Inclusive isolated photons in pp and PbPb collisions at 2.76 TeV with CMS

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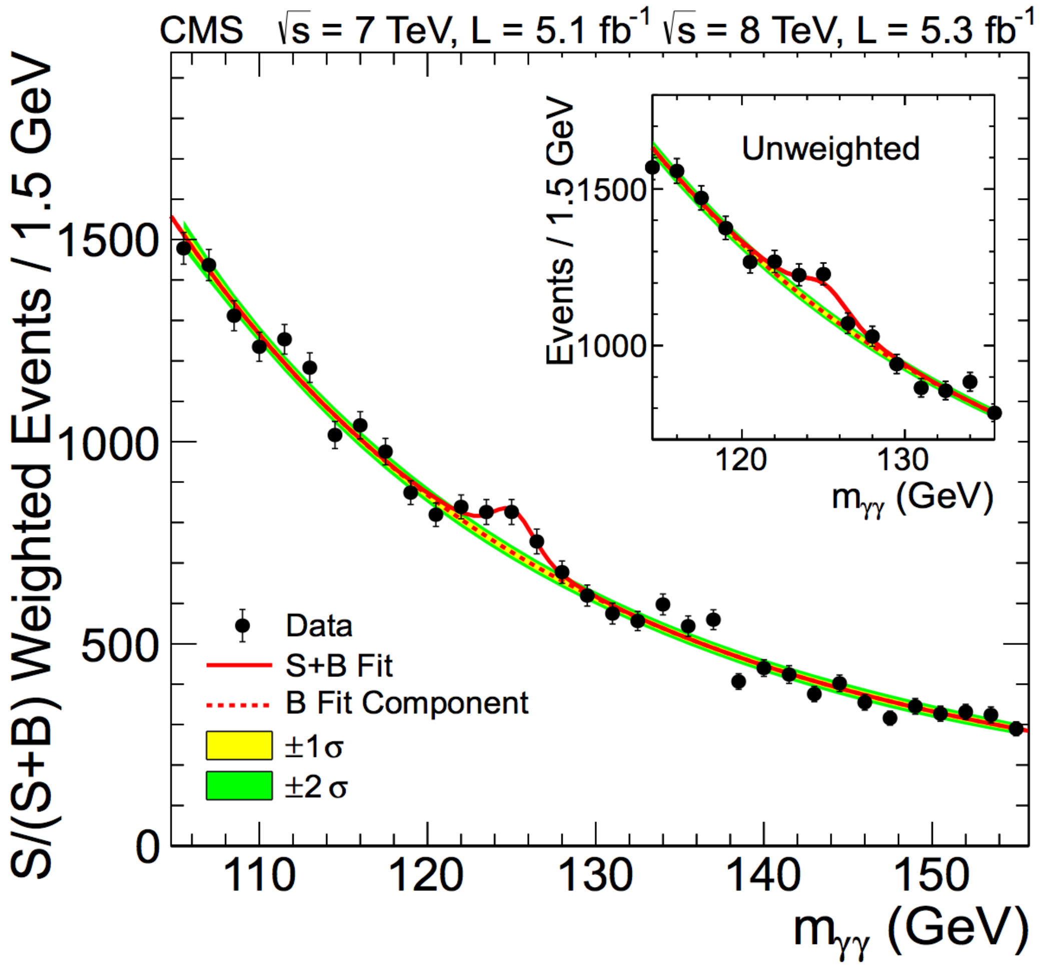
For the CMS Collaboration

Why photons?

- Photons from CMS recently used to explore the fundamental origin of mass

Higgs(?)→γγ



arXiv:1207.7235 (accepted by PLB)

- BUT …

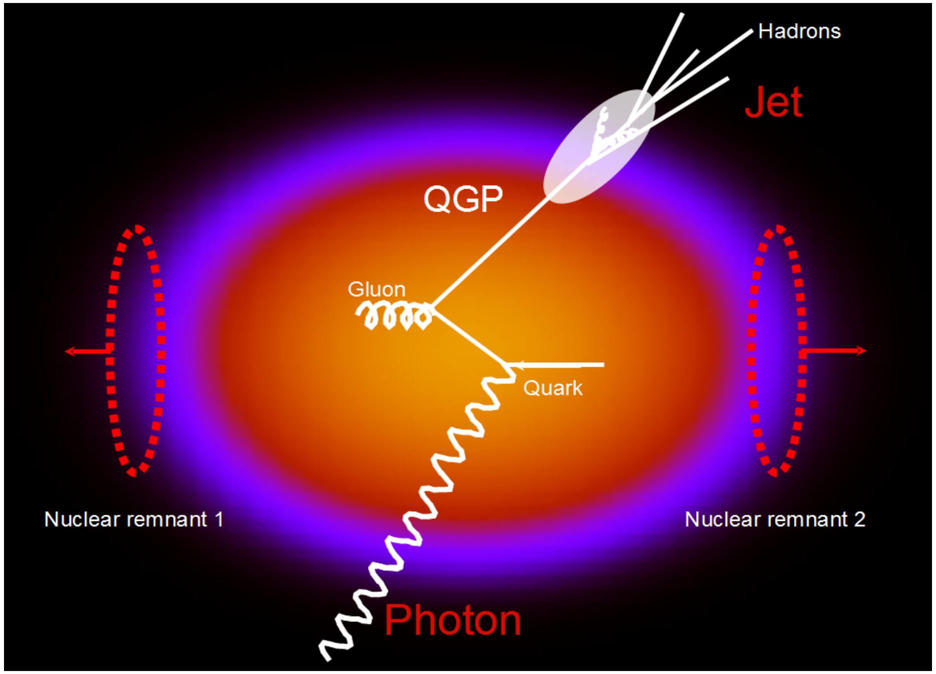
Why photons?

- Higgs mechanism provides only a few % of the mass of things most non-physicists care about (stars, planets, people, iPads …)
  - > The vast majority of the mass is provided by non-perturbative interactions of quarks & gluons

- CMS photons also used to study this "other" source of mass
  - > Probe quarks & gluons pushed to extremes of temperature and density

Why photons?

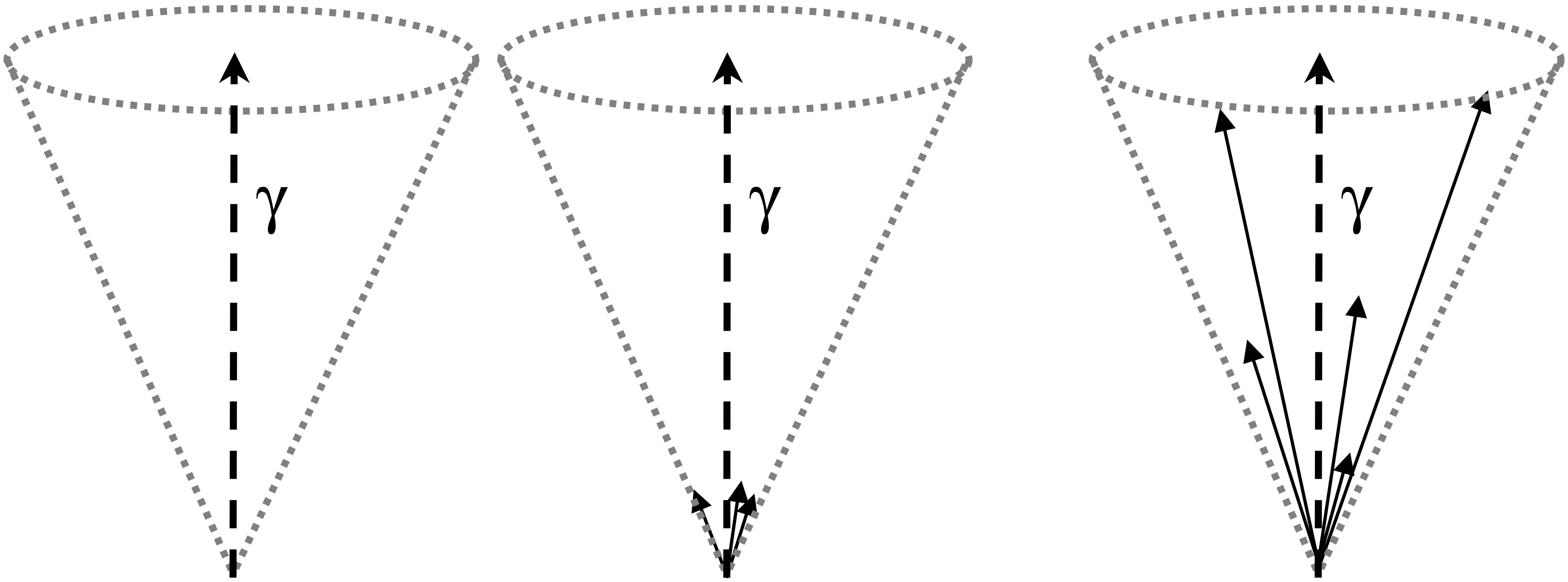
- Yield of directly produced high pT photons can be predicted theoretically
  - > Properties of the initial state (parton density functions in nuclei, number of nucleon-nucleon collisions)
- Photons are unaffected by the medium



This talk: Test these two assumptions

What is an *isolated* photon?

- An “isolated” photon is one which has very little, if any, energy carried by particles emitted close to the photon direction



Isolated | Isolated | Non-isolated

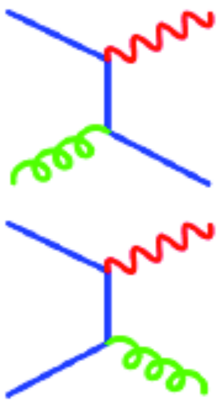
Why *isolated* photons?

- Photons mechanisms: Direct production (the needle we want), particle decay (the haystack), fragmentation (small effect), bremsstrahlung (negligibly small effect)

Direct production

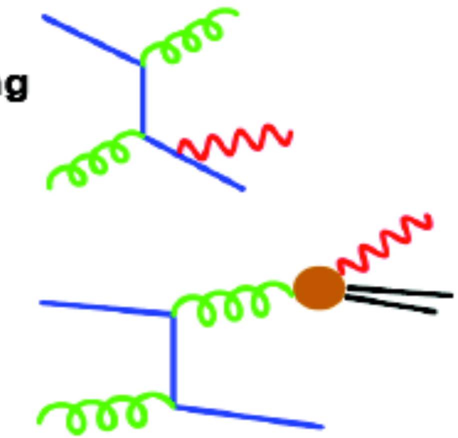
Compton

Annihilation



Bremsstrahlung

Fragmentation

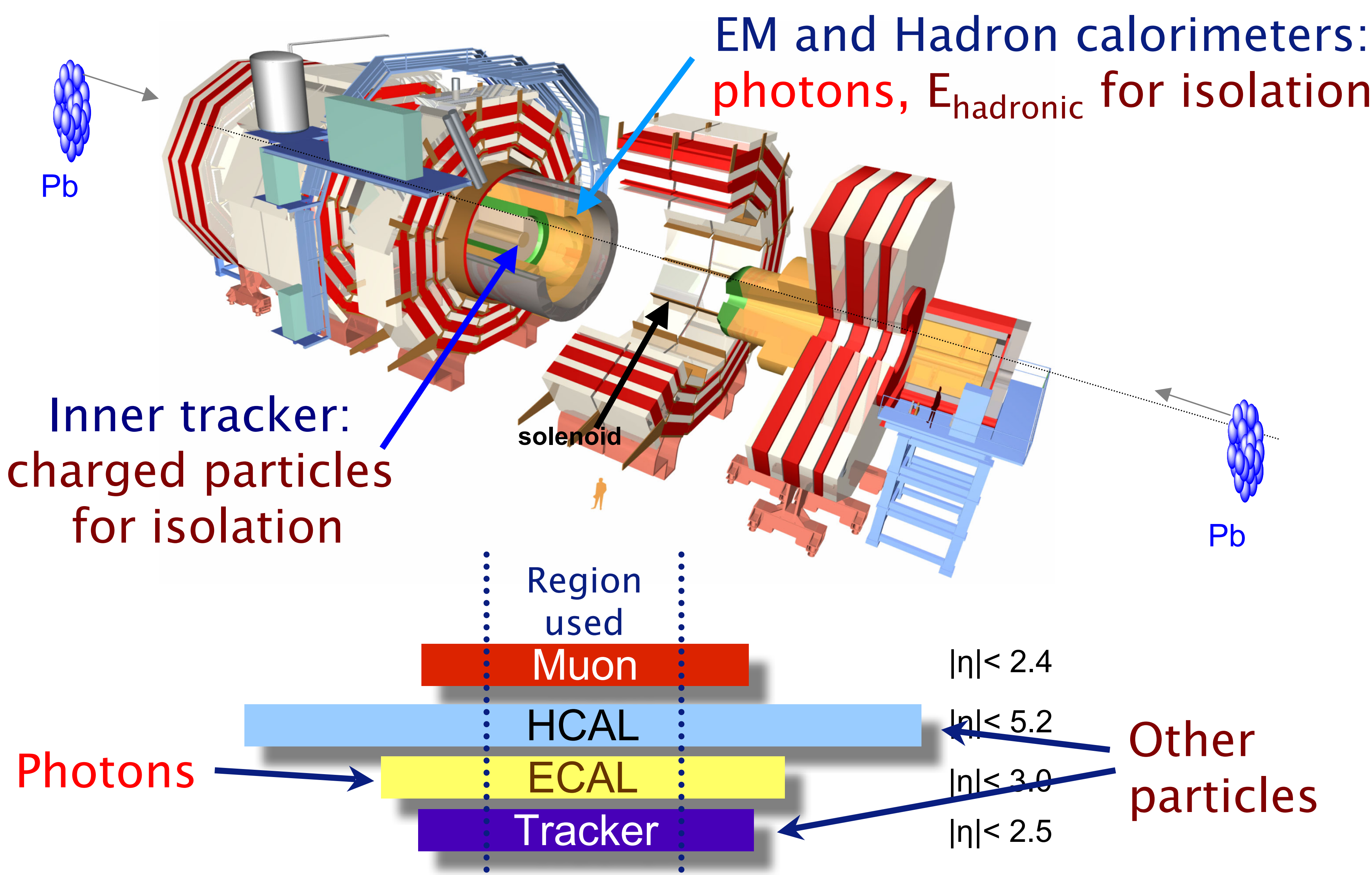


Processes we want produce isolated photons

Processes we don't want, incl. decay (not shown), dominated by non-isolated photons

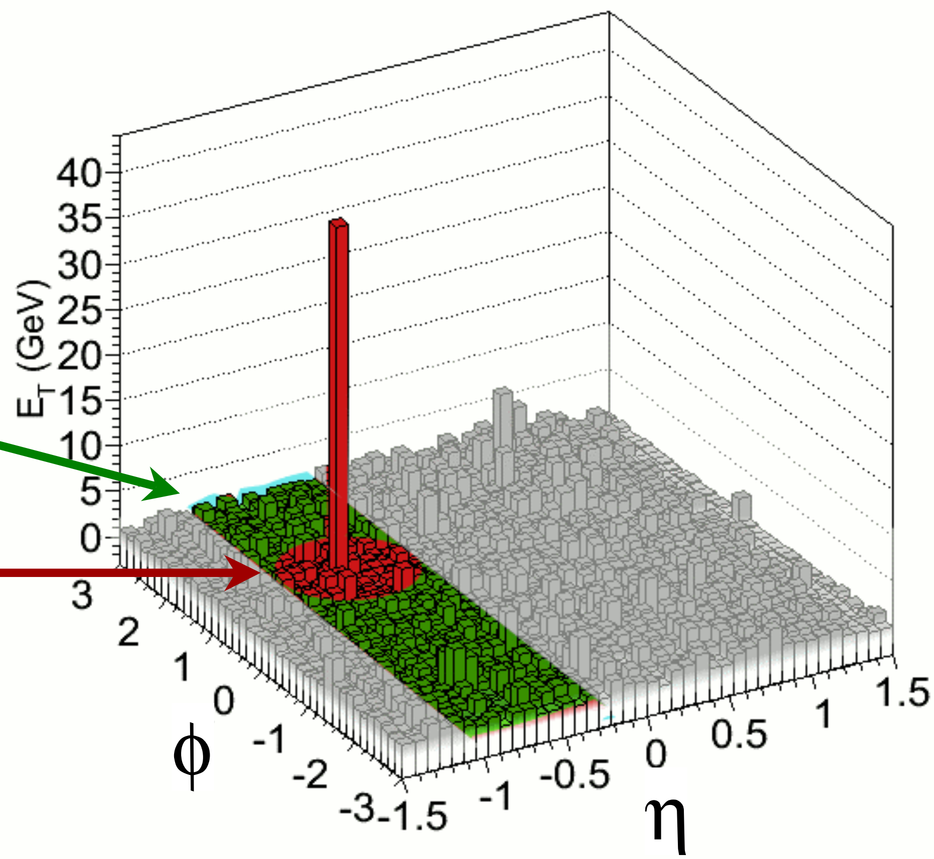
PYTHIA photons ~80% decay ~15% direct ~5% fragmentation

CMS detector



Background subtraction in PbPb

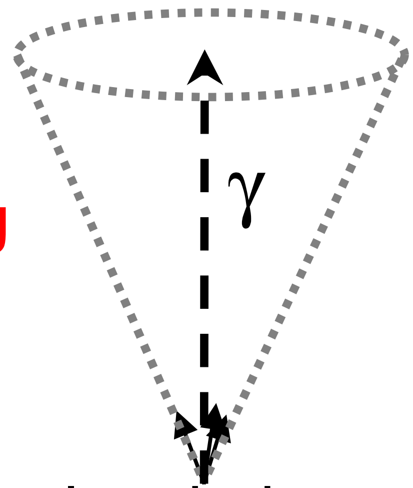
- In PbPb collisions, almost ***no*** photons are isolated due to other particles from the underlying event
- Use the mean E_T per unit area in an η strip to subtract background inside the isolation cone $\Delta R<0.4$



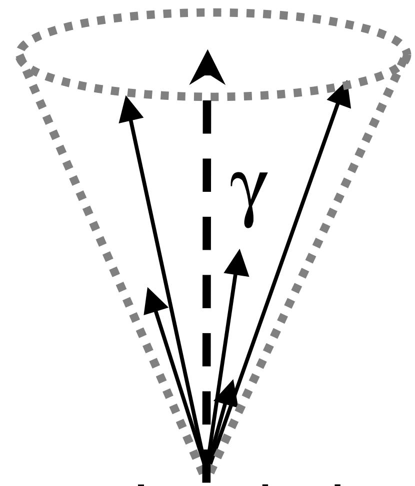
Photon isolation criteria

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

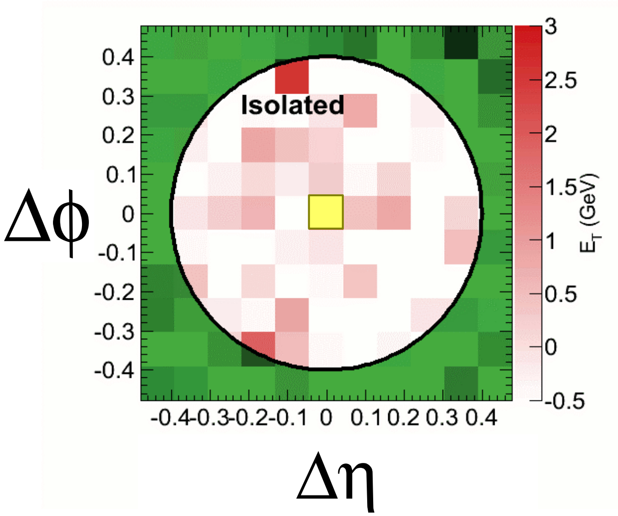
CMS Data: $\Delta R<0.4$
$\Sigma E_T^{IsoCone} < 5$ GeV
using the calorimeter and tracker minus background

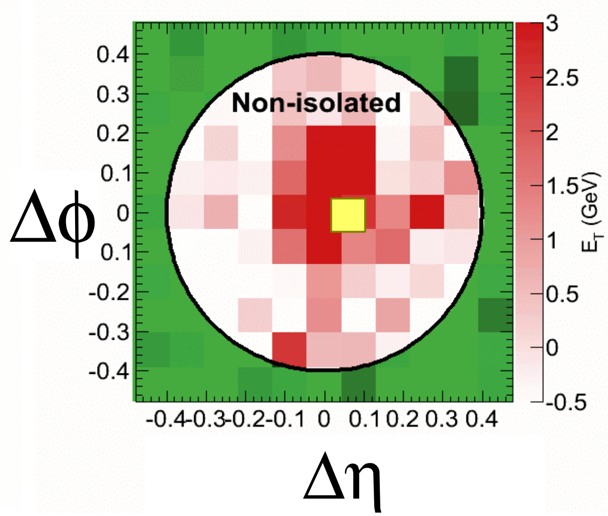


Isolated photon



Non-isolated photon

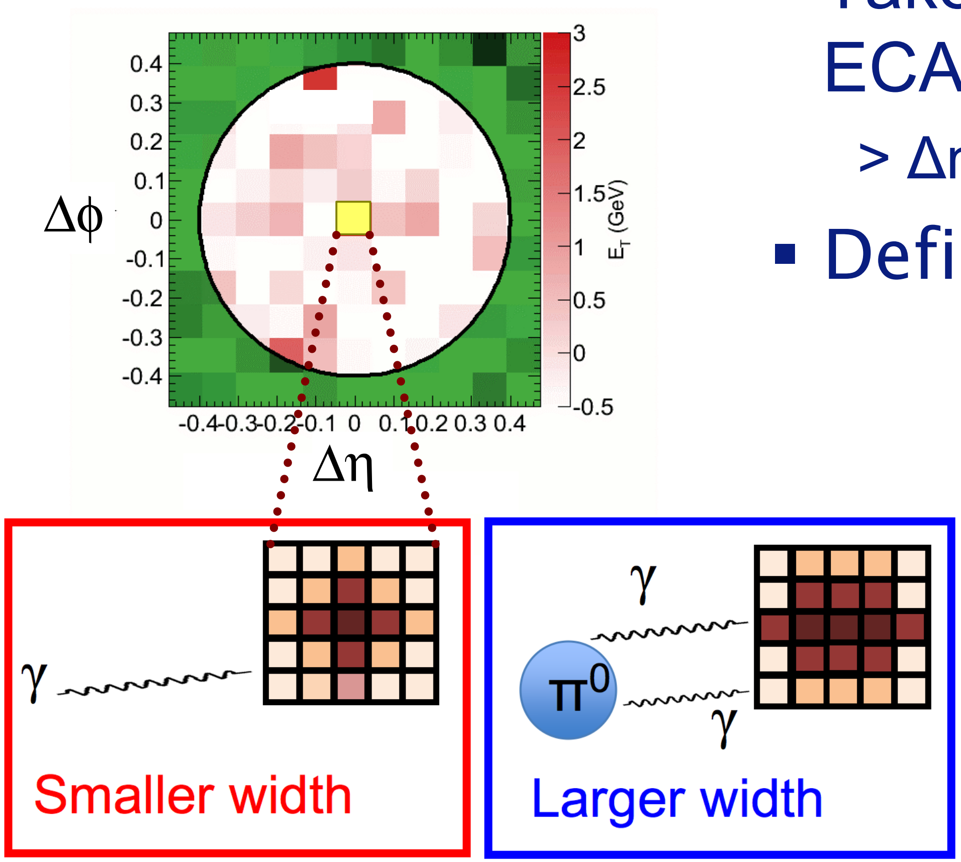




Removing electrons

- Isolated electrons are rejected using tracking
  - > Reject "photons" that are close in η and ϕ to tracked electron candidates
- Fraction of electrons that "escape" these cuts estimated from PYTHIA $W \rightarrow e\nu$ decays embedded into minimum bias PbPb data
- Small correction (~4-8%) to photons found using this "escape" ratio and measured electron yields

Removing decay photons

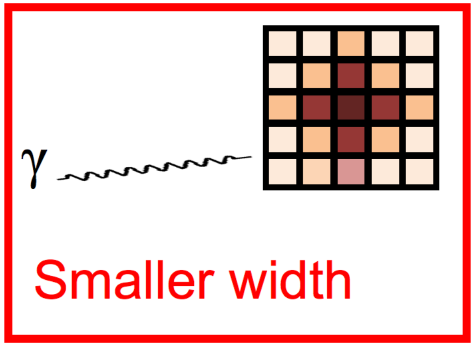


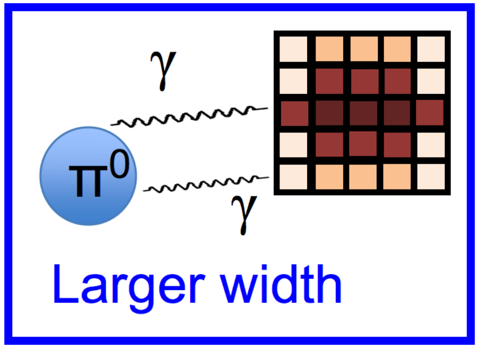
- Take advantage of CMS ECAL's fine segmentation
  - > $\Delta\eta \times \Delta\Phi = 0.0174 \times 0.0174$
- Define a "width" parameter:

$$\sigma_{\eta\eta}^2 = \frac{\sum w_i \left(\eta_i - \langle\eta\rangle\right)^2}{\sum w_i}$$

$$w_i = \max\left(0,\ 4.7 + \ln\left(\frac{E_i}{E_{Total}}\right)\right)$$

Removing decay photons





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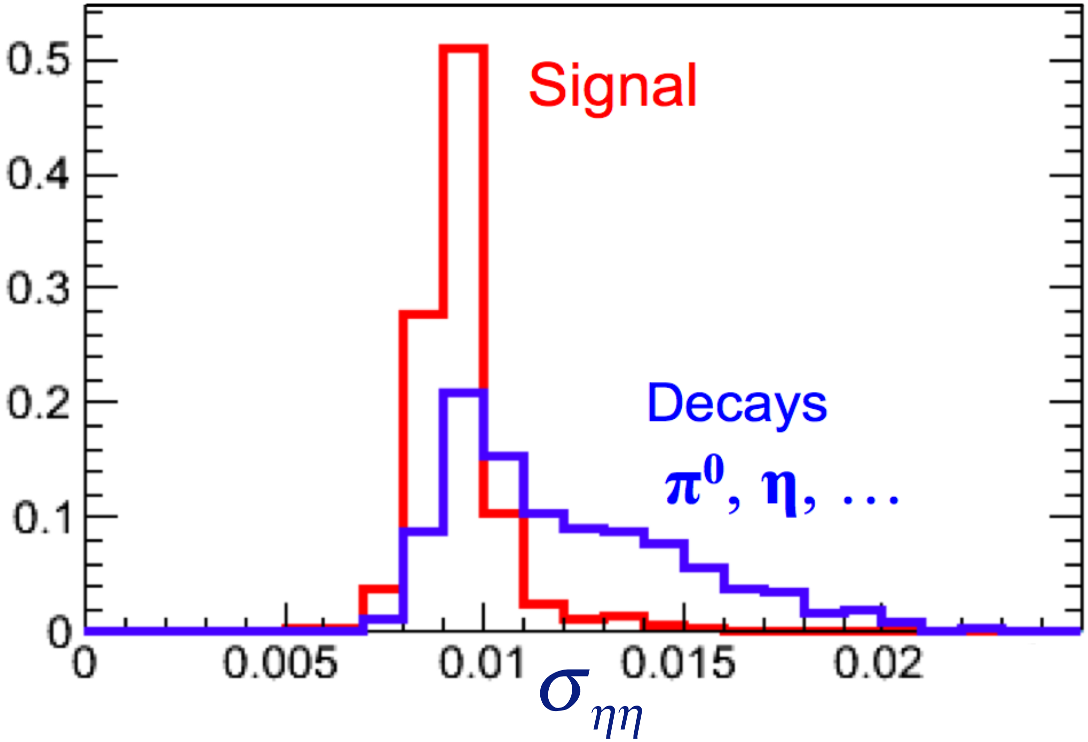


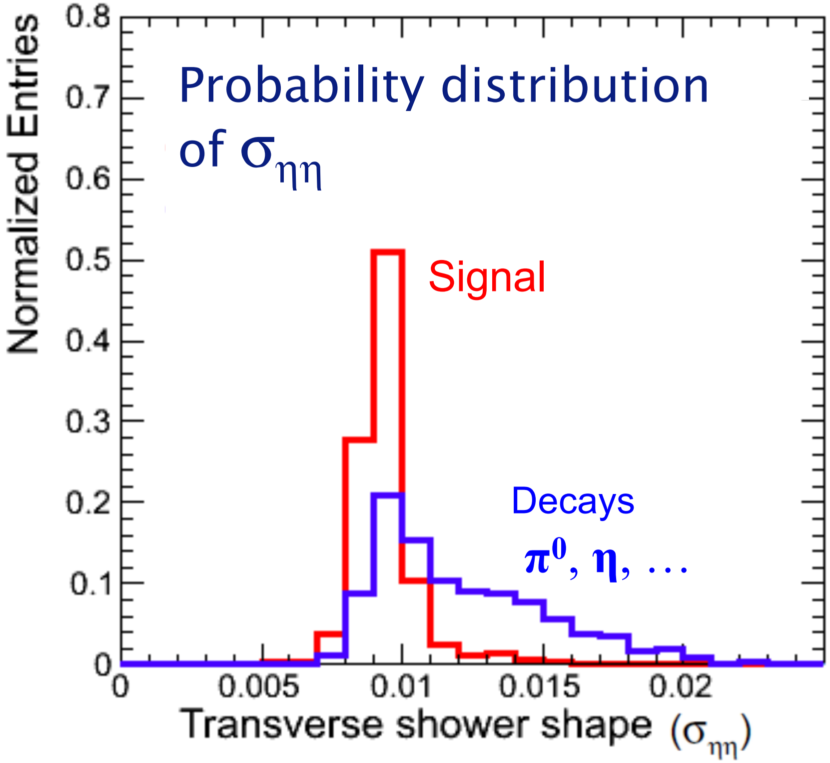
After isolation & shower shape cut:

~70% direct

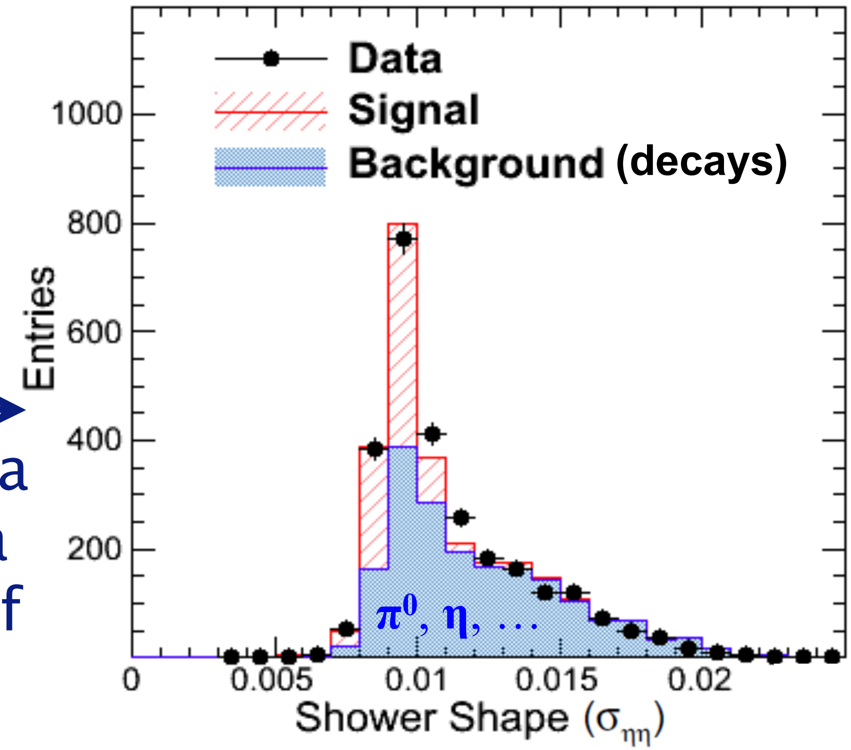
~20% decay

~10% fragmentation

Details of removing decay photons



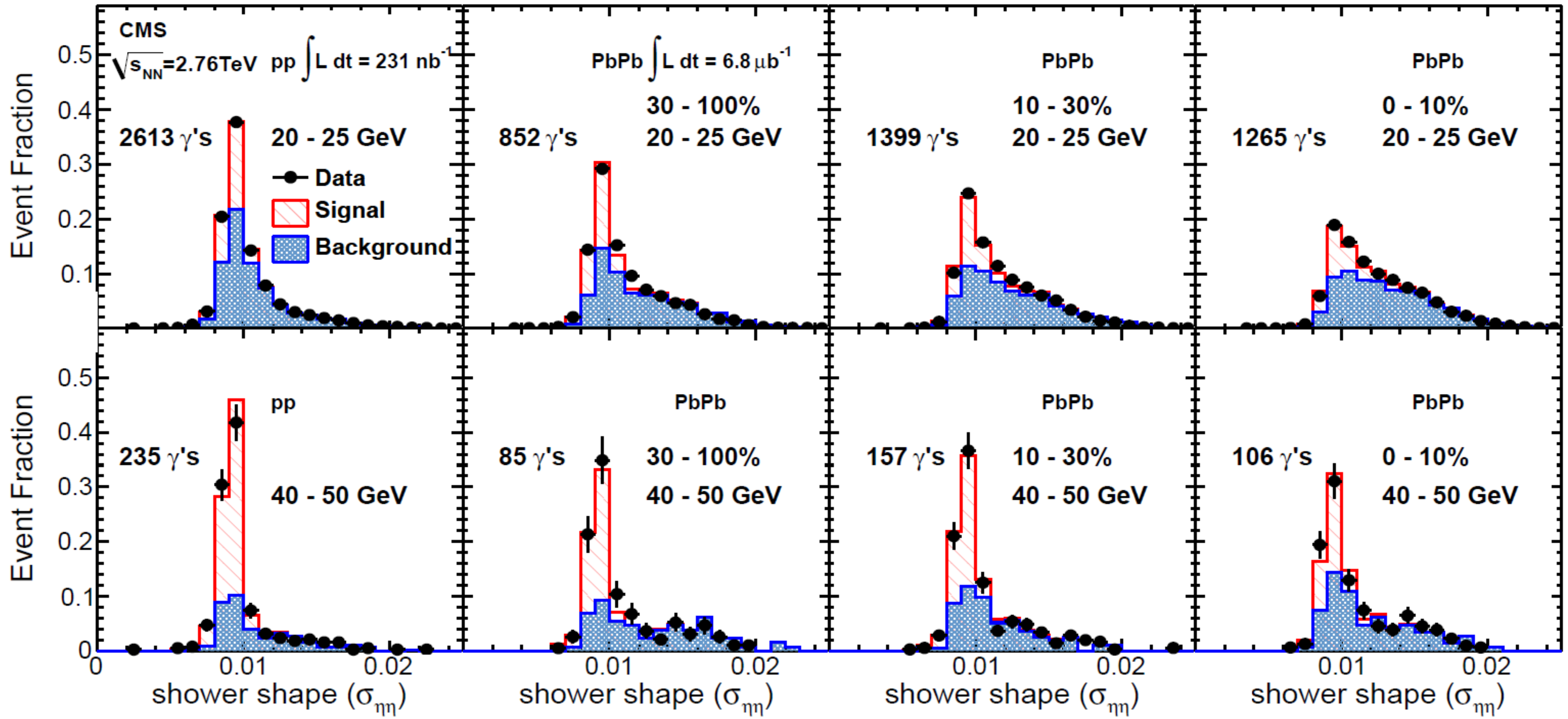
Fit data with a sum of the 2



A technique also used in CMS pp analysis:

- Signal template: obtained from PYTHIA+MinBias data
- Decay template: Using a data-driven method with non-isolated photons: $\Delta R<0.4$, $6\ \text{GeV} < \Sigma E_T^{IsoCone} < 11\ \text{GeV}$

Fitting signal+decay photons



Signal template and background (decay) template extracted in separate bins of photon E_T and collision centrality

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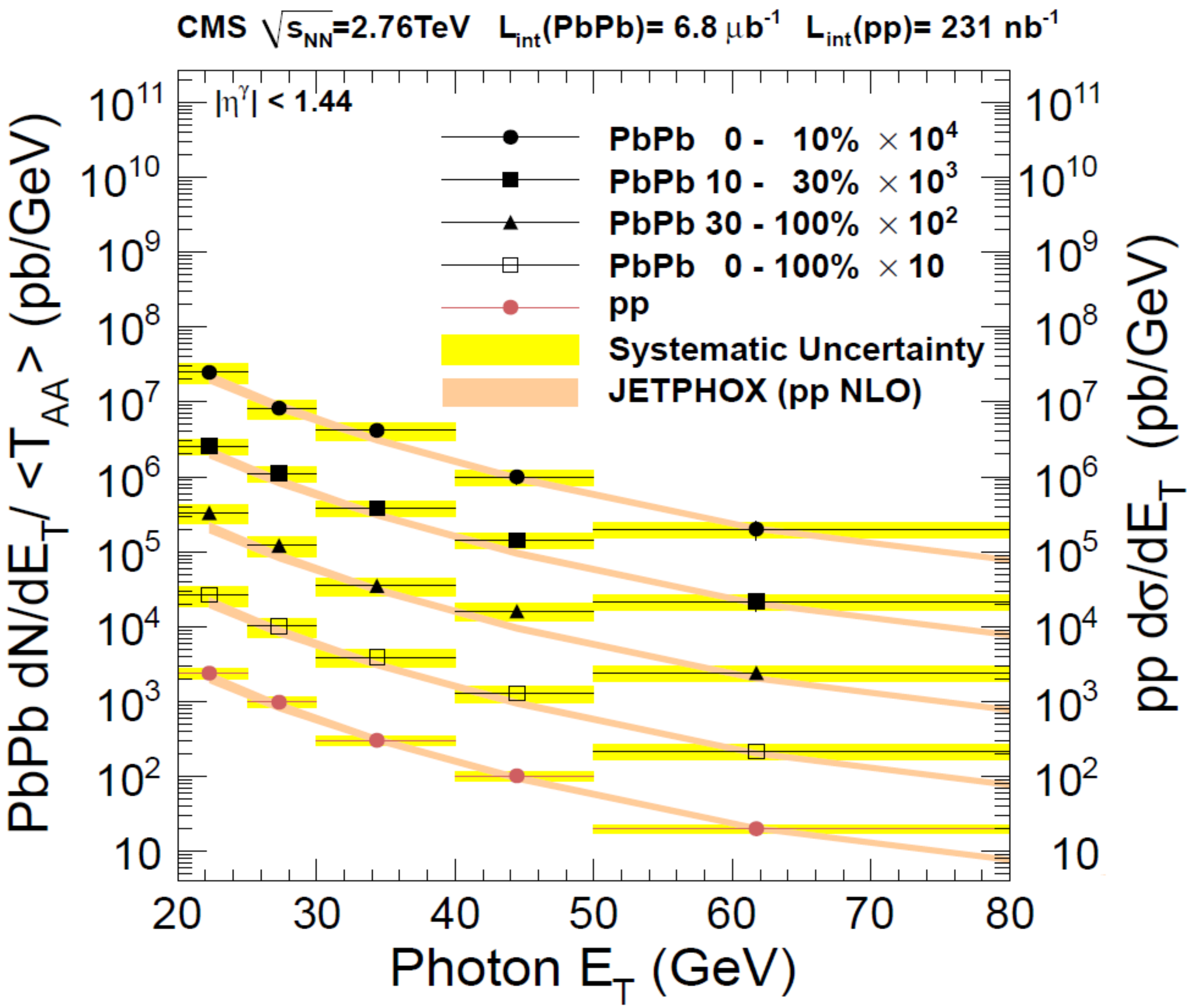
Systematic uncertainties

Source	pp	PbPb centrality 0–10%	PbPb centrality 10–30%	PbPb centrality 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

- Reconstructed photon spectra scaled by T_{AA}
- Consistent with JETPHOX using pp PDF (CT10).



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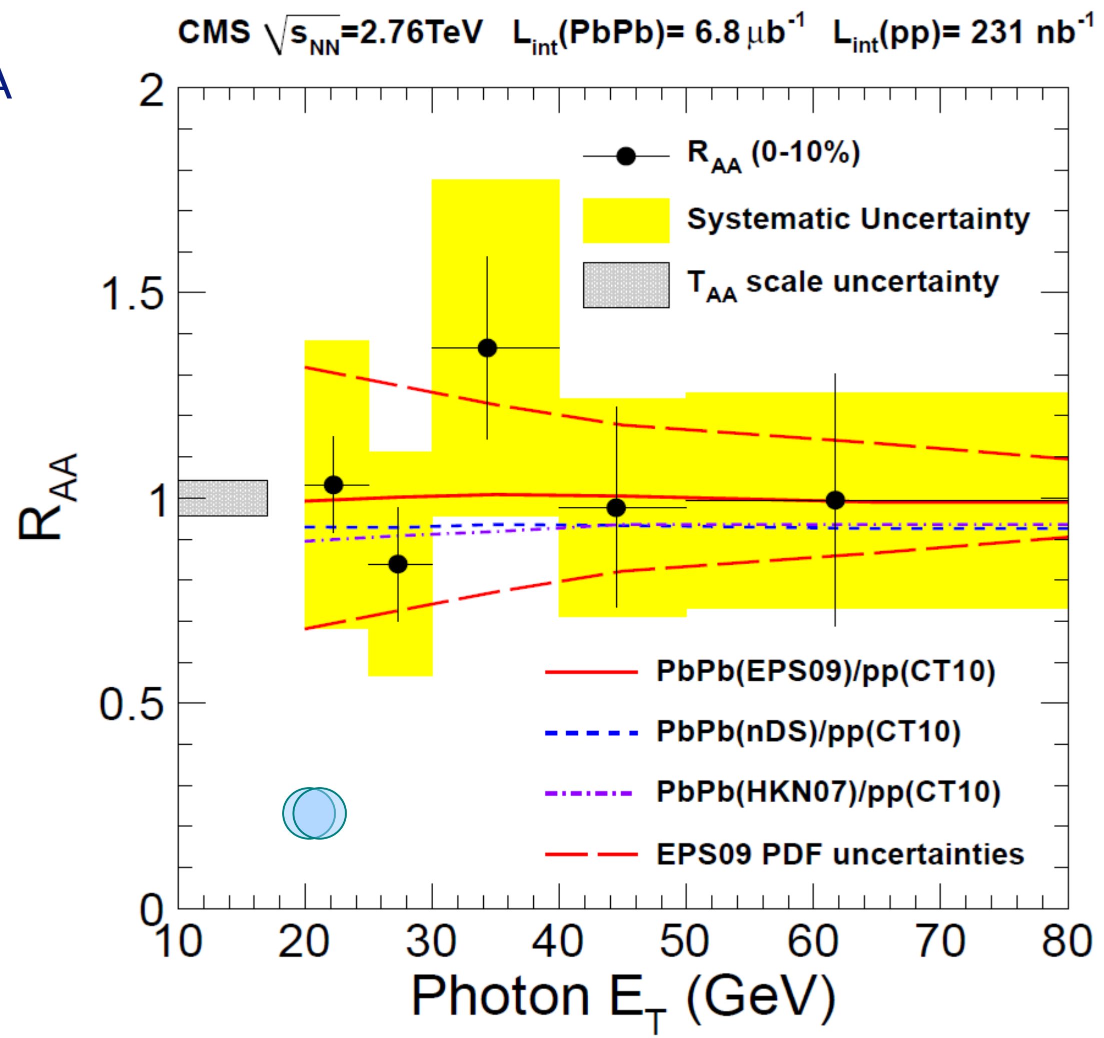
Isolated photon R_{AA} in 0-10% PbPb collisions

- CMS extracted first R_{AA} for isolated photons
- pp reference:
  pp data at 2.76 TeV
- R_{AA} consistent with 1
- Compare to NLO with nPDFs: EPS09, nDS, HKN07

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



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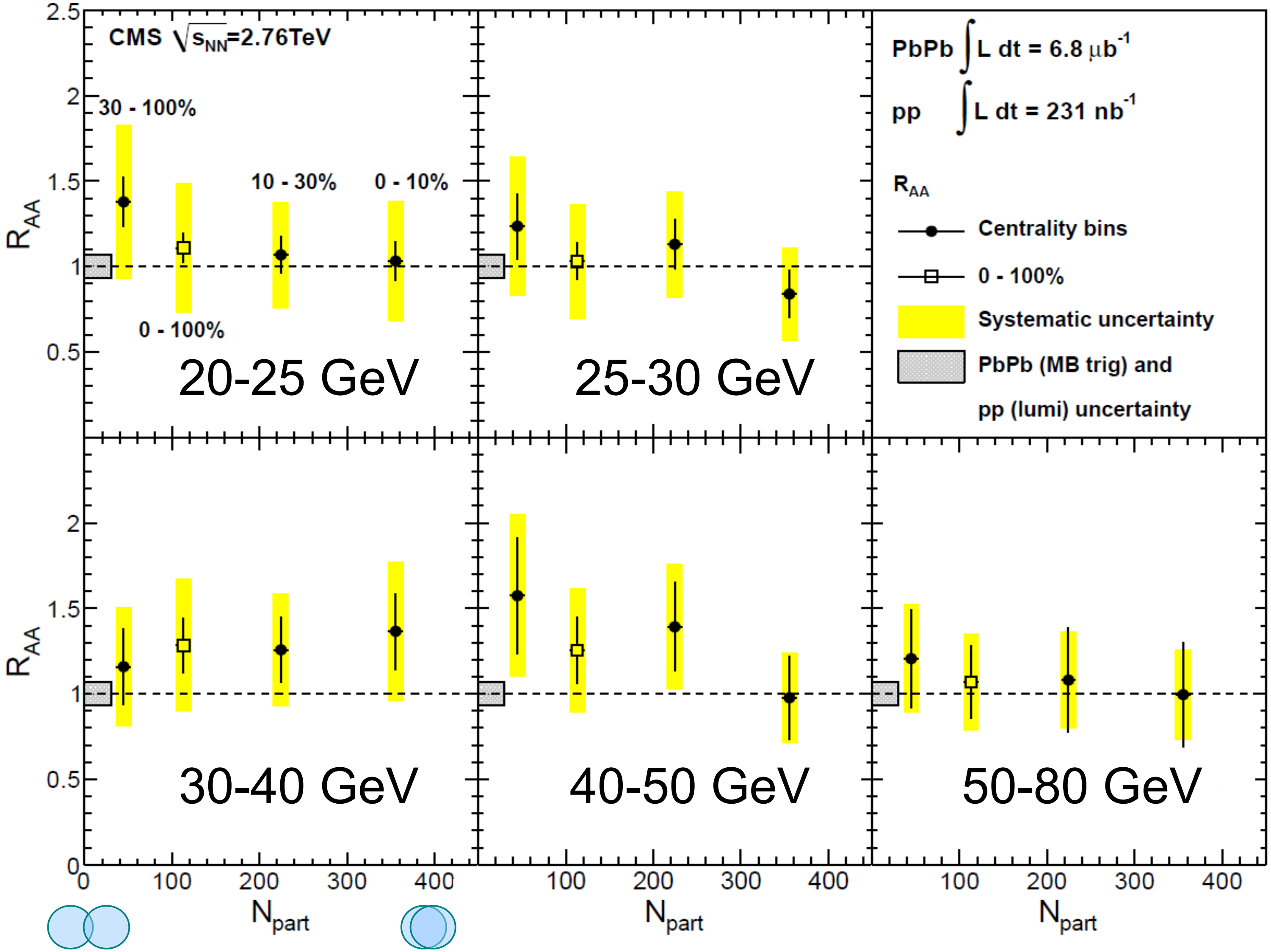
Isolated photon R_{AA} vs E_T & Centrality



No dependence on centrality or E_T

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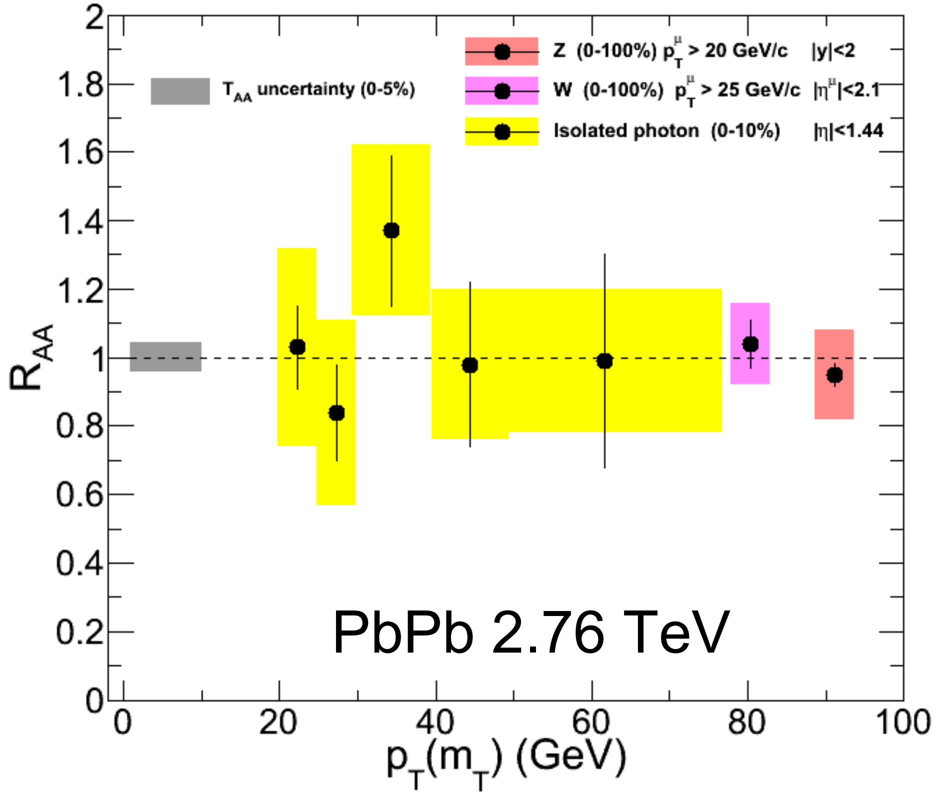
Conclusions

- Results are consistent with expectations:
  - >Hard scattering processes scale with the number of nucleon-nucleon collisions
  - >Photons not quenched
- Establishes the basis for studies using photons as unmodified hard probes
  - >Photons as “tags” for unquenched jet energy
    - Talk by Yue Shi Lai yesterday
    - See also arXiv:1205.0206



https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsHIN