Measurement of isolated photon R_{AA} in PbPb collisions at 2.76 TeV with CMS

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for the CMS Collaboration

Motivation: isolated photons

- Probe the initial state (nPDF)

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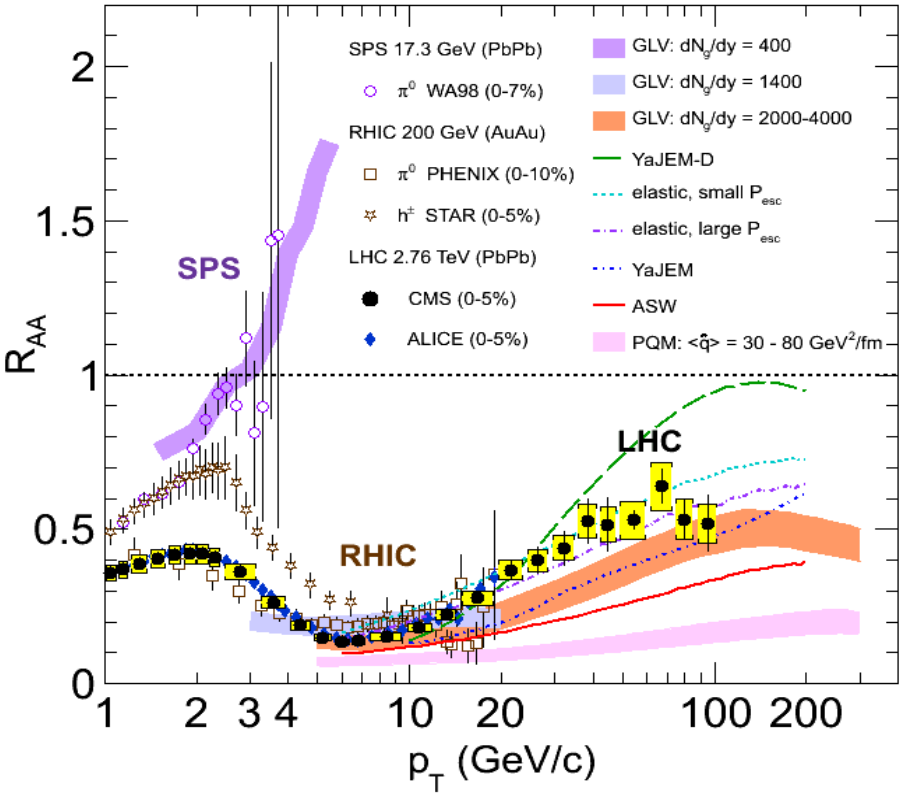
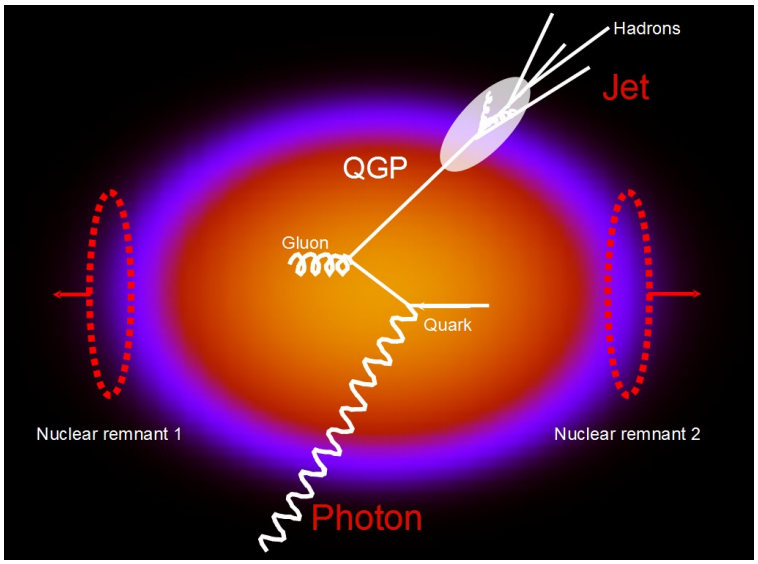
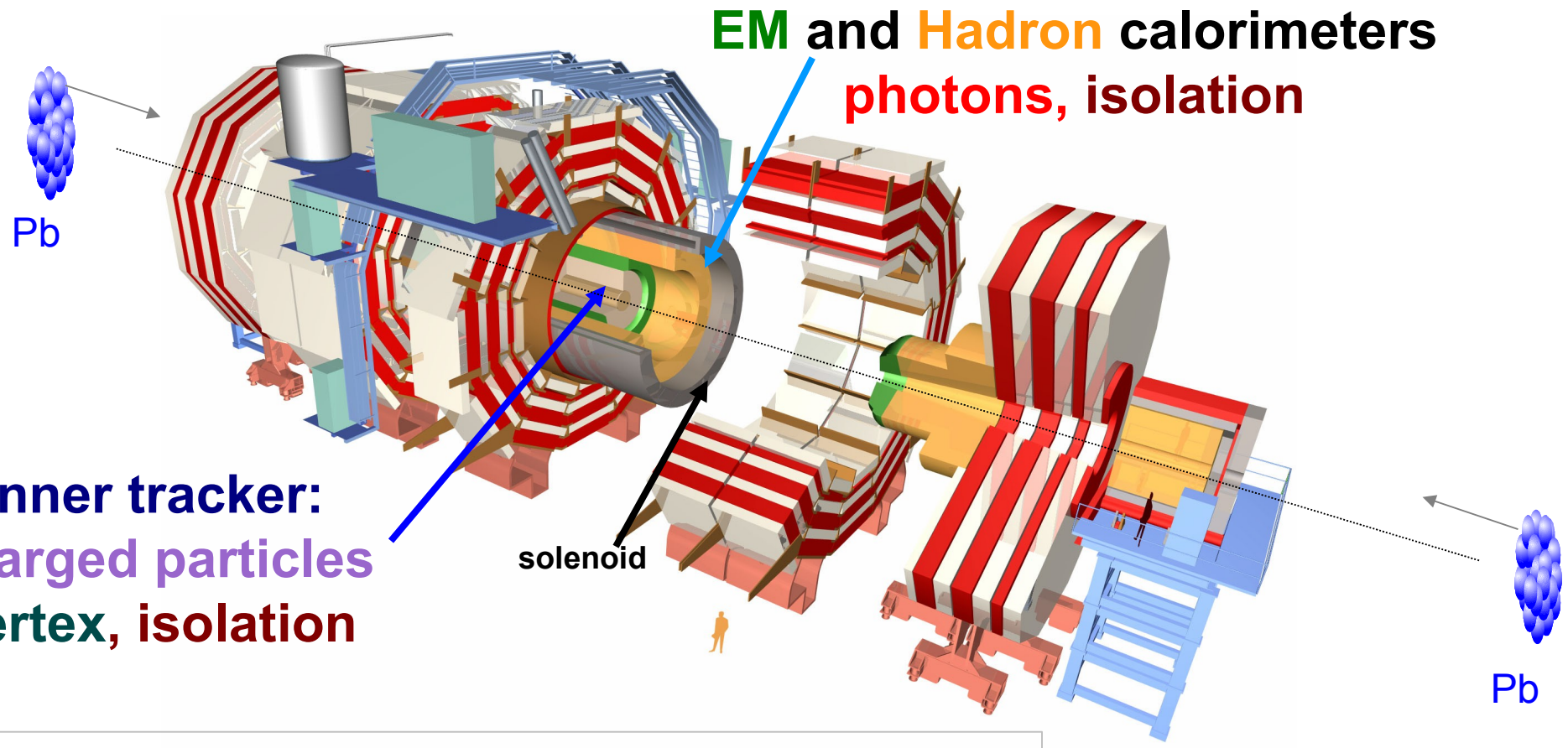


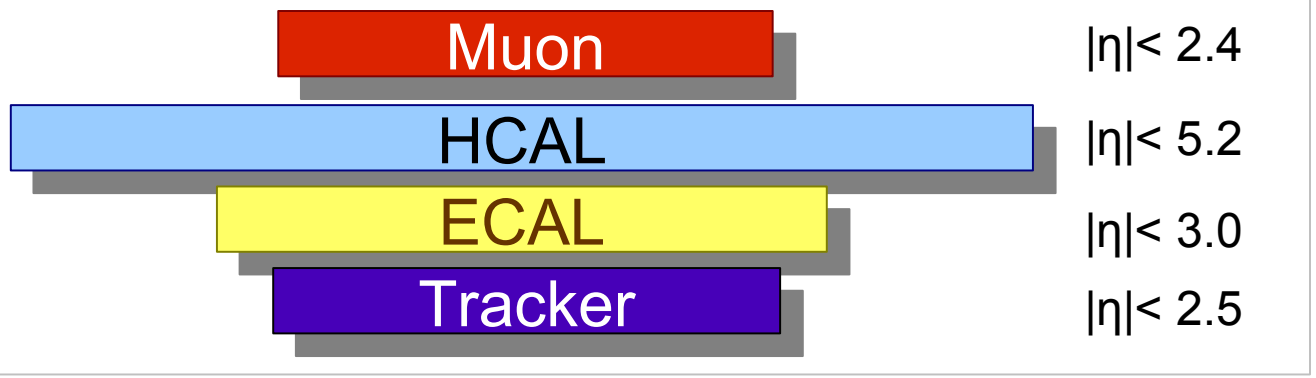
- Important baseline of charged particle / jet R_{AA} measurements



- Basis for the photon-jet correlation analysis

CMS detector





Data sample and event selection

- Data sample used:
  - pp: 231 nb^{-1}
  - PbPb: 6.8 μb^{-1}

- Photon trigger:
  - Uncorrected photon E_T > 15 GeV
  - ~ fully efficient for E_T > 20 GeV

- Event selection:
  - Passing collision event selection
  - One good photon candidate with $|\eta|<1.44$ and E_T > 20 GeV

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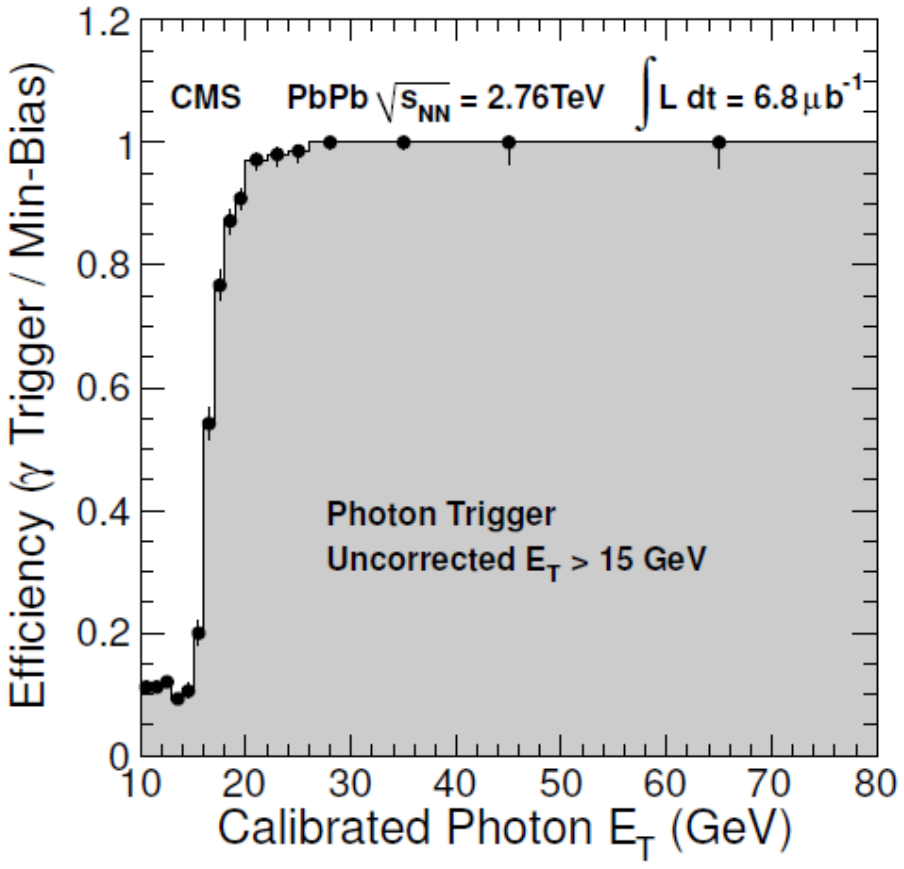
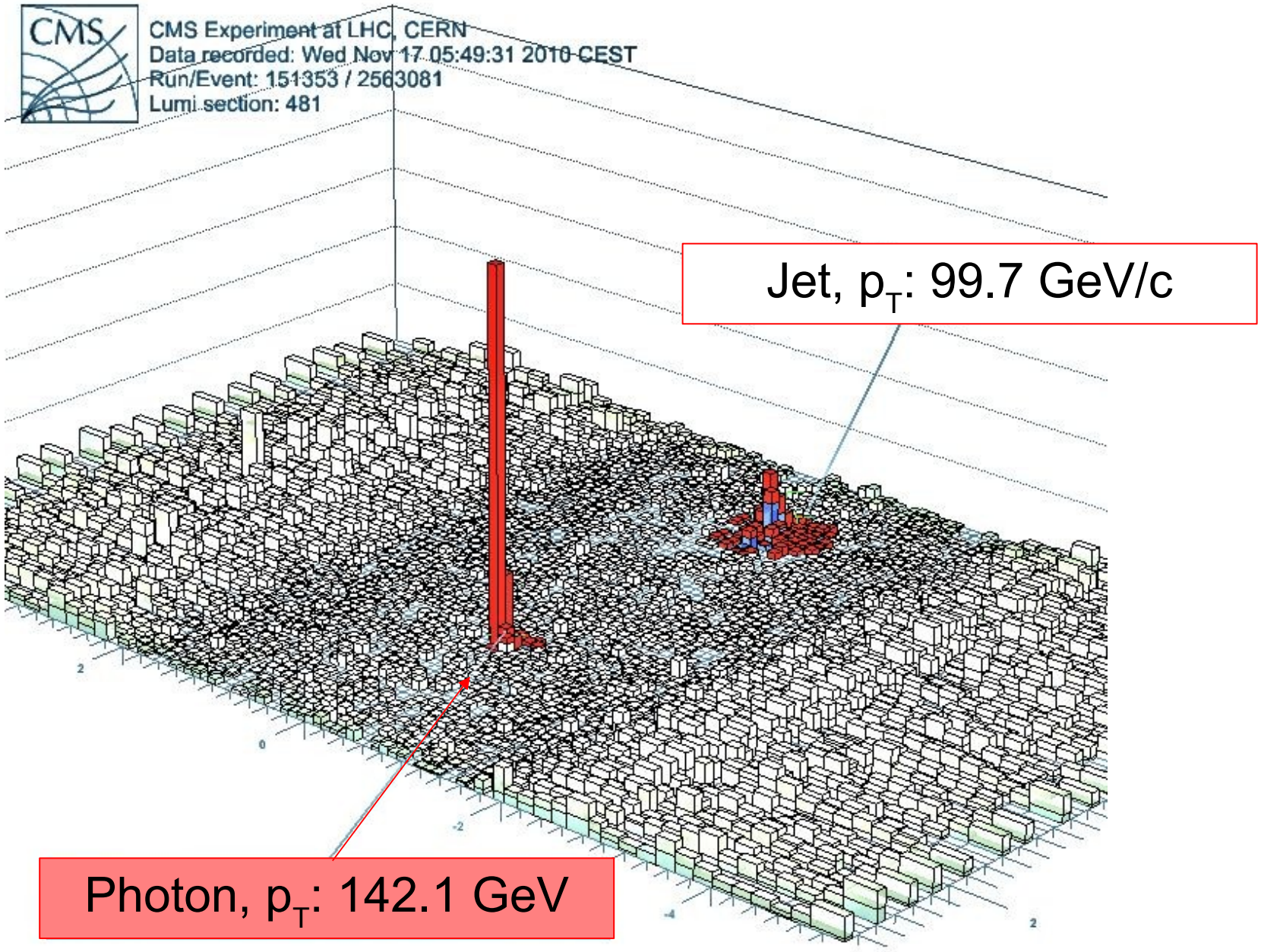
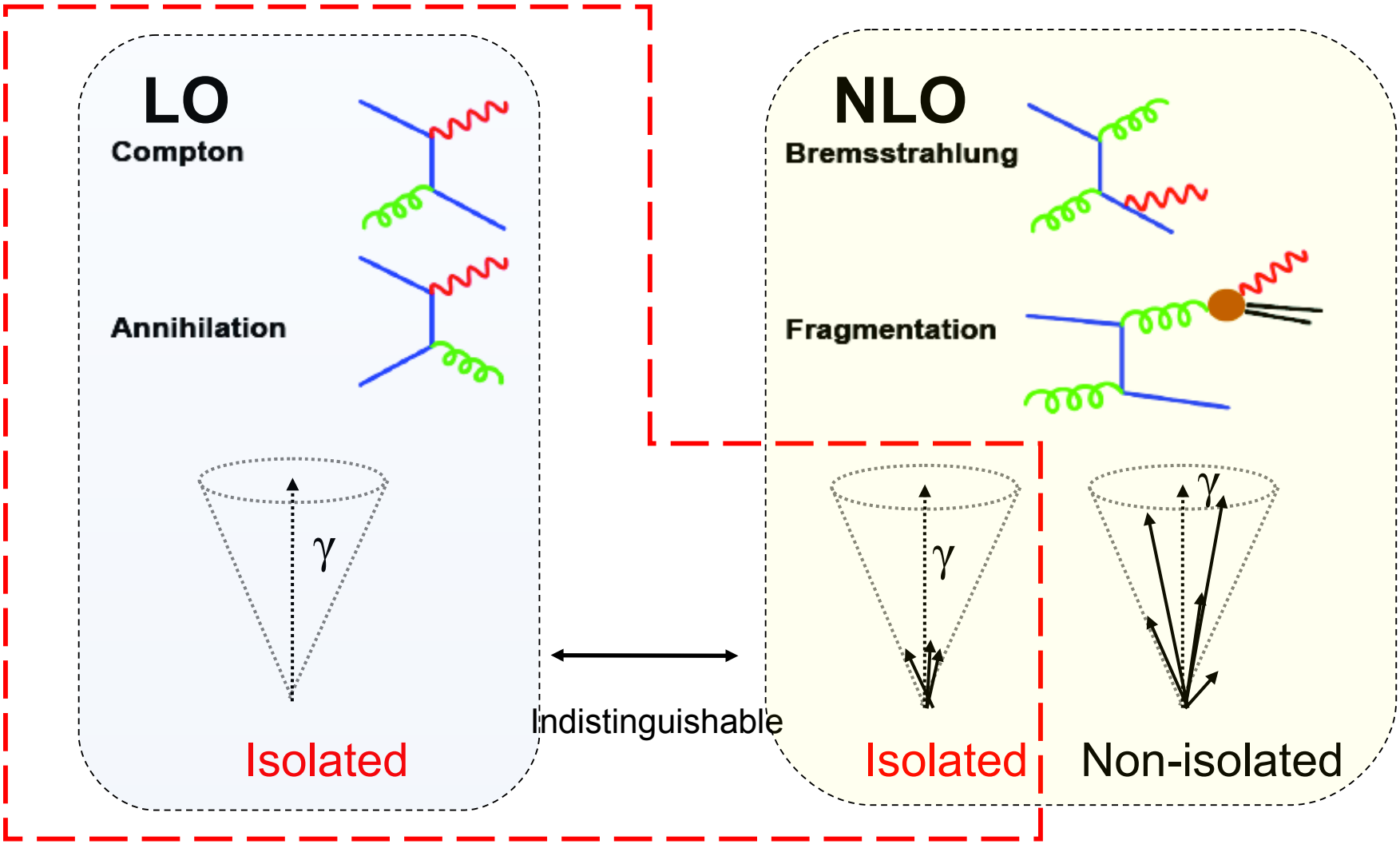


Isolated photons in PbPb collisions



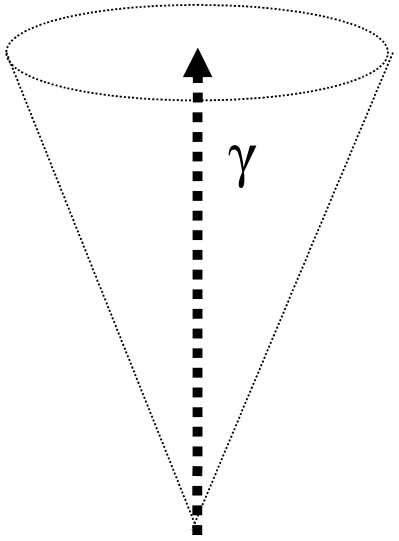
Isolated high p_T photons

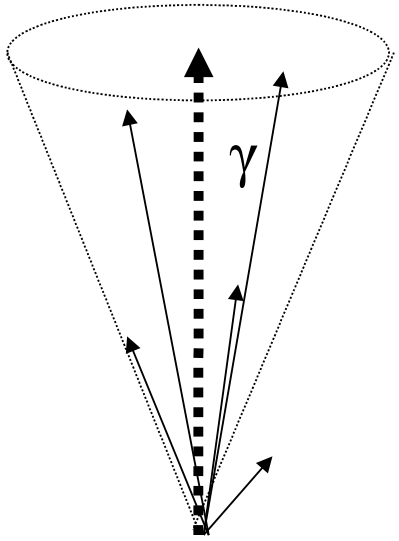
- Ideal: direct photon from hard scattering
- Real world: background from the decay and fragmentation photons.
- Solution: measurement of the isolated photons



Photon isolation in PbPb

Generator level
$\Delta R<0.4$, $\Sigma E_T^{\text{IsoCone}} < 5$ GeV
with only particles from the same hard scattering



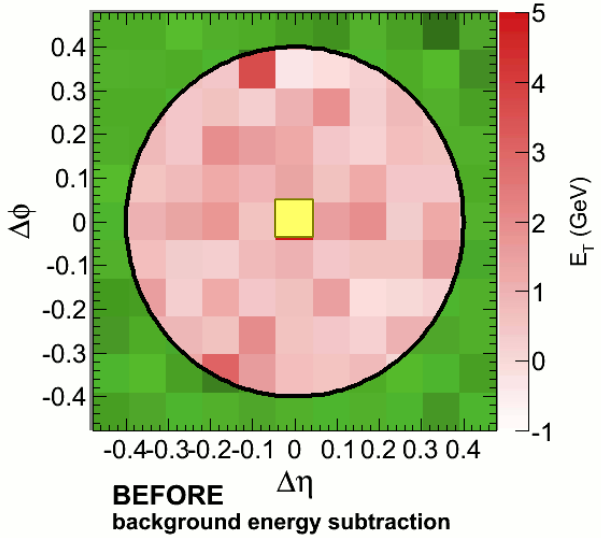


CMS Experiment

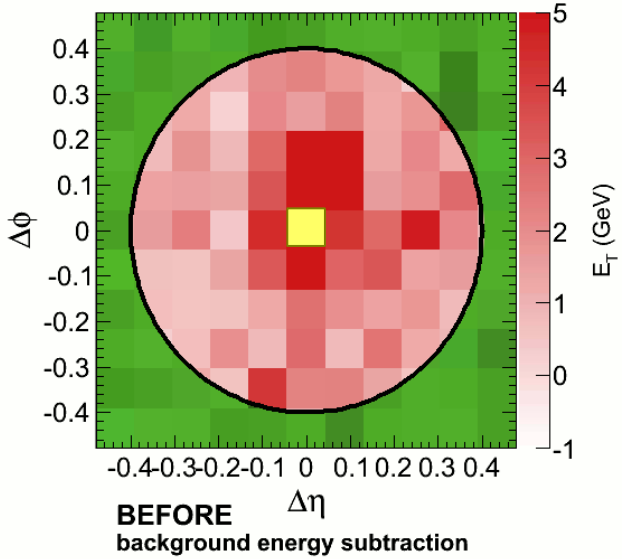
Sum E_T (p_T) from Calorimeter and tracker

Contribution from underlying event

Isolated photon

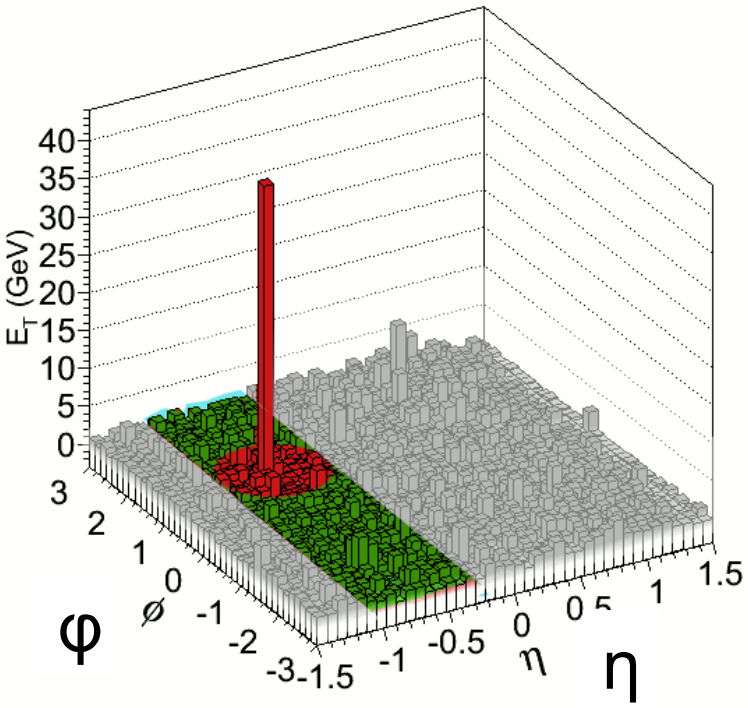


Photon candidate from jet

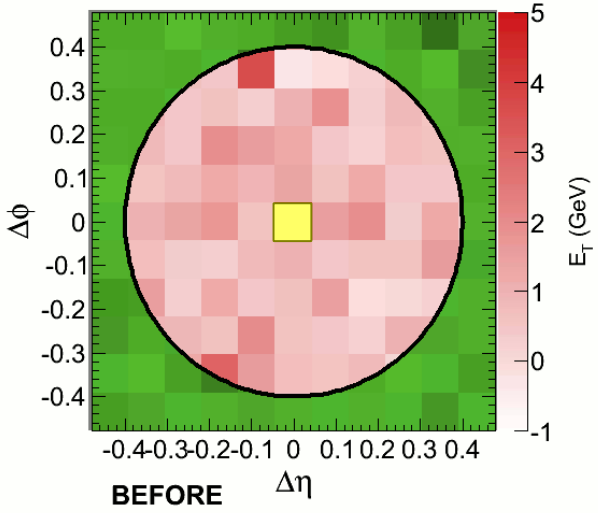


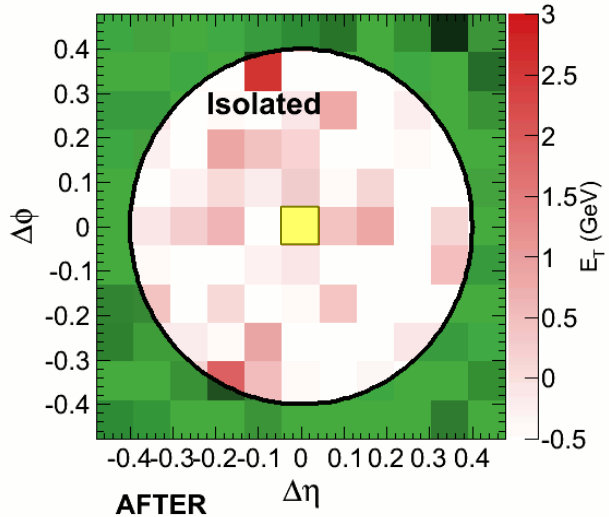
Background subtraction

- Background subtracted isolation variables by using the mean E_T per unit area in the η strip and remove the underlying event contribution inside the isolation cone ΔR<0.4



Isolated photon





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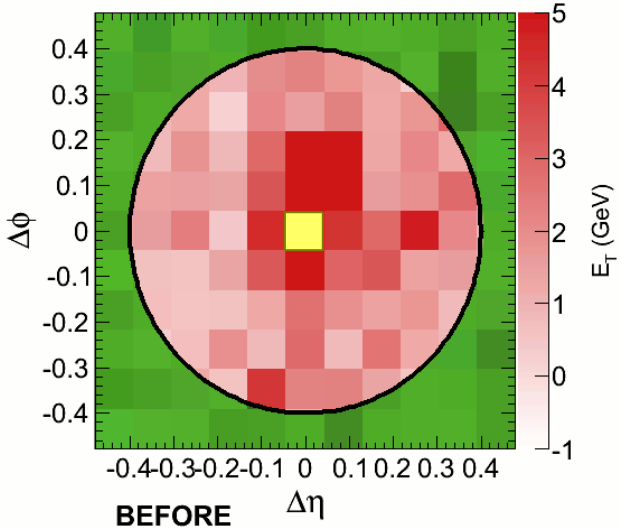

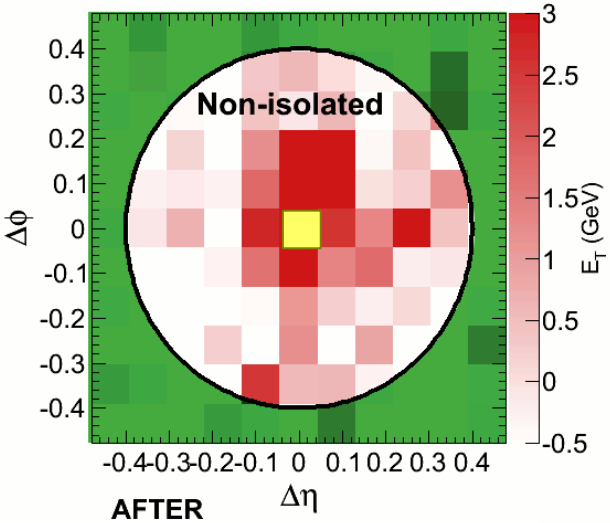

Background subtracted isolation in PbPb

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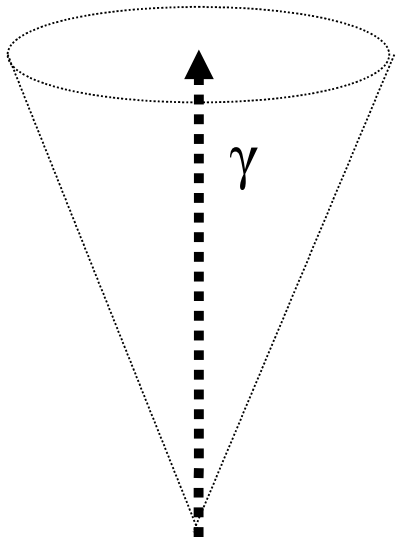
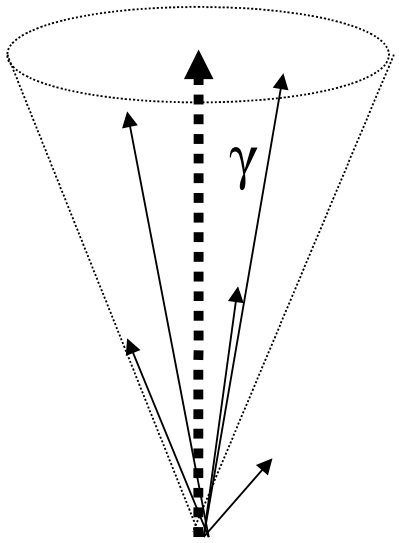
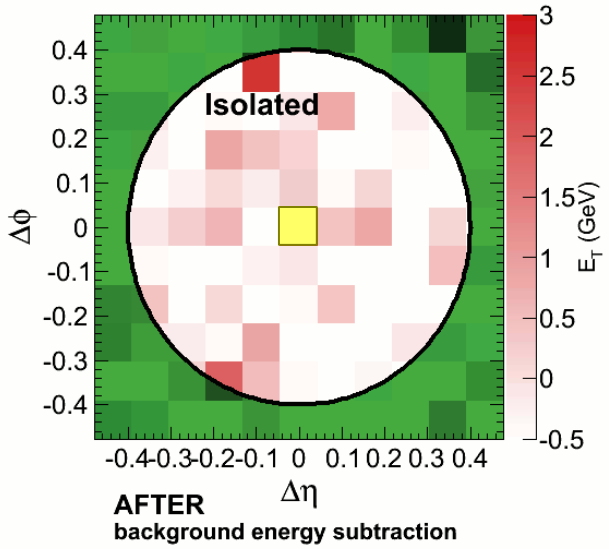




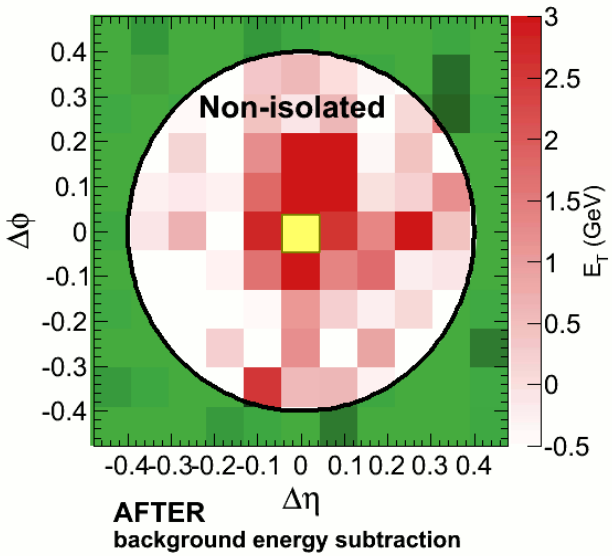
CMS Experiment

Sum E_T (p_T) from Calorimeter and tracker < 5 GeV with background subtracted

Isolated photon

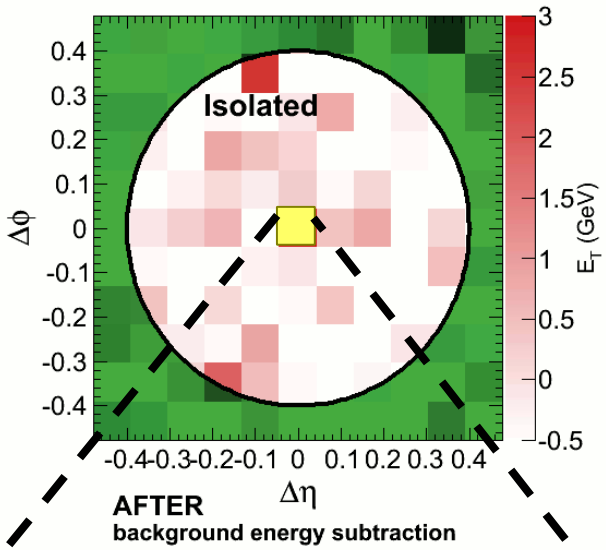


Photon candidate from jet

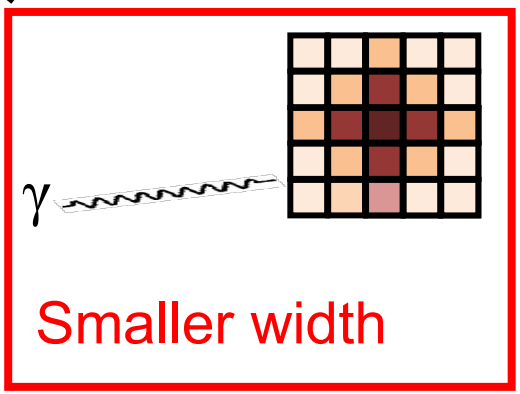


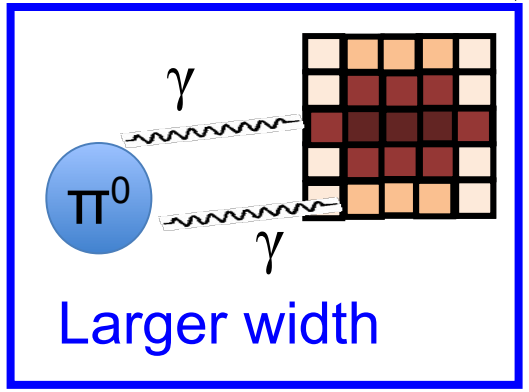
Photon signal extraction

- Isolated electrons are rejected by tracking information
- Even after isolation cut, some π^0 and η still remain
  - Fragmented from jets with high-z, becoming isolated π^0 and η
- Impossible to reject event-by-event
- Solution: Use CMS ECAL's fine segmentation
  - $\Delta\eta \times \Delta\Phi$ = 0.0174 x 0.0174

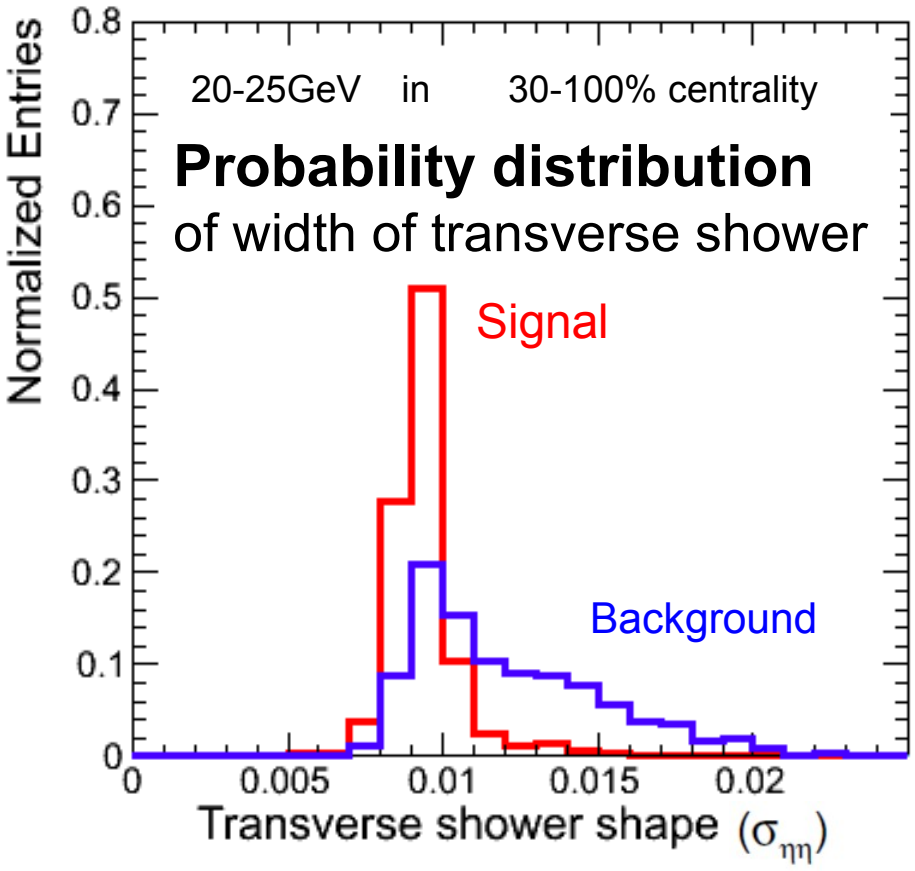


Transverse shower shape with ECAL crystals

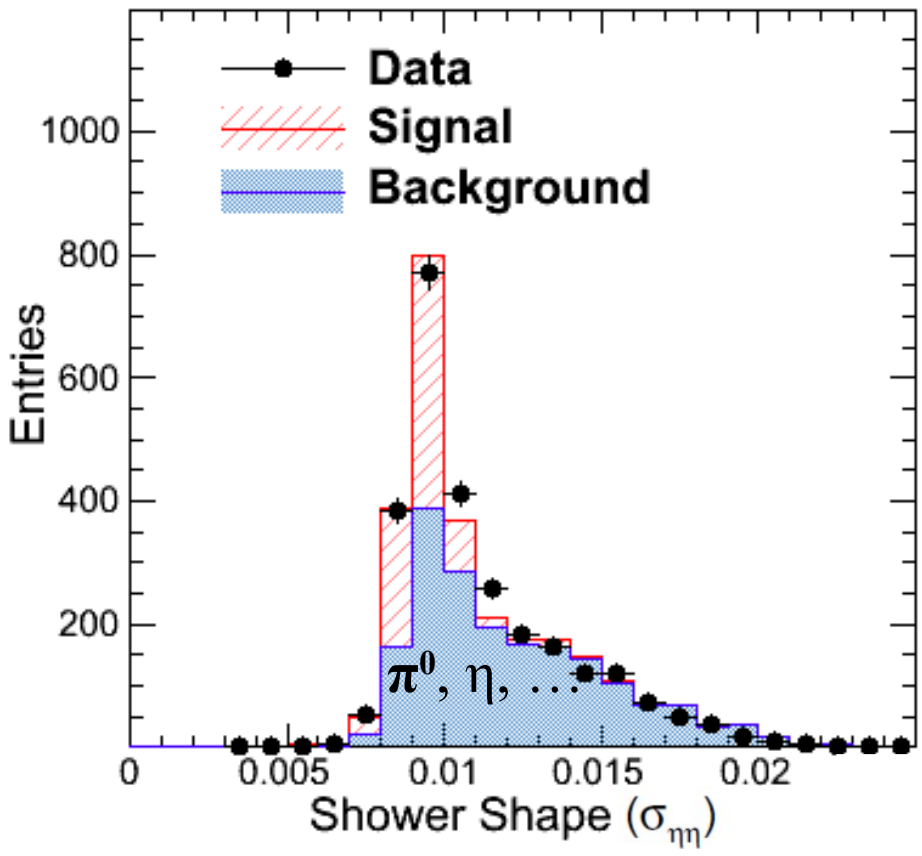




Photon signal extraction



Fit



$$\sigma_{\eta\eta}^2 = \frac{\sum_i w_i(\eta_i - \bar{\eta})^2}{\sum_i w_i}, \quad w_i = \max\left(0, 4.7 + \ln\frac{E_i}{E}\right)$$

- A technique also used in CMS pp analysis
- Signal template: obtained from PYTHIA+MinBias data
- Background template: obtained from non-isolated π^0,η in jet, (a data driven method)

Template fit performance

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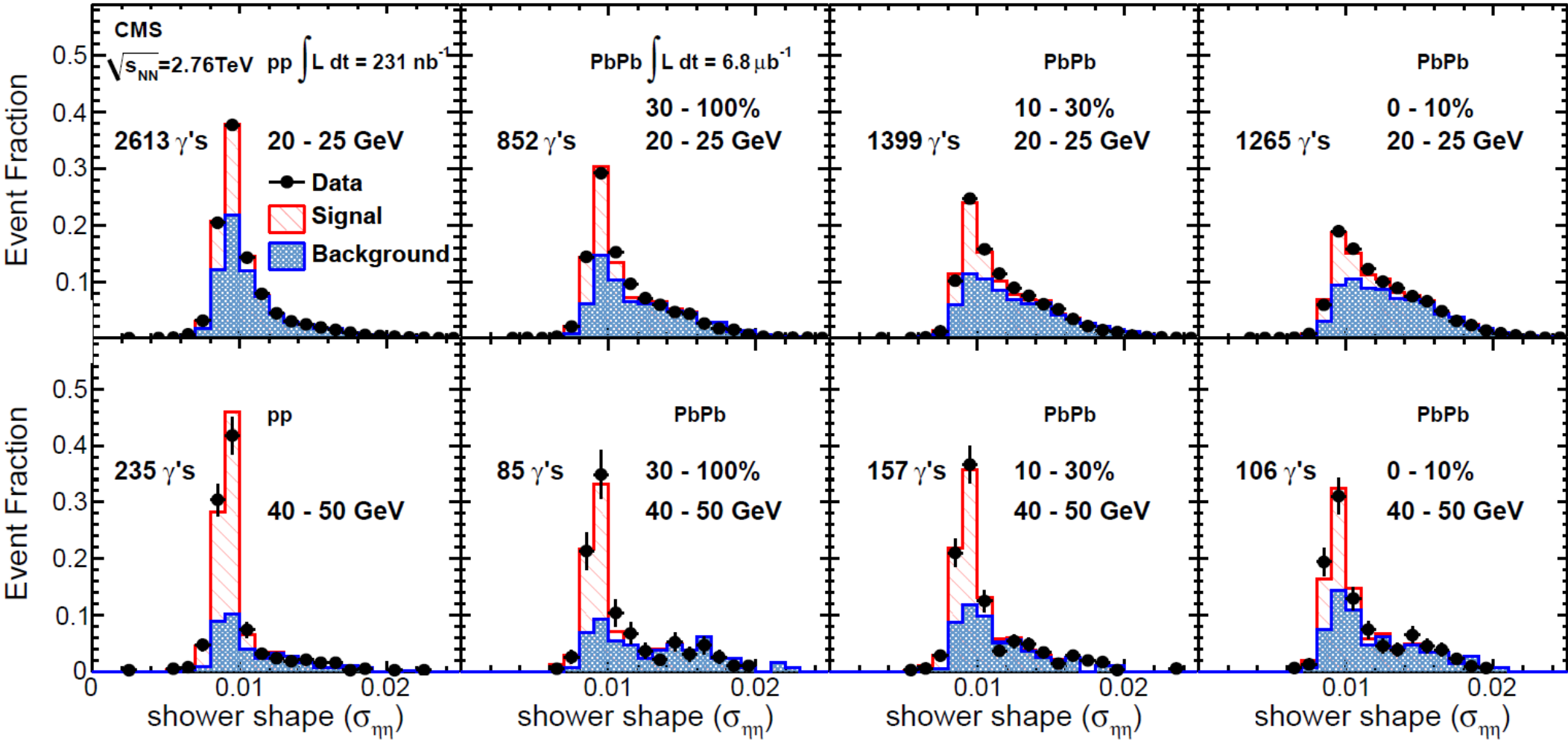

- Signal template and background template are obtained in photon E_T and collision centrality bins

Systematic uncertainties

Source	pp	PbPb centrality 0–10%	10–30%	30–100%
Efficiency	1–5%	5–9%	5–7%	5–6%
Signal modeling	3–5%	1–5%	3–5%	1–4%
Background modeling	9–13%	15–23%	14–16%	12–21%
Electron veto	1%	3–6%	3–5%	3–5%
Photon isolation definition	2%	7%	5%	2%
Energy scale	3–6%	9%	9%	9%
Energy smearing	1%	4%	4%	4%
Shower-shape fit	3%	5%	5%	5%
Anomalous signal cleaning	1%	1%	1%	1%
N_{MB}	–	3%	3%	3%
Luminosity	6%	–	–	–
Total without T_{AA}	14–16%	23–30%	22–25%	23–28%
T_{AA}	–	4%	6%	12%
Total	14–16%	23–30%	23–26%	26–31%

- Main sources of systematic uncertainties:
  Background modeling and photon energy scale.

Photon E_T spectra in pp and PbPb collisions

- The reconstructed photon spectra in each centrality bin is scaled by T_{AA}

- Results are consistent JETPHOX calculation using pp PDF (CT10).

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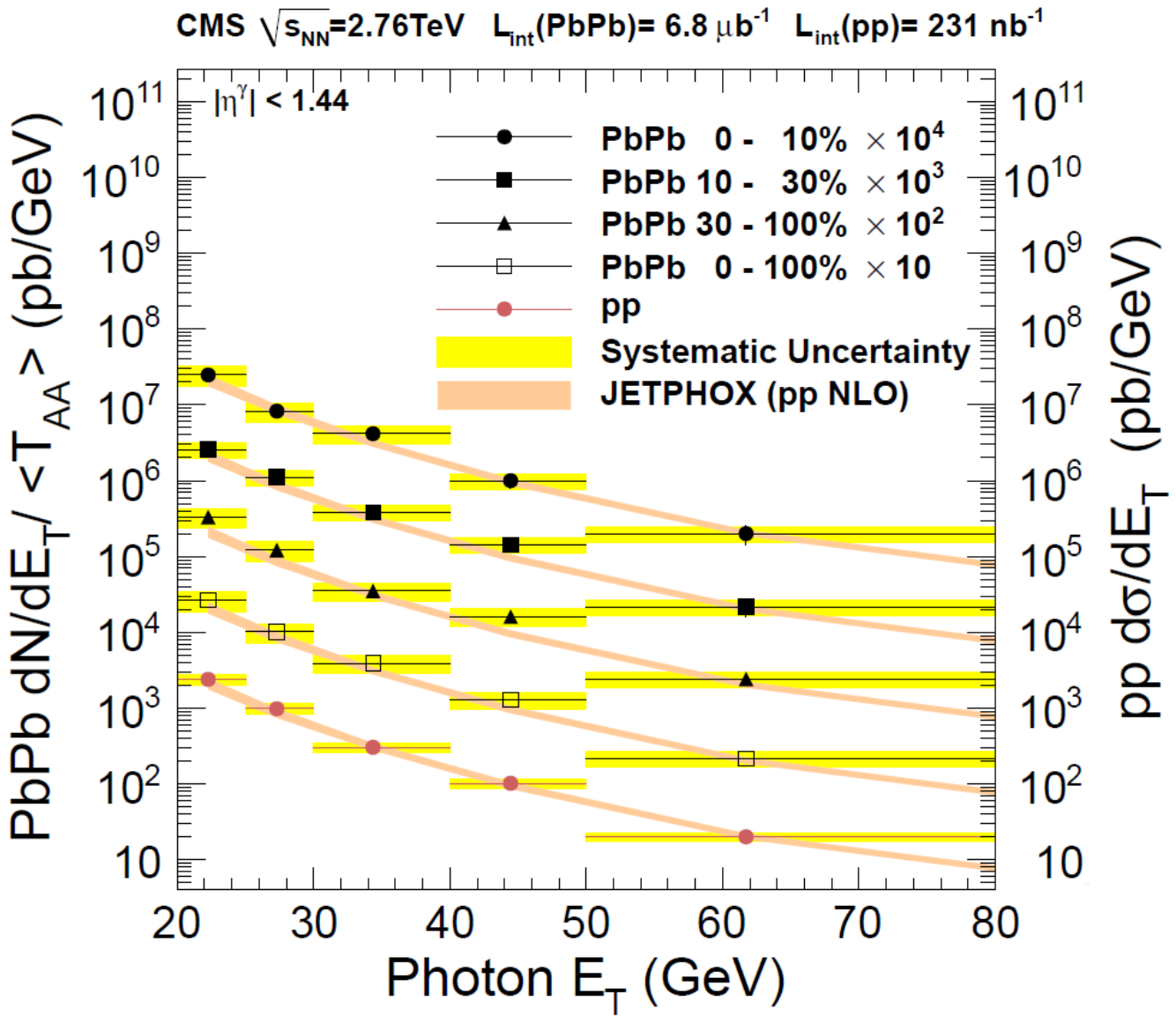

Isolated photon R_{AA} in 0-10% PbPb collisions

- CMS measured the isolated photon R_{AA} for the first time

$$R_{AA} = \frac{\sigma_{pp}^{inel}}{\langle N_{coll} \rangle} \frac{d^2 N_{AA}/dp_T d\eta}{d^2 \sigma_{pp}/dp_T d\eta}$$

- pp reference:
  pp collisions at 2.76 TeV

- Photon R_{AA} at 0-10% is consistent with unity

- Results are compared to NLO calculations with nPDFs: EPS09, nDS and HKN07

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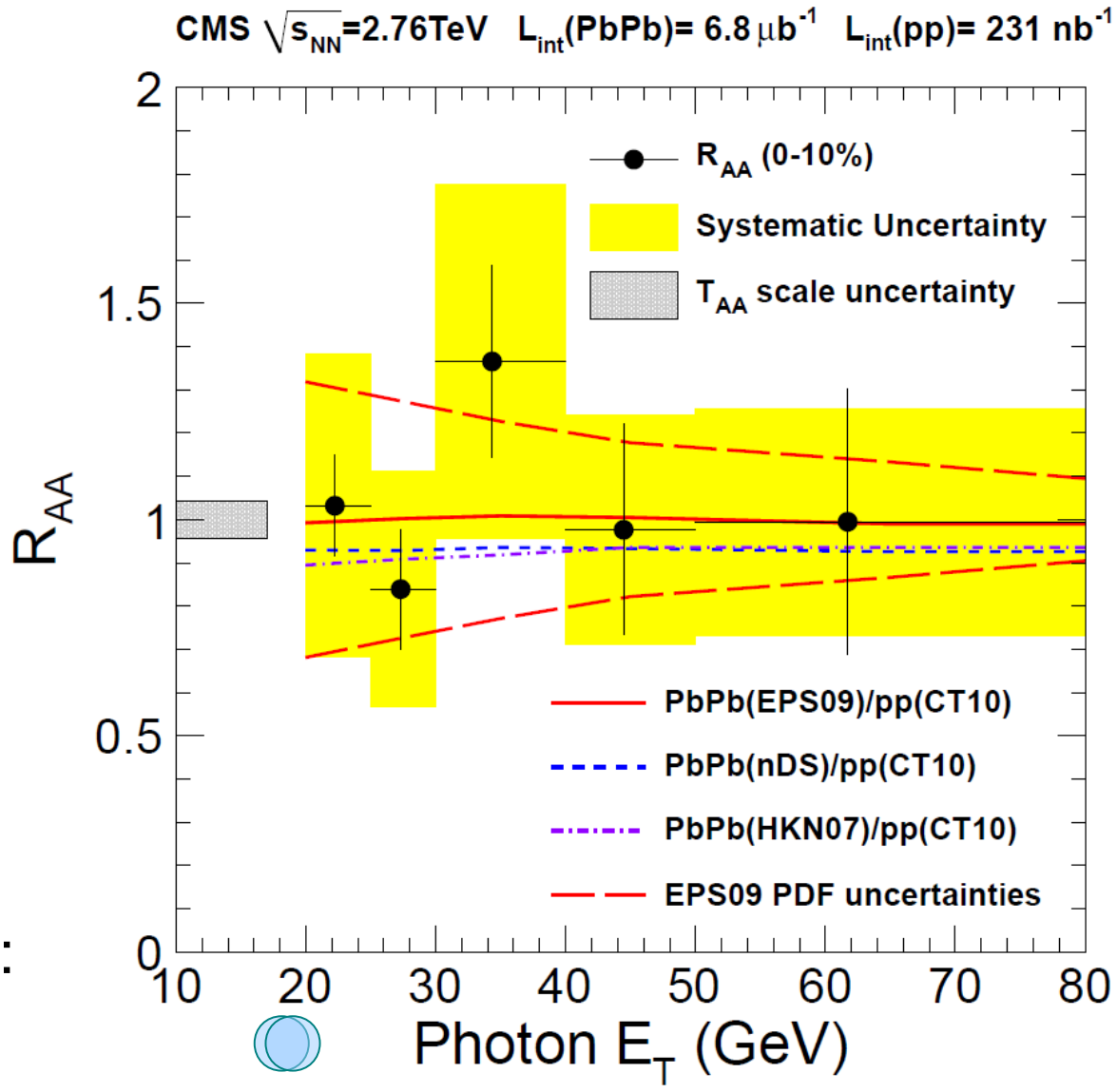
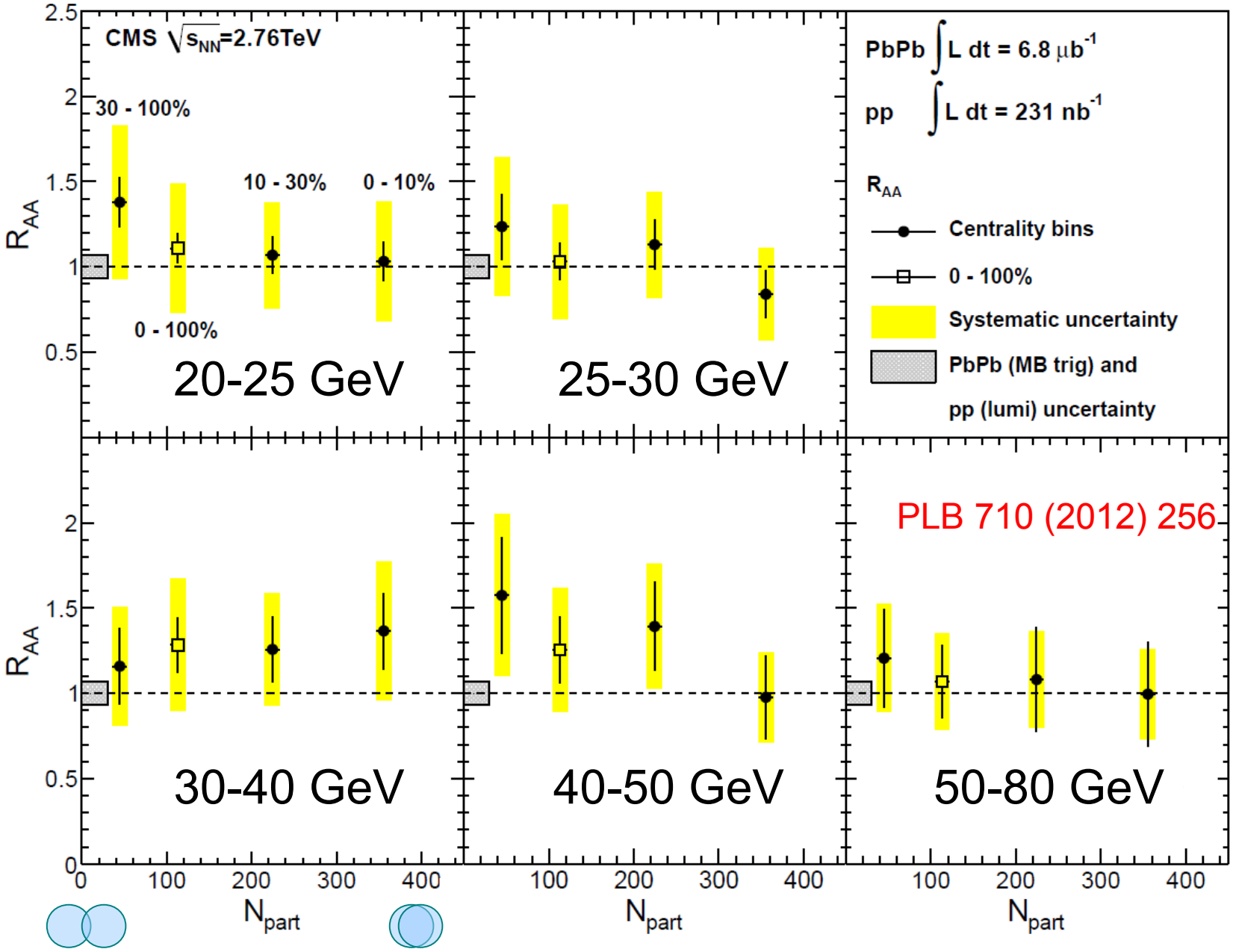


Isolated photon R_{AA} vs N_{Part}



No centrality and E_T dependence

Summary

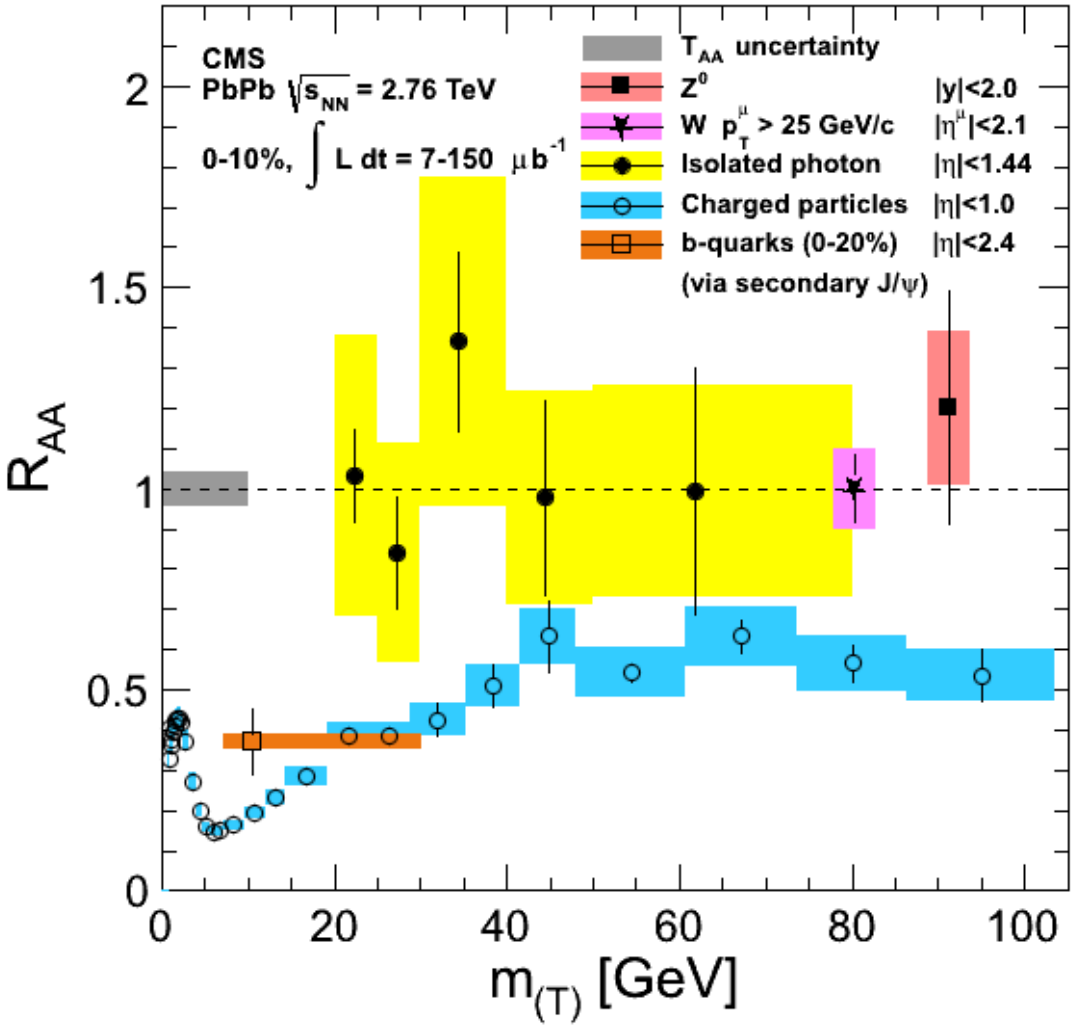
- No strong modification of the initial state observed

- Hard scattering processes scale with the number of binary collisions from the Glauber model

- Baseline for the study of charged particle and jet production

- Establishes the basis for the studies which use photons as unmodified hard probes

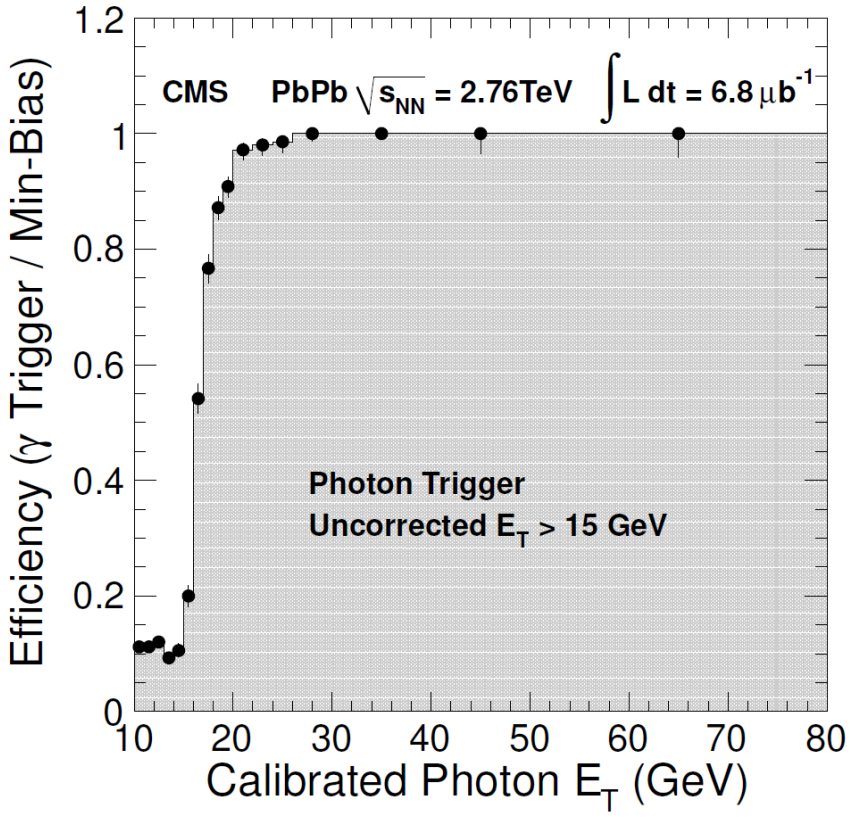
PbPb 0-10% Central

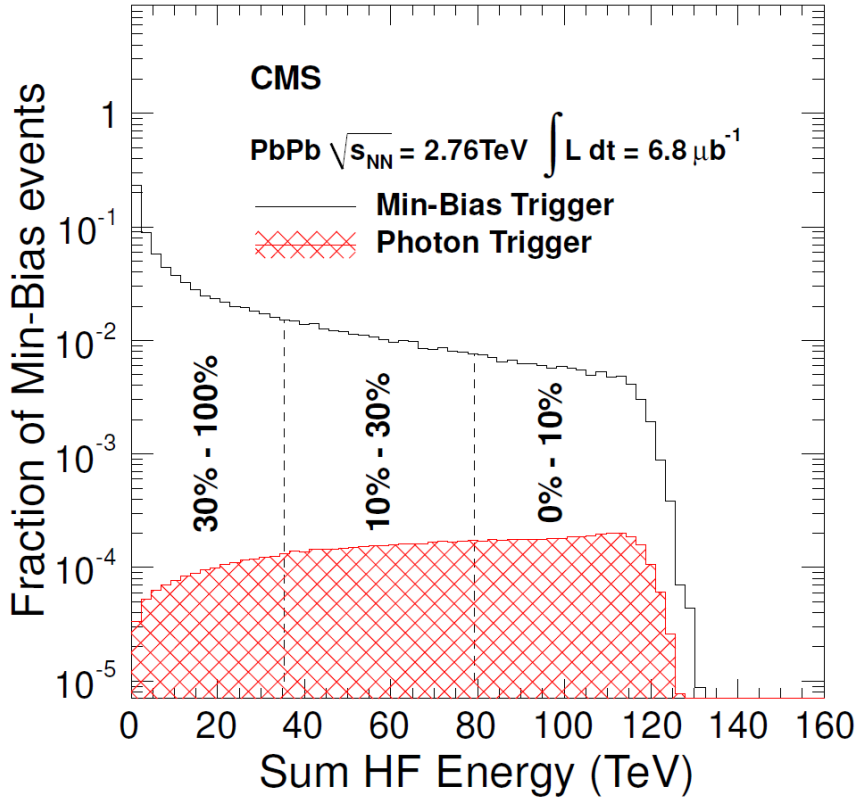


Data Table: https://twiki.cern.ch/twiki/bin/view/CMSPublic/HIN11002Data

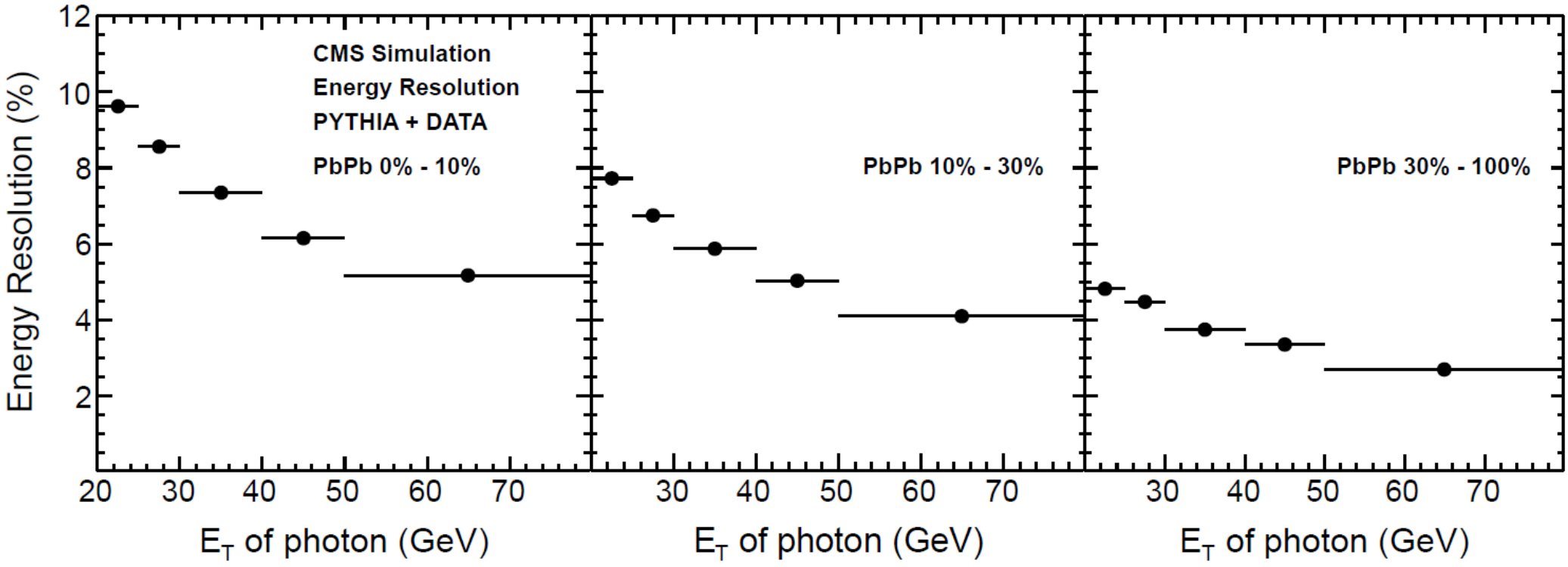
Backup slides

Trigger and event centrality distributions





Photon reconstruction performance



Photon selection efficiency

Isolated photon identification	PbPb centrality 0–10%	10–30%	30–100%
Supercluster reconstruction	96–99%	97–99%	97–99%
Anomalous signal removal	99–100%	99–100%	99–100%
$H/E < 0.2$	96–99%	98–99%	99–100%
$\mathrm{SumIso}^{\mathrm{UE-sub}} < 5\,\mathrm{GeV}$ 4	82–84%	86–88%	96–97%
Total	77–82%	83–86%	92–95%

pQCD factorization