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MEASUREMENTS ON THE $\pi^{\pm}$-p TOTAL SCATTERING CROSS SECTIONS IN THE ENERGY RANGE OF 0.4 to 1.5 Bev

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Studies on the photoproduction of π mesons in hydrogen have shown the probable existence of a new π-nucleon "resonance state" at a total energy (proton mass deducted) of $E^* - m_p \simeq 570$ Mev[1] in the center-of-mass system. The π^--p scattering cross sections[2] appear to confirm the existence of such a state. Recent scattering measurements[3] gave the position of this state at 615 Mev which is slightly different from that obtained in the photoproduction results. These same measurements also show a second maximum in the π^--p total scattering cross section at around 780 Mev.

We have undertaken to make absorption measurements of $\pi^{\pm}$ in hydrogen with a highly energy-selected π beam. The mean energy of the π beam is determined to an accuracy of $\pm 1\%$ and the energy resolution is $\pm 1.8\%$ including multiple scattering effects in the window and counters (the resolution is $\pm 0.9\%$ not including the multiple scattering effects).

The results obtained in the present experiment confirm the existence of the two maxima in the π^--p total cross sections but the energy values for these maxima differ appreciably from the previous results.[3] The absolute values of the cross sections in the region of the peaks obtained in the present experiment are also considerably higher than those obtained in the previous measurements.

The π beam is obtained from a carbon target which is placed in one of the straight sections of the Saclay proton synchrotron at an angle of 18.5° from the direction of the accelerated proton beam. The π beam is then momentum analyzed and focussed on to a liquid hydrogen target. The direction of the π is defined by a counter telescope to about $\pm 0.5°$ and within a circular area of a diameter of 6 cm at the entrance of the target. The separation of π^+ from protons was achieved by the time-of-flight method. The hydrogen target is 40 cm long and it subtends an angle of 6° at its center by the last counter (15 cm in diameter) of the telescope at a distance of 72 cm. The attenuation of the beam by the empty target does not exceed 20% of that by the filled target.

The energy of the π is determined by the wire method in terms of current values in the analyzing magnet. In order to avoid possible errors due to hysteresis effects when reversing and changing the field, a Hall-effect gauge is provided to monitor the magnetic field constantly. A magnetic shield at the exit of the beam from the straight section of the proton synchrotron serves to eliminate any effect on the π beam due to the fringing field of the machine, thus assuring a symmetry of the beam for the two polarities. The energy of the π is measured directly as well as indirectly by the following methods: (a) by a differential range curve of the protons of 800 Mev/c; (b) by differential range curves of π^+ of 400 and 500 Mev/c and π^- of 400 Mev/c; (c) by a determination of the velocity of the protons of 800 Mev/c by the time-of-flight method. All these measurements are in agreement within $\pm 1\%$. We have adopted the energy values obtained by the wire measurement taking into account the corrections due to energy losses in the counters and in the air.

The μ-meson and electron contamination in the beam have been determined at six different energies by means of a gas Čerenkov counter employing CO_2 or C_2H_4, the details of which will be described elsewhere. These contaminations amount to about 30% at 400 Mev and they drop to around 7% at 1 Bev. The other corrections which have been taken into account here are as follows: (a) correction due to accidentals in the background $\lesssim 1.1\%$; (b) correction due to elastic scattering of π or proton in the last counter $\lesssim 1.7$ mb; (c) correction due to inelastic scattering in the last counter $\lesssim 0.5$ mb; (d) correction due to scattering in air in the empty target $\lesssim 0.5$ mb.

The correction due to elastic scattering has been estimated by using the scattering cross-section values in the forward direction which are deduced from the dispersion relations[2] and which are in agreement with the experimental results.[4] The correction due to inelastic scattering is estimated based on experimental results[2] and assuming an isotropic distribution in the center-of-mass system.

The results are given in Fig. 1 and in Table I.

We wish to express our thanks to the staff of

Table I. Total scattering cross sections.

Pion kinetic energy[a] (lab) (Mev)	Corrections: For beam contamination[b] (%)	Corrections: Others[c] (mb)	Errors: Statistical (mb)	Errors: On beam contamination (mb)	Errors: Others (mb)	Total scattering cross section (mb)
			π^--p total scattering cross section			
373	35	0.95	0.9	0.9	0.5	28.9 ± 1.4
426	28	0.95	1.0	0.9	0.5	29.5 ± 1.4
468	25	1.00	0.64	0.9	0.5	30.0 ± 1.2
518	20	1.05	0.55	1.0	0.5	34.9 ± 1.3
567	18	1.14	1.27	1.3	0.5	44.6 ± 1.9
591	17	1.20	0.82	1.4	0.6	45.8 ± 1.7
604	16	1.25	1.15	1.4	0.6	45.5 ± 1.8
616	16	1.30	0.84	1.4	0.6	45.1 ± 1.7
643	15	1.36	1.57	1.3	0.7	44.4 ± 2.2
665	14	1.46	0.63	1.0	0.7	39.2 ± 1.4
719	12	1.70	0.86	0.9	0.8	35.1 ± 1.5
749	12	1.84	0.94	0.9	0.9	37.6 ± 1.6
769	10	1.90	1.48	0.9	0.9	37.4 ± 2.0
819	10	2.10	0.99	1.2	1.0	47.9 ± 1.9
840	9.5	2.20	1.17	1.4	1.1	54.6 ± 2.1
868	9.5	2.30	1.56	1.5	1.1	58.6 ± 2.4
890	9.5	2.37	1.26	1.4	1.2	57.8 ± 2.2
918	9.0	2.46	1.35	1.6	1.2	54.5 ± 2.4
943	9.0	2.60	1.72	1.5	1.3	50.4 ± 2.6
972	8.5	2.64	1.15	1.3	1.3	44.7 ± 2.2
1014	8.0	2.64	0.95	1.2	1.3	39.6 ± 2.0
1076	8.0	2.56	0.96	1.1	1.3	35.9 ± 2.0
1150	7.5	2.40	1.17	1.1	1.2	35.5 ± 2.0
			π^+-p total scattering cross section			
382	30.7	1.64	0.76	1.2	0.8	40.78 ± 1.62
476	20.5	1.25	0.56	0.7	0.6	23.67 ± 1.08
574	17.0	1.0	0.42	0.5	0.5	17.37 ± 0.82
633	13.0	0.9	0.40	0.45	0.4	15.16 ± 0.72
673	11.7	0.86	0.39	0.37	0.4	14.77 ± 0.67
778	9.3	0.92	0.39	0.49	0.5	19.44 ± 0.80
827	8.5	0.95	0.34	0.53	0.5	21.36 ± 0.81
847	8.2	0.95	0.34	0.57	0.5	22.42 ± 0.83
872	8.1	1.0	0.44	0.55	0.5	21.85 ± 0.86

[a]The uncertainty on the energy is ±1%. The momentum spread of the beam is ±1.8%.
[b]The contamination is the ratio $(\mu+e)/\pi$ of the total number of μ's and electrons in the beam to the number of π's.
[c]These include correction for elastic and inelastic scattering of particles into the last counter, and correction for scattering by air in the dummy target.

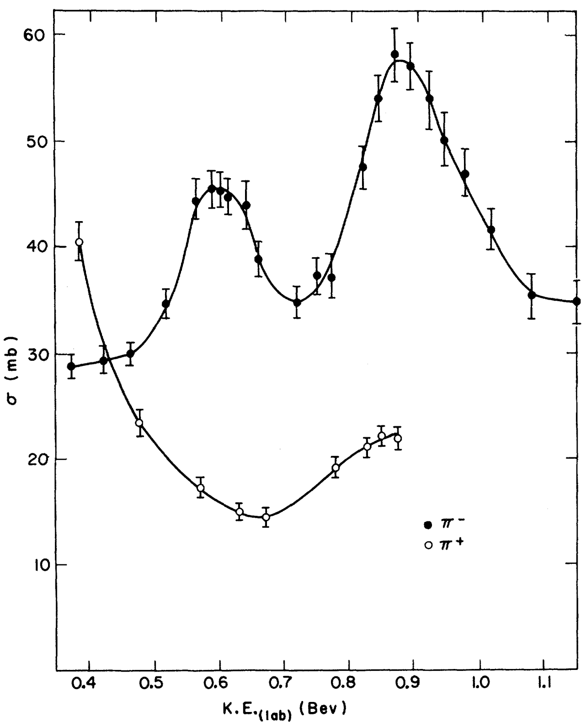

FIG. 1. Total π^--p and π^+-p scattering cross sections as a function of the π energy in the laboratory system.

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NEUTRAL BRANCHING RATIOS OF Λ AND K^0 PARTICLES*

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The neutral branching ratios of Λ and K^0 particles, defined by the relations

$$B_\Lambda \equiv \frac{w(\Lambda \to n + \pi^0)}{w(\Lambda \to n + \pi^0) + w(\Lambda \to p + \pi^-)},$$

$$B_K \equiv \frac{w(K_1^0 \to \pi^0 + \pi^0)}{w(K_1^0 \to \pi^0 + \pi^0) + w(K_1^0 \to \pi^+ + \pi^-)},$$

have already been investigated in hydrogen and propane bubble chamber experiments.[1-3] Because of the low gamma-ray detection efficiency of these devices, the statistically most significant results of these experiments have been based on comparisons of the numbers of associated ΛK_1^0, single Λ, and single K_1^0 decays via charged modes, rather than on direct detection of the neutral decay modes. On the other hand, the short radiation length of xenon makes it an ideal bubble chamber liquid for gamma-ray observation, and its use therefore permits the direct detection of the neutral decay modes with high efficiency.[4] We have taken 160 000 photographs in a 21-liter xenon bubble chamber exposed to a π^- beam of 1.0-1.1 Bev energy at the Berkeley Bevatron, for the purpose of making direct observations of the neutral decay modes. The results reported in this Letter are based on an analysis of about half of these pictures. Work on the rest of these data is now in progress.

Decay events with neutral secondaries were accepted in the samples used for the determination of B_Λ and B_K only if they contain two, three, or four electron pairs whose parent gammas originate at a common point inside the xenon. Furthermore, all charged and neutral Λ decays used in the measurement of B_Λ are associated with a K^0 decaying via its charged mode inside the chamber. Similarly all K^0 de-