TMD parton distributions parton shower MCs

Hannes Jung (DESY)

- Why TMDs at small AND large k_t are needed

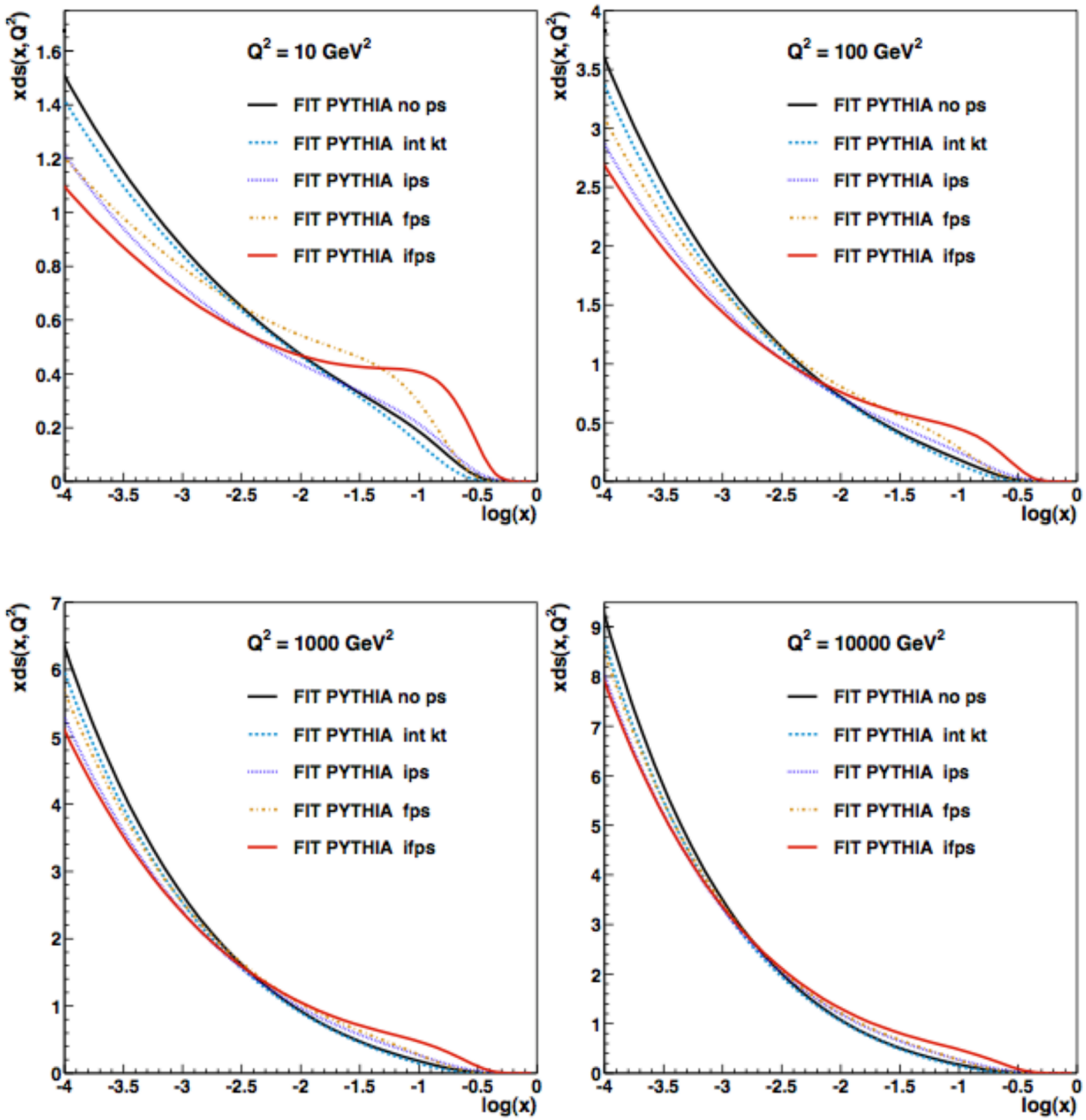
- TMDs from shower MC event generators

Kinematic effects in PDF determination

Determination of parton density functions using Monte Carlo event generator Federicon Samson-Himmelstjerna /afs/desy.de/group/h1/psfiles/theses/h1th-516.pdf

- perform fits to F_2 using a Monte Carlo event generator which includes parton showers and intrinsic k_t
- the resulting PDFs agree with standard LO ones if no PS and intrinsic k_t is applied.
- the final PDFs are different because of kinematic effects coming from transverse momenta of PS and intrinsic k_t

Remember the "old" discussion on parton shower for DIS in LEPTO/PYTHIA



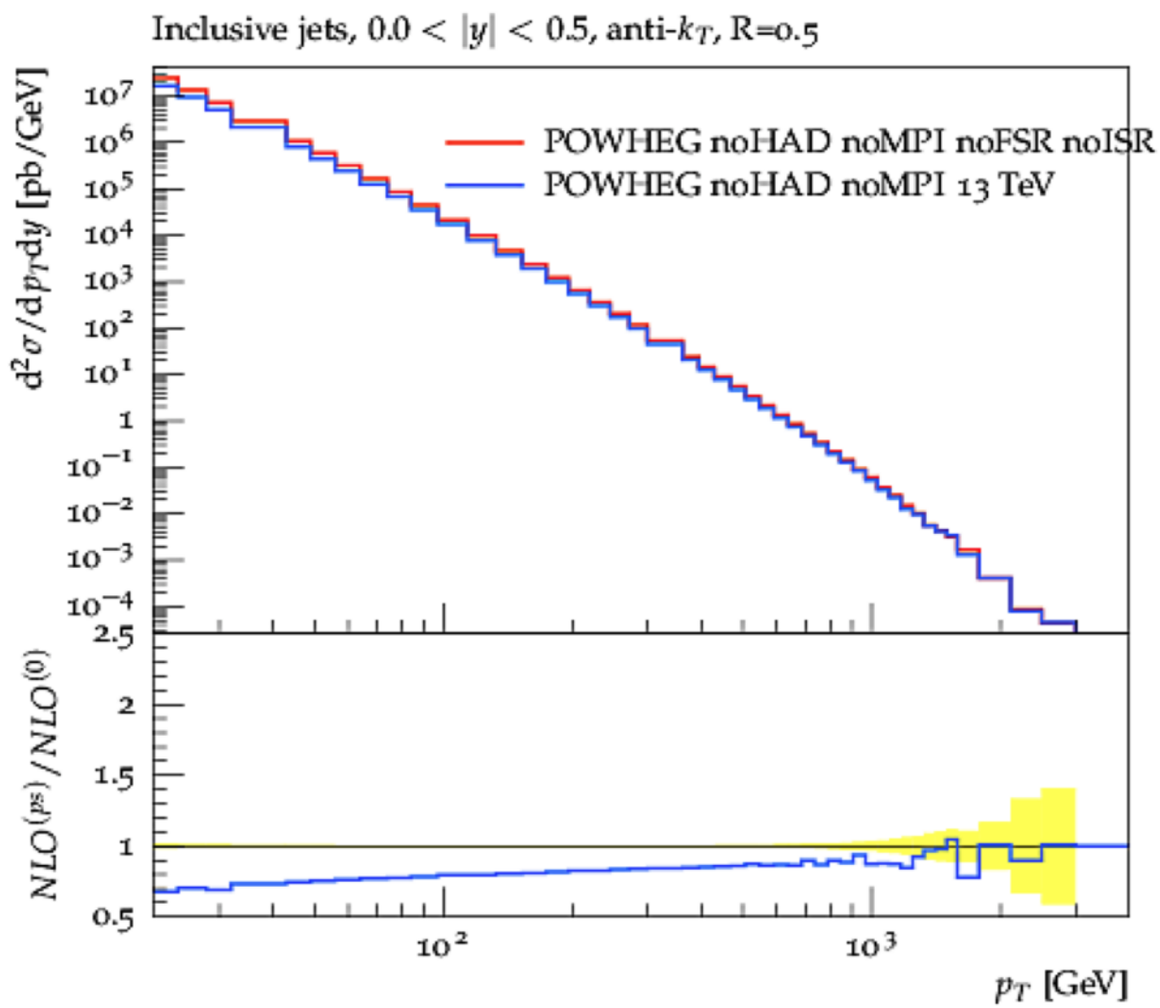
Parton shower corrections

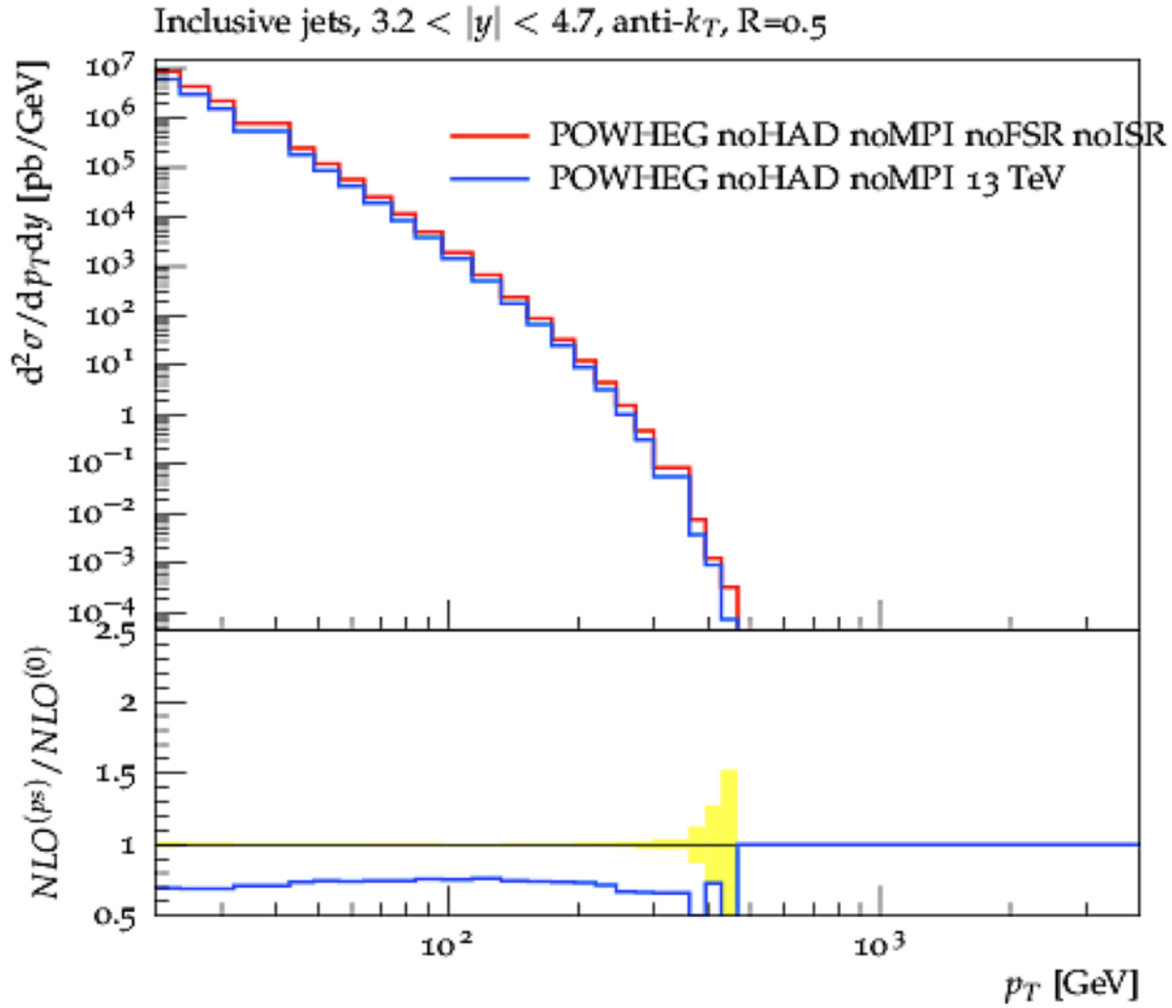
- use NLO+PS to calculate:

$$K^{PS} = \frac{N^{(ps)}_{NLO-MC}}{N^{(0)}_{NLO-MC}}$$

Approach described in: S. Dooling et al
Phys.Rev., D87:094009, 2013.

- Corrections to be applied to fixed order NLO calculations:
  - kinematic effects: TMDs !
  - radiation outside of jet-cone





Factorization breaking effects in pp

- factorization breaking in $pp \to j_1\, j_2\, X$

  J. Collins, J.W. Qiu hep-ph 0705.2141

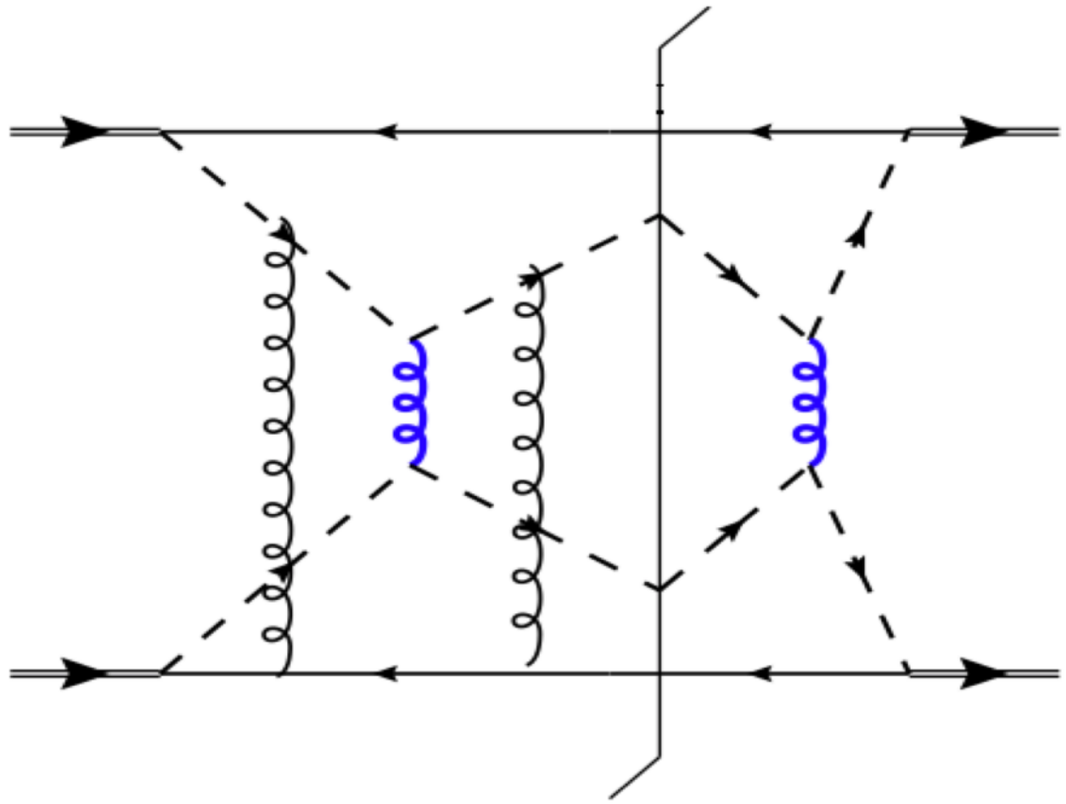


FIG. 8 (color online). The exchange of two extra gluons, as in this graph, will tend to give nonfactorization in unpolarized cross sections.

Factorization breaking in heavy quark production ?

- Compare fixed NLO calculation of top production with resummed calculation from Monte Carlo

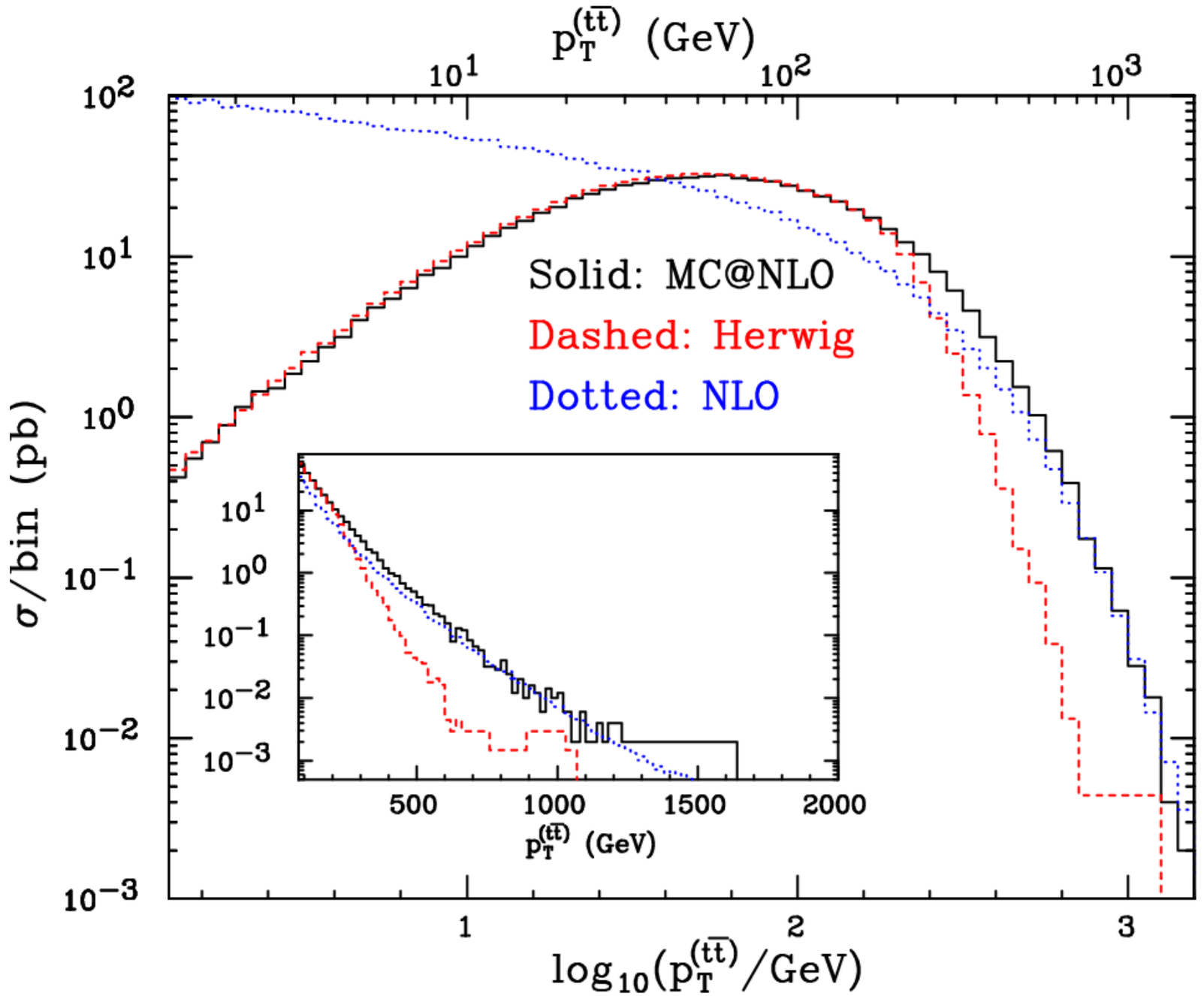
- factorization breaking also in tt production at large p_t^{top} ?

S. Catani, M. Grazzini, and A. Torre. Transverse-momentum resummation for heavy-quark hadroproduction. arXiv 1408.4564

- where does this show up ?

- Is this included in PS approaches ?

Frixione et al, hep-ph/035252



TMDs from Monte Carlo event generators

- Transverse momentum effects are naturally coming from intrinsic k_t and parton showers

- TMD effects can be significant in all distributions, even for inclusive (or semi-inclusive) distributions at large pt

TMDs from Monte Carlo event generators

- Transverse momentum effects are naturally coming from intrinsic k_t and parton showers

- TMD effects can be significant in all distributions, even for inclusive (or semi-inclusive) distributions at large pt

- Can we extract an effective TMD from standard MC parton shower generators ?

  - Project started with summer-students 2015/2016:
    - **Pamela Ornelas Silva, Jose Fragoso Negrin, Tania Martinez Cortes, Aleksandra Lelek**
    - **with help from T. Sjostrand on PYTHIA**

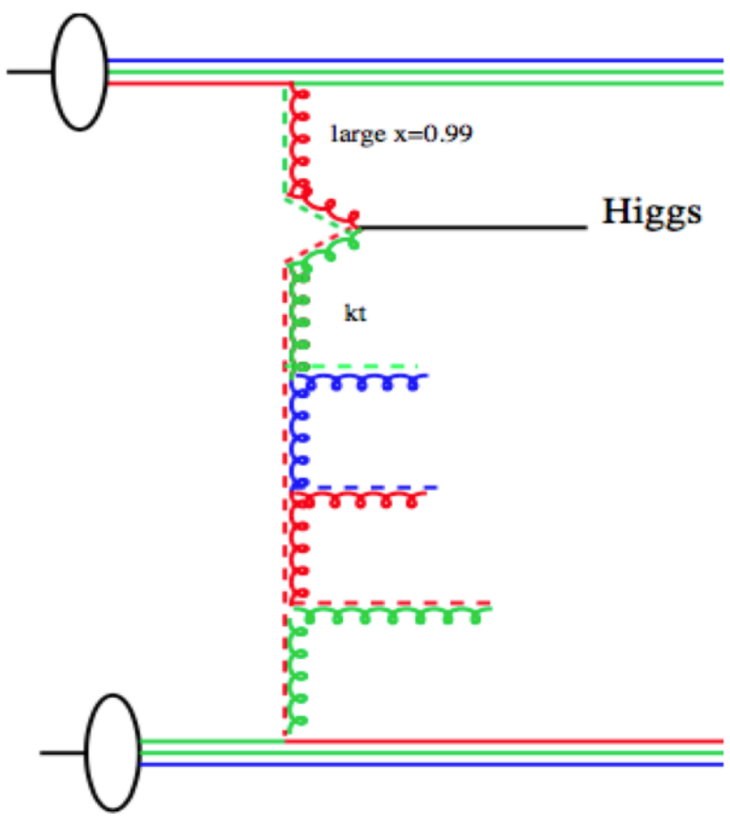
TMD effects from MC parton shower generators

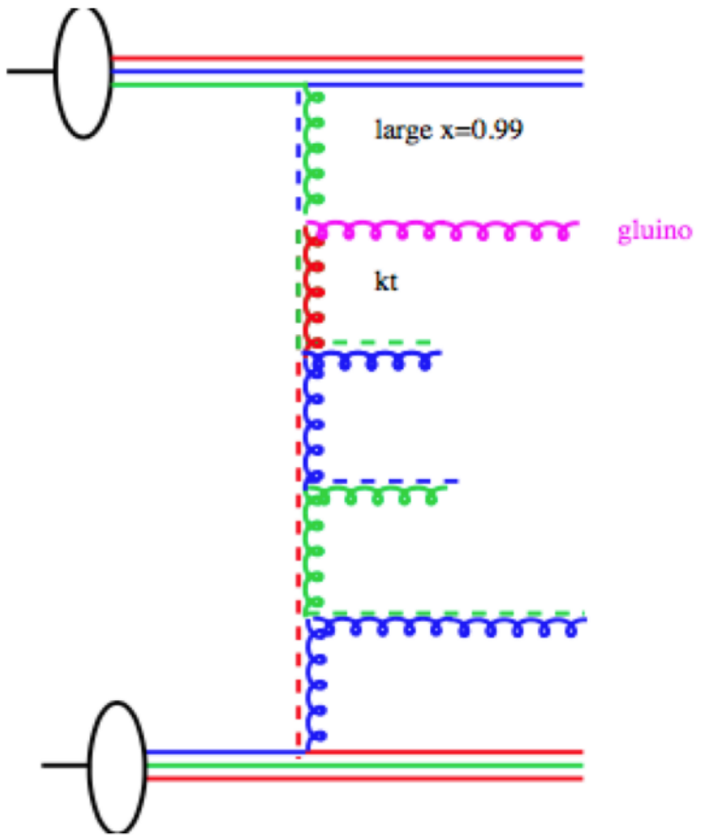
- Goal: define TMD from MC parton shower generator
  - interest only in parton shower – NOT in hard process
  - define a simple “hard process”, from which one can easily calculate kinematics, just using 4-vectors:
    - k_t, x and μ^2

TMD effects from MC parton shower generators

- Goal: define TMD from MC parton shower generator
  - Define a simple processes (for identifying hard probe after shower):
    - $gg \to H$ for a color singlet final state
    - $gg \to \tilde{g}$ for a color octed final state
  - do not rely on generator internal quantities, reconstruct k_t and x from 4-vector
  - fix $x_1 = 0.99$ (no intrinsic k_t, no PS from parton 1), mass 0.5< m <1000 GeV

Idea Z. Nagy: study factorization breaking effects





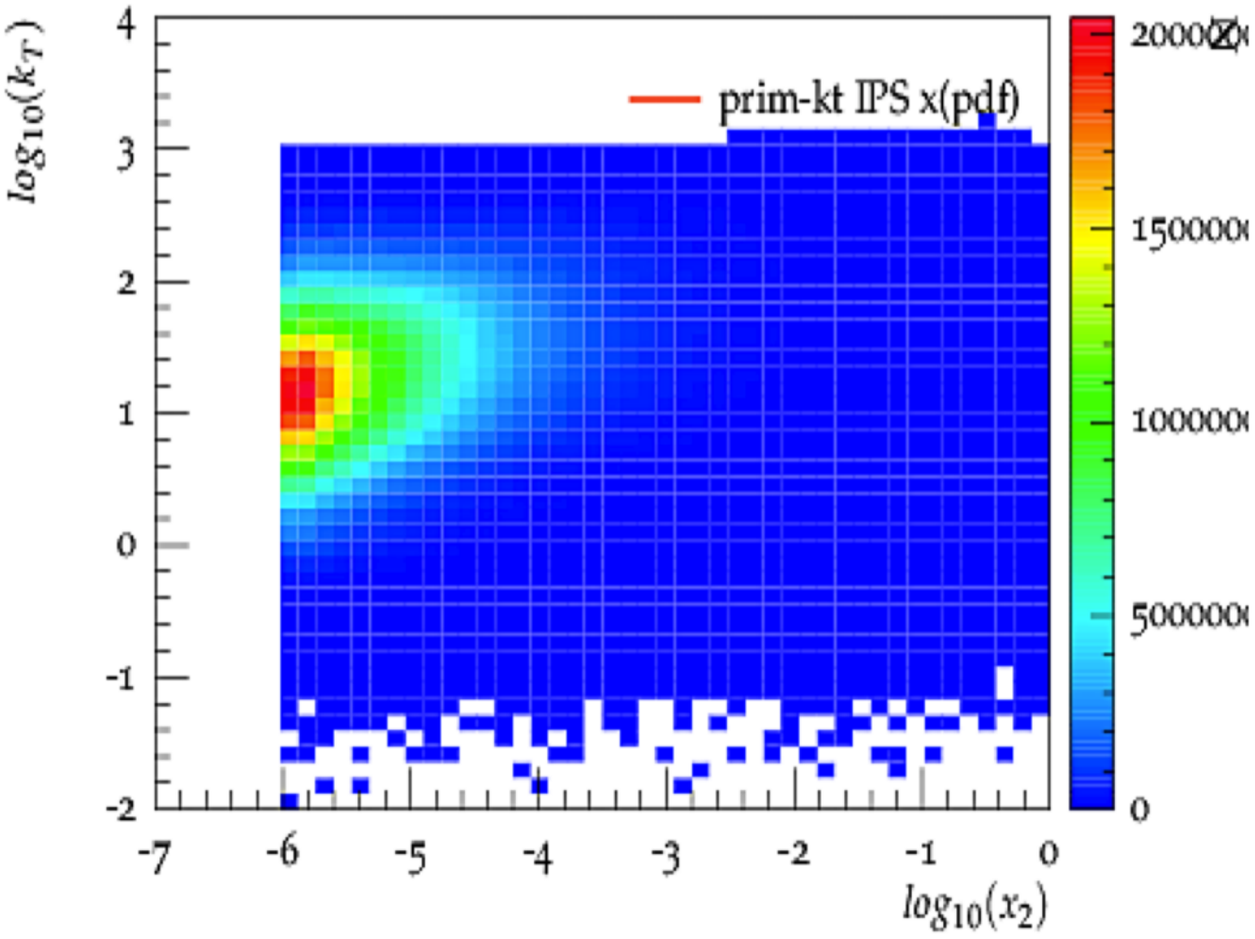
The effect of initial state parton shower

fix $x1 = 0.99$ (no intrinsic k_t, no PS from parton 1), mass 0.5< m <1000 GeV

- momentum fraction definition:
  - **from mass (or original pdf):**

$$x = \frac{m}{\sqrt{s}} \exp(\pm y)$$

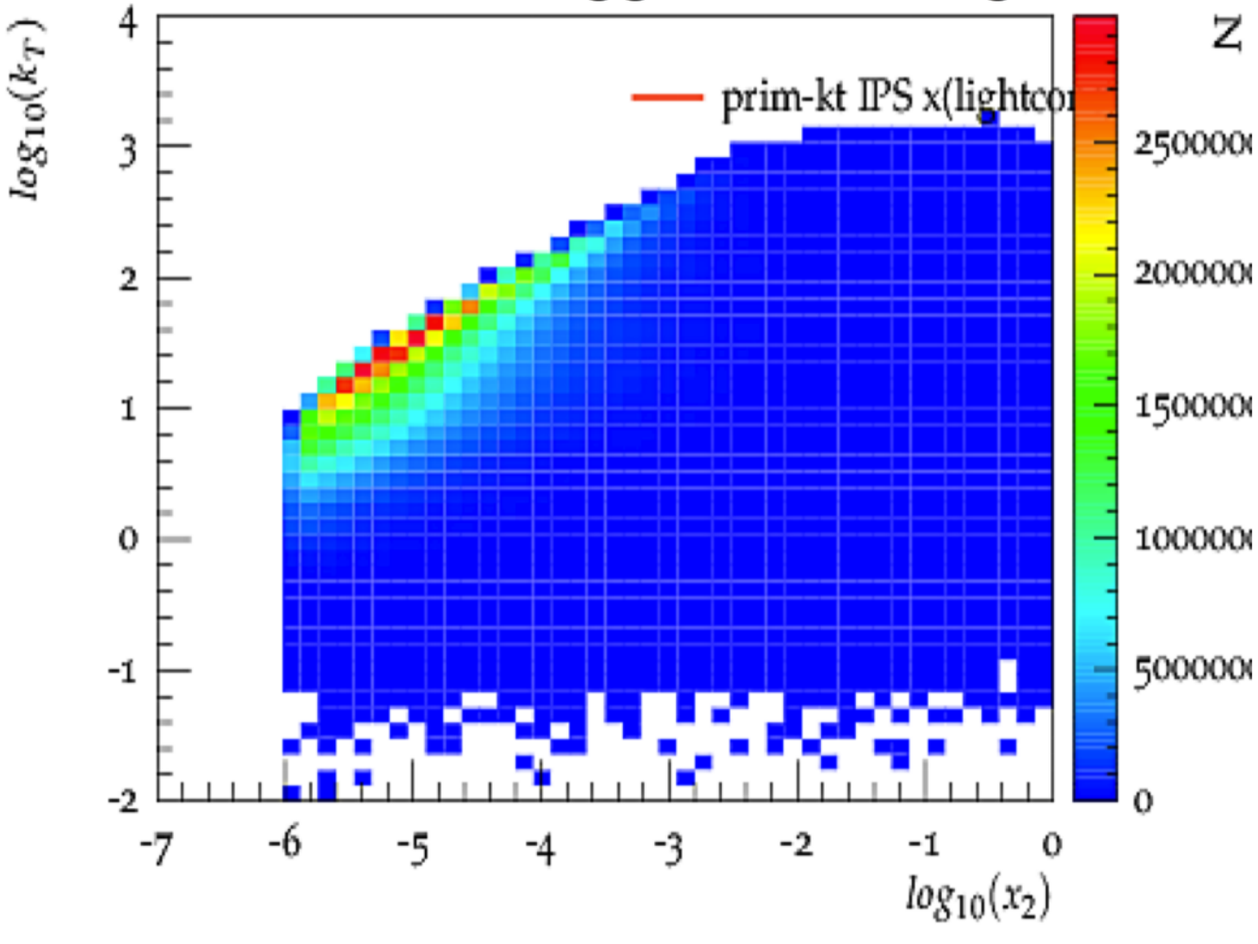
TMDfromMC **Higgs: color-singlet**



- from light-cone momentum fraction:

$$x = \frac{E + p_z}{(E + p_z)_{beam}}$$

TMDfromMC **Higgs: color-singlet**



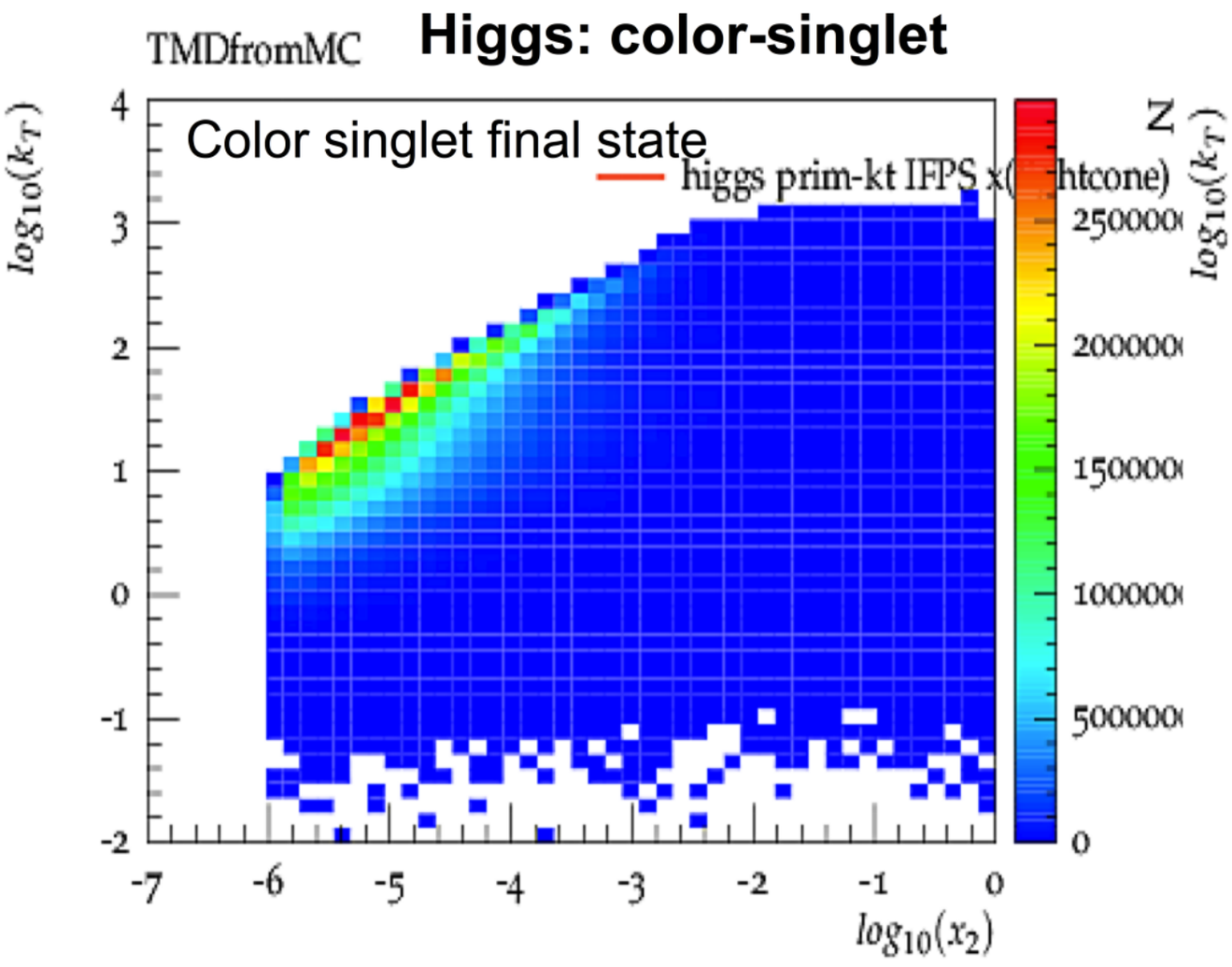
- Significant differences from definition of momentum fraction after k_t

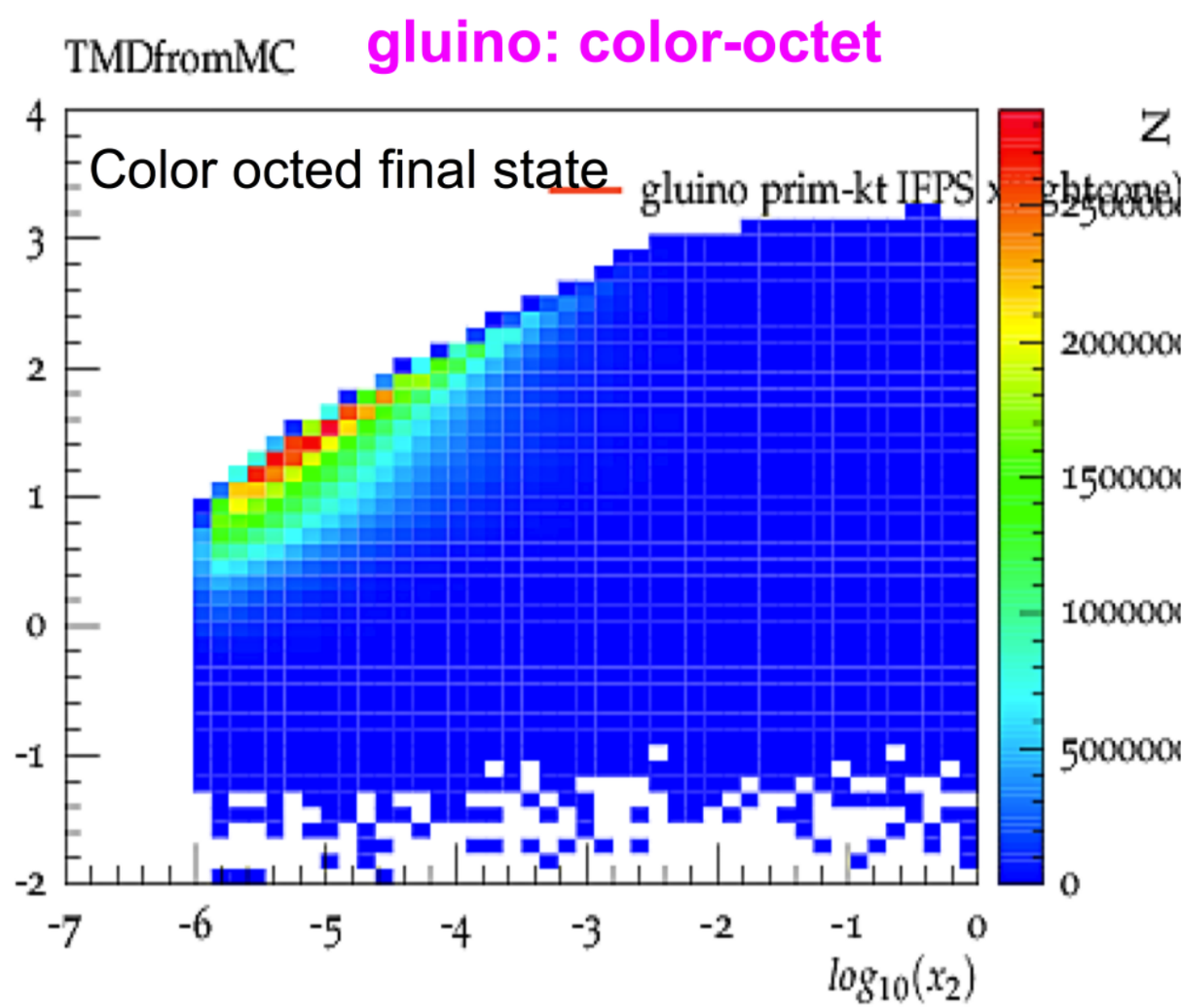
The effect of initial & final state parton shower

fix $x_1 = 0.99$ (no intrinsic k_t, no PS from parton 1), mass 0.5< m <1000 GeV

- momentum fraction definition:
- from light-cone momentum fraction:

$$x = \frac{E + p_z}{(E + p_z)_{beam}}$$

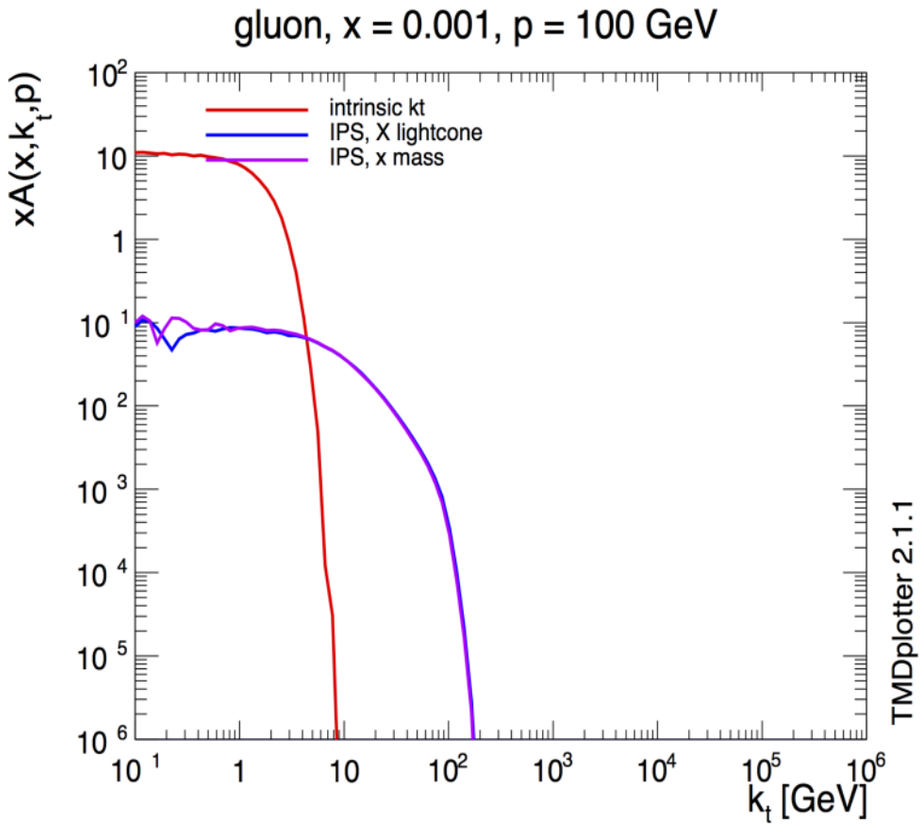


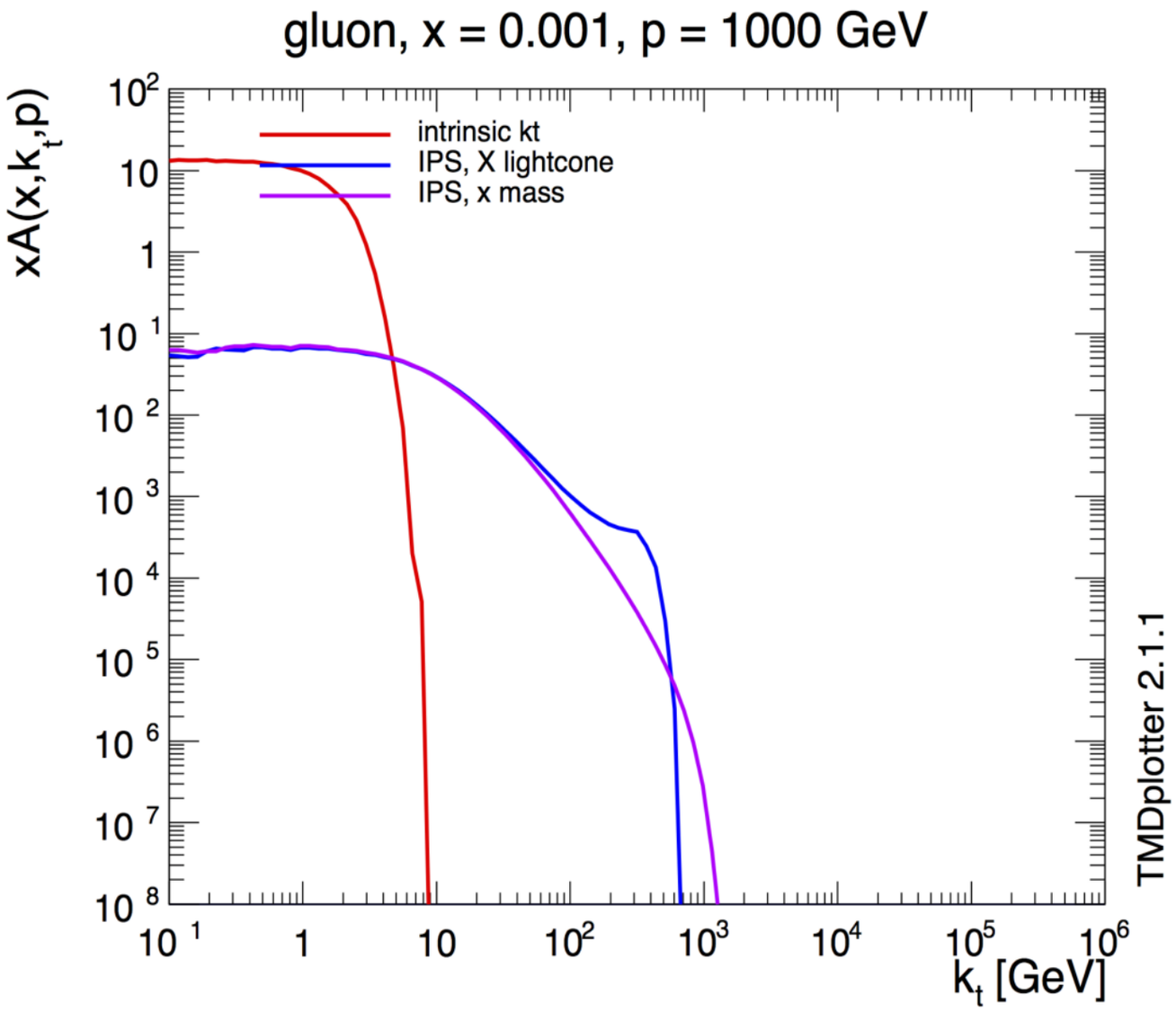


- in PYTHIA8, no difference in k_t for color-singlet or color-octet !

TMDfromMC: initial parton shower TMD (PYTHIA8)

- Use processes defined before (Higgs) to extract real TMD form MC:
  - **determine quark and gluon TMDs (here only gluon is investigated)**



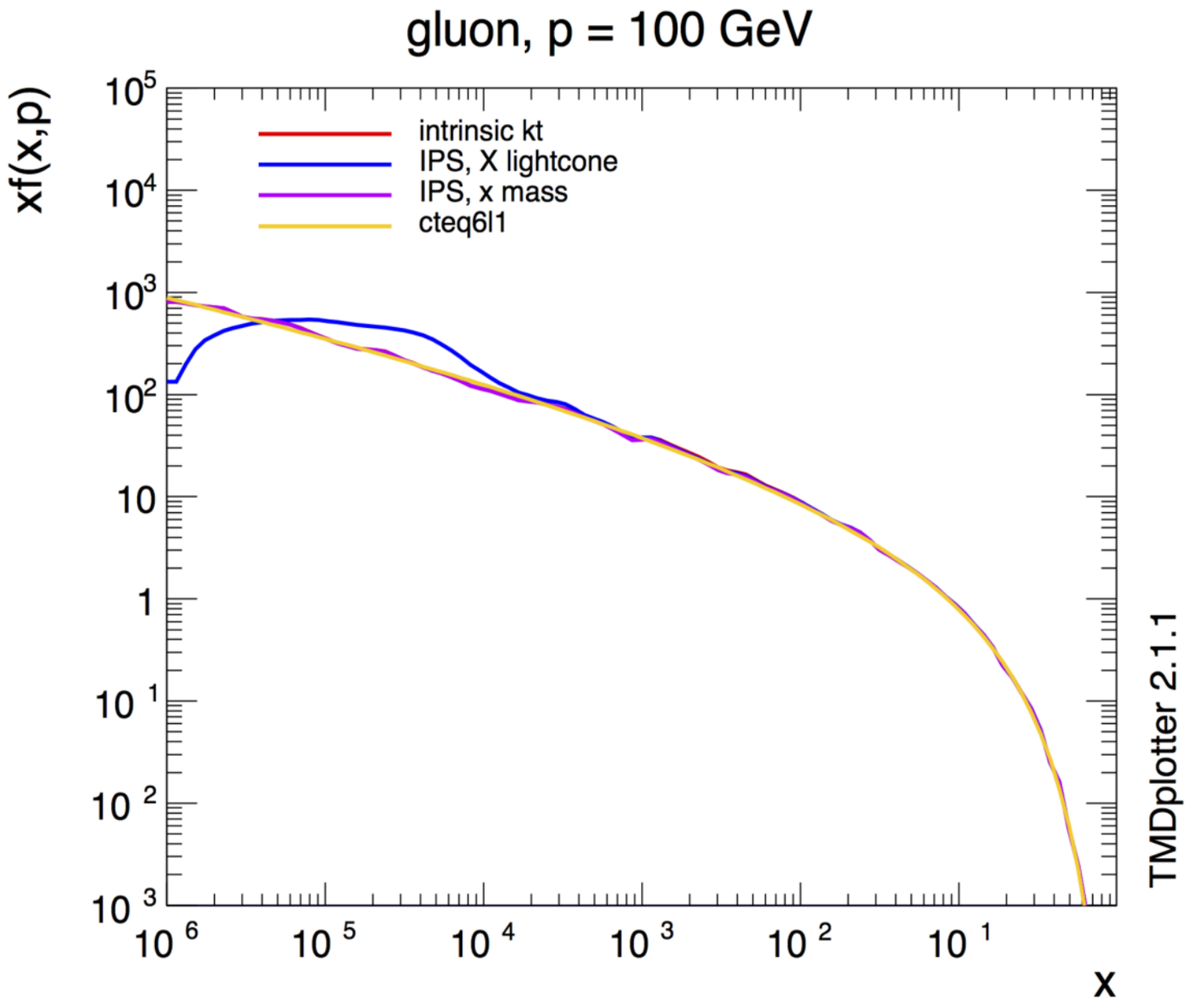


- Effect of x-definition visible at large scales and small x !

TMDfromMC: integrated

- Does one get back integrated pdf ?
  - **using** $x = \frac{m}{\sqrt{s}} \exp(\pm y)$

    μ=100 GeV
  - **but not** $x = \frac{E + p_z}{(E + p_z)_{beam}}$

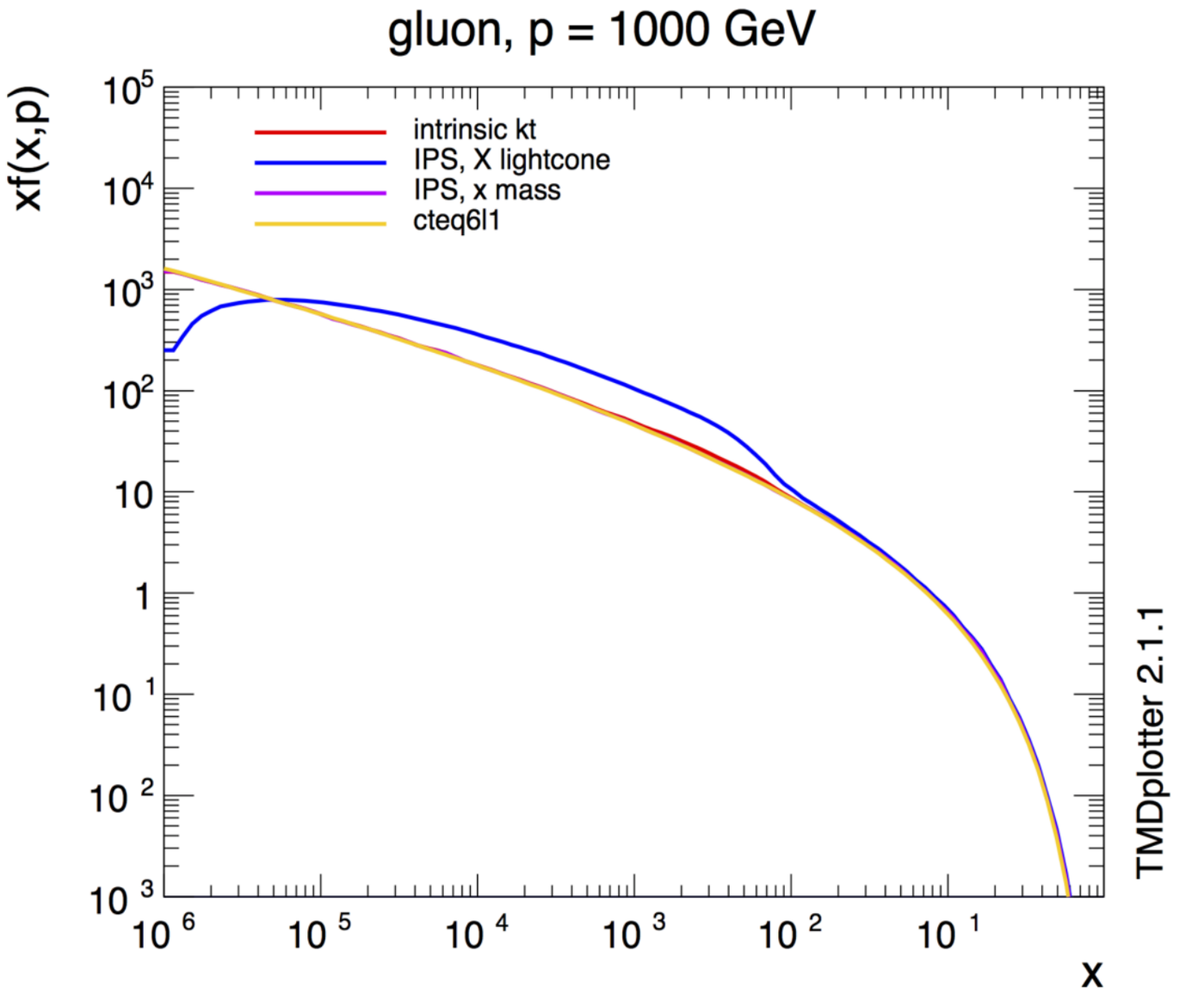


- Effect of x-definition visible at small x, even for integrated distribution !

TMDfromMC: integrated

- Does one get back integrated pdf ?
  - **using** $x = \frac{m}{\sqrt{s}} \exp(\pm y)$

    μ=100 GeV
  - **but not** $x = \frac{E + p_z}{(E + p_z)_{beam}}$

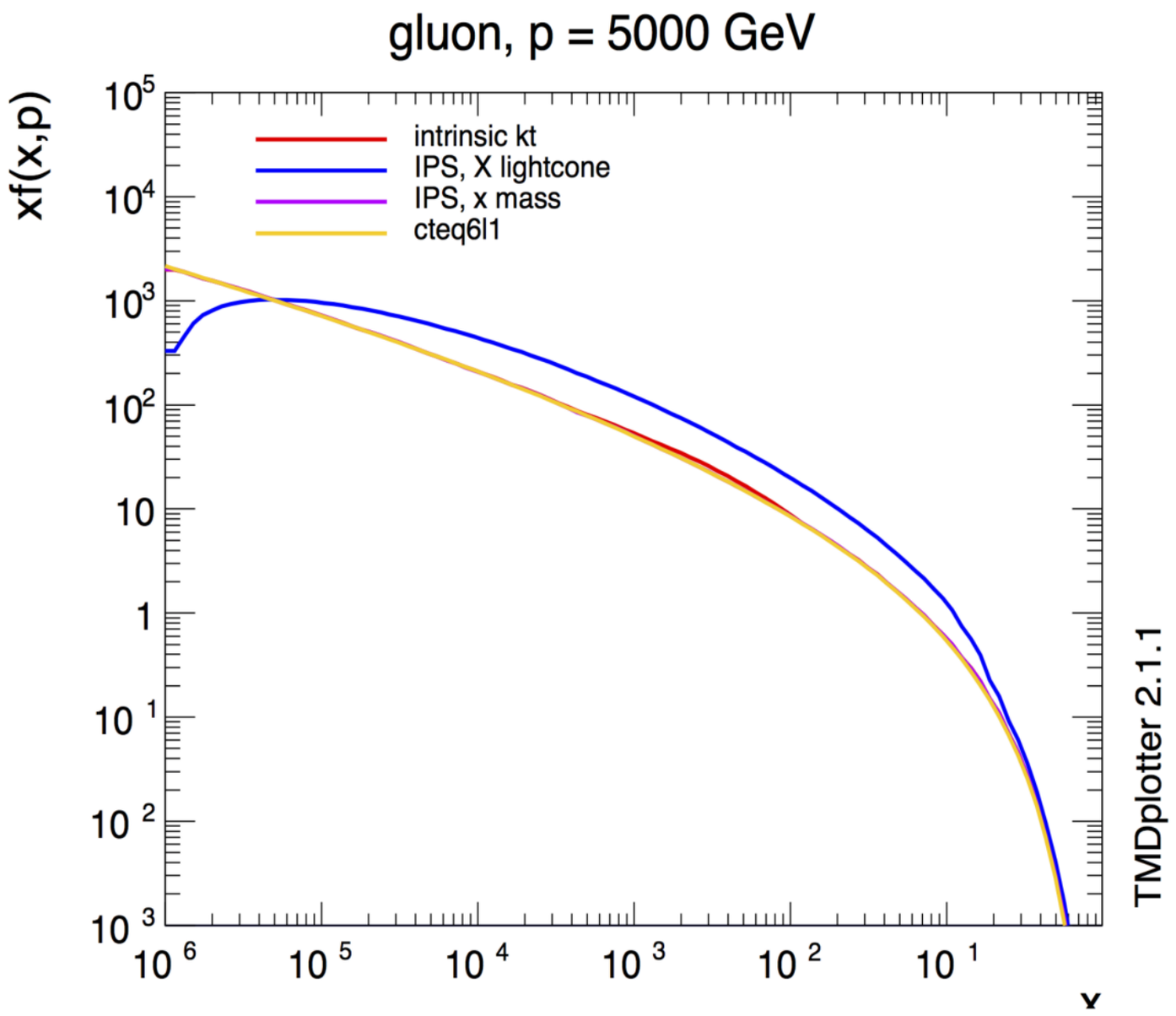


- Effect of x-definition visible at larger x, even for integrated distribution !

TMDfromMC: integrated

- Does one get back integrated pdf ?
  - **using** $x = \frac{m}{\sqrt{s}} \exp(\pm y)$

    μ=100 GeV
  - **but not** $x = \frac{E + p_z}{(E + p_z)_{beam}}$



- Effect of x-definition visible at large x, even for integrated distribution !

Conclusion

- TMDs (parton shower effects) are important for most observables

- TMDs can be determined by shower MCs:
  - TMDfromPS can be obtained from different PS generators, including color coherence and color exchange effects
  - TMDfromPS allows an easy and direct comparison of effects from shower (without the complication of the hard process)

Appendix

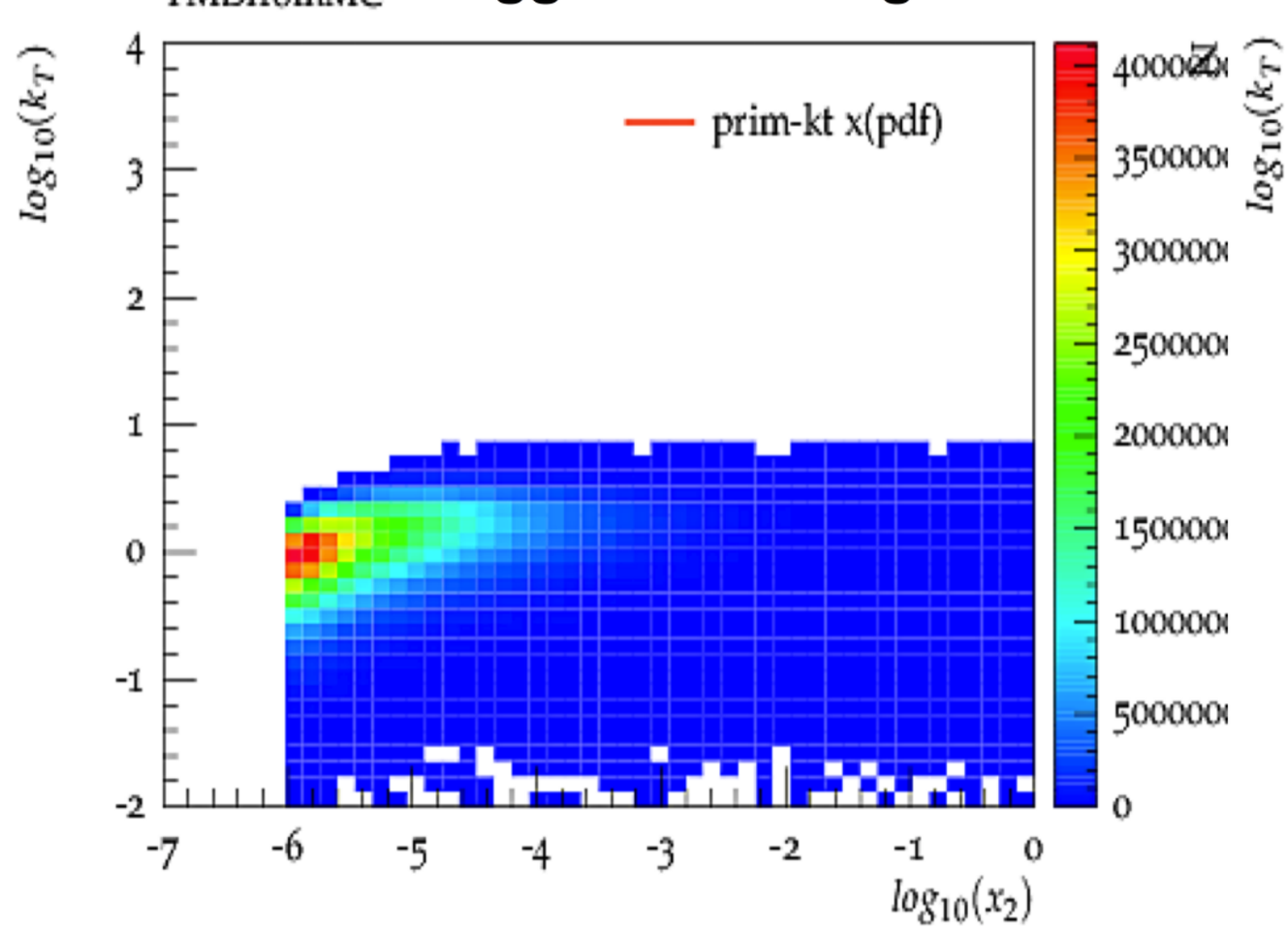
Studying intrinsic k_t vers x and definition of x

fix $x1 = 0.99$ (no intrinsic k_t, no PS from parton 1), mass 0.5< m <1000 GeV

- momentum fraction definition:
  - **from mass (or original pdf):**

$$x = \frac{m}{\sqrt{s}} \exp(\pm y)$$

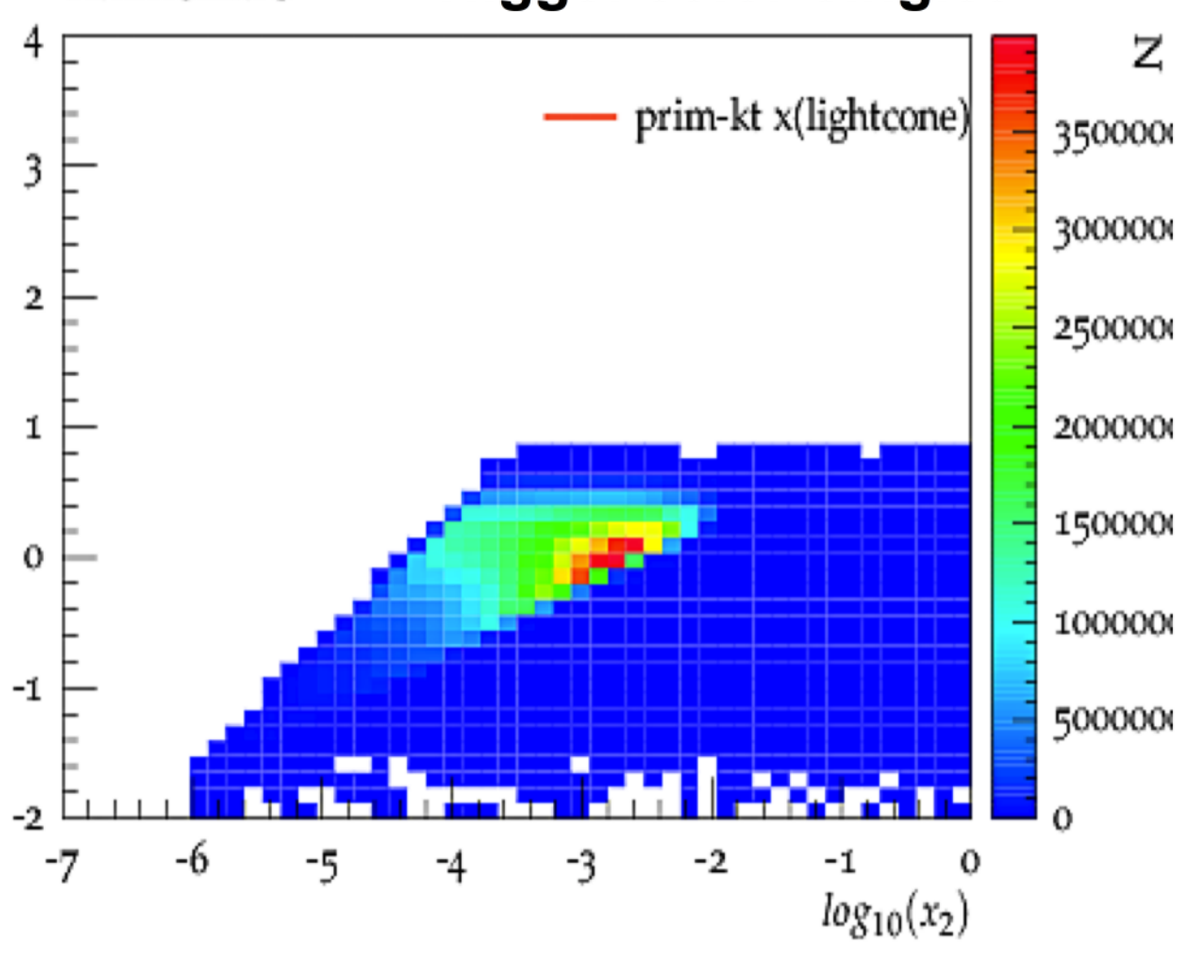
Higgs: color-singlet



- from light-cone momentum fraction:

$$x = \frac{E + p_z}{(E + p_z)_{beam}}$$

Higgs: color-singlet

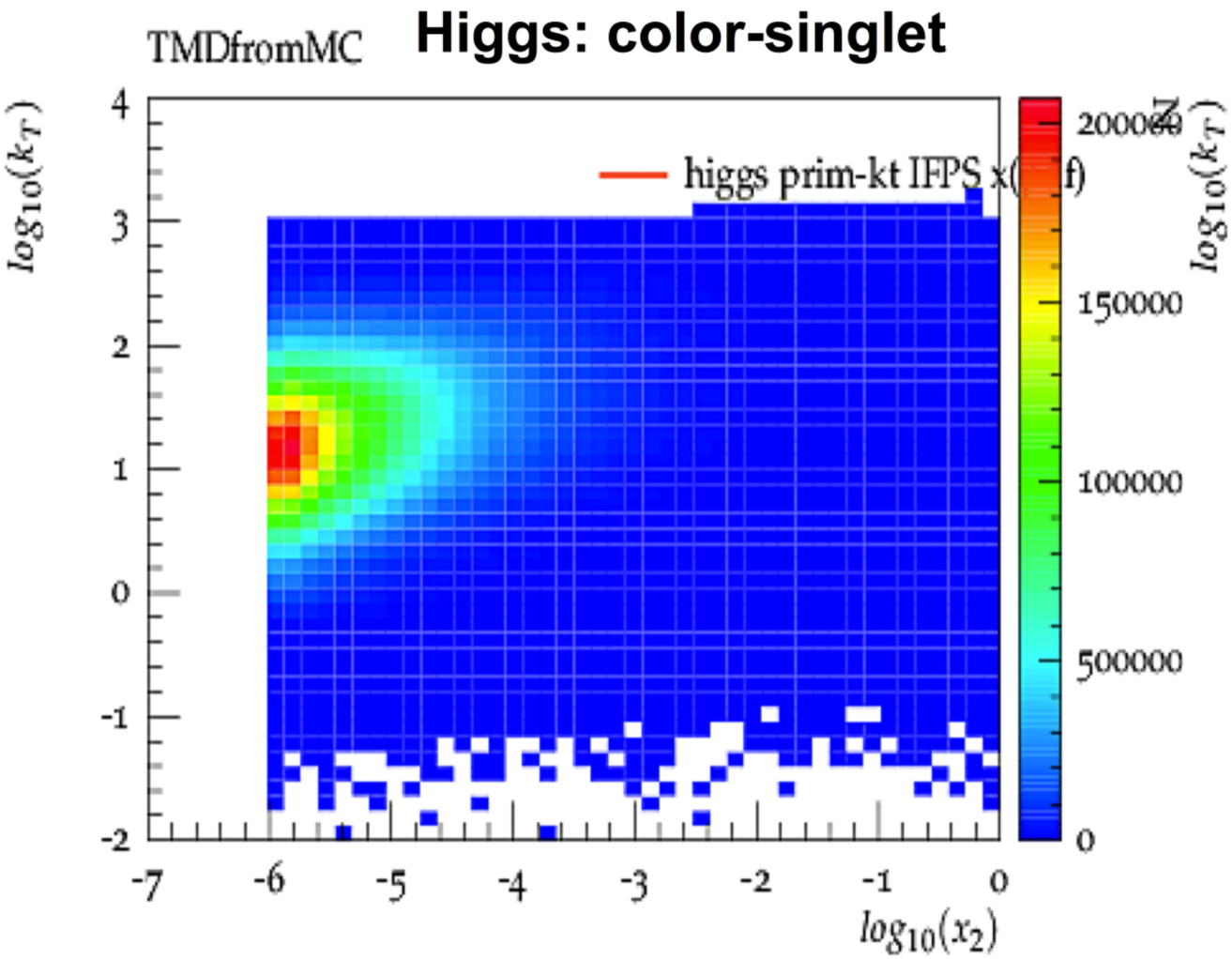


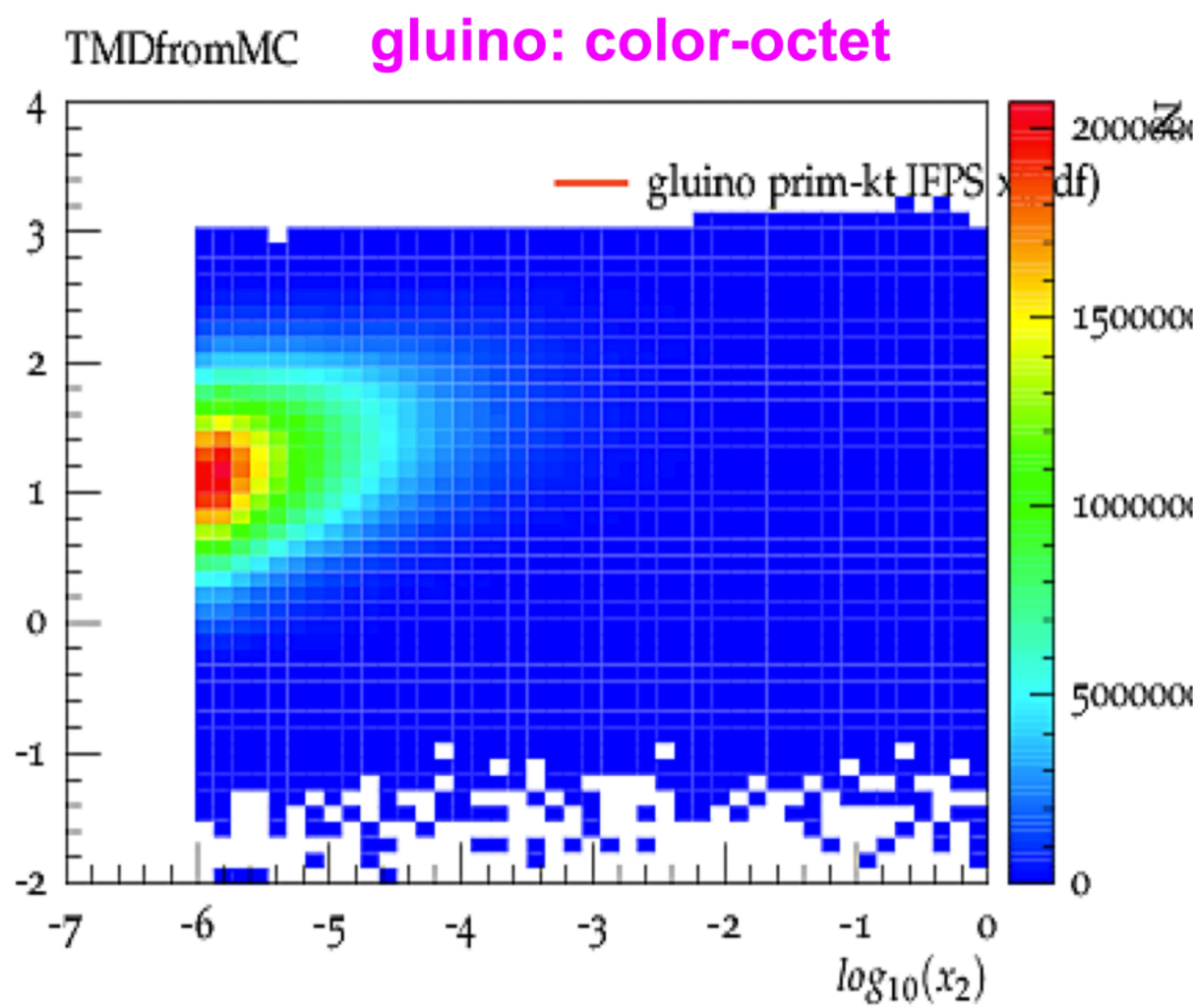
- Significant differences from definition of momentum fraction after k_t

The effect of initial & final state parton shower

fix $x_1 = 0.99$ (no intrinsic k_t, no PS from parton 1), mass 0.5< m <1000 GeV

- momentum fraction definition:
  - **from mass (or original pdf):** $x = \frac{m}{\sqrt{s}} \exp(\pm y)$





- in PYTHIA8, no difference in k_t for color-singlet or color-octet !