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SLOPE PARAMETER AND THE REAL PART OF THE p-n ELASTIC SCATTERING AMPLITUDE IN THE ENERGY RANGE OF 10-70 GEV

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Summary

The slope parameter of the $p-n$ elastic scattering differential cross section and a_{pn} (the ratio of the real to the imaginary part of the $p-n$ elastic scattering amplitude) have been determined in the framework of the Glauber model using the $p-d$ and $p-p$ elastic scattering data at small angles obtained at the Serpukhov accelerator. It is shown that the properties of the $p-n$ scattering amplitude are similar to those of the $p-p$ scattering amplitude: the slope parameter increases with increasing energy, a_{pn} is negative and decreases in its absolute value when energy increases in accordance with dispersion relations.

Introduction

Experimental data on the $p-n$ scattering at high energies make it possible to test various models of the theory of strong interactions. It is of great interest to compare a_{pn} (the ratio of the real to the imaginary part of the $p-n$ elastic scattering amplitude) at $t=0$ with the predictions of dispersion relations. The comparison of the $p-n$ and $n-p$ scattering amplitudes permits to check the Glauber model.

In order to determine the properties of the $p-n$ elastic scattering amplitude, the differential cross section of the $p-d$ /1,2/ and $p-p$ /3,4/ elastic scattering were measured at the Serpukhov accelerator in the energy range of 10 - 70 GeV. The data were taken in the interval $0.002 \le |t| \le 0.2\ (\mathrm{GeV/c})^2$. For analysis the Glauber model was used. In the framework of this model it is possible to express the $p-d$ elastic scattering differential cross section through the $p-p$ and $p-n$ elastic scattering amplitudes on free nucleons $f_{pp}(t)$ and $f_{pn}(t)$ at small values of the squared four-momentum transfer t:

$$\left|\frac{d\sigma}{dt}\right| = \left| S\left(\frac{t}{4}\right)\left[f_c(t) + \exp(i\chi_{cp}) f_{pp}(t) + \exp(i\chi_{cn}) f_{pn}(t)\right] + \right.$$

$$\left. + \frac{i\hbar}{\sqrt{\pi}} \exp(i\chi_{cpn}) \cdot f_{pn}\left(\frac{t}{4}\right) f_{pp}\left(\frac{t}{4}\right) \cdot IG \right|^2 . \qquad (1)$$

For the scattering amplitudes on free nucleons the following parametrization was used:

$$f(t) = \frac{\sigma}{4\sqrt{\pi}\,\hbar}(i + a)\exp\left(\frac{bt}{2}\right),$$

where σ - are the total cross sections, their values were taken from ref. /6/ , b is the slope parameter, $f_c = \frac{2n \hbar \sqrt{\pi}}{t} \cdot F(t) \cdot e^{-i\eta}$ is the Coulomb scattering amplitude, where $F(t)$ is the proton electromagnetic formfactor

$$\eta = 2n \cdot \ln \frac{1.06 \hbar}{a\sqrt{|t|}},$$

$n = 1/137\beta_{lab.}$ ($\beta_{lab.}$ is the velocity of the incident particle in the lab. system in units of c), a is the value of the order of the nucleon-nucleon radius (1 fm).

$$S^2(\frac{t}{4}) = S_0^2(\frac{t}{4}) + S_2^2(\frac{t}{4}),$$

$S_0(t)$ and $S_2(t)$ are the deuteron form factors in S- and D-states. The value $S^2(\frac{t}{4})$ is taken from ref. /7/.

χ_i (i = cp, cn, cpn) represent mean values of phase shifts of the Coulomb amplitude with respect to nuclear scattering (χ_{cp}, χ_{cn} and χ_{cpn} are correspondingly phase shifts with respect to $p-p$, $p-n$ and double nuclear scatterings). It is shown in ref. /8/ that $\chi_{cp} = \chi_{cn} = \chi_{cpn} = 0.06$, it is practically possible to neglect the dependence of these values on energy.

IG is the Glauber integral. It was taken to be equal to 0.028 mb^{-1} /7/. Having the $p-d$ elastic scattering differential cross sections, the parameters of the $p-p$ elastic scattering amplitude and the deuteron form factor, we have calculated the parameters of the $p-n$ elastic scattering amplitude by the formula (1).

1. Slope Parameter of the $p-n$ Elastic Scattering

The obtained values of b_{pn} are given in fig. 1 and Table. The Table shows only the statistical errors. The systematic error in b_{pn} is mainly based on the assumption that the slope parameter of b_{pp} coincides with that of the $n-p$ scattering (b_{np}) at the energies of 10 - 26 GeV. This assumption was made from the analysis of the experimental data on the $p-p$ and $n-p$ elastic scattering /9-14/.

As is seen from fig. 1, the slope parameter of the $p-n$ elastic scattering increases with increasing energy. It is important to note that using theoretical values of the deuteron form factor the calculation of b_{pn} gives a similar dependence of b_{pn} on energy. For comparison fig. 1 presents the straight line corresponding to the dependence of the $p-p$ slope parameter in the same energy range found in /4/. For $(0.008<|t|<0.12 (\text{GeV}/c)^2)$ the energy dependence of the $p-p$ slope parameter was approximated by the formula:

$$b_{pp}(S) = b_0 + 2b_1 \ln(S/S_0), \qquad (2)$$

where b_0 and b_1 are equal to: $b_0 = 7.32 \pm 0.25 (\text{GeV}/c)^{-2}$, $b_1 = 0.41 \pm 0.06 (\text{GeV}/c)^{-2}$. In the framework of the Regge-pole model the slope of the Pomeranchuk trajectory makes a main contribution to b_1. It is seen that the obtained values of b_{pn} satisfactorily lie on this straight line (χ^2/number degree ≈ 2). The energy dependence of the $p-n$ slope parameter as well as that of the $p-p$ slope parameter shows that the cone gets narrow with increasing energy. In the framework of the complex momentum theory this fact points to that the slope of the Pomeranchuk trajectory is different from zero.

2. Ratio of the Real to the Imaginary Part of the $p-n$ Elastic Scattering Amplitude at $t=0$

The energy dependence of the real part of the $p-n$ elastic scattering amplitude found by formula (1) is presented in fig. 2. The values of $a_{pn} = Re\, f_{pn}(0)/Im\, f_{pn}(0)$ together with the data on the slope parameter b_{pn} are presented in Table. The statistical errors are given. The systematic errors in the $p-d$ elastic scattering differential cross section are discussed in ref. /1/. They give a main source of systematic error in a_{pn} and b_{pn}. Figure 2 also presents the data from refs. /15, 16/ and the results of dispersion relation calculations from refs. /17, 18/. One can see that the real part of the

$p-n$ elastic scattering amplitude is negative and falls in its absolute value with increasing energy in agreement with the calculations obtained by dispersion relations. Thus, the a_{pn} and a_{pp} /3/ data agree with the dispersion relations. In order to check the influence of χ_{cp}, χ_{cn}, χ_{cpn} on the result, the version has been calculated in which all these values are equal to zero. It has been found out that in this case b_{pn} increases by $\approx 0.6 - 0.7\ (\mathrm{GeV/c})^{-2}$ and a_{pn} increases in its absolute value by ≈ 0.05.

One can see from the Table that in the considered energy range the parameters of the $p-p$ amplitude (a_{pp} and b_{pp}) are similar to those of the $p-n$ amplitude (a_{pn} and b_{pn}). These data permit to conclude that scattering amplitudes in isotopic states $T=1$ and $T=0$ are similar at high energies and at small t.

Analogous conclusions have been drawn in ref. /6/ by measuring the total $p-p$ and $p-n$ cross sections.

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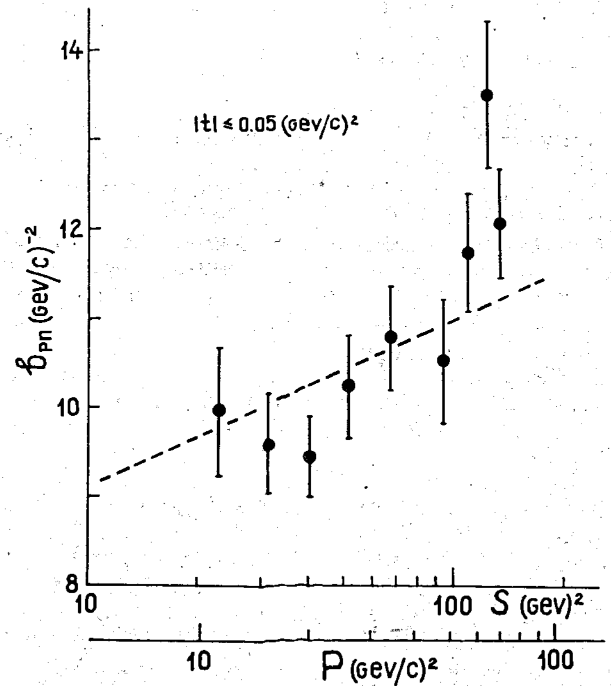

Fig. 1. Slope parameter of the $p-n$ elastic scattering at 10 - 70 GeV. For comparison the straight line is plotted describing the energy dependence of the slope parameter of the $p-p$ elastic scattering [4].

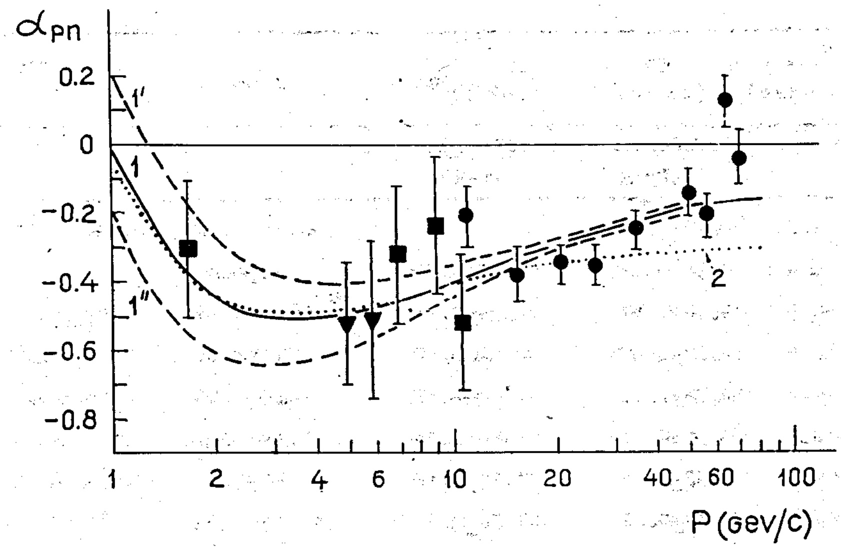

Fig. 2. $\alpha_{pn} = \frac{Re\, f_{pn}(0)}{Im\, f_{pn}(0)}$ in the energy range of 1 - 70 GeV.

● - this paper, systematic error $\Delta\alpha_{pn} = \pm 0.13$. ■ -ref. [15] ▼ - ref. [16]. Curve 1 with the corridor of errors 1' and 1'' is taken from ref. [17], curve 2 - from ref. [18].

Table

Slope parameter b_{pn} and value $a_{pn} = \frac{Re\ f_{pn}(0)}{Im\ f_{pn}(0)}$

For comparison we present values b_{pp} and a_{pp} for $p-p$ scattering measured at the nearest momenta.

$P_{lab.}$ (GeV/c)	b_{pn} $(GeV/c)^{-2}$	b_{pp} /4/ $(GeV/c)^{-2}$	α_{pn}	α_{pp} /3,11/
	$0.002 \leq /t/ \leq 0.05$ $(GeV/c)^2$	$0.008 \leq /t/ \leq 0.12$ $(GeV/c)^2$		
11.2	9.95±0.72		−0.21±0.07	−0.290±0.013
15.9	9.58±0.56	10.31±0.15	−0.38±0.06	
20.5	9.42±0.44	10.24±0.11	−0.35±0.06	−0.258±0.020
26.5	10.22±0.58	10.52±0.12	−0.35±0.06	−0.154±0.025
34.8	10.77±0.58	10.69±0.12	−0.25±0.06	−0.171±0.029
48.9	10.51±0.70	10.84±0.11	−0.14±0.07	−0.159±0.030
57.2	11.72±0.66	11.11±0.10	−0.20±0.06	−0.154±0.022
64.8	13.49±0.82	11.50±0.11	+0.13±0.08	
70.2	12.05±0.61	11.48±0.15	−0.14±0.08	−0.092±0.011

Note: systematic errors are

$\Delta b_{pp} = \pm\ 0.3\ (GeV/c)^{-2}$ /4/

$\Delta b_{pn} = \pm\ 0.8\ (GeV/c)^{-2}$ (this paper)

$\Delta a_{pp} = \pm\ 0.028$ /3/

$\Delta a_{pp} = \pm\ 0.02$ /11/

$\Delta a_{pn} = \pm\ 0.13$ (this paper).