRY	83	PRL 50 1354	+Lande, Lee, Steinberg, Cleveland (PENN, BNL)
DOVER	83	PR D27 1090	+Gal, Richards (BNL)
KABIR	83	PRL 51 231	(HARV)
MOSTOVOY	83	JETPL 37 196	(KIAE)
		Translated from ZETFP	37 162.

ROY	83	PR D28 1770	+Vaidya, Ephraim, Datar, Bhatki+	(TATA)
VAIDYA	83	PR D27 486	+Roy, Ephraim, Datar, Bhattacherjee	(TATA)
GAEHLER	82	PR D25 2887	+Kalus, Mampe	(BAYR, ILLG)
GREENE	82	Metrologia 18 93	+ (YALE, HARV, ILLG, SUSS,	
ALTAREV	81	PL 102B 13	+Borisov, Borovikova, Brandin, Egorov+	(PNPI)
BARABANOV	80	JETPL 32 359	+Veretenkin, Gavrin+	(PNPI)
BARABANOV	00	Translated from ZETEP		(FINE)
BYRNE	80	PL 92B 274	+Morse, Smith, Shaikh, Green, Greene	(SUSS, RL)
KOSVINTSEV	80	JETPL 31 236	+Kushnir, Morozov, Terekhov	(JINR)
KOSVINTSEV	60	Translated from ZETFP		(Allalic)
MOHAPATRA	80	PRL 44 1316	+Marshak	(CUNY, VPI)
ALTAREV	79	JETPL 29 730	+Borisov, Brandin, Egorov, Ezhov, Ivanov+	(PNPI)
ACIANCY	, ,	Translated from ZETFP		(1.141.1)
EROZOLIM	79	SJNP 30 356	Erozolimskii, Frank, Mostovoy+	(KIAE)
CHOZOCHI	.,	Translated from YAF 30		(11112)
NORMAN	79	PRL 43 1226	+Seamster	(WASH)
BONDAREN	78	JETPL 28 303	Bondarenko, Kurguzov, Prokofev+	(KIAE)
DONOMINE		Translated from ZETFP		(11.11.0)
Also	82	Smolenice Conf.	Bondarenko	(KIAE)
EROZOLIM	78	SJNP 28 48	Erozolimskii, Mostovov, Fedunin, Frank+	(KIAE)
EITOLOLINIII		Translated from YAF 28		(11.11.2)
STRATOWA	78	PR D18 3970	+Dobrozemsky, Weinzierl	(SEIB)
EROZOLIM	77	JETPL 23 663	Erozolimskii, Frank, Mostovov+	(KIAE)
ENOLULIA		Translated from ZETFP		(11171)
STEINBERG	76	PR D13 2469	+Liaud, Vignon, Hughes	(YALE, ISNG)
DOBROZE	75	PR D11 510	Dobrozemsky, Kerschbaum, Moraw, Paul+	(SEIB)
KROHN	75	PL 55B 175	+Ringo	(ANL)
EROZOLIM	74	JETPL 20 345	Erozolimskii, Mostovoy, Fedunin, Frank+	(/)
LINGEGENMIN		Translated from ZETFP	20 745.	
KROPF	74	ZPHY 267 129	+Paul	(LINZ)
Also	70	NP A154 160	Paul	(VIEN)
STEINBERG	74	PRL 33 41	+Liaud, Vignon, Hughes	(YALE, ISNG)
COHEN	73	JPCRD 2 663	+Taylor	(RISC, NBS)
CHRISTENSEN		PR D5 1628	+Nielson, Bahnsen, Brown+	(RISO)
CHRISTENSEN		PR C1 1693	+Krohn, Ringo	(ANL)
EROZOLIM	70C	PL 33B 351	Erozolimskii, Bondarenko, Mostovov, Obinyako	
	68	S INP 6 239	Grigor'ev, Grishin, Vladimirsky, Nikolaevskii+	
GRIGOREV	06	Translated from YAF 6		(ITEP)
		mansiated from TAP 6	347.	

#### NOTE ON N AND A RESONANCES

#### I. Introduction

The excited states of the nucleon have been studied in a large number of formation and production experiments. The masses, widths, and elasticities of the N and  $\Delta$  resonances in the Baryon Summary Table come almost entirely from partial-wave analyses of  $\pi N$  total, elastic, and charge-exchange scattering data (Sec. II). Partial-wave analyses have also been performed on much smaller data sets to get  $N\eta$ ,  $\Lambda K$ , and  $\Sigma K$  branching fractions. Other branching fractions come from isobar-model analyses of  $\pi N \to N\pi\pi$  data (Sec. III). Finally, many  $N\gamma$ branching fractions have been determined from photoproduction experiments (Sec. IV).

Table 1 lists all the N and  $\Delta$  entries in the Baryon Listings and gives our evaluation of the status of each, both overall and channel by channel. Only the "established" resonances (overall status 3 or 4 stars) appear in the Baryon Summary Table. We consider a resonance to be established only if it has been seen in at least two independent analyses of elastic scattering and if the relevant partial-wave amplitudes do not behave erratically or have large uncertainties.

The Baryon Particle Listings give, in addition to the usual Breit-Wigner parameters, the positions and residues of the nearest poles of the resonant partial waves on the second sheet of the complex energy plane. These come from  $\pi N \to \pi N$ partial-wave analyses and from a  $\pi N \to N\pi\pi$  isobar-model analysis (Sec. III).

The interested reader will find further discussions in two extensive (but now somewhat dated) reviews [1,2] and in the Proceedings of the 6th International Symposium on Meson-Nucleon Physics and the Structure of the Nucleon [3].

(References for this Section are at the end of Sec. II.)

Table 1. The status of the N and  $\Delta$  resonances. Only those with an overall status of *** or **** are included in the main Baryon Summary Table

		o	Status as seen in —						
Particle	$L_{2I\cdot 2.}$	Overall status	$N\pi$	$N\eta$	$\Lambda K$	$\Sigma K$	$\Delta\pi$	$N\rho$	$N\gamma$
N(939)	P ₁₁	****							
N(1440)	$P_{11}$	****	****	*			***	*	***
N(1520)	$D_{13}$	****	****	*			****	****	***
N(1535)	$S_{11}$	****	****	****			*	**	***
N(1650)	$S_{11}$	****	****	*	***	**	***	**	***
N(1675)	$D_{15}$	****	****	*	*		****	*	****
N(1680)	$F_{15}$	****	****				****	****	****
N(1700)	$D_{13}$	***	***	*	**	*	**	*	**
N(1710)	$P_{11}$	***	***	**	**	*	**	*	***
N(1720)	$P_{13}$	****	****	*	**	*	*	**	**
N(1900)	$P_{13}$	**	**					*	
N(1990)	$F_{17}$	**	**	*	*	*			*
N(2000)	$F_{15}$	**	**	*	*	*	*	**	
N(2080)	$D_{13}$	**	**	*	*				*
N(2090)	$S_{11}$	*	*						
N(2100)	$P_{11}$	*	*	*					
N(2190)	$G_{17}$	****	****	*	*	*		*	*
N(2200)	$D_{15}$	**	**	*	*				
N(2220)	$H_{19}$	****	***	*					
N(2250)	$G_{19}$	****	***	*					
N(2600)	$I_{1 \ 11}$	***	***						
N(2700)	$K_{113}$	**	**						
$\Delta(1232)$	$P_{33}$	****	****	F					****
$\Delta(1600)$	$P_{33}$	***	***	O			***	*	**
$\Delta(1620)$	$S_{31}$	****	****	r			****	****	***
$\Delta(1700)$	$D_{33}$	****	****	b		*	***	**	***
$\Delta(1750)$	$P_{31}$	*	*	i					
$\Delta(1900)$	$S_{31}$	***	***	C		*	*	**	*
$\Delta(1905)$	$F_{35}$	****	****		d	*	**	**	***
$\Delta(1910)$	$P_{31}$	****	****		e	*	*	*	*
$\Delta(1920)$	$P_{33}$	***	***		n	*	**		*
$\Delta(1930)$	$D_{35}$	***	***	_		*			**
$\Delta(1940)$	$D_{33}$	*	*	F					
$\Delta(1950)$	$F_{37}$	****	****	0		*	****	*	****
$\Delta(2000)$	$F_{35}$	**		r				**	
$\Delta(2150)$	$S_{31}$	*	*	b					
$\Delta(2200)$	$G_{37}$	*	*	i	_				
$\Delta(2300)$	$H_{39}$	**	**	Ċ					
$\Delta(2350)$	$D_{35}$	*	*		d				
$\Delta(2390)$	$F_{37}$	*	*		e				
$\Delta(2400)$	$G_{39}$	**	**		n				
$\Delta(2420)$	$H_{311}$	****	****						*
$\Delta(2750)$	$I_{313}$	**	**						
$\Delta(2950)$	$K_{315}$	**	**						

Existence is certain, and properties are at least fairly well explored. Existence ranges from very likely to certain, but further confirmation is desirable and/or quantum numbers, branching fractions, etc. are not well determined. Evidence of existence is only fair.

Evidence of existence is poor

## II. Elastic partial-wave analyses and resonance param-

(by R.L. Workman, Virginia Polytechnic Institute and State University)

A general discussion was given in previous editions [4]. In the following, we only consider new results.

New data: Experimental activity over the past two years has mainly concentrated on the region below 600 MeV [5]. Some of these data remain in preliminary form. The new pionic atom measurement [6] from PSI is particularly interesting as it has updated the  $\pi N$  scattering lengths used in dispersion

## N's and $\Delta$ 's

relations. An experiment at the ITEP accelerator has measured spin-rotation parameters for  $\pi^+p$  elastic scattering at 1.43 GeV/c [7]. The results are surprising, as they strongly contradict predictions from the CMU-Berkeley (CMB) [8] and Karlsruhe-Helsinki (KH) [9] analyses. More spin-rotation measurements are planned for this energy region.

**New Partial-Wave Analyses:** The VPI group has updated its resonance parameters [10]. The new determinations are based upon a partial-wave analysis with fixed-t dispersion relation constraints. A search was made for 'small' structures, and two new resonance candidates were found. Discrepancies between this analysis and the CMB [8] and KH [9] analyses still exist.

Batinić et al. [11] have used a coupled-channel model to describe the elastic  $\pi N$  amplitudes together with data for  $\pi N \to \eta N$ . One variant of this model contains two additional  $(S_{11} \text{ and } P_{11})$  resonances with masses near 1750 MeV. The extra  $S_{11}$  resonance is similar to one of the small structures found in the VPI analysis. While there is other circumstantial evidence [12] for this state, further verification is needed.

The Petersburg analysis [13] is now published. The associated preprint was described in the 1992 review. While the published version does not report some of the higher partial waves, the partial-wave solutions are identical.

Resonance Parameters: Höhler has generated pole parameters for the KH solution using the speed-plot method. This study is continuing [14]. Manley [15] has related and compared the pole and Breit-Wigner parameters from the KSU [16], CMB [8], KH [9], and VPI [10] analyses. Good agreement was found for the  $\Delta(1232) P_{33}$ ,  $N(1520) D_{13}$ ,  $N(1650) S_{11}$ ,  $N(1675) D_{15}$ ,  $N(1680) F_{15}$ , and  $\Delta(1950) F_{37}$  pole parameters. The most recent VPI analysis has added a small structure to the high-energy shoulder of the  $N(1650) S_{11}$ . As a result, the associated parameters have changed significantly.

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## III. Inelastic two-body and quasi-two-body reactions

(by D.M. Manley, Kent State University)

Since the last edition, no new data nor partial-wave analyses have been published for the inelastic two-body reactions  $\pi N \to \Lambda K$  and  $\pi N \to \Sigma K$ . However, new data have been measured and a new analysis published for the  $\pi N \to N\eta$  reaction. In particular, an experiment [1] that measured the cross section for  $\pi^-p \to n\eta$  from threshold to  $p_\pi = 750~{\rm MeV/c}$  ( $\sqrt{s} = 1527~{\rm MeV}$ ) was recently completed using the AGS at Brookhaven National Laboratory. In addition, the same collaboration also measured the cross section for  $K^-p \to \Lambda \eta$ . The data from these measurements are currently being analyzed.

A new energy-dependent partial-wave analysis of the reaction  $\pi N \to N \eta$  has also been published [2]. The analysis used a coupled three-channel model to describe reactions involving the  $N\pi$  and  $N\eta$  channels simultaneously. (The third channel was an effective nonphysical two-body  $N\pi\pi$  channel.) The eight lowest  $I=\frac{1}{2}$   $\pi N\to N\eta$  partial waves were fitted up to a c.m. energy of 2.5 GeV using the  $\pi N$  elastic amplitudes from the Karlsruhe-Helsinki partial-wave analysis [3] as part of the input data base.

Essentially all information on quasi-two-body reactions such as  $\pi N \to \Delta \pi$  and  $\pi N \to N \rho$  comes from isobar-model analyses of  $\pi N \to N \pi \pi$  reactions. Since the last edition, no new analysis of these reactions has been published. A brief review of  $\pi N \to N \pi \pi$  analyses can be found in our 1992 edition; for a more recent and extensive review, the interested reader should see [4].

Since the last edition, two new narrow resonance candidates were observed in experiments investigating the diffractive production of hadrons by 70-GeV protons at the SPHINX facility of the IHEP accelerator [5]. In the reaction on carbon nuclei,  $p+C \rightarrow [\varSigma(1385)^0K^+]+C$ , evidence was found for an N(2050) with mass  $M=(2052\pm 6)$  MeV and width  $\Gamma=35^{+22}_{-35}$  MeV. In the reaction,  $p+C \rightarrow [\varSigma^0K^+]+C$ , evidence was found for an N(2000) with  $M=1999\pm 6$  MeV and  $\Gamma=91\pm 17$  MeV.

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The small decay widths and large branching ratios for decays involving hyperons make these states candidates for exotic  $qqqs\bar{s}$  baryons. Further evidence suggesting the possible existence of narrow exotic baryons was found by a recent analysis of photographic data obtained during irradiation of the 2-meter hydrogen bubble chamber at CERN by a 16-GeV/c  $\pi^-$  beam [6]. A narrow peak that may be due to the production of a neutral baryon with  $M=3521\pm3$  MeV and  $\Gamma=6^{+21}_{-6}$  MeV was observed in the invariant mass spectrum of the  $K^0_sK^+p\pi^-\pi^-$  system.

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## IV. Electromagnetic interactions

(by R.L. Crawford, University of Glasgow)

Nearly all the entries in the Listings relating to electromagnetic properties of the N and  $\Delta$  resonances are  $N\gamma$  couplings. These couplings, the helicity amplitudes  $A_{1/2}$  and  $A_{3/2}$ , have been obtained in a large number of partial-wave analyses of single-pion photoproduction,  $\gamma N \to \pi N$ , on protons and neutrons. The large amount of data has permitted an accurate evaluation of the couplings for many of the resonances with masses below 2 GeV, and has given at least qualitative information about most of the others. Most photoproduction analyses take as input the existence, masses, and widths of the resonances derived from the  $\pi N \to \pi N$  analyses, and only determine the  $N\gamma$ couplings. In addition to the pion photoproduction analyses, a few couplings have been extracted from  $\eta$  photoproduction and from Compton scattering. A brief description of the various methods of analysis of photoproduction data may be found in our 1992 edition [1]

Our Listings omit a number of analyses that are now obsolete. Most of the older results may be found in our 1982 edition [2]. The errors quoted for the couplings in the Listings are calculated in different ways in different analyses and therefore should be used with care. In general, the systematic differences between the analyses caused by using different

parametrization schemes are probably more indicative of the true uncertainties than are the quoted errors.

Probably the most reliable analyses are ARAI 80, CRAW-FORD 80, AWAJI 81, FUJII 81, CRAWFORD 83, and ARNDT 96. The Listings include our estimates of the couplings, using the results of these analyses. The errors we give are a combination of the stated statistical errors on the analyses and the systematic differences between them. The analyses are given equal weight, except ARNDT 96 is weighted, rather arbitrarily, by a factor of two because its data set is at least 50% larger than those of the other analyses and contains many new high-quality measurements.

The Baryon Summary Table gives  $N\gamma$  branching fractions for those resonances whose couplings are considered to be reasonably well established. The  $N\gamma$  partial width  $\Gamma_{\gamma}$  is given in terms of the helicity amplitudes  $A_{1/2}$  and  $A_{3/2}$  by

$$\Gamma_{\gamma} = \frac{k^2}{\pi} \frac{2M_N}{(2J+1)M_R} \left[ |A_{1/2}|^2 + |A_{3/2}|^2 \right].$$

Here  $M_N$  and  $M_R$  are the nucleon and resonance masses, J is the resonance spin, and k is the photon c.m. decay momentum.

The Listings include results of several new analyses of the  $N(1535) \to N\gamma$  couplings obtained using recent accurate measurements of the reaction  $\gamma N \to N\eta$  near threshold.

Burkert and Elouadrhiri [4] report the result of an analysis of  $\pi^0$  electroproduction on protons at a virtual photon mass of  $Q^2 = -3.2 \; (\text{GeV}/c)^2$  using data from DESY. They evaluated the ratio of electric quadrupole and scalar quadrupole to magnetic dipole amplitudes for the  $\Delta(1232)$ . Their values,

$$E_{1+}/M_{1+} = 0.06 \pm 0.02 \pm 0.03$$

and

$$S_{1+}/M_{1+} = 0.07 \pm 0.02 \pm 0.03$$
,

agree with typical quark model predictions and are qualitatively similar to those obtained from previous analyses for smaller values of  $|Q^2|$ . They disagree with the predictions from perturbative QCD that  $E_{1+}/M_{1+} \to 1$  and  $S_{1+}/M_{1+} \to 0$  at large  $|Q^2|$ .

Mart, Bennhold, and Hyde-Wright [5] apply isobar models developed for  $\gamma p \to K^+ \varSigma^0$  and  $\gamma p \to K^+ \Lambda$  to  $\gamma p \to K^0 \varSigma^+$  and  $\gamma n \to K^- \varSigma^+$  and find that they can drastically overpredict the measurements. Including the data for charged  $\varSigma$  production results in drastically reduced values for the Born-term couplings,  $g_{K\varSigma N}$  and  $g_{K\Lambda N}$ , to values well below the SU(3) predictions and values obtained from hadronic processes. The resulting description of the process is resonance dominated. They point out the importance for future analyses of including data for all channels. Their results are not included in the Listings because of the scatter of the values obtained.

Additional information about recent results for the electromagnetic interactions may be found in our 1992 and 1994

## N's and $\Delta$ 's

editions [1,3]. These include Compton scattering,  $K\Lambda$  photoproduction, pion electroproduction, the E2/M1 ratio, and the magnetic moment of the  $\Delta(1232)$ .

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#### V. Outlook

(by D.M. Manley, Kent State University)

Much new data related to the study of nucleon resonances will soon come from experiments with electromagnetic probes at CEBAF, which can provide beams of electrons to three experimental halls (A, B, and C) with energies up to 4 GeV. Experiments are now being carried out in Hall C and the commissioning experiments for Hall A are expected to run in mid 1996. The majority of experiments to study nucleon resonances will be carried out in Hall B, which is expected to be completed in late 1996. A very short summary of the experimental program in Hall B can be found in our last edition.

New experiments to study nucleon resonances at European laboratories are already producing interesting results. For example, measurements of total cross sections for the reaction  $\gamma p \rightarrow p \eta$  at eight c.m. energies between 1487 and 1493 MeV were performed at the ELSA electron facility at Bonn [1] by solely detecting the recoil proton. In addition, very precise measurements of total and differential cross sections for  $\gamma p \to p \eta$ from threshold to 1537 MeV (c.m. energy) were performed using the MAMI accelerator in Mainz [2] with the neutral meson spectrometer TAPS. Other facilities are or will be involved in such programs using hadronic beams. For example, two experiments were approved in 1995 to study baryon spectroscopy at the AGS of Brookhaven National Laboratory. The processes,  $\pi^- p \to n\eta$ ,  $K^-p \to \Lambda \eta$ , and  $K^-p \to \Sigma^0 \eta$ , among others, will be studied by using the Crystal Ball detector (formerly located at SLAC) to identify multiphoton final states [3,4]. As by-products of these investigations, new and improved data also will be obtained for  $\pi^- p \to n\pi^0$ , and for the inverse photoproduction reactions,  $K^-p \to \Lambda \gamma$  and  $K^-p \to \Sigma^0 \gamma$ .

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 Brookhaven experiment E914, "Neutral Hyperon Spectroscopy," spokespersons B.M.K. Nefkens, A. Efendiev, and S. Kruglov.

## VI. Non-qqq baryon candidates

The standard quark-model assignments for baryons are outlined in Sec. 12.3 "Baryons: qqq states". As in the meson spectrum (see the "Note on Non- $q\bar{q}$  mesons"), there have been suggestions that some states fall outside this assignment scheme. These include hybrid (qqqg) baryons and unstable meson-nucleon bound states [1] (see the "Note on the  $\Lambda(1405)$ ").

If non-qqq states exist, they will be more difficult to verify than hybrid mesons. Hybrid baryons would not have the clean signature of exotic quantum numbers. They should also mix with ordinary qqq states. The identification of such states will be based upon (a) characteristics of their formation and decay, and (b) an over-population of expected qqq states.

Most investigations have focused on the properties of the lightest predicted hybrids. If the first hybrid state lies below 2 GeV, as is suggested by bag-model calculations [2,3,4], it may already exist in the Baryon Particle Listings. (Note, however, that some estimates [5] put the lightest state significantly above 2 GeV.) At present, there are actually not enough known resonances to fill the known multiplets. This is the 'missing resonance' problem. If an existing resonance is identified as a hybrid, we must also account for the expected qqq state.

The Roper resonance,  $N(1440) P_{11}$ , has been considered as a hybrid candidate based upon its quantum numbers [2] and difficulties with its mass and electromagnetic couplings. If so, this would alter our interpretation of the low-lying  $P_{11}$ ,  $P_{13}$ ,  $P_{31}$ , and  $P_{33}$  resonances [2,6]. In Ref. 6, both the  $N(1440) P_{11}$  and  $\Delta(1600) P_{33}$  are hybrid candidates, and the  $N(1540) P_{13}$  and  $\Delta(1550) P_{31}$  states are predicted. The  $P_{13}$  and  $P_{31}$  (1-star) states were listed in the 1990 RPP [7] but were removed from the listings in 1992 [8].

Both photoproduction [6,9,10] and electroproduction [10,11] have been considered in the search for a unique hybrid signature. In Ref. 12, QCD counting rules were used to reveal a characteristic of hybrid electroproduction at high  $Q^2$ . If the Roper is a hybrid, its transverse form factor is expected to fall asymptotically  $\mathrm{O}(1/Q^2)$  faster than a pure qqq state. However, mixing between qqq and qqqg states will make this identification more difficult.

A number of recent experiments have searched for pentaquark  $(qqqq\bar{q})$  resonances and H-dibaryon (six-quark uuddss states). Narrow structures found in proton-nucleus scattering [13] have been attributed to  $qqqs\bar{s}$  states (see Sec. III), but these require confirmation. The H-dibaryon experiments, while finding possible candidates, have generally quoted upper limits [14] for exotic resonance production. Searches for narrow dibaryons in the nucleon-nucleon interaction are also continuing [15].

For an extensive review of exotic hadrons, see Landsberg [16].

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## $N(1440) P_{11}$

 $I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$  Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters **111B** (1982).

## N(1440) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1430 to 1470 (≈ 1440)	OUR ESTIMATE			
1462±10	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
$1440 \pm 30$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
$1410 \pm 12$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • We do not use t	he following data for average	s, fits	s, limitș,	etc. • • •
1463± 7	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
1467	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
421±18	BATINIC	95	DPWA	$\pi N \rightarrow N \pi, N \eta$
.465	LI	93	IPWA	$\gamma N \rightarrow \pi N$
471	CUTKOSKY	90	IPWA	$\pi N \rightarrow \pi N$
411	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
.472	¹ BAKER	79	DPWA	$\pi^- \rho \rightarrow n\eta$
.417	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
.460	BERENDS	77	IPWA	$\gamma N \rightarrow \pi N$
.380	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
.390	³ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

## N(1440) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
250 to 450 (≈ 350) OUR ESTIMA	TE			
391 ± 34	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
545±170	CUTKOSKY	90	IPWA	$\pi N \rightarrow \pi N$
340 ± 70	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
135 ± 10	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	data for average	s, fit:	s, limits,	etc. • • •
360± 20	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
440	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
250 ± 63	BATINIC	95	DPWA	$\pi N \rightarrow N \pi$ , $N \eta$
315	LI	93	IPWA	$\gamma N \rightarrow \pi N$
334	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
113	¹ BAKER	79	DPWA	$\pi^- \rho \rightarrow n\eta$
331	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
279	BERENDS	77	IPWA	$\gamma N \rightarrow \pi N$
200	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
200	³ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

## N(1440) POLE POSITION

REAL PART				
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1346	⁴ ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1385	⁵ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
1370	CUTKOSKY	90	IPWA	$\pi N \rightarrow \pi N$
$1375 \pm 30$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
<ul> <li>◆ ◆ We do not use th</li> </ul>	e following data for average	s, fit	s, limits,	etc. • • •
1360	⁶ ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$
1381 or 1379	⁷ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
1360 or 1333	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
-2×IMAGINARY P	ART			
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
176	⁴ ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
164	⁵ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
228	CUTKOSKY	90	IPWA	$\pi N \rightarrow \pi N$
180 ± 40	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use th	e following data for average	s, fit:	s, limits,	etc. • • •
252	⁶ ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$
209 or 210	⁷ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
167 or 234	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$

## N(1440) ELASTIC POLE RESIDUE

## MODULUS |r|

1 1	
VALUE (MeV)	DOCUMENT ID TECN COMMENT
42	⁴ ARNDT 95 DPWA $\pi N \rightarrow N \pi$
40	HOEHLER 93 SPED $\pi N \rightarrow \pi N$
74	CUTKOSKY 90 IPWA $\pi N \rightarrow \pi N$
52±5	CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$
• • We do not use the	e following data for averages, fits, limits, etc. • • •
109	⁶ ARNDT 91 DPWA $\pi N \rightarrow \pi N$ Soln SM90
PHASE θ	
VALUE (°)	DOCUMENT ID TECN COMMENT
- 101	⁴ ARNDT 95 DPWA $\pi N \rightarrow N \pi$
- 84	CUTKOSKY 90 IPWA $\pi N \rightarrow \pi N$
$-100 \pm 35$	CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$
• • We do not use the	e following data for averages, fits, limits, etc. • •

## N(1440) DECAY MODES

91 DPWA  $\pi N \rightarrow \pi N \text{ Soln SM90}$ 

⁶ ARNDT

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction $(\Gamma_i/\Gamma)$	
Γ ₁	Nπ	60-70 %	
$\Gamma_2$	$N\eta$		
$\Gamma_3$	$N\pi\pi$	30-40 %	
$\Gamma_4$	$\Delta\pi$	20-30 %	
$\Gamma_5$	$\Delta(1232)\pi$ , $\it P$ -wave		
$\Gamma_6$	$N \rho$	<8 %	
$\Gamma_7$	$N\rho$ , $S=1/2$ , $P$ -wave		
Γ8	$N\rho$ , $S=3/2$ , $P$ -wave		
Γ9	$N(\pi\pi)_{S-\text{wave}}^{I=0}$	5-10 %	
$\Gamma_{10}$	$p\gamma$	0.035-0.048 %	
$\Gamma_{11}$	$p\gamma$ , helicity $=1/2$	0.035-0.048 %	
$\Gamma_{12}$	$n\gamma$	0.009-0.032 %	
Γ ₁₃	$n\gamma$ , helicity=1/2	0.009-0.032 %	

## N(1440) BRANCHING RATIOS

				$\Gamma_1/\Gamma$
DOCUMENT: ID		TECN	COMMENT	
MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N$	$V\pi\pi$
CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$	
ing data for averag	es, fit	s, limits,	etc. • • •	
ARNDT	95	DPWA	$\pi N \rightarrow N \pi$	
BATINIC	95	DPWA	$\pi N \rightarrow N \pi$ , $N \tau$	)
	MANLEY CUTKOSKY HOEHLER ing data for average	CUTKOSKY 80 HOEHLER 79 ing data for averages, fit ARNDT 95	MANLEY 92 IPWA CUTKOSKY 80 IPWA HOEHLER 79 IPWA ing data for averages, fits, limits, ARNDT 95 DPWA	MANLEY 92 IPWA $\pi N \rightarrow \pi N \& N$ CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$ HOEHLER 79 IPWA $\pi N \rightarrow \pi N$ ing data for averages, fits, limits, etc. • •  ARNDT 95 DPWA $\pi N \rightarrow N \pi$

## Baryon Particle Listings N(1440), N(1520)

 $(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma$  $(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\pi \to N(1440) \to N\eta$ DOCUMENT ID TECN COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • ¹ BAKER 79 DPWA  $\pi^- p \rightarrow n \eta$ seen ⁸ FELTESSE +0.32875 DPWA 1488-1745 MeV

Note: Signs of couplings from  $\pi\,{\it N}\,\rightarrow\,{\it N}\,\pi\,\pi$  analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the  $\Delta(1620)~S_{31}$ coupling to  $\Delta(1232)\pi$ .

	$V\pi \rightarrow N(1440) \rightarrow \Delta(1232)$				(Г₁Г₅) ^⅓ /Г
VALUE	DOCUMENT ID		TECN	COMMENT	
+0.37 to +0.41 OUR					
$+0.39\pm0.02$	MANLEY ^{2,9} LONGACRE	92	IPWA	$\pi N \rightarrow \pi N$	& Nππ
+0.41					
+0.37	³ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi$	$\pi$
					1/
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}}$ in $I$	$V\pi  o N(1440)  o N ho$ , $S=$				(Г₁Г ₇ ) ^⅓ 2/Г
VALUE	DOCUMENT ID				(Γ ₁ Γ ₇ ) ⁷² /Γ
VALUE	5 OUR ESTIMATE		TECN	COMMENT	
VALUE	DOCUMENT ID  5 OUR ESTIMATE  2,9 LONGACRE	77	TECN IPWA	$\pi N \rightarrow N \pi$	π
<u>VALUE</u> ±0.07 to ±0.2	5 OUR ESTIMATE	77	TECN IPWA	$\pi N \rightarrow N \pi$	π
$ \frac{\text{$2.07$ to $\pm 0.2$}}{\text{$\pm 0.07$ to $\pm 0.2$}} $ $ -0.11 $ $ +0.23 $ $ (\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total in } I} $	5 OUR ESTIMATE  2.9 LONGACRE 3 LONGACRE $V\pi \rightarrow N(1440) \rightarrow N\rho$ , S=	77 75 = <b>3/</b> 2	IPWA IPWA IPWA <b>2, <i>P</i>-w</b> a	$\begin{array}{ccc} \underline{COMMENT} \\ \pi \ N \ \longrightarrow \ N \ \pi \\ \pi \ N \ \longrightarrow \ N \ \pi \end{array}$	π
$\frac{VALUE}{\pm 0.07 \text{ to } \pm 0.2}$ - 0.11 + 0.23	5 OUR ESTIMATE  2,9 LONGACRE 3 LONGACRE	77 75 = <b>3/</b> 2	IPWA IPWA 2, P-wa	$\begin{array}{c} COMMENT \\ \pi \ N \rightarrow N \pi \\ \pi \ N \rightarrow N \pi \end{array}$	π π (Γ1Γ8) ¹ /2/Γ

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N$	$\pi \to N(1440) \to N(\pi\pi)_{\rm S}^I$	=0 5-wave	(۲ ₁ ۲ ₉ ) ^½ /۲
VALUE	DOCUMENT ID	TE	CNCOMMENT
±0.17 to ±0.25	OUR ESTIMATE		
$+0.24\pm0.03$	MANLEY	92 IP	WA $\pi N \rightarrow \pi N \& N \pi \pi$
-0.18	^{2,9} LONGACRE	77 IP	$VA \pi N \rightarrow N \pi \pi$
-0.23	3 LONGACRE	75 IP	WA $\pi N \rightarrow N \pi \pi$

## N(1440) PHOTON DECAY AMPLITUDES

## $N(1440) \rightarrow p\gamma$ , helicity-1/2 amplitude A_{1/2}

VALUE (GeV ^{-1/2} )	DOCUMENT ID	TECN	COMMENT
-0.065 ±0.004 OUR ESTIMAT	E		
$-0.063 \pm 0.005$	ARNDT 96	IPWA	$\gamma N \rightarrow \pi N$
$-0.069 \pm 0.018$	CRAWFORD 83	IPWA	$\gamma N \rightarrow \pi N$
$-0.063 \pm 0.008$	AWAJI 81		$\gamma N \rightarrow \pi N$
$-0.069 \pm 0.004$	ARAI 80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
$-0.066 \pm 0.004$	ARAI 80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
$-0.079 \pm 0.009$	BRATASHEV 80	DPWA	$\gamma N \rightarrow \pi N$
$-0.068 \pm 0.015$	CRAWFORD 80	DPWA	$\gamma N \rightarrow \pi N$
$-0.0584 \pm 0.0148$	ISHII 80	DPWA	Compton scattering
• • • We do not use the following	data for averages, fit	s, limits,	etc. • • •
$-0.085 \pm 0.003$		IPWA	$\gamma N \rightarrow \pi N$
-0.129	¹⁰ WADA 84	DPWA	Compton scattering
$-0.075 \pm 0.015$	BARBOUR 78	DPWA	$\gamma N \rightarrow \pi N$
-0.125	¹¹ NOELLE 78		$\gamma N \rightarrow \pi N$
-0.076	BERENDS 77	IPWA	$\gamma N \rightarrow \pi N$
$-0.087 \pm 0.006$	FELLER 76	DPWA	$\gamma N \rightarrow \pi N$

## $N(1440) \rightarrow n\gamma$ , helicity-1/2 amplitude A_{1/2}

VALUE (GeV ^{-1/2} )	DOCUMENT ID	TECN	COMMENT
+0.040 ±0.010 OUR ESTIMA	ATE		
$0.045 \pm 0.015$	ARNDT	96 IPW	$A \gamma N \rightarrow \pi N$
$0.037 \pm 0.010$	ILAWA	81 DPW	$VA \gamma N \rightarrow \pi N$
$0.030 \pm 0.003$	FUJII	81 DPW	$VA \gamma N \rightarrow \pi N$
$0.023 \pm 0.009$	ARAI	80 DPW	$VA \gamma N \rightarrow \pi N \text{ (fit 1)}$
$0.019 \pm 0.012$	ARAI	80 DPW	$VA \gamma N \rightarrow \pi N \text{ (fit 2)}$
$0.056 \pm 0.015$	CRAWFORD	80 DPW	$VA \gamma N \rightarrow \pi N$
$-0.029 \pm 0.035$	TAKEDA	80 DPW	$VA \gamma N \rightarrow \pi N$
• • • We do not use the follow	owing data for average	s, fits, limi	ts, etc. • • •
$0.085 \pm 0.006$	LI	93 IPW	$A \gamma N \rightarrow \pi N$
$+0.059\pm0.016$	BARBOUR	78 DPW	$VA \gamma N \rightarrow \pi N$
0.062	¹¹ NOELLE	78	$\gamma N \rightarrow \pi N$

## N(1440) FOOTNOTES

- $^1\, {\rm BAKER}$  79 finds a coupling of the N(1440) to the N  $\eta$  channel near (but slightly below)
- threshold. 
  2 LONGACRE 77 pole positions are from a search for poles in the unitarized T-matrix; the first (second) value uses, in addition to  $\pi N \to N\pi\pi$  data, elastic amplitudes from a Saclay (CERN) partial-wave analysis. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes. 
  3 From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix

- From method II of LONGACKE 75. Eyeuan inc with real part = 1383 MeV, -2×imaginary part = 210 MeV, and residue with modulus 92 MeV and phase = -54°.
   See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and A resonances as determined from Argand diagrams of π N elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.

- 6  ARNDT 91 (Soin SM90) also finds a second-sheet pole with real part =1413 MeV,  $-2\times$  imaginary part =256 MeV, and residue  $=(78-153\emph{i})$  MeV.
- ⁷ LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to  $\pi N \to N \pi \pi$  data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.
- An alternative which cannot be distinguished from this is to have a  $P_{13}$  resonance with M=1530 MeV,  $\Gamma=79$  MeV, and elasticity =+0.271. PLONGACRE 77 considers this coupling to be well determined.
- 10  WADA 84 is inconsistent with other analyses; see the Note on N and  $\Delta$  Resonances.
- 11  Converted to our conventions using M=1486 MeV,  $\Gamma=613$  MeV from NOELLE 78.

## N(1440) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

ARNDT	96	PR C53 430	+Strakovsky, Workman	(VPI)
ARNDT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BŘCO)
BATINIC	95	PR C51 2310	+Slaus, Svarc, Nefkens	(BOSK, UCLA)
HOEHLER	93	π N Newsletter 9 1		(KARL)
LI	93	PR C47 2759	+Arndt, Roper, Workman	` (VPI)
MANLEY	92	PR D45 4002	+Saleski	(KÈNT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	` (VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
CUTKOSKY	90	PR D42 235	+Wang	` (CMU)
WADA	84	NP B247 313	+Egawa, Imanishi, Ishii, Kato, Ukai+	(INUS)
CRAWFORD	83	NP B211 1	+Morton	(GLAS)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
AWAJI	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
FUJII	81	NP B187 53	+Hayashii, Iwata, Kajikawa+	(NAGO, OSAK)
ARAI	80	Toronto Conf. 93		(INUS)
Also	82	NP B194 251	Arai, Fujii	(INUS)
BRATASHEV	80	NP B166 525	Bratashevskij, Gorbenko, Derebchinskij+	(KFTI)
CRAWFORD	80	Toronto Conf. 107		(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMÚ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
ISHII	80	NP B165 189	+Egawa, Kato, Miyachi+	(KYOT, INUS)
TAKEDA	80	NP B168 17	+Arai, Fujii, Ikeda, Iwasaki+	(TOKY, INUS)
BAKER	79	NP B156 93	+Brown, Clark, Davies, Depagter, Evans+	(RHEL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)
NOELLE	78	PTP 60 778		(NAGO)
BERENDS	77	NP B136 317	+Donnachie	(LEID, MCHS) IJP
LONGACRE	77	NP B122 493	+Dolbeau	(SACL) IJP
Also	76	NP B108 365	Dolbeau, Triantis, Neveu, Cadiet	(SACL) IJP
FELLER	76	NP B104 219	+Fukushima, Horikawa, Kajikawa+	(NAGO, OSAK) IJP
FELTESSE	75	NP B93 242	+Ayed, Bareyre, Borgeaud, David+	(SACL) IJP
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC) IJP

## $N(1520) D_{13}$

$$I(J^P) = \frac{1}{2}(\frac{3}{2}^-)$$
 Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

## N(1520) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1515 to 1530 (≈ 1520) OUR	ESTIMATE			
1524± 4	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
1525 ± 10	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1519± 4	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the following the fol	owing data for average	s, fit	s, limits,	etc. • • •
1516±10	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
1515	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
$1526 \pm 18$	BATINIC	95	DPWA	$\pi N \rightarrow N \pi$ , $N \eta$
1510	LI	93	IPWA	$\gamma N \rightarrow \pi N$
1504	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
1503	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
1510	BERENDS	77	IPWA	$\gamma N \rightarrow \pi N$
1510	¹ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
1520	² LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

#### N(1520) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
110 to 135 (≈ 120) OUR ES	TIMATE			
124 ± 8	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
120 ± 15	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
114 ± 7	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the foll	owing data for average	s, fit	s, limits,	etc. • • •
106± 4	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
106	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
143±32	BATINIC	95	DPWA	$\pi N \rightarrow N \pi, N \eta$
120	LI	93	IPWA	$\gamma N \rightarrow \pi N$
124	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
183	BAKER	79	DPWA	$\pi^- \rho \rightarrow n\eta$
135	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
105	BERENDS	77	IPWA	$\gamma N \rightarrow \pi N$
110	1 LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
150	² LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

# Baryon Particle Listings N(1520)

	N(1520) POLE PO	SIT	ION	
REAL PART VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1515	ARNDT			$\pi N \rightarrow N \pi$
1510	3 HOEHLER			$\pi N \rightarrow \pi N$
1510±5	CUTKOSKY	80		$\pi N \rightarrow \pi N$
	e following data for average	es, fit	s, limits,	etc. • • •
511	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$
1514 or 1511	⁴ LONGACRE			$\pi N \rightarrow N \pi \pi$
1508 or 1505	¹ LONGACRE		IPWA	$\pi N \rightarrow N \pi \pi$
−2×IMAGINARY P	ART			
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
110	ARNDT			$\pi N \rightarrow N \pi$
120	³ HOEHLER	93		$\pi N \rightarrow \pi N$
$114 \pm 10$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • We do not use th	e following data for average	s, fit	s, limits,	etc. • • •
108	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$
146 or 137	⁴ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
109 or 107	¹ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
MODULUS  r				
VALUE (MeV)	DOCUMENT ID			COMMENT
34	ARNDT			$\pi N \rightarrow N \pi$
32 35 ± 2	HOEHLER CUTKOSKY	93 80	IPWA	$\pi N \rightarrow \pi N$ $\pi N \rightarrow \pi N$
	e following data for average			
33	ARNDT	91		$\pi N \rightarrow \pi N$ Soln SM90
	ARNOT	91	DEVVA	# N → # N 30111 31V190
PHASE 0	DOCUMENT 10		TECH	COLUMNIT
VALUE (°)	DOCUMENT ID			
7	ARNDT HOEHLER	95		$\pi N \rightarrow N \pi$ $\pi N \rightarrow \pi N$
- 8 -12±5	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$ $\pi N \rightarrow \pi N$
	e following data for average			
	-			
-10	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$
	N(1520) DECAY I	MOD	DES	
The following b	N(1520) DECAY I			fits or averages.
The following b	oranching fractions are our e	estima		

	Mode	Fraction $(\Gamma_j/\Gamma)$
$\Gamma_1$	Nπ	50-60 %
$\Gamma_2$	$N\eta$	
Гз	$N\pi\pi$	40-50 %
$\Gamma_4$	$\Delta \pi$	15-25 %
$\Gamma_5$	$\Delta(1232)\pi$ , <i>S</i> -wave	5-12 %
$\Gamma_6$	$\Delta(1232)\pi$ , <i>D</i> -wave	10-14 %
$\Gamma_7$	$N\rho$	15-25 %
Γ8	$N\rho$ , $S=1/2$ , $D$ -wave	
Г9	$N\rho$ , $S=3/2$ , $S$ -wave	
$\Gamma_{10}$	$N\rho$ , $S=3/2$ , $D$ -wave	
$\Gamma_{11}$	$N(\pi\pi)_{S-\text{wave}}^{I=0}$	<8 %
$\Gamma_{12}$	$p\gamma$	0.46-0.56 %
$\Gamma_{13}$	$p\gamma$ , helicity= $1/2$	0.001-0.034 %
$\Gamma_{14}$	$p\gamma$ , helicity=3/2	0.44-0.53 %
$\Gamma_{15}$	$n\gamma$	0.30-0.53 %
Γ ₁₆	$n\gamma$ , helicity= $1/2$	0.04-0.10 %
Ţ ₁₇	$n\gamma$ , helicity=3/2	0.25-0.45 %

## N(1520) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$				$\Gamma_1/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT
0.5 to 0.6 OUR ESTIMATE				
$0.59 \pm 0.03$	MANLEY	92	<b>IPWA</b>	$\pi N \rightarrow \pi N \& N \pi \pi$
$0.58 \pm 0.03$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
$0.54 \pm 0.03$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
ullet $ullet$ We do not use the follow	ing data for average	es, fit	s, limits,	, etc. • • •
0.61	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
$0.46 \pm 0.06$	BATINIC	95	DPWA	$\pi N \rightarrow N \pi$ , $N \eta$
$\Gamma(N\eta)/\Gamma_{\text{total}}$				$\Gamma_2/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT
ullet $ullet$ We do not use the follow	ing data for average	es, fit	s, limits,	etc. • • •
$0.001 \pm 0.002$	BATINIC	95	DPWA	$\pi N \rightarrow N \pi, N \eta$

(Γ _Ι Γ _Γ ) ¹ VALUE	$^{1/2}/\Gamma_{ m total}$ in N $\pi$ $-$	→ N(1520) → Nη  DOCUMENT ID		TECN	COMMENT	(Γ ₁ Γ ₂ ) ^{1/2} /
	Ve do not use the fo	ollowing data for average				
0.02		BAKER	79	DPWA	$\pi^- p \rightarrow$	$n\eta$
+0.011		FELTESSE	75	DPWA	Soln A; s	ee BAKER 79
	1986 edition to ag	plings from $\pi N \to N \pi \tau$ ree with the baryon-first yed by choosing a negat $2)\pi$ .	conv	éntion;	the overal	phase
$(\Gamma_i\Gamma_f)^{\frac{1}{2}}$	$\frac{1}{2}/\Gamma_{\text{total}}$ in $N\pi$ —	→ N(1520) → Δ(123	2)π.	. <i>S</i> -wav	e	(Γ ₁ Γ ₅ ) ^{1/2} /
VALUE		DOCUMENT ID		TECN	COMMENT	,
	o -0.20 OUR ESTI					
$-0.18 \pm$	0.05	MANLEY	92	IPWA		Ν & Νππ
0.26 0.24		^{1,5} LONGACRE ² LONGACRE	77 75	IPWA IPWA	$\pi N \rightarrow N$ $\pi N \rightarrow N$	
(Г.Г.) ¹	½/Γ _{total} in Nπ →	→ N(1520) → Δ(123	2)π.	D-wav	re .	(Γ ₁ Γ ₆ ) ^{1/2} /
VALUE		DOCUMENT ID				
-0.28 to	o -0.24 OUR ESTI	IMATE				
$-0.29 \pm$	0.03	MANLEY		IPWA		Ν & Νππ
-0.21		^{1,5} LONGACRE		IPWA	$\pi N \rightarrow N$	
-0.30		² LONGACRE	75	IPWA	$\pi N \rightarrow N$	Ιππ
$(\Gamma_i\Gamma_i)^{\frac{1}{2}}$	$\frac{1}{2}$ / $\Gamma_{\text{total}}$ in $N\pi$	$N(1520) \rightarrow N\rho$ , S=	=3/2	S-wa	ve	(Γ ₁ Γ ₉ ) ^{1/2} /
VALUE	/ · total ······	DOCUMENT ID	-,-	TECN	COMMENT	
-0.35 to	-0.31 OUR ESTI	MATE				
$-0.35 \pm$	0.03	MANLEY		IPWA	$\pi N \rightarrow \pi$	Ν & Νππ
0.35		^{1,5} LONGACRE	77	IPWA	$\pi N \rightarrow N$	Ιππ
-0.24		² LONGACRE	75	IPWA	$\pi N \rightarrow N$	Ιππ
$(\Gamma_I\Gamma_f)^{\frac{1}{2}}$	$\frac{1}{2}/\Gamma_{\text{total}}$ in $N\pi \rightarrow$	$N(1520) \rightarrow N(\pi\pi)$	/=0 S-w	ave		(Γ ₁ Γ ₁₁ ) ^{1/2} /
		DOCUMENT ID			COMMENT	
VALUE						
<i>VALUE</i> <b> 0.22 t</b> e	-0.06 OUR ESTI	MATE				
VALUE	0 -0.06 OUR ESTI	1,5 LONGACRE 2 LONGACRE	77 75	IPWA IPWA	$\pi N \rightarrow N$ $\pi N \rightarrow N$	

## N(1520) PHOTON DECAY AMPLITUDES

## $N(1520) \rightarrow p\gamma$ , helicity-1/2 amplitude $A_{1/2}$

		•	-/-		
VALUE (GeV ^{-1/2} )		DOCUMENT I	D	TECN	COMMENT
-0.024 ±0.009	OUR ESTIMATE				
$-0.020 \pm 0.007$		ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
$-0.028 \pm 0.014$		CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
$-0.007 \pm 0.004$		AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$
$-0.032 \pm 0.005$		ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
$-0.032 \pm 0.004$		ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
$-0.031 \pm 0.009$		BRATASHE	V80	DPWA	$\gamma N \rightarrow \pi N$
$-0.019 \pm 0.007$		CRAWFORD	08	DPWA	$\gamma N \rightarrow \pi N$
$-0.0430 \pm 0.0063$		ISHII	80	DPWA	Compton scattering
• • We do not	use the following d	ata for avera	ges, fits	, limits,	etc. • • •
-0.020 ±0.002		LI	93	IPWA	$\gamma N \rightarrow \pi N$
-0.012		WADA	84	DPWA	Compton scattering
$-0.016 \pm 0.008$		BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
-0.008	6	NOELLE	78		$\gamma N \rightarrow \pi N$
-0.021		BERENDS	77	IPWA	$\gamma N \rightarrow \pi N$
-0.005 + 0.005		FELLER	76	DPWA	$\gamma N \rightarrow \pi N$

#### $N(1520) \rightarrow p\gamma$ , helicity-3/2 amplitude A_{3/2}

VALUE (GeV-1/2)	DOCUMENT ID		TECN	COMMENT
$+0.166 \pm 0.005$ OUR ESTIMATE				
0.167 ±0.005	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
0.156 ±0.022	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
0.168 ±0.013	AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$
0.178 ±0.003	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
$0.162 \pm 0.003$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
0.166 ±0.005	BRATASHEV	. 80	DPWA	$\gamma N \rightarrow \pi N$
$0.167 \pm 0.010$	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
$0.1695 \pm 0.0014$	ISHII	80	DPWA	Compton scattering
• • We do not use the following of	lata for averages	, fits	, limits,	etc. • • •
0.167 ±0.002	LI	93	IPWA	$\gamma N \rightarrow \pi N$
0.168	WADA	84	DPWA	Compton scattering
$+0.157 \pm 0.007$	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
0.206	NOELLE	78		$\gamma N \rightarrow \pi N$
+0.075	BERENDS	77	IPWA	$\gamma N \rightarrow \pi N$
$+0.164 \pm 0.008$	FELLER	76	DPWA	$\gamma N \rightarrow \pi N$

## **Baryon Particle Listings** N(1520), N(1535)

$N(1520) \rightarrow n\gamma$ , helicity-1/2 amplitude A
----------------------------------------------------------

VALUE (GeV ^{-1/2} )	DOCUMENT ID		TECN	COMMENT	
-0.059±0.009 OUR ESTIMATE					_
$-0.048 \pm 0.008$	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$	1
$-0.066 \pm 0.013$	AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$	
$-0.067 \pm 0.004$	FUJII	81	DPWA	$\gamma N \rightarrow \pi N$	
$-0.076 \pm 0.006$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$	
$-0.071 \pm 0.011$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$	
$-0.056 \pm 0.011$	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$	
$-0.050\pm0.014$	TAKEDA	80	DPWA	$\gamma N \rightarrow \pi N$	
ullet $ullet$ We do not use the following	data for averages	, fits	, limits,	etc. • • •	
$-0.058 \pm 0.003$	LI	93	IPWA	$\gamma N \rightarrow \pi N$	
$-0.055 \pm 0.014$	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$	
-0.060	⁶ NOELLE	78		$\gamma N \rightarrow \pi N$	

## $N(1520) \rightarrow n\gamma$ , helicity-3/2 amplitude A_{3/2}

VALUE (GeV ^{-1/2} )	DOCUMENT ID		TECN	COMMENT
$-0.139\pm0.011$ OUR ESTIMATE				
$-0.140 \pm 0.010$	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
$-0.124 \pm 0.009$	AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$
$-0.158 \pm 0.003$	FUJII	81	DPWA	$\gamma N \rightarrow \pi N$
$-0.147 \pm 0.008$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
$-0.148 \pm 0.009$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
$-0.144 \pm 0.015$	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
$-0.118 \pm 0.011$	TAKEDA	80	DPWA	$\gamma N \rightarrow \pi N$
• • We do not use the following	g data for average	s, fit	s, limits,	etc. • • •
$-0.131 \pm 0.003$	LI	93	IPWA	$\gamma N \rightarrow \pi N$
$-0.141 \pm 0.015$	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
-0.127	⁶ NOELLE	78		$\gamma N \rightarrow \pi N$

## N(1520) FOOTNOTES

- LONGACRE 77 pole positions are from a search for poles in the unitarized T-matrix; the first (second) value uses, in addition to  $\pi\,N\,\rightarrow\,N\pi\pi$  data, elastic amplitudes from a Saclay (CERN) partial-wave analysis. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.
- This with Breit-Wigner Circles to the 1-matrix amplitudes.

  2 From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.
- amplitudes. ³ See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and  $\Delta$  resonances as determined from Argand diagrams of  $\pi N$  elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams. ⁴ LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to  $\pi N \to N \pi \pi$  data, elastic amplitudes from a Saclay (CERN) partial-wave analysis. ⁵ LONGACRE 77 considers this coupling to be well determined.
- Converted to our conventions using M=1528 MeV,  $\Gamma=187$  MeV from NOELLE 78.

## N(1520) REFERENCES

For early references, see Physics Letters 111B 70 (1982). For very early references, see Reviews of Modern Physics 37 633 (1965).

		00 650 100	. 6	(1/01)
ARNDT	96	PR C53 430	+Strakovsky, Workman	(VPI)
ARNDT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BRCO)
BATINIC	95	PR C51 2310	+Slaus, Svarc, Nefkens	(BOSK, UCLA)
HOEHLER	93	π N Newsletter 9 1		(KARL)
LI	93	PR C47 2759	+Arndt, Roper, Workman	(VPI)
MANLEY	92	PR D45 4002	+Saleski	(KENT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
WADA	84	NP B247 313	+Egawa, Imanishi, Ishii, Kato, Ukai+	(INUS)
CRAWFORD	83	NP B211 1	+ Morton	(GLAS)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
AWA JI	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
FUJII	81	NP B187 53	+Hayashii, Iwata, Kajikawa+	(NAGO, OSAK)
ARAI	80	Toronto Conf. 93	· ·	(INUS)
Also	82	NP B194 251	Arai, Fujii	(INUS)
BRATASHEV	. 80	NP B166 525	Bratashevskij, Gorbenko, Derebchinskij+	- (KFTI)
CRAWFORD	80	Toronto Conf. 107		(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMŮ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
ISHII	80	NP B165 189	+Egawa, Kato, Miyachi+	(KYOT, INUS)
TAKEDA	80	NP B168 17	+Arai, Fujii, Ikeda, Iwasaki+	(TOKY, INUS)
BAKER	79	NP B156 93	+Brown, Clark, Davies, Depagter, Evans+	
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)
NOELLE	78	PTP 60 778	+Lasinski, Rosemeiu, Sinauja+	(NAGO)
BERENDS	77	NP B136 317	+Donnachie	(LEID, MCHS) IJP
	77	NP B136 317 NP B122 493	+ Donnachie + Dolbeau	(SACL) IJP
LONGACRE	76		Dolbeau, Triantis, Neveu, Cadiet	(SACL) IJP
Also		NP B108 365		(NAGO, OSAK) IJP
FELLER	76	NP B104 219	+Fukushima, Horikawa, Kajikawa+	(SACL) IJP
FELTESSE	75	NP B93 242	+Ayed, Bareyre, Borgeaud, David+	
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC) IJP

## $N(1535) S_{11}$

 $I(J^P) = \frac{1}{2}(\frac{1}{2}^-)$  Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

## N(1535) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1520 to 1555 (≈ 1535) OUR ESTI			TECIV	COMMENT
1534 ± 7	MANLEY	92	ΙΡ\Λ/Δ	$\pi N \rightarrow \pi N \& N \pi \pi$
1550±40	CUTKOSKY			$\pi N \rightarrow \pi N$
1526± 7	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the following			s, limits,	etc. • • •
1549+ 2	ABAEV	96	DPWA	$\pi^- p \rightarrow \eta n$
1525 ± 10	ARNDT	96		$\gamma N \rightarrow \pi N$
1535	ARNDT	95		$\pi N \rightarrow N \pi$
1542± 6	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$
1537	BATINIC	95E	DPWA	$\pi N \rightarrow N\pi, N\eta$
$1544 \pm 13$	KRUSCHE	95	DPWA	$\gamma p \rightarrow p \eta$
1518	LI	93	IPWA	$\gamma N \rightarrow \pi N$
1513	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
1511	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
1500	BERENDS	77	IPWA	$\gamma N \rightarrow \pi N$
1547 ± 6	BHANDARI	77	DPWA	Uses $N\eta$ cusp
1520	¹ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
1510	² LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

## N(1535) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
100 to 250 (≈ 150) OUR ESTIMA	ATE.			
$151 \pm 27$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
240±80	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
$120 \pm 20$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the following	g data for average	s, fit	s, limits,	etc. • • •
169±12	ABAEV	96	DPWA	$\pi^- \rho \rightarrow \eta n$
103± 5	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
66	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
$150 \pm 15$	BATINIC	95	DPWA	$\pi N \rightarrow N \pi, N \eta$
145	BATINIC	95B	DPWA	$\pi N \rightarrow N \pi, N \eta$
200 ± 40	KRUSCHE	95	DPWA	$\gamma p \rightarrow p \eta$
84	LI	93	IPWA	$\gamma N \rightarrow \pi N$
136	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
180	BAKER	79	DPWA	$\pi^- \rho \rightarrow n\eta$
132	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
57	BERENDS	77	IPWA	$\gamma N \rightarrow \pi N$
139±33	BHANDARI	77	DPWA	Uses $N\eta$ cusp
135	¹ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
100	² LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

## N(1535) POLE POSITION

DOCUMENT ID TECN COMMENT

## **REAL PART**

1501	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1487	³ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
1510 ± 50	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the	following data for average	s, fits	s, limits,	etc. • • •
1499	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$
1496 or 1499	⁴ LONGACRE	78	<b>IPWA</b>	$\pi N \rightarrow N \pi \pi$
1519± 4	BHANDARI	77	DPWA	Uses $N\eta$ cusp
1525 or 1527	¹ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
-2×IMAGINARY PAI	₹T			
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
124	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
260 ± 80	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
$\bullet$ $\bullet$ We do not use the	following data for average	es, fit	s, limits,	etc. • • •
110	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM} 90$
103 or 105	4 LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
140±32	BHANDARI	77	DPWA	Uses $N\eta$ cusp
135 or 123	1 LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$

## N(1535) ELASTIC POLE RESIDUE

## MODULUS |r|

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
31	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
120±40	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the follow	ing data for average	es, fit	s, limits,	etc. • • •
23	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$

PHASE $\theta$	DOCUMENT ID		TECN	COMMENT
-12	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
$+15\pm45$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use th	e following data for average	s, fits	s, limits,	etc. • • •
-13	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$

## N(1535) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction $(\Gamma_i/\Gamma)$	
Γ ₁	Nπ	35-55 %	
$\Gamma_2$	$N\eta$	30-55 %	
$\Gamma_3$	$N\pi\pi$	1-10 %	
$\Gamma_4$	$\Delta\pi$	<1 %	
Γ ₅	$\Delta(1232)\pi$ , $D$ -wave		
$\Gamma_6$	$N\rho$	<4 %	
$\Gamma_7$	$N\rho$ , $S=1/2$ , $S$ -wave		
Γ8	$N\rho$ , $S=3/2$ , $D$ -wave		
Γ9	$N(\pi\pi)_{S-\text{wave}}^{I=0}$	<3 %	
$\Gamma_{10}$	$N(1440)\pi$	<7 %	
$\Gamma_{11}$	$p\gamma$	0.08-0.27 %	
$\Gamma_{12}$	$p\gamma$ , helicity=1/2	0.08-0.27 %	
$\Gamma_{13}$	$n\gamma$	0.004-0.29 %	
Γ ₁₄	$n\gamma$ , helicity=1/2	0.004-0.29 %	

#### N(1535) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$				$\Gamma_1/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT
0.35 to 0.55 OUR ESTIM	ATE			
0.51 ±0.05	MANLEY	92	<b>IPWA</b>	$\pi N \rightarrow \pi N \& N \pi \pi$
0.50 ±0.10	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
0.38 ±0.04	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the f	ollowing data for average	s, fit	s, limits,	etc. • • •
0.31	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
0.34 ±0.09	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$
$0.297 \pm 0.026$	BHANDARI	77	DPWA	Uses $N\eta$ cusp
$\Gamma(N\eta)/\Gamma_{\text{total}}$				Γ ₂ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the f	ollowing data for average	s, fit	s, limits,	etc. • • •
$0.59 \pm 0.02$	ABAEV	96	DPWA	$\pi^- \rho \rightarrow \eta n$
$0.63 \pm 0.07$	BATINIC	95	DPWA	$\pi N \rightarrow N\pi$ , $N\eta$
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\pi -$	$\rightarrow N(1535) \rightarrow N\eta$			(Γ₁Γ₂) ¹ /2/Γ
VALUE	DOCUMENT ID		TECN	COMMENT
+0.44 to +0.50 OUR EST	IMATE			
$+0.47\pm0.02$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N & N \pi \pi$

Note: Signs of couplings from  $\pi N \to N \pi \pi$  analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the  $\Delta(1620)$   $S_{31}$ coupling to  $\Delta(1232)\pi$ .

79 DPWA  $\pi^- p \rightarrow n\eta$ 

75 DPWA 1488-1745 MeV

BAKER

FELTESSE

+0.33

+0.48

$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\pi \to N($	1535) → ∆(123	32)π.	D-way	νe (Γ ₁ Γ ₅ ) ^{1/2} /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
<u>VALUE</u> <b>−0.04 to +0.06 OUR ESTIMAT</b>	E			
$+0.00\pm0.04$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
0.00	1 LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
+0.06	² LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\pi \to N($	1535) $\rightarrow N\rho$ , S	=1/2	2, <i>S</i> -wa	ve (Γ ₁ Γ ₇ ) ^{1/2} /Γ
			TECN	COMMENT
-0.14 to -0.06 OUR ESTIMAT	Ε			
$-0.10 \pm 0.03$				$\pi N \rightarrow \pi N \& N \pi \pi$
-0.10	¹ LONGACRE			
-0.09	² LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \to N($	1535) $\rightarrow N(\pi\pi$	)/=0 S-wa	ave	(Γ₁Γ ₉ ) ^½ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
+0.03 to +0.13 OUR ESTIMAT				
$+0.07\pm0.04$	MANLEY		IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
+0.08	1 LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
+0.09	² LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \to I$	$V(1535) \rightarrow N(1440)\pi$		(Γ₁Γ₁₀) ^{1/2} /Γ
VALUE	DOCUMENT ID	TECN	COMMENT
$+0.10\pm0.05$	MANLEY 92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$

## N(1535) PHOTON DECAY AMPLITUDES

## $N(1535) \rightarrow p\gamma$ , helicity-1/2 amplitude A_{1/2}

$VALUE$ (GeV $^{-1/2}$ )		DOCUMENT ID		TECN	COMMENT
+0.070 ±0.012	OUR ESTIMATE				
$0.060 \pm 0.015$		ARNDT .	96	IPWA	$\gamma N \rightarrow \pi N$
$0.097 \pm 0.006$	_	BENMERROU.			
$0.095 \pm 0.011$	5	BENMERROU.	.91		$\gamma p \rightarrow p \eta$
$0.053 \pm 0.015$		CRAWFORD			
$0.077 \pm 0.021$		AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$
$0.083 \pm 0.007$		ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
$0.080 \pm 0.007$		ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
$0.029 \pm 0.007$		BRATASHEV			
$0.065 \pm 0.016$		CRAWFORD			
$0.0704 \pm 0.0091$		ISHII	80	DPWA	Compton scattering
<ul> <li>◆ ◆ We do not</li> </ul>	use the following d	lata for averages	, fits	, limits,	etc. • • •
0.110 to 0.140		KRUSCHE	95	DPWA	$\gamma p \rightarrow p \eta$
$0.125 \pm 0.025$		KRUSCHE	95C	IPWA	$\gamma d \rightarrow \eta N(N)$
$0.061 \pm 0.003$		LI	93	IPWA	$\gamma N \rightarrow \pi N$
0.055		WADA	84	DPWA	Compton scattering
$+0.082 \pm 0.019$		BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
0.046	6	NOELLE	78		$\gamma N \rightarrow \pi N$
+0.034		BERENDS	77	IPWA	$\gamma N \rightarrow \pi N$
$+0.070 \pm 0.004$		FELLER	76	DPWA	$\gamma N \rightarrow \pi N$

## $N(1535) \rightarrow n\gamma$ , helicity-1/2 amplitude A_{1/2}

VALUE (GeV-1/2)	DOCUMENT ID		TECN	COMMENT
-0.046±0.027 OUR EST	MATE			
$-0.020\pm0.035$	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
$0.035 \pm 0.014$	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
$-0.062\pm0.003$	FUJII	81	DPWA	$\gamma N \rightarrow \pi N$
$-0.075\pm0.019$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
$-0.075 \pm 0.018$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
$-0.098 \pm 0.026$	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
$-0.011 \pm 0.017$	TAKEDA	80	DPWA	$\gamma N \rightarrow \pi N$
<ul> <li>We do not use the f</li> </ul>	following data for average	s, fits	, limits,	etc. • • •
$-0.100\pm0.030$	KRUSCHE	<b>95</b> C	IPWA	$\gamma d \rightarrow \eta N(N)$
$-0.046 \pm 0.005$	LI	93	IPWA	$\gamma N \rightarrow \pi N$
$-0.112 \pm 0.034$	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
-0.048	⁶ NOELLE	78		$\gamma N \rightarrow \pi N$

## $N(1535) \rightarrow N\gamma$ , ratio $A_{1/2}^n/A_{1/2}^p$

VALUE (GeV-1/2)	DOCUMENT ID	TECN			
ullet $ullet$ We do not use the following	data for averages, fits,	limits, etc.	•	•	•
$-0.84 \pm 0.15$	MUKHOPAD 95B	IPWA			

## N(1535) FOOTNOTES

- 1  LONGACRE 77 pole positions are from a search for poles in the unitarized T-matrix; the first (second) value uses, in addition to  $\pi\,N\to\,N\pi\,\pi$  data, elastic amplitudes from a Saclay (CERN) partial-wave analysis. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.
- ² From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.
- amplitudes.  3  See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and  $\Delta$  resonances as determined from Argand diagrams of  $\pi N$  elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.
- 4 LONGACE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to  $\pi N \to N \pi \pi$  data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.
- 5 BENMERROUCHE 91 uses an effective Lagrangian approach to analyze  $\eta$  photoproduc-
- tion data. 6 Converted to our conventions using M=1548 MeV,  $\Gamma=73$  MeV from NOELLE 78.

## N(1535) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

ABAEV	96	PR C53 385	+Nefkens	(UCLA)
ARNDT	96	PR C53 430	+Strakovsky, Workman	` (VPI)
ARNDT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BŘCO)
BATINIC	95	PR C51 2310	+Slaus, Svarc, Nefkens	(BOSK, UCLA)
BATINIC	95B	PR C52 2188	+Slaus, Svarc	(BOSK)
	.95	PR D51 3237	Benmerrouche, Mukhopadhyay, Zhang	(RPI, SASK)
KRUSCHE	95	PRL 74 3736	+Ahrens, Anton+ (GIES, MANZ, GLAS	, BONN, DARM)
KRUSCHE	95C	PL B358 40	+Ahrens+ (GIES, MANZ, GLAS	, BONN, DARM)
MUKHOPAD	95B	PL B364 1	Mukhopadhyay, Zhang, Benmerrouche	(RPI, SASK)
HOEHLER	93	π N Newsletter 9 1		(KARL)
LI ·	93	PR C47 2759	+Arndt, Roper, Workman	(VPI)
MANLEY	92	PR D45 4002	+Saleski	(KĖNT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
BENMERROU	.91	PRL 67 1070	Benmerrouche, Mukhopadhyay	(RPI)
WADA	84	NP B247 313	+Egawa, Imanishi, Ishii, Kato, Ukai+	(INUS)
CRAWFORD	83	NP B211 1	+Morton	(GLAS)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+ (HI	ELS, CIT, CERN)
AWA JI	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)

## N(1535), N(1650)

FUJII	81	NP B187 53	+Hayashii, Iwata, Kajikawa+	(NAGO, OSAK)
ARAI	80	Toronto Conf. 93		(INUS)
Also	82	NP B194 251	Arai, Fujii	(INUS)
BRATASHEV	80	NP B166 525	Bratashevskij, Gorbenko, Derebchinskij+	(KFTI)
CRAWFORD	80	Toronto Conf. 107		(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMÚ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
ISHII	80	NP B165 189	+Egawa, Kato, Miyachi+	(KYOT, INUS)
TAKEDA	80	NP B168 17	+Arai, Fujii, Ikeda, Iwasaki+	(TOKY, INUS)
BAKER	79	NP B156 93	+Brown, Clark, Davies, Depagter, Evans+	(RHEL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)
NOELLE	78	PTP 60 778		(NAGO)
BERENDS	77	NP B136 317	+Donnachie	(LEID, MCHS) IJP
BHANDARI	77	PR D15 192	+Chao	(CMU) IJP
LONGACRE	77	NP B122 493	+Dolbeau	(SACL) IJP
Also	76	NP B108 365	Dolbeau, Triantis, Neveu, Cadiet	(SACL) IJP
FELLER	76	NP B104 219	+Fukushima, Horikawa, Kajikawa+	(NAGO, OSAK) IJP
FELTESSE	75	NP B93 242	+Ayed, Bareyre, Borgeaud, David+	(SACL) IJP
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC) IJP

## $N(1650) S_{11}$

$$I(J^P) = \frac{1}{2}(\frac{1}{2})$$
 Status: ****

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters **111B** (1982).

## N(1650) MASS

	• •			
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1640 to 1680 (≈ 1650) OUR EST	IMATE			
1659± 9	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
$1650 \pm 30$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1670 ± 8	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the following	g data for average	s, fits	s, limits,	etc. • • •
1677± 8	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
1667	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1712	¹ ARNDT	95		$\pi N \rightarrow N \pi$
$1669 \pm 17$	BATINIC			$\pi N \rightarrow N \pi$ , $N \eta$
1713 ± 27	² BATINIC	95	DPWA	$\pi N \rightarrow N \pi$ , $N \eta$
1674	LI	93	IPWA	$\gamma N \rightarrow \pi N$
1688	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
1672	MUSETTE	80	IPWA	$\pi^- p \rightarrow \Lambda K^0$
1680	SAXON	80	DPWA	$\pi^- \rho \rightarrow \Lambda K^0$
1680	BAKER	78	DPWA	$\pi^- \rho \rightarrow \Lambda K^0$
1694	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
1700 ± 5	³ BAKER	77	IPWA	$\pi^- p \rightarrow \Lambda K^0$
1680	³ BAKER	77	DPWA	$\pi^- p \rightarrow \Lambda K^0$
1700	⁴ LONGACRE	77	<b>IPWA</b>	$\pi N \rightarrow N \pi \pi$
1675	KNASEL	75	DPWA	$\pi^- p \rightarrow \Lambda K^0$
1660	⁵ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

## N(1650) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
145 to 190 (≈ 150) OUR ESTIMA	TE			
173±12	MANLEY	92	<b>IPWA</b>	$\pi N \rightarrow \pi N \& N \pi \pi$
$150 \pm 40$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
$180 \pm 20$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	data for averages	i, fits	, limits,	etc. • • •
160 ± 12	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
90	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
184	¹ ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
$215 \pm 32$	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$
279 ± 54	² BATINIC	95	DPWA	$\pi N \rightarrow N \pi$ , $N \eta$
225	LI	93	IPWA	$\gamma N \rightarrow \pi N$
183	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
179	MUSETTE	80	IPWA	$\pi^- p \rightarrow \Lambda K^0$
120	SAXON	80	DPWA	$\pi^{-} p \rightarrow \Lambda K^{0}$
90	BAKER	78	DPWA	$\pi^- p \rightarrow \Lambda K^0$
193	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
$130 \pm 10$	³ BAKER	77	IPWA	$\pi^- p \rightarrow \Lambda K^0$
90	3 BAKER	77	DPWA	$\pi^- p \rightarrow \Lambda K^0$
170	⁴ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
170	KNASEL	75	DPWA	$\pi^- p \rightarrow \Lambda K^0$
130	⁵ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

## N(1650) POLE POSITION

REAL PART
VALUE (MeV)

DOCUMENT ID		TECN	COMMENT		
			$\pi N \rightarrow N \pi$		
¹ ARNDT	95	DPWA	$\pi N \rightarrow N \pi$		
⁶ HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$		
CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$		
<ul> <li>• • We do not use the following data for averages, fits, limits, etc.</li> </ul>					
⁷ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$		
⁴ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$		
	<ul> <li>ARNDT</li> <li>HOEHLER</li> <li>CUTKOSKY</li> <li>data for averages</li> <li>ARNDT</li> <li>LONGACRE</li> </ul>	ARNDT 95 1 ARNDT 95 6 HOEHLER 93 CUTKOSKY 80 data for averages, fits ARNDT 91 7 LONGACRE 78	ARNDT 95 DPWA 1 ARNDT 95 DPWA 6 HOEHLER 93 ARGD CUTKOSKY 80 IPWA		

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
82	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
192	¹ ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
163	⁶ HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
150±30	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use t	he following data for average	es, fit	s, limits,	etc. • • •
160	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$
117 or 119	⁷ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
174 or 173	⁴ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$

## N(1650) ELASTIC POLE RESIDUE

## MODULUS |r|

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
22	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
72	$^{ m 1}$ ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
39	HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
$60 \pm 10$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the following	g data for average	s, fit	s, limits,	etc. • • •
54	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$

#### PHASE A

VALUE (°)	DOCUMENT ID		TECN	COMMENT
29	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
<b>- 85</b>	¹ ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
- 37	HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
$-75 \pm 25$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the following	g data for average	es, fit	s, limits,	etc. • • •
_ 38	ARNDT	91	DP\//Δ	πN → πN Soin SM90

## N(1650) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction $(\Gamma_j/\Gamma)$
$\overline{\Gamma_1}$	Nπ	55-90 %
$\Gamma_2^-$	$N\eta$	3-10 %
$\Gamma_3$	ΛK	3-11 %
$\Gamma_4$	ΣΚ	
$\Gamma_5$	$N\pi\pi$	10-20 %
$\Gamma_6$	$\Delta\pi$	1-7 %
$\Gamma_7$	$\Delta(1232)\pi$ , $ extit{D}\! ext{-}$ wave	
Γ8	$N\rho$	4-12 %
Гэ	$N\rho$ , $S=1/2$ , $S$ -wave	
$\Gamma_{10}$	$N\rho$ , $S=3/2$ , $D$ -wave	
$\Gamma_{11}$	$N(\pi\pi)_{S-\text{wave}}^{I=0}$	<4 %
$\Gamma_{12}$	$N(1440)\pi$	<5 %
$\Gamma_{13}$	$p\gamma$	0.04-0.18 %
Γ ₁₄	$p\gamma$ , helicity $=1/2$	0.04-0.18 %
$\Gamma_{15}$	$n\gamma$	0.003-0.17 %
$\Gamma_{16}$	$n\gamma$ , helicity $=1/2$	0.003-0.17 %

## N(1650) BRANCHING RATIOS

Γ(Nπ)/Γ _{total}	DOCUMENT ID		TECN	COMMENT
0.65 to 0.90 OUR ESTI			1201	COMMENT
0.89 ± 0.07	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
0.65 ± 0.10	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
$0.61 \pm 0.04$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use th	ne following data for average	s, fit	s, limits,	etc. • • •
0.99	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
0.27	¹ ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
0.94 ± 0.07	BATINIC	95	DPWA	$\pi N \rightarrow N \pi, N \eta$
$0.49 \pm 0.21$	² BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\pi$

VALUE	DOCUMENT ID		TECN	COMMENT	
• • • We do not use the following	data for average	s, fits	s, limits,	etc. • • •	
$0.06 \pm 0.05$	BATINIC	95	DPWA	$\pi N \rightarrow N \pi, N \tau$	1
$0.02 \pm 0.03$	² BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\tau$	,

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N$	$\tau \to N(1650) \to N\eta$			$(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma$
VALUE	DOCUMENT ID	TECN	COMMENT	
• • • We do not use th	e following data for averages, fi	ts, limits,	etc. • • •	
-0.09	8 BAKER 79	DPWA	$\pi^- p \rightarrow r$	$\eta$

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \to N(16)$	550) → <i>Λ K</i> - <u>DOCUMENT IE</u>		TECN	$(\Gamma_1\Gamma_3)^{\frac{1}{2}}$
-0.27 to -0.17 OUR ESTIMATE	DOCUMENT IL		1ECN	COMMENT
-0.22	BELL	83	DPWA	$\pi^- p \rightarrow \Lambda K^0$
-0.22	SAXON	80		$\pi^- p \rightarrow \Lambda K^0$
• • We do not use the following				
-0.25	9 BAKER			See SAXON 80
$-0.23 \pm 0.01$	3 BAKER	77		$\pi^- p \rightarrow \Lambda K^0$
-0.25	3 BAKER	77	DPWA	$\pi^- p \rightarrow \Lambda K^0$
0.12	KNASEL	75	DPWA	$\pi^- \rho \rightarrow \Lambda K^0$
$\left( \Gamma_I \Gamma_f \right)^{1/2} / \Gamma_{ ext{total}}$ in $N\pi  o N(16)$	550) → ΣK		TECN	(Γ ₁ Γ ₄ ) ^{1/2} /
• • We do not use the following				
0.254		80	DPWA	$\pi p \rightarrow \Sigma K$
	.0 DEANS			$\pi N \rightarrow \Sigma K$
0.20	KNASEL	75	DPWA	
Note: Signs of couplings fr 1986 edition to agree with ambiguity is resolved by c coupling to $\Delta(1232)\pi$ .	the baryon-firs choosing a nega	t con tive s	vention; ign for t	the overall phase the $\Delta(1620)$ $S_{31}$
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{ ext{total}}$ in $N\pi  o N(16)$	$50) \rightarrow \Delta(123)$ DOCUMENT ID	32)π	, <i>D</i> -wav	ν <b>e (Γ₁Γ₇)^{1/2}/</b> Ι
+0.15 to 0.23 OUR ESTIMATE +0.12±0.04	MANLEY	00	IPWA	- A/ A/ 0: A/
$+0.12\pm0.04$ +0.29 4,1	LONGACRE			$\pi N \rightarrow \pi N \& N \pi \pi$ $\pi N \rightarrow N \pi \pi$
+0.15	5 LONGACRE		IPWA	
				1/
$(\Gamma_I \Gamma_f)^{1\!\!/\!2}/\Gamma_{ ext{total}}$ in $N\pi o N(16)$	$50) \rightarrow N \rho$ , $S$	=1/2	2, <i>S</i> -wa	ve (۲٫۱۲ _۶ ) ^½ /۱
±0.03 to ±0.19 OUR ESTIN	DOCUMENT ID		TECN	COMMENT
-0.01±0.09	MANLEY	02	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
+0.17 4,1	1 LONGACRE	77		$\pi N \rightarrow \pi N \otimes N \pi \pi$ $\pi N \rightarrow N \pi \pi$
-0.16	5 LONGACRE	75		$\pi N \rightarrow N \pi \pi$
$(\Gamma_{\rm I}\Gamma_{\rm f})^{1/2}/\Gamma_{\rm total}$ in $N\pi \to N(16)$ (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE) (NLUE)	DOCUMENT ID  MANLEY  LONGACRE	92	<i>TECN</i> IPWA	COMMENT
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{ ext{total}}$ in $N\pi  o N(16)$		)/=0 /5-w	ave	(Γ ₁ Γ ₁₁ ) ^{1/2} /Γ
/ALUE +0.04 to +0.18 OUR ESTIMATE	DOCUMENT ID			COMMENT
+0.12±0.08	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
0.00 4,1:	LONGACRE	77		$\pi N \rightarrow \pi N \otimes N \pi \pi$ $\pi N \rightarrow N \pi \pi$
+0.25	5 LONGACRE	75		$\pi N \rightarrow N \pi \pi$
4				.,,
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{ ext{total}}$ in $N\pi  o N(165)$	$50) \rightarrow N(144)$	$0)\pi$		(Γ ₁ Γ ₁₂ ) ^{1/2} /Γ
ALUE	DOCUMENT ID			COMMENT
$+0.11 \pm 0.06$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
N(1650) PHC	TON DECA	/ A N	DUT	DEC
• • •			IPLITO	DES
$V(1650)  ightarrow p\gamma$ , helicity- $1/2$ a	$mplitude A_{1}$	2		
ALUE (GeV ^{-1/2} )	DOCUMENT ID		TECN	COMMENT
-0.053±0.016 OUR ESTIMATE				
0.069±0.005	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
0.033±0.015	CRAWFORD		IPWA	$\gamma N \rightarrow \pi N$
0.050±0.010 0.065±0.005	AWAJI	81		$\gamma N \rightarrow \pi N$
0.065 ± 0.005 0.061 ± 0.005	ARAI ARAI	80		$\gamma N \rightarrow \pi N \text{ (fit 1)}$
0.001 T 0.002	CRAWFORD	80 80		$\gamma N \rightarrow \pi N \text{ (fit 2)}$ $\gamma N \rightarrow \pi N$
$0.031 \pm 0.017$		s, fits		
$0.031 \pm 0.017$ • We do not use the following of	data for average		IPW/A	$\gamma N \rightarrow \pi N$
$0.031 \pm 0.017$		93		$\gamma N \rightarrow \pi N$ Compton scattering
$0.031\pm0.017$ • We do not use the following of $0.068\pm0.003$ $0.091$	data for average LI	93 84	DPWA	$\gamma N \rightarrow \pi N$ Compton scattering $\gamma N \rightarrow \pi N$
$0.031\pm0.017$ • We do not use the following ( $0.068\pm0.003$ $0.091$ $-0.048\pm0.017$	data for average LI WADA	93 84 78	DPWA DPWA	Compton scattering
$0.031\pm0.017$ • We do not use the following $0.068\pm0.003$ $0.091$ $0.048\pm0.017$ $0.068\pm0.009$	data for average LI WADA BARBOUR FELLER	93 84 78 76	DPWA DPWA	Compton scattering $\gamma N \rightarrow \pi N$
0.031 $\pm$ 0.017 • • We do not use the following of 0.068 $\pm$ 0.003 0.091 -0.048 $\pm$ 0.017 -0.068 $\pm$ 0.009 V(1650) $\rightarrow n\gamma$ , helicity-1/2 a	data for average LI WADA BARBOUR FELLER	93 84 78 76	DPWA DPWA DPWA	Compton scattering $\gamma N \to \pi N$ $\gamma N \to \pi N$
0.031 $\pm$ 0.017 • We do not use the following of 0.068 $\pm$ 0.003 0.091 0.048 $\pm$ 0.017 -0.068 $\pm$ 0.009 <b>/(1650)</b> $\rightarrow n\gamma$ , helicity-1/2 a	data for average LI WADA BARBOUR FELLER	93 84 78 76	DPWA DPWA DPWA	Compton scattering $\gamma N \rightarrow \pi N$
0.031 $\pm$ 0.017 • • We do not use the following of 0.068 $\pm$ 0.003 0.091 0.048 $\pm$ 0.017 -0.068 $\pm$ 0.009 /(1650) $\rightarrow n\gamma$ , helicity-1/2 at $\Delta t \cup E (\text{GeV}^{-1/2})$	LI WADA BARBOUR FELLER  mplitude A ₁ / DOCUMENT ID	93 84 78 76	DPWA DPWA DPWA	Compton scattering $\gamma N \to \pi N$ $\gamma N \to \pi N$ $\sim \kappa N$
0.031 $\pm$ 0.017 • • We do not use the following of 0.068 $\pm$ 0.003 0.091 0.048 $\pm$ 0.017 0.068 $\pm$ 0.009 //(1650) $\rightarrow n\gamma$ , helicity-1/2 a $\frac{4LUE (GeV^{-1/2})}{0.015 \pm 0.002}$ OUR ESTIMATE 0.015 $\pm$ 0.005	LI WADA BARBOUR FELLER IMPlitude A ₁ / DOCUMENT ID ARNDT	93 84 78 76 <b>2</b> 96	DPWA DPWA DPWA	Compton scattering $ \begin{array}{l} \gamma  N  \to  \pi  N \\  \gamma  N  \to  \pi  N \end{array} $ $ \begin{array}{l} \gamma  N  \to  \pi  N \end{array} $ $ \begin{array}{l} COMMENT \\  \gamma  N  \to  \pi  N \end{array} $
0.031 $\pm$ 0.017 • • We do not use the following of 0.068 $\pm$ 0.003 0.091 0.048 $\pm$ 0.017 0.068 $\pm$ 0.009 //(1650) $\rightarrow n\gamma$ , helicity-1/2 a $\frac{4LUE (GeV^{-1/2})}{0.015 \pm 0.002}$ OUR ESTIMATE 0.015 $\pm$ 0.005	LI WADA BARBOUR FELLER  mplitude A ₁ / DOCUMENT ID	93 84 78 76 <b>2</b> 96 81	DPWA DPWA DPWA TECN IPWA DPWA	Compton scattering $ \gamma N \to \pi N $ $ \gamma N \to \pi N $ $ COMMENT $ $ \gamma N \to \pi N $ $ \gamma N \to \pi N $ $ \gamma N \to \pi N $
0.031 $\pm$ 0.017 • • We do not use the following 0.068 $\pm$ 0.003 0.091 -0.048 $\pm$ 0.007 0.068 $\pm$ 0.009 /(1650) $\rightarrow n\gamma$ , helicity-1/2 a $\frac{\lambda LUE (GeV^{-1/2})}{0.015 \pm 0.021 \text{ OUR ESTIMATE}}$ 0.015 $\pm$ 0.005 0.008 $\pm$ 0.004	LI WADA BARBOUR FELLER IMPlitude A ₁ / DOCUMENT ID ARNDT AWAJI	93 84 78 76 <b>2</b> 96 81 81	DPWA DPWA DPWA TECN IPWA DPWA DPWA	Compton scattering $ \begin{array}{l} \gamma  N  \to  \pi  N \\  \gamma  N  \to  \pi  N \end{array} $ $ \begin{array}{l} \gamma  N  \to  \pi  N \end{array} $ $ \begin{array}{l} COMMENT \\  \gamma  N  \to  \pi  N \end{array} $
0.031 $\pm$ 0.017 • • We do not use the following (0.068 $\pm$ 0.003 (0.091) -0.048 $\pm$ 0.017 -0.068 $\pm$ 0.009 $V(1650) \rightarrow n\gamma$ , helicity-1/2 a ALUE (GeV ^{-1/2} ) -0.015 $\pm$ 0.021 OUR ESTIMATE (0.008 $\pm$ 0.004 (0.004 $\pm$ 0.004	data for average LI WADA BARBOUR FELLER IMPLITURE ARNOT ARNOT AWAJI FUJII	93 84 78 76 <b>2</b> 96 81 81 80 80	DPWA DPWA DPWA  IPWA DPWA DPWA DPWA DPWA DPWA	Compton scattering $ \gamma N \to \pi N $ $ \gamma N \to \pi N $ $ \gamma N \to \pi N $ $ COMMENT $ $ \gamma N \to \pi N $ (fit 1) $ \gamma N \to \pi N $ (fit 2)
0.031 $\pm$ 0.017  • • We do not use the following of 0.068 $\pm$ 0.003 0.091 -0.048 $\pm$ 0.017 -0.068 $\pm$ 0.009  V(1650) $\rightarrow n\gamma$ , helicity-1/2 a  ALUE (GeV ^{-1/2} ) -0.015 $\pm$ 0.021 OUR ESTIMATE -0.015 $\pm$ 0.005 -0.008 $\pm$ 0.004 -0.004 $\pm$ 0.004 -0.010 $\pm$ 0.004 -0.008 $\pm$ 0.019 -0.008 $\pm$ 0.019	LI WADA BARBOUR FELLER IMPlitude A ₁ / DOCUMENT ID  ARNDT AWAJI FUJII ARAI ARAI CRAWFORD	93 84 78 76 <b>2</b> 96 81 81 80 80 80	DPWA DPWA DPWA  TECN IPWA DPWA DPWA DPWA DPWA DPWA DPWA	Compton scattering $ \gamma  N \to \pi  N \\ \gamma  N \to \pi  N $ $ \gamma  N \to \pi  N $ $ \frac{COMMENT}{\gamma  N \to \pi  N} \\ \gamma  N \to \pi  N \\ \gamma  N \to \pi  N \\ \gamma  N \to \pi  N \text{ (fit 1)} \\ \gamma  N \to \pi  N \text{ (fit 2)} \\ \gamma  N \to \pi  N \text{ (fit 2)} $
0.031 $\pm$ 0.017  • • We do not use the following of 0.068 $\pm$ 0.003 (0.091)  -0.048 $\pm$ 0.017 -0.068 $\pm$ 0.009 <b>V(1650)</b> $\rightarrow n\gamma$ , helicity-1/2 at $UU = (GeV^{-1/2})$ -0.015 $\pm$ 0.005 -0.008 $\pm$ 0.004 -0.004 $\pm$ 0.004 -0.010 $\pm$ 0.020 -0.008 $\pm$ 0.019	LI WADA BARBOUR FELLER mplitude A _{1/} DOCUMENT ID  ARNDT AWAJI FUJII ARAI CRAWFORD TAKEDA	93 84 78 76 <b>2</b> 96 81 81 80 80 80 80	DPWA DPWA  TECN  IPWA DPWA DPWA DPWA DPWA DPWA DPWA DPWA	Compton scattering $ \gamma  N \to \pi  N \\  \gamma  N \to \pi  N $ $ \gamma  N \to \pi  N $ $ \frac{COMMENT}{\gamma  N \to \pi  N} \\  \gamma  N \to \pi  N $ $ \gamma  N \to \pi  N $ $ \gamma  N \to \pi  N $ $ \gamma  N \to \pi  N $ (fit 1) $ \gamma  N \to \pi  N $ (fit 2) $ \gamma  N \to \pi  N $ $ \gamma  N \to \pi  N $ $ \gamma  N \to \pi  N $

93 IPWA  $\gamma N \rightarrow \pi N$ 78 DPWA  $\gamma N \rightarrow \pi N$ 

BARBOUR

 $-0.002 \pm 0.002$  $-\,0.045\pm0.024$ 

#### N(1650) $\gamma p \rightarrow \Lambda K^+$ AMPLITUDES

VALUE (units 10 ⁻³ )	DOCUMENT ID		TECN	
7.8 ±0.3	WORKMAN	90	DPWA	
• • We do not use the	e following data for average	s, fit	s, limits, et	C. • • •
8.13	TANABE	89	DPWA	
$p\gamma \rightarrow N(1650) \rightarrow$	$\Lambda K^+$ phase angle $ heta$			( <i>E</i> ₀₊ amplitude)
	ΛK ⁺ phase angle θ		TECN	(E ₀₊ amplitude)
$p\gamma \rightarrow N(1650) \rightarrow VALUE \text{ (degrees)} -107 \pm 3$		90	<u>TECN</u> DPWA	( <i>E</i> ₀₊ amplitude)
VALUE (degrees) -107 ±3	DOCUMENT ID		DPWA	,

## N(1650) FOOTNOTES

- 1  ARNDT 95 finds two distinct states.  2  BATINIC 95 finds two distinct states. This second resonance was associated with the  $N(2090)~S_{11}$ .  3  The two BAKER 77 entries are from an IPWA using the Barrelet-zero method and from
- The two BAKER 77 entries are from an IPWA using the Barrelet-zero method and from a conventional energy-dependent analysis. LONGACRE 77 pole positions are from a search for poles in the unitarized T-matrix; the first (second) value uses, in addition to  $\pi N \to N \pi \pi$  data, elastic amplitudes from a Saclay (CERN) partial-wave analysis. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.

  From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.
- rion mention in LONGACE 73: eyeball its win Breit-Wigner circles to the 1-matrix amplitudes. See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and  $\Delta$  resonances as determined from Argand diagrams of  $\pi N$  elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.
- TLONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to  $\pi N \to N \pi \pi$  data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.
- (CERN) partial-wave analysis.

  8 BAKER 79 fixed this coupling during fitting, but the negative sign relative to the N(1535) is well determined.

  9 The overall phase of BAKER 78 couplings has been changed to agree with previous conventions. Superseded by SAXON 80.

  10 The range given for DEANS 75 is from the four best solutions.

  11 LONGACRE 77 considers this coupling to be well determined.

## N(1650) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

ARNDT	96	PR C53 430	+Strakovsky, Workman	(VPI)
ARNDT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BŘCO)
BATINIC	95	PR C51 2310	+Slaus, Svarc, Nefkens	(BOSK, UCLA)
HOEHLER	93	$\pi$ N Newsletter 9 1		(KARL)
LI	93	PR C47 2759	+Arndt, Roper, Workman	(VPI)
MANLEY	92	PR D45 4002	+Saleski	(KENT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
WORKMAN	90	PR C42 781		(VPI)
TANABE	89	PR C39 741	+Kohno, Bennhold	(MÀNZ)
Also	89	NC 102A 193	Kohno, Tanabe, Bennhold	(MANZ)
WADA	84	NP B247 313	+Egawa, Imanishi, Ishii, Kato, Ukai+	`(INUS)
BELL	83	NP B222 389	+Blissett, Broome, Daley, Hart, Lintern+	
CRAWFORD	83	NP B211 1	+ Morton	(GLAS)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
AWA JI	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
FUJII	81	NP B187 53	+Hayashii, Iwata, Kajikawa+	(NAGO, OSAK)
ARAI	80	Toronto Conf. 93		(INUS)
Also	82	NP B194 251	Arai, Fujii	(INUS)
CRAWFORD	80	Toronto Conf. 107	,	(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMÚ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
LIVANOS	80	Toronto Conf. 35	+Baton, Coutures, Kochowski, Neveu	(SACL) IJP
MUSETTE	80	NC 57A 37	Touton Courses, Mochowski, 140400	(BRUX) IJP
SAXON	80	NP B162 522	+Baker, Bell, Blissett, Bloodworth+	(RHEL, BRIS) IJP
TAKEDA	80	NP B168 17	+Arai, Fujii, Ikeda, Iwasaki+	(TOKY, INUS)
BAKER	79	NP B156 93	+Brown, Clark, Davies, Depagter, Evans+	
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BAKER	78	NP B141 29	+Blissett, Bloodworth, Broome+	(RL, CAVE) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadia+	
BAKER	77	NP B126 365	+Blissett, Bloodworth, Broome, Hart+	(LBL, SLAC)
LONGACRE	77	NP B122 493	+Dolbeau	(RHEL) IJP
Also	76	NP B108 365	Dolbeau, Triantis, Neveu, Cadiet	(SACL) IJP
FELLER	76	NP B104 219	+Fukushima, Horikawa, Kajikawa+	(SACL) IJP
DEANS	75	NP B96 90	+ Mitchell, Montgomery+	(NAGO, OSAK) IJP
KNASEL	75	PR D11 1		(SFLA, ALAH) IJP
LONGACRE	75	PL 55B 415	+Lindquist, Nelson+ (CHIC +Rosenfeld, Lasinski, Smadia+	, WUSL, OSU, ANL) IJP
LONGACKE	, 3	1 5 220 412	Trivosemeiu, Lasinski, Smadja+	(LBL, SLAC) IJP

# Baryon Particle Listings N(1675)

## $N(1675) D_{15}$

 $I(J^P) = \frac{1}{2}(\frac{5}{2}^-)$  Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

## N(1675) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1670 to 1685 (≈ 1675) OUR EST	IMATE			
1676± 2	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
1675±10	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1679± 8	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
ullet $ullet$ We do not use the following	g data for average	s, fit	s, limits,	etc. • • •
1673± 5	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
1673	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1683±19	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$
1666	LI	93	IPWA	$\gamma N \rightarrow \pi N$
1685	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
1670	SAXON	80	DPWA	$\pi^- p \rightarrow \Lambda K^0$
1680	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
1650	¹ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
1660	² LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

## N(1675) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
140 to 180 (≈ 150) OL	IR ESTIMATE			
159± 7	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
160 ± 20	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
120±15	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use t	he following data for average	s, fit	s, limits,	etc. • • •
154± 7	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
154	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
142±23	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$
136	LI	93	IPWA	$\gamma N \rightarrow \pi N$
191	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
40	SAXON	80	DPWA	$\pi^- p \rightarrow \Lambda K^0$
88	BAKER	79	DPWA	$\pi^- \rho \rightarrow n\eta$
192	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
130	¹ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
150	² LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

## N(1675) POLE POSITION

REAL PART VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1663	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1656	³ HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
$1660 \pm 10$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	data for average	s, fit	s, limits,	etc. • • •
1655	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ SoIn SM90}$
1663 or 1668	⁴ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
1649 or 1650	¹ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
-2×IMAGINARY PART				
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
152	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
126	³ HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
140±10	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	g data for average	s, fit	s, limits,	etc. • • •
124	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$
146 or 171	⁴ LONGACRE	78	<b>IPWA</b>	$\pi N \rightarrow N \pi \pi$
127 or 127	¹ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$

## N(1675) ELASTIC POLE RESIDUE

## MODULUS |r|

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
29	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
23	HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
31 ± 5	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the follo	wing data for average	es, fit	s, limits,	etc. • • •
28	ARNDT	91	DPWA	$\pi\text{\it N}\to\pi\text{\it N}$ Soln SM90
PHASE θ				
VALUE (°)	DOCUMENT ID		TECN	COMMENT
- 6	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
-22	HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
$-30 \pm 10$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the follow	wing data for average	es, fit	s, limits,	etc. • • •
-17	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$

## N(1675) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction $(\Gamma_i/\Gamma)$	
Γ ₁	Νπ	40-50 %	
$\Gamma_2$	$N\eta$		
Γ3	ΛK	<1 %	
$\Gamma_4$	ΣΚ		
$\Gamma_5$	$N\pi\pi$	50-60 %	
$\Gamma_6$	$\Delta\pi$	50-60 %	
$\Gamma_7$	$\Delta(1232)\pi$ , $\emph{D} ext{-}$ wave		
Γ8	$\Delta$ (1232) $\pi$ , $G$ -wave		
Γ9	$N\rho$	< 1-3 %	
$\Gamma_{10}$	$N\rho$ , $S=1/2$ , $D$ -wave		
$\Gamma_{11}$	$N\rho$ , $S=3/2$ , $D$ -wave		
$\Gamma_{12}$	$N\rho$ , $S=3/2$ , G-wave		
Γ ₁₃	$N(\pi\pi)_{S-\text{wave}}^{I=0}$		
$\Gamma_{14}$	$p\gamma$	0.004-0.023 %	
$\Gamma_{15}$	$p\gamma$ , helicity=1/2	0.0-0.015 %	
$\Gamma_{16}$	$p\gamma$ , helicity=3/2	0.0-0.011 %	
$\Gamma_{17}$	$n\gamma$	0.02-0.12 %	
Γ ₁₈	$n\gamma$ , helicity=1/2	0.006-0.046 %	
Γ ₁₉	$n\gamma$ , helicity=3/2	0.01-0.08 %	

## N(1675) BRANCHING RATIOS

			Γ ₁ /Γ
DOCUMENT ID		TECN	COMMENT
MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
ng data for average	s, fit	s, limits,	etc. • • •
ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
BATINIC	95	DPWA	$\pi N \rightarrow N \pi$ , $N \eta$
			Γ ₂ /Γ
DOCUMENT ID		TECN	COMMENT
ng data for average	s, fit	s, limits,	etc. • • •
BATINIC	95	DPWA	$\pi N \rightarrow N \pi, N \eta$
	MANLEY CUTKOSKY HOEHLER ng data for average ARNDT BATINIC  DOCUMENT ID	MANLEY 92 CUTKOSKY 80 HOEHLER 79 ng data for averages, fit ARNDT 95 BATINIC 95	MANLEY 92 IPWA CUTKOSKY 80 IPWA HOEHLER 79 IPWA ng data for averages, fits, limits, ARNDT 95 DPWA BATINIC 95 DPWA  DOCUMENT ID TECN ng data for averages, fits, limits,

(I /I f)'-/I total IN /I	$I\pi \rightarrow N(1675) \rightarrow N\eta$ DOCUMENT ID		TECN	$(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma$
• • • We do not use	the following data for averag	es, fit	s, limits,	etc. • • •
-0.07	BAKER	79	DPWA	$\pi^- \rho \rightarrow n \eta$
+0.009	FELTESSE	75	DPWA	Soln A; see BAKER 79
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}}$ in $\Lambda$	$I\pi \to N(1675) \to \Lambda K$			(Г₁Г₃) ^⅓ /Г

$(\Gamma_I \Gamma_f)^{72} / \Gamma_{\text{total}} \text{ in } N\pi \rightarrow$	$N(1675) \rightarrow \Lambda K$			(Γ ₁ Γ ₃ ) ⁷	2
VALUE	DOCUMENT ID		TECN	COMMENT	_
±0.04 to ±0.08 OL	IR ESTIMATE				
-0.01	BELL	83	DPWA	$\pi^- p \rightarrow \Lambda K^0$	
+0.036	⁵ SAXON	80	DPWA	$\pi^- p \rightarrow \Lambda K^0$	
We do not use the foll	owing data for average	s fits	limits	etc	

• • • We do not use the following data for averages, fits, limits, etc. • • • - 0.034±0.006 DEVENISH 74B Fixed-t dispersion rel.

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N_{\pi}$	$r \rightarrow N(1675) \rightarrow \Sigma K$	(Γ₁Γ₄) ^½ /Γ
VALUE	DOCUMENT ID TEC	N COMMENT
• • • We do not use th	e following data for averages, fits, lim	its, etc. • • •
< 0.003	⁶ DEANS 75 DP\	$NA \pi N \rightarrow \Sigma K$

Note: Signs of couplings from  $\pi N \to N\pi\pi$  analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the  $\Delta(1620)~S_{31}$  coupling to  $\Delta(1232)\pi$ .

VALUE	$\rightarrow N(1675) \rightarrow \Delta(123)$			COMME	NT
+0.46 to +0.50 OUR E	STIMATE				
$+0.496\pm0.003$	MANLEY	92	IPWA	$\pi N \rightarrow$	$\pi N \& N \pi \pi$
+0.46	1,7 LONGACRE	77	IPWA	$\pi N \rightarrow$	Νππ
+0.50	² LONGACRE	75	IPWA	$\pi N \rightarrow$	Νππ
• • We do not use the	following data for average	s, fit	s, limits,	etc. • •	•
+0.5	⁸ NOVOSELLER	78	IPWA	$\pi N \rightarrow$	Νππ

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \pi \rightarrow N(1)$	$.675) \rightarrow N\rho, S=$	1/2, <i>D</i> -wa	ve (Γ ₁ Γ ₁₀ ) ^{1/2} /Γ
VALUE	DOCUMENT ID	TECN	COMMENT
$+0.04\pm0.02$	MANLEY	92 IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$

$(\Gamma_I\Gamma_f)^{1/2}/\Gamma_{ ext{total}}$ in N $\pi$ -	$\rightarrow N(1675) \rightarrow N \rho$ , S	5=3/: >	2, <i>D</i> -wave (Γ ₁ Γ ₁₁ ) ^½ /Γ
-0.12 to -0.06 OUR EST	IMATE		
$-0.03\pm0.02$	MANLEY	92	
-0.15	^{1,7} LONGACRE	77	IPWA $\pi N \rightarrow N \pi \pi$
$(\Gamma_I\Gamma_f)^{1/2}/\Gamma_{ ext{total}}$ in $N\pi$ -	$\rightarrow N(1675) \rightarrow N(\pi n)$	r)/=0 S-w	ο (Γ ₁ Γ ₁₃ ) ^{1/2} /Γ - <u>ΤΕCN</u> <u>COMMENT</u>
+0.03	1,7 LONGACRE	77	
N(16	75) PHOTON DECA	Y A	MPLITUDES
$N(1675)  ightarrow p\gamma$ , helic	ity-1/2 amplitude $A_1$	./2	
VALUE (GeV ^{-1/2} ) +0.019±0.008 OUR ESTI	DOCUMENT IE	)	TECN COMMENT
0.015±0.010	ARNDT	96	IPWA $\gamma N \rightarrow \pi N$
$0.013 \pm 0.010$ $0.021 \pm 0.011$	CRAWFORD		
$0.034 \pm 0.005$	ILAWA	81	DPWA $\gamma N \rightarrow \pi N$
	ARAI	80	
0.006±0.005 0.006±0.004	ARAI	80	- · · · · · · · · · · · · · · · · · · ·
	CRAWFORD		
0.023±0.015 • • We do not use the f			
	-		
0.012±0.002	LI	93	IPWA $\gamma N \rightarrow \pi N$
+0.022±0.010	BARBOUR	78	DPWA $\gamma N \rightarrow \pi N$
-0.034±0.004	FELLER	76	DPWA $\gamma N \rightarrow \pi N$
$V(1675)  ightarrow p \gamma$ , helici		•	
ALUE (GeV-1/2) -0.015±0.009 OUR ESTI	DOCUMENT ID		TECN COMMENT
0.010±0.007	ARNDT	96	IPWA $\gamma N \rightarrow \pi N$
0.015 ± 0.009	CRAWFORD		IPWA $\gamma N \rightarrow \pi N$
	AWAJI		
0.024 ± 0.008		81	DPWA $\gamma N \rightarrow \pi N$
0.030 ± 0.004	ARAI	80	DPWA $\gamma N \rightarrow \pi N \text{ (fit 1)}$
$0.029 \pm 0.004$	ARAI	80	DPWA $\gamma N \rightarrow \pi N \text{ (fit 2)}$
0.003±0.012	CRAWFORD		DPWA $\gamma N \rightarrow \pi N$
We do not use the f	-		
$0.021 \pm 0.002$	LI	93	IPWA $\gamma N \rightarrow \pi N$
-0.015±0.006 -0.019±0.009	BARBOUR FELLER	78 76	DPWA $\gamma N \rightarrow \pi N$ DPWA $\gamma N \rightarrow \pi N$
			DEVVA $\gamma N \rightarrow \pi N$
$V(1675) \rightarrow n\gamma$ , helici $VALUE (GeV^{-1/2})$		•	TECN COMMENT
-0.043±0.012 OUR ESTI	MATE		
$-0.049 \pm 0.010$	ARNDT	96	IPWA $\gamma N \rightarrow \pi N$
$-0.057 \pm 0.024$	ILAWA	81	DPWA $\gamma N \rightarrow \pi N$
$-0.033 \pm 0.004$	FUJII	81	DPWA $\gamma N \rightarrow \pi N$
$-0.039 \pm 0.017$	ARAI	80	DPWA $\gamma N \rightarrow \pi N$ (fit 1)
- 0.025 ± 0.027	ARAI	80	DPWA $\gamma N \rightarrow \pi N$ (fit 2)
$-0.059 \pm 0.015$	CRAWFORD	80	DPWA $\gamma N \rightarrow \pi N$
$-0.021 \pm 0.011$	TAKEDA	80	
We do not use the f	ollowing data for averag	es, fit	s, limits, etc. • • •
$-0.060 \pm 0.003$	LI	93	IPWA $\gamma N \rightarrow \pi N$
$-0.066 \pm 0.020$	BARBOUR	78	DPWA $\gamma N \rightarrow \pi N$
$V(1675)  ightarrow n \gamma$ , helici	ty-3/2 amplitude A ₃	/2	
	DOCUMENT ID		TECN COMMENT
ALUE (GeV-1/2)		06	ID\\\\\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\
-0.058±0.013 OUR ESTI		96	IPWA $\gamma N \rightarrow \pi N$ DPWA $\gamma N \rightarrow \pi N$
-0.058±0.013 OUR ESTI -0.051±0.010	ARNDT		
-0.058±0.013 OUR ESTI -0.051±0.010 -0.077±0.018	ILAWA	81	
-0.058±0.013 OUR ESTI -0.051±0.010 -0.077±0.018 -0.069±0.004	AWA JI FUJII	81	DPWA $\gamma N \rightarrow \pi N$
-0.058±0.013 OUR ESTI -0.051±0.010 -0.077±0.018 -0.069±0.004 -0.066±0.026	AWAJI FUJII ARAI	81 80	DPWA $\gamma N \rightarrow \pi N$ DPWA $\gamma N \rightarrow \pi N$ (fit 1)
$-0.058\pm0.013$ OUR ESTI $-0.051\pm0.010$ $-0.077\pm0.018$ $-0.069\pm0.004$ $-0.066\pm0.026$ $-0.071\pm0.022$	AWAJI FUJII ARAI ARAI	81 80 80	DPWA $\gamma N \rightarrow \pi N$ DPWA $\gamma N \rightarrow \pi N$ (fit 1) DPWA $\gamma N \rightarrow \pi N$ (fit 2)
ALUE (GeV $^{-1/2}$ ) -0.058±0.013 OUR ESTI -0.051±0.010 -0.077±0.018 -0.069±0.004 -0.066±0.026 -0.071±0.022 -0.059±0.020 -0.030±0.012	AWAJI FUJII ARAI	81 80	DPWA $\gamma N \rightarrow \pi N$ DPWA $\gamma N \rightarrow \pi N$ (fit 1) DPWA $\gamma N \rightarrow \pi N$ (fit 2) DPWA $\gamma N \rightarrow \pi N$

## N(1675) FOOTNOTES

LI BARBOUR

\$\$ LONGACRE 77 pole positions are from a search for poles in the unitarized T-matrix; the first (second) value uses, in addition to \$\pi N \to N\pi\pi\$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.

\$\$\$ From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.

93 IPWA  $\gamma N \rightarrow \pi N$ 78 DPWA  $\gamma N \rightarrow \pi N$ 

- amplitudes.

  ³ See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters
- 3 See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and Δ resonances as determined from Argand diagrams of π N elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.
   4 LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to π N → Nππ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.
   5 SAXON 80 finds the coupling phase is near 90°.
   6 The range given is from the four best solutions. DEANS 75 disagrees with π⁺ p → Σ⁺ K⁺ data of WINNIK 77 around 1920 MeV.
   7 LONGACRE 77 considers this coupling to be well determined.
   8 A Breit-Wigner fit to the HERNDON 75 IPWA.

 $-0.074 \pm 0.003$ 

 $-0.073 \pm 0.014$ 

## N(1675) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

ARNDT	96	PR C53 430	+Strakovsky, Workman	(VPI)
ARNDT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BRCO)
BATINIC	95	PR C51 2310	+Slaus, Svarc, Nefkens	(BOSK, UCLA)
HOEHLER	93	π N Newsletter 9 1		(KARL)
LI	93	PR C47 2759	+Arndt, Roper, Workman	(VPI)
MANLEY	92	PR D45 4002	+Saleski	(KENT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
BELL	83	NP B222 389	+Blissett, Broome, Daley, Hart, Lintern+	· (RL) IJP
CRAWFORD	83	NP B211 1	+Morton	(GLAS)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
IL AWA	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
FUJII	81	NP B187 53	+Hayashii, Iwata, Kajikawa+	(NAGO, OSAK)
ARAI	80	Toronto Conf. 93		(INUS)
Also	82	NP B194 251	Arai, Fujii	(INUS)
CRAWFORD	80	Toronto Conf. 107		(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMŮ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
SAXON	80	NP B162 522	+Baker, Bell, Blissett, Bloodworth+	(RHEL, BRIS) IJP
TAKEDA	80	NP B168 17	+Arai, Fujii, Ikeda, Iwasaki+	(ŤOKY, INUS)
BAKER	79	NP B156 93	+Brown, Clark, Davies, Depagter, Evans-	+ (RHEL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)
NOVOSELLER	78	NP B137 509		(CIT) IJP
Also	78B	NP B137 445	Novoseller	(CIT) IJP
LONGACRE	77	NP B122 493	+Dolbeau	(SACL) IJP
Also	76	NP B108 365	Dolbeau, Triantis, Neveu, Cadiet	(SACL) IJP
WINNIK	77	NP B128 66	+Toaff, Revel, Goldberg, Berny	(HAIF) I
FELLER	76	NP B104 219	+Fukushima, Horikawa, Kajikawa+	(NAGO, ÒSAK) IJP
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ALAH) IJP
FELTESSE	75	NP B93 242	+Ayed, Bareyre, Borgeaud, David+	(SACL) IJP
HERNDON	75	PR D11 3183	+Longacre, Miller, Rosenfeld+	(LBL, SLAC)
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC) IJP
DEVENISH	74B	NP B81 330	+Froggatt, Martin (D	DESY, NÔRD, LOUC)
			,	

 $N(1680) F_{15}$ 

 $I(J^P) = \frac{1}{2}(\frac{5}{2}^+)$  Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

## N(1680) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1675 to 1690 (≈ 1680) OUR EST	MATE			
1684± 4	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
$1680 \pm 10$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1684± 3	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	data for average	s, fit	s, limits,	etc. • • •
1679± 5	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
1678	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1674±12	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$
1682	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
1680	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
1660	¹ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
1685	KNASEL	75	DPWA	$\pi^- p \rightarrow \Lambda K^0$
1670	² LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

## N(1680) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
120 to 140 (≈ 130) O	UR ESTIMATE			
139± 8	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
$120 \pm 10$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
128± 8	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use	the following data for average	s, fit	s, limits,	etc. • • •
124 ± 4	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
126	, ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
$126 \pm 20$	BATINIC	95	DPWA	$\pi N \rightarrow N\pi$ , $N\eta$
121	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
119	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
150	¹ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
155	KNASEL	75	DPWA	$\pi^- p \rightarrow \Lambda K^0$
130	² LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

## N(1680) POLE POSITION

REAL PART VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1670	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1673	³ HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
1667±5	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the	following data for average	s, fits	s, limits,	etc. • • •
1670	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ SoIn SM90}$
1668 or 1674	⁴ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
1656 or 1653	¹ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$

## N(1680)

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
120	ARNDT			$\pi N \rightarrow N \pi$
135	³ HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
110±10	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • We do not use t	he following data for average	s, fit	s, limits,	etc. • • •
116	ARNDT			$\pi N \rightarrow \pi N \text{ Soln SM90}$
132 or 137	⁴ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
145 or 143	1 LONGACRE	77	ID\A/A	N . N

## N(1680) ELASTIC POLE RESIDUE

## MODULUS |r|

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
40	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$	- 1
44	HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$	
34±2	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
• • We do not use the following the fol	owing data for averages	, fits	, limits,	etc. • • •	
37	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$	)

## PHASE $\theta$

VALUE (°)	DOCUMENT ID		TECN	COMMENT
+ 1	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
-17	HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
$-25 \pm 5$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the following	data for averages	, fits	, limits,	etc. • • •
-14	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ SoIn SM90}$

## N(1680) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction $(\Gamma_i/\Gamma)$
$\Gamma_1$	Nπ	60-70 %
$\Gamma_2$	$N\eta$	
Гз	ΛK	
$\Gamma_4$	ΣΚ	
$\Gamma_5$	$N\pi\pi$	30-40 %
$\Gamma_6$	$\Delta \pi$	5-15 %
$\Gamma_7$	$\Delta(1232)\pi$ , $\it P-wave$	6-14 %
Γ8	$\Delta(1232)\pi$ , <i>F</i> -wave	<2 %
Гэ	$N \rho$	3-15 %
$\Gamma_{10}$	$N\rho$ , $S=1/2$ , $F$ -wave	
$\Gamma_{11}$	$N\rho$ , $S=3/2$ , $P$ -wave	<12 %
$\Gamma_{12}$	$N\rho$ , $S=3/2$ , $F$ -wave	1-5 %
$\Gamma_{13}$	$N(\pi\pi)_{S-\text{wave}}^{I=0}$	5-20 %
$\Gamma_{14}$	$p\gamma$	0.21-0.32 %
$\Gamma_{15}$	$p\gamma$ , helicity=1/2	0.001-0.011 %
$\Gamma_{16}$	$p\gamma$ , helicity=3/2	0.20-0.32 %
$\Gamma_{17}$	$n\gamma$	0.021-0.046 %
$\Gamma_{18}$	$n\gamma$ , helicity=1/2	0.004-0.029 %
$\Gamma_{19}$	$n\gamma$ , helicity=3/2	0.01-0.024 %

## N(1680) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$	0.000		*****	Γ ₁ /Γ
VALUE 0.6 to 0.7 OUR ESTIMATION	DOCUMENT ID		TECN	COMMENT
0.70±0.03	MANLEY	92	IP\A/A	$\pi N \rightarrow \pi N \& N \pi \pi$
0.62 + 0.05	CUTKOSKY	80		$\pi N \rightarrow \pi N$
0.65 ± 0.02	HOEHLER	79		$\pi N \rightarrow \pi N$
0.68	ARNDT	95		$\pi N \rightarrow N \pi$
0.69 ± 0.04	BATINIC	95		$\pi N \rightarrow N \pi$ $\pi N \rightarrow N \pi$ , $N \eta$
1/				1/
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \rightarrow$				$(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow \frac{1}{2}$	N(1680) → Nη		TECN	$(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma$
	DOCUMENT ID			COMMENT
• • • We do not use the fo	DOCUMENT ID	es, fit	s, limits,	COMMENT
• • • We do not use the fo	DOCUMENT ID  Illowing data for average	es, fit	s, limits,	$\begin{array}{c} \underline{COMMENT} \\ \text{etc.} \bullet \bullet \bullet \\ \pi^- p \to n\eta \end{array}$
• • • We do not use the fo	DOCUMENT ID  Illowing data for average	es, fit	s, limits,	COMMENT etc. • •
VALUE  • • • We do not use the form the seen $\Gamma(N\eta)/\Gamma_{\text{total}}$	DOCUMENT ID  BAKER  DOCUMENT ID	es, fit	s, limits, DPWA	etc. • • • $\pi^- p \to n \eta$ $\Gamma_2/\Gamma$
VALUE  • • • We do not use the for not seen  \( \lambda(N \eta) \rangle \Gamma_{\text{total}} \) VALUE	DOCUMENT ID  BAKER  DOCUMENT ID	es, fit	DPWA  TECN  s, limits,	etc. • • • $\pi^- p \to n \eta$ $\Gamma_2/\Gamma$
VALUE  • • • We do not use the formot seen $\Gamma(N\eta)/\Gamma_{\text{total}}$ VALUE  • • • We do not use the form	DOCUMENT ID  BAKER  DOCUMENT ID  BOUNDED TO THE PROPERTY OF T	79 es, fit:	TECN s, limits,	$\begin{array}{c} \underline{COMMENT} \\ \text{etc.} \bullet \bullet \bullet \\ \pi^- \rho \to n \eta \\ \hline \\ \underline{COMMENT} \\ \text{etc.} \bullet \bullet \bullet \\ \pi  N \to N \pi, N \eta \end{array}$
VALUE  • • • We do not use the formot seen $\Gamma(N\eta)/\Gamma_{\text{total}}$ VALUE  • • • We do not use the formotion of the control of	DOCUMENT ID  BAKER  DOCUMENT ID  Illowing data for average	79 es, fit:	TECN s, limits, DPWA s, limits, DPWA MPWA	$\begin{array}{c} \underline{COMMENT} \\ \text{etc.} \bullet \bullet \bullet \\ \pi^- \rho \to n \eta \\ \hline \\ \underline{COMMENT} \\ \text{etc.} \bullet \bullet \bullet \end{array}$

$\Gamma(N\eta)/\Gamma(N\pi)$	Γ ₂ /Γ
ALUE	DOCUMENT ID TECN COMMENT
• • We do not use the f	following data for averages, fits, limits, etc. • •
< 0.027	HEUSCH 66 RVUE $\pi^0$ , $\eta$ photoproduction
•/	•
$(\Gamma_I \Gamma_f)^{rac{1}{2}}/\Gamma_{ m total}$ in $N\pi$ -	$\rightarrow N(1680) \rightarrow \Lambda K \qquad (\Gamma_1 \Gamma_3)^{\frac{1}{2}}/$
Coupling to AK not	required in the analyses of BAKER 77, SAXON 80, or BELL 8
ALUE	DOCUMENT ID TECN COMMENT
	following data for averages, fits, limits, etc. • •
0.01	KNASEL 75 DPWA $\pi^- \rho \rightarrow \Lambda K^0$
$-0.009\pm0.009$	DEVENISH 74B Fixed-t dispersion rel.
$\left(\Gamma_I\Gamma_f ight)^{1\!\!/2}/\Gamma_{ m total}$ in N $\pi$ -	$\rightarrow N(1680) \rightarrow \Sigma K \qquad (\Gamma_1 \Gamma_4)^{\frac{1}{2}}/$
(I /I f)'-/I total In Nπ -	
MEUE	following data for averages, fits, limits, etc. • •
	_
< 0.001	⁶ DEANS 75 DPWA $\pi N \rightarrow \Sigma K$
Nata Class of as	and the second s
	puplings from $\pi N \rightarrow N \pi \pi$ analyses were changed in the agree with the baryon-first convention; the overall phase
	with the baryon-mist convention, the overlain phase solved by choosing a negative sign for the $\Delta(1620)$ $S_{31}$
coupling to $\Delta(12$	
•/	1/
$(\Gamma_I\Gamma_f)^{7/2}/\Gamma_{ m total}$ in N $\pi$ -	$\rightarrow N(1680) \rightarrow \Delta(1232)\pi$ , <i>P</i> -wave $(\Gamma_1\Gamma_7)^{\frac{1}{2}}/$
ALUE	DOCUMENT ID TECN COMMENT
-0.31 to -0.21 OUR EST	
- 0.26 ± 0.04 - 0.27	MANLEY 92 IPWA $\pi N \rightarrow \pi N \& N \pi \pi$ 1,7 LONGACRE 77 IPWA $\pi N \rightarrow N \pi \pi$
- 0.25	² LONGACRE 75 IPWA $\pi N \rightarrow N \pi \pi$
	following data for averages, fits, limits, etc. • • •
-0.38	⁸ NOVOSELLER 78 IPWA $\pi N \rightarrow N \pi \pi$
$(\Gamma_t \Gamma_t)^{1/2} / \Gamma_{total}$ in $N\pi$ -	$\rightarrow N(1680) \rightarrow \Delta(1232)\pi$ , F-wave $(\Gamma_1\Gamma_8)^{\frac{1}{2}}/$
/ALUE	DOCUMENT ID TECN COMMENT
+0.03 to +0.11 OUR EST	
$+0.07\pm0.03$	MANLEY 92 IPWA $\pi N \rightarrow \pi N \& N \pi \pi$
+0.07	^{1,7} LONGACRE 77 IPWA $\pi N \rightarrow N \pi \pi$ ² LONGACRE 75 IPWA $\pi N \rightarrow N \pi \pi$
+0.08	LONGACRE 75 IPWA $\pi N \rightarrow N \pi \pi$ following data for averages, fits, limits, etc. • •
+0.05	⁸ NOVOSELLER 78 IPWA $\pi N \rightarrow N \pi \pi$
1 0.03	
$(\Gamma_{\ell}\Gamma_{\ell})^{\frac{1}{2}}/\Gamma_{\rm total}$ in $N\pi$ -	$\rightarrow N(1680) \rightarrow N\rho$ , $S=3/2$ , $P$ -wave $(\Gamma_1\Gamma_{11})^{\frac{1}{2}}/2$
VALUE	DOCUMENT ID TECN COMMENT
-0.30 to -0.10 OUR EST	TIMATE
$-0.20 \pm 0.05$	MANLEY 92 IPWA $\pi N \rightarrow \pi N \& N \pi \pi$
- 0.23	1,7 LONGACRE 77 IPWA $\pi N  ightarrow N \pi \pi$ 2 LONGACRE 75 IPWA $\pi N  ightarrow N \pi \pi$
-0.30	LONGACRE 75 IPWA $\pi N \rightarrow N \pi \pi$ following data for averages, fits, limits, etc. • • •
- 0.34	8 NOVOSELLER 78 IPWA $\pi N \rightarrow N \pi \pi$
- 0.34	NOVOSELLER 78 IPVVA $\pi N \rightarrow N \pi \pi$
(F.F.) 1/2 /F in N	$\rightarrow N(1680) \rightarrow N \rho$ , $S=3/2$ , $F$ -wave $(\Gamma_1 \Gamma_{12})^{1/2}/$
(' 'f) /'total''''''	DOCUMENT ID TECH COMMENT
-0.18 to -0.10 OUR EST	TIMATE
$-0.13 \pm 0.03$	MANLEY 92 IPWA $\pi N \rightarrow \pi N \& N \pi \pi$
-0.15	1,7 LONGACRE 77 IPWA $\piN  ightarrow N\pi\pi$
1/	
$(\Gamma_I \Gamma_f)^{\prime 2} / \Gamma_{total}$ in $N\pi$ -	→ $N(1680)$ → $N(\pi\pi)_{S-wave}^{I=0}$ $(\Gamma_1\Gamma_{13})^{\frac{1}{2}}/$
ALUE	DOCUMENT ID TECN COMMENT
	MANLEY 92 IPWA $\pi N \rightarrow \pi N \& N \pi \pi$
$+0.29\pm0.04$	1,7 LONGACRE 77 IPWA $\pi N \rightarrow N \pi \pi$
+0.29±0.04 +0.31	1,7 LONGACRE 77 IPWA $\pi N \rightarrow N \pi \pi$ 2 LONGACRE 75 IPWA $\pi N \rightarrow N \pi \pi$
+ 0.29 ± 0.04 + 0.31 + 0.30	1,7 LONGACRE 77 IPWA $\pi N \rightarrow N \pi \pi$
+0.29±0.04 +0.31 +0.30 • • • We do not use the	1,7 LONGACRE 77 IPWA $\pi N  ightarrow N \pi \pi$ 2 LONGACRE 75 IPWA $\pi N  ightarrow N \pi \pi$
+0.29±0.04 +0.31 +0.30 • • • We do not use the	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$
+ 0.29 ± 0.04 + 0.31 + 0.30 • • • We do not use the + 0.42	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$
+0.29±0.04 +0.31 +0.30 ••• We do not use the +0.42	1,7 LONGACRE 77 IPWA $\pi N \rightarrow N\pi\pi$ 2 LONGACRE 75 IPWA $\pi N \rightarrow N\pi\pi$ following data for averages, fits, limits, etc. • • • 8 NOVOSELLER 78 IPWA $\pi N \rightarrow N\pi\pi$ 80) PHOTON DECAY AMPLITUDES
$+0.29\pm0.04$ +0.31 +0.30 $\bullet$ • • We do not use the +0.42 $N(1680) \rightarrow p\gamma$ , helic	1.7 LONGACRE 77 IPWA $\pi N \rightarrow N\pi\pi$ 2 LONGACRE 75 IPWA $\pi N \rightarrow N\pi\pi$ following data for averages, fits, limits, etc. • • • 8 NOVOSELLER 78 IPWA $\pi N \rightarrow N\pi\pi$
$+0.29\pm0.04$ +0.31 +0.30 $\bullet$ • • We do not use the $+0.42$ $N(1680) \rightarrow p\gamma$ , helic $ALUE (GeV^{-1/2})$	1.7 LONGACRE 77 IPWA $\pi N \rightarrow N\pi\pi$ 2 LONGACRE 75 IPWA $\pi N \rightarrow N\pi\pi$ following data for averages, fits, limits, etc. • • 8 NOVOSELLER 78 IPWA $\pi N \rightarrow N\pi\pi$ 80) PHOTON DECAY AMPLITUDES  Sity-1/2 amplitude $A_{1/2}$ DOCUMENT ID TECN COMMENT
$+0.29\pm0.04$ +0.31 +0.30 $\bullet$ • • • We do not use the $+0.42$ $N(1680) \rightarrow p\gamma$ , helic $VALUE (GeV^{-1/2})$ $-0.015\pm0.006$ OUR EST	1.7 LONGACRE 77 IPWA $\pi N \rightarrow N\pi\pi$ 2 LONGACRE 75 IPWA $\pi N \rightarrow N\pi\pi$ following data for averages, fits, limits, etc. • • • 8 NOVOSELLER 78 IPWA $\pi N \rightarrow N\pi\pi$ 80) PHOTON DECAY AMPLITUDES  city-1/2 amplitude $A_{1/2}$ DOCUMENT ID TECN COMMENT
$+0.29\pm0.04$ +0.31 +0.30 • • • We do not use the +0.42	1.7 LONGACRE 77 IPWA $\pi N \rightarrow N\pi\pi$ 2 LONGACRE 75 IPWA $\pi N \rightarrow N\pi\pi$ following data for averages, fits, limits, etc. • • • 8 NOVOSELLER 78 IPWA $\pi N \rightarrow N\pi\pi$ 80) PHOTON DECAY AMPLITUDES  Sity-1/2 amplitude $A_{1/2}$ DOCUMENT ID TECN COMMENT  ARNDT 96 IPWA $\gamma N \rightarrow \pi N$
$+0.29\pm0.04$ +0.31 +0.30 •• • We do not use the $+0.42$ $N(1680) \rightarrow p\gamma$ , helic $VALUE (GeV^{-1/2})$ $-0.015\pm0.006$ OUR EST $-0.010\pm0.004$ $-0.010\pm0.004$	1.7 LONGACRE 77 IPWA $\pi N \rightarrow N\pi\pi$ 2 LONGACRE 75 IPWA $\pi N \rightarrow N\pi\pi$ following data for averages, fits, limits, etc. • •  8 NOVOSELLER 78 IPWA $\pi N \rightarrow N\pi\pi$ 80) PHOTON DECAY AMPLITUDES  city-1/2 amplitude A _{1/2} DOCUMENT ID TECN COMMENT  IMATE  ARNDT 96 IPWA $\gamma N \rightarrow \pi N$ CRAWFORD 83 IPWA $\gamma N \rightarrow \pi N$
+ 0.42 <b>N(16</b>	1.7 LONGACRE 77 IPWA $\pi N \rightarrow N\pi\pi$ 2 LONGACRE 75 IPWA $\pi N \rightarrow N\pi\pi$ following data for averages, fits, limits, etc. • • • 8 NOVOSELLER 78 IPWA $\pi N \rightarrow N\pi\pi$ 80) PHOTON DECAY AMPLITUDES  Sity-1/2 amplitude $A_{1/2}$ DOCUMENT ID TECN COMMENT  ARNDT 96 IPWA $\gamma N \rightarrow \pi N$

VALUE (GeV ^{-1/2} )	DOCUMENT ID		TECN	COMMENT
-0.015±0.006 OUR ESTIMATE				
$-0.010\pm0.004$	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
$-0.017\pm0.018$	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
$-0.009\pm0.006$	AWA JI	81	DPWA	$\gamma N \rightarrow \pi N$
$-0.028 \pm 0.003$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
$-0.026 \pm 0.003$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
$-0.018 \pm 0.014$	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
	data for average	es, fit	s, limits,	etc. • • •
$-0.006\pm0.002$	LI	93	IPWA	$\gamma N \rightarrow \pi N$
$-0.005 \pm 0.015$	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
$-0.009\pm0.002$	FELLER	76	DPWA	$\gamma N \rightarrow \pi N$

## **Baryon Particle Listings** N(1680), N(1700)

VALUE (GeV ^{-1/2} )	DOCUMENT ID		TECN	COMMENT
+0.133±0.012 OUR EST	TMATE			
$0.145 \pm 0.005$	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
$0.132 \pm 0.010$	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
$0.115 \pm 0.008$	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
$0.115 \pm 0.003$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
$0.122 \pm 0.003$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
$0.141 \pm 0.014$	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
• • We do not use the	following data for average	es, fits	s, limits,	etc. • • •
$0.154 \pm 0.002$	LI	93	IPWA	$\gamma N \rightarrow \pi N$
$+0.138 \pm 0.021$	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
$+0.121 \pm 0.010$	FELLER	76	DPWA	$\gamma N \rightarrow \pi N$
$N(1680) \rightarrow n\gamma$ , helic	city-1/2 amplitude A _{1/}	/2		
VALUE (GeV ^{-1/2} )	DOCUMENT ID		TECN	COMMENT
$+$ 0.029 $\pm$ 0.010 OUR EST	TMATE			
$0.030 \pm 0.005$	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
$0.017 \pm 0.014$	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
$0.032 \pm 0.003$	FUJII	81	DPWA	$\gamma N \rightarrow \pi N$
$0.026 \pm 0.005$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
	4541	80	D DW/A	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
$0.028 \pm 0.014$	ARAI	οu	DI VVA	710 1110 (111 2)
$0.028 \pm 0.014$ $0.044 \pm 0.012$	CRAWFORD			$\gamma N \rightarrow \pi N$ (III 2)

 $\bullet$  . We do not use the following data for averages, fits, limits, etc.  $\bullet$  .

			,,		
$0.022 \pm 0.002$	LI	93	IPWA	$\gamma N \rightarrow$	$\pi N$
$+0.037\pm0.010$	BARBOUR	78	DPWA	$\gamma N \rightarrow$	$\pi N$

$N(1680) \rightarrow n\gamma$ , helicity-3/2 amplitude $A_{3/2}$					
VALUE (GeV ^{-1/2} )	DOCUMENT ID		TECN	COMMENT	
-0.033±0.009 OUR ESTIMATE					
$-0.040\pm0.015$	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$	
$-0.033\pm0.013$	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$	
$-0.023\pm0.005$	FUJII	81	DPWA	$\gamma N \rightarrow \pi N$	
$-0.024 \pm 0.009$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$	
$-0.029 \pm 0.017$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$	
$-0.033 \pm 0.015$	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$	
$-0.035 \pm 0.012$	TAKEDA	80	DPWA	$\gamma N \rightarrow \pi N$	
ullet $ullet$ We do not use the following	data for average	s, fit	s, limits,	etc. • • •	
$-0.048 \pm 0.002$	LI	93	IPWA	$\gamma N \rightarrow \pi N$	
$-0.038\pm0.018$	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$	

## N(1680) FOOTNOTES

- \$\$ LONGACRE 77 pole positions are from a search for poles in the unitarized T-matrix; the first (second) value uses, in addition to \$\pi N \to N\pi\pi\$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.

  \$\$\$ From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.
- amplitudes. 3 See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and  $\Delta$  resonances as determined from Argand diagrams of  $\pi$  N elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.
- 4  LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to  $\pi\,N\to N\pi\pi$  data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.
- ⁵ The parametrization used may be double counting.
- ⁶ The range given is from 3 of 4 best solutions; not present in solution 1. DEANS 75 disagrees with  $\pi^+ p \to \Sigma^+ K^+$  data of WINNIK 77 around 1920 MeV.
- 7 LONGACRE 77 considers this coupling to be well determined.
  8 A Breit-Wigner fit to the HERNDON 75 IPWA.

## N(1680) REFERENCES

For early references, see Physics Letters 111B 70 (1982). For very early references, see Reviews of Modern Physics 37 633 (1965).

ARNDT	96	PR C53 430	+Strakovsky, Workman	(VPI)
ARNDT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BŘCO)
BATINIC	95	PR C51 2310	+Slaus, Svarc, Nefkens	(BOSK, UCLA)
HOEHLER	93	π N Newsletter 9 1		(KARL)
LI	93	PR C47 2759	+Arndt, Roper, Workman	` (VPI)
MANLEY	92	PR D45 4002	+ Saleski	(KÈNT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
BELL	83	NP B222 389	+Blissett, Broome, Daley, Hart, Lintern+	` (RL) IJP
CRAWFORD	83	NP B211 1	+ Morton	(GLAS)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
AWA JI	81	Bonn Conf. 352	+ Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
FUJII	81	NP B187 53	+Hayashii, Iwata, Kajikawa+	(NAGO, OSAK)
ARAI	80	Toronto Conf. 93	· ·	(INUS)
Also	82	NP B194 251	Arai, Fujii	(INUS)
CRAWFORD	80	Toronto Conf. 107	· · ·	(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMŮ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
SAXON	80	NP B162 522	+Baker, Bell, Blissett, Bloodworth+	(RHEL, BRIS) IJP
TAKEDA	80	NP B168 17	+Arai, Fujii, Ikeda, Iwasaki+	(ŤOKY, INUS)
BAKER	79	NP B156 93	+Brown, Clark, Davies, Depagter, Evans+	· (RHEL) IJP

HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)
NOVOSELLER	78	NP B137 509	· · · · · · · · · · · · · · · · · · ·	(CIT) IJP
Also	78B	NP B137 445	Novoseller	(CIT) IJP
BAKER	77	NP B126 365	+Blissett, Bloodworth, Broome, H	art+ (RHEL) IJP
LONGACRE	77	NP B122 493	+Dolbeau	(SACL) IJP
Also	76	NP B108 365	Dolbeau, Triantis, Neveu, Cadiet	(SACL) IJP
WINNIK	77	NP B128 66	+Toaff, Revel, Goldberg, Berny	(HAIF) I
FELLER	76	NP B104 219	+Fukushima, Horikawa, Kajikawa+	(NAGO, ÒSAK) IJP
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ALAH) IJP
HERNDON	75	PR D11 3183	+Longacre, Miller, Rosenfeld+	(LBL, SLAC)
KNASEL	75	PR D11 1	+Lindquist, Nelson+	(CHIC, WUSL, OSU, ANL) IJP
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC) IJP
DEVENISH	74B	NP B81 330	+Froggatt, Martin	(DESY, NORD, LOUC)
CARRERAS	70	NP B16 35	+ Donnachie	(DARE, MCHS)
BOTKE	69	PR 180 1417		(UCSB)
DEANS	69	PR 185 1797	+Wooten	(SFLA)
HEUSCH	66	PRL 17 1019	+Prescott, Dashen	`(CIT)

## $N(1700) D_{13}$

$$I(J^P) = \frac{1}{2}(\frac{3}{2}^-)$$
 Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

The various partial-wave analyses do not agree very well.

## N(1700) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1650 to 1750 (≈ 1700) OUI	RESTIMATE			
$1737 \pm 44$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
$1675 \pm 25$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
$1731 \pm 15$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
ullet $ullet$ We do not use the fo	llowing data for average	s, fit	s, Iimits,	etc. • • •
$1791 \pm 46$	BATINIC	95	DPWA	$\pi N \rightarrow N \pi$ , $N \eta$
1709	CRAWFORD	80		$\gamma N \rightarrow \pi N$
1650	SAXON	80	DPWA	$\pi^- p \rightarrow \Lambda K^0$
1690 to 1710	BAKER	78	DPWA	$\pi^- \rho \rightarrow \Lambda K^0$
1719	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
$1670 \pm 10$	¹ BAKER	77	IPWA	$\pi^- \rho \rightarrow \Lambda K^0$
1690	¹ BAKER	77	DPWA	$\pi^- p \rightarrow \Lambda K^0$
1660	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
1710	³ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

## N(1700) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
50 to 150 (≈ 100) OUR ESTIMA	TE			
$250 \pm 220$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
90 ± 40	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
110± 30	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	data for average	s, fit	s, limits,	etc. • • •
215± 60	BATINIC	95	DPWA	$\pi N \rightarrow N \pi, N \eta$
166	CRAWFORD			$\gamma N \rightarrow \pi N$
70	SAXON			$\pi^- \rho \rightarrow \Lambda K^0$
70 to 100	BAKER	78	DPWA	$\pi^- \rho \rightarrow \Lambda K^0$
126	BARBOUR			$\gamma N \rightarrow \pi N$
90 ± 25	¹ BAKER	77	IPWA	$\pi^- \rho \rightarrow \Lambda K^0$
100	¹ BAKER	77	DPWA	$\pi^- p \rightarrow \Lambda K^0$
600	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
300	³ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

## N(1700) POLE POSITION

R	EA!	LΡ	ΆF	ľ

KEAL PAK I				
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1700	⁴ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
1660 ± 30	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use th	e following data for average	s, fit	s, limits,	etc. • • •
not seen	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$
1710 or 1678	⁵ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
1616 or 1613	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
-2×IMAGINARY P	ART			
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
120	⁴ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
90 ± 40	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use th	e following data for average	s, fit	s, limits,	etc. • • •
not seen	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$
607 or 567	⁵ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
577 or 575	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$

## Baryon Particle Listings N(1700)

N(1700) ELASTIC POLE RESIDUE						
MODULUS  r						
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT		
5	HOEHLER	93	SPED	$\pi N \rightarrow \pi N$		
6±3	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$		
PHASE θ						
VALUE (°)	DOCUMENT ID		TECN	COMMENT		
$0\pm 50$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$		

## N(1700) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction $(\Gamma_i/\Gamma)$
$\Gamma_1$	Nπ	5-15 %
$\Gamma_2$	$N\eta$	
$\Gamma_3$	ΛK	<3 %
$\Gamma_4$	ΣΚ	
$\Gamma_5$	Νππ	85-95 %
$\Gamma_6$	$\Delta \pi$	
$\Gamma_7$	$\Delta(1232)\pi$ , $\it S-wave$	
Γ8	$\Delta(1232)\pi$ , $\it D-wave$	
Г9	$N\rho$	<35 %
$\Gamma_{10}$	$N\rho$ , $S=1/2$ , $D$ -wave	
$\Gamma_{11}$	$N\rho$ , $S=3/2$ , $S$ -wave	
$\Gamma_{12}$	$N\rho$ , $S=3/2$ , D-wave	
$\Gamma_{13}$	$N(\pi\pi)_{S-\text{wave}}^{I=0}$	
$\Gamma_{14}$	$p\gamma$	0.01-0.05 %
$\Gamma_{15}$	$p\gamma$ , helicity $=1/2$	0.0-0.024 %
$\Gamma_{16}$	$p\gamma$ , helicity=3/2	0.002-0.026 %
$\Gamma_{17}$	$n\gamma$	0.01-0.13 %
$\Gamma_{18}$	$n\gamma$ , helicity $=1/2$	0.0-0.09 %
Γ ₁₉	$n\gamma$ , helicity=3/2	0.01-0.05 %

## N(1700) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$				$\Gamma_1/\Gamma$	
VALUE	DOCUMENT ID		TECN	COMMENT	
0.05 to 0.15 OUR ESTIMATE					
$0.01 \pm 0.02$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$	
$0.11 \pm 0.05$	CUTKOSKY	80	<b>IPWA</b>	$\pi N \rightarrow \pi N$	
$0.08 \pm 0.03$	HOEHLER	79	<b>IPWA</b>	$\pi N \rightarrow \pi N$	
• • We do not use the following	g data for average	es, fits	s, limits,	etc. • • •	
$0.04 \pm 0.05$	BATINIC	95	DPWA	$\pi N \rightarrow N \pi$ , $N \eta$	ı
$\Gamma(N\eta)/\Gamma_{\text{total}}$				Γ ₂ /Γ	
VALUE	DOCUMENT ID		TECN	COMMENT	
• • We do not use the following	g data for average	es, fits	s, limits,	etc. • • •	
$0.10 \pm 0.06$	BATINIC	95	DPWA	$\pi N \rightarrow N \pi$ , $N \eta$	I
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \to N(1)$				(Γ₁Γ ₃ ) ^½ /Γ	
VALUE	DOCUMENT ID		TECN	COMMENT	

$( f f)^{r}/ total  \ln N\pi \rightarrow$	$N(1/00) \rightarrow VK$			(  1  3) /2/
VALUE	DOCUMENT ID		TECN	COMMENT
-0.06 to +0.04 OUR EST	IMATE			
-0.012	BELL	83	DPWA	$\pi^- \rho \rightarrow \Lambda K^0$
-0.012	SAXON	80	DPWA	$\pi^- \rho \rightarrow \Lambda K^0$
• • We do not use the form	llowing data for average	es, fits	s, limits,	etc. • • •
-0.04	⁶ BAKER	78	DPWA	See SAXON 80
$-0.03 \pm 0.004$	¹ BAKER			$\pi^- p \rightarrow \Lambda K^0$
-0.03	¹ BAKER	77	DPWA	$\pi^- p \rightarrow \Lambda K^0$
$+0.026\pm0.019$	DEVENISH	74B		Fixed-t dispersion rel.

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \to N(1700) \to \Sigma K$				$(\Gamma_1\Gamma_4)^{\frac{1}{2}}/\Gamma$
VALUE	DOCUMENT ID	TECN	COMMENT	
• • • We do not use the following	data for averages, fit	s, limits,	etc. • • •	

not seen <0.017 LIVANOS 7 DEANS 80 DPWA  $\pi p \rightarrow \Sigma K$ 75 DPWA  $\pi N \rightarrow \Sigma K$ 

Note: Signs of couplings from  $\pi\,N\to\,N\,\pi\,\pi$  analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the  $\Delta(1620)~S_{31}$  coupling to  $\Delta(1232)\,\pi.$ 

$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\pi \to N(17)$	700) → ∆(1232	2)π	S-wav	e (Γ ₁ Γ ₇ ) ^{1/2} /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
0.00 to ±0.08 OUR ESTIMATE				
$+0.02\pm0.03$				$\pi N \rightarrow \pi N & N \pi \pi$
0.00	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
-0.16	³ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \to I$	N(1700) → △(12	32) <i>π</i>	, <i>D</i> -wav	re (Γ₁Γ ₈ ) ^½
$\pm$ 0.04 to $\pm$ 0.20 OUR I	_ DOCUMENT ID	1	TECN	COMMENT
$+0.10\pm0.09$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
-0.12	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
+0.14	² LONGACRE ³ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{ ext{total}}  ext{ in } N\pi  o N$	$N(1700) \rightarrow N \rho$ , S	5=3/:	2, <i>S</i> -wa	ve (Γ ₁ Γ ₁₁ ) ¹ ⁄ ₂
±0.01 to ±0.13 OUR I	ESTIMATE			
	MANLEY	92	IPVVA	$\pi N \rightarrow \pi N \& N \pi \pi$ $\pi N \rightarrow N \pi \pi$
- 0.07 + 0.07	3 LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N_\pi \to I$	$N(1700) \rightarrow N(\pi\pi$	)/=0 S-w	ave	(Γ ₁ Γ ₁₃ ) ^½
±0.02 to ±0.28 OUR I	. <u>DOCUMENT ID</u> ESTIMATE		TECN	COMMENT
$+0.02\pm0.02$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
0.00	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
+0.2	³ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$
N(1700)	PHOTON DECA	Y AN	//PLITU	JDES
$N(1700)  ightarrow p\gamma$ , helicity-	$1/2$ amplitude $A_1$	/2		
VALUE (GeV ^{−1/2} ) −0.018±0.013 OUR ESTIMA	DOCUMENT ID		TECN	COMMENT
-0.016±0.014	CRAWFORD	83	ΙΡ\Λ/Δ	~ N -> # N
$-0.002\pm0.013$	ILAWA	91	DDIA/A	$\gamma N \rightarrow \pi N$
-0.002±0.013	ARAI	91	DDWA	$\gamma N \rightarrow \pi N$
			DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
$-0.029 \pm 0.006$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
$-0.024\pm0.019$	CRAWFORD			$\gamma N \rightarrow \pi N$
<ul> <li>• • We do not use the follo</li> </ul>	wing data for averag	es, fit	s, limits,	etc. • • •
$-0.033 \pm 0.021$	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
$-0.014 \pm 0.025$	FELLER	76	DPWA	$\gamma N \rightarrow \pi N$
$N(1700)  ightarrow p\gamma$ , helicity-	3/2 amplitude A ₃	/2		
VALUE (GeV ^{-1/2} )	DOCUMENT ID		TECN	COMMENT
-0.002±0.024 OUR ESTIMA	TE			
$-0.009\pm0.012$	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
$0.029 \pm 0.014$	AWA JI	81	DPWA	$\gamma N \rightarrow \pi N$
$-0.002 \pm 0.005$	ARAI	80	DPWA	$ \gamma N \to \pi N  \gamma N \to \pi N  \gamma N \to \pi N (fit 1) $
$0.014 \pm 0.005$	AKAI	80	DPVVA	$\gamma N \rightarrow \pi N (HEZ)$
$-0.017 \pm 0.014$	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
• • We do not use the follo	wing data for averag	es. fit	s, limits,	etc. • • •
$-0.014 \pm 0.025$	BARBOUR	78		$\gamma N \rightarrow \pi N$
0.0 ± 0.014	FELLER	76	DPWA	$\gamma N \rightarrow \pi N$
$V(1700)  o n\gamma$ , helicity-	1/2 amplitude A			
/ALUE (GeV ^{-1/2} )	DOCUMENT ID	•	TECN	COMMENT
0.000 ± 0.050 OUR ESTIMA	TE			
0.006 ± 0.024	ILAWA	81	DΡWΔ	$\gamma N \rightarrow \pi N$
-0.000±0.024 -0.002±0.013	FUJII	81		$\gamma N \rightarrow \pi N$
-0.052±0.013	ARAI	80		
-0.055±0.030				$\gamma N \rightarrow \pi N \text{ (fit 1)}$
	ARAI	80		$\gamma N \rightarrow \pi N \text{ (fit 2)}$
0.052±0.035	CRAWFORD wing data for average	80 es fita	DPWA S limits	$\gamma N \rightarrow \pi N$
	BARBOUR			$\gamma N \rightarrow \pi N$
$+0.050\pm0.042$	3/2 amplitude A ₃	/2		
$+0.050\pm0.042$ $N(1700) \rightarrow n\gamma$ , helicity- $N(1700) \rightarrow n\gamma$	DOCUMENT ID		TECN	COMMENT
$+0.050\pm0.042$ $N(1700) \rightarrow n\gamma$ , helicity: $ALUE (GeV^{-1/2})$ $-0.003\pm0.044$ OUR ESTIMA	DOCUMENT ID			
$+0.050\pm0.042$ <b>N(1700)</b> $\rightarrow n\gamma$ , helicity- $\frac{1}{2}$ $-0.003\pm0.044$ OUR ESTIMA $-0.033\pm0.017$	TE AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$
• • • We do not use the follo $+0.050\pm0.042$ <b>W(1700)</b> $\rightarrow n\gamma$ , helicity- $\frac{1}{2}$ $$	TE  AWAJI FUJII	81 81	DPWA DPWA	$ \begin{array}{ccc} \gamma  N \to & \pi  N \\ \gamma  N \to & \pi  N \end{array} $
$+0.050\pm0.042$ <b>N(1700)</b> $\rightarrow n\gamma$ , helicity- $\frac{1}{2}$ $-0.003\pm0.044$ OUR ESTIMA $-0.033\pm0.017$ $-0.018\pm0.018$ $-0.037\pm0.036$	TE  AWAJI FUJII ARAI	81 81 80	DPWA DPWA DPWA	$ \gamma N \to \pi N  \gamma N \to \pi N  \gamma N \to \pi N  $ (fit 1)
$+0.050\pm0.042$ <b>N(1700)</b> $\rightarrow$ $n\gamma$ , helicity- $\frac{1}{2}$ $-0.003\pm0.044$ OUR ESTIMA $-0.033\pm0.017$ $0.018\pm0.018$	TE  AWAJI FUJII	81 81	DPWA DPWA DPWA	$ \begin{array}{ccc} \gamma  N \to & \pi  N \\ \gamma  N \to & \pi  N \end{array} $

#### $\gamma p \rightarrow \Lambda K^+$ AMPLITUDES N(1700)

BARBOUR 78 DPWA  $\gamma N \rightarrow \pi N$ 

• • • We do not use the following data for averages, fits, limits, etc. • • •

 $+\,0.035\pm0.030$ 

-7.09

$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}}$ in $\rho$	$\gamma \rightarrow N(1700) \rightarrow \Lambda K^+$		(E ₂ _ amplitude)
VALUE (units 10-3)		TECN	
• • • We do not use t	he following data for averages,	fits, limits, etc	. • • •
4.09	TANABE 8	9 DPWA	

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } p \gamma \rightarrow$	$N(1700) \rightarrow \Lambda K^+$		(M ₂ _ amplitude)
VALUE (units 10 ⁻³ )	DOCUMENT ID	TECN	
a a M/a do not use the follo	wing data for averages fits	limits atc	

TANABE 89 DPWA

$p\gamma \rightarrow N(1700) \rightarrow \Lambda K^+ \text{ ph}$	ase angle $\theta$		(E ₂ _ amplitude)
VALUE (degrees)	DOCUMENT ID	TECN	
• • • We do not use the following	data for averages, fit	ts, limits, etc.	• • •
-35.9	TANABE 89	DPWA	

## N(1700) FOOTNOTES

- $^{\rm 1}\,{\rm The}$  two BAKER 77 entries are from an IPWA using the Barrelet-zero method and from
- ^ Ine two BAKER // entries are from an IPWA using the Barrelet-zero method and from a conventional energy-dependent analysis. 
  ^ LONGACRE 77 pole positions are from a search for poles in the unitarized T-matrix; the first (second) value uses, in addition to  $\pi N \to N\pi\pi$  data, elastic amplitudes from a Saclay (CERN) partial-wave analysis. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.
- ³ From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix
- ⁴ See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and  $\Delta$  resonances as determined from Argand diagrams of  $\pi N$  elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams. 5 LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to  $\pi N \rightarrow N \pi \pi$  data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.
- 6 The overall phase of BAKER 78 couplings has been changed to agree with previous conventions.
  7 The range given is from the four best solutions.

## N(1700) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

BATINIC	95	PR C51 2310	+Slaus, Svarc, Nefkens	(BOSK, UCLA)
HOEHLER	93	π N Newsletter 9 1		(KARL)
MANLEY	92	PR D45 4002	+Saleski	(KENT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
TANABE	89	PR C39 741	+Kohno, Bennhold	(MANZ)
Also	89	NC 102A 193	Kohno, Tanabe, Bennhold	(MANZ)
BELL	83	NP B222 389	+Blissett, Broome, Daley, Hart, Lintern	
CRAWFORD	83	NP B211 1	+Morton	(GLAS)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
AWA JI	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
FUJII	81	NP B187 53	+Hayashii, lwata, Kajikawa+	(NAGO, OSAK)
ARAI	80	Toronto Conf. 93		(INUS)
Also	82	NP B194 251	Arai, Fujii	(INUS)
CRAWFORD	80	Toronto Conf. 107		(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMÚ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
LIVANOS	80	Toronto Conf. 35	+Baton, Coutures, Kochowski, Neveu	(SACL) IJP
SAXON	80	NP B162 522	+Baker, Bell, Blissett, Bloodworth+	(RHEL, BRIS) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BAKER	78	NP B141 29	+Blissett, Bloodworth, Broome+	(RL, CAVE) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)
BAKER	77	NP B126 365	+Blissett, Bloodworth, Broome, Hart+	(RHEL) IJP
LONGACRE	77	NP B122 493	+ Dolbeau	(SACL) IJP
Also	76	NP B108 365	Dolbeau, Triantis, Neveu, Cadiet	(SACL) IJP
FELLER	76	NP B104 219	+Fukushima, Horikawa, Kajikawa+	(NAGO, OSAK) IJP
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ALAH) IJP
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC) IJP
DEVENISH	74B	NP B81 330		(DESY, NORD, LOUC)
				, , , , , , , , , , , , , , , , , , , ,

## $\overline{N(1710)} \ P_{11}$

$$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$$
 Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

The various partial-wave analyses do not agree very well.

## N(1710) MASS

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
1680 to 1740 (≈ 1710) OUR EST	IMATE		
1717±28	MANLEY 9	2 IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
$1700 \pm 50$	CUTKOSKY 8	0 IPWA	$\pi N \rightarrow \pi N$
1723 ± 9	HOEHLER 7	9 IPWA	$\pi N \rightarrow \pi N$
• • We do not use the following	g data for averages,	fits, limits,	, etc. • • •
1720 ± 10		6 IPWA	$\gamma N \rightarrow \pi N$
1766±34	¹ BATINIC 9	5 DPWA	$\pi N \rightarrow N \pi, N \eta$
1706	CUTKOSKY 9	0 IPWA	$\pi N \rightarrow \pi N$
1692	CRAWFORD 8	0 DPWA	$\gamma N \rightarrow \pi N$
1730	SAXON 8	0 DPWA	$\pi^- p \rightarrow \Lambda K^0$
1690	BAKER 7		$\pi^- p \rightarrow n\eta$
1650 to 1680	BAKER 7	'8 DPWA	$\pi^- \rho \rightarrow \Lambda K^0$
1721			$\gamma N \rightarrow \pi N$
$1625 \pm 10$			$\pi^- p \rightarrow \Lambda K^0$
1650		7 DPWA	$\pi^- \rho \rightarrow \Lambda K^0$
1720	³ LONGACRE 7		$\pi N \rightarrow N \pi \pi$
1670		5 DPWA	$\pi^- p \rightarrow \Lambda K^0$
1710	⁴ LONGACRE 7	5 IPWA	$\pi N \rightarrow N \pi \pi$

## N(1710) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
50 to 250 (≈ 100) OUR ESTIM	MATE			
480 ± 230	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
93 ± 30	CUTKOSKY	90	IPWA	$\pi N \rightarrow \pi N$
90 ± 30	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
120± 15	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the follow	ing data for average	s, fit	s, Iimits,	etc. • • •
105 ± 10	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
185 ± 61	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$
540	BELL	83	DPWA	$\pi^- \rho \rightarrow \Lambda K^0$
200	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
550	SAXON	80	DPWA	$\pi^- \rho \rightarrow \Lambda K^0$
97	BAKER	79	DPWA	$\pi^- \rho \rightarrow n\eta$
90 to 150	BAKER	78	DPWA	$\pi^- p \rightarrow \Lambda K^0$
167	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
160± 6	² BAKER	77	IPWA	$\pi^- \rho \rightarrow \Lambda K^0$
95	² BAKER	77	DPWA	$\pi^- p \rightarrow \Lambda K^0$
120	³ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
174	KNASEL	75	DPWA	$\pi^- p \rightarrow \Lambda K^0$
75	⁴ LONGACRE	75	IPWA	

## N(1710) POLE POSITION

REAL PART	DOCUMENT ID		TECN	COMMENT
1770	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1690	⁵ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
1698	CUTKOSKY	90	IPWA	$\pi N \rightarrow \pi N$
1690 ± 20	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the follow	ing data for average	es, fit	s, limits,	etc. • • •
1636	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ SoIn SM90}$
1708 or 1712	⁶ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
1720 or 1711	³ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
-2×IMAGINARY PART				
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
378	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
200	⁵ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
88	CUTKOSKY	90	<b>IPWA</b>	$\pi N \rightarrow \pi N$
80±20	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the follow	ing data for average	s, fit	s, limits,	etc. • • •
544	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$
17 or 22	6 LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
123 or 115	3 LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$

## N(1710) ELASTIC POLE RESIDUE

## MODULUS |r|

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
37	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
15	HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
9	CUTKOSKY	90	IPWA	$\pi N \rightarrow \pi N$
8 ± 2	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	data for average	s, fit:	s, limits,	etc. • • •
149	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM}90$

VALUE (°)	DOCUMENT ID		TECN	COMMENT
- 167	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
-167	CUTKOSKY	90	IPWA	$\pi N \rightarrow \pi N$
$175 \pm 35$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the	e following data for average	s, fits	s, limits,	etc. • • •
149	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM}90$

## N(1710) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction $(\Gamma_i/\Gamma)$	
$\overline{\Gamma_1}$	Νπ	10-20 %	
$\Gamma_2$	$N\eta$		
$\Gamma_3$	ΛK	5-25 %	
$\Gamma_4$	ΣΚ		
Γ ₅	$N\pi\pi$	40-90 %	
$\Gamma_6$	$\Delta\pi$	15-40 %	
Γ ₇	$\Delta(1232)\pi$ , $\it P-wave$		

## Baryon Particle Listings N(1710)

Г8	$N\rho$	5–25 %	
Гэ	$N\rho$ , $S=1/2$ , $P$ -wave		
$\Gamma_{10}$	$N\rho$ , $S=3/2$ , $P$ -wave		
$\Gamma_{11}$	$N(\pi\pi)_{S-\text{wave}}^{I=0}$	10-40 %	
$\Gamma_{12}$	$p\gamma$	0.002-0.05%	
$\Gamma_{13}$	$p\gamma$ , helicity=1/2	0.002-0.05%	
$\Gamma_{14}$	$n\gamma$	0.0-0.02%	
Γ ₁₅	$n\gamma$ , helicity=1/2	0.0-0.02%	

#### N(1710) BRANCHING RATIOS

Γ(Nπ)/Γ _{total} VALUE  0.10 to 0.20 OUR ESTIMATE	DOCUMENT ID		<u>TECN</u>	Γ ₁ /Γ
0.09±0.04 0.20±0.04 0.12±0.04	MANLEY CUTKOSKY HOEHLER		IPWA IPWA IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	data for average	s, fit	s, limits,	etc. • • •
$0.08 \pm 0.14$	BATINIC	95	DPWA	$\pi N \rightarrow N \pi$ , $N \eta$
$\Gamma(N\eta)/\Gamma_{\text{total}}$	DOGUMENT ID		TC641	Γ ₂ /Γ
• • • We do not use the following	DOCUMENT ID			
_				
$0.16 \pm 0.10$	BATINIC	95	DPWA	$\pi N \rightarrow N \pi, N \eta$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \to N(1)$	710) → Nη		TECN	$(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma$
• • We do not use the following				etc. • • •
0.22	BAKER	79	DPWA	$\pi^- p \rightarrow n\eta$
+0.383	FELTESSE	75	DPM/A	Soln A: see BAKER 79
	I LLI LOOL	13	DI WA	John A, See BARER 19
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\pi \to N(1)$	710) → <i>∧K</i>			(Γ ₁ Γ ₃ ) ^{1/2} /Γ
VALUE				(Γ ₁ Γ ₃ ) ^{1/2} /Γ
	710) → <i>∧K</i>		TECN	(Γ ₁ Γ ₃ ) ^{1/2} /Γ
<b>*************************************</b>	710) → AK  DOCUMENT ID  BELL SAXON	83 80	<i>TECN</i> DPWA DPWA	$\frac{(\Gamma_1\Gamma_3)^{\frac{1}{2}}/\Gamma}{\pi^-\rho \to \Lambda \kappa^0}$ $\pi^-\rho \to \Lambda \kappa^0$
+0.12 to +0.18 OUR ESTIMATE +0.16	710) → ΛΚ  DOCUMENT ID  BELL  SAXON  data for average	83 80 es, fit	TECN  DPWA  DPWA  s, limits,	$\begin{array}{c} (\Gamma_1\Gamma_3)^{\frac{1}{1/2}}/\Gamma \\ \\ \underline{COMMENT} \\ \pi^- \rho \to \Lambda K^0 \\ \pi^- \rho \to \Lambda K^0 \\ \text{etc.} \bullet \bullet \bullet \end{array}$
VALUE  +0.12 to +0.18 OUR ESTIMATE +0.16 +0.14  • • • • We do not use the following −0.12	710) → ΛΚ  DOCUMENT ID  BELL  SAXON  data for average  7 BAKER	83 80 es, fit	DPWA DPWA s, limits, DPWA	$\frac{\left(\Gamma_{1}\Gamma_{3}\right)^{\frac{1}{2}}/\Gamma}{\sigma^{-}\rho \to \Lambda K^{0}}$ $\pi^{-}\rho \to \Lambda K^{0}$ $\pi^{-}\rho \to \Lambda K^{0}$ etc. • • •  See SAXON 80
VALUE $+0.12$ to $+0.18$ OUR ESTIMATE $+0.16$ $+0.14$ • • • We do not use the following $-0.12$ $-0.05\pm0.03$	710) → ΛΚ  DOCUMENT ID  BELL  SAXON  data for average  7 BAKER  2 BAKER	83 80 es, fit 78 77	DPWA DPWA s, limits, DPWA IPWA	$(\Gamma_1\Gamma_3)^{\frac{1}{2}}/\Gamma$ $COMMENT$ $\pi^- p \to \Lambda K^0$ $\pi^- p \to \Lambda K^0$ etc. • • • See SAXON 80 $\pi^- p \to \Lambda K^0$
VALUE $+0.12 \text{ to } +0.18 \text{ OUR ESTIMATE}$ $+0.16 +0.16 +0.16$ $+0.14$ • • We do not use the following $-0.12 -0.05 \pm 0.03 -0.10$	710) → ΛΚ  DOCUMENT ID  BELL  SAXON  data for average  7 BAKER  2 BAKER  2 BAKER	83 80 es, fit 78 77	DPWA DPWA s, limits, DPWA IPWA DPWA	$(\Gamma_1\Gamma_3)^{\frac{1}{12}}/\Gamma$ $COMMENT$ $\pi^- \rho \to \Lambda K^0$ $\pi^- \rho \to \Lambda K^0$ etc. • •  See SAXON 80 $\pi^- \rho \to \Lambda K^0$ $\pi^- \rho \to \Lambda K^0$
VALUE $+0.12$ to $+0.18$ OUR ESTIMATE $+0.16$ $+0.14$ • • • We do not use the following $-0.12$ $-0.05\pm0.03$	710) → ΛΚ  DOCUMENT ID  BELL  SAXON  data for average  7 BAKER  2 BAKER	83 80 es, fit 78 77	DPWA DPWA s, limits, DPWA IPWA DPWA	$(\Gamma_1\Gamma_3)^{\frac{1}{2}}/\Gamma$ $COMMENT$ $\pi^- p \to \Lambda K^0$ $\pi^- p \to \Lambda K^0$ etc. • • • See SAXON 80 $\pi^- p \to \Lambda K^0$
VALUE $+0.12$ to $+0.18$ OUR ESTIMATE $+0.16$ $+0.14$ • • • We do not use the following $-0.12$ $-0.05\pm0.03$ $-0.10$ $0.10$ $(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\pi \rightarrow N(1)$	710) → ΛΚ DOCUMENT ID  BELL SAXON data for average 7 BAKER 2 BAKER 2 BAKER KNASEL  710) → ΣΚ	83 80 es, fit 78 77 77	DPWA DPWA s, limits, DPWA IPWA DPWA	$(\Gamma_1\Gamma_3)^{\frac{1}{2}}/\Gamma$ $\frac{COMMENT}{\Gamma}$ $\pi^-\rho \to \Lambda K^0$ $\pi^-\rho \to \Lambda K^0$ etc. • • •  See SAXON 80 $\pi^-\rho \to \Lambda K^0$ $\pi^-\rho \to \Lambda K^0$ $\pi^-\rho \to \Lambda K^0$ $(\Gamma_1\Gamma_4)^{\frac{1}{2}}/\Gamma$
VALUE  +0.12 to +0.18 OUR ESTIMATE +0.16 +0.14  • • • We do not use the following -0.12 -0.05±0.03 -0.10 0.10	710) → ΛΚ  DOCUMENT ID  BELL SAXON data for average 7 BAKER 2 BAKER 2 BAKER KNASEL  710) → ΣΚ  DOCUMENT ID	83 80 es, fit 78 77 77	DPWA DPWA s, limits, DPWA IPWA DPWA DPWA	$(\Gamma_1\Gamma_3)^{\frac{1}{2}}/\Gamma$ $\frac{COMMENT}{\pi^- p \to \Lambda K^0}$ $\pi^- p \to \Lambda K^0$ etc. • • • See SAXON 80 $\pi^- p \to \Lambda K^0$ $(\Gamma_1\Gamma_4)^{\frac{1}{2}}/\Gamma$ $COMMENT$
VALUE $+0.12$ to $+0.18$ OUR ESTIMATE $+0.16$ $+0.16$ $+0.16$ $+0.14$ • • We do not use the following $-0.12$ $-0.05\pm0.03$ $-0.10$ $0.10$ $(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\pi \rightarrow N(1)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\pi \rightarrow N(1)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\pi \rightarrow N(1)^{\frac{1}{2}}/\Gamma_{\text{total}}$	710) → ΛΚ  DOCUMENT ID  BELL SAXON data for average 7 BAKER 2 BAKER 2 BAKER KNASEL  710) → ΣΚ  DOCUMENT ID	83 80 88, fit 78 77 77 75	DPWA DPWA s, limits, DPWA IPWA DPWA DPWA DPWA TECN s, limits,	$(\Gamma_1\Gamma_3)^{\frac{1}{2}}/\Gamma$ $\frac{COMMENT}{\pi^- p \to \Lambda K^0}$ $\pi^- p \to \Lambda K^0$ etc. • • • See SAXON 80 $\pi^- p \to \Lambda K^0$ $(\Gamma_1\Gamma_4)^{\frac{1}{2}}/\Gamma$ $COMMENT$
VALUE $+0.12$ to $+0.18$ OUR ESTIMATE $+0.16$ $+0.16$ $+0.16$ $+0.14$ • • • We do not use the following $-0.12$ $-0.05 \pm 0.03$ $-0.10$ $0.10$ $(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\pi \rightarrow N(1)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\pi \rightarrow N(1)^{\frac{1}{2}}/\Gamma_{\text{total}}$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$ $+0.00$	710) → ΛΚ  DOCUMENT ID  BELL SAXON data for average 7 BAKER 2 BAKER 2 BAKER KNASEL  710) → ΣΚ  DOCUMENT ID data for average	83 80 78 77 77 75	DPWA DPWA s, limits, DPWA IPWA DPWA DPWA TECN s, limits,	$(\Gamma_1\Gamma_3)^{\frac{1}{2}}/\Gamma$ $\frac{COMMENT}{\pi^- p \to \Lambda K^0}$ $\pi^- p \to \Lambda K^0$ etc. • • • See SAXON 80 $\pi^- p \to \Lambda K^0$ $(\Gamma_1\Gamma_4)^{\frac{1}{2}}/\Gamma$ etc. • • •

Note: Signs of couplings from  $\pi\,{\it N}\,\rightarrow\,{\it N}\,\pi\,\pi$  analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the  $\Delta(1620)~S_{31}$ coupling to  $\Delta(1232)\pi$ .

$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N \pi \to N(1)$	1710) → <b>△</b> (123	$2)\pi$	, <i>P</i> -wav	re (Γ ₁ Γ ₇ ) ^{1/2} /Γ
VALUE	DOCUMENT ID			COMMENT
±0.16 to ±0.22 OUR EST				
$-0.21 \pm 0.04$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$ $\pi N \rightarrow N \pi \pi$
-0.17	³ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
+0.20	⁴ LONGACRE			$\pi N \rightarrow N \pi \pi$
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\pi \to N(1)$	1710) $\rightarrow N \rho$ , S	=1/:	2, <i>P</i> -wa	ve (Γ ₁ Γ ₉ ) ^½ /Γ
±0.09 to ±0.19 OUR EST	DOCUMENT ID		TECN	COMMENT
$\pm 0.09$ to $\pm 0.19$ OUR EST				
$+0.05\pm0.06$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$ $\pi N \rightarrow N \pi \pi$
+0.19	³ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
-0.20	⁴ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\pi \to N(1)$	$1710) \rightarrow N\rho$ , S	=3/	2, <i>P</i> -wa	ve $(\Gamma_1\Gamma_{10})^{\frac{1}{2}}/\Gamma$
VALUE	DOCUMENT ID		TECN	$\pi N \rightarrow N \pi \pi$
+0.31	³ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\pi \to N(1)$				(Γ₁Γ₁1) ¹ /2/Γ
±0.14 to ±0.22 OUR EST	DOCUMENT ID		TECN	COMMENT
$\pm 0.14$ to $\pm 0.22$ OUR EST	TIMATE			
$+0.04 \pm 0.05$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$ $\pi N \rightarrow N \pi \pi$
-0.26			IPWA	$\pi N \rightarrow N \pi \pi$
-0.28	⁴ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

## N(1710) PHOTON DECAY AMPLITUDES

## $N(1710) \rightarrow p\gamma$ , helicity-1/2 amplitude A_{1/2}

VALUE (GeV ^{-1/2} )	DOCUMENT ID		TECN	COMMENT
+0.009±0.022 OUR ESTIMATE				
$0.007 \pm 0.015$	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
$0.006 \pm 0.018$	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
$0.028 \pm 0.009$	AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$
$-0.009\pm0.006$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
$-0.012 \pm 0.005$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
$0.015 \pm 0.025$	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
• • We do not use the following	data for average	s, fits	s, limits,	etc. • • •
$-0.037 \pm 0.002$	LI	93	<b>IPWA</b>	$\gamma N \rightarrow \pi N$
$+0.001\pm0.039$	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
$+0.053\pm0.019$	FELLER	76	DPWA	$\gamma N \rightarrow \pi N$

## $N(1710) \rightarrow n\gamma$ , helicity-1/2 amplitude A_{1/2}

1/

VALUE (GeV ^{-1/2} )	DOCUMENT ID		TECN	COMMENT
-0.002±0.014 OUR ESTIMATE				
$-0.002\pm0.015$	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
$0.000 \pm 0.018$	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
$-0.001 \pm 0.003$	FUJII	81	DPWA	$\gamma N \rightarrow \pi N$
$0.005 \pm 0.013$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
$0.011 \pm 0.021$	ARAL	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
$-0.017 \pm 0.020$	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
	lata for averages	, fits	, limits,	etc. • • •
$0.052 \pm 0.003$	LI	93	IPWA	$\gamma N \rightarrow \pi N$
$-0.028 \pm 0.045$	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$

#### N(1710) $\gamma p \rightarrow \Lambda K^+$ AMPLITUDES

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } p \gamma$	$\rightarrow$ N(1710) $\rightarrow$ $\Lambda K^{+}$			$(M_{1-}$ amplitude)
VALUE (units 10 ⁻³ )	DOCUMENT ID		TECN	
$-10.6 \pm 0.4$	WORKMAN	90	DPWA	
• • • We do not use the	following data for averages,	fit	s, limits, etc.	• • •
- 7.21	TANABE	89	DPWA	
$p\gamma \rightarrow N(1710) \rightarrow I$	$\Lambda K^+$ phase angle $\theta$			$(M_{1-}$ amplitude)
VALUE (degrees)	DOCUMENT ID		TECN	
215 ±3	WORKMAN	90	DPWA	
• • • We do not use the	following data for averages,	fit	s, limits, etc.	• • •
176.3	TANABE		DPWA	

## N(1710) FOOTNOTES

- $^1\,\text{BATINIC}$  95 finds a second state with a 6 MeV mass difference.  $^2\,\text{The}$  two BAKER 77 entries are from an IPWA using the Barrelet-zero method and from a conventional energy-dependent analysis.
- a Conventional energy-dependent analysis. 3 LONGACRE 77 pole positions are from a search for poles in the unitarized T-matrix; the first (second) value uses, in addition to  $\pi N \to N \pi \pi$  data, elastic amplitudes from a Saclay (CERN) partial-wave analysis. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.
- ⁴ From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix
- See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and  $\Delta$  resonances as determined from Argand diagrams of  $\pi$  N elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.
- amplitudes and from piots of the speeds with which the amplitudes traverse the diagrams. CLONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to  $\pi N \to N \pi \pi$  data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.

  7 The overall phase of BAKER 78 couplings has been changed to agree with previous
- conventions.

  8 The range given for DEANS 75 is from the four best solutions.

## N(1710) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

ARNDT	96	PR C53 430	+Strakovsky, Workman	(VPI)
ARNDT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BRCO)
BATINIC	95	PR C51 2310	+Slaus, Svarc, Nefkens	(BOSK, UCLA)
HOEHLER	93	π N Newsletter 9 1		(KARL)
LI	93	PR C47 2759	+Arndt, Roper, Workman	(VPI)
MANLEY	92	PR D45 4002	+Saleski	(KĖNT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	` (VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
CUTKOSKY	90	PR D42 235	+Wang	(CMU)
WORKMAN	90	PR C42 781	-	(VPI)
TANABE	89	PR C39 741	+Kohno, Bennhold	(MÀNZ)
Also	89	NC 102A 193	Kohno, Tanabe, Bennhold	(MANZ)
BELL	83	NP B222 389	+Blissett, Broome, Daley, Hart, Lintern+	(RL) IJP
CRAWFORD	83	NP B211 1	+Morton	(GLAS)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
AWA JI	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
FUJII	81	NP B187 53	+Hayashii, Iwata, Kajikawa+	(NAGO, OSAK)
ARAI	80	Toronto Conf. 93	•	(INUS)
Also	82	NP B194 251	Arai, Fujii	(INUS)

CRAWFORD	80	Toronto Conf. 107		(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMÚ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
LIVANOS	80	Toronto Conf. 35	+Baton, Coutures, Kochowski, Neveu	` (SACL) IJP
SAXON	80	NP B162 522	+Baker, Bell, Blissett, Bloodworth+	(RHEL, BRIS) IJP
BAKER	79	NP B156 93	+Brown, Clark, Davies, Depagter, Evans+	(RHEL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BAKER	78	NP B141 29	+Blissett, Bloodworth, Broome+	(RĹ, CAVE) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)
BAKER	77	NP B126 365	+Blissett, Bloodworth, Broome, Hart+	(RHEL) IJP
LONGACRE	77	NP B122 493	+Dolbeau	(SACL) IJP
Also	76	NP B108 365	Dolbeau, Triantis, Neveu, Cadiet	(SACL) IJP
FELLER	76	NP B104 219	+Fukushima, Horikawa, Kajikawa+	(NAGO, OSAK) IJP
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ALAH) IJP
FELTESSE	75	NP B93 242	+Ayed, Bareyre, Borgeaud, David+	(SACL) IJP
KNASEL	75	PR D11 1	+Lindquist, Nelson+ (CHIC, V	VUSL, OSU, ANL) IJP
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC) IJP

## $N(1720) P_{13}$

$$I(J^P) = \frac{1}{2}(\frac{3}{2}^+)$$
 Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters **111B** (1982).

## N(1720) MASS

	• •			
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1650 to 1750 (≈ 1720)	OUR ESTIMATE			
1717±31	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
1700 ± 50	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
$1710 \pm 20$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use th	ne following data for average	s, fit	s, limits,	etc. • • •
1713±10	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
1820	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
$1711 \pm 26$	BATINIC	95	DPWA	$\pi N \rightarrow N \pi, N \eta$
1720	LI	93	IPWA	$\gamma N \rightarrow \pi N$
1785	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
1690	SAXON	80	DPWA	$\pi^- p \rightarrow \Lambda K^0$
1710 to 1790	BAKER	78	DPWA	$\pi^- p \rightarrow \Lambda K^0$
1809	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
1640 ± 10	¹ BAKER	77	IPWA	$\pi^- \rho \rightarrow \Lambda K^0$
1710	¹ BAKER	77	DPWA	$\pi^- p \rightarrow \Lambda K^0$
1750	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
1850	KNASEL	75	DPWA	$\pi^- p \rightarrow \Lambda K^0$
1720	³ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

## N(1720) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
100 to 200 (≈ 150) OUR ES	TIMATE			
$380 \pm 180$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
125± 70	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
190± 30	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the foll	owing data for average	s, fit	s, limits,	etc. • • •
153± 15	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
354	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
235 ± 51	BATINIC	95	DPWA	$\pi N \rightarrow N \pi, N \eta$
200	LI	93	IPWA	$\gamma N \rightarrow \pi N$
308	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
120	SAXON	80	DPWA	$\pi^- \rho \rightarrow \Lambda K^0$
447	BAKER	79	DPWA	$\pi^- p \rightarrow n\eta$
300 to 400	BAKER	78	DPWA.	$\pi^- p \rightarrow \Lambda K^0$
285	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
200± 50	¹ BAKER	77	IPWA	$\pi^- \rho \rightarrow \Lambda K^0$
500	1 BAKER	77	DPWA	$\pi^- p \rightarrow \Lambda K^0$
130	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
327	KNASEL	75	DPWA	$\pi^- p \rightarrow \Lambda K^0$
150	3 LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

## N(1720) POLE POSITION

REAL PART	-
1717	

VALUE (MeV)	DOCUMENT ID		TECN	COMME	VT
1717	ARNDT	95	DPWA	$\pi N \rightarrow$	Nπ
1686	⁴ HOEHLER	93	SPED	$\pi N \rightarrow$	$\pi N$
$1680 \pm 30$	CUTKOSKY	80	IPWA	$\pi N \rightarrow$	π N
<ul> <li>◆ ◆ We do not use the</li> </ul>	e following data for average	s, fits	, limits,	etc. • •	•
1675					πN Soln SM90
1716 or 1716	⁵ LONGACRE	78	IPWA	$\pi N \rightarrow$	Νππ
1745 or 1748	² LONGACRE	77	IPWA	$\pi N \rightarrow$	Νππ

-2×IMAGINARY I	PART			
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
388	ARNDT			$\pi N \rightarrow N \pi$
187	⁴ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
$120 \pm 40$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
<ul> <li>• • We do not use t</li> </ul>	he following data for average	s, fits	, limits,	etc. • • •
114	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$
124 or 126	⁵ LONGACRE	78	<b>IPWA</b>	$\pi N \rightarrow N \pi \pi$
135 or 123	² LONGACRE	77	ΙΡ\Λ/Δ	$\pi N \rightarrow N \pi \pi$

## N(1720) ELASTIC POLE RESIDUE

## MODULUS |r|

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
39	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
15	HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
8±2	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	g data for average	s, fit	s, limits,	etc. • • •
11	ARNDT	91	DPWA	$\pi{\it N}  ightarrow \pi{\it N}$ Soln SM90
PHASE $\theta$				
VALUE (°)	DOCUMENT ID		TECN	COMMENT

VALUE (°)	DOCUMENT ID		TECN	COMMENT
- 70	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
$-160 \pm 30$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the following	data for average	s, fits	s, limits,	etc. • • •
130	ARNIDT	Q1	DPM/A	# N → # N Soln SM90

## N(1720) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction $(\Gamma_i/\Gamma)$
Γ1	Nπ	10-20 %
$\Gamma_2$	$N\eta$	
Γ3	ΛK	1-15 %
$\Gamma_4$	ΣΚ	
$\Gamma_5$	$N\pi\pi$	>70 %
$\Gamma_6$	$\Delta\pi$	
$\Gamma_7$	$\Delta(1232)\pi$ , $\it P$ -wave	
Γ ₈	$N\rho$	70-85 %
Γ9	$N\rho$ , $S=1/2$ , $P$ -wave	
Γ ₁₀	$N\rho$ , $S=3/2$ , $P$ -wave	
Γ11	$N(\pi\pi)_{S-\text{wave}}^{I=0}$	
$\Gamma_{12}$	$p\gamma$	0.003-0.10 %
$\Gamma_{13}$	$p\gamma$ , helicity=1/2	0.003-0.08 %
$\Gamma_{14}$	$p\gamma$ , helicity=3/2	0.001-0.03 %
$\Gamma_{15}$	$n\gamma$	0.002-0.39 %
Γ ₁₆	$n\gamma$ , helicity=1/2	0.0-0.002 %
Γ ₁₇	$n\gamma$ , helicity=3/2	0.001-0.39 %

## N(1720) BRANCHING RATIOS

				•
VALUE	DOCUMENT ID		TECN	COMMENT
0.10 to 0.20 OUR ESTIMA	ATE			
$0.13 \pm 0.05$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
$0.10 \pm 0.04$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
$0.14 \pm 0.03$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the	following data for average	s, fit	s, limits,	etc. • • •
0.16	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
$0.18 \pm 0.04$	BATINIC	95	DPWA	$\pi N \rightarrow N \pi, N \eta$
	BATINIC	95	DPWA	$\pi N \rightarrow N \pi, N \eta$ $\Gamma_2/\Gamma$
0.18±0.04 Γ(Νη)/Γ _{total} VALUE	BATINIC  DOCUMENT ID	95	DPWA	
$\Gamma(N\eta)/\Gamma_{\text{total}}$	DOCUMENT ID		TECN	Γ ₂ /Γ

$0.002 \pm 0.01$	BATINIC	95	DPWA $\pi N \rightarrow N \pi$ ,	$N\eta$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N$	$\pi \rightarrow N(1720) \rightarrow N \eta$ DOCUMENT ID			1 ₁ ₂ ) ^{1/2} /Γ
• • • We do not use t	he following data for averag	es, fit	, limits, etc. • • •	
-0.08	BAKER	79	DPWA $\pi^- p \rightarrow n\eta$	
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N$ VALUE  -0.14 to -0.06 OUR	$\pi \to N(1720) \to \Lambda K$ DOCUMENT ID			1Γ ₃ ) ^{1/2} /Γ
-0.09		83	DPWA $\pi^- p \rightarrow \Lambda K^0$	)
-0.11	SAXON	80	DPWA $\pi^- p \rightarrow \Lambda K^0$	)
• • • We do not use t	he following data for averag	es, fit	, limits, etc. • • •	
-0.09	⁶ BAKER	78	DPWA See SAXON 8	
				0
$-0.06 \pm 0.02$	¹ BAKER		IPWA $\pi^- p \rightarrow \Lambda K^0$	

## N(1720)

$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{ ext{total}}$ in $N\pi$	DOCUMENT ID		TECN	(Γ ₁ Γ ₄ ) ^{1/2}
• • We do not use the	following data for average	s, fit	s, limits	etc. • • •
0.051 to 0.087	⁷ DEANS	75	DPWA	$\pi N \rightarrow \Sigma K$
1986 edition to a	couplings from $\pi N \to N \pi$ agree with the baryon-firs blved by choosing a negarized.	con	vention;	the overall phase
$(\Gamma_{\ell}\Gamma_{\ell})^{\frac{1}{2}}/\Gamma_{\ell+1}$ in $N\pi$	$\rightarrow N(1720) \rightarrow \Delta(123)$	2)π	, <b>P-wav</b>	re (Γ ₁ Γ ₇ ) ^{1/2}
VALUE	DOCUMENT ID			
±0.27 to ±0.37 O	UR ESTIMATE			
±0.27 to ±0.37 O	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
$\begin{array}{c} \begin{array}{c} \begin{array}{c} \text{VALUE} \\ \pm 0.27 \text{ to } \pm 0.37 \text{ O} \end{array} \\ -0.17 \\ (\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \end{array} \\ \begin{array}{c} \begin{array}{c} \text{VALUE} \\ +0.34 \pm 0.05 \end{array} \end{array}$	2 LONGACRE  → $N(1720)$ → $N\rho$ , $S$ DOCUMENT ID	77 =1/2	IPWA <b>2, <i>P</i>-wa</b>	$\pi  {\cal N}  ightarrow  {\cal N} \pi \pi$ ve $( \Gamma_1 \Gamma_9 )^{1/2}$ ${COMMENT}$
$ \begin{array}{c} \pm 0.27 \text{ to } \pm 0.37 \text{ O} \\ -0.17 \\ (\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \\ + 0.34 \pm 0.05 \\ -0.26 \end{array} $	2 LONGACRE  → $N(1720)$ → $N\rho$ , $S$ DOCUMENT ID	77 =1/:	IPWA  2, P-wa  TECN  IPWA  IPWA	$\pi N \rightarrow N \pi \pi$ ve $\frac{(\Gamma_1 \Gamma_9)^{\frac{1}{2}}}{\pi N \rightarrow \pi N \& N \pi \pi}$ $\pi N \rightarrow N \pi \pi$
$\begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c} \begin{array}{c} $	² LONGACRE  → N(1720) → N p, S  DOCUMENT ID  MANLEY ² LONGACRE ³ LONGACRE	77 =1/2 92 77 75	2, <b>P-wa</b> TECN IPWA IPWA IPWA	$\pi N \rightarrow N \pi \pi$ ve $(\Gamma_1 \Gamma_9)^{\frac{1}{2}}$ $\pi N \rightarrow \pi N \& N \pi \pi$ $\pi N \rightarrow N \pi \pi$ $\pi N \rightarrow N \pi \pi$
$ \begin{array}{c} \pm 0.27 \text{ to } \pm 0.37 \text{ O} \\ - 0.17 \\ (\Gamma_{I}\Gamma_{I})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \\ + 0.34 \pm 0.05 \\ - 0.26 \\ + 0.40 \end{array} $	² LONGACRE  → N(1720) → N p, S  DOCUMENT ID  MANLEY ² LONGACRE ³ LONGACRE  → N(1720) → N p, S  DOCUMENT ID ² LONGACRE	77 =1/3 92 77 75 =3/3 77	IPWA  2, P-wa IPWA IPWA IPWA IPWA IPWA	$\pi N \rightarrow N \pi \pi$ ve $(\Gamma_1 \Gamma_9)^{\frac{1}{2}}$ $\pi N \rightarrow \pi N \& N \pi \pi$ $\pi N \rightarrow N \pi \pi$ $\pi N \rightarrow N \pi \pi$ $\pi N \rightarrow N \pi \pi$ ve $(\Gamma_1 \Gamma_{10})^{\frac{1}{2}}$ $\pi N \rightarrow N \pi \pi$ $\pi N \rightarrow N \pi \pi$ $(\Gamma_1 \Gamma_{11})^{\frac{1}{2}}$

## $N(1720) \rightarrow p\gamma$ , helicity-1/2 amplitude $A_{1/2}$

VALUE (GeV ^{-1/2} )	DOCUMENT ID		TECN	COMMENT
+0.018±0.030 OUR ESTIMATE				
$-0.015 \pm 0.015$	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
$0.044 \pm 0.066$	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
$-0.004 \pm 0.007$	AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$
$0.051 \pm 0.009$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
$0.071 \pm 0.010$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
$0.038 \pm 0.050$	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
$\bullet~\bullet~$ We do not use the following	data for average	s, fit	s, limits,	etc. • • •
$0.012 \pm 0.003$	LI	93	IPWA	$\gamma N \rightarrow \pi N$
$+0.111\pm0.047$	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$

## $N(1720) \rightarrow p\gamma$ , helicity-3/2 amplitude A_{3/2}

VALUE (GeV ^{-1/2} )	DOCUMENT ID		TECN	COMMENT	
$-0.019\pm0.020$ OUR ESTIMATE					_
$0.007 \pm 0.010$	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$	
$-0.024 \pm 0.006$	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$	
$-0.040\pm0.016$	AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$	
$-0.058 \pm 0.010$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$	
$-0.011 \pm 0.011$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$	
$-0.014 \pm 0.040$	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$	
• • • We do not use the following	data for average	s, fits	s, limits,	etc. • • •	
$-0.022 \pm 0.003$	LI	93	IPWA	$\gamma N \rightarrow \pi N$	
$-0.063\pm0.032$	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$	

## $N(1720) \rightarrow n\gamma$ , helicity-1/2 amplitude A_{1/2}

VALUE (GeV ^{-1/2} )	DOCUMENT ID		TECN COMMENT	_
+0.001±0.015 OUR ESTIMATE				_
$0.007 \pm 0.015$	ARNDT	96	IPWA $\gamma N \rightarrow \pi N$	1
$0.002 \pm 0.005$	AWA JI	81	DPWA $\gamma N \rightarrow \pi N$	
$-0.019 \pm 0.033$	ARAI	80	DPWA $\gamma N \rightarrow \pi N$ (fit 1)	
$0.001 \pm 0.038$	ARAI	80	DPWA $\gamma N \rightarrow \pi N$ (fit 2)	
$-0.003\pm0.034$	CRAWFORD	80	DPWA $\gamma N \rightarrow \pi N$	
• • We do not use the following of	data for average	s, fit	s, limits, etc. • •	
$0.050 \pm 0.004$	LI	93	IPWA $\gamma N \rightarrow \pi N$	
$+0.007\pm0.020$	BARBOUR	78	DPWA $\gamma N \rightarrow \pi N$	

## $N(1720) \rightarrow n\gamma$ , helicity-3/2 amplitude A_{3/2}

• • • • •	, , , , , , , , , , , , , , , , , , , ,		
VALUE (GeV ^{-1/2} )	DOCUMENT ID	TECN	COMMENT
-0.029±0.061 OUR ESTIMA	ATE		
$-0.005 \pm 0.025$	ARNDT	96 IPWA	$\gamma N \rightarrow \pi N$
$-0.015 \pm 0.019$	AWAJI	81 DPWA	$\gamma N \rightarrow \pi N$
$-0.139 \pm 0.039$	ARAI	80 DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
$-0.134 \pm 0.044$	ARAI	80 DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
$0.018 \pm 0.028$	CRAWFORD	80 DPWA	$\gamma N \rightarrow \pi N$
• • We do not use the foll	owing data for averages	, fits, limits,	etc. • • •
$-0.017 \pm 0.004$	LI	93 IPWA	$\gamma N \rightarrow \pi N$
$+0.051 \pm 0.051$	BARBOUR	78 DPWA	$\gamma N \rightarrow \pi N$

#### N(1720) $\gamma p \rightarrow \Lambda K^+$ AMPLITUDES

$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } p \gamma \rightarrow N(1)$	720) → <i>∧K</i> +	-	$(E_{1+} \text{ amplitude})$
VALUE (units 10 ⁻³ )	DOCUMENT ID		TECN
10.2 ±0.2	WORKMAN	90	DPWA
• • • We do not use the following	data for average	s, fit	s, limits, etc. • •
9.52	TANABE	89	DPWA
$p\gamma \rightarrow N(1720) \rightarrow \Lambda K^+$ pha	ase angle $\theta$		$(E_{1+} \text{ amplitude})$
VALUE (degrees)	DOCUMENT ID		TECN
-124 ±2	WORKMAN	90	DPWA
• • • We do not use the following	data for average	s, fit	s, limits, etc. • • •
-103.4	TANABE	89	DPWA
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } p \gamma \rightarrow N(1)$	720) → ΛK ⁺	-	(M ₁₊ amplitude)
VALUE (units 10 ⁻³ )	DOCUMENT ID		TECN
$-4.5 \pm 0.2$	WORKMAN	90	DPWA
• • • We do not use the following	data for average	s, fit	ts, limits, etc. • •
3.18	TANABE	89	DPWA

## N(1720) FOOTNOTES

- 1  The two BAKER 77 entries are from an IPWA using the Barrelet-zero method and from a conventional energy-dependent analysis.  2  LONGACRE 77 pole positions are from a search for poles in the unitarized T-matrix; the first (second) value uses, in addition to  $\pi N \to N\pi\pi$  data, elastic amplitudes from a Saclay (CERN) partial-wave analysis. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.
- fits with Breit-Wigner circles to the 1-matrix amplitudes. 3 From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix amplitudes. 4 See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and  $\Delta$  resonances as determined from Argand diagrams of  $\pi$  N elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.
- 5 LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to  $\pi N \to N \pi \pi$  data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.
- ⁶ The overall phase of BAKER 78 copulings has been changed to agree with previous
- conventions. ⁷ The range given is from the four best solutions. DEANS 75 disagrees with  $\pi^+ p \rightarrow$  $\Sigma^+ K^+$  data of WINNIK 77 around 1920 MeV.

## N(1720) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

ARNDT	96	PR C53 430	+Strakovsky, Workman	(VPI)
ARNDT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BRCO)
BATINIC	95	PR C51 2310	+Slaus, Svarc, Nefkens	(BOSK, UCLA)
HOEHLER	93	π N Newsletter 9 1		(KARL)
LI	93	PR C47 2759	+Arndt, Roper, Workman	(VPI)
MANLEY	92	PR D45 4002	+Saleski	(KENT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
WORKMAN	90	PR C42 781		(VPI)
TANABE	89	PR C39 741	+Kohno, Bennhold	(MÁNZ)
Also	89	NC 102A 193	Kohno, Tanabe, Bennhold	(MANZ)
BELL	83	NP B222 389	+Blissett, Broome, Daley, Hart, Lintern+	` (RL) IJP
CRAWFORD	83	NP B211 1	+ Morton	(GLAS)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
AWA II	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
ARAI	80	Toronto Conf. 93		`(INUS)
Also	82	NP B194 251	Arai, Fujii	(INUS)
CRAWFORD	80	Toronto Conf. 107	,,	(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMÙ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
SAXON	80	NP B162 522	+Baker, Bell, Blissett, Bloodworth+	(RHEL, BRIS) IJP
BAKER	79	NP B156 93	+Brown, Clark, Davies, Depagter, Evans-	
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BAKER	78	NP B141 29	+Blissett, Bloodworth, Broome+	(RL, CAVE) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)
BAKER	77	NP B126 365	+Blissett, Bloodworth, Broome, Hart+	(RHEL) IJP
LONGACRE	77	NP B122 493	+Dolbeau	(SACL) IJP
Also	76	NP B108 365	Dolbeau, Triantis, Neveu, Cadiet	(SACL) IJP
WINNIK	77	NP B128 66	+Toaff, Revel, Goldberg, Berny	(HAIF) I
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ALAH) IJP
KNASEL	75	PR D11 1		, WUSL, OSU, ANL) IJP
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC) IJP
				() 02.10) 12.

N(1900) DECAY MODES  Mode  N(1900) DECAY MODES  Mode  N(1900) DECAY MODES  N(1900) BRANCHING RATIOS  N(1900) $P$ PR D45 4002 Also B4 PR D30 904  N(1900) F17  N(1900) F17  N(1900) F17	& Νππ
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8 1900 OUR ESTIMATE $1879\pm17$ MANLEY  92 IPWA $\pi N \rightarrow \pi N$ N(1900) WIDTH  MANLEY  98 $\pm78$ N(1900) DECAY MODES  N(1900) DECAY MODES  Mode  1 N $\pi$ 2 N $\pi \pi$ , 3 N $\rho$ , $S=1/2$ , $P$ -wave  N(1900) BRANCHING RATIOS  N(1900) BRANCHING RATIOS  T(N $\pi$ )/ $\Gamma$ total  MANLEY  92 IPWA $\pi N \rightarrow \pi N$ N(1900) DECAY MODES  N(1900) BRANCHING RATIOS  T(N $\pi$ )/ $\Gamma$ total  MANLEY  92 IPWA $\pi N \rightarrow \pi N$ N(1900) BRANCHING RATIOS  N(1900) N $\rho$ , $S=1/2$ , $P$ -wave  DOCUMENT ID  MANLEY  92 IPWA $\pi N \rightarrow \pi N$ N(1900) N $\rho$ , $S=1/2$ , $P$ -wave  DOCUMENT ID  MANLEY  92 IPWA $\pi N \rightarrow \pi N$ N(1900) REFERENCES  MANLEY  92 PR D45 4002  MANLEY  94 PR D30 904  Manley, Arndt, Goradia, Teplitz  N(1990) $F_{17}$ DMITTED FROM SUMMARY TABLE	& Νππ
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ALUE (MeV)  98 $\pm$ 78  MANLEY  92  IPWA $\pi N \rightarrow \pi N$ N(1900) DECAY MODES   Mode  1 $N\pi$ 2 $N\pi\pi$ 3 $N\rho$ , $S=1/2$ , $P$ -wave  N(1900) BRANCHING RATIOS $(N\pi)/\Gamma_{\text{total}}$ ALUE  2.26 $\pm$ 0.06  MANLEY  MANLEY  92  IPWA $\pi N \rightarrow \pi N$ 1	
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Mode $ \begin{array}{ccccccccccccccccccccccccccccccccccc$	& Nππ
N/(1900) BRANCHING RATIOS  N/(1900) TECN COMMENT ID TE	
$N(1900)$ BRANCHING RATIOS $(N\pi)/\Gamma_{\text{total}}$ $(N\pi)/\Gamma_{total$	
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	
ALUE $.26\pm0.06 \qquad \frac{DOCUMENT\ ID}{MANLEY} \qquad \frac{TECN}{92} \qquad \frac{COMMENT}{\pi N \rightarrow \pi N}$ $\Gamma_{J}\Gamma_{J}^{1/2}/\Gamma_{total} \text{ in } N\pi \rightarrow N (1900) \rightarrow N\rho, S = 1/2, P-wave}$ $\frac{ALUE}{10.03} \qquad \frac{DOCUMENT\ ID}{MANLEY} \qquad \frac{TECN}{92} \qquad \frac{COMMENT}{\pi N \rightarrow \pi N}$ $N (1900) \text{ REFERENCES}$ $\frac{IANLEY}{10.03} \qquad \frac{92}{94}  \frac{PR\ D45}{PR\ D30}  \frac{4002}{904} \qquad \frac{+Saleski}{Manley, Arndt, Goradia, Teplitz}$ $N (1990)  F_{17}$ $I(J^P) = \frac{1}{2}(\frac{7}{2}^+)  \text{Status:}$ $OMITTED  FROM  SUMMARY  TABLE$	
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$(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \rightarrow N(1900) \rightarrow N\rho, S = 1/2, P-\text{wave}$ $\frac{N(1900)}{N} = \frac{1}{2} \frac{PR}{2} \frac{N}{2} + \frac{N}{2} \frac{N(1900)}{N} = \frac{1}{2} \frac{N}{2} + \frac{N}{2} + \frac{N}{2} = \frac{N}{2} + \frac{N}{2} + \frac{N}{2} + \frac{N}{2} = \frac{N}{2} +	
$\frac{DOCUMENT ID}{MANLEY} \underbrace{\frac{TECN}{92}}_{PR \ D45} \underbrace{\frac{COMMENT ID}{MNLEY}}_{N(1900)} \underbrace{\frac{TECN}{REFRENCES}}_{FSaleski} \underbrace{\frac{COMMENT}{\pi N \to \pi N}}_{Manley, \ Arndt, \ Goradia, \ Teplitz}$ $\frac{N(1990)}{N(1990)} \underbrace{F_{17}}_{I(J^P)} = \frac{1}{2}(\frac{7}{2}^+) \text{ Status:}$ $\frac{DMITTED \ FROM \ SUMMARY \ TABLE}{N(1990)} \underbrace{\frac{TECN}{\pi N}}_{IV} \underbrace{\frac{COMMENT ID}{\pi N \to \pi N}}_{IV} \underbrace{\frac{COMMENT ID}{\pi N \to \pi N}}_{IV}$	
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OMITTED FROM SUMMARY TABLE  Most of the results published before 1975 are now obsolete and h	ጥጥ
Most of the results published before 1975 are now obsolete and h	
been omitted. They may be found in our 1982 edition, Phy	
Letters <b>111B</b> (1982).	ясэ
The various analyses do not agree very well with one another.	
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ALUE (MeV) DOCUMENT ID TECN COMMENT	
$pprox$ 1990 OUR ESTIMATÉ $2086\pm~28$ MANLEY 92 IPWA $\piN ightarrow~\piN$	
2018 CRAWFORD 80 DPWA $\gamma N  ightarrow \pi N$	& N = =
1970 ± 50 CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$ 2005 ± 150 HOEHLER 79 IPWA $\pi N \rightarrow \pi N$	& Νππ

2018	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
1970 ± 50	CUTKOSKY	80	<b>IPWA</b>	$\pi N \rightarrow \pi N$
$2005 \pm 150$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
1999	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
	N(1990) WID	тн		
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
535 ± 120	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
295	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
$350 \pm 120$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
$350 \pm 100$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
216	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
REAL PART VALUE (MeV)	N(1990) POLE PO	1311		COMMENT
1900 + 30	CUTKOSKY	90		$\pi N \rightarrow \pi N$
	ne following data for average			
not seen	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ SoIn SM90}$
-2×IMAGINARY P			×5.011	
	DOCUMENT ID		TECN	COMMENT
260±60	CUTKOSKY			$\pi N \rightarrow \pi N$
<i>VALUE</i> (MeV) 260 ± 60 • • • We do not use th				

MODULUS  r	
VALUE (MeV)	DOCUMENT ID TECN COMMENT
9±3	CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$
PHASE θ	
VALUE (°)	DOCUMENT ID TECN COMMENT
$-60 \pm 30$	CUTKOSKY 80 IPWA $\pi N \to \pi N$
^	V(1990) DECAY MODES
Mode	
$\Gamma_1$ $N\pi$	
$\Gamma_2 N \eta$	
$\Gamma_3$ $\Lambda K$ $\Gamma_{\Lambda}$ $\Sigma K$	
$\Gamma_4$ $\Sigma K$ $\Gamma_5$ $N\pi\pi$	
$\Gamma_6$ $p\gamma$ , helicity=1/2	
$\Gamma_7$ $p\gamma$ , helicity=3/2	
$\Gamma_8$ $n\gamma$ , helicity=1/2	
$\Gamma_9$ $n\gamma$ , helicity=3/2	
•	990) BRANCHING RATIOS
$\Gamma(N\pi)/\Gamma_{\text{total}}$	Γ ₁ DOCUMENT ID TECN COMMENT
0.06±0.02	MANLEY 92 IPWA $\pi N \rightarrow \pi N \& N \pi \pi$
$0.06 \pm 0.02$	CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$
$0.04 \pm 0.02$	HOEHLER 79 IPWA $\pi N \rightarrow \pi N$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \to N$	
<u>VALUE</u> - 0.043	$\begin{array}{cccc} \underline{\textit{DOCUMENT ID}} & \underline{\textit{TECN}} & \underline{\textit{COMMENT}} \\ \text{BAKER} & 79 & \text{DPWA} & \pi^- \rho \rightarrow n \eta \end{array}$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \to N$	$I(1990) \rightarrow \Lambda K \qquad (\Gamma_1 \Gamma_3)^{\frac{1}{2}}$
VALUE	DOCUMENT ID TECN COMMENT
+0.01	BELL 83 DPWA $\pi^- p \rightarrow \Lambda K_0^0$
not seen -0.021 ±0.033	SAXON 80 DPWA $\pi^- p \rightarrow \Lambda K^0$ DEVENISH 74B Fixed-t dispersion rel.
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \to N$	$\Gamma(1990) \to \Sigma K \qquad (\Gamma_1 \Gamma_4)^{\frac{1}{2}}$
VALUE 0.010 to 0.023	$1 \text{ DEANS}$ 75 DPWA $\pi N \rightarrow \Sigma K$
VALUE 0.010 to 0.023 0.06	$ \begin{array}{c cccc} \hline \textit{DOCUMENT ID} & \textit{TECN} & \textit{COMMENT} \\ \hline 1 \text{ DEANS} & 75 & \text{DPWA} & \pi N \rightarrow \Sigma K \\ \text{LANGBEIN} & 73 & \text{IPWA} & \pi N \rightarrow \Sigma K \text{ (sol. 1)} \\ \hline \end{array} $
VALUE 0.010 to 0.023 0.06 $(\Gamma_I \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \to N$ VALUE	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
VALUE 0.010 to 0.023 0.06 $(\Gamma_I \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \to N$ VALUE	$\begin{array}{c ccccc} & DOCUMENT ID & TECN & COMMENT \\ 1 \text{ DEANS} & 75 & DPWA & \pi N \to \Sigma K \\ \text{LANGBEIN} & 73 & IPWA & \pi N \to \Sigma K \text{ (sol. 1)} \end{array} (1990) \to N\pi\pi$
VALUE 0.010 to 0.023 0.06 $(\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \to N$ VALUE not seen $N(1990) \text{ F}$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
VALUE 0.010 to 0.023 0.06 $(\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \to N$ VALUE not seen $N(1990) \to \rho\gamma, \text{ helicity-1}.$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
VALUE $(\Gamma_i \Gamma_f)^{\frac{1}{2}}/\Gamma_{ ext{total}} \text{ in } N\pi  o N$ VALUE $(\Gamma_i \Gamma_f)^{\frac{1}{2}}/\Gamma_{ ext{total}} \text{ in } N\pi  o N$ N(1990) $\rightarrow N(1990)  o p\gamma$ , helicity-1 VALUE $(\text{GeV}^{-1/2})$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
VALUE 0.010 to 0.023 0.06 $(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \to N$ VALUE N(1990) F  N(1990) $\rightarrow p\gamma$ , helicity-1 VALUE (GeV ^{-1/2} ) 0.030 ± 0.029 0.001 ± 0.040	PHOTON DECAY AMPLITUDES    DOCUMENT ID   TECN COMMENT   TO DPWA $\pi N \rightarrow \Sigma K$ (sol. 1)    1 DEANS   75 DPWA $\pi N \rightarrow \Sigma K$ (sol. 1)    1 DPWA $\pi N \rightarrow \Sigma K$ (sol. 1)    1 DPWA $\pi N \rightarrow \Sigma K$ (sol. 1)    1 DPWA $\pi N \rightarrow \Sigma K$ (sol. 1)    1 DPWA $\pi N \rightarrow \Sigma K$ (sol. 1)    1 DPWA $\pi N \rightarrow \Sigma K$ (sol. 1)    1 DPWA $\pi N \rightarrow K M \pi M$   DPWA $\pi N \rightarrow K M M M M M M M M M M M M M M M M M M$
VALUE 0.010 to 0.023 0.06 $(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \to N$ VALUE N(1990) F  N(1990) $\rightarrow p\gamma$ , helicity-1 VALUE (GeV ^{-1/2} ) 0.030 ± 0.029 0.001 ± 0.040	PHOTON DECAY AMPLITUDES $ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
VALUE  0.010 to 0.023 0.06 $(\Gamma_{I}\Gamma_{I})^{\frac{1}{2}}/\Gamma_{total} \text{ in } N\pi \rightarrow N$ VALUE  N(1990) $\rightarrow p\gamma$ , helicity-1  VALUE (GeV ^{-1/2} ) 0.030 $\pm$ 0.029 0.001 $\pm$ 0.040  • • • We do not use the follow 0.040	PHOTON DECAY AMPLITUDES    DECUMENT ID   TECN COMMENT   TECN $\pi N \rightarrow \Sigma K$ (sol. 1)    Company ID   TECN $\pi N \rightarrow \Sigma K$ (sol. 1)   DOCUMENT ID   TECN $\pi N \rightarrow N \pi \pi$   PHOTON DECAY AMPLITUDES    DOCUMENT ID   TECN $\pi N \rightarrow N \pi \pi$   PHOTON DECAY AMPLITUDES    DOCUMENT ID   TECN $\pi N \rightarrow \pi N$ (CRAWFORD 80 DPWA $\pi N \rightarrow \pi N$ fing data for averages, fits, limits, etc. • • • BARBOUR 78 DPWA $\pi N \rightarrow \pi N$
VALUE  0.010 to 0.023  0.06 $(\Gamma_{I}\Gamma_{I})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \rightarrow N$ VALUE  N(1990) $\rightarrow p\gamma$ , helicity-1  VALUE (GeV ^{-1/2} )  0.030 ± 0.029  0.001 ± 0.040  N(1990) $\rightarrow p\gamma$ , helicity-3  N(1990) $\rightarrow p\gamma$ , helicity-3	PHOTON DECAY AMPLITUDES    DECUMENT ID   TECN COMMENT   TECN $\pi N \rightarrow \Sigma K$ (sol. 1)    Company ID   TECN $\pi N \rightarrow \Sigma K$ (sol. 1)   DOCUMENT ID   TECN $\pi N \rightarrow N \pi \pi$   PHOTON DECAY AMPLITUDES    DOCUMENT ID   TECN $\pi N \rightarrow N \pi \pi$   PHOTON DECAY AMPLITUDES    DOCUMENT ID   TECN $\pi N \rightarrow \pi N$ (CRAWFORD 80 DPWA $\pi N \rightarrow \pi N$ fing data for averages, fits, limits, etc. • • • BARBOUR 78 DPWA $\pi N \rightarrow \pi N$
VALUE $0.010 \text{ to } 0.023$ $0.06$ $(\Gamma_I\Gamma_f)^{1/2}/\Gamma_{\text{total}}$ in $N\pi \to N$ NALUE not seen $N(1990) \to p\gamma$ , helicity-1, $N(1990) \to p\gamma$ , helicity-1, $N(1990) \to p\gamma$ , helicity-1, $N(1990) \to p\gamma$ , helicity-3, $N(1990) \to p\gamma$	PHOTON DECAY AMPLITUDES    AMP   AMP   AMP   AMP   AMP   AMP
VALUE 0.010 to 0.023 0.06  ( $\Gamma_I \Gamma_f$ ) $\frac{1}{2}$ / $\Gamma_{total}$ in $N\pi \to N$ VALUE  not seen  N(1990) $\rightarrow p\gamma$ , helicity-1  VALUE (GeV ^{-1/2} ) 0.030±0.029 0.001±0.040  • • • We do not use the follow 0.040  N(1990) $\rightarrow p\gamma$ , helicity-3  VALUE (GeV ^{-1/2} ) 0.086±0.060	PHOTON DECAY AMPLITUDES    1 DEANS   75 DPWA $\pi N \rightarrow \Sigma K$ (sol. 1)    1 DEANS   75 DPWA $\pi N \rightarrow \Sigma K$ (sol. 1)    1 DEANS   75 DPWA $\pi N \rightarrow \Sigma K$ (sol. 1)    1 DEANS   75 DPWA $\pi N \rightarrow \Sigma K$ (sol. 1)    2 DOCUMENT ID TECN COMMENT   N \to N \pi \pi    2 AMPAJI   81 DPWA $\gamma N \rightarrow \pi N$   N \to
$VALUE$ 0.0.00 0.006 (Γ _Γ Γ _Γ ) $\frac{1}{2}$ /Γ _{total} in Nπ → N $VALUE$ not seen  N(1990) → $p\gamma$ , helicity-1 0.030±0.029 0.001±0.040 • • • We do not use the follow 0.040 N(1990) → $p\gamma$ , helicity-3 $VALUE$ (GeV ^{-1/2} ) 0.050±0.000 0.060±0.060 0.060±0.060 0.004±0.025	PHOTON DECAY AMPLITUDES    1 DEANS   75 DPWA $\pi N \rightarrow \Sigma K$   Sol. 1)    1 DEANS   75 DPWA $\pi N \rightarrow \Sigma K$   Sol. 1)    1 DPWA $\pi N \rightarrow \Sigma K$   Sol. 1)    2 DOCUMENT ID   TECN   COMMENT   TECN
VALUE 0.010 to 0.023 0.006 $(\Gamma_f \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \to N$ VALUE NOT seen  N(1990) $\rightarrow p\gamma$ , helicity-1, VALUE (GeV ^{-1/2} ) 0.030 $\pm$ 0.029 0.001 $\pm$ 0.040 $\rightarrow$ • • • We do not use the follow 0.040 $\rightarrow$ • • • We do not use the follow 0.040 0.040 $\rightarrow$ 0.086 $\pm$ 0.060 0.004 $\pm$ 0.086 $\pm$ 0.060 0.004 $\pm$ 0.025 $\rightarrow$ • • • We do not use the follow	PHOTON DECAY AMPLITUDES    1 DEANS   75 DPWA $\pi N \rightarrow \Sigma K$ (sol. 1)    1 DEANS   75 DPWA $\pi N \rightarrow \Sigma K$ (sol. 1)    1 DEANS   75 DPWA $\pi N \rightarrow \Sigma K$ (sol. 1)    1 DEANS   75 DPWA $\pi N \rightarrow \Sigma K$ (sol. 1)    2 DOCUMENT ID TECN COMMENT   N \to N \pi \pi    2 AMPAJI   81 DPWA $\gamma N \rightarrow \pi N$   N \to
$VALUE$ 0.010 to 0.023 0.010 to 0.029 0.001 ±0.040 • • • We do not use the follow 0.040  N(1990) → $p\gamma$ , helicity-1 0.030 ±0.029 0.001 ±0.040 • • • We do not use the follow 0.040  N(1990) → $p\gamma$ , helicity-3 0.086 ±0.060 0.004 ±0.025 • • • We do not use the follow +0.004	PHOTON DECAY AMPLITUDES    1 DEANS   75 DPWA $\pi N \rightarrow \Sigma K$ (sol. 1)    1 DEANS   75 DPWA $\pi N \rightarrow \Sigma K$ (sol. 1)    1 DOCUMENT ID LONGACRE   75 TECN COMMENT   $\pi N \rightarrow N \pi \pi$   2 Amplitude A _{1/2}   $\pi N \rightarrow N \pi N$   2 CRAWFORD   80 DPWA $\pi N \rightarrow \pi N$   3 CRAWFORD   80 DPWA $\pi N \rightarrow \pi N$   4 CRAWFORD   80 DPWA $\pi N \rightarrow \pi N$   5 CRAWFORD   80 DPWA $\pi N \rightarrow \pi N$   6 CRAWFORD   80 DPWA $\pi N \rightarrow \pi N$   7 CRAWFORD   80 DPWA $\pi N \rightarrow \pi N$   8 DPWA $\pi N \rightarrow \pi N$   9 DPWA $\pi N \rightarrow \pi N$   1 DPWA $\pi N \rightarrow \pi N$   2 CRAWFORD   80 DPWA $\pi N \rightarrow \pi N$   2 CRAWFORD   80 DPWA $\pi N \rightarrow \pi N$   3 DPWA $\pi N \rightarrow \pi N$   4 CRAWFORD   80 DPWA $\pi N \rightarrow \pi N$   5 DPWA $\pi N \rightarrow \pi N$   6 DPWA $\pi N \rightarrow \pi N$   7 S DPWA $\pi N \rightarrow \pi N$   7 S DPWA $\pi N \rightarrow \pi N$   8 DPWA $\pi N \rightarrow \pi N$   9 DPWA $\pi N \rightarrow \pi N$   1 DPWA $\pi N \rightarrow \pi N$   1 DPWA $\pi N \rightarrow \pi N$   2 S DPWA $\pi N \rightarrow \pi N$   3 DPWA $\pi N \rightarrow \pi N$   4 DPWA $\pi N \rightarrow \pi N$   5 DPWA $\pi N \rightarrow \pi N$   6 DPWA $\pi N \rightarrow \pi N$   7 S DPWA $\pi N \rightarrow \pi N$   8 DPWA $\pi N \rightarrow \pi N$   9 DPWA $\pi N \rightarrow \pi N$   9 DPWA $\pi N \rightarrow \pi N$   1 DPWA $\pi N \rightarrow \pi N$   1 DPWA $\pi N \rightarrow \pi N$   2 DPWA $\pi N \rightarrow \pi N$   3 DPWA $\pi N \rightarrow \pi N$   4 DPWA $\pi N \rightarrow \pi N$   5 DPWA $\pi N \rightarrow \pi N$   6 DPWA $\pi N \rightarrow \pi N$   7 S DPWA $\pi N \rightarrow \pi N$   7 S DPWA $\pi N \rightarrow \pi N$   9 DPWA $\pi N \rightarrow \pi N$   1 DPWA $\pi N \rightarrow \pi N$   1 DPWA $\pi N \rightarrow \pi N$   1 DPWA $\pi N \rightarrow \pi N$   2 DPWA $\pi N \rightarrow \pi N$   3 DPWA $\pi N \rightarrow \pi N$   4 DPWA $\pi N \rightarrow \pi N$   5 DPWA $\pi N \rightarrow \pi N$   7 S DPWA $\pi N \rightarrow \pi N$   7 S DPWA $\pi N \rightarrow \pi N$   9 DPWA $\pi N \rightarrow \pi N$   1 DPWA $\pi N \rightarrow \pi N$   1 DPWA $\pi N \rightarrow \pi N$   1 DPWA $\pi N \rightarrow \pi N$   2 DPWA $\pi N \rightarrow \pi N$   3 DPWA $\pi N \rightarrow \pi N$   4 DPWA $\pi N \rightarrow \pi N$   5 DPWA $\pi N \rightarrow \pi N$   7 S DPWA $\pi N \rightarrow \pi N$
$VALUE$ 0.06  (Γ _Γ Γ _Γ ) $V_2$ /Γ _{total} in Nπ → N $VALUE$ not seen  N(1990) → $p\gamma$ , helicity-1 $VALUE$ (GeV ^{-1/2} ) 0.030±0.029 0.001±0.040 • • We do not use the follow 0.040  N(1990) → $p\gamma$ , helicity-3 $VALUE$ (GeV ^{-1/2} ) 0.086±0.060 0.096±0.060 0.004±0.025 • • • We do not use the follow +0.004  N(1990) → $p\gamma$ , helicity-3 $VALUE$ (GeV ^{-1/2} ) 0.086±0.060 0.096±0.060 0.096±0.060 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096 0.096±0.096	PHOTON DECAY AMPLITUDES    1 DEANS   75 DPWA $\pi N \rightarrow \Sigma K$ (sol. 1)    1 DEANS   75 DPWA $\pi N \rightarrow \Sigma K$ (sol. 1)    1 DOCUMENT ID LONGACRE   75 TECN COMMENT   $\pi N \rightarrow N \pi \pi$   2 Amplitude A _{1/2}   $\pi N \rightarrow N \pi N$   2 CRAWFORD   80 DPWA $\pi N \rightarrow \pi N$   3 CRAWFORD   80 DPWA $\pi N \rightarrow \pi N$   4 CRAWFORD   80 DPWA $\pi N \rightarrow \pi N$   5 CRAWFORD   80 DPWA $\pi N \rightarrow \pi N$   6 CRAWFORD   80 DPWA $\pi N \rightarrow \pi N$   7 CRAWFORD   80 DPWA $\pi N \rightarrow \pi N$   8 DPWA $\pi N \rightarrow \pi N$   9 DPWA $\pi N \rightarrow \pi N$   1 DPWA $\pi N \rightarrow \pi N$   2 CRAWFORD   80 DPWA $\pi N \rightarrow \pi N$   2 CRAWFORD   80 DPWA $\pi N \rightarrow \pi N$   3 DPWA $\pi N \rightarrow \pi N$   4 CRAWFORD   80 DPWA $\pi N \rightarrow \pi N$   5 DPWA $\pi N \rightarrow \pi N$   6 DPWA $\pi N \rightarrow \pi N$   7 S DPWA $\pi N \rightarrow \pi N$   7 S DPWA $\pi N \rightarrow \pi N$   8 DPWA $\pi N \rightarrow \pi N$   9 DPWA $\pi N \rightarrow \pi N$   1 DPWA $\pi N \rightarrow \pi N$   1 DPWA $\pi N \rightarrow \pi N$   2 S DPWA $\pi N \rightarrow \pi N$   3 DPWA $\pi N \rightarrow \pi N$   4 DPWA $\pi N \rightarrow \pi N$   5 DPWA $\pi N \rightarrow \pi N$   6 DPWA $\pi N \rightarrow \pi N$   7 S DPWA $\pi N \rightarrow \pi N$   8 DPWA $\pi N \rightarrow \pi N$   9 DPWA $\pi N \rightarrow \pi N$   9 DPWA $\pi N \rightarrow \pi N$   1 DPWA $\pi N \rightarrow \pi N$   1 DPWA $\pi N \rightarrow \pi N$   2 DPWA $\pi N \rightarrow \pi N$   3 DPWA $\pi N \rightarrow \pi N$   4 DPWA $\pi N \rightarrow \pi N$   5 DPWA $\pi N \rightarrow \pi N$   6 DPWA $\pi N \rightarrow \pi N$   7 S DPWA $\pi N \rightarrow \pi N$   7 S DPWA $\pi N \rightarrow \pi N$   9 DPWA $\pi N \rightarrow \pi N$   1 DPWA $\pi N \rightarrow \pi N$   1 DPWA $\pi N \rightarrow \pi N$   1 DPWA $\pi N \rightarrow \pi N$   2 DPWA $\pi N \rightarrow \pi N$   3 DPWA $\pi N \rightarrow \pi N$   4 DPWA $\pi N \rightarrow \pi N$   5 DPWA $\pi N \rightarrow \pi N$   7 S DPWA $\pi N \rightarrow \pi N$   7 S DPWA $\pi N \rightarrow \pi N$   9 DPWA $\pi N \rightarrow \pi N$   1 DPWA $\pi N \rightarrow \pi N$   1 DPWA $\pi N \rightarrow \pi N$   1 DPWA $\pi N \rightarrow \pi N$   2 DPWA $\pi N \rightarrow \pi N$   3 DPWA $\pi N \rightarrow \pi N$   4 DPWA $\pi N \rightarrow \pi N$   5 DPWA $\pi N \rightarrow \pi N$   7 S DPWA $\pi N \rightarrow \pi N$
$VALUE$ 0.010 to 0.023 0.06  (Γ _Γ Γ _f ) $V_2$ /Γ _{total} in Nπ → N  VALUE  N(1990) → $\rho\gamma$ , helicity-1  VALUE (GeV ^{-1/2} ) 0.030 ± 0.029 0.001 ± 0.040  N(1990) → $\rho\gamma$ , helicity-3  VALUE (GeV ^{-1/2} ) 0.086 ± 0.060 0.004 ± 0.025 • • • We do not use the follow +0.004  N(1990) → $\rho\gamma$ , helicity-3  VALUE (GeV ^{-1/2} ) -0.004  N(1990) → $\rho\gamma$ , helicity-1  VALUE (GeV ^{-1/2} ) -0.001	DOCUMENT ID 1 DEANS 75 DPWA $\pi N \rightarrow \Sigma K$ LANGBEIN 73 IPWA $\pi N \rightarrow \Sigma K$ (sol. 1)  (1990) → $N\pi\pi$ DOCUMENT ID LONGACRE 75 IPWA $\frac{TECN}{\pi N \rightarrow N\pi\pi}$ PHOTON DECAY AMPLITUDES  /2 amplitude A _{1/2} DOCUMENT ID CRAWFORD 80 DPWA $\gamma N \rightarrow \pi N$ ring data for averages, fits, limits, etc. • • •  BARBOUR 78 DPWA $\gamma N \rightarrow \pi N$ /2 amplitude A _{3/2} DOCUMENT ID AWAJI 81 DPWA $\gamma N \rightarrow \pi N$ FECN COMMENT  AWAJI 81 DPWA $\gamma N \rightarrow \pi N$ CRAWFORD 80 DPWA $\gamma N \rightarrow \pi N$ PHOTON DECAY  TECN TECN TECN TECN TECN TECN TECN TEC
$VALUE$ 0.010 to 0.023 0.06  (Γ _I Γ _Γ ) $\frac{1}{2}$ /Γ _{total} in $Nπ → N$ $VALUE$ not seen $N(1990) → pγ, helicity-1$ $VALUE (GeV^{-1/2})$ 0.030 ± 0.029 0.001 ± 0.040 $N(1990) → pγ, helicity-3$ $VALUE (GeV^{-1/2})$ 0.086 ± 0.060 0.004 ± 0.025 • • • We do not use the follow +0.004 $N(1990) → pγ, helicity-3$ $VALUE (GeV^{-1/2})$ 0.086 ± 0.060 0.004 ± 0.025 • • • We do not use the follow +0.004 $N(1990) → pγ, helicity-1$ $VALUE (GeV^{-1/2})$ 0.001 -0.001	POCUMENT ID TECN COMMENT  1 DEANS 75 DPWA $\pi N \rightarrow \Sigma K$ LANGBEIN 73 IPWA $\pi N \rightarrow \Sigma K$ (sol. 1)  1 (1990) $\rightarrow N \pi \pi$ POCUMENT ID TECN COMMENT  LONGACRE 75 IPWA $\pi N \rightarrow N \pi \pi$ PHOTON DECAY AMPLITUDES  1 DPWA $\gamma N \rightarrow \pi N$ CRAWFORD 80 DPWA $\gamma N \rightarrow \pi N$ CRAWFORD 80 DPWA $\gamma N \rightarrow \pi N$ 1 DPWA $\gamma N \rightarrow \pi N$ 1 DPWA $\gamma N \rightarrow \pi N$ 2 amplitude A _{3/2} DOCUMENT ID TECN COMMENT  AWAJI 81 DPWA $\gamma N \rightarrow \pi N$ 1 DPWA $\gamma N \rightarrow \pi N$ 2 amplitude A _{3/2} DOCUMENT ID TECN COMMENT  AWAJI 81 DPWA $\gamma N \rightarrow \pi N$ 2 amplitude A _{3/2} DOCUMENT ID TECN COMMENT  AWAJI 81 DPWA $\gamma N \rightarrow \pi N$ 3 DPWA $\gamma N \rightarrow \pi N$ 4 AMABI 81 DPWA $\gamma N \rightarrow \pi N$ 5 DPWA $\gamma N \rightarrow \pi N$ 6 DPWA $\gamma N \rightarrow \pi N$ 7 DPWA $\gamma N \rightarrow \pi N$ 8 DPWA $\gamma N \rightarrow \pi N$
$VALUE$ 0.010 to 0.023 0.06  (Γ _I Γ _I ) $\frac{1}{2}$ /Γ _{total} in Nπ → N $VALUE$ not seen  N(1990) → $p\gamma$ , helicity-1 $VALUE$ (GeV ^{-1/2} ) 0.030 ± 0.029 0.001 ± 0.040 0.040  N(1990) → $p\gamma$ , helicity-3 $VALUE$ (GeV ^{-1/2} ) 0.086 ± 0.060 0.004 ± 0.025 • • • We do not use the follow  +0.004  N(1990) → $p\gamma$ , helicity-3 $VALUE$ (GeV ^{-1/2} ) -0.086 ± 0.060 0.004 ± 0.025 • • • We do not use the follow  +0.004  N(1990) → $p\gamma$ , helicity-1 $VALUE$ (GeV ^{-1/2} ) -0.001	DOCUMENT ID 1 DEANS 75 DPWA $\pi N \rightarrow \Sigma K$ LANGBEIN 73 IPWA $\pi N \rightarrow \Sigma K$ (sol. 1)  (1990) → $N\pi\pi$ DOCUMENT ID LONGACRE 75 IPWA $\frac{TECN}{\pi N \rightarrow N\pi\pi}$ PHOTON DECAY AMPLITUDES  /2 amplitude A _{1/2} DOCUMENT ID CRAWFORD 80 DPWA $\gamma N \rightarrow \pi N$ ring data for averages, fits, limits, etc. • • •  BARBOUR 78 DPWA $\gamma N \rightarrow \pi N$ /2 amplitude A _{3/2} DOCUMENT ID AWAJI 81 DPWA $\gamma N \rightarrow \pi N$ FECN COMMENT  AWAJI 81 DPWA $\gamma N \rightarrow \pi N$ CRAWFORD 80 DPWA $\gamma N \rightarrow \pi N$ PHOTON DECAY  TECN TECN TECN TECN TECN TECN TECN TEC
$VALUE$ 0.010 to 0.023 0.06  (Γ _I Γ _I ) $\frac{1}{2}$ /Γ _{total} in $N\pi \rightarrow N$ $VALUE$ not seen $N(1990) \rightarrow p\gamma$ , helicity-1, $VALUE (GeV^{-1/2})$ 0.030 ± 0.029 0.001 ± 0.040 $N(1990) \rightarrow p\gamma$ , helicity-3, $VALUE (GeV^{-1/2})$ 0.086 ± 0.060 0.004 ± 0.025 • • • We do not use the follow $N(1990) \rightarrow p\gamma$ , helicity-1, $VALUE (GeV^{-1/2})$ 0.086 ± 0.060 0.004 ± 0.025 • • • We do not use the follow $VALUE (GeV^{-1/2})$ 0.001 0.001 0.001 0.001 0.001 0.009 0.009 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090 0.0090	POCUMENT ID  1 DEANS  75 DPWA $\pi N \rightarrow \Sigma K$ LANGBEIN  73 IPWA $\pi N \rightarrow \Sigma K$ (sol. 1)  1 (1990) $\rightarrow N \pi \pi$ POCUMENT ID  LONGACRE  75 IPWA  78 PHOTON DECAY AMPLITUDES  78 DOCUMENT ID  AWAJI  AWAJI  B1 DPWA $\gamma N \rightarrow \pi N$ CRAWFORD  BARBOUR  78 DPWA $\gamma N \rightarrow \pi N$ 70 DPWA $\gamma N \rightarrow \pi N$ 71 IPWA  71 DPWA  72 AMPLITUDES  72 AMPLITUDES  73 IPWA  74 AMPLITUDES  75 IPWA  76 AMPLITUDES  77 IPWA  77 AMPLITUDES  78 DPWA  78 AMPLITUDES  78 AMPLITU
VALUE 0.010 to 0.023 0.06  (Γ _I Γ _Γ ) $\frac{1}{2}$ /Γ _{total} in Nπ → N VALUE not seen  N(1990) → $p\gamma$ , helicity-1 VALUE (GeV ^{-1/2} ) 0.030 ± 0.029 0.001 ± 0.040 0.040  N(1990) → $p\gamma$ , helicity-3 VALUE (GeV ^{-1/2} ) 0.086 ± 0.060 0.004 ± 0.025 • • • We do not use the follow +0.004  N(1990) → $n\gamma$ , helicity-1 VALUE (GeV ^{-1/2} ) -0.078 ± 0.030 • • • We do not use the follow -0.069 N(1990) → $n\gamma$ , helicity-3 VALUE (GeV ^{-1/2} )	DOCUMENT ID 1 DEANS 75 DPWA $\pi N \rightarrow \Sigma K$ LANGBEIN 73 IPWA $\pi N \rightarrow \Sigma K$ (sol. 1)  (1990) → $N \pi \pi$ DOCUMENT ID LONGACRE 75 IPWA $\pi N \rightarrow \Sigma K$ (sol. 1)  PHOTON DECAY AMPLITUDES  /2 amplitude A _{1/2} DOCUMENT ID AWAJI 81 DPWA $\gamma N \rightarrow \pi N$ crawFORD 80 DPWA $\gamma N \rightarrow \pi N$ ing data for averages, fits, limits, etc. • • BARBOUR 78 DPWA $\gamma N \rightarrow \pi N$ /2 amplitude A _{3/2} DOCUMENT ID AWAJI 81 DPWA $\gamma N \rightarrow \pi N$ /2 amplitude A _{3/2} DOCUMENT ID BARBOUR 78 DPWA $\gamma N \rightarrow \pi N$ /2 amplitude A _{1/2} DOCUMENT ID AWAJI 81 DPWA $\gamma N \rightarrow \pi N$ crawFORD 80 DPWA $\gamma N \rightarrow \pi N$ ing data for averages, fits, limits, etc. • • BARBOUR 78 DPWA $\gamma N \rightarrow \pi N$ /2 amplitude A _{1/2} DOCUMENT ID AWAJI 81 DPWA $\gamma N \rightarrow \pi N$ /2 amplitude A _{1/2} DOCUMENT ID AWAJI 81 DPWA $\gamma N \rightarrow \pi N$ ing data for averages, fits, limits, etc. • • BARBOUR 78 DPWA $\gamma N \rightarrow \pi N$ ing data for averages, fits, limits, etc. • • BARBOUR 78 DPWA $\gamma N \rightarrow \pi N$ ing data for averages, fits, limits, etc. • • BARBOUR 78 DPWA $\gamma N \rightarrow \pi N$ /2 amplitude A _{3/2} DOCUMENT ID DOCUMENT ID TECN COMMENT AN A
$VALUE$ 0.006  (Γ _Γ Γ _Γ ) $\frac{1}{2}$ /Γ _{total} in Nπ → N  VALUE  not seen  N(1990) → $\rho\gamma$ , helicity-1  VALUE (GeV ^{-1/2} ) 0.030±0.029 0.001±0.040  N(1990) → $\rho\gamma$ , helicity-3  VALUE (GeV ^{-1/2} ) 0.086±0.060 0.004±0.025  • • We do not use the follow  +0.004  N(1990) → $\rho\gamma$ , helicity-3  VALUE (GeV ^{-1/2} ) 0.086±0.060 0.004±0.025 • • • We do not use the follow  +0.004  N(1990) → $\rho\gamma$ , helicity-1  VALUE (GeV ^{-1/2} ) 0.001 -0.001	POCUMENT ID  1 DEANS  75 DPWA $\pi N \rightarrow \Sigma K$ LANGBEIN  73 IPWA $\pi N \rightarrow \Sigma K$ (sol. 1)  1 (1990) $\rightarrow N \pi \pi$ POCUMENT ID  LONGACRE  75 IPWA  78 PHOTON DECAY AMPLITUDES  78 DOCUMENT ID  AWAJI  AWAJI  B1 DPWA $\gamma N \rightarrow \pi N$ CRAWFORD  BARBOUR  78 DPWA $\gamma N \rightarrow \pi N$ 70 DPWA $\gamma N \rightarrow \pi N$ 71 IPWA  71 DPWA  72 AMPLITUDES  72 AMPLITUDES  73 IPWA  74 AMPLITUDES  75 IPWA  76 AMPLITUDES  77 IPWA  77 AMPLITUDES  78 DPWA  78 AMPLITUDES  78 AMPLITU

## **Baryon Particle Listings** N(1990), N(2000), N(2080)

## N(1990) FOOTNOTES

 $^{1}\,\mathrm{The}$  range given for DEANS 75 is from the four best solutions.

## N(1990) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

MANLEY Also	92	PR D45 4002	+Saleski	(KENT) IJP
	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
BELL	83	NP B222 389	+Blissett, Broome, Daley, Hart, Linte	
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
ILAWA	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Aiso	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
CRAWFORD	80	Toronto Conf. 107		(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMÚ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
SAXON	80	NP B162 522	+Baker, Bell, Blissett, Bloodworth+	(RHEL, BRIS) IJP
BAKER	79	NP B156 93	+Brown, Clark, Davies, Depagter, Eva	ins+ (RHEL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ALAH) IJP
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC) IJP
DEVENISH	74B	NP B81 330	+Froggatt, Martin	(DESY, NÒRD, LOUC)
LANGBEIN	73	NP B53 251	+Wagner	(MUNI) LJP

## $N(2000) F_{15}$

$$I(J^P) = \frac{1}{2}(\frac{5}{2}^+)$$
 Status: **

#### OMITTED FROM SUMMARY TABLE

Older results have been retained simply because there is little information at all about this possible state.

## N(2000) MASS

ALUE (MeV)	DOCUMENT ID		TECN	COMMENT
2000 OUR ESTIMATE				
1903 ± 87	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
$1882 \pm 10$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
2025	AYED	76	IPWA	$\pi N \rightarrow \pi N$
1970	¹ LANGBEIN	73	IPWA	$\pi N \rightarrow \Sigma K \text{ (sol. 2)}$
2175	ALMEHED	72	IPWA	$\pi N \rightarrow \pi N$
1930	DEANS	72	MPWA	$\gamma p \rightarrow \Lambda K \text{ (sol. D)}$
• • We do not use the	following data for averag	es, fit	s, limits,	etc. • •
1814	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$

## N(2000) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
490±310	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
95 ± 20	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
157	AYED	76	IPWA	$\pi N \rightarrow \pi N$
170	¹ LANGBEIN	73	IPWA	$\pi N \rightarrow \Sigma K \text{ (sol. 2)}$
150	ALMEHED	72	IPWA	$\pi N \rightarrow \pi N$
112	DEANS	72	MPWA	$\gamma \rho \rightarrow \Lambda K$ (sol. D)
• • We do not use the following	data for average	s, fit	s, limits,	etc. • • •
176	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$

## N(2000) DECAY MODES

	Mode
Γ ₁	$N\pi$
$\Gamma_2$	$N\eta$
Гз	ΛK
Γ4	$\Sigma K$
$\Gamma_5$	$N\pi\pi$
Γ ₆	$\Delta(1232)\pi$ , $ extit{P}$ -wave
$\Gamma_7$	$N\rho$ , $S=3/2$ , $P$ -wave
Γ8	$N \rho$ , $S=3/2$ , $F$ -wave
Γ9	$p\gamma$

## N(2000) BRANCHING RATIOS

VALUE	DOCUMENT ID		TECN	COMMENT	
$0.08 \pm 0.05$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N &$	ι Νππ
$0.04 \pm 0.02$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$	
80.0	AYED	76	IPWA	$\pi N \rightarrow \pi N$	
0.25	ALMEHED	72	IPWA	$\pi N \rightarrow \pi N$	
<ul> <li>• • We do not use the</li> </ul>	following data for averag	es, fit	s, limits,	etc. • • •	
0.10	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$	

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \to N$	$(2000) \rightarrow N\eta$		(Γ₁Γ₂) ^⅓ /Γ
VALUE	DOCUMENT ID	TECN	COMMENT
1.0.03	DAKED 7	O DDW/A	n . nn

	$I\pi \to N(2000) \to \Lambda K$			(Γ ₁ Γ ₃ ) ^{1/2} /Γ
value not seen	SAXON	80	DPWA	$\frac{COMMENT}{\pi^- p \to \Lambda K^0}$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}}$ in N	$I\pi \to N(2000) \to \Sigma K$			(┌₁┌₄) ^⅓ /┌
VALUE	DOCUMENT ID		TECN	$\frac{COMMENT}{\pi N \to \Sigma K}$
0.022	² DEANS	75	DPWA	$\pi N \rightarrow \Sigma K$
0.05	¹ LANGBEIN	73	IPWA	$\pi N \rightarrow \Sigma K$ (sol. 2)
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N$	$I\pi \to N(2000) \to \Delta(12)$	32) <i>π</i>	, <i>P</i> -wav	e (Γ ₁ Γ ₆ ) ^{1/2} /Γ
VALUE				
VALUE				
$+0.10\pm0.06$			IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
+0.10±0.06	MANLEY $I\pi  o N(2000)  o N ho$ , S	92 5 <b>=3/</b> 3	2, <i>P</i> -wa	
$+0.10\pm0.06$ $(\Gamma_I\Gamma_f)^{1/2}/\Gamma_{ ext{total}}$ in $N$	MANLEY $I\pi  o N(2000)  o N ho, S$	92 5 <b>=3/</b> 2	<b>2, <i>P</i>-wa</b>	ve (Γ ₁ Γ ₇ ) ^{1/2} /Γ
$+0.10\pm0.06$ $\left(\Gamma_{I}\Gamma_{f}\right)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in N}$ $\frac{VALUE}{-0.22\pm0.08}$ $\left(\Gamma_{I}\Gamma_{f}\right)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in N}$	MANLEY $ \frac{1}{\pi} \rightarrow N(2000) \rightarrow N\rho, S $ $ \frac{DOCUMENT ID}{MANLEY} $ $ \frac{1}{\pi} \rightarrow N(2000) \rightarrow N\rho, S$	92 5=3/3 92 5=3/3	2, <i>P</i> -wa TECN IPWA 2, <i>F</i> -wa	ve $(\Gamma_1\Gamma_7)^{\frac{1}{2}}/\Gamma$ $\pi N \to \pi N \& N\pi\pi$ ve $(\Gamma_1\Gamma_8)^{\frac{1}{2}}/\Gamma$
$+0.10\pm0.06$ $\left(\Gamma_{I}\Gamma_{I}\right)^{\frac{1}{2}}/\Gamma_{\text{total}}$ in $N_{VALUE}$ $-0.22\pm0.08$ $\left(\Gamma_{I}\Gamma_{I}\right)^{\frac{1}{2}}/\Gamma_{\text{total}}$ in $N_{VALUE}$	MANLEY $ \frac{1\pi \to N(2000) \to N\rho, S}{DOCUMENT ID} $ MANLEY $ \frac{1\pi \to N(2000) \to N\rho, S}{DOCUMENT ID} $	92 5=3/5 92 5=3/5	2, <i>P</i> -wa TECN IPWA 2, <i>F</i> -wa TECN	ve $(\Gamma_1\Gamma_7)^{\frac{1}{2}}/\Gamma_7$ $\pi N \to \pi N \& N\pi\pi$ ve $(\Gamma_1\Gamma_8)^{\frac{1}{2}}/\Gamma_7$ $COMMENT$
$+0.10\pm0.06$ $\left(\Gamma_{I}\Gamma_{f}\right)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in N}$ $\frac{VALUE}{-0.22\pm0.08}$ $\left(\Gamma_{I}\Gamma_{f}\right)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in N}$	MANLEY $ \frac{1\pi \to N(2000) \to N\rho, S}{DOCUMENT ID} $ MANLEY $ \frac{1\pi \to N(2000) \to N\rho, S}{DOCUMENT ID} $	92 5=3/5 92 5=3/5	2, <i>P</i> -wa TECN IPWA 2, <i>F</i> -wa TECN	ve $(\Gamma_1\Gamma_7)^{\frac{1}{2}}/\Gamma$ $\pi N \to \pi N \& N\pi\pi$ ve $(\Gamma_1\Gamma_8)^{\frac{1}{2}}/\Gamma$
$+0.10\pm0.06$ $(\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in N}$ $VALUE$ $-0.22\pm0.08$ $(\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in N}$ $VALUE$ $+0.11\pm0.06$ $(\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in p}$	MANLEY $ \frac{1\pi \to N(2000) \to N\rho, S}{DOCUMENT ID} $ MANLEY $ \frac{1\pi \to N(2000) \to N\rho, S}{DOCUMENT ID} $ MANLEY $ \gamma \to N(2000) \to \Lambda K $	92 5=3/5 92 5=3/5 92	2, <i>P</i> -wa TECN IPWA 2, <i>F</i> -wa TECN IPWA	ve $(\Gamma_1\Gamma_7)^{\frac{1}{2}}/\Gamma$ $\pi N \to \pi N \& N\pi\pi$ ve $(\Gamma_1\Gamma_8)^{\frac{1}{2}}/\Gamma$ $\pi N \to \pi N \& N\pi\pi$ $(\Gamma_9\Gamma_3)^{\frac{1}{2}}/\Gamma$
$+0.10\pm0.06$ $\left(\Gamma_{I}\Gamma_{f}\right)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in N}$ $\frac{VALUE}{C}$ $-0.22\pm0.08$ $\left(\Gamma_{I}\Gamma_{f}\right)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in N}$ $\frac{VALUE}{C}$ $+0.11\pm0.06$	MANLEY $ \frac{1\pi \to N(2000) \to N\rho, S}{DOCUMENT ID} $ MANLEY $ \frac{1\pi \to N(2000) \to N\rho, S}{DOCUMENT ID} $ MANLEY	92 5=3/5 92 5=3/5 92	2, P-wa TECN IPWA 2, F-wa TECN IPWA	ve $(\Gamma_1\Gamma_7)^{\frac{1}{2}}/\Gamma$ $\pi N \to \pi N \& N\pi\pi$ ve $(\Gamma_1\Gamma_8)^{\frac{1}{2}}/\Gamma$ $\pi N \to \pi N \& N\pi\pi$

## N(2000) FOOTNOTES

 1  Not seen in solution 1 of LANGBEIN 73.  2  Value given is from solution 1 of DEANS 75; not present in solutions 2, 3, or 4.

## N(2000) REFERENCES

ARNDT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BRCO)
MANLEY	92	PR D45 4002	+Saleski	` (KENT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
SAXON	80	NP B162 522	+Baker, Bell, Blissett, Bloodworth+	(RHEL, BRIS) IJP
BAKER	79	NP B156 93	+Brown, Clark, Davies, Depagter, Evans+	(RHEL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
AYED	76	Thesis CEA-N-1921		(SACL) IJP
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ALAH) IJP
LANGBEIN	73	NP B53 251	+Wagner	(MUNI) IJP
ALMEHED	72	NP B40 157	+Lovelace	(LUND, RUTG) IJP
DEANS	72	PR D6 1906	+Jacobs, Lyons, Montgomery	(SFLA) IJP

## $N(2080) D_{13}$

$$I(J^P) = \frac{1}{2}(\frac{3}{2})$$
 Status: **

## OMITTED FROM SUMMARY TABLE

There is some evidence for two resonances in this wave between 1800 and 2200 MeV (see CUTKOSKY 80). However, the solution of HOEHLER 79 is quite different.

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

## N(2080) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 2080 OUR ESTIMATE				
1804 ± 55	MANLEY	92		$\pi N \rightarrow \pi N \& N \pi \pi$
1920	BELL	83	DPWA	$\pi^- p \rightarrow \Lambda K^0$
$1880 \pm 100$	¹ CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
2060 ± 80	¹ CUTKOSKY	80		$\pi N \rightarrow \pi N$
1900	SAXON	80	DPWA	$\pi^- p \rightarrow \Lambda K^0$
2081 ± 20	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	data for average	s, fits	s, limits,	etc. • • •
1986 ± 75	BATINIC	95	DPWA	$\pi N \rightarrow N \pi, N \eta$
1880	BAKER	79	DPWA	$\pi^- p \rightarrow n \eta$

## N(2080) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
$450 \pm 185$	MANLEY			$\pi N \rightarrow \pi N \& N \pi \pi$
320	BELL	83	DPWA	$\pi^- p \rightarrow \Lambda K^0$
180± 60	¹ CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N \text{ (lower } m)$
$300 \pm 100$	¹ CUTKOSKY			$\pi N \rightarrow \pi N \text{ (higher } m\text{)}$
240	SAXON	80	DPWA	$\pi^- p \rightarrow \Lambda K^0$
265± 40	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the following	data for average	s, fit	s, limits,	etc. • • •
$1050 \pm 225$	BATINIC	95	DPWA	$\pi N \rightarrow N \pi, N \eta$
87	BAKER	79	DPWA	$\pi^- \rho \rightarrow n\eta$

# Baryon Particle Listings *N*(2080)

REAL PART	N(2080) POLE POSITION	$(\Gamma_I \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \to N(2080) \to \Delta(1232)\pi$ , <i>D</i> -wave $(\Gamma_1 \Gamma_7)^{\frac{1}{2}}/\Gamma_{\text{total}}$
VALUE (MeV)	DOCUMENT ID TECN COMMENT	VALUEDOCUMENT IDTECNCOMMENT $+0.22\pm0.07$ MANLEY92IPWA $\pi N \rightarrow \pi N \& N\pi\pi$
1880 ± 100	$1 \text{ CUTKOSKY}$ 80 IPWA $\pi N \rightarrow \pi N \text{ (lower } m)$	
2050 ± 70	¹ CUTKOSKY 80 IPWA $\pi N \to \pi N$ (higher $m$ )	$(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}}$ in $N\pi \to N(2080) \to N\rho$ , $S=3/2$ , $S$ -wave $(\Gamma_1\Gamma_8)^{\frac{1}{2}}/\Gamma_{\text{total}}$
not seen	lowing data for averages, fits, limits, etc. $\bullet$ $\bullet$ ARNDT 91 DPWA $\pi N \rightarrow \pi N$ Soln SM90	$-0.24 \pm 0.06$ MANLEY 92 IPWA $\pi N \rightarrow \pi N \& N \pi \pi$
-2×IMAGINARY PART		$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \pi \rightarrow N(2080) \rightarrow N(\pi \pi)^{I=0}_{\text{Surger}}$ $(\Gamma_1 \Gamma_9)^{\frac{1}{2}} / \Gamma_{\text{total}}$
VALUE (MeV)	DOCUMENT ID TECN COMMENT	$(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \to N(2080) \to N(\pi\pi)^{f=0}_{\text{S-wave}}$ VALUE  DOCUMENT ID  TECH COMMENT  COMMENT
160±80 200±80	1 CUTKOSKY 80 IPWA $\pi N \to \pi N$ (lower $m$ ) 1 CUTKOSKY 80 IPWA $\pi N \to \pi N$ (higher $m$ )	$+0.25\pm0.06$ MANLEY 92 IPWA $\pi$ N $\rightarrow$ $\pi$ N & N $\pi$
	lowing data for averages, fits, limits, etc. • •	$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln p \gamma \rightarrow N(2080) \rightarrow N \eta$ $(\Gamma_{14} \Gamma_2)^{\frac{1}{2}} / \Gamma_{\text{total}} = 0$
ot seen	ARNDT 91 DPWA $\pi N \rightarrow \pi N$ Soln SM90	VALUE DOCUMENT ID TECN COMMENT
N(2	080) ELASTIC POLE RESIDUE	0.0037 HICKS 73 MPWA $\gamma p \rightarrow p \eta$
MODULUS  r	•	N(2080) PHOTON DECAY AMPLITUDES
/ALUE (MeV)	DOCUMENT ID TECN COMMENT	$N(2080) \rightarrow p\gamma$ , helicity-1/2 amplitude $A_{1/2}$
10± 5	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	VALUE (GeV ^{-1/2} ) DOCUMENT ID TECN COMMENT
60 ± 20	¹ CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$ (higher $m$ )	$-0.020\pm0.008$ AWAJI 81 DPWA $\gamma N \rightarrow \pi N$
PHASE <b>0</b> VALUE (°)	DOCUMENT ID TECN COMMENT	<ul> <li>• • We do not use the following data for averages, fits, limits, etc.</li> <li>• •</li> </ul>
00± 80	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	0.026 $\pm$ 0.052 DEVENISH 74 DPWA $\gamma$ $N  ightarrow \pi$ $N$
0 ± 100	¹ CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$ (higher m)	$N(2080) \rightarrow p\gamma$ , helicity-3/2 amplitude $A_{3/2}$
	N/2080) DECAY MODES	VALUE (GeV ^{-1/2} ) DOCUMENT ID TECN COMMENT
	N(2080) DECAY MODES	$0.017 \pm 0.011$ AWAJI 81 DPWA $\gamma N \rightarrow \pi N$
Mode		• • • We do not use the following data for averages, fits, limits, etc. • • • 0.128 $\pm$ 0.057 DEVENISH 74 DPWA $\gamma N \rightarrow \pi N$
1 <b>Ν</b> π		·
₂ Νη 3 ΛΚ		$N(2080) \rightarrow n\gamma$ , helicity-1/2 amplitude $A_{1/2}$ VALUE (GeV ^{-1/2} )  DOCUMENT ID  TECN COMMENT
₃ ΛΚ ₄ ΣΚ		$0.007 \pm 0.013$ AWAJI 81 DPWA $\gamma N \rightarrow \pi N$
$5 N\pi\pi$		<ul> <li>• • We do not use the following data for averages, fits, limits, etc.</li> </ul>
$_{6}$ $\Delta(1232)\pi$ , S-wa		0.053 $\pm$ 0.083 DEVENISH 74 DPWA $\gamma$ $N \to \pi$ $N$
$\Delta(1232)\pi$ , D-wa		$N(2080) \rightarrow n\gamma$ , helicity-3/2 amplitude $A_{3/2}$
$N \rho, S=3/2, S-w$ $N (\pi \pi)_{S-wave}^{I=0}$	vave	VALUE (GeV ^{-1/2} ) DOCUMENT ID TECN COMMENT
$p_{\gamma}$ , helicity=1/2		$-0.053\pm0.034$ AWAJI 81 DPWA $\gammaN  ightarrow \piN$
$p_{\gamma}$ , helicity=3/2		• • We do not use the following data for averages, fits, limits, etc. • •
$n\gamma$ , helicity=1/2		$0.100\pm0.141$ DEVENISH 74 DPWA $\gamma N  ightarrow \pi N$
		$N(2080)$ $\gamma p \rightarrow \Lambda K^+$ AMPLITUDES
14 <i>P Y</i>	(2000) BRANCUING RATIOS	. ,
14 PY	(2080) BRANCHING RATIOS	$(\Gamma_1\Gamma_f)^{1/2}/\Gamma_{ ext{total}}  ext{ in } p\gamma  o N(2080)  o \Lambda K^+ $ $(E_{2-}  ext{ amplitude})$
$\frac{14  p\gamma}{N(N\pi)/\Gamma_{\text{total}}}$	Γ ₁ /Γ	. ,
$\rho_{14} = \rho_{\gamma}$ $\rho_{1$	•	$(\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{total}$ in $p\gamma \rightarrow N(2080) \rightarrow \Lambda K^{+}$ ( $E_{2-}$ amplitude $\frac{VALUE \text{ (units }10^{-3})}{5.5 \pm 0.3}$ WORKMAN 90 DPWA  • • • We do not use the following data for averages, fits, limits, etc. • • •
$(N\pi)/\Gamma_{\text{total}}$ $UUE$ $23\pm0.03$ $10\pm0.04$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
(N $\pi$ )/ $\Gamma$ total  MUE 23±0.03 10±0.04 14±0.07	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{llll} (\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} & \text{in } p\gamma \rightarrow N(2080) \rightarrow \Lambda K^{+} & (E_{2-} \text{ amplitude}) \\ \frac{VALUE  (\text{units } 10^{-3})}{5.5 \pm 0.3} & \frac{DOCUMENT  ID}{\text{WORKMAN}} & 90 & \text{DPWA} \\ \bullet \bullet \bullet & \text{We do not use the following data for averages, fits, limits, etc.} & \bullet \bullet \\ 4.09 & \text{TANABE} & 89 & \text{DPWA} \\ p\gamma \rightarrow N(2080) \rightarrow \Lambda K^{+} & \text{phase angle } \theta & (E_{2-} \text{ amplitude}) \end{array}$
(N $\pi$ )/ $\Gamma$ total  (N $\pi$ )/ $\Gamma$ total  (10±0.03  10±0.04  14±0.07  06±0.02	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
(N $\pi$ )/ $\Gamma$ total  LUE 23±0.03 10±0.04 14±0.07 06±0.02 • • We do not use the follo	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
(N $\pi$ )/ $\Gamma$ total  (N $\pi$ )/ $\Gamma$ total  (1 $\pm$ 0.03  10 $\pm$ 0.04  14 $\pm$ 0.07  06 $\pm$ 0.02  • We do not use the follo  09 $\pm$ 0.02	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
(N $\pi$ )/ $\Gamma$ total  (N $\pi$ )/ $\Gamma$ total  (N $\pi$ )/ $\Gamma$ total  ( $\pi$ )	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
$N(N\pi)/\Gamma$ total	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{llll} & (\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } \rho\gamma \to \textit{N}(2080) \to \textit{\Lambda}\textit{K}^+ & (\textit{E}_{2-} \text{ amplitude}) \\ & \frac{\textit{VALUE}  (\text{units } 10^{-3})}{5.5 \pm 0.3} & \frac{\textit{DOCUMENT } 1D}{\textit{WORKMAN}} & 90 & \textit{DPWA} \\ \bullet \bullet & \text{We do not use the following data for averages, fits, limits, etc.} \bullet \bullet \bullet \\ & 4.09 & \text{TANABE} & 89 & \textit{DPWA} \\ & \rho\gamma \to \textit{N}(2080) \to \textit{\Lambda}\textit{K}^+ & \text{phase angle } \theta & (\textit{E}_{2-} \text{ amplitude}) \\ & \frac{\textit{VALUE}  (\text{degrees})}{-48 \pm 5} & \frac{\textit{DOCUMENT } 1D}{\textit{WORKMAN}} & 90 & \textit{DPWA} \\ \bullet \bullet \bullet & \text{We do not use the following data for averages, fits, limits, etc.} \bullet \bullet \bullet \\ & -35.9 & \text{TANABE} & 89 & \text{DPWA} \\ & (\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} & \text{in } \rho\gamma \to \textit{N}(2080) \to \textit{\Lambda}\textit{K}^+ & (\textit{M}_{2-} \text{ amplitude}) \\ & (\textit{M}_{2-} \text{ amplitude}) & \text{M}_{2-} \text{ amplitude} \\ & (\textit{M}_{2-} \text{ amplitude}) & \text{M}_{2-} \text{ amplitude} \\ & (\textit{M}_{2-} \text{ amplitude}) & \text{M}_{2-} \text{ amplitude} \\ & (\textit{M}_{2-} \text{ amplitude}) & \text{M}_{2-} \text{ amplitude} \\ & (\textit{M}_{2-} \text{ amplitude}) & \text{M}_{2-} \text{ amplitude} \\ & (\textit{M}_{2-} \text{ amplitude}) & \text{M}_{2-} \text{ amplitude} \\ & (\textit{M}_{2-} \text{ amplitude}) & \text{M}_{2-} \text{ amplitude} \\ & (\textit{M}_{2-} \text{ amplitude}) & \text{M}_{2-} \text{ amplitude} \\ & (\textit{M}_{2-} \text{ amplitude}) & \text{M}_{2-} \text{ amplitude} \\ & (\textit{M}_{2-} \text{ amplitude}) & \text{M}_{2-} \text{ amplitude} \\ & (\textit{M}_{2-} \text{ amplitude}) & \text{M}_{2-} \text{ amplitude} \\ & (\textit{M}_{2-} \text{ amplitude}) & \text{M}_{2-} \text{ amplitude} \\ & (\textit{M}_{2-} \text{ amplitude}) & \text{M}_{2-} \text{ amplitude} \\ & (\textit{M}_{2-} \text{ amplitude}) & \text{M}_{2-} \text{ amplitude} \\ & (\textit{M}_{2-} \text{ amplitude}) & \text{M}_{2-} \text{ amplitude} \\ & (\textit{M}_{2-} \text{ amplitude}) & \text{M}_{2-} \text{ amplitude} \\ & (\textit{M}_{2-} \text{ amplitude}) & \text{M}_{2-} \text{ amplitude} \\ & (\textit{M}_{2-} \text{ amplitude}) & \text{M}_{2-} \text{ amplitude} \\ & (\textit{M}_{2-} \text{ amplitude}) & \text{M}_{2-} \text{ amplitude} \\ & (\textit{M}_{2-} \text{ amplitude}) & \text{M}_{2-} \text{ amplitude} \\ & (\textit{M}_{2-} \text{ amplitude}) & \text{M}_{2-} \text{ amplitude} \\ & (\textit{M}_{2-} \text{ amplitude}) & \text{M}_{2-} \text{ amplitude} \\ & (\textit{M}_{2-} \text{ amplitude}) & \text{M}_{2-} \text{ amplitude} \\ & (\textit{M}_{2-} \text{ amplitude}) & \text{M}_{2-$
$N(N\pi)/\Gamma$ total	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
(N $\pi$ )/ $\Gamma$ total  LUE 23±0.03 10±0.04 14±0.07 06±0.02 • We do not use the follo 09±0.02 (N $\pi$ )/ $\Gamma$ total  LUE • We do not use the follo 07±0.04	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{llllllllllllllllllllllllllllllllllll$
(N $\pi$ )/ $\Gamma$ total  (1 $\pi$ ).07  (0 $\pi$ ).02  • We do not use the following the fol	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
(N $\pi$ )/ $\Gamma$ total  ALUE 23±0.03 10±0.04 14±0.07 06±0.02 • • We do not use the folk 09±0.02 (N $\pi$ )/ $\Gamma$ total  ALUE 07±0.04	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
(N $\pi$ )/ $\Gamma$ total  ALUE  • We do not use the folk  (N $\pi$ )/ $\Gamma$ total  (N $\pi$ )/ $\Gamma$ total  • We do not use the folk  (N $\pi$ )/ $\Gamma$ total  ALUE  • We do not use the folk  (N $\pi$ )/ $\Gamma$ total  n N $\pi$ $\rightarrow$ (N $\pi$ )/ $\Gamma$ total in N $\pi$	DOCUMENT ID  MANLEY 92 IPWA $\pi N \rightarrow \pi N \& N\pi\pi$ 1 CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N $ (lower m) 1 CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N $ (lower m) HOEHLER 79 IPWA $\pi N \rightarrow \pi N $ (nigher m) HOEHLER 8ATINIC 95 DPWA $\pi N \rightarrow \pi N $ ( $\pi N \rightarrow \pi N $ m)  owing data for averages, fits, limits, etc.  BATINIC 95 DPWA $\pi N \rightarrow N\pi$ , $N\eta$ T2/ $\Gamma$ owing data for averages, fits, limits, etc.  BATINIC 95 DPWA $\pi N \rightarrow N\pi$ , $N\eta$ $\pi N \rightarrow N\pi$ , $N\eta$ N(2080) $\pi N \rightarrow N\pi$ $\pi N \rightarrow $	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
N( $(N\pi)/\Gamma$ total  ALUE  23 ± 0.03  .10 ± 0.04  .14 ± 0.07  .06 ± 0.02  • We do not use the folion  09 ± 0.02 $(N\eta)/\Gamma$ total  ALUE  • We do not use the folion  7 ± 0.04 $\Gamma_{\Gamma}\Gamma_{\Gamma}^{\frac{1}{2}}/\Gamma_{\Gamma}$ total in $N\pi \rightarrow \frac{4UU}{605}$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
(N $\pi$ )/ $\Gamma$ total  (N $\pi$ )/ $\Gamma$ total  (UUE 23±0.03 10±0.04 14±0.07 06±0.02 • We do not use the follo 09±0.02 (N $\eta$ )/ $\Gamma$ total  (UUE 07±0.04  (I $\Gamma$ )/ $\Gamma$ / $\Gamma$ / $\Gamma$ total in N $\pi$ $\rightarrow$ (UUE 065	DOCUMENT ID  MANLEY 92 IPWA $\pi N \rightarrow \pi N \& N\pi\pi$ 1 CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N $ (lower m) 1 CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N $ (lower m) HOEHLER 79 IPWA $\pi N \rightarrow \pi N $ (nigher m) HOEHLER 8ATINIC 95 DPWA $\pi N \rightarrow \pi N $ ( $\pi N \rightarrow \pi N $ m)  owing data for averages, fits, limits, etc.  BATINIC 95 DPWA $\pi N \rightarrow N\pi$ , $N\eta$ T2/ $\Gamma$ owing data for averages, fits, limits, etc.  BATINIC 95 DPWA $\pi N \rightarrow N\pi$ , $N\eta$ $\pi N \rightarrow N\pi$ , $N\eta$ N(2080) $\pi N \rightarrow N\pi$ $\pi N \rightarrow $	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
(N $\pi$ )/ $\Gamma$ total  (1 $\pi$ ).00  (0 $\pi$ ).00  (0 $\pi$ ).00  • We do not use the follow  (0 $\pi$ )/ $\Gamma$ total  (1 $\pi$ )/ $\Gamma$ total  (1 $\pi$ )/ $\Gamma$ total  (1 $\pi$ )/ $\Gamma$ / $\Gamma$ $\Gamma$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
$(N\pi)/\Gamma_{\text{total}}$ $\frac{AUE}{23\pm0.03}$ $10\pm0.04$ $14\pm0.07$ $06\pm0.02$ • • We do not use the folkoop $09\pm0.02$ $(N\eta)/\Gamma_{\text{total}}$ $\frac{AUE}{2}$ • • We do not use the folkoop $07\pm0.04$ $\Gamma_1\Gamma_1$ $\Gamma_2$ $\Gamma_2$ $\Gamma_3$ $\Gamma_4$ $\Gamma_4$ $\Gamma_4$ $\Gamma_5$ $\Gamma_7$ $\Gamma_4$ $\Gamma_4$ $\Gamma_7$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
(N $\pi$ )/ $\Gamma$ total  ALUE  • We do not use the folk  (N $\eta$ )/ $\Gamma$ total  14±0.07  06±0.02  • We do not use the folk  09±0.02  (N $\eta$ )/ $\Gamma$ total  ALUE  • We do not use the folk  07±0.04 $\Gamma$ [ $\Gamma$ [ $\gamma$ ]/ $^{1/2}$ / $\Gamma$ total in N $\pi$ $\rightarrow$ ALUE  065 $\Gamma$ [ $\Gamma$ [ $\gamma$ ]/ $^{1/2}$ / $\Gamma$ total in N $\pi$ $\rightarrow$ ALUE  0.04  0.03 $\Gamma$ [ $\Gamma$ [ $\gamma$ ]/ $^{1/2}$ / $\Gamma$ total in N $\pi$ $\rightarrow$ ALUE	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{llllllllllllllllllllllllllllllllllll$
(N $\pi$ )/ $\Gamma$ total  (1 $\pi$ ).00  (1 $\pi$ ).00  • We do not use the following the	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
(N $\pi$ )/ $\Gamma$ total  (23±0.03 10±0.04 14±0.07 06±0.02 • We do not use the folk  (99±0.02 (N $\pi$ )/ $\Gamma$ total  (N $\pi$ )/ $\Gamma$ total  (N $\pi$ )/ $\Gamma$ total in N $\pi$ $\rightarrow$ (N $\pi$ )/ $\Gamma$ total in N $\pi$ $\rightarrow$ (N $\pi$ )/ $\Gamma$ total in N $\pi$ $\rightarrow$ (N $\pi$ )/ $\Gamma$ total in N $\pi$ $\rightarrow$ (N $\pi$ )/ $\Gamma$ / $\Gamma$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$

## N(2080), N(2090), N(2100)

## N(2080) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

BATINIC	95	PR C51 2310	+Slaus, Svarc, Nefkens	(BOSK, UCLA)
MANLEY	92	PR D45 4002	+Saleski	(KENT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
WORKMAN	90	PR C42 781		(VPI)
TANABE	89	PR C39 741	+Kohno, Bennhold	(MÀNZ)
Also	89	NC 102A 193	Kohno, Tanabe, Bennhold	(MANZ)
BELL	83	NP B222 389	+Blissett, Broome, Daley, Hart, Linter	rn+ `(RL)́IJP
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
AWA JI	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMÙ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
SAXON	80	NP B162 522	+Baker, Bell, Blissett, Bloodworth+	(RHEL, BRIS) IJP
BAKER	79	NP B156 93	+Brown, Clark, Davies, Depagter, Eva	ins+ (RHEL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
WINNIK	77	NP B128 66	+Toaff, Revel, Goldberg, Berny	(HAIF) I
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ÀLAH) IJP
DEVENISH	74	PL 52B 227	+Lyth, Rankin	(DESY, LANC, BONN) IJP
HICKS	73	PR D7 2614	+Deans, Jacobs, Lyons+	` (CMÚ, ORNÍ, SFLA) IJP

## $N(2090) S_{11}$

 $I(J^P) = \frac{1}{2}(\frac{1}{2})$  Status: *

## OMITTED FROM SUMMARY TABLE

Any structure in the  $S_{11}$  wave above 1800 MeV is listed here. A few early results that are now obsolete have been omitted.

## N(2090) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 2090 OUR ESTIMATE				
1928±59	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
2180 ± 80	CUTKOSKY 8	80	IPWA	$\pi N \rightarrow \pi N$
$1880 \pm 20$	HOEHLER 7	79	IPWA	$\pi N \rightarrow \pi N$

## N(2090) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
414±157	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
$350 \pm 100$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
95 ± 30	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$

## N(2090) POLE POSITION

REAL PART	
1741115 (14-17)	

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
2150±70	CUTKOSKY 80	IPWA	$\pi N \rightarrow \pi N$
1937 or 1949	¹ LONGACRE 78	IPWA	$\pi N \rightarrow N \pi \pi$
-2×IMAGINARY PART			
VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
$350 \pm 100$			$\pi N \rightarrow \pi N$
139 or 131	¹ LONGACRE 78	IPWA	$\pi N \rightarrow N \pi \pi$

## N(2090) ELASTIC POLE RESIDUE

CUTKOSKY 80 IPWA  $\pi N \to \pi N$ 

## MODULUS |r|

DOCUMENT ID		TECN	COMMENT
CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
			COMMENT
		CUTKOSKY 80	CUTKOSKY 80 IPWA

## N(2090) DECAY MODES

	Mode			
Γ ₁	Νπ			
	ΛK			
$\Gamma_3$	$N \pi \pi$			

## N(2090) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$				Γ ₁ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
$0.10 \pm 0.10$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
$0.18 \pm 0.08$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
$0.09 \pm 0.05$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\pi \to N(20)$				(Γ₁Γ₂) ^⅓ 2/Γ
VALUE	DOCUMENT ID		TECN	COMMENT
not seen	SAXON	80	DPWA	$\pi^- p \rightarrow \Lambda K^0$

## N(2090) FOOTNOTES

 1  LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to  $\pi\,N\,\to\,\,N\,\pi\,\pi$  data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.

## N(2090) REFERENCES

MANLEY Also CUTKOSKY Also SAXON HOEHLER Also LONGACRE	92 84 80 79 80 79 80 78	PR D45 4002 PR D30 904 Toronto Conf. PR D20 2839 NP B162 522 PDAT 12-1 Toronto Conf. PR D17 1795		+Saleski Manley, Arndt, Goradia, Teplitz +Forsyth, Babcock, Kelly, Hendrick Cutkosky, Forsyth, Hendrick, Kelly +Baker, Bell, Blissett, Bloodworth+ +Kaiser, Koch, Pietarinen Koch +Lasinski, Rosenfeld, Smadja+	(KENT) IJP (VPI) (CMU, LBL) IJP (CMU, LBL) (RHEL, BRIS) IJP (KARLT) IJP (KARLT) IJP (LBL, SLAC)
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## $N(2100) P_{11}$

 $I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$  Status: *

TECN COMMENT

## OMITTED FROM SUMMARY TABLE

## N(2100) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 2100 OUR ESTIMATE				
$1885 \pm 30$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
$2125 \pm 75$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
$2050 \pm 20$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
ullet $ullet$ We do not use the	following data for average	s, fit	s, limits,	etc. • • •
2203 ± 70	BATINIC	95	DPWA	$\pi N \rightarrow N \pi, N \eta$

## N(2100) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
113± 44	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
$260\pm100$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
200 ± 30	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
ullet $ullet$ We do not use the following	data for average	s, fit	s, limits,	etc. • • •
$418\pm171$	BATINIC	95	DPWA	$\pi N \rightarrow N \pi$ , $N \eta$

## N(2100) POLE POSITION DOCUMENT ID

## REAL PART VALUE (MeV)

$2120\pm40$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	g data for average	s, fit	s, limits,	etc. • • •
not seen	ARNDT	91	DPWA	$\pi{\it N}  ightarrow$
-2×IMAGINARY PART				
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
240 ± 80	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the following	data for average	s, fit	s, limits,	etc. • • •
not seen	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM}90$

## N(2100) ELASTIC POLE RESIDUE

## MODULUS |r|

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
14±7	CUTKOSKY 80	IPWA	$\pi N \rightarrow \pi N$
PHASE $\theta$			
VALUE (°)	DOCUMENT ID	TECN	COMMENT
$35 \pm 25$	CUTKOSKY 80	IPWA -	$\pi N \rightarrow \pi N$

## N(2100) DECAY MODES

	Mode
$\Gamma_1$	Νπ
$\Gamma_2$	$N\eta$
$\Gamma_3$	$N\pi\pi$
Γ ₄	$\Delta$ (1232) $\pi$ , $P$ -wave

## N(2100) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$					$\Gamma_1/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT	
$0.15 \pm 0.06$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \&$	Νππ
$0.12 \pm 0.03$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
$0.10 \pm 0.04$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$	
ullet $ullet$ We do not use the following	owing data for average	s, fit	s, limits,	etc. • • •	
$0.11 \pm 0.07$	BATINIC	95	DPWA	$\pi N \rightarrow N \pi$ , N	η

**New do not use the following data for averages, fits, limits, etc. • • • Name ( $\Gamma_1\Gamma_1$ ) $\Gamma_2$ / $\Gamma_1$ ( $\Gamma_2$ ) $\Gamma_2$ / $\Gamma_3$ ( $\Gamma_4$ ) $\Gamma_4$ (	$\Gamma(N\eta)/\Gamma_{\text{total}}$	Γ ₂ /Γ
$(\Gamma_{\Gamma}\Gamma_{\Gamma})^{\frac{1}{2}}/\Gamma_{\text{total in }N\pi \to N(2100)} \to \Delta(1232)\pi, P_{\text{wave}} = \frac{(\Gamma_{\Gamma}\Gamma_{\alpha})^{\frac{1}{2}}/\Gamma_{\text{total in }N\pi \to N(2100)} \to \Delta(1232)\pi, P_{\text{wave}} = \frac{(\Gamma_{\Gamma}\Gamma_{\alpha})^{\frac{1}{2}}/\Gamma_{\text{total in }N\pi \to N(2100)} \to \Delta(1232)\pi, P_{\text{wave}} = \frac{(\Gamma_{\Gamma}\Gamma_{\alpha})^{\frac{1}{2}}/\Gamma_{\text{total in }N\pi \to N(2100)} \to \Delta(1232)\pi, P_{\text{wave}} = \frac{(\Gamma_{\Gamma}\Gamma_{\alpha})^{\frac{1}{2}}/\Gamma_{\text{total in }N\pi \to N\pi}}{NANLEY} = \frac{1}{2} \frac{(\Gamma_{\Gamma}\Gamma_{\alpha})^{\frac{1}{2}}/\Gamma_{\text{total in }N\pi \to N\pi}}{NANLEY} \times N(2100) \text{ ReFERENCES}$ BATINIC 95 PR C51 2310	VALUE • • • We do not use the foll	
DOCUMENT ID.  MANLEY 92 IPWA $\pi N \rightarrow \pi N \& N \pi \pi$ N(2100) REFERENCES  BATNIC 95 PR C51 2310  MANLEY 92 PR D43 4002  MANUTY 91 PP D43 2131  LUCKOSKY 90 Townoto Conf. 19  AND 79 PP D20 2839  N(2100) MASS  DOCUMENT ID.  N(2190) MASS  N(2190) MASS  DOCUMENT ID.  N(2190) MASS  DOCUMENT ID.  N(2190) MASS  DOCUMENT ID.  TECN (CMU, IBL) IPW.  (KARLT) IPW.  (KARLT) IPW.  N(2190) MASS  DOCUMENT ID.  TECN (CMU, IBL) IPW.  N(ARLT) IPW.  N(2190) MASS  DOCUMENT ID.  TECN (CMU, IBL) IPW.  N(ARLT) IPW.  N(2190) MASS  DOCUMENT ID.  TECN (CMU, IBL) IPW.  N(ARLT) IPW.  N(2190) MASS  DOCUMENT ID.  TECN (CMU, IBL) IPW.  N(ARLT) IPW.  N(2190) MASS  DOCUMENT ID.  TECN (CMU, IBL) IPW.  N(ARLT) IPW.  N(2190) MASS  DOCUMENT ID.  TECN (CMU, IBL) IPW.  N(ARLT) IPW.  N(2190) MASS  DOCUMENT ID.  TECN (CMU, IBL) IPW.  N(ARLT) IPW.  N(2190) MASS  DOCUMENT ID.  TECN (CMU, IBL) IPW.  N(ARLT) IPW.  N(2190) MASS  DOCUMENT ID.  N(2190) MASS  DOCUMENT ID.  N(2190) MASS  DOCUMENT ID.  N(2190) MIDTH  DOCUMENT ID.  N(2190) WIDTH  DOCUMENT ID.  TECN (CMMENT)  N(2190) WIDTH  DOCUMENT ID.  TECN (CMMENT)  N(2190) WIDTH  DOCUMENT ID.  TECN (CMMENT)  N(2190) POLE POSITION  REAL PART  MAULE (MeV)  DOCUMENT ID.  TECN (CMMENT)  N(2190) POLE POSITION  REAL PART  MAULE (MeV)  DOCUMENT ID.  TECN (CMMENT)  N(2190) POLE POSITION  REAL PART  MAULE (MeV)  DOCUMENT ID.  TECN (CMMENT)  N(2190) POLE POSITION  N(2190) POLE POSITION  REAL PART  MAULE (MeV)  DOCUMENT ID.  TECN (CMU, IBL) IPW.  N N N N N N N N N N N N N N N N N N N		
MANLEY   92   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   92   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   92   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   92   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   92   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   92   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   92   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   92   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   92   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   92   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   92   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   92   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   93   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   94   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   95   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   95   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   95   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   95   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   95   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   95   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   95   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   95   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   96   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   97   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   98   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   99   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   90   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   90   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   90   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   90   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   90   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   90   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   90   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   90   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   90   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   90   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   90   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   90   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   90   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   90   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   90   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   90   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   90   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   90   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   90   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   90   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   90   IPWA   $\pi N \rightarrow \pi N \& N \pi \pi$   MANLEY   90   IPWA		
N(2100) REFERENCES  BATNIC 95 PR C51 2210  MANIETY 92 PR 051 4002  MANIETY 92 PR 051 4002  MARINOT 91 PR 051 2313  LINE PR 051 2313  LINE PR 051 2313  Marie, Arindt, Goadia, Tepitz  Hi, Roper, Workman, Ford Cuthosky, Fonyth, Hendrick, Kelly  Marie PR 051 2313  LINE PR 051 2313  IN(2190) G ₁₇ I(J ^P ) = $\frac{1}{2}$ ( $\frac{7}{2}$ ) Status: ***  Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics  Letters 111B (1982).  N(2190) MASS	<i>VALUE</i> −0.19±0.08	
BATINIC 95 PR CSI 2310 $+$ Slaus, Svarc, Neftens $+$ Slaus,		
MANLEY 92 PR DAS 5002 Along A		•
ARNDT 91 PR D33 2131 +11, Roper, Workman, Ford CUTKOSKY 80 PRODUCTION CONT. 91 PROJECT 2839 PRO	MANLEY 92 PR D45 4002	+Saleski (KENT) IJP
Also 79 PR D20 2839 (Cutbooky, Foreyth, Hendrick, Kelly PDAT 121 Kaser, Koch, Pletainen (KART) 11P Koch (KART) 11P Ko	ARNDT 91 PR D43 2131	+Li, Roper, Workman, Ford (VPI, TELE) IJP
Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).  **N(2190)** MASS**  **N(2190)** MANUEY**  **N(2190)** MIDTH**  **N(2190)** MIDTH	Also 79 PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly (CMU, LBL)
Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).    N(2190) MASS	HOEHLER 79 PDAT 12-1	+Kaiser, Koch, Pietarinen (KARLT) IJP
Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).    N(2190) MASS	N(2190) Ga	$I(J^P) = \frac{1}{2}(\frac{7}{2})$ Status: ****
December 111B (1982).   N(2190) MASS		
N(2190) MASS		
2210 to 2200 (≈ 2190) OUR ESTIMATE 2127± 9  MANLEY 2120±12  HOEHLER 79  HOEHLER 79  HOWA $\pi N \rightarrow \pi N$ $\pi N \rightarrow \pi N$ $\pi N \rightarrow \pi N$ 2140±12  HOEHLER 79  19WA $\pi N \rightarrow \pi N$ $\pi N \rightarrow \pi N$ 2140±12  HOEHLER 79  19WA $\pi N \rightarrow \pi N$ 10WA $\pi N \rightarrow \pi N$ 10WA $\pi N \rightarrow \pi N$ 11WA 1219±68  BATINIC 2180  SAXON 80  DPWA $\pi N \rightarrow \pi N$ 10WA $\pi N \rightarrow \pi N$ 10WA 12190  BAREBOUR 78  DPWA $\pi N \rightarrow \pi N$ 10WA $\pi N \rightarrow \pi N$ 10WA 10WA 10WA 10WA 10WA 10WA 10WA 10WA		
2100 to 2200 ( $\approx$ 2190) OUR ESTIMATE  21107 ± 9  MANLEY 92 IPWA $\pi N \rightarrow \pi N \& N\pi\pi$ 22100±70  CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$ 2140±12  HOFHLER 79 IPWA $\pi N \rightarrow \pi N$ HENDRY 78 MPWA $\pi N \rightarrow \pi N$ • • • We do not use the following data for averages, fits, limits, etc. • •  2131  ARNDT 95 DPWA $\pi N \rightarrow \pi N$ 2180  ARNDT 95 DPWA $\pi N \rightarrow \pi N$ 2180  SAXON 80 DPWA $\pi N \rightarrow \pi N$ RABBOUR 78 DPWA $\pi N \rightarrow \pi N$ (2190) WIDTH   VALUE (MeV)  DOCUMENT ID  **OUTKOSKY** 80 IPWA $\pi N \rightarrow \pi N$ **N  **N  **N  **N  **N  **N  **N		N(2190) MASS
2127 $\pm$ 9		DOCUMENT ID TECN COMMENT
2200 $\pm$ 70 2140 $\pm$ 10 2140 $\pm$ 12 2140 $\pm$ 12 2140 $\pm$ 12 2140 $\pm$ 14 0 • • • We do not use the following data for averages, fits, limits, etc. • • •  2131  ARNDT 95 DPWA $\pi N \rightarrow \pi N$ 2198 $\pm$ 68 BATINIC 2098  CRAWFORD 80 DPWA $\pi N \rightarrow \pi N$ 2180 SAXON 80 DPWA $\pi N \rightarrow \pi N$ 2140 217 BARBOUR 78 DPWA $\pi N \rightarrow \pi N$ 78 N/2190 WIDTH   VALUE (MeV)  DOCUMENT ID 218  ARNDT 95 DPWA $\pi N \rightarrow \pi N$ 78 N $\pi \pi$ 79 DPWA $\pi P \rightarrow \pi N$ 80 N $\pi \pi$ 70 N $\pi \pi$ 70 N/2190 WIDTH  VALUE (MeV)  AND T 10 CUTKOSKY 10 BARBOUR 11 BARBOUR 12 BARBOUR 13 BARBOUR 14 BARBOUR 15 BARBOUR 16 BARBOUR 17 BARBOUR 18	, ,	
2140 ± 40 HENDRY 78 MPWA $\pi N \rightarrow \pi N$ • • We do not use the following data for averages, fits, limits, etc. • • • 12131 2198 ± 68 2098 CRAWFORD 80 DPWA $\pi N \rightarrow N\pi$ 2180 SAXON 80 DPWA $\pi N \rightarrow N\pi$ 2140 BAKER 79 DPWA $\pi N \rightarrow N\pi$ 21417 BARBOUR 78 DPWA $\pi N \rightarrow N\pi$ 2140 BAKER 79 DPWA $\pi N \rightarrow N\pi$ 2140 BARBOUR 78 DPWA $\pi P \rightarrow N\pi$ 21417 BARBOUR 78 DPWA $\pi P \rightarrow N\pi$ 2140  **N(2190)**WIDTH  **N(2190)**WID		
■ ● ● We do not use the following data for averages, fits, limits, etc. ● ● ● 12131  ARNDT 95 DPWA π N → Nπ 2098 CRAWFORD 80 DPWA γ N → π N 2180 SAXON 80 DPWA π ¬ P → π N 2140 BAKER 79 DPWA π ¬ P → π N 2117 BARBOUR 78 DPWA π ¬ P → π N 2117 BARBOUR 78 DPWA π ¬ P → π N 2117 BARBOUR 78 DPWA π ¬ P → π N 2117 BARBOUR 78 DPWA π N → π N 2117 BARBOUR 78 DPWA π N → π N 2117 BARBOUR 78 DPWA π N → π N 2117 BARBOUR 78 DPWA π N → π N 2118 DOCUMENT ID TECN COMMENT 2119 DOCUMENT ID TECN COMMENT 2119 BARBOUR 78 DPWA π N → π N 2119 DPWA π N → π N 2111		
2131 $2198\pm68$ $21781$ $2198\pm68$ $21781$ $2198\pm68$ $21781$ $21998$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $2180$ $218$		
2198±68 2098  CRAWFORD 80 DPWA $\pi N \rightarrow N\pi$ , $N\eta$ 2180 SAXON 80 DPWA $\pi^{-}P \rightarrow NN$ 2140 BAKER 79 DPWA $\pi^{-}P \rightarrow N\eta$ 2117 BARBOUR 78 DPWA $\pi^{-}P \rightarrow N\eta$ 2117  N(2190) WIDTH   VALUE (MeV) DOCUMENT ID TECN COMMENT  350 to 550 ( $\approx$ 450) OUR ESTIMATE 550±50 CUTKOSKY 80 CUTKOSKY 80 PWA $\pi N \rightarrow \pi N$ N HOEHLER 79 PWA $\pi N \rightarrow \pi N$ N HOEHLER 79 PWA $\pi N \rightarrow \pi N$ N HOEHLER 79 PWA $\pi N \rightarrow \pi N$ N ARNOT 95 DPWA $\pi N \rightarrow N\pi$ , $N\eta$ 238 CRAWFORD 80 SAXON 80 DPWA $\pi N \rightarrow N\pi$ , $N\eta$ 238 CRAWFORD 80 DPWA $\pi N \rightarrow N\pi$ , $N\eta$ 238 CRAWFORD 80 DPWA $\pi N \rightarrow N\pi$ , $N\eta$ 80 SAXON 80 DPWA $\pi N \rightarrow N\pi$ N N(2190) POLE POSITION  REAL PART VALUE (MeV) DOCUMENT ID DOCUMENT ID TECN COMMENT 2030 ARNOT 95 DPWA $\pi N \rightarrow N\pi$ N  V(2190) POLE POSITION  REAL PART VALUE (MeV) DOCUMENT ID TECN COMMENT 2030 ARNOT 95 DPWA $\pi N \rightarrow \pi N$ Soln SM90  - 2×IMAGINARY PART VALUE (MeV) DOCUMENT ID TECN COMMENT VALUE (MeV) DOCUMENT ID TECN TON THO THO TON TON TON TON TON TON TON TON TON TO		
2098  2180  SAXON  SO  DPWA $\tau P \rightarrow \pi N$ SAXON  SO  DPWA $\tau P \rightarrow \pi N$ DOUMENT ID  TECN  COMMENT  TO  THE STO  TO  THE STO  THE S		
2140 2117  BAKER 79 DPWA $\pi^- p \rightarrow n\eta$ BARBOUR 78 DPWA $\gamma N \rightarrow \pi N$ (2190) WIDTH  VALUE (MeV)  DOCUMENT ID  TECN  COMMENT  350 to 550 ( $\approx$ 450) OUR ESTIMATE  550 $\pm$ 50  UTKOSKY 80 IPWA $\pi N \rightarrow \pi N \& N\pi\pi$ HOEHLER 79 IPWA $\pi N \rightarrow \pi N & N\pi\pi$ 270 $\pm$ 50  We do not use the following data for averages, fits, limits, etc. • • • • • • • • • • • • • • • • • • •	2098	
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	2180	
VALUE (MeV)  DOCUMENT ID  TECN  COMMENT  350 to 550 (≈ 450) OUR ESTIMATE  550 ± 50  MANLEY  500 ± 150  CUTKOSKY 80  PWA $\pi N \rightarrow \pi N \& N\pi \pi$ HENDRY  78  MPWA $\pi N \rightarrow \pi N$ NOF HENDRY  78  MPWA $\pi N \rightarrow \pi N$ NOF HENDRY  78  MPWA $\pi N \rightarrow \pi N$ NOF HENDRY  78  MPWA $\pi N \rightarrow \pi N$ NOF HENDRY  79  MPWA $\pi N \rightarrow \pi N$ NOF HENDRY  78  MPWA $\pi N \rightarrow \pi N$ NOF HENDRY  78  MPWA $\pi N \rightarrow \pi N$ NOF HENDRY  79  MPWA $\pi N \rightarrow \pi N$ NOF HENDRY  70  MPWA $\pi N \rightarrow \pi N$ NOF HENDRY  70  MPWA $\pi N \rightarrow \pi N$ NOF HENDRY  70  MPWA $\pi N \rightarrow \pi N$ NOF HENDRY  NOF HENDR		
VALUE (MeV)         DOCUMENT ID         TECN         COMMENT           380 to 550 (≈ 450) OUR ESTIMATE         550 ± 50         MANLEY         92         IPWA $\pi N \rightarrow \pi N & N\pi \pi$ 550 ± 50         MANLEY         92         IPWA $\pi N \rightarrow \pi N & N\pi \pi$ 500 ± 150         CUTKOSKY         80         IPWA $\pi N \rightarrow \pi N$ 390 ± 30         HOEHLER         79         IPWA $\pi N \rightarrow \pi N$ 270 ± 50         HENDRY         78         MPWA $\pi N \rightarrow \pi N$ 476         ARNDT         95         DPWA $\pi N \rightarrow \pi N$ 476         ARNDT         95         DPWA $\pi N \rightarrow \pi N$ 805 ± 140         BATINIC         95         DPWA $\pi N \rightarrow \pi N$ 80         SAXON         80         DPWA $\pi N \rightarrow \pi N$ 80         SAXON         80         DPWA $\pi P \rightarrow \pi N$ 319         BARBOUR         78         DPWA $\pi P \rightarrow \pi N$ 2020         BARBOUR         78         DPWA $\pi N \rightarrow \pi N$ V(2190) POLE POSITION         TECN         COMMENT           Value (MeV)         DOCUMENT ID         TECN		N(2190) WIDTH
350 to 550 (≈ 450) OUR ESTIMATE  550 ± 50  MANLEY  20 IPWA $\pi N \rightarrow \pi N \& N \pi \pi$ 390 ± 30  HOEHLER  79 IPWA $\pi N \rightarrow \pi N & N \pi N$ 390 ± 50  HENDRY  78 MPWA $\pi N \rightarrow \pi N$ 476  476  476  476  477  478  478  479  479  470  470  470  470  471  470  470  471  470  470	VALUE (MeV)	, ,
500 $\pm$ 150   300 $\pm$ 150   300 $\pm$ 150   AND T 91 PWA $\pi N \rightarrow \pi N$ 370 $\pm$ 50   HENDRY 78 MPWA $\pi N \rightarrow \pi N$ HENDRY 78 MPWA $\pi N \rightarrow \pi N$ • • • We do not use the following data for averages, fits, limits, etc. • • •  476   805 $\pm$ 140   BATINIC 95 DPWA $\pi N \rightarrow \pi N$ 70238   CRAWFORD 80 DPWA $\pi N \rightarrow \pi N$ 80 SAXON 80 DPWA $\pi N \rightarrow \pi N$ 80 SAXON 80 DPWA $\pi N \rightarrow \pi N$ 80 SAXON 80 DPWA $\pi P \rightarrow \pi N$ 80 SAXON 80 DPWA $\pi P \rightarrow \pi N$ 819 BAKER 79 DPWA $\pi P \rightarrow \pi N$ 819 BARBOUR 78 DPWA $\pi P \rightarrow \pi N$ 810   811   811   812   814   815   SAXON 80 DPWA $\pi P \rightarrow \pi N$ 817   SAXON 80 DPWA $\pi P \rightarrow \pi N$ 818   SAXON 80 DPWA $\pi P \rightarrow \pi N$ 819   SAXON 80 DPWA $\pi P \rightarrow \pi N$ 810   SAXON 80 DPWA $\pi P \rightarrow \pi N$ 811   SAXON 80 DPWA $\pi P \rightarrow \pi N$ 812   SAXON 80 DPWA $\pi P \rightarrow \pi N$ 813   SAXON 80 DPWA $\pi P \rightarrow \pi N$ 814   SAXON 80 DPWA $\pi P \rightarrow \pi N$ 815   SAXON 80 DPWA $\pi P \rightarrow \pi N$ 816   SAXON 80 DPWA $\pi P \rightarrow \pi N$ 817   SAXON 80 DPWA $\pi P \rightarrow \pi N$ 818   819   SAXON 80 DPWA $\pi P \rightarrow \pi N$ 819   SAXON 80 DPWA $\pi P \rightarrow \pi N$ 819   SAXON 80 DPWA $\pi P \rightarrow \pi N$ 819   SAXON 80 DPWA $\pi P \rightarrow \pi N$ 819   SAXON 80 DPWA $\pi P \rightarrow \pi N$ 819   SAXON 80 DPWA $\pi P \rightarrow \pi N$ 819   SAXON 80 DPWA $\pi N \rightarrow \pi N$ 819   SAXON 80 DPWA $\pi N \rightarrow \pi N$ 819   SAXON 80 DPWA $\pi N \rightarrow \pi N$ 819   SAXON 80 DPWA $\pi N \rightarrow \pi N$ 819   SAXON 80 DPWA $\pi N \rightarrow \pi N$ 819   SAXON 80 DPWA $\pi N \rightarrow \pi N$ 819   SAXON 80 DPWA $\pi N \rightarrow \pi N$ 819   SAXON 80 DPWA $\pi N \rightarrow \pi N$ 819   SAXON 80 DPWA $\pi N \rightarrow \pi N$ 819   SAXON 80 DPWA $\pi N \rightarrow \pi N$ 819   SAXON 80 DPWA $\pi N \rightarrow \pi N$ 819   SAXON 80 DPWA $\pi N \rightarrow \pi N$ 819   SAXON 80 DPWA $\pi N \rightarrow \pi N$ 819   SAXON 80 DPWA $\pi N \rightarrow \pi N$ 819   SAXON 80 DPWA $\pi N \rightarrow \pi N$ 819   SAXON 80 DPWA $\pi N \rightarrow \pi N$ 819   SAXON 80 DPWA $\pi N \rightarrow \pi N$ 819   SAXON 80 DPWA $\pi N \rightarrow \pi N$ 810 DPWA $\pi N \rightarrow \pi N$	350 to 550 (≈ 450) OUR ES	TIMATE
390 ± 30  390 ± 30  HOEHLER  79  IPWA $\pi N \rightarrow \pi N$ $\pi N$ • • We do not use the following data for averages, fits, limits, etc.  476  805 ± 140  8ARNDT  95  DPWA $\pi N \rightarrow \pi N$ 80  SAXON  80  DPWA $\pi N \rightarrow \pi N$ 80  SAXON  80  DPWA $\pi N \rightarrow \pi N$ 80  SAXON  80  DPWA $\pi N \rightarrow \pi N$ 80  SAXON  80  DPWA $\pi N \rightarrow \pi N$ 80  SAXON  80  DPWA $\pi N \rightarrow \pi N$ 80  SAXON  80  DPWA $\pi P \rightarrow \pi N$ 80  SAXON  80  DPWA $\pi P \rightarrow \pi N$ 80  SAXON  80  PPWA $\pi P \rightarrow \pi N$ 80  SAXON  80  PPWA $\pi P \rightarrow \pi N$ 80  SAXON  80  PPWA $\pi P \rightarrow \pi N$ 80  CUTKOSKY  80  PPWA $\pi N \rightarrow \pi N$ 80  ARNDT  91  DPWA $\pi N \rightarrow \pi N$ Soin SM90  -2×IMAGINARY PART  VALUE (MeV)  DOCUMENT ID  TECN  COMMENT  ARNDT  91  DPWA $\pi N \rightarrow \pi N$ Soin SM90  -2×IMAGINARY PART  VALUE (MeV)  DOCUMENT ID  TECN  COMMENT  TECN  COMMENT  TECN  COMMENT  THOEHLER  93  SPED $\pi N \rightarrow \pi N$ Soin SM90  -2×IMAGINARY PART  VALUE (MeV)  DOCUMENT ID  TECN  COMMENT  TECN  COMMENT  TECN  COMMENT  TECN  TO  TECN  TECN  TECN  TECN  TO  TECN  TECN  TECN  TO  TECN  TECN  TO  TECN  TECN  TO  TECN  TECN  TECN  TO  TECN  TO  TECN  TECN  TO  TO  TECN  TO  TO  TO  TO  TO  TO  TO  TO  TO  T	550 ± 50	
270 $\pm$ 50		
• • • We do not use the following data for averages, fits, limits, etc. • • • • $476$ ARNDT 95 DPWA $\pi N \rightarrow N\pi$ 805±140 BATINIC 95 DPWA $\pi N \rightarrow N\pi$ , $N\eta$ 238 CRAWFORD 80 DPWA $\gamma N \rightarrow \pi N$ 80 SAXON 80 DPWA $\pi^- \rho \rightarrow \Lambda K^0$ 319 BAKER 79 DPWA $\pi^- \rho \rightarrow \Lambda K^0$ 320 BARBOUR 78 DPWA $\gamma N \rightarrow \pi N$ W(2190) POLE POSITION  REAL PART  VALUE (MeV)  DOCUMENT ID  ARNDT 95 DPWA $\pi N \rightarrow N\pi$ 1 HOEHLER 93 SPED $\pi N \rightarrow \pi N$ 2010 $\pm 50$ CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$ Soln SM90  -2×IMAGINARY PART  VALUE (MeV)  DOCUMENT ID  TECN  COMMENT  2060 ARNDT 91 DPWA $\pi N \rightarrow \pi N$ Soln SM90  -2×IMAGINARY PART  VALUE (MeV)  DOCUMENT ID  TECN  COMMENT  TECN  COMMENT  TECN  TO  TECN  TECN  TO  TO  TECN  TO  TECN  TO  TO  TO  TECN  T		
805 $\pm$ 140  80  8ATINIC  95  DPWA $\pi N \rightarrow N\pi$ , $N\eta$ 238  CRAWFORD  80  DPWA $\tau P \rightarrow \Lambda K^0$ 319  BAKER  79  DPWA $\tau P \rightarrow \Lambda K^0$ 319  BARBOUR  78  DPWA $\tau P \rightarrow \Lambda K^0$ 319  BARBOUR  78  DPWA $\tau P \rightarrow \Lambda K^0$ 319  BARBOUR  78  DPWA $\tau P \rightarrow \Lambda K^0$ DPWA $\tau P \rightarrow \Lambda K^0$ 319  BARBOUR  78  DPWA $\tau N \rightarrow \pi N$ N(2190) POLE POSITION  REAL PART  VALUE (MeV)  DOCUMENT ID  1 HOEHLER  2100 $\pm$ 50  ••• We do not use the following data for averages, fits, limits, etc.  •••  ARNDT  91  DPWA $\tau N \rightarrow \pi N$ Soin SM90  -2×IMAGINARY PART  VALUE (MeV)  DOCUMENT ID  TECN  TECN  COMMENT  AND  THOEHLER  93  SPED  THOEHLER  94  SPED  THOEHLER  95  DPWA  THOEHLER  96  THOEHLER  97  THOEHLER  98  SPED  THOEHLER  99  THOEHLER  99  THOEHLER  90  THOEHLER  90  THOEHLER  91  DPWA  THOEHLER  93  THOEHLER  94  THOEHLER  95  THOEHLER  96  THOEHLER  97  THOEHLER  97  THOEHLER  98  THOEHLER  99  THOEHLER  99  THOEHLER  90  THOEHLER  90  THOEHLER  90  THOEHLER  91  THOEHLER  93  THOEHLER  94  THOEHLER  95  THOEHLER  96  THOEHLER  97  THOEHLER  97  THOEHLER  98  THOEHLER  99  THOEHLER  99  THOEHLER  90  THOEHLER  90  THOEHLER  90  THOEHLER  90  THOEHLER  90  THOEHLER  90  THOEHLER  THOEHLER  90  THOEHLER		
238  80  SAXON  80  DPWA $\gamma N \rightarrow \pi N$ 80  SAXON  80  DPWA $\pi^- \rho \rightarrow \Lambda K^0$ BAKER  79  DPWA $\pi^- \rho \rightarrow \Lambda K^0$ 220  BARBOUR  78  DPWA $\gamma N \rightarrow \pi N$ 80  N(2190) POLE POSITION  REAL PART  VALUE (MeV)  DOCUMENT ID  1 HOEHLER  93  SPED  ARNDT  91  DPWA  TECN  COMMENT  2030  ARNDT  91  DPWA  TO  TECN  TECN  COMMENT  2042  1 HOEHLER  93  SPED  TO  TO  TO  TO  TO  TO  TO  TO  TO  T	476	ARNDT 95 DPWA $\pi N \rightarrow N \pi$
80  319  SAXON  80  DPWA $\pi^- p \rightarrow \Lambda K^0$ BAKER  79  DPWA $\pi^- p \rightarrow \eta \eta$ BARBOUR  78  DPWA $\pi^- p \rightarrow \eta \eta$ BARBOUR  78  PPWA $\pi^- p \rightarrow \eta \eta$ BARBOUR  78  PPWA $\pi^- p \rightarrow \eta \eta$ DPWA $\pi^- p \rightarrow \eta \eta$ BARBOUR  78  PPWA $\pi^- p \rightarrow \eta \eta$ DPWA $\pi^- p \rightarrow \eta \eta$ DPWA $\pi^- p \rightarrow \eta \eta$ DPWA $\pi^- p \rightarrow \Lambda K^0$ PPWA $\pi^- p \rightarrow \eta \eta$ PPWA $\pi^- p \rightarrow \Lambda K^0$ PP		• •
319     BAKER 79 DPWA $\pi^- \rho \rightarrow n\eta$ BARBOUR 78 DPWA $\gamma N \rightarrow \pi N$ N(2190) POLE POSITION  REAL PART  VALUE (MeV)  2030     ARNDT 95 DPWA $\pi N \rightarrow N\pi$ 1 HOEHLER 93 SPED $\pi N \rightarrow \pi N$ 2042     1 HOEHLER 93 SPED $\pi N \rightarrow \pi N$ 2010±50     • • • We do not use the following data for averages, fits, limits, etc. • • •  2060     ARNDT 91 DPWA $\pi N \rightarrow \pi N$ Soin SM90  -2×IMAGINARY PART  VALUE (MeV)  DOCUMENT ID     TECN     TECN     TECN     TECN     TOMMENT     N     N     N     N     N     N     N     Soin SM90  -2×IMAGINARY PART  VALUE (MeV)  DOCUMENT ID     TECN		
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$		
REAL PART  VALUE (MeV)  DOCUMENT ID  TECN  COMMENT  ARNDT  95 DPWA $\pi N \rightarrow N\pi$ 2010±50  ••• We do not use the following data for averages, fits, limits, etc.  ARNDT  91 DPWA $\pi N \rightarrow \pi N$ Soin SM90  —2×IMAGINARY PART  VALUE (MeV)  DOCUMENT ID  ARNDT  95 DPWA $\pi N \rightarrow \pi N$ Soin SM90  ARNDT  96 ••• We do not use the following data for averages, fits, limits, etc.  ARNDT  97 DPWA $\pi N \rightarrow \pi N$ Soin SM90  CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N \rightarrow \pi N$ ARNDT  98 DPWA $\pi N \rightarrow \pi N \rightarrow \pi N \rightarrow \pi N$ 482  1 HOEHLER  98 SPED $\pi N \rightarrow \pi N$		· · ·
VALUE (MeV) DOCUMENT ID TECN COMMENT  2030 ARNDT 95 DPWA $\pi N \rightarrow N\pi$ 21042 1 HOEHLER 93 SPED $\pi N \rightarrow \pi N$ 2100 $\pm 50$ CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$ 2060 ARNDT 91 DPWA $\pi N \rightarrow \pi N$ 2060 ARNDT 91 DPWA $\pi N \rightarrow \pi N$ Soln SM90  -2×IMAGINARY PART  VALUE (MeV) DOCUMENT ID TECN COMMENT  460 ARNDT 95 DPWA $\pi N \rightarrow \pi N$ 482 1 HOEHLER 93 SPED $\pi N \rightarrow \pi N$ 482 CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$ 484 ARNDT 95 DPWA $\pi N \rightarrow \pi N$ 485 ARNDT 97 DPWA $\pi N \rightarrow \pi N$ 486 ARNDT 98 DPWA $\pi N \rightarrow \pi N$ 487 ARNDT 99 DPWA $\pi N \rightarrow \pi N$ 488 ARNDT 99 DPWA $\pi N \rightarrow \pi N$ 489 ARNDT 99 DPWA $\pi N \rightarrow \pi N$		N(2190) POLE POSITION
2030  ARNDT 95 DPWA $\pi N \rightarrow N \pi$ 2042 93 SPED $\pi N \rightarrow \pi N$ 2100 $\pm$ 50		
2042 $\frac{1}{\text{CUTKOSKY}} = \frac{3}{80} \text{ SPED}  \pi N \rightarrow \pi N$ 2100 $\pm 50$ CUTKOSKY $\frac{3}{80} = \frac{1}{\text{PWA}} = \frac{\pi N \rightarrow \pi N}{\pi N \rightarrow \pi N}$ • • • We do not use the following data for averages, fits, limits, etc. • • • • • • • • • • • • • • • • • • •		
2100 $\pm$ 50		
2060 ARNDT 91 DPWA $\pi N \rightarrow \pi N$ Soln SM90  -2×IMAGINARY PART  VALUE (MeV)  DOCUMENT ID  TECN  COMMENT  TECN  OMMENT  TECN  TECN  OMMENT  TECN  TO  TECN  TECN  TECN  TECN  TO  TECN  TECN  TECN  TO  TECN  TECN  TECN  TECN  TECN  TECN  TO  TECN  TECN  TECN  TECN  TO  TECN  TECN  TO  TECN  TO  TECN  TECN  TECN  TECN  TECN  TO  TECN  TECN  TECN  TECN  TO  TECN  TECN  TECN  TECN  TECN  TECN  TECN  TECN  TO  TECN  TECN  TO  TECN  TECN  TECN  TECN  TO  TECN  TECN  TO  TECN  TO  TECN  TO  TECN  TECN  TO  TO  TECN  TO  TECN  TO  TO  TECN  TO  TO  TECN  TO  TO  TO  TO  TO  TECN  TO  TO  TO  TO  TO  TECN  TO  TO  TO  TO  TO  TO  TO  TO  TO  T		
-2×IMAGINARY PART  VALUE (MeV)  460  ARNDT  95  DPWA $N \rightarrow N \pi$ 482 $1 \text{ HOEHLER}$ 93  SPED $N \rightarrow \pi N$ 400±160  CUTKOSKY  80  PWA $N \rightarrow N \pi$ $N \rightarrow N \pi$ 464  ARNDT  91  DPWA $N \rightarrow N \pi$ $N \rightarrow N \pi$ 91  DPWA $N \rightarrow N \rightarrow N \pi$ 91  DPWA $N \rightarrow N \rightarrow N \pi$ 91  DPWA $N \rightarrow N \rightarrow N \rightarrow N \pi$ 91  DPWA $N \rightarrow N \rightarrow N \rightarrow N \pi$ 91  DPWA $N \rightarrow N \rightarrow N \rightarrow N \rightarrow N \pi$	• • We do not use the foll	owing data for averages, fits, limits, etc. • • •
VALUE (MeV)DOCUMENT IDTECNCOMMENT460ARNDT95DPWA $\pi N \rightarrow N\pi$ 482 1 HOEHLER93SPED $\pi N \rightarrow \pi N$ 400±160CUTKOSKY80IPWA $\pi N \rightarrow \pi N$ • • • We do not use the following data for averages, fits, limits, etc.• • •464ARNDT91DPWA $\pi N \rightarrow \pi N$ Soln SM90	2060	ARNDT 91 DPWA $\pi N \rightarrow \pi N$ Soln SM90
460 ARNDT 95 DPWA $\pi N \rightarrow N \pi$ 482 1 HOEHLER 93 SPED $\pi N \rightarrow \pi N$ 400±160 CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$ 400±0 We do not use the following data for averages, fits, limits, etc. • • 464 ARNDT 91 DPWA $\pi N \rightarrow \pi N$ Soln SM90		DOCUMENT ID TECN COMMENT
482 $\frac{1}{\text{HOEHLER}}$ 93 SPED $\pi N \rightarrow \pi N$ 400 ± 160 CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$ • • We do not use the following data for averages, fits, limits, etc. • •  464 ARNDT 91 DPWA $\pi N \rightarrow \pi N$ Soln SM90		
<ul> <li>• • We do not use the following data for averages, fits, limits, etc. • • •</li> <li>464 ARNDT 91 DPWA πN → πN Soln SM90</li> </ul>		1 HOEHLER 93 SPED $\pi N  ightarrow \pi N$
464 ARNDT 91 DPWA $\pi N  o \pi N$ Soln SM90		
N(2100) EL ASTIC DOLE DESIDILE		190) ELASTIC POLE RESIDUE
	MODULUS  r  VALUE (MeV)	DOCUMENT ID TECN COMMENT

ARNDT

91 DPWA  $\pi N \rightarrow \pi N$  Soln SM90

	N(2100), N(2190
PHASE θ	
VALUE (°)	DOCUMENT ID TECN COMMENT
-23	ARNDT 95 DPWA $\pi N \rightarrow N \pi$
-30±50	CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$ following data for averages, fits, limits, etc. • •
-44	ARNDT 91 DPWA $\pi N \to \pi N$ Soln SM
<u> </u>	N(2190) DECAY MODES
The following bra	nching fractions are our estimates, not fits or averages.
Mode	Fraction $(\Gamma_i/\Gamma)$
 Γ ₁ Νπ	10–20 %
$\Gamma_2$ $N\eta$	
$\Gamma_3$ $\Lambda K$	
$\Gamma_4 \Sigma K$	
$\Gamma_5 N\pi\pi$	
$\Gamma_6 N\rho$	D
$\Gamma_7$ $N\rho$ , $S=3/2$	
$\Gamma_8$ $p\gamma$ , helicity=1/2	
$\Gamma_9$ $p\gamma$ , helicity=3/2	
$\Gamma_{10}$ $n\gamma$ , helicity=1/2 $\Gamma_{11}$ $n\gamma$ , helicity=3/2	
	N(2190) BRANCHING RATIOS
Γ(Nπ)/Γ _{total}	Γ:
0.1 to 0.2 OUR ESTIMAT	
0.22±0.01 0.12±0.06	MANLEY 92 IPWA $\pi N \rightarrow \pi N \& N \pi \pi$ CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$
0.12±0.06 0.14±0.02	CUTKOSKY 80 IPWA $\pi N  o \pi N$ HOEHLER 79 IPWA $\pi N  o \pi N$
0.16±0.04	HENDRY 78 MPWA $\pi N \rightarrow \pi N$
	following data for averages, fits, limits, etc. • •
0.23	ARNDT 95 DPWA $\pi N \rightarrow N \pi$
$0.19 \pm 0.05$	BATINIC 95 DPWA $\pi N \rightarrow N \pi$ , $N \eta$
$\Gamma(N\eta)/\Gamma_{\text{total}}$	Г:
• • • We do not use the f	DOCUMENT ID TECN COMMENT following data for averages, fits, limits, etc. • • •
$0.001 \pm 0.003$	BATINIC 95 DPWA $\pi N  o N \pi$ , $N \eta$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}}$ in $N\pi$ -	
• • • We do not use the f	DOCUMENT ID TECN COMMENT following data for averages, fits, limits, etc. • • •
+0.052	BAKER 79 DPWA $\pi^- p \rightarrow n \eta$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi$ –	$\rightarrow N(2190) \rightarrow \Lambda K \qquad (\Gamma_1 \Gamma_3)^{\frac{1}{2}}$
VALUE	DOCUMENT ID TECN COMMENT
-0.02 -0.02	BELL 83 DPWA $\pi^- p \rightarrow \Lambda K^0$ SAXON 80 DPWA $\pi^- p \rightarrow \Lambda K^0$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N_{\pi} -$	$\rightarrow N(2190) \rightarrow \Sigma K \qquad (\Gamma_1 \Gamma_4)^{\frac{1}{2}}$
VALUE	DOCUMENT ID TECN COMMENT
0.014 to 0.019	following data for averages, fits, limits, etc. $ullet$ $ullet$ $ullet$ DEANS 75 DPWA $\pi N  o oldsymbol{\Sigma} K$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi$ -	$\rightarrow N(2190) \rightarrow N\rho$ , $S=3/2$ , $D$ -wave $(\Gamma_1\Gamma_7)^{\frac{1}{2}}$
<u>VALUE</u> -0.25±0.03	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$
•	90) PHOTON DECAY AMPLITUDES
$N(2190) \rightarrow p\gamma$ , helici $VALUE(GeV^{-1/2})$	ity-1/2 amplitude A _{1/2}
	following data for averages, fits, limits, etc. • •
-0.055	CRAWFORD 80 DPWA $\gamma N \rightarrow \pi N$
-0.030	BARBOUR 78 DPWA $\gamma N \rightarrow \pi N$
	ity-3/2 amplitude A _{3/2}
VALUE (GeV-1/2)	DOCUMENT ID TECN COMMENT
	following data for averages, fits, limits, etc. • • •
0.081	CRAWFORD 80 DPWA $\gamma N \rightarrow \pi N$
+0.180	BARBOUR 78 DPWA $\gamma N \to \pi N$
$N(2190) \rightarrow n\gamma$ , helici	lty-1/2 amplitude A _{1/2}
VALUE (GeV ^{-1/2} )	DOCUMENT ID TECN COMMENT
	following data for averages, fits, limits, etc. • • •
-0.042	CRAWFORD 80 DPWA $\gamma N \to \pi N$

CRAWFORD 80 DPWA  $\gamma N \rightarrow \pi N$ BARBOUR 78 DPWA  $\gamma N \rightarrow \pi N$ 

 $-0.042 \\ -0.085$ 

## Baryon Particle Listings N(2190), N(2200)

VALUE (GeV ^{-1/2} )	DOCUMENT ID		TECN	COMMENT	
	e following data for averag	es, fit	s, limits,	etc. • • •	
-0.126	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$	
+0.007	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$	
N(	$2190)  \gamma p \to \Lambda K^+$	- AM	PLITU	DES	
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } p_{\gamma}$	$\gamma \rightarrow N(2190) \rightarrow \Lambda K$	+		(E ₄ _	amplitude
VALUE (units 10 ⁻³ )	DOCUMENT ID		TECN		
2.5 ±1.0	WORKMAN	90	DPWA		
• • We do not use the	e following data for averag	es, fit	s, limits,	etc. • • •	
2.04	TANABE	89	DPWA		
$p\gamma \rightarrow N(2190) \rightarrow$	$\Lambda K^+$ phase angle $\theta$			(E4_	amplitude
VALUE (degrees)			TECN		
- 4 ±9	WORKMAN	90	DPWA		
• • We do not use the	e following data for averag	es, fits	s, limits,	etc. • • •	
27.5	TANABE	89	DPWA		
		+		(M ₄ _	amplitude
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } p_{\gamma}$	$r \rightarrow N(2190) \rightarrow \Lambda K$	•			
	$\gamma \rightarrow N(2190) \rightarrow \Lambda K$ $\frac{DOCUMENT ID}{}$		TECN	•	
VALUE (units 10 ⁻³ )				•	
VALUE (units 10 ⁻³ )  -7.0 ±0.7	DOCUMENT ID	90	DPWA	-	

## N(2190) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

ARNDT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BRCO)
BATINIC	95	PR C51 2310	+Slaus, Svarc, Nefkens	(BÒSK, UCLA)
HOEHLER	93	π N Newsletter 9 1		(KARL)
MANLEY	92	PR D45 4002	+ Saleski	(KENT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	` (VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
WORKMAN	90	PR C42 781		(VPI)
TANABE	89	PR C39 741	+Kohno, Bennhold	(MÀNZ)
Also	89	NC 102A 193	Kohno, Tanabe, Bennhold	(MANZ)
BELL	83	NP B222 389	+Blissett, Broome, Daley, Hart, Lintern+	(RL) IJP
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
CRAWFORD	80	Toronto Conf. 107		(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMŮ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
SAXON	80	NP B162 522	+Baker, Bell, Blissett, Bloodworth+	(RHEL, BRIS) IJP
BAKER	79	NP B156 93	+Brown, Clark, Davies, Depagter, Evans+	· (RHEL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	`(GLAS)
HENDRY	78	PRL 41 222		(INĎ, LBL) IJP
Also	81	ANP 136 1	Hendry	(IND)
WINNIK	77	NP B128 66	+Toaff, Revel, Goldberg, Berny	(ĤAIF) I
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ÀLAH) IJP



 $I(J^P) = \frac{1}{2}(\frac{5}{2})$  Status: **

## OMITTED FROM SUMMARY TABLE

The mass is not well determined. A few early results have been

N(2200) MASS					
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
≈ 2200 OUR ESTIMATE					
1900	BELL	83	DPWA	$\pi^- \rho \rightarrow \Lambda K^0$	
$2180 \pm 80$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
1920	SAXON	80	DPWA	$\pi^- p \rightarrow \Lambda K^0$	
$2228 \pm 30$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$	
• • • We do not use the following	g data for average	es, fit	s, limits,	etc. • • •	
2240 ± 65	RATINIC	95	DPM/A	$\pi M \rightarrow M \pi M n$	

N(2200) WIDTH								
VALUE (MeV)	DOCUMENT ID		TECN COMMENT					
130	BELL	83	DPWA $\pi^- p \rightarrow \Lambda K^0$					
$400 \pm 100$	CUTKOSKY		IPWA $\pi N \rightarrow \pi N$					
220	SAXON	80	DPWA $\pi^- p \rightarrow \Lambda K^0$					
310± 50	HOEHLER	79	IPWA $\pi N \rightarrow \pi N$					
● ● We do not use the following data for averages, fits, limits, etc. ● ●								
$761 \pm 139$	BATINIC	95	DPWA $\pi N \to N \pi$ , $N \eta$					
N(22	N(2200) POLE POSITION							
DEAL DADT								

REAL PART VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
$2100 \pm 60$	CUTKOSKY 8	0 IPWA	$\pi N \rightarrow \pi N$
-2×IMAGINARY PART			
VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
$360\pm80$	CUTKOSKY 8	0 IPWA	$\pi N \rightarrow \pi N$

## N(2200) ELASTIC POLE RESIDUE

MODULUS  r   VALUE (MeV)  20 ± 10	DOCUMENT ID	TECN IDMA	$\frac{COMMENT}{\pi N \rightarrow \pi N}$
PHASE $\theta$ VALUE (°)	DOCUMENT ID	TECN_	COMMENT
$-90 \pm 50$	CUTKOSKY 80	IPWA	$\pi N \rightarrow \pi N$

## N(2200) DECAY MODES

	Mode
$\Gamma_1$	Νπ
$\Gamma_2$	$N\eta$
Γ3	ΛK

## N(2200) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$					$\Gamma_1/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT	
$0.10 \pm 0.03$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
$0.07 \pm 0.02$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$	
• • We do not use the	following data for averages	, fit	s, limits,	etc. • • •	
$0.08 \pm 0.04$	BATINIC	95	DPWA	$\pi  N   o  N  \pi$ , $N  \eta$	
$\Gamma(N\eta)/\Gamma_{\text{total}}$					$\Gamma_2/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT	
• • • We do not use the	following data for averages	, fit	s, limits,	etc. • • •	
$0.001 \pm 0.01$	BATINIC	95	DPWA	$\pi N \rightarrow N \pi$ , $N \eta$	
•1					.,

ı

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \to N($	[2200] → Nη DOCUMENT ID		TECN_	$(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma$
0.066	BAKER	79	DPWA	$\pi^- \rho \rightarrow n\eta$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \pi \to N($	(2200) → <i>ΛK</i>			(Γ₁Γ₃) ^{1/₂} /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
-0.03	BELL			$\pi^- \rho \rightarrow \Lambda K^0$
-0.05				$\pi^- p \rightarrow \Lambda K^0$

## N(2200) REFERENCES

BATINIC	95	PR C51 2310		+Slaus, Svarc, Nefkens	(BOSK, UCLA)
BELL	83	NP B222 389		+Blissett, Broome, Daley, Hart, Lintern+	(RL) IJP
CUTKOSKY	80	Toronto Conf.	19	+Forsyth, Babcock, Kelly, Hendrick	(CMU, LBL) IJP
Also	79	PR D20 2839		Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL)
SAXON	80	NP B162 522		+Baker, Bell, Blissett, Bloodworth+	(RHEL, BRIS) IJP
BAKER	79	NP B156 93		+Brown, Clark, Davies, Depagter, Evans+	(RHEL) IJP
HOEHLER	79	PDAT 12-1		+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf.	3	Koch	(KARLT) IJP

 $^{^1}$  See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and  $\Delta$  resonances as determined from Argand diagrams of  $\pi$  N elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.  2  The range given for DEANS 75 is from the four best solutions. Disagrees with  $\pi^+ \, \rho \to \Sigma^+ \, K^+$  data of WINNIK 77 around 1920 MeV.

## $N(2220) H_{19}$

 $I(J^P) = \frac{1}{2}(\frac{9}{2}^+)$  Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

## N(2220) MASS

CUTKOSKY	80		
	RΛ		
	30	IPWA	$\pi N \rightarrow \pi N$
HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
HENDRY	78	MPWA	$\pi N \rightarrow \pi N$
g data for average	s, fit	s, limits,	etc. • • •
ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
BAKER	79	DPWA	$\pi^- p \rightarrow n\eta$
	-	ARNDT 95	

## N(2220) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
320 to 550 (≈ 400) OUR ESTIMA	TE			
$500 \pm 150$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
365± 30	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
450 ± 150	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$
• • We do not use the following	g data for average	s, fits	s, limits,	etc. • • •
334	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$

## N(2220) POLE POSITION

## REAL PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
2203	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
2135	¹ HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
$2160 \pm 80$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the f	ollowing data for average	s, fits	s, limits,	etc. • • •
2253	ARNDT	91	DPWA	$\pi{\it N}  ightarrow \pi{\it N} {\rm Soln} {\rm SM90}$
-2×IMAGINARY PAR	RT			

-2×IMAGINARY PARI				
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
536	ARNDT			$\pi N \rightarrow N \pi$
400	¹ HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
$480 \pm 100$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	g data for average	s, fits	s, limits,	etc. • • •
640	ARNDT	91	DPWA	$\pi{\it N}  ightarrow$

## N(2220) ELASTIC POLE RESIDUE

## MODULUS |r|

SF A					
	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln	SM90
We do not use the follow	ving data for average	s, fit	s, limits,	etc. • • •	
0	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
	HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$	
	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$	
(MeV)	DOCUMENT ID		TECN	COMMENT	
1 1					

#### PHASE $\theta$

VALUE (°)	DOCUMENT ID		TECN	COMMENT
-43	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
-50	HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
$-45 \pm 25$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	data for average	s, fit:	s, limits,	etc. • • •
-62	ARNDT	91	DPWA	$\pi{\it N}  ightarrow\pi{\it N}$ Soln SM90

## N(2220) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction $(\Gamma_i/\Gamma)$
Γ ₁	$N\pi$	10-20 %
$\Gamma_2$	$N\eta$	
$\Gamma_3$	ΛK	

## N(2220) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$				Γ ₁ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
0.1 to 0.2 OUR ESTIMAT	E			
$0.15 \pm 0.03$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
$0.18 \pm 0.015$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
$0.12 \pm 0.04$	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$
• • • We do not use the fo	ollowing data for average	s, fit	s, limits,	etc. • • •
0.26	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi -$	→ N(2220) → Nη			(Γ₁Γ₂) ^½ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the fo	ollowing data for average	s, fit	s, limits,	etc. • • •
0.034	BAKER	79	DPWA	$\pi^-  ho  ightarrow n \eta$
·- · · · · · · · · · · · · · · · · · ·				14 .

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \to N(2220) \to \Lambda K$			(Γ₁Γ₃) ^{1/2} /	Г	
VALUE	DOCUMENT ID		TECN	COMMENT	_
not required	BELL	83	DPWA	$\pi^- \rho \rightarrow \Lambda K^0$	
not seen	SAXON	80	DPWA	$\pi^- p \rightarrow \Lambda K^0$	

## N(2220) FOOTNOTES

## N(2220) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

ARNDT HOEHLER	95 93	PR C52 2120 π N Newsletter 9 1	+Strakovsky, Workman, Pavan	(VPI, BRCO) (KARL)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
BELL	83	NP B222 389	+Blissett, Broome, Daley, Hart, Lintern+	` (RL) IJP
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMU, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
SAXON	80	NP B162 522	+Baker, Bell, Blissett, Bloodworth+	(RHEL, BRIS) IJP
BAKER	79	NP B156 93	+Brown, Clark, Davies, Depagter, Evans+	(RHEL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
HENDRY	78	PRL 41 222		(IND, LBL) IJP
Also	81	ANP 136 1	Hendry	(IND)



 $I(J^P) = \frac{1}{2}(\frac{9}{2}^-)$  Status: ***

## N(2250) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
2170 to 2310 (≈ 2250) OUR ESTI	MATE			
2250± 80	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
2268± 15	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
$2200 \pm 100$	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	data for average	s, fit	s, limits,	etc. • • •
2291	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$

## N(2250) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
290 to 470 (≈ 400) OU	R ESTIMATE			
$480 \pm 120$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
300 ± 40	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
$350 \pm 100$	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$
• • • We do not use th	ne following data for average	s, fit	s, limits,	etc. • • •
772	ARNOT	95	DP\//Δ	$\pi N \rightarrow N \pi$

## N(2250) POLE POSITION

## REAL PART

I

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
2087	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
2187	¹ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
2150 ± 50	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use th	e following data for averages	s, fits	s, limits,	etc. • • •
2243	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$
-2×IMAGINARY PA	ART			
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT

VALUE (IVIEV)	DOCOMENT 1D		1 2 0 14	COMMENT	
680	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$	
388	¹ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$	
$360 \pm 100$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
• • We do not use the following	data for average	s, fits	s, limits,	etc. • • •	
650	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM}90$	

 $^{^1}$  See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and  $\Delta$  resonances as determined from Argand diagrams of  $\pi$  N elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.

N(2250), N(2600), N(2700)

## N(2250) ELASTIC POLE RESIDUE

MODULUS  r					
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
24	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$	1
21	HOEHLER	93	SPED	$\pi N \rightarrow \pi N$	
20±6	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
• • We do not use the following d	lata for averages	s, fits	s, limits,	etc. • • •	
47	ARNDT	91	DPWA	$\pi{\it N}  ightarrow \pi{\it N}$ Soln SM90	
PHASE θ					
VALUE (°)	DOCUMENT ID		TECN	COMMENT	
-44	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$	1
$-50 \pm 20$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
• • We do not use the following of	lata for averages	s, fits	s, limits,	etc. • • •	
-37	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$	

## N(2250) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction $(\Gamma_i/\Gamma)$
$\Gamma_1$	Nπ	5–15 %
Γ ₂ Γ ₃	$N\eta$	
$\Gamma_3$	ΛK	

## N(2250) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$					$\Gamma_1/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT	
0.05 to 0.15 OUR ESTIMATE					
$0.10 \pm 0.02$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
$0.10 \pm 0.02$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$	
$0.09 \pm 0.02$	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$	
• • We do not use the following	g data for average	s, fit	s, limits,	etc. • • •	
0.10	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$	

$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N \pi \to N(2)$	$(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma$			
VALUE	DOCUMENT ID	TECN	COMMENT	
• • • We do not use the following	data for averages, fits	s, limits,	etc. • • •	

BAKER 79 DPWA  $\pi^- p \rightarrow n \eta$ -0.043

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \pi \to \Lambda$	(Γ ₁ Γ ₃ ) ^⅓ 2/Γ		
VALUE	DOCUMENT ID	TECN	COMMENT
-0.02	BELL	B3 DPWA	$\pi^- p \rightarrow \Lambda K^0$
not seen	SAXON	BO DPWA	$\pi^- p \rightarrow \Lambda K^0$

## N(2250) FOOTNOTES

 1  See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and  $\Delta$  resonances as determined from Argand diagrams of  $\pi$  N elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.

## N(2250) REFERENCES

ARNDT HOEHLER	95 93	PR C52 2120 πN Newsletter 9 1	+Strakovsky, Workman, Pavan	(VPI, BRCO) (KARL)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
BELL	83	NP B222 389	+Blissett, Broome, Daley, Hart, Lintern+	(RL) IJP
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMU, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
SAXON	80	NP B162 522	+Baker, Bell, Blissett, Bloodworth+	(RHEL, BRIS) IJP
BAKER	79	NP B156 93	+Brown, Clark, Davies, Depagter, Evans+	(RHEL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
HENDRY	78	PRL 41 222		(IND, LBL) IJP
Also	81	ANP 136 1	Hendry	(IND)

 $N(2600) I_{1,11}$ 

 $I(J^P) = \frac{1}{2}(\frac{11}{2})$  Status: ***

N(2600) MASS						
VALUE (MeV)	DOCUMENT ID	TECN	COMMENT			
2550 to 2750 (≈ 2600) OUR ES 2577± 50 2700±100	HOEHLER		$ \begin{array}{ccc} \pi  N \to & \pi  N \\ A  \pi  N \to & \pi  N \end{array} $			
N(2600) WIDTH						
		••				
VALUE (MeV) 500 to 800 (≈ 650) OUR ESTIN	DOCUMENT ID	TECN	COMMENT			

## N(2600) DECAY MODES

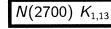
	Mode	Fraction $(\Gamma_i/\Gamma)$
Γ ₁	Nπ	5–10 %

## N(2600) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$					$\Gamma_1/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT	
0.05 to 0.1 OUR ESTIMATE					
$0.05 \pm 0.01$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$	
$0.08 \pm 0.02$	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$	

## N(2600) REFERENCES

HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
HENDRY	78	PRL 41 222		(IND, LBL) IJP
Also	81	ANP 136 1	Hendry	(IND)



 $I(J^P) = \frac{1}{2}(\frac{13}{2}^+)$  Status: **

OMITTED FROM SUMMARY TABLE

	N(2700) MA	ASS		
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 2700 OUR ESTIMATE			10144	
2612± 45	HOEHLER			$\pi N \rightarrow \pi N$
$3000 \pm 100$	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$
	N(2700) WIE	тн		
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
350 ± 50	HOEHLER	79	<b>IPWA</b>	$\pi N \rightarrow \pi N$
$900\pm150$	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$
	V(2700) DECAY	MOE	DES	

	Mode		
Γ ₁	$N\pi$		

## N(2700) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$					$\Gamma_1/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT	
$0.04 \pm 0.01$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$	
$0.07 \pm 0.02$	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$	

## N(2700) REFERENCES

			•	•	
HOEHLER	79	PDAT 12-1		+Kaiser, Koch, Pietarinen	(KARLT) IJ
Also	80	Toronto Conf.	3	Koch	(KARLT) IJ
HENDRY	78	PRL 41 222			(IND, LBL) IJ
Also	81	ANP 136 1		Hendry	` (IND)

## Baryon Particle Listings N(2700), $N(\sim 3000)$

# $N(\sim 3000 \text{ Region})$ Partial-Wave Analyses

OMITTED FROM SUMMARY TABLE
We list here miscellaneous high-mass candidates for isospin-1/2 resonances found in partial-wave analyses.

> Our 1982 edition had an N(3245), an N(3690), and an N(3755), has been heard from them since the 1960's, we declare them to be dead. There was also an N(3030), deduced from total cross-section and 180° elastic cross-section measurements; it is the KOCH 80  $L_{1,15}$  state below. each a narrow peak seen in a production experiment. Since nothing

N(~ 3000) MASS					
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
≈ 3000 OUR ESTIMATE					
2600	KOCH	80	IPWA	$\pi N \rightarrow \pi N D_{13}$	
3100	косн	80	IPWA	$\pi N \rightarrow \pi N L_{1.15}$ wave	
3500	косн	80	IPWA	$\pi N \rightarrow \pi N M_{1,17}$ wave	
3500 to 4000	косн	80	IPWA	$\pi N \rightarrow \pi N N_{1.19}$ wave	
$3500 \pm 200$	HENDRY	78	MPWA	$\pi N \rightarrow \pi N L_{1.15}$ wave	
$3800 \pm 200$	HENDRY	78	MPWA	$\pi N \rightarrow \pi N M_{1.17}$ wave	
$\textbf{4100} \pm \textbf{200}$	HENDRY	78	MPWA	$\pi{\sf N}   ightarrow  \pi{\sf N} {\sf N}_{1,19}$ wave	

			N(∼ 3000) W	DTF	1	
VALUE (Me	V)		DOCUMENT ID		TECN	COMMENT
$1300 \pm 20$	0		HENDRY	78	MPWA	$\pi N \rightarrow \pi N L_{1.15}$ wave
$1600 \pm 20$	0		HENDRY			$\pi N \rightarrow \pi N M_{1,17}$ wave
1900 ± 30	0		HENDRY	78		$\pi N \rightarrow \pi N N_{1,19}$ wave
-		N(~	3000) DECAY	′ MC	DES	
М	ode					
$\Gamma_1$ N	π					
		N(~ 30	00) BRANCH	NG I	RATIOS	<b>3</b>
$\Gamma(N\pi)/$	Γ _{total}					Γ ₁ /Γ
VALUE			DOCUMENT ID		TECN	COMMENT
$0.055 \pm 0.0$	02		HENDRY	78	MPWA	$\pi extsf{N}  ightarrow ~\pi extsf{N} ~L_{1.15}$ wave
$0.040 \pm 0.0$	015		HENDRY	78	MPWA	$\pi  N   ightarrow  \pi  N   M_{1.17}   { m wave}$
0.030±0.	015		HENDRY	78	MPWA	$\pi N \rightarrow \pi N N_{1,19}$ wave
		N(	~ 3000) REFE	REN	CES	
KOCH HENDRY Also	80 78 81	Toronto Conf. 3 PRL 41 222 ANP 136 1	Hendry			(KARLT) IJP (IND, LBL) IJP (IND) IJP

## $\Delta(1232)$

# $\triangle$ BARYONS (S = 0, I = 3/2)

 $\Delta^{++}=uuu$ ,  $\Delta^{+}=uud$ ,  $\Delta^{0}=udd$ ,  $\Delta^{-}=ddd$ 

## $\Delta(1232) P_{33}$

 $I(J^P) = \frac{3}{2}(\frac{3}{2}^+)$  Status: ***

Most of the results published before 1977 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters **111B** (1982).

## △(1232) MASSES

MIXED CHARGES  VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1230 to 1234 (≈ 1232) OUR EST	IMATE			
1231±1	MANLEY	92	<b>IPWA</b>	$\pi N \rightarrow \pi N \& N \pi \pi$
1232±3	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1233±2	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$

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$\Delta$ (1232) ⁺⁺ MASS	Δ	(1232)	++	MASS
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VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
1230.9±0.3	косн	80B IPWA	$\pi N \rightarrow \pi N$
$1231.1 \pm 0.2$	PEDRONI	78	$\pi N \rightarrow \pi N 70-370$
			Man /

## △(1232)+ MASS

VALUE (MeV)	DOCUMENT ID		TECN_	COMMENT
1234.9±1.4	MIROSHNIC	. 79		Fit photoproduction
• • We do not use the follow	ing data for average	s, fits	s, limits,	etc. • • •
1231.6	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
1231.2	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
1231.8	BERENDS	75	IPWA	$\gamma \rho \rightarrow \pi N$

## △(1232)⁰ MASS

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
1233.6±0.5	косн	80B IPWA	$\pi N \rightarrow \pi N$
$1233.8 \pm 0.2$	PEDRONI	78	$\pi N \rightarrow \pi N 70-370$ MeV

## $m_{\Delta^0} - m_{\Delta^{++}}$

VALUE (MeV)	DOCUMENT ID	COMMENT
• • We do not use the followin	g data for averages, fit	s, limits, etc. • • •
$2.7 \pm 0.3$	¹ PEDRONI 78	See the masses

## **∆(1232) WIDTHS**

## **MIXED CHARGES**

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
115 to 125 (≈ 120) OUR ESTIMA	TE			
118±4	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
120±5	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
116±5	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the following	g data for average	s, fit	s, limits,	etc. • • •
114	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$

## △(1232)⁺⁺ WIDTH

DOCUMENT ID	TECN	COMMENT
косн	80B IPWA	$\pi N \rightarrow \pi N$
PEDRONI	78	$\pi N \rightarrow \pi N 70-370$
	косн	KOCH 80B IPWA

## △(1232)+ WIDTH

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
$131.1 \pm 2.4$	MIROSHNIC	79	Fit photoproduction
• • We do not use the following	g data for averages	, fits, limits,	etc. • • • .
111.2	CRAWFORD	80 DPWA	$\gamma N \rightarrow \pi N$
111.0	BARBOUR	78 DPWA	$\gamma N \rightarrow \pi N$

## △(1232)⁰ WIDTH

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
113.0±1.5	косн	80B IPWA	$\pi N \rightarrow \pi N$
117.9±0.9	PEDRONI	78	$\pi N \rightarrow \pi N 70-370$
			Me\/

## △0-△++ WIDTH DIFFERENCE

VALUE (MeV)	DOCUMENT ID		COMMENT	
• • We do not use the follow	ving data for average	es, fits	s, limits, etc. • • •	
$6.6 \pm 1.0$	PEDRONI	78	See the widths	

## △(1232) POLE POSITIONS

## **REAL PART, MIXED CHARGES**

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1211	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1209	² HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
1210±1	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the following	g data for average	s, fits	s, limits,	etc. • • •

1210 ARNDT 91 DPWA  $\pi N \rightarrow \pi N$  Soln SM90

## -IMAGINARY PART, MIXED CHARGES

VALUE (MeV)	DOCUMENT ID		TECN	COMMEN	Γ	
50	ARNDT	95	DPWA	$\pi N \rightarrow i$	Vπ	ı
50	² HOEHLER	93	ARGD	$\pi N \rightarrow \tau$	τN	
50±1	CUTKOSKY	80	IPWA	$\pi N \rightarrow \tau$	τ <b>/</b>	
• • We do not use the following	ng data for average	s, fits	, limits,	etc. • •	•	
F0	ADNIDT	01	D DIA/A		N/ C+1- C1400	

#### REAL PART, △(1232)++

VALUE (MeV)	DOCUMENT ID	<u> </u>	COMMENT	
1209.6±0.5	³ VASAN	76B	Fit to CARTER 73	
• • • We do not use the follow	ing data for averag	ges, fits	, limits, etc. • • •	
	1			

## -IMAGINARY PART, △(1232)++

VALUE (MeV)	DOCUMENT ID		COMMENT	
$50.4 \pm 0.5$	3 VASAN	76B	Fit to CARTER 73	
• • • We do not use the	following data for averag	es, fits	, limits, etc. • • •	
49.9 to 50.0	⁴ VASAN	76B	Fit to CARTER 73	

## REAL PART, △(1232)+

11212 11111 1 <del>21</del> (2202)		
VALUE (MeV)	DOCUMENT ID	COMMENT
1206.9±0.9 to 1210.5 ± 1.8	MIROSHNIC 79	Fit photoproduction
1208 0 + 2 0	CAMPBELL 76	Fit photoproduction

## -IMAGINARY PART, △(1232)+

VALUE (MeV)	DOCUMENT ID	COMMENT
55.6 $\pm$ 1.0 to 58.3 $\pm$ 1.1	MIROSHNIC 79	Fit photoproduction
53.0 ± 2.0	CAMPBELL 76	Fit photoproduction

## REAL PART, △(1232)0

,,,			
VALUE (MeV)	DOCUMENT ID		COMMENT
$1210.75 \pm 0.6$	³ VASAN	76B	Fit to CARTER 73
ullet $ullet$ We do not use the following	data for averages	, fits	, limits, etc. • • •
1210.2	4 VASAN	76B	Fit to CARTER 73

## -IMAGINARY PART, △(1232)0

VALUE (MeV)	DOCUMENT ID	DOCUMENT ID		COMMENT		
$52.8 \pm 0.6$	³ VASAN	76B	Fit to CARTER 73			
• • We do not use	the following data for average	s, fits	s, limits, etc. • • •			
52.9 to 53.1	⁴ VASAN	<b>76</b> B	Fit to CARTER 73			

## △(1232) ELASTIC POLE RESIDUES

## ABSOLUTE VALUE, MIXED CHARGES

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
38	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
50	HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
53±2	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the foll	owing data for average	s, fit	s, limits,	etc. • • •
52	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soin SM90}$

## PHASE, MIXED CHARGES

VALUE (°)	DOCUMENT ID		TECN	COMMENT
- 22	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
<b>-48</b>	HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
$-47 \pm 1$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the foll	owing data for average	es, fit	s, limits,	etc. • • •
-31	ARNDT	91	DPWA	$\piN \to \piN{\rm Soln}{\rm SM}90$

## ABSOLUTE VALUE, △(1232)++

VALUE (MeV)	DOCUMENT ID	COMMENT
ullet $ullet$ We do not use the following	data for averages,	fits, limits, etc. • • •
52.4 to 53.2	3 VASAN	76B Fit to CARTER 73
52.1 to 52.4	⁴ VASAN	768 Fit to CARTER 73

PHASE, △(1232)++				
VALUE (rad)	DOCUMENT ID		сомм	ENT
• • We do not use the following		es, fits	s, limits	, etc. • • •
-0.822 to $-0.833$	3 VASAN			CARTER 73
-0.823 to -0.830	⁴ VASAN	76B	Fit to	CARTER 73
ABSOLUTE VALUE, △(123	32) ⁰			
VALUE (MeV)	DOCUMENT ID		СОММЕ	ENT
• • We do not use the following		es, fits	s, limits	, etc. • • •
54.8 to 55.0	3 VASAN			CARTER 73
55.2 to 55.3	⁴ VASAN	76B	Fit to	CARTER 73
PHASE, △(1232) ⁰				
VALUE (rad)	DOCUMENT ID			
• • We do not use the following				
-0.840 to -0.847	³ VASAN ⁴ VASAN			CARTER 73 CARTER 73
-0.848 to -0.856	VASAN	708	FIL LO	CARTER 73
<b>Δ</b>	(1232) DECAY	MOD	ES	
The following branching	fractions are our	estima	ites, not	t fits or averages.
The following branching	Tractions and our	05111110	,	a nes si avolugosi
Mode		Fract	ion $(\Gamma_i)$	/Γ <b>)</b>
Γ ₁ Νπ		>99	%	
$\Gamma_2 = N \gamma$			-0.61 %	
$N_{\gamma}$ , helicity=1/2		0.12-	0.14 %	
$\Gamma_4$ $N\gamma$ , helicity=3/2		0.41-	0.47 %	
4/10	an) DDANGUIA		ATIOC	
•	32) BRANCHIN	WG K/	41105	
$\Gamma(N\pi)/\Gamma_{\text{total}}$				Γ ₁ /Γ
VALUE 0.993 to 0.995 OUR ESTIMATE	DOCUMENT ID		TECN	COMMENT
1.0	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
1.0	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1.0 • • • We do not use the following	HOEHLER	79 oc fits	IPWA	$\pi N \rightarrow \pi N$
0	ARNDT	95		$\pi N \rightarrow N \pi$
	7,11,101		D1 117	
△(1232) P	HOTON DECA	Y AN	IPLIT	JDES
$\Delta$ (1232) $\rightarrow N\gamma$ , helicity-1,	/2 amplitude A	1/2		
VALUE (GeV ^{-1/2} )	DOCUMENT ID	•	TECN	COMMENT
-0.140±0.005 OUR ESTIMATE				
$-0.141 \pm 0.005$	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
$-0.135 \pm 0.016$ $-0.145 \pm 0.015$	DAVIDSON CRAWFORD		FIT IPWA	$\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$
-0.138±0.004	ILAWA	81		$\gamma N \rightarrow \pi N$
$-0.147 \pm 0.001$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
-0.145±0.001	ARAI	80		$\gamma N \rightarrow \pi N \text{ (fit 2)}$
- 0.136 ± 0.006 • • • We do not use the followir	CRAWFORD og data for average	80 es. fits		$\gamma N \rightarrow \pi N$ etc. • • •
-0.143±0.004	LI	93	IPWA	$\gamma N \rightarrow \pi N$
$-0.140 \pm 0.007$	DAVIDSON	90	FIT	See DAVIDSON 91B
-0.142 ± 0.007	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
- 0.140 - 0.141 ± 0.004	⁵ NOELLE FELLER	78 76	D D/V/A	$\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$
			JI WA	Tim - Kin
$\Delta(1232) \rightarrow N\gamma$ , helicity-3/		•		
/ALUE (GeV ^{-1/2} ) -0.258±0.006.0HP.ESTIMATE	DOCUMENT ID		TECN	COMMENT
-0.258±0.006 OUR ESTIMATE -0.261±0.005	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
$-0.251 \pm 0.003$	DAVIDSON		FIT	$\gamma N \rightarrow \pi N$
$-0.263 \pm 0.026$	CRAWFORD		IPWA	$\gamma N \rightarrow \pi N$
-0.259±0.006	AWAJI	81		$\gamma N \rightarrow \pi N$
- 0.264 ± 0.002 - 0.261 ± 0.002	ARAI ARAI	80 80		$\gamma N \rightarrow \pi N \text{ (fit 1)}$ $\gamma N \rightarrow \pi N \text{ (fit 2)}$
$-0.247 \pm 0.002$	CRAWFORD	80		$\gamma N \rightarrow \pi N \text{ (iii 2)}$ $\gamma N \rightarrow \pi N$
• We do not use the following		es, fits	, limits,	
	LI		IPWA	$\gamma N \rightarrow \pi N$
		90	FIT	See DAVIDSON 91B
$-0.254 \pm 0.011$	DAVIDSON	78	DPMA	
$-0.254 \pm 0.011$ $-0.271 \pm 0.010$	BARBOUR 5 NOELLE	78 78	DPWA	$\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$
- 0.254 ± 0.011 - 0.271 ± 0.010 - 0.247	BARBOUR			
$-0.254 \pm 0.011 -0.271 \pm 0.010 -0.247 -0.256 \pm 0.003$	BARBOUR 5 NOELLE FELLER	78		$\gamma N \rightarrow \pi N$
$-0.254 \pm 0.011$ $-0.271 \pm 0.010$ -0.247 $-0.256 \pm 0.003$ $\Delta(1232) \rightarrow N\gamma, E_2/M_1$ rathable	BARBOUR  5 NOELLE FELLER  tio	78 76	DPWA	$ \begin{array}{ccc} \gamma  N \to & \pi  N \\ \gamma  N \to & \pi  N \end{array} $
$^{-0.254\pm0.0011}_{-0.271\pm0.010}$ $^{-0.271\pm0.010}_{-0.256\pm0.003}$ $^{-0.256\pm0.003}_{-0.256\pm0.003}$ $^{-0.256\pm0.003}_{-0.004}$ N $_{\gamma}$ , $^{-0.004}_{-0.015\pm0.004}$ OUR AVERAG	BARBOUR  5 NOELLE FELLER  tio  DOCUMENT ID	78 76	DPWA	$\gamma N \to \pi N$ $\gamma N \to \pi N$ $COMMENT$
$^{-0.254\pm0.0011}_{-0.271\pm0.010}$ $^{-0.271\pm0.010}_{-0.247}$ $^{-0.256\pm0.003}$ $^{-0.266\pm0.003}_{-0.015\pm0.004}$ $^{-0.015\pm0.004}_{-0.015\pm0.005}$ OUR AVERAG	BARBOUR  5 NOELLE FELLER  tio	78 76	DPWA <u>TECN</u> IPWA	$\gamma N \to \pi N$ $\gamma N \to \pi N$ $\gamma N \to \pi N$
$\begin{array}{l} -0.254 \pm 0.011 \\ -0.271 \pm 0.010 \\ -0.247 \\ -0.256 \pm 0.003 \\ \Delta \text{(1232)} \rightarrow N\gamma, E_2/M_1 \text{ rat} \\ \frac{MLUE}{0.015} \pm 0.004 \text{ OUR AVERAG} \\ -0.015 \pm 0.005 \\ -0.0157 \pm 0.0072 \\ \end{array}$	BARBOUR  NOELLE FELLER  LIO  DOCUMENT ID  WORKMAN DAVIDSON	78 76 92 918	DPWA <u>TECN</u> IPWA FIT	$\begin{array}{ll} \gamma  N  \to  \pi  N \\ \gamma  N  \to  \pi  N \\ \\ \hline \\ COMMENT \\ \\ \gamma  N  \to  \pi  N \\ \gamma  N  \to  \pi  N \end{array}$
$-0.254 \pm 0.011$ $-0.271 \pm 0.010$ -0.247 $-0.256 \pm 0.003$ $\Delta(1232) \rightarrow N\gamma, E_2/M_1$ rate $\Delta UE$ $-0.015 \pm 0.004$ OUR AVERAG $-0.015 \pm 0.005$ $-0.0157 \pm 0.0072$ •• • We do not use the following $-0.0107 \pm 0.0037$	BARBOUR NOELLE FELLER  tio  E  WORKMAN DAVIDSON  g data for average DAVIDSON	78 76 92 91B es, fits 90	DPWA  TECN  IPWA FIT , limits, FIT	$\begin{array}{lll} \gamma  N & \rightarrow & \pi  N \\ \gamma  N & \rightarrow & \pi  N \end{array}$ $\begin{array}{lll} \hline COMMENT & & & \\ \gamma  N & \rightarrow & \pi  N \\ \gamma  N & \rightarrow & \pi  N \\ etc. & \bullet & \bullet & \\ \gamma  N & \rightarrow & \pi  N \end{array}$
$-0.262\pm0.004$ $-0.254\pm0.011$ $-0.271\pm0.010$ -0.247 $-0.256\pm0.003$ $\Delta(1232) \rightarrow N\gamma, E_2/M_1$ rai $\mu$ LUE $-0.015\pm0.004$ OUR AVERAG $-0.015\pm0.005$ $-0.0157\pm0.007$ $-0.0157\pm0.0037$ $-0.0107\pm0.0037$ $-0.0157\pm0.002$ $+0.037\pm0.002$	BARBOUR 5 NOELLE FELLER  tio  DOCUMENT ID  WORKMAN DAVIDSON Ig data for average	78 76 92 91B es, fits 90 86	DPWA  TECN  IPWA FIT , limits,	$\begin{array}{ll} \gamma  N  \to  \pi  N \\ \gamma  N  \to  \pi  N \\ \\ \hline \\ COMMENT \\ \\ \gamma  N  \to  \pi  N \\ \gamma  N  \to  \pi  N \\ \text{etc.}  \bullet  \bullet  \bullet \end{array}$

#### $\Delta$ (1232) PHASE OF M1+(3/2) PHOTOPRODUCTION MULTIPOLE AMPLITUDE POLE RESIDUE

Information on the phase (and magnitude) of the M1+(3/2) multipole amplitude pole residue is contained implicitly in the paper of MIROSH-NICHENKO 79. They find that the phase is consistent with being equal to that of the elastic pole residue.

## △(1232)⁺⁺ MAGNETIC MOMENT

The values are extracted from UCLA and SIN data on  $\pi^+\,p$  bremsstrahlung using a variety of different theoretical approximations and methods. Our estimate is only a rough guess of the range we expect the moment to lie

3.7 to 7.5 OUR EST	TIMATE	
• • We do not use	the following dat	a for averages, fits, limits, etc. • •
1.52 ± 0.50 ± 0.45	BOSSHARD	91 $\pi^+ \rho \rightarrow \pi^+ \rho \gamma$ (SIN data)
3.7 to 4.2	LIN	918 $\pi^+ p \rightarrow \pi^+ p \gamma$ (from UCLA data)
1.6 to 4.9	LIN	91B $\pi^+ p \rightarrow \pi^+ p \gamma$ (from SIN data)
5.6 to 7.5	WITTMAN	88 $\pi^+ p \rightarrow \pi^+ p \gamma$ (from UCLA data)
5.9 to 9.8	HELLER	87 $\pi^+ p \rightarrow \pi^+ p \gamma$ (from UCLA data)
1.7 to 6.7	NEFKENS	78 $\pi^+ p \rightarrow \pi^+ p \gamma$ (UCLA data)

## △(1232) FOOTNOTES

- 1 Using  $\pi^\pm d$  as well, PEDRONI 78 determine  $(M^- M^{++}) + (M^0 M^+)/3 = 4.6 \pm 0.2$  MeV. 2 See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and  $\Delta$  resonances as determined from Argand diagrams of  $\pi$  N elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.
- ³ This VASAN 76B value is from fits to the coulomb-barrier-corrected CARTER 73 phase
- shift. 4 This VASAN 768 value is from fits to the CARTER 73 nuclear phase shift without coulomb barrier corrections. 5 Converted to our conventions using M=1232 MeV,  $\Gamma=110$  MeV from NOELLE 78.

## △(1232) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

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ARNDT	96	PR C53 430	+Strakovsky, Workman	(VPI)	
ARNDT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BRCO)	
HOEHLER	93	π N Newsletter 9 1		(KARL)	
LI	93	PR C47 2759	+Arndt, Roper, Workman	` (VPI)	
MANLEY	92	PR D45 4002	+Saleski	(KÈNT) IJP	
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)	
WORKMAN	92	PR C46 1546	+Arndt, Li	(VPI)	
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP	
BOSSHARD	91	PR D44 1962		L, LAUS, UCLA, CATH)	
Also	90	PRL 64 2619		BL, VILL, UCLA, ZURI)	
DAVIDSON	91B	PR D43 71	+Mukhopadhyay, Wittman	(RPI)	
LIN	91B	PR C44 1819	+Liou, Ding	(CUNY, CSOK)	
Also	91	PR C43 R930	Lin, Liou	(CUNY)	
DAVIDSON	90	PR D42 20	+Mukhopadhyay	(RPI)	
WITTMAN	88	PR C37 2075	,,	(TRIU)	
HELLER	87	PR C35 718	+Kumano, Martinez, Moniz	(LANL, MIT, ILL)	
DAVIDSON	86	PRL 56 804	+Mukhopadhyay, Wittman	(RPI)	
TANABE	85	PR C31 1876	+Ohta	(KOMAB)	
CRAWFORD	83	NP B211 1	+Morton	(GLAS)	
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)	
AWAJI	81	Bonn Conf. 352	+Kajikawa	(NAGO)	
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)	
ARAI	80	Toronto Conf. 93	* * * * * * *	`(INUS)	
Also	82	NP B194 251	Arai, Fujii	(INUS)	
CRAWFORD	80	Toronto Conf. 107		(GLAS)	
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMŮ, LBL) IJP	
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL)	
KOCH	80B	NP A336 331	+Pietarinen	(KARLT) IJP	
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP	
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP	
MIROSHNIC	79	SJNP 29 94	Miroshnichenko, Nikiforov, Sanin+	(KFTI) IJP	
		Translated from YAF 29	188.	` ,	
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)	
NEFKENS	78	PR D18 3911	+Arman, Ballagh, Glodis, Haddock+	(UCLA, CATH) IJP	
NOELLE	78	PTP 60 778		(NAGO)	
PEDRONI	78	NP A300 321	+Gabathuler, Domingo, Hirt+	(SIN, ISNG, KARLE+) IJP	
CAMPBELL	76	PR D14 2431	+Shaw, Ball	(BOIS, UCI, UTAH) IJP	
FELLER	76	NP B104 219	+Fukushima, Horikawa, Kajikawa+	(NAGO, OSAK) IJP	
VASAN	76B	NP B106 535		(CMU) IJP	
Also	76	NP B106 526	Vasan	(CMU) IJP	
BERENDS	75	NP B84 342	+Donnachie	(LEID, MCHS)	
CARTER	73	NP B58 378	+Bugg, Carter	(ČAVE, LOQM) IJP	
				·	

## **Baryon Particle Listings** $\Delta(1600)$

## $\Delta(1600) P_{33}$

 $I(J^P) = \frac{3}{2}(\frac{3}{2}^+)$  Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

The various analyses are not in good agreement.

## △(1600) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1550 to 1700 (≈ 1600) OUR ESTI	MATE			
1706±10	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
$1600 \pm 50$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
$1522 \pm 13$	HOEHLER	79	<b>IPWA</b>	$\pi N \rightarrow \pi N$
• • • We do not use the following	data for average	s, fits	, limits,	etc. • • •
1672±15	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
1706	LI	93	IPWA	$\gamma N \rightarrow \pi N$
1690	BARNHAM	80	IPWA	$\pi N \rightarrow N \pi \pi$
1560	¹ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
1640	² LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

## △(1600) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
250 to 450 (≈ 350) OUR ES	TIMATE			
430± 73	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
$300 \pm 100$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
220± 40	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the following the following the following that the following the following that the following the followi	llowing data for average	s, fit	s, limits,	etc. • • •
315± 20	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
215	LI	93	IPWA	$\gamma N \rightarrow \pi N$
250	BARNHAM	80	<b>IPWA</b>	$\pi N \rightarrow N \pi \pi$
180	¹ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
300	² LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

## △(1600) POLE POSITION

REAL	PART
VALUE	(MeV)

VALUE (MeV)	DOCUMENT ID		TECN	COMMEN	IT
1675	ARNDT			$\pi N \rightarrow$	
1550	³ HOEHLER	93	SPED	$\pi N \rightarrow$	πN
1550 ± 40	CUTKOSKY	80	IPWA	$\pi N \rightarrow$	πN
• • We do not use the following	g data for average	s, fit	s, limits,	etc. • •	•
1612	ARNDT				πN Soln SM90
1609 or 1610	⁴ LONGACRE				
1541 or 1542	¹ LONGACRE	77	IPWA	$\pi N \rightarrow$	Νππ
-2×IMAGINARY PART					
VALUE (MaV)	DOCUMENT ID		TECN	COMMEN	IT.

VALUE (MeV)	DOCUMENT ID		TECN	сомме	NT.
386	ARNDT				
200±60	CUTKOSKY	-			
• • We do not use the following					
230					$\pi N$ Soln SM90
323 or 325	4 LONGACRE				
178 or 178	¹ LONGACRE	77	IPWA	$\pi N \rightarrow$	Νππ

## △(1600) ELASTIC POLE RESIDUE

DOCUMENT ID TECN COMMENT

#### MODULUS |r| VALUE (MeV)

52	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
17±4	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	data for average	s, fit	s, limits,	etc. • • •
16	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$
PHASE $\theta$				
VALUE (°)	DOCUMENT ID		TECN	COMMENT
	DOCUMENT ID			$\frac{COMMENT}{\pi N \rightarrow N \pi}$
VALUE (°)		95	DPWA	$\pi N \rightarrow N \pi$
VALUE (°) + 14	ARNDT CUTKOSKY	95 80	DPWA IPWA	$ \begin{array}{ccc} \pi  N \to & N  \pi \\ \pi  N \to & \pi  N \end{array} $

## △(1600) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction $(\Gamma_i/\Gamma)$	
$\overline{\Gamma_1}$	Νπ	10-25 %	
$\Gamma_2$	ΣΚ		
$\Gamma_3$	$N\pi\pi$	75-90 %	
$\Gamma_4$	$\Delta\pi$	40-70 %	
$\Gamma_5$	$\Delta(1232)\pi$ , $ extit{P}$ -wave		
$\Gamma_6$	$\Delta(1232)\pi$ , $\emph{F}$ -wave		
$\Gamma_7$	$N\rho$	<25 %	
Γ8	$N\rho$ , $S=1/2$ , $P$ -wave		
Г9	$N\rho$ , $S=3/2$ , $P$ -wave		
$\Gamma_{10}$	$N\rho$ , $S=3/2$ , $F$ -wave		
$\Gamma_{11}$	$N(1440)\pi$	10-35 %	
$\Gamma_{12}$	$\mathcal{N}(1440)\pi$ , $\mathit{P} ext{-}$ wave		
$\Gamma_{13}$	$N\gamma$	0.001-0.02 %	
$\Gamma_{14}$	$N\gamma$ , helicity=1/2	0.0-0.02 %	
Γ ₁₅	$N\gamma$ , helicity=3/2	0.001-0.005 %	

## △(1600) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$				Γ ₁ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
0.10 to 0.25 OUR ESTIMA	TE			
$0.12 \pm 0.02$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
$0.18 \pm 0.04$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
$0.21 \pm 0.06$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}}$ in $N\pi$ –	→ Δ(1600) → ΣK			(Γ ₁ Γ ₂ ) ¹ /⁄2/Γ
VALUE	DOCUMENT ID		TECN	COMMENT
-0.36 to -0.28 OUR ES	TIMATE			
• • • We do not use the f	ollowing data for average	s. fit	s. limits.	etc. • • •

Note: Signs of couplings from  $\pi\,N \to N\,\pi\,\pi$  analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the  $\Delta(1620)~S_{31}$  coupling to  $\Delta(1232)\,\pi$ .

75 DPWA  $\pi N \rightarrow \Sigma K$ 

⁵ DEANS

0.006 to 0.042

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \to \Delta($	1600) → △(123	2)π	, <i>P</i> -wav	re .	(Г ₁ Г ₅ )	½ _{/Γ}
VALUE	DOCUMENT ID			COMME	VT	
+0.27 to +0.33 OUR ESTIMAT	Έ					
$+0.29\pm0.02$	MANLEY	92	IPWA	$\pi N \rightarrow$	πΝ & Νππ	
$+0.24\pm0.05$	BARNHAM	80	IPWA	$\pi N \rightarrow$	Νππ	
+0.34	^{1,6} LONGACRE	77	IPWA	$\pi N \rightarrow$	Νππ	
+0.30	² LONGACRE	75	IPWA	$\pi N \rightarrow$	$N\pi\pi$	

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \to \Delta$	(1600) → ∆(1232	2)π	, <i>F</i> -wav	e (Γ ₁ Γ ₆ ) ^½ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
-0.15 to -0.03 OUR ESTIMAT				
-0.07	^{1,6} LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow 1$	$\Delta(1600) \rightarrow N\rho$ , $S=1$	$Ve = (\Gamma_1 \Gamma_8)^{\frac{1}{12}} / \Gamma_1$	
VALUE	DOCUMENT ID	TECN	COMMENT
+0.10	1,6 LONGACRE 7	7 IPWA	$\pi N \rightarrow N \pi \pi$

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N_{\pi} -$	ve (	Γ ₁ Γ ₉ ) ^{1/2} /Γ		
VALUE	DOCUMENT ID	TECN	COMMENT	
+0.10	1,6 LONGACRE	77 IPWA	$\pi N \rightarrow N \pi \pi$	г

$(\Gamma_I \Gamma_f)^{72} / \Gamma_{\text{total}} \text{ in } N\pi \to \Delta(160)$	$N(1440) \rightarrow N(1440)$	$)\pi$	P-wav	e	$(\Gamma_1\Gamma_{12})^{72}/$	ľ
VALUE	DOCUMENT ID		TECN	COMMENT	Τ	
+0.15 to +0.23 OUR ESTIMATE						
$+0.16\pm0.02$	MANLEY	92	IPWA	$\pi N \rightarrow \tau$	τΝ & Νππ	
$+0.23\pm0.04$	BARNHAM	80	IPWA	$\pi N \rightarrow I$	Vππ	

## △(1600) PHOTON DECAY AMPLITUDES

## $\Delta(1600) \rightarrow N\gamma$ , helicity-1/2 amplitude $A_{1/2}$

VALUE (GeV ^{-1/2} )	DOCUMENT ID		TECN	COMMENT
-0.023±0.020 OUR ESTIMATE				
$-0.018 \pm 0.015$	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
$-0.039\pm0.030$	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
$-0.046 \pm 0.013$	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
$0.005 \pm 0.020$	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
• • We do not use the following	g data for average	es, fit	s, limits,	etc. • • •
$-0.026 \pm 0.002$	LI	93	IPWA	$\gamma N \rightarrow \pi N$
-0.200	⁷ WADA	84	DPWA	Compton scattering
$0.000 \pm 0.030$	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
0.0 +0.020	FELLER	76	DPWA	$\gamma N \rightarrow \pi N$

## $\Delta(1600) \rightarrow N\gamma$ , helicity-3/2 amplitude A_{3/2}

VALUE (GeV ^{-1/2} )	DOCUMENT ID		TECN	COMMENT
-0.009±0.021 OUR ESTIMATE				
$-0.025 \pm 0.015$	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
$-0.013\pm0.014$	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
$0.025 \pm 0.031$	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
$-0.009 \pm 0.020$	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
• • We do not use the following	data for average	s, fit	s, limits,	etc. • • •
$-0.016\pm0.002$	LI	93	IPWA	$\gamma N \rightarrow \pi N$
0.023	WADA	84	DPWA	Compton scattering
$0.000 \pm 0.045$	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
$0.0 \pm 0.015$	FELLER	76	DPWA	$\gamma N \rightarrow \pi N$

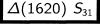
## △(1600) FOOTNOTES

- ¹ LONGACRE 77 pole positions are from a search for poles in the unitarized T-matrix; the first (second) value uses, in addition to  $\pi N \to N \pi \pi$  data, elastic amplitudes from a Saclay (CERN) partial-wave analysis. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.
- ² From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix
- See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and  $\Delta$  resonances as determined from Argand diagrams of  $\pi N$  elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams. 4 LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first
- (second) value uses, in addition to  $\pi\,N\to\,$   $\dot{N}\,\pi\,\pi$  data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.
- The range given is from the four best solutions. DEANS 75 disagrees with  $\pi^+ \rho \rightarrow$  $\Sigma^+ K^+$  data of WINNIK 77 around 1920 MeV.
- 6 LONGACRE 77 considers this coupling to be well determined.
- 7  WADA 84 is inconsistent with other analyses see the Note on N and  $\Delta$  Resonances.

## △(1600) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

ARNDT	96	PR C53 430	+Strakovsky, Workman	(VPI)
ARNDT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BRCO)
HOEHLER	93	π N Newsletter 9 1	**	` (KARL)
LI	93	PR C47 2759	+Arndt, Roper, Workman	` (VPI)
MANLEY	92	PR D45 4002	+Saleski	(KÈNT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	` (VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
WADA	84	NP B247 313	+Egawa, Imanishi, Ishii, Kato, Ukai+	` (INUS)
CRAWFORD	83	NP B211 1	+Morton	(GLAS)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
AWA JI	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
BARNHAM	80	NP B168 243	+Glickman, Mier-Jedrzejowicz+	(LOIC)
CRAWFORD	80	Toronto Conf. 107		(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMŮ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)
LONGACRE	77	NP B122 493	+ Dolbeau	(SACL) IJP
Also	76	NP B108 365	Dolbeau, Triantis, Neveu, Cadiet	(SACL) IJP
WINNIK	77	NP B128 66	+Toaff, Revel, Goldberg, Berny	(HAIF) I
FELLER	76	NP B104 219	+Fukushima, Horikawa, Kajikawa+	(NAGO, OSAK) IJP
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ALAH) IJP
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC) IJP



$$I(J^P) = \frac{3}{2}(\frac{1}{2})$$
 Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

## △(1620) MASS

VALUE (May)	DOCUMENT ID		TECN	COMMENT
VALUE (MeV)			TECN	COMMENT
1615 to 1675 (≈ 1620) OUR E	SIIMAIE			
1672 ± 7	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
1620 ±20	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1610 ± 7	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
ullet $ullet$ We do not use the followi	ng data for average	s, fit	s, limits,	etc. • • •
1672 ± 5	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
1617	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1669	LI	93	IPWA	$\gamma N \rightarrow \pi N$
1620	BARNHAM	80	IPWA	$\pi N \rightarrow N \pi \pi$
1712.8± 6.0	¹ CHEW	80	BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho$
1786.7± 2.0	¹ CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
1657	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
1662	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
1580	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
1600	³ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

## △(1620) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
120 to 180 (≈ 150) OUR ES	TIMATE			
154 ±37	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
140 ±20	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
139 ±18	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the follow	ving data for average	s, fits	s, limits,	etc. • • •
147 ± 8	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
108	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
184	LI	93	IPWA	$\gamma N \rightarrow \pi N$
120	BARNHAM	80	IPWA	$\pi N \rightarrow N \pi \pi$
$228.3 \pm 18.0$	¹ CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$ (lower mass)
30.0 ± 6.4	¹ CHEW	80	BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho$ (higher mass)
161	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
180	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
120	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
150	³ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

## △(1620) POLE POSITION

REAL PART VALUE (MeV)	DOCUMENT ID		TECN	COMMENT		
1585	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$		
1608	⁴ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$		
$1600 \pm 15$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$		
• • • We do not use the followin	g data for average	s, fit	s, limits,	etc. • • •		
1587	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$		
1583 or 1583	⁵ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$		
1575 or 1572	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$		
-2×IMAGINARY PART						
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT		
104	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$		
116	⁴ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$		
120±20	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$		
• • We do not use the following data for averages, fits, limits, etc. • •						
120	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$		
143 or 149	⁵ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$		
119 or 128	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$		

## △(1620) ELASTIC POLE RESIDUE

DOCUMENT ID

TECN COMMENT

91 DPWA  $\pi N \rightarrow \pi N$  Soln SM90

#### MODULUS |r| VALUE (MeV)

14	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
19	HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
15±2	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	data for average	s, fit	s, limits,	etc. • • •
15	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$
DUIACE A				
PHASE θ				
VALUE (°)	DOCUMENT ID		TECN	COMMENT
	DOCUMENT ID	95		$\frac{COMMENT}{\pi \ N \rightarrow \ N \pi}$
VALUE (°)			DPWA	
VALUE (°) - 121	ARNDT		DPWA SPED	$\pi N \rightarrow N \pi$

## △(1620) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

ARNDT

	Mode	Fraction $(\Gamma_i/\Gamma)$	
Γ ₁	Νπ	20-30 %	
$\Gamma_2$	$N\pi\pi$	70-80 %	
$\Gamma_3$	$\Delta\pi$	30-60 %	
$\Gamma_4$	$\Delta(1232)\pi$ , $D$ -wave		
$\Gamma_5$	$N\rho$	7-25 %	
Γ6	$N\rho$ , $S=1/2$ , $S$ -wave		
Γ ₇	$N\rho$ , $S=3/2$ , $D$ -wave		
Γ8	$N(1440)\pi$		
Γ9	$N\gamma$	0.004-0.044 %	
$\Gamma_{10}$	$N\gamma$ , helicity=1/2	0.004-0.044 %	

## **Baryon Particle Listings** $\Delta(1620), \Delta(1700)$

## △(1620) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$				Γ ₁ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
0.2 to 0.3 OUR ESTI	MATE			
$0.09 \pm 0.02$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
$0.25 \pm 0.03$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
$0.35 \pm 0.06$	HOEHLER	79	<b>IPWA</b>	$\pi N \rightarrow \pi N$
• • • We do not use t	he following data for average	es, fit	s, limits,	etc. • • •
0.29	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
0.60	¹ CHEW	80	BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho$ (lower
	_			mass)
0.36	¹ CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$ (higher
				mass)

Note: Signs of couplings from  $\pi\,N \to N\pi\pi$  analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the  $\Delta(1620)~S_{31}$ coupling to  $\Delta(1232)\pi$ .

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \to A$	$\Delta(1620) \rightarrow \Delta(123)$	Ι2)π,	D-wav	⁄е (Г₁Г₄) ^⅓ 2/Г
VALUE	DOCUMENT ID		TECN	
-0.36 to -0.28 OUR ESTIM	ATE			
$-0.24 \pm 0.03$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
$-0.33 \pm 0.06$	BARNHAM	80	IPWA	$\pi N \rightarrow N \pi \pi$
-0.39	^{2,6} LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
-0.40	³ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\pi \to A$	$\Delta(1620) \rightarrow N\rho, S$	=1/2	. <i>S</i> -wa	ve (Γ ₁ Γ ₆ ) ^½ /Γ
VALUE	DOCUMENT ID	•	TECN	COMMENT
VALUE +0.12 to +0.22 OUR ESTIM	ATE			
$+0.15\pm0.02$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
$+0.40\pm0.10$	BARNHAM	80	IPWA	$\pi N \rightarrow N \pi \pi$
+0.08	^{2,6} LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
+0.28	³ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\pi \to A$	$\Delta(1620) \rightarrow N\rho, S$	=3/2	, <i>D</i> -wa	ive (Γ ₁ Γ ₇ ) ^{1/2} /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
-0.15 to -0.03 OUR ESTIM	ATE			
$-0.06\pm0.02$				$\pi N \rightarrow \pi N \& N \pi \pi$
-0.13	^{2,6} LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\pi \rightarrow A$				(Γ ₁ Γ ₈ ) ^{1/2} /Γ
VALUE	DOCUMENT ID		TECN	
0.11±0.05	BARNHAM	80	IPWA	$\pi N \rightarrow N \pi \pi$

## △(1620) PHOTON DECAY AMPLITUDES

## $\Delta(1620) \rightarrow N\gamma$ , helicity-1/2 amplitude A_{1/2}

VALUE (GeV ^{-1/2} )	DOCUMENT ID		TECN	COMMENT
+0.027±0.011 OUR ESTIMATE				
$0.035 \pm 0.020$	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
$0.035 \pm 0.010$	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
$0.010 \pm 0.015$	AWA JI	81	DPWA	$\gamma N \longrightarrow \pi N$
$-0.022 \pm 0.007$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
$-0.026 \pm 0.008$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
$0.021 \pm 0.020$	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
$0.126 \pm 0.021$	TAKEDA	80	DPWA	$\gamma N \rightarrow \pi N$
• • • We do not use the following	data for average	es, fits	, limits,	etc. • • •
$0.042 \pm 0.003$	LI	93	IPWA	$\gamma N \rightarrow \pi N$
0.066	WADA	84	DPWA	Compton scattering
$+0.034 \pm 0.028$	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
$-0.005\pm0.016$	FELLER	76	DPWA	$\gamma N \rightarrow \pi N$

## △(1620) FOOTNOTES

- ¹ CHEW 80 reports two  $S_{31}$  resonances at somewhat higher masses than other analyses. Problems with this analysis are discussed in section 2.1.11 of HOEHLER 83. 
  ² LONGACRE 77 pole positions are from a search for poles in the unitarized T-matrix; the first (second) value uses, in addition to  $\pi N \to N\pi \pi$  data, elastic amplitudes from a Saclay (CERN) partial-wave analysis. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.
- ³ From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix
- From method no LONGACKE 75: eyebali its with breit-wigher circles to the 1-matrix amplitudes. 4 See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and  $\Delta$  resonances as determined from Argand diagrams of  $\pi$  N elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.
- 5 LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to  $\pi N \to N\pi\pi$  data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.
- ⁶ LONGACRE 77 considers this coupling to be well determined.

## △(1620) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

ARNDT	96	PR C53 430	+Strakovsky, Workman	(VPI)
ARNDT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BŘCO)
HOEHLER	93	π N Newsletter 9 1	*	` (KARL)
LI	93	PR C47 2759	+Arndt, Roper, Workman	`(VPI)
MANLEY	92	PR D45 4002	+Saleski	(KĖNT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	` (VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
WADA	84	NP B247 313	+Egawa, Imanishi, Ishii, Kato, Ukai+	(INUS)
CRAWFORD	83	NP B211 1	+Morton	(GLAS)
HOEHLER	83	Landolt-Boernstein 1/	9B2	(KARLT)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
AWA JI	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
ARAI	80	Toronto Conf. 93		(INUS)
Also	82	NP B194 251	Arai, Fujii	(INUS)
BARNHAM	80	NP B168 243	+Glickman, Mier-Jedrzejowicz+	(LOIC)
CHEW	80	Toronto Conf. 123		(LBL) IJP
CRAWFORD	80	Toronto Conf. 107		(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMÚ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
TAKEDA	80	NP B168 17	+Arai, Fujii, Ikeda, Iwasaki+	(TÖKY, INUS)
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)
LONGACRE	77	NP B122 493	+Dolbeau	(SACL) IJP
Also	76	NP B108 365	Dolbeau, Triantis, Neveu, Cadiet	(SACL) IJP
FELLER	76	NP B104 219	+Fukushima, Horikawa, Kajikawa+	(NAGO, OSAK) IJP
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC) IJP

 $\Delta(1700) D_{33}$ 

 $I(J^P) = \frac{3}{2}(\frac{3}{2}^-)$  Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

## △(1700) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1670 to 1770 (≈ 1700) (			TECH	COMMENT
1762 ±44 1710 +30	MANLEY CUTKOSKY			$\pi N \rightarrow \pi N \& N \pi \pi$ $\pi N \rightarrow \pi N$
1680 ±70	HOEHLER			$\pi N \rightarrow \pi N$ $\pi N \rightarrow \pi N$
• • We do not use the records.	following data for average	s, fits	, limits,	etc. • • •
1690 ±15 1680 1655 1650 1718.4 + 13.1	ARNDT ARNDT LI BARNHAM ¹ CHEW	95 93 80	DPWA IPWA IPWA	$ \begin{array}{cccc} \gamma  N \to & \pi  N \\ \pi  N \to & N \pi \\ \gamma  N \to & \pi  N \\ \pi  N \to & N \pi \pi \\ \pi^+  \rho \to & \pi^+  \rho \end{array} $
1622 1629 1600 1680	CRAWFORD BARBOUR ² LONGACRE ³ LONGACRE	80 78 77	DPWA DPWA IPWA	$\begin{array}{cccc} \gamma  N \to & \pi  N \\ \gamma  N \to & \pi  N \\ \gamma  N \to & \pi  N \\ \pi  N \to & N \pi  \pi \\ \pi  N \to & N \pi  \pi \end{array}$

## △(1700) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
200 to 400 (≈ 300) OU	R ESTIMATE			
600 ±250	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
280 ± 80	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
230 ± 80	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
<ul> <li>• • We do not use the</li> </ul>	following data for average	s, fit	s, limits,	etc. • • •
285 ± 20	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
272	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
348	LI	93	IPWA	$\gamma N \rightarrow \pi N$
160	BARNHAM	80	IPWA	$\pi N \rightarrow N \pi \pi$
193.3 ± 26.0	¹ CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
209	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
216	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
200	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
240	³ LONGACRE	75	IPWA	$\pi N \longrightarrow N \pi \pi$

## △(1700) POLE POSITION

RE	Αl	. F	'nΑ	R	Т
VA.I	HE	(NA	'/اه	١.	

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1655	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1651	⁴ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
1675±25	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the following	owing data for average	s, fits	s, limits,	etc. • • •
1646	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$
1681 or 1672	⁵ LONGACRE			
1600 or 1594	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
242	ARNDT			$\pi N \rightarrow N \pi$
159	⁴ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
220 ± 40	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
	the following data for average	es, fit	s, limits,	etc. • • •
208	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$
245 or 241	⁵ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
208 or 201	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$

#### △(1700) ELASTIC POLE RESIDUE

## MODULUS |r|

 $-20 \pm 25$ 

- 22

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
16	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
10	HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
13±3	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the	following data for average	s, fits	s, limits,	etc. • • •
13	ARNDT	91	DPWA	$\pi N \to \pi N \; {\rm Soln} \; {\rm SM90}$
PHASE $\theta$				
VALUE (°)	DOCUMENT ID		TECN	COMMENT
-12	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$

80 IPWA  $\pi N \rightarrow \pi N$ 

91 DPWA  $\pi N \rightarrow \pi N$  Soln SM90

## ARNDT △(1700) DECAY MODES

 $\bullet$   $\,\bullet\,$  We do not use the following data for averages, fits, limits, etc.  $\,\bullet\,$   $\,\bullet\,$ 

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction $(\Gamma_j/\Gamma)$
Г	Nπ	10-20 %
$\Gamma_2$	ΣΚ	
$\Gamma_3$	$N\pi\pi$	80-90 %
$\Gamma_4$	$\Delta \pi$	30-60 %
$\Gamma_5$	$\Delta(1232)\pi$ , $\it S-wave$	25-50 %
Γ ₆	$\Delta(1232)\pi$ , $D$ -wave	1-7 %
$\Gamma_7$	$N \rho$	30-55 %
Γ8	$N \rho$ , $S=1/2$ , $D$ -wave	
Γ9	$N\rho$ , $S=3/2$ , $S$ -wave	5-20 %
$\Gamma_{10}$	$N\rho$ , $S=3/2$ , $D$ -wave	
$\Gamma_{11}$	$N\gamma$	0.12-0.26 %
$\Gamma_{12}$	$N\gamma$ , helicity=1/2	0.08-0.16 %
Γ ₁₃	$N\gamma$ , helicity=3/2	0.025-0.12 %

## △(1700) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$				Γ ₁ /Ι
VALUE	DOCUMENT ID		TECN	COMMENT
0.10 to 0.20 OUR ESTI	MATE			
$0.14 \pm 0.06$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
$0.12 \pm 0.03$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
$0.20 \pm 0.03$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the	ne following data for average	es, fit	s, limits,	etc. • • •
0.16	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
0.16	1 CHEW	80	R D\A/A	$\pi^{\pm} a \rightarrow \pi^{\pm} a$

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N$	$\pi \to \Delta(1700) \to \Sigma K$		(Γ ₁ Γ;	2) ¹ /2/Γ
VALUE	DOCUMENT ID	TECN	COMMENT	
• • • We do not use the	ne following data for averages	s, fits, limits	, etc. • • •	
0.002	LIVANOS	80 DPWA	$\pi \rho \rightarrow \Sigma K$	
0.001 to 0.011	⁶ DEANS	75 DPWA	$\pi N \rightarrow \Sigma K$	

Note: Signs of couplings from  $\pi N \to N \pi \pi$  analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the  $\Delta(1620)$   $S_{31}$ coupling to  $\Delta(1232)\pi$ .

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{ ext{total}}$ in $N\pi$	→ Δ(1700) → Δ(123	2)π, <i>S</i> -w	ave $(\Gamma_1\Gamma_5)^{\frac{1}{2}}/\Gamma$
VALUE	DOCUMENT ID	TEC	
+0.21 to +0.29 OUR ES	TIMATE		
$+0.32\pm0.06$	MANLEY	92 IPW	$A \pi N \rightarrow \pi N \& N \pi \pi$
$+0.18\pm0.04$	BARNHAM	80 IPW	$A \pi N \rightarrow N \pi \pi$
+0.30	^{2,7} LONGACRE	77. IPW	$A \pi N \rightarrow N \pi \pi$
+0.24	3 LONGACRE	75 IPW	$\Delta = N \rightarrow N = \pi$

(F,F _f ) ^{1/2} /F _{total} in N	DOCUMENT ID		TECN	COMMENT
+0.05 to +0.11 OUR	$\pi \rightarrow \Delta(1700) \rightarrow \Delta(120)$ DOCUMENT ID  ESTIMATE			
$+0.08 \pm 0.03$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
$0.14 \pm 0.04$		80	IPWA	$\pi N \rightarrow N \pi \pi$
+0.05		77	IPWA	$\pi N \rightarrow N \pi \pi$
+0.10	³ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$
([,[,c,) ¹ /2,, in N	π → Λ(1700) → Nα S	=1/	2. <i>D</i> -wa	ave (Γ ₁ Γ ₈ ) ^{1/2} ,
('/'T) /'total''''	" - = (1100) - 714 p; 3			
	DOCUMENT ID		TECN	COMMENT
$\frac{VALUE}{+0.17\pm0.05}$ $\left(\Gamma_{L}\Gamma_{F}\right)^{\frac{1}{2}}/\Gamma_{total}$ in $N$	$\frac{DOCUMENT ID}{\text{BARNHAM}}$ $\pi \to \Delta(1700) \to N\rho, S$	80 = <b>3/</b> 2	1PWA 2, <i>S</i> -wa	$rac{COMMENT}{\pi N  o N \pi \pi}$ ve $(\Gamma_1 \Gamma_2)^{\frac{1}{2}}$
$\frac{VALUE}{+0.17\pm0.05}$ $\left(\Gamma_{L}\Gamma_{F}\right)^{\frac{1}{2}}/\Gamma_{total}$ in $N$	$\frac{DOCUMENT ID}{\text{BARNHAM}}$ $\pi \to \Delta(1700) \to N\rho, S$	80 = <b>3/</b> 2	1PWA 2, <i>S</i> -wa	$rac{COMMENT}{\pi N  o N \pi \pi}$ ve $(\Gamma_1 \Gamma_2)^{\frac{1}{2}}$
VALUE $+0.17\pm0.05$ $\left(\Gamma_{I}\Gamma_{f}\right)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N$ VALUE $\pm 0.11 \text{ to } \pm 0.19$	$\pi  o \Delta(1700)  o N  ho, S$ OUR ESTIMATE	80 = <b>3/</b> 2	TECN IPWA  2, S-wa TECN	$COMMENT \ \pi N  o N \pi \pi$ Ve $(\Gamma_1 \Gamma_9)^{\frac{1}{2}}$ $COMMENT$
$VALUE + 0.17 \pm 0.05$ $(\Gamma_{I}\Gamma_{f})^{1/2}/\Gamma_{\text{total}} \text{ in } N$ $VALUE \pm 0.11 \text{ to } \pm 0.19$ $+ 0.10 \pm 0.03$	$\pi  o \Delta(1700)  o N  ho, S$ OUR ESTIMATE	80 = <b>3/</b> 2	TECN IPWA  2, S-wa TECN	$COMMENT \ \pi N  o N \pi \pi$ Ve $(\Gamma_1 \Gamma_9)^{\frac{1}{2}}$ $COMMENT$
VALUE + 0.17 $\pm$ 0.05 $\left(\Gamma_{I}\Gamma_{f}\right)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N$ VALUE $\pm$ 0.11 to $\pm$ 0.19 + 0.10 $\pm$ 0.03 + 0.04	$\frac{DOCUMENT ID}{BARNHAM}$ $\pi \to \Delta(1700) \to N\rho, S$ $\frac{DOCUMENT ID}{OUR ESTIMATE}$ $\frac{MANLEY}{2,7} LONGACRE$	80 = <b>3/</b> 5 	IPWA  2, S-wa  TECN  IPWA  IPWA  IPWA	$ \frac{COMMENT}{\pi N \to N\pi \pi} $ ve $ \frac{(\Gamma_1 \Gamma_9)^{\frac{1}{2}}}{\pi N \to \pi N \& N\pi \pi} $ $ \pi N \to N\pi \pi $
VALUE $+0.17\pm0.05$ $(\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N$ VALUE $\pm 0.11 \text{ to } \pm 0.19$ $+0.10\pm0.03$ $+0.04$ $-0.30$	$\frac{DOCUMENT ID}{BARNHAM}$ $\pi \to \Delta(1700) \to N\rho, S$ $\frac{DOCUMENT ID}{DOCUMENT ID}$ OUR ESTIMATE  MANLEY 2,7 LONGACRE 3 LONGACRE	92 77 75	IPWA  2, S-wa  TECN  IPWA  IPWA  IPWA  IPWA	$\begin{array}{c} \underline{COMMENT} \\ \pi N \rightarrow N \pi \pi \end{array}$ $\begin{array}{c} \text{Ve} \\ \underline{COMMENT} \\ \pi N \rightarrow \pi N \& N \pi \pi \\ \pi N \rightarrow N \pi \pi \\ \pi N \rightarrow N \pi \pi \end{array}$
VALUE $+0.17 \pm 0.05$ $(\Gamma_{I}\Gamma_{I})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N$ VALUE $\pm 0.11 \text{ to } \pm 0.19$ $+0.10 \pm 0.03$ $+0.04$ $-0.30$ $(\Gamma_{I}\Gamma_{I})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N$	$\frac{DOCUMENT ID}{BARNHAM}$ $\pi \to \Delta(1700) \to N\rho, S$ $\frac{DOCUMENT ID}{DOCUMENT ID}$ OUR ESTIMATE  MANLEY 2.7 LONGACRE 3 LONGACRE $\pi \to \Delta(1700) \to N\rho, S$	92 77 75	1PWA  2, S-wa  TECN  IPWA  IPWA  IPWA  IPWA  IPWA	$\begin{array}{c} \underline{COMMENT} \\ \pi N \rightarrow N \pi \pi \end{array}$ $\begin{array}{c} \text{Ve} \qquad \qquad (\Gamma_1 \Gamma_9)^{\frac{1}{2}} \\ \underline{COMMENT} \\ \pi N \rightarrow \pi N & N \pi \pi \\ \pi N \rightarrow N \pi \pi \\ \pi N \rightarrow N \pi \pi \end{array}$ $\text{IVe} \qquad (\Gamma_1 \Gamma_{10})^{\frac{1}{2}} \\ \underline{(\Gamma_1 \Gamma_{10})^{\frac{1}{2}}} \\ \end{array}$
VALUE $+0.17\pm0.05$ $(\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N$ VALUE $\pm 0.11 \text{ to } \pm 0.19$ $+0.10\pm0.03$ $+0.04$ $-0.30$	$\frac{DOCUMENT ID}{BARNHAM}$ $\pi \to \Delta(1700) \to N\rho, S$ $\frac{DOCUMENT ID}{DOCUMENT ID}$ $\frac{MANLEY}{2.7 LONGACRE}$ $\frac{3 LONGACRE}{3 LONGACRE}$ $\pi \to \Delta(1700) \to N\rho, S$ $\frac{DOCUMENT ID}{DOCUMENT ID}$	92 77 75	TECN IPWA 2, S-wa TECN IPWA IPWA IPWA 1PWA 2, D-wa TECN	$\begin{array}{c} \underline{COMMENT} \\ \pi N \rightarrow N \pi \pi \end{array}$ $\begin{array}{c} \text{Ve} \qquad \qquad (\Gamma_1 \Gamma_9)^{\frac{1}{2}} \\ \underline{COMMENT} \\ \pi N \rightarrow \pi N & N \pi \pi \\ \pi N \rightarrow N \pi \pi \\ \pi N \rightarrow N \pi \pi \end{array}$ $\text{IVe} \qquad (\Gamma_1 \Gamma_{10})^{\frac{1}{2}} \\ \underline{(\Gamma_1 \Gamma_{10})^{\frac{1}{2}}} \\ \end{array}$

## $\Delta(1700) \rightarrow N\gamma$ , helicity-1/2 amplitude A_{1/2}

, ,			• •	•	1/2		
VALUE (GeV	-1/2)			DOCUMENT	ID	TECN	COMMENT
$+0.104\pm0$	0.015 O	UR ESTIN	MATE				
$0.090 \pm 0$	.025			ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
$0.111 \pm 0$	.017			CRAWFORI	D 83	IPWA	$\gamma N \rightarrow \pi N$
$0.089 \pm 0$	.033			AWA JI	81	DPWA	$\gamma N \rightarrow \pi N$
$0.112 \pm 0$	.006			ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
$0.130 \pm 0$	.006			ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
$0.123 \pm 0$	.022			CRAWFORE	O8 C	DPWA	$\gamma N \rightarrow \pi N$
• • • We	do not	use the fo	llowing	lata for avera	iges, fits	, limits,	etc. • • •
$0.121 \pm 0$	.004			LI	93	IPWA	$\gamma N \rightarrow \pi N$
$+0.130 \pm 0$	.037			BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
$+0.072\pm0$	.033			FELLER	76	DPWA	$\gamma N \rightarrow \pi N$

#### $\Delta(1700) \rightarrow N\gamma$ , helicity-3/2 amplitude A_{3/2}

VALUE (GeV ^{-1/2} )	DOCUMENT ID		TECN	COMMENT
+0.085±0.022 OUR ESTI	MATE			
$0.097 \pm 0.020$	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
$0.107 \pm 0.015$	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
$0.060 \pm 0.015$	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
$0.047 \pm 0.007$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
$0.050 \pm 0.007$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
$0.102 \pm 0.015$	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
• • We do not use the f	ollowing data for average	s, fit	s, limits,	etc. • • •
$0.115 \pm 0.004$	LI .	93	IPWA	$\gamma N \rightarrow \pi N$
$+0.098\pm0.036$	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
$+0.087\pm0.023$	FELLER	76	DPWA	$\gamma N \rightarrow \pi N$

## △(1700) FOOTNOTES

 1  Problems with CHEW 80 are discussed in section 2.1.11 of HOEHLER 83.  2  LONGACRE 77 pole positions are from a search for poles in the unitarized T-matrix; the first (second) value uses, in addition to  $\pi N \to N\pi\pi$  data, elastic amplitudes from a Saclay (CERN) partial-wave analysis. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.  3  From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.

Shrom method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix amplitudes. See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and  $\Delta$  resonances as determined from Argand diagrams of  $\pi N$  elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams. SLONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to  $\pi N \to N \pi \pi$  data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.

 6  The range given is from the four best solutions. DEANS 75 disagrees with  $\pi^+p \to$ 

 7  K+ data of WINNIK 77 around 1920 MeV. 7 LONGACRE 77 considers this coupling to be well determined.

## △(1700) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

ARNDT	96	PR C53 430	+Strakovsky, Workman	(VPI)
ARNDT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BŘCO)
HOEHLER	93	π N Newsletter 9 1		(KARL)
LI	93	PR C47 2759	+Arndt, Roper, Workman	` (VPI)
MANLEY	92	PR D45 4002	+Saleski	(KĖNT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	` (VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
CRAWFORD	83	NP B211 1	+Morton	(GLAS)
HOEHLER	83	Landolt-Boernstein 1/	9B2	(KARLT)
PDG	82	Pl. 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
AWA JI	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
ARAI	80	Toronto Conf. 93		(INUS)
Also	82	NP B194 251	Arai, Fujii	(INUS)
BARNHAM	80	NP B168 243	+Glickman, Mier-Jedrzejowicz+	(LOIC)

# Baryon Particle Listings $\Delta(1700)$ , $\Delta(1750)$ , $\Delta(1900)$

CHEW	80	Toronto Conf. 123		(LBL) IJP
CRAWFORD	80	Toronto Conf. 107		(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMÚ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
LIVANOS	80	Toronto Conf. 35	+Baton, Coutures, Kochowski, Neveu	(SACL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)
LONGACRE	77	NP B122 493	+Dolbeau	(SACL) IJP
Also	76	NP B108 365	Dolbeau, Triantis, Neveu, Cadiet	(SACL) IJP
WINNIK	77	NP B128 66	+Toaff, Revel, Goldberg, Berny	(HAIF) I
FELLER	76	NP B104 219	+Fukushima, Horikawa, Kajikawa+	(NAGO, OSAK) IJP
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ALAH) IJP
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC) IJP

## $\Delta(1750) P_{31}$

 $I(J^{P}) = \frac{3}{2}(\frac{1}{2}^{+})$  Status: *

OMITTED FROM SUMMARY TABLE

## △(1750) MASS

DOCUMENT I	TECN	COMMENT
MANLEY	92 IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
ing data for avera	ges, fits, limits	s, etc. • • •
¹ CHEW	80 BPW	$\lambda \pi^+ p \rightarrow \pi^+ p$
$^{ m 1}$ CHEW	80 BPW	$A \pi^+ \rho \rightarrow \pi^+ \rho$
	MANLEY ring data for average  1 CHEW	MANLEY 92 IPWA ring data for averages, fits, limits

## △(1750) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
300 ±120	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
• • • We do not use the following	data for averages	, fits	s, limits,	etc. • • •
93.3± 55.0	¹ CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
23.0 ± 29.0	¹ CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$

## △(1750) DECAY MODES

	Mode
-	Δ/

 $\Gamma_1 N\pi$   $\Gamma_2 N\pi\pi$   $\Gamma_3 N(1440)\pi$ 

-/	`	-		

' ('*')/' total					• т
VALUE	DOCUMENT ID		TECN	COMMENT	
$0.08 \pm 0.03$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N$	$I\pi\pi$
$\bullet~\bullet~$ We do not use the following	data for averages	s, fits	s, limits,	etc. • • •	
0.18	¹ CHEW	80	BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho$	
0.20	¹ CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$	

$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\pi \to A$	(Γ₁Γ₃) ^½ /Γ		
VALUE	DOCUMENT ID	TECN	COMMENT
$+0.15\pm0.03$	MANLEY 9	2 IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$

## △(1750) FOOTNOTES

 1  CHEW 80 reports four resonances in the  $P_{31}$  wave — see also the  $\Delta(1910).$  Problems with this analysis are discussed in section 2.1.11 of HOEHLER 83.

## △(1750) REFERENCES

MANLEY	92	PR D45 4002 +Saleski	(KENT)
Also	84	PR D30 904 Manley, Arndt, Goradia, Teplitz	(VPI)
HOEHLER	83	Landolt-Boernstein 1/9B2	(KARLT)
CHEW	80	Toronto Conf. 123	(LBL)

 $\Delta(1900) S_{31}$ 

 $I(J^P) = \frac{3}{2}(\frac{1}{2}^-)$  Status: ***

## △(1900) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1850 to 1950 (≈ 1900) OUR EST	IMATE			
1920 ±24	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
1890 ±50	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1908 ±30	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the following	data for average	s, fit	s, limits,	etc. • • •
1918.5±23.0	CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
1803	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$

## **∆(1900)** WIDTH

VALU	E (MeV)	DOCUMENT ID		TECN	COMMENT
140	to 240 (≈ 200) OUR ESTIMA	TE			
263	±39	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
170	±50	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
140	±40	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• •	<ul> <li>We do not use the following of</li> </ul>	data for averages	, fits	, limits,	etc. • • •
93.5 137	5±54.0	CHEW CRAWFORD			$ \begin{array}{ccc} \pi^+ p \to & \pi^+ p \\ \gamma N \to & \pi N \end{array} $

## $\Delta$ (1900) POLE POSITION

## REAL PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1780	¹ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
$1870 \pm 40$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use th	e following data for average	s, fit	s, limits,	etc. • • •
not seen				$\pi N \rightarrow \pi N \text{ Soln SM90}$
2029 or 2025	² LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
-2×IMAGINARY P	DOCUMENT ID		TECN	COMMENT
180±50	CUTKOSKY			$\pi N \rightarrow \pi N$
	ne following data for average			
not seen				$\pi N \rightarrow \pi N \text{ Soin SM90}$
164 or 163	² LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$

## △(1900) ELASTIC POLE RESIDUE

## MODULUS |r|

VALUE (MeV)	DOCUMENT ID	TECN_	COMMENT	
10±3	CUTKOSKY 8	0 IPWA	$\pi N \rightarrow \pi N$	
PHASE $\theta$				
VALUE (°)	DOCUMENT ID	TECN	COMMENT	
$+20 \pm 40$	CUTKOSKY 8	0 IPWA	$\pi N \rightarrow \pi N$	

## △(1900) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction $(\Gamma_i/\Gamma)$
Γ ₁	Nπ	10-30 %
$\Gamma_2$	ΣΚ	
$\Gamma_3$	Νππ	
$\Gamma_4$	$\Delta\pi$	
$\Gamma_5$	$\Delta(1232)\pi$ , $ extit{D}$ -wave	
Γ6	$N \rho$	
$\Gamma_7$	$N\rho$ , $S=1/2$ , $S$ -wave	
Γ8	$N\rho$ , $S=3/2$ , $D$ -wave	
Γ9	$\mathcal{N}(1440)\pi$ , $\mathit{S} ext{-wave}$	
$\Gamma_{10}$	$N\gamma$ , helicity=1/2	

## △(1900) BRANCHING RATIOS

Γ(Nπ)/Γ _{total}				$\Gamma_1/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT
0.1 to 0.3 OUR ESTIM	ATE			
$0.41 \pm 0.04$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
$0.10 \pm 0.03$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
$0.08 \pm 0.04$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the	e following data for average	s, fit	s, limits,	etc. • • •
				$\pi^+ p \rightarrow \pi^+ p$
0.28	CHEW	80	BPWA	, ,
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{ ext{total}}$ in $N\pi$	· → Δ(1900) → ΣK			(Γ ₁ Γ ₂ ) ^{1/2} /Γ
		•	<u>TECN</u>	, ,
$(\Gamma_I \Gamma_f)^{1/2}/\Gamma_{\text{total}} \text{ in } N\pi$ $VALUE$ $< 0.03$	$\rightarrow \Delta(1900) \rightarrow \Sigma K$ DOCUMENT ID	84	TECN DPWA	$\frac{(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma}{\pi^+\rho \to \Sigma^+\kappa^+}$
$(\Gamma_I \Gamma_f)^{1/2}/\Gamma_{\text{total}} \text{ in } N\pi$ $VALUE$ $< 0.03$	$T \rightarrow \Delta(1900) \rightarrow \Sigma K$ DOCUMENT ID  CANDLIN	84 s, fit	TECN DPWA s, limits,	$\frac{(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma}{\pi^+\rho \to \Sigma^+\kappa^+}$
$(\Gamma_i \Gamma_f)^{\frac{1}{12}}/\Gamma_{\text{total}} \text{ in } N\pi$ VALUE  <0.03  • • • We do not use the	$T  o \Delta(1900)  o \Sigma K$ DOCUMENT ID  CANDLIN  e following data for average	84 s, fit: 75	TECN DPWA s, limits, DPWA	$(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma$ $\frac{COMMENT}{\pi^+p\to\Sigma^+K^+}$ etc. • • •
$(\Gamma_i \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi$ $\frac{VALUE}{<0.03}$ • • • We do not use the 0.076	$T  o \Delta(1900)  o \Sigma K$ DOCUMENT ID  CANDLIN  e following data for average  3 DEANS	84 s, fit: 75 73	TECN DPWA s, limits, DPWA IPWA	$(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma_2$ $\frac{COMMENT}{\pi^+p \to \Sigma^+K^+}$ etc. • • • $\pi N \to \Sigma K$

$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\pi \to \Delta(1)$	(Г₁Г₅) ^½ /Г				
VALUE	DOCUMENT ID		TECN	COMME	NT
$+0.25\pm0.07$	MANLEY	92	IPWA	$\pi N \rightarrow$	$\pi$ N & N $\pi$
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\pi \to \Delta(1)$	(Г₁Г ₇ ) ^½ /Г				

$( I f)^{2}/ I_{\text{total}}$ in $N\pi \to \Delta(1900) \to N\rho$ , $S=1/2$ , S-wave							٦/٢
	VALUE	DOCUMENT ID		TECN	COMMENT		
	$-0.14 \pm 0.11$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$	<b>ν &amp; Ν</b> ππ	

$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\pi \to \Delta(19)$	ive (Γ ₁ Γ ₈ ) ^½ /Γ		
VALUE	DOCUMENT ID	TECN	COMMENT
$-0.37 \pm 0.07$	MANLEY 92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$

$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\pi \to A$	∆(1900) → N(1440):	τ, S-wav	e (Γ ₁ Γ ₉ ) ^{1/2} /Γ
VALUE	DOCUMENT ID	TECN	COMMENT
$-0.16\pm0.11$	MANLEY 9	2 IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$

## △(1900) PHOTON DECAY AMPLITUDES

## $\Delta$ (1900) $\rightarrow N\gamma$ , helicity-1/2 amplitude A_{1/2}

VALUE (GeV ^{-1/2} )	DOCUMENT ID		TECN	COMMENT
$-0.004 \pm 0.016$	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
$0.029 \pm 0.008$	AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$
ullet $ullet$ We do not use the following	data for averages	s, fits	i, limits,	etc. • • •
-0.006 to $-0.025$	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$

## △(1900) FOOTNOTES

 1  See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and  $\Delta$  resonances as determined from Argand diagrams of  $\pi$  N elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams. amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams. 2 LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to  $\pi N \to N \pi \pi$  data, elastic amplitudes from a Saclay (CERN) partial-wave analysis. 3 The value given is from solution 1; the resonance is not present in solutions 2, 3, or 4.

## △(1900) REFERENCES

For early references, see Physics Letters  $\mathbf{111B}$  70 (1982).

HOEHLER MANLEY Also ARNDT CANDLIN CRAWFORD AWAJI Also CHEW CRAWFORD CUTKOSKY Also HOEHLER	93 92 84 91 84 83 81 82 80 80 79 79	π N Newsletter 9 1 PR D45 4002 PR D30 904 PR D43 2131 NP B238 477 NP B211 1 Bonn Conf. 352 NP B197 365 Toronto Conf. 107 Toronto Conf. 107 Toronto Conf. 107 Toronto Conf. 107 PR D20 2839 PDAT 12-1	+-Saleski Manley, Arndt, Goradia, Teplitz +Li, Roper, Workman, Ford +Lowe, Peach, Scotland+ +Morton +Kajikawa Fujii, Hayashii, Iwata, Kajikawa+ +Forsyth, Babcock, Kelly, Hendrick Cutkosky, Forsyth, Hendrick, Kelly +Kalser, Koch, Pletarinen	(KARL) (KENT) IJP (VPI, TELE) IJP (EDIN, RAL, LOWC) (MAGO) (MAGO) (MBL) IJP (GLAS) (CMU, LBL) IJP (CMU, LBL) IJP (CARL T) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
LONGACRE DEANS LANGBEIN	78 75 73	PR D17 1795 NP B96 90 NP B53 251	+Lasinski, Rosenfeld, Smadja+ +Mitchell, Montgomery+ +Wagner	(LBĽ, SLAC) (SFLA, ALAH) IJP (MUNI) IJP

## $\Delta(1905) F_{35}$

 $I(J^P) = \frac{3}{2}(\frac{5}{2}^+)$  Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

## △(1905) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1870 to 1920 (≈ 1905) O	UR ESTIMATE			
1881 ±18	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
1910 ±30	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1905 ±20	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the form	llowing data for average	s, fit	s, limits,	etc. • • •
1895 ± 8	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
1850	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1960 ±40	CANDLIN	84	DPWA	$\pi^+ \rho \rightarrow \Sigma^+ K^+$
1787.0 + 6.0 - 5.7	CHEW	80	BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho$
1880	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
1892	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
1830	¹ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

## △(1905) WIDTH

/ALUE (MeV)	DOCUMENT ID		TECN	COMMENT
280 to 440 (≈ 350) OL	IR ESTIMATE			
327 ± 51	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
100 ±100	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
260 ± 20	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the	following data for average	s, fit	s, limits,	etc. • • •
854 ± 10	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
294	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
270 ± 40	CANDLIN	84	DPWA	$\pi^+ \rho \rightarrow \Sigma^+ K^+$
66.0 ⁺ 24.0 - 16.0	CHEW	80	BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho$
.93	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
.59	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
220	1 LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

## △(1905) POLE POSITION

REAL	DAD"
KEAL	FMR

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1832	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1829	² HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
1830 ± 40	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	g data for average	s, fits	s, limits,	etc. • • •
1794	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$
1813 or 1808	³ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
-2×IMAGINARY PART				
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT

MEDE (MEV)	DOCUMENT ID		1 L C IV	COMME	· v /
254	ARNDT	95	DPWA	$\pi N \rightarrow$	Νπ
303	² HOEHLER	93	SPED	$\pi N \rightarrow$	$\pi N$
280 ± 60	CUTKOSKY	80	IPWA	$\pi N \rightarrow$	$\pi N$
• • We do not use the	following data for average	s, fits	s, limits,	etc. • •	•
230	ARNDT	91	DPWA	$\pi N \rightarrow$	π N Soln SM90
193 or 187	3 LONGACRE	78	IPWA	$\pi N \rightarrow$	$N\pi\pi$

## △(1905) ELASTIC POLE RESIDUE

## MODULUS |r|

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
12	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$	ı
25	HOEHLER	93	SPED	$\pi N \rightarrow \pi N$	
$25\pm 8$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
ullet $ullet$ We do not use the following	ng data for average	s, fits	, limits,	etc. • • •	
14	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ SoIn SM90}$	

## PHASE $\theta$

VALUE (°)	DOCUMENT ID		TECN	COMMENT
- 4	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
$-50 \pm 20$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the following	data for average	s, fits	s, limits,	etc. • • •
<b>-40</b>	ARNDT	91	DPWA	$\pi{\it N}  ightarrow$

### $\Delta(1905), \Delta(1910)$

### △(1905) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction $(\Gamma_j/\Gamma)$	
Γ ₁	Nπ	5-15 %	
$\Gamma_2$	ΣΚ		
$\Gamma_3$	$N\pi\pi$	85-95 %	
$\Gamma_4$	$\Delta \pi$	<25 %	
$\Gamma_5$	$\Delta(1232)\pi$ , $\it P-wave$		
$\Gamma_6$	$\Delta$ (1232) $\pi$ , $\emph{F}$ -wave		
$\Gamma_7$	$N\rho$	>60 %	
Γ8	$N\rho$ , $S=3/2$ , $P$ -wave		
Γ9	$N\rho$ , $S=3/2$ , $F$ -wave		
$\Gamma_{10}$	$N\rho$ , $S=1/2$ , $F$ -wave		
$\Gamma_{11}$	$N\gamma$	0.01-0.03 %	
$\Gamma_{12}$	$N\gamma$ , helicity=1/2	0.0-0.1 %	
Γ ₁₃	$N\gamma$ , helicity=3/2	0.004-0.03 %	

### △(1905) BRANCHING RATIOS

VALUE	DOCUMENT ID		TECN	COMMENT
0.05 to 0.15 OUR ESTI	MATE			
$0.12 \pm 0.03$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
$0.08 \pm 0.03$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
0.15 ± 0.02	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use th	e following data for average	s, fit	s, limits,	etc. • • •
0.12	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
0.11	CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \to A$	Δ(1905) → Σ <i>K</i>			(Γ ₁ Γ ₂ ) ^{1/2} ,	/г
VALUE	DOCUMENT ID		TECN	COMMENT	
$-0.015 \pm 0.003$	CANDLIN	84	DPWA	$\pi^+ \rho \rightarrow \Sigma^+ K^+$	
• • • We do not use the folio	wing data for average	s, fits	s, limits,	etc. • • •	
-0.013	LIVANOS	80	DPWA	$\pi p \rightarrow \Sigma K$	
0.021 to 0.054	⁴ DEANS	75	DPWA	$\pi N \rightarrow \Sigma K$	

Note: Signs of couplings from  $\pi N \rightarrow N \pi \pi$  analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the  $\Delta(1620)$   $S_{31}$  coupling to  $\Delta(1232)\pi$ .

$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\pi \to 1$	<b>∆</b> (1905) → <b>∆</b> (1232	)π, <i>P</i> -	-wave	(Γ₁Γ₅) ^½ /Γ
VALUE	DOCUMENT ID	TE	CN COMME	NT
$-0.04 \pm 0.05$	MANLEY	92 IP	WA $\pi N \rightarrow$	πΝ & Νππ

$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\pi \to \Delta(19)$	905) → <b>Δ</b> (123	2)π	, F-wav	e	(Г₁Г ₆ ) ^⅓ /Г
VALUE	DOCUMENT ID		TECN	COMMENT	
$+0.02\pm0.03$	MANLEY				
+0.20	¹ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi$	$\pi$
• • We do not use the following	data for average	s, fits	s, limits,	etc. • • •	
+0.17	⁵ NOVOSELLER				
+0.06	⁶ NOVOSELLER	78	IPWA	$\pi N \rightarrow N \pi$	π

$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\pi \to \Delta(1)$	1905) $\rightarrow N\rho$ , S	=3/:	2, <i>P</i> -wa	ve	(Γ ₁ Γ ₈ ) ^{1/2} /
VALUE	DOCUMENT ID		TECN	COMME	NT
+0.030 to +0.36 OUR ESTIMAT	ΓΕ				
$+0.33 \pm 0.03$	MANLEY				
+0.33	1 LONGACRE	75	IPWA	$\pi N \rightarrow$	Νππ
• • • We do not use the following	ng data for average	s, fit	s, limits,	etc. • •	•
+0.26	⁵ NOVOSELLE	R 78	IPWA	$\pi N \rightarrow$	Νππ
+0.11 to +0.33	⁷ NOVOSELLE	78	IPWA	$\pi N \rightarrow$	$N\pi\pi$

### △(1905) PHOTON DECAY AMPLITUDES

### $\Delta$ (1905) $\rightarrow N\gamma$ , helicity-1/2 amplitude A_{1/2}

VALUE (GeV-1/2)	DOCUMENT ID		TECN	COMMENT
+0.026±0.011 OUR ESTIMATE	7			
$0.022 \pm 0.005$	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
$0.021 \pm 0.010$	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
$0.043 \pm 0.020$	AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$
$0.022 \pm 0.010$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
$0.031 \pm 0.009$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
$0.024 \pm 0.014$	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
• • • We do not use the following	data for average	s, fit	s, limits,	etc. • • •
$0.055 \pm 0.004$	LI	93	IPWA	$\gamma N \rightarrow \pi N$
$+0.033\pm0.018$	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$

### $\Delta(1905) \rightarrow N\gamma$ , helicity-3/2 amplitude A_{3/2}

VALUE (GeV-1/2)	DOCUMENT ID		TECN	COMMENT
-0.045±0.020 OUR ESTIMATE				
$-0.045\pm0.005$	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
$-0.056\pm0.028$	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
$-0.025\pm0.023$	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
$-0.029\pm0.007$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
$-0.045\pm0.006$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
$-0.072\pm0.035$	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
• • We do not use the following	data for average	s, fit	s, limits,	etc. • • •
$0.002 \pm 0.003$	LI	93	IPWA	$\gamma N \rightarrow \pi N$
$-0.055\pm0.019$	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$

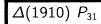
### △(1905) FOOTNOTES

- $^{\rm 1}$  From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.
- amplitudes. 2 See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and  $\Delta$  resonances as determined from Argand diagrams of  $\pi N$  elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams. 3 LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first
- (second) value uses, in addition to  $\pi N \to N \pi \pi$  data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.
- ⁴ The range given for DEANS 75 is from the four best solutions.
  ⁵ A Breit-Wigner fit to the HERNDON 75 IPWA.
- ⁶ A Breit-Wigner fit to the NOVOSELLER 78B IPWA.
- 7 A Breit-Wigner fit to the NOVOSELLER 788 IPWA; the phase is near 90 $^\circ$ .

### △(1905) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

ARNDT	96	PR C53 430	+Strakovsky, Workman	(VPI)
ARNDT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BRCO)
HOEHLER	93	π N Newsletter 9 1	+Strakovsky, vvorkinan, r avan	(KARL)
LI	93	PR C47 2759	A de De-se- Marelinea	(VPI)
			+Arndt, Roper, Workman	
MANLEY	92	PR D45 4002	+Saleski	(KENT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
CANDLIN	84	NP B238 477	+Lowe, Peach, Scotland+	(EDIN, RAL, LOWC)
CRAWFORD	83	NP B211 1	+Morton	(GLAS)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
AWA JI	81	Bonn Conf. 352	+ Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
ARAI	80	Toronto Conf. 93	3. 3	`(INUS)
Also	82	NP B194 251	Arai, Fujii	(INUS)
CHEW	80	Toronto Conf. 123		`(LBL) IJP
CRAWFORD	80	Toronto Conf. 107		(ĠLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMŮ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
LIVANOS	80	Toronto Conf. 35	+Baton, Coutures, Kochowski, Neveu	(SACL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)
NOVOSELLER	78	NP B137 509	r cashishi, rioschicia, Sinaaja r	(CIT) IJP
NOVOSELLER	78B	NP B137 445		(CIT) IJP
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ALAH) IJP
HERNDON	75	PR D11 3183	+Longacre, Miller, Rosenfeld+	(LBL, SLAC)
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC) IJP



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$$I(J^P) = \frac{3}{2}(\frac{1}{2}^+)$$
 Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

### △(1910) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1870 to 1920 (≈ 1910) OUR ES	TIMATE			
1882 ±10	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
1910 ±40	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1888 ±20	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the following	g data for average	s, fit	s, limits,	etc. • • •
2152	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
$1960.1 \pm 21.0$	¹ CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
$2121.4 + 13.0 \\ -14.3$	¹ CHEW	80	BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho$
1921	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
1899	BARBOUR		DPWA	$\gamma N \rightarrow \pi N$
1790	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$

### △(1910) WIDTH

VALU	E (MeV)	DOCUMENT ID		TECN	COMMENT
190	to 270 (≈ 250) OUR ESTIMA	TE			
239	±25	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
225	±50	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
280	$\pm 50$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$

### **Baryon Particle Listings** $\Delta(1910)$

• • • We do not use the	following data for average	s, fits	s, limits, etc. • •
760	ARNDT	95	DPWA $\pi N \rightarrow N \pi$
$152.9 \pm 60.0$	¹ CHEW	80	BPWA $\pi^+ p \rightarrow \pi^+ p$
172.2±37.0	¹ CHEW	80	BPWA $\pi^+ p \rightarrow \pi^+ p$
351	CRAWFORD	80	DPWA $\gamma N \rightarrow \pi N$
230	BARBOUR		DPWA $\gamma N \rightarrow \pi N$
170	² LONGACRE	77	IPWA $\pi N \rightarrow N \pi \pi$

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### △(1910) POLE POSITION

REAL PART					
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
1810	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$	
1874	³ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$	
1880 ± 30	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
• • We do not use the follo	wing data for average	s, fits	s, limits,	etc. • • •	
1950	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$	
1792 or 1801	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$	
-2×IMAGINARY PART					
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
494	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$	
283	3 HOEHLER	93	SPED	$\pi N \rightarrow \pi N$	
$200 \pm 40$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
• • We do not use the follow	wing data for average	s, fits	s, limits,	etc. • • •	
398	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$	
172 or 165	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$	

### △(1910) ELASTIC POLE RESIDUE DOCUMENT ID

TECN COMMENT

MODULUS	r
MALLIE (MAN)	

VALUE (WEV)	DOCUMENT		7207	COMMENT
53	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
38	HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
20±4	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	data for average	s, fit	s, Iimits,	etc. • • •
37	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$
DHASE A				

	LUE(°)	DOCUMENT ID		TECN	COMMENT
_	176	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
_	$90 \pm 30$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
•	<ul> <li>We do not use the following</li> </ul>	data for averages	, fits	, limits,	etc. • • •
o Paracia	91	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$

### △(1910) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction $(\Gamma_i/\Gamma)$	
$\Gamma_1$	Νπ	15-30 %	
$\Gamma_2$	ΣΚ		
$\Gamma_3$	$N \pi \pi$		
Γ4	$\Delta\pi$		
$\Gamma_5$	$\Delta(1232)\pi$ , $P$ -wave		
$\Gamma_6$	$N\rho$		
$\Gamma_7$	$N\rho$ , $S=3/2$ , $P$ -wave		
Γ8	$N(1440)\pi$		
$\Gamma_9$	$N(1440)\pi$ , $\it P$ -wave		
$\Gamma_{10}$	$N\gamma$	0.0-0.2 %	
$\Gamma_{11}$	$N\gamma$ , helicity=1/2	0.0-0.2 %	

### △(1910) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$				$\Gamma_1/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT
0.15 to 0.3 OUR ESTIMATE				
$0.23 \pm 0.08$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
$0.19 \pm 0.03$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
$0.24 \pm 0.06$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the following	g data for average	s, fits	s, limits,	etc. • • •
0.26	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
0.17	¹ CHEW			$\pi^+ \rho \rightarrow \pi^+ \rho$
0.40	¹ CHEW	80	BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho$

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N_{\pi} -$	$\rightarrow \Delta(1910) \rightarrow \Sigma K$			(Γ ₁ Γ ₂ ) ¹ /2/Γ
VALUE	DOCUMENT ID		TECN	COMMENT
< 0.03	CANDLIN			$\pi^+ \rho \rightarrow \Sigma^+ K^+$
<ul> <li>• • We do not use the f</li> </ul>	ollowing data for average	s, fit	s, limits,	etc. • • •
-0.019	LIVANOS	80	DPWA	$\pi \rho \rightarrow \Sigma K$
0.082 to 0.184	⁴ DEANS	75	DPWA	$\pi N \rightarrow \Sigma K$

Note: Signs of couplings from  $\pi\,N\to N\pi\pi$  analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the  $\Delta(1620)\,S_{31}$  coupling to  $\Delta(1232)\pi$ .

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N_1$		r, $P$ -wave $(\Gamma_1\Gamma_5)^{\frac{1}{2}}/\Gamma$
+0.06	² LONGACRE 77	TECN COMMENT  IPWA $\pi N \rightarrow N \pi \pi$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N_2$		/2, <i>P</i> -wave (Γ ₁ Γ ₇ ) ^{1/2} /Γ
+0.29	² LONGACRE 77	IPWA $\pi N \rightarrow N \pi \pi$
• • • We do not use th	ne following data for averages, fi	ts, limits, etc. • • •
+0.17	⁵ NOVOSELLER 78	IPWA $\pi N \rightarrow N \pi \pi$
		$\Gamma$ , $P$ -wave $(\Gamma_1\Gamma_9)^{\frac{1}{2}}/\Gamma$
VALUE	DOCUMENT ID	TECN COMMENT
$-0.39 \pm 0.04$	MANLEY 92	PIPWA $\pi N \rightarrow \pi N \& N \pi \pi$

### △(1910) PHOTON DECAY AMPLITUDES

### $\Delta(1910) \rightarrow N\gamma$ , helicity-1/2 amplitude A_{1/2}

VALUE (GeV ^{-1/2} )	DOCUMENT ID		TECN	COMMENT
+0.003±0.014 OUR ESTIMATE	•			
$-0.002\pm0.008$	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
$0.014 \pm 0.030$	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
$0.025 \pm 0.011$	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
$-0.012\pm0.005$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
$-0.031 \pm 0.004$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
$-0.005\pm0.030$	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
• • We do not use the following	ng data for average	s, fit	s, limits,	etc. • • •
$0.032 \pm 0.003$	LI	93	IPWA	$\gamma N \rightarrow \pi N$
$-0.035 \pm 0.021$	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
				****

### △(1910) FOOTNOTES

- $^1\text{CHEW}$  80 reports four resonances in the  $P_{31}$  wave see also the  $\Delta(1750).$  Problems with this analysis are discussed in section 2.1.11 of HOEHLER 83.  2  LONGACRE 77 pole positions are from a search for poles in the unitarized T-matrix; the first (second) value uses, in addition to  $\pi N \to N\pi\pi$  data, elastic amplitudes from a Saclay (CERN) partial-wave analysis. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.
- Its with Breit-Wigner circies to the 1-matrix amplitudes. 3 See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and  $\Delta$  resonances as determined from Argand diagrams of  $\pi N$  elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams. 4 The range given for DEANS 75 is from the four best solutions. 5 Evidence for this coupling is weak; see NOVOSELLER 78. This coupling assumes the mass is near 1820 MeV.

### △(1910) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

ARNDT	96	PR C53 430	+Strakovsky, Workman	(VPI)
ARNDT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BŘCO)
HOEHLER	93	π N Newsletter 9 1		` (KARL)
LI	93	PR C47 2759	+Arndt, Roper, Workman	(VPI)
MANLEY	92	PR D45 4002	+Saleski	(KÈNT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
CANDLIN	84	NP B238 477	+Lowe, Peach, Scotland+	(EDIN, RAL, LOWC)
CRAWFORD	83	NP B211 1	+Morton	(GLAS)
HOEHLER	83	Landolt-Boernstein 1/9	9B2	(KARLT)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
ILAWA	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
ARAI	80	Toronto Conf. 93		(INUS)
Also	82	NP B194 251	Arai, Fujii	(INUS)
CHEW	80	Toronto Conf. 123		`(LBL) IJP
CRAWFORD	80	Toronto Conf. 107		(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMŮ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
LIVANOS	80	Toronto Conf. 35	+Baton, Coutures, Kochowski, Neveu	(SACL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
NOVOSELLER	78	NP B137 509		`(CIT) IJP
Also	78B	NP B137 445	Novoseller	(CIT) IJP
LONGACRE	77	NP B122 493	+Dolbeau	(SACL) IJP
Also	76	NP B108 365	Dolbeau, Triantis, Neveu, Cadiet	(SACL) IJP
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ALAH) IJP

 $\Delta(1920), \Delta(1930)$ 

 $\Delta$ (1920)  $P_{33}$ 

 $I(J^P) = \frac{3}{2}(\frac{3}{2}^+)$  Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics

### △(1920) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1900 to 1970 (≈ 1920) OUR ES	TIMATE			
2014 ±16	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
1920 ±80	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1868 ±10	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the following	data for average	s, fit	s, limits,	etc. • • •
1840 ±40	CANDLIN			$\pi^+ p \rightarrow \Sigma^+ K^+$
$1955.0 \pm 13.0$	¹ CHEW	80	BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho$
$2065.0^{+13.6}_{-12.9}$	¹ CHEW	80	BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho$

### △(1920) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
150 to 300 (≈ 200) OUR EST	IMATE			
152 ± 55	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
300 ±100	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
220 ± 80	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the follow	ing data for average	s, fit	s, limits,	etc. • • •
200 ± 40	CANDLIN			$\pi^+ \rho \rightarrow \Sigma^+ K^+$
88.3 ± 35.0	¹ CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
62.0 ± 44.0	¹ CHEW	80	BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho$

### △(1920) POLE POSITION

RE/	N۱	D۸	РΤ
	٦.	гΜ	nп

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1900	² HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
1900 ± 80	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the following	g data for averages	s, fits	, limits,	etc. • • •
not seen	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$

### -2×IMAGINARY PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
$300 \pm 100$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
ullet $ullet$ We do not use the following of	data for averages	, fits	, limits,	etc. • • •
not seen	ARNDT	91	DPWA	$\pi{\it N} \rightarrow \pi{\it N}{\rm Soln}{\rm SM90}$

### △(1920) ELASTIC POLE RESIDUE

### MODULUS |r|

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
24±4	CUTKOSKY 80	IPWA	$\pi N \rightarrow \pi N$
PHASE θ			
VALUE (°)	DOCUMENT ID	TECN	COMMENT
$-150 \pm 30$	CUTKOSKY 80	IPWA	$\pi N \rightarrow \pi N$

### △(1920) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction $(\Gamma_j/\Gamma)$	
Γ ₁	Nπ	5–20 %	
$\Gamma_2$	ΣΚ		
Гз	$N\pi\pi$		
$\Gamma_4$	$\Delta(1232)\pi$ , $P$ -wave		
$\Gamma_5$	$N(1440)\pi$ , $P$ -wave		
$\Gamma_6$	$N\gamma$ , helicity=1/2		
Γ ₇	$N\gamma$ , helicity=3/2		

### △(1920) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$				Γ ₁ /Ι
VALUE	DOCUMENT ID		TECN	COMMENT
0.05 to 0.2 OUR ESTIMATI				
$0.02 \pm 0.02$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
$0.20 \pm 0.05$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
$0.14 \pm 0.04$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the fo	llowing data for average	es, fit	s, limits,	etc. • • •
0.24	¹ CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
0.18	¹ CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}}$ in $N\pi$	DOCUMENT ID		TECN	(Γ ₁ Γ ₂ ) ^{1/2}
$-0.052\pm0.015$	CANDLIN	84	DPWA	$\pi^+ p \rightarrow \Sigma^+ K^+$
<ul> <li>• • We do not use the</li> </ul>	e following data for average	es, fit	s, limits,	etc. • • •
-0.049	LIVANOS ³ DEANS	80	DPWA	$\pi p \rightarrow \Sigma K$
0.048 to 0.120	³ DEANS	75	DPWA	$\pi N \rightarrow \Sigma K$
	$\rightarrow \Delta(1920) \rightarrow \Delta(123)$			
VALUE -0.13±0.04 0.3 0.27	DOCUMENT ID	92 R 78	IPWA IPWA	$ \begin{array}{cccc} COMMENT \\ \pi N \to & \pi N & N \pi \pi \\ \pi N \to & N \pi \pi \end{array} $

### $\Delta$ (1920) $\rightarrow N\gamma$ , helicity-1/2 amplitude A_{1/2}

VALUE (GeV-1/2)

 $0.023 \pm 0.017$ 

VALUE (GeV-1/2)	DOCUMENT ID		TECN	COMMENT
$0.040 \pm 0.014$	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
$\Delta(1920)  ightarrow N\gamma$ , helicity-3/2	amplitude A _{3,}	/2		

### △(1920) FOOTNOTES

DOCUMENT ID

- ¹ CHEW 80 reports two  $P_{33}$  resonances in this mass region. Problems with this analysis are discussed in section 2.1.11 of HOEHLER 83.

  See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and  $\Delta$  resonances as determined from Argand diagrams of  $\pi N$  elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.

  The range given for DEANS 75 is from the four best solutions.

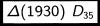
  A Breit-Wigner fit to the HERNDON 75 IPWA; the phase is near  $-90^\circ$ .

- 5  A Breit-Wigner fit to the NOVOSELLER 78B IPWA; the phase is near  $-90^{\circ}$ .

### △(1920) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

HOEHLER	93	π N Newsletter 9 1		(KARL)
MANLEY	92	PR D45 4002	+Saleski	(KENT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
CANDLIN	84	NP B238 477	+Lowe, Peach, Scotland+	(EDIN, RAL, LOWC)
HOEHLER	83	Landolt-Boernstein 1/9	B2	` (KARLT)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
AWA JI	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
CHEW	80	Toronto Conf. 123		(LBL) IJP
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMU, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
LIVANOS	80	Toronto Conf. 35	+Baton, Coutures, Kochowski, Neveu	(SACL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
NOVOSELLER	78	NP B137 509		(CIT)
NOVOSELLER	788	NP B137 445		(CIT)
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, AĹAH) IJP
HERNDON	75	PR D11 3183	+Longacre, Miller, Rosenfeld+	(LBL, SLAC)



$$I(J^{P}) = \frac{3}{2}(\frac{5}{2}^{-})$$
 Status: ***

TECN COMMENT

81 DPWA  $\gamma N \rightarrow \pi N$ 

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters **111B** (1982).

The various analyses are not in good agreement.

### △(1930) MASS

VALUE	(MeV)	DOCUMENT ID		TECN	COMMENT
L <b>92</b> 0	to 1970 (≈ 1930)	OUR ESTIMATE			
1956	±22	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
1940	±30	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1901	$\pm 15$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • •	We do not use the	following data for average	s, fit	s, limits,	etc. • • •
1955	±15	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
2056		ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1963		LI	93	IPWA	$\gamma N \rightarrow \pi N$
1910.0	+15.0 -17.2	CHEW	80	BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho$
2000	=	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
2024		BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$

	△(1930) WID	TH			$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \to \Delta(19)$		(Γ₁Γ₃) ¹ /2
VALUE (MeV)	DOCUMENT ID	TEC	N COMMENT		NOT SEEN		$COMMENT$ $\pi N \rightarrow N \pi \pi$
250 to 450 (≈ 350) OUR ESTI 530 ±140	MATE MANLEY	92 IPV	/A - A/ - A/ 0 A/		not seen	LONGACKE 75 II WA	
320 ± 60	CUTKOSKY	80 IPV			<b>⊿</b> (1930) PH	OTON DECAY AMPLITU	DES
195 ± 60	HOEHLER	79 IPV			$\Delta(1930) \rightarrow N\gamma$ , helicity-1/2	amplitude A _{1/2}	
<ul> <li>• • We do not use the following</li> <li>350 ± 20</li> </ul>	ng data for average ARNDT		VA $\gamma N \rightarrow \pi N$		VALUE (GeV ^{-1/2} )	- <i>t</i> -	COMMENT
590	ARNDT		$VA  \gamma N \rightarrow \pi N$ $VA  \pi N \rightarrow N \pi$	1	-0.009±0.028 OUR ESTIMATE		
260	LI	93 IPV	$VA  \gamma N \rightarrow \pi N$	-	$-0.007\pm0.010$ $0.009\pm0.009$		$\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$
$74.8^{+}_{-}$ $\begin{array}{c} 17.0 \\ 16.0 \end{array}$	CHEW	80 BP	$NA \pi^+ p \rightarrow \pi^+ p$		$-0.030\pm0.003$		$\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$
442	CRAWFORD		$NA \gamma N \rightarrow \pi N$		<ul> <li>◆ ◆ We do not use the following</li> </ul>		
462 	BARBOUR	78 DP	$NA \gamma N \rightarrow \pi N$		$-0.019\pm0.001 \\ -0.062\pm0.064$		$\gamma N \rightarrow \pi N$
Δ(	1930) POLE PO	SITION					$\gamma N \rightarrow \pi N$
REAL PART	•				$\Delta(1930) \rightarrow N\gamma$ , helicity-3/2	-1-	
VALUE (MeV)	DOCUMENT ID	TEC	N COMMENT		VALUE (GeV ^{-1/2} ) -0.018±0.028 OUR ESTIMATE	DOCUMENT ID TECN	COMMENT
1913	ARNDT	95 DP		ı	0.005 ± 0.010	ARNDT 96 IPWA	$\gamma N \rightarrow \pi N$
1850	1 HOEHLER	93 SPI			$-0.025\pm0.011$		$\gamma N \rightarrow \pi N$
1890±50 • • • We do not use the followi	CUTKOSKY  ng data for average	80 IPV s, fits, lim			-0.033±0.060		$\gamma N \rightarrow \pi N$
2018	ARNDT		$NA \pi N \rightarrow \pi N Soln SM9$	0	<ul> <li>• • We do not use the following</li> <li>0.009±0.001</li> </ul>	•	etc. • • • $\gamma N \rightarrow \pi N$
-2×IMAGINARY PART					+0.019±0.054		$\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$
VALUE (MeV)	DOCUMENT ID	TEC	N COMMENT	_			
246	ARNDT		$NA \rightarrow N\pi$			1930) FOOTNOTES	
180 260±60	1 HOEHLER CUTKOSKY	93 SPI 80 IPV			1 See HOEHLER 93 for a detaile	d discussion of the evidence for rmined from Argand diagrams o	
• • • We do not use the following						e speeds with which the amplitude	
398	ARNDT	91 DP	$NA \pi N \rightarrow \pi N \text{ Soln SM9}$	0	² The range given for DEANS 75	is from the four best solutions.	
				_	Δ(	1930) REFERENCES	
<b>∆</b> (1930	) ELASTIC PO	LE RESI	DUE		•	hysics Letters <b>111B</b> 70 (1982).	
MODULUS  r					ror carry references, see r	nysics Ectters 1110 70 (1702).	
VALUE (MeV)	DOCUMENT ID	TEC			ARNDT 96 PR C53 430 ARNDT 95 PR C52 2120	+Strakovsky, Workman +Strakovsky, Workman, Pavan	(VPI) (VPI, BRCO)
8 20	ARNDT HOEHLER	95 DP' 93 SPE		ı	HOEHLER 93 π N Newsletter 9 1 LI 93 PR C47 2759	+Arndt, Roper, Workman	(KARL) (VPI)
18±6	CUTKOSKY		$A \pi N \rightarrow \pi N$		MANLEY 92 PR D45 4002	+Saleski	(KĖNT) I.
• • We do not use the following	g data for average				ARNDT 91 PR D43 2131	Manley, Arndt, Goradia, Teplitz +Li, Roper, Workman, Ford	(VPI) (VPI, TELE) I.
15	ARNDT	91 DP	$NA \pi N \rightarrow \pi N Soln SM9$	0	CANDLIN 84 NP B238 477 PDG 82 PL 111B	+Lowe, Peach, Scotland+ Roos, Porter, Aguilar-Benitez+	(EDIN, RAL, LOWC) (HELS, CIT, CERN)
PHASE θ					AWA JI 81 Bonn Conf. 352 Also 82 NP B197 365	+Kajikawa Fujii, Hayashii, Iwata, Kajikawa+	(NAGO) (NAGO)
VALUE (°)	DOCUMENT ID	TEC			CHEW 80 Toronto Conf. 123 CRAWFORD 80 Toronto Conf. 107		(LBL) I. (GLAS)
-47 -20±40	ARNDT		$NA \pi N \rightarrow N\pi$	ı	CUTKOSKY 80 Toronto Conf. 19 Also 79 PR D20 2839	+Forsyth, Babcock, Kelly, Hendrick Cutkosky, Forsyth, Hendrick, Kelly	(CMŮ, LBL) I. (CMU, LBL) I.
- 20 ± 40 • • • We do not use the following	CUTKOSKY g data for average		$'A  \pi N \rightarrow \pi N$ its, etc. • •		LIVANOS 80 Toronto Conf. 35 HOEHLER 79 PDAT 12-1	+Baton, Coutures, Kochowski, Neve +Kaiser, Koch, Pietarinen	u (SACL) I. (KARLT) I.
- 24	ARNDT		$NA \pi N \rightarrow \pi N Soln SM90$	0	Also 80 Toronto Conf. 3 BARBOUR 78 NP B141 253	Koch +Crawford, Parsons	(KARLT) I (GLAS)
	1020) DECAY	40056		_	DEANS 75 NP B96 90 LONGACRE 75 PL 55B 415	+Mitchell, Montgomery+ +Rosenfeld, Lasinski, Smadja+	(SFLA, ALAH) I. (LBL, SLAC) I.
· ·	1930) DECAY I						
The following branching	tractions are our e	stimates,	not fits or averages.		$\Delta(1940) D_{33}$	$I(J^P) = \frac{3}{2}(\frac{3}{2})$	) Status: *
Mode		Fraction (	Γ ₁ /Γ)		_(		
$\Gamma_1$ $N\pi$		10-20 %		<del></del>	OMITTED FROM SUMMAR	RY TABLE	
$\Gamma_2 \Sigma K$						△(1940) MASS	
$\Gamma_3 N\pi\pi$						MILETAN) INIVIOS	
$\Gamma_4 = N \gamma$		0.0-0.02			VALUE (MeV)	DOCUMENT ID TECN	COMMENT
$\Gamma_5$ $N\gamma$ , helicity=1/2		0.0-0.01			≈ 1940 OUR ESTIMATE 2057 ±110	MANLEY 92 IPWA 1	πN → πN & Nππ
$\Gamma_6$ $N\gamma$ , helicity=3/2		0.0-0.01	<b>6</b>	_	2057 ±110 2058.1± 34.5		$\pi^+ \rho \rightarrow \pi^+ \rho$
<b>∆</b> (19:	30) BRANCHIN	G RATIO	os		1940 ±100		$\pi N \rightarrow \pi N$
$\Gamma(N\pi)/\Gamma_{ ext{total}}$			Γ _{1/}	/r		△(1940) WIDTH	
VALUE	DOCUMENT ID	TEC		_		~(~)TO) WID III	
0.1 to 0.2 OUR ESTIMATE				-	VALUE (MeV)		COMMENT
0.18±0.02 0.14±0.04	MANLEY CUTKOSKY		$^{\prime}A$ $\pi N \rightarrow \pi N \& N \pi \pi$ $^{\prime}A$ $\pi N \rightarrow \pi N$		460 ±320		$\pi N \rightarrow \pi N \& N \pi \pi$
0.04±0.03	HOEHLER		$A \pi N \rightarrow \pi N$ $A \pi N \rightarrow \pi N$		$198.4 \pm 45.5$ $200 \pm 100$		$\pi^+ \rho \rightarrow \pi^+ \rho$ $\pi N \rightarrow \pi N$
• • We do not use the following							
.11	ARNDT CHEW		VA $\pi N \rightarrow N \pi$ VA $\pi^+ p \rightarrow \pi^+ p$	1	<b>∆</b> (19	40) POLE POSITION	
1.1			$VA = \pi : D \rightarrow \pi : D$				
0.11	CHEW	OU DEV			REAL PART		
$\Gamma_I \Gamma_f)^{1/2} / \Gamma_{ ext{total}}  ext{ in } N\pi  o \Delta(1)$		ou bry	(Γ ₁ Γ ₂ ) ^{1/2} /	<b>′</b> Γ	REAL PART VALUE (MeV) 1900 ± 100		$\tau N \to \pi N$

 $\bullet$   $\bullet$   $\bullet$  We do not use the following data for averages, fits, limits, etc.  $\bullet$   $\bullet$ 

-0.031

0.018 to 0.035

LIVANOS ² DEANS

80 DPWA  $\pi p \rightarrow \Sigma K$ 75 DPWA  $\pi N \rightarrow \Sigma K$ 

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \rightarrow$	$\Delta(1930) \rightarrow N\pi\pi$ $(\Gamma_1\Gamma_3)^{\frac{1}{2}}/I$
VALUE	DOCUMENT ID TECN COMMENT
not seen	LONGACRE 75 IPWA $\pi N  o N \pi \pi$
<b>∆</b> (1930	) PHOTON DECAY AMPLITUDES
$\Delta$ (1930) $ ightarrow$ $N\gamma$ , helicit	y-1/2 amplitude A _{1/2}
VALUE (GeV ^{-1/2} )	DOCUMENT ID TECN COMMENT
0.009±0.028 OUR ESTIM 0.007±0.010	ARNDT 96 IPWA $\gamma N \rightarrow \pi N$
$0.009 \pm 0.009$	AWAJI 81 DPWA $\gamma N \rightarrow \pi N$
$-0.030\pm0.047$	CRAWFORD 80 DPWA $\gamma N \rightarrow \pi N$
• • We do not use the fol	owing data for averages, fits, limits, etc. • • •
-0.019±0.001	LI 93 IPWA $\gamma N \rightarrow \pi N$
$-0.062 \pm 0.064$	BARBOUR 78 DPWA $\gamma N \to \pi N$
$\Delta(1930)  o N\gamma$ , helicit	/-3/2 amplitude A _{3/2}
/ALUE (GeV ^{-1/2} )	DOCUMENT ID TECN COMMENT
-0.018±0.028 OUR ESTIM	ATE
0.005 ± 0.010	ARNDT 96 IPWA $\gamma N \rightarrow \pi N$
-0.025±0.011	AWAJI 81 DPWA $\gamma N \rightarrow \pi N$
-0.033±0.060	CRAWFORD 80 DPWA $\gamma N \to \pi N$
	owing data for averages, fits, limits, etc. • •
0.009±0.001	LI 93 IPWA $\gamma N \rightarrow \pi N$
⊦0.019±0.054	BARBOUR 78 DPWA $\gamma N \rightarrow \pi N$
amplitudes and from plots	letailed discussion of the evidence for and the pole parameter determined from Argand diagrams of $\pi$ $N$ elastic partial-wave of the speeds with which the amplitudes traverse the diagrams NS 75 is from the four best solutions.
amplitudes and from plot: ² The range given for DEA	determined from Argand diagrams of π N elastic partial-wave of the speeds with which the amplitudes traverse the diagrams NS 75 is from the four best solutions.  Δ(1930) REFERENCES
amplitudes and from plot.  The range given for DEA  For early references,	determined from Argand diagrams of $\pi$ $N$ elastic partial-wave of the speeds with which the amplitudes traverse the diagrams NS 75 is from the four best solutions. $\Delta (1930) \text{ REFERENCES}$ see Physics Letters 111B 70 (1982).
amplitudes and from plot.  2 The range given for DEA  For early references,  ARNDT 96 PR C53 430  ARNDT 95 PR C52 2120  IOEHICER 93 TA Newslett  AISO 84 PR D39 030  AISO 84 PR D39 040  AISO 84 PR D39 040  AISO 84 PR D39 040  AISO 82 NP B197 365  IANDLIN 84 NP B238 477  PDG 82 PL 111B  WAJI 81 Bonn Conf. 3  AISO 82 NP B197 365  ICHEW 80 Toronto Conf  CRAWFORD 80 Toronto Conf  AISO 97 PR D20 2839  IVANOS 80 Toronto Conf  OEHICER 79 PDAT 12-1  AISO 80 TORONTO CONF  AISO 80 TORONTO C	s determined from Argand diagrams of $\pi$ $N$ elastic partial-wave of the speeds with which the amplitudes traverse the diagrams NS 75 is from the four best solutions.  **A(1930) REFERENCES**  see Physics Letters 1118 70 (1982).  + Strakovsky, Workman Pavan (VPI) Partial North Parti
amplitudes and from plot. 2 The range given for DEA  For early references, ARNDT 96 PR C53 430  RRNDT 95 PR C52 2120  IOEHLER 93 #A Newslett AINDLIN 92 PR D45 4002  AISO 84 PR D39 080  AISO 84 PR D39 080  AISO 82 PL 111B  WAJI 81 Bonn Conf. 3  AISO 82 PR B197 365  HEW 80 Toronto Conf  RAWFORD 80 Toronto Conf  AISO 97 PR D20 2839  ICANOS 80 TORONTO CONF  AISO 80 TORONTO CONF  AISO 90 PR D20 2839  ICANOS 80 TORONTO CONF  AISO 80 TORONTO CONF  AISO 80 TORONTO CONF  AISO 90 TORONTO CONF  AISO 90 TORONTO CONF  AISO 80 TORONTO C	determined from Argand diagrams of $\pi$ $N$ elastic partial-wave of the speeds with which the amplitudes traverse the diagrams NS 75 is from the four best solutions.  A(1930) REFERENCES  see Physics Letters 111B 70 (1982).  +Strakovsky, Workman +Strakovsky, Workman, Pavan (VPI, BRCO)  f 9 1  +Arndt, Roper, Workman +Saleski (KENT) UP +Saleski (KENT) UP +Li, Roper, Workman, Ford +Lowe, Pach, Scotland+ (EDIN, RAL, LOWC) Roos, Porter, Aguilar-Benitez+ (HELS, CIT, CERN)  123 107 107 108 109 109 119 120 130 140 150 150 150 150 150 150 150 150 150 15
amplitudes and from plot.  2 The range given for DEA  For early references,  IRNDT 96 PR C53 430  IRNDT 95 PR C52 2120  IOEHLER 93 TA Newslett  Also 84 PR D39 078  ANLEY 92 PR D45 4002  Also 84 PR D39 084  IRNDT 91 PR D43 2131  ANDLIN 84 NP B238 477  DG 82 PL 111B  WAJI 81 Bonn Conf. 3  Also 82 NP B197 365  HEW 80 Toronto Conf.  ICHOW S0 TORONTO CONF.  ICHOW S0 TORONTO CONF.  Also 80 TORONTO CONF.  ALSO 90 TOR	of determined from Argand diagrams of $\pi$ $N$ elastic partial-wave of the speeds with which the amplitudes traverse the diagrams NS 75 is from the four best solutions.  A(1930) REFERENCES  see Physics Letters 111B 70 (1982).  + Strakovsky, Workman + Strakovsky, Workman, Pavan + Arndt, Roper, Workman + Saleski Manley, Arndt, Goradia, Tepitz + Li, Roper, Workman, Ford + Lowe, Peach, Scotland+ + Koos, Porter, Aguilar-Benitez+ + Kajikawa 107 19 + Forsyth, Babcock, Kelly, Hendrick Cutbosky, Forsyth, Hendrick, Kelly 35 + Baton, Coutures, Kochowski, Neveu + Kaiser, Koch, Pietarinen Koch + Crawford, Parsons + Mitchell, Montgomey+ + Rosenfeld, Lasinski, Smadja+ $I(J^P) = \frac{3}{2}(\frac{3}{2}) \text{ Status: } *$
amplitudes and from plot.  2 The range given for DEA  For early references,  ARNDT 96 PR C53 430  ARNDT 95 PR C52 2120  Also 34 PR D30 904  ARNDT 91 PR D43 2131  ANDLIN 34 NP B238 477  PG 92 PL 118  WAJ II 81 Bonn Conf. 3  Also 84 PR D30 904  Also 84 PR D30 904  ARNDT 91 PR D43 2131  CANDLIN 84 NP B238 477  PG 92 PL 118  WAJ II 81 Bonn Conf. 3  LINEW 80 Toronto Conf.  CHEW 80 Toronto Conf.  CUTKOSKY 80 Toronto Conf.  Also 79 PR D20 280  Also 80 Toronto Conf.  CHEW 90 PR D20 280  AND 9 PR D20 2	determined from Argand diagrams of $\pi$ $N$ elastic partial-wave of the speeds with which the amplitudes traverse the diagrams NS 75 is from the four best solutions.  A(1930) REFERENCES  see Physics Letters 111B 70 (1982).  +Strakovsky, Workman + Strakovsky, Workman Pavan (VPI) + Arndt, Roper, Workman + Saleski Manley, Arndt, Goradia, Teplitz + Li., Roper, Workman, Ford + Lowe, Peach, Scotland+ Roos, Porter, Aguilar-Benitez+ (HELS, CIT, CERN) + Kajikawa + Ka
amplitudes and from plot.  2 The range given for DEA  For early references,  ARNDT 96 PR C53 430  ARNDT 95 PR C52 210  AISO 37 PR PO43 213  ANDLIN 38 PR D30 904  AISO 84 PR D30 904  AISO 97 PR D20 280  AISO 80 PB 197 365  HEW 80 Toronto Conf  CUTKOSKY 80 Toronto Conf  CUTKOSKY 80 Toronto Conf  CUTKOSKY 80 Toronto Conf  CUTKOSKY 80 Toronto Conf  AISO 97 PR D20 280  JUANOS 80 Toronto Conf  AISO 97 PR D20 280  AISO 80 Toronto Conf  OICHILER 97 PDAT 125  AISO 80 TORONTO CONF  AISO 75 PR D86 90  ONGACRE 75 PL 558 415   DMITTED FROM SUM  ALUE (MeV)	determined from Argand diagrams of π N elastic partial-wave of the speeds with which the amplitudes traverse the diagrams NS 75 is from the four best solutions.  A(1930) REFERENCES  see Physics Letters 111B 70 (1982).  +Strakovsky, Workman +Strakovsky, Workman, Pavan +Strakovsky, Workman, Pavan (VPI, BRCO)  1 +Arndt, Roper, Workman +Saleski, Arndt, Goradia, Tepitz +Li, Roper, Workman, Ford +Lowe, Peach, Scotland+ +Lowe, Peach, Scotland+ +Kajikawa  12 + Kajikawa 107  19 + Forsyth, Babcock, Kelly, Hendrick Cutbocky, Fortyth, Hendrick, Kelly 103 + Babon, Coutures, Kordonski, Neveu +Kajier, Kord, Pietarinen Noch
amplitudes and from plot.  2 The range given for DEA  For early references,  ARNDT 96 PR C53 430 ARNDT 95 PR C52 2120 HOEHLER 93 PR C47 2759 MANLEY 92 PR D45 4020 MANULEY 92 PR D45 903 MANULEY 93 PR D45 923 MANULEY 94 PR D45 923 MANULEY 95	determined from Argand diagrams of $\pi$ $N$ elastic partial-wave of the speeds with which the amplitudes traverse the diagrams NS 75 is from the four best solutions.           A(1930) REFERENCES         see Physics Letters 111B 70 (1982).         +Strakovsky, Workman       (VPI), BRCO)         +Strakovsky, Workman, Pavan       (VPI), BRCO)         + Arndt, Roper, Workman       (VRI)         + Arndt, Roper, Workman       (VPI)         + Asieski       (KENT) UP         + Li, Roper, Workman, Ford       (VPI, TELE) UP         + Li, Roper, Workman, Ford       (VPI, TELE) UP         + Lowe, Peach, Scotland+       (EDIN, RAL, LOWC)         + Kajikawa       (NAGO)         Fujii, Hayashii, Iwata, Kajikawa+       (HELS, CIT, CERN)         123       (GLAS)         104       (GLAS)         105       + Forsyth, Babcock, Kelly, Hendrick       (CMU, LBL) UP         35       + Baton, Coutures, Kochowski, Neveu       (SACL) UP         + Kaliser, Koch, Pietarinen       (KARTI) UP         3       Koch       (KARTI) UP         4       (SACL) UP         1       (FLA, ALAH) UP         4       (RART) UP         4       (RART) UP         4       (RART) UP         5       (SACL) UP

-2×IMAGINARY PART

VALUE (MeV)

 $200\pm60$ 

# Baryon Particle Listings $\Delta(1940)$ , $\Delta(1950)$

### △(1940) ELASTIC POLE RESIDUE

MODULUS  r
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VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
8±3	CUTKOSKY 80	IPWA	$\pi N \rightarrow \pi N$

### PHASE $\theta$

VALUE (-)	DOCUMENT ID		TECH	COMMENT
135±45	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

### △(1940) DECAY MODES

	Mode
Γ1	Nπ
$\Gamma_2$	$\Sigma K$
$\Gamma_3$	$N\pi\pi$
$\Gamma_4$	$\Delta(1232)\pi$ , <i>S</i> -wave
$\Gamma_5$	$\Delta(1232)\pi$ , $D$ -wave
$\Gamma_6$	$N\rho$ , $S=3/2$ , S-wave
$\Gamma_7$	$N\gamma$ , helicity=1/2
Γ8	$N\gamma$ , helicity=3/2

### △(1940) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$			Γ ₁ /Γ
VALUE	DOCUMENT ID	TECN	COMMENT
$0.18 \pm 0.12$	MANLEY	92 · IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
0.18	CHEW	80 BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho$
$0.05 \pm 0.02$	CUTKOSKY	80 IPWA	$\pi N \rightarrow \pi N$

$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\pi \to \Delta$	Δ(1940) → Σ <i>K</i>		(Γ₁Γ₂) ^½ /Γ
VALUE	DOCUMENT ID	TECN	COMMENT
< 0.015	CANDLIN 84	DPWA	$\pi^+ p \rightarrow \Sigma^+ K^+$

$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\pi \to \Delta$	(1940) → △(1232)	π , <i>S</i> -wav	e (Γ ₁ Γ ₄ ) ^{1/2} /Γ
VALUE	DOCUMENT ID	TECN	COMMENT
1011 ± 010	MANIEV	22 IDVVV	-NN & N

$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N \pi \to \infty$	$\Delta$ (1940) $\rightarrow \Delta$ (1232) $\pi$	, <i>D</i> -wav	re (Γ ₁ Γ ₅ ) ^{1/2} /Γ
VALUE	DOCUMENT ID	TECN	COMMENT
$+0.27 \pm 0.16$	MANLEY 92	<b>IPWA</b>	$\pi N \rightarrow \pi N \& N \pi \pi$

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \to \Delta(1)$	$940) \rightarrow N\rho, S=3$	/2, <i>S</i> -wa	ve $(\Gamma_1\Gamma_6)^{\frac{1}{2}}/\Gamma$
VALUE	DOCUMENT ID	TECN	COMMENT
$+0.25\pm0.10$	MANLEY 92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$

### △(1940) PHOTON DECAY AMPLITUDES

### $\Delta$ (1940) $\rightarrow N\gamma$ , helicity-1/2 amplitude A_{1/2}

VALUE (GeV-1/2)	DOCUMENT ID		TECN	COMMENT
$-0.036 \pm 0.058$	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
4(4040) 44 4 11 11 0 0 0				

### $\Delta$ (1940) $\rightarrow N\gamma$ , helicity-3/2 amplitude A_{3/2}

VALUE (GeV ^{-1/2} )	DOCUMENT ID	TECN	COMMENT
$-0.031 \pm 0.012$	AWAJI 81	DPWA	$\gamma N \rightarrow \pi N$

### △(1940) FOOTNOTES

### △(1940) REFERENCES

MANLEY	92	PR D45 4002	+Saleski	(KENT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
CANDLIN	84	NP B238 477	+Lowe, Peach, Scotland+	(EDIN, RAL, LOWC)
ILAWA	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
CHEW	80	Toronto Conf. 123		(LBL) IJP
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMU, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)

## $\Delta(1950) F_{37}$

 $I(J^P) = \frac{3}{2}(\frac{7}{2}^+)$  Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

### △(1950) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1940 to 1960 (≈ 1950) (	OUR ESTIMATE			
1945 ± 2	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
1950 ±15	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
l913 ± 8	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the f	following data for average	s, fit	s, limits,	etc. • • •
1947 ± 9	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
921	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
.940	LI	93	IPWA	$\gamma N \rightarrow \pi N$
1925 ±20	CANDLIN	84	DPWA	$\pi^+ p \rightarrow \Sigma^+ K^+$
1855.0 + 11.0 - 10.0	CHEW	80	BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho$
902	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
912	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
925	¹ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

### △(1950) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
290 to 350 (≈ 300) OUR ESTIM	IATE			
300 ± 7	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
340 ±50	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
224 ±10	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the following	data for average	s, fit	s, limits,	etc. • • •
302 ± 9	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
232	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
306	LI			$\gamma N \rightarrow \pi N$
330 ±40	CANDLIN	84	DPWA	$\pi^+ p \rightarrow \Sigma^+ K^+$
$157.2^{+22.0}_{-19.0}$	CHEW	80	BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho$
225	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
198	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
240	¹ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

### $\Delta$ (1950) POLE POSITION

### REAL PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1880	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1878	² HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
1890±15	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the follow	ing data for average	s, fit	s, limits,	etc. • • •
1884	ARNDT			$\pi N \rightarrow \pi N \text{ SoIn SM90}$
1924 or 1924	³ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
-2×IMAGINARY PART				
-ZXIIVIAGIIVAN I FAN I				
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
	ARNDT	95		$\frac{\textit{COMMENT}}{\pi  \textit{N}  \rightarrow   \textit{N}  \pi}$
VALUE (MeV)	ARNDT		DPWA	
VALUE (MeV)	ARNDT	93	DPWA ARGD	$\pi N \rightarrow N \pi$
VALUE (MeV) 236 230	ARNDT  PROBLER CUTKOSKY	93 80	DPWA ARGD IPWA	$ \begin{array}{ccc} \pi  N \to & N \pi \\ \pi  N \to & \pi  N \\ \pi  N \to & \pi  N \end{array} $
236 230 260 ± 40	ARNDT  PROBLER CUTKOSKY	93 80 s, fit	DPWA ARGD IPWA s, limits,	$ \begin{array}{ccc} \pi  N \to & N \pi \\ \pi  N \to & \pi  N \\ \pi  N \to & \pi  N \end{array} $

### △(1950) ELASTIC POLE RESIDUE

DOCUMENT ID TECN COMMENT

# MODULUS |r|

54	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
47	HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
50±7	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
ullet $ullet$ We do not use the following d	ata for averages	, fits,	, limits, e	etc. • • •
61	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
PHASE θ				
VALUE (°)	DOCUMENT ID		TECN	COMMENT
		95		$\frac{COMMENT}{\pi N \rightarrow N \pi}$
VALUE (°)			DPWA	$\pi N \rightarrow N \pi$
<u>VALUE</u> (°) — 17	ARNDT	93	DPWA ARGD	$ \begin{array}{ccc} \pi  N \to & N  \pi \\ \pi  N \to & \pi  N \end{array} $
VALUE (°) -17 -32	ARNDT HOEHLER CUTKOSKY	93 80	DPWA ARGD IPWA	$ \begin{array}{ccc} \pi  N \longrightarrow & N  \pi \\ \pi  N \longrightarrow & \pi  N \\ \pi  N \longrightarrow & \pi  N \end{array} $

 $^{^1}$  LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to  $\pi\,N\to~N\,\pi\,\pi$  data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.

### △(1950) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction $(\Gamma_i/\Gamma)$	
$\overline{\Gamma_1}$	Νπ	35-40 %	
$\Gamma_2$	ΣΚ		
Γ3	$N\pi\pi$		
$\Gamma_4$	$\Delta\pi$	20-30 %	
$\Gamma_5$	${\it \Delta}(1232)\pi$ , $\it F-wave$		
$\Gamma_6$	$\Delta$ (1232) $\pi$ , $\emph{H}$ -wave		
Γ ₇	$N\rho$	<10 %	
Γ8	$N\rho$ , $S=1/2$ , $F$ -wave		
Г9	$N\rho$ , $S=3/2$ , $F$ -wave		
$\Gamma_{10}$	$N\gamma$	0.08-0.13 %	
Γ11	$N\gamma$ , helicity=1/2	0.03-0.055 %	
$\Gamma_{12}$	$N\gamma$ , helicity=3/2	0.05-0.075 %	

### △(1950) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$				$\Gamma_1/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT
0.35 to 0.4 OUR ESTIMAT	ΓE			
0.38 ± 0.01	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
0.39 ± 0.04	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
0.38±0.02	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
<ul> <li>• • We do not use the f</li> </ul>	following data for average	s, fit	s, limits,	etc. • • •
0.49	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
0.44	CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{ ext{total}}$ in $N\pi$ -	$\rightarrow \Delta(1950) \rightarrow \Sigma K$ DOCUMENT ID		TECN	$(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma$
	CANDLIN	0.4		$\pi^+ \rho \rightarrow \Sigma^+ K^+$
$-0.053 \pm 0.005$		84	DPVVA	

Note: Signs of couplings from  $\pi N \to N \pi \pi$  analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the  $\Delta(1620)$   $S_{31}$ coupling to  $\Delta(1232)\pi$ .

75 DPWA  $\pi N \rightarrow \Sigma K$ 

⁴ DEANS

VALUE	$N\pi \to \Delta(1950) \to \Delta(1232)\pi$ , F-wave $(\Gamma_1\Gamma_5)^{\frac{1}{2}}$
+0.28 to +0.32 OU	
$+0.27\pm0.02$	MANLEY 92 IPWA $\pi N \rightarrow \pi N \& N \pi \pi$
+0.32	1 LONGACRE 75 IPWA $\pi$ N $ ightarrow$ N $\pi$ $\pi$
• • • We do not us	e the following data for averages, fits, limits, etc. • •
0.21	⁵ NOVOSELLER 78 IPWA $\pi N \rightarrow N \pi \pi$
0.38	6 NOVOSELLER 78 IPWA $\pi N \to N \pi \pi$
$(\Gamma_I\Gamma_f)^{\frac{1}{2}}/\Gamma_{ ext{total}}$ in	$N\pi \rightarrow \Delta(1950) \rightarrow N\rho$ , $S=3/2$ , $F$ -wave $(\Gamma_1\Gamma_9)^{\frac{1}{2}}/2$
	DOCUMENT ID TECN COMMENT
$(\Gamma_I \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}}$ in $\frac{VALUE}{+0.24}$	
+0.24	DOCUMENT ID TECN COMMENT
+0.24	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$

### △(1950) PHOTON DECAY AMPLITUDES

### $\Delta(1950) \rightarrow N\gamma$ , helicity-1/2 amplitude A_{1/2}

VALUE (GeV ^{-1/2} )	DOCUMENT ID		TECN	COMMENT
-0.076±0.012 OUR ESTIMATE				
$-0.079 \pm 0.006$	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
$-0.068 \pm 0.007$	AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$
$-0.091 \pm 0.005$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
$-0.083 \pm 0.005$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
$-0.067 \pm 0.014$	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
• • • We do not use the following	data for average	s, fit	s, limits,	etc. • • •
$-0.102 \pm 0.003$	LI	93	IPWA	$\gamma N \rightarrow \pi N$
$-0.058 \pm 0.013$	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$

### $\Delta(1950) \rightarrow N\gamma$ , helicity-3/2 amplitude A_{3/2}

VALUE (GeV ^{-1/2} )	DOCUMENT ID		TECN	COMMENT
-0.097±0.010 OUR ESTIMATE				
$-0.103 \pm 0.006$	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
$-0.094 \pm 0.016$	AWA JI	81	DPWA	$\gamma N \rightarrow \pi N$
$-0.101 \pm 0.005$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
$-0.100 \pm 0.005$	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
$-0.082 \pm 0.017$	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
• • We do not use the following	data for average	s, fit	s, limits,	etc. • • •
$-0.115 \pm 0.003$	LI	93	<b>IPWA</b>	$\gamma N \rightarrow \pi N$
$-0.075\pm0.020$	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$

### △(1950) FOOTNOTES

- $^{
  m 1}$  From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix
- amplitudes.  2  See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and  $\Delta$  resonances as determined from Argand diagrams of  $\pi N$  elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.  2  LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to  $\pi N \to N\pi\pi$  data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.
- (LERN) partial-wave analysis.

  4 The range given is from the four best solutions. DEANS 75 disagrees with  $\pi^+ \rho \to \Sigma^+ K^+$  data of WINNIK 77 around 1920 MeV.

  5 A Breit-Wigner fit to the HERNDON 75 IPWA; the phase is near  $-60^\circ$ .

  6 A Breit-Wigner fit to the NOVOSELLER 788 IPWA; the phase is near  $-60^\circ$ .

- ⁷A Breit-Wigner fit to the HERNDON 75 IPWA; the phase is near 120°.
- ⁸ A Breit-Wigner fit to the NOVOSELLER 78B IPWA; the phase is near 120°.

### △(1950) REFERENCES

ARNDT ARNDT	96 95	PR C53 430 PR C52 2120	+Strakovsky, Workman +Strakovsky, Workman, Pavan	(VPI) (VPI, BRCO)
HOEHLER	93 93	π N Newsletter 9 1 PR C47 2759	And Dens Malana	(KARL) (VPI)
LI			+Arndt, Roper, Workman +Saleski	
MANLEY	92	PR D45 4002		(KENT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
CANDLIN	84	NP B238 477	+Lowe, Peach, Scotland+	(EDIN, RAL, LOWC)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
AWA JI	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
ARAI	80	Toronto Conf. 93		(INUS)
Also	82	NP B194 251	Arai, Fujii	(INUS)
CHEW	80	Toronto Conf. 123		(LBL) IJP
CRAWFORD	80	Toronto Conf. 107		(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMÚ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)
NOVOSELLER	78	NP B137 509		(CIT) IJP
NOVOSELLER	788	NP B137 445		(CIT) IJP
WINNIK	77	NP B128 66	+Toaff, Revel, Goldberg, Berny	(ĤAIF) I
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ALAH) IJP
HERNDON	75	PR D11 3183	+Longacre, Miller, Rosenfeld+	(LBL, SLAC)
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC) IJP
				(== 2) 02.10) 131

 $\Delta$ (2000)  $F_{35}$ 

 $I(J^P) = \frac{3}{2}(\frac{5}{2}^+)$  Status: **

OMITTED FROM SUMMARY TABLE

### △(2000) MASS

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
≈ 2000 OUR ESTIMATE			
1752± 32	MANLEY 92	PWA	$\pi N \rightarrow \pi N \& N \pi \pi$
$2200 \pm 125$	CUTKOSKY 80	IPWA	$\pi N \rightarrow \pi N$

### △(2000) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
251 ± 93	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
$400 \pm 125$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

### △(2000) POLE POSITION

### **REAL PART**

DOCUMENT ID TECN COMMENT  $2150\pm100$ CUTKOSKY 80 IPWA  $\pi N \rightarrow \pi N$ 

### -2×IMAGINARY PART

DOCUMENT ID TECN COMMENT VALUE (MeV) 350 ± 100 CUTKOSKY 80 IPWA  $\pi N \rightarrow \pi N$ 

### △(2000) ELASTIC POLE RESIDUE

### MODULUS |r|

VALUE (MeV) DOCUMENT ID TECN COMMENT CUTKOSKY 80 IPWA  $\pi N \rightarrow \pi N$  $16\pm5$ 

### PHASE $\theta$

DOCUMENT ID TECN COMMENT CUTKOSKY 80 IPWA  $\pi N \rightarrow \pi N$ 150±90

### △(2000) DECAY MODES

### Mode Nπ

 $\Gamma_1$ Νππ  $\Gamma_2$ 

 $\Delta(1232)\pi$ , P-wave Гз

 $\Delta(1232)\pi$  ,  $\emph{F} ext{-wave}$ 

 $N\rho$ , S=3/2, P-wave

 $\Delta(2000)$ ,  $\Delta(2150)$ ,  $\Delta(2200)$ 

$\Delta(2000)$	BRANCHING	RATIOS
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$\Gamma(N\pi)/\Gamma_{\text{total}}$			Γ ₁ /Γ
VALUE	DOCUMENT ID	TECN	COMMENT
$0.02 \pm 0.01$	MANLEY 92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
$0.07 \pm 0.04$	CUTKOSKY 80	IPWA	$\pi N \rightarrow \pi N$
(F.F.)1/2/Fin N=	A(2000) . A(1222)-	. Dum	re (Γ.Γ.)½/Γ

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \to A$	$\Delta(2000) \rightarrow \Delta(123)$	$2)\pi$	, <i>P</i> -wav	e $(\Gamma_1\Gamma_3)^{72}/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT
+0.07±0.03	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \to \Delta(2)$	ve (Γ ₁ Γ ₄ ) ^{1/2} /Γ		
VALUE	DOCUMENT ID	TECN	COMMENT
+0.09±0.04	MANLEY	92 IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \to \Delta(2000) \to N\rho$ , $S=3/2$ , $P$ -wave						
VALUE	DOCUMENT ID	TECN	COMMENT			
$-0.06 \pm 0.01$	MANLEY 92	IPWA	$\pi N \rightarrow \pi N \&$	$N\pi\pi$		

### △(2000) REFERENCES

MANLEY	92	PR D45 4002	+Saleski	(KENT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMU, LBL)
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL)

$\Delta$ (21	50)	$S_{31}$

 $I(J^P) = \frac{3}{2}(\frac{1}{2}^-)$  Status: *

### OMITTED FROM SUMMARY TABLE

△(2150) MASS							
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT			
≈ 2150 OUR ESTIMATE							
2047.4± 27.0	¹ CHEW	80	<b>BPWA</b>	$\pi^+ p \rightarrow \pi^+ p$			
2203.2± 8.4	¹ CHEW	80	<b>BPWA</b>	$\pi^+ p \rightarrow \pi^+ p$			
2150 ±100	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$			

### △(2150) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
ELIO L GEIG	¹ CHEW			$\pi^+ p \rightarrow \pi^+ p$
120.5 ± 45.0	¹ CHEW	80	BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho$
200 ±100	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

### $\Delta$ (2150) POLE POSITION

REAL PART VALUE (MeV)	DOCUMENT ID		TECN_	COMMENT
2140±80	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
-2×IMAGINARY PART				
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
200 ± 80	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

### △(2150) ELASTIC POLE RESIDUE

MODULUS  r	DOCUMENT ID	TECN	COMMENT
7±2	CUTKOSKY 80	IPWA	$\pi N \rightarrow \pi N$
PHASE $\theta$			
VALUE (°)	DOCUMENT ID	TECN	COMMENT
-60±90	CUTKOSKY 80	IPWA	$\pi N \rightarrow \pi N$

### △(2150) DECAY MODES

	Mode				
Γ ₁	Νπ				
$\Gamma_2$	$\Sigma K$				

### △(2150) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$					$\Gamma_1/$
VALUE	DOCUMENT ID		TECN	COMMENT	
0.41	¹ CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$	
0.37	¹ CHEW	80	<b>BPWA</b>	$\pi^+ p \rightarrow \pi^+ p$	
$0.08 \pm 0.02$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	

$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\pi \to \Delta(21)$	50) → Σ <i>K</i>				(Γ ₁ Γ ₂ ) ^{1/2} /Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
<0.03	CANDLIN	84	DPWA	$\pi^+ p \rightarrow$	$\Sigma^+ \kappa^+$

### △(2150) FOOTNOTES

 1  CHEW 80 reports two  $S_{31}$  resonances in this mass region. Problems with this analysis are discussed in section 2.1.11 of HOEHLER 83.

### △(2150) REFERENCES

CANDLIN	84	NP B238 477 +Lowe, Peach, Scotland+	(EDIN, RAL, LOWC)
HOEHLER	83	Landolt-Boernstein 1/9B2	(KARLT)
CHEW	80	Toronto Conf. 123	(LBL) IJP
CUTKOSKY	80	Toronto Conf. 19 +Forsyth, Babcock, Kelly, Hendrick	(CMU, LBL) IJP
Also	79	PR D20 2839 Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL)

 $\Delta(2200) G_{37}$ 

 $I(J^P) = \frac{3}{2}(\frac{7}{2})$  Status: *

OMITTED FROM SUMMARY TABLE

The various analyses are not in good agreement.

### △(2200) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 2200 OUR ESTIMATE				
2200 ± 80	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
2215±60	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
2280±80	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$
• • We do not use the following	g data for average	es, fit	s, limits,	etc. • • •
$2280\pm40$	CANDLIN	84	DPWA	$\pi^+ \rho \rightarrow \Sigma^+ K^+$

### △(2200) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
450±100	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
$400 \pm 100$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
$400 \pm 150$	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following d	ata for averages	, fits	, limits,	etc. • • •
400 ± 50	CANDLIN	84	DPWA	$\pi^+ \rho \rightarrow \Sigma^+ K^+$

### $\Delta$ (2200) POLE POSITION

REAL PART  VALUE (MeV)	DOCUMENT ID	TEC	CN	COMMENT
$2100 \pm 50$	CUTKOSKY 8	30 IPV	VΑ	$\pi N \rightarrow \pi N$
-2×IMAGINARY PART				
VALUE (MeV)	DOCUMENT ID	TEC	CN	COMMENT
$340\pm80$	CUTKOSKY 8	30 IPV	NΑ	$\pi N \rightarrow \pi N$

# Δ(2200) ELASTIC POLE RESIDUE

MODULUS	r	
VALUE (MeV)		

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
8±3	CUTKOSKY 8	80	IPWA	$\pi N \rightarrow \pi N$
PHASE $\theta$				
VALUE (°)	DOCUMENT ID		TECN	COMMENT
$-70\pm40$	CUTKOSKY 8	80	IPWA	$\pi N \rightarrow \pi N$

### $\Delta$ (2200) DECAY MODES

	Mode	
Γ ₁	Νπ	
$\Gamma_2$	$\Sigma K$	

### $\Delta$ (2200) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$					$\Gamma_1/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT	
$0.06 \pm 0.02$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
$0.05 \pm 0.02$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$	
$0.09 \pm 0.02$	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$	

$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N \pi \to \Delta 0$	(2200) → Σ <i>K</i>				$(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT	
$-0.014 \pm 0.005$	CANDLIN	84	DPWA	$\pi^+ p \rightarrow$	$\Sigma^+ K^+$

### △(2200) REFERENCES

		•	•	
84	NP B238 477		+Lowe, Peach, Scotland+	(EDIN, RAL, LOWC)
80	Toronto Conf.	19	+Forsyth, Babcock, Kelly, Hendrick	(CMU, LBL) IJI
79	PR D20 2839		Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJI
79	PDAT 12-1		+Kaiser, Koch, Pietarinen	(KARLT) IJI
80	Toronto Conf.	3	Koch	(KARLT) IJI
78	PRL 41 222			(IND, LBL) IJF
81	ANP 136 1		Hendry	(IND)
	80 79 79 80 78	80 Toronto Conf. 79 PR D20 2839 79 PDAT 12-1 80 Toronto Conf. 78 PRL 41 222	80 Toronto Conf. 19 79 PR D20 2839 79 PDAT 12-1 80 Toronto Conf. 3 78 PRL 41 222	80 Toronto Conf. 19 +Forsyth, Babcock, Kelly, Hendrick 79 PR D20 2839 Cutkosky, Forsyth, Hendrick, Kelly 79 PDAT 12-1 +Kaiser, Koch, Pietarinen 80 Toronto Conf. 3 80 PRL 41 222 Koch

$\Delta(2300)~H_{39}$		² ) =	$=\frac{3}{2}(\frac{9}{2})^{-1}$	⁺ ) Status: **
OWITTED TROOF SOMM	△(2300) MA	SS		
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 2300 OUR ESTIMATE	BOCOMENT ID		7207	
2204.5± 3.4	CHEW			$\pi^+ \rho \rightarrow \pi^+ \rho$
$2400 \pm 125$ $2217 \pm 80$	CUTKOSKY HOEHLER	80 79		$\pi N \rightarrow \pi N$ $\pi N \rightarrow \pi N$
2450 ±100	HENDRY	78		$\pi N \rightarrow \pi N$
<ul> <li>We do not use the following</li> </ul>				
2400	CANDLIN	84	DPWA	$\pi^+ \rho \rightarrow \Sigma^+ K^+$
	△(2300) WID	HT		
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
32.3± 1.0	CHEW			$\pi^+ p \rightarrow \pi^+ p$
425 ±150 300 ±100	CUTKOSKY HOEHLER	80 79		$\pi N \rightarrow \pi N$ $\pi N \rightarrow \pi N$
500 ±200	HENDRY	78		$\pi N \rightarrow \pi N$
• • We do not use the following	ng data for average	es, fits	, limits,	etc. • • •
200	CANDLIN	84	DPWA	$\pi^+ \rho \rightarrow \Sigma^+ K^+$
Δ	(2300) POLE PO	OSIT	ION	
REAL PART	DOCUMENT ID		TECN	COMMENT
VALUE (MeV) 2370±80	CUTKOSKY			$\pi N \rightarrow \pi N$
	2311123111	•		
-2×IMAGINARY PART VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
420±160	CUTKOSKY		IPWA	
VALUE (MeV)	DOCUMENT ID			$\frac{COMMENT}{\pi N \rightarrow \pi N}$
		80	IPVVA	
10±4	CUTKOSKY	80	IPVVA	
10±4 <b>PHASE</b> <i>θ</i>	CUTKOSKY			
10±4 <b>PHASE</b> <i>θ</i>			TECN	
10±4  PHASE # WALUE (*) - 20±30	CUTKOSKY	80	TECN IPWA	COMMENT
10±4  PHASE # WALUE (*) - 20±30	DOCUMENT ID	80	TECN IPWA	COMMENT
PHASE θ  (ALUE(°)  -20±30  Mode  1 Nπ	DOCUMENT ID	80	TECN IPWA	COMMENT
PHASE θ  ALUE (°)  -20±30  Mode  1 Nπ 2 Σ K	CUTKOSKY  DOCUMENT ID CUTKOSKY  (2300) DECAY	80 <b>MO</b> E	TECN IPWA DES	COMMENT
PHASE θ  VALUE (°)  -20±30  Mode  Γ ₁ Nπ  Γ ₂ Σ Κ	DOCUMENT ID	80 <b>MO</b> E	TECN IPWA DES	COMMENT
PHASE $\theta$ VALUE (°) $-20\pm30$ Mode $ \Gamma_1  N\pi $ $ \Gamma_2  \Sigma K $ $ \Delta (23)$	CUTKOSKY  DOCUMENT ID CUTKOSKY  (2300) DECAY	MOE	TECN IPWA DES	$rac{COMMENT}{\piN ightarrow\piN}$
PHASE $\theta$ VALUE (°) $-20\pm30$ Mode $\Gamma_{1}  N\pi$ $\Gamma_{2}  \Sigma K$ $\Delta (23)$ $\Gamma(N\pi)/\Gamma_{\text{total}}$ VALUE 0.05	CUTKOSKY  DOCUMENT ID CUTKOSKY  (2300) DECAY  DOCUMENT ID CHEW	80 MOE	TECN IPWA DES  ATIOS  TECN BPWA	$\frac{\textit{COMMENT}}{\pi  \textit{N}  \rightarrow  \pi  \textit{N}}$ $\frac{\textit{COMMENT}}{\pi^+  \textit{p}  \rightarrow  \pi^+  \textit{p}}$
PHASE θ  VALUE (°)  -20±30  Mode  Γ ₁ Nπ  Γ ₂ Σ Κ  Δ(23)  Γ(Nπ)/Γtotal  VALUE  0.05  0.06±0.02	CUTKOSKY  DOCUMENT ID CUTKOSKY  (2300) DECAY  DOCUMENT ID CHEW CUTKOSKY	80 BG R.	TECN IPWA DES	$\begin{array}{c} \textit{COMMENT} \\ \pi  \textit{N}  \rightarrow  \pi  \textit{N} \end{array}$
PHASE $\theta$ VALUE (°) $-20\pm30$ Mode $\Gamma_1  N\pi$ $\Gamma_2  \Sigma K$ $\Delta (23)$ $\Gamma(N\pi)/\Gamma_{\text{total}}$ VALUE $0.05$ $0.06\pm0.02$ $0.03\pm0.02$	CUTKOSKY  DOCUMENT ID CUTKOSKY  (2300) DECAY  DOCUMENT ID CHEW	80 MOE	TECN IPWA DES ATIOS TECN BPWA IPWA	$\frac{\textit{COMMENT}}{\pi  \textit{N}  \rightarrow  \pi  \textit{N}}$ $\frac{\textit{COMMENT}}{\pi^+  \textit{p}  \rightarrow  \pi^+  \textit{p}}$
PHASE θ $VALUE(^{\circ})$ $-20\pm30$ Mode $ \Gamma_{1}  N\pi $ $ \Gamma_{2}  \Sigma K $ $ \Delta(23)$ $ \Gamma(N\pi)/\Gamma_{\text{total}} $ $VALUE$ $0.05$ $0.06\pm0.02$ $0.03\pm0.02$ $0.08\pm0.02$	CUTKOSKY  DOCUMENT ID CUTKOSKY  (2300) DECAY  DOCUMENT ID CHEW CUTKOSKY HOEHLER HENDRY	80 MOE IG RA 80 80 79	TECN IPWA DES ATIOS TECN BPWA IPWA	$\begin{array}{c} \textit{COMMENT} \\ \pi  \textit{N}  \rightarrow  \pi  \textit{N} \end{array}$ $\begin{array}{c} \textit{\Gamma}_{1} \textit{I} \\ \\ \textit{COMMENT} \\ \pi^+  p  \rightarrow  \pi^+  p \\ \pi  \textit{N}  \rightarrow  \pi  \textit{N} \end{array}$
PHASE $\theta$ VALUE (°) $-20\pm30$ Mode $\Gamma_{1}  N\pi$ $\Gamma_{2}  \Sigma K$ $\Delta (23)$ $\Gamma(N\pi)/\Gamma_{\text{total}}$ VALUE $0.05$ $0.06\pm0.02$ $0.03\pm0.02$ $(\Gamma_{1}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\pi \rightarrow \Delta (VALUE)$ VALUE	CUTKOSKY  DOCUMENT ID CUTKOSKY  (2300) DECAY  DOCUMENT ID CHEW CUTKOSKY HOEHLER HENDRY  (2300) → ∑K DOCUMENT ID	80 MOE 80 80 79 78	TECN IPWA DES  ATIOS  TECN BPWA IPWA IPWA MPWA TECN	$\begin{array}{c} \text{COMMENT} \\ \pi  N  \to  \pi  N \\ \\ \hline \\ \frac{\text{COMMENT}}{\pi^+ p  \to  \pi^+ \rho} \\ \pi  N  \to  \pi  N \\ \hline \\ \text{COMMENT} \\ \\ \end{array}$
PHASE $\theta$ VALUE (°) $-20\pm30$ Mode $\Gamma_{1}  N\pi$ $\Gamma_{2}  \Sigma K$ $\Delta (23)$ $\Gamma(N\pi)/\Gamma_{\text{total}}$ VALUE $0.05$ $0.06\pm0.02$ $0.03\pm0.02$ $(\Gamma_{1}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\pi \rightarrow \Delta (VALUE)$ VALUE	CUTKOSKY  DOCUMENT ID CUTKOSKY  (2300) DECAY  DOCUMENT ID CHEW CUTKOSKY HOEHLER HENDRY  (2300) → ∑K	80 MOE IG RA 80 80 79	TECN IPWA DES  ATIOS  TECN BPWA IPWA IPWA MPWA TECN	$\begin{array}{c} \textit{COMMENT} \\ \pi  \textit{N}  \rightarrow  \pi  \textit{N} \end{array}$ $\begin{array}{c} \textit{COMMENT} \\ \pi^+  \rho  \rightarrow  \pi^+  \rho \\ \pi  \textit{N}  \rightarrow  \pi  \textit{N} \\ \pi  \textit{N}  \rightarrow  \pi  \textit{N} \\ \pi  \textit{N}  \rightarrow  \pi  \textit{N} \end{array}$ $(\Gamma_1 \Gamma_2)^{\frac{1}{2}} \mathcal{I}_{2}^{1}$
10 $\pm$ 4  PHASE $\theta$ VALUE (°) $-20\pm30$	CUTKOSKY  DOCUMENT ID CUTKOSKY  (2300) DECAY  DOCUMENT ID CHEW CUTKOSKY HOEHLER HENDRY  (2300) → ∑K DOCUMENT ID	80 B0 80 79 78	TECN IPWA  TECN BPWA IPWA IPWA MPWA TECN DPWA	$\begin{array}{c} \text{COMMENT} \\ \pi  N  \to  \pi  N \\ \\ \hline \\ \frac{\text{COMMENT}}{\pi^+ p  \to  \pi^+ \rho} \\ \pi  N  \to  \pi  N \\ \hline \\ \text{COMMENT} \\ \\ \end{array}$
10 $\pm$ 4  PHASE $\theta$ VALUE (°) $-20\pm30$	CUTKOSKY  DOCUMENT ID CUTKOSKY  (2300) DECAY  DOCUMENT ID CHEW CUTKOSKY HOEHLER HENDRY (2300) → ∑K DOCUMENT ID CANDLIN  (2300) REFER! +Lowe, Peach,	80 MOE 80 80 79 78	TECN IPWA  DES  ATIOS  TECN IPWA IPWA IPWA IPWA DPWA TECN DPWA	$\begin{array}{c} COMMENT \\ \pi N \to \pi N \end{array}$ $\begin{array}{c} \Gamma_{1} \\ COMMENT \\ \pi^{+} p \to \pi^{+} p \\ \pi N \to \pi N \\ \pi N \to \pi N \\ \pi N \to \pi N \end{array}$ $\begin{array}{c} (\Gamma_{1} \Gamma_{2})^{\frac{1}{2}} \\ COMMENT \\ \pi^{+} p \to \Sigma^{+} K^{+} \end{array}$ $(FDIN RALLOWC)$
PHASE $\theta$ VALUE (°) $-20\pm30$ Mode $\Gamma_{1}  N\pi$ $\Gamma_{2}  \Sigma K$ $\Delta (23)$ $\Gamma(N\pi)/\Gamma_{\text{total}}$ VALUE $0.05$ $0.06\pm0.02$ $0.03\pm0.02$ $0.08\pm0.02$ $(\Gamma_{1}\Gamma_{7})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \rightarrow \Delta (17)$ VALUE $-0.017$ CANDLIN $0.01$ $0.02$ $0.01$ $0.01$ $0.02$ $0.01$ $0.03$ $0.02$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$ $0.03$	CUTKOSKY  DOCUMENT ID CUTKOSKY  (2300) DECAY  DOCUMENT ID CHEW CUTKOSKY HOEHLER HENDRY  (2300) → FK DOCUMENT ID CANDLIN  A(2300) REFER: +Lowe, Peach, 13	80  MOE  80 80 79 78  84  ENCI	TECN IPWA  DES  ATIOS  TECN IPWA IPWA IPWA MPWA  TECN DPWA  TECN DPWA	$\begin{array}{c} COMMENT \\ \pi N \to \pi N \end{array}$ $\begin{array}{c} \Gamma_{1} \\ COMMENT \\ \pi^{+} p \to \pi^{+} p \\ \pi N \to \pi N \\ \pi N \to \pi N \\ \pi N \to \pi N \end{array}$ $\begin{array}{c} (\Gamma_{1} \Gamma_{2})^{\frac{1}{2}} \\ COMMENT \\ \pi^{+} p \to \Sigma^{+} K^{+} \end{array}$ $(FDIN RALLOWC)$
PHASE $\theta$ VALUE (°) $-20\pm30$ Mode $\Gamma_1 \qquad N\pi$ $\Gamma_2 \qquad \Sigma \qquad K$ $\Delta (23)$ $\Gamma(N\pi)/\Gamma_{total}$ VALUE  0.05  0.06 $\pm$ 0.02  0.08 $\pm$ 0.02 $(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{total} \text{ in } N\pi \rightarrow \Delta (100)$ CANDLIN  84  NP B238 477  TOTORIO Conf. 15  Also  79  PR D20 2839  PR D20 2839  OEHLER 79  PP D20 2839  PP D20 2839  POEHLER 79  PP D412-1	CUTKOSKY  DOCUMENT ID CUTKOSKY  (2300) DECAY  DOCUMENT ID CHEW CUTKOSKY HOEHLER HENDRY (2300) → ∑K DOCUMENT ID CANDLIN  1(2300) REFER  + Forsyth, Babec Cutkosky, Forsy + Kaiser, Koch,	80  MOE  80  80  79  78  84  ENCI.	TECN IPWA  DES  TECN IPWA IPWA IPWA IPWA IPWA IPWA IPWA IPWA	$\begin{array}{c} COMMENT \\ \pi  N  \rightarrow  \pi  N \end{array}$ $\begin{array}{c} \Gamma_{1}, \\ COMMENT \\ \pi^{+}  \rho  \rightarrow  \pi^{+}  \rho \\ \pi  N  \rightarrow  \pi  N \\ \pi  N  \rightarrow  \pi  N \\ \pi  N  \rightarrow  \pi  N \end{array}$ $\begin{array}{c} (\Gamma_{1} \Gamma_{2})^{\frac{1}{2}}, \\ COMMENT \\ \pi^{+}  \rho  \rightarrow  \Sigma^{+}  K^{+} \end{array}$ $\begin{array}{c} (EDIN, RAL, LOWC) \\ (LBL)I \\ (CMU, LBL) \\ (CMU, LBL) \\ (CMU, LBL) \\ (KARLT)I \\ (KARLT$
10 $\pm$ 4  PHASE $\theta$ VALUE (°) $-20 \pm 30$ Mode $ \Gamma_1  N\pi $ $ \Gamma_2  \Sigma  K $ $ \Delta(23) $ $ \Gamma(N\pi)/\Gamma_{\text{total}} $ VALUE  0.05  0.06 $\pm$ 0.02  0.08 $\pm$ 0.02  0.08 $\pm$ 0.02  ( $\Gamma_1\Gamma_\Gamma$ )\frac{1/2}{2}/\Gamma_{\text{total}} \text{ in } N\pi \rightarrow \Delta(\text{VALUE}\)  -0.017  CANDLIN  84   \text{NP B238 477}  \text{CHEW}  \text{80}  \text{Toronto Conf. 15}  \text{CUTKOSKY 80}  \text{Toronto Conf. 15}  \text{COTKOSKY 80}  \text{Toronto Conf. 15}  \text{Toronto Conf. 15}  \text{NP D20 2839}  \text{Toronto Conf. 15}   \text{Toronto Conf. 15}  \text{Toronto Conf. 15}   \text{Toronto Conf. 15}   \text{Toronto Conf. 15}  \text{Toronto Conf. 15}   \text{Toronto Conf. 15}   \text{Toronto Conf. 15}   \text{Toronto Conf. 15}   \text{Toronto Conf. 15}    \text{Toronto Conf. 15}        \text{Toronto Conf. 15}                                                                                 \qu	CUTKOSKY  DOCUMENT ID CUTKOSKY  (2300) DECAY  (2300) BRANCHIN  DOCUMENT ID CHEW CUTKOSKY HOEHLER HENDRY  (2300) → FK DOCUMENT ID CANDLIN  1(2300) REFERI  + Lowe, Peach, Forsyth, Babec Cutkosky, Forsyth, Babec Cutkosky, Forsyth, Babec	80  MOE  80  80  79  78  84  ENCI.	TECN IPWA  DES  TECN IPWA IPWA IPWA IPWA IPWA IPWA IPWA IPWA	$\begin{array}{c} COMMENT \\ \pi  N  \rightarrow  \pi  N \end{array}$ $\begin{array}{c} \Gamma_{1/2} \\ \hline COMMENT \\ \pi^{+}  p  \rightarrow  \pi^{+}  p \\ \pi  N  \rightarrow  \pi  N \\ \pi  N  \rightarrow  \pi  N \\ \pi  N  \rightarrow  \pi  N \end{array}$ $\begin{array}{c} COMMENT \\ \pi^{+}  \rho  \rightarrow  \Sigma^{+}  K^{+} \end{array}$ $\begin{array}{c} COMMENT \\ \hline \pi^{+}  \rho  \rightarrow  \Sigma^{+}  K^{+} \end{array}$ $\begin{array}{c} COMMENT \\ \hline \pi^{+}  \rho  \rightarrow  \Sigma^{+}  K^{+} \end{array}$ $\begin{array}{c} COMMENT \\ \hline (EDIN, RAL, LOWC) \\ (LBL)I. \\ (CMU, LBL)I. \\ (EMI, LBL)I. \\ (CMU, LBL)I. \\ (CMU, LBL)I. \end{array}$

OMITTED FROM SUMM				
	△(2350) MA	SS		
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 2350 OUR ESTIMATE 2171± 18	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
2400 ± 125	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
2305 ± 26	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
	△(2350) WID	тн		
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
264 ± 51	MANLEY	92		$\pi N \rightarrow \pi N \& N \pi \pi$
400 ± 150	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
300± 70	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
Δ	(2350) POLE PO	SIT	ION	
REAL PART VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
2400±125	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
-2×IMAGINARY PART	DOCUMENT ID		TECN	COMMENT
VALUE (MeV) 400 ± 150	DOCUMENT ID	80		$\pi N \rightarrow \pi N$
400 ± 150	COTROSKT	- 00	IFVVA	# 1V → # 1V
△(2356	) ELASTIC PO	LE F	RESIDU	E
MODULUS  r				
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
15±8	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
PHASE θ				
VALUE (°)	DOCUMENT ID		TECN	COMMENT
-70±70	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
		MOI	DES	
Δ	(2350) DECAY			
<b>∆</b> Mode	(2350) DECAY			
Mode Γ ₁	(2350) DECAY		<del></del>	
Mode Γ ₁	(2350) DECAY			
Mode Γ ₁	(2350) DECAY		ATIOS	
Mode $ \frac{\Gamma_1  N\pi}{\Gamma_2  \Sigma K} $ $ \Delta(23) $	50) BRANCHIN			Γ ₁ /
Mode $ \Gamma_1  N\pi $ $ \Gamma_2  \Sigma K $ $ \Delta (23) $ $ \Gamma(N\pi)/\Gamma_{\text{total}} $ VALUE	550) BRANCHIN	IG R	<u>TECN</u>	COMMENT
Mode $ \Gamma_1 \qquad N\pi \\ \Gamma_2 \qquad \Sigma K $ $ \Delta (23) $ $ \Gamma(N\pi)/\Gamma_{\text{total}} $ VALUE $ 0.020 \pm 0.003 $	B50) BRANCHIN  DOCUMENT ID  MANLEY		<u>TECN</u>	
Mode $ \Gamma_1 \qquad N\pi \\ \Gamma_2 \qquad \Sigma K $ $ \Delta (23) $ $ \Gamma(N\pi)/\Gamma_{\text{total}} $ $ VALUE $ $ 0.020 \pm 0.003 $ $ 0.20 \pm 0.10 $	550) BRANCHIN	<b>IG R</b>	TECN IPWA	$\frac{COMMENT}{\pi N \rightarrow \pi N \& N \pi \pi}$
Mode	DOCUMENT ID  MANLEY CUTKOSKY HOEHLER	92 80	TECN IPWA IPWA	$\begin{array}{c} COMMENT \\ \hline \pi \ N \ \rightarrow \ \pi \ N \ \& \ N \pi \pi \\ \hline \pi \ N \ \rightarrow \ \pi \ N \\ \hline \pi \ N \ \rightarrow \ \pi \ N \end{array}$
Mode $ \Gamma_1 \qquad N\pi \\ \Gamma_2 \qquad \Sigma K $ $ \Delta(23) $ $ \Gamma(N\pi)/\Gamma_{\text{total}} $ $ \frac{VAUUE}{0.020 \pm 0.103} $ $ 0.02  \pm 0.10 $ $ 0.04  \pm 0.02 $ $ (\Gamma_I \Gamma_I)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\pi \rightarrow \Delta I $	DOCUMENT ID  MANLEY CUTKOSKY HOEHLER  (2350) → Σ Κ	92 80	TECN IPWA IPWA IPWA	$ \begin{array}{c} COMMENT \\ \pi N \to \pi N \& N \pi \pi \\ \pi N \to \pi N \\ \pi N \to \pi N \end{array} $ $ \pi (\Gamma_1 \Gamma_2)^{\frac{1}{2}} $
Mode $ \Gamma_{1} \qquad N\pi \\ \Gamma_{2} \qquad \Sigma K $ $ \Delta (23) $ $ \Gamma(N\pi)/\Gamma_{\text{total}} $ $ \frac{NALUE}{0.020 \pm 0.003} $ $ 0.20 \pm 0.10 $ $ 0.04 \pm 0.02 $ $ (\Gamma/\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\pi \rightarrow \Delta (23) $ $ \frac{N\pi}{N} = \frac{1}{N\pi} \left( \frac{1}{N\pi} \right)^{\frac{1}{2}} \left( \frac{1}{N\pi} \right)^{1$	DOCUMENT ID  MANLEY CUTKOSKY HOEHLER  (2350) → Σ K DOCUMENT ID	92 80 79	TECN IPWA IPWA IPWA	$\begin{array}{c} \underline{COMMENT} \\ \pi  N \to \pi  N  \&  N \pi \pi \\ \pi  N \to \pi  N \\ \pi  N \to \pi  N \end{array}$ $(\Gamma_1 \Gamma_2)^{\frac{1}{2}} \mathcal{COMMENT}$
Mode $ \Gamma_1 \qquad N\pi \\ \Gamma_2 \qquad \Sigma K $ $ \Delta(23) $ $ \Gamma(N\pi)/\Gamma_{\text{total}} $ $ \frac{VAUUE}{0.020 \pm 0.103} $ $ 0.02  \pm 0.10 $ $ 0.04  \pm 0.02 $ $ (\Gamma_I \Gamma_I)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\pi \rightarrow \Delta I $	DOCUMENT ID  MANLEY CUTKOSKY HOEHLER  (2350) → Σ Κ	92 80	TECN IPWA IPWA IPWA	$ \frac{COMMENT}{\pi N \to \pi N \& N\pi\pi} $ $ \pi N \to \pi N $ $ \pi N \to \pi N $ $ \pi N \to \pi N $ $ (\Gamma_1 \Gamma_2)^{\frac{1}{2}} $
Mode $ \Gamma_{1}  N\pi \\ \Gamma_{2}  \Sigma K $ $ \Delta (23) $ $ \Gamma(N\pi)/\Gamma_{\text{total}} $ $ \frac{VALUE}{\sqrt{\Gamma_{1}}} $ $ \frac{VALUE}{\sqrt{\Gamma_{1}}} $ $ \sqrt{\Gamma_{1}} $ $ \sqrt{\Gamma_{2}} $ $ \sqrt{\Gamma_{1}} $ $ \sqrt{\Gamma_{1}} $ $ \sqrt{\Gamma_{2}} $ $ \sqrt{\Gamma_{2}} $ $ \sqrt{\Gamma_{2}} $ $ \sqrt{\Gamma_{1}} $ $ \sqrt{\Gamma_{2}} $ $ \sqrt{\Gamma_{2}} $ $ \sqrt{\Gamma_{1}} $ $ \sqrt{\Gamma_{2}} $ $ \sqrt{\Gamma_{2}} $ $ \sqrt{\Gamma_{2}} $ $ \sqrt{\Gamma_{2}} $ $ \sqrt{\Gamma_{1}} $ $ \sqrt{\Gamma_{2}} $ $ \sqrt{\Gamma_{2}} $ $ \sqrt{\Gamma_{2}} $ $ \sqrt{\Gamma_{1}} $ $ \sqrt{\Gamma_{2}} $ $ \Gamma_{$	DOCUMENT ID  MANLEY CUTKOSKY HOEHLER  (2350) → Σ K DOCUMENT ID	92 80 79	TECN IPWA IPWA IPWA TECN DPWA	$\begin{array}{c} \underline{COMMENT} \\ \pi  N \to \pi  N  \&  N \pi \pi \\ \pi  N \to \pi  N \\ \pi  N \to \pi  N \\ \hline \pi  N \to \pi  N \\ \hline (\Gamma_1 \Gamma_2)^{1/2} / \\ \underline{COMMENT} \\ \pi^+  \rho \to \Sigma^+  K^+ \end{array}$
Mode $ \Gamma_{1}  N\pi $ $ \Gamma_{2}  \Sigma K $ $ \Delta(23) $ $ \Gamma(N\pi)/\Gamma_{\text{total}} $ $ VALUE $ $ 0.020 \pm 0.003 $ $ 0.04 \pm 0.02 $ $ (\Gamma_{1}\Gamma_{1})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\pi \rightarrow \Delta(1) $ $ VALUE $ $ < 0.015 $ MANLEY  92 PR D45 4002	DOCUMENT ID  MANLEY CUTKOSKY HOEHLER  (2350) → ∑ K DOCUMENT ID CANDLIN  1(2350) REFERI	92 80 79 84	TECN IPWA IPWA IPWA TECN DPWA	$\begin{array}{c} \underline{COMMENT} \\ \pi  N \to \pi  N  \&  N \pi \pi \\ \pi  N \to \pi  N \\ \pi  N \to \pi  N \end{array}$ $\begin{array}{c} (\Gamma_1 \Gamma_2)^{\frac{1}{2}} \\ \underline{COMMENT} \\ \pi^+ \rho \to \Sigma^+ K^+ \end{array}$ $(KENT)  L$
Mode  Γ ₁ $N\pi$ Γ ₂ $\Sigma K$ Δ(23)  Γ(Nπ)/Γtotal  VALUE 0.020±0.003 0.02 ±0.10 0.04 ±0.02  (Γ _Γ Γ _Γ ) ^{1/2} /Γtotal in Nπ → Δ(100)  MANLEY 92 PR D45 4002 Also 84 PR D30 904 CANDLIN 84 PR D30 904 CANDLIN 84 PR D38 477	DOCUMENT ID  MANLEY CUTKOSKY HOEHLER  (2350) → ∑ K DOCUMENT ID CANDLIN  1(2350) REFERI  +Saleski Manley, Arndt, +Lowe, Peach, S	92 80 79 84 ENC	TECN IPWA IPWA IPWA DPWA  ES	$\begin{array}{c} \underline{COMMENT} \\ \pi  N \to \pi  N  \&  N \pi \pi \\ \pi  N \to \pi  N \\ \pi  N \to \pi  N \\ \hline \\ \underline{(\Gamma_1 \Gamma_2)^{\frac{1}{2}}}_{\ell_2} \\ \underline{COMMENT} \\ \pi^+  \rho \to \Sigma^+  K^+ \\ \hline \\ (KENT)  I. \\ (VP) \\ (VP) \end{array}$
Mode $ \Gamma_{1}  N\pi $ $ \Gamma_{2}  \Sigma K $ $ \Delta(23) $ $ \Gamma(N\pi)/\Gamma_{\text{total}} $ $ \frac{VALUE}{0.020 \pm 0.003} $ $ 0.20 \pm 0.10 $ $ 0.04 \pm 0.02 $ $ (\Gamma/\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \rightarrow \Delta(100) $ $ \frac{VALUE}{Also} $ MANLEY  92  PR D30 904	DOCUMENT ID  MANLEY CUTKOSKY HOEHLER  (2350) → ∑K DOCUMENT ID CANDLIN  1(2350) REFERI  +Saleski Manley, Arndt, LOWe, Peach, 5	92 80 79 84 ENC	TECN IPWA IPWA IPWA DPWA  ES	$\begin{array}{c} \underline{COMMENT} \\ \pi  N \to \pi  N  \&  N \pi \pi \\ \pi  N \to \pi  N \\ \pi  N \to \pi  N \\ \hline \chi  N \to \pi  N \\ \underline{COMMENT} \\ \pi^+  p \to \Sigma^+  K^+ \\ \vdots \\ (EDIN, RAL, LOWC) \\ \text{ick} \\ (CMU, LBL), \end{array}$

 $\Delta(2390), \Delta(2400)$ 

$\Delta(2390) F_{37}$	I(J ^F	) =	$=\frac{3}{2}(\frac{7}{2})^{-1}$	⁺ ) Status: *
OMITTED FROM SUMM	ARY TABLE			
	<b>∆(2390)</b> MA	SS		
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 2390 OUR ESTIMATE	CUTKOSKY	00	IPWA	$\pi N \rightarrow \pi N$
2350±100 2425± 60	CUTKOSKY HOEHLER			$\pi N \rightarrow \pi N$ $\pi N \rightarrow \pi N$
	△(2390) WID	ТН		
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
300±100	CUTKOSKY		IPWA	
300± 80	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
Δ	(2390) POLE PO	SIT	ION	
REAL PART	DOCUMENT ID		TECN	COMMENT
VALUE (MeV) 2350 ± 100	DOCUMENT ID			
	COTROSKT	00	" "	x 10 → x 10
-2×IMAGINARY PART	DOCUMENT ID		TECN	COMMENT
260±100	CUTKOSKY		IPWA	
Δ(239	0) ELASTIC PO	LE F	RESIDU	JE
MODULUS  r				
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
12±6	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
PHASE <i>0</i>				
VALUE (°)	DOCUMENT ID			COMMENT
- 90±60	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
Δ	(2390) DECAY	OM	DES	
Mode				
Γ ₁ Νπ Γ ₂ ΣΚ				
	390) BRANCHIN	G R	ATIOS	
$\Gamma(N\pi)/\Gamma_{\text{total}}$				Γ ₁ /Γ
VALUE	DOCUMENT ID			COMMENT
0.08±0.04	CUTKOSKY HOEHLER		IPWA IPWA	$\pi N \rightarrow \pi N$ $\pi N \rightarrow \pi N$
0.07±0.04		19	IF VVA	
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi  o \Delta 0$				(Γ₁Γ₂) ^⅓ 2/Γ
VALUE	DOCUMENT ID			COMMENT
< 0.015	CANDLIN	84	DPWA	$\pi^+ \rho \rightarrow \Sigma^+ K^+$

△(2390) REFERENCES

NP B238 477 Toronto Conf. 19 PR D20 2839 PDAT 12-1 Toronto Conf. 3

CANDLIN CUTKOSKY Also HOEHLER Also

+Lowe, Peach, Scotland+ +Forsyth, Babcock, Kelly, Hendrick Cutkosky, Forsyth, Hendrick, Kelly +Kaiser, Koch, Pietarinen Koch

(EDIN, RAL, LOWC) (CMU, LBL) IJP (CMU, LBL) (KARLT) IJP (KARLT) IJP

$\Delta$ (2400)	$G_{39}$

 $I(J^P) = \frac{3}{2}(\frac{9}{2}^-)$  Status: **

	<b>⊿(2400)</b> MA	SS			
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
≈ 2400 OUR ESTIMATE					
2300 ± 100	CUTKOSKY HOEHLER		IPWA IPWA		
2468 ± 50 2200 ± 100	HENDRY			$\pi N \rightarrow \pi N$ $\pi N \rightarrow \pi N$	
	△(2400) WID	ТН			
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
$330 \pm 100$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
480±100	HOEHLER		IPWA		
450±200	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$	
Δ	(2400) POLE PO	SIT	ION		
REAL PART VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
2260±60	CUTKOSKY		IPWA		
	COTROSKT	80	IF VVA	$\pi W \rightarrow \pi W$	
-2×IMAGINARY PART	DOCUMENT ID		TECN	COMMENT	
$320 \pm 160$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
△(240	0) ELASTIC PO	LE F	RESIDU	E	
MODULUS  r					
VALUE (MeV)	DOCUMENT ID				
B±4	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
PHASE θ					
VALUE (°)	DOCUMENT ID				
- 25 ± 15	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
4	(2400) DECAY	MOI	DES		
Mode	***************************************				
$\Gamma_1 N\pi$					
Γ ₂ ΣΚ					
Δ(2	400) BRANCHIN	G R	ATIOS		
$\Gamma(N\pi)/\Gamma_{total}$					1/
VALUE	DOCUMENT ID			COMMENT	
0.05 ± 0.02	CUTKOSKY	80			
0.06±0.03 0.10±0.03	HOEHLER HENDRY	79 78		$\pi N \rightarrow \pi N$ $\pi N \rightarrow \pi N$	
		10	WIL ANN		
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi  o \Delta$	(2400) → ΣK			$(\Gamma_1\Gamma_2)$	⅓
VALUE	DOCUMENT ID			COMMENT	
< 0.015	CANDLIN			$\pi^+ \rho \rightarrow \Sigma^+ K^+$	

# △(2400) REFERENCES

< 0.015

CANDLIN CUTKOSKY Also HOEHLER Also HENDRY Also	84 80 79 79 80 78 81	NP B238 477 Toronto Conf. PR D20 2839 PDAT 12-1 Toronto Conf. PRL 41 222 ANP 136 1	+Lowe, Peach, Scotland+ +Forsyth, Babcock, Kelly, Hendrick Cutkosky, Forsyth, Hendrick, Kelly +Kaiser, Koch, Pietarinen Koch Hendry	(EDIN,	RAL, LOWC) (CMU, LBL) IJP (CMU, LBL) (KARLT) IJP (KARLT) IJP (IND, LBL) IJP (IND)

## $\Delta$ (2420) $H_{3,11}$

 $I(J^P) = \frac{3}{2}(\frac{11}{2}^+)$  Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

### △(2420) MASS

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
2300 to 2500 (≈ 2420) OUR EST	IMATE		
2400 ±125	CUTKOSKY 8	0 IPWA	$\pi N \rightarrow \pi N$
2416 ± 17	HOEHLER 7	9 IPWA	$\pi N \rightarrow \pi N$
2400 ± 60	HENDRY 7	8 MPWA	$\pi N \rightarrow \pi N$
ullet $ullet$ We do not use the following	data for averages, t	fits, limits,	etc. • • •
2400	CANDLIN 8	4 DPWA	$\pi^+ \rho \rightarrow \Sigma^+ K^+$
$2358.0 \pm 9.0$	CHEW 8	0 BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho$

### △(2420) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
300 to 500 (≈ 400) OUR ESTIMA	TE			
450 ±150	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
340 ± 28	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
460 ±100	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following of	data for averages,	fits	, limits,	etc. • • •
400				$\pi^+ p \rightarrow \Sigma^+ K^+$
202.2± 45.0	CHEW	80	BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho$

### △(2420) POLE POSITION

REAL PART VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
2300	$^{ m 1}$ HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
$2360 \pm 100$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
-2×IMAGINARY PART				
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
620	¹ HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
420±100	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

### △(2420) ELASTIC POLE RESIDUE

MODULUS  r			
VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
39	HOEHLER 9	93 ARGD	$\pi N \rightarrow \pi N$
18±6	CUTKOSKY 8	80 IPWA	$\pi N \rightarrow \pi N$
PHASE θ			
VALUE (°)	DOCUMENT ID	TECN	COMMENT
-60	HOEHLER 9	93 ARGD	$\pi N \rightarrow \pi N$
20   40	CHTKOCKY	ON IDMAA	- N N

### △(2420) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction $(\Gamma_i/\Gamma)$	
$\Gamma_1$	Νπ	5-15 %	
Г	ΣΚ		

### △(2420) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$				$\Gamma_1/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT
0.05 to 0.15 OUR ESTIMATE				
$0.08 \pm 0.03$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
$0.08 \pm 0.015$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
$0.11 \pm 0.02$	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	data for average	s, fits	s, limits,	etc. • • •
0.22	CHEW	80	BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \to \Delta(24)$	<b>20)</b> → Σ K  DOCUMENT ID		TECN	$(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma$

### $\Delta$ (2420) FOOTNOTES

-0.016

84 DPWA  $\pi^+ p \rightarrow \Sigma^+ K^+$ 

### △(2420) REFERENCES

HOEHLER	93	π N Newsletter 9 1		(KARL)
CANDLIN	84	NP B238 477	+Lowe, Peach, Scotland+	(EDIN, RAL, LOWC)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
CHEW	80	Toronto Conf. 123	•	(LBL) IJP
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMU, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL)
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
HENDRY	78	PRL 41 222		(IND, LBL) IJP
Also	81	ANP 136 1	Hendry	` (IND)

# $\Delta(2750) I_{3,13}$

 $I(J^P) = \frac{3}{2}(\frac{13}{2}^-)$  Status: **

### OMITTED FROM SUMMARY TABLE

△(2750) MASS						
<u>VALUE (MeV)</u> <b>≈ 2750 OUR ESTIMATE</b> 2794 ± 80 2650 ± 100	DOCUMENT ID HOEHLER HENDRY	79 78		$ \begin{array}{ccc} COMMENT \\ \pi N \to & \pi N \\ \pi N \to & \pi N \end{array} $		
Δ(2750) WIDTH						
	△(2750) WID	тн				

### △(2750) DECAY MODES

	Mode		
Γ ₁	Νπ		

### △(2750) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$					$\Gamma_1/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT	
$0.04 \pm 0.015$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$	
$0.05 \pm 0.01$	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$	

△(2750) REFERENCES							
	HOEHLER	79	PDAT 12-1	2	+Kaiser, Koch, Pietarin	nen	(KARLT) IJP
	Also HENDRY	80 78	Toronto Conf. PRL 41 222	3	Koch		(KARLT) IJP (IND, LBL) IJP
	Also	81	ANP 136 1		Hendry		(IND)

## $\Delta$ (2950) $K_{3,15}$

 $I(J^P) = \frac{3}{2}(\frac{15}{2}^+)$  Status: **

### OMITTED FROM SUMMARY TABLE

21(2950) MASS							
VALUE (MeV)	DOCUMENT ID	DOCUMENT ID		COMMENT			
≈ 2950 OUR ESTIMATE							
2990 ± 100	HOEHLER			$\pi N \rightarrow \pi N$			
2850 ± 100	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$			
	∆(2950) Wil	ЭТН					
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT			
330±100	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$			
$700\pm200$	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$			
	△(2950) DECAY	МОГ	DES				
Mode							
$\Gamma_1$ $N\pi$							

VIOLUI MVCC

### △(2950) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$					$\Gamma_1/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT	
$0.04 \pm 0.02$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$	
$0.03 \pm 0.01$	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$	

### △(2950) REFERENCES

HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also HENDRY	80 78	Toronto Conf. 3 PRL 41 222	Koch	(KARLT) IJP (IND. LBL) IJP
Also	81	ANP 136 1	Hendry	(IND)

 $^{^1}$  See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and  $\Delta$  resonances as determined from Argand diagrams of  $\pi$  N elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.

 $\Delta$ ( $\sim$  3000)

# $\Delta (\sim$ 3000 Region) Partial-Wave Analyses

OMITTED FROM SUMMARY TABLE

We list here miscellaneous high-mass candidates for isospin-3/2 resonances found in partial-wave analyses.

Our 1982 edition also had a  $\Delta(2850)$  and a  $\Delta(3230)$ . The evidence for them was deduced from total cross-section and 180° elastic cross-section measurements. The  $\Delta(2850)$  has been resolved into the  $\Delta(2750)$  /_{3,13} and  $\Delta(2950)$   $K_{3,15}$ . The  $\Delta(3230)$  is perhaps related to the  $K_{3,13}$  of HENDRY 78 and to the  $L_{3,17}$  of KOCH 80.

### △(~ 3000) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 3000 OUR ESTIMATE				
3300	¹ косн	80	IPWA	$\pi N \rightarrow \pi N L_{3.17}$ wave
3500	¹ KOCH	80	IPWA	$\pi N \rightarrow \pi N M_{3,19}$ wave
$2850\pm150$	HENDRY	78	MPWA	$\pi N \rightarrow \pi N I_{3,11}$ wave
$3200 \pm 200$	HENDRY	78	MPWA	$\pi N \rightarrow \pi N K_{3,13}$ wave
$3300 \pm 200$	HENDRY	78	MPWA	$\pi N \rightarrow \pi N L_{3,17}$ wave
$3700 \pm 200$	HENDRY	78	MPWA	$\pi N \rightarrow \pi N M_{3,19}$ wave
$4100\pm300$	HENDRY	78	MPWA	$\pi N \rightarrow \pi N N_{3,21}$ wave

### $\Delta$ ( $\sim$ 3000) WIDTH

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
700 ± 200	HENDRY 78	MPWA	$\pi N \rightarrow \pi N I_{3.11}$ wave
$1000\pm300$	HENDRY 78	MPWA	$\pi N \rightarrow \pi N K_{3,13}$ wave
$1100\pm300$	HENDRY 78	MPWA	$\pi N \rightarrow \pi N L_{3,17}$ wave
$1300\pm400$	HENDRY 78	MPWA	$\pi N \rightarrow \pi N M_{3,19}$ wave
$1600\pm500$	HENDRY 78	MPWA	$\pi N \rightarrow \pi N N_{3,21}$ wave

### $\Delta$ (~ 3000) DECAY MODES

	Mode
$\Gamma_1$	Νπ

### $\Delta$ ( $\sim$ 3000) BRANCHING RATIOS

Γ(Nπ)/Γ _{total}	DOCUMENT ID		Γ ₁ /Γ	
VALUE	DOCUMENT ID		TECH CONTRICT	
0.06 ±0.02	HENDRY	78	MPWA $\pi N \rightarrow \pi N I_{3.11}$ wave	
$0.045 \pm 0.02$	HENDRY	78	MPWA $\pi N \rightarrow \pi N K_{3,13}$ wave	
0.03 ±0.01	HENDRY	78	MPWA $\pi N \rightarrow \pi N L_{3.17}$ wave	
$0.025 \pm 0.01$	HENDRY	78	MPWA $\pi N \rightarrow \pi N M_{3,19}$ wave	
$0.018 \pm 0.01$	HENDRY	78	MPWA $\pi N \rightarrow \pi N N_{3,21}$ wave	

### $\Delta$ ( $\sim$ 3000) FOOTNOTES

 $^{1}\,\mathrm{In}$  addition, KOCH 80 reports some evidence for an  $\mathit{S}_{31}\,\Delta(2700)$  and a  $\mathit{P}_{33}\,\Delta(2800).$ 

### $\Delta$ ( $\sim$ 3000) REFERENCES

ЮСН	80	Toronto Conf.	3	(KARLT) IJP
IENDRY	78	PRL 41 222		(IND, LBL) IJP
Also	81	ANP 136 1	Hendry	(IND)

### **1 BARYONS** (S=-1, I=0)

$$\Lambda^0 = uds$$



$$I(J^P) = O(\frac{1}{2}^+)$$
 Status: ***

We have omitted some results that have been superseded by later experiments. See our earlier editions.

#### **A MASS**

The fit uses  $\Lambda$ ,  $\Sigma^+$ ,  $\Sigma^0$ ,  $\Sigma^-$  mass and mass-difference measurements.

VALUE (MeV)	<b>EVTS</b>	DOCUMENT ID		TECN	COMMENT
1115.684±0.006 OUR FI	Т				
1115.683±0.006 OUR AV	/ERAGE				
$1115.678 \pm 0.006 \pm 0.006$	20k	HARTOUNI	94	SPEC	pp 27.5 GeV/c
$1115.690 \pm 0.008 \pm 0.006$	18k	¹ HARTOUNI	94	SPEC	pp 27.5 GeV/c
<ul> <li>• • We do not use the</li> </ul>	following	data for averages	, fits,	limits,	etc. • • •
1115.59 ±0.08	935	HYMAN	72	HEBC	
1115.39 ±0.12	195	MAYEUR	67	<b>EMUL</b>	
1115.6 ±0.4		LONDON	66	HBC	
1115.65 ±0.07	488	² SCHMIDT	65	HBC	
1115.44 ±0.12		³ BHOWMIK	63	RVUE	

- 1  We assume CPT invariance: this is the  $\overline{\Lambda}$  mass as measured by HARTOUNI 94. See below for the fractional mass difference, testing CPT.
- 2  The SCHMIDT 65 masses have been reevaluated using our April 1973 proton and  $K^\pm$ and  $\pi^{\pm}$  masses. P. Schmidt, private communication (1974).
- ³ The mass has been raised 35 keV to take into account a 46 keV increase in the proton mass and an 11 keV decrease in the  $\pi^{\pm}$  mass (note added Reviews of Modern Physics **39** 1 (1967)).

$$(m_A - m_{\overline{A}}) / m_A$$

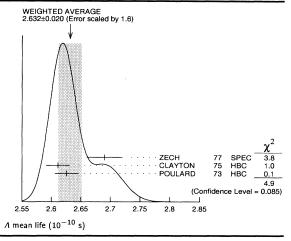
A test of CPT invariance.

VALUE (units 10 ⁻⁵ )  — 1.0 ± 0.9 OUR AVERAGE	DOCUMENT ID		TECN	COMMENT
$\begin{array}{ccc} -& 1.08 \pm & 0.90 \\ -& 26 & \pm 13 \\ & 4.5 & \pm & 5.4 \end{array}$	HARTOUNI BADIER CHIEN	67	нвс	pp 27.5 GeV/ $c2.4 GeV/c \overline{p}p6.9 GeV/c \overline{p}p$

### **1 MEAN LIFE**

Measurements with an error  $~\geq~0.1\times10^{-10}$  s have been omitted altogether, and only the latest high-statistics measurements are used for the average.

EVTS	DOCUMENT ID		TECN	COMMENT
IR AVERAGE	Error includes scale	facto	or of 1.6.	See the ideogram below.
53k	ZECH	77	SPEC	Neutral hyperon beam
34k	CLAYTON	75	HBC	0.96-1.4 GeV/c K-p
36k	POULARD	73	HBC	0.4-2.3 GeV/c K-p
t use the follow	ing data for averages	s, fits	, limits,	etc. • • •
6582	ALTHOFF	73B	OSPK	$\pi^+ n \rightarrow \Lambda K^+$
4572	BALTAY	71B	HBC	$K^-p$ at rest
8342	GRIMM	68	HBC	
2600	HEPP	68	HBC	
916	BURAN	66	HLBC	
2213	ENGELMANN	66	нвс	
794	HUBBARD	64	HBC	
1378	SCHWARTZ	64	HBC	
2239	BLOCK	63	HEBC	
	F AVERAGE 53k 34k 36k t use the follow 6582 4572 8342 2600 916 2213 794 1378	STATE   Error includes scale	Section   Sect	STATE



$$( au_{\Lambda} - au_{\overline{\Lambda}}) / au_{\text{average}}$$

A test of CPT invariance.

VALUE	DOCUMENT ID		TECN	COMMENT
0.044±0.085	BADIER	67	нвс	2.4 GeV/c p̄p

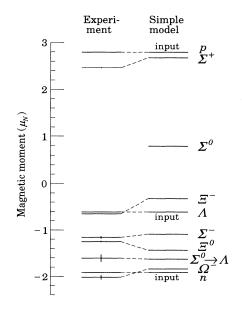
### BARYON MAGNETIC MOMENTS

The figure shows the measured magnetic moments of the stable baryons. It also shows the predictions of the simplest quark model, using the measured p, n, and  $\Lambda$  moments as input. In this model, the moments are [1]

$$\begin{array}{ll} \mu_p = (4\mu_u - \mu_d)/3 & \mu_n = (4\mu_d - \mu_u)/3 \\ \mu_{\varSigma^+} = (4\mu_u - \mu_s)/3 & \mu_{\varSigma^-} = (4\mu_d - \mu_s)/3 \\ \mu_{\varSigma^0} = (4\mu_s - \mu_u)/3 & \mu_{\varSigma^-} = (4\mu_s - \mu_d)/3 \\ \mu_{\varLambda} = \mu_s & \mu_{\varSigma^0} = (2\mu_u + 2\mu_d - \mu_s)/3 \\ \mu_{\varOmega^-} = 3\mu_s \end{array}$$

and the  $\Sigma^0 \to \Lambda$  transition moment is

$$\mu_{\Sigma^0\Lambda} = (\mu_d - \mu_u)/\sqrt{3} .$$



### Λ

The quark moments that result from this model are  $\mu_u = +1.852 \, \mu_N$ ,  $\mu_d = -0.972 \, \mu_N$ , and  $\mu_s = -0.613 \, \mu_N$ . The corresponding effective quark masses, taking the quarks to be Dirac point particles, where  $\mu = q\hbar/2m$ , are 338, 322, and 510 MeV. As the figure shows, the model gives a good first approximation to the experimental moments. For efforts to make a better model, we refer to the literature [2].

### References

- See, for example, D.H. Perkins, Introduction to High Energy Physics (Addison-Wesley, Reading, MA, 1987), or D. Griffiths, Introduction to Elementary Particles (Harper & Row, New York, 1987).
- See, for example, J. Franklin, Phys. Rev. **D29**, 2648 (1984);
   H.J. Lipkin, Nucl. Phys. **B241**, 477 (1984);
  - K. Suzuki, H. Kumagai, and Y. Tanaka, Europhys. Lett. 2, 109 (1986);
  - S.K. Gupta and S.B. Khadkikar, Phys. Rev. **D36**, 307 (1987);
  - M.I. Krivoruchenko, Sov. J. Nucl. Phys. 45, 109 (1987);L. Brekke and J.L. Rosner, Comm. Nucl. Part. Phys. 18,
  - K.-T. Chao, Phys. Rev. **D41**, 920 (1990) and references cited therein Also, see references cited in discussions of results in the experimental papers..

### **A MAGNETIC MOMENT**

See the "Note on Baryon Magnetic Moments" above. Measurements with an error  $~\geq 0.15~\mu_N$  have been omitted.

$VALUE(\mu_N)$ EVT	S DOCUMENT ID		TECN	COMMENT
-0.613 ±0.004 OUR AVE	RAGE			
$-0.606 \pm 0.015$ 200	k COX	81	SPEC	
$-0.6138 \pm 0.0047$ 3N	SCHACHIN	78	SPEC	
$-0.59 \pm 0.07$ 350	k HELLER	77	SPEC	
$-0.57 \pm 0.05$ 1.2N	1 BUNCE	76	SPEC	
$-0.66 \pm 0.07$ 130	DAHL-JENSE	N 71	EMUL	200 kG field

### A ELECTRIC DIPOLE MOMENT

A nonzero value is forbidden by both T invariance and P invariance.

VALUE (10 ⁻¹⁶ ecm)	CL%	DOCUMENT I	0	TECN
< 1.5	95	⁴ PONDROM	81	SPEC
• • • We do not u	se the follow	ng data for avera	ges, fit	s, limits, etc. • • •
<100	95	⁵ BARONI	71	EMUL
< 500	95	GIBSON	66	EMUL
⁴ PONDROM 81				cm.
5 D A D O N L 71		1 0 0) 10-15		

### A DECAY MODES

	Mode	Fraction $(\Gamma_{m i}/\Gamma)$
Γ ₁	pπ-	(63.9 ±0.5 )%
$\Gamma_2$	$n\pi^0$	(35.8 $\pm 0.5$ ) %
$\Gamma_3$	$n\gamma$	$(1.75\pm0.15)\times10^{-3}$
$\Gamma_4$	$p\pi^-\gamma$	[a] ( 8.4 $\pm 1.4$ ) $\times$ 10 ⁻⁴
$\Gamma_5$	$pe^-\overline{\nu}_e$	$(8.32\pm0.14)\times10^{-4}$
$\Gamma_6$	$p\mu^-\overline{\nu}_{\mu}$	$(1.57\pm0.35)\times10^{-4}$

[a] See the Particle Listings below for the pion momentum range used in this measurement

#### CONSTRAINED FIT INFORMATION

An overall fit to 5 branching ratios uses 20 measurements and one constraint to determine 5 parameters. The overall fit has a  $\chi^2=10.5$  for 16 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients  $\left\langle \delta \kappa_i \delta \kappa_j / (\delta \kappa_i \cdot \delta \kappa_j) \right\rangle$ , in percent, from the fit to the branching fractions,  $\kappa_i \equiv \Gamma_i / \Gamma_{\text{total}}.$  The fit constrains the  $\kappa_i$  whose labels appear in this array to sum to one.

<i>x</i> ₂	-100			
<i>x</i> ₃	-2	-1		
<i>×</i> ₅	46	-46	-1	
<i>x</i> ₆	0	0	0	0
	$x_1$	<i>x</i> ₂	<i>x</i> ₃	×5

 $\frac{\Gamma(\rho\mu^-\overline{\nu}_\mu)/\Gamma(N\pi)}{VALUE (units 10^{-4})} = \frac{EV}{1.57 \pm 0.35 \text{ OUR FIT}}$  1.57  $\pm 0.35 \text{ OUR AVERAGE}$ 

 $2.4\ \pm0.8$ 

 $1.3 \pm 0.7$ 

 $1.5\ \pm1.2$ 

### **A BRANCHING RATIOS**

$\Gamma(p\pi^-)/\Gamma(N\pi)$					$\Gamma_1/(\Gamma_1+\Gamma_2)$
VALUE	EVTS	DOCUMENT ID		CN COMMENT	
0.641±0.005 OUR FI					
0.640 ± 0.005 OUR AV					
$0.646 \pm 0.008$	4572	BALTAY	718 HE		
$0.635 \pm 0.007$	6736	DOYLE	69 HE		ΛK ⁰
$0.643 \pm 0.016$	903	HUMPHREY	62 HE		
$0.624 \pm 0.030$		CRAWFORD	59B HE	$\pi^- p \rightarrow$	ΛK ^U
$\Gamma(n\pi^0)/\Gamma(N\pi)$					$\Gamma_2/(\Gamma_1+\Gamma_2)$
VALUE	EVTS	DOCUMENT ID	TE	CN	-/ ( 1 · -/
0.359±0.005 OUR FI	Г				
0.310 ± 0.028 OUR AV	ERAGE				
$0.35 \pm 0.05$		BROWN		.BC	
$0.291 \pm 0.034$	75	CHRETIEN	63 HL	.BC	
$\Gamma(n\gamma)/\Gamma_{\text{total}}$					$\Gamma_3/\Gamma$
VALUE (units 10 ⁻³ )	EVTS	DOCUMENT ID	т,	ECN COMMEN	τ.
1.75±0.15 OUR FIT		DOCOMENT 1D		<u> </u>	
1.75±0.15	1816	LARSON	93 SI	PEC K-pat	rest
• • We do not use				,	•
		-			
$1.78 \pm 0.24 ^{+0.14}_{-0.16}$	287	NOBLE	92 SI	PEC See LAR	SON 93
$\Gamma(n\gamma)/\Gamma(n\pi^0)$					$\Gamma_3/\Gamma_2$
,, . ,					-, -
VALUE (units 10 ⁻³ )	EVTS	DOCUMENT ID		CN COMMENT	
• • We do not use	the followin	g data for average	s, fits, lir	nits, etc. • • •	•
$2.86 \pm 0.74 \pm 0.57$	24	BIAGI	86 SP	EC SPS hype	ron beam
$\Gamma(p\pi^-\gamma)/\Gamma(p\pi^-)$					$\Gamma_4/\Gamma_1$
VALUE (units 10 ⁻³ )	EVTS	DOCUMENT ID	TE	CN COMMENT	
1.32±0.22	72	BAGGETT	72C HE	$\pi^- < 95$	MeV/c
F/ \ /F/	`				- /-
$\Gamma(pe^-\overline{\nu}_e)/\Gamma(p\pi^-$	)				$\Gamma_5/\Gamma_1$
VALUE (units 10 ⁻³ )	EVTS	DOCUMENT ID	TE	CN COMMENT	
1.301 ±0.019 OUR FIT					
1.301 ±0.019 OUR AV		DOLLDOLLIN	00 60	EC CDC h	
1.335±0.056 1.313±0.024	7111 10k	BOURQUIN WISE	83 SP 80 SP		ron beam
	544				√0 a
1.23 ±0.11 1.27 ±0.07	1089	LINDQUIST KATZ	77 SP 73 HE	,	N - /I
1.31 ±0.06	1078	ALTHOFF		PK	
1.17 ±0.13	86	6 CANTER	71 HE		ect
1.20 ±0.12	143	7 MALONEY	69 HE		CSC
1.17 ±0.18	120	7 BAGLIN	64 FB		1.45 GeV/c
1.23 ±0.20	150	7 ELY	63 FB		1 dc v / c
• • We do not use to				_	,
1.32 ±0.15	218	6 LINDQUIST		PK See LIND	
6 Changed by us fro		· · · · · · · · · · · · · · · · · · ·			•
2/3.					
⁷ Changed by us fror sured quantity.	n Γ(pe [−] ν̄	$_{\rm e})/\Gamma(N\pi)$ because	Γ( <i>pe</i> - ι	$(pπ^-)$ is the	ne directly mea-

BAGGETT

CANTER

LIND

72B HBC

718 HBC 64 RVUE  $\Gamma_6/(\Gamma_1+\Gamma_2)$ 

### **1 DECAY PARAMETERS**

See the "Note on Baryon Decay Parameters" in the neutron Listings. Some early results have been omitted.

### $\alpha_-$ FOR $\Lambda \to p\pi^-$

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.642±0.013 OUR	<b>AVERAGE</b>				
$0.584 \pm 0.046$	8500	ASTBURY	75	SPEC	
$0.649 \pm 0.023$	10325	CLELAND	72	OSPK	
$0.67 \pm 0.06$	3520	DAUBER	69	HBC	From $\Xi$ decay
$0.645 \pm 0.017$	10130	OVERSETH	67	OSPK	$\Lambda$ from $\pi^- p$
$0.62 \pm 0.07$ .	1156	CRONIN	63	CNTR	$\Lambda$ from $\pi^- \rho$
φ ANGLE FOR	$\Lambda \to p\pi^-$				$(\tan\phi=\beta\ /\ \gamma)$
VALUE (°)	EVTS	DOCUMENT ID		TECN	COMMENT
- 6.5± 3.5 OUR	AVERAGE				
$-7.0 \pm 4.5$	10325	CLELAND	72	OSPK	$\Lambda$ from $\pi^- p$
$-8.0 \pm 6.0$	10130	OVERSETH	67	OSPK	$\Lambda$ from $\pi^- p$
$13.0 \pm 17.0$	1156	CRONIN	63	OSPK	$\Lambda$ from $\pi^- \rho$
$\alpha_0 / \alpha = \alpha(\Lambda)$	$\rightarrow n\pi^0)$ /	$\alpha(\Lambda \rightarrow p\pi^{-})$			
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
1.01 ±0.07 OUR	AVERAGE				
$1.000 \pm 0.068$	4760	⁸ OLSEN	70	OSPK	$\pi^+ n \rightarrow \Lambda K^+$
$1.10 \pm 0.27$		CORK	60	CNTR	
801 051 70					

 $^8\,\text{OLSEN}$  70 compares proton and neutron distributions from  $\varLambda$  decay.

$$\left[\alpha_{-}(\Lambda) + \alpha_{+}(\overline{\Lambda})\right] / \left[\alpha_{-}(\Lambda) - \alpha_{+}(\overline{\Lambda})\right]$$

Zero if CP is	conserved. EVTS	DOCUMENT ID		TECN	COMMENT
-0.03±0.06 OUR		DOCOMENT ID		72014	COMMENT
$+0.01\pm0.10$	770	TIXIER	88	DM2	$J/\psi \rightarrow \Lambda \overline{\Lambda}$
$-0.07 \pm 0.09$	4063	BARNES	87	CNTR	$\overline{p}p \rightarrow \overline{\Lambda}\Lambda LEAR$
$-0.02 \pm 0.14$	10k	⁹ CHAUVAT	85	CNTR	ρρ, <del>p</del> ρ ISR

 9  CHAUVAT 85 actually gives  $\alpha_+(\overline{\Lambda})/\alpha_-(\Lambda)=-1.04\pm0.29$ . Assumes polarization is same in  $\overline{p}\,p\to\overline{\Lambda}{\rm X}$  and  $p\,p\to\Lambda{\rm X}$ . Tests of this assumption, based on C-invariance and fragmentation, are satisfied by the data.

 $g_A$  /  $g_V$  FOR  $\Lambda \to pe^-\overline{\nu}_e$  Measurements with fewer than 500 events have been omitted. Where necessary, signs have been changed to agree with our conventions, which are given in the "Note on Baryon Decay Parameters" in the neutron Listings. The measurements all assume that the form factor  $g_2=0$ . See also the footnote on DWORKIN 90. EVTS DOCUMENT ID TECN COMMENT

-0.718±0.015 OUR A	VERAGE						
$-0.719 \pm 0.016 \pm 0.012$	37k	¹⁰ DWORKIN	90	SPEC	e   u angular corr.		
$-0.70 \pm 0.03$	7111	BOURQUIN	83	SPEC	$\Xi \rightarrow \Lambda \pi^-$		
$-0.734 \pm 0.031$	10k	¹¹ WISE	81	SPEC	e u angular correl.		
<ul> <li>◆ We do not use the following data for averages, fits, limits, etc.</li> </ul>							
$-0.63 \pm 0.06$	817	ALTHOFF	73	OSPK	Polarized A		
10 The tabulated resul	t assume	s the weak-magnet	ism c	oupling	$w \equiv g_{i,i}(0)/g_{i,i}(0)$ to be		

 $^{^{10}}$  The tabulated result assumes the weak-magnetism coupling  $w\equiv g_W(0)/g_V(0)$  to be 0.97, as given by the CVC hypothesis and as assumed by the other listed measurements. However, DWORKIN 90 measures w to be 0.15  $\pm$  0.30, and then  $g_A/g_V=-0.731$   $\pm$  0.016.

#### **A REFERENCES**

We have omitted some papers that have been superseded by later experiments. See our earlier editions.

HARTOUNI	94	PRL 72 1322	+Jensen, Kreisler+ (BNL E766 Collab.)
Also	94B	PRL 72 2821 (erratum)	Hartouni, Jensen+ (BNL E766 Collab.)
LARSON	93	PR D47 799	+Noble, Bassalleck+ (BNL-811 Collab.)
NOBLE DWORKIN	92 90	PRL 69 414 PR D41 780	+ (BIRM, BOST, BRCO, BNL, CASE, BUDA, LANL+)
TIXIER	88	PL B212 523	+Cox, Dukes, Overseth+ (MICH, WISC, RUTG, MINN) +Ajaltouni, Falvard, Jousset+ (DM2 Collab.)
BARNES	87	PL B199 147	+ (CMU, SACL, LANL, VIEN, FREIB, ILL, UPPS+)
BIAGI	86	ZPHY C30 201	+ (BRIS, CERN, GEVA, HEIDP, LAUS, LOQM, RAL)
CHAUVAT	85	PL 163B 273	+Erhan, Hayes+ (CERN, CLER, UCLA, SACL)
BOURQUIN	83	ZPHY C21 1	+Brown+ (BRIS, GEVA, HEIDP, LALO, RL, STRB)
COX	81	PRL 46 877	+Dworkin+ (MICH, WISC, RUTG, MINN, BNL)
PONDROM	81	PR D23 814	+Handler, Sheaff, Cox+ (WISC, MICH, RUTG, MINN)
WISE	81	PL 98B 123	+Jensen, Kreisler, Lomanno, Poster+ (MASA, BNL)
WISE	80	PL 91B 165	+Jensen, Kreisler, Lomanno, Poster+ (MASA, BNL)
SCHACHIN	78	PRL 41 1348	Schachinger, Bunce, Cox+ (MICH, RUTG, WISC)
HELLER	77 77	PL 68B 480 PR D16 2104	+Overseth, Bunce, Dydak+ (MICH, WISC, HEIDH)
LINDQUIST Also	76	JPG 2 L211	+Swallow, Sumner+ (EFI, OSU, ANL) Lindquist, Swallow+ (EFI, WUSL, OSU, ANL)
ZECH	77	NP B124 413	+Dydak, Navarria+ (SIEG, CERN, DORT, HEIDH)
BUNCE	76	PRL 36 1113	+Handler, March, Martin+ (WISC, MICH, RUTG)
ASTBURY	75	NP B99 30	+Gallivan, Jafar+ (LOIC, CERN, ETH, SACL)
CLAYTON	75	NP B95 130	+Bacon, Butterworth, Waters+ (LOIC, RHEL)
ALTHOFF	73	PL 43B 237	+Brown, Freytag, Heard, Heintze+ (CERN, HEID)
ALTHOFF	73B	NP B66 29	+Brown, Freytag, Heard, Heintze+ (CERN, HEID)
KATZ	73	Thesis MDDP-TR-74-04	
POULARD	73	PL 46B 135	+Givernaud, Borg (SACL)
BAGGETT BAGGETT	72B 72C	ZPHY 252 362 PL 42B 379	+Baggett, Eisele, Filthuth, Frehse+ (HEID) +Baggett, Eisele, Filthuth, Frehse, Hepp+ (HEID)
CLELAND	72	NP B40 221	+Baggett, Eisele, Filthuth, Frehse, Hepp+ (HEID) +Conforto, Eaton, Gerber+ (CERN, GEVA, LUND)
HYMAN	72	PR D5 1063	+Bunnell, Derrick, Fields, Katz+ (ANL, CMU)
ALTHOFF	71	PL 37B 531	+Brown, Freytag, Heard, Heintze+ (CERN, HEID)
BALTAY	71B	PR D4 670	+Bridgewater, Cooper, Habibi+ (COLU, BING)
BARONI	71	LNC 2 1256	+Petrera, Romano (ROMA)
CANTER	71	PRL 26 868	+Cole, Lee-Franzini, Loveless+ (STON, COLU)
CANTER	71B	PRL 27 59	+Cole, Lee-Franzini, Loveless+ (STON, COLU)
DAHL-JENSEN		NC 3A 1	+ (CERN, ANKA, LAUS, MPIM, ROMA)
LINDQUIST	71	PRL 27 612	+Sumner+ (EFI, WUSL, OSU, ANL)
OLSEN DAUBER	70 69	PRL 24 843 PR 179 1262	+Pondrom, Handler, Limon, Smith+ +Berge, Hubbard, Merrill, Miller (URL)
DOYLE	69	Thesis UCRL 18139	(LRL)
MALONEY	69	PRL 23 425	+Sechi-Zorn (UMD)
GRIMM	68	NC 54A 187	(HEID)
HEPP	68	ZPHY 214 71	+Schleich (HEID)
BADIER	67	PL 25B 152	+Bonnet, Briandet, Sadoulet (EPOL)
MAYEUR	67	U.Libr.Brux.Bul. 32	+Tompa, Wickens (BELG, LOUC)
OVERSETH	67	PRL 19 391	+Roth (MICH, PRIN)
PDG	67	RMP 39 1	Rosenfeld, Barbaro-Galtieri, Podolsky+ (LRL, CERN, YALE)
BURAN	66	PL 20 318	+Eivindson, Skjeggestad, Tofte+ (OSLO)
CHIEN ENGELMANN	66 66	PR 152 1171 NC 45A 1038	+Lach, Sandweiss, Taft, Yeh, Oren+ (YALE, BNL)
GIBSON	66	NC 45A 1036 NC 45A 882	+Filthuth, Alexander+ (HEID, REHO) +Green (BRIS)
LONDON	66	PR 143 1034	+Rau, Goldberg, Lichtman+ (BNL, SYRA)
SCHMIDT	65	PR 140B 1328	(COLU)
BAGLIN	64	NC 35 977	+Bingham+ (EPOL, CERN, LOUC, RHEL, BERG)
HUBBARD	64	PR 135B 183	+Berge, Kalbfleisch, Shafer+ (LRL)
LIND	64	PR 135B 1483	+Binford, Good, Stern (WISC)
RONNE	64	PL 11 357	+ (CERN, EPOL, LOUC, BERG+)
SCHWARTZ	64	Thesis UCRL 11360	(LRL)
BHOWMIK	63	NC 28 1494 PR 130 766	+Goyal (DELH)
BLOCK BROWN	63 63	PR 130 766 PR 130 769	+Gessaroli, Ratti+ (NWES, BGNA, SYRA, ORNL) +Kadyk, Trilling, Roe+ (LRL, MICH)
CHRETIEN	63	PR 131 2208	+ (BRAN, BROW, HARV, MIT)
CRONIN	63	PR 129 1795	+Overseth (PRIN)
ELY	63	PR 131 868	+Gidal, Kalmus, Oswald, Powell+ (LRL)
HUMPHREY	62	PR 127 1305	+Ross (LRL)
CORK	60	PR 120 1000	+Kerth, Wenzel, Cronin+ (LRL, PRIN, BNL)
CRAWFORD	59B	PRL 2 266	+Cresti, Douglass, Good, Ticho+ (LRL)

### $\Lambda$ AND $\Sigma$ RESONANCES

**Introduction:** There are no new results at all on  $\Lambda$  and  $\Sigma$  resonances. The field remains at a standstill and will only be revived if a kaon factory is built. What follows is a much abbreviated version of the note on  $\Lambda$  and  $\Sigma$  Resonances from our 1990 edition. In particular, see that edition for some representative Argand plots from partial-wave analyses.

Table 1 is an attempt to evaluate the status, both overall and channel by channel, of each  $\Lambda$  and  $\Sigma$  resonance in the Particle Listings. The evaluations are of course partly subjective. A blank indicates there is no evidence at all: either the relevant couplings are small or the resonance does not really exist. The main Baryon Summary Table includes only the established resonances (overall status 3 or 4 stars). A number of the 1- and 2-star entries may eventually disappear, but there are certainly many resonances yet to be discovered underlying the established ones.

Sign conventions for resonance couplings: In terms of the isospin-0 and -1 elastic scattering amplitudes  $A_0$  and  $A_1$ , the amplitude for  $K^-p \to \overline{K}^0 n$  scattering is  $\pm (A_1 - A_0)/2$ , where the sign depends on conventions used in conjunction with the Clebsch-Gordan coefficients (such as, is the baryon or the meson the "first" particle). If this reaction is partial-wave analyzed and if the overall phase is chosen so that, say, the  $\Sigma(1775)D_{15}$  amplitude at resonance points along the positive imaginary axis (points "up"), then any  $\Sigma$  at resonance will point "up" and any  $\Lambda$  at resonance will point "down" (along the negative imaginary axis). Thus the phase at resonance determines the isospin. The above ignores background amplitudes in the resonating partial waves.

That is the basic idea. In a similar but somewhat more complicated way, the phases of the  $\overline{K}N \to \Lambda\pi$  and  $\overline{K}N \to \Sigma\pi$  amplitudes for a resonating wave help determine the SU(3) multiplet to which the resonance belongs. Again, a convention has to be adopted for some overall arbitrary phases: which way is "up"? Our convention is that of Levi-Setti [1] and is shown in Fig. 1, which also compares experimental results with theoretical predictions for the signs of several resonances. In the Listings, a + or - sign in front of a measurement of an inelastic resonance coupling indicates the sign (the absence of a sign means that the sign is not determined, not that it is positive). For more details, see Appendix II of our 1982 edition [2].

Errors on masses and widths: The errors quoted on resonance parameters from partial-wave analyses are often only statistical, and the parameters can change by more than these errors when a different parametrization of the waves is used.

Table 1. The status of the  $\Lambda$  and  $\Sigma$  resonances. Only those with an overall status of *** or **** are included in the main Baryon Summary Table.

		Overall		Stat	us as seer	ı in —
Particle	$L_{I\cdot 2J}$	status	$N\overline{K}$	$\Lambda\pi$	$\Sigma\pi$	Other channels
$\Lambda(1116)$	$P_{01}$	****		F		$N\pi(\text{weakly})$
$\Lambda(1405)$	$S_{01}$	****	****	0	****	
A(1520)	$D_{03}$	****	****	r	****	$\Lambda\pi\pi,\Lambda\gamma$
$\Lambda(1600)$	$P_{01}$	***	***	b	**	
$\Lambda(1670)$	$S_{01}$	****	****	i	****	$\Lambda\eta$
A(1690)	$D_{03}$	****	****	d	****	$\Lambda\pi\pi, \Sigma\pi\pi$
$\Lambda(1800)$	$S_{01}$	***	***	d	**	$N\overline{K}^*$ , $\Sigma(1385)\pi$
$\Lambda(1810)$	$P_{01}$	***	***	e	**	$N\overline{K}^*$
$\Lambda(1820)$	$F_{05}$	****	****	n	****	$\Sigma(1385)\pi$
A(1830)	$D_{05}$	****	***	$\mathbf{F}$	****	$\Sigma(1385)\pi$
A(1890)	$P_{03}$	****	****	О	**	$N\overline{K}^*, \Sigma(1385)\pi$
A(2000)		*		r	*	$\Lambda\omega, N\overline{K}^*$
$\Lambda(2020)$	$F_{07}$	*	*	b	*	
A(2100)	$G_{07}$	****	****	i	***	$\Lambda\omega, N\overline{K}^*$
$\Lambda(2110)$	$F_{05}$	***	**	d	*	$\Lambda\omega, N\overline{K}^*$
$\Lambda(2325)$	$D_{03}$	*	*	d		$\Lambda\omega^{'}$
$\Lambda(2350)$		***	***	e	*	
$\Lambda(2585)$		**	**	n		
$\Sigma(1193)$	$P_{11}$	****				$N\pi(\text{weakly})$
$\Sigma(1385)$	$P_{13}$	****		****	****	, ,,
$\Sigma(1480)$		*	*	*	*	
$\Sigma(1560)$		**		**	**	
$\Sigma(1580)$	$D_{13}$	**	*	*		
$\Sigma(1620)$	$S_{11}$	**	**	*	*	
$\Sigma(1660)$	$P_{11}$	***	***	*	**	
$\Sigma(1670)$	$D_{13}$	****	****	****	****	several others
$\Sigma(1690)$	~	**	*	**	*	$\Lambda\pi\pi$
$\Sigma(1750)$	$S_{11}$	***	***	**	*	$\Sigma\eta$
$\Sigma(1770)$	$P_{11}$	*				1 41
$\Sigma(1775)$	$D_{15}$	****	****	****	***	several others
$\Sigma(1840)$	$P_{13}$	*	*	**	*	*
$\Sigma(1880)$	$P_{11}$	**	**	**		$N\overline{K}^*$
$\Sigma(1915)$	$F_{15}$	****	***	****	***	$\Sigma(1385)\pi$
$\Sigma(1940)$	$D_{13}$	***	*	***	**	quasi-2-body
$\Sigma(2000)$	$S_{11}$	*		*		$N\overline{K}^*, \Lambda(1520)\pi$
$\Sigma(2030)$	$F_{17}$	****	****	****	**	several others
$\Sigma(2070)$	$F_{15}$	*	*	dist	*	
$\Sigma(2080)$ $\Sigma(2100)$	$P_{13}$	**		**		
$\Sigma(2100)$ $\Sigma(2250)$	$G_{17}$	*	***	*	*	
$\Sigma(2250)$ $\Sigma(2455)$		***	***	*	*	
$\Sigma(2433)$ $\Sigma(2620)$		**	*			
$\Sigma(3000)$		*	*	*		
				**		multi-body
$\Sigma(3170)$		*				multi-body

- **** Existence is certain, and properties are at least fairly well explored.

  Existence ranges from very likely to certain, but further confirmation is desirable and/or quantum numbers, branching fractions, etc. are not well determined.
- ** Evidence of existence is only fair.
- * Evidence of existence is only

Furthermore, the different analyses use more or less the same data, so it is not really appropriate to treat the different determinations of the resonance parameters as independent or to average them together. In any case, the spread of the masses, widths, and branching fractions from the different analyses is certainly a better indication of the uncertainties than are the quoted errors. In the Baryon Summary Table, we usually give a range reflecting the spread of the values rather than a particular value with error.

For three states, the  $\Lambda(1520)$ , the  $\Lambda(1820)$ , and the  $\Sigma(1775)$ , there is enough information to make an overall fit to the various branching fractions. It is then necessary to use the quoted errors, but the errors obtained from the fit should not be taken seriously.

**Production experiments:** Partial-wave analyses of course separate partial waves, whereas a peak in a cross section or an invariant mass distribution usually cannot be disentangled from background and analyzed for its quantum numbers; and more than one resonance may be contributing to the peak. Results from partial-wave analyses and from production experiments are generally kept separate in the Listings, and in the Baryon Summary Table results from production experiments are used only for the low-mass states. The  $\Sigma(1385)$  and  $\Lambda(1405)$  of course lie below the  $\overline{K}N$  threshold and nearly everything about them is learned from production experiments; and production and formation experiments agree quite well in the case of  $\Lambda(1520)$  and results have been combined. There is some disagreement between production and formation experiments in the 1600-1700 MeV region: see the note on the  $\Sigma(1670)$ .

### References

- R. Levi-Setti, in Proceedings of the Lund International Conference on Elementary Particles (Lund, 1969), p. 339.
- 2. Particle Data Group, Phys. Lett. 111B (1982).

 $\Lambda(1405) S_{01}$ 

 $I(J^P) = 0(\frac{1}{2})$  Status: ***

THE  $\Lambda(1405)$ 

(by R.H. Dalitz, Oxford University)

It is generally accepted that the  $\Lambda(1405)$  is a well-established  $J^P = 1/2^-$  resonance. It is assigned to the lowest L = 1supermultiplet of the 3-quark system and paired with the  $J^P = 3/2^- \Lambda(1520)$ . Lying about 30 MeV below the  $N\overline{K}$ threshold, the  $\Lambda(1405)$  can be observed directly only as a resonance bump in the  $(\Sigma\pi)^0$  subsystem in final states of production experiments. It was first reported by ALSTON 61B in the reaction  $K^-p \to \Sigma\pi\pi\pi$  at 1.15 GeV/c and has since been seen in at least eight other experiments. However, only two of them had enough events for a detailed analysis: THOMAS 73. with about 400  $\Sigma^{\pm}\pi^{\mp}$  events from  $\pi^{-}p \to K^{0}(\Sigma\pi)^{0}$  at 1.69 GeV/c; and HEMINGWAY 85, with 766  $\Sigma^+\pi^-$  and 1106  $\Sigma^-\pi^+$  events from  $K^-p \to (\Sigma\pi\pi)^+\pi^-$  at 4.2 GeV/c, after the selections  $1600 \le M(\Sigma \pi \pi)^+ \le 1720$  MeV and momentum transfer  $< 1.0 \, (\text{GeV}/c)^2$  to purify the  $\Lambda(1405) \to (\Sigma \pi)^0$  sample. These experiments agree on a mass of about 1395-1400 MeV and a width of about 60 MeV. (Hemingway's mass of 1391  $\pm$  1 MeV is from his best, but unacceptably poor, Breit-Wigner fit.)

The Byers-Fenster tests on these data allow any spin and either parity: neither J nor P has yet been determined directly. The early indications for  $J^P=1/2^-$  came from finding Re  $A_{I=0}$  to be large and negative in a constant-scattering-length analysis of low-energy  $N\overline{K}$  reaction data (see KIM 65, SAKITT 65, and earlier references cited therein). The first multichannel energy-dependent K-matrix analysis (KIM 67) strengthened the case for a resonance around 1400–1420 MeV strongly coupled to the I=0 S-wave  $N\overline{K}$  system.

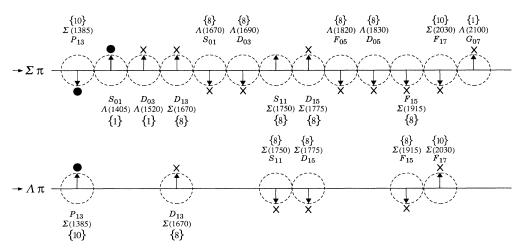


Figure 1. The signs of the imaginary parts of resonating amplitudes in the  $\overline{K}N \to \Lambda\pi$  and  $\Sigma\pi$  channels. The signs of the  $\Sigma(1385)$  and  $\Lambda(1405)$ , marked with a  $\bullet$ , are set by convention, and then the others are determined relative to them. The signs required by the SU(3) assignments of the resonances are shown with an arrow, and the experimentally determined signs are shown with an  $\times$ .

### Baryon Particle Listings A(1405)

THOMAS 73 and HEMINGWAY 85 both found the  $\Lambda(1405)$  bump to be asymmetric and not well fitted by a Breit-Wigner resonance function with constant parameters. The asymmetry involves a rapid fall in intensity as the  $N\overline{K}$  threshold energy is approached from below. This is readily understood as due to a strong coupling of the  $\Lambda(1405)$  to the S-wave  $N\overline{K}$  channel (see DALITZ 81). This striking S-shaped cusp behavior at a new threshold is characteristic of S-wave coupling; the other below-threshold hyperon, the  $\Sigma(1385)$ , has no such threshold distortion because its  $N\overline{K}$  coupling is P-wave. For the  $\Lambda(1405)$ , this asymmetry is the sole direct evidence that  $J^P=1/2^-$ .

Following the early work cited above, a considerable literature has developed on proper procedures for phenomenological extrapolation below the  $N\overline{K}$  threshold, partly in order to strengthen the evidence for the spin-parity of the  $\Lambda(1405)$ , and partly to provide an estimate for the amplitude  $f(N\overline{K})$  in the unphysical domain below the  $N\overline{K}$  threshold; the latter is needed for the evaluation of the dispersion relation for  $N\overline{K}$  and NK forward scattering amplitudes. For recent reviews, see MILLER 84 and BARRETT 89. In most recent work, the  $(\Sigma\pi)^0$  production spectrum is included in the data fitted (see, e.g., CHAO 73, MARTIN 81).

It is now accepted that the data can be fitted only with an S-wave pole in the reaction amplitudes below  $N\overline{K}$  threshold (see, however, FINK 90), but there is still controversy about the physical origin of this pole (for a review, see DALITZ 81 and DALITZ 82). Two extreme possibilities are: (a) an L=1 SU(3)-singlet uds state coupled with the S-wave meson-baryon systems; or (b) an unstable  $N\overline{K}$  bound state, analogous to the (stable) deuteron in the NN system. The problem with (a) is that the  $\Lambda(1405)$  mass is so much lower than that of its partner, the  $\Lambda(1520)$ . This requires, in the QCD-inspired quark model, rather large spin-orbit couplings, whether or not one uses relativistic kinetic energies. ISGUR 80, CAPSTICK 86, and CAPSTICK 89 conclude that a proper QCD calculation leads only to small energy splittings, whereas LEINWEBER 90, using QCD sum rules, obtains a good fit to this splitting.

On the other hand, the problem with (b) is that then another  $J^P=1/2^-\Lambda$  is needed to replace the  $\Lambda(1405)$  in the L=1 supermultiplet, and it would have to lie close to the  $\Lambda(1520)$ , a region already well explored by  $N\overline{K}$  experiments without result. Intermediate structures are possible; for example, the cloudy bag model allows the configurations (a) and (b) to mix and finds the intensity of (a) in the  $\Lambda(1405)$  to be only 14% (VEIT 84, VEIT 85, JENNINGS 86). Such models naturally predict a second  $1/2^-\Lambda$  close to the  $\Lambda(1520)$ .

The determination of the mass and width of the resonance from  $(\Sigma\pi)^0$  data is usually based on the "Watson approximation," which states that the production rate  $R(\Sigma\pi)$  of the  $(\Sigma\pi)^0$  state has a mass dependence proportional to  $(\sin^2\!\delta_{\Sigma\pi})/q$ , q being the  $\Sigma\pi$  c.m. momentum, in a  $\Sigma\pi$  mass range where  $\delta_{\Sigma\pi}$  is not far from  $\pi/2$  and only the  $\Sigma\pi$  channel is open, i.e., between the  $\Sigma\pi$  and the  $N\overline{K}$  thresholds. Then  $q\,R(\Sigma\pi)$  is proportional to  $\sin^2\!\delta_{\Sigma\pi}$ , and the mass M may be defined as the energy at

which  $\sin^2 \delta_{\Sigma\pi} = 1$ . The width  $\Gamma$  may be determined from the rate at which  $\delta_{\Sigma\pi}$  goes through  $\pi/2$ , or from the FWHM; this is a matter of convention.

This determination of M and  $\Gamma$  from the data suffers from the following defects:

- (i) The determination of  $\sin^2 \delta_{\Sigma\pi}$  requires that  $R(\Sigma\pi)$  be scaled to give  $\sin^2 \delta_{\Sigma\pi} = 1$  at the peak for the best fit to the data; *i.e.*, the bump must be assumed to arise from a resonance. However, this assumption is supported by the analysis of the low-energy  $N\overline{K}$  data and its extrapolation below threshold.
- (ii) Owing to the nearby  $N\overline{K}$  threshold, the shape of the best fit to the  $M(\Sigma\pi)$  bump is uncertain. For energies below this threshold at  $E_{N\overline{K}}$ , the general form for  $\delta_{\Sigma\pi}$  is

$$q\cot\delta_{\varSigma\pi} = \frac{1+\kappa\alpha}{\gamma+\kappa(\alpha\gamma-\beta^2)} \ .$$

Here  $\alpha, \beta$ , and  $\gamma$  are the (generally energy-dependent)  $NN, N\Sigma$ , and  $\Sigma\Sigma$  elements of the I=0 S-wave K-matrix for the  $(\Sigma\pi, N\overline{K})$  system, and  $\kappa$  is the magnitude of the (imaginary) c.m. momentum  $k_K$  for the  $N\overline{K}$  system below threshold. The elements  $\alpha, \beta, \gamma$  are real functions of E; they have no branch cuts at the  $\Sigma\pi$  and  $N\overline{K}$  thresholds, but they are permitted to have poles in E along the real E axis. The resonance asymmetry arises from the effect of  $\kappa$  on  $\delta_{\Sigma\pi}$ . We note that  $\delta_{\Sigma\pi}=\pi/2$  when  $\kappa=-1/\alpha$ .

Accepting this close connection of  $\delta_{\Sigma\pi}$  with the low-energy  $N\overline{K}$  data, it is natural to analyze the two sets of data together (e.g., MARTIN 81), and there is now a large body of accurate  $N\overline{K}$  data for laboratory momenta between 100 and 300 MeV/c (see MILLER 84). The two sets of data span c.m. energies from 1370 MeV to 1490 MeV, and the K-matrix elements will not be energy independent over such a broad range. For the I = 0 channels, a linear energy dependence for  $K^{-1}$  has been adopted routinely ever since the work of KIM 67, and it is essential when fitting the  $qR(\Sigma\pi)$  and  $N\overline{K}$  data together. However,  $q R(\Sigma \pi)$  is not always well fitted in this procedure; the value obtained for the  $\Lambda(1405)$  mass M varies a good deal with the type of fit, not a surprising result when the  $\Sigma\pi$ mass spectrum contributes only nine data points in a total of about 200. The value of M obtained from an overall fit is not necessarily much better than from one using only the  $qR(\Sigma\pi)$  data; and M may be a function of the representation— K-matrix, K⁻¹-matrix, relativistic-separable or nonseparable potentials, etc.— used in fitting over the full energy range. DALITZ 90 fitted the  $qR(\Sigma^+\pi^-)$  Hemingway data with each of the first three representations just mentioned, constrained to the I=0  $N\overline{K}$  threshold scattering length from low-energy  $N\overline{K}$  data. The (nonseparable) meson-exchange potentials of MÜLLER-GROELING 90, fitted to the low-energy  $N\overline{K}$  (and NK) data, predicted an unstable  $N\overline{K}$  bound state with mass and width compatible with the  $\Lambda(1405)$ .

The present status of the  $\Lambda(1405)$  thus depends heavily on theoretical arguments, a somewhat unsatisfactory basis for a four-star rating. Nevertheless, there is no known reason to

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doubt its existence or quantum numbers. A measurement of the energy-level shifts and widths for the atomic levels of kaonic hydrogen (and deuterium) would give a valuable check on analyses of the  $(\Sigma \pi, N\overline{K})$  amplitudes, since the energy of the  $K^-p$  atom lies roughly midway between those for the two sets of data. The three measurements of  $(\Delta E - i\Gamma/2)$  for kaonic hydrogen are inconsistent with one another and require that the sign of  $Re(A_{I=0} + A_{I=1})$  be opposite that deduced from  $N\overline{K}$  reaction data (see BATTY 89). Accurate measurements of  $(\Delta E - i\Gamma/2)$  values for kaonic hydrogen are badly needed, but may not be possible until the KAON factory becomes operational.

To definitively settle the nature of the  $\Lambda(1405)$  will require much further work, both experimental and theoretical. Higherstatistics experiments on the production and decay of the  $\Lambda(1405)$  are needed, but suitable  $K^-$  beams will not be available until KAON. The low-energy reaction cross sections, especially for the  $\overline{K}^0p$  interactions, last studied 25 years ago, need to be better determined.

### **Λ(1405) MASS**

PROD	UCTION	EXPERIMEN'	TS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
1406.5± 4.0		¹ DALITZ	91		M-matrix fit
• • We do not use	the following	data for averages	, fits,	limits,	etc. • • •
$1391 \pm 1$	700	¹ HEMINGWAY	85 H	нвс	$K^-p$ 4.2 GeV/ $c$
$\sim 1405$	400	² THOMAS	73 H	нвс	$\pi^- p$ 1.69 GeV/c
1405	120	BARBARO	68B [	DBC	$K^- d 2.1-2.7 \text{ GeV}/c$
$1400 \pm 5$	67	BIRMINGHAM			$K^-p$ 3.5 GeV/c
1382 ± 8		ENGLER	65 H	HDBC	$\pi^- p$ , $\pi^+ d$ 1.68 GeV/c
1400 $\pm 24$		MUSGRAVE	65 H	HBC	pp 3-4 GeV/c
1410		ALEXANDER	62 H	4BC	$\pi^- p$ 2.1 GeV/c
1405		ALSTON	62 H	HBC	K ⁻ p 1.2−0.5 GeV/c
1405		ALSTON	61B F	HBC	$K^- p 1.15 \text{ GeV}/c$

### EXTRAPOLATIONS BELOW NK THRESHOLD

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following	data for averages	, fits	, limits,	etc. • • •
1411	3 MARTIN	81		K-matrix fit
1406	⁴ CHAO	73	DPWA	0-range fit (sol. B)
1421	MARTIN	70	RVUE	Constant K-matrix
1416 ±4	MARTIN	69	HBC	Constant K-matrix
1403 ±3	KIM	67	HBC	K-matrix fit
1407.5±1.2	⁵ KITTEL	66	HBC	0-effective-range fit
$1410.7 \pm 1.0$	KIM	65	HBC	0-effective-range fit
$1409.6 \pm 1.7$	⁵ SAKITT	65	HBC	0-effective-range fit

### **Λ(1405) WIDTH**

### PRODUCTION EXPERIMENTS

		ION EXPERIMEN			
VAL	UE (MeV)	<u>EVTS</u>	DOCUMENT ID	TECN	COMMENT
50	± 2		¹ DALITZ	91	M-matrix fit
• •	• We do	not use the following	data for averages,	fits, limits	, etc. • • •
32	± 1	700	¹ HEMINGWAY	85 HBC	$K^- p$ 4.2 GeV/c
45	to 55	400	² THOMAS	73 HBC	$\pi^- p \ 1.69 \ \text{GeV}/c$
35		120	BARBARO	68B DBC	$K^- d 2.1-2.7 \text{ GeV}/c$
50	$\pm 10$	67	BIRMINGHAM	66 HBC	$K^- p \ 3.5 \ \text{GeV}/c$
89	$\pm 20$		ENGLER	65 HDBC	
60	$\pm 20$		MUSGRAVE	65 HBC	
35	± 5		ALEXANDER	62 HBC	
50				62 HBC	
20			ALSTON	61B HBC	

### EXTRAPOLATIONS BELOW NK THRESHOLD

VALUE (MeV)	DOCUMENTIL		IECN	COMMENT
ullet $ullet$ We do not use	the following data for averag	es, fit	s, limits,	etc. • • •
30	³ MARTIN	81		K-matrix fit
55	^{4,6} CHAO	73	DPWA	0-range fit (sol. B)
20	MARTIN	70	RVUE	Constant K-matrix
29 ±6	MARTIN	69	HBC	Constant K-matrix
50 ±5	KIM	67	HBC	K-matrix fit
$34.1 \pm 4.1$	⁵ KITTEL	66	HBC	
$37.0 \pm 3.2$	KIM	65	HBC	
$28.2 \pm 4.1$	⁵ SAKITT	65	HBC	

### Λ(1405) DECAY MODES

	Mode	Fraction $(\Gamma_i/\Gamma)$
Γ ₁	Σπ	100 %
$\Gamma_2$	$\Lambda_{\gamma}$ $\Sigma^{0}_{\gamma}$	
Γ ₂ Γ ₃ Γ ₄	$\Sigma^0\gamma$	
$\Gamma_4$	NK NK	

### Λ(1405) PARTIAL WIDTHS

'('')			' 2
VALUE (keV)	DOCUMENT ID	COMMENT	
• • We do not use th	e following data for averages, fits	, limits, etc. • • •	
27±8	BURKHARDT 91	Isobar model fit	
$\Gamma(\Sigma^0\gamma)$			Гз
VALUE (keV)	DOCUMENT ID	COMMENT	
• • We do not use th	e following data for averages, fits	, limits, etc. • • •	
10 + 4 or 23 + 7	BURKHARDT 91	Isobar model fit	

#### A(1405) BRANCHING RATIOS

$\Gamma(N\overline{K})/\Gamma(\Sigma\pi)$					$\Gamma_4/\Gamma_1$
VALUE	CL%	DOCUMENT ID	TECN	COMMENT	
• • • We do not use the	following	data for averages, fit	s, limits,	etc. • • •	
<3	95	HEMINGWAY 85	HBC	K [−] p 4.2 GeV/c	

### **Λ(1405) FOOTNOTES**

 $\Gamma(\Lambda_{\sim})$ 

- 1  DALITZ 91 fits the HEMINGWAY 85 data.  2  THOMAS 73 data is fit by CHAO 73 (see next section).  3  The MARTIN 81 fit includes the  $K^\pm \, p$  forward scattering amplitudes and the dispersion relations they must satisify.
- See also the accompanying paper of THOMAS 73.
- ⁵ Data of SAKITT 65 are used in the fit by KITTEL 66.
- 6  An asymmetric shape, with  $\Gamma/2=41$  MeV below resonance, 14 MeV above.

#### Λ(1405) REFERENCES

BURKHARDT DALITZ HEMINGWAY MARTIN CHAO THOMAS MARTIN MARTIN Also BARBARO KIM BIRMINGHAM KITTEL ENGLER KIM	66 65 65	PR C44 607 JPG 17 289 NP B253 742 NP B179 33 NP B56 46 NP B56 46 NP B56 479 PR 183 1352 PRL 19 1074 PR 152 1148 PRL 19 1074 PR 152 1148 PRL 15 224 PRL 15 224 PRL 15 224 PRL 15 224	+Deloff  +Kraemer, Thomas, Martin +Engler, Fisk, Kraemer +Ross +Sakitt Martin, Sakitt Barbaro-Galtieri, Chadwick+  Older, Wacek +Fisk, Kraemer, Meltzer, Westgard+	(NOTT, UNM, BIRM) (OXFTP, WINN) (OXFTP, WINN) (CERN) J (DURH) (RHEL, CML, LOUC) (CMU) J (DURH) (LOUC, BNL) (LOUC, BNL) (LOUC, BNL) (LOUC, BNL) (LRI, SLAC) (YALE) (YALE) (CMU, BNL) IJ (COUL)
BIRMINGHAM	66	PR 152 1148		S, LOIC, OXF, RHEL)
				(CMU, BNL) IJ
KIM MUSGRAVE	65 65	PRL 14 29 NC 35 735	+Petmezas+ (BIRM, CERN	(COLU) I. EPOL. LOIC. SACL)
SAKITT	65	PR 139B 719	+Day, Glasser, Seeman, Friedman+	(UMD, LRL)
ALEXANDER	62	PRL 8 447	+Kalbfleisch, Miller, Smith	(LRL) I
ALSTON	62	CERN Conf. 311	+Alvarez, Ferro-Luzzi+	(LRL) I
ALSTON	61B	PRL 6 698	+Alvarez, Eberhard, Good+	(LRL) I

### - OTHER RELATED PAPERS -

FINK 90	PR C41 2720	+He, Landau, Schnick	(IBMY, ORST, ANSM)
LEINWEBER 90	ANP 198 203		(MCMS)
MUELLER-GR90	NP A513 557	Mueller-Groeling, Holinde, Spe	th `(JULI)
BARRETT 89	NC 102A 179		(ŠURR)
BATTY 89	NC 102A 255	+Gal	(RAL, HEBR)
CAPSTICK 89	Excited Baryons '88, p.	. 32	(GUEL)
LOWE 89	NC 102A 167		(BIRM)
WHITEHOUSE 89	PRL 63 1352	<ul> <li>+ (BIRM, BOST, BRCO,</li> </ul>	BNL, CASE, BUDA, TRIU)
SIEGEL 88	PR C38 2221	+Weise	(REGE)
WORKMAN 88	PR D37 3117	+Fearing	(TRIU)
SCHNICK 87	PRL 58 1719	+Landau	(ORST)
CAPSTICK 86	PR D34 2809	+lsgur	(TNTO)
JENNINGS 86	PL B176 229	-	(TRIU)
MALTMAN 86	PR D34 1372	+lsgur	(LANL, TNTO)
ZHONG 86	PL B171 471	+Thomas, Jennings, Barrett	(ADLD, TRIU, SURR)
BURKHARDT 85	NP A440 653	+Lowe, Rosenthal	(NOTT, BIRM, WMIU)
DAREWYCH 85	PR D32 1765	+Koniuk, Isgur	(YORKC, TNTO)
VEIT 85	PR D31 1033	+Jennings, Thomas, Barrett	(TRIÙ, ADLD, SURR)
KIANG 84	PR C30 1638	+Kumar, Nogami, VanDijk	(DALH, MCMS)
MILLER 84			(LOUC)
Conf. Intersectio	ns between Particle and	Nuclear Physics, p. 783	, ,
VANDIJK 84	PR D30 937		(MCMS)
VEIT 84	PL 137B 415	+Jennings, Barrett, Thomas	(TRIU, SURR, CERN)
DALITZ 82		+McGinley, Belyea, Anthony	(OXFTP)
Heidelberg Conf.,	p. 201		
DALITZ 81		+McGinley	(OXFTP)
	diate Energy Kaon-Nucle		
		Energy Kaon-Nucleon Phys., p. 9	
OADES 77	NC 42A 462	+Rasche	(AARH, ZURI)
SHAW 73	Purdue Conf. 417		(UCI)
BARBARO 72	LBL-555	Barbaro-Galtieri	(LBL)
DOBSON 72	PR D6 3256	+McElhaney	(HAWA)
RAJASEKA 72	PR D5 610	Rajasekaran	(TATA)
	o cited in RAJASEKAR		
CLINE 71	PRL 26 1194	+Laumann, Mapp	(WISC)
MARTIN 71	PL 35B 62	+Martin, Ross	(DURH, LOUC, RHEL)
DALITZ 67	PR 153 1617	+Wong, Rajasekaran	(OXFTP, BOMB)
DONALD 66	PL 22 711	+Edwards, Lys, Nisar, Moore	(LIVP)
KADYK 66	PRL 17 599	+Oren, Goldhaber, Goldhaber, T	
ABRAMS 65	PR 139B 454	+Sechi-Zorn	(UMD)

### $\Lambda(1520)$

 $\Lambda(1520) D_{03}$ 

 $I(J^P) = O(\frac{3}{2}^-)$  Status: ***

Discovered by FERRO-LUZZI 62; the elaboration in WATSON 63 is the classic paper on the Breit-Wigner analysis of a multichannel resonance.

The measurements of the mass, width, and elasticity published before 1975 are now obsolete and have been omitted. They were last listed in our 1982 edition Physics Letters 111B (1982).

Production and formation experiments agree quite well, so they are listed together here.

Λ(1520) MASS							
	OUR ESTIMATE OUR AVERAGE	DOCUMENT ID		TECN	COMMENT		
1517.3 ±1.5 1519 ±1	300	BARBER GOPAL			$\begin{array}{ccc} \gamma p \to & \Lambda(1520) K^+ \\ \overline{K} N \to & \overline{K} N \end{array}$		
1517.8 ±1.2 1520.0 ±0.5	5k	BARLAG ALSTON	79 78		$K^- p$ 4.2 GeV/c $\overline{K}N \to \overline{K}N$		
$1519.7 \pm 0.3$ $1519 \pm 1$	4k	CAMERON GOPAL	77 77	HBC DPWA	$K^- p$ 0.96–1.36 GeV/ $c$ $\overline{K} N$ multichannel		
1519.4 ±0.3	2000	CORDEN	75	DBC	K [−] d 1.4–1.8 GeV/c		

### Λ(1520) WIDTH

VALUE (MeV) 15.6 ±1.0 OUR 15.59±0.27 OUR		DOCUMENT ID		TECN	COMMENT
16.3 ±3.3 16 +1	300	BARBER GOPAL			$\frac{\gamma p}{K} \stackrel{\longrightarrow}{N} \stackrel{\Lambda(1520)}{K} \stackrel{K^+}{N}$
16 ±1 14 ±3	677	BARLAG			$K^- p$ 4.2 GeV/c
$15.4 \pm 0.5$		ALSTON	78		$\overline{K}N \rightarrow \overline{K}N$
16.3 ±0.5	4k	CAMERON	77		$K^- p$ 0.96–1.36 GeV/c $\overline{K}N$ multichannel
15.0 ±0.5 15.5 ±1.6	2000	CORDEN	75		$K^- d$ 1.4–1.8 GeV/c
15.0 $\pm 0.5$ 15.5 $\pm 1.6$	2000	GOPAL CORDEN			

### A(1520) DECAY MODES

	Mode	Fraction $(\Gamma_j/\Gamma)$
$\overline{\Gamma_1}$	NK	45 ± 1%
$\Gamma_2$	$\Sigma \pi$	42 ± 1%
Гз	$\Lambda \pi \pi$	10 ± 1%
$\Gamma_4$	$\Sigma(1385)\pi$	
$\Gamma_5$	$\Sigma(1385)\pi(\rightarrow \Lambda\pi\pi)$	
$\Gamma_6$	$\Lambda(\pi\pi)_{S\text{-wave}}$	
$\Gamma_7$	$\Sigma \pi \pi$	$0.9 \pm 0.1\%$
Γ8	$\Lambda\gamma$	0.8 ± 0.2%
Γ9	$\Sigma^0 \gamma$	

#### CONSTRAINED FIT INFORMATION

An overall fit to 9 branching ratios uses 24 measurements and one constraint to determine 6 parameters. The overall fit has a  $\chi^2$  = 16.5 for 19 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients  $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$ , in percent, from the fit to the branching fractions,  $x_i \equiv \Gamma_i / \Gamma_{\text{total}}$ . The fit constrains the  $x_i$  whose labels appear in this array to sum to

### Λ(1520) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on  $\varLambda$  and  $\varSigma$ 

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$				Γ ₁ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
0.45 ±0.01 OUR ESTIMAT	E			
0.448 ± 0.007 OUR FIT Erro	or includes scale factor	r of 1.	2.	
0.455 ± 0.011 OUR AVERAGE	E			
0.47 ±0.02	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
0.45 ±0.03	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
$0.448 \pm 0.014$	CORDEN	75	DBC	$K^- d 1.4-1.8 \text{ GeV}/c$
• • • We do not use the foll	owing data for averag	es, fits	s, limits,	etc. • • •

•				
0.47 ±0.01 0.42	GOPAL MAST	77 76	DPWA HBC	See GOPAL 80 $K^- p \rightarrow \overline{K}^0 n$
$\Gamma(\Sigma\pi)/\Gamma_{total}$				Γ ₂ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
0.42 ±0.01 OUR ESTIMATE 0.421±0.007 OUR FIT Error inclu 0.423±0.011 OUR AVERAGE	udes scale factor	of 1.	.2.	
$\begin{array}{c} 0.426 \pm 0.014 \\ 0.418 \pm 0.017 \end{array}$	CORDEN BARBARO		DBC HBC	$K^- d$ 1.4–1.8 GeV/ $c$ $K^- p$ 0.28–0.45 GeV/ $c$
• • • We do not use the following 0.46	data for average KIM	s, fit 71		etc. • • •  K-matrix analysis
	KIIVI	'.	DI WA	
$\Gamma(\Sigma\pi)/\Gamma(NK)$	DOCUMENT ID		TECN	$\Gamma_2/\Gamma_1$
	ides scale factor			
	or includes scale ² GOPAL	fact		. See the ideogram below. $\overline{K}N$ multichannel
0.82 ±0.08	BURKHARDT		HBC	K p 0.8-1.2 GeV/c
1.06 ±0.14	SCHEUER	68	DBC	K- N 3 GeV/c
0.96 ±0.20	DAHL	67	нвс	$\pi^- p$ 1.6–4 GeV/c
0.73 ±0.11	DAUBER	67	HBC	K [−] p 2 GeV/c
• • We do not use the following	_			
1.06 ±0.12 1.72 ±0.78	BERTHON MUSGRAVE	74 65	нвс нвс	Quasi-2-body $\sigma$
WEIGHTED AVERAG 0.95±0.04 (Error scal				
	and : this i sarily obtai utiliz	scale deog the ned t ing m tities	factor ar ram only same as from a le neasurem	eighted average, error, eve based upon the data in . They are not necesour 'best' values, ast-squares constrained fit lents of other (related) ional information.
	<del>-  *   </del>	B	OFFICE SCHEUEI SAHL SAUBER	RDT 69 HBC 2.7
				(Confidence Level = 0.083)
0.4 0.6 0.8	1 1.2	_	1.4	 1.6
$\Gamma(\Sigma\pi)/\Gamma(N\overline{K})$				
$\Gamma(\Lambda\pi\pi)/\Gamma_{\text{total}}$				Г ₃ /Г
VALUE	DOCUMENT ID		TECN	COMMENT
0.10 ±0.01 OUR ESTIMATE 0.095±0.005 OUR FIT Error inclu	udes scale factor	of 1	.2.	
	or includes scale			
$0.091 \pm 0.006$	CORDEN	75	DBC	$K^- d$ 1.4–1.8 GeV/ $c$
0.11 ±0.01	³ MAST	73E	3 IPWA	$K^- p \rightarrow \Lambda \pi \pi$
$\Gamma(\Lambda\pi\pi)/\Gamma(N\overline{K})$				$\Gamma_3/\Gamma_1$
VALUE	DOCUMENT ID		TECN	COMMENT
0.213±0.012 OUR FIT Error incl	udes scale factor	of 1	.2.	
0.202 ±0.021 OUR AVERAGE 0.22 ±0.03	BIIDKHADDT	- 60	HBC	K [−] ρ 0.8−1.2 GeV/c
0.19 ±0.04	SCHEUER			$K = N \times GeV/C$
0.17 ±0.05	DAHL			$\pi^-  \rho  1.6$ –4 GeV/ $c$
0.21 ±0.18	DAUBER	67	HBC	$K^-p$ 2 GeV/ $c$
• • We do not use the following				
0.27 ±0.13 0.2	BERTHON KIM		HBC DPWA	Quasi-2-body $\sigma$ K-matrix analysis
$\Gamma(\Sigma\pi)/\Gamma(\Lambda\pi\pi)$				$\Gamma_2/\Gamma_3$
VALUE	DOCUMENT ID			
4.42±0.25 OUR FIT Error include 3.9 ±0.6 OUR AVERAGE	es scale factor of	1.2.		
3.9 ±1.0	UHLIG	67	нвс	K ⁻ ρ 0.9-1.0 GeV/c
3.3 ±1.1	BIRMINGHAN	1 66	HBC	K-p 3.5 GeV/c
4.5 ±1.0	ARMENTERO	S650	HBC	

TECN COMMENT

72 HBC  $K^-p \rightarrow \Lambda\pi\pi$ 

DOCUMENT ID

CHAN

 $\Gamma_4/\Gamma$ 

 $\Gamma(\Sigma(1385)\pi)/\Gamma_{\text{total}}$ 

VALUE 0.041±0.005

### Baryon Particle Listings $\Lambda(1520), \Lambda(1600)$

$\Gamma(\Sigma(1385)\pi(\rightarrow \Lambda\pi\pi))/\Gamma(\Lambda\pi\pi)$		S I		Γ ₅ /Γ ₃
The $\Lambda\pi\pi$ mode is largely dugiven by MAST 73B and CC				
The discrepancy between th				
made concerning the shape	of the $(\pi\pi)_{S\text{-wave}}$	e stai	te.	
VALUE	DOCUMENT ID		TECN	COMMENT
$0.58 \pm 0.22$	CORDEN	75		$K^- d$ 1.4–1.8 GeV/ $c$
$0.82 \pm 0.10$	⁴ MAST	73B	IPWA	$K^- p \rightarrow \Lambda \pi \pi$
• • We do not use the following	g data for average	s, fits	, limits,	etc. • • •
$0.39\!\pm\!0.10$	⁵ BURKHARDT	71	нвс	$K^- p \rightarrow (\Lambda \pi \pi) \pi$
$\Gamma(\Lambda(\pi\pi)_{S\text{-wave}})/\Gamma(\Lambda\pi\pi)$				$\Gamma_6/\Gamma_3$
VALUE	DOCUMENT ID		TECN	COMMENT
0.20±0.08	CORDEN	75	DBC	$K^- d 1.4-1.8 \text{ GeV}/c$
$\Gamma(\Sigma\pi\pi)/\Gamma_{\text{total}}$				Γ ₇ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
0.009 ±0.001 OUR ESTIMATE				
0.0086±0.0005 OUR FIT				
0.0086±0.0005 OUR AVERAGE	_			
$0.007 \pm 0.002$	6 CORDEN	75	DBC	$K^- d$ 1.4–1.8 GeV/ $c$
$0.0085 \pm 0.0006$	⁷ MAST	73	MPWA	$K^- p \rightarrow \Sigma \pi \pi$
$0.010 \pm 0.0015$	BARBARO	<b>69</b> B	HBC	K ⁻ p 0.28−0.45 GeV/c
$\Gamma(\Lambda\gamma)/\Gamma_{\text{total}}$				Γ ₈ /Γ
VALUEEVTS	DOCUMENT ID		TECN	COMMENT
0.008 ±0.002 OUR ESTIMATE				
0.0079±0.0014 OUR FIT				
0.0080±0.0014 238	MAST	68B	нвс	Using $\Gamma(N\overline{K})/\Gamma_{\text{total}} = 0.45$
$\Gamma(\Sigma^0 \gamma)/\Gamma_{\text{total}}$				Г9/Г
VALUE	DOCUMENT ID		TECN	COMMENT
0.0195±0.0034 OUR FIT				
0.02 ±0.0035	⁸ MAST	68B	нвс	Not measured; see note

### Λ(1520) FOOTNOTES

- $^1\,\mathrm{From}$  the best-resolution sample of  $\varLambda\,\pi\,\pi$  events only.

- 1 From the best-resolution sample of  $A\pi\pi$  events only. 2 The  $\overline{K} N \to \Sigma \pi$  amplitude at resonance is  $+0.46 \pm 0.01$ . 3 Assumes  $\Gamma(N\overline{K})/\Gamma_{\text{total}} = 0.46 \pm 0.02$ . 4 Both  $\Sigma$  (1385)  $\pi$   $DS_{03}$  and  $\Sigma$  ( $\pi\pi$ )  $DP_{03}$  contribute. 5 The central bin (1514–1524 MeV) gives 0.74  $\pm$  0.10; other bins are lower by 2-to-5 standard deviations. 6 Much of the  $\Sigma \pi\pi$  decay proceeds via  $\Sigma$  (1385)  $\pi$ . 7 Assumes  $\Gamma(A|\overline{K})/\Gamma$  ... 0.46

- 7 Assumes  $\Gamma(NK)/\Gamma_{\rm total}=0.46$ . 8 Calculated from  $\Gamma(\Lambda\gamma)/\Gamma_{\rm total}$ , assuming SU(3). Needed to constrain the sum of all the branching ratios to be unity.

### ∧(1520) REFERENCES

		•	
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+ (HELS, CIT, CERN)
BARBER	80D	ZPHY C7 17	+Dainton, Lee, Marshall+ (DARE, LANC, SHEF)
GOPAL	80	Toronto Conf. 159	(RHEL) IJP
BARLAG	79	NP B149 220	+Blokzijl, Jongejans+ (AMST, CERN, NIJM, OXF)
ALSTON	78	PR D18 182	Alston-Garnjost, Kenney+ (LBL, MTHO, CERN) IJP
Also	77	PRL 38 1007	Alston-Garnjost, Kenney+ (LBL, MTHO, CERN) IJP
CAMERON	77	NP B131 399	+Franek, Gopal, Kalmus, McPherson+ (RHEL, LOIC) IJP
GOPAL	77	NP B119 362	+Ross, VanHorn, McPherson+ (LOIC, RHEL) IJP
MAST	76	PR D14 13	+Alston-Garnjost, Bangerter+ (LBL)
CORDEN	75	NP B84 306	+Cox, Dartnell, Kenyon, O'Neale+ (BIRM)
BERTHON	74	NC 21A 146	+Tristram+ (CDEF, RHEL, SACL, STRB)
MAST	73	PR D7 3212	+Bangerter, Alston-Garnjost+ (LBL) IJP
MAST	73B	PR D7 5	+Bangerter, Alston-Garnjost+ (LBL) IJP
CHAN	72	PRL 28 256	+Button-Shafer, Hertzbach, Kofler+ (MASA, YALE)
BURKHARDT	71	NP B27 64	+Filthuth, Kluge+ (HEID, CERN, SACL)
KIM	71	PRL 27 356	(HARV) IJP
Also	70	Duke Conf. 161	Kim (HARV) IJP
BARBARO	69B	Lund Conf. 352	Barbaro-Galtieri, Bangerter, Mast, Tripp (LRL)
Also	70	Duke Conf. 95	Tripp (LRL)
BURKHARDT		NP B14 106	+Filthuth, Kluge+ (HEID, EFI, CERN, SACL)
MAST	68B	PRL 21 1715	+Alston-Garnjost, Bangerter, Galtieri+ (LRL) +Merrill, Verglas, DeWitt+ (SABRE Collab.)
SCHEUER	68	NP B8 503	+Merrill, Verglas, DeWitt+ (SABRE Collab.)
DAHL	67	PR 163 1377	+Hardy, Hess, Kirz, Miller (LRL) +Malamud, Schlein, Slater, Stork (UCLA)
DAUBER	67	PL 24B 525	+Malamud, Schlein, Slater, Stork (UCLA)
UHLIG	67	PR 155 1448	+Chariton, Condon, Glasser, Youn+ (OND, NRL)
BIRMINGHAM		PR 152 1148	(BIRM, GLAS, LOIC, OXF, RHEL)
ARMENTEROS		PL 19 338	+Ferro-Luzzi+ (CERN, HEID, SACL)
MUSGRAVE	65	NC 35 735	+Petmezas+ (BIRM, CERN, EPOL, LOIC, SACL)
WATSON	63	PR 131 2248	+Ferro-Luzzi, Tripp (LRL) IJP
FERRO-LUZZI	62	PRL 8 28	+Tripp, Watson (LRL) IJP



 $I(J^P) = O(\frac{1}{2}^+)$  Status: ***

See also the  $\Lambda(1810)$   $P_{01}.$  There are quite possibly two  $P_{01}$  states in this region.

### Λ(1600) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1560 to 1700 (≈ 1600) OUR EST	IMATE			
1568± 20	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
$1703 \pm 100$	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
1573± 25	GOPAL	77	DPWA	$\overline{K}N$ multichannel
1596± 6	KANE	74	DPWA	$K^- \rho \rightarrow \Sigma \pi$
1620± 10	LANGBEIN	72	IPWA	$\overline{K}N$ multichannel
• • • We do not use the following	g data for average	es, fit:	s, limits,	etc. • • •
1572 or 1617	¹ MARTIN	77	DPWA	KN multichannel
1646± 7	² CARROLL	76	DPWA	Isospin-0 total $\sigma$
1570	KIM	71	DPWA	K-matrix analysis

### **Λ(1600) WIDTH**

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
50 to 250 (≈ 150) OUR ESTIMA	TE			
116± 20	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
593 ± 200	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
147± 50	GOPAL	77	DPWA	$\overline{K}$ N multichannel
175 ± 20	KANE			$K^- p \rightarrow \Sigma \pi$
60 ± 10	LANGBEIN	72	IPWA	<b>K</b> N multichannel
• • We do not use the following	data for average	s, fit	s, limits,	etc. • • •
247 or 271	¹ MARTIN	77	DPWA	KN multichannel
20	² CARROLL	76	DPWA	Isospin-0 total $\sigma$
50	KIM	71	DPWA	K-matrix analysis

### **Λ(1600) DECAY MODES**

	Mode	Fraction $(\Gamma_i/\Gamma)$
$\Gamma_1$	NK	15-30 %
$\Gamma_2$	$\Sigma \pi$	10–60 %

The above branching fractions are our estimates, not fits or averages.

### **Λ(1600) BRANCHING RATIOS**

See "Sign conventions for resonance couplings" in the Note on  $\varLambda$  and  $\varSigma$ 

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$					$\Gamma_1/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT	
0.15 to 0.30 OUR ESTIMATE					
$0.23 \pm 0.04$	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
$0.14 \pm 0.05$	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
$0.25 \pm 0.15$	LANGBEIN	72	IPWA	K N multichannel	
• • We do not use the following	g data for averag	es, fit	s, limits,	etc. • • •	
$0.24 \pm 0.04$	GOPAL	77	DPWA	See GOPAL 80	
0.30 or 0.29	¹ MARTIN	77	DPWA	KN multichannel	

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to \Lambda$	(1600) → Σπ			(Γ ₁ Γ ₂ ) ^{1/2} /
VALUE	DOCUMENT ID		TECN	COMMENT
$-0.16 \pm 0.04$	GOPAL	77	DPWA	$\overline{K}N$ multichannel
$-0.33 \pm 0.11$	KANE	74	DPWA	$K^- \rho \rightarrow \Sigma \pi$
$0.28 \pm 0.09$	LANGBEIN	72	IPWA	KN multichannel
• • • We do not use the followi	ng data for average	es, fits	, limits,	etc. • • •
-0.39 or -0.39	¹ MARTIN	77	DPWA	KN multichannel
not seen	HEPP	<b>76</b> B	DPWA	$K^- N \rightarrow \Sigma \pi$

#### Λ(1600) FOOTNOTES

 1  The two MARTIN 77 values are from a T-matrix pole and from a Breit-Wigner fit.  2  A total cross-section bump with (J+1/2)  $\Gamma_{el}$  /  $\Gamma_{total}=$  0.04.

### **Λ(1600) REFERENCES**

GOPAL	80	Toronto Conf. 159		(RHEL) IJP
ALSTON	78	PR D18 182	Alston-Garniost, Kenney+ (LBL	MTHO, CERN) IJP
Also	77	PRL 38 1007	Alston-Garnjost, Kenney+ (LBL	MTHO, CERN) IJP
GOPAL	77	NP B119 362	+Ross, VanHorn, McPherson+	(LOIC, RHEL) IJP
MARTIN	77	NP B127 349	+Pidcock, Moorhouse	(LOUC, GLAS) IJP
Also	77B	NP B126 266	Martin, Pidcock	(LOUC)
Also	77C	NP B126 285	Martin, Pidcock	(LOUC) IJP
CARROLL	76	PRL 37 806	+Chiang, Kycia, Li, Mazur, Michael+	(BNL) I
HEPP	76B	PL 65B 487	+Braun, Grimm, Strobele+ (CERN,	HEIDH, MPIM) IJP
KANE	74	LBL-2452		(LBL) IJP
LANGBEIN	72	NP B47 477	+Wagner	(MPIM) IJP
KIM	71	PRL 27 356		(HARV) IJP

# Baryon Particle Listings $\Lambda(1670)$ , $\Lambda(1690)$

 $\Lambda(1670) S_{01}$ 

 $I(J^P) = O(\frac{1}{2}^-)$  Status: ***

The measurements of the mass, width, and elasticity published before 1974 are now obsolete and have been omitted. They were last listed in our 1982 edition Physics Letters 111B (1982).

### Λ(1670) MASS

VALUE	(MeV)	DOCUMENT ID		TECN	COMMENT
1660	to 1680 (≈ 1670) OUR EST	IMATE			
1670.8	3±1.7	KOISO	85	DPWA	$K^- \rho \rightarrow \Sigma \pi$
1667	±5	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
1671	±3	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
1670	±5	GOPAL	77	DPWA	KN multichannel
1675	±2	HEPP	76B	DPWA	$K^- N \rightarrow \Sigma \pi$
1679	±1	KANE	74	DPWA	$K^- p \rightarrow \Sigma \pi$
1665	±5	PREVOST	74	DPWA	$K^- N \rightarrow \Sigma(1385)\pi$
• • •	We do not use the following	data for averages	, fits	, limits,	etc. • • •
1669	±2	ABAEV	96	DPWA	$\pi^- p \rightarrow \eta n$
1664	1	L MARTIN			$\overline{K}N$ multichannel

### **Λ(1670) WIDTH**

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
25 to 50 (≈ 35) OUR ESTIMATE				
34.1 ± 3.7	KOISO	85	DPWA	$K^- p \rightarrow \Sigma \pi$
29 ± 5	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
29 ± 5	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
45 ±10	GOPAL	77	DPWA	<b>K</b> N multichannel
46 ± 5	HEPP	<b>76</b> B	DPWA	$K^- N \rightarrow \Sigma \pi$
40 ± 3	KANE	74	DPWA	$K^- p \rightarrow \Sigma \pi$
19 ± 5	PREVOST	74	DPWA	$K^- N \rightarrow \Sigma(1385)\pi$
• • We do not use the following d	lata for averages	, fits	, limits,	etc. • • •
21 ± 4	ABAEV	96	DPWA	$\pi^- p \rightarrow \eta n$
12	MARTIN	77	DPWA	$\overline{K}N$ multichannel

### A(1670) DECAY MODES

	Mode	Fraction $(\Gamma_i/\Gamma)$	
$\Gamma_1$	NK	15-25 %	
$\Gamma_2^-$	$\Sigma \pi$	20-60 %	
Γ3	$\Lambda\eta$	15-35 %	
$\Gamma_4$	$\Sigma(1385)\pi$		

The above branching fractions are our estimates, not fits or averages.

### **Λ(1670) BRANCHING RATIOS**

See "Sign conventions for resonance couplings" in the Note on  $\varLambda$  and  $\varSigma$  Resonances.

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$					Γ1,
VALUE	DOCUMENT ID		TECN	COMMENT	
0.15 to 0.25 OUR ESTIMAT	TE .				
$0.18 \pm 0.03$	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
$0.17 \pm 0.03$	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
• • • We do not use the fo	llowing data for averag	es, fits	s, limits,	etc. • • •	
$0.20 \pm 0.03$	GOPAL	77	DPWA	See GOPAL 80	
0.15	¹ MARTIN	77	DPWA	$\overline{K}N$ multichannel	

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K}$	(Γ ₁ Γ ₂ ) ^½ /Γ			
VALUE	DOCUMENT ID		TECN	COMMENT
$-0.26 \pm 0.02$	KOISO	85	DPWA	$K^- p \rightarrow \Sigma \pi$
$-0.31 \pm 0.03$	GOPAL	77	DPWA	$\overline{K}$ N multichannel
$-0.29 \pm 0.03$	HEPP			$K^- N \rightarrow \Sigma \pi$
$-0.23 \pm 0.03$	LONDON	75	HLBC	$K^- \rho \rightarrow \Sigma^0 \pi^0$
$-0.27 \pm 0.02$	KANE	74	DPWA	$K^- p \rightarrow \Sigma \pi$
• • • We do not use the	e following data for averages	s, fits	s, limits,	etc. • • •
-0.13	¹ MARTIN	77	DPWA	$\overline{K}N$ multichannel

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K}$	$(\Gamma_1\Gamma_3)^{\frac{1}{2}}/\Gamma$			
VALUE	DOCUMENT ID		TECN	COMMENT
$+0.20\pm0.05$	BAXTER	73	DPWA	$K^-p \rightarrow \text{neutrals}$
• • • We do not use the	following data for average	s, fit	s, limits,	etc. • • •
0.06	ABAEV	96	DPWA	$\pi^- p \rightarrow \eta n$
0.24	KIM	71	DPWA	K-matrix analysis
0.26	ARMENTERO	S690	HBC	
0.20 or 0.23	BERLEY	65	HBC	

$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N \overline{K} \rightarrow \Lambda(167)$		$(\Gamma_1\Gamma_4)^{\frac{1}{2}}/\Gamma$			
VALUE	DOCUMENT ID		TECN	COMMENT	
$-0.18\pm0.05$	PREVOST	74	DPWA	$\kappa^- N \rightarrow$	$\Sigma(1385)\pi$

### ∧(1670) FOOTNOTES

 $^{1}\,\mathrm{MARTIN}$  77 obtains identical resonance parameters from a T-matrix pole and from a Breit-Wigner fit.

### Λ(1670) REFERENCES

ABAEV KOISO PDG GOPAL	96 85 82 80	PR C53 385 NP A433 619 PL 111B Toronto Conf. 159	+Nefkens +Sai, Yamamoto, Kofler Roos, Porter, Aguilar-Benitez+	(UCLA) (TOKY, MASA) (HELS, CIT, CERN) (RHEL) IJP
ALSTON	78	PR D18 182	Alston-Garnjost, Kenney+	(LBL, MTHO, CERN) IJP
Also	77	PRL 38 1007	Alston-Garnjost, Kenney+	(LBL, MTHO, CERN) IJP
GOPAL	77	NP B119 362	+Ross, VanHorn, McPherson+	(LOIC, RHEL) IJP
MARTIN	77	NP B127 349	+Pidcock, Moorhouse	(LOUC, GLAS) IJP
Also	77B	NP B126 266	Martin, Pidcock	(LOUC)
Also	77C	NP B126 285	Martin, Pidcock	(LOUC) IJP
HEPP	76B	PL 65B 487		(CERN, HEIDH, MPIM) IJP
LONDON	75	NP B85 289	+Yu, Boyd+ (BNL, CERN	I, EPOL, ORSAY, TORI)
KANE	74	LBL-2452		(LBL) IJP
PREVOST	74	NP B69 246	+Barloutaud+	(SACL, CERN, HEID)
BAXTER	73	NP B67 125	+Buckingham, Corbett, Dunn+	(OXF) IJP
KIM	71	PRL 27 356	-	(HARV) IJP
Also	70	Duke Conf. 161	Kim	(HARV) IJP
ARMENTEROS Values are		Lund Paper 229 d in LEVI-SETTI 69.	+Baillon+	(CERN, HEID, SACL) IJP
BERLEY	65	PRL 15 641	+Connolly, Hart, Rahm, Stonehill+	(BNL) IJP

### $\Lambda(1690) D_{03}$

 $I(J^P) = O(\frac{3}{2}^-)$  Status: ***

The measurements of the mass, width, and elasticity published before 1974 are now obsolete and have been omitted. They were last listed in our 1982 edition Physics Letters 111B (1982).

### Λ(1690) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1685 to 1695 (≈ 1690) OUR ES	TIMATE			
$1695.7 \pm 2.6$	KOISO	85	DPWA	$K^- p \rightarrow \Sigma \pi$
1690 ±5	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
1692 ±5	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
1690 ±5	GOPAL	77	DPWA	$\overline{K}N$ multichannel
1690 ±3	HEPP	76B	DPWA	$K^- N \rightarrow \Sigma \pi$
1689 ±1	KANE	74	DPWA	$K^- \rho \rightarrow \Sigma \pi$
• • • We do not use the following	data for average	s, fits	s, limits,	etc. • • •
1687 or 1689	¹ MARTIN	77	DPWA	$\overline{K}N$ multichannel
1692 ±4	CARROLL	76	DPWA	Isospin-0 total $\sigma$

### 1/(1690) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
50 to 70 ( $\approx$ 60) OUR ESTIMATE				
67.2± 5.6	KOISO	85	DPWA	$K^- p \rightarrow \Sigma \pi$
61 ± 5	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
64 ±10	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
60 ± 5	GOPAL	77	DPWA	KN multichannel
82 ± 8	HEPP	76B	DPWA	$K^- N \rightarrow \Sigma \pi$
60 ± 4	KANE	74	DPWA	$K^- p \rightarrow \Sigma \pi$
• • We do not use the following of	lata for averages	, fits	, limits,	etc. • • •
62 or 62 1	MARTIN	77	DPWA	K N multichannel
38	CARROLL	76	DPWA	Isospin-0 total $\sigma$

### Λ(1690) DECAY MODES

	Mode	Fraction $(\Gamma_{\hat{I}}/\Gamma)$	
$\overline{\Gamma_1}$	NK	20-30 %	
$\Gamma_2$	$\Sigma \pi$	20-40 %	
$\Gamma_3$	Λππ	$\sim$ 25 %	
$\Gamma_4$	$\Sigma \pi \pi$	$\sim$ 20 %	
$\Gamma_5$	$\Lambda\eta$		
Γ ₆	$\Sigma(1385)\pi$ , $S$ -wave		

The above branching fractions are our estimates, not fits or averages.

### **Baryon Particle Listings** $\Lambda(1690), \Lambda(1800)$

### Λ(1690) BRANCHING RATIOS

The sum of all the quoted branching ratios is more than 1.0. The twobody ratios are from partial-wave analyses, and thus probably are more reliable than the three-body ratios, which are determined from bumps in cross sections. Of the latter, the  $\Sigma\,\pi\pi$  bump looks more significant. (The error given for the  $\Lambda\pi\pi$  ratio looks unreasonably small.) Hardly any of the  $\Sigma \pi \pi$  decay can be via  $\Sigma$ (1385), for then seven times as much  $\Lambda \pi \pi$  decay would be required. See "Sign conventions for resonance couplings" in the Note on  $\varLambda$  and  $\varSigma$  Resonances.

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$				Γ ₁ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
0.2 to 0.3 OUR ESTIMATE				
$0.23 \pm 0.03$	GOPAL			$\overline{K}N \rightarrow \overline{K}N$
$0.22 \pm 0.03$	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
• • We do not use the foll	owing data for averag	es, fits	s, limits,	etc. • • •
$0.24 \pm 0.03$	GOPAL	77	DPWA	See GOPAL 80
0.28 or 0.26	¹ MARTIN	77	DPWA	$\overline{K}$ N multichannel
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \rightarrow$	$\Lambda(1690) \rightarrow \Sigma \pi$		TECN	(Γ ₁ Γ ₂ ) ^{1/2} /Γ
VALUE				
-0.34±0.02	KOISO	85		$K^- p \rightarrow \Sigma \pi$ $\overline{K} N$ multichannel
-0.25±0.03	GOPAL	77		
$-0.29 \pm 0.03$	HEPP			$K^- N \rightarrow \Sigma \pi$
$-0.28 \pm 0.03$	LONDON			$K^- \rho \rightarrow \Sigma^0 \pi^0$
$-0.28 \pm 0.02$	KANE	74		$K^- p \rightarrow \Sigma \pi$
• • We do not use the following	-			
			D D	
−0.30 or −0.28	¹ MARTIN	//	DPWA	$\overline{K}N$ multichannel
	$\Lambda(1690) \rightarrow \Lambda \eta$			(Γ₁Γ₅) ^½ /Ι
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to$	$\Lambda(1690) \rightarrow \Lambda \eta$ DOCUMENT ID		TECN	(Γ ₁ Γ ₅ ) ^{1/2} /Ι
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to VALUE}$	$\Lambda(1690) \rightarrow \Lambda \eta$ DOCUMENT ID		TECN	(Γ₁Γ₅) ^½ /Ι
$(\Gamma_1\Gamma_r)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \frac{VALUE}{0.000 \pm 0.03}$ $(\Gamma_1\Gamma_r)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \frac{1}{2}$	$\Lambda(1690) \rightarrow \Lambda \eta$ $\begin{array}{c} \Lambda(1690) \rightarrow \Lambda \eta \\ \text{BAXTER} \end{array}$ $\Lambda(1690) \rightarrow \Lambda \pi \pi$	73	<u>TECN</u> DPWA	$\frac{(\Gamma_1\Gamma_5)^{\frac{1}{2}}/\Gamma_5}{K^- p \rightarrow \text{ neutrals}}$ $\frac{(\Gamma_1\Gamma_3)^{\frac{1}{2}}/\Gamma_5}{(\Gamma_1\Gamma_3)^{\frac{1}{2}}/\Gamma_5}$
$(\Gamma_{l}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow VALUE}$ $0.00\pm0.03$ $(\Gamma_{l}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow VALUE}$	$\Lambda(1690) \rightarrow \Lambda \eta$ $DOCUMENT ID$ BAXTER $\Lambda(1690) \rightarrow \Lambda \pi \pi$ $DOCUMENT ID$	73	TECN DPWA	$\frac{(\Gamma_1\Gamma_5)^{\frac{1}{2}}/I}{K^-\rho \to \text{neutrals}}$ $\frac{(\Gamma_1\Gamma_3)^{\frac{1}{2}}/I}{COMMENT}$
$(\Gamma_{l}\Gamma_{r})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow VALUE}$ $0.00 \pm 0.03$ $(\Gamma_{l}\Gamma_{r})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow VALUE}$ • • • We do not use the following	$\Lambda(1690) \rightarrow \Lambda \eta$ $DOCUMENT ID$ BAXTER $\Lambda(1690) \rightarrow \Lambda \pi \pi$ DOCUMENT ID  owing data for average	73	TECN DPWA  TECN s, limits,	$\frac{(\Gamma_1\Gamma_5)^{\frac{1}{2}}/I}{K^-p \to \text{neutrals}}$ $\frac{(\Gamma_1\Gamma_3)^{\frac{1}{2}}/I}{(\Gamma_1\Gamma_3)^{\frac{1}{2}}/I}$ etc. • • •
$(\Gamma_{I}\Gamma_{I})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow VALUE}$ 0.00±0.03 $(\Gamma_{I}\Gamma_{I})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow VALUE}$ • • • We do not use the folloo.25±0.03 $(\Gamma_{I}\Gamma_{I})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow VALUE}$	$\Lambda(1690) \rightarrow \Lambda \eta$ $\rho$	73 res, fits 68	TECN DPWA TECN s, limits,	$\frac{(\Gamma_1\Gamma_5)^{\frac{1}{2}}/I}{K^-\rho \rightarrow \text{ neutrals}}$ $\frac{(\Gamma_1\Gamma_3)^{\frac{1}{2}}/I}{\text{etc.} \bullet \bullet \bullet}$ $K^-\rho \rightarrow \Lambda\pi\pi$ $\frac{(\Gamma_1\Gamma_4)^{\frac{1}{2}}/I}{(\Gamma_1\Gamma_4)^{\frac{1}{2}}/I}$
$(\Gamma_{1}\Gamma_{r})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow VALUE}$ $0.00\pm0.03$ $(\Gamma_{1}\Gamma_{r})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow VALUE}$ $\bullet \bullet \bullet \text{ We do not use the folloop}$ $0.25\pm0.02$ $(\Gamma_{1}\Gamma_{r})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow VALUE}$	$\Lambda(1690) \rightarrow \Lambda \eta$ $0 \rightarrow \Lambda \eta$ $0 \rightarrow \Lambda \eta$ $0 \rightarrow \Lambda \pi \pi$ $0 \rightarrow \Lambda \pi \pi$ Dowling data for average 2 BARTLEY $\Lambda(1690) \rightarrow \Sigma \pi \pi$ $0 \rightarrow \Omega \pi \pi \pi$ $0 \rightarrow \Omega \pi \pi \pi \pi$	73 es, fits 68	TECN DPWA  TECN s, limits, HDBC	$\frac{(\Gamma_1\Gamma_5)^{\frac{1}{2}}/I}{K^-p \to \text{neutrals}}$ $\frac{(\Gamma_1\Gamma_3)^{\frac{1}{2}}/I}{\text{etc.} \bullet \bullet \bullet$ $K^-p \to \Lambda\pi\pi$ $\frac{(\Gamma_1\Gamma_4)^{\frac{1}{2}}/I}{COMMENT}$
$(\Gamma_{1}\Gamma_{r})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow VALUE}$ $0.00\pm0.03$ $(\Gamma_{1}\Gamma_{r})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow VALUE}$ $\bullet \bullet \bullet \text{ We do not use the folloop}$ $0.25\pm0.02$ $(\Gamma_{1}\Gamma_{r})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow VALUE}$	$\Lambda(1690) \rightarrow \Lambda \eta$ $0 \rightarrow \Lambda \eta$ $0 \rightarrow \Lambda \eta$ $0 \rightarrow \Lambda \pi \pi$ $0 \rightarrow \Lambda \pi \pi$ Dowling data for average 2 BARTLEY $\Lambda(1690) \rightarrow \Sigma \pi \pi$ $0 \rightarrow \Omega \pi \pi \pi$ $0 \rightarrow \Omega \pi \pi \pi \pi$	73 es, fits 68	TECN DPWA  TECN s, limits, HDBC	$\frac{(\Gamma_1\Gamma_5)^{\frac{1}{2}}/l}{K^-\rho \rightarrow \text{ neutrals}}$ $\frac{(\Gamma_1\Gamma_3)^{\frac{1}{2}}/l}{\text{etc.} \bullet \bullet \bullet}$ $K^-\rho \rightarrow \Lambda\pi\pi$ $\frac{(\Gamma_1\Gamma_4)^{\frac{1}{2}}/l}{(\Gamma_1\Gamma_4)^{\frac{1}{2}}/l}$
$(\Gamma_{1}\Gamma_{r})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow VALUE}$ 0.00±0.03 $(\Gamma_{1}\Gamma_{r})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow VALUE}$ • • • We do not use the folloo.25±0.02 $(\Gamma_{1}\Gamma_{r})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow VALUE}$ 0.21 $(\Gamma_{1}\Gamma_{r})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow VALUE}$ $(\Gamma_{1}\Gamma_{r})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow VALUE}$	$\Lambda(1690) \rightarrow \Lambda \eta$ $DOCUMENT ID$ BAXTER $\Lambda(1690) \rightarrow \Lambda \pi \pi$ $DOCUMENT ID$ owing data for averag 2 BARTLEY $\Lambda(1690) \rightarrow \Sigma \pi \pi$ $DOCUMENT ID$ ARMENTER: $\Lambda(1690) \rightarrow \Sigma(136)$	73 es, fits 68 OS680	TECN DPWA  TECN I, limits, HDBC  TECN HDBC	$\frac{(\Gamma_1\Gamma_5)^{\frac{1}{2}}/I}{K^-\rho \rightarrow \text{ neutrals}}$ $\frac{(\Gamma_1\Gamma_3)^{\frac{1}{2}}/I}{\text{etc.} \bullet \bullet \bullet}$ $K^-\rho \rightarrow \Lambda\pi\pi$ $\frac{(\Gamma_1\Gamma_4)^{\frac{1}{2}}/I}{K^-N \rightarrow \Sigma\pi\pi}$ $\bullet \qquad (\Gamma_1\Gamma_6)^{\frac{1}{2}}/I$ $\bullet \qquad (\Gamma_1\Gamma_6)^{\frac{1}{2}}/I$
$(\Gamma_{l}\Gamma_{r})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \frac{VALUE}{0.00\pm0.03}$ $(\Gamma_{l}\Gamma_{r})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \frac{VALUE}{VALUE}$	$\Lambda(1690) \rightarrow \Lambda \eta$ $DOCUMENT ID$ BAXTER $\Lambda(1690) \rightarrow \Lambda \pi \pi$ $DOCUMENT ID$ owing data for averag 2 BARTLEY $\Lambda(1690) \rightarrow \Sigma \pi \pi$ $DOCUMENT ID$ ARMENTER	73 es, fits 68 OS68c	TECN DPWA  TECN 5, limits, HDBC  TECN HDBC	$\frac{(\Gamma_1\Gamma_5)^{\frac{1}{2}}/I}{K^-\rho \rightarrow \text{ neutrals}}$ $\frac{(\Gamma_1\Gamma_3)^{\frac{1}{2}}/I}{\text{etc.} \bullet \bullet \bullet}$ $K^-\rho \rightarrow \Lambda\pi\pi$ $\frac{(\Gamma_1\Gamma_4)^{\frac{1}{2}}/I}{K^-N \rightarrow \Sigma\pi\pi}$ $\bullet \qquad (\Gamma_1\Gamma_6)^{\frac{1}{2}}/I$ $\bullet \qquad (\Gamma_1\Gamma_6)^{\frac{1}{2}}/I$

### **Λ(1690) FOOTNOTES**

 1  The two MARTIN 77 values are from a T-matrix pole and from a Breit-Wigner fit. Another  $D_{03}$  A at 1966 MeV is also suggested by MARTIN 77, but is very uncertain.

²BARTLEY 68 uses only cross-section data. The enhancement is not seen by PRE-

### ∧(1690) REFERENCES

KOISO	85	NP A433 619	+Sai, Yamamoto, Kofler	(TOKY, MASA)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
GOPAL.	80	Toronto Conf. 159		(RHEL) IJP
ALSTON	78	PR D18 182	Alston-Garnjost, Kenney+	(LBL, MTHO, CERN) IJP
Also	77	PRL 38 1007	Alston-Garnjost, Kenney+	(LBL, MTHO, CERN) IJP
GOPAL	77	NP B119 362	+Ross, VanHorn, McPherson+	(LOIC, RHEL) IJP
MARTIN	77	NP B127 349	+Pidcock, Moorhouse	(LOUC, GLAS) IJP
Also	77B	NP B126 266	Martin, Pidcock	(LOUC)
Also	77C	NP B126 285	Martin, Pidcock	(LOUC) IJP
CARROLL	76	PRL 37 806	+Chiang, Kycia, Li, Mazur, Michael	
HEPP	76B	PL 65B 487	+Braun, Grimm, Strobele+	
LONDON	75	NP B85 289	+Yu, Boyd+ (BNL, CERN,	, EPOL, ORSAY, TORI)
KANE	74	LBL-2452		(LBL) IJP
PREVOST	74	NP B69 246	+Barloutaud+	(SACL, CERN, HEID)
BAXTER	73	NP B67 125	+Buckingham, Corbett, Dunn+	(OXF) IJP
PREVOST	71	Amsterdam Conf.		(CERN, HEID, SACL)
ARMENTEROS	68C	NP B8 216	+Baillon+	(CERN, HEID, SACL) I
BARTLEY	68	PRL 21 1111	+Chu, Dowd, Greene+	(TUFTS, FSU, BRAN) I

### $\Lambda(1800) S_{01}$

 $I(J^P) = O(\frac{1}{2})$  Status: ***

This is the second resonance in the  $S_{01}$  wave, the first being the

### Λ(1800) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1720 to 1850 (≈ 1800) OUF	RESTIMATE			
1841 ± 10	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
1725±20	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
1825±20	GOPAL	77	DPWA	KN multichannel
1830±20	LANGBEIN	72	IPWA	KN multichannel
• • We do not use the fo	llowing data for average	es, fit	s, limits,	etc. • • •
1767 or 1842	¹ MARTIN	77	DPWA	$\overline{K}N$ multichannel
1780	KIM	71	DPWA	K-matrix analysis
1872±10	BRICMAN	708	DPWA	$\overline{K}N \to \overline{K}N$

### **Λ(1800) WIDTH**

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
200 to 400 (≈ 300) OUR ES	TIMATE			
228±20	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
185 ± 20	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
230±20	GOPAL	77	DPWA	KN multichannel
70 ± 15	LANGBEIN	72	IPWA	KN multichannel
• • We do not use the following the fol	owing data for average	es, fits	, limits,	etc. • • •
435 or 473	¹ MARTIN	77	DPWA	KN multichannel
40	KIM	71	DPWA	K-matrix analysis
100 ± 20	BRICMAN	70B	DPWA	$\overline{K}N \rightarrow \overline{K}N$

### A(1800) DECAY MODES

	Mode	Fraction $(\Gamma_i/\Gamma)$
Γ ₁	N₩	25-40 %
$\Gamma_2$	$\Sigma \pi$	seen
Гз	$\Sigma(1385)\pi$	seen
$\Gamma_4$	N K*(892)	seen
Γ ₅	$N\overline{K}^*(892)$ , $S=1/2$ , S-wave	
Γ ₆	$N\overline{K}^*(892)$ , $S=3/2$ , $D$ -wave	

The above branching fractions are our estimates, not fits or averages.

### A(1800) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on  $\varLambda$  and  $\varSigma$ Resonances.

F(NK)/I total					11/1
VALUE	DOCUMENT ID		TECN	COMMENT	
0.25 to 0.40 OUR ESTIMATE					
$0.36 \pm 0.04$	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
$0.28 \pm 0.05$	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
$0.35 \pm 0.15$	LANGBEIN	72	IPWA	KN multichannel	
ullet $ullet$ We do not use the following	data for average	s, fits	, limits,	etc. • • •	
$0.37 \pm 0.05$	GOPAL	77	DPWA	See GOPAL 80	

¹ MARTIN 77 DPWA  $\overline{K}N$  multichannel 1.21 or 0.70 71 DPWA K-matrix analysis 708 DPWA  $\overline{K}N \to \overline{K}N$ 0.80 KIM BRICMAN  $0.18 \pm 0.02$ 

 $(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\overline{K} \to \Lambda(1800) \to \Sigma \pi$ TECN COMMENT DOCUMENT ID GOPAL ullet ullet We do not use the following data for averages, fits, limits, etc. ullet ullet¹ MARTIN 77 DPWA  $\overline{K}N$  multichannel -0.74 or -0.4371 DPWA K-matrix analysis

 $\frac{\left( \Gamma_1 \Gamma_7 \right)^{\frac{1}{2}} / \Gamma_{\text{total in } N \overline{K}} \rightarrow \Lambda (1800) \rightarrow \Sigma (1385) \pi}{\frac{DOCUMENT ID}{+ 0.056 \pm 0.028}}$ 78 DPWA  $K^- \rho \rightarrow \Sigma(1385)\pi$ 

 $(\Gamma_I \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \to \Lambda(1800) \to N\overline{K}^*(892), S=1/2, S\text{-wave } (\Gamma_1 \Gamma_5)^{\frac{1}{2}}/\Gamma$ 

 $(\Gamma_I \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Lambda(1800) \rightarrow N\overline{K}^*(892), S=3/2, D\text{-wave } (\Gamma_1 \Gamma_6)^{\frac{1}{2}}/\Gamma_6$ DOCUMENT ID TECN COMMENT 788 DPWA  $K^-p \rightarrow N\overline{K}^*$ CAMERON

# Baryon Particle Listings $\Lambda(1800)$ , $\Lambda(1810)$ , $\Lambda(1820)$

### A(1800) FOOTNOTES

 1  The two MARTIN 77 values are from a T-matrix pole and from a Breit-Wigner fit.  2  The published sign has been changed to be in accord with the baryon-first convention.

### ∧(1800) REFERENCES

GOPAL	80	Toronto Conf. 159		(RHEL) IJP
ALSTON	78	PR D18 182	Alston-Garnjost, Kenney+ (LBL	, MTHO, CERN) IJP
Also	77	PRL 38 1007	Alston-Garnjost, Kenney+ (LBL	, MTHO, CERN) IJP
CAMERON	78	NP B143 189	+Franek, Gopal, Bacon, Butterworth+	(RHEL, LOIC) IJP
CAMERON	78B	NP B146 327	+Franek, Gopal, Kalmus, McPherson+	(RHEL, LOIC) IJP
GOPAL	77	NP B119 362	+Ross, VanHorn, McPherson+	(LOIC, RHEL) IJP
MARTIN	77	NP B127 349	+Pidcock, Moorhouse	(LOUC, GLAS) IJP
Also	77B	NP B126 266	Martin, Pidcock	(LOUC)
Also	77C	NP B126 285	Martin, Pidcock	(LOUC) IJP
LANGBEIN	72	NP B47 477	+Wagner	(MPIM) IJP
KIM	71	PRL 27 356		(HARV) IJP
Also	70	Duke Conf. 161	Kim	(HARV) IJP
BRICMAN	70B	PL 33B 511	+Ferro-Luzzi, Lagnaux	(CERN) IJP

## $\Lambda(1810) P_{01}$

$$I(J^P) = O(\frac{1}{2}^+)$$
 Status: ***

Almost all the recent analyses contain a  $P_{01}$  state, and sometimes two of them, but the masses, widths, and branching ratios vary greatly. See also the  $\Lambda(1600)$   $P_{01}$ .

#### Λ(1810) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1750 to 1850 (≈ 1810) O	JR ESTIMATE			
1841±20	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
1853±20	GOPAL	77	DPWA	KN multichannel
1735 ± 5	CARROLL	76	DPWA	Isospin-0 total $\sigma$
1746±10	PREVOST	74	DPWA	$K^- N \rightarrow \Sigma(1385)\pi$
1780 ± 20	LANGBEIN	72	IPWA	KN multichannel
• • We do not use the	following data for average	s, fits	s, limits,	etc. • • •
1861 or 1953	¹ MARTIN	77	DPWA	$\overline{K}$ N multichannel
1755	KIM	71	DPWA	K-matrix analysis
1800	ARMENTERO	S70	HBC	$\overline{K}N \rightarrow \overline{K}N$
1750	ARMENTERO	<b>S</b> 70	HBC	$\overline{K}N \rightarrow \Sigma \pi$
$1690 \pm 10$	BARBARO	70	HBC	$\overline{K}N \rightarrow \Sigma \pi$
1740	BAILEY	69	DPWA	$\overline{K}N \rightarrow \overline{K}N$
1745	ARMENTERO	<b>S</b> 68B	HBC	$\overline{K}N \rightarrow \overline{K}N$

### **Λ(1810) WIDTH**

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
50 to 250 (≈ 150) OUR ESTIMAT	Έ		
164±20	GOPAL 80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
$90\pm20$	CAMERON 78	B DPWA	$K^- p \rightarrow N \overline{K}^*$
$166 \pm 20$	GOPAL 77	DPWA	$\overline{K}N$ multichannel
46±20	PREVOST 74	DPWA	$K^- N \rightarrow \Sigma(1385)\pi$
120±10	LANGBEIN 72	IPWA	KN multichannel
ullet $ullet$ We do not use the following	data for averages, fi	ts, limits,	etc. • • •
535 or 585	¹ MARTIN 77	DPWA	K N multichannel
28	CARROLL 76	DPWA	Isospin-0 total $\sigma$
35	KIM 71	DPWA	K-matrix analysis
30	ARMENTEROS70	HBC	$\overline{K}N \rightarrow \overline{K}N$
70	ARMENTEROS70	HBC	$\overline{K}N \rightarrow \Sigma \pi$
22	BARBARO 70	HBC	$\overline{K}N \rightarrow \Sigma \pi$
300	BAILEY 69	DPWA	$\overline{K}N \rightarrow \overline{K}N$
147	ARMENTEROS68	в НВС	

### A(1810) DECAY MODES

	Mode	Fraction $(\Gamma_i/\Gamma)$	
Γ ₁	NK	20-50 %	
$\Gamma_2$	$\Sigma \pi$	10-40 %	
Гз	$\Sigma(1385)\pi$	seen	
Γ4	N\overline{K}*(892)	30-60 %	
Γ ₅	$N\overline{K}^*(892)$ , $S=1/2$ , $P$ -wave		
Γ ₆	$N\overline{K}^*(892)$ , $S=3/2$ , $P$ -wave		

The above branching fractions are our estimates, not fits or averages.

### Λ(1810) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on  $\varLambda$  and  $\varSigma$  Resonances.

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$					$\Gamma_1/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT	
0.2 to 0.5 OUR ESTIMATE					
$0.24 \pm 0.04$	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
$0.36 \pm 0.05$	LANGBEIN	72	IPWA	$\overline{K}$ N multichannel	

0.21 ± 0.04 0.52 or 0.49 0.50 0.50 0.50 0.50 0.50 0.50 0.50 0.5	• • We do not use the following					
0.30 0.15 0.15 0.16 0.17 0.19 0.19 0.19 0.19 0.19 0.19 0.19 0.19						
0.15 0.55 0.54 0.55 0.56 0.57 0.58 0.64  ARMENTEROS68B DPWA $\overline{K}N \rightarrow \overline{K}N$ 0.74  ( $\Gamma_{1}\Gamma_{1}$ )\(^{1/2}/\Gamma_{\text{total}}\) In $N\overline{K} \rightarrow \Lambda$ (1810) $\rightarrow \Sigma\pi$ \[ \begin{array}{c ccccccccccccccccccccccccccccccccccc						
0.55 0.4 BAILEY 69 DPWA $\overline{K}N \to \overline{K}N$ 0.4 ARMENTEROS688 DPWA $\overline{K}N \to \overline{K}N$ 0.4 ( $\Gamma_1\Gamma_1$ ) $\frac{1}{2}$ / $\Gamma_{total}$ in $N\overline{K} \to \Lambda$ (1810) $\to \Sigma \pi$ ( $\Gamma_1\Gamma_2$ ) $\frac{1}{2}$ / $\Lambda$ VALUE DOCUMENT ID TECN COMMENT OF N multichannel 4 on the onot use the following data for averages, fits, limits, etc. • • • + 0.25 or + 0.23 1 MARTIN 77 DPWA $\overline{K}N$ multichannel 1.4 NGBEIN 72 IPWA $\overline{K}N$ multichannel 2.5 or + 0.23 2 ARMENTEROS70 DPWA $\overline{K}N \to \Sigma \pi$ 1.5 DPWA $\overline{K}N \to \Sigma \pi$ 1.6 DPWA $\overline{K}N \to \Sigma \pi$ 1.7 DPWA $\overline{K}N \to \Sigma \pi$ 1.7 DPWA $\overline{K}N \to \Sigma \pi$ 1.8 DPWA $\overline{K}N \to \Sigma \pi$						
0.4 ARMENTEROS688 DPWA $\overline{K}N \rightarrow \overline{K}N$ $ (\Gamma_{\Gamma}\Gamma_{\Gamma})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Lambda(1810) \rightarrow \Sigma\pi $ $ (\Gamma_{1}\Gamma_{2})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Lambda(1810) \rightarrow \Sigma\pi $ $ -0.24 \pm 0.04 \qquad GOPAL \qquad 77 \qquad DPWA \qquad \overline{K}N \text{ multichannel} $ • • We do not use the following data for averages, fits, limits, etc. • • • • • • • • • • • • • • • • • • •						
VALUE $0.24\pm0.04$ $0.24\pm0.04$ $0.204\pm0.04$ $0.204\pm0.04$ $0.204\pm0.04$ $0.204\pm0.04$ $0.204\pm0.04$ $0.204\pm0.04$ $0.204\pm0.04$ $0.204\pm0.02$ $0.204\pm0.04$ $0.204\pm0.02$	0.4	ARMENTER	OS68B	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
• • • We do not use the following data for averages, fits, limits, etc. • • • • • +0.25 or +0.23	$(\Gamma_I \Gamma_I)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \overline{K} \to \Lambda$	1810) → Σπ DOCUMENT IE		TECN	$(\Gamma_1\Gamma_2)^{\frac{1}{2}}$	٦/'
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$						
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	• • We do not use the following					
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	+0.25 or +0.23	¹ MARTIN	77	DPWA	KN multichannel	
$ \begin{array}{c} +0.20 \\ -0.13\pm0.03 \end{array} \begin{array}{c} 2 \text{ ARMENTEROS70} \\ \text{BARBARO} & 70 \end{array} \begin{array}{c} \text{DPWA}  \overline{K}N \rightarrow  \Sigma \pi \\ \text{DOCUMENT IO} \\ +0.18\pm0.10 \end{array} \begin{array}{c} \Lambda(1810) \rightarrow  \Sigma(1385)\pi \\ \text{PREVOST}  74 \end{array} \begin{array}{c} \frac{COMMENT}{KN \rightarrow  \Sigma \pi} \end{array} \\ \begin{array}{c} \Gamma_1 \Gamma_3 \right)^{\frac{1}{2}} / \\ \text{DOCUMENT IO} \\ \text{PREVOST}  74 \end{array} \begin{array}{c} \frac{COMMENT}{KN \rightarrow  \Sigma \pi} \end{array} \\ \begin{array}{c} \Gamma_1 \Gamma_3 \right)^{\frac{1}{2}} / \\ \text{DOCUMENT IO} \\ \frac{DOCUMENT IO}{KN} & \frac{1}{KN} \rightarrow  \frac{1}{KN} \times $	< 0.01					
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	0.17	KIM	71	DPWA	K-matrix analysis	
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	+0.20	² ARMENTER	OS70	DPWA	$\overline{K}N \rightarrow \Sigma \pi$	
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$-0.13 \pm 0.03$	BARBARO	. 70	DPWA	$\overline{K}N \rightarrow \Sigma \pi$	
$ \begin{array}{c c} (\Gamma_1\Gamma_\Gamma)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=1/2, P\text{-wave} & (\Gamma_1\Gamma_5)^{\frac{1}{2}}/\Gamma_{\text{total}} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=1/2, P\text{-wave} & (\Gamma_1\Gamma_5)^{\frac{1}{2}}/\Gamma_{\text{total}} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} & (\Gamma_1\Gamma_6)^{\frac{1}{2}}/\Gamma_{\text{total}} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} & (\Gamma_1\Gamma_6)^{\frac{1}{2}}/\Gamma_{\text{total}} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} & (\Gamma_1\Gamma_6)^{\frac{1}{2}}/\Gamma_{\text{total}} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} & (\Gamma_1\Gamma_6)^{\frac{1}{2}}/\Gamma_{\text{total}} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), S=3/2, P\text{-wave} \\ \hline NK \rightarrow \Lambda(1810) \rightarrow N\overline{K}^*(892), N\overline{K}^*(89$					$(\Gamma_1\Gamma_3)^{\frac{1}{2}}$	² /Γ
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	+0.18±0.10	PREVOST	74	DPWA	$K^- N \rightarrow \Sigma(1385)\pi$	
$(\Gamma_{l}\Gamma_{l})^{\frac{1}{2}}/\Gamma_{total}$ in $N\overline{K} \rightarrow \Lambda(1810) \rightarrow N\overline{K}^{*}(892)$ , $S=3/2$ , $P$ -wave $(\Gamma_{1}\Gamma_{6})^{\frac{1}{2}}/\Gamma_{total}$		DOCUMENT IE		TECN	COMMENT	¹/r
VALUE DOCUMENT ID TECN COMMENT	$-0.14 \pm 0.03$	² CAMERON	<b>78</b> B	DPWA	$K^- p \rightarrow N \overline{K}^*$	
						²/Г
TOURS TOURS OF WAR A P - NA						_
	T 0.33 ± 0.00	CAMERON	700	DI WA	$N \rightarrow NN$	

a a We do not use the following data for averages fits limits atc. a a

### A(1810) FOOTNOTES

 $^1\,\mathrm{The}$  two MARTIN 77 values are from a T-matrix pole and from a Breit-Wigner fit.  $^2\,\mathrm{The}$  published sign has been changed to be in accord with the baryon-first convention.

### **Λ(1810) REFERENCES**

GOPAL CAMERON GOPAL MARTIN	80 78B 77 77	Toronto Conf. 159 NP B146 327 NP B119 362 NP B127 349	+Franek, Gopal, Kalmus, McPherson+ +Ross, VanHorn, McPherson+ +Pidcock, Moorhouse	(LOIC, RHEL) IJP (LOUC, GLAS) IJP
Also	77B	NP B126 266	Martin, Pidcock	(LOUC)
Also	77C	NP B126 285	Martin, Pidcock	(LOUC) IJP
CARROLL	76	PRL 37 806	+Chiang, Kycia, Li, Mazur, Michael+	(BNL) I
PREVOST	74	NP B69 246	+Barloutaud+	(SACL, CERN, HEID)
LANGBEIN	72	NP B47 477	+Wagner	(MPIM) IJP
KIM	71	PRL 27 356	<del>-</del>	(HARV) IJP
Also	70	Duke Conf. 161	Kim	(HARV) IJP
ARMENTEROS	70	Duke Conf. 123	+Baillon+	(CERN, HEID, SACL) IJP
BARBARO BAILEY	70 69	Duke Conf. 173 Thesis UCRL 50617	Barbaro-Galtieri	(LRL) IJP (LLL) IJP
ARMENTEROS	68B	NP B8 195	+Baillon+	(CERN, HEID, SACL) IJP

### $\Lambda(1820) F_{05}$

$$I(J^P) = O(\frac{5}{2}^+)$$
 Status:  $****$ 

This resonance is the cornerstone for all partial-wave analyses in this region. Most of the results published before 1973 are now obsolete and have been omitted. They may be found in our 1982 edition Physics Letters **111B** (1982).

Most of the quoted errors are statistical only; the systematic errors due to the particular parametrizations used in the partial-wave analyses are not included. For this reason we do not calculate weighted averages for the mass and width.

### Λ(1820) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1815 to 1825 (≈ 1820)	OUR ESTIMATE			
1823±3	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
1819±2	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
1822±2	GOPAL	77	DPWA	KN multichannel
1821±2	KANE	74	DPWA	$K^- \rho \rightarrow \Sigma \pi$
<ul> <li>• • We do not use th</li> </ul>	e following data for average	s, fit	s, limits,	etc. • • •
1830	DECLAIS	77	DPWA	$\overline{K}N \rightarrow \overline{K}N$
1817 or 1819	¹ MARTIN	77	DPWA	KN multichannel

### **Λ(1820) WIDTH**

VALUE (MeV) 70 to 90 (≈ 80) OUR ESTIMATE	DOCUMENT ID		TECN	COMMENT
77±5	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
72±5	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
81±5	GOPAL	77	DPWA	KN multichannel
87±3	KANE	74	DPWA	$K^- p \rightarrow \Sigma \pi$
• • • We do not use the following	data for average	s, fit	s, limits,	etc. • • •
82	DECLAIS	77	DPWA	$\overline{K}N \rightarrow \overline{K}N$
76 or 76	¹ MARTIN	77	DPWA	KN multichannel

### A(1820) DECAY MODES

	Mode	Fraction $(\Gamma_i/\Gamma)$	
$\overline{\Gamma_1}$	NK	55–65 %	
$\Gamma_2$	$\Sigma \pi$	8-14 %	
$\Gamma_3$	$\Sigma(1385)\pi$	5-10 %	
Γ4	$\Sigma(1385)\pi$ , <i>P</i> -wave		
Γ ₅	$\Sigma(1385)\pi$ , F-wave		
Γ6	$\Lambda\eta$		
Γ ₇	Σππ		

The above branching fractions are our estimates, not fits or averages.

### Λ(1820) BRANCHING RATIOS

Errors quoted do not include uncertainties in the parametrizations used in the partial-wave analyses and are thus too small. See also "Sign conventions for resonance couplings" in the Note on  $\varLambda$  and  $\varSigma$  Resonances.

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$					$\Gamma_1/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT	
0.55 to 0.65 OUR ESTIMATE					
$0.58 \pm 0.02$				$\overline{K}N \to \overline{K}N$	
$0.60 \pm 0.03$	ALSTON				
<ul> <li>We do not use the following</li> </ul>	ng data for averag	es, fits	, limits,	etc. • • •	
0.51	DECLAIS	77	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
$0.57 \pm 0.02$	GOPAL	77	DPWA	See GOPAL 80	
0.59 or 0.58	¹ MARTIN	77	DPWA	KN multichani	nel
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to \Lambda$					Γ ₂ ) ^{1/2} /Γ
VALUE	DOCUMENT ID				
$-0.28 \pm 0.03$				KN multichan	nel
$-0.28 \pm 0.01$				$K^- p \rightarrow \Sigma \pi$	
<ul> <li>We do not use the following</li> </ul>	ng data for averag	es, fits	, limits,	etc. • • •	
	1			77 41 141-1	
	1 MARTIN	77	DPWA		
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to \Lambda$			DPWA <u>TECN</u>		^{тег} .Г ₆ ) ^⅓ 2/Г
$-0.25 \text{ or } -0.25$ $\left(\Gamma_{I}\Gamma_{f}\right)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \to \Lambda$ $VALUE$ $-0.096 \stackrel{+0.040}{-0.020}$	(1820) → Λη DOCUMENT ID				
$(\Gamma_I \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \to \Lambda$ $(\Gamma_I \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \to \Lambda$ $(\Gamma_I \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \to \Lambda$	(1820) → Λη DOCUMENT ID		TECN		.Γ ₆ ) ^½ /Γ
$\frac{(\Gamma_i \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \to \Lambda(N\overline{K})}{(N^2 + N^2)^{\frac{1}{2}}} = 0.096^{\frac{1}{2} \cdot 0.040}$ $\Gamma(\Sigma \pi \pi)/\Gamma_{\text{total}}$	( <b>1820)</b> → Λη <u>DOCUMENT ID</u> RADER	73	<i>TECN</i> MPWA	(F ₃	.Γ ₆ ) ^½ /Γ
$(\Gamma_I \Gamma_I)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N \overline{K} \to \Lambda$ $(VALUE) - 0.096 + 0.040 - 0.020$ $\Gamma(\Sigma \pi \pi)/\Gamma_{\text{total}}$ $VALUE$	( <b>1820)</b> → Λη <u>DOCUMENT ID</u> RADER	73	<i>TECN</i> MPWA		Γ ₆ ) ^½ /Γ
$\frac{\left(\Gamma_{I}\Gamma_{f}\right)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \to \Lambda(\frac{VALUE}{-0.096^{+0.040}})}{-0.096^{+0.040}}$ $\frac{\Gamma\left(\Sigma\pi\pi\right)/\Gamma_{\text{total}}}{VALUE}$ no clear signal	(1820) → Λη  DOCUMENT ID  RADER  DOCUMENT ID  2 ARMENTER	73 OS68c	TECN MPWA TECN HDBC	$\begin{array}{c} (\Gamma_1 \\ \hline \\ COMMENT \\ \hline \\ K^- N \rightarrow \Sigma \pi \end{array}$	Γ ₆ ) ^½ /Γ
$\frac{\left(\Gamma_{I}\Gamma_{f}\right)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \to \Lambda\right)}{VALUE}$ $-0.096^{+0.040}_{-0.020}$ $\Gamma\left(\Sigma\pi\pi\right)/\Gamma_{\text{total}}$ $VALUE$ no clear signal $\left(\Gamma_{I}\Gamma_{f}\right)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \to \Lambda\right)$	(1820) $\rightarrow \Lambda \eta$ DOCUMENT ID  RADER  DOCUMENT ID  2 ARMENTER  (1820) $\rightarrow \Sigma(13)$	73 OS68c	TECN MPWA  TECN HDBC	$\begin{array}{ccc} & & & & & & & & \\ & & & & & & & \\ & & & & & & & \\ & & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ & & & & \\ & & & & \\ & & & & \\ & & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & \\ & & \\ & \\ & & \\ & \\ & \\ & & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\$	Γ ₆ ) ^½ /Γ
$\begin{array}{l} \left(\Gamma_{I}\Gamma_{f}\right)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \to \Lambda\right) \\ \frac{VALUE}{-0.096 + 0.020} \\ \Gamma\left(\Sigma\pi\pi\right)/\Gamma_{\text{total}} \\ \frac{VALUE}{1000} \\ \left(\Gamma_{I}\Gamma_{f}\right)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \to \Lambda\right) \\ \frac{VALUE}{VALUE} \end{array}$	(1820) → Λη  DOCUMENT ID  RADER  DOCUMENT ID  2 ARMENTER  (1820) → Σ(13)	73 OS68c	TECN MPWA  TECN HDBC	$(\Gamma_1)$ $COMMENT$ $K^-N \to \Sigma \pi^+$ $COMMENT$	Γ ₆ ) ^½ /Γ Γ ₇ /Γ
$\frac{\left(\Gamma_{l}\Gamma_{r}\right)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \to \Lambda\right)}{(VALUE)}$ $-0.096^{+0.040}_{-0.020}$ $\Gamma\left(\Sigma\pi\pi\right)/\Gamma_{\text{total}}$ $VALUE$ no clear signal $\frac{\left(\Gamma_{l}\Gamma_{r}\right)^{\frac{1}{2}}}{\Gamma_{\text{total}}} \text{ in } N\overline{K} \to \Lambda\left(\frac{1}{2}\right)$ $VALUE$ $-0.167 \pm 0.054$	(1820) → Λη  DOCUMENT ID  RADER  DOCUMENT ID  ARMENTER  (1820) → Σ(13)  DOCUMENT ID  3 CAMERON	73 OS680 85) π	TECN MPWA  TECN HDBC  P-wav TECN DPWA	$\begin{array}{ccc} & & & & & & & & \\ & & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ & & & & \\ & & & & \\ & & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & \\ & & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & \\ & & \\ & \\ & & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\$	$(\Gamma_6)^{\frac{1}{2}}/\Gamma$ $\Gamma_7/\Gamma$ $\Gamma_7$ $(\Gamma_4)^{\frac{1}{2}}/\Gamma$ $(185)\pi$
$\begin{array}{l} (\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \to \Lambda \\ \frac{VALUE}{\sqrt{N}} & -0.096^{+0.040} \\ \Gamma(\Sigma\pi\pi)/\Gamma_{\text{total}} \\ \frac{VALUE}{\sqrt{N}} & \text{no clear signal} \\ (\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \to \Lambda \\ \frac{VALUE}{\sqrt{N}} & \text{value} \end{array}$	(1820) → Λη  DOCUMENT ID  RADER  DOCUMENT ID  ARMENTER  (1820) → Σ(13)  DOCUMENT ID  3 CAMERON	73 OS680 85) π	TECN MPWA  TECN HDBC  P-wav TECN DPWA	$(\Gamma_1)$ $COMMENT$ $K^-N \to \Sigma \pi^+$ $COMMENT$	Γ ₆ ) ^½ /Γ Γ ₇ /Γ π Γ ₄ ) ^½ /Γ
$\begin{array}{l} (\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Lambda(\\ \frac{NKUUE}{\sqrt{LUE}} \\ -0.096^{+0.040}_{-0.020} \\ \Gamma(\Sigma\pi\pi)/\Gamma_{\text{total}} \\ \frac{NKUUE}{\sqrt{LUE}} \\ \text{no clear signal} \\ (\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Lambda(\\ \frac{NKUUE}{\sqrt{LUE}} \\ -0.167 \pm 0.054 \end{array}$	(1820) $\rightarrow \Lambda \eta$ DOCUMENT ID  RADER  DOCUMENT ID  2 ARMENTER  (1820) $\rightarrow \Sigma$ (13)  3 CAMERON  PREVOST  (1820) $\rightarrow \Sigma$ (13)	73 OS68c 85) π, 78 74	TECN MPWA  TECN HDBC  P-wav TECN DPWA DPWA  F-wave	$\begin{array}{c} (\Gamma_1 \\ \hline COMMENT \\ K^- N \to \Sigma \pi : \end{array}$ $\begin{array}{c} \mathbf{e} \\ \hline (\Gamma_1 \\ \hline COMMENT \\ K^- P \to \Sigma (1:K^- N $	Γ ₆ ) ^½ /Γ Γ ₇ /Γ π Γ ₄ ) ^½ /Γ
$\begin{array}{c} (\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \to \Lambda \\ (\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \to \Lambda \\ (-0.096^{+0.040} - 0.020) \\ \Gamma(\Sigma\pi\pi)/\Gamma_{\text{total}} \\ (\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \to \Lambda \\ (\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \to \Lambda \\ (-0.167 \pm 0.054 + 0.027 \pm 0.03) \end{array}$	(1820) → Λη  DOCUMENT ID  RADER  2 ARMENTER  (1820) → Σ(13) 3 CAMERON  PREVOST  (1820) → Σ(13)	73 OS68c 85)π, 78 74	TECN MPWA  TECN HDBC  P-wav TECN DPWA DPWA  F-wav TECN	$\begin{array}{c} (\Gamma_1 \\ \hline COMMENT \\ K^- N \to \Sigma \pi : \end{array}$ $\begin{array}{c} \mathbf{e} \\ \hline (\Gamma_1 \\ \hline COMMENT \\ K^- P \to \Sigma (1:K^- N $	$\Gamma_{6}$ ) $^{\frac{1}{2}}/\Gamma$ $\Gamma_{7}/\Gamma$ $\Gamma_{4}$ ) $^{\frac{1}{2}}/\Gamma$ $\Gamma_{85}$ ) $\pi$ $\Gamma_{5}$ ) $^{\frac{1}{2}}/\Gamma$

### **Λ(1820) FOOTNOTES**

- 1  The two MARTIN 77 values are from a T-matrix pole and from a Breit-Wigner fit.  2  There is a suggestion of a bump, enough to be consistent with what is expected from  $\Sigma(1385) \to \Sigma \pi$  decay.
- 3 The published sign has been changed to be in accord with the baryon-first convention.

### Λ(1820) REFERENCES

PDG GOPAL	82 80	PL 111B Toronto Conf. 159	Roos, Porter, Aguilar-Benitez+ (HELS, CIT, CERN) (RHEL) IJP
	78	PR D18 182	Alston-Garnjost, Kenney+ (LBL, MTHO, CERN) IJP
ALSTON	78		
Also	77	PRL 38 1007	Alston-Garnjost, Kenney+ (LBL, MTHO, CERN) IJP
CAMERON	78	NP B143 189	+Franek, Gopal, Bacon, Butterworth+ (RHEL, LOIC) IJP
DECLAIS	77	CERN 77-16	+Duchon, Louvel, Patry, Seguinot+ (CAEN, CERN) IJP
GOPAL	77	NP B119 362	+Ross, VanHorn, McPherson+ (LOIC, RHEL) IJP
MARTIN	77	NP B127 349	+Pidcock, Moorhouse (LOUC, GLAS) IJP
Also	77B	NP B126 266	Martin, Pidcock (LOUC)
Also	77C	NP B126 285	Martin, Pidcock (LOUC) IJP
KANE	74	LBL-2452	(LBL) IJP
PREVOST	74	NP B69 246	+Barloutaud+ (SACL, CERN, HEID)
RADER	73	NC 16A 178	+Barloutaud+ (SACL, HEID, CERN, RHEL, CDEF)
ARMENTERO	S 68C	NP B8 216	+Baillon+ (CERN, HEID, SACL) I

 $\Lambda(1830) \ \overline{D}_{05}$ 

 $I(J^P) = O(\frac{5}{2}^-)$  Status: ***

For results published before 1973 (they are now obsolete), see our 1982 edition Physics Letters **111B** (1982).

The best evidence for this resonance is in the  $\Sigma\pi$  channel.

### Λ(1830) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1810 to 1830 (≈ 1830) OUR EST	IMATE			
$1831 \pm 10$	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
$1825 \pm 10$	GOPAL	77	DPWA	<b>K</b> N multichannel
1825± 1	KANE	74	DPWA	$K^- \rho \rightarrow \Sigma \pi$
• • We do not use the following	g data for averag	es, fit	s, limits,	etc. • • •
1817 or 1818	¹ MARTIN	77	DPWA	KN multichannel

### Λ(1830) WIDTH

VALUE (MeV)	DOCUMENT I	D	TECN	COMMENT
60 to 110 (≈ 95) OUR ES	TIMATE			
100 ± 10	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
94±10	GOPAL	77	DPWA	<b>K</b> N multichannel
119± 3	KANE			$K^- \rho \rightarrow \Sigma \pi$
• • We do not use the form	llowing data for avera	ges, fits	s, limits,	etc. • • •
56 or 56	¹ MARTIN	77	DPWA	<b>K</b> N multichannel

### Λ(1830) DECAY MODES

	Mode	Fraction $(\Gamma_i/\Gamma)$	
$\overline{\Gamma_1}$	NK	3-10 %	
$\Gamma_2$	$\Sigma \pi$	35-75 %	
Γ3	$\Sigma(1385)\pi$	>15 %	
Γ4	$\Sigma(1385)\pi$ , <i>D</i> -wave		
$\Gamma_5$	$\Lambda\eta$		

The above branching fractions are our estimates, not fits or averages.

### A(1830) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on  $\varLambda$  and  $\Sigma$  Resonances.

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$					$\Gamma_1/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT	
0.03 to 0.10 OUR ESTIMATE					
$0.08 \pm 0.03$	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
$0.02 \pm 0.02$	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
• • • We do not use the following	data for average	s, fit	s, limits,	etc. • • •	
$0.04 \pm 0.03$	GOPAL	77	DPWA	See GOPAL 80	
0.04 or 0.04	¹ MARTIN	77	DPWA	KN multichannel	

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to \Lambda(18)$	(Γ ₁ Γ ₂ ) ^⅓ 2/Γ			
VALUE	DOCUMENT ID		TECN	COMMENT
$-0.17 \pm 0.03$	GOPAL	77	DPWA	KN multichannel
$-0.15 \pm 0.01$	KANE	74	DPWA	$K^- \rho \rightarrow \Sigma \pi$
• • • We do not use the following	data for average	s, fits	s, limits,	etc. • • •
0.17 0.17	LAAADTINI	77	D DIA/A	TAI multiphonnol

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### Λ(1830) FOOTNOTES

¹ The two MARTIN 77 values are from a T-matrix pole and from a Breit-Wigner fit.
² The CAMERON 78 upper limit on G-wave decay is 0.03. The published sign has been changed to be in accord with the baryon-first convention.

### Λ(1830) REFERENCES

PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
GOPAL	80	Toronto Conf. 159		(RHEL) IJP
ALSTON	78	PR D18 182	Alston-Garnjost, Kenney+	(LBL, MTHO, CERN) IJP
Also	77	PRL 38 1007	Alston-Garnjost, Kenney+	(LBL, MTHO, CERN) IJP
CAMERON	78	NP B143 189	+Franek, Gopal, Bacon, Butterwor	th+ (RHEL, LOIC) IJP
GOPAL	77	NP B119 362	+Ross, VanHorn, McPherson+	(LOIC, RHEL) IJP
MARTIN	77	NP B127 349	+Pidcock, Moorhouse	(LOUC, GLAS) IJP
Also	77B	NP B126 266	Martin, Pidcock	(LOUC)
Also	77C	NP B126 285	Martin, Pidcock	(LOUC) IJP
KANE	74	LBL-2452		(LBL) IJP
PREVOST	74	NP B69 246	+Barloutaud+	(SACL, CERN, HEID)
RADER	73	NC 16A 178	+Barloutaud+ (SACL, HE	ID, ČERN, RHEL, CDEF)

 $\Lambda(1890), \Lambda(2000)$ 

 $\Lambda(1890) P_{03}$ 

$$I(J^P) = O(\frac{3}{2}^+)$$
 Status: ***

For results published before 1974 (they are now obsolete), see our 1982 edition Physics Letters 111B (1982).

The  $J^P=3/2^+$  assignment is consistent with all available data (including polarization) and recent partial-wave analyses. The dominant inelastic modes remain unknown.

### Λ(1890) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1850 to 1910 (≈ 1890) OUI	R ESTIMATE			
1897± 5	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
1908±10	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
1900± 5	GOPAL	77	DPWA	KN multichannel
$1894 \pm 10$	HEMINGWAY	75	DPWA	$K^- p \rightarrow \overline{K} N$
• • We do not use the form	llowing data for averages	, fits	s, limits,	etc. • • •
1856 or 1868	¹ MARTIN	77	DPWA	KN multichannel
1900	² NAKKASYAN	75	DPWA	$K^- p \rightarrow \Lambda \omega$

### **Λ(1890) WIDTH**

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
60 to 200 (≈ 100) OUR ESTIMA	TE			
74±10	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
119±20	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
$72 \pm 10$	GOPAL	77	DPWA	KN multichannel
$107 \pm 10$	HEMINGWAY	75	DPWA	$K^- p \rightarrow \overline{K} N$
• • We do not use the following	data for average	s, fits	s, limits,	etc. • • •
191 or 193	¹ MARTIN	77	DPWA	KN multichannel
100	² NAKKASYAN	75	DPWA	$K^- p \rightarrow \Lambda \omega$

### A(1890) DECAY MODES

	Mode	Fraction $(\Gamma_i/\Gamma)$
Γ ₁	NK	20-35 %
$\Gamma_2$	$\Sigma \pi$	3-10 %
$\Gamma_3$	$\Sigma(1385)\pi$	seen
$\Gamma_4$	$\Sigma(1385)\pi$ , <i>P</i> -wave	
$\Gamma_5$	$\Sigma(1385)\pi$ , F-wave	
Γ ₆	NK*(892)	seen
Γ7	$N\overline{K}^*(892)$ , $S=1/2$ , $P$ -wave	
Γ8	$\Lambda \omega$	

The above branching fractions are our estimates, not fits or averages.

### A(1890) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on  $\varLambda$  and  $\varSigma$ 

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$				$\Gamma_1/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT
0.20 to 0.35 OUR ESTIMATE				_
$0.20 \pm 0.02$	GOPAL			
$0.34 \pm 0.05$	ALSTON			
$0.24 \pm 0.04$	HEMINGWAY	75	DPWA	$K^- p \rightarrow \overline{K} N$
• • We do not use the following	data for average	s, fit	s, limits,	etc. • • •
$0.18 \pm 0.02$	GOPAL	77	DPWA	See GOPAL 80
0.36 or 0.34	¹ MARTIN	77	DPWA	$\overline{K}N$ multichannel
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to \Lambda (18)$	390) → Σπ DOCUMENT ID		TECN	$(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma$
$-0.09\pm0.03$	GOPAL	77	DPWA	K N multichannel
• • • We do not use the following	data for average	s, fit	s, limits,	etc. • • •
+0.15  or  +0.14	¹ MARTIN	77	DPWA	$\overline{K}$ $N$ multichannel
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K} \to \Lambda(18)$	390) → Λω DOCUMENT ID		TECN	$(\Gamma_1\Gamma_8)^{\frac{1}{2}}/\Gamma$
seen	BACCARI	77	IPWA	$K^- p \rightarrow \Lambda \omega$
0.032	² NAKKASYAN			
	DOCUMENT ID		TECN	COMMENT
< 0.03	CAMERON	78	DPWA	$K^- p \rightarrow \Sigma(1385) \pi$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \to \Lambda(18)$	DOCUMENT ID		TECN	COMMENT
$-0.126 \pm 0.055$	³ CAMERON	78	DPWA	$K^- \rho \rightarrow \Sigma(1385)\pi$

$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to A$	1(1890) → NK*(892)	)	(	Γ₁Γ ₆ ) ^⅓ /Γ
VALUE	DOCUMENT ID	TECN	COMMENT	
$-0.07 \pm 0.03$	3,4 CAMERON 78	B DPWA	$K^-p \rightarrow N7$	₹*

### **Λ(1890) FOOTNOTES**

- ¹ The two MARTIN 77 values are from a T-matrix pole and from a Breit-Wigner fit.
- ² Found in one of two best solutions. ³ The published sign has been changed to be in accord with the baryon-first convention. ⁴ Upper limits on the  $P_3$  and  $F_3$  waves are each 0.03.

#### **Λ(1890) REFERENCES**

PDG	82	PL 111B		Roos, Porter, Aguilar-Benitez+	/HE	LS, CIT, CERN)
GOPAL	80	Toronto Conf. 15	59	11003, 1 orter, Agailar Benitez+	(112	(RHEL) IJP
ALSTON	78	PR D18 182		Alston-Garnjost, Kenney+	(LBL.	MTHO, CERN) IJP
Also	77	PRL 38 1007		Alston-Garnjost, Kenney+		MTHO, CERN) IJP
CAMERON	78	NP B143 189		+Franek, Gopal, Bacon, Butterwort	h+`	(RHEL, LOIC) IJP
CAMERON	78B	NP B146 327		+Franek, Gopal, Kalmus, McPherso	n+	(RHEL, LOIC) IJP
BACCARI	77	NC 41A 96		+Poulard, Revel, Tallini+		(SACL, CDEF) IJP
GOPAL	77	NP B119 362		+Ross, VanHorn, McPherson+		(LOIC, RHEL) IJP
MARTIN	77	NP B127 349		+Pidcock, Moorhouse		(LOUC, GLAS) IJP
Also	77B	NP B126 266		Martin, Pidcock		(LOUC)
Also	77C	NP B126 285		Martin, Pidcock		(LOUC) IJP
HEMINGWAY	75	NP B91 12		+Eades, Harmsen+	(CERN,	HEIDH, MPIM) IJP
NAKKASYAN	75	NP B93 85				(CERN) IJP

## $\Lambda(2000)$

 $+0.09\pm0.03$ 

 $I(J^P) = 0(??)$  Status: *

#### OMITTED FROM SUMMARY TABLE

We list here all the ambiguous resonance possibilities with a mass around 2 GeV. The proposed quantum numbers are  $D_3$  (BARBARO-GALTIERI 70 in  $\Sigma \pi$ ),  $D_3+F_5$ ,  $P_3+D_5$ , or  $P_1+D_3$  (BRANDSTET-TER 72 in  $\Lambda\omega$ ), and  $S_1$  (CAMERON 78B in  $N\overline{K}^*$ ). The first two of the above analyses should now be considered obsolete. See also NAKKASYAN 75.

#### Λ(2000) MASS

VALUE (MeV)	DOCUMENT ID TECN COMMENT	
≈ 2000 OUR ESTIMATE		
2030 ± 30	CAMERON 78B DPWA $K^-p \rightarrow N\overline{K}^*$	
1935 to 1971	1 BRANDSTET72 DPWA $K^{-}p \rightarrow \Lambda \omega$	
1951 to 2034	¹ BRANDSTET72 DPWA $K^-p \rightarrow \Lambda \omega$	
$2010 \pm 30$	BARBARO 70 DPWA $K^-p \rightarrow \Sigma \pi$	

### **Λ(2000) WIDTH**

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
125±25	CAMERON 78B	DPWA	$K^- p \rightarrow N \overline{K}^*$
180 to 240	¹ BRANDSTET72		
73 to 154	¹ BRANDSTET72	DPWA	(higher mass)
$130 \pm 50$	BARBARO 70	DPWA	$K^- p \rightarrow \Sigma \pi$

### A(2000) DECAY MODES

	Widde
Γ ₁	NK
$\Gamma_2$	$\Sigma\pi$
$\Gamma_3$	$\Lambda \omega$
$\Gamma_4$	$N\overline{K}^*$ (892), $S=1/2$ , $S$ -wave
$\Gamma_5$	$N\overline{K}^*(892)$ , $S=3/2$ , <i>D</i> -wave

### 1(2000) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on  $\varLambda$  and  $\varSigma$ 

VALUE - 0.20±0.04	DOCUMENT ID  BARBARO 70		$COMMENT$ $C \rightarrow \Sigma \pi$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K}$			(Γ₁Γ₃) ^⅓ 2/Ι
0.17 to 0.25	1 BRANDSTET72	DPWA (	lower mass)
0.04 to 0.15	¹ BRANDSTET72 ¹ BRANDSTET72	DPWA (	higher mass)
$(\Gamma_I \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K}$ $VALUE$ $-0.12+0.03$		TECN C	OMMENT

CAMERON

78B DPWA  $K^-p \rightarrow N\overline{K}^*$ 

### **Λ(2000) FOOTNOTES**

 1  The parameters quoted here are ranges from the three best fits; the lower state probably has  $J \le 3/2$ , and the higher one probably has  $J \le 5/2$ .

² The published sign has been changed to be in accord with the baryon-first convention.

### **Λ(2000) REFERENCES**

CAMERON	78B I	NP B146 327	+Franek, Gopal, Kalmus, McPh	erson+ (RHEL, LO!C) IJP
NAKKASYAN	75 1	NP B93 85		(CERN) IJP
BRANDSTET		NP B39 13	Brandstetter, Butterworth+	(RHEL, CDEF, SACL)
BARBARO	70 1	Duke Conf. 173	Barbaro-Galtieri	(LRL) IJP

 $\Lambda(2020) F_{07}$ 

$$I(J^P) = O(\frac{7}{2}^+)$$
 Status: *

#### OMITTED FROM SUMMARY TABLE

In LITCHFIELD 71, need for the state rests solely on a possibly inconsistent polarization measurement at 1.784 GeV/c. HEMINGWAY 75 does not require this state. GOPAL 77 does not need it in either  $N \overline{K}$  or  $\Sigma \pi$ . With new  $K^- n$  angular distributions included, DECLAIS 77 sees it. However, this and other new data are included in GOPAL 80 and the state is not required. BACCARI 77 weakly supports it.

#### **Λ(2020) MASS**

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 2020 OUR ESTIMATE				
2140	BACCARI			$K^- \rho \rightarrow \Lambda \omega$
2117	DECLAIS	77	DPWA	$\overline{K}N \rightarrow \overline{K}N$
2100 ± 30	LITCHFIELD	71	DPWA	$K^- \rho \rightarrow \overline{K} N$
2020 ± 20	BARBARO	70	DPWA	$K^- p \rightarrow \Sigma \pi$

### **Λ(2020) WIDTH**

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
128	BACCARI	77	DPWA	$K^- \rho \rightarrow \Lambda \omega$
167	DECLAIS	77	DPWA	$\overline{K}N \rightarrow \overline{K}N$
$120 \pm 30$	LITCHFIELD	71	DPWA	$K^- \rho \rightarrow \overline{K} N$
$160\pm30$	BARBARO	70	DPWA	$K^- p \rightarrow \Sigma \pi$

### A(2020) DECAY MODES

	Mode		
Γ ₁ Γ ₂ Γ ₃	$\Sigma \pi$		

### Λ(2020) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on  $\varLambda$  and  $\varSigma$  Resonances.

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$					Γ1/Ι
VALUE	DOCUMENT ID		TECN	COMMENT	
0.05	DECLAIS	77	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
$0.05 \pm 0.02$	LITCHEIELD	71	DPW/A	$K^- n \rightarrow \overline{K}N$	

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to \Lambda(20)$	20) → Λω			(Γ₁Γ₃) ^½ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
< 0.05	BACCARI	77	DPWA	$K^- p \rightarrow \Lambda \omega$

### ∧(2020) REFERENCES

	GOPAL BACCARI DECLAIS GOPAL	77 77 77	Toronto Conf. 159 NC 41A 96 CERN 77-16 NP B119 362	+Poulard, Revel, Tallini+ +Duchon, Louvel, Patry, Seguinot+ +Ross, VanHorn, McPherson+	(LOIC, RHEL)
- 1	HEMINGWAY	75	NP B91 12	+Eades, Harmsen+	(CERN, HEIDH, MPIM) IJP
	LITCHFIELD	71	NP B30 125	+, Lesquoy+	(RHEL, CDEF, SACL) IJP
- 1	BARBARO	70	Duke Conf. 173	Barbaro-Galtieri	(LRL) IJP



$$I(J^P) = 0(\frac{7}{2})$$
 Status: ***

Discovered by COOL 66 and by WOHL 66. Most of the results published before 1973 are now obsolete and have been omitted. They may be found in our 1982 edition Physics Letters **111B** (1982).

This entry only includes results from partial-wave analyses. Parameters of peaks seen in cross sections and in invariant-mass distributions around 2100 MeV used to be listed in a separate entry immediately following. It may be found in our 1986 edition Physics Letters 170B (1986).

#### A(2100) MASS

VALUE (MeV) 2090 to 2110 (≈ 2100) OUR EST	DOCUMENT ID		TECN	COMMENT
2104±10	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
2106±30	DEBELLEFON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
$2110 \pm 10$	GOPAL	77	DPWA	KN multichannel
$2105 \pm 10$	HEMINGWAY	75	DPWA	$K^- p \rightarrow \overline{K} N$
2115±10	KANE	74	DPWA	$K^- p \rightarrow \Sigma \pi$
• • We do not use the following	g data for average	, fit	s, limits,	etc. • • •
2094	BACCARI	77	DPWA	$K^- p \rightarrow \Lambda \omega$
2094	DECLAIS			
2110 or 2089	¹ NAKKASYAN	75	DPWA	$K^- p \rightarrow \Lambda \omega$

### **Λ(2100) WIDTH**

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
100 to 250 (≈ 200) OUR ESTIMA	TE			
157±40	DEBELLEFON			
$250 \pm 30$	GOPAL	77	DPWA	K N multichannel
$241 \pm 30$	HEMINGWAY	75	DPWA	$K^- \rho \rightarrow \overline{K} N$
152±15	KANE	74	DPWA	$K^- p \rightarrow \Sigma \pi$
• • • We do not use the following	data for average	s, fits	, limits,	etc. • • •
98	BACCARI	77	DPWA	$K^- p \rightarrow \Lambda \omega$
250	DECLAIS			
244 or 302	¹ NAKKASYAN	75	DPWA	$K^-p \rightarrow \Lambda \omega$

### A(2100) DECAY MODES

	Mode	Fraction $(\Gamma_i/\Gamma)$	
$\overline{\Gamma_1}$	NK	25-35 %	
$\Gamma_2$	$\Sigma \pi$	~ 5 %	
$\Gamma_3$	$\Lambda\eta$	<3 %	
$\Gamma_4$	ΞK	<3 %	
$\Gamma_5$	$\Lambda \omega$	<8 %	
$\Gamma_6$	N K*(892)	10-20 %	
$\Gamma_7$	$N\overline{K}^*$ (892), $S=1/2$ , $G$ -wave		
$\Gamma_8$	$N\overline{K}^*$ (892), $S=3/2$ , $D$ -wave		

The above branching fractions are our estimates, not fits or averages.

### A(2100) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on  $\varLambda$  and  $\varSigma$  Resonances.

				$\Gamma_1/\Gamma$
DOCUMENT IE	)	TECN	COMMENT	
GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
DEBELLEFO	N 78	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
HEMINGWA'	Y 75	DPWA	$K^- p \rightarrow \overline{K} N$	
ing data for averag	es, fit	s, limits,	etc. • • •	
DECLAIS	77	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
GOPAL	77	DPWA	See GOPAL 80	
	GOPAL DEBELLEFO HEMINGWA' ing data for average DECLAIS	DEBELLEFON 78 HEMINGWAY 75 ing data for averages, fit: DECLAIS 77	GOPAL 80 DPWA DEBELLEFON 78 DPWA HEMINGWAY 75 DPWA ing data for averages, fits, limits, DECLAIS 77 DPWA	GOPAL 80 DPWA $\overline{K}N \to \overline{K}N$ DEBELLEFON 78 DPWA $\overline{K}N \to \overline{K}N$ HEMINGWAY 75 DPWA $K^-p \to \overline{K}N$ ing data for averages, fits, limits, etc. • • • DECLAIS 77 DPWA $\overline{K}N \to \overline{K}N$

$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to \Lambda($	(Γ₁Γ₂) ¹ /2/Γ			
VALUE	DOCUMENT ID		TECN	COMMENT
$+0.12\pm0.04$	GOPAL	77	DPWA	$\overline{K}N$ multichannel
$+0.11 \pm 0.01$	KANE	74	DPWA	$K^- p \rightarrow \Sigma \pi$

$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to \Lambda(2100) \to \Lambda \eta$					(Γ₁Γ₃) ^⅓ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
$-0.050\pm0.020$	RADER	73	MPWA	$K^-p \rightarrow$	$\Lambda\eta$

 $\Lambda(2100), \Lambda(2110), \Lambda(2325)$ 

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \rightarrow$	Λ(2100) → Ξ K			(Γ ₁ Γ ₄ ) ^{1/2} /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
$0.035 \pm 0.018$	LITCHFIELD	71	DPWA	$K^- p \rightarrow \Xi K$
<ul> <li>• • We do not use the foll</li> </ul>	owing data for averages	s, fits	, limits,	etc. • • •
0.003	MULLER	69B	DPWA	$K^- p \rightarrow \Xi K$
0.05	TRIPP	67	RVUE	$K^- p \rightarrow \Xi K$
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow$	$\Lambda(2100) \rightarrow \Lambda \omega$			(Γ₁Γ₅) ¹ ⁄2/Ι
VALUE	DOCUMENT ID		TECN	COMMENT
-0.070	2 BACCARI	77	D DIA/A	GD Wave
+0.011	² BACCARI ² BACCARI	77	DPWA	GG ₁₇ wave
+0.008	⁻² BACCARI	77	DPWA	GG ₃₇ wave
0.122 or 0.154	$^{ m 1}$ NAKKASYAN	75	DPWA	$K^-\rho \rightarrow \Lambda \omega$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K} \to$				
VALUE	DOCUMENT ID			
$+0.21\pm0.04$	CAMERON	78B	DPWA	$K^- p \rightarrow N \overline{K}^*$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \rightarrow$	$\Lambda(2100) \rightarrow N\overline{K}^*(8)$			
VALUE	3 CAMERON			

### A(2100) FOOTNOTES

- 1  The NAKKASYAN 75 values are from the two best solutions found. Each has the  $\Lambda(2100)$  and one additional resonance ( $P_3$  or  $F_5).$
- 2  Note that the three for BACCARI 77 entries are for three different waves.  3  The published sign has been changed to be in accord with the baryon-first convention. The upper limit on the  $\it G_3$  wave is 0.03.

### A(2100) REFERENCES

PDG	86	PL 170B	Aguilar-Benitez, Porter+		(CERN, CIT+)
PDG	82	PL 111B	Roos, Porter, Aguilar-Ben		HELS, CIT, CERN)
GOPAL	80	Toronto Conf. 159	-	,	(RHEL) IJP
CAMERON	78B	NP B146 327	+Franek, Gopal, Kalmus, N		(RHEL, LOIC) IJP
DEBELLEFON	78	NC 42A 403	De Bellefon, Berthon, Bill	loir+	(CDEF, SACL) IJP
BACCARI	77	NC 41A 96	+Poulard, Revel, Tallini+		(SACL, CDEF) IJP
DECLAIS	77	CERN 77-16	+Duchon, Louvel, Patry, Se		
GOPAL	77	NP B119 362	+Ross, VanHorn, McPherso		(LOIC, RHEL) IJP
HEMINGWAY	75	NP B91 12	+Eades, Harmsen+	(CER	N, HEIDH, MPIM) IJP
NAKKASYAN	75	NP B93 85			(CERN) IJP
KANE	74	LBL-2452			(LBL) IJP
RADER	73	NC 16A 178			RN, RHEL, CDEF)
LITCHFIELD	71	NP B30 125	+, Lesquoy+	(RI	HEL, CDEF, SACL) IJP
MULLER	69B	Thesis UCRL 19372			(LRL)
TRIPP	67	NP B3 10			ERN, HEID, SACL)
COOL	66	PRL 16 1228	+Giacomelli, Kycia, Leontic	, Lundby+	
WOHL	66	PRL 17 107	+Solmitz, Stevenson		(LRL) IJP



$$I(J^P) = O(\frac{5}{2}^+)$$
 Status: ***

For results published before 1974 (they are now obsolete), see our 1982 edition Physics Letters 111B (1982). All the references have

This resonance is in the Baryon Summary Table, but the evidence  $% \left\{ 1,2,\ldots ,n\right\}$ 

### **Λ(2110) MASS**

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
2090 to 2140 (≈ 2110) OUR ESTI	MATE			
$2092 \pm 25$	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
$2125 \pm 25$	CAMERON	78B	DPWA	$K^- \rho \rightarrow N \overline{K}^*$
2106±50	DEBELLEFON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
$2140 \pm 20$	DEBELLEFON	77	DPWA	$K^- \rho \rightarrow \Sigma \pi$
2100 ± 50	GOPAL	77	DPWA	KN multichannel
2112± 7	KANE	74	DPWA	$K^- p \rightarrow \Sigma \pi$
ullet $ullet$ We do not use the following	data for averages	, fits	, limits,	etc. • • •
2137	BACCARI			
2103	¹ NAKKASYAN	75	DPWA	$K^- \rho \rightarrow \Lambda \omega$

### **Λ(2110) WIDTH**

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
150 to 250 (≈ 200) OUR ESTIMAT	ΓE			
245±25	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
160±30	CAMERON	78B	DPWA	$K^- p \rightarrow N \overline{K}^*$
251 ± 50	DEBELLEFON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
140±20	DEBELLEFON	77	DPWA	$K^- p \rightarrow \Sigma \pi$
$200 \pm 50$	GOPAL	77	DPWA	$\overline{K}N$ multichannel
190±30	KANE	74	DPWA	$K^- \rho \rightarrow \Sigma \pi$
<ul> <li>◆ ◆ We do not use the following</li> </ul>	data for averages	, fits	, limits,	etc. • • •
132	BACCARI			
391	¹ NAKKASYAN	75	DPWA	$K^- p \rightarrow \Lambda \omega$

### A(2110) DECAY MODES

	Mode	Fraction $(\Gamma_i/\Gamma)$	
$\overline{\Gamma_1}$	NK	5-25 %	
$\Gamma_2$	$\Sigma \pi$	10-40 %	
$\Gamma_3$	$\Lambda\omega$	seen	
Γ4	$\Sigma(1385)\pi$	seen	
$\Gamma_5$	$\Sigma(1385)\pi$ , <i>P</i> -wave		
$\Gamma_6$	N K*(892)	10-60 %	
Γ ₇	$N\overline{K}^*$ (892), $S=1/2$ , $F$ -wave		

The above branching fractions are our estimates, not fits or averages.

### A(2110) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on  $\varLambda$  and  $\varSigma$ 

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$					$\Gamma_1/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT	
0.05 to 0.25 OUR ESTIMATE					
$0.07 \pm 0.03$	GOPAL				
$0.27 \pm 0.06$	² DEBELLEFON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
	g data for averages	, fits	s, limits,	etc. • • •	
$0.07 \pm 0.03$	GOPAL	77	DPWA	See GOPAL 80	

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to \Lambda(21)$	.10) → Σπ			(Γ₁Γ₂) ^⅓ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
$+0.14\pm0.01$	DEBELLEFON	77	DPWA	$K^- p \rightarrow \Sigma \pi$
$+0.20\pm0.03$	KANE	74	DPWA	$K^-p \rightarrow \Sigma \pi$
• • • We do not use the following	data for averages	, fits	s, limits,	etc. • • •
+0.10+0.03	GOPAL	77	DPWA	KN multichannel

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} -$	→ Λ(2110) → Λω		(Γ₁Γ₃) ^½ /Γ
VALUE	DOCUMENT ID	TECN	COMMENT
< 0.05	BACCARI 7	7 DPWA	$K^- p \rightarrow \Lambda \omega$
0.112	¹ NAKKASYAN 7	5 DPWA	$K^- \rho \rightarrow \Lambda \omega$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K} - VALUE}$	→ Λ(2110) → Σ(1385)	π <u>TECN</u>	$(\Gamma_1\Gamma_4)^{\frac{1}{2}}/\Gamma$
+0.071±0.025	3 CAMEDON 7	O DDMA	$K^- p \rightarrow \Sigma(1385)\pi$

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to I$	$N(2110) \rightarrow N\overline{K}^*(892)$	2)	(F:	ւՐ ₆ ) ^½ /Ր
VALUE	DOCUMENT ID	TECN	COMMENT	
$-0.17 \pm 0.04$	⁴ CAMERON 78	BB DPWA	$K^- p \rightarrow N \overline{K}^*$	*

### ∧(2110) FOOTNOTES

- ¹ Found in one of two best solutions.
  ² The published error of 0.6 was a misprint.
  ³ The CAMERON 78 upper limit on *F*-wave decay is 0.03. The sign here has been changed to be in accord with the baryon-first convention.
  ⁴ The published sign has been changed to be in accord with the baryon-first convention. The CAMERON 78B upper limits on the *P*₃ and *F*₃ waves are each 0.03.

### A(2110) REFERENCES

PDG GOPAL CAMERON CAMERON DEBELLEFON BACCARI	82 80 78 78B 78 77	PL 111B Toronto Conf. 1 NP B143 189 NP B146 327 NC 42A 403 NC 41A 96	159	Roos, Porter, Aguilar-Benitez+ +Franek, Gopal, Bacon, Butterworth+ +Franek, Gopal, Kalmus, McPherson+ De Bellefon, Berthon, Billoir+ +Poulard, Revel, Tallini+	(HELS, CIT, CERN) (RHEL) IJP (RHEL, LOIC) IJP (RHEL, LOIC) IJP (CDEF, SACL) IJP (SACL, CDEF) IJP
	77	NC 37A 175		De Bellefon, Berthon, Billoir+	(CDEF, SACL) IJP
GOPAL	77	NP B119 362		+Ross, VanHorn, McPherson+	(LOIC, RHEL) IJP
NAKKASYAN	75	NP B93 85			(CERN) IJP
KANE	74	LBL-2452			(LBL) IJP

## $\Lambda(2325) D_{03}$

$$I(J^P) = O(\frac{3}{2}^-)$$
 Status: *

OMITTED FROM SUMMARY TABLE BACCARI 77 finds this state with either  $J^P=3/2^-$  or  $3/2^+$  in a energy-dependent partial-wave analyses of  $K^-p\to \Lambda\omega$  from 2070 to 2436 MeV. A subsequent semi-energy-independent analysis from threshold to 2436 MeV selects 3/2 $^-$ . DEBELLEFON 78 (same group) also sees this state in an energy-dependent partial-wave analysis of  $K^-p \to \overline{K} N$  data, and finds  $J^P = 3/2^-$  or  $3/2^+$ . They again prefer  $J^P = 3/2^-$ , but only on the basis of model-dependent considerations.

### **Λ(2325) MASS**

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
≈ 2325 OUR ESTIMATE 2342±30	DEBELLEFON 78	DPWA	$\overline{K}N \to \overline{K}N$
$2327 \pm 20$	BACCARI 77	DPWA	$K^- p \rightarrow \Lambda \omega$

### **Λ(2325) WIDTH**

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
177±40	DEBELLEFON 78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
160 ± 40	BACCARI 77	IPWA	$K^- p \rightarrow \Lambda \omega$

### A(2325) DECAY MODES

	Mode				
Γ ₁	NK				
$\Gamma_2$	$\Lambda \omega$				

### **Λ(2325) BRANCHING RATIOS**

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$				$\Gamma_1/$
VALUE	DOCUMENT ID	TECN	COMMENT	
$0.19 \pm 0.06$	DEBELLEFON 78	DPWA	$\overline{K}N \rightarrow \overline{K}N$	

$(\Gamma_I \Gamma_f)^{72} / \Gamma_{\text{total}} \ln N \overline{K} \rightarrow \Lambda(2325) \rightarrow \Lambda \omega$				$(\Gamma_1\Gamma_2)^{72}/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT
$0.06 \pm 0.02$	¹ BACCARI	77	<b>IPWA</b>	DS ₃₃ wave
$0.05 \pm 0.02$	¹ BACCARI	77	DPWA	DD ₁₃ wave
$0.08 \pm 0.03$	¹ BACCARI	77	DPWA	DD ₃₃ wave

### **Λ(2325) FOOTNOTES**

 $^{1}\,\mathrm{Note}$  that the three BACCARI 77 entries are for three different waves.

### 1(2325) REFERENCES

DEBELLEFON 78 NC 42A 403 BACCARI 77 NC 41A 96 De Bellefon, Berthon, Billoir+ +Poulard, Revel, Tallini+ (CDEF, SACL) IJP (SACL, CDEF) IJP

Λ(2350) H₀₉

$$I(J^P) = O(\frac{9}{2}^+)$$
 Status: ***

DAUM 68 favors  $J^P=7/2^-$  or  $9/2^+$ . BRICMAN 70 favors  $9/2^+$ . LASINSKI 71 suggests three states in this region using a Pomeron + resonances model. There are now also three formation experiments from the College de France-Saclay group, DEBELLEFON 77, BACCARI 77, and DEBELLEFON 78, which find  $9/2^+$  in energy-dependent partial-wave analyses of  $\overline{K} N \to \Sigma \pi$ ,  $\Lambda \omega$ , and  $N \overline{K}$ .

### Λ(2350) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
2340 to 2370 (≈ 2350) OUR EST	IMATE			
$2370 \pm 50$	DEBELLEFO	V 78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
$2365 \pm 20$	DEBELLEFO	N 77	DPWA	$K^- p \rightarrow \Sigma \pi$
2358± 6	BRICMAN	70	CNTR	Total, charge exchange
• • We do not use the following	g data for average	es, fits	s, limits,	etc. • • •
2372	BACCARI	77	DPWA	$K^- p \rightarrow \Lambda \omega$
$2344 \pm 15$	COOL	70	CNTR	$K^- p$ , $K^- d$ total
$2360 \pm 20$	LU	70	CNTR	$\gamma p \rightarrow K^+ Y^*$
2340 ± 7	BUGG	68	CNTR	$K^-p$ , $K^-d$ total

### **Λ(2350) WIDTH**

	DO0/4/54/7 ID			COLUMENT
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
100 to 250 (≈ 150) OUR ESTIMAT	Έ			
$204\pm50$	DEBELLEFON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
110±20	DEBELLEFON	77	DPWA	$K^- \rho \rightarrow \Sigma \pi$
$324\pm30$	BRICMAN	70	CNTR	Total, charge exchange
$\bullet$ $\bullet$ We do not use the following	data for averages	, fits	s, limits,	etc. • • •
257	BACCARI	77	DPWA	$K^-p \rightarrow \Lambda \omega$
190	COOL			$K^-p$ , $K^-d$ total
55	LU	70	CNTR	$\gamma p \rightarrow K^+ Y^*$
$140 \pm 20$	BUGG	68	CNTR	$K^-p$ , $K^-d$ total

### A(2350) DECAY MODES

	Mode	Fraction $(\Gamma_i/\Gamma)$
Γ ₁	NK	~ 12 %
$\Gamma_2$	$\Sigma \pi$	$\sim$ 10 %
$\Gamma_3$	$\Lambda \omega$	

The above branching fractions are our estimates, not fits or averages.

### **Λ(2350) BRANCHING RATIOS**

See "Sign conventions for resonance couplings" in the Note on  $\varLambda$  and  $\varSigma$  Resonances.

$\Gamma(N\overline{K})/\Gamma_{\text{tot}}$ $\sim 0.12 \text{ OUR E}$ $0.12 \pm 0.04$		DOCUMENT ID	<i>TECN</i> DPWA	COMMENT KN → KN	Γ ₁ /Γ		
$(\Gamma_I\Gamma_f)^{\frac{1}{2}}/\Gamma_{tc}$ VALUE $-0.11\pm0.02$	otal in NK → Λ(2	2350) → Σπ  DOCUMENT ID  DEBELLEFON 77	<u>TECN</u> DPWA	$\frac{COMMENT}{K^- p \to \Sigma}$	(Γ₁Γ₂) ^⅓ /Γ		
	$h_{tal} \text{ in } N\overline{K} \to \Lambda(2)$		<u>TECN</u>	•	(Г₁Г₃) ^⅓ /Г		
	A(2350) REFERENCES						
DEBELLEFON 7: BACCARI 7: DEBELLEFON 7: LASINSKI 7: BRICMAN 7: COOL 7: Also 66 LU 7: BUGG 66 DAUM 66	NC 41A 96 7 NC 37A 175 NP B29 125 D PL 31B 152 D PR D1 1887 6 PRL 16 1228 D PR D2 1846 B PR 168 1466	De Bellefon, Bertho +Poulard, Revel, Tall De Bellefon, Bertho +Ferro-Luzzi, Perreau +Giacomelli, Kycia, L Cool, Giacomelli, Ky +Greenberg, Hughes, +Gilmore, Knight+ +Erne, Lagnaux, Sen:	ni+ n, Billoir+ + eontic, Li+ /cia, Leonti Minehart,	(SA (CE (CERN, CA c, Lundby+ Mori+ (RHEL, BII	DEF, SACL) IJP CL, CDEF) IJP DEF, SACL) IJP (EFI) IJP EN, SACL) (BNL) I (BNL) I (YALE) (CERN) JP		

## *Л*(2585) Bumps

 $I(J^P) = 0(??)$  Status: **

OMITTED FROM SUMMARY TABLE

### Λ(2585) MASS (BUMPS)

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 2585 OUR ESTIMATE				
$2585 \pm 45$	ABRAMS	70	CNTR	$K^-p$ , $K^-d$ total
2530±25	LU	70	CNTR	$\gamma p \rightarrow K^+ Y^*$

### Λ(2585) WIDTH (BUMPS)

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
300	ABRAMS	70	CNTR	$K^-p$ , $K^-d$ total
150	LU	70	CNTR	$\gamma p \rightarrow K^+ Y^*$

## Λ(2585) DECAY MODES (BUMPS)

 $\Gamma_1 = N \overline{K}$ 

# Λ(2585) BRANCHING RATIOS (BUMPS)

$(J+\frac{1}{2})\times\Gamma(N\overline{K})/\Gamma_{\text{total}}$ J is not known, so o	nly $(J+\frac{1}{2}) \times \Gamma(N\overline{K})/\Gamma_{to}$	tal Ci	an be giv	Γ ₁ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
1 .	ABRAMS	70	CNTR	$K^-p$ , $K^-d$ total
$0.12 \pm 0.12$	¹ BRICMAN	70	CNTR	Total, charge exchange

## Λ(2585) FOOTNOTES (BUMPS)

 $^{
m 1}$  The resonance is at the end of the region analyzed — no clear signal.

### Λ(2585) REFERENCES (BUMPS)

ABRAMS	70	PR D1 1917	+Cool, Giacomelli, Kycia, Leontic, Li+	(BNL) I
Also	66	PRL 16 1228	Cool, Giacomelli, Kycia, Leontic, Lundby+	(BNL) I
BRICMAN	70	PL 31B 152	+Ferro-Luzzi, Perreau+ (CERN, CAEN,	SACL)
LU	70	PR D2 1846	+Greenberg, Hughes, Minehart, Mori+	(YALE)

# $\Sigma$ BARYONS (S = -1, I = 1)

$$\Sigma^+ = uus$$
,  $\Sigma^0 = uds$ ,  $\Sigma^- = dds$ 



$$I(J^P) = 1(\frac{1}{2}^+)$$
 Status: ***

We have omitted some results that have been superseded by later experiments. See our earlier editions.

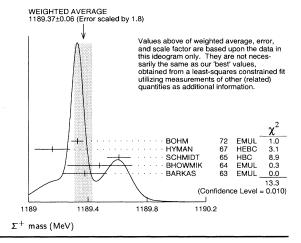
#### Σ+ MASS

The fit uses  $\Sigma^+$  ,  $\Sigma^0$  ,  $\Sigma^-$  , and  $\Lambda$  mass and mass-difference measurements.

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
1189.37±0.07 OUF	FIT Error i	ncludes scale fact	or of 3	2.2.	
1189.37±0.06 OUF	RAVERAGE	Error includes sca below.	ile fac	tor of 1.	8. See the ideogram
$1189.33 \pm 0.04$	607	$^{ m 1}$ BOHM	72	EMUL	
$1189.16 \pm 0.12$		HYMAN	67	HEBC	
$1189.61 \pm 0.08$	4205	SCHMIDT	65	HBC	See note with A mass
$1189.48 \pm 0.22$	58	² BHOWMIK	64	EMUL	
1189.38 ± 0.15	144	² BARKAS	63	EMUL	

 $^{^1}$  BOHM 72 is updated with our 1973  $K^-$  ,  $\pi^-$  , and  $\pi^0$  masses (Reviews of Modern Physics **45** No. 2 Pt. II (1973)).

These masses have been raised 30 keV to take into account a 46 keV increase in the proton mass and a 21 keV decrease in the  $\pi^0$  mass (note added 1967 edition, Reviews of Modern Physics **39** 1 (1967)).



### Σ+ MEAN LIFE

Measurements with an error  $\,\geq\,$  0.1  $\times$  10  $^{-10}$  s have been omitted.

VALUE (10 ⁻¹⁰ s)	EVTS	DOCUMENT ID		TECN	COMMENT
1.799±0.004 OUR AVERAGE     1.798±0.005   30k   MARRAFFIN     1.807±0.013   5719   CONFORTO     1.83 ±0.04   526   BAKKER     1.795±0.010   20k   EISELE     1.803±0.008   10664   BARLOUTAI     1.83 ±0.032   1300   3 CHANG     1.80 ±0.07   381   COOK     1.84 ±0.09   181   BALTAY     1.76 ±0.03   900   CARAYAN					
$0.798 \pm 0.005$	30k	MARRAFFING	80	HBC	K-p 0.42-0.5 GeV/c
$0.807 \pm 0.013$	5719	CONFORTO	76	HBC	$K^- p$ 1–1.4 GeV/ $c$
$0.83 \pm 0.04$	526	BAKKER	71	DBC	$K^- n \rightarrow \Sigma^+ \pi^- \pi^-$
$0.795 \pm 0.010$	20k	EISELE	70	HBC	$K^-p$ at rest
$0.803 \pm 0.008$		BARLOUTAU	069	HBC	$K^- p$ 0.4–1.2 GeV/c
$0.83 \pm 0.032$	1300	³ CHANG	66	HBC	
0.80 ±0.07	381	COOK	66	OSPK	
0.84 ±0.09	181	BALTAY	65	HBC	
$0.76 \pm 0.03$	900	CARAYAN	65	HBC	
$0.749^{+0.056}_{-0.052}$	192	GRARD	62	нвс	
$0.765 \pm 0.04$	456	HUMPHREY	62	HBC	

 $^{^3\,\}mbox{We}$  have increased the CHANG 66 error of 0.018; see our 1970 edition, Reviews of Modern Physics 42 No. 1 (1970).

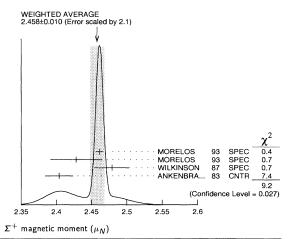
#### **Σ**⁺ MAGNETIC MOMENT

See the "Note on Baryon Magnetic Moments" in the  $\it \Lambda$  Listings. Measurements with an error  $~\geq~0.1~\mu_{\it N}$  have been omitted.

VALUE (μ _N )	EVTS	DOCUMENT ID		TECN	COMMENT
2.458 ±0.010 OUR AVERAGE	E Error		r of	2.1. See	the ideogram
		below.			
$2.4613 \pm 0.0034 \pm 0.0040$	250k	MORELOS	93	SPEC	p Cu 800 GeV
$2.428 \pm 0.036 \pm 0.007$	12k	⁴ MORELOS	93	SPEC	p Cu 800 GeV
$2.479 \pm 0.012 \pm 0.022$	137k	WILKINSON	87	SPEC	p Be 400 GeV
$2.4040 \pm 0.0198$	44k	⁵ ANKENBRA	83	CNTR	<i>p</i> Cu 400 GeV

 $^{^4}$  We assume *CPT* invariance: this is (minus) the  $\overline{\Sigma}^-$  magnetic moment as measured by MORELOS 93. See below for the moment difference testing *CPT*.

 $^{^5}$  ANKENBRANDT 83 gives the value 2.38  $\pm$  0.02  $\mu_N$  . MORELOS 93 uses the same hyperon magnet and channel and claims to determine the field integral better, leading to the revised value given here.



 $(\mu_{\Sigma^+} - |\mu_{\overline{\Sigma}^-}|) / |\mu|_{\text{average}}$ 

_	. –	-	
A test of CPT invariance.			
ALUE	DOCUMENT ID	TECN	COMMENT
.014±0.015	6 MORELOS 93	SPEC	<i>p</i> Cu 800 GeV

⁶ This is our calculation from the MORELOS 93 measurements of the  $\Sigma^+$  and  $\overline{\Sigma}^-$  magnetic moments given above. The statistical error on  $\mu_{\overline{\Sigma}^-}$  dominates the error here.

### $\Sigma^+$ DECAY MODES

	Mode	Fraction $(\Gamma_{\hat{I}}/\Gamma)$ Confidence leve
Γ ₁	$p\pi^0$	(51.57±0.30) %
$\Gamma_2$	$n\pi^+$	$(48.31 \pm 0.30) \%$
$\Gamma_3$	$p\gamma$	$(1.23\pm0.05)\times10^{-3}$
$\Gamma_4$	$n\pi^+\gamma$	[a] $(4.5 \pm 0.5) \times 10^{-4}$
$\Gamma_5$	$\Lambda e^+ \nu_e$	$(2.0 \pm 0.5) \times 10^{-5}$

# $\Delta S = \Delta Q$ (SQ) violating modes or $\Delta S = 1$ weak neutral current (S1) modes

[a] See the Particle Listings below for the pion momentum range used in this measurement.

#### CONSTRAINED FIT INFORMATION

An overall fit to 2 branching ratios uses 14 measurements and one constraint to determine 3 parameters. The overall fit has a  $\chi^2=7.7$  for 12 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients  $\left\langle \delta s_i \delta s_j \right\rangle/(\delta x_i \cdot \delta x_j),$  in percent, from the fit to the branching fractions,  $x_i \equiv \Gamma_i/\Gamma_{\rm total}.$  The fit constrains the  $x_i$  whose labels appear in this array to sum to one.

$$\begin{array}{c|cccc} x_2 & -100 & \\ x_3 & 12 & -14 \\ \hline & x_1 & x_2 \end{array}$$

		Σ+	BRANCHIN	IG RA	TIOS		
Γ <b>(nπ⁺)/Γ(N</b> 1 VALUE	,	/TS	DOCUMENT	ID	TEC		′(Γ ₁ +Γ ₂ )
0.4836±0.0030	OUR FIT		DOCOMENT.			COMMENT	
0.4836±0.0030 (			7				
$0.4828 \pm 0.0036$		.0k	⁷ MARRAFF				GeV/c
0.488 ±0.008		861	NOWAK	7			
.484 ±0.015		37	TOVEE	7			c
.488 ±0.010		31	BARLOUT				GeV/C
.46 ±0.02		34 308	CHANG HUMPHRE	6 Y 6			
7.440 ±0.024			_				
⁷ MARRAFFIN		ally giv	es $I(p\pi^{\circ})/I(t$	otar)	= 0.51	2 ± 0.0036.	
$(p\gamma)/\Gamma(p\pi^0)$	•		0.0004545				$\Gamma_3/\Gamma_1$
ALUE (units 10 ⁻³ )		/TS	DOCUMENT	ID	TECI	COMMENT	
.38±0.10 OUR							
.32±0.11±0.10		2k	TIMM	9!	5 E76	ι Σ ⁺ 375 GeV	
01   0 20 + 0.21		.08	HESSEY	89			
-0.43	4	.00			CIVI	rest	
$.52 \pm 0.28$	1	90	⁸ KOBAYASI	11 8	7 CNT	$R \pi^+ \rho \rightarrow \Sigma^+ \rho$	κ+
$46^{+0.30}_{-0.35}$	1	.55	BIAGI	8	5 CNT	R CERN hyperor	beam
				-		**	
11±0.38		46	MANZ	80			π
1 ±0.3		45	ANG	-	B HBC		
76±0.51		31	GERSHWIN		в НВС	•	π
7 ±0.8		24	BAZIN	6!			
⁸ KOBAYASHI		y gives	$\Gamma(p\gamma)/\Gamma(\text{total})$	1) = (1	1.30 ±	$0.15) \times 10^{-3}$ .	
$(n\pi^+\gamma)/\Gamma(n$	$\pi^+)$						$\Gamma_4/\Gamma_2$
				not av	erage t	he results but sim _l	oly use the
latest value		,					
ALUE (units 10 ⁻³ )	EV	TS	DOCUMENT	ID	TEC	COMMENT	
$0.93 \pm 0.10$	1	80	EBENHOH	73	з нвс	$\pi^+$ < 150 Me	·V/c
• • We do not	use the fo	llowing	data for avera	ages, f	its, limi	ts, etc. • • •	
$0.27 \pm 0.05$		29	ANG	69	в нвс	$\pi^+$ < 110 Me	V/c
1.8			BAZIN		в нвс		
$(\Lambda e^+ \nu_e)/\Gamma_{to}$							Γ ₅ /Γ
(// E · <i>Ve)</i> / I to 4 <i>LUE</i> (units 10 ⁻⁵ )		TS	DOCUMENT	ID.	TECN	I COMMENT	15/1
.0±0.5 OUR AV			DOCOMENT			COMMENT	
.6±0.7		5	BALTAY	69	нвс	$K^-p$ at rest	
9±1.0		10	EISELE	69		•	
8.0±0.8		6	BARASH	67			
have been	$S = \Delta Q$ rulomitted.	-				enominator less tha	Γ ₆ /Γ ₂ an 100,000
<i>FFECTIVE DENOM</i> 1.1 × 10 ⁻⁵ Ol			CUMENT ID			OMMENT	
1.1 × 10 - 00	UK LIMITI	Our		ber of		/(effective denomi increased to 2.3 f	
11000	0	9 FR	ENHOH 7	•	ic k	− p at rest	
05000	0		CHI-ZORN 7			- p at rest	
⁹ Effective deno				•		F	
		aicuiate	u by us.				- /-
$(n\mu^+\nu_\mu)/\Gamma(n\mu^+\nu_\mu)$	$D\pi^{\perp}$ ) $S = \Delta Q \text{ rul}$	e.					$\Gamma_7/\Gamma_2$
FFECTIVE DENOM			CUMENT ID	TE	CN		
6.2 × 10 ⁻⁵ Ol	JR LIMIT	Our 9	0% CL limit =	(6.7	events)	/(effective denomi	nator
			sum). [Num	ber of	events	increased to 6.7 fe	or a 90%
1000	^	٠.	confidence I	-			
3800	0 2	10 EIS		98 HB			
2000 0150	0	11 00	URANT 6	9в НВ 4 НВ			
710	0		UENBERG 6				
120	1		LTIERI 6		IUL		
⁰ Effective deno							
¹ Effective deno							
$(pe^+e^-)/\Gamma_{tc}$	otal						Г8/Г
LUE (units 10 ⁻⁶ )			DOCUMENT	ID	TECN	COMMENT	
7			L2 ANG		в НВС		
² ANG 69B four		e+ e-		ement	with γ	$\rightarrow e^+e^-$ conve	rsion from
$(\Sigma^+ \rightarrow ne^+)$	ν _α )/Γ(Σ	,	ne-Va)				
LUE	CL% EV		DOCUMENT I	ID.	TECN	COMMENT	
0.009 OUR LIN			Limit, using F				
• • We do not							
0.019	90	0	EBENHOH	74		,	
0.018	90	0	SECHI-ZOR			K p at rest	
(0.12	95 90	0	COLE	71	HBC	K p at rest	

< 0.03

90

0

EISELE

69B HBC See EBENHOH 74

```
\frac{\Gamma(\Sigma^{+} \to n\mu^{+}\nu_{\mu})/\Gamma(\Sigma^{-} \to n\mu^{-}\overline{\nu}_{\mu})}{\frac{EVTS}{}}
                                                                    TECN COMMENT
                                             DOCUMENT ID
 QUITE SOLUTION SOLUTION TECH COMMENT TO TECH COMMENT OUT 90% CL limit, using \Gamma(n\mu^+\nu_\mu)/\Gamma(n\pi^+) above.
 • • • We do not use the following data for averages, fits, limits, etc. • • •
   0.06^{+0.045}_{-0.03}
                                  2
                                             EISELE
                                                                69B HBC K-p at rest
\frac{\Gamma(\Sigma^{+} \to n\ell^{+}\nu)/\Gamma(\Sigma^{-} \to n\ell^{-}\overline{\nu})}{\text{Test of } \Delta S = \Delta Q \text{ rule.}}
\frac{VALUE}{EVTS}
\frac{DOC}{EVTS}
                                             DOCUMENT ID TECN
                            EVTS
 <0.043 OUR LIMIT Our 90% CL limit, using \left[\Gamma(ne^+\nu_e) + \Gamma(n\mu^+\nu_\mu)\right]/\Gamma(n\pi^+).
\bullet \,\bullet\, We do not use the following data for averages, fits, limits, etc. \,\bullet\, \,\bullet\,
                                             NORTON
 < 0.08
                                                                 69 HBC
                                   0
                                             BAGGETT
                                   Σ<sup>+</sup> DECAY PARAMETERS
           See the "Note on Baryon Decay Parameters" in the neutron Listings. A
           few early results have been omitted.
\alpha_0 FOR \Sigma^+ \to p\pi^0
VALUE EVTS
                                             DOCUMENT ID TECN COMMENT
-0.980^{\,+\,0.017}_{\,-\,0.015} OUR FIT
-0.980^{\,+\,0.017}_{\,-\,0.013} OUR AVERAGE
-0.945^{\,+\,0.055}_{\,-\,0.042}
                        1259 <sup>13</sup> LIPMAN
                                                                73 OSPK \pi^+ \rho \rightarrow \Sigma^+
                             16k BELLAMY 72 ASPK \pi^+ \rho \rightarrow \Sigma^+ K^+
1335 <sup>14</sup> HARRIS 70 OSPK \pi^+ \rho \rightarrow \Sigma^+ K^+
-0.940 \pm 0.045
-0.98 \begin{array}{l} +0.05 \\ -0.02 \end{array}
-0.999 \pm 0.022
                             32k
                                         BANGERTER 69 HBC K^-p 0.4 GeV/c
 13 Decay protons scattered off aluminum.
 14 Decay protons scattered off carbon.
\phi_0 ANGLE FOR \Sigma^+ 	o p \pi^0
                                                                                         (\tan\phi_0=\beta/\gamma)
VALUE (°) EVT.
36 ±34 OUR AVERAGE
                              EVTS
                                             DOCUMENT ID TECN COMMENT
38.1^{\,+35.7}_{\,-37.1}
                             1259
                                       <sup>15</sup> LIPMAN
                                                                73 OSPK \pi^+ p \rightarrow \Sigma^+ K^+
                                         <sup>16</sup> HARRIS
22 ±90
                                                                70 OSPK \pi^+ p \rightarrow \Sigma^+ K^+
 ^{\rm 15}\,{\rm Decay} proton scattered off aluminum.
 <sup>16</sup> Decay protons scattered off carbon.
Older results have been omitted.
                                             DOCUMENT ID TECN COMMENT
 -0.069±0.013 OUR FIT
-0.073\pm0.021
                             23k
                                             MARRAFFINO 80 HBC K^-p 0.42-0.5 GeV/c
\alpha_+ FOR \Sigma^+ \rightarrow n\pi^+
<u>VALUE</u> <u>EVTS</u>
0.068±0.013 OUR FIT
                                             DOCUMENT ID TECN COMMENT
0.066 \pm 0.016 OUR AVERAGE
                                                              70B HBC
0.037 \pm 0.049
                                             BERLEY
                                             BANGERTER 69 HBC K^-p 0.4 GeV/c
0.069 \pm 0.017
                              35k
\phi_+ ANGLE FOR \Sigma^+ 	o n \pi^+

        VALUE (°)
        EVTS
        DOLUMENT ID

        167±20 OUR AVERAGE
        Error includes scale factor of 1.1.

        184±24
        1054
        17 BERLEY
        708 HBC

        CAMCEPTER
        698 HBC

                             EVTS DOCUMENT ID
                                                                      TECN COMMENT
                                            BANGERTER 698 HBC K^-p 0.4 GeV/c
                              560
 ^{17}\,\mathrm{Changed} from 176 to 184° to agree with our sign convention.
\alpha_{\gamma} FOR \Sigma^{+} \rightarrow p\gamma
<u>VALUE</u> <u>EVTS</u>
−0.76 ±0.08 OUR AVERAGE
                                             DOCUMENT ID TECN COMMENT
                                         ^{18} FOUCHER 92 SPEC \Sigma^+ 375 GeV
-0.720\pm0.086\pm0.045 35k
                                             KOBAYASHI 87 CNTR \pi^+ p \rightarrow \Sigma^+ K^+
-0.86 \pm 0.13 \pm 0.04
                               190
^{-0.53} \,\, {}^{+0.38}_{-0.36}
                                             MANZ
                                                                80 HBC K^- p \rightarrow \Sigma^+ \pi^-
                                46
-1.03 \begin{array}{l} +0.52 \\ -0.42 \end{array}
                                 61
                                             GERSHWIN 698 HBC K^- p \rightarrow \Sigma^+ \pi^-
 ^{18}\,\mathrm{See} TIMM 95 for a detailed description of the analysis.
```

 $\Sigma^+$  ,  $\Sigma^0$ 

#### **Σ**⁺ REFERENCES

We have omitted some papers that have been superseded by later experiments. See our earlier editions.

TIMM	95	PR D51 4638	+Albuquerque, Bondar+ (FNAL E761 Collab.)
MORELOS	93	PRL 71 3417	+Albuquerque, Bondar, Carrigan+ (FNAL E761 Collab.)
FOUCHER	92	PRL 68 3004	+Albuquerque, Bondar+ (FNAL E761 Collab.)
HESSEY	89	ZPHY C42 175	+Booth, Fickinger, Gall+ (BNL-811 Collab.)
KOBAYASHI	87	PRL 59 868	+Haba, Homma, Kawai, Miyake+ (KYOT)
WILKINSON	87	PRL 58 855	+Handler+ (WISC, MICH, RUTG, MINN)
BIAGI	85	ZPHY C28 495	+Bourguin+ (CERN WA62 Collab.)
ANKENBRA	83	PRL 51 863	Ankenbrandt, Berge+ (FNAL, IOWA, ISU, YALE)
MANZ	80	PL 96B 217	+Reucroft, Settles, Wolf+ (MPIM, VAND)
MARRAFFINO		PR D21 2501	+Reucroft, Roos, Waters+ (VAND, MPIM)
NOWAK	78	NP B139 61	+Armstrong, Davis+ (LOUC, BELG, DURH, WARS)
CONFORTO	76	NP B105 189	+Gopal, Kalmus, Litchfield, Ross+ (RHEL, LOIC)
EBENHOH	74	ZPHY 266 367	+Eisele, Engelmann, Filthuth, Hepp+ (HEIDT)
EBENHOH	73	ZPHY 264 413	+Eisele, Filthuth, Hepp, Leitner, Thouw+ (HEIDT)
LIPMAN	73	PL 43B 89	+Uto, Walker, Montgomery+ (RHEL, SUSS, LOWC)
PDG	73	RMP 45 No. 2 Pt. II	Lasinski, Barbaro-Galtieri, Kelly+ (LBL, BRAN, CERN+)
SECHI-ZORN	73	PR D8 12	+Snow (UMD)
BELLAMY	72	PL 39B 299	
вонм	72	NP B48 1	+ (BERL, KIDR, BRUX, IASD, DUUC, LOUC+)
Also	73	IIHE-73.2 Nov	Bohm (BERL, KIDR, BRUX, IASD, DUUC, LOUC+)
BAKKER	71	LNC 1 37	+Hoogland, Kluyver, Massard+ (SABRE Collab.)
COLE	71	PR D4 631	+Lee-Franzini, Loveless, Baltay+ (STON, COLU)
TOVEE	71	NP B33 493	<ul> <li>+ (LOUC, KIDR, BERL, BRUX, DUUC, WARS)</li> </ul>
BERLEY	70B	PR D1 2015	+Yamin, Hertzbach, Kofler+ (BNL, MASA, YALE)
EISELE	70	ZPHY 238 372	+Filthuth, Hepp, Presser, Zech (HEID)
HARRIS	70	PRL 24 165	+Overseth, Pondrom, Dettmann (MICH, WISC)
PDG	70	RMP 42 No. 1	Barbaro-Galtieri, Derenzo, Price+ (LRL, BRAN, CERN+)
ANG	69B	ZPHY 228 151	+Ebenhoh, Eisele, Engelmann, Filthuth+ (HEID)
BAGGETT	69B	Thesis MDDP-TR-973	
			(UMD)
BALTAY	69	PRL 22 615	+Franzini, Newman, Norton+ (COLU, STON)
BANGERTER	69	Thesis UCRL 19244	(LRL)
BANGERTER	69B	PR 187 1821	+Alston-Garnjost, Galtieri, Gershwin+ (LRL)
BARLOUTAUD	69	NP B14 153	+DeBellefon, Granet+ (SACL, CERN, HEID)
EISELE	69	ZPHY 221 1	+Engelmann, Filthuth, Fohlisch, Hepp+ (HEID)
Also	64	PRL 13 291	Willis, Courant+ (BNL, CERN, HEID, UMD)
EISELE	69B	ZPHY 221 401	+Engelmann, Filthuth, Fohlisch, Hepp+ (HEID)
GERSHWIN	69B	PR 188 2077	+Alston-Garnjost, Bangerter+ (LRL)
Also	69	Thesis UCRL 19246	Gershwin (LRL)
NORTON	69	Thesis Nevis 175	(COLU)
BAGGETT	67	PRL 19 1458	
Also	68		
		Vienna Abs. 374	Baggett, Kehoe (UMD)
Also	68B	Private Comm.	Baggett (UMD)
BARASH	67	PRL 19 181	+Day, Glasser, Kehoe, Knop+ (UMD)
EISELE	67	ZPHY 205 409	+Engelmann, Filthuth, Folish, Hepp+ (HEID)
HYMAN	67	PL 25B 376	+Loken, Pewitt, McKenzie+ (ANL, CMU, NWES)
PDG	67	RMP 39 1	Rosenfeld, Barbaro-Galtieri, Podolsky+ (LRL, CERN, YALE)
CHANG	66	PR 151 1081	(COLU)
Also	65	Thesis Nevis 145	Chang (COLU)
COOK	66	PRL 17 223	+Ewart, Masek, Orr, Platner (WASH)
BALTAY	65	PR 140B 1027	+Sandweiss, Culwick, Kopp+ (YALE, BNL)
BAZIN	65	PRL 14 154	+Blumenfeld, Nauenberg+ (PRIN, COLU)
BAZIN	65B	PR 140B 1358	+Plano, Schmidt+ (PRIN, RUTG, COLU)
CARAYAN	65	PR 138B 433	Carayannopoulos, Tautfest, Willmann (PURD)
SCHMIDT	65	PR 140B 1328	(COLU)
BHOWMIK	64	NP 53 22	+Jain, Mathur, Lakshmi (DELH)
COURANT	64	PR 136B 1791	+Filthuth+ (CERN, HEID, UMD, NRL, BNL)
NAUENBERG	64	PRL 12 679	+Marateck+ (COLU, RUTG, PRIN)
BARKAS	63	PRL 11 26	+Dyer, Heckman (LRL)
Also		Thesis UCRL 9450	Dyer (LRL)
	61		
GALTIERI	62	PRL 9 26	+Barkas, Heckman, Patrick, Smith (LRL)
GALTIERI	62	PRL 9 26	+Barkas, Heckman, Patrick, Smith (LRL)

$$I(J^P) = 1(\frac{1}{2}^+)$$
 Status: ***

The spin and parity have not been measured directly. They are of course assumed to be the same as for the  $\Sigma^+$  and  $\Sigma^-$ .

### $\Sigma^0$ MASS

The fit uses  $\Sigma^+$  ,  $\Sigma^0$  ,  $\Sigma^-$  , and  $\Lambda$  mass and mass-difference measurements.

VALUE (MeV)	DOCUMENT ID							
1192.55±0.08 OUR FIT	Error includes scale factor of 1.2.							

$m_{\Sigma^{-}}-m_{\Sigma^{0}}$								
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT			
4.88±0.08 OUR FIT	Error includ	des scale factor of	1.2.					
4.86±0.08 OUR AVE	RAGE Erro	r includes scale fa	ctor	of 1.2.				
$4.87 \pm 0.12$	37	DOSCH	65	HBC				
$5.01 \pm 0.12$	12	SCHMIDT	65	HBC	See note with $\Lambda$ mass			
$4.75 \pm 0.1$	18	BURNSTEIN	64	HBC				

 $m_{\Sigma^0} - m_A$ 

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
76.87±0.08 OUR FIT		udes scale factor	of 1.2	· .	
76.55±0.25 OUR AVE	RAGE				
$76.23 \pm 0.55$	109	COLAS	75	HLBC	$\Sigma^0  o \Lambda\gamma$
$76.63 \pm 0.28$	208	SCHMIDT	65	HBC	See note with A mass

### **Σ**⁰ MEAN LIFE

These lifetimes are deduced from measurements of the cross sections for the Primakoff process  $\Lambda \to \Sigma^0$  in nuclear Coulomb fields. An alternative expression of the same information is the  $\Sigma^{0}$ - $\Lambda$  transition magnetic moment given in the following section. The relation is  $(\mu_{\Sigma}\Lambda/\mu_{N})^2$   $\tau=1.92951\times 10^{-19}$  s (see DEVLIN 86).

VALUE (10 ⁻²⁰ s)	DOCUMENT ID		TECN	COMMENT
7.4±0.7 OUR EVALUATION	Using $\mu_{\sum \Lambda}$ (see th	e abo	ve note	١.
$6.5^{+1.7}_{-1.1}$	¹ DEVLIN	86	SPEC	Primakoff effect
$7.6 \pm 0.5 \pm 0.7$	² PETERSEN	86	SPEC	Primakoff effect
• • We do not use the follow	wing data for average	es, fit	s, limits	, etc. • • •
$5.8 \pm 1.3$	¹ DYDAK	77	SPEC	See DEVLIN 86
¹ DEVLIN 86 is a recalculati- imation made in that work ² An additional uncertainty of	on of the results of D of the Primakoff form	YDA alism	K 77 rer i is estim	noving a numerical approx- nated to be $<$ 5%.

### $|\mu(\Sigma^0 o extit{$\varLambda$})|$ Transition magnetic moment

See the note in the  $\Sigma^0$  mean-life section above. Also, see the "Note on Baryon Magnetic Moments" in the  $\varLambda$  Listings.

VALUE (µN)	DOCUMENT ID		TECN	COMMENT	
1.61±0.08 OUR AVERAGE					
$1.72^{+0.17}_{-0.19}$	3 DEVLIN	86	SPEC	Primakoff effect	
$1.59 \pm 0.05 \pm 0.07$	⁴ PETERSEN	86	SPEC	Primakoff effect	
• • We do not use the foll	owing data for averag	es, fit	s, limits	etc. • • •	
$1.82^{+0.25}_{-0.18}$	³ DYDAK	77	SPEC	See DEVLIN 86	

 $^{^3}$  DEVLIN 86 is a recalculation of the results of DYDAK 77 removing a numerical approximation made in that work.  4  An additional uncertainty of the Primakoff formalism is estimated to be < 2.5%.

### **Σ**⁰ DECAY MODES

	Mode	Fraction $(\Gamma_i/\Gamma)$	Confidence level
$\overline{\Gamma_1}$	Λγ	100 %	
$\Gamma_2$	$\Lambda \gamma \gamma$	< 3 %	90%
$\Gamma_3$	$\Lambda e^+ e^-$	[a] $5 \times 10^{-3}$	

[a] A theoretical value using QED.

### **Σ**⁰ BRANCHING RATIOS

$\Gamma(\Lambda\gamma\gamma)/\Gamma_{\text{total}}$					$\Gamma_2/\Gamma$
VALUE	CL%	DOCUMENT ID		TECN	•
<0.03	90	COLAS	75	HLBC	
$\Gamma(\Lambda e^+ e^-)/\Gamma_{\text{total}}$					$\Gamma_3/\Gamma$
VALUE		DOCUMENT ID		COMMENT	
0.00545		FEINBERG	58	Theoretical QED	calculation

### **Σ**⁰ REFERENCES

DEVLIN PETERSEN	86 86	PR D34 1626 PRL 57 949	+Petersen, Beretvas +Beretvas, Devlin, Luk+ (RUTG, WISC, MI	(RUTG)
DYDAK	77	NP B118 1	+Navarria, Overseth, Steffen+ (CERN, DOR	
COLAS	75	NP B91 253	+Farwell, Ferrer, Six	(ORSAY)
DOSCH	65	PL 14 239	+Engelmann, Filthuth, Hepp, Kluge+	(HEID)
SCHMIDT	65	PR 140B 1328	- '' -	(COLU)
BURNSTEIN	64	PRL 13 66	+Day, Kehoe, Zorn, Snow	(UMD)
FEINBERG	58	PR 109 1019	•	(BNL)



$$I(J^P) = 1(\frac{1}{2}^+)$$
 Status: ***

We have omitted some results that have been superseded by later experiments. See our earlier editions.

#### Σ- MASS

The fit uses  $\Sigma^+$ ,  $\Sigma^0$ ,  $\Sigma^-$ , and  $\Lambda$  mass and mass-difference measurements.

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT	
1197.436±0.033 OUF	RFIT Error	includes scale fa	actor o	of 1.2.		
1197.45 ±0.04 OUF	RAVERAGE	Error includes	scale	factor of	1.2.	
$1197.417 \pm 0.040$		GUREV	93	SPEC	$\Sigma^-$ C atom, crystal diff.	
$1197.532 \pm 0.057$		GALL	88	CNTR	$\Sigma^-$ Pb, $\Sigma^-$ W atoms	
1197.43 $\pm 0.08$	3000	SCHMIDT	65	HBC	See note with A mass	
<ul> <li>◆ We do not use the following data for averages, fits, limits, etc.</li> </ul>						
$1197.24 \ \pm 0.15$		¹ DUGAN	75	CNTR	Exotic atoms	
¹ GALL 88 concludes that the DUGAN 75 mass needs to be reevaluated.						

VALUE (MeV)	EVTS	DOCUMENT I	DOCUMENT ID				
8.07±0.08 OUR FIT	Error inclu	des scale factor	of 1.9.				
8.09±0.16 OUR AVERAGE							
$7.91 \pm 0.23$	86	вонм	72	EMUL			
$8.25 \pm 0.25$	2500	DOSCH	65	HBC			
$8.25 \pm 0.40$	87	BARKAS	63	EMUL			

#### $m_{\Sigma^-} - m_{\Lambda}$

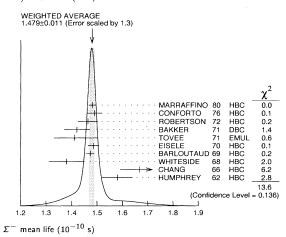
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
81.752±0.034 OUR	FIT Error in	cludes scale facto	r of 1	.2.	
81.69 ±0.07 OUR	AVERAGE				
81.64 ±0.09	2279	HEPP	68	HBC	
81.80 ±0.13	85	SCHMIDT	65	HBC	See note with $\Lambda$ mass
81.70 ±0.19		BURNSTEIN	64	HBC	

#### **Σ**- MEAN LIFE

Measurements with an error  $\,\geq\,0.2\times10^{-10}$  s have been omitted.

VALUE (10 ⁻¹⁰ s)	EVTS	DOCUMENT ID		TECN	COMMENT
1.479±0.011 OUR	AVERAGE	Error includes scale	fact	or of 1.3.	See the ideogram below.
$1.480 \pm 0.014$	16k	MARRAFFINO	80	HBC	K-p 0.42-0.5 GeV/c
$1.49 \pm 0.03$	8437	CONFORTO	76	HBC	$K^- p$ 1–1.4 GeV/c
$1.463 \pm 0.039$	2400	ROBERTSON	72	HBC	K ⁻ p 0.25 GeV/c
$1.42 \pm 0.05$	1383	BAKKER	71	DBC	$K^- N \rightarrow \Sigma^- \pi \pi$
$1.41 \begin{array}{c} +0.09 \\ -0.08 \end{array}$		TOVEE	71	EMUL	
$1.485 \pm 0.022$	100k	EISELE	70	HBC	$K^-p$ at rest
$1.472 \pm 0.016$	10k	BARLOUTAUE	69	HBC	$K^- p 0.4-1.2 \text{ GeV}/c$
$1.38 \pm 0.07$	506	WHITESIDE	68	нвс	$K^-p$ at rest
$1.666 \pm 0.075$	3267	² CHANG	66	HBC	$K^-p$ at rest
$1.58 \pm 0.06$	1208	HUMPHREY	62	HBC	$K^-p$ at rest

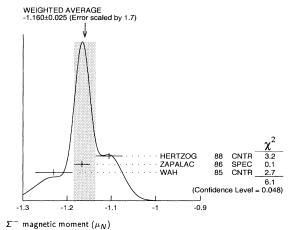
 $^{^2}$  We have increased the CHANG 66 error of 0.018; see our 1970 edition, Reviews of Modern Physics  $\bf 42$  No. 1 (1970).



#### **Σ**- MAGNETIC MOMENT

See the "Note on Baryon Magnetic Moments" in the A Listings. Measurements with an error  $\geq$  0.3  $\mu_N$  have been omitted.

VALUE (μ _N )	EVTS	DOCUMENT ID		TECN	COMMENT
-1.160±0.025 OUR AVERA	GE Error in	ncludes scale facto below.	or of	1.7. See	the ideogram
$-1.105\pm0.029\pm0.010$		HERTZOG	88	CNTR	Σ-Pb, Σ-W atoms
$-1.166\pm0.014\pm0.010$	671k	ZAPALAC	86	SPEC	$ne^-\nu$ , $n\pi^-$ decays
$-1.23 \pm 0.03 \pm 0.03$		WAH	85	CNTR	$pCu \rightarrow \Sigma^{-}X$
• • We do not use the following the fol	owing data f	or averages, fits, I	limits	s, etc. •	• •
$-0.89 \pm 0.14$	516k	DECK	83	SPEC	$\rho {\sf Be}   o   \Sigma^-  {\sf X}$



### **Σ**- DECAY MODES

	Mode	Fraction $(\Gamma_{\tilde{I}}/\Gamma)$
Γ ₁	$n\pi$	(99.848±0.005) %
$\Gamma_2$	$n\pi^-\gamma$	[a] ( 4.6 $\pm 0.6$ ) $\times 10^{-4}$
$\Gamma_3$	$ne^-\overline{ u}_e$	$(1.017\pm0.034)\times10^{-3}$
$\Gamma_4$	n $\mu^-\overline{ u}_\mu$	$(4.5 \pm 0.4) \times 10^{-4}$
$\Gamma_5$	$\Lambda e^- \overline{ u}_e$	$(5.73 \pm 0.27) \times 10^{-5}$

[a] See the Particle Listings below for the pion momentum range used in this measurement.

### CONSTRAINED FIT INFORMATION

An overall fit to 3 branching ratios uses 16 measurements and one constraint to determine 4 parameters. The overall fit has a  $\chi^2$  = 8.7 for 13 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients  $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$ , in percent, from the fit to the branching fractions,  $x_i \equiv$  $\Gamma_i/\Gamma_{
m total}$ . The fit constrains the  $x_i$  whose labels appear in this array to sum to one.



### **Σ**- BRANCHING RATIOS

 $\Gamma(n\pi^-\gamma)/\Gamma(n\pi^-)$ 

 $\Gamma_2/\Gamma_1$ 

The  $\pi^+$  momentum cuts differ, so we do not average the results but simply use the latest value for the Summary Table.

VALUE (units 10 ⁻³ )	EVTS	DOCUMENT ID	TECN	COMMENT
0.46±0.06	292	EBENHOH	73 HBC	$\pi^+ < 150~{ m MeV}/c$
• • • We do not use t	he followin	g data for averag	es, fits, limits	s, etc. • • •
$0.10 \pm 0.02$	23	ANG	69B HBC	$\pi^ <$ 110 MeV/ $c$
$\sim 1.1$		BAZIN	65B HBC	$\pi^-~< 166~{ m MeV}/c$

$\Gamma(ne^-\overline{\nu}_e)/\Gamma(ne^-\overline{\nu}_e)$		$r \ge 0.2 \times 10^{-3} h$	ave been om	$\Gamma_3/\Gamma_1$
VALUE (units 10 ⁻³ )	EVTS	DOCUMENT ID	TECN	COMMENT
1.019±0.034 OUF				
1.019 + 0.031 OUF	R AVERAGE			
$0.96 \pm 0.05$	2847	BOURQUIN	83C SPEC	SPS hyperon beam
$1.09 \begin{array}{l} +0.06 \\ -0.08 \end{array}$	601	³ EBENHOH	74 HBC	K−p at rest
$1.05 \begin{array}{l} +0.07 \\ -0.13 \end{array}$	455	³ SECHI-ZORN	73 HBC	$K^-p$ at rest
$0.97 \pm 0.15$	57	COLE	71 HBC	$K^-p$ at rest
$1.11 \pm 0.09$	180	BIERMAN	68 HBC	

 $^{^3}$  An additional negative systematic error is included for internal radiative corrections and latest form factors; see BOURQUIN 83C.

$\Gamma(n\mu^-\overline{\nu}_\mu)/\Gamma(n\pi^-$	)				$\Gamma_4/\Gamma_1$
VALUE (units 10 ⁻³ )	EVTS	DOCUMENT ID		TECN	COMMENT
0.45±0.04 OUR FIT					
0.45±0.04 OUR AVER	AGE				
$0.38 \pm 0.11$	13	COLE	71	HBC	$K^-p$ at rest
$0.43 \pm 0.06$	72	ANG	69	HBC	$K^-p$ at rest
$0.43 \pm 0.09$	56	BAGGETT	69	HBC	K [−] p at rest
$0.56 \pm 0.20$	11	BAZIN	65B	HBC	K p at rest
$0.66 \pm 0.15$	22	COURANT	64	HBC	
$\Gamma(\Lambda e^{-}\overline{\nu}_{e})/\Gamma(n\pi^{-})$	)				Γ ₅ /Γ ₁
VALUE (units 10-4)	EVTS	DOCUMENT ID		TECN	COMMENT
0.574±0.027 OUR FIT	-				
0.574 ± 0.027 OUR AV	ERAGE				
$0.561 \pm 0.031$	1620	⁴ BOURQUIN	82	SPEC	SPS hyperon beam
$0.63 \pm 0.11$	114	THOMPSON	80	ASPK	Hyperon beam
0.52 ±0.09	31	BALTAY	69	HBC	$K^- p$ at rest
0.69 ±0.12	31	EISELE	69	HBC	K−p at rest
0.64 ±0.12	35	BARASH	67	нвс	K-p at rest
0.75 ±0.28	11	COURANT	64	HBC	K [−] p at rest
⁴ The value is from	BOURQUI	N 83B, and include	s rad	iation c	orrections and new accep-

#### **Σ**- DECAY PARAMETERS

See the "Note on Baryon Decay Parameters" in the neutron Listings. Older, outdated results have been omitted.

DOCUMENT ID

TECN COMMENT

### $\alpha_-$ FOR $\Sigma^- \to n\pi^-$

VALUE	EVIS	DOCUMENT ID		IECIV	COMMENT
$-0.068\pm0.008$ OUF	AVERAGE				
$-0.062 \pm 0.024$	28k	HANSL	78	HBC	$K^- p \rightarrow \Sigma^- \pi^+$
$-0.067 \pm 0.011$	60k	BOGERT	70	HBC	K [−] p 0.4 GeV/c
$-0.071\pm0.012$	51k	BANGERTER	69	HBC	K [−] p 0.4 GeV/c
$\phi$ ANGLE FOR $\Sigma$	$- \rightarrow n\pi^-$	-			$(\tan\phi=\beta\ /\ \gamma)$
φ ANGLE FOR Σ	EVTS	DOCUMENT ID		TECN	$(\tan\phi = \beta \ / \ \gamma)$
•	EVTS			TECN	
VALUE (°)	EVTS		70B	TECN_	
VALUE (°) 10±15 OUR AVE	EVTS RAGE	DOCUMENT ID		нвс	COMMENT

 $g_A/g_V$  FOR  $\Sigma^- \to ne^-\overline{\nu}_e$ Measurements with fewer than 500 events have been omitted. Where necessary, signs Measurements with fewer than 500 events have been omitted. Where necessary, signs have been changed to agree with our conventions, which are given in the "Note on Baryon Decay Parameters" in the neutron Listings. What is actually listed is  $|g_1/f_1 - 0.237g_2/f_1|$ . This reduces to  $g_A/g_V \equiv g_1(0)/f_1(0)$  on making the usual assumption that  $g_2 = 0$ . See also the note on HSUEH 88.

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.340 ± 0.017 OUR AV	ERAGE				
$+0.327\pm0.007\pm0.019$	50k	⁶ HSUEH			Σ- 250 GeV
$+0.34 \pm 0.05$	4456				SPS hyperon beam
$0.385 \pm 0.037$	3507	⁸ TANENBAUM	74	ASPK	
• • • We do not use th	e following	data for averages	, fits	s, limits,	etc. • • •
$0.29\ \pm0.07$	25k	HSUEH	85	SPEC	See HSUEH 88
$0.17 \begin{array}{c} +0.07 \\ -0.09 \end{array}$	519	DECAMP	77	ELEC	Hyperon beam

 $^{^{\}rm 6}\, {\rm The}\, {\rm sign}$  is, with our conventions, unambiguously positive. The value assumes, as usual, that  $g_2=0$ . If  $g_2$  is included in the fit, than (with our sign convention)  $g_2=-0.56\pm0.37$ , with a corresponding reduction of  $g_A/g_V$  to  $+0.20\pm0.08$ .

 $f_2(0)/f_1(0)$  FOR  $\Sigma^- \to ne^- \overline{\nu}_e$ The signs have been changed to be in accord with our conventions, given in the "Note on Baryon Decay Parameters" in the neutron Listings.

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.97±0.14 OUR AV	/ERAGE				
$+0.96\pm0.07\pm0.13$	50k	HSUEH	88	SPEC	Σ - 250 GeV
$+1.02 \pm 0.34$	4456	BOURQUIN	83C	SPEC	SPS hyperon beam

TRIPLE CORRELATION COEFFICIENT D for  $\Sigma^- \to ne^- \overline{\nu}_e$ The coefficient D of the term D  $\mathbf{P} \cdot (\mathbf{p}_e \times \mathbf{p}_{\nu})$  in the  $\Sigma^- \to ne^- \overline{\nu}$  decay angular distribution. A nonzero value would indicate a violation of time-reversal invariance.

VALUE 

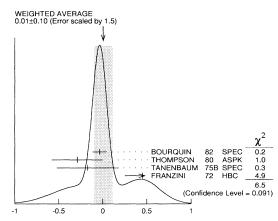
EVTS DOCUMENT ID TECN COMMENT  $0.11 \pm 0.10$ 50k HSUEH 88 SPEC  $\Sigma^-$  250 GeV

 $g_V/g_A$  FOR  $\Sigma^- o \Lambda e^- \overline{\nu}_e$ For the sign convention, see the "Note on Baryon Decay Parameters" in the neutron Listings. The value is predicted to be zero by conserved vector current theory. The values averaged assume CVC-SU(3) weak magnetism term.

VALUE	EVTS	DOCUMENT ID		TECN_	COMMENT
$0.01 \pm 0.10$	OUR AVERAGE	Error includes scal	le fac	tor of 1	.5. See the ideogram
		below.			
$-0.034 \pm 0.080$	1620	⁹ BOURQUIN	82	SPEC	SPS hyperon beam
$-0.29 \pm 0.29$	114	THOMPSON	80	ASPK	BNL hyperon beam
$-0.17 \pm 0.35$	55		75B	SPEC	BNL hyperon beam
$+0.45 \pm 0.20$	186	^{9,10} FRANZINI	72	HBC	

⁹ The sign has been changed to agree with our convention.

¹⁰ The FRANZINI 72 value includes the events of earlier papers.



 $g_V/g_A$  for  $\Sigma^- \to \Lambda e^- \overline{\nu}_e$ 

 $g_{WM}/g_A$  FOR  $\Sigma^- \to \Lambda e^- \overline{\nu}_e$ The values quoted assume the CVC prediction  $g_V = 0$ .

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
2.4 ±1.7 QUR AVERAG	iΕ			
$1.75 \pm 3.5$	114	THOMPSON	80 ASPK	BNL hyperon beam
3.5 ±4.5	55	TANENBAUM	75B SPEC	BNL hyperon beam
$2.4 \pm 2.1$	186	FRANZINI	72 HBC	

### **Σ**[−] REFERENCES

We have omitted some papers that have been superseded by later experiments. See our earlier editions.

GUREV	93	JETPL 57 400 Translated from ZETFF	Gur'ev, Denisov, Zhelamkov, Ivanov+ (PNPI)	
GALL	88	PRL 60 186	+Austin+ (BOST, MIT, WILL, CIT, CMU, WYOM)	
HERTZOG	88	PR D37 1142	+Eckhause+ (WILL, BOST, MIT, CIT, CMU, WYOM)	
HSUEH	88	PR D38 2056	<ul> <li>+ (CHIC, ELMT, FNAL, IOWA, ISU, PNPI, YALE)</li> </ul>	
ZAPALAC	86	PRL 57 1526	<ul> <li>(EFI, ELMT, FNAL, IOWA, ISU, PNPI, YALE)</li> </ul>	
HSUEH	85	PRL 54 2399	+Muller+ (CHIC, ELMT, FNAL, ISU, PNPI, YALE)	
WAH	85	PRL 55 2551	+Cardello, Cooper, Teig+ (FNAL, IOWA, ISU)	
BOURQUIN	83B	ZPHY C21 27	+ (BRIS, GEVA, HEIDP, LALO, RL, STRB)	
BOURQUIN	83C	ZPHY C21 17	+ (BRIS, GEVA, HEIDP, LALO, RL, STRB)	
DECK	83	PR D28 1	+Beretvas, Devlin, Luk+ (RUTG, WISC, MICH, MINN)	
BOURQUIN	82	ZPHY C12 307	+Brown+ (BRIS, GEVA, HEIDP, LALO, RL, STRB)	
MARRAFFINO	80	PR D21 2501	+Reucroft, Roos, Waters+ (VAND, MPIM)	
THOMPSON	80	PR D21 25	+Cleland, Cooper, Dris, Engels+ (PITT, BNL)	
HANSL	78	NP B132 45	+Manz, Matt, Reucroft, Settles+ (MPIM, VAND)	
DECAMP	77	PL 66B 295	+Badier, Bland, Chollet, Gaillard+ (LALO, EPOL)	
CONFORTO	76	NP B105 189	+Gopal, Kalmus, Litchfield, Ross+ (RHEL, LOIC)	
DUGAN	75	NP A254 396	+Asano, Chen, Cheng, Hu, Lidofsky+ (COLU, YALE)	
TANENBAUM	75B	PR D12 1871	+Hungerbuhler+ (YALE, FNAL, BNL)	
FBENHOH	74	7PHY 266 367	+Eisele, Engelmann, Filthuth, Hepp+ (HEIDT)	
TANENBAUM	74	PRL 33 175	+Hungerbuhler+ (YALE, FNAL, BNL)	
EBENHOH	73	ZPHY 264 413	+Eisele, Filthuth, Hepp, Leitner, Thouw+ (HEIDT)	
SECHI-ZORN	73	PR D8 12	+Snow (UMD)	
BOHM	72	NP B48 1	+ (BERL, KIDR, BRUX, IASD, DUUC, LOUC+)	
FRANZINI	72	PR D6 2417	+ (COLU, HEID, UMD, STON)	
ROBERTSON	72	Thesis UMI 78-00877	(IIT)	
BAKKER	71	LNC 1 37	+Hoogland, Kluyver, Massard+ (SABRE Collab.)	
COLE	71	PR D4 631	+Lee-Franzini, Loveless, Baltay+ (STON, COLU)	
Also	69	Thesis Nevis 175	Norton (COLU)	
TOVEE	71	NP B33 493	+ (LOUC, KIDR, BERL, BRUX, DUUC, WARS)	
BERLEY	70B	PR D1 2015	+Yamin, Hertzbach, Kofler+ (BNL, MASA, YALE)	
DENCE	100	I II DI ZOIS	+ runni, ricitzacii, ricitzi	

 $^{^{7}\,\}mathrm{BOURQUIN}$  83C favors the positive sign by at least 2.6 standard deviations.

⁸ TANENBAUM 74 gives 0.435  $\pm$  0.035, assuming no  $q^2$  dependence in  $g_A$  and  $g_V$ . The listed result allows  $q^2$  dependence, and is taken from HSUEH 88.

BOGERT   70
PDG
ANG   69
ANG   698   ZPHY 228 151   +Ebenhoh, Eisele, Engelmann, Filthuth+ (HEID)
ANG   698   ZPHY 228 151   +Ebenhoh, Eisele, Engelmann, Filthuth+ (HEID)
BALTAY   69   PRL 22 615   Franzini, Newman, Norton+   (COLU, ŚTON)
BANGERTER   69
BANGERTER         698         PR 187 1821         +Alston-Garnjost, Galtieri, Gershwin+         (LRL)           BARLOUTAUD         69         PR 184 153         +DeBellerion, Granet+         (SACL, CERN, HeID)           BIEERMAN         68         PRL 20 1459         +Engelmann, Filthuth, Fohlisch, Hepp+         (HEID)           HEPP         68         ZPHY 214 71         +Schleich         (HEID)           WHITESIDE         68         CS 4A 537         +Gollub         (OBER)           BARASH         67         PRI 19 181         +Day, Glasser, Kehoe, Knop+         (UMD)           CHANG         65         PR 1408 1358         +Plano, Schmidt+         (PRIN, RUTG, COLU)           BOSCH         65         PL 14 239         +Engelmann, Filthuth, Hepp, Kluge+         (PRIN, RUTG, COLU)
BARLOUTAUD 69         NP B14 153         +DeBellefon, Granet+         (SACL, CERN, HEID)           EISELE         69         ZPHY 221 1         +Engelman, Filhutuh, Fohlisch, Hepp+         (HEID)           BIERNAN         68         PRL 20 1459         +Kounosu, Nauenberg+         (PRIN)           HEPP         68         ZPHY 214 71         +Schleich         (HEID)           WHITESIDE         68         NC 54A 537         +Gollub         (OBER)           BARASH         67         PRI. 19 181         +Day, Glasser, Kehoe, Knop+         (UMD)           CHANG         69         PR 151 1081         +Plano, Schmidt+         (PRIN, RUTG, COLU)           BAZIN         658         PR 140B 1358         +Plano, Schmidt+         (PRIN, RUTG, COLU)           +Engelmann, Filthuth, Hepp, Kluge+         +HEID         +HEID
EISELE         69         ZPHY 221 1         +Engelmann, Filthuth, Fohlisch, Hepp+         (HEID)           BIERMAN         68         PRL 20 1459         +Kounosu, Nauenberg+         (PRIN)           HEPP         68         ZPHY 214 71         +Schleich         (HEID)           WHITESIDE         68         K 54A 537         +Gollub         (OBER)           BARASH         67         PRI. 19 181         +Day, Glasser, Kehoe, Knop+         (UMD)           CHANG         65         PR 1408 1358         +Plano, Schmidt+         (PRIN, RUTG, COLU)           DOSCH         65         PL14 239         +Engelmann, Filthuth, Hepp, Kluge+         (HEID)
BIERMAN         68         PRL 20 1459         + Kounosu, Nauenberg+         (PRIN)           HEPP         68         ZPHY 214 71         + Schleich         (HEID)           WHITESIDE         68         NC 54A 537         + Gollub         (OBER)           BARASH         67         PRL 19 181         + Day, Glasser, Kehoe, Knop+         (UMD)           CHANG         66         PR 151 1081         + Plano, Schmidt+         (PRIN, RUTG, COLU)           BAZIN         658         PR 140B 1358         + Plano, Schmidt+         (PRIN, RUTG, COLU)           DOSCH         65         PL 14 239         + Engelmann, Filthuth, Hepp, Kluge+         (HEID)
HEPP
WHITESIDE         68         NC 54A 537         +Gollub         (ÖBER)           BARASH         67         PRL 19 181         +Day, Glasser, Kehoe, Knop+         (UMD)           CHANG         66         PR 151 1081         (CCU.U)         (CCU.U)           BAZIN         65B         PR 140B 1355         +Plano, Schmidt+         (PRIN, RUTG, COU.U)           DOSCH         65         PL 142 239         +Engelmann, Filthuth, Hepp, Kluge+         (HEID)
BARASH         67         PRL 19 181         +Day, Glasser, Kehoe, Knop+         (UMD)           CHANG         66         PR 151 1081         (COLU)           BAZIN         658         PR 140B 1358         +Plano, Schmidt+         (PRIN, RUTG, COLU)           DOSCH         65         PL 14 239         +Engelmann, Filthuth, Hepp, Kluge+         (HEID)
CHANG         66         PR 151 1081         (COLU)           BAZIN         65B         PR 140B 1358         +Plano, Schmidt+         (PRIN, RUTG, COLU)           DOSCH         65         PL 14 239         +Engelmann, Filthuth, Hepp, Kluge+         (HEID)
BAZIN         65B         PR 140B 1358         +Plano, Schmidt+         (PRIN, RUTG, COLU)           DOSCH         65         PL 14 239         +Engelmann, Filthuth, Hepp, Kluge+         (HEID)
DOSCH 65 PL 14 239 +Engelmann, Filthuth, Hepp, Kluge+ (HEID)
Also 66 PR 151 1081 Chang (COLU)
SCHMIDT 65 PR 140B 1328 (COLU)
BURNSTEIN 64 PRL 13 66 +Day, Kehoe, Zorn, Snow (UMD)
COURANT 64 PR 136B 1791 +Filthuth+ (CERN, HEID, UMD, NRL, BNL)
BARKAS 63 PRL 11 26 +Dyer, Heckman (LRL)
HUMPHREY 62 PR 127 1305 +Ross (LRL)

### $\Sigma$ (1385) $P_{13}$

$$I(J^P) = 1(\frac{3}{2}^+)$$
 Status: ***

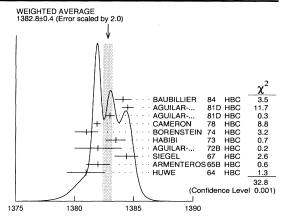
Discovered by ALSTON 60. Early measurements of the mass and width for combined charge states have been omitted. They may be found in our 1984 edition Reviews of Modern Physics **56** No. 2 Pt. II (1984).

We average only the most significant determinations. We do not average results from inclusive experiments with large backgrounds or results which are not accompanied by some discussion of experimental resolution. Nevertheless systematic differences between experiments remain. (See the ideograms in the Listings below.) These differences could arise from interference effects that change with production mechanism and/or beam momentum. They can also be accounted for in part by differences in the parametrizations employed. (See BORENSTEIN 74 for a discussion on this point.) Thus BORENSTEIN 74 uses a Breit-Wigner with energy-independent width, since a P-wave was found to give unsatisfactory fits. CAMERON 78 uses the same form. On the other hand HOLM-GREN 77 obtains a good fit to their  $\Lambda\pi$  spectrum with a P-wave Breit-Wigner, but includes the partial width for the  $\Sigma\pi$  decay mode in the parametrization. AGUILAR-BENITEZ 81D gives masses and widths for five different Breit-Wigner shapes. The results vary considerably. Only the best-fit S-wave results are given here.

### **Σ**(1385) MASSES

Σ(1385) ⁺	MASS
1 /4 L LUE (14 - 1 / 1)	

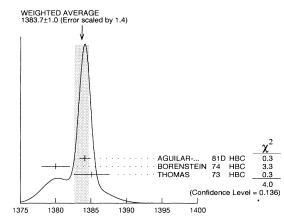
VALUE (MeV)	EVTS	DOCUMENT ID TECN COMMENT
$1382.8 \pm 0.4$	OUR AVERAGE	Error includes scale factor of 2.0. See the ideogram below.
$1384.1\pm0.7$	1897	BAUBILLIER 84 HBC $K^-p$ 8.25 GeV/c
$1384.5 \pm 0.5$	5256	AGUILAR 81D HBC $K^-p  ightarrow \Lambda \pi \pi$ 4.2 ${\sf GeV}/c$
$1383.0 \pm 0.4$	9361	AGUILAR 81D HBC $K^-p  ightarrow \Lambda 3\pi$ 4.2 GeV/ $c$
$1381.9 \pm 0.3$	6900	CAMERON 78 HBC $K^{-}p$ 0.96–1.36 GeV/ $c$
1381 $\pm 1$	6846	BORENSTEIN 74 HBC $K^-p$ 2.18 GeV/c
$1383.5 \pm 0.85$	2300	HABIBI 73 HBC $K^-p \rightarrow \Lambda\pi\pi$
1382 ±2	400	AGUILAR 72B HBC $K^-p \rightarrow \Lambda \pi$ 's
$1384.4 \pm 1.0$	1260	SIEGEL 67 HBC $K^-p$ 2.1 GeV/ $c$
1382 ±1	750	ARMENTEROS65B HBC $K^-p$ 0.9–1.2 GeV/ $c$
$1381.0\pm1.6$	859	HUWE 64 HBC $K^- p$ 1.22 GeV/c
• • • We do	not use the follow	ring data for averages, fits, limits, etc. • • •
$1385.1\pm1.2$	600	BAKER 80 HYBR $\pi^+ p$ 7 GeV/c
$1383.2 \pm 1.0$	750	BAKER 80 HYBR $K^- p$ 7 GeV/c
1381 $\pm 2$	7k	1 BAUBILLIER 798 HBC $K^{-}$ $p$ 8.25 GeV/ $c$
1391 ±2	2k	CAUTIS 79 HYBR $\pi^+ p/K^- p$ 11.5 GeV
1390 ±2	100	1 SUGAHARA 79B HBC $\pi^{-}p$ 6 GeV/ $c$
1385 $\pm 3$	22k	1,2 BARREIRO 778 HBC $K^-p$ 4.2 GeV/ $c$
1385 ±1	2594	HOLMGREN 77 HBC See AGUILAR 81D
$1380 \pm 2$		¹ BARDADIN 75 HBC $K^-p$ 14.3 GeV/ $c$
1382 ±1	3740	³ BERTHON 74 HBC $K^- \rho$ 1263–1843 MeV/ $c$
1390 ±6	46	AGUILAR 70B HBC $K^-p o\Sigma\pi$ 's 4 GeV $/c$
1383 ±8	62	⁴ BIRMINGHAM 66 HBC $K^-p$ 3.5 GeV/ $c$
1378 ±5	135	LONDON 66 HBC $K^-p$ 2.24 GeV/c
$1384.3 \pm 1.9$	250	⁴ SMITH 65 HBC $K^- p$ 1.8 GeV/c
$1382.6\pm2.1$	250	⁴ SMITH 65 HBC $K^- p$ 1.95 GeV/c
$1375.0\pm3.9$	170	COOPER 64 HBC $K^-p$ 1.45 GeV/c
$1376.0 \pm 3.9$	154	⁴ ELY 61 HLBC $K^- p$ 1.11 GeV/c



 $\Sigma(1385)^+$  mass (MeV)

### Σ(1385)0 MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
1383.7±1.0 OUR	AVERAGE Er	ror includes scale f	actor	of 1.4.	See the ideogram below.
$1384.1 \pm 0.8$	5722	AGUILAR	<b>81</b> D	нвс	$K^- p \rightarrow \Lambda 3\pi 4.2$ GeV/c
1380 ±2	3100	⁵ BORENSTEIN	74	нвс	$K^- p \rightarrow \Lambda 3\pi \ 2.18$ GeV/c
$1385.1 \pm 2.5$	240	⁴ THOMAS	73	HBC	$\pi^- \rho \rightarrow \Lambda \pi^0 K^0$
• • • We do not	use the followin	g data for average	s, fits	, limits,	etc. • • •
1389 ±3	500	⁶ BAUBILLIER	79B	нвс	$K^{-}p$ 8.25 GeV/c

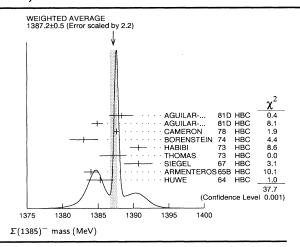


 $\Sigma$ (1385) 0  mass (MeV)

### $\Sigma$ (1385) $^-$ MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
			actor		See the ideogram below.
1388.3±1.7	<b>62</b> 0	AGUILAR	<b>81</b> D	нвс	$K^- p \rightarrow \Lambda \pi \pi 4.2$ GeV/c
1384.9±0.8	3346	AGUILAR	81D	нвс	$K^- p \rightarrow \Lambda 3\pi 4.2$ GeV/c
$1387.6 \pm 0.3$	9720	CAMERON	78	HBC	K [−] p 0.96–1.36 GeV/c
1383 ±2	2303	BORENSTEIN	74	нвс	$K^- p \ 2.18 \ \text{GeV}/c$
$1390.7 \pm 1.2$	1900	HABIBI	73	HBC	$K^- p \rightarrow \Lambda \pi \pi$
$1387.1 \pm 1.9$	630	⁴ THOMAS	73	HBC	$\pi^- p \rightarrow \Lambda \pi^- K^+$
1390.7±2.0	370	SIEGEL	67	HBC	$K^- p$ 2.1 GeV/ $c$
1384 ±1	1380	ARMENTEROS	665B	HBC	$K^- p 0.9-1.2 \text{ GeV}/c$
1385.3±1.9	1086	⁴ HUWE	64	HBC	K-p 1.15-1.30 GeV/c
• • • We do not ι	ise the follow	wing data for averages	, fits	, limits,	etc. • • •
1383 ±1	4.5k	¹ BAUBILLIER	79B	нвс	K [−] p 8.25 GeV/c
1380 ±6	150	¹ SUGAHARA	79B	HBC	$\pi^- p$ 6 GeV/c
1387 ±3	12k	^{1,2} BARREIRO	778	HBC	K-p 4.2 GeV/c
1391 ±3	193	HOLMGREN	77	HBC	See AGUILAR 81D
1383 ±2		1 BARDADIN	75	HBC	$K^- p$ 14.3 GeV/c
1389 ±1	3060	³ BERTHON	74	HBC	K-p 1263-1843 MeV/c
1389 ±9	15	LONDON	66	HBC	K-p 2.24 GeV/c
1391.5±2.6	120	⁴ SMITH	65	HBC	K-p 1.8 GeV/c
1399.8 ± 2.2	58	⁴ SMITH	65	нвс	K [−] p 1.95 GeV/c
1392.0±6.2	200	COOPER	64	HBC	K [−] p 1.45 GeV/c
1382 ±3	93	DAHL	61	DBC	K-d 0.45 GeV/c
1376.0 ± 4.4	224	⁴ ELY	61	HLBC	$K^{-}p$ 1.11 GeV/c

### $\Sigma(1385)$



### $m_{\Sigma(1385)^{-}} - m_{\Sigma(1385)^{+}}$

VALUE (MeV)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the	following	data for averages	, fits	, limits,	etc. • • •
- 2 to +6		⁷ BORENSTEIN	74	HBC	$K^-p$ 2.18 GeV/ $c$
$7.2 \pm 1.4$			73	HBC	$K^- p \rightarrow \Lambda \pi \pi$
$6.3 \pm 2.0$		⁷ SIEGEL	67	HBC	$K^-p$ 2.1 GeV/c
11 ±9		⁷ LONDON	66	HBC	K [−] p 2.24 GeV/c
9 ±6				HBC	Λ3π events
$2.0 \pm 1.5$		⁷ ARMENTEROS	65B	HBC	$K^- p$ 0.9–1.2 GeV/ $c$
$7.2 \pm 2.1$		⁷ SMITH	65	HBC	$K^-p$ 1.8 GeV/c
$17.2 \pm 2.0$		⁷ SMITH	65	нвс	$K^-p$ 1.95 GeV/c
17 ±7		⁷ COOPER	64	HBC	K [−] p 1.45 GeV/c
4.3 ± 2.2		⁷ HUWE	64	HBC	$K^- p$ 1.22 GeV/c
$\textbf{0.0} \pm \textbf{4.2}$		⁷ ELY	61	HLBC	$K^-p$ 1.11 GeV/ $c$

### $m_{\Sigma(1385)^0} - m_{\Sigma(1385)^+}$

V	411	UΕ	(Me	/)				CL%	DC	CUN	ENT ID		TECN	CON	IM.	ENT		
•	•	•	We	d٥	not	use	the	following	data	for	average	s, fits	, limits,	etc.	•	• •		
	4	to	+4					95	7 BC	DRE	NSTEIN	74	нвс	ĸ-	D	2.18	GeV/c	

### $m_{\Sigma(1385)^-} - m_{\Sigma(1385)^0}$

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following	data for averages	, fits, limits,	etc. • • •
$2.0\pm2.4$	⁷ THOMAS	73 HBC	$\pi^- \rho \rightarrow \Lambda \pi^- K^+$

### Σ(1385) WIDTHS

$\Sigma(1385)^{+}$	WIDTH
VALUE (MeV)	

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
35.8± 0.8 OUR AV	ERAGE			
37.2± 2.0	1897	BAUBILLIER 84	1 HBC	K [−] p 8.25 GeV/c
35.1 ± 1.7	5256	AGUILAR 81	LD HBC	$K^-p \rightarrow \Lambda\pi\pi 4.2$
				GeV/c
37.5± 2.0	9361	AGUILAR 81	ID HBC	$K^- p \rightarrow \Lambda 3\pi 4.2$ GeV/c
35.5± 1.9	6900	CAMERON 78	3 HBC	K [−] p 0.96–1.36 GeV/c
34.0 ± 1.6	6846	8 BORENSTEIN 74	1 HBC	$K^-p$ 2.18 GeV/c
38.3± 3.2	2300	⁹ HABIBI 73	в нвс	$K^- \rho \rightarrow \Lambda \pi \pi$
32.5 ± 6.0	400	AGUILAR 72	2B HBC	$K^- \rho \rightarrow \Lambda \pi$ 's
36 ± 4	1260	⁹ SIEGEL 67	7 HBC	K [−] p 2.1 GeV/c
32.0 ± 4.7	750	9 ARMENTEROS6	в НВС	$K^- p 0.95-1.20 \text{ GeV}/c$
46.5 ± 6.4	859		4 HBC	K  p 1.15−1.30 GeV/c
• • We do not us	se the following	ng data for averages, f	its, limits,	etc. • • •
40 ± 3	600	BAKER 80	) HYBR	$\pi^+ \rho$ 7 GeV/ $c$
37 ± 2	750	BAKER 80	HYBR	K [−] p 7 GeV/c
37 ± 2	7k	¹ BAUBILLIER 79	эв НВС	K [−] p 8.25 GeV/c
30 ± 4	2k	CAUTIS 7	HYBR	$\pi^{+} \rho / K^{-} \rho$ 11.5 GeV
30 ± 6	100		эв НВС	$\pi^- \rho$ 6 GeV/ $c$
43 ± 5	22k	1,2 BARREIRO 7	7в НВС	$K^-p$ 4.2 GeV/ $c$
34 ± 2	2594	HOLMGREN 7		See AGUILAR 81D
40.0± 3.2		¹ BARDADIN 7!	5 HBC	K ⁻ ρ 14.3 GeV/c
48 ± 3	3740	3 BERTHON 7		K [−] p 1263–1843 MeV/c
33 ±20	46		ов НВС	$K^- p \rightarrow \Sigma \pi$ 's 4 GeV/c
25 ±32	62	⁹ BIRMINGHAM 6	6 HBC	$K^- p$ 3.5 GeV/c
30.3± 7.5	250	⁹ SMITH 6	5 HBC	$K^-p$ 1.8 GeV/ $c$
33.1 ± 8.3	250	⁹ SMITH 6:	5 HBC	$K^-p$ 1.95 GeV/ $c$
51 ±16	170	9 COOPER 6	4 HBC	K [−] p 1.45 GeV/c
48 ±16	154	⁹ ELY 6	1 HLBC	$K^-p$ 1.11 GeV/ $c$

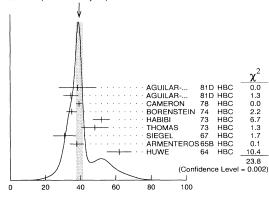
7 (1382),	WIDTH	
ALUE (MeV	)	

VAL	JE (N	iev)	EVIS	DOCUMENT ID		TECN	COMMENT
36	± 5	OUR A	/ERAGE				
34.8	± 5	5.6	5722				$K^- p \rightarrow \Lambda 3\pi 4.2$ GeV/c
39.3	± 10	).2	240	⁹ THOMAS	73	HBC	$\pi^- p \rightarrow \Lambda \pi^0 K^0$
• •	<ul> <li>V</li> </ul>	/e do not u	se the following	data for averages	s, fits	, limits,	etc. • • •
53	± 8	3	3100	⁰ BORENSTEIN	74	нвс	$K^- p \rightarrow \Lambda 3\pi \ 2.18$ GeV/c
30	+ (	•	106	CURTIS	63	OSPK	π n 1.5 GeV/c

### $\Sigma$ (1385)- WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
39.4± 2.1 OUR AVER	GE Erro	or includes scale fac	ctor o	of 1.7. S	ee the ideogram below.
$38.4 \pm 10.7$	620	AGUILAR	81D	нвс	$K^- p \rightarrow \Lambda \pi \pi 4.2$ GeV/c
34.6 ± 4.2	3346	AGUILAR	81D	нвс	$K^- p \rightarrow \Lambda 3\pi 4.2$ GeV/c
39.2 ± 1.7	9720	CAMERON	78	HBC	K-p 0.96-1.36 GeV/c
35 ± 3	2303	⁸ BORENSTEIN	74	HBC	K [−] p 2.18 GeV/c
51.9± 4.8	1900	⁹ HABIBI	73	HBC	$K^- p \rightarrow \Lambda \pi \pi$
48.2 ± 7.7	630	⁹ THOMAS	73	HBC	$\pi^- p \rightarrow \Lambda \pi^- K^0$
31.0 ± 6.5	370	⁹ SIEGEL	67	HBC	K-p 2.1 GeV/c
38.0 ± 4.1	1382	9 ARMENTEROS	\$65B	HBC	K-p 0.95-1.20 GeV/c
62 ± 7	1086	HUWE	64	HBC	K ⁻ p 1.15−1.30 GeV/c
• • • We do not use the	e followin	g data for averages	, fits	, limits,	etc. • • •
44 ± 4	4.5k	¹ BAUBILLIER	79B	нвс	K [−] p 8.25 GeV/c
58 ± 4	150	¹ SUGAHARA	79B	HBC	$\pi^- p$ 6 GeV/ $c$
45 ± 5	12k	^{1,2} BARREIRO	77B	HBC	K [−] p 4.2 GeV/c
35 ±10	193	HOLMGREN	77	HBC	See AGUILAR 81D
47 ± 6		¹ BARDADIN	75	HBC	K [−] p 14.3 GeV/c
40 ± 3	3060	³ BERTHON	74	HBC	K-p 1263-1843 MeV/c
$29.2 \pm 10.6$	120	⁹ SMITH	65	HBC	$K^-p$ 1.80 GeV/ $c$
17.1 ± 8.9	58	⁹ SMITH	65	HBC	K [−] p 1.95 GeV/c
88 ±24	200	⁹ COOPER	64	HBC	K [−] p 1.45 GeV/c
40		DAHL	61	DBC	$K^- d 0.45 \text{ GeV}/c$
66 ±18	224	⁹ ELY	61	HLBC	K-p 1.11 GeV/c





 $\Sigma(1385)^-$  width (MeV)

### $\Sigma$ (1385) POLE POSITIONS

### $\Sigma$ (1385)+ REAL PART

VALUE	DOCUMENT ID	COMMENT
1379+1	LICHTENBERG74	Extrapolates HABIBI 73

### $\Sigma$ (1385)⁺ -IMAGINARY PART

17.5±1.5	LICHTENBERG74	Extrapolates HABIBI 73
Σ(1385)- REAL PART		

COMMENT

VALUE	DOCUMENT ID	COMMENT
1383±1	LICHTENBERG74	Extrapolates HABIBI 73

### $\Sigma$ (1385)- -IMAGINARY PART

VALUE		DOCUMENT ID	COMMENT
$22.5 \pm 1.5$	5	LICHTENBERG74	Extrapolates HABIBI 73

### Σ(1385) DECAY MODES

	Mode	Fraction $(\Gamma_i/\Gamma)$
Γ ₁	Λπ	88±2 %
$\Gamma_2$	$\Sigma \pi$	12±2 %
Γ3	$\Lambda\gamma$	
	$\Sigma \gamma$	
Γ ₄ Γ ₅	NK	

The above branching fractions are our estimates, not fits or averages.

### Σ(1385) BRANCHING RATIOS

$\Gamma(\Sigma\pi)/\Gamma(\Lambda\pi)$		,				$\Gamma_2/\Gamma_1$
VALUE		DOCUMENT ID		TECN	CHG	COMMENT
0.135±0.011 OUR AV	ERAGE	DIGNICI	70-	1100		V= V* V\\
0.20 ±0.06 0.16 ±0.03		DIONISI BERTHON	78B	HBC HBC	± +	$K^- p \rightarrow Y^* K \overline{K}$ $K^- p 1.26-1.84$
0.10 ±0.03		BERTHON	/4	пьс	+	GeV/c
0.11 ±0.02		BERTHON	74	нвс	-	K ⁻ p 1.26-1.84 GeV/c
0.21 ±0.05		BORENSTEIN	74	нвс	+	$K^- p \rightarrow \Lambda \pi^+ \pi^-, $ $\Sigma^0 \pi^+ \pi^-$
0.18 ±0.04		MAST	73	MPWA	±	$K^- p \rightarrow \Lambda \pi^+ \pi^-,$
$0.10\ \pm0.05$		THOMAS	73	нвс	-	$\Sigma^0 \pi^+ \pi^- \\ \pi^- p \rightarrow \Lambda K \pi, \\ \Sigma K \pi$
$0.16\ \pm0.07$		AGUILAR	72B	нвс	+	$K^{-}p$ 3.9, 4.6 GeV/c
$0.13 \pm 0.04$		COLLEY	71B	DBC	-0	K-N 1.5 GeV/c
$0.13 \pm 0.04$		PAN	69	нвс	+	$\pi^+ p \rightarrow \Lambda K \pi$ ,
0.08 ±0.06		LONDON	66	нвс	+	$\Sigma K \pi$ $K^- p$ 2.24 GeV/c
$0.163 \pm 0.041$		ARMENTERO	S65B		±	K-p 0.95-1.20 GeV/c
0.09 ±0.04 • • • We do not use the	• following	HUWE	64 fits	HBC	± etc.	K [−] p 1.2–1.7 GeV
< 0.04	. Tollowing (	ALSTON	62	HBC	±0	K ⁻ p 1.15 GeV/c
0.04 ±0.04		BASTIEN	61	НВС	±	κ p 1.15 GeV/C
$\Gamma(\Lambda\gamma)/\Gamma_{\text{total}}$						Г ₃ /Г
	<u>EVTS</u>	DOCUMENT ID		TECN	COMM	
• • We do not use the	_	_				
$0.17 \pm 0.17$	1	MEISNER	72	HBC	1 eve	nt only
$\Gamma(\Lambda\gamma)/\Gamma(\Lambda\pi)$						$\Gamma_3/\Gamma_1$
VALUE	CL%	DOCUMENT ID			COMN	
• • We do not use the	following o	data for averages	, fits	, limits,	etc. •	• •
< 0.06	90	COLAS	75	HLBC	κ- p	575-970 MeV
$\Gamma(\Sigma\gamma)/\Gamma(\Lambda\pi)$	m. #/					Γ ₄ /Γ ₁
• • • We do not use the	CL%	DOCUMENT ID			COMN	
< 0.05	90	COLAS	75			575–970 MeV
	,,,	COLAG	, ,		., р	
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N^{\frac{1}{2}}$	₹ → Σ(13	85) → Λπ DOCUMENT ID		сна с	ОММЕ	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,
+0.586±0.319	11	DEVENISH	74B			dispersion rel.

### Σ(1385) FOOTNOTES

- 1  From fit to inclusive  $\Lambda\pi$  spectrum.

- Includes data of HOLMGREN 77.

  3 The errors are statistical only. The resolution is not unfolded.

  4 The error is enlarged to  $\Gamma/\sqrt{N}$ . See the note on the  $K^*(892)$  mass in the 1984 edition.

  5 From a fit to  $\Lambda \pi^0$  with the width fixed at 34 MeV.

  From fit to inclusive  $\Lambda \pi^0$  spectrum with the width fixed at 40 MeV.

- 7 Redundant with data in the mass Listings.

  8 Results from  $\Lambda\pi^+\pi^-$  and  $\Lambda\pi^+\pi^-\pi^0$  combined by us.

  9 The error is enlarged to  $4\Gamma/\sqrt{N}$ . See the note on the  $K^*(892)$  mass in the 1984 edition.

  10 Consistent with +, 0, and widths equal.
- $^{11}\,\mathrm{An}$  extrapolation of the parametrized amplitude below threshold.

### Σ(1385) REFERENCES

0.4110111150		75107 Con ore		
BAUBILLIER	84	ZPHY C23 213	<ul> <li>+ (BIRM, CERN, GLAS, MSU,</li> </ul>	
PDG	84		Wohl, Cahn, Rittenberg+ (LBL, CIT,	
AGUILAR		AFIS A77 144		(MADR)
BAKER	80	NP B166 207	+Chima, Dornan, Gibbs, Hall, Miller+	(LOIC)
BAUBILLIER	79B	NP B148 18	<ul> <li>(BIRM, CERN, GLAS, MSU,</li> </ul>	
CAUTIS	79	NP B156 507	+Ballam, Bouchez, Carroll, Chadwick+	(SLAC)
SUGAHARA	79B	NP B156 237	+Ochiai, Fukui, Cooper+ (KEK, OSKC	, KINK)
CAMERON	78	NP B143 189		L, LOIC)
DIONISI	78B	PL 78B 154	+Armenteros, Diaz (CERN, AMST, NIJA	vi. OXF)
BARREIRO	77B	NP B126 319	+Berge, Ganguli, Blokzijl+ (CERN, AMST	(MLIN
HOLMGREN	77	NP B119 261	+Aguilar-Benitez, Kluyver+ (CERN, AMST	
BARDADIN	75	NP B98 418	Bardadin-Otwinowska+ (SACL, EPOL	
COLAS	75	NP B91 253		ORSAY)
BERTHON	74	NC 21A 146	+Tristram+ (CDEF, RHEL, SACL)	
BORENSTEIN	74	PR D9 3006		, MICH)
DEVENISH	74B	NP B81 330	+Froggatt, Martin (DESY, NORD,	
LICHTENBERG		PR D10 3865	(0.501) (0.015)	(IND)
Also	74B		Lichtenberg	(IND)
HABIBI	73	Thesis Nevis 199		(COLU)
Also	73	Purdue Conf. 387		BING)
MAST	73	PR D7 3212	+Bangerter, Alston-Garniost+	(LBL) IJP
Also		PR D7 5	Mast, Bangerter, Alston-Garnjost+	(LBL) IJP
THOMAS	73	NP B56 15	+Engler, Fisk, Kraemer	(CMU) JP
AGUILAR	72B	PR D6 29	Aguilar-Benitez, Chung, Eisner, Samios	(BNL)
MEISNER	72	NC 12A 62		C, LBL)
COLLEY		NP B31 61	+Cox, Eastwood, Fry+ (BIRM, EDIN, GLAS	
AGUILAR	70B	PRL 25 58	Aguilar-Benitez, Barnes, Bassano+ (BNL,	
PAN	69	PRL 23 808		(PENN) I
SIEGEL	67	Thesis UCRL 18041	+roiman	(LRL)
BIRMINGHAM		PR 152 1148	(BIRM, GLAS, LOIC, OXF,	
LONDON	66	PR 143 1034		, SYRA) J
ARMENTEROS		PL 19 75	+ (CERN, HEID	
SMITH	65	Thesis UCLA	+ (CERN, HEID	(UCLA)
COOPER	64	PL 8 365	+Filthuth, Fridman, Malamud+ (CERN,	AMST)
HUWE	64	Thesis UCRL 11291	+FILLHOLII, FROMAII, MAIAMOU+ (CERN,	
			House	(LRL) JP
Also	69	PR 180 1824	Huwe	(LRL)
CURTIS	63	PR 132 1771	+Coffin, Meyer, Terwilliger	(MICH) J
ALSTON	62	CERN Conf. 311	+Alvarez, Ferro-Luzzi+	(LRL)
BASTIEN	61	PRL 6 702	+Ferro-Luzzi, Rosenfeld	(LRL)
DAHL	61	PRL 6 142	+Horwitz, Miller, Murray, White	(LRL)
ELY	61	PRL 7 461	+Fung, Gidal, Pan, Powell, White	(LRL) J
ALSTON	60	PRL 5 520	+Alvarez, Eberhard, Good, Graziano+	(LRL) I

### $\Sigma$ (1480) Bumps

 $I(J^P) = 1(??)$  Status: *

#### OMITTED FROM SUMMARY TABLE

These are peaks seen in  $\Lambda\pi$  and  $\Sigma\pi$  spectra in the reaction  $\pi^+p\to$  $(Y\pi)K^+$  at 1.7 GeV/c. Also, the Y polarization oscillates in the samé region.

MILLER 70 suggests a possible alternate explanation in terms of a reflection of  $N(1675) \rightarrow \Lambda K$  decay. However, such an explanation for the  $(\Sigma^+\pi^0)K^+$  channel in terms of  $\Delta(1650) o \Sigma K$  decay seems unlikely (see PAN 70). In addition such reflections would also have to account for the oscillation of the Y polarization in the 1480

HANSON 71, with less data than PAN 70, can neither confirm nor deny the existence of this state. MAST 75 sees no structure in this region in  $K^-\,p\to~\Lambda\pi^0.$ 

ENGELEN 80 performs a multichannel analysis of  $K^- p \to p \overline{K}{}^0 \pi^$ at 4.2 GeV/c. They observe a 3.5 standard-deviation signal at 1480 MeV in  $p\overline{K}^0$  which cannot be explained as a reflection of any competing channel.

# $\Sigma$ (1480) MASS (PRODUCTION EXPERIMENTS)

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
≈ 1480 OUR ESTIN	MATE					
1480	120	ENGELEN	80	HBC	+	$\kappa^- p \rightarrow$
						$(p\overline{K}^0)\pi^-$
$1485\pm10$		CLINE	73	MPWA		$K^-d \rightarrow$
						$(\Lambda \pi^{-}) p$
$1479 \pm 10$		PAN	70	HBC	+	$\pi^+ \rho \rightarrow$
						$(\Lambda \pi^{+}) K^{+}$ $\pi^{+} \rho \rightarrow$
$1465\pm15$		PAN	70	HBC	+	$\pi^+ \rho \rightarrow$
						$(\Sigma\pi)K^+$

### Σ(1480) WIDTH (PRODUCTION EXPERIMENTS)

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
$80\pm20$	120	ENGELEN	80	нвс	+	$K^- p \rightarrow (p \overline{K}^0) \pi^-$
40±20		CLINE	73	MPWA		K-d
31±15		PAN	70	нвс	+	$(\Lambda \pi^{-}) \rho$ $\pi^{+} \rho \rightarrow$
00.1.00		DAN	70	unc		$(\Lambda \pi^{+}) K^{+}$ $\pi^{+} \rho \rightarrow$
30±20		PAN	70	нвс	+	$\pi \cdot \rho \rightarrow (\Sigma \pi) K^+$

 $\Sigma(1480)$  Bumps,  $\Sigma(1560)$  Bumps,  $\Sigma(1580)$ 

## $\Sigma$ (1480) DECAY MODES (PRODUCTION EXPERIMENTS)

	Mode				
Γ1	NK				
$\Gamma_2^-$	$\Lambda\pi$				
٦	$\Sigma \pi$				

## Σ(1480) BRANCHING RATIOS (PRODUCTION EXPERIMENTS)

$\Gamma(\mathbf{\Sigma}\pi)/\Gamma(\mathbf{\Lambda}\pi)$					$\Gamma_3/\Gamma_2$
VALUE	DOCUMENT ID		TECN	CHG	
$0.82 \pm 0.51$	PAN	70	нвс	+	
$\Gamma(N\overline{K})/\Gamma(\Lambda\pi)$					$\Gamma_1/\Gamma_2$
VALUE	DOCUMENT ID		TECN	CHG	
$0.72 \pm 0.50$	PAN	70	нвс	+	
$\Gamma(N\overline{K})/\Gamma_{\text{total}}$					Γ ₁ /Ι
VALUE	DOCUMENT ID		TECN	COMMENT	
small	CLINE	73	MPWA	$K^- d \rightarrow (\Lambda \pi^-)$	_)p

## Σ(1480) REFERENCES (PRODUCTION EXPERIMENTS)

ENGELEN	80	NP B167 61	+Jongejans, Dionisi+	(NIJM, AMST,	CERN, OXF)
MAST	75	PR D11 3078	+Alston-Garnjost, Bangerter+		(LBL)
CLINE	73	LNC 6 205	+Laumann, Mapp		(ŴISC) IJ
HANSON	71	PR D4 1296	+Kalmus, Louie		(LBL) I
MILLER	70	Duke Conf. 229			(PÙRD)
PAN	70	PR D2 49	+Forman, Ko, Hagopian, Selov	e	(PENN)
Also	69	PRL 23 808	Pan, Forman		(PENN) I
Also	69B	PRL 23 806	Pan, Forman		(PENN) I

## $\Sigma$ (1560) Bumps

 $I(J^P) = 1(?^?)$  Status: **

#### OMITTED FROM SUMMARY TABLE

This entry lists peaks reported in mass spectra around 1560 MeV without implying that they are necessarily related.

DIONISI 78B observes a 6 standard-deviation enhancement at 1553 MeV in the charged  $\Lambda/\varSigma\pi$  mass spectra from  $K^-p\to (\Lambda/\varSigma)\pi\, K\, \overline{K}$  at 4.2 GeV/c. In a CERN ISR experiment, LOCK-MAN 78 reports a narrow 6 standard-deviation enhancement at 1572 MeV in  $\Lambda\pi^\pm$  from the reaction  $pp\to\Lambda\pi^+\pi^-X$ . These enhancements are unlikely to be associated with the  $\varSigma(1580)$  (which has not been confirmed by several recent experiments – see the next entry in the Listings).

CARROLL 76 observes a bump at 1550 MeV (as well as one at 1580 MeV) in the isospin-1  $\overline{K}$  N total cross section, but uncertainties in cross section measurements outside the mass range of the experiment preclude estimating its significance.

See also MEADOWS 80 for a review of this state.

## $\Sigma$ (1560) MASS (PRODUCTION EXPERIMENTS)

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
≈ 1560 OUR ESTIN	MATE				
$1553 \pm 7$	121	DIONISI	78B HBC	±	$K^- p \rightarrow$
					$(Y\pi)K\overline{K}$
$1572 \pm 4$	40	LOCKMAN	78 SPEC	土	$pp \rightarrow \Lambda \pi^+ \pi^- X$

## $\Sigma$ (1560) WIDTH (PRODUCTION EXPERIMENTS)

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
79±30	121	DIONISI	78B	HBC	±	K ⁻ p → _
15± 6	40 1	LOCKMAN	78	SPEC	±	$(Y\pi)K\overline{K}$ $pp \to \Lambda\pi^+\pi^-X$

## $\Sigma$ (1560) DECAY MODES (PRODUCTION EXPERIMENTS)

	Mode	Fraction $(\Gamma_i/\Gamma)$
Γ ₁	$\Lambda\pi$	seen
$\Gamma_2$	$\Sigma \pi$	

## $\Sigma$ (1560) BRANCHING RATIOS (PRODUCTION EXPERIMENTS)

$\Gamma(\Sigma\pi)/[\Gamma(\Lambda\pi)+\Gamma(\Sigma\pi)]$	DOCUMENT ID		<u>TECN</u>	<u>CHG</u>	$\Gamma_2/(\Gamma_1+\Gamma_2)$
$0.35 \pm 0.12$	DIONISI	788	нвс	±	$K^- p \rightarrow (Y\pi) K \overline{K}$
$\Gamma(\Lambda\pi)/\Gamma_{\text{total}}$					Γ1/Ι
VALUE	DOCUMENT ID		TECN	CHG	COMMENT
seen	LOCKMAN	78	SPEC	$\pm$	$pp \rightarrow \Lambda \pi^+ \pi^- \times$

## $\Sigma$ (1560) FOOTNOTES (PRODUCTION EXPERIMENTS)

¹ The width observed by LOCKMAN 78 is consistent with experimental resolution.

## $\Sigma$ (1560) REFERENCES (PRODUCTION EXPERIMENTS)

MEADOWS	80	Toronto Conf. 283			(CINC)
DIONISI	78B	PL 78B 154	+Armenteros, Diaz	(CERN,	AMST, NIJM, OXF) I
LOCKMAN	78	Saclay DPHPE 78-01	+Meyer, Rander, Poster, Schle	ein+	(UCLA, SACL)
CARROLL	76	PRL 37 806	+Chiang, Kycia, Li, Mazur, M	lichael+	(BNL) I

 $\Sigma(1580) D_{13}$ 

 $I(J^P) = 1(\frac{3}{2}^-)$  Status: **

#### OMITTED FROM SUMMARY TABLE

Seen in the isospin-1  $\overline{K}$  N cross section at BNL (LI 73, CARROLL 76) and in a partial-wave analysis of  $K^-p \to \Lambda\pi^0$  for c.m. energies 1560–1600 MeV by LITCHFIELD 74. LITCHFIELD 74 finds  $J^P=3/2^-$ . Not seen by ENGLER 78 or by CAMERON 78C (with larger statistics in  $K^0_L p \to \Lambda\pi^+$  and  $\Sigma^0\pi^+$ ).

#### Σ(1580) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 1580 OUR ESTIMATE				
1583±4	¹ CARROLL	76	DPWA	Isospin-1 total $\sigma$
1582±4	² LITCHFIELD	74	DPWA	$K^- p \rightarrow \Lambda \pi^0$

#### Σ(1580) WIDTH

VALUE (MeV)	DOCUMENT ID	 TECN	COMMENT
	¹ CARROLL ² LITCHFIELD		Isospin-1 total $\sigma$ $K^- p \rightarrow \Lambda \pi^0$

#### Σ(1580) DECAY MODES

	Mode
$\Gamma_1$	NK
$\Gamma_2^-$	$\Lambda\pi$
Γ ₃	$\Sigma \pi$

### $\Sigma$ (1580) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on  $\varLambda$  and  $\varSigma$  Resonances.

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$				$\Gamma_1/\Gamma$	
VALUE	DOCUMENT ID		TECN	COMMENT	
$+0.03\pm0.01$	² LITCHFIELD	74	DPWA	$\overline{K}N$ multichannel	
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \rightarrow 1$	<b>Σ</b> (1580) → Λπ			$(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma$	
VALUE	DOCUMENT ID		TECN	COMMENT	
not seen	CAMERON ENGLER ² LITCHFIELD	78c	HBC	$K_I^0 \rho \rightarrow \Lambda \pi^+$	
not seen	ENGLER	78	HBC	$K_I^{\bar{0}} p \rightarrow \Lambda \pi^+$	
$+0.10\pm0.02$	² LITCHFIELD	74	DPWA	$\kappa^{-} \rho \rightarrow \Lambda \pi^{0}$	
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to \Sigma(1580) \to \Sigma \pi$ $(\Gamma_1 \Gamma_3)^{\frac{1}{2}} / \Gamma$					
VALUE	DOCUMENT ID		TECN	COMMENT	
	CAMEDON	700	LIDC	v0 - <b>-</b> 0 +	

# VALUE DOCUMENT ID TECN COMMENT not seen CAMERON 78C HBC $K_p^0 p \rightarrow \Sigma^0 \pi^+$ not seen ENGLER 78 HBC $K_p^0 p \rightarrow \Sigma^0 \pi^+$ +0.03 ± 0.04 LITCHFIELD 74 DPWA TN multichannel

#### $\Sigma$ (1580) FOOTNOTES

- ¹ CARROLL 76 sees a total-cross-section bump with  $(J+1/2) \Gamma_{el} / \Gamma_{total} = 0.06$ .
- ² The main effect observed by LITCHFIELD 74 is in the  $\Lambda\pi$  final state; the  $\overline{K}N$  and  $\Sigma\pi$  couplings are estimated from a multichannel fit including total-cross-section data of LI 73.

### $\Sigma$ (1580), $\Sigma$ (1620), $\Sigma$ (1620) Production Experiments

### Σ(1580) REFERENCES

CAMERON ENGLER CARROLL LITCHFIELD LI	78	NP B132 189 PR D18 3061 PRL 37 806 PL 51B 509 Purdue Conf. 283	+Capiluppi+ (BGNA, EDIN +Keyes, Kraemer, Tanaka, Cho+ +Chiang, Kycia, Li, Mazur, Michael+	, GLAS, PISA, RHEL) I (CMU, ANL) (BNL) I (CERN) IJP (BNL) I
--------------------------------------------------	----	----------------------------------------------------------------------------	-------------------------------------------------------------------------------------------------	-------------------------------------------------------------------------

## $\Sigma(1620) S_{11}$

$$I(J^P) = 1(\frac{1}{2})$$
 Status: **

#### OMITTED FROM SUMMARY TABLE

The  $\mathcal{S}_{11}$  state at 1697 MeV reported by VANHORN 75 is tentatively listed under the  $\Sigma(1750)$ . CARROLL 76 sees two bumps in the isospin-1 total cross section near this mass.

Production experiments are listed separately in the next entry.

### Σ(1620) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 1620 OUR ESTIMATE				
1600± 6	¹ MORRIS	78	DPWA	$K^- n \rightarrow \Lambda \pi^-$
1608± 5	² CARROLL	76	DPWA	Isospin-1 total $\sigma$
$1633 \pm 10$	³ CARROLL			Isospin-1 total $\sigma$
$1630 \pm 10$	LANGBEIN	72	IPWA	<b>K</b> N multichannel
1620	KIM	71	DPWA	K-matrix analysis

#### Σ(1620) WIDTH

VALUE (MeV) DOCU	MENT ID TECN COMMENT
87±19 ¹ MOR	RIS 78 DPWA $K^- n \rightarrow \Lambda \pi^-$
15 ² CARF	ROLL 76 DPWA isospin-1 total σ
10 3 CARF	ROLL 76 DPWA Isospin-1 total σ
65 ± 20 LANC	BEIN 72 IPWA $\overline{K}N$ multichannel
40 KIM	71 DPWA K-matrix analysis

#### Σ(1620) DECAY MODES

	Mode			
$\Gamma_1$	NK			
$\Gamma_2$	$\Lambda\pi$			
Γ3	$\Sigma \pi$			

### Σ(1620) BRANCHING RATIOS

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$					$\Gamma_1/\Gamma_1$
VALUE	DOCUMENT ID		TECN	COMMENT	
$0.22 \pm 0.02$	LANGBEIN	72	IPWA	KN multichannel	
0.05	KIM	71	DPWA	K-matrix analysis	

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \rightarrow$	(Γ ₁ Γ ₂ ) ^{1/2} ,		
VALUE	DOCUMENT ID	TECN	COMMENT
$0.12 \pm 0.02$	¹ MORRIS 7	B DPWA	$K^- n \rightarrow \Lambda \pi^-$
not seen	BAILLON 7	5 IPWA	$\overline{K}N \rightarrow \Lambda\pi$
0.15	KIM 7	1 DPWA	K-matrix analysis

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K} \to \Sigma(16)$	<b>20)</b> → Σπ			(Γ ₁ Γ ₃ ) ^{1/2} /Ι
VALUE	DOCUMENT ID		TECN	COMMENT
not seen	HEPP			$K^- N \rightarrow \Sigma \pi$
$0.40 \pm 0.06$	LANGBEIN	72	IPWA	$\overline{K}$ N multichannel
0.08	KIM	71	DPWA	K-matrix analysis

### $\Sigma$ (1620) FOOTNOTES

- 1 MORRIS 78 obtains an equally good fit without including this resonance.
- ² Total cross-section bump with (J+1/2)  $\Gamma_{\rm el}$  /  $\Gamma_{\rm total}$  is 0.06 seen by CARROLL 76. ³ Total cross-section bump with (J+1/2)  $\Gamma_{\rm el}$  /  $\Gamma_{\rm total}$  is 0.04 seen by CARROLL 76.

### Σ(1620) REFERENCES

MORRIS	78	PR D17 55	+Albright, Colleraine, Kimel, Lannutti	(FSU) IJP
CARROLL	76	PRL 37 806	+Chiang, Kycia, Li, Mazur, Michael+	(BNL) I
HEPP	76B	PL 65B 487	+Braun, Grimm, Strobele+ (CERN,	HEIDH, MPIM) IJP
BAILLON	75	NP B94 39	+Litchfield	(CERN, RHEL) IJP
VANHORN	75	NP B87 145		(LBL) IJP
Also	75B	NP B87 157	VanHorn	(LBL) IJP
LANGBEIN	72	NP B47 477	+Wagner	(MPIM) IJP
KIM	71	PRL 27 356		(HARV) IJP
Aiso	70	Duke Conf. 161	Kim	(HARV) IJP

### $\Sigma(1620)$ Production Experiments

 $I(J^P) = 1(?^?)$ OMITTED FROM SUMMARY TABLE
Formation experiments Formation experiments are listed separately in the previous entry.

> The results of CRENNELL 69B at 3.9  ${
> m GeV}/c$  are not confirmed by SABRE 70 at 3.0 GeV/c. However, at 4.5 GeV/c, AMMANN 70 sees a peak at 1642 MeV which on the basis of branching ratios they do not associate with the  $\Sigma(1670)$ . See MILLER 70 for a review of these conflicts.

#### Σ(1620) MASS (PRODUCTION EXPERIMENTS)

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
≈ 1620 OUR ESTI	MATE					
$1642 \pm 12$		AMMANN	70	DBC		$K^- N$ 4.5 GeV/c
1618± 3	20	BLUMENFELD	69	HBC	+	$\kappa_{IP}^{0}$
1619± 8		CRENNELL	69B	DBC	±	$K^- N \rightarrow \Lambda \pi \pi \pi$
• • • We do not u	ise the following	data for averages	, fits	, limits,	etc. •	• •
1616± 8		CRENNELL	68	DBC	±	See CREN- NELL 69B

#### Σ(1620) WIDTH (PRODUCTION EXPERIMENTS)

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
55 ± 24		AMMANN	70	DBC		$K^- N$ 4.5 GeV/c
$30\pm10$	20	BLUMENFELD	69	HBC	+	
72 ^{+ 22} _{- 15}		CRENNELL	<b>69</b> B	DBC	±	
• • • We do not us	se the following	data for averages	, fits	, limits,	etc. •	• •
$66\pm16$		CRENNELL	68	DBC	±	See CREN-

#### Σ(1620) DECAY MODES (PRODUCTION EXPERIMENTS)

	Mode
Γ,	$N\overline{K}$
$\Gamma_2$	$\Lambda\pi$
$\Gamma_3$	$\Sigma\pi$
$\Gamma_4$	$\Lambda\pi\pi$
$\Gamma_5$	$\Sigma(1385)\pi$
$\Gamma_6$	$\Lambda(1405)\pi$

#### $\Sigma$ (1620) BRANCHING RATIOS (PRODUCTION EXPERIMENTS)

$\Gamma(\Lambda\pi\pi)/\Gamma(\Lambda\pi)$						$\Gamma_4/\Gamma_2$
VALUE	EVTS	DOCUMENT ID		TECN	CHG	
$\sim 2.5$	14	BLUMENFEL	D 69	HBC	+	
$\Gamma(N\overline{K})/\Gamma(\Lambda\pi)$						$\Gamma_1/\Gamma_2$
VALUE		DOCUMENT ID		TECN	CHG	COMMENT
$0.4 \pm 0.4$		AMMANN	70	DBC		$K^- p$ 4.5 GeV/c
$0.0 \pm 0.1$		CRENNELL	68	DBC	+	See CREN- NELL 69B
$\Gamma(\Lambda\pi)/\Gamma_{\text{total}}$						$\Gamma_2/\Gamma$
VALUE		DOCUMENT ID		TECN	CHG	
large		CRENNELL	68	DBC	土	
$\Gamma(\Sigma(1385)\pi)/\Gamma(1$	<b>Λ</b> π)					$\Gamma_5/\Gamma_2$
VALUE	CL%	DOCUMENT ID		TECN	CHG	COMMENT
< 0.3	95	AMMANN	70	DBC		$K^-p$ 4.5 GeV/c
$0.2\pm0.1$		CRENNELL	68	DBC	±	
$\Gamma(\Sigma\pi)/\Gamma(\Lambda\pi)$						$\Gamma_3/\Gamma_2$
VALUE	CL%	DOCUMENT ID		TECN	сом	MENT
<1.1	95	AMMANN	70	DBC	K-1	V 4.5 GeV/ <i>c</i>
$\Gamma(\Lambda(1405)\pi)/\Gamma(\Lambda(1405)\pi)$	<b>(π</b> )	*				$\Gamma_6/\Gamma_2$
VALUE	-	DOCUMENT ID		TECN	COMI	MENT
$0.7 \pm 0.4$		AMMANN	70	DBC	K-L	4.5 GeV/c

### $\Sigma(1620)$ Production Experiments, $\Sigma(1660)$ , $\Sigma(1670)$

#### Σ(1620) REFERENCES (PRODUCTION EXPERIMENTS)

AMMANN	70	PRL 24 327	+Garfinkel, Carmony, Gutay+	(PURD, IND)
Also	73	PR D7 1345	Ammann, Carmony, Garfinkel+	(PURD, IUPU)
MILLER	70	Duke Conf. 229		(PURD)
SABRE	70	NP B16 201	Barloutaud, Merril, Schever+	(SABRE Collab.)
BLUMENFELD	69	PL 29B 58	+Kalbfleisch	(BNL) I
CRENNELL	69B	Lund Paper 183	+Karshon, Lai, O'Neil, Scarr+	(BNL, CUNY) I
Results are	quote	d in LEVI-SETTI 69C.		
Also	69C	Lund Conf.	Levi-Setti	(EFI)
CRENNELL	68	PRL 21 648	+Delaney, Flaminio, Karshon+	(BNL, CÙNY) I

## $\Sigma(1660) P_{11}$

$$I(J^P) = 1(\frac{1}{2}^+)$$
 Status: ***

For results published before 1974 (they are now obsolete), see our 1982 edition Physics Letters **111B** (1982).

#### Σ(1660) MASS

VALUE	(MeV)	DOCUMENT ID		TECN	COMMENT
1630	to 1690 (≈ 1660) OUR ES	TIMATE			
1665.1	1±11.2	¹ KOISO	85	DPWA	$K^- p \rightarrow \Sigma \pi$
1670	±10	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
1679	±10	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
1676	±15	GOPAL			$\overline{K}N$ multichannel
1668	±25	VANHORN	75	DPWA	$K^- \rho \rightarrow \Lambda \pi^0$
1670	±20	KANE	74	DPWA	$K^- p \rightarrow \Sigma \pi$
	We do not use the following	data for average	s, fits	s, limits,	etc. • • •
1565	or 1597	² MARTIN	77	DPWA	KN multichannel
1660	±30	3 BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda\pi$
1671	± 2	⁴ PONTE	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$

### Σ(1660) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
40 to 200 (≈ 100) OUR ESTIM	ATE			
81.5± 22.2	¹ KOISO	85	DPWA	$K^- p \rightarrow \Sigma \pi$
152 ± 20	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
38 ± 10	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
120 ± 20	GOPAL	77	DPWA	KN multichannel
$230 \begin{array}{c} +165 \\ -60 \end{array}$	VANHORN	75	DPWA	$K^- \rho \rightarrow \Lambda \pi^0$
250 ±110	KANE	74	DPWA	$K^- \rho \rightarrow \Sigma \pi$
• • • We do not use the following	data for averages	, fit	s, limits,	etc. • • •
202 or 217 80 ± 40 81 ± 10		75	IPWA	$\overline{K} N$ multichannel $\overline{K} N \to \Lambda \pi$ $K^- p \to \Lambda \pi^0$

#### Σ(1660) DECAY MODES

	Mode	Fraction $(\Gamma_i/\Gamma)$
$\overline{\Gamma_1}$	NK	10-30 %
$\Gamma_2$	$\Lambda\pi$	seen
Γ3	$\Sigma \pi$	seen

### Σ(1660) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on  $\varLambda$  and  $\varSigma$ Resonances.

				$\Gamma_1/\Gamma$
DOCUMENT ID		TECN	COMMENT	
GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
g data for average	s, fit	s, limits,	etc. • • •	
GOPAL				
² MARTIN	77	DPWA	$\overline{K}$ N multichanne	1
1660) → Λπ				- ₂ ) ¹ ⁄2/Γ
	GOPAL ALSTON g data for average GOPAL 2 MARTIN	GOPAL 80 ALSTON 78 g data for averages, fit: GOPAL 77 2 MARTIN 77	GOPAL 80 DPWA ALSTON 78 DPWA g data for averages, fits, limits, GOPAL 77 DPWA 2 MARTIN 77 DPWA	GOPAL 80 DPWA $\overline{K}N \to \overline{K}N$ ALSTON 78 DPWA $\overline{K}N \to \overline{K}N$ g data for averages, fits, limits, etc. • • •  GOPAL 77 DPWA See GOPAL 80 2 MARTIN 77 DPWA $\overline{K}N$ multichanne  1660) $\to \Lambda\pi$ ( $\Gamma_1\Gamma_1$

(	$ f f$ )"/ $ total$ in N K $\rightarrow \sum (1)$	$660) \rightarrow \Lambda \pi$			(1112)
ī	ALUE	DOCUMENT ID		TECN	COMMENT
	< 0.04	GOPAL	77	DPWA	$\overline{K}N$ multichannel
	$0.12^{+0.12}_{-0.04}$	VANHORN	75	DPWA	$K^- \rho \rightarrow \Lambda \pi^0$
•	• We do not use the following	data for averages	, fits	, limits,	etc. • • •
		² MARTIN	77	DPWA	$\overline{K}N$ multichannel
	$-0.04 \pm 0.02$	³ BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda \pi$
	$+0.16\pm0.01$	4 PONTE	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \overline{K}$	. 5(1660) . 5-			(Γ₁Γ₃) ¹ /2/Γ
VALUE	$ \longrightarrow  2(1000) \rightarrow 2\pi $ $  \longrightarrow   DOCUMENT II $		TECN	(1 1 3)/1
$-0.13 \pm 0.04$	¹ KOISO	85	DPWA	$K^- p \rightarrow \Sigma \pi$
$-0.16\pm0.03$	GOPAL	77	DPWA	K N multichannel
$-0.11 \pm 0.01$	KANE	74	DPWA	$K^- \rho \rightarrow \Sigma \pi$
• • • We do not use the f	following data for avera	ges, fits	, limits,	etc. • • •
-0.34 or -0.37	² MARTIN	77	DPWA	K N multichannel
not seen	HEPP	76B	DPWA	$K^- N \rightarrow \Sigma \pi$

#### Σ(1660) FOOTNOTES

- 1  The evidence of KOISO 85 is weak.  2  The two MARTIN 77 values are from a T-matrix pole and from a Breit-Wigner fit.  3  From solution 1 of BAILLON 75; not present in solution 2.
- ⁴ From solution 2 of PONTE 75; not present in solution 1.

#### Σ(1660) REFERENCES

KOISO PDG GOPAL	85 82 80	NP A433 619 PL 111B Toronto Conf. 159	+Sai, Yamamoto, Kofler Roos, Porter, Aguilar-Benitez+	(TOKY, MASA) (HELS, CIT, CERN) (RHEL) IJP
ALSTON	78	PR D18 182	Alston-Garnjost, Kenney+	(LBL, MTHO, CERN) IJP
Also	77	PRL 38 1007	Alston-Garnjost, Kenney+	(LBL, MTHO, CERN) IJP
GOPAL	77	NP B119 362	+Ross, VanHorn, McPherson+	(LOIC, RHEL) IJP
MARTIN	77	NP B127 349	+Pidcock, Moorhouse	(LOUC, GLAS) IJP
Also	77B	NP B126 266	Martin, Pidcock	(LOUC)
Also	77C	NP B126 285	Martin, Pidcock	(LOUC) IJP
HEPP	76B	PL 65B 487	+Braun, Grimm, Strobele+	(CERN, HEIDH, MPIM) IJP
BAILLON	75	NP B94 39	+Litchfield	(CERN, RHEL) IJP
PONTE	75	PR D12 2597	+Hertzbach, Button-Shafer+	(MASA, TENN, UCR) IJP
VANHORN	75	NP B87 145		(LBL) IJP
Also	75B	NP B87 157	VanHorn	(LBL) IJP
KANE	74	LBL-2452		(LBL) IJP

### THE $\Sigma(1670)$ REGION

**Production experiments:** The measured  $\Sigma \pi / \Sigma \pi \pi$ branching ratio for the  $\Sigma(1670)$  produced in the reaction  $K^-p \to \pi^- \Sigma (1670)^+$  is strongly dependent on momentum transfer. This was first discovered by EBERHARD 69, who suggested that there exist two  $\Sigma$  resonances with the same mass and quantum numbers: one with a large  $\Sigma\pi\pi$  (mainly  $\Lambda(1405)\pi$ ) branching fraction produced peripherally, and the other with a large  $\Sigma\pi$  branching fraction produced at larger angles. The experimental results have been confirmed by AGUILAR-BENITEZ 70, ASPELL 74, ESTES 74, and TIMMERMANS 76. If, in fact, there are two resonances, the most likely quantum numbers for both the  $\Sigma\pi$  and the  $\Lambda(1405)\pi$  states are  $D_{13}$ . There is also possibly a third  $\Sigma$  in this region, the  $\Sigma(1690)$  in the Listings, the main evidence for which is a large  $\Lambda\pi/\Sigma\pi$  branching ratio. These topics have been reviewed by EBERHARD 73 and by MILLER 70.

Formation experiments: Two states are also observed near this mass in formation experiments. One of these, the  $\Sigma(1670)D_{13}$ , has the same quantum numbers as those observed in production and has a large  $\Sigma \pi / \Sigma \pi \pi$  branching ratio; it may well be the  $\Sigma(1670)$  produced at larger angles (see TIM-MERMANS 76). The other state, the  $\Sigma(1660)P_{11}$ , has different quantum numbers, its  $\Sigma \pi / \Sigma \pi \pi$  branching ratio is unknown, and its relation to the produced  $\Sigma(1670)$  states is obscure.

 $\Sigma(1670) D_{13}$ 

$$I(J^P) = 1(\frac{3}{2}^-)$$
 Status: ***

For most results published before 1974 (they are now obsolete), see our 1982 edition Physics Letters **111B** (1982).

Results from production experiments are listed separately in the next

#### Σ(1670) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1665 to 1685 (≈ 1670) OUR EST	IMATE			
1665.1 ± 4.1	KOISO	85	DPWA	$K^- \rho \rightarrow \Sigma \pi$
1682 ± 5	GOPAL	80		$\overline{K}N \rightarrow \overline{K}N$
1679 ±10	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
1670 ± 5	GOPAL	77	DPWA	KN multichannel
1670 ± 6	HEPP			$K^- N \rightarrow \Sigma \pi$
1685 ±20	BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda\pi$
1659 ⁺¹² _{- 5}	VANHORN	75	DPWA	$K^- \rho \rightarrow \Lambda \pi^0$
1670 ± 2	KANE	74	DPWA	$K^- p \rightarrow \Sigma \pi$
• • We do not use the following	data for averages	, fits	, limits,	etc. • • •
1667 or 1668	¹ MARTIN	77	DPWA	KN multichannel
1650	DEBELLEFON	76	IPWA	$K^- p \rightarrow \Lambda \pi^0$
1671 ± 3	PONTE	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$ (sol. 1)
1655 ± 2	PONTE	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$ (sol. 2)

### Σ(1670) WIDTH

VAL	UE (MeV)	DOCUMENT ID		TECN	COMMENT
40	to 80 (≈ 60) OUR ESTIMATE				
65.0	0± 7.3	KOISO	85		$K^- \rho \rightarrow \Sigma \pi$
79	±10	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
56	±20	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
50	± 5	GOPAL	77	DPWA	$\overline{K}N$ multichannel
56	± 3	HEPP	76B	DPWA	$K^- N \rightarrow \Sigma \pi$
85	±25	BAILLON			$\overline{K}N \rightarrow \Lambda\pi$
32	±11	VANHORN	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$
79	± 6	KANE	74	DPWA	$K^- p \rightarrow \Sigma \pi$
• •	We do not use the following a	data for averages	, fits	, limits,	etc. • • •
46	or 46	MARTIN	77	DPWA	KN multichannel
80		DEBELLEFON	76	IPWA	$K^- \rho \rightarrow \Lambda \pi^0$
44	±11	PONTE	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$ (sol. 1)
76	± 5	PONTE	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$ (sol. 2)

### $\Sigma$ (1670) DECAY MODES

	Mode	Fraction $(\Gamma_i/\Gamma)$	
$\overline{\Gamma_1}$	NK	7–13 %	
$\Gamma_2$	$\Lambda\pi$	5-15 %	
$\Gamma_3$	$\Sigma \pi$	30-60 %	
$\Gamma_4$	$\Lambda\pi\pi$		
$\Gamma_5$	$\Sigma \pi \pi$		
$\Gamma_6$	$\Sigma(1385)\pi$		
$\Gamma_7$	$\Sigma(1385)\pi$ , S-wave		
Γ8	$\Lambda(1405)\pi$		
Γ9	$\Lambda(1520)\pi$		

The above branching fractions are our estimates, not fits or averages.

### Σ(1670) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on  $\varLambda$  and  $\varSigma$ 

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$				Γ ₁ /Ι	-
VALUE	DOCUMENT ID		TECN	COMMENT	
0.07 to 0.13 OUR ESTIM.	ATE				_
$0.10 \pm 0.03$	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
$0.11 \pm 0.03$	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
• • • We do not use the	following data for averages	, fits	, limits,	etc. • • •	
$0.08 \pm 0.03$	GOPAL	77	DPWA	See GOPAL 80	
0.07 or 0.07		77	DPWA	KN multichannel	
0.07 or 0.07 $(\Gamma_I \Gamma_I)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K}$ VALUE		77	DPWA	$\overline{K}N$ multichannel $(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma_2$	-
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K}$	$\rightarrow \Sigma(1670) \rightarrow \Lambda\pi$	77	TECN	(Γ ₁ Γ ₂ ) ^{1/2} /Γ	-
(「「「「」) ^{1/2} /「 _{total} in NK	$\rightarrow \Sigma(1670) \rightarrow \Lambda \pi$ DOCUMENT ID		TECN_	(Γ ₁ Γ ₂ ) ^{1/2} /Γ	_
$(\Gamma_I \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K}$ $0.17 \pm 0.03$	$ \begin{array}{c}                                     $	78	<i>TECN</i> DPWA DPWA	$\frac{(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma_2}{K^- n \to \Lambda \pi^-}$	-
(Γ _I Γ _f ) ^{1/2} /Γ _{total} in N K VALUE  0.17 ±0.03  0.13 ±0.02  +0.10 ±0.02		78 78	TECN DPWA DPWA DPWA	$\frac{\left(\Gamma_{1}\Gamma_{2}\right)^{\frac{1}{2}}/\Gamma_{2}}{K^{-}n \rightarrow \Lambda\pi^{-}}$ $K^{-}n \rightarrow \Lambda\pi^{-}$	
$(\Gamma_{I}\Gamma_{I})^{\frac{1}{2}}/\Gamma_{\text{total}}$ in $N\overline{K}$ VALUE  0.17 ±0.03  0.13 ±0.02  +0.10 ±0.02  +0.06 ±0.02		78 78 77	TECN DPWA DPWA DPWA IPWA	$\frac{(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma_2}{K^- n \to \Lambda \pi^-}$ $\frac{K^- n \to \Lambda \pi^-}{K^- N \text{ multichannel}}$	
(Γ _I Γ _f ) ^{1/2} /Γ _{total} in N κ VALUE 0.17 ±0.03 0.13 ±0.02		78 78 77 75	TECN DPWA DPWA DPWA IPWA DPWA	$\frac{\left(\Gamma_{1}\Gamma_{2}\right)^{\frac{1}{2}}/\Gamma}{K^{-}n \rightarrow \Lambda\pi^{-}}$ $\frac{K^{-}n \rightarrow \Lambda\pi^{-}}{K}N \text{ multichannel}$ $\frac{K}{K}N \rightarrow \Lambda\pi$	

+0.08 or +0.08	wing data for averag  1 MARTIN	77	DPWA	$\overline{K}N$ multio	
+0.05	DEBELLEFO	N 76	IPWA	$K^-p \rightarrow I$	$1\pi^{0}$
0.08 ±0.01	PONTE	75	DPWA	$K^-p \rightarrow r$	$4\pi^{0}$ (sol. 1)
0.17 ±0.01	PONTE	75	DPWA	$K^-p \rightarrow K$	$4\pi^{0}$ (sol. 2)
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to 1$	<b>Σ</b> (1670) → <b>Σ</b> π				(Γ ₁ Γ ₃ ) ^{1/2} /
VALUE	DOCUMENT ID				
$+0.20\pm0.02$	KOISO			$K^- p \rightarrow .$	
$+0.21\pm0.02$	GOPAL			KN multic	
$+0.20\pm0.01$	HEPP			$K^-N \rightarrow$	
+0.21±0.03	KANE			$K^-p \rightarrow .$	Σπ
• • We do not use the following the fol					
+0.18 or +0.17	¹ MARTIN	77	DPWA	KN multic	hannel
$\Gamma(\Lambda\pi\pi)/\Gamma_{\text{total}}$					Γ4/
VALUE	DOCUMENT ID				
• • We do not use the following the fol	wing data for averag	es, fit	s, limits,	etc. • • •	
< 0.11	ARMENTER	<b>DS68</b> E	нвс	$K^-p$ ( $\Gamma_1$	:0.09)
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to 1$	Σ(1670) → Σ(13	85)~	Cwa	<b>.</b>	(Γ ₁ Γ ₇ ) ^{1/2} /
VALUE	DOCUMENT ID				(1117) /
$+0.11\pm0.03$	PREVOST			$K^- N \rightarrow$	$\Sigma$ (1385) $\pi$
• • We do not use the following the fol					
$0.17 \pm 0.02$	³ SIMS	68		$K^-N \rightarrow$	Λππ
F/ <del>F</del>					_
Γ(Σππ)/Γ _{total}	DOCUMENT ID		TECN	COMMENT	Γ ₅ /
• • We do not use the follow					
<0.14	⁴ ARMENTER				d (F. =0.09
	7			<i>p</i> ,	
$\Gamma(\Lambda(1405)\pi)/\Gamma_{\text{total}}$					Г8/
VALUE	DOCUMENT ID				
• • We do not use the follow	wing data for averag	es, fit	s, limits,	etc. • • •	
< 0.06	ARMENTER	<b>)\$68</b> E	HBC	K-p, K-	$d (\Gamma_1 = 0.09)$
$\Gamma_I \Gamma_f / \Gamma_{\text{total}}^2$ in $N\overline{K} \to \Sigma (10)$	670) → A(1405) 7	г			Γ ₁ Γ ₈ /Ι
			TECN	COMMENT	
VALUE	DOCUMENT ID				
	DOCUMENT ID  5 BRUCKER		DBC	$K^-N \rightarrow$	Σππ
VALUE	⁵ BRUCKER	70	DBC		Σππ
0.007±0.002	⁵ BRUCKER wing data for averag	70 es, fits	DBC	etc. • • •	Σππ 0.82 GeV/c
0.007±0.002  ■ ● ● We do not use the follow <0.03	⁵ BRUCKER wing data for averag BERLEY	70 es, fits	DBC s, limits,	etc. • • •	0.82 GeV/ <i>c</i>
VALUE 0.007±0.002 • • • We do not use the follow <0.03 Γ(Λ(1405)π)/Γ(Σ(1385)π	⁵ BRUCKER wing data for averag BERLEY π)	70 es, fits 69	DBC s, limits, HBC	etc. • • • K ⁻ p 0.6-4	0.82 GeV/ <i>c</i>
0.007±0.002  ■ ● ● We do not use the follow <0.03	⁵ BRUCKER wing data for averag BERLEY	70 es, fits 69	DBC s, limits, HBC	etc. • • • K ⁻ p 0.6-4	0.82 GeV/ <i>c</i> Γ ₈ /Γ
VALUE 0.007±0.002 • • • We do not use the follow <0.03 Γ(Λ(1405)π)/Γ(Σ(1385)π ΛΑLUE 0.23±0.08	⁵ BRUCKER wing data for averag BERLEY T) <u>DOCUMENT ID</u> BRUCKER	70 es, fits 69 70	DBC s, limits, HBC <u>TECN</u>	etc. • • • • <i>K</i> – <i>p</i> 0.6–4	Σππ
VALUE $0.007 \pm 0.002$ • • • We do not use the follow $< 0.03$ $\Gamma(\Lambda(1405)\pi)/\Gamma(\Sigma(1385)\pi)$ VALUE	5 BRUCKER wing data for average BERLEY <b>r</b> ) $^{DOCUMENT\ ID}$ BRUCKER <b>Σ(1670)</b> → Λ(152)	70 es, fits 69 70 70 <b>20)</b> π	DBC s, limits, HBC <u>TECN</u> DBC	etc. • • • • $K^- p \ 0.6 \rightarrow 0$	Σππ
VALUE 0.007±0.002 • • • We do not use the follow <0.03 Γ(Λ(1405)π)/Γ(Σ(1385)π ΛΑLUE 0.23±0.08	5 BRUCKER wing data for averag BERLEY  π)  DOCUMENT ID BRUCKER  Σ(1670) → Λ(152 DOCUMENT ID	70 es, fits 69 70 <b>20)</b> π	DBC s, limits, HBC TECN DBC	etc. • • • $K^- p$ 0.6- $K^- p$	Σππ (Γ ₁ Γ ₉ ) ^{1/2} /
WALUE $0.007 \pm 0.002$ • • • We do not use the follow $<0.03$ $\Gamma(\Lambda(1405)\pi)/\Gamma(\Sigma(1385)\pi)$ $VALUE$ $0.23\pm 0.08$ $(\Gamma_{\Gamma}\Gamma_{\Gamma})^{1/2}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma$	⁵ BRUCKER wing data for averag BERLEY T) <u>DOCUMENT ID</u> BRUCKER	70 es, fits 69 70 <b>20)</b> π	DBC s, limits, HBC TECN DBC	etc. • • • $K^- p$ 0.6- $K^- p$	Σππ (Γ ₁ Γ ₉ ) ^{1/2} /

- Assuming the  $\Lambda(1405)\pi$  cross-section bump is due only to  $3/2^-$  resonance.
- ⁶ The CAMERON 77 upper limit on F-wave decay is 0.03.

### Σ(1670) REFERENCES

KOISO	85	NP A433 619		+Sai, Yamamoto, Kofler	(TOKY, MASA)
PDG	82	PL 111B		Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
GOPAL	80	Toronto Conf.	159		(RHEL) IJP
ALSTON	78	PR D18 182		Alston-Garnjost, Kenney+	(LBL, MTHO, CERN) IJP
Also	77	PRL 38 1007		Alston-Garnjost, Kenney+	(LBL, MTHO, CERN) IJP
MORRIS	78	PR D17 55		+Albright, Colleraine, Kimel, Lannu	tti (FSU) IJP
CAMERON	77	NP B131 399		+Franek, Gopal, Kalmus, McPherso	n+ (RHEL, LOIC) IJP
GOPAL	77	NP B119 362		+Ross, VanHorn, McPherson+	(LOIC, RHEL) IJP
MARTIN	77	NP B127 349		+Pidcock, Moorhouse	(LOUC, GLAS) IJP
Also	77B	NP B126 266		Martin, Pidcock	(LOUC)
Also	77C	NP B126 285		Martin, Pidcock	(LOUC) IJP
DEBELLEFON	76	NP B109 129		De Bellefon, Berthon	(CDEF) IJP
HEPP	76B	PL 65B 487		+Braun, Grimm, Strobele+	(CERN, HEIDH, MPIM) IJP
BAILLON	75	NP B94 39		+Litchfield	(CERN, RHEL) IJP
PONTE	75	PR D12 2597		+Hertzbach, Button-Shafer+	(MASA, TENN, UCR) IJP
VANHORN	75	NP B87 145			(LBL) IJP
Also	75B	NP B87 157		VanHorn	(LBL) IJP
DEVENISH	74B	NP B81 330		+Froggatt, Martin	(DESY, NORD, LÒUC)
KANE	74	LBL-2452			(LBL) IJP
PREVOST	74	NP B69 246		+Barloutaud+	(SACL, CERN, HEID)
BRUCKER	70	Duke Conf. 155	5	+Harrison, Sims, Albright, Chandler	+ (FSU) I
BERLEY	69	PL 30B 430		+Hart, Rahm, Willis, Yamamoto	(BNL)
ARMENTEROS	68E	PL 28B 521		+Baillon+	(CERN, HEID, ŠACL) I
SIMS	68	PRL 21 1413		+Albright, Bartley, Meer+	(FSU, TUFTS, BRAN)

## Baryon Particle Listings $\Sigma$ (1670) Bumps

## $\Sigma(1670)$ Bumps

 $I(J^P) = 1(??)$ 

OMITTED FROM SUMMARY TABLE

Formation experiments are listed separately in the preceding entry.

Probably there are two states at the same mass with the same quantum numbers, one decaying to  $\Sigma\pi$  and  $\Lambda\pi$ , the other to  $\Lambda(1405)\pi$ . See the note in front of the preceding entry.

## $\Sigma$ (1670) MASS (PRODUCTION EXPERIMENTS)

VALUE (MeV) ≈ 1670 OUR ESTIMATE	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
1670 ± 4	1	CARROLL	76	DPWA		Isospin-1 total $\sigma$
$1675 \pm 10$	2	HEPP	76	DBC		K-N 1.6-1.75 GeV/c
1665 ± 1		APSELL	74	нвс		K− p 2.87 GeV/c
1688 $\pm$ 2 or 1683 $\pm$ 5	1200	BERTHON	74	HBC	0	Quasi-2-body $\sigma$
1670± 6		AGUILAR	70B	HBC		$K^- p \rightarrow \Sigma \pi \pi$ 4 GeV
$1668 \pm 10$		AGUILAR	70B	HBC		$K^- \rho \rightarrow \Sigma 3\pi$ 4 GeV
$1660 \pm 10$		ALVAREZ	63	HBC	+	K [−] p 1.51 GeV/c
• • • We do not use the	following da	ta for averages,	fits, I	imits, et	c. • •	•
$1668\pm10$	150 3	FERRERSORIA	81	OMEG	-	$\pi^- p$ 9,12 GeV/c
1655 to 1677		TIMMERMANS	376	HBC	+	K- p 4.2 GeV/c
1665± 5		BUGG	68	CNTR		$K^-p$ , d total $\sigma$
1661± 9	70	PRIMER	68	нвс	+	See BARNES 69E
1685		ALEXANDER	<b>62</b> C	нвс	-0	$\pi^- p$ 2–2.2 GeV/c

## $\Sigma$ (1670) WIDTH (PRODUCTION EXPERIMENTS)

VALU	E (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
67.0	0± 2.4		APSELL	74	нвс		K [−] p 2.87 GeV/c
110	$\pm12$		AGUILAR	70B	нвс		$\begin{array}{c} K^-  p \to & \Sigma  \pi  \pi  4 \\ GeV \end{array}$
135	+40 -30		AGUILAR	70B	HBC		$K^- p \rightarrow \Sigma 3\pi 4$ GeV
40	$\pm 10$		ALVAREZ	63	HBC	+	
• •	<ul> <li>We do not use the</li> </ul>	following	data for averages	, fits	, limits,	etc. •	• •
90	±20	150	3 FERRERSORIA	81	OMEG	-	$\pi^- p$ 9,12 GeV/c
52			¹ CARROLL	76	DPWA		Isospin-1 total $\sigma$
48	to 63		TIMMERMANS	576	HBC	+	$K^- p$ 4.2 GeV/ $c$
30	$\pm 15$		BUGG	68	CNTR		
60	$\pm 20$	70	PRIMER	68	HBC	+	See BARNES 69E
45			ALEXANDER	62C	HBC	-0	

## $\Sigma$ (1670) DECAY MODES (PRODUCTION EXPERIMENTS)

	Mode
Γ ₁	NK
$\Gamma_2$	$\Lambda\pi$
Γ3	$\Sigma \pi$
$\Gamma_4$	$\Lambda\pi\pi$
$\Gamma_5$	$\Sigma \pi \pi$
$\Gamma_6$	$\Sigma(1385)\pi$
$\Gamma_7$	$\Lambda(1405)\pi$

## $\Sigma$ (1670) BRANCHING RATIOS (PRODUCTION EXPERIMENTS)

$\Gamma(N\overline{K})/\Gamma(\Sigma\pi)$						$\Gamma_1/\Gamma_3$
VALUE	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
< 0.03		TIMMERMAN	IS76	нвс	+	K [−] p 4.2 GeV/c
< 0.10		BERTHON	74	HBC	0	Quasi-2-body $\sigma$
< 0.2		AGUILAR	70B	HBC		
<0.26		BARNES	69E	нвс	+	K− p 3.9–5 GeV/c
0.025		BUGG	68	CNTR	0	Assuming $J = 3/2$
<0.24	0	PRIMER	68	HBC	+	K [−] p 4.6-5 GeV/c
< 0.6		LONDON	66	HBC.	+	K [−] p 2.25 GeV/c
< 0.19	0	ALVAREZ	63	нвс	+	K ⁻ p 1.15 GeV/c
> 0.5 ± 0.25		SMITH	63	HBC	-0	

F/4-)/F/F-)		<u></u>
Γ(Λπ)/Γ(Σπ) VALUE <u>EVTS</u>	DOCUMENT ID TECN CHG COMMENT	<u>-</u> /Γ:
$0.76 \pm 0.09$	ESTES 74 HBC 0 $K^-p$ 2.1,2.6 $GeV/c$	
$0.45 \pm 0.15$	BARNES 69E HBC + $K^{}p$ 3.9–5 GeV/c	
$0.15 \pm 0.07$ $0.11 \pm 0.06$ 33	HUWE 69 HBC + BUTTON 68 HBC + $K^- p$ 1.7 GeV	//c
• • We do not use the follow	ing data for averages, fits, limits, etc. • • •	
$\leq 0.45 \pm 0.07$ $0.55 \pm 0.11$	TIMMERMANS76 HBC + K ⁻ p 4.2 GeV BERTHON 74 HBC 0 Quasi-2-body	
0 0	PRIMER 68 HBC + See BARNES	
<0.6 1.2 130	LONDON 66 HBC + $K^-p$ 2.25 Ge ALVAREZ 63 HBC + $K^-p$ 1.15 Ge	
1.2	SMITH 63 HBC -0	<b>v</b> /c
$\Gamma(\Lambda\pi\pi)/\Gamma(\Sigma\pi)$		ι/Γ:
<u>VALUE EVTS</u> <0.6	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	V/c
0.56 90	ALVAREZ 63 HBC + $K^-p$ 1.15 Ge	
0.17	SMITH 63 HBC -0	
$\Gamma(\Sigma\pi\pi)/\Gamma(\Sigma\pi)$		·/F:
VALUE EVTS argest at small angles	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	
• • We do not use the follow	GeV/c ing data for averages, fits, limits, etc. • •	
<0.2	² HEPP 76 DBC K ⁻ N 1.6-1.7	5
0.56 180	$\frac{{\sf GeV}/c}{{\sf ALVAREZ}}$ 63 HBC + $K^-p$ 1.15 Ge	V/c
$\Gamma(\Lambda(1405)\pi)/\Gamma(\Sigma\pi)$	Γ ₇	<b>,/Γ</b> ;
/ALUE EVTS	DOCUMENT ID TECN CHG COMMENT	
1.8 ±0.3 to 0.02 ± 0.07	3,4 TIMMERMANS76 HBC + $K^-p$ 4.2 GeV ESTES 74 HBC $\pm$ $K^-p$ 2.1,2.6	'/c
argest at small angles	GeV/c	/.
$3.0 \pm 1.6$ 50 • • We do not use the follow	LONDON 66 HBC + $K^-p$ 2.25 Ge ing data for averages, fits, limits, etc. • •	V/C
0.58±0.20 17	PRIMER 68 HBC + See BARNES	69E
$\Gamma(\Sigma\pi)/\Gamma(\Sigma\pi\pi)$	DOCUMENT ID TECN CHG COMMENT	3/F
varies with prod. angle	⁵ APSELL 74 HBC + K ⁻ p 2.87 Ge	V/0
1.39±0.16	BERTHON 74 HBC 0 Quasi-2-body	
2.5 to 0.24 <0.4	4 EBERHARD 69 HBC $K^-p$ 2.6 GeV BIRMINGHAM 66 HBC $+$ $K^-p$ 3.5 GeV	
$0.30 \pm 0.15$	LONDON 66 HBC + $K^-p$ 2.25 Ge	
$\Gamma(\Lambda(1405)\pi)/\Gamma(\Sigma\pi\pi)$	-	/Г
VALUE 0.97 ± 0.08	TIMMERMANS76 HBC  TOUCHMENT ID  TECN CHG COMMENT    //c	
1.00±0.02	APSELL 74 HBC K-p 2.87 Ge	,
$0.90^{+0.10}_{-0.16}$	EBERHARD 65 HBC $+$ $K^-p$ 2.45 Ge	V/
$\Gamma(\Lambda(1405)\pi)/\Gamma(\Sigma(1385)\pi)$		,/r
VALUE	DOCUMENT ID TECN CHG COMMENT  EBERHARD 65 HBC + K ⁻ p 2.45 Ge	
<0.8		
Γ <b>(Λππ)/Γ(Σππ)</b> VALUE	DOCUMENT ID TECN CHG COMMENT	ş/Г 
0.35±0.2	BIRMINGHAM 66 HBC + K-p 3.5 GeV	//c
$\Gamma(\Lambda\pi)/\Gamma(\Sigma\pi\pi)$	Г2	2/٢
VALUE	DOCUMENT ID TECN CHG COMMENT	
<0.2	BIRMINGHAM 66 HBC + K ⁻ p 3.5 GeV	
$\Gamma(\Lambda\pi)/[\Gamma(\Lambda\pi)+\Gamma(\Sigma\pi)]$	Γ ₂ /(Γ ₂ +	-Γ3
<0.6	AGUILAR 708 HBC	
	DOCUMENT ID TECN COMMENT	5/F
	DOCUMENT ID TECH COMMENT	
VALUE	TIMMERMANS76 HBC $K^-p$ 4.2 GeV/ $c$	
<u>VALUE</u> ≤ 0.21±0.05		
<u>VALUE</u> ≤ 0.21 ± 0.05 <b>Σ(16</b>	TIMMERMANS76 HBC K ⁻ p 4.2 GeV/c	
(PRO	TIMMERMANS76 HBC K-p 4.2 GeV/c  570) QUANTUM NUMBERS DUCTION EXPERIMENTS)  DOCUMENT ID TECN CHG COMMENT	
<u>VALUE</u> ≤ 0.21±0.05 <b>Σ(16</b> (PRO	TIMMERMANS76 HBC K-p 4.2 GeV/c  570) QUANTUM NUMBERS DUCTION EXPERIMENTS)	

#### Σ(1670) FOOTNOTES

- ¹ Total cross-section bump with (J+1/2)  $\Gamma_{el}$  /  $\Gamma_{total}$  = 0.23.
- ² Enhancements in  $\Sigma \pi$  and  $\Sigma \pi \pi$  cross sections. ³ Backward production in the  $\Lambda \pi^- K^+$  final state.
- Depending on production angle.

  A Depending on production angle.

  APSELL 74, ESTES 74, and TIMMERMANS 76 find strong branching ratio dependence on production angle, as in earlier production experiments.

## Σ(1670) REFERENCES (PRODUCTION EXPERIMENTS)

FERRERSORIA CARROLL HEPP TIMMERMANS APSELL BERTHON ESTES	76 76	NP B178 373 PRL 37 806 NP B115 82 NP B112 77 PR D10 1419 NC 21A 146 Thesis LBL-3827	+Treille, Rivet, Volte+ (CERN, CDEF, +Chiang, Kycia, Li, Mazur, Michael+ Haraun, Grimm, Stroebel+ +Engelen+ Hord, Gourevitch+ +Tristram+ (RNJM, CERN, MRAN, UMD, S' (CDEF, RHEL,	(BNL) I HEID, MPIM) I AMST, OXF) JP YRA, TUFTS) I
AGUILAR	70B	PRL 25 58	Aguilar-Benitez, Barnes, Bassano+	(BNL, SYRA)
BARNES	69E	BNL 13823	+Chung, Eisner, Flaminio+	(BNL, SYRA)
EBERHARD	69	PRL 22 200	+Friedman, Pripstein, Ross	(LRL)
HUWE	69	PR 180 1824		(LRL)
BUGG	68	PR 168 1466	+Gilmore, Knight+ (RHEL,	BIRM, CAVE) I
BUTTON	68	PRL 21 1123	Button-Shafer	(MASA, LRL) JP
PRIMER	68	PRL 20 610	+Goldberg, Jaeger, Barnes, Dornan+	(SYRA, BNL)
EBERHARD	67	PR 163 1446	+Pripstein, Shively, Kruse, Swanson	(LRL, ILL) IJP
BIRMINGHAM	66	PR 152 1148	(BIRM, GLAS, LOIC,	OXF, RHEL)
LONDON	66	PR 143 1034	+Rau, Goldberg, Lichtman+	(BNL, SYRA) IJ
EBERHARD	65	PRL 14 466	+Shively, Ross, Siegal, Ficenec+	(LRL, ILL) I
LEVEQUE	65	PL 18 69	<ul> <li>+ (SACL, EPOL, GLAS, LOIC,</li> </ul>	
ALVAREZ	63	PRL 10 184	+Alston, Ferro-Luzzi, Huwe+	(LRL) I
SMITH	63	Athens Conf. 67		(LRL)
ALEXANDER	62C	CERN Conf. 320	+Jacobs, Kalbfleisch, Miller+	(LRL) I

## $\Sigma$ (1690) Bumps

 $I(J^P) = 1(??)$  Status: **

#### OMITTED FROM SUMMARY TABLE

See the note preceding the  $\Sigma(1670)$  Listings. Seen in production experiments only, mainly in  $\Lambda \pi$ .

## $\Sigma$ (1690) MASS (PRODUCTION EXPERIMENTS)

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
≈ 1690 OUR ESTI	MATE					
$1698\pm20$	70	¹ GODDARD	79	HBC	+	$\pi^{+} p$ 10.3 GeV/c
$1707\pm20$	40	² GODDARD	79	HBC	+	$\pi^{+} p$ 10.3 GeV/c
$\textbf{1698} \pm \textbf{20}$	15	ADERHOLZ	69	HBC	+	$\pi^+ p$ 8 GeV/ $c$
$1682\pm\ 2$	46	BLUMENFELD	69	HBC	+	$\kappa_{IP}^{0}$
$1700\pm20$		MOTT	69	HBC	+	K ⁻ ρ 5.5 GeV/c
1694±24	60	³ PRIMER	68	нвс	+	K [−] p 4.6–5 GeV/c
1700 ± 6		⁴ SIMS	68	HBC	~	$K^- N \rightarrow \Lambda \pi \pi$
$1715\pm12$	30	COLLEY	67	нвс	+	$K^- p$ 6 GeV/ $c$

#### Σ(1690) WIDTH (PRODUCTION EXPERIMENTS)

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
240± 60	70	¹ GODDARD	79	нвс	+	$\pi^{+} p \ 10.3 \ \text{GeV}/c$
$130 + 100 \\ - 60$	40	² GODDARD	79	нвс	+	$\pi^+  ho$ 10.3 GeV/c
$142 \pm 40$	15	ADERHOLZ	69	HBC	+	$\pi^+ \rho$ 8 GeV/ $c$
$25\pm~10$	46	BLUMENFEL	D 69	HBC	+	$\kappa_{IP}^{0}$
130± 25		MOTT	69	нвс	+	$K^{-}$ p 5.5 GeV/c
105± 35	60	³ PRIMER	68	нвс	+	K [−] p 4.6–5 GeV/c
62± 14		⁴ SIMS	68	HBC		$K^- N \rightarrow \Lambda \pi \pi$
100± 35	30	COLLEY	67	HBC	+	$K^- p$ 6 GeV/ $c$

#### Σ(1690) DECAY MODES (PRODUCTION EXPERIMENTS)

	Mode
Γ ₁	NK
$\Gamma_2$	$\Lambda\pi$
$\Gamma_3$	$\Sigma\pi$
$\Gamma_4$	$\Sigma(1385)\pi$
Γ ₅	$\Lambda\pi\pi$ (including $\Sigma(1385)\pi$ )

#### Σ(1690) BRANCHING RATIOS (PRODUCTION EXPERIMENTS)

$\Gamma(N\overline{K})/\Gamma(\Lambda\pi)$						$\Gamma_1/\Gamma_2$
VALUE	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
small		GODDARD	79	HBC	+	$\pi^{+} p$ 10.2 GeV/c
< 0.2		MOTT	69	HBC	+	$K^{-} p$ 5.5 GeV/c
$0.4 \pm 0.25$	18	COLLEY	67	HBC	+	6/30 events

$\Gamma(\Sigma\pi)/\Gamma(\Lambda\pi)$						Γ ₃ /Γ ₂
VALUE	CL%	DOCUMENT I	0	TECN	CHG	COMMENT
small		GODDARD	79	нвс	+	$\pi^{+}p$ 10.2 GeV/c
< 0.4	90	MOTT	69	нвс	+	$K^- p$ 5.5 GeV/c
$0.3 \pm 0.3$		COLLEY	67	HBC	+	4/30 events
$\Gamma(\Sigma(1385)\pi)/\Gamma($	$(\Lambda\pi)$					$\Gamma_4/\Gamma_2$
VALUE		DOCUMENT I	2	TECN	CHG	COMMENT
< 0.5		MOTT	69	нвс	+	K [−] p 5.5 GeV/c
$\Gamma(\Lambda\pi\pi(including))$	Σ(1385)π)	$)/\Gamma(\Lambda\pi)$				Γ ₅ /Γ ₂
VALUE		DOCUMENT IL		TECN	CHG	COMMENT
		D1 114 4E41EE	D.CO	нвс	+	31/15 events
$2.0 \pm 0.6$		BLUMENFE	レレッタ	1100	-	31/13 events
2.0±0.6 0.5±0.25		COLLEA	67	нвс	+	15/30 events
	$(\Lambda\pi\pi$ (include	COLLEY	67			
0.5±0.25	$(\Lambda\pi\pi$ (include)	COLLEY	67 ·))			15/30 events
^{0.5±0.25} <b>Γ(Σ(1385)π)</b> /Γ(	(Λππ (includ	COLLEY $oxed{ ing \Sigma (1385) \pi}$	67 ·))	нвс	+	15/30 events $\Gamma_4/\Gamma_5$

## (PRODUCTION EXPERIMENTS)

- ¹ From  $\pi^+ p \rightarrow (\Lambda \pi^+) K^+$ . J > 1/2 is not required by the data.
- ² From  $\pi^+ p \rightarrow (\Lambda \pi^+)(K\pi)^+$ . J > 1/2 is indicated, but large background precludes a
- definite conclusion.  3  See the  $\Sigma(1670)$  Listings. AGUILAR-BENITEZ 70B with three times the data of PRIMER 68 find no evidence for the  $\Sigma(1690)$ .
- ⁴ This analysis, which is difficult and requires several assumptions and shows no unambiguous  $\Sigma(1690)$  signal, suggests  $J^P=5/2^+$ . Such a state would lead all previously known  $Y^*$  trajectories.

#### Σ(1690) REFERENCES (PRODUCTION EXPERIMENTS)

GODDARD	79	PR D19 1350	+Key, Luste, Prentice, Yoon, Gordon+ (TNTO, E	3NL) IJ
AGUILAR	70B	PRL 25 58	Aguilar-Benitez, Barnes, Bassano+ (BNL, SY	(RA)
ADERHOLZ	69	NP B11 259	+Bartsch+ (AACH3, BERL, CERN, JAGL, WA	ARS) I
BLUMENFELD	69	PL 29B 58	+Kalbfleisch (E	BNL) I
MOTT	69	PR 177 1966	+Ammar, Davis, Kropac, Slate+ (NWES, A	ANL) I
Also	67	PRL 18 266	Derrick, Fields, Loken, Ammar+ (ANL, NV	vES) I
PRIMER	68	PRL 20 610	+Goldberg, Jaeger, Barnes, Dornan+ (SYRA, E	3NL) I
SIMS	68	PRL 21 1413	+Albright, Bartley, Meer+ (FSU, TUFTS, BR	(NA
COLLEY	67	PL 24B 489	(BIRM, GLAS, LOIC, MUNI, OXF, RE	

## $\Sigma(1750) S_{11}$

 $I(J^P) = 1(\frac{1}{2})$  Status: ***

For most results published before 1974 (they are now obsolete), see our 1982 edition Physics Letters **111B** (1982).

There is evidence for this state in many partial-wave analyses, but with wide variations in the mass, width, and couplings. The latest analyses indicated significant couplings to  $N\overline{K}$  and  $\Lambda\pi$ , as well as to  $\Sigma\eta$  whose threshold is at 1746 MeV (JONES 74).

### Σ(1750) MASS

VALUE (MeV)		DOCUMENT ID		TECN	COMMENT		
1730 to 1800 (≈ 1750) OUR ESTI	М	ATE					
$1756 \pm 10$		GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$		
$1770 \pm 10$		ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$		
$1770 \pm 15$		GOPAL	77	DPWA	KN multichannel		
1800 or 1813	1	MARTIN	77	DPWA	KN multichannel		
$1715 \pm 10$	2	CARROLL	76	DPWA	Isospin-1 total $\sigma$		
1730		DEBELLEFON	76	IPWA	$K^- \rho \rightarrow \Lambda \pi^0$		
$1780 \pm 30$		BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda\pi \text{ (sol. 1)}$		
$1700 \pm 30$		BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda\pi$ (sol. 2)		
$1697 + 20 \\ -10$		VANHORN	75	DPWA	$K^- \rho \rightarrow \Lambda \pi^0$		
1785±12		CHU	74		Fits $\sigma(K^- n \rightarrow \Sigma^- \eta)$		
1760 ± 5	3	JONES	74	HBC	Fits $\sigma(K^- p \rightarrow \Sigma^0 \eta)$		
$1739 \pm 10$		PREVOST	74	DPWA	$K^- N \rightarrow \Sigma(1385)\pi$		

### Σ(1750) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
60 to 160 (≈ 90) OUR ESTIMATE				
64±10	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
$161 \pm 20$	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
60±10	GOPAL	77	DPWA	KN multichannel

## Baryon Particle Listings $\Sigma(1750), \Sigma(1770)$

<ul> <li>We do not use the following</li> </ul>	ng data for average:	s, fits	s, limits,	etc. • • •
117 or 119	¹ MARTIN	77	DPWA	KN multichannel
10	² CARROLL	76	DPWA	Isospin-1 total $\sigma$
110	DEBELLEFON	76	IPWA	$K^- \rho \rightarrow \Lambda \pi^0$
140±30	BAILLON	75	<b>IPWA</b>	$\overline{K}N \rightarrow \Lambda\pi \text{ (sol. 1)}$
160±50	BAILLON	75	<b>IPWA</b>	$\overline{K}N \rightarrow \Lambda\pi$ (sol. 2)
$66^{+14}_{-12}$	VANHORN	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$
89±33	CHU	74	DBC	Fits $\sigma(K^- n \rightarrow \Sigma^- \eta)$
92± 7	³ JONES	74	HBC	Fits $\sigma(K^-p \rightarrow \Sigma^0\eta)$
108 ± 20	PREVOST	74	DPWA	$K^- N \rightarrow \Sigma(1385)\pi$

### Σ(1750) DECAY MODES

	Mode	Fraction $(\Gamma_i/\Gamma)$
Γ ₁	NK	10-40 %
$\Gamma_2$	$\Lambda\pi$	seen
$\Gamma_3$	$\Sigma \pi$	<8 %
$\Gamma_4$	$\Sigma \eta$	15-55 %
$\Gamma_5$	$\Sigma(1385)\pi$	
$\Gamma_6$	$\Lambda(1520)\pi$	

The above branching fractions are our estimates, not fits or averages.

#### Σ(1750) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on  $\varLambda$  and  $\varSigma$ 

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$				Γ ₁ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
0.1 to 0.4 OUR ESTIMATE				77
0.14±0.03	GOPAL			$\overline{K}N \to \overline{K}N$
0.33±0.05	ALSTON			$\overline{K}N \to \overline{K}N$
• • We do not use the follow				
$0.15 \pm 0.03$	GOPAL	77		See GOPAL 80
0.06 or 0.05	¹ MARTIN	77	DPWA	KN multichannel
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K} \to \Sigma$	Σ(1750) → Λπ			(Γ₁Γ₂) ^½ /Γ
VALUE	DOCUMENT ID			
$0.04 \pm 0.03$	GOPAL			$\overline{K}N$ multichannel
• • We do not use the follow			, limits,	etc. • • •
-0.10 or $-0.09$	¹ MARTIN	77	DPWA	K N multichannel
-0.12	DEBELLEFON	76	IPWA	$K^- p \rightarrow \Lambda \pi^0$
$-0.12 \pm 0.02$	BAILLON			$\overline{K}N \rightarrow \Lambda\pi \text{ (sol. 1)}$
$-0.13 \pm 0.03$	BAILLON	75	IPWA	$\overline{K}N \to \Lambda\pi \text{ (sol. 2)}$ $K^- p \to \Lambda\pi^0$
$-0.13 \pm 0.04$	VANHORN	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$
$-0.120 \pm 0.077$	DEVENISH	74B		Fixed-t dispersion rel.
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to X$ VALUE	$\Sigma(1750) \rightarrow \Sigma \pi$ DOCUMENT ID		TECN	(Γ ₁ Γ ₃ ) ^{1/2} /Γ
$-0.09 \pm 0.05$	GOPAL			K N multichannel
• • • We do not use the follow	ving data for averages	, fits	, limits,	etc. • • •
+0.06 or +0.06	¹ MARTIN	77	DPWA	$\overline{K}$ N multichannel
$0.13 \pm 0.02$	LANGBEIN	72	IPWA	$\overline{K}N$ multichannel
$0.13\pm0.02$ $\frac{\left(\Gamma_{I}\Gamma_{f}\right)^{\frac{1}{2}}/\Gamma_{total} \text{ in } N\overline{K} \rightarrow 2}{2MLUE}$ $0.23\pm0.01$ • • • We do not use the follow	$\Sigma(1750) \rightarrow \Sigma \eta$ DOCUMENT ID		TECN	(Γ ₁ Γ ₄ ) ^{1/2} /Γ
$0.23 \pm 0.01$	3 JONES	74	HBC	Fits $\sigma(K^-p \rightarrow \Sigma^0\eta)$
ullet $ullet$ We do not use the follow	ving data for averages	, fits	, limits,	etc. • • •
seen	CLINE	69	DBC	Threshold bump
$\frac{\left(\Gamma_{I}\Gamma_{f}\right)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \to J}{\frac{VALUE}{+0.18 \pm 0.15}}$	DOCUMENT ID		TECN	$\frac{(\Gamma_1\Gamma_5)^{\frac{1}{2}}/\Gamma}{COMMENT}$ $K^- N \to \Sigma(1385)_{\pi}$
10.10 ±0.10	I NEVOSI	14	DI WA	N W - Z(1303)π
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K} \to X$	$E(1750) \rightarrow \Lambda(1520)$ DOCUMENT ID			$(\Gamma_1\Gamma_6)^{\frac{1}{2}}/\Gamma$
• • We do not use the follow	ving data for averages	. fits	. limits.	etc. • • •
$\bullet$ $\bullet$ We do not use the follow $0.032 \pm 0.021$	ving data for averages CAMERON			etc. • • •  P-wave decay

### $\Sigma$ (1750) FOOTNOTES

- 1  The two MARTIN 77 values are from a T-matrix pole and from a Breit-Wigner fit.  2  A total cross-section bump with  $(J+1/2)\;\Gamma_{\text{el}}\;/\;\Gamma_{\text{total}}=0.30.$   3  An S-wave Breit-Wigner fit to the threshold cross section with no background and errors statistical only.

### Σ(1750) REFERENCES

PDG GOPAL	82 80	PL 111B Toronto Conf. 1	159	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN) (RHEL) IJP
ALSTON	78	PR D18 182		Alston-Garnjost, Kenney+	(LBL, MTHO, CERN) IJP
Also	77	PRL 38 1007		Alston-Garnjost, Kenney+	(LBL, MTHO, CERN) IJP
CAMERON	77	NP B131 399		+Franek, Gopal, Kalmus, McPherso	n+ (RHEL, LOIC) IJP
GOPAL	77	NP B119 362		+Ross, VanHorn, McPherson+	(LOIC, RHEL) IJP
MARTIN	77	NP B127 349		+Pidcock, Moorhouse	(LOUC, GLAS) IJP
Also	77B	NP B126 266		Martin, Pidcock	` (Louc)
Also	77C	NP B126 285		Martin, Pidcock	(LOUC) IJP
CARROLL	76	PRL 37 806		+Chiang, Kycia, Li, Mazur, Michae	el+ `(BNL)Î
DEBELLEFON	76	NP B109 129		De Bellefon, Berthon	(ČDEF) IJP
BAILLON	75	NP B94 39		+Litchfield	(CERN, RHEL) IJP
VANHORN	75	NP B87 145			(LBL) IJP
Also	75B	NP B87 157		VanHorn	(LBL) IJP
CHU	74	NC 20A 35		+Bartley+	(PLAT, TUFTS, BRAN) IJP
DEVENISH	74B	NP B81 330		+Froggatt, Martin	(DESY, NORD, LOUC)
JONES	74	NP B73 141			(CHIC) IJP
PREVOST	74	NP B69 246		+Barloutaud+	(SACL, CERN, HEID)
LANGBEIN	72	NP B47 477		+Wagner	(MPIM) IJP
CLINE	69	LNC 2 407		+Laumann, Mapp	(WISC)

## $\Sigma(1770) P_{11}$

 $I(J^P) = 1(\frac{1}{2}^+)$  Status: *

#### OMITTED FROM SUMMARY TABLE

Evidence for this state now rests solely on solution 1 of BAILLON 75, (see the footnotes) but the  $\Lambda\pi$  partial-wave amplitudes of this solution are in disagreement with amplitudes from most other  $\Lambda\pi$  analyses.

### Σ(1770) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 1770 OUR ESTIMATE				
1738±10	¹ GOPAL	77	DPWA	KN multichannel
1770 ± 20	² BAILLON	75	<b>IPWA</b>	$\overline{K}N \rightarrow \Lambda \pi$
1772	³ KANE	72	DPWA	$K^- \rho \rightarrow \Sigma \pi$

#### Σ(1770) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
72±10	¹ GOPAL	77	DPWA	KN multichannel
$80 \pm 30$	² BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda\pi$
80	³ KANE	72	DPWA	$K^- p \rightarrow \Sigma \pi$

### Σ(1770) DECAY MODES

	Mode			
Γ ₁	NK			
$\Gamma_2$	$\Lambda\pi$			
$\Gamma_3$	$\Sigma \pi$			

#### Σ(1770) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on  $\varLambda$  and  $\varSigma$ 

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$				Γ ₁ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
$0.14 \pm 0.04$	¹ GOPAL	77	DPWA	$\overline{K}N$ multichannel

$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N \overline{K} \rightarrow$	$\Sigma(1770) \rightarrow \Lambda\pi$			(Γ₁Γ₂) ¹ /⁄2/Γ
VALUE	DOCUMENT ID		TECN	COMMENT
< 0.04	GOPAL			K N multichannel
$-0.08 \pm 0.02$	² BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda\pi$

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K}$	$\rightarrow \Sigma(1770) \rightarrow \Sigma \pi$		(Γ ₁ Γ ₃ ) ¹ ⁄2/Γ
VALUE	DOCUMENT ID	TECN	COMMENT
< 0.04		7 DPWA	KN multichannel
-0.108	3 KANE 73	2 DPWA	$K^- p \rightarrow \Sigma \pi$

### $\Sigma$ (1770) FOOTNOTES

- 1  Required to fit the isospin-1 total cross section of CARROLL 76 in the  $\overline{K}\,N$  channel. The addition of new  $K^-p$  polarization and  $K^-n$  differential cross-section data in GOPAL 80 find it to be more consistent with the  $\Sigma(1660)$   $P_{11}$ .  2  From solution 1 of BAILLON 75; not present in solution 2.
- ³ Not required in KANE 74, which supersedes KANE 72.

### Σ(1770) REFERENCES

GOPAL GOPAL CARROLL BAILLON KANE KANE	80 77 76 75 74 72	Toronto Conf. 159 NP B119 362 PRL 37 806 NP B94 39 LBL-2452 PR D5 1583	+Ross, VanHorn, McPherson+ +Chiang, Kycia, Li, Mazur, Michael+ +Litchfield	(RHEL) (LOIC, RHEL) IJP (BNL) I (CERN, RHEL) IJP (LBL) IJP (LBL)
------------------------------------------------------	----------------------------------	---------------------------------------------------------------------------------------	----------------------------------------------------------------------------------	---------------------------------------------------------------------------------

 $\Sigma(1775) D_{15}$ 

$$I(J^P) = 1(\frac{5}{2}^-)$$
 Status: ***

Discovered by GALTIERI 63, this resonance plays the same role as cornerstone for isospin-1 analyses in this region as the  $\Lambda(1820)$  does in the isospin-0 channel.

For most results published before 1974 (they are now obsolete), see our 1982 edition Physics Letters 111B (1982).

#### Σ(1775) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1770 to 1780 (≈ 1775) OUR ESTIM	MATE			
1778± 5	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
1777± 5	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
1774± 5	GOPAL	77	DPWA	KN multichannel
$1775 \pm 10$	BAILLON			$\overline{K}N \rightarrow \Lambda\pi$
1774±10	VANHORN	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$
1772± 6	KANE	74	DPWA	$K^- \rho \rightarrow \Sigma \pi$
	data for averages	, fits	i, limits,	etc. • • •
1772 or 1777	¹ MARTIN	77	DPWA	KN multichannel
1765	DEBELLEFON	76	IPWA	$K^- p \rightarrow \Lambda \pi^0$

#### Σ(1775) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
105 to 135 (≈ 120) OUR	ESTIMATE			
137±10	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
116±10	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
$130 \pm 10$	GOPAL	77	DPWA	KN multichannel
125±15	BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda\pi$
146±18	VANHORN	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$
154±10	KANE	74	DPWA	$K^- \rho \rightarrow \Sigma \pi$
• • We do not use the	following data for average	s, fit	s, limits,	etc. • • •
102 or 103	¹ MARTIN	77	DPWA	KN multichannel
120	DEBELLEFON	J 76	IPWA	$K^- \rho \rightarrow \Lambda \pi^0$

#### Σ(1775) DECAY MODES

	Mode	Fraction $(\Gamma_i/\Gamma)$
$\overline{\Gamma_1}$	NK	37–43%
$\Gamma_2$	$\Lambda\pi$	14-20%
Гз	$\Sigma \pi$	2-5%
$\Gamma_4$	$\Sigma(1385)\pi$	8-12%
$\Gamma_5$	$\Sigma(1385)\pi$ , <i>D</i> -wave	
$\Gamma_6$	$\Lambda(1520)\pi$	17-23%
$\Gamma_7$	$\Sigma \pi \pi$	

The above branching fractions are our estimates, not fits or averages.

#### CONSTRAINED FIT INFORMATION

An overall fit to 8 branching ratios uses 16 measurements and one constraint to determine 5 parameters. The overall fit has a  $\chi^2$  = 63.9 for 12 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients  $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$ , in percent, from the fit to the branching fractions,  $x_i \equiv$  $\Gamma_i/\Gamma_{\text{total}}$ . The fit constrains the  $x_i$  whose labels appear in this array to sum to

#### Σ(1775) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on  $\varLambda$  and  $\varSigma$ Resonances. Also, the errors quoted do not include uncertainties due to the parametrization used in the partial-wave analyses and are thus too  $% \left\{ 1\right\} =\left\{  

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$					$\Gamma_1/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT	
0.37 to 0.43 OUR ESTIMATE					
0.45 ±0.04 OUR FIT Error inc	ludes scale facto	r of 3.	1.		
0.391 ±0.017 OUR AVERAGE					
0.40 ±0.02	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
0.37 ±0.03	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
	data for averag	es, fits	s, limits,	etc. • • •	
0.41 ±0.03	GOPAL	77	DPWA	See GOPAL 80	

¹ MARTIN

77 DPWA  $\overline{K}N$  multichannel

(FIFF)#	2/F _{total} in A	$ abla \overline{K} \rightarrow \Sigma (17)$	$775) \rightarrow \Lambda \pi$ DOCUMENT ID		TECN	$(\Gamma_1\Gamma_2)^{\frac{1}{12}}$
			cludes scale fact	or of	2.4.	
	0.015 OUR	AVERAGE				
$-0.28 \pm$			GOPAL	77		$\overline{K}N$ multichannel
$-0.25 \pm$			BAILLON	75		$\overline{K}N \rightarrow \Lambda\pi$
-0.28 <del>+</del>	0.04		VANHORN	75	DPWA	$K^- \rho \rightarrow \Lambda \pi^0$
-0.259±			DEVENISH	748		Fixed-t dispersion rel.
		the following	data for average	s, fit:	, limits,	
-0.29 o	r - 0.28		1 MARTIN	77	DPWA	KN multichannel
-0.30	. 0,20		DEBELLEFON		IPWA	$\kappa^- p \rightarrow \Lambda \pi^0$
(Γ,Γ _f ) ^½	² /Γ _{total} in Λ	VK → Σ(17	75) → Σπ			(Γ ₁ Γ ₃ ) ^{1/2}
0 105+	0.025 OUR I	FIT Error inc	DOCUMENT ID			COMMENT
	0.016 OUR		rror includes sca			8
+0.13 ±			GOPAL			KN multichannel
0.09 ±			KANE	74		$K^- \rho \rightarrow \Sigma \pi$
		the following	data for average			•
+0.08 o			1 MARTIN			$\overline{K}N$ multichannel
. 1/		_				1/
$(\Gamma_I \Gamma_f)^{\frac{1}{2}}$	$^2/\Gamma_{ ext{total}}$ in $\Lambda$	$V\overline{K}  o \Sigma(17)$	75) → Λ(152			(Γ₁Γ ₆ ) ^½
VALUE			DOCUMENT ID		TECN	COMMENT
			cludes scale fact			
	0.009 OUR	_	igns on measure			
$-0.305 \pm$		*	² CAMERON	77		$K^- p \rightarrow \Lambda(1520) \pi^0$
0.31 ±	0.02		BARLETTA	72		$K^- \rho \rightarrow \Lambda(1520) \pi^0$
0.27 土	0.03		ARMENTERO	<b>S65</b> C	нвс	$K^- \rho \rightarrow \Lambda(1520) \pi^0$
(F _I F _F ) ^{1/2}	² /Γ _{total} in Λ	√K → Σ(17	75) → Σ(138	35)π	TECN	$(\Gamma_1\Gamma_4)^{\frac{1}{2}}$
	0.022 OUR I	FIT Error inc	ludes scale fact			
	0.010 OUR		igns on measure			gnored.
-0.184±	0.011	3	CAMERON	78	DPWA	$K^- \rho \rightarrow \Sigma(1385)\pi$
+0.20 ±			PREVOST	74		$K^- N \rightarrow \Sigma(1385)\pi$
		the following	data for average	s, fits		
0.32 ±		•	SIMS		DBC	$K^- N \rightarrow \Lambda \pi \pi$
0.32 ±			ARMENTERO			$K^- p \rightarrow \Lambda \pi \pi$
U.24 ±	0.03		ARMENTERO	3670	пьс	$\kappa \rho \rightarrow \Lambda \pi \pi$
$\Gamma(\Lambda\pi)/\Gamma$	$\Gamma(N\overline{K})$					Γ ₂ /
VALUE			DOCUMENT ID		TECN	COMMENT
0.46±0.0	9 OUR FIT	Error include	s scale factor of	2.9.		
0.33±0.0	5		UHLIG	67	нвс	$K^-p$ 0.9 GeV/c
Γ(Σππ	) / Facasal					Г ₇
•	//·total		DOCUMENT ID		TECN	
	a do not use	the following	data for average			
	ao not use					
• • • We		-	ARMENTERO	S68C	HDBC	$K^- N \rightarrow \Sigma \pi \pi$
• • • We						- /
• • • We 0.12 Γ(Σ(136  VALUE	85)π)/Γ( <i>N</i>	ı <b>κ</b> )	DOCUMENT ID		TECN	COMMENT
0.12 Γ(Σ(136 <u>VALUE</u> 0.22±0.0	7 OUR FIT	ı <b>κ</b> )	s scale factor of	3.6.		COMMENT
0.12 <b>Γ(Σ(13</b> 8 VALUE	7 OUR FIT	ı <b>κ</b> )	DOCUMENT ID s scale factor of UHLIG	3.6. 67	TECN HBC	•••
0.12 Γ(Σ(136) VALUE 0.22±0.0 0.25±0.0	7 OUR FIT	Error include	s scale factor of	3.6.		<i>COMMENT K</i> [−] <i>p</i> 0.9 GeV/ <i>c</i>
0.12 Γ(Σ(136 VALUE 0.22±0.0 0.25±0.0 Γ(Λ(152	7 OUR FIT	Error include	s scale factor of UHLIG	3.6. 67	нвс	<u>COMMENT</u> K ⁻ p 0.9 GeV/c  Γ6/
0.12 Γ(Σ(134 VALUE 0.22±0.0 0.25±0.0 Γ(Λ(152 VALUE	7 OUR FIT 19 20)π)/Γ( <i>N</i>	Error include	s scale factor of UHLIG DOCUMENT ID	3.6. 67	нвс	<i>COMMENT K</i> [−] <i>p</i> 0.9 GeV/ <i>c</i>
0.12 Γ(Σ(134 VALUE 0.22±0.0 0.25±0.0 Γ(Λ(152 VALUE	7 OUR FIT 9 20)π)/Γ( <i>N</i>	Error include	s scale factor of UHLIG	3.6. 67	нвс	<u>COMMENT</u> K ⁻ p 0.9 GeV/c  Γ6/

### $\Sigma$ (1775) FOOTNOTES

- ¹ The two MARTIN 77 values are from a T-matrix pole and from a Breit-Wigner fit.
- The two MARTIN // Values are from a 1-matrix pole and from a preti-viginer in.

  This rate combines P-wave- and F-wave decays. The CAMERON 77 results for the separate P-wave- and F-wave decays are -0.303 ± 0.010 and -0.037 ± 0.014. The published signs have been changed here to be in accord with the baryon-first convention.

  The CAMERON 78 upper limit on G-wave decay is 0.03.
- For about 3/4 of this, the  $\Sigma\pi$  system has I=0 and is almost entirely  $\Lambda(1520)$ . For the rest, the  $\Sigma\pi$  has I=1, which is about what is expected from the known  $\Sigma(1775) \to \Sigma(1385)\pi$  rate, as seen in  $\Lambda\pi\pi$ .

#### Σ(1775) REFERENCES

PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
GOPAL	80	Toronto Conf. 159		(RHEL) IJP
ALSTON	78	PR D18 182	Alston-Garnjost, Kenney+ (1	BL, MTHO, CERN) IJP
Also	77	PRL 38 1007	Alston-Garnjost, Kenney+ (1	LBL, MTHO, CERN) IJP
CAMERON	78	NP B143 189	+Franek, Gopal, Bacon, Butterworth+	(RHEL, LOIC) IJP
CAMERON	77	NP B131 399	+Franek, Gopal, Kalmus, McPherson+	(RHEL, LOIC) IJP
GOPAL	77	NP B119 362	+Ross, VanHorn, McPherson+	(LOIC, RHEL) IJP
MARTIN	77	NP B127 349	+Pidcock, Moorhouse	(LOUC, GLAS) IJP
Also	77B	NP B126 266	Martin, Pidcock	(LOUC)
Also	77C	NP B126 285	Martin, Pidcock	(LOUC) IJP
DEBELLEFON	76	NP B109 129	De Bellefon, Berthon	(CDEF) IJP
BAILLON	75	NP B94 39	+Litchfield	(CERN, RHEL) IJP
VANHORN	75	NP B87 145		(LBL) IJP
Also	75B	NP B87 157	VanHorn	(LBL) IJP

# Baryon Particle Listings $\Sigma(1775)$ , $\Sigma(1840)$ , $\Sigma(1880)$

DEVENISH :	74B	NP B81 330	+Froggatt, Martin	(DESY, NORD, LOUC)
KANE	74	LBL-2452		(LBL) IJP
PREVOST	74	NP B69 246	+Barloutaud+	(SACL, CERN, HEID)
BARLETTA	72	NP B40 45		(EFI) IJP
	66	PRL 17 841	Fenster, Gelfand, Harmsen+	(CHIC, ANL, CÉRN) IJP
ARMENTEROS (	68C	NP B8 216	+Baillon+	(ČERN, HEID, SACL) I
SIMS	68	PRL 21 1413	+Albright, Bartley, Meer+	(FSU, TUFTS, BRAN)
ARMENTEROS (	67C	ZPHY 202 486	+Ferro-Luzzi+	(CERN, HEID, SACL)
	67	PR 155 1448	+Chariton, Condon, Glasser, Yodh+	
ARMENTEROS (	65C	PL 19 338	+Ferro-Luzzi+	(CERN, HEID, SACL) IJP
GALTIERI (	63	PL 6 296	+Hussain, Tripp	(LRL) IJ

## $\Sigma(1840) P_{13}$

 $I(J^P) = 1(\frac{3}{2}^+)$  Status: *

#### OMITTED FROM SUMMARY TABLE

For the time being, we list together here all resonance claims in the  $P_{13}$  wave between 1700 and 1900 MeV.

	Σ(1840) MA	SS		
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 1840 OUR ESTIMATE				
1798 or 1802	¹ MARTIN	77	DPWA	$\overline{K}N$ multichannel
1720 ± 30	² BAILLON	75		$\overline{K}N \rightarrow \Lambda \pi$
1925 ± 200	VANHORN	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$
1840± 10	LANGBEIN	72		$\overline{K}N$ multichannel
	Σ(1840) WID	тн		
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
93 or 93	¹ MARTIN	77	DPWA	KN multichannel
120±30	² BAILLON	75	<b>IPWA</b>	$\overline{K}N \rightarrow \Lambda\pi$
65 ^{+ 50} _{- 20}	VANHORN	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$
- 20				

#### Σ(1840) DECAY MODES

	Mode	
$\Gamma_1$	$N\overline{K}$ $\Lambda\pi$ $\Sigma\pi$	
$\Gamma_2$	$\Lambda\pi$	
$\Gamma_3$	$\Sigma \pi$	

#### Σ(1840) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on  $\varLambda$  and  $\varSigma$  Resonances.

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$					$\Gamma_1/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT	
0 or 0	¹ MARTIN	77	DPWA	$\overline{K}$ N multichannel	
$0.37 \pm 0.13$	LANGBEIN	72	IPWA	$\overline{K}N$ multichannel	
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\overline{K}$	$\rightarrow \Sigma(1840) \rightarrow \Lambda\pi$			(F ₁ F ₂	₂ ) ^{1/2} /Γ

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \rightarrow$	$\Sigma(1840) \rightarrow \Lambda\pi$			(Γ₁Γ₂) ^⅓ 2/Γ
VALUE	DOCUMENT ID		TECN	COMMENT
+0.03 or $+0.03$	¹ MARTIN	77	DPWA	KN multichannel
$+0.11 \pm 0.02$	² BAILLON			$\overline{K}N \rightarrow \Lambda\pi$
+0.06 ±0.04	VANHORN	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$
$+0.122\pm0.078$	DEVENISH	74B		Fixed-t dispersion rel.
$0.20 \pm 0.04$	LANGBEIN	72	IPWA	K N multichannel

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \overline{K} \rightarrow \Sigma$	$(\Gamma_1\Gamma_3)^{\frac{1}{2}}$		
VALUE	DOCUMENT ID	TECN	COMMENT
-0.04 or -0.04	¹ MARTIN 77	DPWA	$\overline{K}N$ multichannel
$0.15 \pm 0.04$	LANGBEIN 72	IPWA	$\overline{K}N$ multichannel

#### Σ(1840) FOOTNOTES

 $^1\,\rm The$  two MARTIN 77 values are from a T-matrix pole and from a Breit-Wigner fit.  $^2\,\rm From$  solution 1 of BAILLON 75; not present in solution 2.

### Σ(1840) REFERENCES

MARTIN	77	NP B127 349	+Pidcock, Moorhouse	(LOUC, GLAS) IJP
Also	77B	NP B126 266	Martin, Pidcock	(LOUC)
Also	77C	NP B126 285	Martin, Pidcock	(LOUC) IJP
BAILLON	75	NP B94 39	+Litchfield	(CERN, RHEL) IJP
VANHORN	75	NP B87 145		(LBL) IJP
Aīso	75B	NP B87 157	VanHorn	(LBL) IJP
DEVENISH	74B	NP B81 330	+Froggatt, Martin	(DESY, NORD, LÖUC)
LANGBEIN	72	NP B47 477	+Wagner	(MPIM) IJP

## $\Sigma(1880) P_{11}$

 $I(J^P) = 1(\frac{1}{2}^+)$  Status: **

#### OMITTED FROM SUMMARY TABLE

A  $P_{11}$  resonance is suggested by several partial-wave analyses, but with wide variations in the mass and other parameters. We list here all claims which lie well above the  $P_{11}$   $\Sigma(1770)$ .

### Σ(1880) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 1880 OUR ESTIMATE				
$1826 \pm 20$	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
$1870 \pm 10$	CAMERON	78B	DPWA	$K^- p \rightarrow N \overline{K}^*$
1847 or 1863	¹ MARTIN	77	DPWA	K N multichannel
1960±30	² BAILLON			$\overline{K}N \rightarrow \Lambda\pi$
1985±50	VANHORN	75	DPWA	$K^- \rho \rightarrow \Lambda \pi^0$
1898	³ LEA	73	DPWA	Multichannel K-matrix
$\sim$ 1850	ARMENTERO:	S70	IPWA	$\overline{K}N \rightarrow \overline{K}N$
1950 ± 50	BARBARO	70	DPWA	$K^- N \rightarrow \Lambda \pi$
$1920 \pm 30$	LITCHFIELD	70	DPWA	$K^- N \rightarrow \Lambda \pi$
1850	BAILEY	69	DPWA	$\overline{K}N \rightarrow \overline{K}N$
$\textbf{1882} \pm \textbf{40}$	SMART	68	DPWA	$K^- N \rightarrow \Lambda \pi$

### Σ(1880) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
86± 15	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
80± 10	CAMERON	78B	DPWA	$K^- p \rightarrow N \overline{K}^*$
216 or 220	¹ MARTIN	77	DPWA	K N multichannel
260± 40	² BAILLON			$\overline{K}N \rightarrow \Lambda\pi$
$220 \pm 140$	VANHORN	75	DPWA	$K^- \rho \rightarrow \Lambda \pi^0$
222	³ LEA	73	DPWA	Multichannel K-matrix
~ 30	ARMENTEROS	S70	IPWA	$\overline{K}N \to \overline{K}N$
200 ± 50	BARBARO	70	DPWA	$K^- N \rightarrow \Lambda \pi$
170 ± 40	LITCHFIELD	70	DPWA	$K^- N \rightarrow \Lambda \pi$
200	BAILEY	69	DPWA	$\overline{K}N \to \overline{K}N$
$222\pm150$	SMART	68	DPWA	$K^- N \rightarrow \Lambda \pi$

### Σ(1880) DECAY MODES

	Mode
$\Gamma_1$	NK
$\Gamma_2$	$\Lambda\pi$
Гз	$\Sigma \pi$
Γ4	$N\overline{K}^*$ (892), $S=1/2$ , $P$ -wave
$\Gamma_5$	$N\overline{K}^*(892)$ , $S=3/2$ , $P$ -wave

#### Σ(1880) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on  $\varLambda$  and  $\varSigma$  Resonances.

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$				Γ ₁ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
$0.06 \pm 0.02$	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
0.27 or 0.27	¹ MARTIN	77	DPWA	$\overline{K}N$ multichannel
0.31	3 LEA	73	DPWA	Multichannel K-matrix
0.20	ARMENTERO	OS70	IPWA	$\overline{K}N \rightarrow \overline{K}N$
0.22	BAII FY	69	DPWA	$\overline{K}N \rightarrow \overline{K}N$

$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to \Sigma(1)$	(Γ₁Γ₂) ^{1/2} /Γ			
VALUE	DOCUMENT ID		TECN	COMMENT
-0.24 or -0.24				K N multichannel
$-0.12 \pm 0.02$	² BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda\pi$
$+0.05 \begin{array}{c} +0.07 \\ -0.02 \end{array}$	VANHORN	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$
$-0.169\pm0.119$	DEVENISH	74B		Fixed-t dispersion rel.
-0.30	³ LEA	73	DPWA	Multichannel K-matrix
$-0.09 \pm 0.04$	BARBARO	70	DPWA	$K^- N \rightarrow \Lambda \pi$
$-0.14 \pm 0.03$	LITCHFIELD	70	DPWA	$K^- N \rightarrow \Lambda \pi$
$-0.11 \pm 0.03$	SMART	68	DPWA	$K^- N \rightarrow \Lambda \pi$

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K} \to \Sigma$	<b>Σ(1880)</b> → Σπ				(Γ ₁ Γ ₃ ) ^{1/2} /Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
+0.30 or +0.29	¹ MARTIN	77	DPWA	KN multic	hannel
not seen	31 ⊏ ∆	73	DPMA	Multichann	el K-matriy

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to 1$	Σ(1880) → <i>NK</i> *(892	), <i>S</i> =1/	2, <i>P</i> -wave (Γ ₁ Γ ₄ ) ^{1/2} /Γ
VALUE	DOCUMENT ID	TECN	COMMENT
0.05.1.0.03	4 CAMEDON 700	DDIAM	K-0 NF*

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \overline{K} \to \Sigma(1)$	1880) → NK*(8	892), <i>5</i> =3/	2, <i>P</i> -wave (Γ ₁ Γ ₅ )	<del>⅓</del> /г
VALUE	DOCUMENT ID	TECN	COMMENT	
$+0.11\pm0.03$	CAMERON	78B DPWA	$K^- p \rightarrow N \overline{K}^*$	

### $\Sigma$ (1880) FOOTNOTES

- ¹ The two MARTIN 77 values are from a T-matrix pole and from a Breit-Wigner fit.
   ² From solution 1 of BAILLON 75; not present in solution 2.
   ³ Only unconstrained states from table 1 of LEA 73 are listed.
   ⁴ The published sign has been changed to be in accord with the baryon-first convention.

### Σ(1880) REFERENCES

GOPAL CAMERON MARTIN AISO AISO BAILLON VANHORN AISO DEVENISH LEA ARMENTEROS BARBARO LITCHFIELD BAILEY SMART	80 78B 77 77B 77C 75 75 75B 74B 73 70 70 69 68	Toronto Conf. 159 NP B146 327 NP B127 349 NP B126 266 NP B126 285 NP B87 145 NP B87 157 NP B87 157 NP B81 330 NP B87 17 Duke Conf. 123 Duke Conf. 173 NP B22 269 Thesis UCRL 50617 PR 169 1330	+Franek, Gopal, Kalmus, +Pidcock, Moorhouse Martin, Pidcock Martin, Pidcock +Litchfield VanHorn +Froggatt, Martin +Martin, Moorhouse+ +Baillon+ Barbaro-Galtieri	(RHEL) JIP  McPherson+ (RHEL, IOC) JIP (LOUC, GLAS) JIP (LOUC) (LOUC) (CERN, RHEL) JIP (LEL) JIP (DESY, NORD, LOUC) (RHEL, LOUC, GLAS, AARH) JIP (CERN, HEID, SACL) JIP (RHEL) JIP (RHEL) JIP (LLL) JIP (LLL) JIP (LLL) JIP
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## $\Sigma$ (1915) $F_{15}$

$$I(J^P) = 1(\frac{5}{2}^+)$$
 Status: ***

Discovered by COOL 66. For results published before 1974 (they are now obsolete), see our 1982 edition Physics Letters 111B (1982).

This entry only includes results from partial-wave analyses. Parameters of peaks seen in cross sections and invariant-mass distributions in this region used to be listed in in a separate entry immediately following. They may be found in our 1986 edition Physics Letters 170B (1986).

### Σ(1915) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1900 to 1935 (≈ 1915) OUR ESTI	MATE			
1937 ± 20	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
1894 ± 5	¹ CORDEN	77C		$K^- n \rightarrow \Sigma \pi$
1909± 5	¹ CORDEN	77C		$K^- n \rightarrow \Sigma \pi$
$1920\pm10$				KN multichannel
1900 ± 4	² CORDEN	76	DPWA	$K^- n \rightarrow \Lambda \pi^-$
$1920 \pm 30$	BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda\pi$
$1914 \pm 10$	HEMINGWAY	75	DPWA	$K^- \rho \rightarrow \overline{K} N$
$1920 + 15 \\ -20$	VANHORN	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$
1920 ± 5	KANE	74	DPWA	$K^- \rho \rightarrow \Sigma \pi$
ullet $ullet$ We do not use the following	data for averages	, fits	, limits,	etc. • • •
not seen	DECLAIS	77	DPWA	$\overline{K}N \rightarrow \overline{K}N$
1925 or 1933	³ MARTIN	77	DPWA	KN multichannel
1915	DEBELLEFON	76	IPWA	$K^- \rho \rightarrow \Lambda \pi^0$

#### Σ(1915) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
80 to 160 (≈ 120) OUR ESTIMA	TE			
$161\pm20$	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
$107 \pm 14$	¹ CORDEN	77C		$K^- n \rightarrow \Sigma \pi$
85 ± 13	¹ CORDEN	<b>77</b> C		$K^- n \rightarrow \Sigma \pi$
$130 \pm 10$	GOPAL	77	DPWA	KN multichannel
$75 \pm 14$	² CORDEN	76	DPWA	$K^- n \rightarrow \Lambda \pi^-$
70 ± 20	BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda\pi$
$85 \pm 15$	HEMINGWAY			$K^- p \rightarrow \overline{K} N$
$102\pm18$	VANHORN	75	DPWA	$K^- \rho \rightarrow \Lambda \pi^0$
$162 \pm 25$	KANE	74	DPWA	$K^- p \rightarrow \Sigma \pi$
ullet $ullet$ We do not use the following	data for averages	, fits	, limits,	etc. • • •
171 or 173	³ MARTIN	77	DPWA	$\overline{K}$ N multichannel
60	DEBELLEFON	76	IPWA	$K^- \rho \rightarrow \Lambda \pi^0$

### Σ(1915) DECAY MODES

	Mode	Fraction $(\Gamma_i/\Gamma)$	
$\Gamma_1$	NK	5–15 %	
$\Gamma_2$	$\Lambda\pi$	seen	
$\Gamma_3$	$\Sigma \pi$	seen	
$\Gamma_4$	$\Sigma(1385)\pi$	<5 %	
$\Gamma_5$	$\Sigma(1385)\pi$ , <i>P</i> -wave		
$\Gamma_6$	$\Sigma(1385)\pi$ , <i>F</i> -wave		

The above branching fractions are our estimates, not fits or averages.

### $\Sigma$ (1915) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on  $\varLambda$  and  $\varSigma$ 

Γ(NK)/Γ _{total}	DOCUMENT ID		TEC.	Γ _{1,}
VALUE 0.05 to 0.15 OUR ESTIMA	DOCUMENT ID		IECN	COMMENT
0.03±0.02	4 GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
0.14±0.05	ALSTON	78	DPWA	$\overline{K}N \to \overline{K}N$
$0.11 \pm 0.04$			DPWA	$K^- p \rightarrow \overline{K} N$
• • • We do not use the f	ollowing data for average	s, fits	s, limits,	etc. • • •
0.05±0.03	GOPAL	77	DPWA	See GOPAL 80
0.08 or 0.08	3 MARTIN	77	DPWA	See GOPAL 80 $\overline{K}N$ multichannel
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}}$ in $N\overline{K}$ -				(Γ ₁ Γ ₂ ) ^{1/2} ,
VALUE	DOCUMENT ID		TECN	
-0.09 ±0.03	GOPAL		DPWA	KN multichannel
-0.10 ±0.01	² CORDEN	76	DPWA	$K^- n \rightarrow \Lambda \pi^-$
$-0.06 \pm 0.02$	BAILLON VANHORN	75	IPWA	$\overline{K}N \rightarrow \Lambda\pi$
$-0.09 \pm 0.02$	VANHORN	75	DPWA	$K^- \rho \rightarrow \Lambda \pi^0$
$-0.087 \pm 0.056$	DEVENISH	74B		Fixed-t dispersion rel.
<ul> <li>We do not use the feature</li> </ul>	ollowing data for average	s, fits	s, limits,	etc. • • •
-0.09 or -0.09	³ MARTIN	77	DPWA	KN multichannel
-0.10	DEDELLEGAN	~-	IDVA/A	
0.10	DEBELLEFON	76	IP VVA	$K^- p \rightarrow \Lambda \pi^0$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{ ext{total}}$ in $N\overline{K}$ -				
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{ ext{total}}$ in $N\overline{K}$ -	$\rightarrow \Sigma(1915) \rightarrow \Sigma \pi$		TECN	(Γ ₁ Γ ₃ ) ^{1/2} /
$(\Gamma_I\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}}$ in $N\overline{K}$ - $VALUE$ $-0.17\pm0.01$	$\rightarrow \Sigma(1915) \rightarrow \Sigma \pi$ $\frac{DOCUMENT ID}{}$		<u>TECN</u>	(Γ ₁ Γ ₃ ) ^{1/2}
$(\Gamma_{l}\Gamma_{r})^{\frac{1}{2}}/\Gamma_{total}$ in $N\overline{K}$ - $\frac{VALUE}{-0.17 \pm 0.01}$ - $0.15 \pm 0.02$	$ \begin{array}{c}                                     $	77c	<u>TECN</u>	$\frac{(\Gamma_1\Gamma_3)^{\frac{1}{2}}}{\kappa^- n \to \Sigma \pi}$
$(\Gamma_{l}\Gamma_{f})^{1/2}/\Gamma_{total}$ in $N\overline{K}$ - $(NLUE)^{-0.17\pm0.01}$ = $0.15\pm0.02$ = $0.19\pm0.03$	$ \begin{array}{c}                                     $	77c	TECN_	$\frac{\left(\Gamma_{1}\Gamma_{3}\right)^{\frac{1}{2}}}{K^{-}n \rightarrow \Sigma \pi}$ $K^{-}n \rightarrow \Sigma \pi$ $K^{-}n \rightarrow \Sigma \pi$
$(\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}}$ in $N\overline{K}$ - $\frac{1}{N}$ $\frac{1}$ $\frac{1}{N}$ $\frac{1}{N}$ $\frac{1}{N}$ $\frac{1}{N}$ $\frac{1}{N}$ $\frac{1}{N}$	→ Σ(1915) → Σπ  DOCUMENT ID  1 CORDEN  1 CORDEN  GOPAL  KANE	77c 77c 77 74	TECN DPWA DPWA	$(\Gamma_1\Gamma_3)^{\frac{1}{2}}$ $\frac{COMMENT}{K^- n \to \Sigma \pi}$ $\frac{K^- n \to \Sigma \pi}{K N \text{ multichannel}}$ $\frac{K^- p \to \Sigma \pi}{K \to \infty}$
$(\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K}$ - $0.17 \pm 0.01$ - $0.15 \pm 0.02$ - $0.19 \pm 0.03$ - $0.16 \pm 0.03$	→ Σ(1915) → Σπ  DOCUMENT ID  1 CORDEN  1 CORDEN  GOPAL  KANE	77C 77C 77 74 5, fits	TECN  DPWA DPWA s, limits,	$(\Gamma_1\Gamma_3)^{\frac{1}{2}}$ $\frac{COMMENT}{K^- n \to \Sigma \pi}$ $\frac{K^- n \to \Sigma \pi}{K N \text{ multichannel}}$ $\frac{K^- p \to \Sigma \pi}{K \to \infty}$
$(\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} - \frac{1}{N}$ $V_{NALUE}$ $-0.17 \pm 0.01$ $-0.15 \pm 0.02$ $-0.19 \pm 0.03$ $-0.16 \pm 0.03$ $\bullet \bullet \bullet \text{ We do not use the form}$ $-0.05 \text{ or } -0.05$ $(\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} - \frac{1}{N}$	$ \begin{array}{c}                                     $	77C 77C 77 74 s, fits 77	DPWA DPWA s, limits, DPWA	$(\Gamma_{1}\Gamma_{3})^{\frac{1}{2}}$ $\frac{COMMENT}{K^{-}n \to \Sigma\pi}$ $\frac{K^{-}n \to \Sigma\pi}{KN \text{ multichannel}}$ $\frac{K^{-}\rho \to \Sigma\pi}{KN \text{ multichannel}}$ $\frac{K^{-}\rho \to \Sigma\pi}{KN \text{ multichannel}}$ $\frac{K^{-}\rho \to \Sigma\pi}{KN \text{ multichannel}}$
$(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} - \frac{1}{N}$ $N = \frac{1}{N}$	$ \begin{array}{c}                                     $	77C 77C 77 74 s, fits 77	DPWA DPWA i, limits, DPWA	$ \frac{\left(\Gamma_{1}\Gamma_{3}\right)^{\frac{1}{2}}}{K \cap n \to \Sigma \pi} $ $ \frac{K \cap n \to \Sigma \pi}{K \cap N \text{ multichannel}} $ $ \frac{K \cap \rho \to \Sigma \pi}{K \cap N \text{ multichannel}} $ $ \text{etc.}                                    $
$(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} - \frac{N}{N}$ $-0.17 \pm 0.01$ $-0.15 \pm 0.02$ $-0.19 \pm 0.03$ $-0.16 \pm 0.03$ •• • We do not use the form $-0.05$ or $-0.05$ $(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K}$	$ \begin{array}{c}                                     $	77C 77C 77 74 s, fits 77	DPWA DPWA i, limits, DPWA	$(\Gamma_{1}\Gamma_{3})^{\frac{1}{2}}$ $\frac{COMMENT}{K-n \to \Sigma\pi}$ $\frac{K-n \to \Sigma\pi}{KN \text{ multichannel}}$ $\frac{K-\rho \to \Sigma\pi}{KN \text{ multichannel}}$ $\frac{K-\rho \to \Sigma\pi}{KN \text{ multichannel}}$ $\frac{K-\rho}{KN \text{ multichannel}}$ $\frac{K-\rho}{KN \text{ multichannel}}$
$(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} - \frac{N}{N}$ $N = \frac{1}{N} + $	DOCUMENT ID  1 CORDEN 1 CORDEN GOPAL KANE  ollowing data for average: 3 MARTIN  → ∑(1915) → ∑(138) DOCUMENT ID CAMERON	77c 77c 77 74 5)π 78	DPWA DPWA S, limits, DPWA P-wav TECN DPWA	$(\Gamma_{1}\Gamma_{3})^{\frac{1}{2}}/2$ $COMMENT$ $K^{-}n \to \Sigma\pi$ $K^{-}n \to \Sigma\pi$ $K^{-}N \text{ multichannel}$ $K^{-}p \to \Sigma\pi$ etc. • • • $K^{-}N \text{ multichannel}$ $K^{-}p \to \Sigma\pi$ $(\Gamma_{1}\Gamma_{5})^{\frac{1}{2}}/2$ $(\Gamma_{1}\Gamma_{5})^{\frac{1}{2}}/2$ $(\Gamma_{1}\Gamma_{5})^{\frac{1}{2}}/2$ $(\Gamma_{1}\Gamma_{5})^{\frac{1}{2}}/2$ $(\Gamma_{1}\Gamma_{5})^{\frac{1}{2}}/2$ $(\Gamma_{1}\Gamma_{5})^{\frac{1}{2}}/2$ $(\Gamma_{1}\Gamma_{5})^{\frac{1}{2}}/2$ $(\Gamma_{1}\Gamma_{5})^{\frac{1}{2}}/2$

### $\Sigma$ (1915) FOOTNOTES

- 1  The two entries for CORDEN 77C are from two different acceptable solutions.
- ² Preferred solution 3; see CORDEN 76 for other possibilities.
- 3 The two MARTIN 77 values are from a T-matrix pole and from a Breit-Wigner fit.
  4 The mass and width are fixed to the GOPAL 77 values due to the low elasticity.

Σ(1915) REFERENCES

### ⁵ The published sign has been changed to be in accord with the baryon-first convention.

PDG	86	PL 170B	Aguilar-Benitez, Porter+ (CERN, CIT+)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+ (HELS, CIT, CERN)
GOPAL	80	Toronto Conf. 159	(RHEL) IJP
ALSTON	78	PR D18 182	Alston-Garnjost, Kenney+ (LBL, MTHO, CERN) IJP
Also	77	PRL 38 1007	Alston-Garnjost, Kenney+ (LBL, MTHO, CERN) IJP
CAMERON	78	NP B143 189	+Franek, Gopal, Bacon, Butterworth+ (RHEL, LOIC) IJP
CORDEN	77C	NP B125 61	+Cox, Kenyon, O'Neale, Stubbs, Sumorok+ (BIRM) IJP
DECLAIS	77	CERN 77-16	+Duchon, Louvel, Patry, Seguinot+ (CAEN, CERN) IJP
GOPAL	77	NP B119 362	+Ross, VanHorn, McPherson+ (LOIC, RHEL) IJP
MARTIN	77	NP B127 349	+Pidcock, Moorhouse (LOUC, GLAS) IJP
Also	77B	NP B126 266	Martin, Pidcock (LOUC)
Also	77C	NP B126 285	Martin, Pidcock (LOUC) IJP
CORDEN	76	NP B104 382	+Cox, Dartnell, Kenyon, O'Neale+ (BIRM) IJP
DEBELLEFON	76	NP B109 129	De Bellefon, Berthon (CDEF) IJP
BAILLON	75	NP B94 39	+Litchfield (CERN, RHEL) IJP
HEMINGWAY	75	NP B91 12	+Eades, Harmsen+ (CERN, HEIDH, MPIM) IJP
VANHORN	75	NP B87 145	(LBL) IJP
Also	75B	NP B87 157	VanHorn (LBL) IJP
DEVENISH	74B	NP B81 330	+Froggatt, Martin (DESY, NORD, LOUC)
KANE	74	LBL-2452	(LBL) IJP
COOL	66	PRL 16 1228	+Giacomelli, Kycia, Leontic, Lundby+ (BNL)
			. ,

 $\Sigma(1940), \Sigma(2000)$ 

 $\Sigma(1940) D_{13}$ 

 $I(J^P) = 1(\frac{3}{2}^-)$  Status: ***

For results published before 1974 (they are now obsolete), see our 1982 edition Physics Letters 111B (1982).

Not all analyses require this state. It is not required by the GOYAL 77  $\,$ analysis of  $K^- \, n \, o \, (\Sigma \pi)^-$  nor by the GOPAL 80 analysis of  $K^- n \rightarrow K^- n$ . See also HEMINGWAY 75.

### Σ(1940) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1900 to 1950 (≈ 1940) OU	IR ESTIMATE			
1920 ± 50	GOPAL	77	DPWA	$\overline{K}N$ multichannel
1950±30	BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda \pi$
$1949^{+40}_{-60}$	VANHORN	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$
$1935 \pm 80$	KANE			$K^- p \rightarrow \Sigma \pi$
1940 ± 20	LITCHFIELD	74B	DPWA	$K^- \rho \rightarrow \Lambda(1520)\pi^0$
$1950 \pm 20$	LITCHFIELD	74C	DPWA	$K^- p \rightarrow \Delta(1232)\overline{K}$
• • • We do not use the f	ollowing data for averages	, fits	, limits,	etc. • • •
1886 or 1893				KN multichannel
1940	DEBELLEFON	76	IPWA	$K^- \rho \rightarrow \Lambda \pi^0$ , $F_{17}$

### Σ(1940) WIDTH

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
150 to 300 (≈ 220) OUR ESTIN	MATE		
170±25	CAMERON	78B DPW	$A K^- p \rightarrow N \overline{K}^*$
300 ± 80	GOPAL	77 DPW	A $\overline{K}N$ multichannel
150±75	BAILLON	75 IPWA	$\overline{K}N \rightarrow \Lambda\pi$
$160 + 70 \\ -40$	VANHORN	75 DPW	$A K^- \rho \rightarrow \Lambda \pi^0$
330±80	KANE		$A K^- p \rightarrow \Sigma \pi$
$60 \pm 20$	LITCHFIELD	74B DPW	$A  K^- p \rightarrow \Lambda(1520) \pi^0$
$70 + 30 \\ -20$	LITCHFIELD	74c DPW	$A K^- p \rightarrow \Delta(1232)\overline{K}$
• • • We do not use the follow	ing data for average	s, fits, limit	s, etc. • • •
157 or 159	¹ MARTIN	77 DPW	A $\overline{K}N$ multichannel

### $\Sigma$ (1940) DECAY MODES

	Mode	Fraction $(\Gamma_i/\Gamma)$
$\Gamma_1$	NK	<20 %
$\Gamma_2$	$\Lambda\pi$	seen
$\Gamma_3$	$\Sigma \pi$	seen
Γ4	$\Sigma(1385)\pi$	seen
$\Gamma_5$	$\Sigma(1385)\pi$ , S-wave	
$\Gamma_6$	$\Lambda(1520)\pi$	seen
$\Gamma_7$	$\Lambda(1520)\pi$ , <i>P</i> -wave	
Γ8	$\Lambda(1520)\pi$ , F-wave	
Γ9	$\Delta(1232)\overline{K}$	seen
Γ ₁₀	$\Delta(1232)\overline{K}$ , S-wave	
Γ11	$\Delta(1232)\overline{K}$ , D-wave	
Γ ₁₂	N K* (892)	seen
Γ ₁₃	$N\vec{K}^*(892)$ , $S=3/2$ , $S$ -wave	

#### Σ(1940) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on  $\varLambda$  and  $\varSigma$ 

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$					$\Gamma_1/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT	
<0.2 OUR ESTIMATE					
< 0.04	GOPAL	77	DPWA	$\overline{K}$ N multichannel	
0.14 or 0.13	¹ MARTIN	77	DPWA	$\overline{K}N$ multichannel	
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K}$	$\widetilde{A} \rightarrow \Sigma(1940) \rightarrow \Lambda \pi$			(F ₁ F ₂ )	¹ ⁄2/Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
-0.06 ±0.03	GOPAL	77	DPWA	<b>K</b> N multichannel	
$-0.04 \pm 0.02$	BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda\pi$	
$-0.05 \begin{array}{c} +0.03 \\ -0.02 \end{array}$	VANHORN	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$	
$-0.153 \pm 0.070$	DEVENISH	74B		Fixed-t dispersion r	el.
• • • We do not use the	following data for average	s, fits	s, limits,	etc. • • •	
	1 MARTIN				

<u>VALUE</u> -0.08±0.04 -0.14±0.04	$\Sigma$ (1940) $\to \Sigma \pi$		TECN	(Γ ₁ Γ ₃ ) ^{1/2} /
	<u>DOCUMENT ID</u> GOPAL	77	DDIMA	K M multichannel
	KANE			
• • We do not use the fol				
+0.16 or +0.16	_			<b>K</b> N multichannel
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K} - 1$	→ Σ(1940) → Λ(152	0)π,	<i>P</i> -wav	e (Γ ₁ Γ ₇ ) ^{1/2} /
VALUE	DOCUMENT ID		TECN	$\frac{COMMENT}{K^- p \rightarrow \Lambda(1520)\pi^0}$
< 0.03	CAMERON	77	DPWA	$K^- p \rightarrow \Lambda(1520) \pi^0$
$-0.11 \pm 0.04$	LITCHFIELD	74B	DPWA	$K^- p \rightarrow \Lambda(1520) \pi^0$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \rightarrow VALUE}$	$\Sigma(1940) \rightarrow \Lambda(152)$ DOCUMENT ID	0)π,	F-wav	e (Γ ₁ Γ ₈ ) ^{1/2} /Ι
0.062 + 0.021				$K^- p \rightarrow \Lambda(1520) \pi^0$
-0.08 ±0.04				$K^- p \rightarrow \Lambda(1520) \pi^0$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \frac{VALUE}{-0.16 \pm 0.05}$	DOCUMENT ID		<u>TECN</u>	$\frac{COMMENT}{K^- p \rightarrow \Delta(1232)\overline{K}}$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow VALUE}$	→ Σ(1940) → Δ(123	32) <i>K</i>	, <b>D-wa</b>	ve (Γ ₁ Γ ₁₁ ) ^{1/2} /Ι
-0.14±0.05	LITCHFIELD	74C	DPWA	$K^- p \rightarrow \Delta(1232)\overline{K}$
	Σ(1940) → Σ(138	35)π		(Γ₁Γ₄) ^{1/2} /
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \rightarrow VALUE}$	DOCUMENT ID			
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \rightarrow \frac{VALUE}{+0.066 \pm 0.025}$	<u>DOCUMENT ID</u> 2 CAMERON	78	DPWA	$K^- p \rightarrow \Sigma(1385)\pi$
$(\Gamma_{\Gamma}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \frac{NLUE}{VALUE}$ +0.066±0.025 $(\Gamma_{\Gamma}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \frac{NLUE}{VALUE}$	DOCUMENT ID  2 CAMERON	892)	<u>TECN</u>	$(\Gamma_1\Gamma_{12})^{\frac{1}{2}}$

- $^1\,\mathrm{The}$  two MARTIN 77 values are from a T-matrix pole and from a Breit-Wigner fit.  $^2\,\mathrm{The}$  published sign has been changed to be in accord with the baryon-first convention.
- 3  Upper limits on the  ${\it D}_1$  and  ${\it D}_3$  waves are each 0.03.

#### Σ(1940) REFERENCES

PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
GOPAL	80	Toronto Conf. 159		(RHEL)
CAMERON	78	NP B143 189	+Franek, Gopal, Bacon, Butterworth	
CAMERON	78B	NP B146 327	+Franek, Gopal, Kalmus, McPherson	
CAMERON	77	NP B131 399	+Franek, Gopal, Kalmus, McPherson	
GOPAL	77	NP B119 362	+Ross, VanHorn, McPherson+	(LOIC, RHEL) IJP
GOYAL	77	PR D16 2746	+Sodhi	(DELH)
MARTIN	77	NP B127 349	+Pidcock, Moorhouse	(LOUC, GLAS) IJP
Also	77B	NP B126 266	Martin, Pidcock	(LOUC)
Also	77C	NP B126 285	Martin, Pidcock	(LOUC) IJP
DEBELLEFON	76	NP B109 129	De Bellefon, Berthon	(CDEF) IJP
BAILLON	75	NP B94 39	+Litchfield	(CERN, RHEL) IJP
HEMINGWAY	75	NP B91 12	+Eades, Harmsen+	(CERN, HEIDH, MPIM) IJP
VANHORN	75	NP B87 145		(LBL) IJP
Also	75B	NP B87 157	VanHorn	(LBL) IJP
DEVENISH	74B	NP B81 330	+Froggatt, Martin	(DESY, NORD, LOUC)
KANE	74	LBL-2452		(LBL) IJP
LITCHFIELD	74B	NP B74 19	+Hemingway, Baillon+	(CERN, HÉIDH) IJP
LITCHFIELD	74C	NP B74 39	+Hemingway, Baillon+	(CERN, HEIDH) IJP

 $\Sigma(2000) S_{11}$ 

 $I(J^P) = 1(\frac{1}{2})$  Status: *

OMITTED FROM SUMMARY TABLE

We list here all reported  $\mathit{S}_{11}$  states lying above the  $\mathit{\Sigma}(1750)$   $\mathit{S}_{11}.$ 

$\Sigma$ (2000) MASS						
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT		
≈ 2000 OUR ESTIMATE						
1944±15	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$		
1955±15	GOPAL	77	DPWA	K N multichannel		
1755 or 1834	¹ MARTIN	77	DPWA	KN multichannel		
$2004\pm40$	VANHORN	75	DPWA	$K^- \rho \rightarrow \Lambda \pi^0$		
	Σ(2000) WID	ТН				
VALUE (MeV)	<b>Σ(2000) WID</b>	TH	TECN	COMMENT		
VALUE (MeV) 215 ± 25		TH 80		$\frac{COMMENT}{KN \to KN}$		
	DOCUMENT ID		DPWA			
215±25	DOCUMENT ID	80	DPWA DPWA	$\overline{K}N \to \overline{K}N$		

### Σ(2000) DECAY MODES

	Mode	 
$\overline{\Gamma_1}$	NK	
$\Gamma_2^-$	$\Lambda\pi$	
Γ3	$\Sigma \pi$	
Γ4	$\Lambda(1520)\pi$	
$\Gamma_5$	$N\overline{K}^*(892)$ , $S=1/2$ , $S$ -wave	
$\Gamma_6$	$N\overline{K}^*(892)$ , $S=3/2$ , <i>D</i> -wave	

#### Σ(2000) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on  $\varLambda$  and  $\varSigma$  Resonances.

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$				Γ ₁ /Γ
VALUE	DOCUMENT ID			COMMENT
$0.51 \pm 0.05$	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
$0.44 \pm 0.05$	GOPAL	77	DPWA	See GOPAL 80
0.62 or 0.57	¹ MARTIN	77	DPWA	<b>K</b> N multichannel
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K} \to VALUE}$	$\Sigma$ (2000) $\rightarrow \Lambda \pi$		TECN	$(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma_2$
0.08±0.03	GOPAL			K N multichannel
-0.19 or -0.18	¹ MARTIN			KN multichannel
not seen	BAILLON			$\overline{K}N \rightarrow \Lambda\pi$
$+0.07 + 0.02 \\ -0.01$	VANHORN	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to \frac{1}{2}$	DOCUMENT ID			
$+0.20\pm0.04$	GOPAL			$\overline{K}N$ multichannel
+0.26  or  +0.24	¹ MARTIN	77	DPWA	<b>K</b> N multichannel
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \overline{K} \rightarrow$	$\Sigma$ (2000) $\rightarrow \Lambda$ (152	0)π	TECN	$(\Gamma_1\Gamma_4)^{\frac{1}{2}}/I$
$+0.081 \pm 0.021$	DOCUMENT ID  2 CAMERON	77	DPWA	P-wave decay
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to VALUE}$	$\Sigma$ (2000) $\rightarrow N\overline{K}^*$ (	892)	, <b>S=1</b> /	'2, S-wave (Γ ₁ Γ ₅ ) ^{1/2} /Ι
$+0.10\pm0.02$	² CAMERON			
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to$	$\Sigma$ (2000) $ ightarrow$ N $\overline{K}$ *(	892)	), <i>S</i> =3/	′2, <i>D</i> -wave (Γ ₁ Γ ₆ ) ^½ /Ι
VALUE	DOCUMENT ID		TECN	COMMENT
$-0.07 \pm 0.03$	CAMERON	<b>78</b> B	DPWA	$K^- p \rightarrow N \overline{K}^*$
	Σ(2000) FOOTN	OTI	==	

### $\Sigma$ (2000) FOOTNOTES

 1  The two MARTIN 77 values are from a T-matrix pole and from a Breit-Wigner fit.  2  The published sign has been changed to be in accord with the baryon-first convention.

$\Sigma$ (2000) REFERENCES					
GOPAL CAMERON CAMERON GOPAL MARTIN Also Also BAILLON VANHORN Also	80 78B 77 77 77 77B 77C 75 75	Toronto Conf. NP B146 327 NP B131 399 NP B119 362 NP B127 349 NP B126 266 NP B126 285 NP B94 39 NP B87 145 NP B87 157	` ,	(RHEL) IJP (RHEL, LOIC) IJP (RHEL, LOIC) IJP (LOIC, RHEL) IJP (LOUC, GLAS) IJP (LOUC) (LOUC) IJP (CERN, RHEL) IJP (LBL) IJP	

## $\Sigma(2030) F_{17}$

 $I(J^P) = 1(\frac{7}{2}^+)$  Status: ***

Discovered by COOL 66 and by WOHL 66. For most results published before 1974 (they are now obsolete), see our 1982 edition Physics Letters **111B** (1982).

This entry only includes results from partial-wave analyses. Parameters of peaks seen in cross sections and invariant-mass distributions around 2030 MeV may be found in our 1984 edition, Reviews of Modern Physics **56** No. 2 Pt. II (1984).

#### Σ(2030) MASS

VALUE (MeV)	DOCUMENT ID TECN COMMENT
2025 to 2040 (≈ 2030)	OUR ESTIMATE
2036± 5	GOPAL 80 DPWA $\overline{K}N \to \overline{K}N$
2038±10	CORDEN 77B $K^- N \rightarrow N \overline{K}^*$
2040± 5	GOPAL 77 DPWA $\overline{K}N$ multichannel
2030± 3	¹ CORDEN 76 DPWA $K^- n \rightarrow \Lambda \pi^-$
2035±15	BAILLON 75 IPWA $\overline{K}N  o \Lambda\pi$
2038±10	HEMINGWAY 75 DPWA $K^- p \rightarrow \overline{K} N$
2042±11	VANHORN 75 DPWA $K^- p \rightarrow \Lambda \pi^0$
2020 ± 6	KANE 74 DPWA $K^-p \rightarrow \Sigma \pi$
2035 ± 10	LITCHFIELD 74B DPWA $K^-p \rightarrow \Lambda(1520)\pi^0$
2020±30	LITCHFIELD 74C DPWA $K^-p \rightarrow \Delta(1232)\overline{K}$
2025±10	LITCHFIELD 74D DPWA $K^-p \rightarrow \Lambda(1820)\pi^0$
<ul> <li>◆ ◆ We do not use th</li> </ul>	e following data for averages, fits, limits, etc. • • •
2027 to 2057	GOYAL 77 DPWA $K^- N  o \Sigma \pi$
2030	DEBELLEFON 76 IPWA $K^- p \rightarrow \Lambda \pi^0$

### Σ(2030) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
150 to 200 (≈ 180) OUR ESTIMA				COMMENT
172±10	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
137±40	CORDEN	77B		$K^- N \rightarrow N \overline{K}^*$
$190 \pm 10$	GOPAL	77	DPWA	<b>K</b> N multichannel
201 ± 9	¹ CORDEN	76	DPWA	$K^- n \rightarrow \Lambda \pi^-$
$180 \pm 20$	BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda\pi$
172±15	HEMINGWAY	75	DPWA	$K^- p \rightarrow \overline{K} N$
178±13	VANHORN	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$
111 ± 5	KANE	74	DPWA	$K^- \rho \rightarrow \Sigma \pi$
160±20	LITCHFIELD	74B	DPWA	$K^- \rho \rightarrow \Lambda(1520) \pi^0$
200±30	LITCHFIELD	74C	DPWA	$K^- p \rightarrow \Delta(1232)\overline{K}$
• • • We do not use the following	data for averages	s, fits	, limits,	etc. • • •
260	DECLAIS	77	DPWA	$\overline{K}N \rightarrow \overline{K}N$
126 to 195	GOYAL	77	DPWA	$K^- N \rightarrow \Sigma \pi$
160	DEBELLEFON	76	IPWA	$K^- p \rightarrow \Lambda \pi^0$
70 to 125	LITCHFIELD	<b>74</b> D	DPWA	$K^- p \rightarrow \Lambda(1820) \pi^0$

### $\Sigma$ (2030) DECAY MODES

	Mode	Fraction $(\Gamma_j/\Gamma)$
$\Gamma_1$	NK	17–23 %
$\Gamma_2$	$\Lambda\pi$	17–23 %
Γ3	$\Sigma \pi$	5–10 %
$\Gamma_4$	ΞK	<2 %
$\Gamma_5$	$\Sigma(1385)\pi$	5–15 %
$\Gamma_6$	$\Sigma(1385)\pi$ , $\emph{F}$ -wave	
$\Gamma_7$	$\Lambda(1520)\pi$	10-20 %
Γ ₈	$arLambda(1520)\pi$ , $\mathit{D} ext{-}$ wave	
Г9	$\Lambda(1520)\pi$ , $G$ -wave	
$\Gamma_{10}$	$\Delta(1232)\overline{K}_{\underline{}}$	10-20 %
$\Gamma_{11}$	$\Delta(1232)\overline{K}$ , $F$ -wave	
$\Gamma_{12}$	$\Delta$ (1232) $\overline{K}$ , $H$ -wave	
$\Gamma_{13}$	N K* <u>(</u> 892)	<5 %
$\Gamma_{14}$	$N\overline{K}^*(892)$ , $S=1/2$ , $F$ -wave	
$\Gamma_{15}$	$NK^*(892)$ , $S=3/2$ , $F$ -wave	
$\Gamma_{16}$	$\Lambda(1820)\pi$ , $ extit{P}$ -wave	

The above branching fractions are our estimates, not fits or averages.

 $\Sigma(2030), \Sigma(2070)$ 

### Σ(2030) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on  $\varLambda$  and  $\varSigma$ 

Resonances.				
$\Gamma(N\overline{K})/\Gamma_{\text{total}}$				$\Gamma_1/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT
0.17 to 0.23 OUR ESTIMATE 0.19 ± 0.03	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
0.18±0.03				$K^-p \to \overline{K}N$
• • We do not use the following	ig data for average	s, fits	s, limits,	etc. • • •
0.15	DECLAIS	77	DPWA	$\overline{K}N \rightarrow \overline{K}N$
$0.24 \pm 0.02$	GOPAL	77	DPWA	See GOPAL 80
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K} \to \Sigma$	'2030) → Λπ			(Γ₁Γ₂) ^½ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
+0.18 ±0.02	GOPAL	77	DPWA	$\overline{K}N$ multichannel
+0.20 ±0.01	1 CORDEN			$K^- n \rightarrow \Lambda \pi^-$
+0.18 ±0.02 +0.20 ±0.01	BAILLON VANHORN		IPWA DPWA	$\overline{K}N \to \Lambda\pi$ $K^- p \to \Lambda\pi^0$
+0.195±0.053	DEVENISH	74B		Fixed-t dispersion rel.
• • We do not use the following	ng data for average	s, fits	s, limits,	etc. • • •
0.20	DEBELLEFON	76	IPWA	$\kappa^- \rho \rightarrow \Lambda \pi^0$
1/				1/
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to \Sigma$	$(2030) \rightarrow \Sigma \pi$ $DOCUMENT ID$		TECN	(Γ ₁ Γ ₃ ) ^{1/2} /Γ
-0.09 ±0.01	² CORDEN	770		$K^- n \rightarrow \Sigma \pi$
-0.06 ±0.01	² CORDEN	770		$K^- n \rightarrow \Sigma \pi$
$-0.15 \pm 0.03$	GOPAL			KN multichannel
-0.10 ±0.01	KANE			$K^-p \rightarrow \Sigma \pi$
• • We do not use the following	³ GOYAL			$K^-N \rightarrow \Sigma \pi$
$-0.085 \pm 0.02$	GOYAL	"	DPWA	$K N \rightarrow \Sigma \pi$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K} \to \Sigma($	2030) → <i>Ξ K</i>			(Γ₁Γ₄) ^⅓ 2/Γ
VALUE	DOCUMENT ID			
0.023	MULLER BURGUN			$K^- \rho \rightarrow \Xi K$ $K^- \rho \rightarrow \Xi K$
<0.05 <0.05	TRIPP			$K^-p \rightarrow \Xi K$
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\overline{K} \to \Sigma$	2030) → Λ(182	0)π	, P-wav	e (Γ ₁ Γ ₁₆ ) ^½ /Γ
0.14±0.02	CORDEN		DBC	
$0.18 \pm 0.04$	LITCHFIELD	740	DPWA	$K^- \rho \rightarrow \Lambda(1820)\pi^0$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K} \to \Sigma($	2030) 4(152	n\~	Duran	re (Γ₁Γ ₈ ) ^½ /Γ
VALUE	DOCUMENT ID			
$+0.114\pm0.010$	⁴ CAMERON	77	DPWA	$K^- p \rightarrow \Lambda(1520) \pi^0$
0.14 ±0.03				$K^- p \rightarrow \Lambda(1520) \pi^0$
• • We do not use the following				
0.10 ±0.03	⁵ CORDEN	75B	DBC	$K^- n \rightarrow N \overline{K} \pi^-$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to \Sigma($	2030) → Λ(152	0)π	, <i>G</i> -wav	re (Γ ₁ Γ ₉ ) ^{1/2} /Γ
VALUE + 0.146 ± 0.010	4 CAMERON			$K^- \rho \rightarrow \Lambda(1520)\pi^0$
+0.146±0.010 0.02 ±0.02				$K^- p \rightarrow \Lambda(1520)\pi^0$ $K^- p \rightarrow \Lambda(1520)\pi^0$
				, , ,
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K} \to \Sigma($				
VALUE	DOCUMENT ID			
0.16±0.03 • • • We do not use the following				$K^- p \rightarrow \Delta(1232)\overline{K}$
0.17±0.03	⁵ CORDEN		DBC	$K^- n \rightarrow N \overline{K} \pi^-$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to \Sigma$	2030) → Δ(123	32) <i>T</i> k	₹, <i>H</i> -wa	ve (Γ ₁ Γ ₁₂ ) ^{1/2} /Γ
0.00±0.02	LITCHFIELD	740	DPWA	$\frac{COMMENT}{K^- p \to \Delta(1232)\overline{K}}$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to \Sigma$				(Γ ₁ Γ ₅ ) ^{1/2} /Γ
$( f f)^2/ total  \text{ in } NK \rightarrow \Sigma($ VALUE	ZU3U) → Z(13E	$\sigma$	TECN	(1115)"/I
+0.153±0.026	4 CAMERON	78	DPWA	$\frac{COMMENT}{K^- p \rightarrow \Sigma(1385)\pi}$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to \Sigma$				
('I'I) /'total'''AN -7 2	(	رعور	,, 5-1/	$(\Gamma_1\Gamma_{14})^{\frac{1}{2}}/\Gamma$
VALUE	DOCUMENT ID		TECN	( 1 14) / / COMMENT
	4 CAMERON			$K^- p \rightarrow N \overline{K}^*$
$+0.06\pm0.03$	CAMERON	100	DI ***	p

CORDEN 778  $K^- D \rightarrow N \overline{K}^*$   $K^- D \rightarrow N N \overline{K}^*$ 

 $+\,0.06\pm0.03$  $-0.02 \pm 0.01$ 

### $(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}}$ in $N\overline{K} \to \Sigma(2030) \to N\overline{K}^*(892)$ , S=3/2, F-wave

 $(\Gamma_1\Gamma_{15})^{\frac{1}{12}}/\Gamma$ TECN COMMENT DOCUMENT ID 6 CAMERON 788 DPWA  $K^-p \rightarrow N\overline{K}^*$  $+0.04 \pm 0.03$  $K^-d \rightarrow NN\overline{K}^*$  $-0.12 \pm 0.02$ CORDEN 77B

#### $\Sigma$ (2030) FOOTNOTES

- 1 Preferred solution 3; see CORDEN 76 for other possibilities.
  2 The two entries for CORDEN 77c are from two different acceptable solutions.
- ³ This coupling is extracted from unnormalized data.
- This coupling is extracted from uniformatical uses.

  4 The published sign has been changed to be in accord with the baryon-first convention.

  5 An upper limit.
- ⁶ The upper limit on the  $G_3$  wave is 0.03.

### Σ(2030) REFERENCES

PDG	84	RMP 56 No. 2 Pt. II	I Wohl, Cahn, Rittenberg+ (LBL, CIT, CERN)	
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+ (HELS, CIT, CERN)	
GOPAL	80	Toronto Conf. 159	(RHEL) IJ	IP.
CAMERON	78	NP B143 189	+Franek, Gopal, Bacon, Butterworth+ (RHEL, LOIC) IJ	P
CAMERON	78B	NP B146 327	+Franek, Gopai, Kalmus, McPherson+ (RHEL, LOIC) IJ	P
CAMERON	77	NP B131 399	+Franek, Gopal, Kalmus, McPherson+ (RHEL, LOIC) IJ	P
CORDEN	77B	NP B121 365	+Cox, Kenyon, O'Neale, Stubbs, Sumorok+ (BIRM) IJ	P
CORDEN	77C	NP B125 61	+Cox, Kenyon, O'Neale, Stubbs, Sumorok+ (BIRM) IJ	IP.
DECLAIS	77	CERN 77-16	+Duchon, Louvel, Patry, Seguinot+ (CAEN, CERN) IJ	P
GOPAL	77	NP B119 362	+Ross, VanHorn, McPherson+ (LOIC, RHEL) IJ	IP.
GOYAL	77	PR D16 2746	+Sodhi (DELH) IJ	IP.
CORDEN	76	NP B104 382	+Cox, Dartnell, Kenyon, O'Neale+ (BIRM) IJ	iΡ
DEBELLEFON	76	NP B109 129	De Beilefon, Berthon (CDEF) IJ	
BAILLON	75	NP B94 39	+Litchfield (CERN, RHEL) IJ	
CORDEN	75B	NP B92 365	+Cox, Dartnell, Kenyon, O'Neale+ (BIRM) IJ	
HEMINGWAY	75	NP B91 12	+Eades, Harmsen+ (CERN, HEIDH, MPIM) IJ	
VANHORN	75	NP B87 145	(LBL) IJ	
Also	75B	NP B87 157	VanHorn (LBL) IJ	Ρ
DEVENISH	74B	NP B81 330	+Froggatt, Martin (DESY, NORD, LOUC)	
KANE	74	LBL-2452	(LBL) IJ	
LITCHFIELD	74B	NP B74 19	+Hemingway, Baillon+ (CERN, HEIDH) IJ	
LITCHFIELD	74C	NP B74 39	+Hemingway, Baillon+ (CERN, HEIDH) IJ	
LITCHFIELD	74D	NP B74 12	+Hemingway, Baillon+ (CERN, HEIDH) IJ	Ρ
MULLER	69B	Thesis UCRL 19372	(LRL)	
BURGUN	68	NP B8 447	+Meyer, Pauli, Tallini+ (SACL, CDEF, RHEL)	
TRIPP	67	NP B3 10	+Leith+ (LRL, SLAC, CERN, HEID, SACL)	
COOL	66	PRL 16 1228	+Giacomelli, Kycia, Leontic, Lundby+ (BNL)	
WOHL	66	PRL 17 107	+Solmitz, Stevenson (LRL) IJ	P

## $\Sigma(2070) F_{15}$

 $I(J^P) = 1(\frac{5}{2}^+)$  Status: *

### OMITTED FROM SUMMARY TABLE

This state suggested by BERTHON 70B finds support in GOPAL 80 with new  $K^-p$  polarization and  $K^-n$  angular distributions. The very broad state seen in KANE 72 is not required in the later (KANE 74) analysis of  $\overline{K}N \to \Sigma \pi$ .

### Σ(2070) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 2070 OUR ESTIMATE				
$2051 \pm 25$	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
2057	KANE	72	DPWA	$K^- p \rightarrow \Sigma \pi$
$2070 \pm 10$	BERTHON	70B	DPWA	$K^- p \rightarrow \Sigma \pi$

### Σ(2070) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
300±30	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
906	KANE	72	DPWA	$K^- p \rightarrow \Sigma \pi$
140±20	BERTHON	<b>7</b> 08	DPWA	$K^- p \rightarrow \Sigma \pi$

### Σ(2070) DECAY MODES

	Mode	
Γ ₁	NK	
$\Gamma_2$	$\sum \pi$	

#### Σ(2070) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on  $\varLambda$  and  $\varSigma$ Resonances.

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$							$\Gamma_1/\Gamma$
VALUE		DOCUMENT ID		TECN	COMMENT	Г	
$0.08 \pm 0.03$		GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}$	ΚN	
14	=/0/	·=•\ =				<b>/</b> = =	.4. <u>.</u> -

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to \Sigma(2070) \to \Sigma \pi$					$(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT	
+0.104	KANE	72	DPWA	$K^-p \rightarrow$	$\Sigma \pi$
+0.12 ±0.02	BERTHON	70B	DPWA	$K^-p \rightarrow$	$\Sigma \pi$

### Σ(2070) REFERENCES

GOPAL	80	Toronto Conf.
KANE	74	LBL-2452
KANE	72	PR D5 1583
RERTHON	70B	NP R24 417

+Vrana, Butterworth+

(RHEL) IJP (LBL) (LBL) (CDEF, RHEL, SACL) IJP

## $\Sigma(2080) P_{13}$

$$I(J^P) = 1(\frac{3}{2}^+)$$
 Status: **

#### OMITTED FROM SUMMARY TABLE

Suggested by some but not all partial-wave analyses across this region

•	Σ(2080) MASS
VALUE (MeV)	DOCUMENT ID TECN COMMENT
≈ 2080 OUR ESTIMATE	
2091 ± 7	¹ CORDEN 76 DPWA $K^- n \rightarrow \Lambda \pi^-$
2070 to 2120	DEBELLEFON 76 IPWA $K^- p \rightarrow \Lambda \pi^0$
2120±40	BAILLON 75 IPWA $\overline{K}N \rightarrow \Lambda\pi$ (sol. 1)
2140 ± 40	BAILLON 75 IPWA $\overline{K}N \rightarrow \Lambda \pi$ (sol. 2)
2082± 4	COX 70 DPWA See CORDEN 76
$2070\pm30$	LITCHFIELD 70 DPWA $K^-N  o \Lambda\pi$
	Σ(2080) WIDTH
VALUE (MeV)	DOCUMENT ID TECN COMMENT
186±48	¹ CORDEN 76 DPWA $K^- n \rightarrow \Lambda \pi^-$
100	DEBELLEFON 76 IPWA $K^-p \rightarrow \Lambda \pi^0$
240±50	BAILLON 75 IPWA $\overline{K}N \rightarrow \Lambda\pi$ (sol. 1)
200±50	BAILLON 75 IPWA $\overline{K}N \rightarrow \Lambda \pi$ (sol. 2)
87±20	COX 70 DPWA See CORDEN 76
250 ± 40	LITCHFIELD 70 DPWA $K^-N \rightarrow \Lambda\pi$

#### Σ(2080) DECAY MODES

	Mode	
Γ ₁	NK	
$\Gamma_2$	$\Lambda\pi$	

#### $\Sigma$ (2080) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on  $\varLambda$  and  $\varSigma$  Resonances.

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \rightarrow$			$(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma$
VALUE	DOCUMENT ID	TECN	COMMENT
$-0.10 \pm 0.03$			$K^- n \rightarrow \Lambda \pi^-$
-0.10	DEBELLEFON 76	IPWA	$K^- \rho \rightarrow \Lambda \pi^0$
$-0.13 \pm 0.04$	BAILLON 75	IPWA	$\overline{K}N \rightarrow \Lambda\pi$ (sol. 1 and
$-0.16 \pm 0.03$	COX 70	DPWA	See CORDEN 76
$-0.09\pm0.03$	LITCHFIELD 70	DPWA	$K^- N \rightarrow \Lambda \pi$

### Σ(2080) FOOTNOTES

 $^{1}\,\mathrm{Preferred}$  solution 3; see CORDEN 76 for other possibilities, including a  $D_{15}$  at this mass.

### Σ(2080) REFERENCES

CORDEN	76	NP B104 382	+Cox, Dartnell, Kenyon, O'Neale+	(BIRM) IJP
DEBELLEFON	76	NP B109 129	De Bellefon, Berthon	(CDEF) IJP
Also	75	NP B90 1	De Bellefon, Berthon, Brunet+	(CDEF, SACL) IJP
BAILLON	75	NP B94 39	+Litchfield	(CERN, RHEL) IJP
cox	70	NP B19 61	+Islam, Colley+ (BIF	RM, EDIN, GLAS, LOIC) IJP
LITCHFIELD	70	NP B22 269		(RHEL) IJP

## $\Sigma$ (2100) $G_{17}$

 $I(J^P) = 1(\frac{7}{2})$  Status: *

OMITTED FROM SUMMARY TABLE

•	121	nn۱	MASS
2	121	w	MASS

VALUE (MeV)
≈ 2100 OUR ESTIMATE
2060 ± 20
2120±30

DOCUMENT ID TECN COMMENT

BARBARO-... 70 DPWA  $K^-p \rightarrow \Lambda \pi^0$ BARBARO-... 70 DPWA  $K^-p \rightarrow \Sigma \pi$ 

#### Σ(2100) WIDTH

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
70±30	BARBARO 70	DPWA	$K^- \rho \rightarrow \Lambda \pi^0$
$135 \pm 30$	BARBARO 70	DPWA	$K^- p \rightarrow \Sigma \pi$

### Σ(2100) DECAY MODES

	Mode
Γ ₁	NK
$\Gamma_2$	$\Lambda\pi$
Γ ₃	$\Sigma\pi$

#### Σ(2100) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on  $\varLambda$  and  $\varSigma$  Resonances.

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to \Sigma (21)$	(Γ ₁ Γ ₂ ) ^½ /Γ		
VALUE	DOCUMENT ID	TECN	COMMENT
$-0.07 \pm 0.02$	BARBARO 70	DPWA	$K^- \rho \rightarrow \Lambda \pi^0$

$$\begin{array}{c|c} \left( \Gamma_{I} \Gamma_{f} \right)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \rightarrow \underbrace{\Gamma(2100) \rightarrow \Sigma \pi}_{DOCUMENT \ ID} & \underbrace{TECN}_{COMMENT} & \underbrace{COMMENT}_{COMMENT} \\ + 0.13 \pm 0.02 & BARBARO-... & 70 & DPWA & K^{-}p \rightarrow \Sigma \pi \end{array}$$

### $\Sigma$ (2100) REFERENCES

BARBARO-... 70 Duke Conf. 173

Barbaro-Galtieri

(LRL) IJP

 $\Sigma$ (2250)

$$I(J^P) = 1(??)$$
 Status: ***

Results from partial-wave analyses are too weak to warrant separating them from the production and cross-section experiments. LASINSKI 71 in  $\overline{K}N$  using a Pomeron + resonances model, and DEBELLEFON 76, DEBELLEFON 77, and DEBELLEFON 78 in energy-dependent partial-wave analyses of  $\overline{K}N \to \Lambda\pi$ ,  $\Sigma\pi$ , and  $N\overline{K}$ , respectively, suggest two resonances around this mass.

#### Σ(2250) MASS

VALUE (MeV)	DOCUMENT ID TECN COMMENT
2210 to 2280 (≈ 2250)	OUR ESTIMATE
2270±50	DEBELLEFON 78 DPWA D ₅ wave
2210±30	DEBELLEFON 78 DPWA $G_q$ wave
$2275 \pm 20$	DEBELLEFON 77 DPWA D ₅ wave
2215±20	DEBELLEFON 77 DPWA $G_{q}$ wave
2300 ± 30	¹ DEBELLEFON 75B HBC $\kappa^- p \rightarrow \equiv^{*0} \kappa^0$
$2251 + 30 \\ -20$	VANHORN 75 DPWA $K^- p  ightarrow \Lambda \pi^0$ , $F_5$ wave
$2280 \pm 14$	AGUILAR 70B HBC $K^{-}p$ 3.9, 4.6 GeV/c
2237±11	BRICMAN 70 CNTR Total, charge exchange
$2255 \pm 10$	COOL 70 CNTR $K^-p$ , $K^-d$ total
2250± 7	BUGG 68 CNTR $K^-p$ , $K^-d$ total
<ul> <li>• • We do not use th</li> </ul>	ne following data for averages, fits, limits, etc. • • •
2260	DEBELLEFON 76 IPWA D ₅ wave
2215	DEBELLEFON 76 IPWA $G_{q}$ wave
2250 ± 20	LU 70 CNTR $\gamma p \rightarrow K^+ Y^*$
2245	BLANPIED 65 CNTR $\gamma p \rightarrow \kappa^+ Y^*$
2299± 6	BOCK 65 HBC $\overline{p}p$ 5.7 GeV/c

# Baryon Particle Listings $\Sigma$ (2250), $\Sigma$ (2455) Bumps

Σ(2250) WIDTH
---------------

VALUE (MeV)	DOCUMENT ID TECN COMMENT
60 to 150 (≈ 100) OUR ESTIMA	TE
120±40	DEBELLEFON 78 DPWA D ₅ wave
80±20	DEBELLEFON 78 DPWA $G_{q}$ wave
70 ± 20	DEBELLEFON 77 DPWA D ₅ wave
60 ± 20	DEBELLEFON 77 DPWA G ₉ wave
130±20	¹ DEBELLEFON 75B HBC $K^-p \rightarrow \Xi^{*0}K^0$
192±30	VANHORN 75 DPWA $K^-p \rightarrow \Lambda \pi^0$ , $F_5$ wav
100 ± 20	AGUILAR 70B HBC K-p 3.9, 4.6 GeV/c
164±50	BRICMAN 70 CNTR Total, charge exchange
230 ± 20	BUGG 68 CNTR $K^-p$ , $K^-d$ total
<ul> <li>• • We do not use the following</li> </ul>	g data for averages, fits, limits, etc. • • •
100	DEBELLEFON 76 IPWA D ₅ wave
140	DEBELLEFON 76 IPWA $G_9$ wave
170	COOL 70 CNTR $K^-p$ , $K^-d$ total
125	LU 70 CNTR $\gamma \rho \rightarrow K^+ Y^*$
150	BLANPIED 65 CNTR $\gamma p \rightarrow K^+ Y^*$
$21^{+17}_{-21}$	BOCK 65 HBC $\bar{p} p$ 5.7 GeV/c

### Σ(2250) DECAY MODES

	Mode	Fraction $(\Gamma_i/\Gamma)$
Γ ₁	NK	<10 %
$\Gamma_2$	$\Lambda\pi$	seen
Γ3	$\Sigma \pi$	seen
Γ ₃ Γ ₄	$N\overline{K}\pi$	
Γ ₅	<i>Ξ</i> (1530) <i>K</i>	
	The above branching fractions are or	ur estimates, not fits or averages.

#### Σ(2250) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on  $\varLambda$  and  $\varSigma$ 

Resonances.		Ü		
$\Gamma(N\overline{K})/\Gamma_{\text{total}}$				Γ ₁ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
<0.1 OUR ESTIMATE				
$0.08 \pm 0.02$	DEBELLEFON	78		
$0.02 \pm 0.01$	DEBELLEFON	78	DPWA	G ₉ wave
$(J+\frac{1}{2})\times\Gamma(N\overline{K})/\Gamma_{\text{total}}$				$\Gamma_1/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following	data for averages	, fits	s, limits,	etc. • • •
$0.16 \pm 0.12$	BRICMAN	70	CNTR	Total, charge exchange
0.42	COOL	70	CNTR	$K^-p$ , $K^-d$ total
0.47	BUGG	68		
1/				14.
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to \Sigma(22)$				(Γ₁Γ₂) ^⅓ /Γ
VALUE	DOCUMENT ID			
$-0.16 \pm 0.03$	VANHORN	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$ , $F_5$ wave
ullet $ullet$ We do not use the following	data for average	, fit	s, limits,	etc. • • •
+0.11	DEBELLEFON	76	IPWA	D ₅ wave
-0.10	DEBELLEFON			
-0.18	BARBARO	70	DPWA	$K^- p \rightarrow \Lambda \pi^0$ , $G_9$ wave
14	>			(Γ₁Γ₃) ^⅓ /Γ
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to \Sigma(22)$				
VALUE	DOCUMENT ID			COMMENT
$+0.06\pm0.02$	DEBELLEFON			
$-0.03 \pm 0.02$	DEBELLEFON			
+0.07	BARBARO	70	DPWA	$K^- p \rightarrow \Sigma \pi$ , $G_9$ wave
$\Gamma(N\overline{K})/\Gamma(\Sigma\pi)$				$\Gamma_1/\Gamma_3$
VALUE	DOCUMENT ID		TECN	COMMENT
<ul> <li>● We do not use the following</li> </ul>	data for average	s, fit	s, limits,	etc. • • •
< 0.18	BARNES	69	нвс	1 standard dev. limit
$\Gamma(\Lambda\pi)/\Gamma(\Sigma\pi)$				$\Gamma_2/\Gamma_3$
VALUE	DOCUMENT ID		TECN	COMMENT
• • We do not use the following		s, fit		

### Σ(2250) FOOTNOTES

69 HBC 1 standard dev. limit

(Г₁Г₅)^½/Г

BARNES

 $(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K} \to \Sigma(2250) \to \Xi(1530) K$ 

 $0.18 \pm 0.04$ 

#### Σ(2250) REFERENCES

DEBELLEFON	78	NC 42A 403	De Bellefon, Berthon, Billoir+	(CDEF, SACL) IJP
DEBELLEFON	77	NC 37A 175	De Bellefon, Berthon, Billoir+	(CDEF, SACL) IJP
DEBELLEFON	76	NP B109 129	De Bellefon, Berthon	(CDEF) IJP
Also	75	NP B90 1	De Bellefon, Berthon, Brunet+	(CDEF, SACL) IJP
DEBELLEFON	75B	NC 28A 289		(CDEF, SACL)
VANHORN	75	NP B87 145		(LBL) IJP
Also	75B	NP B87 157	VanHorn	(LBL) IJP
LASINSKI	71	NP B29 125		(EFI) IJP
AGUILAR	70B	PRL 25 58	Aguilar-Benitez, Barnes, Bassano+	(BNL, SÝRA)
BARBARO	70	Duke Conf. 173	Barbaro-Galtieri	(LRL) IJP
BRICMAN	70	PL 31B 152	+Ferro-Luzzi, Perreau+ (CERN,	CAEN, SACL)
COOL	70	PR D1 1887	+Giacomelli, Kycia, Leontic, Li+	(BNL) I
Also	66	PRL 16 1228	Cool, Giacomelli, Kycia, Leontic, Lundby+	(BNL) I
LU	70	PR D2 1846	+Greenberg, Hughes, Minehart, Mori+	(ŶALE)
BARNES	69	PRL 22 479	+Flaminio, Montanet, Samios+	(BNL, SYRA)
BUGG	68	PR 168 1466	+Gilmore, Knight+ (RHEL,	BIRM, CAVE) I
BLANPIED	65	PRL 14 741	+Greenberg, Hughes, Kitching, Lu+	(YALE, CEA)
BOCK	65	PL 17 166	+Cooper, French, Kinson+	(ČERN, SACL)

## $\Sigma$ (2455) Bumps

 $I(J^P) = 1(??)$  Status: **

### OMITTED FROM SUMMARY TABLE

There is also some slight evidence for  $Y^*$  states in this mass region from the reaction  $\gamma p \rightarrow K^+ X$  — see GREENBERG 68.

#### Σ(2455) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 2455 OUR ESTIMATE				
2455±10	ABRAMS	70	CNTR	$K^-p$ , $K^-d$ total
2455 ± 7	BUGG	68	CNTR	$K^-p$ , $K^-d$ total

### Σ(2455) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
140	ABRAMS	70	CNTR	$K^-p$ , $K^-d$ total	
100 ± 20	BUGG	68	CNTR		

### Σ(2455) DECAY MODES

 $N\overline{K}$ 

### Σ(2455) BRANCHING RATIOS

$(J+\frac{1}{2})\times\Gamma(NK)/\Gamma_{\text{total}}$				$\Gamma_1/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT
0.39	ABRAMS	70	CNTR	$K^-p$ , $K^-d$ total
$0.05 \pm 0.05$	¹ BRICMAN	70	CNTR	Total, charge exchange
0.3	BUGG	68	CNTR	
and the second s				

### $\Sigma$ (2455) FOOTNOTES

¹ Fit of total cross section given by BRICMAN 70 is poor in this region.

### Σ(2455) REFERENCES

ABRAMS	70	PR D1 1917	+Cool, Giacomelli, Kycia, Leontic,	Li+	(BNL) I
Also	67E	PRL 19 678	Abrams, Cool, Giacomelli, Kycia,	Leontic+	(BNL)
BRICMAN	70	PL 31B 152	+Ferro-Luzzi, Perreau+	(CERN,	CAEN, SACL)
BUGG	68	PR 168 1466	+Gilmore, Knight+	(RHEL,	BIRM, CAVE) I
GREENBERG	68	PRL 20 221	+Hughes, Lu, Minehart+		(YALE)
			-		

 $^{^{1}\}mathrm{Seen}$  in the (initial and final state)  $D_{5}$  wave. Isospin not determined.

 $\Sigma$ (2620) Bumps,  $\Sigma$ (3000) Bumps,  $\Sigma$ (3170) Bumps

$\Sigma$ (2620)	Bumps
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 $I(J^P) = 1(?^?)$  Status: **

#### OMITTED FROM SUMMARY TABLE

Σ(2620) MASS					
VALUE (MeV) ≈ 2620 OUR ESTIMATE	DOCUMENT ID		TECN	COMMENT	
2542±22	DIBIANCA	75	DBC	$K^- N \rightarrow \Xi K \pi$	
$2620\pm15$	ABRAMS	70	CNTR	$K^-p$ , $K^-d$ total	
	Σ(2620) WID	тн			
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
$221\pm81$	DIBIANCA	75	DBC	$K^- N \rightarrow \Xi K \pi$	
175	ABRAMS	70	CNTR	$K^-p$ , $K^-d$ total	

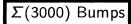
### Σ(2620) DECAY MODES

	Mode			
Γ ₁	NK			

#### Σ(2620) BRANCHING RATIOS

$(J+\frac{1}{2})\times\Gamma(N\overline{K})/\Gamma_{\text{total}}$				Γ ₁ /
VALUE	DOCUMENT ID		TECN	COMMENT
0.32	ABRAMS	70	CNTR	$K^-p$ , $K^-d$ total
$0.36 \pm 0.12$	BRICMAN	70	CNTR	Total, charge exchange

$\Sigma$ (2620) REFERENCES						
DIBIANCA 75	NP B98 137	+Endorf				
ABRAMS 70	PR D1 1917	+Cool, Giacomelli, Kycia, Leontic, Li+				
Also 67E	PRL 19 678	Abrams, Cool, Giacomelli, Kycia, Lei				
BRICMAN 70	PL 31B 152	+Ferro-Luzzi, Perreau+				



 $I(J^P) = 1(??)$  Status: *

### OMITTED FROM SUMMARY TABLE

Seen as an enhancement in  $\Lambda\pi$  and  $\overline{K}\,N$  invariant mass spectra and in the missing mass of neutrals recoiling against a  $K^0$ .

#### Σ(3000) MASS

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
≈ 3000 OUR ESTIMATE 3000	EHRLICH	66	нвс	0	$\pi^- p$ 7.91 GeV/ $c$

### Σ(3000) DECAY MODES

	Mode	 			
Γ ₁	N <del>K</del> Λπ			 	
Γ2	$\Lambda\pi$				

#### Σ(3000) REFERENCES

EHRLICH	66	PR 152 1194	+Selove, Yuta	(PENN) I
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## $\Sigma$ (3170) Bumps

 $I(J^P) = 1(??)$  Status: *

#### OMITTED FROM SUMMARY TABLE

Seen by AMIRZADEH 79 as a narrow 6.5-standard-deviation enhancement in the reaction  $K^-p \rightarrow Y^{*+}\pi^-$  using data from independent high statistics bubble chamber experiments at 8.25 and  $6.5~{
m GeV}/c$ . The dominant decay modes are multibody, multistrange final states and the production is via isospin-3/2 baryon exchange. Isospin 1 is favored.

Not seen in a  $K^-p$  experiment in LASS at 11 GeV/c (ASTON 85B).

#### Σ(3170) MASS (PRODUCTION EXPERIMENTS)

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
≈ 3170 OUR ESTI		A14107 A DELL 30	unc	v v*+ -
3170±5	35	AMIRZADEH 79	HRC	$K^- \rho \rightarrow Y^{*+} \pi^-$

#### Σ(3170) WIDTH (PRODUCTION EXPERIMENTS)

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
<20	35	¹ AMIRZADEH 79	нвс	$K^- p \rightarrow Y^{*+} \pi^-$

#### Σ(3170) DECAY MODES (PRODUCTION EXPERIMENTS)

	Mode	Fraction $(\Gamma_j/\Gamma)$
$\overline{\Gamma_1}$	$\Lambda K \overline{K} \pi$ 's	seen
$\Gamma_2$	$\Sigma K \overline{K} \pi$ 's	seen
$\Gamma_3$	Ξ K π's	seen

#### $\Sigma$ (3170) BRANCHING RATIOS (PRODUCTION EXPERIMENTS)

$\Gamma(\Lambda K \overline{K} \pi 's) / \Gamma_{total}$				$\Gamma_1/\Gamma$
VALUE	DOCUMENT ID		TECN	COMMENT
seen	AMIRZADEH	79	нвс	$K^- \rho \rightarrow Y^{*+} \pi^-$
$\Gamma(\Sigma K \overline{K} \pi's)/\Gamma_{total}$				Γ ₂ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
seen	AMIRZADEH	79	HBC	$K^- \rho \rightarrow Y^{*+} \pi^-$
$\Gamma(\Xi K \pi 's)/\Gamma_{total}$				Г ₃ /Г
VALUE	DOCUMENT ID		TECN	COMMENT
seen	AMIRZADEH	79	нвс	$K^- \rho \rightarrow Y^{*+} \pi^-$

#### $\Sigma$ (3170) FOOTNOTES (PRODUCTION EXPERIMENTS)

#### Σ(3170) REFERENCES (PRODUCTION EXPERIMENTS)

ASTON	85B	PR D32 2270		+Carnegie+	(SLAC, CARL, CNRC, CINC)
AMIRZADEH	79	PL 89B 125		+	(BIRM, CERN, GLAS, MSU, CURIN, CAVE+) I
Also	80	Toronto Conf.	263	Kinson+	(BIRM, CERN, GLAS, MSU, CURIN) I

¹Observed width consistent with experimental resolution.

## **E BARYONS** (S=-2, I=1/2)

$$\Xi^0 = uss$$
,  $\Xi^- = dss$ 



$$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$$
 Status: ***

The parity has not actually been measured, but + is of course expected.

### **≡**⁰ MASS

The fit uses the  $\Xi^0,~\Xi^-,~{\rm and}~\overline{\Xi}{}^+$  mass and mass difference measure-

VALUE (MeV)	EVTS	DOCUMENT ID	TECN		
1314.9±0.6 OUR	-IT				
1314.8±0.8 OUR	<b>WERAGE</b>				
$1315.2 \pm 0.92$	49	WILQUET	72	HLBC	
$1313.4 \pm 1.8$	1	PALMER	68	HBC	

#### $m_{\Xi^-} - m_{\Xi^0}$

The fit uses the  $\Xi^0$ ,  $\Xi^-$ , and  $\overline{\Xi}^+$  mass and mass difference measure-

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT	
6.4±0.6 OUR FIT					
6.3±0.7 OUR AVE	RAGE				
$6.9 \pm 2.2$	29	LONDON	66 HBC		
$6.1 \pm 0.9$	88	PJERROU	65B HBC		
$6.8 \pm 1.6$	23	JAUNEAU	63 FBC		
• • • We do not i	use the followin	g data for averag	es, fits, limits	, etc. • • •	
$6.1 \pm 1.6$	45	CARMONY	64B HBC	See PJERROU 658	3

### **≡**0 MEAN LIFE

VALUE (10-10 s)	EVTS	DOCUMENT ID		TECN	COMMENT
2.90±0.09 OUR AV	ERAGE				
$2.83 \pm 0.16$	6300	¹ ZECH	77	SPEC	Neutral hyperon beam
$2.88^{+0.21}_{-0.19}$	652	BALTAY	74	нвс	1.75 GeV/ $c~K^-p$
$2.90 ^{+ 0.32}_{- 0.27}$	157	² MAYEUR	72	HLBC	$2.1~{\rm GeV}/c~{\rm K}^-$
$3.07 + 0.22 \\ -0.20$	340	DAUBER	69	нвс	
3.0 ±0.5	80	PJERROU	65B	HBC	
$\begin{array}{ccc} +0.4 \\ -0.3 \end{array}$	101	HUBBARD	64	нвс	
$3.9 \begin{array}{c} +1.4 \\ -0.8 \end{array}$	24	JAUNEAU	63	FBC	
• • • We do not us	e the following	ng data for average	es, fits	, limits,	, etc. • • •
$3.5 \begin{array}{c} +1.0 \\ -0.8 \end{array}$	45	CARMONY	64B	нвс	See PJERROU 658
1 The ZECH 77 re $^{2.63 \times 10^{-10}}$ s.		$= [2.77 - (\tau_{\Lambda} - 2.6)]$	59)] ×	10-10	s, in which we use $ au_A$

#### **≡**⁰ MAGNETIC MOMENT

See the "Note on Baryon Magnetic Moments" in the  $\ensuremath{\varLambda}$  Listings.

$VALUE(\mu_N)$	EVTS	DOCUMENT I	TECN	
-1.250±0.014 OUR	AVERAGE			
$-1.253 \pm 0.014$	270k	cox	81	SPEC
$-1.20 \pm 0.06$	42k	BUNCE	79	SPEC

#### **≡**⁰ DECAY MODES

	Mode	Fraction $(\Gamma_{\hat{I}}/\Gamma)$ Co	nfidence level
$\Gamma_1$	$\Lambda \pi^0$	(99.54±0.05) %	
$\Gamma_2$	$\Lambda\gamma$	$(1.06\pm0.16)\times10^{-3}$	
$\Gamma_3^-$	$\Sigma^0 \gamma$	$(3.5 \pm 0.4) \times 10^{-3}$	
Γ₄	$\Sigma^+ e^- \overline{\nu}_e$	$< 1.1 \times 10^{-3}$	90%
Γ ₅	$\Sigma^+\mu^-\overline{\nu}_{\mu}$	$< 1.1 \times 10^{-3}$	90%

#### $\Delta S = \Delta Q$ (SQ) violating modes or $\Delta S = 2$ forbidden (S2) modes × 10⁻⁴ SQ 90% × 10⁻⁴ SQ 90% < 9 $\times$ 10⁻⁵ 52 < 4 90% × 10⁻³ S2 < 1.3 52 $\times$ 10⁻³

### CONSTRAINED FIT INFORMATION

An overall fit to 2 branching ratios uses 2 measurements and one constraint to determine 3 parameters. The overall fit has a  $\chi^2=$ 0.0 for 0 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients  $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$ , in percent, from the fit to the branching fractions,  $x_i \equiv$  $\Gamma_i/\Gamma_{\mathrm{total}}$ . The fit constrains the  $x_i$  whose labels appear in this array to sum to

$$\begin{array}{c|cccc}
x_2 & -35 \\
x_3 & -94 & 0 \\
\hline
& x_1 & x_2
\end{array}$$

 $\varSigma^-\,e^+\,\nu_e$ 

 $\Sigma^-\mu^+\nu_\mu 
onumber 
onumber$ 

 $pe^-\overline{\nu}_e$ 

 $p\mu^-\overline{\nu}_{\mu}$ 

Γ₆ Γ₇ Γ₈ Γ₉

### **≡**⁰ BRANCHING RATIOS

$\Gamma(\Lambda\gamma)/\Gamma(\Lambda\pi^0)$						$\Gamma_2/\Gamma_1$
VALUE (units 10 ⁻³ )	EVTS	DOCUMENT ID		TECN	COMMENT	-, -
1.06±0.16 OUR FIT						
1.06±0.12±0.11	116	JAMES	90	SPEC	FNAL hyperons	
• • • We do not us	e the following	data for average	s, fit	s, limits,		
5 ±5	1	YEH	74	нвс	Effective denom.	=200
$\Gamma(\Sigma^0\gamma)/\Gamma(\Lambda\pi^0)$						$\Gamma_3/\Gamma_1$
VALUE (units 10 ⁻³ )	CL%EVTS	DOCUMEN	T ID	TE	CN COMMENT	
3.6 ±0.4 OUR 3.56±0.42±0.10		TEIGE		89 SF	PEC FNAL hypero	nnc .
• • • We do not us			s. fit			7115
< 8 <65	90 90 0-1	BENSING YEH	EK	88 M 74 H	PS2 K ⁻ W 6 Ge ¹ BC Effective de- nom.=60	V / C
$\Gamma(\Sigma^+ e^- \overline{\nu}_e) / \Gamma(e^+ e^- \overline{\nu}_e) / \Gamma(e^- e^- e^- \overline{\nu}_e) / \Gamma(e^- e^- e^- e^- e^- e^- e^- e^- e^- e^- $	1π ⁰ )					$\Gamma_4/\Gamma_1$
VALUE (units 10 ⁻³ )	L% EVTS	DOCUMENT ID		TECN	COMMENT	
<b>&lt;1.1</b> 9	0 0	YEH	74	HBC	Effective denom.:	=2100
• • We do not us	e the following	data for average	s, fit	s, limits,	etc. • • •	
<1.5		DAUBER	69	HBC		
<7		HUBBARD	66	HBC		
$\Gamma(\Sigma^+\mu^-\overline{\nu}_\mu)/\Gamma($	$\Lambda\pi^0$ )					$\Gamma_5/\Gamma_1$
VALUE (units 10 ⁻³ )	L% EVTS	DOCUMENT ID		TECN	COMMENT	
<1.1 9	0 0	YEH	74	HBC	Effective denom.	=2100
• • • We do not us	e the following	data for average	s, fit	s, limits,	etc. • • •	
<1.5		DAUBER	69	НВС		
<7		HUBBARD	66	HBC		
$\Gamma(\Sigma^- e^+ \nu_e) / \Gamma(\nu_e)$ Test of $\Delta S =$						Γ ₆ /Γ ₁
VALUE (units 10 ⁻³ )		DOCUMENT ID		TECN	COMMENT	
	0 0	YEH	74	HBC	Effective denom.	=2500
• • We do not us	e the following	data for average	s, fit	s, limits,		
<1.5		DAUBER	69	нвс		
<6		HUBBARD	66	нвс		
$\Gamma(\Sigma^-\mu^+\nu_\mu)/\Gamma(\mu^+\nu_\mu)$	$\Lambda \pi^0$ )					Γ ₇ /Γ ₁
Test of $\Delta S =$	$\Delta Q$ rule.					
VALUE (units 10 ⁻³ )		DOCUMENT ID		TECN	COMMENT	
<b>&lt;0.9</b> 9 • • • We do not us	0 0	YEH	74	HBC	Effective denom.	=2500
	c the following	J				
<1.5 <6		DAUBER HUBBARD	69 66	нвс нвс		
<b>\</b> 0		HODDAND	00	1100		
$\Gamma(p\pi^-)/\Gamma(\Lambda\pi^0)$	ldon in first ord	or work interacti	on			$\Gamma_8/\Gamma_1$
VALUE (units 10 ⁻⁵ )		er weak interacti DOCUMENT ID	on.	TECN	COMMENT	
	0	GEWENIGER	75			
• • • We do not us					etc. • • •	
<180 9	_	YEH	74	нвс	Effective denom.:	=1300
< 90	- 0	DAUBER	69	HBC		_000
< 500		HUBBARD	66	HBC		

² The MAYEUR 72 value is modified by the erratum.

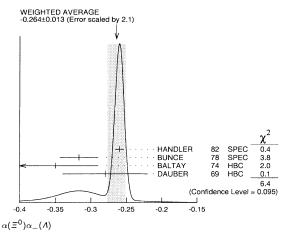
er weak interaction		Γ ₉ /Γ ₁				
DOCUMENT ID	TECN	COMMENT				
DAUBER 6	9 HBC					
data for averages,	fits, limits	, etc. • • •				
YEH 7	4 HBC	Effective denom.=670				
HUBBARD 6	6 HBC					
$\Gamma(\rho\mu^-\overline{\nu}_\mu)/\Gamma(\Lambda\pi^0)$ $\Delta S=2$ . Forbidden in first-order weak interaction.						
DOCUMENT ID	TECN	COMMENT				
DAUBER 6	9 HBC					
data for averages,	fits, limits	, etc. • • •				
YEH 7	4 HBC	Effective denom.=664				
HUBBARD 6	6 HBC					
	DOCUMENT ID DAUBER 6 data for averages, YEH 7 HUBBARD 6  er weak interaction DOCUMENT ID DAUBER 6 data for averages, YEH 7	DAUBER 69 HBC data for averages, fits, limits YEH 74 HBC HUBBARD 66 HBC der weak interaction.  DOCUMENT ID TECN DAUBER 69 HBC data for averages, fits, limits YEH 74 HBC				

#### **≡**⁰ DECAY PARAMETERS

See the "Note on Baryon Decay Parameters" in the neutron Listings.

### $\alpha(\Xi^0) \; \alpha_-(\Lambda)$

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
-0.264±0.013 OUR AVERAG	E Error in	cludes scale facto	or of	2.1. See	the ideogram
		below.			
$-0.260\pm0.004\pm0.005$	300k	HANDLER	82	SPEC	FNAL hyperons
$-0.317 \pm 0.027$	6075	BUNCE	78	SPEC	FNAL hyperons
$-0.35 \pm 0.06$	505	BALTAY	74	нвс	K ⁻ ρ 1.75 GeV/c
$-0.28 \pm 0.06$	739	DAUBER	69	HBC	K  p 1.7−2.6 GeV/c



### $\alpha$ FOR $\Xi^0 \to \Lambda \pi^0$

The above average,  $\alpha(\Xi^0)\alpha_-(\Lambda)=-0.264\pm0.013$ , where the error includes a scale factor of 2.1, divided by our current average  $lpha_{-}(\varLambda)=$  0.642  $\pm$  0.013, gives the following value for  $\alpha(\Xi^0)$ .

### DOCUMENT ID

-0.411 ±0.022 OUR EVALUATION	Error includes scale factor of 2.1.
A ANGLE FOR =0 → Aπ ⁰	

$\phi$ ANGLE FOR $\equiv$	$^{0} \rightarrow \Lambda \pi^{0}$				$(\tan\!\phi=\beta/\gamma)$
VALUE (°)	EVTS	DOCUMENT ID		TECN	COMMENT
21±12 OUR AVE	RAGE				
$16\pm17$	652	BALTAY	74	HBC	1.75 GeV/c K-p
$38\pm19$	739	³ DAUBER	69	HBC	
- 8±30	146	⁴ BERGE	66	HBC	
3 DALIBED 60 USA	0 6 4 7	1 0 000			

The errors have been multiplied by 1.2 due to approximations used for the  $\Xi$  polarization; see DAUBER 69 for a discussion.

$\alpha$ FOR $\Xi^0 \to \Lambda \gamma$					
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
+0.43±0.44	87	JAMES	90	SPEC	FNAL hyperons
$\alpha \text{ FOR } \equiv^0 \rightarrow \Sigma^0 \gamma$					
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
$+0.20\pm0.32\pm0.05$	85	TEIGE	89	SPEC	FNAL hyperons

### **=**⁰ REFERENCES

JAM TEIC		9 PR	L 64 843 L 63 2717 B215 195	+Heller, Border, Dwor +Beretvas, Caracappa, +Fortner, Kirsch, Piek	Devlin+	(RUTG, M	ICH, MINN
HAN	DLER 8	2 PR 1 PR	D25 639 L 46 877	+Grobel, Pondrom+ +Dworkin+	(WISC	, MICH, MI C, RUTG, N	INN, RUTG MINN, BNL
BUN BUN ZEC	CE 7:	B PR	86B 386 D18 633 B124 413	+Overseth, Cox+ +Handler, March, Mar +Dvdak, Navarria+	rtin+	., MICH, RI (WISC, MI CERN, DOI	ICH, RUTG
	ENIGER 7		57B 193	+Gjesdal, Presser+	(SIEG,		RN, HEIDH RN, HEIDH

BALTAY	74	PR D9 49	+Bridgewater, Cooper, Gershwin+	(COLU, BING) J
YEH	74	PR D10 3545	+Gaigalas, Smith, Zendle, Baltay+	(BING, COLU)
MAYEUR	72	NP B47 333	+VanBinst, Wilquet+ (BRUX, CERN	TUFTS, LOUC)
Also	73	NP B53 268 erratum	Mayeur	
WILQUET	72	PL 42B 372	+Fliagine, Guy+ (BRUX, CERN	TUFTS, LOUC)
DAUBER	69	PR 179 1262	+Berge, Hubbard, Merrill, Miller	(LRL)
PALMER	68	PL 26B 323	+Radojicic, Rau, Richardson+	(BNL, SYRA)
BERGE	66	PR 147 945	+Eberhard, Hubbard, Merrill+	(LRL)
HUBBARD	66	Thesis UCRL 11510		(LRL)
LONDON	66	PR 143 1034	+Rau, Goldberg, Lichtman+	(BNL, SYRA)
PJERROU	65B	PRL 14 275	+Schlein, Slater, Smith, Stork, Ticho	(UCLA)
Also	65	Thesis	Pierrou	(UCLA)
CARMONY	64B	PRL 12 482	+Pierrou, Schlein, Slater, Stork+	(UCLA)
HUBBARD	64	PR 135B 183	+Berge, Kalbfleisch, Shafer+	`(LRL)
JAUNEAU	63	PL 4 49	+ (EPOL, CERN, LOU	C. RHEL. BERGÍ
Also	63C	Siena Conf. 1 1	Jauneau+ (EPOL, CERN, LOU	C, RHEL, BERG)



$$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$$
 Status: ***

The parity has not actually been measured, but + is of course ex-

We have omitted some results that have been superseded by later experiments. See our earlier editions.

The fit uses the  $\Xi^-,\,\overline\Xi^+,$  and  $\Xi^0$  mass and mass difference measurements. It assumes the  $\Xi^-$  and  $\Xi^+$  masses are the same.

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
1321.32 ± 0.13 OUR FIT	•				
1321.34 ± 0.14 OUR AV	ERAGE				
$1321.46 \pm 0.34$	632	DIBIANCA	75	DBC	4.9 GeV/c K-d
$1321.12 \pm 0.41$	268	WILQUET	72	HLBC	
$1321.87 \pm 0.51$	195	1 GOLDWASSER	70	HBC	5.5 GeV/c K-p
$1321.67 \pm 0.52$	6	CHIEN	66	HBC	6.9 GeV/c p̄p
1321.4 ±1.1	299	LONDON	66	HBC	
1321.3 ±0.4	149	PJERROU	65B	HBC	
1321.1 ±0.3	241	² BADIER	64	HBC	
1321.4 ±0.4	517	² JAUNEAU	<b>63</b> D	FBC	
1321.1 ±0.65	62	² SCHNEIDER	63	HBC	
•					

 $^{^{1}}$  GOLDWASSER 70 uses  $m_{ extstyle \Lambda} = 1115.58$  MeV.

### $\overline{\Xi}^+$ MASS

The fit uses the  $\Xi^-$ ,  $\overline{\Xi}^+$ , and  $\Xi^0$  mass and mass difference measurements. It assumes the  $\Xi^-$  and  $\overline{\Xi}^+$  masses are the same.

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
1321.32±0.13 OUR F	-IT				
1321.20±0.33 OUR A	WERAGE				
1321.6 $\pm 0.8$	35	VOTRUBA	72	HBC	10 GeV/c K ⁺ p
$1321.2 \pm 0.4$	34	STONE	70	HBC	
$1320.69 \pm 0.93$	5	CHIEN	66	HBC	6.9 GeV/c p̄p

$$(m_{\equiv -} - m_{\equiv +}) / m_{\text{average}}$$

A test of CPT invariance. We calculate it from the average  $\Xi^-$  and  $\Xi^+$ masses above.

DOCUMENT ID

### $(1.1\pm2.7)\times10^{-4}$ OUR EVALUATION

### **=** MEAN LIFE

Measurements with an error  $>~0.2\times10^{-10}$  s or with systematic errors not included have been omitted.

••					
VALUE (10 ⁻¹⁰ s)	EVTS	DOCUMENT ID		TECN	COMMENT
1.639 ± 0.015 OUR A	VERAGE				
$1.652 \pm 0.051$	32k	BOURQUIN	84	SPEC	Hyperon beam
$1.665 \pm 0.065$	41k	BOURQUIN	79	SPEC	Hyperon beam
$1.609 \pm 0.028$	4286	HEMINGWAY	78	нвс	4.2 GeV/c K-p
1.67 ±0.08		DIBIANCA	75	DBC	4.9 GeV/c K-d
$1.63 \pm 0.03$	4303	BALTAY	74	HBC	1.75 GeV/c K-p
$1.73 \begin{array}{c} +0.08 \\ -0.07 \end{array}$	680	MAYEUR	72	HLBC	$2.1~{ m GeV}/c~K^-$
$1.61 \pm 0.04$	2610	DAUBER	69	HBC	
$1.80 \pm 0.16$	299	LONDON	66	HBC	
$1.70 \pm 0.12$	246	PJERROU	65B	нвс	
$1.69 \pm 0.07$	794	HUBBARD	64	HBC	
$1.86 \begin{array}{l} +0.15 \\ -0.14 \end{array}$	517	JAUNEAU	63D	FBC	

 $^{^2\,\}text{These}$  masses have been increased 0.09 MeV because the  $\Lambda$  mass increased.

=-

### 三+ MEAN LIFE

EVTS	DOCUMENT ID		TECN	COMMENT
34	STONE	70	HBC	
e the followi	ng data for averag	es, fit	s, limits	, etc. • • •
35	³ VOTRUBA	72	нвс	10 GeV/c K ⁺ p
12	³ SHEN	67	нвс	
5	³ CHIEN	66	HBC	6.9 GeV/c pp
	34 e the following 35	34 STONE e the following data for averag 35 ³ VOTRUBA 12 ³ SHEN	34 STONE 70 e the following data for averages, filt 35 3 VOTRUBA 72 12 3 SHEN 67	34 STONE 70 HBC e the following data for averages, fits, limits 35 3 VOTRUBA 72 HBC 12 3 SHEN 67 HBC

### $( au_{\Xi^-} - au_{\Xi^+}) \, / \, au_{ m average}$

A test of *CPT* invariance. Calculated from the  $\Xi^-$  and  $\overline{\Xi}^+$  mean lives, above.

VALUE

0.02±0.18 OUR EVALUATION

DOCUMENT ID

### =- MAGNETIC MOMENT

See the "Note on Baryon Magnetic Moments" in the  $\Lambda$  Listings.

VALUE (μ _N )	EVTS	DOCUMENT ID	,	TECN	COMMENT
-0.6507±0.0025 OUR AVE	RAGE				
$-0.6505 \pm 0.0025$	4.36M	DURYEA	92	SPEC	800 GeV p Be
$-0.661 \pm 0.036 \pm 0.036$	44k	TROST	89	SPEC	$\Xi^ \sim$ 250 GeV
-0.69 ±0.04	218k	RAMEIKA	84	SPEC	400 GeV <i>p</i> Be
• • We do not use the following the following the following that the following the following that the following the followi	llowing data 1	for averages, fits,	limits	, etc. •	• •
$-0.674 \pm 0.021 \pm 0.020$	122k	но	90	SPEC	See DURYEA 92
-2.1 ±0.8	2436	COOL	74	OSPK	1.8 GeV/c K-p
$-0.1$ $\pm 2.1$	2724	BINGHAM	70B	OSPK	1.8 GeV/c K-p

### **T**+ MAGNETIC MOMENT

DOCUMENT ID

TECN COMMENT

90 SPEC 800 GeV pBe

See the "Note on Baryon Magnetic Moments" in the  $\Lambda$  Listings.

EVTS

 $VALUE(\mu_N)$ 

+0.657±0.028±0.020 70k

	.≡− DECAY MODES								
	Mode	Fraction $(\Gamma_j/\Gamma)$ Confidence level							
Γ ₁	Λπ-	(99.887±0.035) %							
$\Gamma_2$	$\Sigma^-\gamma$	$(1.27 \pm 0.23) \times 10^{-4}$							
$\Gamma_3^-$	$\Lambda e^- \overline{ u}_e$	$(5.63 \pm 0.31) \times 10^{-4}$							
	Λ $\mu^- \overline{ u}_\mu$	$(3.5 \begin{array}{c} +3.5 \\ -2.2 \end{array}) \times 10^{-4}$							
$\Gamma_5$	$\Sigma^0 e^- \overline{ u}_e$	$(8.7 \pm 1.7) \times 10^{-5}$							
r T	<u>-0 – -</u>	10-4							

$\Gamma_6$	$\Sigma^0 \mu^- \overline{ u}_{\mu}$		<	8	× 10 ⁻⁴	90%
$\Gamma_7$	$\equiv^0 e^- \overline{\nu}_e$		<	2.3	$\times$ 10 ⁻³	90%
		$\Delta S = 2$ forbidden (S	2)	modes		
Γ ₈	$n\pi^-$	S2	<	1.9	$\times$ 10 ⁻⁵	90%
و۲	$ne^-\overline{\nu}_e$	S2	<	3.2	$\times$ 10 ⁻³	90%
Γ ₁₀	$n\mu^-\overline{\nu}_{\mu}$	52	<	1.5	%	90%
$\Gamma_{11}$	$p\pi^-\pi^-$	S2	<	4	× 10 ⁻⁴	90%
Γ ₁₂	$p\pi^-e^-\overline{\nu}_e$	52	<	4	× 10 ⁻⁴	90%
Γ ₁₃	$p\pi^-\mu^-\overline{\nu}_{\mu}$	52	<	4	× 10 ⁻⁴	90%
$\Gamma_{1\Delta}$	$p\mu^{-}\mu^{-}$	L	<	4	× 10 ⁻⁴	90%

#### CONSTRAINED FIT INFORMATION

An overall fit to 4 branching ratios uses 5 measurements and one constraint to determine 5 parameters. The overall fit has a  $\chi^2=1.0$  for 1 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients  $\left\langle \delta x_i \delta x_j \right\rangle / \left(\delta x_i \cdot \delta x_j \right),$  in percent, from the fit to the branching fractions,  $x_i \equiv \mathbf{f}_i / \mathbf{f}_{\text{total}}.$  The fit constrains the  $x_i$  whose labels appear in this array to sum to one

 $\Gamma(\Xi^0 e^- \overline{\nu}_e) / \Gamma(\Lambda \pi^-)$ 

VALUE (units  $10^{-3}$ ) CL% EVTS

#### **E**- BRANCHING RATIOS

A number of early results have been omitted.

	•					
$\Gamma(\Sigma^-\gamma)/\Gamma(\Lambda\pi^-)$						$\Gamma_2/\Gamma_1$
VALUE (units 10 ⁻⁴ )	EVTS	DOCUMENT ID		TECN	COMMENT	
1.27±0.24 OUR FIT 1.27±0.23 OUR AVER	AGE					
1.22±0.23±0.06	211	⁴ DUBBS	94	E761	Ξ− 375 GeV	
$2.27 \pm 1.02$	9	BIAGI	87B	SPEC	SPS hyperon be	am
⁴ DUBBS 94 also fir	ds weak e	vidence that the a	sym m	netry pai	rameter $\alpha_{\gamma}$ is po	sitive ( $\alpha_{\gamma}$
$= 1.0 \pm 1.3$ ).					,	
$\Gamma(\Lambda e^- \overline{\nu}_e) / \Gamma(\Lambda \pi^-$	)					$\Gamma_3/\Gamma_1$
VALUE (units 10 ⁻³ )	EVTS	DOCUMENT ID		TECN	COMMENT	
VALUE (units 10 ⁻³ ) 0.564±0.031 OUR FIT		DOLLDOLLIN		CDEC	CDC house on I	
0.564±0.031 • • • We do not use t	2857	BOURQUIN			SPS hyperon be	eam
0.30 ±0.13	11	THOMPSON	80		Hyperon beam	
$\Gamma(\Lambda\mu^-\overline{\nu}_{\mu})/\Gamma(\Lambda\pi^-$	.)					$\Gamma_4/\Gamma_1$
VALUE (units 10 ⁻³ ) CL%	•	DOCUMENT ID		TECN	COMMENT	•, -
0.35 +0.35 OUR F						
					==	
0.35±0.35 • • • We do not use t	1 the following	YEH	74 es fit	HBC s limits	Effective denon	1.=2859
< 2.3 90	0	THOMPSON	80	ASPK		-1017
< 1.3	·	DAUBER	69	HBC	Encetive denon	
<12		BERGE	66	HBC		
$\Gamma(\Sigma^0 e^- \overline{\nu}_e) / \Gamma(\Lambda \pi$	<del>-</del> )					Γ ₅ /Γ ₁
VALUE (units 10 ⁻³ )	EVTS	DOCUMENT ID		TECN	COMMENT	
0.087±0.017 OUR FIT	Γ					
0.087±0.017	154	BOURQUIN	83	SPEC	SPS hyperon b	eam
$\Gamma(\Sigma^0 \mu^- \overline{\nu}_\mu)/\Gamma(\Lambda \pi$	r ⁻ )					$\Gamma_6/\Gamma_1$
VALUE (units 10-3) CL%		DOCUMENT ID		TECN	COMMENT	
<b>&lt;0.76</b> 90	0	YEH	74	нвс	Effective denon	n.=3026
• • We do not use to	he followi	ng data for averag	es, fit	s, limits	, etc. • • •	
<5		BERGE	66	HBC		
$[\Gamma(\Lambda e^- \overline{\nu}_e) + \Gamma(\Sigma$	$^{0}e^{-}\overline{\nu}_{e})$	$/\Gamma(\Lambda\pi^-)$			(Γ ₃ .	+Γ ₅ )/Γ ₁
VALUE (units 10 ⁻³ )	EVTS	DOCUMENT ID		TECN	COMMENT	
• • We do not use to	the followi	ng data for averag	es, fit	s, limits	, etc. • • •	
$0.651 \pm 0.031$	3011	5 BOURQUIN	83		SPS hyperon b	eam
0.68 ±0.22	17	⁶ DUCLOS	71			
⁵ See the separate	30URQUI	N 83 values for F	(Λe ⁻	- <del>v</del> e)/Γ	$(A\pi^-)$ and $\Gamma(\Sigma$	$^{\cup}e^{-}\overline{\nu}_{e})/$
$\Gamma(\Lambda\pi^-)$ above.		0				-0
⁶ DUCLOS 71 canno is about a factor 6			The C	Cabibbo	theory predicts th	ie Σ ^o rate
about a factor o	Sruner ti	an one /i ruter				

 $\Gamma_7/\Gamma_1$ 

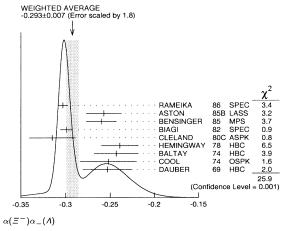
DOCUMENT ID TECN COMMENT
YEH 74 HBC Effective denom.=1000

$\Gamma(n\pi^{-})/\Gamma(\Lambda\pi$		in first-ord	ler weak interact	ion.		Γ ₈ /Γ ₁
VALUE (units 10-3)			DOCUMENT ID		TECN	COMMENT
<0.019	90		BIAGI	82E	SPEC	SPS hyperon beam
• • • We do not	use the	following	data for averag	es, fit	s, limits,	etc. • • •
<3.0	90	0	YEH	74	нвс	Effective denom.=760
<1.1			DAUBER	69	HBC	
< 5.0			FERRO-LUZZ	ZI 63	нвс	
$\Gamma(ne^-\overline{\nu}_e)/\Gamma(ne^-\overline{\nu}_e)$	1π ⁻ )					Γ ₉ /Γ ₁
$\Delta S=2$ . For VALUE (units $10^{-3}$ )			ler weak interact  DOCUMENT ID		TECN	COMMENT
< 3.2	90	0	YEH	74		Effective denom.=715
• • • We do not						
<10	90	. 101101111115	BINGHAM	65		
$\Gamma(n\mu^-\overline{\nu}_{\mu})/\Gamma(n\mu^-\overline{\nu}_{\mu})$	Λπ ⁻ )	in first-ord	ler weak interac	tion.		Γ ₁₀ /Γ ₁
VALUE (units 10-3)			DOCUMENT ID		TECN	COMMENT
<15.3	90	0	YEH	74	нвс	Effective denom.=150
$\Gamma(p\pi^-\pi^-)/\Gamma(p\pi^-\pi^-)$	$(\Lambda\pi^{-})$	in first-ord	ler weak interac	tion.		Γ ₁₁ /Γ ₁
VALUE (units 10 ⁻⁴ )			DOCUMENT ID		TECN	COMMENT
<3.7	90	0	YEH	74	нвс	Effective denom.=6200
$\Gamma(p\pi^-e^-\overline{\nu}_e)/\Delta S=2$ . For	/Γ(Λπ [*]	-) in first-ord	ler weak interac	tion.		$\Gamma_{12}/\Gamma_{1}$
VALUE (units 10-4)			DOCUMENT ID		TECN	COMMENT
<3.7	90	0	YEH	74	HBC	Effective denom.=6200
$\Gamma(p\pi^-\mu^-\overline{\nu}_{\mu})$ $\Delta S=2$ . For	/Γ(Λπ	-) in first-ord	ler weak interac	tion.		Γ ₁₃ /Γ ₁
VALUE (units 10-4)	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
<3.7	90	0	YEH	74	HBC	Effective denom. $=6200$
$\Gamma(\rho\mu^-\mu^-)/\Gamma(A\Delta L=2 de$		bidden by	total lepton nu	mber	conserva	Γ ₁₄ /Γ ₁
VALUE (units 10-4)		CL%	DOCUMENT ID		TECN	COMMENT
<3.7		90	7 LITTENBER	G 92	в НВС	Uses YEH 74 data
modes all res	ult from	nonobse		prong		its for the preceding three of the $\Xi^-$ . One could a

### **=** DECAY PARAMETERS

See the "Note on Baryon Decay Parameters" in the neutron Listings.

$\alpha(\Xi^-)\alpha(\Lambda)$					
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
-0.293±0.007 OUR AVERAGE	Error incl	udes scale factor	of 1	.8. See	the ideogram
		below.			
$-0.303\pm0.004\pm0.004$	192k	RAMEIKA	86	SPEC	400 GeV pBe
$-0.257 \pm 0.020$	11k	ASTON	85B	LASS	11 GeV/c K-p
$-0.260 \pm 0.017$	21k	BENSINGER	85	MPS	5 GeV/c K-p
$-0.299 \pm 0.007$	150k	BIAGI	82	SPEÇ	SPS hyperon beam
$-0.315\pm0.026$	9046	CLELAND	<b>8</b> 0c	ASPK	BNL hyperon beam
$-0.239 \pm 0.021$	6599	HEMINGWAY	78	HBC	4.2 GeV/c K-p
$-0.243 \pm 0.025$	4303	BALTAY	74	HBC	1.75 GeV/c
					K - p
$-0.252 \pm 0.032$	2436	COOL	74	OSPK	1.8 GeV/c K- p
$-0.253\pm0.028$	2781	DAUBER	69	HBC	
$-0.243\pm0.025$ $-0.252\pm0.032$	4303 2436	BALTAY	74	HBC OSPK	1.75 GeV/ <i>c</i> <i>K</i> ⁻ <i>p</i>



The above average,  $\alpha(\Xi^-)$   $\alpha_-(\Lambda)=-0.293\pm0.007$ , where the error includes a scale factor of 1.8, divided by our current average  $\alpha_-(\Lambda)=0.642\pm0.013$ , gives the following value for  $\alpha(\Xi^-)$ .

VALUE	DOCUMENT ID
-0.456±0.014 OUR EVALUATION	Error includes scale factor of 1.8.

φAN	IGLE I	FOR $\Xi^- \rightarrow \Lambda \pi^-$				$(\tan\phi=\beta/\gamma)$
VALUE	(°)	EVTS	DOCUMENT ID		TECN	COMMENT
4	± 4	OUR AVERAGE				
5	$\pm 10$	11k	ASTON	85B	LASS	K-p
14.7	±16.0	21k	⁸ BENSINGER	85	MPS	5 GeV/c K ⁻ p
11	± 9	4303	BALTAY	74	HBC	1.75 GeV/c K-p
5	$\pm 16$	2436	COOL	74	OSPK	1.8 GeV/c K-p
26	$\pm 30$	2724	BINGHAM	70B	OSPK	
- 14	$\pm 11$	2781	DAUBER	69	HBC	Uses $\alpha_{\Lambda} = 0.647 \pm 0.020$
0	$\pm 12$	1004	⁹ BERGE	66	HBC	
0	$\pm 20.4$	364	⁹ LONDON	66	HBC	Using $\alpha_{\Lambda} = 0.62$
54	$\pm 30$	356	⁹ CARMONY	64B	HBC	
_						

 $^{^8}$  BENSINGER 85 used  $\alpha_{\Lambda}=0.642\pm0.013.$   9  The errors have been multiplied by 1.2 due to approximations used for the  $\varXi$  polarization; see DAUBER 69 for a discussion.

gA / gV FOR =-	→ Ae-	$\overline{\nu}_e$				
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT	
-0.25±0.05	1992	10 BOURQUIN	83	SPEC	SPS hyperon beam	

 $^{^{10}\, {\}rm BOURQUIN}$  83 assumes that  $g_2=0.$  Also, the sign has been changed to agree with our conventions, given in the "Note on Baryon Decay Parameters" in the neutron Listings.

#### **=**- REFERENCES

We have omitted some papers that have been superseded by later experiments. See our earlier editions.

DUBBS	94	PRL 72 808	+Albuquerque, Bondar+ (FNAL E761 Collab.)
DURYEA	92	PRL 68 768	+Guglielmo, Heller+ (MINN, FNAL, MICH, RUTG)
LITTENBERG	92B		+Shrock (BNL, STON)
HO	90	PRL 65 1713	+Longo, Nguyen, Luk+ (MICH, FNAL, MINN, RUTG)
Also	91	PR D44 3402	Ho, Longo, Nguyen, Luk+ (MICH, FNAL, MINN, RUTG)
TROST	89	PR D44 3402 PR D40 1703	+McCliment, Newsom, Hseuh, Mueller+ (FNAL-715 Collab.)
		ZPHY C35 143	+ (BRIS, CERN, GEVA, HEIDP, LAUS, LOQM, RAL)
BIAGI RAMEIKA	87B 86	PR D33 3172	+ Beretvas, Deck+ (RUTG, MICH, WISC, MINN)
	85B		
ASTON		PR D32 2270 NP B252 561	
BENSINGER	85		
BOURQUIN	84 84	NP B241 1 PRL 52 581	+ (BRIS, GEVA, HEIDP, LALO, RAL, STRB) +Beretvas, Deck+ (RUTG, MICH, WISC, MINN)
RAMEIKA			
BOURQUIN	83	ZPHY C21 1	+Brown+ (BRIS, GEVA, HEIDP, LALO, RL, STRB)
BIAGI	82	PL 112B 265	+ (BRIS, CAVE, GEVA, HEIDP, LAUS, LOQM, RL)
BIAGI	82B	PL 112B 277	+ (LOQM, GEVA, RL, HEIDP, CAVE, LAUS, BRIS)
CLELAND	80C	PR D21 12	+Cooper, Dris, Engels, Herbert+ (PITT, BNL)
THOMPSON	80	PR D21 25	+Cleland, Cooper, Dris, Engels+ (PITT, BNL)
BOURQUIN	79	PL 87B 297	<ul> <li>(BRIS, GEVA, HEIDP, ORSAY, RHEL, STRB)</li> </ul>
HEMINGWAY	78	NP B142 205	+Armenteros+ (CERN, ZEEM, NIJM, OXF)
DIBIANCA	75	NP B98 137	+Endorf (CMU)
BALTAY	74	PR D9 49	+Bridgewater, Cooper, Gershwin+ (COLU, BING) J
COOL	74	PR D10 792	+Giacomelli, Jenkins, Kycia, Leontic, Li+ (BNL)
Also	72	PRL 29 1630	Cool, Giacomelli, Jenkins, Kycia, Leontic+ (BNL)
YEH	74	PR D10 3545	+Gaigalas, Smith, Zendle, Baltay+ (BING, COLU)
MAYEUR	72	NP B47 333	+VanBinst, Wilquet+ (BRUX, CERN, TUFTS, LOUC)
VOTRUBA	72	NP B45 77	+Safder, Ratcliffe (BIRM, EDIN)
WILQUET	72	PL 42B 372	+Fliagine, Guy+ (BRUX, CERN, TÜFTS, LOUC)
DUCLOS	71	NP B32 493	+Freytag, Heintze, Heinzelmann, Jones+ (CERN)
BINGHAM	70B	PR D1 3010	+Cook, Humphrey, Sander+ (UCSD, WASH)
GOLDWASSER	70	PR D1 1960	+Schultz (ILL)
STONE	70	PL 32B 515	+Berlinghieri, Bromberg, Cohen, Ferbel+ (ROCH)
DAUBER	69	PR 179 1262	+Berge, Hubbard, Merrill, Miller (LRL) J
SHEN	67	PL 25B 443	+Firestone, Goldhaber (UCB, LRL)
BERGE	66	PR 147 945	+Eberhard, Hubbard, Merrill+ (LRL)
CHIEN	66	PR 152 1171	+Lach, Sandweiss, Taft, Yeh, Oren+ (YALE, BNL)
LONDON	66	PR 143 1034	+Rau, Goldberg, Lichtman+ (BNL, SYRA)
BINGHAM	65	PRSL 285 202	(CERN)
PJERROU	65B	PRL 14 275	+Schlein, Slater, Smith, Stork, Ticho (UCLA)
Also	65	Thesis	Pierrou (UCLA)
BADIER	64	Dubna Conf. 1 593	+Demoulin, Barloutaud+ (EPOL, SACL, ZEEM)
CARMONY	64B	PRL 12 482	+Pjerrou, Schlein, Slater, Stork+ (UCLA) J
HUBBARD	64	PR 135B 183	+Berge, Kalbfleisch, Shafer+ (LRL)
FERRO-LUZZI		PR 130 1568	+Alston-Garnjost, Rosenfeld, Wojcicki (LRL)
JAUNEAU	63D		+ (EPOL, CERN, LOUC, RHEL, BERG)
Also	63B	PL 5 261	Jauneau+ (EPOL, CERN, LOUC, RHEL, BERG)
SCHNEIDER	63	PL 4 360	(CERN)
			(00)

### $\Xi$ 's, $\Xi$ (1530)

### **E** RESONANCES

The accompanying table gives our evaluation of the present status of the  $\Xi$  resonances. Not much is known about  $\Xi$ resonances. This is because (1) they can only be produced as a part of a final state, and so the analysis is more complicated than if direct formation were possible, (2) the production cross sections are small (typically a few  $\mu$ b), and (3) the final states are topologically complicated and difficult to study with electronic techniques. Thus early information about  $\Xi$ resonances came entirely from bubble chamber experiments, where the numbers of events are small, and only in the 1980's did electronic experiments make any significant contributions. However, there has not been a single new piece of data on  $\Xi$ resonances since our 1988 edition.

For a detailed earlier review, see Meadows [1].

#### Reference

1. B.T. Meadows, in Proceedings of the IVth International Conference on Baryon Resonances (Toronto, 1980), ed. N. Isgur, p. 283.

Table 1. The status of the  $\varXi$  resonances. Only those with an overall status of *** or **** are included in the Baryon Summary Table.

				Status as seen in —				
Particle	$L_{2I\cdot 2J}$	Overall status	Ξπ	$\Lambda K$	$\Sigma K$	$\Xi(1530)\pi$	Other channels	
$\Xi(1318)$	P ₁₁	****					Decays weakly	
$\Xi(1530)$	$P_{13}$	****	****					
$\Xi(1620)$		*	*					
$\Xi(1690)$		***		***	**			
$\Xi(1820)$	$D_{13}$	***	**	***	**	**		
$\Xi(1950)$		***	**	**		*		
$\Xi(2030)$	1	***		**	***			
$\Xi(2120)$		*		*				
$\Xi(2250)$		**					3-body decays	
$\Xi(2370)$	1	**					3-body decays	
$\Xi(2500)$		*		*	*		3-body decays	

- Existence is certain, and properties are at least fairly well explored. Existence ranges from very likely to certain, but further confirmation is desirable and/or quantum numbers, branching fractions, etc. are not well determined.

  Evidence of existence is only fair.
- Evidence of existence is poor

## $\Xi(1530) P_{13}$

$$I(J^P) = \frac{1}{2}(\frac{3}{2}^+)$$
 Status: ***

This is the only  $\Xi$  resonance whose properties are all reasonably well known. Spin-parity  $3/2^+$  is favored by the data.

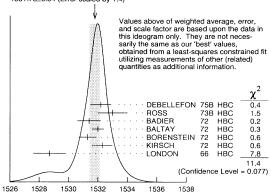
We use only those determinations of the mass and width that are accompanied by some discussion of systematics and resolution.

#### **Ξ(1530) MASSES**

#### **Ξ(1530)⁰ MASS**

VALUE (MeV)	EVTS	DOCUMENT ID	TEC	V COMMENT
1531.80±0.32 OUR	FIT Error in	cludes scale factor	of 1.3.	
1531.78±0.34 OUR	AVERAGE E	Error includes scale	factor of	1.4. See the ideogram
		below.		
1532.2 $\pm 0.7$		DEBELLEFON	758 HB0	$K^- p \rightarrow \Xi^- \overline{K} \pi$
1533 ±1		ROSS	73B HB0	$K^- p \rightarrow \Xi \overline{K} \pi(\pi)$
1531.4 $\pm 0.8$	59	BADIER	72 HB0	K [−] p 3.95 GeV/c
$1532.0 \pm 0.4$	1262	BALTAY	72 HB0	$K^- p$ 1.75 GeV/c
1531.3 ±0.6	324	BORENSTEIN	72 HB0	K [−] p 2.2 GeV/c
$1532.3 \pm 0.7$	286	KIRSCH	72 HB0	K ⁻ p 2.87 GeV/c
1528.7 $\pm 1.1$	76	LONDON	66 HB0	K [−] p 2.24 GeV/c
• • We do not us	se the following	data for averages	, fits, lim	its, etc. • • •
1532.1 ±0.4	1244	ASTON	85B LAS	S K-p 11 GeV/c
1532.1 ±0.6	2700	¹ BAUBILLIER	81B HB0	K - p 8.25 GeV/c
1530 ±1	450	BIAGI	81 SPE	C SPS hyperon beam
1527 $\pm 6$	80	SIXEL	79 HB0	K [−] p 10 GeV/c
1535 ±4	100	SIXEL	79 HB0	K ⁻ p 16 GeV/c
1533.6 $\pm 1.4$	97	BERTHON	74 HBC	Quasi-2-body $\sigma$

### WEIGHTED AVERAGE 1531.78±0.34 (Error scaled by 1.4)



 $\Xi(1530)^0$  mass (MeV)

=(r2	SU) MASS					
VALUE	(MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
1535.0	±0.6 OUR FIT					
1535.2	±0.8 OUR AVER	RAGE				
1534.5	$\pm 1.2$		DEBELLEFON	<b>75</b> B	HBC	$K^- p \rightarrow \Xi^- \overline{K} \pi$
1535.3	$\pm 2.0$		ROSS	73B	HBC	$K^- p \rightarrow \Xi \overline{K} \pi(\pi)$
1536.2	$\pm 1.6$	185	KIRSCH	72	HBC	K [−] p 2.87 GeV/c
1535.7	$\pm 3.2$	38	LONDON	66	HBC	K- p 2.24 GeV/c
<ul> <li>◆ We do not use the following data for averages, fits, limits, etc.</li> </ul>						
1540	±3	48	BERTHON	74	HBC	Quasi-2-body $\sigma$
1534.7	$\pm 1.1$	334	BALTAY	72	HBC	K [−] p 1.75 GeV/c

#### $m_{\Xi(1530)^{-}} - m_{\Xi(1530)}$

VALUE (MeV) 3.2±0.6 OUR FIT	DOCUMENT ID		TECN	COMMENT		
3.2±0.6 OUR FIT 2.9±0.9 OUR AVERAGE						
	DALTAN	70		V= 1.75.6.344		
$2.7 \pm 1.0$	BALTAY	12	HRC	K [−] p 1.75 GeV/c		
$2.0 \pm 3.2$	MERRILL	66	HBC	K [−] p 1.7–2.7 GeV/c		
5.7±3.0	PJERROU	65B	HBC	K ⁻ p 1.8−1.95 GeV/c		
● ● We do not use the following data for averages, fits, limits, etc. ● ●						
$3.9 \pm 1.8$	² KIRSCH	72	нвс	K [−] p 2.87 GeV/c		
7 ±4	² LONDON	66	нвс	K−p 2.24 GeV/c		

#### **Ξ**(1530) WIDTHS

<i>≣</i> (1530) ⁰ WID7					
VALUE (MeV) 9.1±0.5 OUR AV	EVTS	DOCUMENT ID		TECN	COMMENT
9.1±0.5 OUR AV	ERAGE	DEBELLEFON	750	UDC	$K^- p \rightarrow \Xi^- \overline{K} \pi$
9.5 ± 1.2 9.1 ± 2.4		ROSS		HBC	
9.1 ± 2.4 11 + 2		BADIER		HBC	
9.0±0.7		BALTAY		HBC	$K^{-}p$ 1.75 GeV/c
8.4±1.4		BORENSTEIN			$= \pi^+$
		KIRSCH		HBC	- ".
11.0±1.8		BERGE			$= \pi^{+}$ $K^{-} p 1.5-1.7 \text{ GeV}/c$
7 ±7					
8.5±3.5		LONDON			K-p 2.24 GeV/c
7 ±2		SCHLEIN		HBC	K-p 1.8, 1.95 GeV/c
• • • We do not i	use the following	ng data for averages	, fits	, limits	, etc. • • •
$12.8 \pm 1.0$	2700	¹ BAUBILLIER	81B	HBC	$K^- p$ 8.25 GeV/c
19 ±6	80	³ SIXEL	79	HBC	K [−] p 10 GeV/c
L4 ±5	100	³ SIXEL	79	нвс	K [−] p 16 GeV/c
≣(1530) [—] WID	тн				
/ALUE (MeV)		DOCUMENT ID		TECN	COMMENT
9.9+1.7 OUR AV	'ERAGE				
9.6±2.8		DEBELLEFON	75B	нвс	$K^- p \rightarrow \Xi^- \overline{K} \pi$
$8.3 \pm 3.6$		ROSS		нвс	
$7.8^{+3.5}_{-7.8}$		BALTAY	72	нвс	K [−] p 1.75 GeV/c
′.0 _— 78					

#### **Ξ**(1530) POLE POSITIONS

DOCUMENT ID COMMENT

LICHTENBERG74 Using HABIBI 73

<b>Ξ</b> (1530) ⁰	REAL	PART
VALUE		

$1531.6 \pm 0.4$	LICHTENBERG74	Using HABIBI 73
≡(1530) ⁰ IMAGINARY PART	DOCUMENT ID	COMMENT
<u>VALUE</u> 4.45 ± 0.35	LICHTENBERG74	***************************************
<b>≡(1530)</b> [−] REAL PART	DOCUMENT ID	COMMENT

### =(1530)= IMAGINARY PART

1534.4±1.1

=(1000)	INIAGINANT PANT		
VALUE		DOCUMENT ID	COMMENT
$3.9^{+1.75}_{-3.9}$		LICHTENBERG74	Using HABIBI 73

#### ≡(1530) DECAY MODES

	Mode	Fraction $(\Gamma_i/\Gamma)$	Confidence level
$\Gamma_1$	$\equiv \pi$	100 %	
$\Gamma_2$	$\equiv \gamma$	<4 %	90%

### **Ξ(1530) BRANCHING RATIOS**

$\Gamma(\equiv \gamma)/\Gamma_{\text{total}}$					$\Gamma_2/\Gamma$
VALUE	CL%	DOCUMENT ID	TECN	COMMENT	
<0.04	90	KALBFLEISCH 75	нвс	$K^-p$ 2.18 GeV/ $c$	

### **Ξ(1530) FOOTNOTES**

- ¹ BAUBILLIER 81B is a fit to the inclusive spectrum. The resolution (5 MeV) is not unfolded.

  Redundant with data in the mass Listings.
- $^3 \, \text{SIXEL}$  79 doesn't unfold the experimental resolution of 15 MeV.

#### **Ξ(1530) REFERENCES**

ASTON BAUBILLIER BIAGI	85B 81B 81	PR D32 2270 NP B192 1 ZPHY C9 305	+Carnegie+ (SLAC, CARL, CNRC, CINC) + (BIRM, CERN, GLAS, MSU, CURIN) + (BRIS, CAVE, GEVA, HEIDP, LAUS, LOQM, RHEL)
SIXEL	79	NP B159 125	+Bottcher+ (AACH3, BERL, CERN, LOIC, VIEN)
DEBELLEFON	75B	NC 28A 289	De Bellefon, Berthon, Billoir+ (CDEF, SACL)
KALBFLEISCH	75	PR D11 987	+Strand, Chapman (BNL, MICH)
BERTHON	74	NC 21A 146	+Tristram+ (CDEF, RHEL, SACL, STRB)
LICHTENBERG	74	PR D10 3865	(IND)
Also	74B	Private Comm.	Lichtenberg (IND)
HABIBI	73	Thesis Nevis 199	(CÒLU)
ROSS	73B	Purdue Conf. 355	+Lloyd, Radojicic (OXF)
BADIER	72	NP B37 429	+Barrelet, Charlton, Videau (ÉPOL)
BALTAY	72	PL 42B 129	+Bridgewater, Cooper, Gershwin+ (COLU, BING)
BORENSTEIN	72	PR D5 1559	+Danburg, Kalbfleisch+ (BNL, MICH) I
KIRSCH	72	NP B40 349	+Schmidt, Chang+ (BRAN, UMD, SYRA, TUFTS) I
BERGE	66	PR 147 945	+Eberhard, Hubbard, Merrill+ (LRL) I
LONDON	66	PR 143 1034	+Rau, Goldberg, Lichtman+ (BNL, SYRA) I.
MERRILL	66	Thesis UCRL 16455	(LRL) J
PJERROU	65B	PRL 14 275	+Schlein, Slater, Smith, Stork, Ticho (UCLA)
SCHLEIN	63B	PRL 11 167	+Carmony, Pjerrou, Slater, Stork, Ticho (UCLA) I.

### OTHER RELATED PAPERS

MAZZUCATO BRIEFEL BRIEFEL HUNGERBU BUTTON	77 75 74	NP B178 1 PR D16 2706 PR D12 1859 PR D10 2051 PR 142 883	+Pennino+ +Gourevitch, Chang+ +Gourevitch+ Hungerbuhler, Majka+ Button-Shafer, Lindsey,	(AMST, CERN, NIJM, OXF) (BRAN, UMD, SYRA, TUFTS) (BRAN, UMD, SYRA, TUFTS) (YALE, FNAL, BNL, PITT) Murray, Smith (LRL) Ji
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## $\Xi$ (1620)

 $I(J^P) = \frac{1}{2}(??)$  Status: * J, P need confirmation.

#### OMITTED FROM SUMMARY TABLE

What little evidence there is consists of weak signals in the  $\Xi\pi$ channel. A number of other experiments (e.g., BORENSTEIN 72 and HASSALL 81) have looked for but not seen any effect.

### **Ξ(1620) MASS**

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
≈ 1620 OUR ESTIM	ATE			
1624± 3	31	BRIEFEL	77 HBC	K [−] p 2.87 GeV/c
$1633 \pm 12$	34	DEBELLEFON	75B HBC	$K^- \rho \rightarrow \Xi^- \overline{K} \pi$
1606± 6	29	ROSS	72 HBC	$K^- p 3.1-3.7 \text{ GeV}/c$

### **Ξ(1620) WIDTH**

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
22.5	31	¹ BRIEFEL 77	нвс	K [−] p 2.87 GeV/c
40 ±15	34	DEBELLEFON 75	в НВС	$K^- p \rightarrow \Xi^- \overline{K} \pi$
21 ± 7	29	ROSS 72	HBC	$K^- \rho \rightarrow$
				$\equiv \pi^+ K^{*0}$ (892)

#### **Ξ(1620) DECAY MODES**

#### **Ξ(1620) FOOTNOTES**

 $^{1}\,\mathrm{The}$  fit is insensitive to values between 15 and 30 MeV.

### ≡(1620) REFERENCES

HASSALL	81	NP B189 397	+Ansorge, Carter, Neale+			(CAVI	E, MSU)	
BRIEFEL	77	PR D16 2706	+Gourevitch, Chang+	(BRAN,	UMD,	SYRA,	TUFTS)	
Also	70	Duke Conf. 317	Briefel+	BRAN,	UMD,	SYRA,	TUFTS)	
Also	75	PR D12 1859	Briefel, Gourevitch+	(BRAN,	UMD,	SYRA,	TUFTS)	
DEBELLEFON	75B	NC 28A 289	De Bellefon, Berthon, Billo	ir+		(CDEF	, SACL)	
BORENSTEIN	72	PR D5 1559	+Danburg, Kalbfleisch+			(BNL	, MICH)	ı
ROSS	72	PL 38B 177	+Buran, Lloyd, Mulvey, Rado	oiicic			(OXF)	ı

### OTHER RELATED PAPERS -



 $I(J^P) = \frac{1}{2}(??)$  Status: ***

DIONISI 78 sees a threshold enhancement in both the neutral and negatively charged  $\Sigma \overline{K}$  mass spectra in  $K^- p \rightarrow (\Sigma \overline{K}) K \pi$  at 4.2 GeV/c. The data from the  $\Sigma \overline{K}$  channels alone cannot distinguish between a resonance and a large scattering length. Weaker evidence at the same mass is seen in the corresponding  $\Lambda\overline{K}$  channels, and a coupled-channel analysis yields results consistent with a new  $\varXi.$ 

BIAGI 81 sees an enhancement at 1700 MeV in the diffractively produced  $\Lambda K^-$  system. A peak is also observed in the  $\Lambda \overline{K}^0$  mass spectrum at 1660 MeV that is consistent with a 1720 MeV resonance decaying to  $\Sigma^0 \overline{K}{}^0$ , with the  $\gamma$  from the  $\Sigma^0$  decay not detected.

BIAGI 87 provides further confirmation of this state in diffractive dissociation of  $\Xi^-$  into  $\Lambda K^-$ . The significance claimed is 6.7 standard deviations.

### **Ξ(1690)** MASSES

#### **MIXED CHARGES**

DOCUMENT ID This is only an educated guess; the error given is larger than the error on the average of the published values. 1690±10 OUR ESTIMATE

#### ≡(1690)⁰ MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT	
1699±5	175	¹ DIONISI	78	нвс	$K^-p$ 4.2 GeV/c	
1684 + 5	183	² DIONISI	78	HBC	K = p 4.2 GeV/c	

 $\Xi(1690), \Xi(1820)$ 

E(1690) - MASS /ALUE (MeV)	EVTS	DOCUMENT ID		TECN	соми	<i>AENT</i>
1691.1± 1.9±2.0	104	BIAGI	87	SPEC		Be 116 GeV
1700 ±10	150	³ BIAGI	81	SPEC		1 100, 135 GeV
1694 ± 6	45	⁴ DIONISI	78	нвс	K- p	4.2 GeV/ <i>c</i>
		Ξ(1690) WID7	THS			
MIXED CHARGES		DOCUMENT ID				
ALUE (MeV)  <50 OUR ESTIMATE		DOCUMENT ID				
E(1690) ⁰ WIDTH	51.75	DOCUMENT ID		<b>T</b> F.C.1.		4545
/ALUE (MeV) 14±23	EVTS	1 DIONISI	70	TECN HBC	COM	
0 ± 4	175 183	² DIONISI	78 78	HBC		9 4.2 GeV/ <i>c</i> 9 4.2 GeV/ <i>c</i>
E(1690) - WIDTH	EVEC	DOCUMENT ID		TECN	com	ACAIT
<u>ALUE (MeV)                                    </u>	104	DOCUMENT ID BIAGI	87	TECN SPEC	<u>COM</u>	Be 116 GeV
47±14	150	³ BIAGI	81	SPEC		110 GeV
26± 6	45	⁴ DIONISI	78	нвс		4.2 GeV/c
	Ξ	(1690) DECAY N	MOE	DES		
Mode		••••	Fract	ion (F _{1/}	/Γ)	
			seen			
$\sum_{i=1}^{n} \Sigma \overline{K}$			seen			
$ \begin{array}{ccc}  & \Sigma \overline{K} \\ 3 & \Xi \pi \\ 4 & \Xi^- \pi^+ \pi^0 \\ 5 & \Xi^- \pi^+ \pi^- \end{array} $				bly seen		
$ \begin{array}{cccc}  & \Sigma \overline{K} \\  & \Xi \pi \\  & \Xi - \pi + \pi^{0} \\  & \Xi - \pi + \pi^{-} \end{array} $				bly seen		
$ \begin{array}{ccc} \Gamma_2 & \Sigma \overline{K} \\ \Gamma_3 & \Xi \pi \\ \Gamma_4 & \Xi^- \pi^+ \pi^0 \\ \Gamma_5 & \Xi^- \pi^+ \pi^- \end{array} $	<i>Ξ</i> (16		possi			
$ \begin{array}{cccc}  & \Sigma \overline{K} \\  & \Xi \pi \\  & \Xi \pi + \pi^0 \\  & \Xi & \pi + \pi^0 \\  & \Xi & \Xi & \pi + \pi^- \\  & \Xi & \Xi & \Xi & \Xi \\  & \Xi & \Xi & \Xi & \Xi & \Xi \\  & \Xi & \Xi & \Xi & \Xi & \Xi & \Xi \\  & \Xi \\  & \Xi & $	•	90) BRANCHIN	possi	ATIOS		Γ ₁ /
$ \begin{array}{cccc} \frac{1}{2} & \Sigma \overline{K} \\ 3 & \Xi \pi \\ 4 & \Xi^{-} \pi^{+} \pi^{0} \\ 5 & \Xi^{-} \pi^{+} \pi^{-} \\ 6 & \Xi(1530) \pi \end{array} $	<u>EVTS</u>	90) BRANCHIN	possi	ATIOS	<u>CHG</u>	COMMENT
$ \begin{array}{cccc}  & 2 & \Sigma \overline{K} \\  & 3 & \Xi \pi \\  & 4 & \Xi^- \pi^+ \pi^0 \\  & 5 & \Xi^- \pi^+ \pi^- \\  & 5 & \Xi (1530) \pi \end{array} $ $ \frac{\Gamma(\Lambda \overline{K})}{\Gamma_{\text{total}}} / \Gamma_{\text{total}} $ where	•	90) BRANCHIN	possi G R	ATIOS		
$ \begin{array}{cccc} 1 & \Sigma  \overline{K} \\ 3 & \Xi  \pi \\ 4 & \Xi^- \pi^+ \pi^0 \\ 5 & \Xi^- \pi^+ \pi^- \\ 6 & \Xi(1530) \pi \end{array} $ $ \frac{\Gamma(\Lambda K)}{\Gamma_{\text{total}}} / \Gamma_{\text{total}} / \Gamma_{t$	<u>EVTS</u>	90) BRANCHIN	possi G R	ATIOS		COMMENT  Ξ Be 116 GeV  Γ ₂ /Γ
$ \begin{array}{cccc} \frac{1}{2} & \Sigma \overline{K} \\ 3 & \Xi \pi \\ 4 & \Xi^- \pi^+ \pi^0 \\ 5 & \Xi^- \pi^+ \pi^- \\ 6 & \Xi(1530) \pi \end{array} $ $ \frac{\Gamma(\Lambda \overline{K})}{\Gamma \text{total}} / \Gamma_{\text{total}} / \Gamma_{$	<u>EVTS</u>	90) BRANCHING  DOCUMENT ID BIAGI  DOCUMENT ID DIONISI	978	TECN SPEC TECN HBC	<u>CHG</u> –	COMMENT $ \Xi^{-} \text{ Be 116 GeV} $ $ \Gamma_{2}/\Gamma $ COMMENT $ K^{-} \rho \text{ 4.2 GeV}/C $
$ \begin{array}{cccc} \frac{1}{2} & \sum \overline{K} \\ 3 & \equiv \pi \\ 4 & \equiv -\pi + \pi^0 \\ 5 & \equiv -\pi + \pi^- \\ 6 & \equiv (1530)\pi \end{array} $ $ \frac{\Gamma(\Lambda \overline{K})/\Gamma_{\text{total}}}{ALUE}$ eeen $ \frac{\Gamma(\Sigma \overline{K})/\Gamma(\Lambda \overline{K})}{ALUE}$ $\frac{ALUE}{ALUE}$ $\frac{ALUE}{ALUE}$ $\frac{ALUE}{ALUE}$ $\frac{ALUE}{ALUE}$	<u>EVTS</u>	90) BRANCHINI  DOCUMENT ID  BIAGI  DOCUMENT ID	G R	TECN SPEC	CHG -	COMMENT $ \Xi^{-} \text{ Be 116 GeV} $ $ \Gamma_{2}/\Gamma $ $ COMMENT $ $ K^{-} p 4.2 \text{ GeV}/C $ $ K^{-} p 4.2 \text{ GeV}/C $
$ \begin{array}{cccc} \frac{1}{2} & \sum \overline{K} \\ 3 & \equiv \pi \\ 4 & \equiv -\pi + \pi^0 \\ 5 & \equiv -\pi + \pi^- \\ 6 & \equiv (1530)\pi \end{array} $ $ \frac{\Gamma(\Lambda \overline{K})/\Gamma_{\text{total}}}{ALUE}$ een $ \frac{\Gamma(\Sigma \overline{K})/\Gamma(\Lambda \overline{K})}{ALUE}$ $\frac{ALUE}{1.7 \pm 0.9}$ $\frac{1.1 \pm 1.4}{1.4}$ $\frac{\Gamma(\Xi \overline{K})/\Gamma(\Sigma \overline{K})}{\Gamma(\Xi \overline{K})}$	<u>EVTS</u>	90) BRANCHINI  DOCUMENT ID BIAGI  DOCUMENT ID DIONISI DIONISI	978	TECN SPEC TECN HBC HBC	<u>CHG</u> - <u>CHG</u> 0	COMMENT $\Xi^- \text{ Be 116 GeV}$ $\Gamma_2/\Gamma$ $COMMENT$ $K^- p 4.2 \text{ GeV/c}$ $K^- p 4.2 \text{ GeV/c}$ $\Gamma_3/\Gamma$
$ \begin{array}{cccc} \frac{1}{2} & \Sigma  \overline{K} \\ 3 & \Xi  \pi \\ 4 & \Xi^- \pi^+ \pi^0 \\ 5 & \Xi^- \pi^+ \pi^- \\ 6 & \Xi(1530) \pi \end{array} $ $ \begin{array}{cccc} \frac{\Gamma(\Lambda \overline{K})}{\Gamma \text{total}} \\ \frac{\Lambda L U E}{L 1 \pm 1.4} \\ \frac{\Gamma(\Xi \pi)}{\Gamma(\Sigma \overline{K})} & \Gamma(\Sigma \overline{K}) \\ \frac{\Lambda L U E}{\Lambda L U E} \end{array} $	<u>EVTS</u>	90) BRANCHING  DOCUMENT ID BIAGI  DOCUMENT ID DIONISI	978	TECN SPEC TECN HBC	CHG -	COMMENT $ \Xi^{-} \text{ Be 116 GeV} $ $ \Gamma_{2}/\Gamma $ $ COMMENT $ $ K^{-} p 4.2 \text{ GeV}/C $ $ K^{-} p 4.2 \text{ GeV}/C $
$ \begin{array}{cccc} \frac{1}{2} & \Sigma \overline{K} \\ 3 & \Xi \pi \\ 4 & \Xi^- \pi^+ \pi^0 \\ 5 & \Xi^- \pi^+ \pi^- \\ 6 & \Xi(1530)\pi \end{array} $ $ \begin{array}{cccc} -(\Lambda \overline{K})/\Gamma_{\text{total}} \\ ALUE \\ eeen \\ -(\Sigma \overline{K})/\Gamma(\Lambda \overline{K}) \\ ALUE \\ 7.7 \pm 0.9 \\ 5.1 \pm 1.4 \\ -(\Xi \pi)/\Gamma(\Sigma \overline{K}) \\ -(\Xi \pi)/\Gamma(\Sigma \overline{K}) \end{array} $	104	90) BRANCHINI  DOCUMENT ID BIAGI  DOCUMENT ID DIONISI DIONISI DOCUMENT ID	900 POSSI	TECN HBC HBC	<u>CHG</u> - <u>CHG</u> 0 -	COMMENT $\Xi^{-} \text{ Be 116 GeV}$ $\Gamma_{2}/I$ $COMMENT$ $K^{-} p 4.2 \text{ GeV/c}$ $K^{-} p 4.2 \text{ GeV/c}$ $\Gamma_{3}/I$ $COMMENT$
$ \begin{array}{cccc} \frac{1}{2} & \Sigma \overline{K} \\ 3 & \Xi \pi \\ 4 & \Xi^- \pi^+ \pi^0 \\ 5 & \Xi^- \pi^+ \pi^- \\ 6 & \Xi(1530)\pi \end{array} $ $ \begin{array}{cccc} -(\Lambda \overline{K})/\Gamma_{\text{total}} \\ ALUE \\ 0.7 \pm 0.9 \\ 0.1 \pm 1.4 \\ -(\Xi \pi)/\Gamma(\Sigma \overline{K}) \\ ALUE \\ <0.09 $ $ \begin{array}{cccc} (\Xi \pi)/\Gamma(\Sigma \overline{K}) \\ -(\Xi \pi)/\Gamma(\Sigma \overline{K}) \\ -(\Xi \pi)/\Gamma(\Sigma \overline{K}) \end{array} $	104	90) BRANCHINI  DOCUMENT ID BIAGI  DOCUMENT ID DIONISI DIONISI DOCUMENT ID	900 POSSI	TECN HBC HBC	<u>CHG</u> - <u>CHG</u> 0 -	COMMENT  = Be 116 GeV  Γ2/Γ  COMMENT  K - p 4.2 GeV/C  K - p 4.2 GeV/C  COMMENT  K - p 4.2 GeV/C  Γ3/Γ  COMMENT  K - p 4.2 GeV/C
$ \begin{array}{cccc} -\frac{1}{2} & \Sigma \overline{K} \\ -3 & \equiv \pi \\ 4 & \equiv -\pi + \pi^0 \\ -5 & \equiv -\pi + \pi^{-1} \\ -6 & \equiv (1530)\pi \end{array} $ $ \begin{array}{cccc} \Gamma(\Lambda \overline{K})/\Gamma_{\text{total}} \\ ALUE \\ 0.7 \pm 0.9 \\ 0.1 \pm 1.4 \\ \Gamma(\Xi \pi)/\Gamma(\Sigma \overline{K}) \\ ALUE \\ < 0.09 \\ \Gamma(\Xi - \pi + \pi^0)/\Gamma(\Sigma \overline{K}) \\ ALUE \\ < 0.04 $	104	90) BRANCHINI  DOCUMENT ID BIAGI  DOCUMENT ID DIONISI DIONISI DIONISI DIONISI	900 POSSI	TECN SPEC TECN HBC HBC TECN HBC	<u>CHG</u> - - - 0 - <u>CHG</u> 0	COMMENT  = Be 116 GeV  Γ2/Γ  COMMENT  K - p 4.2 GeV/C  K - p 4.2 GeV/C  COMMENT  K - p 4.2 GeV/C  Γ3/Γ  COMMENT  K - p 4.2 GeV/C
$ \begin{array}{ll} \Gamma_{2} & \Sigma \overline{K} \\ \Gamma_{3} & \Xi \pi \\ \Gamma_{4} & \Xi^{-} \pi^{+} \pi^{0} \\ \Gamma_{5} & \Xi^{-} \pi^{+} \pi^{-} \\ \Gamma_{6} & \Xi^{-} (1530) \pi \end{array} $ $ \Gamma(\Lambda \overline{K}) / \Gamma_{\text{total}} $ Execution $ \Gamma(\Sigma \overline{K}) / \Gamma(\Lambda \overline{K}) $ $ VALUE $ $ 2.7 + 0.9 $ $ 3.1 \pm 1.4 $ $ \Gamma(\Xi \pi) / \Gamma(\Sigma \overline{K}) $ $ VALUE $ $ <0.09 $ $ \Gamma(\Xi^{-} \pi^{+} \pi^{0}) / \Gamma(\Sigma \overline{K}) $ $ VALUE $ $ <0.04 $	104	90) BRANCHINI  DOCUMENT ID  BIAGI  DOCUMENT ID  DIONISI  DOCUMENT ID  DIONISI	<b>G R</b> 87 78 78	TECN HBC HBC TECN HBC	<u>CHG</u> - <u>CHG</u> 0 - <u>CHG</u> 0	COMMENT  = Be 116 GeV  Γ2/Γ  COMMENT  K - p 4.2 GeV/C  κ - p 4.2 GeV/C  Γ3/Γ  COMMENT  K - p 4.2 GeV/C  Γ4/Γ  COMMENT
$\begin{array}{cccc} \frac{1}{2} & \sum \overline{K} \\ -3 & \equiv \pi \\ 4 & \equiv -\pi + \pi^0 \\ -5 & \equiv -\pi + \pi^- \\ -6 & \equiv (1530)\pi \end{array}$ $\begin{array}{cccc} \Gamma(\Lambda \overline{K})/\Gamma_{\text{total}} \\ \frac{ALUE}{E} \\ \frac{ALUE}{$	104	90) BRANCHINI  DOCUMENT ID  BIAGI  DOCUMENT ID  DIONISI  DOCUMENT ID  DIONISI	<b>G R</b> 87 78 78	TECN HBC HBC TECN HBC	<u>CHG</u> - <u>CHG</u> 0 - <u>CHG</u> 0	COMMENT  = Be 116 GeV  COMMENT  K − p 4.2 GeV/c  COMMENT  K − p 4.2 GeV/c  COMMENT  K − p 4.2 GeV/c  F4/I  COMMENT  K − p 4.2 GeV/c  COMMENT  K − p 4.2 GeV/c  F6/COMMENT
$\begin{array}{cccc} \frac{1}{2} & \sum \overline{K} \\ -3 & \equiv \pi \\ 4 & \equiv -\pi + \pi^0 \\ -5 & \equiv -\pi + \pi^- \\ -6 & \equiv (1530)\pi \end{array}$ $\begin{array}{cccc} \Gamma(\Lambda \overline{K})/\Gamma_{\text{total}} \\ \frac{ALUE}{E} \\ \frac{ALUE}{$	) EVTS 104	POODMENT ID BIAGI  DOCUMENT ID DIONISI DIONISI DIONISI DIONISI DIONISI DOCUMENT ID DIONISI	<b>G R</b> 87 78 78	TECN SPEC  TECN HBC HBC TECN HBC HBC	CHG 0 CHG 0 CHG 0	COMMENT  = Be 116 GeV  Γ2/Γ  COMMENT  K - p 4.2 GeV/C  K - p 4.2 GeV/C  COMMENT  K - p 4.2 GeV/C  COMMENT  K - p 4.2 GeV/C  Γ4/Γ  COMMENT  K - p 4.2 GeV/C  Γ5/F
$\begin{array}{ll} \Gamma_2 & \Sigma \overline{K} \\ \Gamma_3 & \equiv \pi \\ \Gamma_4 & \equiv -\pi + \pi^0 \\ \Gamma_5 & \equiv -\pi + \pi^- \\ \Gamma_6 & \equiv (1530) \pi \\ \end{array}$ $\begin{array}{ll} \Gamma(\Lambda \overline{K})/\Gamma_{\text{total}} \\ \text{veen} \\ \Gamma(\Sigma \overline{K})/\Gamma(\Lambda \overline{K}) \\ \text{value} \\ 2.7 \pm 0.9 \\ 3.1 \pm 1.4 \\ \Gamma(\Xi \pi)/\Gamma(\Sigma \overline{K}) \\ \text{value} \\ < 0.09 \\ \Gamma(\Xi - \pi + \pi^0)/\Gamma(\Sigma \overline{K}) \\ \text{value} \\ < 0.04 \\ \Gamma(\Xi - \pi + \pi^-)/\Gamma_{\text{total}} \\ \text{value} \\ \text{possibly seen} \\ \Gamma(\Xi - \pi + \pi^-)/\Gamma(\Sigma \overline{K}) \\ \end{array}$	) EVTS 104	POCUMENT ID DIONISI  DOCUMENT ID DIONISI  DOCUMENT ID DIONISI  DOCUMENT ID DIONISI  DOCUMENT ID DIONISI	78 78 87	TECN HBC TECN HBC TECN HBC TECN HBC	CHG 0 CHG 0 CHG 0 CHG 0	COMMENT  = Be 116 GeV  Γ2/Γ  COMMENT  K - p 4.2 GeV/C  K - p 4.2 GeV/C  COMMENT  K - p 4.2 GeV/C  Γ3/Γ  COMMENT  K - p 4.2 GeV/C  Γ5/Γ  COMMENT  = Be 116 GeV  Γ5/Γ
$\begin{array}{ll} \Gamma_2 & \Sigma \overline{K} \\ \Gamma_3 & \equiv \pi \\ \Gamma_4 & \equiv -\pi + \pi^0 \\ \Gamma_5 & \equiv -\pi + \pi^- \\ \Gamma_6 & \equiv (1530) \pi \\ \end{array}$ $\begin{array}{ll} \Gamma(\Lambda \overline{K})/\Gamma_{\text{total}} \\ \text{veen} \\ \Gamma(\Sigma \overline{K})/\Gamma(\Lambda \overline{K}) \\ \text{value} \\ 2.7 \pm 0.9 \\ 3.1 \pm 1.4 \\ \Gamma(\Xi \pi)/\Gamma(\Sigma \overline{K}) \\ \text{value} \\ < 0.09 \\ \Gamma(\Xi - \pi + \pi^0)/\Gamma(\Sigma \overline{K}) \\ \text{value} \\ < 0.04 \\ \Gamma(\Xi - \pi + \pi^-)/\Gamma_{\text{total}} \\ \text{value} \\ \text{possibly seen} \\ \Gamma(\Xi - \pi + \pi^-)/\Gamma(\Sigma \overline{K}) \\ \end{array}$	) EVTS 104	POCUMENT ID DIONISI DOCUMENT ID DIONISI DIONISI DOCUMENT ID DIONISI DOCUMENT ID DIONISI	78 78 87	TECN HBC TECN HBC TECN HBC TECN HBC TECN TECN TECN TECN TECN TECN TECN TEC	CHG 0 CHG 0 CHG 0 CHG 0	COMMENT  = Be 116 GeV  Γ2/Γ  COMMENT  K - p 4.2 GeV/C  K - p 4.2 GeV/C  COMMENT  E - Be 116 GeV/C  COMMENT  E - Be 116 GeV
$\begin{array}{cccc} \frac{1}{2} & \sum \overline{K} \\ -3 & \equiv \pi \\ 4 & \equiv -\pi + \pi^0 \\ -5 & \equiv -\pi + \pi^- \\ -6 & \equiv (1530)\pi \end{array}$ $\begin{array}{cccc} \Gamma(\Lambda \overline{K})/\Gamma_{\text{total}} \\ -6 & \equiv (1530)\pi \end{array}$ $\begin{array}{cccc} \Gamma(\Lambda \overline{K})/\Gamma_{\text{total}} \\ -6 & \equiv (1530)\pi \end{array}$ $\begin{array}{cccc} \Gamma(\Lambda \overline{K})/\Gamma_{\text{total}} \\ -6 & \equiv (1530)\pi \end{array}$ $\begin{array}{cccc} \Gamma(\Lambda \overline{K})/\Gamma_{\text{total}} \\ -6 & \equiv (1530)\pi \end{array}$ $\begin{array}{ccccc} \Gamma(\Lambda \overline{K})/\Gamma(\Lambda \overline{K}) \\ -6 & \equiv (1530)\pi \end{array}$ $\begin{array}{ccccc} \Gamma(\Lambda \overline{K})/\Gamma(\Lambda \overline{K}) \\ -6 & \equiv (1530)\pi \end{array}$ $\begin{array}{ccccc} \Gamma(\Lambda \overline{K})/\Gamma(\Lambda \overline$	EVTS 104	POOLIMENT ID DIONISI  DOCUMENT ID DIONISI	78 78 87	TECN HBC TECN HBC TECN HBC TECN HBC	CHG 0 - CHG 0 CHG - CHG -	COMMENT  = Be 116 GeV  Γ2/Γ  COMMENT  K - p 4.2 GeV/c  K - p 4.2 GeV/c  COMMENT  K - p 4.2 GeV/c  Γ4/Γ  COMMENT  K - p 4.2 GeV/c  Γ5/Γ  COMMENT  E - Be 116 GeV  Γ5/Γ  COMMENT  K - p 4.2 GeV/c  Γ5/Γ  COMMENT  F - β 4.2 GeV/c  Γ6/Γ
$\begin{array}{ll} \Gamma_2 & \Sigma \overline{K} \\ \Gamma_3 & \equiv \pi \\ \Gamma_4 & \equiv -\pi + \pi^0 \\ \Gamma_5 & \equiv -\pi + \pi^- \\ \Gamma_6 & \equiv (1530) \pi \\ \end{array}$ $\begin{array}{ll} \Gamma(\Lambda \overline{K})/\Gamma_{\text{total}} \\ \text{value} \\ \text{value} \\ 2.7 \pm 0.9 \\ \text{2.7} \pm 0.9 \\ \text{2.09} \\ \Gamma(\Xi \pi)/\Gamma(\Sigma \overline{K}) \\ \text{value} \\ < 0.09 \\ \Gamma(\Xi - \pi + \pi^0)/\Gamma(\Sigma \overline{K}) \\ \text{value} \\ < 0.04 \\ \Gamma(\Xi - \pi + \pi^-)/\Gamma_{\text{total}} \\ \text{value} \\ \text{possibly seen} \\ \Gamma(\Xi - \pi + \pi^-)/\Gamma(\Sigma \overline{K}) \\ \text{value} \\ \Gamma(\Xi - \pi + \pi^-)/\Gamma(\Sigma \overline{K}) \\ \text{value} \\ \Gamma(\Xi - \pi + \pi^-)/\Gamma(\Sigma \overline{K}) \\ \text{value} \\ \Gamma(\Xi - \pi + \pi^-)/\Gamma(\Sigma \overline{K}) \\ \text{value} \\ \Gamma(\Xi - \pi + \pi^-)/\Gamma(\Sigma \overline{K}) \\ \text{value} \\ \Gamma(\Xi - \pi + \pi^-)/\Gamma(\Sigma \overline{K}) \\ \text{value} \\ \Gamma(\Xi - \pi + \pi^-)/\Gamma(\Sigma \overline{K}) \\ \text{value} \\ \Gamma(\Xi - \pi + \pi^-)/\Gamma(\Sigma \overline{K}) \\ \text{value} \\ \Gamma(\Xi - \pi + \pi^-)/\Gamma(\Sigma \overline{K}) \\ \text{value} \\ \Gamma(\Xi - \pi + \pi^-)/\Gamma(\Sigma \overline{K}) \\ \text{value} \\ \end{array}$	EVTS 104	POOLUMENT ID DIONISI  DOCUMENT ID BIAGI	78 78 87	TECN HBC TECN HBC TECN HBC TECN HBC	CHG 0 - CHG 0 CHG - CHG -	COMMENT  = Be 116 GeV  Γ2/Γ  COMMENT  K - p 4.2 GeV/C  Γ3/Γ  COMMENT  K - p 4.2 GeV/C  Γ4/Γ  COMMENT  K - p 4.2 GeV/C  Γ5/Γ  COMMENT  = Be 116 GeV  Γ5/Γ  COMMENT  K - p 4.2 GeV/C  Γ5/Γ  COMMENT  K - p 4.2 GeV/C

- ³ A fit to the inclusive spectrum from  $\Xi^-N \to \Lambda K^-X$ .
  ⁴ From a coupled-channel analysis of the  $\Sigma^0K^-$  and  $\Lambda K^-$  spectra.

#### ≡(1690) REFERENCES

+ (BRIS, CERN, GEVA, HEIDP, LAUS, LOQM, RAL) I + (BRIS, CAVE, GEVA, HEIDP, LAUS, LOQM, RHEL) +Diaz, Armenteros+ (CERN, AMST, NIJM, OXF) I BIAGI BIAGI DIONISI

 $\Xi(1820) D_{13}$ 

 $I(J^P) = \frac{1}{2}(\frac{3}{2}^-)$  Status: ***

The clearest evidence is an 8-standard-deviation peak in  $\Lambda K^-$  seen by GAY 76. TEODORO 78 favors J=3/2, but cannot make a parity discrimination. BIAGI 87C is consistent with J=3/2 and favors negative parity for this J value.

### ≡(1820) MASS

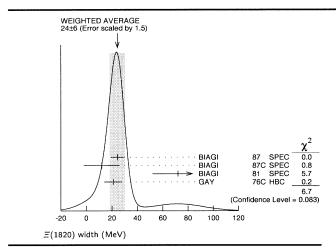
We only average the measurements that appear to us to be most significant  $% \left( 1\right) =\left( 1\right) \left( 1\right)$ 

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
1823 ± 5 OUR E	STIMATE					
1823.4± 1.4 OUR A	VERAGE					
$1819.4 \pm 3.1 \pm 2.0$	280	¹ BIAGI	87	SPEC	0	Ξ-Be →
		511.61			_	(AK ⁻ ) X
$1826 \pm 3 \pm 1$	54	BIAGI	87C	SPEC	0	$\Xi^- \text{Be} \to (\Lambda \overline{K}^0)$
1822 ± 6		JENKINS	83	MPS	_	$\kappa^{-} p \rightarrow \kappa^{+}$
						(MM)
1830 $\pm$ 6	300	BIAGI	81	SPEC	-	SPS hyperon
1823 ± 2	130	GAY	76C	нвс	_	beam $K^- p$ 4.2 GeV/c
• • We do not use					etc. •	
	74	BRIEFEL		нвс		
			77		0	K-p 2.87 GeV/c
1829 ± 9	68	BRIEFEL	77	нвс	-0	$\Xi(1530)\pi$
1860 ±14	39	BRIEFEL	77	нвс	_	$\Sigma - \overline{K}^0$
1870 $\pm$ 9	44	BRIEFEL	77	HBC	0	$\Lambda \overline{K}^0$
$1813 \pm 4$	57	BRIEFEL	77	HBC	-	ΛK ⁻
1807 ±27		DIBIANCA	75	DBC	-0	$\Xi \pi \pi$ , $\Xi^* \pi$
$1762 \pm 8$	28	² BADIER	72	HBC	-0	$\Xi \pi$ , $\Xi \pi \pi$ , YK
1838 ± 5	38	² BADIER	72	HBC	-0	$\Xi \pi$ , $\Xi \pi \pi$ , YK
1830 ±10	25	³ CRENNELL	70B	DBC	-0	3.6, 3.9 GeV/c
1826 ±12		⁴ CRENNELL	70B	DBC	-0	3.6, 3.9 GeV/c
1830 ±10	40	ALITTI	69	HBC	_	Λ, Σ Κ
1814 $\pm$ 4	30	BADIER	65	HBC	0	$\Lambda \overline{K}^0$
1817 ± 7	29	SMITH	<b>65</b> C	нвс	-0	$\Lambda \overline{K}^0$ , $\Lambda K^-$
1770		HALSTEINSLI	D63	FBC	-0	K Treon 3.5
						GeV/c

### *≡*(1820) WIDTH

VALUE (	MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
24	+15 -10	OUR ESTIMATE					
24	± 6	OUR AVERAGE	Error includes scale below.	fact	or of 1.	5. See	the ideogram
24.0	6± 5.3	3 280	¹ BIAGI	87	SPEC	0	Ξ- Be → (ΛΚ-) X
12	$\pm14$	$\pm1.7$ 54	BIAGI	<b>87</b> C	SPEC	0	$\Xi \stackrel{\sim}{\to} Be \stackrel{\sim}{\to} (\Lambda \overline{K}^0)$
72	$\pm20$	300	BIAGI	81	SPEC	_	SPS hyperon beam
21	± 7	130	GAY	<b>76</b> C	нвс	_	$K^- p$ 4.2 GeV/c
• • •	We do	not use the following	ng data for averages	, fits	, limits,	etc. •	• •
99	±57	74	BRIEFEL	77	HBC	0	K-p 2.87 GeV/c
52	$\pm 34$	68	BRIEFEL	77	HBC	-0	$\Xi(1530)\pi$
72	$\pm 17$	39	BRIEFEL	77	HBC	_	$\Sigma - \overline{K}^0$
44	$\pm 11$	44	BRIEFEL	77	HBC	0	$\Lambda \overline{K}^0$
26	$\pm 11$	57	BRIEFEL	77	HBC	-	ΛK-
85	$\pm 58$		DIBIANCA	75	DBC	-0	$\Xi \pi \pi, \Xi^* \pi$
51	$\pm 13$		² BADIER	72	HBC	-0	Lower mass
58	$\pm 13$		² BADIER	72	HBC	-0	Higher mass
103	+38 -24		³ CRENNELL	70B	DBC	-0	3.6, 3.9 GeV/c
48	+36 -19		⁴ CRENNELL	70B	DBC	-0	3.6, 3.9 GeV/c
55	$^{+40}_{-20}$		ALITTI	69	нвс	_	$\Lambda$ , $\Sigma \overline{K}$
12	± 4		BADIER	65	HBC	0	$\Lambda \overline{K}^0$
30	± 7		SMITH	<b>65</b> B	HBC	-0	$\Lambda \overline{K}$
< 80			HALSTEINSLII	263	FBC	-0	$K^-$ freon 3.5 GeV/ $c$

## **Baryon Particle Listings** $\Xi(1820), \Xi(1950)$



### ≡(1820) DECAY MODES

	Mode	Fraction $(\Gamma_i/\Gamma)$
$\overline{\Gamma_1}$	ΛK	large
$\Gamma_2$	$\Sigma \overline{K}$	small
$\Gamma_3$	$\Xi \pi$	small
$\Gamma_4$	$\Xi(1530)\pi$	small
$\Gamma_5$	$\equiv \pi \pi  (not  \equiv (1530) \pi)$	

### **Ξ(1820) BRANCHING RATIOS**

The dominant modes seem to be  $\varLambda \overline{K}$  and (perhaps)  $\Xi(1530)\pi$ , but the branching fractions are very poorly determined.

-	* * *				
$\Gamma(\Lambda \overline{K})/\Gamma_{\text{total}}$					Γ ₁ /Γ
VALUE	DOCUMENT ID		TECN	CHG	COMMENT
0.30±0.15	ALITTI	69	нвс		K ⁻ ρ 3.9-5 GeV/c
$\Gamma(\Xi\pi)/\Gamma_{total}$					$\Gamma_3/\Gamma$
VALUE	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
0.10±0.10	ALITTI	69	нвс	-	K [−] p 3.9–5 GeV/c
$\Gamma(\Xi\pi)/\Gamma(\Lambda\overline{K})$					$\Gamma_3/\Gamma_1$
VALUE CL%			TECN	<u>CHG</u>	COMMENT
<b>&lt;0.36</b> 95	GAY		HBC	_	$K^- p$ 4.2 GeV/c
0.20±0.20	BADIER	65	нвс	0	K [−] p 3 GeV/c
$\Gamma(\Xi\pi)/\Gamma(\Xi(1530)\pi)$					Γ3/Γ4
VALUE	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
$1.5^{+0.6}_{-0.4}$	APSELL	70	нвс	0	$K^- p$ 2.87 GeV/ $c$
$\Gamma(\Sigma \overline{K})/\Gamma_{\text{total}}$					Γ ₂ /Γ
VALUE	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
$0.30 \pm 0.15$	ALITTI	69	нвс	-	K [−] p 3.9–5 GeV/c
• • • We do not use the follo	owing data for average	s, fits	, limits,	etc.	
< 0.02	TRIPP	67	RVUE		Use SMITH 65C
$\Gamma(\Sigma \overline{K})/\Gamma(\Lambda \overline{K})$					$\Gamma_2/\Gamma_1$
VALUE	DOCUMENT ID		TECN	CHG	COMMENT
0.24±0.10	GAY	76C	нвс	-	$K^- p$ 4.2 GeV/ $c$
$\Gamma(\Xi(1530)\pi)/\Gamma_{total}$					$\Gamma_4/\Gamma$
VALUE	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
0.30±0.15	ALITTI	69	нвс	-	K [−] p 3.9–5 GeV/c
• • We do not use the following the fol				etc. •	
seen	ASTON		LASS		$K^- p$ 11 GeV/c
not seen	5 HASSALL	81	HBC		K- p 6.5 GeV/c
< 0.25	⁶ DAUBER	69	нвс		K [−] p 2.7 GeV/c
$\Gamma(\Xi(1530)\pi)/\Gamma(\Lambda\overline{K})$					$\Gamma_4/\Gamma_1$
0.38±0.27 OUR AVERAGE	DOCUMENT ID Error includes scale fa-		TECN_	<u>CHG</u>	COMMENT
1.0 ±0.3	GAY		HBC		K [−] p 4.2 GeV/c
0.26±0.13	SMITH		HBC	-0	$K^{-} p 2.45-2.7$
0.20 ± 0.13	JIVITTI	000	1100	-0	GeV/c

$\Gamma(\Xi\pi\pi(\text{not}\Xi(1530)\pi)$	)/Γ( <i>ΛK</i> )				$\Gamma_5/\Gamma_1$
VALUE	DOCUMENT ID		TECN	CHG	COMMENT
$0.30 \pm 0.20$	BIAGI	87	SPEC	_	Ξ − Be 116 GeV
• • • We do not use the fo	ollowing data for average	s, fits	, limits,	etc. •	• •
< 0.14	7 BADIER	65	нвс	0	1 st. dev. limit
>0.1	SMITH	65C	нвс	-0	K ⁻ p 2.45-2.7 GeV/c
$\Gamma(\Xi\pi\pi(\text{not}\Xi(1530)\pi)$	))/Γ( <i>Ξ</i> (1530) <i>π</i> )				Γ ₅ /Γ ₄
VALUE	DOCUMENT ID		TECN	CHG	COMMENT
consistent with zero	GAY	76C	HBC	_	K-p 4.2 GeV/c
• • • We do not use the fo	ollowing data for average	s, fits	, limits,	etc. •	• •
0.3±0.5	8 APSELL	70	HBC	0	K [−] p 2.87 GeV/c

#### **Ξ(1820) FOOTNOTES**

- 1  BIAGI 87 also sees weak signals in the in the  $\Xi^-\,\pi^+\,\pi^-$  channel at 1782.6  $\pm$  1.4 MeV ( $\Gamma=6.0\pm1.5$  MeV) and 1831.9  $\pm$  2.8 MeV ( $\Gamma=9.6\pm9.9$  MeV).
- (1 = 6.0  $\pm$  1.5 MeV) and 1531.9  $\pm$  2.6 MeV (1 = 5.0  $\pm$  9.7 MeV).

  2 BADIER 72 adds all channels and divides the peak into lower and higher mass regions. The data can also be fitted with a single Breit-Wigner of mass 1800 MeV and width 150 MeV.

  3 From a fit to inclusive  $\pm \pi$ ,  $\pm \pi$ , and  $\Lambda K^-$  spectra.
- ⁴ From a fit to inclusive  $\Xi\pi$  and  $\Xi\pi\pi$  spectra only. ⁵ Including  $\Xi\pi\pi$ .

- 6 DAUBER 69 uses in part the same data as SMITH 65c. 7 For the decay mode  $\Xi^-\pi^+\pi^0$  only. This limit includes  $\Xi(1530)\pi$ . 8 Or less. Upper limit for the 3-body decay.

### ≡(1820) REFERENCES

BIAGI	87	ZPHY C34 15	<ul> <li>+ (BRIS, CERN, GEVA, HEIDP, LAUS, LOQM, RAL)</li> </ul>
BIAGI	87C	ZPHY C34 175	+ (BRIS, CERN, GEVA, HEIDP, LAUS, LOQM, RAL) JP
ASTON	85B	PR D32 2270	+Carnegie+ (SLAC, CARL, CNRC, CINC)
JENKINS	83	PRL 51 951	+Albright, Diamond+ (FSU, BRAN, LBL, CINC, MASD)
BIAGI	81	ZPHY C9 305	+ (BRIS, CAVE, GEVA, HEIDP, LAUS, LOQM, RHEL)
HASSALL	81	NP B189 397	+Ansorge, Carter, Neale+ (CAVE, MSU)
TEODORO	78	PL 77B 451	+Diaz, Dionisi, Blokzijl+ (AMST, CERN, NIJM, OXF) JP
BRIEFEL	77	PR D16 2706	+Gourevitch, Chang+ (BRAN, UMD, SYRA, TUFTS)
Also	69	PRL 23 884	Apsell+ (BRAN, UMD, SYRA, TUFTS)
GAY	76	NC 31A 593	+Jeanneret, Bogdanski+ (NEUC, LAUS, LIVP, CURIN)
GAY	76C	PL 62B 477	+Armenteros, Berge+ (AMST, CERN, NIJM) IJ
DIBIANCA	75	NP B98 137	+Endorf (CMU)
BADIER	72	NP B37 429	+Barrelet, Charlton, Videau (EPOL)
APSELL	70	PRL 24 777	+ (BRAN, UMD, SYRA, TUFTS) I
CRENNELL	70B	PR D1 847	+Karshon, Lai, O'Neall, Scarr, Schumann (BNL)
ALITTI	69	PRL 22 79	+Barnes, Flaminio, Metzger+ (BNL, SYRA) I
DAUBER	69	PR 179 1262	+Berge, Hubbard, Merrill, Miller (LRL)
TRIPP	67	NP B3 10	+Leith+ (LRL, SLAC, CERN, HEID, SACL)
BADIER	65	PL 16 171	+Demoulin, Goldberg+ (EPOL, SACL, AMST) I
SMITH	65B	Athens Conf. 251	+Lindsey (LRL)
SMITH	65C	PRL 14 25	+Lindsey, Button-Shafer, Murray (LRL) IJP
HALSTEINSLI	63	Siena Conf. 1 73	+ (BERG, ČERN, EPOL, RHEL, LÖUC) I

#### OTHER RELATED PAPERS -

TEODORO BRIEFEL	78 75	PL 77B 451 PR D12 1859	+Diaz, Dionisi, Blokzijl+ +Gourevitch+ (AMST, CERN, NIJ (BRAN, UMD, SYRA,	
SCHMIDT	73	Purdue Conf. 363		(BRAN)
MERRILL	68	PR 167 1202	+Shafer	(LRL)
SMITH	64	PRL 13 61	+Lindsey, Murray, Button-Shafer+	(LRL) IJP

## $\Xi(1950)$

$$I(J^P) = \frac{1}{2}(?^?)$$
 Status: ***

We list here everything reported between 1875 and 2000 MeV. The accumulated evidence for a  $\Xi$  near 1950 MeV seems strong enough to include a  $\Xi(1950)$  in the main Baryon Table, but not much can be said about its properties. In fact, there may be more than one  $\Xi$ near this mass.

### ≡(1950) MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
1950±15 OUR EST	TIMATE				
1944± 9	129	BIAGI	87	SPEC	$\Xi^-$ Be $\to$ $(\Xi^-\pi^+)\pi^- \times$
1963 ± 5 ± 2	63	BIAGI	8 <b>7</b> C	SPEC	$\Xi^-$ Be $\rightarrow (\Lambda \overline{K}^0)$ X
1937± 7	150	BIAGI	81	SPEC	SPS hyperon beam
$1961 \pm 18$	139	BRIEFEL	77	HBC	2.87 $K^- p \rightarrow \Xi^- \pi^+ X$
1936 ± 22	44	BRIEFEL	77	HBC	2.87 $K^- p \to \Xi^0 \pi^- X$
$1964 \pm 10$	56	BRIEFEL	77	HBC	$\Xi(1530)\pi$
$1900 \pm 12$		DIBIANCA	75	DBC	$\Xi \pi$
$\textbf{1952} \pm \textbf{11}$	25	ROSS	73C		$(\Xi\pi)^-$
1956± 6	29	BADIER	72	HBC	$\Xi \pi$ , $\Xi \pi \pi$ , YK
$1955\pm14$	21	GOLDWASSER	70	HBC	$\Xi \pi$
$1894\pm18$	66	DAUBER	69	HBC	$\equiv \pi$
$1930 \pm 20$	27	ALITTI	68	HBC	$\equiv -\pi^+$
$1933\pm16$	35	BADIER	65	нвс	$\equiv -\pi^+$

 $\Xi(1950), \Xi(2030)$ 

### **Ξ**(1950) WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
60±20 OUR ESTIM	ATE				
$100\pm31$	129	BIAGI	87	SPEC	$\Xi^-$ Be $\rightarrow$
					$(\Xi^-\pi^+)\pi^-\times$
$25 \pm 15 \pm 1.2$	63	BIAGI	87C	SPEC	$\Xi^-$ Be $\rightarrow (\Lambda \overline{K}^0)$ X
60± 8	150	BIAGI	81	SPEC	SPS hyperon beam
$159 \pm 57$	139	BRIEFEL	77	нвс	2.87 $K^- p \to \Xi^- \pi^+ X$
87 ± 26	44	BRIEFEL	77	HBC	$2.87 \ K^- \rho \rightarrow \Xi^0 \pi^- X$
$60 \pm 39$	56	BRIEFEL	77	HBC	$\Xi(1530)\pi$
63±78		DIBIANCA	75	DBC	$\Xi \pi$
$38\pm10$		ROSS	<b>73</b> C		$(\Xi\pi)^-$
$35 \pm 11$	29	BADIER	72	HBC	$\Xi \pi$ , $\Xi \pi \pi$ , YK
56±26	21	GOLDWASSER	70	HBC	$\Xi \pi$
98±23	66	DAUBER	69	HBC	$\equiv \pi$
$80 \pm 40$	27	ALITTI	68	HBC	$\equiv -\pi^+$
$140\pm35$	35	BADIER	65	HBC	$\Xi^-\pi^+$

### ≡(1950) DECAY MODES

Mode	Fraction $(\Gamma_i/\Gamma)$
$ \begin{array}{l} \Lambda \overline{K} \\ \Sigma \overline{K} \\ \Xi \pi \\ \Xi (1530) \pi \\ \Xi \pi \pi (\text{not } \Xi (1530) \pi) \end{array} $	seen possibly seen seen

### ≡(1950) BRANCHING RATIOS

$\Gamma(\Sigma \overline{K})/\Gamma(\Lambda \overline{K})$	2)						$\Gamma_2/\Gamma_1$	
VALUE	CL%	EVTS	DOCUMENT ID		TECN	COMMENT		
<2.3	90	0	BIAGI	87C	SPEC	Ξ-Be 116 GeV		
$\Gamma(\Sigma \overline{K})/\Gamma_{\text{total}}$							$\Gamma_2/\Gamma$	
VALUE		EVTS	DOCUMENT ID		TECN	COMMENT		
possibly seen		17	HASSALL	81	нвс	K− p 6.5 GeV/c		
$\Gamma(\Xi\pi)/\Gamma(\Xi(1$	.530) π	)					$\Gamma_3/\Gamma_4$	
VALUE		, 	DOCUMENT ID		TECN			
$2.8^{+0.7}_{-0.6}$			APSELL	70	нвс			
$\Gamma(\equiv \pi \pi (\text{not} \equiv (1530)\pi))/\Gamma(\equiv (1530)\pi)$								
VALUE			DOCUMENT ID		TECN			
0.0 ± 0.3			APSELL	70	HBC			

### ≡(1950) REFERENCES

BIAGI	87	ZPHY C34 15	+ (BRIS, CERN, GEVA, HEID	
BIAGI	87C	ZPHY C34 175	<ul> <li>+ (BRIS, CERN, GEVA, HEID</li> </ul>	P, LAUS, LOQM, RAL)
BIAGI	81	ZPHY C9 305	<ul> <li>+ (BRIS, CAVE, GEVA, HEIDP,</li> </ul>	LAUS, LOQM, RHEL)
HASSALL	81	NP B189 397	+Ansorge, Carter, Neale+	(CAVE, MSU)
BRIEFEL	77	PR D16 2706	+Gourevitch, Chang+ (BRAN,	UMD, SÝRA, TUFTS)
Also	70	Duke Conf. 317	Briefel+ (BRAN,	UMD, SYRA, TUFTS)
DIBIANCA	75	NP B98 137	+Endorf	(CMU)
ROSS	73C	Purdue Conf. 345	+Lloyd, Radojicic	(OXF)
BADIER	72	NP B37 429	+Barrelet, Charlton, Videau	(EPOL)
APSELL	70	PRL 24 777	+ (BRAN,	UMD, SYRA, TUFTS) I
GOLDWASSER	70	PR D1 1960	+Schultz	(ILL)
DAUBER	69	PR 179 1262	+Berge, Hubbard, Merrill, Miller	(ĹRL) I
ALITTI	68	PRL 21 1119	+Flaminio, Metzger, Radojicic+	(BNL, SYRA) I
BADIER	65	PL 16 171	+Demoulin, Goldberg+	(EPOL, SACL, AMST) I

## $\Xi(2030)$

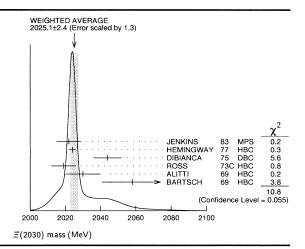
$$I(J^P) = \frac{1}{2}(\geq \frac{5}{2}?)$$
 Status: ***

The evidence for this state has been much improved by HEMINGWAY 77, who see an eight standard deviation enhancement in  $\Sigma \overline{K}$  and a weaker coupling to  $\Lambda \overline{K}$ . ALITTI 68 and HEMINGWAY 77 observe no signals in the  $\Xi \pi \pi$  (or  $\Xi(1530)\pi$ ) channel, in contrast to DIBIANCA 75. The decay  $(\Lambda/\Sigma)\overline{K}\pi$  reported by BARTSCH 69 is also not confirmed by HEMINGWAY 77.

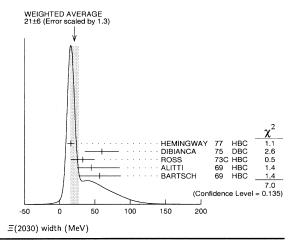
A moments analysis of the HEMINGWAY 77 data indicates at a level of three standard deviations that  $J \geq 5/2$ .

### ≡(2030) MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
2025 ± 5 OUF 2025.1± 2.4 OUF		ror includes scale	facto	or of 1.3	. See	the ideogram below.
$2022 \ \pm \ 7$		JENKINS	83	MPS	_	$K^- p \rightarrow K^+$ MM
2024 ± 2	200	HEMINGWAY	77	нвс	_	$K^{-}p$ 4.2 GeV/c
2044 ± 8		DIBIANCA	75	DBC	-0	$\Xi \pi \pi, \Xi^* \pi$
$2019 \pm 7$	15	ROSS	73C	HBC	-0	$\Sigma \overline{K}$
2030 ±10	42	ALITTI	69	нвс	-	K [−] p 3.9–5 GeV/ <i>c</i>
2058 +17	40	BARTSCH	69	HBC	-0	$K^- p$ 10 GeV/c



<i>Ξ</i> (2030) WIDTH									
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT			
20 + 15 OUR ESTIMATE	20 + 15 OUR ESTIMATE								
21± 6 OUR AVERAGE	Error inclu	ides scale factor	of 1	.3. See	the ide	ogram below.			
16± 5	200	HEMINGWAY	77	HBC	_	K [−] p 4.2 GeV/c			
60 ± 24		DIBIANCA	75	DBC	-0	$\Xi \pi \pi$ , $\Xi^* \pi$			
33±17	15	ROSS	<b>73</b> C	HBC	-0	$\Sigma \overline{K}$			
$45 + 40 \\ -20$		ALITTI	69	нвс	-	K [−] p 3.9−5 GeV/c			
57±30		BARTSCH	69	HBC	-0	K- p 10 GeV/c			



### ≡(2030) DECAY MODES

	Mode	Fraction $(\Gamma_i/\Gamma)$	
Γ ₁	ΛK	~ 20 %	
$\Gamma_2$	$\Sigma \overline{K}$	~ 80 %	
$\Gamma_3$	$\equiv \pi$	small	
	$\Xi(1530)\pi$	small	
$\Gamma_5$	$\Xi \pi \pi (\text{not }\Xi(1530)\pi)$	small	
$\Gamma_6$	$\Lambda \overline{K} \pi$	small	
Γ ₇	$\Sigma \overline{K} \pi$	small	

### ≡(2030) BRANCHING RATIOS

$\Gamma(\Xi\pi)/ \Gamma(\Lambda \overline{K}) +$	$\Gamma(\Sigma K) +$	$-\Gamma(\Xi\pi)+\Gamma(\Xi\pi)$	E(153	i0)π)∐	Γ3/	$(\Gamma_1+\Gamma_2+\Gamma_3$	ı+Γ4)
VALUE		DOCUMENT IL		TECN	CHG	COMMENT	
<ul> <li>◆ ◆ We do not use</li> </ul>	the followin	g data for averag	ges, fit	s, limits	, etc. •	• •	
<0.30		ALITTI	69	нвс	-	1 standard o	lev.
$\Gamma(\Xi\pi)/\Gamma(\Sigma\overline{K})$						ı	Γ3/Γ2
VALUE	CL%	DOCUMENT IL		TECN	CHG	COMMENT	
< 0.19	95	HEMINGWA	Y 77	HBC		K- p 4.2 G	eV/c

≡(2120) DECAY MODES

Fraction  $(\Gamma_i/\Gamma)$ 

seen

See key on page 199

25 ± 12

Mode  $\Lambda \overline{K}$ 

### **Ξ**(2120) BRANCHING RATIOS

Γ ₁ /Γ
MENT ID TECN COMMENT
APNIK 79 HBC $K^+p \rightarrow (\overline{\Lambda}K^+)X$
76C HBC $K^{-}p$ 4.2 GeV/c
7

#### **Ξ**(2120) FOOTNOTES

 1  CHLIAPNIKOV 79 does not uniquely identify the  $K^+$  in the  $(\overline{\Lambda}K^+)$  X final state. It also reports bumps with fewer events at 2240, 2540, and 2830 MeV.

### ≡(2120) REFERENCES

CHLIAPNIK... 79 NP B158 253 HEMINGWAY 77 PL 68B 197 GAY 76C PL 62B 477 Chliapnikov, Gerdyukov+ +Armenteros+ +Armenteros, Berge+ (CERN, BELG, MONS) (AMST, CERN, NIJM, OXF) (AMST, CERN, NIJM)

三(2250)

 $I(J^P) = \frac{1}{2}(?^?)$  Status: ** J, P need confirmation.

#### OMITTED FROM SUMMARY TABLE

The evidence for this state is mixed. BARTSCH 69 sees a bump of not much statistical significance in  $\Lambda \overline{K} \pi$ ,  $\Sigma \overline{K} \pi$ , and  $\Xi \pi \pi$  mass spectra. GOLDWASSER 70 sees a narrower bump in  $\Xi\pi\pi$  at a higher mass. Not seen by HASSALL 81 with 45 events/ $\mu$ b at 6.5  ${\rm GeV}/c$ . Seen by JENKINS 83. Perhaps seen by BIAGI 87.

Ξ(2250) MASS								
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT		
≈ 2250 OUR EST	MATE							
2189± 7	66	BIAGI	87	SPEC	-	$\Xi^{-} \stackrel{\text{Be}}{\underset{(\Xi^{-}\pi^{+}\pi^{-})}{\to}}$		
2214± 5		JENKINS	83	MPS	Name .	$K \stackrel{\frown}{p} \rightarrow K^+$		
$2295 \pm 15$	18	GOLDWASSER	70	HBC		$K^-p$ 5.5 GeV/c		
2244±52	35	BARTSCH	69	нвс		K [−] p 10 GeV/c		
		<i>Ξ</i> (2250) WIDT	Н					
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT		
46±27	66	BIAGI	87	SPEC	-	$\Xi^{-} \stackrel{Be}{\underset{X}{\overset{-}}} \to \pi^{+} \pi^{-})$		
< 30		GOLDWASSER	70	нвс	_	$K^{-p}$ 5.5 GeV/c		
130 ± 80		BARTSCH	69	нвс		,		

### ≡(2250) DECAY MODES

	Mode	
	$\Xi\pi\pi$	
Γ ₂ Γ ₃	$\Lambda \overline{K} \pi \Sigma \overline{K} \pi$	

### ≡(2250) REFERENCES

² GAY 76c sees a 4-standard deviation signal. However, HEMINGWAY 77, with more events from the same experiment points out that the signal is greatly reduced if a cut is made on the 4-momentum u. This suggests an anomalous production mechanism if the  $\Xi(2120)$  is real.

 $\Xi(2370), \Xi(2500)$ 

|--|

 $I(J^P) = \frac{1}{2}(?^?)$  Status: ** J, P need confirmation.

OMITTED FROM SUMMARY TABLE

		<i>Ξ</i> (2370) MA	SS			
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
≈ 2370 OUR EST	MATE					
$2356\pm10$		JENKINS	83	MPS	-	$K^- p \rightarrow K^+$ MM
2370	50	HASSALL	81	HBC	-0	K [−] p 6.5 GeV/c
2373± 8	94	AMIRZADEH	80	HBC	-0	K- p 8.25 GeV/c
$2392 \pm 27$		DIBIANCA	75	DBC		$\Xi 2\pi$
		<i>Ξ</i> (2370) WID	ТН			
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
80	50	HASSALL	81	HBC	-0	$K^- p$ 6.5 GeV/c
80 ± 25	94	AMIRZADEH	80	HBC	-0	K- p 8.25 GeV/c
75 ± 69		DIBIANCA	75	DBC		$\Xi 2\pi$

### ≡(2370) DECAY MODES

	Mode	Fraction $(\Gamma_i/\Gamma)$	
Γ ₁	$\frac{\Lambda \overline{K} \pi}{\ln \text{cludes } \Gamma_4 + \Gamma_6.}$	seen	
$\Gamma_2$	$\Sigma \overline{K} \pi$ Includes $\Gamma_5 + \Gamma_6$ .	seen	
Гз	$\Omega^-K$		
Γ ₃ Γ ₄	Λ\( \overline{K}^*(892)		
$\Gamma_5$	$\Sigma \overline{K}^*$ (892)		
Γ ₆	$\Sigma(1385)\overline{K}$		

### **Ξ**(2370) BRANCHING RATIOS

$\Gamma(\Lambda \overline{K}\pi)/\Gamma_{\text{total}}$					$\Gamma_1/\Gamma$
VALUE	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
seen	AMIRZADEH	80	нвс	-0	K [−] p 8.25 GeV/c
$\Gamma(\Sigma \overline{K}\pi)/\Gamma_{total}$					$\Gamma_2/\Gamma$
VALUE	DOCUMENT ID		TECN	CHG	COMMENT
seen	AMIRZADEH	80	нвс	-0	K− p 8.25 GeV/c
$[\Gamma(\Lambda \overline{K}\pi) + \Gamma(\Sigma \overline{K}\pi)]/\Gamma_{\text{total}}$	ai				$(\Gamma_1+\Gamma_2)/\Gamma$
VALUE EVTS	DOCUMENT ID		TECN	CHG	COMMENT
seen 50	HASSALL	81	HBC	_0	$K^- p$ 6.5 GeV/ $c$
$\Gamma(\Omega^-K)/\Gamma_{\text{total}}$					Γ ₃ /Γ
VALUE	DOCUMENT ID		TECN	CHG	COMMENT
$0.09 \pm 0.04$	¹ KINSON	80	нвс	-	K [−] p 8.25 GeV/c
$\Gamma(\Lambda \overline{K}^*(892)) + \Gamma(\Sigma \overline{K}^*(892))$	2))]/Γ _{total}				$(\Gamma_4+\Gamma_5)/\Gamma$
VALUE	DOCUMENT ID		TECN	CHG	COMMENT
$0.22 \pm 0.13$	¹ KINSON	80	HBC	-	K [−] p 8.25 GeV/c
$\Gamma(\Sigma(1385)\overline{K})/\Gamma_{\text{total}}$					Γ ₆ /Γ
VALUE	DOCUMENT ID		TECN	CHG	COMMENT
$0.12 \pm 0.08$	¹ KINSON	80	нвс	-	K [−] p 8.25 GeV/c

### ≡(2370) FOOTNOTES

### (2370) REFERENCES

JENKINS HASSALL AMIRZADEH KINSON	83 81 80 80	PRL 51 951 NP B189 397 PL 90B 324 Toronto Conf. NP B98 137	263	+Ansorge, + +	CERN,	GLAS,	(CAVE	MASD) E, MSU) CURIN) I CURIN) I (CMU)	
DIBIANCA	75	NP B98 137		+Endorf				(CMU)	



VALUE

 $\Gamma(\Xi\pi\pi)/\Gamma_{\text{total}}$ 

 $\left[\Gamma\big(\Lambda\overline{K}\pi\big)+\Gamma\big(\Sigma\overline{K}\pi\big)\right]/\Gamma_{\mathsf{total}}$ 

 $I(J^P) = \frac{1}{2}(?^?)$  Status: * J, P need confirmation.

OMITTED FROM SUMMARY TABLE  The ALITTI 69 peak might be instead the $\Xi(2370)$ or might be neither the $\Xi(2370)$ nor the $\Xi(2500)$ .						
		<i>Ξ</i> (2500) MA	SS			
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
≈ 2500 OUR ESTI 2505 ± 10	MATE	JENKINS	83	MPS	_	$K^- p \rightarrow K^+$
2430±20	30	ALITTI	69	нвс	_	ММ К−р 4.6–5
2500±10	45	BARTSCH	69	нвс	-0	GeV/ <i>c</i> K ⁻ <i>p</i> 10 GeV/ <i>c</i>
		<i>Ξ</i> (2500) WID	тн			
VALUE (MeV)		DOCUMENT ID		TECN	<u>CHG</u>	
$150^{+60}_{-40}$		ALITTI	69	нвс		
59±27		BARTSCH	69	нвс	-0	
≘(2500) DECAY MODES						
Mode			Frac	tion (Γ _i	/ <b>r</b> )	
$ \Gamma_{2}^{2} \qquad \Lambda \overline{K}  \Gamma_{3} \qquad \Sigma \overline{K}  \Gamma_{4} \qquad \Xi \pi \pi  \Gamma_{5} \qquad \Xi (1530) \pi  \Gamma_{6} \qquad \Lambda \overline{K} \pi +  $			seen seen			
≡(2500) BRANCHING RATIOS						
$\Gamma(\Xi\pi)/[\Gamma(\Xi\pi)]$ VALUE	$+\Gamma(\Lambda\overline{K})+$	$\Gamma(\Sigma\overline{K}) + \Gamma(\Xi)$				(Γ ₁ +Γ ₂ +Γ ₃ +Γ ₁ _{ΜΕΝΤ}
<0.5		ALITTI		нвс		ndard dev. limit
$\frac{\Gamma(\Lambda \overline{K})/[\Gamma(\Xi \pi)]}{\frac{VALUE}{0.5 \pm 0.2}}$	) + Γ(Λ <i>K</i> ) +	- Γ( <b>Σ</b> K) + Γ(Ξ <u>DOCUMENT ID</u> ALITTI				
$\frac{\Gamma(\Sigma\overline{K})/[\Gamma(\Xi\pi)]}{\sum_{\substack{VALUE\\0.5\pm0.2}}$	) + Γ(Λ <i>K</i> ) +	+ Γ(Σ K) + Γ(Ξ <u>DOCUMENT ID</u> ALITTI				((Γ ₁ +Γ ₂ +Γ ₃ +Γ ₁
Γ(Ξ(1530)π)/[	[Γ( <i>Ξπ</i> ) + Γ(	$(\Lambda \overline{K}) + \Gamma(\Sigma \overline{K})$	+ F	(Ξ(15	30)π) Γ-	] ′(Γ ₁ +Γ ₂ +Γ ₃ +Γ
VALUE		DOCUMENT ID		TECN	сом	MENT
< 0.2		ALITTI	69	HBC	1 sta	indard dev. limit

### ≡(2500) REFERENCES

DOCUMENT ID TECN CHG
BARTSCH 69 HBC -0

DOCUMENT ID TECN CHG
BARTSCH 69 HBC -0

 $\Gamma_4/\Gamma$ 

 $\Gamma_6/\Gamma$ 

ALITTI 69 PRL 22 79 +Barnes, Flaminio, Metzger+ (BNL, SYRA) BARTSCH 69 PL 28B 439 + (AACH, BERL, CERN, LOIC, VIEN)	JENKINS		PRL 51 951	+Albright, Diamond+ (FSU, BRAN, LBL, CINC, MASD)	
BARTSCH 69 PL 28B 439 + (AACH, BERL, CERN, LOIC, VIEN)	ALITTI	69	PRL 22 79	+Barnes, Flaminio, Metzger+ (BNL, SYRA) I	
	BARTSCH	69	PL 28B 439	+ (AACH, BERL, CERN, LOIC, VIEN)	

 $^{^{1}\,\}mathrm{KINSON}$  80 is a reanalysis of AMIRZADEH 80 with 50% more events.

## $\Omega$ BARYONS (S=-3, I=0)

 $\Omega^- = sss$ 

$$I(J^P) = O(\frac{3}{2}^+)$$
 Status: ***

The unambiguous discovery in both production and decay was by BARNES 64. The quantum numbers have not actually been measured, but follow from the assignment of the particle to the baryon decuplet. DEUTSCHMANN 78 and BAUBILLIER 78 rule out J=1/2 and find consistency with J=3/2.

We have omitted some results that have been superseded by later experiments. See our earlier editions.

#### $\Omega^-$ MASS

The fit assumes the  $\Omega^-$  and  $\overline{\Omega}^+$  masses are the same.

VALUE (MeV) 1672.45±0.29 OUR FIT	EVTS	DOCUMENT ID		TECN	COMMENT
1672.43±0.32 OUR AV					
1673 ±1	100	HARTOUNI	85	SPEC	80-280 GeV K10 C
1673.0 ±0.8	41	BAUBILLIER	78	HBC	8.25 GeV/c K = p
1671.7 ±0.6	27	HEMINGWAY	78	HBC	4.2 GeV/c K-p
$1673.4 \pm 1.7$	4	¹ DIBIANCA	75	DBC	4.9 GeV/c K-d
$1673.3 \pm 1.0$	3	PALMER	68	HBC	$K^- p$ 4.6, 5 GeV/c
1671.8 ±0.8	3	SCHULTZ	68	HBC	K [−] p 5.5 GeV/c
1674.2 ±1.6	5	SCOTTER	68	HBC	$K^-p$ 6 GeV/c
$1672.1 \pm 1.0$	1	² FRY	55	<b>EMUL</b>	
• • • We do not use the	e followin	g data for average	s, fits	, limits,	etc. • • •
$1671.43 \pm 0.78$	13	3 DEUTSCH	73	нвс	K [−] p 10 GeV/c
1671.9 ±1.2	6	³ SPETH	69	нвс	See
1673.0 ±8.0 1670.6 ±1.0	1	ABRAMS ² FRY		HBC EMUL	DEUTSCHMANN 73 $= \pi^0$
1615	1	⁴ EISENBERG	54	EMUL	

- $^{1}\,\mathsf{DIBIANCA}$  75 gives a mass for each event. We quote the average.
- 2  The FRY 55 and FRY 558 events were identified as  $\Omega^-$  by ALVAREZ 73. The masses ² The FRY 55 and FRY 55s events were identified as  $\Omega^-$  by ALVAREZ 73. The masses assume decay to  $\Lambda K^-$  at rest. For FRY 55s, decay from an atomic orbit could Doppler shift the  $K^-$  energy and the resulting  $\Omega^-$  mass by several MeV. This shift is negligible for FRY 55 because the  $\Omega$  decay is approximately perpendicular to its orbital velocity, as is known because the  $\Lambda$  strikes the nucleus (L.Alvarez, private communication 1973). We have calculated the error assuming that the orbital  $\Omega$  is 4 or larger.

  ³ Excluded from the average; the  $\Omega^-$  lifetimes measured by the experiments differ significantly from other measurements.
- The EISENBERG 54 mass was calculated for decay in flight. ALVAREZ 73 has shown that the  $\Omega$  interacted with an Ag nucleus to give  $K^- \Xi Ag$ .

### $\overline{\Omega}^+$ MASS

The fit assumes the  $\Omega^-$  and  $\overline{\Omega}^+$  masses are the same.

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
1672.45±0.29 OUI				
1672 ±1	72	HARTOUNI	85 SPEC	80-280 GeV K10 C
1673.1 ±1.0	1	FIRESTONE	71B HBC	12 GeV/c K+ d

#### $(m_{O^-} - m_{\overline{O}^+}) / m_{average}$

A test of CPT invariance. Calculated from the average  $\Omega^-$  and  $\overline{\Omega}^+$ masses, above.

DOCUMENT ID

 $(0\pm5) \times 10^{-4}$  OUR EVALUATION

#### Ω- MEAN LIFE

Measurements with an error  $>~0.1\times10^{-10}$  s have been omitted.

VALUE (10 ⁻¹⁰ s)	EVTS	DOCUMENT ID		TECN	COMMENT	
0.822±0.012 OUR	AVERAGE					
$0.811 \pm 0.037$	1096	LUK	88	SPEC	pBe 400 GeV	
$0.823 \pm 0.013$	12k	BOURQUIN	84	SPEC	SPS hyperon beam	
$0.822 \pm 0.028$	2437	BOURQUIN	79B	SPEC	See BOURQUIN 84	

#### $\Omega^-$ MAGNETIC MOMENT

VALUE (μ _N )	EVTS	DOCUMENT ID		TECN	COMMENT
-2.02 ±0.05 OUR	AVERAGE				
$-2.024 \pm 0.056$	235k	WALLACE	95	SPEC	$\Omega^-$ 300–550 GeV
$-1.94 \pm 0.17 \pm 0.14$	25k	DIEHL	91	SPEC	Spin-transfer production

#### Ω- DECAY MODES

	Mode	Fraction $(\Gamma_i/\Gamma)$	Confidence level				
$\overline{\Gamma_1}$	ΛK-	(67.8±0.7) %					
$\Gamma_2$	$\equiv^0 \pi^-$	(23.6±0.7) %					
Γ3	$\equiv -\pi^0$	( 8.6±0.4) %					
$\Gamma_4$	$\bar{z}^-\pi^+\pi^-$	$(4.3^{+3.4}_{-1.3}) \times 10^{-4}$					
_	$\equiv$ (1530) $^{0}\pi^{-}$	$(6.4^{+5.1}_{-2.0}) \times 10^{-4}$					
$\Gamma_6$	$\equiv^0 e^- \overline{\nu}_e$	$(5.6\pm2.8)\times10^{-3}$					
Γ ₇	$\equiv -\gamma$	$< 4.6 \times 10^{-4}$	90%				
$\Delta S = 2$ forbidden (S2) modes							
Γ8	$\Lambda\pi^-$	$52 < 1.9 \times 10^{-4}$	90%				

#### $\Omega^-$ Branching ratios

The BOURQUIN 84 values (which include results of BOURQUIN 79B, a

		much more accurate been omitted.	ate than ar	y other results, and	
$\Gamma(\Lambda K^-)/\Gamma_{\text{total}}$					Γ1/Γ
VALUE	EVTS	DOCUMENT ID	TECI	COMMENT	
0.678±0.007	14k	BOURQUIN	84 SPE		n
<ul> <li>• • We do not use</li> </ul>	the followin	g data for average	s, fits, limi	ts, etc. • • •	
$0.686 \pm 0.013$	1920	BOURQUIN	79B SPE	C See BOURQUIN 8	14
$\Gamma(\Xi^0\pi^-)/\Gamma_{\text{total}}$					$\Gamma_2/\Gamma$
VALUE	EVTS	DOCUMENT ID	TEC	COMMENT	
$0.236 \pm 0.007$	1947	BOURQUIN	84 SPE		n
• • • We do not use	the followin	g data for average	s, fits, limi	ts, etc. • • •	
$0.234 \pm 0.013$	317	BOURQUIN	79B SPE	C See BOURQUIN 8	4
$\Gamma(\Xi^-\pi^0)/\Gamma_{\text{total}}$					$\Gamma_3/\Gamma$
VALUE	EVTS	DOCUMENT ID			
$0.086 \pm 0.004$	759	BOURQUIN	84 SPE		n
• • We do not use	the followin	g data for average	s, fits, limi	ts, etc. • • •	
$0.080 \pm 0.008$	145	BOURQUIN	79B SPE	C See BOURQUIN 8	4
$\Gamma(\Xi^-\pi^+\pi^-)/\Gamma_{\rm tot}$	:al				Γ4/Γ
VALUE (units 10-4)	EVTS	DOCUMENT ID	TEC	COMMENT	
4.3 ^{+3.4} -1.3	4	BOURQUIN	84 SPE	SPS hyperon bean	n
Γ(Ξ(1530) ⁰ π ⁻ )/Γ	total				Г ₅ /Г
VALUE (units 10 ⁻⁴ )	EVTS	DOCUMENT ID	TEC	COMMENT	
6.4 +5.1	4	5 BOURQUIN	84 SPE	C SPS hyperon bean	n
• • We do not use	the followin	g data for average	s, fits, limi	ts, etc. • • •	
~ 20	1			See BOURQUIN 8	4
⁵ The same 4 events $\Xi(1530)^0 \rightarrow \Xi^0$	s as in the p $\pi^0$ decays in	revious mode, with		n factor to take into a	
$\Gamma(\Xi^0 e^- \overline{\nu}_e) / \Gamma_{\text{total}}$	, 1				Γ ₆ /Γ
VALUE (units 10 ⁻³ )	EVTS	DOCUMENT ID	TEC	COMMENT	-
5.6±2.8	14	BOURQUIN	84 SPE		1
• • • We do not use	the followin	g data for average	s, fits, limi		
~ 10	3	BOURQUIN	79B SPE	See BOURQUIN 8	4
$\Gamma(\Xi^-\gamma)/\Gamma_{total}$					$\Gamma_7/\Gamma$
	v 51.050	DOGUMENT ID	T.C.	COLUMENT	.,,.

#### VALUE (units 10-4) CL% EVTS DOCUMENT ID ALBUQUERQ...94 E761 $\Omega^-$ 375 GeV $\bullet$ $\,\bullet\,$ We do not use the following data for averages, fits, limits, etc. $\,\bullet\,$ $\,\bullet\,$ <22 90 BOURQUIN 84 SPEC SPS hyperon beam <31 90 0 BOURQUIN 79B SPEC See BOURQUIN 84

$\Gamma(\Lambda\pi^-)/\Gamma$ $\Delta S=2$		in first-c	rder weak interaction	on.		Γ ₈ /
VALUE (units 1	0-4) CL%	EVTS	DOCUMENT ID		TECN	COMMENT
< 1.9	90	0	BOURQUIN	84	SPEC	SPS hyperon beam
• • • We d	o not use th	e followir	ng data for average	s, fit	s, limits,	etc. • • •
<13	90	0	BOURQUIN	79E	SPEC	See BOURQUIN 84

 $\Omega^{-}$ ,  $\Omega(2250)^{-}$ ,  $\Omega(2380)^{-}$ ,  $\Omega(2470)^{-}$ 

#### **Ω**[−] DECAY PARAMETERS

#### $\alpha$ FOR $\Omega^- \rightarrow \Lambda K^-$

Some early results have been omitted.

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.026±0.026 Ol	JR AVERAGE				
$-0.034 \pm 0.079$	1743	LUK	88	SPEC	pBe 400 GeV
$-0.025 \pm 0.028$	12k	BOURQUIN	84	SPEC	SPS hyperon beam
	•				
$\alpha$ FOR $\Omega^- \rightarrow$	$\Xi^{0}\pi^{-}$				
VALUE	<u>EVTS</u>	DOCUMENT ID		TECN	COMMENT
$+0.09\pm0.14$	1630	BOURQUIN	84	SPEC	SPS hyperon beam
	•				
$\alpha$ FOR $\Omega^- \rightarrow$	$\Xi^-\pi^0$				
VALUE	<u>EVTS</u>	DOCUMENT ID		TECN	COMMENT
$+0.05\pm0.21$	614	BOURQUIN	84	SPEC	SPS hyperon beam

#### Ω⁻ REFERENCES

We have omitted some papers that have been superseded by later experiments. See our earlier editions.

WALLACE 95 PRL 74 3732	+Border+ (MINN, ARIZ, MICH, FNAL)
ALBUQUERQ 94 PR D50 R18	Albuquerque, Bondar, Carrigan+ (FNAL E761 Collab.)
DIEHL 91 PRL 67 804	+Teige, Thompson, Zou+ (RUTG, FNAL, MICH, MINN)
LUK 88 PR D38 19	+Beretvas, Deck+ (RUTG, WISC, MICH, MINN)
HARTOUNI 85 PRL 54 628	+Atiya, Holmes, Knapp, Lee+ (COLU, ILL, FNAL)
BOURQUIN 84 NP B241 1	+ (BRIS, GEVA, HEIDP, LALO, RAL, STRB)
Also 79 PL 87B 297	Bourguin+ (BRIS, GEVA, HEIDP, ORSAY, RHEL, STRB)
BOURQUIN 79B PL 88B 192	+ (BRIS, GEVA, HEIDP, LALO, RAL)
BAUBILLIER 78 PL 78B 342	+ (BIRM, CERN, GLAS, MSU, CURIN, PARIN) J
DEUTSCH 78 PL 73B 96	Deutschmann+ (AACH3, BERL, CERN, INNS, LOIC+) J
HEMINGWAY 78 NP B142 205	+Armenteros+ (CERN, ZEEM, NIJM, OXF)
DIBIANCA 75 NP B98 137	+Endorf (CMU)
	(LBL)
ALVAREZ 73 PR D8 702	
DEUTSCH 73 NP B61 102	Deutschmann, Kaufmann, Besliv+ (ABCLV Collab.)
FIRESTONE 71B PRL 26 410	+Goldhaber, Lissauer, Sheldon, Trilling (LRL)
SPETH 69 PL 29B 252	<ul> <li>+ (AACH, BERL, CERN, LOIC, VIEN)</li> </ul>
PALMER 68 PL 26B 323	+Radojicic, Rau, Richardson+ (BNL, SYRA)
SCHULTZ 68 PR 168 1509	+ (ILL, ANL, NWES, WISC)
SCOTTER 68 PL 26B 474	+ (BIRM, GLAS, LOIC, MUNI, OXF)
ABRAMS 64 PRL 13 670	+Burnstein, Glasser+ (UMD, NRL)
BARNES 64 PRL 12 204	+Connolly, Crennell, Culwick+ (BNL)
FRY 55 PR 97 1189	+Schneps, Swami (WISC)
FRY 55B NC 2 346	+Schneps, Swami (WISC)
EISENBERG 54 PR 96 541	(CORN)
COLINGE ST. 111 70 341	(com)

## $\Omega(2250)^-$

$$I(J^P) = 0(?^?)$$
 Status: ***

### $\Omega(2250)^-$ MASS

VALUE (MeV) 2252± 9 OUR AVERAG	EVTS	DOCUMENT ID	TECN	COMMENT
$2253 \pm 13$	44	ASTON	87B LASS	K [−] p 11 GeV/c
$2251 \pm9 \pm 8$	78	BIAGI	86B SPEC	SPS Ξ [−] beam

### $\Omega(2250)^-$ WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
55±18 OUR AVERAGE				
$81\pm38$	44	ASTON	87B LASS	K [−] p 11 GeV/c
$48\pm20$	78	BIAGI	868 SPEC	SPS $\mathcal{\Xi}^-$ beam

#### $\Omega(2250)^-$ DECAY MODES

	Mode	Fraction $(\Gamma_i/\Gamma)$
$\overline{\Gamma_1}$	$\Xi^-\pi^+K^-$	seen
$\Gamma_2$	$\Xi(1530)^0 K^-$	seen

### $\Omega(2250)^-$ BRANCHING RATIOS

Γ(Ξ(1530) ⁰ K ⁻	)/Γ(Ξ ⁻ π ⁺ K	-)		Γ:	2/Γ1
VALUE	<u>EVTS</u>	DOCUMENT ID	TECN	COMMENT	
$\sim 1.0$	44	ASTON	87B LASS	$K^- p$ 11 GeV/ $c$	
$0.70 \pm 0.20$	49	BIAGI	86B SPEC	Ξ − Be 116 GeV/c	

### $\Omega(2250)^-$ REFERENCES

ASTON	87B	PL B194 579	+Awaji,	Bienz, Bird+	(SLAC,	NAGO, CINC, INUS)
BIAGI	86B	ZPHY C31 33	+	(LOQM, GEVA, RAL,	HEIDP,	LAUS, BRIS, CERN)

## $\Omega(2380)^{-1}$

Status: **

OMITTED FROM SUMMARY TABLE

### $\Omega(2380)^-$ MASS

VALUE (MeV) ≈ 2380 OUR ESTIM	<u>EVTS</u>	DOCUMENT ID	TECN	COMMENT
2384±9±8	45	BIAGI	86B SPEC	SPS = beam

#### $\Omega(2380)^-$ WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT	
26 ± 23	45	BIAGI	868 SPEC	SPS = beam	

### $\Omega(2380)^-$ DECAY MODES

	Mode		_
Γ2	$\Xi^{-}\pi^{+}K^{-}$ $\Xi(1530)^{0}K^{-}$ $\Xi^{-}\overline{K}^{*}(892)^{0}$		

### $\Omega(2380)^-$ BRANCHING RATIOS

Γ(Ξ(1530)°K⁻	·)/[(	=-π+K	<del>-</del> )			12/11
VALUE	CL%	EVTS	DOCUMENT ID		<u>TECN</u>	COMMENT
< 0.44	90	9	BIAGI	<b>86</b> B	SPEC	$\Xi^-$ Be 116 GeV/ $c$
$\Gamma(\Xi^-\overline{K}^*(892)^0)/\Gamma(\Xi^-\pi^+K^-)$ $\Gamma_3/\Gamma$						$\Gamma_3/\Gamma_1$
VALUE		EVTS	DOCUMENT ID		<u>TECN</u>	COMMENT
0.5±0.3		21	BIAGI	8 <b>6</b> B	SPEC	Ξ− Be 116 GeV/c

#### $\Omega(2380)^-$ REFERENCES

BIAGI 86B ZPHY C31 33 + (LOQM, GEVA, RAL, HEIDP, LAUS, BRIS, CERN)

## $\Omega(2470)^{-1}$

Status: **

### OMITTED FROM SUMMARY TABLE

A peak in the  $\Omega^-\pi^+\pi^-$  mass spectrum with a signal significance claimed to be at least 5.5 standard deviations. There is no reason to seriously doubt the existence of this state, but unless the evidence is overwhelming we usually wait for confirmation from a second experiment before elevating peaks to the Summary Table.

### $\Omega(2470)^-$ MASS

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
2474±12	59	ASTON	88G LASS	K− ρ 11 GeV/c

### $\Omega(2470)^-$ WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
72±33	59	ASTON	88G LASS	$K^-p$ 11 GeV/ $c$

### $\Omega(2470)^-$ DECAY MODES

Mode  $\Gamma_1 \qquad \Omega^-\pi^+\pi^-$ 

#### Ω(2470) - REFERENCES

ASTON 88G PL B215 799 +Awaji, Bienz, Bird+ (SLAC, NAGO, CINC, INUS)

# CHARMED BARYONS (C = +1)

#### CHARMED BARYONS

Figure 1 shows the SU(4) multiplets that have as their lowest levels (a) the SU(3) octet that contains the nucleon, and (b) the SU(3) decuplet that contains the  $\Delta(1232)$ . All the particles in a given SU(4) multiplet have the same spin and parity. The only known charmed baryons each contain one charmed quark and thus belong to the second level of an SU(4) multiplet. Figure 2 shows this level for the SU(4) multiplet of Fig. 1(a). The level splits apart into two SU(3) multiplets, a  $\overline{3}$  that contains the  $\Lambda_c(2285)$  and the  $\Xi_c(2470)$ , both of which decay weakly, and a 6 that contains the  $\Sigma_c(2455)$ , which decays strongly to  $\Lambda_c \pi$ , and the  $\Omega_c(2710)$ , which decays weakly. A second  $\Xi_c$  remains to be discovered to fill out the 6, and a host of other baryons with one or more charmed quarks are needed to fill out the full SU(4) multiplets. Furthermore, every N or  $\Delta$  baryon resonance "starts" another SU(4) multiplet, so the woods are full of charmed baryons, most of which no doubt will forever remain undiscovered. The only candidates so far to belong to more massive multiplets are the  $\Lambda_c(2593)$  and the  $\Lambda_c(2625)$ , and perhaps a  $\Xi_c(2645)$ ; see the Listings.

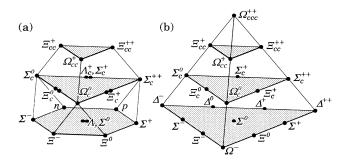


Fig. 1. SU(4) multiplets of baryons made of u, d, s, and c quarks. (a) The 20-plet with an SU(3) octet on the lowest level. (b) The 20-plet with an SU(3) decuplet on the lowest level.

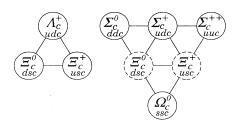


Fig. 2. The SU(3) multiplets on the second level of the SU(4) multiplet of Fig. 1(a). The particles in dashed circles have yet to be discovered.

The states of the  $\overline{\bf 3}$  multiplet in Fig. 2 are antisymmetric under interchange of the two light quarks (the u, d, and s quarks), whereas the states of the  $\bf 6$  multiplet are symmetric under interchange of these quarks. Actually, there may be some mixing between the pure  $\overline{\bf 3}$  and  $\bf 6$   $\Xi_c$  states (they have the same I,J, and P quantum numbers) to form the physical  $\Xi_c$  states.

It need hardly be said that the flavor symmetries Fig. 1 displays are very badly broken, but the figure is the simplest way to see what charmed baryons should exist.

For a review of theory and experiment, see Ref. 1.

#### References

 J.G. Körner, M. Krämer, and D. Pirjol, Prog. in Part. Nucl. Phys. 33, 787 (1994).



$$I(J^P) = 0(\frac{1}{2}^+)$$
 Status: ***

J has not actually been measured yet. Results of an analysis of  $pK^-\pi^+$  decays (JEZABEK 92) are consistent with the expected J=1/2. The quark content is udc.

We have omitted some results that have been superseded by later experiments. The omitted results may be found in earlier editions.

### 1 MASS

Measurements with an error greater than 5 MeV or that are otherwise obsolete have been omitted.

The fit also uses  $\Sigma_c - \Lambda_c^+$  and  $\Lambda_c^{*+} - \Lambda_c^+$  mass-difference measurements.

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
2284.9±0.6 OUR FIT	Ī			
2284.9±0.6 OUR AV	ERAGE			
$2284.7 \pm 0.6 \pm 0.7$	1134	AVERY	91 CLEO	Six modes
$2281.7 \pm 2.7 \pm 2.6$	29	ALVAREZ	90B NA14	$\rho K^- \pi^+$
$2285.8 \pm 0.6 \pm 1.2$	101	BARLAG	89 NA32	$\rho K^- \pi^+$
$2284.7 \pm 2.3 \pm 0.5$	5	AGUILAR	88B LEBC	$pK^-\pi^+$
$2283.1 \pm 1.7 \pm 2.0$	628	ALBRECHT	88c ARG	$\rho K^- \pi^+$ , $\rho \overline{K}{}^0$ , $\Lambda 3\pi$
$2286.2 \pm 1.7 \pm 0.7$	97	ANJOS	88B E691	$\rho K^- \pi^+$
2281 ±3	2	JONES	87 HBC	$\rho K^- \pi^+$
2283 ±3	3	BOSETTI	82 HBC	$pK^-\pi^+$
2290 ±3	1	CALICCHIO	80 HYBR	p K - π +

### A+ MEAN LIFE

Measurements with an error  $\geq 0.1 \times 10^{-12}$  s or with fewer than 20 events have been omitted.

VALUE (10 ⁻¹² s) 0.206±0.012 OUR AV	EVTS ERAGE	DOCUMENT ID	TECN	COMMENT
$0.215 \pm 0.016 \pm 0.008$	1340	FRABETTI	93D E687	$\gamma$ Be, $\Lambda_c^+ \rightarrow p K^- \pi^+$
$0.18 \ \pm 0.03 \ \pm 0.03$	29	ALVAREZ	90 NA14	$\gamma, \Lambda_c^+ \rightarrow pK^-\pi^+$
$0.20\ \pm0.03\ \pm0.03$	90	FRABETTI	90 E687	$\gamma  \text{Be}, \Lambda_c^+ \rightarrow p  K^-  \pi^+$
$0.196^{+0.023}_{-0.020}$	101	BARLAG	89 NA32	$\rho K^- \pi^+ + \text{c.c.}$
$0.22 \ \pm 0.03 \ \pm 0.02$	97	ANJOS	88B E691	$pK^{-}\pi^{+}$ + c.c.

### $\Lambda_c^+$

	Λ ⁺ DECA	Y MODES
	Mode	Scale factor/ Fraction $(\Gamma_i/\Gamma)$ Confidence level
		with a $p$ and one $\overline{K}$
$\Gamma_1$	$ \rho \overline{K}^0 $	( 2.2 ± 0.4 ) %
$\Gamma_2$	$pK^-\pi^+$	( 4.4 ± 0.6 ) %
Γ3	p K*(892) ⁰ Δ(1232) ⁺⁺ K ⁻	[a] $(1.6 \pm 0.4)\%$
Γ ₄		$(7 \pm 4) \times 10^{-3}$
$\Gamma_5$	$\Lambda(1520)\pi^+$	[a] $(4.0 + 2.0 \times 10^{-3}) \times 10^{-3}$
$\Gamma_6$	$pK^-\pi^+$ nonresonant	$(2.5 \ {}^{+}_{-}\ 0.5 \ )\%$
Γ ₇	$p \stackrel{\cdot}{\overline{K}^0} \eta$	( 1.10± 0.29) %
Γ ₈	$p \frac{\kappa}{K^0} \frac{\eta}{\pi^+ \pi^-}$	$(2.1 \pm 0.8)\%$
Γ9	$pK^{-}\pi^{+}\pi^{0}$	seen
Γ ₁₀	$pK^*(892)^-\pi^+$	[a] ( 9 $\pm$ 5 ) $\times$ 10 ⁻³
$\Gamma_{11}$	$p(K-\pi^+)_{\text{nonresonant}}\pi^0$	$(3.2 \pm 0.7)\%$
Γ ₁₂	$\Delta(1232) \overline{K}^*(892)$	seen
	$p K^{-} \pi^{+} \pi^{+} \pi^{-}$ $p K^{-} \pi^{+} \pi^{0} \pi^{0}$	$(10 \pm 7) \times 10^{-4}$
Γ ₁₄ Γ ₁₅	$pK - \pi + \pi^{0}\pi^{0}\pi^{0}$	$(7.0 \pm 3.5) \times 10^{-3}$ $(4.4 \pm 2.8) \times 10^{-3}$
' 15	·	
Γ ₁₆	Hadronic modes with a $p\pi^+\pi^-$	a p and zero or two K's $(3.0 \pm 1.6) \times 10^{-3}$
Γ ₁₇	p f ₀ (980)	[a] $(2.4 \pm 1.6) \times 10^{-3}$
Γ ₁₈	$p\pi^{+}\pi^{+}\pi^{-}\pi^{-}$	$(1.6 \pm 1.0) \times 10^{-3}$
Γ ₁₉	pK+K-	$(2.0 \pm 0.6) \times 10^{-3}$
Γ ₂₀	$p\phi$	[a] $(1.06 \pm 0.33) \times 10^{-3}$
	Hadronic mode	s with a hyperon
$\Gamma_{21}$	$\Lambda\pi^+$	$(7.9 \pm 1.8) \times 10^{-3}$
$\Gamma_{22}$	$\Lambda \pi^+ \pi^0$	$(3.2 \pm 0.9)\%$
$\Gamma_{23}$	$\Lambda  ho^0$	< 4 % CL=95%
Γ ₂₄	$\Lambda \pi^{+} \pi^{+} \pi^{-}$	( 2.9 ± 0.6 ) %
Γ ₂₅	$\Lambda\pi^+\eta \ \Sigma(1385)^+\eta$	$(1.5 \pm 0.4)\%$
Γ ₂₆ Γ ₂₇	$\Lambda K^{+} \overline{K}^{0}$	[a] $(7.5 \pm 2.4) \times 10^{-3}$ $(5.3 \pm 1.4) \times 10^{-3}$
Γ ₂₈	$\Sigma^0 \pi^+$	$(8.8 \pm 2.0) \times 10^{-3}$
Γ29	$\Sigma^+\pi^0$	$(8.8 \pm 2.2) \times 10^{-3}$
Γ ₃₀	$\Sigma^+  \eta$	$(4.8 \pm 1.7) \times 10^{-3}$
Γ ₃₁	$\Sigma^{+}\pi^{+}\pi^{-}$	$(3.0 \pm 0.6)\%$
Γ ₃₂	$\Sigma^+\rho^0$	< 1.2 % CL=95%
Γ ₃₃	$\Sigma^-\pi^+\pi^+  \Sigma^0\pi^+\pi^0$	(1.6 ± 0.6)%
Γ ₃₄ Γ ₃₅	$\sum_{n}^{\infty} \frac{\pi}{n} + \frac{\pi}{n} + \frac{\pi}{n}$	$( 1.6 \pm 0.6 ) \%$ $( 9.2 \pm 3.4 ) \times 10^{-3}$
Γ ₃₆	$\Sigma + \pi + \pi - \pi^0$	( 9.2 ± 3.4 ) × 10
Γ ₃₇	$\Sigma^+\omega$	[a] ( 2.4 ± 0.7 ) %
Γ ₃₈	$\Sigma^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}$	$(2.6 + 3.5 \times 10^{-3}) \times 10^{-3}$
Γ ₃₉	$\Sigma^+ K^+ K^-$	$(3.1 \pm 0.8) \times 10^{-3}$
Γ ₄₀	$\Sigma^+\phi$	[a] $(3.0 \pm 1.3) \times 10^{-3}$
Γ ₄₁	$\Sigma^+ K^+ \pi^-$	$(5.7 + 5.3) \times 10^{-3}$
	$\equiv^0 K^+$	
Γ ₄₂	$\equiv K^+$ $\equiv K^+\pi^+$	$(3.4 \pm 0.9) \times 10^{-3}$ $(4.3 \pm 1.1) \times 10^{-3}$
Γ ₄₃ Γ ₄₄	$\equiv K^{+}\pi^{+}$ $\equiv (1530)^{0}K^{+}$	[a] $(2.3 \pm 0.7) \times 10^{-3}$
' 44		
Γ ₄₅	Semilepto $\Lambda \ell^+  u_\ell$	onic modes [b] ( 2.3 ± 0.5 ) %
Γ ₄₆	e ⁺ anything	
Γ ₄₇	pe ⁺ anything	$(1.8 \pm 0.9)\%$
Γ ₄₈	Λe ⁺ anything	( 1.6 ± 0.6 ) %
Γ49	$\Lambda\mu^+$ anything	( $1.5 \pm 0.9$ ) %
Γ ₅₀	$\Lambda\ell^+ u_\ell$ anything	
_		re modes
Γ ₅₁	p anything (no. 4)	$(50 \pm 16) \%$ $(12 \pm 19) \%$
Γ ₅₂ Γ ₅₃	$p$ anything (no $\Lambda$ ) $p$ hadrons	(12 ±19 )%
Γ ₅₄	n anything	(50 ±16 )%
Γ ₅₅	$n$ anything (no $\Lambda$ )	(30 ±10 ) % (29 ±17 ) %
Γ ₅₆	Λ anything	(35 ±11 )% S=1.4
Γ ₅₇	$\Sigma^\pm$ anything	[c] (10 ± 5 )%

## $\Delta C = 1$ weak neutral current (C1) modes, or Lepton number (L) violating modes

Γ ₅₈	$\rho \mu^+ \mu^-$	C1	< 3.4	$\times$ 10 ⁻⁴	CL=90%
Γ ₅₉	$\Sigma^-\mu^+\mu^+$	L	< 7.0	$\times$ 10 ⁻⁴	CL=90%

 $\Gamma_{60}$  dummy mode used by the fit (92.7  $\pm$  1.0 ) %

- [a] This branching fraction includes all the decay modes of the final-state resonance.
- [b]  $\ell$  indicates e or  $\mu$  mode, not sum over modes.
- [c] The value is for the sum of the charge states of particle/antiparticle states indicated

#### CONSTRAINED FIT INFORMATION

An overall fit to 3 branching ratios uses 9 measurements and one constraint to determine 3 parameters. The overall fit has a  $\chi^2=2.0$  for 7 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients  $\left\langle \delta s_i \delta x_j \right\rangle / (\delta x_i \cdot \delta x_j),$  in percent, from the fit to the branching fractions,  $x_i \equiv \Gamma_i / \Gamma_{\rm total}.$  The fit constrains the  $x_i$  whose labels appear in this array to sum to one

$$\begin{array}{c|cccc} x_{24} & 61 & \\ x_{60} & -90 & -89 \\ \hline & x_2 & x_{24} \end{array}$$

#### A+ BRANCHING RATIOS

Most of the modes are measured relative to the  $pK^-\pi^+$  mode. A few obsolete results have been omitted.

#### — Hadronic modes with a p and one $\overline{K}$ —

$\Gamma(p\overline{K}^0)/\Gamma(pK^{-1})$	π ⁺ )					$\Gamma_1/\Gamma_2$
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT	
0.49±0.07 OUR AVI	ERAGE					
$0.44 \pm 0.07 \pm 0.05$	133	AVERY	91	CLEO	$e^{+}e^{-}$ 10.5 GeV	
$0.55 \pm 0.17 \pm 0.14$	45	ANJOS	90	E691	γ Be 70-260 GeV	
$0.62 \pm 0.15 \pm 0.03$	73	ALBRECHT	880	ARG	$e^+e^-$ 10 GeV	

 $\Gamma(pK^-\pi^+)/\Gamma_{\text{total}}$   $\Gamma_2/\Gamma$ 

LUE	CL% EVT	DOCUMENT ID	TECN	COMMENT
0.044 ±0.006	OUR FIT			
0.044 ±0.006	<b>OUR AVERAG</b>	<b>:</b>		
$0.0594 \pm 0.0031$	±0.0144	¹ BERGFELD	94 CLEO	$e^+e^- \approx \Upsilon(4S)$
$0.040 \pm 0.003$	$\pm 0.008$	² ALBRECHT	920 ARG	$e^+e^- \approx \Upsilon(45)$
0.043 ±0.010	±0.008		92 CLEO	e+e- 10.5 GeV
0.041 ±0.024	20	3 ⁴ ALBRECHT	88E ARG	

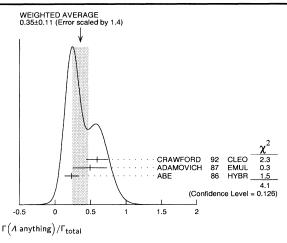
- >0.044 90 6  5  AGUILAR-... 888 LEBC pp 27.4 GeV  1  BERGFELD 94 measures  $\Gamma(pK^-\pi^+)/\Gamma(\Lambda\ell^+\nu_\ell)=1.93\pm0.10\pm0.33$  and calculates  $\Gamma(e^+$  anything)/ $\Gamma_{\rm total}=0.034\pm0.004$  from D-meson data, assuming that all charmed hadrons have the same semileptonic width. Combined, these values give  $\Gamma(pK^-\pi^+)/\Gamma_{\rm total}=f\times(6.67\pm0.35\pm1.35)\%$ , where  $f\equiv\Gamma(\Lambda\ell^+\nu_\ell)/\Gamma(\ell^+$  anything). Since  $f\leq 1$ , this gives an upper bound on  $\Gamma(pK^-\pi^+)/\Gamma_{\rm total}$ . In the spectator model, the quantity corresponding to f in D-meson decay is  $\Gamma(D\to(\overline{K}+\overline{K}^*)\ell^+\nu_\ell)/\Gamma(D\to\ell^+$  anything) = 0.89  $\pm$  0.12. This value of f leads to the value of  $\Gamma(pK^-\pi^+)/\Gamma_{\rm total}$  we give here.
- ² ALBRECHT 920 uses B( $\overline{B} \to \Lambda_c^+ X$ )×B( $\Lambda_c^+ \to \rho K^- \pi^+$ ) = (0.28  $\pm$  0.05)% plus B( $\overline{B} \to \Lambda_c^+ X$ ) = (6.8  $\pm$  0.5  $\pm$  0.3)% and assumes that  $\overline{B} \to \Xi_c X$  and  $\overline{B} \to \Omega_c X$  decays are suppressed and negligible.
- 3  CRAWFORD 92 uses B(\$\overline{B}\to \Lambda_c^+ X)\times B(\Lambda_c^+\to pK^-\pi^+)=(0.273\pm 0.051\pm 0.039)\% and estimates B(\$\overline{B}\$\to \$\Lambda_c^+ X)=(6.4\pm 0.8\pm 0.8)\%. If final states other than \$\Lambda_c^+ \overline{N}\$X contribute to \$\overline{B}\$ decay, the \$\Lambda_c^+\to pK^-\pi^+\$ branching fraction would increase.
- ⁴ ALBRECHT 88E uses their result B( $\overline{B} \to \Lambda_c^+ X$ )×B( $\Lambda_c^+ \to p K^- \pi^+$ ) = (0.30 ± 0.12 ± 0.06)% plus B( $\overline{B} \to \Lambda_c^+ X$ ) = (7.4 ± 2.9)% from other measurements of inclusive proton and  $\Lambda$  yields in B decays.
- 5  This AGUILAR-BENITEZ 888 limit assumes that  $\tau_{A_c}=1.2\times 10^{-13}$  s, and it "decreases by 20% [to > 0.035] assuming a lifetime of 1.7  $\times$  10  $^{-13}$  s instead." Our average for  $\tau_{A_c}$  is still higher (see the mean-life section), which would further reduce the limit.

**1** 

$\Gamma( ho \overline{K}^*(892)^0)/\Gamma( ho K^-\pi^+)$				$\Gamma_3/\Gamma_2$	$\Gamma(\rho K^+ K^-)/\Gamma(\rho K^-)$	π· J				Γ ₁₉ /Γ
Unseen decay modes of the				5, 2	VALUE	<u>EVTS</u>	DOCUMENT ID		COMMENT	
VALUE EVTS	DOCUMENT ID	TECN	COMMENT		0.046±0.012 OUR AVE 0.039±0.009±0.007	214	or includes scal ALEXANDER		.2. D e ⁺ e ⁻ ≈	Υ(45)
0.36 + 0.06 OUR AVERAGE					$0.096 \pm 0.029 \pm 0.010$	30	FRABETTI	93H E687	$\gamma$ Be, $\overline{E}_{\gamma}$ 2	20 GeV
$0.35^{+0.06}_{-0.07} \pm 0.03$ 39	BOZEK	93 NA32	$\pi^-$ Cu 230 GeV		$0.048 \pm 0.027$		BARLAG	90D NA32	2 π ⁻ 230 Ge	eV
0.42±0.24 12	BASILE		$pp \rightarrow \Lambda_c^+ e^- >$	<	$\Gamma(\rho\phi)/\Gamma(\rho K^-\pi^+)$					$\Gamma_{20}/\Gamma_{1}$
• • We do not use the following	_				Unseen decay mo VALUE	des of the $\phi$	are included.  DOCUMENT ID	TECN	COMMENT	
0.35±0.11	BARLAG	90D NA32	See BOZEK 93		0.024±0.006±0.003	54			e ⁺ e ⁻ ≈	T(45)
$\Gamma(\Delta(1232)^{++}K^-)/\Gamma(pK^-\pi$				$\Gamma_4/\Gamma_2$	• • We do not use the	he following				
<u>EVTS</u> <b>).16±0.10 OUR AVERAGE</b> Erro	DOCUMENT ID		COMMENT		$0.040 \pm 0.027$		BARLAG	90D NA32	2 π ⁻ 230 Ge	eV
$0.12^{+0.04}_{-0.05} \pm 0.05$ 14	BOZEK		π  Cu 230 GeV		$\Gamma(\rho\phi)/\Gamma(\rho K^+ K^-)$	)				$\Gamma_{20}/\Gamma_{1}$
0.40±0.17 17	BASILE	81B CNTR	$pp \rightarrow \Lambda_c^+ e^-$	<	Unseen decay mo		are included. DOCUMENT ID	TECN	COMMENT	
					• • • We do not use th					
$\Gamma(\Lambda(1520)\pi^+)/\Gamma(\rho K^-\pi^+)$ Unseen decay modes of the	1(1520) are inclu	ded.		$\Gamma_5/\Gamma_2$	<0.58	90 F	RABETTI	93H E687	$\gamma$ Be, $\overline{E}_{\gamma}$ 220	GeV
ALUE EVTS	DOCUMENT ID		COMMENT			— Hadroni	ic modes witi	n a hypero	n ——	
.09+0.04 ±0.02 12	BOZEK	93 NA32	$\pi^-$ Cu 230 GeV		F(A_+)/F(-W+			, ,		- /-
·/- //- +	ν- ±\			F /F	Γ(Λπ ⁺ )/Γ(ρΚ ⁻ π ⁺	CL% EVTS	DOCUMEN	IT ID	TECN_ COMM	Γ ₂₁ /Γ:
'(ρK - π + nonresonant)/Γ(ρ ['] ALUE <u>EVTS</u>	K π ⁺ ) DOCUMENT ID	TECN	COMMENT	$\Gamma_6/\Gamma_2$	0.180±0.032 OUR A					
0.56 ^{+0.07} _{-0.09} ±0.05 71	BOZEK		π - Cu 230 GeV		$0.18 \pm 0.03 \pm 0.04$ $0.18 \pm 0.03 \pm 0.03$	87	ALBREC AVERY			≅ 10.4 GeV 10.5 GeV
	DULLIN	75 NM32	. Cu 230 GeV							10.3 GEV
$( ho \overline{K}{}^0 \eta) / \Gamma( ho K^- \pi^+)$				$\Gamma_7/\Gamma_2$	•	90	ANJOS	90 I		0-260 GeV
.25±0.04±0.04 57	DOCUMENT ID	95 CLEO	$e^+e^- \approx \Upsilon(45)$	3)	< 0.16	90	ALBREC	HT 88C	ARG e ⁺ e ⁻	10 GeV
	AMMAR	95 CLEO	e·e ≈ /(43	?) [	$\Gamma(\Lambda\pi^+\pi^0)/\Gamma(pK^-)$	$\pi^+)$				$\Gamma_{22}/\Gamma$
$(\rho \overline{K}{}^0 \pi^+ \pi^-)/\Gamma(\rho K^- \pi^+)$				$\Gamma_8/\Gamma_2$	VALUE	EVTS	DOCUMENT ID		COMMENT	20/2.02\ 20/4.0
ALUE EVTS .49±0.17 OUR AVERAGE Erro	DOCUMENT ID includes scale fa	actor of 1.4.	COMMENT		$0.73\pm0.09\pm0.16$	464	AVERY	94 CLEC	) e ⁺ e ⁻ ≈	T(35), T(45
.43±0.12±0.04 83	AVERY	91 CLEO	$e^+e^-$ 10.5 GeV		$\Gamma(\Lambda  ho^0)/\Gamma( ho K^-\pi^+)$	)				Γ ₂₃ /Γ
98±0.36±0.08 12	BARLAG	90D NA32	π  230 GeV		VALUE	<u>CL%</u>	DOCUMENT ID		COMMENT	2(00) 2(10
$(\rho K^- \pi^+ \pi^0)/\Gamma_{\text{total}}$				/	<0.95	95	AVERY	94 CLEC	) e ⁺ e ⁻ ≈	1 (35), 1 (45
(Pr // // // total				۲)و۲						
ALUE EVTS	DOCUMENT ID		COMMENT	ا/و ا ———	$\Gamma(\Lambda\pi^{+}\pi^{+}\pi^{-})/\Gamma_{\text{tot}}$					Γ ₂₄ /
ALUE EVTS	DOCUMENT ID AMENDOLIA			9/I 	VALUE	al <u>EVTS</u>	DOCUMENT ID	TECN	COMMENT	Γ ₂₄ /
ALUE EVTS een 44	AMENDOLIA			Γ ₉ /Ι  Γ ₁₀ /Γ ₈		EVTS	DOCUMENT ID		$\frac{COMMENT}{e^+e^-} = 10.$	
een $\frac{EVTS}{44}$ ( $pK^*(892)^-\pi^+$ )/ $\Gamma(p\overline{K}^0\pi^+$ Unseen decay modes of the	AMENDOLIA $\pi^{-})$ $K^{*}(892)^{-}$ are in	87 SPEC	γ Ge-Si		0.029±0.006 OUR FIT 0.028±0.007±0.011 6 See BOWCOCK 85	70 for assumpt	⁶ BOWCOCK	85 CLEC	o e ⁺ e ⁻ 10.	5 GeV
ALUE EVTS $(\rho K^*(892)^-\pi^+)/\Gamma(\rho \overline{K}^0\pi^+)$ Unseen decay modes of the ALUE EVTS	AMENDOLIA $\pi^ K^*(892)^-$ are in DOCUMENT ID	87 SPEC	γ Ge-Si <u>COMMENT</u>		VALUE 0.029±0.006 OUR FIT 0.028±0.007±0.011	70 for assumpt	⁶ BOWCOCK	85 CLEC	o e ⁺ e ⁻ 10.	5 GeV
een $\frac{EVTS}{44}$ (pK*(892) $^-\pi^+$ )/ $\Gamma$ (p $\overline{K}^0\pi^+$ Unseen decay modes of the ALUE $\frac{EVTS}{17}$	AMENDOLIA  (***(892)** are in  (**DOCUMENT ID  ALEEV	87 SPEC	γ Ge-Si	Γ ₁₀ /Γ ₈	$\frac{VALUE}{0.029 \pm 0.006}$ OUR FIT 0.028 ± 0.007 ± 0.011 6 See BOWCOCK 85 charm to get this re	FVTS 70 for assumptions $F(T)$ $F(T)$ $F(T)$	⁶ BOWCOCK ions made on ch	85 CLEC	$0 e^+e^-$ 10.	5 GeV
een $\frac{EVTS}{44}$ (pK*(892) $^-\pi^+$ )/ $\Gamma$ (p $\overline{K}^0\pi^+$ Unseen decay modes of the ALUE EVTS  44±0.14  (p(K $^-\pi^+$ )nonresonant $\pi^0$ )/ $\Gamma$	AMENDOLIA  (***\( (892 ) - \) are in  \( \frac{DOCUMENT ID}{ALEEV} \)  (**\( (pK - \pi + \))	87 SPEC  cluded.  TECN  94 BIS2	γ Ge-Si <u>COMMENT</u> n N 20-70 GeV		$\frac{VALUE}{0.029 \pm 0.006}$ OUR FIT 0.028 ± 0.007 ± 0.011 6 See BOWCOCK 85 charm to get this re Γ $(\Lambda \pi^+ \pi^+ \pi^-)/\Gamma(\rho^-)$	70 for assumptiesult.	⁶ BOWCOCK	85 CLEC	$0 e^+e^-$ 10.	5 GeV roduction from
een $\frac{EVTS}{44}$ (pK*(892) $^-\pi^+$ )/ $\Gamma$ (p $\overline{K}^0\pi^+$ Unseen decay modes of the ALUE $\frac{EVTS}{17}$ (p(K $^-\pi^+$ )nonresonant $\pi^0$ )/ $\Gamma$ (ALUE $\frac{EVTS}{17}$	AMENDOLIA  (***(892)** are in  (**DOCUMENT ID  ALEEV	87 SPEC  cluded.  7ECN  94 BIS2	γ Ge-Si <u>COMMENT</u>	Γ ₁₀ /Γ ₈   Γ ₁₁ /Γ ₂	$\frac{VALUE}{0.029 \pm 0.006}$ OUR FIT 0.028 ± 0.007 ± 0.011 6 See BOWCOCK 85 charm to get this re	for assumptions $K^-\pi^+$ )  EVTS  AGE	6 BOWCOCK ions made on ch	85 CLEC narm product <u>TECN</u>	$e^+e^-$ 10. tion and $\Lambda_c$ position $e^+e^-$	5 GeV roduction from Γ ₂₄ /Γ
een $\frac{EVTS}{44}$ (pK*(892) $^-\pi^+$ )/ $\Gamma$ (p $\overline{K}^0\pi^+$ Unseen decay modes of the ALUE $EVTS$ 1.44±0.14 17  (p(K $^-\pi^+$ )nonresonant $\pi^0$ )/ $\Gamma$ ALUE $EVTS$ 67	AMENDOLIA  (**\pi^*)  **(*892)^- are in  **DOCUMENT ID  ALEEV  (*pK^-\pi^+)  **DOCUMENT ID  **DO	87 SPEC  cluded.  7ECN  94 BIS2	γ Ge-Si  COMMENT n N 20-70 GeV  COMMENT	Γ ₁₀ /Γ ₈	$VALUE$ 0.029±0.006 OUR FIT 0.028±0.007±0.011 6 See BOWCOCK 85 charm to get this re $\Gamma(\Lambda \pi^+ \pi^+ \pi^-)/\Gamma(\rho)$ $VALUE$ 0.66±0.10 OUR FIT 0.66±0.11 OUR AVERA 0.65±0.11±0.12	70 for assumption the solution of the second	6 BOWCOCK fons made on character of the book of the bo	85 CLEC	$e^+e^-$ 10. $e^-$	5 GeV roduction from \( \Gamma_{24} / \Gamma_{5} \)
PALUE EVTS  ALUE EVTS  Unseen decay modes of the ALUE EVTS $(p(K^*(892)^-\pi^+))/\Gamma(p\overline{K}^0\pi^+)$ Unseen decay modes of the ALUE EVTS $(p(K^-\pi^+)_{nonresonant}\pi^0)/\Gamma$ $(44.50.12\pm0.05 67)$ $(44.50.12\pm0.05 67)$	AMENDOLIA  (**\pi^*)  **(*892)^- are in  **DOCUMENT ID  ALEEV  (*pK^-\pi^+)  **DOCUMENT ID  **DO	87 SPEC  cluded.  TECN  94 BIS2  TECN  93 NA32	γ Ge-Si  COMMENT n N 20-70 GeV  COMMENT	Γ ₁₀ /Γ ₈   Γ ₁₁ /Γ ₂	$VALUE$ 0.029±0.006 OUR FIT 0.028±0.007±0.011 ⁶ See BOWCOCK 85 charm to get this re $\Gamma(\Lambda \pi^+ \pi^+ \pi^-)/\Gamma(\rho)$ VALUE 0.66±0.10 OUR FIT 0.66±0.11 OUR AVERA	for assumptions $K^-\pi^+$ )  EVTS  AGE	6 BOWCOCK ions made on ch	85 CLEC narm product <u>TECN</u>	$e^+e^-$ 10. $e^+e^-$ 10. $e^+e^-$ 10. $e^+e^-$ 10. $e^+e^-$ 10. $e^+e^-$ 230 Ge $e^+$	5 GeV roduction from F24/F
ALUE EVTS  when $\frac{EVTS}{44}$ ( $pK^*(892)^-\pi^+$ )/ $\Gamma(p\overline{K}^0\pi^+)$ Unseen decay modes of the ALUE EVTS $\frac{EVTS}{44\pm0.14}$ $\frac{EVTS}{17}$ $\frac{EVTS}{67}$ $\frac{EVTS}{67}$ ( $p(K^-\pi^+)_{nonresonant}\pi^0$ )/ $\Gamma_{ALUE}$ $\frac{EVTS}{67}$ ( $\Delta(1232)\overline{K}^*(892)$ )/ $\Gamma_{total}$ $\frac{EVTS}{67}$	AMENDOLIA  (***\Pi^*)  K**\Pi^*\Pi^* ALEEV  (**\pi K*-\pi^*)  DOCUMENT ID  BOZEK	87 SPEC  cluded.  7ECN 94 BIS2  7ECN 93 NA32	$\gamma$ Ge-Si  COMMENT $n$ N 20–70 GeV  COMMENT $\pi^-$ Cu 230 GeV  COMMENT	Γ ₁₀ /Γ ₈	$\frac{VALUE}{0.029 \pm 0.006}$ OUR FIT 0.028 ± 0.007 ± 0.011 6 See BOWCOCK 85 charm to get this re $\Gamma(\Lambda \pi^+ \pi^+ \pi^-)/\Gamma(\rho)$ VALUE 0.66 ± 0.10 OUR FIT 0.66 ± 0.11 OUR AVEN 0.65 ± 0.11 ± 0.12 0.82 ± 0.29 ± 0.27	for assumption $(K^-\pi^+)_{EVTS}$ AGE 289 44	6 BOWCOCK ions made on ch  DOCUMENT ID  AVERY ANJOS	85 CLEO narm product  TECN  91 CLEO 90 E691	$e^+e^-$ 10. tion and $A_C$ point $e^+e^-$ 10.5 $_{\gamma}$ Be 70–260	5 GeV roduction from F24/F
ALUE EVTS  Unseen decay modes of the ALUE EVTS $(p(K^*(892)^-\pi^+))/\Gamma(p\overline{K}^0\pi^+)$ Unseen decay modes of the ALUE EVTS $(p(K^-\pi^+)_{nonresonant}\pi^0)/\Gamma$ $(L^0(1232)\overline{K}^*(892))/\Gamma_{total}$ $(L^0(1232)\overline{K}^*(892))/\Gamma_{total}$ $(L^0(1232)\overline{K}^*(892))/\Gamma_{total}$ $(L^0(1232)\overline{K}^*(892))/\Gamma_{total}$ $(L^0(1232)\overline{K}^*(892))/\Gamma_{total}$ $(L^0(1232)\overline{K}^*(892))/\Gamma_{total}$	AMENDOLIA  (***)  **(**892)** are in  **DOCUMENT ID  ALEEV  (**)  **DOCUMENT ID  BOZEK  **DOCUMENT ID  AMENDOLIA	87 SPEC  cluded.  7ECN 94 BIS2  7ECN 93 NA32	$\gamma$ Ge-Si  COMMENT $n$ N 20–70 GeV  COMMENT $\pi^-$ Cu 230 GeV  COMMENT	Γ ₁₀ /Γ ₈   Γ ₁₁ /Γ ₂ Γ ₁₂ /Γ	0.029 $\pm$ 0.006 OUR FIT 0.028 $\pm$ 0.007 $\pm$ 0.011 6 See BOWCOCK 85 charm to get this re $\Gamma(\Lambda \pi^+ \pi^+ \pi^-)/\Gamma(\rho$ 0.66 $\pm$ 0.10 OUR FIT 0.66 $\pm$ 0.11 OUR AVEN, 0.65 $\pm$ 0.11 $\pm$ 0.12 0.82 $\pm$ 0.29 $\pm$ 0.27 0.94 $\pm$ 0.41 $\pm$ 0.13 0.61 $\pm$ 0.16 $\pm$ 0.04	70 for assumptions the suit.  **F'' = T''	6 BOWCOCK ions made on ch DOCUMENT ID AVERY ANJOS BARLAG	85 CLEO narm product	$e^+e^-$ 10. $e^+e^-$ 10. $e^+e^-$ 10. $e^+e^-$ 10. $e^+e^-$ 10. $e^+e^-$ 230 Ge $e^+$	5 GeV roduction from \[ \begin{align*} \Gamma_{24}/\Gamma_{24} \\ \Gamma_{24} \\
ALUE EVTS  when $\frac{EVTS}{44}$ ( $pK^*(892)^-\pi^+$ )/ $\Gamma(p\overline{K}^0\pi^+)$ Unseen decay modes of the ALUE EVTS $44\pm0.14$ $17$ ( $p(K^-\pi^+)_{nonresonant}\pi^0$ )/ $\Gamma$ $4LUE$ EVTS $\frac{EVTS}{67}$ ( $\Delta(1232)\overline{K}^*(892)$ )/ $\Gamma_{total}$ $\frac{ALUE}{2}$ EVTS  when $\frac{EVTS}{35}$ ( $pK^-\pi^+\pi^+\pi^-$ )/ $\Gamma(pK^-\pi^-\pi^+\pi^+\pi^-)$	AMENDOLIA  (***)  **(**892)** are in  **DOCUMENT ID  ALEEV  (**)  **DOCUMENT ID  BOZEK  **DOCUMENT ID  AMENDOLIA	94 BIS2  93 NA32  TECN 94 FECN 95 PEC	$\gamma$ Ge-Si  COMMENT $n$ N 20–70 GeV  COMMENT $\pi^-$ Cu 230 GeV  COMMENT	Γ ₁₀ /Γ ₈	0.029 $\pm$ 0.006 OUR FIT 0.028 $\pm$ 0.007 $\pm$ 0.011 ⁶ See BOWCOCK 85 charm to get this re $\Gamma(\Lambda \pi^+ \pi^+ \pi^-)/\Gamma(\rho^- \nu_{ALUE})$ 0.66 $\pm$ 0.10 OUR FIT 0.66 $\pm$ 0.11 OUR AVER/ 0.65 $\pm$ 0.11 $\pm$ 0.12 0.82 $\pm$ 0.29 $\pm$ 0.27 0.94 $\pm$ 0.41 $\pm$ 0.13	70 for assumptions the suit.  **F'' = T''	6 BOWCOCK ions made on ch DOCUMENT ID AVERY ANJOS BARLAG	85 CLEO narm product TECN 91 CLEO 90 E691 90D NA32 88C ARG	$e^+e^-$ 10. $e^+e^-$ 10. $e^+e^-$ 10. $e^+e^-$ 10. $e^+e^-$ 10. $e^+e^-$ 230 Ge $e^+$	5 GeV roduction from \[ \begin{align*} \Gamma_{24}/\Gamma_{24} \\ \Gamma_{24} \\
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ALUE $EVTS$ when $AEUE$ $EVTS$ 44 $(pK^*(892)^-\pi^+)/\Gamma(pK^0\pi^+)$ Unseen decay modes of the $EVTS$ 44 $\pm 0.14$ $17$ $(p(K^-\pi^+)_{nonresonant}\pi^0)/\Gamma$ $AUE$ $EVTS$ $AU$	AMENDOLIA  (***********************************	87 SPEC  cluded.	$\gamma$ Ge-Si $\frac{COMMENT}{nN 20-70 \text{ GeV}}$ $\frac{COMMENT}{\pi^- \text{ Cu 230 GeV}}$ $\frac{COMMENT}{\gamma}$ Ge-Si $\frac{COMMENT}{\gamma}$	Γ ₁₀ /Γ ₈ Γ ₁₁ /Γ ₂ Γ ₁₂ /Γ Γ ₁₃ /Γ ₂	$VALUE$ 0.029±0.006 OUR FIT 0.028±0.007±0.011 ⁶ See BOWCOCK 85 charm to get this re $\Gamma(\Lambda\pi^+\pi^+\pi^-)/\Gamma(\rho$ VALUE 0.66±0.10 OUR FIT 0.66±0.11 OUR AVER, 0.65±0.11±0.12 0.82±0.29±0.27 0.94±0.41±0.13 0.61±0.16±0.04 $\Gamma(\rho\overline{K}^0\pi^+\pi^-)/\Gamma(\Lambda$ VALUE	70 for assumptisult.  K-π+) EVTS  AGE 289 44 10 105 π+π+π-	6 BOWCOCK ions made on characteristics of the comment of the comme	85 CLEC narm product  TECN  91 CLEO 90 E691 90D NA32 88C ARG	tion and $\Lambda_C$ pi $ \frac{COMMENT}{e^+e^- \ 10.5} $ $ e^+e^- \ 10.5 $ $ \gamma \text{ Be 70-26} $ $ \pi^- \ 230 \text{ Ge} $ $ e^+e^- \ 10 \text{ C} $ $ \frac{COMMENT}{e^+e^- \ 10.5} $ s, etc. • •	5 GeV roduction from  F24/F3 GeV GeV V GeV F8/F2
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	AMENDOLIA  (***********************************	94 BIS2  7ECN 93 NA32  7ECN 87 SPEC  7ECN 90D NA32	$\gamma$ Ge-Si $\frac{COMMENT}{nN 20-70 \text{ GeV}}$ $\frac{COMMENT}{\pi^- \text{ Cu 230 GeV}}$ $\frac{COMMENT}{\gamma}$ Ge-Si $\frac{COMMENT}{\gamma}$	Γ ₁₀ /Γ ₈   Γ ₁₁ /Γ ₂ Γ ₁₂ /Γ	$VALUE$ 0.029±0.006 OUR FIT 0.028±0.007±0.011  6 See BOWCOCK 85 charm to get this re $\Gamma(\Lambda \pi^+ \pi^+ \pi^-)/\Gamma(\rho$ VALUE 0.66±0.11 OUR AVER/ 0.65±0.11±0.12 0.82±0.29±0.27 0.94±0.41±0.13 0.61±0.16±0.04 $\Gamma(\rho \overline{K}^0 \pi^+ \pi^-)/\Gamma(\Lambda$ VALUE • • • We do not use the	for assumption for assumption for assumption for assumption for assumption for a sum of the following following following for a sum of the following following for a sum of the following for a sum of the following following for a sum of the following for a sum of	6 BOWCOCK ions made on characteristics of the boston made of the bosto	85 CLEC harm product  TECN  91 CLEO 90 E691 90D NA32 88C ARG  TECN  TECN	tion and $\Lambda_C$ pi $ \frac{COMMENT}{e^+e^- \ 10.5} $ $ e^+e^- \ 10.5 $ $ \gamma \text{ Be 70-26} $ $ \pi^- \ 230 \text{ Ge} $ $ e^+e^- \ 10 \text{ C} $ $ \frac{COMMENT}{e^+e^- \ 10.5} $ s, etc. • •	5 GeV roduction from  F24/F3 GeV GeV V GeV F8/F2
cen $\frac{EVTS}{44}$ C $(pK^*(892)^-\pi^+)/\Gamma(p\overline{K}^0\pi^+)$ Unseen decay modes of the $\frac{EVTS}{44}$ ALUE $\frac{EVTS}{17}$ C $(p(K^-\pi^+)_{nonresonant}\pi^0)/\Gamma$ ALUE $\frac{EVTS}{67}$ C $(\Delta(1232)\overline{K}^*(892))/\Gamma_{total}$ ALUE $\frac{EVTS}{35}$ C $(pK^-\pi^+\pi^+\pi^-)/\Gamma(pK^-\pi^+)$ ALUE $\frac{EVTS}{17}$ C $(pK^-\pi^+\pi^0\pi^0)/\Gamma(pK^-\pi^+)$ ALUE $\frac{EVTS}{17}$	AMENDOLIA  (***********************************	87 SPEC  cluded.  7ECN 94 BIS2  93 NA32  7ECN 87 SPEC  90D NA32	$\gamma$ Ge-Si $\frac{COMMENT}{n \ N} \ 20-70 \ \text{GeV}$ $\frac{COMMENT}{\pi} = \text{Cu} \ 230 \ \text{GeV}$ $\frac{COMMENT}{\gamma} \text{Ge-Si}$ $\frac{COMMENT}{\pi} = 230 \ \text{GeV}$	Γ ₁₀ /Γ ₈   Γ ₁₁ /Γ ₂ Γ ₁₂ /Γ  Γ ₁₃ /Γ ₂ Γ ₁₄ /Γ ₂	$VALUE$ 0.029±0.006 OUR FIT 0.028±0.007±0.011  6 See BOWCOCK 85 charm to get this re $\Gamma(\Lambda \pi^+ \pi^+ \pi^-)/\Gamma(\rho$ VALUE 0.66±0.10 OUR FIT 0.66±0.11 OUR AVER 0.65±0.11±0.12 0.82±0.29±0.27 0.94±0.41±0.13 0.61±0.16±0.04 $\Gamma(\rho \overline{K}^0 \pi^+ \pi^-)/\Gamma(\Lambda$ VALUE • • • We do not use the 4.3±1.2 $\Gamma(\Lambda \pi^+ \eta)/\Gamma(\rho K^- \pi$ VALUE	70 for assumptisult.  77 for assumptisult.  6 K - π + )  EVTS  AGE 289 44 10 105 π + π + π - ] the following 130 - + ) EVTS	DOCUMENT ID  AVERY ANJOS BARLAG ALBRECHT  DOCUMENT ID  ALBRECHT  DOCUMENT ID	85 CLEC narm product  TECN  91 CLEO 90 E691 900 NA32 88c ARG  TECN  1 TECN  84 BIS2	tion and $\Lambda_C$ pi $\frac{COMMENT}{e^+e^- \ 10.5}$ $\frac{e^+e^- \ 10.5}{\pi^- \ 230 \ Ge^+}$ $\frac{e^+e^- \ 10.5}{e^+e^- \ 10.5}$ $\frac{COMMENT}{e^- \ 40-70}$	5 GeV roduction from  F24/F GeV GeV GeV F8/F2 GeV F25/F
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	AMENDOLIA  (TAT)  K*(892) = are in  DOCUMENT ID  ALEEV  (PK-T+)  DOCUMENT ID  AMENDOLIA  H)  DOCUMENT ID  BARLAG  )  DOCUMENT ID  BARLAG  )  DOCUMENT ID  BOZEK	87 SPEC  cluded.  7ECN 94 BIS2  93 NA32  7ECN 87 SPEC  90D NA32	$\gamma$ Ge-Si $\frac{COMMENT}{nN 20-70 \text{ GeV}}$ $\frac{COMMENT}{\pi^- \text{ Cu 230 GeV}}$ $\frac{COMMENT}{\pi^- 230 \text{ GeV}}$ $\frac{COMMENT}{\pi^- 230 \text{ GeV}}$ $\frac{COMMENT}{\pi^- 230 \text{ GeV}}$	Γ ₁₀ /Γ ₈   Γ ₁₁ /Γ ₂   Γ ₁₂ /Γ    Γ ₁₃ /Γ ₂   Γ ₁₄ /Γ ₂	$VALUE$ 0.029±0.006 OUR FIT 0.028±0.007±0.011  6 See BOWCOCK 85 charm to get this re $\Gamma(\Lambda \pi^+ \pi^+ \pi^-)/\Gamma(\rho$ VALUE 0.66±0.10 OUR FIT 0.66±0.11 OUR AVER, 0.65±0.11±0.12 0.82±0.29±0.27 0.94±0.41±0.13 0.61±0.16±0.04 $\Gamma(\rho \overline{K}^0 \pi^+ \pi^-)/\Gamma(\Lambda$ VALUE • • • We do not use th 4.3±1.2 $\Gamma(\Lambda \pi^+ \eta)/\Gamma(\rho K^- \pi^-)$	70 for assumptisult.  (K-π+) EVTS  AGE 289 44 10 105 π+π+π- EVTS he following 130 .++)	AVERY ANJOS BARLAG ALBRECHT  DOCUMENT ID  DOCUMENT ID  DOCUMENT ID  AVERY ANJOS ALBRECHT	85 CLEC narm product  TECN  91 CLEO 90 E691 900 NA32 88c ARG  TECN  1 TECN  84 BIS2	comment $e^+e^-$ 10. $e^+e^-$ 10. $e^+e^-$ 10. $e^+e^-$ 10. $e^+e^-$ 10. $e^+e^-$ 10. $e^-$ 230 Ge $e^+e^-$ 10. $e^-$ 240—70. $e^-$ 240—70.	5 GeV roduction from  F24/F GeV GeV GeV F8/F2 GeV F25/F
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	AMENDOLIA  (TAT)  K*(892) = are in  DOCUMENT ID  ALEEV  (PK-T+)  DOCUMENT ID  AMENDOLIA  H)  DOCUMENT ID  BARLAG  )  DOCUMENT ID  BARLAG  )  DOCUMENT ID  BOZEK	87 SPEC  cluded.  7ECN 94 BIS2  7ECN 93 NA32  7ECN 87 SPEC  7ECN 90D NA32  7ECN 90D NA32	$\gamma$ Ge-Si $\frac{COMMENT}{nN 20-70 \text{ GeV}}$ $\frac{COMMENT}{\pi^- \text{ Cu 230 GeV}}$ $\frac{COMMENT}{\pi^- 230 \text{ GeV}}$ $\frac{COMMENT}{\pi^- 230 \text{ GeV}}$ $\frac{COMMENT}{\pi^- 230 \text{ GeV}}$	Γ ₁₀ /Γ ₈   Γ ₁₁ /Γ ₂ Γ ₁₂ /Γ  Γ ₁₃ /Γ ₂ Γ ₁₄ /Γ ₂	$VALUE$ 0.029±0.006 OUR FIT 0.028±0.007±0.011  6 See BOWCOCK 85 charm to get this re $\Gamma(\Lambda \pi^+ \pi^+ \pi^-)/\Gamma(\rho$ VALUE 0.66±0.10 OUR FIT 0.66±0.11 OUR AVER 0.65±0.11±0.12 0.82±0.29±0.27 0.94±0.41±0.13 0.61±0.16±0.04 $\Gamma(\rho \overline{K}^0 \pi^+ \pi^-)/\Gamma(\Lambda$ VALUE • • • We do not use the 4.3±1.2 $\Gamma(\Lambda \pi^+ \eta)/\Gamma(\rho K^- \pi$ VALUE	70 for assumptisult.  (K-π+) EVTS  AGE 289 44 10 105 π+π+π 10 105 π+π+π 130 130 130 1-1	DOCUMENT ID  AVERY ANJOS BARLAG ALBRECHT  DOCUMENT ID  ALBRECHT  DOCUMENT ID	85 CLEC narm product  TECN  91 CLEO 90 E691 900 NA32 88c ARG  TECN  1 TECN  84 BIS2	tion and $\Lambda_C$ pi $\frac{COMMENT}{e^+e^- \ 10.5}$ $\frac{e^+e^- \ 10.5}{\pi^- \ 230 \ Ge^+}$ $\frac{e^+e^- \ 10.5}{e^+e^- \ 10.5}$ $\frac{COMMENT}{e^- \ 40-70}$	5 GeV roduction from  F24/F GeV GeV GeV F8/F2 GeV F25/F
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	AMENDOLIA  TAT  K*(892) Tare in  DOCUMENT ID  ALEEV  (PK-A+)  DOCUMENT ID  AMENDOLIA  +)  DOCUMENT ID  BARLAG  )  DOCUMENT ID  BARLAG  )  DOCUMENT ID  BOZEK  AMENDOLIA  +)  DOCUMENT ID  BARLAG  )  DOCUMENT ID  BOZEK  A*+)	87 SPEC    Cluded	$\gamma$ Ge-Si $\frac{COMMENT}{n \ N} \ 20-70 \ \text{GeV}$ $\frac{COMMENT}{\pi^- \text{Cu} \ 230 \ \text{GeV}}$ $\frac{COMMENT}{\pi^- \ 230 \ \text{GeV}}$ $\frac{COMMENT}{\pi^- \ 230 \ \text{GeV}}$ $\frac{COMMENT}{\pi^- \ Cu \ 230 \ \text{GeV}}$	Γ ₁₀ /Γ ₈   Γ ₁₁ /Γ ₂ Γ ₁₂ /Γ  Γ ₁₃ /Γ ₂ Γ ₁₄ /Γ ₂ Γ ₁₅ /Γ ₂	$VALUE$ 0.029±0.006 OUR FIT 0.028±0.007±0.011  6 See BOWCOCK 85 charm to get this re $\Gamma(\Lambda\pi^+\pi^+\pi^-)/\Gamma(\rho$ VALUE 0.66±0.10 OUR FIT 0.66±0.11±0.12 0.82±0.29±0.27 0.94±0.41±0.13 0.61±0.16±0.04 $\Gamma(\rho\overline{K}^0\pi^+\pi^-)/\Gamma(\Lambda$ VALUE • • • We do not use the 4.3±1.2 $\Gamma(\Lambda\pi^+\eta)/\Gamma(\rho K^-\pi$ VALUE 0.35±0.05±0.06 $\Gamma(\Sigma(1385)^+\eta)/\Gamma(\rho$ Unseen decay mo	for assumption for a sum of a	AVERY ANJOS BARLAG ALBRECHT DOCUMENT ID AVERY ANJOS BARLAG ALBRECHT ALBRECHT DOCUMENT ID AMMAR ALBRECHT AMMAR	91 CLEO 90 E691 900 NA32 88c ARG  TECN 1 TECN 95 CLEO 95 CLEO	tion and $\Lambda_c$ pi $\frac{COMMENT}{e^+e^- \ 10.5}$ $\frac{e^+e^- \ 10.5}{7 \ Be \ 70-26(}$ $\frac{r}{\pi^- \ 230 \ Ge^!}$ $\frac{e^+e^- \ 10 \ C}{e^+e^- \ 10 \ C}$ $\frac{COMMENT}{r}$ $\frac{COMMENT}{e^+e^-} \approx \frac{COMMENT}{e^+e^-} \approx \frac{COMMENT}{e^+e^-}$	5 GeV roduction from $\Gamma_{24}/\Gamma_{5}$ GeV GeV $\Gamma_{8}/\Gamma_{2}$ GeV $\Gamma_{25}/\Gamma_{5}$
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	AMENDOLIA  (TAT)  K*(892) are in  DOCUMENT ID  ALEEV  (PK-T+)  DOCUMENT ID  AMENDOLIA  H)  DOCUMENT ID  BARLAG  )  DOCUMENT ID  BARLAG  )  DOCUMENT ID  BOZEK  AMENDOLIA  H)  DOCUMENT ID  BOZEK  The bozek  The bozek  AMENDOLIA	87 SPEC  cluded.  7	$\gamma$ Ge-Si $\frac{COMMENT}{n \ N \ 20-70 \ GeV}$ $\frac{COMMENT}{\pi^- \ Cu \ 230 \ GeV}$ $\frac{COMMENT}{\pi^- \ 230 \ GeV}$ $\frac{COMMENT}{\pi^- \ Cu \ 230 \ GeV}$ $\frac{COMMENT}{\pi^- \ Cu \ 230 \ GeV}$	Γ ₁₀ /Γ ₈   Γ ₁₁ /Γ ₂ Γ ₁₂ /Γ  Γ ₁₃ /Γ ₂ Γ ₁₄ /Γ ₂ Γ ₁₅ /Γ ₂	$VALUE$ 0.029±0.006 OUR FIT 0.028±0.007±0.011 6 See BOWCOCK 85 charm to get this re $\Gamma(\Lambda\pi^+\pi^+\pi^-)/\Gamma(\rho)$ VALUE 0.66±0.10 OUR FIT 0.66±0.11 OUR AVERA 0.65±0.11±0.12 0.82±0.29±0.27 0.94±0.41±0.13 0.61±0.16±0.04 $\Gamma(\rho\overline{K}^0\pi^+\pi^-)/\Gamma(\Lambda)$ VALUE • • • We do not use the 4.3±1.2 $\Gamma(\Lambda\pi^+\eta)/\Gamma(\rho K^-\pi)$ VALUE 0.35±0.05±0.06 $\Gamma(\Sigma(1385)^+\eta)/\Gamma(\rho)$ Unseen decay mo	for assumption for a supplier for a	DOCUMENT ID  AVERY ANJOS BARLAG ALBRECHT  DOCUMENT ID  AVERY ANJOS BARLAG ALBRECHT  ALEEV  DOCUMENT ID  AMMAR  (1385) + are in	91 CLEO 90 E691 900 NA32 88c ARG  TECN 84 BIS2 95 CLEO	tion and $\Lambda_{c}$ pictor and $\Lambda_$	5 GeV roduction from $\Gamma_{24}/\Gamma_{5}$ GeV GeV $\Gamma_{8}/\Gamma_{2}$ GeV $\Gamma_{25}/\Gamma_{5}$
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	AMENDOLIA  TAT  K*(892) Tare in  DOCUMENT ID  ALEEV  (PK-A+)  DOCUMENT ID  AMENDOLIA  +)  DOCUMENT ID  BARLAG  )  DOCUMENT ID  BOZEK  AMENDOLIA  +)  DOCUMENT ID  BOZEK  AMENDOLIA  BOZEK  DOCUMENT ID  BOZEK  AMENDOLIA	87 SPEC  cluded.  7	$\gamma$ Ge-Si $\frac{COMMENT}{n \ N \ 20-70 \ GeV}$ $\frac{COMMENT}{\pi^- \ Cu \ 230 \ GeV}$ $\frac{COMMENT}{\pi^- \ 230 \ GeV}$ $\frac{COMMENT}{\pi^- \ Cu \ 230 \ GeV}$ $\frac{COMMENT}{\pi^- \ Cu \ 230 \ GeV}$	Γ ₁₀ /Γ ₈   Γ ₁₁ /Γ ₂   Γ ₁₂ /Γ    Γ ₁₃ /Γ ₂   Γ ₁₄ /Γ ₂   Γ ₁₅ /Γ ₂	$VALUE$ 0.029±0.006 OUR FIT 0.028±0.007±0.011 6 See BOWCOCK 85 charm to get this re $\Gamma(\Lambda \pi^+ \pi^+ \pi^-)/\Gamma(\rho$ VALUE 0.66±0.10 OUR FIT 0.66±0.11 OUR AVERA 0.65±0.11±0.12 0.82±0.29±0.27 0.94±0.04±0.13 0.61±0.16±0.04 $\Gamma(\rho \overline{K}^0 \pi^+ \pi^-)/\Gamma(\Lambda$ VALUE • • • We do not use the 4.3±1.2 $\Gamma(\Lambda \pi^+ \eta)/\Gamma(\rho K^- \pi$ VALUE 0.35±0.05±0.06 $\Gamma(\Sigma(1385)^+ \eta)/\Gamma(\rho$ Unseen decay mo VALUE 0.17±0.04±0.03	for assumption for a summary for	AVERY ANJOS BARLAG ALBRECHT DOCUMENT ID AVERY ANJOS BARLAG ALBRECHT ALBRECHT DOCUMENT ID AMMAR ALBRECHT AMMAR	91 CLEO 90 E691 900 NA32 88c ARG  TECN 84 BIS2 95 CLEO	tion and $\Lambda_c$ pi $\frac{COMMENT}{e^+e^- \ 10.5}$ $\frac{e^+e^- \ 10.5}{7 \ Be \ 70-26(}$ $\frac{r}{\pi^- \ 230 \ Ge^!}$ $\frac{e^+e^- \ 10 \ C}{e^+e^- \ 10 \ C}$ $\frac{COMMENT}{r}$ $\frac{COMMENT}{e^+e^-} \approx \frac{COMMENT}{e^+e^-} \approx \frac{COMMENT}{e^+e^-}$	5 GeV roduction from $\Gamma_{24}/\Gamma_{5}$ GeV $\Gamma_{26}/\Gamma_{5}$ GeV $\Gamma_{8}/\Gamma_{2}$ GeV $\Gamma_{25}/\Gamma_{5}$ $\Gamma_{26}/\Gamma_{5}$
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	AMENDOLIA  TAT  K*(892) Tare in  DOCUMENT ID  ALEEV  (PK-A+)  DOCUMENT ID  AMENDOLIA  +)  DOCUMENT ID  BARLAG  )  DOCUMENT ID  BOZEK  AMENDOLIA  +)  DOCUMENT ID  BOZEK  AMENDOLIA  BOZEK  DOCUMENT ID  BOZEK  AMENDOLIA	87 SPEC  cluded.  7ECN 94 BIS2  37 NA32  87 SPEC  7ECN 90D NA32  7ECN 93 NA32  7ECN 93 NA32  4 TECN 93 NA32	$\gamma$ Ge-Si $\frac{COMMENT}{n \ N \ 20-70 \ GeV}$ $\frac{COMMENT}{\pi^- \ Cu \ 230 \ GeV}$ $\frac{COMMENT}{\pi^- \ 230 \ GeV}$ $\frac{COMMENT}{\pi^- \ Cu \ 230 \ GeV}$ $\frac{COMMENT}{\pi^- \ Cu \ 230 \ GeV}$	Γ ₁₀ /Γ ₈   Γ ₁₁ /Γ ₂ Γ ₁₂ /Γ  Γ ₁₃ /Γ ₂ Γ ₁₄ /Γ ₂ Γ ₁₅ /Γ ₂	$VALUE$ 0.029±0.006 OUR FIT 0.028±0.007±0.011 6 See BOWCOCK 85 charm to get this re $\Gamma(\Lambda\pi^+\pi^+\pi^-)/\Gamma(\rho$ VALUE 0.66±0.10 OUR FIT 0.66±0.11 OUR AVERA 0.65±0.11±0.12 0.82±0.29±0.27 0.94±0.41±0.13 0.61±0.16±0.04 $\Gamma(\rho\overline{K}^0\pi^+\pi^-)/\Gamma(\Lambda$ VALUE • • • We do not use the 4.3±1.2 $\Gamma(\Lambda\pi^+\eta)/\Gamma(\rho K^-\pi$ VALUE 0.35±0.05±0.06 $\Gamma(\Sigma(1385)^+\eta)/\Gamma(\rho$ Unseen decay mo VALUE 0.17±0.04±0.03 $\Gamma(\Lambda K^+\overline{K}^0)/\Gamma(\rho K^-\pi^+\pi^-)/\Gamma(\Lambda K^+\overline{K}^0)/\Gamma(\rho K^-\pi^-\pi^-)/\Gamma(\Lambda K^+\overline{K}^0)/\Gamma(\rho K^-\pi^-\pi^-)/\Gamma(\Lambda K^+\overline{K}^0)/\Gamma(\rho K^-\pi^-\pi^-)/\Gamma(\Lambda K^+\overline{K}^0)/\Gamma(\rho K^-\pi^-\pi^-)/\Gamma(\Lambda K^+\overline{K}^0)/\Gamma(\rho K^-\pi^-)/\Gamma(\rho K^-\pi^-)/\Gamma(\rho K^-\pi^-)/\Gamma(\rho K^-\pi^-)/\Gamma(\rho K^-)/\Gamma(\rho $	for assumption for a summary for	DOCUMENT ID  AVERY ANJOS BARLAG ALBRECHT  DOCUMENT ID  ALBRECHT  DOCUMENT ID  AMMAR  ALGEV  DOCUMENT ID  AMMAR  (1385) + are in  DOCUMENT ID  AMMAR	91 CLEO 90 E691 90 NA32 88C ARG  7ECN 84 BIS2 7ECN 95 CLEO	tion and $\Lambda_c$ pictor	5 GeV roduction from $\Gamma_{24}/\Gamma_{5}$ GeV GeV $\Gamma_{8}/\Gamma_{2}$ GeV $\Gamma_{25}/\Gamma_{5}$
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	AMENDOLIA  (TAT)  K*(892) are in  DOCUMENT ID  ALEEV  (PK-A+)  DOCUMENT ID  AMENDOLIA  H)  DOCUMENT ID  BARLAG  )  DOCUMENT ID  BOZEK  AMENDOLIA  H)  DOCUMENT ID  BOZEK  AMENDOLIA  H)  DOCUMENT ID  BOZEK  AT+)  DOCUMENT ID  BOZEK  AT+)  DOCUMENT ID  BOZEK  AT+)  DOCUMENT ID  BOZEK  AT+)  AMENDOLIA  AMENDOLIA  H)  DOCUMENT ID  BOZEK  AT+)  DOCUMENT ID  BOZEK  AT+)  AMENDOLIA  AMENDOL	87 SPEC    Cluded.     TECN       94 BIS2       93 NA32       87 SPEC       90D NA32       93 NA32       94 BIS2       10 CN       94 BIS2       10 CN       10 CN	<u>COMMENT</u> π Cu 230 GeV <u>COMMENT</u> γ Ge-Si <u>COMMENT</u> π = 230 GeV <u>COMMENT</u> π = Cu 230 GeV <u>COMMENT</u> π = Cu 230 GeV <u>COMMENT</u> π = Cu 230 GeV <u>COMMENT</u> κ = Cu 230 GeV	Γ ₁₀ /Γ ₈   Γ ₁₁ /Γ ₂   Γ ₁₂ /Γ    Γ ₁₃ /Γ ₂   Γ ₁₄ /Γ ₂   Γ ₁₅ /Γ ₂	$VALUE$ 0.029±0.006 OUR FIT 0.028±0.007±0.011  6 See BOWCOCK 85 charm to get this re $\Gamma(\Lambda\pi^+\pi^+\pi^-)/\Gamma(\rho$ VALUE 0.66±0.10 OUR FIT 0.66±0.11 OUR AVER. 0.65±0.11±0.12 0.82±0.29±0.27 0.94±0.41±0.13 0.61±0.16±0.04 $\Gamma(\rho\overline{K}^0\pi^+\pi^-)/\Gamma(\Lambda$ VALUE • • • We do not use th 4.3±1.2 $\Gamma(\Lambda\pi^+\eta)/\Gamma(\rho K^-\pi$ VALUE 0.35±0.05±0.06 $\Gamma(\Sigma(1385)^+\eta)/\Gamma(\rho$ Unseen decay mo VALUE 0.17±0.04±0.03 $\Gamma(\Lambda K^+\overline{K}^0)/\Gamma(\rho K^-\pi^+)$ VALUE	for assumption the suit.  70  for assumption the suit. $K = \pi^+$ ) $EVTS$ AGE  289  44  10  105 $\pi^+\pi^+\pi^ EVTS$ the following  130 $EVTS$ $EVTS$ 16 $EVTS$ 54 $EVTS$ 54 $EVTS$	DOCUMENT ID  AVERY ANJOS BARLAG ALBRECHT  DOCUMENT ID  AVERY ANJOS BARLAG ALBRECHT  Adata for averag ALEEV  DOCUMENT ID  AMMAR  T(1385) + are in DOCUMENT ID  AMMAR	91 CLEO 90 E691 900 NA32 88c ARG  TECN 95 CLEO 1010ded. 17ECN 95 CLEO	$\begin{array}{c} 0  e^+e^- \ 10. \\ \text{tion and } \Lambda_c \ \text{pi} \\ \\ \hline \\ & e^+e^- \ 10.5 \\ \gamma \ \text{Be } 70-260 \\ \pi^- \ 230 \ \text{Ge}^+e^- \ 10.0 \\ \\ e^+e^- \ 10.0 \\ \\ \hline \\ & COMMENT \\ \hline \\ & e^+e^- \approx \\ \hline \\ & COMMENT \\ \hline \\ & e^+e^- \approx \\ \hline \\ & COMMENT \\ \hline \\ & e^+e^- \approx \\ \hline \\ & COMMENT \\ \hline \\ & e^+e^- \approx \\ \hline \\ & COMMENT \\ \hline \\ & e^+e^- \approx \\ \hline \\ & COMMENT \\ \hline \\ & e^+e^- \approx \\ \hline \\ & COMMENT \\ \hline \\ & e^+e^- \approx \\ \hline \\ & COMMENT \\ \hline \\ & e^+e^- \approx \\ \hline \\ & COMMENT \\ \hline \\ & e^+e^- \approx \\ \hline \\ & COMMENT \\ \hline \\ & e^+e^- \approx \\ \hline \\ & COMMENT \\ \hline \\ & e^+e^- \approx \\ \hline \\ & COMMENT \\ \hline \\ & e^+e^- \approx \\ \hline \\ & COMMENT \\ \hline \\ & e^+e^- \approx \\ \hline \\ & COMMENT \\ \hline \\ \end{array}$	5 GeV roduction from $\Gamma_{24}/\Gamma_{5}$ GeV $\Gamma_{6}$ GeV $\Gamma_{8}/\Gamma_{2}$ GeV $\Gamma_{25}/\Gamma_{5}$ $\Gamma_{26}/\Gamma_{5}$ $\Gamma_{27}/\Gamma_{5}$
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	AMENDOLIA  (TAT)  K*(892) are in  DOCUMENT ID  ALEEV  (PK-T+)  DOCUMENT ID  AMENDOLIA  H)  DOCUMENT ID  BARLAG  )  DOCUMENT ID  BOZEK  TO DOCUMENT ID  BOZEK  AMENDOLIA  H)  DOCUMENT ID  BOZEK  AT+)  DOCUMENT ID  BOZEK  AT+)  DOCUMENT ID  BOZEK  ATO DOCUMENT ID  BOZEK	87 SPEC    Cluded.     TECN       94 BIS2       93 NA32       87 SPEC       90D NA32       93 NA32       94 BIS2       10 CN       94 BIS2       10 CN       10 CN	$\gamma$ Ge-Si  COMMENT $n$ N 20-70 GeV  COMMENT $\pi^-$ Cu 230 GeV  COMMENT $\pi^-$ 230 GeV  COMMENT $\pi^-$ 230 GeV  COMMENT $\pi^-$ Cu 230 GeV  COMMENT $\pi^-$ Cu 230 GeV  COMMENT $\pi^-$ Cu 230 GeV	Γ ₁₀ /Γ ₈   Γ ₁₁ /Γ ₂   Γ ₁₂ /Γ    Γ ₁₃ /Γ ₂   Γ ₁₄ /Γ ₂   Γ ₁₅ /Γ ₂	$VALUE$ 0.029±0.006 OUR FIT 0.028±0.007±0.011 6 See BOWCOCK 85 charm to get this re $\Gamma(\Lambda\pi^+\pi^+\pi^-)/\Gamma(\rho)$ VALUE 0.66±0.10 OUR FIT 0.66±0.11 OUR AVERA 0.65±0.11±0.12 0.82±0.29±0.27 0.94±0.41±0.13 0.61±0.16±0.04 $\Gamma(\rho\overline{K}^0\pi^+\pi^-)/\Gamma(\Lambda)$ VALUE • • • We do not use the distribution of the content of the conte	for assumption for a summary for a	DOCUMENT ID  AVERY ANJOS BARLAG ALBRECHT  DOCUMENT ID  ALBRECHT  DOCUMENT ID  AMMAR  ALGEV  DOCUMENT ID  AMMAR  (1385) + are in  DOCUMENT ID  AMMAR	91 CLEO 90 E691 900 NA32 88c ARG  TECN 95 CLEO 1010ded. 17ECN 95 CLEO	tion and $\Lambda_c$ pictor	5 GeV roduction from $\Gamma_{24}/\Gamma_{5}$ GeV $\Gamma_{26}/\Gamma_{5}$ GeV $\Gamma_{8}/\Gamma_{2}$ GeV $\Gamma_{25}/\Gamma_{5}$ $\Gamma_{26}/\Gamma_{5}$ $\Gamma_{26}/\Gamma_{5}$ $\Gamma_{27}/\Gamma_{5}$
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$\frac{AUUE}{(pK^*(892)^-\pi^+)}/\Gamma(pK^0\pi^+)$ Unseen decay modes of the AUUE EVTS $\frac{A4\pm 0.14}{(44\pm 0.14} \frac{EVTS}{17}$ $\frac{AUE}{(44\pm 0.14} \frac{EVTS}{17}$ $\frac{AUE}{(41232)} \frac{EVTS}{(44\pm 0.18)}/\Gamma \text{ total}$ $\frac{EVTS}{(41232)} \frac{EVTS}{(41232)} \frac{EVTS}{(41232$	AMENDOLIA  (TAT)  K*(892) are in  DOCUMENT ID  ALEEV  (PK-A+)  DOCUMENT ID  BOZEK  DOCUMENT ID  BARLAG  )  DOCUMENT ID  BOZEK  *  DOCUMENT ID  BOZUMENT ID  BOCUMENT ID	87 SPEC    Cluded     TECN       94 BIS2       93 NA32       87 SPEC       90D NA32       93 NA32       93 NA32       94 BIS2       95 TECN       90 NA32       91 TECN       90 NA32       92 TECN       90 NA32       90 NA32       90 NA32       90 TECN       90 TECN	$\gamma$ Ge-Si  COMMENT $\pi$ N 20-70 GeV  COMMENT $\pi^-$ Cu 230 GeV  COMMENT $\pi^-$ 230 GeV  COMMENT $\pi^-$ Cu 230 GeV  COMMENT $\pi^-$ Cu 230 GeV  COMMENT $\pi^-$ Cu 230 GeV $\pi^-$ Cu 230 GeV  COMMENT $\pi^-$ Cu 230 GeV $\pi^-$ 230 GeV	Γ ₁₀ /Γ ₈   Γ ₁₁ /Γ ₂   Γ ₁₂ /Γ    Γ ₁₃ /Γ ₂   Γ ₁₄ /Γ ₂   Γ ₁₅ /Γ ₂	$VALUE$ 0.029±0.006 OUR FIT 0.028±0.007±0.011 6 See BOWCOCK 85 charm to get this re $\Gamma(\Lambda\pi^+\pi^+\pi^-)/\Gamma(\rho)$ VALUE 0.66±0.10 OUR FIT 0.66±0.11 OUR AVERA 0.65±0.11±0.12 0.82±0.29±0.27 0.94±0.41±0.13 0.61±0.16±0.04 $\Gamma(\rho\overline{K}^0\pi^+\pi^-)/\Gamma(\Lambda)$ VALUE • • • We do not use the distribution of the content of the conte	70 for assumptisult.  (K-π+) EVTS  AGE 289 44 10 105 π+π+π- 105 116 0 K-π+) des of the Σ EVTS 59  (F) EVTS 116 116 117 117 117 117 117 117 117 117	DOCUMENT ID  AVERY ANJOS BARLAG ALBRECHT  DOCUMENT ID  AVERY ANJOS BARLAG ALBRECHT  Adata for averag ALEEV  DOCUMENT ID  AMMAR  T(1385) + are in DOCUMENT ID  AMMAR	91 CLEO 90 E691 90D NA32 88c ARG  TECN 95 CLEO 1010404 95 CLEO 95 CLEO	$\begin{array}{c} 0  e^+e^- \ 10. \\ \text{tion and } \Lambda_c \ \text{pi} \\ \\ \hline \\ & e^+e^- \ 10.5 \\ \gamma \ \text{Be } 70-260 \\ \pi^- \ 230 \ \text{Ge}^+e^- \ 10.0 \\ \\ e^+e^- \ 10.0 \\ \\ \hline \\ & COMMENT \\ \hline \\ & e^+e^- \approx \\ \hline \\ & COMMENT \\ \hline \\ & e^+e^- \approx \\ \hline \\ & COMMENT \\ \hline \\ & e^+e^- \approx \\ \hline \\ & COMMENT \\ \hline \\ & e^+e^- \approx \\ \hline \\ & COMMENT \\ \hline \\ & e^+e^- \approx \\ \hline \\ & COMMENT \\ \hline \\ & e^+e^- \approx \\ \hline \\ & COMMENT \\ \hline \\ & e^+e^- \approx \\ \hline \\ & COMMENT \\ \hline \\ & e^+e^- \approx \\ \hline \\ & COMMENT \\ \hline \\ & e^+e^- \approx \\ \hline \\ & COMMENT \\ \hline \\ \\ \\ & COMMENT \\ \hline \\ \\ \\ COMMENT \\ \\ CO$	5 GeV roduction from $\Gamma_{24}/\Gamma_{5}$ GeV $\Gamma_{26}/\Gamma_{5}$ GeV $\Gamma_{8}/\Gamma_{2}$ GeV $\Gamma_{25}/\Gamma_{5}$ $\Gamma_{26}/\Gamma_{5}$ $\Gamma_{26}/\Gamma_{5}$ $\Gamma_{27}/\Gamma_{5}$
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	AMENDOLIA  TAT)  K*(892) are in  DOCUMENT ID  ALEEV  (PK-A+) DOCUMENT ID  BOZEK  DOCUMENT ID  BARLAG  DOCUMENT ID  BOZEK  TO  BOZEK  TO  BOZEK  ALEEV  DOCUMENT ID  BOZEK  TO  BOZEK  BOZEK  TO  BOZEK  BOZEK  BOZEK  BOZEK  BOZEK  BOZ	87 SPEC    Cluded     TECN       94 BIS2       93 NA32       87 SPEC       90D NA32       93 NA32       93 NA32       94 BIS2       95 TECN       90 NA32       91 TECN       90 NA32       92 TECN       90 NA32       90 NA32       90 NA32       90 TECN       90 TECN	$\gamma$ Ge-Si  COMMENT $\pi$ N 20-70 GeV  COMMENT $\pi^-$ Cu 230 GeV  COMMENT $\pi^-$ 230 GeV  COMMENT $\pi^-$ 230 GeV  COMMENT $\pi^-$ Cu 230 GeV	Γ ₁₀ /Γ ₈   Γ ₁₁ /Γ ₂   Γ ₁₂ /Γ    Γ ₁₃ /Γ ₂   Γ ₁₄ /Γ ₂   Γ ₁₅ /Γ ₂	$VALUE$ 0.029±0.006 OUR FIT 0.028±0.007±0.011 6 See BOWCOCK 85 charm to get this re $\Gamma(\Lambda\pi^+\pi^+\pi^-)/\Gamma(\rho$ VALUE 0.66±0.10 OUR FIT 0.66±0.11 OUR AVER/ 0.65±0.11±0.12 0.82±0.29±0.27 0.94±0.41±0.13 0.61±0.16±0.04 $\Gamma(\rho\overline{K}^0\pi^+\pi^-)/\Gamma(\Lambda$ VALUE • • • We do not use the distribution of the content	70 for assumptisult.  (K-π+) EVTS  AGE 289 44 10 105 π+π+π- 105 116 0 K-π+) des of the Σ EVTS 59  (F) EVTS 116 116 117 117 117 117 117 117 117 117	DOCUMENT ID  AVERY ANJOS BARLAG ALBRECHT  DOCUMENT ID  data for averag ALEEV  DOCUMENT ID  AMMAR  (1385) + are in DOCUMENT ID  AMMAR  DOCUMENT ID  AMMAR  DOCUMENT ID  AMMAR	91 CLEO 90 E691 90 NA32 88c ARG	comment $e^+e^-\approx \frac{COMMENT}{e^+e^-\approx \frac{COMMENT}{e^-e^-\approx \frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{$	5 GeV roduction from Γ24/Γ GeV 0 GeV V GeV Γ8/Γ2 GeV Γ25/Γ 7(45) Γ27/Γ 7(45) Γ27/Γ 7(45)
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	AMENDOLIA  TAT)  K*(892) are in  DOCUMENT ID  ALEEV  (PK-A+)  DOCUMENT ID  AMENDOLIA  +)  DOCUMENT ID  BARLAG  )  DOCUMENT ID  BOZEK  AMENDOLIA  +)  DOCUMENT ID  BOZEK  TO  BOZUMENT ID  BARLAG	87 SPEC    Cluded     TECN       94 BIS2       93 NA32       87 SPEC       90D NA32       93 NA32       93 NA32       94 BIS2       95 TECN       90 NA32       91 TECN       90 NA32       92 TECN       90 NA32       90 NA32       90 NA32       90 TECN       90 TECN	$\gamma$ Ge-Si  COMMENT $\pi$ N 20-70 GeV  COMMENT $\pi^-$ Cu 230 GeV  COMMENT $\pi^-$ 230 GeV  COMMENT $\pi^-$ Cu 230 GeV  COMMENT $\pi^-$ Cu 230 GeV  COMMENT $\pi^-$ Cu 230 GeV $\pi^-$ Cu 230 GeV  COMMENT $\pi^-$ Cu 230 GeV $\pi^-$ 230 GeV	Γ ₁₀ /Γ ₈   Γ ₁₁ /Γ ₂ Γ ₁₂ /Γ  Γ ₁₃ /Γ ₂ Γ ₁₄ /Γ ₂ Γ ₁₅ /Γ ₂ Γ ₁₆ /Γ ₂ Γ ₁₇ /Γ ₂	$VALUE$ 0.029±0.006 OUR FIT 0.028±0.007±0.011 6 See BOWCOCK 85 charm to get this re $\Gamma(\Lambda\pi^+\pi^+\pi^-)/\Gamma(\rho$ VALUE 0.66±0.10 OUR FIT 0.66±0.11 OUR AVERA 0.65±0.11±0.12 0.82±0.29±0.27 0.94±0.41±0.13 0.61±0.16±0.04 $\Gamma(\rho \overline{K}^0\pi^+\pi^-)/\Gamma(\Lambda$ VALUE • • • We do not use th 4.3±1.2 $\Gamma(\Lambda\pi^+\eta)/\Gamma(\rho K^-\pi$ VALUE 0.15±0.05±0.06 $\Gamma(\Sigma(1385)^+\eta)/\Gamma(\rho$ Unseen decay mo VALUE 0.17±0.04±0.03 $\Gamma(\Lambda K^+\overline{K}^0)/\Gamma(\rho K^-\pi^+)$ VALUE 0.12±0.02±0.02 $\Gamma(\Sigma^0\pi^+)/\Gamma(\rho K^-\pi^-\pi^+)$ VALUE 0.12±0.02±0.02 $\Gamma(\Sigma^0\pi^+)/\Gamma(\rho K^-\pi^-\pi^-)$ VALUE 0.20±0.04 OUR AVERA	70 for assumptisult.  70 for assumptisult.  6K - π + )  EVTS  AGE 289 44 10 105 π + π + π - )  EVTS the following 130 -+ )  EVTS 116 0K - π + ) des of the Σ  EVTS 59 r + )  EVTS AGE	AVERY ANJOS BARLAG ALBRECHT  DOCUMENT ID  AVERY ANJOS BARLAG ALBRECHT  DOCUMENT ID  AMMAR  (1385) ⁺ are in DOCUMENT ID  AMMAR  DOCUMENT ID  AMMAR	91 CLEO 90 E691 900 NA32 88c ARG	comment $e^+e^-\approx \frac{COMMENT}{e^+e^-\approx \frac{COMMENT}{e^-e^-\approx \frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{$	5 GeV roduction from Γ24/Γ GeV 0 GeV V GeV Γ8/Γ2 GeV Γ25/Γ 7(45) Γ27/Γ 7(45) Γ27/Γ 7(45)
$\frac{EVTS}{44}$ ceen $\frac{EVTS}{44}$ (P K*(892) $^-\pi^+$ )/Γ( $\rho \overline{K}^0\pi^+$ Unseen decay modes of the $\frac{EVTS}{17}$ 1.44±0.14 17 (P(K $^-\pi^+$ )nonresonant $\pi^0$ )/Γ( $\rho K^-\pi^+$ ).73±0.12±0.05 67 (Δ(1232) $\overline{K}^*$ (892))/Γtotal $\frac{EVTS}{35}$ ceen 35 ( $\rho K^-\pi^+\pi^+\pi^-$ )/Γ( $\rho K^-\pi^+$ $\frac{ALUE}{2000}$ 0.022±0.015 ( $\rho K^-\pi^+\pi^0\pi^0$ )/Γ( $\rho K^-\pi^+$ $\frac{ALUE}{2000}$ 0.16±0.07±0.03 15 ( $\rho K^-\pi^+\pi^0\pi^0\pi^0$ )/Γ( $\rho K^-\pi^+$ $\frac{ALUE}{2000}$ 0.10±0.06±0.02 8  Hadronic m ( $\rho \pi^+\pi^-$ )/Γ( $\rho K^-\pi^+$ ) $\frac{ALUE}{2000}$ 0.069±0.036 ( $\rho f_0$ (980))/Γ( $\rho K^-\pi^+$ )	AMENDOLIA  TAT)  K*(892) are in  DOCUMENT ID  ALEEV  (PK-A+)  DOCUMENT ID  AMENDOLIA  +)  DOCUMENT ID  BARLAG  )  DOCUMENT ID  BOZEK  AMENDOLIA  +)  DOCUMENT ID  BOZEK  TO  BOZUMENT ID  BARLAG	87 SPEC    Cluded     TECN       94 BIS2       93 NA32       87 SPEC       90D NA32       93 NA32       94 BIS2       10 FCN       90 NA32       90 NA32	$\gamma$ Ge-Si  COMMENT $\pi$ N 20-70 GeV  COMMENT $\pi^-$ Cu 230 GeV  COMMENT $\pi^-$ 230 GeV  COMMENT $\pi^-$ Cu 230 GeV  COMMENT $\pi^-$ Cu 230 GeV  COMMENT $\pi^-$ Cu 230 GeV $\pi^-$ Cu 230 GeV  COMMENT $\pi^-$ Cu 230 GeV $\pi^-$ 230 GeV	Γ ₁₀ /Γ ₈   Γ ₁₁ /Γ ₂   Γ ₁₂ /Γ    Γ ₁₃ /Γ ₂   Γ ₁₄ /Γ ₂   Γ ₁₅ /Γ ₂	$VALUE$ 0.029±0.006 OUR FIT 0.028±0.007±0.011 6 See BOWCOCK 85 charm to get this re $\Gamma(\Lambda\pi^+\pi^+\pi^-)/\Gamma(\rho$ VALUE 0.66±0.10 OUR FIT 0.66±0.11 OUR AVER/ 0.65±0.11±0.12 0.82±0.29±0.27 0.94±0.41±0.13 0.61±0.16±0.04 $\Gamma(\rho\overline{K}^0\pi^+\pi^-)/\Gamma(\Lambda$ VALUE • • • We do not use the distribution of the content	70 for assumptisult.  70 for assumptisult.  6K - π + )  EVTS  AGE 289 44 10 105 π + π + π - ] the following 130 + ) EVTS 116 6K - π + ) the sof the Σ EVTS 54 - π + ) EVTS 54 - π + ) EVTS 54 - π + ) EVTS 17 18 196	DOCUMENT ID  AVERY ANJOS BARLAG ALBRECHT  DOCUMENT ID  data for averag ALEEV  DOCUMENT ID  AMMAR  (1385) + are in DOCUMENT ID  AMMAR  DOCUMENT ID  AMMAR  DOCUMENT ID  AMMAR	91 CLEO 90 E691 90 NA32 88c ARG	comment $e^+e^-\approx \frac{COMMENT}{e^+e^-\approx \frac{COMMENT}{e^-e^-\approx \frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{e^-e^-=\frac{COMMENT}{$	5 GeV roduction from Γ24/Γ GeV 0 GeV V GeV Γ8/Γ2 GeV Γ25/Γ 7(45) Γ27/Γ 7(45) Γ27/Γ 7(45)

 $\Lambda_{a}^{+}$ 

VALUEEVTS	00000	TTOU	$\Gamma_{30}/\Gamma_2$	Γ(Ξ(1530) ⁰ K ⁺ )/Γ(			_			$\Gamma_{44}/\Gamma_2$
0.11±0.03±0.02 26		$\frac{TECN}{CLEO} \frac{COMMENT}{e^+e^-} \approx r(4.5)$	s)	Unseen decay mo	EVTS	E(1530) ^U are inc DOCUMENT ID	luded	<u>TECN</u>	COMMENT	
$\Gamma(\Sigma^{+}\pi^{+}\pi^{-})/\Gamma(pK^{-}\pi^{+})$			$\Gamma_{31}/\Gamma_2$	0.052±0.014 OUR AVE 0.05 ±0.02 ±0.01	11	ALBRECHT	95B	ARG	$e^+e^- \approx 10.4$	4 GeV
VALUE EVTS  0.68±0.09 OUR AVERAGE	DOCUMENT ID	TECN COMMENT		$0.053 \pm 0.016 \pm 0.010$	24	AVERY	93	CLEO	$e^+e^-\approx 10.5$	5 GeV
$0.74 \pm 0.07 \pm 0.09$ 487	KUBOTA 93 0	CLEO $e^+e^-pprox \gamma$ (45	S)	-	s	emileptonic m	odes		-	
$0.54^{+0.18}_{-0.15}$ 11	BARLAG 92	NA32 $\pi^-$ Cu 230 GeV	<i>,</i>	$\Gamma(\Lambda \ell^+ \nu_\ell)/\Gamma(p K^- \pi$	π+)					$\Gamma_{45}/\Gamma_{2}$
$\Gamma(\Sigma^{+}\rho^{0})/\Gamma(\rho K^{-}\pi^{+})$			$\Gamma_{32}/\Gamma_2$	VALUE 0.518±0.027±0.089		DOCUMENT ID BERGFELD	94	CLEO	$e^+e^- \approx \Upsilon$	45)
VALUE CL%		TECN COMMENT				DENG! EED	,-	CLLO	c c ~ /(	·
<b>&lt;0.27</b> 95	KUBOTA 93 (	CLEO $e^+e^-\approx \Upsilon(45)$	5)	$\Gamma(e^+ \text{ anything})/\Gamma_{\text{tot}}$	tal	DOCUMENT ID		TECN	COMMENT	Г46/Г
$\Gamma(\Sigma^-\pi^+\pi^+)/\Gamma(\Sigma^+\pi^+\pi^-)$			Γ ₃₃ /Γ ₃₁	0.045±0.017		VELLA	82		$e^+e^-$ 4.5-6.	8 GeV
<u>VALUE</u> <u>EVTS</u> <b>0.53±0.15±0.07</b> 56	DOCUMENT ID FRABETTI 94E I	$\frac{TECN}{COMMENT}$ E687 $\gamma$ Be, $\overline{E}_{\gamma}$ 220 G	ieV	$\Gamma(pe^+ \text{ anything})/\Gamma_{to}$	otal					Γ ₄₇ /Γ
		, , ,		VALUE		DOCUMENT ID		TECN	COMMENT	
$\Gamma(\Sigma^0\pi^+\pi^0)/\Gamma(pK^-\pi^+)$ VALUE EVTS	DOCUMENT ID	TECNCOMMENT	Γ ₃₄ /Γ ₂	0.018±0.009		⁷ VELLA	82	MRK2	e ⁺ e ⁻ 4.5-6.	8 GeV
0.36±0.09±0.10 117		CLEO $e^+e^- \approx r(35)$	S), \( \gamma(4S) \)	VELLA 82 includes		п и весау.				
$\Gamma(\Sigma^0\pi^+\pi^+\pi^-)/\Gamma(pK^-\pi^+$	.)		Γ ₃₅ /Γ ₂	$\Gamma(\Lambda e^+ \text{ anything})/\Gamma_t$	total	DOCUMENT ID		TECN	COMMENT	Γ ₄₈ /Γ
VALUE EVTS	DOCUMENT ID	TECN COMMENT		• • We do not use the	he following		s, fits			
<b>0.21±0.05±0.05</b> 90	AVERY 94 (	CLEO $e^+e^-pprox r$ (35	s), <b>γ</b> (4s)	0.011±0.008		⁸ VELLA	82	MRK2	$e^+e^-$ 4.5-6.	8 GeV
$\Gamma(\Sigma^+\omega)/\Gamma(pK^-\pi^+)$ Unseen decay modes of the	are included		$\Gamma_{37}/\Gamma_2$	8 VELLA 82 includes	Λ's from $Σ$ ⁽⁾	decay.				
VALUE EVTS		TECN COMMENT		$\Gamma(\Lambda e^+ \text{ anything})/\Gamma($	. ,					$\Gamma_{48}/\Gamma_{2}$
<b>0.54±0.13±0.06</b> 107	KUBOTA 93	CLEO $e^+e^-pprox \gamma$ (45	<b>S</b> )	VALUE 0.37±0.11±0.08	<u>EVTS</u> 73	DOCUMENT ID ALBRECHT	91G	TECN ARG	$e^+e^-\approx 10.4$	I GeV
$\Gamma(\Sigma^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-})/\Gamma(pK^{-})$	,		$\Gamma_{38}/\Gamma_{2}$	$\Gamma(\Lambda \mu^+ \text{ anything})/\Gamma($	(pK-π+)					Γ ₄₉ /Γ ₂
<u>VALUE</u> <u>EVTS</u> <b>0.06</b> +0.08 1		TECN COMMENT  NA32 $\pi^-$ Cu 230 GeV		VALUE	<u>EVTS</u>	DOCUMENT ID		TECN	COMMENT	
	DANEAG 32 1	14A32 # Ca 230 GCV		0.35±0.18±0.09	30	ALBRECHT	<b>9</b> 1G	ARG	$e^+e^-\approx 10.4$	↓ GeV
$\Gamma(\Sigma^+ K^+ K^-)/\Gamma(pK^-\pi^+)$ VALUE	DOCUMENT ID	TECN COMMENT	Γ ₃₉ /Γ ₂			Inclusive mod	des -		-	
<u>VALUE</u> <u>EVTS</u> <b>0.070±0.011±0.011</b> 59		CLEO $e^+e^- \approx 10.5$ (	GeV	$\Gamma(p \text{ anything})/\Gamma_{\text{tota}}$	al			T-61	501415VT	Γ ₅₁ /Γ
$\Gamma(\Sigma^+\phi)/\Gamma(pK^-\pi^+)$			$\Gamma_{40}/\Gamma_{2}$	VALUE 0.50±0.08±0.14		9 CRAWFORD	92	TECN CLEO	$e^+e^-$ 10.5 C	ieV
Unseen decay modes of the			. 40/ • 2	9 This CRAWFORD 9:	2 value inclu	des protons from	∕l de			
<u>VALUE</u> <u>EVTS</u> <b>0.069±0.023±0.016</b> 26		TECN COMMENT  CLEO $e^+e^- \approx 10.5$ (	GeV	but account is taker		he systematic er	ror.			
$\Gamma(\Sigma^{+}K^{+}\pi^{-})/\Gamma(pK^{-}\pi^{+})$			$\Gamma_{41}/\Gamma_{2}$	Γ(p anything (no Λ))  VALUE	)/F _{total}	DOCUMENT ID		TECN	COMMENT	$\Gamma_{52}/\Gamma$
VALUE EVTS	DOCUMENT ID	TECN COMMENT	- 41/ · 2	0.12±0.10±0.16		CRAWFORD	92		$e^{+}e^{-}$ 10.5 C	ieV
<b>0.13</b> ^{+0.12} _{-0.07} 2	BARLAG 92	NA32 π ⁻ Cu 230 GeV	′	$\Gamma(n \text{ anything})/\Gamma_{\text{tota}}$	al					Г ₅₄ /Г
$\Gamma(\equiv^0 K^+)/\Gamma(pK^-\pi^+)$			$\Gamma_{42}/\Gamma_{2}$	VALUE		DOCUMENT ID		TECN		
VALUE EVTS	DOCUMENT ID	TECN COMMENT		0.50±0.08±0.14 10 This CRAWFORD 9		O CRAWFORD			e ⁺ e ⁻ 10.5 C	
<b>0.078±0.013±0.013</b> 56	AVERY 93	CLEO $e^+e^- \approx 10.5$	GeV	dent, but account is	s taken of th	is in the system	atic e	rror.	The value is in	oder depen-
$\Gamma(\Xi^-K^+\pi^+)/\Gamma(\rho K^-\pi^+)$			$\Gamma_{43}/\Gamma_2$	$\Gamma(n \text{ anything (no } \Lambda))$	)/F _{total}					Γ ₅₅ /Γ
<u>VALUE</u> <u>EVTS</u> <b>0.098±0.021 OUR AVERAGE</b> E	DOCUMENT ID Fror includes scale factor	TECN COMMENT of 1.3. See the ideogra	am below.	VALUE		DOCUMENT ID		TECN	COMMENT	
0.14 ±0.03 ±0.02 34	ALBRECHT 958	ARG $e^+e^- \approx 10.4$ G	GeV	0.29±0.09±0.15		CRAWFORD	92	CLEO	e ⁺ e ⁻ 10.5 C	ieV
$0.079 \pm 0.013 \pm 0.014$ 60 $0.15 \pm 0.04 \pm 0.03$ 30		CLEO $e^+e^-pprox 10.5$ (CLEO $e^+e^-$ 10.5 GeV		Γ(p hadrons)/Γ _{total}		DOCUMENT ID		TECN	COMMENT	Γ ₅₃ /Γ
		2220 0 0 10.0 40	•	• • We do not use the	he following	DOCUMENT ID data for average			COMMENT etc. • • •	
WEIGHTED AVER 0.098±0.021 (Error				$0.41 \pm 0.24$		ADAMOVICH	87	EMUL	γ A 20-70 Ge	V/c
. ↓				$\Gamma(\Lambda \text{ anything})/\Gamma_{\text{tota}}$	al .					Γ ₅₆ /Γ
				0.35±0.11 OUR AVER	EVTS	DOCUMENT ID		TECN S	COMMENT	m helow
				0.59±0.10±0.12	AGE ENO	CRAWFORD			$e^+e^-$ 10.5 G	
				$0.49 \pm 0.24$ $0.23 \pm 0.10$	8 1	ADAMOVICH 1 ABE			γ A 20-70 Ge 20 GeV γ p	V/c
				11 ABE 86 includes A's			00		20 001 / p	
1 1 3 3 3										
			2 ²							
			<u> </u>							
	ALI	BRECHT 95B ARG	1.3							
	· · · · · \	ERY 93 CLEO	1.0							
		ERY 93 CLEO ERY 91 CLEO	) 1.0 ) 1.1 3.4							
	AV	ERY 93 CLEO ERY 91 CLEO  (Confidence Leve	) 1.0 ) 1.1 3.4							
0 0.05 0.1	0.15 0.2 0.25 0	ERY 93 CLEO ERY 91 CLEO	) 1.0 ) 1.1 3.4							
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	0.15 0.2 0.25 0	ERY 93 CLEO ERY 91 CLEO  (Confidence Leve	) 1.0 ) 1.1 3.4							



#### 

## $\Gamma(p\mu^+\mu^-)/\Gamma_{ ext{total}}$ A test for the $\Delta C = 1$ weak neutral current. Allowed by higher-order electroweak interactions

A test for the  $\Delta C=1$  weak neutral current. Allowed by higher-order electroweak interactions.

VALUE CL% EVTS DOCUMENT ID TECN COMMENT

<3.4 × 10⁻⁴ 90 0 KODAMA 95 E653  $\pi^-$  emulsion 600 GeV

$\Gamma(\Sigma^-\mu^+\mu^+)$ A test of $\Gamma$		ımber co	onservation.			Γ ₅₉ /Γ
VALUE	CL%	<b>EVTS</b>	DOCUMENT ID	TECN	COMMENT	
$< 7.0 \times 10^{-4}$	90	Λ	KODAMA 9	5 F653	π ⁻ emulsion 60	) GeV

### A+ DECAY PARAMETERS

See the "Note on Baryon Decay Parameters" in the neutron Listings.

### $\alpha$ FOR $\Lambda_c^+ \rightarrow \Lambda \pi^+$

<u> 15</u>	DOCUMENT ID		TECN_	COMMENT
iΕ				
14 12	BISHAI	95	CLEO	$e^+e^-pprox \Upsilon(4S)$
	ALBRECHT	92	ARG	$e^+e^-pprox$ 10.4 GeV
86	AVERY	<b>90</b> B	CLEO	$e^+e^-pprox$ 10.6 GeV
	<u>75</u> <b>iE</b> 14 12	iE 14 ¹² BISHAI ALBRECHT	iE 14 ¹² BISHAI 95 ALBRECHT 92	14 12 BISHAI 95 CLEO ALBRECHT 92 ARG

 12  BISHAI 95 actually gives  $\alpha{=}-0.94^{+}_{-}0.21^{+}_{-}0.12^{}$ , chopping the errors at the physical limit -1.0. However, for  $\alpha\approx-1.0$ , some experiments should get unphysical values ( $\alpha<-1.0$ ), and for averaging with other measurements such values (or errors that extend below -1.0) should not be chopped.

### $\alpha$ FOR $\Lambda_c^+ \to \Sigma^+ \pi^0$

VALUE	<b>EVTS</b>	DOCUMENT ID	TECN	COMMENT	
$-0.45\pm0.31\pm0.06$	89	BISHAI 95	CLEO	$e^+e^-pprox \ \varUpsilon(4S)$	ı

### $\alpha$ FOR $\Lambda_c^+ \rightarrow \Lambda \ell^+ \nu_\ell$

The experiments don't cover the complete (or same incomplete)  $M(\Lambda \ell^+)$  range, but we average them together anyway.

E DOCUMENT ID TECN COMMENT

$-0.82^{+0.11}_{-0.07}$	OUR	AVERAGE
- U.DZ 0 07	OUR	MACKWOL

$-0.82^{+0.09}_{-0.06}^{+0.06}_{-0.03}$	700	¹³ CRAWFORD	95 CLEO	$e^+e^-pprox \Upsilon(4S)$
$-0.91\pm0.42\pm0.25$		¹⁴ ALBRECHT	94B ARG	$e^+e^-pprox$ 10 GeV
• • • We do not use th	e followi	ng data for average	es, fits, limit	s, etc. • • •
-0.89 + 0.17 + 0.09	350	15 BERGFELD	94 CLEO	See CRAWFORD 95

 13  CRAWFORD 95 measures the form-factor ratio  $R \equiv f_2/f_1$  for  $\Lambda_c^+ \rightarrow \Lambda e^+ \nu_e$  events to be  $-0.25 \pm 0.14 \pm 0.08$  and from this calculates  $\alpha$ , averaged over  $q^2$ , to be the above.  14  ALBRECHT 948 uses  $\Lambda e^+$  and  $\Lambda \mu^+$  events in the mass range  $1.85 < M(\Lambda \ell^+) < 2.20$ 

15 BERGFELD 94 uses  $\Lambda e^+$  events.

### 14 REFERENCES

We have omitted some papers that have been superseded by later experiments. The omitted papers may be found in our 1992 edition (Physical Review D45, 1 June, Part II) or in earlier editions.

ALEXANDER	96C	PR D53 R1013		+Bebek, Berger+	(CLEO	Collab.)
ALBRECHT	95B	PL B342 397		+Hamacher, Hofmann+	(ÀRGUS	
AMMAR	95	PRL 74 3534		+Baringer, Bean, Besson+		Collab.)
BISHAI	95	PL B350 256		+Fast, Gerndt, Hinson+		Collab.)
CRAWFORD	95	PRL 75 624		+Daubenmier, Fulton+		Collab.)
KODAMA	95	PL B345 85		+Ushida, Mokhtarani+	(FNAL E653	
ALBRECHT	94B	PL B326 320		+Ehrlichmann, Hamacher+	(ARGUS	Collab.)
ALEEV	94	PAN 57 1370		+Balandin+	(Serpukhov BIS-2	
		Translated from Y	F 57 1		(	,
AVERY	94	PL B325 257		+Freyberger, Rodriguez+	(CLEO	Collab.)
BERGFELD	94	PL B323 219		+Eisenstein, Gollin, Ong+	(CLEO	Collab.)
FRABETTI	94E	PL B328 193		+Cheung, Cumalat+	(FNAL E687	Collab.)
AVERY	93	PRL 71 2391		+Freyberger, Rodriguez+	(CLEO	Collab.)
BOZEK	93	PL B312 247		+Barlag, Becker, Boehringer+	(CERN NA32	Collab.)
FRABETTI	93D	PRL 70 1755		+Cheung, Cumalat+	(FNAL E687	Collab.)
FRABETTI	93H	PL B314 477		+Cheung, Cumalat+	(FNAL E687	
KUBOTA	93	PRL 71 3255		+Lattery, Nelson, Patton+	` (CLEO	Collab.)
ALBRECHT	92	PL B274 239		+Ehrlichmann, Hamacher, Krueger+		
ALBRECHT	920	ZPHY C56 1		+Cronstroem, Ehrlichmann+	(ARGUS	
BARLAG	92	PL B283 465		+Becker, Bozek, Boehringer+	(ACCMOR	
CRAWFORD	92	PR D45 752		+Fulton, Jensen, Johnson+		Collab.)
JEZABEK	92	PL B286 175		+Rybicki, Rylko	(0220	(CRAC)
ALBRECHT	91G	PL B269 234		+Ehrlichmann, Hamacher+	(ARGUS	
AVERY	91	PR D43 3599		+Besson, Garren, Yelton+		Collab.)
ALVAREZ	90	ZPHY C47 539		+Barate, Bloch, Bonamy+	(CERN NA14/2	
ALVAREZ	90B	PL B246 256		+Barate, Bloch, Bonamy+	(CERN NA14/2	
ANJOS	90	PR D41 801		+Appel, Bean+	(FNAL E691	
AVERY	90B	PRL 65 2842		+Besson, Garren, Yelton, Kinoshita-		Collab.)
BARLAG	90D	ZPHY C48 29		+Becker, Boehringer, Bosman+	(ACCMOR	
FRABETTI	90	PL B251 639		+Bogart, Cheung, Coteus+	(FNAL E687	
BARLAG	89	PL B231 039		+Becker, Boehringer, Bosman+	(ACCMOR	
AGUILAR	88B	ZPHY C40 321		Aguilar-Benitez, Allison, Bailly+	(LEBC-EHS	
Also	87	PL B189 254		Aguilar-Benitez, Allison, Bailly+	(LEBC-EHS	
Also	87B	PL B199 462		Aguilar-Benitez, Allison, Bailly+	(LEBC-EHS	
Also	88	SJNP 48 833		Begalli, Otter, Schulte, Gensch+	(LEBC-EHS	
Also	00	Translated from Y	VE 10		(LEBC-ENS	Collab.
ALBRECHT	88C	PL B207 109	A1 40	+	(ARGUS	Collab.)
ALBRECHT	88E	PL B210 263		+Boeckmann, Glaeser+	(ARGUS	
ANJOS	88B	PRL 60 1379		+Appel+	(FNAL E691	
ADAMOVICH	87	EPL 4 887			(Photon Emulsion	
Also	87	SJNP 46 447			(Photon Emulsion	
Also	01	Translated from Y	ΔF 46	799	(1 HOLOH EIHBISION	Conab.)
AMENDOLIA	87	ZPHY C36 513	, , , ,	+Bagliesi, Batignani, Beck+	(CERN NA1	Collab.)
JONES	87	ZPHY C36 593		+Jones, Kennedy, O'Neale+	(CERN WA21	
ABE	86	PR D33 1		+ (SLAC Hybr	id Facility Photon	
BOWCOCK	85	PRL 55 923		+Giles, Hassard, Kinoshita+		Collab.)
ALEEV	84	ZPHY C23 333		+Arefiev, Balandin, Berdyshev+		Collab.)
BOSETTI	82	PL 109B 234			NN, CERN, MPIN	
VELLA	82	PRL 48 1515		+Trilling, Abrams, Alam+	(SLAC, LB	
BASILE	81B	NC 62A 14			RN, BGNA, PGIA	
CALICCHIO	80	PL 93B 521		+ (BARI, BIRM, BRU		
2,12,00,110	30	, , , , , , , , , , , , , , , , , ,		. (5.4.4, 5.4.4) 510	.,,	

## $\Lambda_c(2593)^+$

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ı

$$I(J^P) = O(\frac{1}{2})$$
 Status: ***

Seen in  $\Lambda_c^+\pi^+\pi^-$  but not in  $\Lambda_c^+\pi^0$ , so this is indeed an excited  $\Lambda_c^+$  rather than a  $\Sigma_c^+$ . The  $\Lambda_c^+\pi^+\pi^-$  mode is largely, and perhaps entirely,  $\Sigma_c\pi$ , which is just at threshold; thus (assuming, as has not yet been proven, that the  $\Sigma_c$  has  $J^P=1/2^+$ ) the  $J^P$  here is almost certainly  $1/2^-$ . This result is in accord with the theoretical expectation that this is the charm counterpart of the strange  $\Lambda(1405)$ .

### $\Lambda_c(2593)^+$ MASS

The value is obtained from the  $m_{\Lambda_c(2593)^+}-m_{\Lambda_c^+}$  mass-difference measurement below.

<u>VALUE (MeV)</u> <u>DOCUMENT ID</u> **2593.6±1.0 OUR FIT** Error includes scale factor of 1.2.

### $m_{\Lambda_c(2593)^+} - m_{\Lambda_c^+}$

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
308.6±0.8 OUR FIT	Error inclu	ides scale factor o	f 1.3.		
308.6±0.8 OUR AVE	RAGE Err	or includes scale f	actor	of 1.3.	
$309.2 \pm 0.7 \pm 0.3$	14	¹ FRABETTI	96	E687	$\gamma$ Be, $\overline{E}_{\gamma} \approx $ 220 GeV
$307.5 \pm 0.4 \pm 1.0$	112	² EDWARDS	95	CLEO	$e^+e^-\stackrel{'}{pprox}$ 10.5 GeV

 1  FRABETTI 96 claims a signal of 13.9  $\pm$  4.5 events.

 2  EDWARDS 95 claims a signal of 112.5  $\pm$  16.5 events in  $\varLambda_{C}^{+}\,\pi^{+}\,\pi^{-}.$ 

### $\Lambda_c(2593)^+$ WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT	
$3.9^{+1.4}_{-1.2}^{+2.0}_{-1.0}$	112	EDWARDS	95	CLEO	$e^+e^-pprox$ 10.5 GeV	

 $\Lambda_c(2593)^+$ ,  $\Lambda_c(2625)^+$ ,  $\Sigma_c(2455)$ 

### $\Lambda_c(2593)^+$ DECAY MODES

 $\Lambda_c^+\pi\pi$  and  $\Sigma_c$ (2455) $\pi$  — the latter just barely — are the only strong decays allowed to an excited  $\Lambda_c^+$  having this mass; and the  $\Lambda_c^+\pi^+\pi^-$  mode seems to be largely via  $\Sigma_c^{++}\pi^-$  or  $\Sigma_c^0\pi^+$ .

	Mode	Fraction $(\Gamma_i/\Gamma)$
$\overline{\Gamma_1}$	$\Lambda_c^+ \pi^+ \pi^-$	seen
$\Gamma_2$	$\Sigma_c$ (2455) ⁺⁺ $\pi^-$	large
$\Gamma_3$	$\Sigma_c$ (2455) $^0\pi^+$	large
$\Gamma_4$	$\Lambda_c^+ \pi^+ \pi^-$ 3-body	small
Γ ₅	$\Lambda_c^+ \pi^0$	not seen
Γ ₆	$\Lambda_c^{+} \gamma$	not seen

#### 1c(2593)+ BRANCHING RATIOS

$\Gamma(\Sigma_c(2455)^{++}\pi^{-}$	$\Gamma)/\Gamma(\Lambda_c^+\pi$	$^{+}\pi^{-})$			$\Gamma_2/\Gamma_1$	
VALUE		DOCUMENT ID		TECN	COMMENT	
$0.36 \pm 0.09 \pm 0.09$		EDWARDS	95	CLEO	$e^+e^-pprox$ 10.5 GeV	ı
$\Gamma(\Sigma_c(2455)^0\pi^+)$	$\Gamma(\Lambda_c^+\pi^+$	$\pi^-$ )			$\Gamma_3/\Gamma_1$	
VALUE		DOCUMENT ID		TECN	COMMENT	_
0.42±0.09±0.09		EDWARDS	95	CLEO	$e^+e^-pprox~10.5~{ m GeV}$	ı
$[\Gamma(\Sigma_c(2455)^{++}\pi^{-1})]$	-)+Γ( <b>Σ</b>	c(2455) ⁰ π ⁺ )]/I	(A _c	$\pi^+\pi^-$	$(\Gamma_2+\Gamma_3)/\Gamma_1$	
		DOCUMENT ID				
• • • We do not use	the followi	ng data for average	s, fits	, limits,	etc. • • •	
>0.51	90	³ FRABETTI	96	E687	$\gamma$ Be, $\overline{E}_{\gamma} pprox $ 220 GeV	ı
³ The results of FR	ABETTI 96	are consistent wit	n this	ratio b	eing 100%.	١
$\Gamma(\Lambda_c^+\pi^0)/\Gamma(\Lambda_c^+\pi^0)$					$\Gamma_5/\Gamma_1$	
$\Lambda_c^+ \pi^0$ decay is	forbidden b	y isospin conservat	ion if	this sta	te is in fact a $\Lambda_C$ .	
	CL%	DOCUMENT ID		TECN	COMMENT	
<3.53	90	EDWARDS	95	CLEO	$e^+e^-pprox$ 10.5 GeV	ı
$\Gamma(\Lambda_c^+ \gamma)/\Gamma(\Lambda_c^+ \pi^+$	$\pi^-)$				Γ ₆ /Γ ₁	
VALUE	CL%	DOCUMENT ID		TECN	COMMENT	
<0.98	90	EDWARDS	95	CLEO	$e^+e^-pprox~$ 10.5 GeV	١

### $\Lambda_c(2593)^+$ REFERENCES

FRABETTI 96 PL B365 461 +Cheung, Cumalat+ (FNAL E687 Collab.) EDWARDS 95 PRL 74 3331 +Ogg, Bellerive, Britton+ (CLEO Collab.)



$$I(J^P) = 0(?^?)$$
 Status: ***

Seen in  $\Lambda_c^+\pi^+\pi^-$  but not in  $\Lambda_c^+\pi^0$  so this is indeed an excited  $\Lambda_c^+$  rather than a  $\Sigma_c^+$ . The spin-parity is expected to be  $3/2^-$ : this is presumably the charm counterpart of the strange  $\Lambda(1520)$ .

### $\Lambda_c$ (2625)+ MASS

The fit also uses the  $m_{\Lambda_c(2625)^+}-m_{\Lambda_c^+}$  mass-difference measurement

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
2626.4±0.9 OUR FIT	Error inc	ludes scale factor	of 1.3.	
2626.6±0.5±1.5	42	¹ ALBRECHT	93F ARG	$e^+e^-pprox\varUpsilon$ (4S)
1 ALDDECUT ONE of		and of 42.4   0.0 a		

#### $m_{\Lambda_c(2625)^+} - m_{\Lambda_c^+}$

		• • •	C		
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
341.5±0.8 OUR FIT	Error inclu	des scale factor o	f 1.9.		
341.5±0.9 OUR AVE	RAGE Erro	or includes scale fa	actor	of 2.1.	
$342.2 \pm 0.2 \pm 0.5$	245	² EDWARDS	95	CLEO	$e^+e^-pprox~10.5~{ m GeV}$
$340.4 \pm 0.6 \pm 0.3$	40	³ FRABETTI	94	E687	$\gamma$ Be, $\overline{E}_{\gamma}=220$ GeV
² EDWARDS 95 cla					,
³ FRABETTI 94 cla	ims a signal	of 39.7 ± 8.7 ev	ents.	·	

#### $\Lambda_c(2625)^+$ WIDTH

VALUE (MeV)	CL% EVTS	DOCUMENT ID	TECN	COMMENT
<1.9	90 245	EDWARDS 95	CLEO	$e^+e^-pprox$ 10.5 GeV
● ● ● We do not	use the followin	g data for averages, fits	, limits,	etc. • • •
< 3.2	90	ALBRECHT 93F	ARG	$e^+e^-pprox \varUpsilon(4S)$

### $\Lambda_c(2625)^+$ DECAY MODES

 $\Lambda_c^+ \, \pi \, \pi$  and  $\Sigma (2455) \pi$  are the only strong decays allowed to an excited  $\Lambda_c^+$  having this mass.

	Mode	Fraction $(\Gamma_{\hat{I}}/\Gamma)$
Γ ₁	$\Lambda_c^+ \pi^+ \pi^-$	seen
$\Gamma_2$	$\Sigma_c (2455)^{++} \pi^- \ \Sigma_c (2455)^0 \pi^+$	small
$\Gamma_3$	$\Sigma_c(2455)^0 \pi^+$	small
$\Gamma_4$	$\Lambda_c^+ \pi^+ \pi^-$ 3-body	large
Γ ₅ Γ ₆	$\Lambda_c^+ \pi^0$	not seen
Γ ₆	$\Lambda_c^{+} \gamma$	not seen

#### $\Lambda_c(2625)^+$ BRANCHING RATIOS

$\Gamma(\Sigma_c(2455)^+$	$+\pi^-$ )/ $\Gamma(\Lambda_c^+\pi^+$	$\pi^{-}$ )				$\Gamma_2/\Gamma_1$
VALUE	CL%	DOCUMENT ID		TECN	COMMENT	
<0.08	90	EDWARDS	95	CLEO	$e^+e^-pprox$ 10.	5 GeV
$\Gamma(\Sigma_c(2455)^0$	$(\pi^+)/\Gamma(\Lambda_c^+\pi^+\pi^-)$	-)				$\Gamma_3/\Gamma_1$
VALUE	CL%	DOCUMENT ID		TECN	COMMENT	
<0.07	90	EDWARDS	95	CLEO	$e^+e^-\approx 10.$	5 GeV
$[\Gamma(\Sigma_c(2455)^{-1})]$	$^{++}\pi^{-})+\Gamma(\Sigma_{c}($	[2455) ⁰ π ⁺ )]/Γ	·(Λ ⁺	π+π-	·) (Γ:	2+Γ3)/Γ1
VALUE	CL% EVTS	DOCUMENT ID		TECN	COMMENT	
• • • We do no	ot use the following	data for average	s, fits	, limits,	etc. • • •	
< 0.36	90	FRABETTI	94	E687	$\gamma$ Be, $\overline{E}_{\gamma}=2$	20 GeV
$0.46\pm0.14$	21	ALBRECHT	93F	ARG	$e^+e^-\approx \Upsilon(4)$	·S)
$\Gamma(\Lambda_c^+\pi^+\pi^-3$	-body)/Γ(Λ _c + π ⁺	+π ⁻ )				$\Gamma_4/\Gamma_1$
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT	
• • • We do no	ot use the following	data for average	s, fits	, limits,	etc. • • •	
$0.54 \pm 0.14$	16	ALBRECHT	93F	ARG	$e^+e^-pprox \Upsilon(4$	·S)
$\Gamma(\Lambda_c^+\pi^0)/\Gamma(\Lambda_c^+\pi^0)$						$\Gamma_5/\Gamma_1$
$\Lambda_c^+ \pi^0$ de	cay is forbidden by	isospin conservat	ion if	this sta	te is in fact a /	1 _c .
VALUE	CL%	DOCUMENT ID			COMMENT	
<0.91	90	EDWARDS	95	CLEO	$e^+e^-\approx 10$	5 GeV
$\Gamma(\Lambda_c^+ \gamma)/\Gamma(\Lambda_c^+$	$_{c}^{+}\pi^{+}\pi^{-})$					$\Gamma_6/\Gamma_1$
VALUE	CL%	DOCUMENT ID		TECN	COMMENT	•

#### $\Lambda_c(2625)^+$ REFERENCES

EDWARDS	95	PRL 74 3331	+Ogg, Bellerive, Britton+	(CLEO Collab.)
FRABETTI	94	PRL 72 961	+Cheung, Cumalat+	(FNAL E687 Collab.)
ALBRECHT		PL B317 227	+Ehrlichmann, Hamacher+	(ARGUS Collab.)

## $\Sigma_c(2455)$

$$I(J^P) = 1(\frac{1}{2}^+)$$
 Status: ***

 $J^P$  is not confirmed.  $1/2^+$  is the quark model prediction.

### $\Sigma_c$ (2455) MASSES

The mass measurements in this section are redundant with the mass difference measurements that follow. We get the masses by adding  $m_{\Sigma_c}(2455)-m_{\Lambda_c^+}$  to the  $\Lambda_c^+$  mass.

#### $\Sigma_c(2455)^{++}$ MASS VALUE (MeV) EVTS 2452.9± 0.6 OUR FIT DOCUMENT ID TECN CHG COMMENT ullet ullet We do not use the following data for averages, fits, limits, etc. ullet ulletJONES 87 HBC ++ $\nu p$ in BEBC ADAMOVICH 84 EMUL ++ γA (OMEGA) BOSETTI 82 HBC ++ See JONES 87 BALTAY 79 HLBC ++ ν Ne-H in 15-ft 2480 2454 ± 5 $2425\phantom{0}\pm10\phantom{0}$ 778 DBC ++ $\nu d$ in 12-ft 75 HBC ++ $\nu p$ in BNL 7-ft >2439 BARISH 2426 ±12 CAZZOLI $\Sigma_c(2455)^+$ MASS VALUE (MeV) EVTS DOCUMENT ID TECN CHG COMMENT 2453.5±0.9 OUR FIT $\bullet$ $\,\bullet$ $\,\bullet$ We do not use the following data for averages, fits, limits, etc. $\,\bullet$ $\,\bullet$ CALICCHIO 80 HBC + $\nu p$ in BEBC-TST

$\Sigma_c$ (2455) ⁰ MASS						
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
2452.1± 0.7 OUR	FIT					
• • • We do not use	the following	g data for average	s, fit	s, limits,	etc.	• •
2462 ±26	1	AMMAR	86	EMUL	0	νΑ
~ 2460	9	KNAPP	76	SPEC	0	$\gamma$ Be
$m_{\Sigma^{++}} - m_{\Lambda^{+}}$						
$m_{\Sigma_c^{++}} - m_{\Lambda_c^+}$						
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
167.95± 0.25 OUR F						
167.94 ± 0.26 OUR A	WERAGE					
$167.6 \pm 0.6 \pm 0.6$	56	FRABETTI	96	E687	++	$\gamma$ Be, $\overline{E}_{\gamma} \approx 220$ $\text{GeV}$ $e^+e^- \approx \Upsilon(45)$

167 ± 1	2	JONES	87	HBC	++	$\nu p$ in BEBC
168 ± 3	6	BALTAY	79	HLBC	++	$\nu$ Ne-H in 15-ft
• • • We do not use	the following	data for average	s, fit	s, limits,	etc.	• •
166 ± 1	1	BOSETTI	82	HBC	++	See JONES 87
166 ±15	1	CAZZOLI	75	HBC	++	$\nu p$ in BNL 7-ft
$m_{\Sigma_c^+} - m_{\Lambda_c^+}$						
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
168.5 ± 0.7 OUR FIT	Error includ	les scale factor of	1.1.			
168 ±3	1	CALICCHIO	80	HBC	+	νρ in BEBC-TST
• • • We do not use	the following	data for average	s, fit	s, limits,	etc.	• •

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111  1  CRAWFORD 93 CLEO +  $e^{+}e^{-}pprox \varUpsilon(4S)$  $^1\, {\rm This}$  result enters the fit through  $m_{\sum_{\, c}^{\, +}} \, - \, m_{\sum_{\, c}^{\, 0}}$  below.

 $167.8 \pm 0.4 \pm 0.3$ 

 $168.2 \pm 0.5 \pm 1.6$ 

167.4  $\pm$  0.5  $\pm$ 2.0

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
167.2±0.4 OUR FIT	Error inclu	des scale factor of	1.1.		
167.2±0.9 OUR AVE	RAGE Erro	or includes scale fa	ctor of 1.4.		
$166.6 \pm 0.5 \pm 0.6$	69	FRABETTI	96 E687	0	$\gamma$ Be, $\overline{E}_{\gamma} \approx 220$
					GeV '
$168.4 \pm 1.0 \pm 0.3$	14	ANJOS	89D E691	0	γ Be 90-260 GeV
• • • We do not use	the following	g data for average	s, fits, limit	s, etc.	• • •
$167.1 \pm 0.3 \pm 0.2$	124	² CRAWFORD	93 CLEC	0	$e^+e^-pprox \Upsilon(45)$
$167.9 \pm 0.5 \pm 0.3$	48	² BOWCOCK	89 CLEC	0	$e^+e^-$ 10 GeV
$167.0\pm0.5\pm1.6$	70	² ALBRECHT	88D ARG	0	$e^+e^-$ 10 GeV
$178.2 \pm 0.4 \pm 2.0$	85	³ DIESBURG	87 SPEC	0	$nA\sim 600~GeV$
163 ±2	1	AMMAR	86 EMU	_ 0	νΑ
² This result enters	the fit throu	gh m — m _	o given bel	w.	

This result enters the fit through  $m_{\Sigma_c^{++}} - m_{\Sigma_c^0}$  given below.

#### $\Sigma_c$ (2455) MASS DIFFERENCES

$\Sigma_{c}^{++}$ $\Sigma_{c}^{c}$			
VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
0.79±0.33 OUR FIT Error	includes scale factor	of 1.2.	
0.8 ±0.4 OUR AVERAGE	Error includes scale	e factor of 1.	2.
$1.1 \pm 0.4 \pm 0.1$	CRAWFORD	93 CLEO	$e^+e^-pprox\varUpsilon$ (45)
$-$ 0.1 $\pm$ 0.6 $\pm$ 0.1	BOWCOCK	89 CLEO	$e^+e^-$ 10 GeV
$+$ 1.2 $\pm$ 0.7 $\pm$ 0.3	ALBRECHT	88D ARG	$e^+e^-\sim~$ 10 GeV
• • • We do not use the follow	ing data for average	s, fits, limits	, etc. • • •
-10.8 ±2.9	⁴ DIESBURG	87 SPEC	$nA\sim 600~{ m GeV}$

 4  DIESBURG 87 is completely incompatible with the other experiments, which is surprising since it agrees with them about  $m_{\sum_{\mathcal{C}}(2455)^{++}}-m_{\Lambda_{\mathcal{C}}^+}$ . We go with the majority here.

$m_{\Sigma_c^+} - m_{\Sigma_c^0}$			
VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
1.4±0.6 OUR FIT			
$1.4 \pm 0.5 \pm 0.3$	CRAWFORD 9	3 CLEO	$e^+e^-pprox \Upsilon$ (45)

#### $\Sigma_c$ (2455) DECAY MODES

 $\Lambda_{C}^{+}\pi$  is the only strong decay allowed to a  $\Sigma_{C}$  having this mass.

Mod	e	Fraction $(\Gamma_i/\Gamma)$
$\Gamma_1 \qquad \Lambda_c^+ \approx$	т	≈ 100 %

### $\Sigma_c$ (2455) REFERENCES

FRABETTI CRAWFORD ANJOS	96 93 89D	PL B365 461 PRL 71 3259 PRL 62 1721	+Cheung, Cumalat+ (FNAL E687 Collab.) +Daubenmier, Fulton+ (CLEO Collab.) +Appel, Bean, Bracker, Browder+ (FNAL E691 Collab.)	
BOWCOCK	89	PRL 62 1240	+Kinoshita, Pipkin, Procario, Wilson+ (CLEO Collab.)	
ALBRECHT	88D	PL B211 489	+Boeckmann, Glaeser+ (ARGUS Collab.)	
DIESBURG	87	PRL 59 2711	+Ladbury, Binkley+ (FNAL E400 Collab.)	
JONES	87	ZPHY C36 593	+Jones, Kennedy, O'Neale+ (CERN WA21 Collab.)	
AMMAR	86	JETPL 43 515	+Ammosov, Bakic, Baranov, Burnett+ (ITEP)	
		Translated from ZETF		
ADAMOVICH	84	PL 140B 119	+Alexandrov, Bolta, Bravo+ (CERN WA58 Collab.)	
BOSETTI	82	PL 109B 234	+Graessler+ (AACH3, BONN, CERN, MPIM, OXF)	
CALICCHIO	80	PL 93B 521	+ (BARI, BIRM, BRUX, CERN, EPOL, RHEL+)	
BALTAY	79	PRL 42 1721	+Caroumbalis, French, Hibbs+ (COLU, BNL) I	
BARISH	77B	PR D15 1	+Derrick, Dombeck, Musgrave+ (ANL, PURD)	
KNAPP	76	PRL 37 882	+Lee, Leung, Smith+ (COLU, HAWA, ILL, FNAL)	
CAZZOLI	75	PRL 34 1125	+Cnops, Connolly, Louttit, Murtagh+ (BNL)	

 $\Sigma_c(2530)$ 

ı

89 CLEO ++  $e^+e^-$  10 GeV 88D ARG ++  $e^+e^-$  10 GeV

87 SPEC ++  $nA \sim 600 \; \text{GeV}$ 

Status: *

OMITTED FROM SUMMARY TABLE

#### $\Sigma_c(2530)$ MASSES

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT	
2530±5±5	6	¹ AMMOSOV	93	HLBC	$\nu p \rightarrow$	$\mu^- \Sigma_c(2530)^{++}$
¹ AMMOSOV 93 sees	a cluster	of 6 events and es	timate	es the b	ackgrou	ind to be 1 event.

### $\Sigma_c$ (2530) REFERENCES

93 JETPL 58 247 +Vasil'ev, Ivanilov, Ivanov+ Translated from ZETFP 58 241. (SERP)



 $I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$  Status: ***

According to the quark model, the  $\Xi_c^+$  (quark content usc) and  $\equiv_{c}^{0}$  form an isospin doublet, and the spin-parity ought to be  $J^{P}$ 1/2+. None of I, J, or P has actually been measured.

### $\equiv_c^+$ MASS

The fit uses the  $\Xi_c^+$  and  $\Xi_c^0$  mass and mass-difference measurements.

VALUE (MeV)	EVTS	DOCUMENT ID		ECN	COMMENT
2465.6± 1.4 OUR FIT 2465.9± 1.4 OUR AVE	RAGE				
2467.0± 1.6± 2.0	147	EDWARDS	96 C	LEO	$e^+e^-pprox \gamma$ (45)
$2464.4 \pm \ 2.0 \pm \ 1.4$	30	FRABETTI	93B E	687	$\gamma$ Be, $\overline{E}_{\gamma} =$ 220 GeV
2465.1 ± 3.6 ± 1.9	30	ALBRECHT	90F A	RG	$e^+e^-$ at $\Upsilon(4S)$
2467 ± 3 ± 4	23	ALAM	89 C	LEO	e ⁺ e ⁻ 10.6 GeV
2466.5± 2.7± 1.2	5	BARLAG	89c A	CCM	$\pi^-$ Cu 230 GeV
• • We do not use the	e following	g data for average:	s, fits, I	limits,	etc. • • •
2459 ± 5 ±30	56	¹ COTEUS	87 S	PEC	nA ≃ 600 GeV
2460 ±25	82	BIAGI	83 S	PEC	Σ – Be 135 GeV

 1  Although COTEUS 87 claims to agree well with BIAGI 83 on the mass and width, there appears to be a discrepancy between the two experiments. BIAGI 83 sees a single peak (stated significance about 6 standard deviations) in the  $^{\prime}$  Kr $^{\prime}$   $^{\prime}$   $^{\prime}$  mass spectrum. COTEUS 87 sees  $\it two$  peaks in the same spectrum, one at the  $\it \Xi ^+_{\it c}$  mass, the other 75 MeV lower. The latter is attributed to  $\Xi_c^+ \to \Sigma^0 K^- \pi^+ \pi^+ \to (\Lambda \gamma) K^- \pi^+ \pi^+$ , with the  $\gamma$  unseen. The *combined* significance of the double peak is stated to be 5.5 standard deviations. But the absence of any trace of a lower peak in BIAGI 83 seems to us to throw into question the interpretation of the lower peak of COTEUS 87.

### E MEAN LIFE

VALUE (10 ⁻¹² s)	EVTS	DOCUMENT ID	TECN	COMMENT
0.35 +0.07 OUR AVERA	<b>IGE</b>			
$0.41^{+0.11}_{-0.08}{\pm}0.02$	30	FRABETTI	93B E687	$\gamma$ Be, $\overline{\it E}_{\gamma} =$ 220 GeV
$0.20  {}^{+ 0.11}_{- 0.06}$	6	BARLAG	89C ACCM	$\pi^-$ ( $K^-$ ) Cu 230 GeV
$0.40^{+0.18}_{-0.12}{\pm}0.10$	102	COTEUS	87 SPEC	$nA \simeq 600 \text{ GeV}$
$0.48 ^{+ 0.21}_{- 0.15} ^{+ 0.20}_{- 0.10}$	53	BIAGI	85c SPEC	$\Sigma^-$ Be 135 GeV

³ See the note on DIESBURG 87 in the  $m_{\Sigma_c^{++}} - m_{\Sigma_c^0}$  section below.

 $\Xi_{c}^{+},\Xi_{c}^{0}$ 

2.34±0.57±0.37

<u> </u>	, — c						
$\Xi_c^+$ DECAY MODES							
	Mode			Fraction (F	_i /Γ)		
Γ ₁	$\Lambda K^- \pi^+ \pi^+$			seen			
$\Gamma_2$	$\Lambda \overline{K}^{*}(892)$			not seen			
Γ3	$\Sigma (1385)^{+} \\ \Sigma^{+} K^{-} \pi^{+}$	$K^-\pi^+$		not seen			
Γ ₄ Γ ₅	$\Sigma^+ \overline{K}^*$ (89	2)0		seen seen			
Γ ₆	$\Sigma^0 K^- \pi^+ \pi^+$			seen			
Γ7	$\equiv^0 \pi^+$			seen			
Γ8	$\Xi^{-}\pi^{+}\pi^{+}$	_+		seen			
Γ ₉ Γ ₁₀	$\Xi(1530)^{0}$ $\Xi^{0} \pi^{+} \pi^{0}$	Τ'		not seen seen			
Γ ₁₁	$=0^{10}\pi^{+}\pi^{+}\pi^{-}$			seen			
$\Gamma_{12}$	$\Xi^0 e^+ \nu_e$			seen			
		<b>=</b> +	BRANCHING	RATIOS			
Γ(Λ	√-π+π+)/Γ _t	otal			Γ ₁ /Γ		
VALUE		<u>EVTS</u>	DOCUMENT ID		COMMENT		
seen seen		56 82	COTEUS ² BIAGI	87 SPEC 83 SPEC			
	IAGI 85B looks				$-\overline{\kappa}^0\pi^+ (\Gamma(\rho\kappa^-\overline{\kappa}^0\pi^+)$		
/	$\Gamma(\Lambda K^- \pi^+ \pi^+)$	<0.08 with	90% CL), $p2K^-$ $\Lambda K^{*0}\pi^+$ , and	$2\pi^+$ ( $\Gamma(p2h)$	$(-2\pi^{+}) / \Gamma(\Lambda K^{-} \pi^{+} \pi^{+})$		
Г(ЛА	(-π+π+)/Γ(	$=-\pi^+\pi^+$	-)		$\Gamma_1/\Gamma_8$		
VALUE	/ ' '	EVTS	DOCUMENT ID	TECN	COMMENT		
0.58±	0.16±0.07	61	BERGFELD	96 CLEO	$e^+e^-\approx \Upsilon(45)$		
Γ(Λ7	<b>(892)</b> π+)/ Unseen decay m		$+\pi^+$ ) $\overline{K}^*$ (892) 0 are in	cluded.	$\Gamma_2/\Gamma_1$		
VALUE		<u>CL%</u>	DOCUMENT ID	TECN			
<0.5		90	BERGFELD	96 CLEO	$e^+e^-\approx \Upsilon(4S)$		
Γ(Σ(	<b>(1385)⁺ Κ⁻ π</b> ⁺ Unseen decay m		$-\pi^+\pi^+)$ $\Sigma$ (1385) $^+$ are in	cluded.	Γ ₃ /Γ ₁		
<u>∨ALUE</u> <b>&lt;0.7</b>		<u>CL%</u> 90	DOCUMENT ID BERGFELD		$e^+e^-\approx \Upsilon(45)$		
				30 CLEO			
	+ <b>κ</b> -π+)/Γ(Ξ			TECN	Γ ₄ /Γ ₈		
VALUE 1.18+	0.26±0.17	EVTS 119	DOCUMENT ID BERGFELD		$e^+e^-\approx \Upsilon(45)$		
			g data for averag				
0.09	0.13 + 0.03 0.06 - 0.02	5	BARLAG	89c ACCM	1 2 $\Sigma^{+} K^{-} \pi^{+}$ , 3 $\Xi^{-} \pi^{+} \pi^{+}$		
Γ(Σ	+ <del>K</del> *(892) ⁰ )/ſ	_(Ξ-π+π	·+)		Γ ₅ /Γ ₈		
•	Unseen decay m	odes of the	$\overline{K}^*(892)^0$ are in				
VALUE 0.92 1	0.27±0.14	<u>EVTS</u> 61	DOCUMENT ID BERGFELD		$e^+e^-\approx \Upsilon(45)$		
			g data for averag		. ,		
seen		59	AVERY	95 CLEO	$e^+e^- \approx r$ (4S)		
Γ(Σ	$(K^-\pi^+\pi^+)/[$	-(ΛK-π+	$\pi^{+}$ )		$\Gamma_6/\Gamma_1$		
VALUE 0.84 ±		<u>EVTS</u> 47	3 COTEUS	97 SPEC	nA ≃ 600 GeV		
			COTEUS 87 = +				
	$(2\pi^+)/\Gamma(\Xi^-\pi^-)$		00 1200 01 = c		Γ ₇ /Γ ₈		
VALUE		EVTS	DOCUMENT ID	TECN	COMMENT		
0.55±	0.13±0.09	39	EDWARDS	96 CLEO	$e^+e^-\approx \Upsilon(4S)$		
Γ(Ξ ⁻	$\pi^+\pi^+)/\Gamma_{\text{tot}}$	al _ <u>EVTS</u>	DOCUMENT ID	TECN	<b>Г₈/Г</b> СОММЕ <b>N</b> Т		
seen		131	BERGFELD		$e^+e^-\approx \Upsilon(4S)$		
seen		160	AVERY	95 CLEO	$e^+e^-\approx \Upsilon(45)$		
seen seen		30 30	FRABETTI ALBRECHT	90F ARG	$\gamma$ Be, $\overline{E}_{\gamma} = 220$ GeV $e^+e^-$ at $\Upsilon(4S)$		
seen		23	ALAM		e ⁺ e ⁻ 10.6 GeV		
Г(Ξ(	$\Gamma(\Xi(1530)^0\pi^+)/\Gamma(\Xi^-\pi^+\pi^+)$ Unseen decay modes of the $\Xi(1530)^0$ are included.						
VALUE		<u>CL%</u>	DOCUMENT ID		COMMENT		
<0.2		90			$e^+e^-\approx \Upsilon(4S)$		
Γ( <i>Ξ</i> ⁰	$^0\pi^+\pi^0)/\Gamma(\Xi^-$	$-\pi^{+}\pi^{+}$ )			$\Gamma_{10}/\Gamma_{8}$		
VALUE		EVTS	DOCUMENT ID	TECN			

EDWARDS 96 CLEO  $e^+e^- \approx \Upsilon(4S)$ 

$\Gamma(\Xi(1530)^0\pi^+)$	′Γ( <i>Ξ</i> ⁰ π ⁺ π ⁰ )	ı				$\Gamma_9/\Gamma_{10}$
VALUE	CL%	DOCUMENT ID		TECN	COMMENT	
<0.3	90	EDWARDS	96	CLEO	$e^+e^-pprox$	<b>Y</b> (45)
$\Gamma(\Xi^0\pi^+\pi^+\pi^-)/\Gamma(\Xi^-\pi^+\pi^+)$ $\Gamma_{11}/\Gamma_8$						$\Gamma_{11}/\Gamma_{8}$
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT	
$1.74 \pm 0.42 \pm 0.27$	57	EDWARDS	96	CLEO	$e^+e^-\approx$	Y(45)
$\Gamma(\Xi^0 e^+ \nu_e) / \Gamma(\Xi^- \pi^+ \pi^+)$ $\Gamma_{12} / \Gamma_8$						
VALUE	EVTS	DOCUMENT ID		TECN_	COMMENT	
$2.3\pm0.6^{+0.3}_{-0.6}$	41	ALEXANDER	95B	CLEO	e+e-≈ 1	r(45)

#### $\Xi_c^+$ REFERENCES

BERGFELD	96	PL B365 431	+Eisenstein, Ernst+	(CLEO	Collab.)
EDWARDS	96	PL B373 261	+McLean, Ogg+	(CLEO	Collab.)
ALEXANDER	95B	PRL 74 3113	+Bebek, Berkelman+	(CLEO	Collab.)
Also	95E	PRL 75 4155 (erratum)		,	,
AVERY	95	PRL 75 4364	+Freyberger, Lingel+	(CLEO	Collab.)
FRABETTI	93B	PRL 70 1381	+Cheung, Cumalat+	(FNAL E687	
ALBRECHT	90F	PL B247 121	+Ehrlichmann, Harder, Kruger, Nau+	` (ARGUS	Collab.)
ALAM	89	PL B226 401	+Katayama, Kim, Li, Lou, Sun+	CLEO	Collab.)
BARLAG	89C	PL B233 522	+Boehringer, Bosman+	(ACCMOR	Collab.)
COTEUS	87	PRL 59 1530	+Binklev+	(FNAL E400	
BIAGI	85B	ZPHY C28 175	+Bourguin, Britten+	(ČERN WA62	
BIAGI	85C	PL 150B 230	+Bourguin, Britten+	(CERN WA62	
BIAGI	83	PL 122B 455	+Bourguin, Britten+	(CERN WA62	
			the state of the s	,	



$$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$$
 Status: ***

I

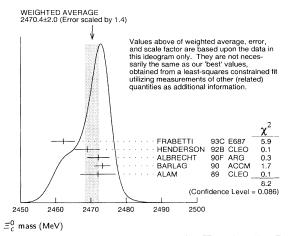
According to the quark model, the  $\Xi_c^0$  (quark content dsc) and  $\Xi_c^+$  form an isospin doublet, and the spin-parity ought to be  $J^P=1/2^+$ . None of I, J, or P has actually been measured.

#### $\Xi_c^0$ MASS

The fit uses the  $\Xi_{\mathcal{C}}^0$  and  $\Xi_{\mathcal{C}}^+$  mass and mass-difference measurements.

VALUE (MeV)		DOCUMENT ID		COMMENT
2470.3±1.8 OUR FIT	Error incl	udes scale factor o	f 1.3.	
2470.4±2.0 OUR AVE	RAGE Er	ror includes scale f	actor of 1.4	I. See the ideogram below.
$2462.1 \pm 3.1 \pm 1.4$	42	¹ FRABETTI	93C E687	$\gamma$ Be, $\overline{E}_{\gamma} =$ 220 GeV
2469 ±2 ±3	9	HENDERSON	92B CLEC	$\Omega^- K^+$
$2472.1 \pm 2.7 \pm 1.6$	54	ALBRECHT	90F ARG	$e^+e^-$ at $\varUpsilon$ (4 $S$ )
$2473.3 \pm 1.9 \pm 1.2$	4			$M$ $\pi^ (K^-)$ Cu 230 GeV
2472 $\pm 3$ $\pm 4$	19	ALAM	89 CLE	e ⁺ e ⁻ 10.6 GeV
	he followin	g data for averages	s, fits, limit	s, etc. • • •
2471 $\pm 3 \pm 4$	14	AVERY	89 CLE	See ALAM 89

 $^{1}\,\mbox{The}$  FRABETTI 93C mass is well below the other measurements.



 $m_{=0} - m_{=+}$ 

		-c -c		
VALUE (MeV)		CUMENT ID	TECN	COMMENT
4.7±2.1 OUR FIT	Error includes sca	ale factor of 1.2	2.	
6.3 ± 2.3 OUR AVE	RAGE			
$+7.0\pm4.5\pm2.2$	AL	BRECHT 90	OF ARG	$e^+e^-$ at $\varUpsilon$ (45)
$+6.8\pm3.3\pm0.5$	BA			$\pi^-$ ( $K^-$ ) Cu 230 GeV
$+5$ $\pm 4$ $\pm 1$	AL	AM 8	9 CLEO	$\Xi_c^0 \rightarrow \Xi^-\pi^+, \Xi_c^+ \rightarrow$
				$\Xi^-\pi^+\pi^+$

 $\Xi_{c}^{0}$ ,  $\Xi_{c}(2645)$ ,  $\Omega_{c}^{0}$ 

Ξ° MEAN LIFE							
VALUE (10 ⁻¹² s)	EVTS	DOCUMENT ID	TECN	COMMENT			
0.098+0.023 OUR AV	ERAGE						
$0.101^{+0.025}_{-0.017}{\pm}0.005$	42	FRABETTI	93c E687	$\gamma$ Be, $\overline{\it E}_{\gamma} =$ 220 GeV			
$0.082^{+0.059}_{-0.030}$	4	BARLAG	90 ACCM	$\pi^-$ ( $K^-$ ) Cu 230 GeV			

#### **≡**⁰ DECAY MODES

	Mode	Fraction $(\Gamma_i/\Gamma)$
Γ ₁	$\Lambda \overline{K}^0$	seen
$\Gamma_2$	$\equiv^-\pi^+$	seen
$\Gamma_3$	$\Xi^{-}\pi^{+}\pi^{+}\pi^{-}$	seen
$\Gamma_4$	p K [−] <del>K</del> *(892) ⁰	seen
$\Gamma_5$	$\Omega^-K^+$	seen
	$\Xi^-e^+\nu_e$	seen
Γ ₇	$\Xi^-\ell^+$ anything	seen

#### **≡**⁰_c BRANCHING RATIOS

	-					
$\Gamma(\Lambda \overline{K}^0)/\Gamma_{\text{total}}$						$\Gamma_1/\Gamma$
VALUE	<u>EVTS</u>	DOCUMENT ID		TECN	COMMENT	
seen	7	ALBRECHT	95B	ARG	$e^+e^-\approx 10.4$ G	ieV
$\Gamma(\Xi^-\pi^+)/\Gamma(\Xi^-\pi^-)$	$^{+}\pi^{+}\pi^{-})$					$\Gamma_2/\Gamma_3$
VALUE		DOCUMENT ID		<u>TECN</u>	COMMENT	
$0.30 \pm 0.12 \pm 0.05$		ALBRECHT	90F	ARG	$e^+e^-$ at $\Upsilon(4S)$	)
Γ(pK-\(\overline{K}\)*(892) ⁰ ),	/Γ _{total}	B 0 0 11 15 15 15				$\Gamma_4/\Gamma$
VALUE		DOCUMENT ID		TECN	COMMENT	
seen		BARLAG	90	ACCM	$\pi^-$ ( $K^-$ ) Cu 23	0 GeV
$\Gamma(\Omega^-K^+)/\Gamma(\Xi^-\pi$						$\Gamma_5/\Gamma_2$
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT	
$0.50 \pm 0.21 \pm 0.05$	9	HENDERSON	92B	CLEO	$e^+e^-pprox 10.6 \ \mathrm{G}$	eV
$\Gamma(\Xi^-e^+ u_e)/\Gamma(\Xi^-$	$^{-}\pi^{+})$					$\Gamma_6/\Gamma_2$
	EVTS	DOCUMENT ID		TECN	COMMENT	
$3.1\pm1.0^{+0.3}_{-0.5}$	54	ALEXANDER	<b>95</b> B	CLEO	$e^+e^-{pprox} \Upsilon(4S)$	
$\Gamma(\Xi^-\ell^+ \text{ anything})$	/Γ(Ξ ⁻ π ⁺ )	)				$\Gamma_7/\Gamma_2$
The ratio is for ti	he <i>average</i> (r	ot the sum) of th	e <i>Ξ</i> –	e ⁺ any	thing and $\Xi^-\mu^+$	anything
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT	
$0.96 \pm 0.43 \pm 0.18$	18	ALBRECHT	93B	ARG	$e^+e^-pprox$ 10.4 G	eV
$\Gamma(\Xi^-\ell^+ \text{ anything})$	/Γ(Ξ ⁻ π ⁺ :	$\pi^{+}\pi^{-}$ )				$\Gamma_7/\Gamma_3$

#### $\equiv_c^0$ REFERENCES

DOCUMENT ID

**EVTS** 

modes.

 $0.29 \pm 0.12 \pm 0.04$ 

VALUE

The ratio is for the  $\it average$  (not the sum) of the  $\it \Xi^-e^+$  anything and  $\it \Xi^-\mu^+$  anything

TECN COMMENT

ALBRECHT 93B ARG  $e^+\,e^-pprox$  10.4 GeV

ALBRECHT ALEXANDER Also	95B 95B 95E	PL B342 397 PRL 74 3113 PRL 75 4155		(ARGUS (CLEO	Collab.) Collab.)
ALBRECHT FRABETTI		PL B303 368 PRL 70 2058	+Cronstroem, Ehrlichmann+ +Cheung, Cumalat+	(ARGUS (FNAL E687	
HENDERSON	92B	PL B283 161	+Kinoshita, Pipkin, Saulnier+	` (CLEO	Collab.)
ALBRECHT BARLAG	90F 90	PL B247 121 PL B236 495	+Ehrlichmann, Harder, Kruger, Nau+ +Becker, Boehringer, Bosman+	(ARGUS (ACCMOR	
ALAM AVERY	89 89	PL B226 401 PRL 62 863	+Katayama, Kim, Li, Lou, Sun+ +Besson, Garren, Yelton, Bowcock+		Collab.) Collab.)

# $\Xi_c(\overline{2645})$

 $I(J^P) = ?(?^?)$  Status: ***

A narrow peak seen in the  $\Xi_c^+\pi^-$  mass spectrum. The natural assignment is that this is the  $J^P=3/2^+$  excitation of the  $\Xi_c$  in the same SU(4) multiplet as the  $\Delta$ (1232). We advance this to the Summary Table since it has also been seen by CLEO in  $\Xi_c^0 \pi^+$ (CLNS 96/1394, submitted but not yet approved, so not reported

#### *Ξ_c*(2645) MASS

VALUE (MeV) DOCUMENT ID 2643.8±1.8 OUR FIT

#### $m_{\Xi_c(2645)^0} - m_{\Xi_c^+}$

VALUE (MeV) DOCUMENT ID TECN COMMENT 178.2±1.1 OUR FIT 178.2±0.5±1.0 **AVERY** 95 CLEO  $e^+e^-\approx \Upsilon(4S)$ 

#### $\Xi_c(2645)$ WIDTH

DOCUMENT ID VALUE (MeV) CL% EVTS TECN CHG COMMENT <5.5 90 55 **AVERY** 95 CLEO 0  $e^+e^-pprox \ \varUpsilon(45)$ 

#### $\equiv_c$ (2645) DECAY MODES

 $\Xi_{\mathcal{C}} \pi$  is the only strong decay allowed to a  $\Xi_{\mathcal{C}}$  resonance having this mass.

	Mode	Fraction $(\Gamma_i/\Gamma)$
$\Gamma_1$	$\Xi_{\epsilon}^{+}\pi^{-}$	seen

#### $\Xi_c$ (2645) BRANCHING RATIOS

$\Gamma(\Xi_c^+\pi^-)/\Gamma_{\text{total}}$						$\Gamma_1/\Gamma$
VALUE	EVTS	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
seen	55	AVERY	95	CLEO	0	$e^+e^-pprox ~ \Upsilon(45)$

 $\Xi_c(2645)$  REFERENCES

+Freyberger, Lingel+ AVERY 95 PRL 75 4364

(CLEO Collab.)



$$I(J^P) = O(\frac{1}{2}^+)$$
 Status: ***

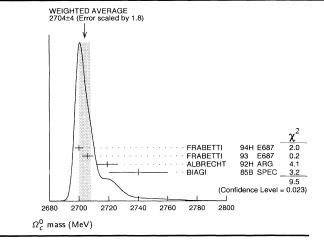
The quantum numbers have not been measured, but are simply assigned in accord with the quark model, in which the  $arOmega_c^0$  is the ssc ground state.

#### $\Omega_c^0$ MASS

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
2704 ± 4 OUR AV	ERAGE	Error includes scale	factor of 1.8	. See the ideogram below.
$2699.9 \pm 1.5 \pm 2.5$	42	¹ FRABETTI	94H E687	$\gamma$ Be, $\overline{E}_{\gamma} =$ 221 GeV
$2705.9 \pm 3.3 \pm 2.0$	10	² FRABETTI	93 E687	$\gamma$ Be, $\overline{E}_{\gamma}^{'}=$ 221 GeV
$2719.0 \pm\ 7.0 \pm 2.5$	11	³ ALBRECHT	92H ARG	$e^+e^-pprox$ 10.6 GeV
$2740 \pm 20$	3	BIAGI	85B SPEC	$\Sigma^-$ Be 135 GeV/ $c$

- 1  FRABETTI 94H claims a signal of 42.5  $\pm$  8.8  $\Sigma^{+}$   $K^{-}$   $K^{-}$   $\pi^{+}$  events. The background
- is about 24 events.  2  FRABETTI 93 claims a signal of 10.3  $\pm$  3.9  $\varOmega^-\pi^+$  events above a background of 5.8 events.  3  ALBRECHT 92H claims a signal of 11.5  $\pm$  4.3  $\it \Xi^- K^- \pi^+ \pi^+$  events. The background

 $\Omega_c^0$ 



#### Ω0 MEAN LIFE

VALUE (10 ⁻¹² s) 0.064±0.020 OUR AVE	EVTS ERAGE	DOCUMENT ID	TECN	COMMENT	_
$0.055 + 0.013 + 0.018 \\ -0.011 - 0.023$	86	ADAMOVICH	95B WA89	$\Omega^{-}\pi^{-}\pi^{+}\pi^{+},$ =- $K^{-}\pi^{+}\pi^{+}$	I
$0.086 ^{+ 0.027}_{- 0.020} \pm 0.028$	25	FRABETTI	95D E687	$\Sigma^+ \kappa^- \kappa^- \pi^+$	I

#### $\Omega_c^0$ DECAY MODES

	Mode	Fraction $(\Gamma_{\hat{I}}/\Gamma)$
Γ ₁	$\Sigma^+ K^- K^- \pi^+$	seen
$\Gamma_2$	$\Xi^{-}K^{-}\pi^{+}\pi^{+}$	seen
Γ3	$\Omega^-\pi^+$	seen
Γ ₄	$\Omega^-\pi^-\pi^+\pi^+$	seen

#### $\Omega_c^0$ Branching ratios

I (Z · N	$K^-\pi$	+)/Γ _{total}					$\Gamma_1/\Gamma$
VALUE		EVTS	DOCUMENT ID		TECN	COMMENT	
seen		42	FRABETTI	94H	E687	$\gamma$ Be, $\overline{E}_{\gamma} = 221$	GeV
Γ( <i>Ξ</i> − <i>K</i> −	$\pi^+\pi^+$	⊢)/Γ _{total}					$\Gamma_2/\Gamma$
VALUE		EVTS	DOCUMENT ID		TECN	COMMENT	
seen		11	ALBRECHT	92H	ARG	$e^+e^-\approx$ 10.6 Ge	٠V
seen		3	BIAGI	8 <b>5</b> B	SPEC	$\Sigma^-$ Be 135 GeV	/c
$\Gamma(\Omega^-\pi^+)$	/Γ _{tota}	al					Г ₃ /Г
VALUE		EVTS	DOCUMENT ID		TECN	COMMENT	
seen		10	FRABETTI	93	E687	$\gamma$ Be, $\overline{E}_{\gamma} =$ 221	GeV
Γ(Ξ- <i>K</i> -	$\pi^+\pi^+$	⁺ )/Γ(Ω ⁻ π ⁺ )	)				$\Gamma_2/\Gamma_3$
VALUE		CL%	DOCUMENT ID		TECN	COMMENT	
• • • We d	o not i	use the following	g data for average	s, fits	, limits,	etc. • • •	
<2.8		90	FRABETTI	93	E687	$\gamma$ Be, $\overline{\it E}_{\gamma} =$ 221	GeV
	1. 4.	·) /[(O=#+)					$\Gamma_4/\Gamma_3$
$\Gamma(\Omega^-\pi^-)$	$\pi^+\pi^-$	// (aa n /					
Γ(Ω¯π¯: VALUE		<u>CL%</u>	DOCUMENT ID		TECN	COMMENT	
•			DOCUMENT ID ADAMOVICH	95B		Σ ⁻ 340 GeV	
VALUE Seen		<u>CL%</u>			WA89	Σ ⁻ 340 GeV	
VALUE Seen		<u>CL%</u>	ADAMOVICH	s, fits	WA89 , limits,	Σ ⁻ 340 GeV	GeV
seen • • • We d		CL% use the following	ADAMOVICH g data for average FRABETTI	s, fits 93	WA89 , limits,	Σ ⁻ 340 GeV etc. • •	GeV
seen • • • We d		CL% use the following	ADAMOVICH g data for average FRABETTI  Ω ⁰ REFEREN	93 CES	WA89 , limits, E687	$\Sigma^-$ 340 GeV etc. • • • $\gamma$ Be, $\overline{E}_{\gamma} = 221$	
Seen  • • • We d  <1.6	o not i	CL% use the following 90 PL B358 151	ADAMOVICH g data for average FRABETTI	93 CES	WA89 , limits, E687	$\overline{\Sigma}^-$ 340 GeV etc. • • • $\gamma$ Be, $\overline{E}_{\gamma} = 221$	ollab.)
seen • • • We d	95B   95D	CL% use the following 90	ADAMOVICH g data for average FRABETTI	es, fits 93 CES androv lat+	WA89 , limits, E687	$\Sigma^-$ 340 GeV etc. • • • $\gamma$ Be, $\overline{E}_{\gamma}$ = 221 (CERN WA89 C (FNAL E687 C (FNAL E687 C	ollab.)
Seen  • • • We d  <1.6  ADAMOVICH FRABETTI	95B   95D   95H   93	CL% use the following 90 PL B358 151 PL B357 678	ADAMOVICH g data for average FRABETTI	es, fits 93 CES androv lat+ lat+ lat, Da	WA89  Imits, E687	$\Sigma^-$ 340 GeV etc. • • • • $\gamma$ Be, $\overline{E}_{\gamma} = 221$ (CERN WA89 C (FNAL E687 C (FNAL E687 C (FNAL E687 C)	ollab.) ollab.) ollab.) ollab.)

### **BOTTOM (BEAUTY) BARYONS** (B=-1)

 $\Lambda_{b}^{0} = u d b, \, \Xi_{b}^{0} = u s b, \, \Xi_{b}^{-} = d s b$ 

$$I(J^P) = O(\frac{1}{2}^+)$$
 Status: ***

In the quark model, a  $\Lambda_b^0$  is an isospin-0 udb state. The lowest  $\Lambda_b^0$ ought to have  $J^P = 1/2^+$ . None of I, J, or P have actually been

$\Lambda_P^b$	MASS
---------------	------

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
5641 ± 50 OUR A	/ERAGE				
$5640 \pm 50 \pm 30$	16	$^{ m 1}$ ALBAJAR	91E	UA1	ρ <del>p</del> 630 GeV
$5640 + 100 \\ -210$	52	BARI	91	SFM	$\Lambda_b^0 \rightarrow \rho D^0 \pi^-$
$5650 + 150 \\ -200$	90	BARI	91	SFM	$\Lambda_b^0 \rightarrow \Lambda_c^+ \pi^+ \pi^- \pi^-$
<ul> <li>● ● We do not use</li> </ul>	the following	g data for average	es, fits	, limits,	etc. • • •
not seen		² ABE			ρ p̄ 1.8 TeV
$\sim$ 5750	4	³ ARENTON	86	FMPS	$\Lambda K_{S}^{0} 2\pi^{+} 2\pi^{-}$
$5425 + 175 \\ -75$		4 BASILE	81	SFM	See BARI 91

 1  ALBAJAR 91E claims 16  $\pm$  5 events above a background of 9  $\pm$  1 events, a significance

Table Jan 18 to Earlins 1 as a svents above a background of 9  $\pm$  1 events, a significance of about 5 standard deviations. ABE 93B states that, based on the signal claimed by ALBAJAR 91E, CDF should have found 30  $\pm$  23  $\Lambda_D^0 \rightarrow J/\psi(1.5)\Lambda$  events. Instead, CDF found not more than 2 events. 3 The decay of the  $\Lambda_D^0$  to the final state observed by ARENTON 86 is Cabibbo suppressed,

whereas the decay of a  $\Xi_{b}^{0}$  to this final state is allowed. ARENTON 86 thus only claims to have observed a baryon which probably has a b quark and has a  $D^0$  among the decay products, not necessarily the  $\Lambda_b^0$ .

 4  The first claim to have discovered the  $\varLambda_b^0$  was reported by BASILE 81. In contrast, DRIJARD 82 reported no observation of  $\Lambda_b^0$ , and this led to some discussion in BASILE 82 and DRIJARD 82B. Further evidence for the  $\Lambda_b^0$  was again reported by the first authors in BARI 91 (see above) in a second, upgraded experiment where two different  $\Lambda_h^0$  decay

#### 18 MEAN LIFE

These are actually measurements of the average lifetime of weakly decaying  $\boldsymbol{b}$  baryons weighted by generally unknown production rates, branching fractions, and detection efficiencies. Presumably, the mix is mainly  $\Lambda_b^0$ with some  $\Xi_b^0$  and  $\Xi_b^-$ 

"OUR EVALUATION" is an average of the data listed below performed by the LEP  ${\cal B}$  Lifetimes Working Group as described in our review "Production and Decay of b-flavored Hadrons" in the  ${\cal B}^\pm$  Section of the Listings. The averaging procedure takes into account correlations between the measurements and asymmetric lifetime errors.

VALUE (10 ⁻¹² s)	EVTS	DOCUMENT ID		TECN	COMMENT
1.14±0.08 OUR EV	ALUATION				
$1.46 + 0.22 + 0.07 \\ -0.21 - 0.09$		ABREU	<b>96</b> D	DLPH	Excess $\Lambda \ell^- \pi^+$ , decay lengths
$1.10^{+0.19}_{-0.17} \pm 0.09$		ABREU	<b>96</b> D	DLPH	Excess $\Lambda\mu^-$ impact parameters
$1.19^{+0.21}_{-0.18}^{+0.07}_{-0.08}$		ABREU	96D	DLPH	Excess $\Lambda_C \ell^-$ , decay lengths
$1.15 \pm 0.12 \pm 0.06$		AKERS	96	OPAL	Excess Λℓ ⁻ , decay lengths
$1.21^{+0.15}_{-0.13}\pm0.10$		AKERS	96	OPAL	Excess $\Lambda \ell^-$ , impact parameters
$1.27^{+0.35}_{-0.29}\pm0.09$		ABREU	95s	DLPH	Excess $p\mu^-$ , decay lengths
$1.14^{+0.22}_{-0.19}\pm0.07$	69	AKERS	95K	OPAL	Excess $\Lambda_C \ell^-$ , decay lengths
$1.05^{+0.12}_{-0.11}\pm0.09$	290	BUSKULIC	95L	ALEP	Excess $\Lambda \ell^-$ , impact parameters
$1.02^{+0.23}_{-0.18}\pm0.06$	44	BUSKULIC	95L	ALEP	Excess $\Lambda_c \ell^-$ , decay lengths
<ul> <li>● ● We do not us</li> </ul>	e the following		es, fits	, limits,	etc. • • •
$1.25 \pm 0.11 \pm 0.05$		5 ABREU	96D	DLPH	Combined result
$1.16 \pm 0.11 \pm 0.06$		⁶ AKERS	96	OPAL	Combined result
$1.04^{+0.48}_{-0.38}\pm0.10$	11	⁷ ABREU	93F	DLPH	Excess $\Lambda \mu^-$ , decay lengths
$1.05^{+0.23}_{-0.20}{\pm}0.08$	157	⁸ AKERS	93	OPAL	Excess $\Lambda \ell^-$ , decay lengths
$1.12^{+0.32}_{-0.29}\pm0.16$	101	⁹ BUSKULIC	921	ALEP	Excess $\Lambda \ell^-$ , impact parameters

5 Combined result of the three ABREU 960 methods and ABREU 96. 6 Combined result of AKERS 96 impact parameter and decay length methods. 7 ABREU 937 superseded by ABREU 960. 8 AKERS 93 superseded by AKERS 96. 9 BUSKULIC 92

#### AD DECAY MODES

These branching fractions are actually an average over weakly decaying b-baryons weighted by their production rates in Z decay (or high-energy  $p\overline{p}$ ), branching ratios, and detection efficiencies. They scale with the LEP  $\Lambda_b$  production fraction B( $b \rightarrow \Lambda_b$ ) and are evaluated for our value B( $b \rightarrow$  $\Lambda_b^{-}$ ) = (13.2 ± 4.1)%.

The branching fractions B( $\varLambda_b^0 \to \Lambda \ell^- \overline{\nu}_\ell$  anything) and B( $\varLambda_b^0 \to$  $\Lambda_{c}^{+}\ell^{-}\overline{\nu}_{\ell}$  anything) are not pure measurements because the underlying measured products of these with B( $b\to\Lambda_b$ ) were used to determine B( $b\to\Lambda_b$ ), as described in the note "Production and Decay of b-Flavored

	Mode	Fraction $(\Gamma_i/\Gamma)$	
$\overline{\Gamma_1}$	$J/\psi(1S)\Lambda$	( 1.4 ± 0.9) %	
$\Gamma_2$	$\rho D^0 \pi^-$	seen	
Γ3	$\Lambda_{c}^{+} \pi^{+} \pi^{-} \pi^{-}$	seen	
Γ4	$\Lambda K^{0} 2\pi^{+} 2\pi^{-}$		
Γ ₅	$p\mu^-\overline{ u}$ anything	( 3.7± 1.7) %	
Γ ₆	$\Lambda \ell^- \overline{ u}_\ell$ anything	[a] $(2.5\pm0.5)\%$	
$\Gamma_7$	$arLambda_c^+ \ell^- \overline{ u}_\ell$ anything	[a] $(10.0 \pm 3.0) \%$	
Γ8	$\Lambda/\overline{\Lambda}$ anything	$(17 \begin{array}{cc} +11 \\ -8 \end{array}) \%$	

[a] Not a pure measurement. See note at head of  $\Lambda_b^0$  Decay Modes.

#### **1** BRANCHING RATIOS

$\Gamma(J/\psi(1S)\Lambda)/\Gamma_{\text{total}}$	I				$\Gamma_1/\Gamma$
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT	
$0.014 \pm 0.008 \pm 0.004$	16	¹⁰ ALBAJAR	91E UA1	$J/\psi(1S)  ightarrow$	$\mu^+\mu^-$
10					

 10  ALBAJAR 91E reports 0.018  $\pm$  0.011 for B(b  $\rightarrow$   $\varLambda_b)=$  0.10. We rescale to our best value B(b  $\rightarrow$   $\varLambda_b)=$  (13.2  $\pm$  4.1)  $\times$  10 $^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

$\Gamma(pD^0\pi^-)/\Gamma$	total					$\Gamma_2/\Gamma$
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT	
seen	52	BARI	91	SFM	$D^0 \rightarrow \kappa^- \pi^+$	
• • • We do n	ot use the following	data for average	s, fit	s, limits,	etc. • • •	
seen		BASILE	81	SFM	$D^0 \rightarrow K^-\pi^+$	
$\Gamma(\Lambda_c^+\pi^+\pi^-\tau)$	τ ⁻ )/Γ _{total}					$\Gamma_3/\Gamma$
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT	
seen	90	BARI	91	SFM	$\Lambda_c^+ \rightarrow p K^- \pi^+$	
Γ(Λ <b>Κ</b> ⁰ 2π ⁺ 2	$\pi^-)/\Gamma_{total}$					Γ4/Γ

VALUE EVTS DOCUMENT ID TECN COMMENT  $\bullet$   $\,\bullet\,$  We do not use the following data for averages, fits, limits, etc.  $\,\bullet\,$   $\,\bullet\,$ 4 11 ARENTON 86 FMPS  $\Lambda K_c^0 2\pi^+ 2\pi^-$ 

 $^{11}\mathrm{See}$  the footnote to the ARENTON 86 mass value.

#### $\Gamma(\rho\mu^{-}\overline{\nu}\text{anything})/\Gamma_{\text{total}}$ $\Gamma_5/\Gamma$ VALUE DOCUMENT ID TECN COMMENT EVTS $0.037^{+0.014}_{-0.012}\pm0.012$ ¹² ABREU 125 95S DLPH $e^+e^- \rightarrow Z$

 $^{12} \, {\rm ABREU}$  95s reports  $[{\rm B}(\Lambda_b^0 \ \rightarrow \ p \, \mu^- \, \overline{\nu} \, {\rm anything}) \, \times \, {\rm B}(b \ \rightarrow \ \Lambda_b)] \, = \, 0.0049 \, \pm$  $0.0011^{+0.0015}_{-0.0011}$ . We divide by our best value B( $b\to\Lambda_b$ ) =  $(13.2\pm4.1)\times10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

 $\Gamma(\Lambda \ell^- \overline{\nu}_{\ell} \text{ anything}) / \Gamma_{\text{total}}$ The values and averages in this section serve only to show what values result if one assumes our  $\mathsf{B}(b \to \Lambda_b)$ . They cannot be thought of as measurements since the underlying product branching fractions were also used to determinine  $\mathsf{B}(b \to \Lambda_b)$  as described in the note on "Production and Decay of b-Flavored Hadrons."

EVTS DOCUMENT ID TECN COMMENT

VALUE	EVIS	DOCUMENTIO	TECH	COMMENT
0.025 ± 0.005 OUR AV	ERAGE			
$0.022 \pm 0.003 \pm 0.007$		¹³ AKERS	96 OPA	L Excess of $\Lambda \ell^-$ over $\Lambda \ell^+$
$0.023 \pm 0.005 \pm 0.007$	262	¹⁴ ABREU	95s DLP	H Excess of $\Lambda \ell^-$ over $\Lambda \ell^+$
$0.046 \pm 0.009 \pm 0.014$	290	¹⁵ BUSKULIC	95L ALE	P Excess of $\Lambda \ell^-$ over $\Lambda \ell^+$
• • • We do not use t	he followi	ng data for average	es, fits, limi	ts, etc. • • •
seen	157	¹⁶ AKERS	93 OPA	L Excess of $\Lambda \ell^-$ over $\Lambda \ell^+$
$0.053 \pm 0.016 \pm 0.016$	101	¹⁷ BUSKULIC	92I ALEI	Excess of $\Lambda \ell^-$ over $\Lambda \ell^+$
¹³ AKERS 96 reports	$[B(\Lambda_b^0 \to$	$\Lambda\ell^-\overline{ u}_\ell$ anything)	$\times$ B( $b \rightarrow b$	$(a_b)$ ] = 0.00291 $\pm$ 0.00023 $\pm$
0.00025. We divide error is their experi	by our t ment's er	pest value B( $b  ightharpoonup$ ror and our second	$\Lambda_b$ ) = (13 error is the	$0.2\pm4.1)\times10^{-2}$ . Our first systematic error from using

14 ABREU 95s reports  $[B(\Lambda_b^0 \to \Lambda \ell^- \overline{\nu}_\ell \text{ anything}) \times B(b \to \Lambda_b)] = 0.0030 \pm 0.0006 \pm 0.0006$ 0.0004. We divide by our best value B( $b \rightarrow \Lambda_b$ ) = (13.2  $\pm$  4.1)  $\times$  10⁻². Our first error is their experiment's error and our second error is the systematic error from using our best value.

 $\Lambda_b^0$ ,  $\Xi_b^0$ ,  $\Xi_b^-$ 

 $^{15}\, {\rm BUSKULIC} \,\, 95L \,\, {\rm reports} \,\, [{\rm B}(\Lambda_b^0 \to \,\, \Lambda \ell^- \,\overline{\nu}_\ell \, {\rm anything}) \,\, \times \,\, {\rm B}(b \to \,\, \Lambda_b)] = 0.0061 \pm 0.0006 \pm \,\, 10^{-10} \,\, {\rm grade} \,\, {\rm g$ 0.0010. We divide by our best value  $B(b \to \Lambda_b) = (13.2 \pm 4.1) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

16 AKERS 93 superseded by AKERS 96.

¹⁷ BUSKULIC 92I reports [B( $\Lambda_b^0 \to \Lambda \ell^- \overline{\nu}_\ell$  anything)  $\times$  B( $b \to \Lambda_b$ )] = 0.0070  $\pm$  0.0010  $\pm$ 0.0018. We divide by our best value  $B(b \to \Lambda_b) = (13.2 \pm 4.1) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value. Superseded by BUSKULIC 95L.

 $\Gamma(\Lambda_c^+\ell^-\overline{\nu}_\ell \text{ anything})/\Gamma_{\text{total}}$ 

The values and averages in this section serve only to show what values result if one assumes our  $B(b \to \Lambda_b)$ . They cannot be thought of as measurements since the underlying product branching fractions were also used to determinine  $B(b \to \Lambda_b)$  as described in the note on "Production and Decay of b-Flavored Hadrons."

VALUE	EVIS	DOCUMENTID	IECN	COMMENT
0.100 ± 0.030 OUR AVER	RAGE			
$0.089^{+0.031}_{-0.025}\pm 0.028$	29	¹⁸ ABREU	95s DLPH	$e^+e^- \rightarrow Z$
$0.11 \pm 0.03 \pm 0.04$	55	¹⁹ BUSKULIC	95L ALEP	$e^+e^- \rightarrow Z$
• • • We do not use the	followi	ng data for average	s, fits, limits,	etc. • • •
$0.23\ \pm0.09\ \pm0.07$	21	²⁰ BUSKULIC	92E ALEP	$\Lambda_c^+ \rightarrow \rho K^- \pi^+$
¹⁸ ABREU 95s reports	$[B(\Lambda_b^0)]$	$\rightarrow \Lambda_c^+ \ell^- \overline{\nu}_\ell$ any	thing) × B(	$b \rightarrow \Lambda_b$ )] = 0.0118 ±
0.0026 + 0.0031 We	divide	by our best value	$B(b \rightarrow \Lambda_b)$	$= (13.2 \pm 4.1) \times 10^{-2}$

 $0.0025_{-0.0021}$ . We divide by our best value  $B(D\to R_B)=(13.2\pm4.1)\times 10^{-3}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value. ¹⁹ BUSKULIC 95L reports  $[B(\Lambda_b^0 \to \Lambda_c^+ \ell^- \overline{\nu}_\ell \text{ anything}) \times B(b \to \Lambda_b)] = 0.0151 \pm$ 

 $0.0029\pm0.0023$ . We divide by our best value B( $b\to \Lambda_b$ ) =  $(13.2\pm4.1)\times10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

Using our best value. 20 BUSKULIC 92E reports  $[B(\Lambda_b^0 \to \Lambda_c^+ \ell^- \overline{\nu}_\ell \text{anything}) \times B(b \to \Lambda_b)] = 0.030 \pm 0.007 \pm 0.009$ . We divide by our best value  $B(b \to \Lambda_b) = (13.2 \pm 4.1) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value. Superseded by BUSKULIC 95L.

$\Gamma(\Lambda/\overline{\Lambda}anything)/\Gamma_{total}$				Γ8,
VALUE	DOCUMENT ID	TECN	COMMENT	
$0.17^{+0.09}_{-0.06}\pm0.05$	²¹ ABREU	95c DLPH	$e^+e^-   o  Z$	

 21  ABREU 95C reports 0.28  $^{+0.17}_{-0.12}$  for B(  $b\to~\Lambda_b)=$  0.08  $\pm$  0.02. We rescale to our best value  $B(b \to \Lambda_b) = (13.2 \pm 4.1) \times 10^{-2}$ . Our first error is their experiment's error and our second error is the systematic error from using our best value.

#### **1**% REFERENCES

ABREU		ZPHY C (submitted)	+Adam, Adye, Agasi+	(DELPHI Collab.)
CERN-PP	E/96-2	1		
AKERS	96	ZPHY C69 195	+Alexander, Allison, Altekamp+	(OPAL Collab.)
ABREU	95C	PL B347 447	+Adam, Adye, Agasi+	(DELPHI Collab.)
ABREU	95S	ZPHY C68 375	+Adam, Adye, Agasi+	(DELPHI Collab.)
AKERS	95K	PL B353 402	+Alexander, Allison, Altekamp+	(OPAL Collab.)
BUSKULIC	95L	PL B357 685	+Casper, De Bonis, Decamp+	(ALEPH Collab.)
ABE	93B	PR D47 R2639	+Amidei, Anway-Wiese, Apollinari+	` (CDF Collab.)
ABREU	93F	PL B311 379	+Adam, Adye, Agasi+	(DELPHI Collab.)
AKERS	93	PL B316 435	+Alexander, Allison, Anderson+	(OPAL Collab.)
Also	92E	PL B281 394	Acton, Alexander, Allison, Allport+	(OPAL Collab.)
BUSKULIC	92E	PL B294 145	+Decamp, Gov. Lees, Minard+	(ALEPH Collab.)
BUSKULIC	921	PL B297 449	+Decamp, Goy, Lees+	(ALEPH Collab.)
Also	92D	PL B278 209	Decamp, Deschizeaux, Goy+	(ALEPH Collab.)
ALBAJAR	91E	PL B273 540	+Albrow, Allkofer, Ankoviak+	(UA1 Collab.)
BARI	91	NC 104A 1787	+Basile, Bruni, Cara Romeo+	
ARENTON	86	NP B274 707	+Chen, Cormell, Dieterle+	
BASILE	82	NC 68A 289	+Bonvicini, Romeo+	
DRUARD	82	PL 108B 361	+ (CERN, CDEF, DORT,	
DRIJARD	82B	CERN-EP/82-31	+ (CERN, CDEF, DORT,	
BASILE	81	LNC 31 97	+Bonvicini, Romeo+	
DAJILE	01	LINE SI M	Tourism, Romeot	(CEINT NATS CONSU.)



ABREU

95V ZPHY C68 541

 $I(J^P) = O(\frac{1}{2}^+)$  Status: *

OMITTED FROM SUMMARY TABLE

ABREU 95V observe an excess of same-sign  $\varXi^\mp\ell^\mp$  events in jets, which they interpret as  $\Xi_b \to \Xi^- \ell^- \overline{\nu}_\ell X$ . They find that the probability for these events to come from non-b-baryon decays is less than 5  $\times$  10  $^{-4}$  and that  $\varLambda_b$  decays can account for less than 10%

In the quark model,  $\Xi_b^0$  and  $\Xi_b^-$  are an isodoublet (usb, dsb) state; the lowest  $\Xi_b^0$  and  $\Xi_b^-$  ought to have  $J^P=1/2^+$ . None of I, J, or P have actually been measured.

#### Ξ_b MEAN LIFE

This is actually a measurement of the average lifetime of b-baryons that decay to a jet containing a same-sign  $\varXi^\mp\ell^\mp$  pair. Presumably the mix is mainly  $\Xi_b$ , with some  $\Lambda_b$ .

VALUE (10 ⁻¹² s)	EVTS	DOCUMENT ID	TECN	COMMENT
$1.5^{+0.7}_{-0.4}\pm0.3$	8	ABREU	95V DLPH	Excess $\Xi^-\ell^-$ , decay lengths

#### **E**_b DECAY MODES

	Mode	Fraction $(\Gamma_j/\Gamma)$
Γ ₁	$ar{arxi}^+\ell^+\overline{ u}_\ell$ anything	seen

#### **≡**_b BRANCHING RATIOS

$\Gamma(\Xi^+\ell^+\overline{\nu}_\ell \text{ anything})/\Gamma_{\text{total}}$ NALUE  seen	DOCUMENT ID	95V DLPH	$\frac{COMMENT}{E\times cess} = -\ell^{-}$ $= -\ell^{+}$	over
	Ξ _b REFEREN			

+Adam, Adye, Agasi+

(DELPHI Collab.)

#### **SEARCHES***

Magnetic Monopole Searches		٠.			٠.		685
Supersymmetric Particle Searches							687
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### Notes in the Search Listings

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Searches for Quark and Lepton Compositeness	١.	٠.		699
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^{*} See the Boson Particle Listings for searches for Higgs bosons, other heavy bosons, and axions and other very light bosons; the Lepton Particle Listings for searches for heavy leptons and for neutrino mixing; the Quark Particle Listings for free quark searches; and the Meson Particle Listings for searches for top and fourth-generation hadrons.

### SEARCHES FOR MONOPOLES, SUPERSYMMETRY, COMPOSITENESS, etc.

### Magnetic Monopole Searches

#### MAGNETIC MONOPOLE SEARCHES

(by W.P. Trower, Virginia Polytechnic Institute and State University)

Although the usual formulation of Maxwell's equations suggests magnetic monopoles, no observed phenomenon requires them for explanation [1]. A monopole anywhere in the universe results in electric charge quantization everywhere, and leads to the prediction of a least magnetic charge  $G = e/2\alpha$ , the Dirac charge [2]. Recently monopoles have become indispensable in many gauge theories, which endow them with a variety of extraordinarily large masses.

Monopole detectors have predominantly used either induction or ionization. Induction experiments measure the monopole magnetic charge and are independent of monopole electric charge, mass, and velocity. Monopole candidate events (CABRERA 82, CAPLIN 86) in single semiconductor loops have been detected by this method, but no two-loop coincidence has been observed. Ionization experiments rely on a magnetic charge producing more ionization than an electrical charge with the same velocity. However, the ability to distinguish a monopole by ionization diminishes with velocity.

Cosmic rays are the most likely source of massive monopoles, since accelerator energies are insufficient to produce them. Evidence for such monopoles may also be obtained from astrophysical observations.

This compilation is only a guide to the literature, since the quoted experimental limits are often only indicative.

#### References

<9.E-37

< 30

- 1. J.D. Jackson, CERN-77-17 (1977).
- 2. P.A.M. Dirac, Proc. Royal Soc. London A133, 60 (1931).

Monopole Production Cross Section — Accelerator Searches

Monopole	rioduction	C1033 3	ection -		ici a coi	Scarcics			
X-SECT (cm ² )	MASS (GeV)	CHG (g)	ENERGY (GeV)	BEAM	EVTS	DOCUMENT ID		TECN	
	<510			$e^+e^-$		¹ ACCIARRI	<b>95</b> C	L3	
<3.E-37	<45.0	1.0	88-94	$e^+e^-$	0	PINFOLD	93	PLAS	
< 3.E - 37	<41.6	2.0	88-94	$e^+e^-$	0	PINFOLD	93	PLAS	
<7.E-35	<44.9	0.2-1.0	89-93	$e^+e^-$	0	KINOSHITA	92	PLAS	
< 2.E - 34	<850	≥ 0.5	1800	$p\overline{p}$	0	BERTANI	90	PLAS	
< 1.2E - 33	<800	$\geq 1$	1800	$p\widetilde{p}$	0	PRICE	90	PLAS	
<1.E-37	<29	1	50-61	$e^+e^-$	0	KINOSHITA	89	PLAS	
< 1.E - 37	<18	2	50-61	$e^+e^-$	0	KINOSHITA	89	PLAS	
<1.E-38	<17	<1	35	$e^+e^-$	0	BRAUNSCH	88B	CNTR	
<8.E-37	<24	1	50-52	$e^+e^-$	0	KINOSHITA	88	PLAS	
< 1.3E - 35	<22	2	50-52	$e^+e^-$	0	KINOSHITA	88	PLAS	
<9.E-37	<4	< 0.15	10.6	$e^+e^-$	0	GENTILE	87	CLEO	
<3.E-32	<800	$\geq 1$	1800	$p\overline{p}$	0	PRICE	87	PLAS	
<3.E-38		<3	29	$e^+e^-$	0	FRYBERGER	84	PLAS	
< 1.E - 31		1,3	540	$p\overline{p}$	0	AUBERT	838	PLAS	
< 4.E - 38	<10	<6	34	$e^+e^-$	0		83	PLAS	
40 E 06	-00					2 DELL	00	CNITD	

KINOSHITA

82 PLAS

<1 F 27	<20	-24	62		•	CARRICAN	70	CNTD
<1.E-37	<20	<24	63	pр	0	CARRIGAN	78	CNTR
<1.E-37	<30	<3	56	pр	0	HOFFMANN	78	PLAS
			62	pр	0	² DELL	76	SPRK
<4.E-33			300	р	0	² STEVENS	76B	SPRK
<1.E-40	<5	<2	70	p	0	³ ZRELOV	76	CNTR
<2.E-30			300	n	0	² BURKE	75	OSPK
<1.E-38			8	ν	0	⁴ CARRIGAN	75	HLBC
<5.E-43	<12	<10	400	p	0	EBERHARD	75B	INDU
< 2.E - 36	<30	<3	60	pр	0	GIACOMELLI	75	PLAS
<5.E-42	<13	<24	400	p	0	CARRIGAN	74	CNTR
<6.E-42	<12	<24	300	р	0	CARRIGAN	73	CNTR
<2.E-36		1	.001	γ	0	³ BARTLETT	72	CNTR
< 1.E - 41	<5		70	p	. 0	GUREVICH	72	EMUL
<1.E-40	<3	<2	28	p	0	AMALDI	63	EMUL
< 2.E - 40	<3	<2	30	p	0	PURCELL	63	CNTR
< 1.E - 35	<3	<4	28	P	0	FIDECARO	61	CNTR
<2.E-35	<1	1	6	p	0	BRADNER	59	<b>EMUL</b>

- 1  ACCIARRI 95C finds a limit B(Z  $\rightarrow~\gamma\gamma\gamma)<0.8\times10^{-5}$  (which is possible via a monopole loop) at 95% CL and sets the mass limit via a cross section model.
- ² Multiphoton events.
- ³ Cherenkov radiation polarization.
- ⁴ Re-examines CERN neutrino experiments.

#### Monopole Flux — Cosmic Ray Searches

FLUX	MASS	CHG	COMMENTS				
FLUX (cm ⁻² sr ⁻¹ s ⁻	1 (GeV)	(g)		/TS	DOCUMENT ID		TECN
<5.6E-15		1	$1.8E-4 < \beta < 3.E-3$		5 AHLEN	94	MCRO
			2 1 10=3	0	6 BECKER-SZ		
<2.7E-15		1	$\beta \sim 1 \times 10^{-3}$				IMB
<8.7E−15		1	>2.E-3	0	THRON	92	SOUD
<4.4E-12		1	all $oldsymbol{eta}$	0	GARDNER	91	INDU
<7.2E-13		1	all $\beta$	0	HUBER	91	INDU
<3.7E-15	>E12	1	β=1.E−4	0	⁷ ORITO	91	PLAS
<3.2E-16	>E10	1	$\beta > 0.05$	0	⁷ ORITO	91	PLAS
<3.2E-16	>E10-E12	2, 3		0	7 ORITO	91	PLAS
<3.8E-13	, 210 212	1	all $\beta$	0	BERMON	90	INDU
<5.E-16			$\beta < 1.E - 3$	0	6 BEZRUKOV	90	CHER
			$\beta < 1.2 = 3$ $\beta > 1.1E = 4$	0	8 BUCKLAND		HEPT
<1.8E-14		1				90	
<1E-18		_	$3.E-4 < \beta < 1.5E-3$		9 GHOSH	90	MICA
<7.2E-13			all β	0	HUBER	90	INDU
<5.E-12	>E7	1		0	BARISH	87	CNTR
<1.E-13			$1.E-5 < \beta < 1$	0	6 BARTELT	87	SOUD
<1.E-10		1	all $eta$	0	EBISU	87	INDU
<2.E-13			$1.E-4 < \beta < 6.E-4$	0	MASEK	87	HEPT
<2.E-14			${\rm 4.E\!-\!5} < \beta < {\rm 2.E\!-\!4}$	0	NAKAMURA	87	PLAS
<2.E-14			$1.E-3 < \beta < 1$	0	NAKAMURA	87	PLAS
<5.E-14			$9.E-4 < \beta < 1.E-2$	0	SHEPKO	87	CNTR
<2.E-13			4.E-4 < $\beta$ <1	0	TSUKAMOTO		CNTR
<5.E-14		1	all $\beta$	1	10 CAPLIN	86	INDU
			all p	0	CROMAR		INDU
<5.E-12		1					
<1.E-13		1	7.E-4 < $\beta$	0	HARA	86	CNTR
<7.E-11		1	all $oldsymbol{eta}$	0	INCANDELA	86	INDU
<1.E-18			$4.E-4 < \beta < 1.E-3$	0	9 PRICE	86	MICA
<5.E-12		1		0	BERMON	85	INDU
<6.E-12		1		0	CAPLIN	85	INDU
<6.E-10		1		0	EBISU	85	INDU
<3.E-15			$5.E-5 \le \beta \le 1.E-3$	0	6 KAJITA	85	KAMI
<2.E-21			β <1.E-3	0	6,11 KAJITA	85	KAMI
<3.E-15			$1.E-3 < \beta < 1.E-1$	0	⁶ PARK	85B	CNTR
<5.E-12		1	$1.E-4 < \beta < 1$	0	BATTISTONI	84	NUSX
<7.E-12		1		0	INCANDELA	84	INDU
<7.E-13		1	3.E-4 < $\beta$	0	8 KAJINO	84	CNTR
<2.E-12		1	3.E-4 < $\beta$ <1.E-1	0	KAJINO		CNTR
<6.E-13		1	5.E-4 < $\beta$ <1	0	KAWAGOE	84	CNTR
<2.E-14			1.E-3 < $\beta$	0	6 KRISHNA	84	CNTR
<4.E-13		1	$6.E-4 < \beta < 2.E-3$	0	LISS	84	CNTR
<1.E-16			$3.E-4 < \beta < 1.E-3$	0	9 PRICE	84	MICA
<1.E-13		1	$1.E-4 < \beta$	0	PRICE	84B	PLAS
<4.E-13		1	$6.E-4 < \beta < 2.E-3$	0	TARLE	84	CNTR
				7	¹² ANDERSON	83	EMUL
<4.E-13		1	$1.E-2 < \beta < 1.E-3$	0	BARTELT	83B	CNTR
<1.E-12		1	$7.E-3 < \beta < 1$	0	BARWICK	83	PLAS
<3.E-13			$1.E-3 < \beta < 4.E-1$	0	BONARELLI	83	CNTR
<3.E-12		_	$5.E-4 < \beta < 5.E-2$	0	6 BOSETTI	83	CNTR
<4.E-11		1	5.L + \ p \ (5.L L	0	CABRERA		INDU
<5.E-15		1	$1.E-2 < \beta < 1$	o	DOKE	83	PLAS
		1			6 ERREDE		
<8.E-15			$1.E-4 < \beta < 1.E-1$	0		83	IMB
<5.E-12		1	$1.E-4 < \beta < 3.E-2$	0	GROOM	83	CNTR
<2.E-12		_	6.E-4 < $\beta$ <1	0	MASHIMO	83	CNTR
<1.E-13			β=3.E-3	0	ALEXEYEV	82	CNTR
<2.E-12		1	$7.E-3 < \beta < 6.E-1$	0	BONARELLI	82	CNTR
6.E-10		1	all $oldsymbol{eta}$	1	¹³ CABRERA	82	INDU
<2.E-11			$1.E\!-\!2<\beta<\!1.E\!-\!1$	0	MASHIMO	82	CNTR
<2.E-15			concentrator	0	BARTLETT	81	PLAS
<1.E-13	>1		$1.E - 3 < \beta$	0	KINOSHITA	81B	PLAS
			*				

### Magnetic Monopole Searches

<5.E $-$ 11	<e17< td=""><td></td><td>$3.E-4 &lt; \beta &lt; 1.E-3$</td><td>0</td><td>ULLMAN</td><td>81</td><td>CNTR</td></e17<>		$3.E-4 < \beta < 1.E-3$	0	ULLMAN	81	CNTR
< 2.E - 11			concentrator	0	BARTLETT	78	PLAS
1.E-1	>200	2		1	¹⁴ PRICE	75	PLAS
< 2.E - 13		>2		0	FLEISCHER	71	PLAS
<1.E-19		>2	obsidian, mica	0	FLEISCHER	69C	PLAS
<5.E-15	<15	<3	concentrator	0	CARITHERS	66	ELEC
<2.E-11		<1-3	concentrator	0	MALKUS	51	<b>EMUL</b>

- <2.E-11</p>
  <1-3 concentrator</p>
  0 MALKUS
  51 EMUL
  5 AHLEN 94 limit for dyons extends down to  $\beta$ =0.9E-4 and a limit of 1.3E-14 extends to  $\beta$  = 0.8E-4. Aso see comment by PRICE 94 and reply of BARISH 94. One loophole in the AHLEN 94 result is that in the case of monopoles catalyzing nucleon decay, relativistic particles could veto the events. New electronics will remove this possibility.
  6 Catalysis of nucleon decay; sensitive to assumed catalysis cross section.
  7 ORITO 91 limits are functions of velocity. Lowest limits are given here.
  8 Used DKMPR mechanism and Penning effect.
  9 Assumes monopole attaches fermion nucleus.
  10 Limit from combining data of CAPLIN 86, BERMON 85, INCANDELA 84, and CABRERA 83. For a discussion of controversy about CAPLIN 86 observed event, see GUY 87. Also see SCHOUTEN 87.
  11 Based on lack of high- energy solar neutrinos from catalysis in the sun.
  12 Anomalous long-range  $\alpha$  (⁴ He) tracks.
  13 CABRERA 82 candidate event has single Dirac charge within ±5%.
  14 ALVAREZ 75, FLEISCHER 75, and FRIEDLANDER 75 explain as fragmenting nucleus. EBERHARD 75 and ROSS 76 discuss conflict with other experiments. HAGSTROM 77 reinterprets as antinucleus. PRICE 78 reassesses.

#### Monopole Flux — Astrophysics

FLUX	MASS	CHG	COMMENTS				
$(cm^{-2}sr^{-1}s^{-1})$	(GeV)	(g)	$(\beta = v/c)$	EVTS	DOCUMENT ID		TECN
<1.E-16	E17	1	galactic field	0	¹⁵ ADAMS	93	COSM
<1.E-23			Jovian planets		¹⁶ ARAFUNE	85	COSM
< 1.E - 16	E15		solar trapping	0	BRACCI	85B	COSM
<1.E-18		1		0	¹⁶ HARVEY	84	COSM
<3.E-23			neutron stars		KOLB	84	COSM
<7.E-22			pulsars	0	16 FREESE	83B	COSM
<1.E-18	<e18< td=""><td>1</td><td>intergalactic field</td><td>0</td><td>16 REPHAELI</td><td>83</td><td>COSM</td></e18<>	1	intergalactic field	0	16 REPHAELI	83	COSM
<1.E-23			neutron stars	0	16 DIMOPOUL	82	COSM
<5.E-22			neutron stars	0	¹⁶ KOLB	82	COSM
<5.E-15	>E21		galactic halo		SALPETER	82	COSM
<1.E-12	E19	1	$\beta=3.E-3$	0	¹⁷ TURNER	82	COSM
<1.E-16		1	galactic field	. 0	PARKER	70	COSM

- 15 ADAMS 93 limit based on "survival and growth of a small galactic seed field" is  $10^{-16} \ (m/10^{17} \ \text{GeV}) \ \text{cm}^{-2} \ \text{s}^{-1} \ \text{sr}^{-1}$ . Above  $10^{17} \ \text{GeV}$ , limit  $10^{-16} \ (10^{17} \ \text{GeV}/m)$  cm  $^{-2} \ \text{s}^{-1} \ \text{s}^{-1}$  (from requirement that monopole density does not overclose the universe) is more stringent. 16 Catalysis of nucleon decay, 17 Re-evaluates PARKER 70 limit for GUT monopoles.

#### Monopole Density — Matter Searches

DENSITY	CHG (g)	MATERIAL	EVTS	DOCUMENT ID		TECN						
<6.9E-6/gram	>1/3	Meteorites and other	0	JEON	95	INDU						
<2.E-7/gram	>0.6	Fe ore	0	¹⁸ EBISU	87	INDU						
>1.E-14/gram	>1/3	iron aerosols	>1	MIKHAILOV	83	SPEC						
<6.E-4/gram		air, seawater	0	CARRIGAN	76	CNTR						
<5.E-1/gram	>0.04	11 materials	0	CABRERA	75	INDU						
<2.E-4/gram	>0.05	moon rock	0	ROSS	73	INDU						
<6.E-7/gram	<140	seawater	0	KOLM	71	CNTR						
<1.E $-$ 2/gram	<120	manganese nodules	0	FLEISCHER	69	PLAS						
<1.E-4/gram	>0	manganese	0	FLEISCHER	<b>69</b> B	PLAS						
<2.E-3/gram	<1-3	magnetite, meteor	0	GOTO	63	EMUL						
<2.E 2/gram		meteorite	0	PETUKHOV	63	CNTR						
18 Mass 1 $\times$ 10 14	$^{18}\text{Mass}~1 \times 10^{14} 1 \times 10^{17}\text{GeV}.$											

#### Monopole Density — Astrophysics

DENSITY	(g)	MATERIAL	EVTS	DOCUMENT ID		TECN
<1.E-9/gram	1	sun, catalysis	0	¹⁹ ARAFUNE	83	COSM
<6.E-33/nucl	1	moon wake	0	SCHATTEN	83	ELEC
<2.E-28/nucl		earth heat	0	CARRIGAN	80	COSM
<2.E-4/prot		42cm absorption	0	BRODERICK	79	COSM
$< 2.E - 13/m^3$		moon wake	0	SCHATTEN	70	ELEC

### $^{19}\,\mathrm{Catalysis}$ of nucleon decay.

#### REFERENCES FOR Magnetic Monopole Searches

ACCIARRI	95C	PL B345 609	+Adam, Adriani, Aguilar-Benitez+ (L3 Collab.)	1
JEON	95	PRL 75 1443	Jeon, Longo (MICH)	,
AHLEN	94	PRL 72 608	+Ambrosio, Antolini, Auriemma+ (MACRO Collab.)	1
BARISH	94	PRL 73 1306	+Giacomelli, Hong (CIT, BGNA, BOST)	,
BECKER-SZ	94	PR D49 2169	Becker-Szendy, Bratton, Breault, Casper+ (IMB Collab.)	,
PRICE	94	PRL 73 1305	(UCB)	,
ADAMS	93	PRL 70 2511	+Fatuzzo, Freese, Tarle+ (MICH, FNAL)	,
PINFOLD	93	PL B316 407	+Du, Kinoshita, Lorazo+ (ALBE, HARV, MONT, UCB)	,
KINOSHITA	92	PR D46 R881	+Du, Giacomelli, Patriziili+ (HARV, BGNA, REHO)	,
THRON	92	PR D46 4846	+Allison, Alner, Ambats+ (SOUDAN-2 Collab.)	
GARDNER	91	PR D44 622	+Cabrera, Huber, Taber (STAN)	,
HUBER	91	PR D44 636	+Cabrera, Taber, Gardner (STAN)	,
ORITO	91	PRL 66 1951	+Ichinose, Nakamura+ (ICEPP, WASCR, NIHO, ICRR)	1
BERMON	90	PRL 64 839	+Chi, Tsuei+ (IBM, BNL)	,
BERTANI	90	EPL 12 613	+Giacomelli, Mondardini, Pal+ (BGNA, INFN)	)
BEZRUKOV	90	SJNP 52 54	+Belolaptikov, Bugaev, Budnev+ (INRM)	,
		Translated from VAF 5	2.86	

BUCKLAND GHOSH	90 90	PR D41 2726 EPL 12 25	+Masek, Vernon, Knapp, Stronsi (UCSD)
HUBER	90	PRL 64 835	+Chatterjea (JADA) +Cabrera, Tabor, Gardner (STAN)
PRICE	90	PRL 65 149	+Guiru, Kinoshita (UCB, HARV)
KINOSHITA BRAUNSCH	89 00P	PL B228 543 ZPHY C38 543	+Fujii, Nakajima+ (HARV, TISA, KEK, UCB, GIFU)
KINOSHITA	88	PRL 60 1610	+Fujii, Nakajima+ (HARV, TISA, KEK, UCB, GIFU)
BARISH	87	PR D36 2641	+Liu, Lane (CIT)
BARTELT	87	PR D36 1990	+Courant, Heller+ (Soudan Collab.)
Also EBISU	89 87	PR D40 1701 erratum PR D36 3359	Bartelt, Courant, Heller+ (Soudan Collab.) +Watanabe (KOBE)
Also	85	JPG 11 883	Ebisu, Watanabe (KOBE)
GENTILE	87	PR D35 1081	+Haas, Hempstead+ (CLEO Collab.)
GUY	87	Nature 325 463	(LOIC)
MASEK NAKAMURA	87 87	PR D35 2758 PL B183 395	+Knapp, Miller, Stronski, Vernon, White (UCSD) +Kawagoe, Yamamoto+ (INUS, WASCR, NIHO)
PRICE	87	PRL 59 2523	+Kawagoe, Yamamoto+ +Guoxiao, Kinoshita (INUS, WASCR, NIHO) (UCB, HARV)
SCHOUTEN	87	PRL 59 2523 JPE 20 850	+Caplin, Guy, Hardiman+ (LOIC)
SHEPKO	87	PR D35 2917	+Gagliardi, Green, McIntyre+ (TAMU)
TSUKAMOTO CAPLIN	87 86	EPL 3 39 Nature 321 402	+Nagano, Anraku+ (ICRR) +Hardiman, Koratzinos, Schouten (LOIC)
Also	87	JPE 20 850	+Hardiman, Koratzinos, Schouten (LOIC) Schouten, Caplin, Guy, Hardiman+ (LOIC)
Also	87	Nature 325 463	Guy (LOIC)
CROMAR	86	PRL 56 2561 PRL 56 553	+Clark, Fickett +Honda, Ohno+ (ICRR, KYOT, KEK, KOBE, ICEPP)
HARA INCANDELA	86 86	PR D34 2637	+Honda, Ohno+ (ICRR, KYOT, KEK, KOBE, ICEPP) +Frisch, Somalwar, Kuchnir+ (CHIC, FNAL, MICH)
PRICE	86	PRL 56 1226	+Salamon (UCB)
ARAFUNE	85	PR D32 2586	+Salamon (UCB) +Fukugita, Yanagita (ICRR, KYOTY, IBAR)
BERMON BRACCI	85 85B	PRL 55 1850 NP B258 726	+Chaudhari, Chi, Tesche, Tsuei (IBM) +Fiorentini, Mezzorani (PISA, CAGL, INFN)
Also	85	LNC 42 123	Bracci, Fiorentini (PISA)
CAPLIN	85	Nature 317 234	+Guy, Hardiman, Park, Schouten (LOIC)
	85	JPG 11 883	+Watanabe (KOBE)
KAJITA PARK	85 85B	JPSJ 54 4065 NP B252 261	+Arisaka, Koshiba, Nakahata+ (ICRR, KEK, NIIG) +Blewitt, Cortez, Foster+ (IMB Collab.)
	84	PL 133B 454	+Bellotti, Bologna, Campana+ (NUSEX Collab.)
FRYBERGER	84	PR D29 1524 NP B236 255	+Coan, Kinoshita, Price (SLAC, UCB)
HARVEY INCANDELA	84 84	NP B236 255	(PRIN)
KAJINO	84	PRL 53 2067 PRI 52 1373	+Campbell, Frisch+ (CHIC, FNAL, MICH)
KAJINO	84B	JPG 10 447	+Matsuno, Yuan, Kitamura (ICRR) +Matsuno, Kitamura, Aoki, Yuan, Mitsui+ (ICRR)
KAWAGOE	84	PRL 52 1373 JPG 10 447 LNC 41 315	+Machimo Nakamura Nozaki Orito (TOKV)
KOLB KRISHNA	84	APJ 286 702	+Turner (FNAL, CHIC)
	84 84	PL 142B 99 PR D30 884	+Turner (FNAL, CHIC) Krishnaswamy, Menon+ (TATA, OSKC, INUS) +Ahlen, Tarle (UCB, IND, MICH)
	84	PRL 52 1265	+Guo, Anien, Fleischer (ROMA, UCB, IND, GESC)
PRICE	84B	PL 140B 112	(CERN)
TARLE	84	PRL 52 90	+Ahlen, Liss (UCB, MICH, IND) +Lord, Strausz, Wilkes (WASH)
ANDERSON ARAFUNE	83 83	PR D28 2308 PL 133B 380	+Lord, Strausz, Wilkes (WASH) +Fukugita (ICRR, KYOTY)
AUBERT	83B	PL 120B 465	+Musset, Price, Vialle (CERN, LAPP)
BARTELT	83B	PRL 50 655	+Courant, Heller, Joyce, Marshak+ (MINN, ANL)
BARWICK BONARELLI	83 83	PR D28 2338 PL 126B 137	+Kinoshita, Price (UCB) +Capiluppi, Dantone (BGNA)
	83	PL 133B 265	+Capiluppi, Dantone (BGNA) +Gorham, Harris, Learned+ (AACH3, HAWA, TOKY) +Taber, Gardner, Bourg (STAN)
CABRERA	83	PRL 51 1933	+Taber, Gardner, Bourg (STAN)
DOKE ERREDE	83 83	PL 129B 370 PRL 51 245	+Hayashi, Hamasaki+ (WASU, RIKK, TTAM, RIKEN) +Stone, Vander Velde, Bionta+ (IMB Collab.)
FREESE	83B	PRL 51 245 PRL 51 1625	+Stone, Vander Velde, Bionta+ (IMB Collab.) +Turner, Schramm (CHIC)
GROOM	83	PRL 50 573	+Loh, Nelson, Ritson (UTAH, STAN)
MASHIMO	83	PL 128B 327	+Orito, Kawagoe, Nakamura, Nozaki (ICEPP)
MIKHAILOV MUSSET	83 83	PL 130B 331	+Price, Lohrmann (CERN, HAMB)
REPHAELI	83	PL 128B 333 PL 121B 115	+Turner (CHIC)
SCHATTEN	83	PR D27 1525	(NASA)
ALEXEYEV	82	LNC 35 413	+Boliev, Chudakov, Makoev, Mikheyev+ (INRM)
BONARELLI CABRERA	82 82	PL 112B 100 PRL 48 1378	+Capiluppi, Dantone+ (BGNA) (STAN)
DELL	82	NP B209 45	
DIMOPOUL	82	NP B209 45 PL 119B 320	Dimopoulos, Preskill, Wilczek (HARV, UCSBT)
KINOSHITA	82	PRL 48 77	
KOLB MASHIMO	82 82	PRL 49 1373 JPSJ 51 3067	+Colgate, Harvey (LASL, PRIN)  +Kawagoe Koshiba (INUS)
SALPETER	82	PRL 49 1114	+Kawagoe, Koshiba (INUS) +Shapiro, Wasserman (CORN)
TURNER	82	PR D26 1296	+Parker, Bogdan (CHIC)
BARTLETT	81	PR D24 612	+Soo, Fleischer, Hart+ (COLO, GESC)
KINOSHITA ULLMAN	81B 81	PR D24 612 PR D24 1707 PRL 47 289	+Price (UCB) (LEHM, BNL)
CARRIGAN	80	Nature 288 348	(FNAL)
BRODERICK	79	PR D19 1046 PR D18 2253	Cicenes Teolity Teolity (VDI)
BARTLETT CARRIGAN	78 78	PR D18 2253 PR D17 1754	+Soo, White (COLO, PRIN) +Strauss, Giacomelli (FNAL, BGNA)
HOFFMANN	78	LNC 23 357	+Kantardjian, Diliberto, Meddi+ (CERN, ROMA)
PRICE	78	PR D18 1382	+Shirk, Osborne, Pinsky (UCB, HOUS)
HAGSTROM CARRIGAN	77 76	PRL 38 729 PR D13 1823	(LBL)
DELL	76	LNC 15 269	+Nezrick, Strauss +Uto, Yuan, Amaldi+ (CERN, BNL, ROMA, ADEL)
ROSS	76	LBL-4665	(LBL)
STEVENS	76B	PR D14 2207	+Collins, Ficenec, Trower, Fischer+ (VPI, BNL)
ZRELOV ALVAREZ	76 75	CZJP B26 1306 LBL-4260	+Kollarova, Kollar, Lupiltsev, Pavlovic+ (JINR) (LBL)
BURKE	75	PL 60B 113	+Gustafson, Jones, Longo (MICH)
CABRERA	75	Thesis	(STAN)
CARRIGAN Also	75	NP B91 279	+ Nezrick (FNAL)
EBERHARD	71 75	PR D3 56 PR D11 3099	Carrigan, Nezrick (FNAL) +Ross, Taylor, Alvarez, Oberlack (LBL, MPIM)
EBERHARD	75B	LBL-4289	(LBL)
FLEISCHER FRIEDLANDER	75	PRL 35 1412	+Walker (GESC, WUSL)
GIACOMELLI	75 75	PRL 35 1167 NC 28A 21	+Rossi+ (BGNA, CERN, SACL, ROMA)
PRICE	75	PRL 35 487	+Shirk, Osborne, Pinsky (UCB, HOUS)
CARRIGAN	74	PR D10 3867	+Nezrick, Strauss (FNAL)
CARRIGAN ROSS	73 73	PR D8 3717 PR D8 698	+Nezrick, Strauss (FNAL) +Eberhard, Alvarez, Watt (LBL, SLAC)
Also	71	PR D4 3260	+Eberhard, Alvarez, Watt (LBL, SLAC) Eberhard, Ross, Alvarez, Watt (LBL, SLAC)
Also	70	Science 167 701	Alvarez, Eberhard, Ross, Watt (LBL, SLAC)
BARTLETT	72	PR D6 1817	+Lahana (COLO)
GUREVICH Also	72 72B	PL 38B 549 JETP 34 917	+Khakimov, Martemyanov+ (KIAE, NOVO, SERP) Barkov, Gurevich, Zolotorev (KIAE, NOVO, SERP)
		Translated from ZETF	61 1721.
Also FLEISCHER	70 71	PL 31B 394 PR D4 24	Gurevich, Khakimov+ (KIAE, NOVO, SERP) +Hart, Nichols, Price (GESC)
LEIGHTEN		5. 2.	(0000)

#### Magnetic Monopole Searches, Supersymmetric Particle Searches

PARKER SCHATTEN FLEISCHER FLEISCHER Also CARITHERS AMALDI GOTO	71 70 70 69 69B 69C 70C 66 63 63	PR D4 1285 APJ 160 383 PR D1 2245 PR 177 2029 PR 184 1393 PR 184 1398 JAP 41 958 PR 149 1070 NC 28 773 PR 132 387 NP 49 87	+Villa, Odian  + Jacobs, Schwartz, Price +Hart, Jacobs+ +Price, Woods Fleischer, Hart, Jacobs, Price+ +Stefanski, Adair +Baroni, Manfredini+ +Kolm, Ford +Yakimenko	(MIT, SLAC) (CHIC) (RASA) (GESC, FSU) (GESC, UNCS, GSCO) (GESC) (GESC) (YALE, BNL) (ROMA, UCSD, CERN) (TOKY, MIT, BRAN) (LEBD)
PURCELL FIDECARO BRADNER	63 61 59 51	PR 129 2326 NC 22 657 PR 114 603 PR 83 899	+Collins, Fujii, Hornbostel, Turkot +Finocchiaro, Giacomelli +Isbell	(HARV, BNL) (CERN) (LBL) (CHIC)
		ОТНЕ	R RELATED PAPERS —	
GROOM Review	86	PRPL 140 323		(UTAH)

### Supersymmetric Particle Searches

#### SUPERSYMMETRY

(by H.E. Haber, Univ. of California, Santa Cruz)

A. Introduction: Supersymmetry is a generalization of the space-time symmetries of quantum field theory that transforms fermions into bosons and vice versa. It also provides a framework for the unification of particle physics and gravity, which takes place at an energy of order the Planck scale ( $\approx 10^{19}$ GeV) [1-3]. However, supersymmetry is clearly not an exact symmetry of nature, and therefore must be broken. In theories of "low-energy" supersymmetry, the effective scale of supersymmetry breaking is tied to the electroweak scale [4-6]. In this way, it is hoped that supersymmetry will ultimately explain the origin of the large hierarchy between the W and Zmasses and the Planck scale. At present, there are no unambiguous experimental results that require the existence of low-energy supersymmetry. However, if experimentation at future colliders uncovers evidence for supersymmetry, this would have a profound effect on the study of TeV-scale physics and the development of a more fundamental theory of mass and symmetry-breaking phenomena in particle physics.

B. Structure of the MSSM: The minimal supersymmetric extension of the Standard Model (MSSM) consists of taking the Standard Model and adding the corresponding supersymmetric partners [7]. In addition, the MSSM contains two hypercharge  $Y=\pm 1$  Higgs doublets, which is the minimal structure for the Higgs sector of an anomaly-free supersymmetric extension of the Standard Model. The supersymmetric structure of the theory also requires (at least) two Higgs doublets to generate mass for both "up"-type and "down"-type quarks (and charged leptons) [8,9]. All renormalizable supersymmetric interactions consistent with (global) B-L conservation (B =baryon number and L =lepton number) are included. Finally, the most general soft-supersymmetry-breaking terms are added [10].

If supersymmetry is relevant for explaining the scale of electroweak interactions, then the mass parameters that occur in the soft-supersymmetry-breaking terms must be of order 1 TeV or below [11]. Some bounds on these parameters exist due to the absence of supersymmetric-particle production at current accelerators (see the Particle Listings following this note). Additional constraints arise from limits on the contributions of

virtual supersymmetric particle exchange to a variety of Standard Model processes [12]. The impact of precision electroweak measurements at LEP and SLC on the MSSM parameter space is discussed briefly at the end of this note.

As a consequence of B-L invariance, the MSSM possesses a discrete R-parity invariance, where  $R=(-1)^{3(B-L)+2S}$  for a particle of spin S [13]. Note that this formula implies that all the ordinary Standard Model particles have even R-parity, whereas the corresponding supersymmetric partners have odd R-parity. The conservation of R-parity in scattering and decay processes has a crucial impact on supersymmetric phenomenology. For example, starting from an initial state involving ordinary (R-even) particles, it follows that supersymmetric particles must be produced in pairs. In general, these particles are highly unstable and decay quickly into lighter states. However, R-parity invariance also implies that the lightest supersymmetric particle (LSP) is absolutely stable, and must eventually be produced at the end of a decay chain initiated by the decay of a heavy unstable supersymmetric particle.

In order to be consistent with cosmological constraints, the LSP is almost certainly electrically and color neutral [14]. Consequently, the LSP is weakly-interacting in ordinary matter, *i.e.* it behaves like a stable heavy neutrino and will escape detectors without being directly observed. Thus, the canonical signature for (*R*-parity conserving) supersymmetric theories is missing (transverse) energy, due to the escape of the LSP.

Some model builders attempt to relax the assumption of R-parity conservation. Models of this type must break B-L and are therefore strongly constrained by experiment [15]. Nevertheless, it is still important to allow for the possibility of R-parity violating processes in the search for supersymmetry. In such models, the LSP is unstable and supersymmetric particles can be singly produced and destroyed in association with B or L violation. These features lead to a phenomenology of broken-R-parity models that is very different from that of the MSSM.

In the MSSM, supersymmetry breaking is accomplished by including the soft-supersymmetry breaking terms mentioned earlier. These terms parametrize our ignorance of the fundamental mechanism of supersymmetry breaking. If this breaking occurs spontaneously, then (in the absence of supergravity) a massless Goldstone fermion called the goldstino  $(\tilde{G})$  must exist. The goldstino would then be the LSP and could play an important role in supersymmetric phenomenology [16]. In models that incorporate supergravity, this picture changes. If supergravity is spontaneously broken, the goldstino is absorbed ("eaten") by the gravitino  $(g_{3/2})$ , the spin-3/2 partner of the graviton [17]. By this super-Higgs mechanism, the gravitino acquires a mass  $(m_{3/2})$ . In many models, the gravitino mass is of order the electroweak-symmetry-breaking scale, while its couplings are gravitational in strength [1,18]. Such a gravitino would play no role in supersymmetric phenomenology at colliders.

#### Supersymmetric Particle Searches

The parameters of the MSSM are conveniently described by considering separately the supersymmetry-conserving sector and the supersymmetry-breaking sector. A careful discussion of the conventions used in defining the MSSM parameters can be found in Ref. 19. Among the parameters of the supersymmetry conserving sector are: (i) gauge couplings:  $g_s$ , g, and g', corresponding to the Standard Model gauge group  $\mathrm{SU}(3)\times\mathrm{SU}(2)\times\mathrm{U}(1)$  respectively; (ii) Higgs-Yukawa couplings:  $\lambda_e$ ,  $\lambda_u$ , and  $\lambda_d$  (which are  $3\times 3$  matrices in flavor space); and (iii) a supersymmetry-conserving Higgs mass parameter  $\mu$ .

The supersymmetry-breaking sector contains the following set of parameters: (i) gaugino Majorana masses  $M_3$ ,  $M_2$  and  $M_1$  associated with the SU(3), SU(2), and U(1) subgroups of the Standard Model; (ii) scalar mass matrices for the squarks and sleptons; (iii) Higgs-squark-squark trilinear interaction terms (the so-called "A-parameters") and corresponding terms involving the sleptons; and (iv) three scalar Higgs mass parameters—two diagonal and one off-diagonal mass terms for the two Higgs doublets. These three mass parameters can be re-expressed in terms of the two Higgs vacuum expectation values,  $v_1$  and  $v_2$ , and one physical Higgs mass. Here,  $v_1$  ( $v_2$ ) is the vacuum expectation value of the Higgs field which couples exclusively to down-type (up-type) quarks and leptons. Note that  $v_1^2 + v_2^2 = (246 \text{ GeV})^2$  is fixed by the W mass (or equivalently by the Fermi constant  $G_F$ ), while the ratio

$$\tan \beta = v_2/v_1 \tag{1}$$

is a free parameter of the model.

The supersymmetric constraints imply that the MSSM Higgs sector is automatically CP-conserving (at tree-level). Thus,  $\tan\beta$  is a real parameter (conventionally chosen to be positive), and the physical neutral Higgs scalars are CP-eigenstates. Nevertheless, the MSSM does contain a number of possible new sources of CP violation. For example, gauginomass parameters, the A-parameters, and  $\mu$  may be complex. Some combination of these complex phases must be less than of order  $10^{-2}$ – $10^{-3}$  (for a supersymmetry-breaking scale of 100 GeV) to avoid generating electric dipole moments for the neutron, electron, and atoms in conflict with observed data [20]. However, these complex phases have little impact on the direct searches for supersymmetric particles, and are usually ignored in experimental analyses.

C. The Higgs sector of the MSSM: Before describing the supersymmetric-particle sector, let us consider the Higgs sector of the MSSM [21]. There are five physical Higgs particles in this model: a charged Higgs pair  $(H^{\pm})$ , two CP-even neutral Higgs bosons (denoted by  $H_1^0$  and  $H_2^0$  where  $m_{H_1^0} \leq m_{H_2^0}$ ) and one CP-odd neutral Higgs boson  $(A^0)$ . The properties of the Higgs sector are determined by the Higgs potential which is made up of quadratic terms [whose squared-mass coefficients were mentioned above Eq. (1)] and quartic interaction terms. The strengths of the interaction terms are directly related to the gauge couplings by supersymmetry (and are not affected

at tree-level by supersymmetry-breaking). As a result,  $\tan\beta$  [defined in Eq. (1)] and one Higgs mass determine: the Higgs spectrum, an angle  $\alpha$  [which indicates the amount of mixing of the original  $Y=\pm 1$  Higgs doublet states in the physical CP-even scalars], and the Higgs boson couplings.

When one-loop radiative corrections are incorporated, additional parameters of the supersymmetric model enter via virtual loops. The impact of these corrections can be significant [22,23]. For example, at tree-level, the MSSM predicts  $m_{H_1^0} \leq m_Z$  [8,9]. If true, this would imply that experiments to be performed at LEP-2 operating at its maximum energy and luminosity would rule out the MSSM if  $H_1^0$  were not found. However, this Higgs mass bound can be violated when the radiative corrections are incorporated. For example, in Ref. 22, the following approximate upper bound was obtained for  $m_{H_1^0}$  (assuming  $m_{A^0} > m_Z$ ) in the limit of  $m_Z \ll m_t \ll M_{\widetilde{t}}$  [where top-squark  $(\widetilde{t}_L - \widetilde{t}_R)$  mixing is neglected]

$$\begin{split} m_{H_1^0}^2 \lesssim m_Z^2 + \frac{3g^2 m_Z^4}{16\pi^2 m_W^2} \\ &\times \left\{ \ln \left( \frac{M_t^2}{m_t^2} \right) \left[ \frac{2m_t^4 - m_t^2 m_Z^2}{m_Z^4} \right] + \frac{m_t^2}{3m_Z^2} \right\}. \end{split} \tag{2}$$

More refined computations (which include the effects of top-squark mixing, renormalization group improvement, and the leading two-loop contributions) yield  $m_{H_1^0} \lesssim 125$  GeV for  $m_t = 175$  GeV and a top-squark mass of  $M_{\widetilde{t}} = 1$  TeV [24]. Clearly, the radiative corrections to the Higgs masses have a significant impact on the search for the Higgs bosons of the MSSM at LEP [25].

D. Supersymmetric-particle spectrum: Consider next the supersymmetric-particle sector of the MSSM. The supersymmetric partners of the gauge and Higgs bosons are fermions, whose names are obtained by appending "ino" at the end of the corresponding Standard Model particle name. The gluino is the color octet Majorana fermion partner of the gluon with mass  $M_{\widetilde{g}} = |M_3|$ . The supersymmetric partners of the electroweak gauge and Higgs bosons (the gauginos and Higgsinos) can mix. As a result, the physical mass eigenstates are model-dependent linear combinations of these states, called charginos and neutralinos, which are obtained by diagonalizing the corresponding mass matrices. The chargino-mass matrix depends on  $M_2$ ,  $\mu$ , tan  $\beta$  and  $m_W$  [26].

The corresponding chargino-mass eigenstates are denoted by  $\widetilde{\chi}_1^+$  and  $\widetilde{\chi}_2^+$ , with masses

$$M_{\widetilde{\chi}_{1}^{+},\widetilde{\chi}_{2}^{+}}^{2} = \frac{1}{2} \left\{ |\mu|^{2} + |M_{2}|^{2} + 2m_{W}^{2} \right.$$

$$\left. \mp \left[ \left( |\mu|^{2} + |M_{2}|^{2} + 2m_{W}^{2} \right)^{2} - 4|\mu|^{2} |M_{2}|^{2} \right.$$

$$\left. - 4m_{W}^{4} \sin^{2} 2\beta + 8m_{W}^{2} \sin 2\beta \operatorname{Re}(\mu M_{2}) \right]^{1/2} \right\}, (3)$$

where the states are ordered such that  $M_{\widetilde{\chi}_1^+} \leq M_{\widetilde{\chi}_2^+}$ . If CP-violating effects are ignored (in which case,  $M_2$  and  $\mu$  are real

parameters), then one can choose a convention where  $\tan \beta$  and  $M_2$  are positive. (Note that the relative sign of  $M_2$  and  $\mu$  is meaningful. The sign of  $\mu$  is convention-dependent; the reader is warned that both sign conventions appear in the literature.) The sign convention for  $\mu$  implicit in Eq. (3) is used by the LEP collaborations [27] in their plots of exclusion contours in the  $M_2$ vs.  $\mu$  plane derived from the non-observation of  $Z \to \widetilde{\chi}_1^+ \widetilde{\chi}_1^-$ . The neutralino mass matrix depends on  $M_1$ ,  $M_2$ ,  $\mu$ ,  $\tan \beta$ ,  $m_Z$ , and the weak mixing angle  $\theta_W$  [26]. The corresponding neutralino eigenstates are usually denoted by  $\widetilde{\chi}_{i}^{0}$   $(i=1,\ldots 4)$ , according to the convention that  $M_{\widetilde{\chi}_1^0} \leq M_{\widetilde{\chi}_2^0} \leq M_{\widetilde{\chi}_3^0} \leq M_{\widetilde{\chi}_4^0}$ . If a chargino or neutralino eigenstate approximates a particular gaugino or Higgsino state, it may be convenient to use the corresponding nomenclature. For example, if  $M_1$  and  $M_2$  are small compared to  $m_Z$  (and  $\mu$ ), then the lightest neutralino  $\tilde{\chi}_1^0$ will be nearly a pure photino,  $\tilde{\gamma}$  (the supersymmetric partner of the photon).

It is common practice in the literature to reduce the supersymmetric parameter freedom by requiring that all three gaugino-mass parameters are equal at some grand unification scale. Then, at the electroweak scale, the gaugino-mass parameters can be expressed in terms of one of them (say,  $M_2$ ). The other two gaugino-mass parameters are given by

$$M_3 = (g_s^2/g^2)M_2$$
,  $M_1 = (5g'^2/3g^2)M_2$ . (4)

Having made this assumption, the chargino and neutralino masses and mixing angles depend only on three unknown parameters: the gluino mass,  $\mu$ , and  $\tan \beta$ . However, the assumption of gaugino-mass unification could prove false and must eventually be tested experimentally.

The supersymmetric partners of the quarks and leptons are spin-zero bosons: the squarks, charged sleptons, and sneutrinos. For a given fermion f, there are two supersymmetric partners  $\widetilde{f}_L$  and  $\widetilde{f}_R$  which are scalar partners of the corresponding left and right-handed fermion. (There is no  $\widetilde{\nu}_R$ .) However, in general,  $\widetilde{f}_L$  and  $\widetilde{f}_R$  are not mass-eigenstates since there is  $\widetilde{f}_L$ - $\widetilde{f}_R$  mixing which is proportional in strength to the corresponding element of the scalar mass-squared matrix [28]:

$$M_{LR}^2 = \begin{cases} m_d(A_d - \mu \tan \beta), & \text{for "down"-type } f \\ m_u(A_u - \mu \cot \beta), & \text{for "up"-type } f, \end{cases}$$
 (5)

where  $m_d$   $(m_u)$  is the mass of the appropriate "down" ("up") type quark or lepton. Here,  $A_d$  and  $A_u$  are (unknown) soft-supersymmetry-breaking A-parameters and  $\mu$  and  $\tan\beta$  have been defined earlier. The signs of the A parameters are also convention-dependent; see Ref. 19. Due to the appearance of the fermion mass in Eq. (5), one expects  $M_{LR}$  to be small compared to the diagonal squark and slepton masses, with the possible exception of the top-squark, since  $m_t$  is large, and the bottom-squark and tau-slepton if  $\tan\beta\gg 1$ .

The (diagonal) L- and R-type squark and slepton masses are given by [2]

$$M_{\widetilde{u}_I}^2 = M_{\widetilde{C}}^2 + m_u^2 + m_Z^2 \cos 2\beta (\frac{1}{2} - \frac{2}{3}\sin^2\theta_W)$$
 (6)

$$M_{\widetilde{\nu}_{R}}^{2} = M_{\widetilde{\nu}_{L}}^{2} + m_{u}^{2} + \frac{2}{3}m_{Z}^{2}\cos 2\beta \sin^{2}\theta_{W}$$
 (7)

$$M_{\widetilde{d}_L}^2 = M_{\widetilde{Q}}^2 + m_d^2 - m_Z^2 \cos 2\beta (\frac{1}{2} - \frac{1}{3}\sin^2\theta_W)$$
 (8)

$$M_{\widetilde{d}_{P}}^{2} = M_{\widetilde{P}}^{2} + m_{d}^{2} - \frac{1}{3}m_{Z}^{2}\cos 2\beta \sin^{2}\theta_{W}$$
 (9)

$$M_{\widetilde{\nu}}^2 = M_{\widetilde{L}}^2 + \frac{1}{2}m_Z^2 \cos 2\beta \tag{10}$$

$$M_{\widetilde{e_{I}}}^{2} = M_{\widetilde{I}}^{2} + m_{e}^{2} - m_{Z}^{2} \cos 2\beta (\frac{1}{2} - \sin^{2}\theta_{W})$$
 (11)

$$M_{\widetilde{e}_R}^2 = M_{\widetilde{E}}^2 + m_e^2 - m_Z^2 \cos 2\beta \sin^2 \theta_W \,.$$
 (12)

The soft-supersymmetry-breaking parameters:  $M_{\widetilde{Q}}$ ,  $M_{\widetilde{U}}$ ,  $M_{\widetilde{D}}$ ,  $M_{\widetilde{L}}$ , and  $M_{\widetilde{E}}$  are unknown parameters. In the equations above, the notation of first generation fermions has been used and generational indices have been suppressed. Further complications such as intergenerational mixing are possible, although there are some constraints from the nonobservation of flavor-changing neutral currents (FCNC) [29].

E. Reducing the MSSM parameter freedom: One way to guarantee the absence of significant FCNC's mediated by virtual supersymmetric-particle exchange is to posit that the diagonal soft-supersymmetry-breaking scalar squared-masses are universal in flavor space at some energy scale (normally taken to be at or near the Planck scale) [5,30,31]. Renormalization group evolution is used to determine the low-energy values for the scalar mass parameters listed above. This assumption substantially reduces the MSSM parameter freedom. For example, supersymmetric grand unified models with universal scalar masses at the Planck scale typically give [32]  $M_{\widetilde{L}} \approx M_{\widetilde{E}} < M_{\widetilde{O}} \approx$  $M_{\widetilde{I}I} \approx M_{\widetilde{D}}$  with the squark masses somewhere between a factor of 1-3 larger than the slepton masses (neglecting generational distinctions). More specifically, the first two generations are thought to be nearly degenerate in mass, while  $M_{\widetilde{O}_2}$  and  $M_{\widetilde{U}_2}$  are typically reduced by a factor of 1–3 from the other soft-supersymmetry-breaking masses because of renormalization effects due to the heavy top quark mass.

As a result, four flavors of squarks (with two squark eigenstates per flavor) and  $\widetilde{b}_R$  will be nearly mass-degenerate and somewhat heavier than six flavors of nearly mass-degenerate sleptons (with two per flavor for the charged sleptons and one per flavor for the sneutrinos). On the other hand, the  $\widetilde{b}_L$  mass and the diagonal  $\widetilde{t}_L$  and  $\widetilde{t}_R$  masses are reduced compared to the common squark mass of the first two generations. In addition, third generation squark masses and tau-slepton masses are sensitive to the strength of the respective  $\widetilde{f}_L - \widetilde{f}_R$  mixing as discussed below Eq. (5).

Two additional theoretical frameworks are often introduced to reduce further the MSSM parameter freedom [1,2,33]. The first involves grand unified theories (GUTs) and the desert

#### Supersymmetric Particle Searches

hypothesis (i.e no new physics between the TeV-scale and the GUT-scale). Perhaps one of the most compelling hints for lowenergy supersymmetry is the unification of  $SU(3) \times SU(2) \times U(1)$ gauge couplings predicted by supersymmetric GUT models [5,34] (with the supersymmetry breaking scale of order 1 TeV or below). The unification, which takes place at an energy scale of order 10¹⁶ GeV, is quite robust (and depends weakly on the details of the GUT-scale theory). For example, a recent analysis [35] finds that supersymmetric GUT unification implies that  $\alpha_s(m_Z) = 0.129 \pm 0.010$ , not including threshold corrections due to GUT-scale particles (which could diminish the value of  $\alpha_s(m_Z)$ ). This result is compatible with the world average of  $\alpha_s(m_Z) = 0.118 \pm 0.003$  as quoted by the Particle Data Group. In contrast, gauge coupling unification in the simplest nonsupersymmetric GUT models fails by many standard deviations [36].

Grand unification can impose additional constraints through the unification of Higgs-fermion Yukawa couplings  $(\lambda_f)$ . There is some evidence that  $\lambda_b = \lambda_\tau$  leads to good low-energy phenomenology [37], and an intriguing possibility that in the MSSM (in the parameter regime where  $\tan \beta \simeq m_t/m_b$ )  $\lambda_b = \lambda_\tau = \lambda_t$  may be phenomenologically viable [38]. However, such unification constraints are GUT-model dependent, and do not address the origin of the first and second generation fermion masses and the CKM mixing matrix. Finally, grand unification imposes constraints on the soft-supersymmetry-breaking parameters. For example, gaugino-mass unification leads to the relations given in Eq. (4). Diagonal squark and slepton soft-supersymmetry-breaking scalar masses may also be unified at the GUT scale (analogous to the unification of Higgs-fermion Yukawa couplings).

In order to further reduce the number of independent softsupersymmetry-breaking parameters (with or without grand unification), an additional simplifying assumption is required. In the minimal supergravity theory, the soft-supersymmetrybreaking parameters are often taken to have the following simple form. Referring to the parameter list given above Eq. (1), the Planck-scale values of the soft-supersymmetry-breaking terms depend on the following minimal set of parameters: (i) a universal gaugino mass  $m_{1/2}$ ; (ii) a universal diagonal scalarmass parameter  $m_0$  [whose consequences were described at the beginning of this section]; (iii) a universal A-parameter, A₀; and (iv) three scalar Higgs mass parameters—two common diagonal-squared masses given by  $|\mu_0|^2 + m_0^2$  and an off-diagonal-squared mass given by  $B_0\mu_0$  (which defines the Planck-scale supersymmetry-breaking parameter  $B_0$ ), where  $\mu_0$ is the Planck-scale value of the  $\mu$ -parameter.

As before, renormalization group evolution is used to compute the low-energy values of the supersymmetry-breaking parameters and determines the supersymmetric-particle spectrum. Moreover, in this approach, electroweak symmetry breaking is induced radiatively if one of the Higgs diagonal-squared masses is forced negative by the evolution. This occurs in models with a large Higgs-top quark Yukawa coupling  $(i.e. \text{ large } m_t)$ .

As a result, the two Higgs vacuum expectation values (or equivalently,  $m_Z$  and  $\tan \beta$ ) can be expressed as a function of the Planck-scale supergravity parameters. The simplest procedure [32] is to remove  $\mu_0$  and  $B_0$  in favor of  $m_Z$  and  $\tan \beta$  (the sign of  $\mu_0$  is not fixed in this process). In this case, the MSSM spectrum and its interactions are determined by  $m_0$ ,  $A_0$ ,  $m_{1/2}$ ,  $\tan \beta$ , and the sign of  $\mu_0$  (in addition to the parameters of the Standard Model). However, the minimal approach above is probably too restrictive. Theoretical considerations suggest that the universality of Planck-scale soft-supersymmetry breaking parameters is not generic [39]. In the absence of a fundamental theory of supersymmetry breaking, further progress will require a detailed knowledge of the supersymmetric-particle spectrum in order to determine the nature of the Planck-scale parameters. Of course, any of the theoretical assumptions described in this section could be wrong and must eventually be tested experimentally.

F. The MSSM and precision of electroweak data: The MSSM (with or without constraints imposed from the theory near the Planck scale) provides a framework that can be tested by precision electroweak data. The level of accuracy of the measured Z decay observables at LEP and SLC is sufficient to test the structure of the one-loop radiative corrections of the electroweak model [40], and is thus potentially sensitive to the virtual effects of undiscovered particles. Combining the most recent LEP and SLC electroweak results [41] with the recent topquark mass measurement at the Tevatron [42], a weak preference is found [41,43] for a light Higgs boson mass of order  $m_Z$ , which is consistent with the MSSM Higgs mass upper bound previously noted. Moreover, for Z decay observables, the effects of virtual supersymmetric-particle exchange are suppressed by a factor of  $m_Z^2/M_{\rm SUSY}^2$ , and therefore decouple in the limit of large supersymmetric-particle masses. It follows that for  $M_{\rm SUSY}^2 \gg$  $m_Z$  (in practice, it is sufficient to have all supersymmetricparticle masses above 200 GeV) the MSSM yields an equally good fit to the precision electroweak data as compared to the Standard Model fit.

On the other hand, there are a few tantalizing hints in the data for deviations from Standard Model predictions. Indeed, if  $R_b \equiv \Gamma(Z \to b\bar{b})/\Gamma(Z \to {\rm hadrons})$  is confirmed to lie above its Standard Model prediction due to the presence of new physics, then a plausible candidate for the new physics would be the MSSM with some light supersymmetric particles (e.g. a light chargino and top-squark and/or a light CP-odd scalar,  $A^0$ ) close in mass to their present LEP bounds [44,45]. Such a scenario would be tested by the search for supersymmetric particles at LEP-2 and the Tevatron.

G. Beyond the MSSM: Nonminimal versions of low-energy supersymmetry can also be constructed. These models add additional matter and/or gauge super-multiplets to the MSSM (at the TeV scale or below). Experimental and theoretical constraints place some restrictions on these approaches, although no comprehensive treatment has yet appeared in the literature.

# Searches Particle Listings Supersymmetric Particle Searches

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#### MINIMAL SUPERSYMMETRIC STANDARD MODEL ASSUMPTIONS

All results shown below (except where stated otherwise) are based on the Minimal Supersymmetric Standard Model (MSSM) as described in the Note on Supersymmetry. This includes the assumption that *R*-parity is conserved. In addition the following assumptions are made in most cases:

- 1) The  $\tilde{\chi}^0_1$  (or  $\tilde{\gamma})$  is the lightest supersymmetric particle (LSP).
- 2)  $m_{\widetilde{f_L}}=m_{\widetilde{f_R}}$  where  $\widetilde{f_L}$  and  $\widetilde{f_R}$  refer to the scalar partners of left-and right-handed fermions.

Limits involving different assumptions either are identified with comments or are in the miscellaneous section.

When needed, specific assumptions of the eigenstate content  $\underbrace{\widetilde{o}}_{}^{}$  neutralinos and charginos are indicated (use of the notation  $\tilde{\gamma}$  (photino),  $\tilde{H}$  (Higgsino),  $\widetilde{W}$  (w-ino), and  $\widetilde{Z}$  (z-ino) indicates the approximation of a pure state was

#### $\widetilde{\chi}_{1}^{0}$ (Lightest Neutralino) MASS LIMIT

 $\widetilde{\chi}_1^0$  is likely to be the lightest supersymmetric particle (LSP). See also the  $\widetilde{\chi}_2^0$ ,  $\widetilde{\chi}_3^0$ ,  $\widetilde{\chi}_4^0$  section below.

We have divided the  $\tilde{\chi}^0_1$  listings below into three sections: 1) Accelerator limits for  $ilde{\chi}_1^0$ , 2) Bounds on  $ilde{\chi}_1^0$  from dark matter searches, and 3) Other bounds on  $ilde{\chi}_1^0$  from astrophysics and cosmology.

#### Accelerator limits for $\tilde{\chi}_1^0$

These papers generally exclude regions in the  $M_2-\mu$  parameter plane based on accelerator experiments. Unless otherwise stated, these papers assume minimal supersymmetry and GUT relations (gaugino-mass unification condition).

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>23	95	¹ ACCIARRI	95E	L3	tan eta > 3
$\bullet$ $\bullet$ We do not	use the followi	ng data for average	s, fits	s, limits,	etc. • • •
≥ 0		² FRANKE	94	RVUE	$\widetilde{\chi}_1^0$ mixed with a singlet
>20	95	³ DECAMP			$tan \beta > 3$
>18.8		⁴ BAER	91	RVUE	tan eta > 1.6
>18.4	90			RVUE	
> (10-13)	90	⁶ ROSZKOWSK	90	RVUE	$taneta \ge 1$
>5	90	⁷ HEARTY	89	ASP	$\tilde{\gamma}$ ; for $m_{\tilde{e}} < 55$ GeV

- 1  ACCIARRI 95E limit for  $an\!eta$  >2 is 20 GeV, and the bound disappears if  $an\!eta$   $\sim$  1.
- $^2\,\mbox{FRANKE}$  94 reanalyzed the LEP constraints on the neutralinos in the MSSM with an additional singlet.
- 3  DECAMP 92 limit for tan $\beta$  >2 is m>13 GeV.  4  BAER 91 limit obtained from LEP and preliminary CDF results assuming tan $\beta$  > 1.6. ⁵ HIDAKA 91 limit obtained from LEP and preliminary CDF limits on the gluino mass (as analyzed in BAER 91).
- 6  ROSZKOWSKI 90 limit obtained from ALEPH and CDF/UA2 results assuming  $an\!eta \geq$
- 7 HEARTY 89 assumed pure  $\widetilde{\gamma}$  eigenstate and  $m_{\widetilde{e}_L}=m_{\widetilde{e}_R}$ . There is no limit for  $m_{\widetilde{e}_L}>$ 58 GeV. Uses  $e^+\,e^- 
  ightarrow ~\gamma \tilde{\gamma} \tilde{\gamma}$ . No GUT relation assumptions are made.

Bounds on  $\widetilde{\chi}_1^0$  from dark matter searches

These papers generally exclude regions in the  $M_2-\mu$  parameter plane assuming that  $\widetilde{\chi}^0_1$  is the dominant form of dark matter in the galactic halo. These limits are based on the lack of detection in laboratory experiments or by the absence of a signal in underground neturino detectors. The latter signal is expected if  $\widetilde{x}_1^0$  accumulates in the Sun or the Earth and annihilates into high-energy  $\nu$ 's.

DOCUMENT ID

<ul> <li>We do not use the following</li> </ul>	ng data for averages	, fits	, limits, etc. •	•
	⁸ MORI	93	KAMI	
		92	COSM	
	¹⁰ BOTTINO	91	RVUE	
	¹¹ GELMINI	91	COSM	
	12 KAMIONKOW.	.91	RVUE	
	¹³ MORI	<b>91</b> B	KAMI	
none 4-15 GeV	¹⁴ OLIVE	88	COSM	

- 8  MORI 93 excludes some region in  $M_2$ – $\mu$  parameter space depending on  $\tan\beta$  and lightest scalar Higgs mass for neutralino dark matter  $m_{\widetilde\chi 0} > m_W$ , using limits on upgoing muons produced by energetic neutrinos from neutralino annihilation in the Sun and the Earth.
- produced by energetic neutrinos from neutralino annihilation in the Sun and the Eartn.  9  BOTTINO 92 excludes some region  $M_{2^-\mu}$  parameter space assuming that the lightest neutralino is the dark matter, using upgoing muons at Kamiokande, direct searches by Ge detectors, and by LEP experiments. The analysis includes top radiative corrections on Higgs parameters and employs two different hypotheses for nucleon-Higgs coupling, Effects of rescaling in the local neutralino density according to the neutralino relic abundance are taken into account.  10  BOTTINO 91 excluded a region in  $M_2-\mu$  plane using upgoing muon data from Kamioka experiment, assuming that the dark matter surrounding us is composed of neutralinos and that the Higgs boson.  11  GFI.MINI 91 exclude a region in  $M_2-\mu$  plane using dark matter searches.
- 11 GELMINI 91 exclude a region in  $M_2-\mu$  plane using dark matter searches.
- 12  KAMIONKOWSKI 91 excludes a region in the  $M_2$ - $\mu$  plane using IMB limit on upgoing muons originated by energetic neutrinos from neutralino annihilation in the sun, assuming that the dark matter is composed of neutralinos and that  $m_{H_1^0} \lesssim$  50 GeV. See Fig. 8
- 13  MORI 91B exclude a part of the region in the  $M_2$ – $\mu$  plane with  $m_{\widetilde{\chi}^0_1}\lesssim 80$  GeV using a limit on upgoing muons originated by energetic neutrinos from neutralino annihilation in the earth, assuming that the dark matter surrounding us is composed of neutralinos and that  $m_{H_1^0} \lesssim 80$  GeV.
- 14  OLIVE 88 result assumes that photinos make up the dark matter in the galactic halo. Limit is based on annihilations in the sun and is due to an absence of high energy neutrinos detected in underground experiments. The limit is model dependent.

#### Other bounds on $\widetilde{\chi}_1^0$ from astrophysics and cosmology

Most of these papers generally exclude regions in the  $M_2$  -  $\mu$  parameter plane by requiring that the  $\tilde{\chi}^0_1$  contribution to the overall cosmological density is less than some maximal value to avoid overclosure of the Universe. Those not based on the cosmological density are indicated. Many of these papers also include LEP and/or other bounds.

VALUE DOCUMENT IDTECNCOMMENTSREDNICKI88COSM $\widetilde{\gamma}$ ;  $m_{\widetilde{\gamma}}$ =100 GeV none 100 eV - 15 GeV

• • We do not use the following	ıg d	lata for averages	, fits	, limits,	etc. • • •
	15	FALK	95	COSM	CP-violating phases
		DREES	93	COSM	Minimal supergravity
		FALK	93	COSM	Sfermion mixing
		KELLEY	93	COSM	Minimal supergravity
		MIZUTA	93	COSM	Co-annihilation
		ELLIS	92F	COSM	Minimal supergravity
		KAWASAKI	92	соѕм	Minimal supergravity, $m_0 = A = 0$
		LOPEZ	92	COSM	Minimal supergravity, $m_0 = A = 0$
		MCDONALD	92	COSM	
		NOJIRI	91	COSM	Minimal supergravity
	16	OLIVE	91	COSM	
		ROSZKOWSKI	91	COSM	
		ELLIS	90	COSM	
	17	GRIEST	90	COSM	
	18	GRIFOLS	90	ASTR	$\tilde{\gamma}$ ; SN 1987A
		KRAUSS	90	COSM	
		OLIVE	89	COSM	
> 100 eV	19	ELLIS	88B	ASTR	$\widetilde{\gamma}$ ; SN 1987A
none 100 eV - (5-7) GeV		SREDNICKI	88	COSM	$\tilde{\gamma}$ ; $m_{\tilde{f}}$ =60 GeV
none 100 eV-5 GeV		ELLIS	84	COSM	$\tilde{\gamma}$ ; for $m_{\tilde{f}} = 100 \text{ GeV}$
		GOLDBERG	83	COSM	$\widetilde{\gamma}$
	20	KRAUSS	83	COSM	$\widetilde{\gamma}$
		VYSOTSKII	83	COSM	$\widetilde{\gamma}$

- 15  Mass of the bino (=LSP) is limited to  $m_{\widetilde{B}}\lesssim 350$  GeV for  $m_t=174$  GeV.  16  Mass of the bino (=LSP) is limited to  $m_{\widetilde{B}}\lesssim 350$  GeV for  $m_t\leq 200$  GeV. Mass of the higgsino (=LSP) is limited to  $m_{\widetilde{H}} \lesssim 1$  TeV for  $m_t \leq 200$  GeV.
- 17  Mass of the bino (=LSP) is limited to  $m_{\widetilde{B}} \lesssim$  550 GeV. Mass of the higgsino (=LSP) is limited to  $m_{\widetilde{H}} \lesssim$  3.2 TeV.
- 18  GRIFOLS 90 argues that SN1987A data exclude a light photino (  $\lesssim 1$  MeV) if  $m_{\widetilde{a}} < 1.1$ TeV,  $m_{\widetilde{e}}$  < 0.83 TeV.
- 19  ELLIS 888 argues that the observed neutrino flux from SN 1987A is inconsistent with a light photino if 60 GeV  $\lesssim m_{\widetilde{q}} \lesssim 2.5$  TeV. If  $m({\rm higgsino})$  is O(100 eV) the same argument leads to limits on the ratio of the two Higgs v.e.v.'s. LAU 93 discusses possible relations of ELLIS 88B bounds.
- $_{20}$  KRAUSS 83 finds  $m_{\widetilde{\gamma}}$  not 30 eV to 2.5 GeV. KRAUSS 83 takes into account the gravitino decay. Find that limits depend strongly on reheated temperature. For example a new allowed region  $m_{\widetilde{\gamma}}=$  4–20 MeV exists if  $m_{\rm gravitino}$  <40 TeV. See figure 2.

 $\widetilde{X}_{2}^{0}$ ,  $\widetilde{X}_{3}^{0}$ ,  $\widetilde{X}_{4}^{0}$  (Neutralinos) MASS LIMITS

Neutralinos are unknown mixtures of photinos, z-inos, and neutral higgsinos (the supersymmetric partners of photons and of Z and Higgs bosons). The limits here apply only to  $\widetilde{X}_{2}^{0}$ ,  $\widetilde{X}_{3}^{0}$ , and  $\widetilde{X}_{4}^{0}$ .  $\widetilde{X}_{1}^{0}$  is the lightest supersymmetric particle (LSP); see  $\widetilde{X}_{1}^{0}$  Mass Limits. It is not possible to quote rigorous mass limits because they are extremely model dependent; i.e. they depend on branching ratios of various  $\widetilde{X}_{1}^{0}$  decay modes, on the masses of decay products  $(\widetilde{e}, \widetilde{\gamma}, \widetilde{q}, \widetilde{g})$ , and on the  $\widetilde{e}$  mass exchanged is  $(\widetilde{e}, \widetilde{\gamma}, \widetilde{q}, \widetilde{g})$ . The masses of decay products  $(\widetilde{e}, \widetilde{\gamma}, \widetilde{q}, \widetilde{g})$  and on the  $\widetilde{e}$  mass exchanged is  $(\widetilde{e}, \widetilde{q}, \widetilde{q}, \widetilde{g})$ . in  $e^+e^- o \widetilde{\chi}^0_i \widetilde{\chi}^0_i$ . Often limits are given as contour plots in the  $m_{\widetilde{\chi}0}-m_{\widetilde{e}}$  plane vs other parameters. When specific assumptions are made, e.g, the neutralino is a pure photino  $(\widetilde{\gamma})$ , pure z-ino  $(\widetilde{Z})$ , or pure neutral higgsino  $(\widetilde{H}^0)$ , the neutralinos will be labelled as such.

be labelled a				
VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
> 52	95	²¹ ACCIARRI	95E L3	$\tilde{\chi}_{2}^{0}$ , tan $\beta > 3$
> 84	95	²¹ ACCIARRI	95E L3	$\widetilde{\chi}_{3}^{0}$ , tan $\beta >$ 3
>127	95	²¹ ACCIARRI	95E L3	$\tilde{\chi}_{m{4}}^{m{0}}$ , tan $eta >$ 3
<ul> <li>• • We do not ι</li> </ul>	ise the followi	ing data for average	s, fits, limits	, etc. • • •
		22 ABACHI	96 D0	$\rho \overline{\rho} \rightarrow \widetilde{\chi}_1^{\pm} \widetilde{\chi}_2^0$
> 45	95	²³ DECAMP		$\tilde{\chi}_{2}^{0}$ , $\tan \beta > 3$
> 45	95	²⁴ HIDAKA	91 RVUE	$\tilde{\chi}_{2}^{\bar{0}}$
> 70	95	²⁴ HIDAKA	91 RVUE	$\tilde{\chi}_{3}^{0}$
>108	95	²⁴ HIDAKA	91 RVUE	$\tilde{\chi}_{4}^{0}$
		²⁵ ABREU		$Z \rightarrow \widetilde{\chi}^0 \widetilde{\chi}^0$
		²⁶ AKRAWY	90N OPAL	$Z \rightarrow \widetilde{\chi}^0 \widetilde{\chi}^0$
> 57	90	²⁷ BAER	90 RVUE	$\tilde{\chi}_{3}^{0}$ ; $\Gamma(Z)$ ; $\tan \beta > 1$
		²⁸ BARKLOW	90 MRK2	$ \begin{array}{ccc} z & \to & \widetilde{\chi}_1^0  \widetilde{\chi}_2^0,  \widetilde{\chi}_2^0  \widetilde{\chi}_2^0 \\ z & \to & \widetilde{\chi}_1^0  \widetilde{\chi}_2^0 \end{array} $
		²⁹ DECAMP	90K ALEP	$Z \rightarrow \widetilde{\chi}^{\dagger}\widetilde{\chi}^{\dagger}$
> 41	95	³⁰ SAKAI	90 AMY	$e^+e^- \rightarrow \tilde{H}_1^0 \tilde{H}_2^0$
				$(\widetilde{H}_{2}^{0} \rightarrow f^{\frac{1}{7}}\widetilde{H}_{1}^{0})$
> 31	95	31 BEHREND	87B CELL	$e^+e^- \rightarrow \tilde{\gamma}\tilde{Z}$
				$(\widetilde{Z} \rightarrow q \overline{q} \widetilde{\gamma}), m_{\widetilde{e}} <$
> 30	95	32 BEHREND	878 CELL	$e^{+} \stackrel{70}{e^{-}} \rightarrow \tilde{\gamma} \tilde{Z}$
, <del>, , , , , , , , , , , , , , , , , , </del>	,,	SERENO	0.5 0000	$(\widetilde{Z} \rightarrow q\overline{q}\widetilde{g})$

> 31.3	95	³³ BEHREND	87B CELL $e^+e^- \rightarrow \widetilde{H}_1^0 \widetilde{H}_2^0$
> 22	95	³⁴ BEHREND	$(\widetilde{H}_2^0  o f \widetilde{7} \widetilde{H}_1^0)$ 87B CELL $e^+e^-  o \gamma \widetilde{\gamma} \widetilde{Z}$
		35 AKERLOF	85 HRS $e^+e^- \rightarrow \widetilde{\gamma}\widetilde{\chi}^0$
none 1-21	95	³⁶ BARTEL	$\begin{array}{ccc} (\widetilde{\chi}^0 \to q \overline{q} \widetilde{\gamma}) \\ \text{85L JADE} & e^+ e^- \to \widetilde{H}_1^0 \widetilde{H}_2^0, \\ \widetilde{\chi}^0 & \widetilde{q} \widetilde{\chi}^0 \end{array}$
		37 BEHREND	$\widetilde{H}_2^0 \rightarrow f \overline{f}  \widetilde{H}_1^0$ 85 CELL $e^+e^- \rightarrow \text{monojet X}$
> 35	95	³⁸ ADEVA	84B MRKJ $e^+e^- \rightarrow \gamma \tilde{Z}$
> 28	95	39 BARTEL	$(\widetilde{Z}  ightarrow \ell \overline{\ell} \widetilde{\gamma})$ 84C JADE $e^+e^-  ightarrow \gamma \widetilde{Z}$
		⁴⁰ ELLIS	$(\widetilde{Z} \rightarrow f \overline{f} \widetilde{\gamma})$ 84 COSM

- 21  ACCIARRI 95E limits go down to 0 GeV  $(\widetilde{\chi}^0_2)$ , 60 GeV  $(\widetilde{\chi}^0_3)$ , and 90 GeV  $(\widetilde{\chi}^0_4)$  for  $\tan\!\beta=1$ .
- ²²ABACHI 96 searches for 3-lepton final states. Efficiencies are calculated using mass relations and branching ratios in the Minimal Supergravity scenario. Results are presented as lower bounds on  $\sigma(\widetilde{X}_1^{\pm}\widetilde{X}_2^0) \times B(\widetilde{X}_1^{\pm} \rightarrow \ell\nu_\ell\widetilde{X}_1^0) \times B(\widetilde{X}_2^0 \rightarrow \ell^+\ell^-\widetilde{X}_2^0)$  as a function of  $m_{\widetilde{\chi}_1^0}$ . Limits range from 3.1 pb  $(m_{\widetilde{\chi}_1^0} = 45 \text{ GeV})$  to 0.6 pb  $(m_{\widetilde{\chi}_1^0} = 100 \text{ GeV})$ .
- ²³ For  $tan\beta > 2$  the limit is >40 GeV; and it disappears for  $tan\beta < 1.6$
- 24 HIDAKA 91 limit obtained from LEP and preliminary CDF limits on the gluino mass (as analyzed in BAER 91).
- ²⁵ABREU 90G exclude B( $Z \to \widetilde{\chi}_1^0 \widetilde{\chi}_2^0$ )  $\geq 10^{-3}$  and B( $Z \to \widetilde{\chi}_2^0 \widetilde{\chi}_2^0$ )  $\geq 2 \times 10^{-3}$ assuming  $\tilde{\chi}^0_2 \to \tilde{\chi}^0_1 f \overline{f}$  via virtual Z. These exclude certain regions in model parameter space, see their Fig. 5.
- space, see their rig. 5.  $26\,\mathrm{AKRAWY}$  90N exclude B( $Z \to \tilde{\chi}^0_1\tilde{\chi}^0_2$ )  $\gtrsim 3-5 \times 10^{-4}$  assuming  $\tilde{\chi}^0_2 \to \tilde{\chi}^0_1f\bar{f}$  or  $\tilde{\chi}^0_1\gamma^0_1f\bar{f}$  or  $\tilde{\chi}^0_1f\bar{f}$  or  $\tilde{\chi}^0_1f\bar{f}$
- 27  BAER 90 is independent of decay modes. Limit from analysis of supersymmetric parameter space restrictions implied by  $\Delta\Gamma(Z) < 120$  MeV. These result from decays of Z to all combinations of  $\tilde{\chi}_i^{\pm}$  and  $\tilde{\chi}_i^0$ . Minimal supersymmetry with  $\tan\beta>1$  is assumed.
- 28 See Figs. 4, 5 in BARKLOW 90 for the excluded regions.

  29 DECAMP 90κ exclude certain regions in model parameter space, see their figures.
- 30 SAKAI 90 assume  $m_{\widetilde{H}_1^0}=0$ . The limit is for  $m_{\widetilde{H}_2^0}$ .
- ³¹ Pure  $\tilde{\gamma}$  and pure  $\tilde{Z}$  eigenstates. B( $\tilde{Z} \to q \bar{q} \tilde{\gamma}$ ) = 0.60 and B( $\tilde{Z} \to e^+ e^- \tilde{\gamma}$ ) = 0.13.  $m_{\tilde{E}_l} = m_{\tilde{E}_R} < 70$  GeV.  $m_{\tilde{\gamma}} < 10$  GeV.
- ³² Pure higgsino. The LSP is the other higgsino and is taken massless. Limit degraded if  $\widetilde{\chi}^0$  not pure higgsino or if LSP not massless.
- 34 Pure  $\tilde{\gamma}$  and pure  $\tilde{Z}$  eigenstates. B( $\tilde{Z} \rightarrow \tilde{\nu}\nu$ ) = 1.  $m_{\tilde{e}_L} = m_{\tilde{e}_R} = 26$  GeV.  $m_{\tilde{\gamma}} = 10$ GeV. No excluded region remains for  $m_{\widetilde{e}}~>$ 30 GeV.
- 35 AKERLOF 85 is  $e^+e^-$  monojet search motivated by UA1 monojet events. Observed only one event consistent with  $e^+e^-\to \gamma+\tilde{\chi}^0$  where  $\tilde{\chi}^0\to$  monojet. Assuming that missing- $p_T$  is due to  $\tilde{\gamma}$ , and monojet due to  $\tilde{\chi}^0$ , limits dependent on the mixing and  $m_{\widetilde{e}}$  are given, see their figure 4.
- ³⁶BARTEL 85L assume  $m_{\widetilde{H}_1^0}=0$ ,  $\Gamma(Z o \widetilde{H}_1^0\widetilde{H}_2^0)\gtrsim rac{1}{2}\;\Gamma(Z o 
  u_e\overline{
  u}_e)$ . The limit is
- 37  BEHREND 85 find no monojet at  $E_{
  m cm}=$  40–46 GeV. Consider  $\widetilde{\chi}^0$  pair production via  $Z^0$ . One is assumed as massless and escapes detector. Limit is for the heavier one, decaying into a jet and massless  $\widetilde{\chi}^0$ . Both  $\widetilde{\chi}^0$ 's are assumed to be pure higgsino. For these very model-dependent results, BEHREND 85 excludes m=1.5–1.9.5 GeV.
- 38  ADEVA 84s observed no events with signature of acoplanar lepton pair with missing energy. Above example limit is for  $m_{\widetilde{\gamma}}$  <2 GeV and  $m_{\widetilde{e}}$  <40 GeV, and assumes
- B( $\widetilde{Z} \to \mu^+ \mu^- \widetilde{\gamma}) = B(\widetilde{Z} \to e^+ e^- \widetilde{\gamma})^-$  0.10. BR = 0.05 gives 33.5 GeV limit. ³⁹ BARTEL 84C search for  $e^+ e^- \to \widetilde{Z} + \widetilde{\gamma}$  with  $\widetilde{Z} \to \widetilde{\gamma} + e^+ e^-$ ,  $\mu^+ \mu^-$ ,  $q\overline{q}$ , etc. They see no acoplanar events with missing- $p_{\widetilde{T}}$  due to two  $\widetilde{\gamma}$ 's. Above example limit is for  $m_{\widetilde{e}}$ = 40 GeV and for light stable  $\widetilde{\gamma}$  with B( $\widetilde{Z} 
  ightarrow e^+e^-\widetilde{\gamma}$ ) = 0.1.
- ⁴⁰ ELLIS 84 find if lightest neutralino is stable, then  $m_{\widetilde{\chi}0}$  not 100 eV 2 GeV (for  $m_{\widetilde{q}}=$ 40 GeV). The upper limit depends on  $m_{\widetilde{q}}$  (similar to the  $\widetilde{\gamma}$  limit) and on nature of  $\widetilde{\chi}^0$ . For pure higgsino the higher limit is 5 GeV.

#### $\tilde{\chi}_{1}^{\pm}$ , $\tilde{\chi}_{2}^{\pm}$ (Charginos) MASS LIMITS

Charginos  $(\widetilde{\chi}^{\pm}$ 's) are unknown mixtures of w-inos and charged higgsinos (the supersymmetric partners of W and Higgs bosons). Mass limits are relatively model dependent, so assumptions concerning branching ratios need to be specified. When specific assumptions are made, e.g. the chargino is a pure w-ino  $(\widetilde{W})$  or pure charged higgsino  $(\widetilde{H}^\pm)$ , the charginos will be labelled as such.

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>44.0	95	⁴¹ ADRIANI	93M L3	$Z \rightarrow \tilde{\chi}^+ \tilde{\chi}^-, \Gamma(Z)$
>45.2	95	42 DECAMP	92 ALEP	$Z \rightarrow \widetilde{\chi}^+ \widetilde{\chi}^-$ , all $m_{\widetilde{\chi}0}$
>47	95	⁴² DECAMP	92 ALEP	$Z  o \widetilde{\chi}^+ \widetilde{\chi}^-$ , $m_{\widetilde{\chi}^0_1} < 41 \text{ GeV}$
>99	95	⁴³ HIDAKA	91 RVUE	$\tilde{\chi}_2^{\pm}$
>44.5	95	⁴⁴ ABREU		$Z \xrightarrow{\widetilde{\chi}} \widetilde{\chi}^+ \widetilde{\chi}^-, m_{\widetilde{\chi}} < 20 \text{ GeV}$
>45	95	⁴⁵ AKRAWY	90D OPAL	$e^+e^- \xrightarrow{\gamma} \widetilde{\chi}^+\widetilde{\chi}^-; m_{\widetilde{\gamma}}^- < 20 \text{ GeV}$

#### Supersymmetric Particle Searches

• •	٠	We do not a	use the	following	data fo	r averages,	fits,	limits, etc.	٠	٠	٠	
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		⁴⁶ ABACHI	96 D0	$\rho \overline{\rho} \rightarrow \widetilde{\chi}_1^{\pm} \widetilde{\chi}_2^0$
		⁴⁷ DATTA	92 RVUE	$Z \rightarrow \tilde{\chi}^{+}\tilde{\chi}^{-}, \tilde{\chi}^{0}\tilde{\chi}^{0}$
>43	90	⁴⁸ DREES	91 RVUE	$\tilde{\chi}_1^{\pm}$
>45	95	ABREU	90G DLPH	Stable $\tilde{\chi}^{\pm}$ , $\tilde{\chi}^{+}\tilde{\chi}^{-}$
>28.2	95	ADACHI	90c TOPZ	Stable $\tilde{\chi}^{\pm}$ , $\tilde{\chi}^{+}\tilde{\chi}^{-}$
>45	95	⁴⁹ AKESSON	90B UA2	$p\overline{p} \rightarrow ZX$
				$(Z \rightarrow \widetilde{W}^+ \widetilde{W}^-)$
>37	90	⁵⁰ BAER		$\Gamma(Z)$ ; tan $\beta > 1$
>45	95	⁵¹ BARKLOW	90 MRK2	$Z \rightarrow \widetilde{W}^+ \widetilde{W}^-$
>42	95	⁵² BARKLOW	90 MRK2	$Z \rightarrow \widetilde{H}^+ \widetilde{H}^-$
>44.5	95	⁵³ DECAMP	90c ALEP	$e^+e^- \rightarrow \tilde{\chi}^+\tilde{\chi}^-$ ;
				$m_{\widetilde{\gamma}} <$ 28 GeV
>25.5	95	⁵⁴ ADACHI	89 TOPZ	$e^+e^- \rightarrow \tilde{\chi}^+\tilde{\chi}^-$
>44	95	⁵⁵ ADEVA	89B L3	$e^+e^- \rightarrow \widetilde{W}^+\widetilde{W}^-$
				$\widetilde{W} \rightarrow \ell \widetilde{\nu} \text{ or } \ell \nu \widetilde{\gamma}$
>45	90	⁵⁶ ANSARI	87D UA2	$p\overline{p} \rightarrow ZX$
				$(Z \rightarrow \widetilde{W}^+\widetilde{W}^-, \widetilde{W}^\pm \rightarrow e^\pm \widetilde{\nu})$
>40		⁵⁷ BAER	87B RVUE	$p\overline{p} \rightarrow W/ZX$
				$(W/Z \rightarrow \widetilde{W}, \widetilde{Z}, \widetilde{\gamma})$
				$\gamma$ )

- ⁴¹ ADRIANI 93M limit from  $\Delta\Gamma(Z)$ < 35.1 MeV. For pure wino, the limit is 45.5 GeV.
- ⁴² DECAMP 92 limit is for a general  $\tilde{\chi}^{\pm}$  (all contents).
- 43 HIDAKA 91 limit obtained from LEP and preliminary CDF limits on the gluino mass (as analyzed in BAER 91).
- ⁴⁴ ABREU 90G limit is for a general  $\widetilde{\chi}^{\pm}$ . They assume charginos have a three-body decay
- 45 AKRAWY 90D assume charginos have three-body decay such as  $\ell^+ \, \nu \, \widetilde{\gamma}$  (i.e.  $m_{\widetilde{
  u}} > m_{\widetilde{\chi}+}$ ).

A two-body decay,  $\tilde{\chi}^+ \to \ell \tilde{\nu}$  would have been seen by their search for acoplanar leptons. The result is independent of the hadronic branching ratio. They search for acoplanar electromagnetic clusters and quark jets.

- electromagnetic clusters and quark jets. 46 ABACHI 96 searches for 3-lepton final states. Efficiencies are calculated using mass relations and branching ratios in the Minimal Supergravity scenario. Results are presented as lower bounds on  $\sigma(\widetilde{\chi}_1^{\pm}\widetilde{\chi}_2^0) \times B(\widetilde{\chi}_1^{\pm} \to \ell\nu_{\ell}\widetilde{\chi}_1^0) \times B(\widetilde{\chi}_2^0 \to \ell^{\pm}\ell^{-}\widetilde{\chi}_1^0)$  as a function of  $m_{\widetilde{\chi}_1^0}$ . Limits range from 3.1 pb  $(m_{\widetilde{\chi}_1^0} = 45~{\rm GeV})$  to 0.6 pb  $(m_{\widetilde{\chi}_1^0} = 100~{\rm GeV})$ . See Fig. 3 for some explicit mass limits as a function of parameters. 47 DATTA 92 avolude some regions in chargino-gluino mass plane from LEP experiments.
- $^{
  m 47\,DATTA}$  92 exclude some regions in chargino-gluino mass plane from LEP experiments.
- **B DREES 91 limit obtained from LEP results within minimal supersymmetry with gauginomass unification condition. They make use of DECAMP 90c analysis plus additional constraint from total Z width. The bound can only be evaded if the chargino mixes with other charged singlets or with gauginos of a right-handed gauge group.

  49 AKESSON 908 assume  $\widetilde{W} \to e\widetilde{\nu}$  with B > 20% and  $m_{\widetilde{\nu}} = 0$ . The limit disappears if  $m_{\widetilde{\nu}} = 0$ . 30 GeV
- 50  BAER 90 is independent of decay modes. Limit from analysis of supersymmetric parameter space restrictions implied by  $\Delta\Gamma(Z)<120$  MeV. These result from decays of Z to all combinations of  $\widetilde{\chi}_i^\pm$  and  $\widetilde{\chi}_j^0$  . Minimal supersymmetry with  $an\!eta>1$  is assumed.
- 51 BARKLOW 90 assume 100%  $\widetilde{W} \to W^* \widetilde{\chi}_1^0$ . Valid up to  $m_{\widetilde{\chi}_1^0} \lesssim [m_{\widetilde{W}} 5 \text{ GeV}]$ . 52 BARKLOW 90 assume 100%  $\widetilde{H} \to H^* \widetilde{\chi}_1^0$ . Valid up to  $m_{\widetilde{\chi}_1^0} \lesssim [m_{\widetilde{H}} 8 \text{ GeV}]$ .
- 53  DECAMP 90C assume charginos have three-body decay such as  $\ell^+ \nu \widetilde{\gamma}$  (i.e.  $m_{\widetilde{\nu}} > m_{\widetilde{\chi}^+}$ ), and branching ratio to each lepton is 11%. They search for acoplanar dimuons, dielectrons, and  $\mu \, e$  events. Limit valid for  $m_{\widetilde{\gamma}} \, < \,$  28 GeV.
- ⁵⁴ ADACHI 89 assume only single photon annihilation in the production. The limit applies for arbitrary decay branching ratios with  $B(\widetilde{X} \to e \nu \widetilde{\gamma}) + B(\widetilde{X} \to \mu \nu \widetilde{\gamma}) + B(\widetilde{X} \to \tau \nu \widetilde{\gamma}) + B(\widetilde{X} \to q \overline{q} \widetilde{\gamma}) = 1$  (lepton universality is *not* assumed). The limit is for  $m_{\widetilde{\gamma}} =$ 0 but a very similar limit is obtained for  $m_{\widetilde{\gamma}}=$  10 GeV. For B $(\widetilde{\chi}\to~q~\overline{q}\,\widetilde{\gamma})=$  1, the limit
- increases to 27.8 GeV. 55 ADEVA 89B assume for  $\ell\nu\tilde{\gamma}$  ( $\ell\tilde{\nu}$ ) mode that B(e) = B( $\mu$ ) = B( $\tau$ ) = 11% (33%) and search for acoplanar dimuons, dielectrons, and  $\mu e$  events. Also assume  $m_{\tilde{\gamma}} <$  20 GeV and for  $\ell \widetilde{\nu}$  mode that  $m_{\widetilde{\nu}}=$  10 GeV.
- ⁵⁶ ANSARI 87D looks for high  $ho_{\mathcal{T}}$   $e^+e^-$  pair with large missing  $ho_{\mathcal{T}}$  at the CERN  $ho_{\mathcal{D}}$ collider at  $E_{\rm cm}=$  546–630 GeV. The limit is valid when  $m_{\widetilde{\nu}}\lesssim$  20 GeV,  ${\rm B}(\widetilde{W}\to e\widetilde{\nu}_e)$
- collider at  $E_{CM} = 546-530$  GeV. The limit is valid when  $m_{\widetilde{\nu}} \gtrsim 20$  GeV, B( $W \rightarrow e V_e$ ) = 1/3, and B( $Z \rightarrow \widetilde{W}^+\widetilde{W}^-$ ) is calculated by assuming pure gaugino eigenstate. See their Fig. 3(b) for excluded region in the  $m_{\widetilde{W}} m_{\widetilde{\nu}}$  plane.

  57 BAER 878 argue that the charged heavy lepton mass limit of 41 GeV obtained by UA1 collaboration (ALBAJAR 878) corresponds to the mass limit of 40 GeV under the assumptions that the LSP (photino) has a mass smaller than 8 GeV and that the gaugino-bird of the properties of the contraction of the properties of the contraction of the contracti higgsino mixing is parametrized by the three minimal supergravity model parameters. In grand unified theories  $m_{\widetilde{\gamma}} < 8$  implies  $m_{\widetilde{g}} < 50$  GeV. For larger gluino masses, this limit can be evaded as discussed in BAER 88.

#### $\tilde{\nu}$ (Sneutrino) MASS LIMIT

The limit depends on the number,  $N(\widetilde{
u})$ , of sneutrinos assumed to be degenerate in mass. Only  $\tilde{\nu}_L$  (not  $\tilde{\nu}_R$ ) exist. It is possible that  $\tilde{\nu}$  could be the lightest supersymmetric particle (LSP).

VALUE (GeV)	CL%	DOCUMENT ID TECN COMMENT
> 41.8	95	⁵⁸ ADRIANI 93M L3 $\Gamma(Z \rightarrow \text{invisible}); N(\widetilde{\nu})=3$
> 37.1	95	⁵⁸ ADRIANI 93M L3 $\Gamma(Z \rightarrow \text{invisible}); N(\tilde{\nu})=1$
> 41	95	⁵⁹ DECAMP 92 ALEP $\Gamma(Z \rightarrow \text{invisible}); N(\tilde{\nu})=3$
> 36	95	ABREU 91F DLPH $\Gamma(Z \rightarrow \text{invisible}); N(\tilde{\nu})=1$
> 32	95	60 ABREU 91F DLPH $\Gamma(Z)$ ; $N(\tilde{\nu})=1$
> 31.2	95	⁶¹ ALEXANDER 91F OPAL $\Gamma(Z \rightarrow \text{invisible}); N(\tilde{\nu})=1$

> 46.0	95	62 BUSKULIC	95E	ALEP	$N(\widetilde{\nu})=1, \ \widetilde{\nu} \rightarrow \nu \nu \ell \overline{\ell}'$
none 20-250	00	63 BECK	94	COSM	Stable $\tilde{\nu}$ , dark matter
<600		64 FALK	94	COSM	$\widetilde{ u}$ LSP, cosmic abundance
> 38.4	90	⁶⁵ DREES	91	RVUE	$\Gamma(Z); N(\widetilde{\nu})=3$
> 28.9	90	⁶⁵ DREES	91	RVUE	$\Gamma(Z); N(\widetilde{\nu})=1$
none 3-90	90	⁶⁶ SATO	91	KAMI	Stable $\tilde{\nu}_e$ or $\tilde{\nu}_\mu$ ,
none 4-90	90	⁶⁶ SATO	91	KAMI	dark matter Stable $\widetilde{\nu}_{ au}$ , dark matter
> 31.4	95	⁶⁷ ADEVA	901	L3	$\Gamma(Z \rightarrow \text{invisible}); N(\widetilde{\nu})=1$
> 39.4	95	⁶⁷ ADEVA	901	L3	$\Gamma(Z \to \text{invisible}); N(\widetilde{\nu})=3$
> 36.5	90	⁶⁸ BAER	90	RVUE	$\Gamma(Z); N(\widetilde{\nu})=3$

- ⁵⁸ ADRIANI 93M limit from  $\Delta\Gamma(Z)$ (invisible)< 16.2 MeV.
- 59  DECAMP 92 limit is from  $\Gamma(\text{invisible})/\Gamma(\ell\ell)=5.91\pm0.15$  (  $\textit{N}_{\nu}=2.97\pm0.07$  ).
- $^{60}\,\mathrm{ABREU}$  91F limit (>32 GeV) is independent of sneutrino decay mode
- 61 ALEXANDER 91F limit is for one species of  $\widetilde{\nu}$  and is derived from  $\Gamma(\text{invisible, new})/\Gamma(\ell\ell)$
- 62 BUSKULIC 95E looked for  $Z \to \widetilde{\nu}\widetilde{\nu}$ , where  $\widetilde{\nu} \to \nu \chi_1^0$  and  $\chi_1^0$  decays via R-parity violating interactions into two leptons and a neutrino.
- following interactions into two reprints and a neutrino. Since the first section of the firs
- ⁶⁴ FALK 94 puts an upper bound on  $m_{\widetilde{
  u}}$  when  $\widetilde{
  u}$  is LSP by requiring its relic density does
- not overclose the Universe. 65 DREES 91 limits from  $\Delta\Gamma(Z)$  (nonhadronic) < 38.3 MeV. Independent of decay modes. Minimal supersymmetry assumed.
- Minimal supersymmetry assumed. 66 SATO 91 search for high-energy neutrinos from the sun produced by annihilation of sneutrinos in the sun. Sneutrinos are assumed to be stable and to constitute dark matter in our galaxy. SATO 91 follow the analysis of NG 87, OLIVE 88, and GAISSER 86. 67 ADEVA 901 limit is from  $\Delta N_{\nu} < 0.19$ . 68 BAER 90 limit from  $\Delta \Gamma(Z)$  (nonhadronic) < 53 MeV. Independent of decay modes. Mininal supersymmetry assumed. The 95%CL bound is 35.6 GeV.

#### e (Selectron) MASS LIMIT

Limits assume  $m_{\widetilde{e}_L} = m_{\widetilde{e}_R}$  unless otherwise stated.

e _L	- ''' e	R ""	icaa otiici wiac at	accu		
VALUE (GeV)	CL%		DOCUMENT ID		TECN	COMMENT
> 45	95	69	ADRIANI	93м	L3	$m_{\widetilde{\chi}_1^0}$ <40 GeV, $\widetilde{e}^+\widetilde{e}^-$
> 45	95	70	DECAMP	92	ALEP	$m_{\widetilde{\chi}_1^0}^{-1}$ <41 GeV, $\widetilde{e}^+\widetilde{e}^-$
> 50	95		HEARTY	89	ASP	$m_{\widetilde{\gamma}}$ <5 GeV; $\gamma \widetilde{\gamma} \widetilde{\gamma}$
• • • We do not use the	followi	ng d	ata for averages	, fits	, limits,	etc. • • •
> 45.6	95	71	BUSKULIC	95E	ALEP	$\tilde{e} \rightarrow e \nu \ell \bar{\ell}'$
> 51.9	90		HOSODA	94	VNS	$m_{\widetilde{\gamma}}=0; \gamma \widetilde{\gamma} \widetilde{\gamma}$
> 72.6	90	72	HOSODA	94	RVUE	$m_{\widetilde{\gamma}} = 0; \ \gamma \ \widetilde{\gamma} \ \widetilde{\gamma}$
> 42	95		ABREU	<b>9</b> 0G	DLPH	$m_{\widetilde{\gamma}}$ < 40 GeV; $\widetilde{e}^+\widetilde{e}^-$
> 38	95	73	AKESSON	<b>9</b> 0B	UA2	$m_{\widetilde{\gamma}}'=0; p\overline{p} \rightarrow ZX$
						$(Z \rightarrow \tilde{e}^+\tilde{e}^-)$
> 43.4	95		AKRAWY	<b>9</b> 0D	OPAL	$m_{\widetilde{\gamma}} <$ 30 GeV; $\widetilde{e}^+\widetilde{e}^-$
> 38.1	90		BAER	90	RVUE	$\tilde{e}_L$ ; $\Gamma(Z)$ ; $\tan \beta > 1$
> 43.5	95	76	DECAMP	<b>9</b> 0C	ALEP	$m_{\widetilde{\gamma}} <$ 36 GeV; $\widetilde{e}^+\widetilde{e}^-$
>830			GRIFOLS	90	ASTR	$m_{\widetilde{\gamma}}$ < 1 MeV
> 29.9	95		SAKAI	90	AMY	$m_{\widetilde{\gamma}}$ < 20 GeV; $\widetilde{e}^+\widetilde{e}^-$
> 29	95		TAKETANI	90	VNS	$m_{\widetilde{\gamma}} < 25 \text{ GeV}; \ \widetilde{e}^+ \widetilde{e}^-$
> 60		77	ZHUKOVSKII	90	ASTR	$m_{\widetilde{\gamma}} = 0$
> 28	95	78	ADACHI	89	TOPZ	$m_{\widetilde{\gamma}} \lesssim 0.85 m_{\widetilde{e}}; \ \widetilde{e}^+ \widetilde{e}^-$
> 41	95	79	ADEVA	89B	L3	$m_{\widetilde{\gamma}} < 20 \text{ GeV}; \ \widetilde{e}^+ \widetilde{e}^-$
> 32	90	80	ALBAJAR	89	UA1	$p\overline{p} \rightarrow W^{\pm}X$
						$(W^{\pm} \rightarrow \tilde{e}_L \tilde{\nu})$
		81				$(\widetilde{e}_L \to e \widetilde{\gamma})^{}$
> 14 > 53	90 95 8	2.83	ALBAJAR HEARTY	89 89	UA1 ASP	$Z \rightarrow \tilde{e}^+\tilde{e}^-$
> 65	95 8	2.84	HEARTY	89	RVUE	$m_{\widetilde{\gamma}}=0; \ \gamma \widetilde{\gamma} \widetilde{\gamma}$
	95	, -				$m_{\widetilde{\gamma}}=0; \ \gamma \widetilde{\gamma} \widetilde{\gamma}$
> 35		5 86	HEARTY BEHREND		ASP	$m_{\widetilde{\gamma}} < 10 \text{ GeV}; \ \gamma \widetilde{\gamma} \widetilde{\gamma}$
> 51.5					CELL	$m_{\widetilde{\gamma}} = 0 \text{ GeV}; \gamma \widetilde{\gamma} \widetilde{\gamma}$
> 64		3,37	BEHREND		RVUE	$m_{\widetilde{\gamma}} = 0 \text{ GeV}; \gamma \widetilde{\gamma} \widetilde{\gamma}$
> 48	90		BEHREND	88B	CELL	$m_{\widetilde{\gamma}} < 5 \;  ext{GeV};  \gamma  \widetilde{\gamma}  \widetilde{\gamma}$

- ⁶⁹ ADRIANI 93M limit is for  $m_{\widetilde{e}_L}\gg m_{\widetilde{e}_R}$  using acolinear di-lepton events.
- ⁷⁰ DECAMP 92 limit is for  $m_{\widetilde{e}_L}^2 \gg m_{\widetilde{e}_R}^7$ ; for equal masses the limit would improve. They looked for acoplanar electrons.
- 71  BUSKULIC 95E looked for  $Z\to \widetilde{e}_R^+\,\widetilde{e}_R^-$  where  $\widetilde{e}_R\to e\chi_1^0$  and  $\chi_1^0$  decays via *R*-parity violating interactions into two leptons and a neutrino.
- 72 HOSODA 94 combines the results of HOSODA 94, HEARTY 89, BEHREND 88B, and FORD 86. 73 AKESSON 90B assume  $m_{\widetilde{\gamma}}=0$ . Very similar limits hold for  $m_{\widetilde{\gamma}}\lesssim 20$  GeV.
- 74  AKRAWY 90D look for acoplanar electrons. For  $m_{\widetilde{e}_L} \ \gg \ m_{\widetilde{e}_R}$ , limit is 41.5 GeV, for  $m_{\widetilde{\gamma}}$  < 30 GeV.
- 75  BAER 90 limit from  $\Delta\Gamma(Z)$  (nonhadronic) <53 MeV. Independent of decay modes. __ Mininal supersymmetry and  $\tan\beta~>1$  assumed.
- ⁷⁶ DECAMP 90C look for acoplanar electrons. For  $m_{\widetilde{e}_L} \gg m_{\widetilde{e}_R}$  limit is 42 GeV, for
- 77 ZHUKOVSKII 90 set limit by saying the luminosity of a magnetized neutron star due to massless photino emission by electrons be small compared with its neutrino luminosity.

- 78  ADACHI 89 assume only photon and photino exchange and  $m_{\widetilde{e}_l}=m_{\widetilde{e}_R}.$  The limit for the nondegenerate case is 26 GeV.
- 79 ADEVA 89B look for acoplanar electrons.
- 80 ALBAJAR 89 limit applies for  $\tilde{e}_L$  when  $m_{\tilde{e}_L}=m_{\widetilde{\nu}_L}$  and  $m_{\widetilde{\gamma}}=0$ . See their Fig. 55 for the 90% CL excluded region in the  $m_{\tilde{e}_L}-m_{\widetilde{\nu}_L}$  plane. For  $m_{\widetilde{\nu}}=m_{\widetilde{\gamma}}=0$ , limit is 50  $^{\mbox{GeV}.}$  81 ALBAJAR 89 assume  $m_{\widetilde{\gamma}}=$  0.
- $^{82}\,\mathrm{HEARTY}$  89 assume  $m_{\widetilde{\gamma}^{'}}=$  0. The limit is very sensitive to  $m_{\widetilde{\gamma}^{'}};$  no limit can be placed for  $m_{\widetilde{\gamma}}\gtrsim$  13 GeV.
- ⁸³ The limit is reduced to 43 GeV if only one  $\tilde{e}$  state is produced ( $\tilde{e}_L$  or  $\tilde{e}_R$  very heavy).
- 84  Results of HEARTY 89, BEHREND 888, ADEVA 87, and FORD 86 are combined. The limit is reduced to 53 GeV if only one  $\tilde{e}$  state is exchanged ( $\tilde{e}_L$  or  $\tilde{e}_R$  very heavy).
- 85 BEHREND 888 limits assume pure photino eigenstate and  $m_{\widetilde{e}_L} = m_{\widetilde{e}_R}$ .
- ⁸⁶ The 95% CL limit for BEHREND 88B is 47.5 GeV for  $m_{\widetilde{\gamma}}=\tilde{0}$ . The limit for  $m_{\widetilde{e}_l}\gg$  $m_{\widetilde{e}_R}$  is 40 GeV at 90% CL.
- ⁸⁷ BEHREND 88B combined their data with those from ASP (HEARTY 87), MAC (FORD 86), and MARK-J (H. Wu, Ph. D. Thesis, University of Hamburg, 1986).

DOCUMENT ID

88 ADRIANI

TECN COMMENT

93M L3

 $m_{\widetilde{\chi}_1^0}$  <40 GeV,  $\widetilde{\mu}^+\widetilde{\mu}^-$ 

#### $\widetilde{\mu}$ (Smuon) MASS LIMIT

VALUE (GeV)

>45

Limits assume  $m_{\widetilde{\mu}_L} = m_{\widetilde{\mu}_R}$  unless otherwise stated.

CL%

95

>45	95	⁸⁹ DECAMP	92 ALEP	$m_{\widetilde{\chi}^0_1}$ <41 GeV, $\widetilde{\mu}^+\widetilde{\mu}^-$
>43	95	⁹⁰ AKRAWY	90D OPAL	$m_{\widetilde{\gamma}}^{-1}$ < 30 GeV; $\widetilde{\mu}^+\widetilde{\mu}^-$
• • • We do not use the	ne followir	ng data for average	s, fits, limits,	etc. • • •
>45.6	95	⁹¹ BUSKULIC	95E ALEP	$\widetilde{\mu} \rightarrow \mu \nu \ell \overline{\ell}'$
>36	95	ABREU	90G DLPH	$m_{\widetilde{\gamma}} <$ 33 GeV; $\widetilde{\mu}^+\widetilde{\mu}^-$
>38.1	90	⁹² BAER	90 RVUE	$\widetilde{\mu}_I$ ; $\Gamma(Z)$ ; $tan\beta > 1$
>42.6	95	93 DECAMP	90c ALEP	$m_{\widetilde{\gamma}} <$ 34 GeV; $\widetilde{\mu}^+\widetilde{\mu}^-$
>27	95	SAKAI	90 AMY	$m_{\widetilde{\gamma}} <$ 18 GeV; $\widetilde{\mu}^+ \widetilde{\mu}^-$
>24.5	95	TAKETANI	90 VNS	$m_{\widetilde{\gamma}} < 15$ GeV; $\widetilde{\mu}^+ \widetilde{\mu}^-$
>24.5	95	⁹⁴ ADACHI	89 TOPZ	$m_{\widetilde{\gamma}} \lesssim 0.8 m_{\widetilde{\mu}};  \widetilde{\mu}^+ \widetilde{\mu}^-$
>41	95	⁹⁵ ADEVA	89B L3	$m_{\widetilde{\gamma}} < 20 \text{ GeV};  \widetilde{\mu}^+ \widetilde{\mu}^-$

- 88 ADRIANI 93M limit is for  $m_{\widetilde{\mu}_L}\gg m_{\widetilde{\mu}_R}$  using acolinear di-lepton events.
- 89 DECAMP 92 limit is for  $m_{\widetilde{\mu}_L} \gg m_{\widetilde{\mu}_R}^{\mu_R}$ ; for equal masses the limit would improve. They looked for acoplanar muons. 90 AKRAWY 900 look for acoplanar muons. For  $m_{\widetilde{\mu}_L} \gg m_{\widetilde{\mu}_R}$ , limit is 41.0 GeV, for
- $m_{\widetilde{\gamma}}$  < 30 GeV.
- $m_{\widetilde{\gamma}} \sim 50$  GeV.

  91 BUSKULIC 95E looked for  $Z \rightarrow \widetilde{\mu}_R^+ \widetilde{\mu}_R^-$ , where  $\widetilde{\mu}_R \rightarrow \mu \chi_1^0$  and  $\chi_1^0$  decays via R-parity violating interactions into two leptons and a neutrino.

  92 BAER 90 limit from  $\Delta \Gamma(Z)$  (nonhadronic) < 53 MeV. Independent of decay modes. Mininal supersymmetry and  $\tan \beta > 1$  assumed.

  93 DECAMP 90C look for acoplanar muons. For  $m_{\widetilde{\mu}_L} \gg m_{\widetilde{\mu}_R}$  limit is 40 GeV, for  $m_{\widetilde{\gamma}} < 20$  CeV.

- 30 GeV. 94 ADACHI 89 assume only photon exchange, which gives a conservative limit.  $m_{\widetilde{\mu}_L}=m_{\widetilde{\mu}_R}$  assumed. The limit for nondegenerate case is 22 GeV.
- 95 ADEVA 89B look for acoplanar muons.

#### $\tilde{\tau}$ (Stau) MASS LIMIT

Limits assume  $m_{\widetilde{ au}_I} = m_{\widetilde{ au}_R}$  unless otherwise stated.

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>44	95	⁹⁶ ADRIANI	93M L3	$m_{\widetilde{\chi}_i^0} <$ 38 GeV, $\widetilde{ au}^+ \widetilde{ au}^-$
>45	95	⁹⁷ DECAMP	92 ALEP	$m_{\widetilde{\chi}_1^0}^{-1}$ <38 GeV, $\widetilde{ au}^+\widetilde{ au}^-$
>43.0	95	⁹⁸ AKRAWY	90D OPAL	$m_{\widetilde{\gamma}}^{-1}$ < 23 GeV; $\widetilde{\tau}^{+}\widetilde{\tau}^{-}$
• • • We do not u	se the follow	ing data for average	s, fits, limits	
>45.6	95	⁹⁹ BUSKULIC	95E ALEP	$\tilde{\tau} \rightarrow \tau \nu \ell \bar{\ell}'$
>35	95	ABREU	90G DLPH	$m_{\widetilde{\gamma}} <$ 25 GeV; $\widetilde{\tau}^+\widetilde{\tau}^-$
>38.1	90	100 BAER		$\widetilde{\tau}_I$ ; $\Gamma(Z)$ ; $\tan \beta > 1$
>40.4	95	101 DECAMP	90c ALEP	$m_{\widetilde{\gamma}} < 15 \text{ GeV}; \ \widetilde{\tau}^+ \widetilde{\tau}^-$
>25	95	SAKAI	90 AMY	$m_{\widetilde{\gamma}}^{\prime} <$ 10 GeV; $\widetilde{ au}^{+}\widetilde{ au}^{-}$
>25.5	95	TAKETANI	90 VNS	$m_{\widetilde{\gamma}}^{'} <$ 15 GeV; $\widetilde{ au}^{+}\widetilde{ au}^{-}$
>21.7	95	¹⁰² ADACHI	89 TOPZ	
96 A D DIANI 024 I				,

- ⁶ ADRIANI 93M limit is for  $m_{\widetilde{ au}_L}\gg m_{\widetilde{ au}_R}$ .
- 97 DECAMP 92 limit is for  $m_{\widetilde{\tau}_L}^{\prime L}\gg m_{\widetilde{\tau}_R}^{\prime R}$ ; for equal masses the limit would improve. They looked for acoplanar particles.  $m_{\widetilde{\tau}_R}^{\prime R}$ ; for equal masses the limit would improve. They looked for acoplanar particles. For  $m_{\widetilde{\tau}_L}\gg m_{\widetilde{\tau}_R}^{\prime R}$ , limit is 41.0 GeV, for

- BUSKULIC 95E looked for  $Z \to \widetilde{\tau}_R^+ \widetilde{\tau}_R^-$ , where  $\widetilde{\tau}_R \to \tau \chi_1^0$  and  $\chi_1^0$  decays via R-parity violating interactions into two leptons and a neutrino. 100 BAER 90 limit from  $\Delta\Gamma(Z)$  (nonhadronic) < 53 MeV. Independent of decay modes. Mininal supersymmetry and  $\tan\beta > 1$  assumed. 101 DECAMP 90c look for acoplanar charged particle pairs. Limit is for  $m_{\widetilde{\tau}_L} = m_{\widetilde{\tau}_R}^-$ . For  $m_{\widetilde{\gamma}} \le 24$  GeV, the limit is 37 GeV. For  $m_{\widetilde{\tau}_L} \gg m_{\widetilde{\tau}_R}^-$  and  $m_{\widetilde{\gamma}} < 15$  GeV, the limit is 33 GeV.

 $^{102} {\rm ADACHI}$  89 assume only photon exchange, which gives a conservative limit.  $m_{\widetilde{\tau}_l} =$  $m_{\widetilde{ au}_R}$  assumed.

#### Stable $\widetilde{\ell}$ (Slepton) MASS LIMIT

Limits on scalar leptons which leave detector before decaying. Limits from Z decays are independent of lepton flavor. Limits from continuum  $e^+e^-$  annihilation are also independent of flavor for smuons and staus. However, selectron limits from continuum  $e^+e^-$  annihilation depend on flavor because there is an additional contribution from neutralino exchange that in general yields stronger limits. All limits assume  $m_{\widetilde{\ell}_{i}}$  $m_{\widetilde{\ell}_B}$  unless otherwise stated.

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>40	95	ABREU	90G	DLPH	
• • We do not	use the followi	ng data for averag	es, fits	, limits,	etc. • • •
>26.3	95	ADACHI	90C	TOPZ	$\widetilde{\mu}$ , $\widetilde{ au}$
>38.8	95	AKRAWY	900	OPAL	$\tilde{\ell}_R$
>27.1	95	103 SAKAI	90	AMY	
>32.6	95	SODERSTRO	M90	MRK2	
>24.5	95	104 ADACHI	89	TOPZ	

 103  SAKAI 90 limit improves to 30.1 GeV for  $\widetilde{e}$  if  $m_{\widetilde{\gamma}} \approx m_{\widetilde{e}}$ .

 104  ADACHI 89 assume only photon (and photino for  $\widetilde{e}$ ) exchange. The limit for  $\widetilde{e}$  improves to 26 GeV for  $m_{\widetilde{\gamma}} \approx m_{\widetilde{e}}$ .

#### q (Squark) MASS LIMIT

For  $m_q^2 >$  60–70 GeV, it is expected that squarks would undergo a cascade decay via a number of neutralinos and/or charginos rather than undergo a direct decay to photinos as assumed by some papers. Limits obtained when direct decay is assumed are usually higher than limits when cascade decays are included. The limits from  ${\it Z}$ decay do not assume GUT relations and are more model independent.

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
> 224	95	¹⁰⁵ ABE	<b>96</b> D	CDF	$m_{\widetilde{g}} \leq m_{\widetilde{q}}$ ; with cascade decays
> 176	95	¹⁰⁶ ABACHI	<b>95</b> C	D0	Any $m_{\widetilde{g}}$ <300 GeV;
> 212	95	106 ABACHI	<b>9</b> 5c	D0	with cascade decays $m_{\widetilde{g}} \leq m_{\widetilde{q}}$ ; with cascade decays

• • • We do not use the	ne follow	ing	data for average	s, fits	, limits,	etc. • • •
		10	⁷ ABE	95T	CDF	$\tilde{q} \rightarrow \tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 \gamma$
> 45.3	95	10	BUSKULIC	95E	ALEP	$\tilde{q} \rightarrow q \nu \ell \bar{\ell}'$
> 239	95	10	AHMED	948	H1	$e p \rightarrow \tilde{q}$ ; <i>R</i> -parity violation, $\lambda$ =0.30
> 135	95		AHMED	94B	HI	$e p \rightarrow \widetilde{q}$ ; <i>R</i> -parity violation, $\underline{\lambda}$ =0.1
> 35.3	95		ADRIANI	93N	1 L3	$Z \rightarrow \widetilde{u} \underline{\widetilde{u}}, \Gamma(Z)$
> 36.8	95	110	ADRIANI	93M		$Z \rightarrow \widetilde{d}\widetilde{d}, \Gamma(Z)$
> 90	90	11.	L ABE	92L	CDF	Any $m_{\widetilde{g}}$ <410 GeV;
		111				with cascade decay
> 218	90		² ABE	92L	CDF	$m_{\widetilde{g}} = m_{\widetilde{q}}$ ; with cascade decay
> 180	90	11:	ABE	<b>92</b> L	CDF	$m_{\widetilde{g}} < m_{\widetilde{q}}$ ; with cascade decay
> 100			ROY	92	RVUE	$p\overline{p} \rightarrow \widetilde{q}\widetilde{q}; R$ -parity violating
		114	NOJIRI	91	COSM	
> 45	95	115	ABREU	<b>9</b> 0F	DLPH	$Z  ightarrow \widetilde{q}  \overline{\widetilde{q}}, \ m_{\widetilde{\gamma}} < 20  \mathrm{GeV}$
> 43	95	116	ABREU	<b>9</b> 0F	DLPH	$Z  ightarrow \widetilde{d}  \overline{\widetilde{d}}, \ m_{\widetilde{\gamma}} < 20  \mathrm{GeV}$
> 42	95	117	ABREU	90F	DLPH	$Z \rightarrow \widetilde{\widetilde{u}} \overline{\widetilde{u}},$ $m_{\widetilde{\gamma}} < 20 \text{ GeV}$
> 27.0	95		ADACHI	90c	TOPZ	Stable $\widetilde{u}$ , $\widetilde{u}$
> 74	90	118	ALITTI	90	UA2	Any $m_{\widetilde{a}}$ ;
						$B(\widetilde{q} \to q \widetilde{g} \text{ or } q \widetilde{\gamma})$ = 1
> 106	90	118	ALITTI	90	UA2	$m_{\widetilde{q}} = m_{\widetilde{g}};$ $B(\widetilde{q} \to q\widetilde{\gamma}) = 1$
> 39.2	90	119	BAER	90	RVUE	$\widetilde{d}_{I}$ ; $\Gamma(Z)$
> 45	95 120	,121	BARKLOW	90	MRK2	$Z \rightarrow \tilde{q} \tilde{\tilde{q}}$
> 40	95 120	,122	BARKLOW	90	MRK2	$Z \rightarrow \hat{d}\hat{d}$
> 39	95 120	,123	BARKLOW	90	MRK2	$Z \rightarrow \widetilde{u}\widetilde{\widetilde{u}}$
>1100			GRIFOLS	90	ASTR	$m_{\widetilde{\gamma}} < 1 \text{ MeV}$
> 24	95		SAKAI	90	AMY	$e^+e^- \rightarrow \widetilde{d}\overline{\widetilde{d}} \rightarrow d\overline{d}\widetilde{\gamma}\widetilde{\gamma};$ $m_{\widetilde{\gamma}} < 10 \text{ GeV}$
> 26	95		SAKAI	90	AMY	$e^+e^- \rightarrow \widetilde{u}\overline{\widetilde{u}} \rightarrow u\overline{u}\widetilde{\gamma}\widetilde{\gamma};$ $m_{\widetilde{\gamma}} < 10 \text{ GeV}$
> 26.3	95		ADACHI	89	TOPZ	$e^+e^- \rightarrow \tilde{q}\bar{\tilde{q}} \rightarrow q\bar{q}\tilde{\gamma}\tilde{\gamma}$
			NATH	88	THEO	$\tau(p \rightarrow \nu K)$ in supergravity GUT
> 45	90	126	ALBAJAR	87D	UA1	Any $m_{\widetilde{g}} > m_{\widetilde{q}}$
> 75	90	126	ALBAJAR	<b>87</b> D	UA1	$m_{\widetilde{g}} = m_{\widetilde{q}}$

105 ABE 96D searched for production of gluinos and five degenerate squarks in final states containing a pair of leptons, two jets, and missing  $E_{\mathcal{T}}$ . The two leptons arise from the semileptonic decays of charginos produced in the cascade decays. The limit is derived for

#### Supersymmetric Particle Searches

- fixed  $\tan\beta=4.0$ ,  $\mu=-400$  GeV, and  $m_{H^+}=500$  GeV, and with the cascade decays of the squarks and gluinos calculated within the framework of the Minimal Supergravity scenario.
- scenario. Scenario. 106 ABACHI 95C assume five degenerate squark flavors with  $m_{\widetilde{q}_L}=m_{\widetilde{q}_R}$ . Sleptons are assumed to be heavier than squarks. The limits are derived for fixed  $\tan\beta=2.0~\mu=-250~{\rm GeV}$ , and  $m_{H^+}{=}500~{\rm GeV}$ , and with the cascade decays of the squarks and gluinos calculated within the framework of the Minimal Supergravity scenario. The bounds are weakly sensitive to the three fixed parameters for a large fraction of parameter space. No limit is given for  $m_{\rm gluino}$  >547 GeV.
- 107  ABE 95T looked for a cascade decay of five degenerate squarks into  $\widetilde{\chi}_2^0$  which further decays into  $\widetilde{\chi}_1^0$  and a photon. No signal is observed. Limits vary widely depending on the choice of parameters. For  $\mu=-40$  GeV,  $\tan\beta=1.5$ , and heavy gluinos, the range  $50{<}m_{\widetilde{q}}$  (GeV)<110 is excluded at 90% CL. See the paper for details.
- 108 BUSKULIC 95E looked for  $Z \to \widetilde{q} \overline{\widetilde{q}}$ , where  $\widetilde{q} \to q \chi_1^0$  and  $\chi_1^0$  decays via R-parity violating interactions into two leptons and a neutrino.
- 109  AHMED 94B looked for squarks as s-channel resonance in ep collision via R-parity violating coupling in the superpotential  $W=\lambda L_1\,Q_1\,d_1$ . The degeneracy of all squarks  $Q_1$  and  $d_1$  is assumed. The squarks decay dominantly via the same R-violating coupling into eq or  $\nu q$  if  $\lambda \gtrsim 0.2$ . For smaller  $\lambda$ , decay into photino is assumed which subsequently decays into  $eq\,q_1$ , and the bound depends on  $m_{\widetilde{\gamma}}$ . See paper for excluded region on  $(m_{\widetilde{q}},\lambda)$  plane.
- 110  ADRIANI 93M limit from  $\Delta\Gamma(Z)<$  35.1 MeV and assumes  $m_{\widetilde{q}_L}\gg m_{\widetilde{q}_R}$
- 111 ABE 92L assume five degenerate squark flavors and  $m_{\widetilde{q}_L} = m_{\widetilde{q}_R}^2$ . ABE 92L includes the effect of cascade decay, for a particular choice of parameters,  $\mu = -250$  GeV,  $\tan\beta = 2$ . Results are weakly sensitive to these parameters over much of parameter space. No limit for  $m_{\widetilde{q}} \leq 50$  GeV (but other experiments rule out that region). Limits are 10–20 GeV higher if  $\mathbb{B}(\widetilde{q} \to q \widetilde{\gamma}) = 1$ . Limit assumes GUT relations between gaugino masses and the gauge coupling; in particular that for  $|\mu|$  not small,  $m_{\widetilde{\chi}\widetilde{q}} \approx m_{\widetilde{g}}/6$ . This last
  - relation implies that as  $m_{\widetilde{g}}$  increases, the mass of  $\widetilde{\chi}_{0}^{0}$  will eventually exceed  $m_{\widetilde{q}}$  so that no decay is possible. Even before that occurs, the signal will disappear; in particular no bounds can be obtained for  $m_{\widetilde{g}} > 410$  GeV.  $m_{H^{+}} = 500$  GeV.
- 112 ABE 92L bounds are based on similar assumptions as ABACHI 95C. No limits for  $\|m_{gluino}\>\!>\!\!410$  GeV.
- 113 ROY 92 reanalyzed CDF limits on di-lepton events to obtain limits on squark production in R-parity violating models. The 100% decay  $\tilde{q} \to q \tilde{\chi}$  where  $\tilde{\chi}$  is the LSP, and the LSP decays either into  $\ell q \bar{d}$  or  $\ell \ell \bar{e}$  is assumed.
- 114 NOJIRI 91 argues that a heavy squark should be nearly degenerate with the gluino in minimal supergravity not to overclose the universe.
- 115  ABREU 90r assume six degenerate squarks and  $m_{\widetilde{q}_L}=m_{\widetilde{q}_R}.~m_{\widetilde{q}}~<$  41 GeV is excluded at 95% CL for  $m_{\rm LSP}~< m_{\widetilde{q}}$  –2 GeV.
- $^{116}\,\mathrm{ABREU}$  90F exclude  $m_{\widetilde{d}}$  < 38 GeV at 95% for  $m_{\mathrm{LSP}}$  <  $m_{\widetilde{d}}$  –2 GeV.
- $^{117}\,\mathrm{ABREU}$  90F exclude  $m_{\widetilde{u}}$   $\,<$  36 GeV at 95% for  $m_{\mathrm{LSP}}$   $\,<$   $m_{\widetilde{u}}$  –2 GeV.
- 118 ALITTI 90 searched for events having  $\geq 2$  jets with  $E_T^1 > 25$  GeV,  $E_T^2 > 15$  GeV,  $|\eta| < 0.85$ , and  $\Delta \phi < 160^\circ$ , with a missing momentum > 40 GeV and no electrons. They assume  $\tilde{q} \to q \tilde{\gamma}$  (if  $m_{\tilde{q}} < m_{\tilde{g}}$ ) or  $\tilde{q} \to q \tilde{g}$  (if  $m_{\tilde{q}} > m_{\tilde{g}}$ ) decay and  $m_{\tilde{\gamma}} \lesssim 20$  GeV. Five degenerate squark flavors and  $m_{\tilde{q}_L} = m_{\tilde{q}_R}$  are assumed. Masses below 50 GeV are not excluded by the analysis.
- 119 BAER 90 limit from  $\Delta \Gamma(Z) <$  120 MeV, assuming  $m_{\widetilde{d}_L} = m_{\widetilde{e}_L} = m_{\widetilde{e}_L}$  Independent of decay modes. Minimal supergravity assumed.
- 120 BARKLOW 90 assume 100%  $\tilde{q} \rightarrow q \tilde{\gamma}$ .
- 121 BARKLOW 90 assume five degenerate squarks (left- and right-handed). Valid up to  $m_{\widetilde{\chi}^0_1} \lesssim [m_{\widetilde{q}}^{-4}~{\rm GeV}].$
- 122 BARKLOW 90 result valid up to  $m_{\widetilde{\chi}_1^0} \lesssim [m_{\widetilde{d}} 5 \text{ GeV}].$
- ¹²³BARKLOW 90 result valid up to  $m_{\widetilde{\chi}_1^0} \lesssim [m_{\widetilde{u}}$  -6 GeV].
- 124  ADACHI 89 assume only photon exchange, which gives a a conservative limit. The limit is only for one flavor of charge  $2/3~\widetilde{q}.~m_{\widetilde{q}_L}=m_{\widetilde{q}_R}$  and  $m_{\widetilde{\gamma}}=0$  assumed. The limit decreases to 26.1 GeV for  $m_{\widetilde{\gamma}}=15$  GeV. The limit for nondegenerate case is 24.4 GeV.
- 125  NATH 88 uses Kamioka limit of  $\tau(p\to \overline{\nu}K^+)>7\times 10^{31}$  yrs to constrain squark mass  $m_{\widetilde{q}}>1000$  GeV by assuming that the proton decay proceeds via an exchange of a color-triplet Higgsino of mass  $<10^{16}$  GeV in the supersymmetric SU(5) GUT. The limit applies for  $m_{\widetilde{\gamma}}\equiv (8/3)\sin^2\!\theta_W\widetilde{m}_2>10$  GeV  $(\widetilde{m}_2$  is the SU(2) gaugino mass) and for a very conservative value of the three-quark proton wave function, barring cancellation between second and third generations. Lower squark mass is allowed if  $m_{\widetilde{\gamma}}$  as defined above in graphic.
- above is smaller.

  126 The limits of ALBAJAR 87D are from  $p\overline{p} \to \widetilde{q}\,\overline{\widetilde{q}}\,X$  ( $\widetilde{q} \to q\widetilde{\gamma}$ ) and assume 5 flavors of degenerate mass squarks each with  $m_{\widetilde{q}_L} = m_{\widetilde{q}_R}$ . They also assume  $m_{\widetilde{g}} > m_{\widetilde{q}}$ . These limits apply for  $m_{\widetilde{\gamma}} \lesssim 20$  GeV.

#### $\tilde{t}$ (Stop) MASS LIMIT

Limit depends on decay mode. In  $e^+e^-$  collisions they also depend on the mixing angle of the mass eigenstate  $\tilde{t}_1=\tilde{t}_L\cos\theta_t+\tilde{t}_R\sin\theta_t$ . Coupling to Z vanishes when  $\theta_t=0.98$ . In the Listings below, we use  $\Delta m\equiv m_{\tilde{t}_1}-m_{\widetilde{\chi}_1^0}$ . See also bound in " $\tilde{q}$  (Squark) MASS LIMIT."

VALUE (GeV)	CL%_	DOCUMENT ID	TECN	COMMENT
none 61-91	95 127	ABACHI	96B D0	$\widetilde{t} \rightarrow c\widetilde{\chi}_1^0$ , $m_{\widetilde{\chi}_1^0}$ <30 GeV
none 6.0-41.2	95	AKERS		$\tilde{t} \rightarrow c\tilde{\chi}_1^0,  \theta_t = 0,  \Delta(m) > 2$
none 5.0-46.0	95	AKERS	94K OPAL	$\widetilde{t} \rightarrow c\widetilde{\chi}_{1}^{0},  \theta_{t}=0,  \Delta(m) > 5$
				GeV

none 11.2-25.5	95	AKERS	94K OPAL	$\tilde{t} \rightarrow c\tilde{\chi}_1^0$ , $\theta_t$ =0.98, $\Delta(m) > 2$
none 7.9-41.2	95	AKERS	94K OPAL	GeV $\widetilde{t} \rightarrow c\widetilde{\chi}_{1}^{0}, \ \theta_{t}=0.98, \ \Delta(m) > 5$
none 7.6-28.0	95	¹²⁸ SHIRAI	94 VNS	$\widetilde{t} \to c\widetilde{\chi}_1^0$ , any $\theta_t$ , $\Delta(m) > 10$
none 10-20	95	¹²⁸ SHIRAI	94 VNS	$\widetilde{t} \to c\widetilde{\chi}_1^0$ , any $\theta_t$ , $\Delta(m) > 2.5$
				GeV

• • We do not use the following data for averages, fits, limits, etc. • •

none 11–41 95 129 BUSKULIC 95E ALEP  $\theta_t$ =0.98,  $\widetilde{t} \rightarrow c \nu \ell \overline{\ell}'$  130 BAER 91B RVUE  $\widetilde{t}$  131 DREES 90 RVUE  $\widetilde{t}$ 

- ¹²⁷ABACHI 96B searches for final states with 2 jets and missing  $E_{\mathcal{T}}$ . Limits on  $m_{\widetilde{\ell}}$  are given as a function of  $m_{\widetilde{\chi}_1^0}$ . See Fig. 4 for details.
- 128 SHIRAI 94 bound assumes the cross section without the s-channel Z-exchange and the QCD correction, underestimating the cross section up to 20% and 30%, respectively. They assume  $m_C$ =1.5 GeV.
- ¹²⁹ BUSKULIC 95E looked for  $Z \to \tilde{t}\tilde{t}$ , where  $\tilde{t} \to c \chi_1^0$  and  $\chi_1^0$  decays via *R*-parity violating interactions into two leptons and a neutrino.
- 130 BAER 91B argue that a top squark as light as 45 GeV may have escaped detection at the CDF detector at the Tevatron Collider (45 GeV is the limit from LEP experiments).
- 131 DREES 90 argue that bounds from Z decay are not valid for  $\tilde{t}$  for a certain range of  $\tilde{t}_L$ - $\tilde{t}_R$  mixing angle.

#### g (Gluino) MASS LIMIT

For  $m_{\widetilde{g}} > 60$ –70 GeV, it is expected that gluinos would undergo a cascade decay via a number of neutralinos and/or charginos rather than undergo a direct decay to photinos as assumed by some papers. Limits obtained when direct decay is assumed are usually higher than limits when cascade decays are included.

There is an ongoing controversy (reflected in these Listings) about whether very light  $\tilde{g}$ 's (1  $\lesssim m_{\widetilde{g}} \lesssim$  4 GeV) are ruled out. These papers sometimes make different assumptions and use different calculational techniques.

VALUE (GeV)	CL% EVTS	DOCUMENT ID		TECN	COMMENT
>224	95	132 ABE	<b>96</b> D	CDF	$m_{\widetilde{q}} = m_{\widetilde{g}}$ ; with cascade
>154	95	¹³² ABE	<b>96</b> D	CDF	decays $m_{\widetilde{g}} < m_{\widetilde{q}}$ ; with cascade
>212	95	133 ABACHI	<b>95</b> C	D0	decays $m_{\widetilde{g}} \geq m_{\widetilde{q}}$ ; with cascade
>144	95	133 ABACHI	<b>95</b> C	D0	decays Any $m_{\widetilde{q}}$ ; with cascade
					decays

• • • We do not use the following data for averages, fits, limits, etc. • • •

• • We do not use the following data for averages, fits, limits, etc. • •							
			¹³⁴ ABE	95T	CDF	$\tilde{g} \rightarrow \tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 \gamma$	
none 1.9-13.6	95		135 AKERS	<b>95</b> R	OPAL	Z decay into a long-lived $(\tilde{g} q \bar{q})^{\pm}$	
< 0.7			136 CLAVELLI	95	RVUE	quarkonia	
			137 HEBBEKER	93	RVUE	e ⁺ e ⁻ jet analyses	
not 3-5			138 LOPEZ	<b>93</b> C	RVUE	LEP	
>218	90		¹³⁹ ABE	<b>92</b> L	CDF	$m_{\widetilde{q}} \leq m_{\widetilde{g}}$ ; with cascade decay	
>100	90		¹³⁹ ABE	92L	CDF	Any $m_{\widetilde{q}}$ ; with cascade decay	
≈ 4			¹⁴⁰ CLAVELLI	92	RVUE	$\alpha_s$ running	
>100			¹⁴¹ ROY	92	RVUE	$p\overline{p} \rightarrow \widetilde{g}\widetilde{g}$ ; R-parity violating	
			¹⁴² ANTONIADIS	91	RVUE	$\alpha_s$ running	
> 1			143 ANTONIADIS	91	RVUE	pN → missing energy	
>132	90		144 HIDAKA	91	RVUE		
			¹⁴⁵ NOJIRI	91	COSM		
> 79	90		146 ALITTI	90	UA2	Any $m_{\widetilde{g}}$ ;	
>106	90		¹⁴⁶ ALITTI	90	UA2	$B(\widetilde{g} \to q \overline{q} \widetilde{\gamma}) = 1$ $m_{\widetilde{q}} = m_{\widetilde{g}};$ $B(\widetilde{g} \to q \overline{q} \widetilde{\gamma}) = 1$	
			¹⁴⁷ NAKAMURA	89	SPEC	$R-\Delta^{++}$	
none 4-53	90		¹⁴⁸ ALBAJAR	87D	UA1	Any $m_{\widetilde{q}} > m_{\widetilde{g}}$	
none 4-75	90		¹⁴⁸ ALBAJAR	87D	UA1	$m_{\widetilde{q}} = m_{\widetilde{g}}$	
none 16-58	90		¹⁴⁹ ANSARI	87D	UA2	$m_{\widetilde{q}} \lesssim 100 \text{ GeV}$	
> 3.8	90		¹⁵⁰ ARNOLD	87	<b>EMUL</b>	$\pi^-$ (350 GeV). $\sigma \simeq A^1$	
> 3.2	90		¹⁵⁰ ARNOLD	87	EMUL	$\pi^-$ (350 GeV). $\sigma \simeq$	
none 0.6-2.2	90		¹⁵¹ TUTS	87	CUSB	$\gamma(1S) \rightarrow \gamma + gluinon-ium$	
none 1 -4.5	90	0	¹⁵² ALBRECHT	8 <b>6</b> C	ARG	$1 \times 10^{-11} \lesssim \tau \lesssim 1 \times 10^{-9} \text{s}$	
none 1-4	90	0	¹⁵³ BADIER	86	BDMP	$1 \times 10^{-10} < \tau < 1 \times 10^{-7}$ s	
none 3-5			154 BARNETT	86	RVUE	pp → gluino gluino gluon	

## Searches Particle Listings Supersymmetric Particle Searches

none none 0.5–2		¹⁵⁵ VOLOSHIN ¹⁵⁶ COOPER		If (quasi) stable; $\tilde{g} uud$ For $m_{\tilde{g}}$ =300 GeV
none 0.5-4		¹⁵⁶ COOPER		For $m_{\widetilde{q}}^{q}$ <65 GeV
none 0.5-3		¹⁵⁶ COOPER	85B BDM	For $m_{\tilde{a}} = 150 \text{ GeV}$
none 2-4		157 DAWSON	85 RVUE	$\tau > 10^{-7} \text{ s}$
none 1-2.5		¹⁵⁷ DAWSON	85 RVUE	For $m_{\tilde{g}}=100 \text{ GeV}$
none 0.5-4.1	90	158 FARRAR	85 RVUE	FNAL beam dump
> 1		159 GOLDMAN	85 RVUE	Gluononium
>1-2		160 HABER	85 RVUE	
		161 BALL	84 CALC	
		162 BRICK	84 RVUE	
		163 FARRAR	84 RVUE	
> 2		¹⁶⁴ BERGSMA	83C RVUE	For $m_{\widetilde{a}} < 100 \text{ GeV}$
		¹⁶⁵ CHANOWIŢZ	83 RVUE	gud, guud
>2-3		166 KANE	82 RVUE	Beam dump
>1.5-2		FARRAR	78 RVUE	R-hadron

- 132  ABE 96D searched for production of gluinos and five degenerate squarks in final states containing a pair of leptons, two jets, and missing  $E_T$ . The two leptons arise from the semileptonic decays of charginos produced in the cascade decays. The limits are derived for fixed  $\tan \beta = 4.0$ ,  $\mu = -400$  GeV, and  $m_{H^+} = 500$  GeV, and with the cascade decays of the squarks and gluinos calculated within the framework of the Minimal Supergravity scenario. The bounds are weakly sensitive to the values of the three fixed parameters for a large fraction of parameter space. See Fig. 2 for the limits corresponding to different parameter choices. parameter choices.
- 133 ABACHI 95C assume five degenerate squark flavors with with  $m_{\widetilde{q}_L}=m_{\widetilde{q}_R}$ . Sleptons are assumed to be heavier than squarks. The limits are derived for fixed  $\tan\beta=2.0~\mu=$ are assumed to be heavier than squarks. The limits are derived for fixed  $\tan\beta = 2.0~\mu = -250~{\rm GeV}$ , and  $m_{H^+} = 500~{\rm GeV}$ , and with the cascade decays of the squarks and gluinos calculated within the framework of the Minimal Supergravity scenario. The bounds are weakly sensitive to the three fixed parameters for a large fraction of parameter space.  $134~{\rm ABE~95T~looked~for~a~cascade~decay~of~gluino~into~\chi_0^2~which further decays~into~\chi_0^2~and a large fraction of~according to the control of the co$

photon. No signal is observed. Limits vary widely depending on the choice of parameters. For  $\mu=-40$  GeV,  $\tan\beta=1.5$ , and heavy squarks, the range  $50< m_{\widetilde{p}}$  (GeV)<140 is excluded at 90% CL. See the paper for details.

135 AKERS 95R looked for Z decay into  $q \bar{q} \tilde{g} \tilde{g}$ , by searching for charged particles with dE/dx

Anema son nounced for z decay into q q g g, by searching for charged particles with dE/dx consistent with  $\tilde{g}$  fragmentation into a state  $(\tilde{g} q \tilde{q})^{\pm}$  with lifetime  $\tau > 10^{-7}$  sec. The fragmentation probability into a charged state is assumed to be 25%. 136 CLAVELLI 95 updates the analysis of CLAVELLI 93, based on a comparison of the hadronic widths of charmonium and bottomonium 5-wave states. The analysis includes a parametrization of relativisitic corrections. Claims that the presence of a light gluino improves agreement with the data by slowing down the running of  $\alpha_s$ .

137 HEBBEKER 93 combined jet analyses at various  $e^+e^-$  colliders. The 4-jet analyses at TRISTAN/LEP and the measured  $\alpha_{\rm S}$  at PEP/PETRA/TRISTAN/LEP are used. A constraint on effective number of quarks  $N\!=\!6.3\pm1.1$  is obtained, which is compared to that with a light gluino,  $N\!=\!8$ .

138 LOPEZ 93C uses combined restraint from the radiative symmetry breaking scenario within the minimal supergravity model, and the LEP bounds on the  $(M_2,\mu)$  plane. Claims that

the light gluino window is strongly disfavored.

139 ABE 92L bounds are based on similar assumptions as ABACHI 95c. Not sensitive to  $m_{\rm gluino}$  <40 GeV (but other experiments rule out that region).

140 CLAVELLI 92 claims that a light gluino mass around 4 GeV should exist to explain the discrepancy between  $\alpha_{\rm S}$  at LEP and at quarkonia ( $\gamma$ ), since a light gluino slows the running of the QCD coupling.

141 ROY 92 reanalyzed CDF limits on di-lepton events to obtain limits on gluino production in *R*-parity violating models. The 100% decay  $\tilde{g} \to q \overline{q} \tilde{\chi}$  where  $\tilde{\chi}$  is the LSP, and the LSP decays either into  $\ell q \overline{d}$  or  $\ell \ell \overline{e}$  is assumed.

 142  ANTONIADIS 91 argue that possible light gluinos (< 5 GeV) contradict the observed running of  $\alpha_{\rm S}$  between 5 GeV and  $m_Z$ . The significance is less than 2 s.d.  143  ANTONIADIS 91 interpret the search for missing energy events in 450 GeV/c  $\rho$  N collibrations.

sions, AKESSON 91, in terms of light gluinos.

144 HIDAKA 91 limit obtained from LEP and preliminary CDF results within minimal supersymmetry with gaugino-mass unification condition. HIDAKA 91 limit extracted from

145 NO JIR 19 1 argues that a heavy gluino should be nearly degenerate with squarks in minimal supergravity not to overclose the universe.

¹⁴⁶ ALITTI 90 searched for events having  $\geq$  2 jets with  $E_T^1$  > 25 GeV,  $E_T^2$  > 15 GeV,  $\left|\eta
ight|~<~0.85$ , and  $\Delta\phi~<160^{\circ}$ , with a missing momentum > 40 GeV and no electrons. They assume  $\widetilde{g} \to q \overline{q} \widetilde{\gamma}$  decay and  $m_{\widetilde{\gamma}} \lesssim$  20 GeV. Masses below 50 GeV are not excluded by the analysis.

 147  NAKAMURA 89 searched for a long-lived (  $au \gtrsim 10^{-7}$  s) charge-( $\pm 2$ ) particle with mass  $\lesssim$  1.6 GeV in proton-Pt interactions at 12 GeV and found that the yield is less than  $10^{-8}$  times that of the pion. This excludes R- $\Delta^{++}$  (a  $\tilde{g}uuu$  state) lighter than 1.6

148 The limits of ALBAJAR 87D are from  $p\overline{p} \to \widetilde{g}\widetilde{g}X$  ( $\widetilde{g} \to q\overline{q}\widetilde{\gamma}$ ) and assume  $m_{\widetilde{q}} >$  $m_{\widetilde{g}}.$  These limits apply for  $m_{\widetilde{\gamma}}\lesssim$  20 GeV and  $au(\widetilde{g})<$   $10^{-10}$  s.

149 The limit of ANSARI 87D assumes  $m_{\widetilde{q}} > m_{\widetilde{g}}$  and  $m_{\widetilde{\gamma}} \approx 0$ .

 $^{150}\,\mathrm{The}$  limits assume  $m_{\widetilde{q}}=$  100 GeV. See their figure 3 for limits vs.  $m_{\widetilde{q}}.$ 

151 The gluino mass is defined by half the bound  $\widetilde{g}\widetilde{g}$  mass. If zero gluino mass gives a  $\widetilde{g}\widetilde{g}$  of mass about 1 GeV as suggested by various glueball mass estimates, then the low-mass bound can be replaced by zero. The high-mass bound is obtained by comparing the data with nonrelativistic potential-model estimates.

with nonrelativistic potential-model estimates. 152 ALBRECHT 86c search for secondary decay vertices from  $\chi_{b1}(1P) \to \tilde{g}\,\tilde{g}\,g$  where  $\tilde{g}$ 's make long-lived hadrons. See their figure 4 for excluded region in the  $m_{\tilde{g}} - m_{\tilde{g}}$  and  $m_{\tilde{g}} - m_{\tilde{g}}$  plane. The lower  $m_{\tilde{g}}$  region below  $\sim 2$  GeV may be sensitive to fragmentation effects. Remark that the  $\tilde{g}$ -hadron mass is expected to be  $\sim 1$  GeV (glueball mass) in the record mass limit the zero  $\widetilde{g}$  mass limit.

 $^{153}\, {\sf BADIER}$  86 looked for secondary decay vertices from long-lived  $\widetilde{\it g}$ -hadrons produced at 300 GeV  $\pi^-$  beam dump. The quoted bound assumes  $\tilde{g}$ -hadron nucleon total cross section of 10 $\mu$ b. See their figure 7 for excluded region in the  $m_{\widetilde{g}}-m_{\widetilde{q}}$  plane for several assumed total cross-section values.

154 BARNETT 86 rule out light gluinos (m=3–5 GeV) by calculating the monojet rate from gluino gluino gluon events (and from gluino gluino events) and by using UA1 data from  $p\bar{p}$  collisions at CERN.

155 VOLOSHIN 86 rules out stable gluino based on the cosmological argument that predicts too much hydrogen consisting of the charged stable hadron  $\tilde{g}$  uud. Quasi-stable ( $\tau >$  $1. \times 10^{-7}$ s) light gluino of  $m_{\widetilde{g}} < 3$  GeV is also ruled out by nonobservation of the stable charged particles,  $\widetilde{g}uud$ , in high energy hadron collisions.

The Cooper-SarkAra 85s is BEBC beam-dump. Gluinos decaying in dump would yield  $\tilde{\gamma}$ 's in the detector giving neutral-current-like interactions. For  $m_{\widetilde{q}} > 330$  GeV, no limit

is set. 157 DAWSON 85 first limit from neutral particle search. Second limit based on FNAL beam

158 FARRAR 85 points out that BALL 84 analysis applies only if the  $\tilde{g}$ 's decay before interacting, i.e.  $m_{\tilde{q}} < 80 m_{\tilde{g}}^{-1.5}$ . FARRAR 85 finds  $m_{\tilde{g}} < 0.5$  not excluded for  $m_{\tilde{q}} = 30$ –1000 GeV and  $m_{\tilde{g}} < 1.0$  not excluded for  $m_{\tilde{q}} = 100$ –500 GeV by BALL 84 experiment.

 159  GOLDMAN 85 use nonobservation of a pseudoscalar  $\widetilde{g} extstyle \widetilde{g}$  bound state in radiative  $\psi$ 

decay.
160 HABER 85 is based on survey of all previous searches sensitive to low mass \( \tilde{g}' \)'s. Limit makes assumptions regarding the lifetime and electric charge of the lightest supersymmetric particle.

161 BALL 84 is FNAL beam dump experiment. Observed no interactions of  $\widetilde{\gamma}$  in the calorimeter, where  $\widetilde{\gamma}$ 's are expected to come from pair-produced  $\widetilde{g}$ 's. Search for long-lived  $\widetilde{\gamma}$  interacting in calorimeter 56m from target. Limit is for  $m_{\widetilde{q}}=40$  GeV and production cross section proportional to A $^{0.72}$ . BALL 84 find no  $\tilde{g}$  allowed below 4.1 GeV at CL = 90%. Their figure 1 shows dependence on  $m_{\tilde{q}}$  and A. See also KANE 82.

 162 BRICK 84 reanalyzed FNAL 147 GeV HBC data for R- $\Delta$ (1232) $^{++}$  with  $au~>10^{-9}$  s and  $p_{\text{lab}} > 2$  GeV. Set CL = 90% upper limits 6.1, 4.4, and 29 microbarns in pp,  $\pi^+p$ , K+p collisions respectively.  $R-\Delta^{4+}$  is defined as being  $\tilde{g}$  and 3 up quarks. If mass = 1.2–1.5 GeV, then limits may be lower than theory predictions.

 163  FARRAR 84 argues that  $m_{\widetilde{g}}$  <100 MeV is not ruled out if the lightest R-hadrons are long-lived. A long lifetime would occur if R-hadrons are lighter than  $\widetilde{\gamma}$ 's or if  $m_{\widetilde{a}} > 100$ 

 164 BERGSMA 83C is reanalysis of CERN-SPS beam-dump data. See their figure 1.

165 CHANOWITZ 83 find in bag-model that charged s-hadron exists which is stable against strong decay if  $m_{\widetilde{g}} < 1$  GeV. This is important since tracks from decay of neutral s-hadron cannot be reconstructed to primary vertex because of missed  $\widetilde{\gamma}$ . Charged s-hadron leaves track from vertex.

166 KANE 82 inferred above  $\widetilde{g}$  mass limit from retroactive analysis of hadronic collision and beam dump experiments. Limits valid if  $\widetilde{g}$  decays inside detector.

#### Unstable $\tilde{\gamma}$ (Photino) MASS LIMIT

Unless stated otherwise, the limits below assume that the  $\tilde{\gamma}$  decays either into  $\gamma \tilde{G}$  (goldstino) or into  $\gamma \tilde{H}^0$  (Higgsino)

Stille) or lift	υγπ-(niggsi	110).		
VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not	use the follow	ing data for average	es, fits, limits,	etc. • • •
>40	95	¹⁶⁷ BUSKULIC	95E ALEP	$e^+e^- \rightarrow \widetilde{\chi}_1^0\widetilde{\chi}_1^0$
		¹⁶⁸ BUSKULIC	95E ALEP	$ \begin{array}{ccc} (\widetilde{\chi}_{1}^{0} \to \nu \ell \overline{\ell}') \\ e^{+} e^{-} \to \widetilde{\gamma} \widetilde{\gamma} \end{array} $
		¹⁶⁹ ACTON	93G OPAL	$e^{+}e^{-} \rightarrow \begin{array}{c} \nu \ell \overline{\ell}' \\ \gamma \rightarrow \end{array}$
		¹⁷⁰ ABE	89J VNS	$(\tilde{\gamma} \to \tau^{\pm} \ell^{\mp} \nu_{\ell'})$ $e^{+} e^{-} \to \tilde{\gamma} \tilde{\gamma}$
>15	95	¹⁷¹ BEHREND	87B CELL	$(\widetilde{\gamma} \to \gamma  \widetilde{G} \text{ or } \gamma  \widetilde{H}^0)$ $e^+ e^- \to \widetilde{\gamma} \widetilde{\gamma}$ $(\widetilde{\gamma} \to \gamma  \widetilde{G} \text{ or } \gamma  \widetilde{H}^0)$
		172 ADEVA 173 BALL	85 MRKJ	(, , , , , , , , , , , , , , , , , , ,
		174 BARTEL	84 CALO 84B JADE	Beam dump
		174 BEHREND	83 CELL	
		175 CABIBBO	81 COSM	

 167  BUSKULIC 95E looked for  $e^+e^- \to \tilde{\chi}^0_1 \tilde{\chi}^0_1$ , where  $\tilde{\chi}^0_1$  decays via R-parity violating interaction into one neutrino and two opposite-charge leptons. The bound applies provided that B( $Z \to \tilde{\chi}^0_1 \tilde{\chi}^0_1 > 3 \times 10^{-5} \beta^3$ ,  $\beta$  being the final state  $\tilde{\chi}^0_1$  velocity.

168 BUSKULIC 95E looked for  $e^+e^- o ilde{\gamma} ilde{\gamma} ilde{\gamma}$ , where  $ilde{\gamma}$  decays via R-parity violating interaction into one neutrino and two opposite-charge leptons. They extend the domain in the  $(m_{\widetilde{e}}, m_{\widetilde{\gamma}})$  plane excluded by ACTON 93G to  $m_{\widetilde{e}} >$  220 GeV/ $c^2$  (for  $m_{\widetilde{\gamma}} =$  15 GeV/ $c^2$ ) and to  $m_{\widetilde{\gamma}} > 2~{\rm GeV}/c^2$  (for  $m_{\widetilde{e}} < 220~{\rm GeV}/c^2).$ 

169 ACTON 93G assume *R*-parity violation and decays  $\widetilde{\gamma} \to \tau^\pm \ell^\mp \nu_\ell$  ( $\ell=e$  or  $\mu$ ). They exclude  $m_{\widetilde{\gamma}}=4$ –43 GeV for  $m_{\widetilde{e}_L}<$ 42 GeV, and  $m_{\widetilde{\gamma}}=7$ –30 GeV for  $m_{\widetilde{e}_L}<$ 100 GeV (95% CL). Assumes  $\widetilde{e}_R$  much heavier than  $\widetilde{e}_L$ , and lepton family number violation but  $L_e$ - $L_\mu$  conservation.

 170  ABE 89J exclude  $m_{\widetilde{\gamma}}=$  0.15–25 GeV (95%CL) for d= (100 GeV) 2  and  $m_{\widetilde{e}}=$  40 GeV in the case  $\widetilde{\gamma} \to \gamma \, \widetilde{G}$ , and  $m_{\widetilde{\gamma}}$  up to 23 GeV for  $m_{\widetilde{e}} =$  40 GeV in the case  $\widetilde{\gamma} \to \gamma \, \widetilde{H}^0$ .

171 BEHREND 878 limit is for unstable photinos only. Assumes B( $\widetilde{\gamma} \to \gamma(\widetilde{G} \, \text{or} \, \widetilde{H}^0)$ ) =1,  $m_{\widetilde{G} \text{or}} H^0 \ll m_{\widetilde{\gamma}}$  and pure  $\widetilde{\gamma}$  eigenstate.  $m_{\widetilde{e}_L} = m_{\widetilde{e}_R} < 100 \, \text{GeV}$ .

 172  ADEVA 85 is sensitive to  $\tilde{\gamma}$  decay path <5 cm. With  $m_{\tilde{\alpha}} = 50$  GeV, limit (CL = 90%) is  $m_{\widetilde{\gamma}} >$  20.5 GeV. Assume  $\widetilde{\gamma}$  decays to photon + goldstino and search for acoplanar photons with large missing  $ho_{\mathcal{T}}$ .

173 BALL 84 is FNAL beam dump experiment. Observed no  $\tilde{\gamma}$  decay, where  $\tilde{\gamma}$ 's are expected to come from  $\tilde{g}$ 's produced at the target. Three possible  $\tilde{\gamma}$  lifetimes are considered. Gluino decay to goldstino + gluon is also considered.

## Supersymmetric Particle Searches

174 BEHREND 83 and BARTEL 84B look for  $2\gamma$  events from  $\widetilde{\gamma}$  pair production. With supersymmetric breaking parameter d =  $(100~{\rm GeV})^2$  and  $m_{\widetilde{\varrho}}=40~{\rm GeV}$  the excluded regions at CL = 95% would be  $m_{\widetilde{\gamma}}=100~{\rm MeV}-13~{\rm GeV}$  for BEHREND 83  $m_{\widetilde{\gamma}}=80~{\rm MeV}-18~{\rm GeV}$  for BARTEL 84B. Limit is also applicable if the  $\widetilde{\gamma}$  decays radiatively within the detector. 
175 CABIBBO 81 consider  $\widetilde{\gamma}\to\gamma+$  goldstino. Photino must be either light enough (<30 eV) to satisfy cosmology bound, or heavy enough (>0.3 MeV) to have disappeared at early universe.

#### Supersymmetry Miscellaneous Results

Results that do not appear under other headings or that make nonminimal assumptions.

VALUE

DOCUMENT ID

TECN
COMMENT

• • We do not use the following data for averages, fits, limits, etc. • •

176 BARBER

176 BARBER 84B RVUE 177 HOFFMAN 83 CNTR  $\pi p \rightarrow n(e^+e^-)$ 

176 BARBER 84B consider that  $\tilde{\mu}$  and  $\tilde{\epsilon}$  may mix leading to  $\mu \to e \tilde{\gamma} \tilde{\gamma}$ . They discuss mass—mixing limits from decay dist asym in LBL-TRIUMF data and  $e^+$  polarization in SIN

data. 177 HOFFMAN 83 set CL = 90% limit  $d\sigma/dt$  B( $e^+e^-$ ) < 3.5 × 10⁻³² cm²/GeV² for spin-1 partner of Goldstone fermions with 140 < m <160 MeV decaying  $\rightarrow e^+e^-$  pair.

#### REFERENCES FOR Supersymmetric Particle Searches

ABACHI	96	PRL 76 2228	+Abbott, Abolins, Acharya+ (Di	Collab.)
ABACHI	96B	PRL 76 2222	+Abbott, Abolins, Acharya+ (De	0 Collab.)
ABE	96D	PRL 76 2006	+Akimoto, Akopian, Albrow+ (CDI	F Collab.)
ABACHI	95C	PRL 75 618	+Abbott, Abolins, Acharya+ (Di	Collab.)
ABE	95T	PRL 75 613	+Albrow, Amidei, Anway-Wiese+ (CDI	F Collab.)
ACCIARRI	95E	PL B350 109	+Adam, Adraiani, Aguilar-Benitez+ (L:	3 Collab.)
AKERS	95R	ZPHY C67 203	+Alexander, Allison, Ametewee, Anderson+ (OPA)	L Collab.)
BUSKULIC	95E	PL B349 238	+Casper, DeBonis, Decamp+ (ALEPI	1 Collab.)
CLAVELLI	95	PR D51 1117	+Coulter	(ALAT)
FALK	95	PL B354 99	+Olive, Srednicki (MINI	v, `ucsbí
AHMED	94 B	ZPHY C64 545	+Aid, Andreev, Andrieu, Appuhn, Arpagaus+ (H	1 Collab.)
AKERS	94K	PL B337 207		L Collab.)
BECK	94	PL B336 141	+Bensch, Bockholt+ (MPIH, KIAE	, SASSO)
FALK	94	PL B339 248	+Olive, Srednicki (UCS)	B, MINN)
FRANKE	94	PL B336 415		z, WIEN)
HOSODA	94	PL B331 211	+Abe, Amako, Arai+ (VENUS	Collab.)
SHIRAI	94	PRL 72 3313	+Ohmoto, Abe, Amako+ (VENUS	Collab.)
ACTON	93G	PL B313 333	+Akers, Alexander, Allison, Anderson+ (OPA)	L Collab.)
ADRIANI	93M	PRPL 236 1	+Aguilar-Benitez, Ahlen, Alcaraz, Aloisio+ (L:	3 Collab.)
CLAVELLI	93	PR D47 1973	+Coulter, Yuan	(ALAT)
DREES	93	PR D47 376	+Nojiri (DES	Y, SLAC)
FALK	93	PL B318 354	+Madden, Olive, Srednicki (UCB, UCS)	
HEBBEKER	93	ZPHY C60 63	·	(CERN)
KELLEY	93	PR D47 2461	+Lopez, Nanopoulos, Pois, Yuan (TAMI	J, `ALAH)
LAU	93	PR D47 1087		(HOUS)
LOPEZ	93C	PL B313 241	+Nanopoulos, Wang (TAMU, HARO	c. CERNÍ
MIZUTA	93	PL B298 120	+Yamaguchi	(TOHO)
MORI	93	PR D48 5505	+(KEK, NIIG, TOKY, TOKA, KOBE, OSAK, TIN	T. GIFU
ABE	92L	PRL 69 3439	+Amidei, Anway-Wiese, Apollinari, Atac+ (CDI	Collab.)
BOTTINO	92	MPL A7 733	+DeAlfaro, Fornengo, Morales, Puimedon+ (TOR	I, ZARA)
Also	91	PL B265 57	Bottino, de Alfaro, Fornengo, Mignola+ (TOI	RI, INFN)
CLAVELLI	92	PR D46 2112		(ALAT)
DATTA	92	ZPHY C54 513	+Guchait, Raychaudhuri (JAD)	A, CALC)
DECAMP	92	PRPL 216 253		( Collab.)
ELLIS	92F	PL B283 252	+Roszkowski	(CERN)
KAWASAKI	92	PR D46 1634	+Mizuta (OSU	, TOHO)
LOPEZ	92	NP B370 445	+Nanopoulos, Yuan	(TAMU)
MCDONALD	92	PL B283 80	+Olive, Srednicki (LISB, MINI	v. ucsbí
ROY	92	PL B283 270		(CERN)
ABREU	91F	NP B367 511	+Adam, Adami, Adye, Akesson+ (DELPH	I Collab.
AKESSON	91	ZPHY C52 219		Collab.)
ALEXANDER	91F	ZPHY C52 175		Collab.)
ANTONIADIS	91	PL B262 109	+Ellis, Nanopoulos (EPOL, CERN, TAMU	
BAER	91	PR D44 207	+Tata, Woodside (FSU, HA	
BAER	91B	PR D44 725	+Drees, Godbole+ (FSU, DESY, BOMB, UCD	
BOTTINO	91	PL B265 57		RI, INFN)
DREES	91	PR D43 2971		I, HAWA)
GELMINI	91	NP B351 623		A, TRST)
HIDAKA	91	PR D44 927	\	(TGAK)
KAMIONKOW.	91	PR D44 3021	Kamionkowski (CHI	C, FNAL)
MORI	91B	PL B270 89	+Nojiri, Oyama, Suzuki+ (Kamiokand	
NOJIRI	91	PL B261 76		(KEK)
OLIVE	91	NP B355 208	+Srednicki (MINI	ν, ùcsΒ)
ROSZKOWSKI	91	PL B262 59	*	(CERN)

SATO ABREU ADREU ADACHI ADEVA AKESSON AKRAWY AKRAWY AKRAWY ALITTI BAER BAER DECAMP DECAMP DECES ELLIS GRIEST GRIFOLS KRAUSS ROSZKOWSKI	91 90F 90G 90C 90I 90B 90D 90O 90 90 90 90 90 90 90 90 90	PR D44 2220 PL 8247 148 PL 8247 157 PL 8249 157 PL 8249 354 PL 8249 342 PL 8240 261 PL 8240 261 PL 8240 261 PL 8252 290 PL 8253 363 PR D41 3414 PL 8256 286 PL 8245 541 PL 8245 551 PR D41 3555 PR D41	+Hirata, Kajita, Kifune, Kihara+ +Adam, Adami, Adye, Alekseev+ +Adam, Adami, Adye, Alekseev+ +Aihara, Doser, Enomoto+ +Adriani, Aguilar-Benitez, Abbari, Alcar +Alitti, Ansari, Ansorge+ +Alexander, Allison, Allport, Anderson+ +Alexander, Allison, Allport, Anderson+ +Alexander, Allison, Allport, Anderson+ +Dress, Tale, Allison, Allport, Anderson+ +Deschizeaux, Ees, Minard, Crespo+ -Deschizeaux, Goy, Lees+ +Hikasa +Nanopoulos, Roszkowski, Schramm (CE+ +Kamionkowski, Turner	(UAZ Collab.) (OPAL Collab.) (OPAL Collab.) (OPAL Collab.) (UAZ Collab.) (UAZ Collab.) (SALEPH Collab.) (EEPH Collab.) (EERN, HAWA) (CERN, KEK) (UAZ CHOLIAB.) (ERN, HARC, TAMU) (UCB, CHIC, FMAL) (BARC) (YALE)
SAKAI	90	PL B234 534	+Gu, Low, Abe, Fujii+	(TAMU, ÌHARC) (AMY Collab.)
SODERSTROM TAKETANI	√1 90 90	PRL 64 2980 PL B234 202	+McKenna, Abrams, Adolphsen, Averill- +Odaka, Abe, Amako+	(Mark II Collab.) (VENUS Collab.)
ZHUKOVSKII	90	SJNP 52 931	+Eminov	(MOSU)
ABE	89J	Translated from YAF	52 1473	
ADACHI	891	ZPHY C45 175 PL B218 105	+Amako, Arai, Fukawa+ +Aihara, Dijkstra, Enomoto, Fujii+	(VENUS Collab.) (TOPAZ Collab.)
ADEVA	89B	PL B233 530	+Adriani, Aguilar-Benitez, Akbari+	(L3 Collab.)
ALBAJAR	89	ZPHY C44 15	+Albrow, Allkofer, Arnison, Astbury+	(UA1 Collab.)
HEARTY Also	89 87	PR D39 3207 PRL 58 1711	+Rothberg, Young, Johnson, Whitaker+ Hearty, Rothberg, Young, Johnson+	(ASP Collab.) (ASP Collab.)
Also	86	PRL 56 685	Bartha, Burke, Extermann+	(ASP Collab.)
NAKAMURA	89	PR D39 1261	+Kobayashi, Konaka, Imai, Masaike+	(KÝOT TMTC)
OLIVE	89	PL B230 78	+Srednicki	(MINN, UCSB) (FSU, KEK, WISC) (FSU, KEK, WISC) (CELLO Collab.)
BAER Also	88 89B	PR D38 1485 PR D39 989 erratum	+Hagiwara, Tata Baer, Hagiwara, Tata	(FSU, KEK, WISC)
BEHREND	88B	PL B215 186	+Criegee, Dainton, Field+	(CELLO Collab.)
ELLIS	88B	PL B215 404	+Olive, Sarkar, Sciama (CERN, 1	MINN, RAL, CAMB) (NEAS, TAMU)
NATH OLIVE	88 88	PR D38 1479 PL B205 553	+Arnowitt +Srednicki	(NEAS, TAMU)
SREDNICKI	88	NP B310 693	+Watkins, Olive	(MINN, UCSB) (MINN, UCSB)
ADEVA	87	PL B194 167	+Anderhub, Ansari, Becker+	(Mark-J Collab.)
ALBAJAR	87B	PL B185 241	+Albrow, Allkofer, Arnison+	(UA1 Collab.)
ALBAJAR ANSARI	87D 87D	PL B198 261 PL B195 613	+Albrow, Allkofer+ +Bagnaia, Banner+	(UA1 Collab.) (UA2 Collab.)
ARNOLD	87	PL B186 435	+Barth+ (BRUX DUUC LOUC BA	ARI AICH CERN+)
BAER	87B	PR D35 1598	+Hagiwara, Tata	(KEK, ANL, WISC) ANL, DESY, WISC) (CELLO Collab.) (ASP Collab.)
Also BEHREND	86 87B	PRL 57 294 ZPHY C35 181	Baer, Hagiwara, Tata (	ANL, DESY, WISC)
HEARTY	87	PRL 58 1711	+Buerger, Criegee, Dainton+ +Rothberg, Young, Johnson+	(ASP Collab.)
NG	87	PL B188 138	+Olive, Srednicki	(MINN, UCSB)
TUTS ALBRECHT	87 86C	PL B186 233 PL 167B 360	+Franzini, Youssef, Zhao+	(CUSB Collab.) (ARGUS Collab.)
BADIER	86	ZPHY*C31 21	+Binder, Harder+ +Bemporad, Boucrot, Callot+	(NA3 Collab )
BARNETT	86	NP B267 625	+Haber, Kane	(LBL, UCSC, MICH) (MAC Collab.)
FORD	86 86	PR D33 3472	+Qi, Read+	(MAC Collab.)
GAISSER VOLOSHIN	86	PR D34 2206 SJNP 43 495	+Steigman, Tilav +Okun	(BART, DELA) (ITEP)
		Translated from YAF	43 779.	
ADEVA Also	85 84C	PL 152B 439 PRPL 109 131	+Becker, Becker-Szendy+ Adeva, Barber, Becker+	(Mark-J Collab.) (Mark-J Collab.)
AKERLOF	85	PL 156B 271	+Bonvicini, Chapman, Errede+	(HRS Collab.)
BARTEL	85L	PL 155B 288	+Becker, Cords, Felst, Hagiwara+	(JADE Collab.)
BEHREND	85 85B	PL 161B 182	+Burger, Criegee, Fenner+ Cooper-Sarkar, Parker, Sarkar+	(CELLO Collab.)
COOPER DAWSON	85	PL 160B 212 PR D31 1581	+Eichten, Quigg	(WA66 Collab.) (LBL, FNAL)
FARRAR	85	PRL 55 895		(RHTG)
GOLDMAN	85	Physica 15D 181	+Haber	(LANL, UCSC) (UCSC, MICH) (Mark-J Collab.)
HABER ADEVA	85 84B	PRPL 117 75 PRL 53 1806	+Kane +Barber, Becker, Berdugo+	(Mark-L Collab.)
BALL	84	PRL 53 1314	+Coffin, Gustafson+ (MICH, FIRZ,	OSU, FNAL, WISC)
BARBER	84B	PL 139B 427	+Shrock	(STON)
BARTEL BARTEL	84B 84C	PL 139B 327	+Becker, Bowdery, Cords+	(JADE Collab.) (JADE Collab.)
BRICK	84	PL 146B 126 PR D30 1134	+Becker, Bowdery, Cords+ + (BROW, CAVE, IIT, IND, M	IT. MONS. NIIM+)
ELLIS	84	NP B238 453	+Hagelin, Nanopoulos, Olive, Srednicki	(CERN)
FARRAR BEHREND	84 83	PRL 53 1029	Chan Farmer Comments	(RUTG)
BERGSMA	83C	PL 123B 127 PL 121B 429	+Chen, Fenner, Gumpel+ +Dorenbosch, Jonker+	(CELLO Collab.) (CHARM Collab.)
CHANOWITZ	83	PL 126B 225	+Sharpe	(UCB, LBL) (NEAS)
GOLDBERG	83	PRL 50 1419		(NEAS)
HOFFMAN KRAUSS	83 83	PR D28 660 NP B227 556	+Frank, Mischke, Moir, Schardt	(LANL, ARZS) (HARV)
VYSOTSKII	83	SJNP 37 948		(ITEP)
KANE	82	Translated from YAF PL 112B 227	37 1597. +Leveille	(MICH)
CABIBBO	81	PL 105B 155	+ Farrar, Maiani	(ROMA, RUTG)
FARRAR	78	PL 76B 575	+Fayet	(CIT)
Also	78B	PL 79B 442	Farrar, Fayet	(CIT)

# Quark and Lepton Compositeness, Searches for

# SEARCHES FOR QUARK AND LEPTON COMPOSITENESS

If quarks and leptons are made of constituents, then at the scale of constituent binding energies, there should appear new interactions among quarks and leptons. At energies much below the compositeness scale  $(\Lambda)$ , these interactions are suppressed by inverse powers of  $\Lambda$ . The dominant effect should come from the lowest dimensional interactions with four fermions (contact terms), whose most general chirally invariant form reads [1]

$$L = \frac{g^2}{2\Lambda^2} \left[ \eta_{LL} \, \overline{\psi}_L \, \gamma_\mu \, \psi_L \, \overline{\psi}_L \, \gamma^\mu \, \psi_L + \eta_{RR} \, \overline{\psi}_R \, \gamma_\mu \, \psi_R \, \overline{\psi}_R \, \gamma^\mu \, \psi_R \right.$$
$$\left. + 2\eta_{LR} \, \overline{\psi}_L \, \gamma_\mu \, \psi_L \, \overline{\psi}_R \, \gamma^\mu \, \psi_R \right] . \tag{1}$$

Chiral invariance provides a natural explanation why quark and lepton masses are much smaller than their inverse size  $\Lambda$ . We may determine the scale  $\Lambda$  unambiguously by using the above form of the effective interactions; the conventional method [1] is to fix its scale by setting  $g^2/4\pi = g^2(\Lambda)/4\pi = 1$  for the new strong interaction coupling and by setting the largest magnitude of the coefficients  $\eta_{\Omega\beta}$  to be unity. In the following, we denote

$$\begin{split} & \Lambda = \Lambda_{LL}^{\pm} \ \, \text{for} \ \, (\eta_{LL},\, \eta_{RR},\, \eta_{LR}) = (\pm 1,\, 0,\, 0) \;, \\ & \Lambda = \Lambda_{RR}^{\pm} \ \, \text{for} \ \, (\eta_{LL},\, \eta_{RR},\, \eta_{LR}) = (0,\, \pm 1,\, 0) \;, \\ & \Lambda = \Lambda_{VV}^{\pm} \ \, \text{for} \ \, (\eta_{LL},\, \eta_{RR},\, \eta_{LR}) = (\pm 1,\, \pm 1,\, \pm 1) \;, \\ & \Lambda = \Lambda_{AA}^{\pm} \ \, \text{for} \ \, (\eta_{LL},\, \eta_{RR},\, \eta_{LR}) = (\pm 1,\, \pm 1,\, \mp 1) \;, \end{split} \label{eq:lambda}$$

as typical examples. Such interactions can arise by constituent interchange (when the fermions have common constituents, e.g., for  $ee \rightarrow ee$ ) and/or by exchange of the binding quanta (whenever binding quanta couple to constituents of both particles).

Another typical consequence of compositeness is the appearance of excited leptons and quarks ( $\ell^*$  and  $q^*$ ). Phenomenologically, an excited lepton is defined to be a heavy lepton which shares leptonic quantum number with one of the existing leptons (an excited quark is defined similarly). For example, an excited electron  $e^*$  is characterized by a nonzero transition-magnetic coupling with electrons. Smallness of the lepton mass and the success of QED prediction for  $g^-2$  suggest chirality conservation, *i.e.*, an excited lepton should not couple to both left- and right-handed components of the corresponding lepton.

Excited leptons may be classified by  $SU(2)\times U(1)$  quantum numbers. Typical examples are:

1. Sequential type

$$\begin{pmatrix} 
u^* \\ \ell^* \end{pmatrix}_L$$
 ,  $[
u_R^*]$  ,  $\ell_R^*$  .

 $\nu_R^*$  is necessary unless  $\nu^*$  has a Majorana mass.

2. Mirror type

$$[
u_L^*] \;, \qquad \ell_L^* \;, \qquad \left(egin{array}{c} 
u^* \ \ell^* \end{array}
ight)_R \;.$$

3. Homodoublet type

$$\begin{pmatrix} \nu^* \\ \ell^* \end{pmatrix}_L \;, \qquad \begin{pmatrix} \nu^* \\ \ell^* \end{pmatrix}_R \;.$$

Similar classification can be made for excited quarks.

Excited fermions can be pair produced via their gauge couplings. The couplings of excited leptons with Z are listed in the following table (for notation see Eq. (1) in "Standard Model of Electroweak Interactions"):

	Sequential type	Mirror type	Homodoublet type
$V^{\ell^*} A^{\ell^*}$	$-\frac{1}{2} + 2\sin^2\theta_W$	$-\frac{1}{2} + 2\sin^2\theta_W$	$-1 + 2\sin^2\theta_W$
	$-\frac{1}{2}$	$+\frac{1}{2}$	0
$V^{ u_D^*}$	$+\frac{1}{2}$	$+\frac{1}{2}$	+1
$A^{ u_D^*}$	$+\frac{1}{2}$	$-\frac{\overline{1}}{2}$	0
$V^{ u_M^*}$	0	0	and the same of th
$A^{ u_M^*}$	+1	-1	-

Here  $\nu_D^*$  ( $\nu_M^*$ ) stands for Dirac (Majorana) excited neutrino. The corresponding couplings of excited quarks can be easily obtained. Although form factor effects can be present for the gauge couplings at  $q^2 \neq 0$ , they are usually neglected.

In addition, transition magnetic type couplings with a gauge boson are expected. These couplings can be generally parametrized as follows:

$$\mathcal{L} = \frac{\lambda_{\gamma}^{(f^{*})} e}{2m_{f^{*}}} \overline{f}^{*} \sigma^{\mu\nu} (\eta_{L} \frac{1-\gamma_{5}}{2} + \eta_{R} \frac{1+\gamma_{5}}{2}) f F_{\mu\nu} 
+ \frac{\lambda_{Z}^{(f^{*})} e}{2m_{f^{*}}} \overline{f}^{*} \sigma^{\mu\nu} (\eta_{L} \frac{1-\gamma_{5}}{2} + \eta_{R} \frac{1+\gamma_{5}}{2}) f Z_{\mu\nu} 
+ \frac{\lambda_{W}^{(\ell^{*})} g}{2m_{\ell^{*}}} \overline{\ell}^{*} \sigma^{\mu\nu} \frac{1-\gamma_{5}}{2} \nu W_{\mu\nu} 
+ \frac{\lambda_{W}^{(\nu^{*})} g}{2m_{\nu^{*}}} \overline{\nu}^{*} \sigma^{\mu\nu} (\eta_{L} \frac{1-\gamma_{5}}{2} + \eta_{R} \frac{1+\gamma_{5}}{2}) \ell W_{\mu\nu}^{\dagger} 
+ \text{h.c.},$$
(3)

where  $g=e/\sin\theta_W$ ,  $F_{\mu\nu}=\partial_{\mu}A_{\nu}-\partial_{\nu}A_{\mu}$  is the photon field strength,  $Z_{\mu\nu}=\partial_{\mu}Z_{\nu}-\partial_{\nu}Z_{\mu}$ , etc. The normalization of the coupling is chosen such that

$$\max(|\eta_L|, |\eta_R|) = 1.$$

Chirality conservation requires

$$\eta_L \eta_R = 0 \ . \tag{4}$$

These couplings can arise from  $SU(2)\times U(1)$ -invariant higher-dimensional interactions. A well-studied model is the interaction of homodoublet type  $\ell^*$  with the Lagrangian [2,3]

$$\mathcal{L} = \frac{1}{2\Lambda} \overline{L}^* (g f \frac{\tau^a}{2} W_{\mu\nu}^a + g' f' Y B_{\mu\nu}) \frac{1 - \gamma_5}{2} L + \text{h.c.} , \qquad (5)$$

#### **Quark and Lepton Compositeness**

where L denotes the lepton doublet  $(\nu,\ell)$ ,  $\Lambda$  is the compositeness scale, g, g' are SU(2) and U(1) $_Y$  gauge couplings, and  $W^a_{\mu\nu}$  and  $B_{\mu\nu}$  are the field strengths for SU(2) and U(1) $_Y$  gauge fields. The same interaction occurs for mirror-type excited leptons. For sequential-type excited leptons, the  $\ell^*$  and  $\nu^*$  couplings become unrelated, and the couplings receive the extra suppression of  $(250\,{\rm GeV})/\Lambda$  or  $m_{L^*}/\Lambda$ . In any case, these couplings satisfy the relation

$$\lambda_W = -\sqrt{2}\sin^2\theta_W(\lambda_Z \cot\theta_W + \lambda_\gamma) \ . \tag{6}$$

Additional coupling with gluons is possible for excited quarks:

$$\mathcal{L} = \frac{1}{2\Lambda} \overline{Q}^* \sigma^{\mu\nu} \left( g_s f_s \frac{\lambda^a}{2} G^a_{\mu\nu} + g f \frac{\tau^a}{2} W^a_{\mu\nu} + g' f' Y B_{\mu\nu} \right)$$

$$\times \frac{1 - \gamma_5}{2} Q + \text{h.c.} , \qquad (7)$$

where Q denotes a quark doublet,  $g_s$  is the QCD gauge coupling, and  $G_{u\nu}^a$  the gluon field strength.

Some experimental analyses assume the relation  $\eta_L = \eta_R = 1$ , which violates chiral symmetry. We encode the results of such analyses if the crucial part of the cross section is proportional to the factor  $\eta_L^2 + \eta_R^2$  and the limits can be reinterpreted as those for chirality conserving cases  $(\eta_L, \eta_R) = (1,0)$  or (0,1) after rescaling  $\lambda$ .

Several different conventions are used by LEP experiments to express the transition magnetic couplings. To facilitate comparison, we reexpress these in terms of  $\lambda_Z$  and  $\lambda_{\gamma}$  using the following relations and taking  $\sin^2 \theta_W = 0.23$ . We assume chiral couplings, i.e., |c| = |d| in the notation of Ref. 2.

1. ALEPH (charged lepton and neutrino)

$$\lambda_Z^{\text{ALEPH}} = \frac{1}{2} \lambda_Z$$
 (1990 papers) (8a)

$$\frac{2c}{\Lambda} = \frac{\lambda_Z}{m_{\ell^*}[\text{or } m_{\nu^*}]} \quad \text{(for } |c| = |d|)$$
 (8b)

2. ALEPH (quark)

$$\lambda_u^{\text{ALEPH}} = \frac{\sin \theta_W \cos \theta_W}{\sqrt{\frac{1}{4} - \frac{2}{3} \sin^2 \theta_W + \frac{8}{9} \sin^4 \theta_W}} \lambda_Z = 1.11 \lambda_Z \quad (9)$$

3. L3 and DELPHI (charged lepton)

$$\lambda^{\text{L3}} = \lambda_Z^{\text{DELPHI}} = -\frac{\sqrt{2}}{\cot \theta_W - \tan \theta_W} \lambda_Z = -1.10 \lambda_Z$$
 (10)

4. L3 (neutrino)

$$f_Z^{L3} = \sqrt{2}\lambda_Z \tag{11}$$

5. OPAL (charged lepton)

$$\frac{f^{\text{OPAL}}}{\Lambda} = -\frac{2}{\cot \theta_W - \tan \theta_W} \frac{\lambda_Z}{m_{\ell^*}} = -1.56 \frac{\lambda_Z}{m_{\ell^*}} \quad (12)$$

6. OPAL (quark)

$$\frac{f^{\text{OPAL}}c}{\Lambda} = \frac{\lambda_Z}{2m_{q^*}} \quad (\text{for } |c| = |d|)$$
 (13)

7. DELPHI (charged lepton)

$$\lambda_{\gamma}^{\rm DELPHI} = -\frac{1}{\sqrt{2}} \, \lambda_{\gamma} \tag{14}$$

If leptons are made of color triplet and antitriplet constituents, we may expect their color-octet partners. Transitions between the octet leptons  $(\ell_8)$  and the ordinary lepton  $(\ell)$  may take place via the dimension-five interactions

$$\mathcal{L} = \frac{1}{2\Lambda} \sum_{\ell} \left\{ \overline{\ell}_{8}^{\alpha} g_{S} F_{\mu\nu}^{\alpha} \sigma^{\mu\nu} \left( \eta_{L} \ell_{L} + \eta_{R} \ell_{R} \right) + h.c. \right\}$$
 (15)

where the summation is over charged leptons and neutrinos. The leptonic chiral invariance implies  $\eta_L$ ,  $\eta_R=0$  as before.

#### References

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- K. Hagiwara, S. Komamiya, and D. Zeppenfeld, Z. Phys. C29, 115 (1985).
- N. Cabibbo, L. Maiani, and Y. Srivastava, Phys. Lett. 139B, 459 (1984).

#### SCALE LIMITS for Contact Interactions: $\Lambda(eeee)$

Limits are for  $\Lambda_{II}^{\pm}$  only. For other cases, see each reference.

$\Lambda_{LL}^{+}(TeV)$	$\Lambda_{LL}^-$ (TeV)	CL%	DOCUMENT ID		TECN	COMMENT
>1.6		95 · 1	,2 BUSKULIC	93Q	RVUE	
	>3.6	95	³ KROHA	92	RVUE	
• • • We	do not use	the follow	wing data for ave	ages	, fits, lin	nits, etc. • • •
>1.6	>2.0	95	² BUSKULIC	93Q	ALEP	E _{cm} =88.25-94.25 GeV
	>2.2	95	BUSKULIC	93Q	RVUE	•
>1.3		95	³ KROHA	92	RVUE	
>0.7	>2.8	95	BEHREND	91C	CELL	E _{cm} =35 GeV
>1.3	>1.3	95	KIM	89	AMY	E _{cm} =50-57 GeV
>1.4	>3.3	95	⁴ BRAUNSCH	88	TASS	E _{cm} =12-46.8 GeV
>1.0	>0.7	95	⁵ FERNANDEZ	87B	MAC	E _{cm} =29 GeV
>1.1	>1.4	95	6 BARTEL	86C	JADE	E _{cm} =12-46.8 GeV
>1.17	>0.87	95	⁷ DERRICK	86	HRS	E _{cm} =29 GeV
>1.1	>0.76	95	⁸ BERGER	85B	PLUT	E _{cm} =34.7 GeV

 $^{\rm 1}$  This BUSKULIC 93Q value is from ALEPH data plus PEP/PETRA/TRISTAN data reanalyzed by KROHA 92.

² BUSKULIC 93Q uses the following prescription to obtain the limit: when the naive 95%CL limit is better than the statistically expected sensitivity for the limit, the latter is adopted for the limit.

3 KROHA 92 limit is from fit to BERGER 858, BARTEL 86c, DERRICK 868, FERNANDEZ 878, BRAUNSCHWEIG 88, BEHREND 918, and BEHREND 91c. The fit gives  $\eta/\Lambda_{LL}^2 = +0.230 \pm 0.206 \,\, {\rm TeV}^{-2}$ .

⁴BRAUNSCHWEIG 88 assumed  $m_Z = 92$  GeV and  $\sin^2 \theta_W = 0.23$ .

 5  FERNANDEZ 87B assumed  $\sin^{2}\! heta_{W}^{-}=$  0.22.

 6  BARTEL 86C assumed  $m_Z=93$  GeV and  $\sin^2\!\theta_W=0.217$ .

⁷ DERRICK 86 assumed  $m_Z = 93$  GeV and  $g_V^2 = (-1/2 + 2\sin^2\theta_W)^2 = 0.004$ .

⁸BERGER 85B assumed  $m_Z = 93$  GeV and  $\sin^2 \theta_W = 0.217$ .

#### SCALE LIMITS for Contact Interactions: $\Lambda(ee\mu\mu)$

Limits are for  $\Lambda_{LL}^{\pm}$  only. For other cases, see each reference.

$\Lambda_{LL}^{+}(TeV)$	$\Lambda_{LL}^{-}(\text{TeV})$	CL%	DOCUMENT ID		TECN	COMMENT
>2.6	>1.9	95	9,10 BUSKULIC	93Q	RVUE	
• • • We	e do not us	e the f	ollowing data for aver	ages,	fits, lin	nits, etc. • • •
>1.7	>2.2	95	¹⁰ VELISSARIS	94	AMY	E _{cm} =57.8 GeV
>1.3	>1.5	95	¹⁰ BUSKULIC	93Q	ALEP	E _{cm} =88.25-94.25 GeV
>2.3	>2.0	95	HOWELL	92	TOPZ	E _{cm} =52-61.4 GeV
	>1.7	95	¹¹ KROHA	92	RVUE	
>2.5	>1.5	95	BEHREND	91c	CELL	E _{cm} =35-43 GeV
>1.6	>2.0	95	¹² ABE	901	VNS	E _{cm} =50-60.8 GeV
>1.9	>1.0	95	KIM	89	AMY	E _{cm} =50-57 GeV
>2.3	>1.3	95	BRAUNSCH	880	TASS	E _{cm} =30-46.8 GeV
>4.4	>2.1	95	¹³ BARTEL	86C	JADE	E _{cm} =12-46.8 GeV
>2.9	>0.86	95	¹⁴ BERGER	85	PLUT	E _{cm} =34.7 GeV

- ⁹ This BUSKULIC 93Q value is from ALEPH data plus PEP/PETRA/TRISTAN data reanalyzed by KROHA 92.
- 10 BUSKULIC 93Q and VELISSARIS 94 use the following prescription to obtain the limit: when the naive 95%CL limit is better than the statistically expected sensitivity for the limit, the latter is adopted for the limit.
- 11  KROHA 92 limit is from fit to BARTEL 86C, BEHREND 87C, BRAUNSCHWEIG 88D, BRAUNSCHWEIG 89C, ABE 90I, and BEHREND 91C. The fit gives  $\eta/\Lambda_{LL}^2=-0.155\pm$ 0.095 TeV $^{-2}$ .  12  ABE 901 assumed  $m_Z$  =91.163 GeV and  $\sin^2\!\theta_W$  = 0.231.  13  BARTEL 86c assumed  $m_Z$  = 93 GeV and  $\sin^2\!\theta_W$  = 0.217.

- ¹⁴ BERGER 85 assumed  $m_Z = 93$  GeV and  $\sin^2 \theta_W = 0.217$ .

#### SCALE LIMITS for Contact Interactions: $\Lambda(ee\tau\tau)$

Limits are for  $\Lambda_{II}^{\pm}$  only. For other cases, see each reference.

$\Lambda_{LL}^{+}(\text{TeV})$	$\Lambda_{LL}^{-}(TeV)$	CL%	DOCUMENT ID		TECN	COMMENT
>1.9	>2.9	95	15 KROHA	92	RVUE	
• • • W	'e do not us	e the	following data for aver	ages	, fits, lin	nits, etc. • • •
>1.4	>2.0	95	16 VELISSARIS	94	AMY	E _{cm} =57.8 GeV
>1.0	>1.5	95	¹⁶ BUSKULIC	93Q	ALEP	E _{cm} =88.25-94.25 GeV
>1.8	>2.3	95	^{16,17} BUSKULIC	93Q	RVUE	
>1.9	>1.7	95	HOWELL	92	TOPZ	E _{cm} =52-61.4 GeV
>1.6	>2.3	95	BEHREND	91C	CELL	E _{cm} =35-43 GeV
>1.8	>1.3	95	¹⁸ ABE	<b>9</b> 0ı	VNS	E _{cm} =50-60.8 GeV
>2.2	>3.2	95	¹⁹ BARTEL	86	JADE	E _{cm} =12-46.8 GeV

- 15 KROHA 92 limit is from fit to BARTEL 86C BEHREND 89B, BRAUNSCHWEIG 89C, ABE 901, and BEHREND 91C. The fit gives  $\eta/\Lambda_{LL}^2=+0.095\pm0.120~{
  m TeV}^{-2}$
- 16 BUSKULIC 930 and VELISSARIS 94 use the following prescription to obtain the limit: when the naive 95%CL limit is better than the statistically expected sensitivity for the
- limit, the latter is adopted for the limit.

  This BUSKULIC 93Q value is from ALEPH data plus PEP/PETRA/TRISTAN data reanalyzed by KROHA 92.
- $^{18}\,\mathrm{ABE}$  901 assumed  $m_Z$  =91.163 GeV and  $\mathrm{sin}^2\theta_W$  = 0.231.
- $^{19}\,\mathrm{BARTEL}$  86 assumed  $m_Z=$  93 GeV and  $\sin^2\!\theta_W^{}=$  0.217.

#### SCALE LIMITS for Contact Interactions: $\Lambda(\ell\ell\ell\ell)$

Lepton universality assumed. Limits are for  $\Lambda_{LL}^{\pm}$  only. For other cases, see each

$\Lambda_{LL}^{+}(\text{TeV})$	$\Lambda_{LL}^-$ (TeV)	CL%	DOCUMENT ID		TECN	COMMENT
>3.5	>2.8	95	^{20,21} BUSKULIC	93Q	RVUE	
• • • We	do not us	e the	following data for aver	ages,	, fits, lim	its, etc. • • •
>3.0	>2.3	95	^{21,22} BUSKULIC	93Q	ALEP	E _{cm} =88.25-94.25 GeV
>2.5	>2.2	95	²³ HOWELL	92	TOPZ	E _{cm} =52-61.4 GeV
>3.4	>2.7	95	²⁴ KROHA	92	RVUE	

- 20 This BUSKULIC 93Q value is from ALEPH data plus PEP/PETRA/TRISTAN data re-
- analyzed by KROHA 92.  21  BUSKULIC 930 uses the following prescription to obtain the limit: when the naive 95%CL limit is better than the statistically expected sensitivity for the limit, the latter is adopted
- for the limit. 22 From  $e^+e^- \rightarrow e^+e^-$ ,  $\mu^+\mu^-$ , and  $\tau^+\tau^-$ . 23 HOWELL 92 limit is from  $e^+e^- \rightarrow \mu^+\mu^-$  and  $\tau^+\tau^-$ .
- 24  KROHA 92 limit is from fit to most PEP/PETRA/TRISTAN data. The fit gives  $\eta/\Lambda_{LL}^2$  $= -0.0200\,\pm\,0.0666\;\text{TeV}^{\textstyle -2}.$

#### SCALE LIMITS for Contact Interactions: $\Lambda(eeqq)$

Limits are for  $\Lambda^{\pm}_{LL}$  only. For other cases, see each reference.

$\Lambda_{LL}^{+}(TeV)$	$\Lambda_{LL}^{-}(\text{TeV})$	CL%	DOCUMENT ID		TECN	COMMENT
> 2.3	> 1.0	95	²⁵ AID	95	H1	(eeqq) (u, d quarks)
> 1.7	> 2.2	95	²⁶ ABE	91D	CDF	(eeqq) (u, d quarks)
>1.2		95 .	²⁷ ADACHI	91	TOPZ	(eeqq) (flavor-universal)
	>1.7	95	²⁸ ABE	89L	VNS	(e e q q) (flavor-universal)

• • • We do not use the following data for averages, fits, limits, etc. • •

	>1.6	95	²⁷ ADACHI	91 TOPZ	(eegg)
					(flavor-universal)
>0.6	>1.7	95	²⁹ BEHREND	91c CELL	(eècc)
>1.1	>1.0	95	²⁹ BEHREND	91c CELL	(eebb)
>0.9		95	²⁸ ABE	89L VNS	(eeqq)
					(flavor-universal)
>1.05	>1.61	95	³⁰ HAGIWARA	89 RVUE	(eecc)
> 1 21	> 0.52	O.F.	31 LLACIMADA	00 01/115	1

- ²⁵ AID 95 limits are from the  $Q^2$  spectrum measurement of  $ep \rightarrow eX$ .
- ²⁶ ABE 91D limits are from  $e^+e^-$  mass distribution in  $p\overline{p} \rightarrow e^+e^-$  X at  $E_{\rm cm}=1.8$  TeV.
- 27  ADACHI 91 limits are from differential jet cross section. Universality of  $\Lambda(eeqq)$  for five flavors is assumed.
- The proof is assumed. 28 ABE 89. I mits are from jet charge asymmetry. Universality of  $\Lambda(eeqq)$  for five flavors is assumed. 29 BEHREND 91c is from data at  $E_{cm} = 35-43$  GeV.
- $^{30}\,\mathrm{The}$  HAGIWARA 89 limit is derived from forward-backward asymmetry measurements of  $D/D^*$  mesons by ALTHOFF 83c, BARTEL 84E, and BARINGER 88.

31 The HAGIWARA 89 limit is derived from forward-backward asymmetry measurement of b hadrons by BARTEL 84D.

#### SCALE LIMITS for Contact Interactions: $\Lambda(\mu\mu qq)$

Λ ⁺ _{LL} (TeV)	Λ _{LL} (TeV)	CL%	DOCUMENT ID		TECN	COMMENT
>1.4	>1.6	95	ABE	92B	CDF	$(\mu\mu q q)$ (isosinglet)

#### SCALE LIMITS for Contact Interactions: $\Lambda(\ell\nu\ell\nu)$

VALUE (TeV)	CL%	DOCUMENT ID		TECN	COMMENT
>3.10	90	32 JODIDIO	86	SPEC	$\Lambda_{LR}^{\pm}( u_{\mu} u_{e}\mue)$
• • • We do not use the	e followi	ng data for average:	s, fits	s, limits,	etc. • • •
>3.8		33 DIAZCRUZ			
>8.1		³³ DIAZCRUZ			
>4.1					$\Lambda_{LL}^{+}( au u_{ au}\mu u_{\mu})$
>6.5		³⁴ DIAZCRUZ	94	RVUE	$\Lambda_{LL}^-( au u_{ au}\mu u_{\mu})$

- ³² JODIDIO 86 limit is from  $\mu^+ \to \overline{\nu}_\mu \, e^+ \, \nu_e$ . Chirality invariant interactions  $L = (g^2/\Lambda^2)$  $\left[\eta_{LL}\left(\overline{\nu}_{\mu}\underline{\iota}\gamma^{\alpha}\mu_{L}\right)\left(\overline{e}_{L}\gamma_{\alpha}\nu_{e\,L}\right)\right.\\ \left.+\left.\eta_{LR}\left(\overline{\nu}_{\mu}\underline{\iota}\gamma^{\alpha}\nu_{e\,L}\left(\overline{e}_{R}\gamma_{\alpha}\mu_{R}\right)\right]\right.\\ \text{with }g^{2}/4\pi=1\text{ and }g$  $(\eta_{LL},\eta_{LR})=(0,\pm 1)$  are taken. No limits are given for  $\Lambda_{LL}^\pm$  with  $(\eta_{LL},\eta_{LR})=(\pm 1,0)$ . For more general constraints with right-handed neutrinos and chirality nonconserving contact interactions, see their text.
- 33 DIAZCRUZ 94 limits are from  $\Gamma(\tau \to e \nu \nu)$  and assume flavor-dependent contact interactions with  $\Lambda(\tau \nu_{\tau} e \nu_{e}) \ll \Lambda(\mu \nu_{\mu} e \nu_{e})$ . 34 DIAZCRUZ 94 limits are from  $\Gamma(\tau \to \mu \nu \nu)$  and assume flavor-dependent contact
- interactions with  $\Lambda(\tau \nu_{\tau} \mu \nu_{\mu}) \ll \Lambda(\mu \nu_{\mu} e \nu_{e})$ .

#### SCALE LIMITS for Contact Interactions: $\Lambda(qqqq)$

Limits are for  $\Lambda_{LL}^{\pm}$  with color-singlet isoscalar exchanges among  $u_L$ 's and  $d_L$ 's only.

See EICHTEN 84 for details.

١

/) CL%	DOCUMENT ID	<u>TE</u>	CN COMMENT
	³⁵ ABE	96 CI	OF $p\overline{p} \rightarrow \text{jets inclusive}$
95	³⁶ ABE	92D CE	OF $p\overline{p} \rightarrow \text{jets inclusive}$
do not use the follow	ing data for averag	es, fits, li	mits, etc. • • •
95	37 ABE	93G CI	OF $p\overline{p} \rightarrow \text{dijet mass}$
99		92M CE	OF $\rho \overline{\rho} \rightarrow \text{dijet angl.}$
95	³⁹ ALITTI	91B U	$\lambda 2  \rho \overline{p} \rightarrow \text{jets inclusive}$
95	³⁶ ABE	89 CI	OF $p\overline{p} \rightarrow \text{jets inclusive}$
95	⁴⁰ ABE	89H C[	OF $p\overline{p} \rightarrow \text{dijet angl.}$
95	⁴¹ ARNISON	86C UA	$\lambda 1 \qquad \rho \overline{\rho} \rightarrow \text{jets inclusive}$
95	⁴² ARNISON	86D U	$\lambda 1  p\overline{p} \rightarrow \text{dijet angl.}$
95	⁴³ APPEL	85 U	$\lambda 2  p \overline{p} \rightarrow \text{jets inclusive}$
95	⁴⁴ BAGNAIA	84C U/	A2 Repl. by APPEL 85
	95 e do not use the follow 95 99 95 95 95 95 95 95	35 ABE 95 36 ABE e do not use the following data for averag 95 37 ABE 99 38 ABE 95 39 ALITTI 95 36 ABE 95 40 ABE 95 41 ARNISON 95 42 ARNISON 95 43 APPEL	35 ABE 96 CE 95 36 ABE 920 CI 95 36 ABE 920 CI 95 37 ABE 936 CE 95 37 ABE 936 CE 95 38 ABE 92M CE 95 39 ALITTI 918 UV 95 36 ABE 89 CE 95 40 ABE 89H CE 95 41 ARNISON 860 UV 95 42 ARNISON 860 UV 95 43 APPEL 85 UV

- 35  ABE 96 finds that the inclusive jet cross section for  $E_{\mathcal{T}}$  >200 GeV is significantly higher than the  $\mathcal{O}(\alpha_3^3)$  perturbative QCD prediction. This could be interpreted as the effect of a contact interaction with  $\Lambda_{LL} \sim 1.6$  TeV. However, ABE 96 state that uncertainty in the parton distribution functions, higher-order QCD corrections, and the detector calibration may possibly account for the effect.
- 36  Limit is from inclusive jet cross-section data in  $p\overline{p}$  collisions at  $E_{\rm Cm}=1.8$  TeV. The limit takes into account uncertainties in choice of structure functions and in choice of
- 37 ABE 93.6 limit is from dijet mass distribution in  $p\overline{p}$  collisions at  $E_{cm}=1.8$  TeV. The limit is the weakest from several choices of structure functions and renormalization scale. 38 ABE 92M limit is from dijet angular distribution for  $m_{dijet} > 550$  GeV in  $p\overline{p}$  collisions at  $E_{\rm cm}$ =1.8 TeV.
- 39 ALITTI 91B limit is from inclusive jet cross section in  $p\bar{p}$  collisions at  $E_{\rm CM}=630$  GeV. The limit takes into account uncertainties in choice of structure functions and in choice of process scale
- 40  ABE 89H limit is from dijet angular distribution for  $m_{\mbox{dijet}} >$  200 GeV at the Fermilab Tevatron Collider with  $E_{\mbox{cm}} = 1.8$  TeV. The QCD prediction is quite insensitive to choice of structure functions and choice of process scale.
- 41 ARNISON 86C limit is from the study of inclusive high- $\rho_T$  jet distributions at the CERN  $\bar{p}_P$  collider ( $E_{\rm Cm}=546$  and 630 GeV). The QCD prediction renormalized to the low- $\rho_T$  region gives a good fit to the data.

  42 ARNISON 86D limit is from the study of dijet angular distribution in the range 240 < m(dijet) < 300 GeV at the CERN  $\bar{p}_P$  collider ( $E_{\rm Cm}=630$  GeV). QCD prediction using
- EHLQ structure function (EICHTEN 84) with  $\Lambda_{QCD}$  = 0.2 GeV for the choice of  $\mathit{Q}^2$  =  $\rho_T^2$  gives the best fit to the data.
- 3 APPEL 85 limit is from the study of inclusive high- p  $_{\mathcal{T}}$  jet distributions at the CERN  $^{\bar{p}}p$  collider ( $E_{\rm Cm}=630$  GeV). The QCD prediction renormalized to the low- p  $_{\mathcal{T}}$  region gives a good description of the data.
- ⁴⁴ BAGNAIA 84C limit is from the study of jet  $p_T$  and dijet mass distributions at the CERN  $\overline{p}p$  collider ( $E_{\rm CM}=540$  GeV). The limit suffers from the uncertainties in comparing the data with the QCD prediction.

#### Quark and Lepton Compositeness

#### MASS LIMITS for Excited e (e*)

Most  $e^+e^-$  experiments assume one-photon or Z exchange. The limits from some  $e^+e^-$  experiments which depend on  $\lambda$  have assumed transition couplings which are chirality violating  $(\eta_L=\eta_R)$ . However they can be interpreted as limits for chirality-conserving interactions after multiplying the coupling value  $\lambda$  by  $\sqrt{2}$ ; see Note.

Excited leptons have the same quantum numbers as other ortholeptons. See also the searches for ortholeptons in the "Searches for Heavy Leptons"

#### Limits for Excited e (e*) from Pair Production

These limits are obtained from  $e^+e^- \rightarrow e^{*+}e^{*-}$  and thus rely only on the (electroweak) charge of e*. Form factor effects are ignored unless noted. For the case of limits from Z decay, the  $e^*$  coupling is assumed to be of sequential type. Possible t channel contribution from transition magnetic coupling is neglected. All limits assume  $e^* \rightarrow e\gamma$  decay except the limits from  $\Gamma(Z)$ .

For limits prior to 1987, see our 1992 edition (Physical Review D45, 1 June, Part II

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>45.6	95	ADRIANI	93M L3	$Z \rightarrow e^* e^*$
>45.6	95	ABREU	92c DLPH	$Z \rightarrow e^* e^*$
>46.1	95	DECAMP	92 ALEP	$Z \rightarrow e^* e^*$
>44.9	95	AKRAWY	901 OPAL	$Z \rightarrow e^* e^*$
• • • We do not u	se the followi	ng data for averages	, fits, limits	, etc. • • •
>29.8	95	⁴⁵ BARDADIN	92 RVUE	$\Gamma(Z)$
>26.1	95	⁴⁶ DECAMP	92 ALEP	$Z \rightarrow e^* e^*; \Gamma(Z)$
>33	95	⁴⁶ ABREU	91F DLPH	$Z \rightarrow e^* e^*; \Gamma(Z)$
>45.0	95	⁴⁷ ADEVA	90F L3	$Z \rightarrow e^* e^*$
>44.6	95	⁴⁸ DECAMP	90G ALEP	$e^+e^- \rightarrow e^*e^*$
>30.2	95	ADACHI	89B TOPZ	e ⁺ e ⁻ → e*e*
>28.3	95	KIM	89 AMY	$e^+e^- \rightarrow e^*e^*$
>27.9	95	⁴⁹ ABE	88B VNS	$e^+e^- \rightarrow e^*e^*$

- 45 BARDADIN-OTWINOWSKA 92 limit is independent of decay modes. Based on  $\Delta\Gamma(Z)$ <36 MeV.
- 46 Limit is independent of e* decay mode
- 47 ADEVA 90F is superseded by ADRIANI 93M.
- 48 Superseded by DECAMP 92.
- 49 ABE 888 limits assume  $e^+e^- \rightarrow e^{*+}e^{*-}$  with one photon exchange only and  $e^* \rightarrow$

#### Limits for Excited e (e*) from Single Production

These limits are from  $e^+e^- \to e^*e$ ,  $W \to e^*\nu$ , or  $ep \to e^*X$  and depend on transition magnetic coupling between e and  $e^*$ . All limits assume  $e^* \to e\gamma$  decay except as noted. Limits from LEP, UA2, and H1 are for chiral coupling, whereas all other limits are for nonchiral coupling,  $\eta_L=\eta_R=1$ . In most papers, the limit is expressed in the form of an excluded region in the  $\lambda-m_{e^*}$  plane. See the original

For limits prior to 1987, see our 1992 edition (Physical Review D45, 1 June, Part II (1992)). VALUE (GeV) CL% DOCUMENT ID TECN COMMENT

>89	95	ADRIANI	93M L3	$Z \rightarrow ee^*, \lambda_Z > 0.5$
>88	95	ABREU	92c DLPH	$Z \rightarrow ee^*, \lambda_Z > 0.5$
>91	95	DECAMP	92 ALEP	$Z \rightarrow ee^*, \lambda_Z > 1$
>87	95	AKRAWY	901 OPAL	$Z \rightarrow ee^*, \lambda_Z > 0.5$
• • • We do not use	the following	ng data for average	es, fits, limits,	etc. • • •
		⁵⁰ DERRICK	95B ZEUS	$e p \rightarrow e^* X$
		⁵¹ ABT	93 H1	$e \rho \rightarrow e^* X$
>86	95	ADRIANI	93M L3	$\lambda_{\gamma} > 0.04$
		⁵² DERRICK		Superseded by DER- RICK 958
>86	95	ABREU	92C DLPH	$e^+e^- \rightarrow ee^*, \lambda_{\gamma} >$
>88	95	⁵³ ADEVA	90F L3	$Z \rightarrow ee^*, \lambda_7 > 0.5$
>86	95	⁵³ ADEVA		$Z \rightarrow ee^*, \lambda_Z > 0.04$
>81	95	54 DECAMP		$Z \rightarrow ee^*, \lambda_Z > 1$
>50	95	ADACHI		$e^+e^- ightarrow e e^*, \lambda_{\gamma} >$
>56	95	KIM	89 AMY	$e^{+}\stackrel{0.04}{e^{-}} \rightarrow ee^*, \lambda_{\gamma} >$
none 23–54	95	55 ABE	88B VNS	$e^{+}e^{-} \rightarrow e e^{*} \lambda_{\gamma} >$
>75	95	⁵⁶ ANSARI	87D UA2	$W \rightarrow e^* \nu; \lambda_W > 0.7$
>63	95	⁵⁶ ANSARI	87D UA2	
>40	95	⁵⁶ ANSARI	87D UA2	$W \rightarrow e^* \nu$ ; $\lambda_W > 0.09$
				**

- ⁵⁰ DERRICK 95B search for single  $e^*$  production via  $e^*e_{\gamma}$  coupling in ep collisions with the decays  $e^* \to e\gamma$ , eZ,  $\nu W$ . See their Fig. 13 for the exclusion plot in the  $m_{e^*} - \lambda \gamma$
- 51 ABT 93 search for single e* production via  $e^*e\gamma$  coupling in ep collisions with the decays e*  $\rightarrow$  e $\gamma$ , eZ,  $\nu W$ . See their Fig. 4 for exclusion plot in the  $m_{e^*}$ - $\lambda_{\gamma}$  plane.
- 52 DERRICK 93B search for single e* production via e*  $e\gamma$  coupling in  $e\rho$  collisions with the decays  $e^* \to e \gamma$ , e Z,  $\nu \bar{W}$ . See their Fig. 3 for exclusion plot in the  $m_{e^*}$ - $\lambda_{\gamma}$  plane.
- 53 Superseded by ADRIANI 93M.
- The state of the
- $e\gamma$  (e) (quasi-real compton scattering). 56 ANSARI 87D is at  $E_{\rm Cm}=$  546–630 GeV.

#### Limits for Excited e (e*) from $e^+e^- \rightarrow \gamma \gamma$

These limits are derived from indirect effects due to  $e^*$  exchange in the t channel and depend on transition magnetic coupling between e and  $e^*$ . All limits are for  $\lambda_\gamma=1$ . All limits except ABE 89J are for nonchiral coupling with  $\eta_L=\eta_R=1$ .

For limits prior to 1987, see our 1992 edition (Physical Review D45, 1 June, Part II

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>146	95	ACCIARRI	95G	L3	
• • • We do not	use the followin	g data for averages	, fits	, limits,	etc. • • •
		57 BUSKULIC	93Q	ALEP	
>127	95		92B	L3	
>114	95	⁵⁹ BARDADIN	92	RVUE	
> 99	95		92	ALEP	
		⁶⁰ SHIMOZAWA	92	TOPZ	
>100	95	ABREU	91E	DLPH	
>116	95	AKRAWY	91F	OPAL	
> 83	95	ADEVA	90K	L3	
> 82	95	AKRAWY	90F	OPAL	
> 68	95	⁶¹ ABE	89J	VNS	$\eta_L = 1,  \eta_R = 0$
> 90.2	95	ADACHI	89B	TOPZ	
> 65	95	KIM	89	AMY	

- $^{57}\,\text{BUSKULIC}$  93Q obtain  $\Lambda^+>$  121 GeV (95%CL) from ALEPH experiment and  $\Lambda^+>$  135 GeV from combined TRISTAN and ALEPH data. These limits roughly correspond to limits on  $m_{e^*}$ .
- 58 ADRIANI 92B superseded by ACCIARRI 95G.
  59 BARDADIN-OTWINOWSKA 92 limit from flt to the combined data of DECAMP 92,
- ABREU 91E, ADEVA 90K, AKRAWY 91F.  60  SHIMOZAWA 92 fit the data to the limiting form of the cross section with  $m_{e^*}\gg E_{\rm cm}$ and obtain  $m_{\rm ex}$  >168 GeV at 95%CL. Use of the full form would reduce this limit by a few GeV. The statistically unexpected large value is due to fluctuation in the data.
- 61 The ABE 89J limit assumes chiral coupling. This corresponds to  $\lambda_{\gamma}=$  0.7 for nonchiral coupling.

#### Indirect Limits for Excited e (e*)

These limits make use of loop effects involving  $e^{*}$  and are therefore subject to theoretical uncertainty.

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DOCUMENT ID TECN COMMENT
VALUE (GeV)
• • • We do not use the following data for averages, fits, limits, etc. • •
                                         62 DORENBOS,.. 89 CHRM \overline{\nu}_{\mu}e \rightarrow \overline{\nu}_{\mu}e and \nu_{\mu}e \rightarrow \nu_{\mu}e
                                          63 GRIFOLS
                                                                 86 THEO \nu_{\mu}\,e^{'} 
ightarrow \, \nu_{\mu}\,e^{'}
                                          64 RENARD
                                                                 82 THEO g-2 of electron
```

- 62  DORENBOSCH 89 obtain the limit  $\lambda_{\gamma}^2 \Lambda_{\rm Cut}^2/m_{e^*}^2 < 2.6$  (95% CL), where  $\Lambda_{\rm Cut}$  is the cutoff scale, based on the one-loop calculation by GRIFOLS 86. If one assumes that  $\Lambda_{\rm cut}=1$  TeV and  $\lambda_{\gamma}=1$ , one obtains  $m_{e^*}>620$  GeV. However, one generally expects  $\lambda_{\gamma}\approx m_{e^*}/\Lambda_{\rm cut}$  in composite models.
- 63  GRIFOLS 86 uses  $v_{\mu}e \rightarrow v_{\mu}e$  and  $\overline{v}_{\mu}e \rightarrow \overline{v}_{\mu}e$  data from CHARM Collaboration to derive mass limits which depend on the scale of compositeness.
- define mass limits which depend on the scale of compositions of embeddings of  $e^*$  and  $\mu^*$ . See figures 2 and 3 of the paper.

#### MASS LIMITS for Excited $\mu$ ( $\mu$ *)

#### Limits for Excited $\mu$ ( $\mu$ *) from Pair Production

These limits are obtained from  $e^+e^- \rightarrow \mu^{*+}\mu^{*-}$  and thus rely only on the (electroweak) charge of  $\mu^*$ . Form factor effects are ignored unless noted. For the case of limits from Z decay, the  $\mu^*$  coupling is assumed to be of sequential type. All limits assume  $\mu^* \to \mu \gamma$  decay except for the limits from  $\Gamma(Z)$ .

For limits prior to 1987, see our 1992 edition (Physical Review D45, 1 June, Part II

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>45.6	95	ADRIANI	93M	L3	$Z \rightarrow \mu^* \mu^*$
>45.6	95	ABREU	<b>92</b> C	DLPH	$Z \rightarrow \mu^* \mu^*$
>46.1	95	DECAMP	92	ALEP	$Z \rightarrow \mu^* \mu^*$
>44.9	95	AKRAWY	90ı	OPAL	$Z \rightarrow \mu^* \mu^*$
• • • We do not use the	following d	lata for averages	, fits	, limits,	etc. • • •
>29.8	95 65	BARDADIN	92	RVUE	Γ(Z)
>26.1	95 66	DECAMP	92	ALEP	$Z \rightarrow \mu^* \mu^*$ ; $\Gamma(Z)$
>33	95 66	ABREU	91F	DLPH	$Z \rightarrow \mu^* \mu^*; \Gamma(Z)$
>45.3	95 67	ADEVA	90F	L3	$Z \rightarrow \mu^* \mu^*$
>44.6	95 68	DECAMP	90G	ALEP	$e^+e^- \rightarrow \mu^*\mu^*$
>29.9	95	ADACHI	89B	TOPZ	$e^+e^- \rightarrow \mu^*\mu^*$
>28.3	95	KIM	89	AMY	$e^+e^- \rightarrow \mu^*\mu^*$

- 65 BARDADIN-OTWINOWSKA 92 limit is independent of decay modes. Based on  $\Delta\Gamma(Z){<}36$  MeV.
- ⁶⁶ Limit is independent of  $\mu^*$  decay mode.
- 67 Superseded by ADRIANI 93M.
- ⁶⁸ Superseded by DECAMP 92.

#### Limits for Excited $\mu$ ( $\mu$ *) from Single Production

These limits are from  $e^+e^- \to \mu^*\mu$  and depend on transition magnetic coupling between  $\mu$  and  $\mu^*$ . All limits assume  $\mu^* \to \mu\gamma$  decay. Limits from LEP are for chiral coupling, whereas all other limits are for nonchiral coupling,  $\eta_L = \eta_R = 1$ . In most papers, the limit is expressed in the form of an excluded region in the  $\lambda - m_{\mu^*}$  plane. See the original papers.

For limits prior to 1987, see our 1992 edition (Physical Review D45, 1 June, Part II

(1332)).				
VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>89	95	ADRIANI	93M L3	$Z \rightarrow \mu \mu^*, \lambda_Z > 0.5$
>88	95	ABREU	92c DLPH	$Z \rightarrow \mu \mu^*, \lambda_Z > 0.5$
>91	95	DECAMP	92 ALEP	$Z \rightarrow \mu \mu^*, \lambda_Z > 1$
>87	95	AKRAWY	90I OPAL	$Z \rightarrow \mu \mu^*, \lambda_Z > 1$
• • We do not use	the followi	ng data for averag	es, fits, limits	, etc. • • •
>85	95	⁶⁹ ADEVA	90F L3	$Z \rightarrow \mu \mu^*, \lambda_Z > 1$
>75	95	⁶⁹ ADEVA	90F L3	$Z \rightarrow \mu \mu^*, \lambda_Z > 0.1$
>80	95	70 DECAMP	90G ALEP	$e^+e^- \rightarrow \mu \mu^*, \lambda_Z=1$
>50	95	ADACHI	89B TOPZ	$e^+e^- \rightarrow \mu\mu^*$
				$\lambda_{\gamma}=0.7$
>46	95	KIM	89 AMY	$e^+e^- \rightarrow \mu \mu^*$ ,
				$\lambda_{\gamma} = 0.2$

⁶⁹Superseded by ADRIANI 93M.

#### Indirect Limits for Excited $\mu$ ( $\mu^*$ )

These limits make use of loop effects involving  $\mu^*$  and are therefore subject to theoretical uncertainty.

retical uncertainty.				
VALUE (GeV)	DOCUMENT ID	TECN	COMMENT	
• • We do not use the following	g data for averages,	fits, limits,	etc. • • •	
	71 RENARD	82 THEO	σ−2 of muon	

 $^{^{71}}$  RENARD 82 derived from g-2 data limits on mass and couplings of  $e^*$  and  $\mu^*$ . See figures 2 and 3 of the paper.

#### MASS LIMITS for Excited $\tau$ ( $\tau$ *)

#### Limits for Excited $\tau$ ( $\tau^*$ ) from Pair Production

These limits are obtained from  $e^+e^- \rightarrow \tau^{*+}\tau^{*-}$  and thus rely only on the (electroweak) charge of  $\tau^*$ . Form factor effects are ignored unless noted. For the case of limits from Z decay, the  $\tau^*$  coupling is assumed to be of sequential type. All limits assume  $\tau^* \to \tau \gamma$  decay except for the limits from  $\Gamma(Z)$ .

For limits prior to 1987, see our 1992 edition (Physical Review D45, 1 June, Part II

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
VALUE (GEV)	CL/0	DOCOMENTID			
>45.6	95	ADRIANI	93M	L3	$Z \rightarrow \tau^* \tau^*$
>45.3	95	ABREU	<b>9</b> 2C	DLPH	$Z \rightarrow \tau^* \tau^*$
>46.0	95	DECAMP	92	ALEP	$Z \rightarrow \tau^* \tau^*$
>44.9	95	AKRAWY	901	OPAL	$Z \rightarrow \tau^* \tau^*$
• • We do not use the	following d	ata for averages	, fits,	limits,	etc. • • •
>29.8	95 72	BARDADIN	92	RVUE	Γ( <b>Z</b> )
>26.1	95 73	DECAMP	92	ALEP	$Z \rightarrow \tau^* \tau^*; \Gamma(Z)$
>33			91F	DLPH	$Z \rightarrow \tau^* \tau^*; \Gamma(Z)$
>45.5					$Z \rightarrow \tau^* \tau^*$
>41.2	95 75	DECAMP	<b>9</b> 0G	ALEP	$e^+e^- \rightarrow \tau^*\tau^*$
>29.0	95	ADACHI	89B	TOPZ	$e^+e^- \rightarrow \tau^*\tau^*$

⁷² BARDADIN-OTWINOWSKA 92 limit is independent of decay modes. Based on  $\Delta\Gamma(Z)$ <36 MeV.

#### Limits for Excited $\tau$ ( $\tau^*$ ) from Single Production

These limits are from  $e^+e^- \to \tau^*\tau$  and depend on transition magnetic coupling between  $\tau$  and  $\tau^*$ . All limits assume  $\tau^* \to \tau\gamma$  decay. Limits from LEP are for chiral coupling, whereas all other limits are for nonchiral coupling,  $\eta_L=\eta_R=1$ . In most papers, the limit is expressed in the form of an excluded region in the  $\lambda-m_{\tau^*}$  plane. See the original papers.

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VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>88	95	ADRIANI	93M L3	$Z \rightarrow \tau \tau^*$ , $\lambda_{7} > 0.5$
>87	95	ABREU	92c DLPH	$Z \rightarrow \tau \tau^*, \lambda_Z > 0.5$
>90	95	DECAMP	92 ALEP	$Z \rightarrow \tau \tau^*, \lambda_Z > 0.18$
>86.5	95	AKRAWY	90I OPAL	$Z \rightarrow \tau \tau^*, \lambda_Z > 1$
• • • We do not	use the followi	ng data for averag	es, fits, limits,	etc. • • •
>88	95	⁷⁶ ADEVA	90L L3	$Z \rightarrow \tau \tau^*, \lambda_Z > 1$
>59	95	77 DECAMP	90G ALEP	$Z \rightarrow \tau \tau^*, \lambda_Z = 1$
>40	95	⁷⁸ BARTEL	86 JADE	$e^+e^- \rightarrow \tau \tau^*, \lambda_{\gamma}=1$
>41.4	95	⁷⁹ BEHREND	86 CELL	$e^+e^- \rightarrow \tau \tau^*, \lambda_{\gamma}=1$
>40.8	95	⁷⁹ BEHREND		$e^+e^- \rightarrow \tau \tau^*, \lambda_{\gamma} = 0.7$
76 Superseded by	ADRIANI 93N	1.		,

⁷⁷ Superseded by DECAMP 92.

#### MASS LIMITS for Excited Neutrino ( $\nu^*$ )

#### Limits for Excited $\nu$ ( $\nu$ *) from Pair Production

These limits are obtained from  $Z \rightarrow \nu^* \nu^*$  decay and thus rely only on the (electroweak) charge of  $\nu^*$ . Form factor effects are ignored unless noted. The  $\nu^*$  coupling is assumed to be of sequential type. Limits assume  $u^* \to 
u \gamma$  decay except for the  $\Gamma(Z)$  measurement which makes no assumption about decay mode.

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>47	95	80 DECAMP	92	ALEP	
• • • We do not	use the follow	ving data for averages	, fits	, limits,	etc. • • •
>43.7	95	⁸¹ BARDADIN	92	RVUE	Γ( <i>Z</i> )
>42.6	95	82 DECAMP	92	ALEP	$\Gamma(Z)$
>35.4	95	83,84 DECAMP	900	ALEP	$\Gamma(Z)$
>46	95	^{84,85} DECAMP	900	ALEP	
⁸⁰ Limit is based	on $B(Z \rightarrow$	$\nu^* \overline{\nu}^*) \times B(\nu^* \rightarrow \nu$	$\gamma)^2$	< 5 ×	$10^{-5}$ (95%CL) assuming
Dirac $\nu^*$ , B( $\nu^*$			.,		, ,

81 BARDADIN-OTWINOWSKA 92 limit is for Dirac  $\nu^*$ . Based on  $\Delta\Gamma(Z){<}36$  MeV. The limit is 36.4 GeV for Majorana  $\nu^*$ . 45.4 GeV for homodoublet  $\nu^*$  82  Limit is for Dirac  $\nu^*$ . The limit is 34.6 GeV for Majorana  $\nu^*$ , 45.4 GeV for homodoublet

⁸³DECAMP 900 limit is from excess  $\Delta\Gamma(Z)<89$  MeV. The above value is for Dirac  $\nu^*$ ;

26.6 GeV for Majorana  $\nu^*$ ; 44.8 GeV for homodoublet  $\nu^*$ . 84 Superseded by DECAMP 92.

⁸⁵ DECAMP 900 limit based on B( $Z \rightarrow \nu^* \nu^*$ )·B( $\nu^* \rightarrow \nu \gamma$ )² < 7 × 10⁻⁵ (95%CL), assuming Dirac  $\nu^*$ , B( $\nu^* \rightarrow \nu \dot{\gamma}$ ) = 1.

#### Limits for Excited $\nu$ ( $\nu^*$ ) from Single Production

CL%

VALUE (GeV)

These limits are from  $Z \to \nu \nu^*$  or  $ep \to \nu^* X$  and depend on transition magnetic coupling between  $\nu/e$  and  $\nu^*$ . Assumptions about  $\nu^*$  decay mode are given in DOCUMENT ID

TECN COMMENT

>91	95	ADRIANI	93M L3	$\lambda_Z > 1, \nu^* \rightarrow \nu \gamma$
>89	95	ADRIANI	93M L3	$\lambda_Z > 1, \nu_e^* \rightarrow eW$
>91	95	⁸⁶ DECAMP	92 ALEP	$\lambda_{Z} > 1$
• • • We do not use the	e follov	ving data for averages	, fits, limits,	etc. • • •
		87 DERRICK	95B ZEUS	$ep \rightarrow \nu^* X$
		⁸⁸ ABT	93 H1	eρ → ν*X
>87	95	ADRIANI	93M L3	$\lambda_7 > 0.1, \nu^* \rightarrow \nu \gamma$
>74	95	ADRIANI	93M L3	$\lambda_Z > 0.1, \nu_A^* \rightarrow eW$
		89 BARDADIN	92 RVUE	_
>74	95	86 DECAMP	92 ALEP	$\lambda_Z > 0.034$
>91	95	^{90,91} ADEVA	900 L3	$\lambda_Z > 1$
>83	95	⁹¹ ADEVA	900 L3	$\lambda_Z^- > 0.1, \nu^* \rightarrow \nu \gamma$
>74	95	⁹¹ ADEVA	900 L3	$\lambda_Z > 0.1, \nu_e^* \rightarrow eW$
>90	95	92,93 DECAMP	900 ALEP	$\lambda_{Z} > 1$
>74.7	95	92,93 DECAMP	900 ALEP	$\lambda_Z > 0.06$
06				E

⁸⁶ DECAMP 92 limit is based on B( $Z \rightarrow \nu^* \overline{\nu}$ )×B( $\nu^* \rightarrow \nu \gamma$ ) < 2.7 × 10⁻⁵ (95%CL)

assuming Dirac  $\nu^*$ , B( $\nu^* \to \nu\gamma$ ) = 1. 87 DERRICK 95B search for single  $\nu^*$  production via  $\nu^*eW$  coupling in ep collisions with the decays  $\nu^* \to \nu \gamma$ ,  $\nu Z$ , eW. See their Fig. 14 for the exclusion plot in the  $m_{\nu^*} - \lambda \gamma$ 

plane.  88  ABT 93 search for single  $\nu^*$  production via  $\nu^*\,e\,W$  coupling in  $e\,p$  collisions with the decays  $\nu^* \to \nu \gamma$ ,  $\nu Z$ , eW. See their Fig. 4 for exclusion plot in the  $m_{i,*}$ - $\lambda_W$  plane.

89 See Fig. 5 of BARDADIN-OTWINOWSKA 92 for combined limit of ADEVA 900, DE-

CAMP 900, and DECAMP 92. 90 Limit is either for  $\nu^* \rightarrow \nu \gamma$  or  $\nu^* \rightarrow eW$ .

91 Superseded by ADRIANI 93M.

92 DECAMP 900 limit based on B(Z  $\rightarrow \nu \nu^*$ )·B( $\nu^* \rightarrow \nu \gamma$ ) < 6  $\times$  10⁻⁵ (95%CL), assuming  $B(\nu^* \rightarrow \nu \gamma) = 1$ .

93 Superseded by DECAMP 92.

#### MASS LIMITS for Excited $q(q^*)$

### Limits for Excited q ( $q^*$ ) from Pair Production

These limits are obtained from  $e^+e^- \rightarrow q^* \overline{q}^*$  and thus rely only on the (electroweak) charge of the  $q^*$ . Form factor effects are ignored unless noted. Assumptions about the  $q^*$  decay are given in the comments and footnotes. CL% DOCUMENT ID TECN COMMENT

>45.6	95	94 ADRIANI	93M L3	u or d type, $Z \rightarrow q^*q^*$
>45	95	⁹⁵ DECAMP	92 ALEF	u or d type,
				$Z \rightarrow q^*q^*$
<ul> <li>• • We do not</li> </ul>	use the follow	ing data for averages	, fits, limit	s, etc. • • •
		⁹⁶ ADRIANI	92F L3	$Z \rightarrow a^* a^*$
>41.7	95	97 BARDADIN	92 RVU	E $u$ -type, $\Gamma(Z)$
>44.7	95	97 BARDADIN	92 RVU	E $d$ -type, $\Gamma(Z)$
>40.6	95	98 DECAMP	92 ALEF	$u$ -type, $\Gamma(Z)$
>44.2	95	98 DECAMP	92 ALEF	$d$ -type, $\Gamma(Z)$
>45	95	⁹⁸ ABREU	91F DLPI	H $u$ -type, $\Gamma(Z)$
>45	95	⁹⁸ ABREU	91F DLPI	$d$ -type, $\Gamma(Z)$
>21.1	95	⁹⁹ BEHREND	86c CELL	$e(q^*) = -1/3, q^* \rightarrow q g$
>22.3	95	99 BEHREND	86c CELL	
>22.5	95	⁹⁹ BEHREND	86C CELL	$e(q^*) = -1/3, q^* \rightarrow$
>23.2	95	99 BEHREND	86C CELL	$e(q^*) = 2/3, q^* \rightarrow q\gamma$

⁷⁰ Superseded by DECAMP 92.

 $^{^{73}}$  Limit is independent of  $au^*$  decay mode.

⁷⁴ Superseded by ADRIANI 93M.

⁷⁵ Superseded by DECAMP 92.

⁷⁸ BARTEL 86 is at  $E_{\rm cm} = 30{\text -}46.78 \; {\rm GeV}.$ 

 $^{^{79}}$  BEHREND 86 limit is at  $E_{\rm Cm} =$  33–46.8 GeV.

#### **Quark and Lepton Compositeness**

- 94 ADRIANI 93M limit is valid for B( $q^* \rightarrow qg$ )> 0.25 (0.17) for up (down) type.
- 95 Limit is for B( $q^* \rightarrow qg$ )+B( $q^* \rightarrow q\gamma$ )=1.
- 96 ADRIANI 92F search for  $Z \to q^*\overline{q}^*$  followed with  $q^* \to q\gamma$  decays and give the limit  $\sigma_Z + \mathsf{B}(Z \to q^*\overline{q}^*) + \mathsf{B}^2(q^* \to q\gamma) < 2\,\mathsf{pb}$  at 95%CL. Assuming five flavors of degenerate  $q^*$  of homodoublet type, B( $q^* \rightarrow q \gamma$ ) <4% is obtained for  $m_{q^*}$  <45 GeV.
- 97  BARDADIN-OTWINOWSKA 92 limit based on  $\Delta\Gamma(Z){<}36$  MeV.
- $^{98}\,\mathrm{These}$  limits are independent of decay modes.
- 99  BEHREND 86C search for  $e^+e^- o q^*\overline{q}^*$  for  $m_{q^*} >$ 5 GeV. But m < 5 GeV excluded by total hadronic cross section. The limits are for point-like photon couplings of excited

#### Limits for Excited q (q*) from Single Production

These limits are from  $e^+e^- \to q^* \overline{q}$  or  $p\overline{p} \to q^* X$  and depend on transition magnetic couplings between q and  $q^*$ . Assumptions about  $q^*$  decay mode are given in the footnotes and comments.

VALUE (GeV)

CL%

DOCUMENT ID

>570 (CL = 95%) OUR	EVAL	JATION			
none 80-570	95	¹⁰⁰ ABE	95N	CDF	$p\overline{p} \rightarrow q^*X, q^* \rightarrow qg$ $q\gamma, qW$
>288	90	101 ALITTI	93	UA2	$p\overline{p} \rightarrow q^*X, q^* \rightarrow qg$
> 88	95	102 DECAMP	92	ALEP	$Z \rightarrow qq^*, \lambda_Z > 1$
> 86	95	¹⁰² AKRAWY	90J	OPAL	$Z \rightarrow qq^*, \lambda_Z > 1.2$
• • • We do not use the	followi	ing data for average	s, fits	, limits,	etc. • • •
		103 DERRICK	95B	ZEUS	$ep \rightarrow q^*X$
none 80–540	95	¹⁰⁴ ABE			$p\overline{p} \xrightarrow{q} q^* X, q^* \rightarrow q\gamma,$
> 79	95	¹⁰⁵ ADRIANI	93M	L3	$\lambda_{Z}(L3) > 0.06$
		106 ABREU			$Z \rightarrow q q^*$
		¹⁰⁷ ADRIANI	92F	L3	$Z \rightarrow qq^*$
> 75	95	105 DECAMP	92	ALEP	$Z \rightarrow qq^*, \lambda_Z > 1$
		¹⁰⁸ ALBAJAR		UA1	$p\overline{p} \rightarrow q^*X$
> 39	95	¹⁰⁹ BEHREND	<b>86</b> C	CELL	$q^* \rightarrow qW$ $e^+e^- \rightarrow q^*\overline{q} (q^* \rightarrow qg,q\gamma), \lambda_{\alpha}=1$

- ¹⁰⁰ ABE 95N assume a degenerate  $u^*$  and  $d^*$  with  $f_S = f = f' = \Lambda/m_{q^*}$ . See their Fig. 4 for the excluded region in  $m_{q^*} - f$  plane.
- 101  ALITTI 93 search for resonances in the two-jet invariant mass. The limit is for  $f_{\mathcal{S}}=f$  $= f' = \Lambda/m_{q^*}. \ u^* \text{ and } d^* \text{ are assumed to be degenerate. If not, the limit for } u^* (d^*)$  is 277 (247) GeV if  $m_{d^*} \gg m_{u^*} (m_{u^*} \gg m_{d^*})$ .
- ¹⁰² Assumes B( $q^* \rightarrow q\gamma$ ) = 0.1.
- the decays  $q^* \to qW$ , qZ, qg,  $q\gamma$ . See their Fig. 15 for the exclusion plot in the  $m_{q^*} \lambda \gamma$  plane.  103  DERRICK 95B search for single  $q^*$  production via  $q^*\,q\,\gamma$  coupling in  $e\,p$  collisions with
- 104 ABE 94 search for resonances in jet- $\gamma$  and jet-W invariant mass in  $\rho \overline{\rho}$  collisions at  $E_{\rm cm}$ = 1.8 TeV. The limit is for  $f_s=f=f'=\Lambda/m_{q^*}$  and  $u^*$  and  $u^*$  are assumed to be degenerate. See their Fig. 4 for the excluded region in  $m_{q^*}$ -f plane.
- ¹⁰⁵ Assumes B( $q^* \rightarrow qg$ ) = 1.
- 106 ABREU 920 give  $\sigma(e^+e^- \to Z \to q^*\overline{q} \text{ or } q\overline{q}^*) \times \text{B}(q^* \to q\gamma) <$ 15 pb (95% CL) for  $m_{q^*} <$ 80 GeV.
- 107  ADRIANI 92F search for Z  $\rightarrow~q\,q^*$  with  $q^*\rightarrow~q\,\gamma$  and give the limit  $\sigma_Z$   $\cdot~$  B(Z  $\rightarrow~$  $q\,q^*)\,\cdot\,{\rm B}(q^*\,\rightarrow\,\,q\gamma)<\!(2\text{--}10)\,{\rm pb}$  (95%CL) for  $m_{\,q^*}^{}=$  (46–82) GeV.
- $^{108}\,\mathrm{ALBAJAR}$  89 give  $\sigma(q^*\to~W+\mathrm{jet})/\sigma(W)<0.019$  (90% CL) for  $m_{q^*}~>$  220 GeV.
- $^{109}\,\mathrm{BEHREND}$  86C has  $E_\mathrm{cm}=$  42.5–46.8 GeV. See their Fig. 3 for excluded region in the  $m_{q^*} - (\lambda_\gamma/m_{q^*})^2$  plane. The limit is for  $\lambda_\gamma = 1$  with  $\eta_L = \eta_R = 1$ .

#### MASS LIMITS for Color Sextet Quarks (q6)

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>84	95	110 ABE 89	CDF	$p\overline{p} \rightarrow q_6\overline{q}_6$

110 ABE 89D look for pair production of unit-charged particles which leave the detector before decaying. In the above limit the color sextet quark is assumed to fragment into a unit-charged or neutral hadron with equal probability and to have long enough lifetime not to decay within the detector. A limit of 121 GeV is obtained for a color decuplet.

#### MASS LIMITS for Color Octet Charged Leptons ( $\ell_8$ ) $\lambda \equiv m_{\ell_0}/\Lambda$

€8′					
VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>86	95	¹¹¹ ABE	89D	CDF	Stable $\ell_8$ : $p\overline{p} \rightarrow \ell_8\overline{\ell}_8$
• • • We do not us	se the follow	ing data for averag	es, fits	, limits,	etc. • • •
		¹¹² ABT	93	H1	$e_{R}: e_{P} \rightarrow e_{R} X$
none 3.0-30.3	95	¹¹³ KIM	90	AMY	e ₈ : e ⁺ e ⁻ → ee +
none 3.5-30.3	95	113 KIM	90	AMY	jets $\mu_8 \colon e^+ e^- \to \mu \mu +$ lets
		¹¹⁴ KIM	90	AMY	$e_8: e^+e^- \rightarrow gg; R$
>19.8	95	¹¹⁵ BARTEL	87B	JADE	$e_8, \mu_8, \tau_8$ : $e^+e^-$ ; R
none 5-23.2	95	¹¹⁵ BARTEL		JADE	$\mu_8$ : $e^+e^- \rightarrow \mu\mu$ +
		116 BARTEL	85K	JADE	jets $e_8: e^+e^- \rightarrow gg; R$

- 111 ABE 890 look for pair production of unit-charged particles which leave the detector before decaying. In the above limit the color octet lepton is assumed to fragment into a unit-charged or neutral hadron with equal probability and to have long enough lifetime not to decay within the detector. The limit improves to 99 GeV if it always fragments
- not to decay within the detector. The into a unit-charged hadron. 112 ABT 93 search for  $e_8$  production via e-gluon fusion in  $e_9$  collisions with  $e_8 \rightarrow e_9$ . See their Fig. 3 for exclusion plot in the  $m_{e_8}$ -A plane for  $m_{e_8}$  = 35-220 GeV.
- 113 KIM 90 is at  $E_{\rm cm} = 50$ –60.8 GeV. The same assumptions as in BARTEL 87B are used.
- 114 KIM 90 result  $(m_{\rm e_8} \Lambda_{\rm M})^{1/2} > 178.4$  GeV (95%CL,  $\alpha_8 = 0.16$  used) is subject to the same restriction as for BARTEL 85K. 115 BARTEL 87B is at  $E_{\rm cm} = 46.3$ –46.78 GeV. The limits assume  $\ell_8$  pair production cross sections to be eight times larger than those of the corresponding heavy lepton pair production.
- 116 In BARTEL 85K, R can be affected by  $e^+e^- \to gg$  via  $e_q$  exchange. Their limit  $m_{e_8} > 173$  GeV (CL=95%) at  $\lambda = m_{e_8}/M = 1$  ( $\eta_L = \eta_R = 1$ ) is not listed above because the cross section is sensitive to the product  $\eta_L \eta_R$ , which should be absent in ordinary theory with electronic chiral invariance.

#### MASS LIMITS for Color Octet Neutrinos ( $\nu_8$ )

$\lambda \equiv m_{\ell_8}/\Lambda$		•				
VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT	
>110	90	¹¹⁷ BARGER	89	RVUE	ν ₈ : p p →	$\nu_8 \overline{\nu}_8$
• • We do not use the	e follow	ing data for average	s, fit	s, limits,	etc. • • •	0 0
none 3.8-29.8	95	¹¹⁸ KIM	90	AMY	ν ₈ : e+e-	$\rightarrow  acoplanar$
none 9-21.9	95	¹¹⁹ BARTEL	878	JADE	jets ν ₈ : e ⁺ e ⁻ iets	$\rightarrow  \text{acoplanar}$

- 117 BARGER 89 used ABE 89B limit for events with large missing transverse momentum. Two-body decay  $\nu_{\rm B} \rightarrow \nu_{\rm Z}$  is assumed. 
  118 KIM 90 is at  $E_{\rm Cm} = 50$ –60.8 GeV. The same assumptions as in BARTEL 87B are used. 
  119 BARTEL 87B is at  $E_{\rm Cm} = 46.3$ –46.78 GeV. The limit assumes the  $\nu_{\rm B}$  pair production cross section to be eight times larger than that of the corresponding heavy neutrino pair production. This assumption is not valid in general for the weak couplings, and the limit can be sensitive to its  ${\rm SU}(2)_L \times {\rm U}(1)_Y$  quantum numbers.

#### MASS LIMITS for W₈ (Color Octet W Boson)

VALUE (GeV)	DOCUMENT ID	TE	CN COMMENT
• • • We do not use th	e following data for averages	, fits, lir	nits, etc. • • •
	¹²⁰ ALBAJAR	89 UA	$1 p \overline{p} \rightarrow W_8 X$
120			$W_8 \rightarrow W_g$

¹²⁰ ALBAJAR 89 give  $\sigma(W_8 \rightarrow W + \text{jet})/\sigma(W) < 0.019$  (90% CL) for  $m_{W_0} > 220$  GeV.

#### Limits on $ZZ\gamma$ Coupling

Limits are for the electric dipole transition form factor for  $Z \rightarrow \gamma Z^*$  parametrized as  $f(s') = \beta(s'/m_Z^2 - 1)$ , where s' is the virtual Z mass. In the Standard Model  $\beta \sim 10^{-5}$ .

VALUE	CL%	DOCUMENT ID	TECN	COMMENT	
• • • We do not use the	ne following	data for average	es, fits, limits,	etc. • • •	
< 0.80	95	ADRIANI	92J L3	$Z \rightarrow \gamma \nu \overline{\nu}$	

#### REFERENCES FOR Searches for Quark and Lepton Compositeness

ABE	96	PRL (submitted)		+Akimoto, Akopian, Albrow+	(CDF Collab.)
		/CDFR/2995			(****
ABE	95N	PRL 74 3538		+Albrow, Amendolia, Amidei, Antos+	(CDF Collab.)
ACCIARRI	95G	PL B353 136		+Adam, Adriani, Aguilar-Benitez, Ahlen+	(L3 Collab.)
AID	95	PL B353 578		+Andreev, Andrieu, Appuhn, Arpagaus+	(H1 Collab.)
DERRICK	95B	ZPHY C65 627		+Krakauer, Magill, Musgrave, Repond+	(ZEUS Collab.)
ABE	94	PRL 72 3004		+Albrow, Amidei, Anway-Wiese, Apollinari	
DIAZCRUZ	94	PR D49 R2149		Diaz Cruz, Sampayo	(CINV)
VELISSARIS	94	Pl. B331 227		+Lusin, Chung, Park, Cho, Bodek, Kim+	(AMY Collab.)
ABE	93G	PRL 71 2542		+Albrow, Akimoto, Amidei, Anway-Wiese+	(CDF Collab.)
ABT	93	NP B396 3		+Andreev, Andrieu, Appuhn, Arpagaus+	(H1 Collab.)
ADRIANI	93M	PRPL 236 1		+Aguilar-Benitez, Ahlen, Alcaraz, Aloisio+	(L3 Collab.)
ALITTI	93	NP B400 3		+Ambrosini, Ansari, Autiero, Bareyre+	(UA2 Collab.)
BUSKULIC	93Q	ZPHY C59 215		+Decamp, Goy, Lees, Minard, Mours+	(ALEPH Collab.)
DERRICK	93B	PL B316 207		+Krakauer, Magill, Musgrave, Repond+	(ZEUS Collab.)
ABE	92B	PRL 68 1463		+Amidei, Apollinari, Atac, Auchincloss+	(CDF Collab.)
ABE	92D	PRL 68 1104		+Amidei, Apollinari, Atac, Auchincloss+	(CDF Collab.)
ABE	92M	PRL 69 2896		+Amidei, Anway-Wiese, Apollinari, Atac+	(CDF Collab.)
ABREU	92C	ZPHY C53 41		+Adam, Adami, Adye, Akesson+	(DELPHI Collab.)
ABREU	92D	ZPHY C53 555		+Adam, Adami, Adye, Akesson, Alekseev+	
ADRIANI	92B	PL B288 404		+Aguilar-Benitez, Ahlen, Akbari, Alcaraz+	(L3 Collab.)
ADRIANI	92F	PL B292 472		+Aguilar-Benitez, Ahlen, Akbari, Alcarez+	(L3 Collab.)
ADRIANI	92J	PL B297 469		+Aguilar-Benitez, Ahlen, Alcarez, Aloisio+	(L3 Collab.)
BARDADIN	92	ZPHY C55 163		Bardadin-Otwinowska	(CLER)
DECAMP	92	PRPL 216 253			(ALEPH Collab.)
HOWELL	92	PL B291 206		+Deschizeaux, Goy, Lees, Minard+ +Koltick, Tauchi, Miyamoto, Kichimi+	
KROHA	92			+Koitick, Tauchi, Wilyamoto, Kichimi+	(TOPAZ Collab.)
	92	PR D46 58		U 100 December 61	(ROCH)
PDG			Part		K, LBL, BOST+)
SHIMOZAWA	92	PL B284 144		+Fujimoto, Abe, Adachi, Doser+	(TOPAZ Collab.)
ABE	91D	PRL 67 2418		+Amidei, Apollinari, Atac, Auchincloss+	(CDF Collab.)
ABREU	91E	PL B268 296		+Adam, Adami, Adye, Akesson+	(DELPHI Collab.)
ABREU	91F	NP B367 511		+Adam, Adami, Adye, Akesson+	(DELPHI Collab.)
ADACHI	91	PL B255 613		+Anazawa, Doser, Enomoto+	(TOPAZ Collab.)
AKRAWY	91F	PL B257 531		+Alexander, Allison, Allport, Anderson+	(OPAL Collab.)
ALITTI	91B	PL B257 232		+Ansari, Autiero, Bareyre, Blaylock+	(UA2 Collab.)
BEHREND	91B	ZPHY C51 143		+Criegee, Field, Franke, Jung+	(CELLO Collab.)
BEHREND	91C	ZPHY C51 149		+Criegee, Field, Franke, Jung, Meyer+	(CELLO Collab.)
Also	91B	ZPHY C51 143		Behrend, Criegee, Field, Franke, Jung+	(CELLO Collab.)
ABE	901	ZPHY C48 13		+Amako, Arai, Asano, Chiba+	(VENUS Collab.)
ADEVA	90F	PL B247 177		+Adriani, Aguilar-Benitez, Akbari, Alcaraz-	
ADEVA	90K	PL B250 199		+Adriani, Aguilar-Benitez, Akbari, Alcarez-	
ADEVA	90L	PL B250 205		+Adriani, Aguilar-Benitez, Akbari, Alcaraz-	
ADEVA	900	PL B252 525		+Adriani, Aguilar-Benitez, Akbari, Alcaraz-	
AKRAWY	90F	PL B241 133		+Alexander, Allison, Allport+	(OPAL Collab.)

AKRAWY	901	PL B244 135	+Alexander, Allison, Allport, Anderson+ (OPAL Collab	٠,
AKRAWY	90J	PL B246 285	+Alexander, Allison, Allport, Anderson+ (OPAL Collab	
DECAMP	90G	PL B236 501	+Deschizeaux, Lees, Minard+ (ALEPH Collab	
DECAMP	900	PL B250 172	+Deschizeaux, Goy, Lees+ (ALEPH Collat	
KIM	90	PL B240 243	+Breedon, Ko, Lander, Maeshima, Malchow+(AMY Collab	
ABE	89	PRL 62 613	+Amidei, Apollinari, Ascori, Atac+ (CDF Collat	
ABE	89B	PRL 62 1825	+Amidei, Apollinari, Ascoli, Atac+ (CDF Collat	
ABE	89D	PRL 63 1447	+Amidei, Apollinari, Ascoli, Atac+ (CDF Collat	
ABE	89H	PRL 62 3020	+Amidei, Apollinari, Ascoli, Atac+ (CDF Collat	
ABE	89J	ZPHY C45 175		
ABE	89L	PL B232 425		
ADACHI	89B	PL B232 423 PL B228 553		
			+Aihara, Doser, Enomoto, Fujii+ (TOPAZ Collat	
ALBAJAR	89	ZPHY C44 15	+Albrow, Allkofer, Arnison, Astbury+ (UA1 Collat	
BARGER	89	PL B220 464	+Hagiwara, Han, Zeppenfeld (WISC, KE	
BEHREND	89B	PL B222 163	+Criegee, Dainton, Field, Franke+ (CELLO Collab	
BRAUNSCH	89C	ZPHY C43 549	Braunschweig, Gerhards, Kirschfink+ (TASSO Collab	
DORENBOS		ZPHY C41 567	Dorenbosch, Udo, Allaby, Amaldi+ (CHARM Collab	
HAGIWARA	89	PL B219 369	+Sakuda, Terunuma (KEK, DURH, HIR)	
KIM	89	PL B223 476	+Kim, Kang, Lee, Myung, Bacala (AMY Collab	
ABE	88B	PL B213 400	+Amako, Arai, Asano, Chiba, Chiba+ (VENUS Collab	
BARINGER	88	PL B206 551	+Bylsma, De Bonte, Koltick, Low+ (HRS Collab	o.)
BRAUNSCH	88	ZPHY C37 171	Braunschweig, Gerhards+ (TASSO Collab	
BRAUNSCH	88D	ZPHY C40 163	Braunschweig, Gerhards, Kirschfink+ (TASSO Collab	
ANSARI	87D	PL B195 613	+Bagnaia, Banner+ (UA2 Collab	o.)
BARTEL	87B	ZPHY C36 15	+Becker, Felst+ (JADE Collab	o.)
BEHREND	87C	PL B191 209	+Buerger, Criegee, Dainton+ (CELLO Collab	).)
FERNANDEZ	87B	PR D35 10	+Ford, Qi, Read, Smith, Camporesi+ (MAC Collab	o.)
ARNISON	86C	PL B172 461	+Albrow, Allkofer+ (UA1 Collab	).)
ARNISON	86D	PL B177 244	+Albajar, Albrow+ (UA1 Collab	).)
BARTEL	86	ZPHY C31 359	+Becker, Felst, Haidt+ (JADE Collab	).)
BARTEL	86C	ZPHY C30 371	+Becker, Cords, Felst, Haidt+ (JADE Collab	o.)
BEHREND	86	PL 168B 420	+Buerger, Criegee, Fenner+ (CELLO Collab	o.)
BEHREND	86C	PL B181 178	+Buerger, Criegee, Dainton+ (CELLO Collab	s.S
DERRICK	86	PL 166B 463	+Gan, Kooijman, Loos+ (HRS Collab	ı.
Also	86B	PR D34 3286	Derrick, Gan, Kooijman, Loos, Musgrave+ (HRS Collab	
DERRICK	86B	PR D34 3286	+Gan, Kooijman, Loos, Musgrave+ (HRS Collab	
GRIFOLS	86	PL 168B 264	+Peris (BAR)	
JODIDIO	86	PR D34 1967	+Balke, Carr, Gidal, Shinsky+ (LBL, NWES, TRIL	
Also	88	PR D37 237 erratum	Jodidio, Balke, Carr+ (LBL, NWES, TRII	
APPEL	85	PL 160B 349	+Bagnaia, Banner+ (UA2 Collab	
BARTEL	85K	PL 160B 337	+Becker, Cords, Eichler+ (JADE Collab	
BERGER	85	ZPHY C28 1	+Genzel, Lackas, Pielorz+ (PLUTO Collab	
BERGER	85B	ZPHY C27 341	+Deuter, Genzel, Lackas, Pielorz+ (PLUTO Collab	
BAGNAIA	84C	PL 138B 430	+Banner, Battiston+ (UA2 Collab	
BARTEL	84D	PL 146B 437	+Becker, Bowdery, Cords+ (JADE Collab	
BARTEL	84E	PL 146B 437		
EICHTEN	84	RMP 56 579	+Becker, Bowdery, Cords, Felst+ (JADE Collab +Hinchliffe, Lane, Quigg (FNAL, LBL, OSI	
ALTHOFF	83C	Pl. 126B 493	+Fischer, Burkhardt+ (TASSO Collab	
RENARD	82	PL 126B 493 PL 116B 264		
KLINAKU	02	FL 110D 204	(CERI	٧)

### Other Particle Searches

#### OMITTED FROM SUMMARY TABLE OTHER PARTICLE SEARCHES

We collect here those searches which do not appear in any of the above search categories. These are listed in the following order:

- 1. Concentration of stable particles in matter
- 2. Galactic WIMP (weakly-interacting massive particle) searches
- 3. Limits on neutral particle production at accelerators
- 4. Limits on jet-jet resonance in hadron collisions
- 5. Limits on charged particles in  $e^+e^-$  collisions
- 6. Limits on charged particles in hadron reactions
- 7. Limits on charged particles in cosmic rays

Note that searches appear in separate sections elsewhere for Higgs bosons (and technipions), other heavy bosons (including  $W_R, W', Z'$ , leptoquarks, axigluons), axions (including pseudo-Goldstone bosons, Majorons, familons), heavy leptons, heavy neutrinos, free quarks, monopoles, supersymmetric particles, and compositeness. We include specific WIMP searches in the appropriate sections when they yield limits on hypothetical particles such as supersymmetric particles, axions, massive neutrinos, monopoles, etc.

We omit papers on CHAMP's, millicharged particles, and other exotic particles. We no longer list for limits on tachyons and centauros. See our 1994 edition for these limits.

#### **CONCENTRATION OF STABLE PARTICLES IN MATTER**

#### Concentration of Heavy (Charge +1) Stable Particles in Matter

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the	e following	data for averages	s, fits	s, limits,	etc. • • •
$< 4 \times 10^{-17}$	95	¹ YAMAGATA	93	SPEC	Deep sea water, $m=5-1600m_D$
$<6 \times 10^{-15}$	95	² VERKERK	92	SPEC	Water, $m=10^5$ to $3 \times 10^7$ GeV
$< 7 \times 10^{-15}$	95	² VERKERK	92	SPEC	Water, $m = 10^4$ , $6 \times 10^7$
$< 9 \times 10^{-15}$	95	² VERKERK	92	SPEC	Water, m= 108 GeV
$< 3 \times 10^{-23}$	90	³ НЕММІСК	90	SPEC	Water, $m = 1000 m_{\rm p}$
$< 2 \times 10^{-21}$	90	³ HEMMICK	90	SPEC	Water, $m = 5000 m_p$
$< 3 \times 10^{-20}$	90	³ HEMMICK	90		Water, $m = 10000 m_{D}$
$<1. \times 10^{-29}$		SMITH	82B		Water, m=30-400mp
$< 2. \times 10^{-28}$		SMITH	82B	SPEC	Water, m=12-1000m _p
$<1. \times 10^{-14}$		SMITH			Water, m >1000 m _n
$<$ (0.2–1.) $\times$ 10 ⁻²¹		SMITH	79	SPEC	Water, $m=6-350  m_p$

¹ YAMAGATA 93 used deep sea water at 4000 m since the concentration is enhanced in deep sea due to gravity.

#### Concentration of Heavy (Charge -1) Stable Particles

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the fo	ollowing dat	a for averages, fits	, limi	ts, etc.	• • •
$<4 \times 10^{-20}$	90	⁴ HEMMICK	90	SPEC	C, $M = 100 m_{p}$
$< 8 \times 10^{-20}$	90	⁴ HEMMICK	90	SPEC	C, $M = 1000 m_{D}$
$< 2 \times 10^{-16}$	90	⁴ HEMMICK			C, $M = 10000 m_D$
$< 6 \times 10^{-13}$	90	⁴ HEMMICK	90	SPEC	Li, $M = 1000 m_D^{-1}$
$<1 \times 10^{-11}$	90	⁴ HEMMICK	90	SPEC	Be, $M = 1000 m_p$
$<6 \times 10^{-14}$	90	⁴ HEMMICK	90	SPEC	B, $M = 1000 m_D^{-1}$
$< 4 \times 10^{-17}$	90	⁴ HEMMICK	90	SPEC	O, $M = 1000 m_{p}$
$<4 \times 10^{-15}$	90	⁴ HEMMICK	90	SPEC	F, $M = 1000 m_p$
$< 1.5 \times 10^{-13}$ /nucleon	68	⁵ NORMAN	89	SPEC	206 _{Pb} X-
$< 1.2  imes 10^{-12} /  ext{nucleon}$	68	⁵ NORMAN	87	SPEC	56,58 _{Fe} X

⁴ See HEMMICK 90 Fig. 7 for other masses 100-10000 m_p.

#### GALACTIC WIMP SEARCHES Cross-Section Limits for Dark Matter Particles (X⁰) on Nuclei

These limits are for weakly-interacting stable particles which may constitute the invisible mass in the Galaxy with a local mass density of 0.3 GeV/cm³. See each paper for assumptions on the velocity distribution. In the papers the limit is given as a function of the  $x^0$  mass. Here we list limits only for typical mass values of 20 GeV, 100 GeV, and 1 TeV. Specific limits on supersymmetric dark matter particles may be found in the Supersymmetry section.

#### For $m_{\chi^0} = 20 \text{ GeV}$

VALUE (nb)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not us	se the followi	ng data for average	s, fit	s, limits,	etc. • • •
< 0.05	95	⁶ GARCIA	95	CNTR	Natural Ge
< 0.1	95	QUENBY	95	CNTR	Na
<90	90	⁷ SNOWDEN	95	MICA	16 _O
$< 4 \times 10^{3}$	90	⁷ SNOWDEN	95	MICA	³⁹ K
< 0.7	90	BACCI	92	CNTR	Na
< 0.12	90	⁸ REUSSER	91	CNTR	Natural Ge
< 0.06	95	CALDWELL	88	CNTR	Natural Ge

⁶ GARCIA 95 limit is from the event rate. A weaker limit is obtained from searches for

#### For $m_{\chi^0}=100~{\rm GeV}$

VALUE (nb)	CL%	DOCUMENT ID		TECN	COMMENT	
• • • We do not u	se the followi	ing data for averages	, fit:	s, limits,	etc. • • •	
< 0.35	95	⁹ GARCIA	95	CNTR	Natural Ge	
< 0.6	95	QUENBY	95	CNTR	Na	
<3	95	QUENBY	95	CNTR	1	
$< 1.5 \times 10^{2}$	90	¹⁰ SNOWDEN	95	MICA	16 _O	
$< 4 \times 10^{2}$	90	10 SNOWDEN	95	MICA	³⁹ K	
< 0.08	90	¹¹ BECK	94	CNTR	⁷⁶ Ge	
<2.5	90	BACCI	92	CNTR	Na	
<3	90	BACCI	92	CNTR	1	
< 0.9	90	¹² REUSSER	91	CNTR	Natural Ge	
< 0.7	95	CALDWELL	88	CNTR	Natural Ge	

VERKERK 92 looked for heavy isotopes in sea water and put a bound on concentration of stable charged massive particle in sea water. The above bound can be translated into into a bound on charged dark matter particle (5  $\times$  10⁶ GeV), assuming the local density,  $\rho$ =0.3 GeV/cm³, and the mean velocity  $\langle v \rangle$ =300 km/s.

³ See HEMMICK 90 Fig. 7 for other masses 100–10000  $m_p$ .

 $^{^5}$  Bound valid up to  $m_{\chi^-}~\sim~100$  TeV.

GARCIA 99 limit is from the event rate. A weaker limit is obtained from searches for diurnal and annual modulation.
 SNOWDEN-IFFT 95 look for recoil tracks in an ancient mica crystal. Similar limits are also given for ²⁷Al and ²⁸Si.
 REUSSER 91 limit here is changed from published (0.04) after reanalysis by authors. J.L. Vuilleumier, private communication, March 29, 1996.

#### Other Particle Searches

- ⁹ GARCIA 95 limit is from the event rate. A weaker limit is obtained from searches for
- diurnal and annual modulation.

  10 SNOWDEN-IFFT 95 look for recoil tracks in an ancient mica crystal. Similar limits are also given for ²⁷Al and ²⁸Si.
- 11 BECK 94 uses enriched ⁷⁶Ge (86% purity).
- 12 REUSSER 91 limit here is changed from published (0.3) after reanalysis by authors.

  J.L. Vuilleumier, private communication, March 29, 1996.

#### For $m_{\chi^0}=1~{\rm TeV}$

VALUE (nb)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not u	se the follow	ing data for average	s, fit	s, limits,	etc. • • •
< 6	95	¹³ GARCIA	95	CNTR	Natural Ge
< 8	95	QUENBY	95	CNTR	Na
<50	95	QUENBY	95	CNTR	1
$< 7 \times 10^{2}$	90	14 SNOWDEN	95	MICA	¹⁶ O
$< 1 \times 10^{3}$	90	14 SNOWDEN	95	MICA	³⁹ K
< 0.8	90	¹⁵ BECK	94	CNTR	⁷⁶ Ge
<30	90	BACCI	92	CNTR	Na
<30	90	BACCI	92	CNTR	1
<15	90	¹⁶ REUSSER	91	CNTR	Natural Ge
< 6	95	CALDWELL	88	CNTR	Natural Ge

- 13 GARCIA 95 limit is from the event rate. A weaker limit is obtained from searches for
- diurnal and annual modulation.

  14 SNOWDEN-IFFT 95 look for recoll tracks in an ancient mica crystal. Similar limits are also given for ²⁷Al and ²⁸Si.
- 15 BECK 94 uses enriched ⁷⁶Ge (86% purity).
- 16 REUSSER 91 limit here is changed from published (5) after reanalysis by authors. J.L. Vuilleumier, private communication, March 29, 1996.

#### LIMITS ON NEUTRAL PARTICLE PRODUCTION

#### Heavy Particle Production Cross Section

VALUE (cm ² /N)	CL%_E	VTS	DOCUMENT ID		TECN	COMMENT
• • • We do not us	se the	following	g data for averages	, fits	, limits,	etc. • • •
< 10-36-10-33			¹⁷ GALLAS	95	TOF	m= 0.5-20 GeV
$<(4-0.3)\times10^{-31}$	95		¹⁸ AKESSON	91	CNTR	m = 0-5  GeV
	90		¹⁹ BADIER	86	BDMP	$\tau = (0.05-1.) \times 10^{-8}$ s
$< 2.5 \times 10^{-35}$		0	²⁰ GUSTAFSON	76	CNTR	$\tau > 10^{-7} \text{ s}$

- 17  GALLAS 95 limit is for a weakly interacting neutral particle produced in 800 GeV/c  $\rho$  N interactions decaying with a lifetime of  $10^{-4}$ – $10^{-8}$  s. See their Figs. 8 and 9. Similar limits are obtained for a stable particle with interaction cross section  $10^{-29}$ – $10^{-33}$  cm².
- 18 AKESSON 91 limit is from weakly interacting neutral long-lived particles produced in pN reaction at 450 GeV/c performed at CERN SPS. Bourquin-Gaillard formula is used as the production model. The above limit is for  $\tau>10^{-7}\,\mathrm{s}$ . For  $\tau>10^{-9}\,\mathrm{s}$ ,  $\sigma<10^{-30}\,\mathrm{cm}^{-2}/\mathrm{nucleon}$  is obtained.
- $\sigma < 10^{-2}$  cm⁻⁷-indepents obtained.

  19 BADIER 86 looked for long-lived particles at 300 GeV  $\pi^-$  beam dump. The limit applies for nonstrongly interacting neutral or charged particles with mass >2 GeV. The limit applies for particle modes,  $\mu^+\pi^-$ ,  $\mu^+\mu^-$ ,  $\pi^+\pi^-$ X,  $\pi^+\pi^-\pi^\pm$  etc. See their figure 5 for the contours of limits in the mass- $\tau$  plane for each mode.
- 20  GUSTAFSON 76 is a 300 GeV FNAL experiment looking for heavy (m>2 GeV) long-lived neutral hadrons in the M4 neutral beam. The above typical value is for m=3 GeV and assumes an interaction cross section of 1 mb. Values as a function of mass and interaction cross section are given in figure 2.

#### Production of New Penetrating Non- $\nu$ Like States in Beam Dump DOCUMENT ID TECN COMMENT

• • • We do not use the following data for averages, fits, limits, etc. • •

- ²¹ LOSECCO 81 CALO 28 GeV protons
- ²¹ No excess neutral-current events leads to  $\sigma(\text{production}) \times \sigma(\text{interaction}) \times \text{acceptance}$ < 2.26 imes  $10^{-71}~\text{cm}^4/\text{nucleon}^2$  (CL = 90%) for light neutrals. Acceptance depends on models (0.1 to 4.  $\times 10^{-4}$ ).

#### **LIMITS ON JET-JET RESONANCES**

#### Heavy Particle Production Cross Section in $p\bar{p}$

VALUE

Limits are for a particle decaying to two hadronic jets.

b) CL% Mass(GeV) DOCUMENT ID TECN COMMENT Units(pb) CL% Mass(GeV)

- ²² ABE 93G CDF < 2603 95 200 1.8 TeV  $p\overline{p} \rightarrow 2$ jets 22 ABE 93G CDF 95 400 1.8 TeV pp → 2jets 44 ²² ABE 95 600 93G CDF 1.8 TeV  $p\overline{p} \rightarrow 2$ jets
- 22  ABE 93G gives cross section times branching ratio into light (d, u, s, c, b) quarks for  $\Gamma$  = 0.02 M. Their Table II gives limits for M = 200–900 GeV and  $\Gamma$  = (0.02–0.2) M.

#### LIMITS ON CHARGED PARTICLES IN e+e-

#### Heavy Particle Production Cross Section in e+e-

Ratio to  $\sigma(e^+e^- \to \mu^+\mu^-)$  unless noted. See also entries in Free Quark Search and Magnetic Monopole Searches.

VALUE	CL% EVTS	DOCUMENT ID	TECN	COMMENT
		wing data for averages,	fits, limits,	etc. • • •
$< 2 \times 10^{-5}$	95		95R OPAL	Q=1, m=5-45  GeV
$< 1 \times 10^{-5}$	95		95R OPAL	Q=2, m=5-45  GeV
$< 2 \times 10^{-3}$	90		93C ALEP	Q=1, m=32-72 GeV
<(10 ⁻² -1)	95	²⁵ ADACHI	90c TOPZ	Q = 1, $m = 1-16$ , 18-27
$< 7 \times 10^{-2}$	90	²⁶ ADACHI	90E TOPZ	Q = 1, m = 5-25  GeV
$< 1.6 \times 10^{-2}$	95 0	²⁷ KINOSHITA	82 PLAS	Q=3-180, $m<14.5$ GeV
$< 5.0 \times 10^{-2}$	90 0	²⁸ BARTEL	80 JADE	Q=(3,4,5)/3 2-12 GeV

- 23  AKERS 95R is a CERN-LEP experiment with W_{cm}  $\sim m_Z$ . The limit is for the production of a stable particle in multihadron events normalized to  $\sigma(e^+e^- \rightarrow \text{hadrons})$ . Constant phase space distribution is assumed. See their Fig. 3 for bounds for  $Q=\pm 2/3$ ,
- ±4/3.

  28 BUSKULIC 93c is a CERN-LEP experiment with W_{cm} = m_Z. The limit is for a pair or single production of heavy particles with unusual ionization loss in TPC. See their Fig. 5 and Table 1.

  29 ADACHI 90c is a KEK-TRISTAN experiment with W_{cm} = 52-60 GeV. The limit is for pair production of a scalar or spin-1/2 particle. See Figs. 3 and 4.
- 26  ADACHI 90E is KEK-TRISTAN experiment with  $\mathrm{W_{cm}} = 52\text{-}61.4$  GeV. The above limit is for inclusive production cross section normalized to  $\sigma(e^+e^-\to \mu^+\mu^-)$ ,  $\beta(3-\beta^2)/2$ , where  $\beta=(1-4m^2/W_{Cm}^2)^{1/2}$ . See the paper for the assumption about the production
- mechanism. 27 KiNOSHITA 82 is SLAC PEP experiment at  $W_{cm}=29$  GeV using lexan and  39 Cr plastic sheets sensitive to highly ionizing particles. 28 BARTEL 80 is DESY-PETRA experiment with  $W_{cm}=27-35$  GeV. Above limit is for inclusive pair production and ranges between  $1.\times10^{-1}$  and  $1.\times10^{-2}$  depending on mass and production momentum distributions. (See their figures 9, 10, 11).

#### Branching Fraction of Z⁰ to a Pair of Stable Charged Heavy Fel

Branching Fraction o	12 10	a rail of Stable	Citatgeu i	icavy i cililions	
VALUE	CL%	DOCUMENT ID	TECN	COMMENT	
• • • We do not use the	followin	g data for averages	s, fits, limits,	etc. • • •	
$< 5 \times 10^{-6}$	95	²⁹ AKERS	95R OPAL	m= 40.4-45.6 GeV	
$< 1 \times 10^{-3}$	95	AKRAWY	900 OPAL	m = 29-40  GeV	

 $^{^{29}}$  AKERS 95R give the 95% CL limit  $\sigma(X\overline{X})/\sigma(\mu\mu)<1.8\times10^{-4}$  for the pair production of singly- or doubly-charged stable particles. The limit applies for the mass range 40.4–45.6 GeV for  $X^{\pm}$  and < 45.6 GeV for  $X^{\pm\pm}$ . See the paper for bounds for  $Q=\pm2/3,\,\pm4/3.$ 

#### LIMITS ON CHARGED PARTICLES IN HADRONIC REACTIONS

#### Heavy Particle Production Cross Section

VALUE (nb)	CL% EV	TS DOCUM	IENT ID	TECN	COMMENT
• • • We do	not use the fo	ollowing data for	averages, fits	, limits,	etc. • • •
< 0.05	95	³⁰ ABE	<b>92</b> J	CDF	m=50-200 GeV
<30-130		31 CARR	OLL 78	SPEC	m=2-2.5 GeV
<100		0 32 LEIPU	NER 73	CNTR	m=3-11 GeV

- 30  ABE 921 look for pair production of unit-charged particles which leave detector before decaying. Limit shown here is for m=50 GeV. See their Fig. 5 for different charges and stronger limits for higher mass.
- stronger limits for inginer mass.  $3^{12}$  CARROLL 78 look for neutral, S=-2 dihyperon resonance in  $pp \to 2K^{+}X$ . Cross section varies within above limits over mass range and  $p_{lab}=5.1$ –5.9 GeV/c.
- 32  LEIPUNER 73 is an NAL 300 GeV p experiment. Would have detected particles with lifetime greater than 200 ns.

#### Heavy Particle Production Differential Cross Section

VALUE							
(cm ² sr ⁻¹ GeV ⁻¹ )	CL%	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
• • • We do not	use th	e followin	ng data for average	s, fits	, limits,	etc. •	• •
$< 2.6 \times 10^{-36}$	90	0	33 BALDIN	76	CNTR		Q= 1, m=2.1-9.4 GeV
$< 2.2 \times 10^{-33}$	90	0	³⁴ ALBROW	75	SPEC	$\pm$	Q= ±1, m=4-15 GeV
$< 1.1 \times 10^{-33}$	90	0	³⁴ ALBROW	75	SPEC	±	Q= ±2, m=6-27 GeV
$< 8. \times 10^{-35}$	90	0	35 JOVANOV	75	CNTR	$\pm$	m=15-26 GeV
$< 1.5 \times 10^{-34}$	90	0	35 JOVANOV	75	CNTR	$\pm$	Q= ±2, m=3-10 GeV
$<6. \times 10^{-35}$	90	0	35 JOVANOV	75	CNTR	±	Q= ±2, m=10-26 GeV
$<1. \times 10^{-31}$	90	0	36 APPEL	74	CNTR	±	m=3.2-7.2 GeV
$< 5.8 \times 10^{-34}$	90	0	³⁷ ALPER	73	SPEC	$\pm$	m=1.5-24 GeV
$< 1.2 \times 10^{-35}$	90	0	38 ANTIPOV	71B	CNTR		Q=-, $m=2.2-2.8$
$< 2.4 \times 10^{-35}$	90	0	³⁹ ANTIPOV	<b>71</b> C	CNTR	-	Q=-, m=1.2-1.7, 2.1-4
$< 2.4 \times 10^{-35}$	90	0	BINON	69	CNTR	_	Q=-, m=1-1.8 GeV
$< 1.5 \times 10^{-36}$		0	⁴⁰ DORFAN	65	CNTR		Be target m=3-7 GeV
$< 3.0 \times 10^{-36}$		0	⁴⁰ DORFAN	65	CNTR		Fe target m=3-7 GeV

- 33  BALDIN 76 is a 70 GeV Serpukhov experiment. Value is per AI nucleus at  $\theta=0.$  For other charges in range -0.5 to -3.0, CL =90% limit is  $(2.6\times10^{-36})/[\text{charge}]$  for mass range (2.1–9.4 GeV)  $\times$  |(charge)|. Assumes stable particle interacting with matter
- 34  ALBROW 75 is a CERN ISR experiment with  $E_{\rm CM}=53$  GeV.  $\theta=40$  mr. See figure 5 for mass ranges up to 35 GeV.

- 35  JOVANOVICH 75 is a CERN ISR 26+26 and 15+15 GeV  $\rho p$  experiment. Figure 4 covers ranges Q=1/3 to 2 and m=3 to 26 GeV. Value is per GeV momentum.
- 36 APPEL 74 is NAL 300 GeV pW experiment. Studies forward production of heavy (up to 24 GeV) charged particles with momenta 24–200 GeV (–charge) and 40–150 GeV (+charge). Above typical value is for 75 GeV and is per GeV momentum per nucleon.
- ³⁷ ALPER 73 is CERN ISR 26+26 GeV pp experiment. p>0.9 GeV,  $0.2 < \beta < 0.65$ .
- 38  ANTIPOV 71B is from same 70 GeV p experiment as ANTIPOV 71C and BINON 69.  39  ANTIPOV 71C limit inferred from flux ratio. 70 GeV p experiment.
- ⁴⁰ DORFAN 65 is a 30 GeV/c p experiment at BNL. Units are per GeV momentum per

#### Long-Lived Heavy Particle Invariant Cross Section

VALUE (cm ² /GeV ² /N)	CL%	FV/TS	DOCUMENT ID		TECN	CHG	COMMENT
• • • We do not u				limi			COMMENT
$< 5 \times 10^{-35} - 7 \times 1$		0	41 BERNSTEIN	88	CNTR	• •	
$< 5 \times 10^{-37} - 7 \times 1$ $< 5 \times 10^{-37} - 7 \times 1$		-					
		0	41 BERNSTEIN	88			
$< 2.5 \times 10^{-36}$	90	0	⁴² THRON	85	CNTR		Q=1
							m=4-12
35		_	⁴² THRON		CNITO		GeV
$<1. \times 10^{-35}$	90	1	42 THRON	85	CNTR	+	Q=1,
							<i>m</i> =4−12 GeV
$<6. \times 10^{-33}$	90	0	43 ARMITAGE	70	SPEC		GeV m=1.87
< 0. X 10	90	U	ARWITAGE	19	SFEC		GeV
$< 1.5 \times 10^{-33}$	90	0	43 ARMITAGE	79	SPEC		m=1.5-3.0
\1.5 \ 10	,,,	Ü			0. 20		GeV
		0	⁴⁴ BOZZOLI	79	CNTR	±	Q = (2/3,
							1, 4/3,
							2)
$< 1.1 \times 10^{-37}$	90	0	⁴⁵ CUTTS	78	CNTR		m=4-10
27			46				GeV
$< 3.0 \times 10^{-37}$	90	0	⁴⁶ VIDAL	78	CNTR		m = 4.5 - 6
							GeV

- 41 BERNSTEIN 88 limits apply at x=0.2 and  $p_{\mathcal{T}}=0$ . Mass and lifetime dependence of limits are shown in the regions: m=1.5–7.5 GeV and  $\tau=10^{-8}$ –2  $\times$   $10^{-6}$  s. First number is for hadrons; second is for weakly interacting particles.
- number is for hadrons; second is for weakly interacting particles. 42 THRON 85 is FNAL 400 GeV proton experiment. Mass determined from measured velocity and momentum. Limits are for  $\tau > 3 \times 10^{-9}$  s. 43 ARMITAGE 79 is CERN-ISR experiment at  $E_{\rm CM} = 53$  GeV. Value is for x = 0.1 and  $p_T = 0.15$ . Observed particles at m = 1.87 GeV are found all consistent with being articles of the constant of the co
- ⁴⁴ BOZZOLI 79 is CERN-SPS 200 GeV pN experiment. Looks for particle with au larger than  $10^{-8}$  s. See their figure 11–18 for production cross-section upper limits vs mass.  45  CUTTS 78 is  $\rho$ Be experiment at FNAL sensitive to particles of  $\tau > 5 \times 10^{-8}$  s. Value is for -0.3 <x <0 and  $\rho_T = 0.175$ .
- ⁴⁶ VIDAL 78 is FNAL 400 GeV proton experiment. Value is for x=0 and  $p_{\mathcal{T}}=0$ . Puts lifetime limit of  $<5\times10^{-8}\,\text{s}$  on particle in this mass range.

#### Long-Lived Heavy Particle Production

#### $(\sigma(\text{Heavy Particle}) / \sigma(\pi))$

VALUE	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
• • • We do not u	ise the following	data for average	s, fits	, limits,	etc. •	• •
<10-8	•	⁴⁷ NAKAMURA	89	SPEC	±	$Q = (-5/3, \pm 2)$
	0 '	48 BUSSIERE	80	CNTR	+	Q=(2/3.1.4/3.2)

 $^{^{47}}$  NAKAMURA 89 is KEK experiment with 12 GeV protons on Pt target. The limit applies for mass  $\lesssim 1.6$  GeV and lifetime  $\gtrsim 10^{-7}\,\rm s.$ 

#### Production and Capture of Long-Lived Massive Particles

VALUE (10-36 cm ² )	EVTS	DOCUMENT ID	TECN	COMMENT
• • • We do not use t	he followir	g data for averages,	fits, limits	, etc. • • •
<20 to 800	0		76 ELEC	au=5 ms to 1 day
<200 to 2000	0		76B ELEC	$\tau$ =100 ms to 1 day
<1.4 to 9	0	⁵⁰ FRANKEL	75 CNTR	$ au{=}50$ ms to 10 hours
<0.1 to 9	0	⁵¹ FRANKEL	74 CNTR	$\tau$ =1 to 1000 hours

 $^{^{49}\,\}mathrm{ALEKSEEV}$  76 and ALEKSEEV 76B are 61–70 GeV p Serpukhov experiment. Cross

#### Long-Lived Particle Search at Hadron Collisions

Limits are for cross section times branching ratio.

(pb/nucleon)	CL% EVTS	DOCUMENT ID	TECN	COMMENT
	use the following	data for averages, fit	s, limits	, etc. • • •

^{0 52} BADIER 86 BDMP  $\tau = (0.05-1.) \times 10^{-8}$ s 90  52  BADIER 86 looked for long-lived particles at 300 GeV  $\pi^-$  beam dump. The limit applies for nonstrongly interacting neutral or charged particles with mass >2 GeV. The limit applies for particle modes,  $\mu^+\pi^-$ ,  $\mu^+\mu^-$ ,  $\pi^+\pi^-$ X,  $\pi^+\pi^-\pi^\pm$  etc. See their figure 5 for the contours of limits in the mass- $\tau$  plane for each mode.

#### Long-Lived Heavy Particle Cross Section

VALUE (pb/sr)	•	DOCUMEN		TECN	COMMENT
• • • We do not	use the followi	ng data for ave	erages, fit	s, limits,	etc. • • •
<34	95	53 RAM	94	SPEC	$1015 < m_{\chi^{++}} < 1085$
<75	95	⁵³ RAM	94	SPEC	MeV 920 <m<sub>V++ &lt;1025</m<sub>
					920< <i>m</i> _{X++} <1025 MeV

 53  RAM 94 search for a long-lived doubly-charged fermion  $X^{++}$  with mass between  $m_N$ and  $m_N+m_\pi$  and baryon number +1 in the reaction  $pp\to X^{++}n$ . No candidate is found. The limit is for the cross section at 15° scattering angle at 460 MeV incident energy and applies for  $\tau(X^{++}) \gg 0.1\,\mu\mathrm{s}$ .

#### LIMITS ON CHARGED PARTICLES IN COSMIC RAYS

#### Heavy Particle Flux in Cosmic Rays

VALUE									
(cm - 2sr - 1s	-1)	CL%	EVTS		DOCUMENT ID		TECN	CHG	COMMENT
• • • We	do not use	the fo	llowing d	ata	for averages, fit	s, lir	nits, etc		•
~ 6	× 10 ⁻⁹		2	54	SAITO	90			$Q \simeq 14, m \simeq 370 m_D$
< 1.4	$\times 10^{-12}$	90	0		MINCER	85	CALO		m ≥ 1 TeV
				56	SAKUYAMA	83B	PLAS		$m\sim~1~{ m TeV}$
< 1.7	$\times 10^{-11}$	99	0		BHAT	82	CC		
< 1.	× 10 ⁻⁹	90	0	58	MARINI	82	CNTR	±	$Q=1, m \sim 4.5 m_p$
2.	× 10 ⁻⁹		3	59	YOCK	81	SPRK	±	$Q=1, m\sim 4.5m_p$
			3		YOCK	81	SPRK		Fractionally charged
3.0	× 10 ⁻⁹		3	60	YOCK	80	SPRK		$m \sim 4.5 m_p$
(4 ±1)	$\times 10^{-11}$		3		GOODMAN	79	ELEC		m ≥ 5 GeV
< 1.3	× 10 ⁻⁹	90		61	BHAT	78	CNTR	±	m > 1  GeV
< 1.0	× 10 ⁻⁹		0		BRIATORE	76	ELEC		
< 7.	× 10 ⁻¹⁰	90	0		YOCK	75	ELEC	±	Q >7e or < -7e
> 6.	$\times 10^{-9}$		5	62	YOCK	74	CNTR		m >6 GeV
< 3.0	$\times 10^{-8}$		0		DARDO	72	CNTR		
< 1.5	$\times 10^{-9}$		0		TONWAR	72	CNTR		m>10 GeV
< 3.0	$\times 10^{-10}$		0		BJORNBOE	68	CNTR		m >5 GeV
< 5.0	$\times 10^{-11}$	90	0		JONES	67	ELEC		m=5-15 GeV

- 54 SAITO 90 candidates carry about 450 MeV/nucleon. Cannot be accounted for by conventional backgrounds. Consistent with strange quark matter hypothesis.
   55 MINCER 85 is high statistics study of calorimeter signals delayed by 20–200 ns. Calibration with AGS beam shows they can be accounted for by rare fluctuations in signals from low-energy hadrons in the shower. Claim that previous delayed signals including BJORNBOE 68, DARDO 72, BHAT 82, SAKUYAMA 838 below may be due to this fake
- 56 SAKUYAMA 83B analyzed 6000 extended air shower events. Increase of delayed particles and change of lateral distribution above 10¹⁷ eV may indicate production of very heavy parent at top of atmosphere.
- parent at top or atmosphere. 57 BHAT 82 observed 12 events with delay  $> 2.\times 10^{-8}$  s and with more than 40 particles. 1 eV has good hadron shower. However all events are delayed in only one of two detectors in cloud chamber, and could not be due to strongly interacting massive particle. 58 MARINI 82 applied PEP-counter for TOF. Above limit is for velocity = 0.54 of light.
- PENNING α applied PEP-Counter for LOF. Above limit is for velocity = 0.54 of light. Limit is inconsistent with YOCK 80 YOCK 81 events if isotropic dependence on zenith angle is assumed.
- angle is assumed.  59  YOCK 81 saw another 3 events with  $Q=\pm 1$  and m about  $4.5m_p$  as well as 2 events with  $m>5.3m_p$ ,  $Q=\pm 0.75\pm 0.05$  and  $m>2.8m_p$ ,  $Q=\pm 0.70\pm 0.05$  and 1 event with  $m=(9.3\pm3.)m_{p}$ ,  $Q=\pm0.89\pm0.06$  as possible heavy candidates.
- 60  YOCK 80 events are with charge exactly or approximately equal to unity.  61  BHAT 78 is at Kolar gold fields. Limit is for  $\tau>10^{-6}$  s.
- 62 YOCK 74 events could be tritons.

#### Superheavy Particle (Quark Matter) Flux in Cosmic Rays

VALUE (cm ⁻² sr ⁻¹ s ⁻¹ ) • • • We do not	CL%	EVTS	DOCUMENT ID	s. fit	TECN s. limits.	COMMENT etc. • • •
$< 1.8 \times 10^{-12}$	90		⁶³ ASTONE	93	CNTR	$m > 1.5 \times 10^{-13} \text{gram}$
$< 1.1 \times 10^{-14}$	90		64 AHLEN	92	MCRO	$10^{-10} < m < 0.1 \text{ gram}$
$< 3.2 \times 10^{-11}$	90	0	⁶⁵ NAKAMURA			$m > 1.5 \times 10^{-13}$ gram
$< 3.5 \times 10^{-11}$	90	0	⁶⁶ ULLMAN	81	CNTR	Planck-mass 10 ¹⁹ GeV
$< 7. \times 10^{-11}$	90	0	66 ULLMAN	81	CNTR	$m < 10^{16} \text{ GeV}$

- 63  ASTONE 93 searched for quark matter ("nuclearites") in the velocity/c range =  $10^{-3}$ -1. Their Table 1 gives a compilation of searches for nuclearites.
- ⁶⁴ AHLEN 92 searched for quark matter ("nuclearites"). The bound applies to velocity/ $c < 2.5 \times 10^{-3}$ . See their Fig. 3 for other velocity/c and heavier mass range.
- 65  NAKAMURA 85 at KEK searched for quark-matter. These might be lumps of strange quark matter with roughly equal numbers of u, d, s quarks. These lumps or nuclearites were assumed to have velocity/c of  $10^{-4}$ – $10^{-3}$ .
- 66  ULLMAN 81 is sensitive for heavy slow singly charge particle reaching earth with vertical velocity 100–350 km/s.

#### Highly Ionizing Particle Flux

(m ⁻² yr ⁻¹ )	CL%	EVTS	DOCUMENT ID	TECN	COMMENT	
ullet $ullet$ We do not use	the fo	llowing data	for averages, f	its, limits, etc.	. • • •	
<0.4	95	0	KINOSHITA	81B PLAS	$Z/\beta$ 30–100	

⁴⁸ BUSSIERE 80 is CERN-SPS experiment with 200–240 GeV protons on Be and AI target. See their figures 6 and 7 for cross-section ratio vs mass.

section is per Pb nucleus.

50 FRANKEL 75 is extension of FRANKEL 74.

51 FRANKEL 74 looks for particles produced in thick Al targets by 300–400 GeV/c protons.

### Other Particle Searches

		KEFEKENCES	POR Other Particle Scarcines
AKERS	95R	ZPHY C67 203	+Alexander, Allison, Ametewee, Anderson+ (OPAL Collab.)
GALLAS	95	PR D52 6	+Abolins, Brock, Cobau+ (MSU, FNAL, MIT, FLOR)
GARCIA	95	PR D51 1458	+Morales, Morales, Sarsa+ (ZARA, SCUC, PNL)
QUENBY	95	PL B351 70	+Sumner+ (LOIC, RAL, SHEF, BIRK, NOTT, RHBL)
SNOWDEN	95	PRL 74 4133	Snowden-Ifft, Freeman, Price (UCB)
BECK	94	PL B336 141	+Bensch, Bockholt+ (MPIH, KIAE, SASSO)
RAM	94	PR D49 3120	+Abegg, Ashery, Frekers, Helmer+ (TELA, TRIU)
ABE	93G	PRL 71 2542	+Albrow, Akimoto, Amidei, Anway-Wiese+ (CDF Collab.)
ASTONE	93	PR D47 4770	+Bassan, Bonifazi, Coccia+(ROMA, ROMAI, CATA, FRAS)
BUSKULIC	93C	PL B303 198	+Decamp, Goy, Lees, Minard+ (ALEPH Collab.)
YAMAGATA	93	PR D47 1231	+Takamori, Utsunomiya (KONAN)
ABE	92 J	PR D46 R1889	+Amidei, Anway-Weiss+ (CDF Collab.)
AHLEN	92	PRL 69 1860	+Ambrosio, Antolini, Auriemma, Baker+ (MACRO Collab.)
BACCI	92	PL B293 460	+Belli, Bernabei+ (Beijing-Roma-Saclay Collab.)
VERKERK	92	PRL 68 1116	+Grynberg, Pichard, Spiro, Zylberajch+(ENSP, SACL, PAST
AKESSON	91	ZPHY C52 219	+Almehed, Angelis, Atherton, Aubry+ (HELIOS Collab.)
REUSSER	91	PL B255 143	+Treichel, Boehm, Broggini+ (NEUC, CIT, PSI)
ADACHI	90C	PL B244 352	+Aihara, Doser, Enomoto+ (TOPAZ Collab.)
ADACHI	90E	PL B249 336	+Anazawa, Doser, Enomoto, Fujii+ (TOPAZ Collab.)
AKRAWY	900	PL B252 290	+Alexander, Allison, Allport, Anderson+ (OPAL Collab.)
HEMMICK	90	PR D41 2074	+Elmore+ (ROCH, MICH, OHIO, RAL, LANL, STON)
SAITO	90	PRL 65 2094	+Hatano, Fukada, Oda (ICRR, KOBE)
NAKAMURA	89	PR D39 1261	+Kobayashi, Konaka, Imai, Masaike+ (KYOT, TMTC)
NORMAN	89	PR D39 2499	+Chadwick, Lesko, Larimer, Hoffman (LBL)
BERNSTEIN	88	PR D37 3103	+Shea, Winstein, Cousins, Greenhalgh+ (STAN, WISC)
CALDWELL	88	PRL 61 510	+Eisberg, Grumm, Witherell+ (UCSB, UCB, LBL)
NORMAN	87	PRL 58 1403	+Gazes, Bennett (LBL)
BADIER	86	ZPHY C31 21	+Bemporad, Boucrot, Callot+ (NA3 Collab.)
MINCER	85	PR D32 541	+Freudenreich, Goodman+ (UMD, GMAS, NSF)
NAKAMURA	85	PL 161B 417	+Horie, Takahashi, Tanimori (KEK, INUS)
THRON	85	PR D31 451	+Cardello, Cooper, Teig+ (YALE, FNAL, IOWA)
SAKUYAMA	83B	LNC 37 17	+Nuzuki (MEIS
Also	83	LNC 36 389	Sakuyama, Watanabe (MEIS
Also	83D	NC 78A 147	Sakuyama, Watanabe (MEIS
Also	83C	NC 6C 371	Sakuyama, Watanabe (MEIS
BHAT	82	PR D25 2820	+Gupta, Murthy, Sreekantan+ (TATA)
KINOSHITA	82	PRL 48 77	+Price, Fryberger (UCB, SLAC
MARINI	82	PR D26 1777	+Peruzzi, Piccolo+ (FRAS, LBL, NWES, STAN, HAWA
SMITH	82B	NP B206 333	+Bennett, Homer, Lewin, Walford, Smith (RAL)

KINOSHITA LOSECCO ULLMAN	81B 81 81	PR D24 1707 PL 102B 209 PRL 47 289		(UCB) PENN, BNL) EHM, BNL)
YOCK	81	PR D23 1207	(-	(AUCK)
BARTEL	80	ZPHY C6 295	+Canzler, Lords, Drumm+ (JA	DE Collab.)
BUSSIERE	80	NP B174 1	+Giacomelli, Lesquoy+ (BGNA, S.	ACL, LAPP)
YOCK	80	PR D22 61		(AUCK)
ARMITAGE	79	NP B150 87	+Benz, Bobbink+ (CERN, DARE, FOM, MC	CHS, UTRE)
BOZZOLI	79	NP B159 363	+Bussiere, Giacomelli+ (BGNA, LAPP, Sa	
GOODMAN	79	PR D19 2572	+Ellsworth, Ito, Macfall, Siohan+	(UMD)
SMITH	79	NP B149 525	+Bennett	(RHEL)
BHAT	78	Pramana 10 115	+Murthy	(TATA)
CARROLL	78	PRL 41 777	+Chiang, Johnson, Kycia, Ki+ (	BNL, PRIN)
CUTTS	78	PRL 41 363	+Dulude+ (BROW, FNAL, ILL, BARI,	
VIDAL	78		+Herb, Lederman+ (COLU, FNAL, S	
ALEKSEEV	76	SJNP 22 531	+Zaitsev, Kalinina, Kruglov+	(JINR)
A . E . / C E E . /	740	Translated from YAF SJNP 23 633		(JINR)
ALEKSEEV	76B	Translated from YAF	+Zaitsev, Kalinina, Kruglov+	(JIMK)
BALDIN	76	SJNP 22 264	+Vertogradov, Vishnevsky, Grishkevich+	(JINR)
DALDIN		Translated from YAF	22 512.	` ′
BRIATORE	76	NC 31A 553	+Dardo, Piazzoli, Mannocchi+ (LCGT, FF	
GUSTAFSON	76	PRL 37 474	+Ayre, Jones, Longo, Murthy	(MICH)
ALBROW	75	NP B97 189	+Barber+ (CERN, DARE, FOM, LANC, M	
FRANKEL	75	PR D12 2561		ENN, FNAL)
JOVANOV	75	PL 56B 105	Jovanovich+ (MANI, AACH, CERN, GEN	
YOCK	75	NP B86 216		UCK, SLAC)
APPEL	74	PRL 32 428		OLU, FNAL)
FRANKEL	74	PR D9 1932	+Frati, Resvanis, Yang, Nezrick (P	ENN, FNAL)
YOCK	74	NP B76 175	(ATT) 1970 1990 BOUR BUT CT	(AUCK)
ALPER	73	PL 46B 265	+ (CERN, LIVP, LUND, BOHR, RHEL, STO	
LEIPUNER	73	PRL 31 1226	+Larsen, Sessoms, Smith, Williams+ (	(TORI)
DARDO	72	NC 9A 319	+ Navarra, Penengo, Sitte	(TATA)
TONWAR	72	JPA 5 569	+Naranan, Sreekantan +Denisov, Donskov, Gorin, Kachanov+	(SERP)
ANTIPOV	71B 71C	NP B31 235 PL 34B 164	+Denisov, Donskov, Gorin, Kachanov+ +Denisov, Donskov, Gorin, Kachanov+	(SERP)
ANTIPOV		PL 34B 164 PL 30B 510	+Duteil, Kachanov, Khromov, Kutvin+	(SERP)
BINON BJORNBOE	69 68	NC B53 241	+Dangard, Hansen+ (BOHR, TATA, B	
JONES	67	PR 164 1584	(MICH, WISC, LBL, UCLA, MINN, CO.	
DORFAN	65	PRL 14 999	+Eades, Lederman, Lee, Ting	(COLU)
DORPAN	05	I IVE 14 322	Trades, reactings, rec, fing	(2020)

### OTHER COMPILATIONS OF INTEREST

#### OTHER COMPILATIONS OF INTEREST

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San Jose, CA 95125 USA
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$A(1680)$ or $[now\ called\ \pi_2(1670)]$	Baryon decay parameters, note on
$A(2100)$ [now called $\pi_2(2100)$ ]	Baryon magnetic moments, note on
$a_0(980) [was \delta(980)]$	Baryons
$a_0(1450)$	Charmed baryons
$a_1(1260)$ [was $A_1(1270)$ or $A_1$ ]	Dibaryons
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$a_6(2450) [was \delta_6(2450)] \dots	Hyperon baryons ( $\Sigma$ baryons)
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$B_s^0$	Cabibbo-Kobayashi-Maskawa mixing
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$\chi_{b0}(2P) = \chi_{b0}(10235)$	Critical energy, muons
$\chi_{b1}(1P) = \chi_{b1}(9890)$	Cross sections and related quantities, plots of
$\chi_{b1}(2P) = \chi_{b1}(10255)$	$e^{+}e^{-},  u N, \overline{ u} N, \Lambda p, \gamma p, \gamma d, \pi^{\pm}p, \pi^{\pm}d, K^{\pm}p, K^{\pm}n, K^{\pm}d,$
	$pp, pn, pd, \overline{p}p, \overline{p}n, $ and $\overline{p}d$ cross sections
$\chi_{b2}(2P) = \chi_{b2}(10270)$	$e^+e^-$ annihilation cross section near $M_Z$
	Fragmentation functions
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