Photon, diphoton and photon+jet production measured with the ATLAS detector

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On behalf of the ATLAS experiment

22-26.4.2013

Sources

- ATLAS Collaboration, *Measurement of the inclusive isolated prompt photon cross-section in pp collisions at $\sqrt{s} = 7$ TeV using 35 pb-1 of ATLAS data*, Phys.Lett. **B706** (2011) 150–167, arXiv:1108.0253 [hep-ex]
- Atlas Collaboration, *Inclusive cross sections of isolated prompt photons in pp collisions at $\sqrt{s} = 7$ TeV measured with the ATLAS detector using 4.7 fb^{-1}*, Tech. Rep. ATLAS-CONF-2013-022, CERN, Geneva, Mar, 2013
- ATLAS Collaboration, *Measurement of isolated-photon pair production in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector*, JHEP **1301** (2013) 086, arXiv:1211.1913 [hep-ex]
- ATLAS Collaboration, *Measurement of the production cross section of an isolated photon associated with jets in proton-proton collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector*, Phys.Rev. **D85** (2012) 092014, arXiv:1203.3161 [hep-ex]
- Atlas Collaboration, *Dynamics of isolated-photon and jet production in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector*, Tech. Rep. ATLAS-CONF-2013-023, CERN, Geneva, Mar, 2013

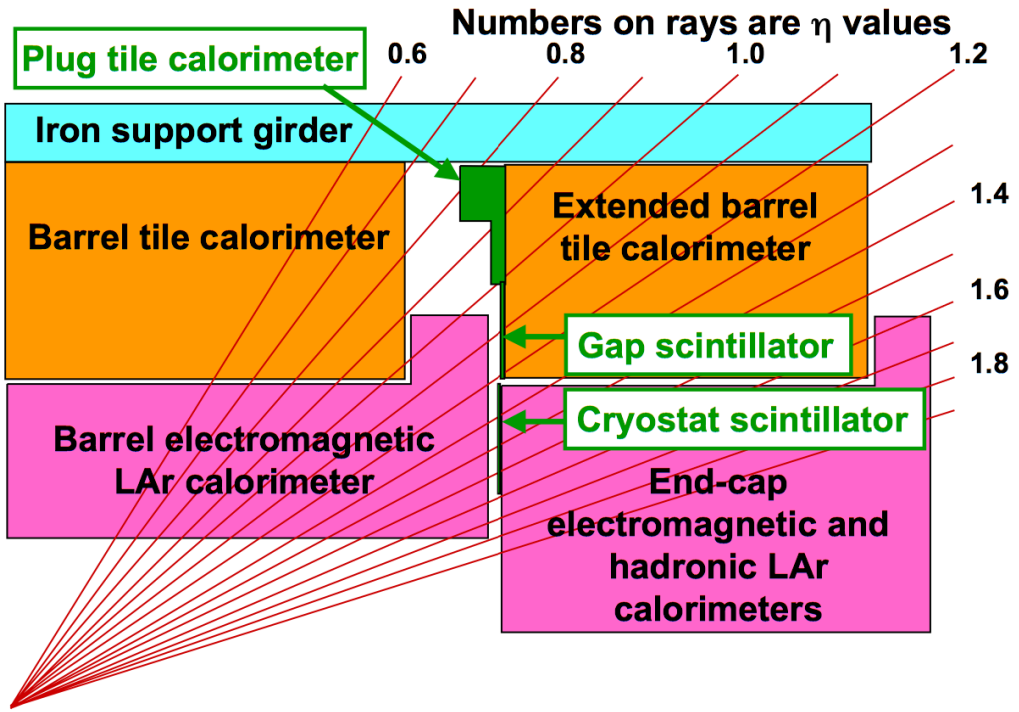
Photons and jets

Photon reconstruction:
from towers in electromagnetic calorimeter

- converted
  photons - cluster has matched
  track(s) in the inner detector
- unconverted
  photons - no matching track(s)

Jet reconstruction:

- topological clusters built from
  calorimeter cells
- using anti-k_t algorithm



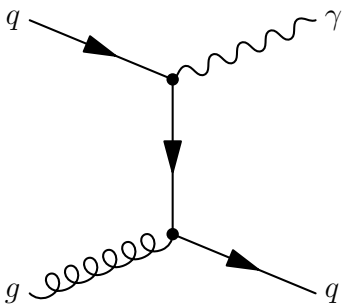
Physics motivation

Photon production

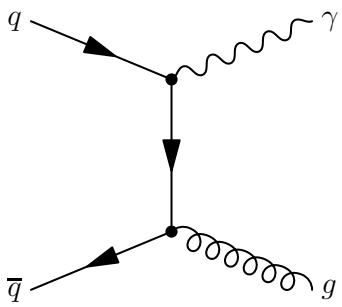
- test of pQCD predictions
- sensitive to the gluon content of proton
- important for many physics signatures (Higgs decay, graviton decay, ...)

Photon+jet

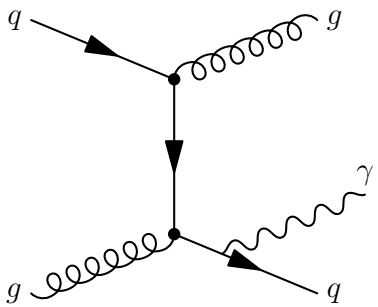
- angular correlations between the photon and the jet can be used to constrain the photon fragmentation functions



Compton



Annihilation



Fragmentation

Tight isolated photon extraction

Tight selection criteria

- choose photons with small hadronic leakage (as expected for true prompt photons)
- choose photons with narrow energy profile (more concentrated in the core)
- reject candidates with wide showers consistent with jets
- reject cases where two showers give separated energy maxima in the first layer
- reject cases where two showers are merged in a wider maximum

Isolation

- based on photon transverse isolation energy

Signal extraction

- 2D sideband method (based on isolation and identification)

Prompt photons

Phys. Lett. B 706 (2011) 150-167

= direct + fragmentation photons

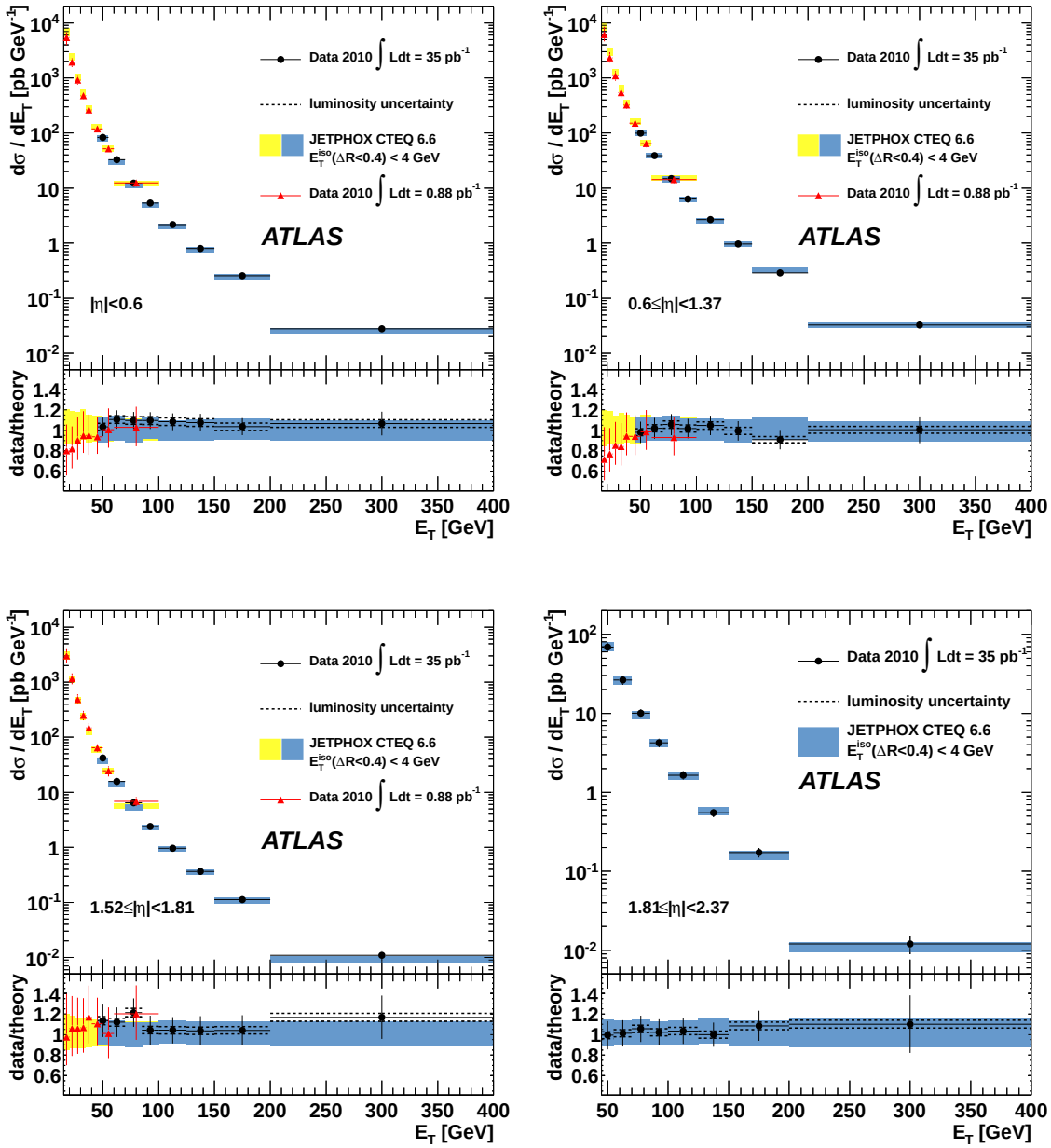
Event selection

- $|\eta^\gamma| < 0.6$, $0.6 \leq |\eta^\gamma| < 1.37$, $1.52 \leq |\eta^\gamma| < 1.81$, and $1.81 \leq |\eta^\gamma| < 2.37$
- $45 < E_T^\gamma < 400$ GeV
- trigger - single photon trigger with threshold of 40 GeV
- tight photon with $E_T^{iso} < 3$ GeV
- events with 1 reconstructed PV with at least 3 tracks

luminosity of (34.6$\pm$1.2) pb^{-1} at $\sqrt{s}$=7 TeV

Prompt photons

- error bars - combination of statistical and systematic uncertainties
- the data agree with the theoretical predictions
- disagreement at low E_T^γ - underestimation of uncertainty associated with the NLO predictions caused by contribution of fragmentation component



Prompt photons

Update (ATLAS-CONF-2013-022)
Event selection

- E_T^γ range between 100 GeV and 1 TeV
- $|\eta^\gamma| < 1.37$, $1.52 \leq |\eta^\gamma| < 2.37$
- high-level photon trigger with threshold of 80 GeV
- tight photon with $E_T^{iso} < 7$ GeV

integrated luminosity of (4.71$\pm$0.09) fb^{-1} at $\sqrt{s}$=7 TeV

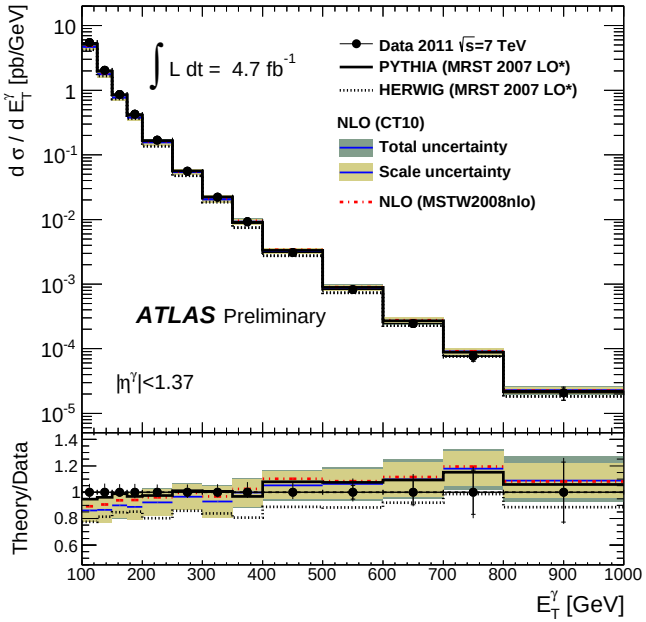
Prompt photons

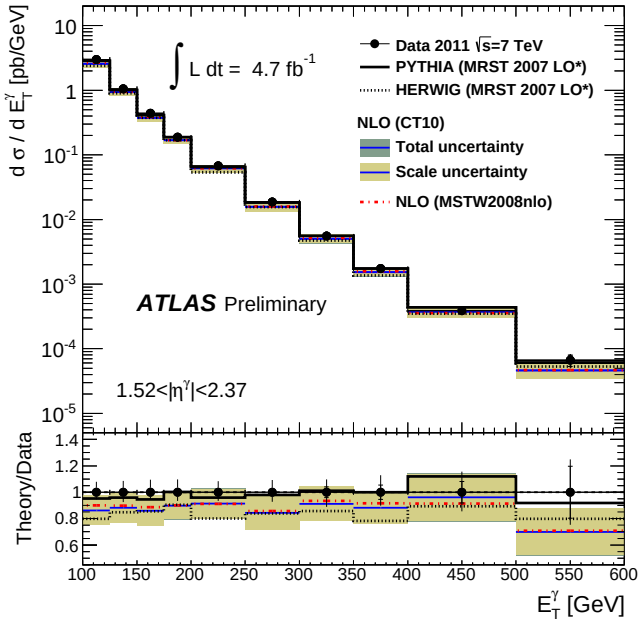
Simulation

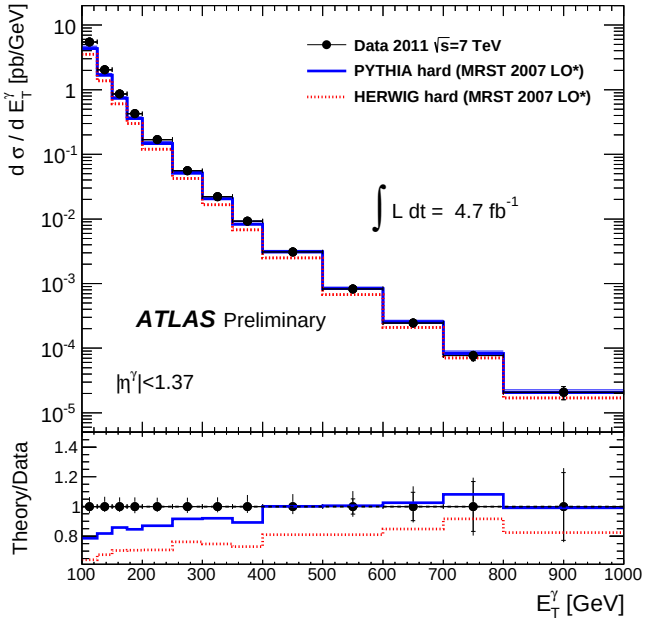
- LO
  - Pythia with MRST2007
  - Herwig with MRST2007
- NLO
  - Jetphox with CT10 or MSTW2008NLO

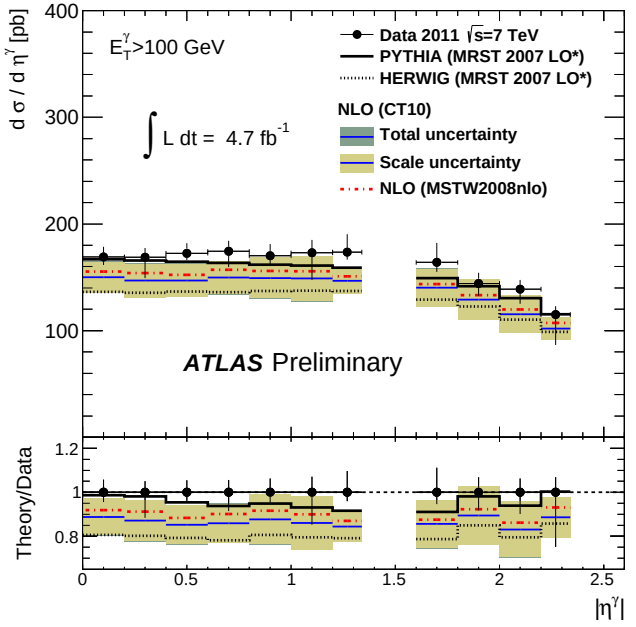
Prompt photons

- NLO calculations - good agreement with the data
- LO simulation - HERWIG cross section lower than in the data









Diphotons

JHEP01(2013)086

Event selection

- $|\eta^{\gamma}| < 1.37$, $1.52 \leq |\eta^{\gamma}| < 2.37$
- E_{T1}^{γ}>25 GeV, E_{T2}^{γ}>22 GeV
- angular separation $\Delta R > 0.4$
- trigger - di-photon trigger with threshold of 20 GeV
- tight photon selection
- isolation ($-4 < E_T^{iso} < 4$ GeV)
- events with 1 reconstructed PV with at least 3 tracks

luminosity of (4.9$\pm$0.2) fb^{-1} at $\sqrt{s}$=7 TeV

Diphotons

MC

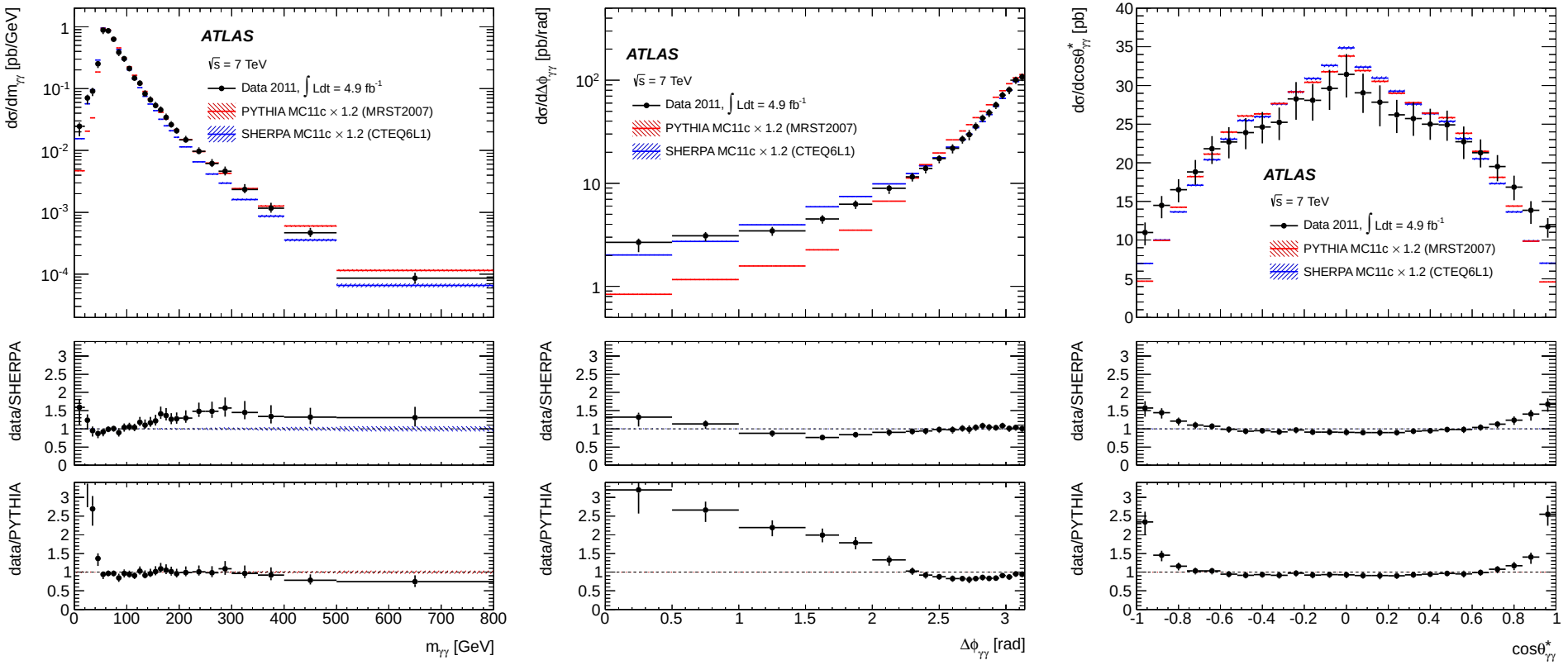
- LO
  - PYTHIA with MRST2007
  - SHERPA with CTEQ6L1
- NLO
  - DIPHOX+GAMMA2MC with CT10 NLO
- NNLO
  - 2γNNLO (neglects fragmentation component) with MSTW2008 NNLO

Signal extraction

- 2D sideband method
- two-dimensional fit

Diphotons

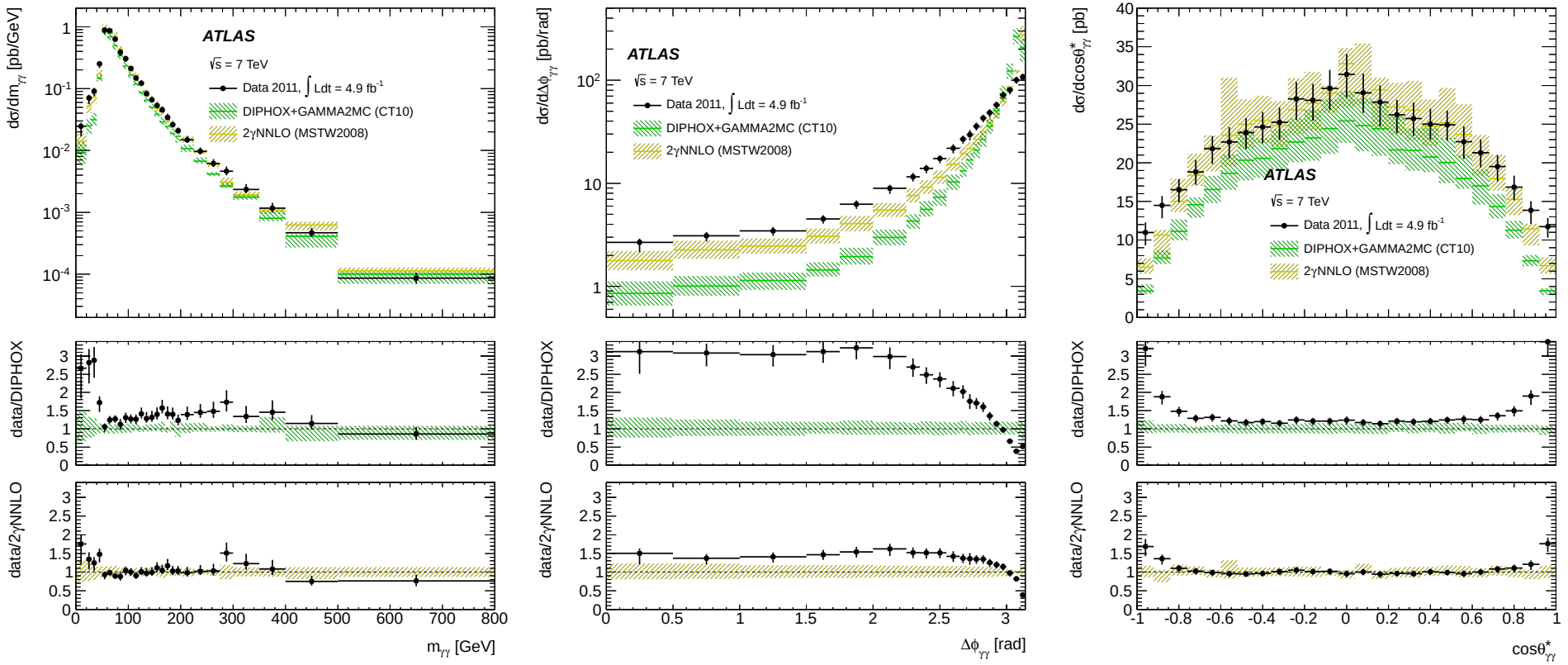
LO simulations



- theoretical uncertainty error bands - statistical uncertainties
- underestimate the total cross section

Diphotons

NLO and NNLO calculations



- theoretical uncertainty error bands - statistical uncertainties + PDF and scale uncertainties
- 2γNNLO is expected to underestimate the data in regions populated by the contribution from fragmentation

Photon+jet

Phys. Rev. D 85, 092014 (2012)
Photon selection

- in ($|\eta^{\gamma}| < 1.37$)
- $E_T^{\gamma} > 25$ GeV
- 2 single photon triggers
  - $E_T^{\gamma} > 45$ GeV - single photon triggers with threshold of 40 GeV (unprescaled)
  - $E_T^{\gamma} \leq 45$ GeV - single photon triggers with threshold of 20 GeV (average prescale factor 5.5)
- tight photon with $E_T^{iso} < 3$ GeV

Jet selection

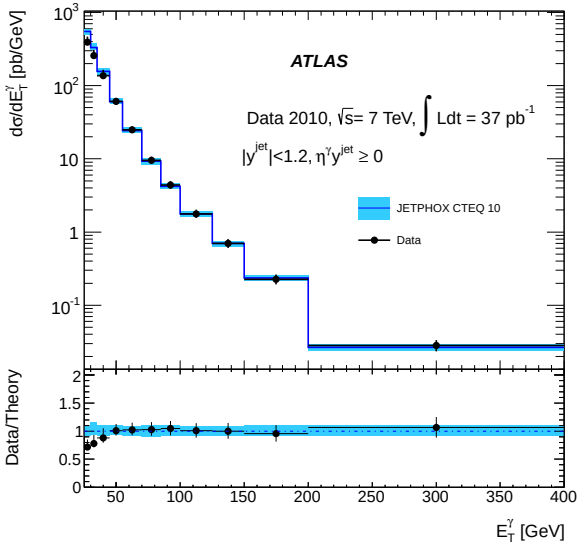
- $|y^{jet}|$ <4.4
- jet axis not in a cone of radius R=1.0 around the photon direction
- jets defined using anti-k_t algorithm with R=0.4

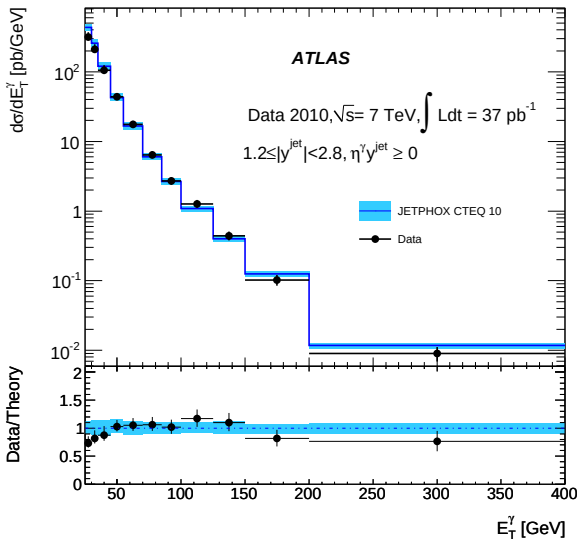
Photon+jet

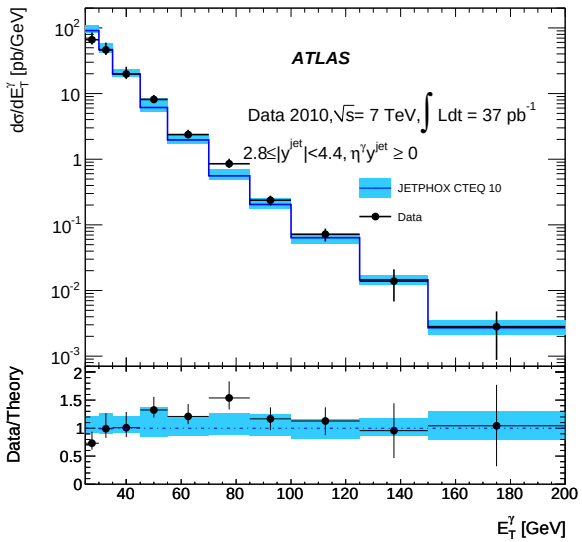
events with 1 reconstructed PV with at least 3 tracks
luminosity of (37.1) pb^{-1} at $\sqrt{s}$=7 TeV
Simulation

- LO
  - Pythia with MSTW 2008 or NNPDF 2.1
  - Herwig+Jimmy with MSTW 2008 or NNPDF 2.1
  - Sherpa with MSTW 2008 or NNPDF 2.1
- NLO
  - Jetphox with CT10

Photon+jet



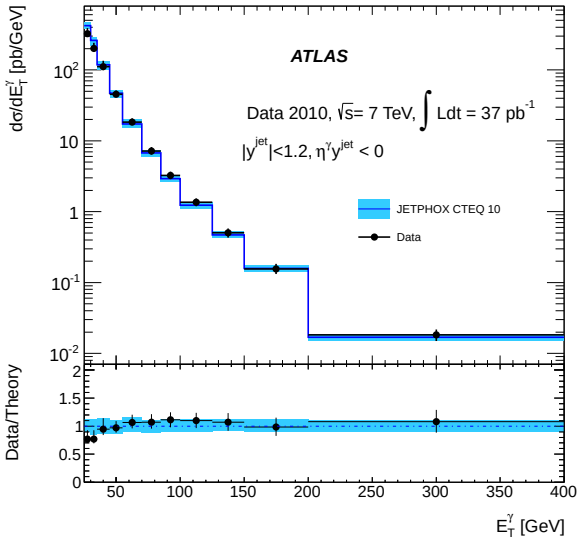




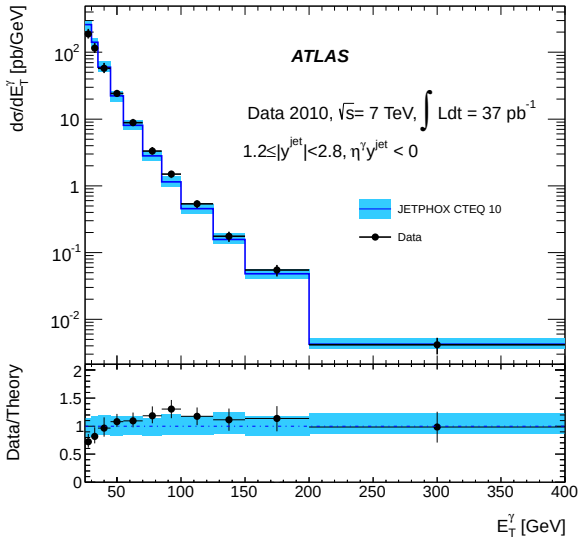
$|y^{jet}| < 1.2, \eta^{\gamma} y^{\text{jet}} \geq 0$ $1.2 < |y^{jet}| < 2.8, \eta^{\gamma} y^{\text{jet}} \geq 0$ $2.8 |y^{jet}| < 4.4, \eta^{\gamma} y^{\text{jet}} \geq 0$

- measured in three $|y^{jet}|$ bins
- cross-section for $(\eta^{\gamma} y^{\text{jet}} \geq 0)$ or $(\eta^{\gamma} y^{\text{jet}} < 0)$
- error bars - combination of statistical and systematic uncertainties
- NLO pQCD predictions are in agreement with the measured cross sections

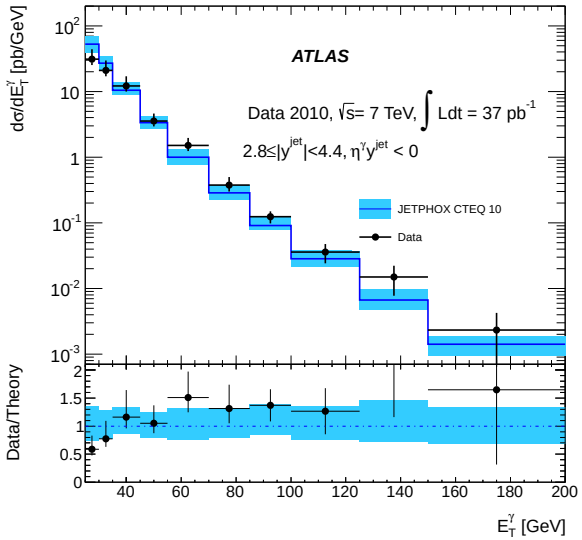
Photon+jet



$|y^{jet}| < 1.2, \eta^{\gamma} y^{\text{jet}} < 0$



$1.2 < |y^{jet}| < 2.8, \eta^{\gamma} y^{\text{jet}} < 0$



$2.8 |y^{jet}| < 4.4, \eta^{\gamma} y^{\text{jet}} < 0$

- measured in three $|y^{jet}|$ bins
- cross-section for $(\eta^{\gamma} y^{\text{jet}} \geq 0)$ or $(\eta^{\gamma} y^{\text{jet}} < 0)$
- error bars - combination of statistical and systematic uncertainties
- NLO pQCD predictions are in agreement with the measured cross sections

Photon+jet

Update (ATLAS-CONF-2013-023)

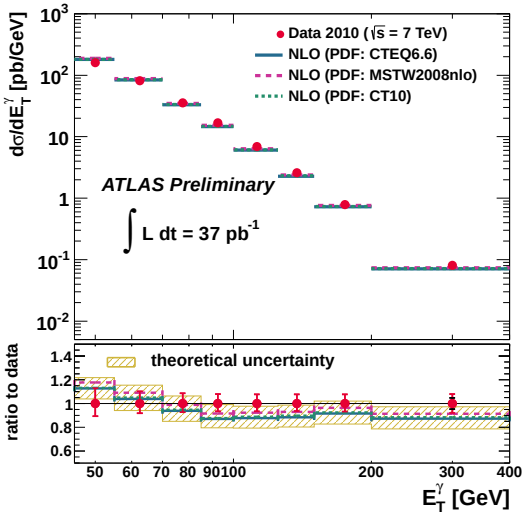
- the dynamics of isolated-photon plus jet production
- investigation of dependence of cross-section on
  - leading-photon transverse energy (E_T^{γ})
  - the leading-jet transverse momentum (P_T^{jet})
  - the leading-jet rapidity (y^{jet})
  - the difference in azimuthal angle between the photon and the jet ($\Delta\phi^{\gamma j}$)
  - the photon-jet invariant mass ($M^{\gamma j}$)
  - the scattering angle in the photon-jet centre-of-mass frame ($\theta^{\gamma j}$)

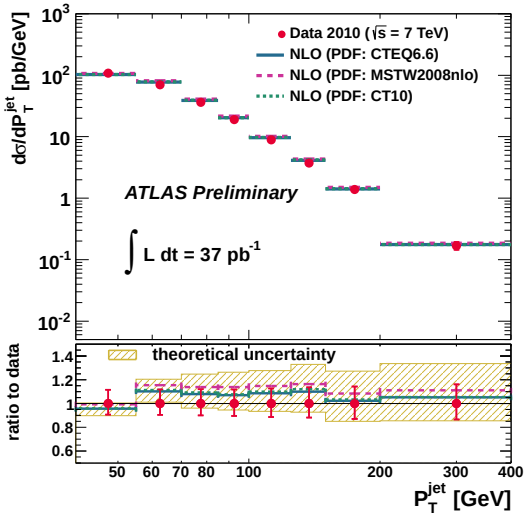
Photon+jet

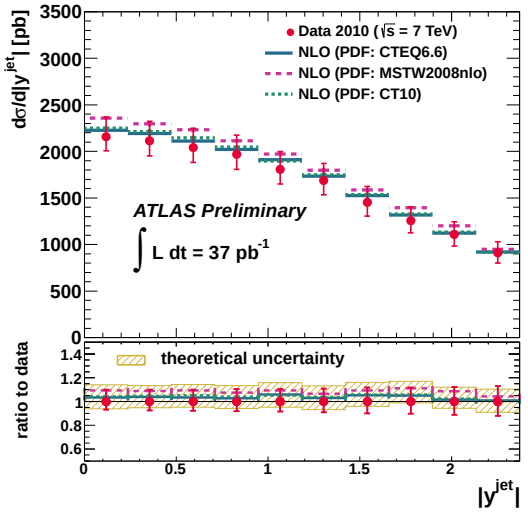
- phase space:
  - photon: $E_T^\gamma > 45$ GeV, $|\eta^\gamma| < 1.37$, $1.52 \leq |\eta^\gamma| < 2.37$
  - jet: $P_T^{\text{jet}} > 40$ GeV, $|\eta^{\text{jet}}| < 2.37$
  - $\Delta R_{\gamma j}^2 > 1$
- jets defined using anti-k_t algorithm with R=0.6
- tight photon with $E_T^{iso} < 3$ GeV

luminosity of (37.1$\pm$1.3) pb^{-1} at $\sqrt{s}$=7 TeV

Photon+jet

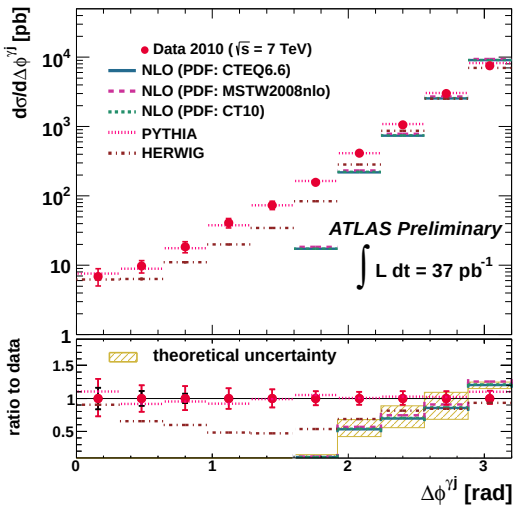


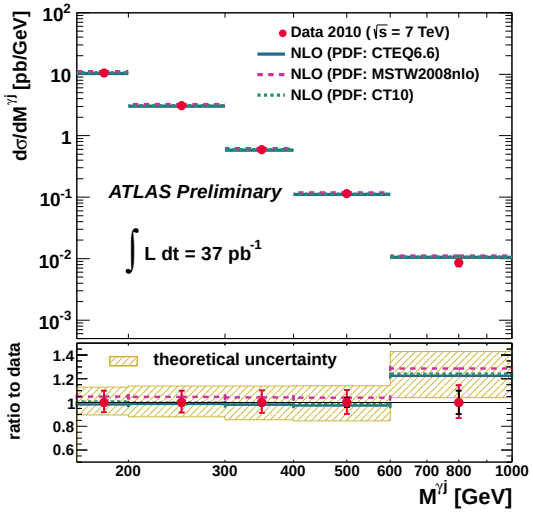


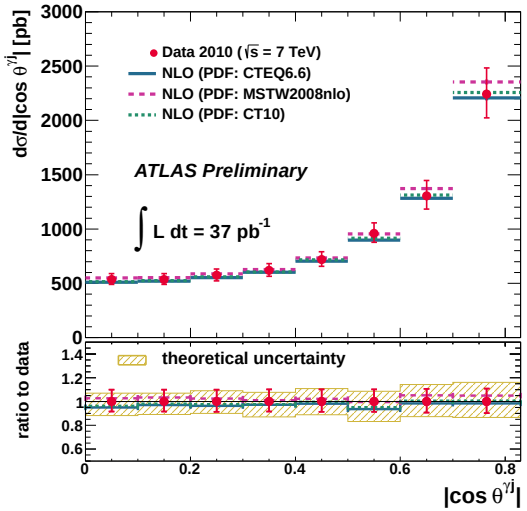


- NLO QCD calculations describe data well as a function of E_T^{γ} and P_T^{jet}
- description of shape and normalisation as a function of $|y^{\text{jet}}|$ is also well

Photon+jet







- NLO QCD calculation fails to describe the measured $\Delta\phi^{\gamma j}$ distribution (PYTHIA gives a good description, HERWIG does not)
- NLO QCD calculations describe data well as a function of $M^{\gamma j}$ and $\theta^{\gamma j}$

Summary

- prompt photon production is in good agreement with predictions
  - except for very low E_T^γ - correspond to small values of x_T (NLO theoretical predictions are less accurate)
- in diphoton production, predictions underestimate data
  - PYTHIA and SHERPA - missing NLO (and higher-order) contributions
  - DIPHOX+GAMMA2MC - missing NNLO contributions
  - 2γNNLO - missing fragmentation component
- photon+jet production is in fair agreement with predictions

Backup slides

Diphoton p_T cross-section