Nonperturbative, Parton Shower Corrections and Longitudinal Shifts in Jet & Heavy-quark Measurements

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arXiv:hep-ph/1212.6164

Content

Motivation

- Phenomenological study of inclusive jet production at the LHC rely on Shower Monte Carlo Event Generators (SMC)

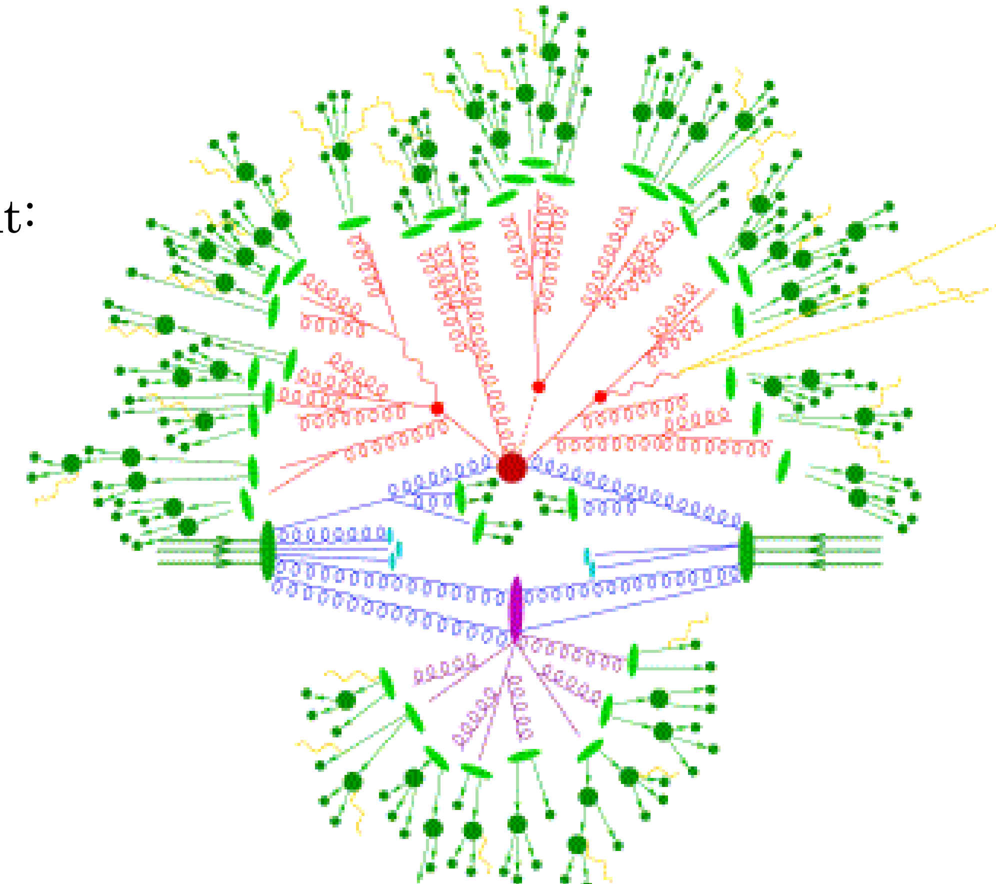
Nonperturbative Corrections from NLO MC

- Corrections to perturbative calculations due to multiparton interaction, parton showering and hadronisation

Longitudinal Momentum Shift

- Combining collinear approximation of partons with energy momentum conservation in SMC lead to kinematic changes due to parton showering

Motivation



Measurements of jet final states are important:

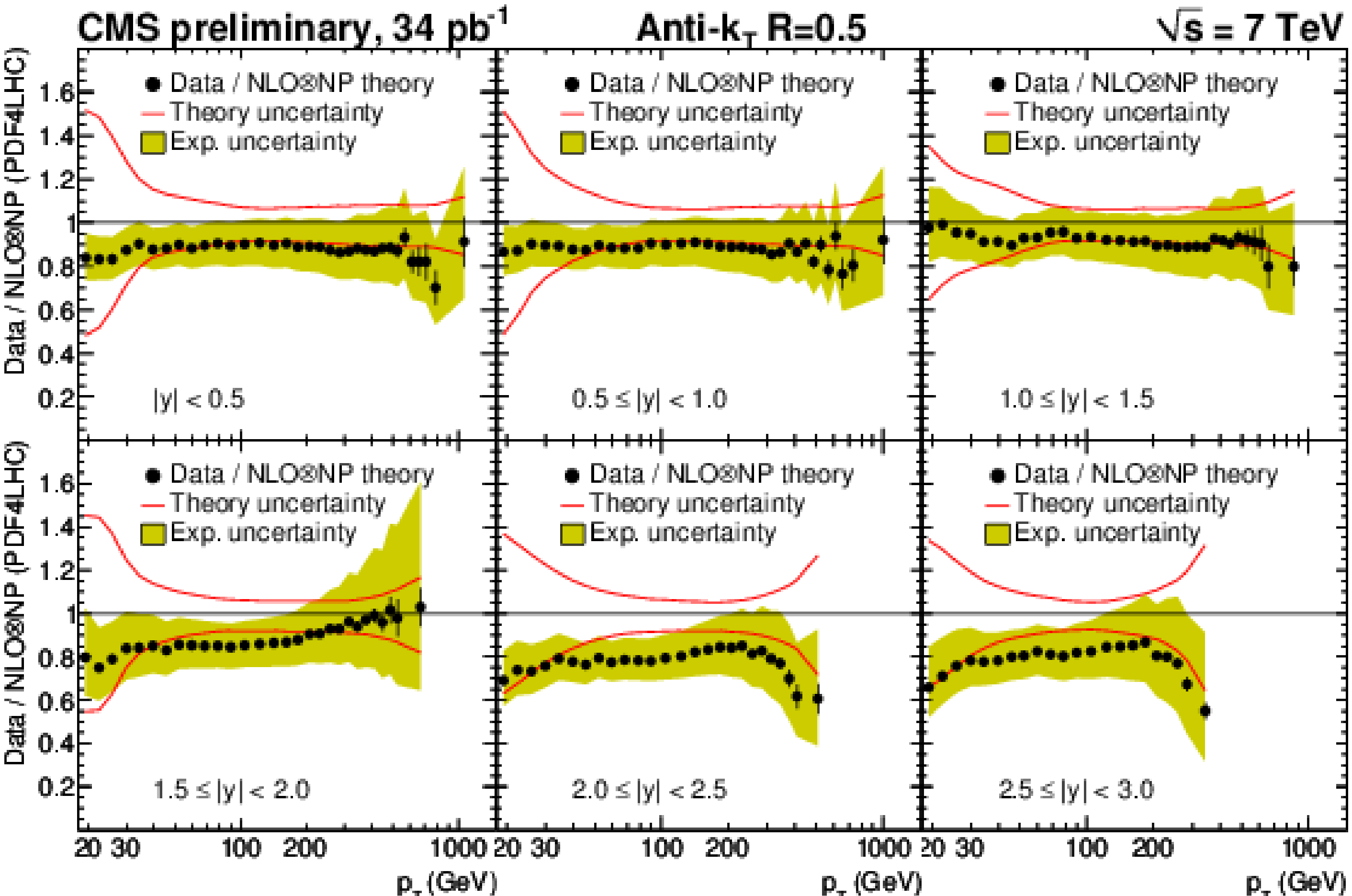
- Stringently test of pQCD
- Constrain PDF (at high x)
- Determine strong coupling constant

▷ In high energy physics experimental data is compared to NLO theory calculations

The theoretical predictions for the jet cross sections consist of next-to-leading order (NLO) QCD calculation and a non-perturbative (NP) correction to account for multiparton interactions (MPI) and hadronisation effects.

❖ Use NLO-matched shower event generator ❖

Motivation



CMS
arXiv:1106.0208

- ▷ Jet measurement over a much larger kinematic range than previous collider experiments
- ▷ Comparison of NLO⊗NP with data shows good agreement at central rapidities, but
- ▷ Large differences at higher rapidity

❖ Study the kinematic of the initial state parton shower at high rapidities ❖

Nonperturbative Correction

In order to compare theory with experimental data corrected to stable particle level, NLO perturbative calculations have to be corrected to account for NP effects by using SMC.

CMS arXiv:1106.0208

ATLAS arXiv:1112.6297

Previously only LO-MC generators were used

$$K_0^{NP} = N_{LO-MC}^{(ps+mpi+had)} / N_{LO-MC}^{(ps)}$$

Combining the NLO parton level calculation and non-perturbative correction derived from LO MC generator, shows a potential inconsistency in treating the first radiative correction differently in the two parts of the calculation.

D., Gunnellini, Hautmann, Jung arXiv:1212.6264

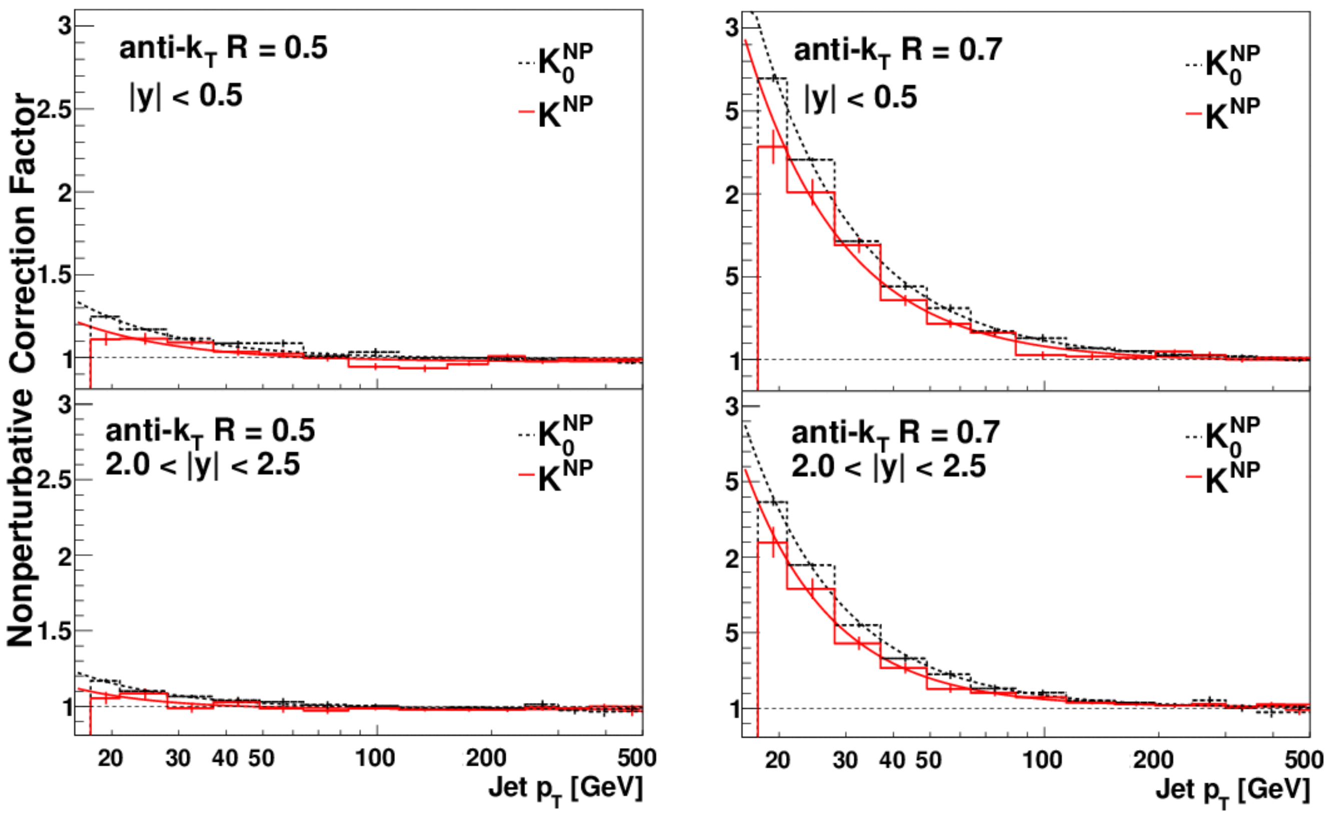
Alternative method use NLO-MC

$$K^{NP} = N_{NLO-MC}^{(ps+mpi+had)} / N_{NLO-MC}^{(ps)}$$

$$K^{PS} = N_{NLO-MC}^{(ps)} / N_{NLO-MC}^{(0)}$$

❖ Study separate corrections factors to single out NP and PS effects ❖

Nonperturbative Correction



Non-negligible effect from nonperturbative effects at small p_T

Difference between LO and NLO correction

▷ Matching of MPI to the NLO calculation because the MPI p_T scale is different in LO and NLO

$$K_0^{NP} = N_{LO-MC}^{(ps+mpi+had)} / N_{LO-MC}^{(ps)}$$

$$K^{NP} = N_{NLO-MC}^{(ps+mpi+had)} / N_{NLO-MC}^{(ps)}$$

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arXiv:1212.6264

Parton Shower Correction

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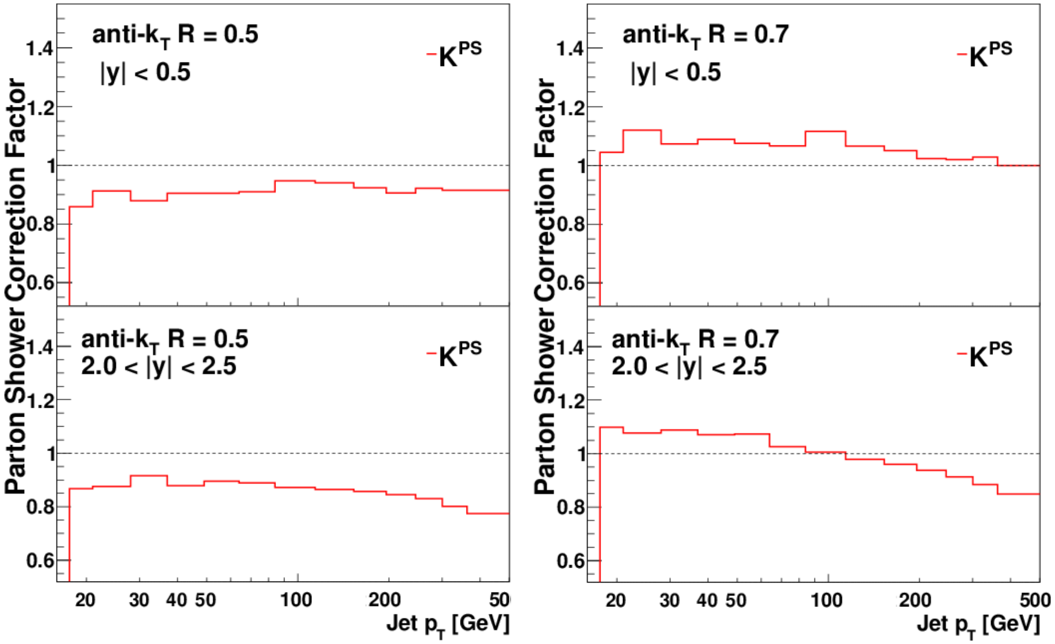


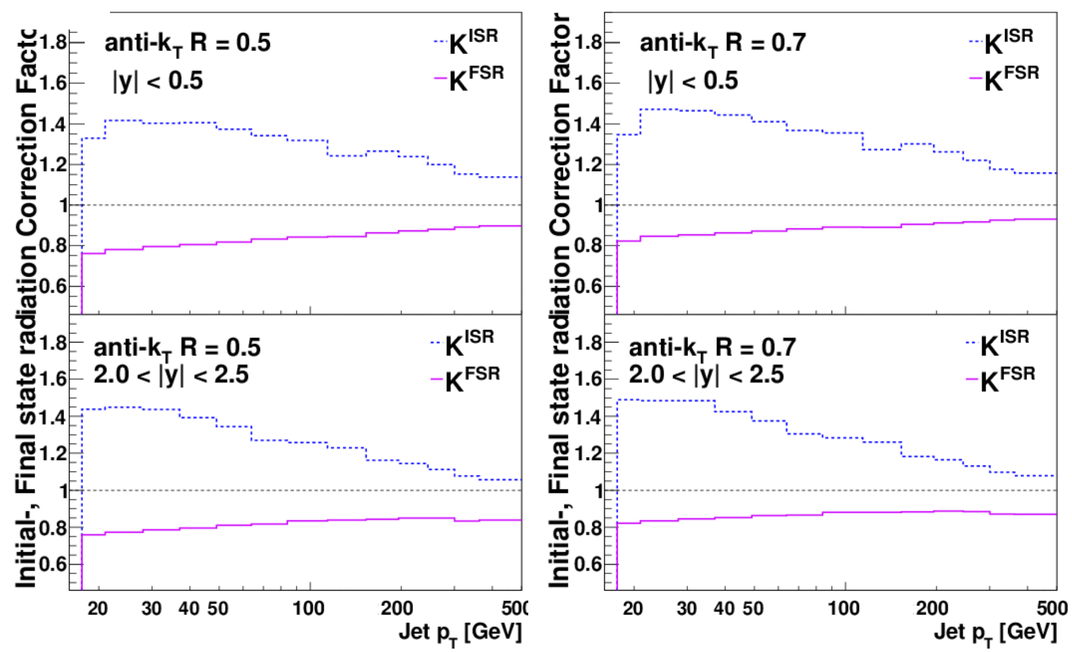
$$K^{PS} = N^{(ps)}_{NLO-MC} / N^{(0)}_{NLO-MC}$$

- Depends on rapidity and p_T especially in the forward region
- Finite effect also at large p_T

- Initial and Final State Parton Shower considered independently
- But they are interconnected:

The combined effects cannot be obtained by adding the individual contributions

- ISR largest at low p_T, FSR significant for all p_T



Longitudinal Momentum Shift

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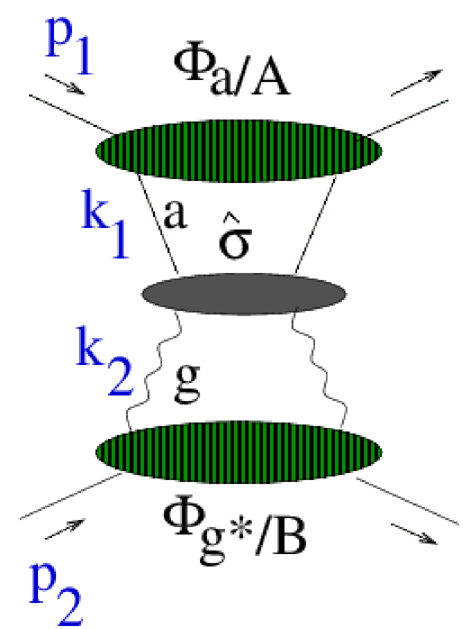
In SMC:

hard subprocess is generated with full 4-momentum for the external lines

Factorized jet cross section at high rapidity



Momentum of the partons initiating the hard scatter: $k_j^{(0)} = x_j p_j$ — on-shell and fully collinear with the incoming momenta

Applying shower algorithm

Complete final states: $k_j \neq x_j p_j$ — no longer collinear

Energy momentum conservation ▷ Reshuffling in x_j (long. mom fraction)

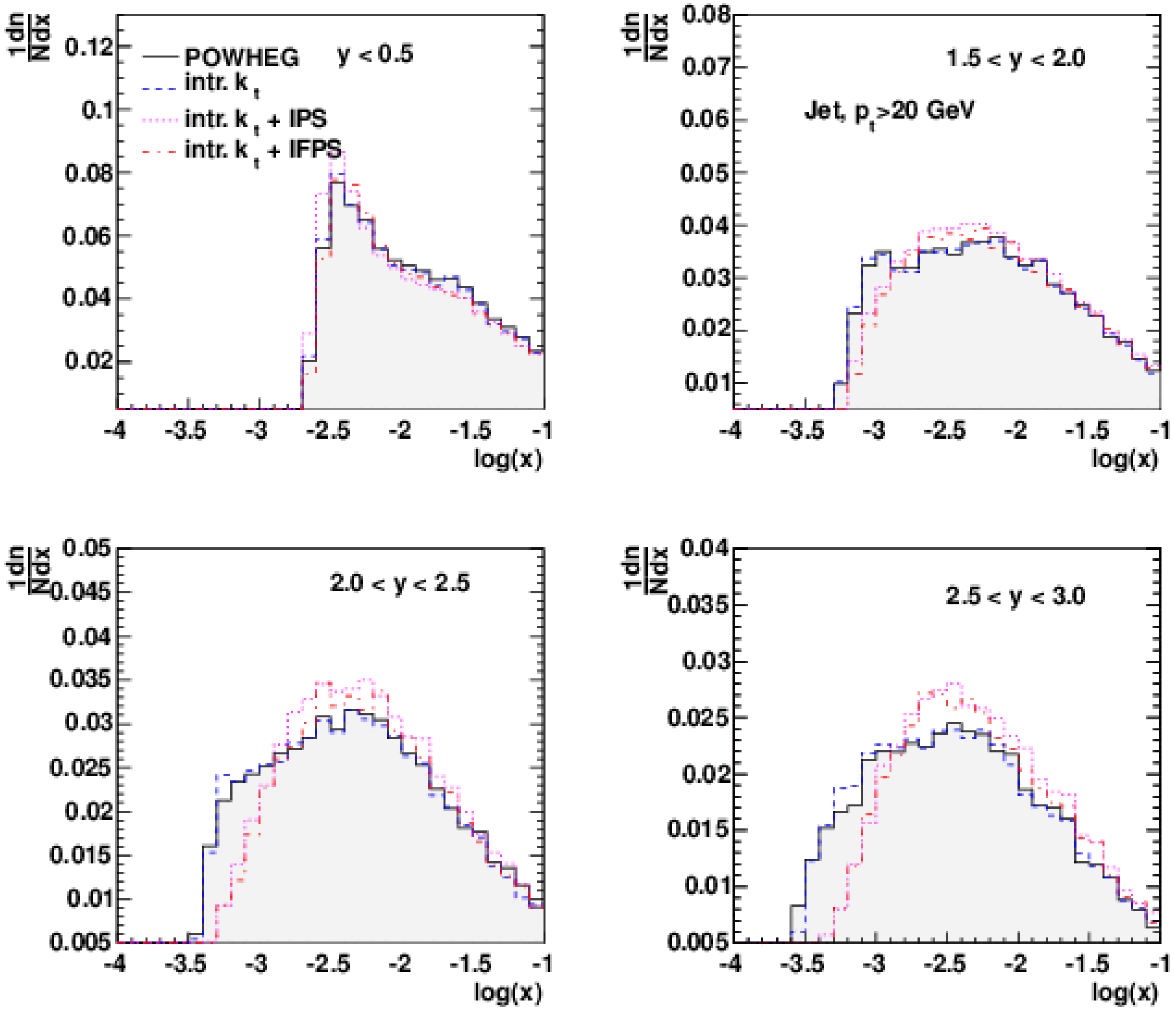
Collinear approximation ⊗ energy momentum conservation

=

kinematic shift in longitudinal momentum distribution due to showering

Longitudinal Momentum Shift – Inclusive Jets

Jet measurement in the rapidity range $y < 2.5$



Compute x_j from POWHEG before parton showering and after parton showering (using PYTHIA6)

Kinematic reshuffling in x is negligible for central rapidities but becomes significant for $y > 1.5$

▷ Kinematic shift can affect predictions through the PDFs

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Longitudinal Momentum Shift – B-Jets

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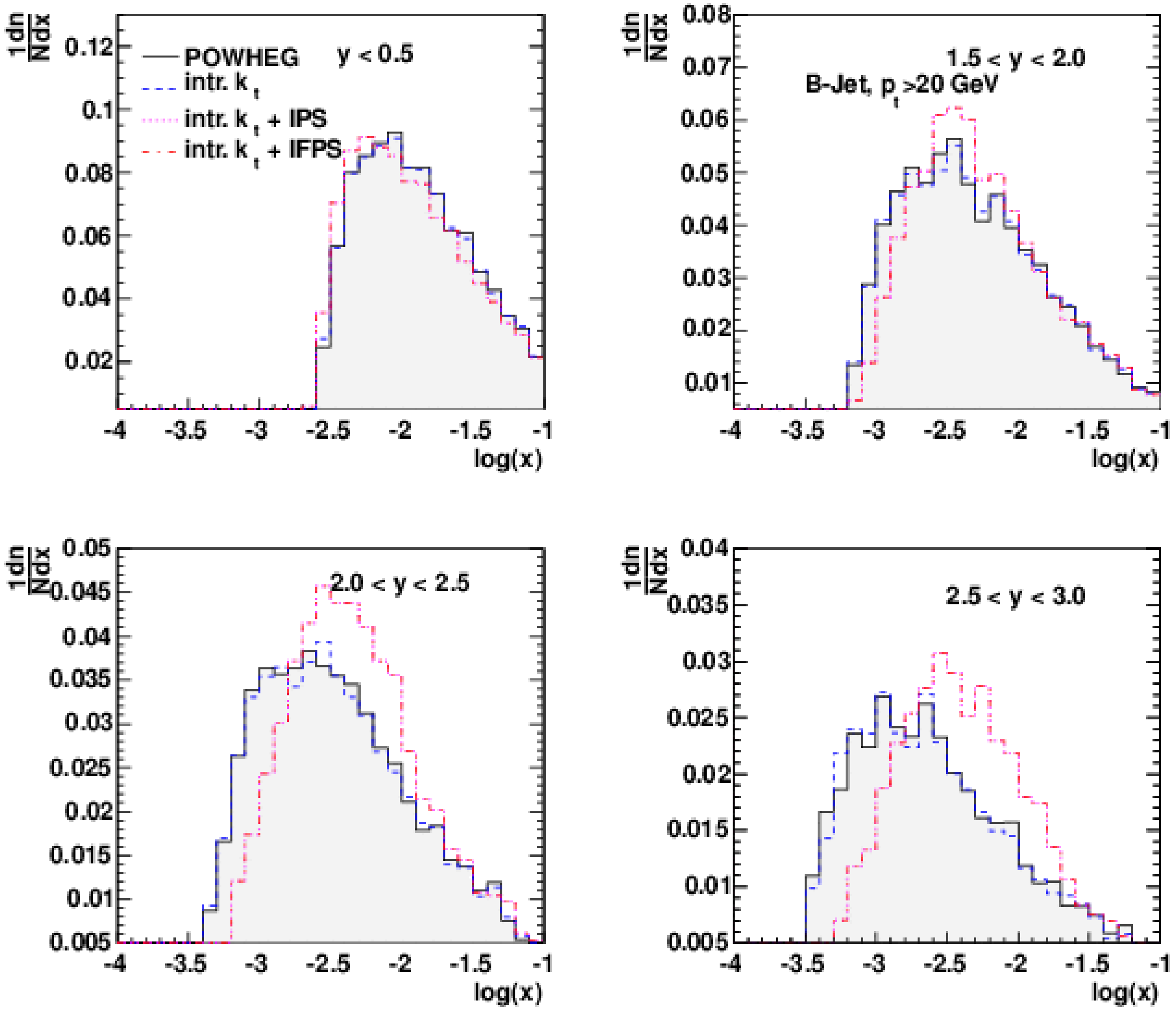
x distribution before and after showering



B-jet production is well described by NLO-matched generators at central rapidities

But data is below the prediction at large y and large p_T

▷ Reshuffling in longitudinal momentum fraction in forward region

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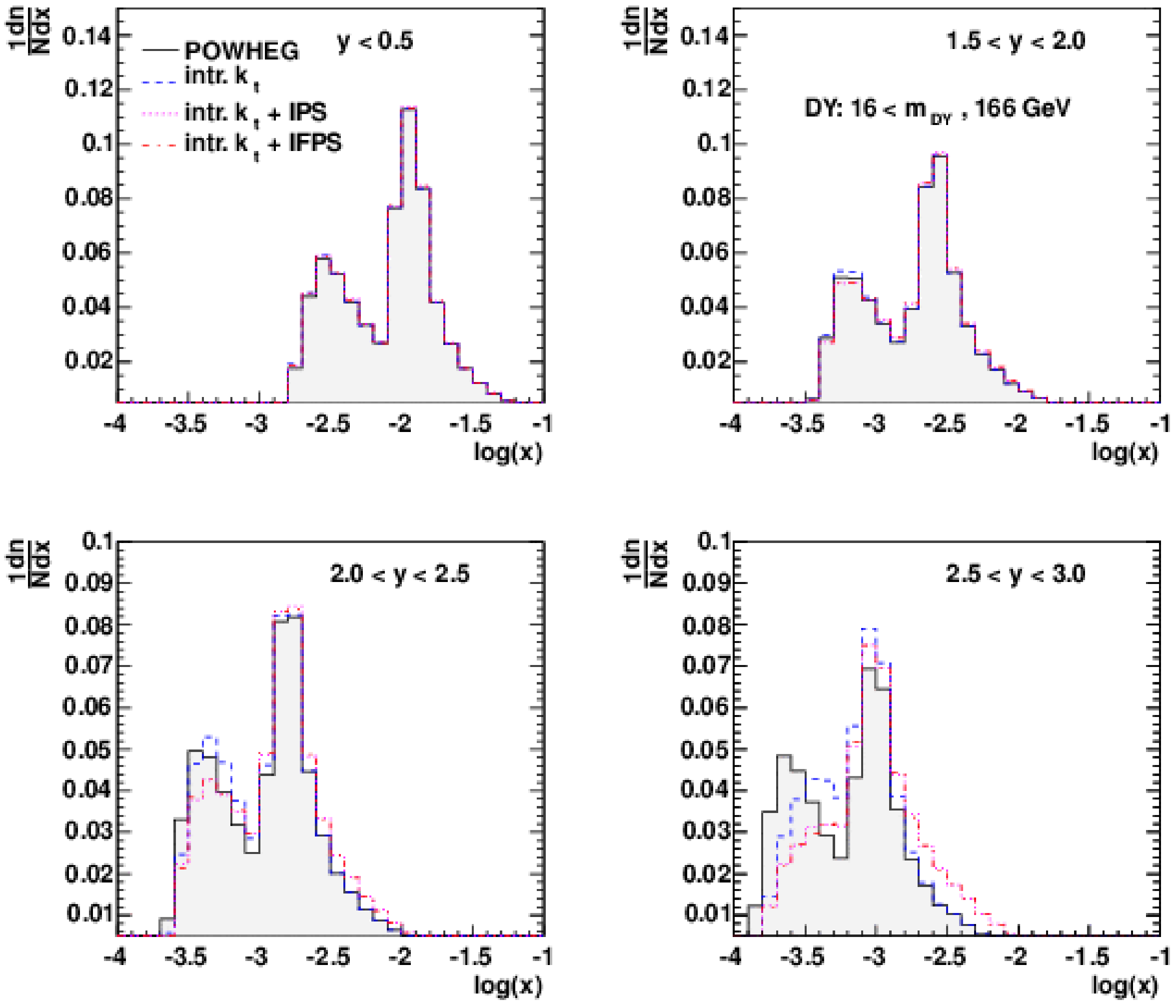
Longitudinal Momentum Shift – Drell-Yan

x distribution before and after showering of DY production in 16 < m < 166 GeV



Double peak structure comes from the continuum DY production in addition to the Z_0

- Kinematic reshuffling in x for forward Drell-Yan production is not negligible

- Kinematic effect influences quark induced processes

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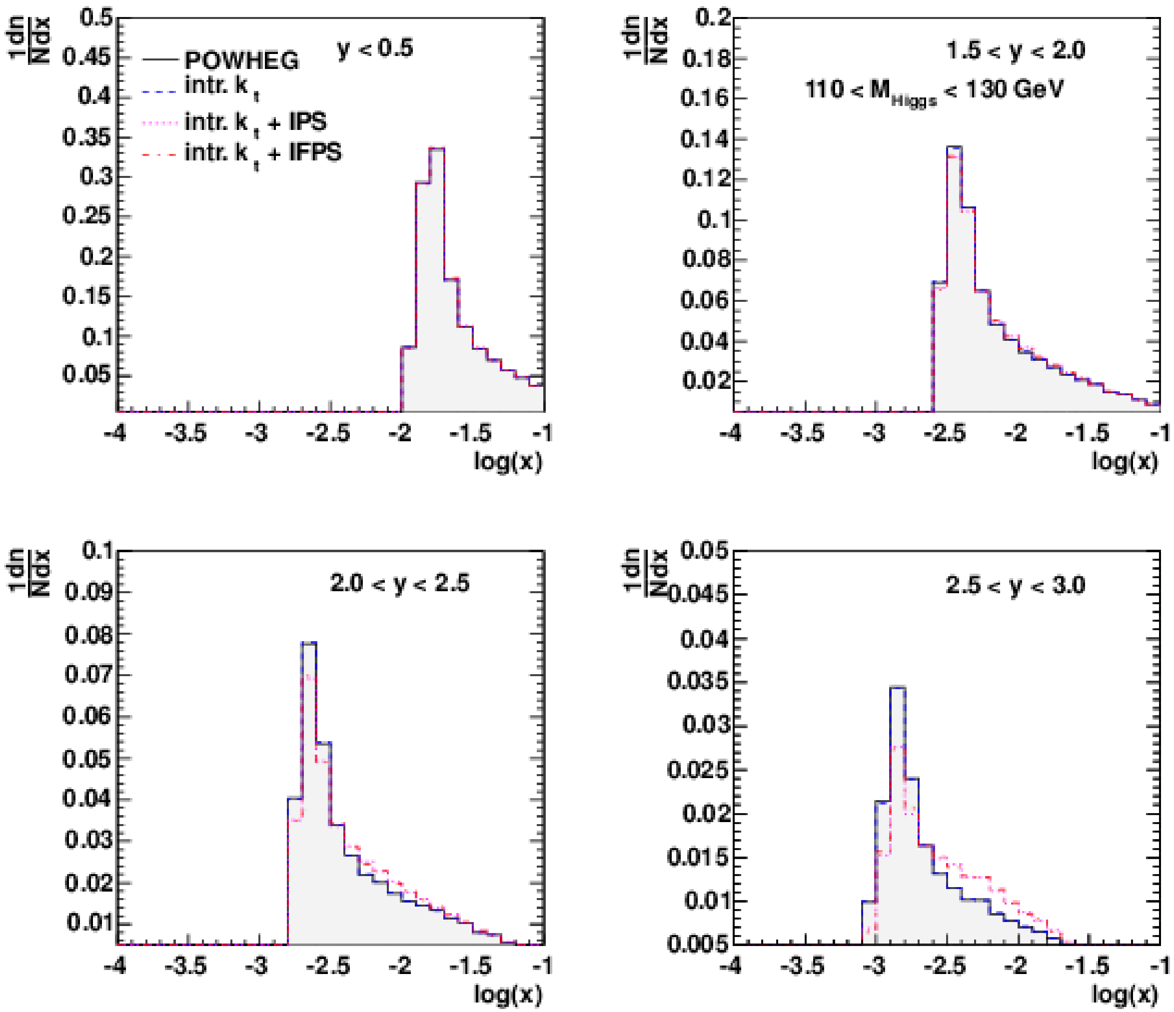
Longitudinal Momentum Shift – Higgs

Higgs production for $110 < m < 130$ GeV at $\sqrt{s} = 7$TeV



The accessible longitudinal momentum fraction x is limited by the Higgs mass

- Reshuffling in x is observed but the effect is smaller compared to the other processes

- The effect of the kinematic shift becomes significantly larger with increasing center-of-mass energy

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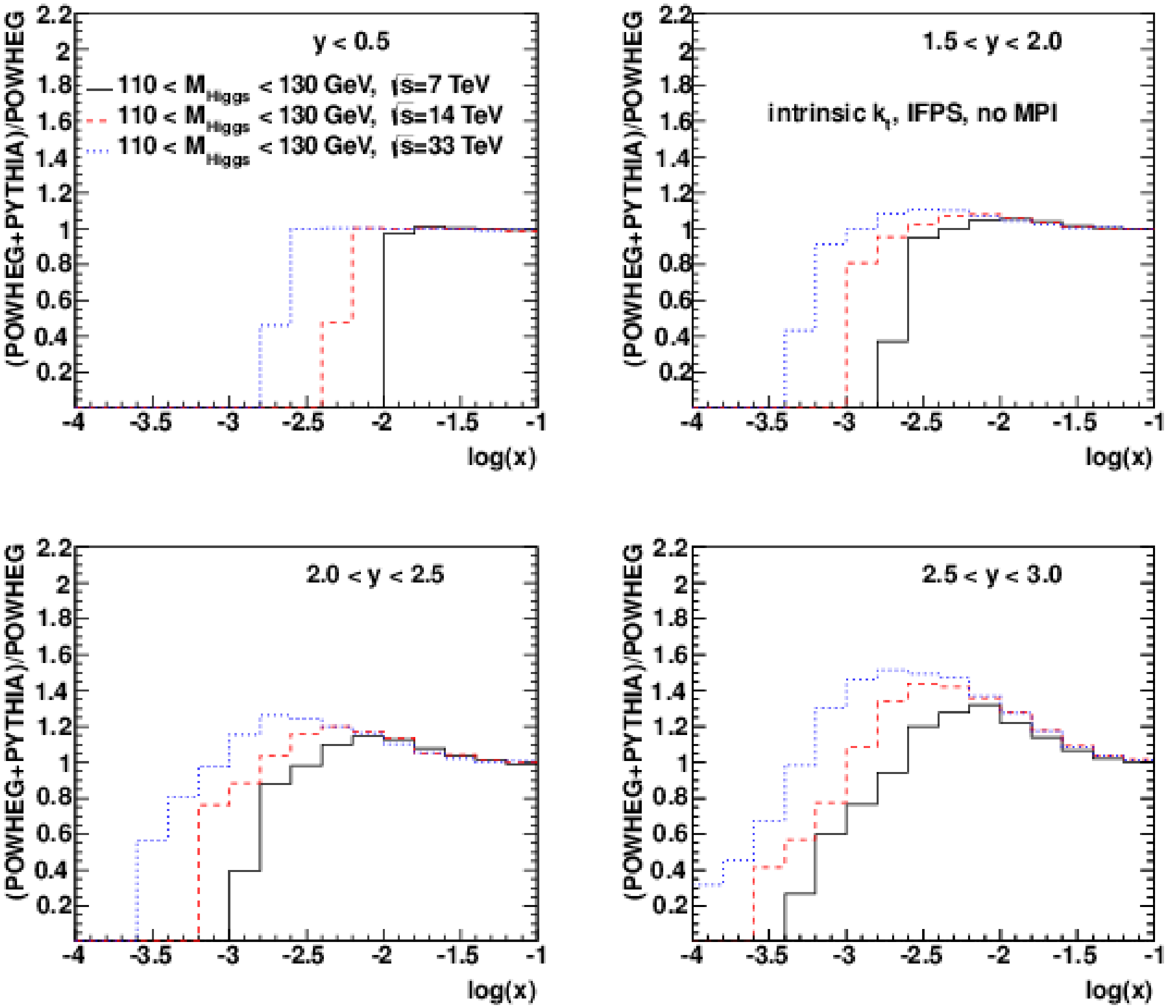
Longitudinal Momentum Shift – Higgs

x distribution before and after showering of the Higgs processes for different energies



Ratio Cross Section before and after the showering versus longitudinal momentum fraction for different energies

▷ More pronounced shift for increasing energy

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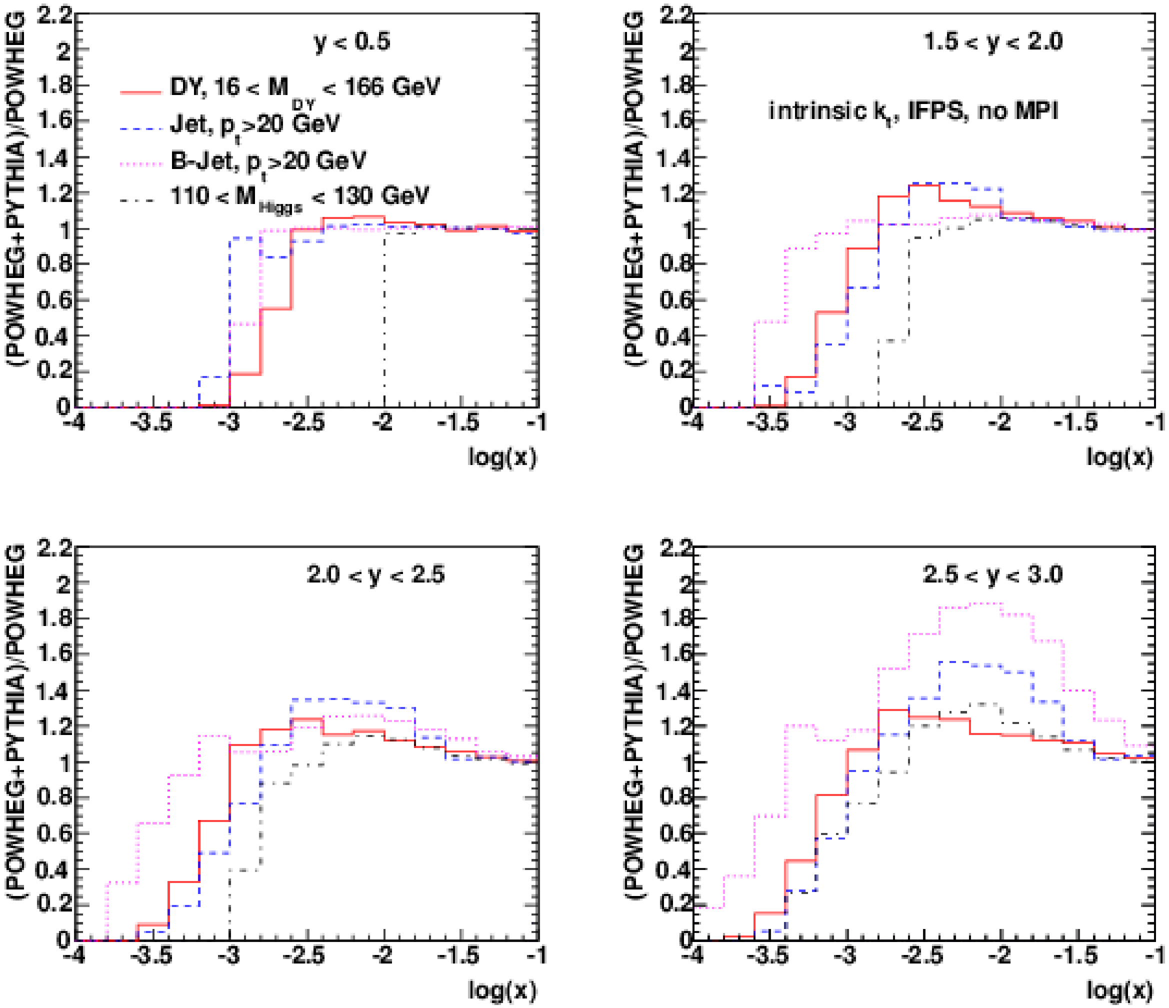
Ratio of Cross Sections

x distribution before and after showering of the different processes



Ratio Cross Section before and after the showering versus longitudinal momentum fraction

- Effect is common in all the different processes

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Summary

New Nonperturbative and Parton Shower Corrections

- Use NLO-matched Shower Monte Carlo generator
- Affect the comparison of theory predictions to inclusive jet measurements
- Parton Shower correction significant over whole p_T range, most significant at large y
- Dependence on p_T and y can influence shape of parton distribution functions

Longitudinal Momentum Shift

- Combining collinear approximation and momentum conservation in SMC leads to a reshuffling in longitudinal momentum space
- Effect is largest for inclusive jets and b-jets for $y > 1.5$
- Non-negligible also for forward Drell-Yan and Higgs production

References

- S.Dooling, P.Gunnellini, F. Hautmann, Hannes Jung "Longitudinal momentum shifts, showering and nonperturbative corrections in matched NLO-shower event generators" ;*arXiv:1212.6164 [hep-ph]*

- H. Jung, F. Hautmann "Collinearity approximations and kinematic shifts in partonic shower algorithms" *EPJC 72 (2012) 2254; arXiv:1209.6549 [hep-ph]*

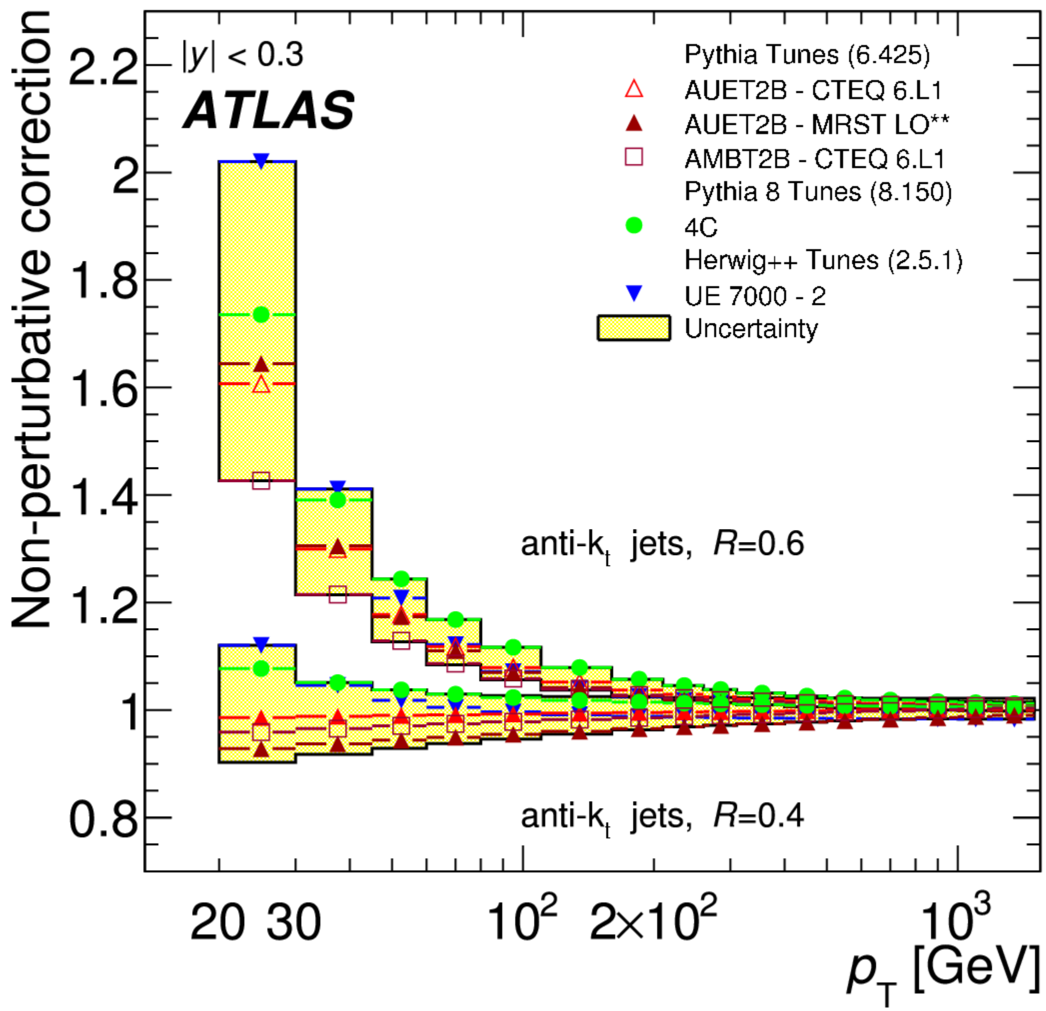
- CMS Collaboration "Measurements of differential jet cross sections in proton-proton collisions at sqrt(s)=7 TeV with the CMS detector" *PRL 107 (2011) 132001; arXiv:1212.6660 [hep-exp]*

- CMS Collaboration "Inclusive b-jet production in pp collisions at sqrt(s)=7 TeV" *JHEP1204 (2012) 084; arXiv:1202.4617 [hep-exp]*

- *ATLAS Collaboration "Measurement of inclusive jet and dijet cross sections in proton-proton collisions at 7 TeV centre-of-mass energy with the ATLAS detector" Phys.Rev. D86 (2012) 014022; arXiv:1112.6297 [hep-exp]*

Backup Slides

Jet size dependence of the nonperturbative correction factor



Backup Slides

Inclusive jet measurement

Ratio of data over theory predictions at NLO compared to POWHEG predictions

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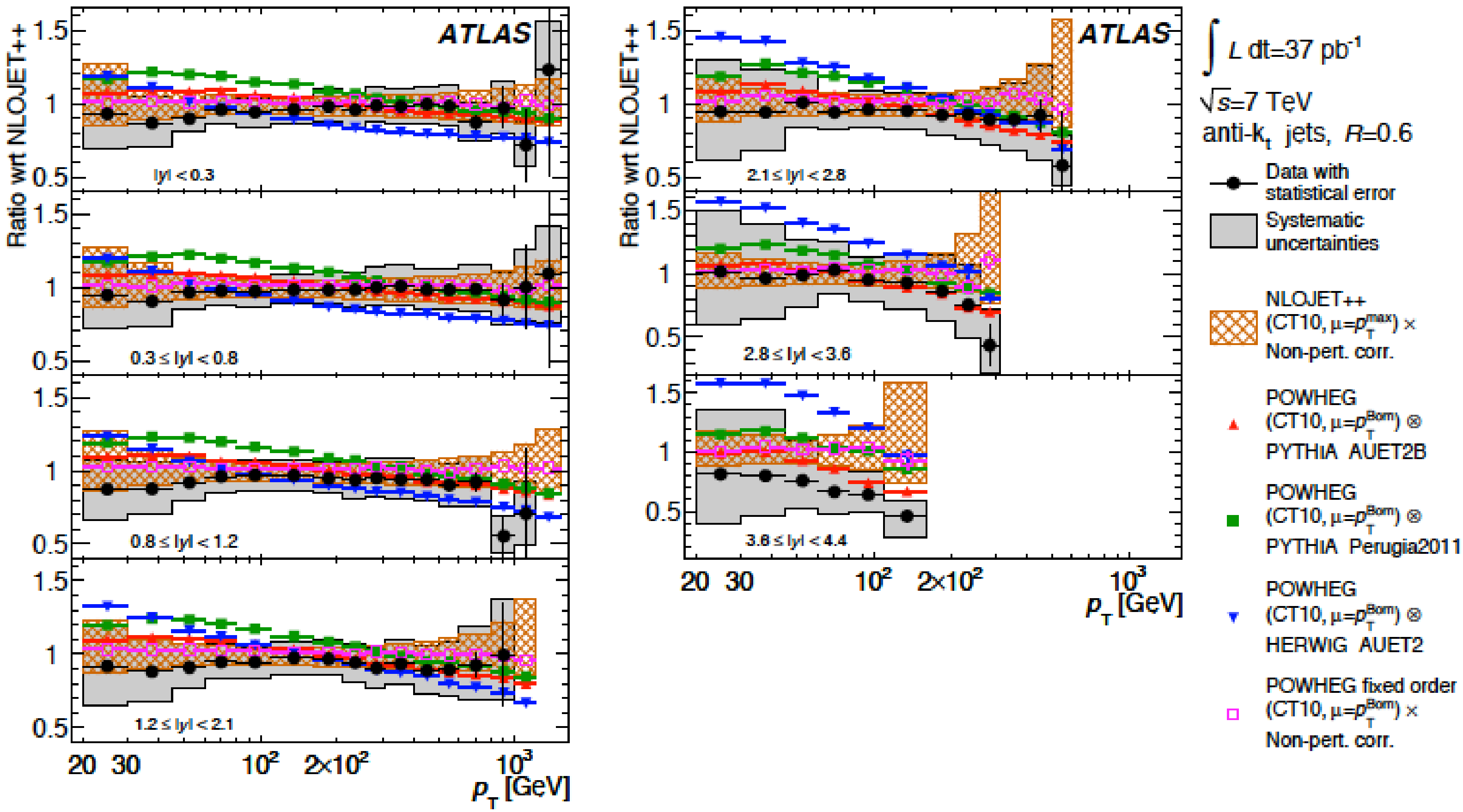

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Inclusive b–jet production in CMS