Spin Effects In Diffractive Processes at HERA

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Abstract

It is shown that the A_{ll} asymmetry in diffractive $Q\bar{Q}$ leptoproduction is not small at HERA energies and dependent on the structure of the pomeron couplings and on the masses of produced quarks. The connection of this asymmetry with the non-forward gluon distribution in the proton is discussed.

Study of diffractive processes at HERA provides an excellent possibility to investigate the nature of the pomeron [1, 2]. Investigation of the vector meson production becomes popular now. On the one hand, these reactions give information on the pomerom structure, and on the other hand, they can be used to analyze the gluon distribution $G(x)$ at small x [3, 4]. The longitudinal double-spin asymmetry in these processes might be proportional to $[\Delta G/G]$. This have initiated proposals to test the polarized gluon distribution ΔG from the A_{LL} asymmetry in J/Ψ production [5].

However, it has been shown in [6] that the double-spin asymmetry in diffractive processes is proportional to the fraction of the initial proton momentum x_p carried off by the pomeron. For the case of diffractive J/Ψ production x_p is fixed by the reaction kinematics: $x_p \sim (m_J^2 + Q^2 + |t|)/(sy)$. As a result, the relevant A_{ll} asymmetry should be very small at HERA energies.

In this report, we shall study the A_{ll} asymmetry for diffractive $Q\bar{Q}$ leptoproduction of light and heavy quarks. In these processes, the A_{ll} asymmetry is not small at high energies [6] because x_p is not fixed in this case. It will be shown that this asymmetry is sensitive to the spin structure of the pomeron couplings and to the mass of the produced quarks.

The pomeron is a vacuum t-channel exchange that contributes to high-energy diffractive reactions. The hadron-hadron scattering amplitude determined by the pomeron exchange can be written in the form

$$T(s,t)^{A,B} = I\!P(s,t) V^{\mu}_{AI\!P} \otimes V^{BI\!P}_{\mu},$$

where $I\!P$ is a "bare" pomeron contribution, and $V_{AI\!P}$ and $V^{BI\!P}$ are the pomeron vertices for particles A and B, respectively.

When the gluons from the pomeron couple to a single quark in the hadron, a simple matrix structure of pomeron vertex $V^{\mu}_{hhI\!P} = \beta_{hhI\!P}\gamma^{\mu}$ appears. 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 spin structure of the quark-pomeron coupling $V^{\mu}_{qq\mathbb{P}}$ has been studied in [7]. It has been shown that in addition to the standard pomeron vertex the gluon-loop contributions are important which have provided the following form of the quark-pomeron vertex:

$$V^{\mu}_{qq\mathbb{P}}(k,r) = \gamma^{\mu}u_0 + 2M_Q k^{\mu}u_1 + 2k^{\mu}\not{k}u_2 + iu_3\epsilon^{\mu\alpha\beta\rho}k_{\alpha}r_{\beta}\gamma_{\rho}\gamma_5 + iM_Q u_4\sigma^{\mu\alpha}r_{\alpha}, \qquad (1)$$

where k is the quark momentum, r is the momentum transfer and M_Q is the quark mass. The functions $u_1(r) - u_4(r)$ have been calculated perturbatively and can reach $30 \div 40\%$ of the $u_0(r)$ term for $|r^2| \simeq$ few GeV^2 [7]. They lead to spin-flip effects in the quark-pomeron coupling which do not decrease with energy growth.

Let us analyze the effects of the quark–pomeron coupling in the polarized diffractive $e + p \to e' + p' + Q\bar{Q}$ reaction and estimate the longitudinal double–spin A_{ll} asymmetry for light and heave quark production at HERA energies. The A_{ll} asymmetry is determined by the relation $A_{ll} = (\sigma(\overrightarrow{\Leftarrow}) - \sigma(\overrightarrow{\Rightarrow}))/(\sigma(\overrightarrow{\Rightarrow}) + \sigma(\overrightarrow{\Leftarrow}))$ where $\sigma(\overrightarrow{\Rightarrow})$ and $\sigma(\overrightarrow{\Leftarrow})$ are the cross sections with parallel and antiparallel longitudinal polarization of lepton and proton.

The trace over the quark loop for the difference of the polarized cross sections for the standard pomeron vertex looks like

$$A^s(\beta, k_{\perp}^2, t) = 16(2(1-\beta)k_{\perp}^2 - |t|\beta - 2M_Q^2(1+\beta))|t|. \qquad (2)$$

Similar forms can be written for the spin–average cross sections. In all the cases the strong dependence of the cross sections on the mass of the produced quarks and $\beta \simeq Q^2/(Q^2 + M_x^2)$ has been observed. Relevant functions for the spin-dependent vertex and the explicit forms for the cross sections can be found in [6, 8].

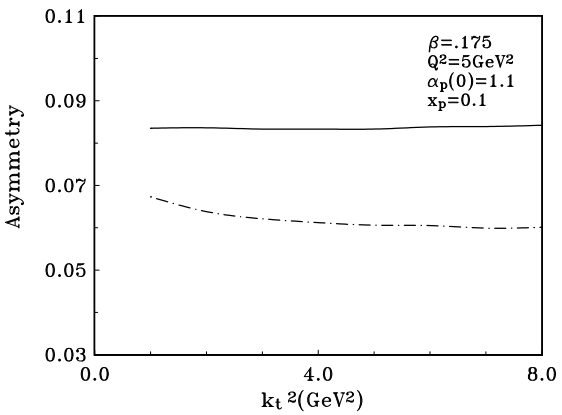

Fig.1 A_{ll} asymmetry of light quark production. Solid line -for the standard vertex; dot-dashed line -for the spin-dependent vertex.

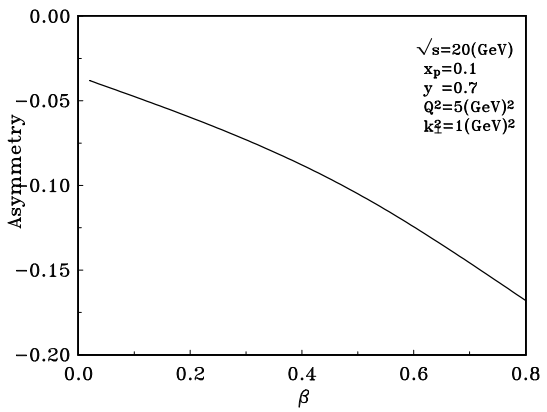

Fig.2 β– dependence of A_{ll} asymmetry for diffractive open charm production for the standard quark-pomeron vertex.

We calculate the cross section integrated over the pomeron momentum transfer because it is usually difficult to detect the recoil proton in diffractive experiments. The asymmetry of the diffractive light $Q\bar{Q}$ production is shown in Fig. 1. The asymmetry for the standard quark–pomeron vertex is very simple in form

$$A_{ll} = \frac{yx_p(2-y)}{2-2y+y^2}. \qquad (3)$$

There is no any $k_{\perp}$ and β dependence here. For the spin–dependent pomeron coupling the A_{ll} asymmetry is smaller than for the standard pomeron vertex and depends on $k_{\perp}^2$. Thus, it is sensitive to the spin structure of the pomeron coupling.

The predicted A_{ll} asymmetry for the diffractive open charm ($c\bar{c}$) production is large and negative (Fig.2). It can be seen that to obtain information about the pomeron–coupling structure, the relevant asymmetries should be measured with accuracy less than 1%. The estimations for the cross sections [6, 8] show that such statistical errors can be obtained at the integrated luminosity about $200(pb)^{-1}$.

The large magnitude of asymmetry in diffractive $Q\bar{Q}$ production is caused by not small $x_p \sim 0.1$ which is typical of these reactions. This means that in contrast with the vector meson production, where the smallness of x_p permits one to connect the two-gluon structure of the pomeron with $G(x)$, the diffractive $Q\bar{Q}$ production might give information on the non-forward gluon distributions in the proton.

We have found that the spin structure of the pomeron coupling should modify the spin average and spin–dependent cross section in diffractive processes. Not small values for the A_{ll} asymmetry in the diffractive $Q\bar{Q}$ production have been predicted. The asymmetry is free from the normalization factors and is sensitive to the dynamics of pomeron interaction. Thus, the A_{ll} asymmetry in diffractive $Q\bar{Q}$ leptoproduction is convenient to test the pomeron coupling structure. Moreover, it can be connected with the the non-forward spin-dependent gluon distributions.

Thus, we can conclude that the pomeron coupling structure can be studied in diffractive processes. Note that the spin–structure of the pomeron vertex is determined by the large–distance contributions. So, the important test of the spin structure of QCD at large distances can be carried out by studying diffractive reactions in future polarized experiments at HERA.

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References

[1] ZEUS Collaboration, M.Derrick et al., *Z.Phys* **C68** (1995) 569;
H1 Collaboration, T.Ahmed et al., *Phys.Lett.* **B348** (1995) 681.

[2] S.V.Levonian, Plen. talk at 28th Int. Conf. on High Energy Phys., Warsaw, 1996, `hep-ph/9611206`.

[3] M.G.Ryskin, *Z.Phys* **C57** (1993) 89;
M.G.Ryskin at al., `hep-ph/9511228`.

[4] M.Diehl, `hep-ph/9707441`.

[5] M.Anselmino et al., Proc. of the Workshop "Future Physics at HERA", DESY May 29-31, 1996.

[6] S.V. Goloskokov, Proc.of 12 Int. Symposium on High Energy Spin Physics, Amsterdam, eds. K. W. de Jager et al., World Sci, 1997, p.334;
S.V. Goloskokov, *Mod.Phys.Lett.* **A12** (1997) 173.

[7] S.V. Goloskokov, *Phys. Lett.* **B315** (1993) 459.

[8] S.V.Goloskokov, `hep-ph 9506347; hep-ph 9509238`.