Diffractive production of heavy mesons at the LHC within k_t - factorization approach

Marta Luszczak[*][†]

University of Rzeszów, PL-35-959 Rzeszów, Poland
E-mail: `luszczak@ur.edu.pl`

Antoni Szczurek

Institute of Nuclear Physics PAN, PL-31-342 Cracow, Poland
E-mail: `antoni.szczurek@ifj.edu.pl`

We discuss diffractive production of heavy mesons at the LHC [1, 2]. The differential cross sections for single- and central-diffractive mechanisms for $c\bar{c}$ pair production are calculated in the framework of the Ingelman-Schlein model corrected for absorption effects. Here, leading-order gluon-gluon fusion and quark-antiquark anihilation partonic subprocesses are taken into consideration. Both pomeron flux factors as well as parton distributions in the pomeron are taken from the H1 Collaboration analysis of diffractive structure function and diffractive dijets at HERA. The extra corrections from subleading reggeon exchanges are also taken into consideration. In addition to standard collinear approach, for the first time the differential cross sections for the diffractive $c\bar{c}$ pair production are calculated in the framework of the k_t-factorization approach, i.e. effectively including higher-order corrections. The unintegrated (transverse momentum dependent) diffractive parton distributions in proton are calculated with the help of the Kimber-Martin-Ryskin prescription where collinear diffractive PDFs are used as input. Some correlation observables, like azimuthal angle correlation between c and $\bar{c}$, and $c\bar{c}$ pair transverse momentum were obtained for the first time. The hadronization of charm quarks is taken into account by means of fragmentation function technique.

XXIV International Workshop on Deep-Inelastic Scattering and Related Subjects
11-15 April, 2016
DESY Hamburg, Germany

---

[*]Speaker.

1. Introduction

Diffractive hadronic processes were studied theoretically in the so-called resolved pomeron model [3]. During the studies performed at Tevatron, it was realized that the model, previously used to describe deep-inelastic diffractive processes must be corrected to take into account absorption effects related to hadron-hadron interactions. Such interactions, unavoidably present in hadronic collisions at high energies are not present in electron/positron induced processes. In theoretical models this effect is taken into account by multiplying the diffractive cross section calculated using HERA diffractive PDFs by a kinematics independent factor called the gap survival probability – S_G. Two theoretical groups specialize in calculating such probabilities [4, 5]. At high energies such factors, interpreted as probabilities, are very small (of the order of few %). This causes that the predictions of the diffractive cross sections are not as precise as those for the standard inclusive non-diffractive cases. This may become a challenge when a precise data from the LHC will become available.

In this study we consider diffractive production of charm for which rather large cross section at the LHC are expected, even within the leading-order (LO) collinear approach [1]. On the other hand, it was shown that for the inclusive non-diffractive charm production the LO collinear approach is a rather poor approximation and higher-order corrections are crucial. Contrary, the k_t-factorization approach, which effectively includes higher-order effects, gives a good description of the LHC data for inclusive charm production at $\sqrt{s}$ = 7 TeV (see *e.g.* Ref. [6]). This strongly suggests that application of k_t-factorization approach to diffractive charm production is useful. This presentation is based on our recent study in [2].

2. Formalism
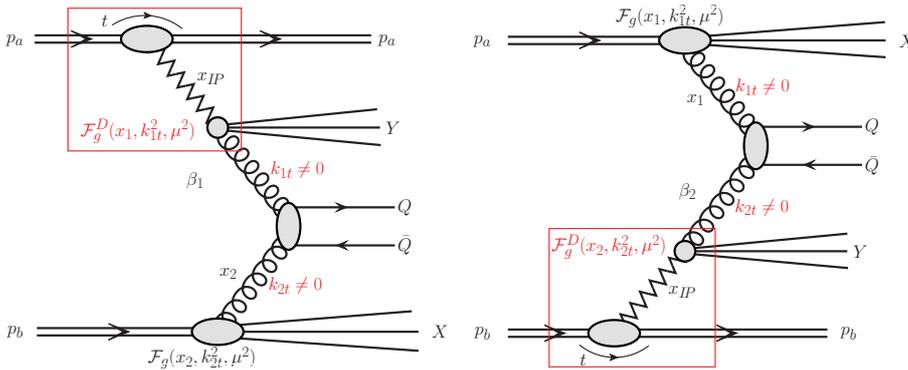
Figure 1: A diagrammatic representation for single-diffractive production of heavy quark pairs within the k_t-factorization approach.

A sketch of the theoretical formalism is shown in Fig. 1. Here, extension of the standard resolved pomeron model based on the LO collinear approach by adopting a framework of the k_t-factorization is proposed as an effective way to include higher-order corrections. According to this model the cross section for a single-diffractive production

of charm quark-antiquark pair, for both considered diagrams (left and right diagram of Fig. 1), can be written as:

$$d\sigma^{SD(a)}(p_a p_b \to p_a c\bar{c}\, XY) = \int dx_1 \frac{d^2 k_{1t}}{\pi} dx_2 \frac{d^2 k_{2t}}{\pi}\, d\hat{\sigma}(g^* g^* \to c\bar{c})$$
$$\times \mathcal{F}_g^D(x_1, k_{1t}^2, \mu^2) \cdot \mathcal{F}_g(x_2, k_{2t}^2, \mu^2), \qquad (2.1)$$

$$d\sigma^{SD(b)}(p_a p_b \to c\bar{c} p_b\, XY) = \int dx_1 \frac{d^2 k_{1t}}{\pi} dx_2 \frac{d^2 k_{2t}}{\pi}\, d\hat{\sigma}(g^* g^* \to c\bar{c})$$
$$\times \mathcal{F}_g(x_1, k_{1t}^2, \mu^2) \cdot \mathcal{F}_g^D(x_2, k_{2t}^2, \mu^2), \qquad (2.2)$$

where $\mathcal{F}_g(x, k_t^2, \mu^2)$ are the unintegrated (k_t-dependent) gluon distributions (UGDFs) in the proton and $\mathcal{F}_g^D(x, k_t^2, \mu^2)$ are their diffractive counterparts – diffractive UGDFs (dUGDFs).

Details of our new calculations can be found in Ref. [2].

3. Results

In Fig. 2 we show rapidity (left panel) and transverse momentum (right panel) distribution of c quarks (antiquarks) for single diffractive production at $\sqrt{s} = 13$ TeV. Distributions calculated within the LO collinear factorization (black long-dashed lines) and for the k_t-factorization approach (red solid lines) are shown separately. We see significant differences between the both approaches, which are consistent with the conclusions from similar studies of standard non-diffractive charm production (see *e.g.* Ref. [6]). Here we confirm that the higher-order corrections are very important also for the diffractive production of charm quarks.
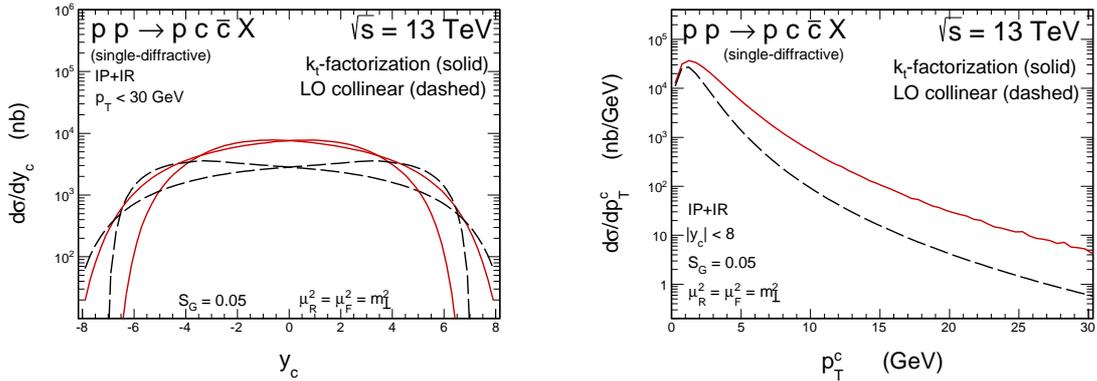
Figure 2: Rapidity (left panel) and transverse momentum (right panel) distributions of c quarks (antiquarks) for a single-diffractive production at $\sqrt{s} = 13$ TeV. Components of the $g(IP)$-$g(p)$, $g(p)$-$g(IP)$, $g(IR)$-$g(p)$, $g(p)$-$g(IR)$ mechanisms are shown.

The correlation observables can not be calculated within the LO collinear factorization but can be directly obtained in the k_t-factorization approach. The distribution of azimuthal angle $\varphi_{c\bar{c}}$ between c quarks and $\bar{c}$ antiquarks is shown in the left panel of Fig. 3.
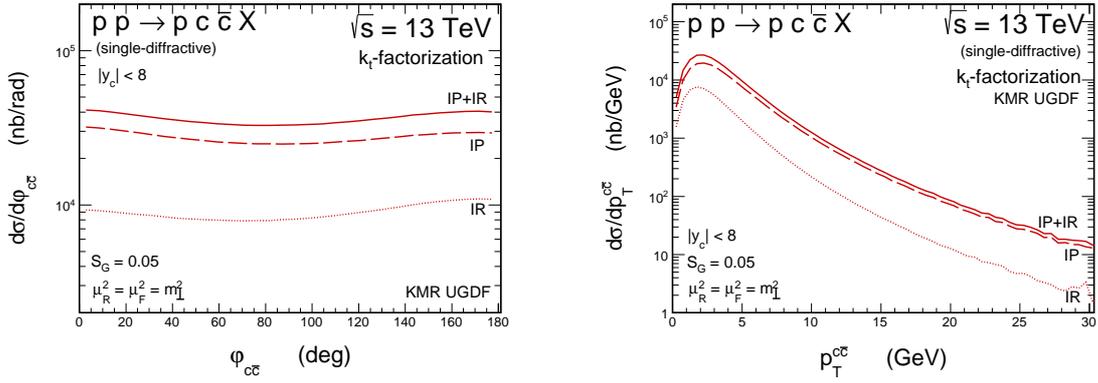
Figure 3: The distribution in $\phi_{c\bar{c}}$ (left panel) and distribution in $p_T^{c\bar{c}}$ (right panel) for k_t-factorization approach at $\sqrt{s}$ = 13 TeV.

The $c\bar{c}$ pair transverse momentum distribution $p_T^{c\bar{c}} = |\vec{p_t^c} + \vec{p_t^{\bar{c}}}|$ is shown on the right panel. Results of the full phase-space calculations illustrate that the quarks and antiquarks in the $c\bar{c}$ pair are almost uncorrelated in the azimuthal angle between them and are often produced in the configuration with quite large pair transverse momenta.   Figures 4 and
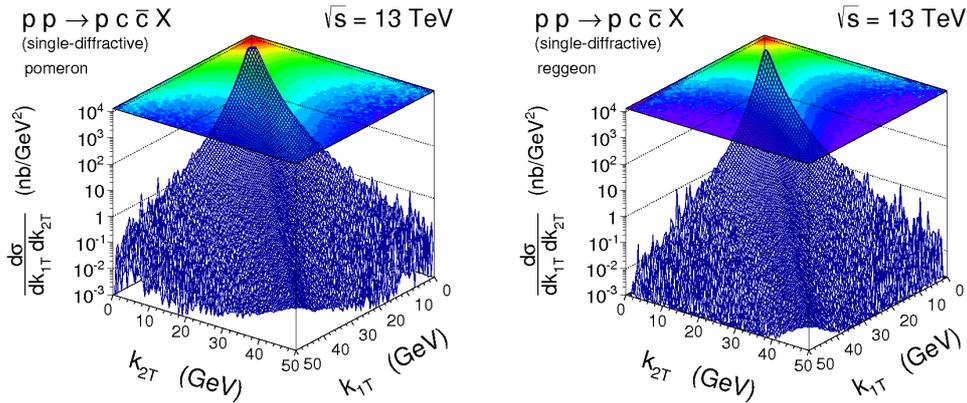
Figure 4: Double differential cross sections as a function of initial gluons transverse momenta k_{1T} and k_{2T} for single-diffractive production of charm at $\sqrt{s} = 13$ TeV. The left and right panels correspond to the pomeron and reggeon exchange mechanisms, respectively.

5 show the double differential cross sections as a functions of transverse momenta of incoming gluons (k_{1T} and k_{2T}) and transverse momenta of outgoing c and $\bar{c}$ quarks (p_{1T} and p_{2T}), respectively. We observe quite large incident gluon transverse momenta. The major part of the cross section is concentrated in the region of small k_t's of both gluons but long tails are present. Transverse momenta of the outgoing particles are not balanced as they were in the case of the LO collinear approximation.

4. Conclusions

Charm production is a good example where the higher-order effects are very impor-
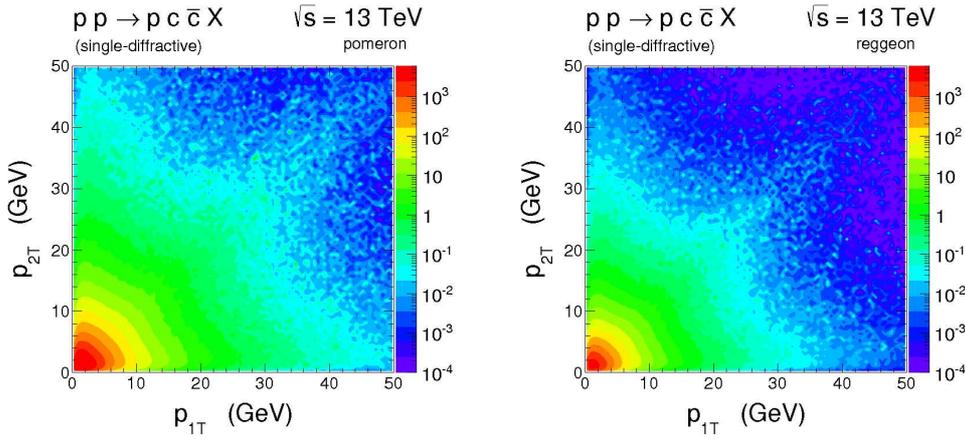
Figure 5: Double differential cross sections as a function of transverse momenta of outgoing c quark p_{1T} and outgoing $\bar{c}$ antiquark p_{2T} for single-diffractive production of charm at $\sqrt{s} = 13$ TeV. The left and right panels correspond to the pomeron and reggeon exchange mechanisms, respectively.

tant. For the inclusive charm production we have shown that these effects can be effectively included in the k_t-factorization approach [6]. In our approach we decided to use the so-called KMR method to calculate unintegrated diffractive gluon distribution. As usually in the KMR approach, we have calculated diffractive gluon UGDFs based on collinear distribution, which in the present case is diffractive collinear gluon distribution. In our calculations we have used the H1 Collaboration parametrization fitted to the HERA data on diffractive structure function and di-jet production. Having obtained unintegrated diffractive gluon distributions we have performed calculations of several single-particle and correlation distributions. In some cases the results have been compared with the results obtained in the leading-order collinear approximation. In general, the k_t-factorization approach leads to larger cross section. However, the K-factor is strongly dependent on phase space point. Some correlation observables, like azimuthal angle correlation between c and $\bar{c}$, and $c\bar{c}$ pair transverse momentum were obtained in [2] for the first time.

References

[1] M. Luszczak, R. Maciula and A. Szczurek, Phys. Rev. D **91** (2015) no.5, 054024 [arXiv:1412.3132 [hep-ph]].

[2] M. Luszczak, R. Maciula, A. Szczurek and M. Trzebinski, arXiv:1606.06528 [hep-ph].

[3] G. Ingelman, P.E. Schlein, Phys. Lett. B **152**, 256 (1985).

[4] V. A. Khoze, A. D. Martin and M. G. Ryskin, Eur. Phys. J. C **18**, 167 (2000) [hep-ph/0007359].

[5] U. Maor, AIP Conf. Proc. **1105**, 248 (2009).

[6] R. Maciula and A. Szczurek, Phys. Rev. D **87**, 094022 (2013) [arXiv:1301.3033 [hep-ph]].