Jet and Photon Physics at the HL-LHC

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October 31, 2017

Outlook

Jet and photon physics play important role in the LHC physics program

- Standard Model tests
- PDF constraints
- Search for ”new physics“ phenomena beyond Standard Model

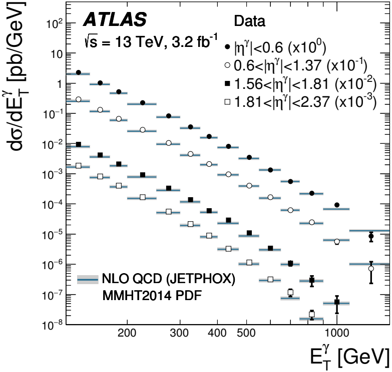
This talk : overview of few recent measurements and expected performance at HL-LHC

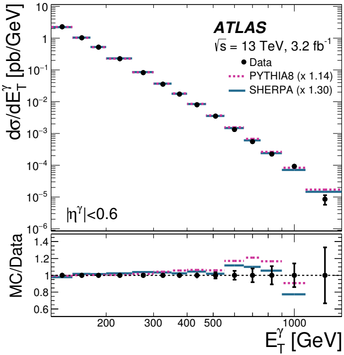
- Recent measurements with photons
- Recent measurements with jets
- Performance in HL-LHC : jet
- Performance in HL-LHC : photon

Inclusive photon measurements

arXiv:1701.06882

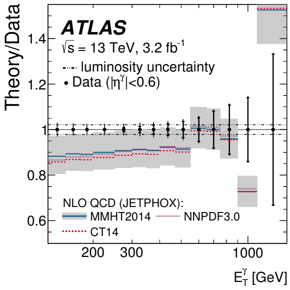
- $\sqrt{s} = 13$ TeV
- $\mathcal{L}_{\text{int}} = 3.2\ \text{fb}^{-1}$
- $E_{\text{T}} > 125$ GeV
- four rapidity bins up to $\eta = \pm 2.3$



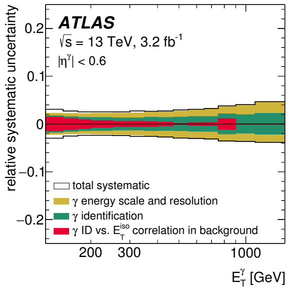


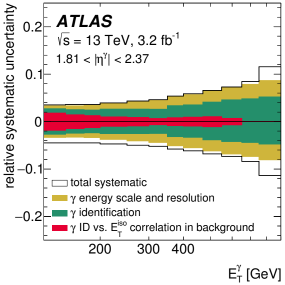
- NLO : about 15% discrepancies, but adequate description within uncertainties
- LO : good description of shape

Inclusive photon Performance



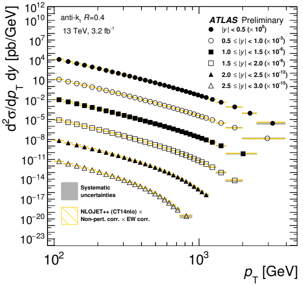
- Theory
  - Current state-of-art : NLO calculations
  - Around 10% theory uncertainty, dominated by scales
- Experimental uncertainty
  - 0.5% photon energy scale
  - 2% in the central region
  - 4-10% in the forward region

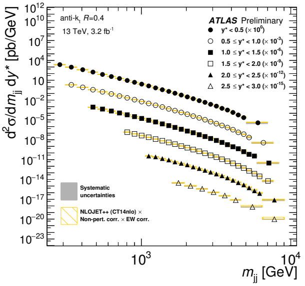




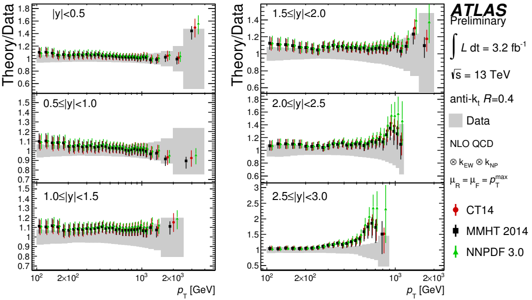
Inclusive jet measurements

ATLAS-CONF-2017-048





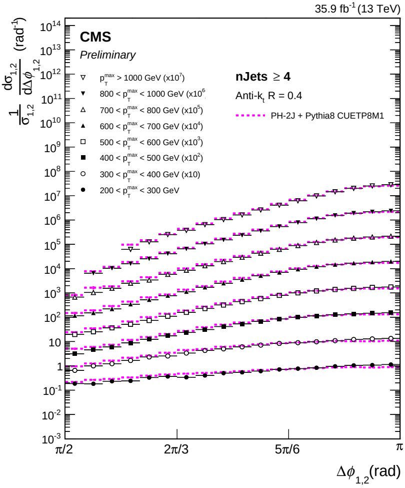
- p_{T} distribution in six rapidity bins
- m_{jj} spectrum in six y^* bins



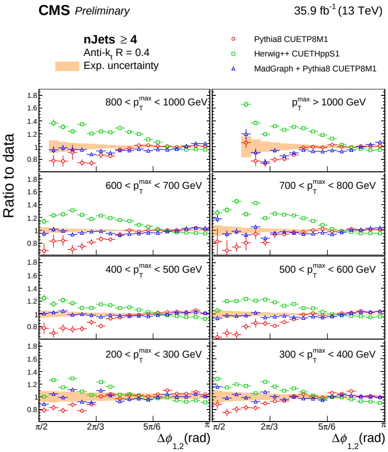
- Adequate description by the NLO cross-section
- NNLO predictions are becoming available

Multijet CMS

Precision test of the multijet matrix elements calculations



- Several topologies : 2-,3-,4 -jets

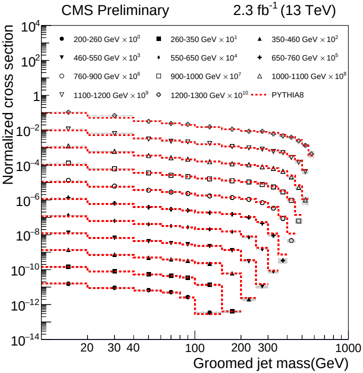


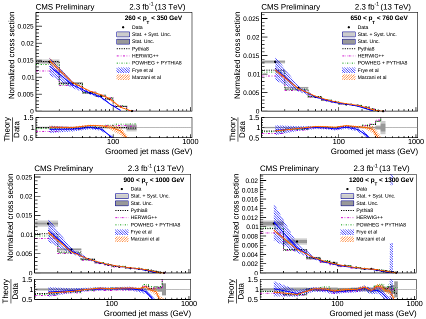
- $\sqrt{s} = 13$ TeV; $\mathcal{L}_{\rm int} = 35.9$ fb^{-1}
- AK4; $p_T > 100$ GeV; $|\eta| < 5$
- Madgraph+Pythia : best description

Jet mass CMS

CMS-PAS-SMP-16-010

Precision test of the jet evolution : jet mass with/without grooming techniques

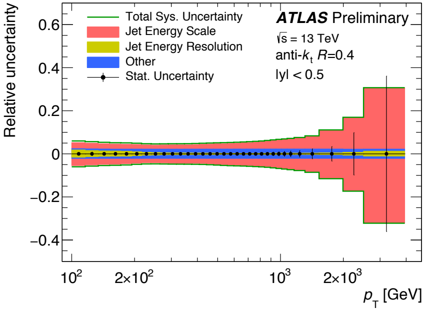


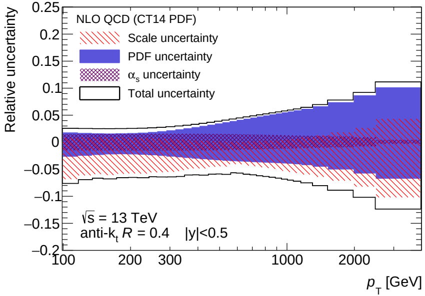


- $\sqrt{s} = 13$ TeV; $\mathcal{L}_{\mathrm{int}} = 2.3$ fb^{-1}
- dijets events with $p_T^{asym} < 0.3$
- AK8, $p_T > 200$ GeV, $|\eta| < 2.4$

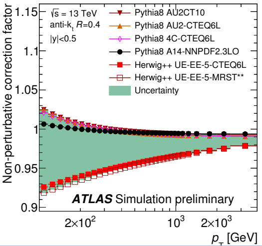
- Beyond NLL calculations agree with data for $m/p_T < 0.3$

Inclusive jet Performance





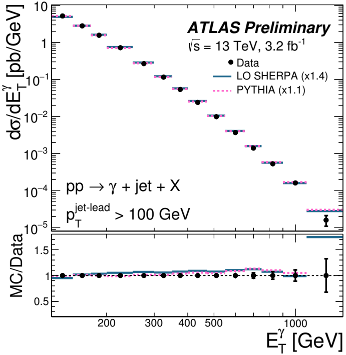
- Experiment
  - 1% JES on the jet level → 5-10% on the XS
  - Dominated by calorimeter energy scale precision
- Theory
  - NLO: scale and PDF uncert.
  - non-perturbative correction : large uncert. from the tune variations



Photon + jet at LO

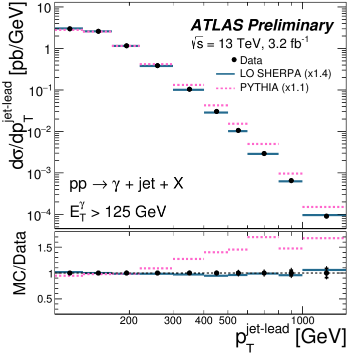
ATLAS-CONF-2017-059

- $\sqrt{s} = 13$ TeV; $\mathcal{L}_{\text{int}} = 3.16$ fb^{-1}



- Good description of photon kinematics

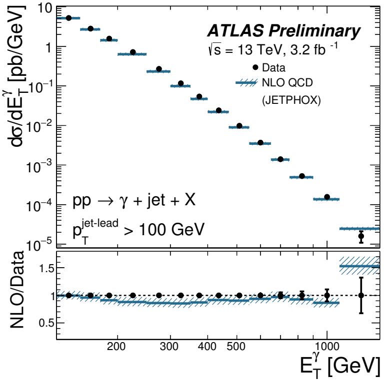
- $E_{\rm T} > 125$ GeV $|\eta^{\gamma}| < 2.37$
- AK4 jets; $p_T^{lead-jet} > 100$ GeV; $|\eta^{jet}| < 2.37; \Delta R(jet, \gamma) > 0.8$

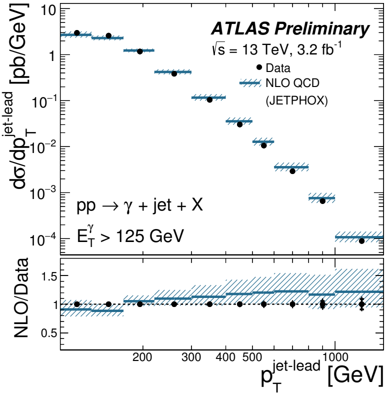


- Poor agreement for high-pT jets for Pythia

Photon + jet NLO

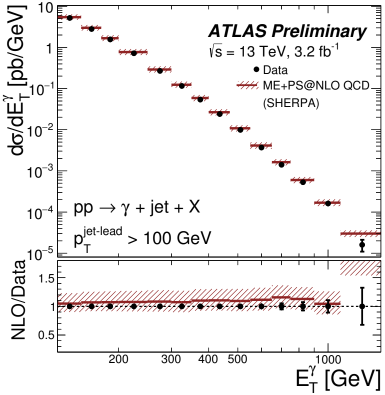
Jetphox is corrected for hadronisation and UE

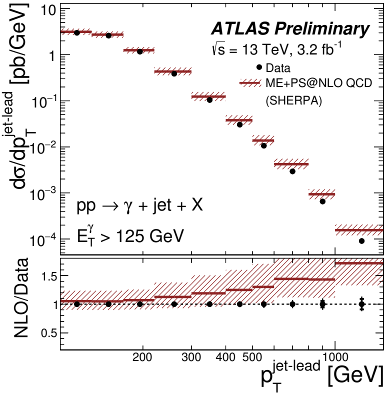




- Very good agreement for photon spectrum
- Slight shape difference for the jet kinematics

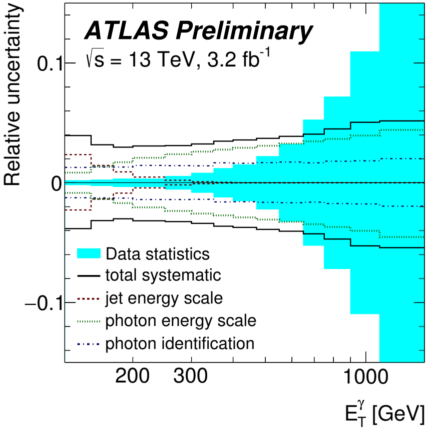
Photon + jet MEPSNLO

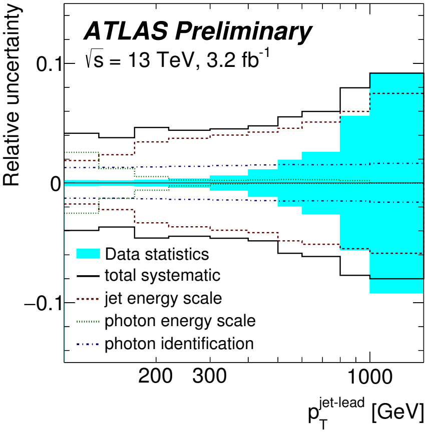




- Excellent description of the photon spectra
- Similar to the pure NLO shape difference

Photon + jet Performance





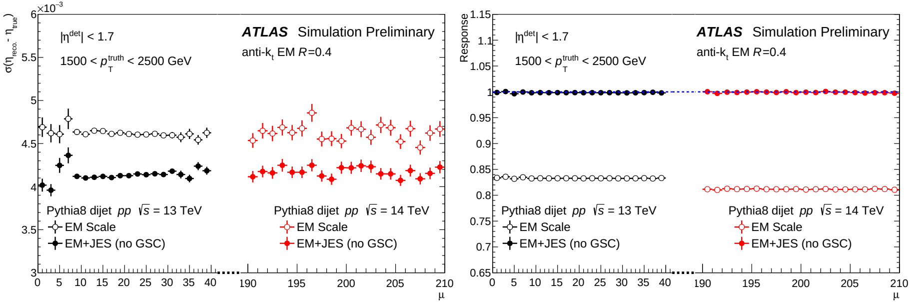
- 3-4 % precision in the photon sprectrum
- Dominated by the photon energy measurement

- 5-10 % precision in the jet sprectrum
- Dominated by the jet energy measurement

Jet performance in HL-LHC (ATLAS)

ATLAS-Tile-Phase2-TDR

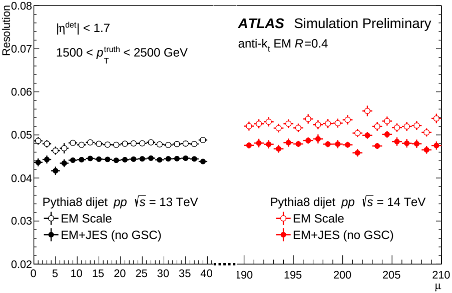
- High pT jet performance in Phase-2 conditions

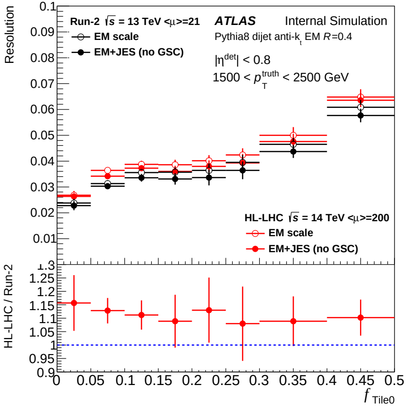


- Very stable jet response and resolution as a function of pileup
- Jet angular resolution is very similar to that in Run-2

Jet performance in HL-LHC (ATLAS)

- Slightly worse jet energy resolution compared to that in Run-2



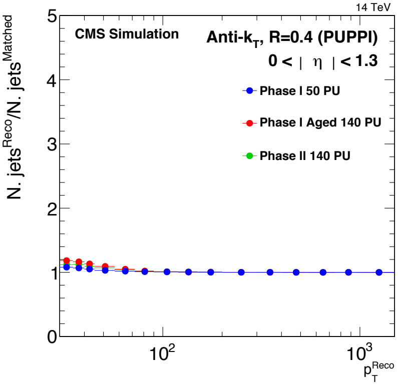


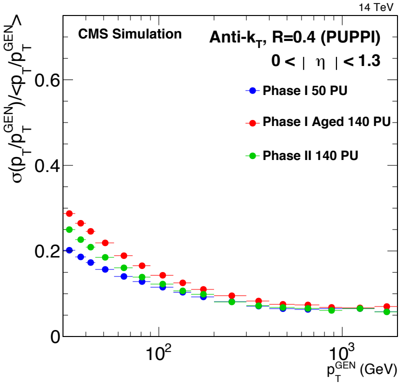
- New methods for pileup mitigation are required

Jet performance in HL-LHC (CMS)

CMS-TDR-15-002

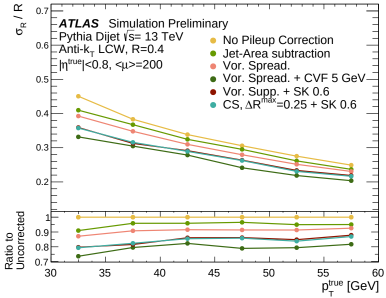
- PUPPI effectively rejects pileup jets

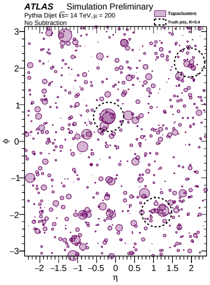


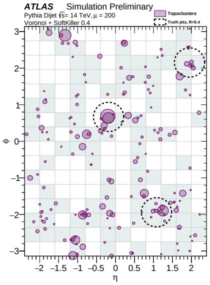


- PUPPI alg. provide about 20% improvement in JER for low-p_T jets

Pileup mitigation and Jet resolution (ATLAS)







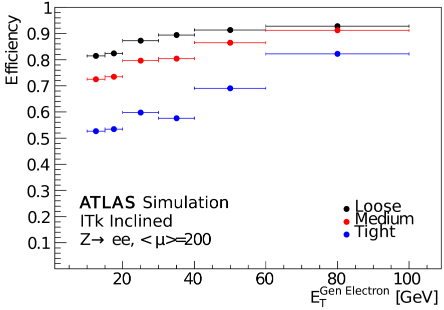
Constituent-level pileup mitigation

- Voronoi suppression (constituent area)
- Soft Killer (event-by-event based p_T cut)
- Voronoi suppression with cluster-vertex fraction : best performance in HL-LHC conditions

Allows to reach jet resolution as in low pileup conditions

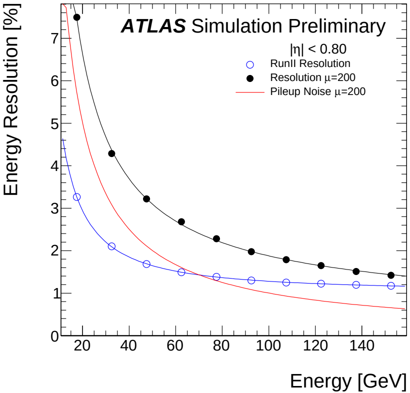
ATLAS-CONF-2017-065

Photon performance in HL-LHC (ATLAS) ATLAS-LAr-Phase2-TDR

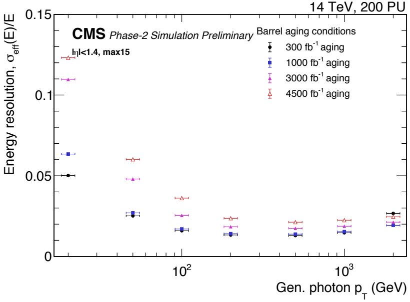


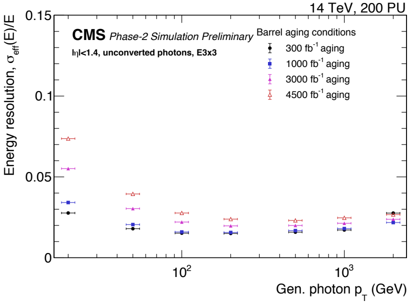
- Cut-based identification alg. (wp: Loose, Medium, Tight)
- 89%–63% truth efficiency, similar to Run-2

- Slightly worse energy resolution due to high pileup level



Photon performance in HL-LHC (CMS)



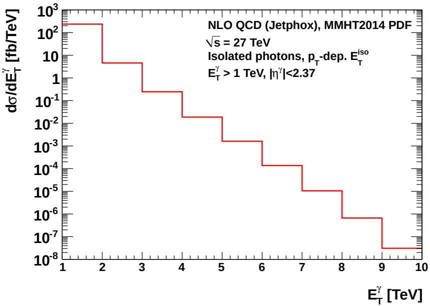


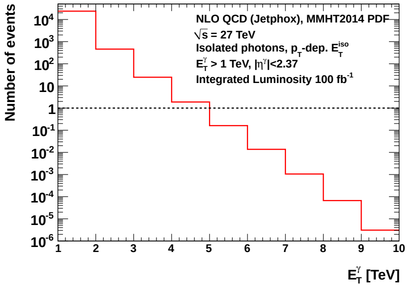
Single photon energy resolution as a function of pT and ageing scenario

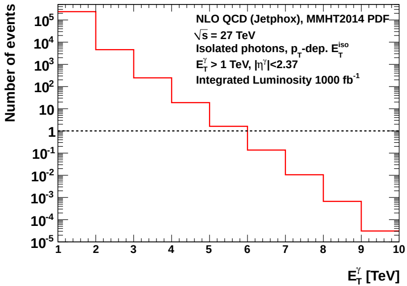
- Photon energy = Sum of the energy of the 15 most energetic crystals in the photon supercluster (max15)
- Photon energy = Sum of the energy of the 3 x 3 region around the seed crystal in the photon supercluster

CMS-TDR-17-002

HE-LHC projections : photons

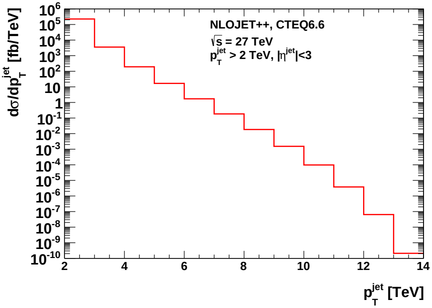




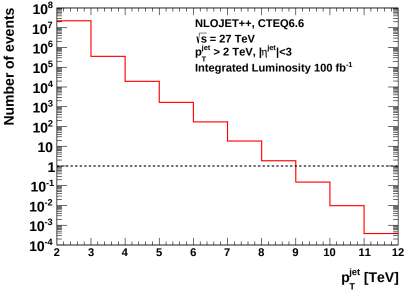


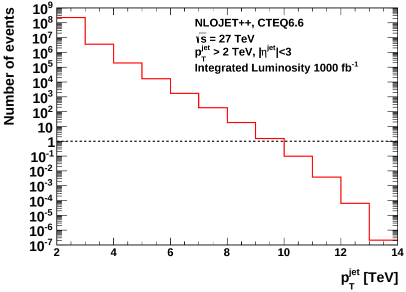
- NLO inclusive photon cross-section
- $\sim$ 4 TeV reach with 100 fb^{-1}
- $\sim$ 5 TeV reach with 1000 fb^{-1}

HE-LHC projections : jets



- NLO inclusive jets cross-section
- $\sim$ 7 TeV reach with 100 fb^{-1}
- $\sim$ 9 TeV reach with 1000 fb^{-1}





Summary

- ATLAS and CMS experiments achieve extremely good jet/photon performance in Run-2
- Recent jet/photon measurements provide high precision tests of Standard Model in the new kinematic regime
- In most of the measurements experimental uncertainties are smaller than the theoretical precision
- Detectors upgrades for HL-LHC will provide similar to Run-2 jet/photon performance