ANGULAR DISTRIBUTIONS IN $\pi^{\pm}$-p ELASTIC SCATTERING IN THE RANGE 500 TO 1600 MeV†

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Angular distributions for pions elastically scattered from protons were measured at the Berkeley Bevatron at incident pion laboratory kinetic energies of 533, 581, 698, 873, and 990 MeV for π^+ and π^-, and 1311 and 1555 MeV for π^+. The differential cross sections were measured at as many as 20 angles simultaneously for each energy.

The data were least-squares fitted with a curve having an equation of the form

$$\frac{d\sigma}{d\Omega^*}(\theta^*) = \sum_{n=0}^{N} a_n \cos^n \theta^*, \qquad (1)$$

where θ^* is the angle in the center of mass at which the pion is scattered. Several criteria were used to determine the value of N, the maximum power of $\cos\theta^*$, in Eq. (1). First, the standard statistical goodness-of-fit parameter $(\chi^2/d)^{1/2}$ was required to be at or near its minimum value, where d is the number of degrees of freedom. Second, the value of N chosen was the one that made the fitted curve, as determined without the dispersion-relations point at $\cos\theta^* = +1.0$, come nearest to the dispersion-relations point. (The final fitted curves, however, were determined by including the dispersion-relations point in the data.) Third, the value of N at any specific energy was never less than that required at a lower energy in the experiment.

The results from the π^--p measurements are in essential agreement with those obtained by Wood et al.,[1] the main difference being that absolute normalizations, and hence total elastic cross sections, were obtained in the present experiment. In addition, the energies of these measurements are slightly lower than Wood's; however, this does not prohibit comparison of the two experiments.

The data points and the fitted curves are shown in Fig. 1. Attention should be directed to the backward peak and subsequent sharp drop-off of the cross section at 180° in the π^--p scattering in the vicinity of the 900-MeV peak, and also to the sharp rise of the cross sections near 180° in the π^+-p scattering in the vicinity of the 1350-MeV peak.

The values of the coefficients a_n in Eq. (1) are plotted as a function of energy in Figs. 2 and 3. The curves of Fig. 3 include data from many experiments in addition to this one.[1,2] At 900 MeV (π^--p) the small value of a_6 suggests that there is little scattering from partial-wave states with total angular momentum $J = \frac{7}{2}$ or higher. The large value of a_5 may indicate that a superposition of $F_{5/2}$ and $D_{5/2}$ partial waves is prominent in the scattering at this energy. One possible explanation is that the $F_{5/2}$ enhancement comes from an elastic resonance in the isotopic-spin $T = \frac{1}{2}$ state, consistent with the Regge pole formalism,[3] and the $D_{5/2}$ partial-wave state may be enhanced by inelastic processes in the $T = \frac{3}{2}$ state.

At 600 MeV (π^--p) the values of the coefficients do not seem to indicate the prominence of any single partial-wave state. The similarity of the differential cross-section curves at 533 and 581 MeV, except for the larger value of the forward

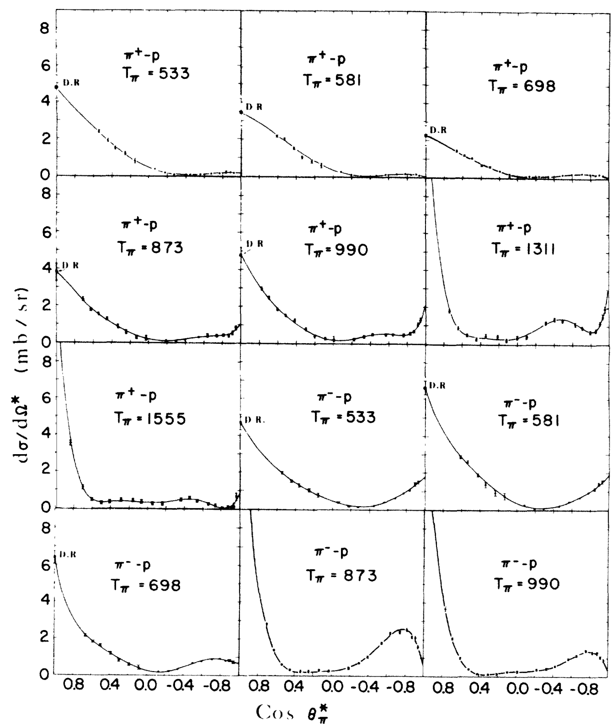

FIG. 1. Differential cross sections for $\pi^{\pm}$-p plotted vs cosine of pion scattering angle in center-of-mass system.

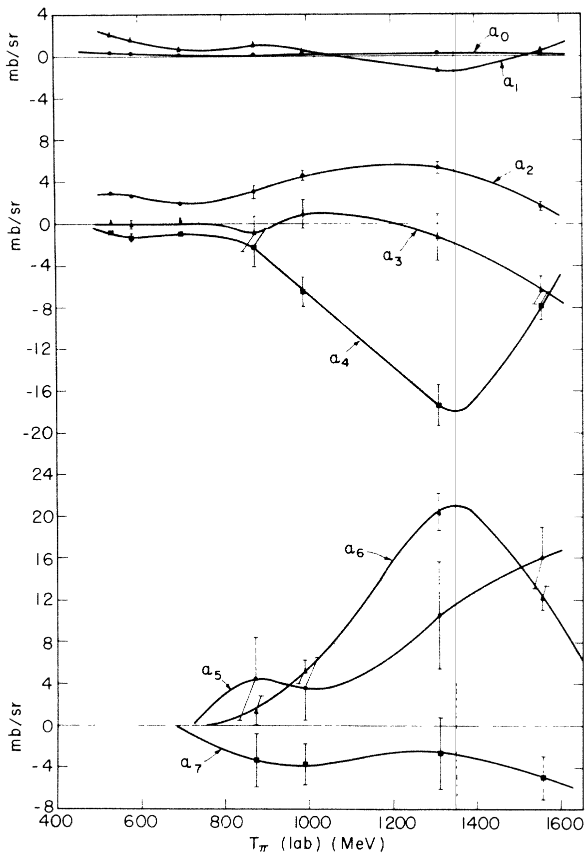

FIG. 2. Coefficients a_n for π^+-p vs incident pion laboratory kinetic energy.

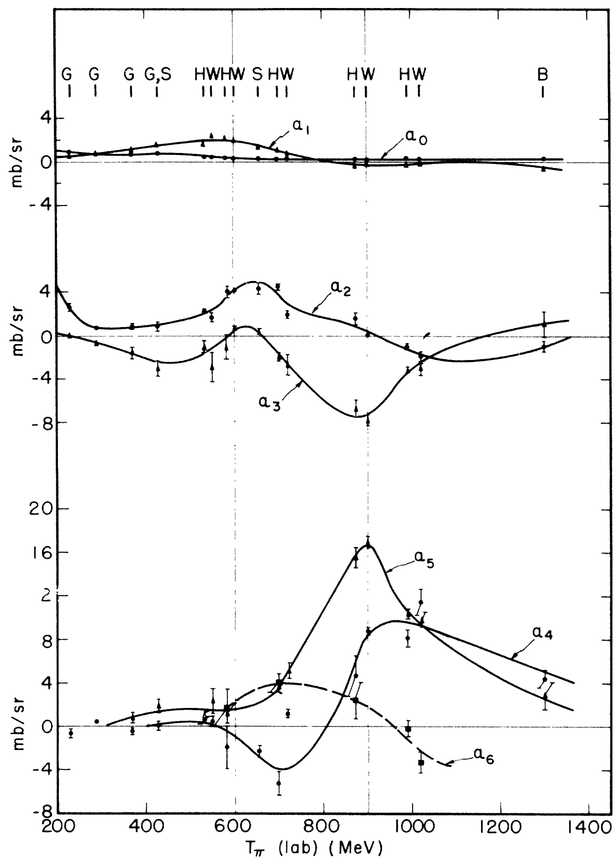

FIG. 3. Coefficients a_n for π^--p plotted vs incident pion laboratory kinetic energy.

diffraction peak at the higher energy, may indicate that the 600-MeV peak is due to inelastic processes rather than an elastic resonance.

At 1350 MeV (π^+-p) the small value of a_7 suggests that there is little scattering from partial-wave states with $J = \frac{9}{2}$ or larger. The large value of a_8 may indicate that $F_{7/2}$ scattering is prominent (although $G_{7/2}$ scattering could give the same results). The $F_{7/2}$ assignment is consistent with the Regge-pole formalism.[3]

The total elastic cross sections, obtained by integrating under the fitted curves, are listed in Table I.

The details of the experiment and data processing will be discussed in a forthcoming article.

Table I. Total elastic cross sections with errors.

Energy (MeV)	Total elastic cross section π^+-p	π^--p
533	15.32 ± 0.47	16.20 ± 0.50
581	12.17 ± 0.57	19.96 ± 0.54
698	8.02 ± 0.22	15.75 ± 0.28
873	12.05 ± 0.45	26.58 ± 0.61
990	14.54 ± 0.31	19.82 ± 0.24
1311	19.31 ± 0.61	···
1555	13.04 ± 0.28	···

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EXISTENCE AND SPIN OF THE PROPOSED "f^0" $\rightarrow \pi^+ + \pi^-$ RESONANCE

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We have studied the reaction

$$\pi^- + p \rightarrow \pi^+ + \pi^- + n \qquad \text{(A)}$$

in the 6.1-GeV/c π^- beam at CERN. The detector was the Ecole Polytechnique 300-liter heavy-liquid bubble chamber[1] filled with a CF_3Br-C_3H_8 mixture (density 0.55, radiation length 52 cm) in a 17.1-kG field. A preliminary report has been presented by F. Muller.[2]

A reaction of type (A) gives rise to a two-prong (one positive, one negative) star, without pointing electron pairs. Other reactions which can give rise to similar stars are the following:

$$\pi^- + p \rightarrow \pi^- + p, \qquad \text{(B)}$$

$$\pi^- + p \rightarrow \pi^+ + \pi^- + n + x\pi^0, \qquad \text{(C)}$$

$$\pi^- + p \rightarrow \pi^- + p + x\pi^0. \qquad \text{(D)}$$

To eliminate such spurious events, we used the following methods:

(a) Ionization and range allow us to reject most of the slow protons [a large part of (B) and (D)].

(b) Kinematical analysis enables us to reject almost all the remaining elastic events [type (B)].

(c) Because of the high probability of observing gamma-ray materialization, the number of types (C) and (D) events in two-prong stars without gamma rays is not very large (about 30 %). We eliminated most of these by a cutoff on the missing mass after comparing the missing-mass spectrum of events with and without observed gamma rays. These spectra are very different, because when π^0's are produced the missing mass generally corresponds to a slow neutron plus fast pions, and is consequently much larger than the nucleon mass.

We were finally left with 457 events of which >85 % are of type (A), $\lesssim$8 % are type (C), and $\lesssim$7 % of type (B) or (D).

We may note, in addition, that most of the events containing gamma-ray materialization described above gave π^+-π^- effective masses smaller than 1000 MeV. On the other hand, a sample of elastic-scattering events, treated in the same way, gave masses centered around 2000 MeV.

Experimental results. —(1) We computed the mass of the "dipion" ($\pi^+ + \pi^-$) for which the individual experimental error was about ±8 %; we constructed a histogram of this mass with 100-MeV intervals [Fig. 1(a)]. One observes a very high peak around 800 MeV, which is centainly connected with the ρ resonance. A second peak is observed around 1250 MeV. This peak was already pointed out by us in reference 2. Selove et al.[3] have also found it and interpret it as a resonance which they suggest calling "f^0."

By interpolating the background, we find that this peak is statistically significant to 3.5 standard deviations. We think that this is further evidence, with comparable accuracy, of the existence of the "f^0." Due to our large experimental errors, we can only say that the mass value that we measured (1260 ± 35 MeV) and our width ($\Gamma \leq 200$ MeV) are consistent with the ones measured by Selove et al.

(2) To investigate this peak further, we studied, in the "dipion" rest system, the distribution of the angle θ^* between the outgoing π^- and the beam. Fig. 1(b) shows the forward-backward asymmetry found, plotted against the dipion mass.

One observes a general forward asymmetry,