



Recent QCD results from ATLAS

Enrico Tassi

for the ATLAS Collaboration



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Tests of QCD in p-p collisions at the LHC

1. Non-perturbative QCD

- Underlying event
- Soft particle production processes
- Test MC phenomenological models (and tunes)

2. Perturbative QCD

- Hard processes
- Test soft and collinear factorization

$$\sigma(pp \rightarrow X) = \sum_{i,j} f_i(\alpha_s(\mu_R^2), \mu_F^2) \otimes f_j(\alpha_s(\mu_R^2), \mu_F^2) \otimes \hat{\sigma}_{i,j}(\alpha_s(\mu_R^2), \mu_F^2, \mu_R^2)$$

- Test higher-order predictions
- Improve proton's parton distribution functions (PDFs)

Results to be presented

- Soft QCD
 - Study of the underlying event
 - $\phi(1020)$ meson production
- Hard QCD
 - Inclusive and dijet production
 - Prompt photon production

Soft QCD

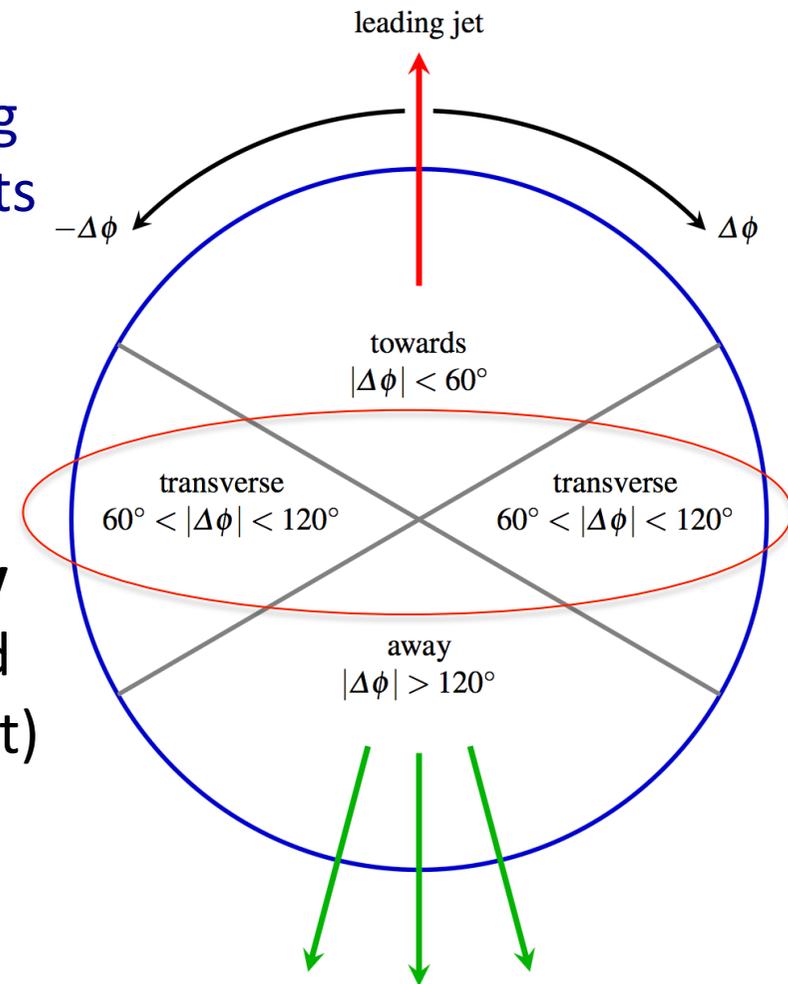
Underlying event

UE is an irreducible background affecting precision and new physics measurements

Study UE properties in inclusive and exclusive dijet events.

Particle production and transverse energy activity in the **region azimuthally transverse** w.r.t. the hardest object (and as a function of the p_T of the hardest jet)

➤ Effective test of MC models



Underlying event: Observables

The following UE-sensitive observables were measured
(2010 run , $\sqrt{s} = 7 \text{ TeV}$, $L=37\text{pb}^{-1}$)

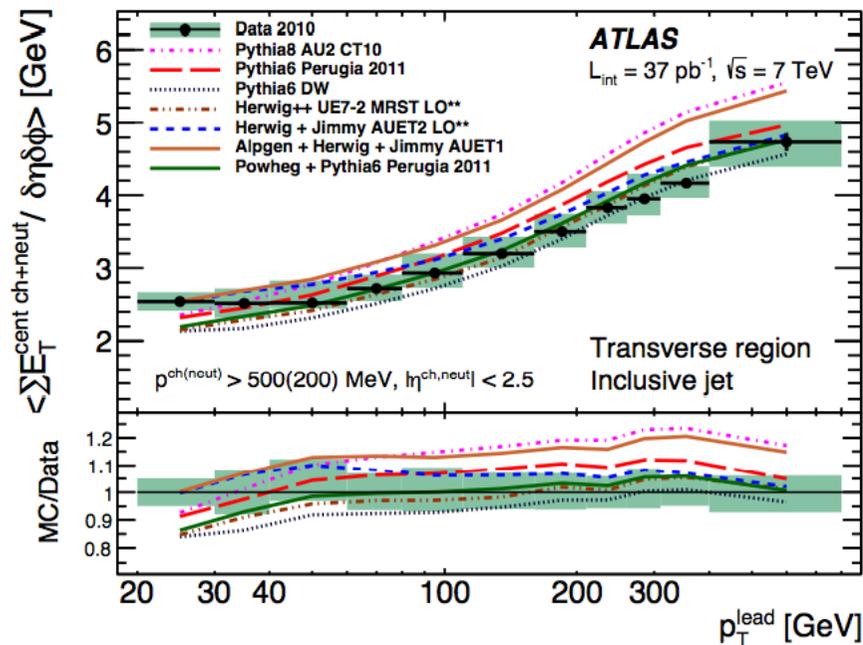
Event-wise observable	Particle level	Detector level
p_T^{lead}	Transverse momentum of the leading jet	
$N_{\text{ch}}/\delta\eta \delta\phi$	Number of stable charged particles per unit $\eta-\phi$	Number of selected tracks per unit $\eta-\phi$
$\sum p_T/\delta\eta \delta\phi$	Scalar p_T sum of stable charged particles per unit $\eta-\phi$	Scalar p_T sum of selected tracks per unit $\eta-\phi$
mean p_T	Mean p_T of stable charged particles (at least one charged particle is required)	Mean p_T of selected tracks (at least one selected track is required)
$\sum E_T/\delta\eta \delta\phi$	Scalar E_T sum of stable charged and neutral particles per unit $\eta-\phi$	Scalar E_T sum of selected calorimeter energy clusters per unit $\eta-\phi$

and compared with various MC models and tunes:

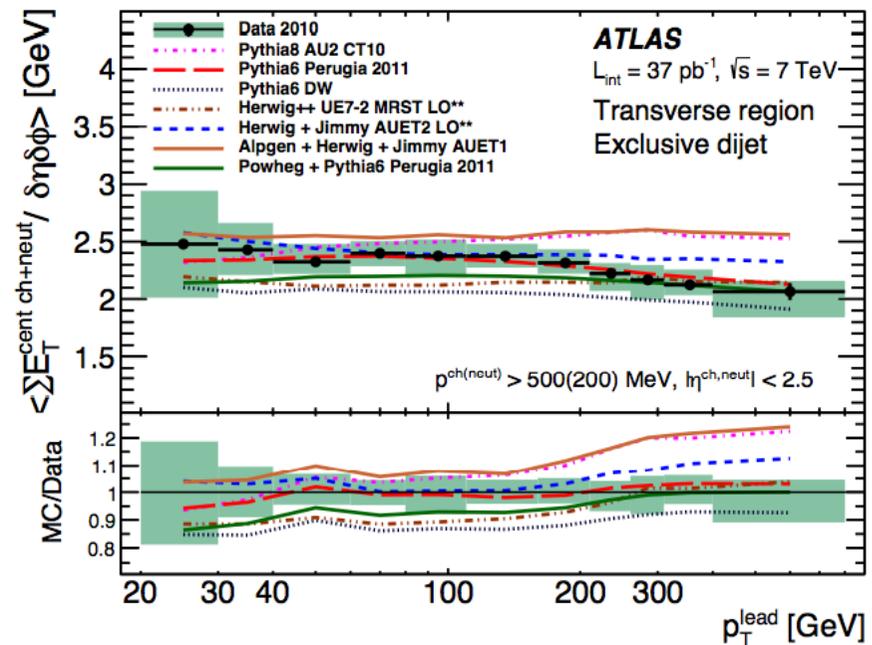
Pythia6, Pythia8, Herwig/JIMMY, Herwig++, Alpgen+Herwig/JIMMY

Underlying event: Results

Inclusive Jet



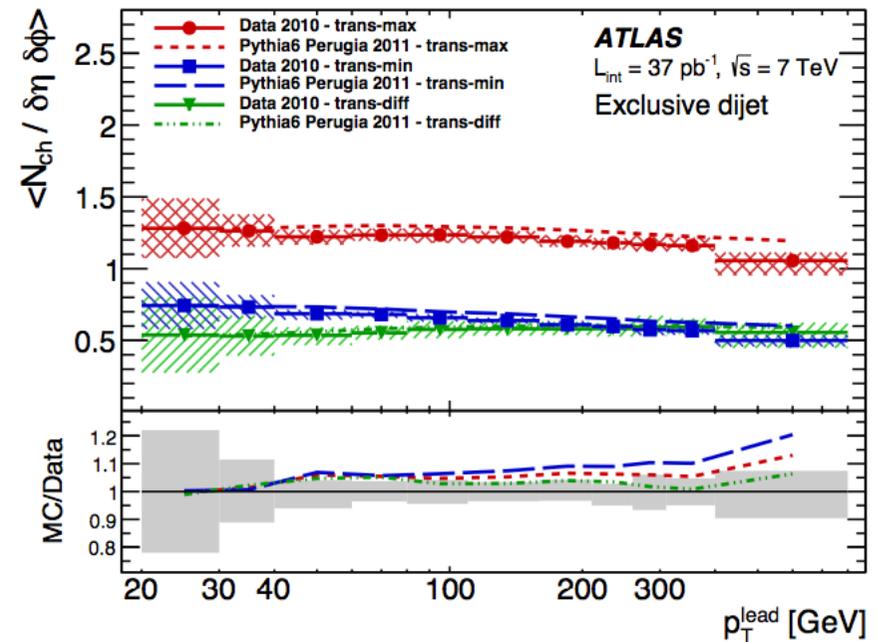
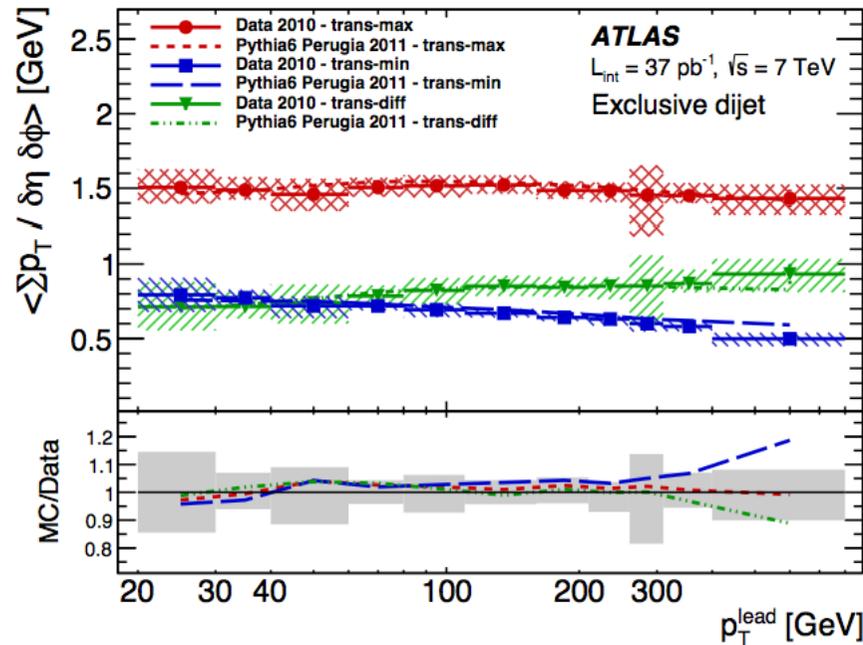
Exclusive dijet



- Rising transverse activity as a function of leading jet p_T is seen in the inclusive jet sample
- Application of an exclusive dijet event selection requirement removes this feature
- No definite interpretation of the slight decrease in transverse activity with the hard scale in exclusive dijet events

Underlying event: Results

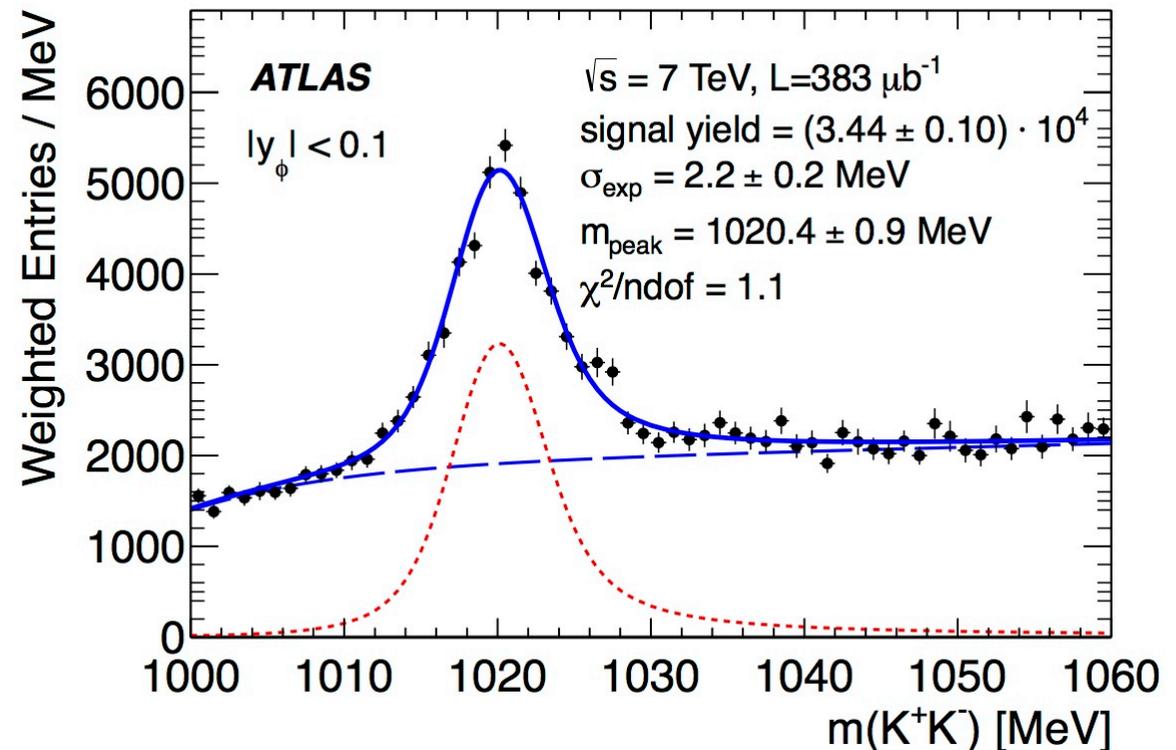
Exclusive dijet



- Particle flow observables in dijet topologies indicate that pure MPI activity can be modeled as independent of the hard process scale

$\phi(1020)$ -meson production

- $\sqrt{s} = 7 \text{ TeV}$, $L=383 \mu\text{b}^{-1}$
- production cross section measured in the decay channel $\Phi \rightarrow K^+K^-$
- probes strangeness production and hadronization models at a scale of $\approx 1 \text{ GeV}$



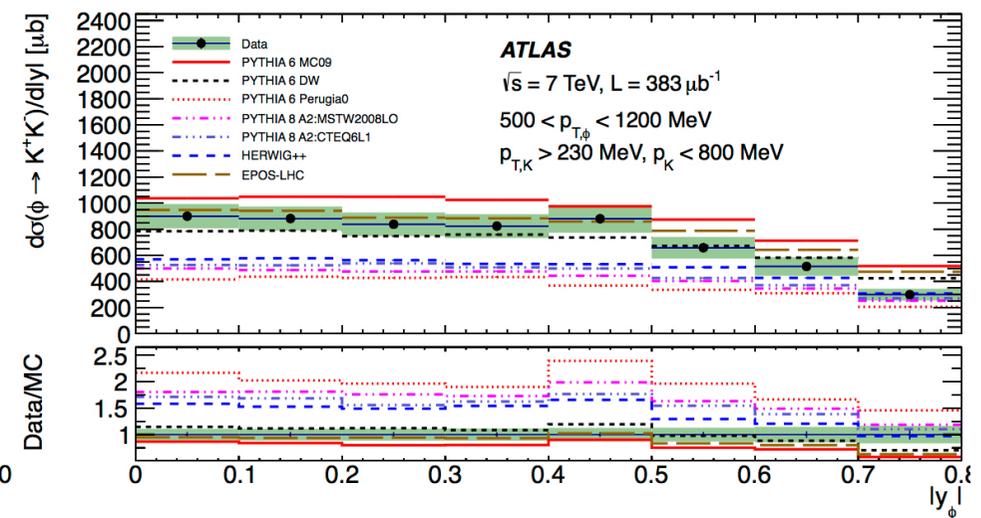
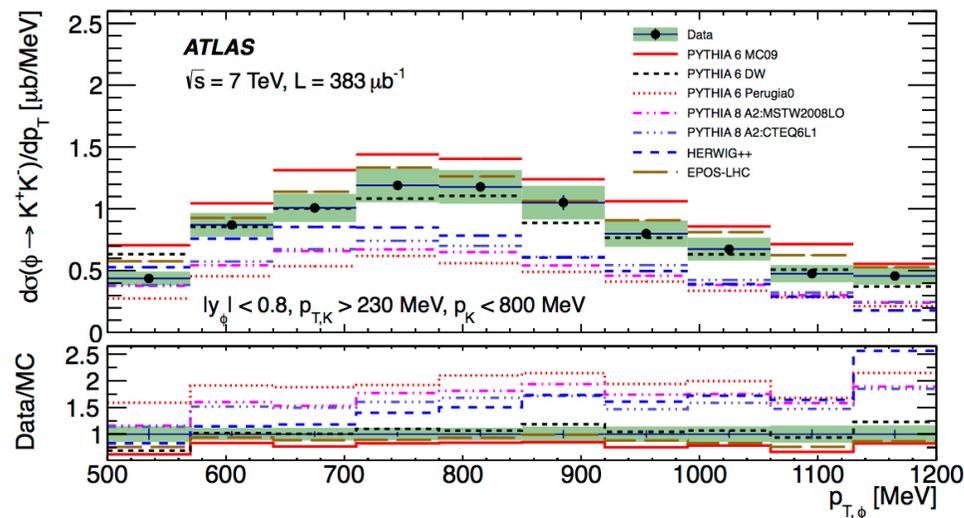
- Kaon identification: Energy deposits in the Pixel detector

$\phi(1020)$ -meson production cross sections

Measured single differential fiducial cross sections:

$$d\sigma / dp_{T,\phi}$$

$$d\sigma / d|y_\phi|$$



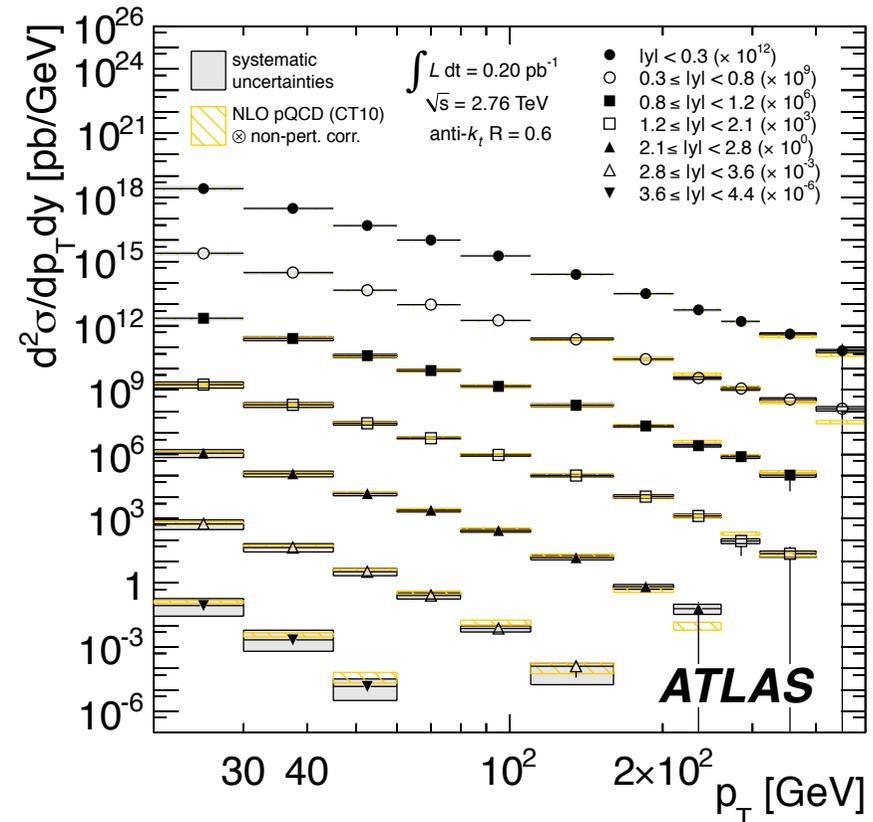
- Fiducial region: $|y_\phi| < 0.8, p_{T,K} > 230 \text{ MeV}, p_K < 800 \text{ MeV}$
- Pythia 6 DW and EPOS-LHC tunes closer to data
- Discriminating power between generator tunes
- Inputs for tuning MC generators

Hard QCD

Inclusive Jet Cross Sections

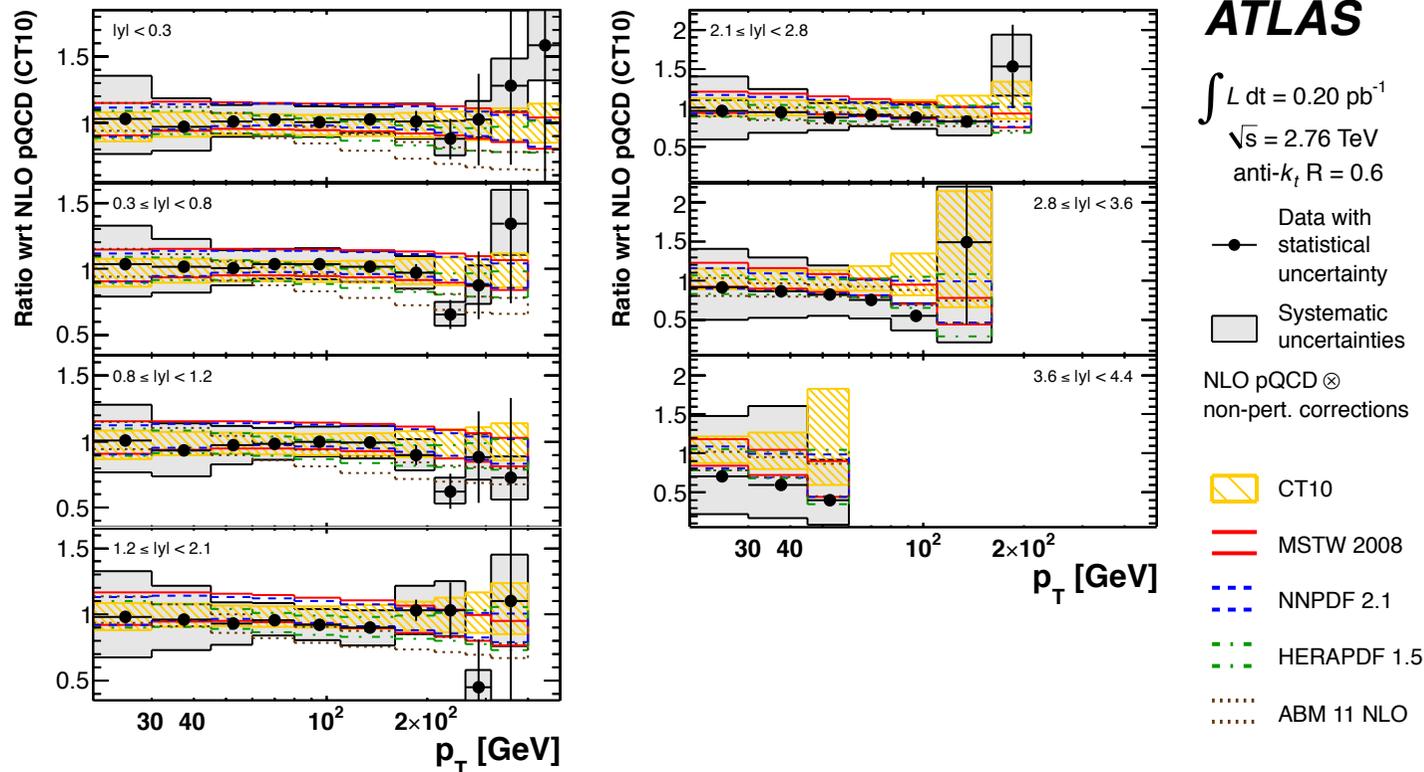
Data set: collected during the early 2011 Run ($\sqrt{s} = 2.76$ TeV, $L_{\text{int}} = 0.20$ pb $^{-1}$)

- anti- k_T jet algorithm ($R=0.4$ and $R=0.6$)
- Experimental Systematic Uncertainty dominated by Jet Energy Scale
- NLOJet++ (corrected for NP effects) describes data well
- Paper includes full information on uncertainties and correlations (very important for DGLAP analyses)



Inclusive Jet Cross Sections

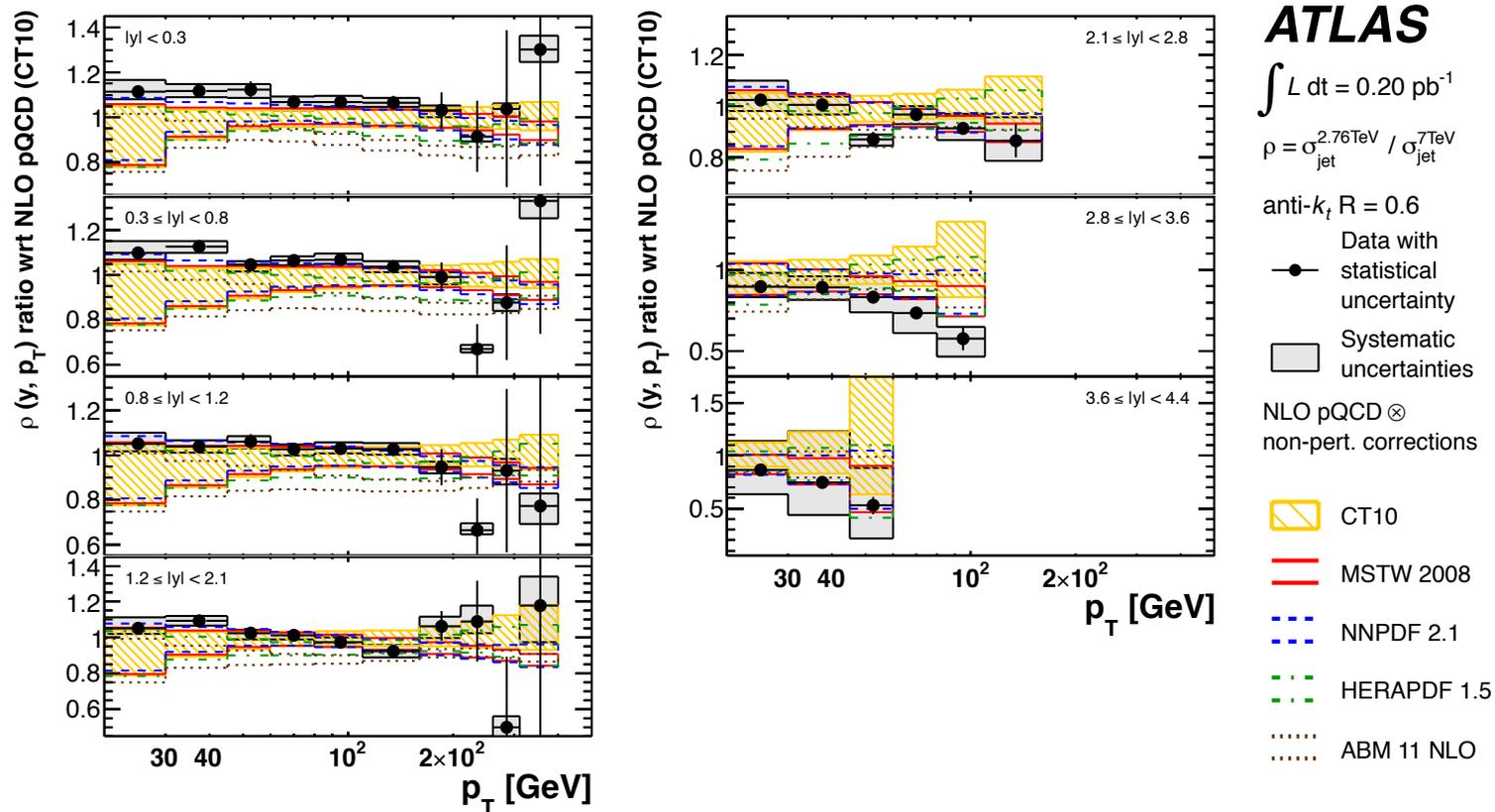
Ratio Theory (NLO QCD+NP)/Data (2.76 TeV)



For more stringent tests we need NNLO calculations and better control of JES

Inclusive Jet Cross Sections

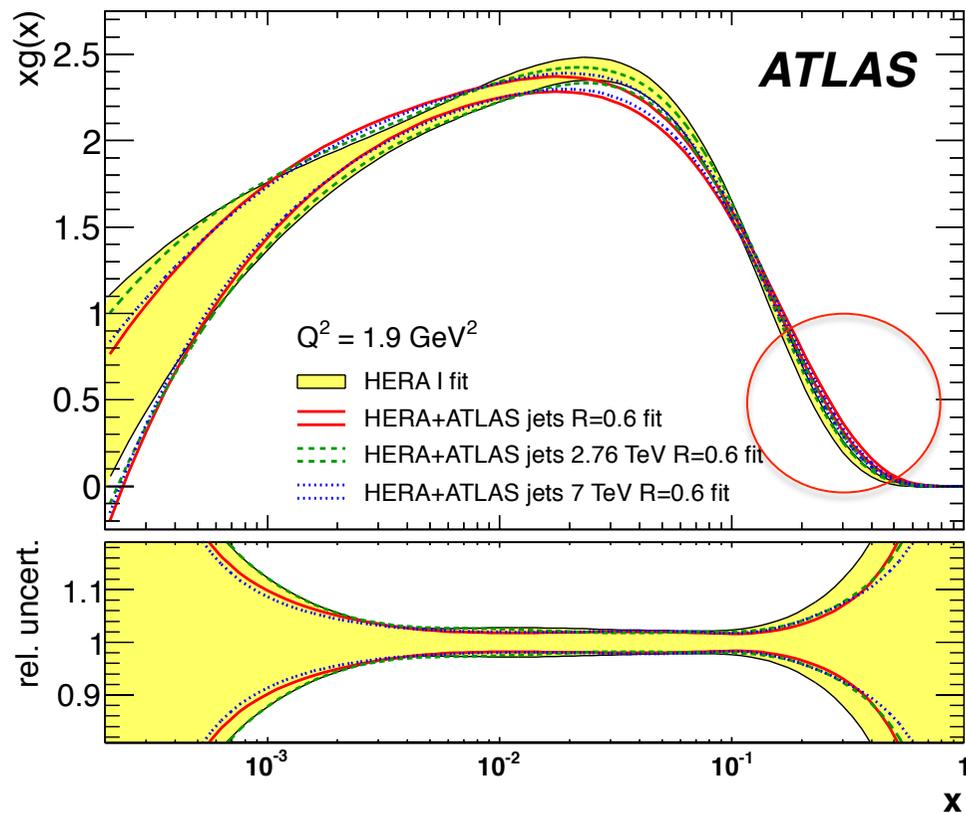
Ratio 2.76 TeV data/7 TeV data compared to pQCD



- Reduction of the correlated uncertainties in the ratio with 7 TeV data

Impact of Jet data on PDFs

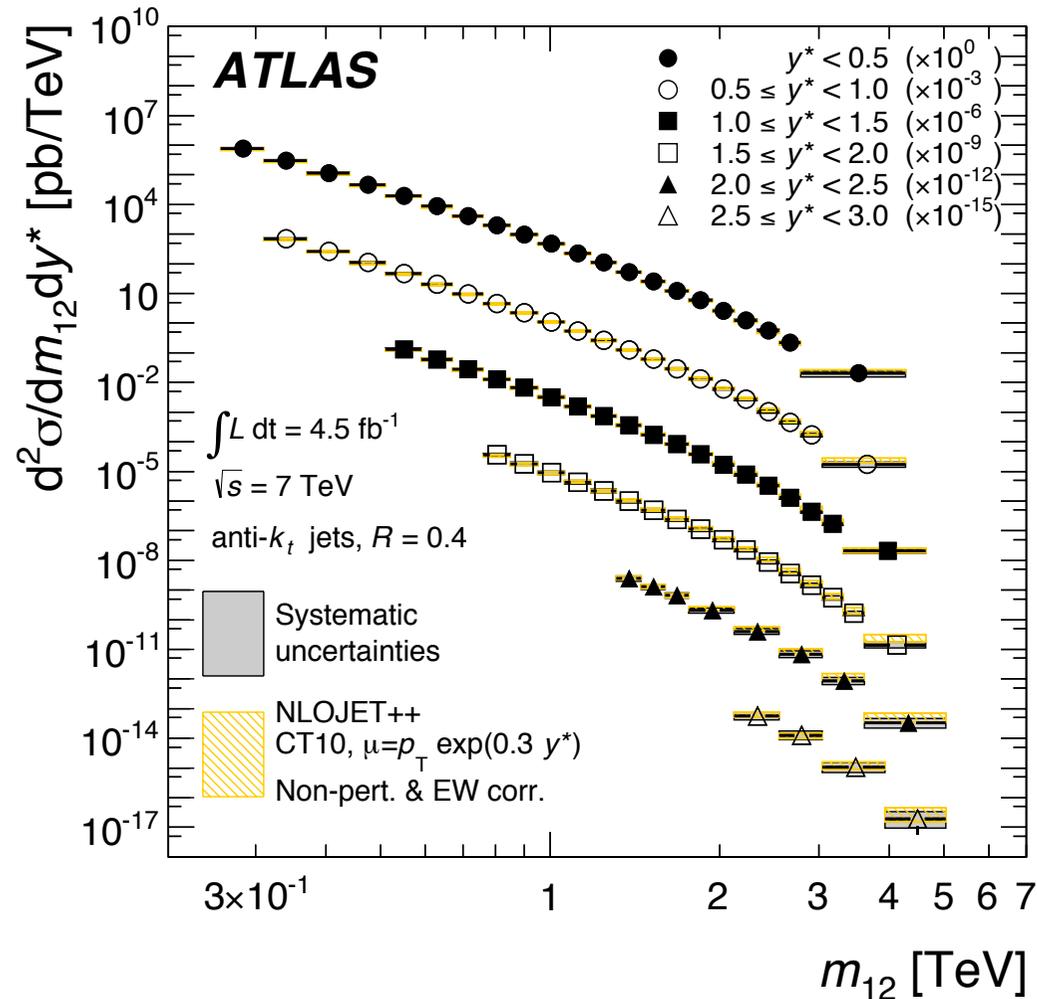
New HERAFitter based PDFs determination
(including 2.76 and 7 TeV ATLAS jet data)



Impact of ATLAS jets on $xg(x)$:

- Gluon slightly harder
- Slightly reduced uncert.

Dijet Cross Sections at 7 TeV



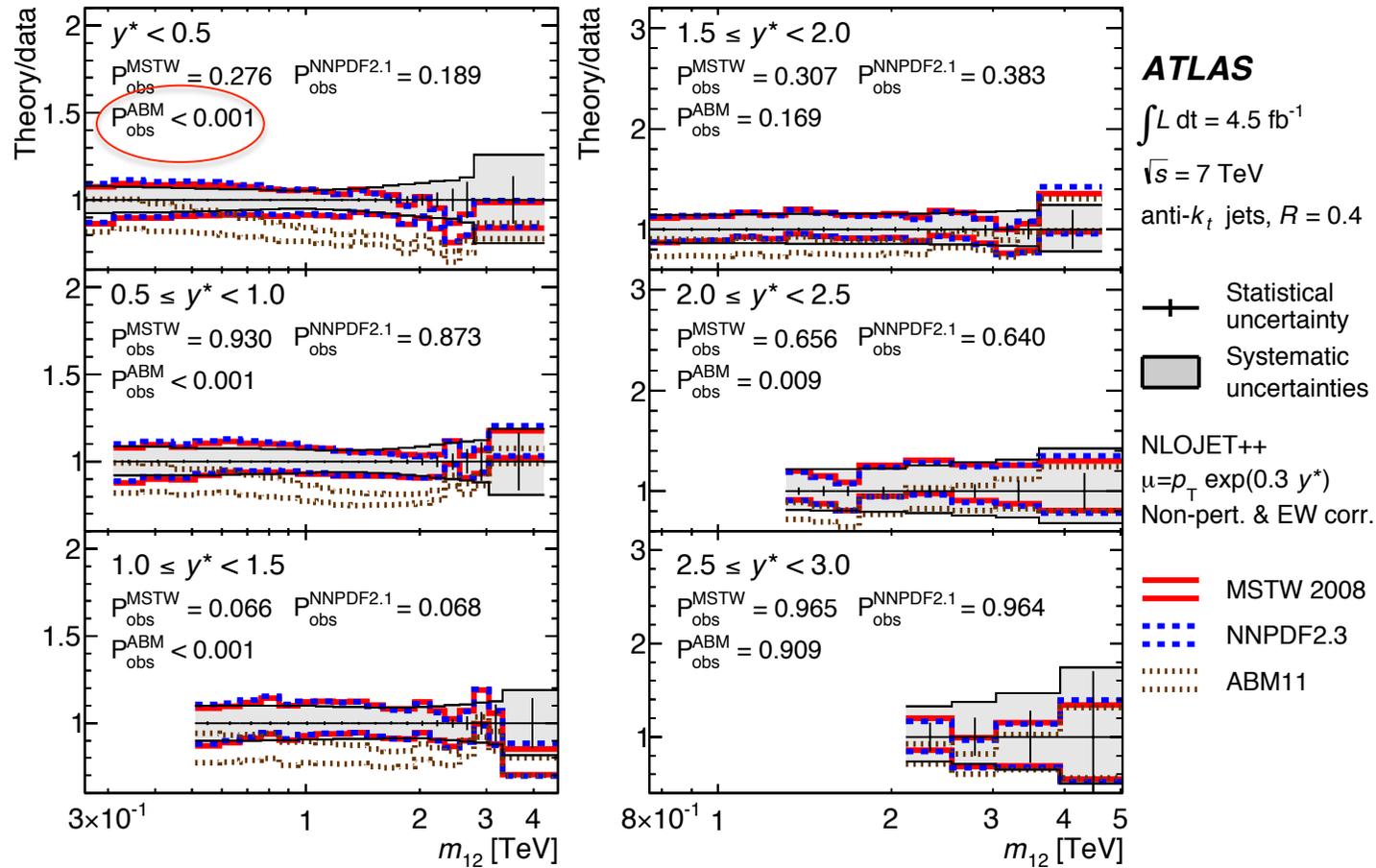
2011 data, JES uncertainty $< 2\%$

NLO pQCD (corrected for EW and non-perturbative effects) does a good job in describing data (extending up to dijet masses of 5 TeV)

Quantitative comparison between data and theory is provided using a frequentist method

includes full information on systematic uncertainties and correlations

Dijet Cross Sections at 7 TeV

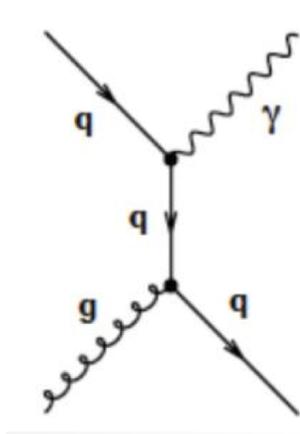


- MSTW08 and NNPDF2.3 agree well with data (see also backup slides)
- ABM11 disfavoured (note low p-values)
- Need NNLO predictions (th.) and to reduce further the JES (exp.)

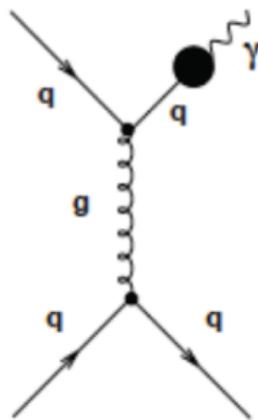
Prompt photon production

Allows precise tests of pQCD in a clean environment

Prompt-photon production processes:



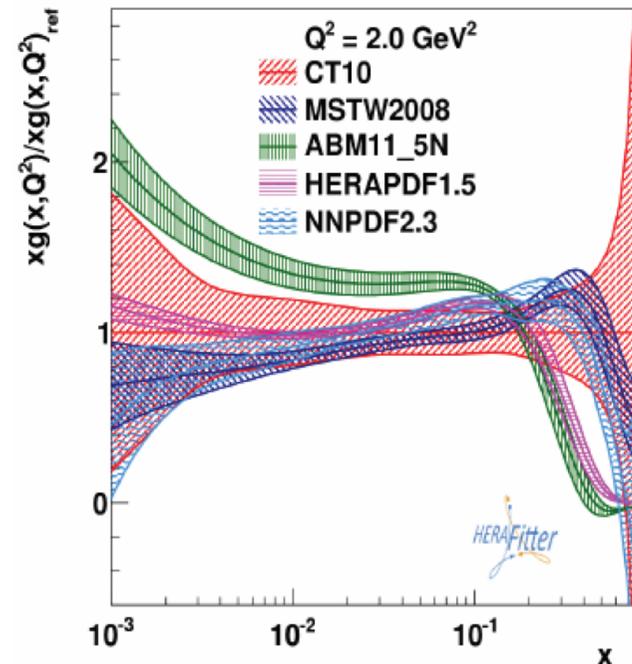
Hard Scattering



Fragmentation

Dominant process:

$$q + g \rightarrow \gamma + q$$

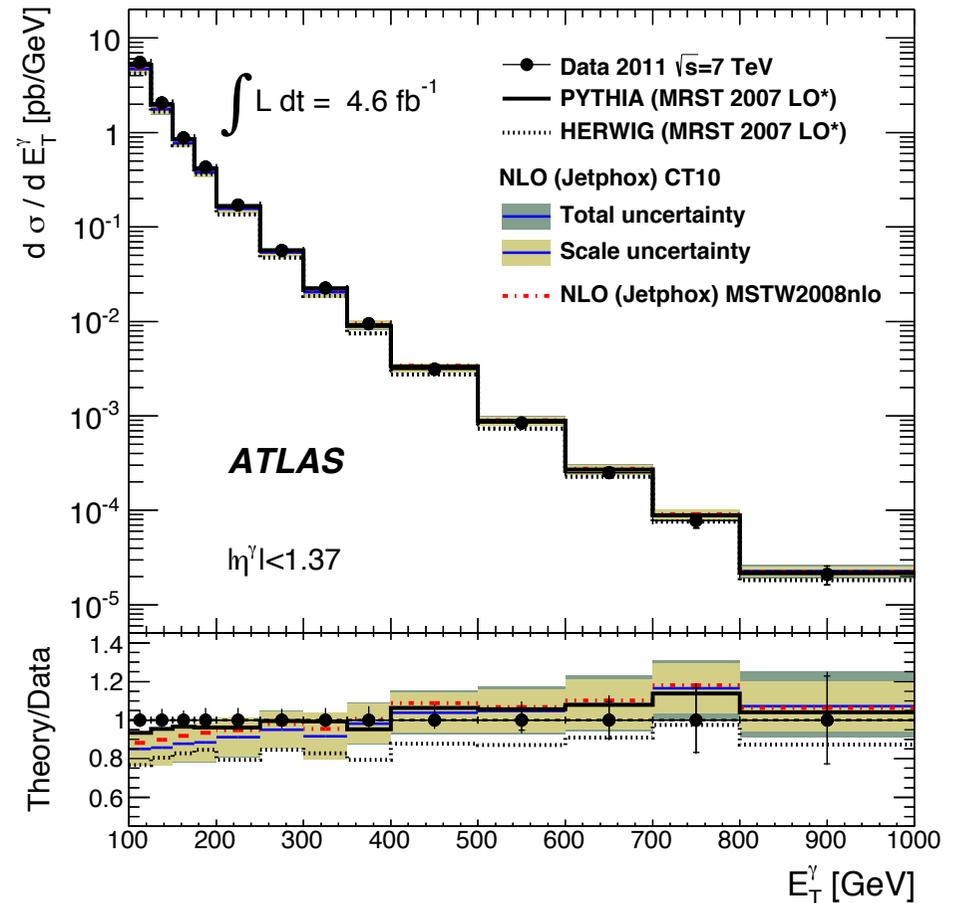


Inclusive isolated prompt γ cross section

Both PYTHIA and HERWIG describe the shape of the differential cross sections (fragmentation component is needed)

The measurements agree with the NLO predictions based on CT10 and MSTW08 up to the highest $E_T^\gamma \approx 1$ TeV

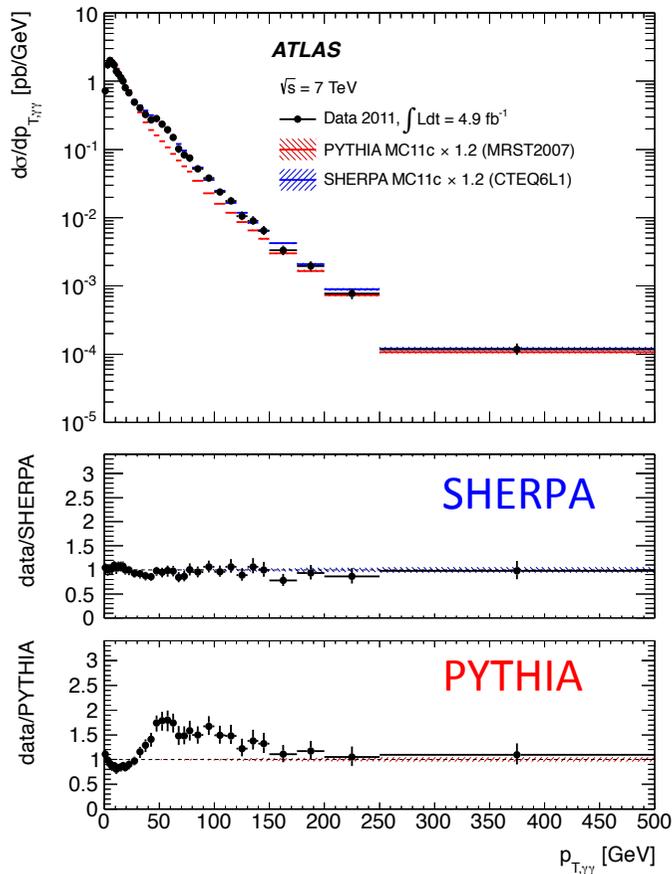
Potential to provide additional constraints on proton's PDFs



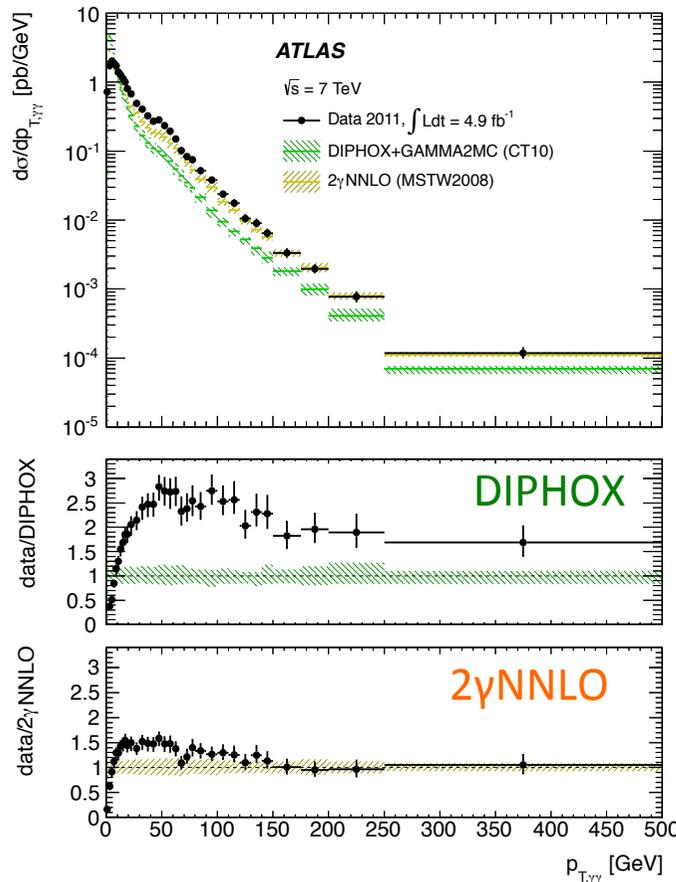
Isolated di-photon cross section

Measured di-photon single differential cross sections: $d\sigma/dm_{\gamma\gamma}$ and $d\sigma/dp_{T,\gamma\gamma}$

Compare to MC predictions



Compare to theory calculations



Good description by 2γ NNLO for $p_T > 150 \text{ GeV}$

20-150 GeV range:
 Fragmentation
 component significant

Need resummed
 calculations at low p_T

Summary

The LHC give us the opportunity to perform tests of QCD both in the soft and hard regimes

Soft QCD:

Many observables (UE, soft particle production, etc...) are measured that can be used to test/ improve MC models and tunes

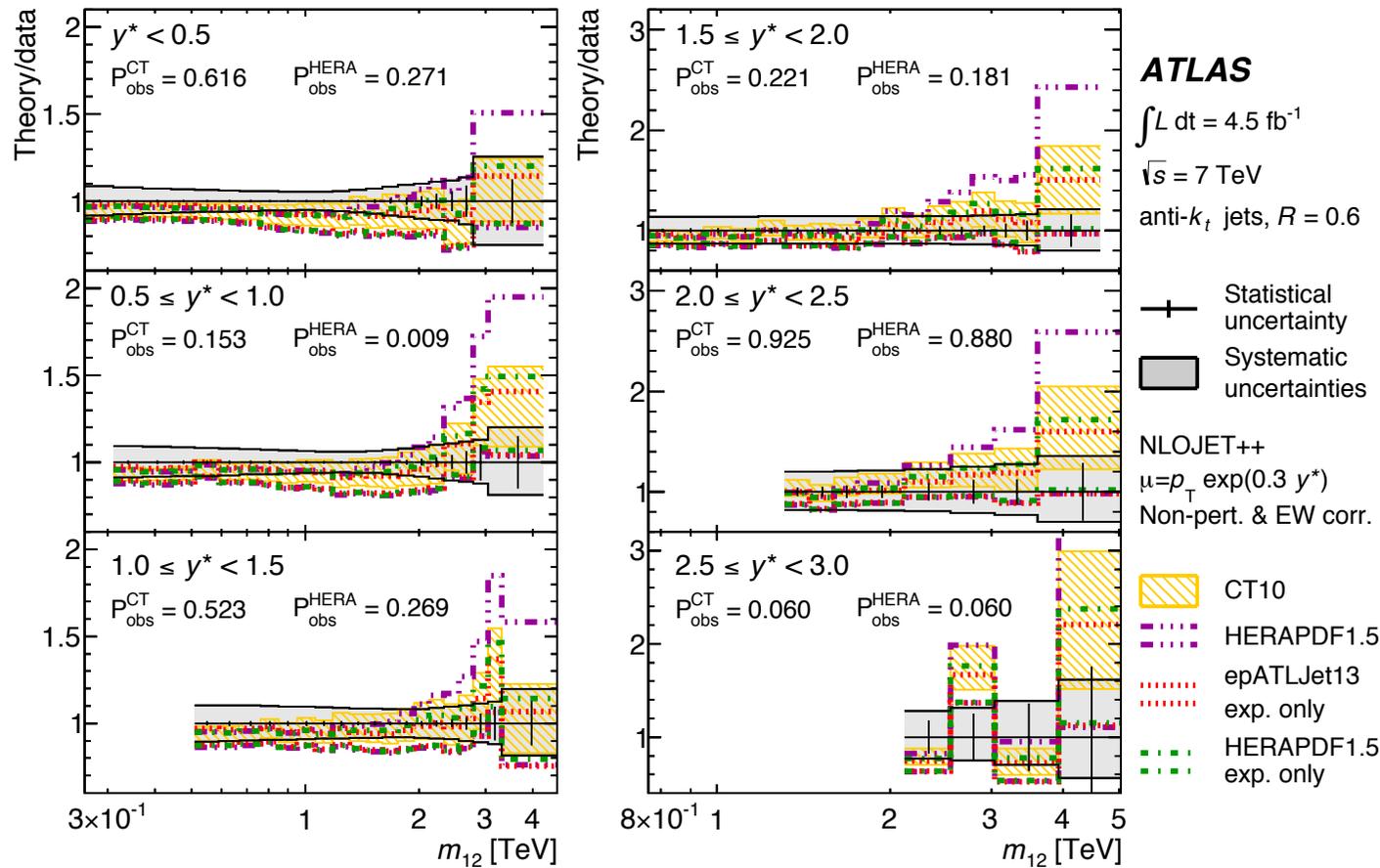
Hard QCD:

Jets and prompt photon production cross section are particularly suitable to perform stringent tests of pQCD and improve our knowledge of PDFs. We need NNLO (resummed) calculations.

Ongoing effort to improve results using 8 TeV data

Back-up Slides

Dijet Cross Sections at 7 TeV



- Good agreement is observed for the CT10 PDF set
- HERAPDF1.5: disagreement observed in some ranges of dijet mass and y^*