Physics at the LHC, June 6th - 11th 2011, Perugia, Italy

Jet Production Measurement with the ATLAS Detector

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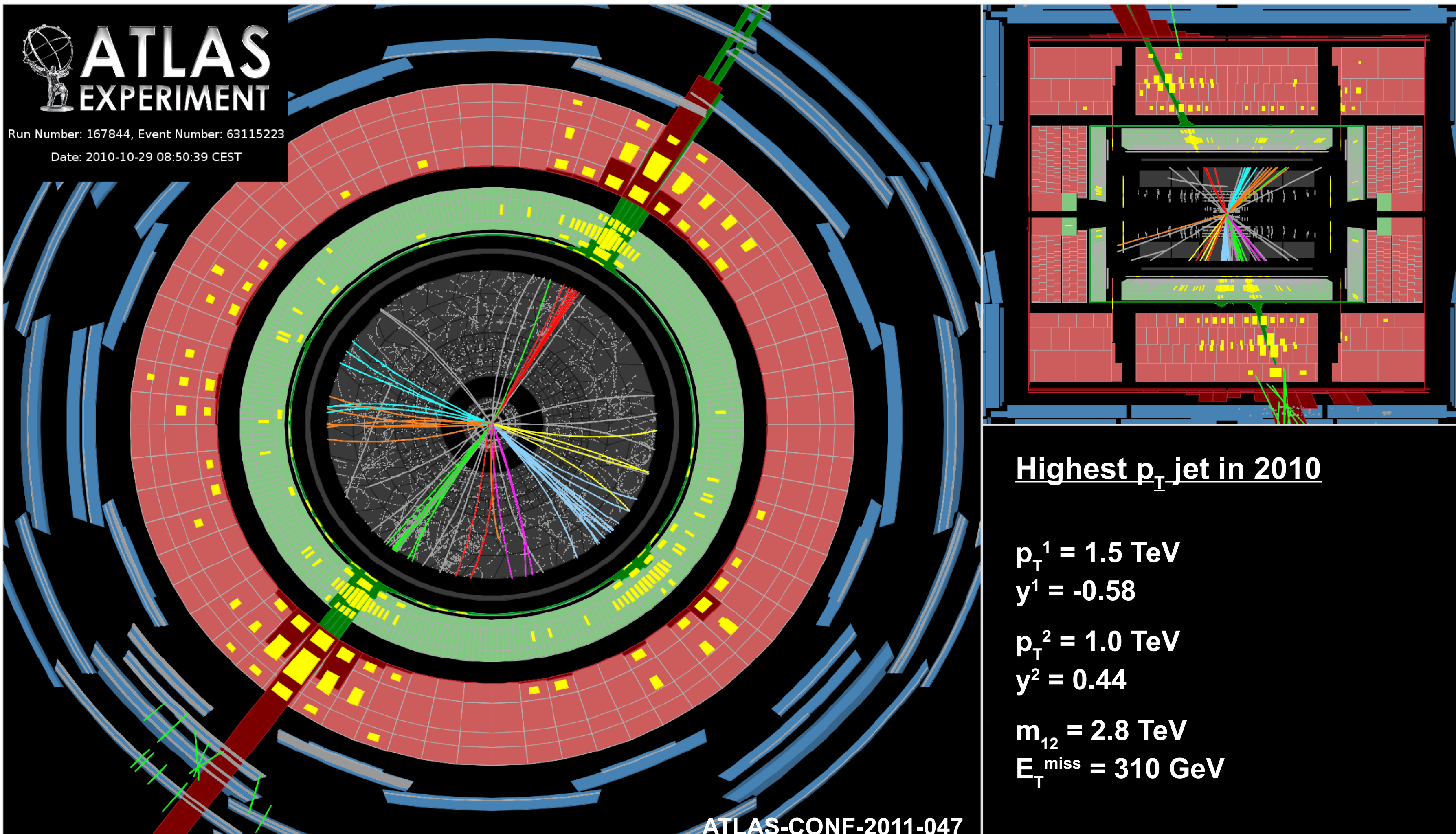
on behalf of the ATLAS collaboration

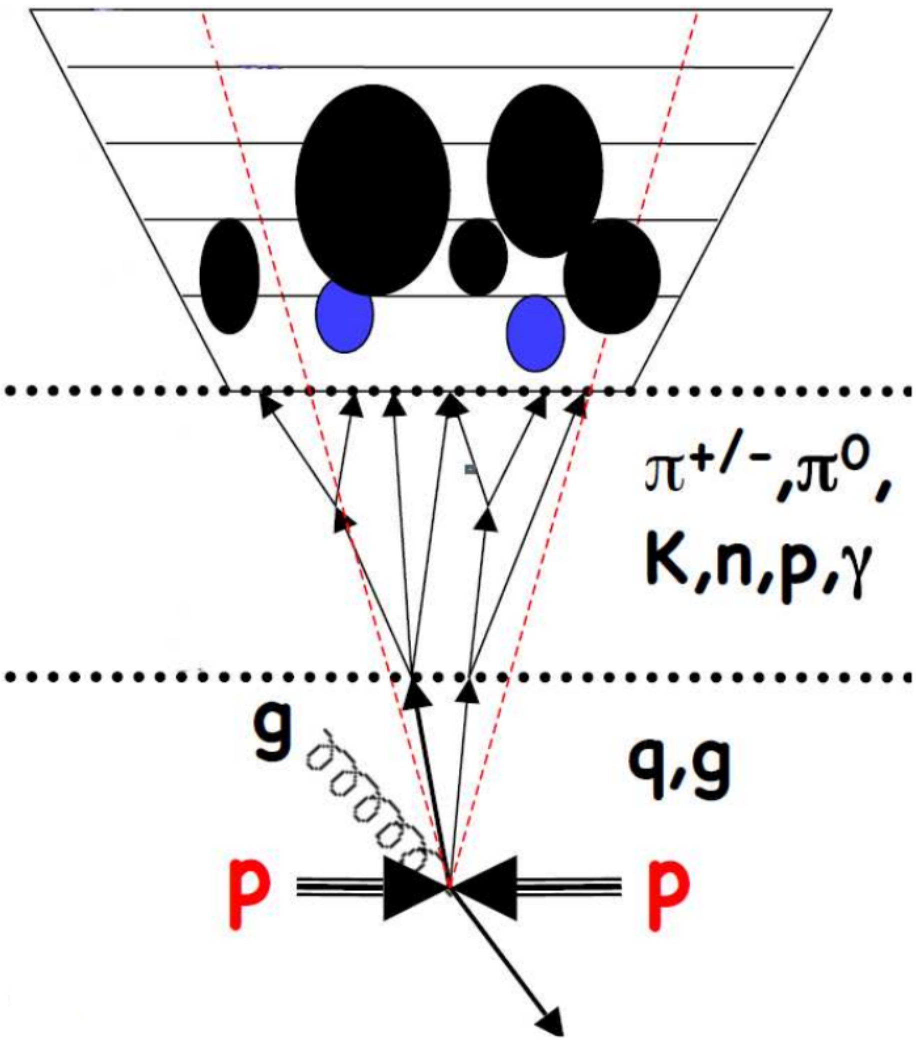
- Inclusive jet and dijet cross section
- Inclusive jet cross section of b-jets
- Azimuthal decorrelation of jets
- Dijet production with a jet veto

Introduction

- Jet production is the dominant process at the LHC
- Explore new kinematic region
  - Probe next-to-leading order pQCD
  - Probe for New Physics at high p_T



Jet Reconstruction



calorimeter cells
(electromagnetic scale)

↓

3-D topological clusters

- Evaluate E / σ_{noise}
- Good noise suppression

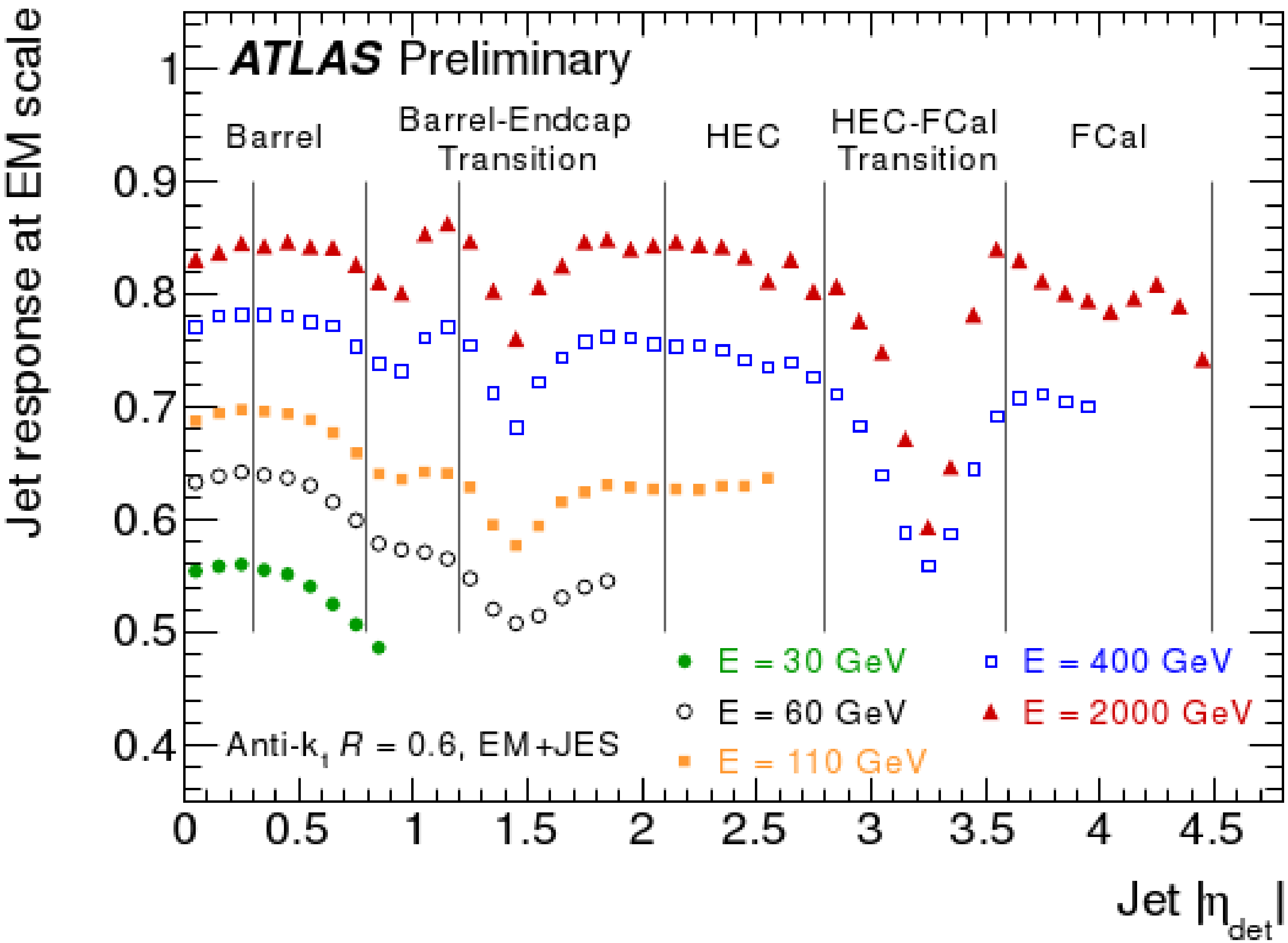
↓

anti-k_T algorithm, R=0.6 (0.4)

- Well defined for truth jets, hadronisation models, detector level

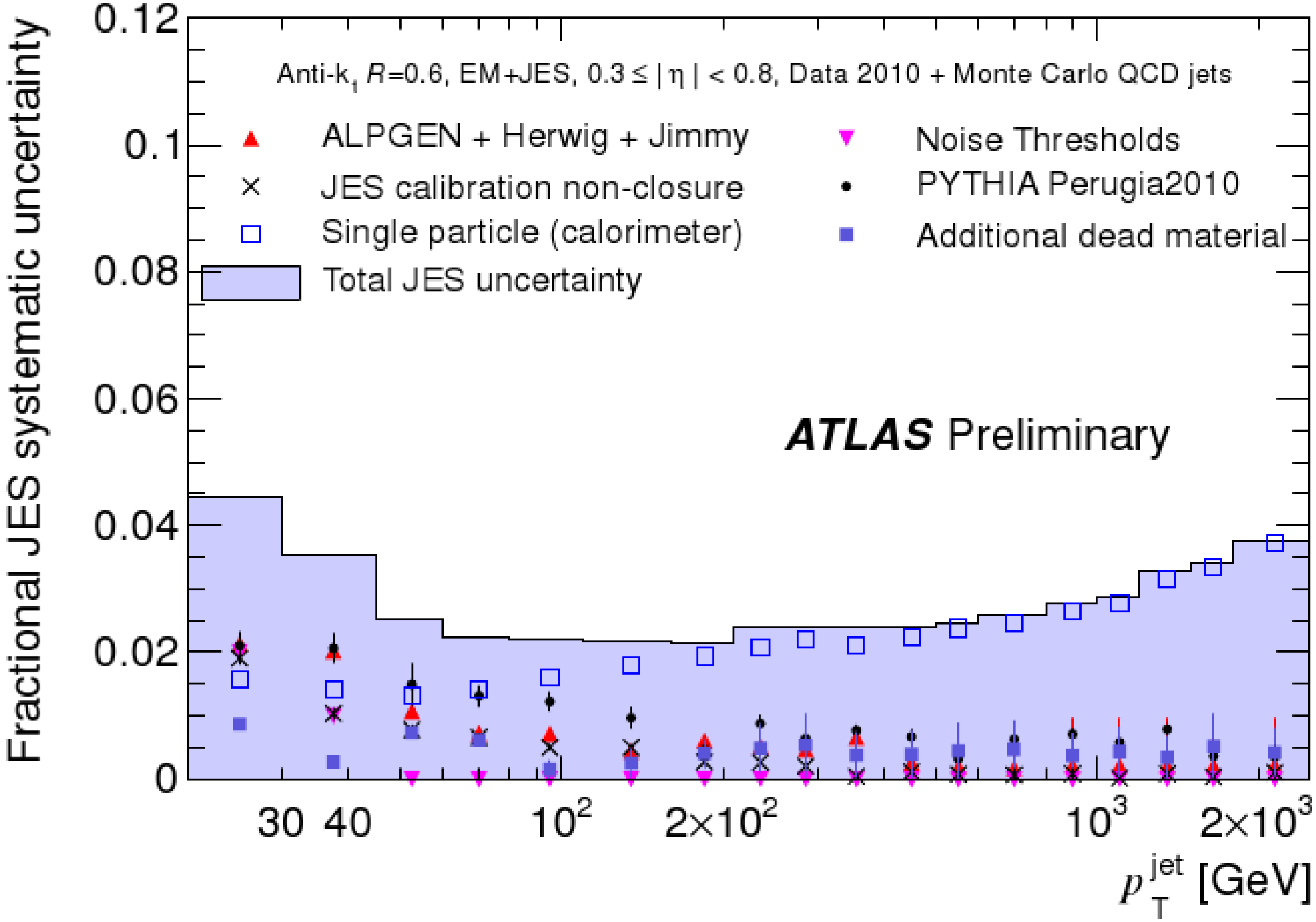
Jet Energy Calibration

- Derived from Monte Carlo truth information
- (η, p_T) dependent correction factor: $E_{truth} / E^{EM}_{calo}$



- *EM + JES scheme* simple default Monte Carlo based calibration
  → simple, well understood uncertainty

Jet Energy Scale Uncertainty

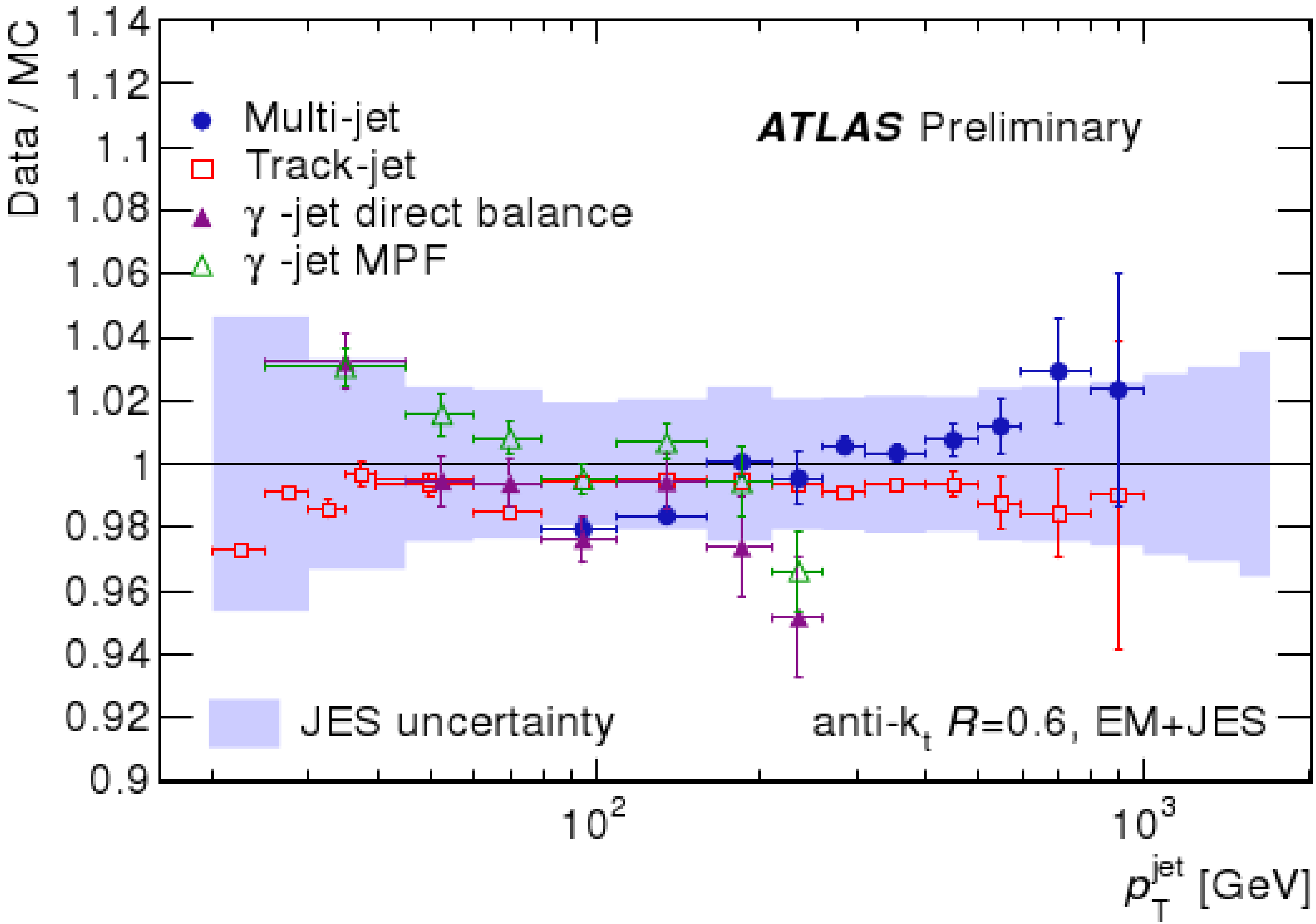


	p_T=20GeV	p_T=200GeV	p_T=1.5TeV
|η|<0.3	4.6 %	2.3%	3.1%
2.1<|η|<2.8	7.1 %	2.5%	
3.6<|η|<4.5	12.6 %	2.9%	

- Single hadrons (see also *Single hadron response measurement in ATLAS, poster session)*
- Monte Carlo (hadronisation, soft physics, generators, noise, dead material)
- Extension to forward region: η – intercalibration
- Additional uncertainty from pile-up (not shown)

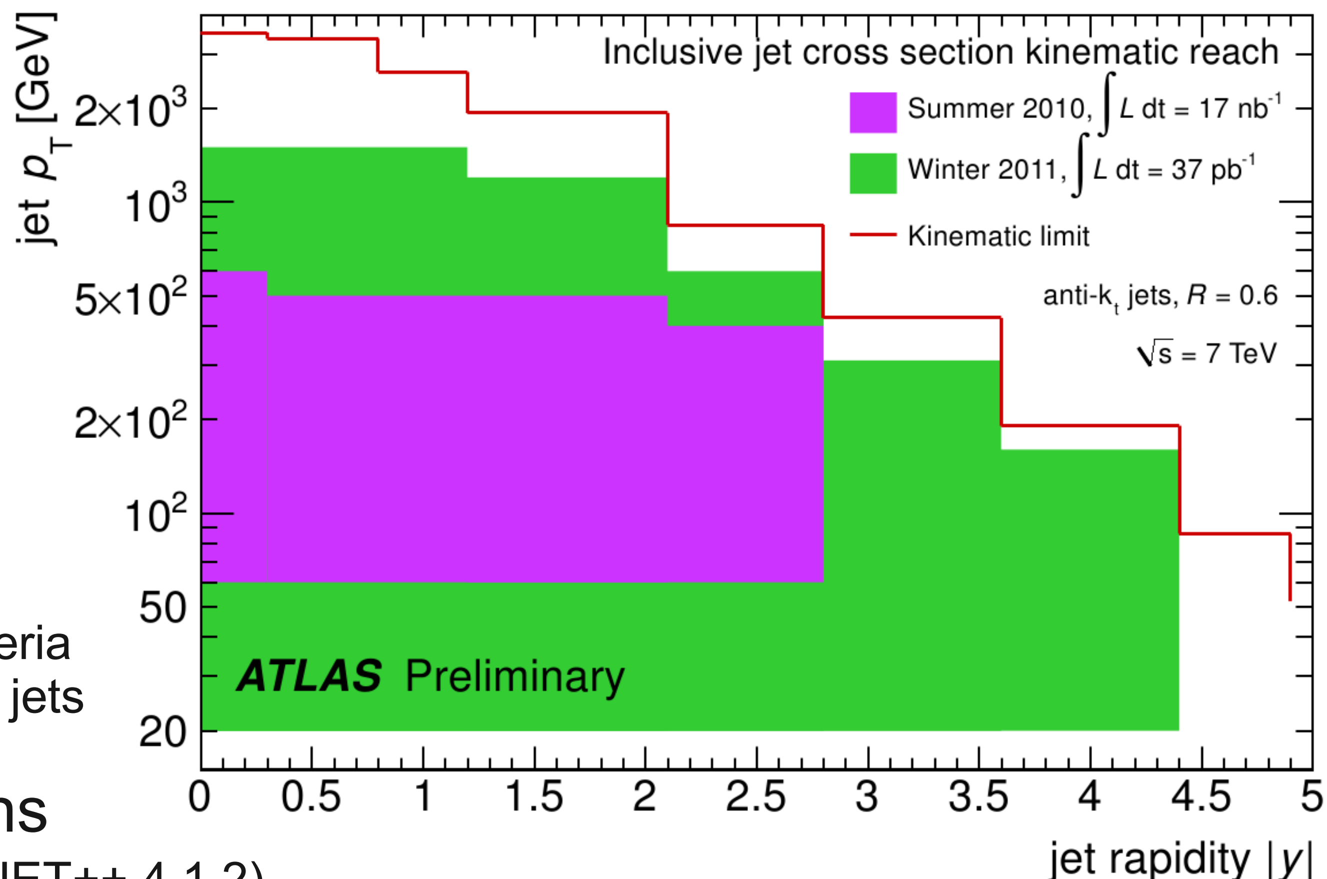
Jet Energy Scale Uncertainty

- In-situ tests in agreement with JES uncertainty estimation from MC



Inclusive and Dijet Cross Section

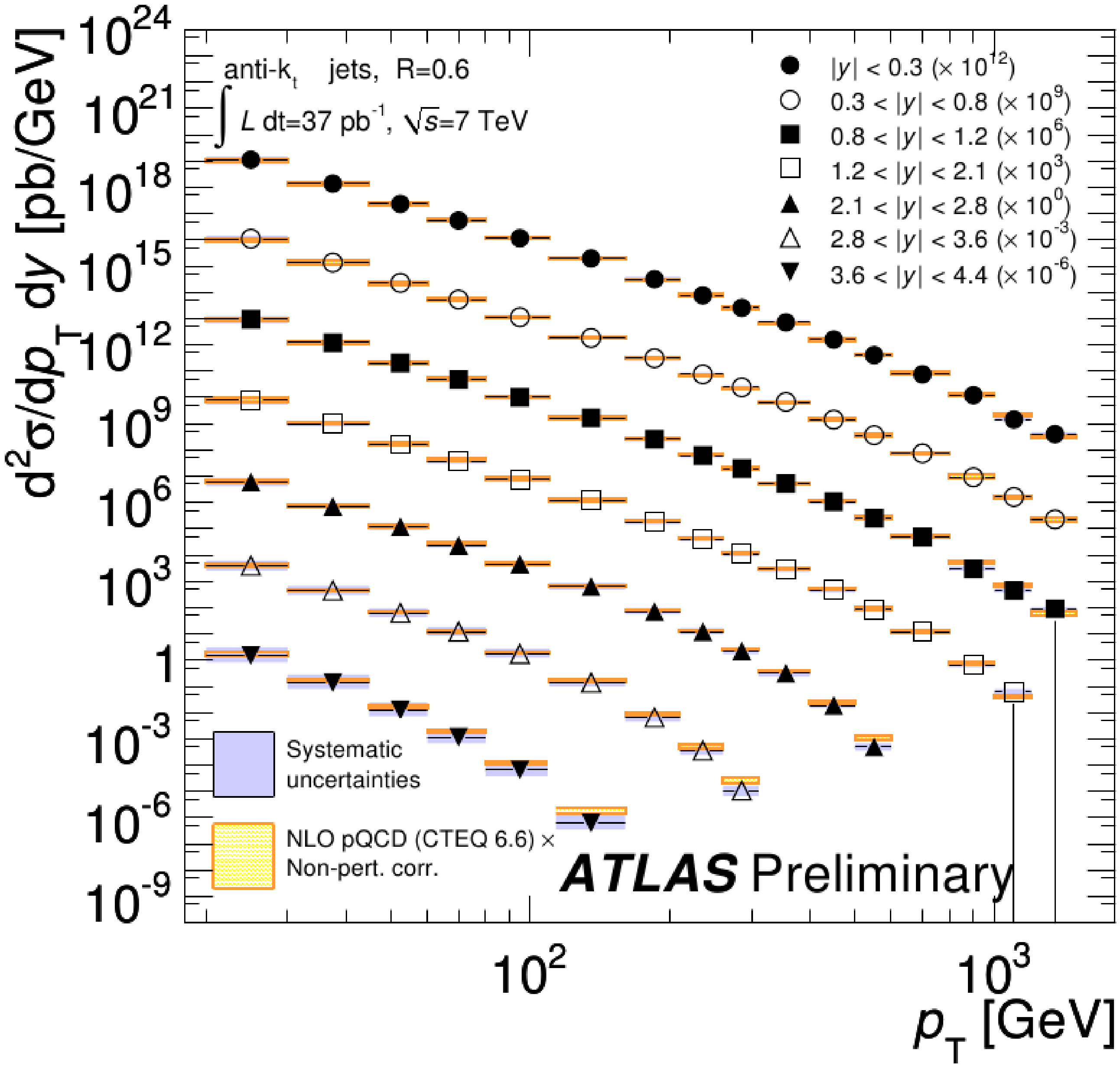
- Full dataset 2010
  - $\int \mathscr{L}\, dt = 37.3 \pm 1.3\ pb^{-1}$
  - Close to kinematic limit



- Event selection
  - ≥1 primary vertex
  - Single jet trigger (minimum bias at low p_T)
  - Jet quality selection criteria → remove non-collision jets
- Theoretical predictions
  - NLO calculations (NLOJET++ 4.1.2) with non-pertubative corrections (Pythia, AMBT1)
  - NLO parton shower MC using POWHEG
  - Uncertainties: PDF, factorisation and renormalisation scale, α_s
- Unfolding: bin-by-bin using Monte Carlo (detector inefficiencies and resolution effects)

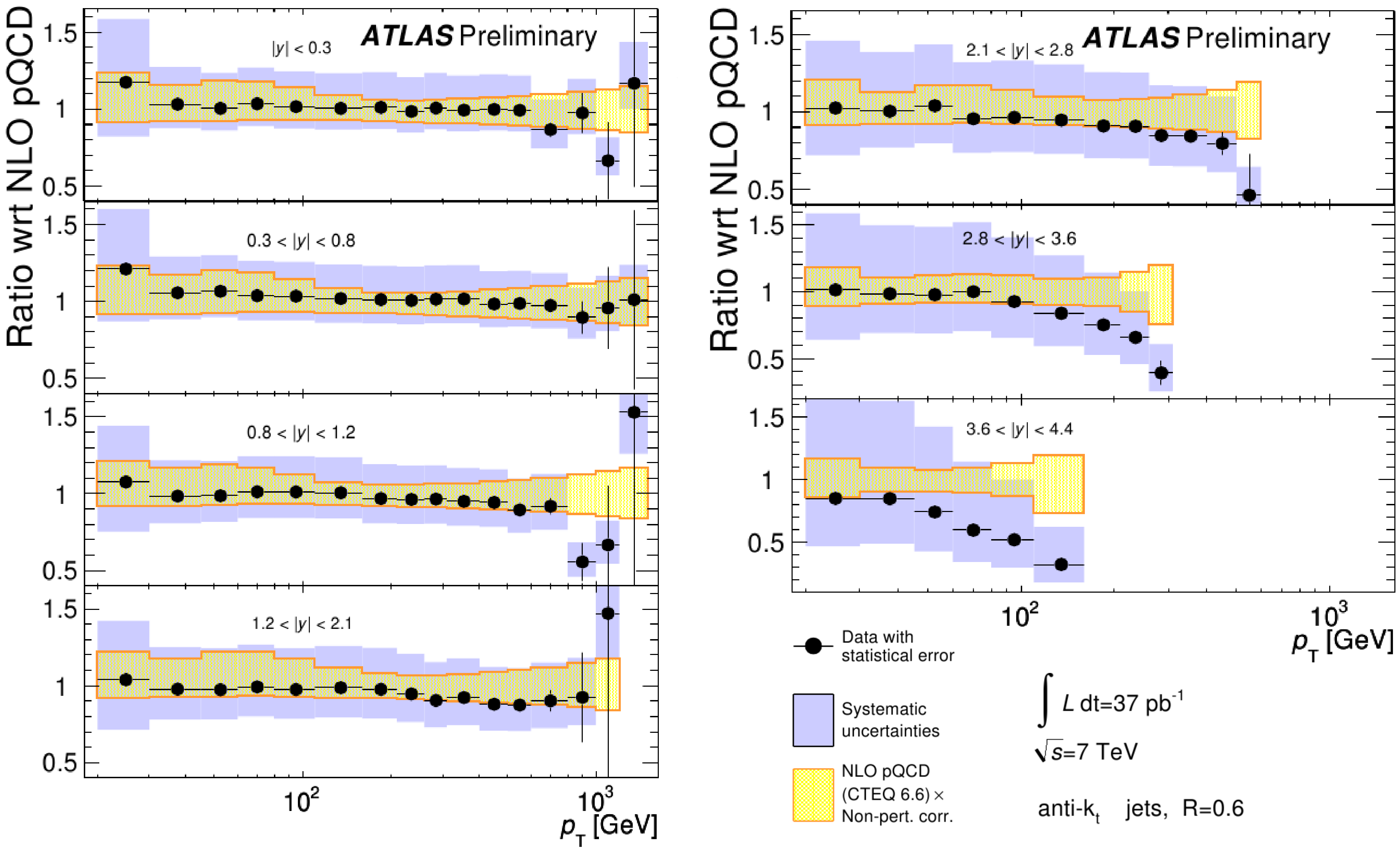
Inclusive Jet Double-Differential Cross Section

- Kinematic reach: 20 GeV < p_T < 1.5TeV, |y| < 4.4
- Comparison to NLO pQCD predictions (including non-pertubative corrections)



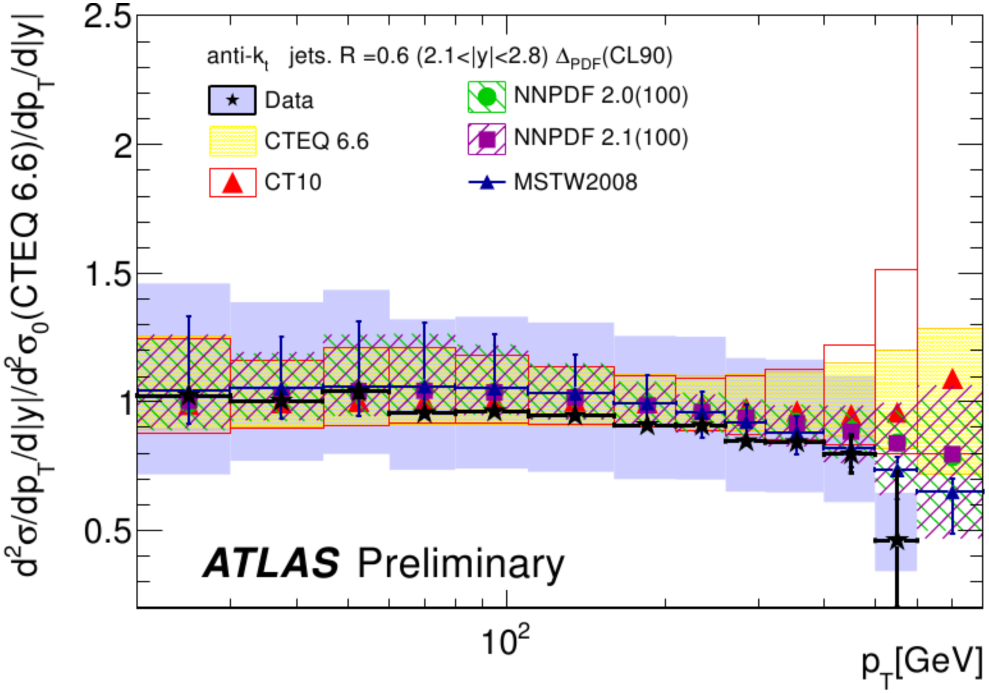
good agreement over 9 orders of magnitude!

Inclusive Jet Double-Differential Cross Section



- Systematic uncertainty: jet energy scale, unfolding, luminosity ~20%
  (80% for p_T = 20 GeV, |y| = 4.4)

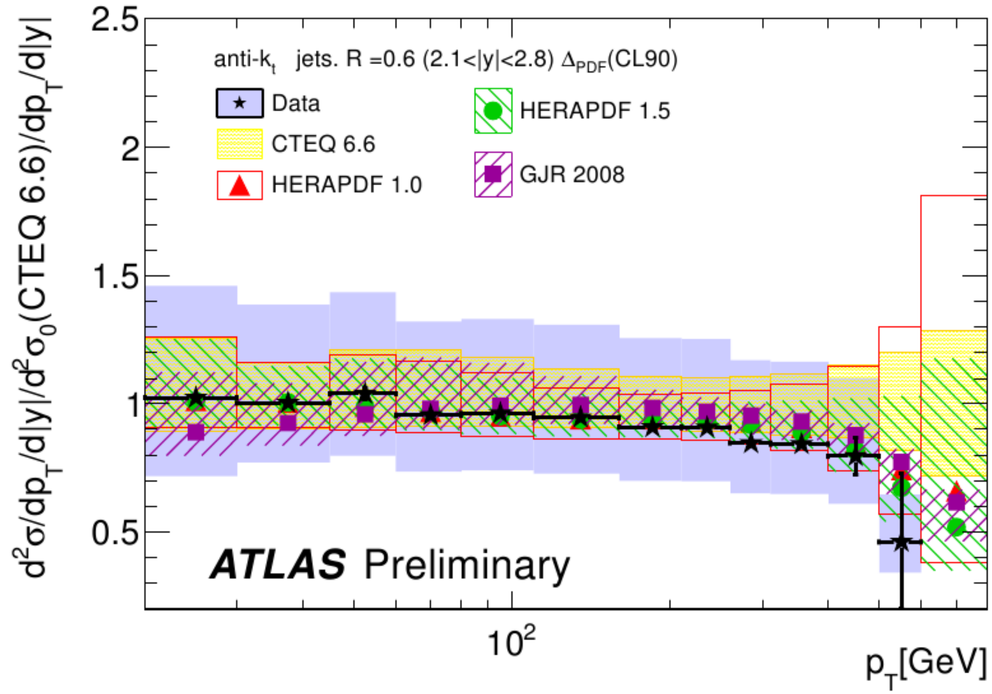
Inclusive Jet Double-Differential Cross Section



Comparison of different PDFs:

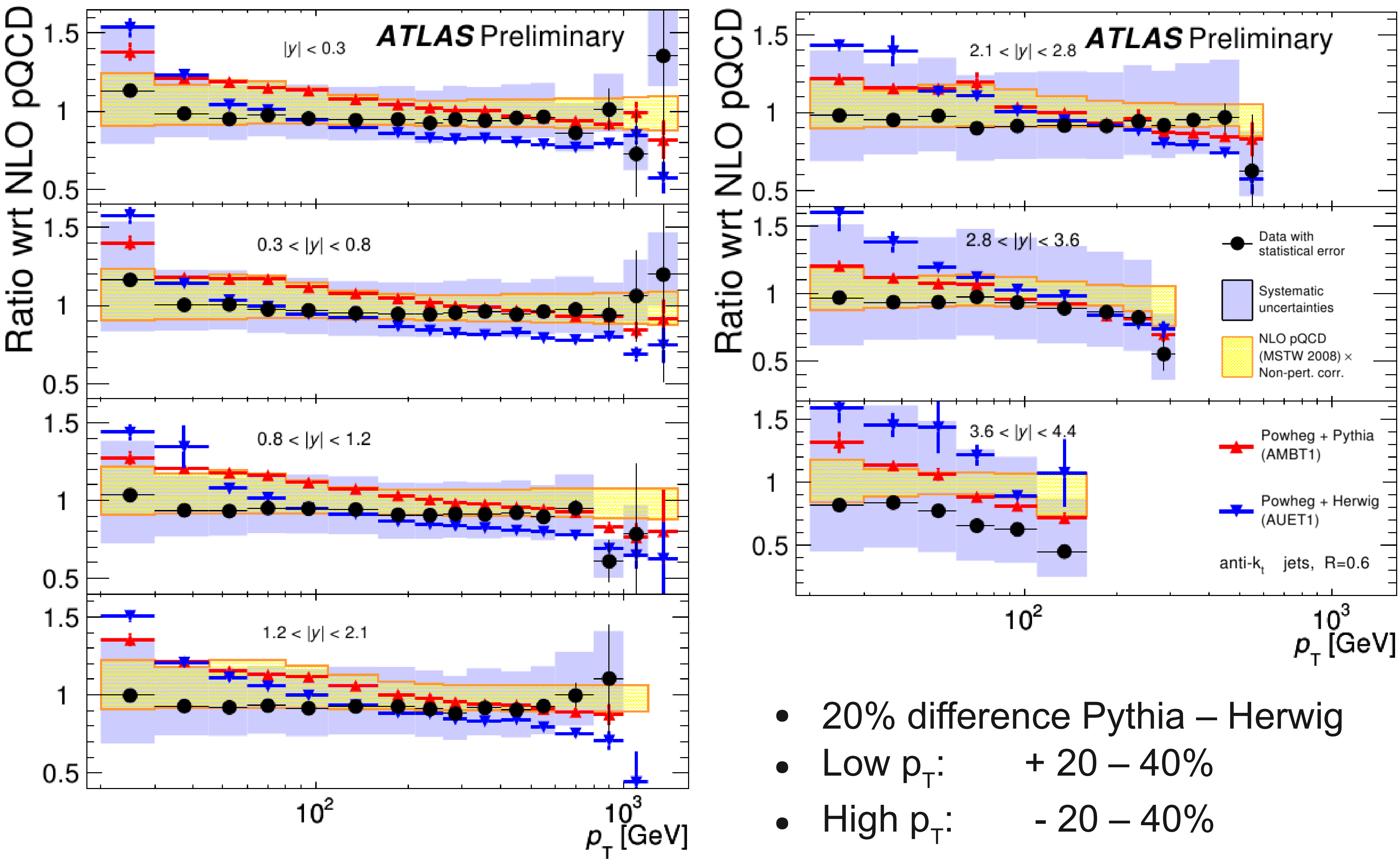
- Rapidity 2.1 < |y| < 2.8
- Baseline is CTEQ 6.6
- CT10 lower than CTEQ 6.6 at high p_T
- NNPDF 2.0 ~ NNPDF 2.1
- MSTW 2008 describes data well

- HERAPDF most accurate
- HERAPDF 1.5 uncertainty reduced at high p_T (compared to HERAPDF 1.0)
- GJR different shape



Inclusive Jet Double-Differential Cross Section

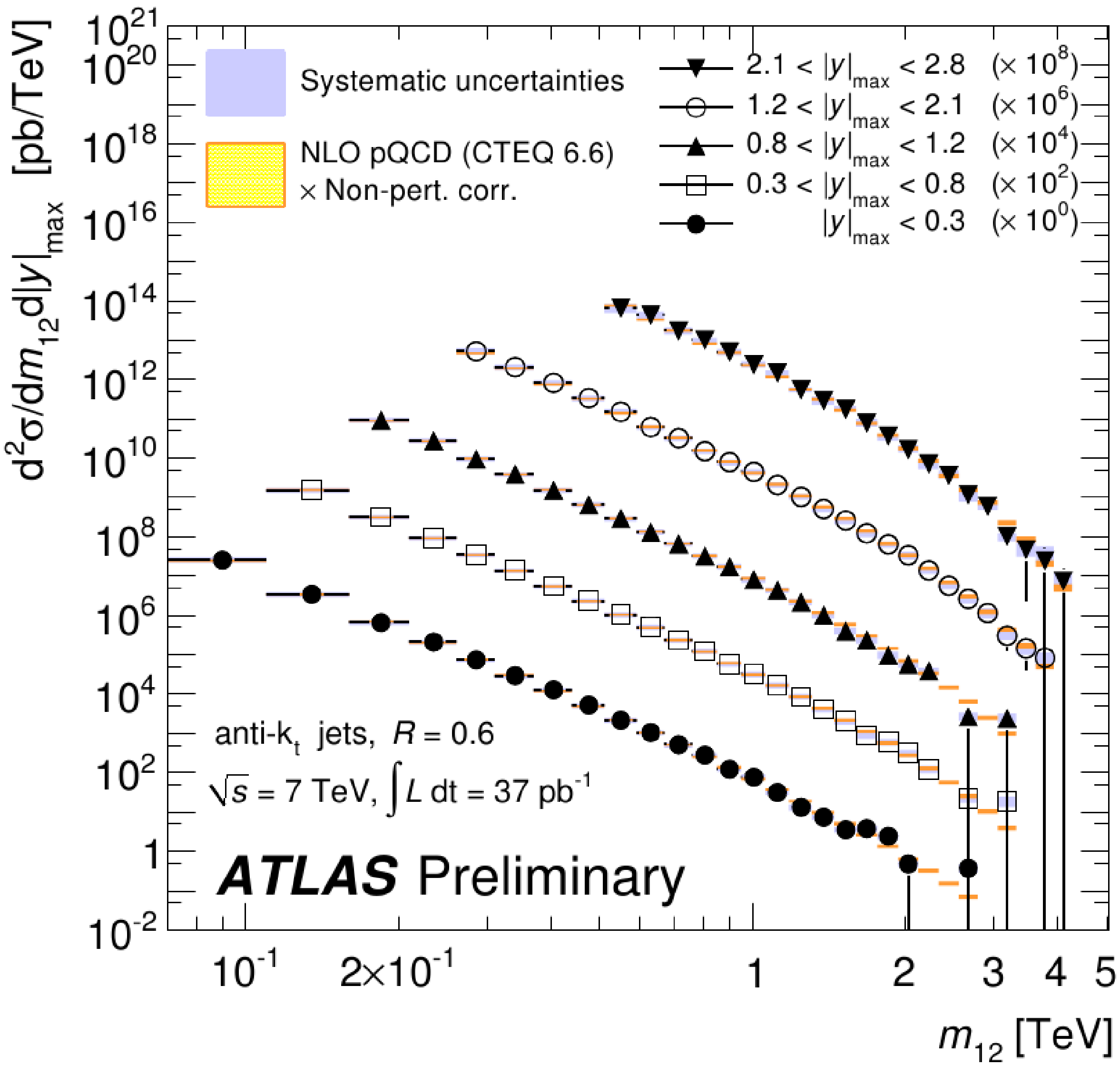
Comparison of NLO parton shower Monte Carlo (POWHEG)

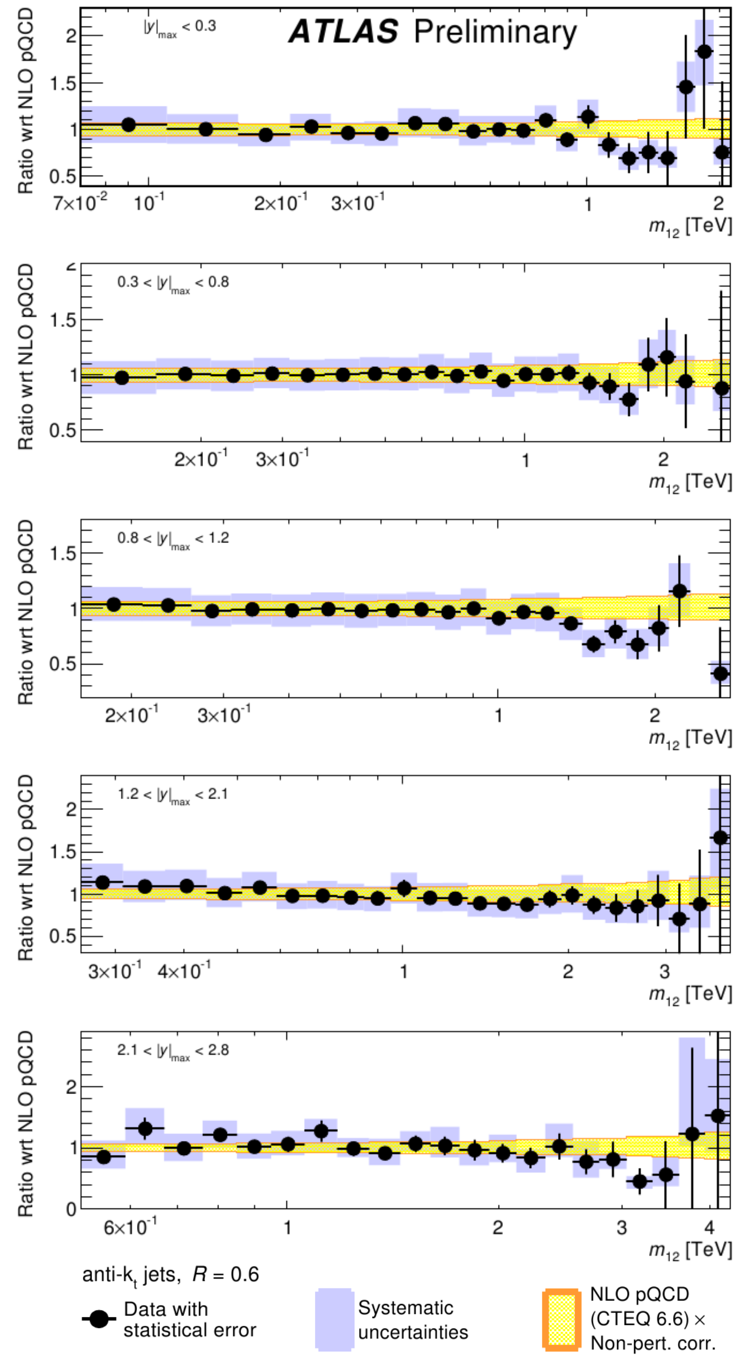


- 20% difference Pythia – Herwig
- Low p_T: + 20 – 40%
- High p_T: - 20 – 40%

Inclusive Double-Differential Dijet Cross Section

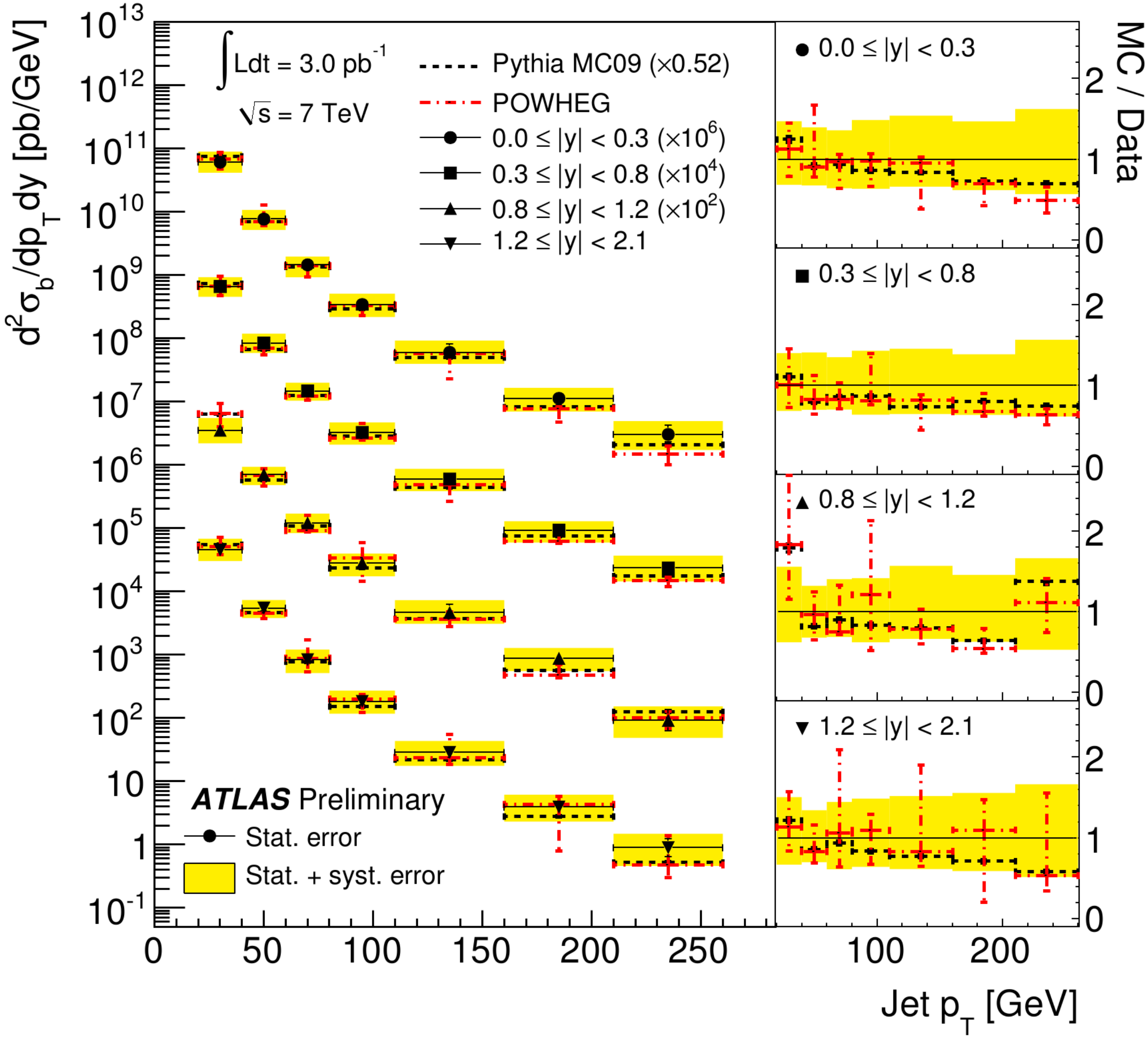
- p_T^1 = 30 GeV, p_T^2 = 20 GeV, |y| < 2.8
- Combining single jet p_T triggers
- Uncertainty ~20%





Inclusive Jet Cross Sections of b-jets

- Dataset
  - L = 3 pb^{-1}
    (full dataset in preparation)
  - anti-k_T R = 0.4
  - p_T > 20 GeV, |y| < 2.1
- Secondary vertex b-tagging
  (see *Measurement of the b-tagging performance with ATLAS, poster session)*
- Uncertainties
  - Jet energy scale + b-jet energy scale (35–40 %)
  - b-tagging efficiency (10–20 %)
- Predictions in agreement with data, but slightly softer



- Further measurements (*see backup*):
  - Dijet mass distribution for b-jets (→ double b-tagging)
  - Comparison with inclusive jet cross section (→ uncertainties partially cancel)

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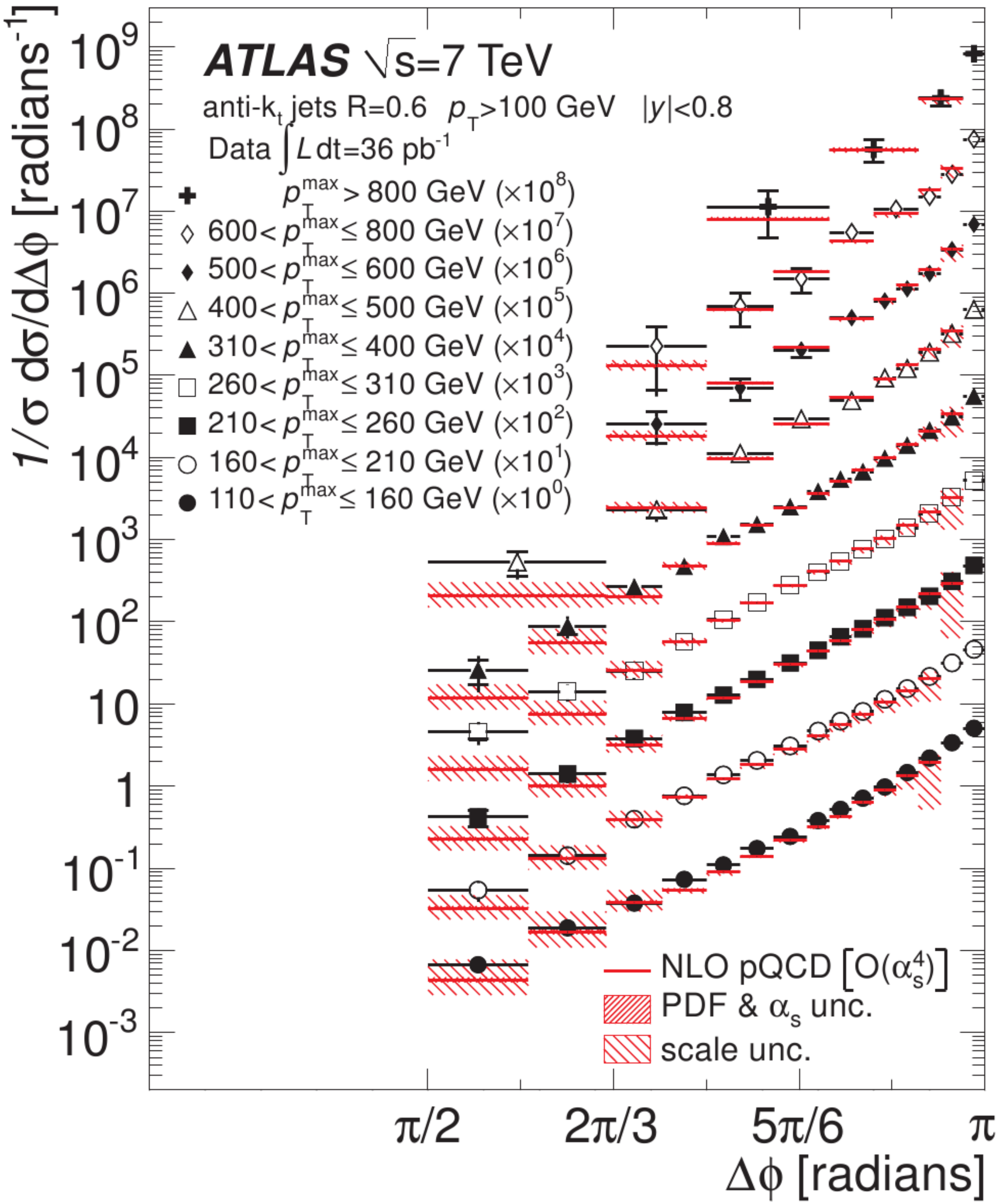
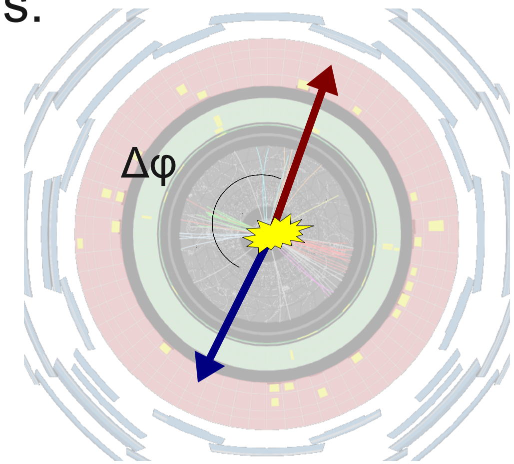
Measurement of Dijet Azimuthal Decorrelation

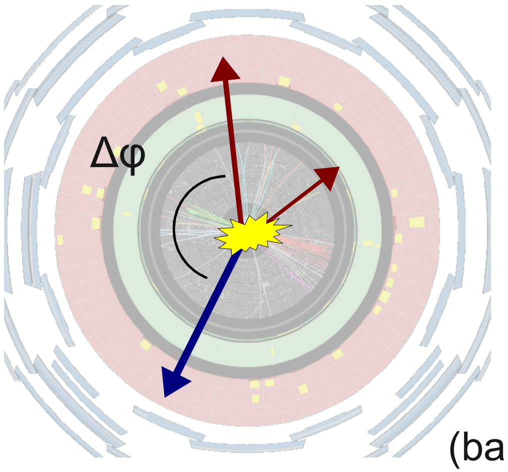


- Azimuthal decorrelation Δφ of leading jets depends on number of partons:

dijet:
Δφ ~ π



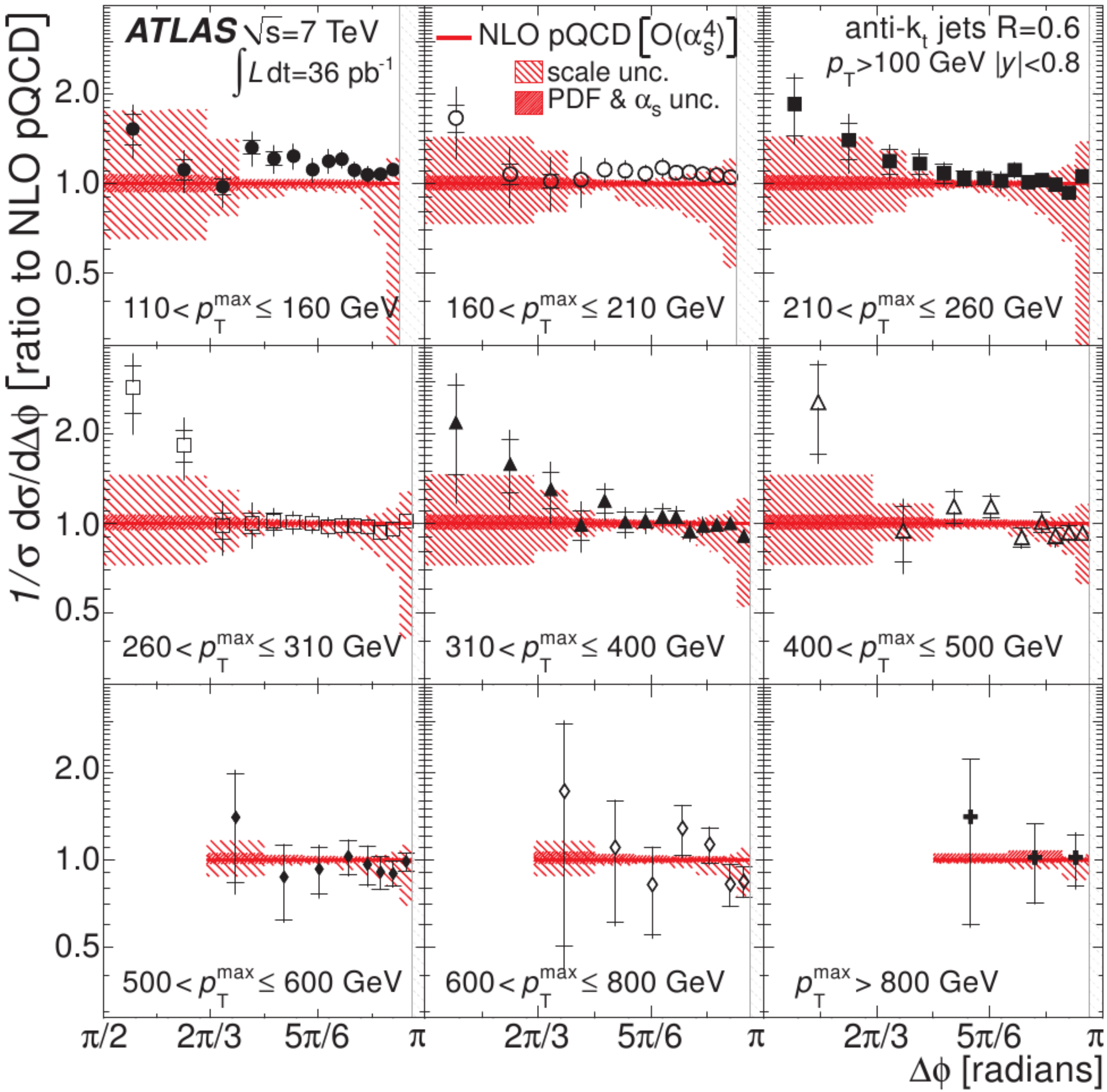
> 2 jets:
Δφ « π



(barrel)

→ sensitive test of QCD predictions

Measurement of Dijet Azimuthal Decorrelation



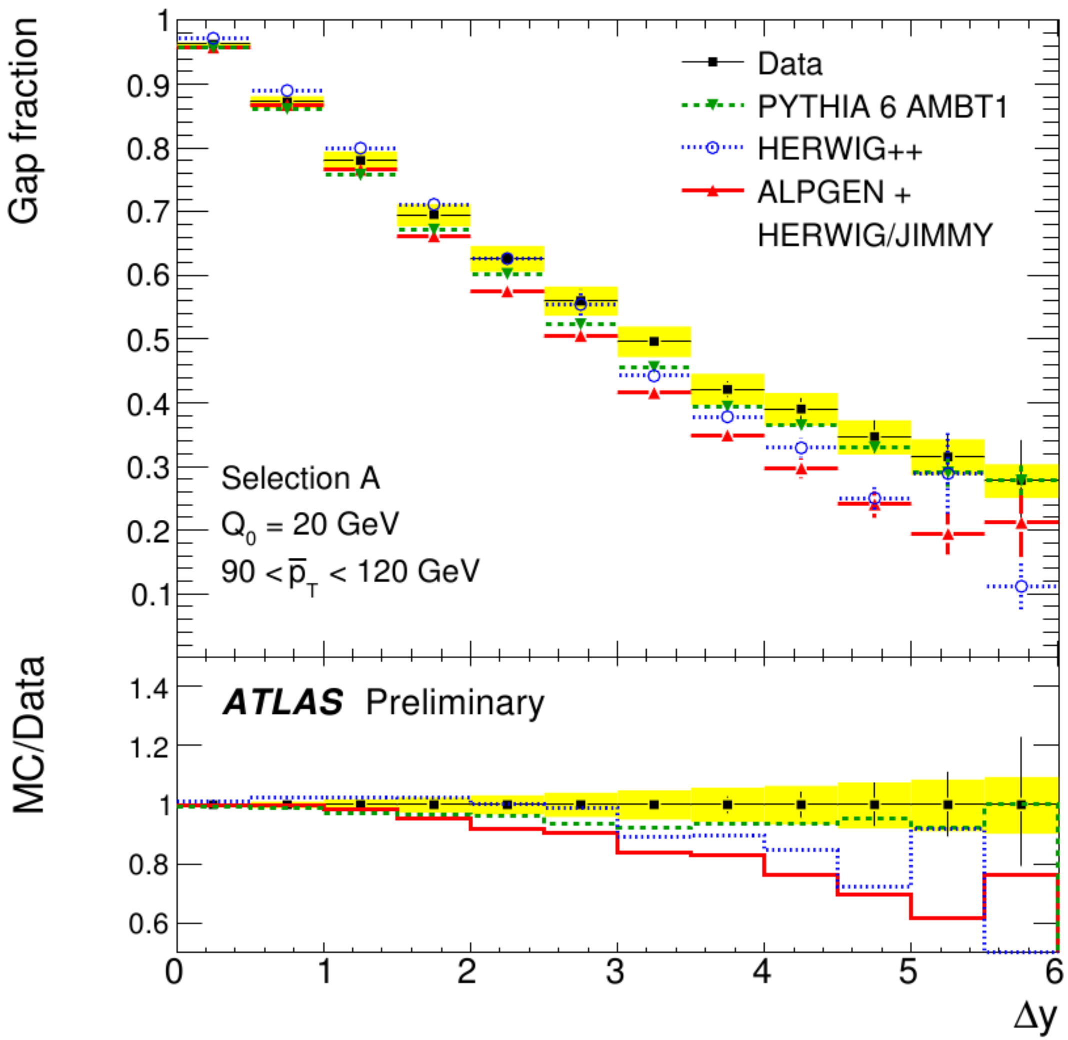
Exp. uncertainties:

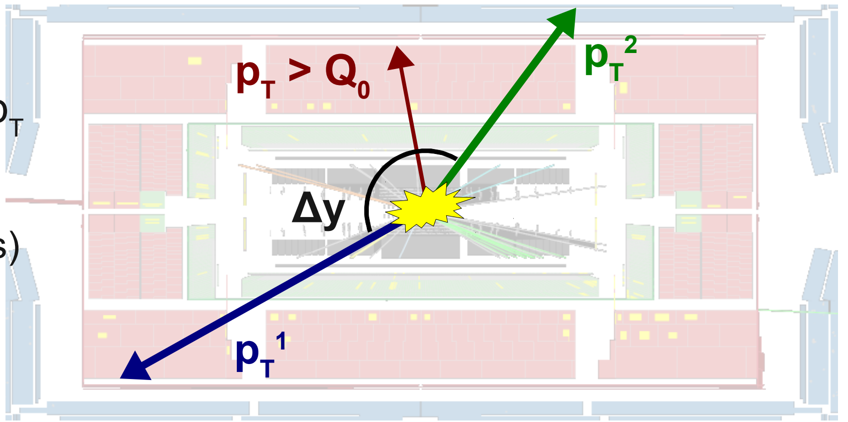
- jet energy scale (2-17%)
- Unfolding (1-19%)
- jet energy and position resolution (0.5-5%)

Theoretical and experimental uncertainties of similar size!

Measurement of Dijet Production with a Jet Veto

- Events with no additional jets in rapidity interval spanned by dijet system (→ gap fraction)
  - Test pQCD radiation in dijet system for large Δy, high p_T
  - Test wide angle soft gluon radiation (BFKL dynamics)
  - Jet vetos in vector boson fusion analyses (Higgs + 2 jets)





$$\text{gap fraction} = \frac{\text{events w/o additional jet}}{\text{all dijet events}}$$

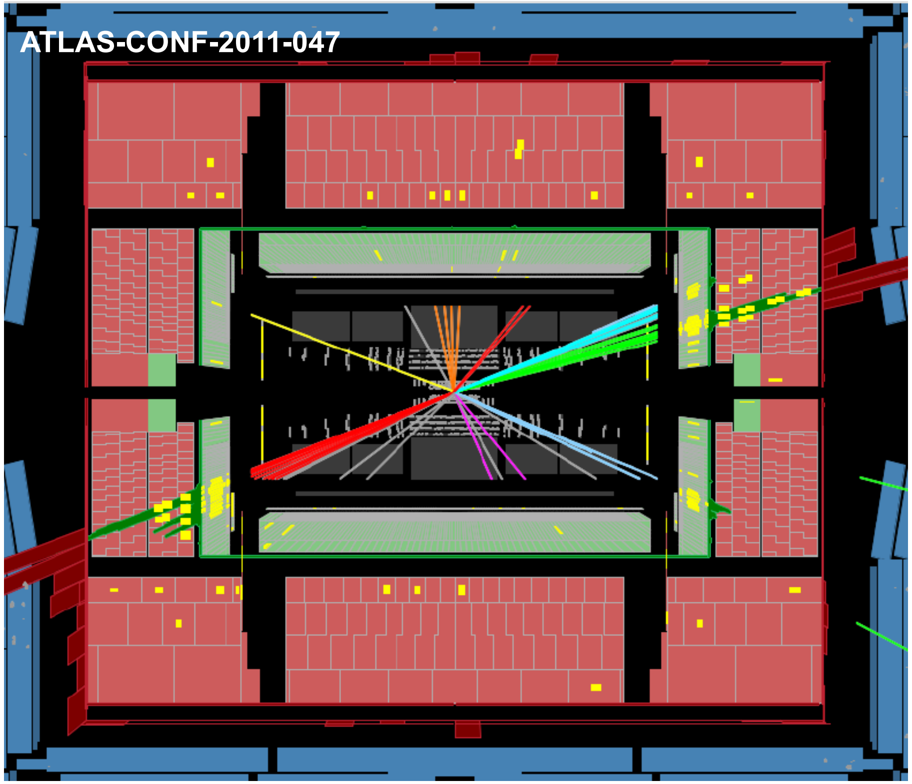
- Data Selection
  - Exactly 1 primary vertex per event
  - Dijet system from 2 leading jets
  - $\bar{p}_T$ > 50 GeV, |y| < 4.5
  - Veto scale Q_0 = 20GeV
- Uncertainties:
  Absolute and relative jet energy scale
- Comparison with several event generators
  - Pythia 6 gives good description
  - HERWIG++ and ALPGEN overestimate gap radiation

Conclusions

- Probe QCD to a new energy regime and larger rapidities
- Presented measurements from ATLAS:
  - Inclusive jet and dijet cross sections
  - Inclusive jet and dijet cross sections from b-jets
  - Dijet azimuthal decorrelations
  - Dijet production with a jet veto

→ many more results available (*see also backup slides*)

- *Multijet production and internal jet structure, Open b- and c-production, dijet resonance, ...*



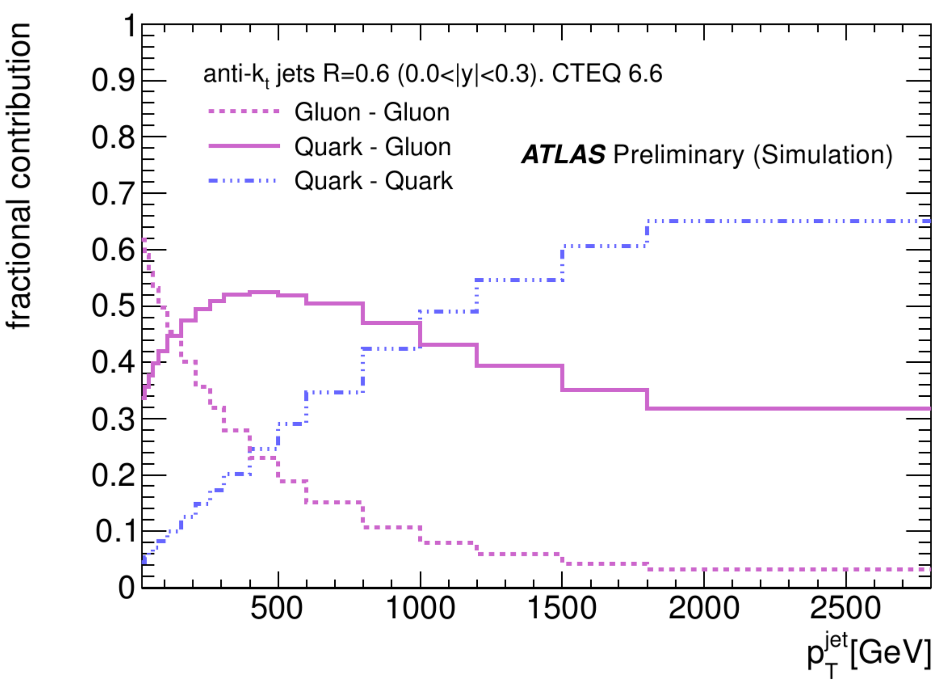
Probe various aspects of NLO pQCD
→ experimental and theoretical uncertainties of similar size

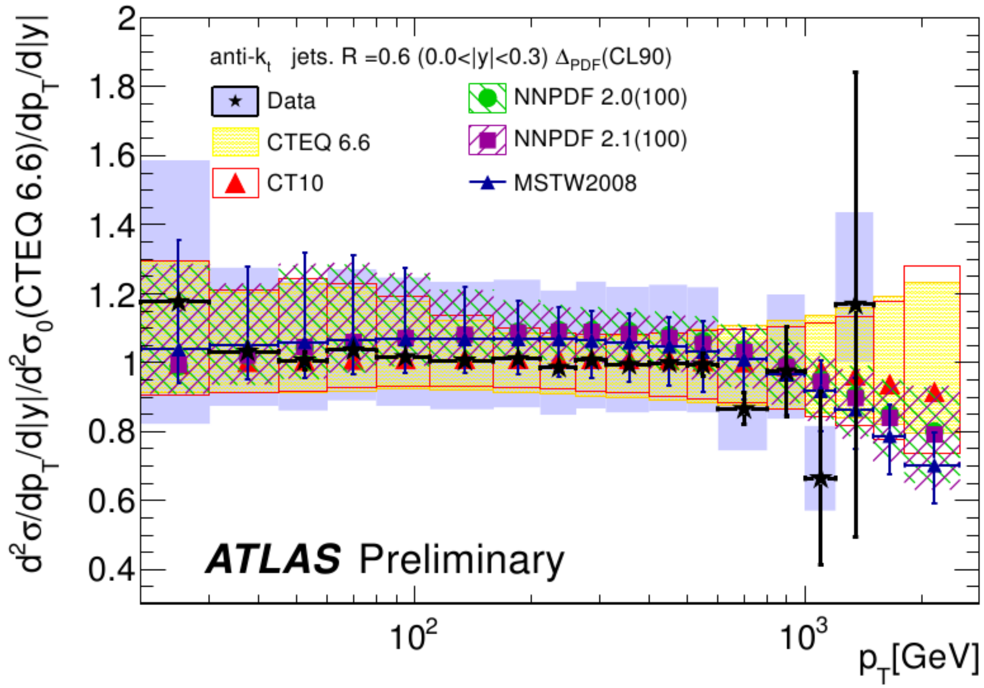
Forward-backward dijet system with invariant mass of $m_{1,2}$ = 4.0 TeV. p_T^1 = 510 GeV, y_1 = -1.9, p_T^2 = 510 GeV, y_2 = 2.2, E_t^{miss} =31 GeV

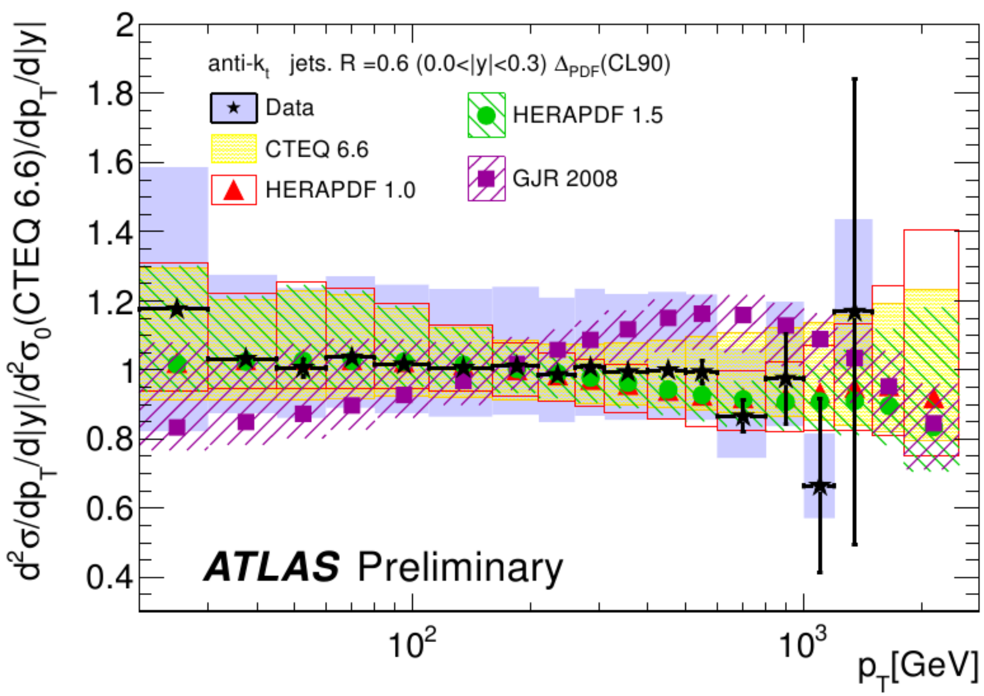
Backup Material

Inclusive Jet Double-Differential Cross Section

- Comparison of different PDFs:
  - CT10 lower than CTEQ 6.6 at high p_T
  - NNPDF 2.0 ~ NNPDF 2.1
  - HERAPDF 1.5 uncertainty reduced at high p_T compared to HERAPDF 1.0
  - GJR compatible with data, but shape is different
- Fractional contributions (CTEQ 6.6)
  - Low p_T: gluon-gluon (60%)
  - Mid p_T: quark-gluon (50%)
  - High p_T: quark-quark (65%)







Inclusive Jet Double-Differential Cross Section

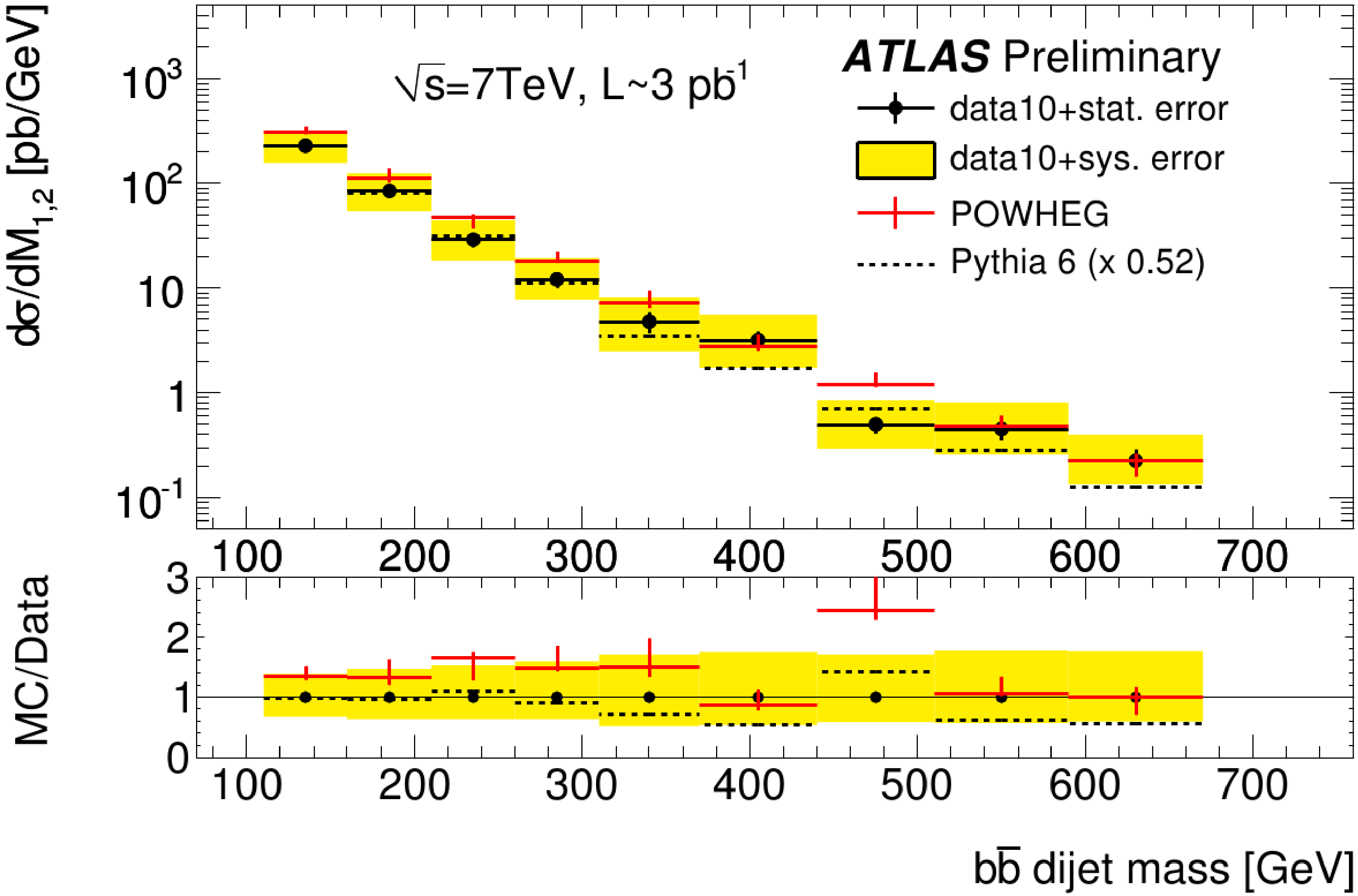
- Systematic uncertainties on the inclusive jet cross section

p_T [GeV]	$\|y\|$	Abs. JES	Unfolding	Cleaning	Trigger	Jet Rec.
20	2.1-2.8	$^{+40\%}_{-30\%}$	20%	0.5%	1%	2%
20	3.6-4.4	$^{+80\%}_{-50\%}$	20%	0.5%	1%	2%
100	< 0.3	10%	2%	0.5%	1%	1%

- Systematic uncertainties on the dijet mass cross section

m_{12} [GeV]	$\|y\|_{max}$	Abs. JES	Rel. JES	Unfolding	Cleaning	Trig.	Jet Rec.
60	2.1-2.8	$^{+30\%}_{-20\%}$	10%	10%	0.5%	1%	2%
200	< 0.3	10%	0%	5%	0.5%	1%	1%

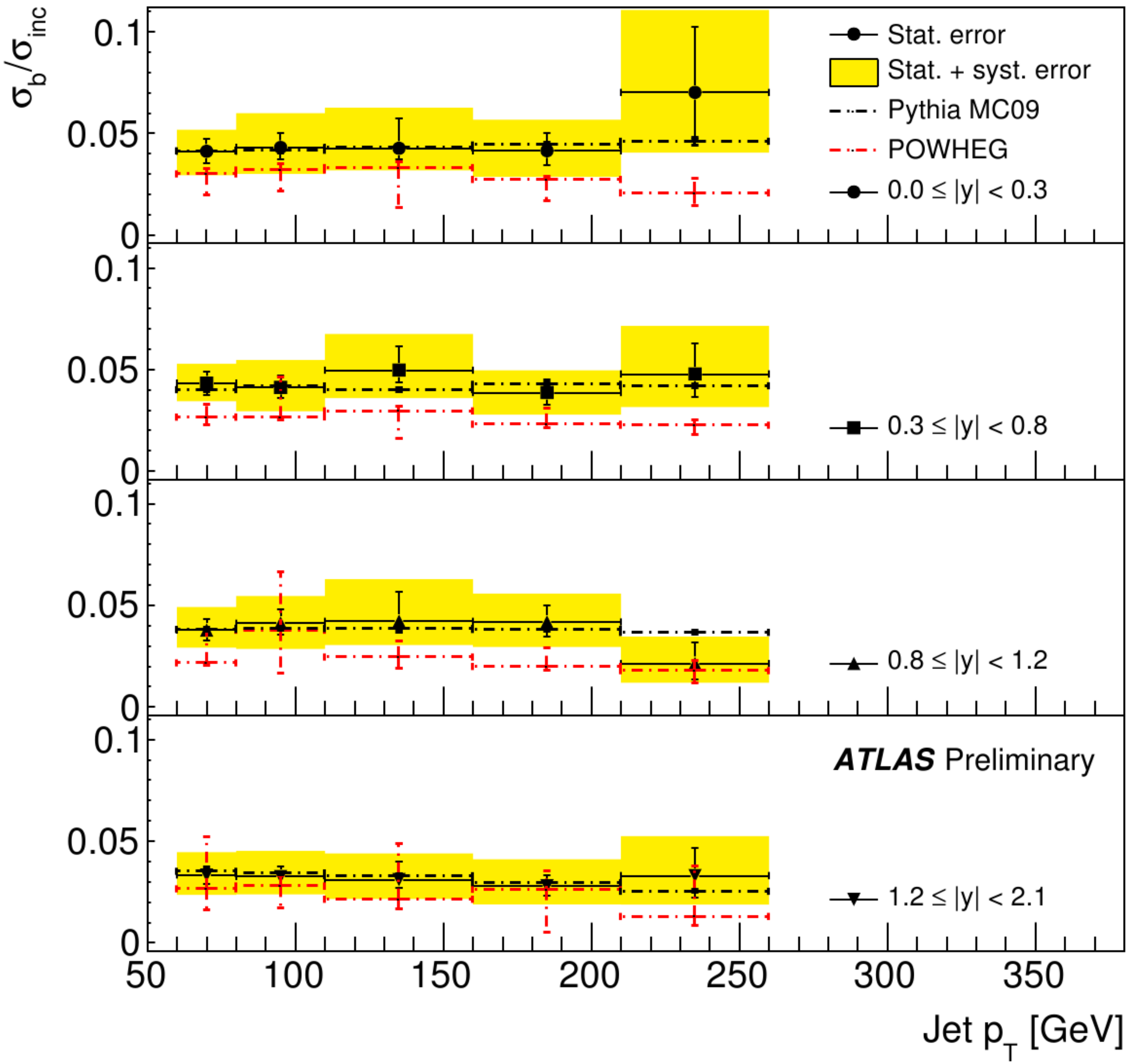
Inclusive $b\bar{b}$ - Dijet Cross Section



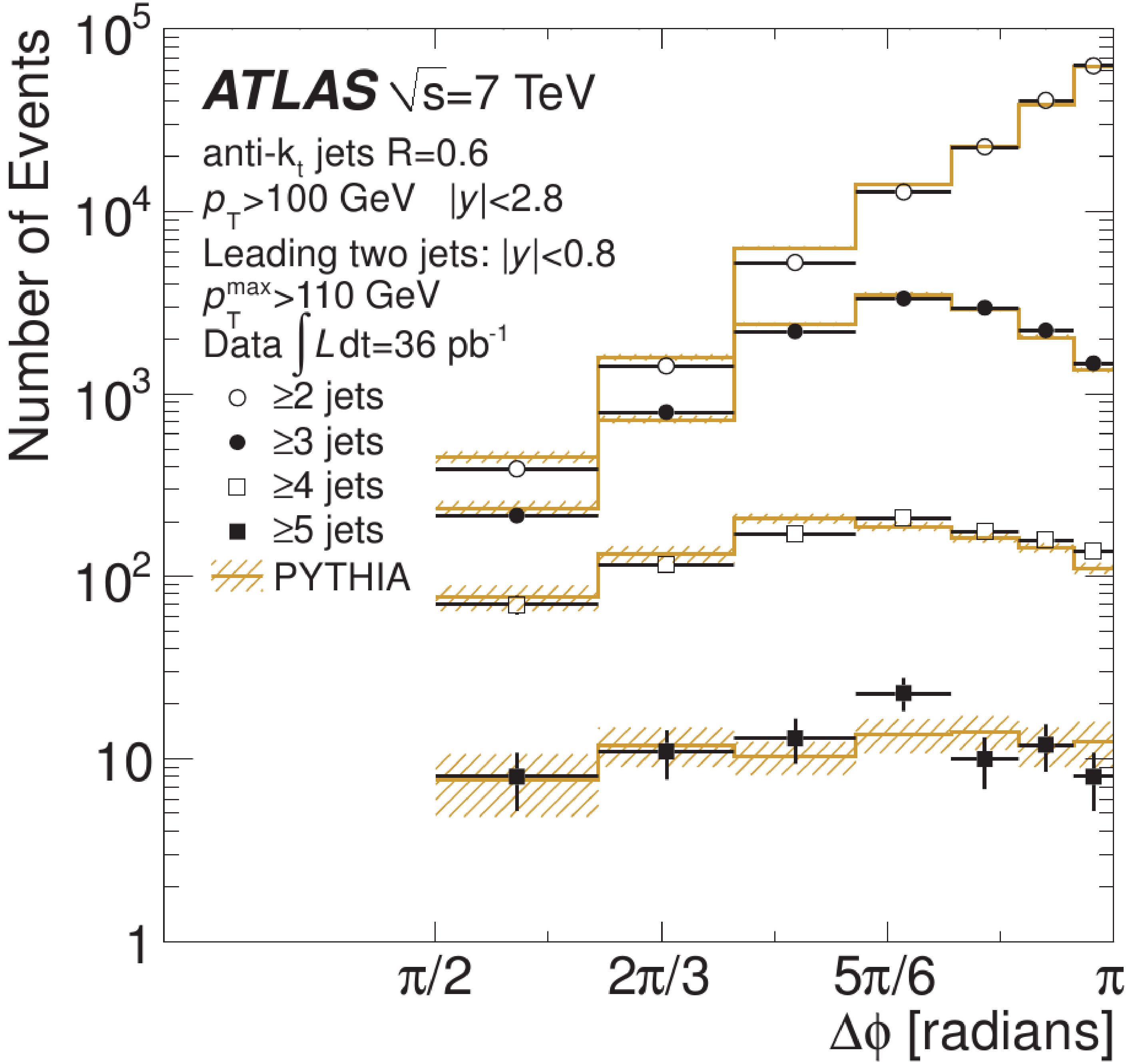
- POWHEG shows steeper drop
- Pythia shape is in good agreement (note: normalized to measurement)

Inclusive Jet Cross Sections of b-jets

Comparison with inclusive jet cross section(→ uncertainties partially cancel)

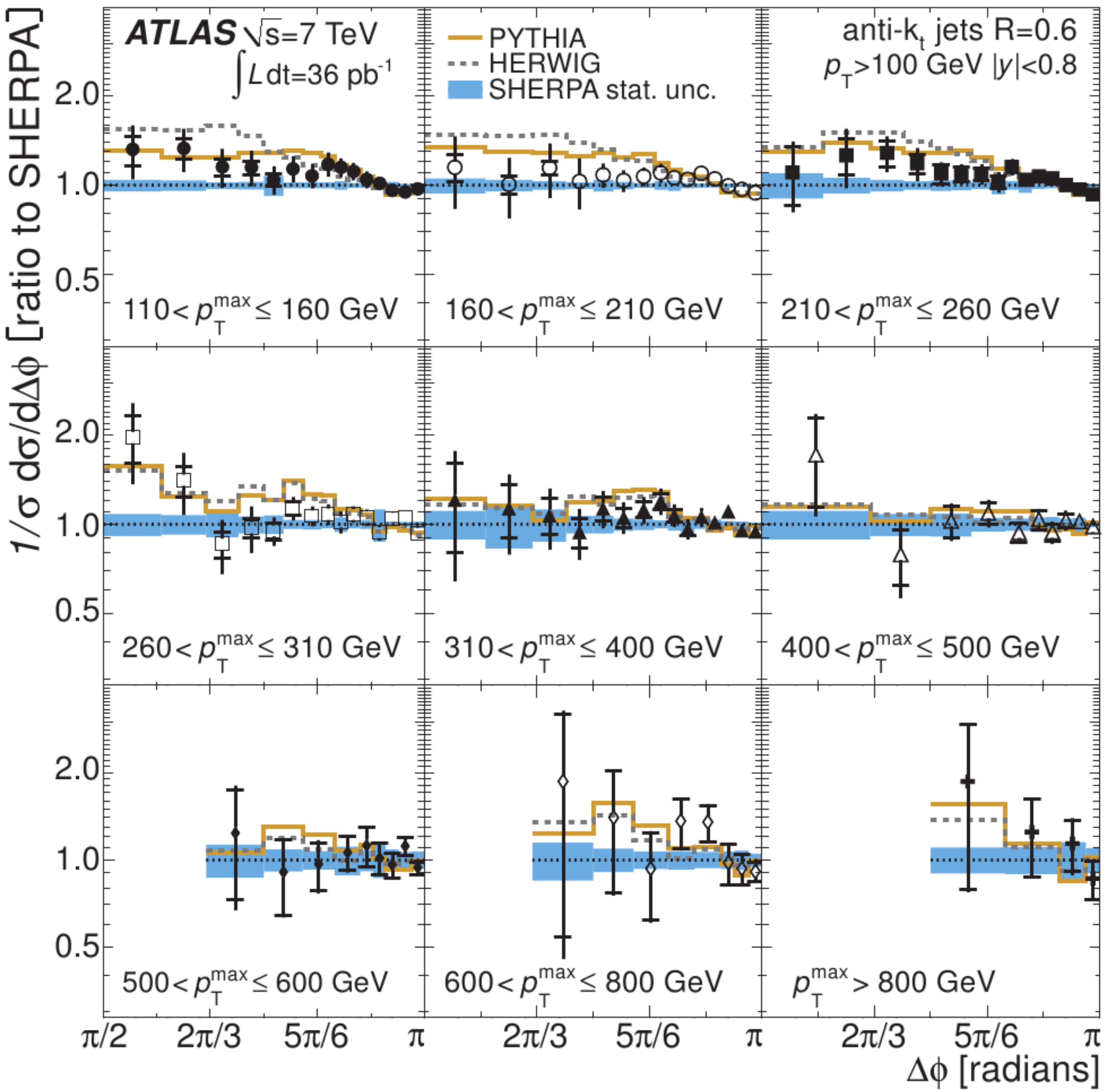


Measurement of Dijet Azimuthal Decorrelation



- Pythia with MRST 2007 LO* PDF and ATLAS MC09 UE
- Additional jets widen the distribution

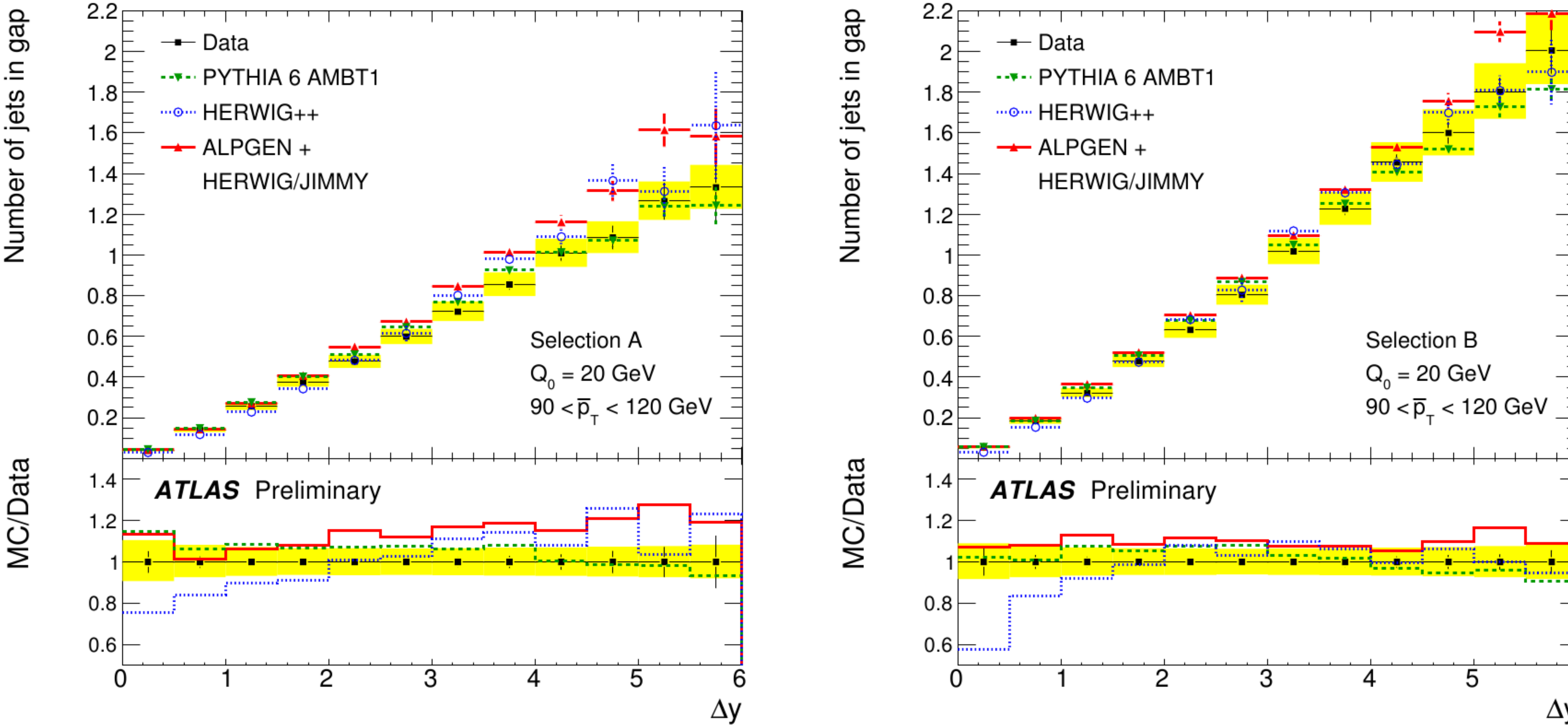
Measurement of Dijet Azimuthal Decorrelation



Comparison of parton shower models

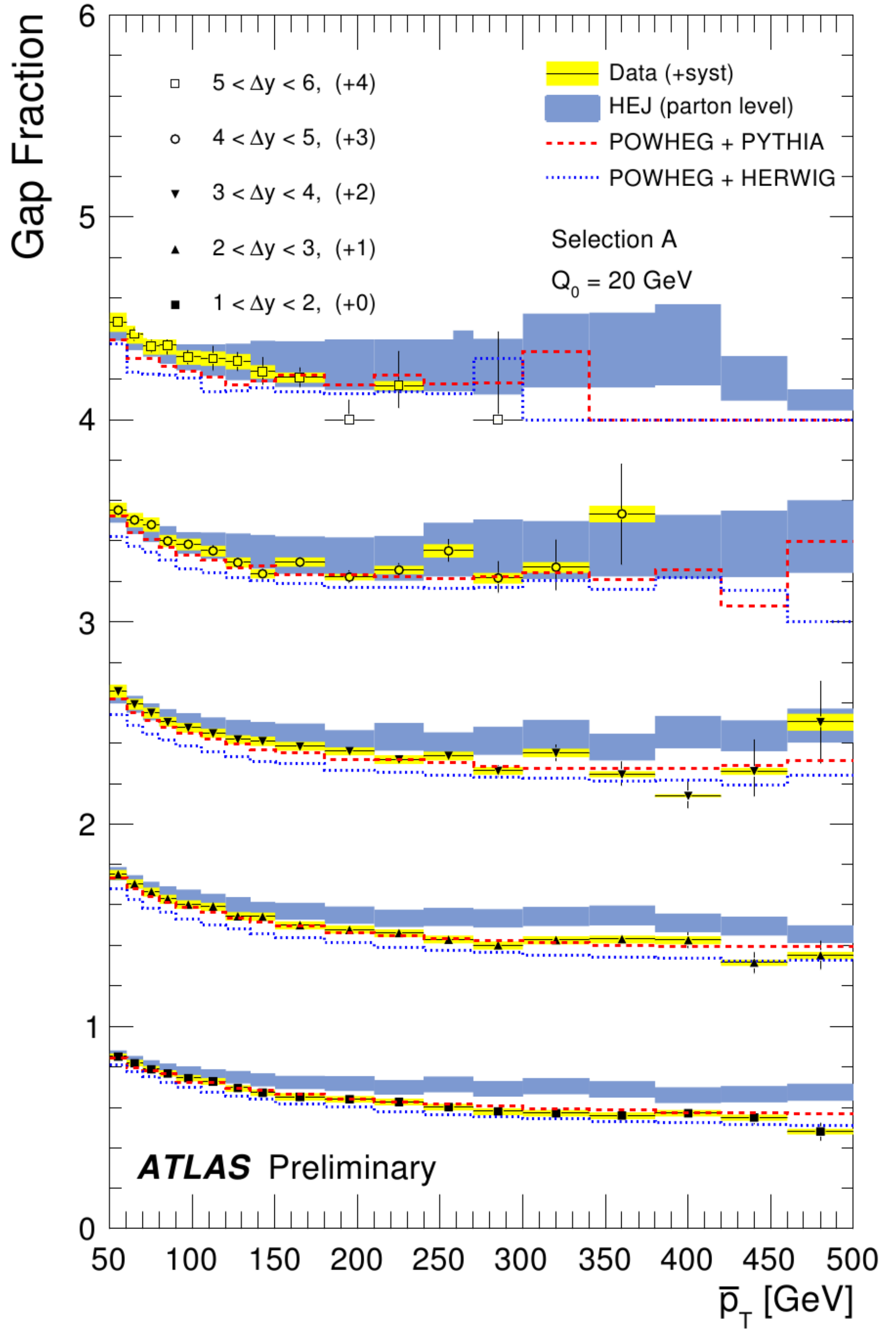
- Leading-log approx. regularize divergence at $\Delta\varphi \rightarrow \pi$
- SHERPA performs well in most p_T / y regions (higher order tree level diagrams)
- PYTHIA and HERWIG agree with data

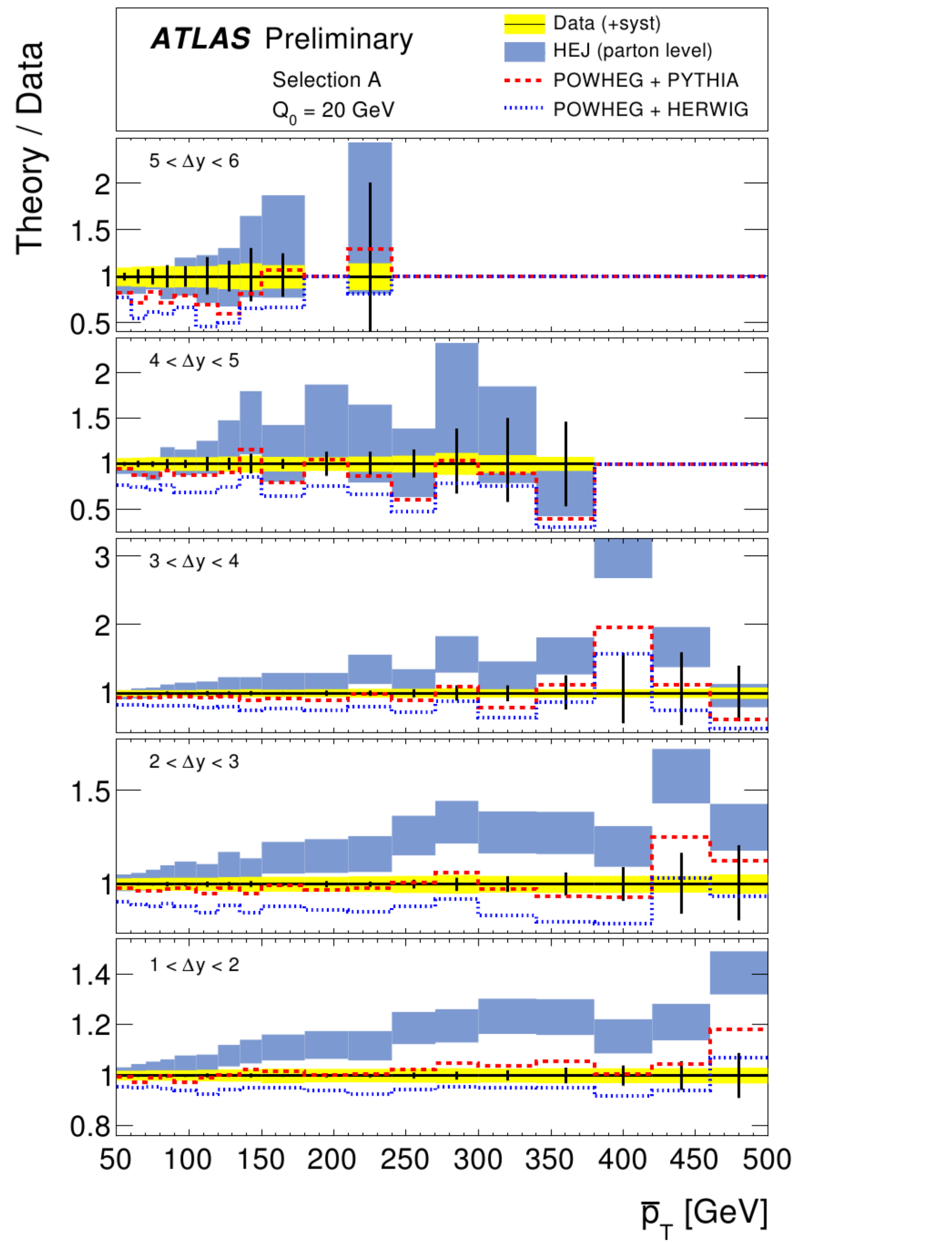
Measurement of Dijet Production with a Jet Veto



- Selection A: dijet system defined by jets with highest p_T
- Selection B: dijet system defined by jest with largest Δy

Measurement of Dijet Production with a Jet Veto





Measurement of Dijet Production with a Jet Veto