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SPIN-FLIP COMPONENT OF THE POMERON

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1. The present understanding of the pomeron spin-structure is very poor. The pomeron seems to possess the nonzero spin-flip part, because the polarization measurements[1-4] in the energy interval 40÷200 GeV indicate some flattening of the polarization decrease at high energy.

The Born approximation in QCD[5-8], although being slightly beyond the well justified perturbative QCD domain, is known to reproduce correctly an order of magnitude of the non-flip part of the elastic scattering amplitude at moderate energies. It is natural to wonder what is the spin-flip part within the same approach.

If the nucleon wave function (WF) is taken in the nonrelativistic approximation with symmetric spatial and SU(6)-symmetric spin-isospin parts, the pomeron spin-flip vanishes[8]. whether relativistic corrections can produce nonzero spin-flip, is still an open issue.

In this note we draw one's attention to the fact that spin-flip term appears, if the nucleon WF contains dynamically enhanced compact diquark[9-14]. Numerical estimations are also presented. Besides, the model-independent method for the measurement of the pomeron spin-flip is proposed.

2. The amplitude of elastic hadron-nucleon scattering is written in the two-gluon exchange approximation as[6]

$$T_{2g}(\vec{Q})=18s\alpha_s^2 \int \prod_{i=1}^{2} \frac{d^2\vec{q}_i}{(q_i^2+m_g^2)} \delta^{(2)}(\vec{Q}-\vec{q}_1-\vec{q}_2)R_h(\vec{q}_1,\vec{q}_2)R_N(\vec{q}_1,\vec{q}_2), \qquad (1)$$

where

$$R_{h,N}= \langle\Phi_{h,N}|\exp[i(\vec{q}_1+\vec{q}_2)\vec{\rho}_1] - \exp[i\vec{q}_1\vec{\rho}_1-i\vec{q}_2\vec{\rho}_2]|\Phi_{h,N}\rangle; \qquad (2)$$

α_s is the QCD coupling; $\Phi_{h,N}$'s are the hadron or nucleon WF's in the c.m. frame; $\vec{\rho}_i$ is the quark impact parameter; m_g is effective gluon mass introduced for the phenomenological treatment of the confinement.

The vertex function $R_N(\vec{q}_1,\vec{q}_2)$ can be represented in the form

$$R_N(\vec{q}_1,\vec{q}_2) = \chi_N^+ \, [a_N(\vec{q}_1,\vec{q}_2) + i\sigma_y \frac{\sqrt{\vec{Q}^2}}{2m_N} b_N(\vec{q}_1,\vec{q}_2)]\chi_N . \qquad (3)$$

Here χ_N is two-component nucleon operator; σ_y is Pauli matrix.

It is worth noting that the presence of the nonzero spin-flip part in the function $R_N(\vec{q}_1,\vec{q}_2)$ doesn't contradict the helicity conservation in the quark-gluon vertex, because the nucleon helicity should not coincide with the sum of quark helicities[15]. Indeed, the quark helicity is defined with respect to its momentum direction which doesn't coincide with the nucleon one.

To compute the amplitudes a_N and b_N from eq.(2) one has to use nucleon WF's defined in c.m. frame, as was done in paper[15] on analysis of the spin structure of the reggeon-amplitudes. It is much more convenient to compute $R_N(\vec{q}_1,\vec{q}_2)$ in the Breit frame, where the nonrelativistic nucleon WF can be used. One should take into account that in this frame qq-scattering amplitude in one-gluon exchange approximation doesn't conserve the quark helicity. If $R_N(\vec{q}_1,\vec{q}_2)$ is calculated in the leading approximation at $s\to\infty$, it can be represented in the Breit-frame in the form (3) by means of the following substitution in formula (2)

$$\exp(i\vec{q}_i\vec{\rho}_j) \to \exp(i\vec{q}_i\vec{\rho}_j)\left(1 - i\frac{\sigma^j_y q_{ix}}{2m_q}\right) , \qquad (4)$$

where σ^j_y is the Pauli-matrix, acting upon the quark j; m_q is the quark mass which is supposed to be equal to $m_N/3$ in the nonrelativistic approach.

Spin amplitudes $\tilde{a}_N$ and $\tilde{b}_N$, written in the Breit frame (see eq. (3)) turn into the functions a_N and b_N after the Lorenz transformation to the c.m. frame. The latter pair is connected with the former by the relations (up to terms of the order of $\vec{Q}^2/16m_N^2$):

$$a = \tilde{a}$$
$$b_N = \tilde{b}_N + \tilde{a}_N \qquad (5)$$

The compact diquark can be introduced into the nucleon WF as follows[11-14]:

$$|N\rangle = A|\Psi_C\rangle(|\Psi_{1,23}\rangle + |\Psi_{2,31}\rangle + |\Psi_{3,12}\rangle) \qquad (6)$$

$$|\Psi_{i,jk}\rangle = |\Psi^{ST}_{i,j,k}\rangle|\Psi^{R}_{i,jk}\rangle \cdot$$

Here A is normalization factor; $|\Psi_C\rangle$ is the colour part of the nucleon WF; $|\Psi^{ST}_{i,jk}\rangle$ is the spin-isospin WF of 3-quark system, containning diquark with S=T=0 built of the quarks q_j and q_k. The corresponding space part $|\Psi^{R}_{i,jk}\rangle$ is taken below as a product of the diquark WF and the WF describing the quark-diquark relative motion. Both are taken in the oscillatory form.

The expressions for the functions $\tilde{a}_N$ and $\tilde{b}_N$ obtained with the

WF (6) are too cumbersome to be presented here, they can be found in Ref.[10]. The non-flip and spin-flip amplitudes are computed using formula (1) where the product $R_N R_h$ is changed by $\tilde{a}_N \tilde{a}_h$ or by $(\tilde{a}_N+\tilde{b}_N)\tilde{a}_h$ respectively.

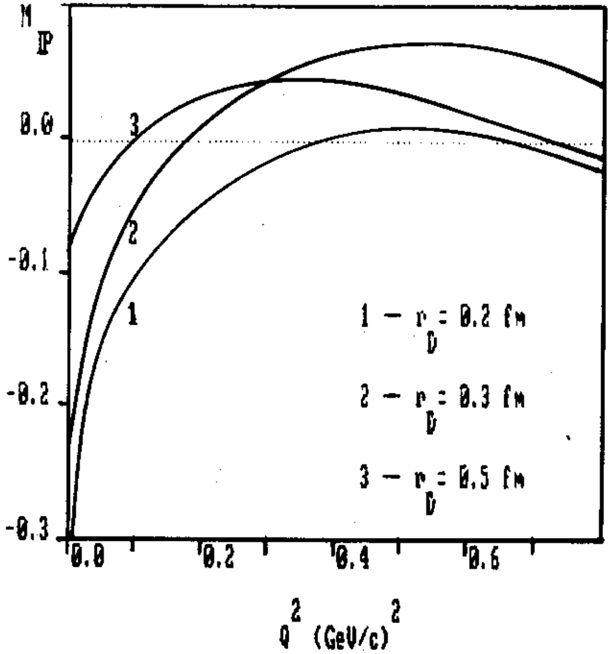

Fig.1. Anomalous magnetic moment of the pomeron computed in the two-gluon exchange approximation vs diquark radius, r_D.

Numerical results for the Q^2-dependence of the pomeron anomalous magnetic moment $M_{\mathbb{P}}(Q^2) = (2m_N/|Q|)T^{\mathbb{P}}_{sf}(Q^2)/T^{\mathbb{P}}_{nf}(Q^2)$, is presented in fig.1 vs diquark mean radius r_D. The charge radius of the proton was fixed by the value r_p=0.8 fm. Gluon mass m_g was chosen 0.17 GeV in order to adjust the diffraction slope of the elastic pp-scattering. As the expression for $M_{\mathbb{P}}$ is infra-red stable, the result also slightly depends on m_g. Note, that in the case of spatially symmetric WF of nucleon, the diquark mean radius is about 0.7 fm. In this case spin-flip disappears due to cancellation of $\tilde{b}_N$ and $\tilde{a}_N$ in eq.4.

The salient feature of the curves in fig.1 is a change of the sign at small values of Q^2. This comes from an interplay of the

Lorenz transformations which are connected with a small parameter - the quark mass squared. This narrow minimum can be filled by some other contributions even up to the positive value of polarization. Rough estimation of the anomalous colour-magnetic moment of constituent quarks adds[17] to $M_{\mathbb{P}}$ a value of about 0.15.

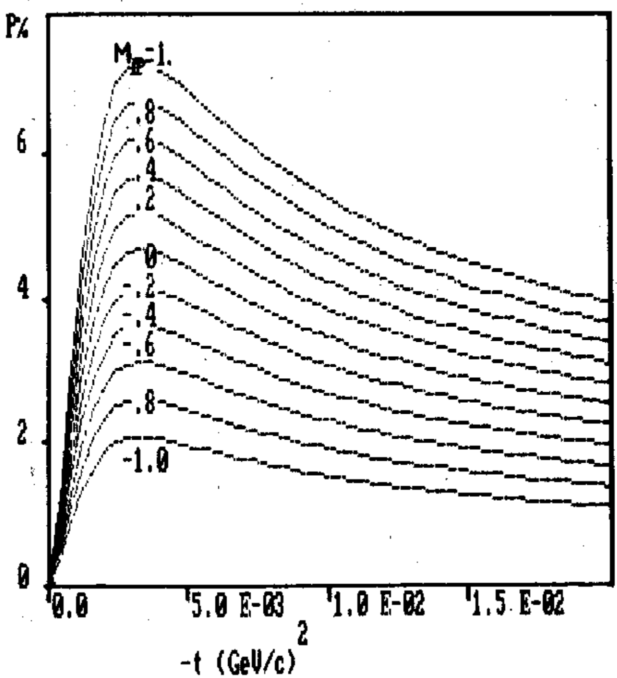

Fig.2. t-dependence of pp-elastic polarization in the Coulomb-Nuclear interference region vs pomeron anomalous magnetic moment, $M_{\mathbb{P}}$.

The consideration of the pion-cloud influence on the pomeron-nucleon residue also provides an additional contribution[18] of about 0.1. Thus the order of magnitude of $M_{\mathbb{P}}$ is known, whereas its sign at $Q^2=0$ is doubtful.

In the pioneering paper[5] by Low, who used the QCD Born approximation and MIT bag model for the nucleon WF, a considerable pomeron spin-flip $|M_{\mathbb{P}}| \approx 1$ was argued. However, the transformation given by eq. (4) was missed there, resulting in a grossly overestimated spin-flip. Cancellation of $\tilde{b}_N$ and $\tilde{a}_N$ mentioned above, proves the statement that large helicity-flip in the Breit-frame doesn't mean a strong pomeron spin-flip.

3. There are some problems with the pomeron spin-flip measurement. It weakly interferes with non-flip part at high energies because of a small relative phase-shift. Its contribution to the elastic scattering polarization at intermediate energies is masked by reggeons having high large spin-flip. The isovector part of the latter can be excluded taking a sum of polarizations measured in π^+p and π^-p elastic scatterings. The rest is connected with f-reggeon-pomeron interference. One can estimate[17] with plausible assumptions the upper limit on the pomeron spin-flip using experimental data[19] at 6 and 10 GeV/c (higher energy data are still too crude): $M_{\mathbb{P}} \cong 0.05 \div 0.1$. This result is consistent with our theoretical estimations.

It is desirable to have a model-independent method for measurement of the pomeron spin-flip at high energies. Collaboration E-704 at Fermilab investigates[20] the Coulomb-Nuclear interference effect in the polarized pp-scattering. It has been predicted long ago[21] that polarization should achieve a maximum of about 4.5% at small value of $|t| \approx 3\ 10^{-3}(\mathrm{GeV/c})^2$, if pomeron amplitude is purely nonflip. Note, however, that finite spin-flip part of the pomeron, changes this conclusion. Fig.2 shows the Q^2-dependence of polarization in pp elastic scattering in the Coulomb-Nuclear interference region vs value of $M_{\mathbb{P}}$. Experiment E-704 is now in progress and it is planned to achieve an accuracy sufficient for pomeron spin-flip resolution.

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