Measurement of the photon and jet production with the ATLAS detector

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On behalf of the ATLAS Collaboration

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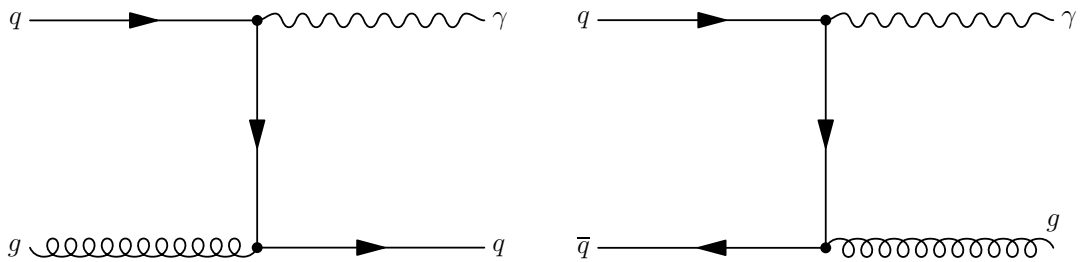
Physics motivation

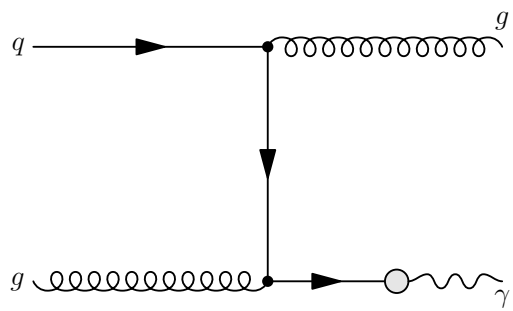
- testing of perturbative Quantum Chromodynamics (pQCD)
- study of parton distribution functions (e.g $qg \rightarrow q\gamma$ can be used to study the gluon parton distribution function)
- improved understanding can improve precision of other measurements (e.g. photon production is background in Higgs production in diphoton channel; jet for SUSY/exotic processes)
- precise jet cross-section measurement allows to extract information about the strong coupling constant α_S

Prompt photons

- direct photons - the photon originates directly from the hard interaction



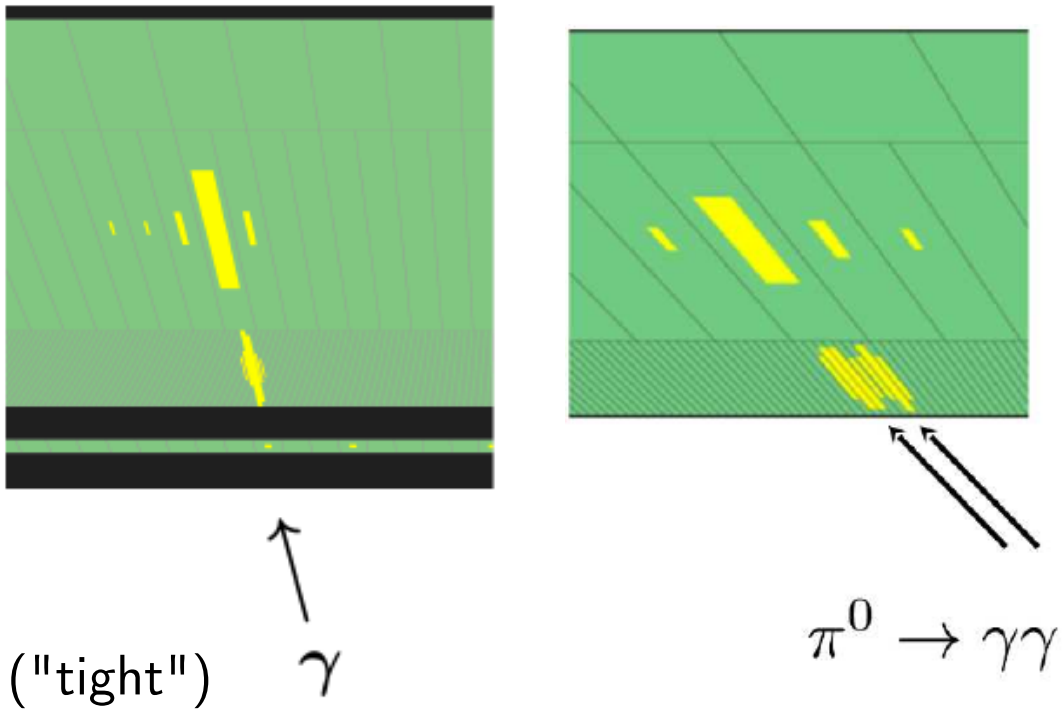
- fragmentation photons - the photon is emitted in the fragmentation of a high transverse momentum parton



Photon reconstruction, identification, isolation

Reconstruction

- from energy deposits in the electromagnetic calorimeter with $E_T >$ 2.5 GeV in towers of 3×5 cells in $\eta \times \phi$



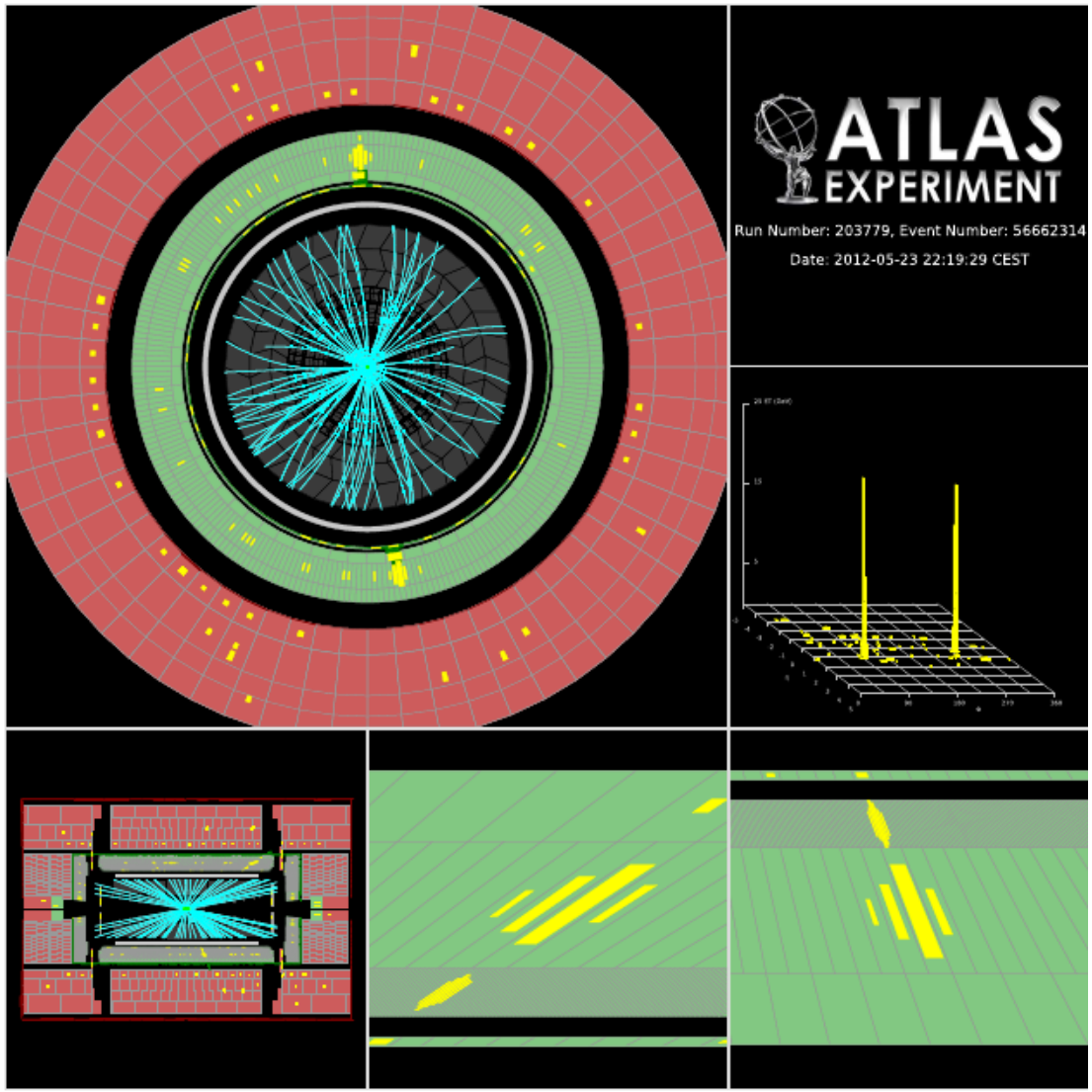
Identification ("tight")

- purpose:rejects hadronic background by applying requirements on
  - the energy leaking into the hadronic calorimeter
  - the shower-shape variables
- aims to reject most of the jet background
- optimised to reduce the contribution from jets with one or more hard π^0 decaying to photons and carrying most of the jet energy

Photon reconstruction, identification, isolation

Isolation

- the E_T^{iso} is based on energy measured in topological clusters within a cone of radius R=0.4 (with the core of the cone removed)
- photon is considered isolated when its E_T^{iso} is less than some isolation cut (in photon measurements presented here, the cut is $4.8\ \text{GeV} + 4.2{\times}10^{-3} \times E_T^{\gamma}$)



Photon cross-section measurement at $\sqrt{s}$=8 TeV

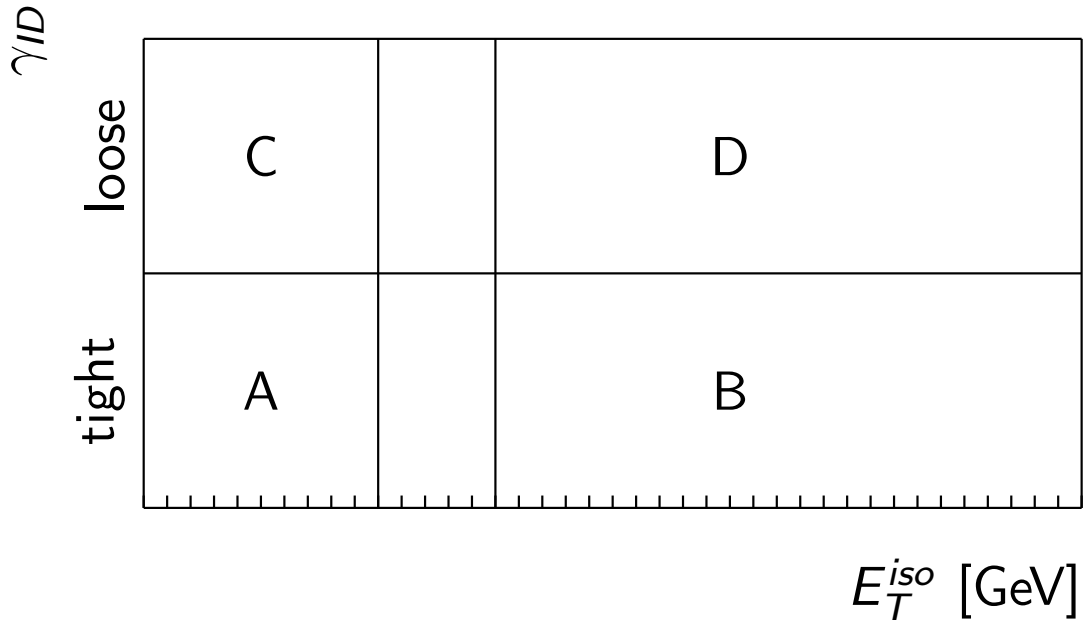
event selection:

- $|\eta^{\gamma}| < 1.37$, $1.56 \leq |\eta^{\gamma}| < 2.37$
- $25 < E_T^{\gamma} < 1500$ GeV
- trigger - single photon triggers with thresholds 20, 40, 60, 80, 100, and 120 GeV
- tight isolated photon

background subtracted using 2D sideband method:

- purpose:to remove the residual background from meson decays and jets
- based on isolation and identification criteria
  - photons separated into four regions (A-tight and isolated;B-tight and non-isolated,C-non-tight and isolated;D-non-tight and non-isolated) with two fractions in regions B,C,D (signal and background) and only signal in region A

Photon cross-section measurement at $\sqrt{s}$=8 TeV



$$N_{signal}^{A,data} = N^{A,data} - R_{bkg}\left(\left(N^{B,data} - f^{B,MC}N_{signal}^{A,data}\right)\frac{\left(N^{C,data} - f^{C,MC}N_{signal}^{A,data}\right)}{\left(N^{D,data} - f^{D,MC}N_{signal}^{A,data}\right)}\right)$$

where

- $f^{K,MC} = N_{signal}^{K,MC}/N_{signal}^{A,MC}$ (for K=B,C,D) is signal leakage fraction
- $R_{bkg} = N_{bkg}^{A,MC}N_{bkg}^{D,MC}/N_{bkg}^{B,MC}N_{bkg}^{C,MC}$ expresses independence of background variables

Photon cross-section measurement at $\sqrt{s}$=8 TeV

data

- luminosity 20.2 fb^{-1}

MC

- LO
  - Pythia 8.165 using CTEQ6L1
  - Sherpa 1.4.0 using CT10
- NLO
  - JetPhox using CT10
    - parton-level generator for the prediction of processes with photons in the final state
    - NLO accuracy for both the direct and fragmentation photon processes
  - PeTer using CT10
    - parton-level generator including the resummation of threshold logarithms

Photon cross-section measurement at $\sqrt{s}$=8 TeV

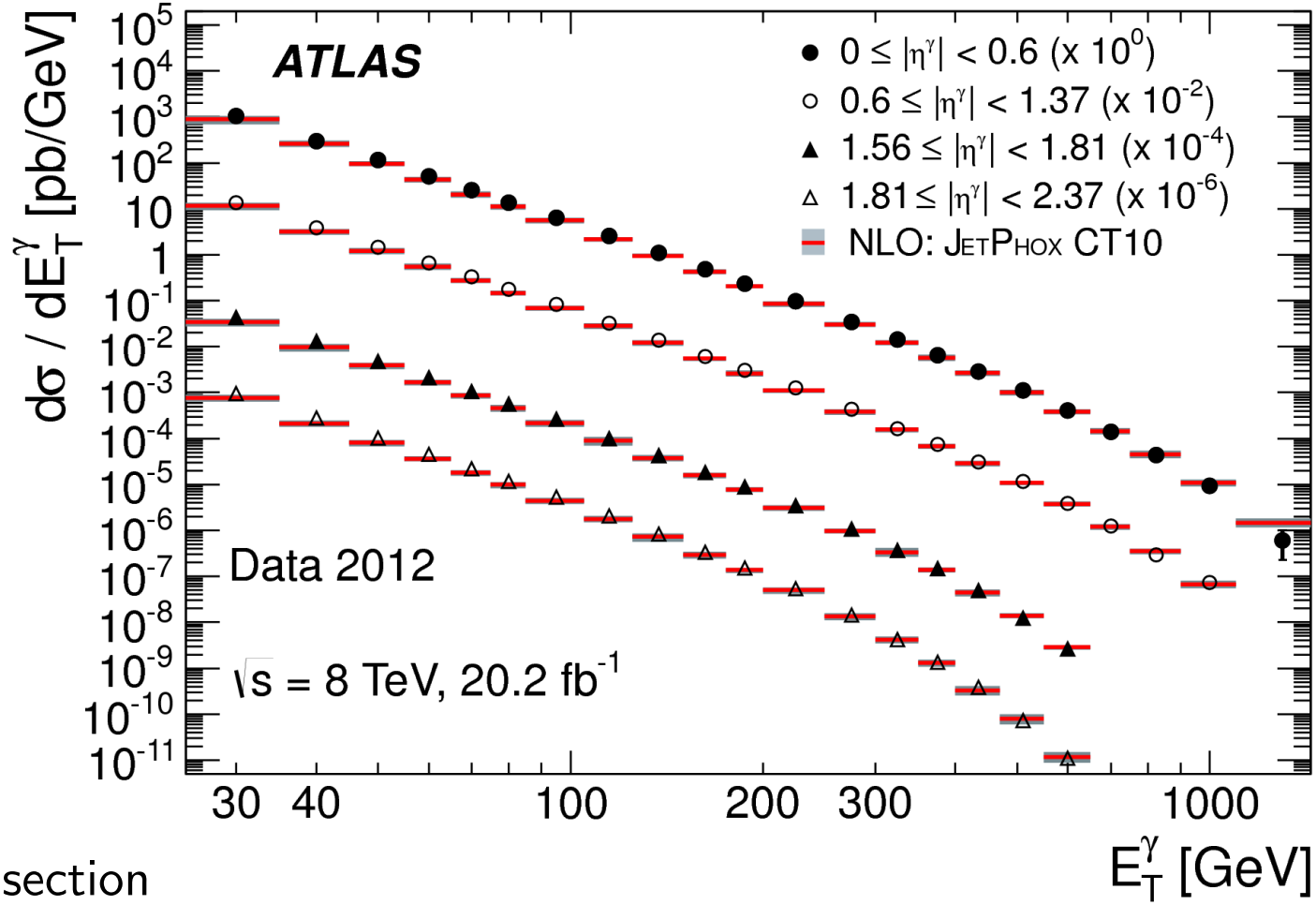
Uncertainties

- systematic uncertainties
  - energy scale uncertainty dominates the high-E_T region
  - low-E_T uncertainties are dominated by R_{bkg} variation and admixture of direct and fragmentation photons uncertainties
- luminosity uncertainty: 1.9%
- statistical uncertainty: 1-2 % (except high E_T *bins*)

the following plots have

- η range split into 4 bins - $0 \leq |\eta^{\gamma}| < 0.6$, $0.6 \leq |\eta^{\gamma}| < 1.37$, $1.56 \leq |\eta^{\gamma}| < 1.81$, and $1.81 \leq |\eta^{\gamma}| < 2.37$
- uncertainties on plots are statistical+systematic

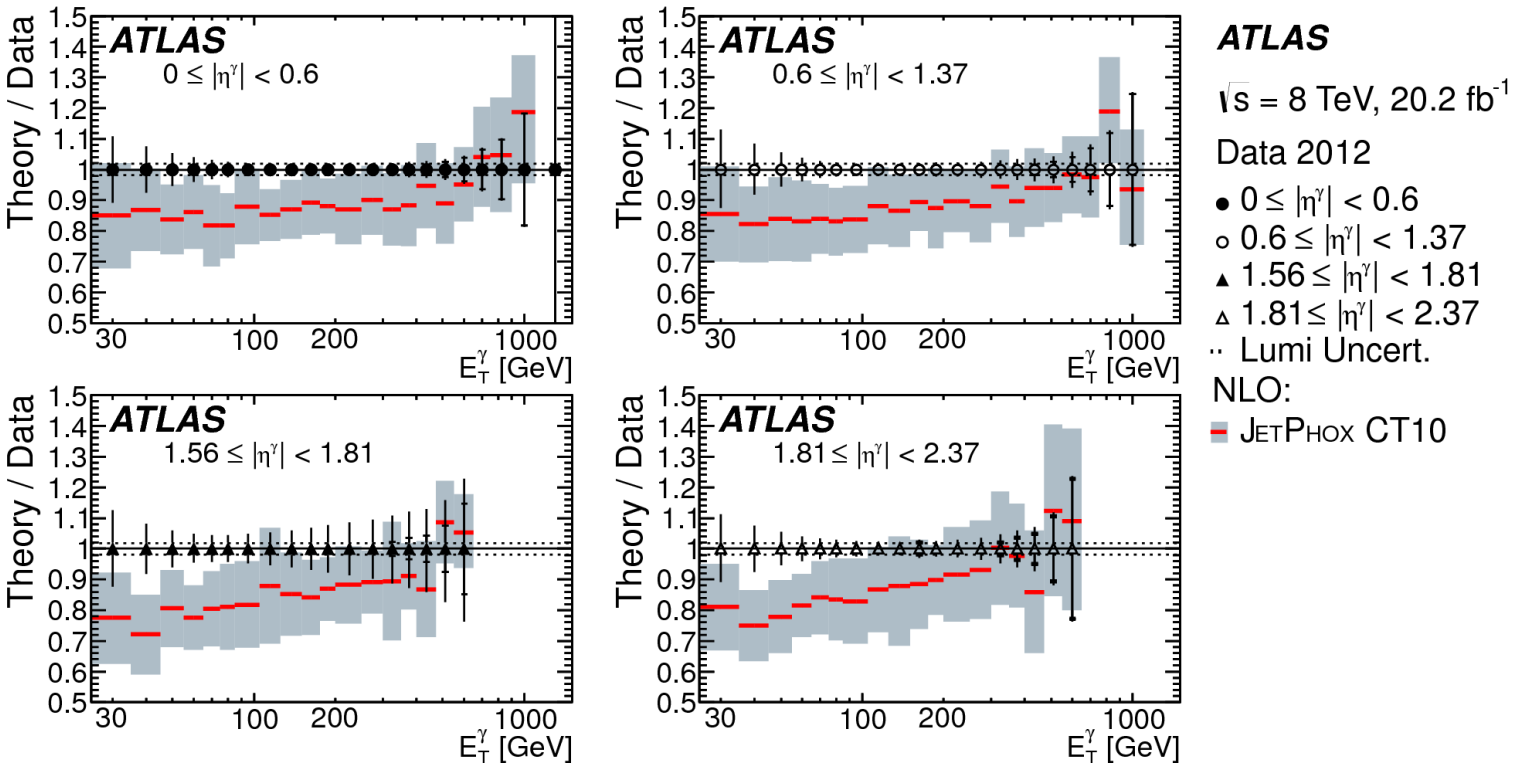
Photon cross-section measurement at $\sqrt{s}$=8 TeV



cross-section

- comparison between data and JetPhox
- JetPhox describes shape of data well over ten orders of magnitude in cross-section

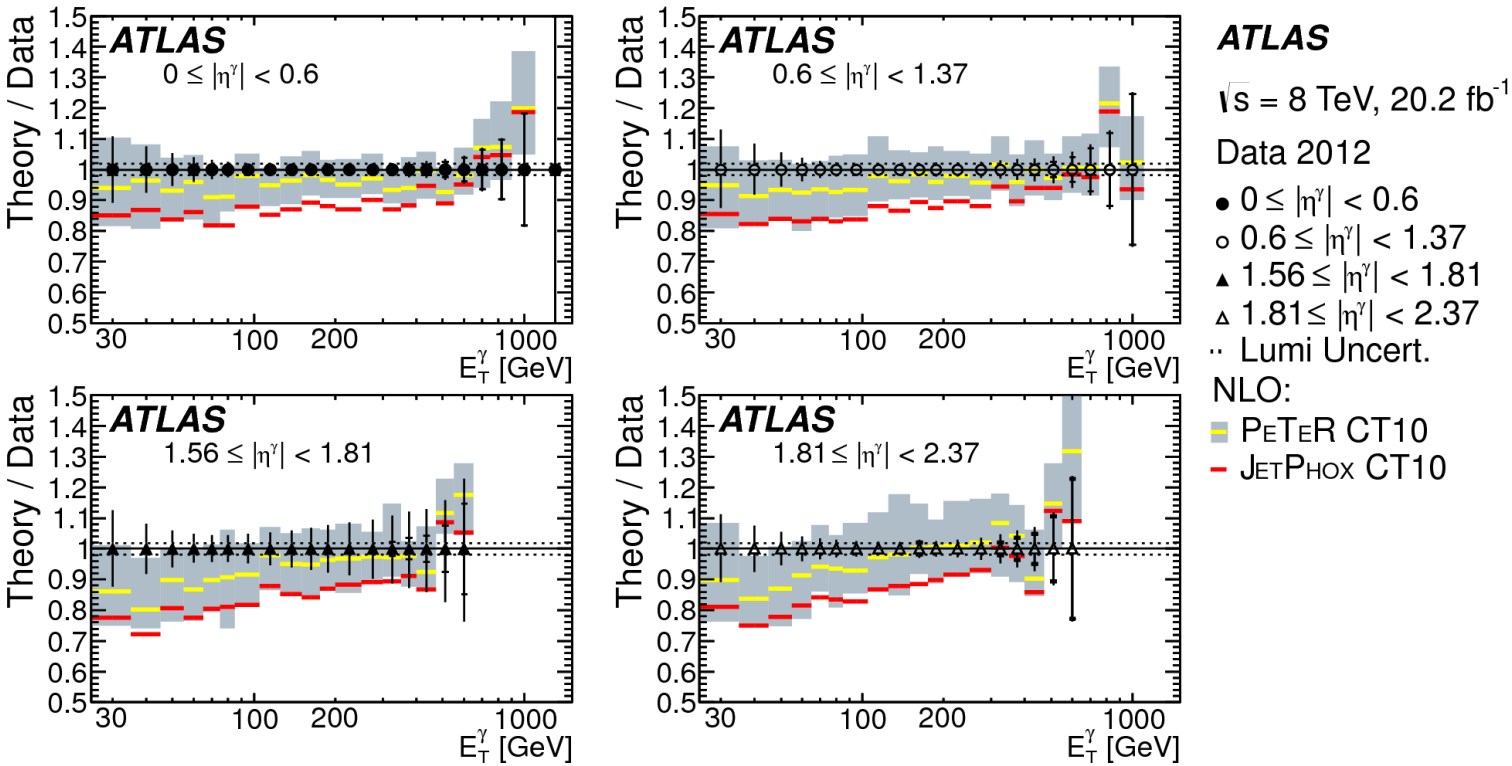
Photon cross-section measurement at $\sqrt{s}$=8 TeV



NLO comparison

- comparison between data and JetPhox
- JetPhox predictions are up to 20% lower than those measured

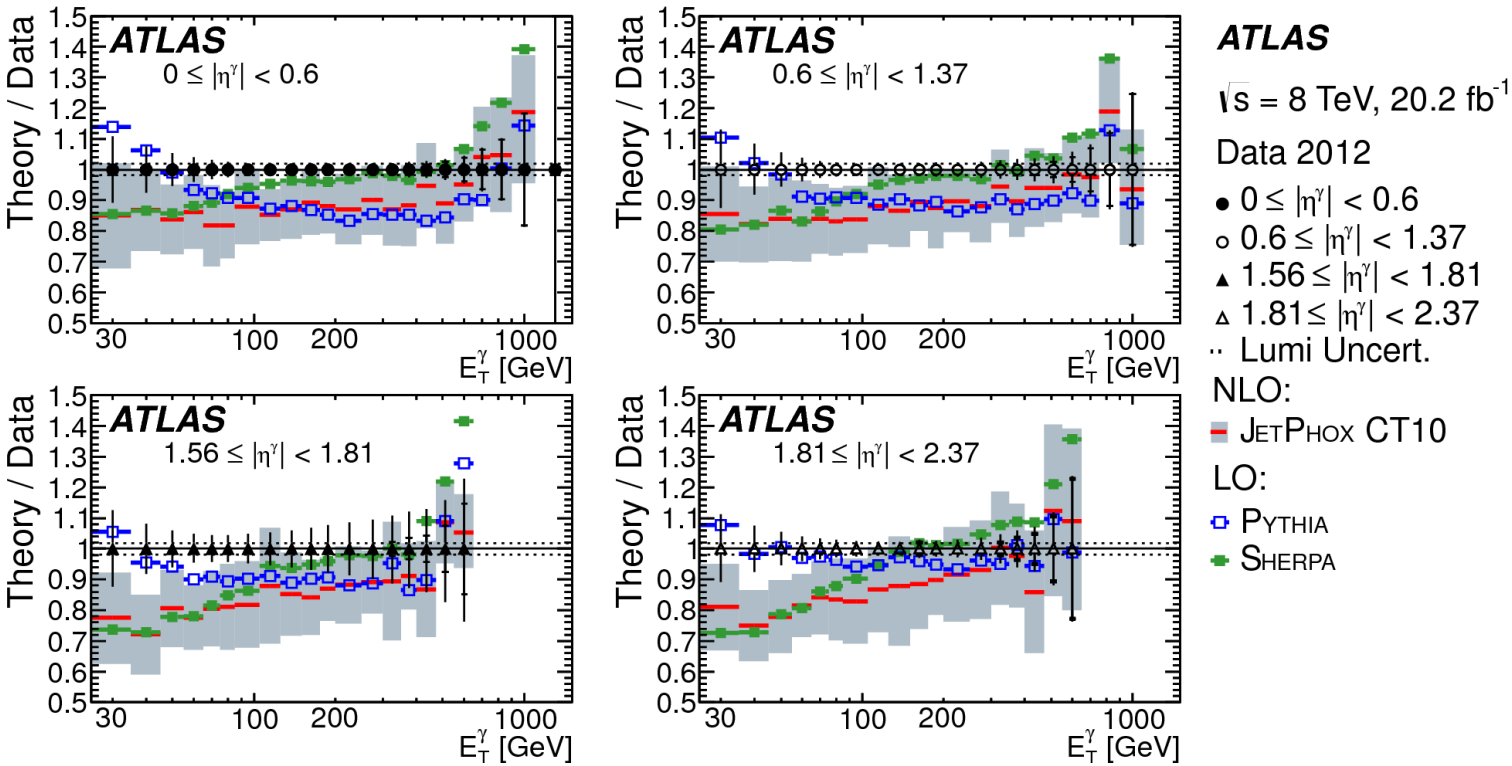
Photon cross-section measurement at $\sqrt{s}$=8 TeV



NLO comparison

- comparison between data and JetPhox and PeTer
- PeTer has much smaller normalization difference to data than JetPhox

Photon cross-section measurement at $\sqrt{s}$=8 TeV



LO comparison

- comparison between data, NLO JetPhox and LO Pythia and Sherpa
- Sherpa matches the data in $100 \leq E_T^\gamma < 500$ GeV; in lower region Sherpa follows the predictions from JetPhox; in high E_T^γ it tends to go above the measured value
- Pythia in low E_T^γ region overestimates the measured cross-section; in the rest is similar to JetPhox

Photon measurement at $\sqrt{s}$=13 TeV

event selection

- $|\eta^{\gamma}| < 1.37$, $1.56 \leq |\eta^{\gamma}| < 2.37$
- $E_T^{\gamma} > 125$ GeV
- trigger - single photon trigger with threshold 120 GeV
- tight isolated photon
- events with at least one reconstructed primary vertex (with at least two associated tracks) consistent with the average beam-spot position

data

- luminosity 6.4 pb^{-1}

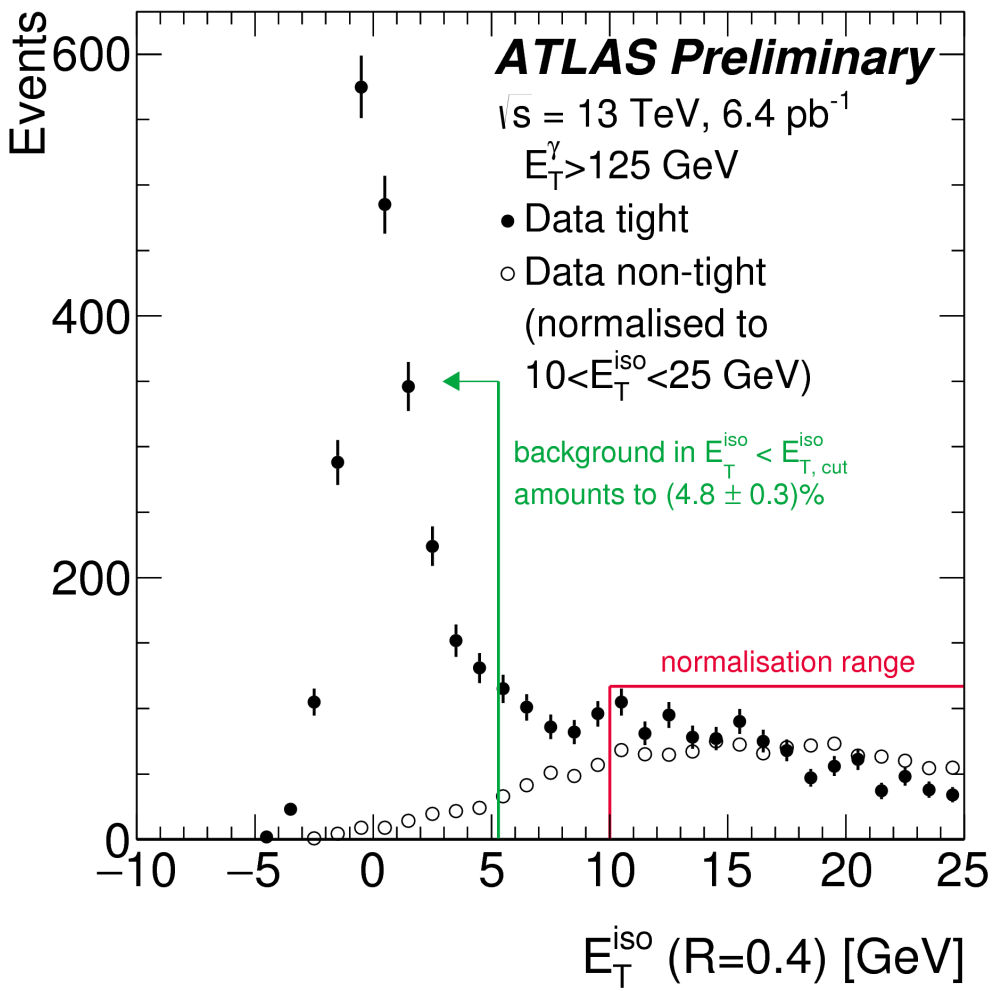
MC

- Sherpa 2.1.1 using CT10

Photon measurement at $\sqrt{s}$=13 TeV

background subtraction

- 2D sideband method
- there is still some background (e.g. from multi-jet processes, in which a jet is misidentified as a photon) after 2D sideband method which requires additional removal



Photon measurement at $\sqrt{s}$=13 TeV

Uncertainties

- systematic uncertainty is dominated by photon energy scale and resolution, identification and trigger efficiency, and by modelling of E_T^{iso} in MC
- 5 % uncertainty conservatively assigned to 2D sideband method

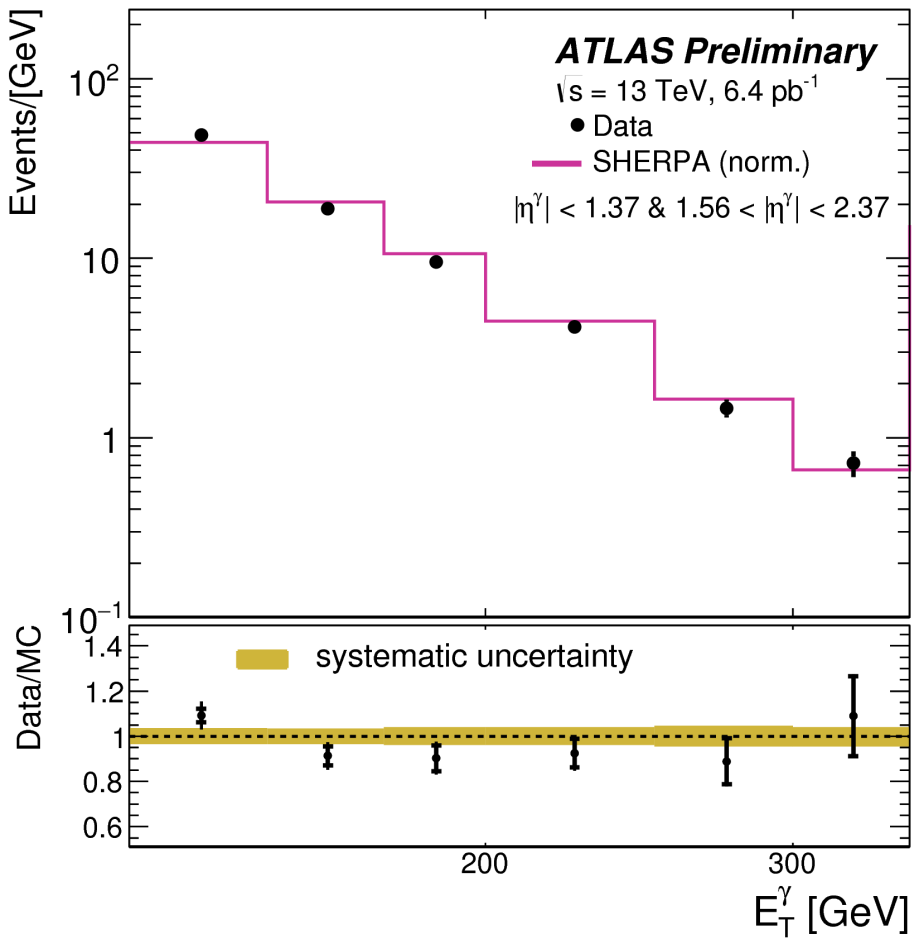
in the following plots

- error bars represent statistical uncertainty and yellow band systematic uncertainty

Photon measurement at $\sqrt{s}$=13 TeV

yield

- comparison between data and Sherpa (LO)
- Sherpa is in relatively good agreement with data



Photon measurement at $\sqrt{s}$=13 TeV

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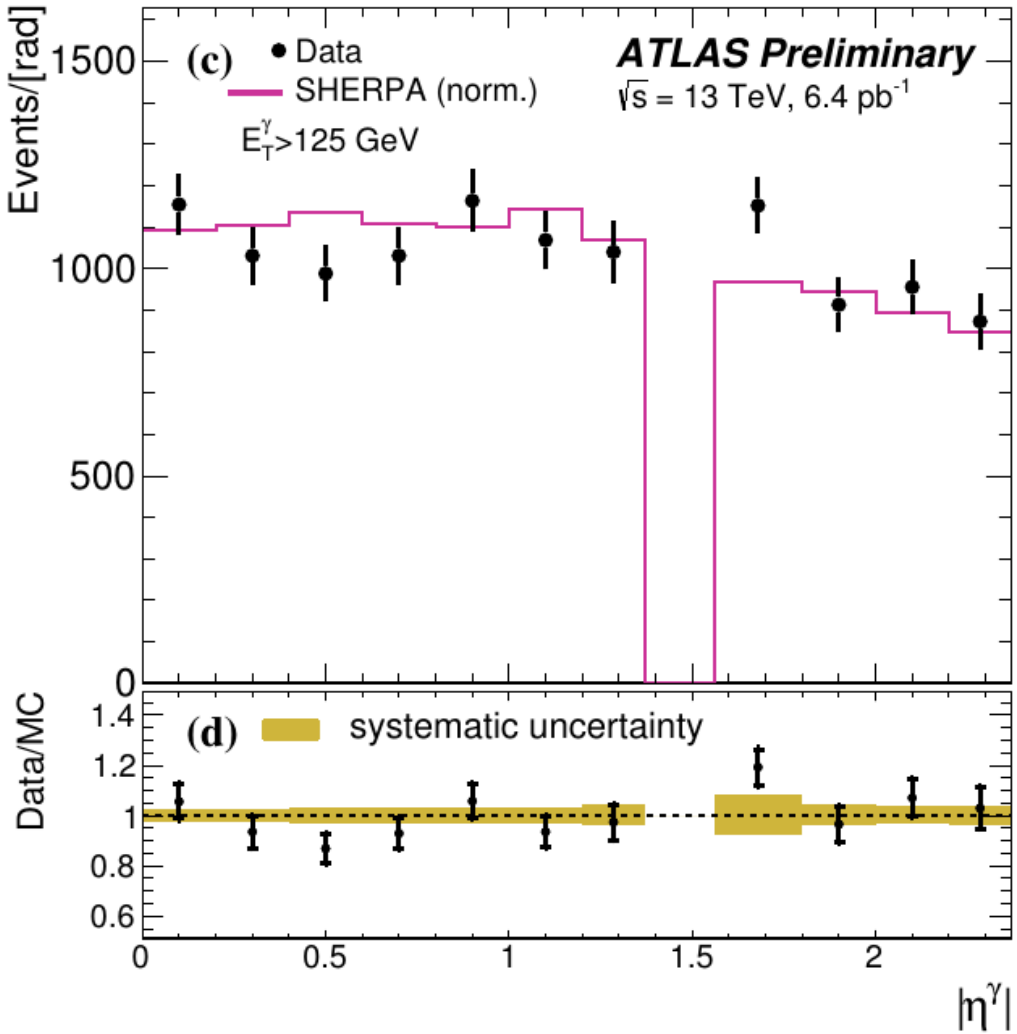


Jet reconstruction and identification

Reconstruction

- jets are reconstructed using anti-k_T algorithm with jet radius R=0.4 from topological clusters of cells in the calorimeter

Jet energy calibration

- jets are calibrated by applying a p_T and η dependent correction derived from MC
- jets in data are corrected by additional factor based on in situ studies performed in 2012

Identification ("looser")

- purpose:reject fake jets reconstructed from non-collision signals (beam-related background, cosmic rays or detector noise, etc.)

Jet cross-section measurement at $\sqrt{s}$=13 TeV

event selection

- $|y| < 0.5$
- $346 \leq p_T \leq 838$ GeV
- trigger - single jet triggers with various thresholds (for jets in $|\eta^{jet}| < 3.2$)
- looser jet
- events are required to have at least one well-reconstructed vertex, which must have at least two associated tracks with p_T >400 MeV and be consistent with the beam spot of the proton–proton collisions

data

- luminosity 78 pb^{-1}

MC

- NLOJET++ 4.1.3 (interfaced to APPLGRID) using CT10, MMHT and NNPDF 3.0

Jet cross-section measurement at $\sqrt{s}$=13 TeV

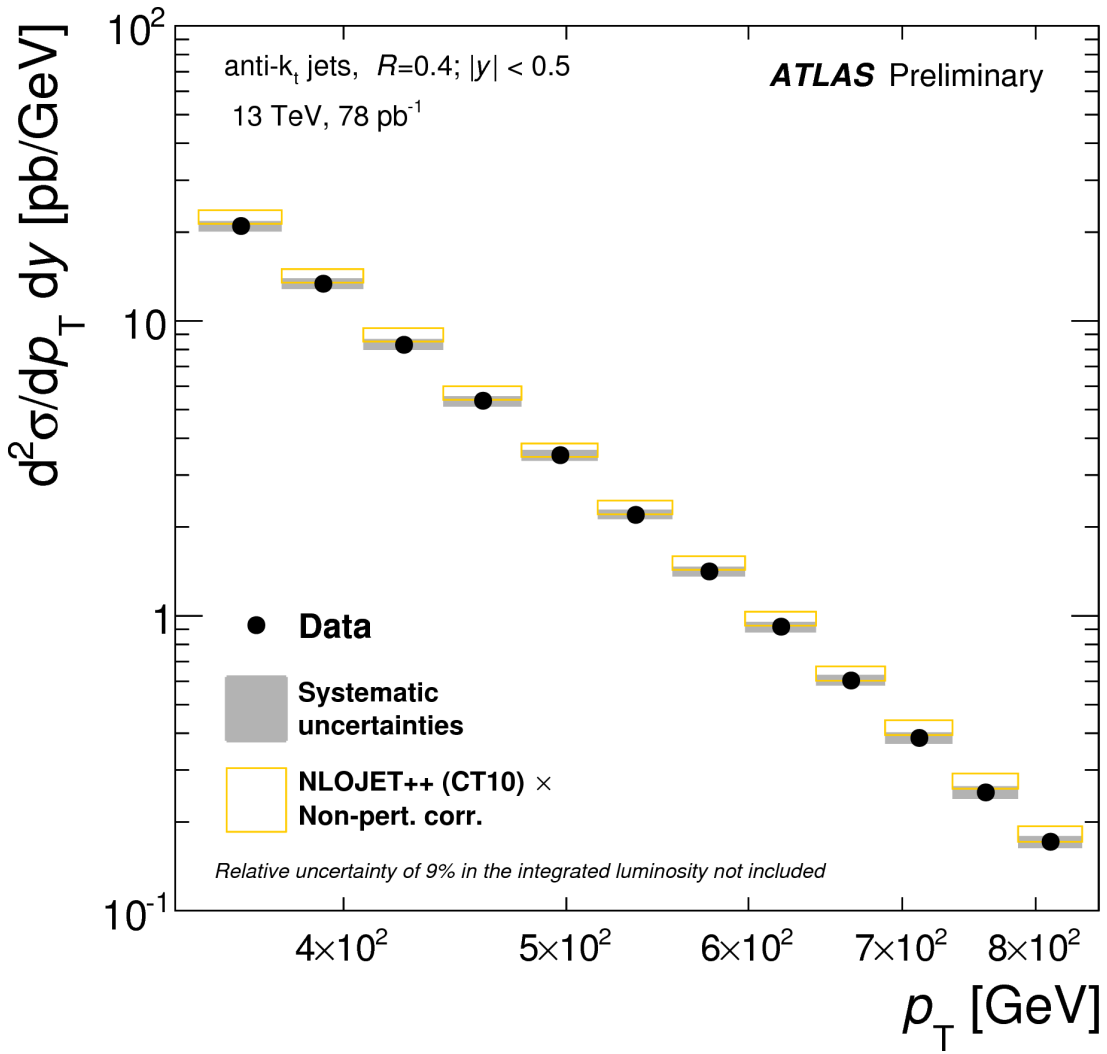
Uncertainties

- systematic uncertainty is dominated by jet energy scale and resolution and unfolding uncertainties
- luminosity uncertainty: 9 %

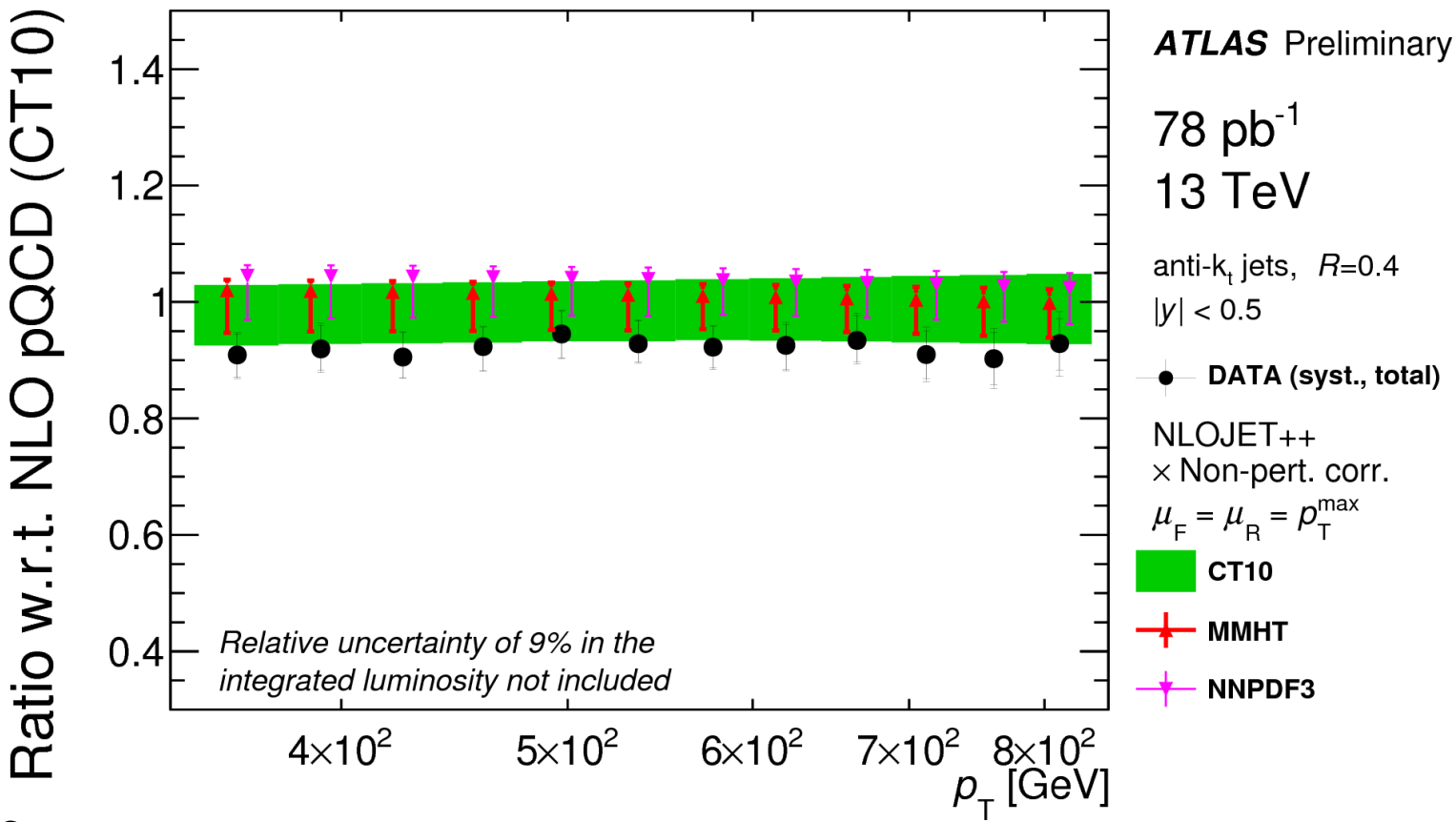
Jet cross-section measurement at $\sqrt{s}$=13 TeV

cross-section

- error bars represent statistical uncertainties; grey band represent systematic uncertainties
- NLO prediction describes data well over two orders of magnitude in cross-section



Jet cross-section measurement at $\sqrt{s}$=13 TeV



NLO comparison

- comparison of data and NLO predictions using different PDFs
- inner error bars represent systematic uncertainties, outer bars total uncertainties, and green band uncertainties in the prediction
- the data and the predictions are in good agreement within uncertainties

Summary

photon cross-section at $\sqrt{s}$=8 TeV

- NLO describes data well within uncertainties
- LO does not provide description as good as NLO (modelling of fragmentation contribution)

photon yield at $\sqrt{s}$=13 TeV

- Monte Carlo is in good agreement with data

jet cross-section at $\sqrt{s}$=13 TeV

- Monte Carlo prediction describes data well over two orders of magnitude in cross-section even with usage of different PDFs

References

- ATLAS Collaboration, G. Aad et al., *Measurement of the inclusive isolated prompt photon cross section in pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector*, arXiv:1605.03495 [hep-ex]
- *Study of inclusive isolated-photon production in pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector*, Tech. Rep. ATL-PHYS-PUB-2015-016, CERN, Geneva, Jul, 2015.

  https://cds.cern.ch/record/2037667
- *Measurement of the inclusive-jet cross section in proton-proton collisions at 13 TeV centre-of-mass energy with the ATLAS detector*, Tech. Rep. ATLAS-CONF-2015-034, CERN, Geneva, Jul, 2015.

  https://cds.cern.ch/record/2038145