Nuclear modification factor of isolated photons in pp and PbPb collisions at 5.02 TeV with CMS

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Korea University

for the CMS collaboration

Quark Matter 2019

Wuhan, China, November 4-8, 2019

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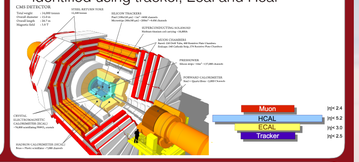
Introduction

- **Prompt photons** are unaffected by the strongly interacting medium produced in the reaction, which are the '**clean**' probes of the initial state of the collision.
- The analysis can give baselines to diagnose any modification of **initial parton states** by the nuclear medium for isolated photon-tagged jet.
- Prompt photons provide a direct way to test perturbative QCD **(pQCD)** and the **(nuclear) parton distribution function (PDF)**
- The transverse momentum spectra and the nuclear modification factors of isolated photon are reported in pp and PbPb collisions at 5.02 TeV using the CMS detector.

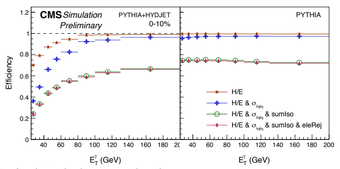
CMS detector

- Photons are reconstructed and identified using tracker, Ecal and Hcal



Analysis methods

Efficiency correction

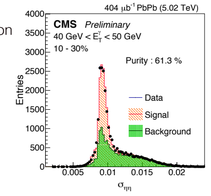


- Isolated photon selection :
  - E ratio of Hcal to Ecal < 0.1
  - sumIso(*) < 1 GeV
  - $\sigma_{i\eta i\eta}$ < 0.1
- Total efficiency = Reconstruction ε x Trigger ε x Selection ε x SF

(*) The isolation variable 'sumIso' is defined as energy sum in an R=0.4 cone around photon candidates, which is tracker E_T + ecal E_T + hcal E_T.

Signal extraction (Purity correction)

- After isolated photon selection, there is still significant contamination from neutral meson decay.
- Decay photons have characteristically wider showers than prompt photons.
- Purity is defined as signal fraction in $\sigma_{i\eta i\eta}$ < 0.01 and estimated using **template fit method.**
  - signal PDF from MC
  - background PDF from DATA in sideband region

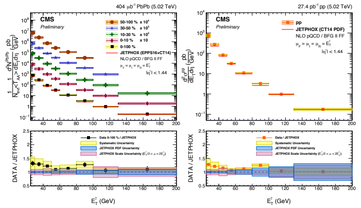


$$\sigma^2_{i\eta i\eta} = \frac{\sum_i^{5\times5} w_i(\eta_i - \bar{\eta}_{5\times5})^2}{\sum_i^{5\times5} w_i}, \; w_i = \max(0, c + \ln\frac{E_i}{E_{5\times5}})$$

- After efficiency and purity corrections, the raw spectra are unfolded for detector resolution

Results

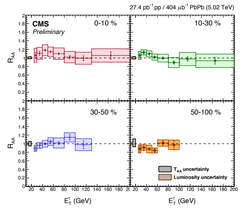
Cross section

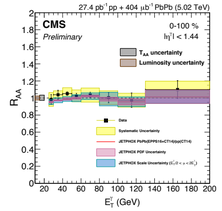


- The data are compared with the NLO pQCD calculations using JETPHOX for CT14 PDF and EPPS16 nuclear PDF sets.

Nuclear modification factor (R_{AA})

$$R_{AA} = \frac{1}{<T_{AA}>}\frac{1}{N_{MB}}\frac{d^2N^{\gamma}_{PbPb}/dE^{\gamma}_T d\eta}{d^2\sigma^{\gamma}_{pp}/dE^{\gamma}_T d\eta}$$





- **No significant modification** of isolated photon cross sections in PbPb collisions with respect to pp collisions is observed in the explored kinematic ranges at various collision centralities.
- The RAA is also sensitive to nuclear modifications of the PDFs in the shadowing and anti-shadowing regions.
- Constraints on nPDF from these data are currently limited by the size of the experimental uncertainties.

Summary

- The prediction from JETPHOX is found to be consistent with the measured R_{AA} and cross sections for both pp and PbPb collisions.
- These results provide baselines to diagnose any modification of **initial parton states** by the nuclear medium for isolated photon-tagged jet.

References

[1] CMS Collaboration, *CMS PAS-HIN-18-016*

[2] P. Aurenche et al., *Phys. Rev. D73 (2006) 094007*

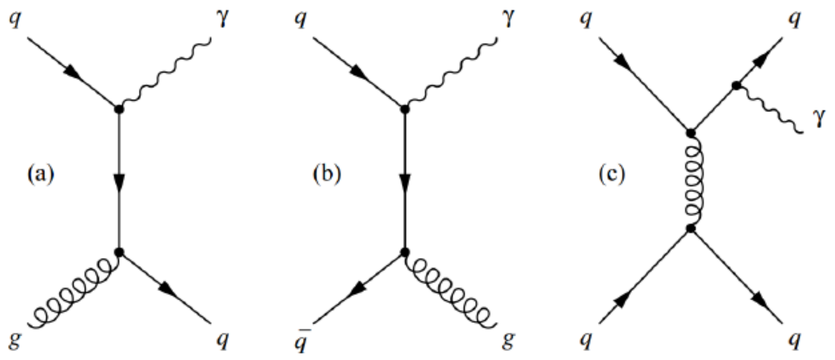
[3] S. Dulat et al., *Phys. Rev. D 93 (2016), no. 3, 033006*

[4] K. J. Eskola, P. Paakkinen, H. Paukkunen, and C. A. Salgado, *Eur. Phys. J. C 77 (2017), no. 3, 163*

Why photons?

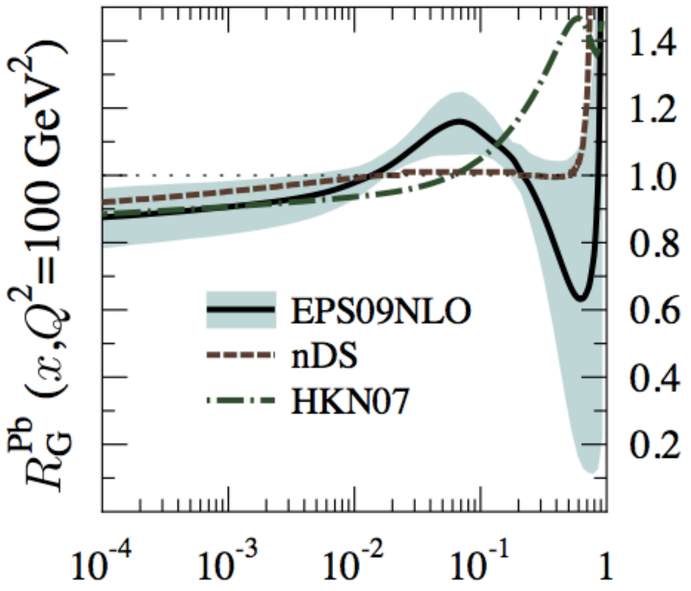
- **Prompt photons**
  - directly produced from **hard scattering** at leading order

    OR
  - **fragmented** collinearly from partons at high-p_T



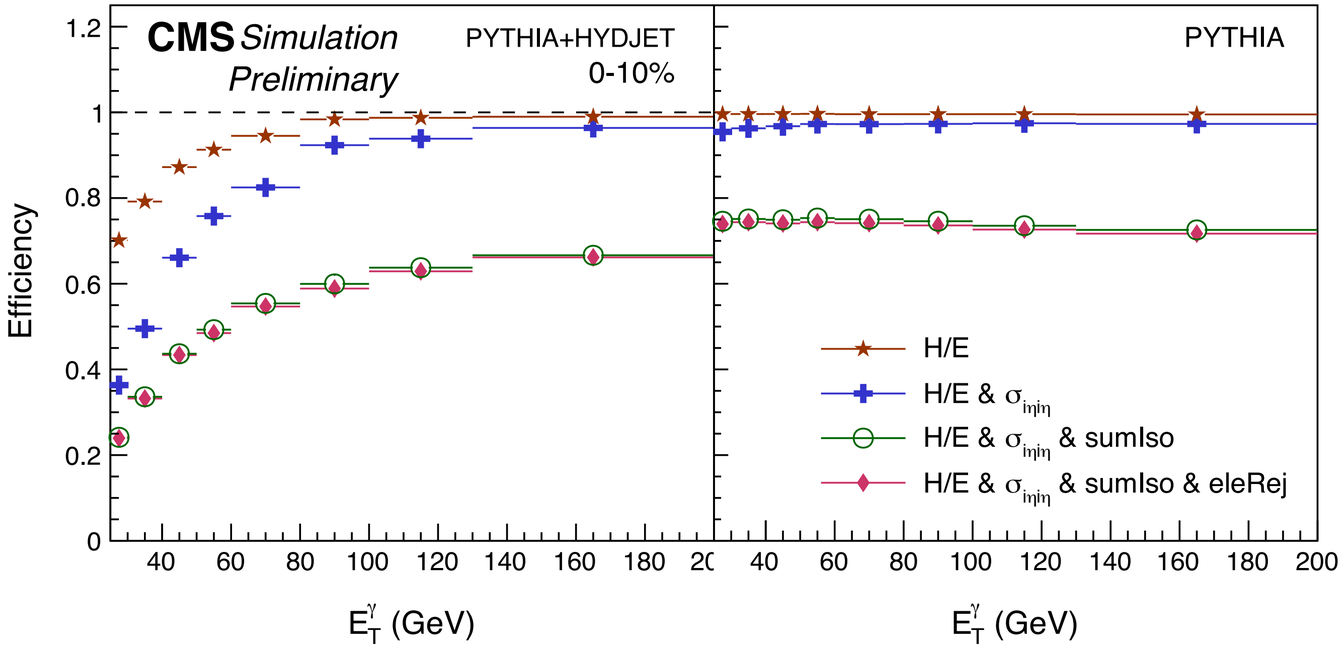
- High-p_T prompt photons do **NOT** interact with hot and dense medium
  - -> proxy to the **initial parton's energy**
  - -> test perturbative QCD
  - -> estimate **nuclear parton distribution function (nPDF)** by comparing pp and PbPb collisions

$$R_{AA} = \frac{1}{< T_{AA} >} \frac{1}{N_{MB}} \frac{d^2 N^{\gamma}_{PbPb}/dE^{\gamma}_T d\eta}{d^2 \sigma^{\gamma}_{pp}/dE^{\gamma}_T d\eta}$$



arxiv:1103.1471v2

Analysis methods: Efficiency & Purity



CMS-PAS-HIN-18-016

- Isolated photon selection requirements
  - 1) E ratio of Hcal to Ecal < 0.1
  - 2) $\sigma_{\eta\eta}$ (shower shape) < 0.01
  - 3) sumIso (Isolation) < 1 GeV

➡ suppress **fragmentation** and **decay** photons

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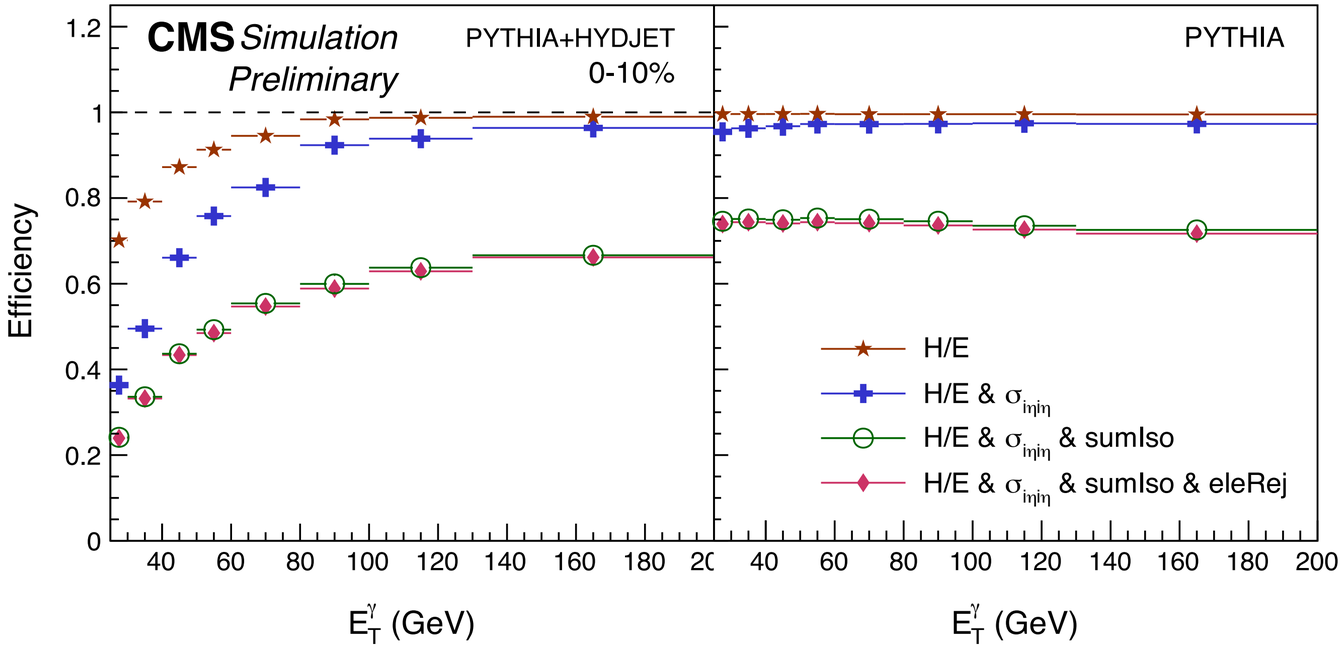

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- Purity is estimated using **template fit method**.

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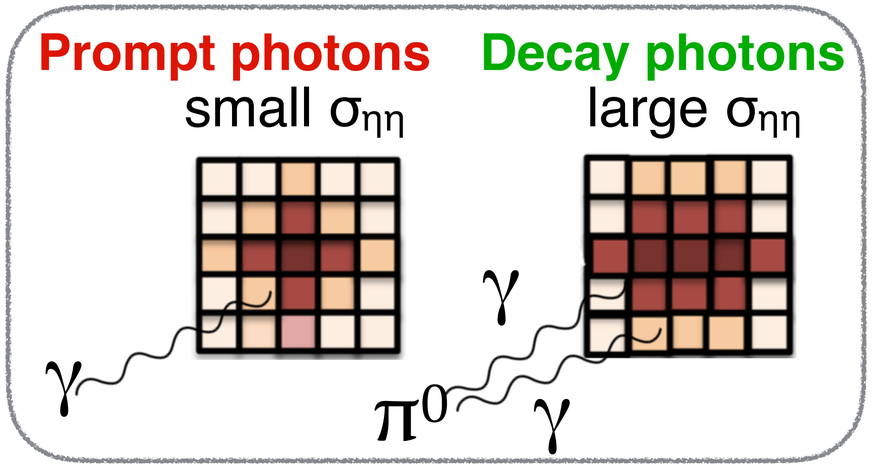

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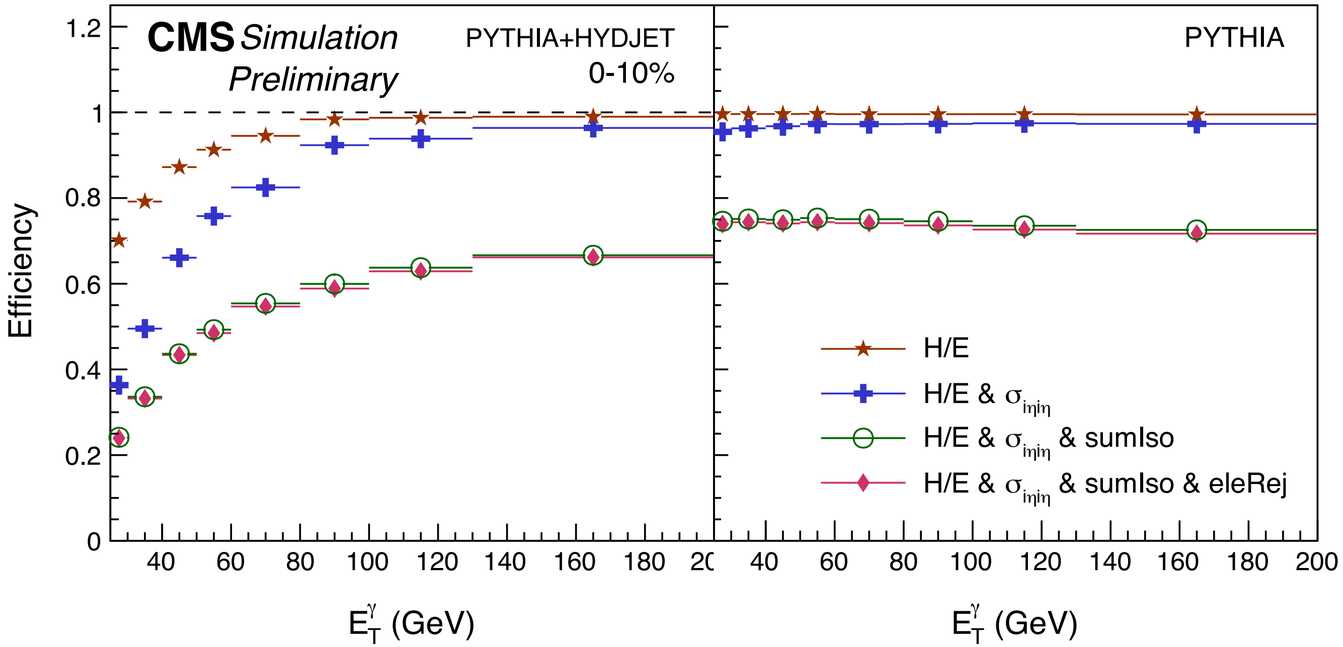

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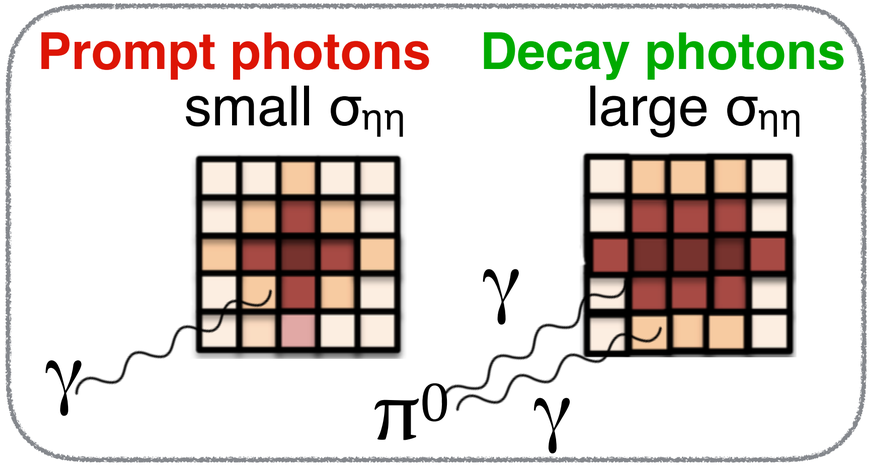
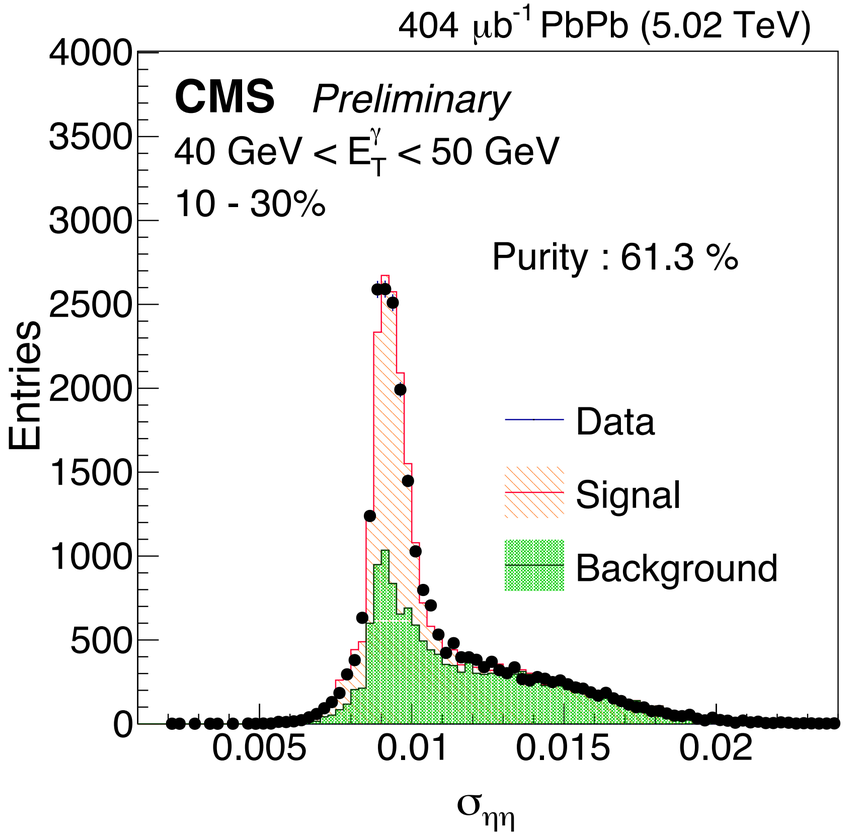
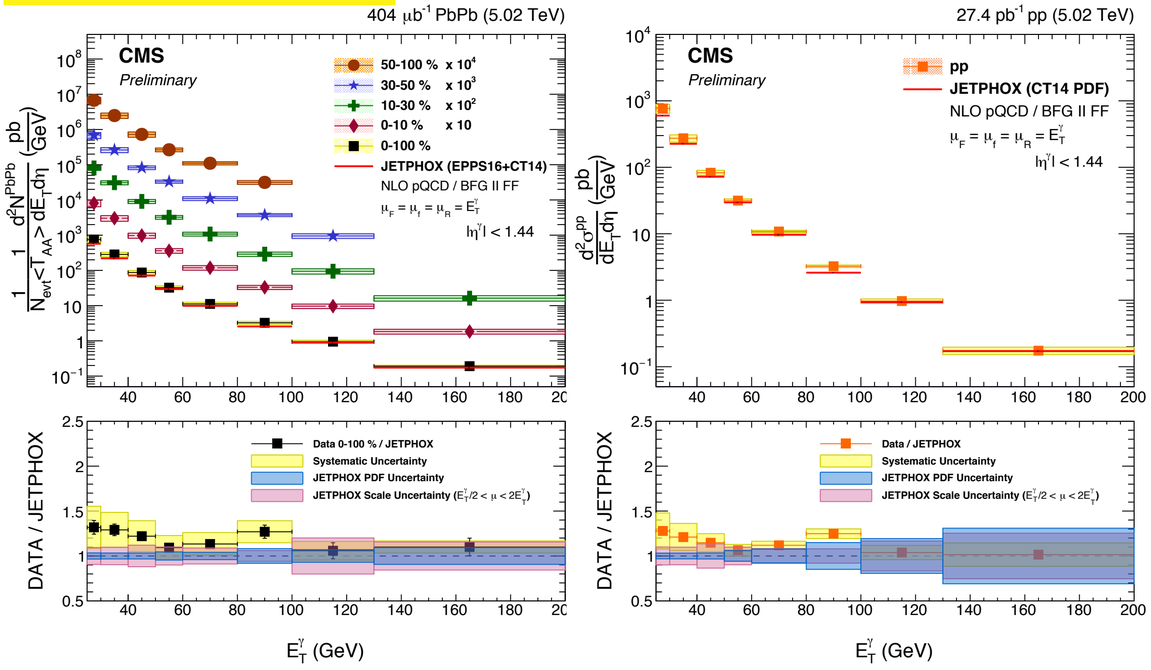




Cross sections & R_{AA} of Isolated photons

CMS-PAS-HIN-18-016



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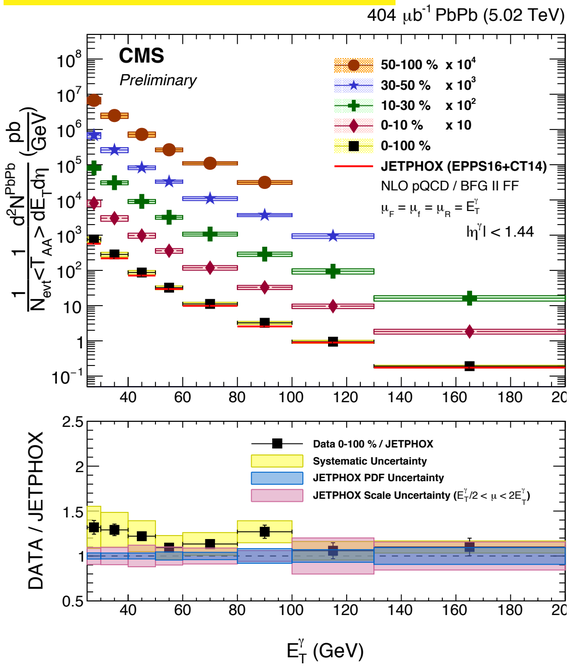

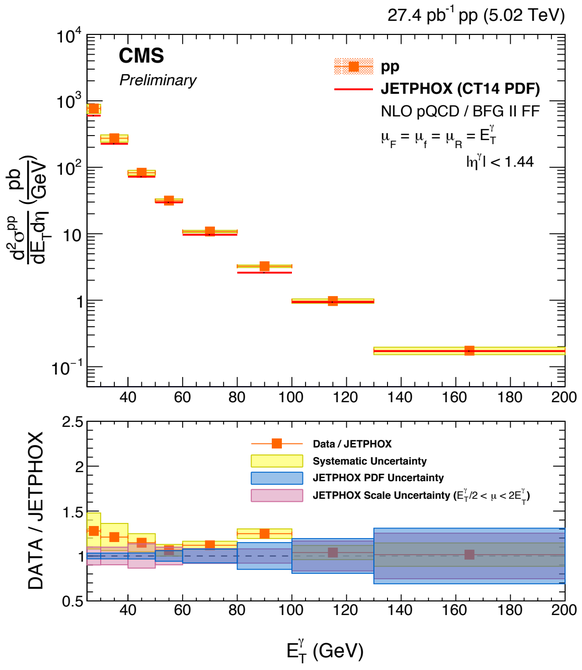

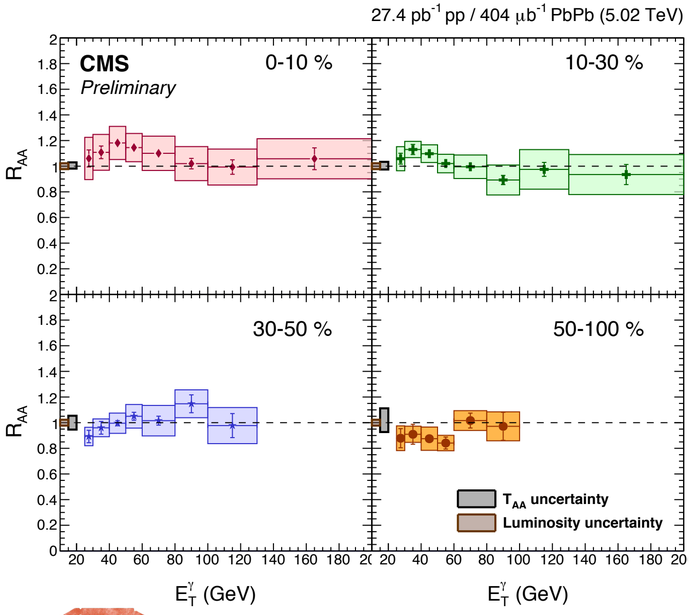

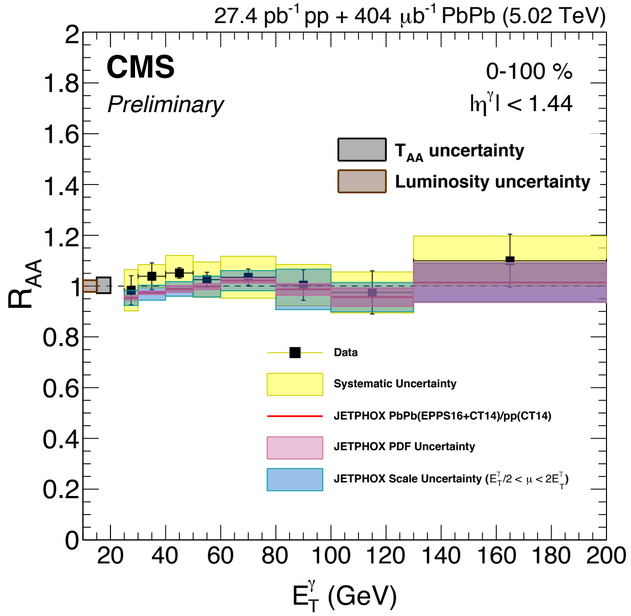

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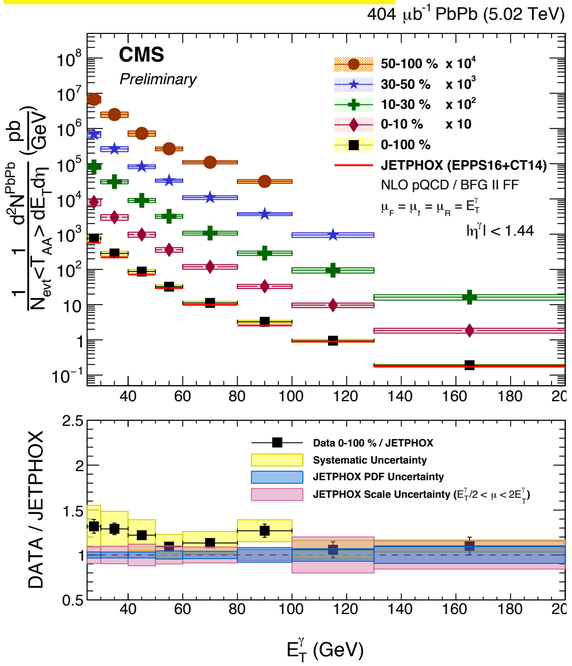

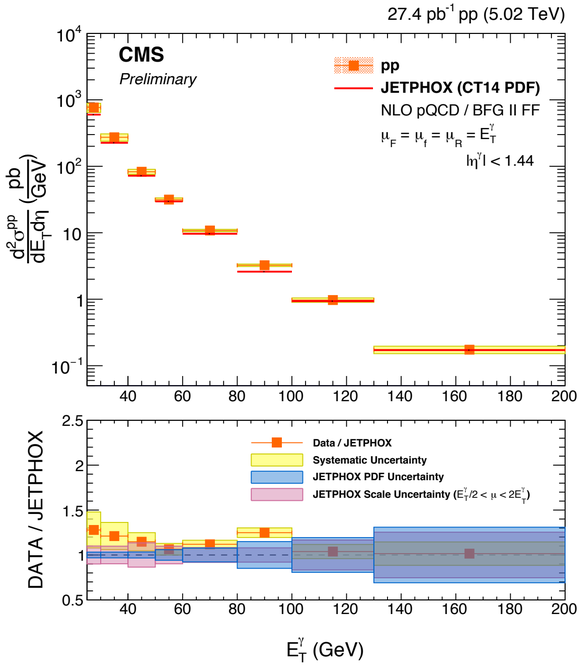

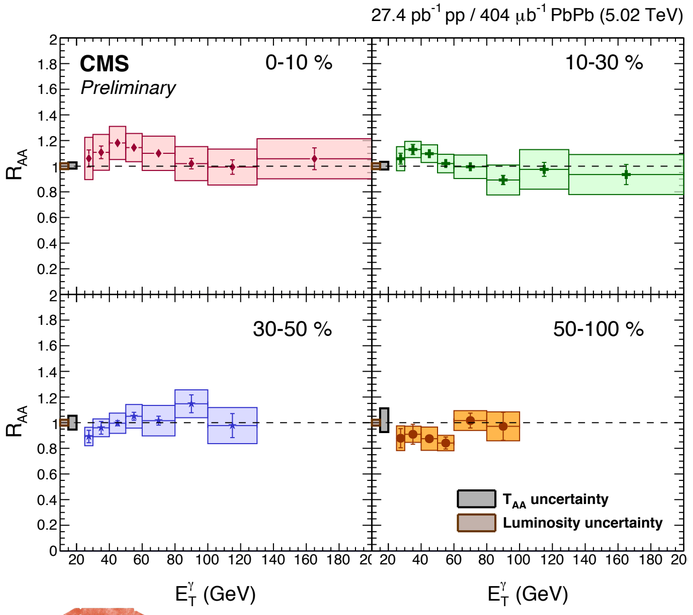

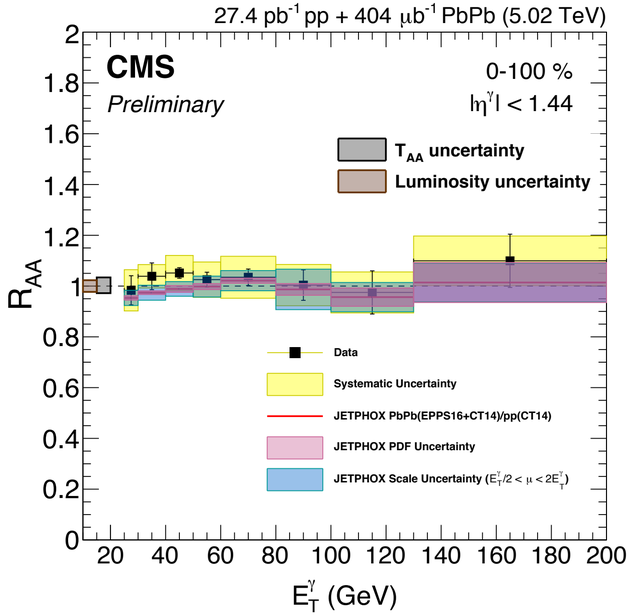

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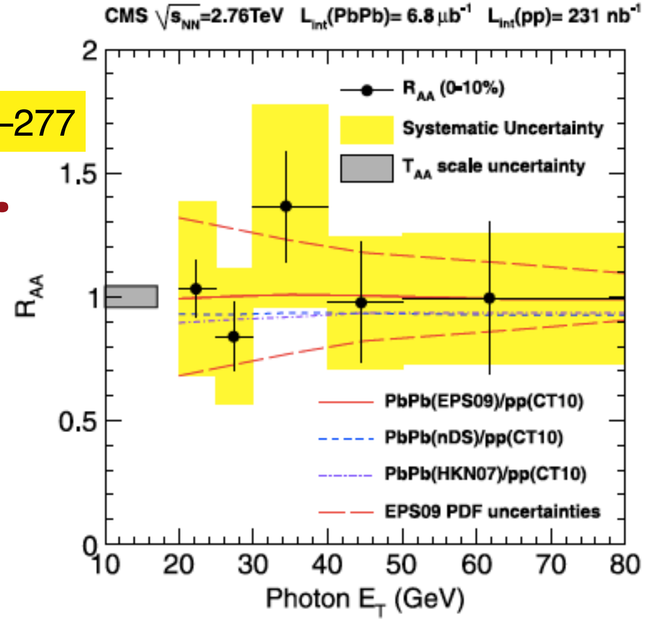

Summary

- The current measurements **significantly improve the accuracy.**
- The JETPHOX prediction is found to be **consistent** with the data.
- **No significant modification** of isolated photons is found
  -> **valuable probes** to access the initial parton's p_T in γ+jet or γ+hadron events.