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Diffractive open charm production from the dipole model analysis

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We present a precise comparison of the results of the dipole models with the newest data from HERA on the diffractive open charm production. We found good agreement with the data on the diffractive open charm production both for the the gluon distributions from the considered dipole models and the DGLAP fits to HERA data from our earlier analysis for diffractive parton distributions with higher twist. We also show that exclusive diffractive charm production can practically be neglected.

European Physical Society Europhysics Conference on High Energy Physics, EPS-HEP 2009,
July 16 - 22 2009
Krakow, Poland

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[†]This work is partially supported by the grant of MNiSW N202 249235.

1. Introduction

In this analysis, we consider two important parameterisations of the dipole scattering amplitude, called GBW [2] and CGC [3], in which parton saturation results are built in. The comparison we performed prompt us to discuss some subtle points of the dipole models, mostly related to the $q\bar{q}g$ component, and connect them to the approach based on the diffractive parton distributions evolved with the Dokshitzer-Gribov-Lipatov-Altarelli-Parisi (DGLAP) equations. Within the latter approach, the diffractive open charm production is particularly interesting since it is sensitive to a diffractive gluon distribution. However, the accuracy of the existing data on such a production does not allow to discriminate between different gluon distributions considered in our analysis.

2. Diffractive charm production in dipole model

In the diffractive scattering heavy quarks are produced in quark-antiquark pairs, $c\bar{c}$ and $b\bar{b}$ for charm and bottom, respectively. Such pairs can be produced provided that the mass of the diffractive system is above the quark pair production threshold

$$M^2 = Q^2\left(\frac{1}{\beta}-1\right) > 4m_{c,b}^2. \tag{2.1}$$

In the lowest order the diffractive state consist of only the $c\bar{c}$ or $b\bar{b}$ pair. In the forthcoming we consider only charm production since bottom production is negligible. For example, for charm production from transverse photons we have

$$\begin{aligned} x_{I\!P}F_T^{(c\bar{c})} &= \frac{3Q^4e_c^2}{64\pi^4\beta B_d}\int_{z_c}^{1/2} dz\, z(1-z), \\ &\times \left\{\left[z^2+(1-z)^2\right]Q_c^2\,\phi_1^2 + m_c^2\,\phi_0^2\right\}, \end{aligned} \tag{2.2}$$

where m_c and e_c are charm quark mass and electric charge, respectively. The minimal value of diffractive mass equals: $M_{min}^2 = 4m_c^2$, thus the maximal value of β is given by

$$\beta_{max} = \frac{Q^2}{Q^2+4m_c^2}\,. \tag{2.3}$$

In such a case, $z_c = 1/2$ in Eq. (2.2), and $F_{T,L}^{(c\bar{c})} = 0$ for $\beta > \beta_{max}$. This is shown in Fig. 1, where on the left side we have: the $c\bar{c}T$ and $c\bar{c}L$ components of F_2^D from the dipole model with the GBW parameterisation together with the $c\bar{c}X$ contribution from the collinear factorisation approach Eq. (2.4), with the diffractive gluon distribution [5] and respectively on the right: the $c\bar{c}X$ component in a different scale against the massless $q\bar{q}T$, $q\bar{q}L$ and $q\bar{q}g$ components. By the comparison with the corresponding curves for three massless quarks $(q\bar{q}T, q\bar{q}L, q\bar{q}g)$, shown in Fig. 1 (right), we see that the exclusive diffractive charm production contributes only $1/30$ to the total structure function F_2^D. Thus it can practically be neglected.

The next component is the $c\bar{c}g$ diffractive state. Unfortunately, formula for the $q\bar{q}g$ production is only known in the massless quark case and cannot be used for heavy quarks. Thus, we have to resort to the collinear factorisation formula, given by Eq. (2.4), in which the charm-(anti)charm pair

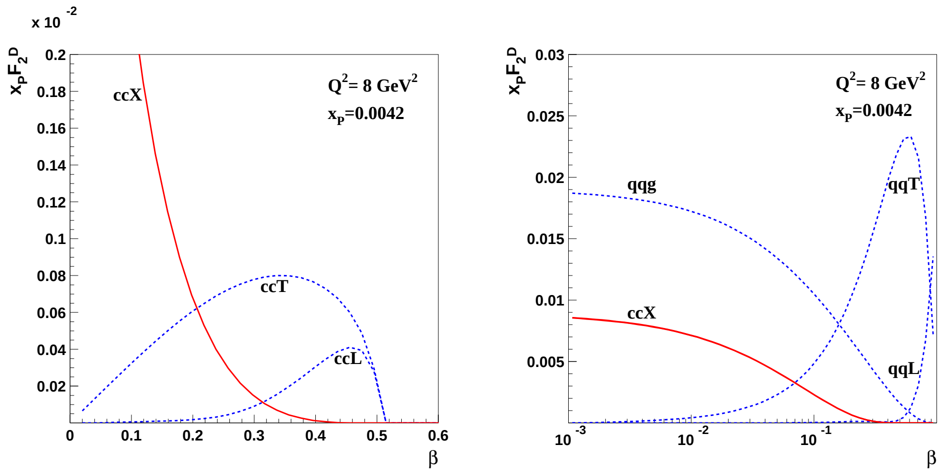

Figure 1: Three components of diffractive F_2^D from the dipole model with GBW parametrization.

is produced via the photon-gluon fusion: $\gamma^* g \to c\bar{c}$ [4]. If such an approach is applied to diffractive scattering, gluon is a "constituent of a pomeron". The diffractive state consists of additional particles X (called "pomeron remnant") in addition to the heavy quark pair, which are well separated in rapidity from the scattered proton. The collinear factorisation formula for the charm contribution to the diffractive structure functions is taken from the fully inclusive case [8] in which the standard gluon distribution is replaced by the diffractive gluon distribution g^D:

$$x_{I\!P} F_{2,L}^{D(c\bar{c}X)} = 2\beta\, e_c^2 \, \frac{\alpha_s(\mu_c^2)}{2\pi} \int_{a\beta}^{1} \frac{dz}{z}\, C_{2,L}\left(\frac{\beta}{z}, \frac{m_c^2}{Q^2}\right) \times\, x_{I\!P}\, g^D(x_{I\!P}, z, \mu_c^2), \tag{2.4}$$

where $a = 1 + 4m_c^2/Q^2$ and the factorisation scale $\mu_c^2 = 4m_c^2$ with the charm quark mass $m_c = 1.4\ GeV$. The leading order coefficient functions are given by

$$C_2(z,r) = \tfrac{1}{2}\left\{z^2 + (1-z)^2 + 4z(1-3z)r - 8z^2r^2\right\} \times\, \ln\frac{1+\alpha}{1-\alpha} + \tfrac{1}{2}\alpha\big\{-1 + 8z(1-z) - 4z(1-z)r\big\}, \tag{2.5}$$

$$C_L(z,r) = -4z^2 r \ln 1 + \alpha 1 - \alpha + 2\alpha z(1-z), \tag{2.6}$$

where $r = m_c^2/Q^2$ and $\alpha = \sqrt{1 - 4rz/(1-z)}$. The lower integration limit in Eq. (2.4), results from the condition for the heavy quark production in the fusion: $\gamma^* g \to c\bar{c}$,

$$(z x_{I\!P}\, p + q)^2 \geq 4m_c^2, \tag{2.7}$$

where we assume that gluon carries a fraction z of the pomeron momentum $x_{I\!P}\, p$.

The $c\bar{c}X$ contribution given by Eq. (2.4), is shown in Fig. 1 as the solid lines. As seen in the left figure, this component becomes significant for $\beta < 0.1$. By a comparison with the massless

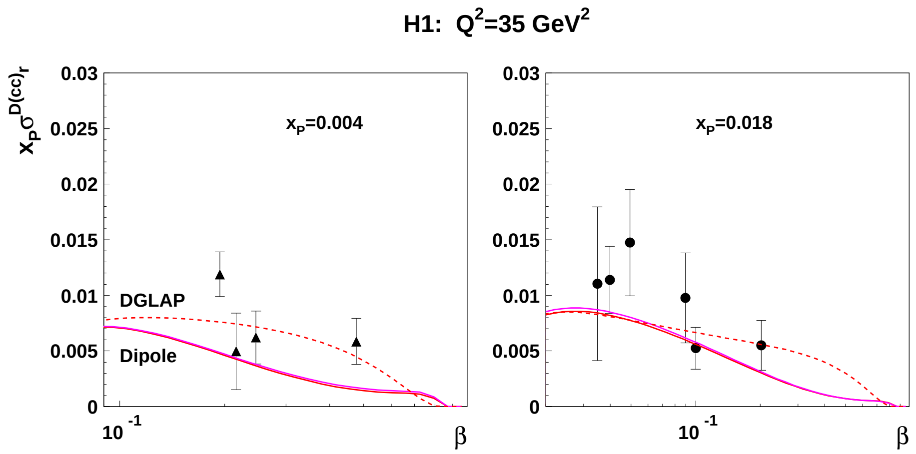

Figure 2: A comparison of the collinear factorisation predictions with the GBW and CGC gluon distributions (solid lines) with the HERA data on the open diffractive charm production. The dashed lines are computed with the gluon distribution obtained in the DGLAP fit [5] to the H1 data on the diffractive structure functions.

quark contributions (the right figure) we see that diffractive charm production contributes up to 30% to the diffractive structure function F_2^D for small values of β. The presented results were obtained assuming the diffractive gluon distribution which results from the dipole models, given in our last paper [6], with the GBW parameterisation of the dipole cross section and with the color factor modification. The CGC parameterisation gives a similar result.

In Fig. 2 we show the collinear factorisation predictions for the diffractive charm production confronted with the new HERA data [1] on the charm component of the reduced cross section:

$$\sigma_r^{D(c\bar{c})} = F_2^{D(c\bar{c})} - \frac{y^2}{1+(1-y)^2} F_L^{D(c\bar{c})} . \tag{2.8}$$

The solid curves, which are barely distinguishable, correspond to the result with the GBW and CGC parameterisations of the diffractive gluon distributions. The dashed lines are computed for the gluon distribution from a fit to the H1 data [5] based on the DGLAP equations. The present accuracy of the charm data does not allow to discriminate between these two approaches although the data seem to prefer the gluon distribution from the DGLAP fit which is much more concentrated in the large z-region as compared to the dipole model gluon distributions, see [6] in Appendix.

The importance of diffractive charm is illustrated in Fig. 3, where the fractional charm contribution

$$f_D^{c\bar{c}} = \sigma_r^{D(c\bar{c})} / \sigma_r^D , \tag{2.9}$$

to the total diffractive cross section, is shown as a function of β for two values of $x_{I\!P} = 0.004$ and 0.018 against the H1 collaboration data [1]. The solid lines are computed for the $c\bar{c}X$ contribution with the GBW and CGC diffractive gluon distributions while the dashed lines are found for the diffractive gluon distribution obtained in the DGLAP fit [5] to the H1 collaboration data. For

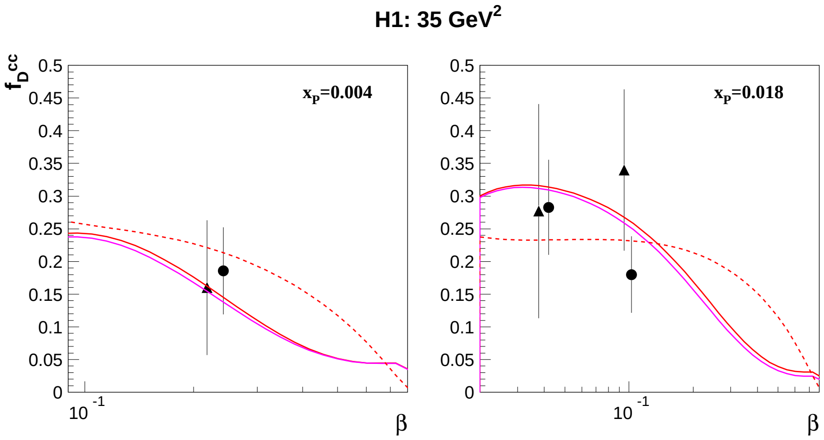

Figure 3: The fractional charm contribution to the total diffractive cross section.

small values of β, the charm contribution equals on average approximately $20-30\%$, which is comparable to the charm fraction in the inclusive cross section for similar values of Q^2 [7].

3. Acknowledgments

I am indebted to Krzysztof Golec-Biernat for collaboration on the subject of this presentation.

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