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A 1 Elastic Scattering in Coulomb-Nuclear Interference Region

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There are three contributions to this conference in which the high energy p–p and p–d[1] as well as π^-–p[2,3] elastic scattering has been studied in the Coulomb-nuclear interference region.

In the Fermilab experiment[1] the ratio ρ_{pp} and ρ_{pd} of the real to imaginary parts of the forward scattering amplitude has been determined for incident laboratory energy from 50 to 400 GeV. The experimental technique was similar to that used by this group earlier[4], *i.e.*, silicon detectors measuring the energy and the angle of the particles recoiled from a hydrogen-jet target. However, the angular resolution was improved considerably (up to ± 0.8 mrad) and also the absolute value of the recoil angle was measured which made it possible to calibrate the $|t|$-scale down to very small $|t|$-values. The $|t|$-values studied were $0.0005<|t|<0.03$ (GeV/c)^2 for hydrogen and $0.0008<|t|<0.03$ (GeV/c)^2 for deuterium. The data on p–p scattering were analyzed using the Bethe interference formula with fixed slope parameter β_{pp} while ρ_{pp} and overall normalization were free parameters in the fits. The statistical errors in ρ_{pp} are typically $\Delta\rho_{pp}=0.01$. A shift in the value of β_{pp} by 1 (GeV/c)^2 produces a shift in ρ_{pp} about $\Delta\rho_{pp}=0.03$. The results

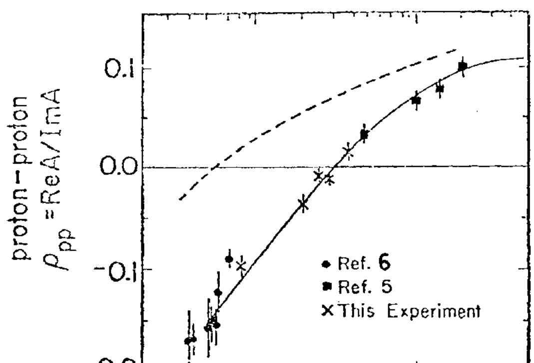


Fig. 1. The ratio of the real to the imaginary parts of the forward p–p nuclear amplitude. The solid line is a dispersion relation calculation, and the dashed line is a one-Pomeron formula.

for ρ_{pp} are shown in Fig. 1. They agree with the earlier measurements at the same energies[4] and join smoothly the high energy ISR data[5] as well as low energy Serpukhov data.[6] There is a good agreement between the experimental data and the dispersion relation calculations (the solid line in Fig. 1) in which σ_{tot}(pp) was assumed to continue increasing up to at least $p_{lab}=40.000$ GeV/c. The dashed line represents the prediction obtained from a simple vacuum exchange model. The comparison shows the importance of other exchanges.

The p–d data were analyzed in a similar way treating the deuteron as a single particle. An empirical expression was found to be valid in the energy range covered by this experiment:

$$\rho_{pd}=(-0.450\pm0.035) + (0.070\pm0.006)\ln \rho_{pp}.$$

ρ_{pp} and ρ_{pd} both cross zero at about 335 GeV. The p–d data were analyzed also using the Glauber approach, and the values of ρ_{pn} have been obtained with statistical errors $\Delta\rho_{pn}\simeq 0.015$. Within the errors, $\rho_{pn}\simeq\rho_{pp}$ thus supporting the isospin invariance in nucleon–nucleon collisions at high energies.

Recently, a new method for detection of the low energy recoils (p, d, He) has been developed in the Leningrad Nuclear Physics Institute.[6] Here, the kinetic energy and the polar angle of the recoiled particles are determined with an ionization chamber filled with hydrogen (helium) which serves both as target and as ionization medium. The $|t|$-resolution in the Coulomb interference region is $\Delta t=10^{-Y}$ (GeV/c)^2. The essential features of the new recoil detector are:

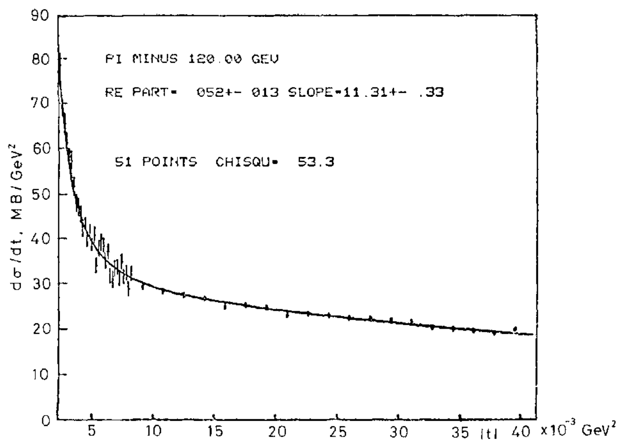
i) It can be used to study not only the small angle scattering of protons but also that of pions from p, d, He-targets,

ii) It provides absolute normalization of the differential cross sections with the accuracy $\pm 1\%$,

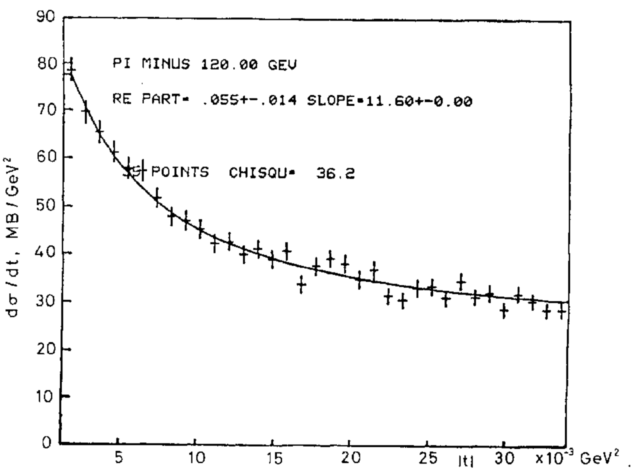
iii) It can be combined with a forward particle spectrometer, such a combination being very efficient in the background rejection even at the highest energies.

The recoil detector combined with a forward particle spectrometer has been used at Serpukhov[2] to study π^-p elastic scattering at the momentum 40 GeV/c and at CERN[2] to study π^-p scattering at the momenta from 30 to 140 GeV/c. The $|t|$-range covered in the Serpukhov experiment was $0.002 \leq |t| \leq 0.008$ $(\text{GeV}/c)^2$ while that in the SPS experiment was $0.002 \leq |t| \leq 0.04$ $(\text{GeV}/c)^2$. As an example a differential cross section measured at 120 GeV/c is shown in Fig. 2a, b. The data were fitted with the Bethe interference formula. When all the experimental points (Fig. 2a) were used in the fit it was possible to determine both $\rho_{\pi p}$ and $\beta_{\pi p}$. The evaluation of the slope parameter over such a small $|t|$-interval became possible due to absolute normalization of the cross sections. The value of $\rho_{\pi p}$ could be determined also using only the data at the lowest $|t|$-values (Fig. 2b), in the latter case $\rho_{\pi p}$ proved to be practically independent on $\beta_{\pi p}$: a shift of $+1$ $(\text{GeV}/c)^2$ in $\beta_{\pi p}$ corresponds to a shift $\Delta\rho = +0.003$ in $\rho_{\pi p}$.

The result from the Serpukhov experiment is $\rho_{\pi p} = -0.037 \pm 0.017$ at 40 GeV/c. In the SPS experiment $\rho_{\pi p}$ was found to be equal to $+0.04 \pm 0.02$; -0.003 ± 0.013; $+0.017 \pm 0.013$; $+0.023 \pm 0.013$; $+0.052 \pm 0.013$; and $+0.03 \pm 0.02$ at the momenta 30, 50, 80, 100, 120, and 140 GeV/c, respectively. The experimental data are presented in Fig. 3. In the discussion, one should point out first a good agreement of the experimental data at 30 and 40 GeV/c with the dispersion relation calculations,[9] contrary to the previous observations made by the Brookhaven group.[8] As to the asymptotic behaviour of the πp amplitude, it is evident from the presented data that the real part



(a)



(b)

Fig. 2. The differential cross section for forward π^-p elastic scattering measured at 120 GeV/c.
a) the $|t|$-region used to determine both $\rho_{\pi p}$ and $\beta_{\pi p}$.
b) the $|t|$-region used to determine only $\rho_{\pi p}$ with fixed value of $\beta_{\pi p}$.
The solid line represents the best fit to the experimental points.

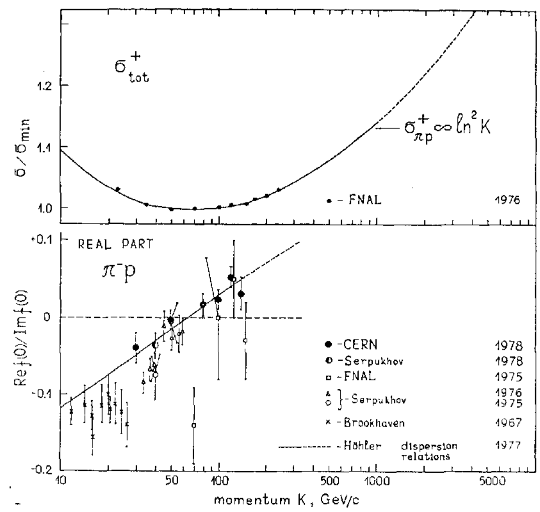


Fig. 3. The ratio of the real to imaginary parts of the forward π^-p nuclear amplitude and the total πp cross section as functions of the incident particle momentum

$$\sigma^{+}_{\text{tot}}(\pi p) = \frac{\sigma_{\pi^+ p} + \sigma_{\pi^- p}}{2}$$

The solid line in the ρ-plot is the dispersion relation calculations made by Höhler *et al.*[9] in which $\sigma^{+}_{\text{tot}}(\alpha)$ was obtained from the fit to the FNAL experimental points and is shown by the solid-dashed line in the σ^{+}_{tot} plot.