$\pi^{\pm}$-p TOTAL CROSS SECTIONS IN THE RANGE 450 Mev TO 1650 Mev*

Thomas J. Devlin, Barry C. Barish, Wilmot N. Hess, Victor Perez-Mendez, and Julius Solomon
Lawrence Radiation Laboratory, University of California, Berkeley, California
(Received February 8, 1960)

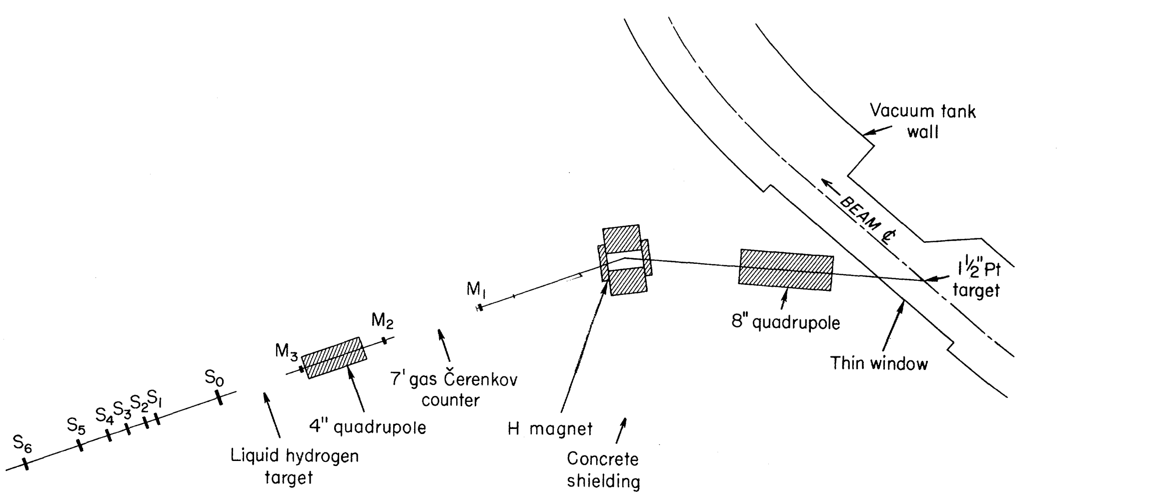
A series of counter experiments is being carried out at the Berkeley Bevatron and 184-inch cyclotron to measure total and differential scattering cross sections for pions at energies above the first resonance.[1-3] In this Letter we report the results of measurements of the total cross section for positive and negative pions on protons in the energy range from 450-Mev to 1650-Mev pion kinetic energy (lab).

The experimental arrangement is shown in Fig. 1. The pions were produced in an internal Pt target, plunged into the circulating proton beam of the Bevatron. The Pt target was located in the field-free tangent tank, allowing us to examine both positive and negative pions with the same experimental setup. Our magnet system consisted of an 8-in.-bore focusing quadrupole doublet, an 18×36-in. bending magnet which deflected the particles through an angle of 23 deg, and a 4-in.-bore focusing quadrupole triplet, used as a field lens. The absorber was a 48-in. target of liquid hydrogen.[4]

The beam incident on the liquid hydrogen target was monitored by coincidence of a set of plastic scintillation counters, M (1.5 and 2 in. in diameter), and a gas Čerenkov counter,[5] for discrimination against protons in the positive beam. In the energy range in which protons of the same momentum had a velocity less than $0.8c$, a liquid nitrogen Čerenkov counter was used in place of the gas counter. The transmission of pions was measured by a set of scintillation counters, S_1 to S_6, in coincidence with the monitor telescope. The scintillation counter, S_0, was placed in coincidence with S_1 to S_6 to reduce the accidental background. Counters S_1 to S_6 subtended different solid angles from the target, ranging from 1.5 to 7.1 millisteradians. The cross section was determined for each of these counters and extrapolated to zero solid angle. Eight transmission measurements were made at each energy, four with the hydrogen target empty and four with it full.

The momentum of the pion beam was determined by deflection through the bending magnet. It was measured by the current-carrying-wire method at four different times, before, during, and after the experiment. The consistency of these measurements was of the order of 1%. The momentum was also measured with a gas Čerenkov counter pressure curve. This gave the same result, but with somewhat less accuracy. The momentum spread determined by the counter telescope and the uncertainty in momentum were both 1.5%.

It was necessary to make several corrections to the data. Several species of accidental counts were monitored continuously during the experiment. These were negligible for negative pions. A fairly significant accidental rate was observed



in the monitor telescope for positive pions. This was due to the high flux of protons in the beam, and can be corrected for with the known proton-proton cross section.

The beam is also contaminated by muons from π decay, and by electrons. The muon contamination originates from two regions: before the bending magnet, and after it. The contribution from pion decays before the bending magnet was measured directly by means of a gas Čerenkov counter pressure curve. An exact calculation of this contribution is difficult, and we were forced to make some simplifying approximations. The measured contamination agreed very well with the approximate calculations. The contribution from decays after the bending magnet was not measurable by the pressure-curve method, but it is calculable in a simple straightforward manner. The total muon contamination varied from $2.5 \pm 1.0\%$ at 1650 Mev to $9.5 \pm 1.0\%$ at 450 Mev. The electron contamination was also measured by the pressure curves, and it was estimated to be less than 1%.

The effect of Coulomb scattering in the hydrogen target was taken into account in the extrapolation of the cross section to zero solid angle. At higher energies, the effect was negligible at all solid angles; at lower energies, the smaller solid angles were affected. Where necessary, the cross sections were corrected by a method similar to that of Sternheimer.[6]

The number of counts taken in each measurement gave a statistical uncertainty of 1% or less in the cross section at each solid angle. The fluctuations in the series of eight transmission measurements for each particular cross section were consistent with this. The errors on the points in Fig. 2 include the systematic errors due to muon, Coulomb, and accidentals corrections in addition to counting statistics.

The total cross sections for positive and negative pions on protons are shown in Fig. 2. Our results show peaks in the π^- cross section at 600 ± 15 Mev and at 900 ± 15 Mev. These are somewhat lower energies than indicated earlier by the MIT experiment,[7] but they are in substantial agreement, within statistics, with the measurements of the group at Saclay,[8] which are also plotted in Fig. 2. The existence of a maximum in the π^+ cross section was indicated earlier by an experiment at Brookhaven.[9] Our results, in this and in a previously reported experiment,[2] confirm its existence and show it to be centered about 1350 Mev.

We wish to acknowledge our indebtedness to Professor Burton J. Moyer and Professor A. C. Helmholz for their constant help and encouragement, to Michael Longo and John Atkinson for

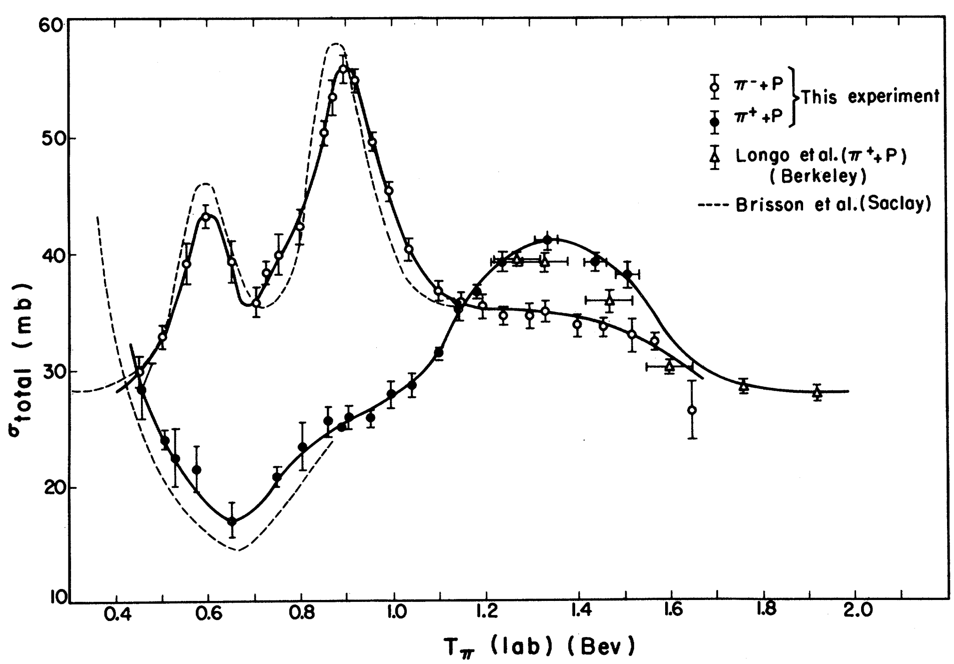


FIG. 2. Total $\pi^{\pm}-p$ cross sections vs pion kinetic energy.

their valuable aid in all phases of the experiment, and to the Bevatron staff and crew.

*Work done under the auspices of the U. S. Atomic Energy Commission.

[1]Victor Perez-Mendez, Bull. Am. Phys. Soc. 8, 451 (1959).

[2]M. J. Longo, J. A. Helland, W. N. Hess, B. J. Moyer, and V. Perez-Mendez, Phys. Rev. Letters 3, 568 (1959).

[3]L. K. Goodwin, R. W. Kenney, and V. Perez-Mendez, Phys. Rev. Letters 3, 522 (1959).

[4]Duane B. Newhart, Victor Perez-Mendez, and William H. Pope, Lawrence Radiation Laboratory Report UCRL-8857, August, 1959 (unpublished).

[5]John H. Atkinson and Victor Perez-Mendez, Rev. Sci. Instr. 30, 865 (1959).

[6]R. M. Sternheimer, Rev. Sci. Instr. 25, 1070 (1954).

[7]H. C. Burrowes, D. O. Caldwell, D. H. Frisch, D. A. Hill, D. M. Ritson, R. A. Schluter, and M. A. Wahlig, Phys. Rev. Letters 2, 119 (1959).

[8]J. C. Brisson, J. Detoef, P. Falk-Vairant, L. van Rossum, G. Valladas, and L. C. L. Yuan, Phys. Rev. Letters 3, 561 (1959).

[9]R. Cool, O. Piccioni, and D. Clark, Phys. Rev. 103, 1082 (1956).

QUESTION OF THE EXISTENCE OF A STRANGENESS 2 MESON*

D. J. Prowse
Department of Physics, University of California, Los Angeles, California
(Received February 3, 1960)

Recently Yamanouchi[1] has suggested that there is strong evidence for the existence of a strangeness 2 meson with a mass of about 720 Mev. Among several events enumerated by Yamanouchi in support of this contention is the Bristol anomalous K^+-meson decay reported by Prowse and Evans.[2]

Yamanouchi points out that if the identity of the primary particle in this event is unknown one could set up a scheme, $D^+ \to \pi^+ + K^0$ rather than $K^+ \to \pi^+ + \pi^0 + \gamma$ or $K^+ \to \pi^+ + x^0$, because the identities of all the neutral particles involved are unknown. The argument on whether or not the decay involves two or three bodies is based upon the fact that in a similar event found by the Columbia group,[3] the π^+-meson energy was the same (approximately 60 Mev). If the existence of two decays giving the same π^+-meson energy can be considered as possible evidence of a unique π^+ energy, then one is justified in postulating the decay mode $K^+ \to \pi^+ + x^0$ or, if the nature of the primary particle is undetermined, $D^+ \to \pi^+ + K^0$ also. The purpose of this Letter is to point out that the mass of the primary particle is known in the Bristol event and it is not consistent with the mass value of 720 Mev.

The event in question was found during a systematic study of the interactions of K^+ mesons with nuclei.[4] In the course of this work it appeared of interest to determine the decay modes of those K^+ mesons which had interacted and to compare them with the decay modes of those K^+ mesons which had not interacted.[5] The decay particles of the K^+ mesons which had been followed to rest in the search for interactions were therefore examined. Details of the pickup criteria used for finding and following these tracks are given in reference 4; the details of the measurements on the secondary particles are given in reference 5. In the course of the grain density measurements on these secondaries it became important to normalize the values obtained very carefully in each pellicle utilized. The normalization used was the grain density of the beam π mesons ($1.01 \times$minimum); this value was carefully determined in each plate as outlined in reference 5 and shown in Fig. 2 of reference 2. A number of K^+-meson identities were established by g^* vs R measurements because not all secondaries were visible owing to the low minimum grain density in the stack. In particular the identity of the primary of the anomalous event was established in this way. Grain density measurements were made at three residual ranges and the values were normalized using the minimum-ionization results mentioned above. The K^+-meson track was quite flat (1.4 cm/pellicle) and so no difficulties were encountered because of steepness. The three values obtained are shown graphically in Fig. 1. The expected variations of g^* vs R are shown for π mesons, K mesons, D particles, and protons. The mass of the primary is thus determined to be 532 ± 24 Mev. The identity can be seen to be well established.

The high strangeness number of 2 suggested by Yamanouchi for the new particle is sufficient to