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THE SPIN FLIP AMPLITUDE OF HIGH ENERGY ELASTIC NN-SCATTERING IN THE CASE OF STRONG FORM FACTORS

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At present a great interest is caused by the problem of the origin of spin phenomena in different reactions at high energies[1]. The energy independence of the polarisation in a number of processes (for example, in inclusive hyperon processes) in a wide energy interval is revealed experimentally. This may be an indication that in other reactions, including elastic, a weak energy dependence of spin effects can be expected as $S \to \infty$ and fixed transfer momenta.

The perturbative QCD, valid in the range where all kinematic variables are large, leads to the power drop of spin effects with growing energy[2]. However, in[3] it is shown, that in the range of fixed transfer momenta QCD can lead to a weak energy dependence of contributions to the spin-flip amplitude:

$$\frac{|T_{flip}|}{|T_{non-flip}|} \propto \frac{m_q \sqrt{|t|}}{Ln(s)\; a^2(m_q,t)}\,, \tag{1}$$

which are connected with the exchange of the two-gluon state in the t-channel (for example, the gluon ladder). Quantitative calculations in QCD are at present impossible in the range of large distances, which necessitates the use of model approaches. Note that some models[4-6] for the description of scattering at small angles lead to spin effects which do not disappear as $S \to \infty$.

In this work, we consider consequences of the model[6] which allows us to obtain the contribution of surrounding hadron quark-antiquark pairs, which are regarded approximately by as π-mesons. In this case spin effects naturally arise which slowly change with growing energy.

Note that early in the framework of this model we calculated only the contribution of the nucleon state in the s-channel. The contribution of higher resonances was taken into account with the use of a phenomenological parameter for the description of polarisation effects of pp-scattering[7]. As a result, the obtained in the model amplitude was about three times smaller. In [8] it is pointed that the inclusion of a Δ_{33}-isobar in the s-channel leads to an effect of that sort. In this work, we calculate the contribution of the nucleon and Δ_{33}-isobar in the intermediate state to the spin-flip amplitude of pp- and $\bar{p}p$-scattering. The consideration of the strong form factors in the corresponding vertices and preasymptotic contributions in the meson-nucleon amplitude allowed us to describe correctly spin effects in pp and $\bar{p}p$ high energy scattering without introducing the phenomenological parameter.

Let us consider the nucleon-nucleon scattering. The contribution of diagram [6] to the scattering amplitude with an N(Δ -isobar) in the intermediate state looks as follows:

$$T^{\lambda_1\lambda_2}_{N(\Delta)}(s,t)=\frac{g^2_{\pi NN(\Delta)}}{i(2\pi)^4}\int d^4q\, T_{\pi N}(s;t)\varphi_{N(\Delta)}[(k-q)^2,q^2]\varphi_{N(\Delta)}[(p-q)^2,q^2] \cdot \frac{\Gamma^{\lambda_1\lambda_2}_{N(\Delta)}(q,p,k)}{([q^2-M^2_{N(\Delta)}+i\varepsilon][(k-q)^2-\mu^2+i\varepsilon][(p-q)^2-\mu^2+i\varepsilon]} . \qquad (2)$$

Here λ_1,λ_2 are relevant helicities of nucleons; $T_{\pi N}$ is the scattering – πN amplitude; Γ, a matrix element of the numerator of diagram ; φ, the vertices functions, which were chosen in a dipole form with the parameters $\beta_{N(\Delta)}$.

Using the light-cone variables and integrating (1) we obtain for the spin-flip amplitude:

$$T^{+-}_{N(\Delta)}(s,t) = \frac{g^2_{\pi NN(\Delta)}}{2(2\pi)^3}\beta^8_{N(\Delta)}\int_0^1 dx\cdot x^5\cdot T_{\pi N}(s(1-x),t)\cdot$$

$$\cdot\int\frac{d^2q_\perp\cdot\Gamma^{+-}_{N(\Delta)}(q_\perp,p,k)}{(q^2_\perp+d)(q'^2_\perp+d)(q^2_\perp+a)^2(q'^2_\perp+a)^2} \qquad (3)$$

$$q' = q_\perp + x(\bar{p}-\bar{k});\quad d = (M^2_{N(\Delta)} - x\, M^2_N)(1-x) + \mu^2 x ;$$

$$a = (M^2_{N(\Delta)} - x\, M^2_N)(1-x) + \beta^2_{N(\Delta)}x .$$

The matrix element of the nucleon intermediate states contribution has the form:

$$\Gamma^{+-}_N = \Delta\, M_N\,(x-1) ,$$

where Δ is the transfer momentum.

For the ordinary choice of the lagrangian of

the $\pi N\Delta$ - interaction and Δ_{33}- propagator (see example [9]) we have:

$$\Gamma^{\lambda_1\lambda_2}_\Delta = \bar{u}(p)^{\lambda_1}(\hat{q}+M_\Delta)[(pk) - \frac{1}{3}\hat{p}\hat{k} - \frac{2(pq)(kq)}{3M^2_\Delta} + \frac{(pq)\hat{k}-(kq)\hat{p}}{3M_\Delta}]\, u(k)^{\lambda_2} .$$

As a result, we obtain for the helicity-flip matrix element:

$$\Gamma^{+-}_\Delta = \Delta\,\{(pk)(xM_N + M_\Delta) + \frac{M_N}{3}(xM_N - M_\Delta) -$$

$$\frac{2}{3}\frac{(pq)(kq)}{M^2_\Delta}(xM_N + 2M_\Delta) + \frac{M_N}{3M_\Delta}((pq) + (kq))(xM_N - M_\Delta)\} ,$$

where (4)

$$(pk) = M^2_N + \frac{\Delta^2}{2};\qquad (kq) = \frac{q^2_\perp + M^2_\Delta}{2\,x} + \frac{x\, M^2_N}{2} ;$$

$$(pq) = \frac{q^2_\perp + M^2_\Delta}{2x} + \frac{x\,(M^2_N + \Delta^2)}{2} - \Delta_\perp q_\perp .$$

Note that in integrating integrals (3) the $x \simeq 0.9$ range is essential, which makes necessary a correctly consideration of the contribution of a sufficiently-low-energy range $s' \simeq 0.1s$. For this, in this work, in calculating integrals (3) we use the spin-non-flip amplitude obtained by us in [10] with $1/\sqrt{s}$ terms, which describes the experimental data of meson-nucleon scattering in a wide energy range.

The consideration of isotopic factors in integrals (3) leads to the following expressions for the amplitude of NN interaction:

$$T^{+-} = 3T^{+-}_N + 2T^{+-}_\Delta . \qquad (5)$$

As a result, the contributions of N and Δ_{33}- states compensate essentially each other in elastic processes, whereas they are summed up in charge-exchange processes. This highly increases the magnitude of the spin-flip amplitude in $\pi^- p \to \pi^0 n$ reactions. The meson-baryon vertices functions are chosen in the dipole form:

$$\varphi_{N(\Delta)}(l^2, q^2 \propto M^2_{N(\Delta)}) = \frac{\beta^4_{N(\Delta)}}{(\beta^2_{N(\Delta)} - l^2)^2} \qquad (6)$$

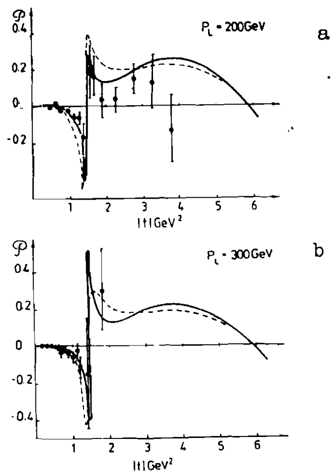
with the parameters:

$$\beta_N^2 = 3.4(GeV^2), \quad \beta_\Delta^2 = 1.5(GeV^2)$$

and coupling constants:

$$\frac{g^2_{\pi NN}}{4\pi} = 14.6 \quad ; \quad \frac{g^2_{\pi N\Delta}}{4\pi} = 21 \; (GeV^{-2}),$$

which corresponds to [11]. Note that these values of the parameters were used by us [12] in calculating the spin-flip amplitude of the charge-exchange process $\pi^- p \to \pi^0 n$, which correctly reproduces the basic feature of the spin-flip amplitude determined with the help of the amplitude analysis of the experimental data at $P_L = 40\,GeV$. Emphasize that in view of the essential compensation in (5), the values of these parameters are especially important in the case of nucleon-nucleon scattering. As a result of fixing the values of these parameters, our model has no freely varying parameters of the spin-flip amplitude of nucleon-nucleon scattering.



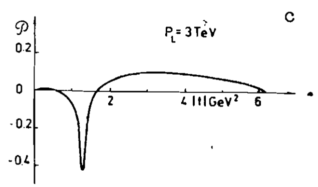


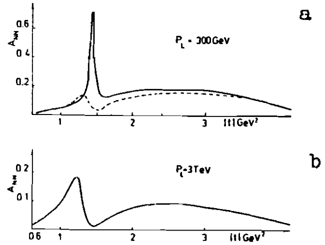
Fig. 1.
The polarization of pp and $\bar{p}p$-scattering at:
a) P_L = 200 GeV; b) P_L = 300 GeV;
c) P_L = 3 TeV
(—— - pp ; --- - $\bar{p}p$).

The obtained spin-flip amplitude allows us to derive the predictions for polarization effects of pp- and pp-scattering. To this end we used the spin-nonflip amplitude obtained early in [7]. The calculated polarization of pp- and pp-scattering at different

energies is shown in fig.1. The change of the polarization in sign at $|t| \simeq 0.6\ GeV^2$ is connected with the form of the calculated spin-flip amplitude and its more sharp change in the range of the diffraction minimum is connected with the change of the sign of the imaginary part of the spin-non-flip amplitude. In the range of low $|t| < 0.1\ GeV^2$ it is also necessary to take account of the contributions of the interference of hadron and electromagnetic scattering amplitudes [13] and a possible contribution of the two-gluon state to the spin-flip amplitude [3].

Fig. 2.

A_{NN} of pp- and $\bar{p}p$-scattering at:
a) P_L = 300 GeV; b) P_L = 3 TeV
(—— - pp ; --- - $\bar{p}p$).



The behaviour of the spin correlation parameter A_{NN} is shown in fig.2. As is seen, the value of A_{NN} becomes essentially large in the range of transfer momenta corresponding, as in the case of polarisation, to the position of the diffraction minimum. It should be noted that the predictions obtained here differ from the ones made earlier [7] in the main in the range of large transfer momenta $|t| > 2\ GeV^2$. The cause is that in this work we have used the strong form factors for the vertex πNN and $\pi N\Delta$, which fall essentially more slowly than the electromagnetic form factors used early. It should be emphasized that the model leads to the same energy dependence of the spin-flip and spin-non-flip amplitudes. Consequently, the spin effects obtained on its base don't disappear in the asymptotic energy range. This behaviour of the spin-flip amplitude is typical of the models [4]. Hence, the model predicts large values of the polarization and spin correlation parameter which decrease slowly from 20% to 10% at $|t| \simeq 3\ GeV^2$ with increasing laboratory energy from 300 GeV to 3 TeV. Also note that the polarizations of pp- and $\bar{p}p$-scattering will coincide above energies $P_L > 1\,TeV$.

Thus, the dynamical model developed here, which takes into account the effects of large distances, the contributions of N and Δ_{33}--isobar excitation in intermediate states with strong form factors in the corresponding vertices, allows us to obtain the spin-flip amplitude of NN-scattering without introducing a free parameter. The model leads to large spin effects in nucleon-nucleon scattering. Note that the results obtained here differ from the predictions of other models [14] at energies above 1 TeV. Thus the polarization research on UNK will provide information about the origin of spin effects at large distances.

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