# TMDs from Monte Carlo event generators

- Transverse momentum effects are naturally coming from intrinsic kt and parton showers
- TMD effects can be significant in all distributions, even for inclusive (or semi-inclusive) distributions at large pt

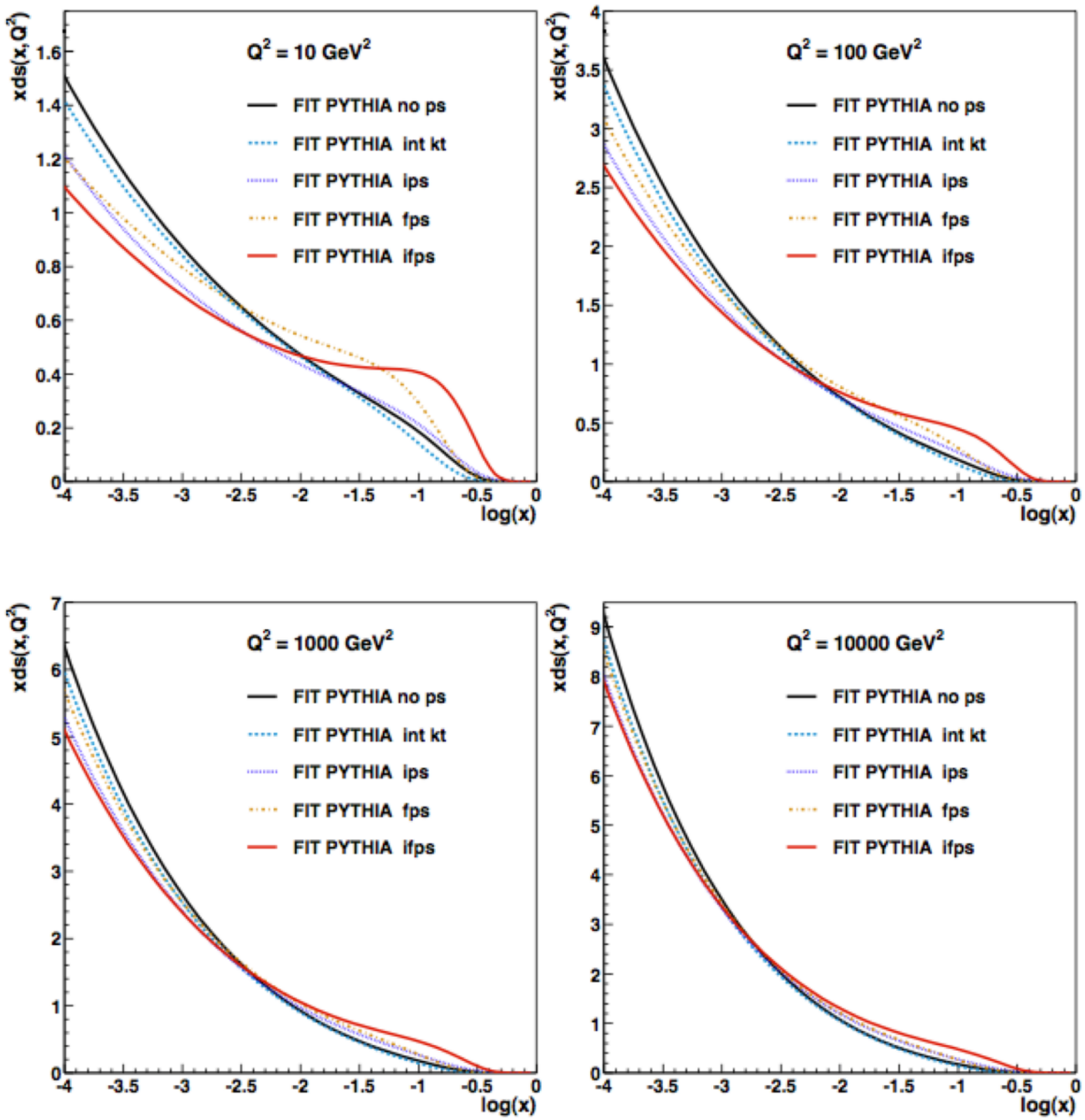
# TMDs from Monte Carlo event generators

- Transverse momentum effects are naturally coming from intrinsic kt 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:
    - **Pamela Ornelas Silva and Jose Fragoso Negrin**
    - **with help from T. Sjostrand on PYTHIA**

# Kinematic effects in PDF determination

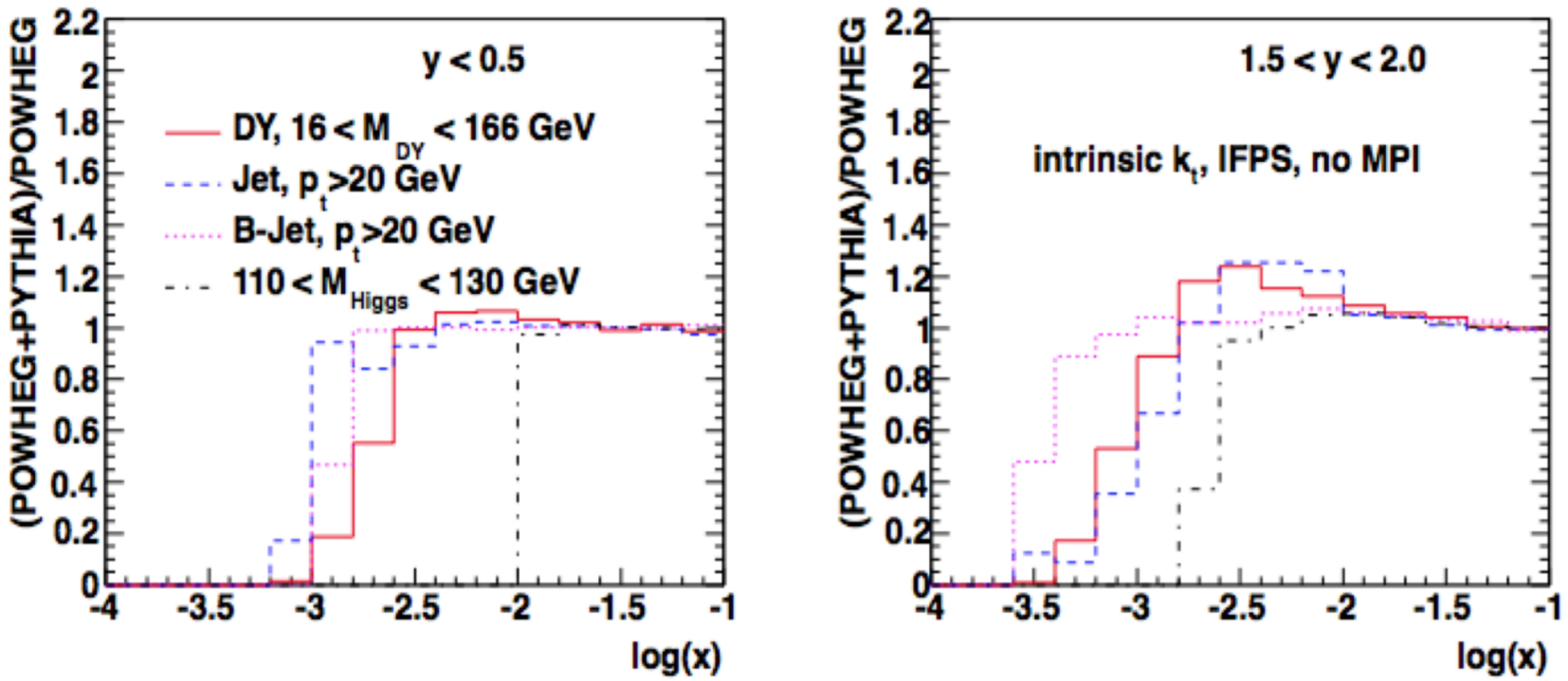
- perform fits to $F_2$ using a Monte Carlo event generator which includes parton showers and intrinsic $k_t$
- the resulting PDFs agree with standard LO ones if no PS and intrinsic $k_t$ is applied.
- the final PDFs are different because of kinematic effects coming from transverse momenta of PS and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

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



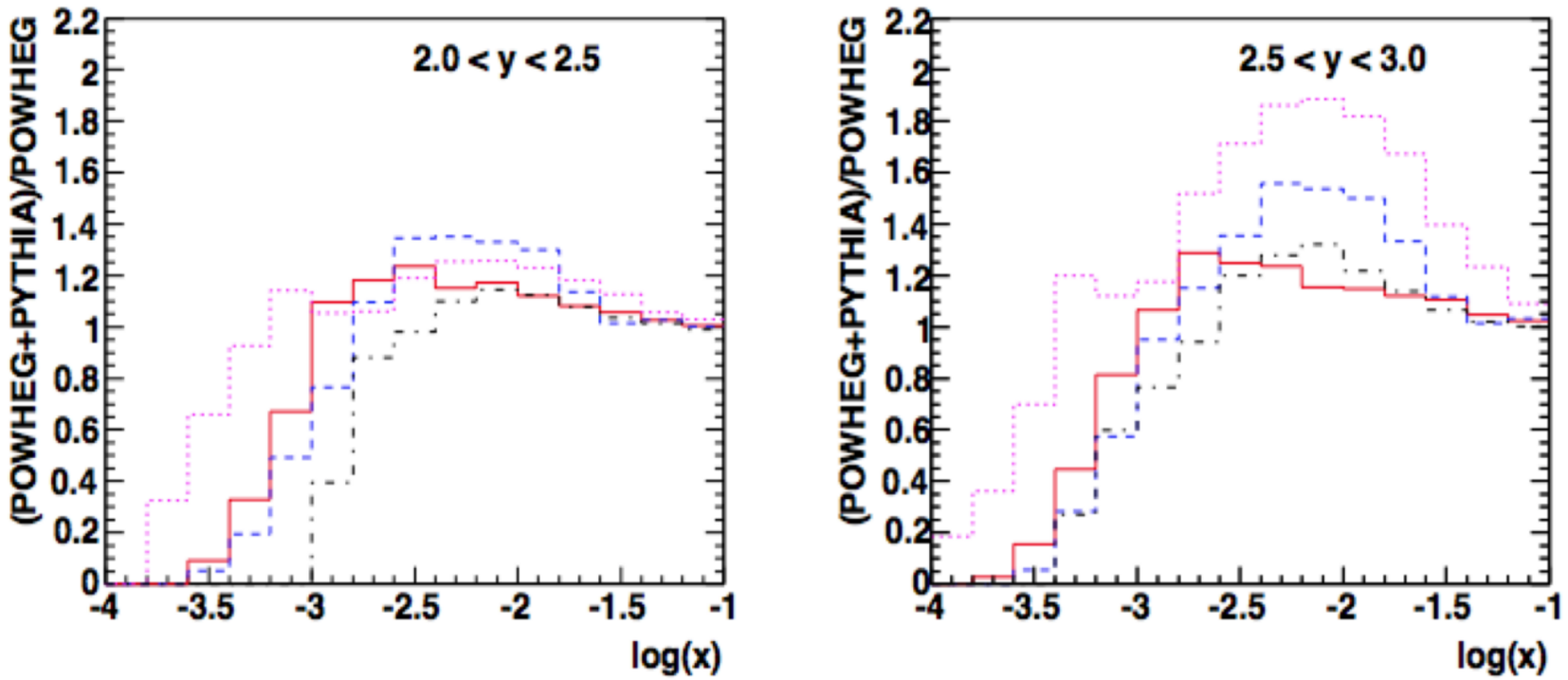
# TMD effects in pp

- TMDs are relevant for many processes at LHC
- parton shower matched with NLO (POWHEG) generates additional $k_t$, leading to energy-momentum mismatch




- Note: x is defined as light-cone momentum fraction:

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



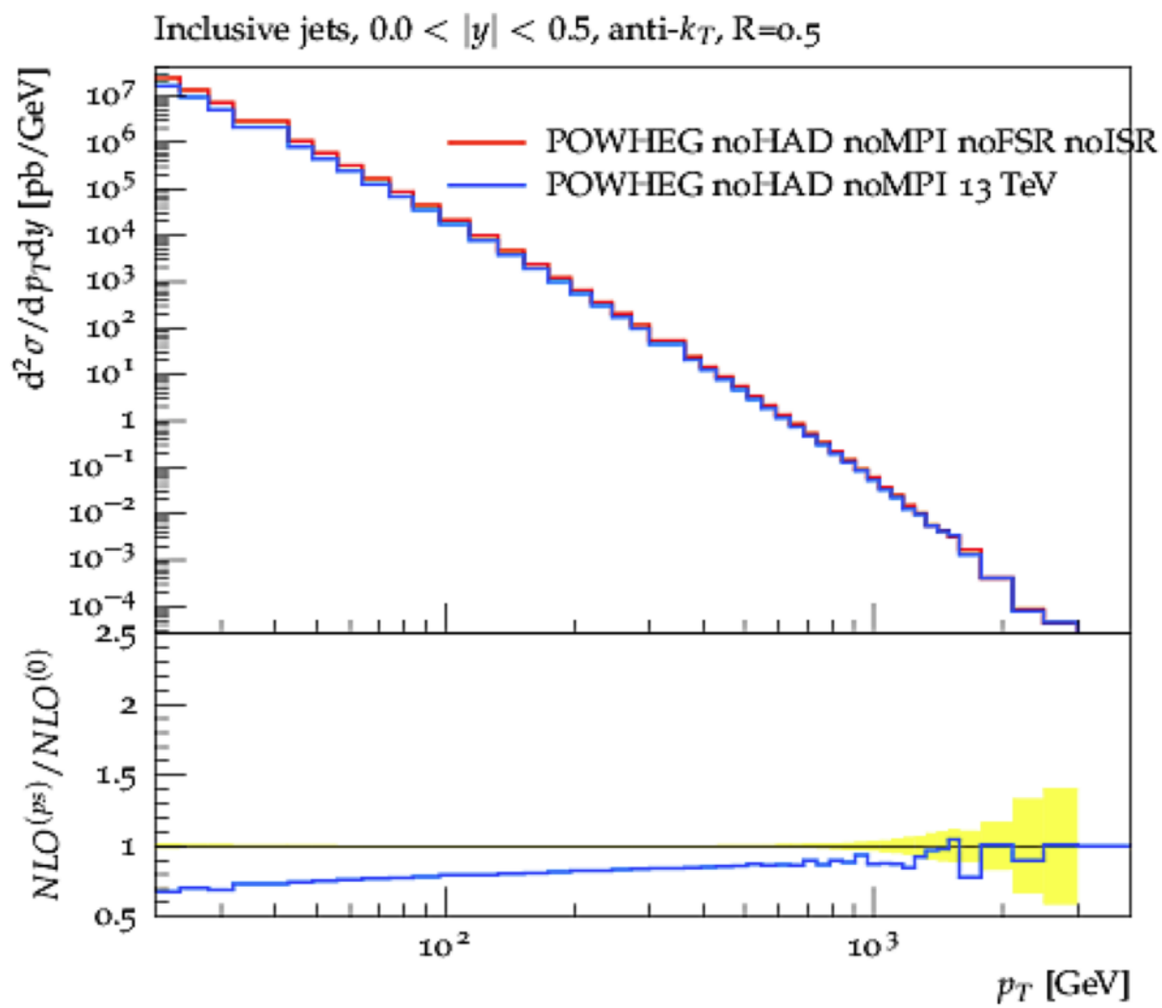
# Parton shower corrections

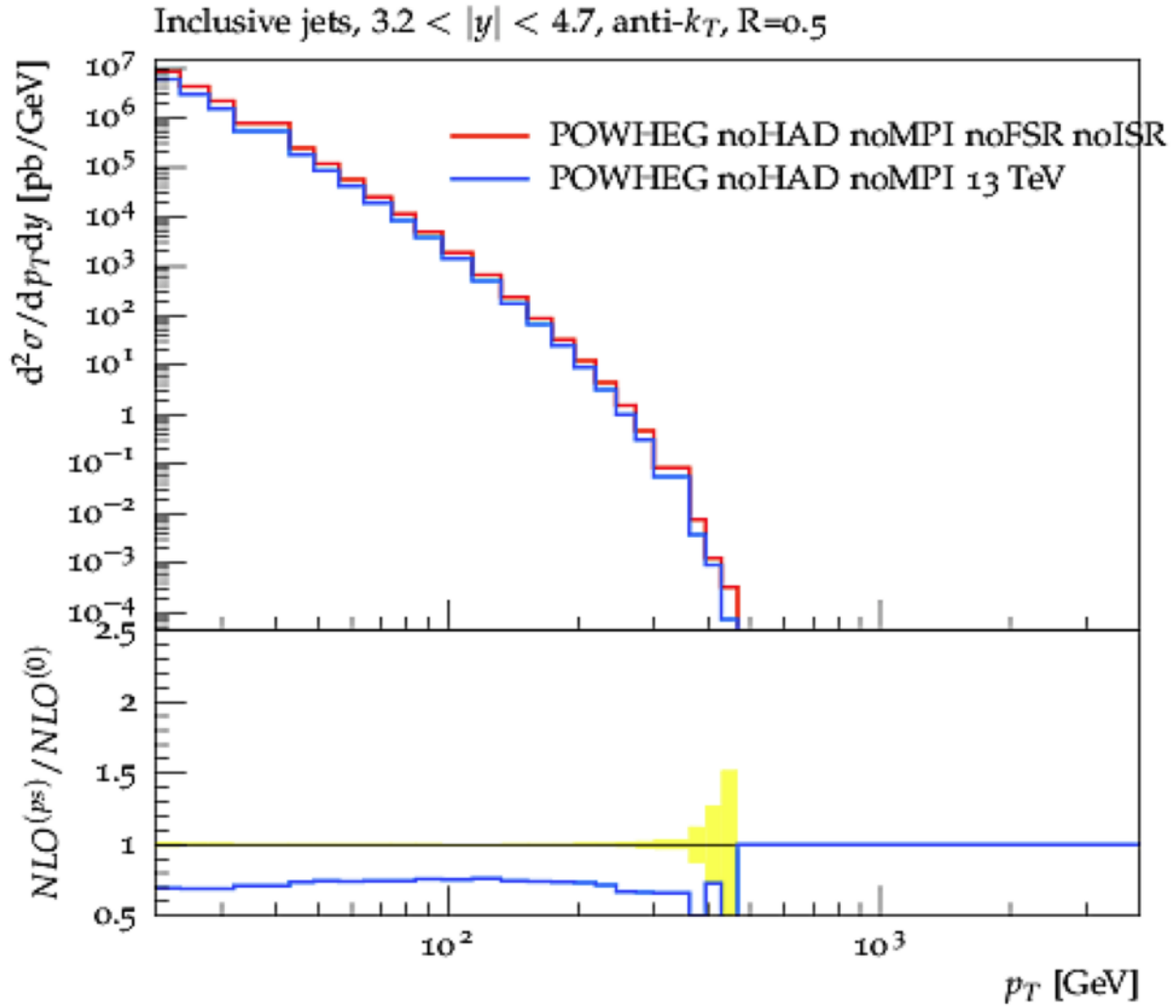
- use NLO+PS to calculate:

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

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



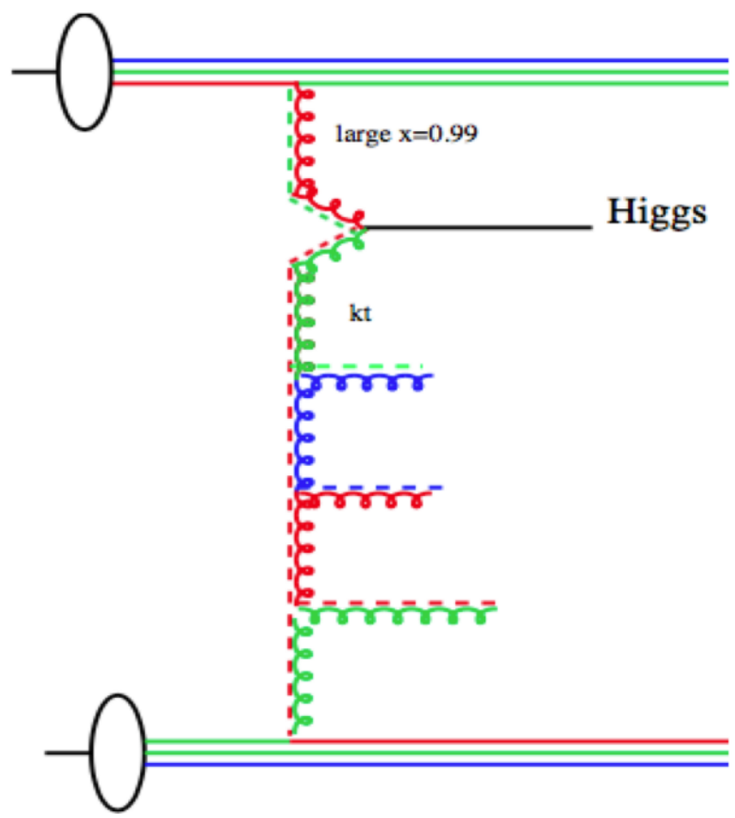
# TMD effects from MC parton shower generators

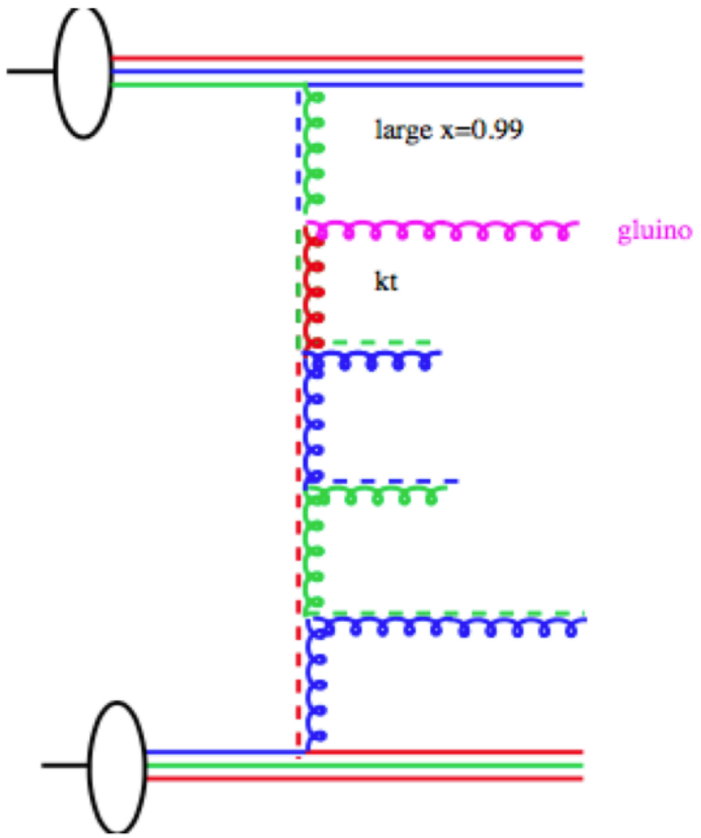
- Goal: define TMD from MC parton shower generator
  - interest only in parton shower – NOT in hard process
  - define a simple “hard process”, from which one can easily calculate kinematics, just using 4-vectors:
    - $k_t$, $x$ and $\mu^2$

# 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
    - $gg \to \widetilde{g}$ 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



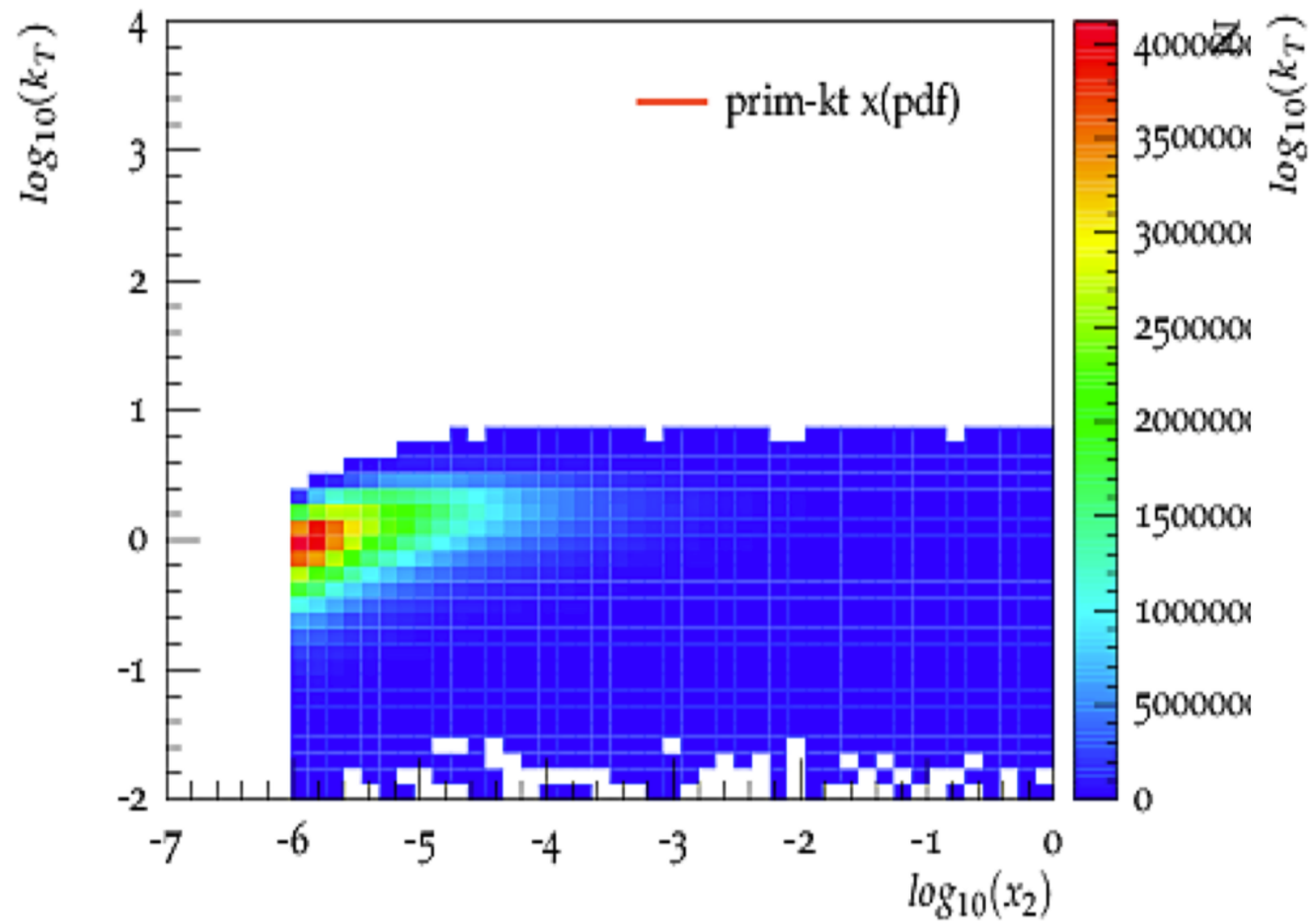
# Studying intrinsic $k_t$ vers x and definition of x

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):

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

TMDfromMC **Higgs: color-singlet**




  - from lightcone momentum fraction:

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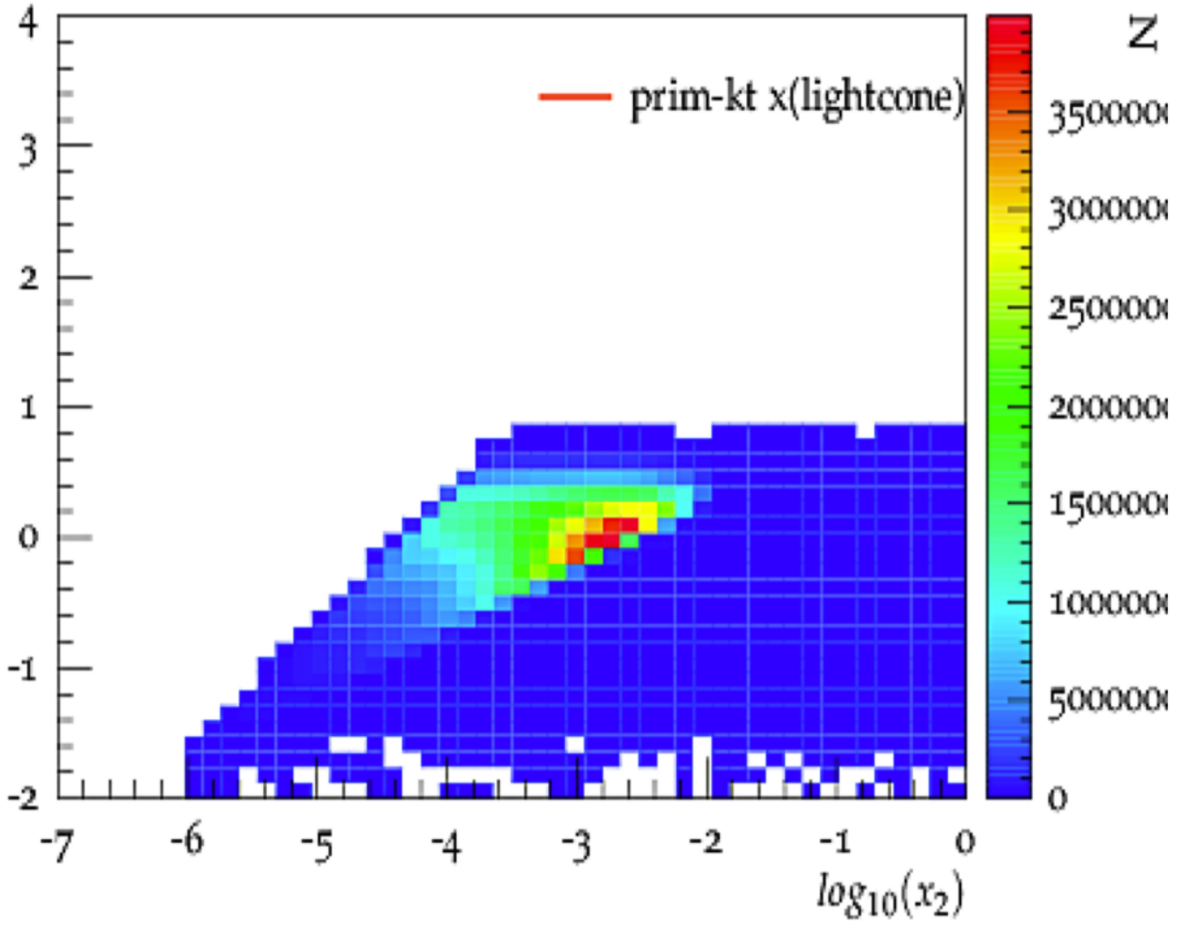
TMDfromMC **Higgs: color-singlet**




- Significant differences from definition of momentum fraction after $k_t$

# The effect of initial state parton shower

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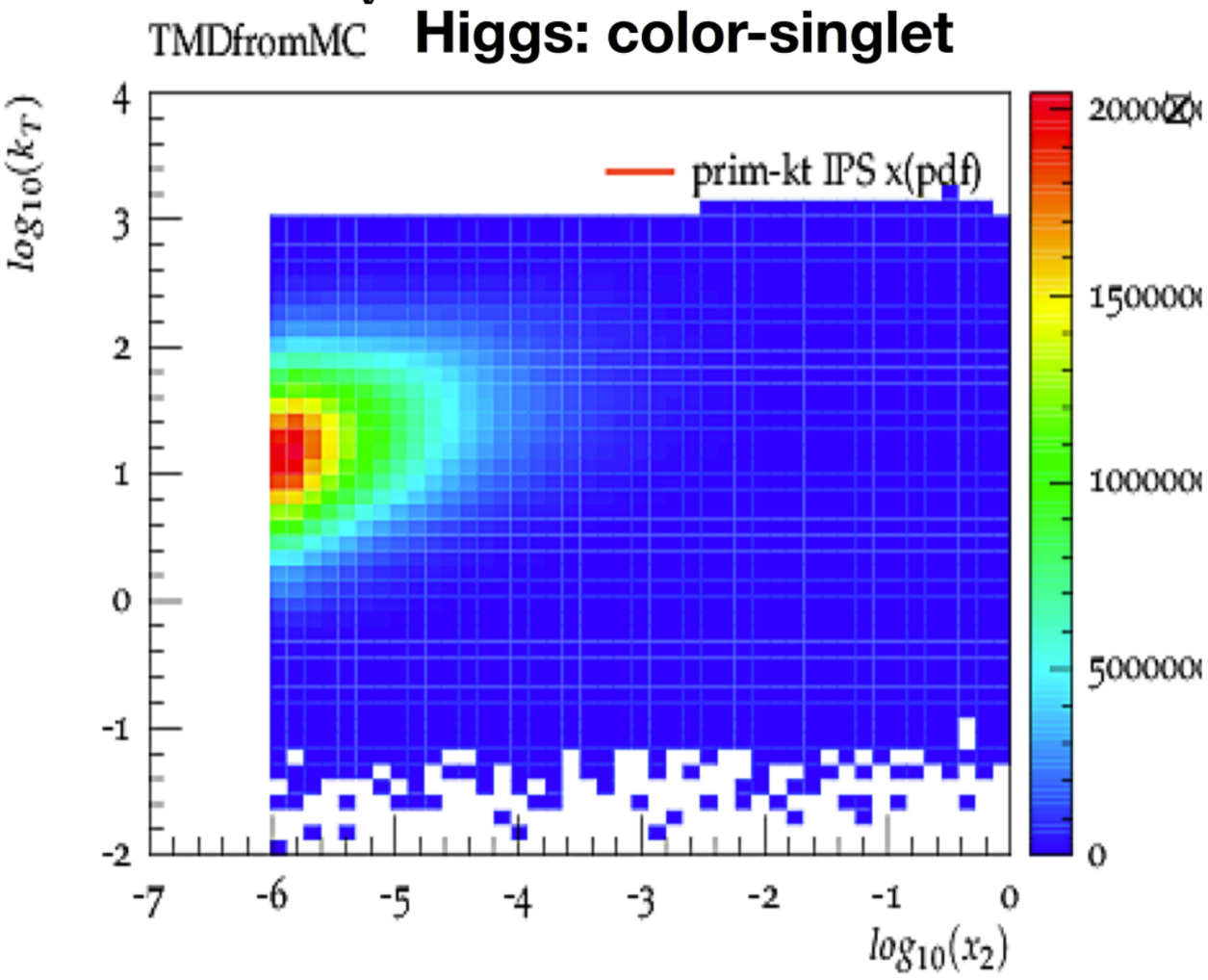


  - from lightcone momentum fraction:

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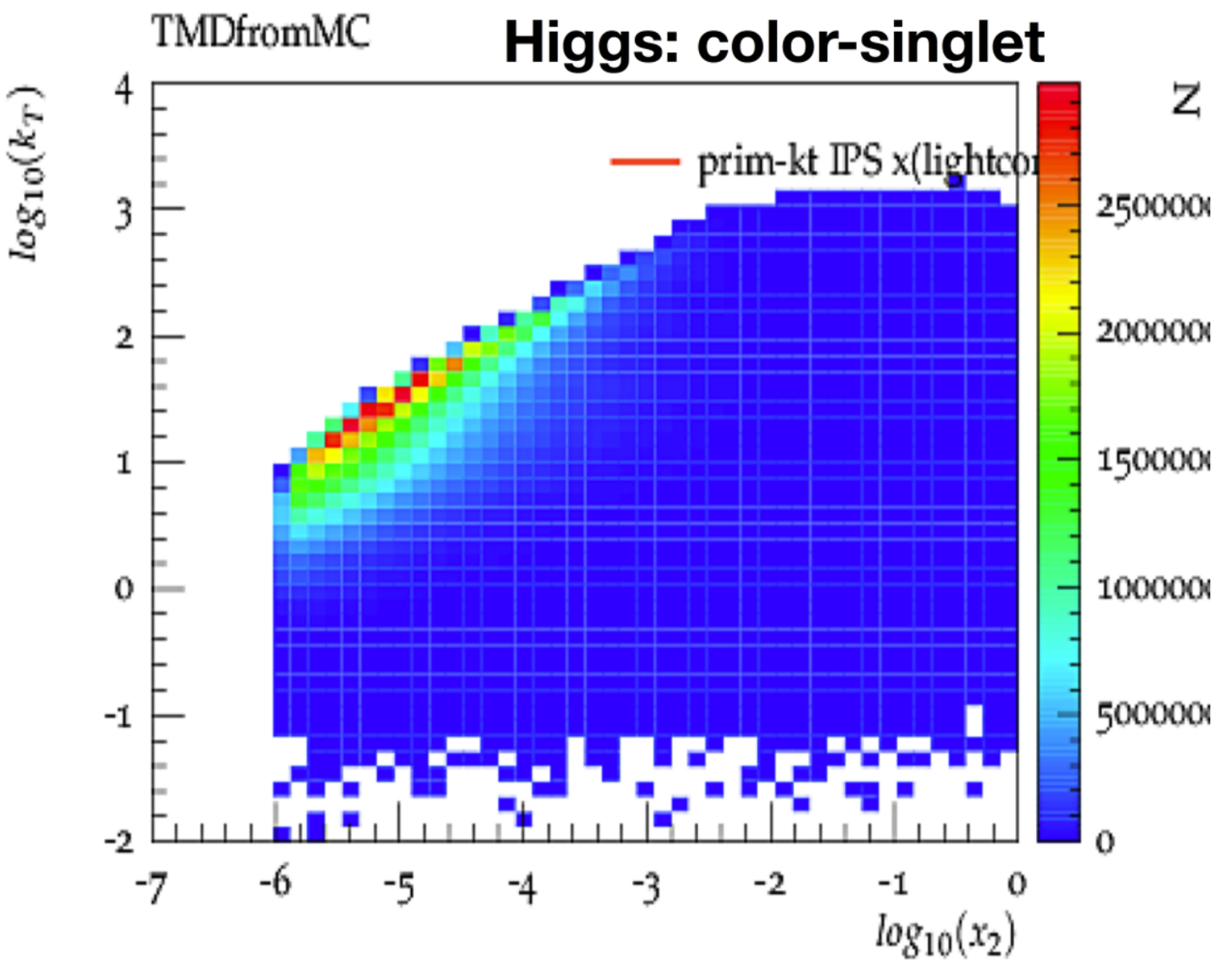


- Significant differences from definition of momentum fraction after $k_t$

# The effect of initial & final state parton shower

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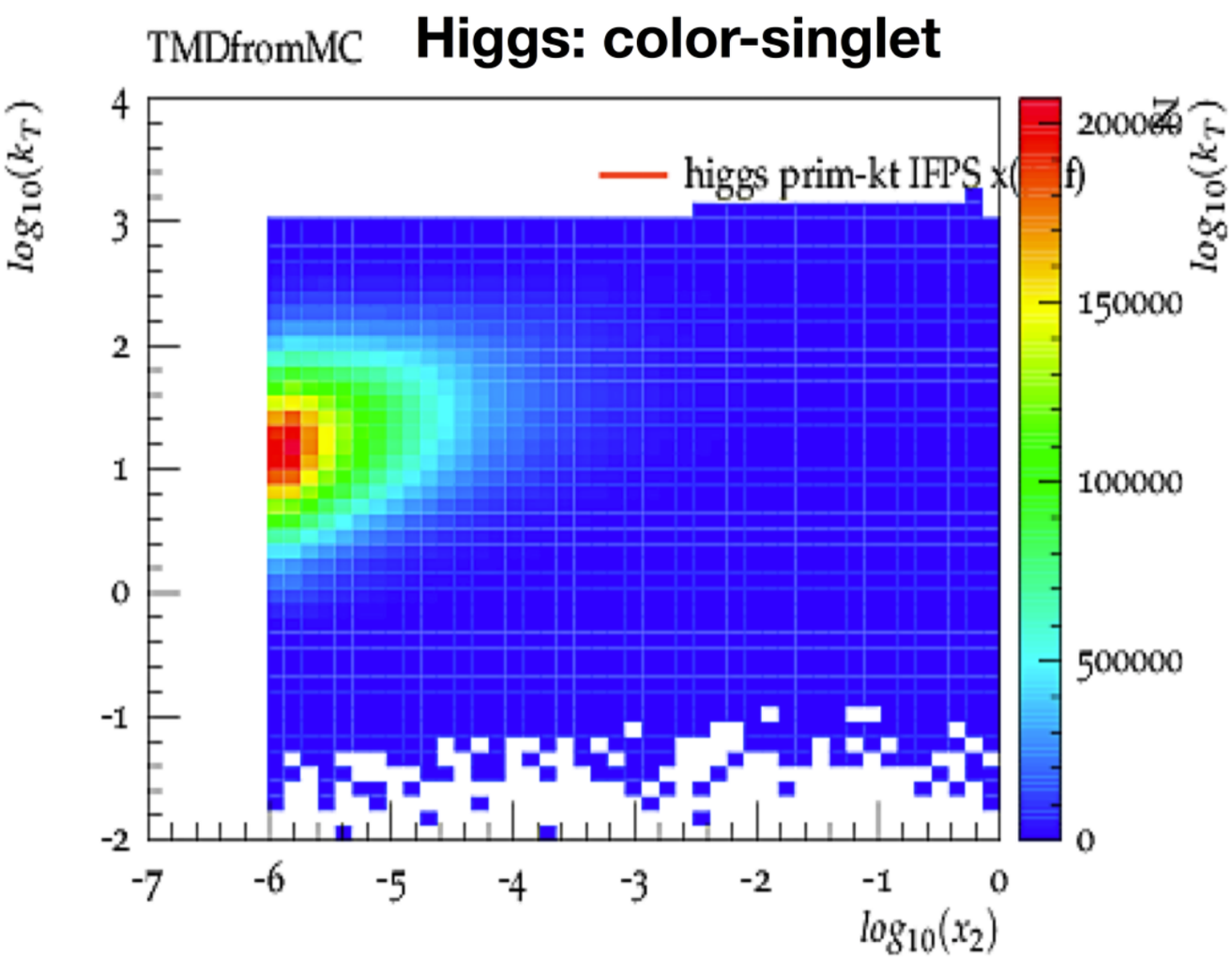
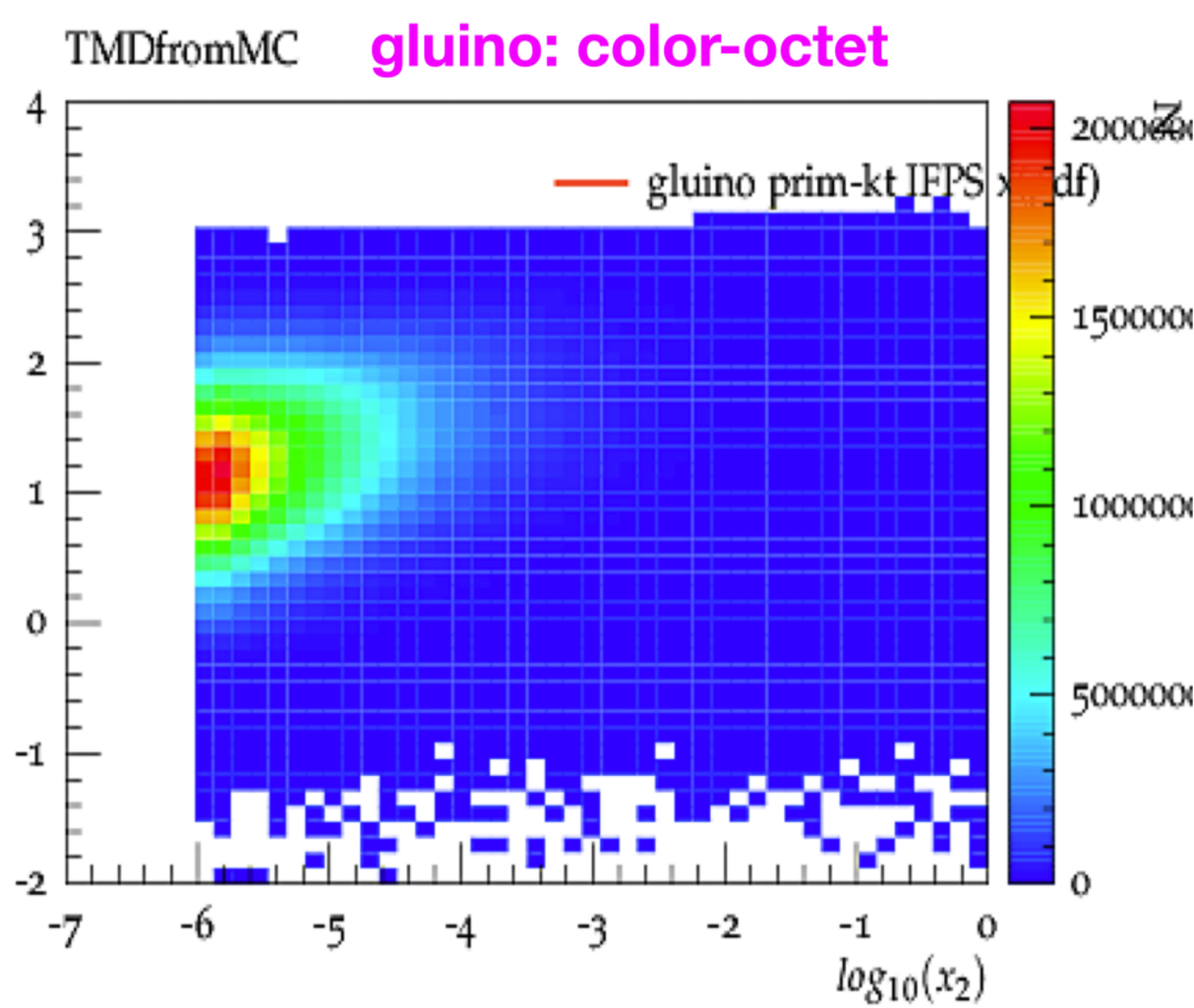
  - from mass (or original pdf): $x = \frac{m}{\sqrt{s}} \exp(\pm y)$




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

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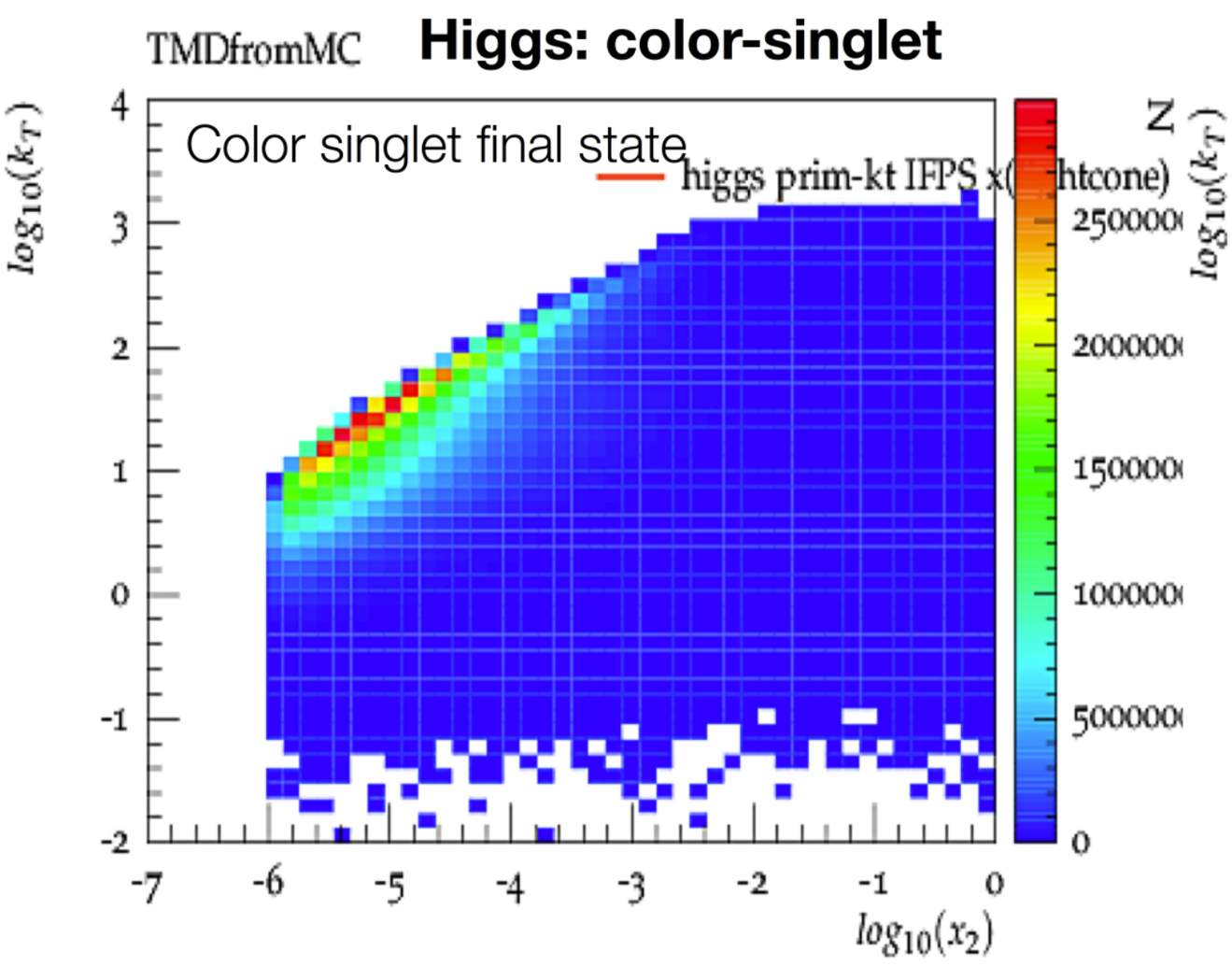


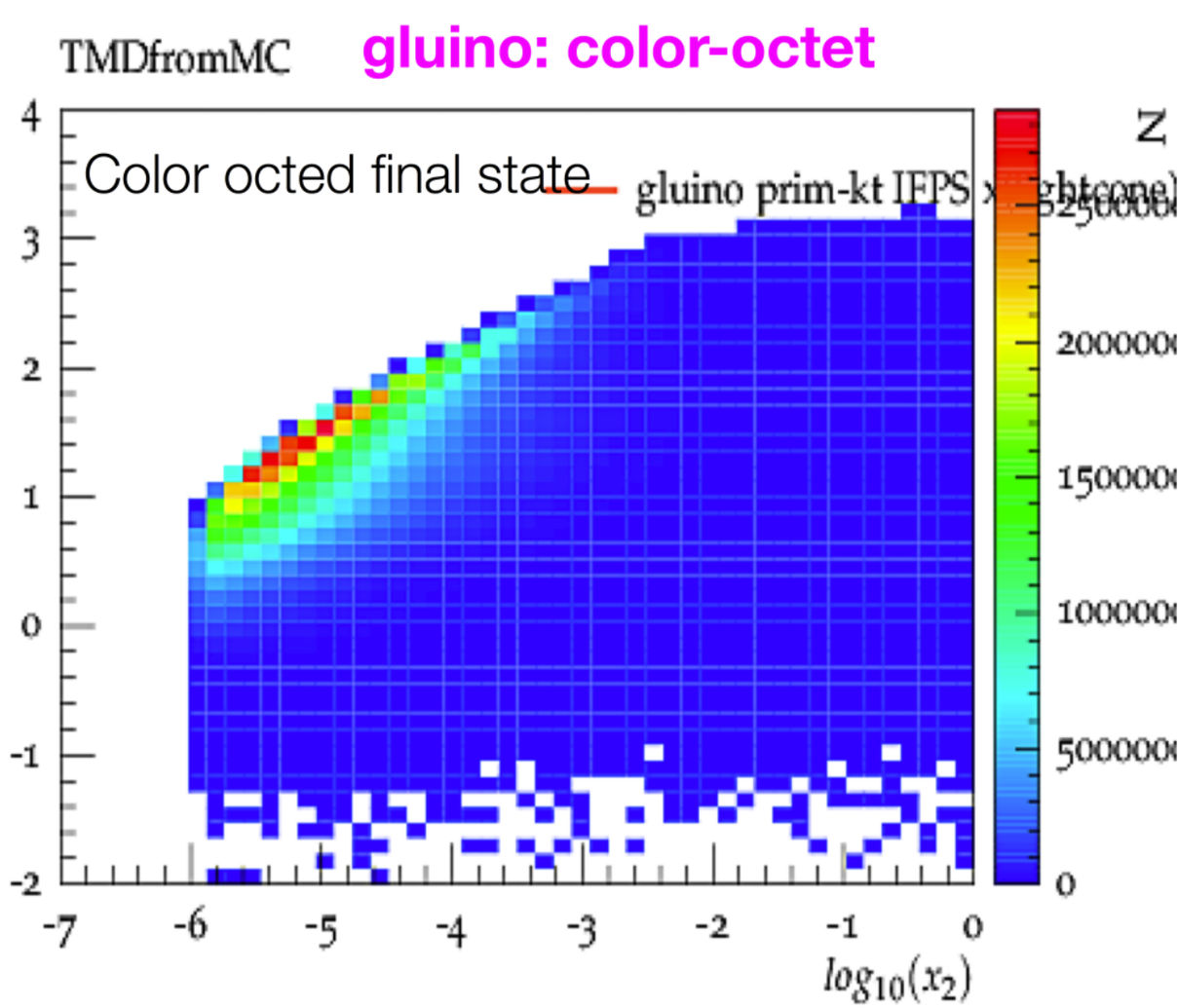


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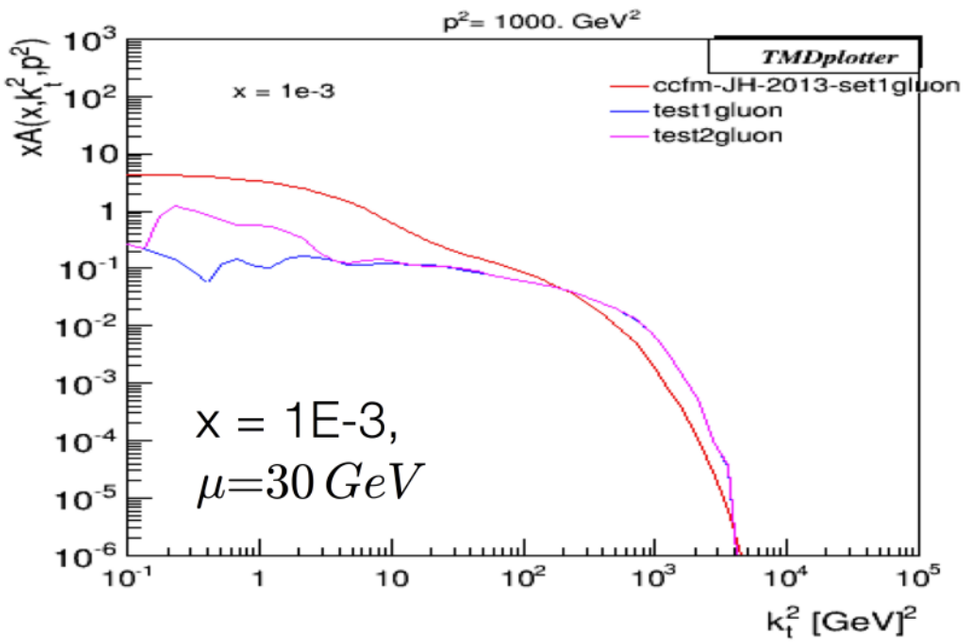
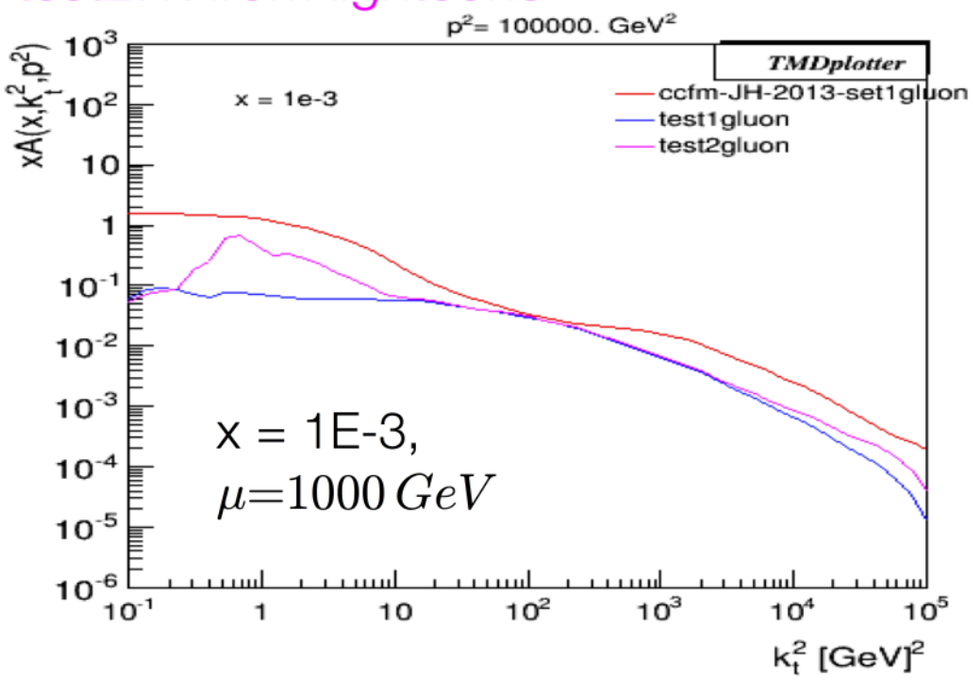
# TMDfromMC

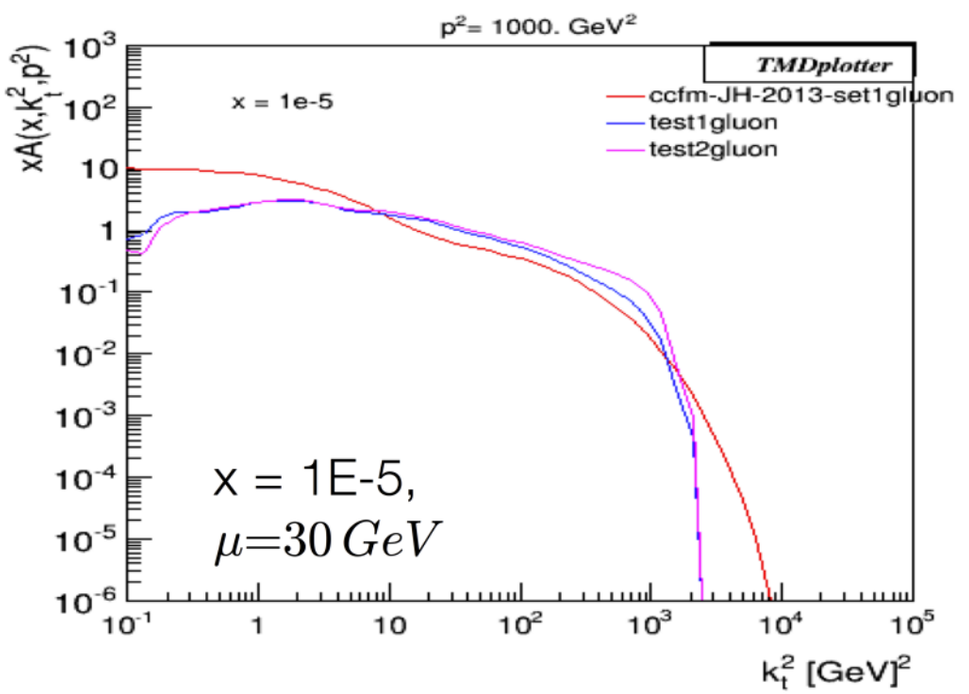
- Use processes defined before (Higgs, gluino) to extract real TMD form MC:
  - determine quark and gluon TMDs (here only gluon is investigated)
  - compare with other TMDs (in TMDlib)

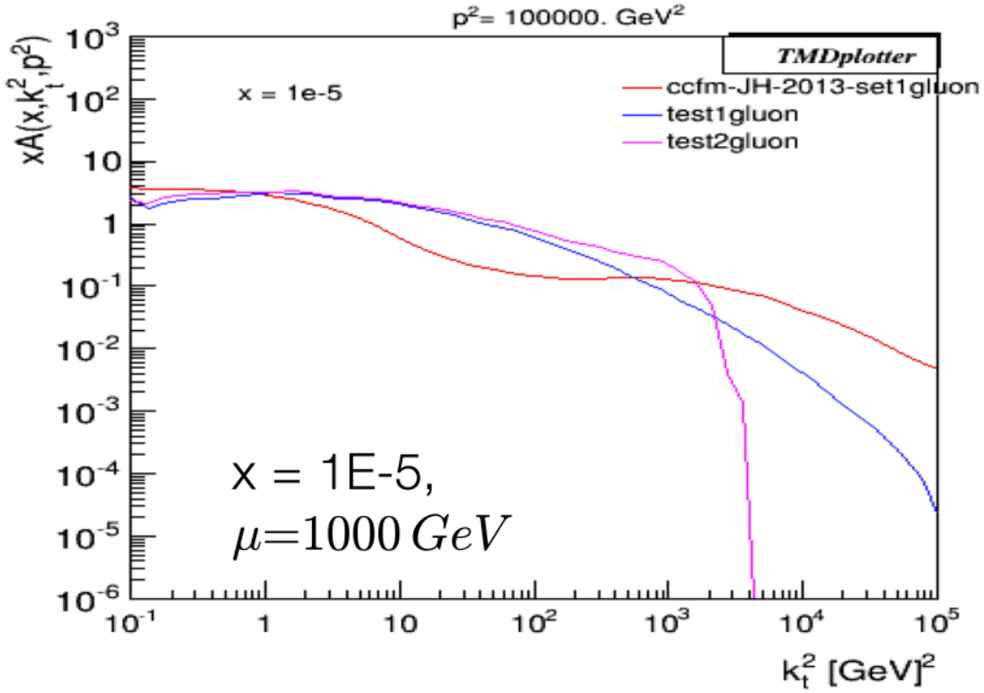
# TMDfromMC: initial parton shower TMD (PYTHIA8)

test1: x from mass , test2: x from lightcone



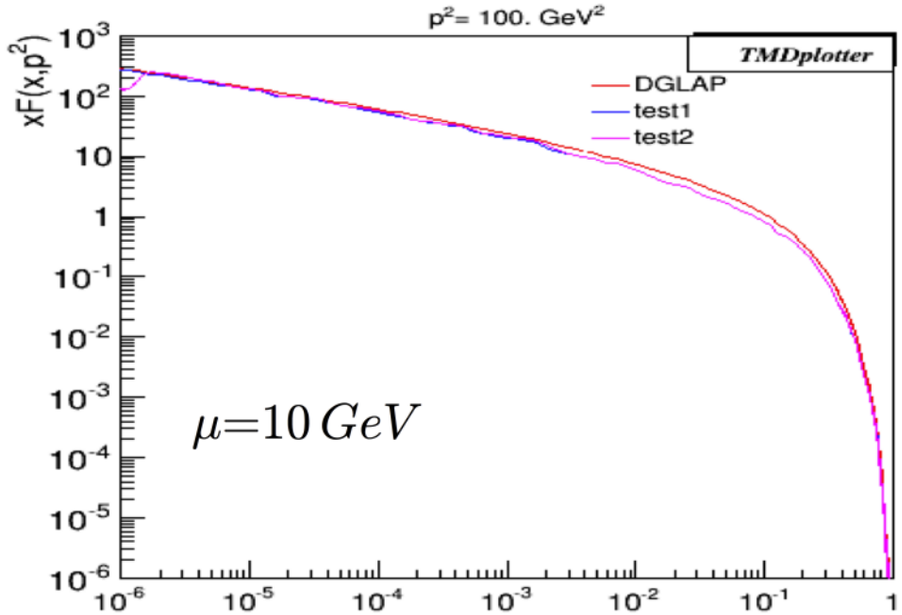



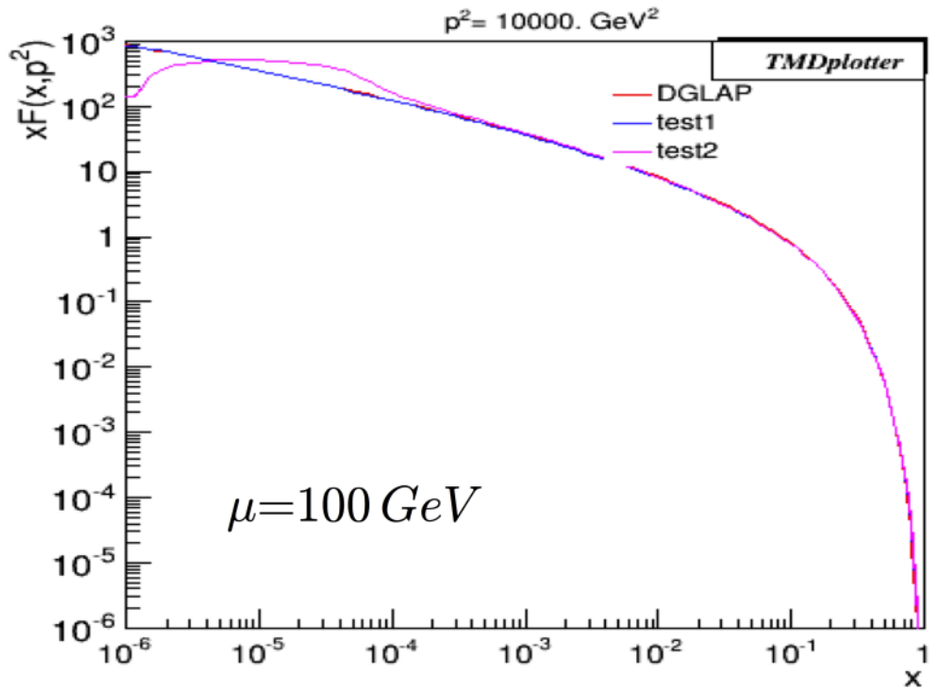

- Effect of x-defintion visible at large scales and small x !

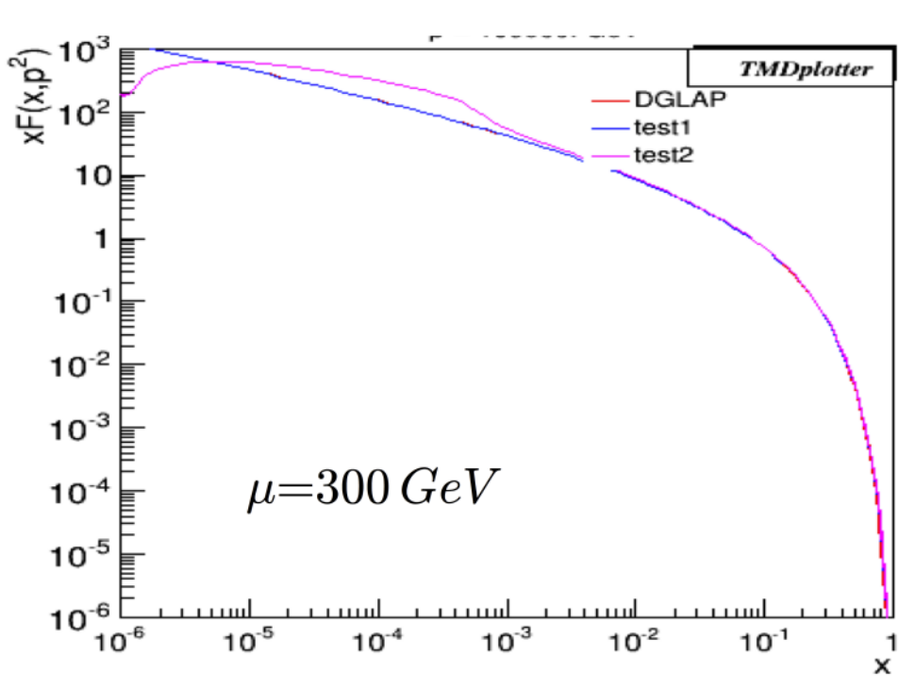
# TMDfromMC: integrated

- Does one get back integrated pdf ?
  - using $$x = \frac{m}{\sqrt{s}} \exp(\pm y)$$
  - but not $$x = \frac{E + p_z}{(E + p_z)_{beam}}$$

test1: x from mass , test2: x from lightcone




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

# TMDfromMC: technicalities

- Hard scattering can be produced in LHE file:
  - easy to interface to any PS MC event generator

- TMDfromMC
  - extracted via Rivet Plugin

- TMDfromMC
  - accessible via TMDlib and TMDplotter

# TMDfromMC: technicalities & further studies

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- options for further studies:
  - study effect of PDF used in PS
  - study details of intrinsic $k_t$
  - study effects on ordering – angular ordering, Q2 ordering etc in shower
  - study ….

# TMDfromMC: summary

- TMD obtained from parton shower MC generators allow to study TMD effects of PS directly
  - Issues are definition of $x$
  - transverse momentum effects can be very important, especially at small $x$
- Study of PYTHIA 8 shows no difference between $k_t$ distribution for IPS in color-singlet or color-octet final state
  - BUT: different generators might give different results:
    - herwig++ has color connection of initial-final state
    - SHERPA also
- TMDfromMC offers new possibilities:
  - direct comparison of parton shower between different approaches without complication of final state observables
  - allows to study “factorization” and “factorization-breaking” effects from MC generators
  - can be used also for any further calculation to treat kinematics correctly !
    - use in NLO – PS calculations using TMDlib with TMDfromMC