ization of photons.

We would like to thank Dr. Roy Schwitter for his advice on crystals and coherent production. Our calculations were based largely on a modification of his computer program. We are grateful to Professor Giordano Diambrini-Palazzi for mentioning to us this method of polarizing photons.

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Search for Violation of CP Invariance in $\tau^{\pm}$ Decay*

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We report a comparison of the Dalitz-plot distributions of 1.6 million τ^+ decays ($K^+ \to \pi^+\pi^+\pi^-$) and an equal number of τ^- decays. No significant asymmetry has been found in any region of the plot. In terms of the difference in the slope parameters a^+ and a^- for the odd-pion c.m.-energy spectra, the asymmetry is $\Delta = (a^+ - a^-)/(a^+ + a^-) = -0.0070 \pm 0.0053$. We also present a preliminary result for the slope parameter itself: $a = 0.283 \pm 0.005$. New measurements of the $\tau^{\pm}$ decay rates and their difference confirm previous results.

In an experiment at the Brookhaven alternating-gradient synchrotron, we have analyzed ~3.2 million τ decays ($K^{\pm} \to \pi^{\pm}\pi^{\pm}\pi^{\mp}$), ~1.6 million for each charge of the kaon. The purpose of the experiment was twofold: (1) To search for a violation of CP invariance in τ decay by comparing the τ^+ and τ^- Dalitz plots. Any difference would indicate a CP violation outside the neutral kaon system, and hence one which could not occur via the "superweak" interaction.[1] (2) To determine the structure of $|M|^2$, the square of the τ-decay matrix element. All existing data on τ decay[2] (~58 000 τ^-, ~37 000 τ^+ events) are consistent with the linear approximation $|M|^2 dX dY \propto (1 + aY) dX dY$, where a is a constant, and $X = \sqrt{3}\,|T_1 - T_2|/Q$ and $Y = (3T_3 - Q)/Q$ are the Dalitz-Fabri coordinates.[3] Here T_1, T_2, and T_3 are the c.m. kinetic energies of the two "even" pions (same charge as the kaon's) and the "odd" pion, respectively; $Q = T_1 + T_2 + T_3$. In addition to reducing the uncertainty in the slope parameter a, this high-statistics experiment should give new information as to the presence of higher terms in the expansion of $|M|^2$. In this Letter we report the final results

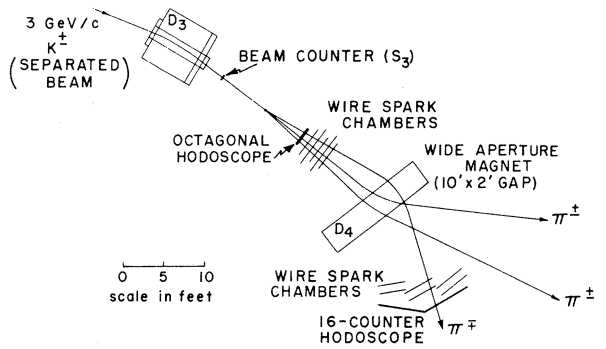

FIG. 1. Experimental arrangement. Upstream of D_3 and not shown are the Cherenkov counter and more scintillation counters.

of the τ^+-τ^- Dalitz-plot comparison and a preliminary value for the slope a.

The experimental arrangement is shown in Fig. 1. The 3.0-GeV/c separated K^+ and K^- beams were defined by a differential gas Cherenkov counter and three scintillation counters, only the last of which is shown. Kaons decaying into three charged pions were detected with <2% background by a threefold coincidence in an eight-counter hodoscope octagonally symmetric about the beam. For 58% of such coincidences the odd pion passed through the wide-aperture spectrometer magnet D_4 and hit the sixteen-counter hodoscope behind it. The eleven magnetostrictive wire spark chambers (each with x and y planes) were then triggered. The five chambers ahead of D_4 measured the directions of all three pions. For three-track events each chamber had >95% efficiency per spark and ~25% probability for an extra spark. Two of the chambers were rotated 45° with respect to the other three to resolve ambiguities. The six chambers behind D_4, which were missed completely by all even pions and beam particles, served to measure the odd-pion momentum. The digitized spark coordinates were fed to a PDP-9 computer, which monitored the chamber and hodoscope performances. The PDP-9 was interfaced to the PDP-6 computer of the Brookhaven on-line data facility, where a substantial fraction of the events were completely reconstructed.[4]

In principle this experiment is more sensitive than previous comparisons[2] not only because it has much larger statistics, but also because the same apparatus and programs were used in the detection and analysis of the τ^+ and τ^- events. Many checks were performed to ensure that the systematic differences between τ^+ and τ^- operation were negligible:

(1) The position, size, momentum, angular spread, rate, accidential rate, etc. of the K^+ and K^- beams were carefully monitored with counters, circuitry, and on-line reconstruction programs. Except for the kaon rates ($R_{K^+} \approx 2R_{K^-}$) the two beams were identical; the central-momentum difference between them, for example, was <0.1%. Accidentals were negligible.

(2) The most critical parameter in the comparison, the field in the spectrometer magnet D_4, was monitored with Hall and NMR probes and further checked by sending through the spark-chamber spectrometer system the K^+ and K^- beams and also π^+ and π^- mesons of 1.5, 1.0, and 0.6 GeV/c. The results showed any positive-vs-negative momentum asymmetry to be $\lesssim$0.05%. As the Earth's magnetic field introduced a systematic error of 0.03%, the correction applied to the difference between the positive and negative odd-pion momenta was (0.03 ± 0.05)%.

(3) The distributions of τ^+ and τ^- events were compared for a series of laboratory parameters, e.g., decay-point position along the beam line, opening angle between decay pions, odd-pion momentum, hodoscope rates, etc., and also for parameters defined in the τ rest frame, namely the directions of the normal to the decay plane and of the odd-pion momentum vector. No asymmetries were observed in any case.

(4) Nuclear interactions of the decay pions in the apparatus caused no noticeable asymmetry.

(5) Monte Carlo studies showed that Dalitz-pair events (e.g., $\pi^{\pm}e^{\pm}e^{\mp}\gamma$) contributed only ~0.5% to the trigger rate, and hence could not cause any significant asymmetry.

(6) Because of the redundancy in the system any biases introduced by reasonable fluctuations in chamber efficiences were negligible, as shown by Monte Carlo studies. Even so, chamber and counter efficiencies were always closely regulated, especially when the magnet polarities were reversed.

Two million events were obtained for each kaon charge; after reconstruction and kinematic fitting (two-constraint fit) 80% of them were accepted as τ decays. The 20% loss, consistent with Monte Carlo predictions, arose mainly from decays of the τ-decay pions within the apparatus. Figure 2 gives the τ^+ and τ^- Dalitz-plot distributions, both containing the same total number of events, and uncorrected for apparatus acceptance. To compare the distributions, an asymmetry parameter $A = (N^+ - N^-)/(N^+ + N^-)$ was calculated for various regions of the plot,

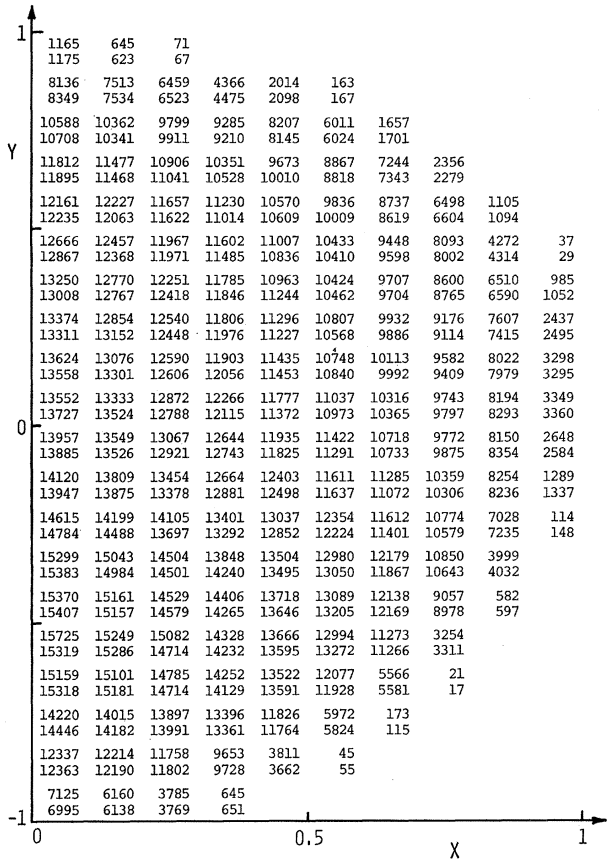

FIG. 2. Arrays of the Dalitz-plot distributions of τ^+ (upper numbers) and τ^- (lower numbers) events, normalized to the same total number (1 626 725) of events, and uncorrected for apparatus acceptance. The variables X and Y are defined in the text.

where N^+ (N^-) is the τ^+ (τ^-) population of the region. We found no region where A differed significantly from zero. Results are summarized in Figs. 3(a) and 3(b), where the X and Y projections of A are plotted, and in Table I, in which the following asymmetry values are listed:

(A) The slope-parameter asymmetry $\Delta = (a^+ - a^-)/(a^+ + a^-)$, calculated from the data of Fig. 3(b). The result, $\Delta = -0.0070 \pm 0.0053$, places a fairly strong limit on predictions of some[5,6] proposed models of CP violation, although most models[5] estimate that $|\Delta| \lesssim 10^{-3}$. (Of the quoted error in Δ, 80% is due to the statistical uncertainty, the rest to the uncertainty in the spectrometer field.)

(B) The asymmetries for various Dalitz-plot sectors defined by straight lines through the point ($X=0$, $Y=0$) and at angles θ with respect to the X axis.

(C) The decay-rate asymmetry, remeasured in this experiment along with the absolute $\tau^\pm$ decay rate. New and previous[7] results are listed.

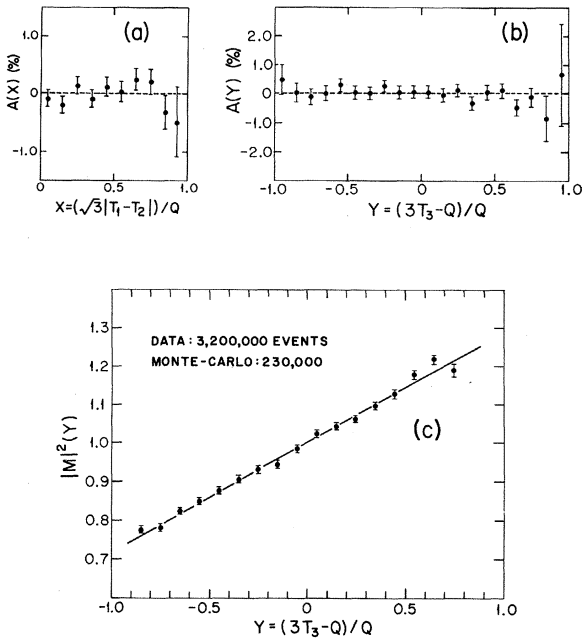

FIG. 3. (a) X projection and (b) Y projection of the asymmetry values $A = (N^+ - N^-)/(N^+ + N^-)$; (c) Y projection of the Dalitz plot, weighted for phase space *and* Coulomb interactions. The line is a best fit to $1 + aY$, where $a = 0.283 \pm 0.005$ (statistical error only).

A preliminary analysis of the pion energy spectra was obtained by combining the already ana-

Table I. Results of the τ^+-τ^- comparison. All quoted errors include the systematic uncertainty of the spectrometer field.

A. Asymmetry in Slope Parameters:

$(a^+ - a^-)/(a^+ + a^-)$

$-.0070 \pm .0053$

B. Asymmetry in Various Sectors of the Dalitz Plot:

Region	$(N^+ - N^-)/(N^+ + N^-)$
$0 < \theta < \pi/2$ (upper half)	$-.0010 \pm .0007$
$-\pi/2 < \theta < 0$ (lower half)	$.0008 \pm .0006$
$\pi/6 < \theta < \pi/2$ (upper third)	$-.0019 \pm .0010$
$-\pi/6 < \theta < \pi/6$ (center third)	$.0014 \pm .0008$
$-\pi/2 < \theta < -\pi/6$ (lower third)	$.0003 \pm .0007$

C. Asymmetry in Decay Rates:

	$(\Gamma^+ - \Gamma^-)/(\Gamma^+ + \Gamma^-)$	$\Gamma(10^6 \text{sec}^{-1})$
This experiment	$.0005 \pm .0007$	4.529 ± 0.032
Previous expt. (Ref. 7)	$-.0002 \pm .0011$	4.496 ± 0.030
Combined[a]	$.0004 \pm .0006$	4.511 ± 0.024

[a]The errors of the two experiments are dominated by systematic uncertainties and hence not completely independent.

lyzed τ^+ and τ^- events and correcting for the apparatus efficiency as determined from ~230 000 Monte Carlo events. The Y projection of $|M|^2$ is shown in Fig. 3(c), in which phase space has been weighted to account for final-state Coulomb interactions,[8] to allow comparison with other 3π decay modes. A linear fit of the form $1+aY$ yields $a=0.283\pm0.005$ (statistical error only). Without correcting for Coulomb interactions we obtained $a=0.247\pm0.005$. Complete results will be presented when possible biases have been thoroughly investigated to the level of a few million Monte Carlo–generated events.

We are indebted to the staffs of the alternating-gradient synchrotron and the on-line data facility of Brookhaven National Laboratory for their support throughout the experiment. We wish also to thank Professor A. Lemonick who worked with us at the early stages of the project, and Professor S. Treiman for many valuable discussions. This work made extensive use of the Princeton University Computer Center, sponsored in part by the National Science Foundation.

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Observation of Coherent Interference Pattern Between ρ and ω Decays*

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We report a high-statistics experiment measuring the structure of e^+e^- mass spectrum from photoproduction of ρ and ω mesons. At 5.1 GeV, based on 4000 events, analysis of the spectra yields a ratio of vector-meson–photon coupling constants $\gamma_\omega^2/\gamma_\rho^2 = 9.4^{+2.6}_{-1.6}$ and a ρ-ω phase difference $\varphi_{\omega\rho}=41°\pm20°$.

We report the observation of interference in the e^+e^- final state from the leptonic decay of ρ and ω mesons, diffractively photoproduced off beryllium:

$$\gamma + \mathrm{Be} \rightarrow \mathrm{Be} + V^0(\rho, \omega), \quad V^0 \rightarrow e^+e^-. \tag{1}$$

Near the mass region $m_{ee} \cong m_\rho \cong m_\omega$, the total amplitude of the e^+e^- pairs is

$$A_T = A_{\mathrm{BH}} + A_\rho + A_\omega + A_x. \tag{2}$$

where A_{BH} is the Bethe-Heitler amplitude,[1] A_ρ (A_ω) is the diffractive photoproduction amplitude of ρ