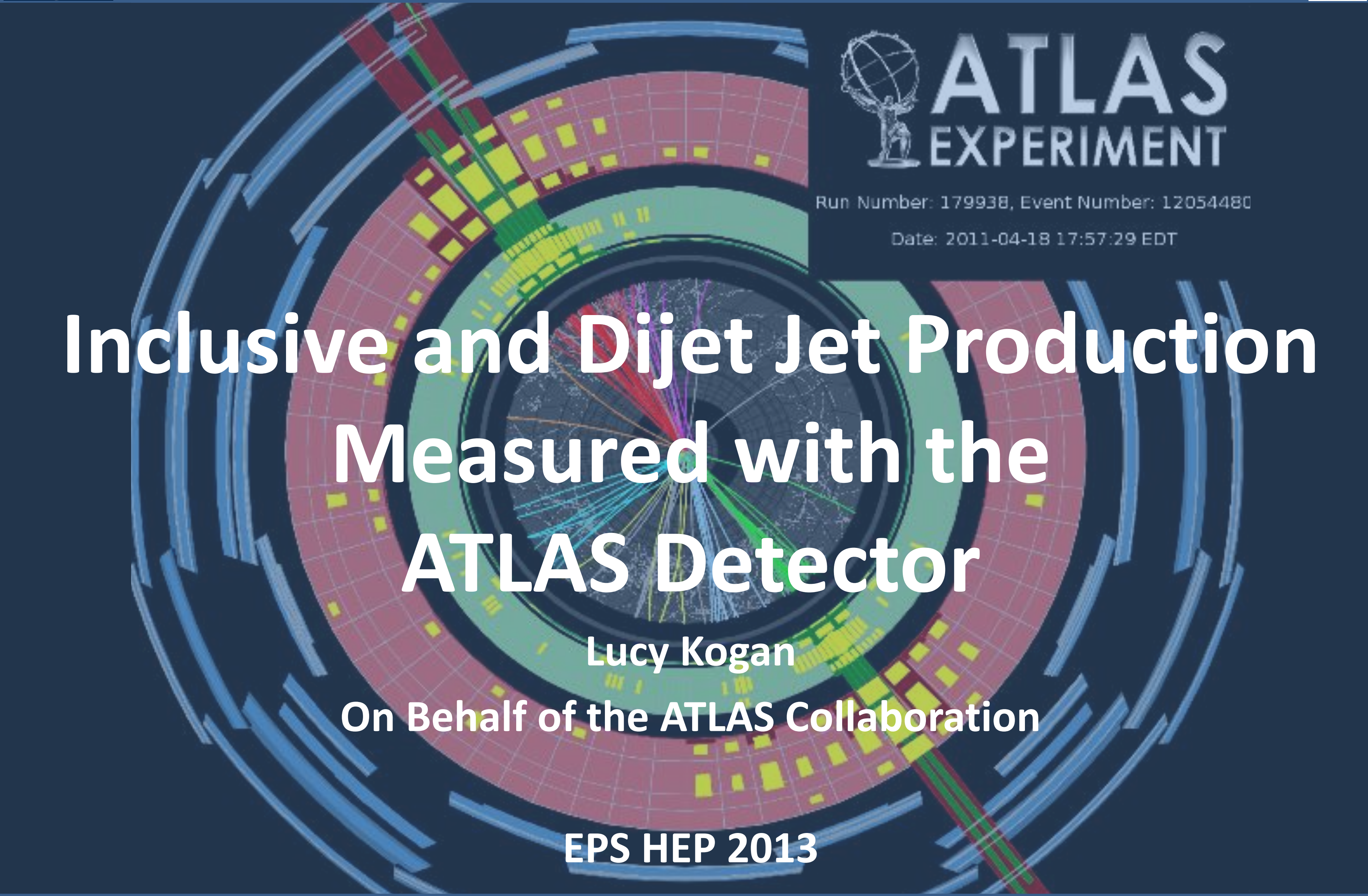


Inclusive and Dijet Jet Production Measured with the ATLAS Detector

Lucy Kogan

On Behalf of the ATLAS Collaboration

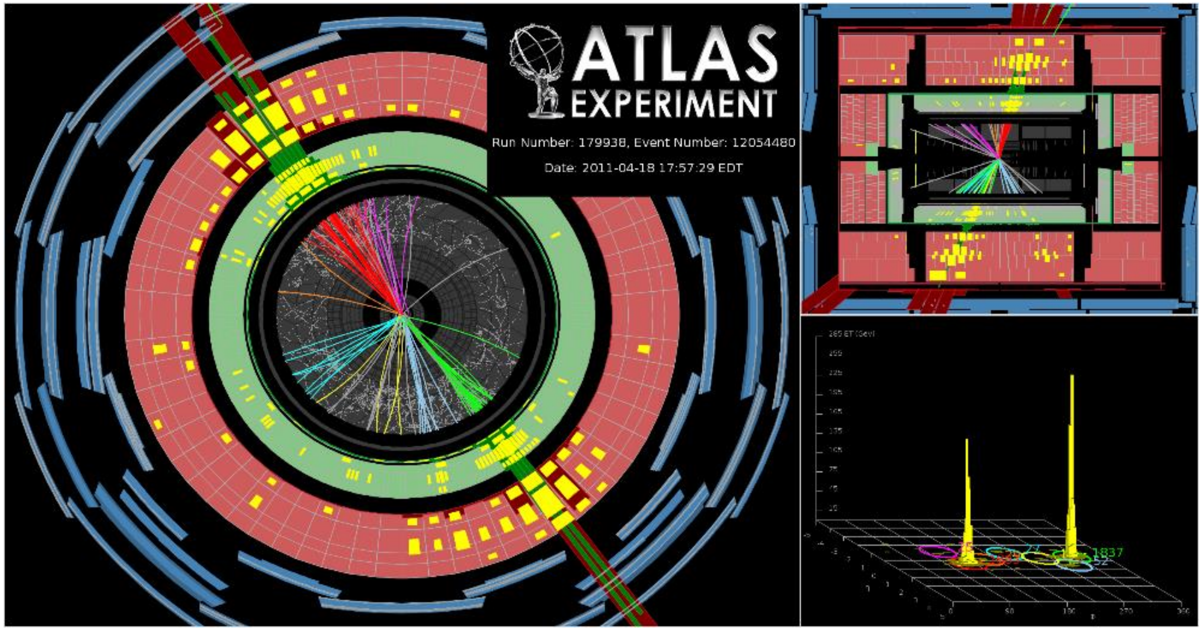
EPS HEP 2013

Overview

- Introduction
- Theory predictions and Jet Reconstruction
- High Mass Dijet cross sections
  - up to invariant mass 4.6 TeV
- Inclusive jet cross sections
  - $\sqrt{s}$ = 7 and $\sqrt{s}$ = 2.76 TeV
- Conclusions

Introduction

- **QCD Jet Production** is a **dominant process** at the LHC
  - Probes the TeV scale
- **Many reasons to study the production of jets**:
  - Test of QCD predictions at high energy
  - Constraints for Parton Distribution Functions
  - Measurement of strong coupling strength
  - Important backgrounds for many analyses
- Many analyses study jets and jet production at ATLAS
  - Presented here: **inclusive and dijet cross section** measurements



2011
dijet event :
invariant mass
4.0 TeV

Theory Predictions

Jet cross sections and ratios compared to NLO theory predictions

- **NLOJET++**
  - pQCD calculations at NLO
  - CT10 NLO Parton Distribution Functions as nominal
  - Also compare to MSTW2008, NNPDF2.1, HERAPDF1.5 PDFs, ABM 11 NLO
  - Bin-by-bin multiplicative factors applied for hadronisation and underlying event
    - Pythia 6.425 with AUET2B tune

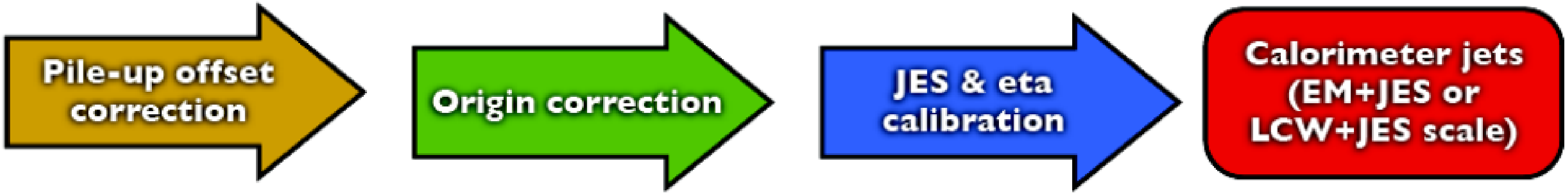
- **POWHEG**
  - NLO matrix element calculation
  - CT10 NLO PDFs
  - Parton shower matched to Pythia or Herwig
    - Improved theoretical predictions expected
    - Additional uncertainties due to matching and tuning of parton shower

Results in **data are unfolded to particle level** for comparison to theory

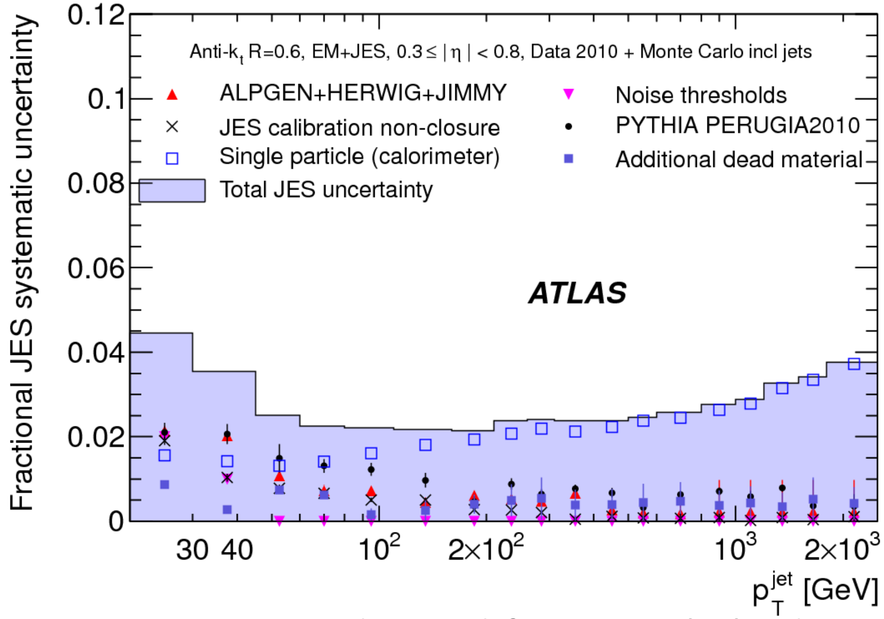
Jet Reconstruction and Calibration

- Jets reconstructed from electromagnetic clusters of calorimeter cells using **Anti-k_t algorithm with R = 0.4 and R = 0.6**

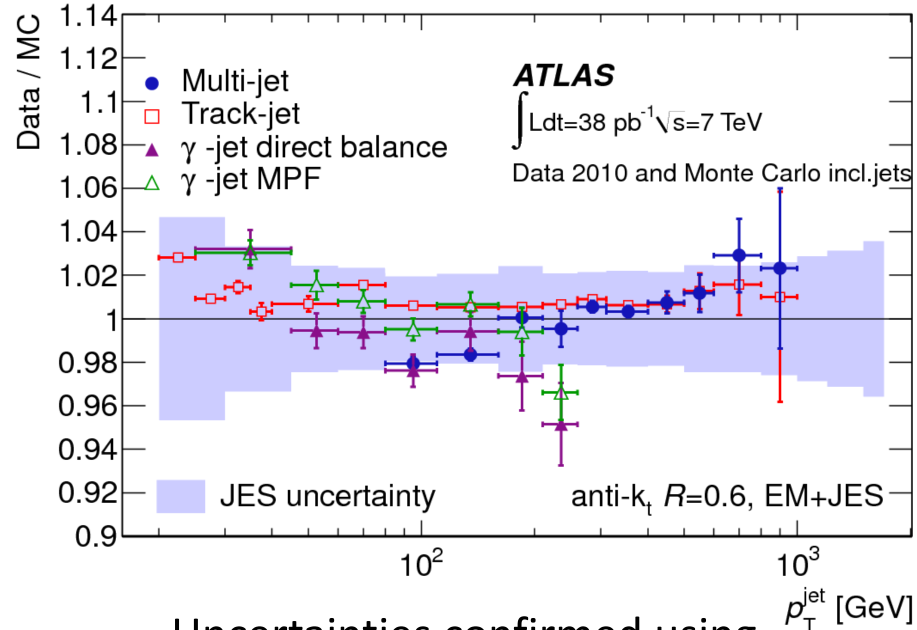
- Jet Energy Scale calibration applied:



- Jet Energy Scale (JES) **dominant experimental uncertainty**



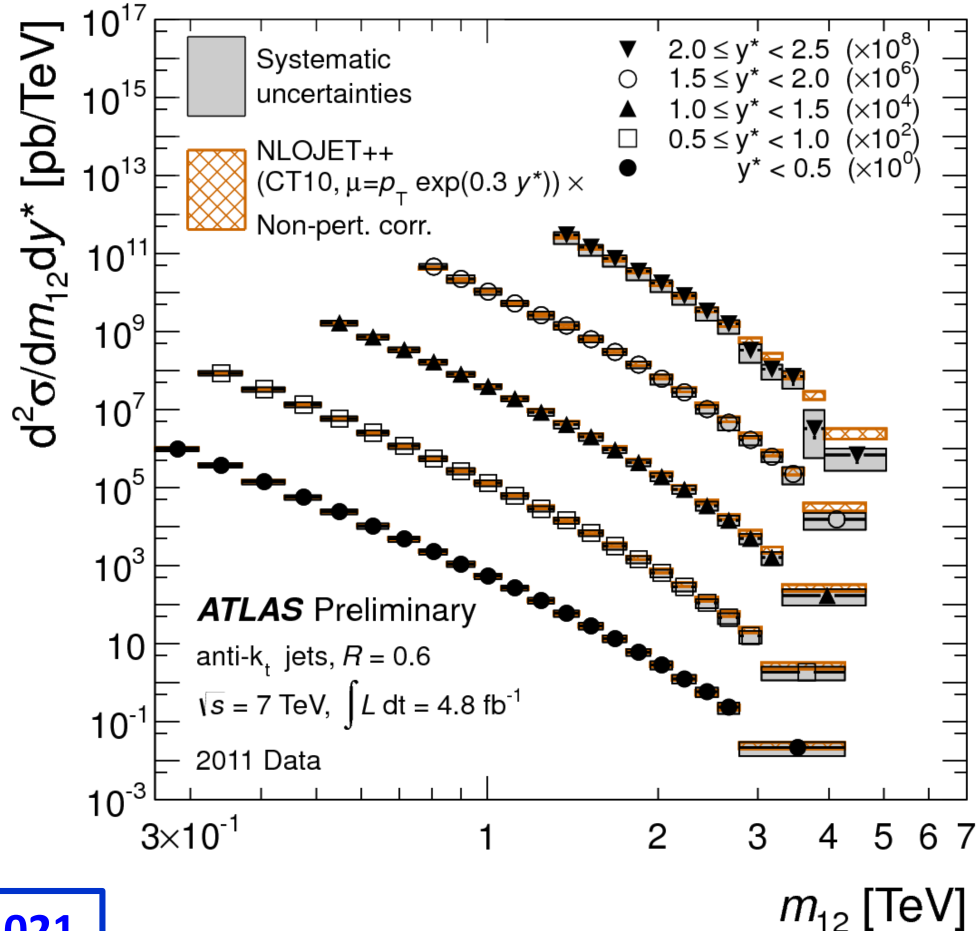
Uncertainties derived from single hadron response and Monte Carlo simulation



Uncertainties confirmed using insitu response measurements

Dijet production at $\sqrt{s}$ = 7 TeV

- **$\sqrt{s}$ = 7 TeV , luminosity 4.8 fb^{-1}**
- 260 GeV ≤ m_{12} ≤ 4.6 TeV
- **Binned in y*** = $\frac{|y_1 - y_2|}{2}$, y* < 2.5



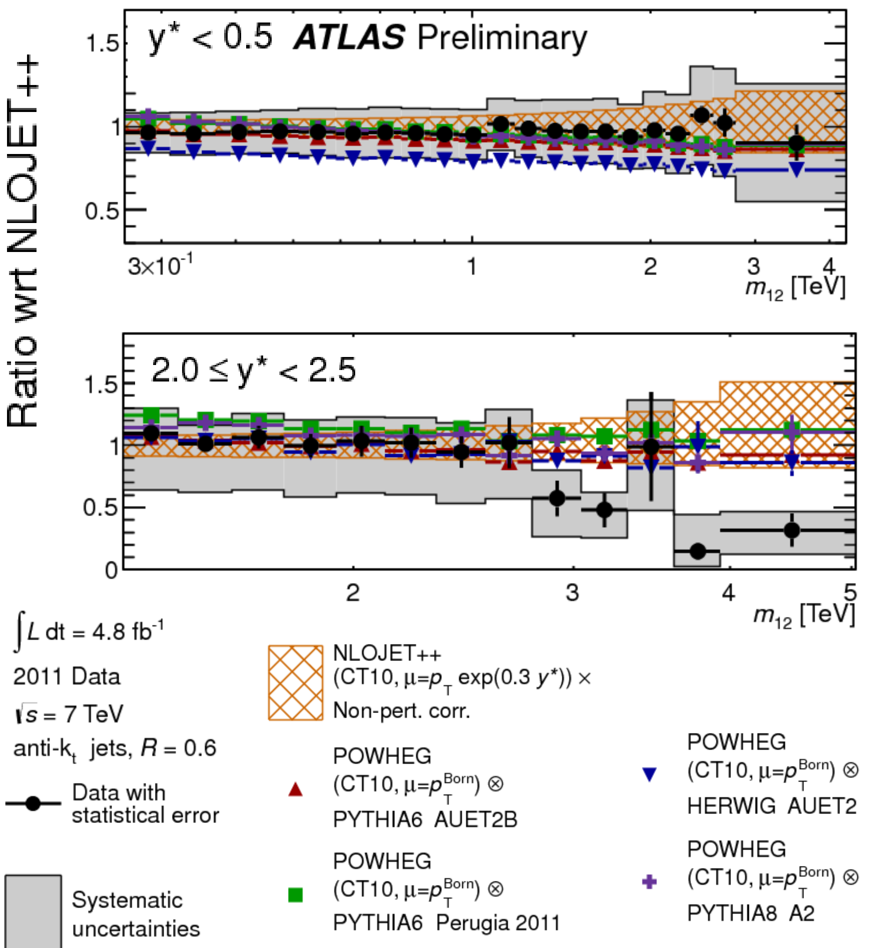
[ATLAS-CONF-2012-021]

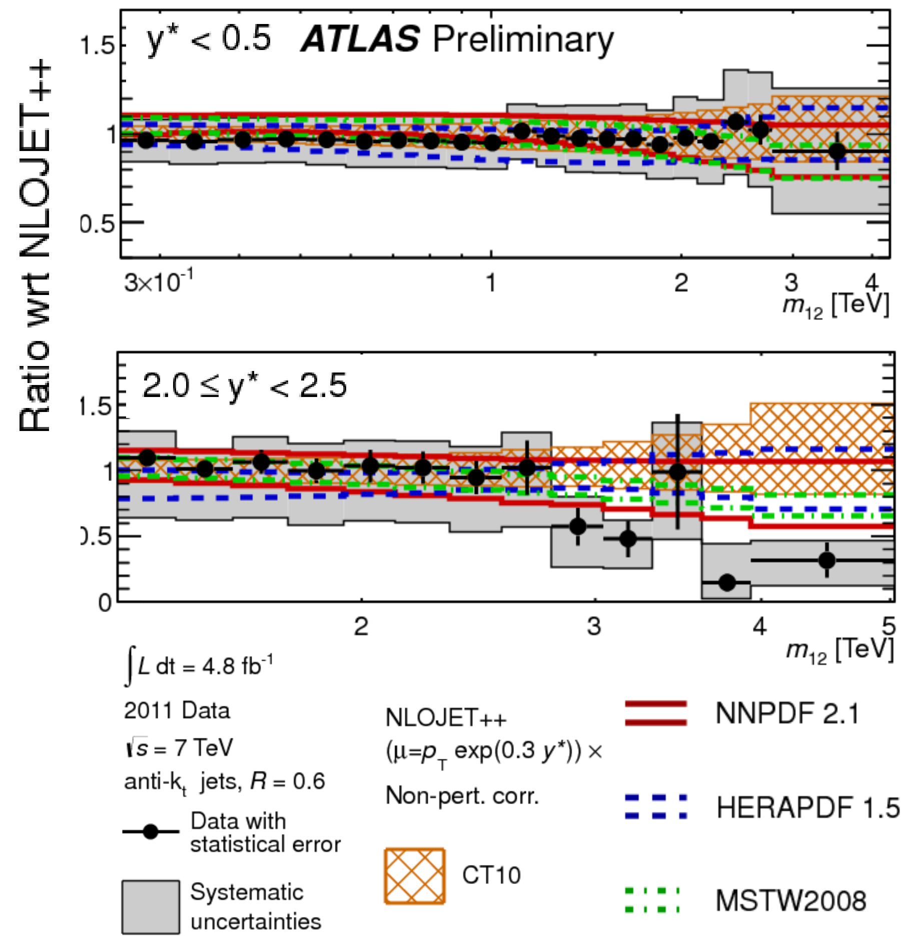
Anti – kt R = 0.6 jets

Dijet production at $\sqrt{s}$ = 7 TeV

ATLAS-CONF-2012-021

- **Ratios to NLOJET++** with CT10 PDF
- In general **data is in agreement** with theory predictions
  - **Differences up to 40% at high y* & dijet mass**: theory predictions overestimate cross section





Anti – kt R = 0.6 jets

NLOJET++ and POWHEG

NLOJET++ with different PDFs

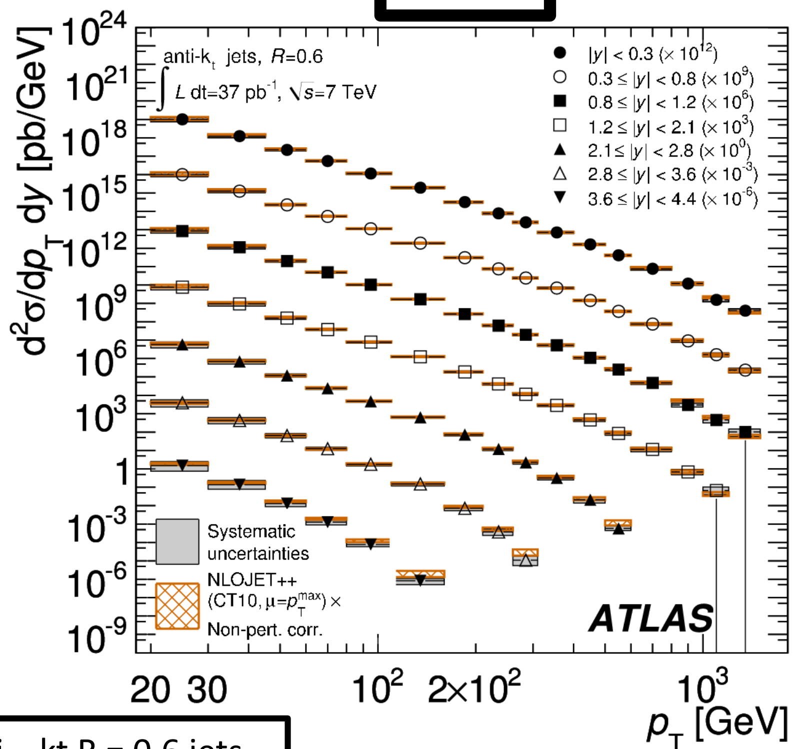
Inclusive Jets: $\sqrt{s}$ = 7 TeV and $\sqrt{s}$ = 2.76 TeV

Inclusive jet cross section measurements at two different $\sqrt{s}$

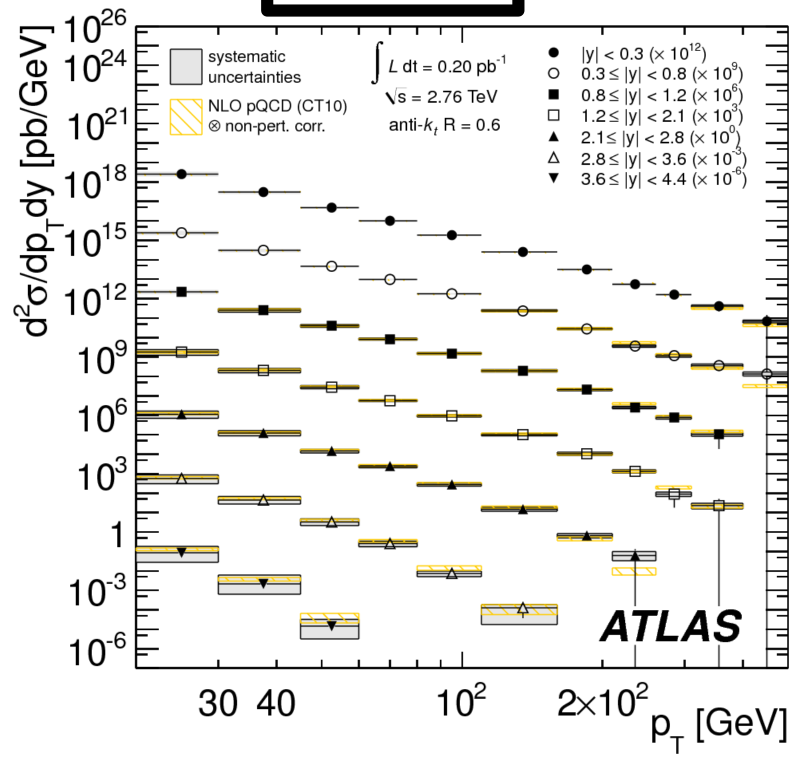
- **$\sqrt{s}$ = 7 TeV, luminosity 37 pb^{-1}**
  - 20 GeV ≤ Jet p_T ≤ 1.5 TeV, |y| < 4.4
- **$\sqrt{s}$= 2.76 TeV, luminosity 0.20 pb^{-1}**
  - Close to highest energy p$\bar{p}$ collisions
  - 20 ≤ p_T ≤ 430 GeV, |y| < 4.4

[Phys.Rev. D86 (2012) 014022](), [arXiv:1304.4739]()

7 TeV



2.76 TeV



Anti – kt R = 0.6 jets

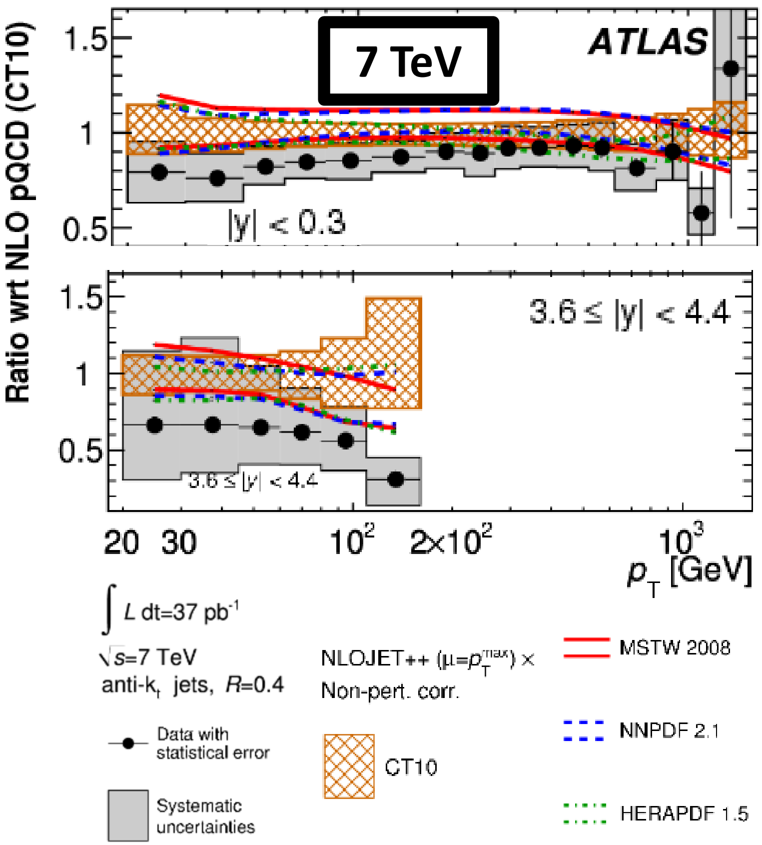
Inclusive Jets: Cross section with NLOJET++

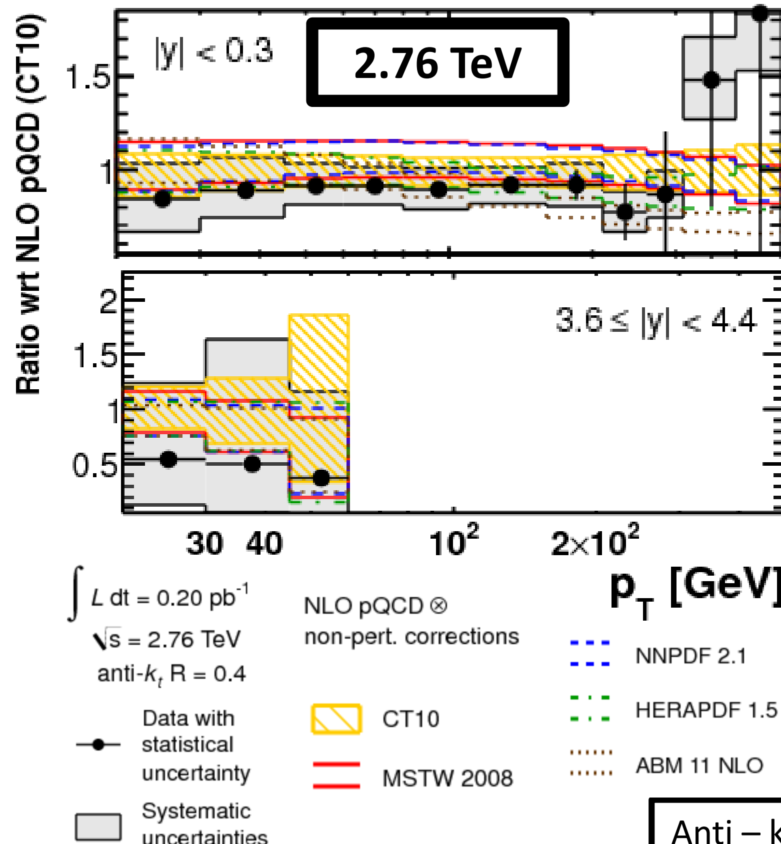
Comparison to NLOJET++ with different PDF sets

- Ratio with respect to NLOJET++, CT10 PDFs
- **Good agreement within systematic uncertainties**
- Data systematically lower than theory prediction
  - Particularly at high pt and rapidity
  - MSTW follows trend better

[Phys.Rev. D86 (2012) 014022](#), [arXiv:1304.4739](#)

NLOJET++



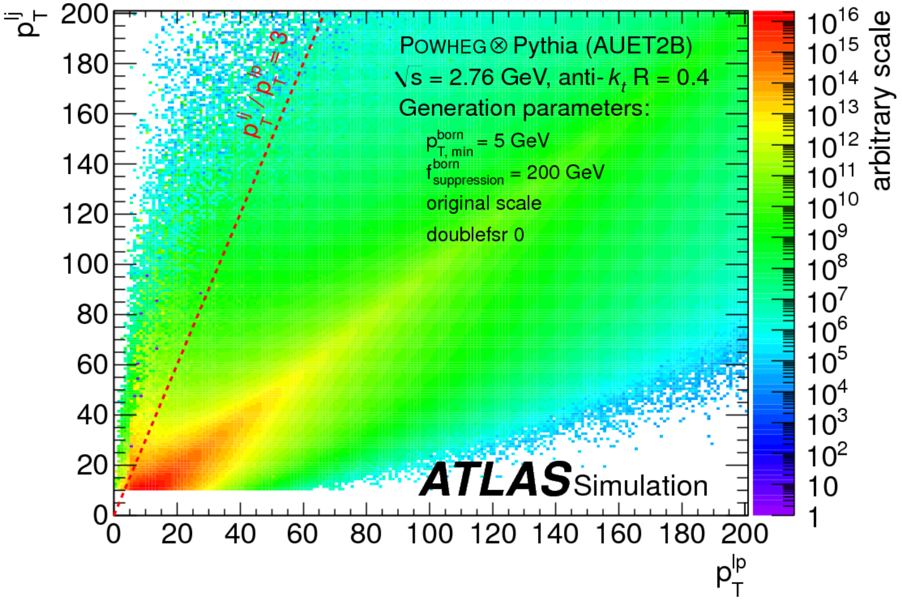


Anti – kt R = 0.4 jets

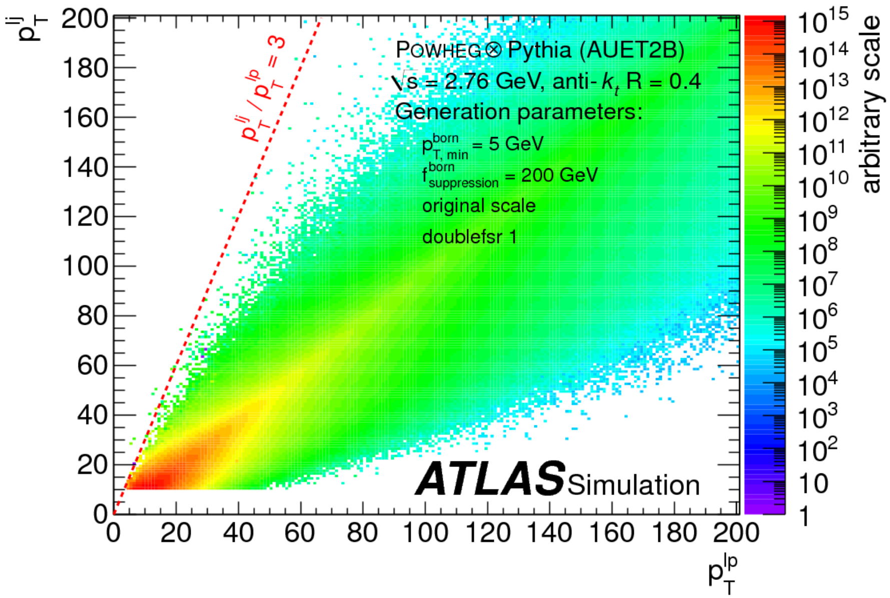
Inclusive Jets: Cross section with POWHEG

New version of POWHEG BOX used for $\sqrt{s}$ = 2.76 TeV predictions

- At $\sqrt{s}$ = 7 TeV problem with parton shower matching caused fluctuations in final observables
- New version with modified matching scale released by POWHEG BOX authors(arXiv:1303.3922v1)



Old version : used for $\sqrt{s}$ = 7 TeV



New version : used for $\sqrt{s}$ = 2.76 TeV

Phys.Rev. D86 (2012) 014022, arXiv:1304.4739

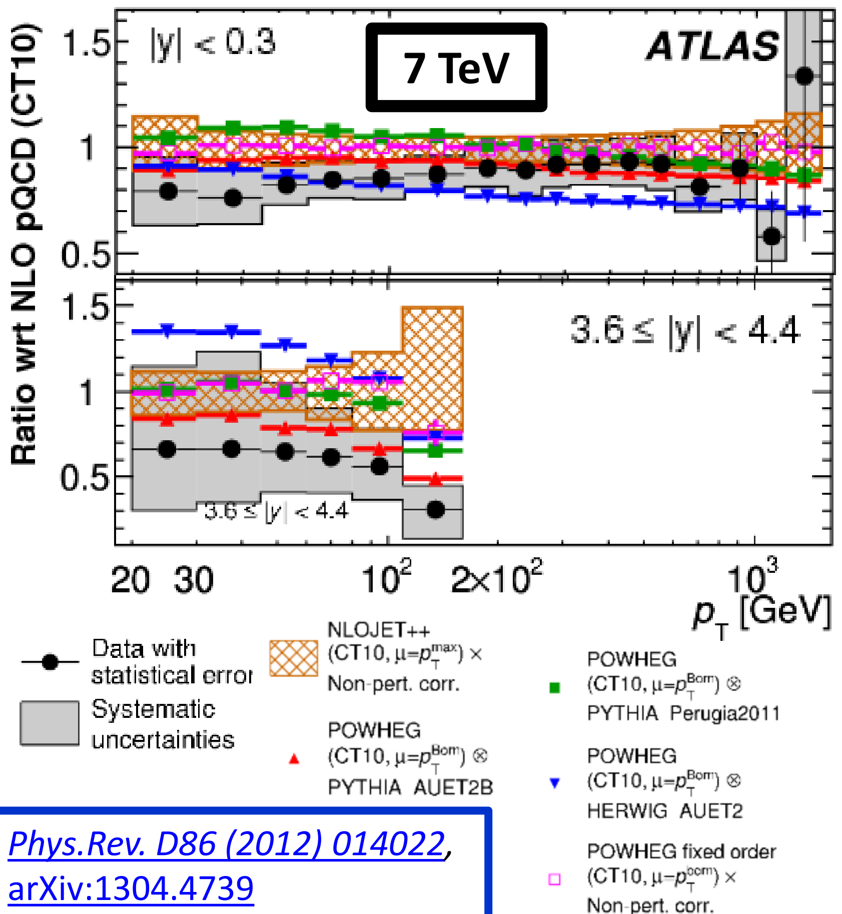
Anti – kt R = 0.4 jets

Inclusive Jets: Cross section with POWHEG

Comparison to POWHEG with different parton showers and tunes

POWHEG

- Ratio with respect to NLOJET++, CT10 PDFs
- Best agreement with POWHEG + Pythia AUET2B
- **New matching parameters in POWHEG for $\sqrt{s}$ = 2.76 TeV**
  - **Agreement with data within uncertainties**



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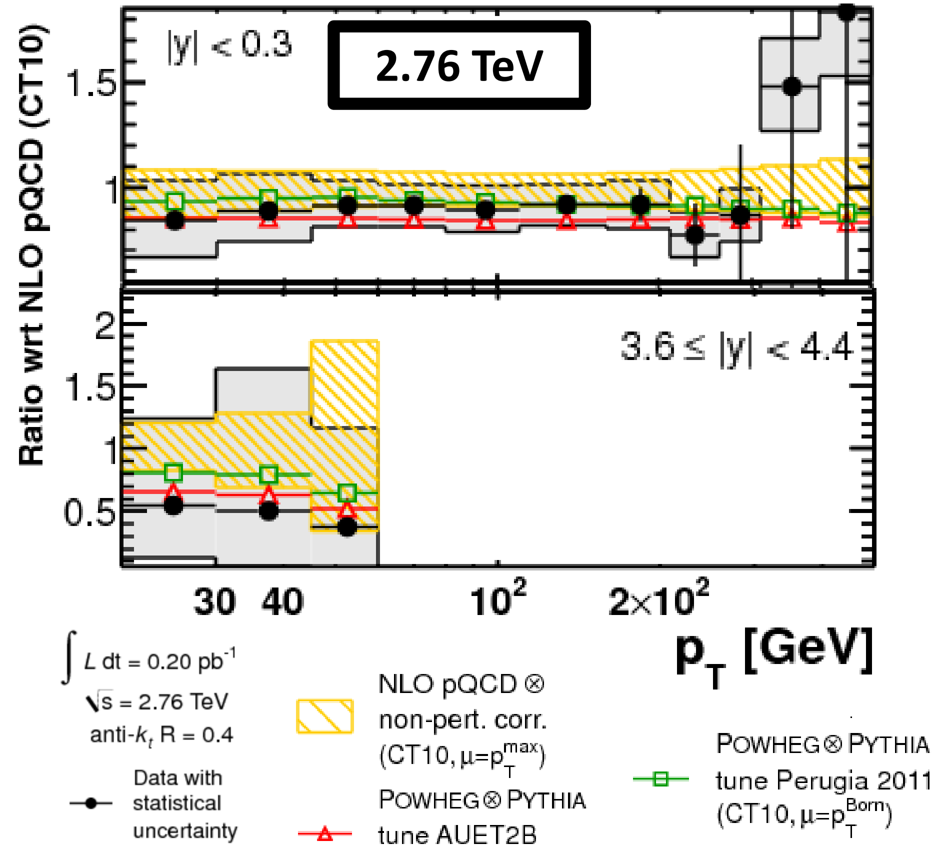


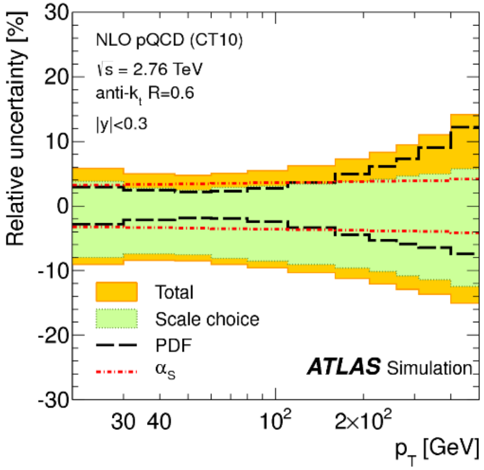
Anti – kt R = 0.4 jets

Inclusive jets: ratio of $\sqrt{s}$ = 7 and 2.76 TeV

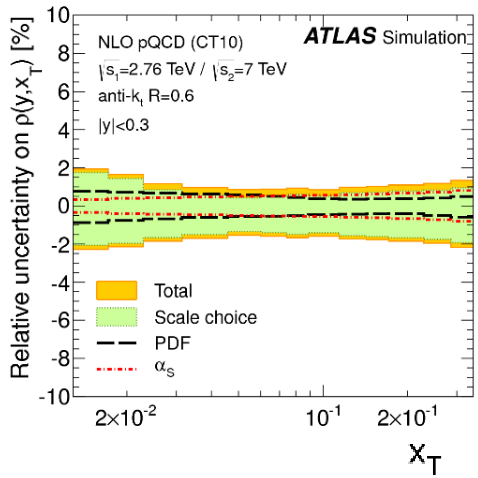
- Jet cross sections as **function of jet p_T and $x_T = \frac{2p_T}{\sqrt{s}}$**
- **Ratios of cross sections** at $\sqrt{s}$ = 7 TeV and $\sqrt{s}$ = 2.76 TeV **reduce uncertainties**:

$$\rho(y, x_T) = \left(\frac{2.76\,TeV}{7\,TeV}\right)^3 \frac{\sigma(y, x_T, 2.76\,TeV)}{\sigma(y, x_T, 7\,TeV)}$$ theoretical uncertainties reduced

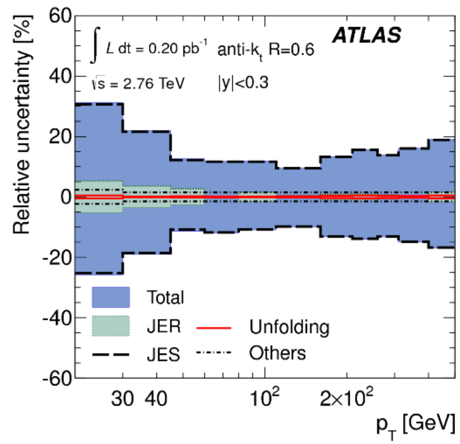
$$\rho(y, p_T) = \frac{\sigma(y, p_T, 2.76\,TeV)}{\sigma(y, p_T, 7\,TeV)}$$ experimental uncertainties reduced



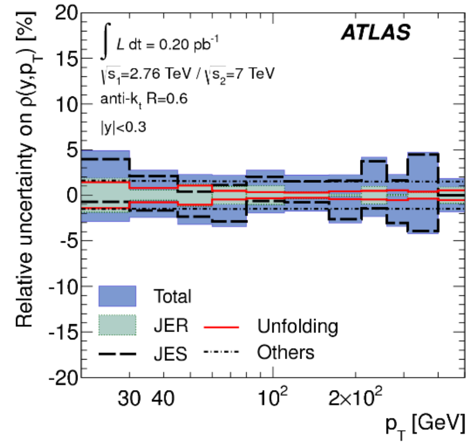
Theoretical uncertainties: cross section



Theoretical uncertainties: $\rho(y, x_T)$



Experimental uncertainties: cross section



Experimental uncertainties: $\rho(y, p_T)$

arXiv:1304.4739

Anti – kt R = 0.6 jets

Cross section ratio theory comparison

- $\rho(y, x_T)$ ratio shows very **good agreement** with NLOJET++ and POWHEG
  - Constant behaviour with x_T
    => QCD asymptotic freedom and evolution of gluon PDF with QCD scale
  - Differences between different tunes are small
  - Theory uncertainties are very small
- $\rho(y, p_T)$ ratio shows **differences in central region** up to 10%
  - POWHEG follows data well in forward region
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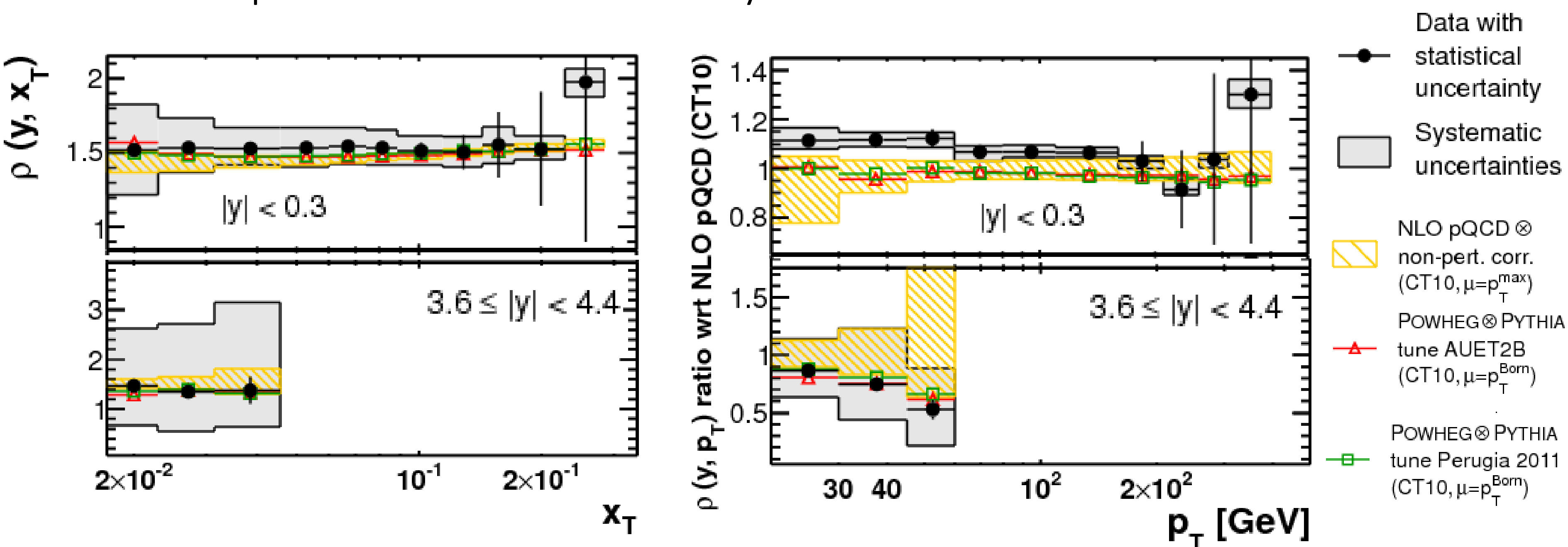


$\rho(y, x_T)$

$\rho(y, p_T)$

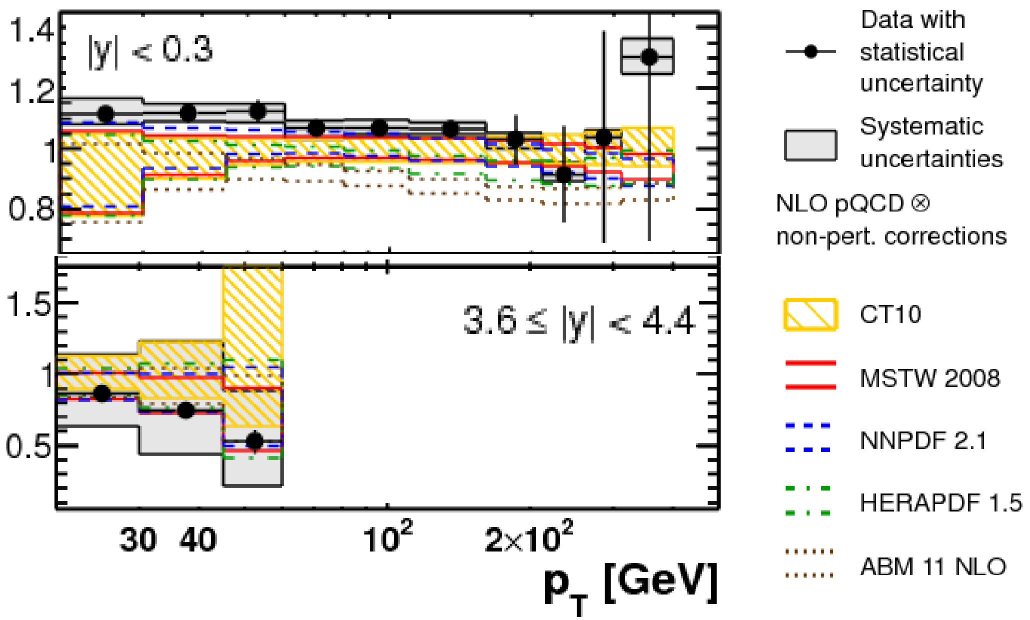
Anti – kt R = 0.6 jets

Cross section ratio PDF comparisons

$\rho(y, p_T)$ ratio compared to different PDFs:

arXiv:1304.4739

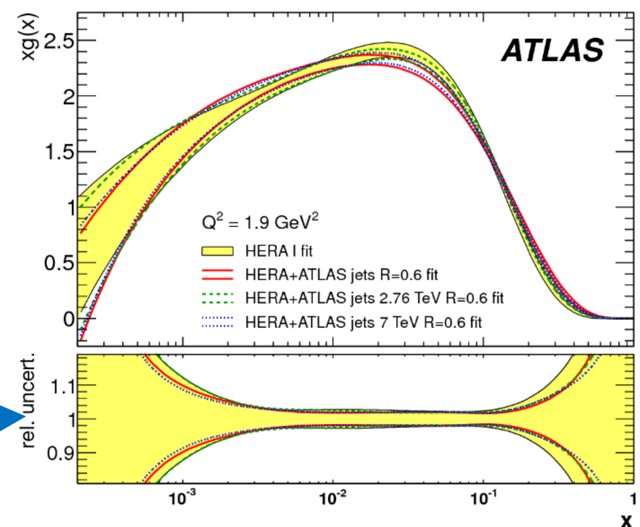
- Data higher in central region and lower in forward region
  - larger deviation for ABM11 NLO



- **Systematic uncertainty smaller than theory uncertainty**

  => $\sqrt{s}$ = 7 TeV and $\sqrt{s}$ = 2.76 TeV inclusive cross sections can be used to **constrain PDFs**

Gluon distribution function



Conclusions

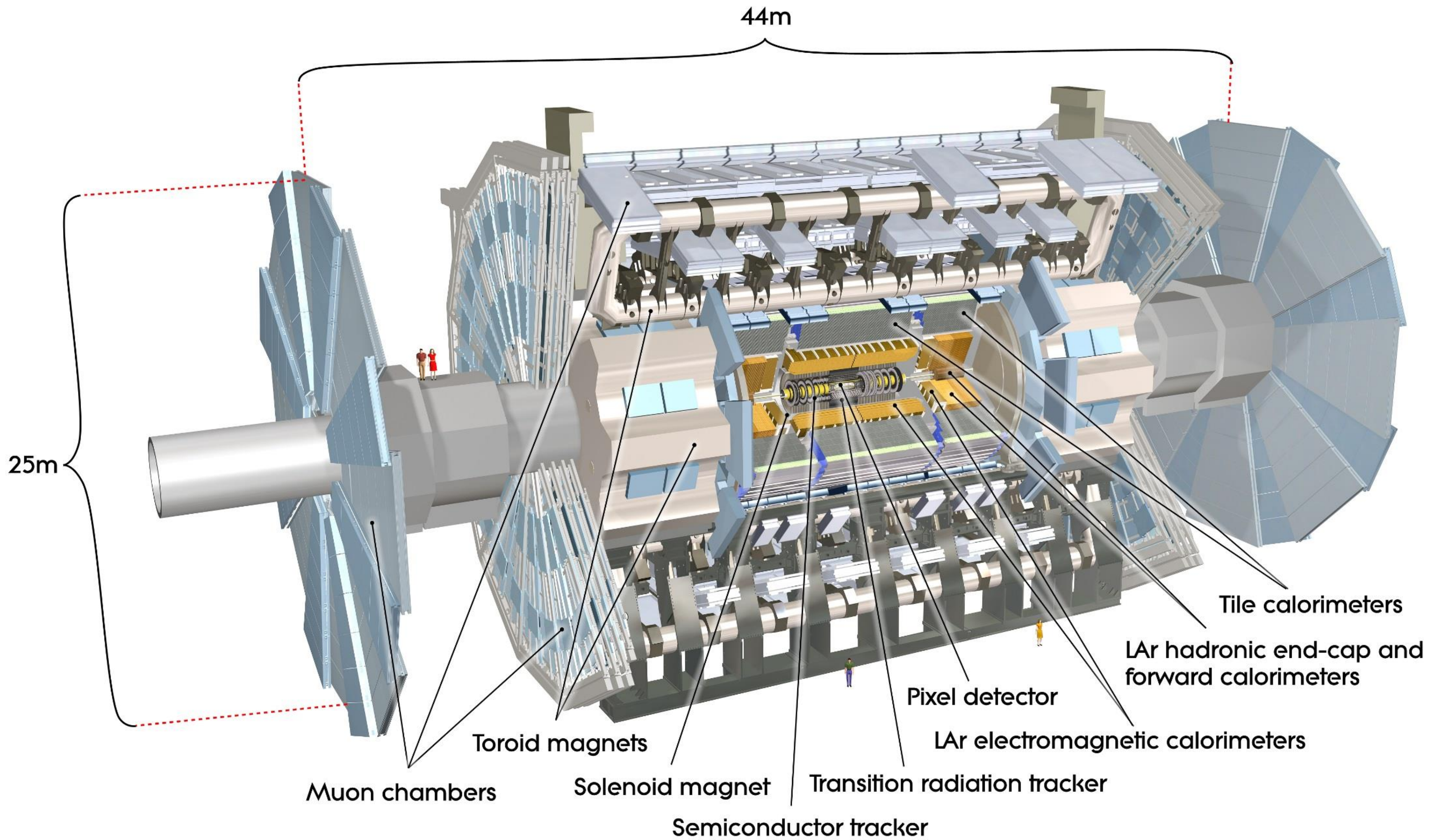
- **Jet cross sections have been measured with the ATLAS detector and compared to NLO pQCD predictions**

- **Dijet cross sections** measured at $\sqrt{s}$ = 7 TeV
  - **Good agreement** with theoretical predictions
  - **Differences at high energies and rapidities** of up to 40%

- **Inclusive jet cross sections** measured at **$\sqrt{s}$ = 7 TeV and $\sqrt{s}$ = 2.76 TeV**
  - In general **good agreement** with theoretical predictions
  - Cross sections can be used to **constrain PDFs**

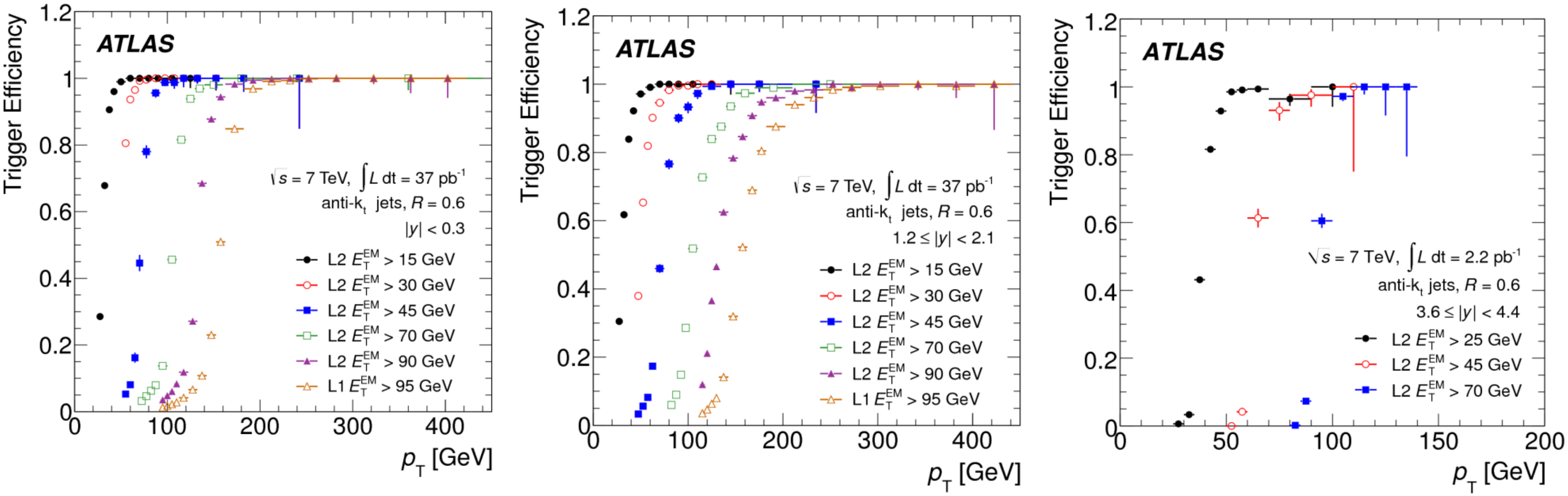
Back-up slides

The ATLAS Detector



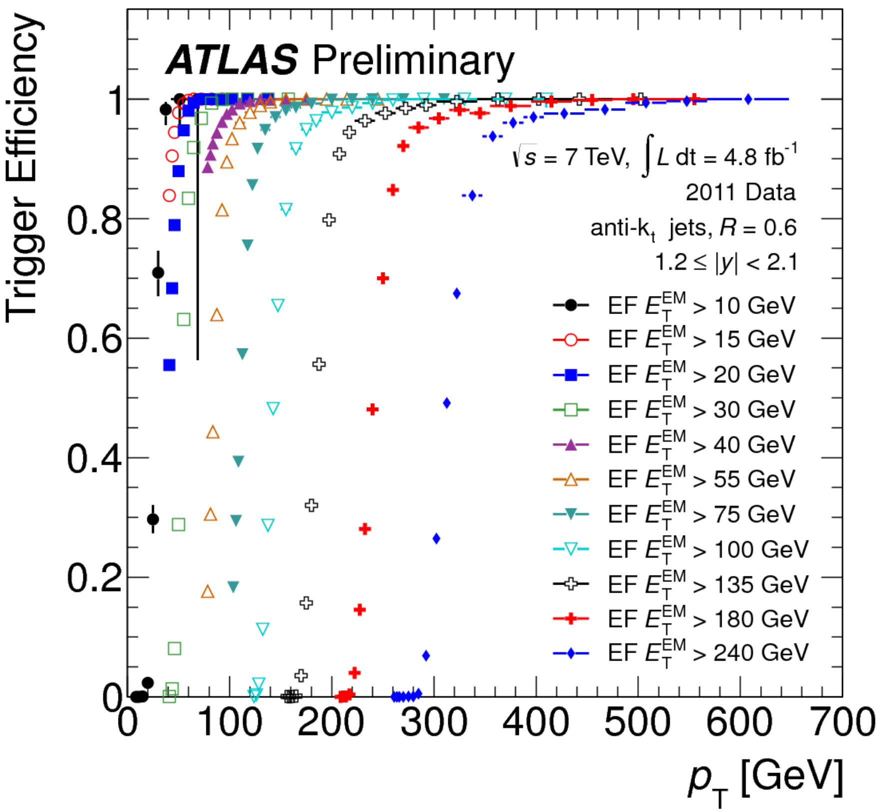
Triggers : Inclusive jet Cross section

- Triggers used:
  - Minimum-Bias trigger scintillators for jets 20 – 60 GeV
  - Central jet trigger : |η| < 3.2
  - Forward jet trigger : 3.1 < |η| < 4.9
- Different trigger in each p_T bin
  efficiency > 99 % with smallest possible prescale



Combined L1 + L2 trigger efficiencies

- Central jet triggers |η| < 3.2
- Jet energy fully contained in central trigger towers => trigger is unbiased
- Highest E_T^{EM} trigger unprescaled
- Different threshold for each trigger in the analysis
  > 99% efficiency with the smallest possible prescale



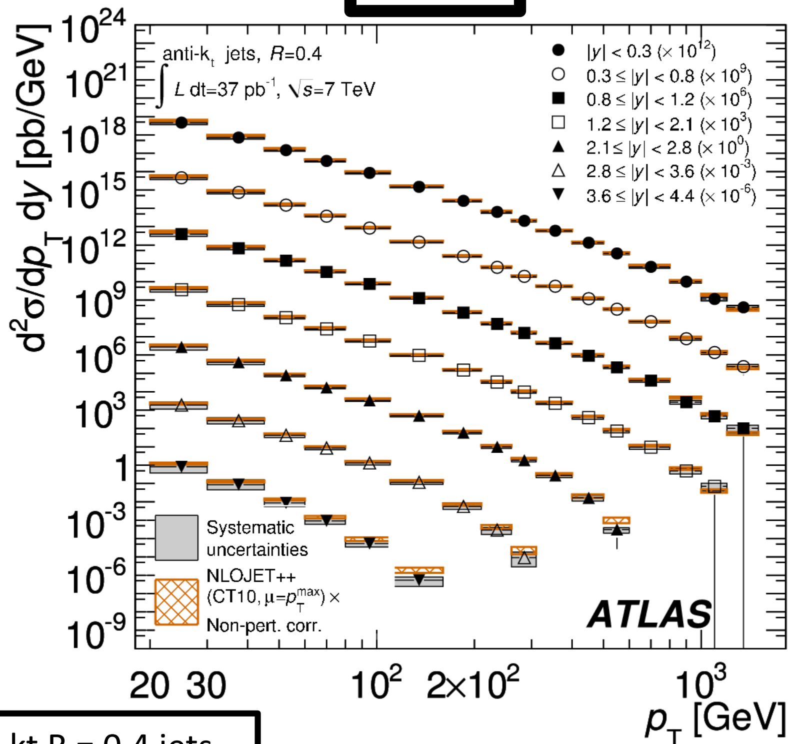
Inclusive Jets: $\sqrt{s}$ = 7 TeV and $\sqrt{s}$ = 2.76TeV

Inclusive jet cross section measurements at two different $\sqrt{s}$

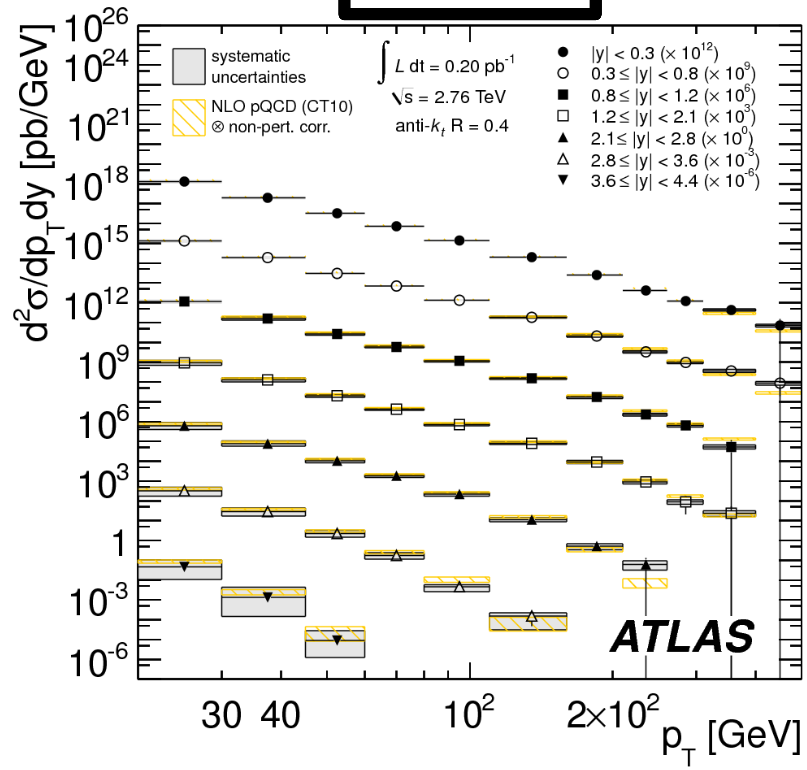
- **$\sqrt{s}$ = 7 TeV, luminosity 37 pb^{-1}**
  - 20 GeV ≤ Jet p_T ≤ 1.5 TeV, |y| < 4.4
- **$\sqrt{s}$= 2.76 TeV, luminosity 0.20 pb^{-1}**
  - Similar $\sqrt{s}$ as at Tevatron
  - 20 ≤ p_T ≤ 430 GeV, |y| < 4.4

Phys.Rev. D86 (2012) 014022, http://arxiv.org/abs/1304.4739

7 TeV



2.76 TeV



Anti – kt R = 0.4 jets

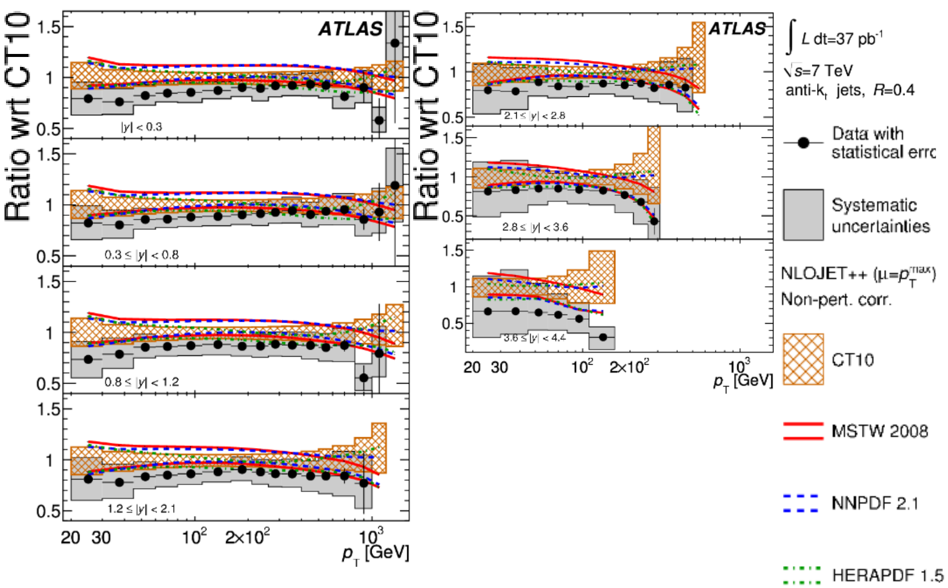
Inclusive Jets: Cross section with NLOJET++

NLOJET++

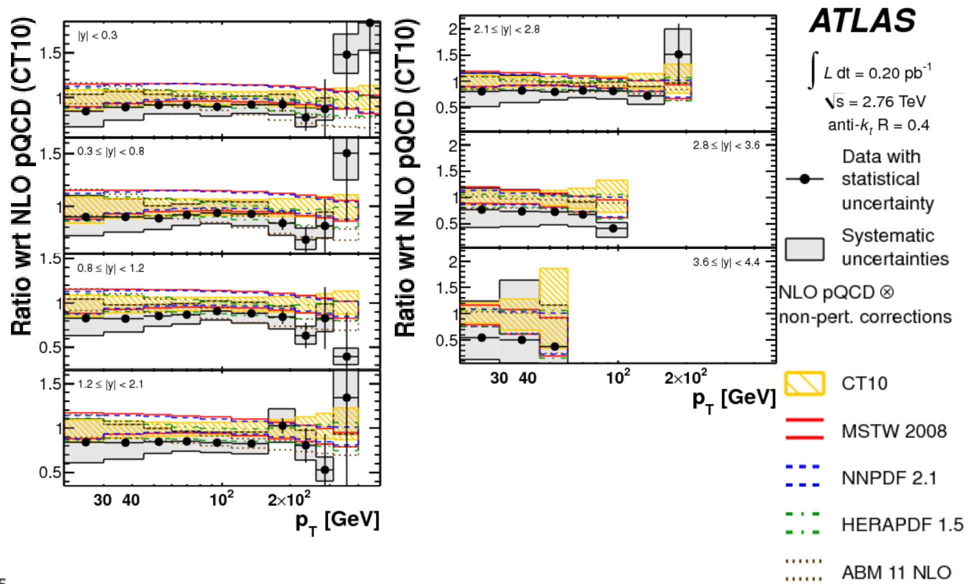
Comparison to NLOJET++ with different PDF sets

- Ratio with respect to NLOJET++, CT10 PDFs
- **Good agreement within systematic uncertainties**
- Data systematically lower than theory prediction
  - Particularly at high pt and rapidity
  - MSTW follows trend better

7 TeV



2.76 TeV



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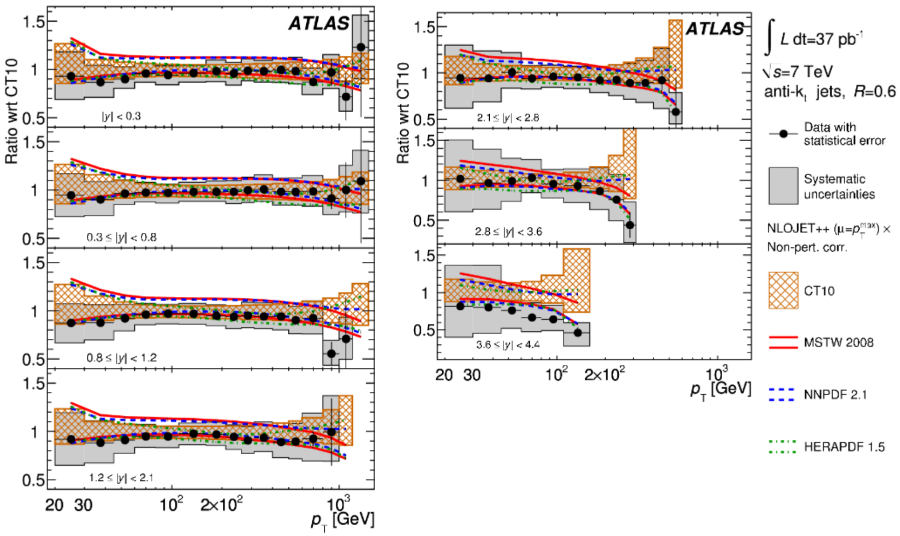
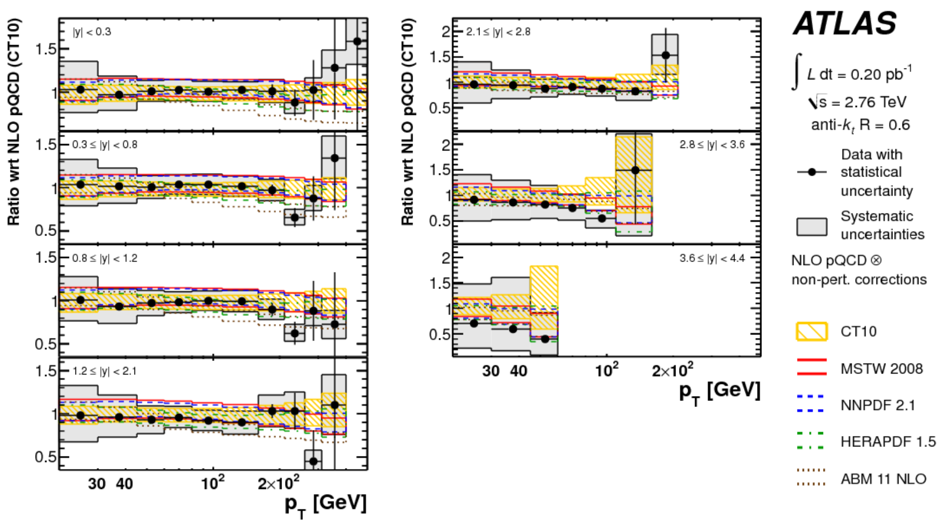
NLOJET++

7 TeV



2.76 TeV



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Anti – kt R = 0.6 jets

Comparison to POWHEG with different parton showers and tunes

POWHEG

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- **Best agreement with POWHEG + Pythia AUET2B**
- **New matching parameters in POWHEG for $\sqrt{s}$ = 2.76 TeV**
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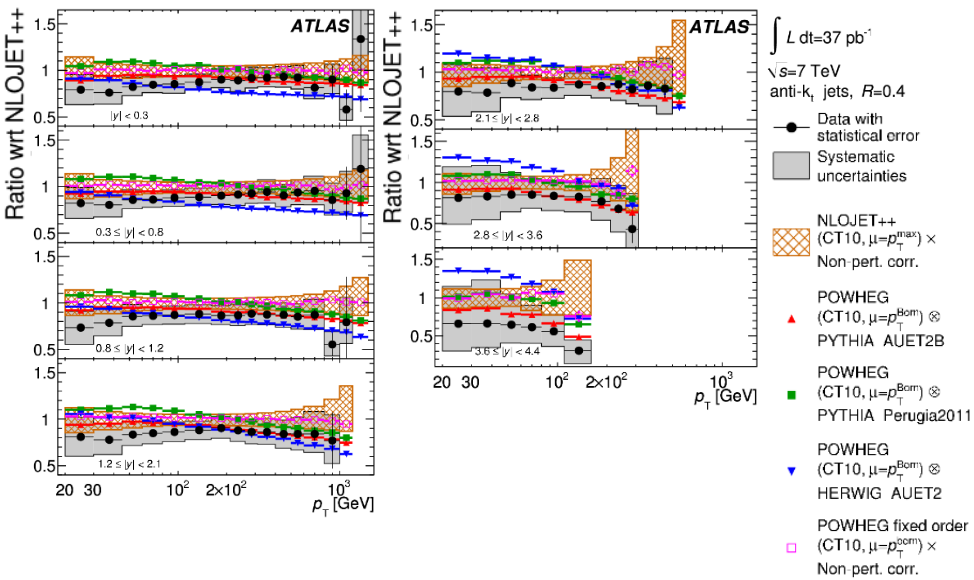
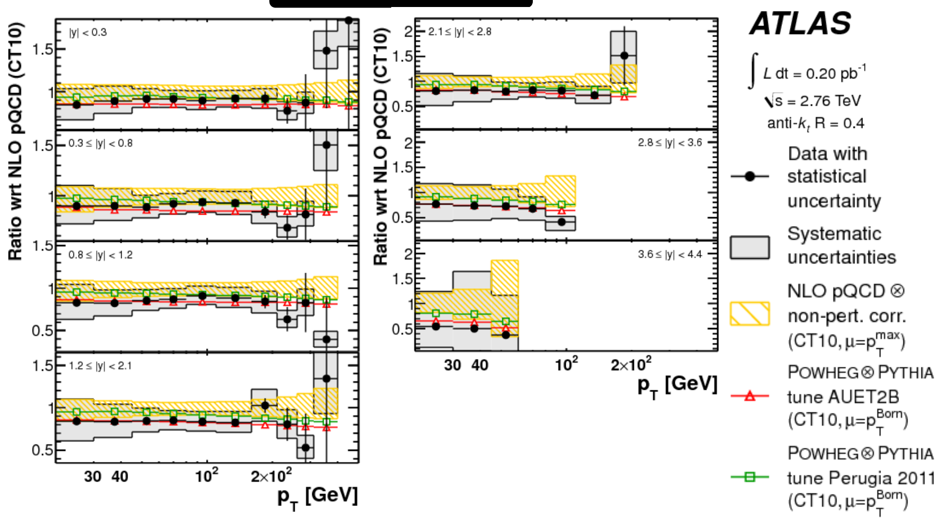
7 TeV



2.76 TeV



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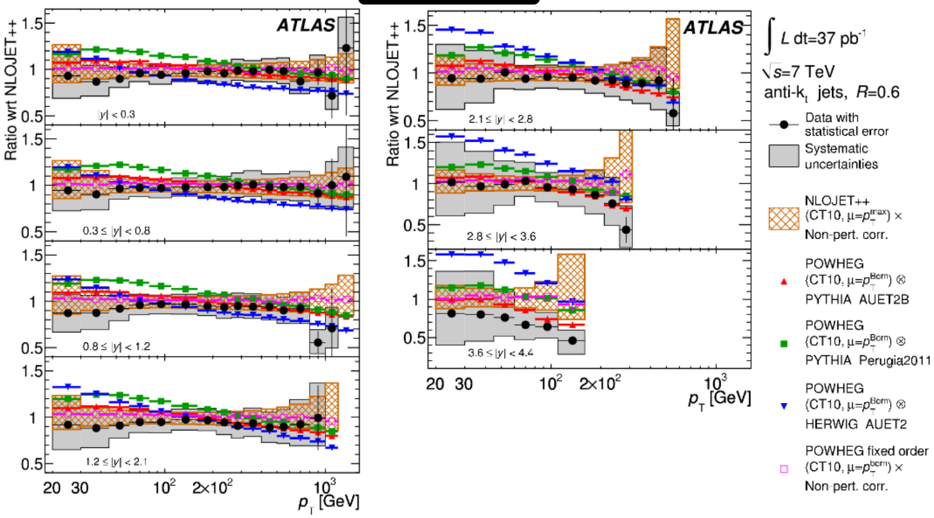

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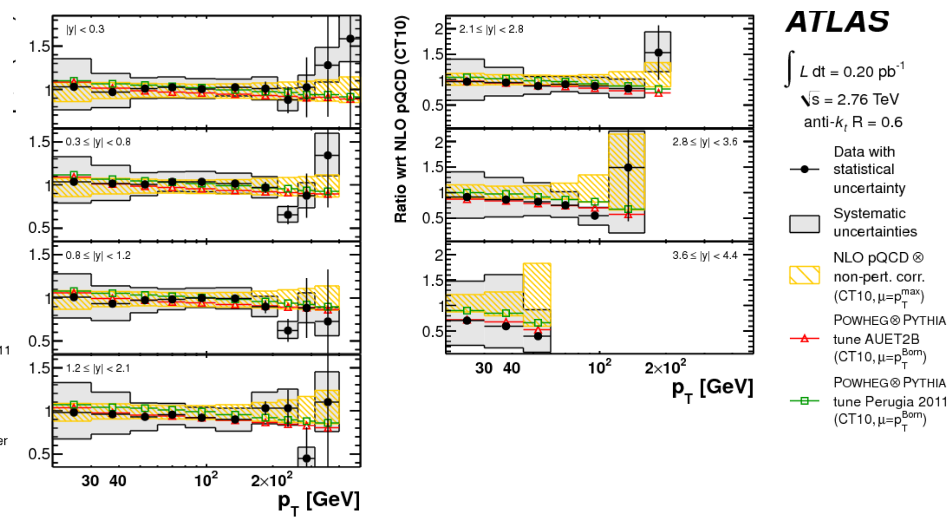

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Anti – kt R = 0.6 jets

Cross section ratio theory comparison

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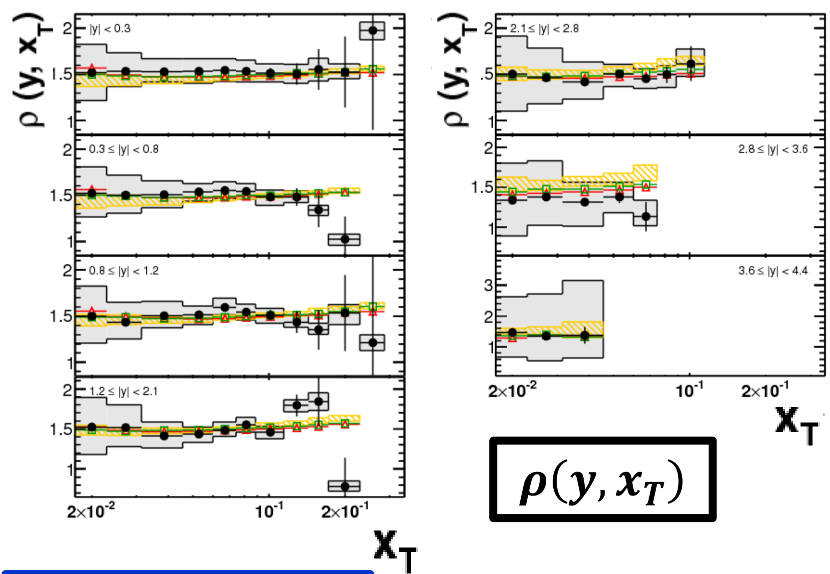

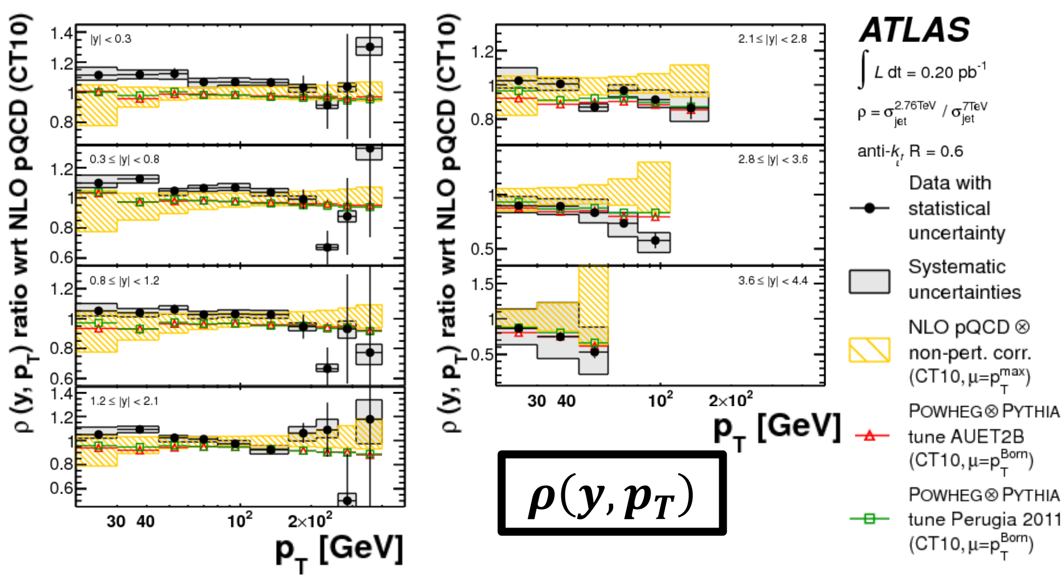

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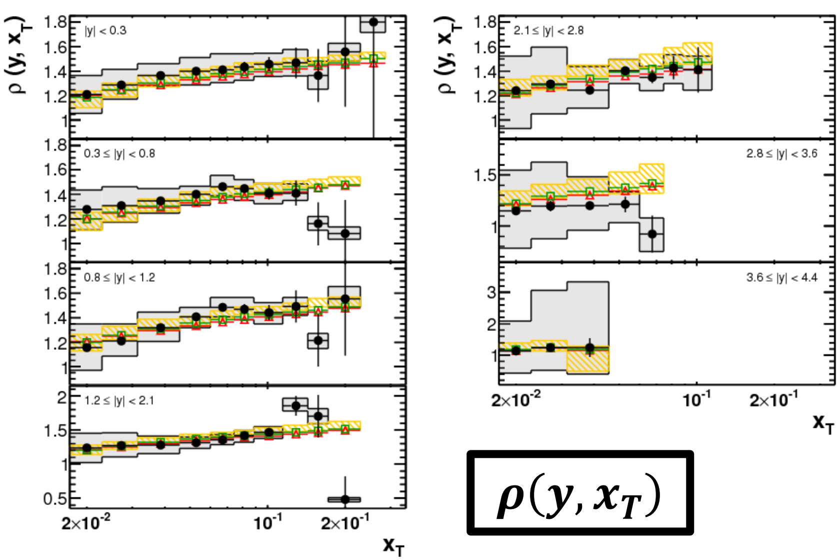
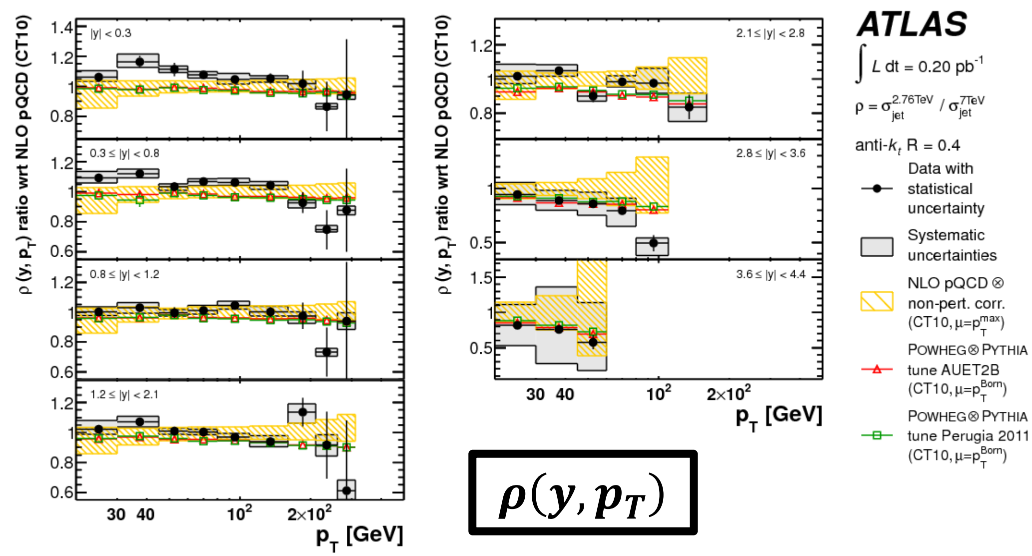


$\rho(y, x_T)$



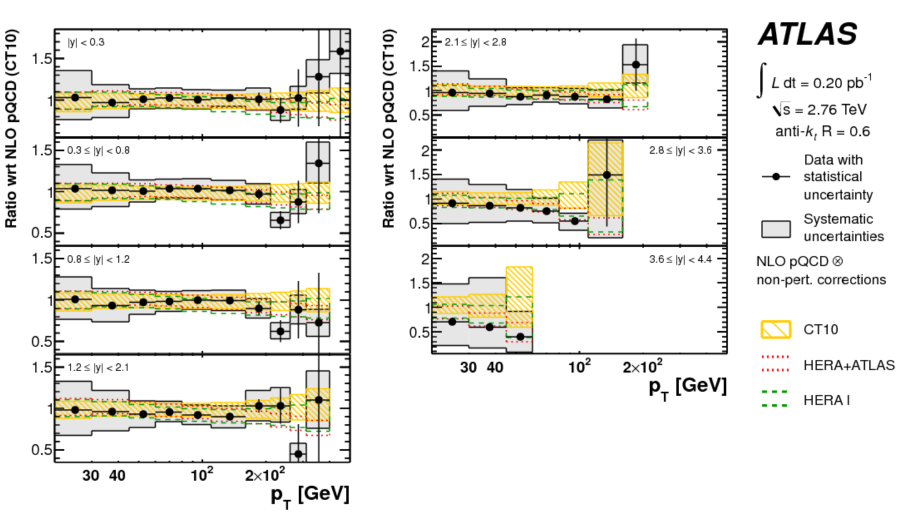
$\rho(y, p_T)$

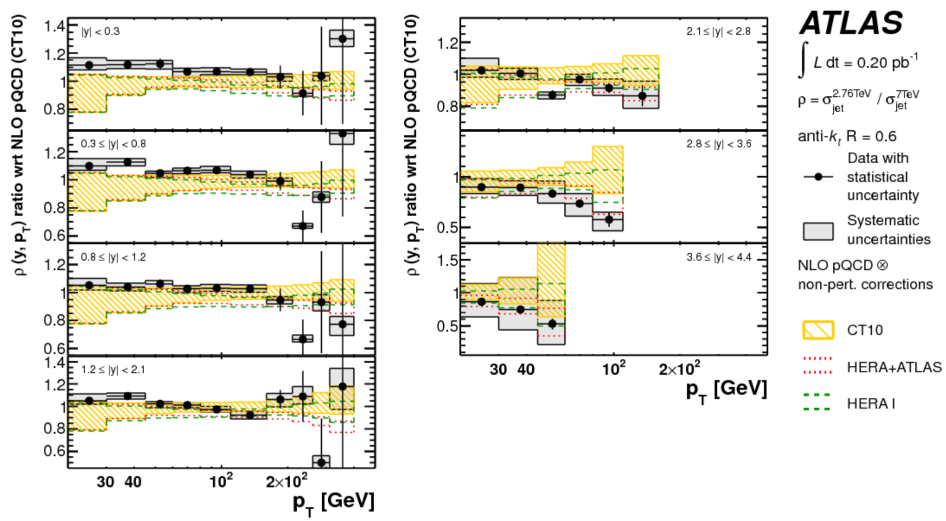
http://arxiv.org/abs/1304.4739

Anti – kt R = 0.4 jets

Inclusive jets : HERA + ATLAS PDFs

- **ATLAS jet cross sections** at $\sqrt{s}$ = 2.76 TeV and $\sqrt{s}$ = 7 TeV **used to constrain PDFs**
  - HERA + ATLAS PDF set
- Comparison to inclusive jet cross section at $\sqrt{s}$ = 2.76 TeV and $\rho(y, p_T)$
- **Good agreement** is seen with **HERA + ATLAS PDF**
  - Particularly in the forward region





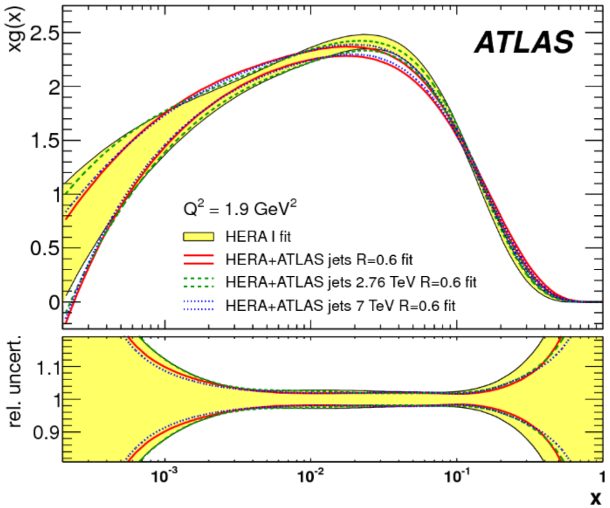
Inclusive jet cross section

$\rho(y, p_T)$

http://arxiv.org/abs/1304.4739

Anti – kt R = 0.4 jets

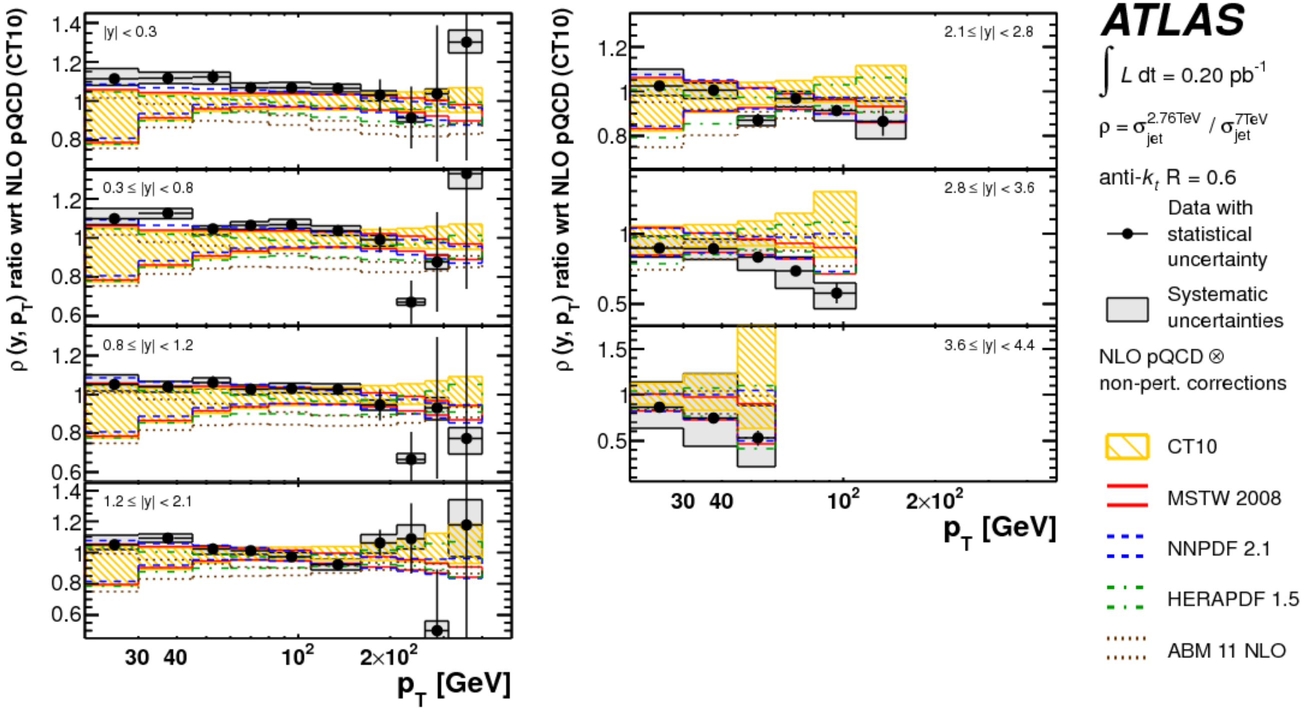
Cross section ratio PDF comparisons



$\rho(y, p_T)$ ratio compared to different PDFs:

- Data higher in central region and lower in forward region
  - larger deviation for ABM11 NLO
- **Systematic uncertainty smaller than theory uncertainty**

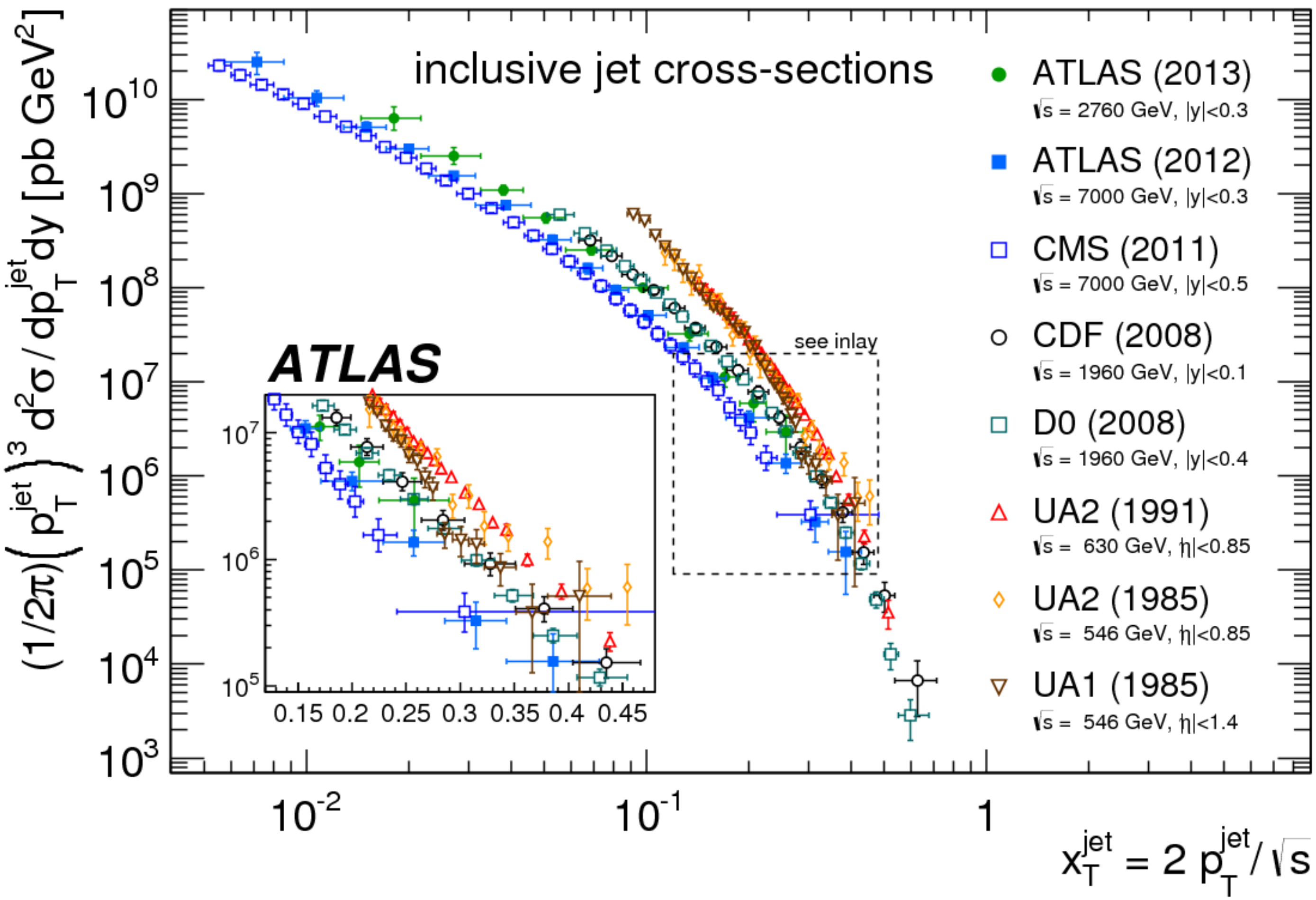
  => $\sqrt{s}$ = 7 TeV and $\sqrt{s}$ = 2.76TeV inclusive cross sections can be used to **constrain PDFs**



arXiv:1304.4739

Inclusive jets: experiment comparisons

http://arxiv.org/abs/1304.4739



Dijet production at $\sqrt{s}$ = 7 TeV

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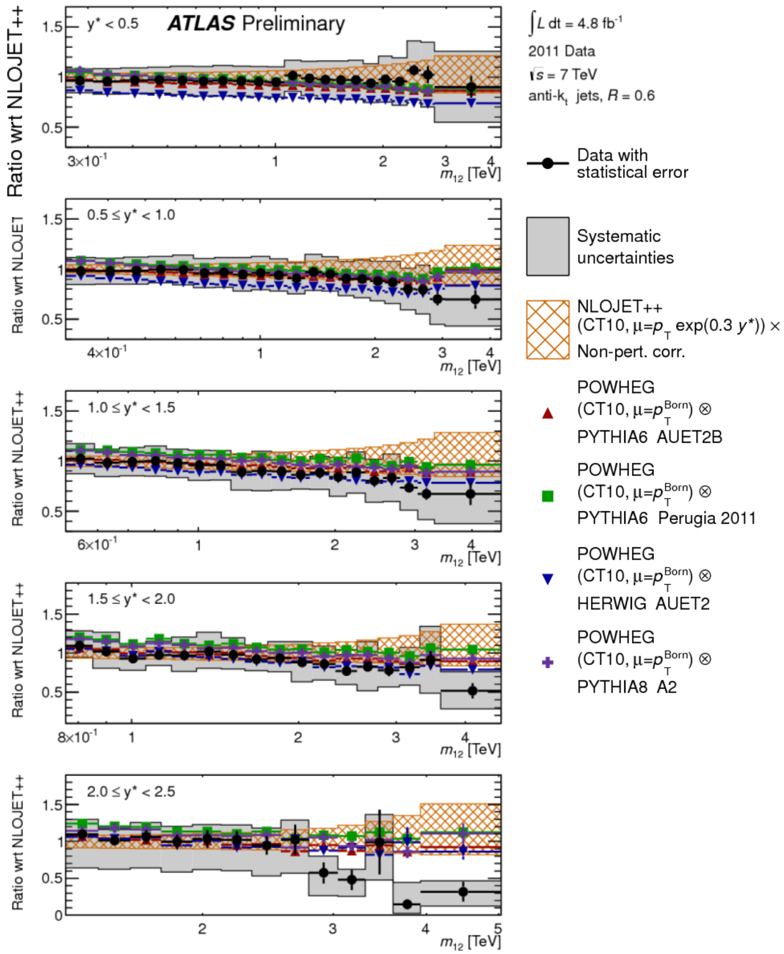
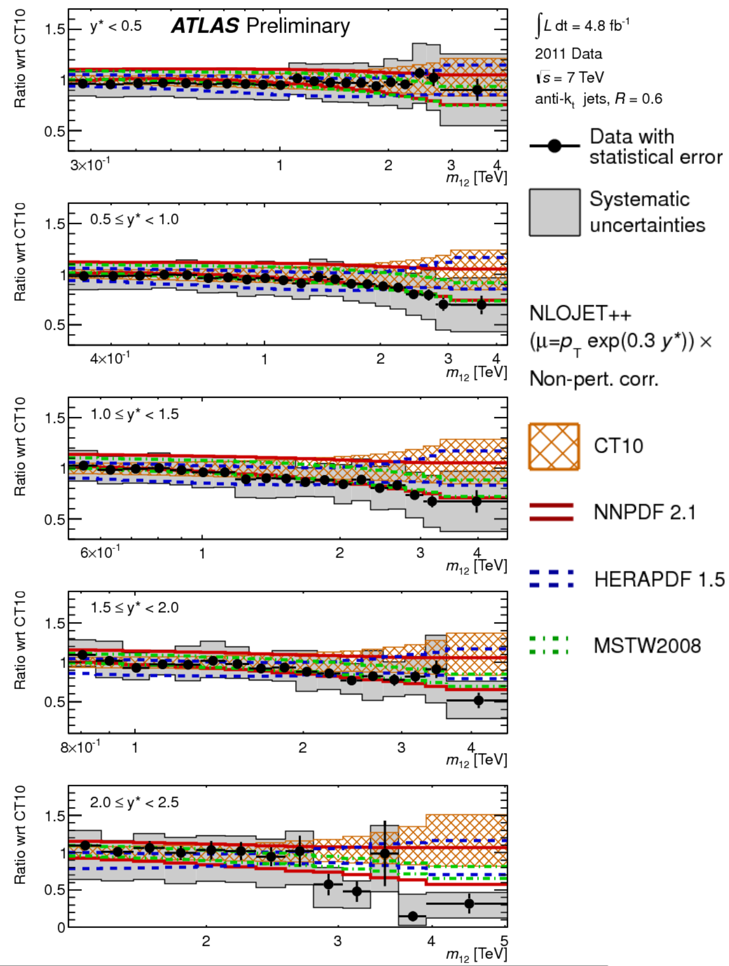
- **Ratios to NLOJET++** with CT10 PDF
- In general **data is in agreement** with theory predictions
  - **Differences up to 40% at high y* & dijet mass**: theory predictions overestimate cross section





Anti – kt R = 0.6 jets

NLOJET++ and POWHEG

NLOJET++ with different PDFs

Dijet production at $\sqrt{s}$ = 7TeV

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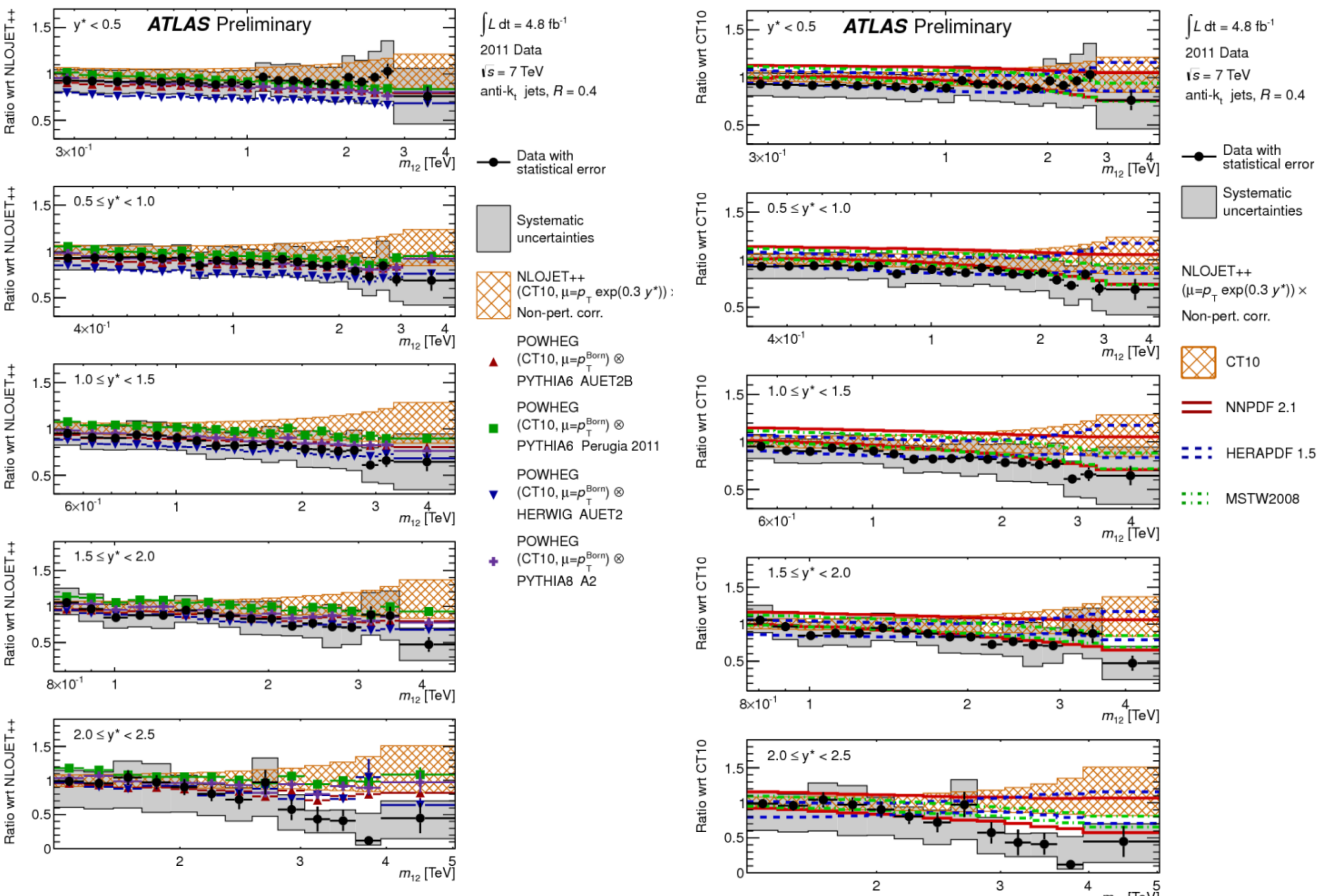


Anti – kt R = 0.4 jets

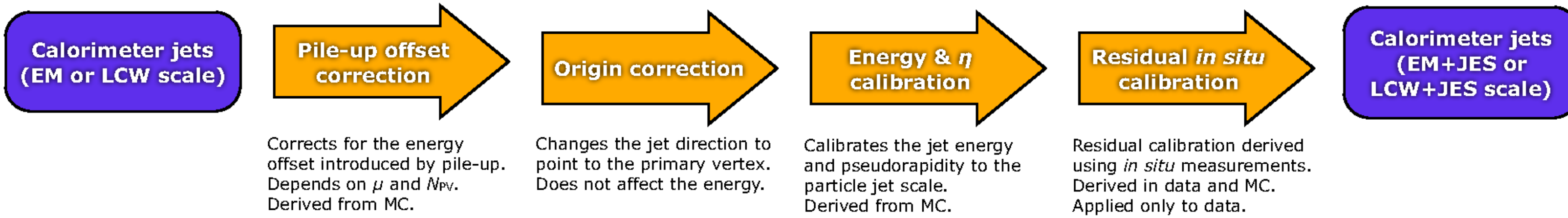
NLOJET++ and POWHEG

NLOJET++ with different PDFs

Jet Energy Scale with 2011 data

- **2010 Jet Energy Scale and uncertainties used for all analyses presented here**

- 2011 Jet Energy Scale calibration scheme :



- Jet Energy Scale (JES) **uncertainties in 2011 derived from insitu analyses**