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THE REAL PART OF THE ELASTIC $\pi^- p$, pp, AND pd SCATTERING AMPLITUDE IN THE ENERGY REGION 2-10 GeV

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The investigation of elastic $\pi^- p$, pp and pd -scattering has been made by detecting the recoil protons or deuterons using the methods described in [1]. The region of momentum transfers over which the differential cross section was measured is restricted to $0.003 < |t| < 0.2$ GeV$^2/c^2$.

The differential elastic pd-scattering cross section in c.m. system at the proton energies E_{kin}=1, 2.4, 6, 8 and 10 GeV is shown in Fig.1. The statistical errors are about 3%. The accuracy of the absolute monitoring is 7%.

The differential cross section in the momentum transfer region where the Coulomb effects are absent is approximated by the curve of the form $\frac{d\sigma}{-dt} = e^{a+bt+ct^2}$ The values of the parameters a, b and c are shown in Fig.1. The magnitude of the total elastic cross section is given in Table 1. In the last column is given the value of the interaction radius calculated in the framework of the optical model according to the slope parameter of the differential cross section at $|t| = 0.06$ GeV/c.

Table 1

E_{kin} GeV	σ_{el}^{tot} mb	R fermi
2	9.5 ± 0.7	2.08 ± 0.04
4	9.9 ± 0.8	2.11 ± 0.04
6	9.5 ± 0.7	2.20 ± 0.04
8	9.5 ± 0.7	2.26 ± 0.04
10	9.3 ± 0.7	2.20 ± 0.04

In the region of small momentum transfers the differential cross section corresponds to the presence of the constructive interference of the Coulomb and nuclear scatterings. An analysis of the experimental data was performed by the Bethe formula [2]. The energy dependence of the real part of the pd-scattering amplitude is shown in Fig. 2.

In Fig. 3 are presented the results of measurements of the real part of the pp-scattering amplitude. The analysis of the experimental data was also done by the Bethe formula with account of the radiative corrections obtained by L.D.Soloviev [3]

$$\frac{d\sigma}{d\Omega} = |g_o|^2 + |g_n|^2 + 2g_c\left(g_{nR} + 2g_{nI}\,\frac{1}{137\beta\varrho}\cdot\ln\frac{2}{\theta}\right) \qquad (1)$$

The difference from the Bethe formula[2] is that under the sign ℓn there is $2/\theta$ but not $\frac{1,06}{ka\,\theta}$ obtained by Bethe. Here k, a, θ are the momenta, nucleon radius and the scattering angle in the c.m.s., respectively. The point at 4 GeV is a new one, for the remaining energies the old results have been made more accurate.

The comparison of the data on the magnitude of the real part of the amplitude for p-p and p d -scattering allows to estimate the real part of the p n -scattering amplitude. With this aim in view, one may, following Glauber[8], use the diffraction approximation in the scattering theory. Making use of the simplest model of the deuteron the amplitude of the scattering on the deuteron at an angle 0° can be expressed in terms of the amplitude of scattering on the nucleons

$$F_d = f_p + f_n + \frac{i}{k} \cdot (\overline{r^{-2}})_d \cdot f_p \cdot f_n \quad . \qquad (2)$$

Distinguishing between the real and imaginary parts of this equality and using the optical theorem we have

$$a_n \approx \frac{1}{\sigma_{pn}} \left[(a_d \cdot \sigma_{pd} - a_p \cdot \sigma_{pp}) \left(1 + \frac{(\overline{r^{-2}})_d}{4\pi} \sigma_{pp} \right) \right] + \frac{(\overline{r^{-2}})_d}{4\pi} a_p \cdot \sigma_{pp} \qquad (3)$$

$$\sigma_{pd} = \sigma_{pp} + \sigma_{pn} + \frac{(\overline{r^{-2}})_d}{4\pi} \sigma_{pp} \cdot \sigma_{pn} (a_p a_n - 1) \quad . \qquad (4)$$

Here σ_{pi}'s are the total p-p, p-d and p-n interaction cross sections, $a_i = \frac{\mathrm{Re}\, A\,(0)}{\mathrm{Im}\, A\,(0)}$. The only parameter characterising the deuteron $(\overline{r^{-2}})_d$ (inverse root mean-square) was found from the experimental data on the total cross sections of $\pi^{\pm}$ d interaction. Galbraith et al.[9] have got a numerical estimate

$$(\overline{r^{-2}})_d = (0,042 \pm 0,003)\ \mathrm{mb}^{-1}.$$

All the quantities entering the formula (3) have been measured experimentally (a measurement of σ_{np} in the neutron beam was made in [10,11]). This permits to state that the diffraction approximation used here (the formulae 2,3,4) holds true with an accuracy not worse than 7%. The value of $a_n = \frac{\mathrm{Re}\, A_{pn}(0)}{\mathrm{Im}\, A_{pn}(0)}$ for p-n scattering together with the values of a_p are given in Table 2.

Table 2

E (GeV)	2	4	6	8	10
a_p	-0.12 ± 0.07	-0.38 ± 0.1	-0.30 ± 0.07	-0.33 ± 0.08	-0.26 ± 0.05
a_n	$+0.19 \pm 0.40$	-	-0.06 ± 0.19	-0.45 ± 0.20	-0.40 ± 0.17

The analysis of the experimental data on $\pi^- p$ -scattering at 3.5 GeV was done by the same formula as p p -scattering. The magnitude of the real part is shown in Fig. 4 in comparison with data[12] at other energies and with the curves obtained from dispersion relations[13,14]. At an energy of 3.5 GeV, just as in the range of 8-12 GeV, the experimental value of the real part of the $\pi^- p$ -scattering amplitude has a tendency to lie below the value obtained from dispersion relations.

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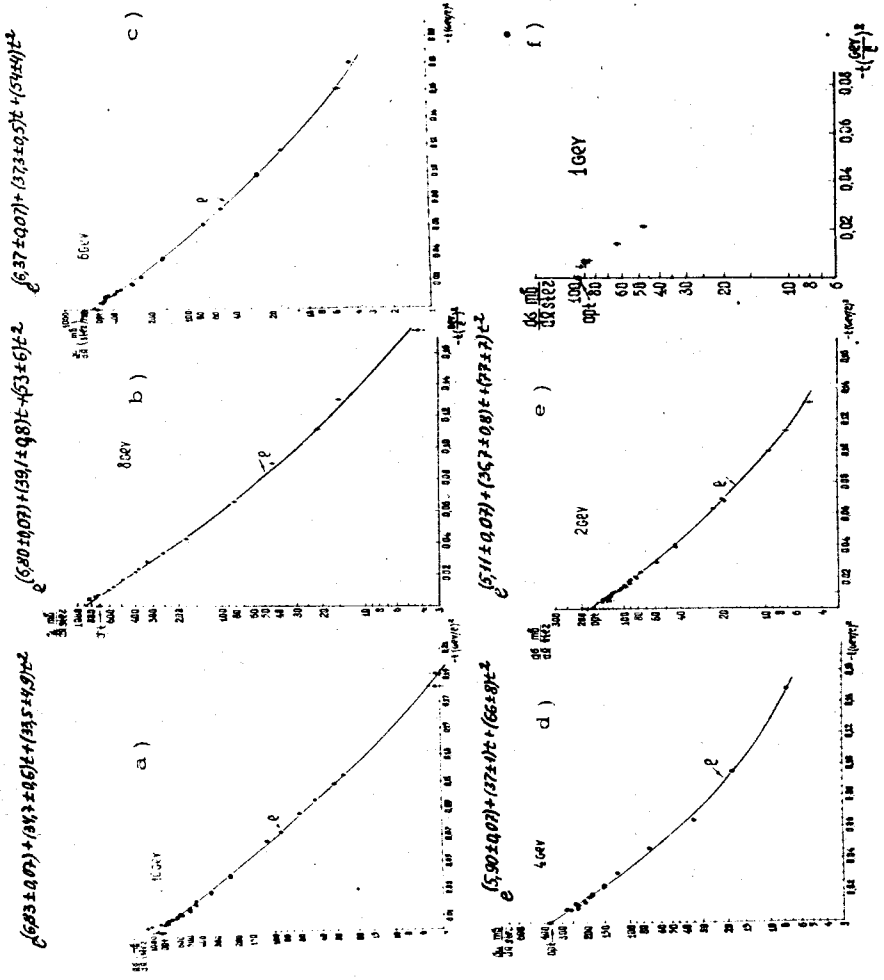

Fig 1

The differential pd -scattering cross sections.

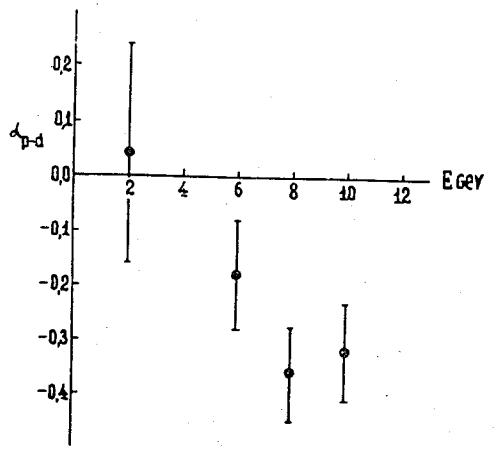

Fig. 2

The real part of pd -scattering amplitude as a function of energy.

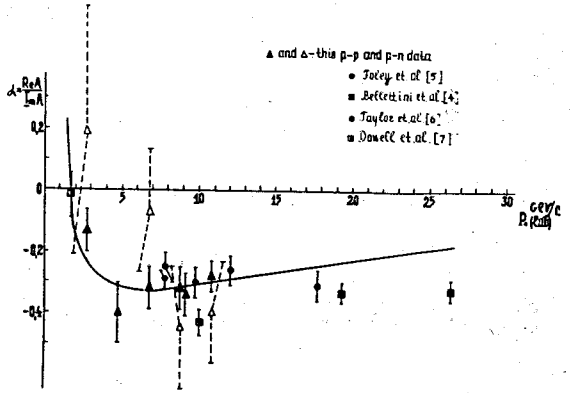

Fig. 3

The real part of the pp and pn-scattering amplitude as a function of energy. The curve is calculated by Söding from the dispersion relations for $p-p$ scattering [15].

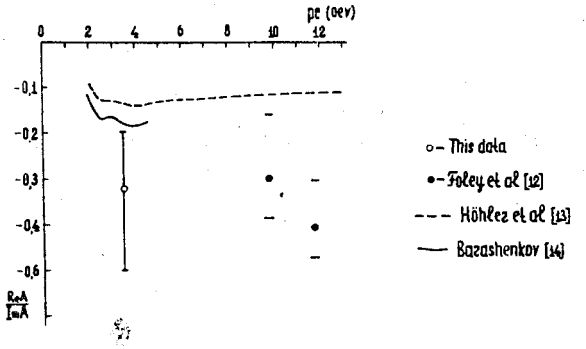

Fig.4.

The real part of the $\pi^- p$-scattering amplitude in the energy range 3–12 GeV. The curves are calculated by the dispersion relations [13,14].