Single inclusive jet production at 13 TeV and estimate of DPS for double inclusive jet production

M. Bury[1], M. Deak[1], K. Kutak[1], S. Sapeta[1,2]

[1]The H. Niewodniczański Institute of Nuclear Physics PAN, Kraków, Poland

[2]Theoretical Physics Department, CERN, Geneva, Switzerland

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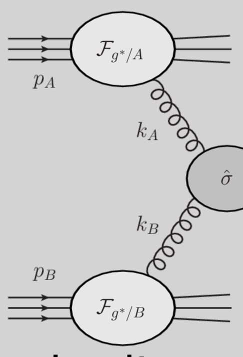
Abstract

- We provide a description of the transverse momentum spectrum of single inclusive forward jets produced at the LHC at the center-of-mass energies of 7 and 13 TeV, using the high energy factorization (HEF) framework
- We test various unintegrated parton distribution functions and asses the relevance of contributions to the hard scattering coming from diagrams with off-shell quarks
- We use the results from single inclusive jet production to construct double-parton scattering (DPS) contributions to dijet processes

High Energy Factorization (k_T-factorization) [1]

$$d\sigma_{AB\to q\bar{q}} = \int d^2k_{TA}\frac{dx_A}{x_A}\mathcal{F}(x_A,k_{TA})\; d^2k_{TB}\frac{dx_B}{x_B}\,\mathcal{F}(x_B,k_{TB})\; d\hat{\sigma}_{g^*g^*}\left(\frac{m^2}{x_Ax_Bs},\frac{k_{TA}}{m},\frac{k_{TB}}{m}\right)$$

- reduces to collinear factorization for $s \gg m^2 \gg k_T^2$, but holds also for $s \gg m^2 \sim k_T^2$
- requires matrix elements with *off-shell* initial-state partons with $k_i^2 = k_{iT}^2 < 0$

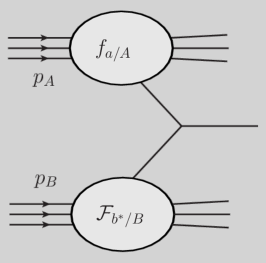


$$k_A^\mu = x_A p_A^\mu + k_{TA}^\mu \qquad k_B^\mu = x_B p_B^\mu + k_{TB}^\mu$$

- allows for higher-order kinematical effects at leading order
- typically associated with small-x and forward physics, saturation, heavy-ions
- k_T-dependent $\mathcal{F}$ may satisfy BFKL, CCFM, BK, KGBJS evolution equations

Single inclusive forward jet production - kinematics

- The hybrid, HEF cross section, $x_A \gg x_B$



$$\frac{d\sigma}{dy_{jet}dp_{t,jet}} = \frac{1}{2}\frac{\pi\, p_{t,jet}}{(x_Ax_Bs)^2}\sum_{a,b,c}\overline{|\mathcal{M}_{ab^*\to c}|}^2 x_A f_{a/A}(x_A,\mu^2)\,\mathcal{F}_{b/B}(x_B,p_{t,jet}^2,\mu^2)$$

- The longitudinal kinematic variables

$$x_A = {}^1\!/\!\sqrt{s}\; p_{t,jet}\, e^{y_{jet}} \qquad x_B = {}^1\!/\!\sqrt{s}\; p_{t,jet}\, e^{-y_{jet}}$$

- Contributing channels

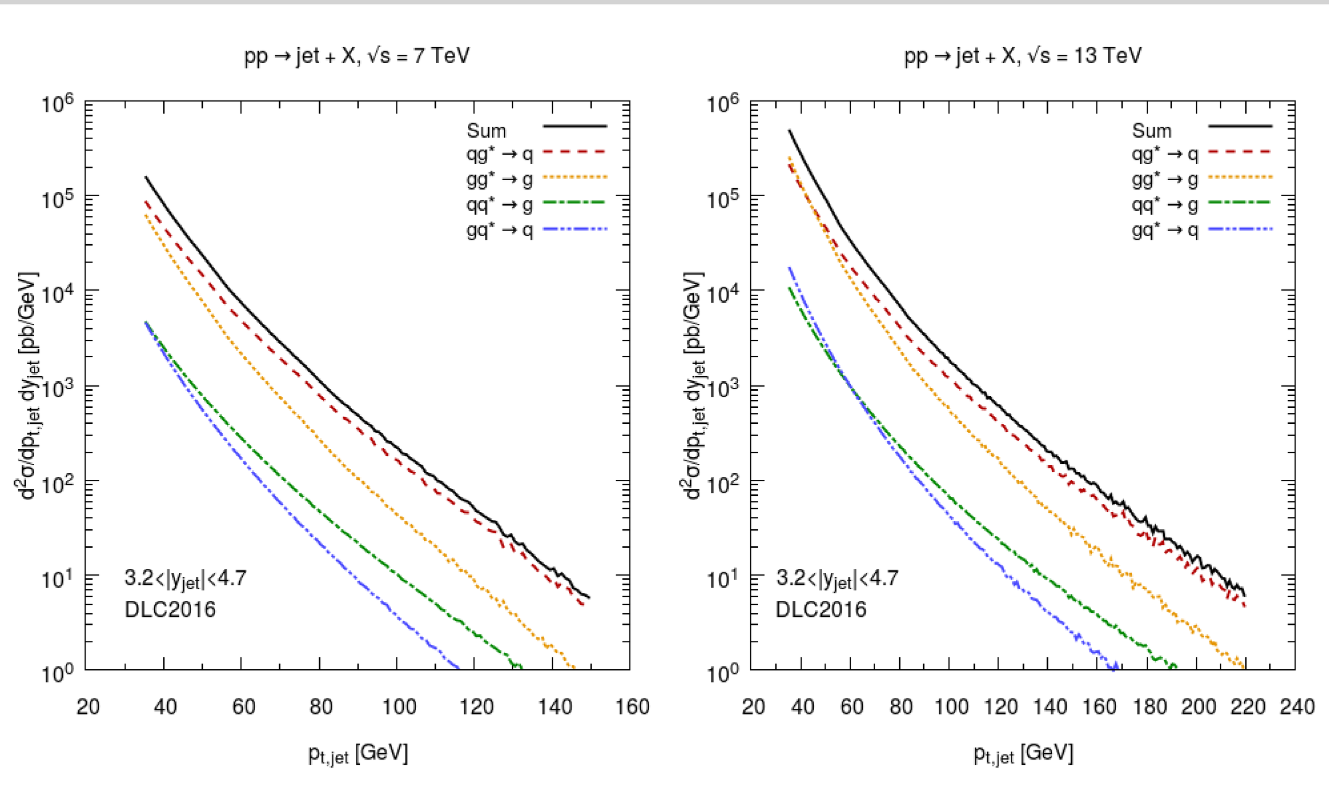
$$gg^* \to g \qquad qg^* \to q \qquad gq^* \to q \qquad \bar{q}q^* \to g$$

Transverse momentum dependent parton densities

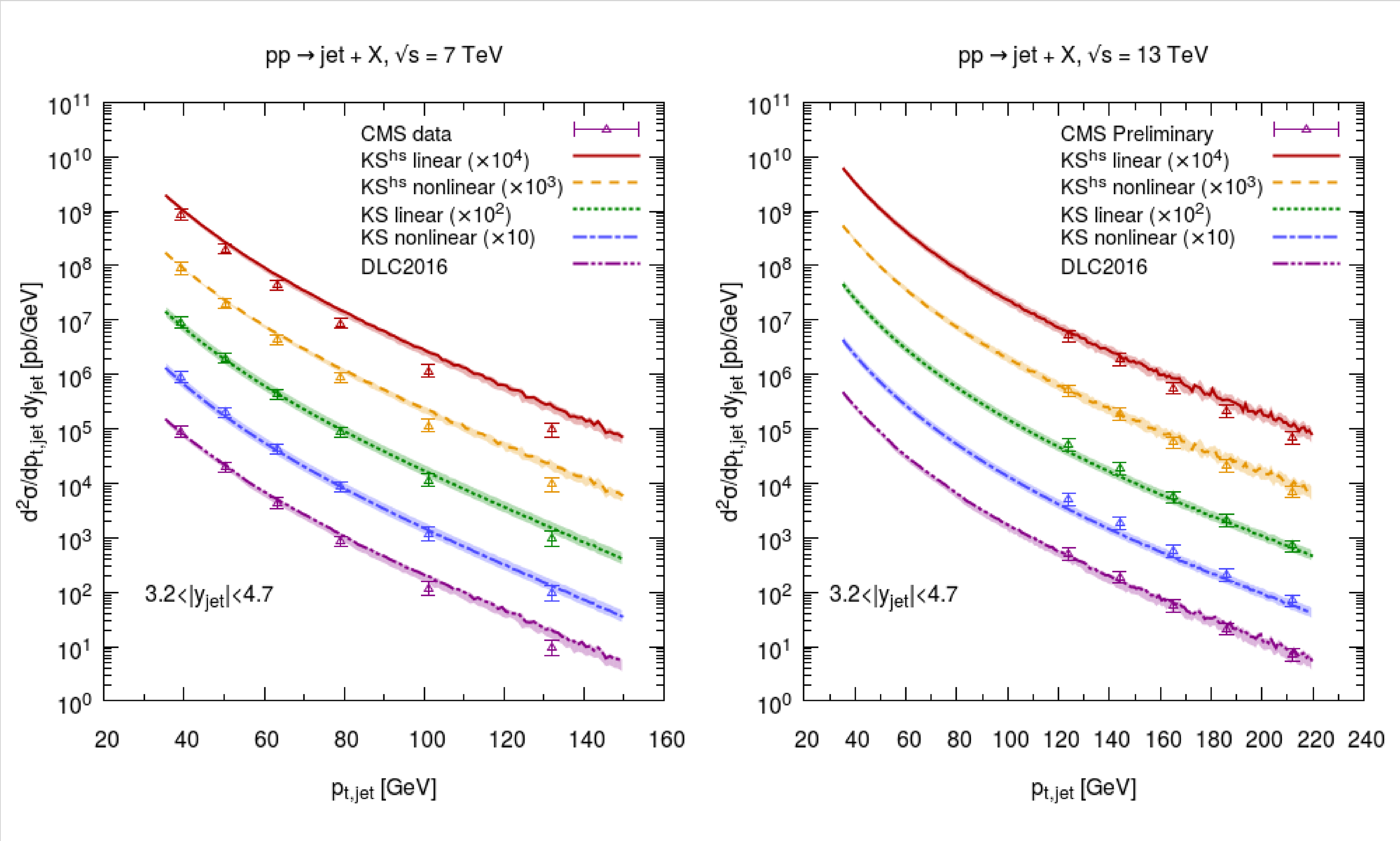
Distributions used for the off-shell partons, $\mathcal{F}_{b/B}(x_2, p_{t,jet}^2, \mu^2)$:

- The *KS nonlinear* [2] - unintegrated gluon density from an extension of the BK equation (include kinematic constraint on the gluons in the chain, non-singular pieces of the splitting functions, contributions from sea quarks)
- The *KS linear* - linearized version of the equation above
- The *KS hardscale nonlinear* [3] - unintegrated gluon density from the *KS nonlinear* + Sudakov resummation
- The *KS hardscale linear* - linearized version of the equation above
- *DLC2016* [4] - unintegrated gluon and quarks distributions from collinear PDFs using the KMR prescription [5] (angular ordering, Sudakov form factor).

Single inclusive forward jet production - contributing channels

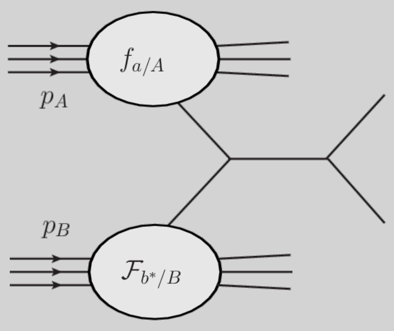


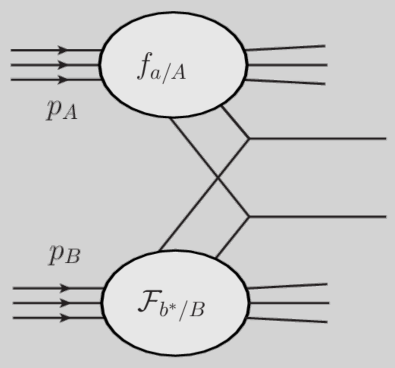
Single inclusive forward jet production - gluon distributions



Forward dijet production

- Dijets can be produced in two ways
  - *Single parton scattering* (SPS)
  - *Double parton scattering* (DPS)





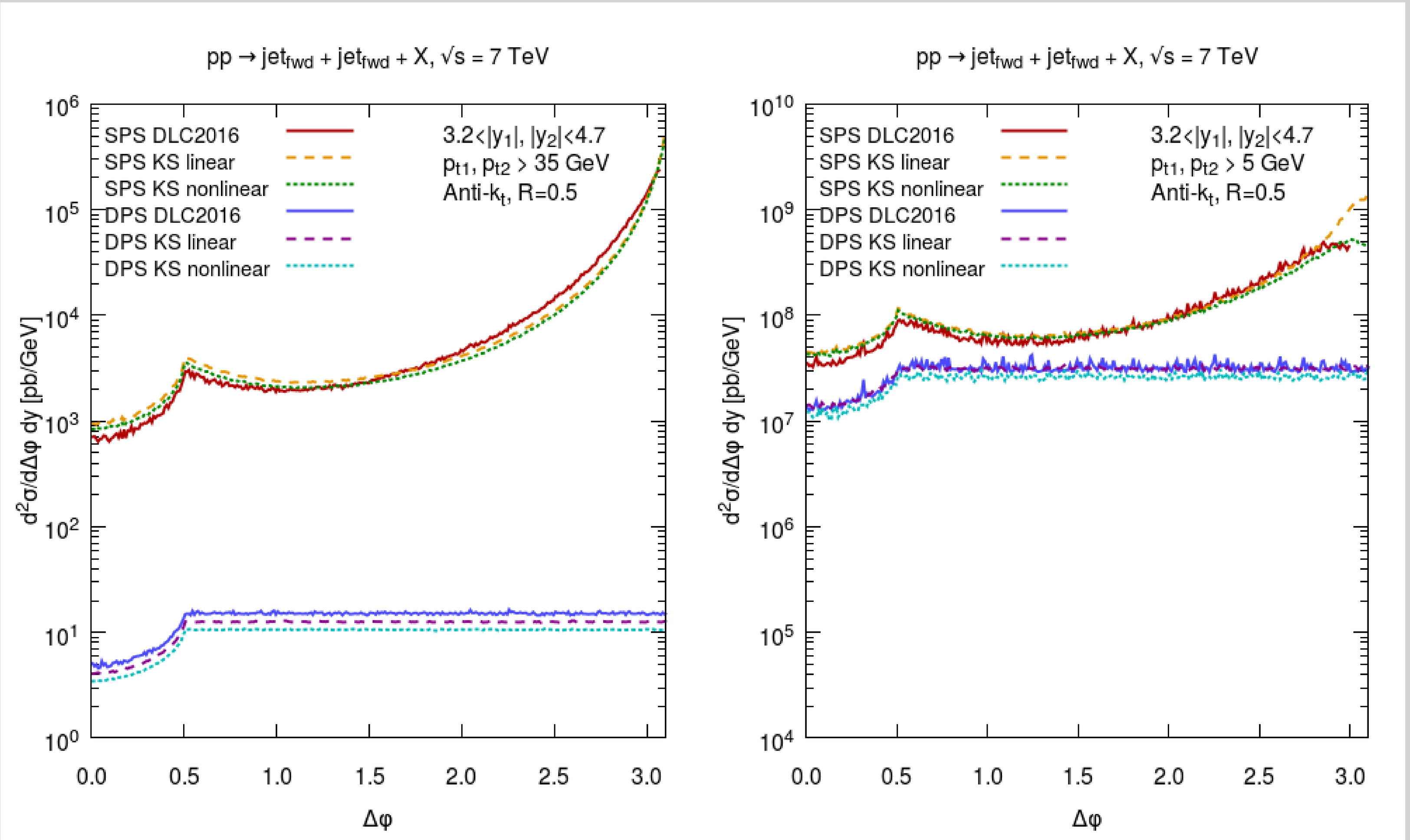
- Cross section formula for SPS

$$d\sigma_{\rm SPS}^{pA\to \rm dijets+X} = \frac{p_{1t}p_{2t}}{8\pi^2(x_Ax_Bs)^2}\sum_{a,c,d} x_A f_{a/p}(x_A,\mu^2)\,\overline{|\mathcal{M}_{ag^*\to cd}|}^2\mathcal{F}_{g/A}(x_B,k_t^2)\frac{1}{1+\delta_{cd}}$$

- Cross section formula for DPS (factorized assumption)

$$\frac{d\sigma_{\rm DPS}^{pA\to \rm dijets+X}}{dy_1d^2p_{1t}dy_2d^2p_{2t}} = \frac{1}{\sigma_{\rm eff}}\frac{d\sigma}{dy_1d^2p_{1t}}\frac{d\sigma}{dy_2d^2p_{2t}}$$

DPS contribution to azimuthal angle distributions



Conclusions

- The HEF framework describes well the single inclusive jet production at the LHC, the main uncertainty comes from the unintegrated parton distributions.
- Contribution from off-shell quarks is negligible for forward jet production
- The double parton scattering contributions to inclusive dijet production processes, although increase with lowering the transverse momentum jet cut, are significantly smaller than single parton scattering at experimentally relevant phase space region.

Main references

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