Vector Bosons from PbPb Collisions with the CMS Detector

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On behalf of the
CMS Collaboration

Outline

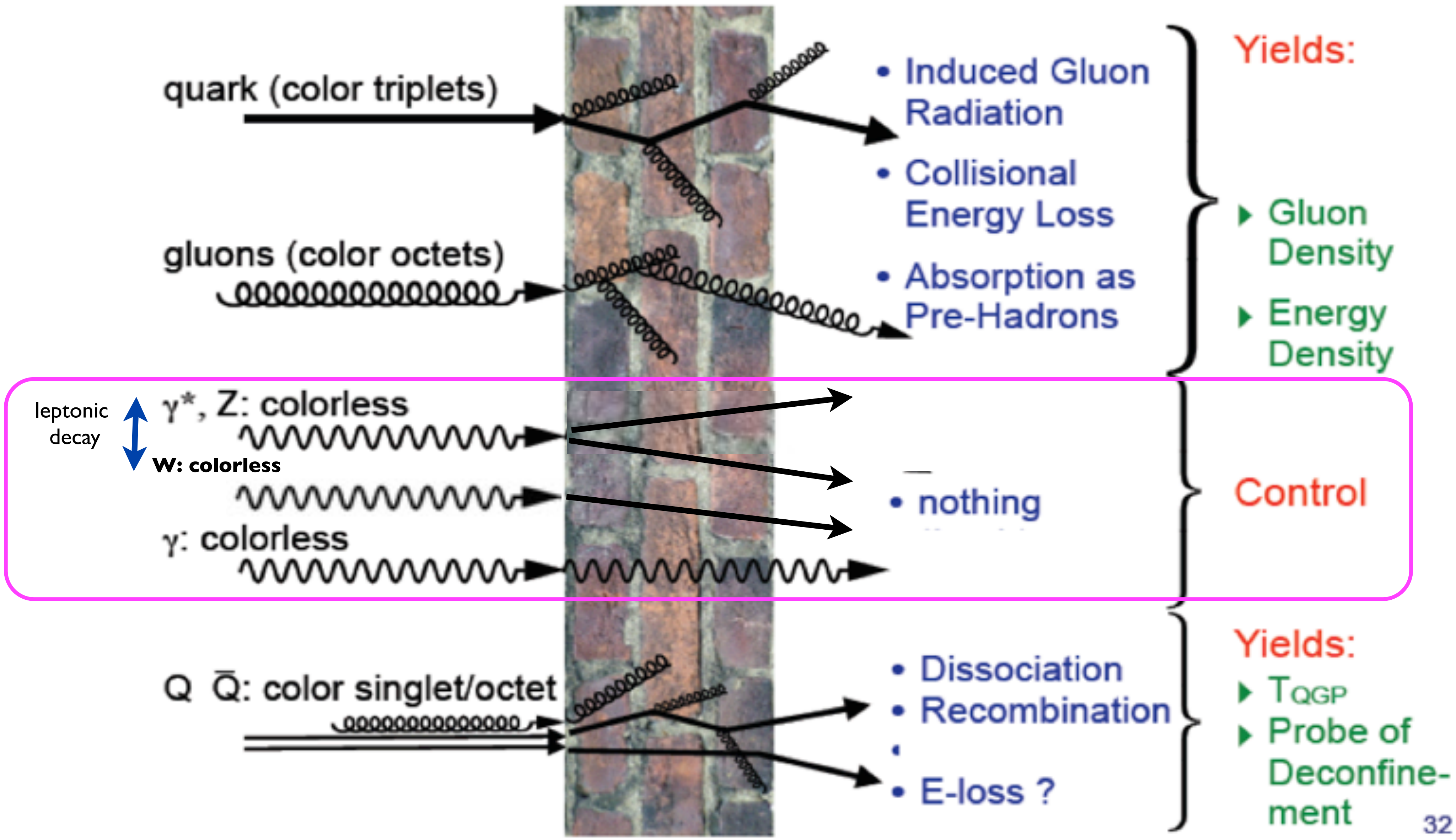
- Vector bosons (γ, Z->ll, W->lν) and heavy-ion physics (this talk l=μ)

- Detection and reconstruction
  - the CMS at the LHC
  - Identification
    - Photons
    - Muons
    - Missing E_T (MET)

- Physics results (2010 PbPb data)
  - Photons
  - Z
  - W

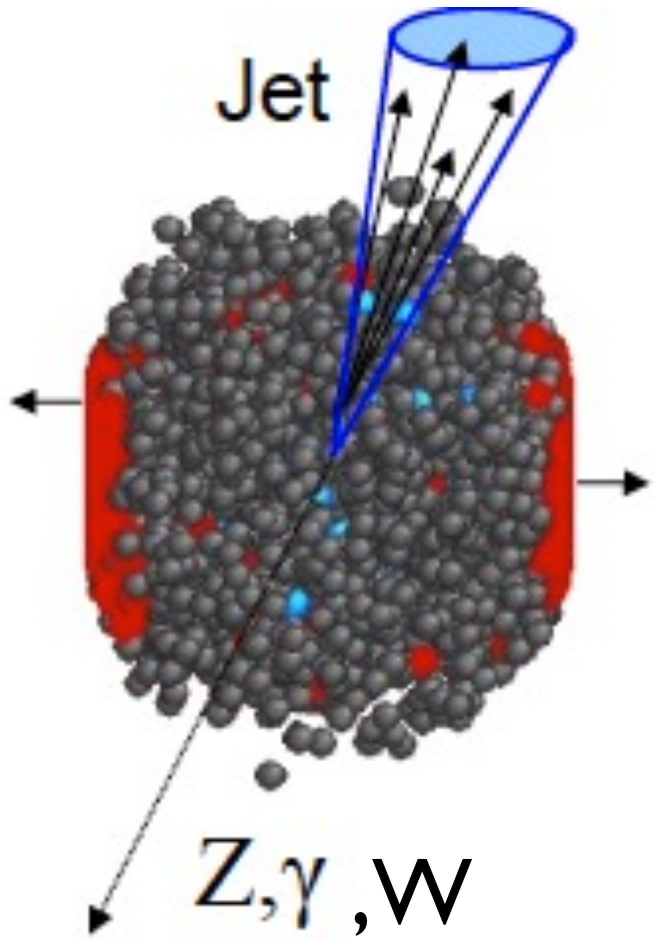
- Conclusions

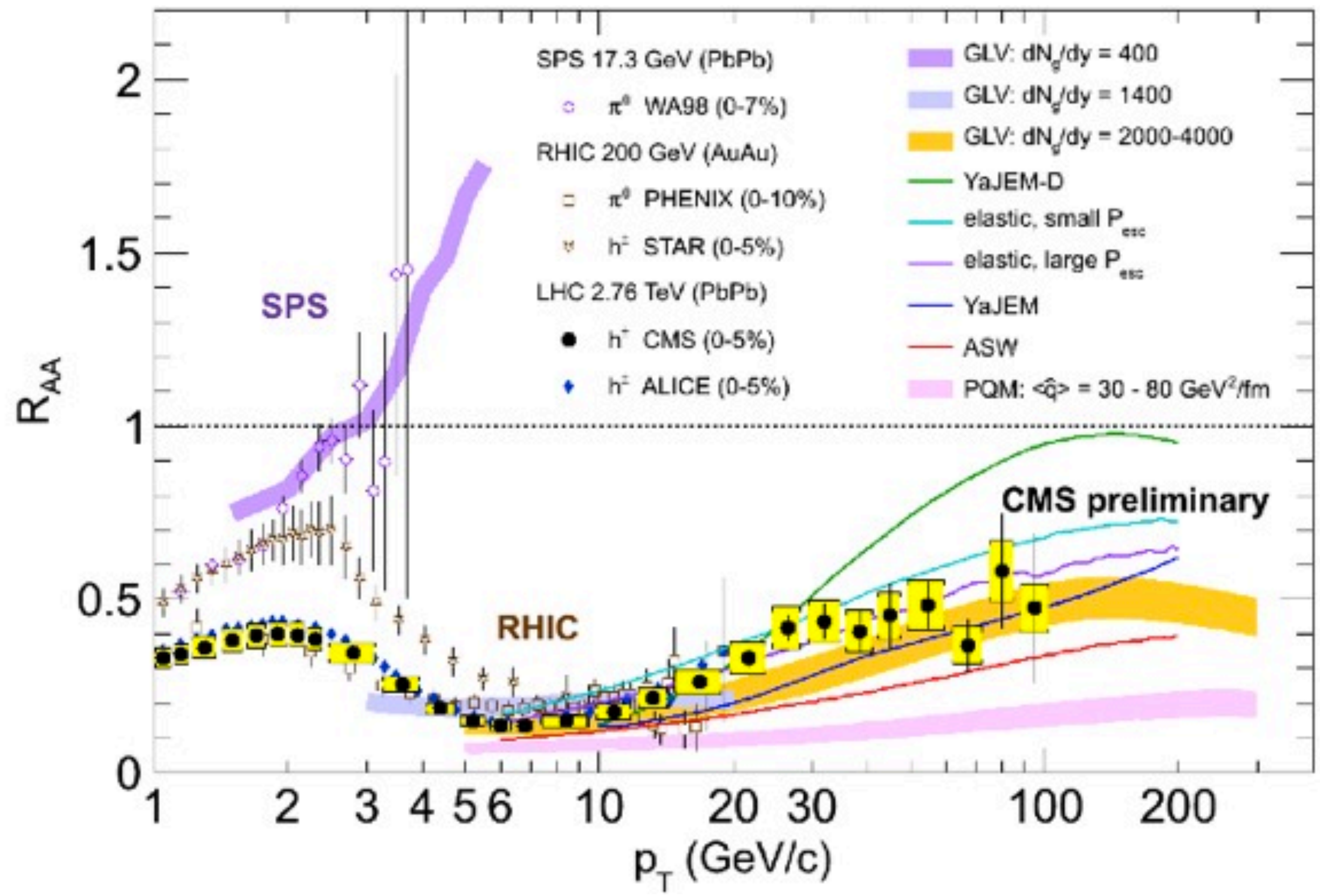
Vector bosons and heavy-ion physics



- A vacuum-like reference (for the final state effects), produced in AA collisions
- Access to cold nuclear matter effects, without specifically running pA collisions

Vector bosons and heavy-ion physics

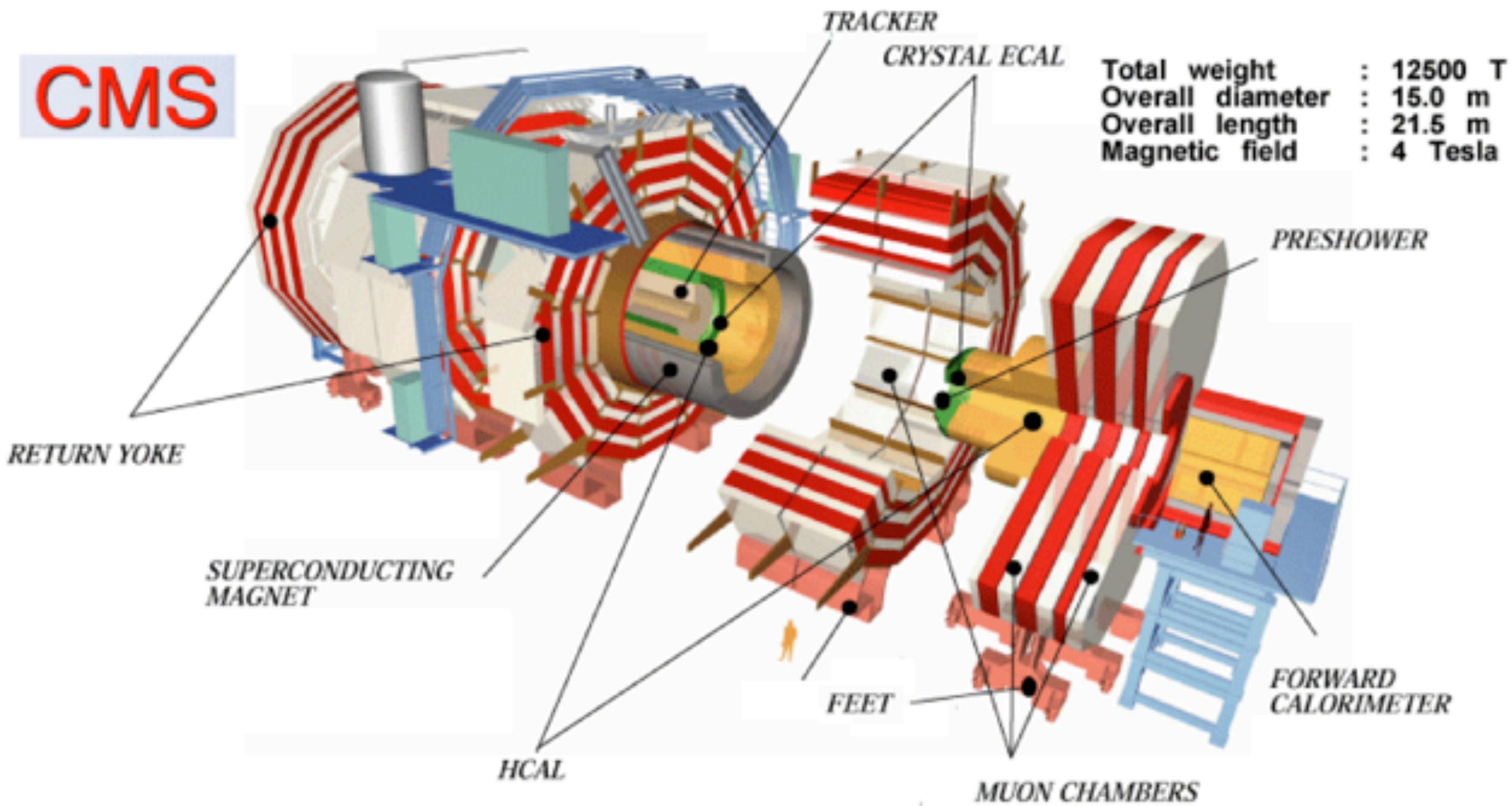




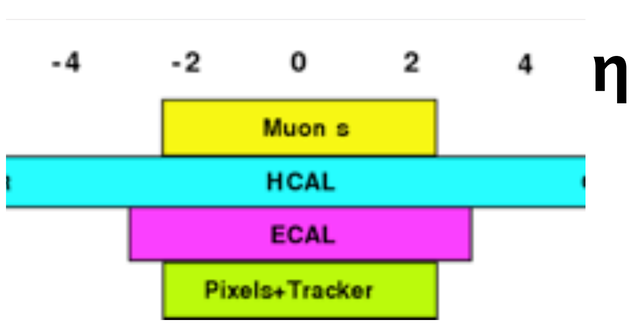
- <u>The best handle/tool for jet energy calibration</u>
  - $\vec{p}_T^{\,\mathrm{Jet(initial\ parton)}} \approx \vec{p}_T^{\,Z,W,\gamma}$
  - R_{AA} gives indirect access to the initial parton energy (basically just the leading hadrons), a convolution of many initial and final state effects (one of the reasons for huge differences between different model calculations/predictions)

- LHC
  - Higher energies → weak bosons energetically possible 1st time in HI
  - Better (than previous HI exp) detection capabilities (coverage and technologies) to reconstruct photons and leptons

Detector: the CMS at the LHC



- Structure:
  - ➡ Tracker+calorimeters (HCAL and ECAL) inside the solenoid coil
  - ➡ Muon detectors embedded in the flux return iron yoke of the magnet
  - ➡ Large acceptance
    - 2π in azimuth
    - Si-tracker $|\eta|<2.5$
    - ECAL $|\eta|<3.0$, HCAL $|\eta|<5.2$
    - Muon detectors $|\eta|<2.4$

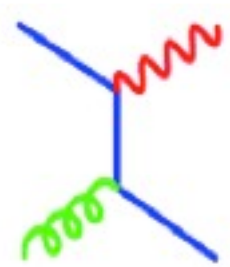


- High resolution
  - Granularity of the **Si-pixel layer+4T mag field** ~ $\Delta p_T/p_T$ < 1.5

Reconstruction

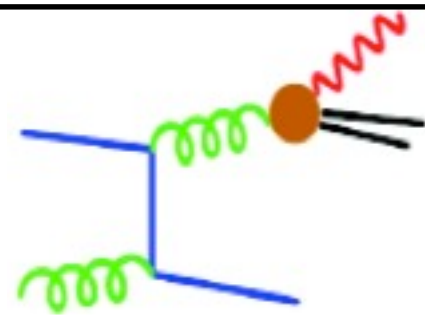
Photons

- Many sources of high-pT photons

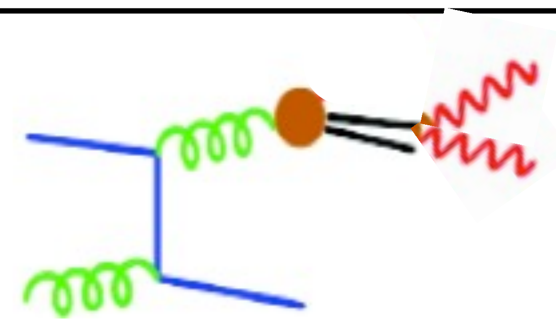


Direct

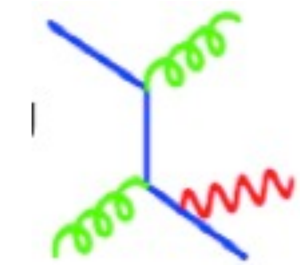
Isolated
Blind to the medium



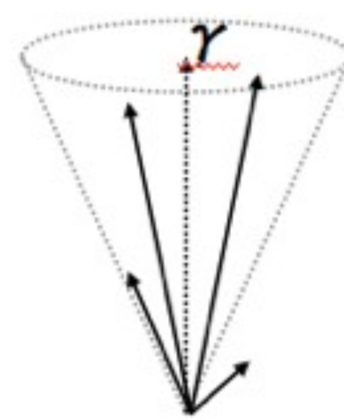
Fragmentation



Meson decay



Bremmstrahlung



Not Isolated (hadronic activity from other fragments of the parton)
Affected by the medium

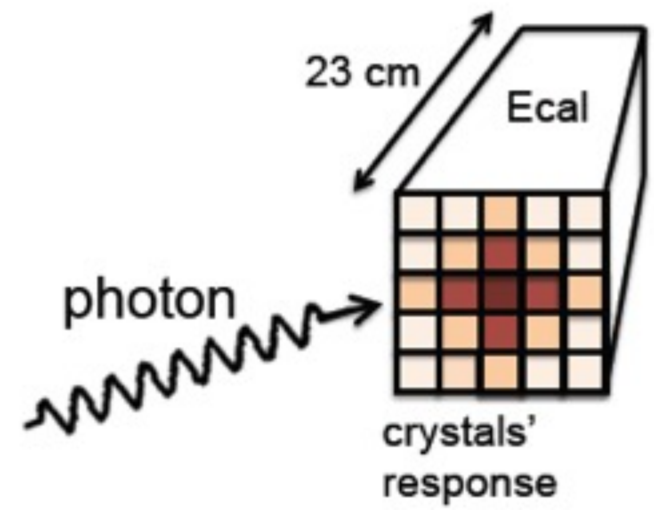
- Reconstruction steps:
  1. ECAL clusters candidates selection
  2. Clusters isolation
  3. Photon signal extraction

Isolated/direct Photons

◉ <u>Clusters/photon candidates identification</u>

➡ algorithm: island clustering (Ref: CERN-LHCC-2006-001)

➡ crystal size: 2.2cm x 2.2cm --> 94% of energy in 3x3 crystals



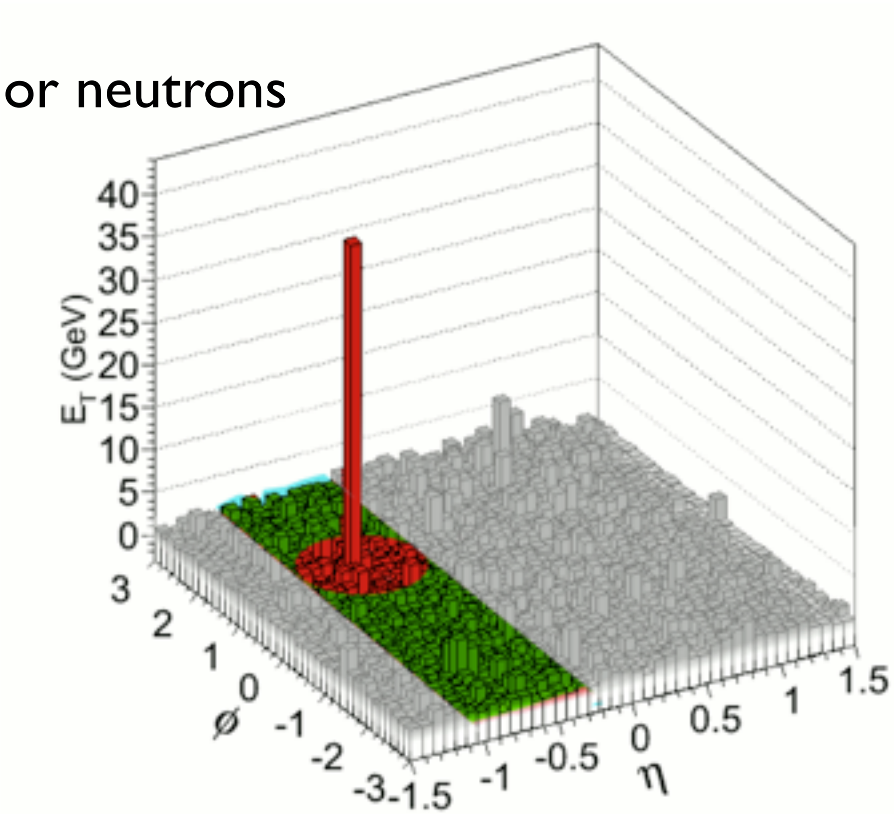
◉ <u>Photon candidates isolation</u>

➡ To reject very energetic (and hence mostly isolated) hadrons or neutrons

- in a cone $\Delta R<0.15$, compare the cluster energies;
- select those for which $E_{HCAL}/E_{ECAL} < 0.2$

➡ To reject indirect photons

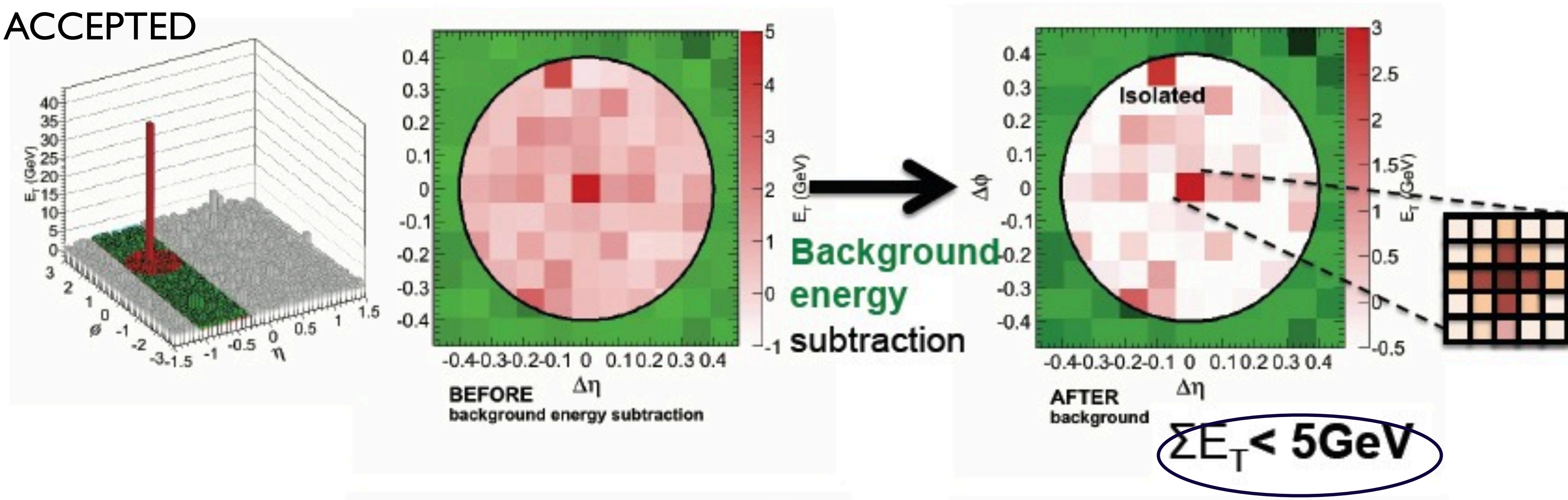
- in cone $\Delta R<0.4$ (that contains signal+uncorrelated background)
  - $\Sigma(E_T^i - \pi\Delta R^2 \langle E_T^{i,background}\rangle) < 5GeV$, where
    - i = HCAL, ECAL, and Tracks with p_T>2GeV/c
    - $\langle E_T^{background}\rangle$: $\langle E_T\rangle$ per unit area in the η-φ space
    - estimated in a rectangular area, 2ΔR wide in η-direction and 2π in φ-direction



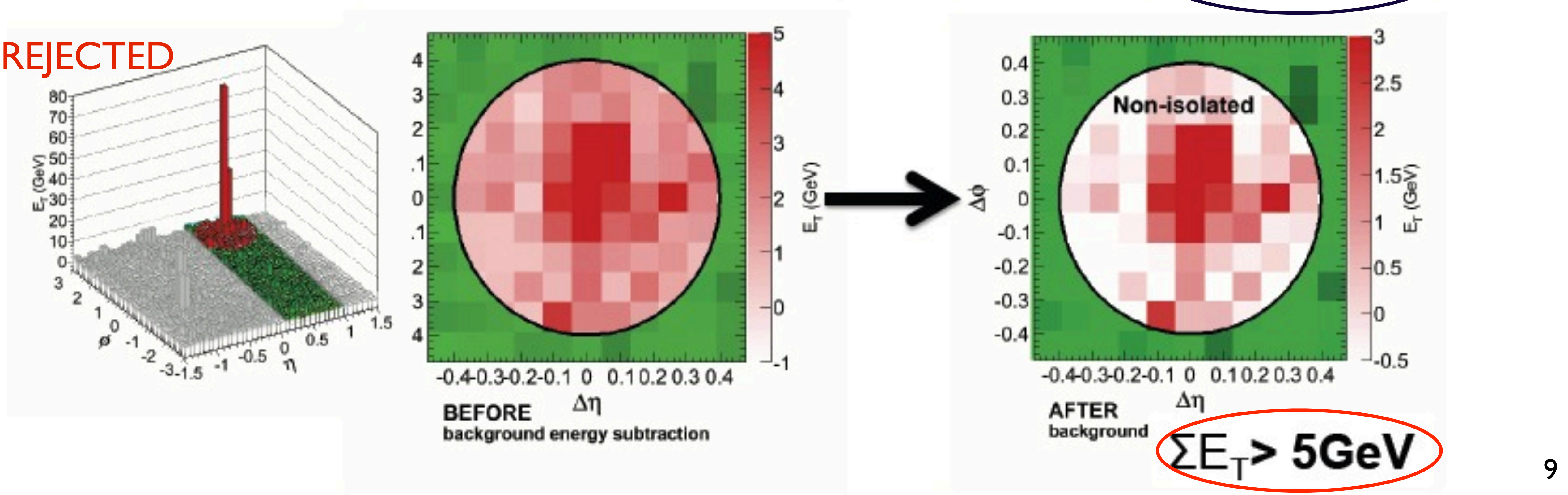
Isolated/direct Photons

- Background corrected isolation:

- ACCEPTED



- REJECTED



Isolated/Direct Photons

- Signal extraction

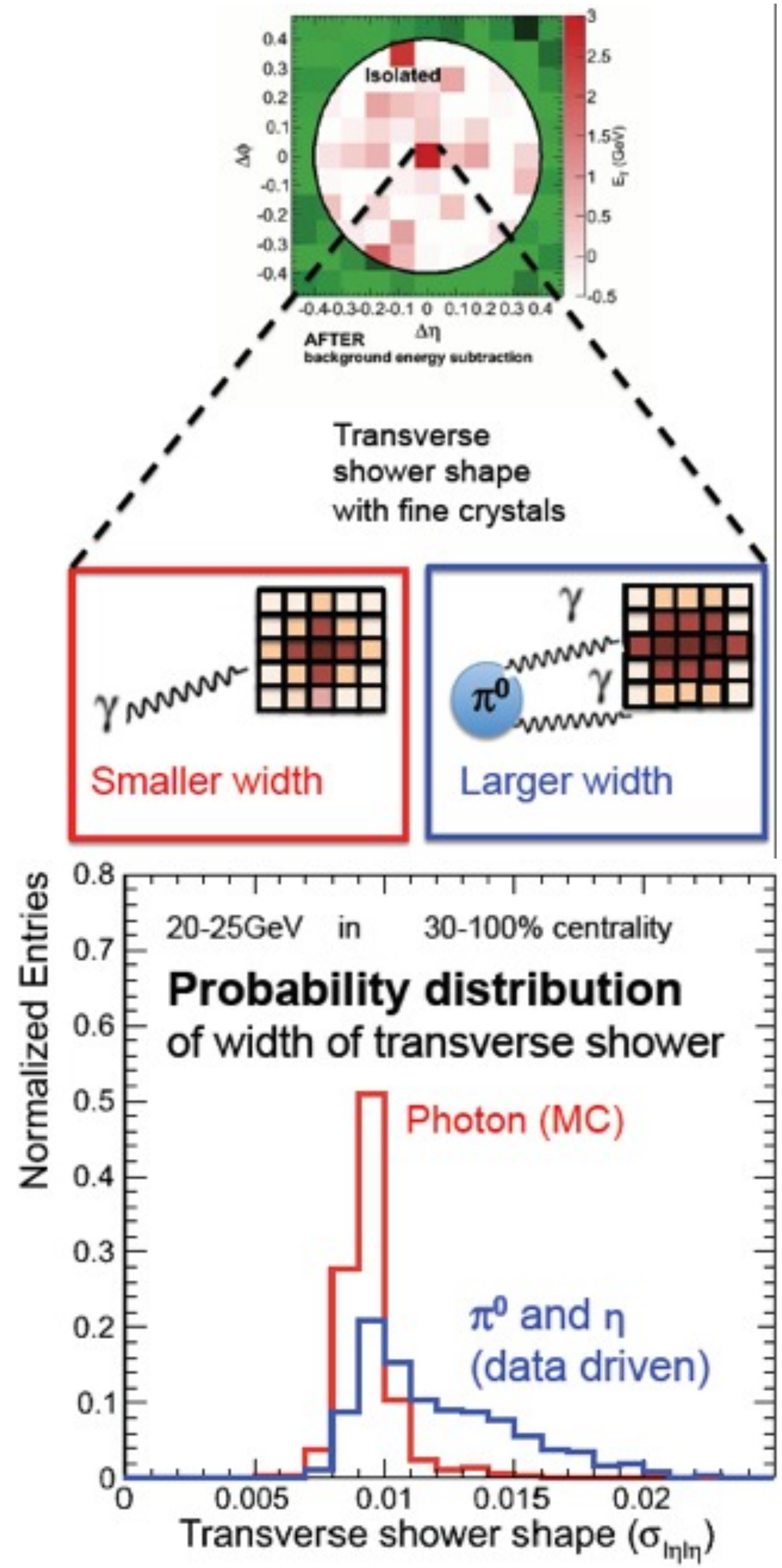
- statistical approach to estimate the number of photons from the remaining background (photons from high-z, isolated π^0 and η decays)

- exploit the fine granularity of the ECAL ($\Delta\varphi \times \Delta\eta = 0.017 \times 0.017$) :
  - ➡ quantify the transverse shower shape in the ECAL crystals

$$\sigma^2_{i\eta i\eta} = \frac{\sum_i^{5\times5} w_i(\eta_i - \bar{\eta}_{5\times5})^2}{\sum_i^{5\times5} w_i}$$

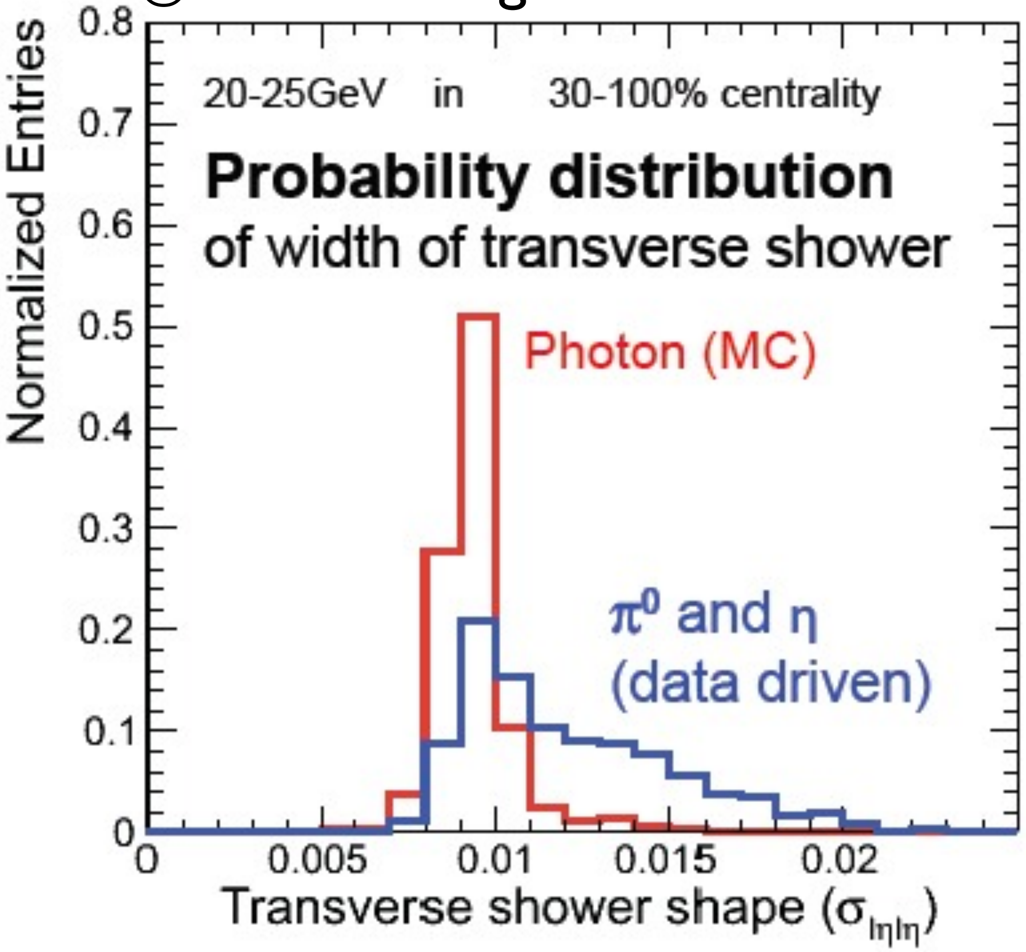
$$w_i = \max(0, 4.7 + \ln(E_i/E))$$

- create the probability distribution functions for $\sigma_{i\eta i\eta}$ (aka *Templates*)
  - ➡ photon templates:
    - from MC, mixing PYTHIA photons in HYDJET HI event
  - ➡ background templates:
    - from Data, using the non-isolated photons

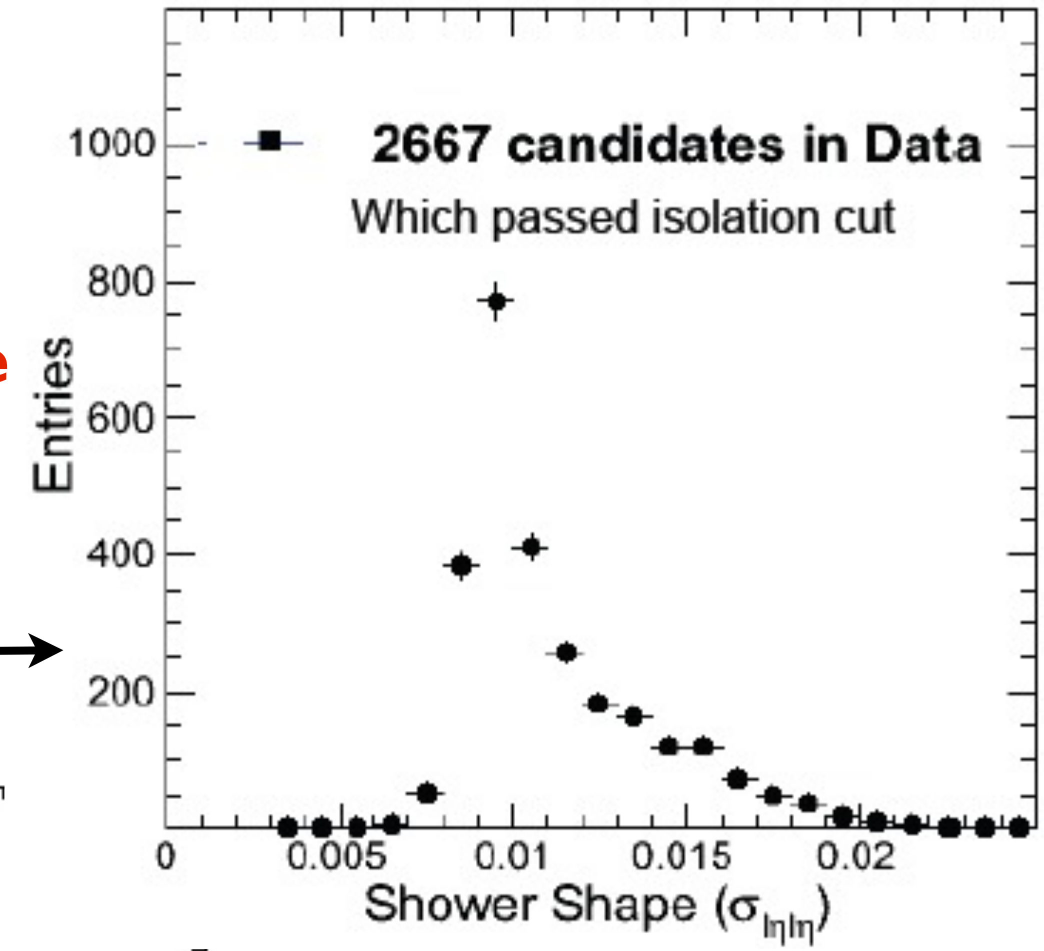


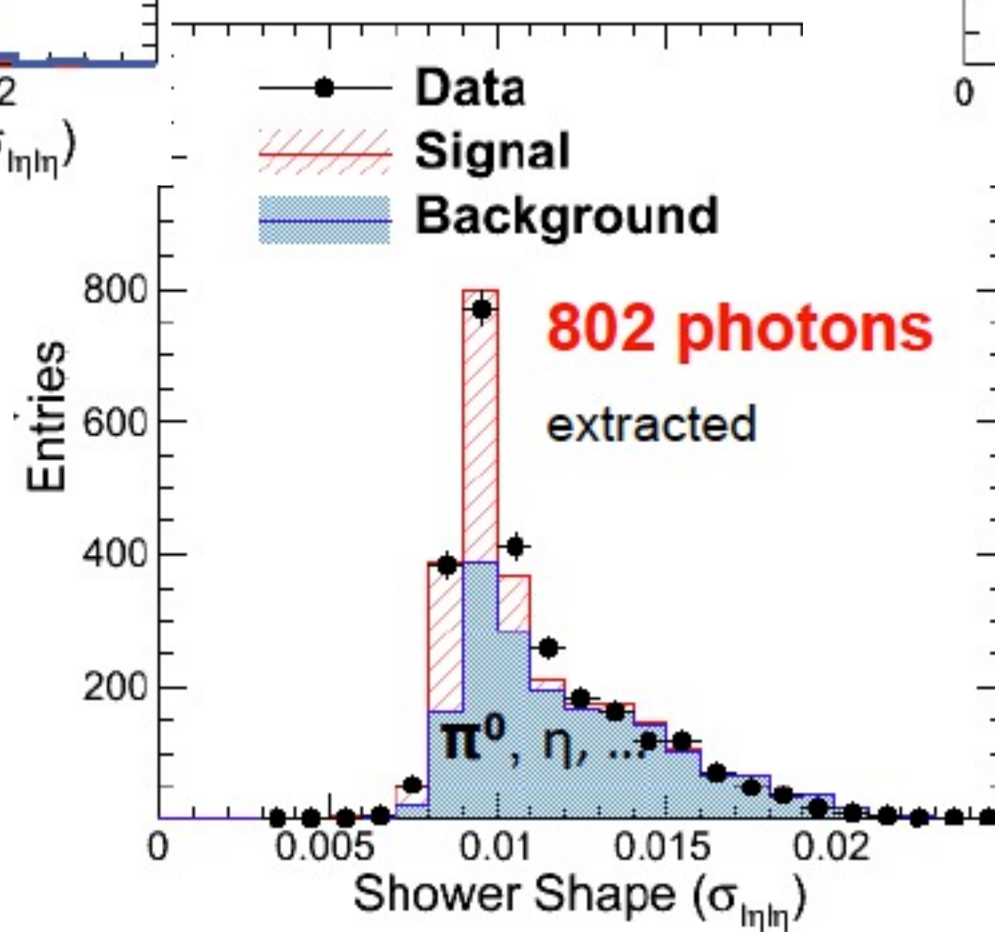
Isolated/Direct Photons

- Photon signal extraction



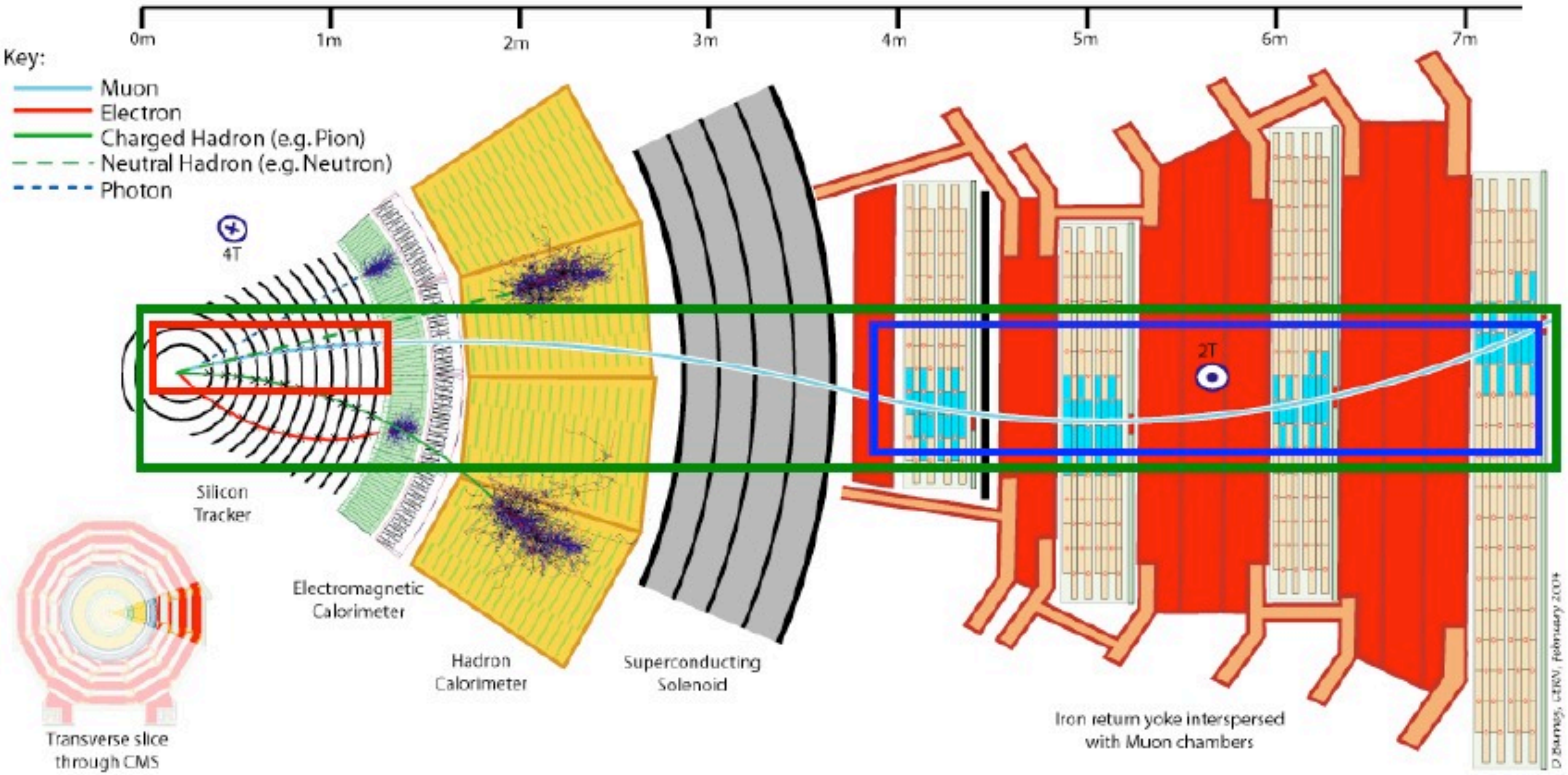
Data
=
signalTemplate
+
bkgTemplate





- repeat for each (pT,centrality) bin

Muons



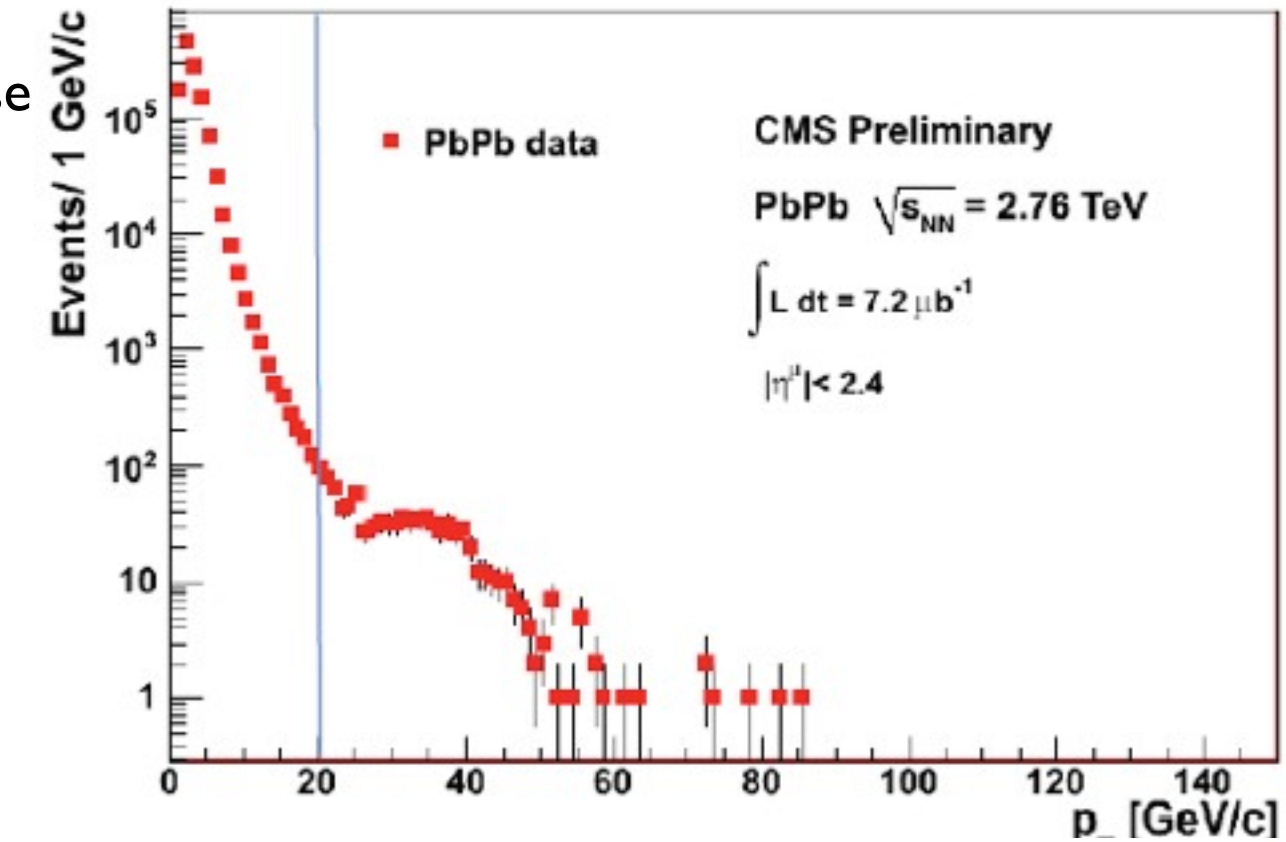
- Global muons = tracker + muon stations informations
  - ➡ need p ≳ 3 GeV to reach muon stations + 2-3 GeV to compensate for the en loss in the absorber
  - ➡ ID cuts at ana level:
    - reco both inside-out and outside-in
    - #hits in the tracker, χ2, DCA, etc

Table 2: Minimum p and p_T to reach first Muon station

$\eta = -\ln\tan\frac{\theta}{2}$	R_T^{min}	$p_T^{min} = 0.3BR_T^{min}$	$p^{min} = p_T^{min} / \sin\theta$
$0 \leq \|\eta\| \leq 1.2$	4 m	4.8 GeV/c	4.8-8.7 GeV/c
$1.2 \leq \|\eta\| \leq 1.5$	3 m	3.6 GeV/c	6.5-8.5 GeV/c $\oplus \overbrace{2GeV}^{Loss\ in\ barrel}$ to $\underbrace{3GeV}_{Loss\ on\ endcaps}$
$1.5 \leq \|\eta\| \leq 2.4$	1 m	1.2 GeV/c	2.8-6.7 GeV/c

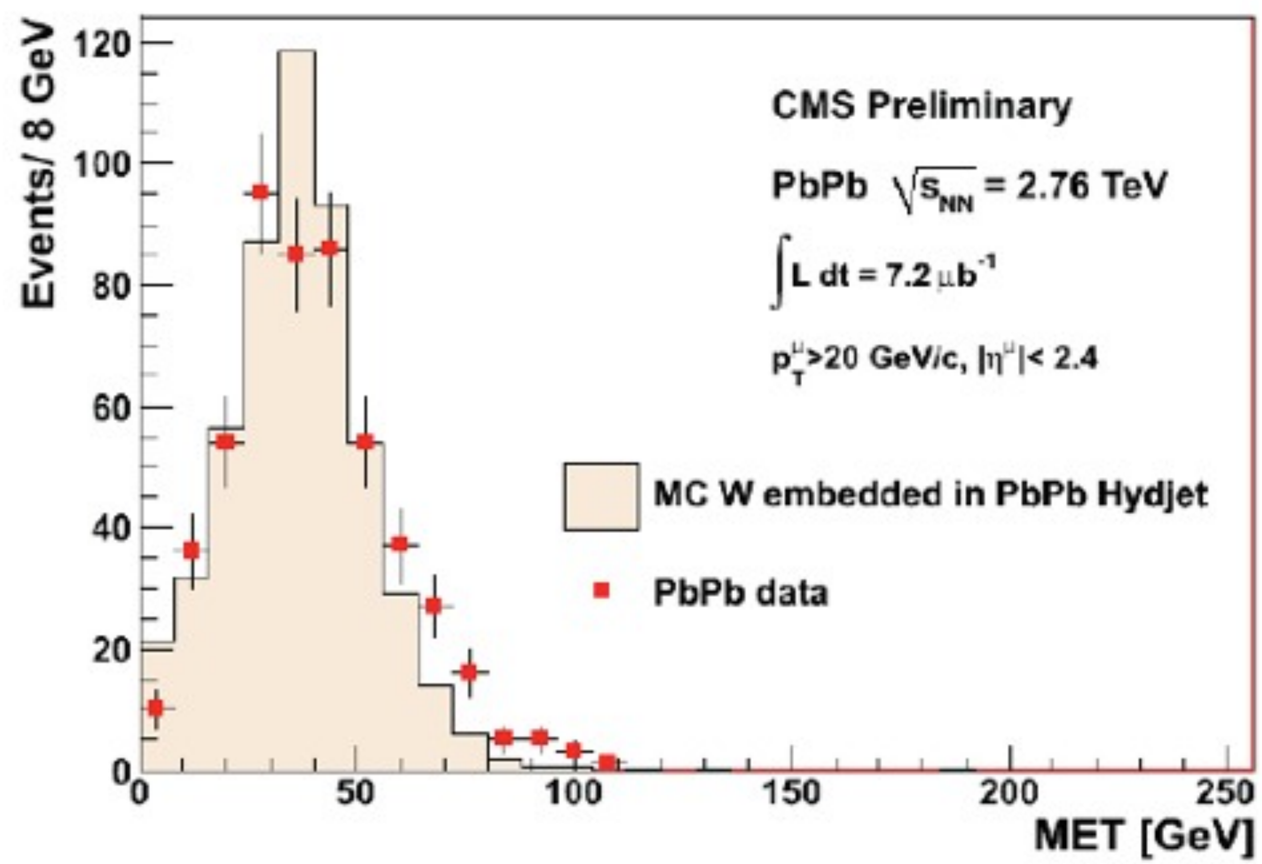
Missing E_T (MET)

- Signatures for W->μν
  - ➡ high-pT isolated muon: p_T>20GeV/c in this case
  - ➡ back-to-back in φ with ν/missing E_T



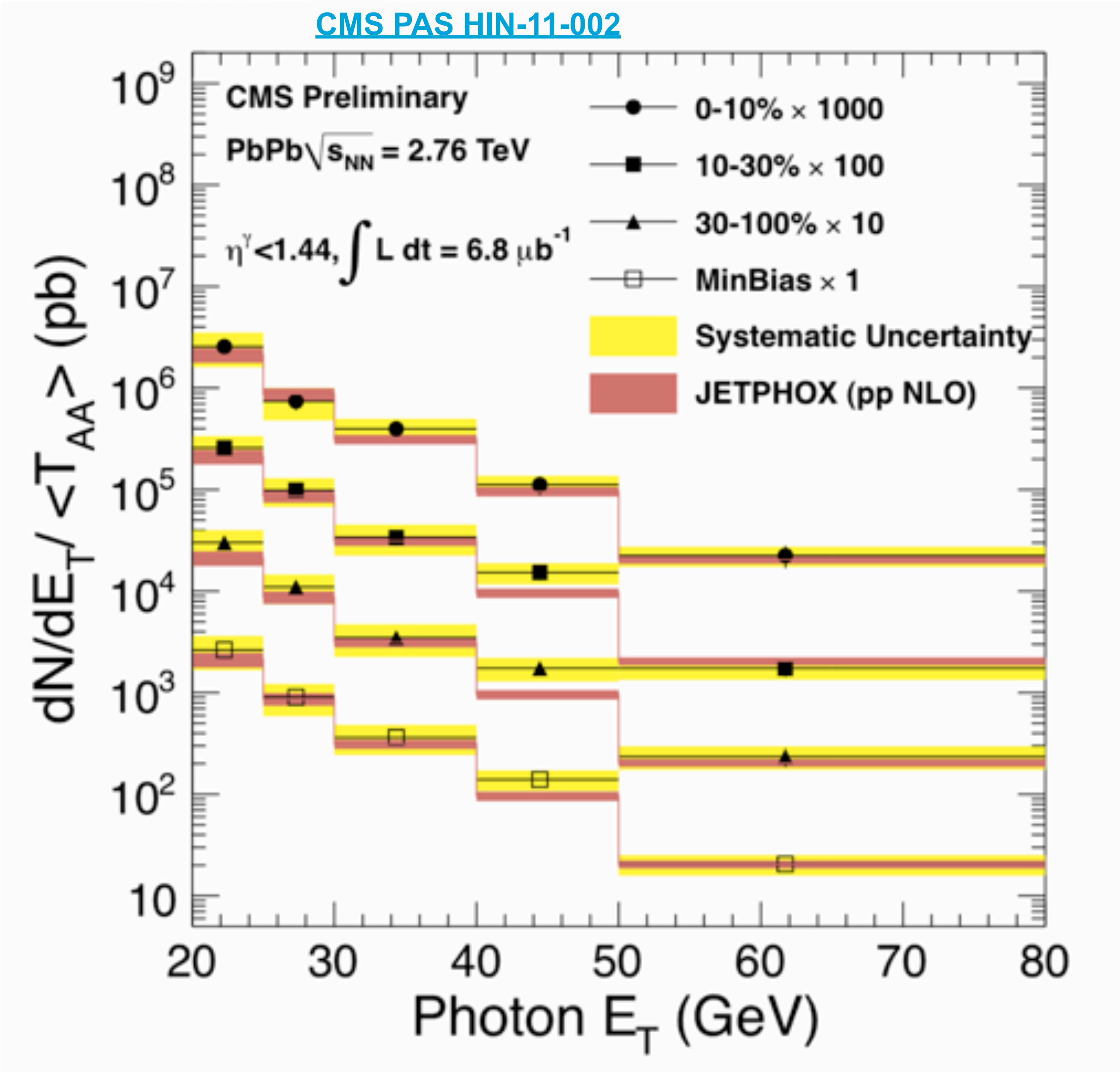
- MET reconstruction:
  - ➡ use tracks reconstructed in tracker
  - ➡ p_T > 2GeV/c

$$MET = -\sum \vec{p_T} \approx p_{T\nu}$$



Results

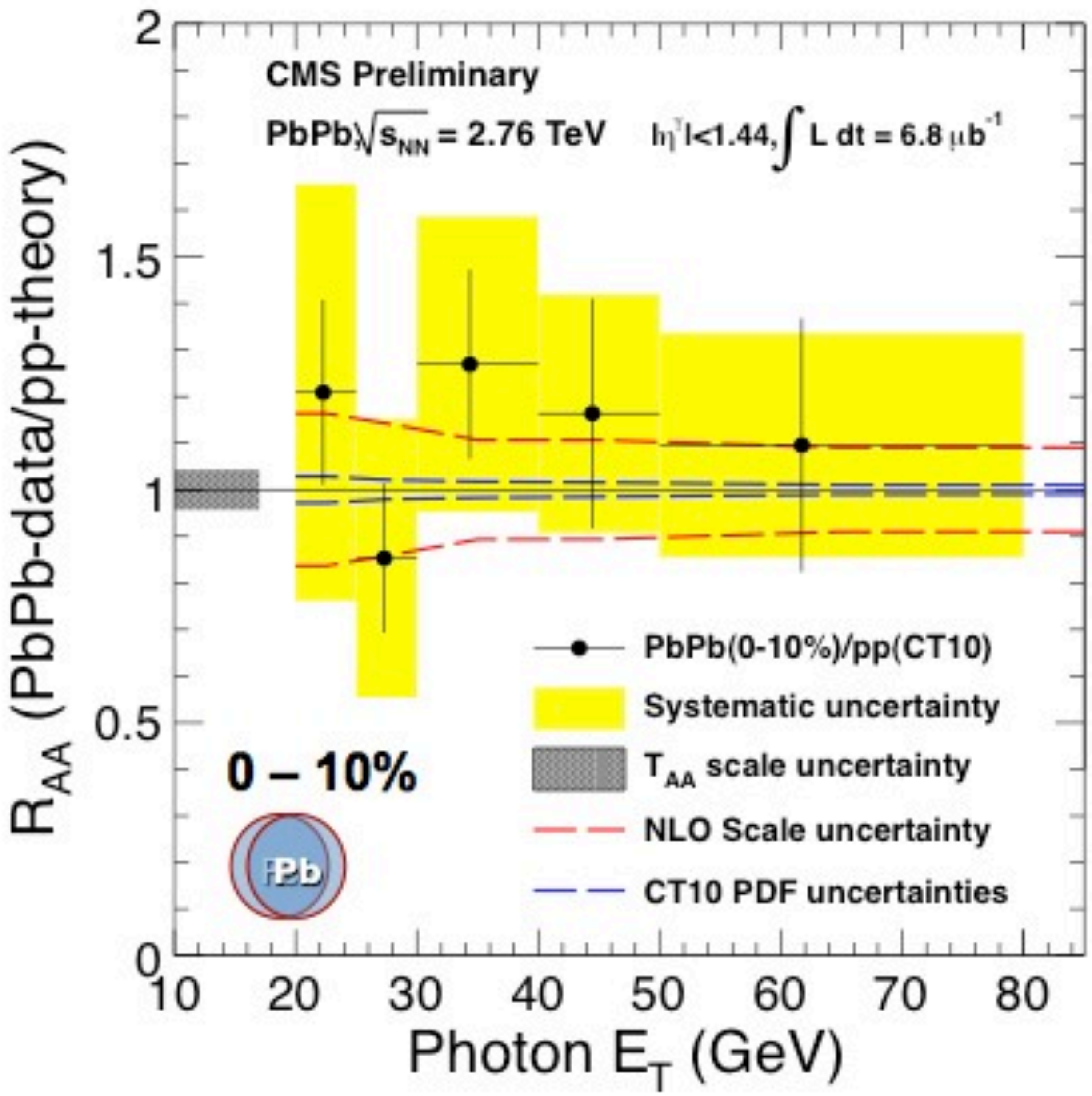
Photons: spectra

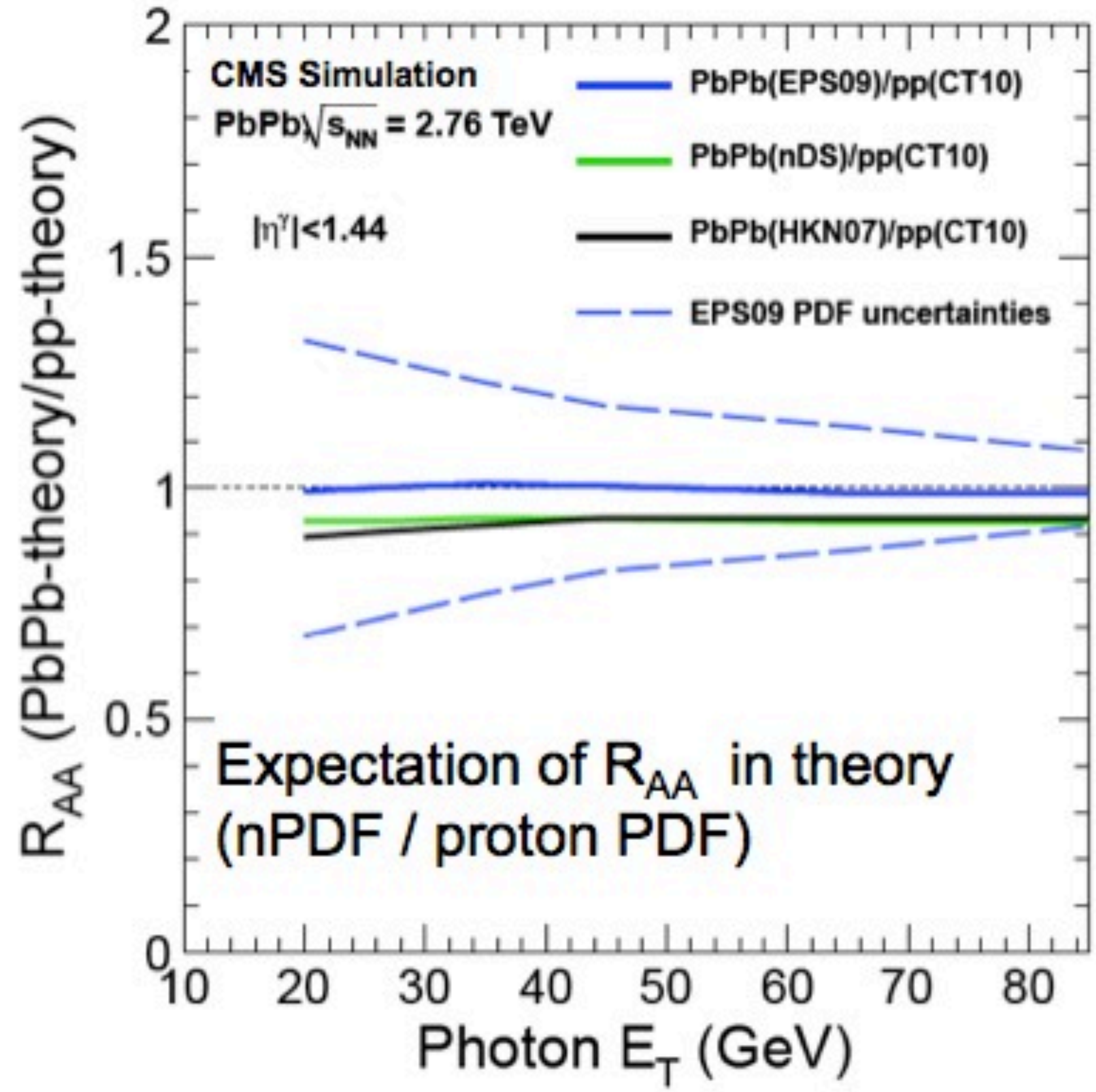


- dN/dE_T scaled by the nuclear thickness function for 3 centrality bins+minbias
- p_T: [20,80]GeV/c
- $|\eta|<1.44$ (barrel only)
- 21-37% systematic uncertainties

Photons: R_{AA} vs E_T

CMS PAS HIN-11-002

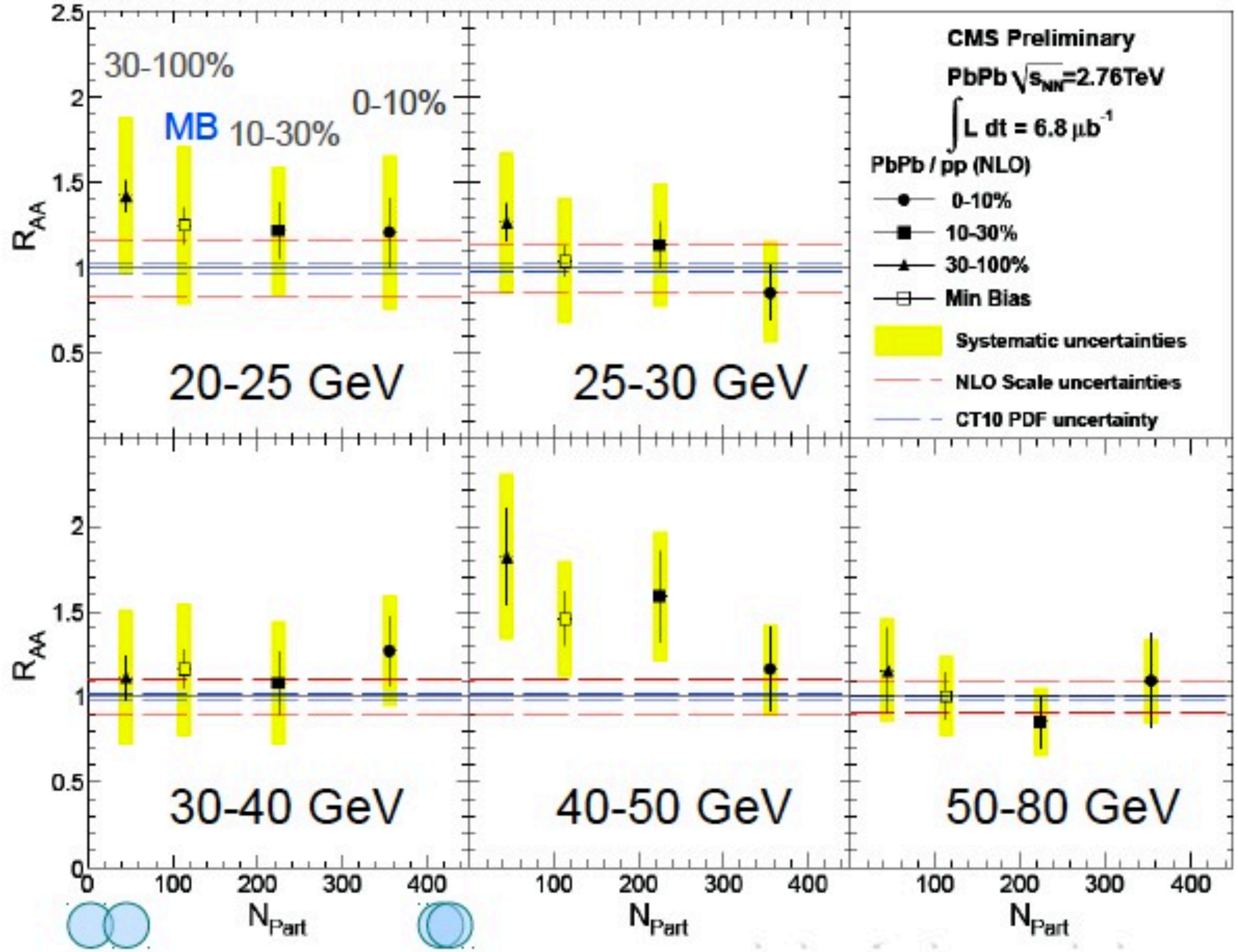




- Photon RAA for 0-10% centrality, is consistent with unity

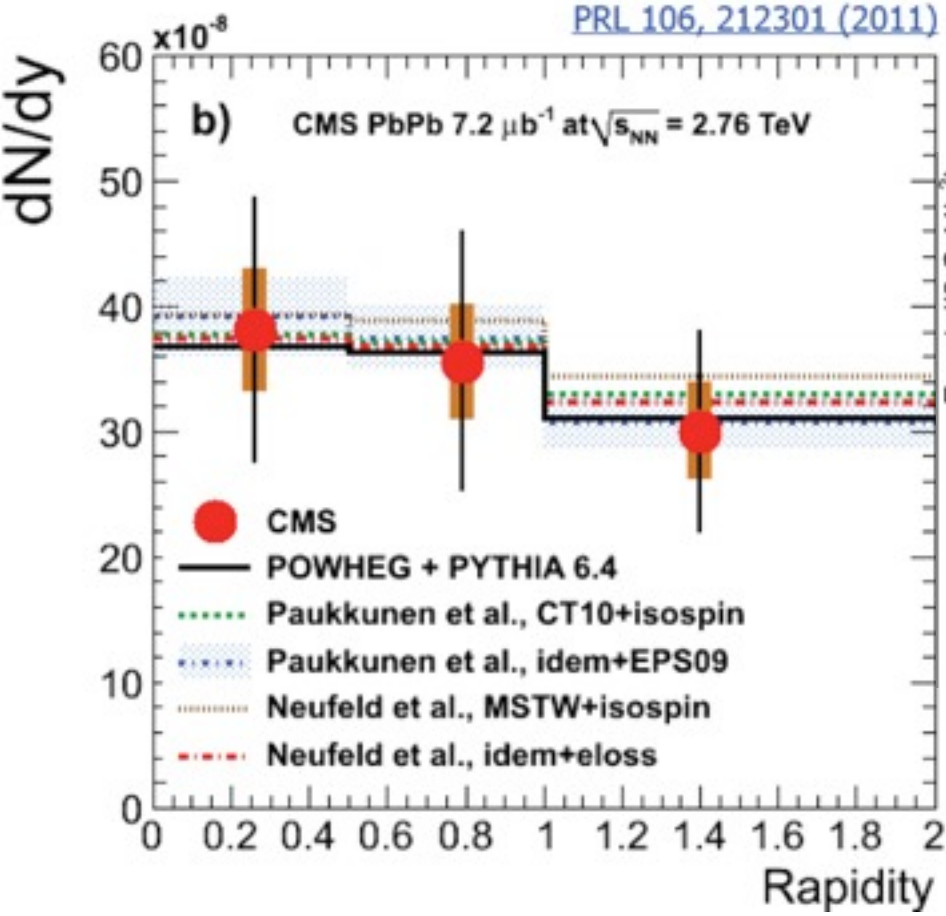
Photons: R_{AA} vs N_{part}

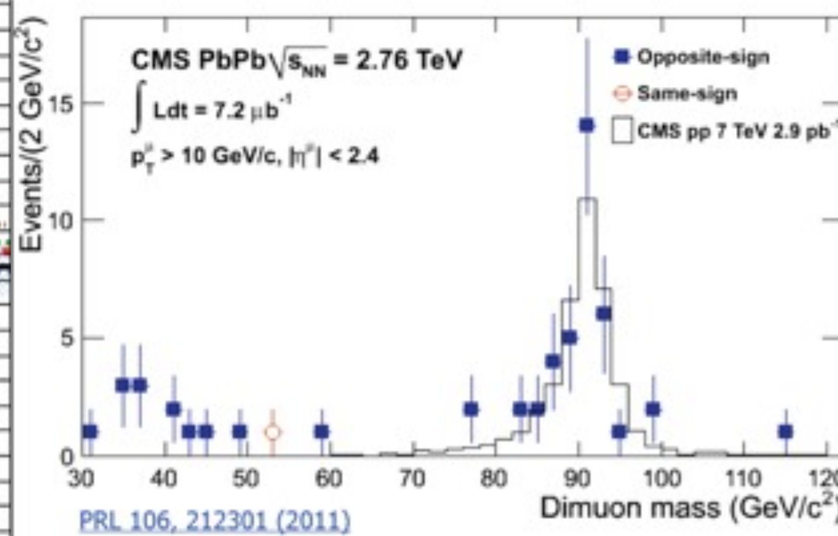
CMS PAS HIN-11-002

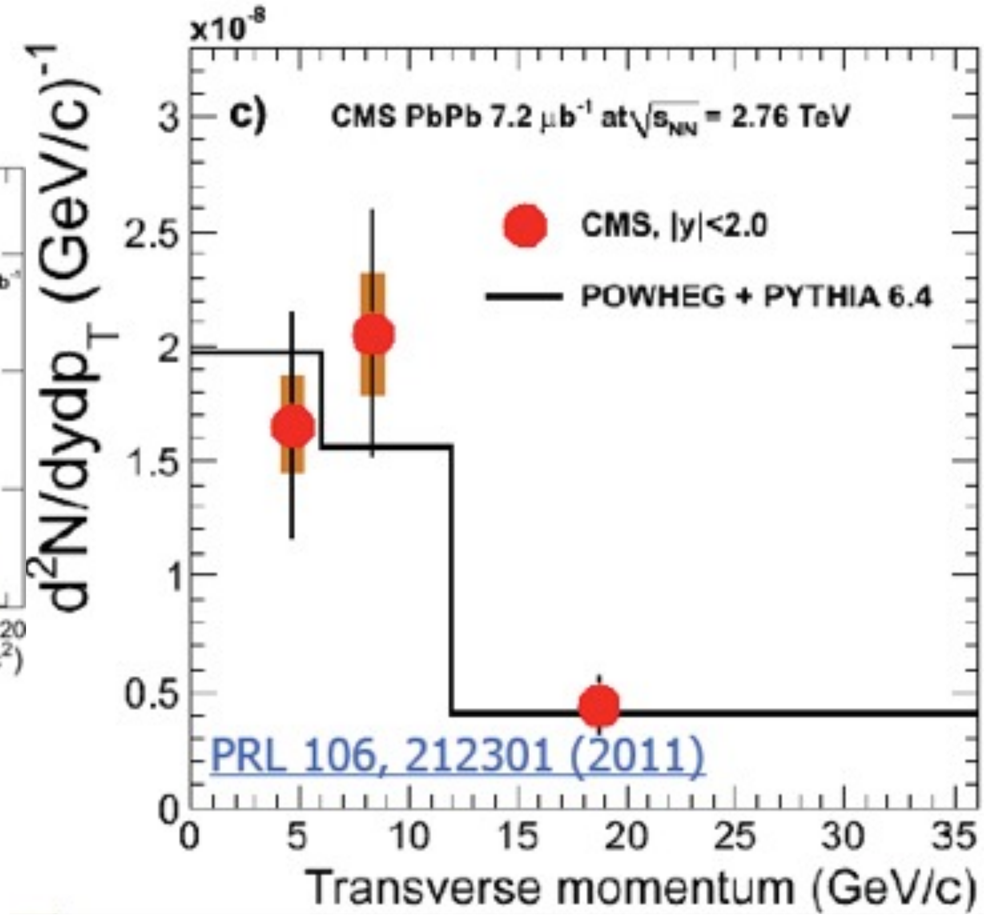


- No dependence on N_{part}, within uncertanties

Z: spectra







- 39 Zs: reconstructed with muons that: p_T^{μ}>10GeV/c, $|\eta^{\mu}|$<2.4
- 3 p_T and 3 rapidity bins: 16% statistical and 14% systematical uncertainties

- very small initial state effects expected theoretically
  - ➡ 10-20% shadowing, ~3%isospin effects, ~2% initial state energy loss

- pT spectra reproduced by pp NLO calculation scaled by a geometric factor (T_{AA}): no final state effects.

Z: ‘R_{AA}’ vs N_{part}

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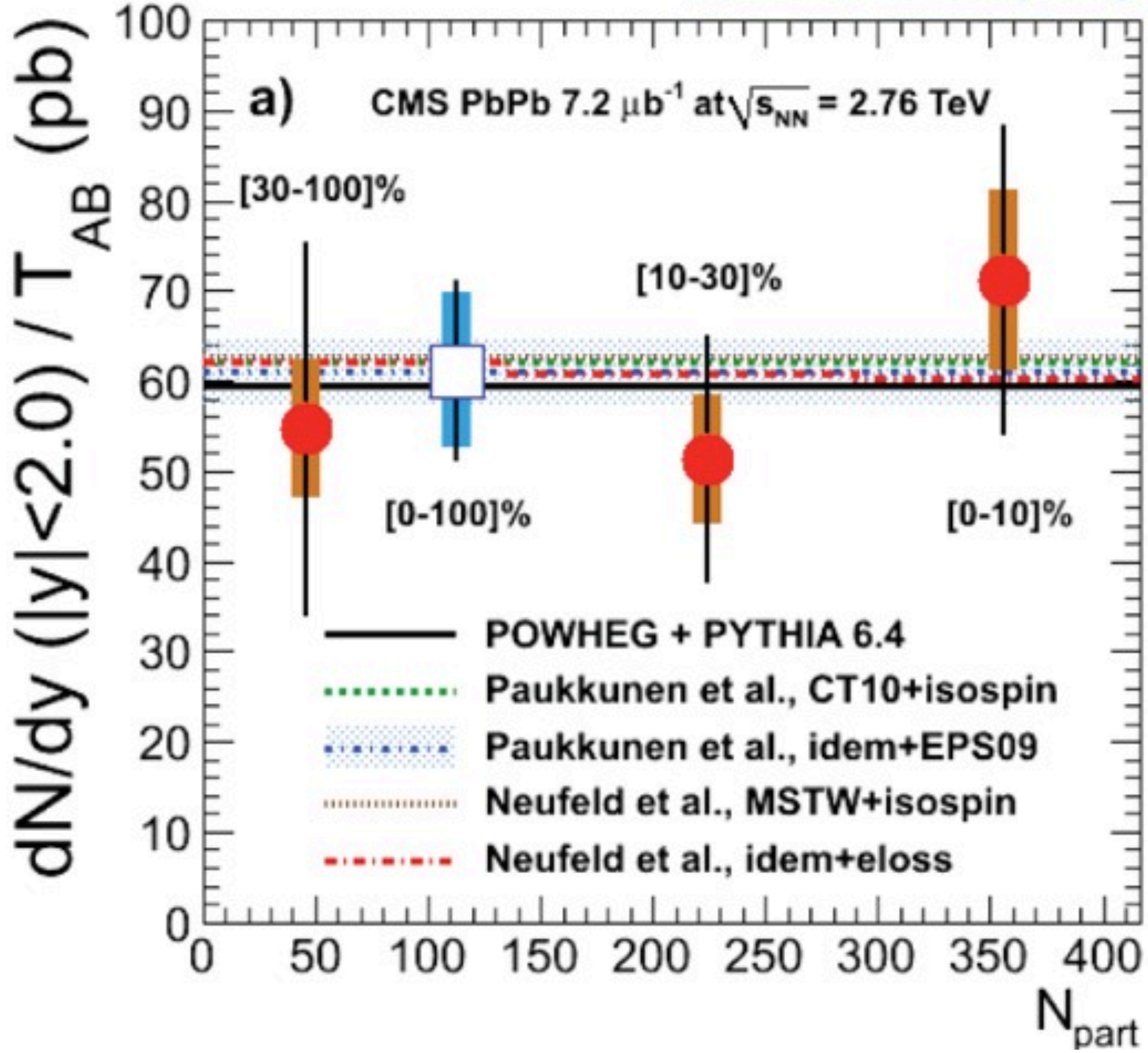
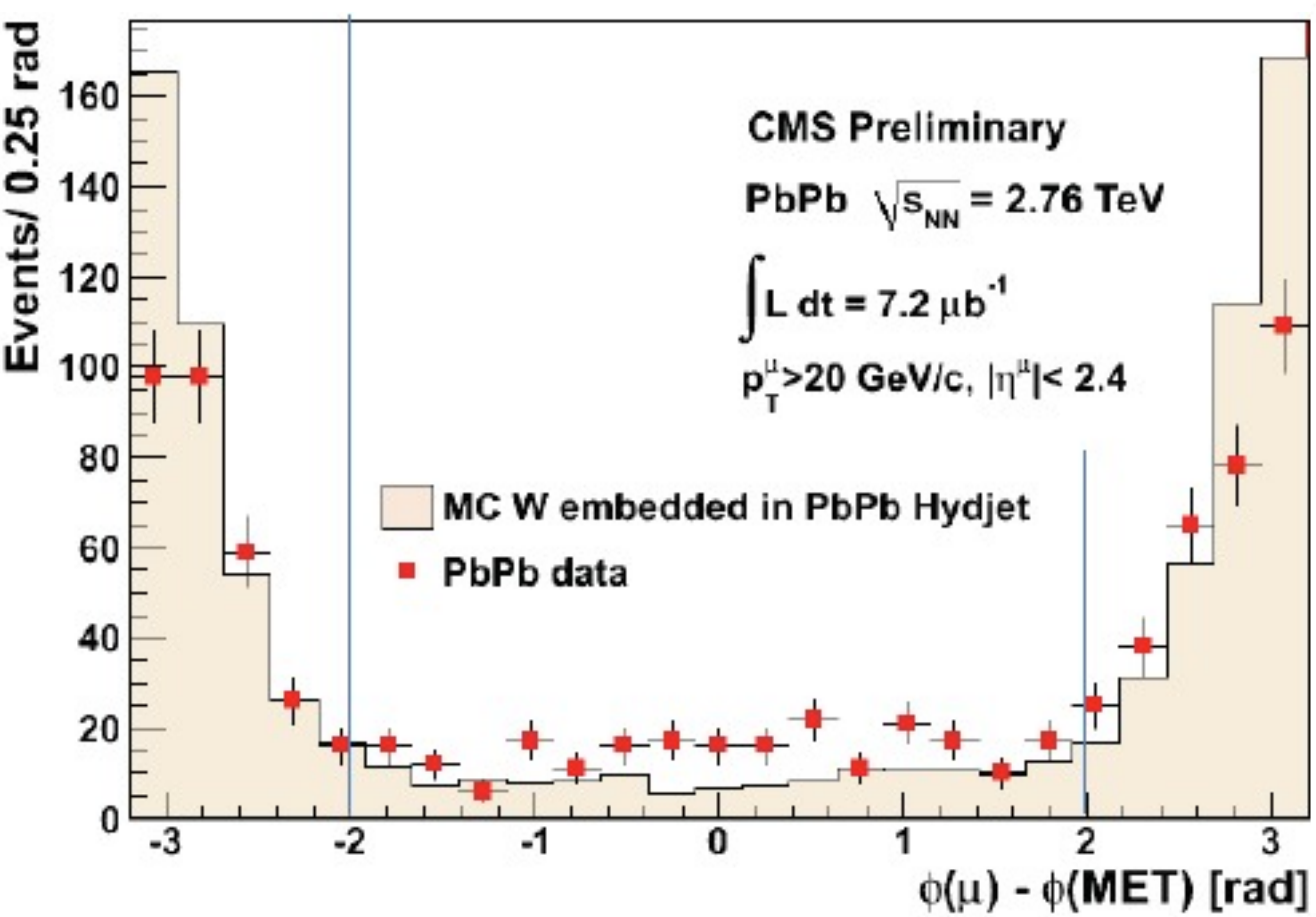
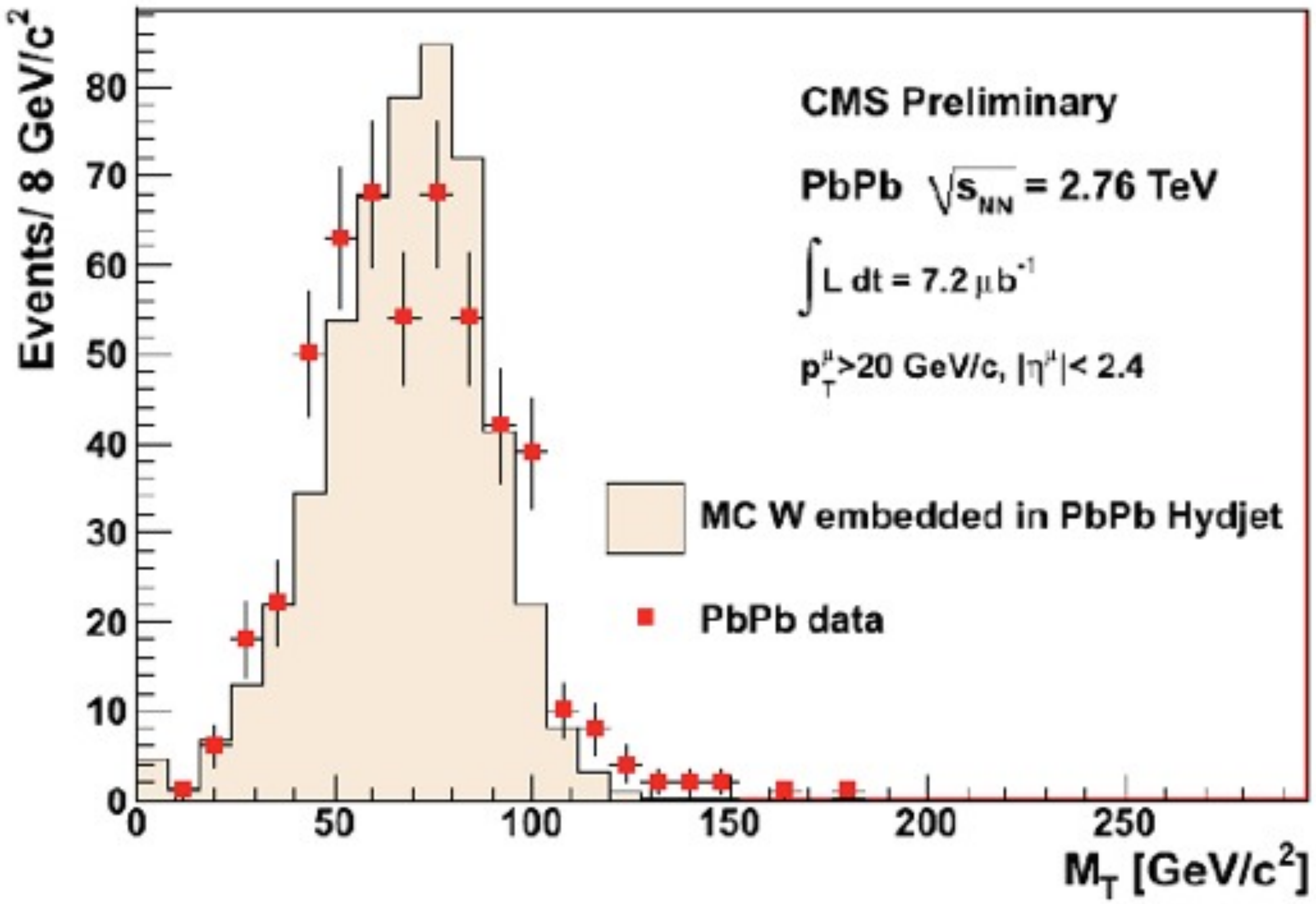


- no centrality dependence of the yield, once the different geometry is considered
- small effects expected from theory, experimental uncertainties too big to help

W

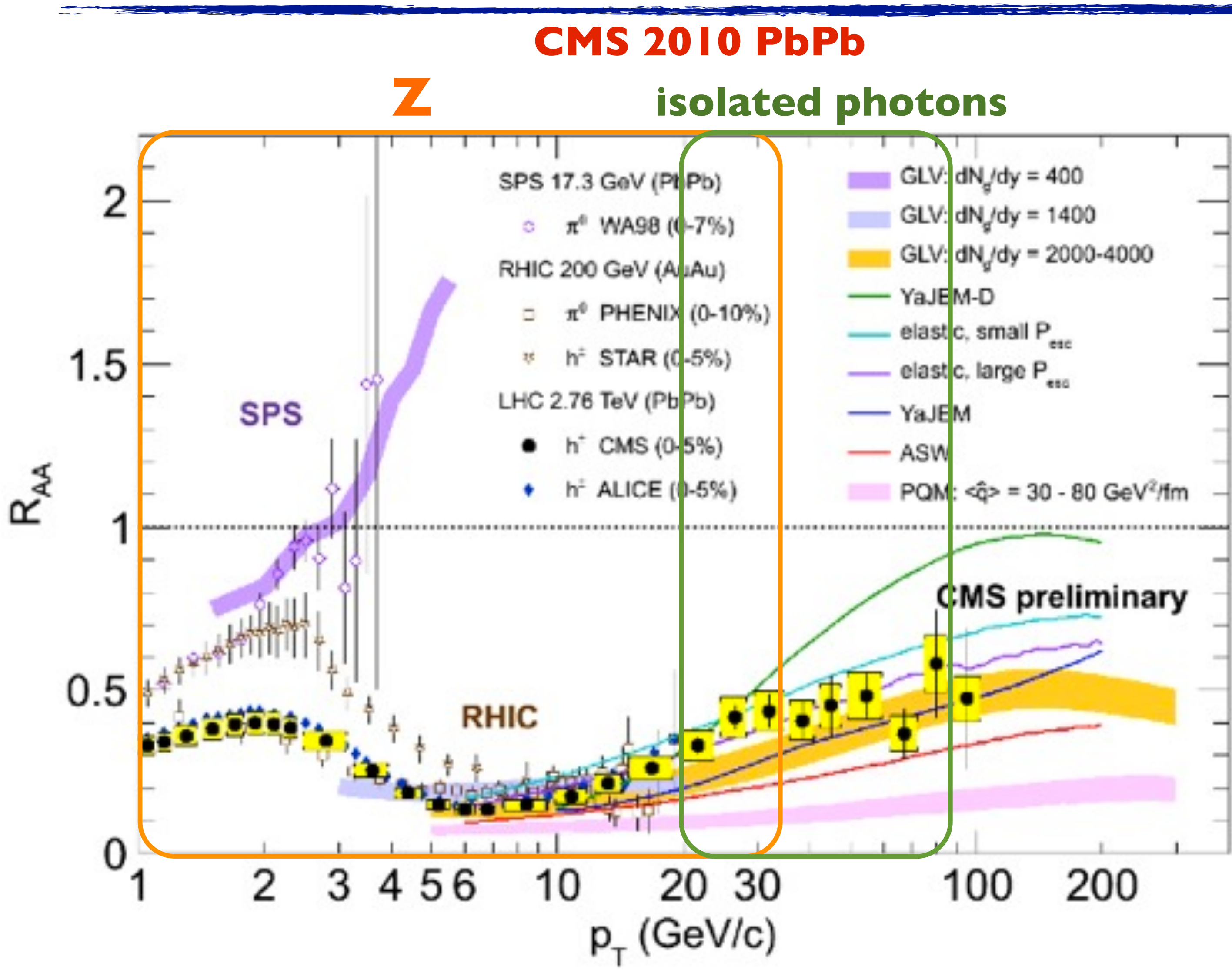


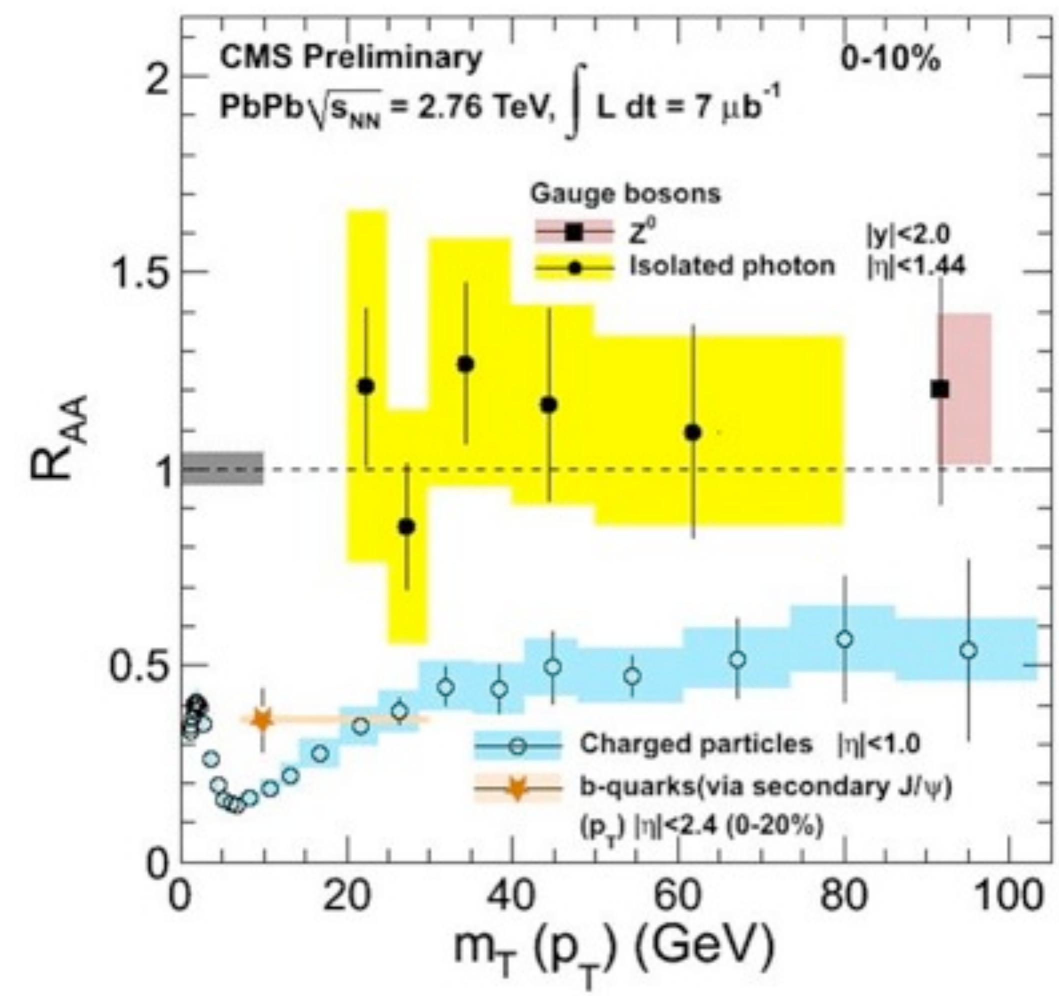


$$M_T = \sqrt{2 p_{T\mu} p_{T\nu} (1 - cos(\phi_{\mu\nu}))}$$

- Analysis cuts:
  - p_T^{μ} > 20GeV/c, $|\eta^{\mu}|$ < 2.4
  - $|\Delta\varphi| = |\varphi^{\mu}-\varphi^{MET}|$ > 2 rad
- Too look for:
  - charge asymmetries
  - R_{AA}

Conclusions





- CMS measured for the first time the Z and direct photons spectra in HI collisions.
  - ➡ on-going work for finalizing the W results
- No modification (initial or final) of the vector bosons is observed, within the uncertainties, in the kinematical regions reached with the 2010 recorded data

- Baseline comparison for _final state_ effects of charged hadrons
- More data needed for investigating/quantifying any _initial state_ effects