ᵓolarization effects in $\pi^{\pm}p$ scattering at high ᵌnergies

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Within the framework of the generalized reaction-matrix method, we analyze the polarizations in $\pi^{\pm}p$ scattering at high energies. The contribution resulting directly from vacuum exchange is considered.

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We investigate in this paper polarization effects in $\pm p$ scattering within the ramework of the method of the generalized reaction matrix,[1] which was uccessfully used to describe elastic hadron scattering in the region of the nergies used at our institute (IHEP), Fermilab, and CERN.[2,3] In this ap- roach, a nonzero polarization arises also directly from vacuum exchange, vhich makes a negative contribution that decreases slowly with energy.

Interest in the mechanism that produces the polarization from vacuum ex- hange [4–6] is due to recent measurements of the polarization in elastic hadron cattering at energies 40 and 45 GeV,[7] which have revealed deviations from he predictions of the Regge-pole model.[8] In elastic $\pi^{\pm}$ scattering and nucleon- ucleon scattering, there are deviations from the predicted mirror symmetry. ll this points to the possibility of the appearance of polarization directly from acuum exchange.[4] Indeed, the rapid decrease of the polarization in elastic p scattering with increasing energy, and the deviation from mirror symmetry an be explained by proposing, for example, that vacuum exchange gives a egative contribution to the polarization, and that the contribution decreases lowly with increasing energy.

In the analysis of the polarization effects in $\pi^{\pm}p$ scattering, we shall use the mplitude parametrization and the values of the parameters from [3], where, n particular, good agreement was obtained with the existing polarization data. t will be shown that the polarization effects noted above and observed in pp cattering should be observable at higher energies in $\pi^{\pm}p$ scattering.

For the case of scattering of a spinless particle by a particle with spin 1/2, he fundamental equation connecting the scattering amplitude with the gen- ralized matrix of the reactions takes in the c.m.s. the form [3]

$$F_{\nu\nu'}(\mathbf{p},\mathbf{q}) = U_{\nu\nu'}(\mathbf{p},\mathbf{q}) + i\rho(s)\sum_{\nu''}\int d\Omega_{\mathbf{k}}^{*}\, U_{\nu\nu''}(\mathbf{p},\mathbf{k})F_{\nu''\nu'}(\mathbf{k},\mathbf{q}), \tag{1}$$

vhere $F_{\nu\nu'}(\mathbf{p},\mathbf{q})$ are the helicity amplitudes in the invariant normalization. In his case there exist only two independent amplitudes: $F_{++}\equiv F_{1/2,1/2}$ and F_{+-} $\equiv F_{1/2,-1/2}$. The solution of (1) is

$$F^{I_s}_{++}(s,t)=\frac{is}{\pi^2}\int_0^\infty bdb\,J_0(b\sqrt{-t})\,\frac{U^{I_s}_{++}(b,s)[1+U^{I_s}_{++}(b,s)]+[U^{I_s}_{+-}(b,s)]^2}{[1+U^{I_s}_{++}(b,s)]^2+[U^{I_s}_{+-}(b,s)]^2},\qquad (2)$$

$$F^{I_s}_{+-}(s,t)=\frac{is}{\pi^2}\int_0^\infty bdb\,J_1(b\sqrt{-t})\,\frac{U^{I_s}_{+-}(b,s)}{[1+U^{I_s}_{++}(b,s)]^2+[U^{I_s}_{+-}(b,s)]},$$

where

$$U^{I_s}_{\substack{++\\+-}}(b,s)=\frac{\pi^2}{is}\int_0^\infty J_{\substack{0\\1}}(b\sqrt{-t})\,U^{I_s}_{\substack{++\\+-}}(s,t)\sqrt{-t}\,d(\sqrt{-t})$$

I_s is the value of the isospin of the s channel. In[1], an asymptotic expression for the U matrix as $s\to\infty$ was obtained in the form $U(s,t)\cong -g(t)\xi(t)(s/s_0)^{\beta(t)}$, where $\xi(t)$ is the signature factor and $\beta(t)$ is the leading trajectory. Assuming that as $s\to\infty$ the main contribution is made by the leading pole with even signature, we obtain in the impact-parameter representation the following expression for $U_{\substack{++\\+-}}(b,s)$:

$$U_{\substack{++\\+-}}(b,s)=\begin{pmatrix}1\\2b/a(s)\end{pmatrix}\frac{g_{\substack{++\\+-}}}{a(s)}\left(\frac{s}{s_0}\right)^{\beta(0)-1}\exp(-b^2/a(s))$$

$$\equiv\begin{pmatrix}1\\b/a(s)\end{pmatrix}u_\pm(s)\exp(-b^2/a(s)),$$

where $a(s)=4\beta'(0)[\ln s/s_0-i\pi/2]$. We assume here linearity of the trajectory $\beta(t):\beta(t)=\beta(0)+t\beta'(0)$ and independence of the residues of t. Then, calculating the integrals of (2) as $s\to\infty$ and at small values of t, we obtain the following expression for the amplitudes:

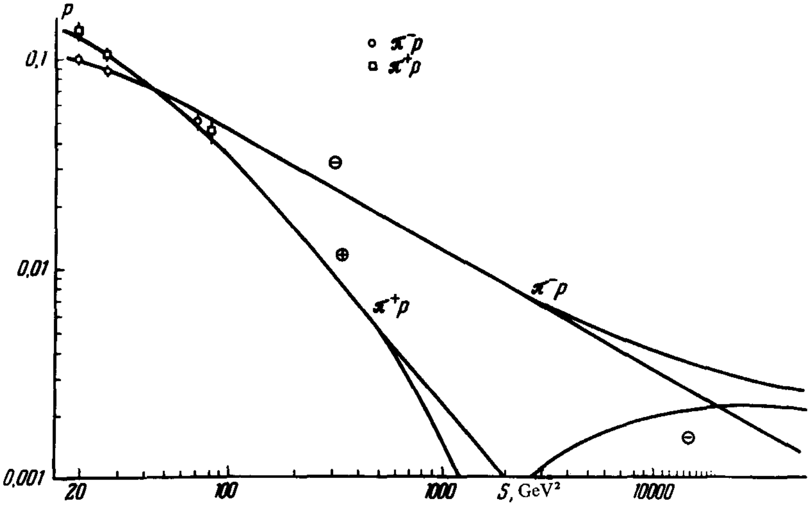
$$F_{++}(s,t)\cong\frac{is}{4\pi^2}\left[1+\frac{\kappa^2(s)}{a(s)}\right]^{-1}\ln^2G_+(s)\left\{2a(s)\frac{\ln u_+(s)}{\ln^2G_+(s)}+\kappa^2(s)\right.$$
$$\left.+\frac{a(s)t}{4}\left[a(s)+2\kappa^2(s)\ln\frac{G_+^{4/3}(s)}{u_+(s)}\right]\right\},$$

$$F_{+-}(s,t)\cong\frac{is}{4\pi^2}\kappa(s)\sqrt{-t}\left[1+\frac{\kappa^2(s)}{a(s)}\right]^{-1}a(s)\ln u_+(s)\left\{1+\frac{a(s)t}{8}\,\frac{\ln^2G_+(s)}{\ln u_+(s)}\right\},$$

where

$$\kappa(s)=\frac{u_-(s)}{u_+(s)},\quad G_+(s)=\frac{g_{++}}{a(s)}\left(\frac{s}{s_0}\right)^{\beta(0)-1}.$$

The expression for the polarization can then be represented in the form



IG. Absolute magnitude of the polarization in elastic $\pi^{\pm}p$ scattering at $t=0.2$ GeV/c)^2 in a logarithmic scale. The signs + and − indicate respectively the ign of the polarization in the given section.

$$P^{\pi^{\pm}p}(s,t) \cong -\frac{\sqrt{-t}}{2}\,\frac{1}{\ln s}\,\frac{\Phi_1(s) - t\,\Phi_2(s)}{\Phi_3(s) - t\,\Phi_4(s)},$$

'here Φ_i are known functions that depend on $\kappa(s)$, $G_+(s)$, $a(s)$, with $\Phi_1, \Phi_3(s)$ $\sim \ln^2 s$, $a\Phi_2, \Phi_4(s) \sim \ln^6 s$ as $s \to \infty$. The functions $\Phi_i(s)$ are positive at $s \to \infty$.

We have thus found that at high energies the vacuum exchange gives the same egative contribution to the polarization of the elastic $\pi^{\pm}p$ scattering, which ecreases slowly (like $1/\ln s$) with increasing energy.

The figure shows the value of $|P(s,t=0.2)|$, calculated at the values of the arameters from [3]. The negative contribution to the polarization, resulting :om the vacuum exchange, leads to an essentially different behavior of the olarization at high energies in π^+p and π^-p scattering. Thus, the polarization ecreases more rapidly in π^+p scattering than in π^-p scattering. It becomes egative at $s = 1500$ GeV^2 and increases in absolute magnitude, after which : starts to decrease like $1/\ln s$. In the range of the variable s from 80 to 00 GeV^2, the behavior of the polarization in π^+p scattering is effectively escribed by a power-law dependence $s^{-1.09}$. At $s = 400$ GeV^2, a deviation from power-law behavior takes place. The behavior of the polarization in π^-p cattering is effectively described by the power-law function $s^{-0.58}$ starting 'ith the value $s = 60$ GeV^2 and ending with $s = 2000$ GeV^2. From there on it ɔllows the $1/\ln s$ law.

Thus, the effects in the behavior of the polarization, which started to manifest themselves for $p^{\pm}p$ scattering at IHEP energies, should be observed also in $\pi^{\pm}p$ scattering, but at higher energies. They were obtained as a result made directly to the polarization by the vacuum exchange.

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