Measurements of isolated prompt photons in pp collisions with the ATLAS detector

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ATLAS EXPERIMENT

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Motivation

Colorless probe of the hard-scattering process

Constrain PDFs in particular for the gluon content

Important for many new physics signatures, including searches for H→γγ, G→γγ and others

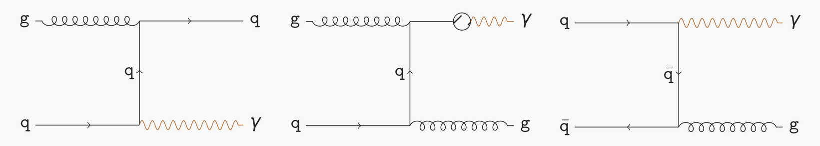
QCD dijet production cross section is orders of magnitude larger than the signal: excellent jet rejection (~ $10^3 \div 10^4$) capability of the detector is required to extract the signal over the background

In general, don't rely too much on MC simulation, try (as often as possible) to use data-driven techniques to estimate the photon yields

No clean source of photons (as Z → ee) to be used to check photon efficiency using some tag and probe technique

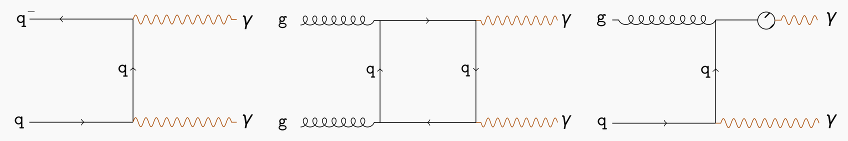
Signal definition

Prompt isolated inclusive photon



$15 < E_T < 400\,\mathrm{GeV}$ (0.88 + 35) pb^{-1} [1] [2]

Prompt isolated di-photon



$E_T > 16\,\mathrm{GeV}$ 37 pb^{-1} [3]

$\Delta R > 0.4$ separation between the two photons

Common definition:

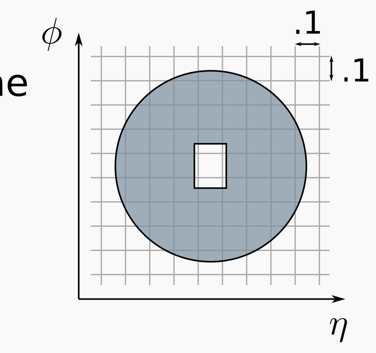
- $|\eta| < 2.37$ except $1.37 < |\eta| < 1.52$
- isolation $E_T^{\mathrm{iso}} < 4\,\mathrm{GeV}$

Isolation

Isolation measures the additional hadronic activity near the photon axis

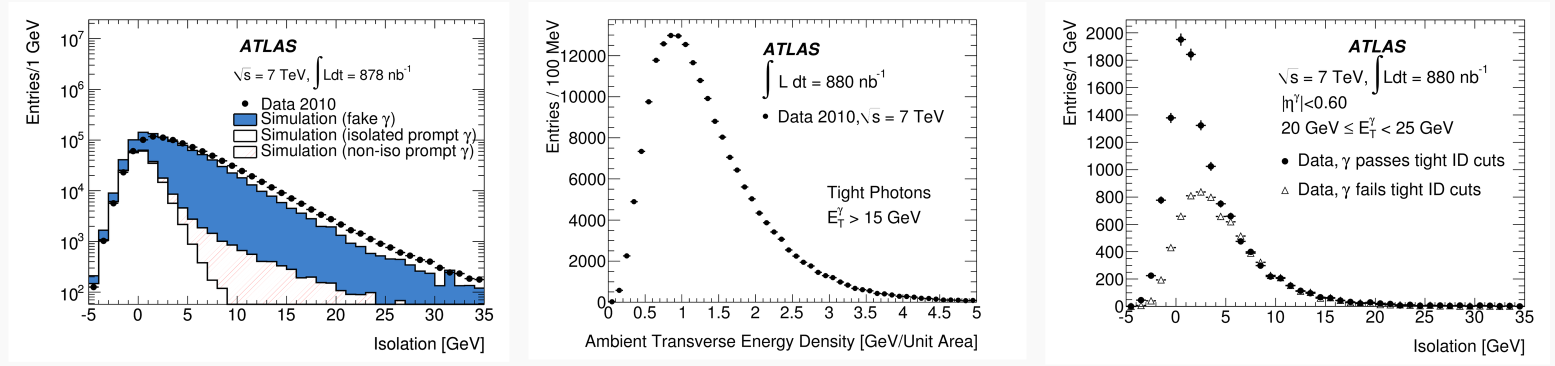
- reduces fragmentation (~30% of total xsec at 15 GeV, <10% above 35 GeV)
- reduces hadronic background

The calorimetric isolation is the energy measured in a cone $R = \sqrt{\Delta\eta^2 + \Delta\phi^2} < 0.4$ centered around the candidate direction minus the energy of the candidate removing the cells in a 5x7 cluster.



Two corrections are applied:

- Residual leakage of photon energy using single photon MC
- Energy from the underlying event using ambient energy density estimated with low-p_T jets. The average correction is ~ 500 MeV



Reconstruction and identification

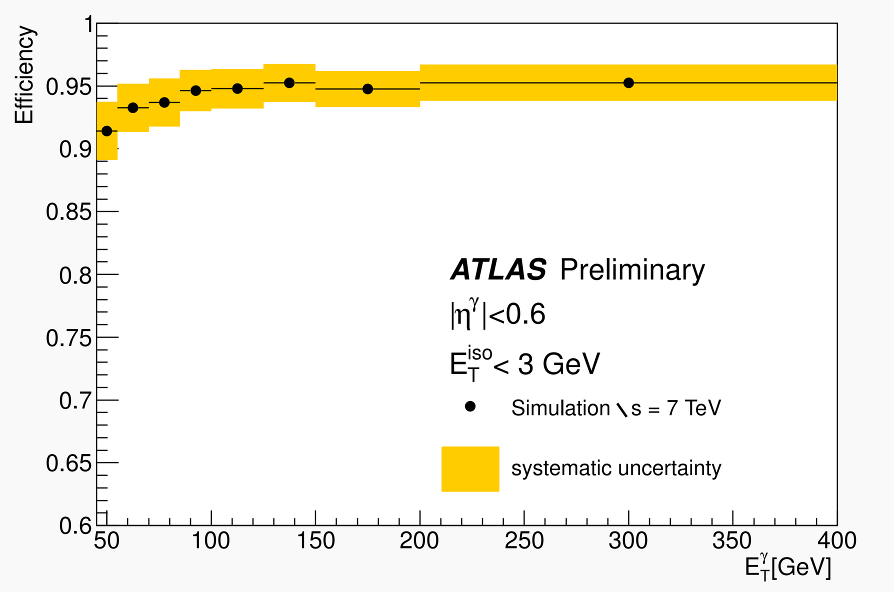
Photons are seeded in the EM calorimeter

- unconverted photons without an associated track
- converted photons with a conversion vertex or single track without b-layer hit

Reconstruction efficiency from MC: 70÷85%, main inefficiency from dead readout

Photons are selected using the shower shapes of the candidates (tight cut), looking at:

- hadronic leackage
- shapes in the middle layer of the calorimeter
- presence of secondary maxima in the strips of the calorimeter



- identification efficiency > 90% for 50 GeV photon

Main systematics:

- method and selection (1÷5%)
- extra material (1÷6%)
- pileup, generator (1÷3%)

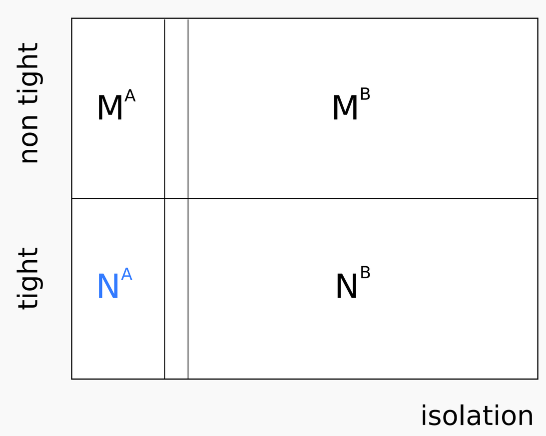
2D sideband background subtraction

inclusive analysis

Data driven method using isolation variable and tight cuts

Define one signal region and three control regions:

- N^A (signal region): tight and isolated
- N^B: tight and non isolated
- M^A: non tight and isolated
- M^B: non tight and non isolated



Basic assumptions:

- tight and isolation uncorrelated → taken as systematics
- no signal leakage (signal only in the signal region) → corrected with MC

$$N^A_{\mathrm{sig}} = N^A - N^B \frac{M^A}{M^B}$$

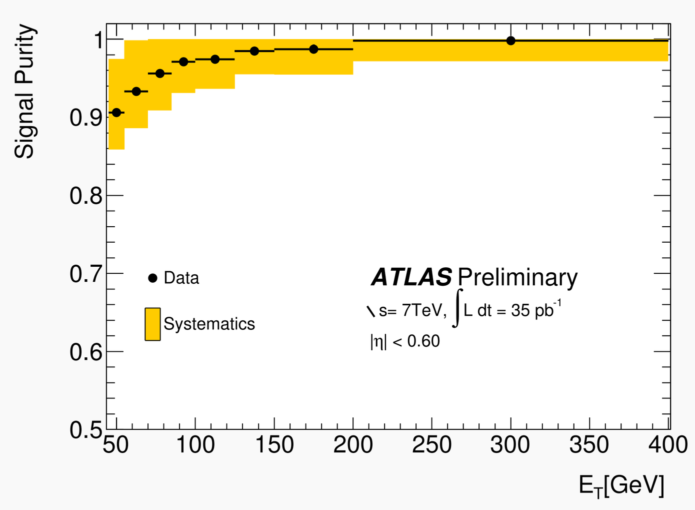
$$P = \frac{N^A_{\mathrm{sig}}}{N^A} = 1 - \frac{N_B M_A}{N_A M_B}$$

Very high purity for E_T > 100 GeV

Main systematics from:

- MC input (<10%)
- background control regions definition (<6%)

Result cross-checked with isolation template fit (signal template: e from W/Z in data; background template: photons failing the ID criteria)
→ Agreement within 5%



4x4 matrix background subtraction

di-photon analysis

Data driven method already used in CDF and DØ

Events containing two photon candidates can be due to di-photon, photon-jet and di-jet final states. For every tight-tight event test if the two photons pass the isolation cut. Four pass/fail outcomes are possible: PP, PF, FP, FF

Count the number of N_{PP}, N_{PF}, N_{FP}, N_{FF}

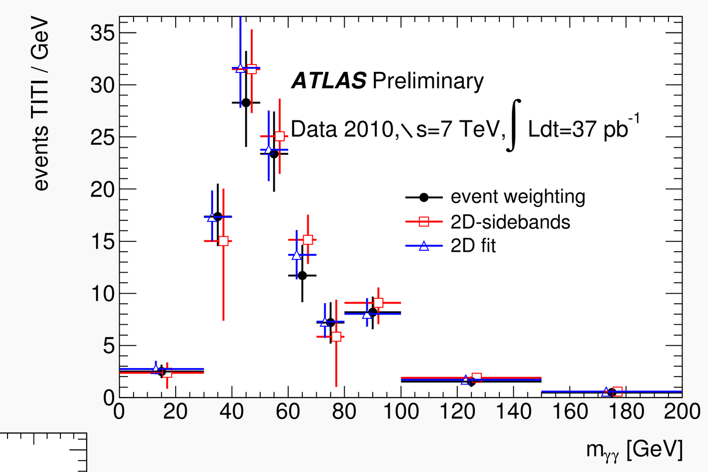
Compute the number of events for each final state $W_{\gamma\gamma}$, $W_{\gamma j}$, $W_{j\gamma}$, W_{jj} solving the linear system

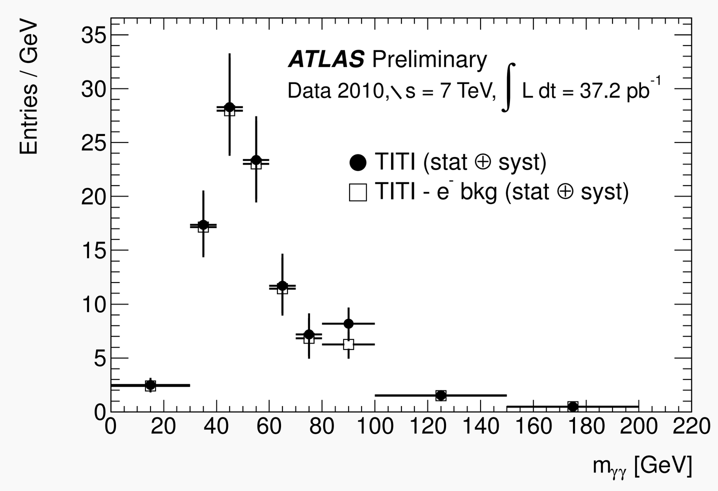
$$\begin{pmatrix} N_{PP} \\ N_{PF} \\ N_{FP} \\ N_{FF} \end{pmatrix} = E \begin{pmatrix} W_{\gamma\gamma} \\ W_{\gamma j} \\ W_{j\gamma} \\ W_{jj} \end{pmatrix}$$

$$E = \begin{pmatrix} \epsilon_1\epsilon_2 & \epsilon_1 f_2 & f_1\epsilon_2 & f_1 f_2 \\ \epsilon_1(1-\epsilon_2) & \epsilon_1(1-f_2) & f_1(1-\epsilon_2) & f_1(1-f_2) \\ (1-\epsilon_1)\epsilon_2 & (1-\epsilon_1)f_2 & (1-f_1)\epsilon_2 & (1-f_1)f_2 \\ (1-\epsilon_1)(1-\epsilon_2) & (1-\epsilon_1)(1-f_2) & (1-f_1)(1-\epsilon_2) & (1-f_1)(1-f_2) \end{pmatrix}$$

Efficiencies and fake rate extracted directly from data

The method is applied event by event so the matrix E depend on (η, E_T) of the two photons.

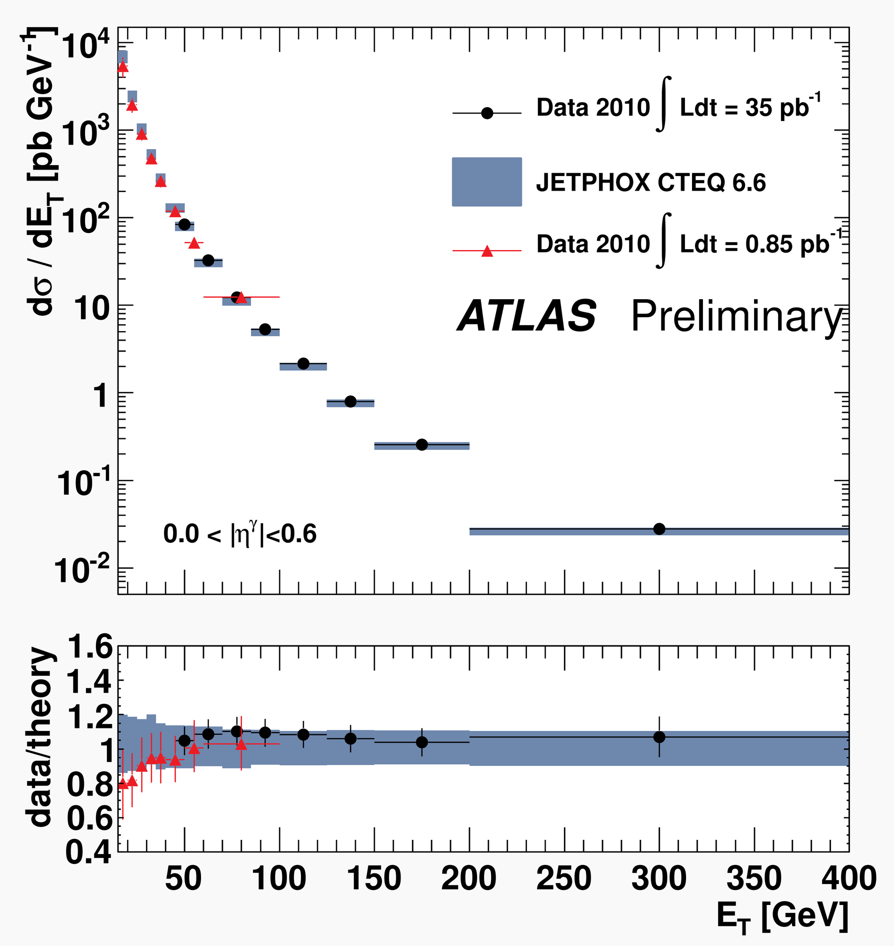




Cross check with isolation template and 2x2D sideband methods

Electrons are removed with a data driven method looking at ee, γe under the Z peak

Direct photon cross section



NLO pQCD prediction by JetPhox, CTEQ 6.6 pdf

Agreement above 35 GeV, some discrepancies at low ET:

- difficult region: in particular larger contribution from fragmentation photons
- theoretical computation not fully under control

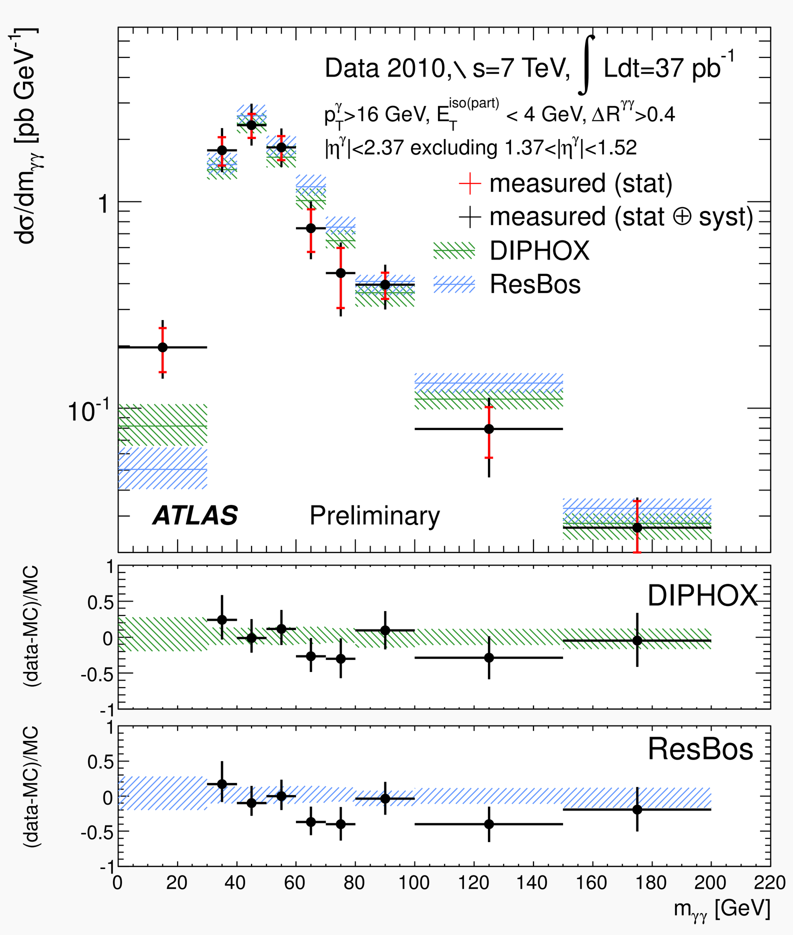
Main systematics:

- energy scale (~10%)
- efficiency (5÷15%)
- purity (5÷10%)

Main theoretical uncertainties:

- PDF (2÷4%)
- scales (8÷20%)

Di-photon cross section

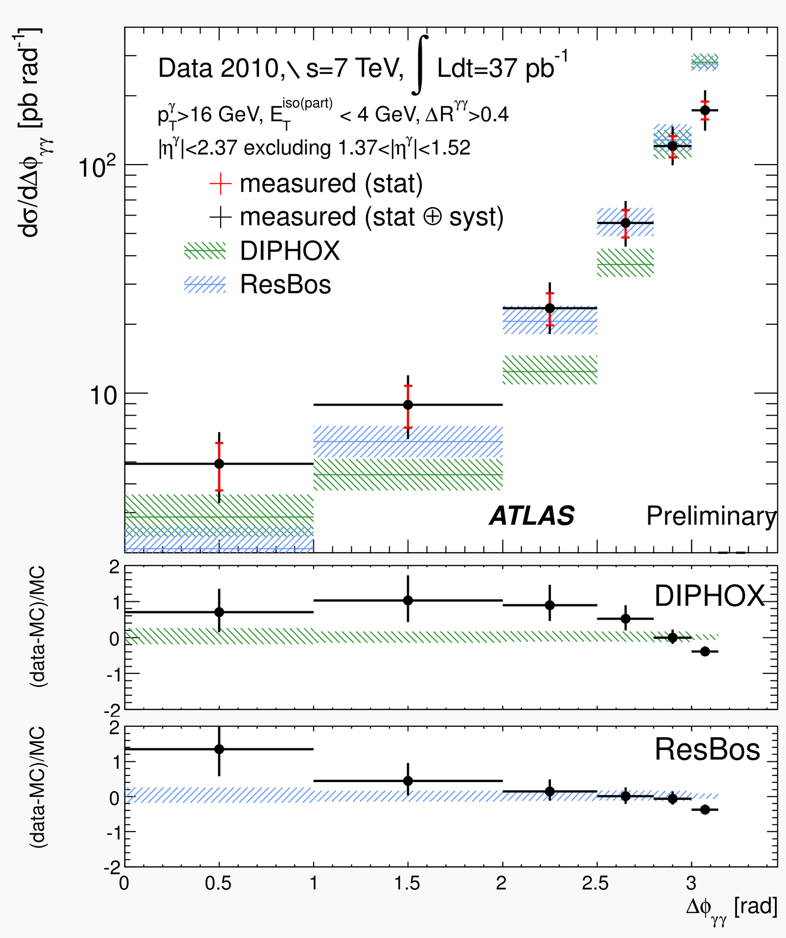


NLO pQCD prediction by DIPHOX and ResBos with CTEQ 6.6 pdf

Good agreement over the mass range, except for low region, dominated by low Δφ events

Main systematics:

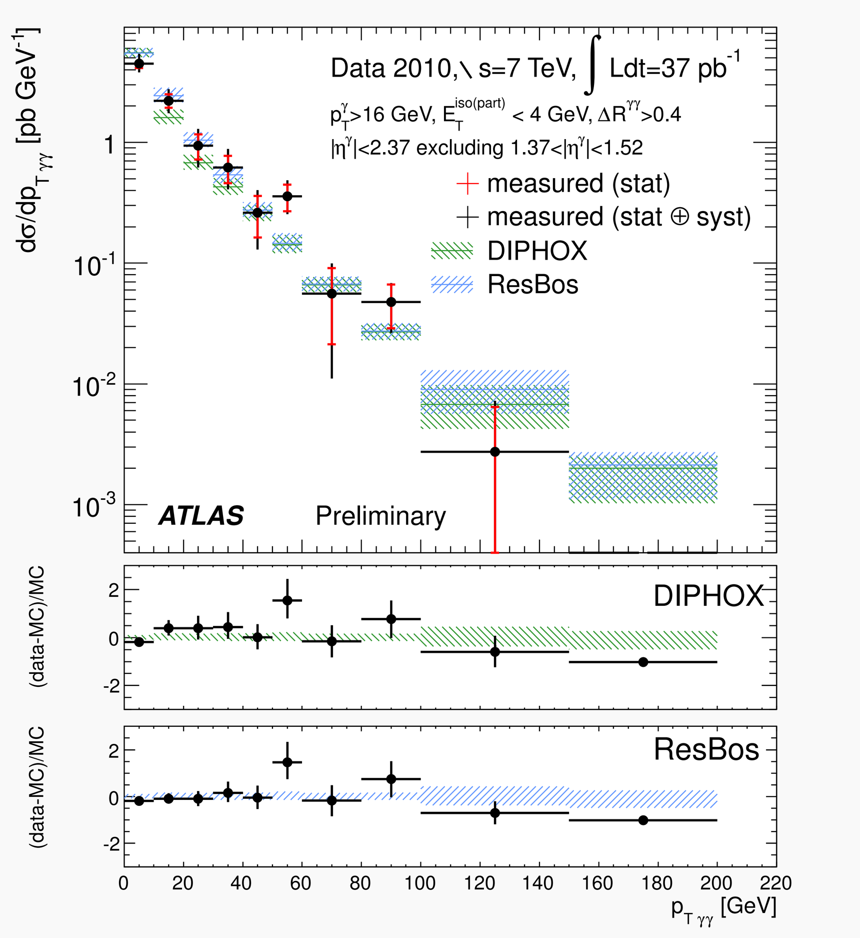
- background control region definition (< 12%)
- matrix coefficient (< 9%)
- electron fake rate
- identification efficiency (< 10%)
- MC model (< 5%)
- extra material (< 10%)



dσ/dΔ$\varphi_{\gamma\gamma}$ is clearly broader than the one computed by DIPHOX and ResBos. This result is qualitatively in agreement with previous measurements at the Tevatron

Main theoretical uncertainties:

- PDF (2÷4%)
- scales (8÷20%)



The result for dσ/d$p_{T\gamma\gamma}$ shows a good agreement with DIPHOX and ResBos, except for the region $p_{T\gamma\gamma} \in [50, 60]$ GeV

References

[1] "Measurement of the inclusive isolated prompt photon cross section in pp collisions at √s=7 TeV with the ATLAS detector" CERN-PH-EP-2010-068, Phys. Rev. D

[2] "Measurement of the inclusive isolated prompt photon cross section in pp collisions at √s=7 TeV with the ATLAS detector using 35 pb⁻¹" ATLAS-CONF-2011-058

[3] "Measurement of isolated di-photon cross section in pp collision at √s=7 TeV with the ATLAS detector" paper under approval