Jets and photon + jets measurements with ATLAS and CMS experiment

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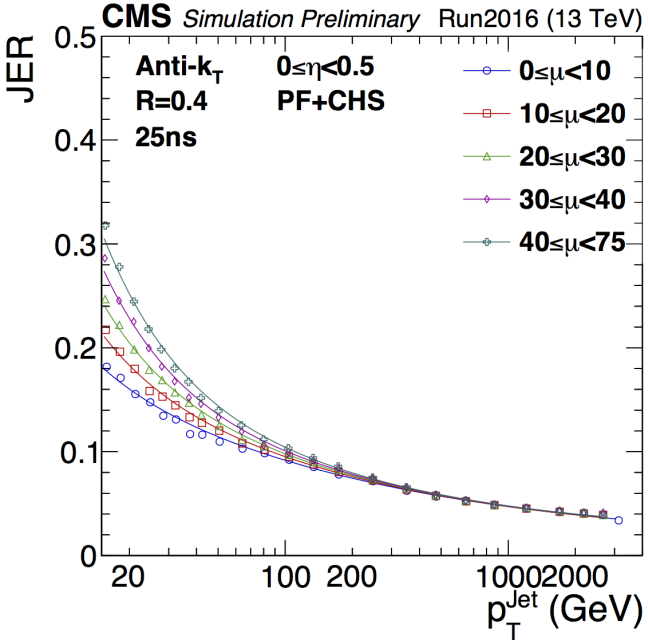
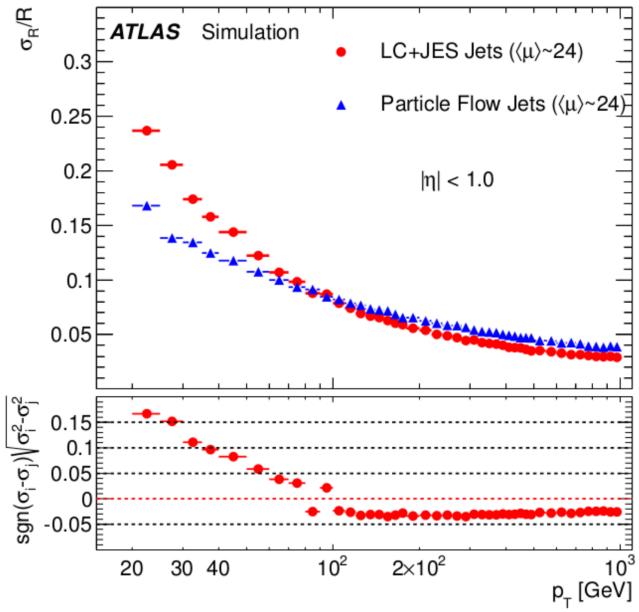
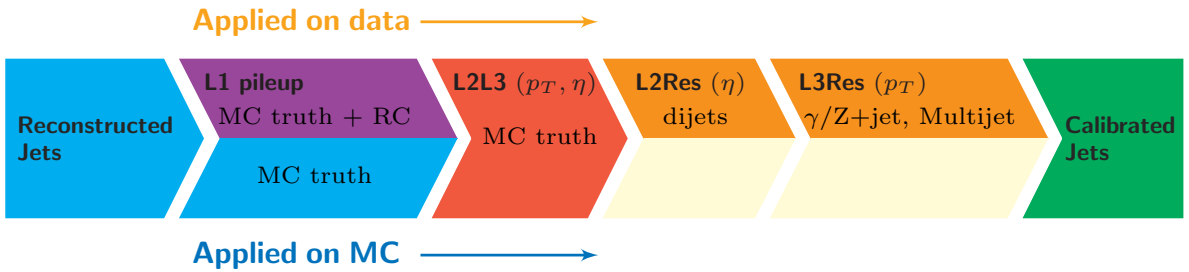
Introduction

- Motivation :
  - Jets and photons :
  - Testing ground for perturbative QCD.
  - Good probes for the content of the proton
  - Could lead to new physics / help constrain model
- Measurements presented in this talk :
- Jets :
  - Transverse energy decorrelation and strong coupling constant determination with multijet event (8 TeV) ATLAS
  - Dijet azimutal decorrelation (8 TeV) ATLAS
  - Azimutal correlation for 2-,4-jets (13 TeV) CMS
  - Azimutal separation in back to back multijet topologies (13 TeV) CMS
- Photon + jet :
  - Photon + jet (13 TeV) ATLAS and CMS
  - $\frac{Z+jet}{\gamma+jet}$ (8 TeV) CMS
  - $\gamma\gamma + jet$ (7 TeV) CMS
  - Photon + heavy flavour jet ATLAS

Reconstruction performances : Jets

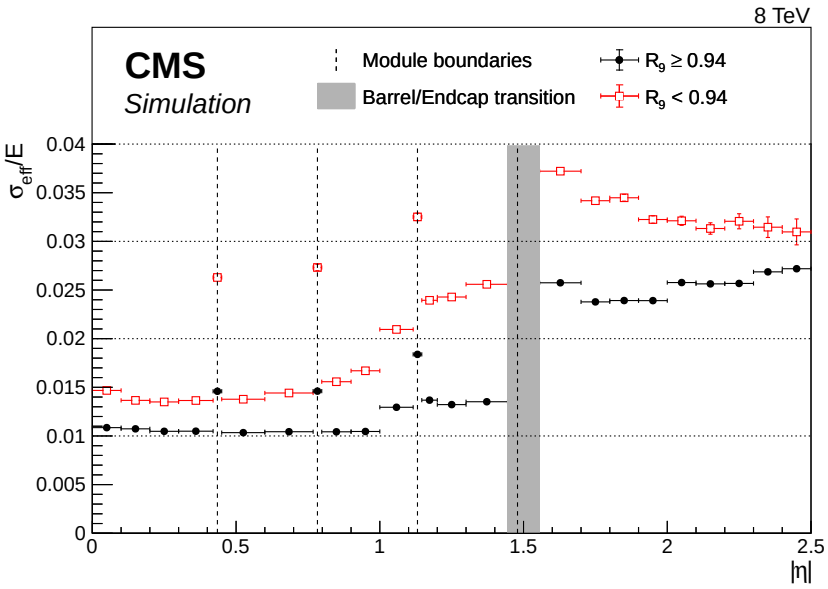


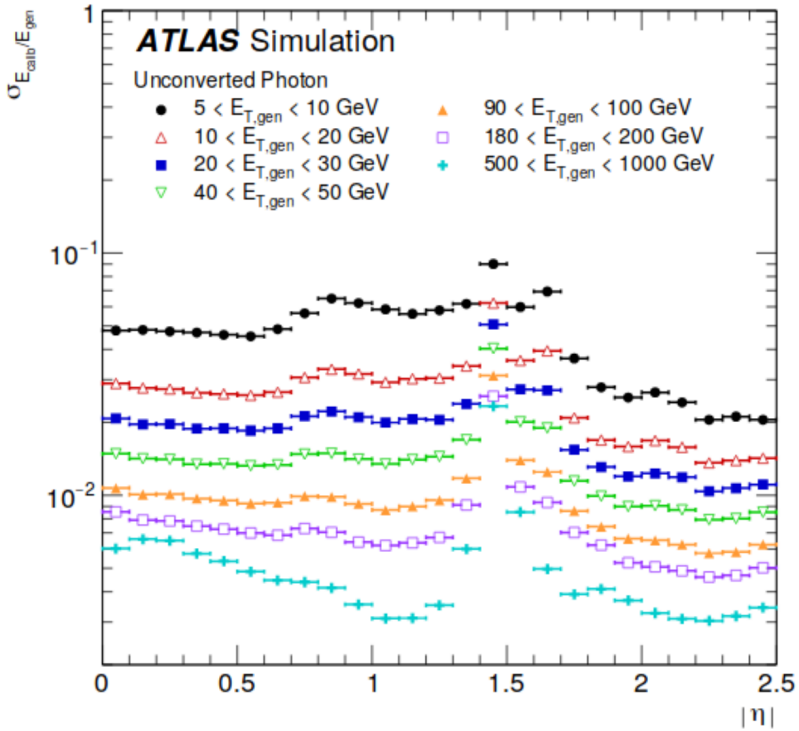




- Jet energy resolution (JER) from CMS (left) and ATLAS (right)
- Both resolution $\rightarrow \approx 10\%$ for 100 GeV jets.
- Uncertainties on calibration : from 2% to sub-percent level for ATLAS and CMS
- Eur.Phys.J.C77(2017) 580 (ATLAS) ; arXiv:1607.03663 [hep-ex] (CMS)

Reconstruction performances : Photons



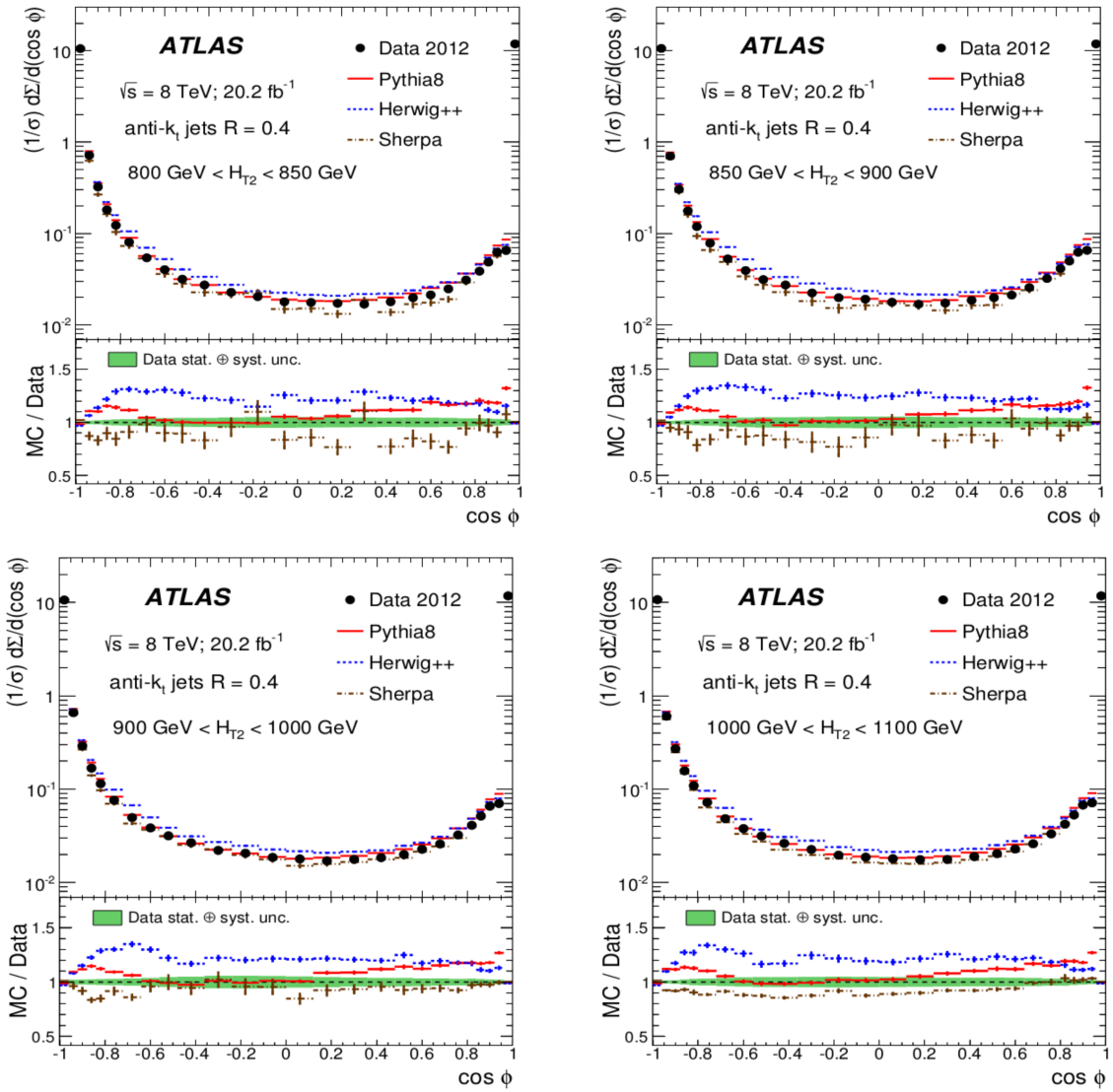


- Photon energy resolution from CMS (left) and ATLAS (right)
- Energy resolution at percent level.
- Eur. Phys. J. C 74 (2014) 3071 (ATLAS) arXiv:1502.02702 (CMS)

Measurement to particle level : unfolding

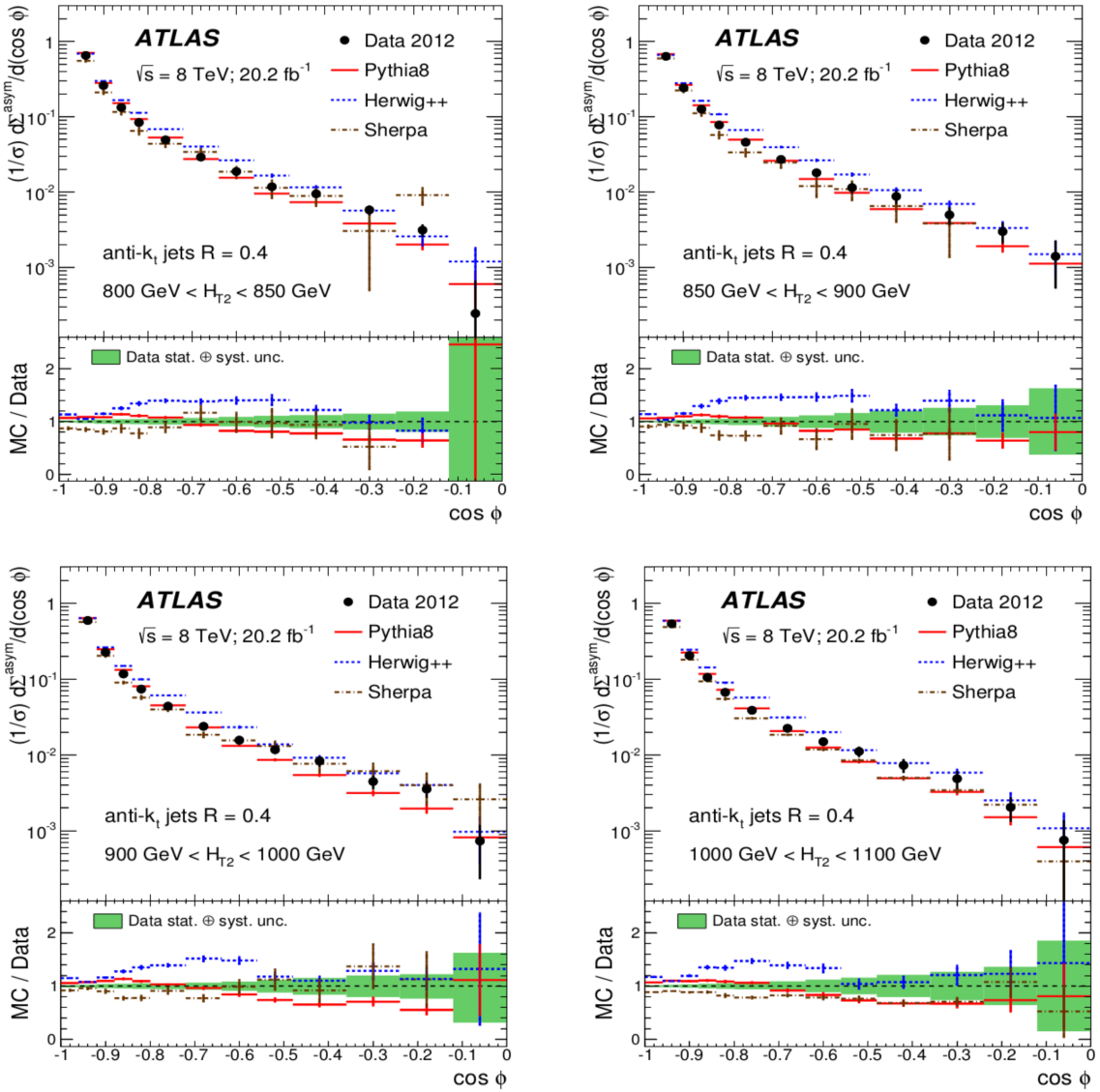
- Measurement are corrected back to particle level.
- Matrix iterative or inversion based methods. (Tunfold, d'Agostini iteration ....)
- Transfer matrix from particle level to reconstructed level is used.
- Uncertainties obtained from different MC

Determination of α_s from transverse energy correlations in multijet events 8 *TeV* : ATLAS (Eur.Phys.J. C77 (2017) no.12, 872)



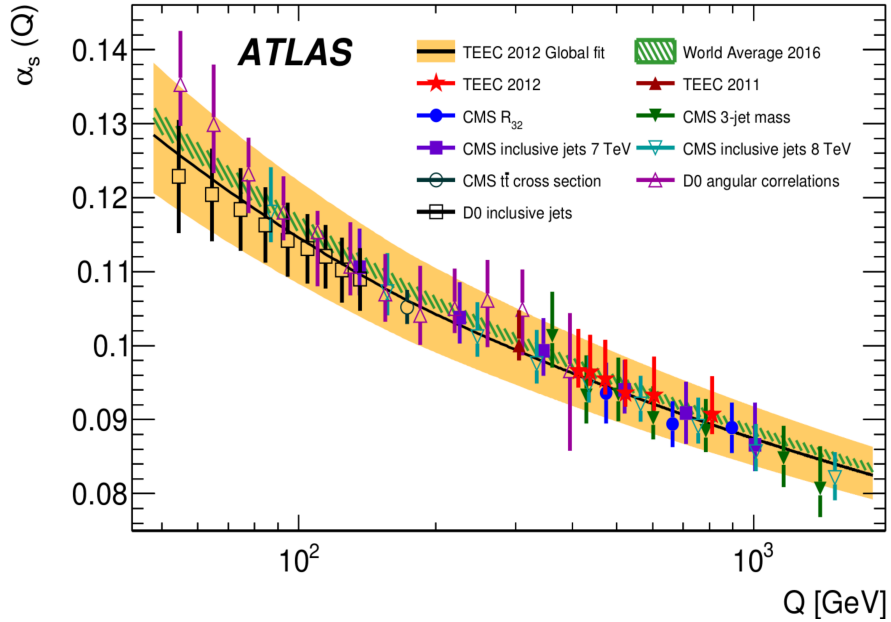
- Use of quality jets
- Cut and count analysis
- TEEC function distribution
- Good description from Pythia and Sherpa
- Disagreement from Herwig++

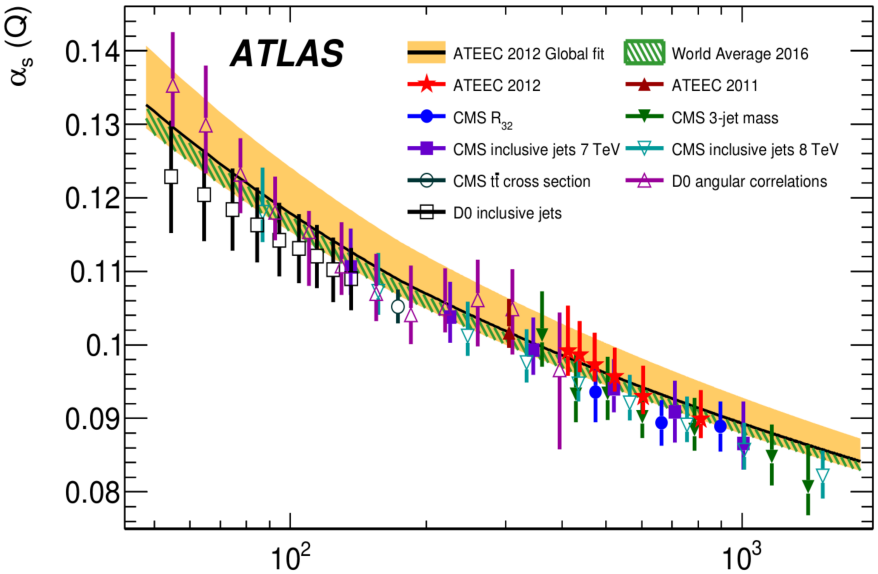
Determination of α_s from transverse energy correlations in multijet events 8 TeV: ATLAS



- ATEEC function distribution
- Good description from Pythia and Sherpa
- Disagreement from Herwig++

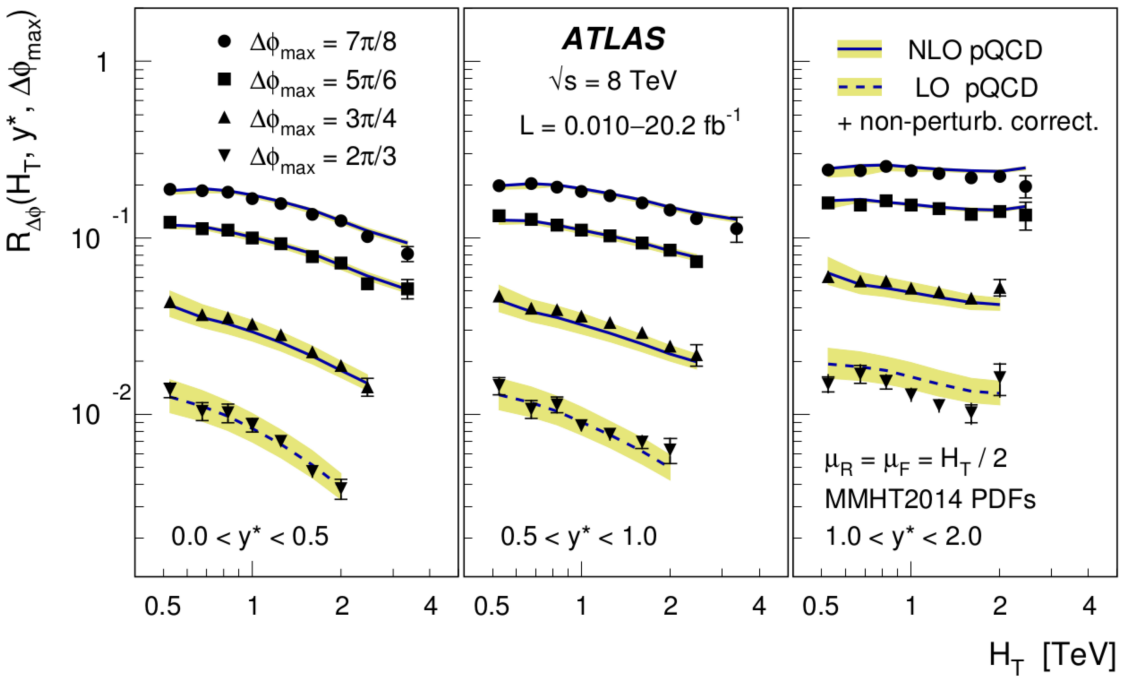
Determination of α_s from transverse energy correlations in multijet events : ATLAS





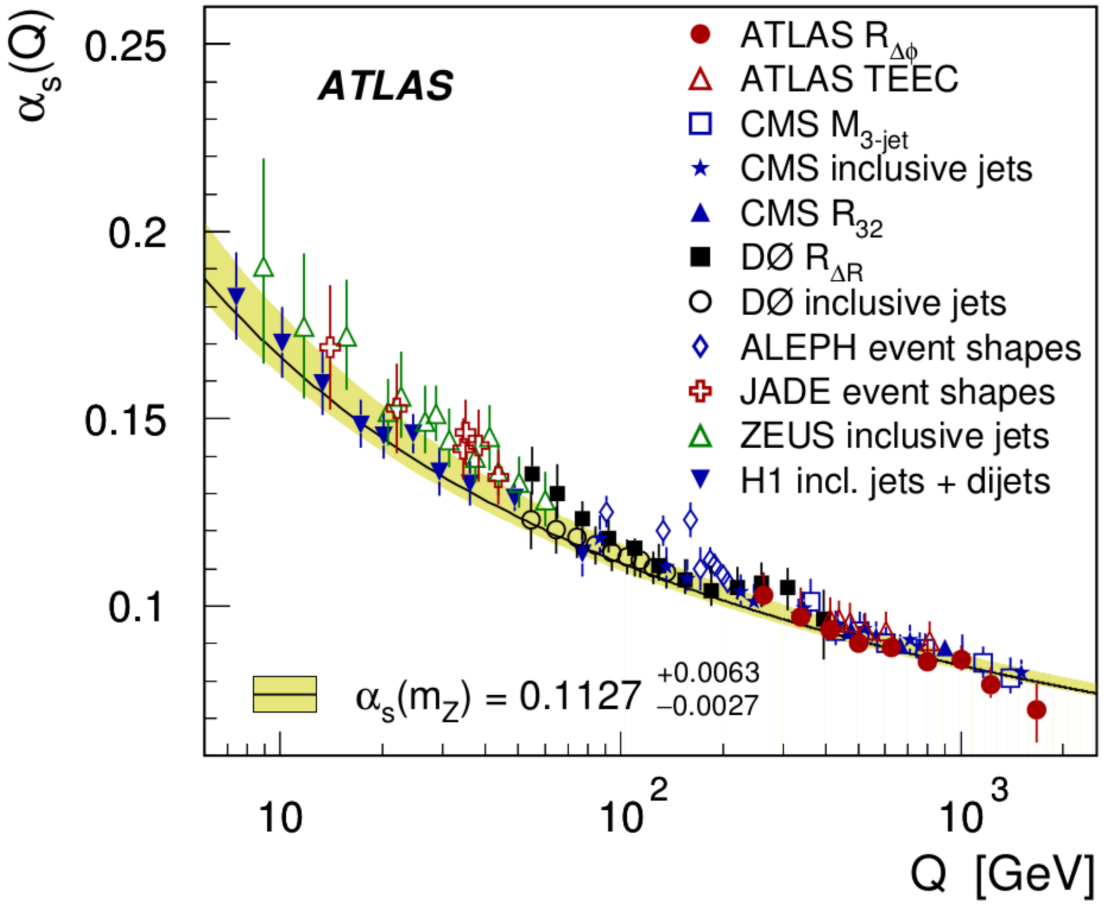
- Value of α_s obtained with TEEC and ATEEC functions.
- Good agreement with world average.
- Measurement limited by theoretical scale uncertainties (TEEC $\approx 6\%$, ATEEC $\approx 4\%$)

Dijet azimutal decorrelation and determination of α_s: ATLAS (Phys.Rev. D98 (2018) no.9, 092004)



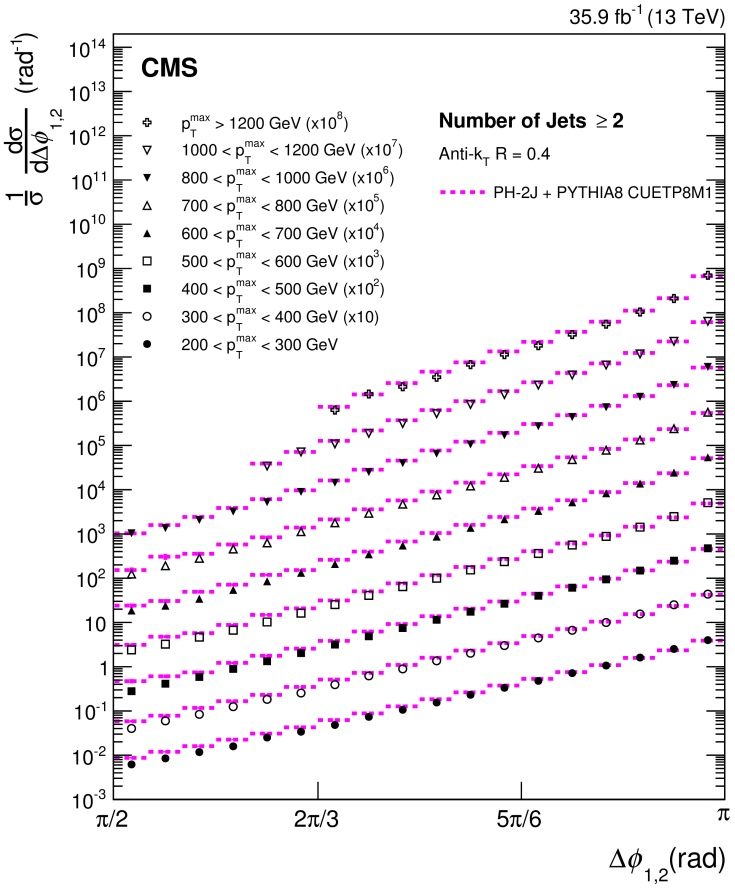
- Use of quality jets
- Cut and count analysis
- Good description of $R_{\Delta\phi}$ with NLO pQCD

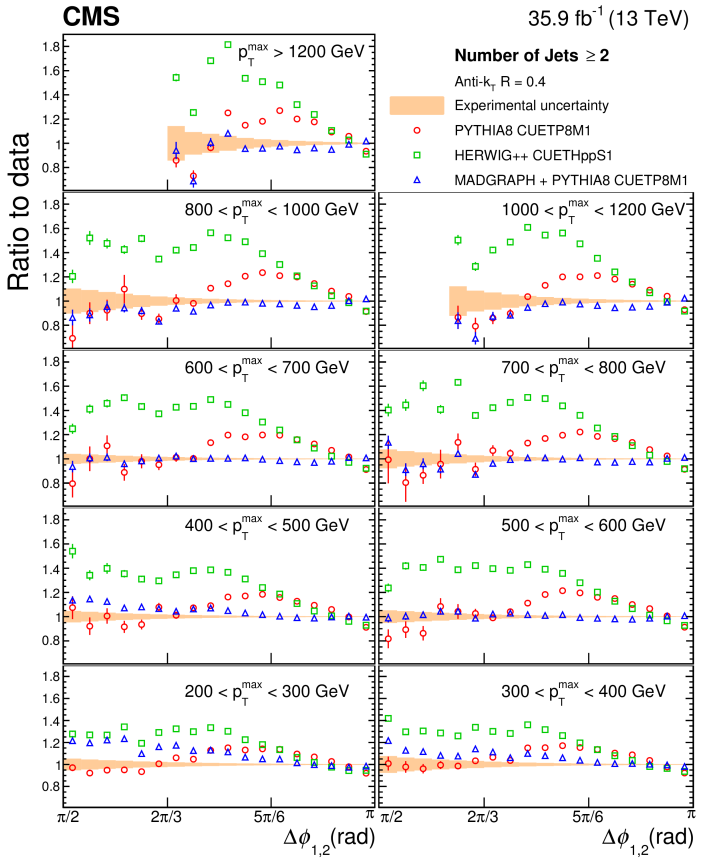
Dijet azimutal decorrelation and determination of α_s: ATLAS (arXiv:1805.04691 [hep-ex])



- α_s from a $\chi^2(\alpha_s)$ minimization
- Good agreement with world average.

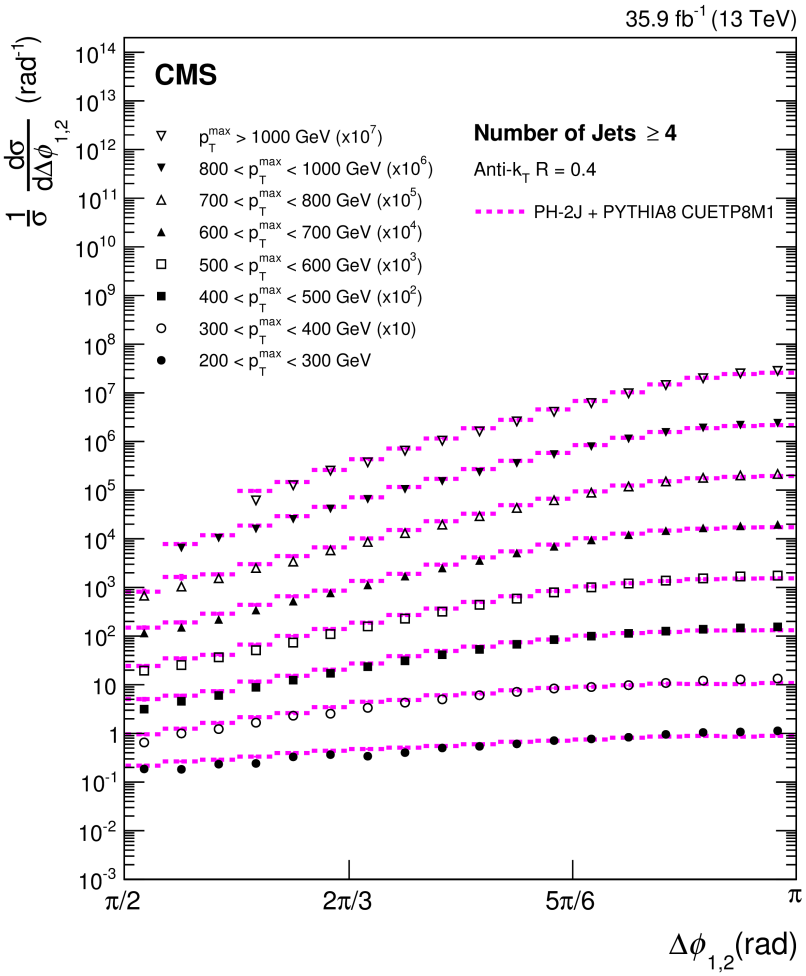
Azimutal correlation for 2jets : CMS (arXiv:1902.04374 [hep-ex])

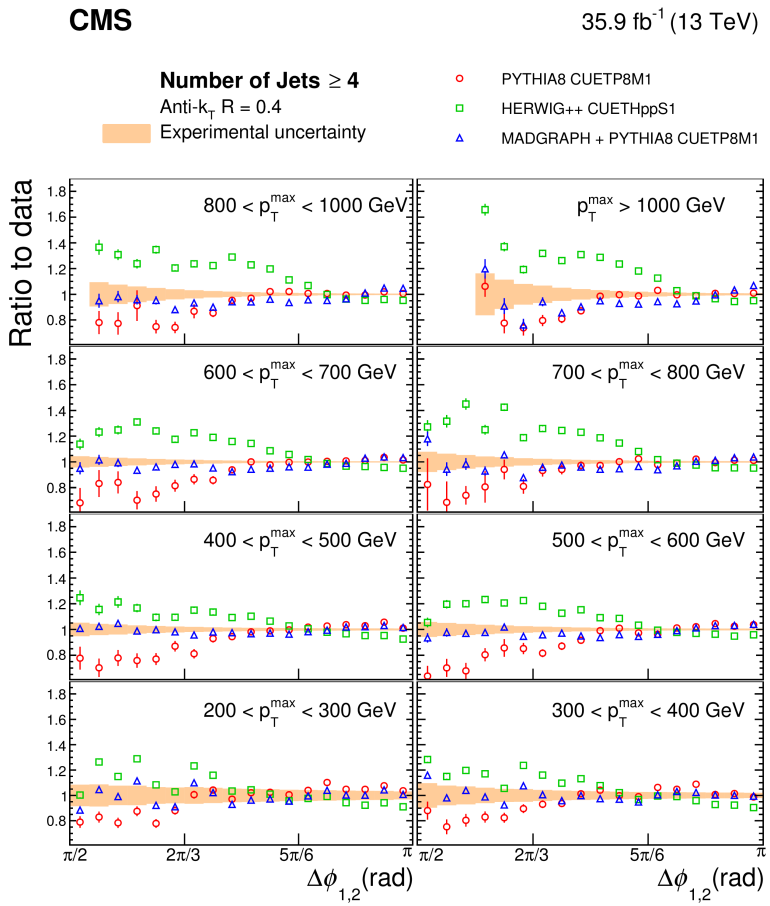




- Tight jet selection
- Cut and count analysis
- Double differential measurement vs y and p_T
- Data / MC ratios depend on generators
- Best agreement for Madgraph

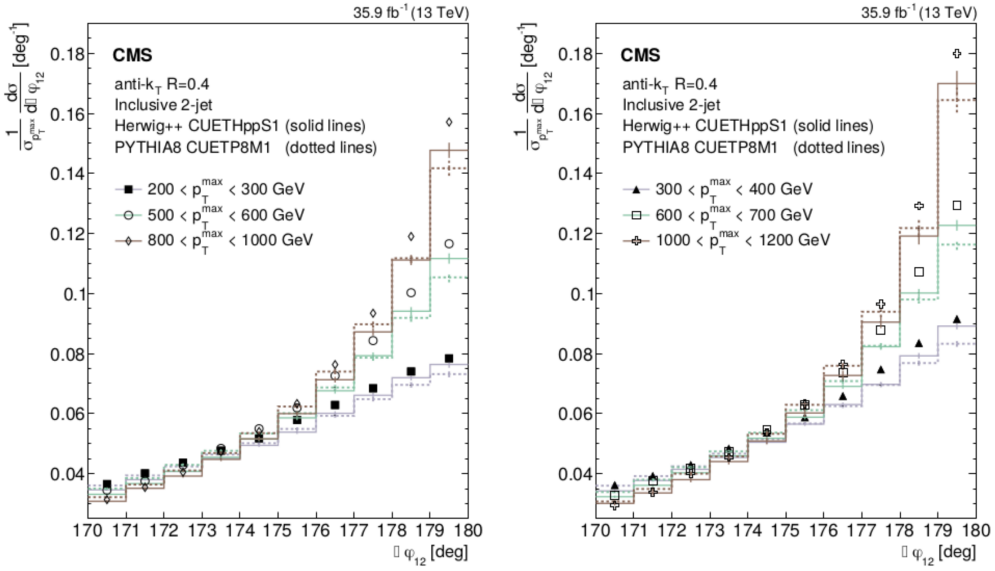
Azimutal correlation for 4-jets : CMS

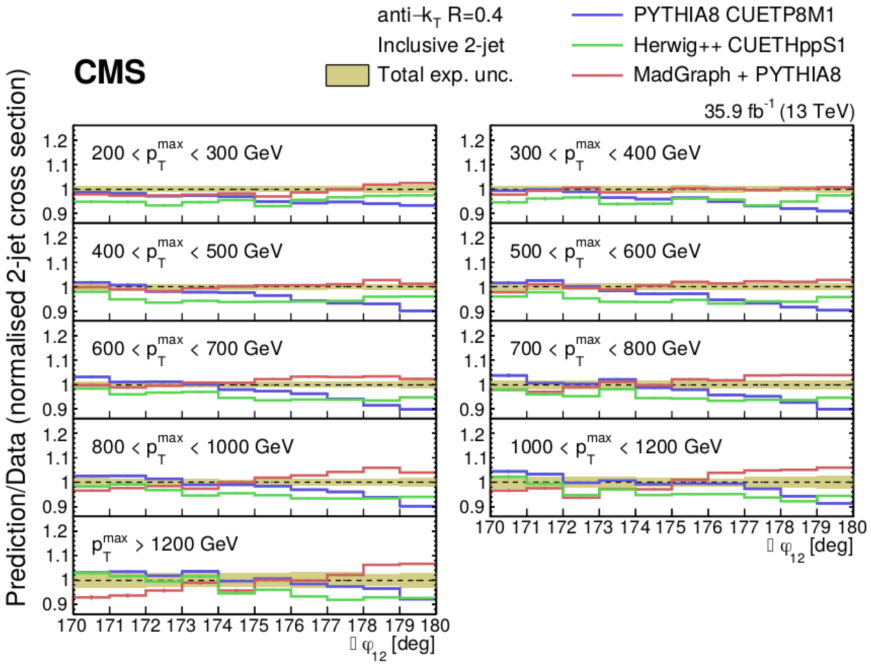




- Best agreement for Madgraph

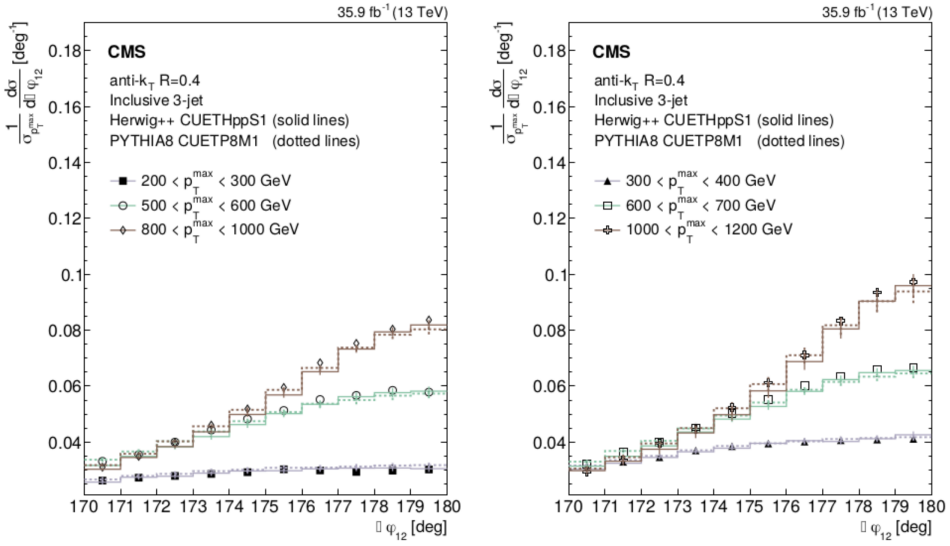
Azimutal separation in back to back 2-jets topologies : CMS (arXiv:1712.05471 [hep-ex])

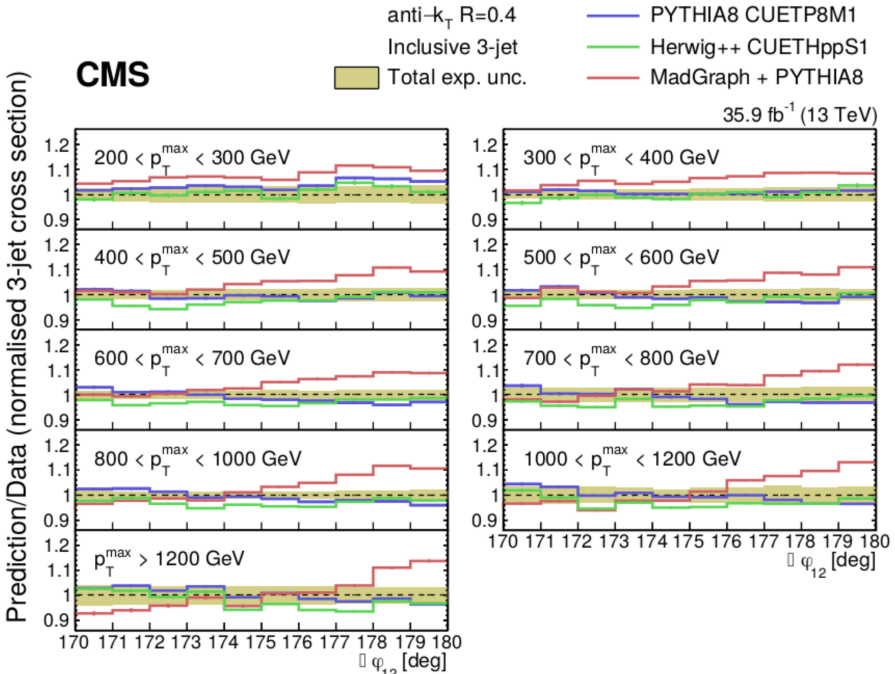




- Cut and count analysis on Multijet events.
- Good agreement with Madgraph
- Deviations up to 10% for other generators

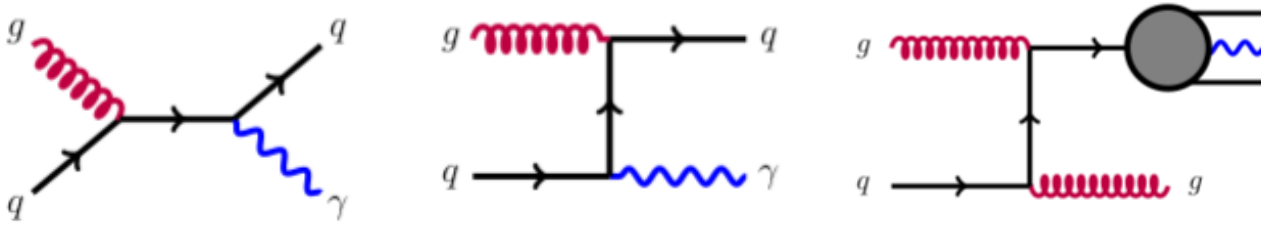
Azimutal separation in back to back 3-jets topologies : CMS (arXiv:1712.05471 [hep-ex])





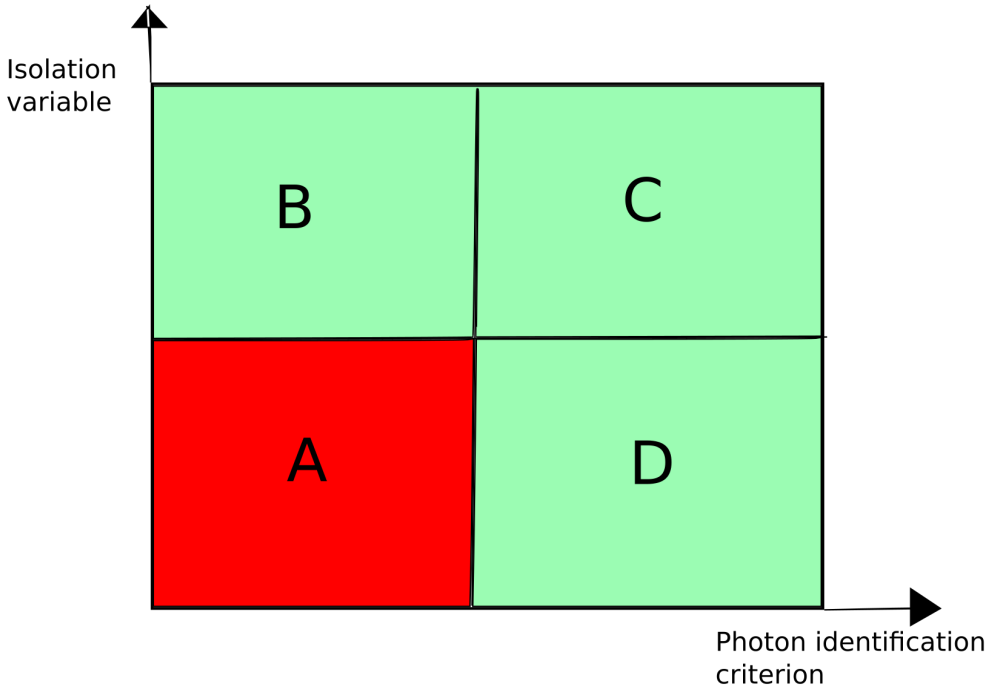
- Good agreement with Pythia and Herwig
- Deviations up to 10% for Madgraph

$\gamma + jet$ differential cross section measurement (13 TeV)



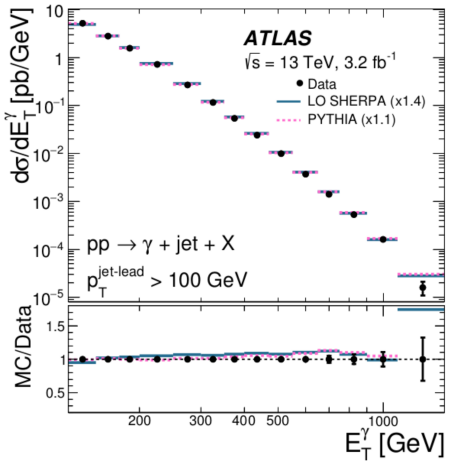
- Measurement performed by ATLAS and CMS
- Include direct photons and fragmentation photons.
- Differential cross section vs kinematic variables is a powerful testing tool.
- Main background : Jet reconstructed as photon in Multijet events.
- Data driven estimation of the background in both analysis : two methods

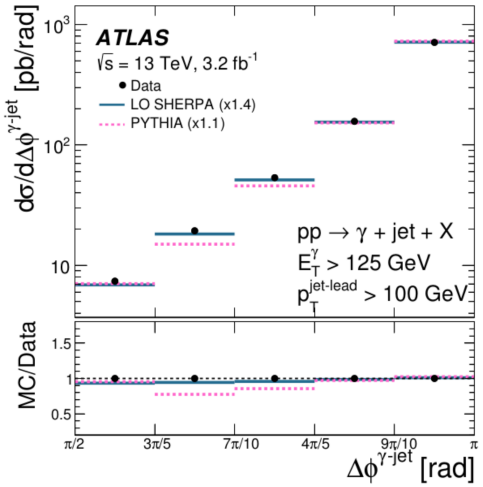
$\gamma + jet$ differential cross section measurement : ATLAS (Phys. Lett. B 780 (2018) 578)

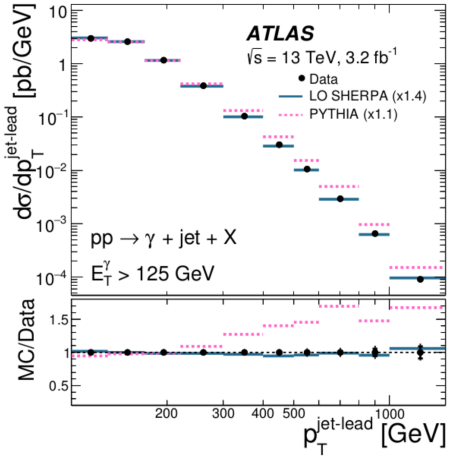


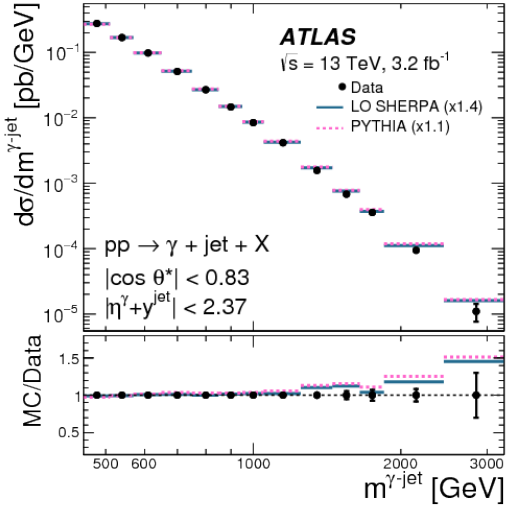
- Event yield obtained by a background substraction methods on isolation and photon identification areas.

$\gamma + jet$ differential cross section measurement : ATLAS (Phys. Lett. B 780 (2018) 578)



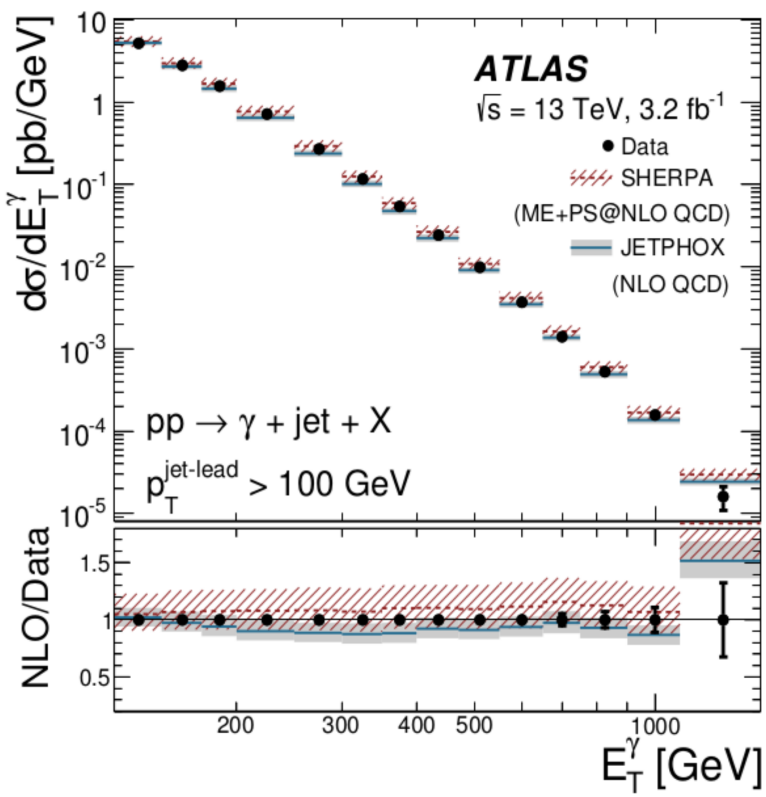


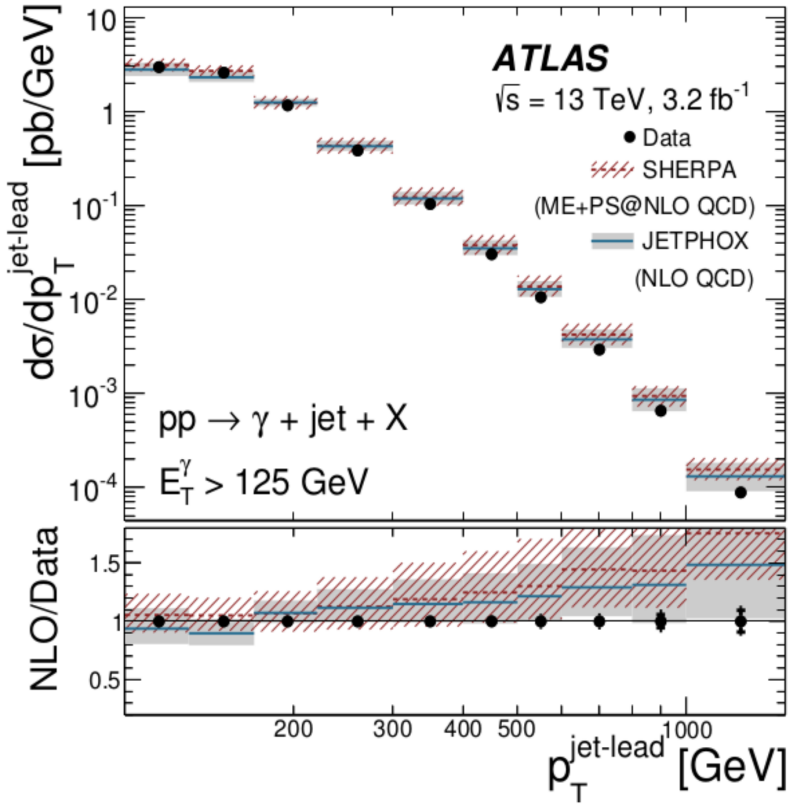




- LO prediction : good agreement with Sherpa prediction

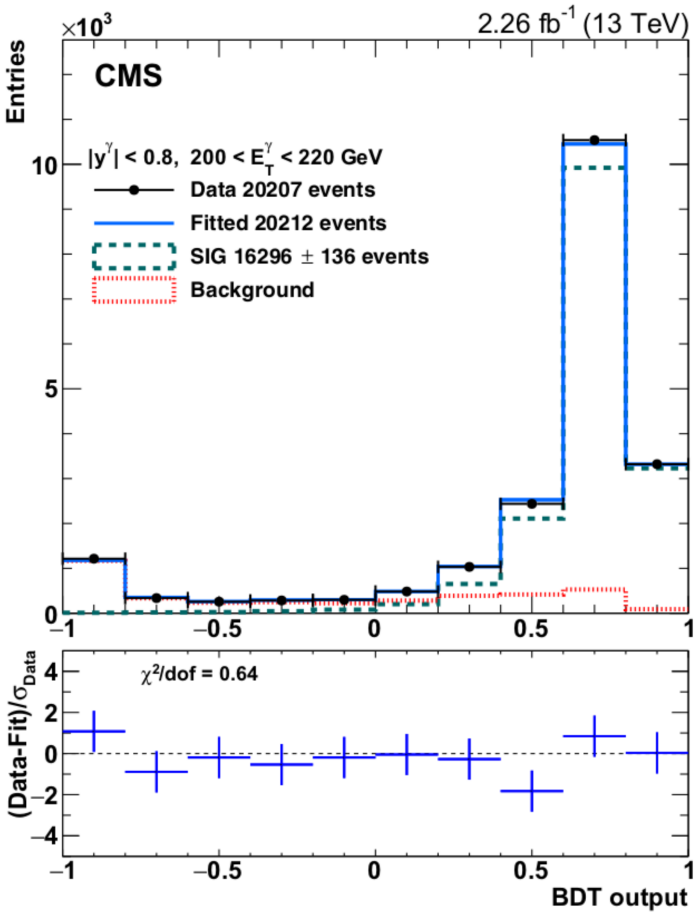
$\gamma + jet$ differential cross section measurement : ATLAS

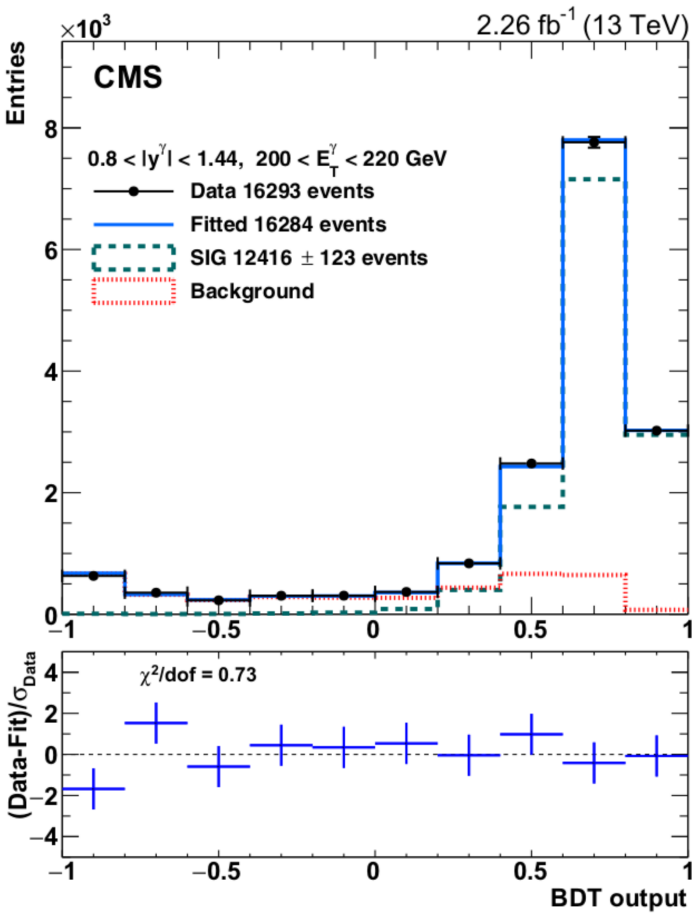




- Comparison to NLO prediction : reasonable agreement with Jetphox

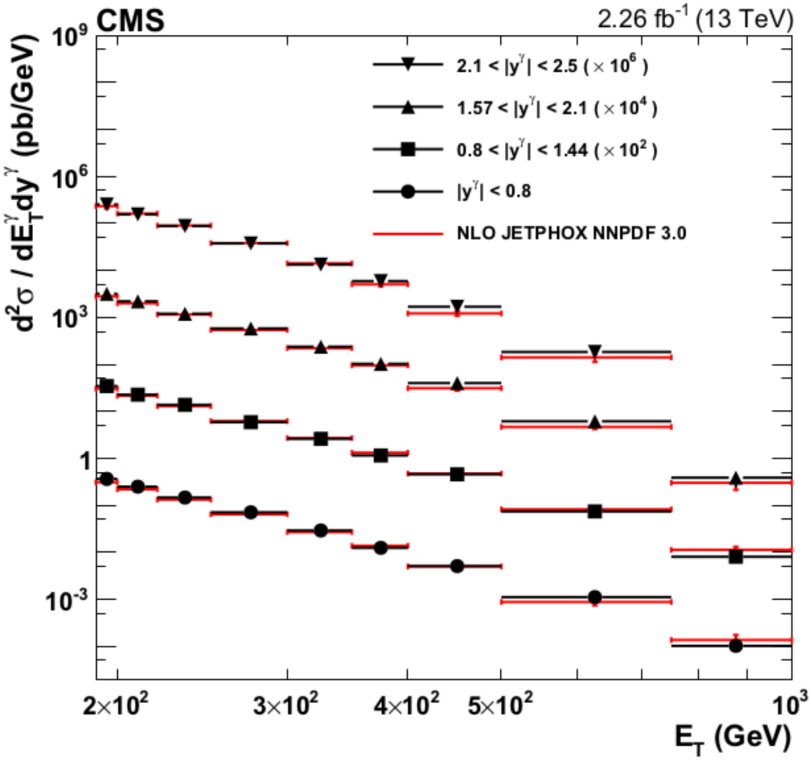
$\gamma + jet$ differential cross section measurement : CMS (EPJC 79 (2019) 20)

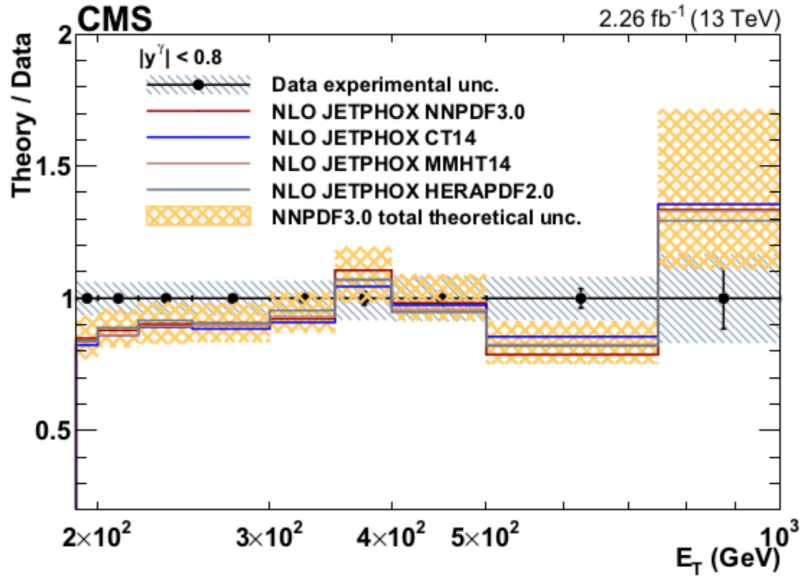


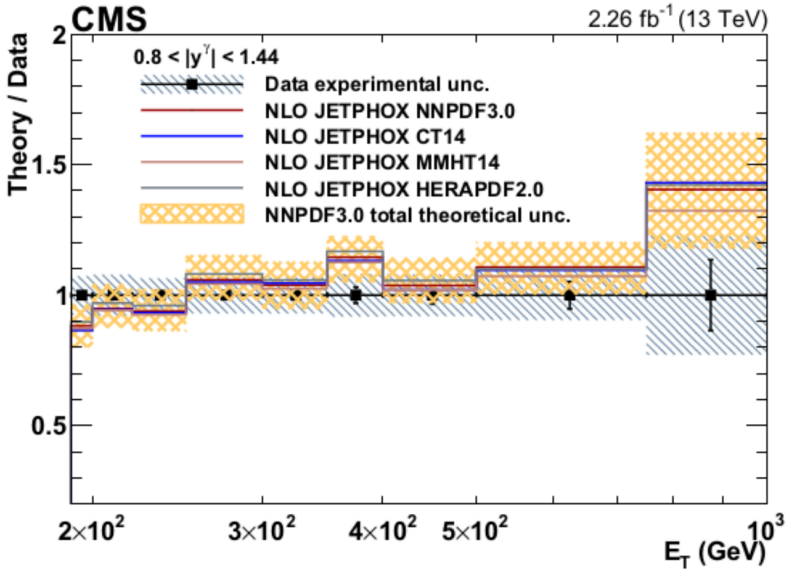


- Event yield extracted with a fit on BDT discriminant.

$\gamma + jet$ differential cross section measurement : CMS

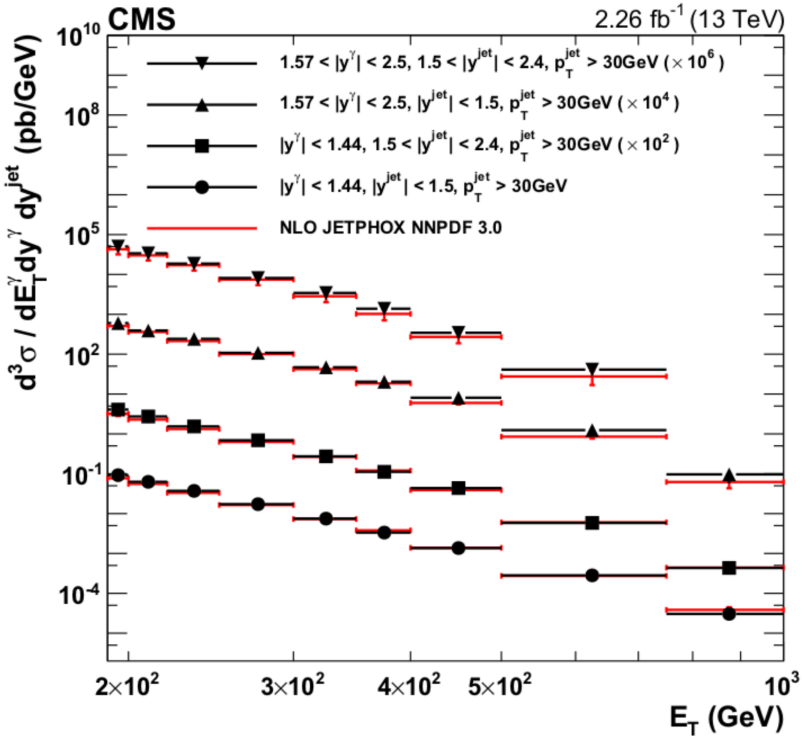


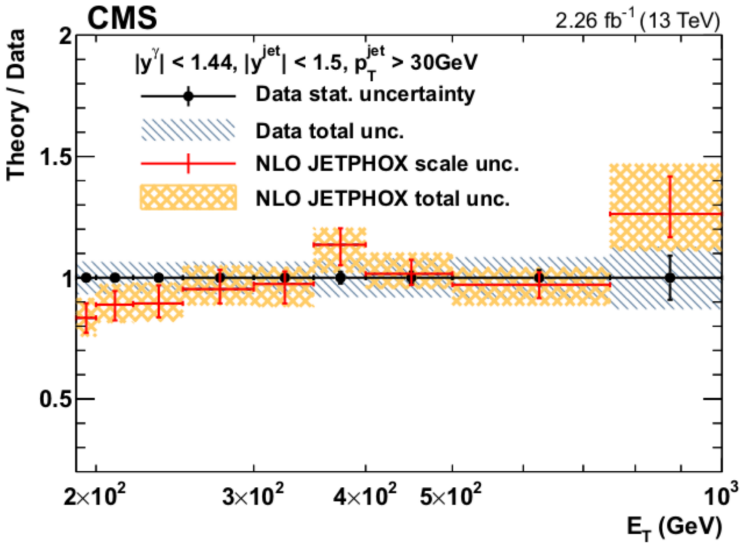


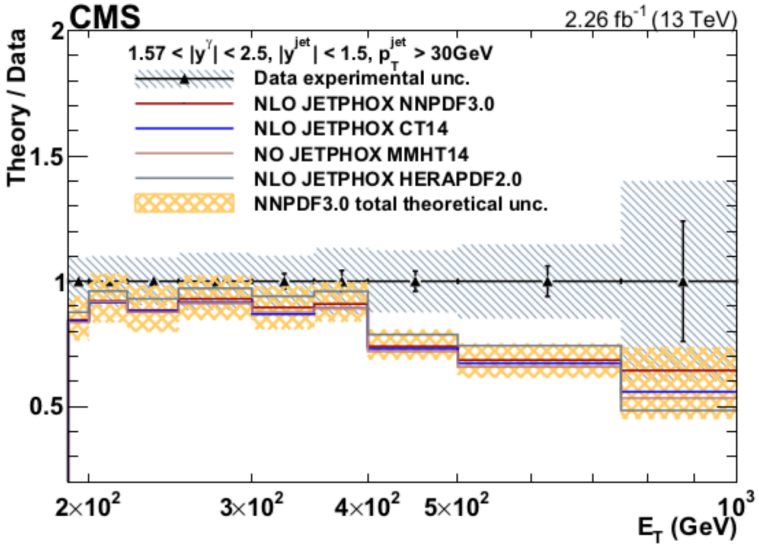


- Comparison to NLO prediction : reasonable agreement with Jetphox.

$\gamma + jet$ double differential cross section measurement : CMS





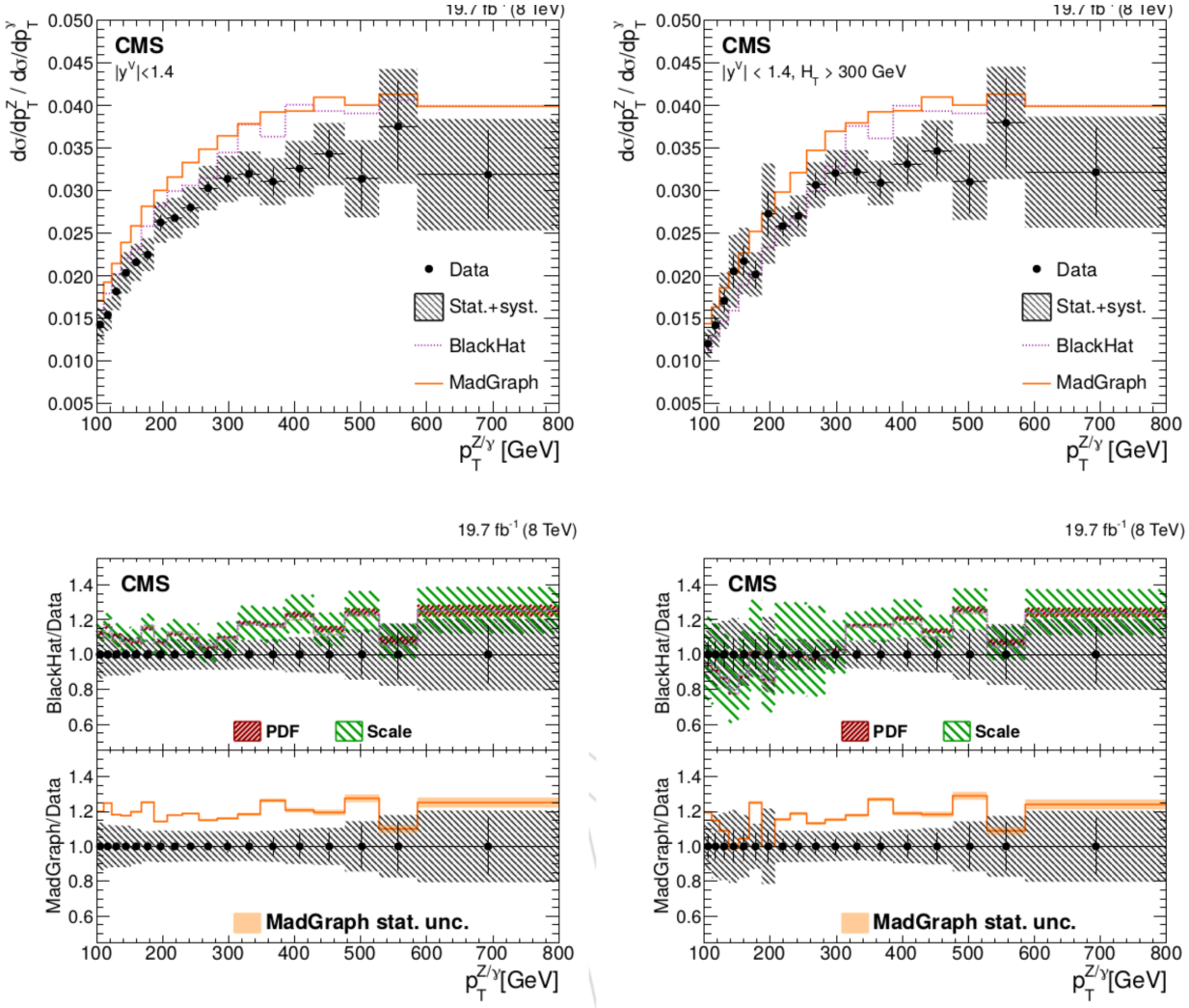


- Comparison to NLO prediction : reasonable agreement with Jetphox.

$\gamma + jet$ differential cross section measurement : results

- Both measurements are in agreement with JETPHOX predictions.
- NLO prediction describe well data within uncertainties
- PDF set used does not affect a lot data description

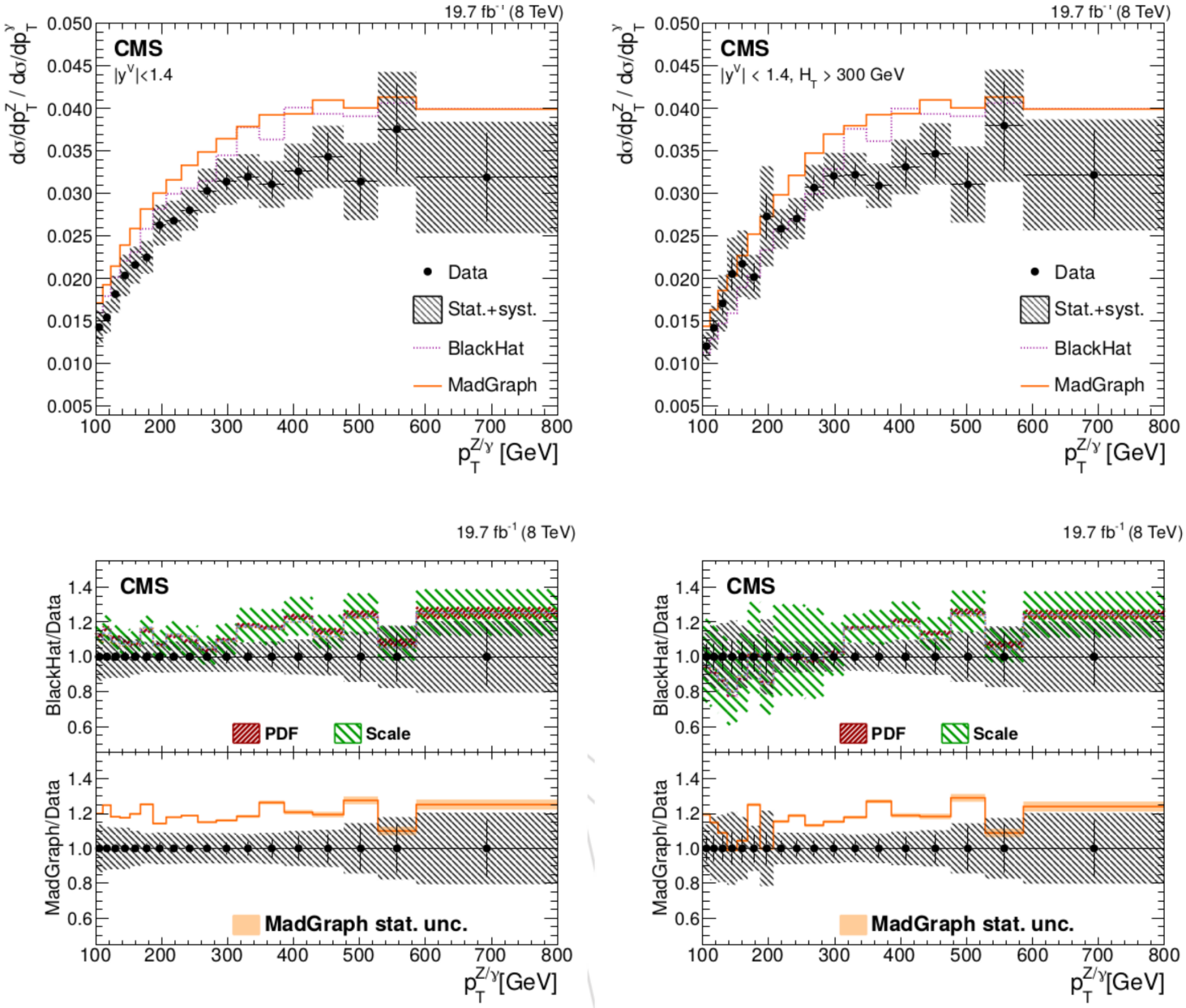
$\frac{Z+jets}{\gamma+jets}$ cross section ratio mesurement (8 TeV) : CMS (JHEP 1510 (2015) 128)



Results for 1 jet

- Test of SM
- background in New physics search
- $Z + jet$ and $\gamma + jet$ treated independently.
- Event yield : $Z + jet$ BKG substraction ; $\gamma + jet$ fit on isolation variable

$\frac{Z+jets}{\gamma+jets}$ cross section ratio mesurement (8 TeV) : CMS

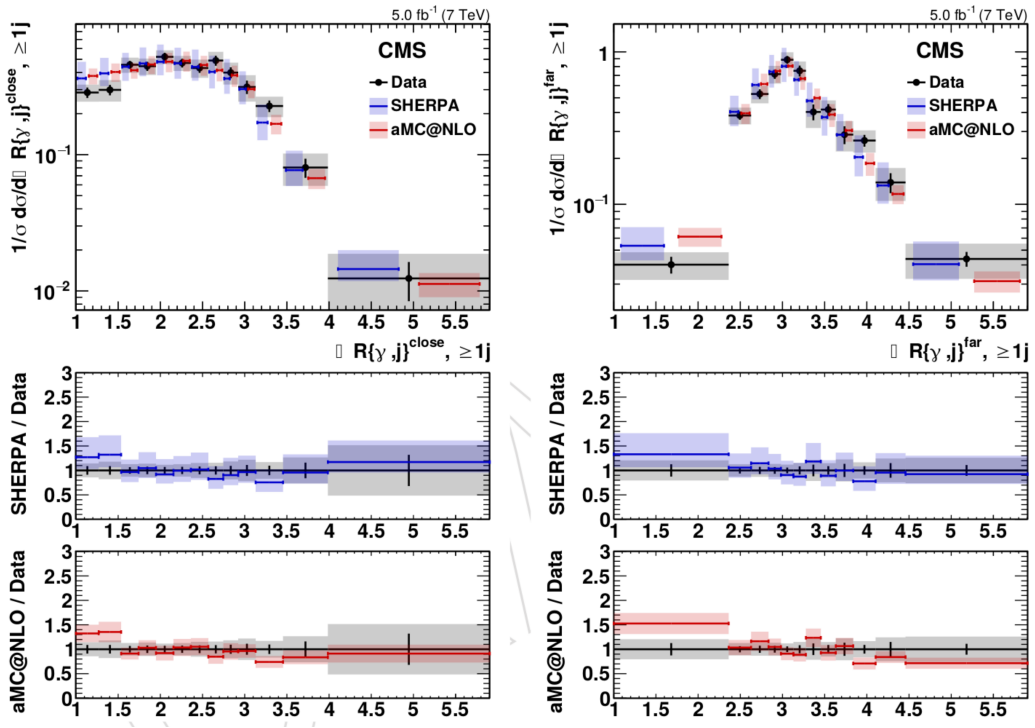


Results for 2 and 3 jets

$\frac{Z+jets}{\gamma+jets}$ cross section ratio mesurement (8 TeV) : CMS

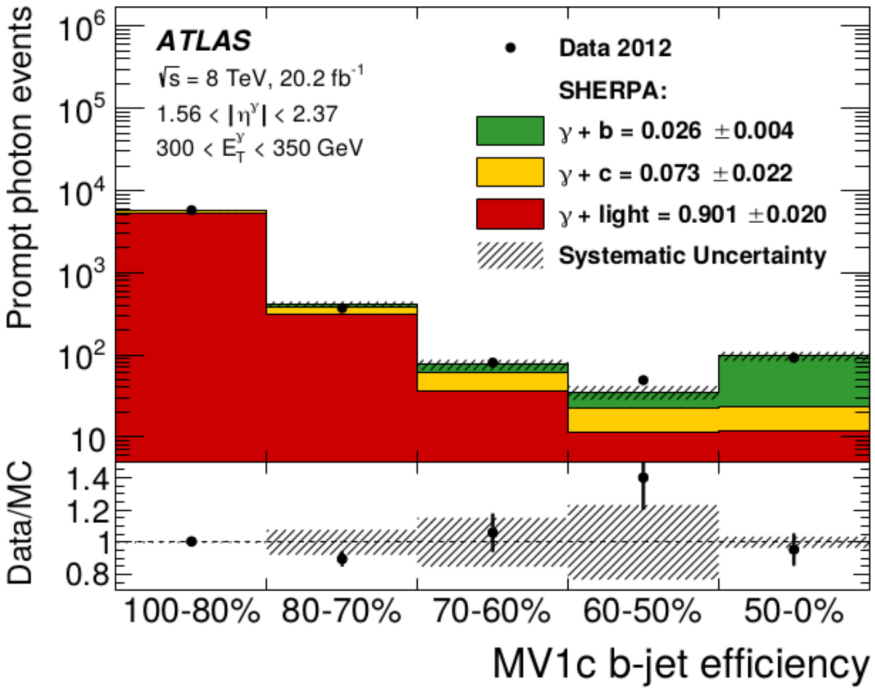
- MADGRAPH + PYTHIA 6 LO generator overestimate data by a factor of 1.21
- BLACKHAT NLO generator overestimate data by a factor of 1.18
- Shapes well modelised

$\gamma\gamma + jets$ differential cross section mesurement ($7\ TeV$) : CMS (arXiv:1405.7225 [hep-ex])



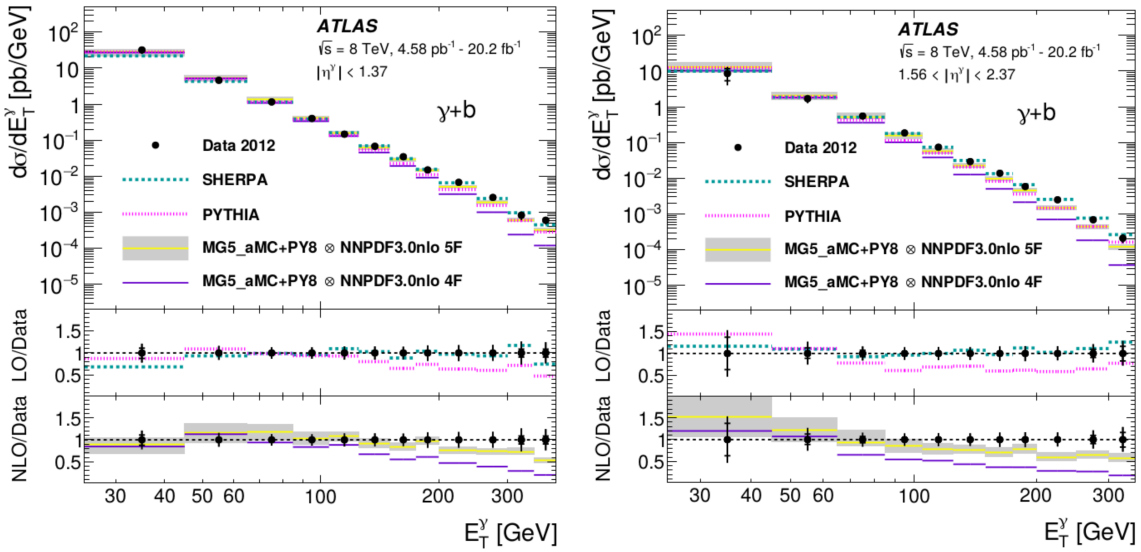
- Select event with two good photons
- Signal yield extracted from template fit.
- Measurement for 1 or 2 jets
- Good agreement with LO and NLO predictions

$\gamma +$ HF-jets differential cross section mesurement (8 TeV) : ATLAS (Phys. Lett. B 776 (2018) 295)



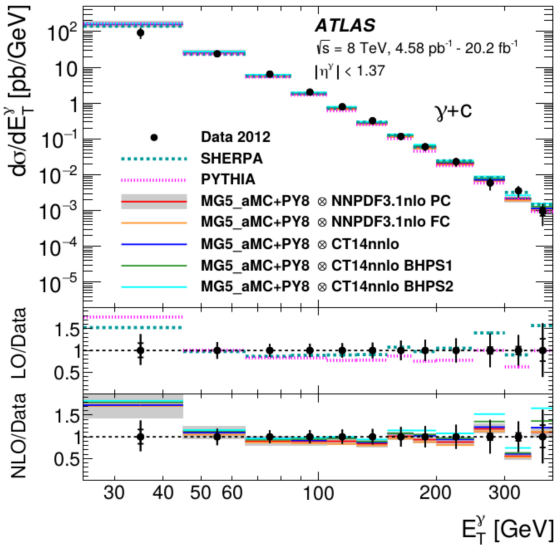
- Direct probe of proton flavour composition.
- Select good $\gamma + jet$ events
- Use MV1 discriminator for selecting events enriched in c- and b-jets
- Backgroud substraction to access event yield.

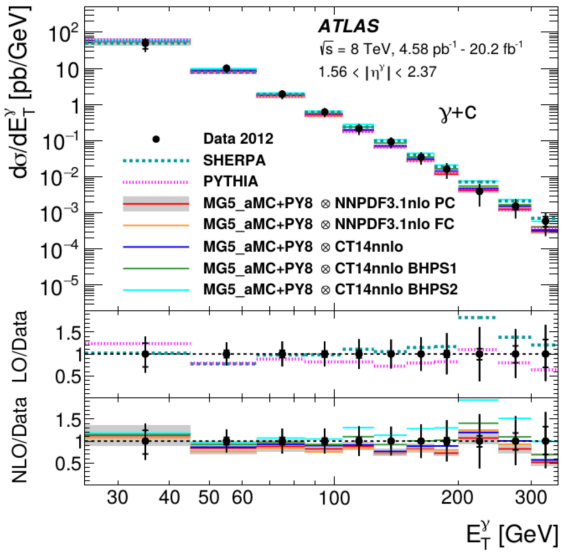
$\gamma +$ HF-jets differential cross section mesurement (8 TeV) : ATLAS



- $\gamma +$ b-jet cross section
- good agreement with SHERPA LO predictions
- NLO best agreement with PDF 5F massive scheme

$\gamma +$ HF-jets differential cross section mesurement (8 TeV) : ATLAS





- $\gamma +$ c-jet cross section
- Similar agreement with LO and NLO predictions.
- Various PDF's used for comparisons.

Conclusion

- ATLAS and CMS produced numerous SM physic results with jets or photon with jets topologies
- Precious comparisons with various generators and PDF sets
- Intrinsic interest as measurements and needed for other analyses (both precision measurements and NP searches)
- We enter the precision era where more and more data will allow us to reduce statistical uncertainties and probe rarer SM processes.

Backup

- TEEC function : $\frac{1}{\sigma}\frac{d\sum}{dcos\phi} = \frac{1}{N}\sum_{A=1}^{N}\sum_{ij}\frac{E_{T,i}^{A}E_{T,j}^{A}}{\sum_{k}E_{T,k}^{A}}\delta(cos\phi - cos\phi_{ij})$
- ATEEC function : $\frac{1}{\sigma}\frac{d\sum^{asym}}{dcos\phi} = \frac{1}{\sigma}\frac{d\sum}{dcos\phi}|_{\phi} - \frac{1}{\sigma}\frac{d\sum}{dcos\phi}|_{\pi-\phi}$