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POLARIZATION EFFECTS AND THE REAL PART OF THE FORWARD SCATTERING AMPLITUDE IN THE QUARK MODEL

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POLARIZATION EFFECTS AND THE REAL PART OF THE FORWARD SCATTERING AMPLITUDE IN THE QUARK MODEL

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In this note we obtain some relations for the polarization parameters of elastic scattering of hadrons at small $|t|$ using the additivity principle of the quark amplitudes[1] and the exchange degeneracy of the leading Regge poles[2]. Furthermore we obtain similar results about the real parts of the forward scattering amplitudes.

1. The polarization parameters of the elastic scattering.

We assume that the Pomeron exchange gives only the contribution to the spin non-flip amplitude and further that the spin dependent amplitude is determined by the contribution of the leading Regge poles. Then the exchange degeneracies of $\rho - A_2$ and $f - \omega$ Regge trajectories imply the behaviour of the polarization parameter P_0 in $K^-p \to K^-p$ and $p\bar{p} \to p\,\bar{p}$ as $t^{3/2}$ if $t \to 0$. These polarization parameters are suppresed with respect to those in K^+p and pp elastic scatterings, respectively.

In the region of small t we shall take into account the leading terms only, i.e., we shall neglect the corrections $\sim t$. Thus, the exchange degeneracy results in the vanishing of antiquark-quark polarizations for small t. Owing to this fact, the quark relations are very simple and we have the possibility to compare them with experimental data. Leaving in the polarizations only the terms leading at high energies, we have

$$P_0^{K^+p}(t,s)\,\sigma^{K^+p}(s) = P_0^{\pi^+p}(t,s)\,\sigma^{\pi^+p}(s)\,, \tag{1}$$

$$P_0^{pp}(t,s)\,\sigma^{pp}(s) = 2P_0^{\pi^+p}\left(t,\frac{2s}{3}\right)\sigma^{\pi^+p}\left(\frac{2}{3}s\right) + P_0^{\pi^-p}\left(t,\frac{2s}{3}\right)\sigma^{\pi^-p}\left(\frac{2}{3}s\right), \tag{2}$$

$$P_0^{pp}(t,s)\,\sigma^{pp}(s) + P_0^{np}(t,s)\,\sigma^{np}(s) = \frac{1}{3}\left[P_0^{\pi^+p}\left(t,\frac{2s}{3}\right)\sigma^{\pi^+p}\left(\frac{2s}{3}\right) + P_0^{\pi^-p}\left(t,\frac{2s}{3}\right)\sigma^{\pi^-p}\left(\frac{2}{3}s\right)\right], \tag{3}$$

$$P_0^{\Lambda p}(t,s)\,\sigma^{\Lambda p}(s) = P_0^{\pi^+p}\left(t,\frac{2s}{3}\right)\sigma^{\pi^+p}\left(\frac{2}{3}s\right) + P_0^{\pi^-p}\left(t,\frac{2s}{3}\right)\sigma^{\pi^-p}\left(\frac{2}{3}s\right), \tag{4}$$

$$P_0^{\Sigma^{\pm}p}(t,s)\,\sigma^{\Sigma^{\pm}p}(s) = 2P_0^{\pi^{\pm}p}\left(t,\frac{2}{3}s\right)\sigma^{\pi^{\pm}p}\left(\frac{2}{3}s\right), \tag{5}$$

where $P_0(t,s)$ and $\sigma^{ap}(s)$ denote the polarization parameter and the total cross section of the $ap \to ap$ scattering, respectively, and s, t are the usual invariant variables. Let us remark that the values of s in (2) - (5) for baryon-baryon and meson-baryon interactions correspond to the equal momentum in quark-quark scattering.

Figure 1 shows the experimental data on $P_0^{\pi^+ p}$ at the momenta of π^+ mesons 10 and 14 GeV/c. This figure also exhibits the polarization P_0 obtained from (1) using the data on K^+p - polarization. Apparently, at $t \to 0$ relation (1) is in agreement with the experimental data.

Comparing (2) with experimental data one can find the strong violation of (2) at energies of 10 - 14 GeV/c. On the other hand, we observe the remarkable improvement of this relation at increasing energy. This is seen from figure 2 where the ratio of the polarization data on pp-scattering, averaged over the interval $0 < |t| \le 0{,}2$ $(\mathrm{GeV})^2$, to the polarization calculated from (5) by means of the data on πp-scattering is presented.

It is well known, that the polarizations $P_0^{\pi^+ p}$ and $P_0^{\pi^- p}$ are approximately equal in absolute values and have the opposite signs in the high-energy region. Thus, according to (3) we expect the same for P_0^{pp} and P_0^{pn}. However, the experimental data are in contradiction with (3) in the region of 2 - 6 GeV/c [3]. Therefore, the new data on the polarization in np-scattering are necessary. It is seen from figure 3 [3] that the spin-flip amplitude with isospin $I_t = 0$ in the t-channel which violates the mirror symmetry of P_0^{pp} and P_0^{np}, is decreasing with energy so fast that we expect at $p_{lab} \sim 8$ GeV/c the change of the sign of P_0. Further, at energies of about several tens GeV/c the contribution of the $I_t = 0$ - amplitude can be very small with respect to the isovector part and one can infer the validity of (3).

Let us focus our attention on eqs. (4) and (5). The assumption of the exchange degeneracy in quark amplitudes leads to some contradictions. For instance, the amplitude of K^-p-scattering must be pure imaginary, while the amplitude of λ-quark-p scattering has large real part which can not be compensated. The solution of this dilemma is the following : λ-quark is decoupled from the leading Reggeons. Our conclusion is, obviously,

in agreement with the Zweig rule. So that the λ-quark is not polarizable and one easily finds eqs.(4) and (5).

Furthermore, we can derive some interesting relations about the spin-rotation parameter R . If we restrict ourselves to relations which can not be obtained from exchange degeneracy only, we have

$$\frac{\sigma^{K^-p}(s)}{\sigma^{\pi^-p}(s)} = \frac{R^{\pi^-p}(t,s) + \cos\theta_p}{R^{K^-p}(t,s) + \cos\theta_p}, \tag{6}$$

$$R^{\pi^-p}(t,s) = -\cos\theta_p + \frac{\sigma^{K^+p}(s)}{\sigma^{\pi^-p}(s)} P_0^{K^+p}(t,s), \tag{7}$$

$$R^{K^-p}(t,s) = -\cos\theta_p + \frac{\sigma^{\pi^+p}(s)}{\sigma^{K^-p}(s)} P_0^{\pi^+p}(t,s), \tag{8}$$

where θ_p is a laboratory scattering angle of the recoil proton. At present these relations can not be compared with experimental data because the latter are not accessible in the small $|t|$ region.

2. The real part of the forward scattering amplitude.

Similarly, we can also obtain some consequences for the real parts of the spin non-flip amplitudes. Starting from the exchange degeneracy of ρ, A_2, ω, f - trajectories we find the following relations for the forward scattering of π, K - mesons and nucleons

$$\rho^{K^+p}(s)\,\sigma^{K^+p}(s) = \rho^{\pi^+p}(s)\,\sigma^{\pi^+p}(s), \tag{9}$$

$$\rho^{pp}(s)\sigma^{pp}(s) + \rho^{np}(s)\sigma^{np}(s) = \tfrac{1}{3}\Big[\rho^{\pi^+p}\big(\tfrac{2s}{3}\big)\sigma^{\pi^+p}\big(\tfrac{2s}{3}\big) + \rho^{\pi^-p}\big(\tfrac{2s}{3}\big)\sigma^{\pi^-p}\big(\tfrac{2s}{3}\big)\Big], \tag{10}$$

$$\rho^{pp}(s)\sigma^{pp}(s) = 2\rho^{\pi^+p}\big(\tfrac{2s}{3}\big)\sigma^{\pi^+p}\big(\tfrac{2s}{3}\big) + \rho^{\pi^-p}\big(\tfrac{2s}{3}\big)\sigma^{\pi^-p}\big(\tfrac{2s}{3}\big), \tag{11}$$

$$\rho(s) = \frac{\mathrm{Re}\,F(s,t=0)}{\mathrm{Im}\,F(s,t=0)},$$

which can be immediately compared with the experimental data. Further, we find the relations

$$\rho^{\Lambda p}(s)\,\sigma^{\Lambda p}(s) = \rho^{\pi^+ p}\left(\tfrac{2s}{3}\right)\sigma^{\pi^+ p}\left(\tfrac{2s}{3}\right) + \rho^{\pi^- p}\left(\tfrac{2s}{3}\right)\sigma^{\pi^- p}\left(\tfrac{2s}{3}\right), \qquad (12)$$

$$\rho^{\Sigma^\pm p}(s)\,\sigma^{\Sigma^\pm p}(s) = 2\rho^{\pi^\pm p}\left(\tfrac{2s}{3}\right)\sigma^{\pi^\pm p}\left(\tfrac{2s}{3}\right) \qquad (13)$$

for testing of which the corresponding hyperon data are necessary.

The equality of the real parts of $\pi^+ p$ and $K^+ p$ -scattering amplitudes was noted in /4/. It was a consequence of exchange degeneracy and the exact SU(3) symmetry of the verteces, where Reggeons are coupled to particles. Relations (10) and (11) can also be obtained from the results of the paper by Kokkedee and Van Hove /5/, by applying exchange degeneracy.

Figures 4 and 5 show the comparison of the data on $\rho^{pp}(s)$ and $\rho^{\bar{p}p}(s)$ with the values of ones calculated from (10) and (11) by means of the data. The good agreement is observed.

Since we have neglected the contribution of the vacuum cuts, we conclude that (9) - (13) can be violated in the region of large s , where $\rho(s)$ changes the sign. The suppression of the verteces where the Reggeons are emitted by the λ-quark implies that ϕ p-scattering amplitude must be pure imaginary and slightly dependent on energy.

The following relation for the total cross sections can also be derived

$$\sigma^{\bar{p}p}(s) - \sigma^{pp}(s) = \sigma^{\pi^+ p}\left(\tfrac{2s}{3}\right) - \sigma^{\pi^- p}\left(\tfrac{2}{3}s\right) + 3\left[\sigma^{K^- p}\left(\tfrac{2s}{3}\right) - \sigma^{K^+ p}\left(\tfrac{2}{3}s\right)\right] \qquad (14)$$

The comparison of the left- and right-hand sides is presented in figure 6.

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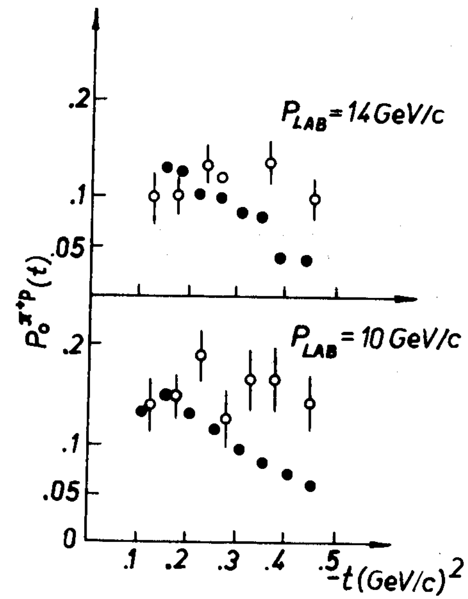

Fig.1 - The polarization parameter P_0 in $\pi^+ p$ elastic scattering for 10 and 14 (GeV/c);
● - tha data from ref.6
○ - the polarization $P_0^{\pi^+ p}$ as a result of calculation according to (1). The data are taken from ref.7.

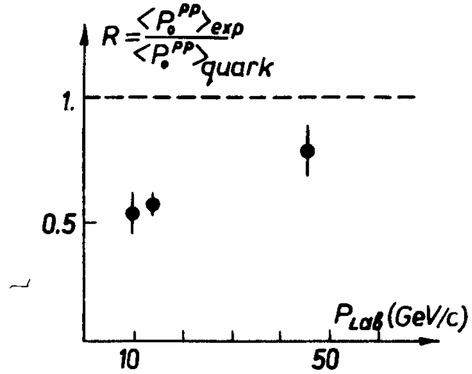

Fig.2 - The ratio of polarizations $\langle P_0^{pp} \rangle_{exp}$ averaged over the interval $0 < |t| \leq 0{,}2$ $(GeV/c)^2$ from refs.8,9 at 10, 14 and 45 GeV/c, and $\langle P_0^{pp} \rangle_{quark}$ calculated from (2) using the data of refs.6,9 . Since the data on $P_0^{\pi^+ p}$ at p_{lab}= 30 GeV/c are not available, we extrapolate the data at 40 GeV/c /10/.

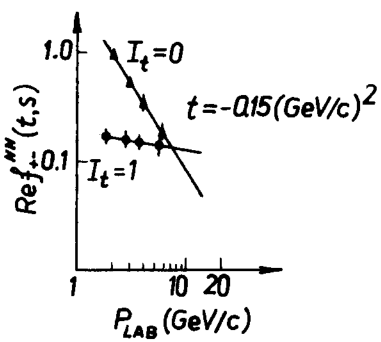

Fig.3 - The contributions to the real part of the spin-flip amplitude having the isospin in the t-channel I_t=0 (▲) and I_t=1 (●) /3/.

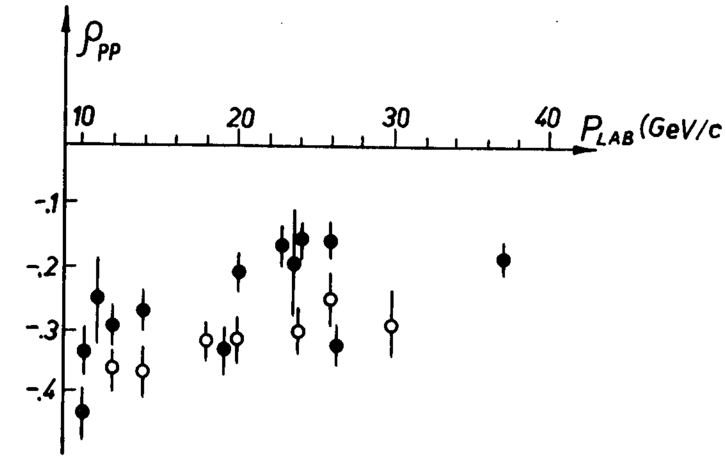

Fig.4 - The ratio of the real part and imaginary part of the forward pp-scattering amplitude;

● - experimental values of ρ^{pp} /11/ ,

○ - the calculation of ρ^{pp} by means of $\rho^{\pi^+ p}$ from ref.12.

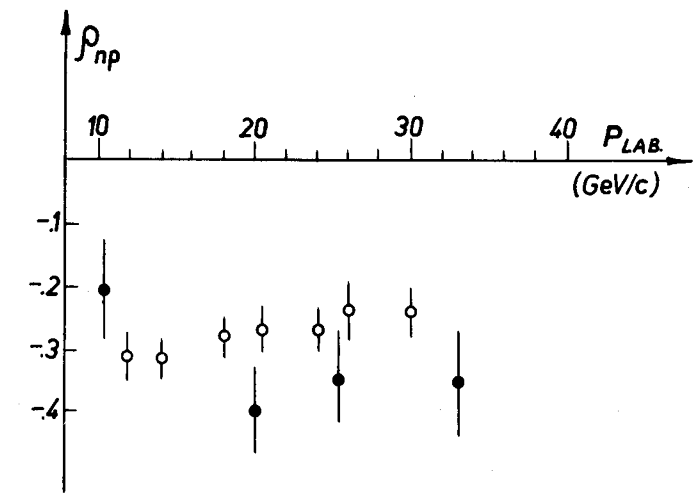

Fig.5 - The analog of fig.3 for np-scattering. ● - data on ρ^{np} from ref.13.

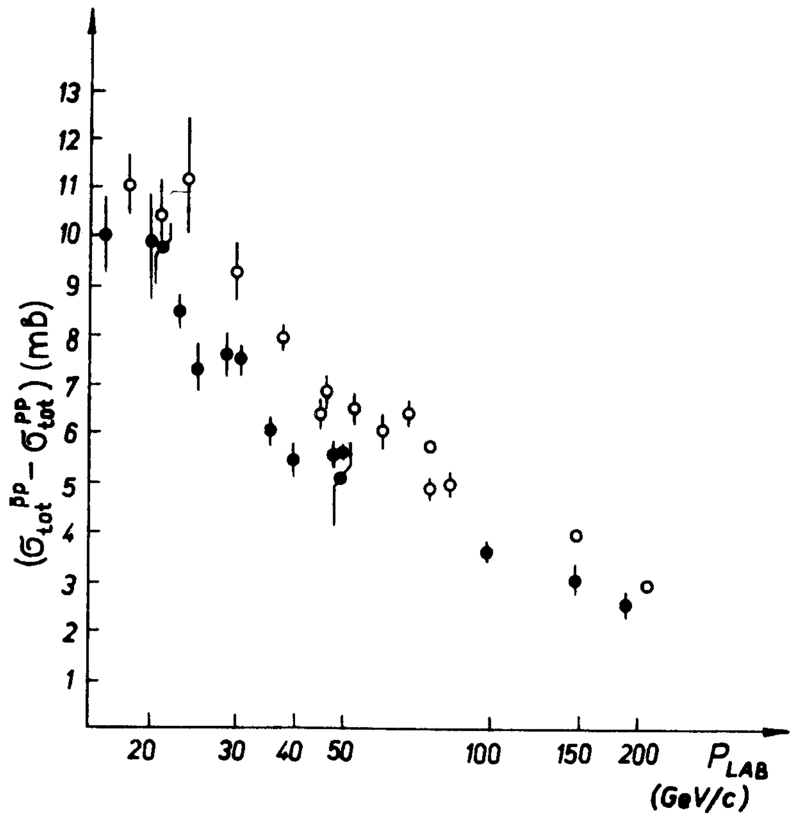

Fig.6 - The difference of $\sigma^{p\bar{p}}$ and σ^{pp} .

- ● - the values obtained by means of the data of ref.14,
- ○ - the values calculated according to (14) using the data of ref.15.

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