Revue EWK in Heavy Ions

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Rencontres QGP France
Etretat, le 11 septembre 2013

Outline

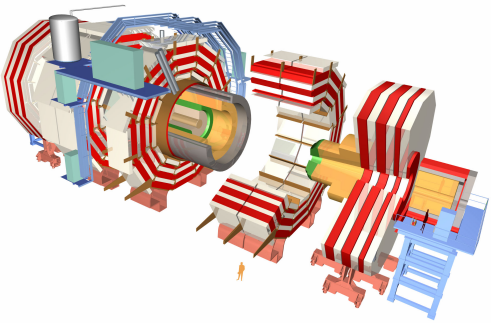
I. Introduction/motivation

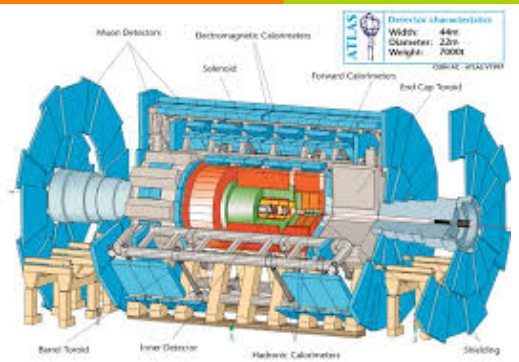
II. Electroweak bosons
- W
- Z
- Photons

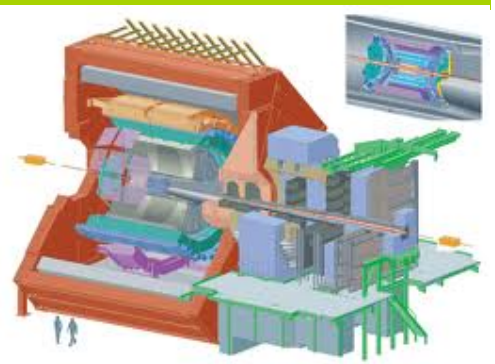
III. Boson-jet correlations
- Isolated photon-jet
- Z-jet

IV. Summary

CMS ATLAS ALICE







	CMS	ATLAS	ALICE
W	PLB 715 (2012) 66		
Z	PRL 106 (2011) 212301 CMS-PAS-HIN-13-004	PRL 110, 022301 (2013) PLB 697 (2011) 294-312	
γ	PLB 710 (2012) 256		QM12 M.WILDE
γ-jet	PLB 718 (2013) 773	ATLAS-CONF-2012-121	
Z-jet		ATLAS-CONF-2012-119	

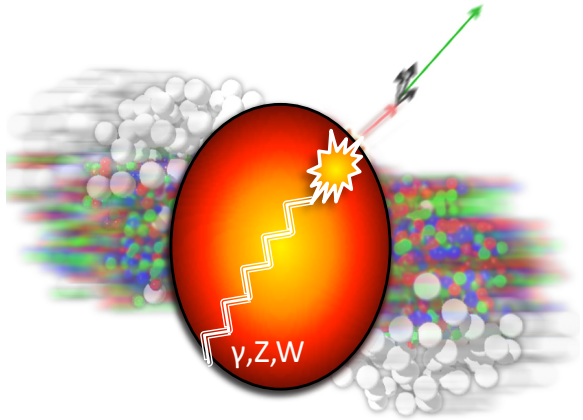
Why electroweak bosons in HI ?

- LHC energy allows for first observation and measurement of W and Z bosons as well as and Isolated photons in Heavy Ion collisions

- Photons, W, Z produced early in the collision with a typical lifetime of 0.1 fm/c, do not interact with the medium and therefore constitute an excellent reference of our measurements:

  - Check the binary scaling
  - Test pQCD predictions
  - Constrain nuclear PDFs

  - Reference for Jets
  - Detector performances

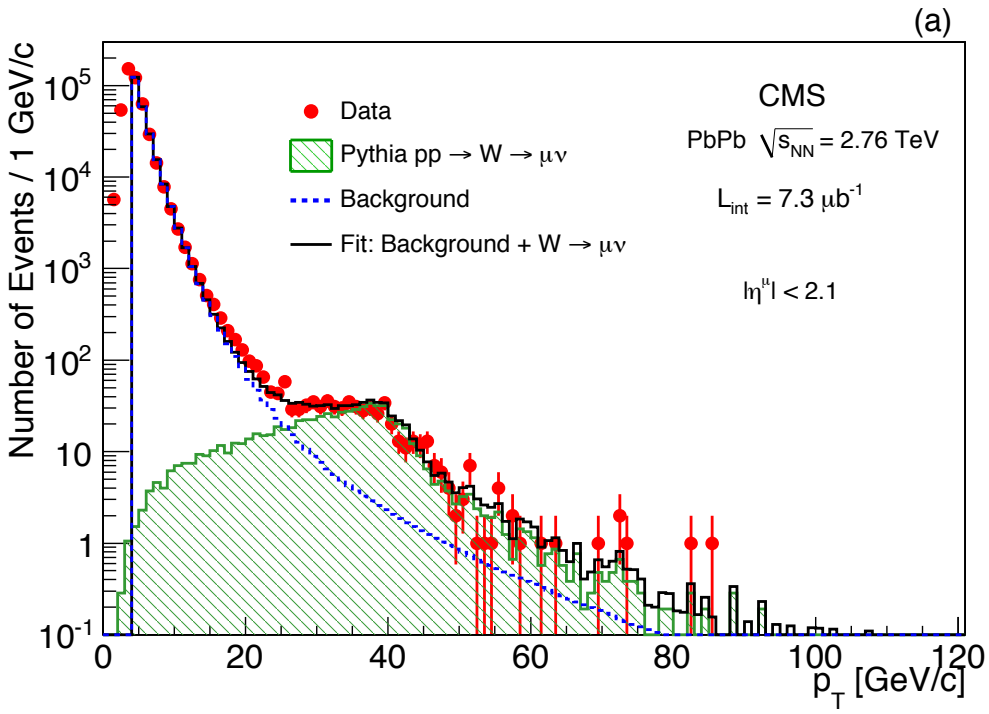


W bosons

- Production: at LO, **W**s are mostly produced via the fusion of a valence quark and a sea antiquark, **$u\bar{d} \rightarrow W^+$** and **$d\bar{u} \rightarrow W^-$**
  - strong **isospin effect** expected
- Signature: high p_T muon recoiling against (undetected) neutrino in transverse plane
- How to extract W yields?

→ Fitting single muon distribution
  - ATLAS Style

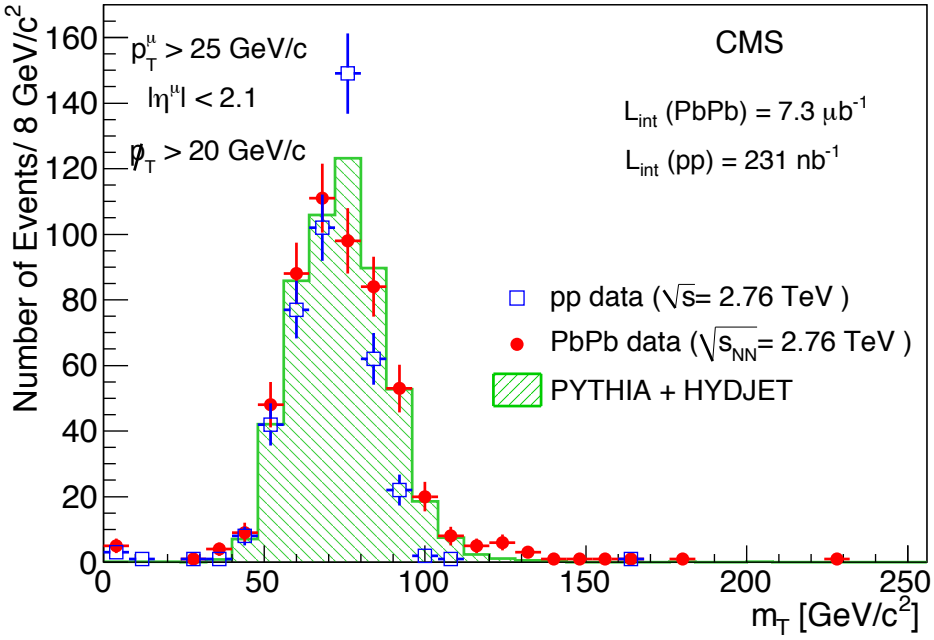
→ Counting from W transverse mass
  - CMS style



W transverse mass in CMS

- Transverse mass: $m_T = \sqrt{2 p_T^{\mu} \not{p}_T (1 - cos\phi)}$ $\phi = \phi(\mu) - \phi(\not{p}_T)$
  - Neutrino based on miss. p_T from track(p_T>3), miss. p_T>20GeV/c
  - p^{μ}_T>25GeV/c
- Sharp peak at $m_T = m_W$
- Residual contamination from Z →μ+μ-, W→ τ ν subtracted (2%), QCD (<1%)

(c)



- Raw W counts

	PbPb	pp
W^+	275	301
W^-	264	165

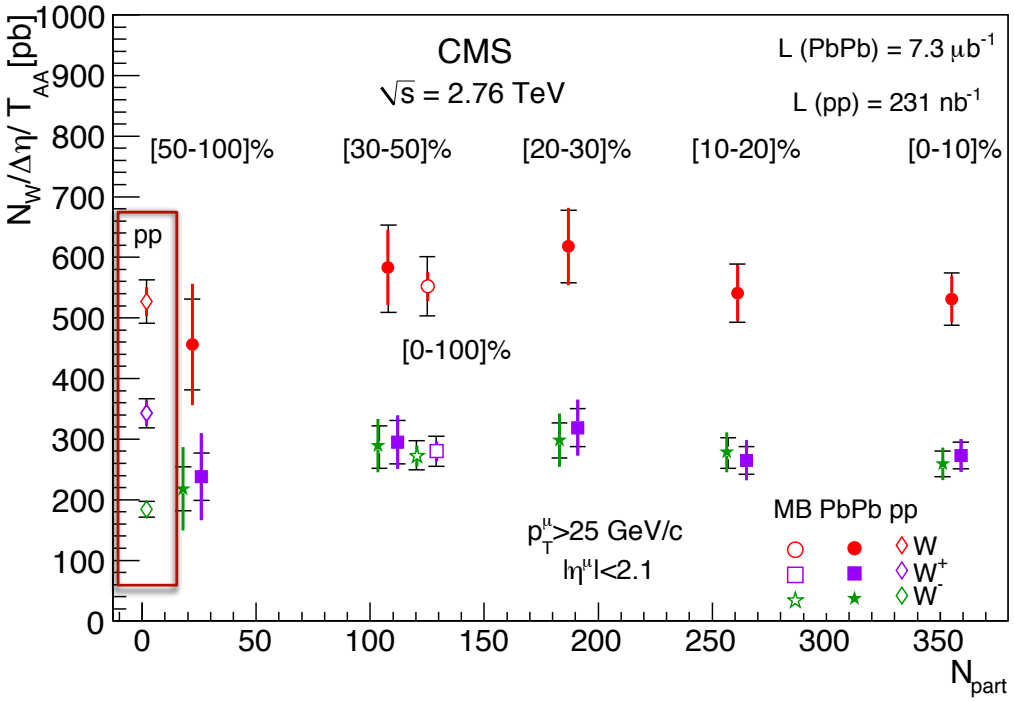
W centrality independence

$dN_{AA} / T_{AA} = d\sigma_{pp} \times R_{AA}$

$R_{AA}(W) = 1.04 \pm 0.07 \pm 0.12$

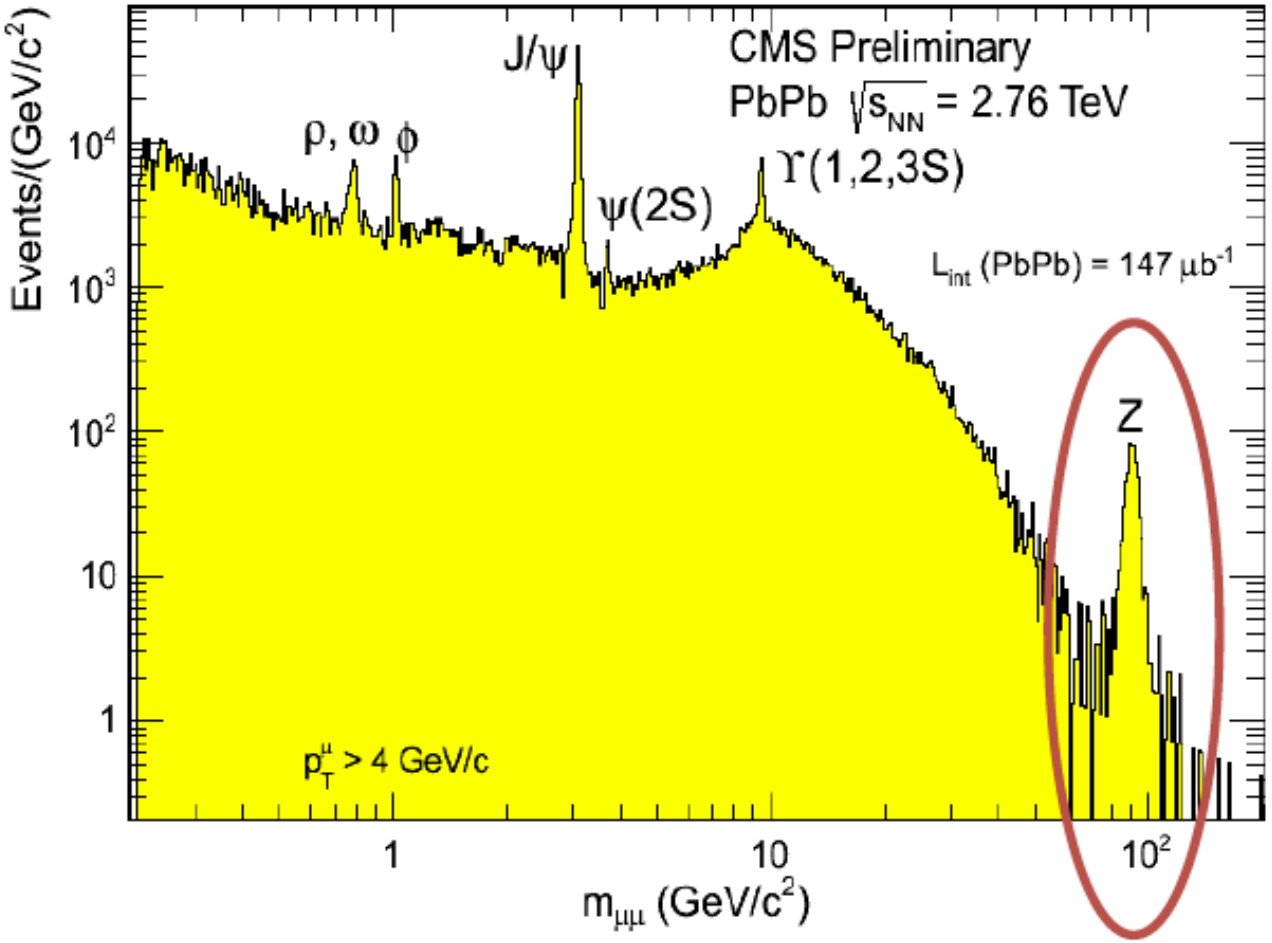
$R_{AA}(W^+) = 0.83 \pm 0.07 \pm 0.09$

$R_{AA}(W^-) = 1.46 \pm 0.14 \pm 0.16$

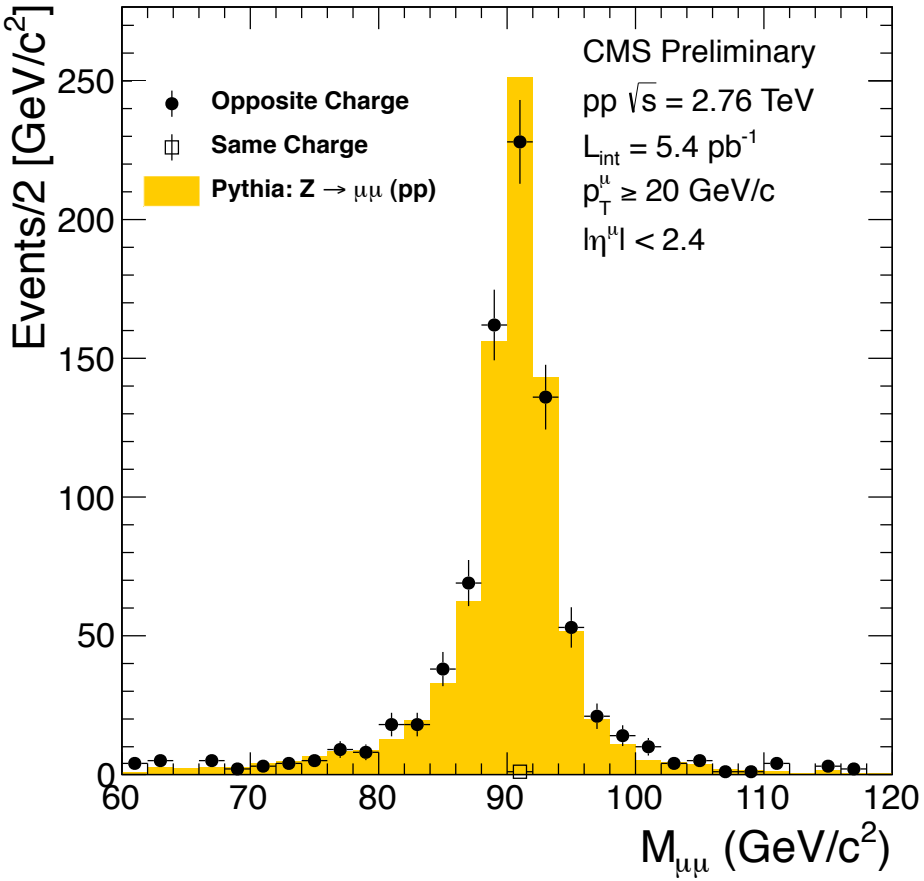


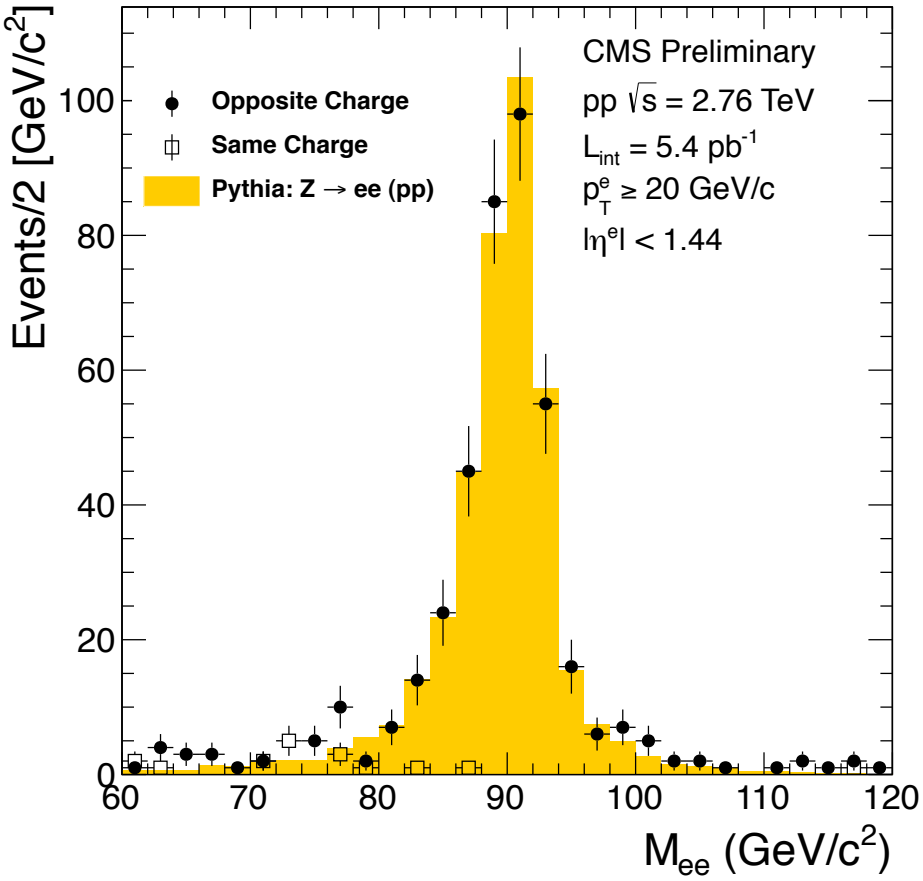
- Individual R_{AA} for W^+ and W^- reflect the different u & d quark content in Pb and proton → isospin effect
- Within uncertainties, no dependence of W production vs. centrality observed in PbPb collisions

Z boson

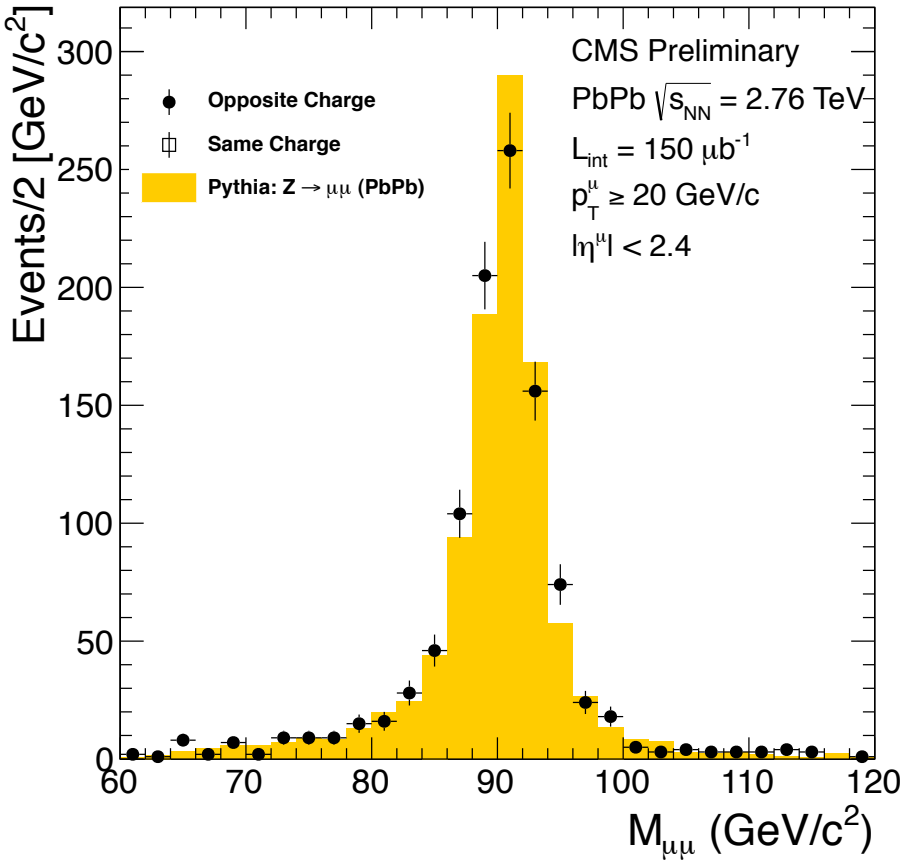

CMS Preliminary
PbPb $\sqrt{s_{NN}}$ = 2.76 TeV
L_{int} (PbPb) = 147 μb^{-1}
J/ψ
ρ, ω ϕ
ψ(2S)
ϒ(1,2,3S)
Z
p_T^μ > 4 GeV/c
Events/(GeV/c^2)
$m_{\mu\mu}$ (GeV/c^2)
10^4
10^3
10^2
10
1
1
10
10^2

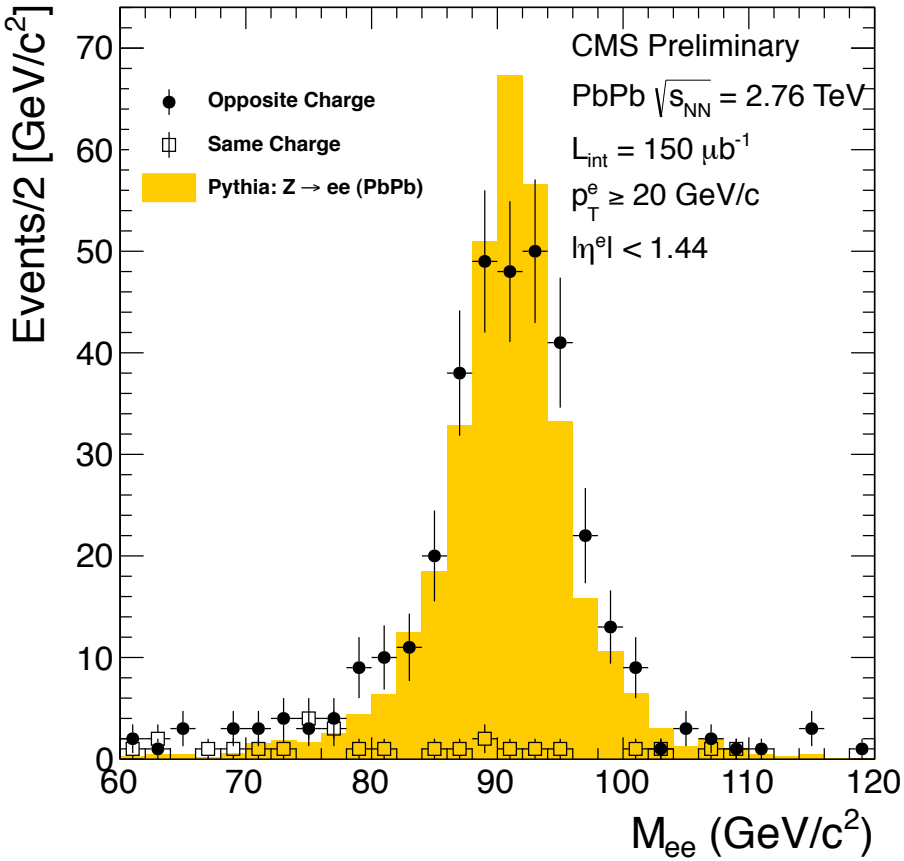
Di-muon/electron Invariant Mass in pp





Di-muon/electron Invariant Mass in PbPb





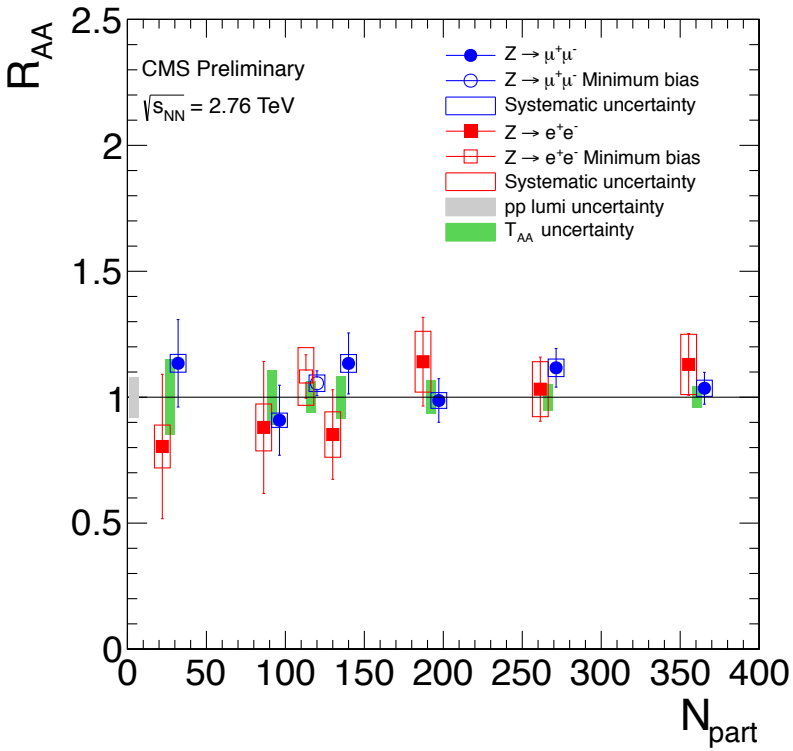
R_{AA} vs. N_{part}

- Nuclear modification factor:

$$R_{AA} = \frac{dN^{AA}}{d\sigma \times T_{AA}}$$

divide PbPb yield normalized by collision geometry (T_{AA}), by pp yield

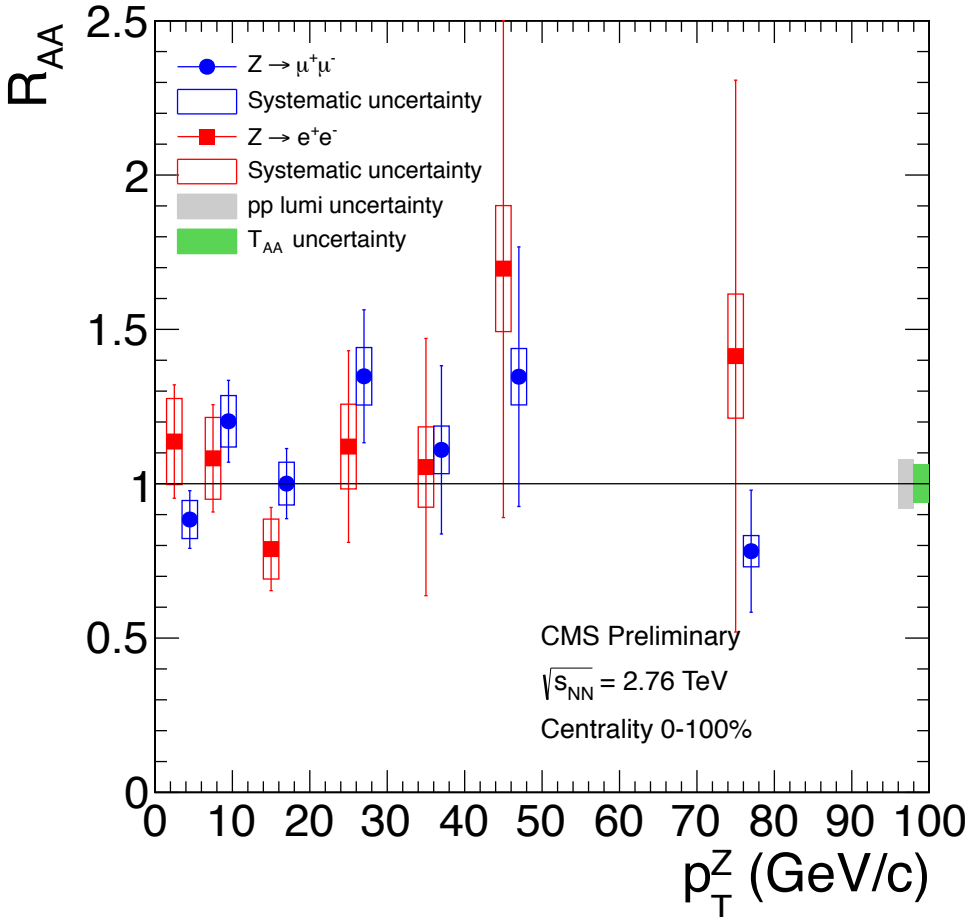
R_{AA}(muon) = 1.06 ± 0.05 ± 0.11
R_{AA}(electron) = 1.08 ± 0.09 ± 0.14

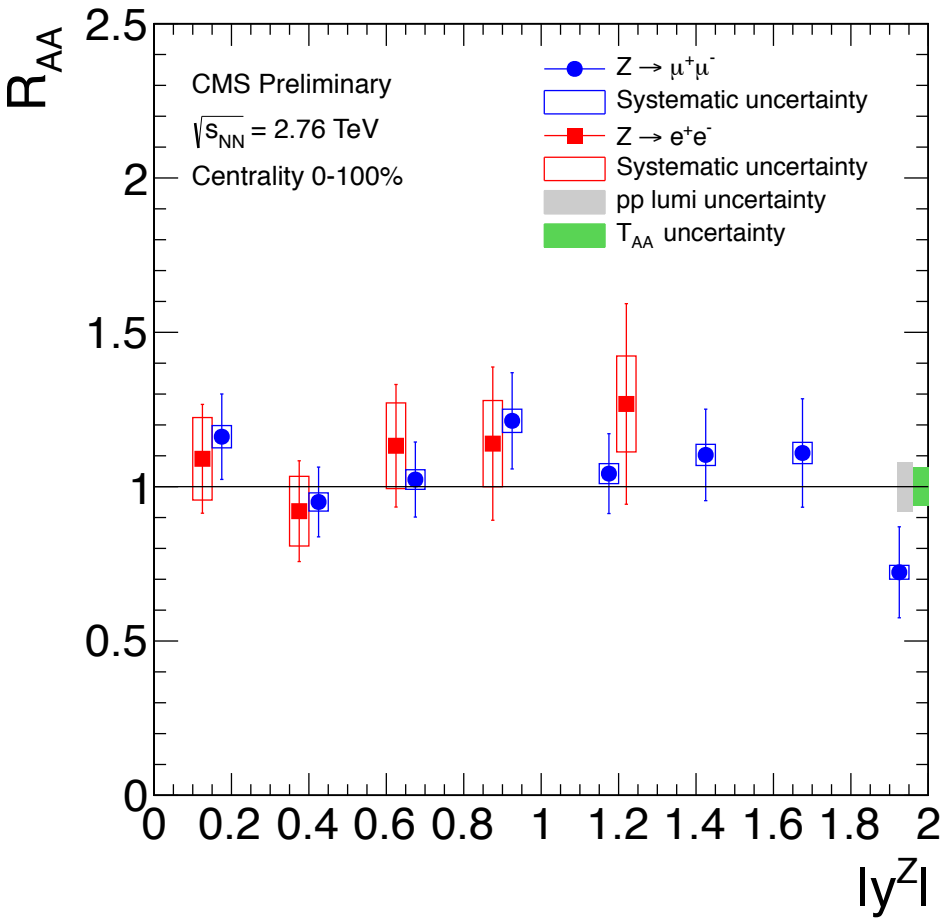


- Z boson production in both channels in PbPb collisions scale with T_{AA}s
- Biggest systematic uncertainty comes from pp luminosity!

R_{AA} vs. p_T

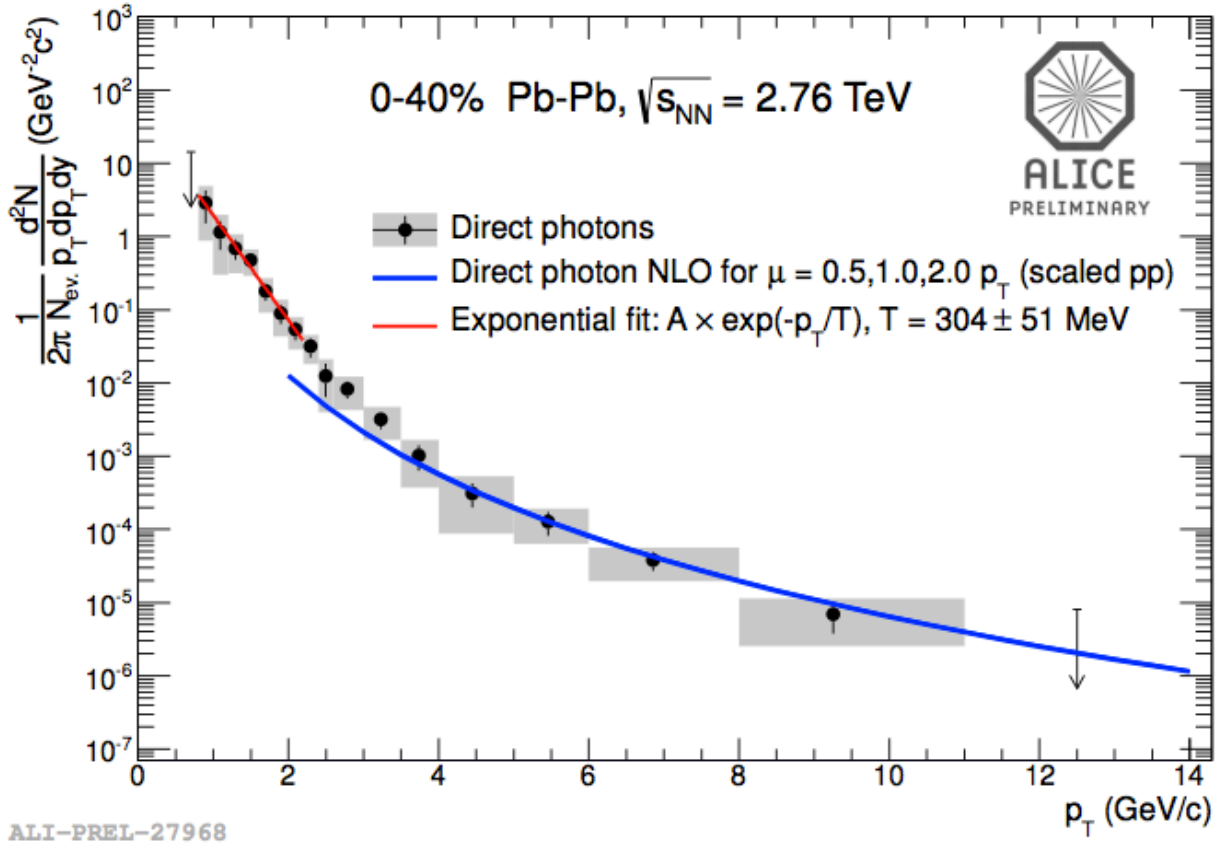
R_{AA} vs. |y|





- R_{AA} compatible with 1
- Nuclear effects: need more statistics to probe this scale

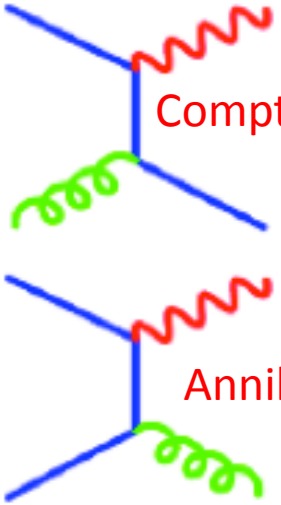
Photons directs

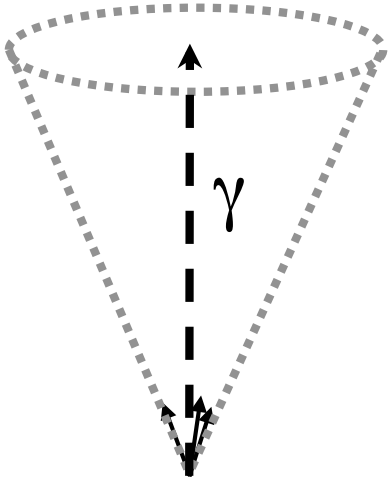


- Spectrum consistent with NLO pQCD calculation for p_T > 4GeV/c
- Excess at low p_T interpreted as thermal photon signal

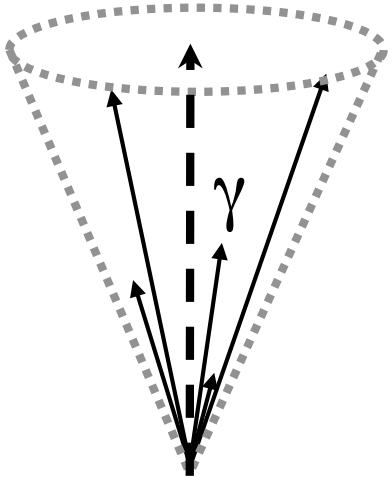
Effective temperature 304 ± 51 MeV

Isolated Photons

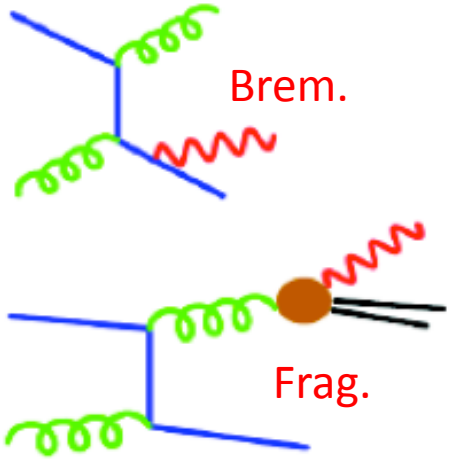


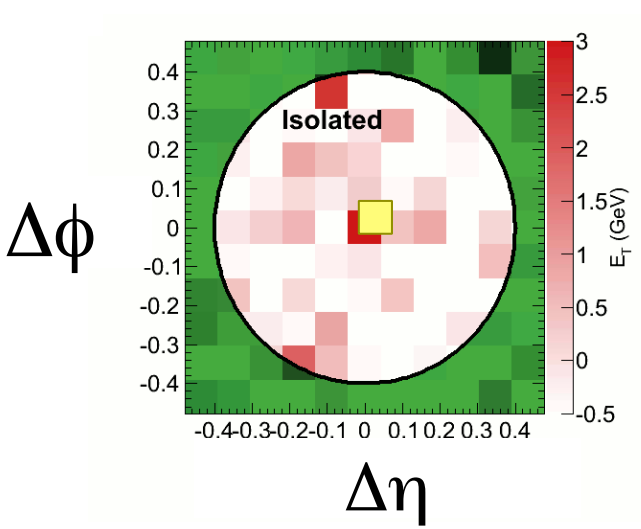


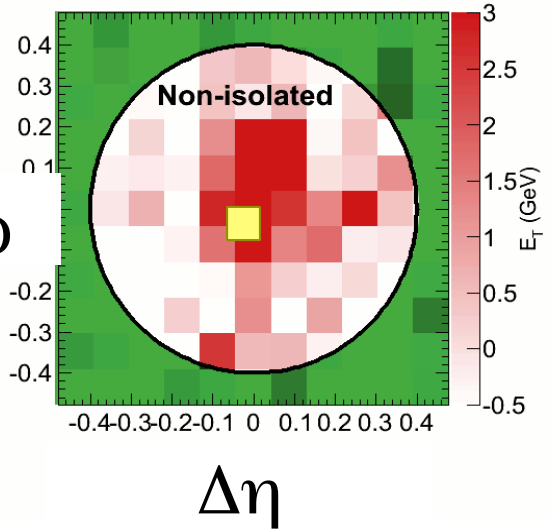
Isolated photon



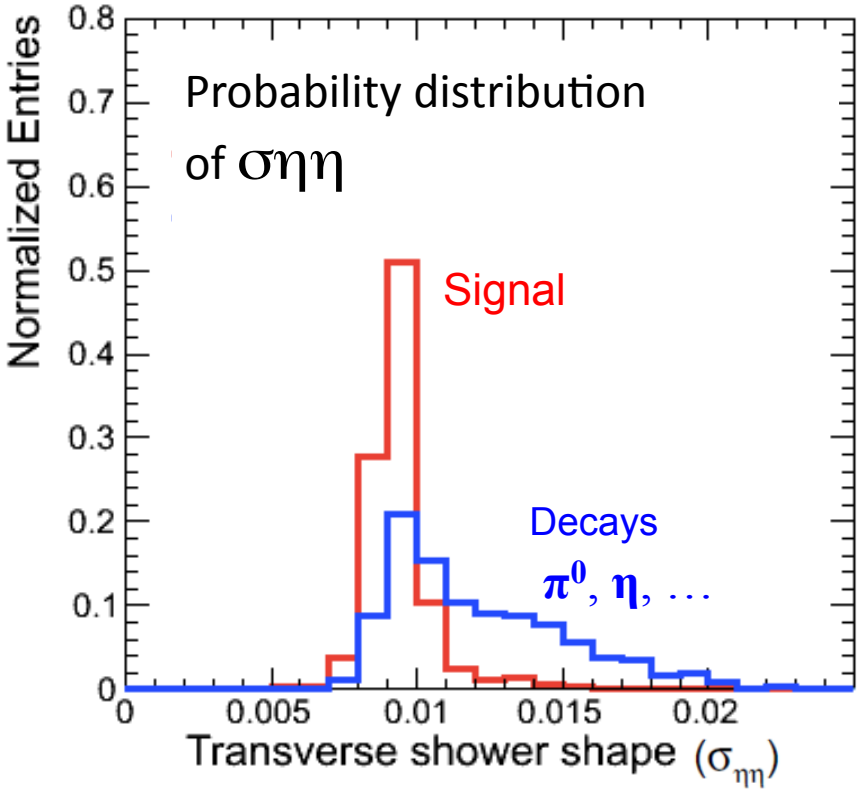
Non-isolated photon



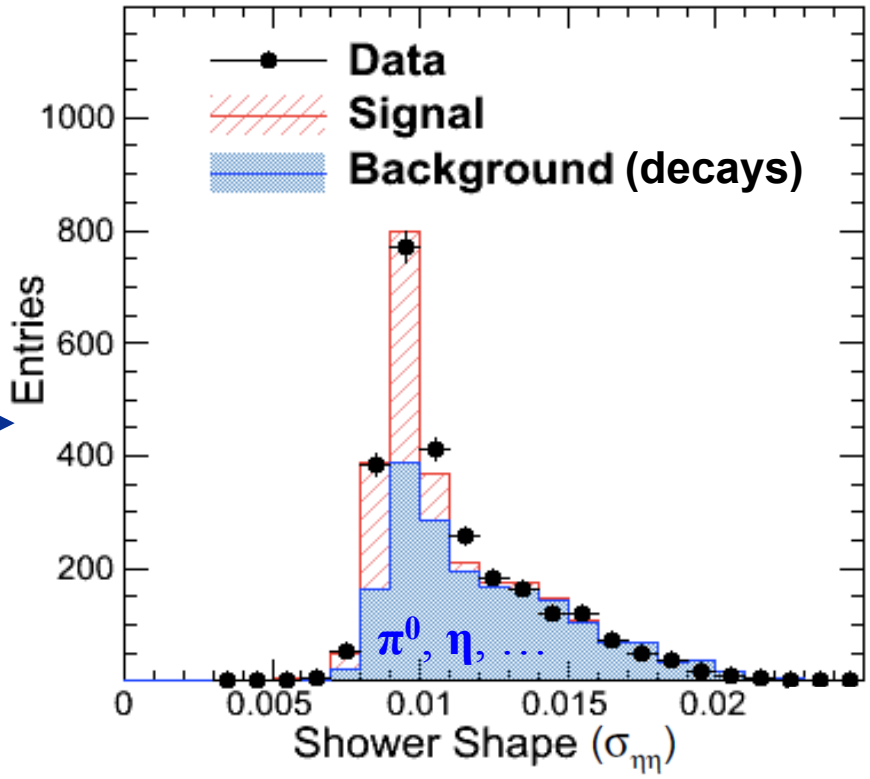




Details of removing decay photons



Fit data with a sum of the 2

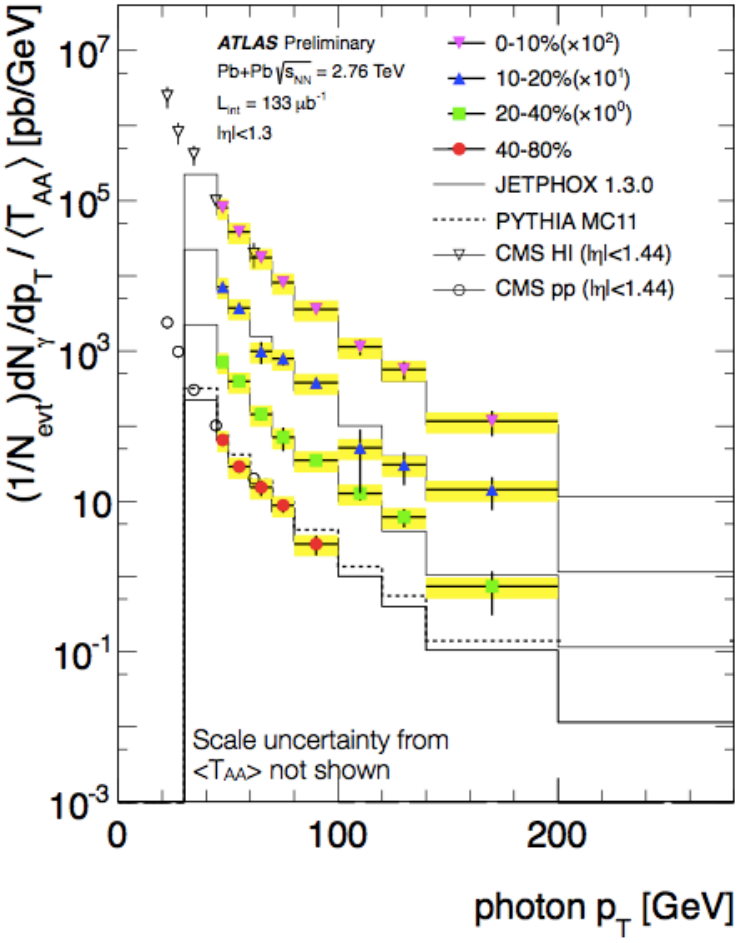


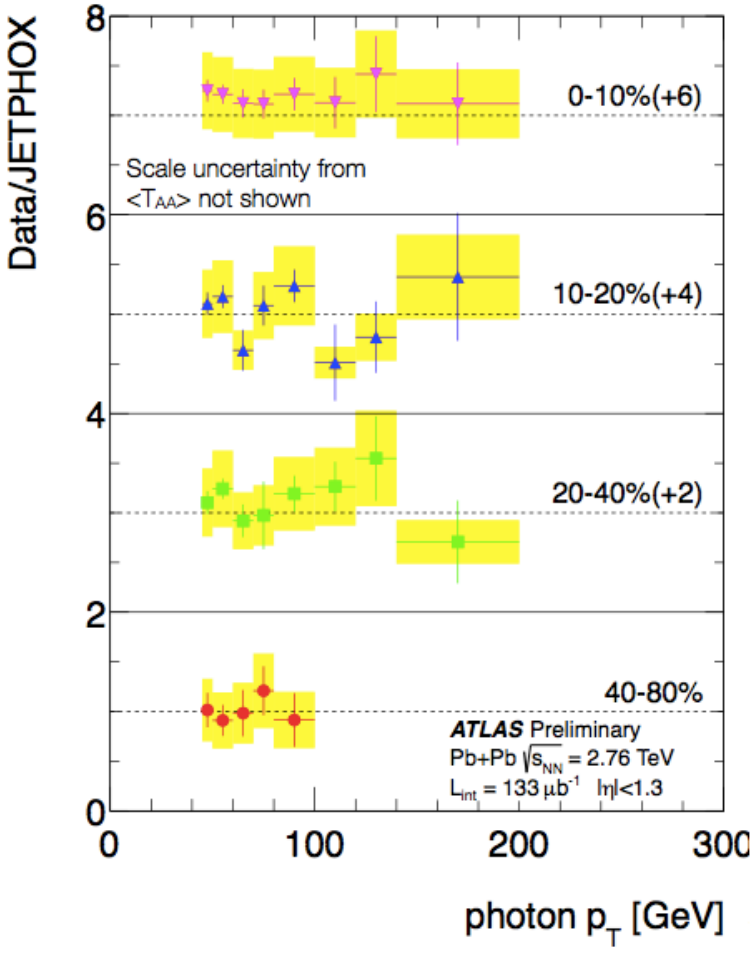
Signal template: obtained from PYTHIA+MinBias data

Decay template: Using a data-driven method with non-isolated photons:

$\Delta R<0.4$, 6 GeV < $\Sigma E_T^{IsoCone}$ < 11 GeV

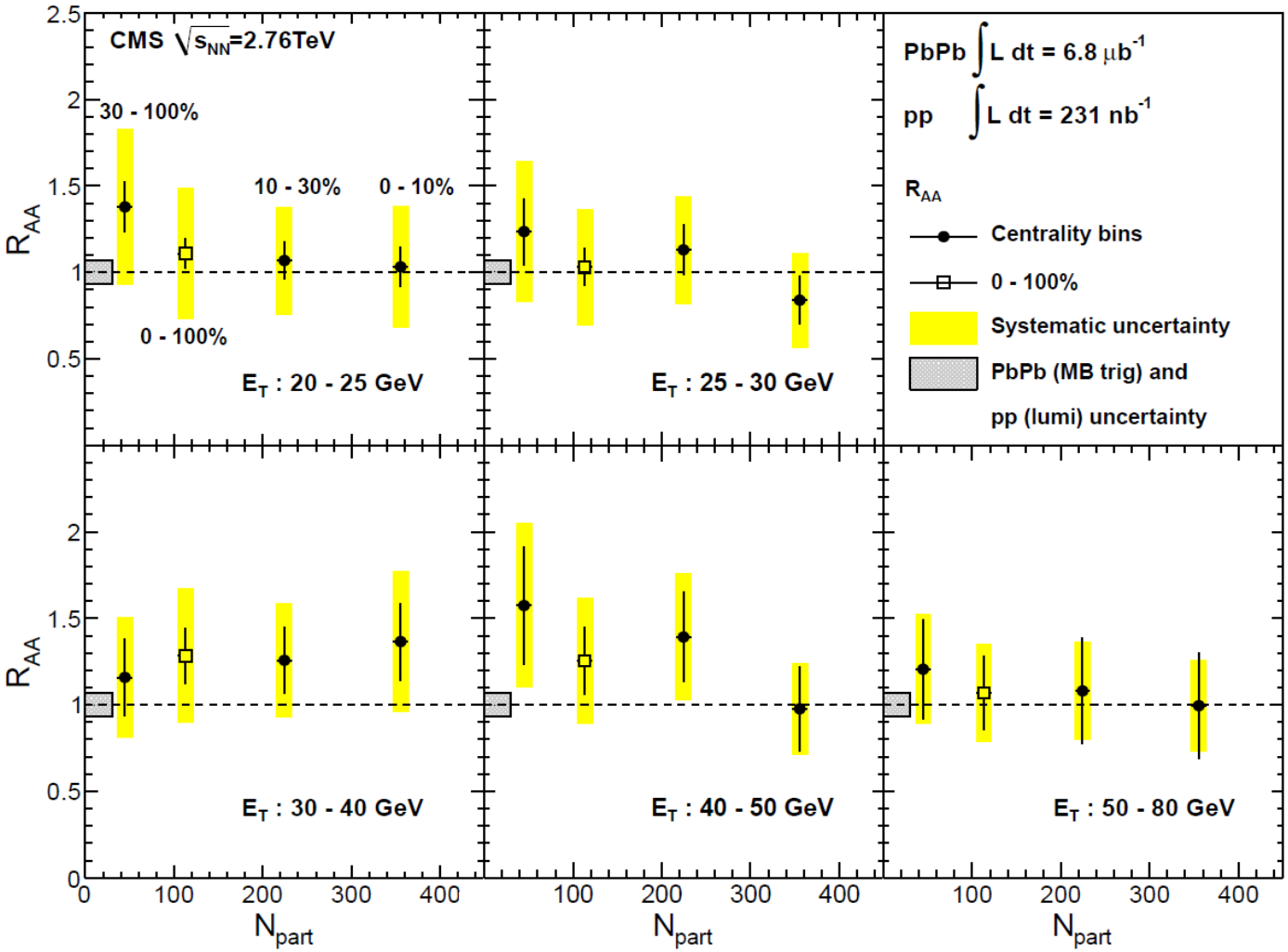
Isolated photon spectrum





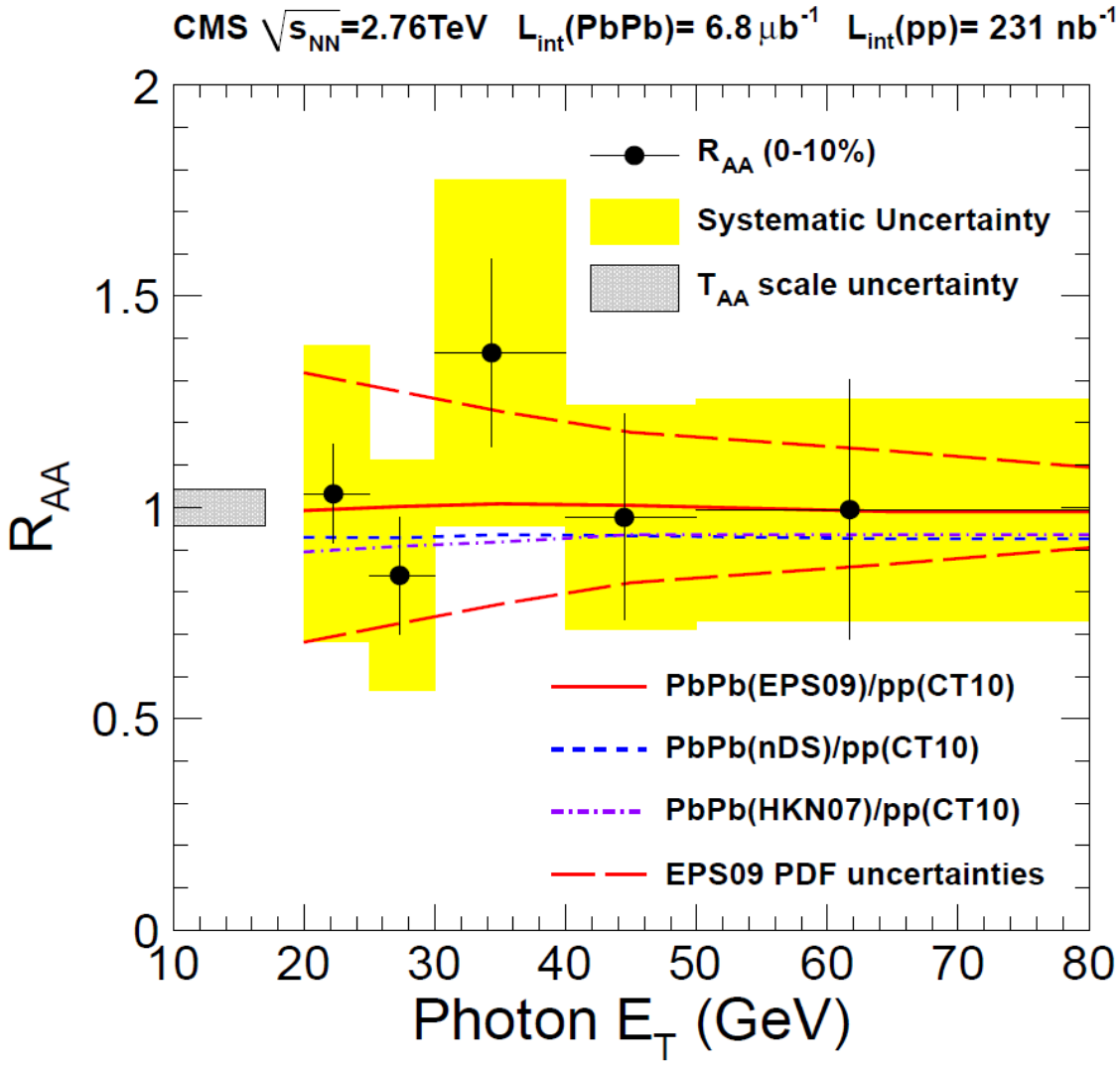
- Consistent with JETPHOX with unmodified pdf (CT10)

Isolated Photon R_{AA}



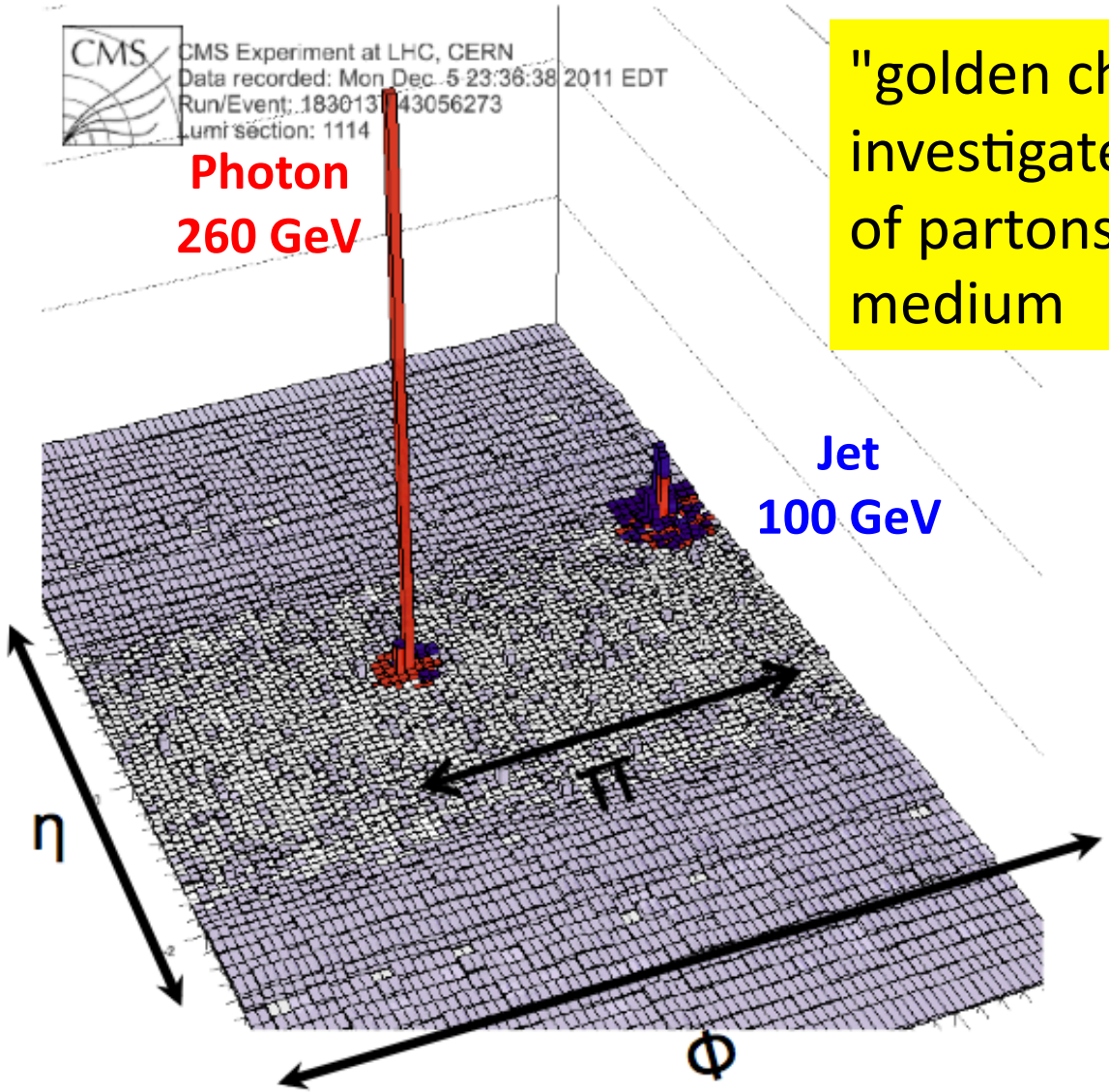
No dependence on centrality or E_T

Isolated Photon R_{AA}



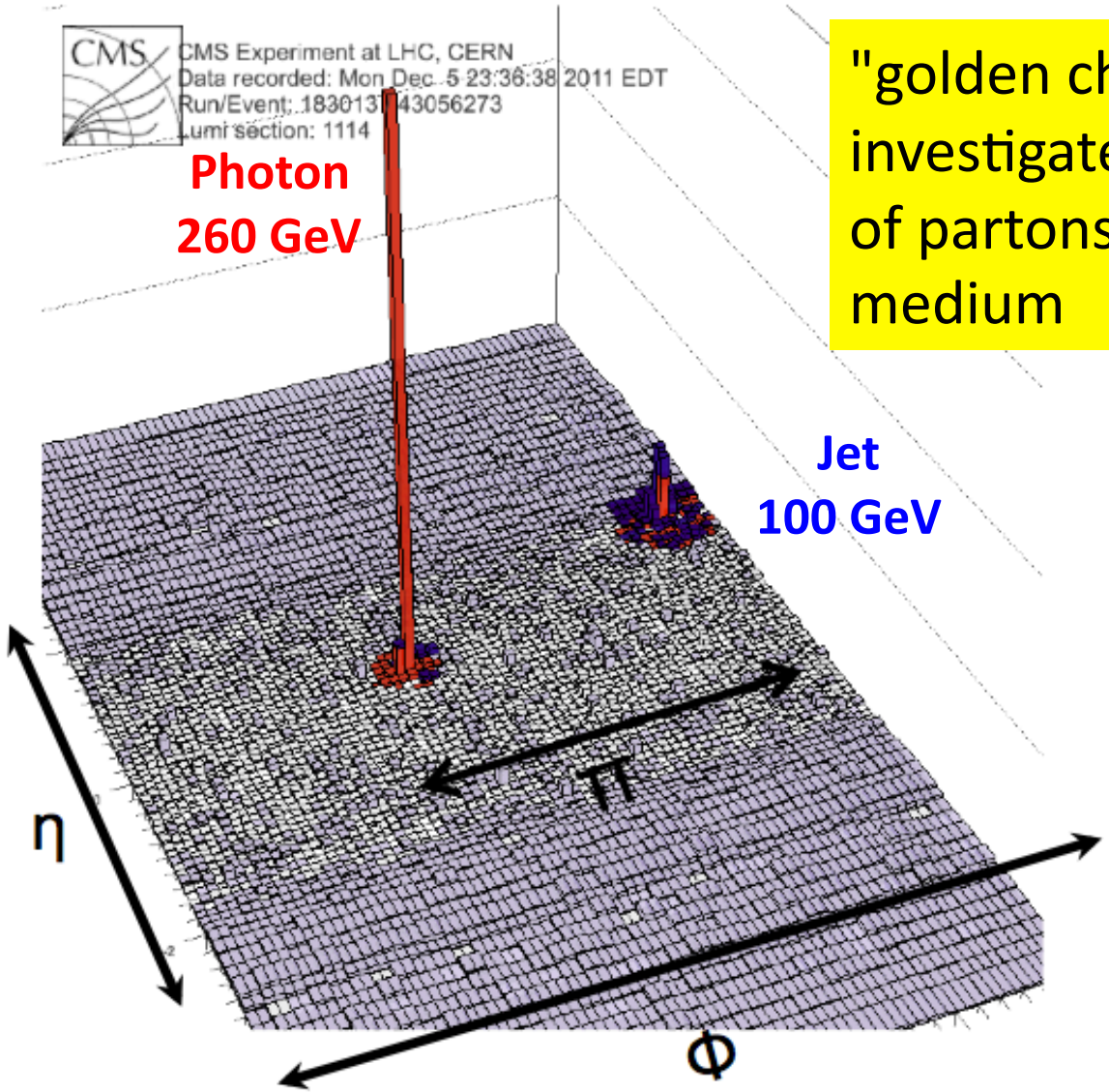
- R_{AA} consistent with 1
- Compare to NLO with nPDFs: EPS09, nDS, HKN07

Boson-jet correlations



"golden channel" to investigate energy loss of partons in the medium

Boson-jet correlations



"golden channel" to investigate energy loss of partons in the medium

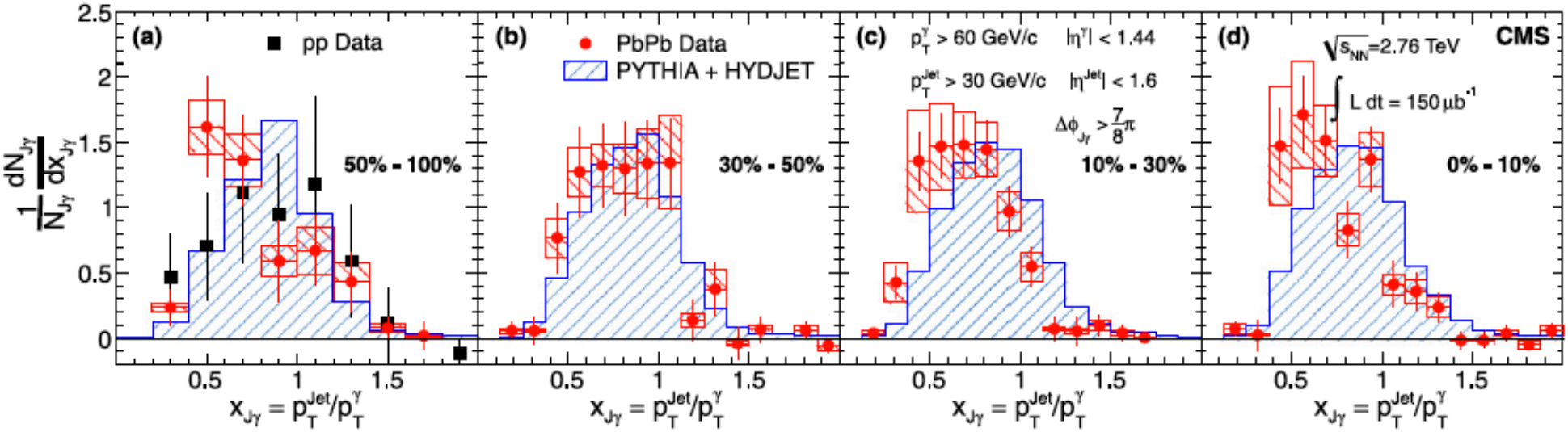
Goal: characterise possible modifications of jet properties as a function of centrality

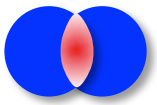
p_T^{jet} / p_T^{γ}

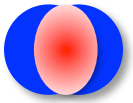
- **$x_{j\gamma} = p_T^{jet} / p_T^{\gamma}$** is a direct measurement of energy loss

Isolated photon: $|\eta^{\gamma}| < 1.44$ and $p_T^{\gamma} > 60$ GeV/c jet: $|\eta^{jet}| < 1.6$ $p_T^{jet} > 30$GeV/c

Back-to-back requirement $\Delta\Phi_{j\gamma} > 7\pi/8$

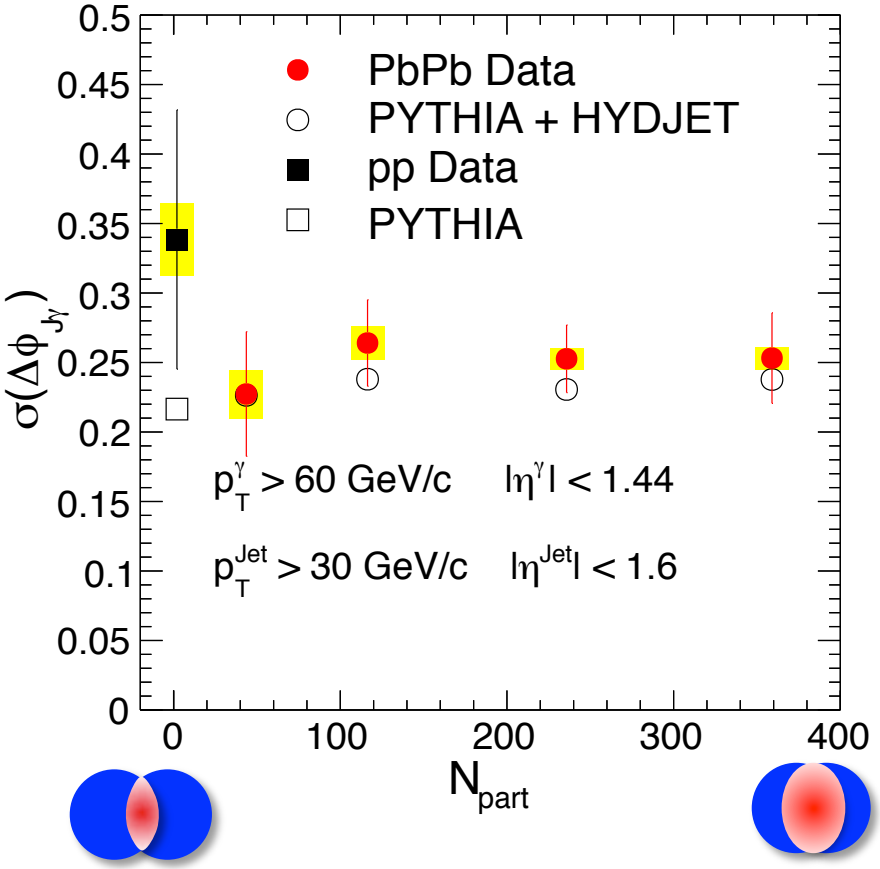


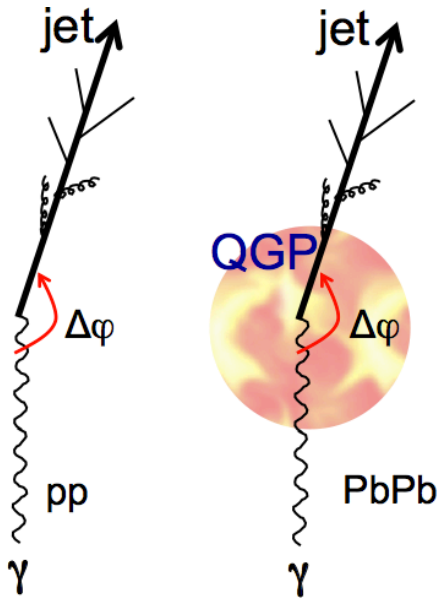




Gradual centrality dependence of the $x_{j\gamma}$ distribution

Angular correlation

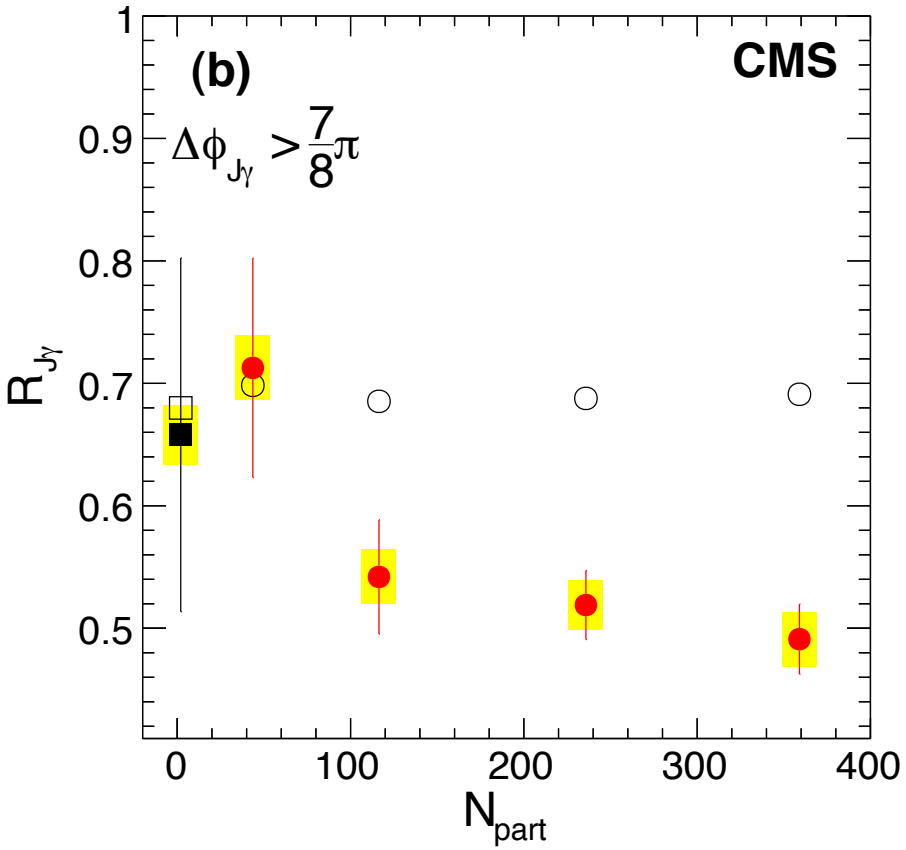


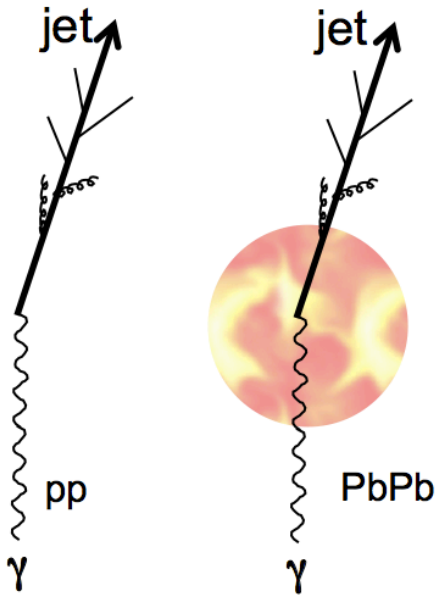


Consistent $\Delta\Phi_{J\gamma}$ distribution in pp and PbPb

Jets partners missing in PbPb

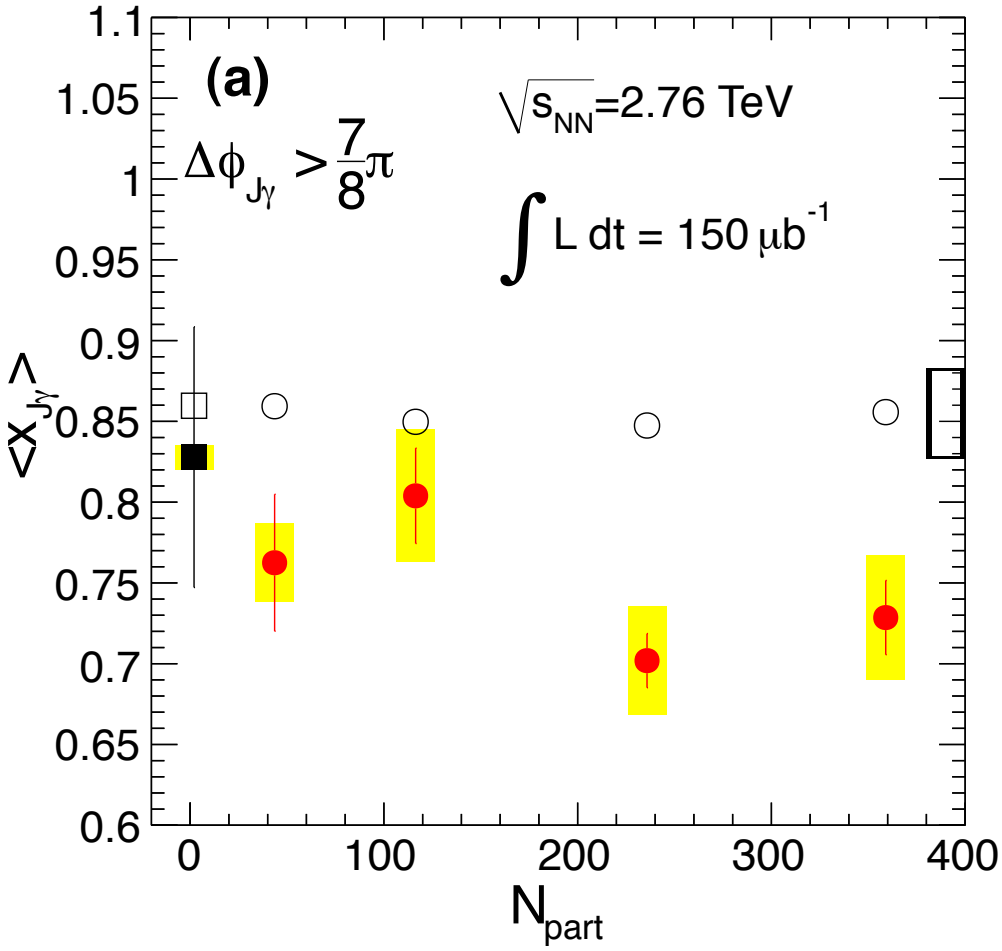
◆ $R_{j\gamma}$: average fraction of isolated photons with associated partner jet above 30 GeV/c

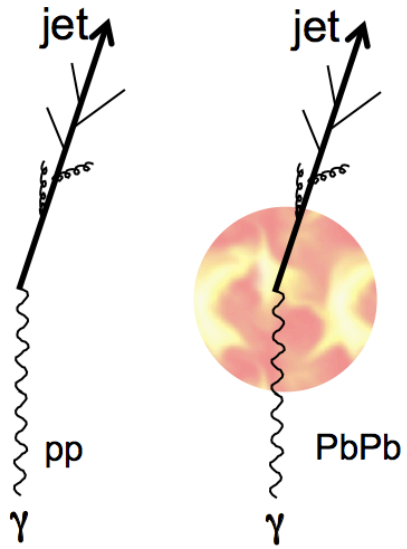




20% of jet partners are missing in PbPb

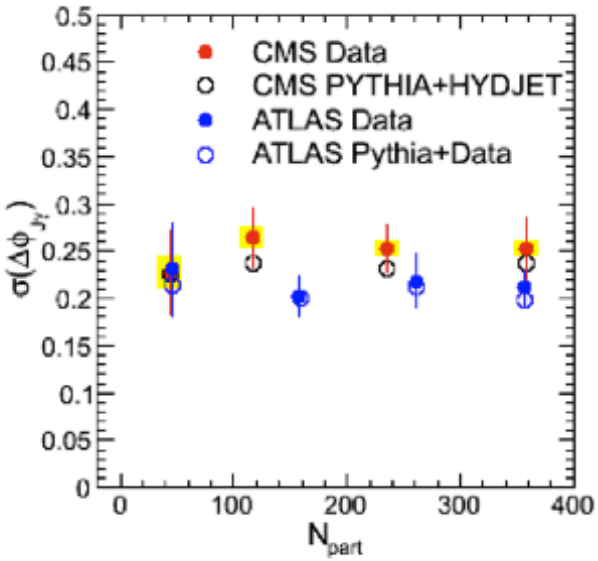
$< p_T^{jet} / p_T^{\gamma} >$

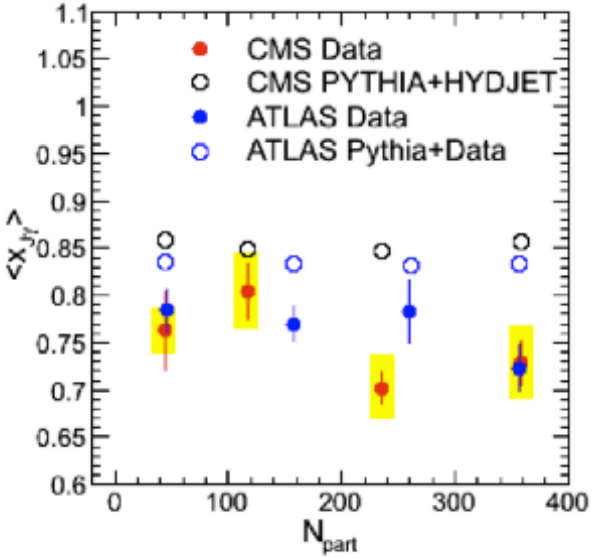


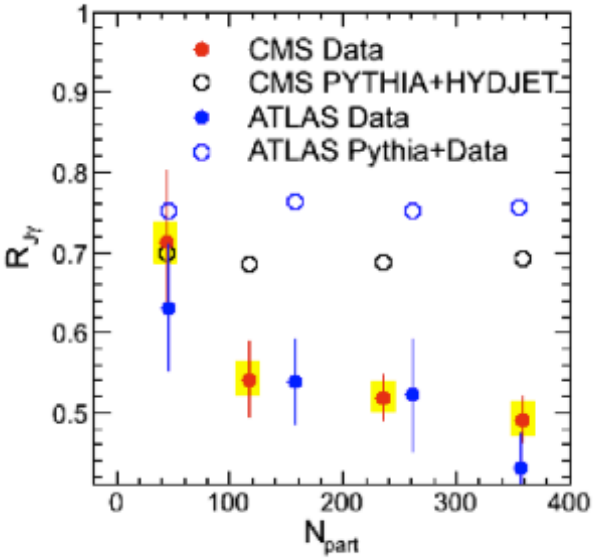


14% of jet energy was lost in PbPb

Comparison ATLAS vs. CMS

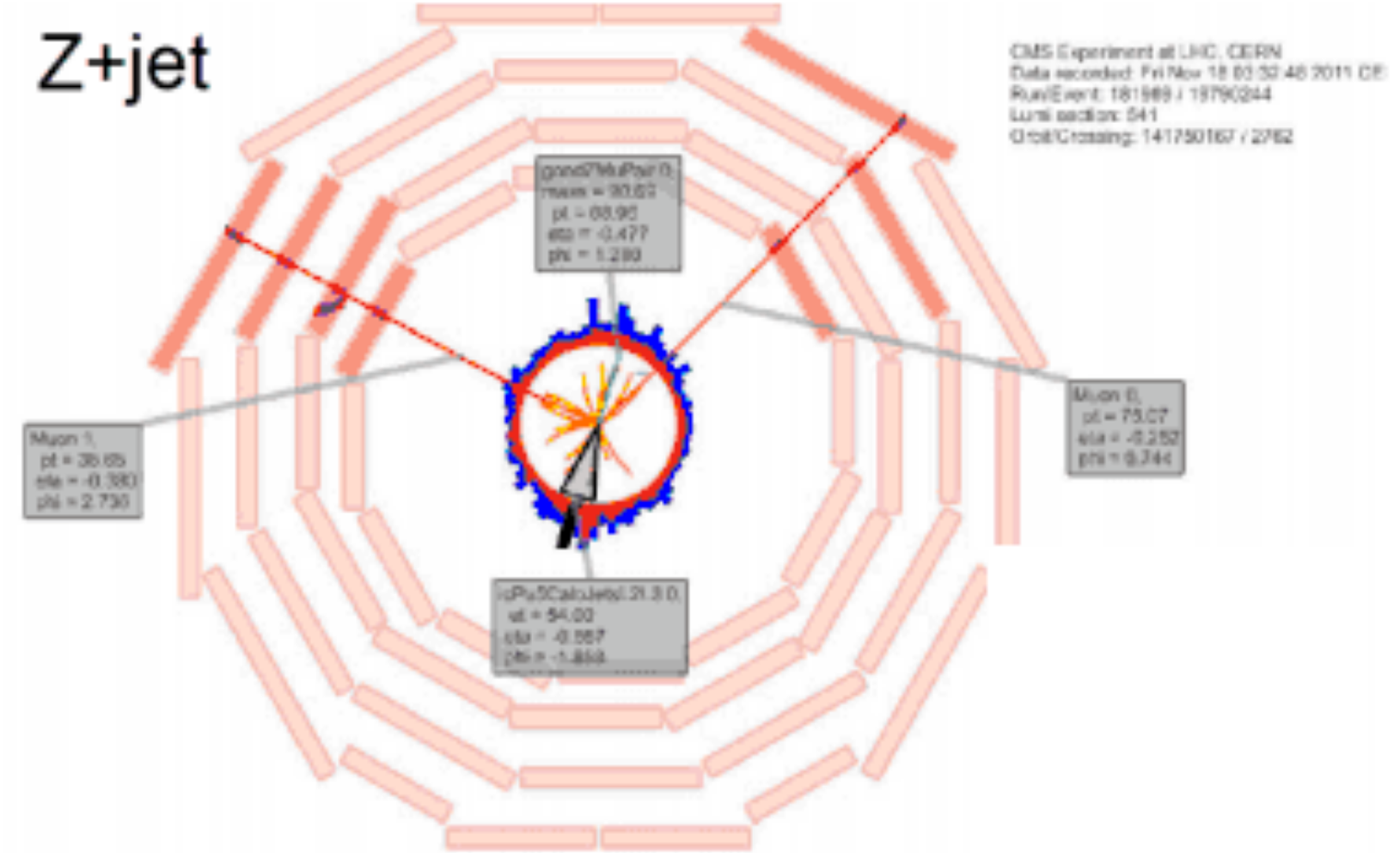




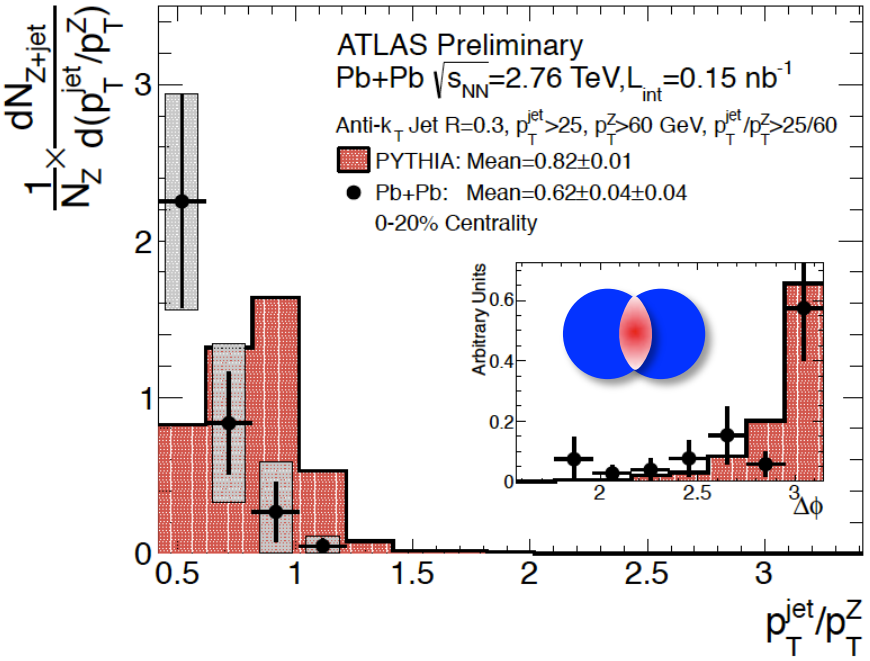


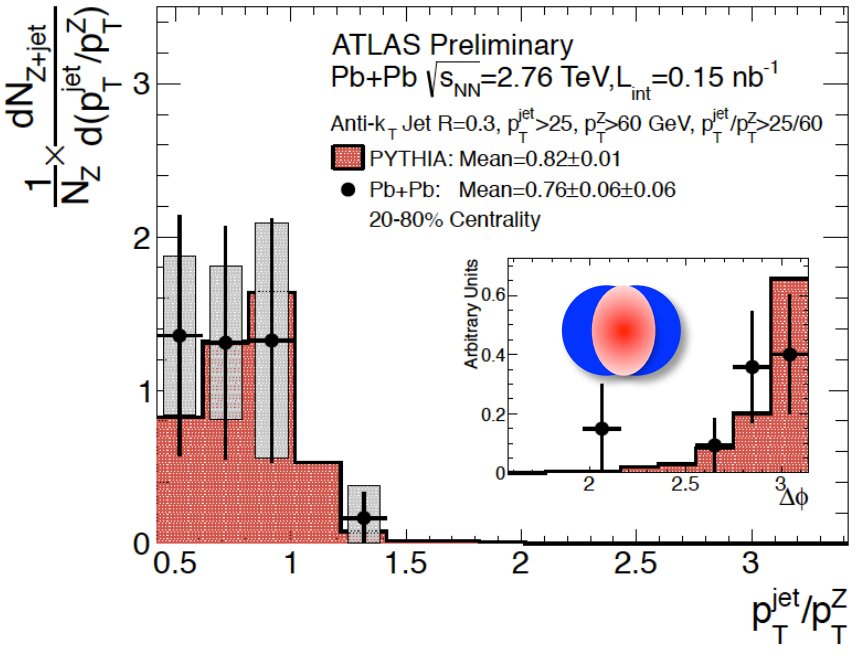
Compatible!

Z-Jet



p_T^{jet} / p_T^{Z}

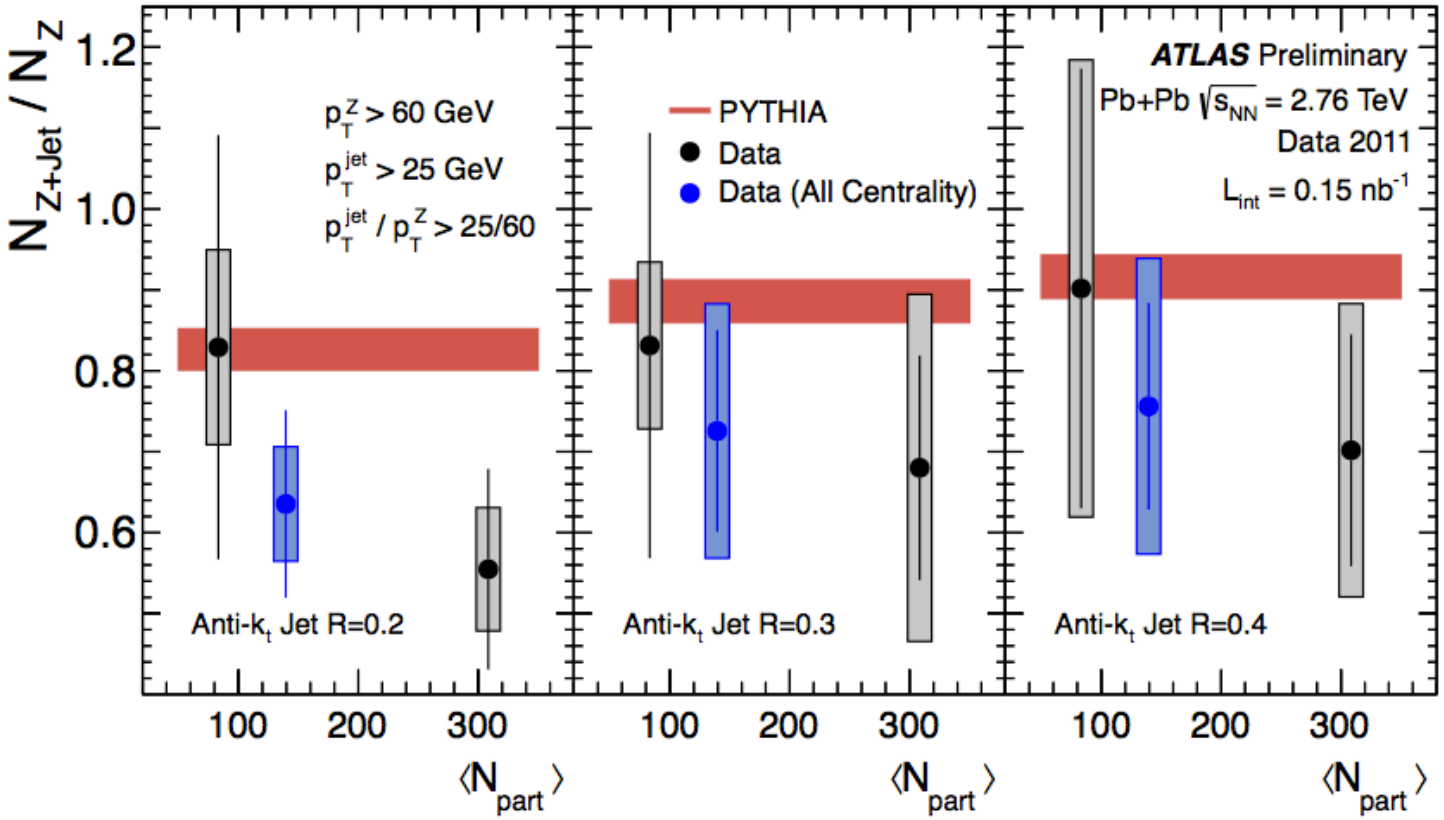




- Back-to back correlation preserved (as seen for photon-jet)
- Reduction in momentum ratio for more central events

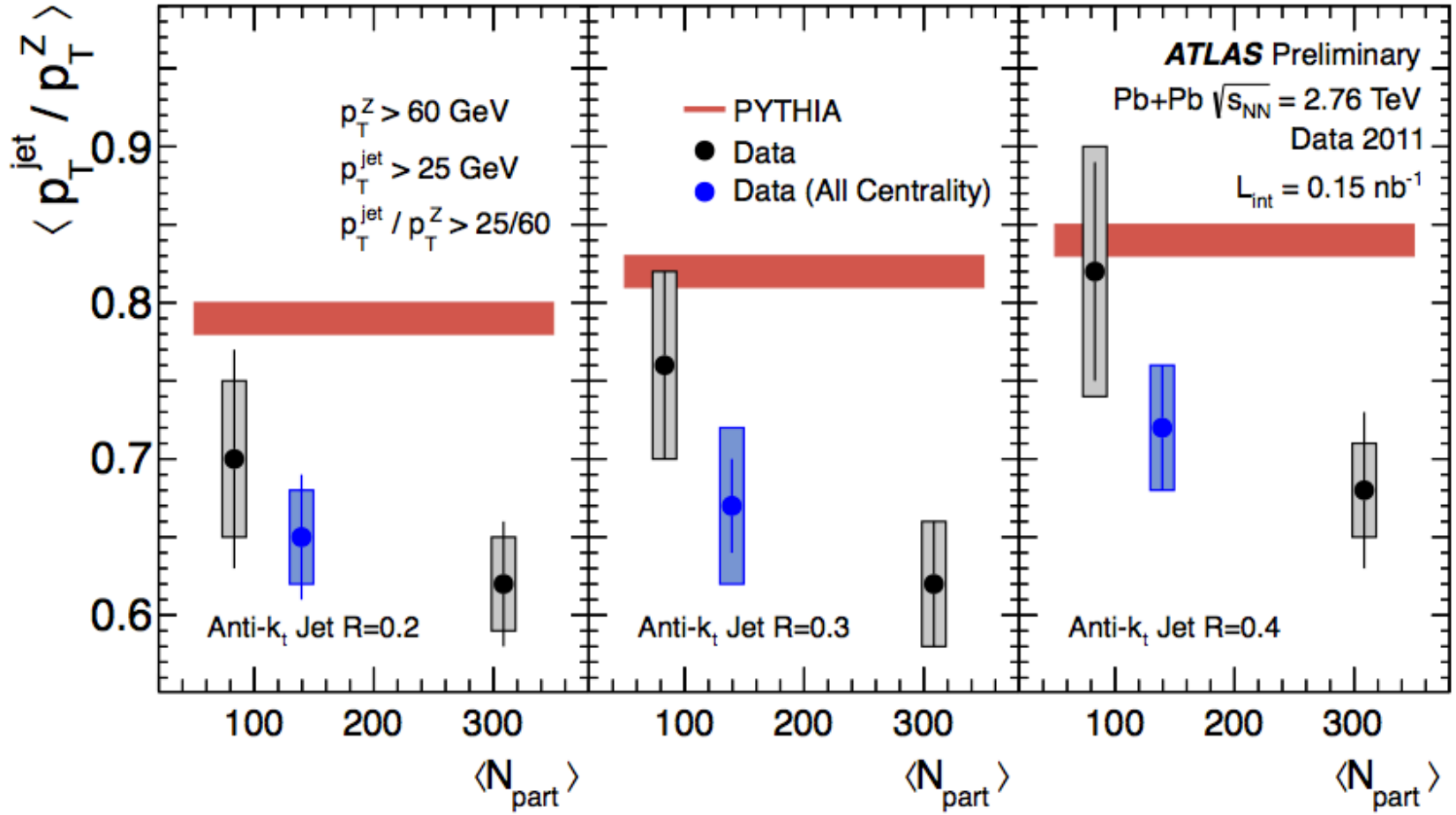
Jets partners missing in PbPb

- N_{Z+Jet} / N_Z: fraction of event with a Z boson (p_T > 60 GeV/c) that also have a jet reconstructed (p_T^{jet} > 25 GeV/c)



- Reduction of jet yields per bosons for 3 considered jet cone sizes

$< p_T^{jet} / p_T^{Z} >$



- Reduction $< p_T^{jet} / p_T^{Z} >$ as a function of centrality for the 3 considered jet cone sizes

Summary

- LHC energy allows for first observation and measurement of W and Z bosons as well as and Isolated photons in Heavy Ion collisions

- Photons, W, Z produced early in the collision with a typical lifetime of 0.1 fm/c, do not interact with the medium and therefore constitute an excellent reference of our measurements:

- Check the binary scaling → Done
- Test pQCD predictions → Done
- Constrain nuclear PDFs → cf. Alice W en pPb

- Reference for Jets → True
- Detector performances → Always

Back up

Z-Jet

- Observe the quenching of the jet energy relative to the Z boson
- Method:
  - Consider the ratio of their relative transverse momentum

  p_T^{jet} / p_T^{Z}

- Jet reconstructed using anti-kT algo using 3 cone sizes 0.2, 0.3, 0.4 following the subtraction of UE R
  - 2 iterative prodedure
  - To reject fake jets all jet $\Delta R < 0.4$
  - Jet minumum pT of 25GeV; jet in |eta| < 2.1
- 36 Z in ll

https://cdsweb.cern.ch/record/1472941

- prompt photons are selected using an isolation requirement, namely that the additional energy in a cone of fixed radius around the direction of the reconstructed photon be less than a specified value
  - pT gamma > 60, |eta gamma|< 1.44
  - pT jet > 30, |eta gamma|< 1.6

- Cut H/E < 0.1 selected
- The detector activity in a cone with R=0.4 with respect to the centroid
- Isolation → reject photon candidates originating from jets
- UE ~20GeV

- To choose Z bosons and jets that are correlated
  - only pairs that are separated by at least Pi/2 are considered
  - Look at how the fake rejection works
  - We should take relatively high-pT Z (above 60)
  - pTjet/pTZ > 25/60 (=0.42)
  - 36 event including 8 that have multi-jets reconstructed with a pT of more than 25 (add them or not didn't change significantly the results)

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