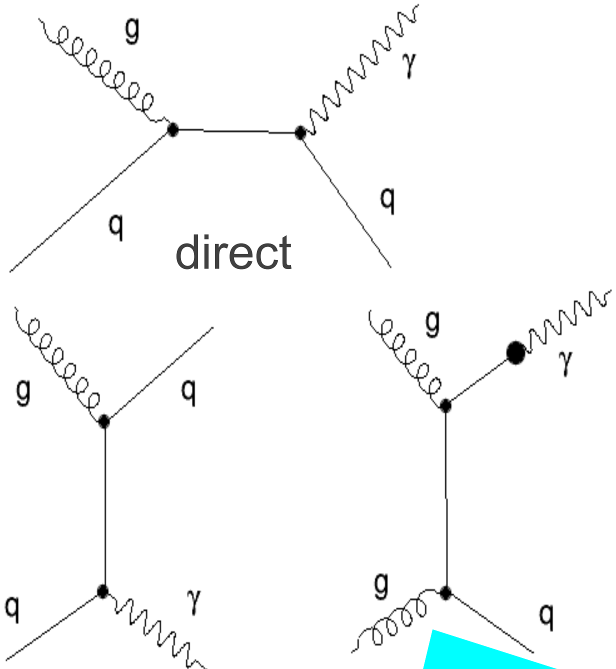
Recent Collider Photon Production Results

A brisk spin through the more recently updated or released (~the last year) photon related results from the colliders (LHC and Tevatron)

R. Blair (ANL) presenting on behalf of ATLAS,CDF,CMS & D0

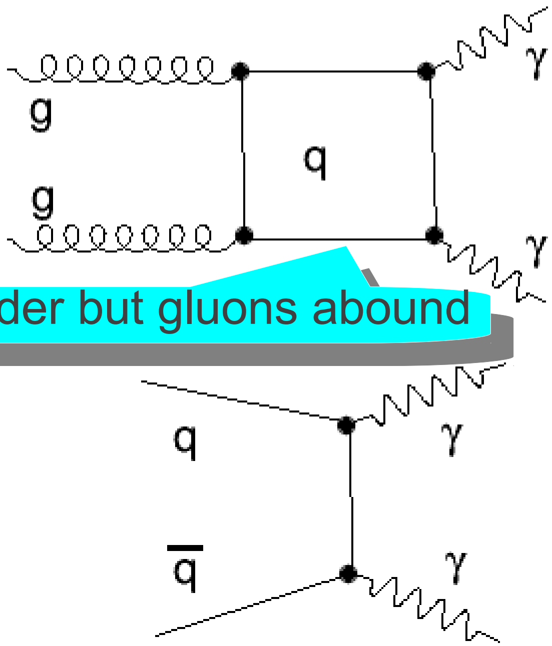
Photon Production Processes

Inclusive or γ plus jet



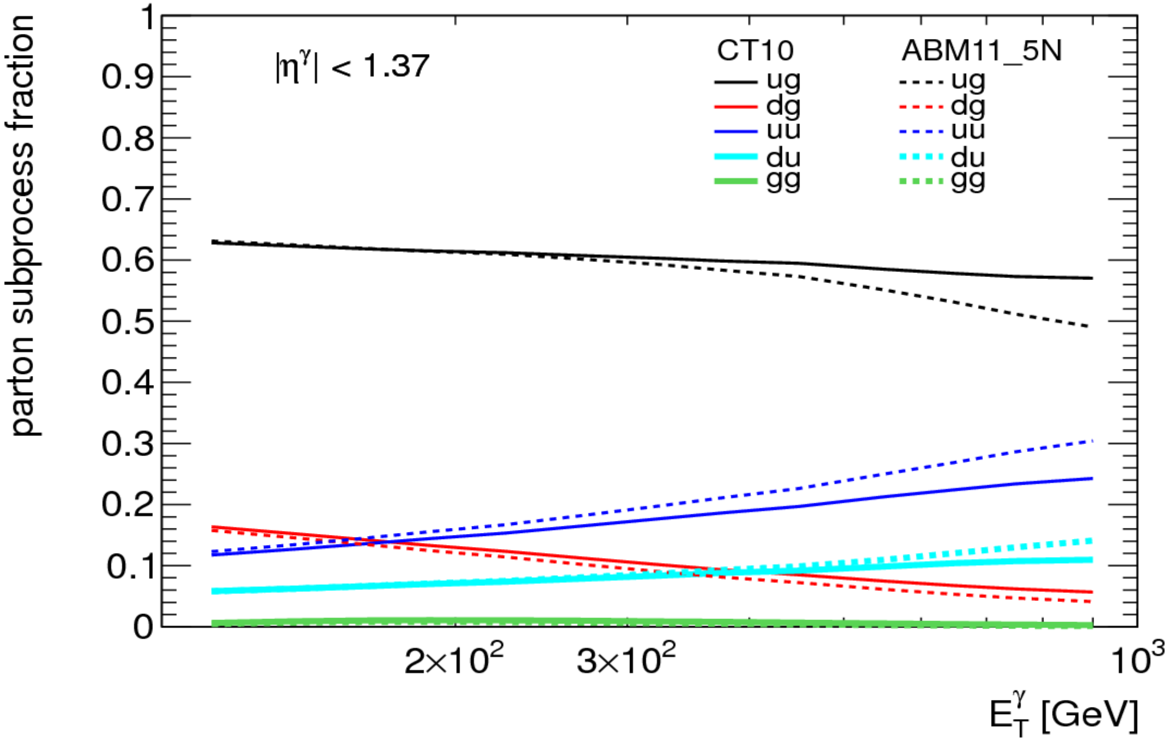
Fragmentation –
hard photon radiation from quark
(or at a lower rate gluon)

Diphotons



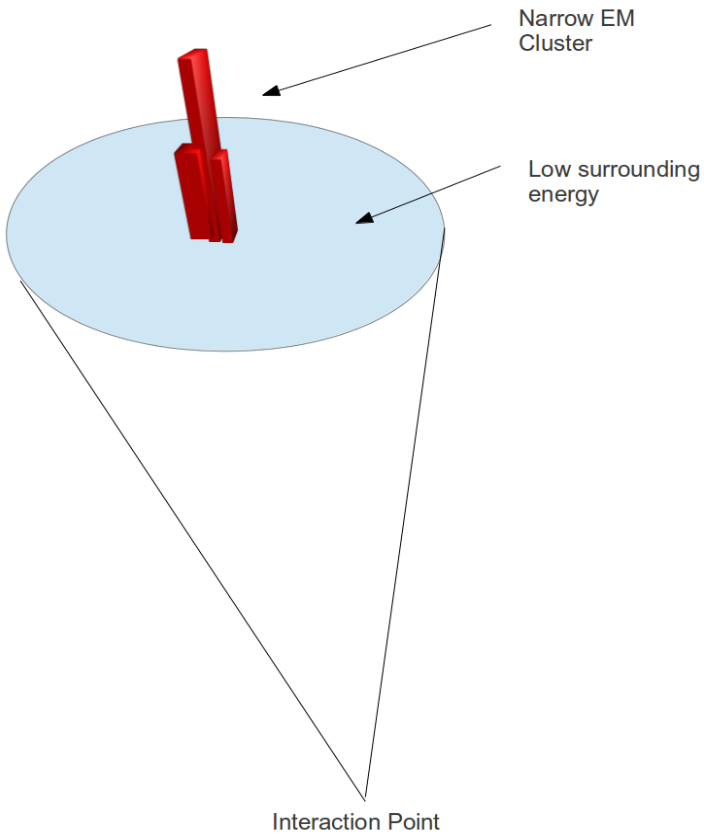
higher order but gluons abound

Cross section for prompt photons & partons



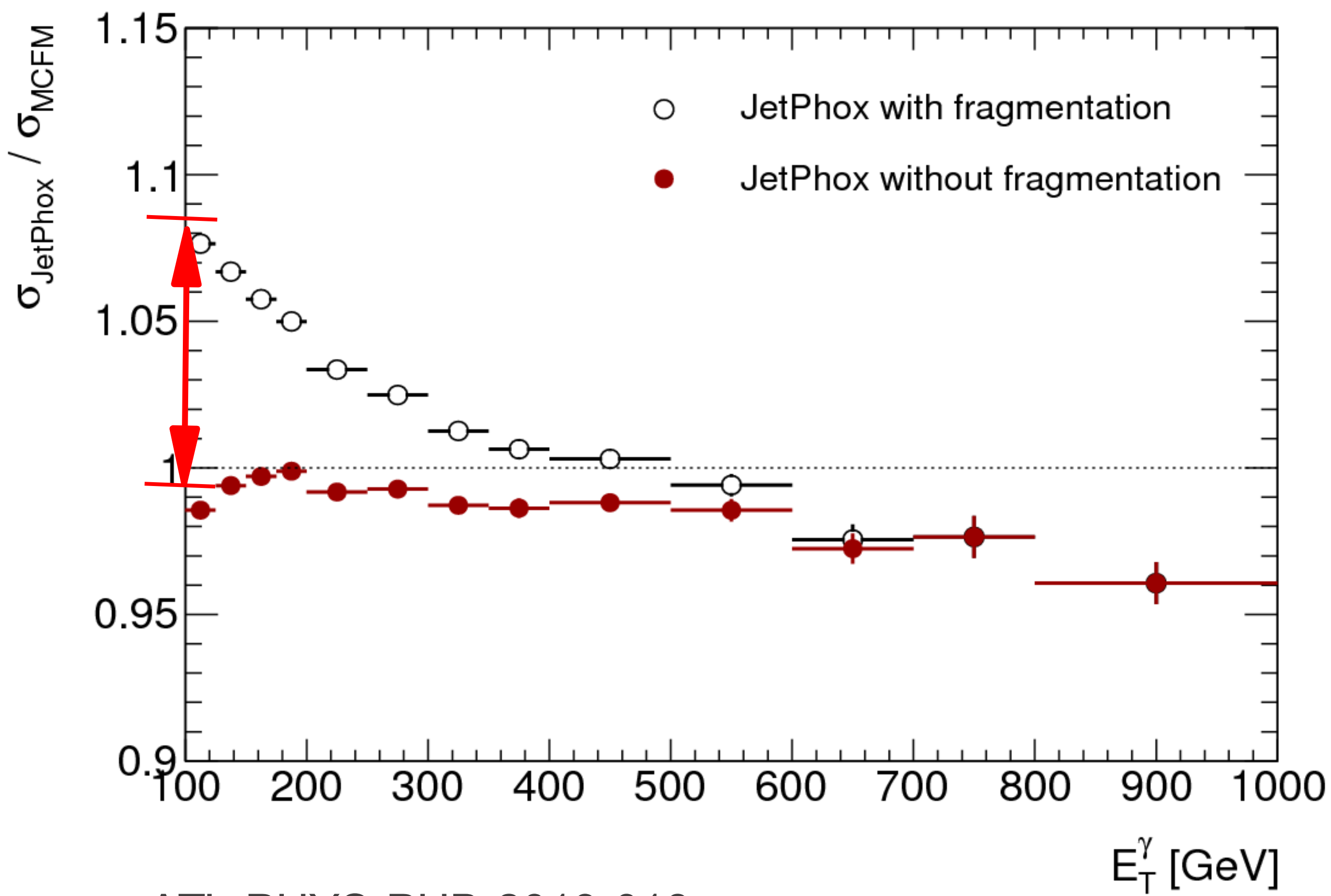
- Cross section is dominated by quark glue scattering
  - this probes the gluon distribution
- see ATL-PHYS-PUB-2013-018 for more on PDF sensitivity

Photon ID



- Generally require isolation (small energy in the region around the neutral electromagnetic cluster)
- Exploit the structure of the electromagnetic deposition (width and shape consistency with a single photon) for additional information
- Inner detector conversions are also reconstructed

Photon Production LHC Relative Contributions



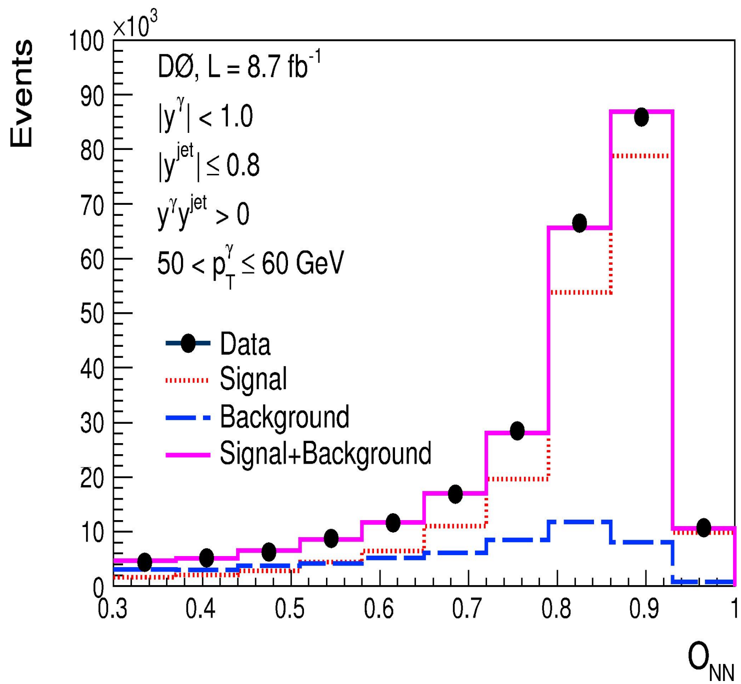
ATL-PHYS-PUB-2013-018

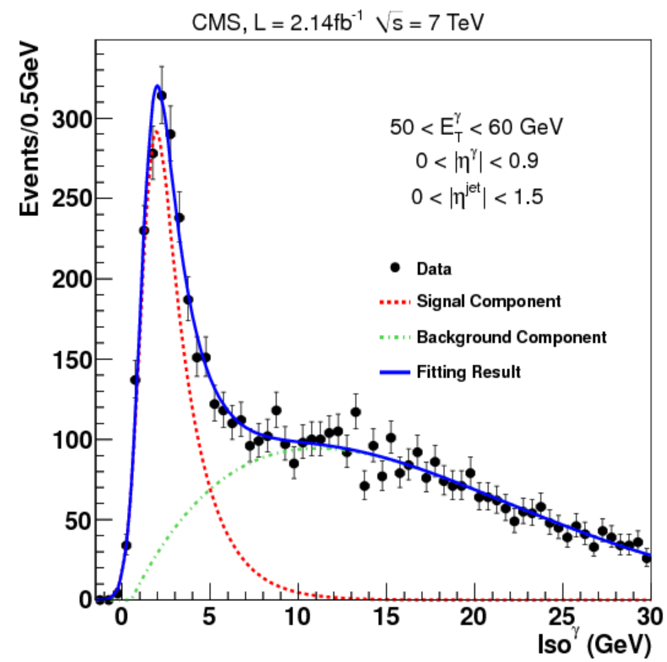
Fragmentation is more important at lower E_T and above 100GeV is expected to be < 8%

Somewhat artificial to split off one piece of the NLO σ

Photon ID Methods

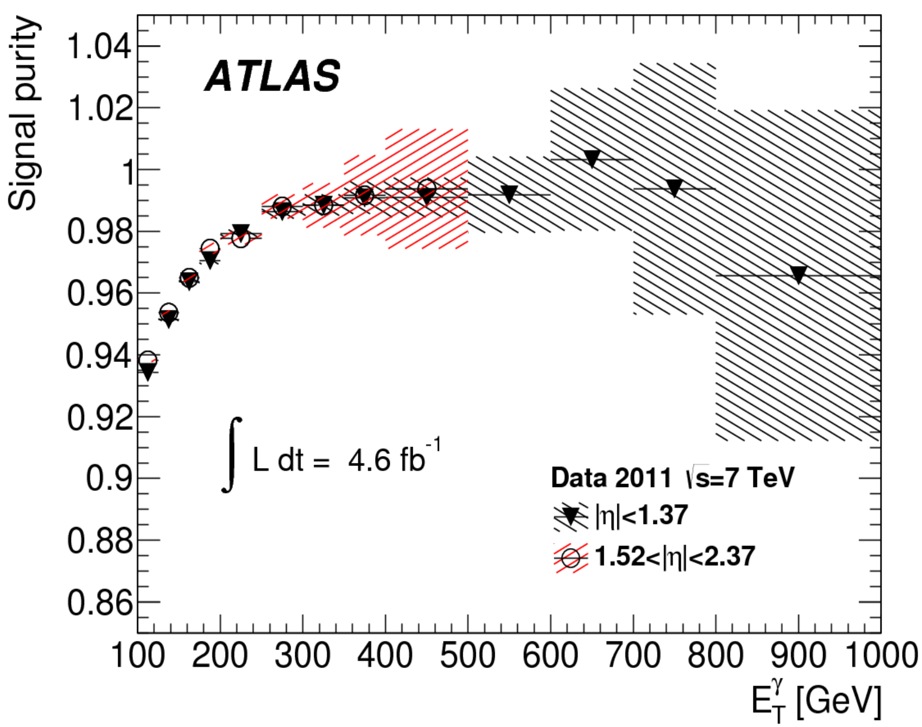
- Generally exploit samples rich in background to get a data driven estimate of the isolation distribution
- samples similar to prompt photons used to evaluate the signal isolation
- fit the isolation distribution, subtract the isolated contribution using the poorly isolated tail for normalization or use a Neural Net, include shower characteristics to discriminate signal and bkgd.

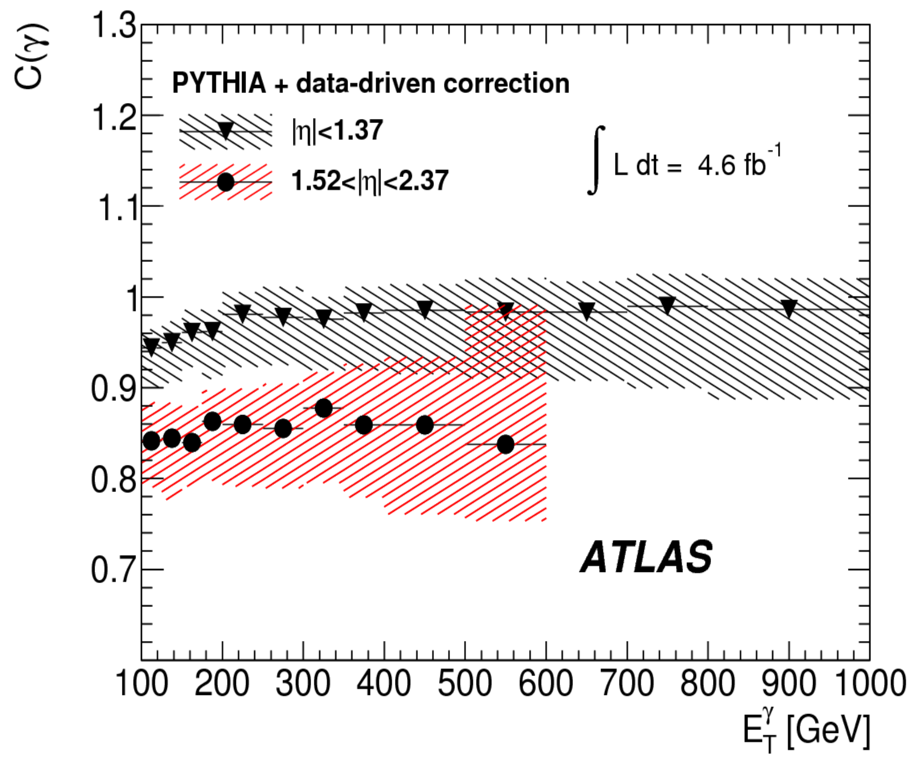




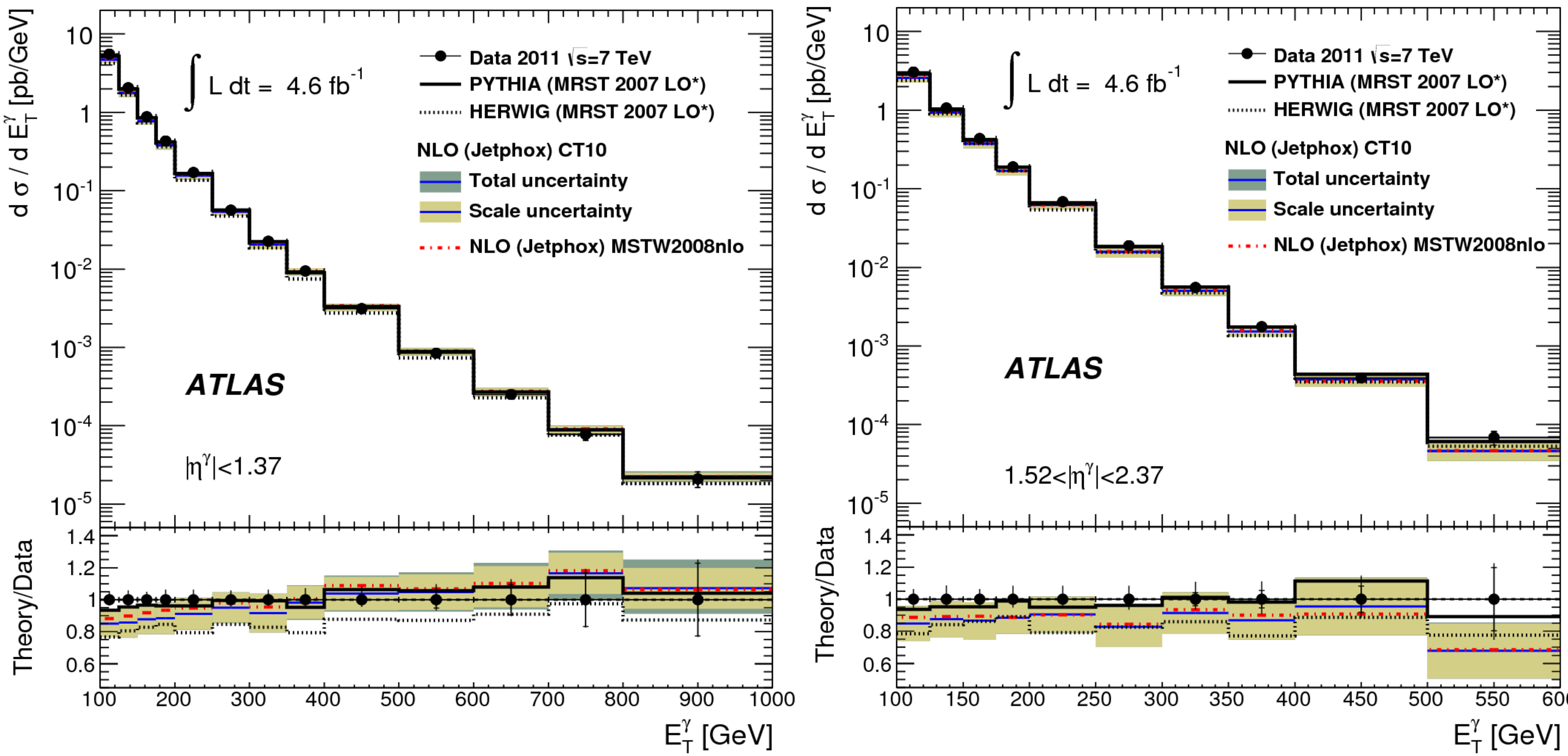
High Energy Photon Candidates Are Mostly Photons

- The background contamination gets much smaller as the P_T goes up
- Corrections are small



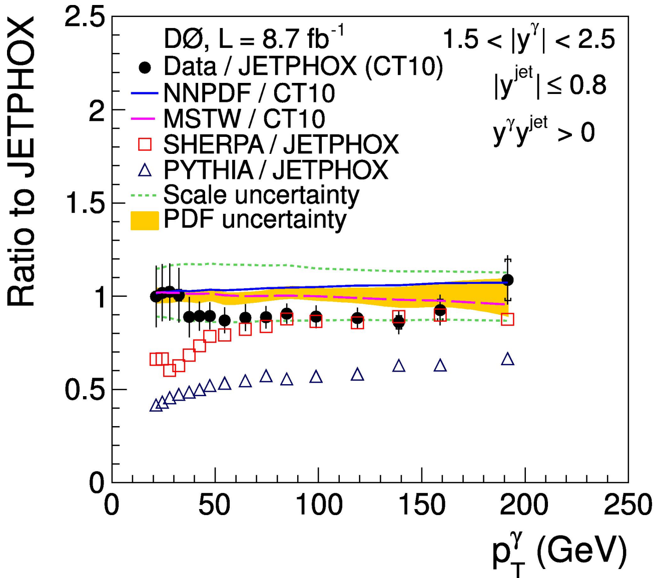


Inclusive Cross Section (ATLAS)



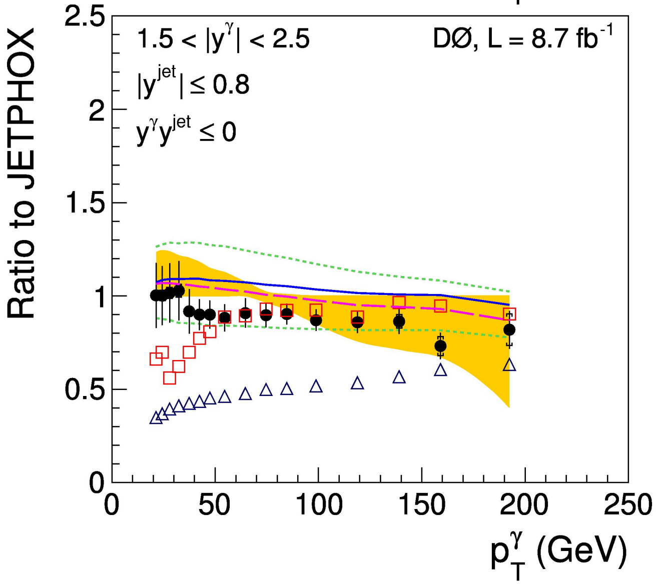
Phys. Rev. D 89, 052004 – Published 24 March 2014

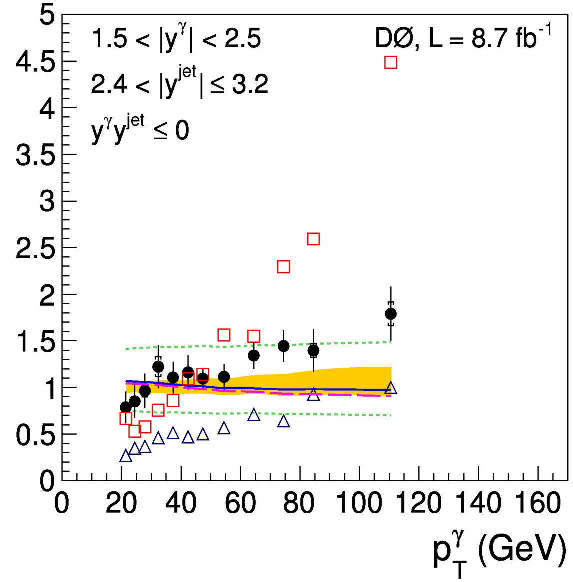
Photon Plus Jet (D0)

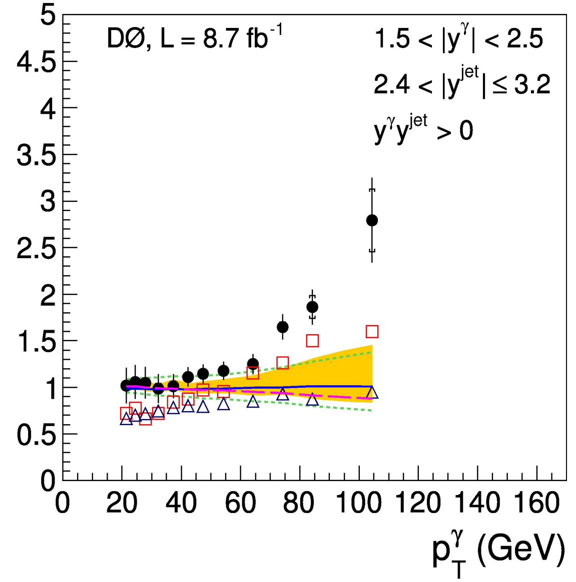


Phys. Rev. D 88, 072008 (2013)

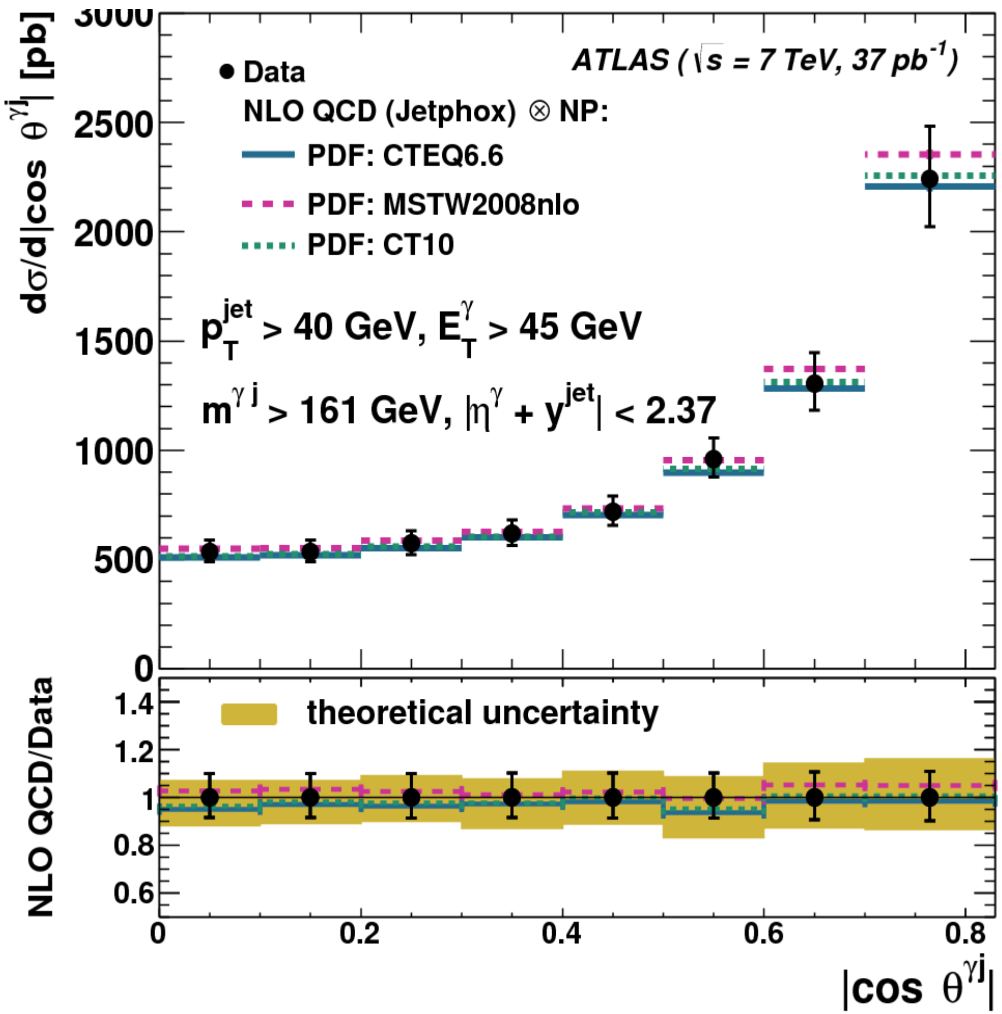
- Explore the x_1x_2 regions by looking at cases where the jet and γ are on the same side (asymmetric x_1x_2) or opposite sides (similar x_1x_2)
- "Triple differential" in that these two categories are broken up into different jet γ rapidity and γ E_T bins







Photon Plus Jet (ATLAS)



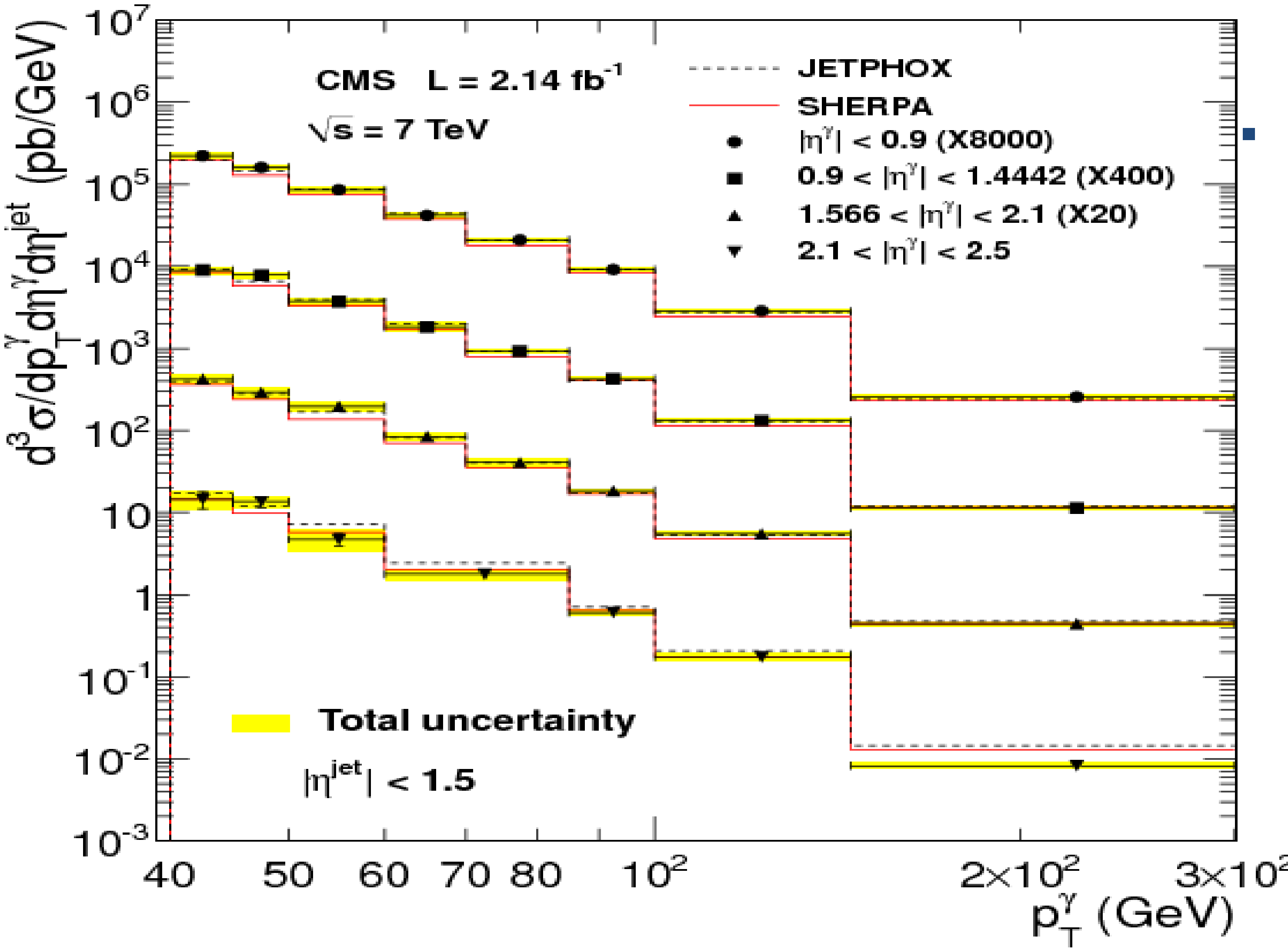
37pb^{-1} dataset explored Versus various photon Jet kinematics:

$E_T^{\gamma}, P_T^{jet}, |\cos\theta^{\gamma j}|$

$\eta^{jet}, M_{\gamma jet}, \Delta\phi^{\gamma jet}$

Nucl. Phys. B 875 (2013) 483-535

Photon Plus Jet Cross Section (CMS)

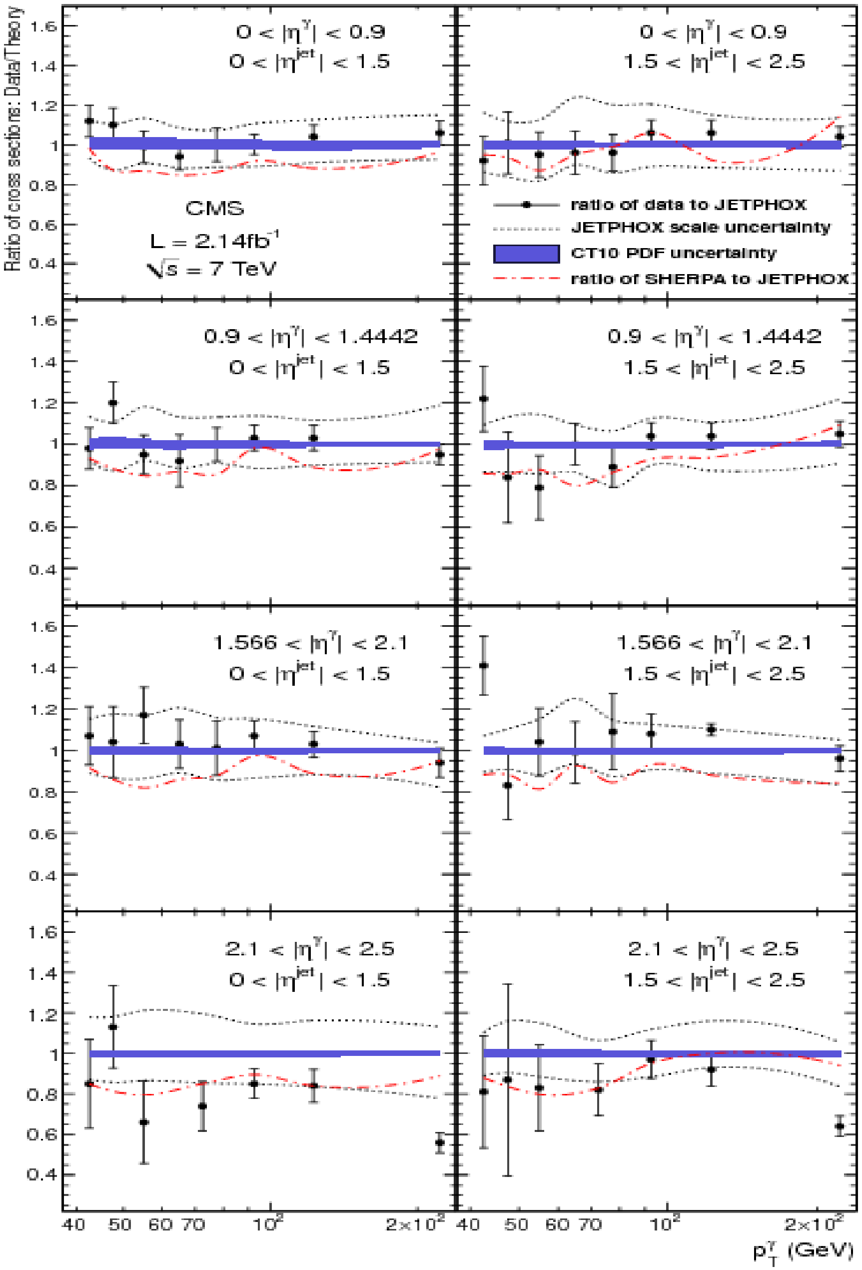


- CMS has done similar measurements at the LHC

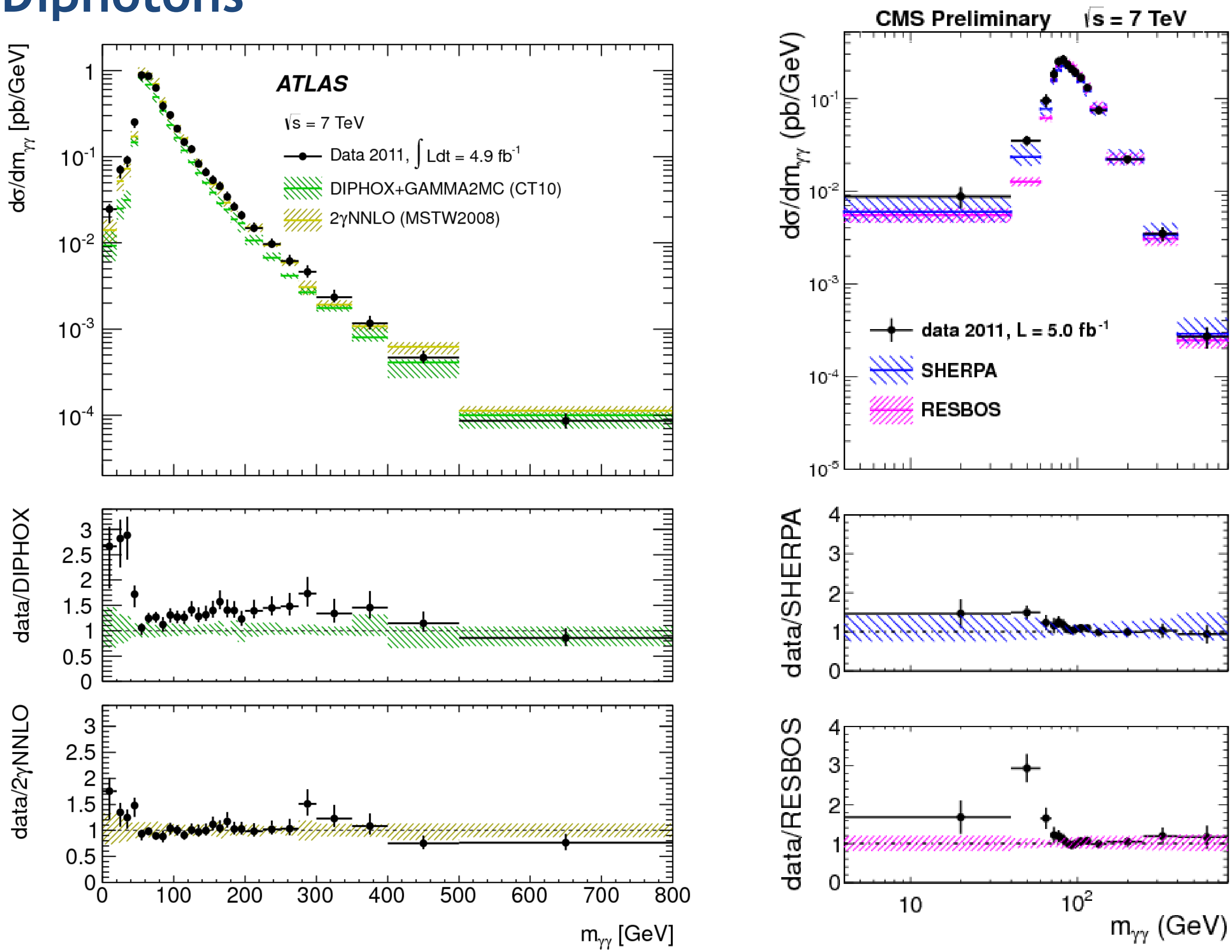
arXiv:1311.6141

Photon Plus Jet Cross Section (CMS)

- In general the theory uncertainty (as indicated by the scale dependence in dotted lines) is comparable or larger than the data uncertainty
- Low η^{jet} on left high η^{jet} right
- low to high η^{γ} from top to bottom

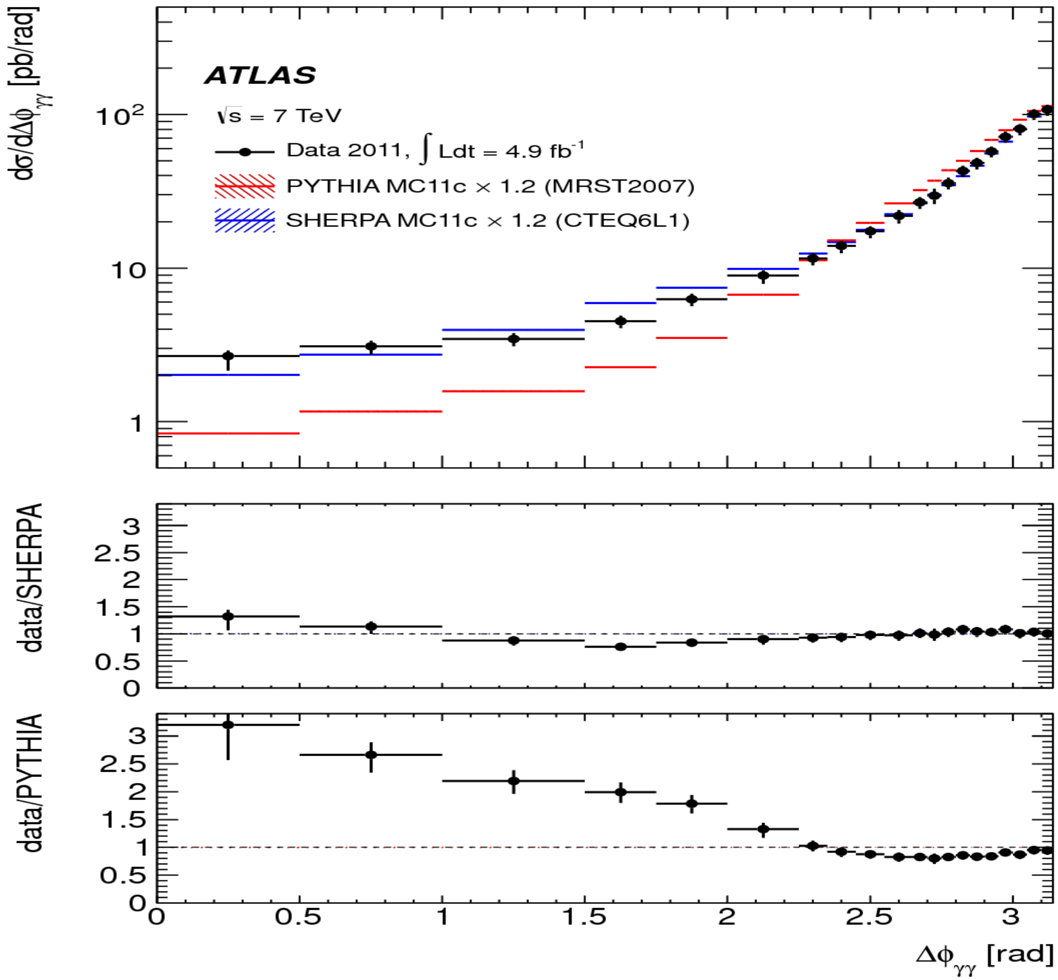


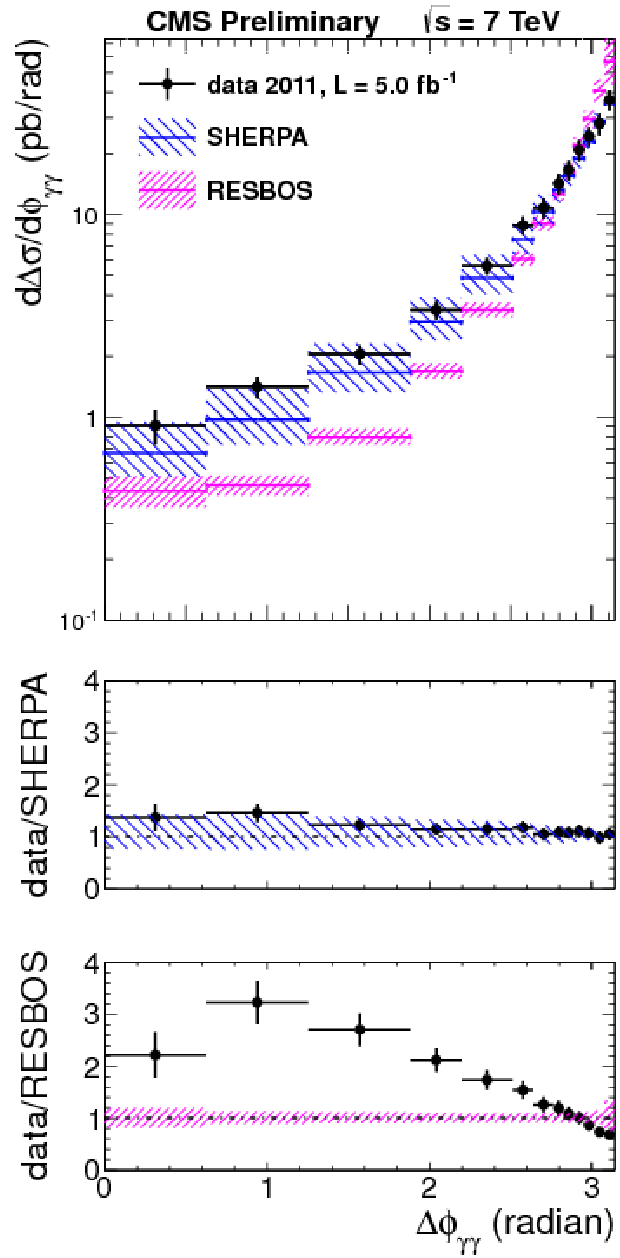
Diphotons



ATLAS
√s = 7 TeV
Data 2011, ∫ Ldt = 4.9 fb-1
DIPHOX+GAMMA2MC (CT10)
2γNNLO (MSTW2008)
dσ/dmγγ [pb/GeV]
data/DIPHOX
data/2γNNLO
mγγ [GeV]
CMS Preliminary √s = 7 TeV
data 2011, L = 5.0 fb-1
SHERPA
RESBOS
dσ/dmγγ (pb/GeV)
data/SHERPA
data/RESBOS
mγγ (GeV)

Diphotons

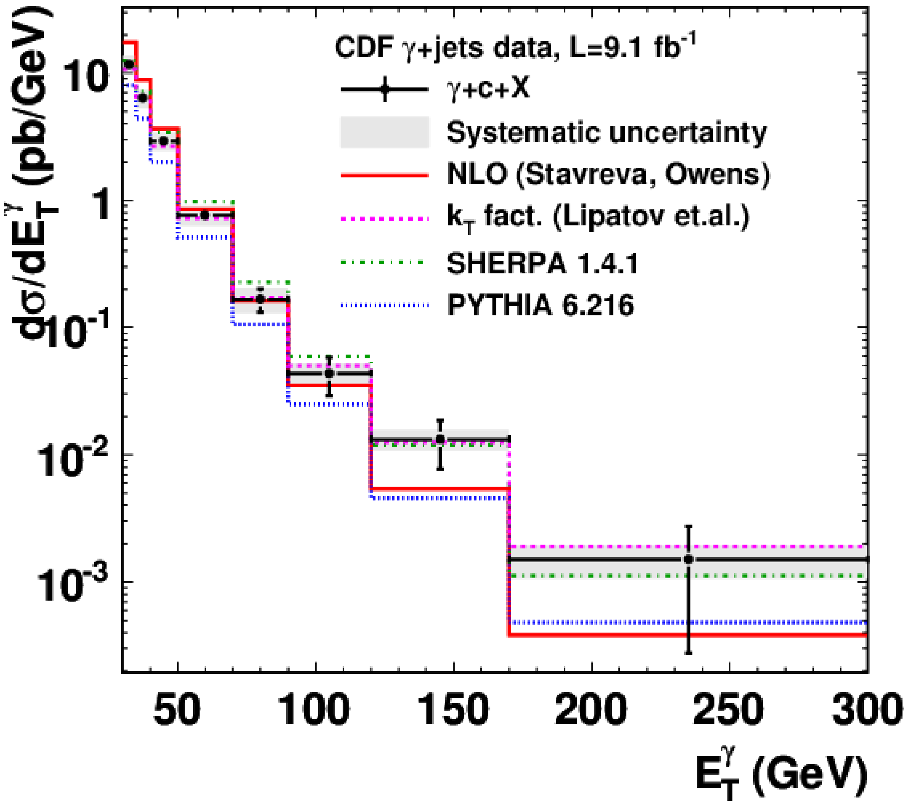


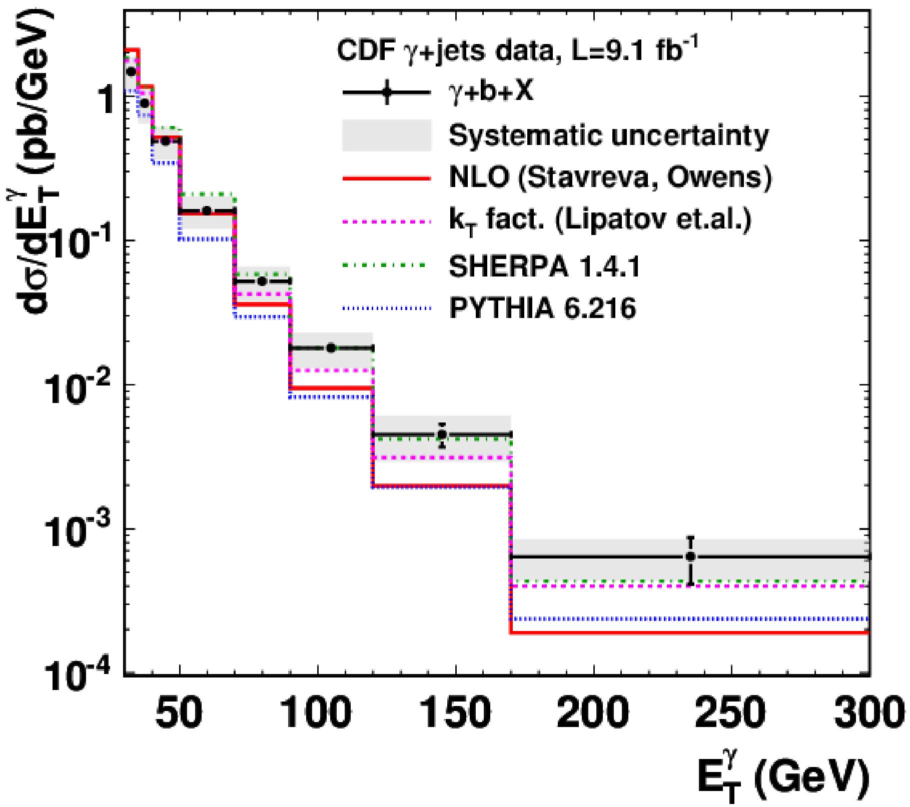


CERN-PH-EP-2012-300 & CMS PAS SMP-13-001

Heavy Flavor Plus Photons

Phys.Rev.Lett.111.042003 (2013)

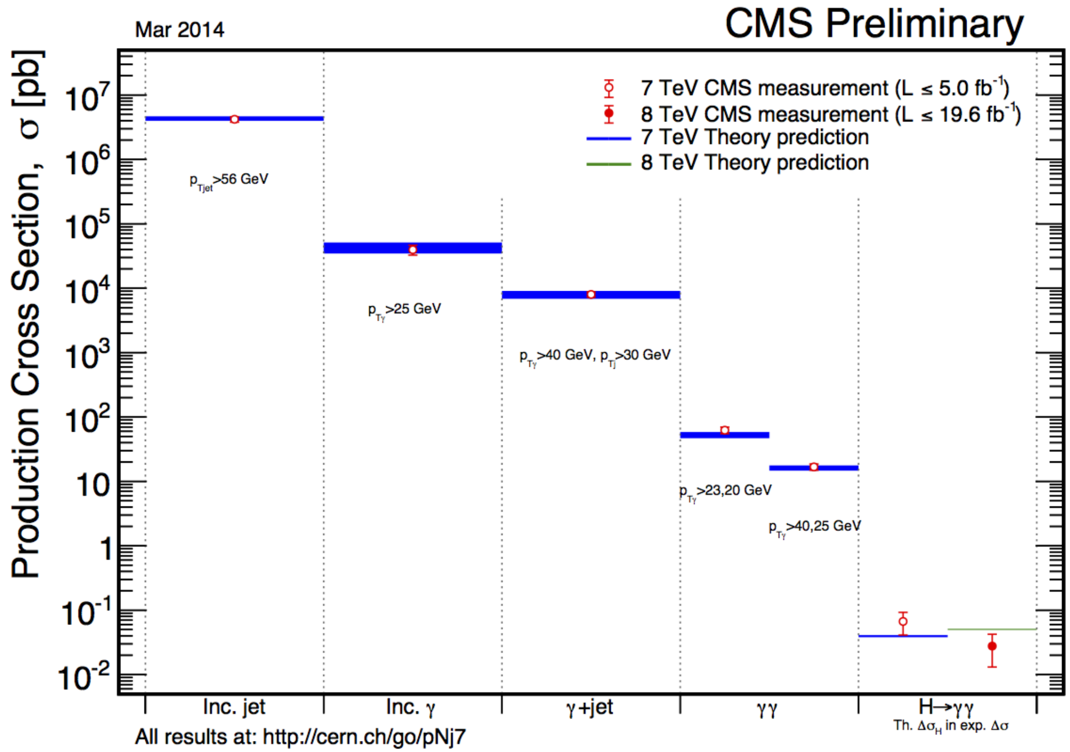




D0 made a similar earlier measurement in Phys. Lett. B 179, 354 (2012)

$t\bar{t}$ plus γ measured at both colliders – perhaps this will be shown in the top talk?

Conclusions



- Many nice results
  - high energy makes photons easier and purer so even more and better are yet to come
- Precision is comparable to our understanding of the calculations
  - some hope to improve the high X gluon understanding
  - some need to improve the theory and reduce the corresponding scale uncertainty

Backup Slides

Diphoton selection

CMS

Table 1: List of photon pre-selection requirements

Variable	Requirement
Photon raw energy	$E_{SC}^{raw+ES} > 20$ GeV
H/E	if ($R_9 > 0.9$): H/E < 0.082 (EB), 0.075 (EE) if ($R_9 < 0.9$): H/E < 0.075
$\sigma_{i\eta i\eta}$	$0.001 < \sigma_{i\eta i\eta} < 0.014$ (EB) $\sigma_{i\eta i\eta} < 0.034$ (EE)
ECAL isolation in 0.3 cone	$Iso_{ECAL}^{03} < 4$ GeV (only if $R_9 < 0.9$)
HCAL isolation in 0.3 cone	$Iso_{HCAL}^{03} < 4$ GeV (only if $R_9 < 0.9$)
TRK isolation in 0.3 cone	$Iso_{TRK}^{03} < 4$ GeV (only if $R_9 < 0.9$)

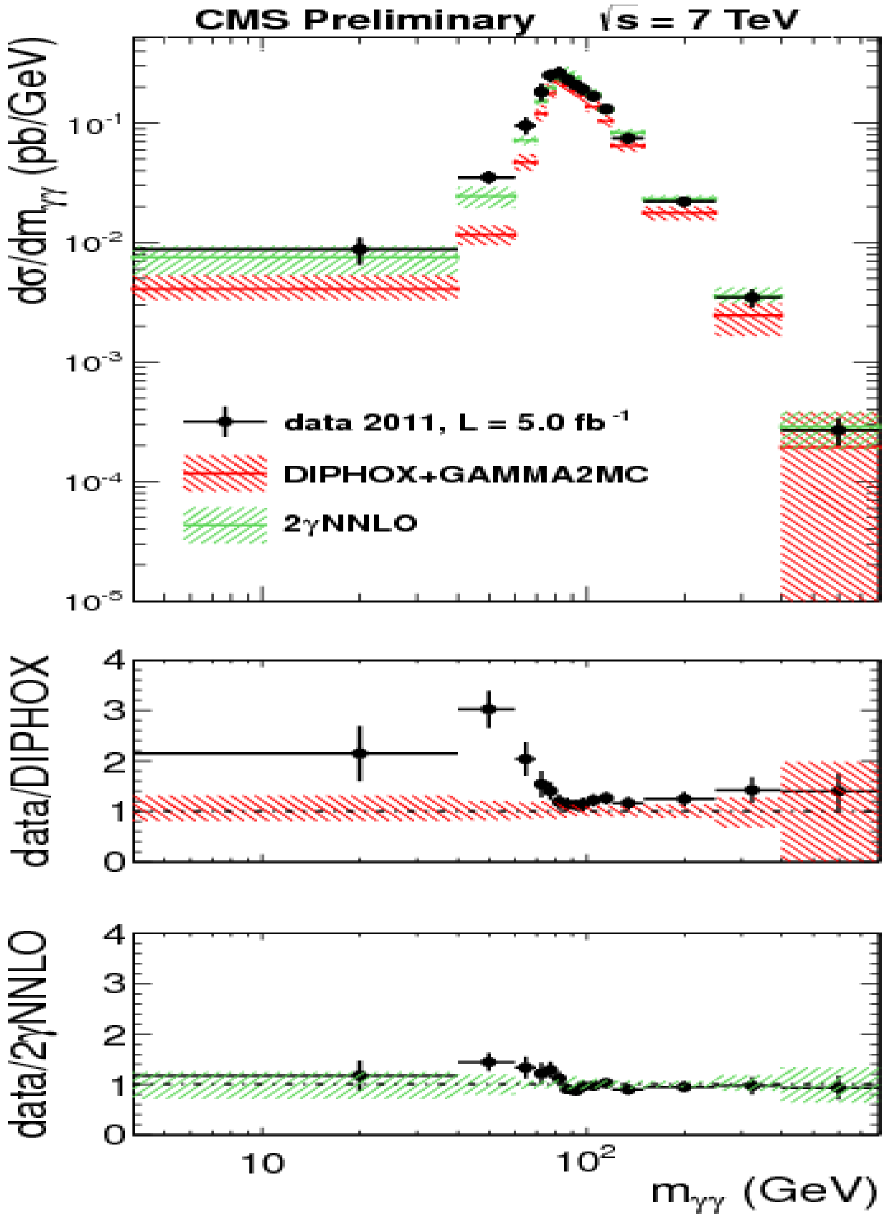
Table 2: List of photon selection requirements

Variable	Requirement
Matched pixel seed	False
H/E	H/E < 0.05
$\sigma_{i\eta i\eta}$	$\sigma_{i\eta i\eta} < 0.011$ (EB), 0.030 (EE)

CMS Diphtoon systematics

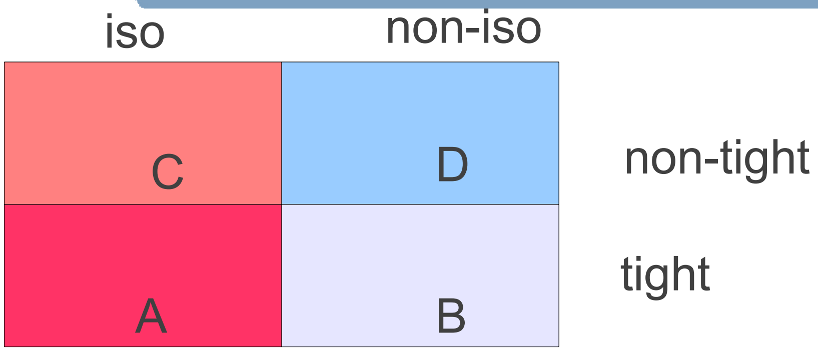
Table 3: Summary of the main sources of systematic uncertainty on the cross section measurement.

Prompt template shape EB	3%
Prompt template shape EE	5%
Fakes template shape EB	5%
Fakes template shape EE	10%
Effect of fragmentation component	1.5%
Template stat. fluctuation	3%
Selection efficiency	2-4%
Integrated luminosity	2.2%



- Shoulder @ ~65GeV due to very asymmetric gammas
- only sherpa which includes 3 jets and 2γNNLO properly capture this
- P_T cuts they apply are 40 and 25 GeV

ATLAS Background evaluation



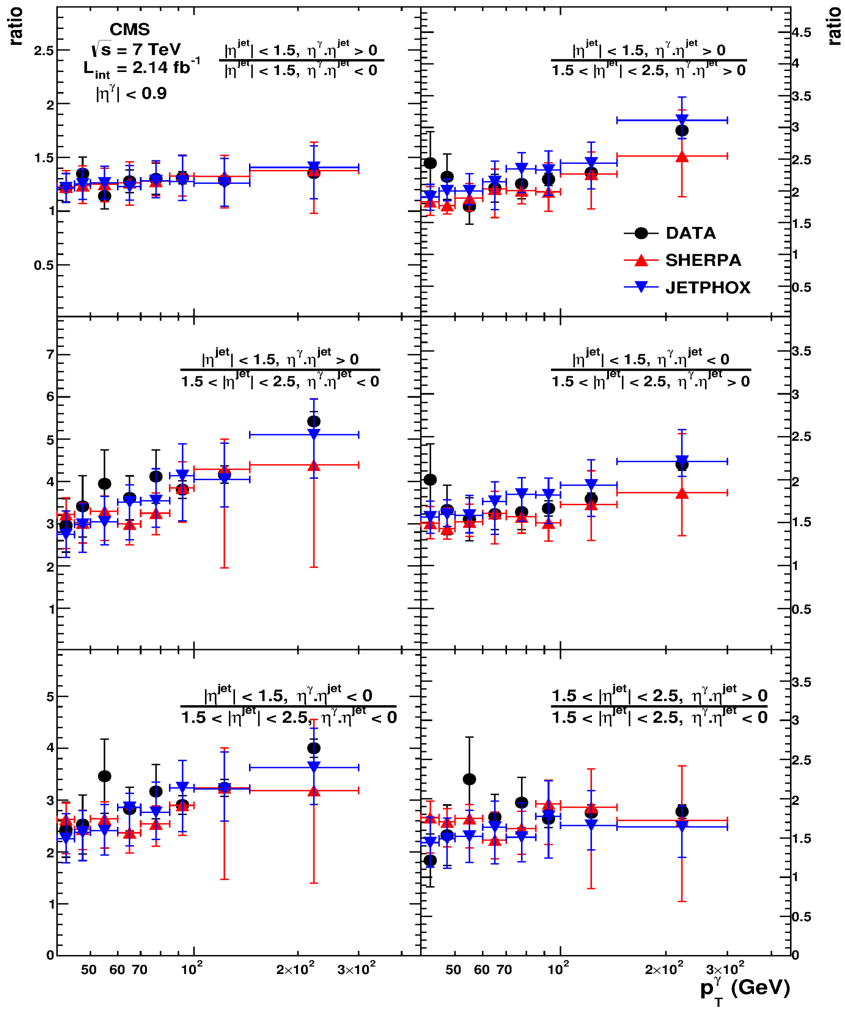
- Standard ABCD method
  - Use the non-tight isolation distribution to evaluate the non-prompt distribution
  - Subtract the remnant of the background in the isolated sample by normalizing the above isolated background to the non-isolated tight sample
  - Apply small corrections from MC for leakage of prompt photons into the non-tight sample
  - Apply small corrections from MC for leakage of prompt photons into non-isolated region
  - Normalization is to the final isolated prompt photon contribution (i.e. the region A prompt contribution)

$$N_S^A = N^A - R\frac{(N^B - C_B N_{SIG}^A)(N^C - C_C N_{SIG}^A)}{(N^D - C_D N_{SIG}^A)}$$

$$C_K = \frac{N_{SIG}^K}{N_{SIG}^A}$$

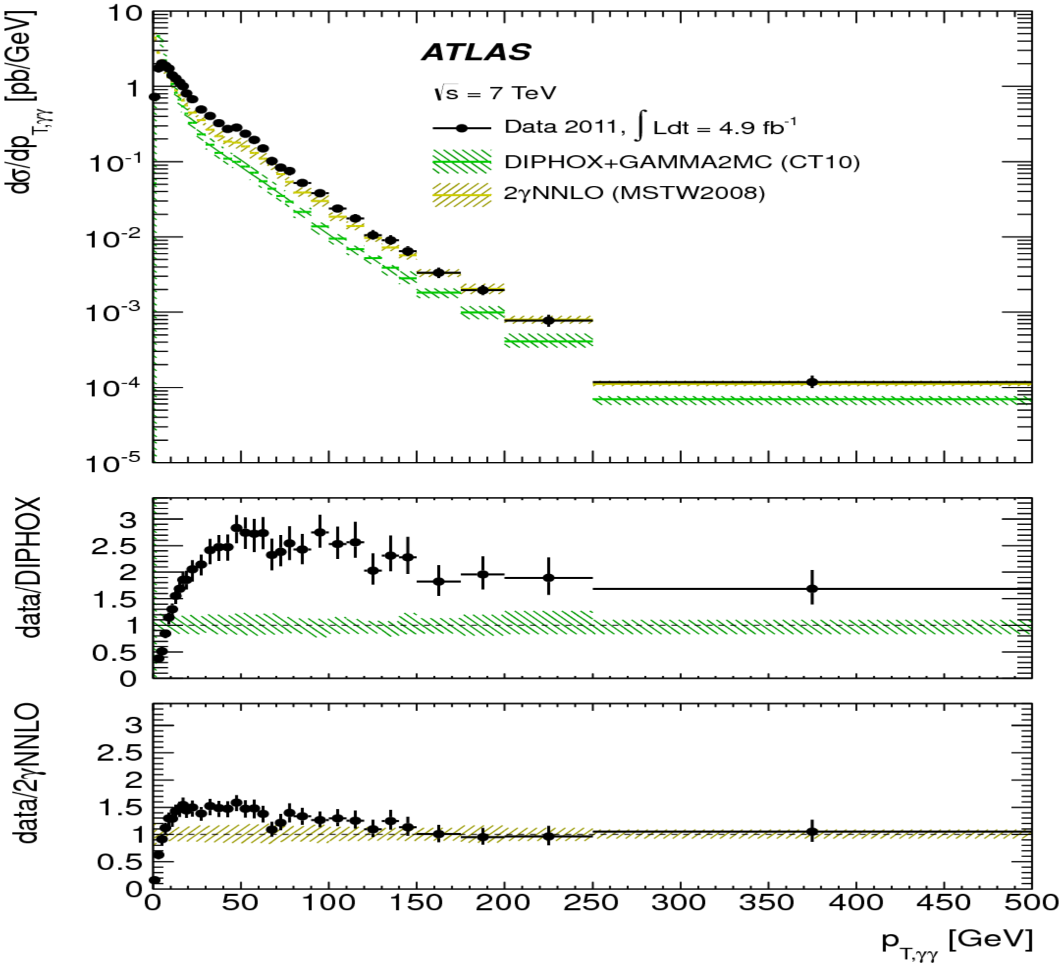
$$R = \frac{N_{BKG}^A N_{BKG}^D}{N_{BKG}^B N_{BKG}^C}$$

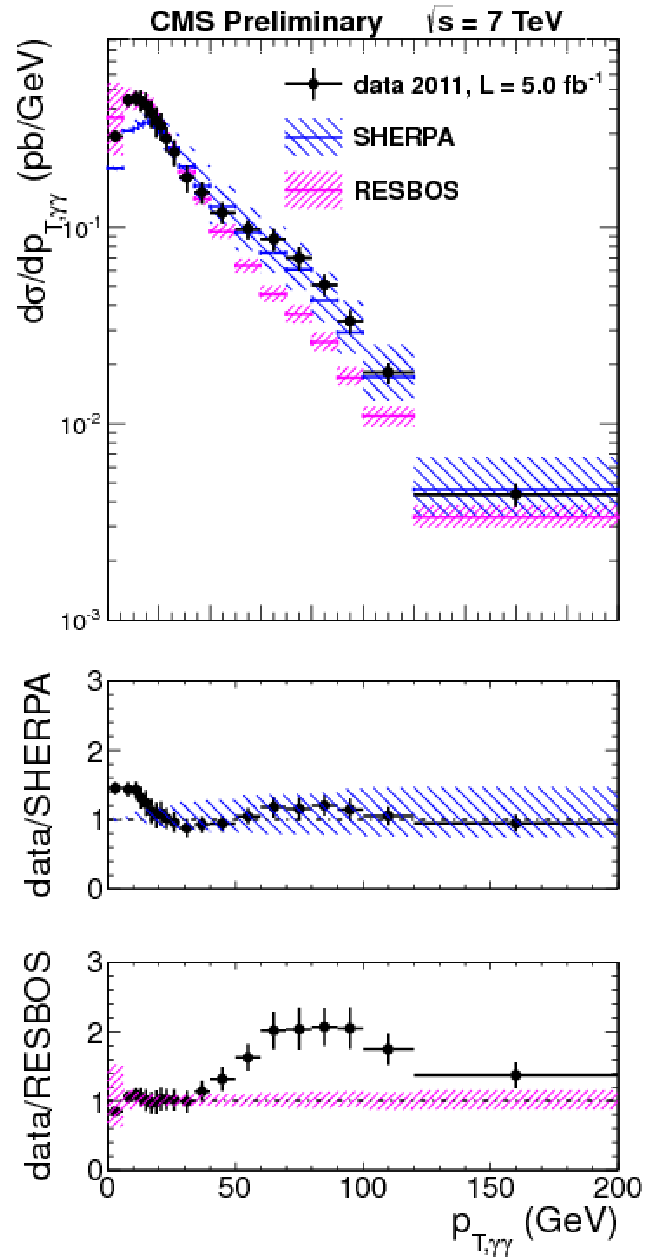
Triple differential cross section



- Same side opposite side measurment like D0
- Uses cross section ratios rather than absolute to minimize uncertainty
  - some uncertainties are common so the ratio divides them out

Diphotons





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