

Direct Photon and Photon+Jet at ATLAS

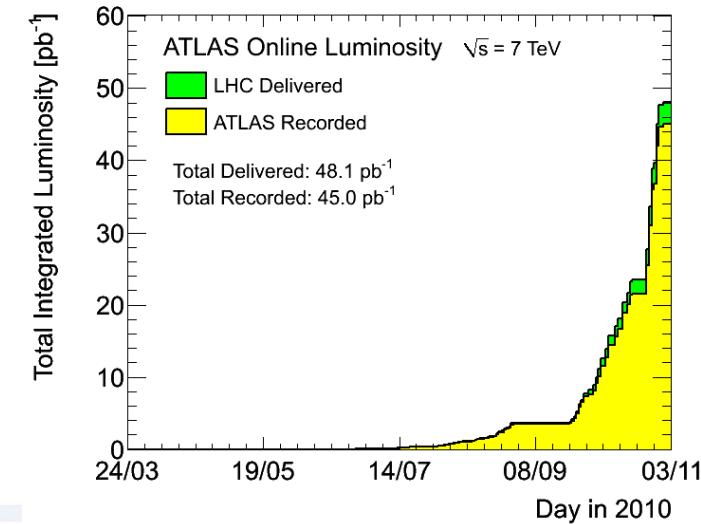
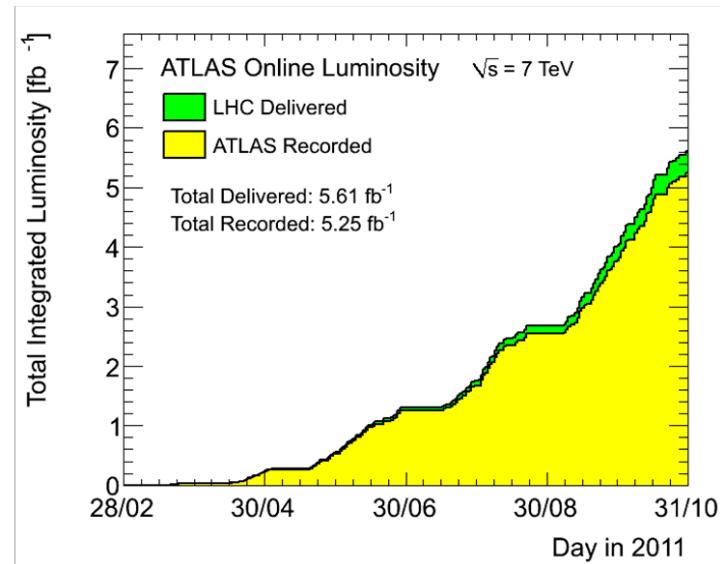
R. Yoshida (ANL) on behalf of the ATLAS Collaboration

Low-X Meeting
Yukawa Institute, Kyoto, Japan
June 17-24, 2014



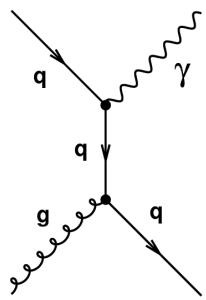
Direct Photons and Photon+Jet at ATLAS

- This talk is mainly based on the following two recent publications
 - ATLAS: Measurement of the inclusive isolated prompt photon cross section in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector using 4.6 fb^{-1}
[Phys. Rev. D 89, 052004 \(2014\)](#)
 - ATLAS: Dynamics of isolated-photon and jet production in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector.
[Nucl. Phys. B 875 \(2013\) 483-535](#)

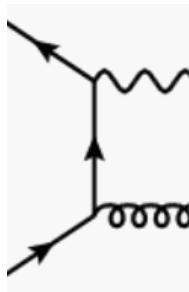


Direct Photon Production

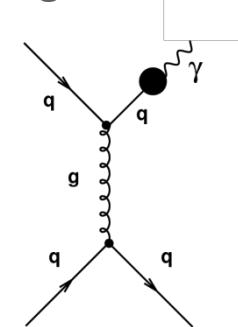
Compton



Annihilation

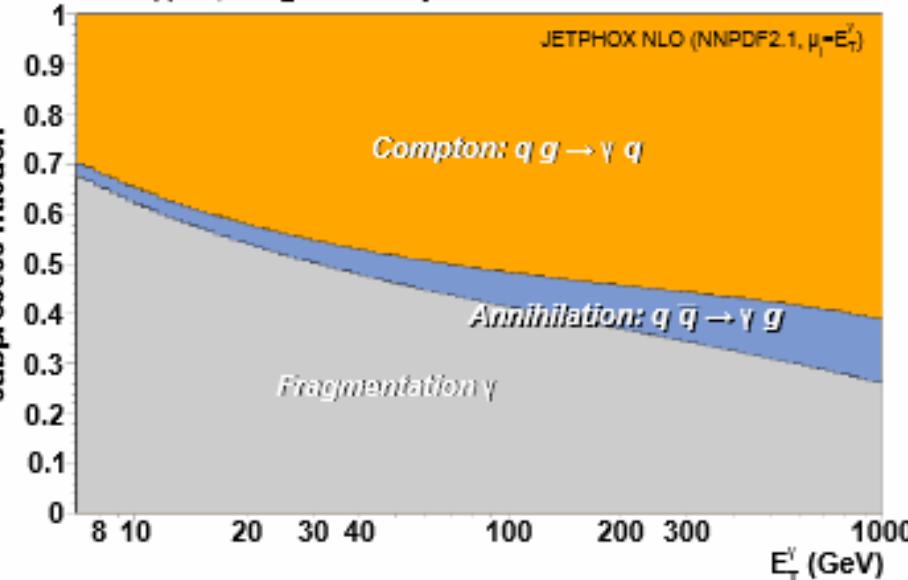


Fragmentation



Without isolation

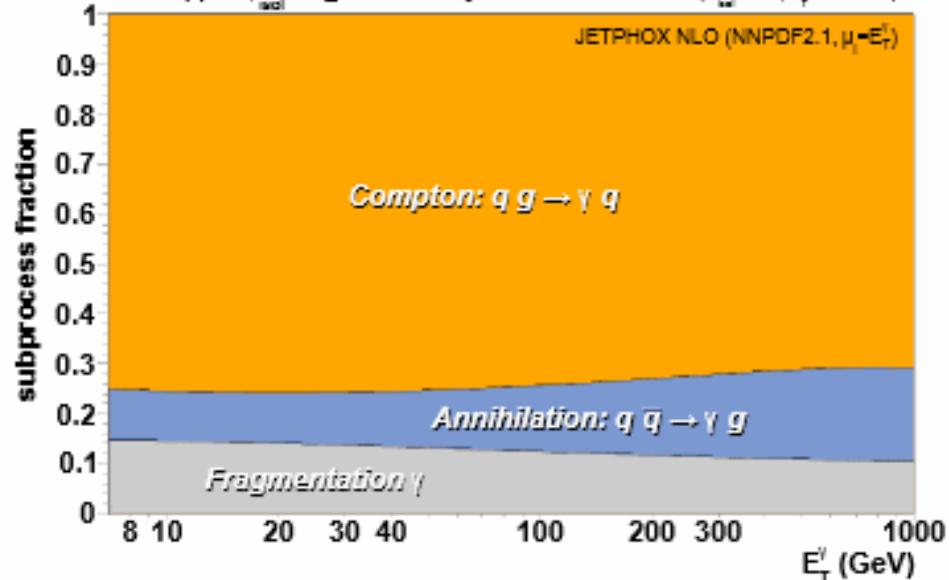
LHC, $pp \rightarrow \gamma + X$ @ $\sqrt{s}=14$ TeV, $y=0$



With isolation

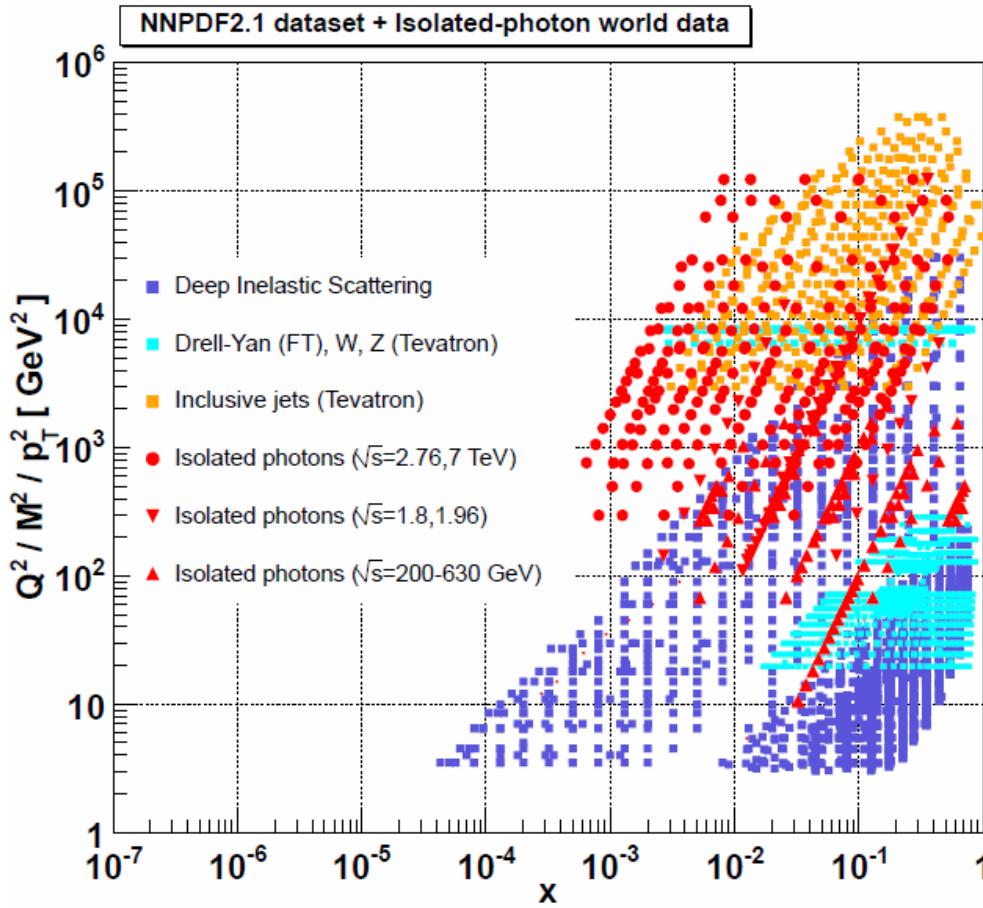
LHC, $pp \rightarrow \gamma_{isol} + X$ @ $\sqrt{s}=14$ TeV, $y=0$

($R_{jet} = 0.4$, $E_T^{miss} < 4$ GeV)



D. d'Enterria, J. Rojo Nucl. Phys. B860 (2012) 311-338

Parton Kinematics for direct photons at pp collider



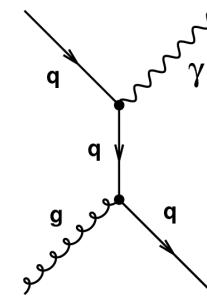
D. d'Enterria, J. Rojo
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Low-x 2014

$$x_{\pm} = x_T \cdot e^{\pm y_{\gamma}/\sqrt{s}}$$

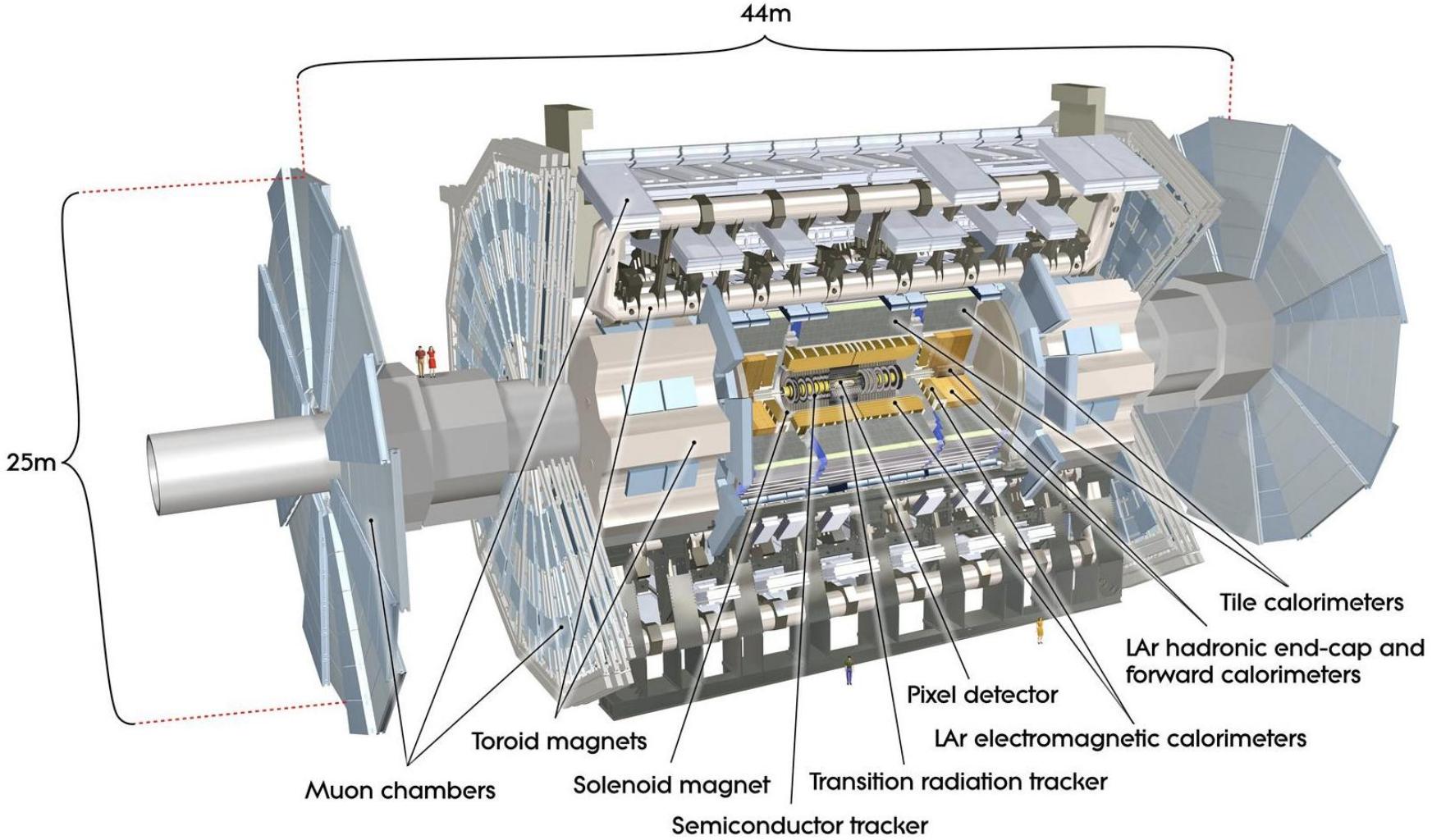
$$x_T = E_T^{\gamma}/\sqrt{s}$$

For LHC at $\sqrt{s} = 7$ TeV
the range of x being probed is
 $\sim 10^{-3} < x < \sim 0.5$

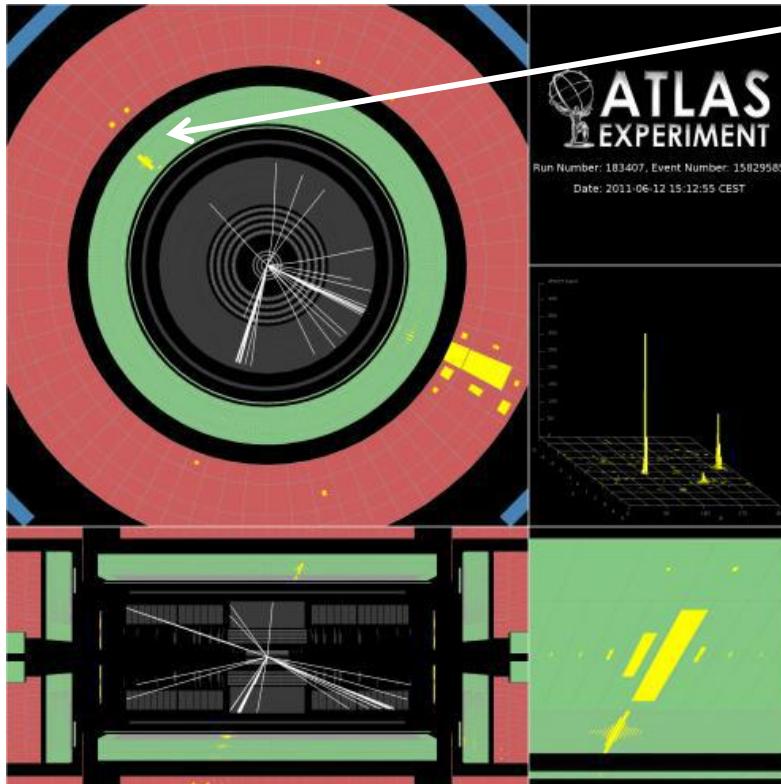


Directly probes gluons

ATLAS Detector



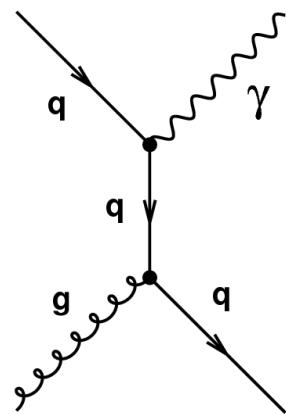
Photons in the ATLAS detector



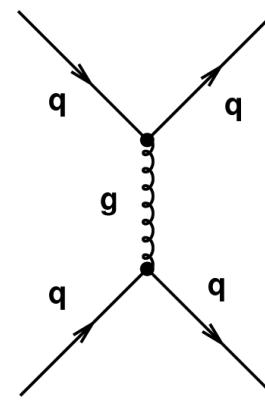
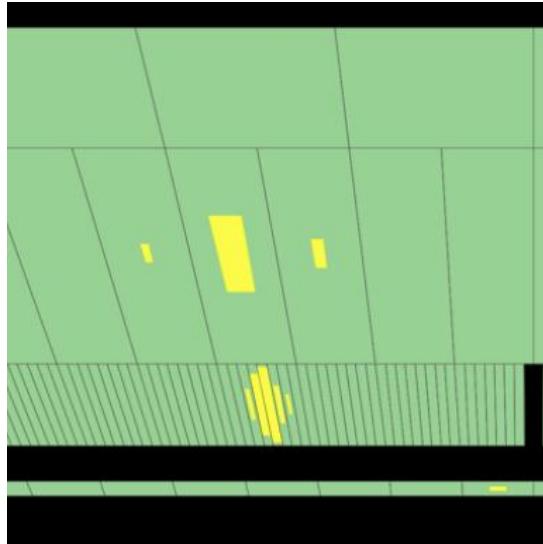
960 GeV Photon at 7 TeV

- EM Calorimeter energy deposit
- No energy in hadronic calorimeter
- No matched track (unconverted)
- One or two matched tracks consistent with conversion
- Photon isolation is required
 - $E_T^{iso} = E_T$ in $\Delta R = 0.4$
 - $E_T^{iso} < 4, 7 \text{ GeV}$ (depends on conditions)

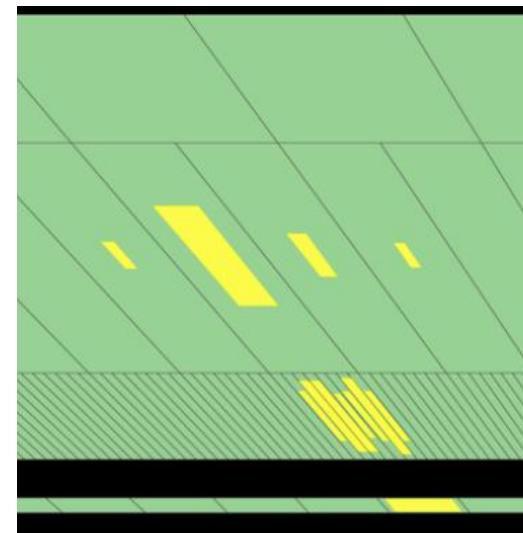
Jet background rejection



Photon

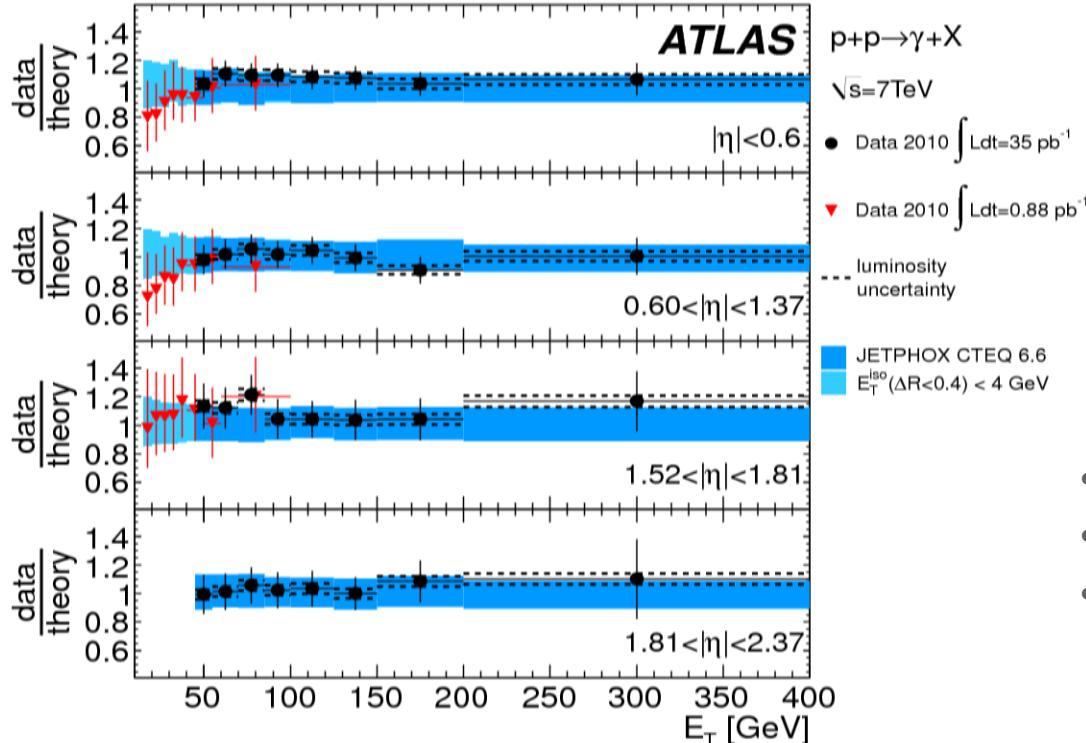


π^0



Shower shape using the granularity in the first layer

Direct photon from 2010 data (35 pb-1)



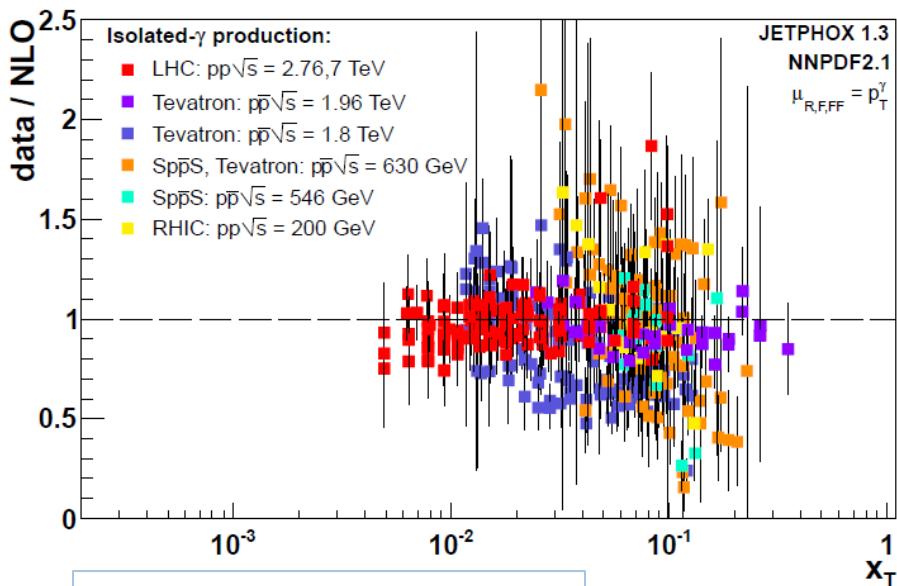
- Measured to $|\eta| < 2.37$
- $15 \text{ GeV} < E_T < 400 \text{ GeV}$
- NLO prediction agree with data within uncertainties.

Phys. Rev. D83 (2011) 052005

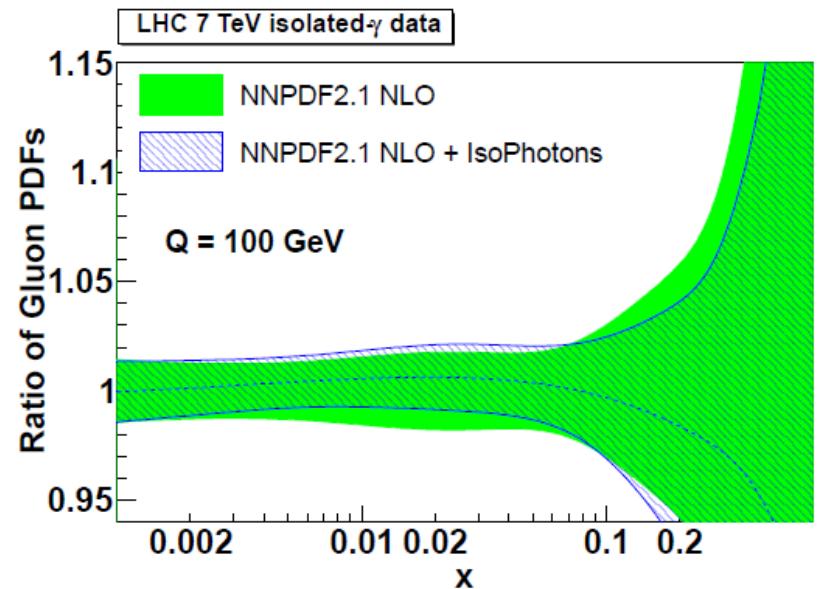
Phys. Rev. D85 (2012) 092014

ATL-PHYS-PUB-2011-013 (compiled data)

Comparison of first LHC isolated-photon data to PDF.

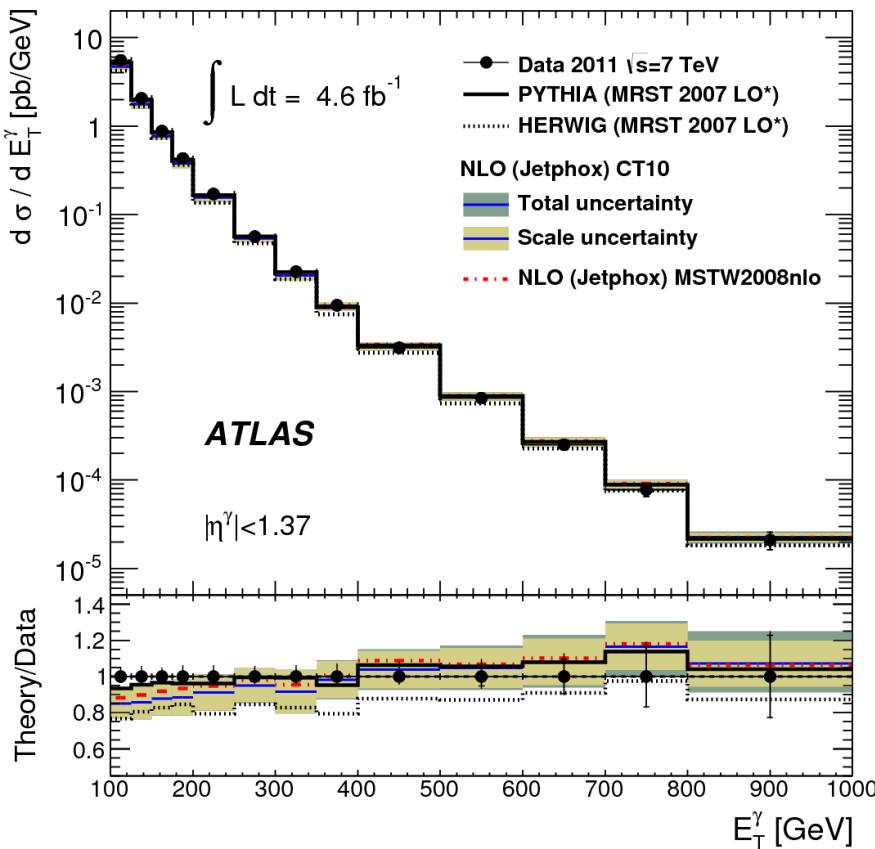


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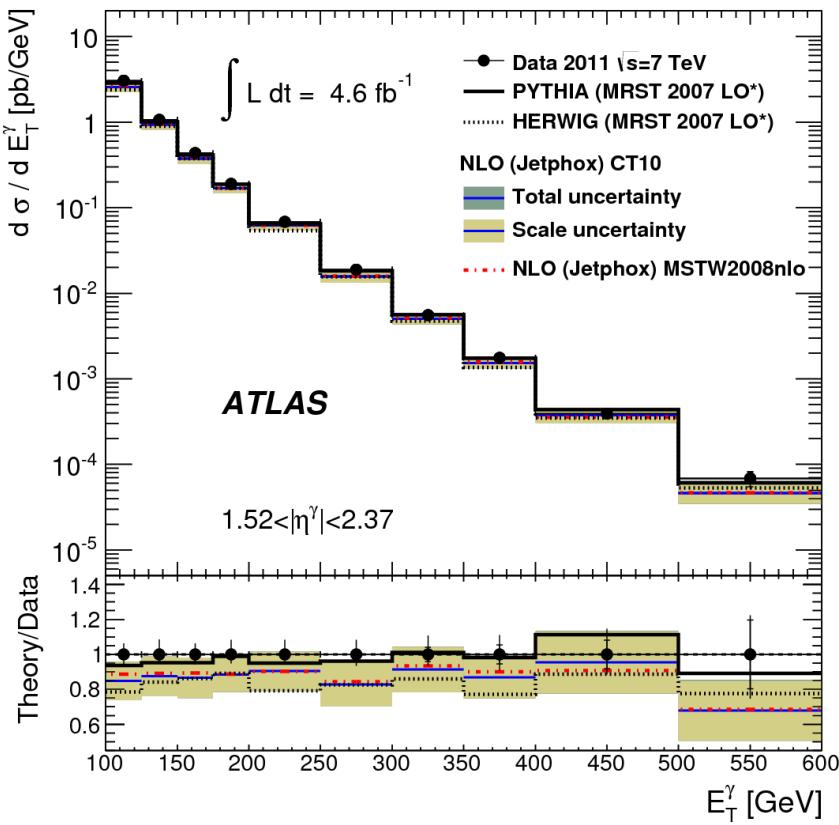
- No impact on quarks from LHC data
- Up to $\sim 20\%$ effect on gluon uncertainty

Direct Photon Cross Sections for 2011 data



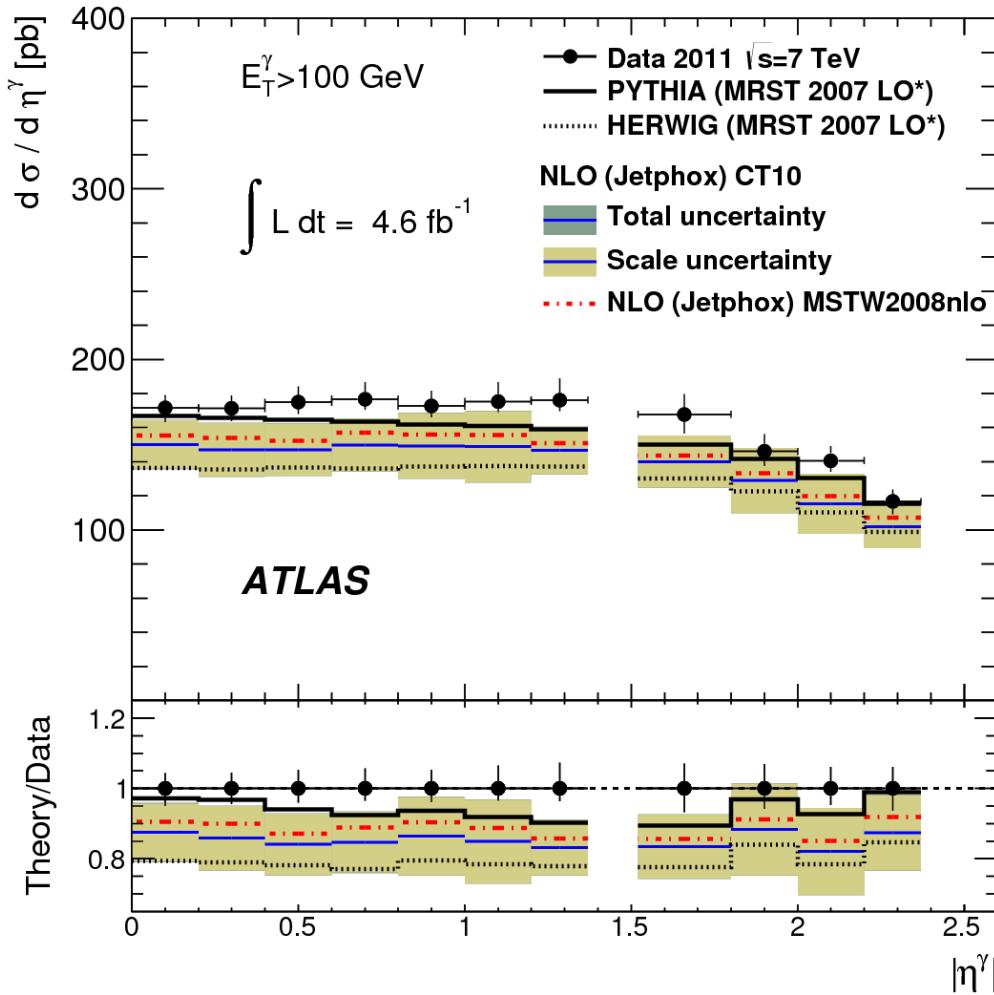
- Measured to $|\eta| < 2.37$
- $100 \text{ GeV} < E_T < 1000 \text{ GeV}$
- This plot for central $|\eta| < 1.37$
- NLO prediction agree with data within uncertainties.
- Largest difference at low E_T but within errors.
- NLO tends to be below data at $E_T < \sim 200 \text{ GeV}$.
- PYTHIA (LO) agrees with data.
- HERWIG systematically underestimates the data by 10%-20%

Isolated Photon Cross Section



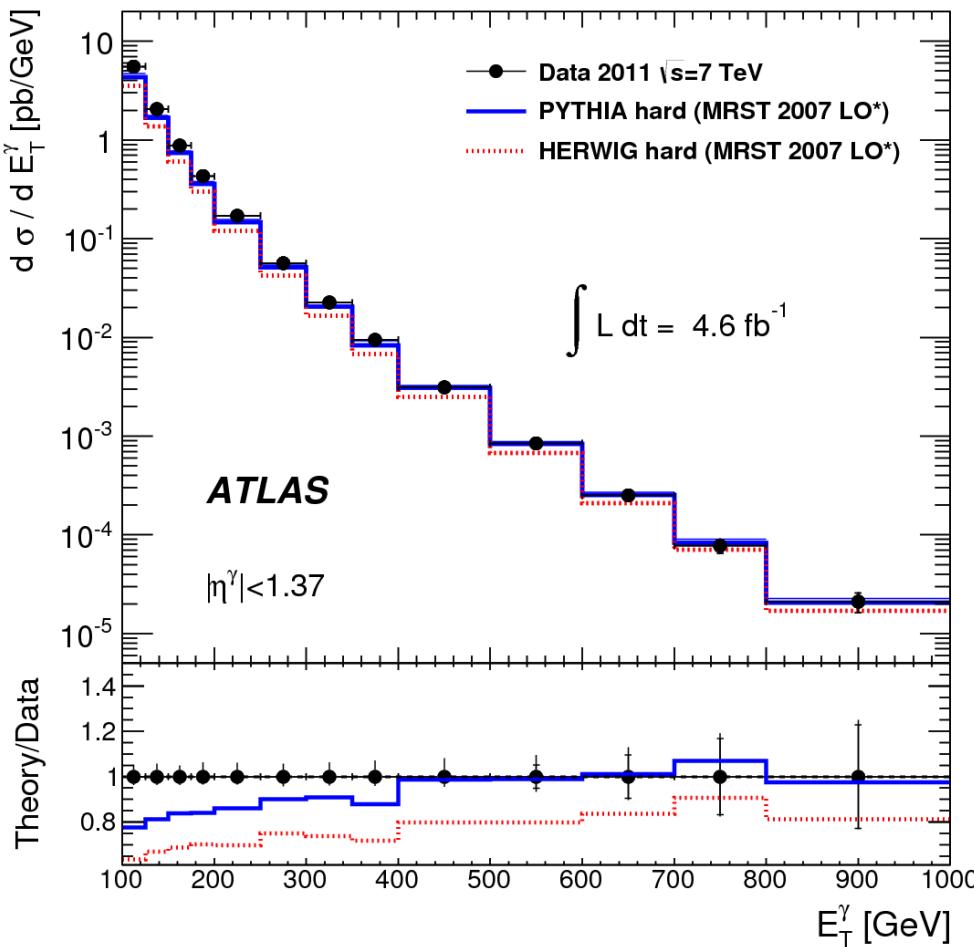
- Forward rapidity $1.52 < |\eta| < 2.37$
- NLO predictions agree with data within uncertainties.
- NLO tends to be below data.
- PYTHIA (LO) agrees with data.
- HERWIG systematically underestimates the data by 10%-20%

Direct Photon Cross Sections for 2011 data



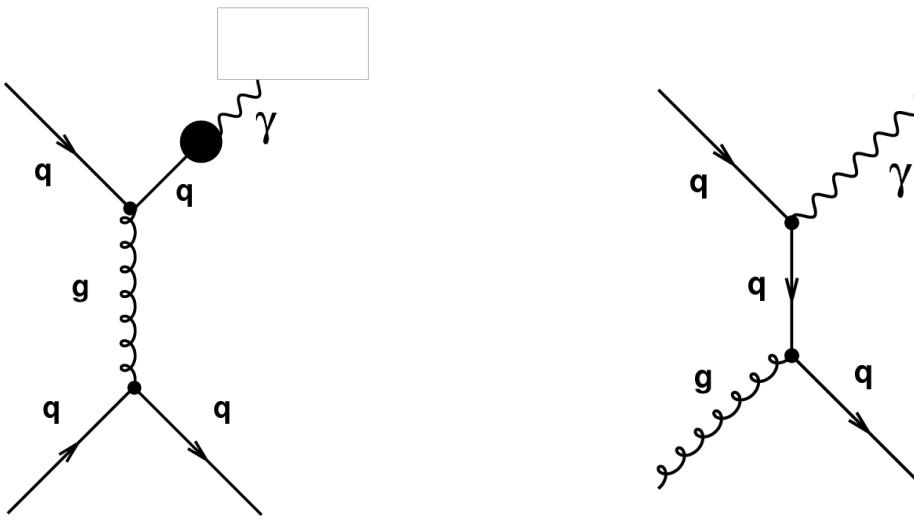
- $E_T > 100$ GeV
- Function of rapidity
- NLO tends to be lower than the data.
- Dominated by “low” E_T region
- PYTHIA (LO) agrees with data.
- HERWIG systematically underestimates the data by 20%

Direct Photon Cross Sections for 2011 data



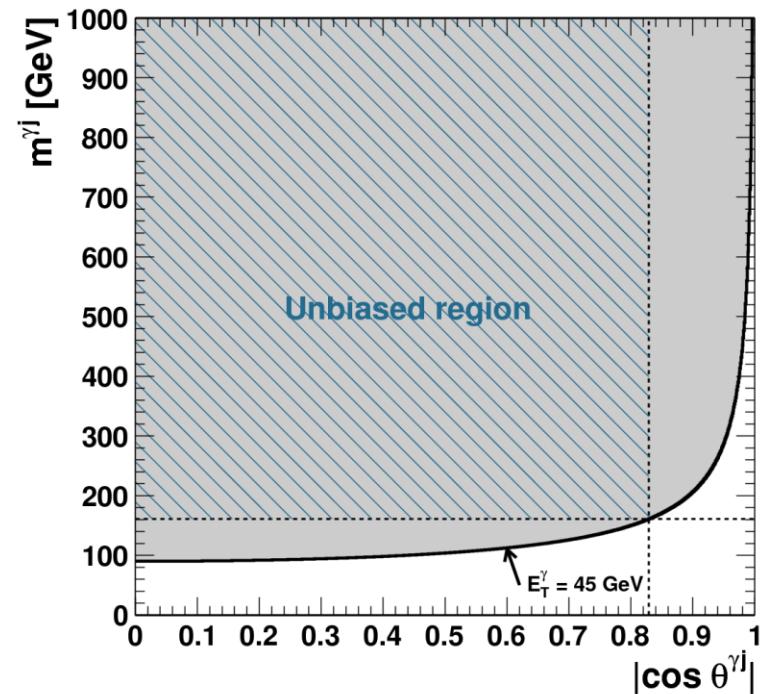
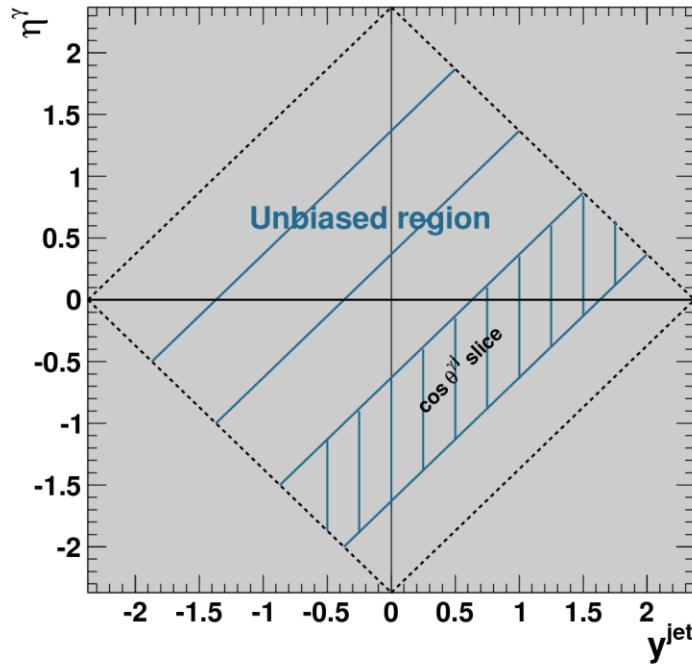
- Central region
- Compare now to LO Monte Carlos.
- Remove the fragmentation component from the MC.
- PYTHIA prediction has up to 20% fragmentation component at $E_T > 100$ GeV.
- PYTHIA describes data above $E_T > 450$ GeV without fragmentation component.
- Dominated by “low” ET region

Dynamics of Underlying Process



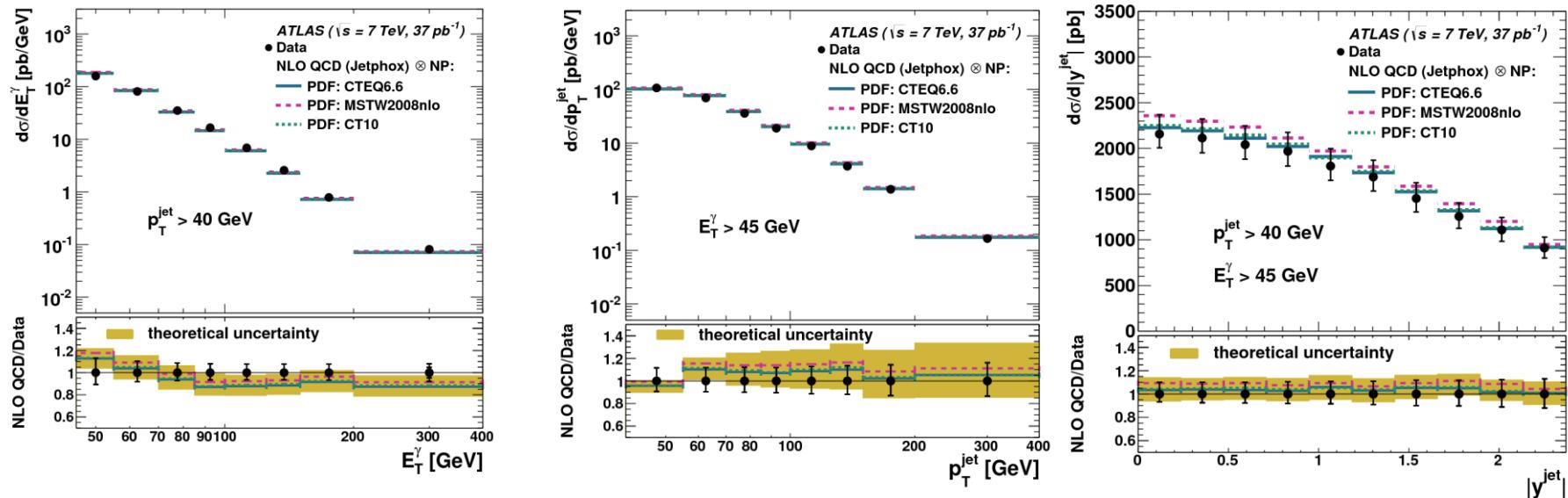
- Can we say something about these components of the cross-section from data?
- Look at the scattering angle $\cos\theta^{vj}$ in the center-of-mass frame.
- Distribution of $\cos\theta^{vj}$ depends on the spin of the exchanged particle.
- $(1 - |\cos\theta^{vj}|)^{-1}$ as $|\cos\theta^{vj}| \rightarrow 1$ for spin 1/2 (quark) exchange, i.e. direct photon.
- $(1 - |\cos\theta^{vj}|)^{-2}$ as $|\cos\theta^{vj}| \rightarrow 1$ for spin 1 (gluon) exchange i.e. fragmentation.

Kinematic selection of Photon+jets sample



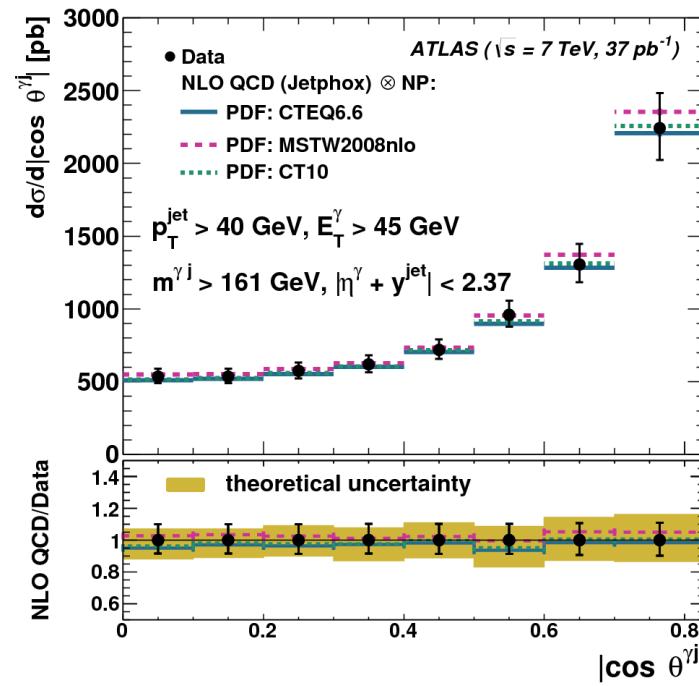
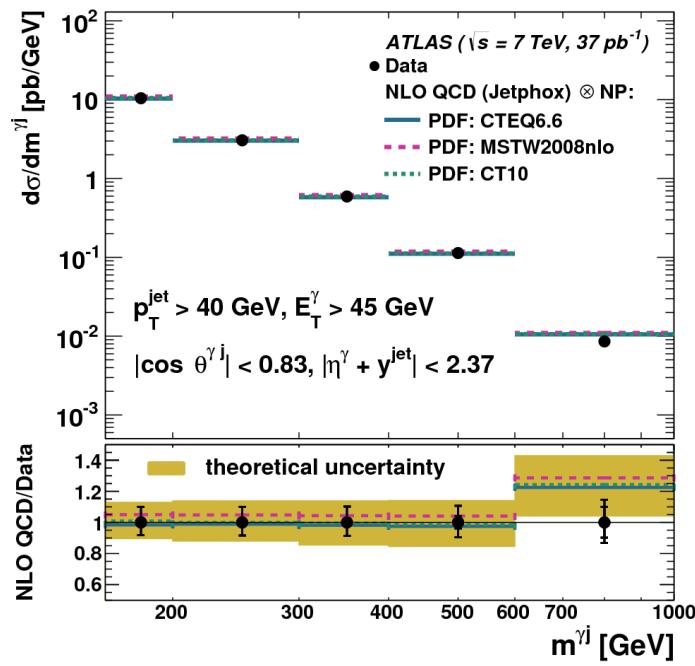
- 2010 data at 7 TeV. (avoid pileup problems)
- $E_T > 45 \text{ GeV}$
- Kinematic cuts made in order to have region unbiased for $\cos \theta^{\gamma j}$ distribution

Photons + jets cross section measurement.



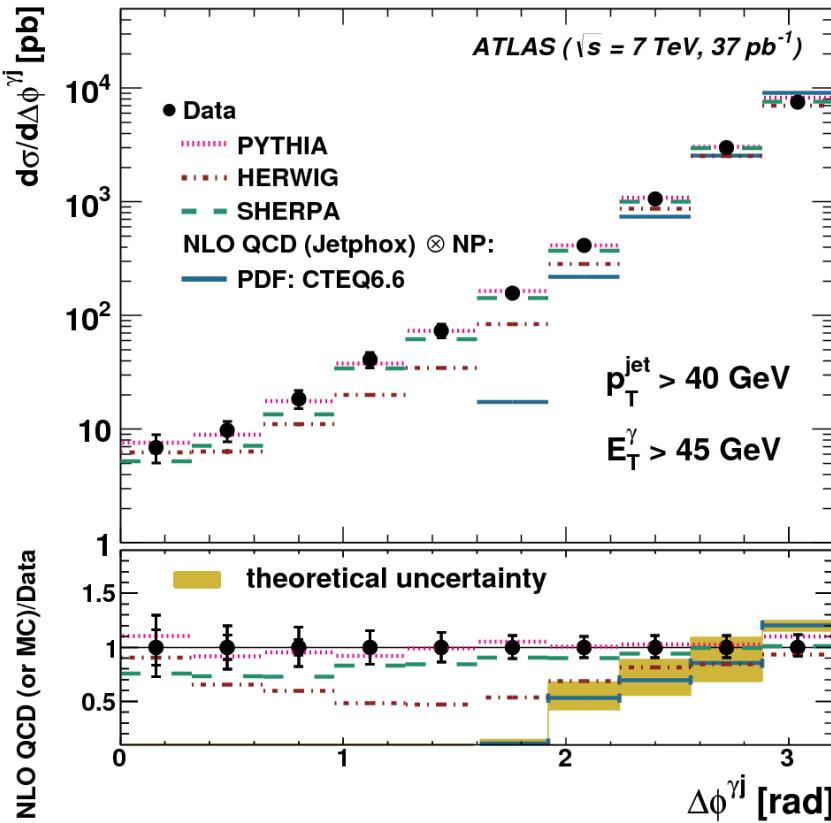
NLO QCD describes the photon+jets data well

Photon + Jets



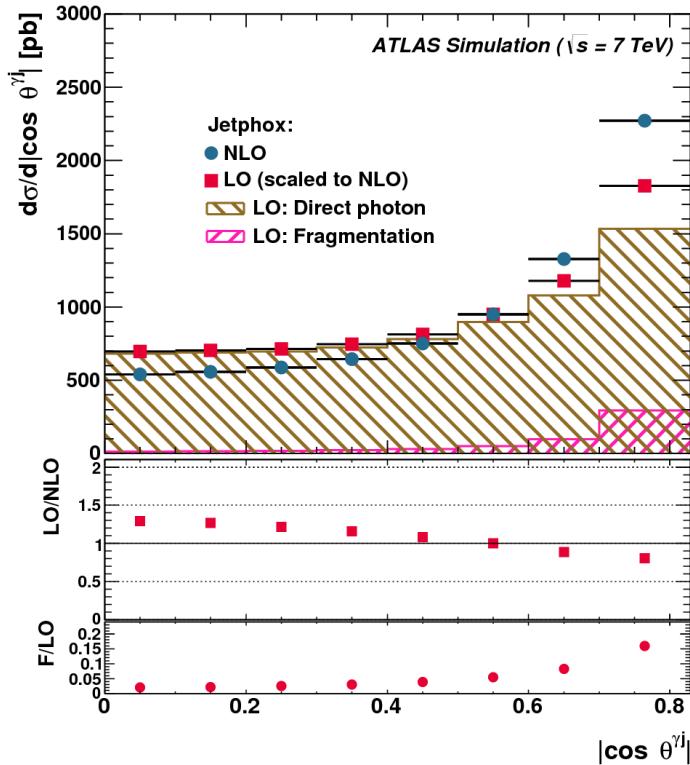
Also the mass and $\cos\theta^{\gamma j}$ are also described well

Photon + Jet



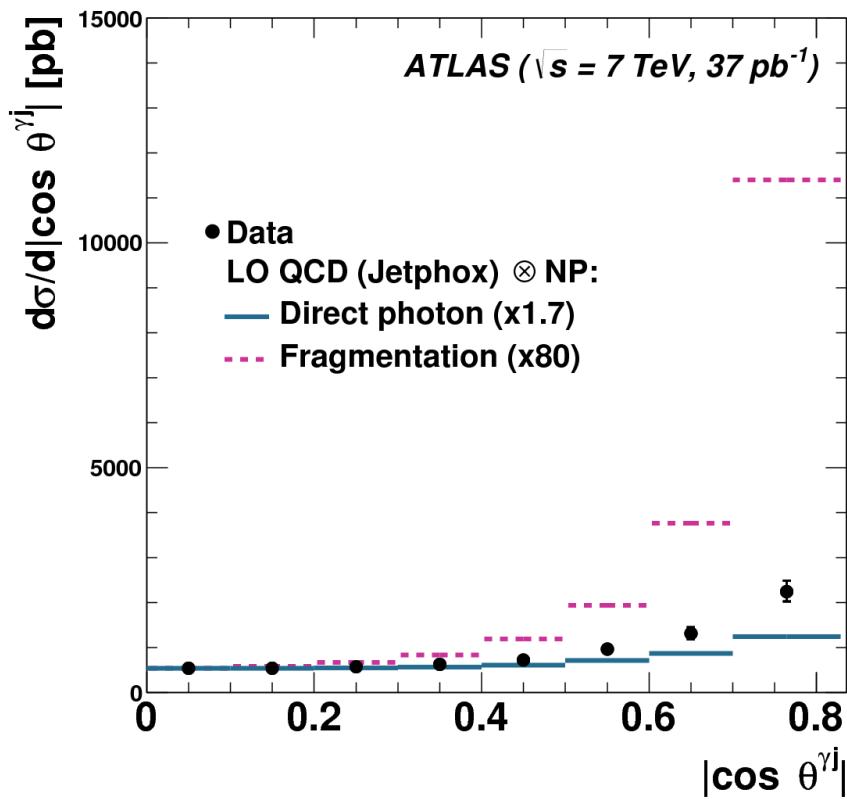
- NLO QCD fails to describe the azimuthal angle distribution
- Expected since “NLO QCD” is really only LO in this variable.
- LO Monte Carlos with parton showers describe the data well.

Photon + Jet



- LO/NLO ratio is flat in E_T , mass and rapidity.
- Strong dependence on $\cos\theta^{\gamma j}$
- Fragmentation contribution (LO) increases from 2 to 16% as a function of $| \cos\theta^{\gamma j} |$.
- Fragmentation contribution decreases as a function of E_T and mass.

Photon + Jet



- Compare the data with LO as a function of $|\cos \theta^{\gamma j}|$
- Fragmentation contribution rises steeply compared to the direct contribution.
- Measurement is closer to the “direct photon” shape.
- Implies dominance of quark exchange.

Conclusions

- Recent results of measurement of isolated photon and photon +jet from ATLAS were presented
- Measured to $E_T = \sim 1$ TeV and η to ~ 2.37 .
- The x range covered is $\sim 10^{-3} < x < \sim 0.5$
- Directly sensitive to the gluon distribution.
- In general well described by NLO QCD calculations with CT10 (for example)
- Has potential to improve the gluon distribution, particularly at x of 0.01 to 0.02.
- The $|\cos\theta^{yj}|$ distribution in photon +jets are shown to be sensitive to the exchanged particle of the subprocesses.