INCLUSIVE JET CROSS SECTION MEASUREMENT IN ATLAS

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on behalf of the ATLAS Collaboration

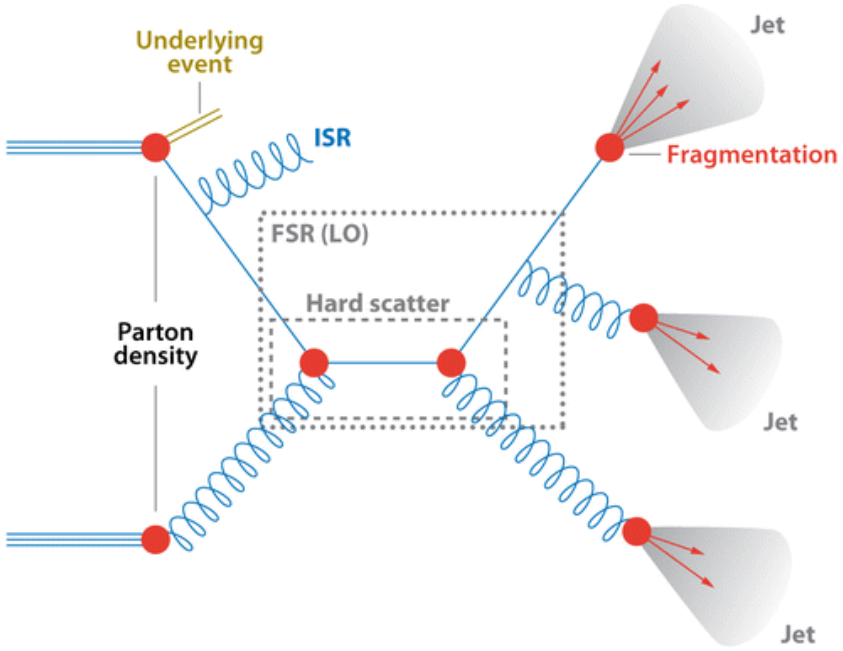
Jet reconstruction and spectroscopy at hadron colliders
Pisa, 18th - 19th April 2011

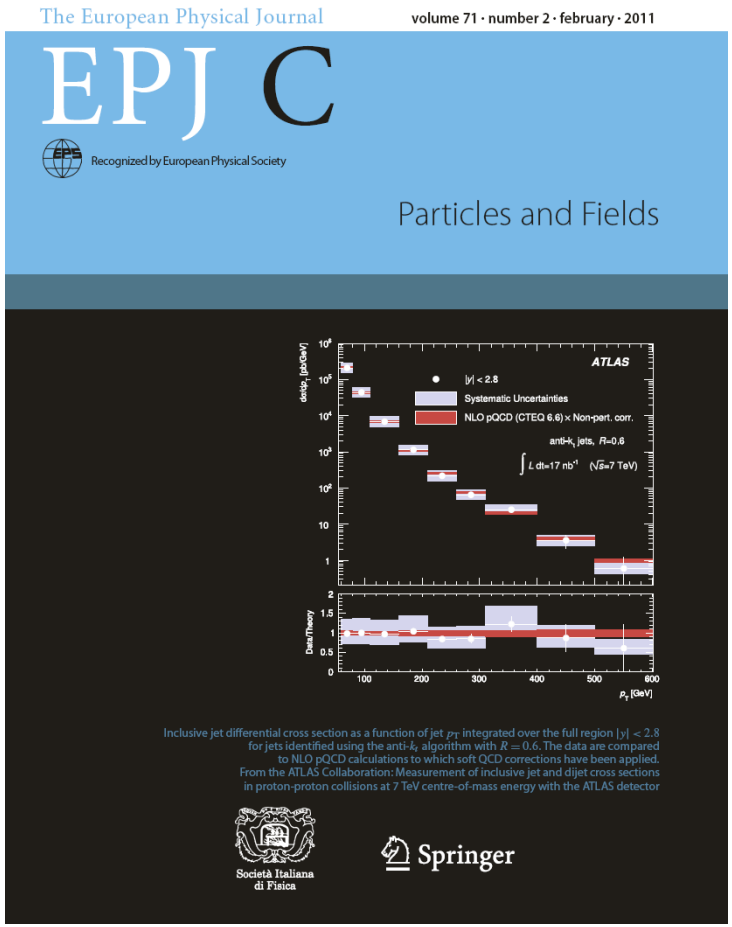
MOTIVATION

Jet production is the dominant high p_T process at hadron colliders

It is sensitive to physics beyond the Standard Model, such as quark compositeness

Jet measurements are used to test QCD predictions, and provide information about PDFs and α_s





First measurement of the inclusive jet cross section in ATLAS based on 17 nb^{-1} is published in the EPJC

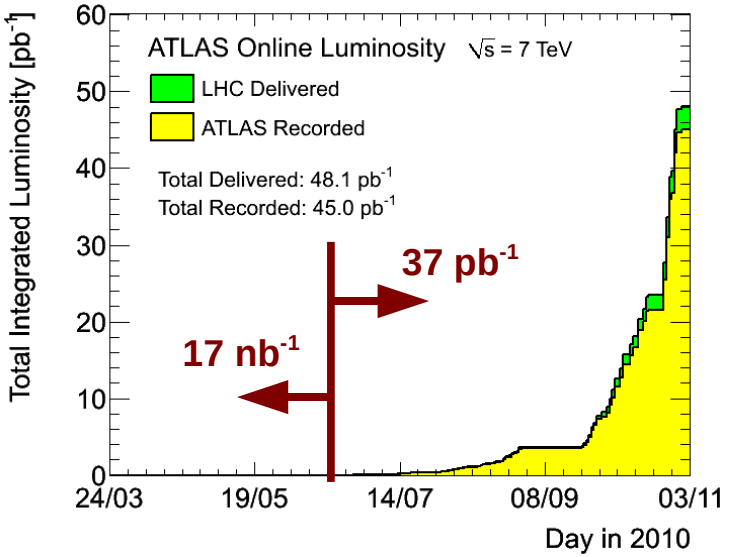
Eur. Phys. J. C71 (2011) 1512

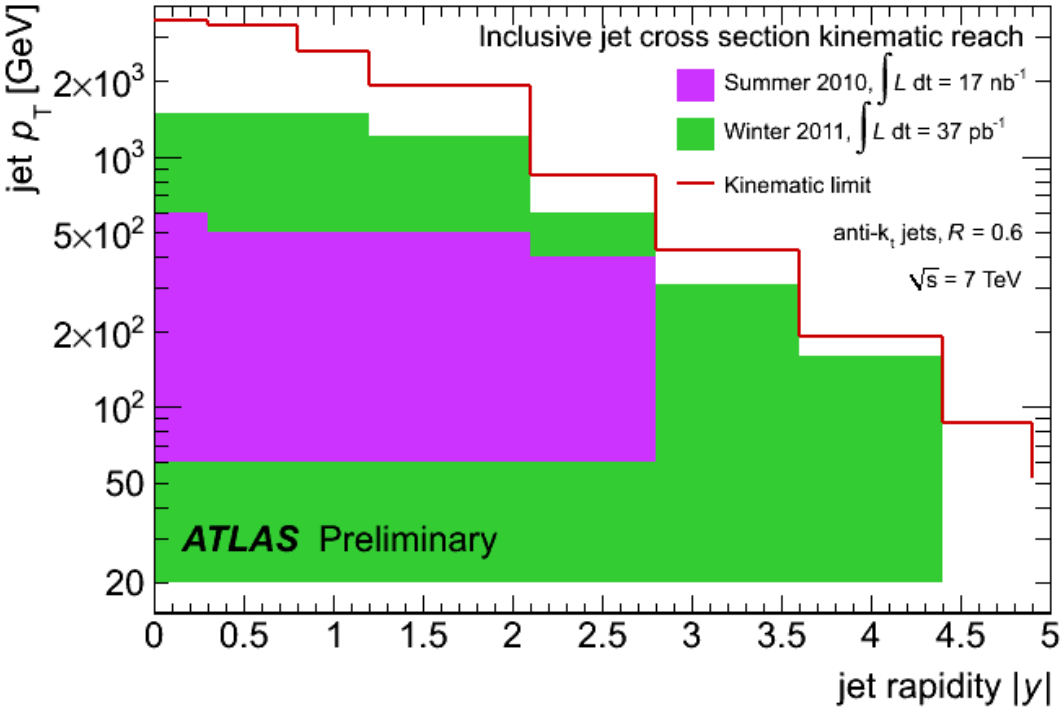
INTRODUCTION

The measurement has been extended using the full 2010 dataset:

- **17nb^{-1} → 37 pb^{-1} (more than 2000 times larger!)**
- **p_T > 60 GeV → p_T > 20 GeV**
- **|y| < 2.8 → |y| < 4.4**
- **Jets with p_T up to 1.5 TeV have been observed**

Public results can be found in:
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2011-047/

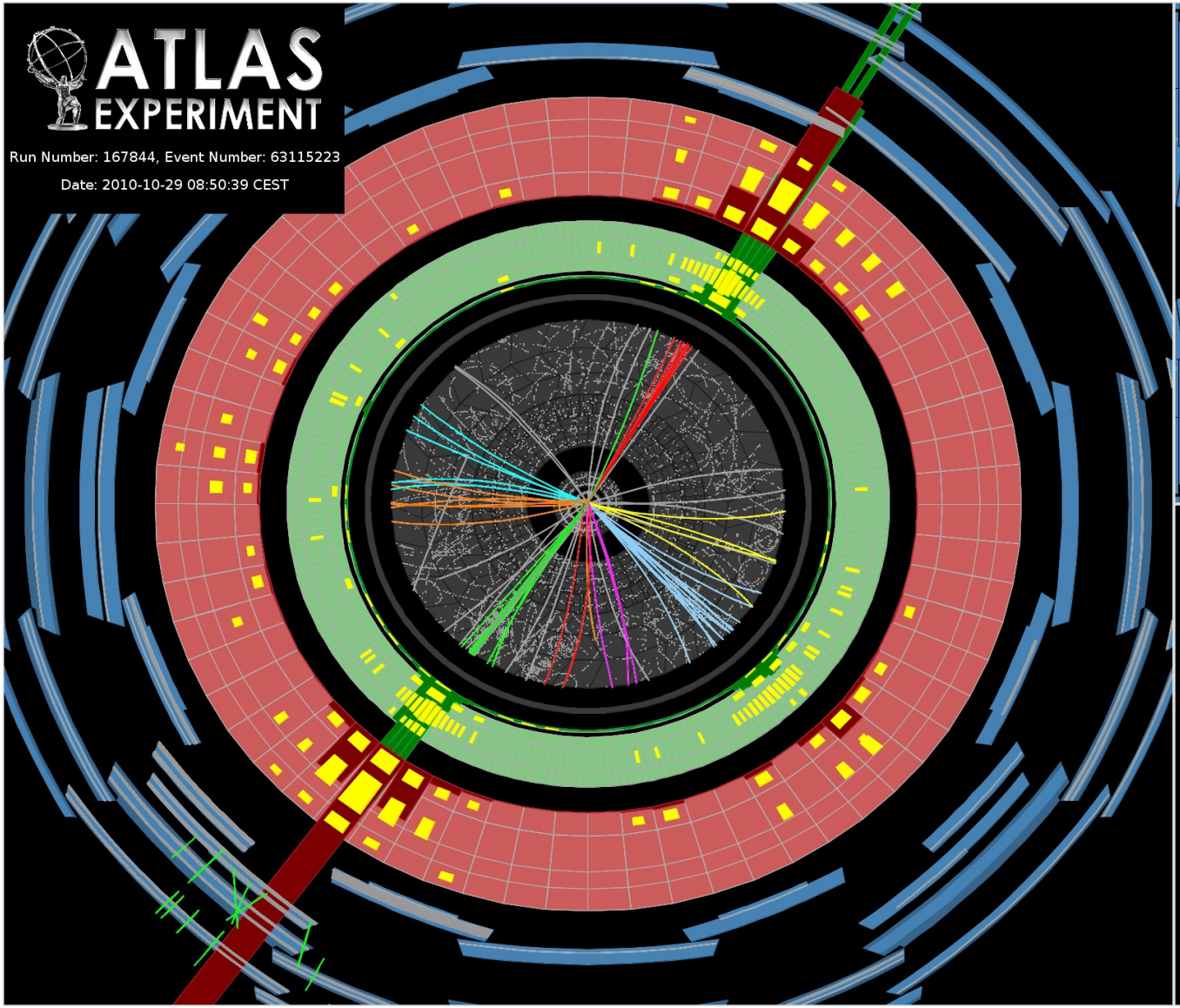


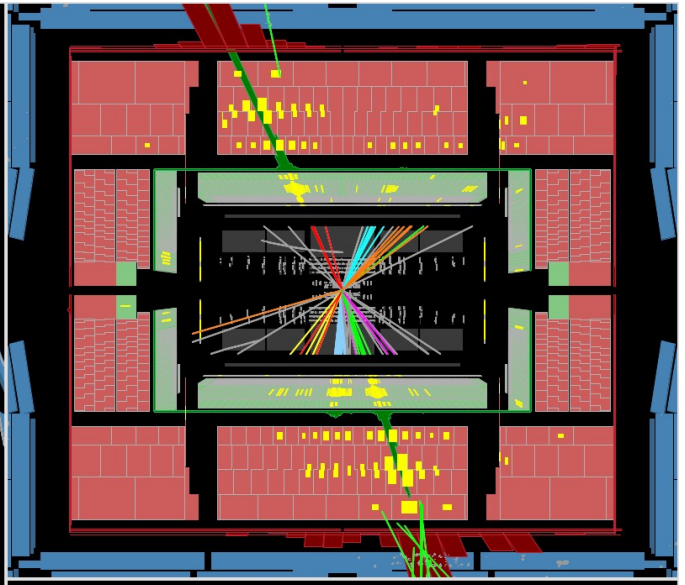


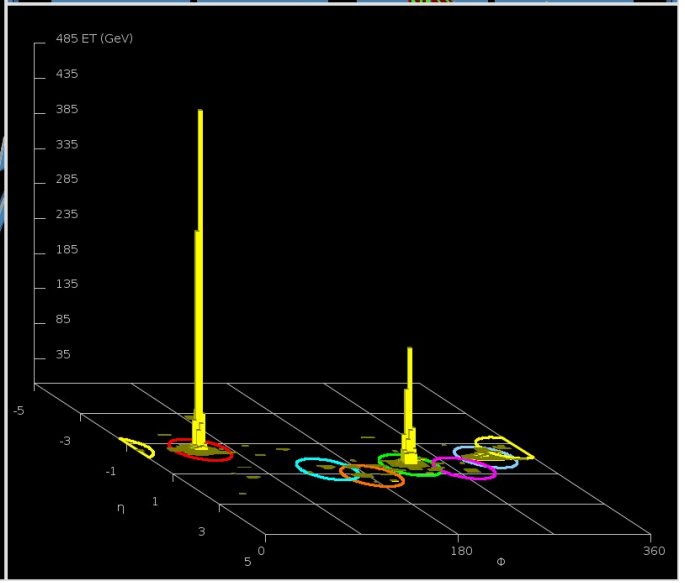
Jets are reconstructed using the anti-k_t algorithm, with R = 0.4 and R = 0.6, run over calorimeter clusters (P. Loch talk)

Data are compared to NLO predictions corrected for non-perturbative effects and to POWHEG predictions

EVENT DISPLAY







Highest-p_T jet collected during 2010, which has p_T of 1.5 TeV. The two leading jets are central high-p_T jets with an invariant mass of 2.8 TeV. They have (p_T, y) of (1.5 TeV, -0.58) and (1.0 TeV, 0.44), respectively. The missing transverse energy in the event is 310 GeV.

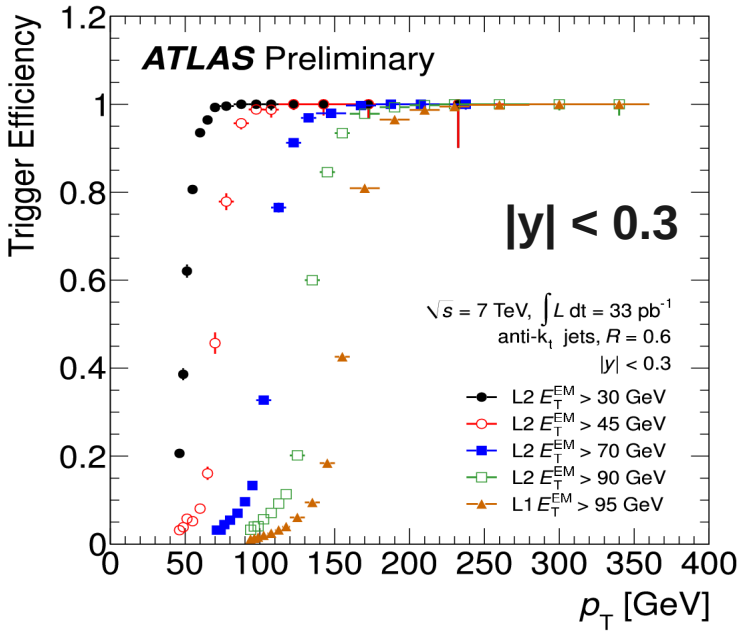
EVENT SELECTION

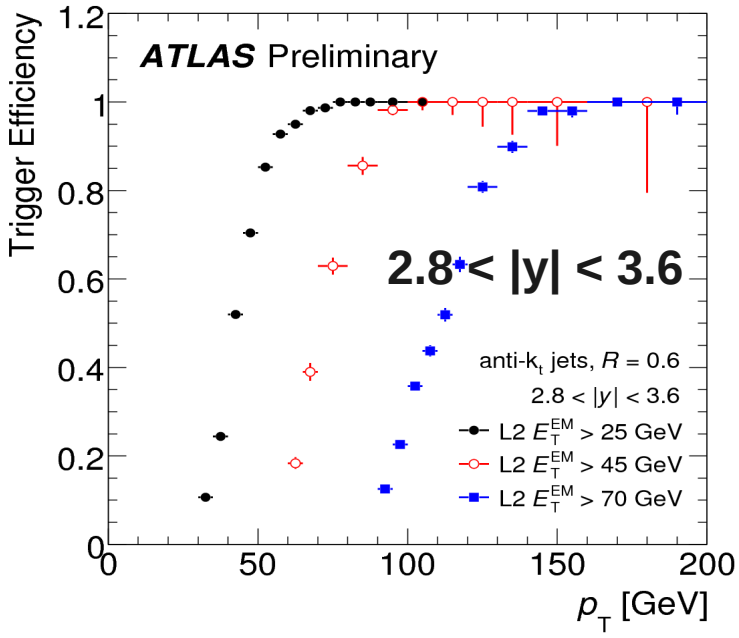
• **Events in the 2010 dataset collected by ATLAS when the detector components relevant for the analysis were operating at nominal conditions**

• **Events with at least one primary vertex consistent with the beamspot position and with 5 or more tracks pointing to it**

→ **to reject events due to cosmic ray muons and other backgrounds**

→ **once a jet with p_T > 20 GeV is also required, the efficiency is > 99%**





Minimum Bias trigger used to select jets with 20 GeV < p_T < 60 GeV

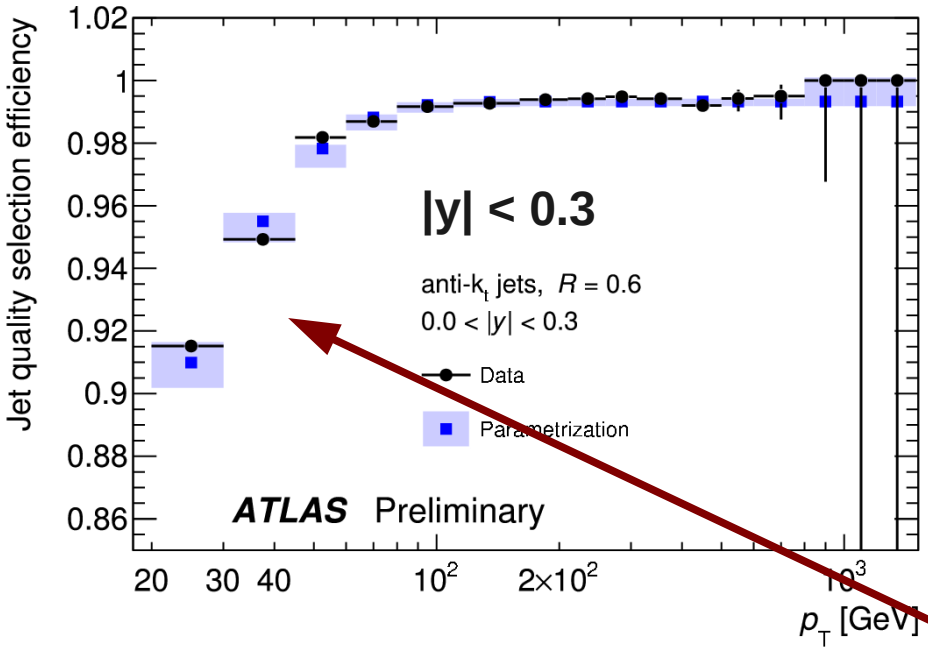
Single jet trigger with different thresholds is used for jets with p_T > 60 GeV

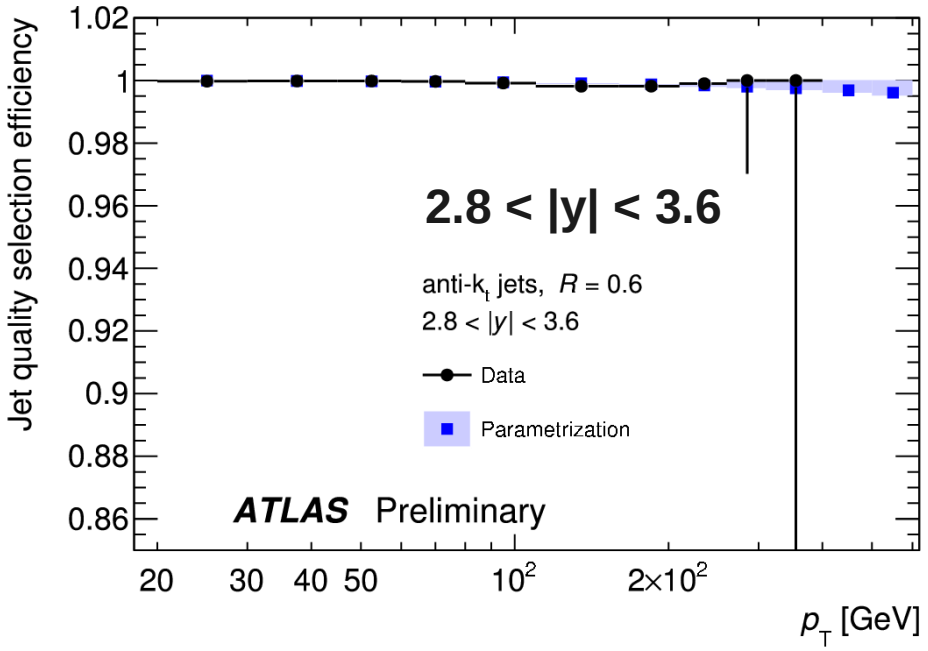
→ Trigger threshold is selected per p_T and y bin such that the efficiency is > 99% while having as small prescale factor as possible

JET SELECTION

- **Calibrated jets (D. Schouten talk) with p_T > 20 GeV and |y| < 4.4**

- **Quality criteria to reject fake jets originating, for example, from noise burst in the hadronic endcap calorimeter electronics or cosmic rays**





The efficiency for identifying real jets was measured using a tag-and-probe method

Final cross section corrected for inefficiency when it is larger than 1%

The systematic uncertainty on the efficiency is taken as a systematic uncertainty on the cross section

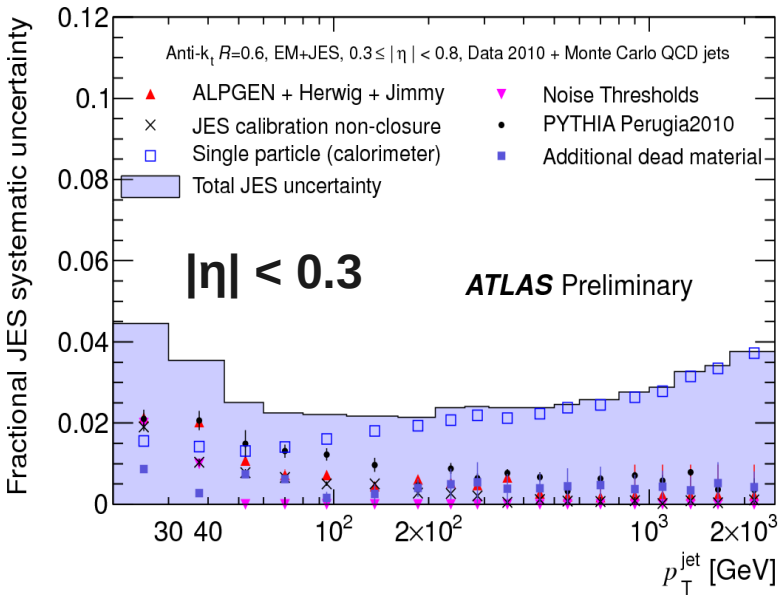
Jet Energy Scale Uncertainty

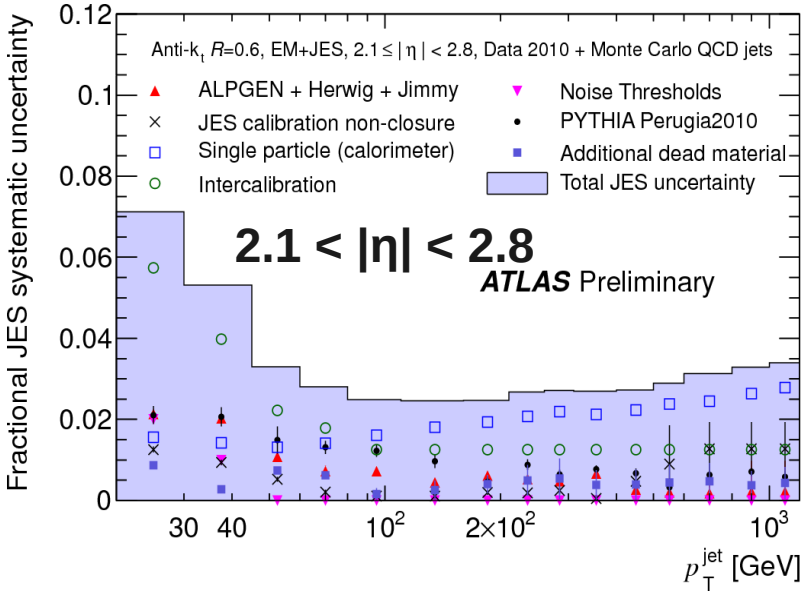
The JES uncertainty is the dominant uncertainty for the measurement

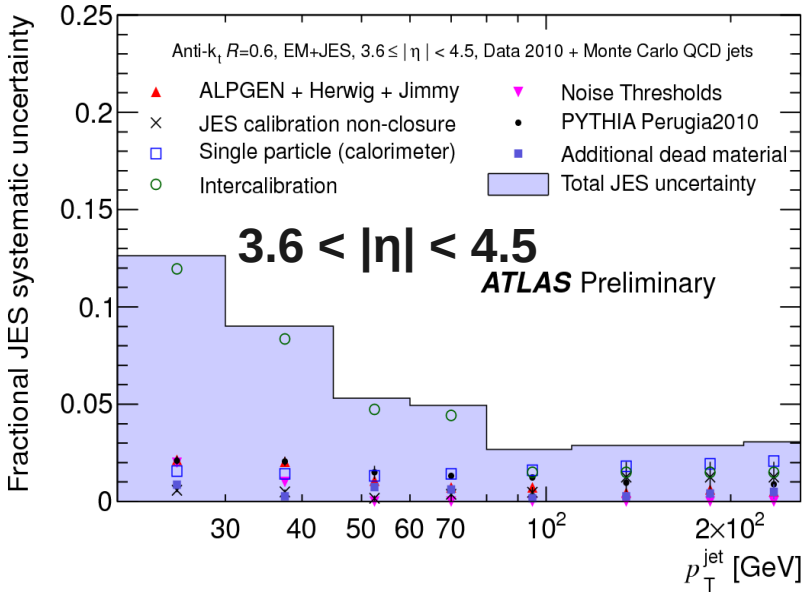
The JES uncertainty has been significantly reduced with respect to the previous measurement

As an example, for central jets above:

→ 20 GeV: from 9% to 4%
→ 60 GeV: from 7% to 3%



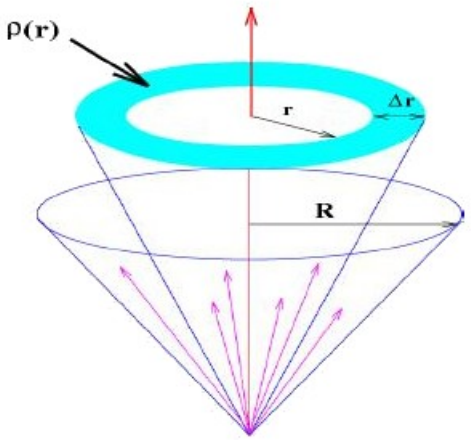




The uncertainty in the calorimeter response to single particles is the dominant one at high p_T, whereas η-intercalibration uncertainty is the largest at low p_T

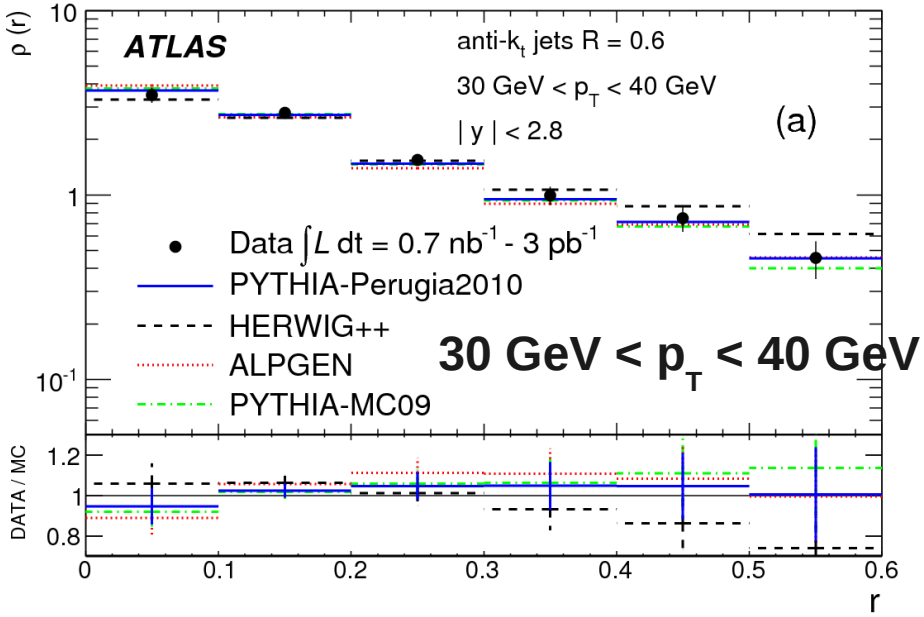
JET SHAPES (I)

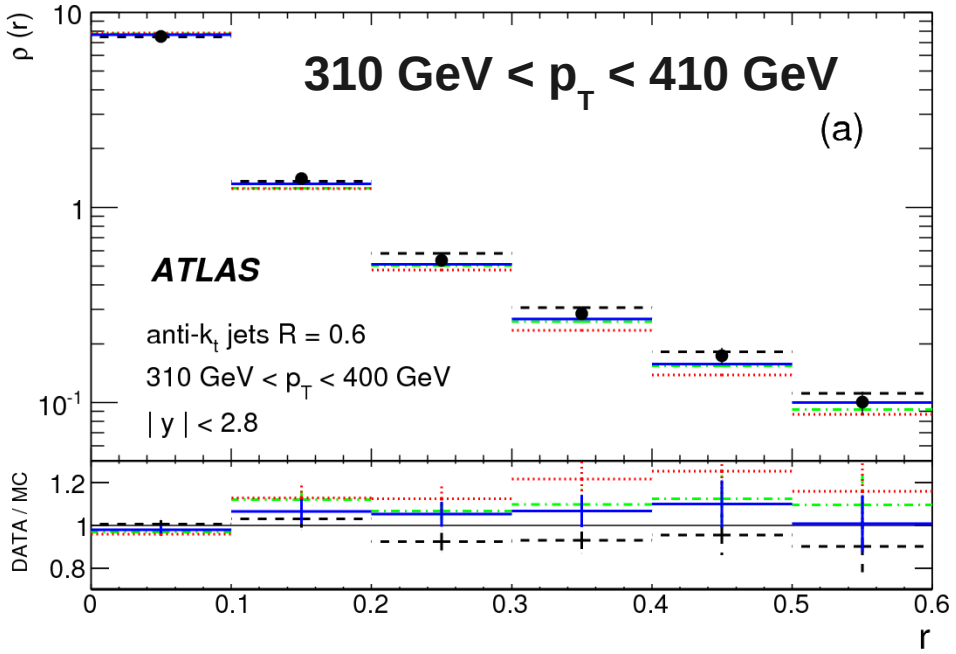
The p_T flow around the jet axis has been measured using jet shape observables: Phys. Rev. D 83 052003 (2011)



Jet shapes validate the QCD description contained in the event generators, such as parton shower, underlying event and fragmentation

Differential jet shape, ρ(r), is the fraction of jet p_T within r - Δr/2 and r + Δr/2



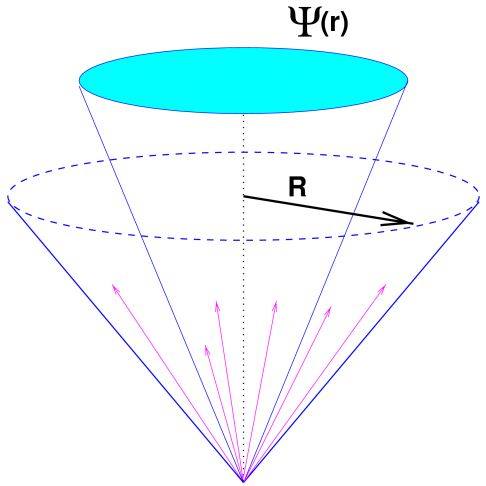


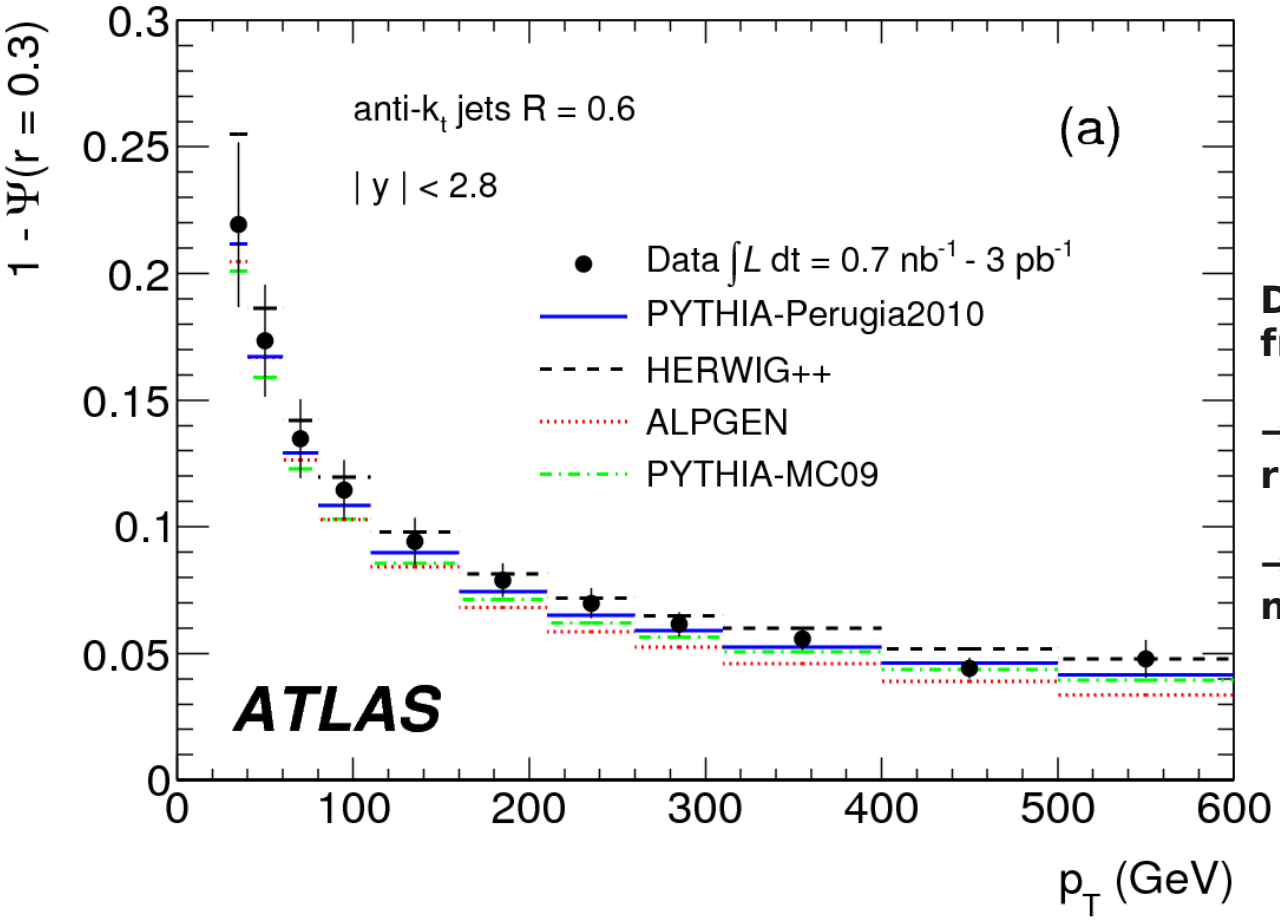
As expected, most of the energy is concentrated in the jet core and jets get narrower as the p_T increases

JET SHAPES (II)

Integral jet shape Ψ(r) is the fraction of jet p_T inside a cone of radius r

1 – Ψ(r=0.3) used to summarize the evolution of shapes vs p_T





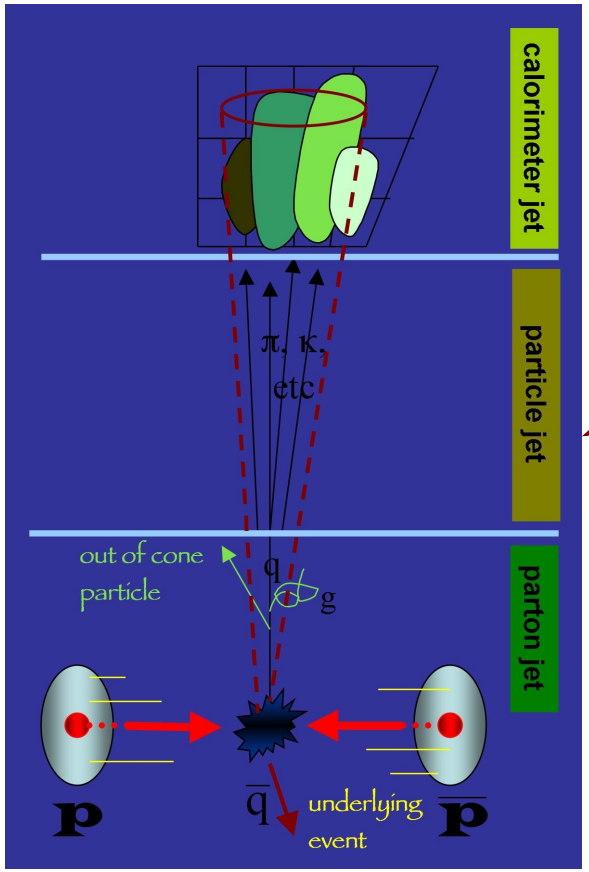
Data are compared to predictions from several MC generators:

→ PYTHIA and HERWIG provide a reasonable description of data

→ Jets in ALPGEN are significantly narrower than jets in data at high p_T

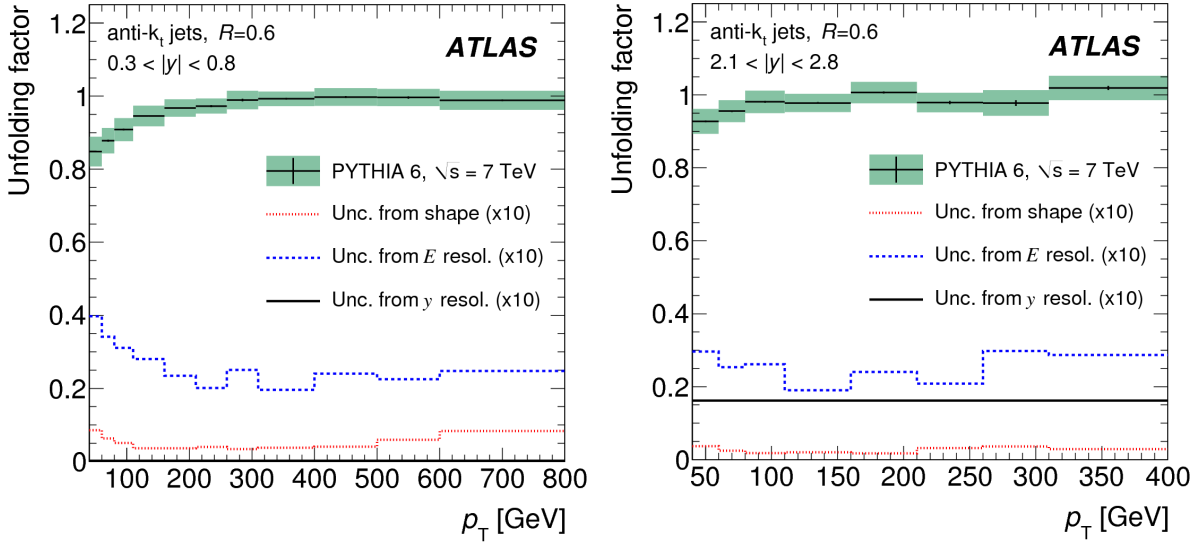
UNFOLDING

A bin-by-bin method is used to correct the measurement for detector effects back to the particle level



- **PYTHIA with AMBT1 tune is used for unfolding, after reweighting it to scale the prediction to that of a NLO PDF, improving the agreement of MC with the data**
- **Uncertainties are derived by varying the jet energy and angular resolution, and the cross section shape in the MC**
- **The uncertainty is ~4-5% at high and low p_T and smaller at intermediate p_T values**

FROM EPJ PAPER:



Cross-checks of the bin-by-bin unfolding results have been performed using an iterative Bayesian method and the SVD method

→ Both give consistent results, and they are being further studied

THEORY PREDICTIONS

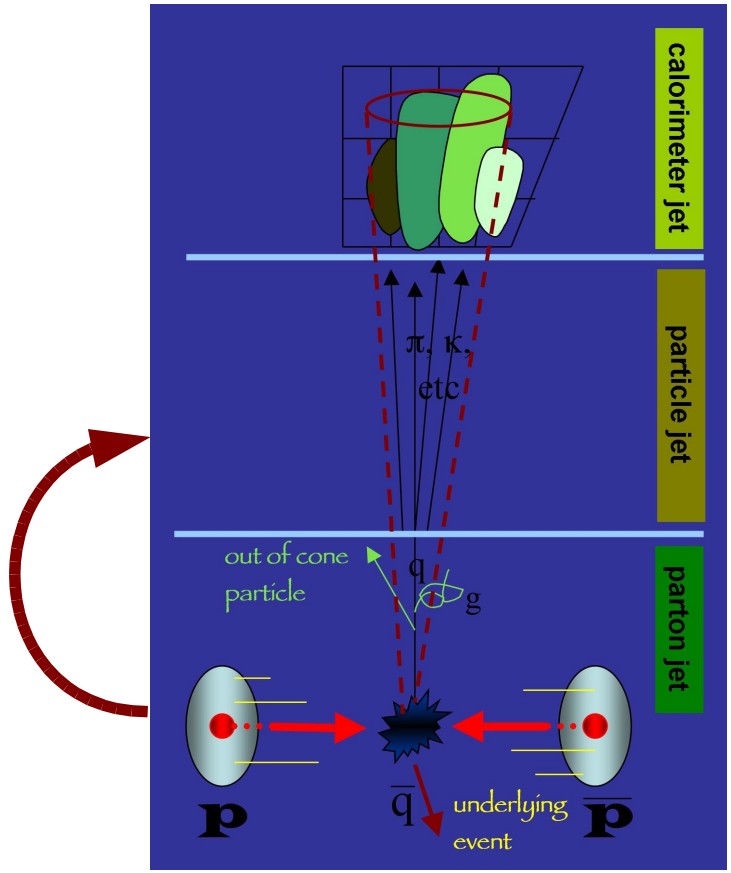
(1) NLO pQCD PREDICTIONS:

- **NLO pQCD predictions computed using NLOJET++ with the CTEQ 6.6 PDF are used for baseline calculations**

- **Predictions have been also computed with other PDFs (MSTW 2008, NNPDF 2.1 and HERAPDF 1.5)**

- **Uncertainties from renormalization and factorization scales, α_s and PDFs derived using APPLGRID**

- **Corrections for non perturbative-effects (hadronization and underlying event) are derived using PYTHIA with the AMBT1 and applied to NLO predictions**

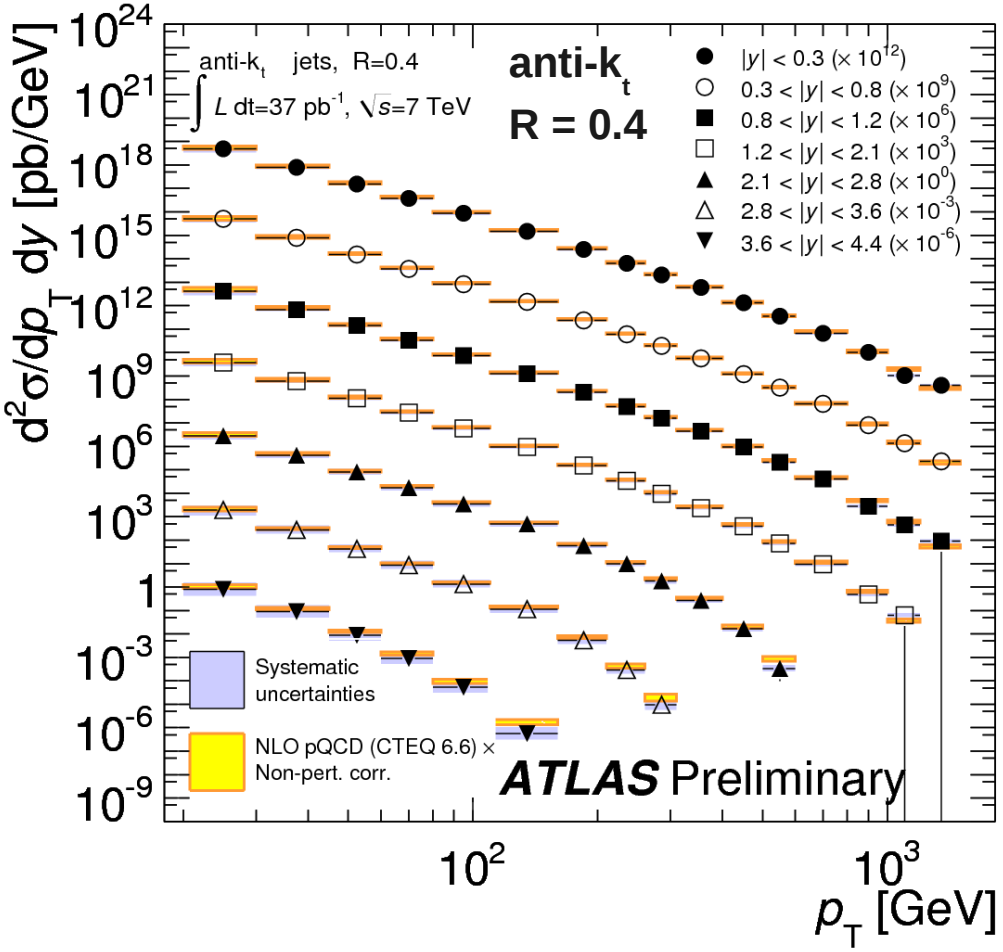


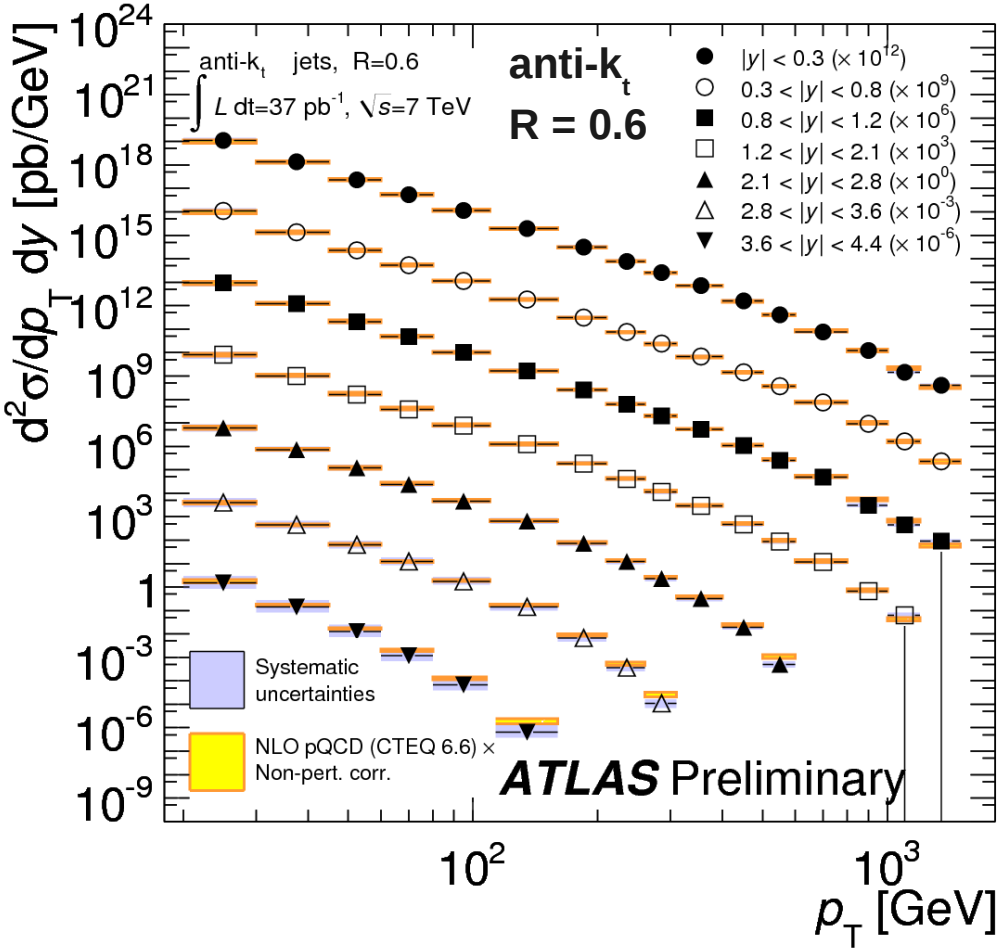
(2) NLO MATRIX ELEMENT + PARTON SHOWER:

- **NLO parton shower Monte Carlo samples of inclusive jets have been generated with POWHEG**

- **Both PYTHIA and HERWIG have been used to shower and hadronize the partons, and to simulate the underlying event**

RESULTS (I)



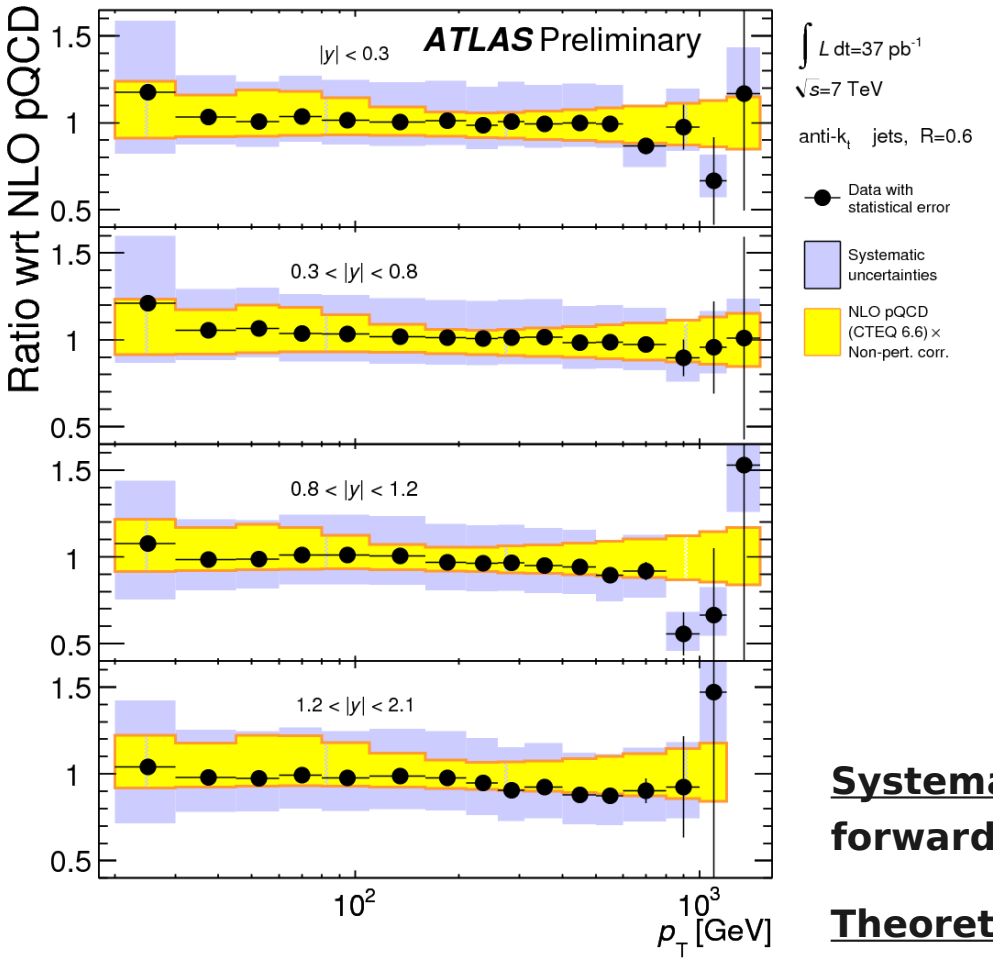


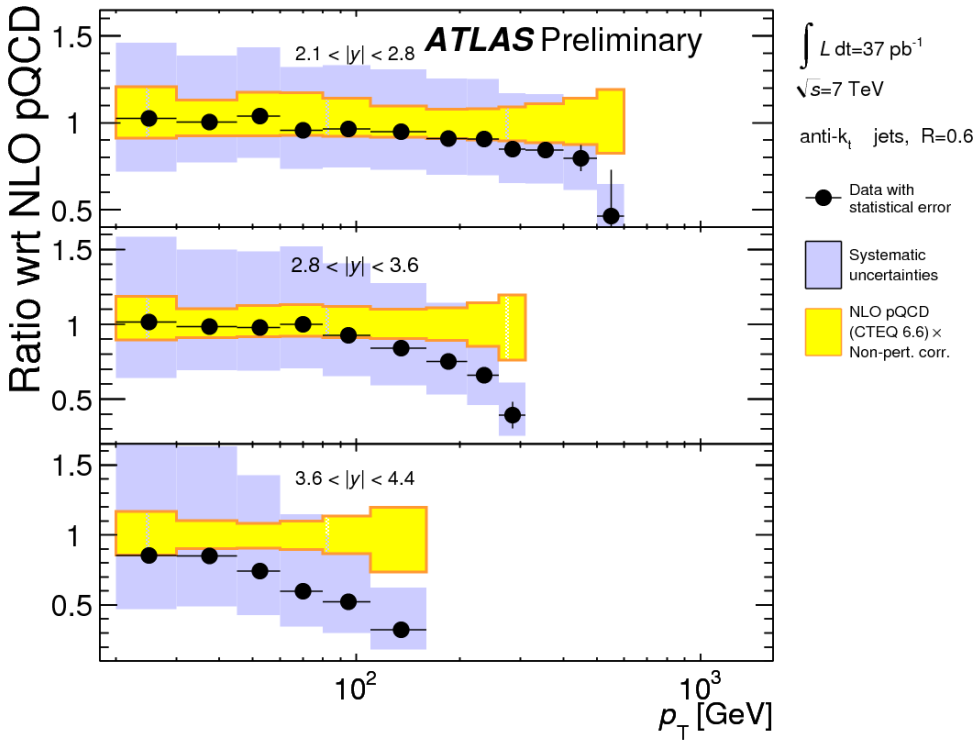
The inclusive jet cross section is measured from p_T of 20 GeV to 1.5 TeV

The measurement proves perturbative QCD over 10 orders of magnitude

Additional uncertainty of 3% due to luminosity measurement is not shown

RESULTS (II)





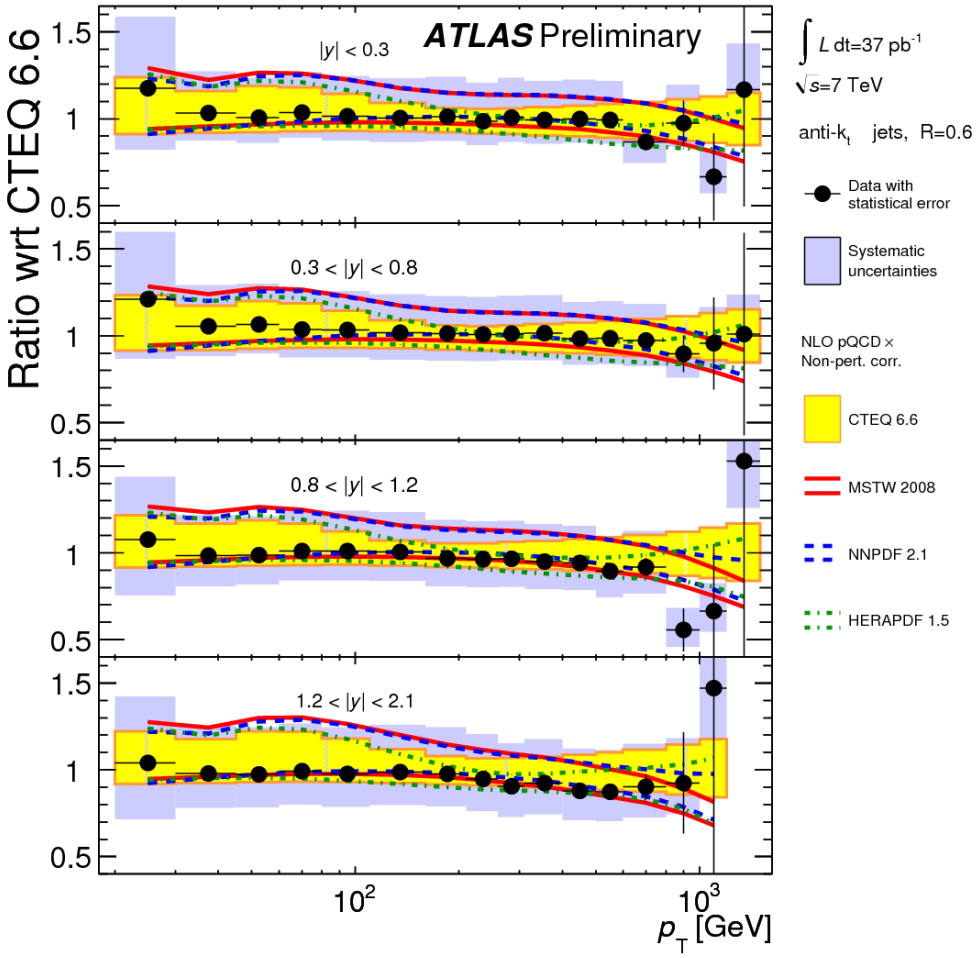
<u>Systematic uncertainty:</u> from 50% at low p_T and in the forward region to ~20% in other regions

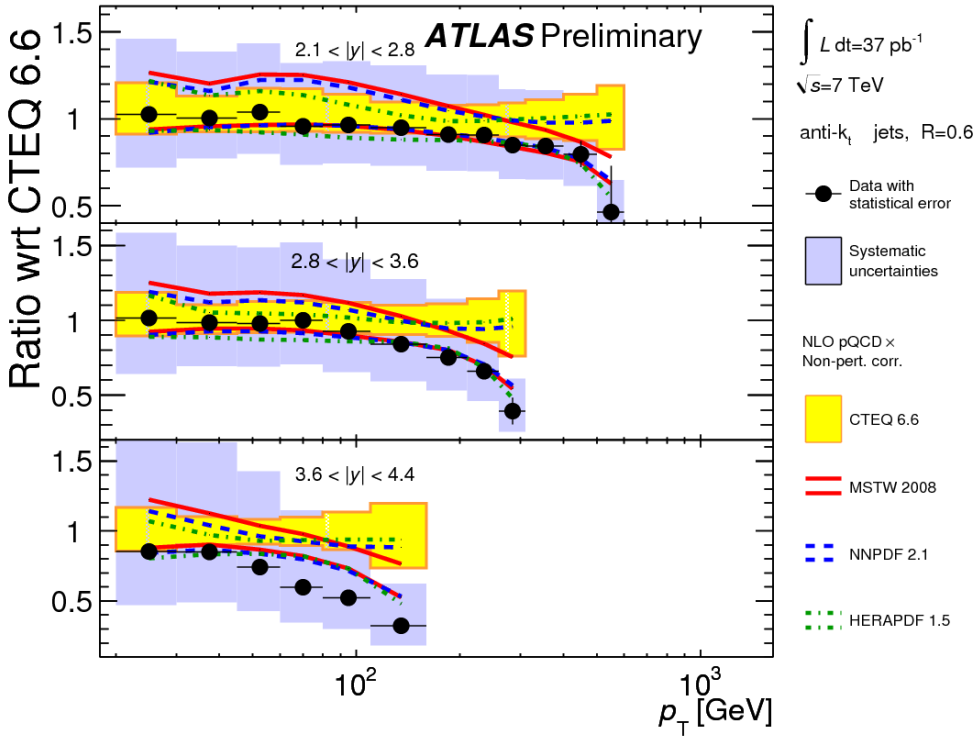
<u>Theoretical uncertainty:</u> typically 10-20%

Data are compared to NLO predictions using CTEQ 6.6 PDFs corrected for non-perturbative effects:

→ Data and theory predictions are in agreement
→ In the forward region, data tend to be below theory predictions at high p_T

RESULTS (III)

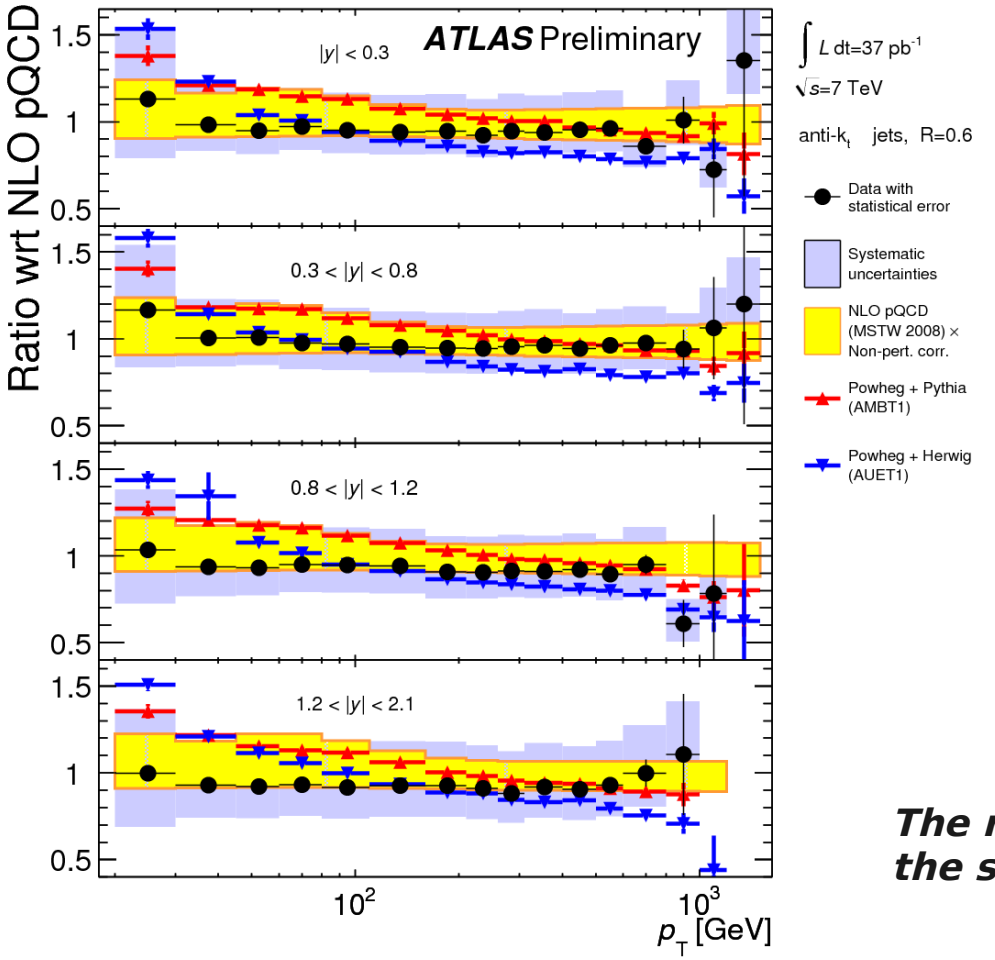


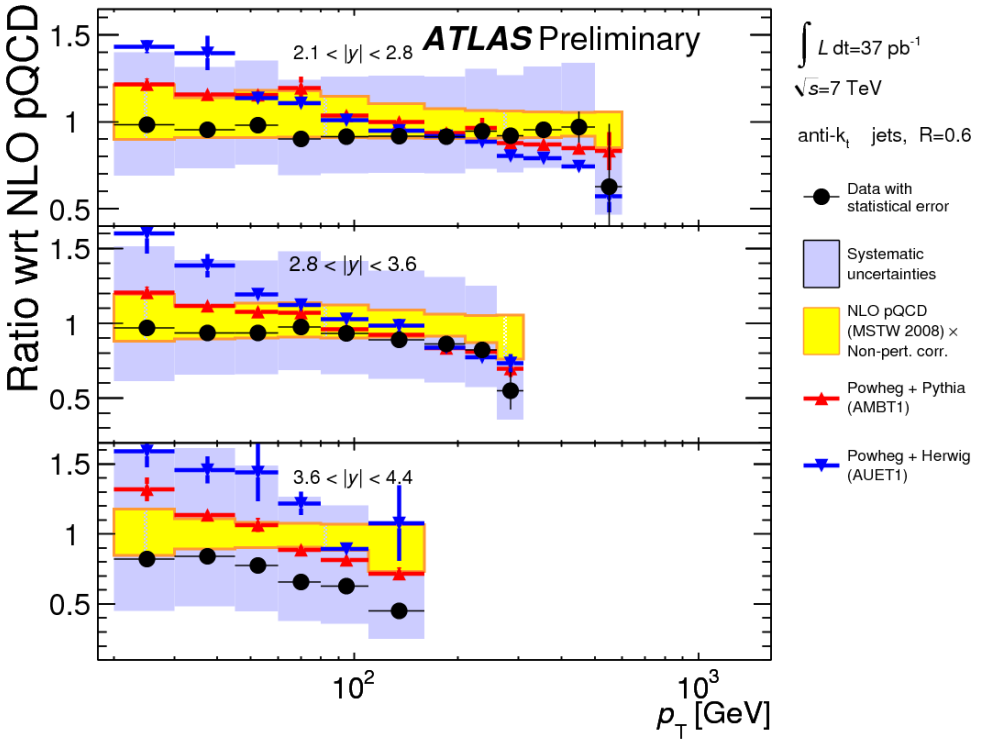


Data are compared to predictions using CTEQ 6.6, MSTW 2008, NNPDF 2.1 and HERAPDF 1.5 PDFS

Data and theoretical predictions are normalized to that obtained with CTEQ 6.6
→ There is agreement between data and theory for these PDFs
→ MSTW 2008, NNPDF 2.1 and HERAPDF 1.5 PDFS give predictions closer to data than CTEQ 6.6

RESULTS (IV)





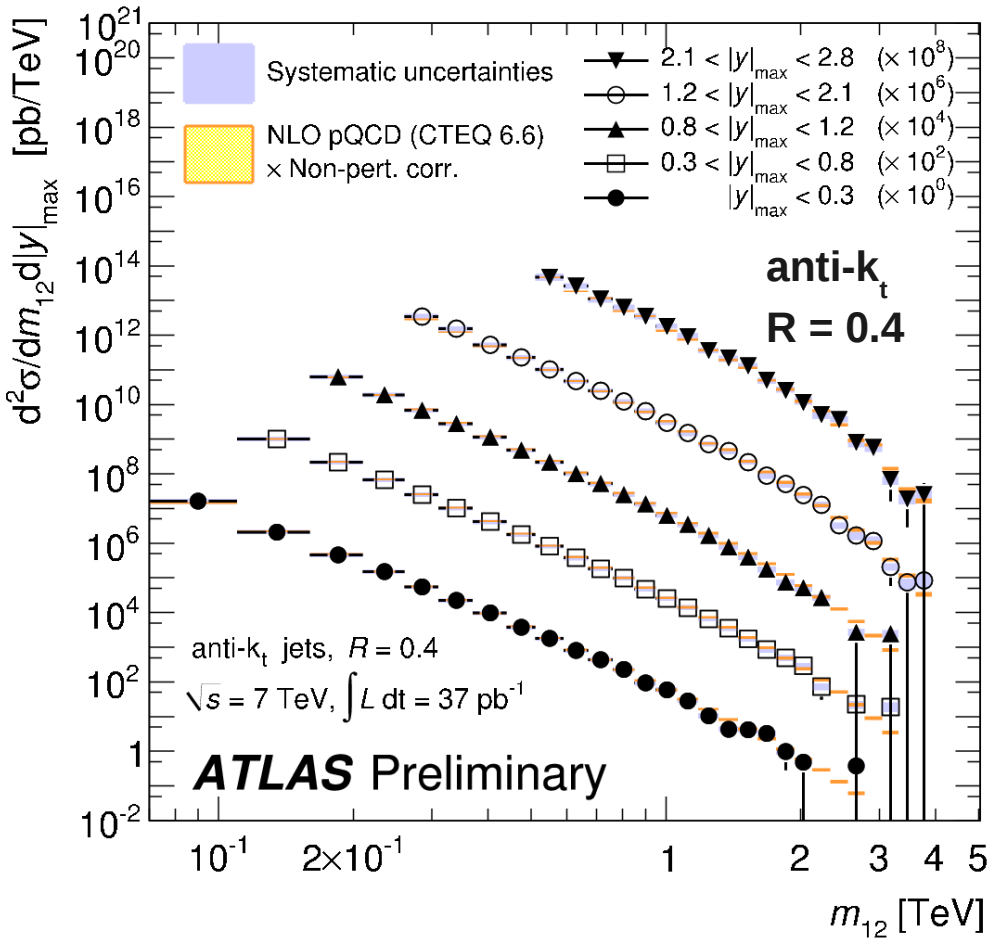
The ratio of the POWHEG predictions shows only the statistical uncertainty on POWHEG

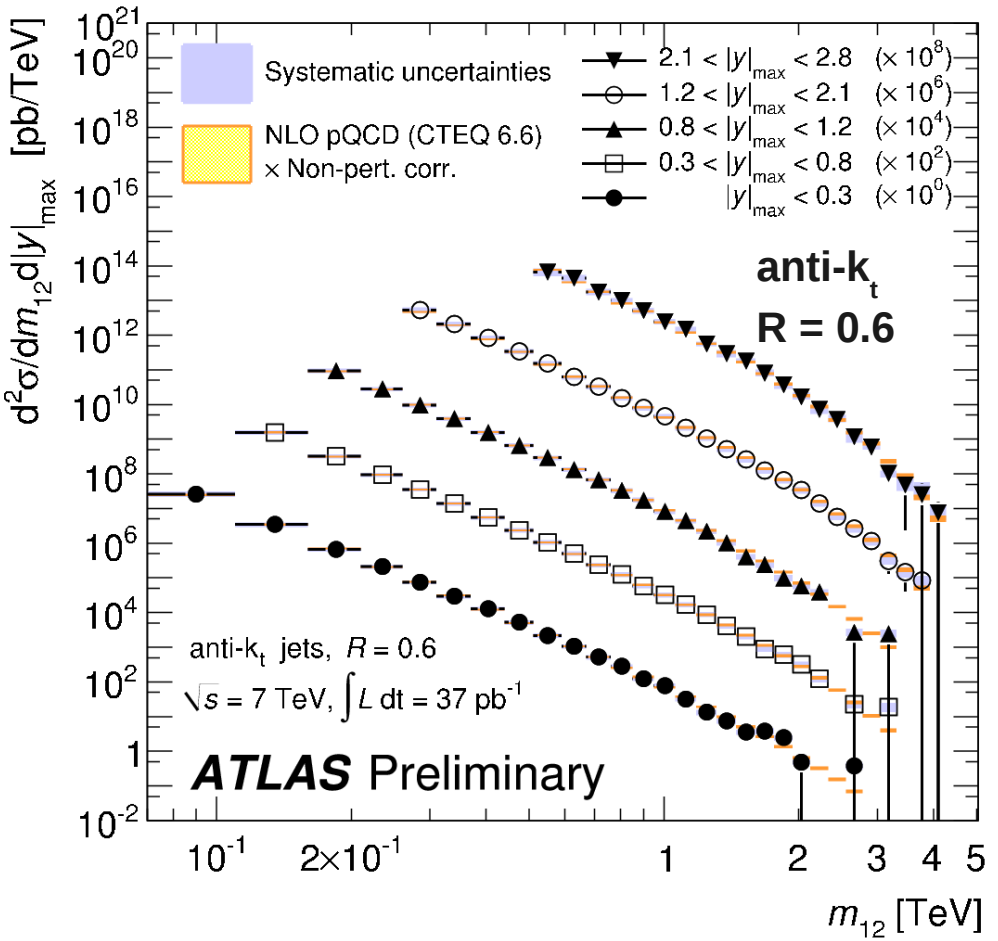
Data are compared to POWHEG predictions (MSTW 2008) showered with PYTHIA and HERWIG, all normalized to NLO predictions derived with MSTW 2008

→ Differences between POWHEG showered with PYTHIA and HERWIG

→ POWHEG tends to predict larger cross section than data and NLOJet++ at low p_T and smaller (but closer to data) cross sections than NLOJet++ at high p_T

DIJET CROSS SECTIONS (I)



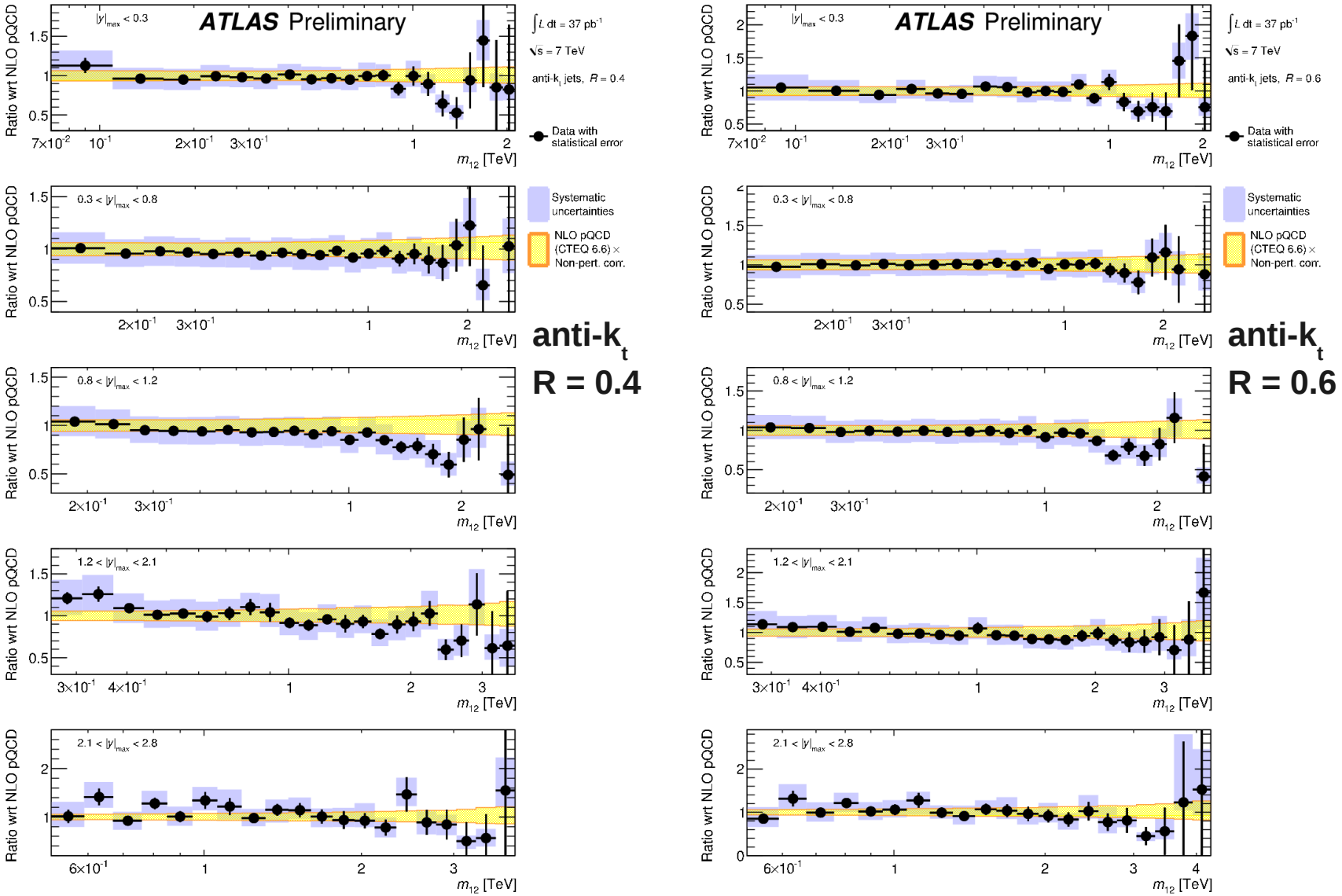


The dijet cross section as a function of the invariant mass has been measured using the same dataset, requiring the two leading jets to have p_T > 30 GeV and p_T > 20 GeV, and |y| < 2.8

The measurement extends up to dijet masses above 4 TeV

Additional uncertainty of 3% due to luminosity measurement is not shown
The uncertainties from the renormalization and factorization scales are not included in the theory uncertainty band

DIJET CROSS SECTIONS (II)



Data are compared to NLO predictions using CTEQ 6.6 PDFs corrected for non-perturbative effects:

→ Data and theory predictions are in agreement within uncertainties

CONCLUSIONS

• The inclusive jet and di-jet cross sections have been measured using all 2010 data recorded by ATLAS, corresponding to 37 pb^{-1}

• The measurement covers the p_T region spanning from 20 GeV to 1.5 TeV, and the |y| range up to y = 4.4

• The measurement of the jet shapes has been used to validate the QCD description contained in the MC used to unfold the measurement to the particle level and compute the corrections for non-perturbative effects

• Cross sections in data are compared to NLO predictions (with several PDFs) corrected for non-perturbative effects and to POWHEG showered with PYTHIA and HERWIG

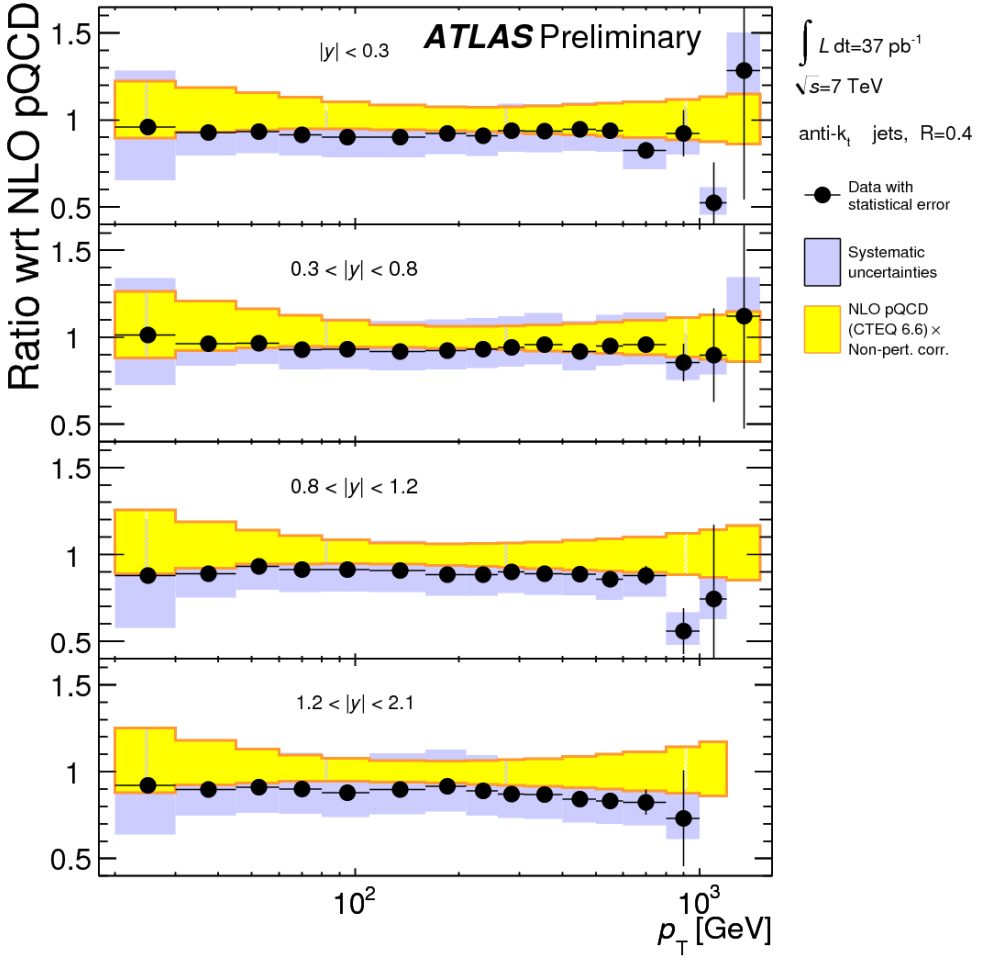
→ The data agree with theory within uncertainties: measurement probes pQCD up to the TeV scale!

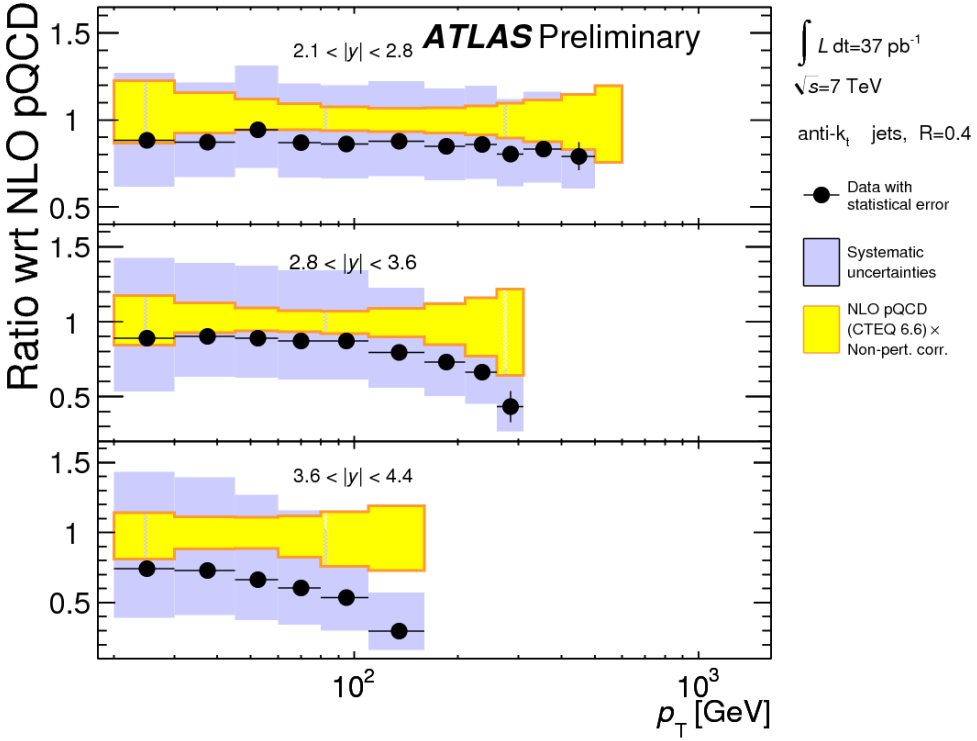
→ Measured cross section tends to be smaller than those predicted by theory in the forward region and at large p_T

→ Measurement probe and may constrain PDFs

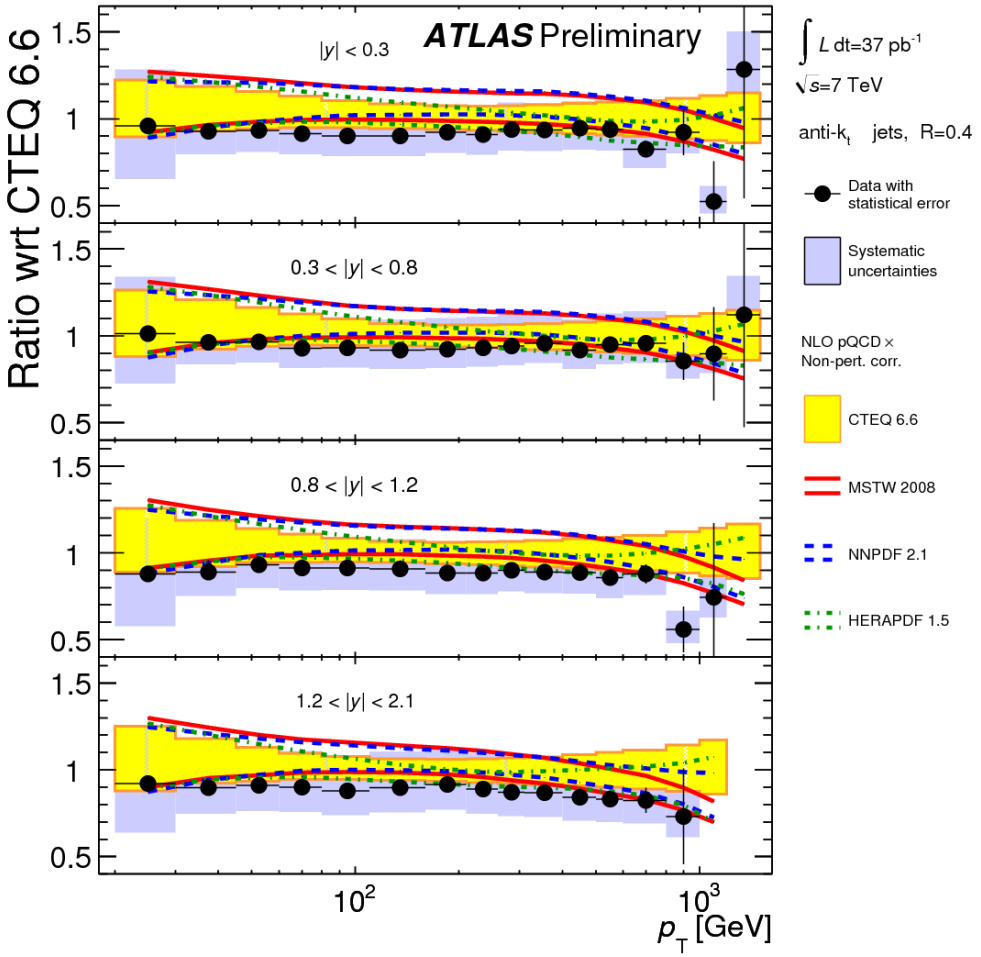
BACKUP

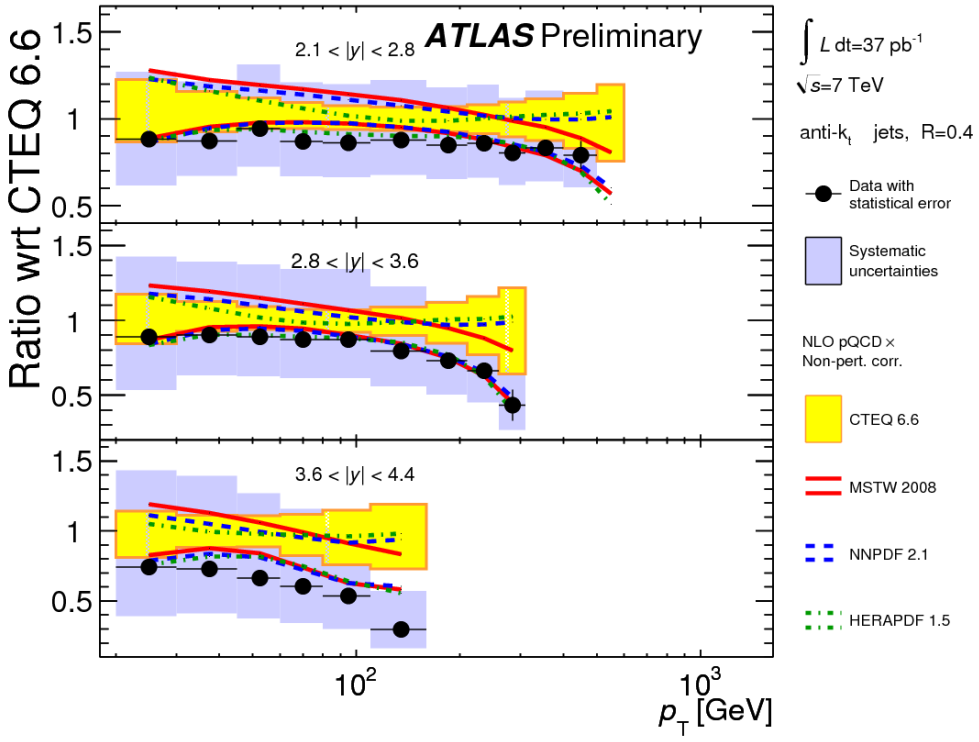
RESULTS WITH R = 0.4 (I)



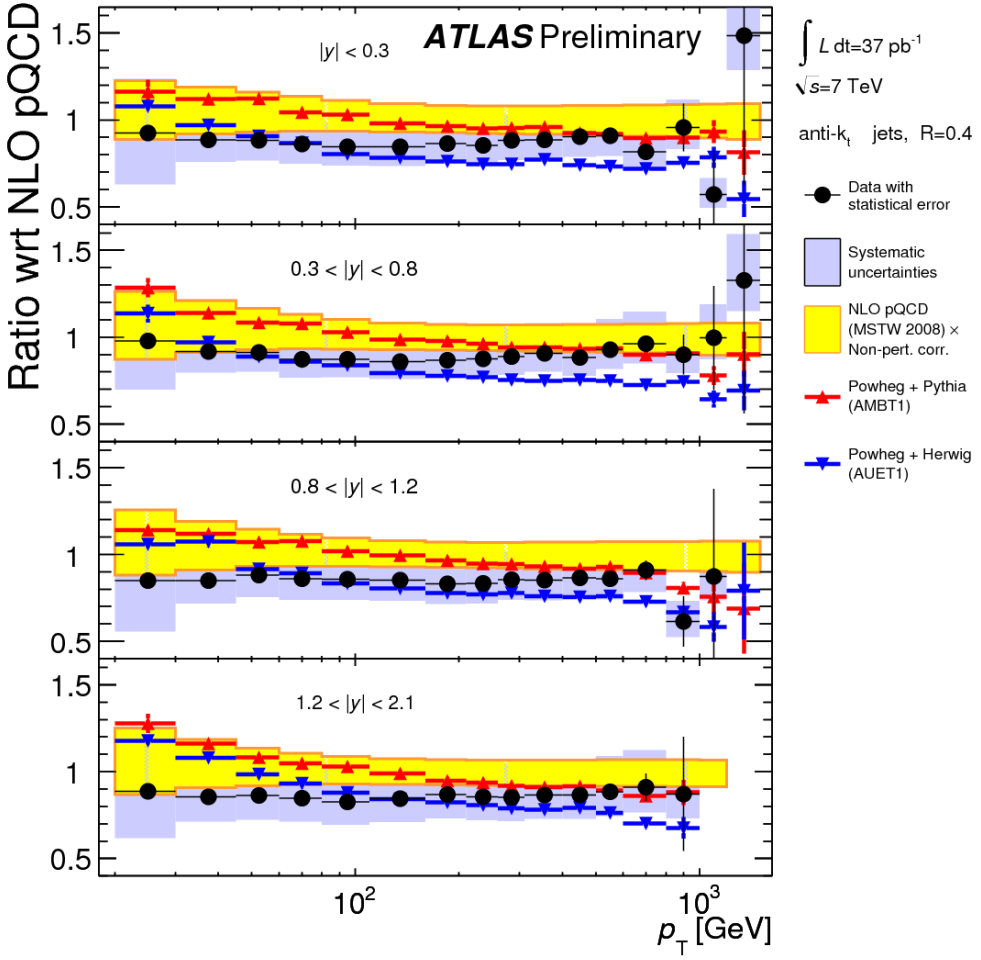


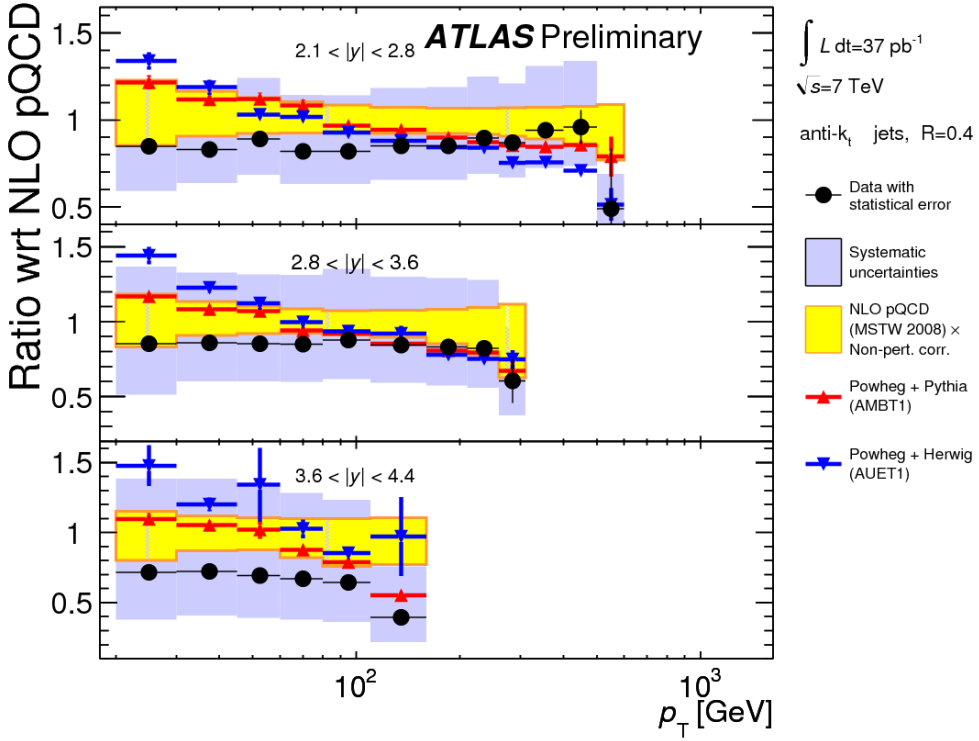
RESULTS WITH R = 0.4 (II)



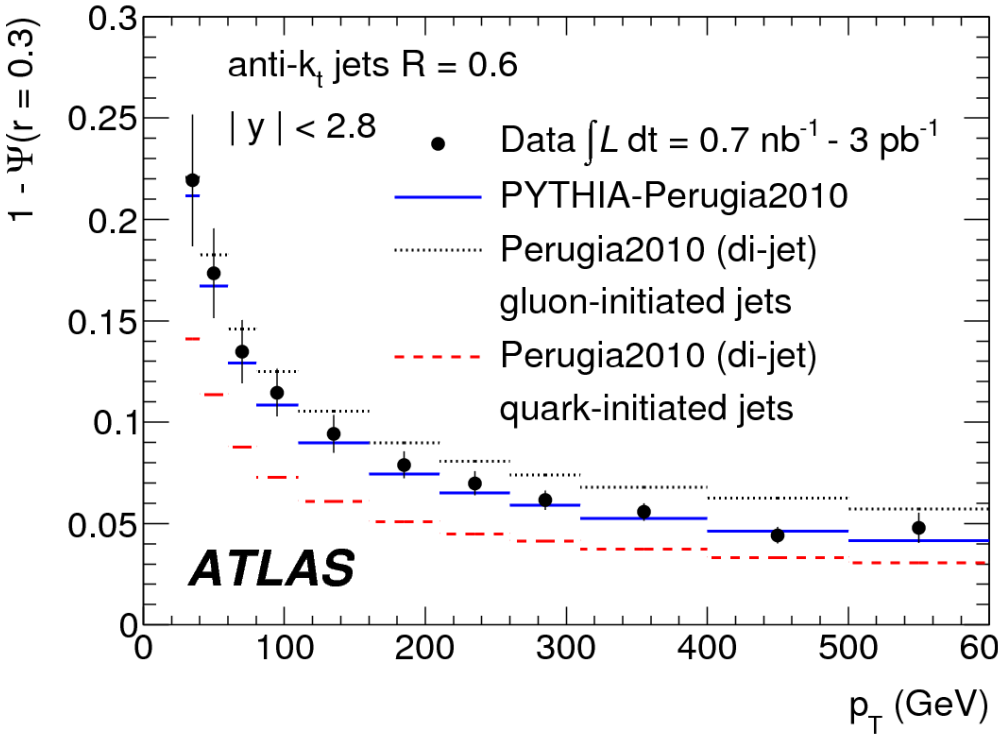


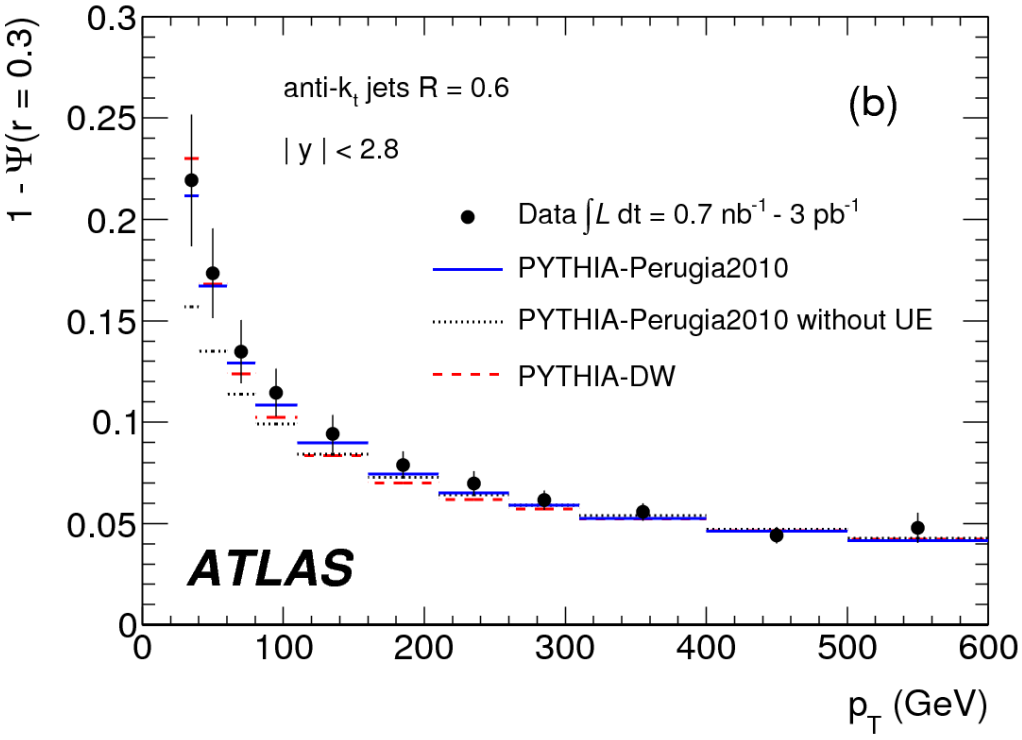
RESULTS WITH R = 0.4 (III)





JET SHAPES


anti-k$_t$ jets R = 0.6
| y | < 2.8
Data $\int L$ dt = 0.7 nb^{-1} - 3 pb^{-1}
PYTHIA-Perugia2010
Perugia2010 (di-jet) gluon-initiated jets
Perugia2010 (di-jet) quark-initiated jets
ATLAS
1 - Ψ(r = 0.3)
p$_T$ (GeV)


anti-k$_t$ jets R = 0.6
(b)
| y | < 2.8
Data $\int L$ dt = 0.7 nb^{-1} - 3 pb^{-1}
PYTHIA-Perugia2010
PYTHIA-Perugia2010 without UE
PYTHIA-DW
ATLAS
1 - Ψ(r = 0.3)
p$_T$ (GeV)