Measurements of jet production properties in pp collisions with the ATLAS detector

Bogdan Malaescu
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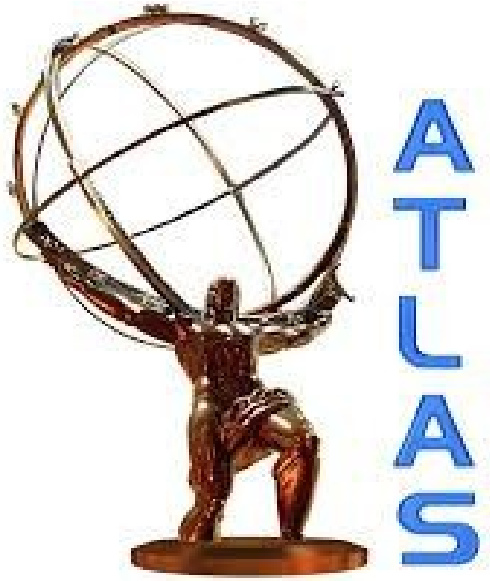
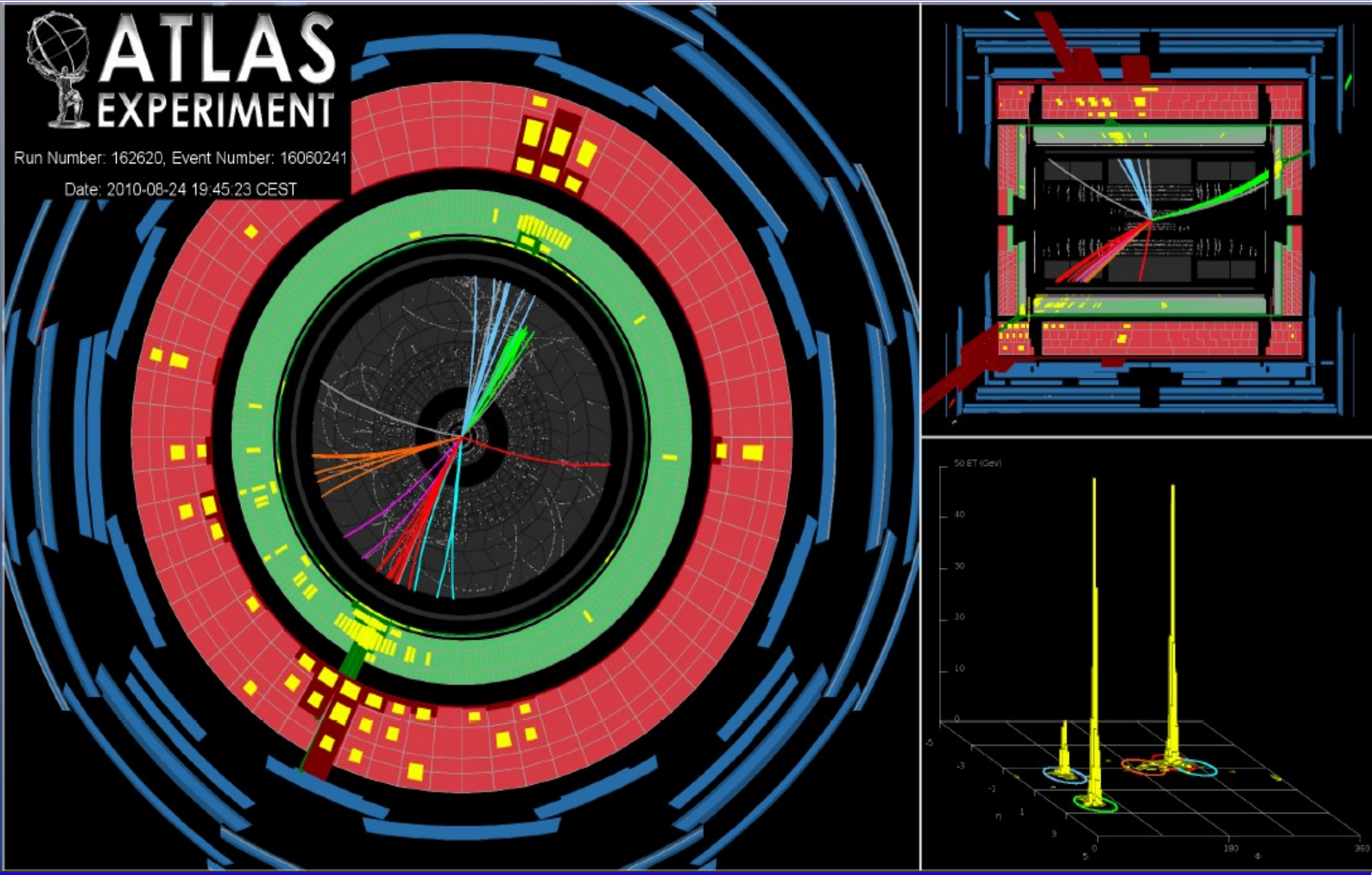
on behalf of the ATLAS collaboration



ICHEP 2014

Introduction: Jet production in ATLAS



Introduction

Jet production measurements in ATLAS:

Motivated by:

→ probe QCD on wide phase-space range

→ important ingredients to PDF fits

→ sensitivity to New Physics

- 17 nb^{-1} analysis

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

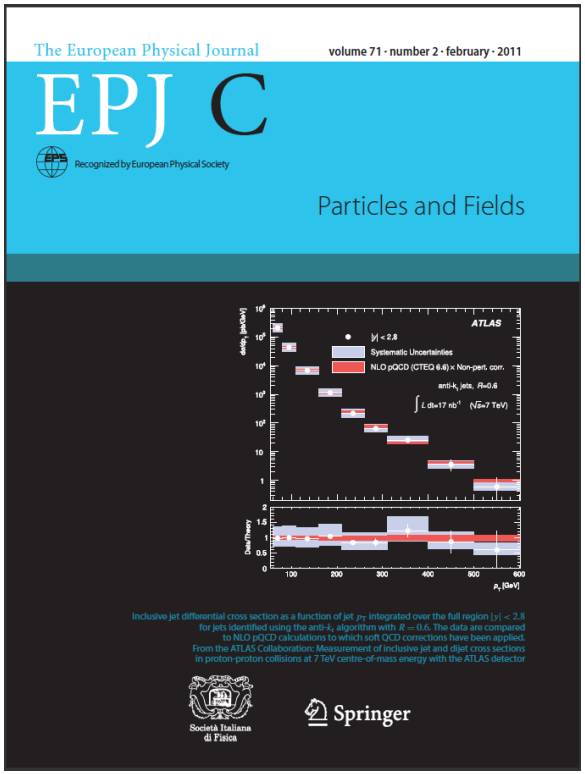
→ Cover of the February 2011 issue of EPJC

(EPJC 71.1512; arXiv:1009.5908)

- 37 pb^{-1} analysis

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

(Phys. Rev. D86 (2012) 014022; arXiv:1112.6297)



Introduction

Measurements since ICHEP 2012:

- 0.2 pb^{-1} analysis

→ Inclusive jet production in *pp* collisions at $\sqrt{s}$ = 2.76 TeV ; comparison to the inclusive jet measurement at $\sqrt{s}$ = 7 TeV

(EPJC 73 (2013) 2509; arXiv:1304.4739)

- 4.5 fb^{-1} analyses

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

(JHEP 1405 (2014) 059; arXiv:1312.3524)

→ Dijet production with a jet veto, at $\sqrt{s}$ = 7 TeV (Preliminary)

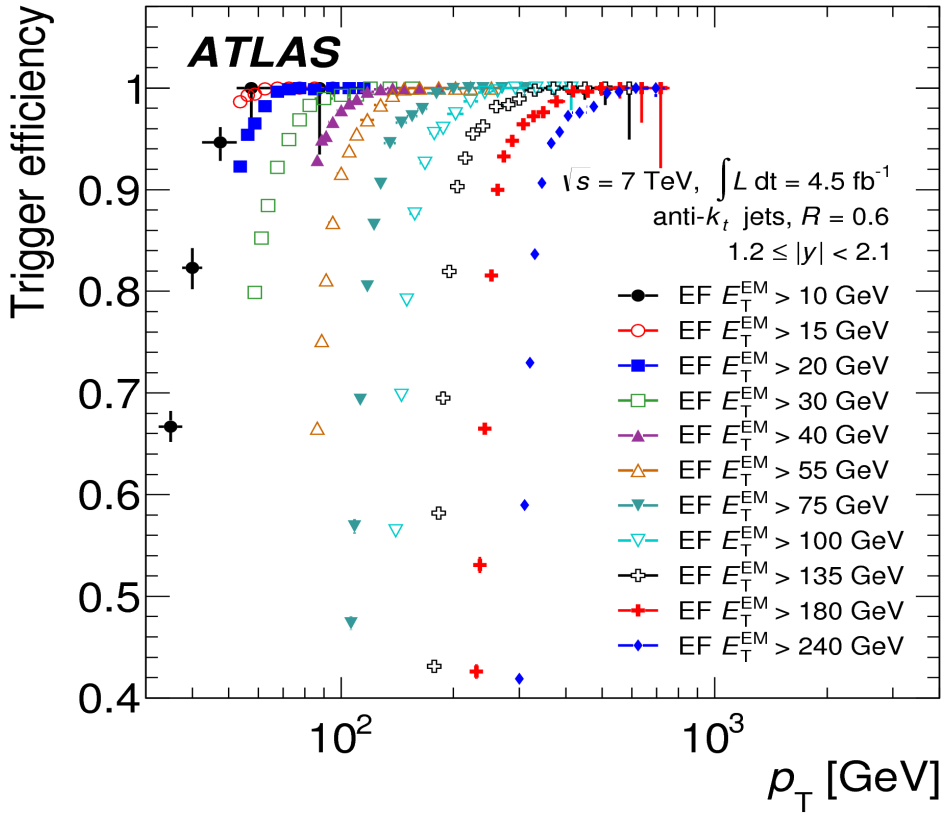
→ Inclusive jet production in *pp* collisions at $\sqrt{s}$ = 7 TeV (NEW)

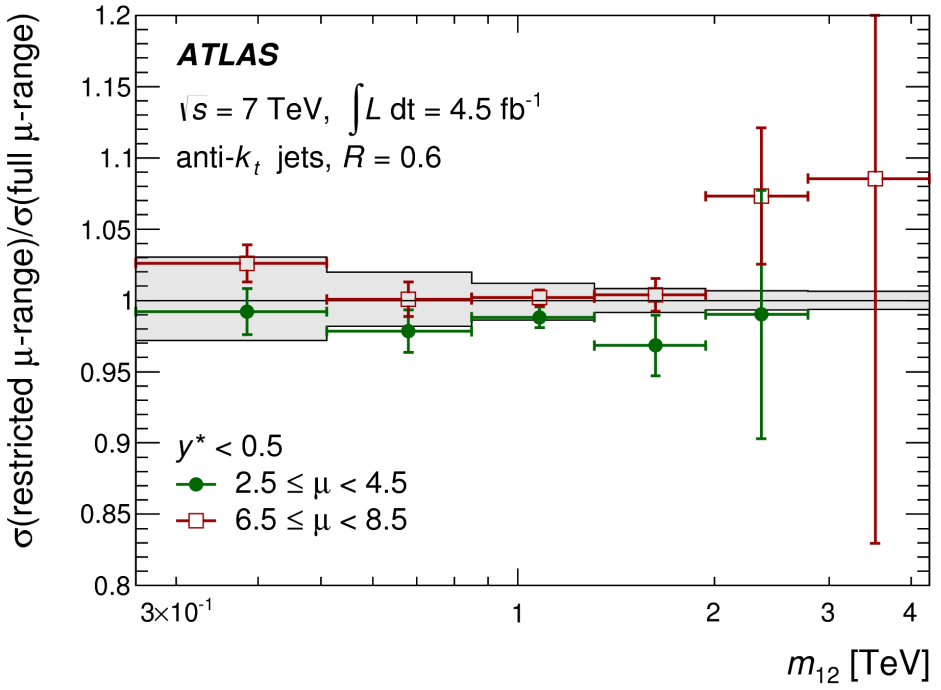
→ 3-jets mass measurement in *pp* collisions at $\sqrt{s}$ = 7 TeV (NEW)

Etc.

Trigger and pile-up

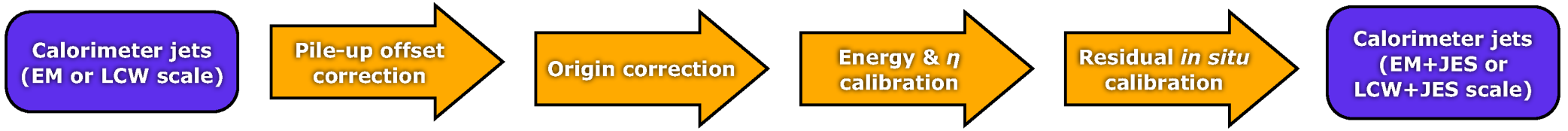
- Trigger prescales and pile-up treatment take into account variations in data-taking conditions
- Jet trigger efficiencies determined in-situu using unbiased samples
- Each trigger used in the region where it is fully efficient





Jet calibration, resolution and uncertainties

- anti-k_T (R=0.4,0.6) calorimeter jets



- Uncertainties: in-situ baseline (strongly reduced); jet flavor; pile-up; close-by

→ Splitting into (~60) components allows to keep track of correlations (between phase-space regions & between measurements)

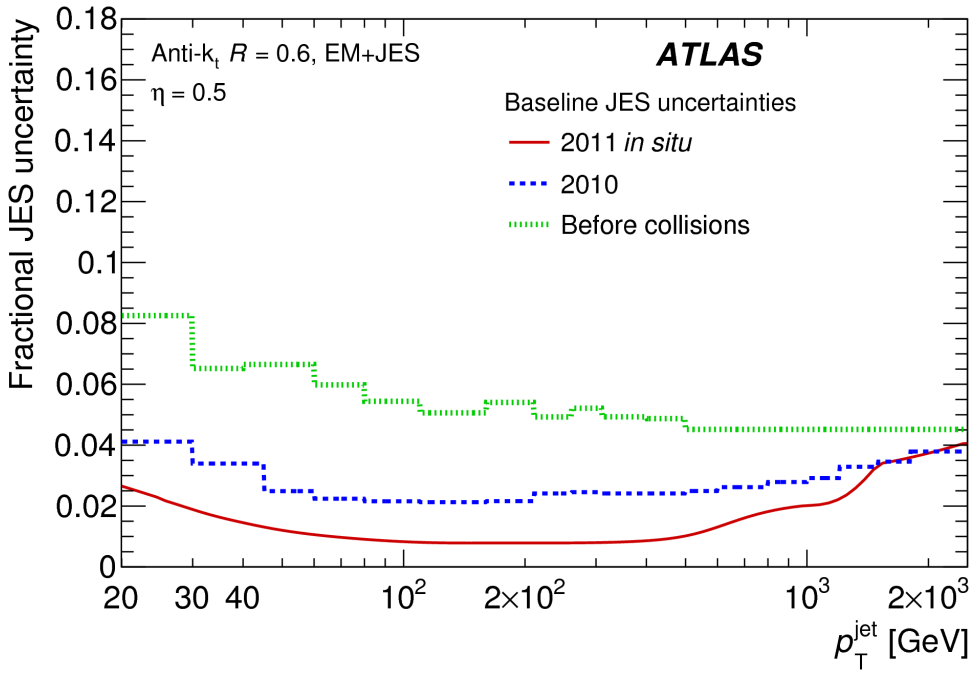
→ Uncertainties on the correlations

available & propagated too

- JER studied in-situ (dijet events)

- *More details in talk by Peter BERTA*

(Detector & performance session)



Data correction to particle level

- Measurements corrected back to particle level using a matrix-based method

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

  → in-situ determination of the shape uncertainty: exploits data/reco MC
  (performed for several unfolding methods; choosing the most precise)

- Full propagation of uncertainties and correlations:

  → statistical uncertainty (data+MC) using pseudo-experiments
  (bootstrap method to keep track of correlations with other measurements)

  → systematic uncertainties using nuisance parameters
  (asymmetric uncertainties taken into account)

Theoretical predictions and uncertainties

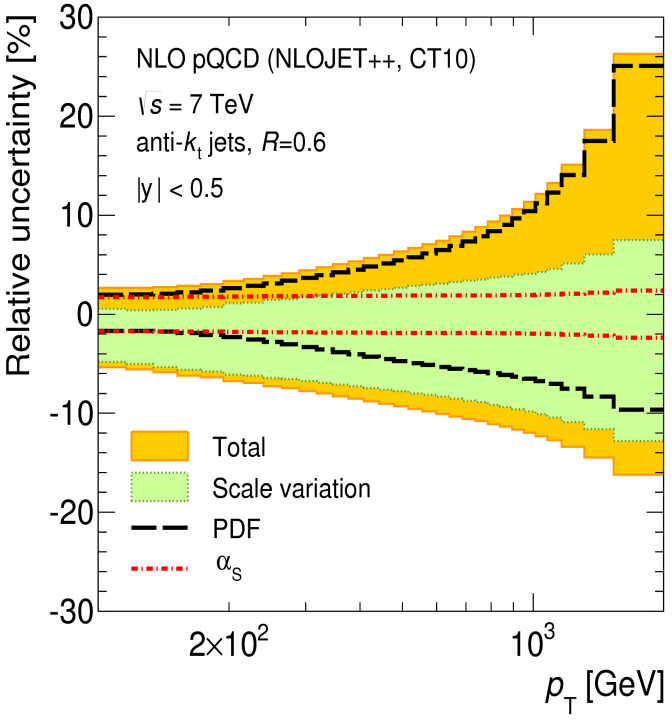
- Perturbative QCD predictions from NLOJET++

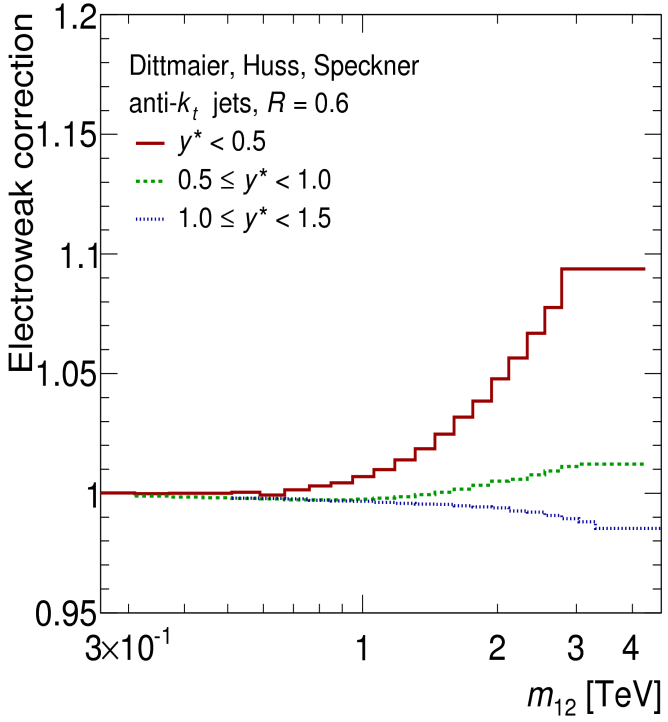
  → Uncertainties: renormalization & factorization scales, PDFs and α_S via APPLGRID

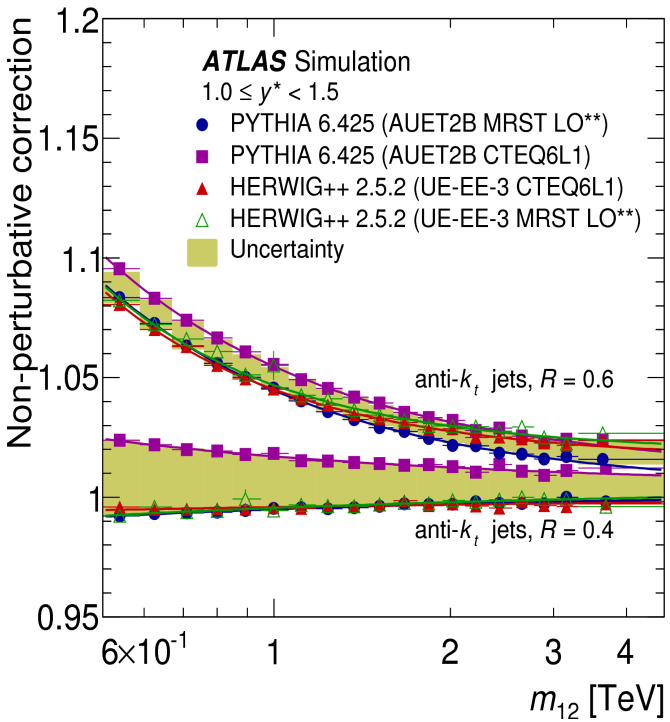
- EW corrections (inclusive jets & dijets): S. Dittmaier et al. JHEP 11 (2012) 095

- Non-perturbative corrections (accounting for hadronization and UE) and uncertainties: various Pythia tunes + different MC generators(Herwig++); strong dependence on R

  → Additional comparisons to Powheg (NLO ME + PS)



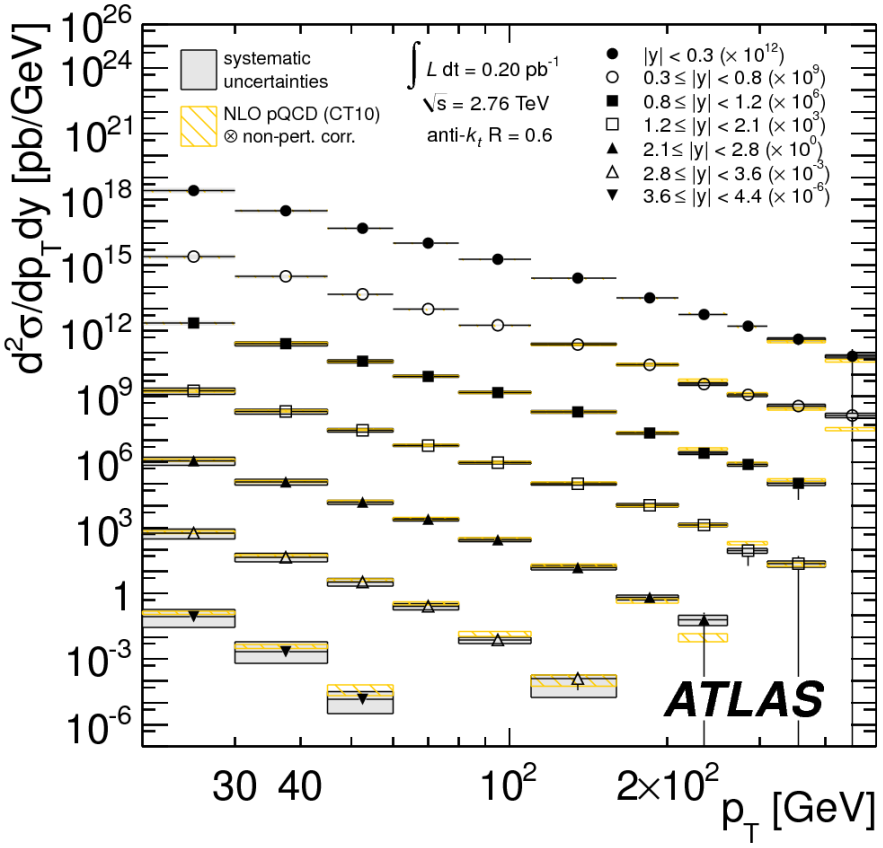


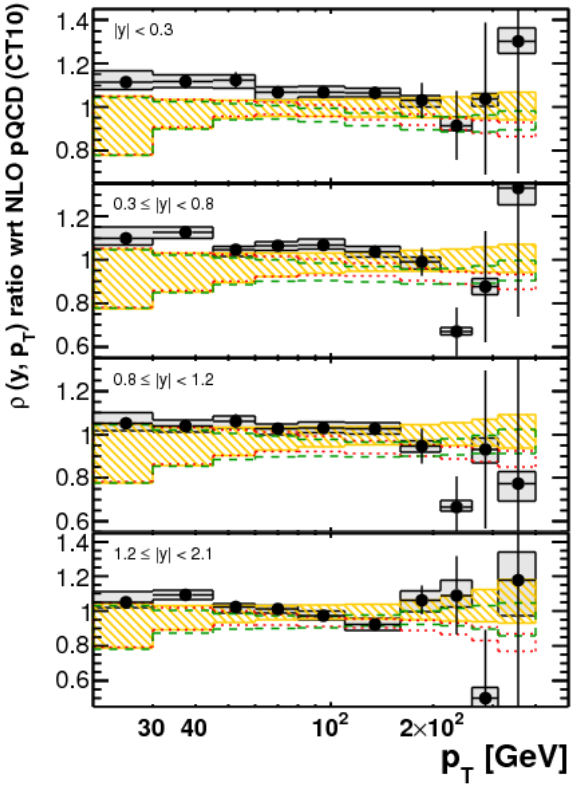


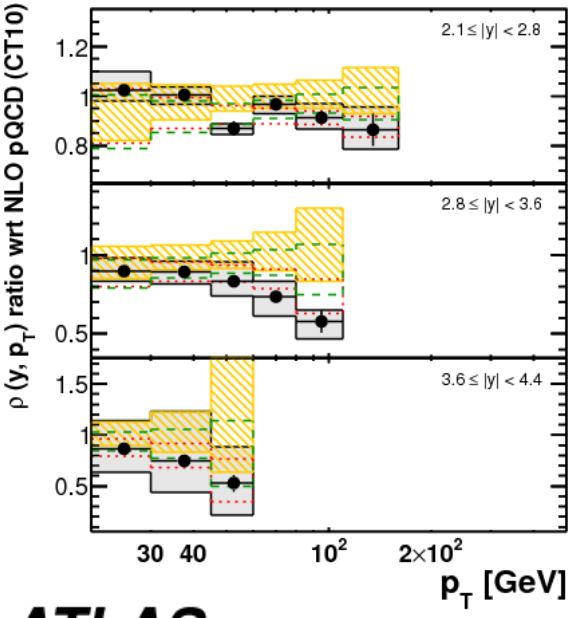
Inclusive jet cross sections at √s=2.76 TeV

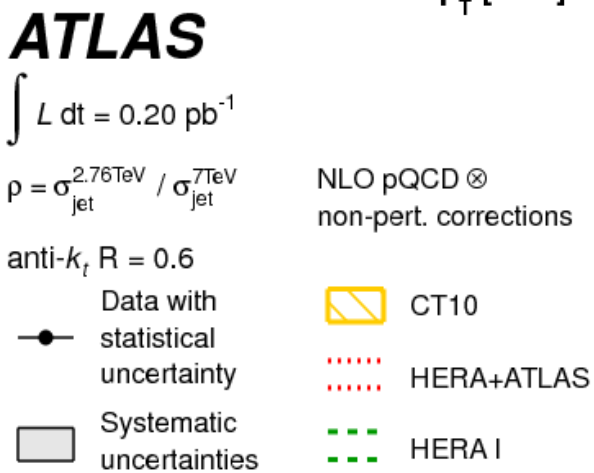
- Double-differential measurement for R=0.4 and 0.6

$\sigma^{2.76\ TeV} / \sigma^{7\ TeV}$









- Systematic uncertainties strongly reduced for the ratio of cross sections:

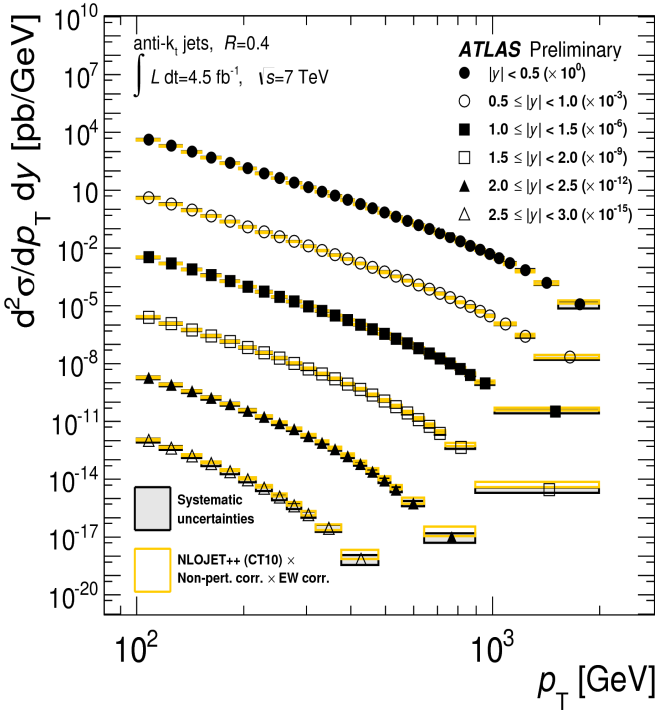
  sensitivity to PDFs

2011 Inclusive jet, dijet, 3-jet cross sections

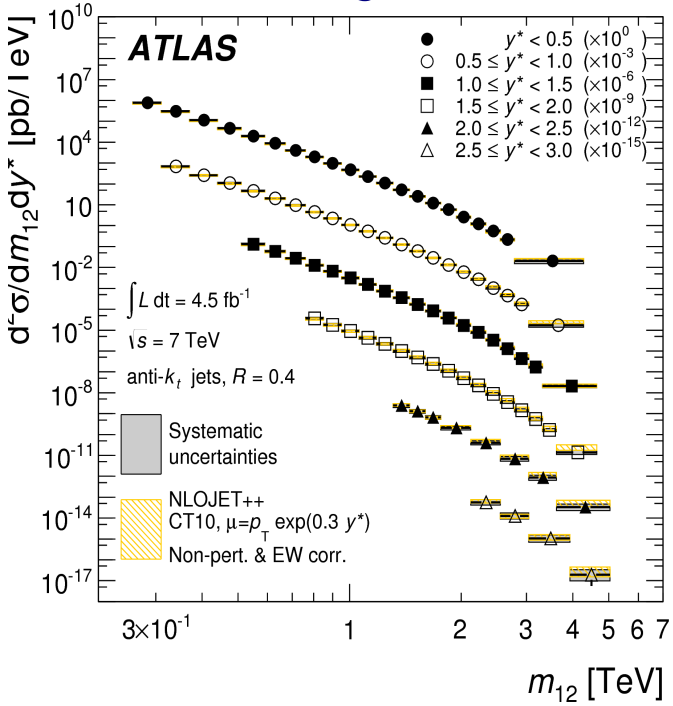
- Experimental double-differential cross-section compared to NLO pQCD + non-pert. (+ EW) corrections

R=0.4, L=4.5fb^{-1}, $\sqrt{s}$=7 TeV

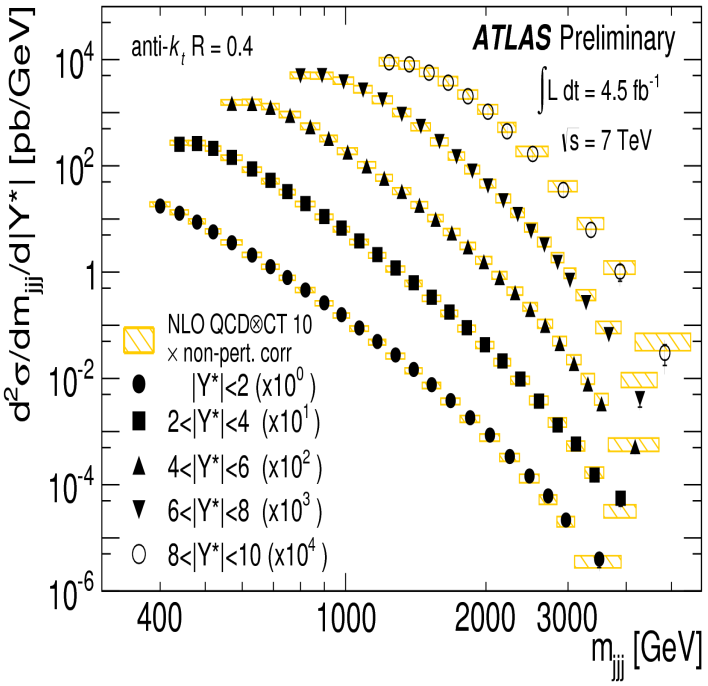
Inclusive jets



Dijets



Three jets



$y^* = |y_1 - y_2|/2$

$p_{T1;2} > 100;\ 50$ GeV

$Y^* = |y_1 - y_2| + |y_1 - y_3| + |y_2 - y_3|$

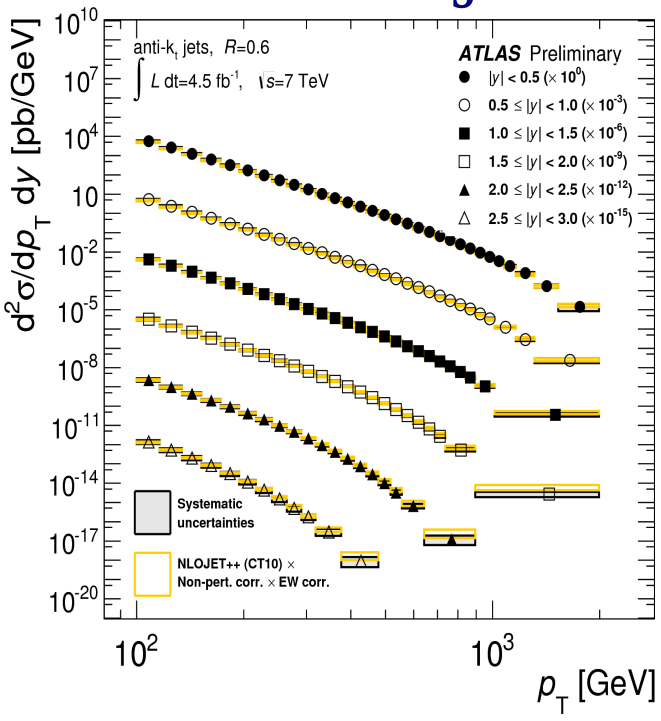
$p_{T1;2;3} > 150;\ 100;\ 50$ GeV

2011 Inclusive jet, dijet, 3-jet cross sections

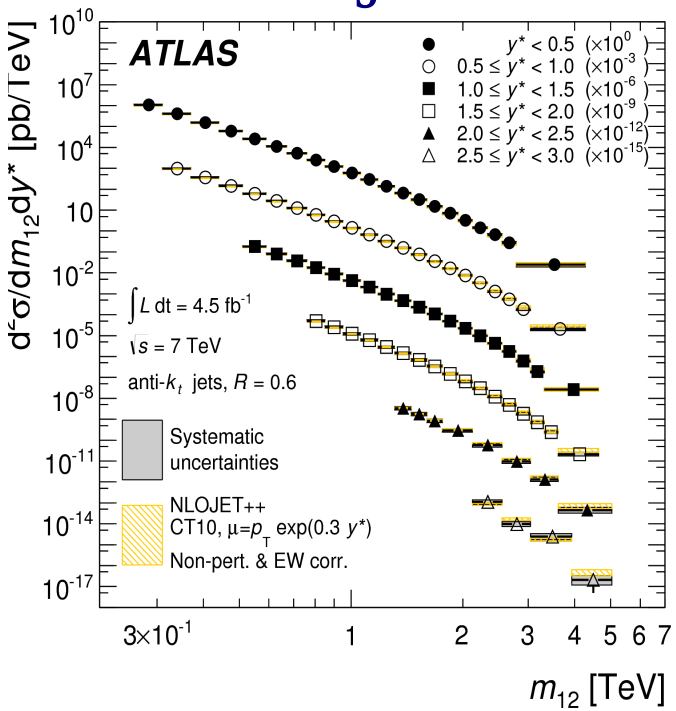
- Experimental double-differential cross-section compared to NLO pQCD + non-pert. (+ EW) corrections

R=0.6, L=4.5fb^{-1}, $\sqrt{s}$=7 TeV

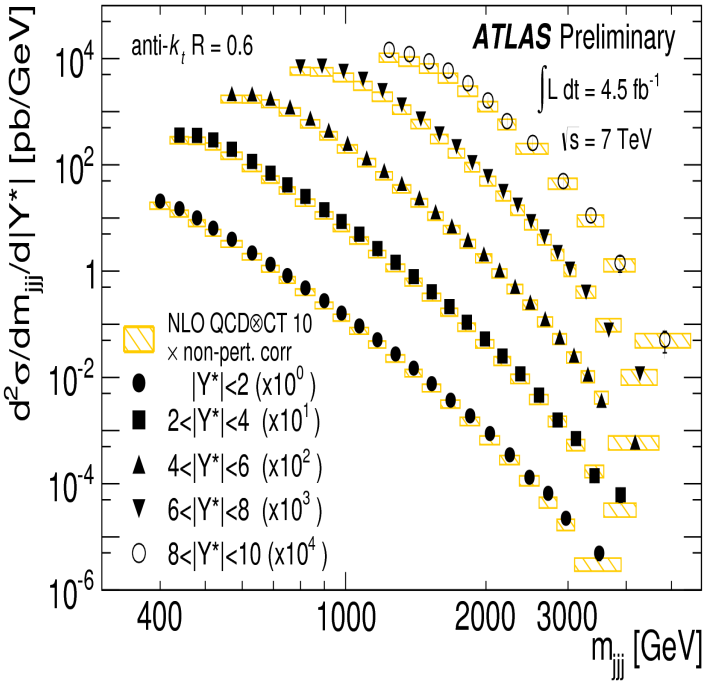
Inclusive jets



Dijets



Three jets



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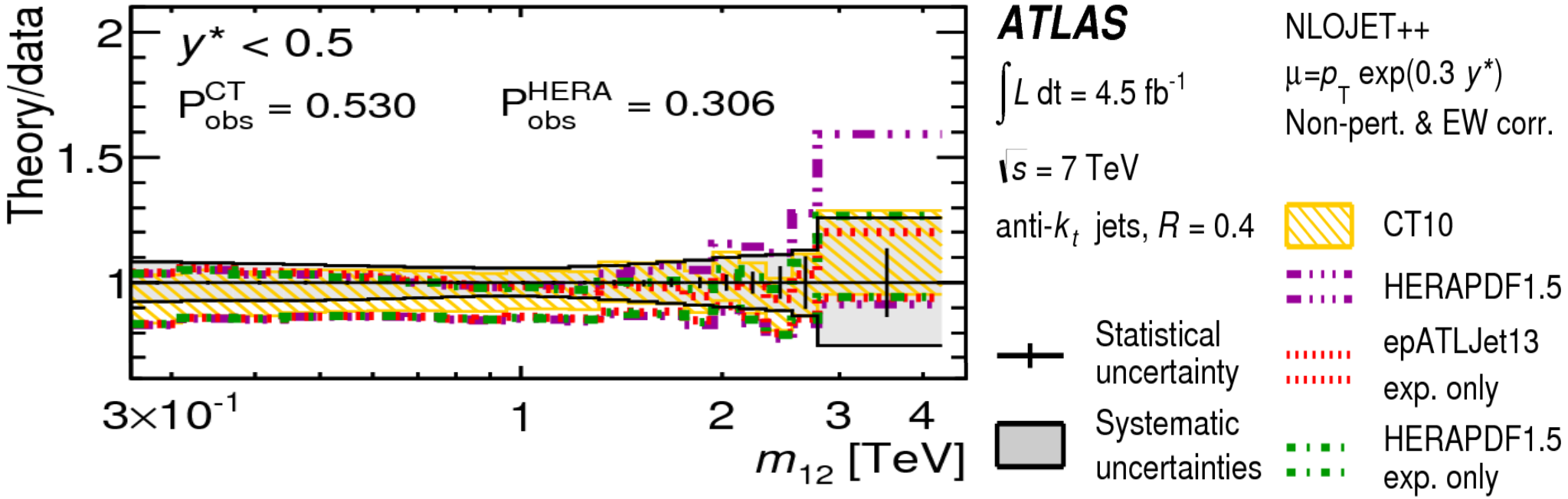
$p_{T1;2;3} > 150;\ 100;\ 50$ GeV

PDF comparisons

- Comparisons to CT10, MSTW2008, NNPDF2.3, HERAPDF1.5, and ABM11 (following PDF4LHC recommendations)



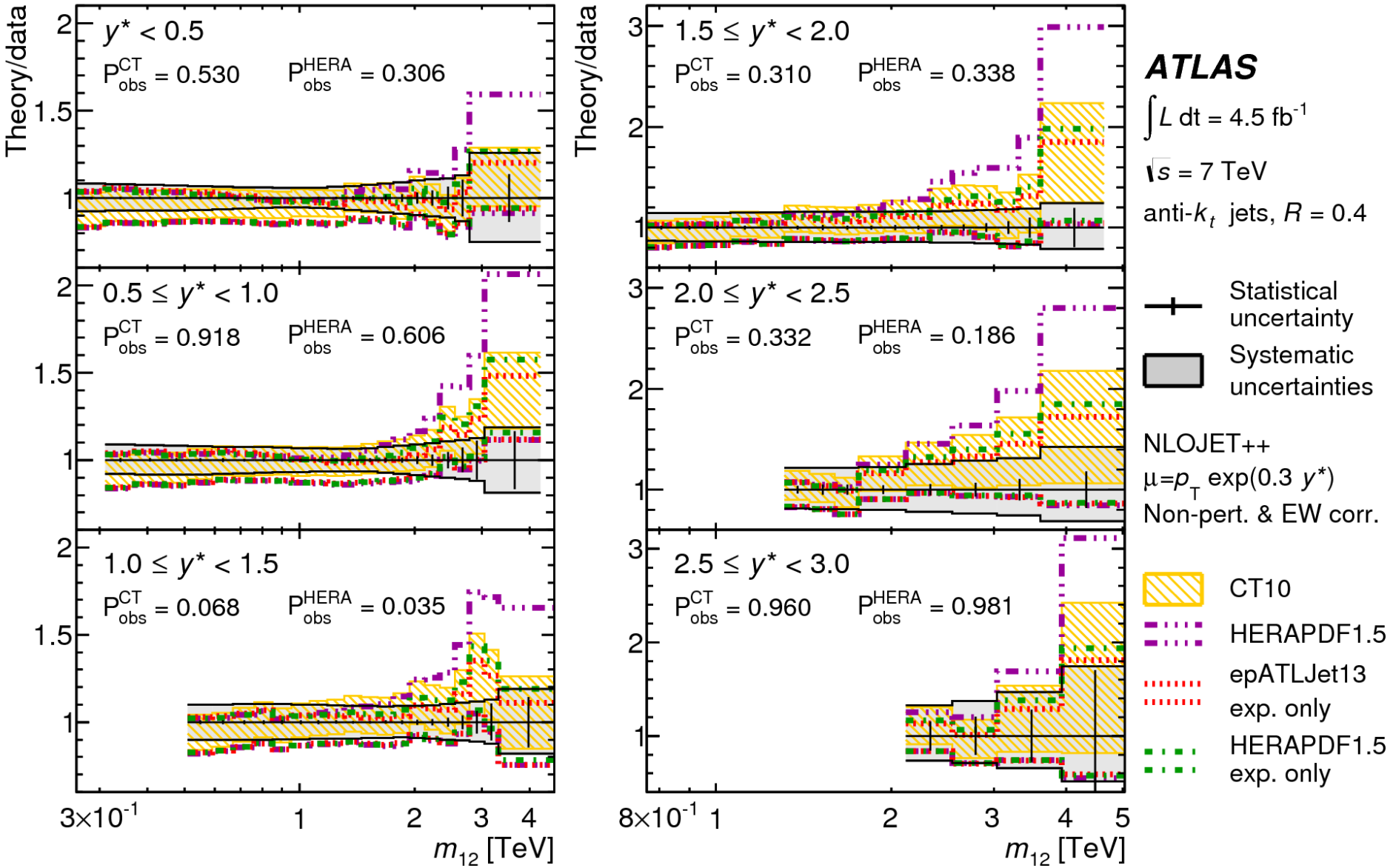
- Quantitative data/theory comparison:

  using frequentist method with a generalized χ^2 to compute p-value (P_{obs})

  → accounts for correlations and asymmetries of uncertainties (stat. & syst.)

PDF comparisons for dijets

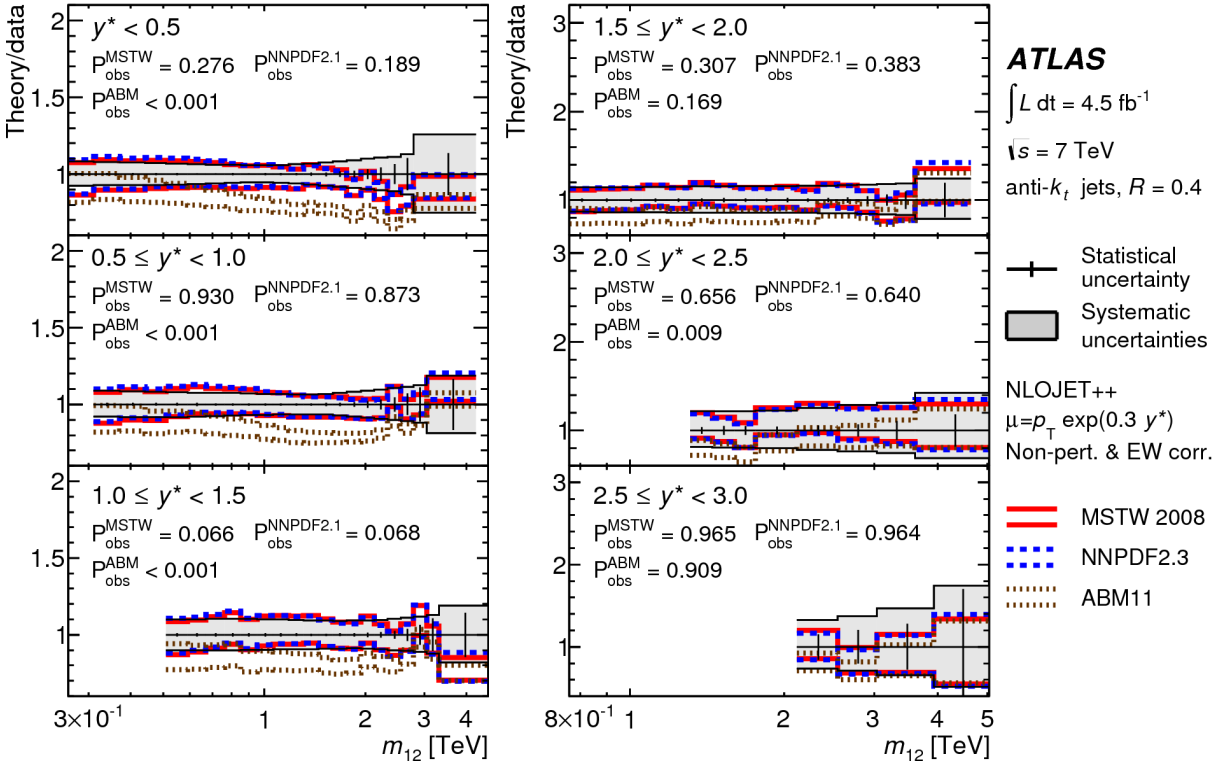
- Comparisons to CT10 and HERAPDF1.5



PDF comparisons for dijets

- Comparisons to MSTW2008,

  NNPDF2.3 and ABM11

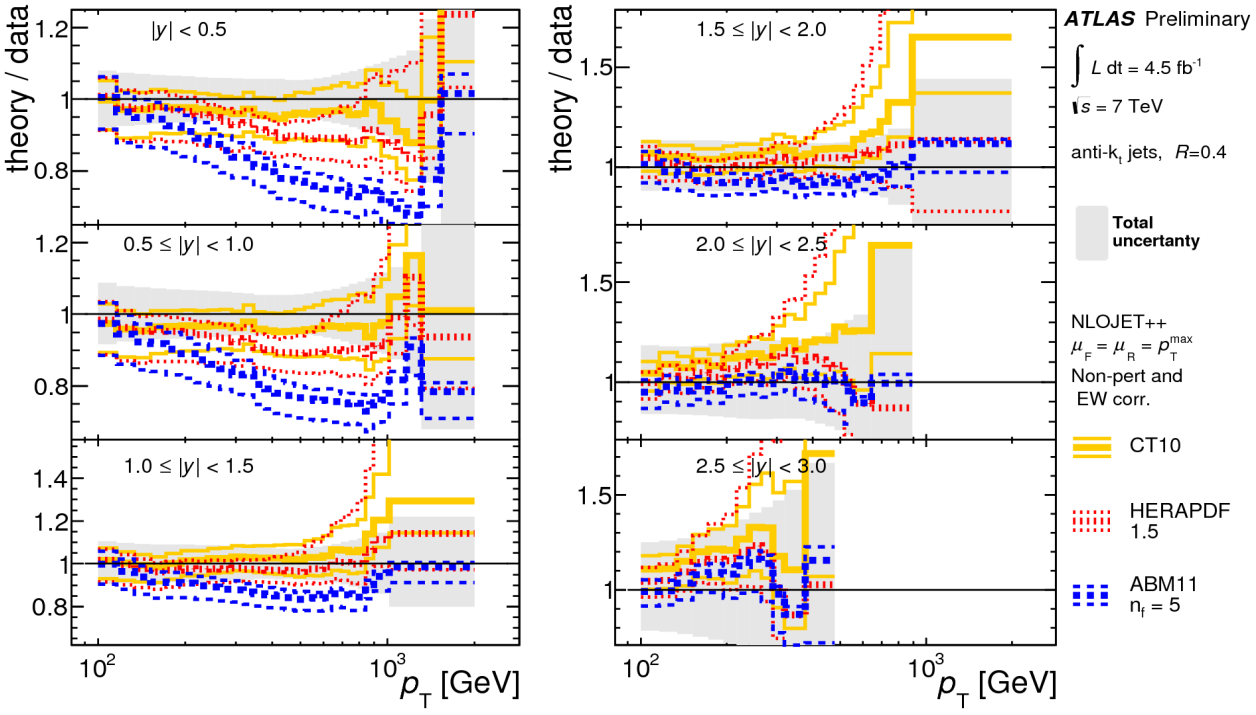


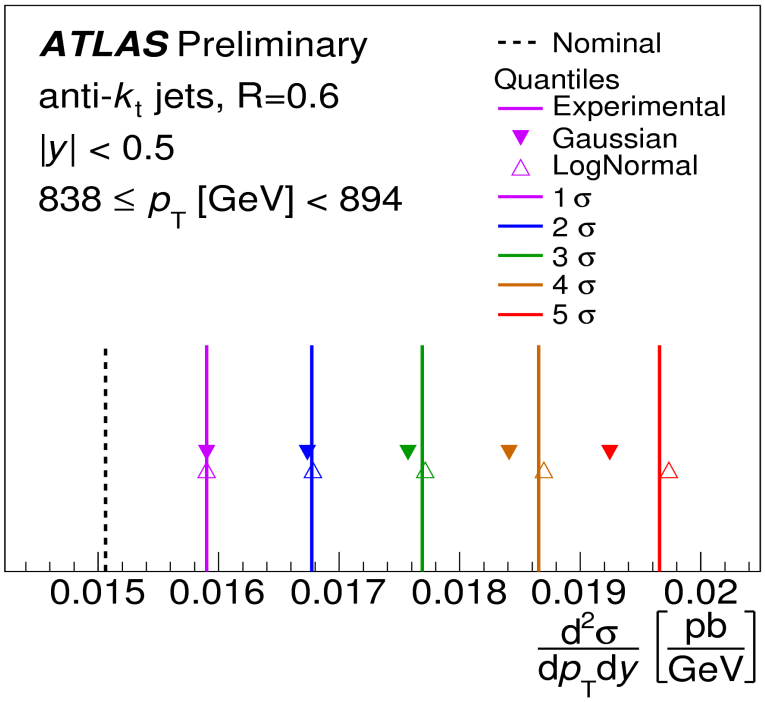
PDF set	y^* ranges	mass range (full/high)	P_{obs} $R = 0.4$	P_{obs} $R = 0.6$
CT10	$y^* < 0.5$	high	0.742	0.785
	$y^* < 1.5$	high	0.080	0.066
	$y^* < 1.5$	full	0.324	0.168
HERAPDF1.5	$y^* < 0.5$	high	0.688	0.504
	$y^* < 1.5$	high	0.025	0.007
	$y^* < 1.5$	full	0.137	0.025
MSTW 2008	$y^* < 0.5$	high	0.328	0.533
	$y^* < 1.5$	high	0.167	0.183
	$y^* < 1.5$	full	0.470	0.352
NNPDF2.1	$y^* < 0.5$	high	0.405	0.568
	$y^* < 1.5$	high	0.151	0.125
	$y^* < 1.5$	full	0.431	0.242
ABM11	$y^* < 0.5$	high	0.024	$< 10^{-3}$
	$y^* < 1.5$	high	$< 10^{-3}$	$< 10^{-3}$
	$y^* < 1.5$	full	$< 10^{-3}$	$< 10^{-3}$

- Sensitivity to PDFs: level of agreement strongly depends on the PDF set and phase-space region

→ Valuable experimental inputs to constrain proton PDFs: Published information on cross-sections & uncertainties, with their correlations and asymmetries

PDF comparisons for inclusive jets

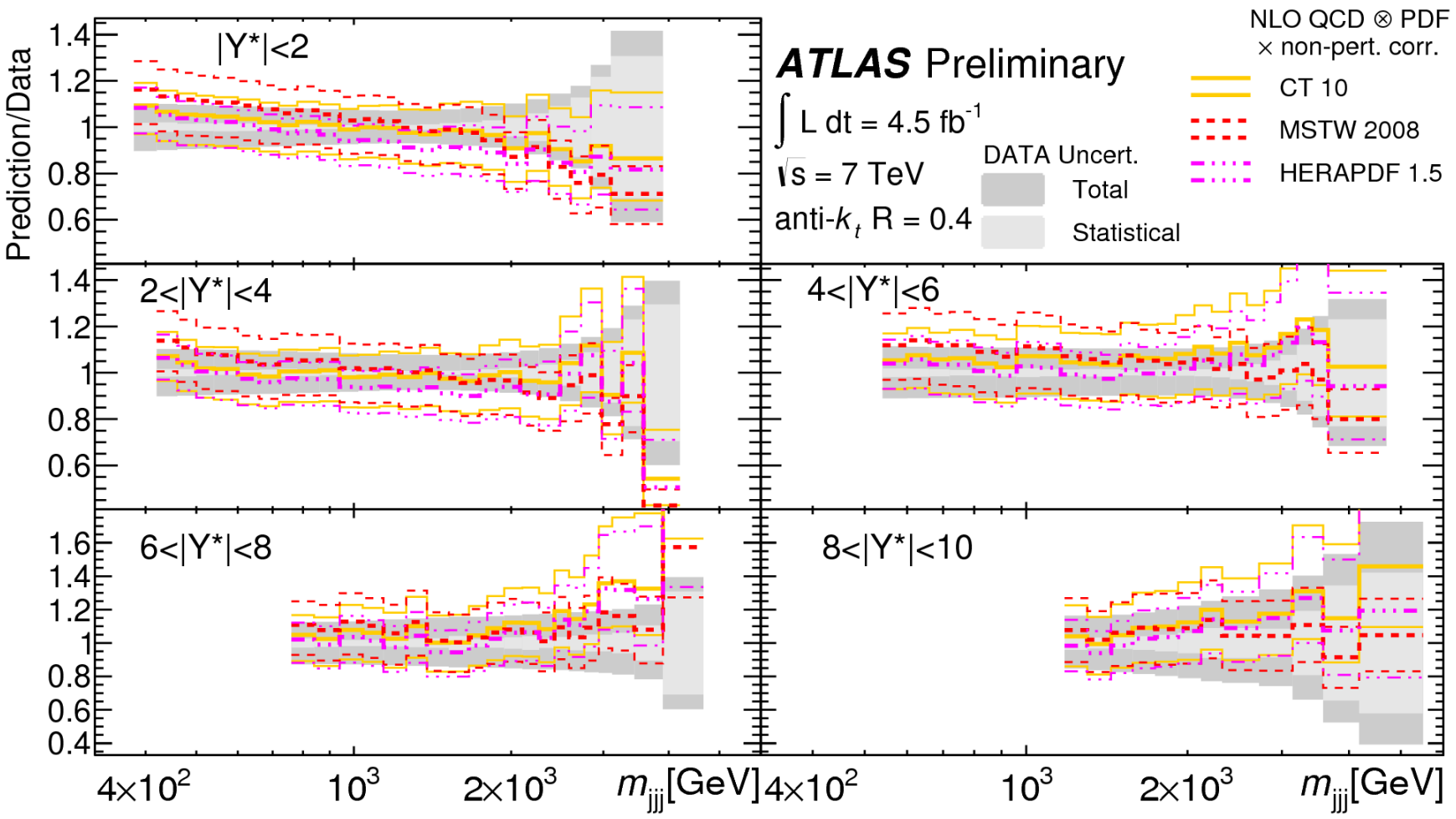




y ranges	P_{obs} (ATLAS Preliminary)				
NLO PDF set:	CT10	MSTW2008	NNPDF2.1	HERAPDF1.5	ABM11
$\lvert y\rvert < 0.5$	84%	61%	72%	56%	$< 0.1\%$
$0.5 \le \lvert y\rvert < 1.0$	91%	93%	89%	49%	$< 0.1\%$
$1.0 \le \lvert y\rvert < 1.5$	89%	88%	85%	93%	2.7%
$1.5 \le \lvert y\rvert < 2.0$	93%	88%	91%	75%	55%
$2.0 \le \lvert y\rvert < 2.5$	86%	82%	85%	26%	57%
$2.5 \le \lvert y\rvert < 3.0$	95%	94%	97%	82%	85%

- P_{obs} strongly depends on the PDF set and phase-space region
- Systematics: ±nσ scan; Log-normal provides better description than Gaussian

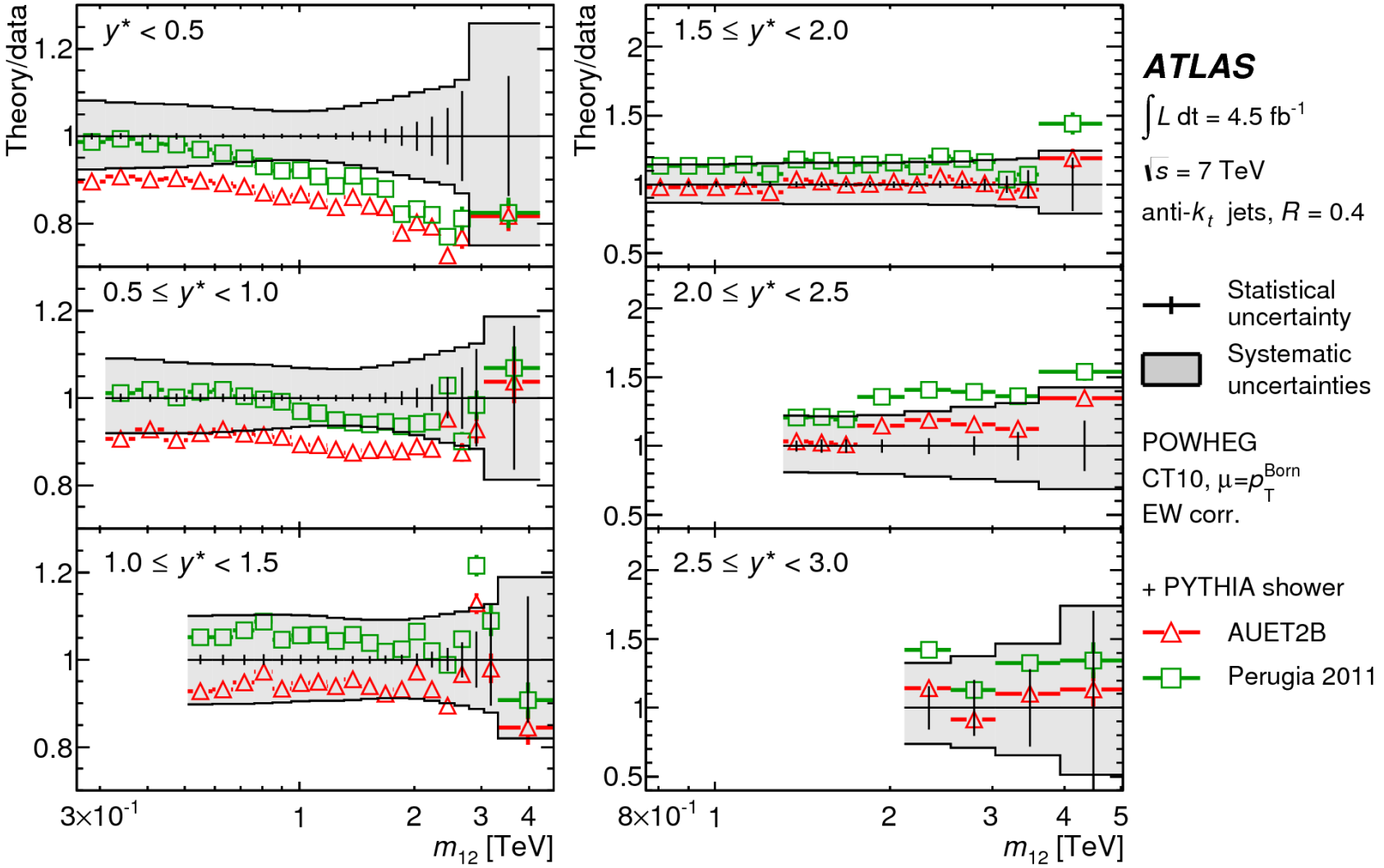
PDF comparisons for 3-jets



- Sensitivity to PDFs
- *More details on sensitivity of ATLAS data to PDFs in talk by Frank ELLINGHAUS*

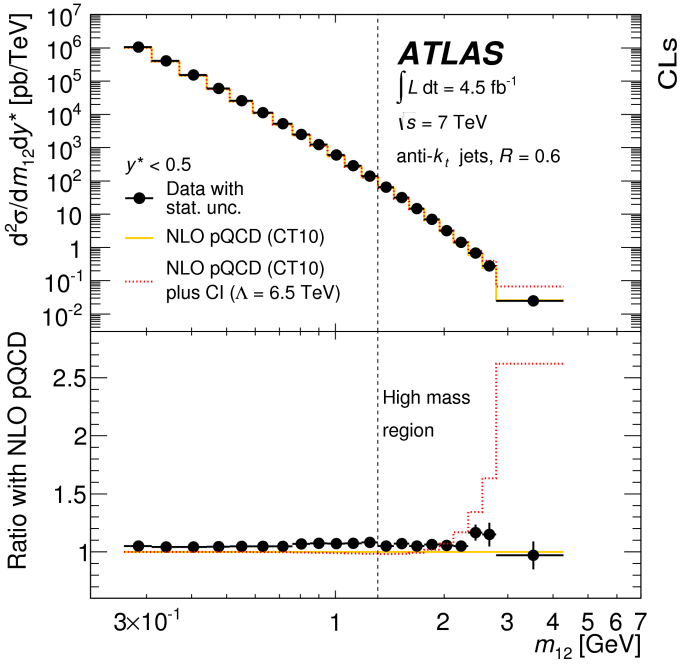
POWHEG comparisons for dijets

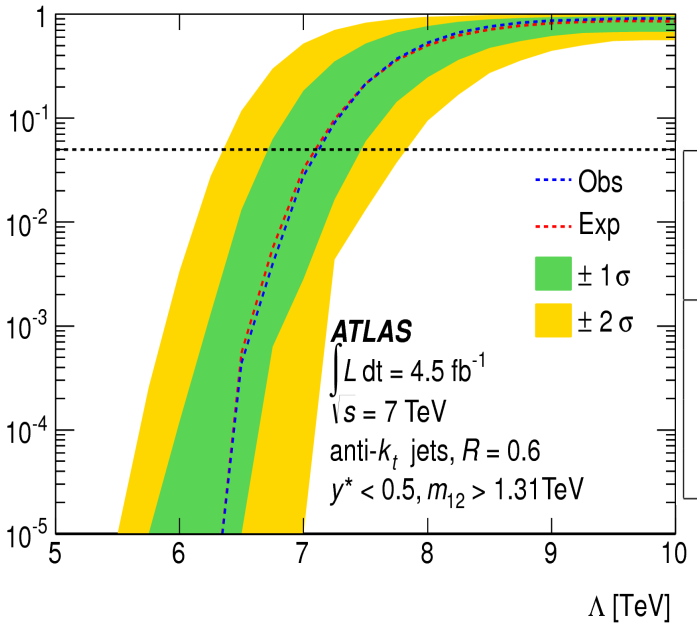
- Comparisons to POWHEG BOX (NLO matrix element + parton shower)
  → Important differences between PYTHIA tunes (smaller for R=0.6)



Limits on New Physics using unfolded distributions

- Explore BSM physics, directly at particle level
- Model of contact interactions (CI) used as example





PDF set	Λ [TeV]			
	$R = 0.4$		$R = 0.6$	
	Exp	Obs	Exp	Obs
CT10	7.3	7.2	7.1	7.1
HERAPDF1.5	7.5	7.7	7.3	7.7
MSTW 2008	7.3	7.0	7.1	6.9
NNPDF2.1	7.3	7.2	7.2	7.0

- Full frequentist analysis (CLs), with generalized χ^2 as test statistic

→ accounts for correlations and asymmetries of uncertainties (stat. & syst.)

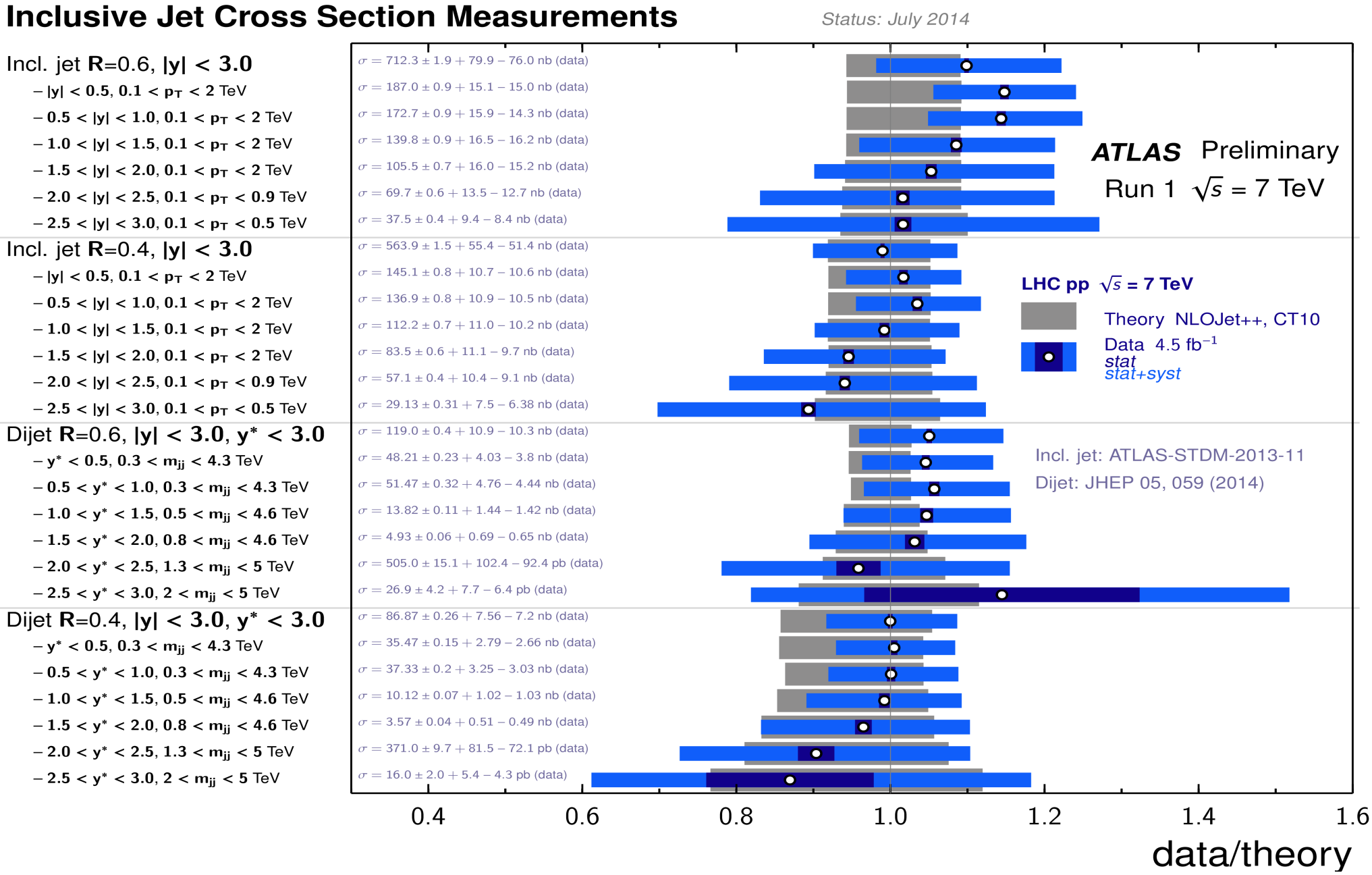
- Limits similar to the ones obtained by dedicated searches (comparing reco-level data with theory predictions folded with detector effects)

Summary and conclusions

- Measurements of inclusive jet p_T, dijet and three-jet mass cross sections performed using full ATLAS datasets at 2.76 and 7 TeV
- Measured cross sections corrected for all detector effects
- Full propagation of (asymmetric) uncertainties and correlations
- ATLAS jet data provide constraints on PDFs and New Physics
- One of the most comprehensive tests of QCD ever made
- More measurements to come at 8 TeV

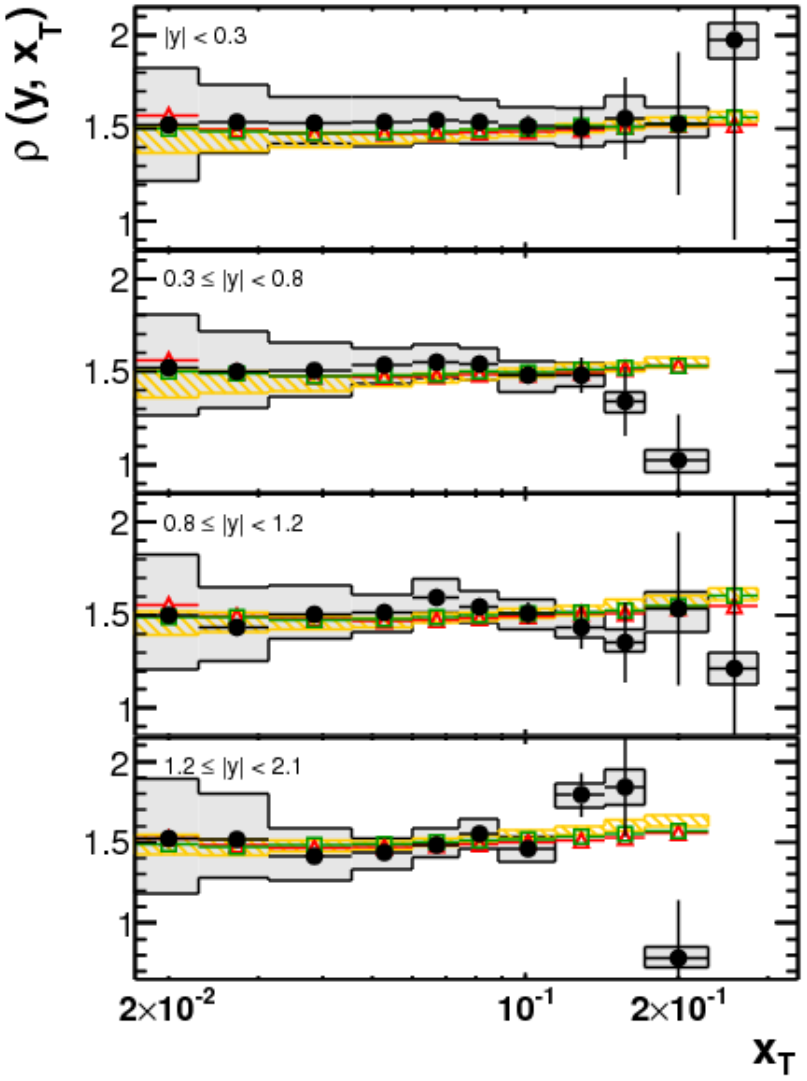
BACKUP

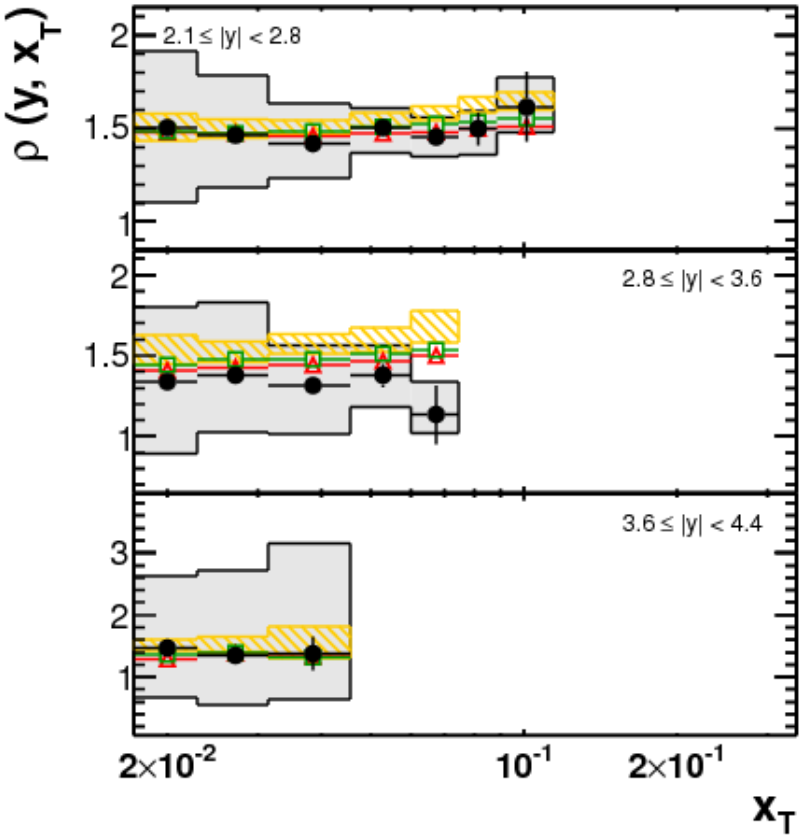
Summary: 7TeV inclusive jets & dijets



Inclusive jet cross sections at √s=2.76 TeV

- Double-differential measurement for R=0.4 and 0.6, compared to the one at 7 TeV: ratio of dimensionless scale-invariant cross-sections





ATLAS

$\int L\,dt = 0.20\ pb^{-1}$

$\rho = \left[\frac{2.76TeV}{7TeV}\right]^3 \frac{\sigma_{jet}^{2.76TeV}}{\sigma_{jet}^{7TeV}}$

anti-k_t R = 0.6

Data with statistical uncertainty

Systematic uncertainties

NLO pQCD ⊗ non-pert. corr. (CT10, $\mu=p_T^{max}$)

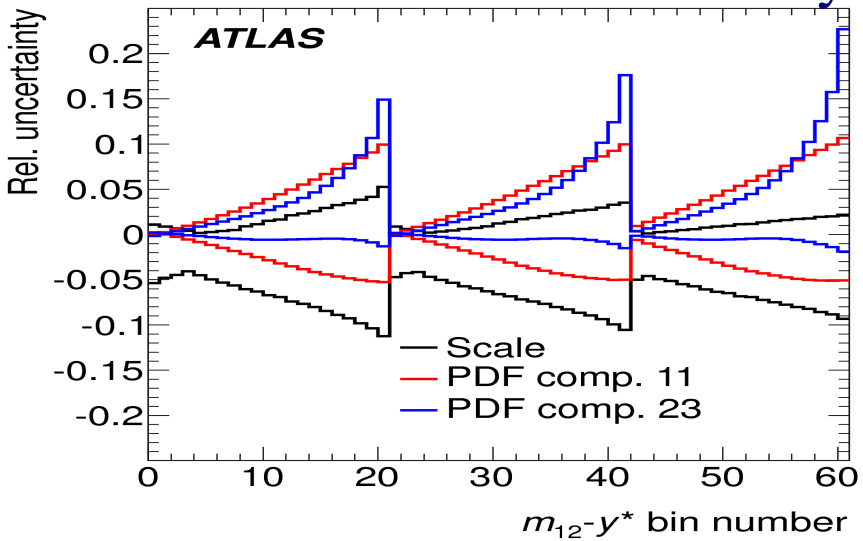
POWHEG ⊗ PYTHIA tune AUET2B (CT10, $\mu=p_T^{Born}$)

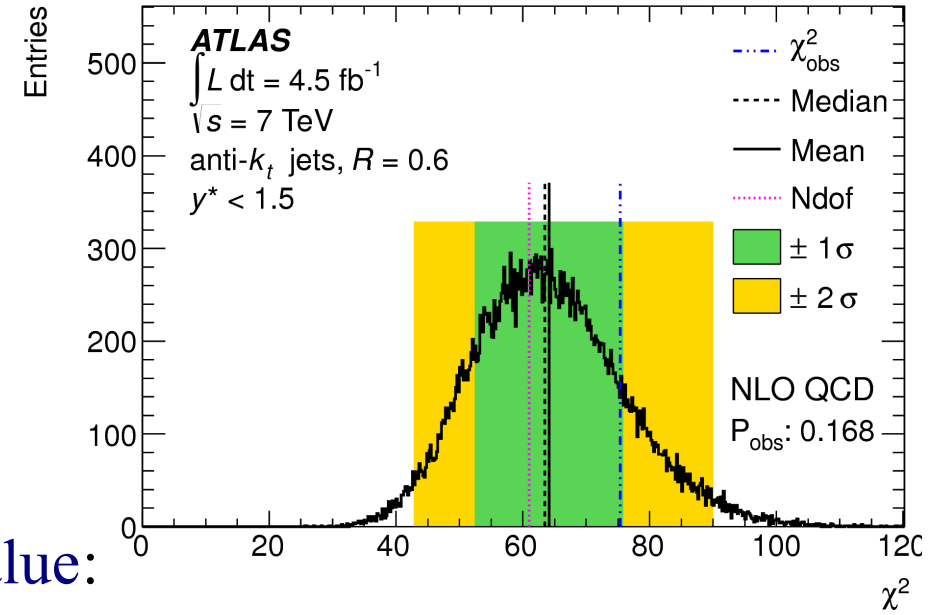
POWHEG ⊗ PYTHIA tune Perugia 2011 (CT10, $\mu=p_T^{Born}$)

Quantitative data/theory comparisons

- Generalized $\chi^2(\mathbf{d};\mathbf{t}) = \min_{\beta_a} \left\{ \sum_{i,j} \left[d_i - \left(1 + \sum_a \beta_a \cdot \left(\epsilon_a^{\pm}(\beta_a) \right)_i \right) t_i \right] \cdot \left[C_{\mathrm{su}}^{-1}(\mathbf{t}) \right]_{ij} \cdot \left[d_j - \left(1 + \sum_a \beta_a \cdot \left(\epsilon_a^{\pm}(\beta_a) \right)_j \right) t_j \right] + \sum_a \beta_a^2 \right\},$

→ accounts for correlations and asymmetries of uncertainties





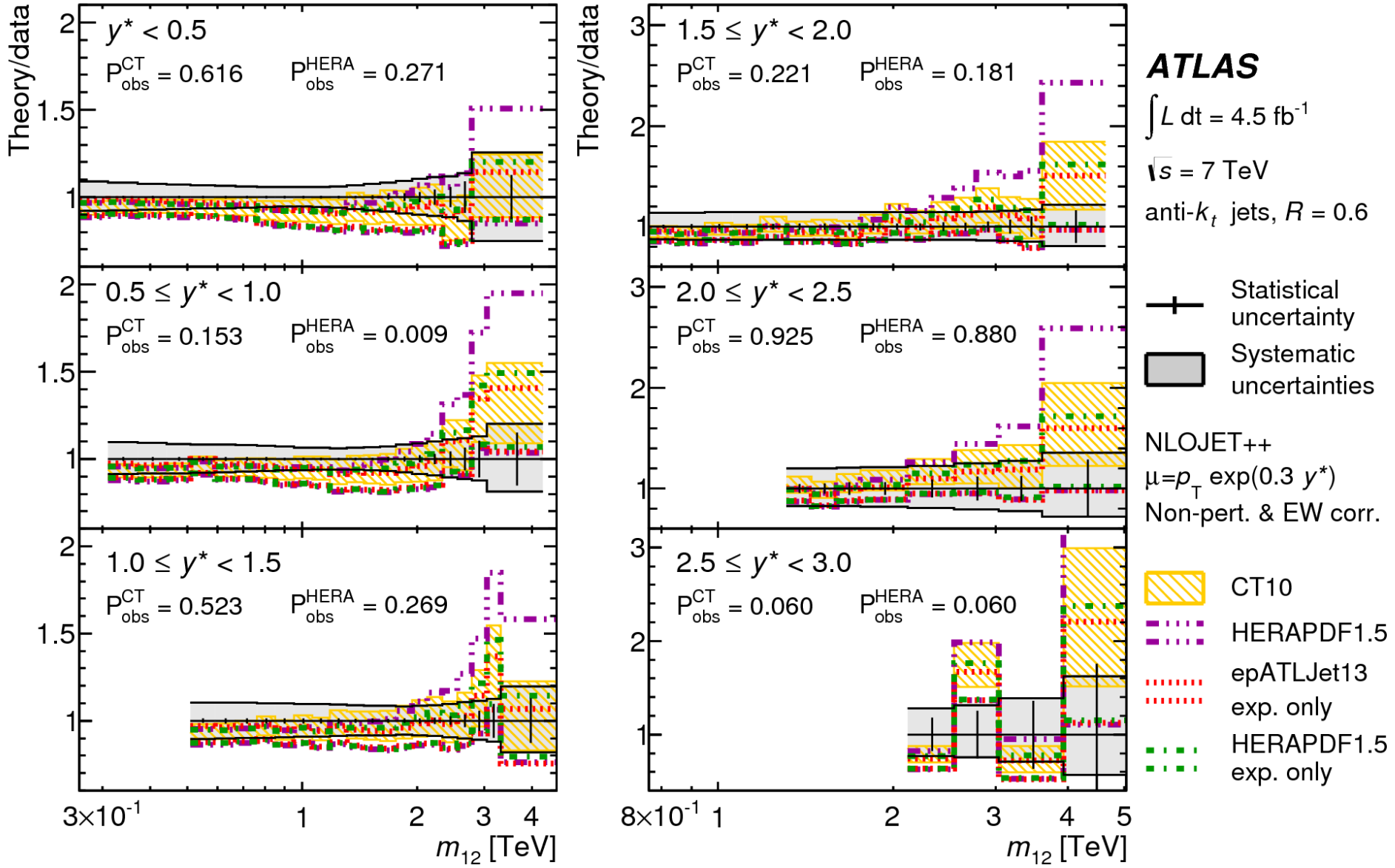
- Using frequentist method to compute p-value:

→ pseudo-experiments from theory prediction, with the full information on the uncertainties: build the generalized χ^2 distribution (no assumption needed)

→ observed χ^2 from the data/theory comparison

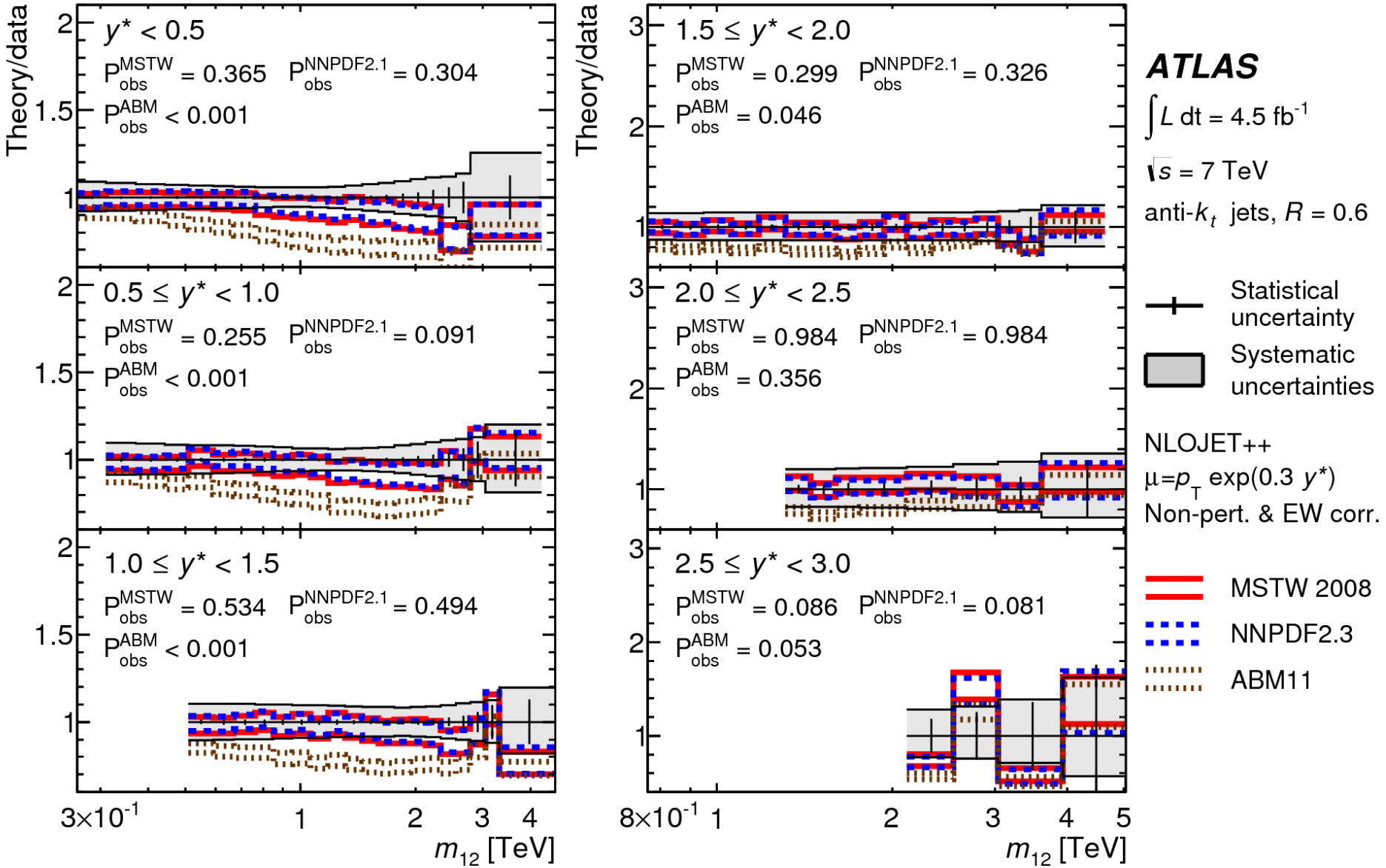
PDF comparisons for dijets, R=0.6

- Comparisons to CT10 and HERAPDF1.5



PDF comparisons for dijets, R=0.6

- Comparisons to MSTW2008, NNPDF2.3 and ABM11



POWHEG comparisons for dijets, R=0.6

- Comparisons to POWHEG BOX (NLO matrix element + parton shower)
  → Smaller differences between PYTHIA tunes, compared to R=0.4