



Recent QCD Results at ATLAS

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on behalf of the ATLAS Collaboration



Outline



A selection of recent ATLAS QCD results:

- total proton-proton cross section
- underlying event characteristics
- inclusive single and 3-jet cross sections
- direct photon production



Large Hadron Collider



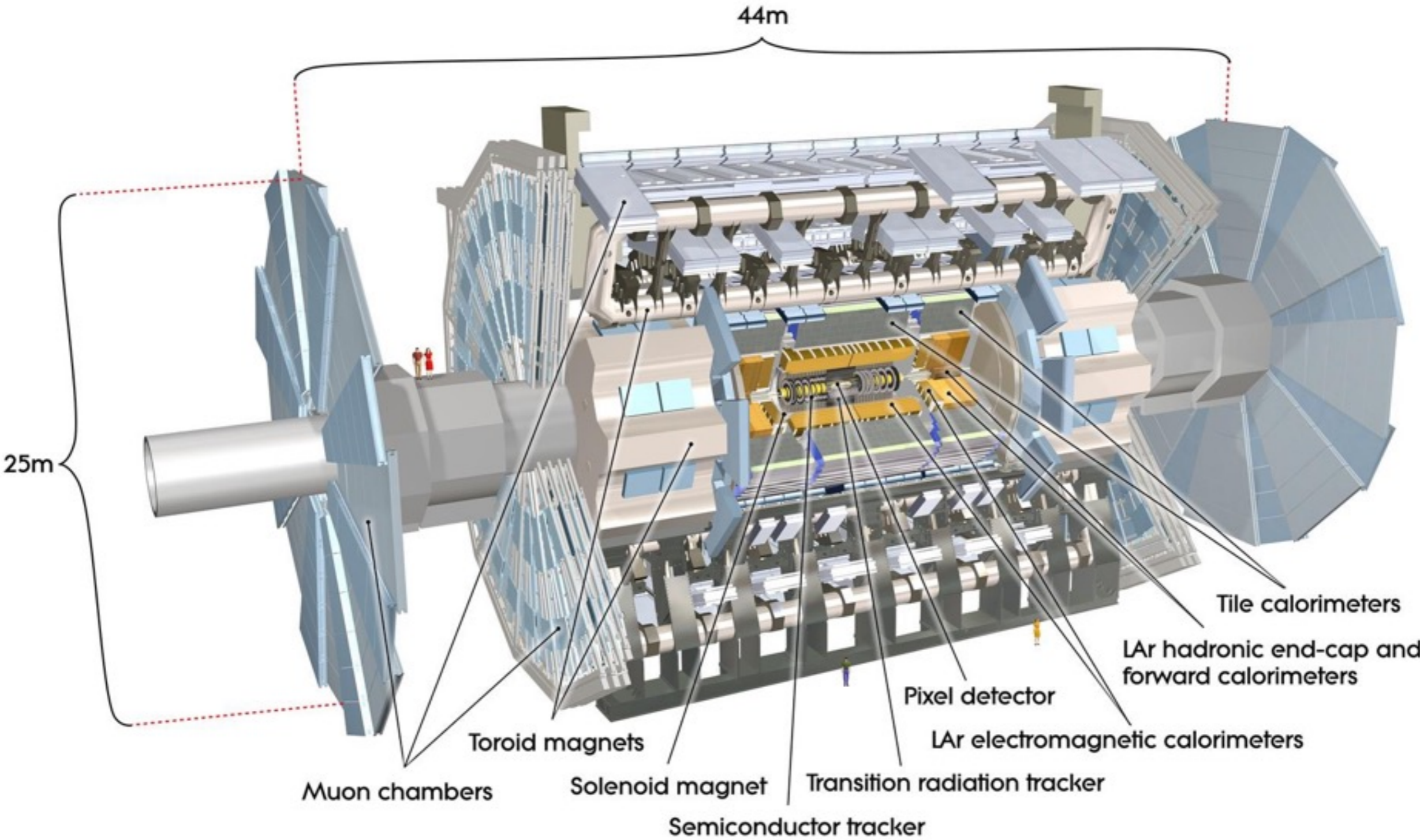
Running Periods:

- 2010 special run
- 2011 7 TeV with 4.5 fb^{-1}

8 TeV analysis in progress

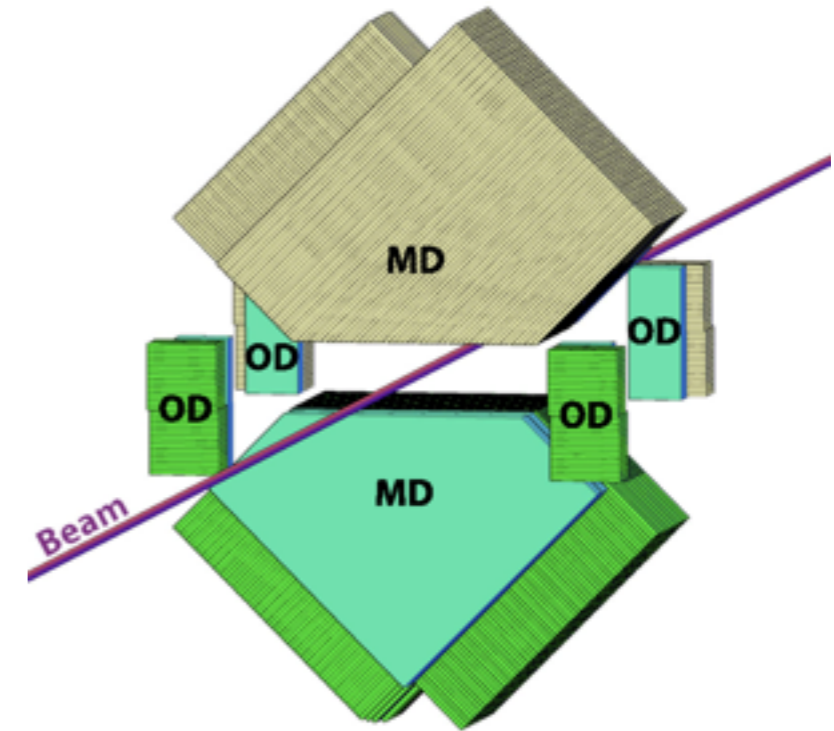
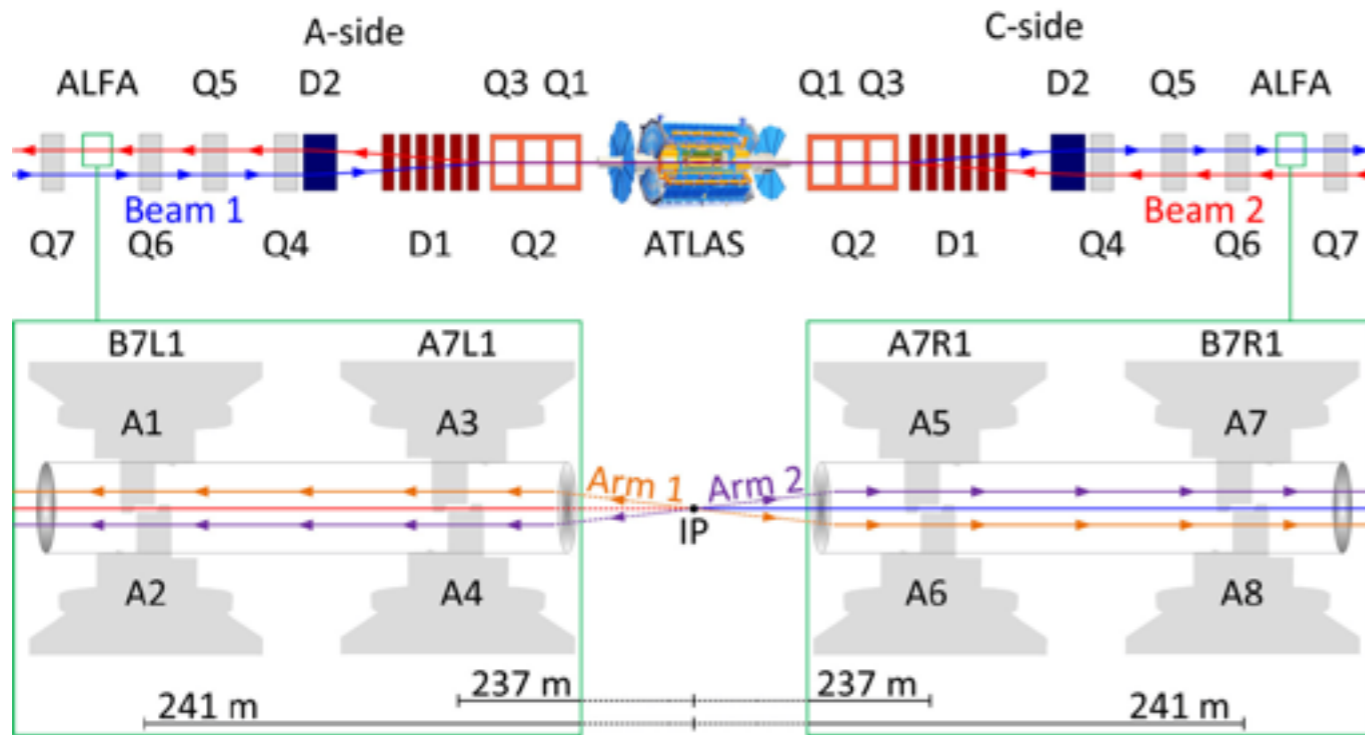


ATLAS Detector



Total Cross Section

Nuclear Physics, Section B (2014), pp. 486-548



Special run with:

beam optics $\beta^* = 90 \text{ m}$

luminosity $80 \mu\text{b}$

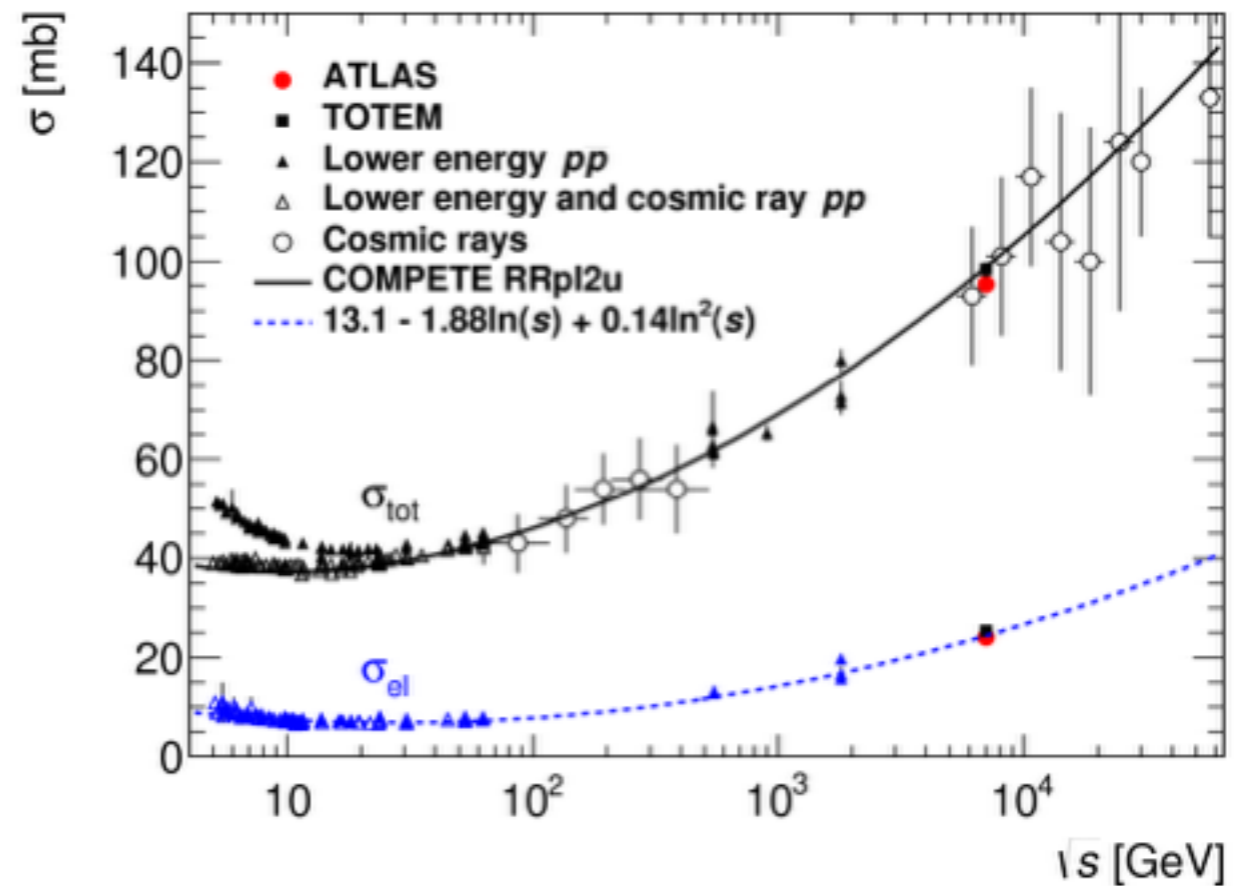
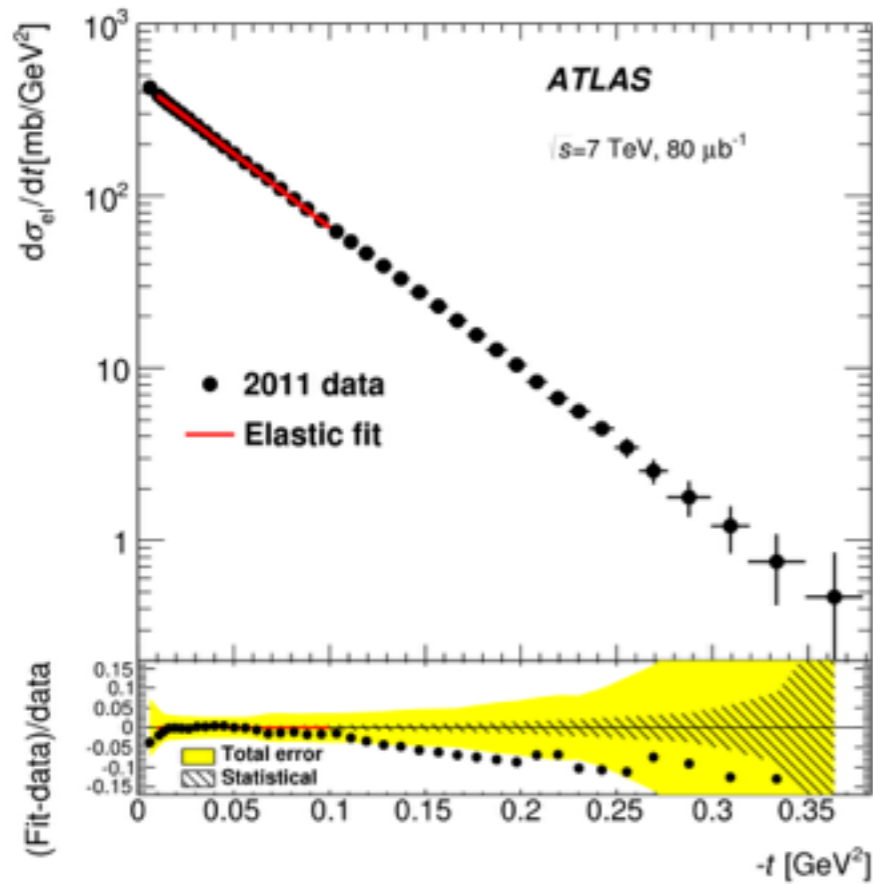
ALFA spectrometer:

1280 scintillator fibres

resolution $30 - 35 \mu\text{m}$

measure θ to extract t : $-t = (\theta^* \times p)^2$,

Total Cross Section



$$\frac{d\sigma}{dt} = \frac{4\pi\alpha^2(\hbar c)^2}{|t|^2} \times G^4(t) - \sigma_{\text{tot}} \times \frac{\alpha G^2(t)}{|t|} [\sin(\alpha\phi(t)) + \rho \cos(\alpha\phi(t))] \times \exp\left(\frac{-B|t|}{2}\right) + \sigma_{\text{tot}}^2 \frac{1 + \rho^2}{16\pi(\hbar c)^2} \times \exp(-B|t|),$$

Coulomb

Coulomb-nuclear interference

hadronic interaction

Elastic fit

$$\sigma_{\text{tot}} = 95.35 \pm 1.30 \text{ mb},$$

$$B = 19.73 \pm 0.24 \text{ GeV}^{-2},$$

exclude Coulomb and interference terms

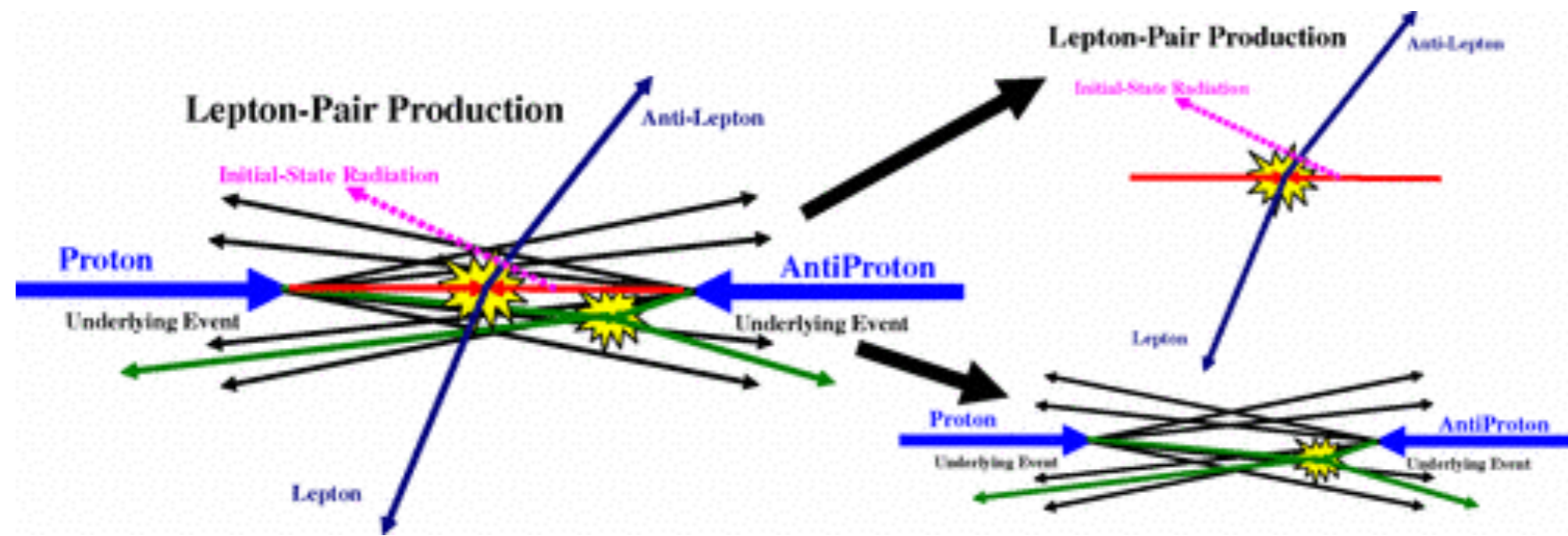
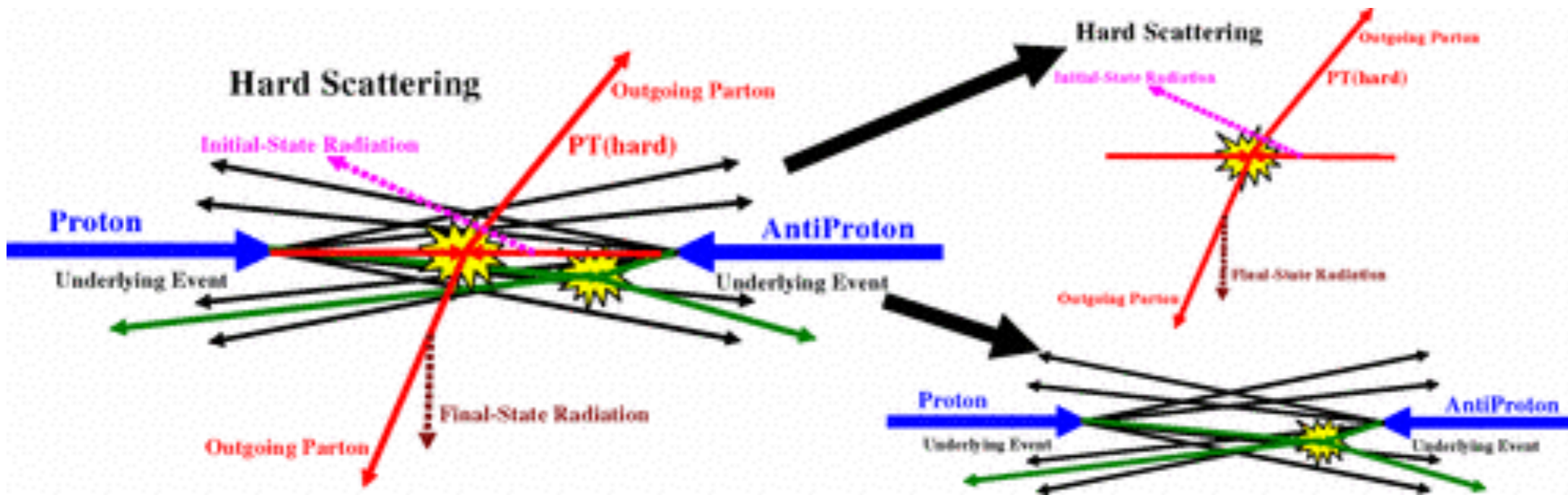
$$\sigma_{\text{el}}(pp \rightarrow pp) = 24.00 \pm 0.19 \text{ (stat.)} \pm 0.57 \text{ (syst.) mb},$$

$$\sigma_{\text{inel}} = 71.34 \pm 0.36 \text{ (stat.)} \pm 0.83 \text{ (syst.) mb},$$



Underlying Event with Z-boson Events

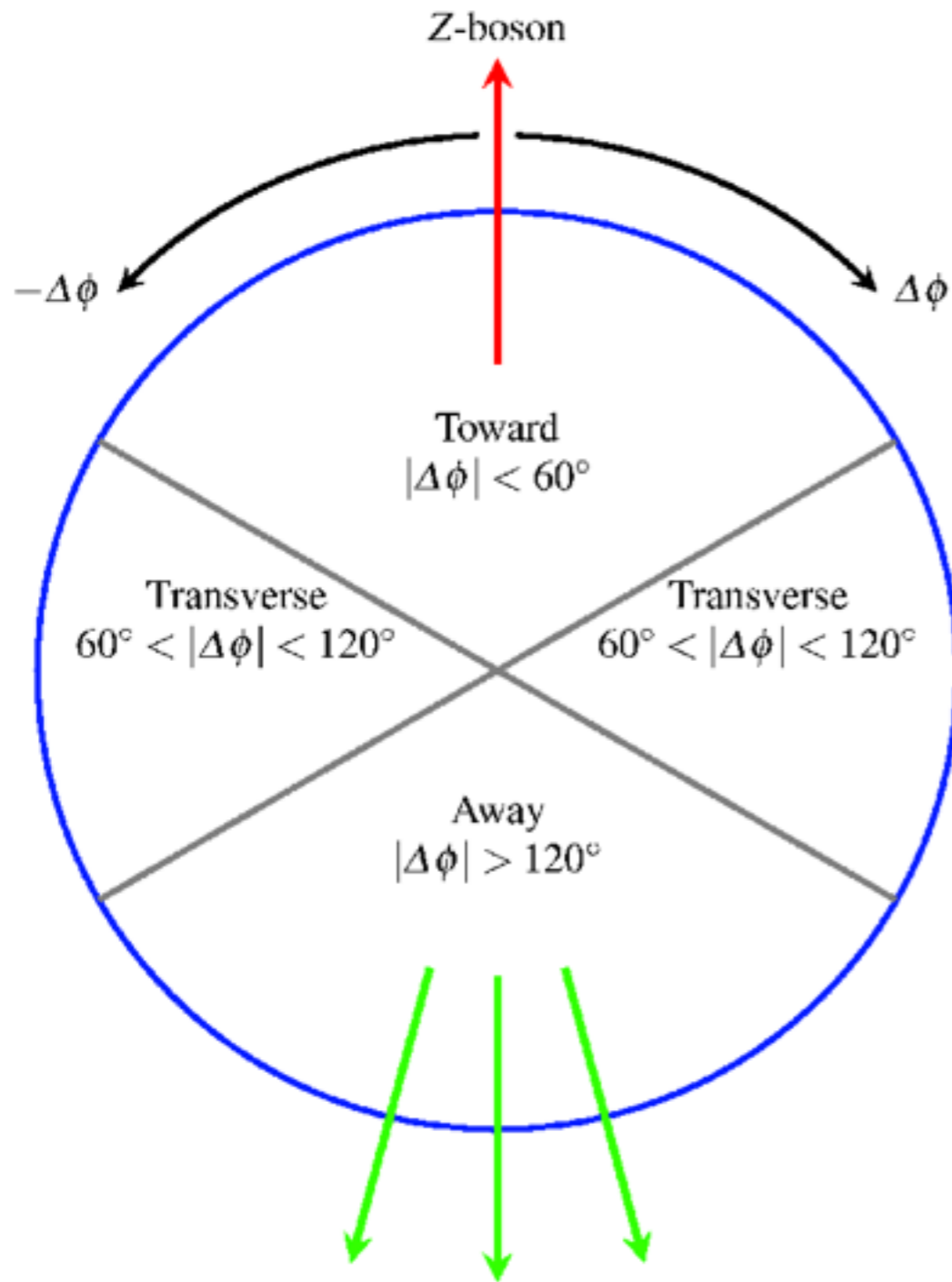
arXiv:1409.3433



(images from PhysRevD.82.034001)



Underlying Event with Z-boson Events



| Observable | Definition |
|------------------------------------|---|
| p_T^Z | Transverse momentum of the Z-boson |
| $N_{ch}/\delta\eta \delta\phi$ | Number of stable charged particles per unit $\eta-\phi$ |
| $\Sigma p_T/\delta\eta \delta\phi$ | Scalar p_T sum of stable charged particles per unit $\eta-\phi$ |
| Mean p_T | Average p_T of stable charged particles |

Also:

trans-max (min) = transverse side with max (min) activity.

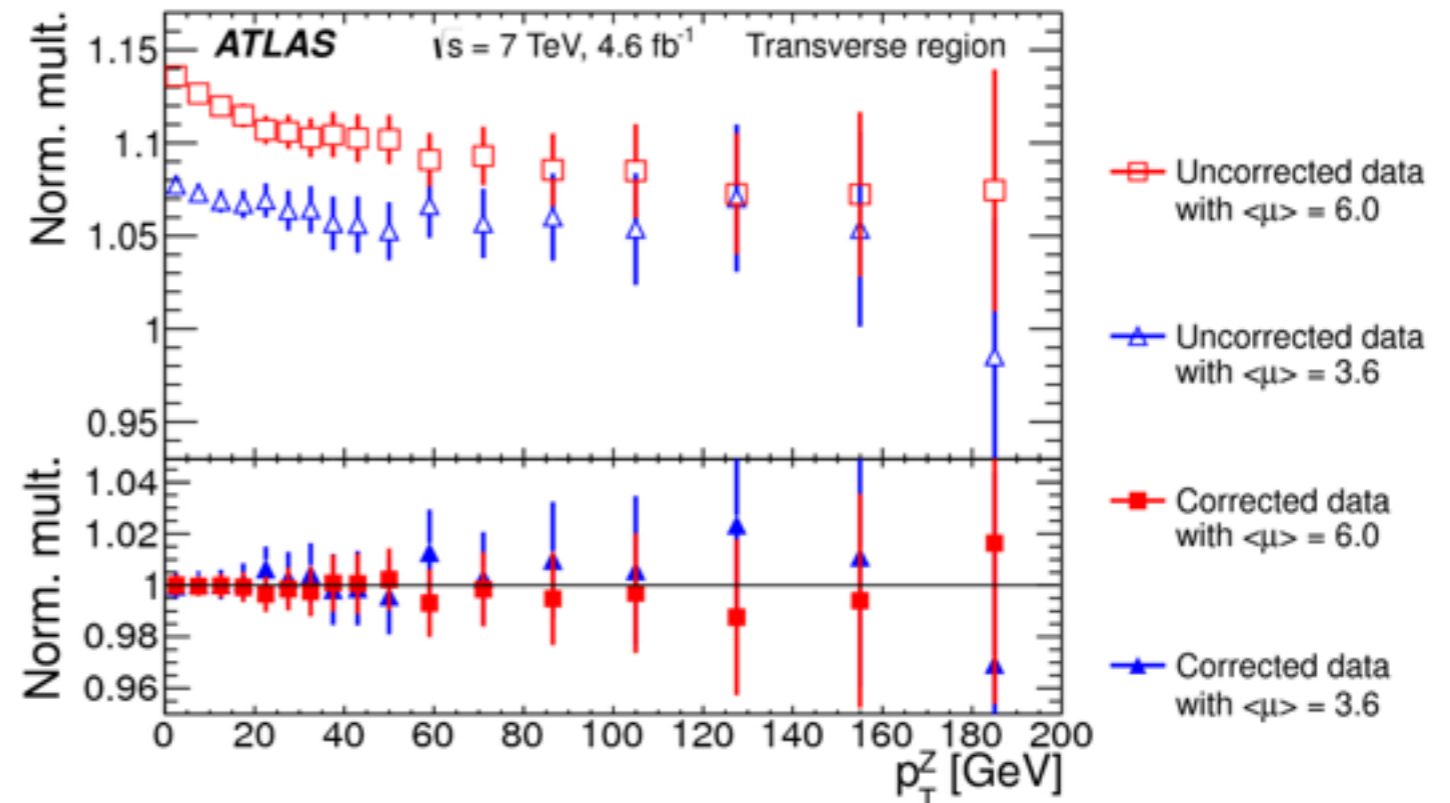
(only tracks with $p_T > 0.5 \text{ GeV}$ and $|\eta| < 2.5$ considered)

Underlying Event with Z-boson Events

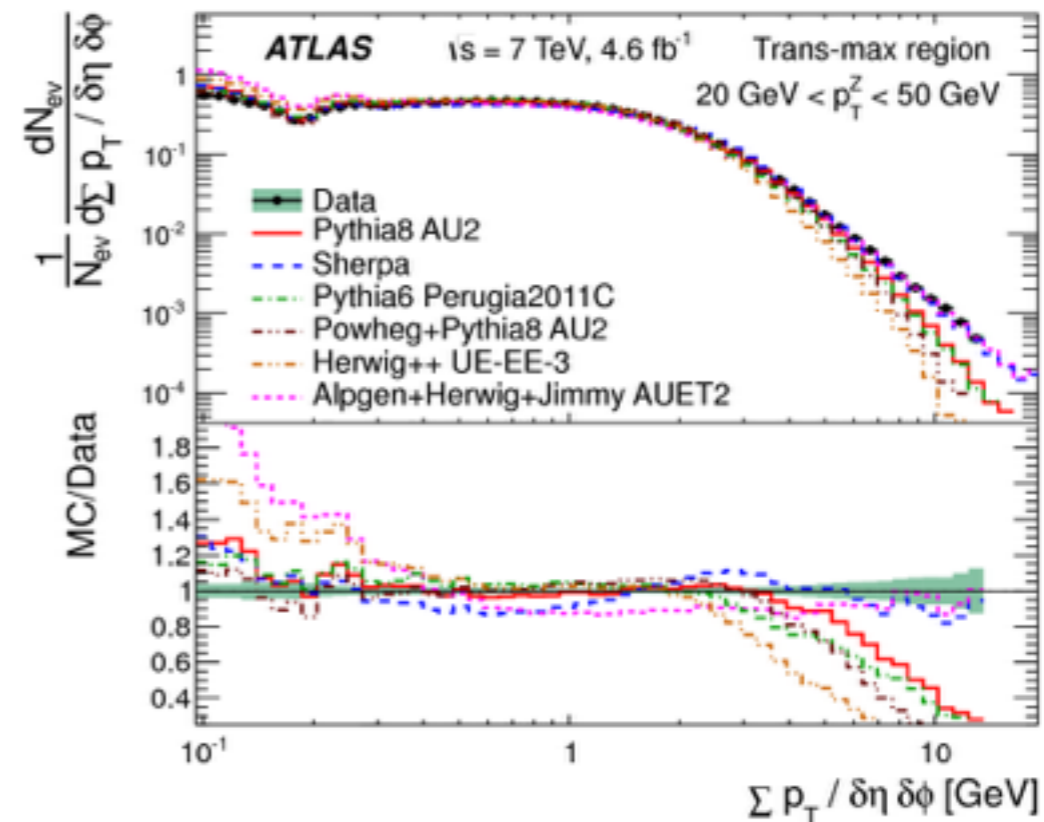
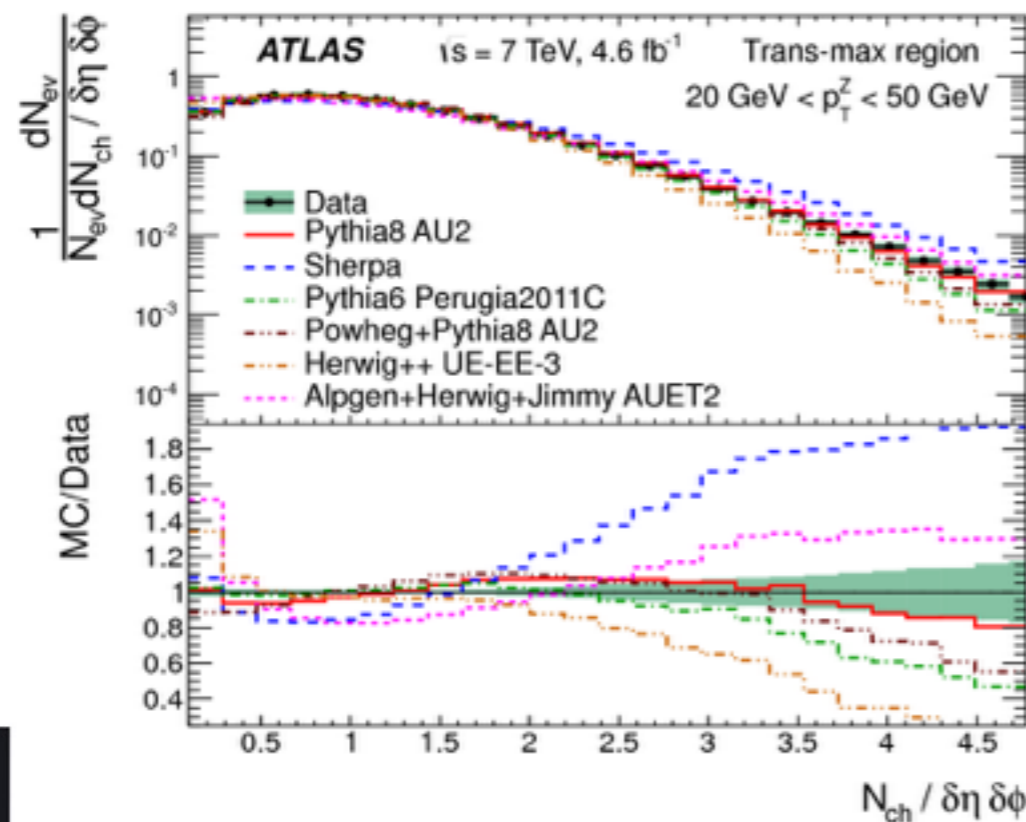
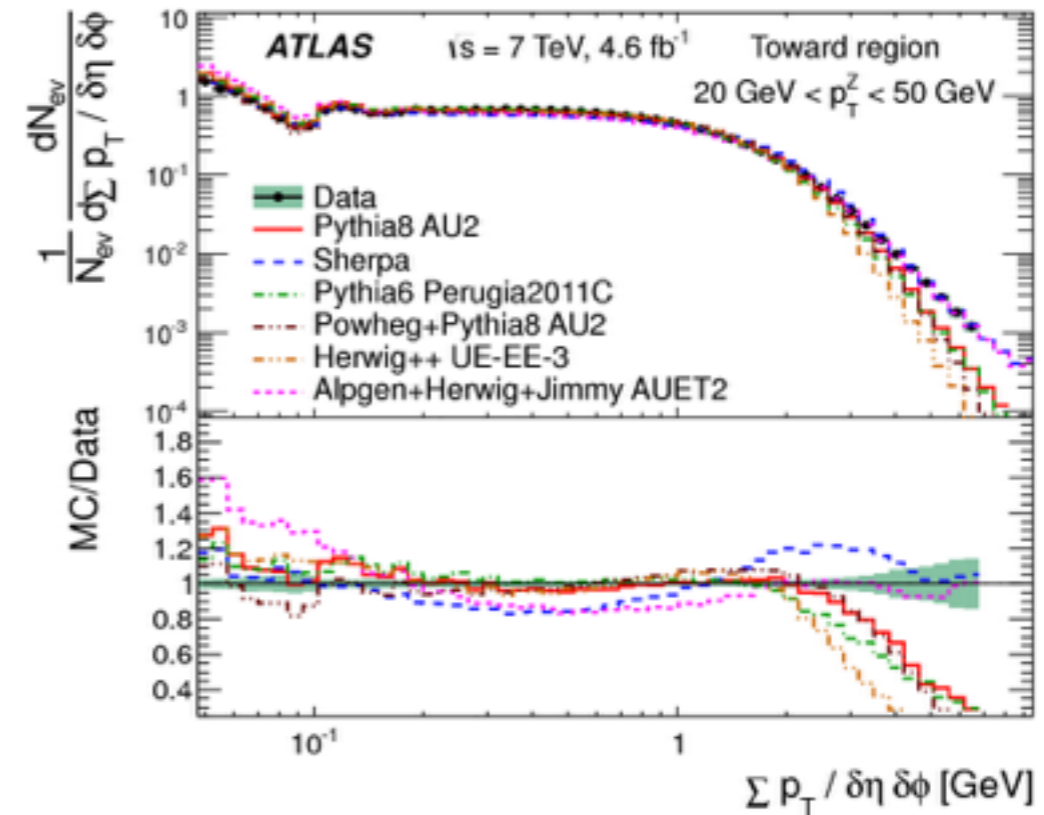
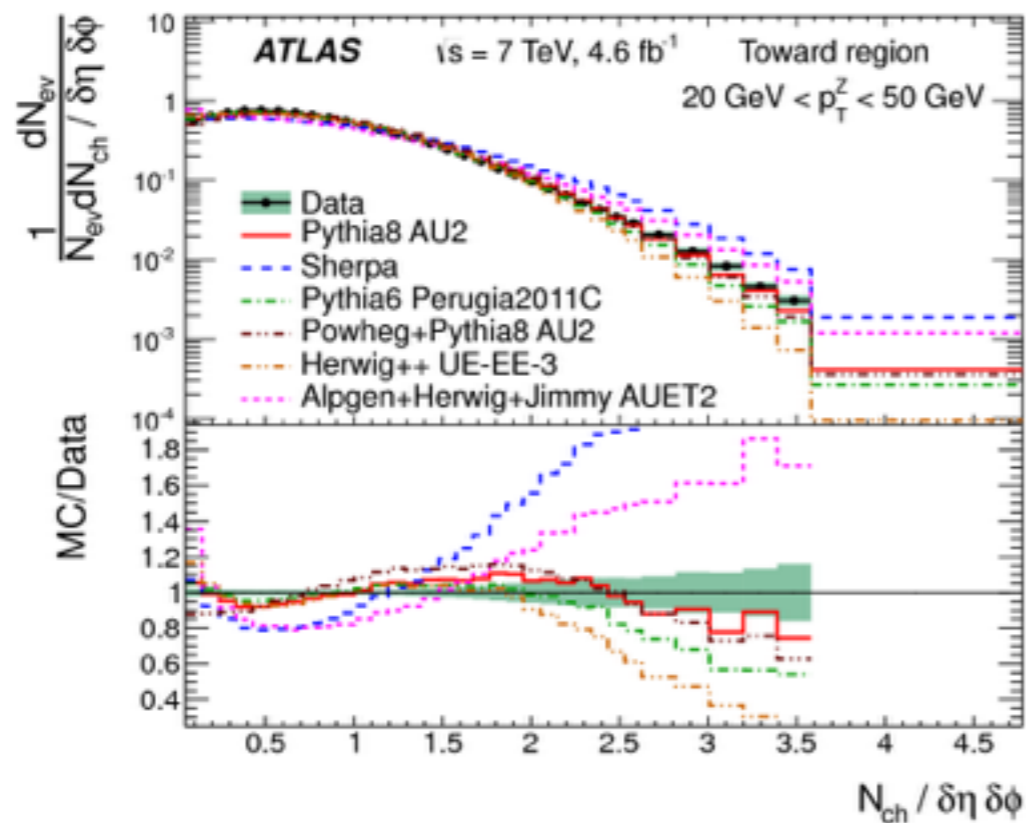
| Generator | Type | Version | PDF | Tune |
|------------------------------|---------------------------------------|-----------------------|----------------------|-------------------|
| PYTHIA 6 | LO PS | 6.425 | CTEQ6L1 [29] | Perugia2011C [30] |
| PYTHIA 8 | LO PS | 8.165 | CTEQ6L1 | AU2 [31] |
| HERWIG++ | LO PS | 2.5.1 | MRST LO** [32] | UE-EE-3 [33] |
| Sherpa | LO multi-leg ME + PS | 1.4.0 /1.3.1 | CT10 [34] | Default |
| ALPGEN + HERWIG +JIMMY | LO multi-leg ME + PS (adds MPI) | 2.14 6.520 4.31 | CTEQ6L1 MRST LO** | AUET2 [35] |
| POWHEG + PYTHIA 8 | NLO ME + PS | - 8.165 | CT10 CT10 | AU2 |

Generators Compared

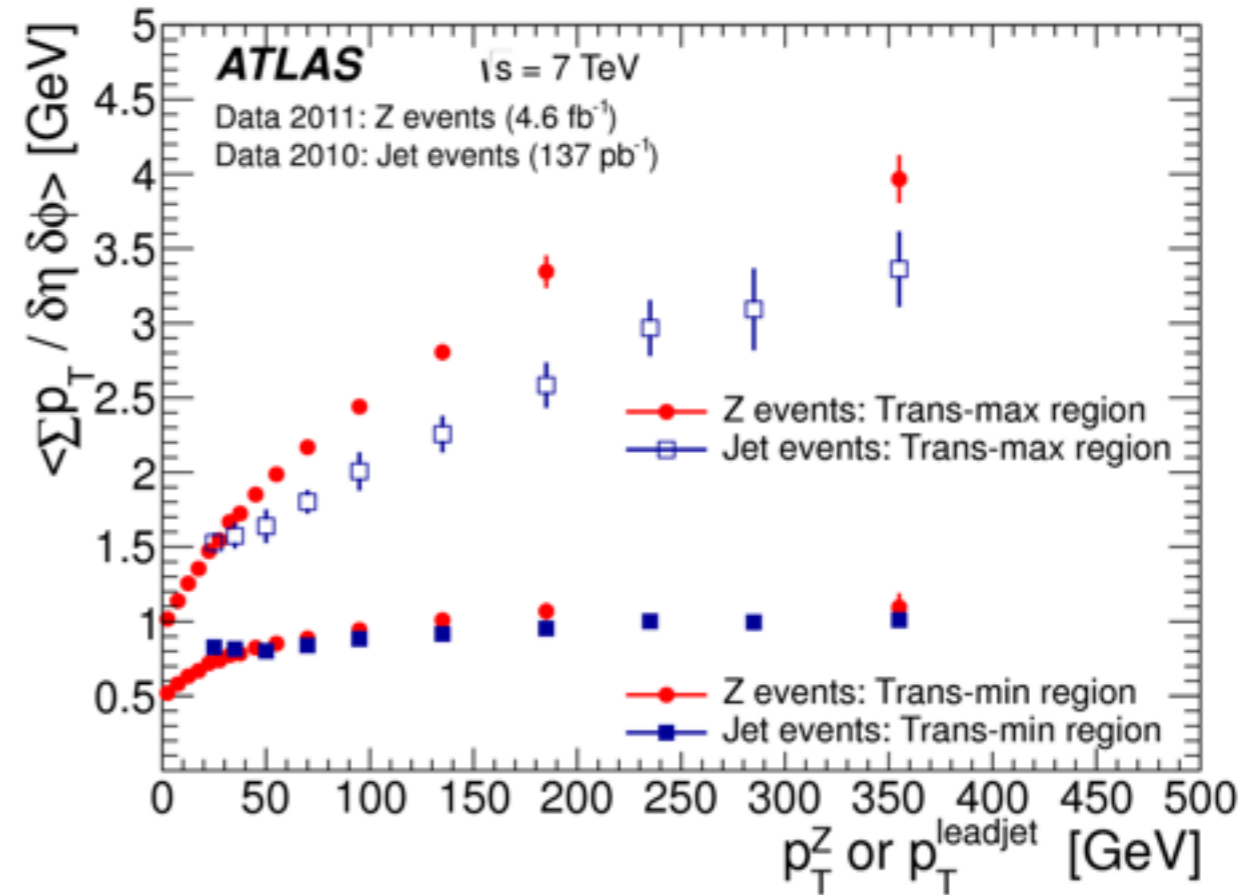
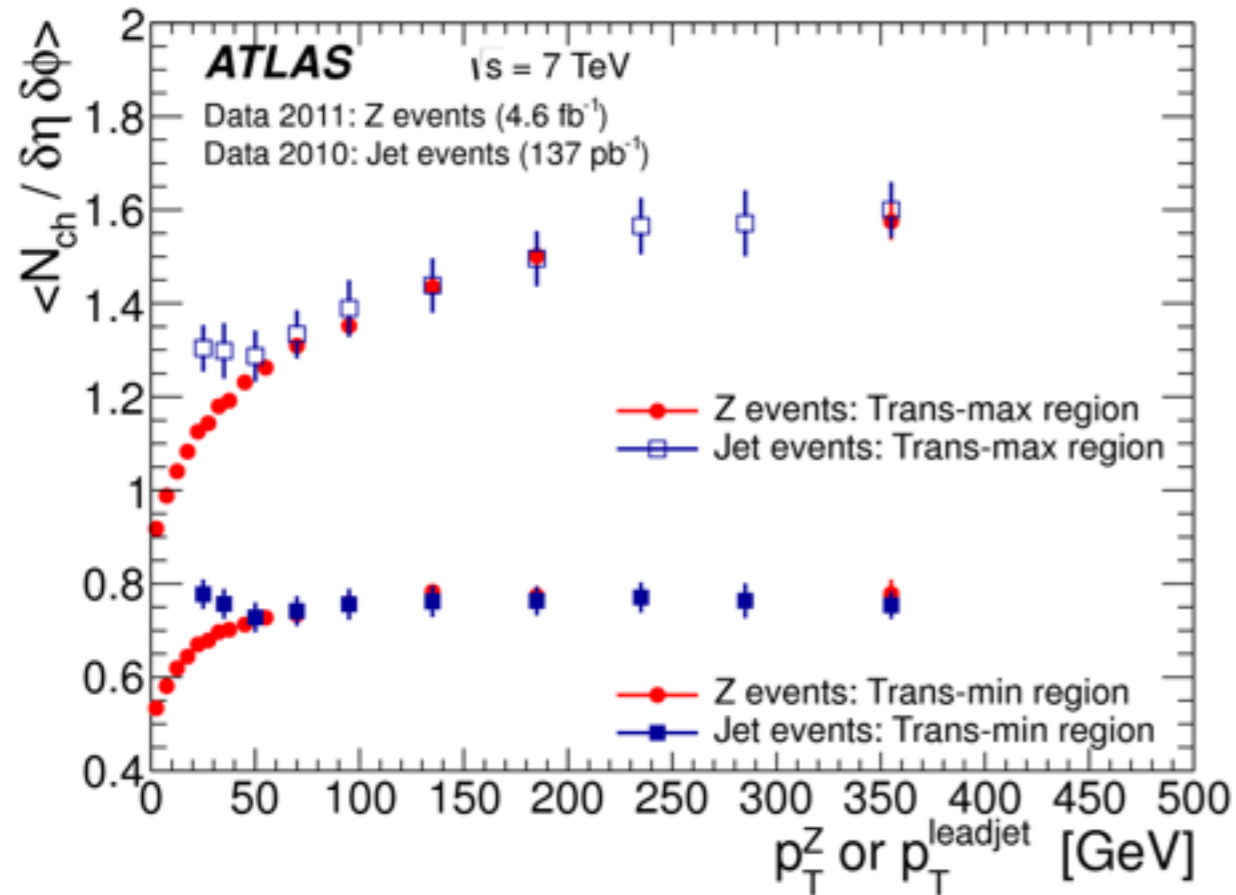
Pile-up Corrections



Underlying Event with Z-boson Events



Underlying Event with Z-boson Events



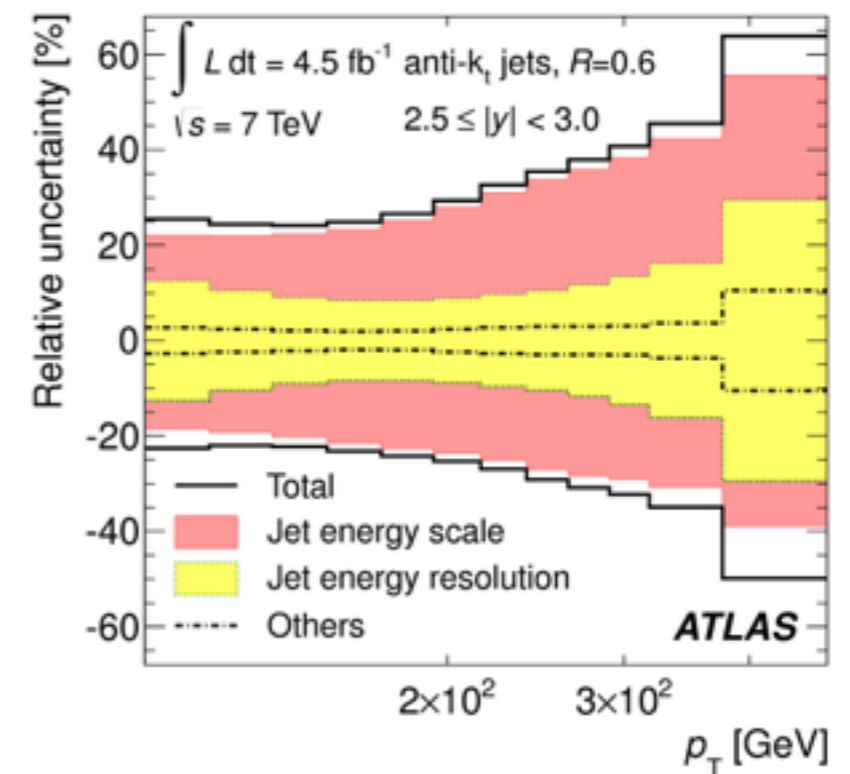
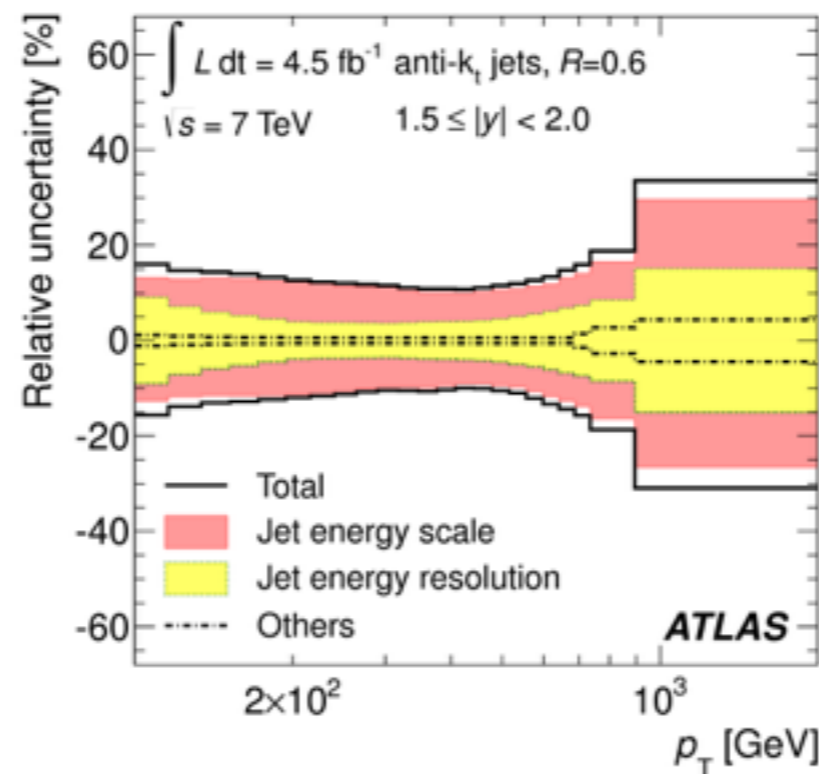
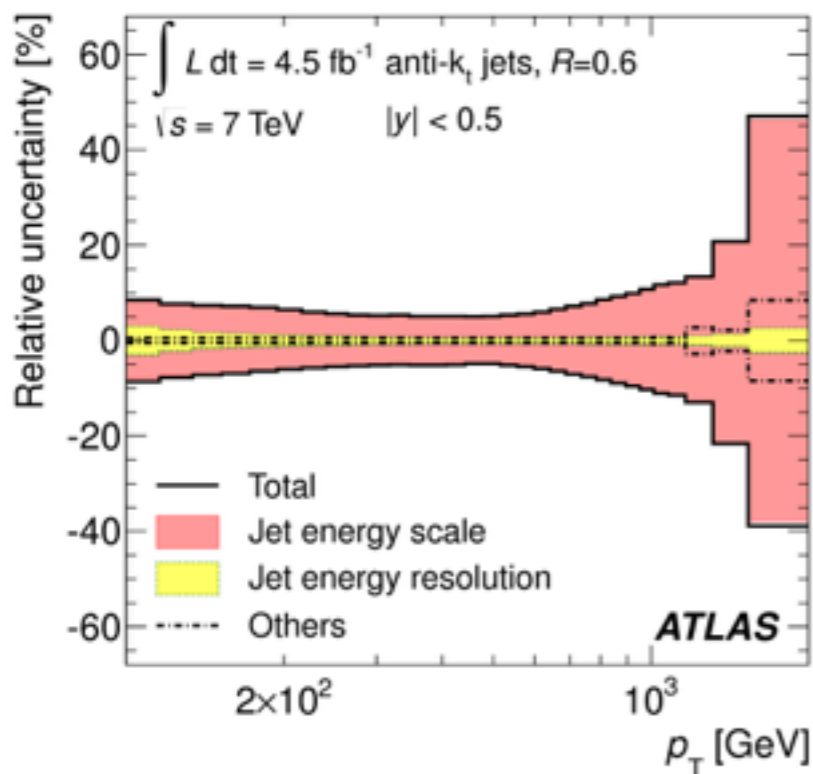
Inclusive Jet Cross Section

arxiv:1410.8857

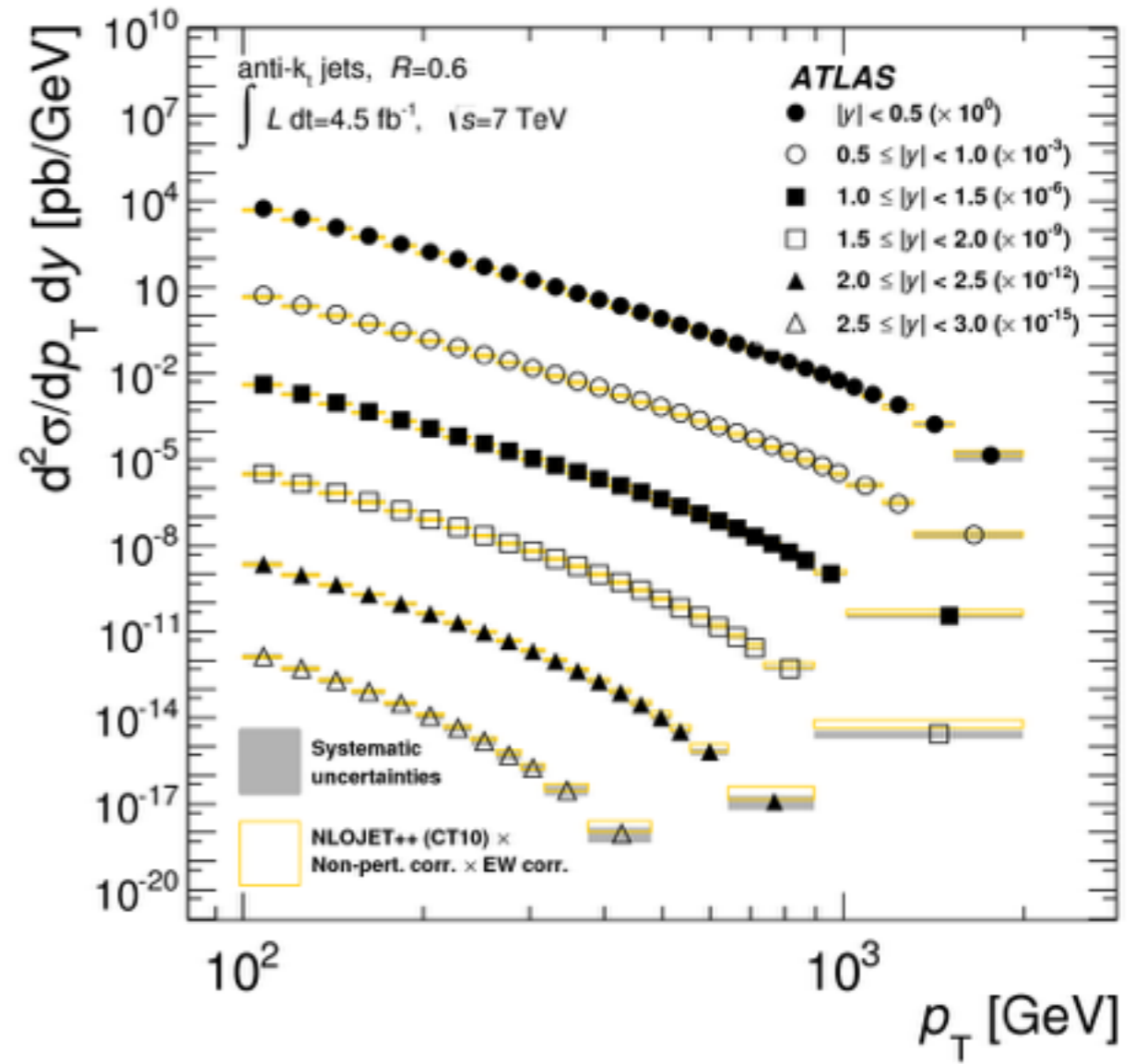
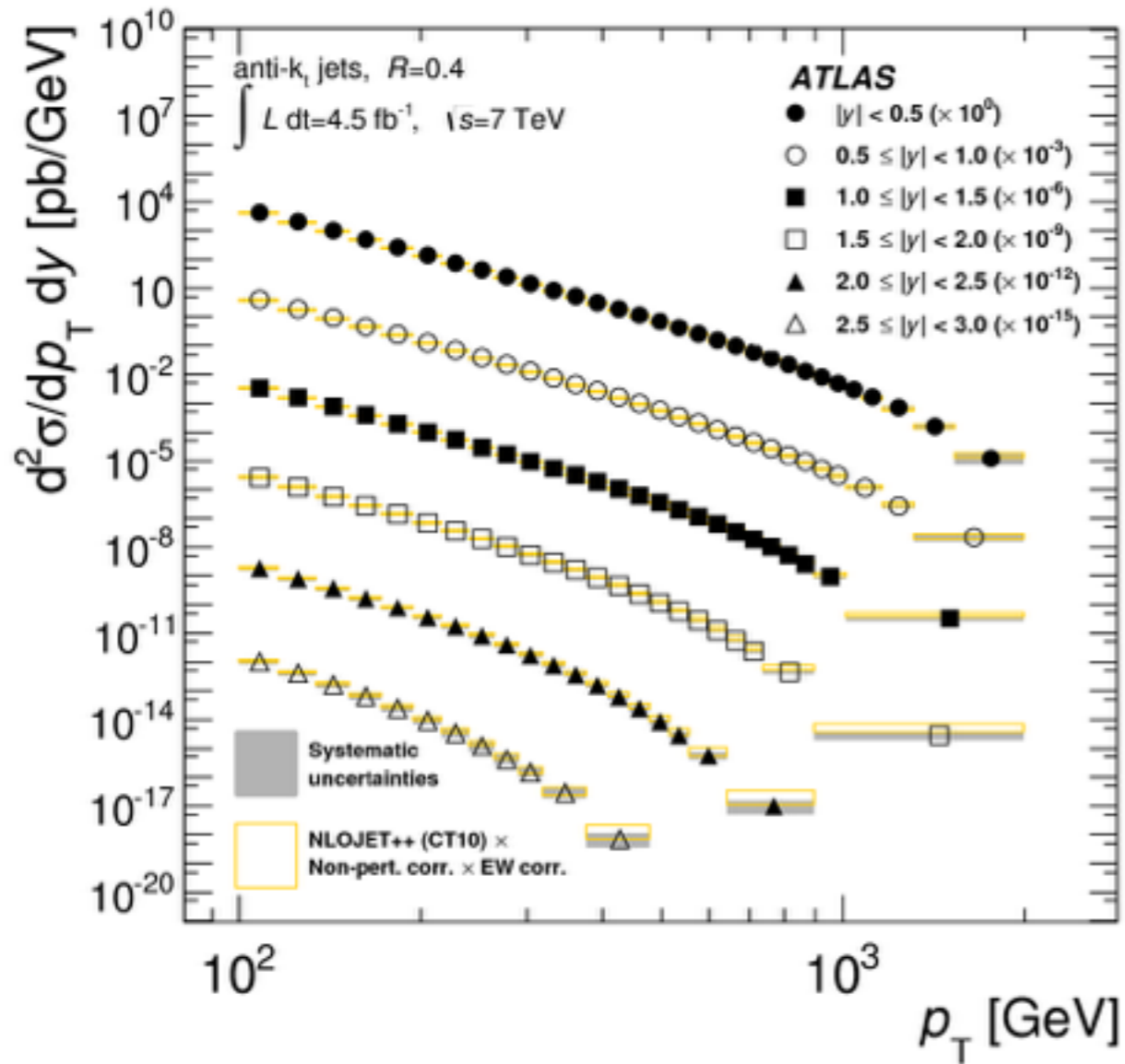


A test of next-to-leading order QCD calculations with non-pQCD and EWK corrections

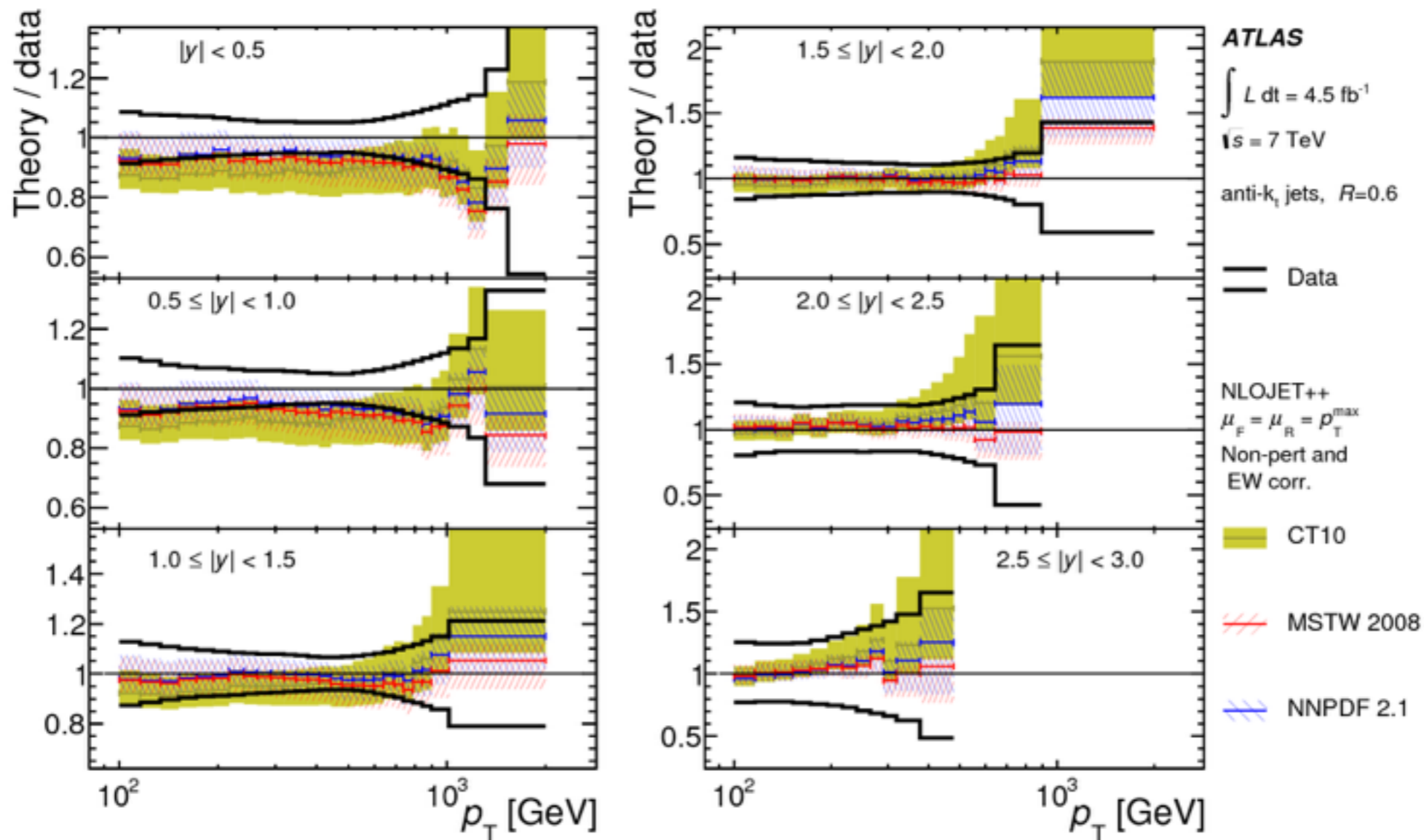
Dominated by jet energy scale uncertainties.



Inclusive Jet Cross Section



Inclusive Jet Cross Section



generators:

NLOJET++ (shown here)
 POWHEG+PYTHIA (see paper)

PDF sets:

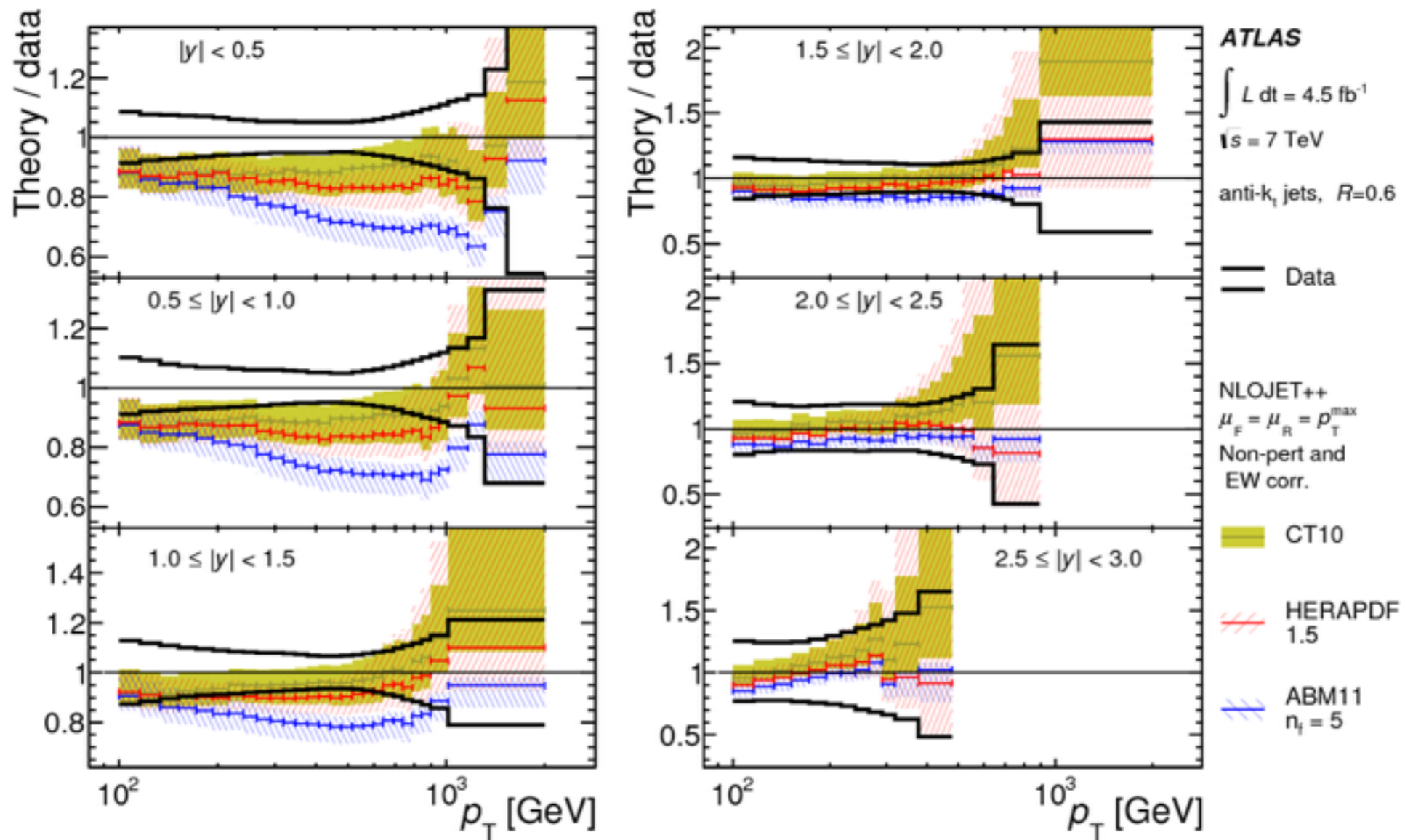
CT10, MSTW2008, NNPDF2.1,

general agreement shown

(see paper for POWHEG+PYTHIA and $R=0.4$ results)



Inclusive Jet Cross Section



generators:

NLOJET++ (shown here)
 POWHEG+PYTHIA (see paper)

PDF sets:

HERAPDF1.5, and ABM11

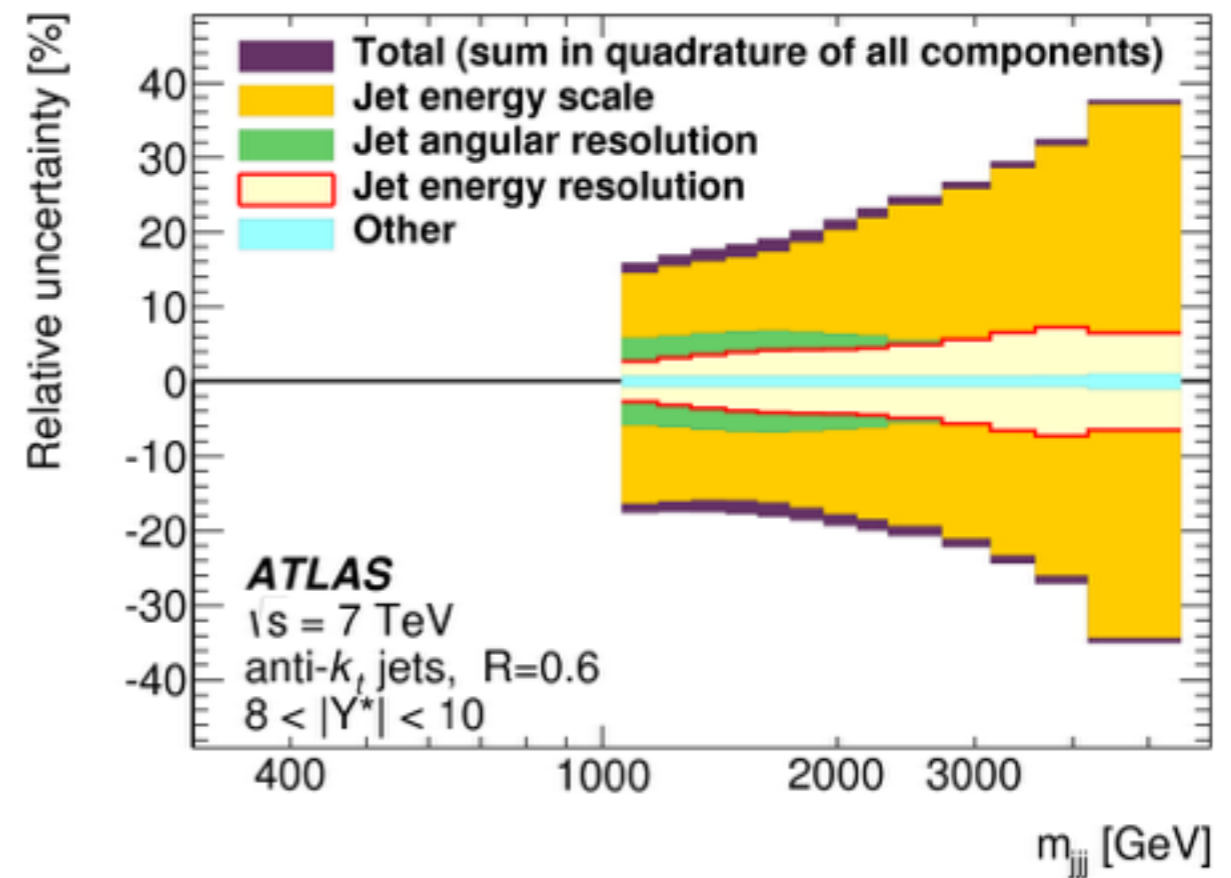
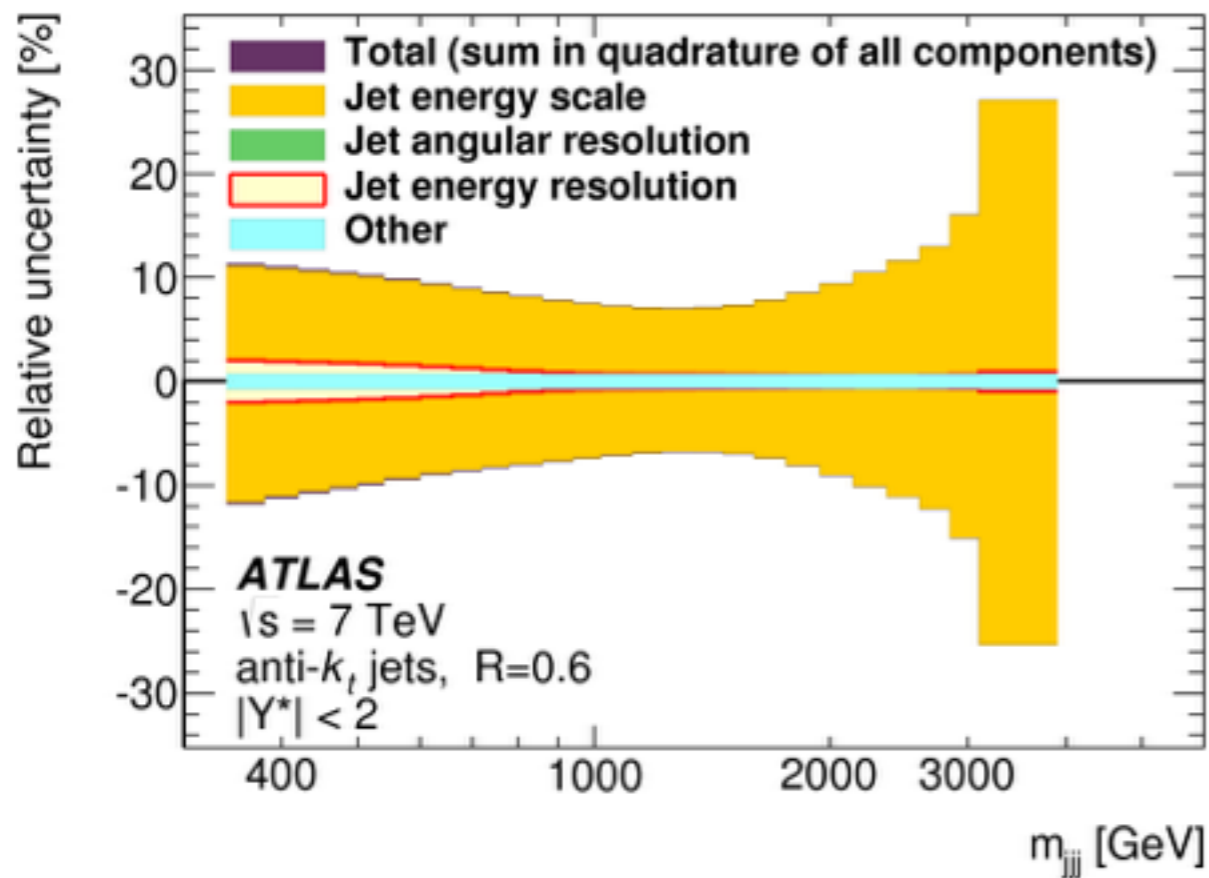
some disagreement shown in mid- p_T region

Three-Jet Cross Section

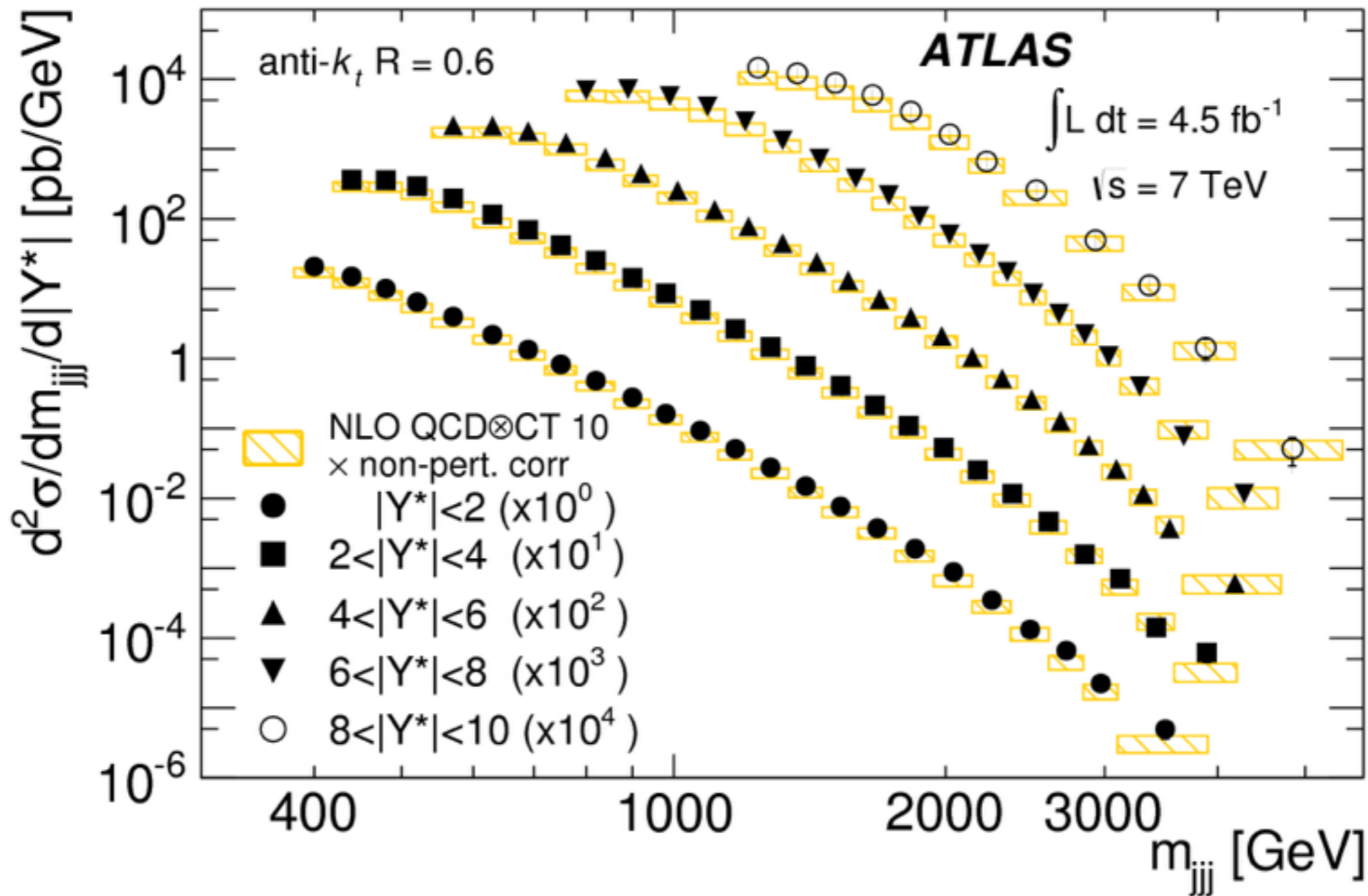
arxiv:1411.1855v1



Again, jet energy scale is the dominant uncertainty.

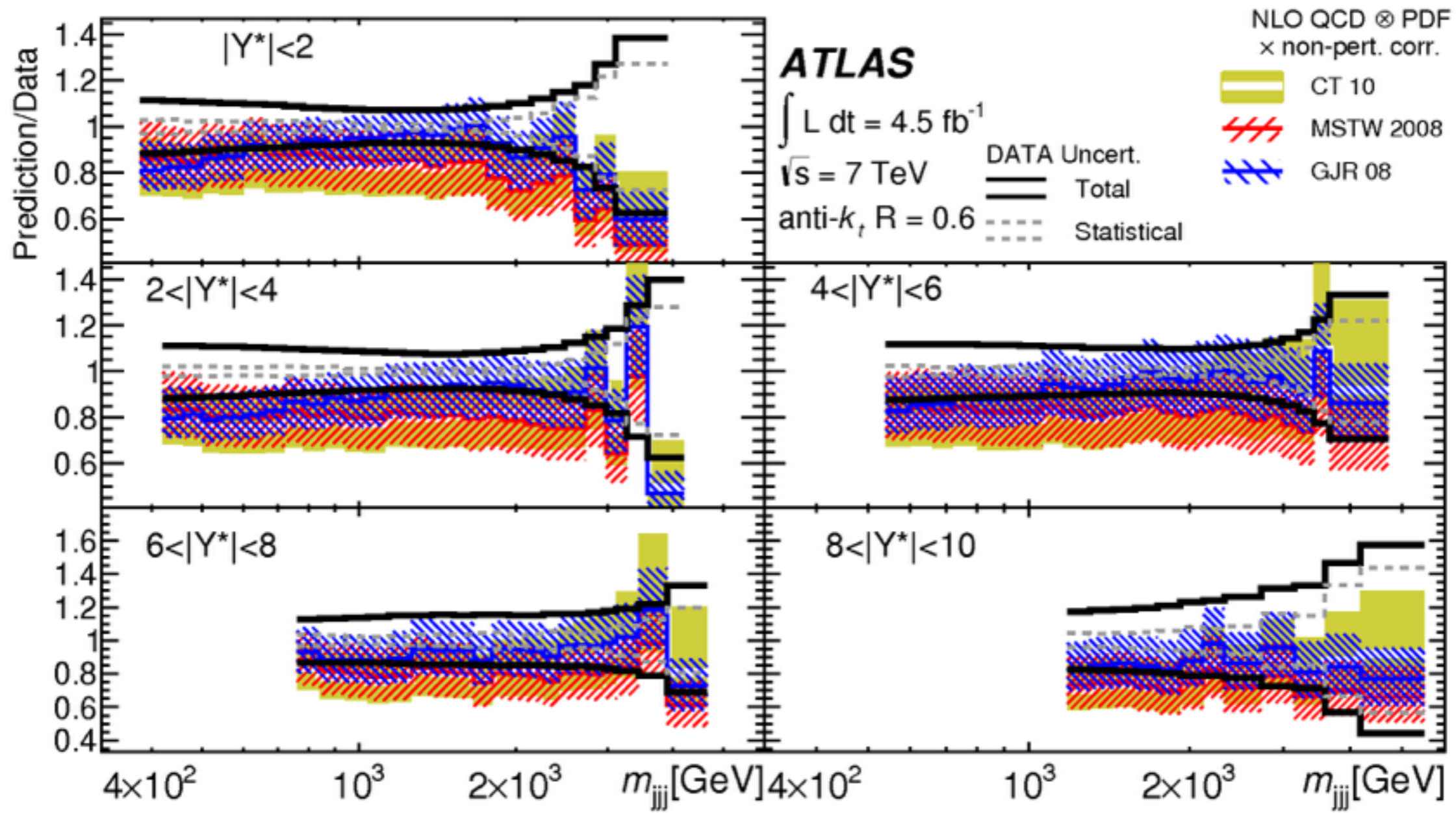


Three-Jet Cross Section

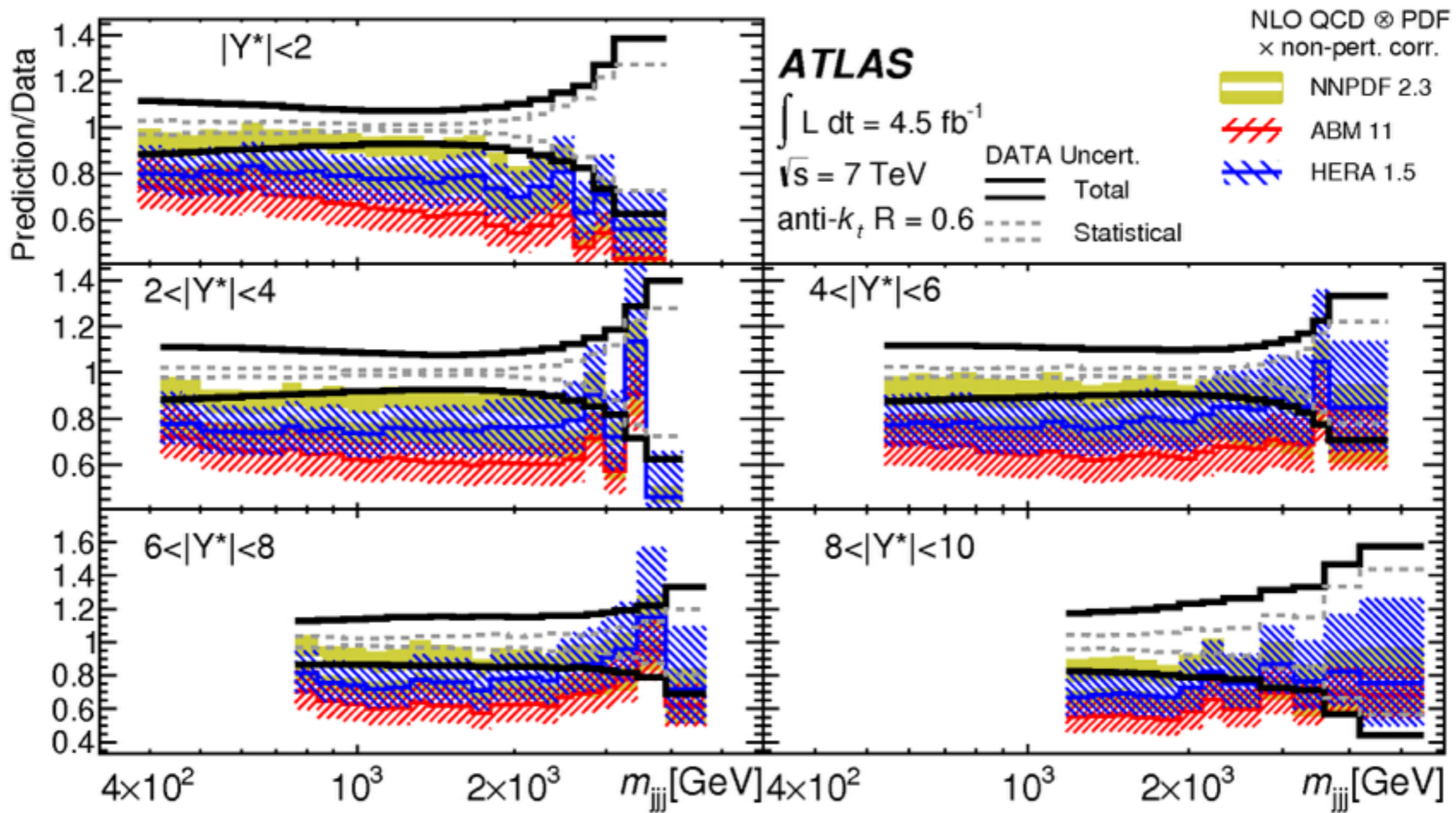


very good agreement over several orders of magnitude

Three-Jet Cross Section



Three-Jet Cross Section

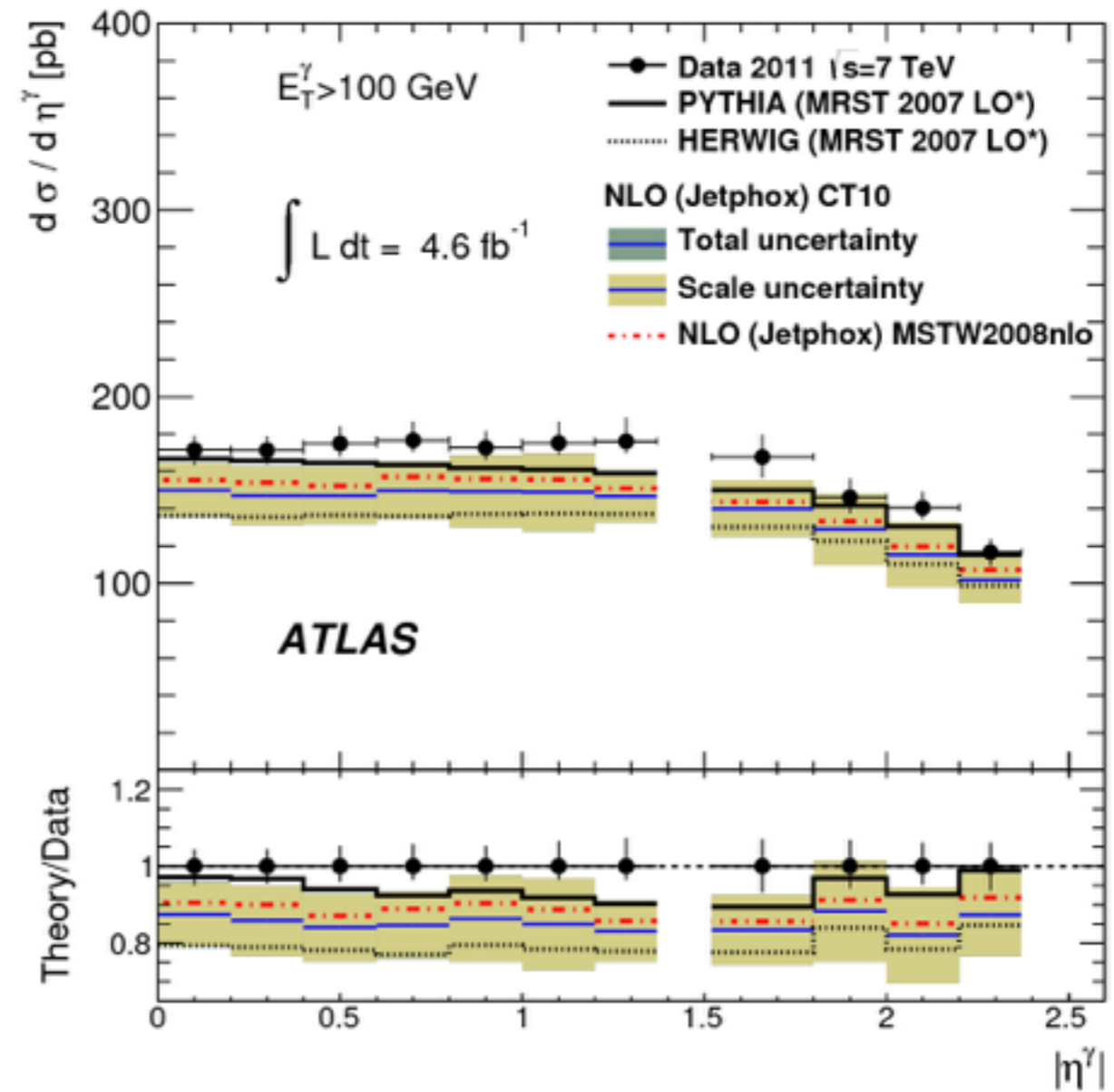
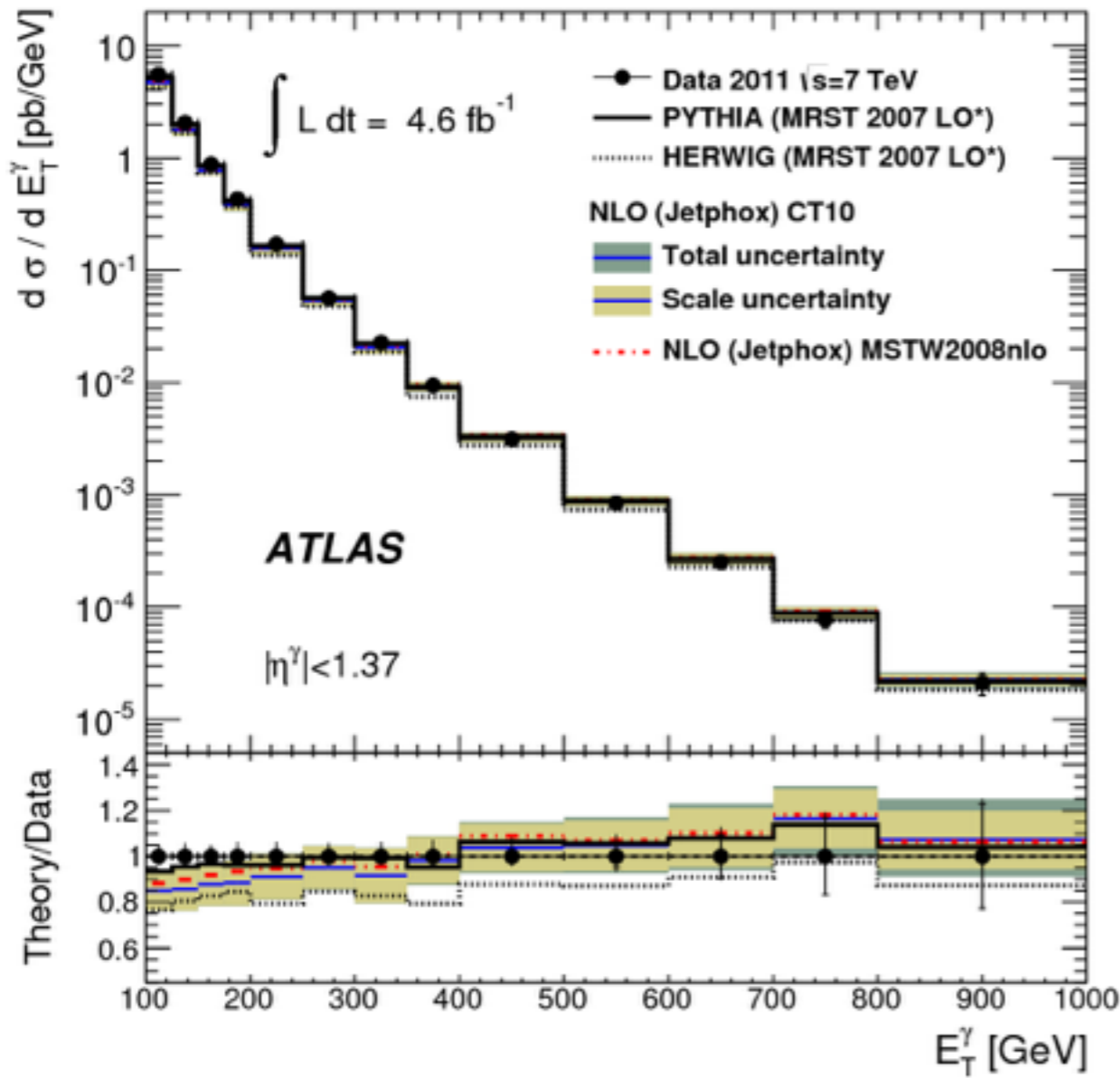


again, ABM 11 and HERA 1.5 tunes are low in mid-pT region



Direct Photon Production

Phys. Rev. D 89, 052004



PYTHIA and HERWIG both describe the shape well

HERWIG normalisation is slightly low



Conclusions

ATLAS is constraining our understanding of QCD in:

- total proton-proton cross section
- underlying event characteristics
- inclusive single and 3-jet cross sections
- direct photon production

Looking forward to new results early in Run II at 13 TeV.



Backup Slides

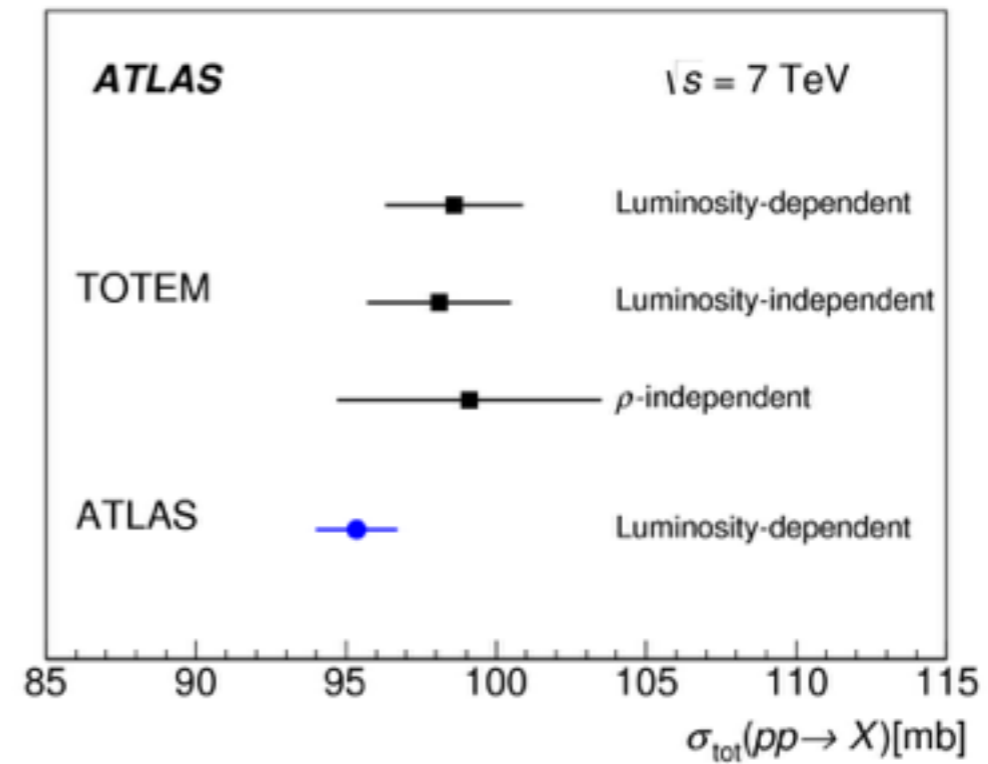
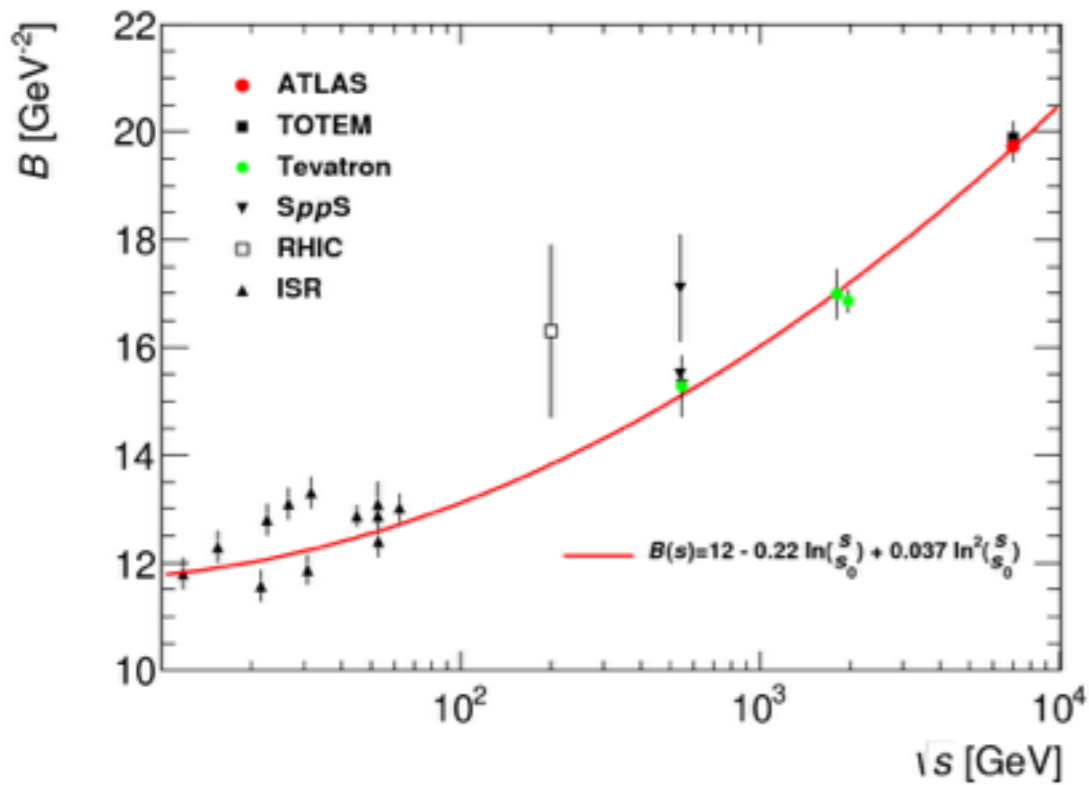
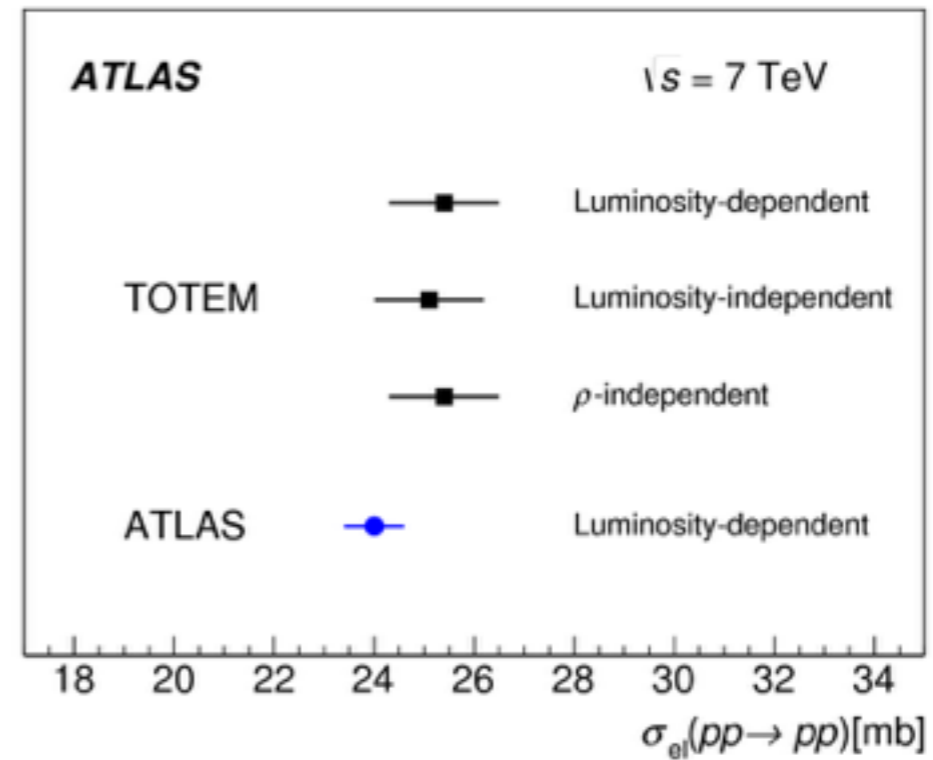
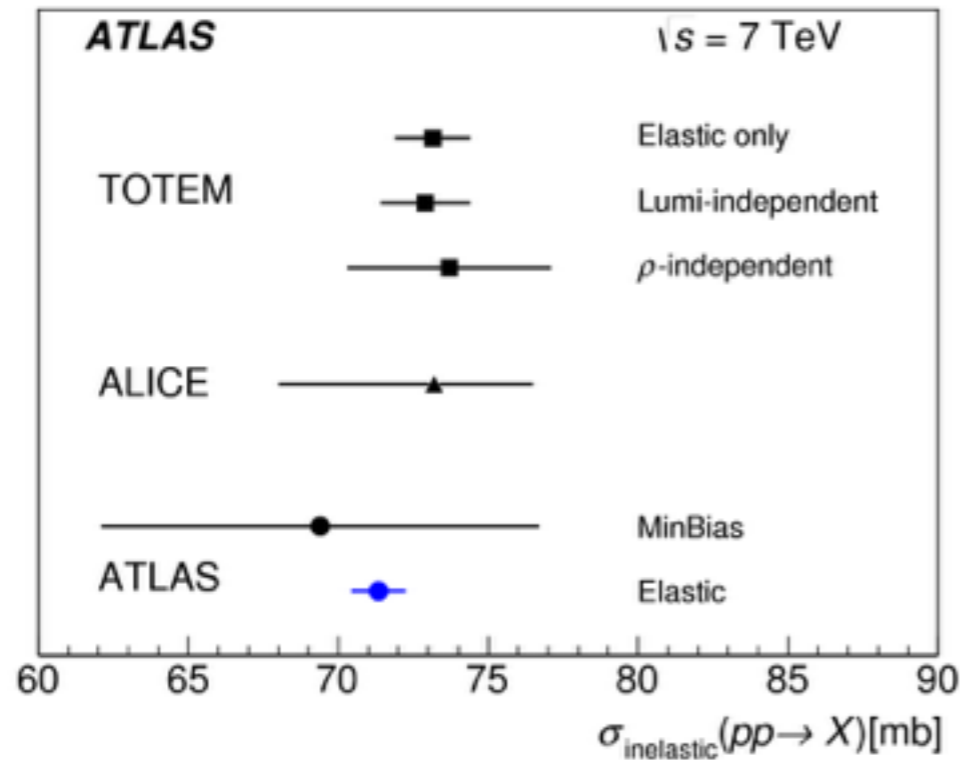
ATLAS & CMS Specs



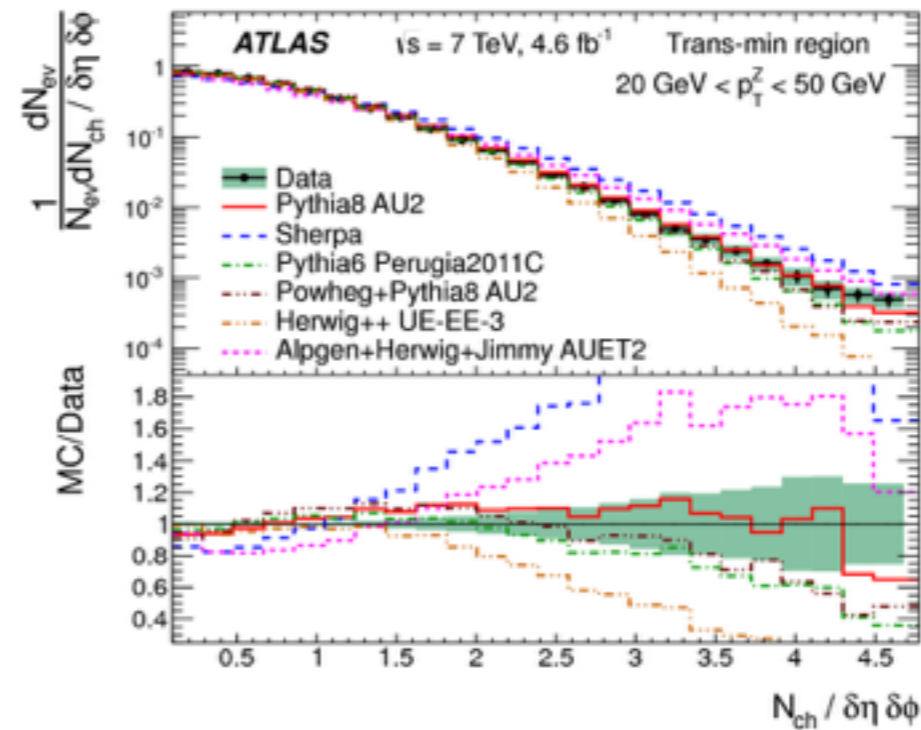
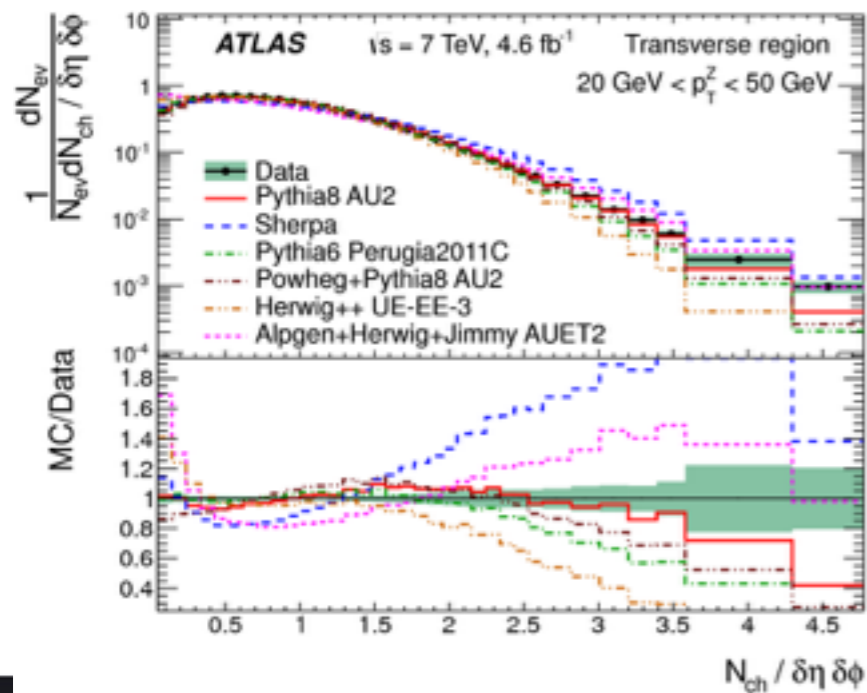
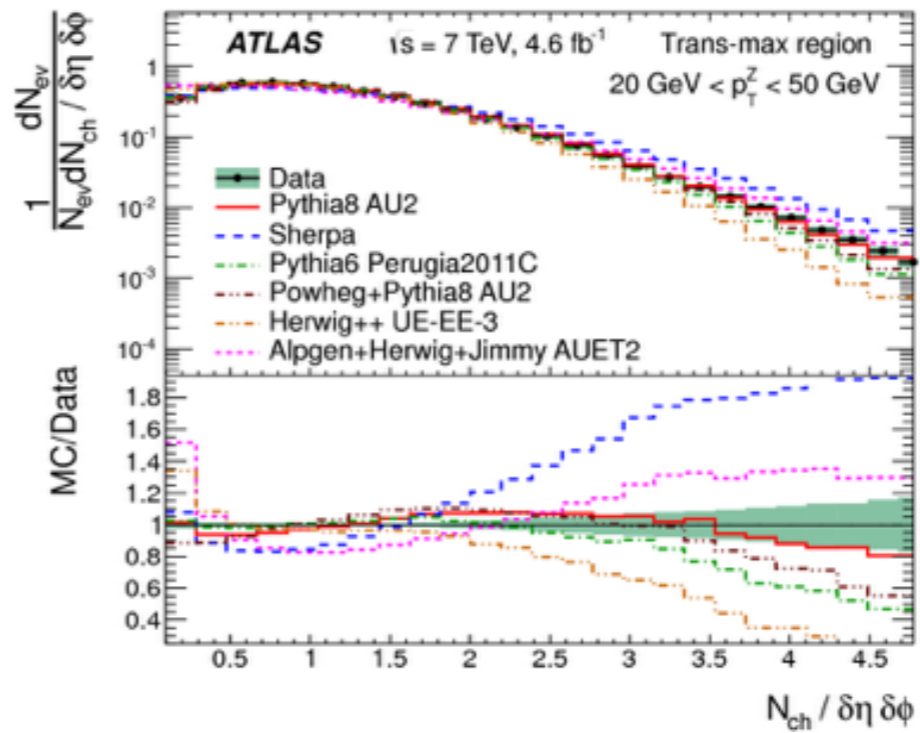
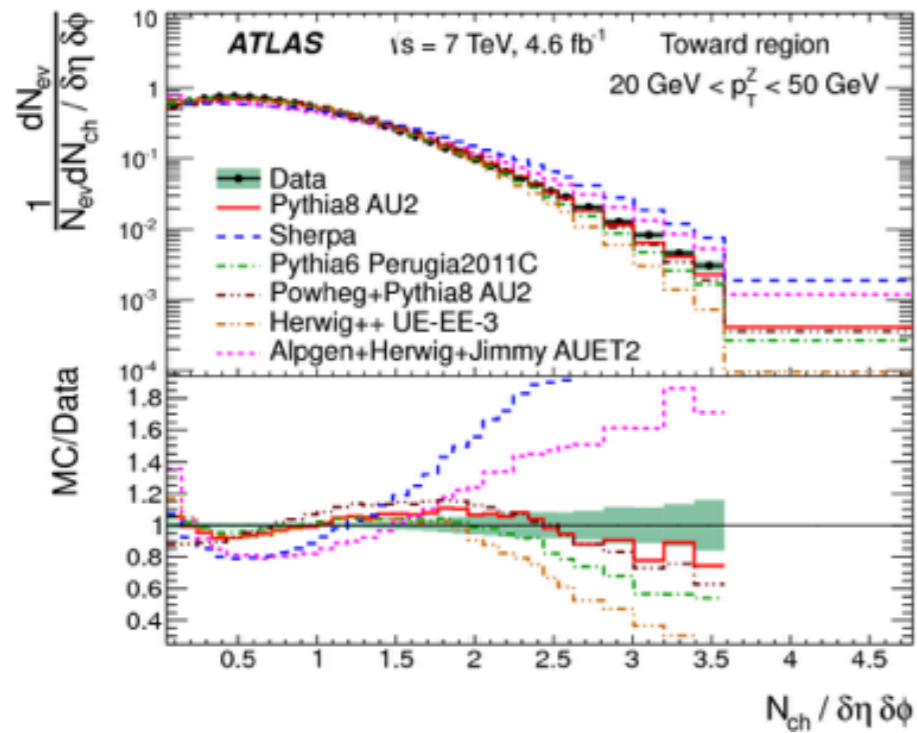
| Sub System | ATLAS | CMS |
|--|--|--|
| Design | | |
| Magnet(s) | Solenoid (within EM Calo) 2T 3 Air-core Toroids | Solenoid 3.8T Calorimeters Inside |
| Inner Tracking | Pixels, Si-strips, TRT PID w/ TRT and dE/dx $\sigma_{p_T}/p_T \sim 5 \times 10^{-4} p_T \oplus 0.01$ | Pixels and Si-strips PID w/ dE/dx $\sigma_{p_T}/p_T \sim 1.5 \times 10^{-4} p_T \oplus 0.005$ |
| EM Calorimeter | Lead-Larg Sampling w/ longitudinal segmentation $\sigma_E/E \sim 10\%/\sqrt{E} \oplus 0.007$ | Lead-Tungstate Crys. Homogeneous w/o longitudinal segmentation $\sigma_E/E \sim 3\%/\sqrt{E} \oplus 0.5\%$ |
| Hadronic Calorimeter | Fe-Scint. & Cu-Larg (fwd) $\gtrsim 11\lambda_0$ $\sigma_E/E \sim 50\%/\sqrt{E} \oplus 0.03$ | Brass-scint. $\gtrsim 7\lambda_0$ Tail Catcher $\sigma_E/E \sim 100\%/\sqrt{E} \oplus 0.05$ |
| Muon Spectrometer System Acc. ATLAS 2.7 & CMS 2.4 | Instrumented Air Core (std. alone) $\sigma_{p_T}/p_T \sim 4\%$ (at 50 GeV) $\sim 11\%$ (at 1 TeV) | Instrumented Iron return yoke $\sigma_{p_T}/p_T \sim 1\%$ (at 50 GeV) $\sim 10\%$ (at 1 TeV) |



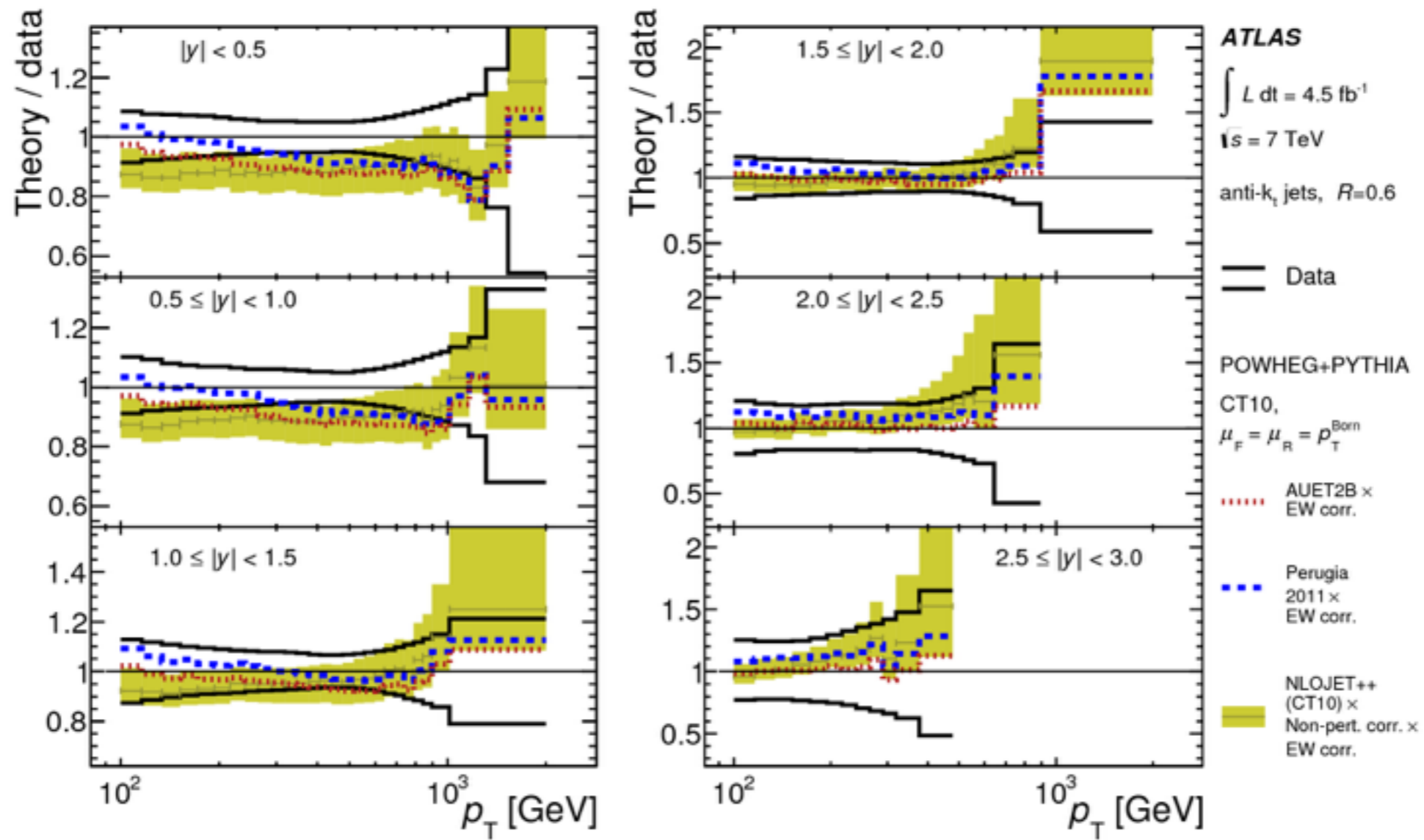
Total Cross Section



Underlying Event with Z-boson Events



Inclusive Jet Cross Section

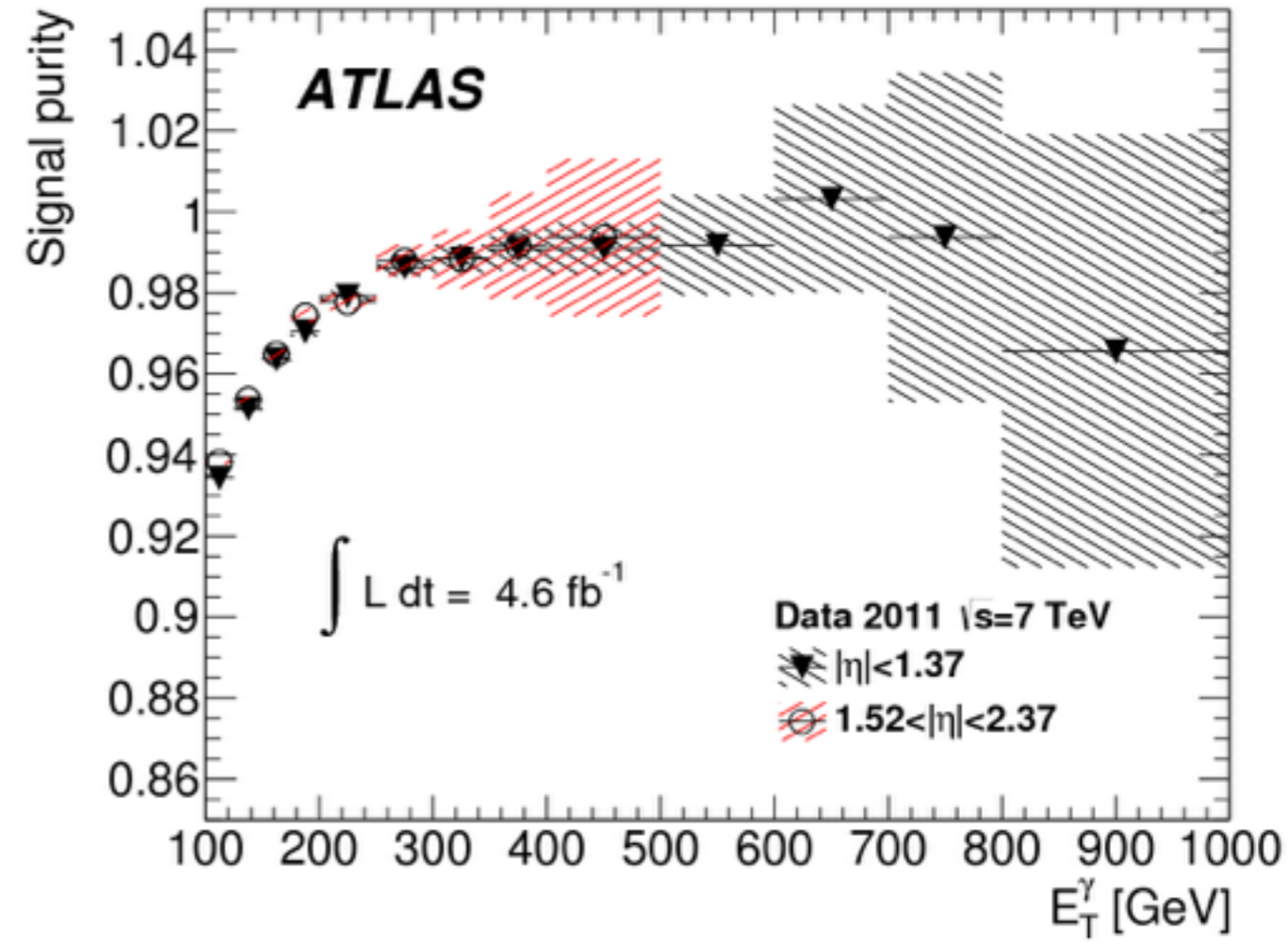
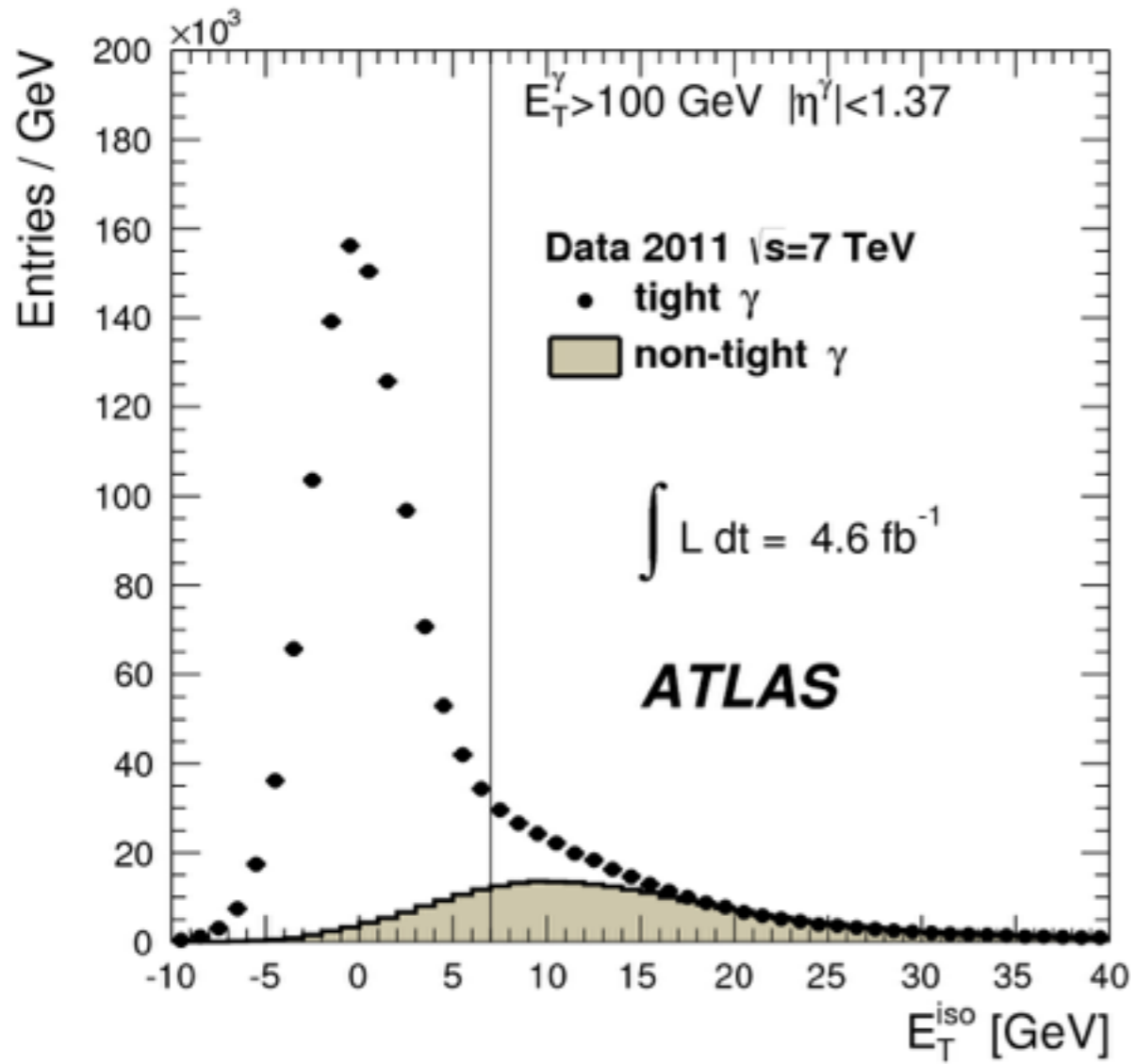


POWHEG+PYTHIA



Direct Photon Production

Phys. Rev. D 89, 052004



purity estimate with two-dimensional side band subtraction

