Single and double inclusive forward jet production at the LHC

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in collaboration with

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related to talks of A. van Hammeren
and M. Serino

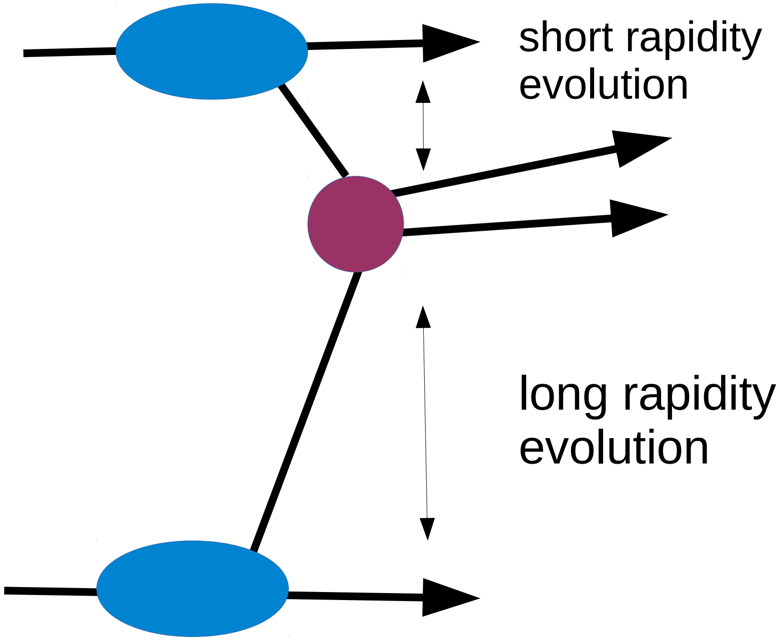
REF 2016, Antwerp, Belgium

Outline

1. **Motivation**
2. **High Energy Factorization**
3. **Single forward jet production**
4. **Forward dijet production**
5. **Conclusions and Outlook**

Motivation

- **Possibility to probe small *x* physics**
  - forward physics, saturation, heavy-ions
  - available experimental data
  - test significance of multi-parton interactions in the forward region and other effects
  - test TMDs

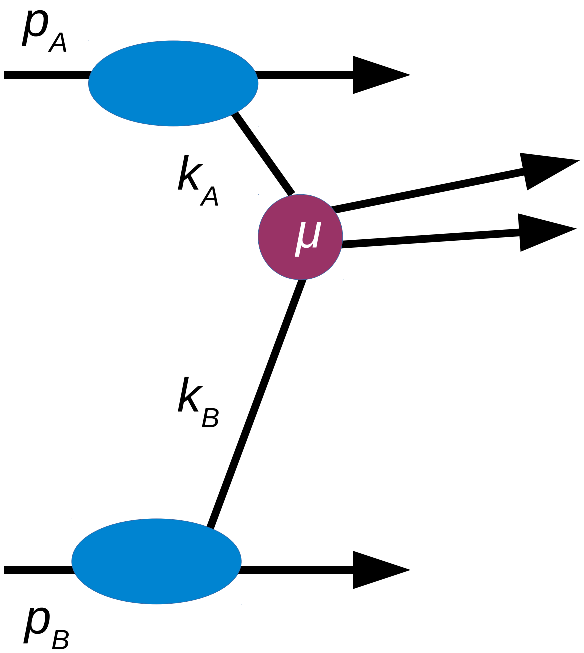


Framework – High Energy Factorization

High Energy Factorization (k_T-factorization) [1]

$$d\sigma_{AB\to q\bar{q}} = \int d^2k_{AT}\frac{dx_A}{x_A}\mathcal{F}\left(x_A, k_{AT}\right) d^2k_{BT}\frac{dx_B}{x_B}\mathcal{F}\left(x_B, k_{BT}\right) d\hat{\sigma}_{g^*g^*}\left(\frac{\mu^2}{x_A x_B s}, \frac{k_{AT}}{\mu}, \frac{k_{AT}}{\mu}\right)$$

$$k_A^\nu = x_A\, p_A^\nu + k_{AT}^\nu \qquad\qquad k_B^\nu = x_B\, p_B^\nu + k_{BT}^\nu$$



- **Reduces to collinear factorization for s >> μ^2 >> k_T^2, but holds also for s >> μ^2 ~ k_T^2**
- Kinematical effects at leading order

[1] S. Catani, M. Ciafaloni and F. Hautmann, Nucl. Phys. B 366 (1991) 135.

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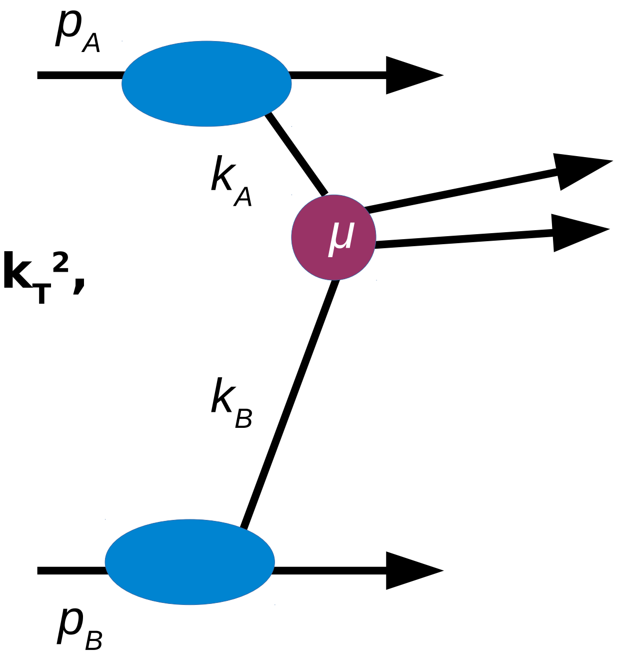
$$k_A^\nu = x_A\,p_A^\nu + \xcancel{k_{AT}^\nu} \qquad\qquad k_B^\nu = x_B\,p_B^\nu + k_{BT}^\nu$$

hybrid factorization



- **Reduces to collinear factorization for s >> m_2 >> k_T^2, but holds also for s >> m_2 ~ k_T^2**

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[1] S. Catani, M. Ciafaloni and F. Hautmann, Nucl. Phys. B 366 (1991) 135.

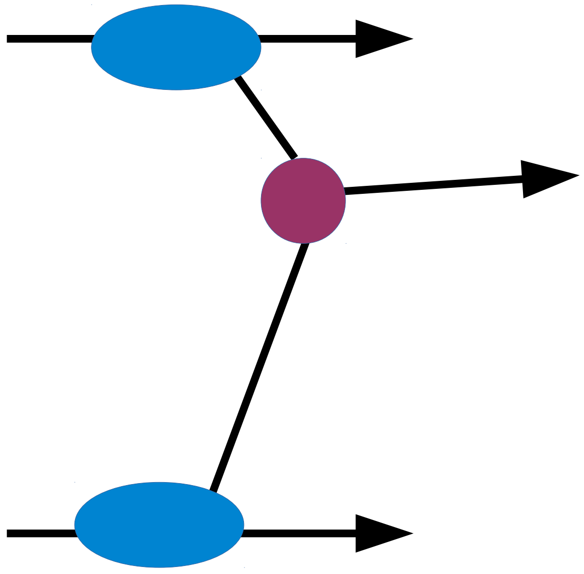
TMDs/uPDFs

- **KS non-linear [2] – unintegrated gluon density from an extension of the BK equation (includes kinematic constraint, non-singular pieces of the splitting functions, contributions from sea quarks)**
- **KS linear – linearized version of the above**
- **KS hardscale non-linear [3] – KS non-linear + Sudakov resummation**
- **KS hardscale linear – linearized version of the above**
- **DLC2016 [4] – gluon and quark TMDs from collinear PDFs using the KMR prescription [5]**

[2] K. Kutak and S. Sapeta, Phys. Rev. D 86 (2012) 094043.
[3] K. Kutak, Phys. Rev. D 91 (2015) no.3, 034021.
[4] K. Kutak, R. Maciula, M. Serino, A. Szczurek and A. van Hameren, arXiv:1602.06814 [hep-ph].
[5] M. A. Kimber, A. D. Martin and M. G. Ryskin, Eur. Phys. J. C 12 (2000) 655

Single inclusive forward jet

Hybrid factorization used



$$A + B \mapsto a + b \to \mathrm{jet} + X$$

Cross section

$$\frac{d\sigma}{dy_{\mathrm{jet}}\, dp_{t,\mathrm{jet}}} = \frac{1}{2} \frac{\pi\, p_{t,\mathrm{jet}}}{(x_1 x_2 s)^2} \sum_{a,b,c} \overline{|\mathcal{M}_{ab^* \to c}|}^2 x_1 f_{a/A}(x_1, \mu^2)\, \mathcal{F}_{b/B}(x_2, p_{t,\mathrm{jet}}^2, \mu^2)$$

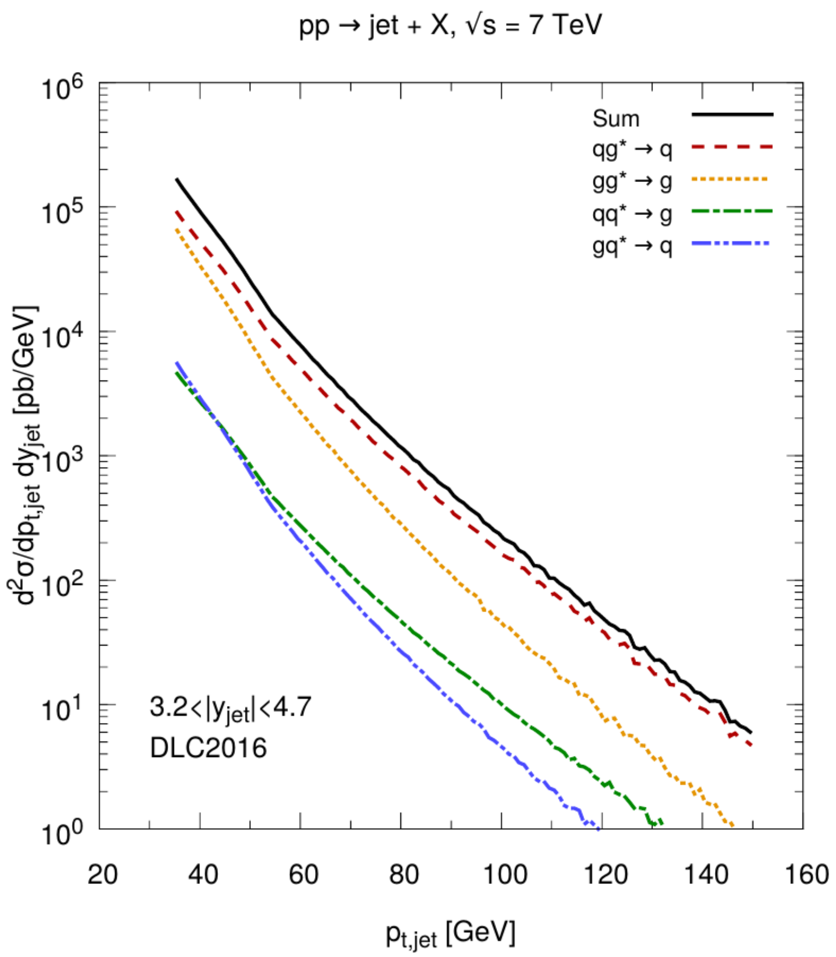
Single jet production – Jet selection

$3.2 < y < 4.7$

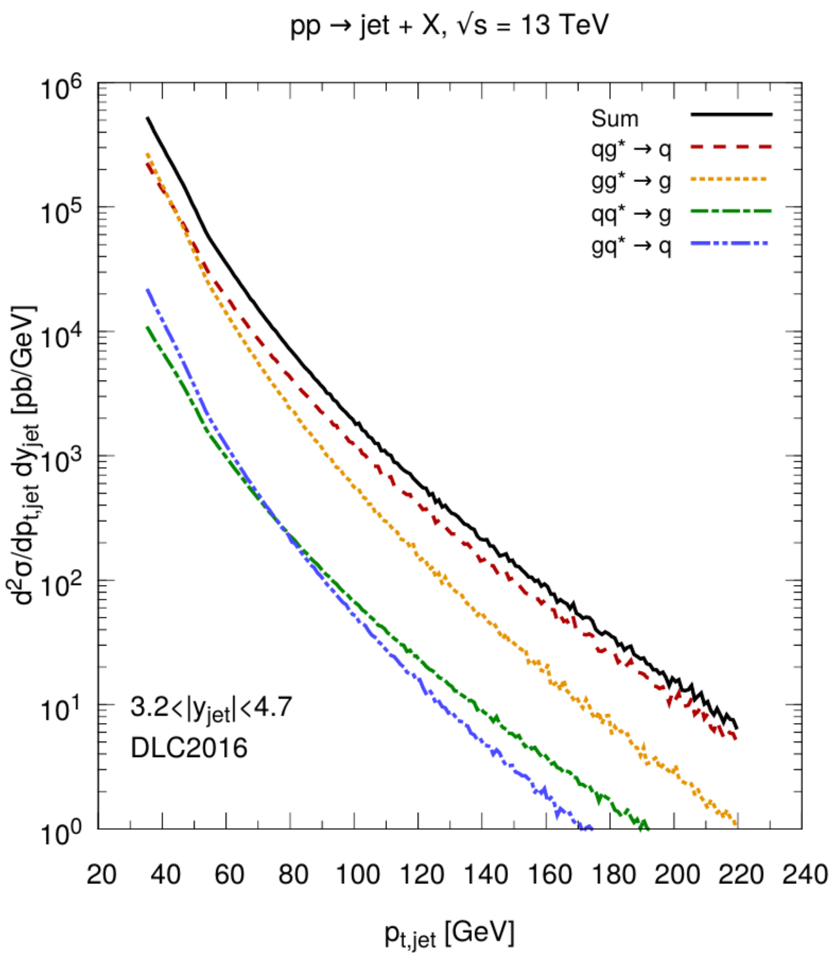
$p_T > 20$ GeV

- **Anti-k_T algorithm, R=0.5**

Single jet production – Contributing channels



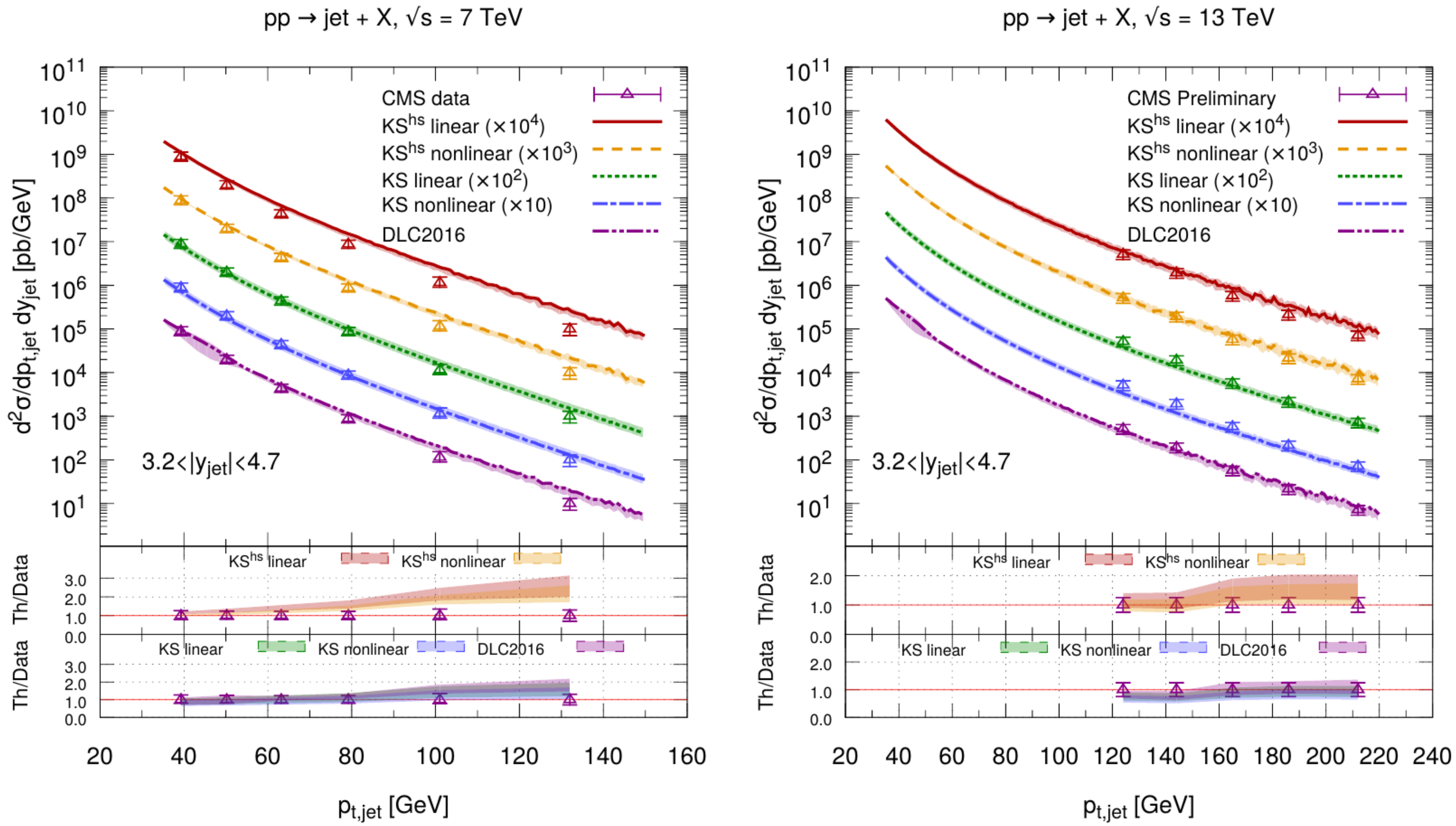
pp → jet + X, √s = 7 TeV



pp → jet + X, √s = 13 TeV

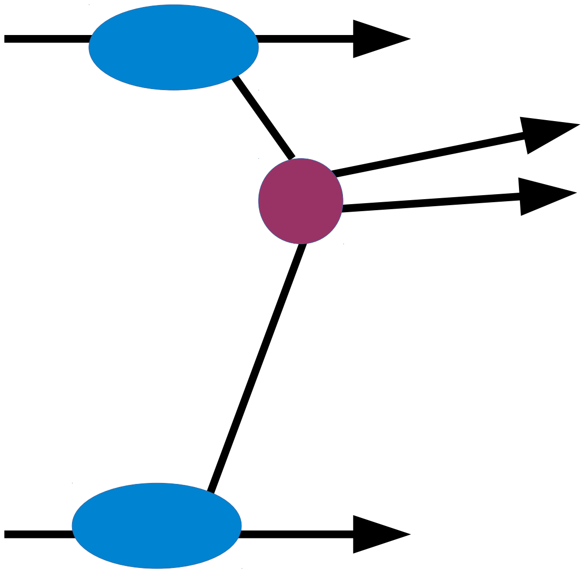
Single jet production vs. data

JHEP06(2012)036, arXiv:1202.0704 [hep-ex]



Forward inclusive dijet

SPS contribution



$$A + B \mapsto a + b \to \text{jet} + \text{jet} + X$$

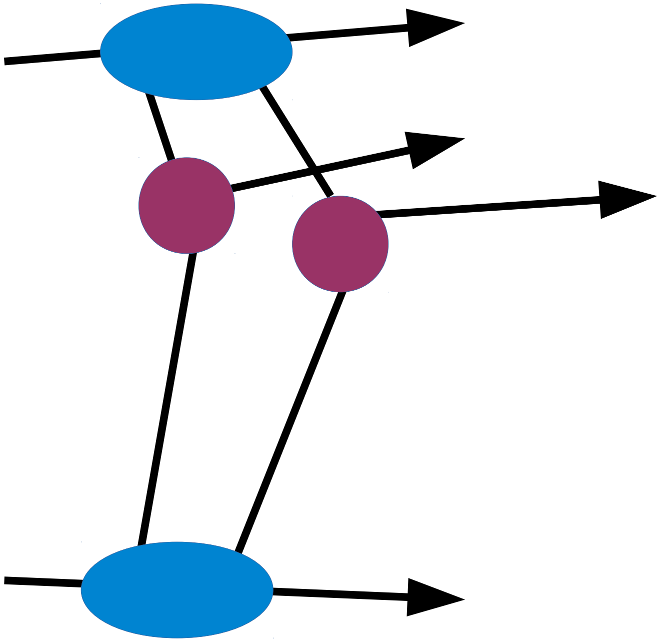
Cross section

$$\frac{d\sigma_{\text{SPS}}^{pA\to\text{dijets}+X}}{dy_1 dy_2 dp_{1t} dp_{2t} d\Delta\phi} = \frac{p_{1t}p_{2t}}{8\pi^2(x_1x_2s)^2}\sum_{a,c,d} x_1 f_{a/p}(x_1,\mu^2)\,|\overline{\mathcal{M}_{ag^*\to cd}}|^2 \mathcal{F}_{g/A}(x_2,k_t^2)\frac{1}{1+\delta_{cd}}$$

Forward inclusive dijet

DPS contribution

$$A + B \mapsto a_1 + b_1 + a_2 + b_2 \to \text{jet} + \text{jet} + X$$



Cross section

$$\frac{d\sigma_{\text{DPS}}^{pA\to \text{dijets}+X}}{dy_1 d^2p_{1t} dy_2 d^2p_{2t}} = \frac{1}{\sigma_{\text{effective}}} \frac{d\sigma}{dy_1 d^2p_{1t}} \frac{d\sigma}{dy_2 d^2p_{2t}}$$

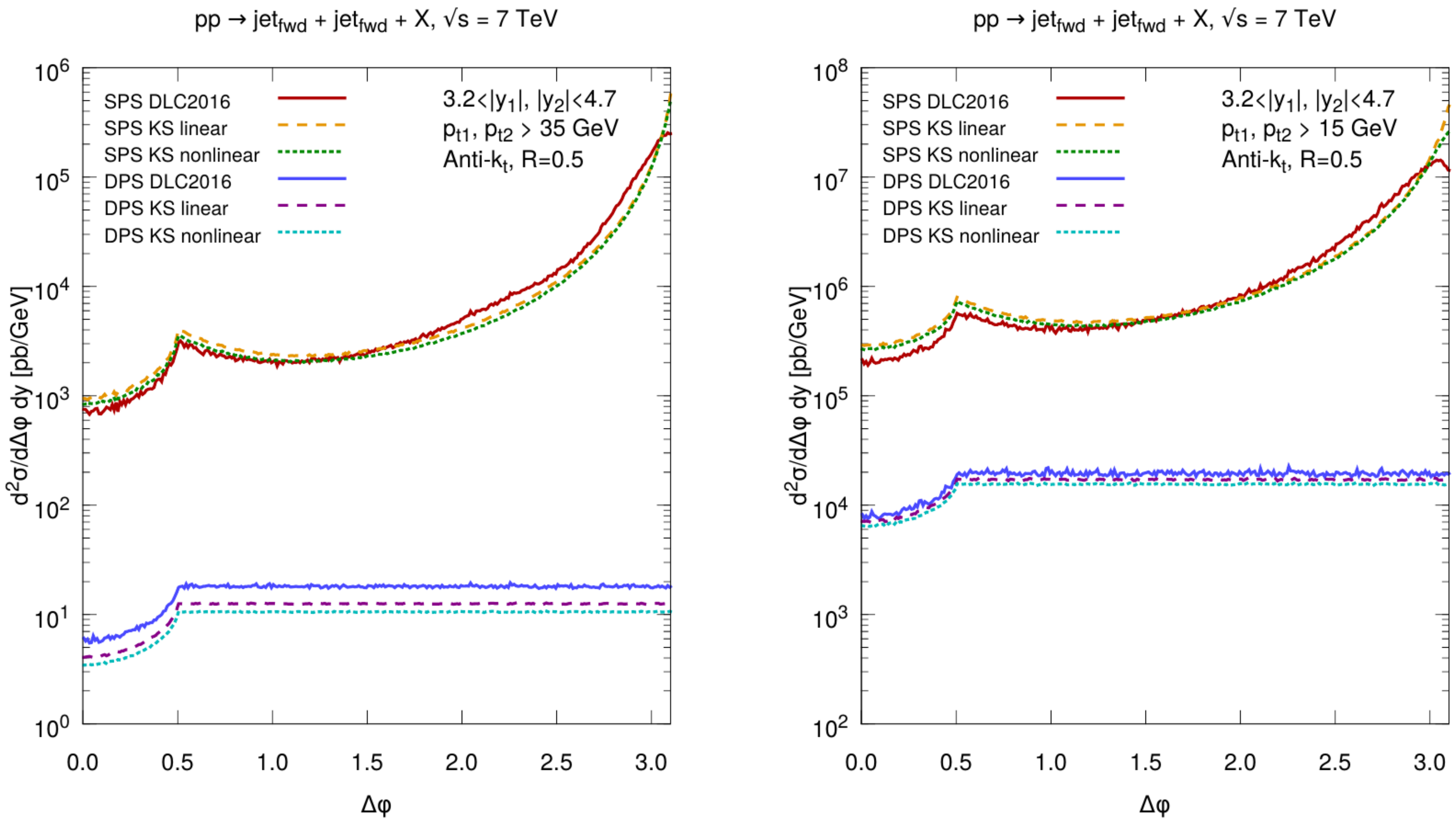
Dijet forward production – Jet selection

$3.2 < y_1, y_2 < 4.7$

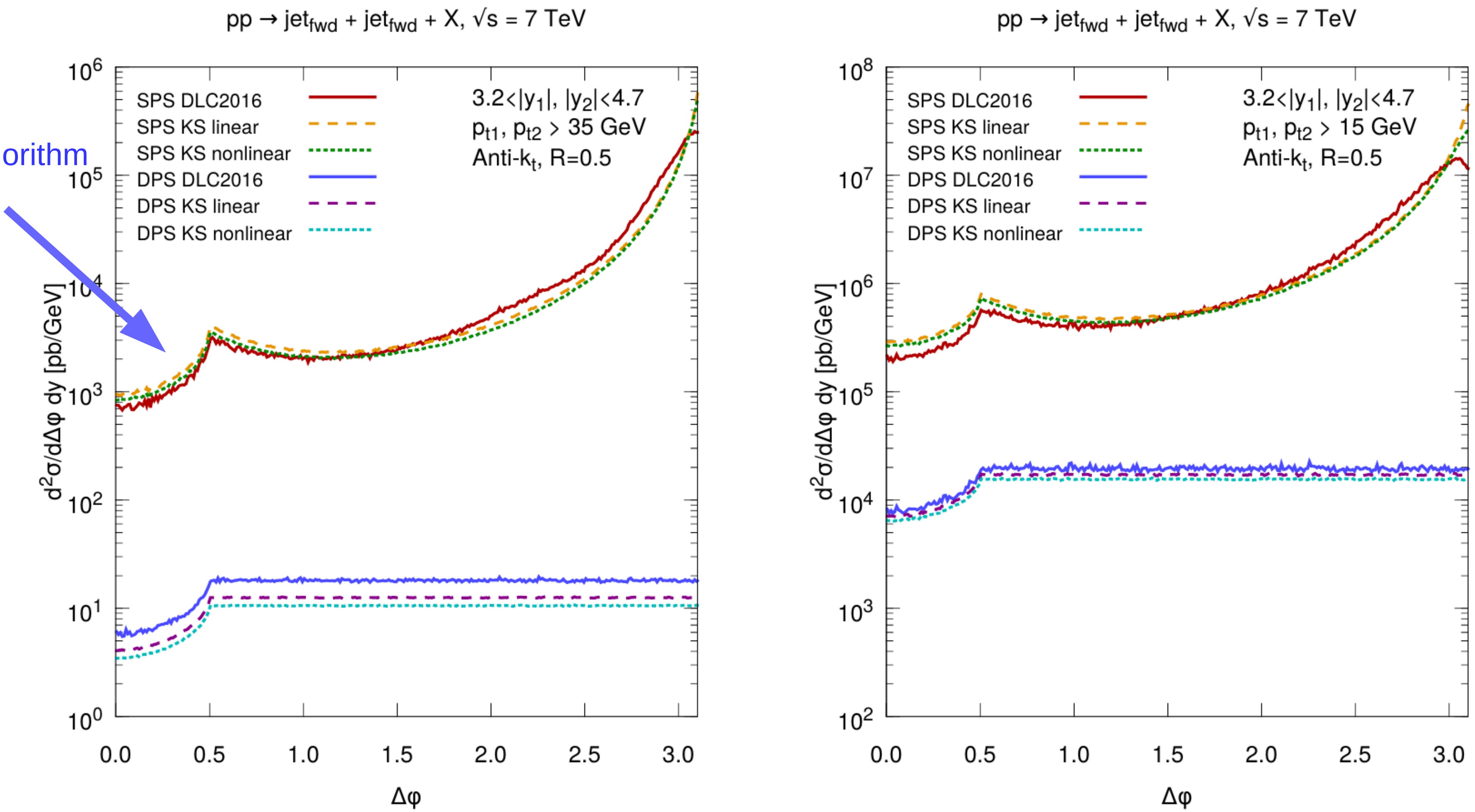
$p_{T\ 1,2} > 5, 10, 15, 35$ GeV

- Anti-k_T algorithm, R=0.5

Forward dijet production

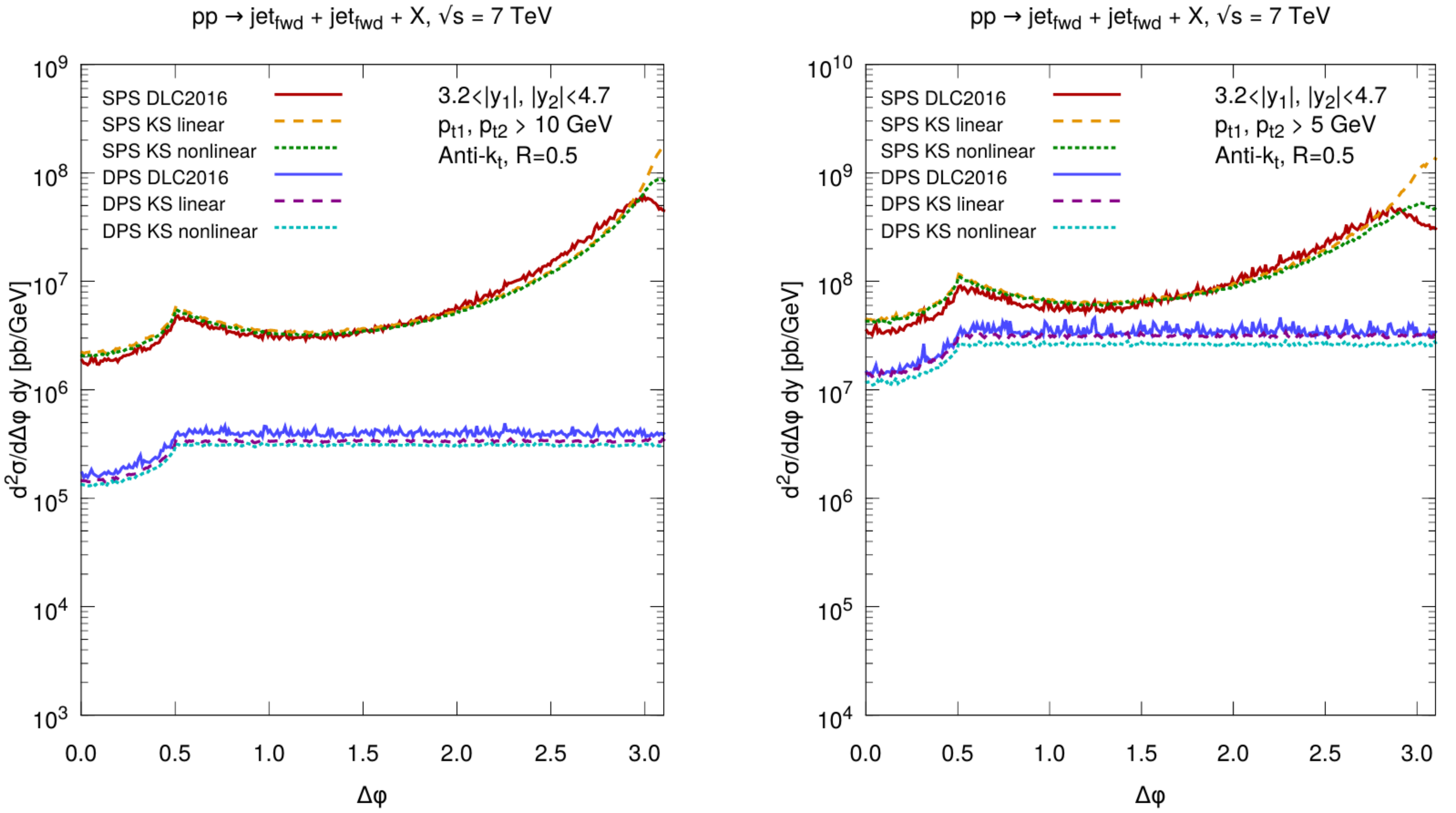


Forward dijet production



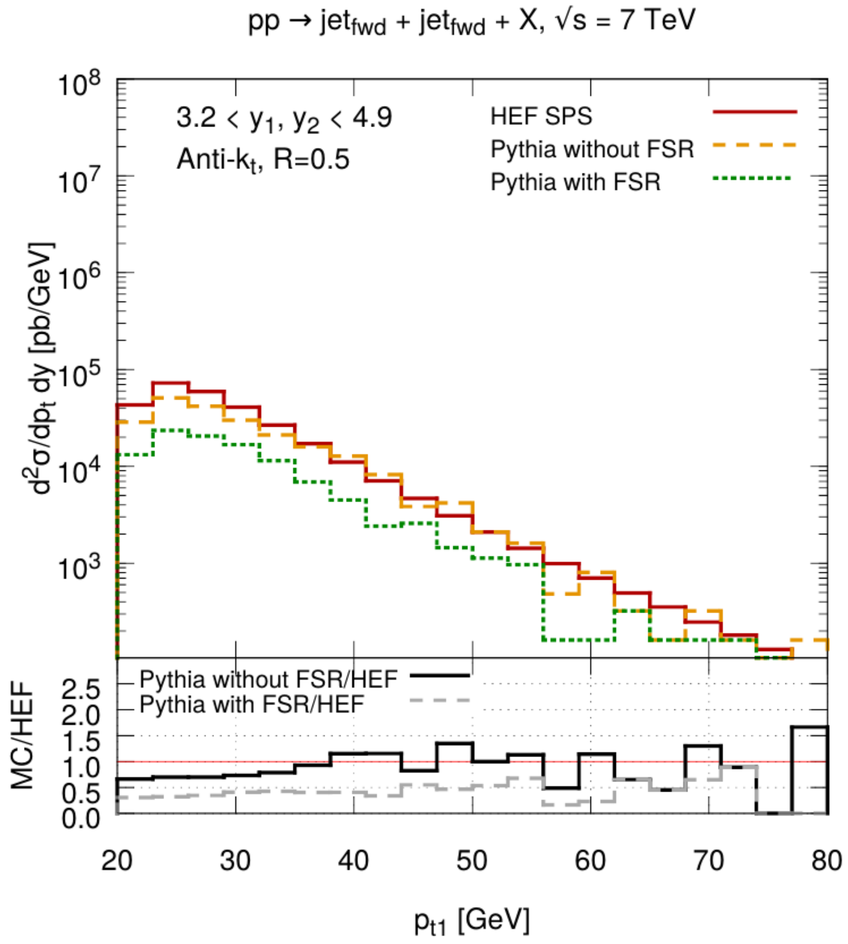
Jet algorithm effect

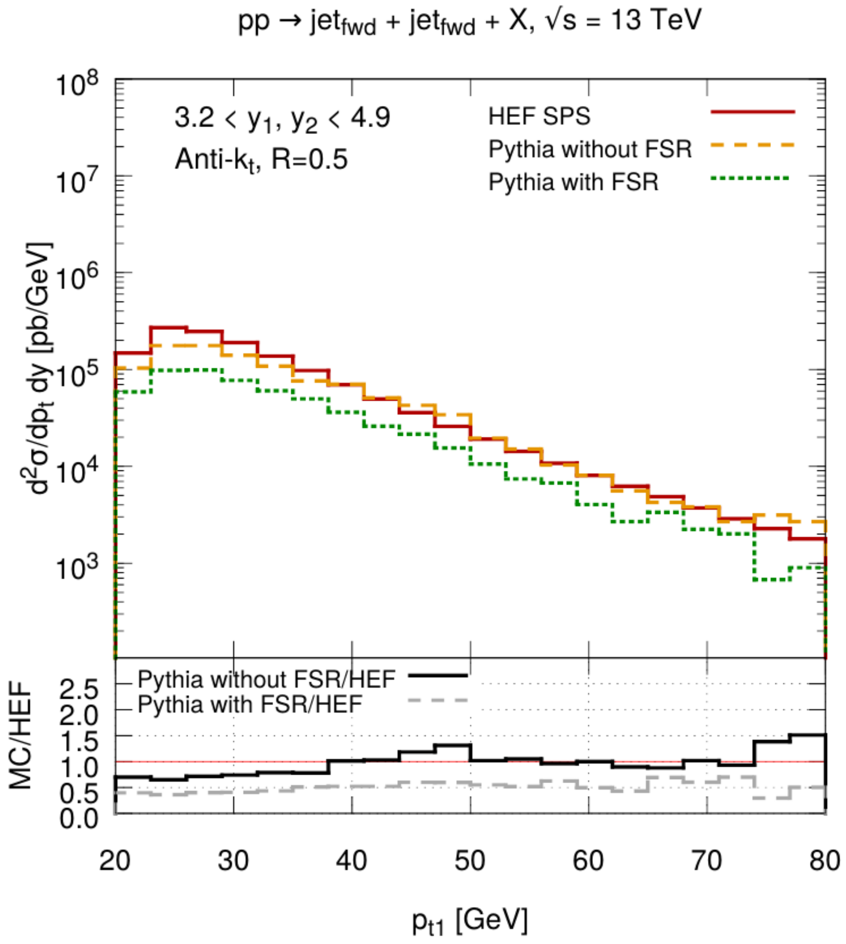
Forward dijet production



Dijets – HEF vs. Pythia

by switching off the FSR HEF and Pythia get closer





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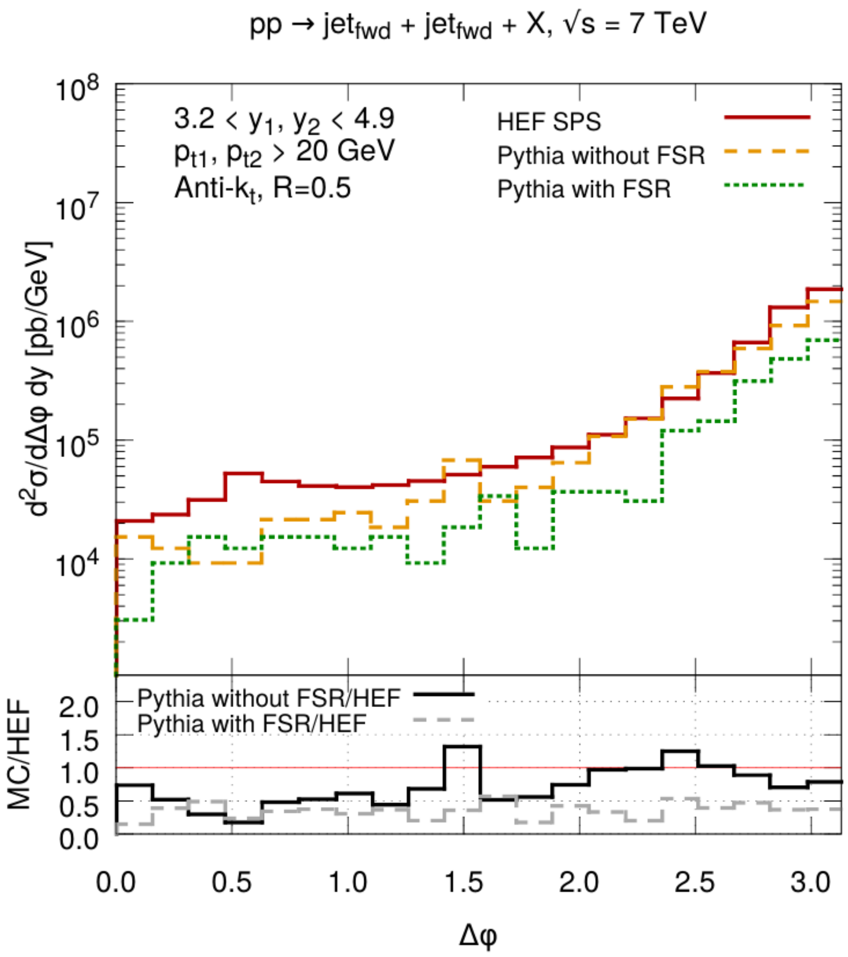

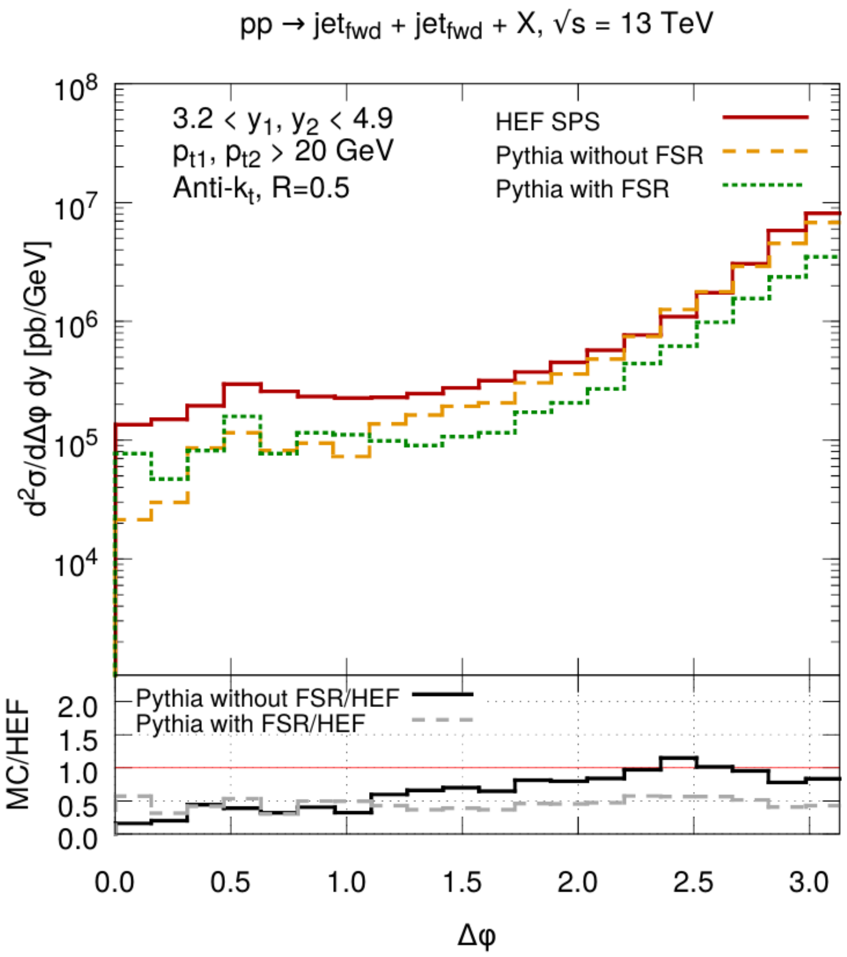

Conclusions and Outlook

- 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 in experimentally relevant phase space region.