ELASTIC SCATTERING OF 4-BeV/c π^- MESONS BY PROTONS

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Elastic π^--p scattering at 4.0 BeV/c is studied with photographic emulsions for four-momentum transfers $0.0046 < |t| \leq 0.115$ $(BeV/c)^2$. 222 elastic scattering events were identified. The ratio of the real part of the scattering amplitude to the imaginary is $\alpha = -0.01 \pm 0.30$. The total elastic scattering cross section $\sigma_{el} = 5.9 \pm 0.5$ mb. The differential cross section slope parameter $A = 7.5 \pm 0.6$ $(BeV/c)^{-2}$ for $0.01 < |t| < 0.2$ $(BeV/c)^2$.

DESCRIPTION OF THE EXPERIMENT

THE study of elastic π-p scattering at high energies is of considerable interest. The scattering occurs in the forward hemisphere in the small angle region, and is almost completely diffraction scattering. By bombarding hydrogen-enriched emulsions in a beam perpendicular to the emulsion plane[1], it is possible to obtain the elastic scattering differential cross section for small momentum transfers and thus supplement high-momentum-transfer experiments performed by other techniques.

Three emulsion chambers were irradiated at right angles to the emulsion plane in a 4 BeV/c π^--meson beam from the synchrotron at the Joint Institute for Nuclear Research. Each chamber consisted of 50 layers of glass-mounted NIKFI-BR emulsion saturated with ethylene glycol for enrichment in hydrogen. The number of hydrogen nuclei per cm^3 in two of the chambers was $(5.0 \pm 0.1) \times 10^{22}$, and in the third chamber $(5.2 \pm 0.1) \times 10^{22}$. The primary particle flux density in the working regions of these three chambers was $(0.90 \pm 0.02) \times 10^5$, $(0.78 \pm 0.03) \times 10^5$, and $(4.37 \pm 0.06) \times 10^5$ per cm^2, respectively. The μ-meson and fast electron contamination in the π^--meson beam was 13%[2]. A total of 155 cm^2 was scanned, approximately equally in each of the three chambers. The technique of scanning, measuring, and identifying elastic scattering events with perpendicular irradiation has been described in detail earlier[1].

The properties of emulsion chambers saturated with water or ethylene glycol, and their advantages over standard chambers in the study of elastic scattering processes, have been discussed by Do In Seb et al.[3] The accuracy of measurement of the recoil proton range R was 3—5%, the accuracy of the recoil proton emission angle measurement for events with $R > 1000\,\mu$ was about 1%, and for events with $R < 1000\,\mu$, about 2—3%.

The momentum spectrum of the primary beam of π^- mesons was determined from the π^--meson emission angle ψ, which was measured with an accuracy of $\sim 6'$, and from the recoil proton range R. For this purpose we used events satisfying the following three criteria:

1) absence of a recoil nucleus at the point of scattering;

2) correlation between the recoil proton range R and its angle φ with the primary meson direction, satisfying the kinematics of relativistic π-meson elastic scattering;

3) coplanarity of all three tracks.

Figure 1 gives the primary π^--meson momentum spectrum obtained.

The differential cross section was determined

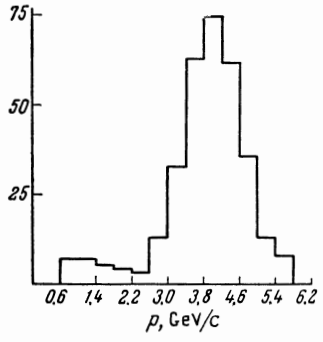

FIG. 1. Primary π^--meson momentum spectrum. The ordinate is the number of events.

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Differential cross section for π^--p elastic scattering in the region $3° < \theta_{cms} \leq 15°$

θ_{cms}, degrees	$-t$, (BeV/c)^2	No. of events observed	No. of events, corrected according to Janossy's formulas	$d\sigma/d\Omega$, mb/sr	$-d\sigma/dt$, mb-c^2/BeV^2
3—6	0.0046—0.018	48	52.8±7.8	27.5±4.1	50.8±7.6
6—9	0.018—0.042	55	60.7±8.4	19.3±2.7	35.6±5.2
9—12	0.042—0.074	59	66.8±9.0	15.0±2.0	27.7±3.7
12—15	0.074—0.115	38	56.5±12.8	9.9±2.2	18.3±4.1

only for events in the momentum interval $2.6 < p \leq 5.4$ BeV/c; the remaining events were not analyzed and were discarded, taking into account the cross section corresponding to them. In determination of the differential cross section we also did not consider events occurring close to the glass or the emulsion surface.

A total of 222 elastic scattering events were selected for determination of the differential cross section; 200 of these were in the range $3° < \theta_{cms} \leq 15°$. Quasielectric and other events similar to elastic scattering formed a background amounting to ~3%. For evaluation of this background we plotted (Fig. 2) the distribution of events in the momentum interval $2.6 < p \leq 5.4$ BeV/c as a function of the quantity $\Gamma = |\gamma/\Delta\gamma|$, where γ is the angle of non-coplanarity, and $\Delta\gamma$ is the error in its measurement. Events satisfying the three criteria listed above for $\Gamma \leq 2$ were considered elastic scattering.

The number of events in each angle interval, taking into account the double-scanning efficiency, and the related statistical error were determined using the formulas of Janossy [4]. From these data we determined the differential cross section and its experimental error.

DISCUSSION OF EXPERIMENTAL RESULTS

The table lists the number of events observed, the corrected number of events, and the differential cross section. The present experiment was carried out at small c.m. scattering angles (3—15°). Coulomb scattering makes some contribution in the first interval. Ting et al. [5] performed an experiment with spark chambers at 4.1 BeV/c at large c.m. scattering angles (14.6—43.9°).

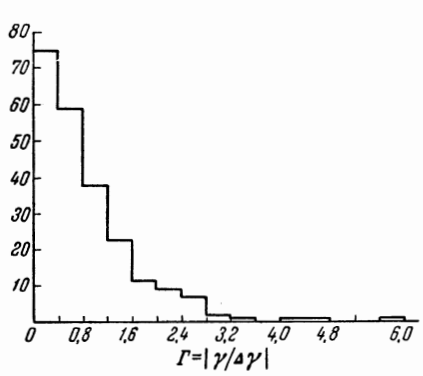

FIG. 2. Distribution of events satisfying the first two criteria, as a function of $\Gamma = |\gamma/\Delta\gamma|$. The ordinate is the number of events.

We analyzed the results of both experiments to obtain values of four-momentum transfer $t < 0.7$ (BeV/c)^2, according to Bethe's formula [6]:

$$\left[\frac{d\sigma}{d\Omega}\right]_{cms} = \left[\left(\frac{2nF(\theta)}{k\theta^2}\right)^2 + g_I^2(1+\alpha^2) - \frac{4nF(\theta)}{k\theta^2}\left(\alpha g_I + 2ng_I \ln\frac{\varphi_0}{\theta}\right)\right],$$

where

$$F(\theta) = \exp[-\theta^2 \ln 2 / 2\theta_0^2]$$

represents the nuclear and electromagnetic form factors of the nucleon, which are assumed identical;

$$n = 1/137\,\beta_{1s}, \qquad \varphi_0 = 1.06/ka, \qquad a = 1\cdot10^{-13}\ \text{cm},$$

k is the wave number (c.m.s.), and β_{1s} is the π-meson velocity in the laboratory system in units of c;

$$g_I = \sqrt{\left(\frac{d\sigma}{d\Omega}\right)_{opt}}\,F(\theta), \qquad \left(\frac{d\sigma}{d\Omega}\right)_{opt} = \frac{k^2\sigma_{tot}^2}{16\pi^2},$$

σ_{tot} is the total π^--p elastic scattering cross section, which, according to the data of Diddens et al. [7] at 4 BeV/c is 30.3 ± 0.2 mb; $\alpha = g_R(\theta)/g_I(\theta)$ is the ratio of the real part of the nuclear scattering amplitude to the imaginary part.

The results of the calculation are as follows: $\alpha = -0.01 \pm 0.30$; $\chi^2 = 14.8$ (the number of experimental points $n = 13$); $\theta_0 = 13.1° \pm 0.1°$ (see Fig. 3). Thus, the present experiment and that of Ting et al. [5] indicate a small value of the real part of the scattering amplitude, which is in good agreement with Barashenkov's estimate using dispersion relations [8]: $\alpha = -0.1$ for E = 4 BeV.

Representing the differential cross section after subtraction of the Coulomb scattering in the form

$$-\frac{d\sigma_{nuc}}{dt}\left[\frac{\sigma_{tot}(20\ \text{GeV/c})}{\sigma_{tot}(4\ \text{GeV/c})}\right]^2 = \exp(a + At),$$

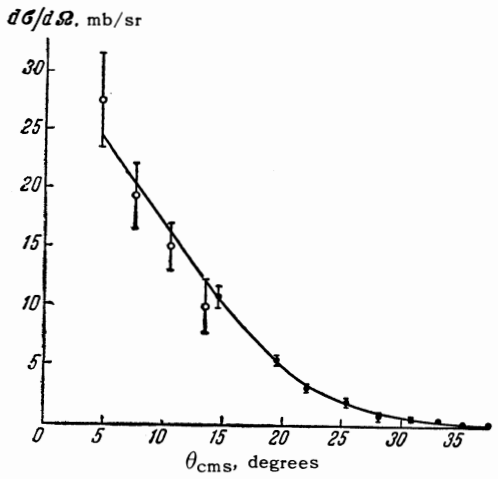

FIG. 3. Differential cross section for π^--p elastic scattering: o – data of the present experiment; • – results of Ting et al.[5] The curve is calculated from Bethe's formula for $\alpha = -0.01 \pm 0.30$, $\theta_0 = 13.1° \pm 0.1°$.

we determined the slope parameter A and the coefficient a in the interval $0.01 < |t| < 0.2$ (BeV/c)^2 from the four experimental points of the present experiment and the two points of Ting et al[5]: $A = 7.5 \pm 0.6$ (BeV/c)$^{-2}$, $a = 3.46 \pm 0.09$.

The value of A obtained in the present experiment agrees with the values calculated by other authors. This fact indicates, first, the independence of A on energy within the limits 1 to 18 BeV and, second, the independence of A on t within the limits $0.01 < |t| < 0.9$ (BeV/c)^2 for a momentum of 4 BeV/c.

The slope parameters of the π^--meson differential cross section agree with the values of A for π^+ mesons. Analyzing the present experiment and the work of Ting et al., we obtained the total cross section for π^--p elastic scattering

$$\sigma_{el}\,[4\text{GeV}/c] = 5.9 \pm 0.5\ \text{mb}.$$

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