HYPERON POLARIZATION FROM MESON-BARYON REACTIONS IN REGGE MODELS

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The hyperon polarization resulting in high-energy meson-baryon strangeness-exchange processes is discussed. The general predictions of various Regge models are compared with experiment. It is shown that the absorption corrections to the strongly degenerate pair of K*(890) and K**(1420) trajectories describe correctly the observed polarization. The qualitative predictions for cross-sections are also discussed.

1. *Introduction*

The standard Regge pole model [1] is known to reproduce the main features of high energy scattering. So the experimental facts which cannot be described in the framework of this model are of particular interest. There are some well-known examples of such effects (polarization in πN charge-exchange scattering, the cross-over effect, pn and $p\bar{p}$ forward charge-exchange scattering, Serpukhov total cross-sections, line-reversal symmetry breaking *etc.*). Several ways of describing them were proposed: absorptive cuts, dipoles, complex poles or additional trajectories with no known particles lying on them.

In this paper we will discuss the line-reversal symmetric pairs of meson-baryon strangeness-exchange reactions. The exchange degeneracy hypothesis for K*(890) and K**(1420) trajectories following from the duality diagrams predicts the equality of cross--sections for such pairs of reactions. This is known to disagree with experiment [2]. In Section 2 we show that the polarization data disagree with assumption of arbitrary two--pole exchange (with neither strong, nor weak degeneracy). In Section 3 also the complex Regge pole model of the form used to explain the cross-section difference is shown to disagree with experiment. In Section 4 we discuss the absorption corrections to the strongly degenerate pair of poles. They can describe the polarization correctly if non-zero Pomeron slope is assumed. They do not describe correctly the cross-sections, however. We conclude with Section 5.

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2. *The two-pole exchange approximation*

We consider the high-energy processes

$$K^{-}n \to \pi^{-}\Lambda \tag{1}$$

and

$$\pi^{+}n \to K^{+}\Lambda \quad \text{or} \quad \pi^{-}p \to K^{0}\Lambda. \tag{2}$$

All the results will be valid also for similar reactions with Σ production.

The processes (1) and (2) are described by two spin amplitudes. We choose helicity as the spin index. Denoting trajectory and residua for K*(890) by index 1 and for K**(1420) by index 2 we have for reaction (1)

$$A_{++} = (1+e^{-i\pi\alpha_1})\beta_1^{++}s^{\alpha_1}+(1-e^{-i\pi\alpha_2})\beta_2^{++}s^{\alpha_2} \tag{3}$$

$$A_{+-} = (1+e^{-i\pi\alpha_1})\beta_1^{+-}s^{\alpha_1}+(1-e^{-i\pi\alpha_2})\beta_2^{+-}s^{\alpha_2} \tag{4}$$

and for reaction (2)

$$\bar{A}_{++} = (1+e^{-i\pi\alpha_1})\beta_1^{++}s^{\alpha_1}-(1-e^{-i\pi\alpha_2})\beta_2^{++}s^{\alpha_2} \tag{5}$$

$$\bar{A}_{+-} = (1+e^{-i\pi\alpha_1})\beta_1^{+-}s^{\alpha_1}-(1-e^{-i\pi\alpha_2})\beta_2^{+-}s^{\alpha_2} \tag{6}$$

Denoting the cross-section and Λ polarization for reaction (1) and (2) by indexes $\pm$, respectively, we have

$$\frac{d\sigma^{\pm}}{dt}P^{\pm} = \pm 2(ad-bc)\sin\varphi \tag{7}$$

$$\frac{d\sigma^{\pm}}{dt} = a^2+b^2+c^2+d^2\pm 2(ab+cd)\cos\varphi \tag{8}$$

where

$$\varphi = -\frac{\pi}{2}(1+\alpha_1-\alpha_2) \tag{9}$$

$$a = 2\beta_1^{++}s^{\alpha_1}\cos\frac{\pi}{2}\alpha_1 \tag{10}$$

$$b = 2\beta_2^{++}s^{\alpha_2}\sin\frac{\pi}{2}\alpha_2 \tag{11}$$

$$c = 2\beta_1^{+-}s^{\alpha_1}\cos\frac{\pi}{2}\alpha_1 \tag{12}$$

$$d = 2\beta_2^{+-}s^{\alpha_2}\sin\frac{\pi}{2}\alpha_2. \tag{13}$$

In the case of the so-called weak degeneracy ($\alpha_1 = \alpha_2$) we have

$$\frac{d\sigma^+}{dt} = \frac{d\sigma^-}{dt} \tag{14}$$

$$P^+ = -P^- \sim s^0. \tag{15}$$

Assuming also strong degeneracy, as demanded by duality diagrams [3]

$$\beta_1^{++} = \beta_2^{++} \tag{16}$$

$$\beta_1^{+-} = \beta_2^{+-} \tag{17}$$

we obtain simply

$$P^{\pm} = 0. \tag{18}$$

In Fig. 1 the existing high-energy data for Λ polarization in reactions (1) and (2) are collected [4]. Since they do not exhibit any clear energy dependence, we can discuss together data at all energies. We see that neither relation (18), nor (15) is fulfilled. This was often used as an argument against the idea of strong degeneracy. However, also in general case (no degeneracy) formula (7) implies some restrictions. Since cross-sections are positive, and, experimentally, different from zero in all measured points, the polarizations in processes (1) and (2) must have opposite signs and can vanish only simultaneously:

$$-\infty < \frac{P^-}{P^+} < 0. \tag{19}$$

Asymptotically we should have

$$P^+ = -P^- \sim s^{-|\alpha_1 - \alpha_2|}. \tag{20}$$

From Fig. 1 we can see that in the small $-t$ region ($-t < 0.5\ \mathrm{GeV}^2/c^2$) both P^+ and P^- seem to be positive in disagreement with (19). The mean values in this interval are $\langle P^+\rangle = +0.43 \pm 0.07$, $\langle P^-\rangle = +0.10 \pm 0.06$. For $0.1 < -t < 0.4\ \mathrm{GeV}^2/c^2$ we have

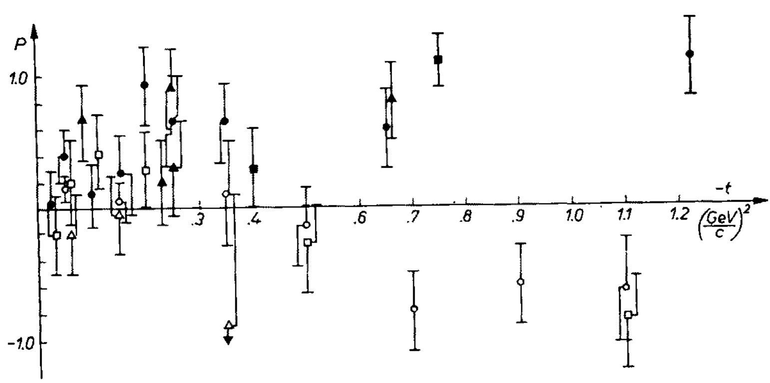

Fig. 1. Comparison of experimental data for Λ polarization in reactions (1) and (2). Full circles, squares and triangles are for reaction (1) at $p_L = 3.0$, 3.9 and 4.48 GeV/c, respectively; open circles, squares and triangles are for reaction (2) at $p_L = 3.0$, 3.9 and 6.0 GeV/c, respectively

$\langle P^- \rangle = +0.17 \pm 0.10$. Since P^- is very small, better data are needed to draw doubtless conclusions. At the moment, however, we can treat data from Fig. 1 as a strong argument against any possibility of fitting data for reaction (1) and (2) by the simple Regge pole model in two-pole approximation. Thus using these data as evidence against degeneracy is very doubtful.

3. *Complex Regge pole model*

It was claimed recently [5] that the use of complex Regge poles can explain the observed inequalities between cross-sections for line-reversal symmetric pairs of strangeness--exchange meson-baryon reactions. Assuming that the poles go into the complex plane in the presence of a dynamical cut and choosing their residues to be equal to zero according to the assumption, that they appear on the unphysical sheet, one obtains very simple formulae for amplitudes of reaction (1)

$$M_i = \frac{1}{\pi} \int\limits_{-\infty}^{\alpha_c} \frac{l^i \, \mathrm{Im} f_i(t, l) \left(\frac{s}{s_0}\right)^{l-i}}{(l-\alpha_R)^2 + \alpha_I^2} \, dl \qquad i = 0,1 \tag{21}$$

α_c is the trajectory of the branching point, M_0 and M_1 are A' and B amplitudes, respectively, α_R is the real and α_I the imaginary part of the pole trajectory. For reaction (2) the only difference is an additional $e^{-i\pi l}$ factor in the integrand.

Since the phase factor is absent in the amplitudes for reaction (1), they are larger than the amplitudes for reaction (2) which are reduced by the phase cancellations.

This is just what is needed to explain the data for cross-sections. Assuming for simplicity the smoothness of the "cut strength function" Im $f(t, l)$ it is possible to evaluate the integral (21) and a similar integral for reaction (2). Fitting the free parameters one can describe reasonably well the observed ratio of cross-sections for reactions (1) and (2).

The model describes also correctly the polarization in reaction (2). It cannot, however, explain the observed polarization in reaction (1), since both amplitudes (21) are real. The possibility mentioned in Ref. [5] that a "small imaginary part in the unperturbed pole contributions" may provide "large polarization in the region $\alpha_R \simeq 0$" cannot explain the data. This can be seen in the following way. Using the trajectory given in Ref. [5] we see that $\alpha_R = 0$ corresponds to $-t = 0.4$ GeV$^2/c^2$. As is clear from Fig. 1 the polarization can be equal to zero exactly in this region, and is significantly large everywhere else.

4. *Absorption corrections*

As remarked by Krzywicki [6] absorptive Regge cuts added to the strongly degenerate pair of poles provide a simple explanation of the main features of polarization in hypercharge exchange reactions. We will show briefly that simple predictions can be obtained just by using the first approximation for absorption corrections.

Let us use the exponential form for uncorrected amplitudes

$$M^{++} = De^{B\frac{t}{2}} \tag{22}$$

$$M^{+-} = D'\sqrt{-t}\,e^{B\frac{t}{2}} \tag{23}$$

and for the elastic scattering amplitude

$$M_{el}^{\lambda\mu} = -ik\sqrt{s}\,\sigma_t e^{A\frac{t}{2}}\,\delta_{\lambda\mu}. \tag{24}$$

According to the usual absorption prescription [7], using power expansions of exponents in the small parameter [8] and neglecting possible differences between initial and final channels one obtains in the first approximation simply

$$\delta M^{++} = -\frac{\Lambda D}{4\pi}\sigma_t\frac{1}{A+B}e^{\frac{AB}{A+B}\frac{t}{2}} \tag{25}$$

$$\delta M^{+-} = -\frac{\Lambda' D'\sqrt{-t}}{4\pi}\sigma_t\frac{A}{(A+B)^2}e^{\frac{AB}{A+B}\frac{t}{2}} \tag{26}$$

Λ and Λ' are real constants, originally assumed to be equal 1, recently used as free parameters to fit particular reactions.

In the following we take them to be equal 1. D and D' are real for reaction (1) and have a phase factor

$$\gamma = e^{-i\pi\alpha_{K^*}(0)} \tag{27}$$

for reaction (2). A is given by

$$A = a(s) - i\pi\alpha'_P \tag{28}$$

where $a(s)$ is the slope of the elastic cross-section and α'_P is the slope of the Pomeron trajectory. B is real for reaction (1) and has the imaginary part

$$\mathrm{Im}\,B = -2\pi\alpha'_{K^*} \tag{29}$$

for reaction (2).

It is evident that the model with flat Pomeron ($\alpha'_P = 0$) cannot describe the data, since in this case the amplitudes for process (1) remain real also after correction and no polarization in this reaction is possible, in obvious disagreement with experiment. The condition $\alpha'_P > 0$ is compatible with the recently observed shrinkage of the diffraction peak at highest energies [9].

From formulae (25) and (26) some conclusions can be drawn immediately:

i) The phase of absorption correction (cut) is different from that of uncorrected amplitude (pole), so one can obtain non-zero polarization for both reactions (1) and (2).

ii) The slope of the cut is nearly half of the pole term slope, so the cut will dominate for larger $-t$.

iii) The relative magnitude of corrections to the spin-flip amplitude is nearly two times smaller than that to the non-flip amplitude.

iv) The phase difference between the cut and the pole terms is for both reactions (1) and (2) of the same sign and less than π at $t = 0$. For increasing $-t$ this difference increases for reaction (2), since in this case the phase of the pole term decreases faster $\left(\left|\mathrm{Im}\, B\right| > \left|\mathrm{Im}\, \frac{A \cdot B}{A+B}\right|\right)$, and decreases for reaction (1), when the pole term has a constant phase equal zero.

v) According to *ii*) and *iv*) the change of phase of the non-flip amplitude for reaction (1) is smooth. The flip amplitude remains mainly real, so the polarization has a constant sign (the phase difference between flip and non-flip does not pass through π).

vi) In the region, where pole and cut terms are of comparable magnitude, for reaction (2) the phase difference between these terms goes through π. So the polarization, initially of the same sign as for reaction (1), changes sign when the cut begins to dominate (in the dip).

vii) From *ii*) and *iv*) it follows also that the interference between the pole and the cut should produce in reaction (2) a strong dip in the region, where polarization changes sign. The analogous dip for reaction (1) can be smeared out due to phase difference.

All these predictions were already obtained in different, more complicated versions of the absorption model. They are known to agree with experiment [2, 6, 7, 10, 12][1].

We conclude that the absorption model just in the simplest version can describe correctly the t-dependence of polarization and cross-sections. Note, however, that the comparison of cross-sections for different reactions gives in this model uncorrect results, unless different parameters for each reaction are chosen (*e. g.* the wrong direction of inequality between cross-section for reaction (1) and (2) is obtained).

Good agreement with experiment can be obtained using only weak degeneracy for poles and absorption corrections. In this case the cross-sections can be fitted much better. The large number of free parameters can be reduced using SU(3) symmetry restrictions [11]. The phases of pole terms in spin-flip amplitudes for reactions (1) and (2) are, however, exchanged in this model in disagreement with duality arguments.

5. *Summary*

We have discussed the recent data for hyperon polarization in the strangeness-exchange meson-baryon scattering in the framework of various Regge models. It was shown that the data indicate the necessity of additional terms apart from the leading K*(890) and K**(1420) trajectories. Such possible terms can be absorptive cuts. It is shown that the absorption model reflects correctly the main features of experimental data already in the first approximation. It does not describe correctly the observed inequality of cross-sections, however, until a drastic violation of the duality rules is introduced.

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[1] Note that in the model with flat Pomeron there was a strong dip in the cross-section for reaction (1) and a smooth break for (2) in opposition to *vii*) [12].

The complex Regge poles model, which explains simply the inequality for cross-sections, predicts no polarization in reaction (1) in drastic disagreement with experiment.

We conclude that of the discussed models only the absorption model can describe correctly the observed polarization. The incompatibility of this model with data for cross-sections suggests, however, that also some exchange degeneracy breaking will be necessary to obtain full agreement with experiment. Better data are desired to draw definite conclusions. It seems, however, that the Regge models give no simple and natural explanation of all the main features of data for line-reversal symmetric pairs of strangeness-exchange meson-baryon reactions.

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