DIFFRACTIVE CONTRIBUTION TO $A_\perp$ ASYMMETRY*

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We consider double spin asymmetries for longitudinally polarized leptons and transversely polarized protons in diffractive $Q\bar{Q}$ production which is connected with $A_\perp$ asymmetry. The predicted asymmetry is large and can be used to obtain the information on the polarized skewed gluon distributions in the proton.

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1. Introduction

Sensitivity of diffractive lepto and photoproduction to the gluon density in the proton gives an excellent tool to test these structure functions. Intensive experimental study of diffractive processes were performed in DESY [1,2]. Theoretical analysis shows that the cross sections of diffractive hadron production are expressed in terms of skewed parton distributions (SPD) [3,4]. The diffractive charm $Q\bar{Q}$ production and J/Ψ production are determined by the gluon SPD $\mathcal{F}_\zeta(x)$ because the charm component in the proton is small. For light hadron production effects of the quark SPD should be important for not small x. In the polarized case, the spin-dependent gluon distributions can be investigated. In future, there will be an excellent possibility of studying spin effects with transversely polarized target at HERMES and COMPASS.

In this report, we consider double spin asymmetries for longitudinally polarized leptons and transversely polarized protons in diffractive vector $Q\bar{Q}$ production at high energies (see [5]) which is expressed in terms of the

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polarized cross sections

$$A_{\perp}=\frac{(d\sigma(\rightarrow\Downarrow)-d\sigma(\rightarrow\Uparrow))}{(d\sigma(\rightarrow\Downarrow)+d\sigma(\rightarrow\Uparrow))}\,. \tag{1}$$

At small x the diffractive contribution to the asymmetry $A_{\perp}$ determined by the Pomeron exchange should be important. In the QCD-based models the Pomeron is usually regarded as a two-gluon state. Within the two-gluon exchange model the two-gluon coupling with the proton can be written as follows:

$$\begin{aligned} V_{pgg}^{\alpha\beta}(p,t,x_P,l_{\perp}) &= B(t,x_P,l_{\perp})(\gamma^{\alpha}p^{\beta}+\gamma^{\beta}p^{\alpha}) \\ &+ \frac{iK(t,x_P,l_{\perp})}{2m}(p^{\alpha}\sigma^{\beta\gamma}r_{\gamma}+p^{\beta}\sigma^{\alpha\gamma}r_{\gamma})+\dots\,. \end{aligned} \tag{2}$$

Here the structure proportional to $B(t,\ldots)$ determines the spin-non-flip contribution. The term $\propto K(t,\ldots)$ leads to the transverse spin-flip at the vertex. It has been found within the model approaches [6, 7] that the ratio $|\tilde{K}|/|\tilde{B}|\sim 0.1$ and has a weak energy dependence (weak x dependence). The weak energy dependence of spin asymmetries in exclusive reactions is not in contradiction with the experiment [6].

2. Diffractive contribution to $A_{\perp}$ asymmetry

The diffractive $Q\bar{Q}$ production in the lepton–proton reaction is determined by the photon–two-gluon fusion. The spin-average and spin-dependent cross section can be written in the form

$$\frac{d^5\sigma(\pm)}{dQ^2dydx_pdtdk_{\perp}^2}=\begin{pmatrix}(2-2y+y^2)\\(2-y)\end{pmatrix}\frac{C(x_P,Q^2)\;N(\pm)}{\sqrt{1-4(k_{\perp}^2+m_q^2)/M_X^2}}\,. \tag{3}$$

Here $C(x_P,Q^2)$ is a normalization coefficient, the functions $N(\pm)$ are determined by a sum of all graphs integrated over the gluon momenta l and l'. We calculate here the imaginary parts of the photon-two-gluon fusion amplitudes which are expressed directly in terms of the functions B and K from (2).

The function $N(+)$ has the form

$$N(+)=\left(|\tilde{B}|^2+|t|/m^2|\tilde{K}|^2\right)\Pi^{(+)}(t,k_{\perp}^2,Q^2)\,. \tag{4}$$

Here

$$\tilde{B}\sim\int_0^{l_{\perp}^2<k_0^2}\frac{d^2l_{\perp}(l_{\perp}^2+\vec{l}_{\perp}\vec{r}_{\perp})}{(l_{\perp}^2+\lambda^2)((\vec{l}_{\perp}+\vec{r}_{\perp})^2+\lambda^2)}B(t,l_{\perp}^2,x_P,\ldots)=\mathcal{F}_{x_P}^{g}(x_P,t,k_0^2)\,, \tag{5}$$

and

$$\tilde{K} \sim \int\limits_0^{l_\perp^2<k_0^2} \frac{d^2 l_\perp (l_\perp^2 + \vec{l}_\perp \vec{r}_\perp)}{(l_\perp^2+\lambda^2)((\vec{l}_\perp+\vec{r}_\perp)^2+\lambda^2)} K(t, l_\perp^2, x_P, \ldots) = \mathcal{K}^g_{x_P}(x_P, t, k_0^2) \quad (6)$$

with $k_0^2 \sim \frac{k_\perp^2+m_q^2}{1-\beta}$. The gluon structures $\tilde{B}(\tilde{K})$ are connected with the $\mathcal{F}^g_{x_P}(x_P)(\mathcal{K}^g_{x_P}(x_P))$ SPD (see (5), (6)). Thus, the functions B and K are the nonintegrated gluon distributions. The hard part $\Pi^{(+)}$ in (4) can be calculated perturbatively when $k_\perp^2$ is not small, about $1\,\mathrm{GeV}^2$ or larger.

The spin-dependent contribution $N(-)$ has two terms proportional to the scalar products $(\vec{k}_\perp \vec{S}_\perp)$ and $(\vec{Q}\vec{S}_\perp)$ [5]. We consider here only the term proportional to $(\vec{Q}\vec{S}_\perp)$ which can be written as follows:

$$N(-) = \sqrt{\frac{|t|}{m^2}} \left(\tilde{B}\tilde{K}^* + \tilde{B}^*\tilde{K}\right) \left[\frac{(\vec{Q}\vec{S}_\perp)}{m} \Pi_Q^{(-)}(t, k_\perp^2, Q^2)\right]. \quad (7)$$

The other term $\propto (\vec{k}_\perp \vec{S}_\perp)$ has been discussed in [5].

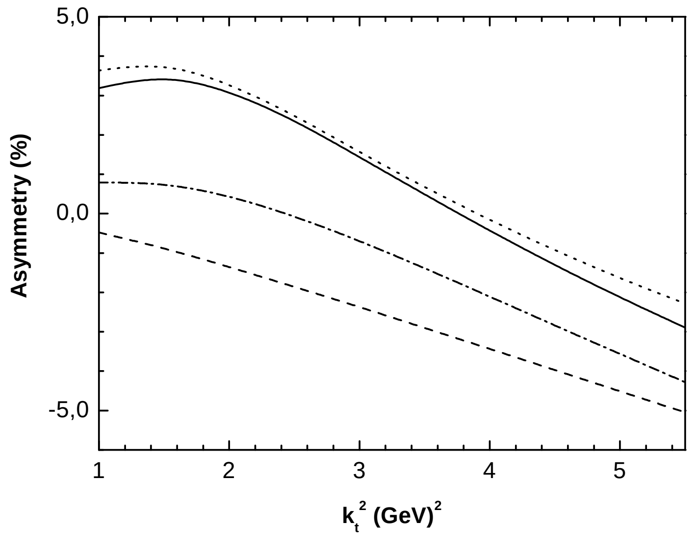

Fig. 1. $A_\perp$ asymmetry in diffractive light $Q\bar{Q}$ production at $\sqrt{s} = 20\,\mathrm{GeV}$ for $x_P = 0.1$, $y = 0.5$, $|t| = 0.3\,\mathrm{GeV}^2$: dotted line-for $Q^2 = 0.5\,\mathrm{GeV}^2$; solid line-for $Q^2 = 1\,\mathrm{GeV}^2$; dot-dashed line-for $Q^2 = 5\,\mathrm{GeV}^2$; dashed line-for $Q^2 = 10\,\mathrm{GeV}^2$.

The asymmetry is determined by the ratio $A_\perp = \sigma(-)/\sigma(+)$. At small x the gluon structure functions have large imaginary part. In this case the asymmetry can be approximated as

$$A_\perp \sim C_\perp \frac{\tilde{K}}{\tilde{B}} = C_\perp \frac{\mathcal{K}^g_\zeta(\zeta)}{\mathcal{F}^g_\zeta(\zeta)} \quad \text{with } \zeta = x_P \, . \tag{8}$$

In numerical calculations we use a simple parameterization of the SPD as a product of the form factor and the ordinary gluon distribution [5]. In our estimations we use the value $|\tilde{K}|/|\tilde{B}| \sim 0.1$. We analyze the case when the $A_\perp$ asymmetry has a maximal value (the momentum $\vec{Q}_\perp$ is parallel to the target polarization $\vec{S}_\perp$). The predicted $A_\perp$ asymmetry in diffractive light $Q\bar{Q}$ production at $\sqrt{s} = 20\,\mathrm{GeV}$ is shown in Fig. 1. This asymmetry is not small for $Q^2 \sim (0.5-1)\,\mathrm{GeV}^2$. The $A_\perp$ asymmetry has a strong mass dependence. For heavy quark production this asymmetry becomes negative, Fig. 2.

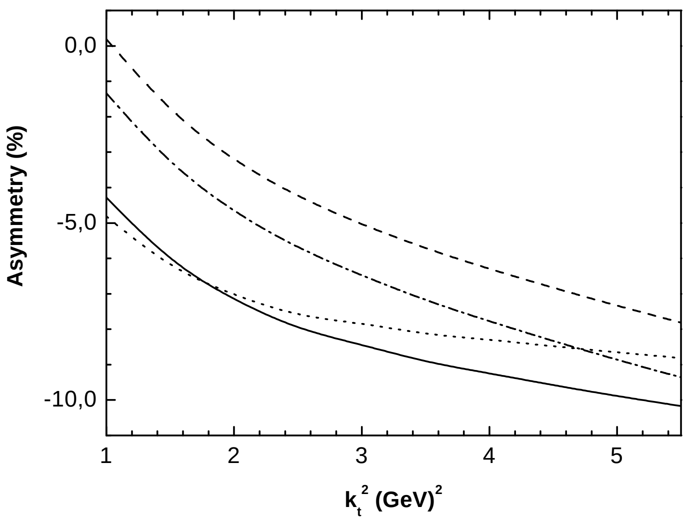

Fig. 2. $A_\perp$ asymmetry in diffractive heavy quark production. Lines are the same as in Fig. 1.

It is interesting to have predictions for a light quark production at the SLAC and HERMES low–energy range $\sqrt{s} \sim 7\,\mathrm{GeV}$. Here the "window" for perturbative calculation is quite small. Really, it can be found in this case that the maximum value of the transverse momentum is limited by $k_\perp^2 < 2\,\mathrm{GeV}^2$ because we have the restriction $k^2 \le M_X^2/4$ from (3). In fixed–target experiments, it is usually difficult to detect the final hadron and determine the momentum transfer. In this case, we estimate the asymmetry integrated over momentum transfer

$$\bar{A}_\perp = \frac{\int_{t_{\min}}^{t_{\max}} \sigma(-)\, dt}{\int_{t_{\min}}^{t_{\max}} \sigma(+)\, dt} \,. \tag{9}$$

$t_{\min} \sim 0$; $t_{\max} = 4\,\mathrm{GeV}^2$. The predicted integrated asymmetry is about 3%. Note that we have calculated here only the gluon contribution to the asymmetry. At HERMES energies the contribution of the quark SPD to the $A_\perp$ asymmetry should be important.

3. Conclusion

To conclude, we would like to emphasize that the diffraction contribution to the $A_\perp$ asymmetry is found to be proportional to the ratio of $\mathcal{K}/\mathcal{F}$ structure functions. The predicted coefficient $C_\perp$ in (8) is not small, about 0.3–0.5. This shows the possibility of studying the transverse distribution $\mathcal{K}^g_{x_P}(x_P, t)$ in future experiments with a transversely polarized target (HERMES, COMPASS and future eRHIC facilities). These results could be applicable to reactions with heavy quarks. For processes with light hadron production, our predictions can be used in the small x region ($x \leq 0.1$ *e.g.*) where the contribution of the quark SPD is expected to be small. The recoil particle detector is needed to distinguish the diffractive events. Really, in the case when the recoil detector is absent, the diffractive events are detected together with nondiffractive ones. The measured asymmetry in this case looks like

$$A_{\mathrm{exp}} = \frac{\Delta\sigma_{\mathrm{ND}} + \Delta\sigma_{\mathrm{D}}}{\sigma_{\mathrm{ND}} + \sigma_{\mathrm{D}}} = A_{\mathrm{ND}}(1-R) + A_{\mathrm{D}}R, \quad R = \frac{\sigma_{\mathrm{D}}}{\sigma_{\mathrm{ND}} + \sigma_{\mathrm{D}}} \,. \tag{10}$$

Here $A_{\mathrm{ND}} = \Delta\sigma_{\mathrm{ND}}/\sigma_{\mathrm{ND}}$ and $A_D = \Delta\sigma_{\mathrm{D}}/\sigma_{\mathrm{D}}$. The ratio R integrated over x has been found at HERA to be about 0.20–0.30 [8]. In this case, the diffractive contribution to asymmetry will be smaller by the factor 3–5.

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