

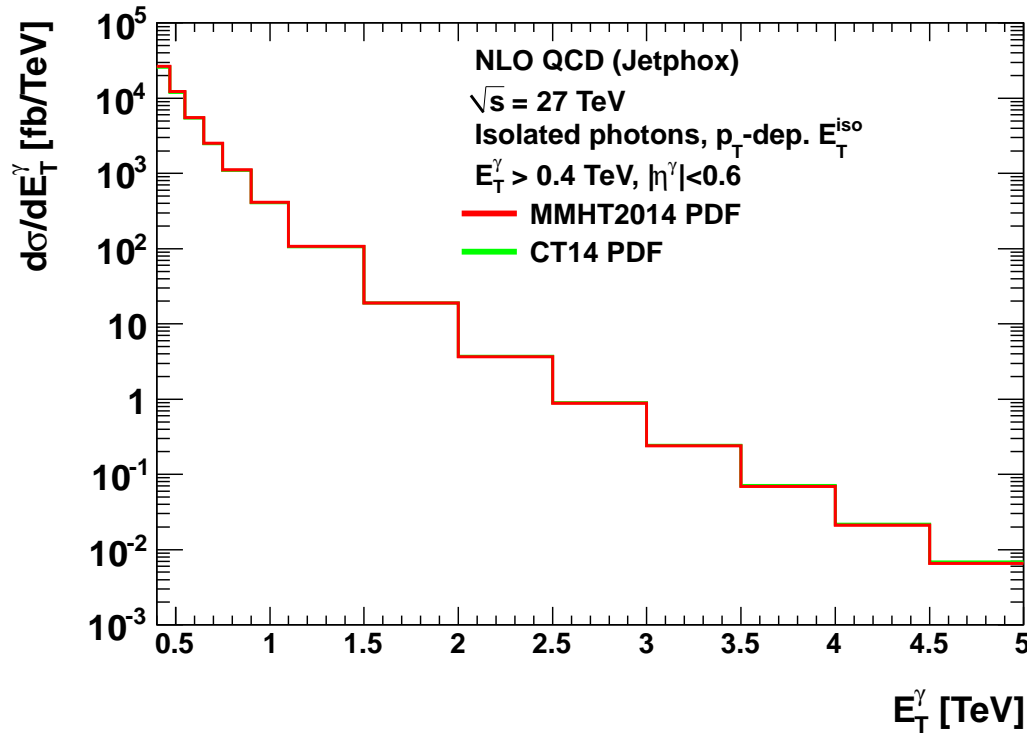
Prospects on photon physics at HE-LHC with ATLAS

J. Terrón (Universidad Autonoma de Madrid)

- **Outline:**

- Predictions for inclusive γ production at $\sqrt{s} = 27$ TeV
- Comparison between MMHT2014 and CT14 PDFs
- Predicted number of events for $\mathcal{L} = 15 \text{ ab}^{-1}$
- Theoretical uncertainties from terms beyond NLO
- Latest ATLAS measurement at 13 TeV
- $\sqrt{s} = 13$ TeV vs. $\sqrt{s} = 27$ TeV
- Ratio of cross sections $\sigma(27\text{TeV})/\sigma(13\text{TeV})$

Predictions for inclusive photon production at $\sqrt{s} = 27$ TeV



- Predicted $d\sigma/dE_T^\gamma$ for inclusive isolated photon production in pp collisions

→ $\sqrt{s} = 27$ TeV

→ NLO QCD for direct and fragmentation contributions

→ Photon Isolation in a cone of $R = 0.4$:

$$E_T^{\text{iso}} < 0.0042 \cdot E_T^\gamma + 4.8 \text{ GeV}$$

→ program JetPhox

→ Proton PDFs: MMHT2014 or CT14

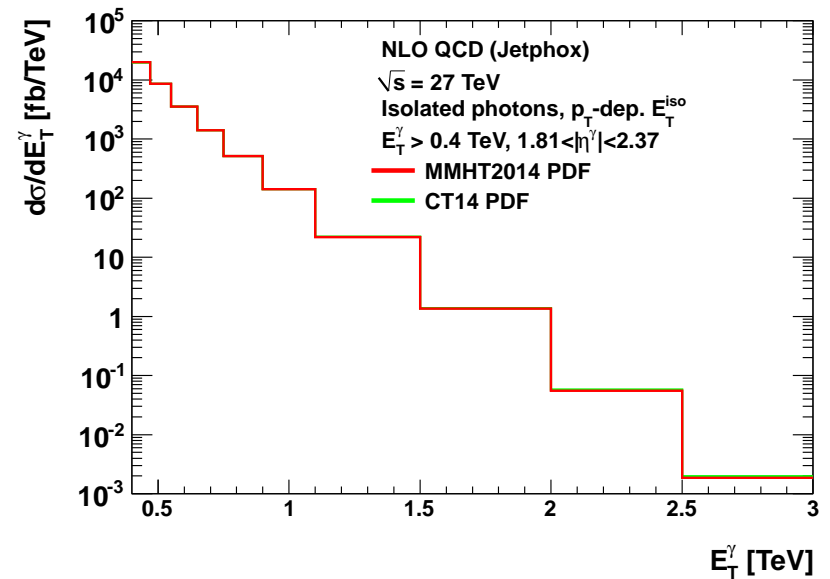
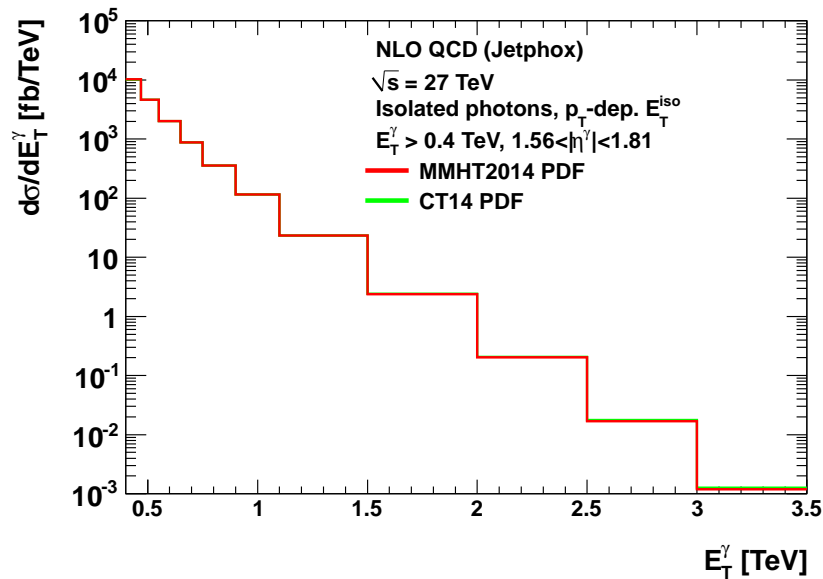
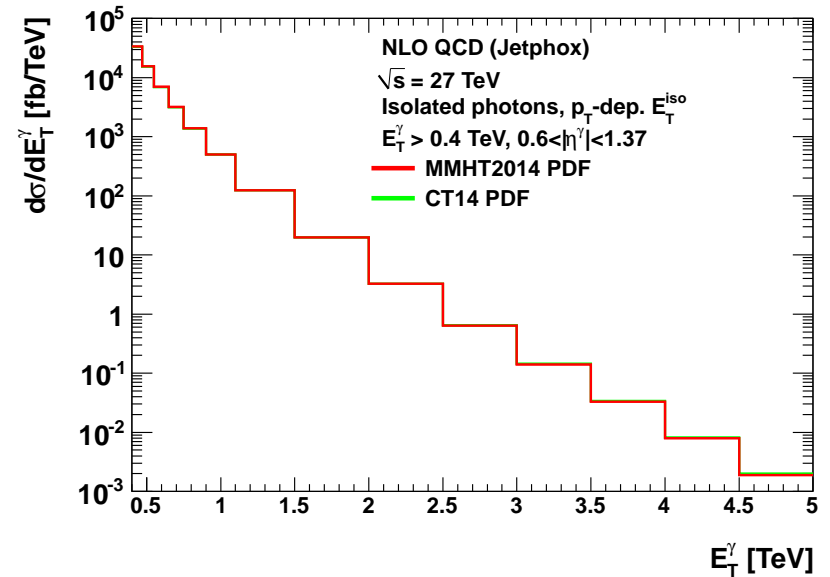
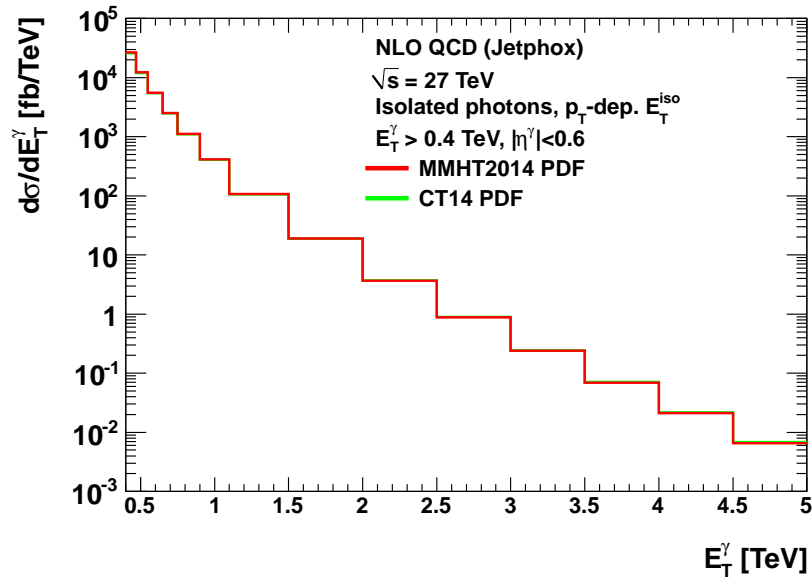
→ Fragmentation functions (parton-to-photon): BFG set II

- Range in E_T^γ : 0.4–5 TeV

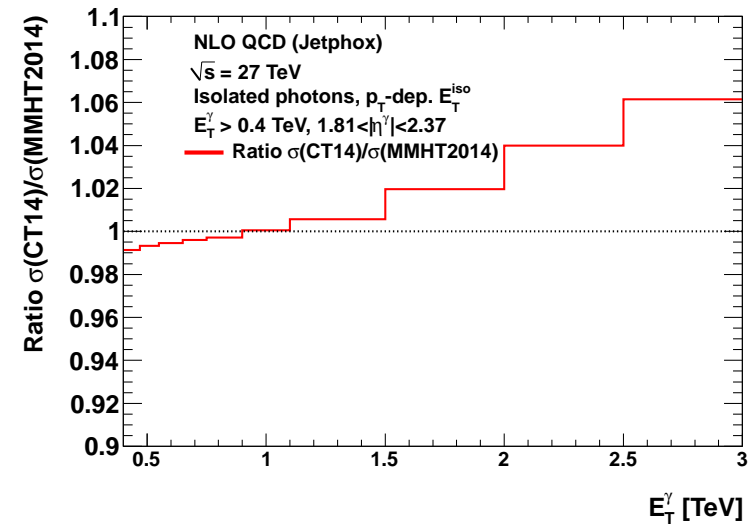
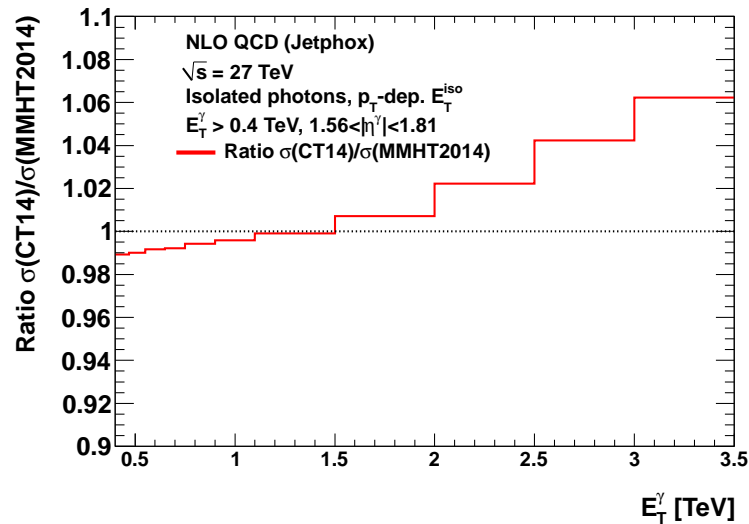
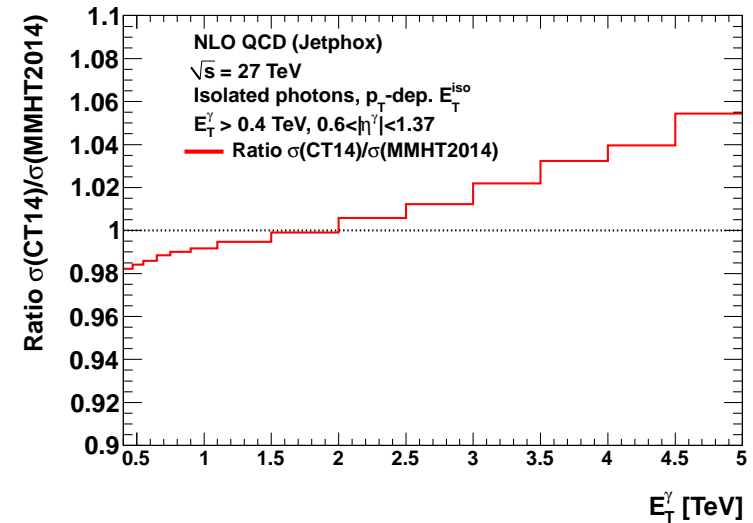
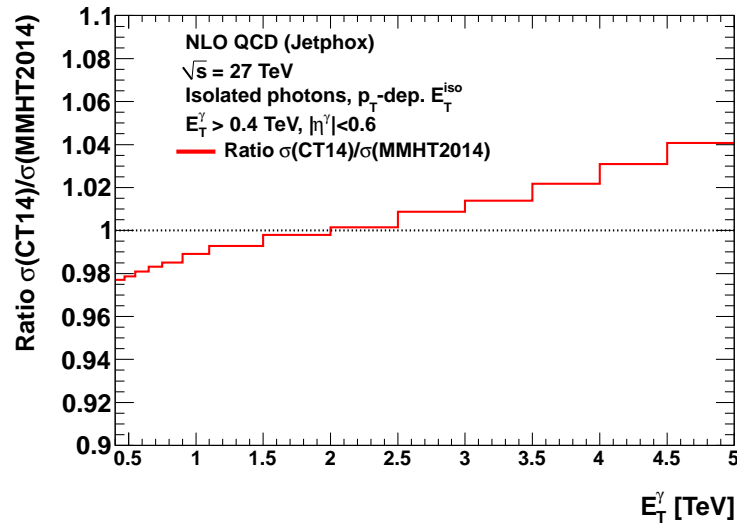
- Range in $|\eta^\gamma|$: $|\eta^\gamma| < 2.37$ excluding $1.37 < |\eta^\gamma| < 1.56$

four regions in $|\eta^\gamma|$, namely, 0–0.6, 0.6–1.37, 1.56–1.81, 1.81–2.37

Predictions for inclusive photon production in $|\eta^\gamma|$ ranges

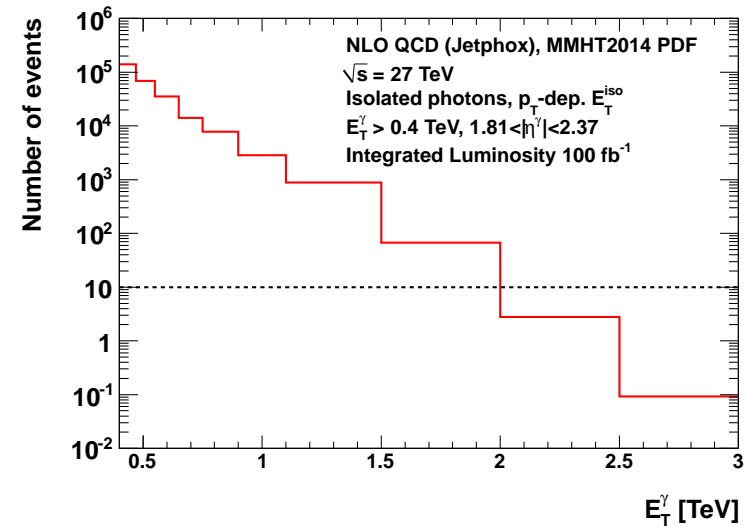
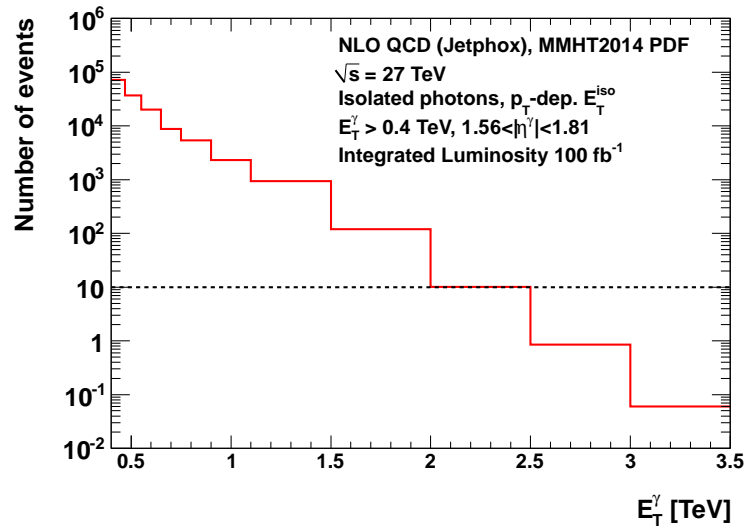
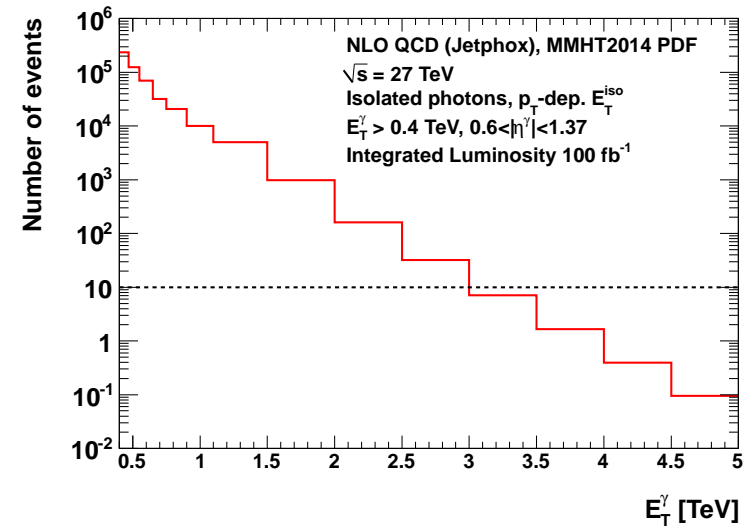
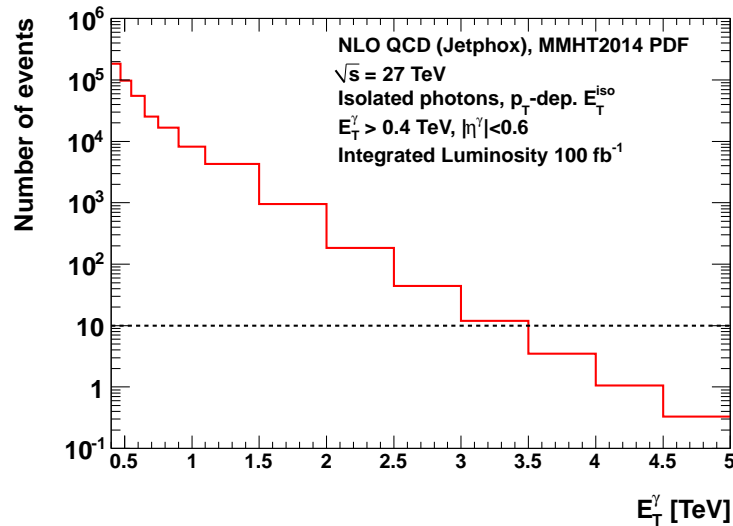


MMHT2014 vs CT14-based predictions



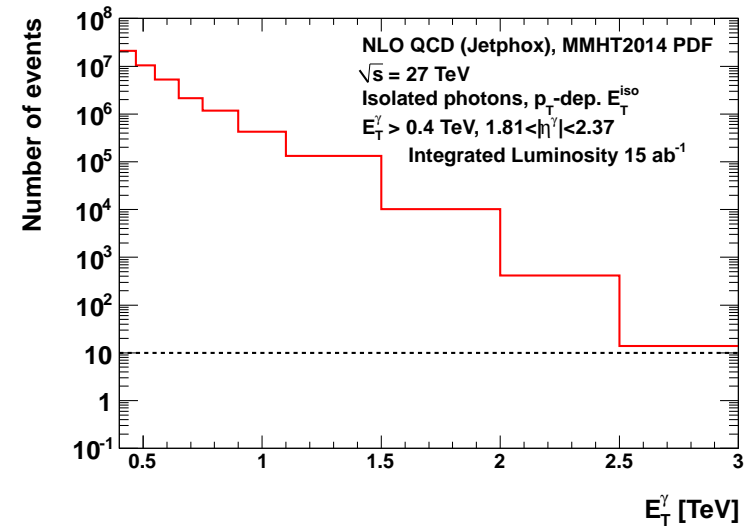
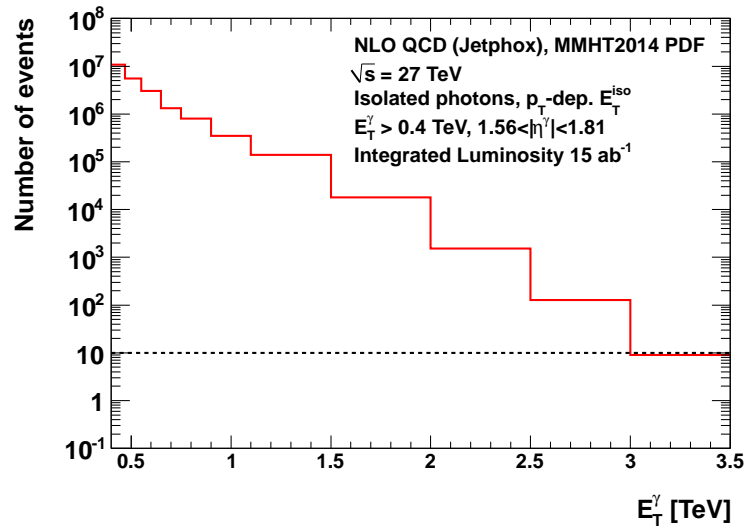
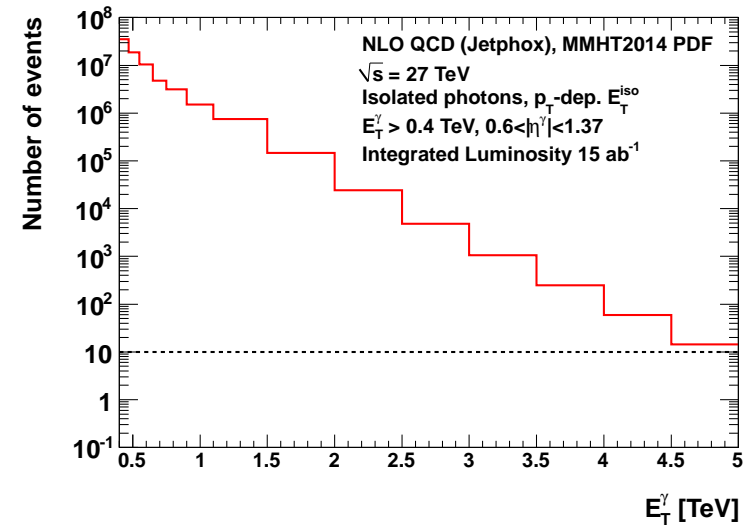
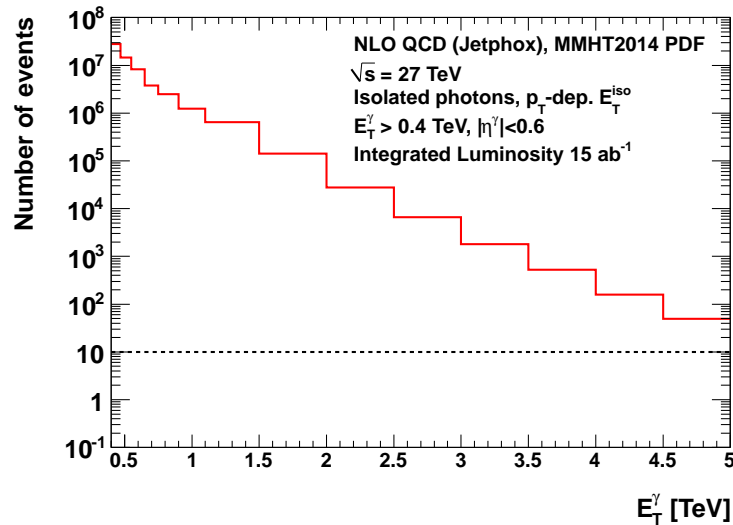
- Differences up to $\sim 6\%$; the study will be extended to other parameterisations of the PDFs; uncertainties due to the PDFs will also be evaluated

Predicted number of events for $\mathcal{L} = 100 \text{ fb}^{-1}$



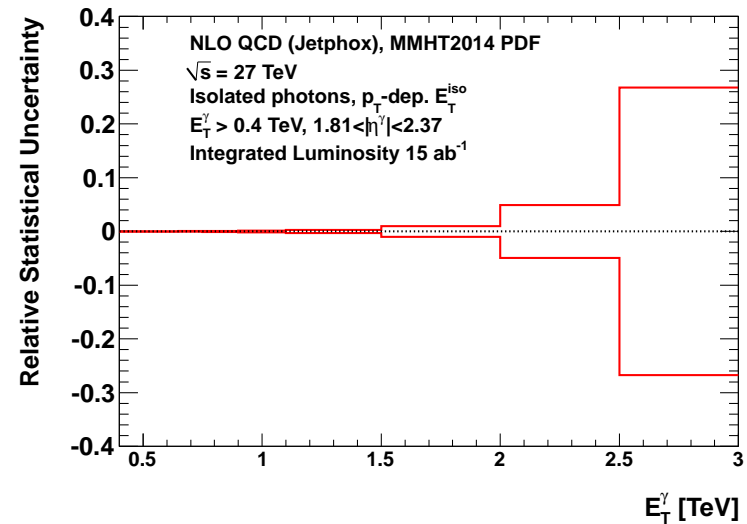
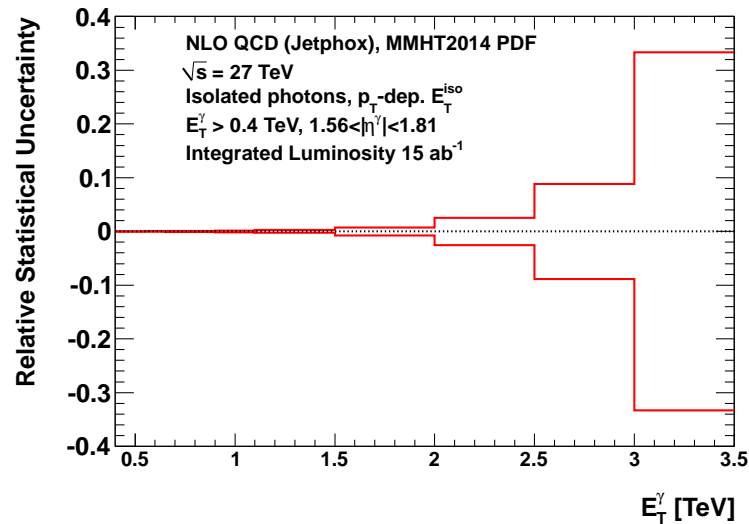
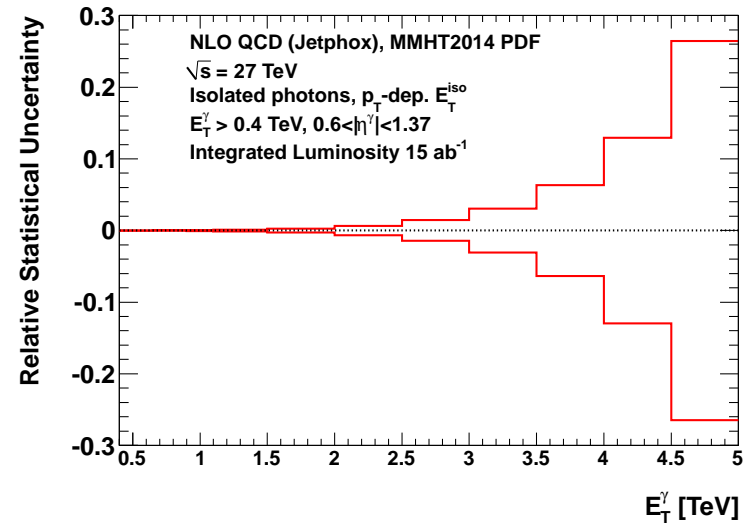
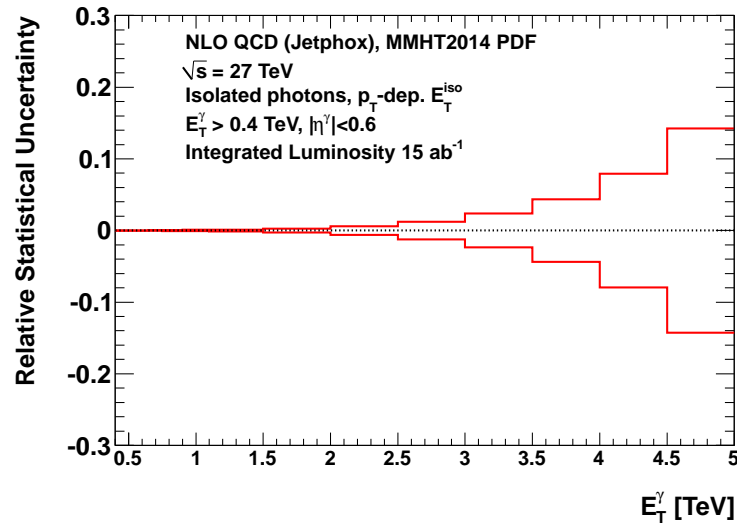
- E_T^γ reach with 100 fb^{-1} : **3-3.5 TeV** ($|\eta^\gamma| < 1.37$), **2-2.5 TeV** ($1.56 < |\eta^\gamma| < 1.81$), **1.5-2 TeV** ($1.81 < |\eta^\gamma| < 2.37$)

Predicted number of events for $\mathcal{L} = 15 \text{ ab}^{-1}$



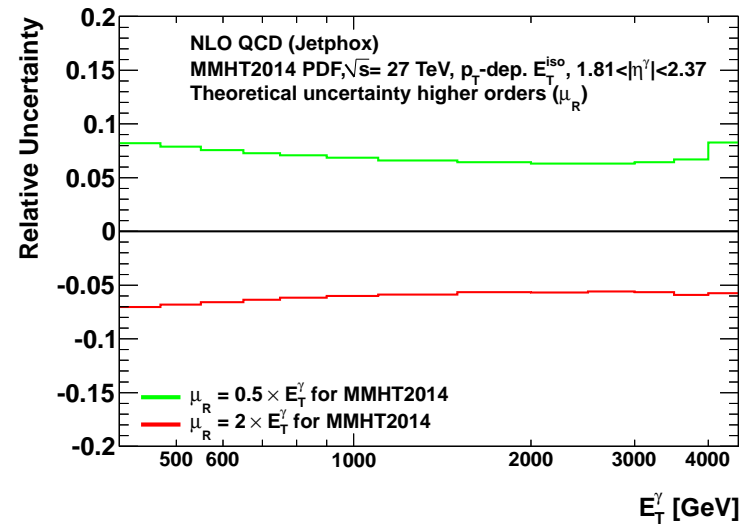
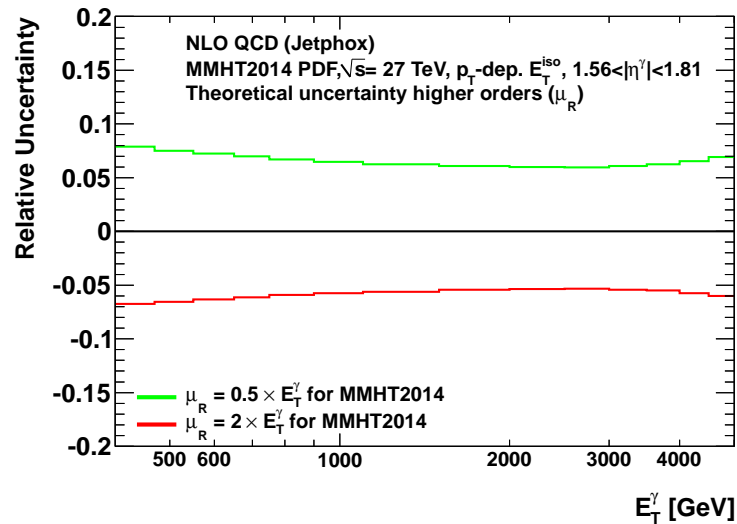
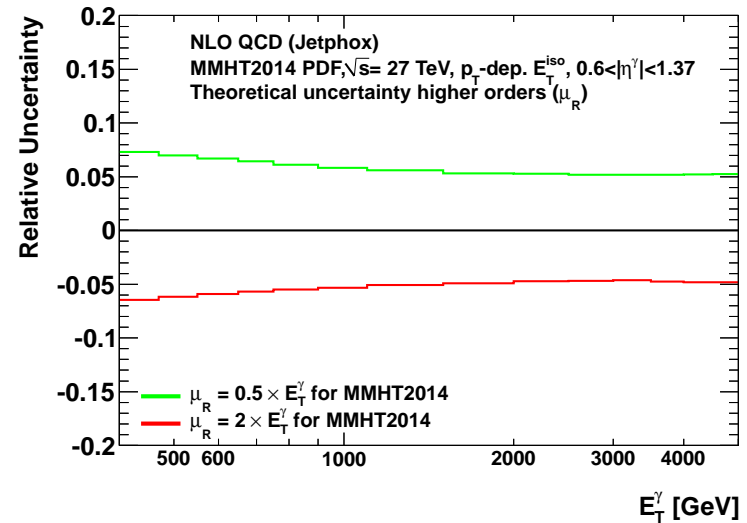
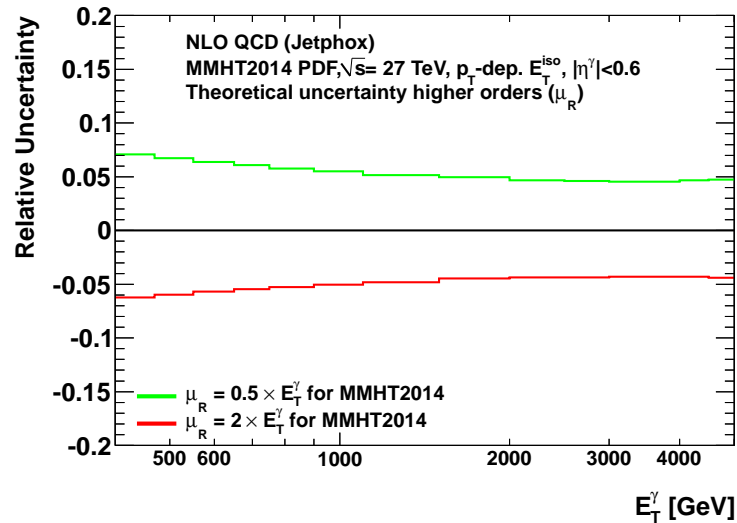
- E_T^γ reach with 15 ab^{-1} : **4.5-5 TeV** ($|\eta^\gamma| < 1.37$), **3-3.5 TeV** ($1.56 < |\eta^\gamma| < 1.81$), **2.5-3 TeV** ($1.81 < |\eta^\gamma| < 2.37$); **10^6 photons with 1 TeV** (\rightarrow jet calibration)

Relative statistical uncertainty for $\mathcal{L} = 15 \text{ ab}^{-1}$



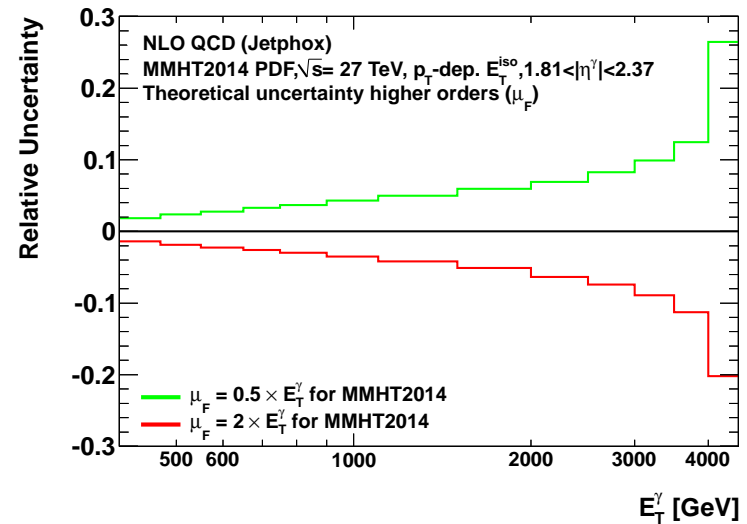
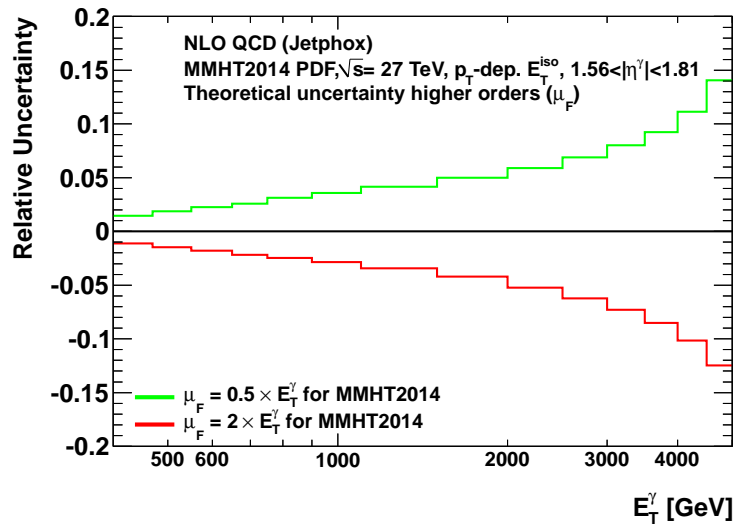
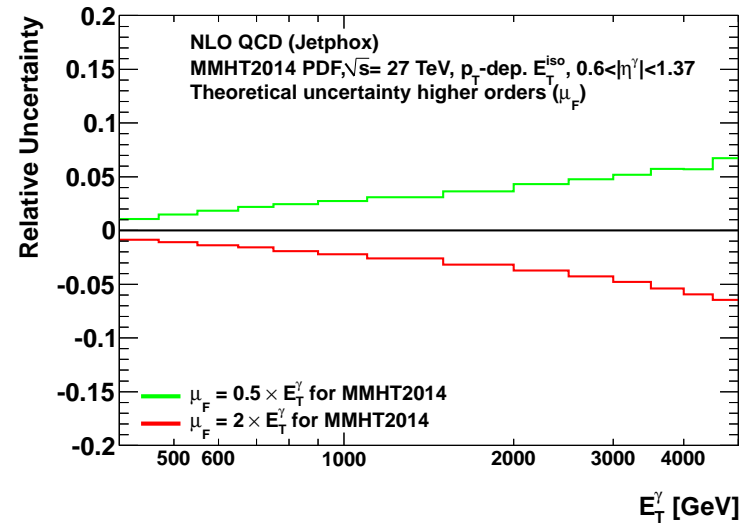
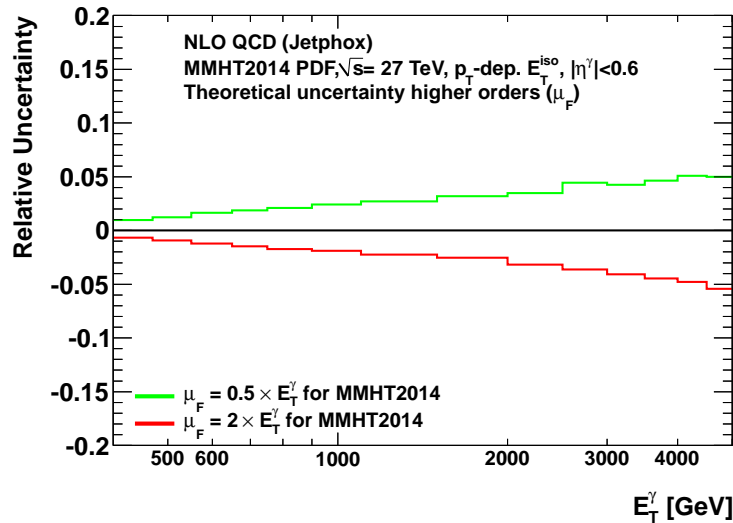
- Relative statistical uncertainty below 10% for E_T^{γ} up to **4.5 TeV** ($|\eta^{\gamma}| < 0.6$), **4 TeV** ($0.6 < |\eta^{\gamma}| < 1.37$), **3 TeV** ($1.56 < |\eta^{\gamma}| < 1.81$), **2.5 TeV** ($1.81 < |\eta^{\gamma}| < 2.37$)

Theoretical uncertainties from terms beyond NLO (μ_R)



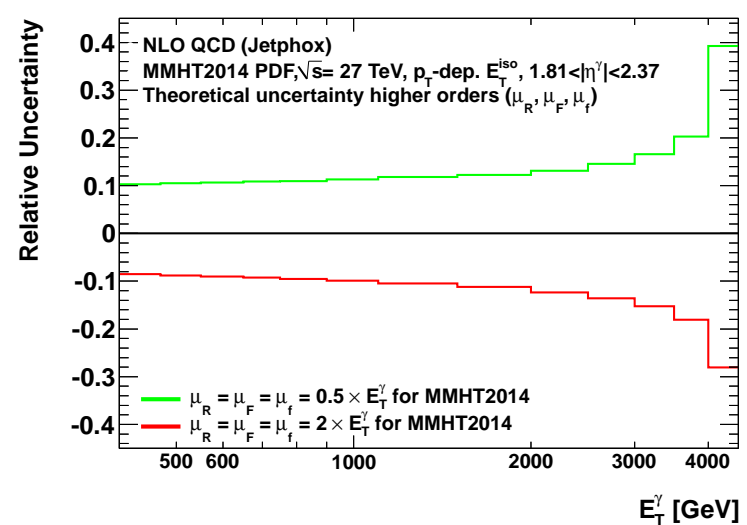
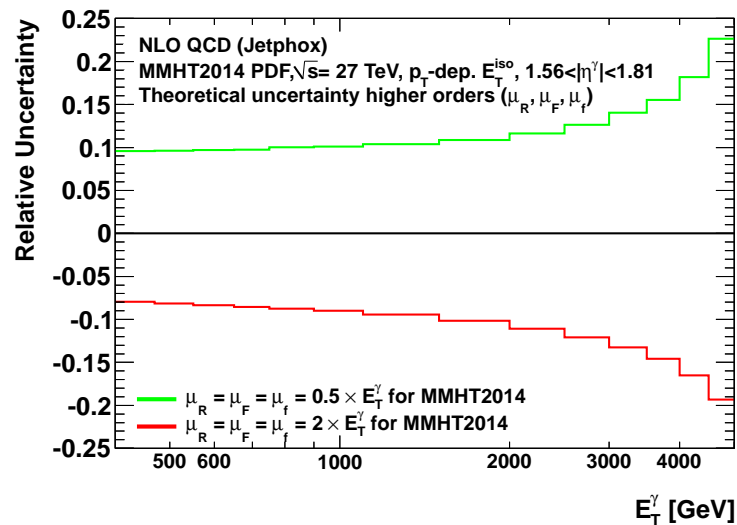
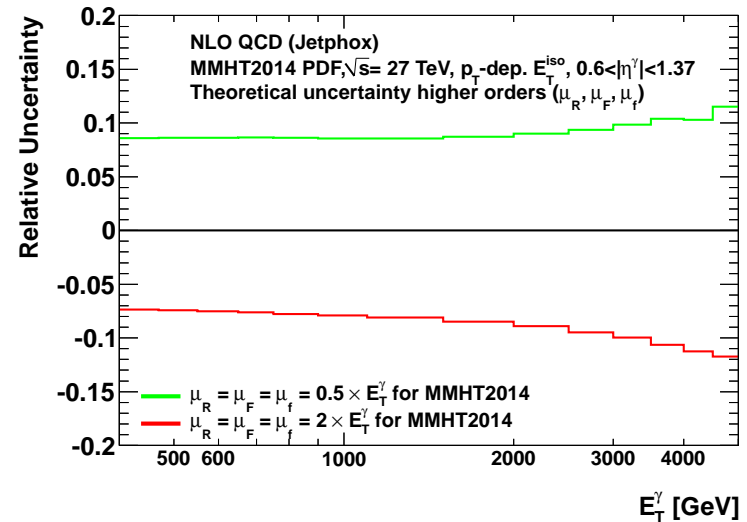
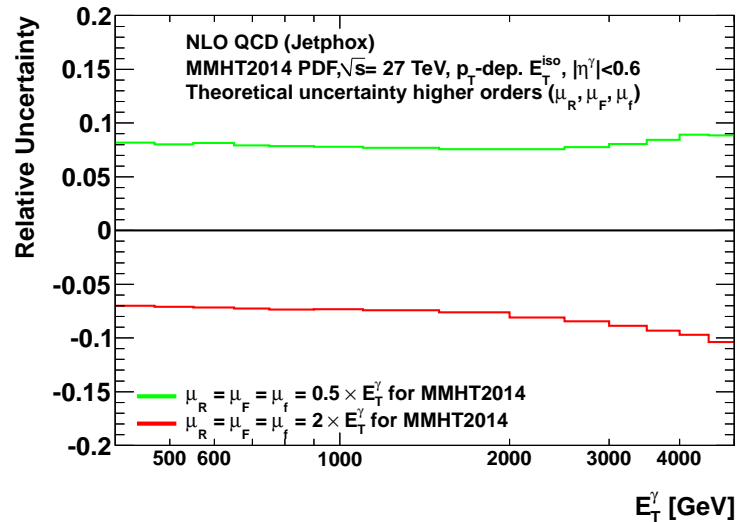
- Variation of μ_R by a factor two up and down
- It will benefit from NNLO QCD calculations (Campbell et al PRL118 (2017) 222001)

Theoretical uncertainties from terms beyond NLO (μ_F)



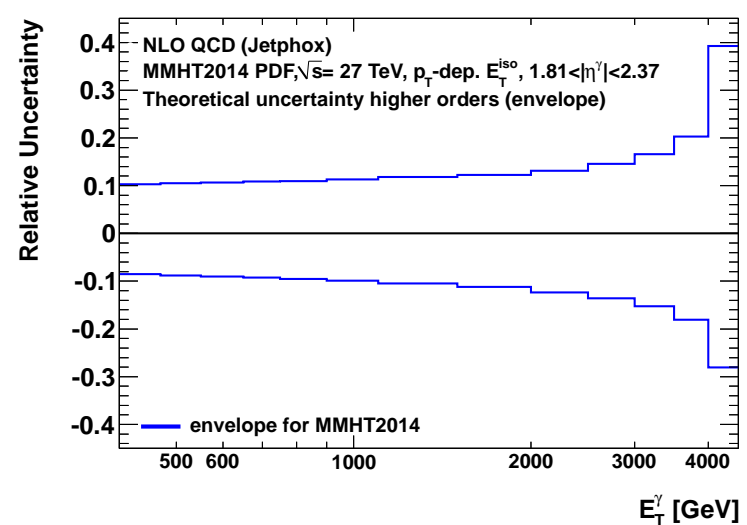
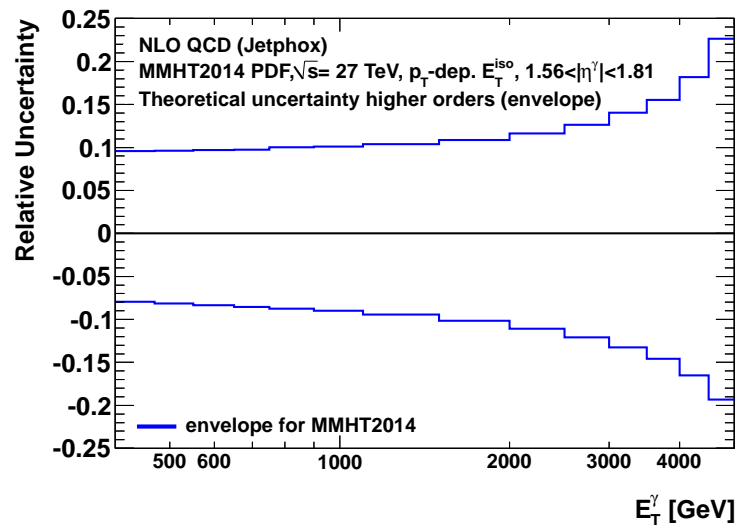
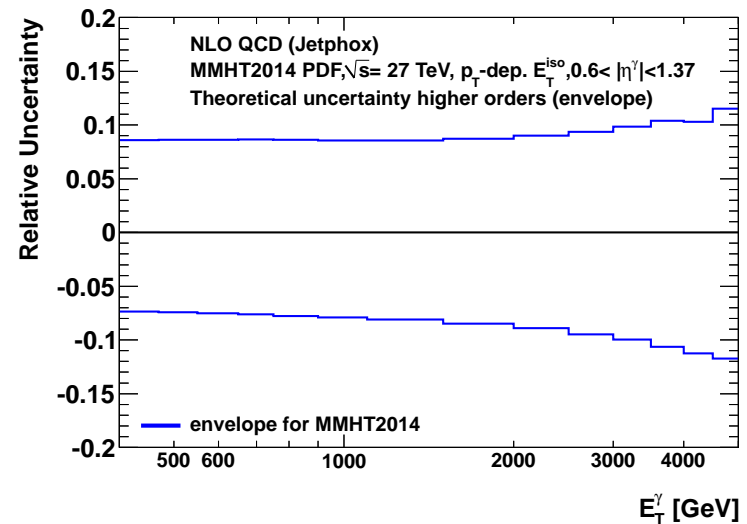
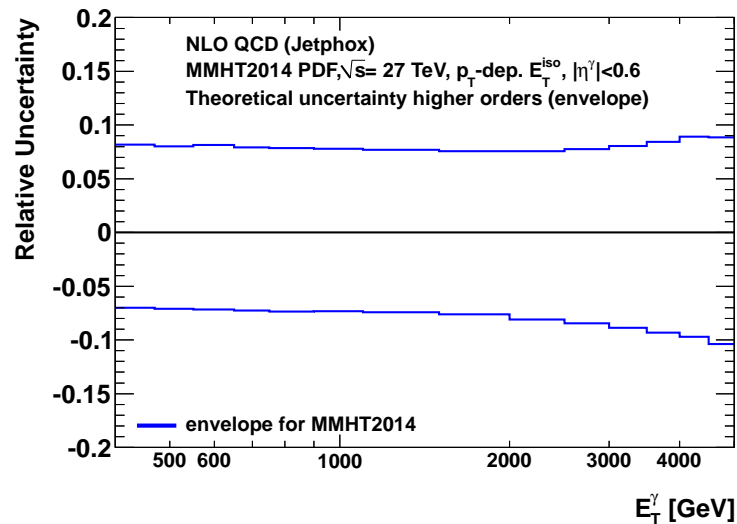
- Variation of μ_F by a factor two up and down
- It will benefit from NNLO QCD calculations (Campbell et al PRL118 (2017) 222001)

Theoretical uncertainties from terms beyond NLO (μ_R, μ_F, μ_f)



- Simultaneous variation of μ_R, μ_F and μ_f by a factor two up and down
- It will benefit from NNLO QCD calculations (Campbell et al PRL118 (2017) 222001)

Theoretical uncertainties from terms beyond NLO (envelope of variations)



- Envelope of variations of μ_R , μ_F and μ_f
- It will benefit from NNLO QCD calculations (Campbell et al PRL118 (2017) 222001)

NNLO QCD calculations and electroweak corrections

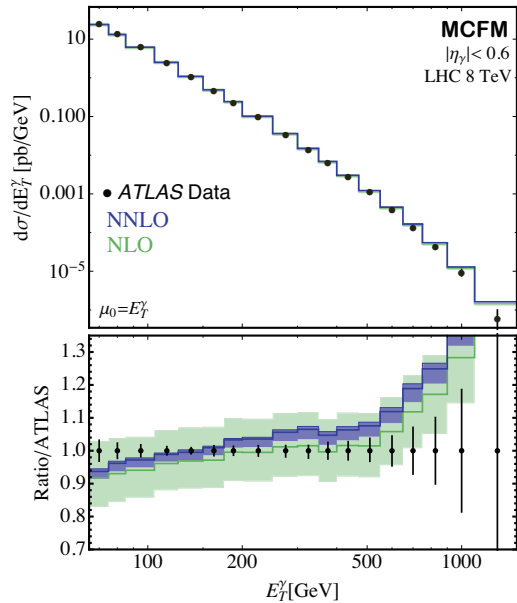


Figure 4: A comparison of the MCFM predictions for the transverse momentum of the photon to ATLAS 8 TeV data [4].

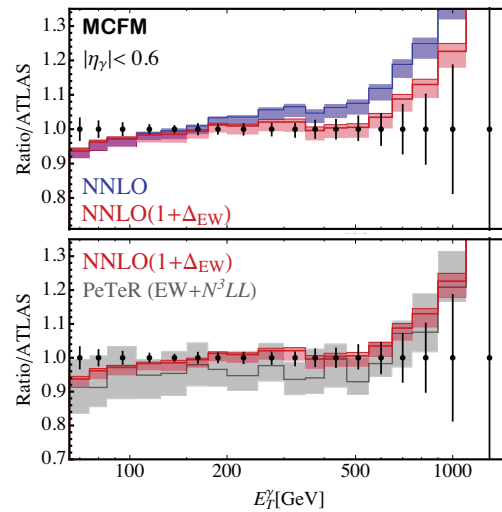


Figure 5: Upper: the effect of including electroweak corrections in addition to the NNLO predictions provided by MCFM. Lower: a comparison of the NNLO+EW prediction of MCFM with the N^3LL+EW prediction of PeTeR [8].

↑ **NLO vs NNLO: reduction of uncertainties**

Importance of electroweak corrections ↑

Campbell et al PRL118 (2017) 222001

- **Comparison of ATLAS measurements at 13 TeV with NNLO QCD (+EW corr.) ↑ using two sets of PDFs: NNPDF3.1 and NNPDF3.1+ATLAS γ (the extraction of the PDF set includes ATLAS measurements of inclusive photon production at 8 TeV)**

Campbell et al arXiv:1802.03021

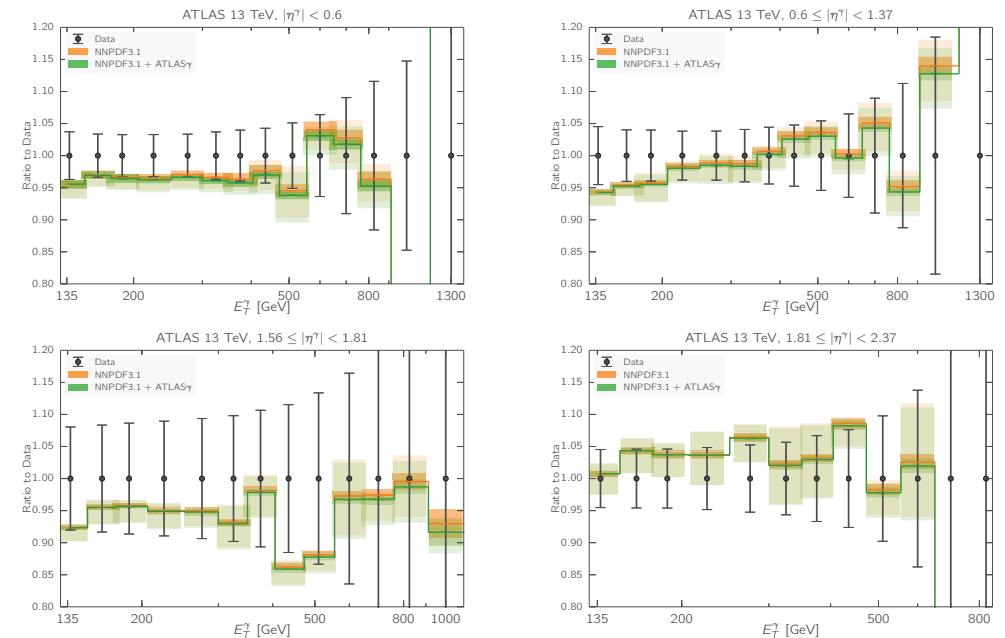
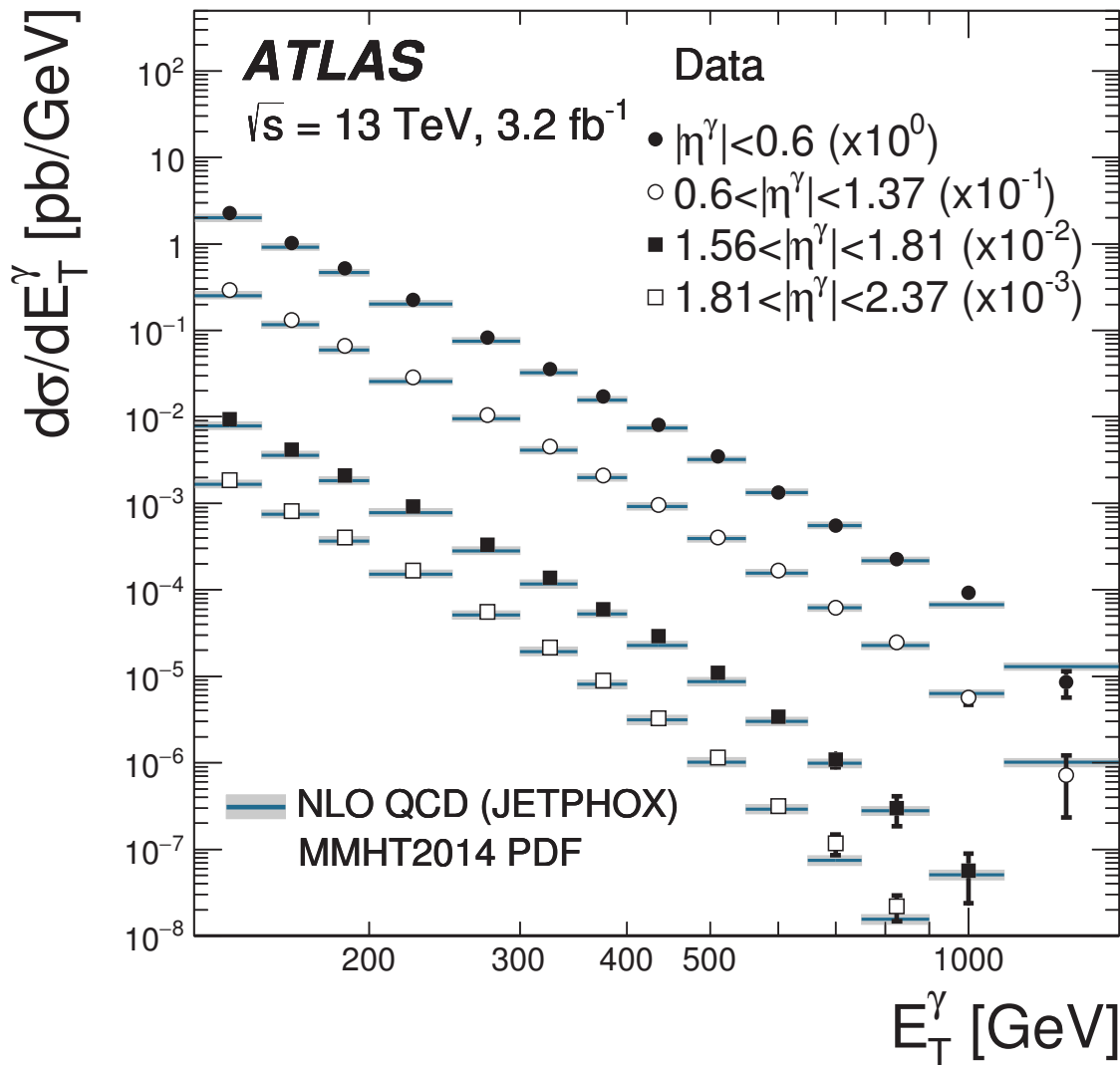


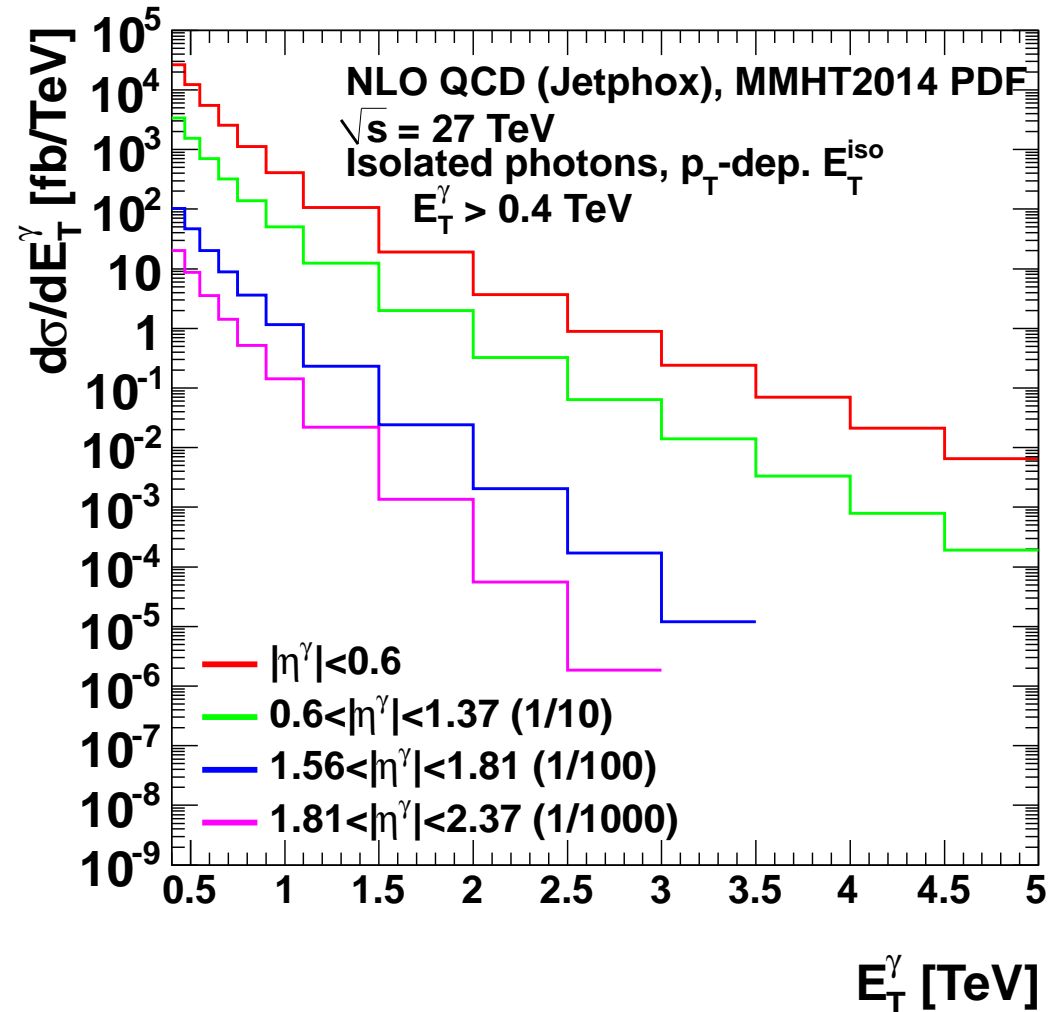
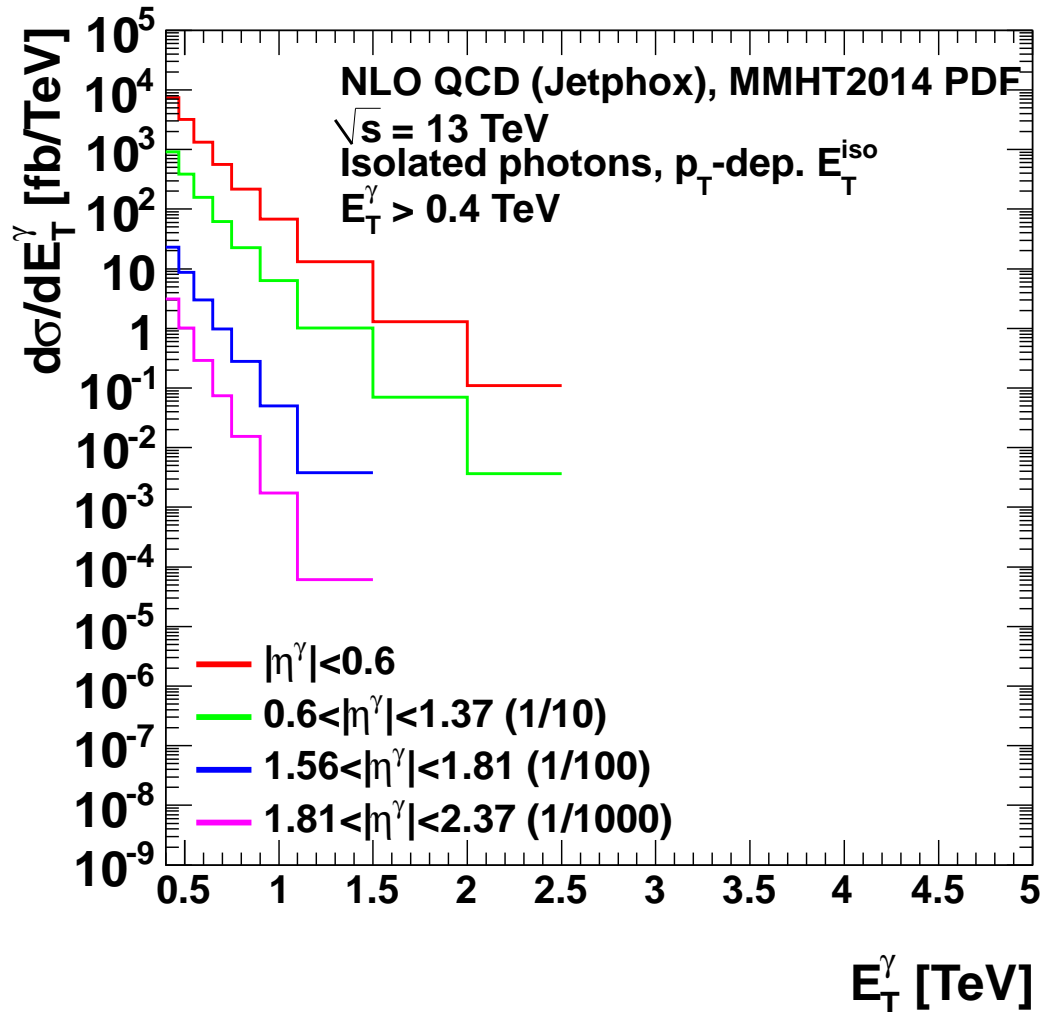
Figure 5.1. Same as Fig. 4.4 for the ATLAS 13 TeV direct photon measurements. In addition to the PDF uncertainties shown in the previous cases (darker bands), here we also include the scale uncertainties associated to the NNLO QCD calculation (lighter bands).

Inclusive isolated-photon production in pp collisions at $\sqrt{s} = 13$ TeV



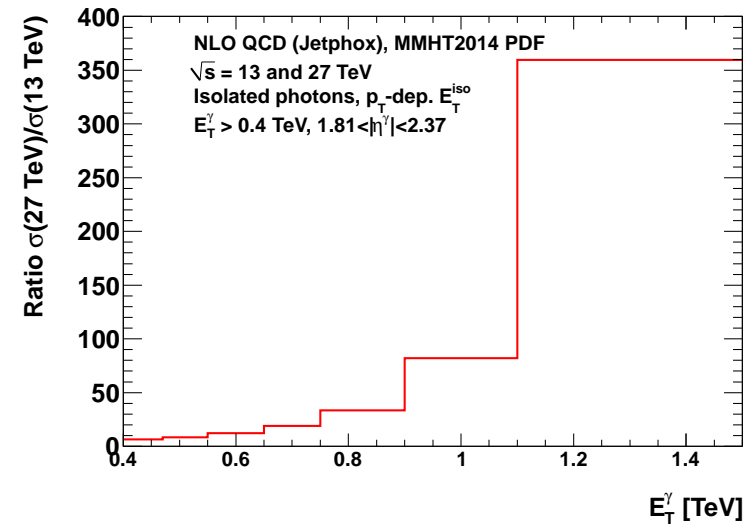
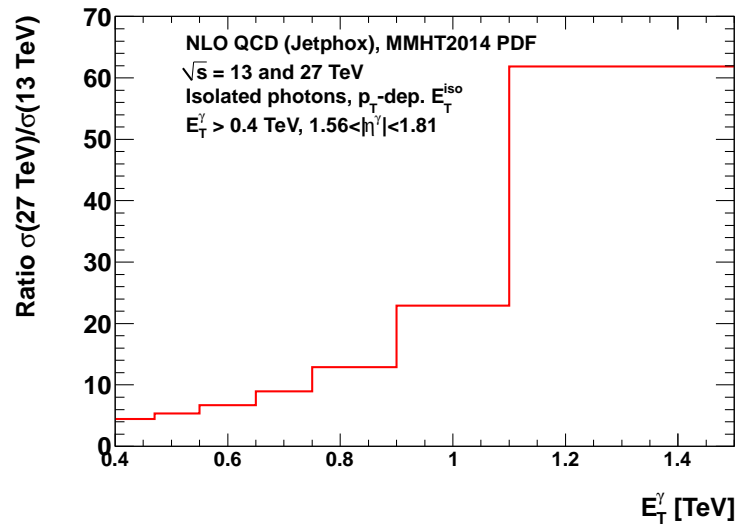
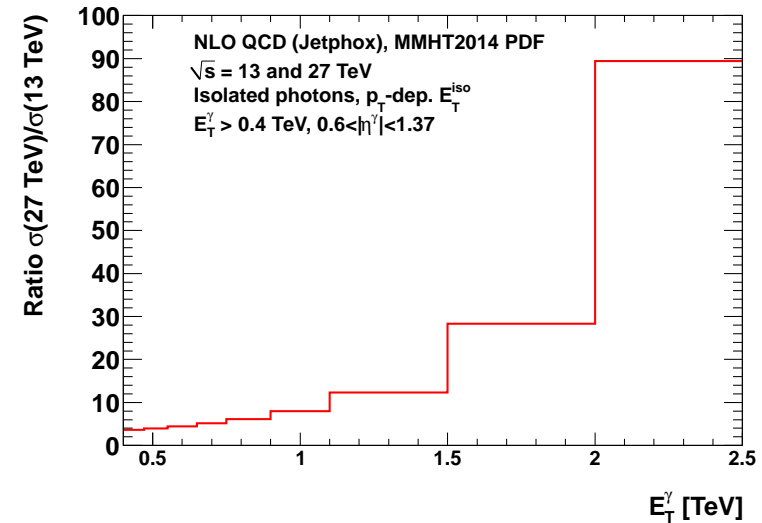
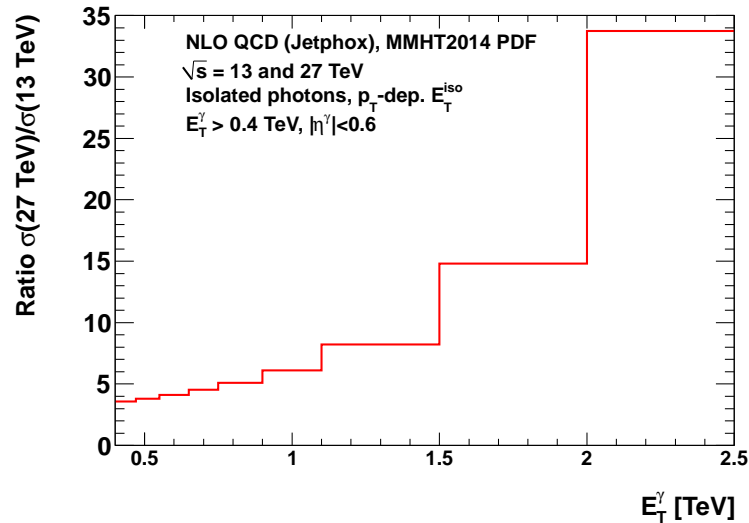
ATLAS Coll., PLB770 (2017) 473

- Measurement of $d\sigma/dE_T^\gamma$ in different ranges in η^γ for $125 < E_T^\gamma < 1500$ GeV using $\mathcal{L} = 3.2 \text{ fb}^{-1}$ of pp collision data at $\sqrt{s} = 13$ TeV
- Isolation: $E_T^{\text{iso}} < 4.2 \cdot 10^{-3} \cdot E_T^\gamma + 4.8$ GeV
- The measurement covers more than five orders of magnitude in cross section
- $d\sigma/dE_T^\gamma$ increases by a factor 2 (10) at $E_T^\gamma = 125$ (1000) GeV with respect to at $\sqrt{s} = 8$ TeV
- Comparison to NLO QCD predictions computed with JetPhox using the MMHT2014 PDFs

$$\sqrt{s} = 13 \text{ TeV vs } \sqrt{s} = 27 \text{ TeV}$$


- For now study at 13 TeV with extra bins added (wrt measurements shown in previous slide)
- Study at 13 TeV to be replaced by HL-LHC prospects at 14 TeV

Ratios of cross sections $\sigma(27\text{TeV})/\sigma(13\text{TeV})$



- Ratio of isolated photon $d\sigma/dE_T^{\gamma}$ at different center-of-mass energies
- The ratio benefits from reduced experimental and theoretical uncertainties

Summary and outlook

- Prospects for inclusive isolated-photon production in pp collisions at HE-LHC have been presented using as a proxy the NLO QCD predictions
- E_T^γ reach with 15 ab^{-1} :
 - 4.5-5 TeV ($|\eta^\gamma| < 1.37$)
 - 3-3.5 TeV ($1.56 < |\eta^\gamma| < 1.81$)
 - 2.5-3 TeV ($1.81 < |\eta^\gamma| < 2.37$)
 - 10^6 photons with 1 TeV \Rightarrow jet calibration
- Differences up to $\sim 6\%$ between the predictions based on MMHT2014 and CT14; other PDF sets will be considered as well
- Ratio of isolated photon $d\sigma/dE_T^\gamma$ at different \sqrt{s} : $\sigma(27\text{TeV})/\sigma(13\text{TeV})$ benefits from reduced uncertainties; it will be revised: $\sigma(27\text{TeV})/\sigma(14\text{TeV HL} - \text{LHC})$
- ★ Outlook: in addition to the pending items above, isolated photon production in association with jets and diphoton production