Inclusive Jet Production Measured with ATLAS and Constraints on PDFs

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on behalf of the ATLAS collaboration

DIS 2012

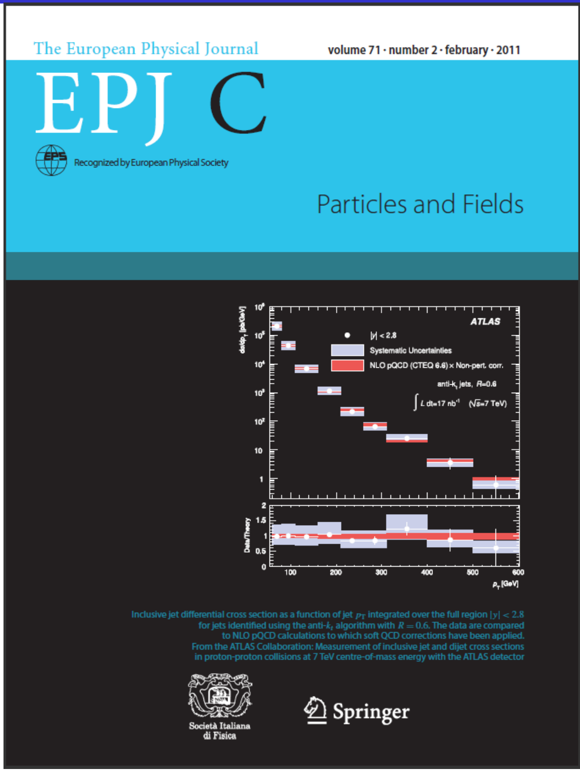
Introduction

- 17 nb^{-1} analysis

→inclusive jet and dijet production in *pp* collisions at $\sqrt{s}$=7 TeV

→ Cover of the February 2011 issue of EPJC

(EPJC 71.1512; arXiv:1009.5908)



- 37 pb^{-1} analysis

→inclusive jet and dijet production in *pp* collisions at $\sqrt{s}$=7 TeV

(arXiv:1112.6297; submitted to PRD)

- 4.7 fb^{-1} analysis

→high mass dijet production in *pp* collisions at $\sqrt{s}$=7 TeV

(ATLAS-CONF-2012-021)

Analysis of 2010 data

Final 2010 paper extends first publication in many ways:

- 2200 times more integrated lumi:

  17 nb^{-1} → 37 pb^{-1}

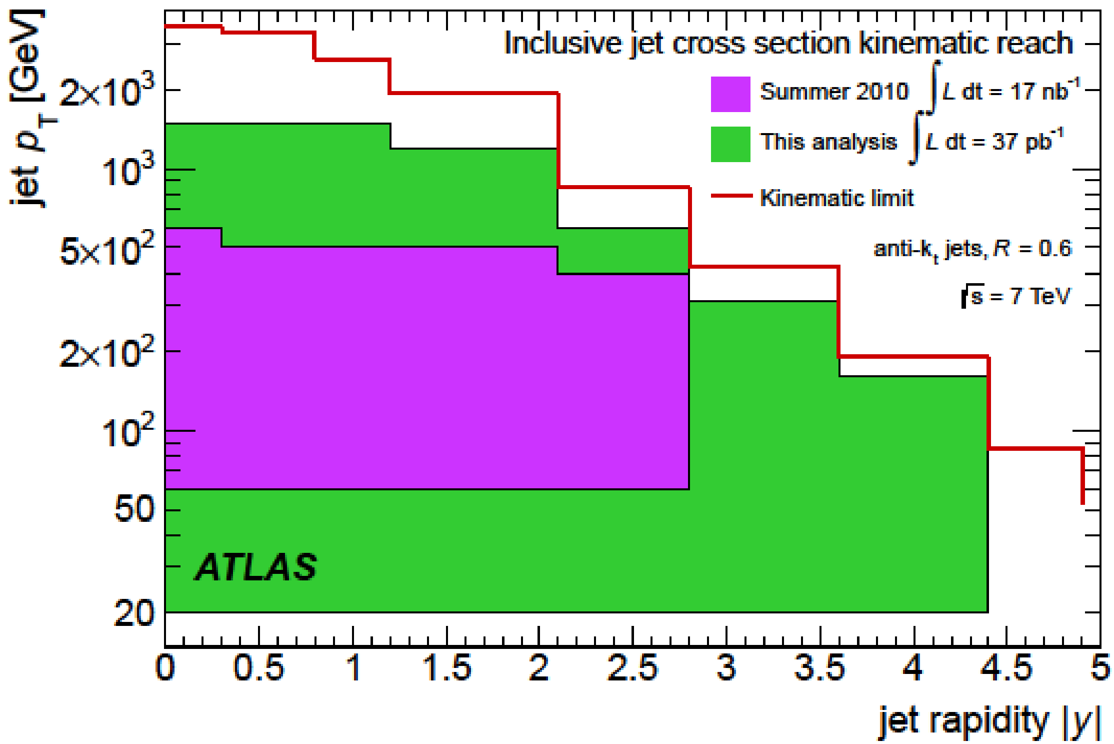
- Max jet p_T: **600 GeV → 1.5 TeV**

- Extension to low p_T:

  60 GeV → 20 GeV

- Max dijet mass:
  m_{12}: **1.8 TeV → 4.8 TeV;**

  p_{T1} > 30 GeV, p_{T2} > 20 GeV



- Forward rapidity:

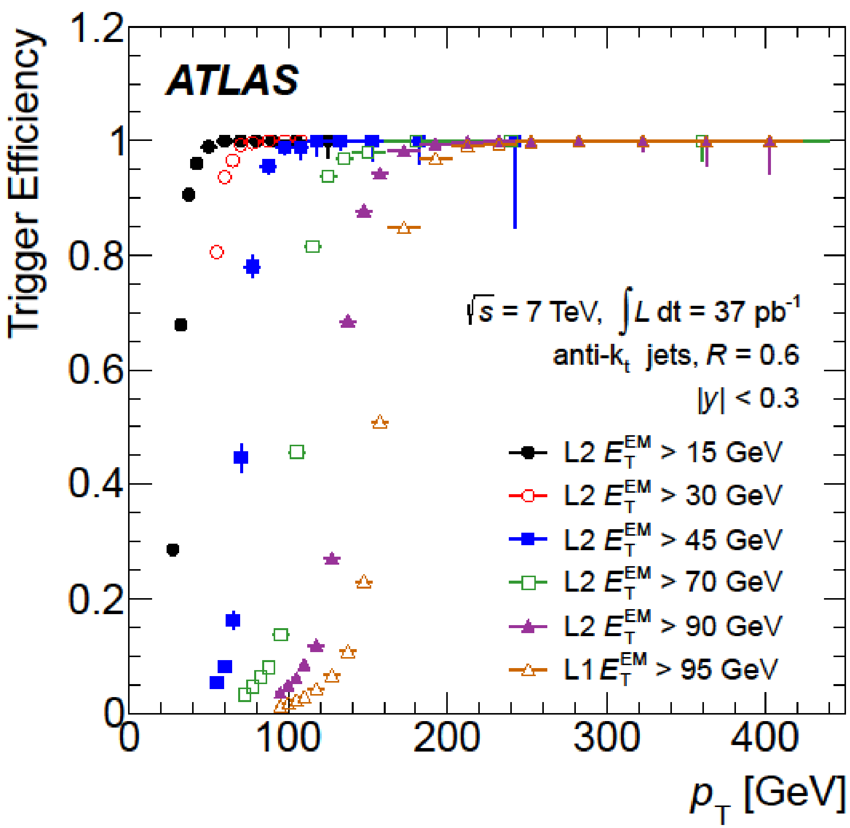
  |y| < 2.8 → |y| < 4.4; (binning follows calorimeter geometry)

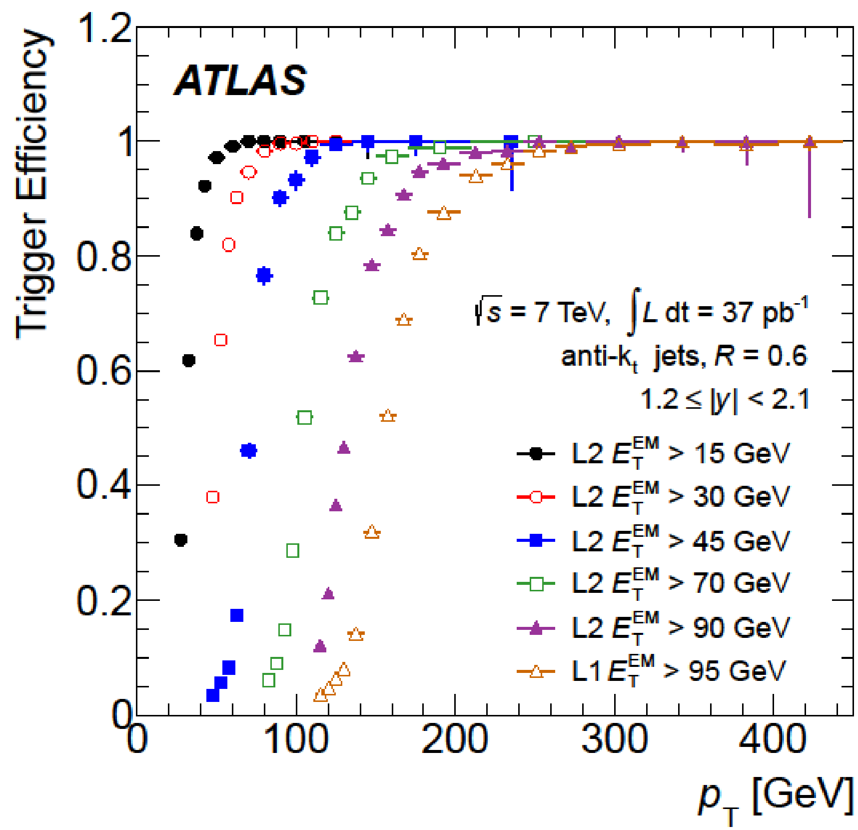
- Dijet y* = $|y_1 - y_2| / 2 < 4.4$; (replaces y_{max} used in the previous publication)

- **Large new kinematic regime & coherent treatment of inclusive jets and dijet measurements**

Inclusive jet and dijet trigger efficiencies

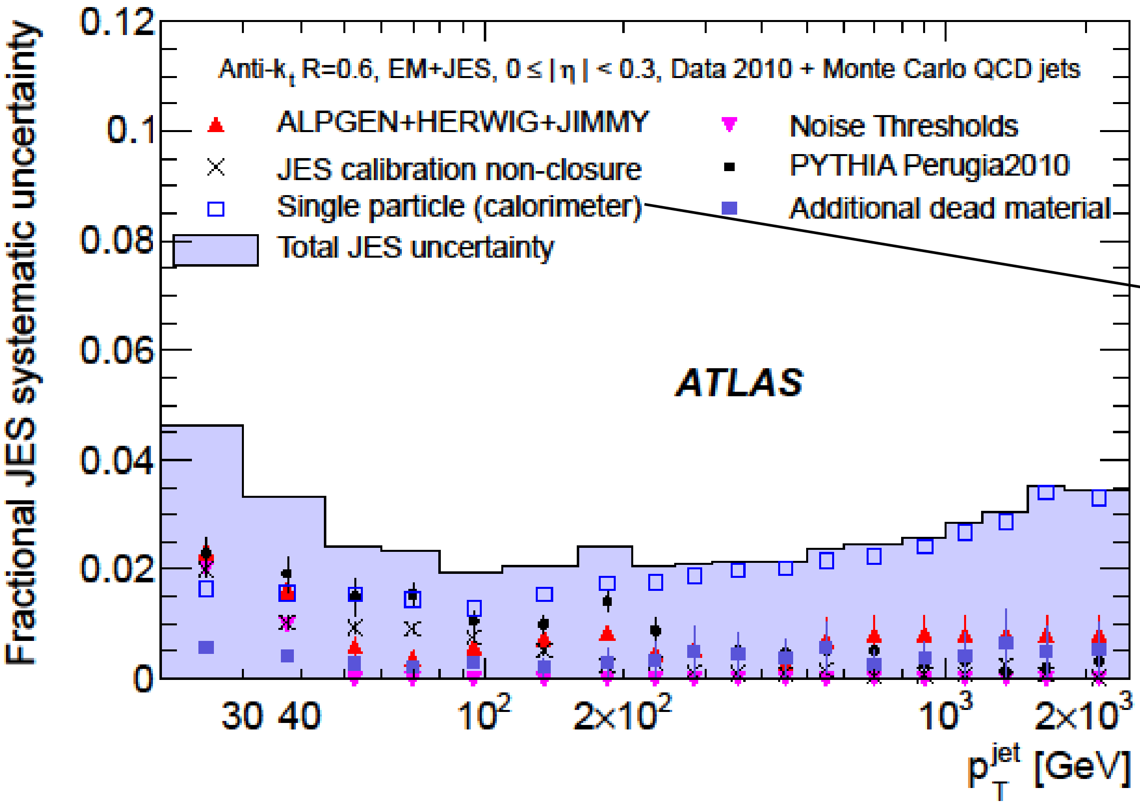
- "Inclusive jet" ("per-jet" for dijets) trigger efficiencies determined in-situ using orthogonal and bootstrap methods – probability for *any* (*each* for dijets) jet to fire the trigger
- Each trigger used in the region where it is fully efficient





Jet Calibration and Uncertainty

- Calibration: pile-up correction; origin correction; final energy and η correction
- Improved JES uncertainty: less than 2.5% in central region for 60-800 GeV jets!
- Calorimeter component dominant in central region (from test beam and single particle response)
- η intercalibration component due to MC modeling uncertainty, dominant in forward region



Calorimeter JES uncertainty component split into several sources:
- 100% correlated between bins
- uncorrelated between each other

→ important for fits

Data correction to particle level

- Measurement corrected back to particle level using a matrix-based unfolding method

  → transfer matrix relating the particle level & reconstructed observable (MC): matching needed

  → 3 steps procedure: 1) matching (in)efficiency correction at reconstructed level;

  2) IDS / SVD / bin-by-bin unfolding for jets with matching;

  3) matching (in)efficiency correction at particle level.

  → In-situ determination of the shape uncertainty:

  - reweight MC by smooth function: improved data/recoMC agreement;
  - unfold the reweighted reconstructed MC
  - compare with reweighted particle level MC.

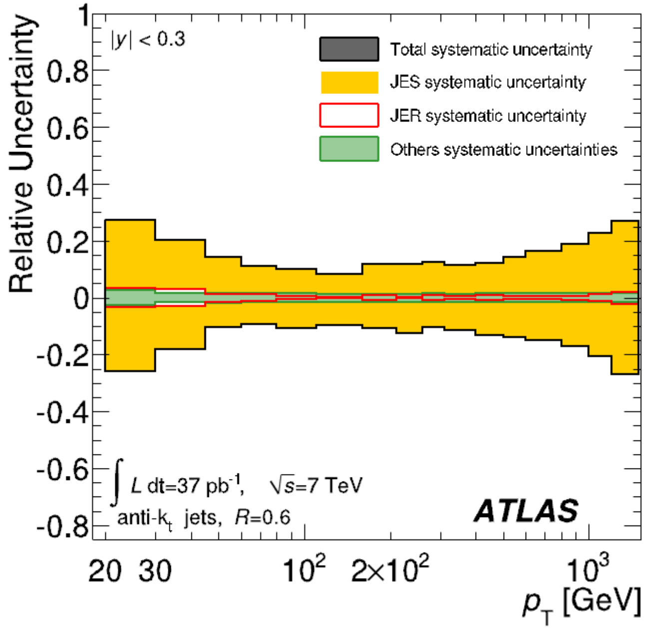
  →Measurement unfolded using IDS: smallest bias in the closure test

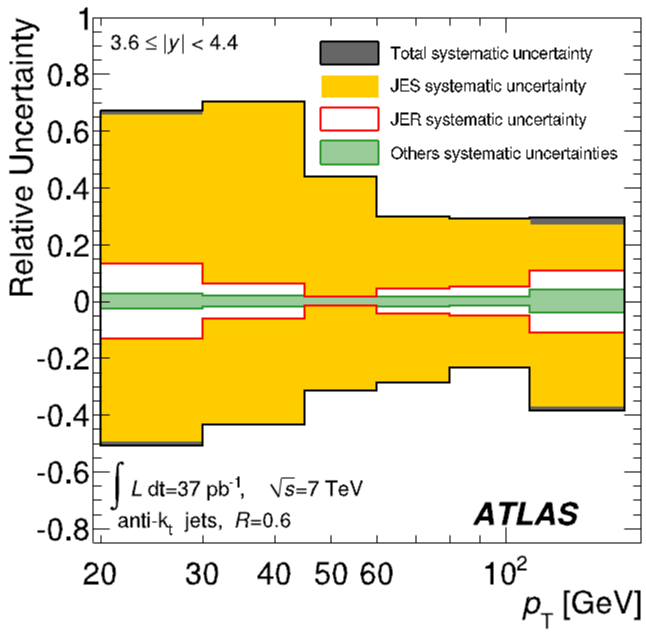
- Full uncertainty propagation: statistical uncertainty (data+MC) using pseudo-experiments (covariance matrix obtained); systematic uncertainties using nuisance parameters

  → asymmetric uncertainties taken into account

Systematic uncertainties

- Largest systematic uncertainty from JES
- Luminosity uncertainty now 3%



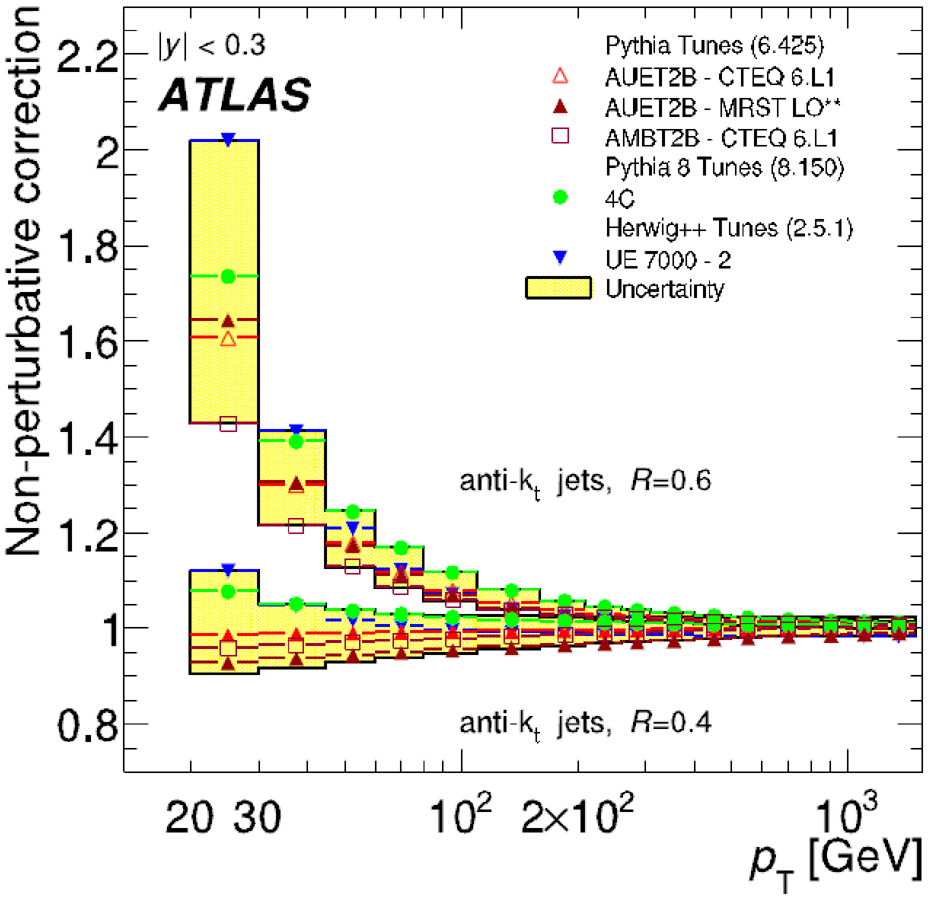


	$\|y\|$-bins						
Uncertainty Source	0-0.3	0.3-0.8	0.8-1.2	1.2-2.1	2.1-2.8	2.8-3.6	3.6-4.4
Noise thresholds	1	1	2	3	4	5	6
PYTHIA Perugia2010	7	7	8	9	10	11	12
ALPGEN+HERWIG+JIMMY	13	13	14	15	16	17	18
JES calibration non closure	19	19	20	21	22	23	24
Additional dead material	25	25	26	27	28	29	30
Intercalibration	31	31	31	31	31	31	31
Calorimeter: E/p	32	32	33	34	35	36	37
Calorimeter: Cluster thresholds	38	38	39	40	41	42	43
Calorimeter: LAr E-scale	44	44	45	46	47	48	49
Calorimeter: Tile E-scale	50	50	51	52	53	54	55
Calorimeter: CTB High p_T	56	56	57	58	59	60	61
Calorimeter: E/p bias	62	62	63	64	65	66	67
Calorimeter: CTB bias	68	68	69	70	71	72	73
Unfolding: closure test	74	74	74	74	74	74	74
Unfolding: truth matching	75	75	75	75	75	75	75
Jet energy resolution	76	76	77	78	79	80	81
Angular resolution	82	82	82	82	82	82	82
Trigger modelling	uncorr	uncorr	uncorr	uncorr	uncorr	uncorr	uncorr
Jet cleaning	uncorr	uncorr	uncorr	uncorr	uncorr	uncorr	uncorr
Jet reconstruction efficiency	83	83	83	83	84	85	86
Pile-up	uncorr	uncorr	uncorr	uncorr	uncorr	uncorr	uncorr
Luminosity	87	87	87	87	87	87	87

Theoretical uncertainties

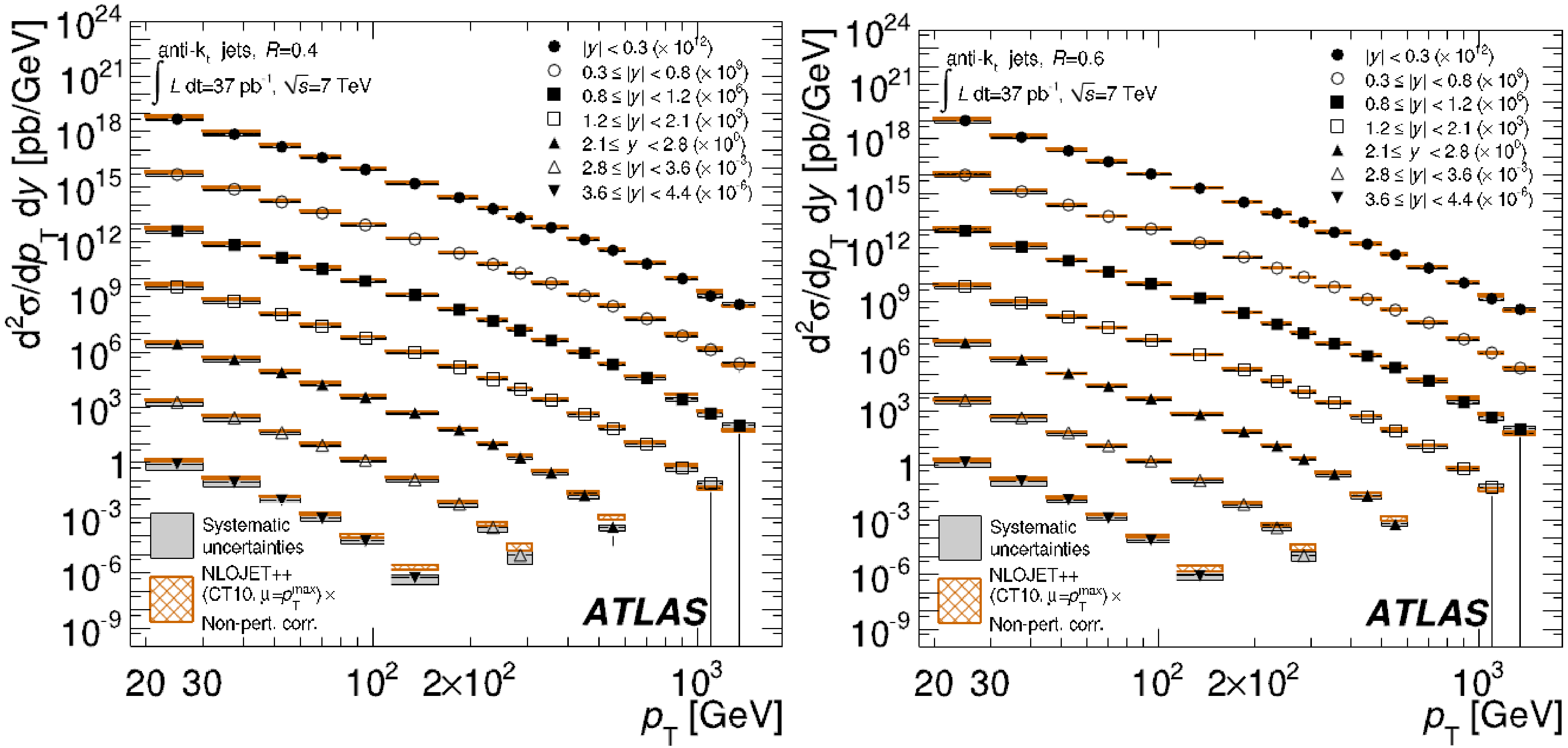
- QCD predictions from NLOJET++
- Uncertainties from renormalization & factorization scales, α_S and PDFs via APPLGRID
- Non-perturbative correction applied (bin-by-bin) to parton level NLO cross sections: account for hadronization and UE
  - Derived using Pythia MC10 (AMBT1)
  - Uncertainties envelope of deviations from Pythia tunes (Perugia 0, Perugia 2010, Perugia X) + different MC generators (Herwig++)

→Additional comparisons to Powheg (NLO ME + PS)



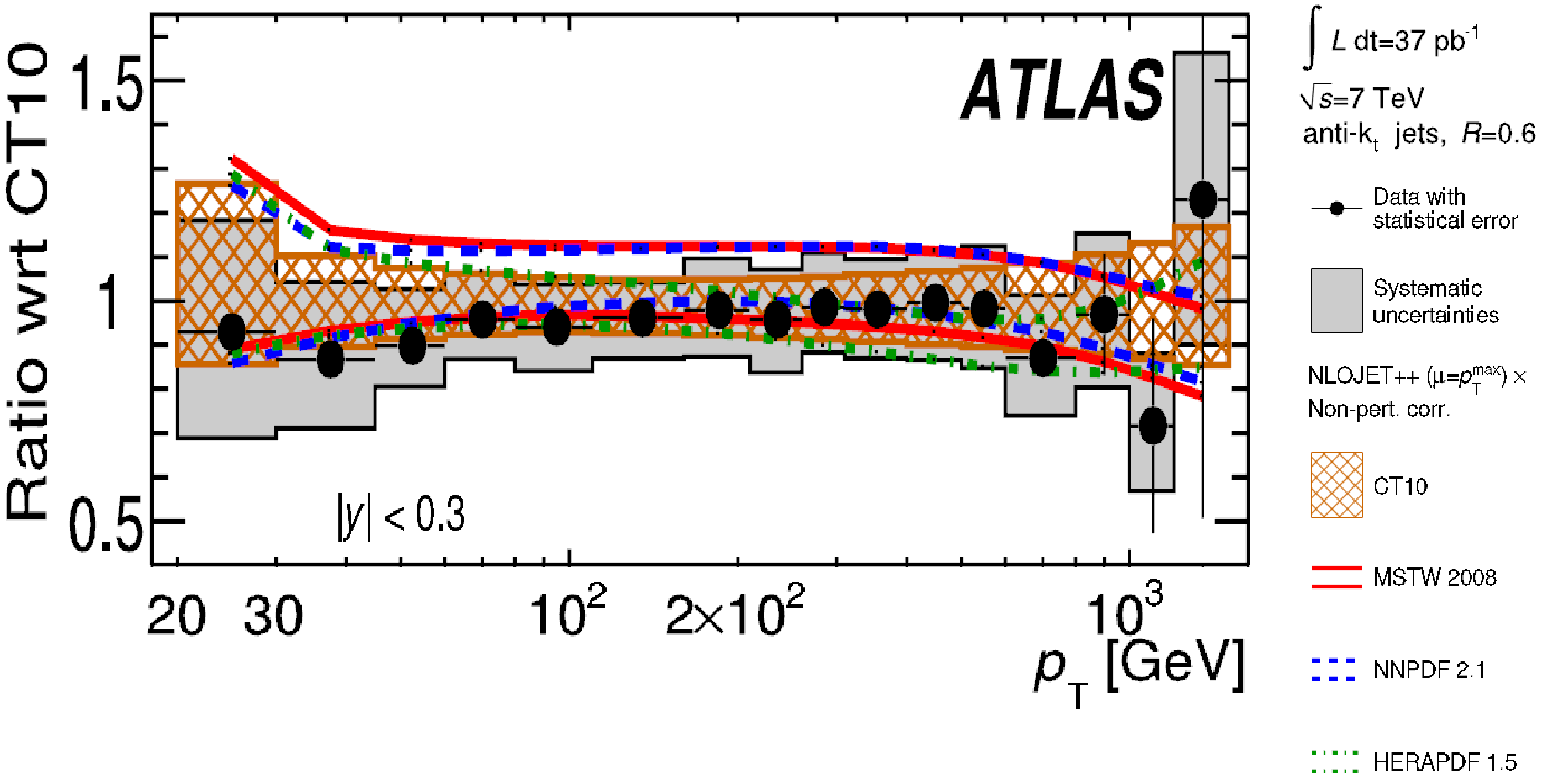
2010 Inclusive jet cross section

- Inclusive jet pT cross-section compared to NLO pQCD + non-pert. corrections
- Measured for R=0.4 and R=0.6



PDF comparisons for R=0.6

- Comparisons to CT10, MSTW2008, NNPDF2.1, and HERAPDF1.5 (following PDF4LHC recommendations)



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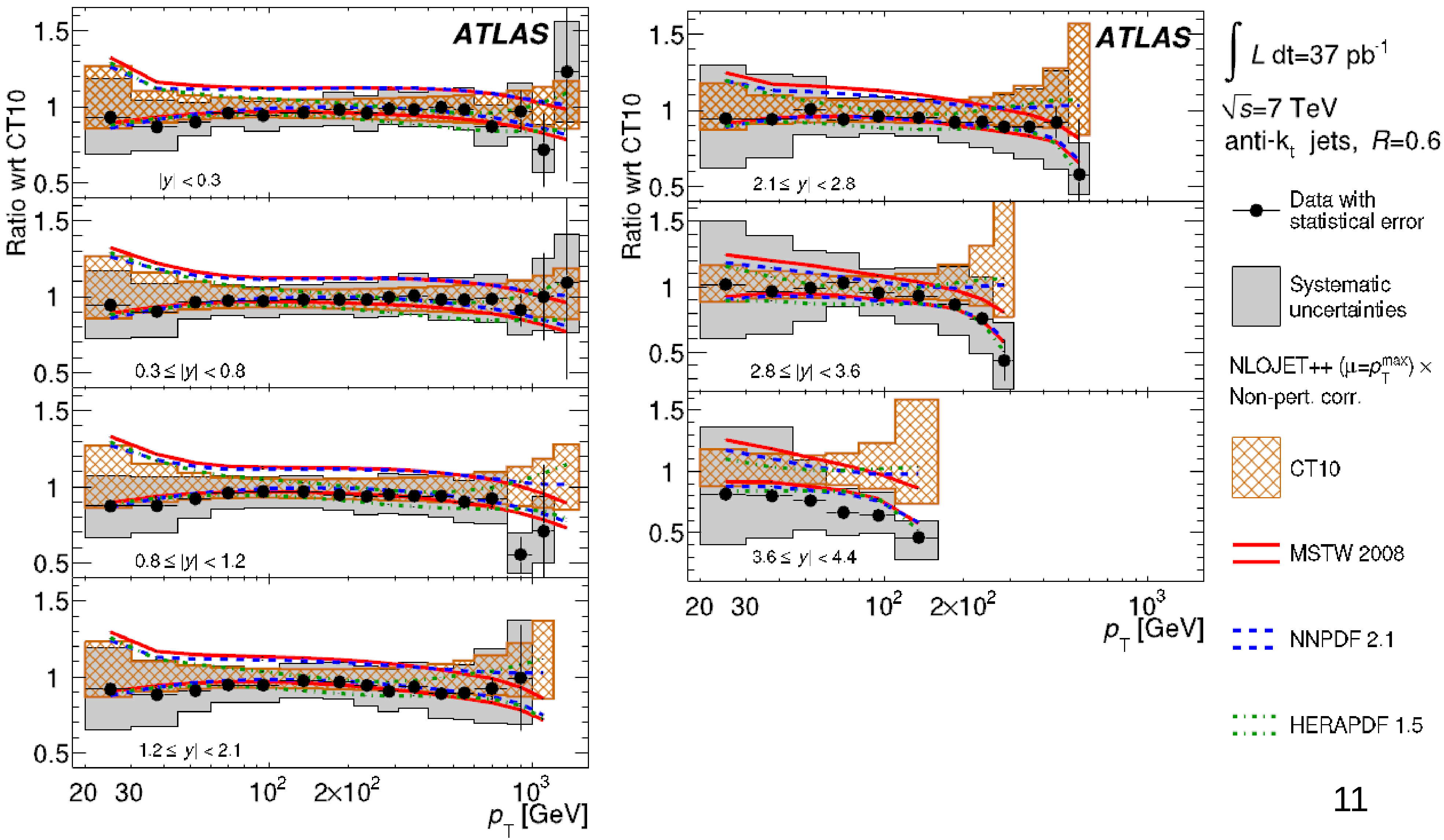
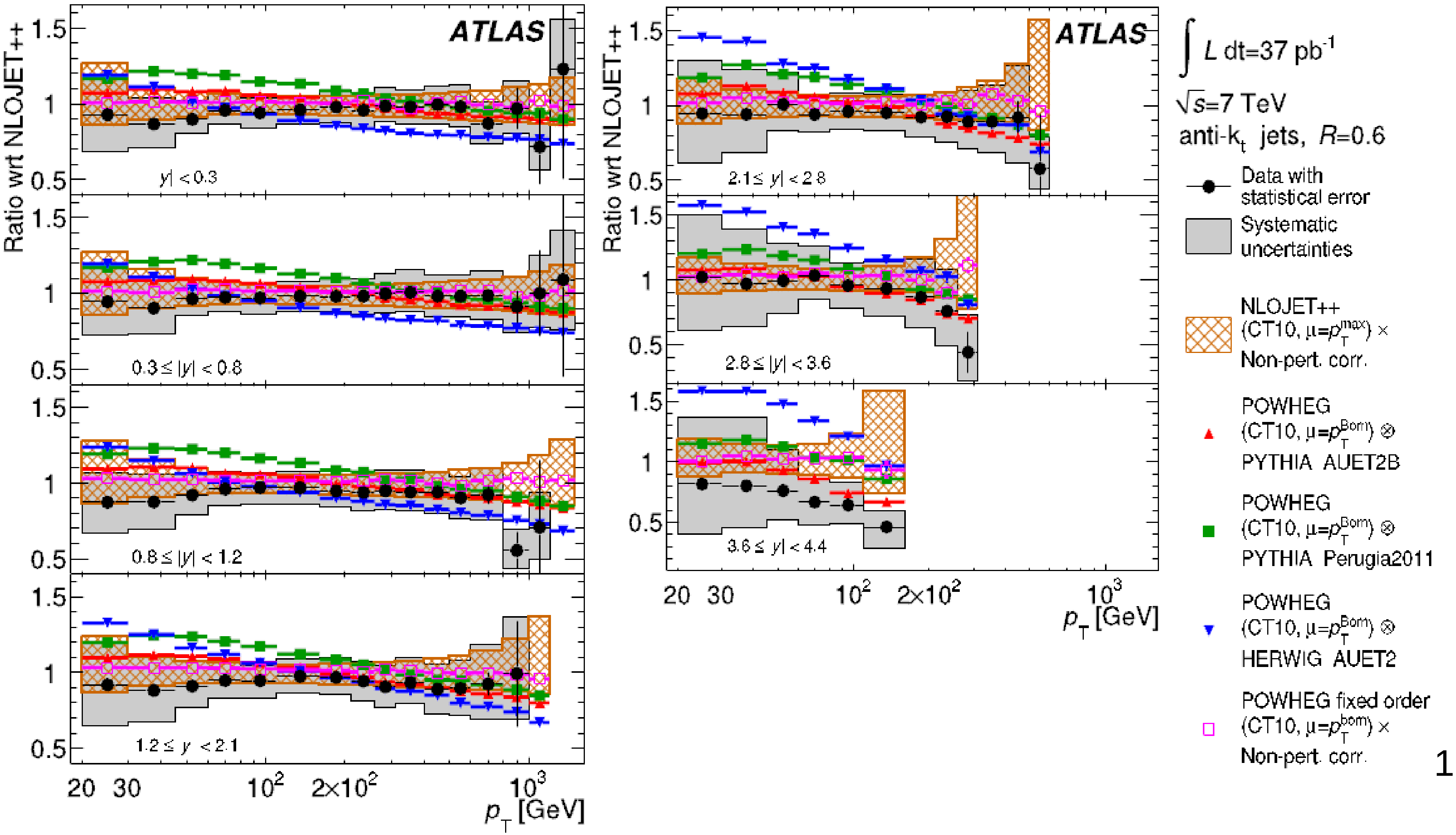


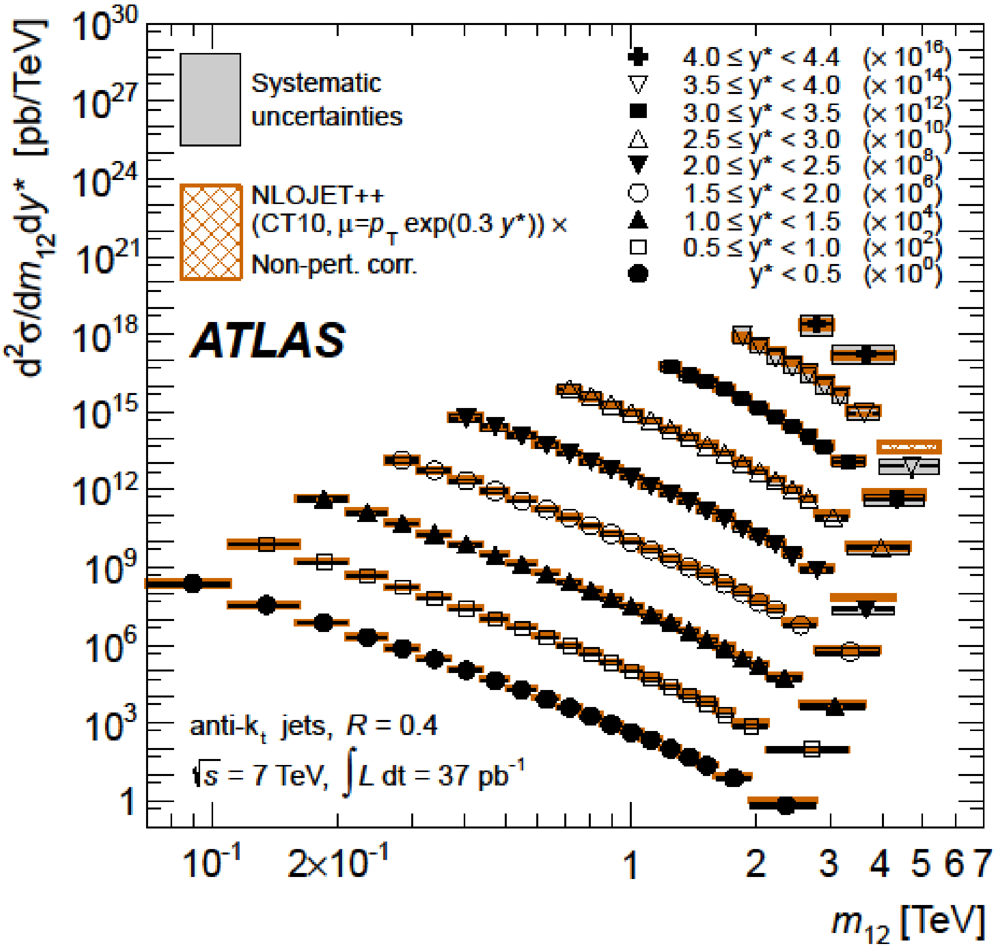
POWHEG comparisons for R=0.6

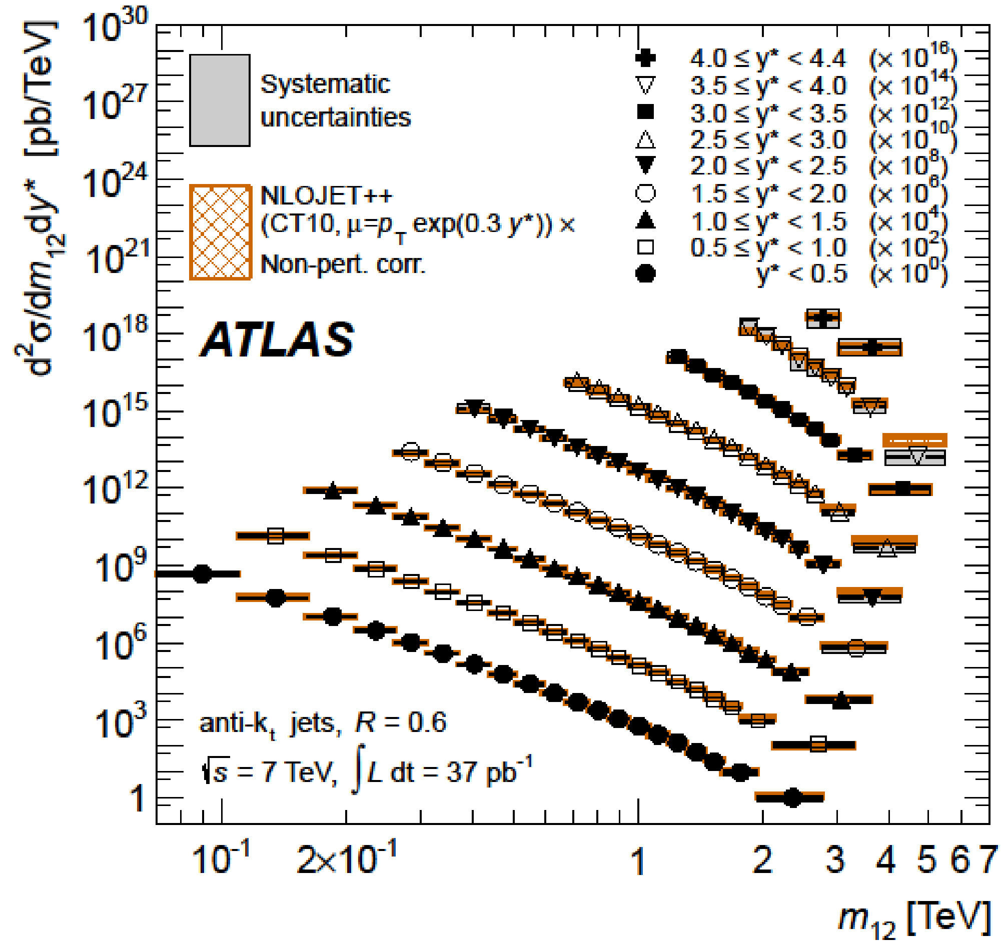
- Comparisons to POWHEG BOX (NLO matrix element + parton shower)
  - First ever comparisons for inclusive jet / dijet production
  - Important differences between HERWIG and PYTHIA



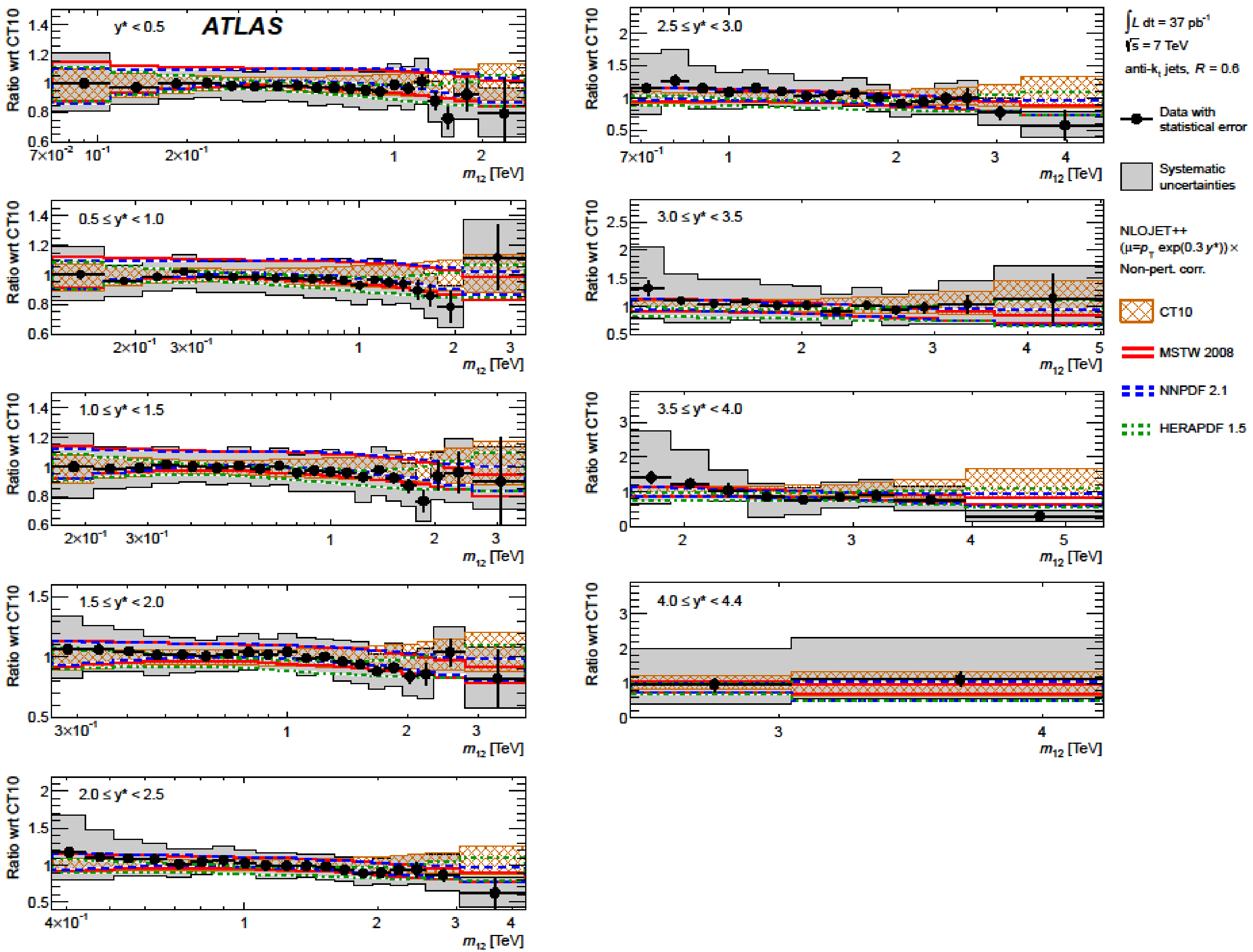
2010 Dijet mass spectrum

- Dijet mass cross-section compared to NLO pQCD + non-pert. corrections
- Measured for R=0.4 and R=0.6



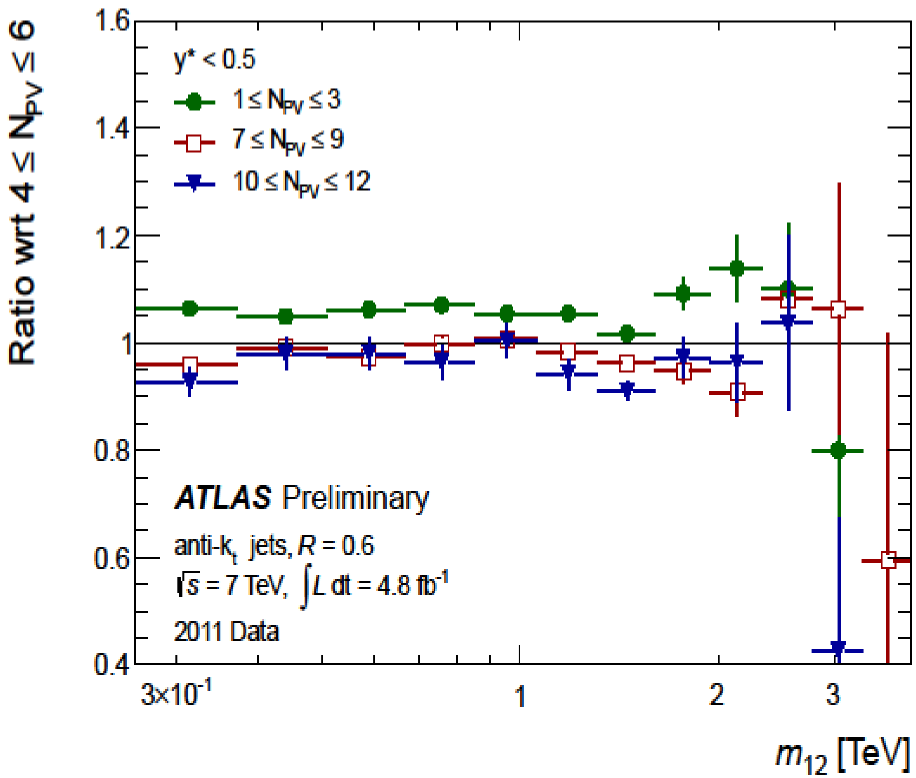


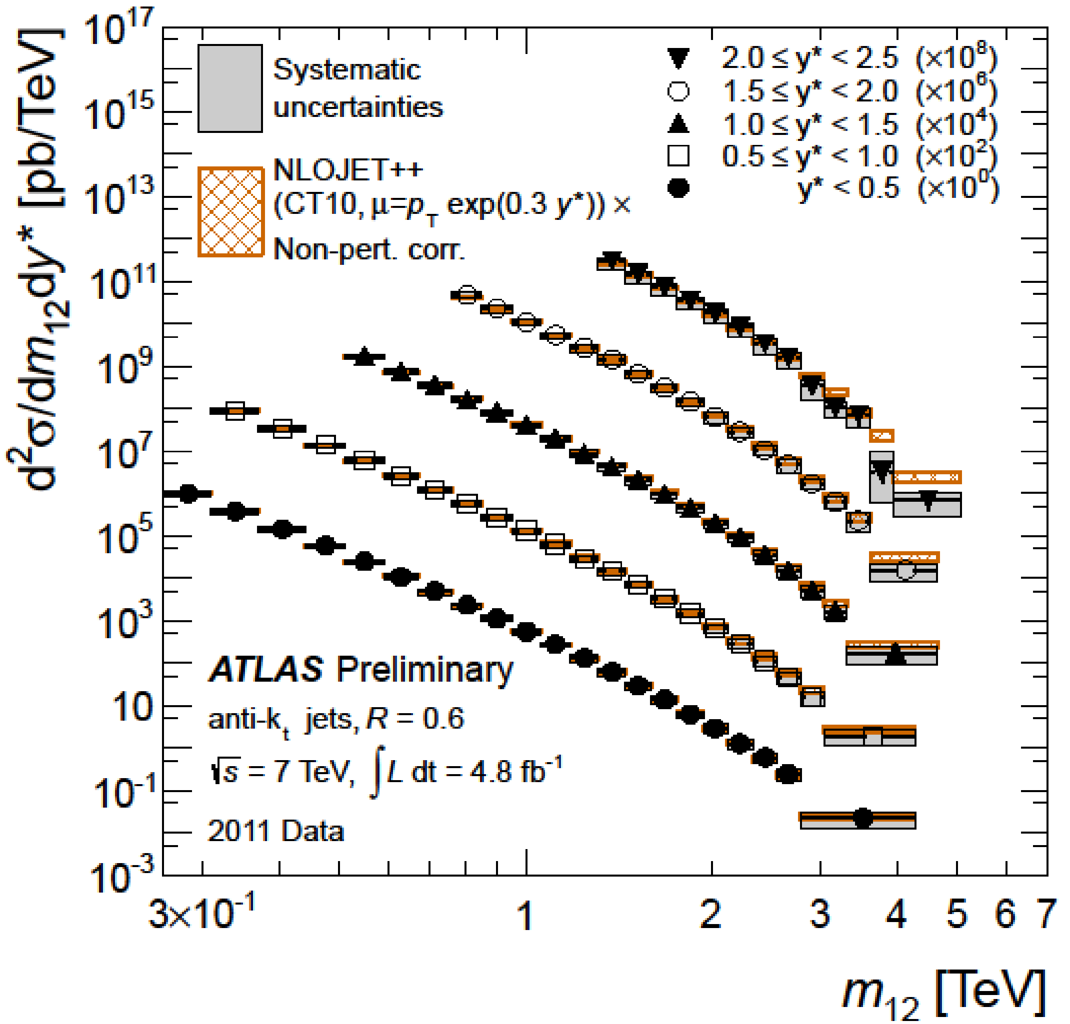
PDF comparisons – dijet; R=0.6



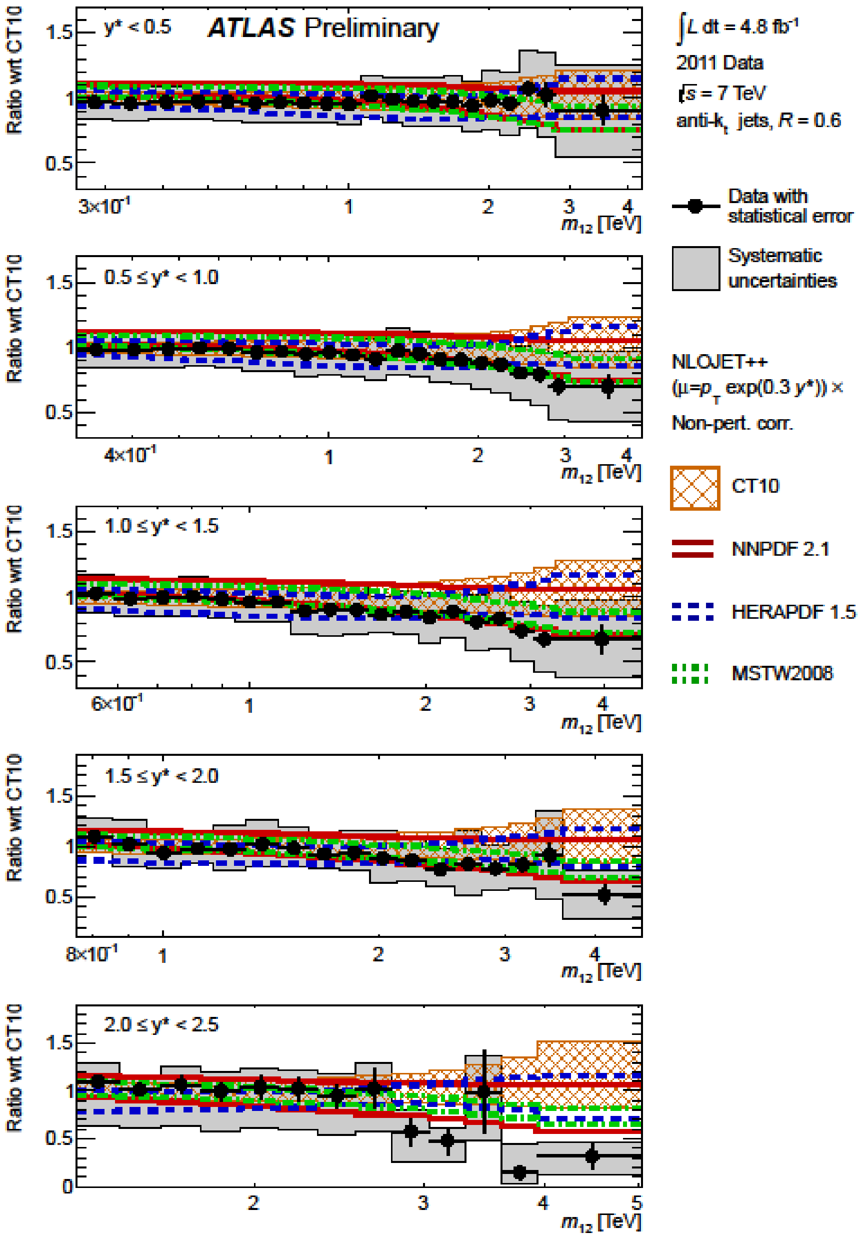
2011 Dijet mass spectrum

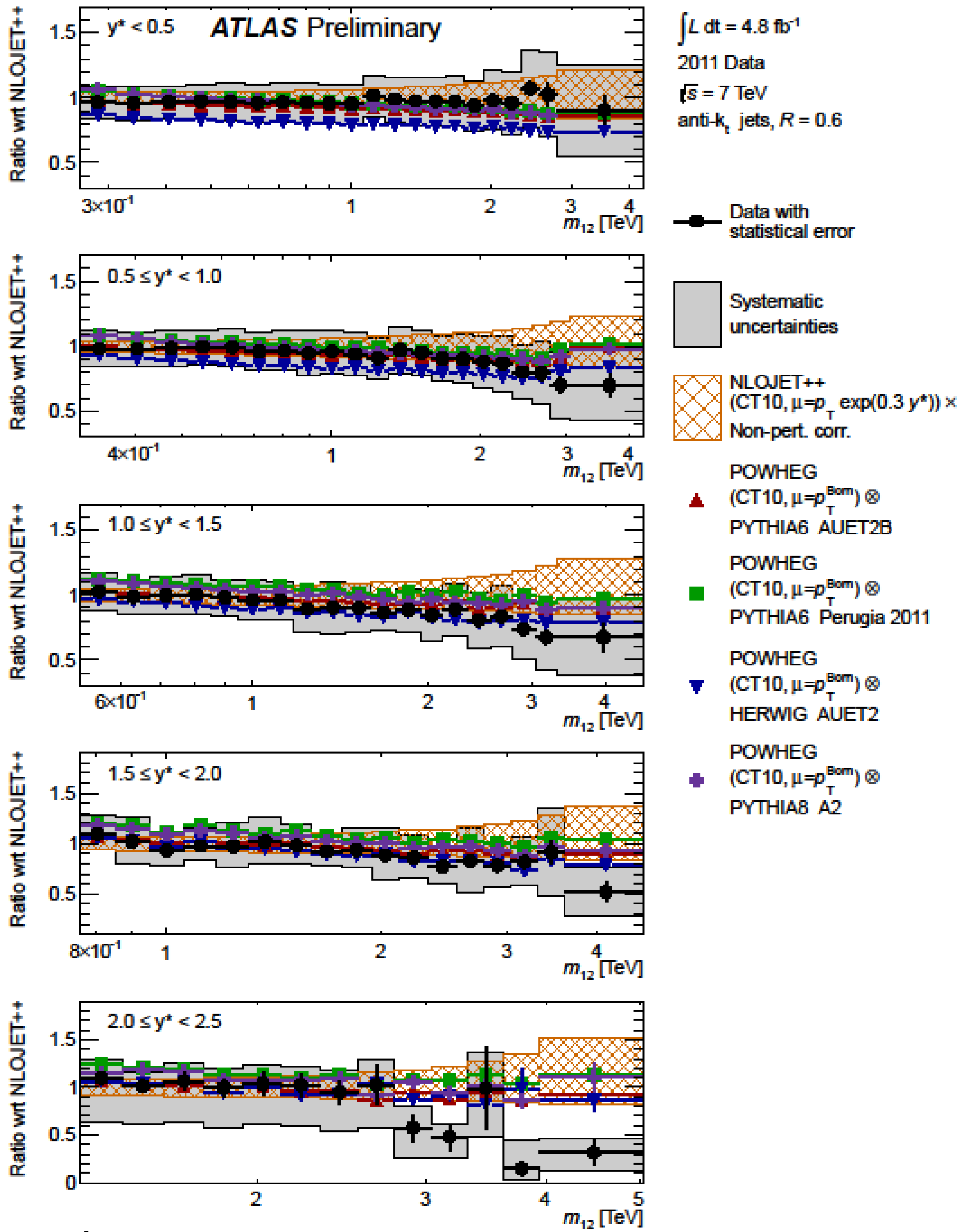
- Trigger prescales and pile-up treatment take into account variations in data-taking conditions





PDF&POWHEG comparisons – dijet; R=0.6





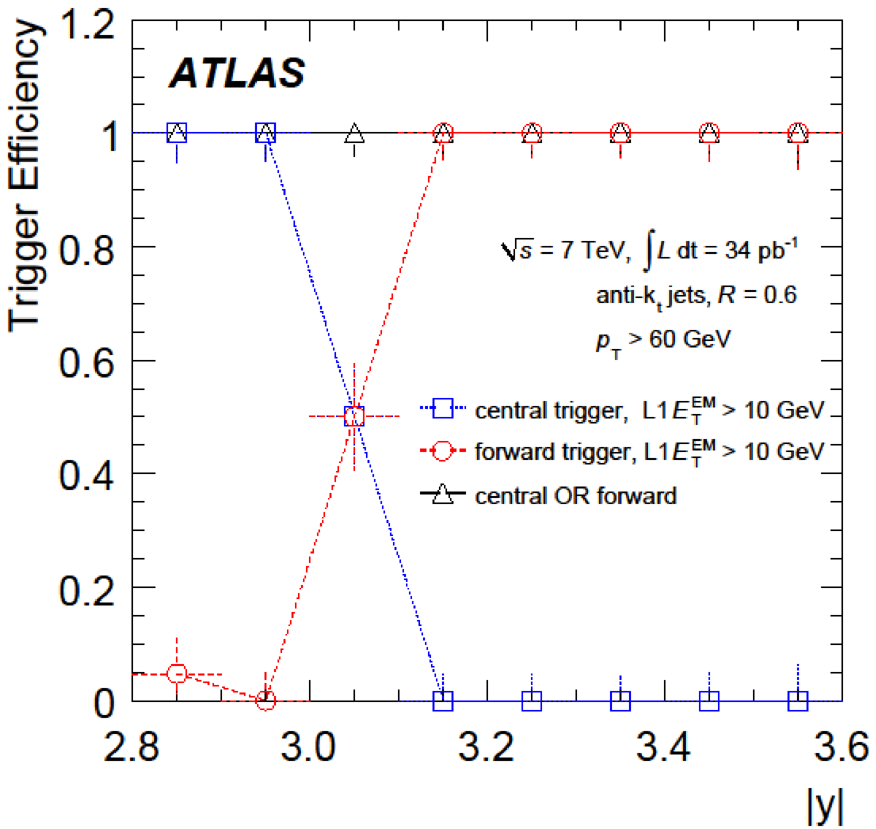
Conclusions

- Measurements of inclusive jet p_T and dijet mass cross sections performed using full 2010 ATLAS dataset of 37 pb^{-1}
- Measurement of the dijet cross section also performed for the full 2011 dataset (4.7 fb^{-1})
- Major extensions to previous EPJC publication: low & high p_T/dijet mass, forward rapidity
- Measured cross sections corrected for all detector effects
- Full propagation of (asymmetric) uncertainties and correlations
- Comparisons to predictions from NLO pQCD and NLO+parton shower (POWHEG)
  - QCD agrees well with the data across a large kinematic range in jet pT, dijet mass, and rapidity
  - Will help to constrain various PDF sets
- One of the most comprehensive tests of QCD ever made

BACKUP

Trigger in transition region

- Central jet trigger covers |eta|<3.2, Forward jet trigger |eta|>3.1
- Neither central nor forward jet triggers fully efficient individually for HEC-FCal transition
  - OR of central and forward triggers are fully efficient



Luminosity classes

- Central and forward triggers prescaled independently
- For inclusive jets, subdivide into three classes of events:

  01: triggered by central, but not forward

  10: triggered by forward, but not central

  11: triggered by both
- For dijets, first identify whether each of two leading jets fires central or forward trigger using angular matching to trigger objects
  - Then categorize into classes of events in analogy with above
- Count jets and calculate int. lumi for each class:
- Method validated using closure tests in MC

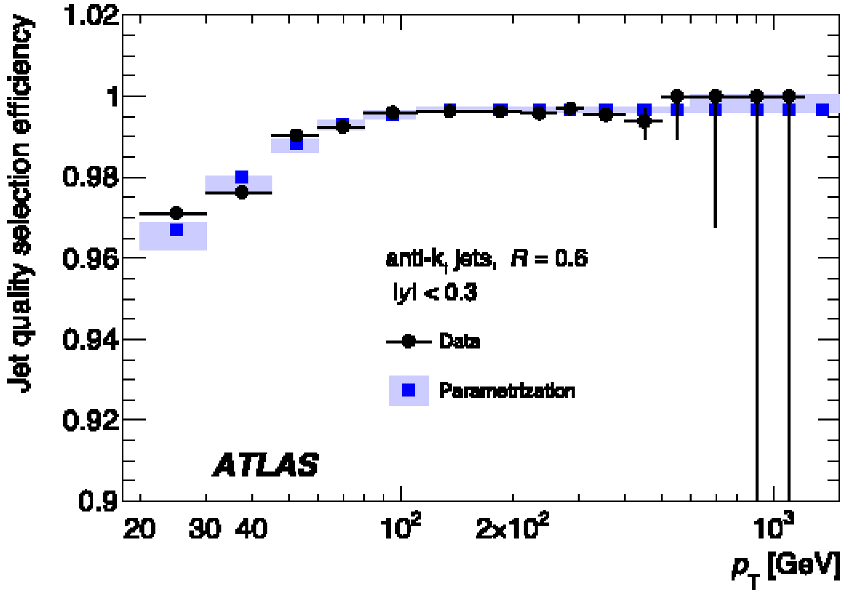
$$\mathcal{L}_{\mathrm{J}} = \Sigma_{\mathrm{LB}} \frac{\mathcal{L}_{\mathrm{LB}}}{P^{\mathrm{J}}_{\mathrm{LB}}}$$

$$\mathcal{L}_{\mathrm{FJ}} = \Sigma_{\mathrm{LB}} \frac{\mathcal{L}_{\mathrm{LB}}}{P^{\mathrm{FJ}}_{\mathrm{LB}}}$$

$$\mathcal{L}_{\mathrm{JFJ}} = \Sigma_{\mathrm{LB}} \frac{\mathcal{L}_{\mathrm{LB}}}{P^{\mathrm{J}}_{\mathrm{LB}} P^{\mathrm{FJ}}_{\mathrm{LB}} / (P^{\mathrm{J}}_{\mathrm{LB}} + P^{\mathrm{FJ}}_{\mathrm{LB}} - 1)}$$

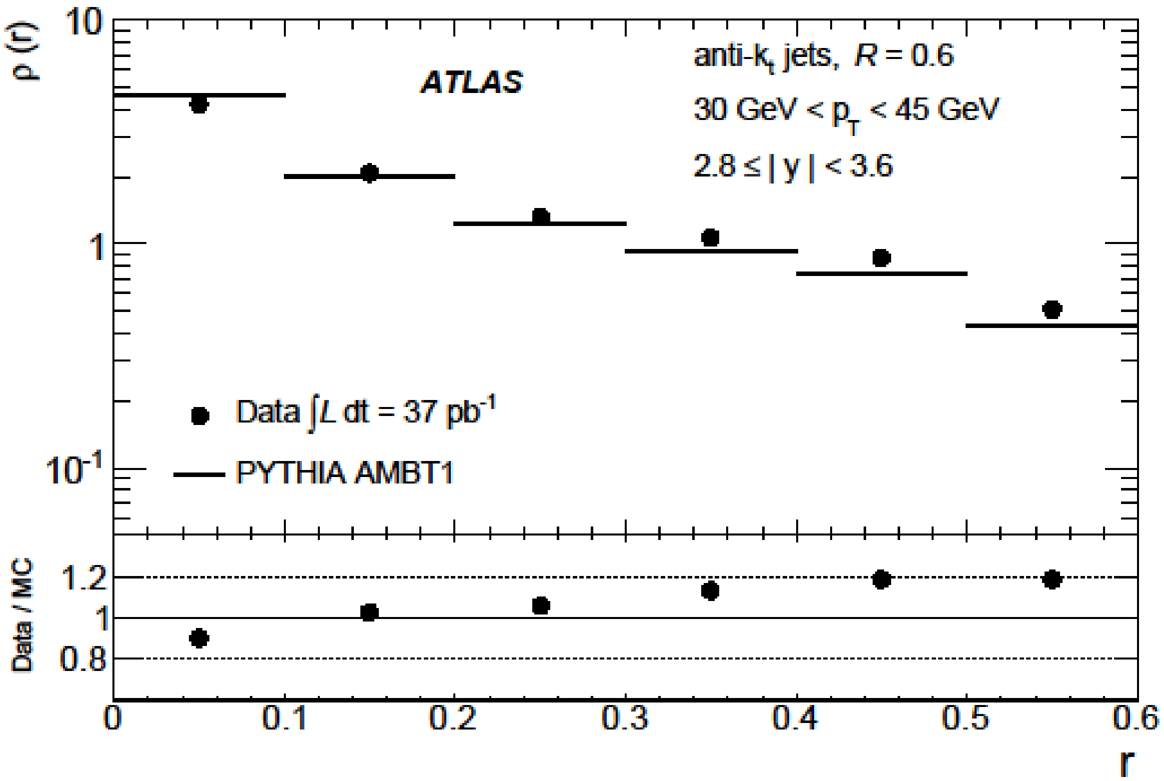
Event and jet selection

- Event selection: Good data quality (GRL+no LArError), PV with 5+ tracks
- New release 16 jet quality selection applied: MEDIUM operating point
- Improved rejection of fake jets, originating from
  - HEC spikes
  - EM coherent noise
  - Cosmic rays / beam backgrounds
- Selection efficiency for real jets measured in-situ using dijet tag-probe



Forward jet shapes

- Detector-level jet shapes in forward region
- Used as crude validation of MC modeling
  - Energy distribution within jet reasonably well-modeled (agreement within 20%)
  - Differences between data and MC covered by unfolding uncertainty due to shape of MC jet p_T spectrum (dijet mass)



PDF comparisons for R=0.4

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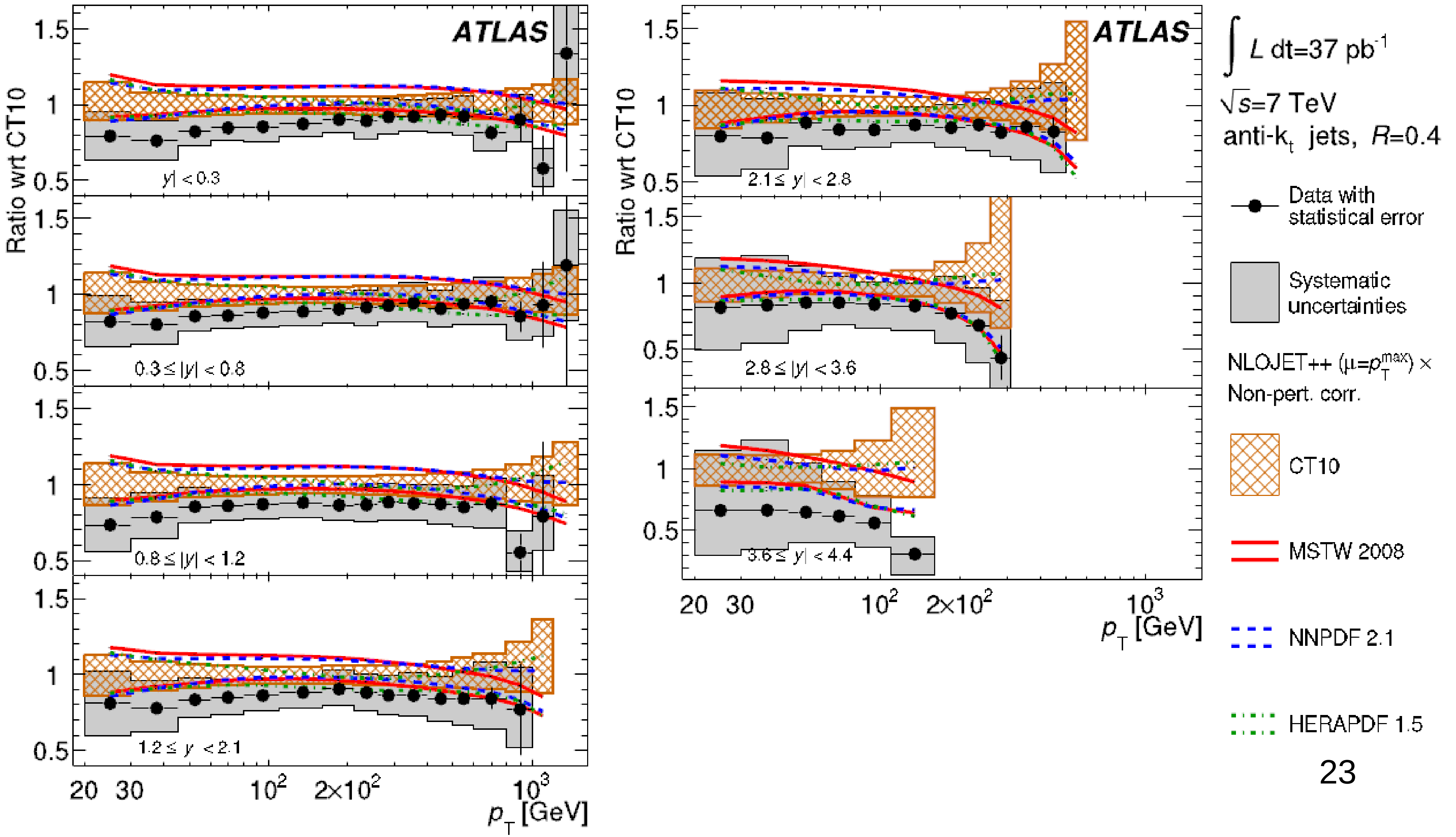

POWHEG comparisons for R=0.4

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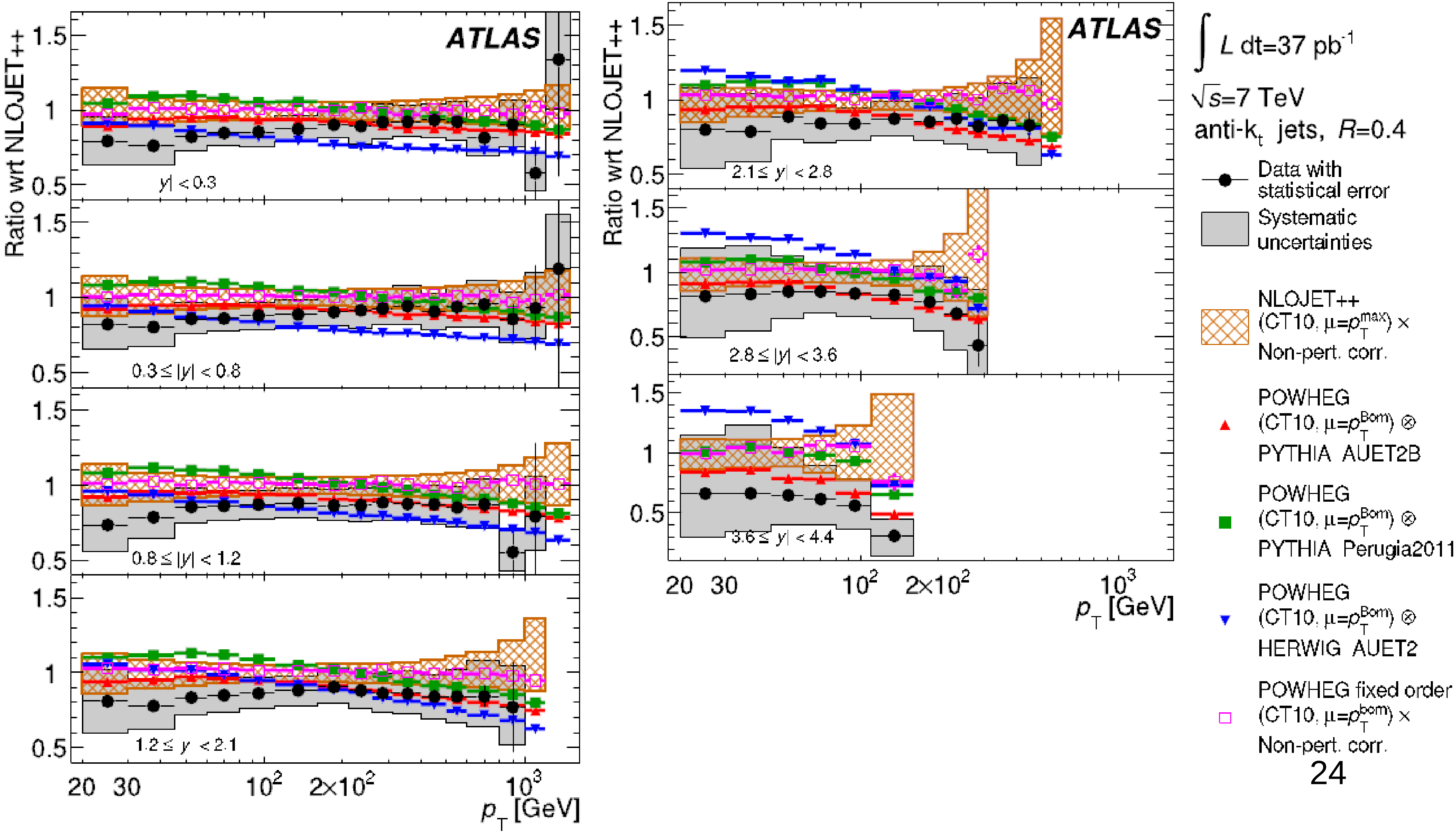
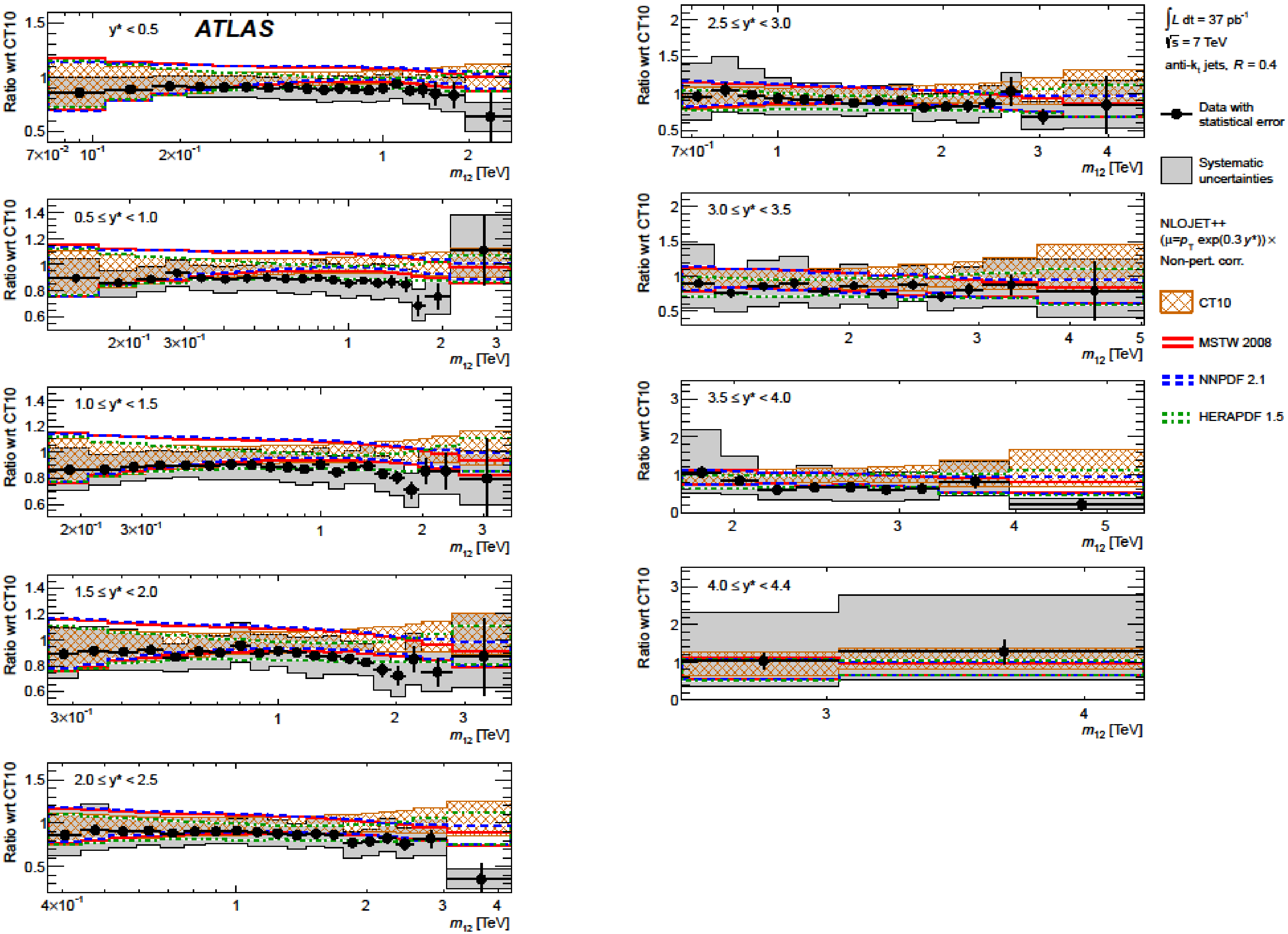
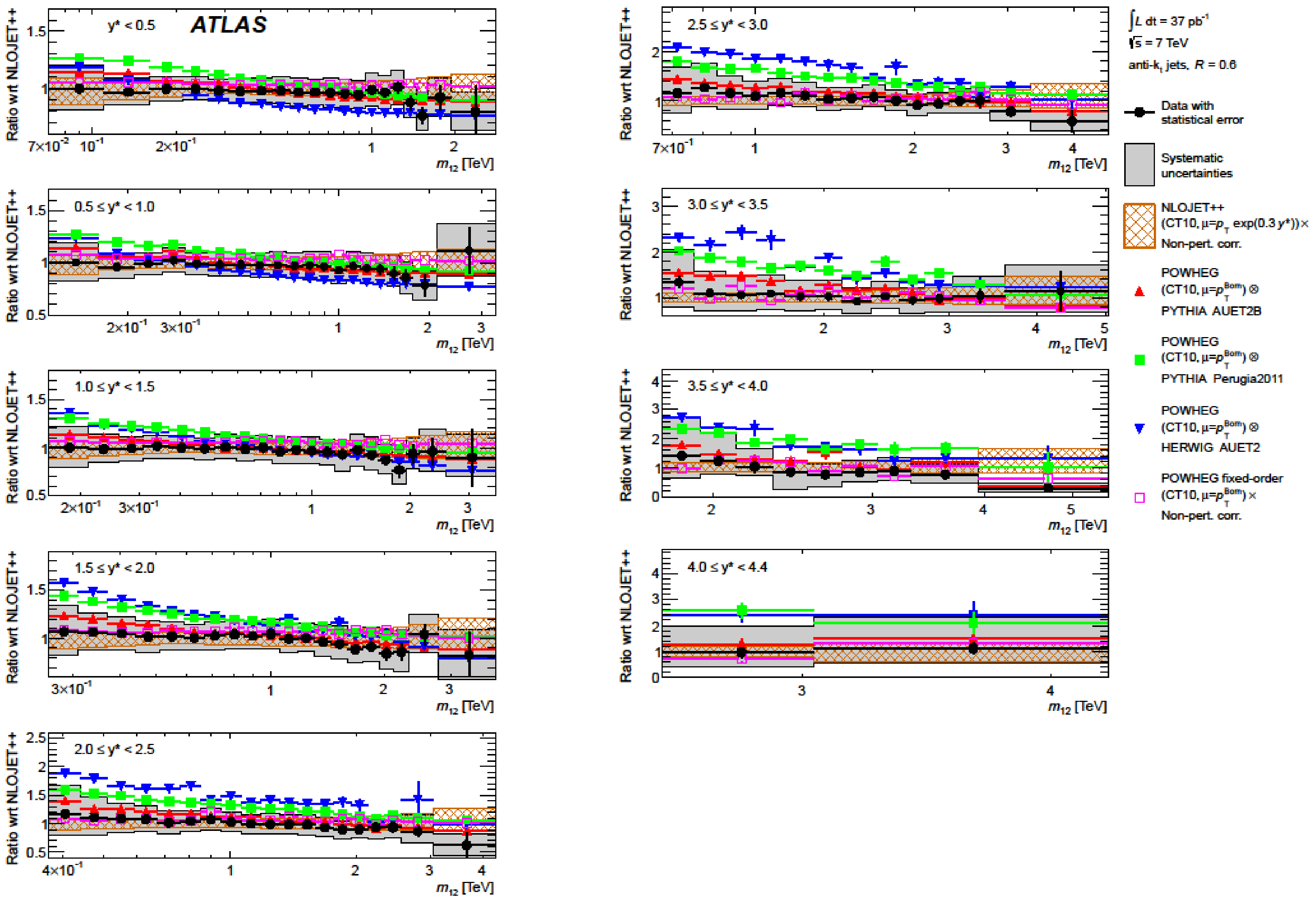


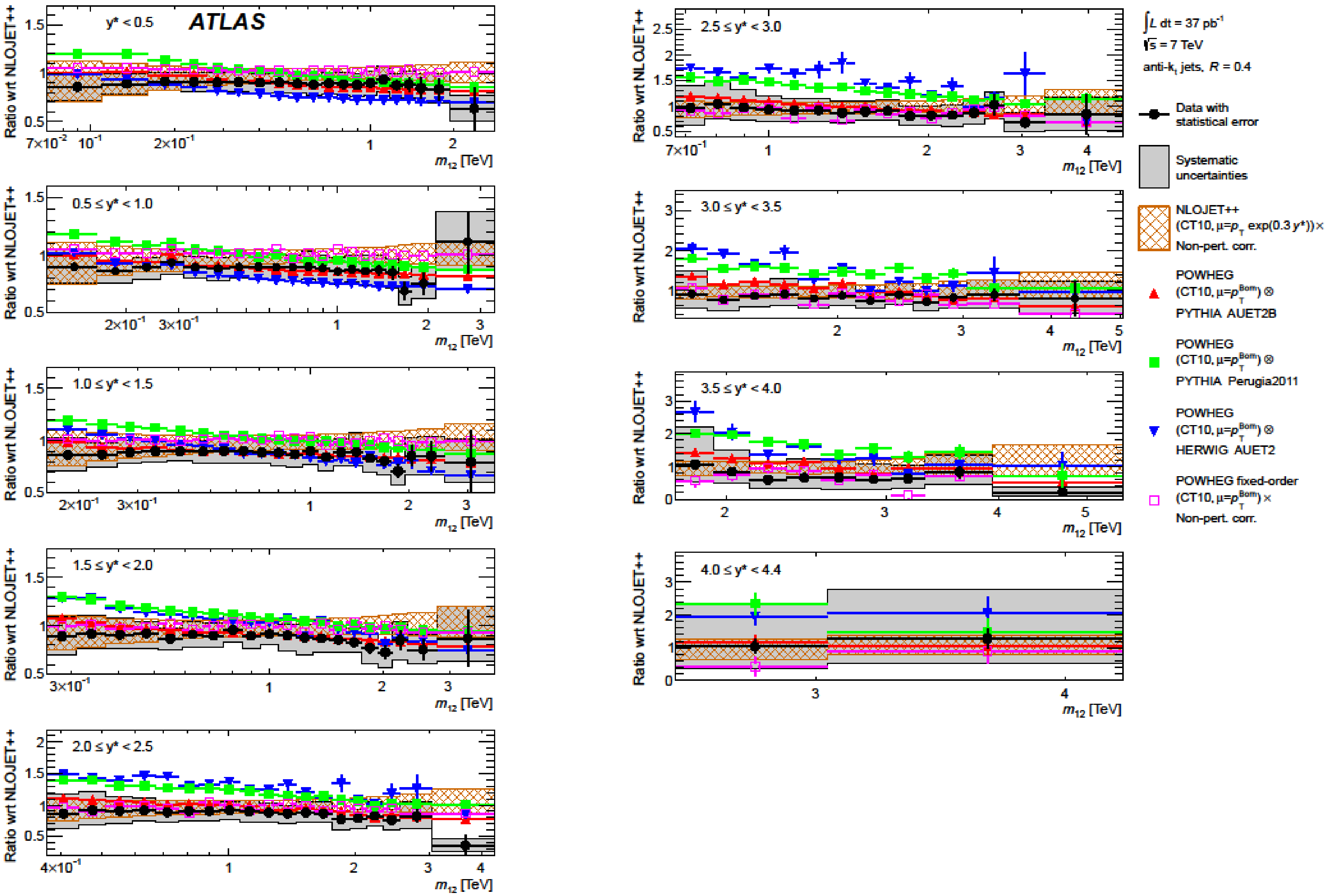
PDF comparisons – dijet; R=0.4



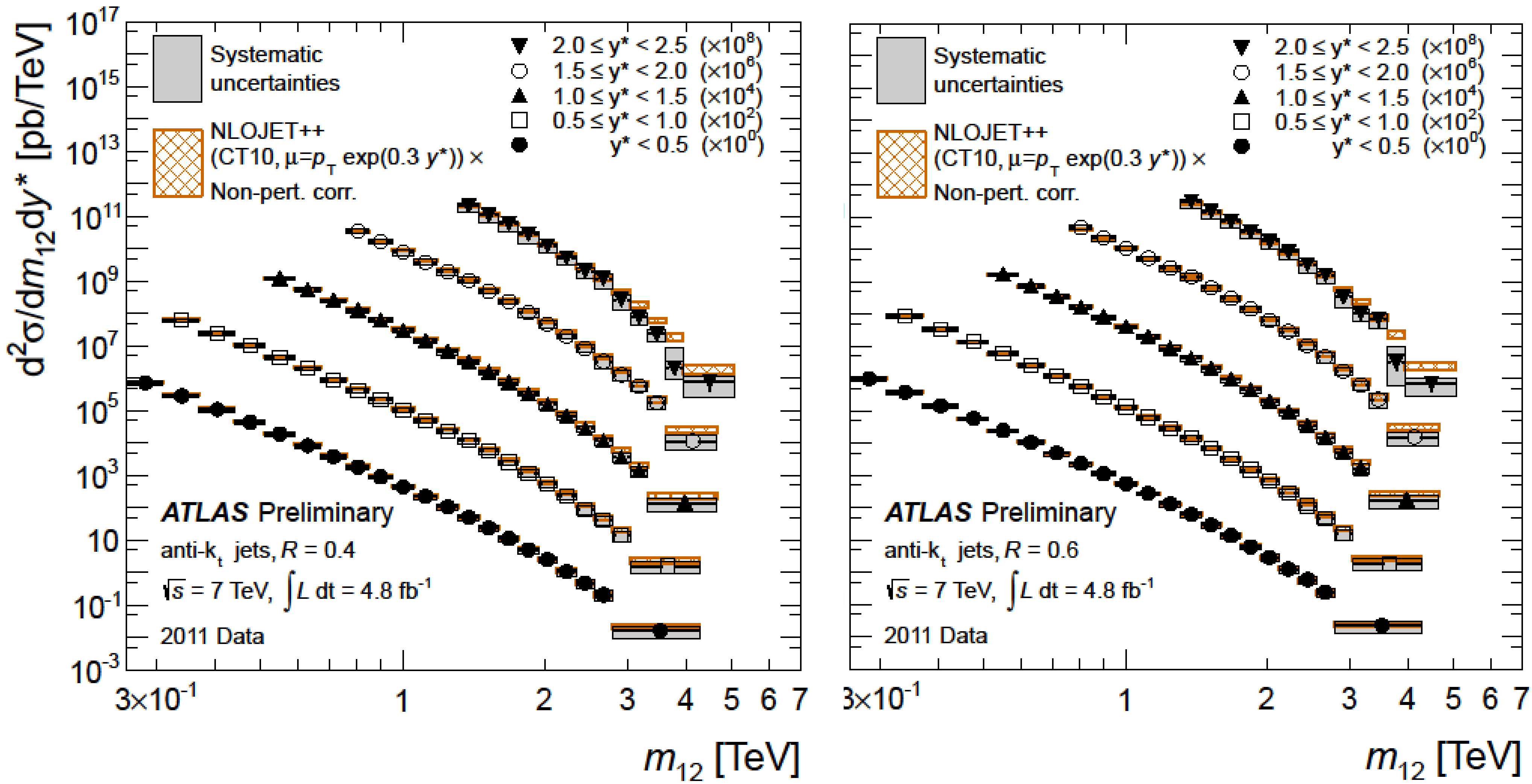
POWHEG comparisons – dijet; R=0.6



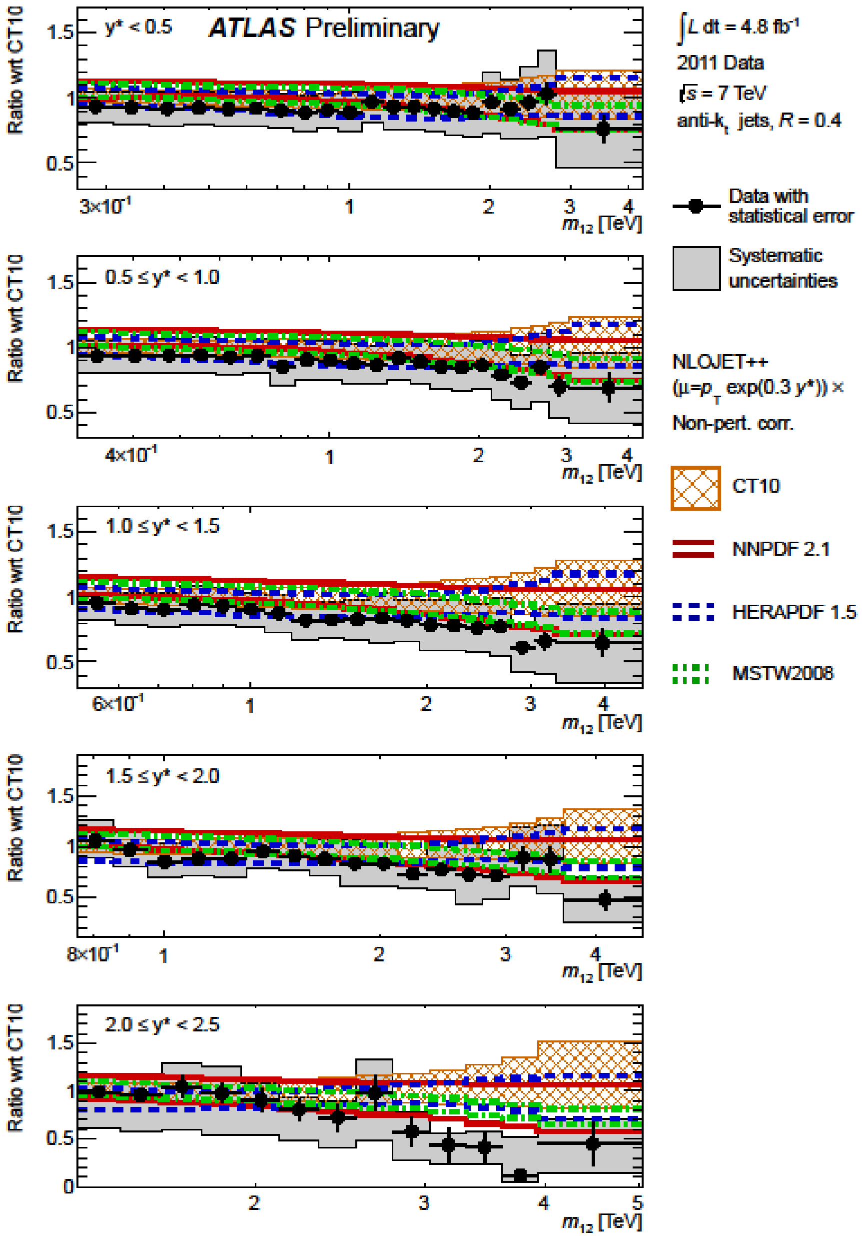
POWHEG comparisons – dijet; R=0.4

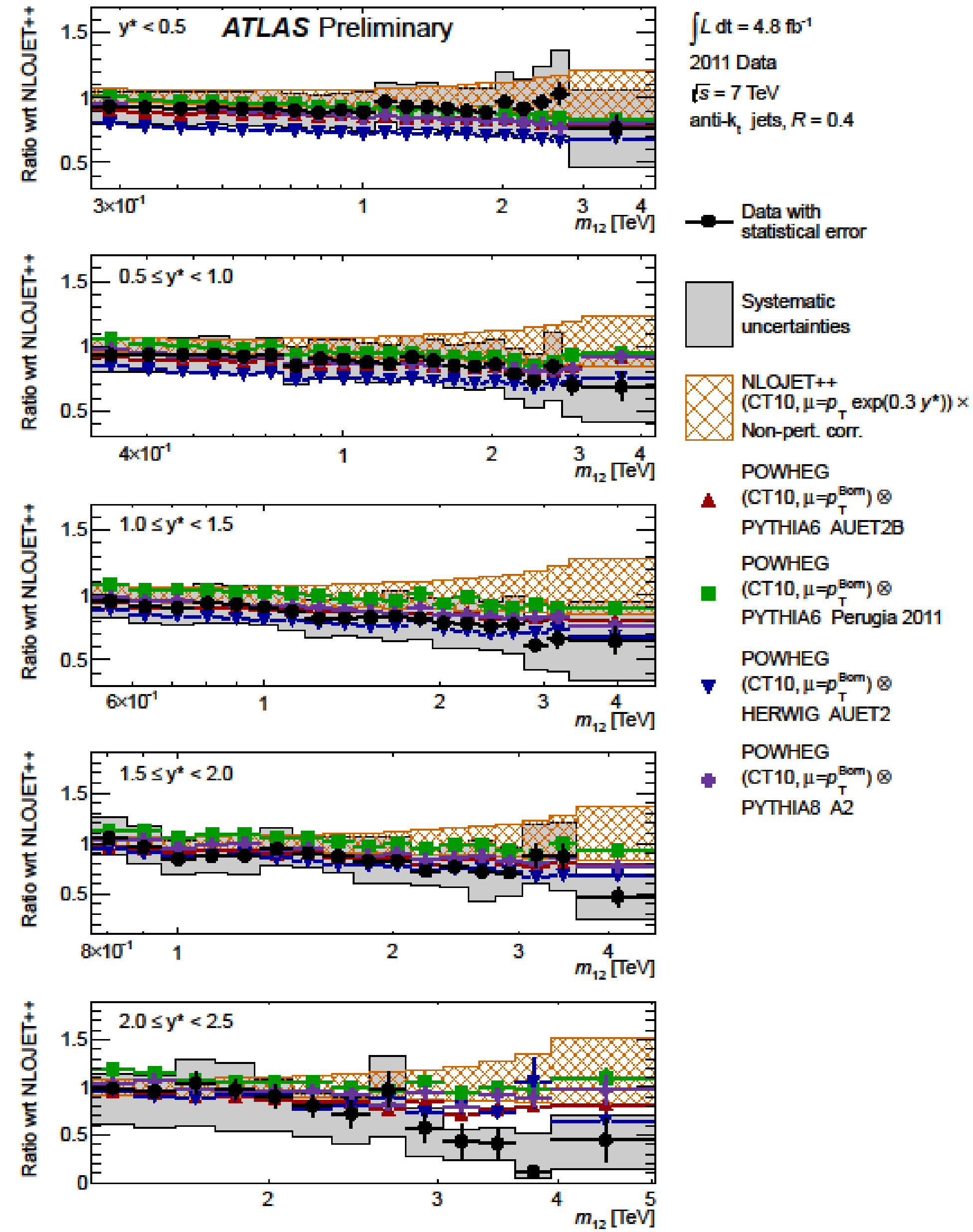


2011 Dijet mass spectrum



PDF&POWHEG comparisons – dijet; R=0.4





Systematic uncertainties

- Largest systematic uncertainty from JES
  - Luminosity uncertainty now 3%
- Representative uncertainties for inclusive jet pT spectrum:

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%

- Representative uncertainties for dijet mass spectrum:

m_{12} [GeV]	y^*	Abs. JES	Unfolding	Cleaning	Trig.	Jet Rec.
100	0.0-0.5	20%	10%	0.5%	2%	1%
2500	4.0-4.4	$^{+100\%}_{-70\%}$	10%	0.5%	5%	1%