Single-diffractive dijet production at high energies within the k_t -factorization approach

Marta Łuszczak

Institut of Physics

University of Rzeszów

EDS Blois 2017

17th International Conference on Elastic and Diffractive Scattering

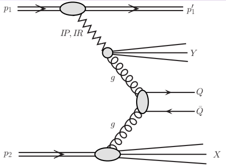
Prague, Czech Republic, 26-30 June 2017

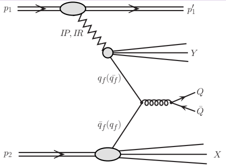
Introduction

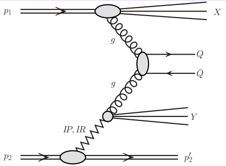
- There are two alternative approaches in the literature how to calculate hard-diffractive processes
- In the so-called dipole approach the amplitudes are modeled using a phenomenological ingredient: dipole-proton interaction cross section which is fitted to HERA data. The dipole model by construction violates Regge factorization
- The resolved pomeron model is constructed according to quite different philosophy based on the so-called diffractive parton distributions. The latter objects are constructed based on the Regge picture but are adjusted to experimental data measured at HERA

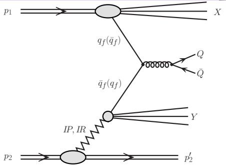
Introduction

single- diffractive production

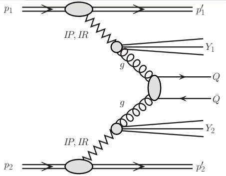


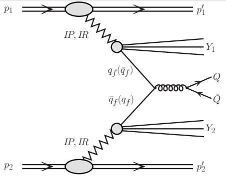






central- diffractive production





- M. Łuszczak, R. Maciuła and A. Szczurek, Phys. Rev. D**91**, 054024 (2015)

Introduction

- some new ideas for calculation of diffractive cross sections were put forward and applied in the case of single-diffractive production of charm at the LHC
- the standard resolved pomeron model, usually based on the leading-order (LO) collinear approximation, is extended by adopting a framework of the k_t-factorization as an effective way to include higher-order corrections
- M. Łuszczak, R. Maciuła, A. Szczurek and M. Trzebinski JHEP02 (2017) 089

Theoretical framework

In this approach (Ingelman-Schlein model) one assumes that the Pomeron has a well defined partonic structure, and that the hard process takes place in a Pomeron–proton or proton–Pomeron (single diffraction) or Pomeron–Pomeron (central diffraction) processes.

$$\frac{d\sigma_{SD(1)}}{dy_1 dy_2 dp_t^2} = \frac{1}{16\pi^2 \hat{s}^2} \times \Big[|\mathcal{M}_{gg\to Q\bar{Q}}|^2 \cdot x_1 g^D(x_1,\mu^2) x_2 g(x_2,\mu^2) + |\mathcal{M}_{q\bar{q}\to Q\bar{Q}}|^2 \cdot \Big(x_1 q^D(x_1,\mu^2) x_2 \bar{q}(x_2,\mu^2) + x_1 \bar{q}^D(x_1,\mu^2) x_2 q(x_2,\mu^2) \Big) \Big],$$

$$\frac{d\sigma_{SD(2)}}{dy_1 dy_2 dp_t^2} = \frac{1}{16\pi^2 \hat{s}^2} \times \Big[|\mathcal{M}_{gg\to Q\bar{Q}}|^2 \cdot x_1 g(x_1,\mu^2) x_2 g^D(x_2,\mu^2) + |\mathcal{M}_{q\bar{q}\to Q\bar{Q}}|^2 \cdot \Big(x_1 q(x_1,\mu^2) x_2 \bar{q}^D(x_2,\mu^2) + x_1 \bar{q}(x_1,\mu^2) x_2 q^D(x_2,\mu^2) \Big) \Big],$$

$$\frac{d\sigma_{CD}}{dy_1 dy_2 dp_t^2} = \frac{1}{16\pi^2 \hat{s}^2} \times \Big[|\mathcal{M}_{gg\to Q\bar{Q}}|^2 \cdot x_1 g^D(x_1,\mu^2) x_2 g^D(x_2,\mu^2) + |\mathcal{M}_{q\bar{q}\to Q\bar{Q}}|^2 \cdot \Big(x_1 q^D(x_1,\mu^2) x_2 \bar{q}^D(x_2,\mu^2) + x_1 \bar{q}^D(x_1,\mu^2)\, x_2 q^D(x_2,\mu^2) \Big) \Big],$$

- standard collinear MSTW08LO parton distributions (A.D. Martin, W.J. Stirling, R.S. Thorne and G. Watt)
- diffractive distribution function (diffractive PDF)

The diffractive distribution function (diffractive PDF) can be obtained by a convolution of the flux of pomerons $f_{\mathbf{P}}(x_{\mathbf{P}})$ in the proton and the parton distribution in the pomeron, e.g. $g_{\mathbf{P}}(\beta, \mu^2)$ for gluons:

$$g^D(x, \mu^2) = \int dx_{\mathbf{P}} d\beta\, \delta(x - x_{\mathbf{P}}\beta) g_{\mathbf{P}}(\beta, \mu^2)\, f_{\mathbf{P}}(x_{\mathbf{P}}) \;=\; \int_x^1 \frac{dx_{\mathbf{P}}}{x_{\mathbf{P}}}\, f_{\mathbf{P}}(x_{\mathbf{P}}) g_{\mathbf{P}}(\frac{x}{x_{\mathbf{P}}}, \mu^2)\,.$$

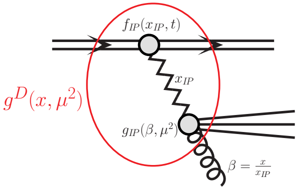
The flux of Pomerons $f_{\mathbf{P}}(x_{\mathbf{P}})$:

$$f_{\mathbf{P}}(x_{\mathbf{P}}) = \int_{t_{min}}^{t_{max}} dt\, f(x_{\mathbf{P}}, t)\,,$$

with t_{min}, t_{max} being kinematic boundaries.

Both pomeron flux factors $f_{\mathbf{P}}(x_{\mathbf{P}}, t)$ as well as parton distributions in the pomeron were taken from the H1 collaboration analysis of diffractive structure function at HERA.

Model for diffractive UGDF



Resolved pomeron model (Ingelman-Schlein model):

- convolution of the flux of pomerons in the proton and the parton distribution in the pomeron
- both ingredients known from the H1 Collaboration analysis of diffractive structure function and diffractive dijets at HERA

First step ⇒ diffractive collinear PDF:

$$g^D(x, \mu^2) = \int dx_{\mathbf{P}} d\beta\, \delta(x - x_{\mathbf{P}}\beta) g_{\mathbf{P}}(\beta, \mu^2)\, f_{\mathbf{P}}(x_{\mathbf{P}}) = \int_x^1 \frac{dx_{\mathbf{P}}}{x_{\mathbf{P}}} f_{\mathbf{P}}(x_{\mathbf{P}}) g_{\mathbf{P}}\left(\frac{x}{x_{\mathbf{P}}}, \mu^2\right)$$

where the flux of pomerons: $f_{\mathbf{P}}(x_{\mathbf{P}}) = \int_{t_{min}}^{t_{max}} dt\, f(x_{\mathbf{P}}, t)$

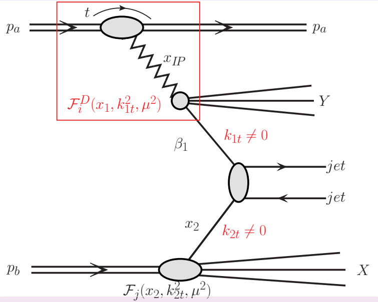
Second step ⇒ diffractive unintegrated gluon within Kimber-Martin-Ryskin method:

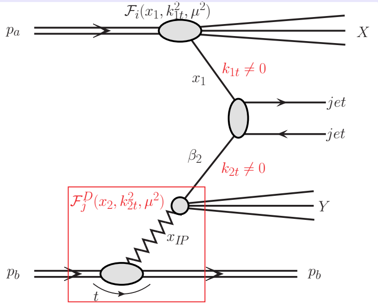
$$f_g^D(x, k_t^2, \mu^2) \equiv \frac{\partial}{\partial \log k_t^2}\left[g^D(x, k_t^2)\, T_g(k_t^2, \mu^2)\right] = T_g(k_t^2, \mu^2)\, \frac{\alpha_S(k_t^2)}{2\pi} \times$$

$$\int_x^1 dz \left[\sum_q P_{gq}(z) \frac{x}{z}\, q^D\left(\frac{x}{z}, k_t^2\right) + P_{gg}(z) \frac{x}{z}\, g^D\left(\frac{x}{z}, k_t^2\right) \Theta\left(\Delta - z\right)\right]$$

- $T_g(k_t^2, \mu^2)$ - Sudakov form factor

Single-diffractive cross section

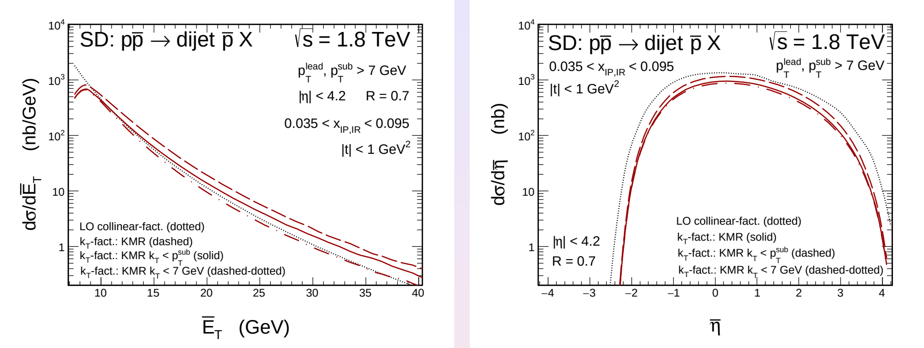




$$d\sigma^{SD(1)}(p_1 p_2 \to p_1 jj\, XY) = \int dx_1 \frac{d^2 k_{1t}}{\pi} dx_2 \frac{d^2 k_{2t}}{\pi}\, d\hat{\sigma}(g^* g^* \to jj) \times \mathcal{F}_g^D(x_1, k_{1t}^2, \mu^2) \cdot \mathcal{F}_g(x_2, k_{2t}^2, \mu^2)$$

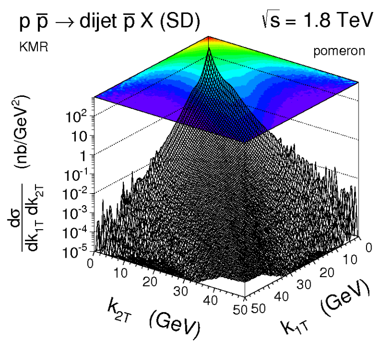
$$d\sigma^{SD(2)}(p_1 p_2 \to jj p_2\, XY) = \int dx_1 \frac{d^2 k_{1t}}{\pi} dx_2 \frac{d^2 k_{2t}}{\pi}\, d\hat{\sigma}(g^* g^* \to jj) \times \mathcal{F}_g(x_1, k_{1t}^2, \mu^2) \cdot \mathcal{F}_g^D(x_2, k_{2t}^2, \mu^2)$$

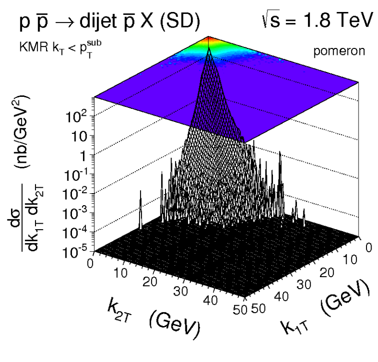
Results for Tevatron cuts



- $\overline{E}_T = \frac{E_{1T}+E_{2T}}{2}$
- $\overline{\eta} = \frac{\eta_1+\eta_2}{2}$
- $0.035 < x_{IP,IR} < 0.095$
- the large difference can be seen close to the lower transverse momentum cut

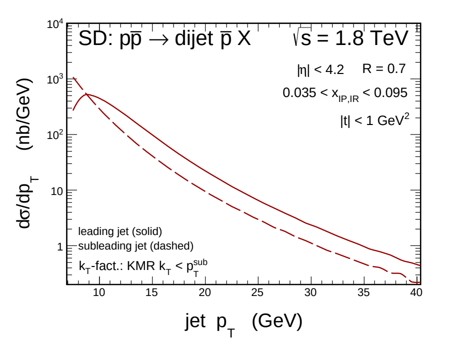
Results for Tevatron cuts

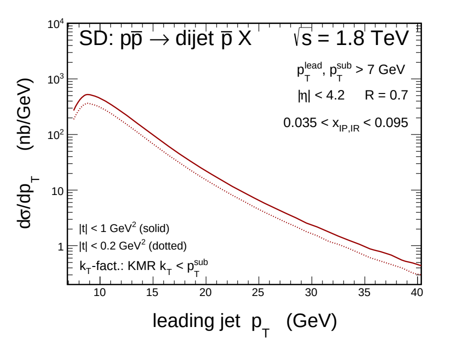




- almost symmetric in k_{1T} and k_{2T}
- the limitation on $k_T < p_T^{sub}$ makes the two-dimensional distribution much narrower although the consequences on distribution in transverse momenta and rapidity are not dramatic

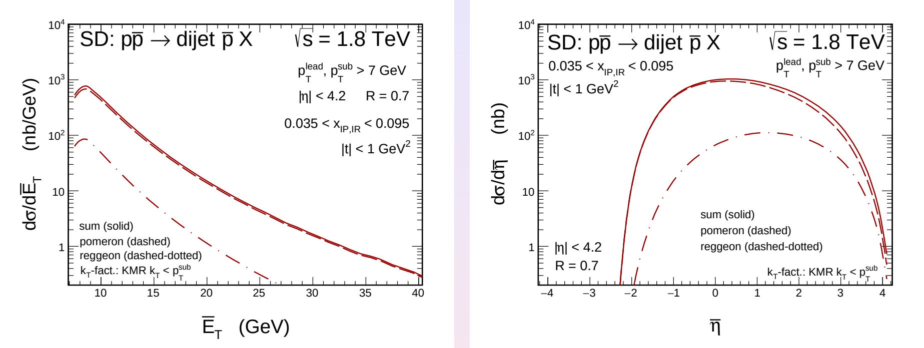
Results for Tevatron cuts





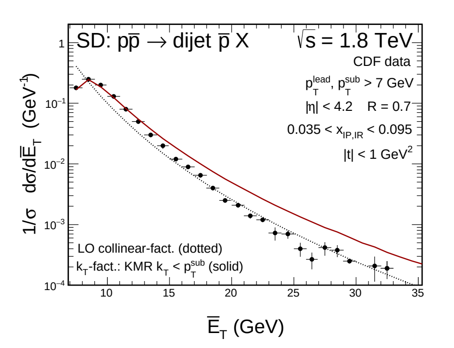
- the transverse momentum distribution of leading and subleading jets differ
- SD cross section depends on the cut on four-momentum squared transferred to the outgoing antiproton
- the cut changes the cross section normalization but does not modify the shape of the distribution

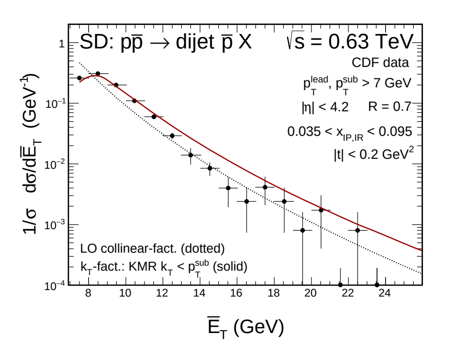
Results for Tevatron cuts



- in the selected range of x_{IP} the pomeron contribution is much bigger than the contribution of the subleading reggeon
- subleading reggeon contribution is about 10 %
- for the average jet rapidity distribution both contributions are of the same order for large $\overline{\eta}$.

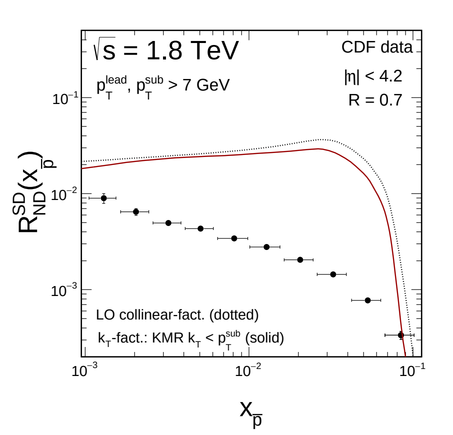
Results for Tevatron cuts

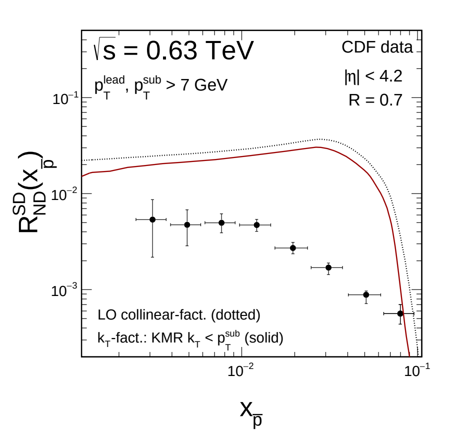




- while the k_t-factorization approach gives a better description of the data close to the lower experimental cut on jet transverse momenta, the collinear-factorization approach seems to be better for larger transverse momenta

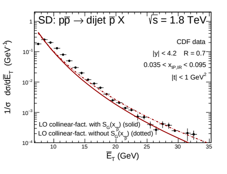
Kinematical dependence of gap survival factor

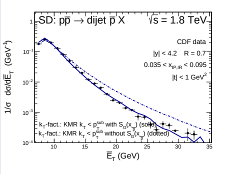


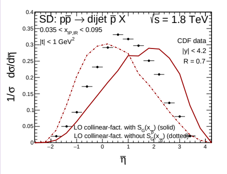


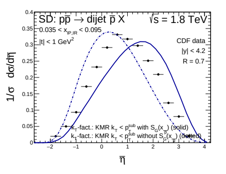
- both the experimental distributions in $\overline{E}_T$ and in $\overline{\eta}$ are not absolutely normalized
- the absolute cross section depends on gap survival factor which is not easy to calculated from first principle
- the CDF collaboration showed also distribution in $x_{\bar{p}}$ normalized to the inclusive cross section

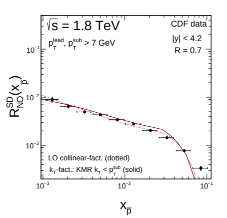
Kinematical dependence of gap survival factor

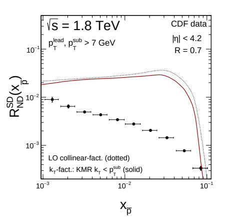






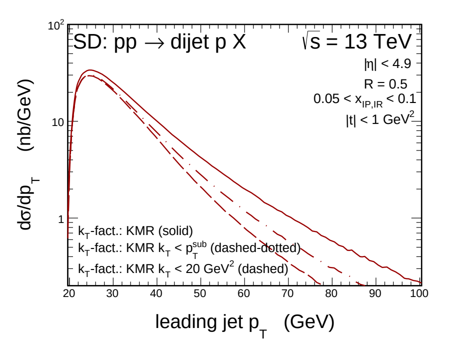


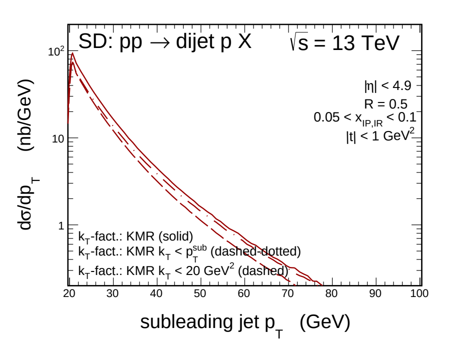




- the gap survival factor is a function of $x_{\bar{p}}$ only
- we wish to check if such a dependence could modify the measured distributions in rapidity and transverse momentum of jets
- models motivated by the theory of dynamics of such a process should be considered in this context in a future

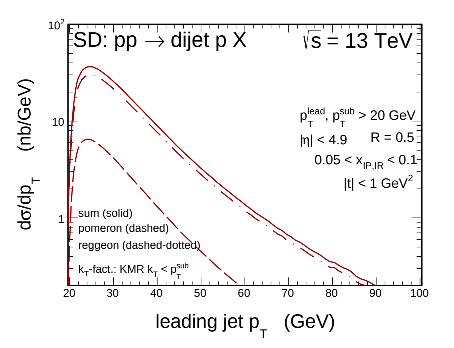
Predictions for the LHC

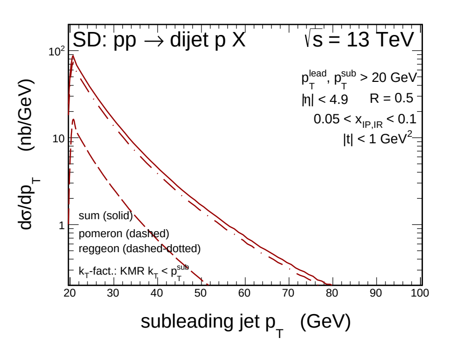




- $\sqrt{s} = 13$ TeV.
- $-4.9 < y_1, y_2 < 4.9$
- $p_t > 20$ GeV
  $S_G = 0.05$

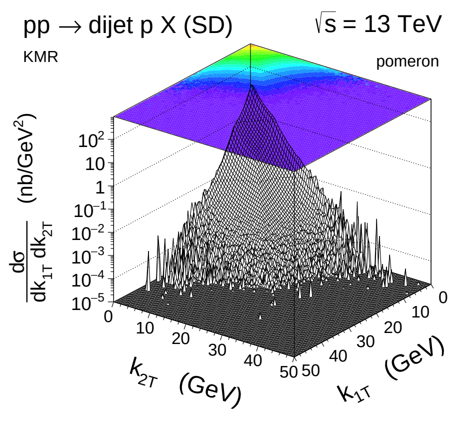
Predictions for the LHC

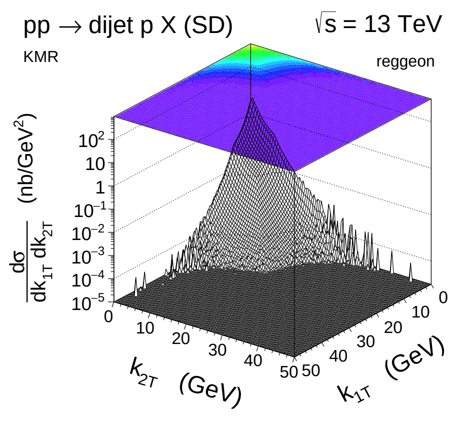




- no evident dependence on the value of the transverse momentum

Predictions for the LHC





- no extra cuts on parton transverse momenta have been imposed
- very large transverse momenta of partons enter the considered dijet production

Conclusions

- We have presented for the first time results for the single-diffractive production of dijets within k_t-factorization approach
- Results of our calculations were compared with the Tevatron data where forward antiprotons and rapidity gaps were measured
- A resonable agreement has been achieved
- The k_t-factorization leads to a better description in E_T close to the lower transverse momentum cut
- Several other distributions have been presented and discussed, many of them for a first time
- It is rather difficult to describe the distributions in $x_{\bar{p}}$ with a constant value of gap survival factor
- Our preliminary study suggest that the dependence of gap survival factor on kinematical variables can be also an important ingredient in order to understand details of rapidity distributions