Spin Effects in Diffractive Deep Inelastic Scattering

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ABSTRACT

We discuss the contribution of diffractive $Q\bar{Q}$ production to the longitudinal double-spin asymmetry in polarized deep–inelastic $lp$ scattering. We show the strong dependence of the $A_L$ asymmetry on the pomeron spin structure.

The study of diffractive events with a large rapidity gap in deep inelastic lepton–proton scattering at HERA Ref. [1] has given excellent tools to test the structure of the pomeron and its couplings. The future polarized diffractive experiments at HERA, HERA -$\vec{N}$ and RHIC Ref. [2] might give the possibility to investigate the spin structure of the pomeron. Then, the question how large the spin–flip component of the pomeron should be very important.

The pomeron contribution to the hadron high energy amplitude can be written as a product of two pomeron vertices $V_{\mu}^{hhP}$ multiplied by some function $P$ of the pomeron. As a result, the quark-proton high-energy amplitude looks like

$$T(s, t) = i P(s, t)V_{\mu}^{hhP}(t) \otimes V_{\mu}^{hhP}(t).$$

The contributions where the pomeron couples to a single quark lead to a simple matrix structure of pomeron vertex

$$V_{hhP}^{\mu} = \beta_{hhP} \gamma^\mu. \quad (1)$$

This standard coupling leads to spin-flip effects decreasing with energy like $1/s$.

The large-distance loop contributions complicate the spin structure of the pomeron coupling. These effects are determined by the hadron wave function for the pomeron-hadron couplings or by the gluon-loop corrections for the quark-pomeron case.

The model calculations Ref. [3] give the following form of the pomeron–proton vertex

$$V_{ppP}^{\mu}(p, r) = m_p^{\mu} A(r) + \gamma^{\mu} B(r),$$

where $m$ is the proton mass. The ratio of amplitudes $m^2 |A|/|B|$ has been found of about 0.2 for $|t| \sim 1 GeV^2$. The predicted single and double transverse spin asymmetries (Ref.[4]) are about 10 – 15% and have a weak energy dependence. They can be studied in future experiments at RHIC.

The spin structure of the quark-pomeron coupling $V_{qqP}^{\mu}$ has been studied in Ref. [5]. It has been shown that in addition to the standard pomeron vertex (1) the gluon-loop contributions should be important which have been calculated perturbatively. As a result, the following form of quark-pomeron vertex has found in Ref. [5]:

$$V_{qqP}^{\mu}(k, r) = \gamma^{\mu} u_0 + 2 M_Q k^{\mu} u_1 + 2 k^{\mu} k_2 + i u_3 \gamma^\rho k_\alpha r^\gamma \rho \gamma_5 + i M_Q u_4 \sigma^{\mu \alpha} r_\alpha, \quad (2)$$
where $k$ is the quark momentum, $r$ is the momentum transfer and $M_Q$ is the quark mass. The functions $u_1(r) - u_4(r)$ are proportional to $\alpha_s$ and lead to spin-flip at the quark-pomeron coupling. These functions can reach $30 \div 40\%$ of the standard pomeron term $u_0(r)$ for $|r^2| \simeq$ few GeV$^2$ (Ref. [6]).

The new form of the quark-pomeron coupling (3) should modify various spin asymmetries in high-energy diffractive reactions (Ref. [7,8]). In this report we shall discuss spin asymmetries in diffractive $ep$ reactions, which may be analyzed in the future polarized HERA experiments to test the spin structure of the pomeron.

Let us study the effects of spin–dependent quark–pomeron coupling (Ref. [9]) in diffractive deep inelastic scattering. The longitudinal double spin $A_{ll}$ asymmetry is determined by the relation

$$A_{ll} = (\sigma(\uparrow\uparrow) - \sigma(\downarrow\downarrow))/(\sigma(\uparrow\downarrow) + \sigma(\downarrow\uparrow))$$

where $\sigma(\uparrow\uparrow)$ and $\sigma(\downarrow\downarrow)$ are the cross sections with parallel and antiparallel longitudinal polarization of lepton and proton. We calculate here the cross section integrated over the momentum transfer at the pomeron-proton vertex.

The results of calculation for the $A_{ll}$ asymmetry of the light quark production in diffractive deep inelastic scattering for $\beta = 0.175, Q^2 = 12(GeV)^2, x_p = 0.1, y = 0.7$ and the pomeron intercept $\alpha_P(0) = 1.1$ are shown in Fig. 1 for the standard and spin-dependent pomeron couplings.

It is found that the $A_{ll}$ spin asymmetry of diffractive $Q\bar{Q}$ production for the standard quark–pomeron vertex is very simple in form (Ref. [9])

$$A_{ll} = \frac{yx_p(2-y)}{2 - 2y + y^2}.$$

For the spin–dependent pomeron coupling the asymmetry is dependent on $k^2_{\perp}$ of jets and smaller than for the standard pomeron vertex. Thus, one can use the $A_{ll}$ asymmetry to test the quark-pomeron coupling structure.

From the difference of the polarized cross sections the diffractive contribution to the spin–dependent structure function $g_1$ can be defined as

$$\frac{d^4\sigma(\uparrow\uparrow)}{dx dy dx_p dt} - \frac{d^4\sigma(\downarrow\downarrow)}{dx dy dx_p dt} = \frac{8\pi\alpha^2}{Q^2}(2-y)g_1^D(x, Q^2, x_p, t).$$

The diffractive contribution to $g_1$ can be found from the integrated $g_1^D(x, Q^2, x_p, t)$ structure function.
\[ g_1^D(x, Q^2) = \int dx_\rho dtg_1^D(x, Q^2, x_\rho, t). \]

The obtained low-\(x\) behaviour of \(g_1\) has a singular form like \(1/(x^{0.3}\ln^2(x))\) (Ref. [10]) which is compatible with the SMC data for \(g_1^D\) at \(Q^2 = 10(GeV)^2\) (Fig.2).

We can conclude that the study of the longitudinal double spin asymmetry in diffractive deep inelastic scattering can give an important information about the spin structure of the pomeron coupling. For testing the pomeron–proton vertex the transverse polarization of the proton should be more relevant. The future spin facilities at HERA is one of the best places to study properties of the pomeron and to test the size of its spin–flip component.

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