

Measurement of charged hadron R_{AA} at high p_T in PbPb collisions at $\sqrt{s_{NN}} = 2.76 \text{ TeV}$ with CMS

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on behalf of the CMS Collaboration

Introduction

- Nuclear modification factor:

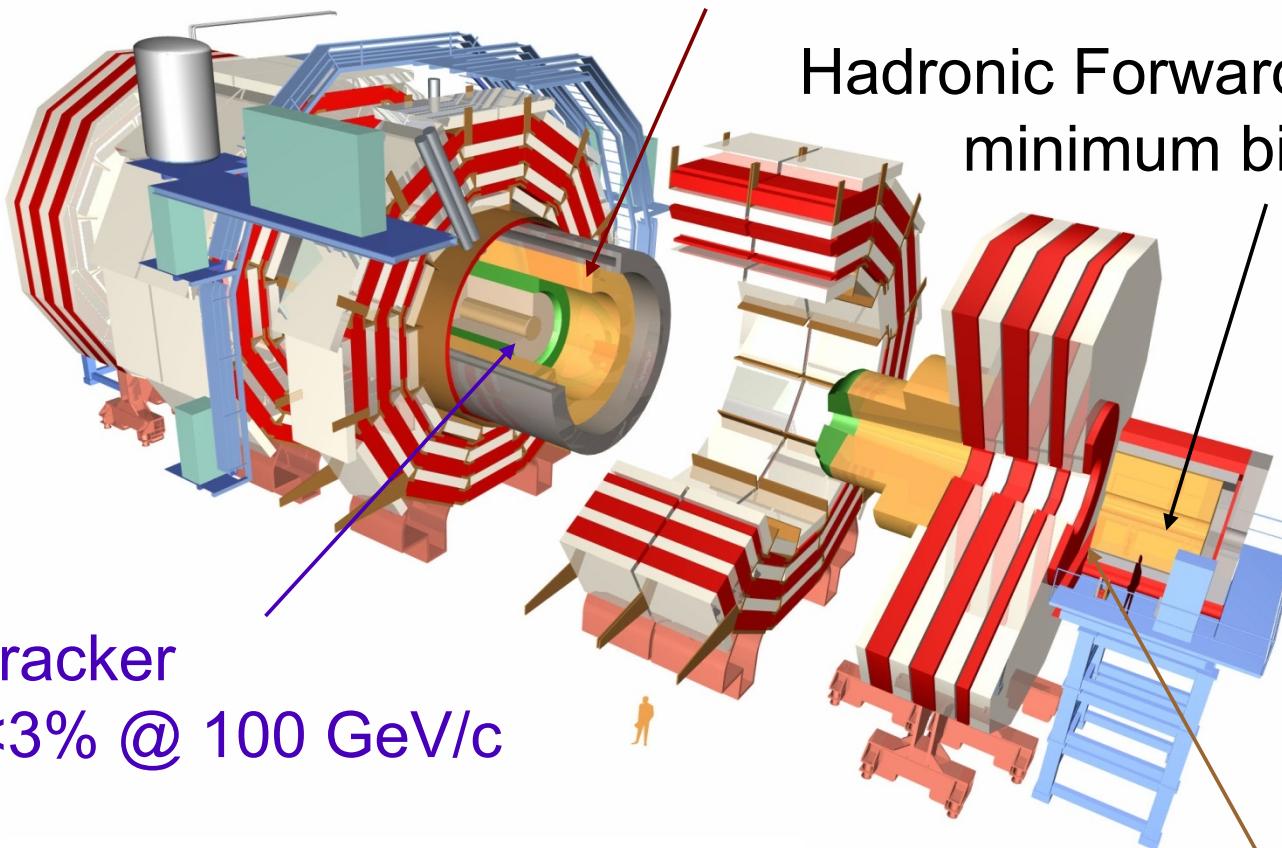
$$R_{AA} = \frac{1}{\langle T_{AA} \rangle} \frac{d^2 N_{AA}/dp_T d\eta}{d^2 \sigma_{pp}/dp_T d\eta} \sim \frac{\text{"QCD medium"}}{\text{"QCD vacuum"}}$$

$\left. \begin{array}{l} R_{AA} > 1 \text{ (enhancement)} \\ R_{AA} = 1 \text{ (no effect)} \\ R_{AA} < 1 \text{ (suppression)} \end{array} \right\}$

- Requires:
 - Measurement of PbPb spectrum
 - Measurement of pp spectrum
 - Normalization calculated from a Glauber model
 - Access to high-momentum particles
 - jet triggers

CMS Detector

EM and Hadronic calorimeters: jets



Silicon Tracker
 $\sigma(p_T)/p_T < 3\% @ 100 \text{ GeV}/c$

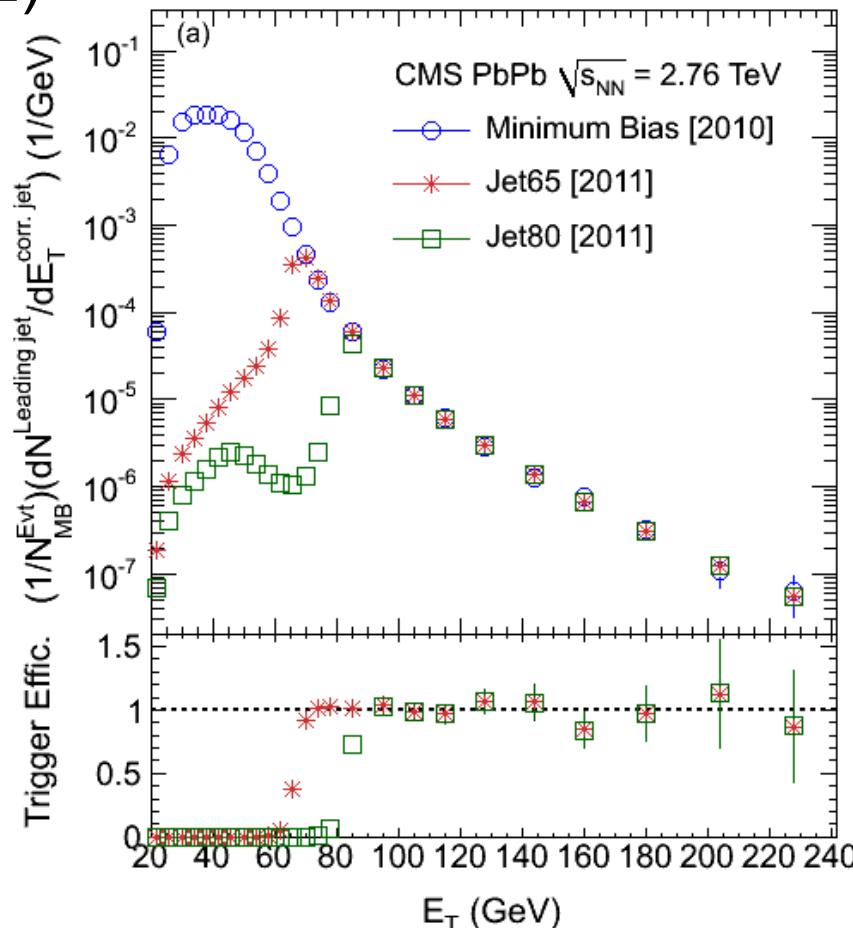
Hadronic Forward (HF) calorimeter:
minimum bias triggering

Beam Scintillator Counters (BSC):
minimum bias triggering



Triggering and event selection

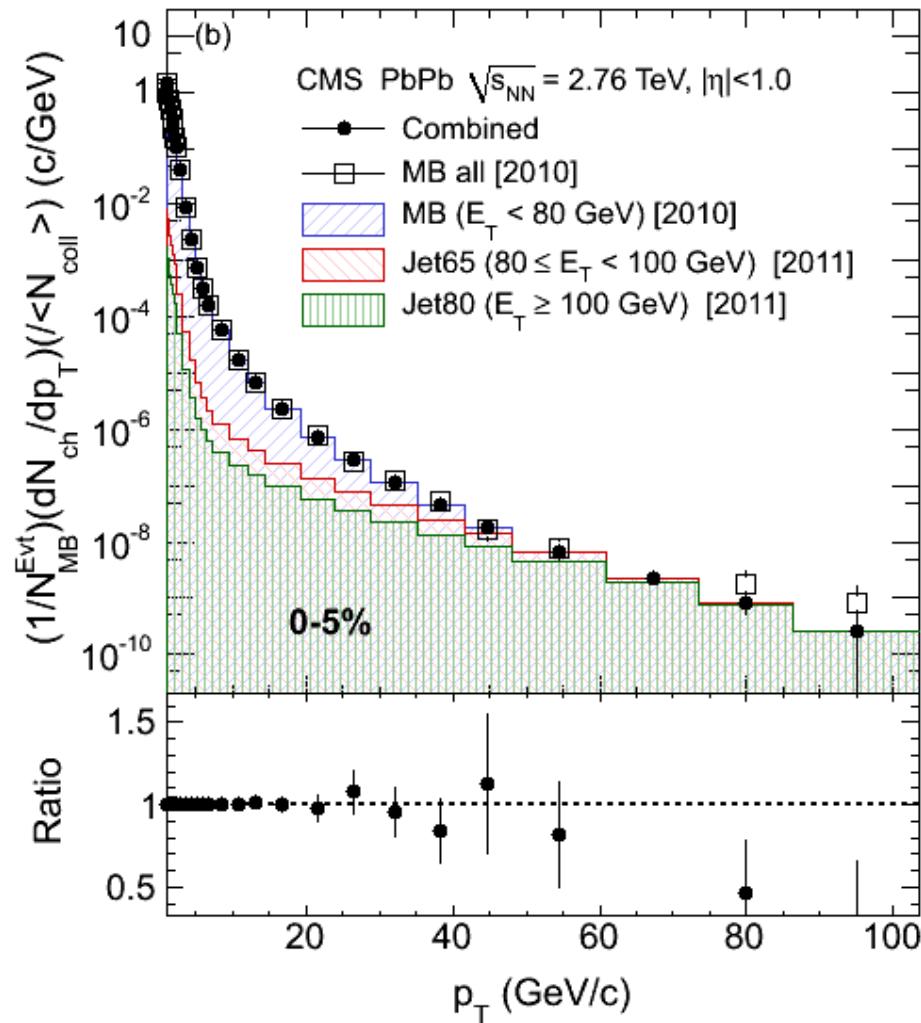
- **Triggering:**
 - Min. bias: coincidence triggers
BSC ($3.2 < |\eta| < 4.7$) or HF ($2.9 < |\eta| < 5.2$)
 - Jets: Iterative cone + bckgrnd sub.
Thresholds: 65 and 80 GeV
- **Event selection:**
 - Beam halo veto
 - ECAL, HCAL noise cleaning
 - Vertex with at least 2 tracks
 - 3 towers ($E > 3$ GeV) in HF \pm
 - Beam-scraping cleaning



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Combining particle spectra

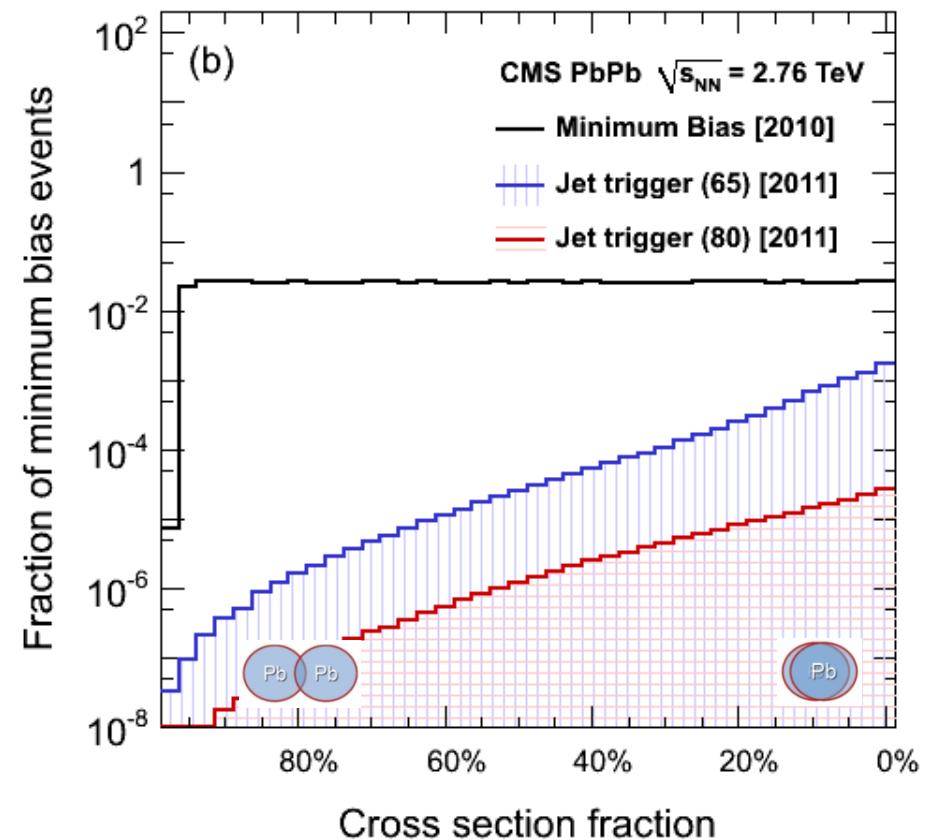
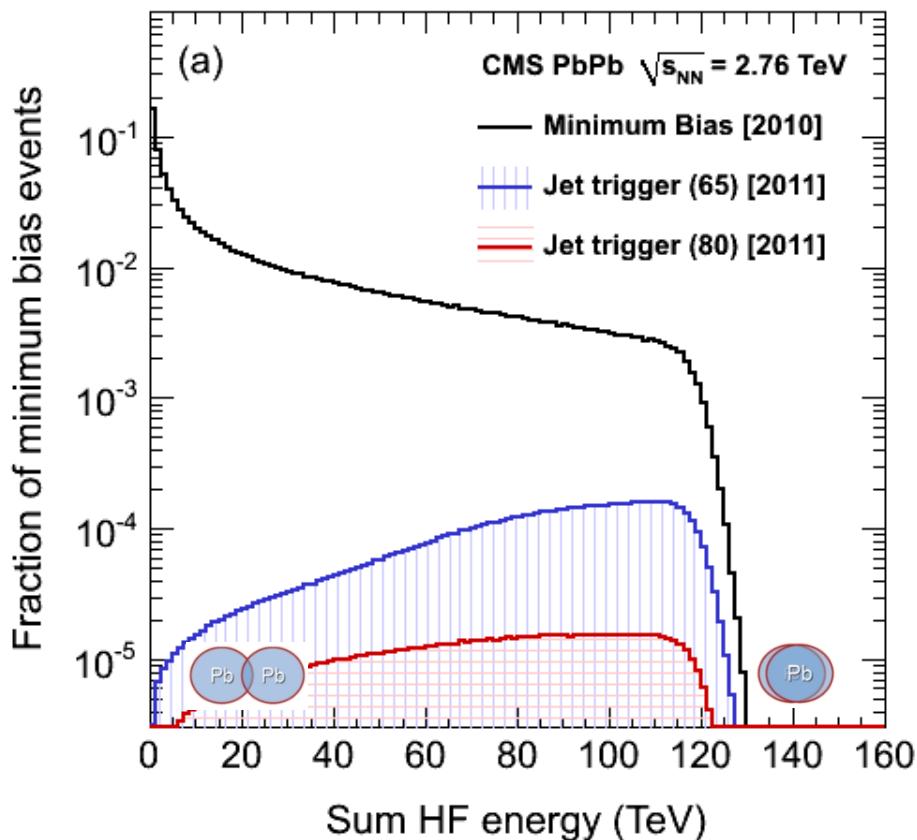
- Events classified according to the leading jet energy
- Particle spectra evaluated separately using minbias and jet-triggered events
- The three spectra are combined
- Result: minimum bias shape with high statistics



Jet triggers play an important role above ~ 40 GeV/c

Centrality

- **Centrality:**
 - The degree of the overlap of the two nuclei
 - Based on the total energy in HF ($2.9 < |\eta| < 5.2$)



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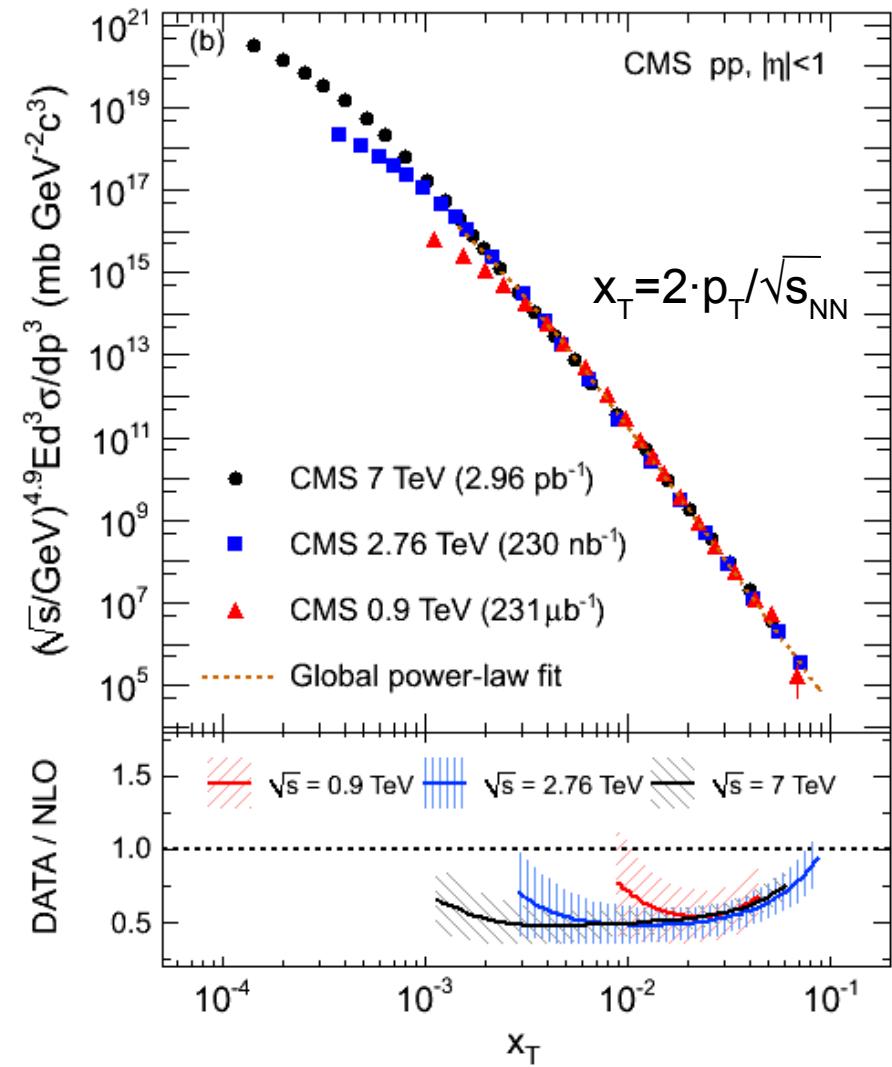
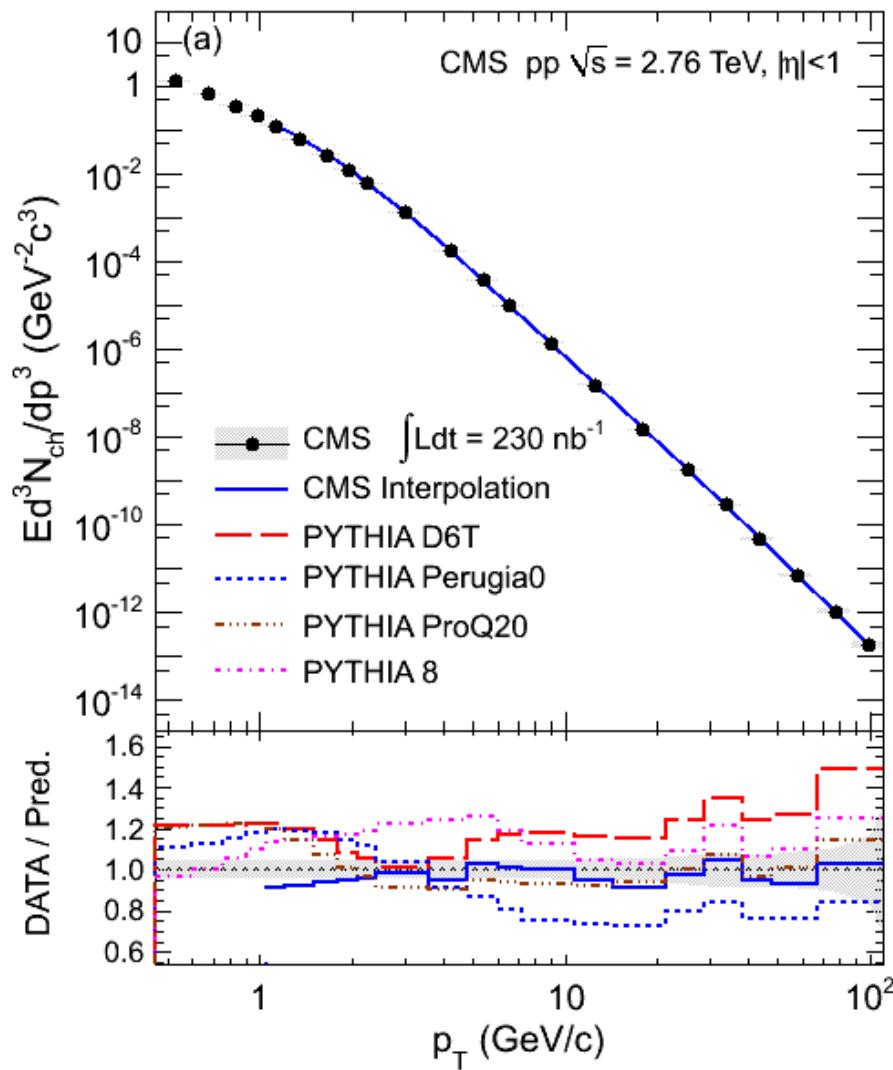
Track reconstruction

- **Track reconstruction:** iterative algorithm
 - Find tracks in consecutive steps
 - Remove hits belonging to tracks in each step
 - Merge tracks based on the fraction of shared hits
 - “Calorimeter compatibility”: tracks are matched to closest calorimeter cells
- high efficiency, low fake track rate at high- p_T

Systematic uncertainties

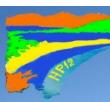
Source	Uncertainty [%]	
	PbPb	pp
Track reconstruction efficiency	3.0–5.7	2.2–3.6
Non-primary and misidentified tracks	2.5–4.0	1.0–3.2
Momentum resolution and binning	3.0	0.3–2.7
Normalization of jet-triggered spectra	0.0–4.0	0.0–6.0
Event selection	3.0	3.5
Pile-up estimation	<0.1	1.2
Total for p_T spectra	5.8–9.1	4.4–9.0
Luminosity	–	6.0
T_{AA} determination	4.1–18.0	–
Total for R_{CP}	6.7–20.0	–
Total for R_{AA}	9.9–23.0	–

pp spectrum

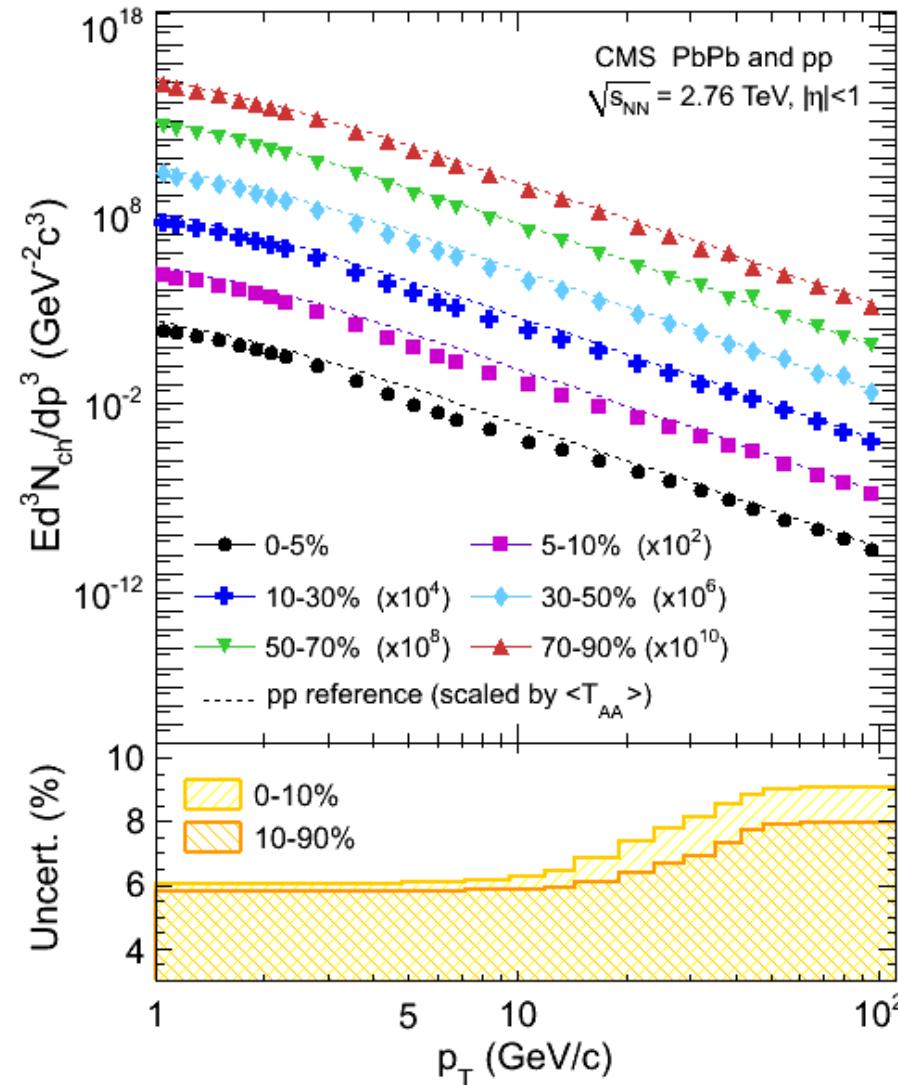


- Reference spectrum measured up to 100 GeV/c
- x_T scaling seen at high p_T

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JHEP 08 (2011) 086



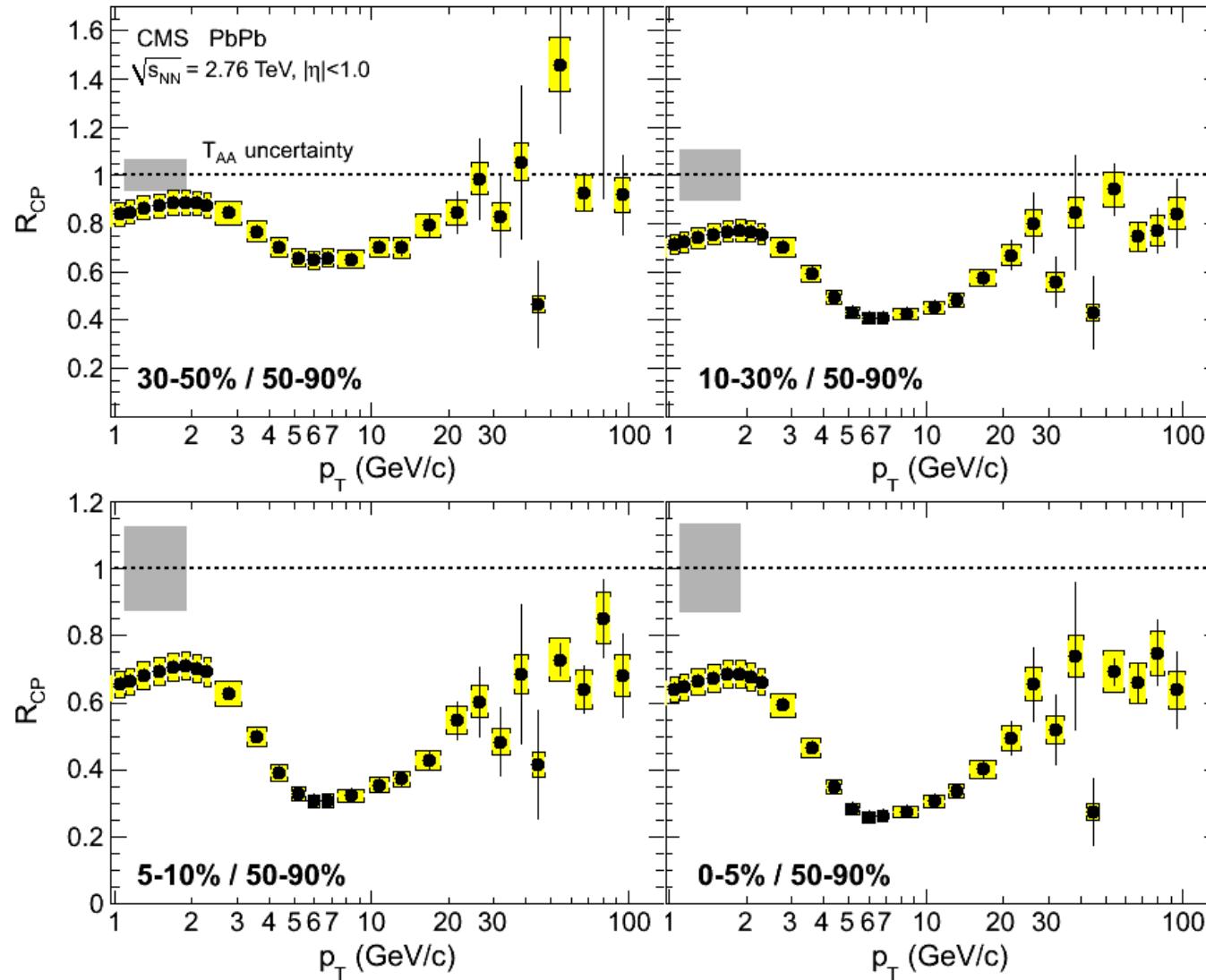
PbPb spectra



- Measured up to 100 GeV/c in six centrality bins
- Uses full 2011 run statistics at high p_T ($150 \mu\text{b}^{-1}$)

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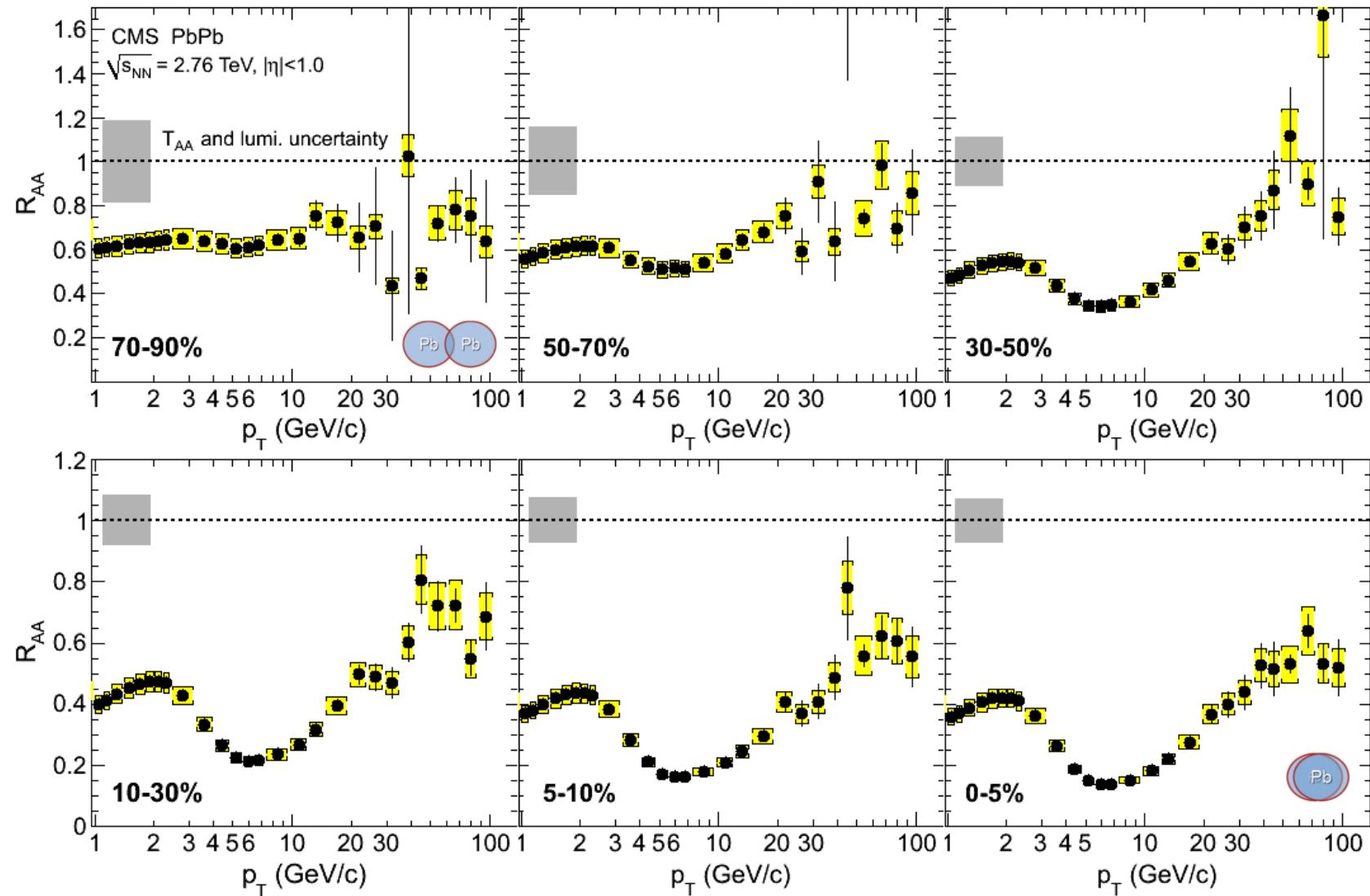
Charged particle R_{CP}



- R_{CP} : T_{AA} scaled ratio of “central” and “peripheral” spectra

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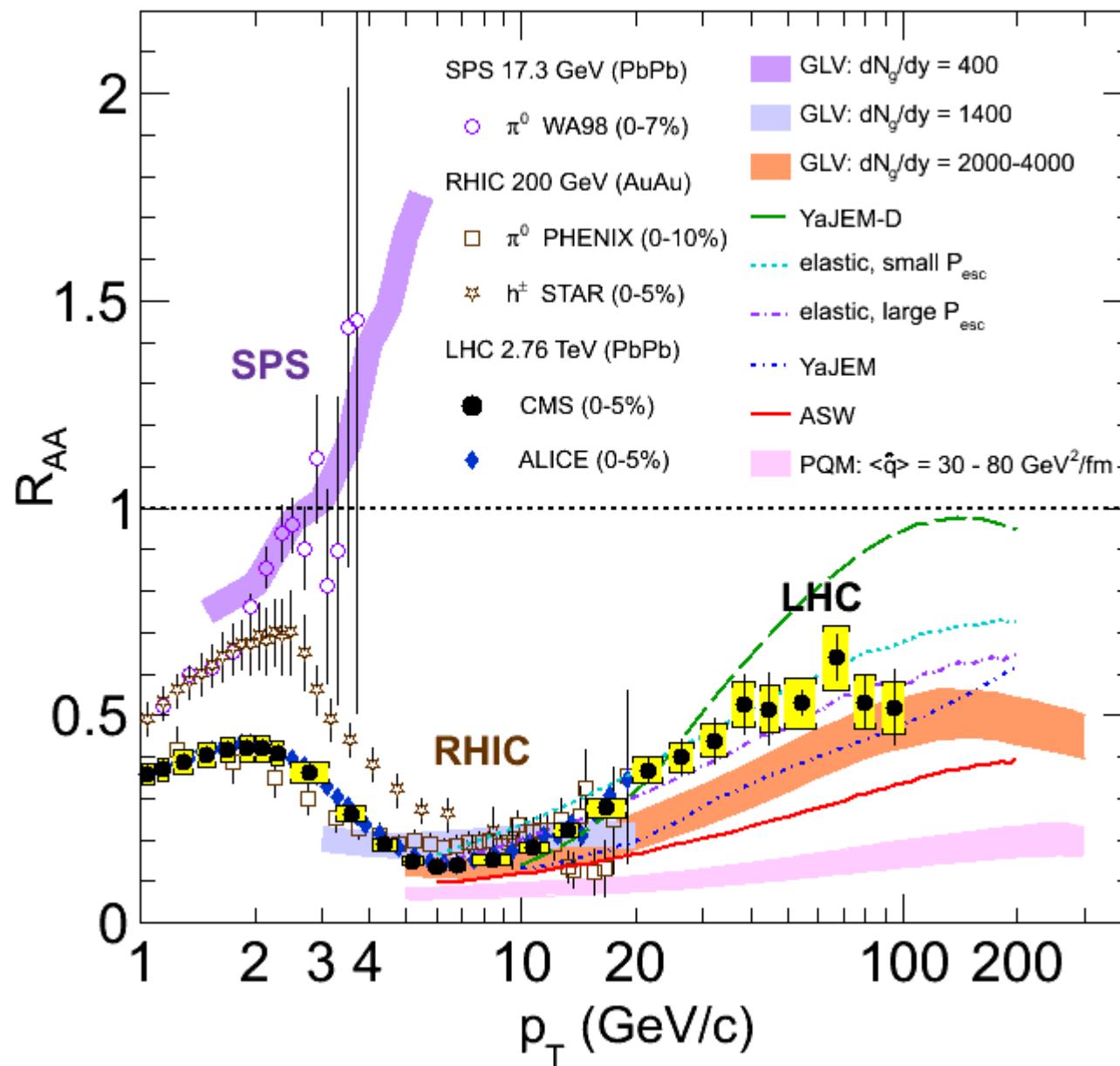
Charged particle R_{AA}



- Dip structure develops as a function of centrality
- R_{AA} increases at high p_T

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Charged particle R_{AA} compared to models



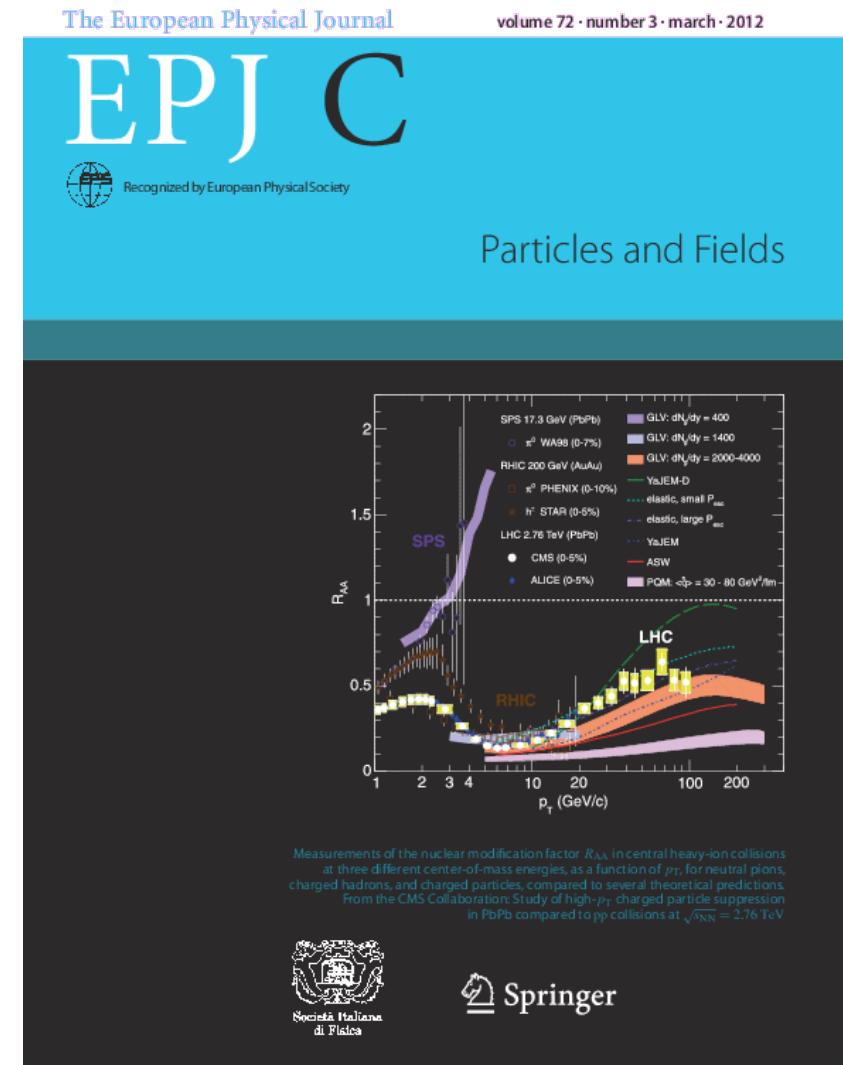
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Summary

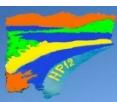
- pp and PbPb spectra measured up to 100 GeV/c
- Charged hadron R_{AA} in 0-5% centrality
 - Shows unambiguous suppression of high-momentum particles
 - Has a minimum around 6 GeV/c, R_{AA} of ~0.13
 - Rises above 6 GeV/c approaching an R_{AA} of ~0.5 above 40 GeV/c
 - R_{AA} does not approach 1 at high p_T
- High statistics in PbPb, but pp is limited to 100 GeV/c

Summary

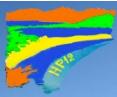
Thank you for your attention!



Eur. Phys. J. C. 72 (2012) 1945

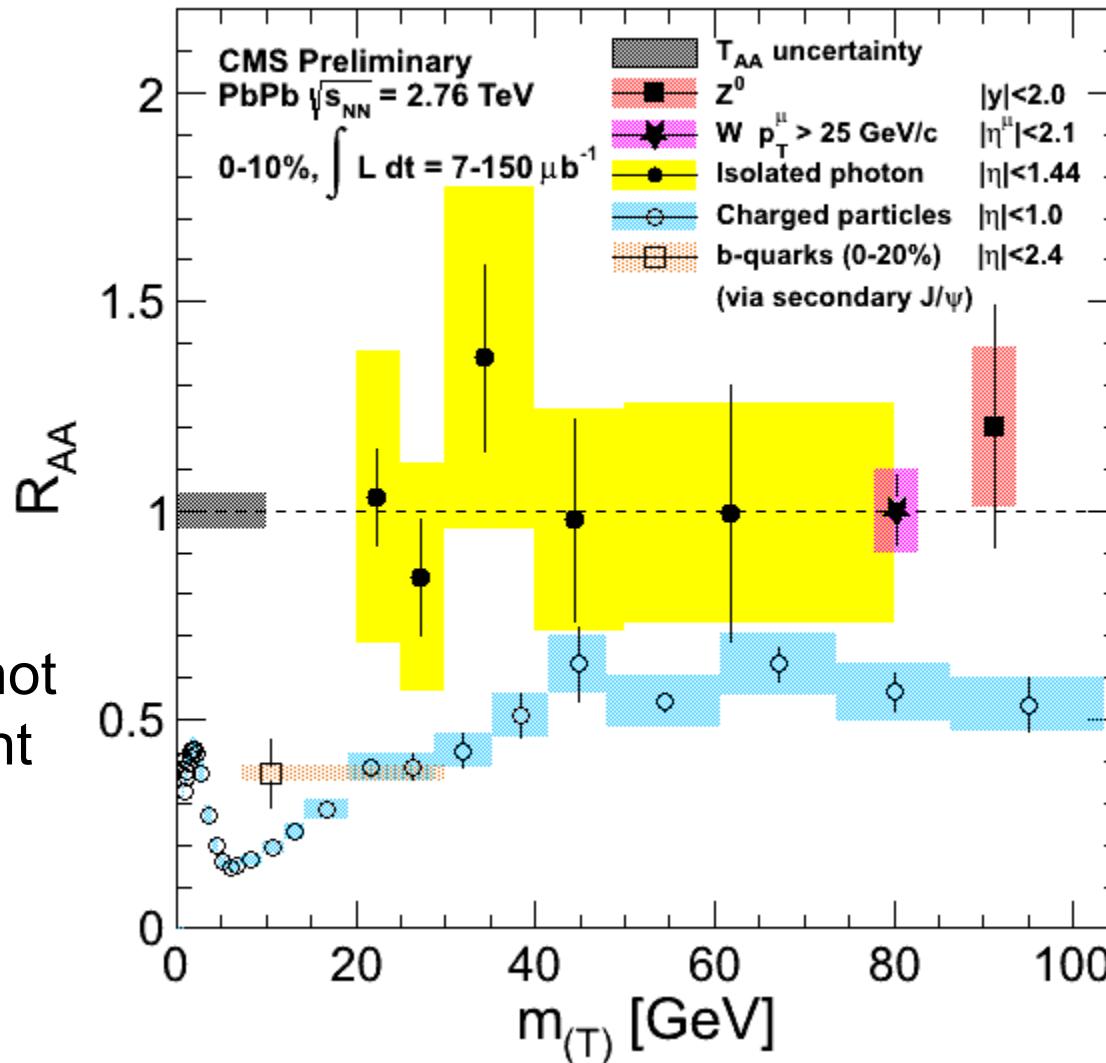


Backup slides



Summary of CMS R_{AA} results

b-quarks are quenched (but not as much as light hadrons)
arxiv:1201.5069



Colorless probes are unsuppressed
Phys. Lett. B (2012) 710
Phys. Rev. Lett. (2011) 106

Strong quenching for light hadrons
Eur. Phys. J. C. (2012) 72

CMS Heavy Ion Physics Results

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

CMS Heavy-Ion Public Physics Results

Final Results

The table contains papers and public results, with links to arXiv, CERN preprint, and the final paper, if available.

Plots are provided through dedicated twiki pages , the CERN Document Server database , and the arXiv source .

Analysis	Reports	Publication	Plots	Data	Comment
Transverse energy flow (submitted to PRL)	CMS-HIN-11-003 arXiv:1205.2488 CERN-PH-EP-2012-116	-		-	0.306/ub
Gamma-jet correlations in PbPb collisions (submitted to PLB)	CMS-HIN-11-010 arXiv:1205.0206 CERN-PH-EP-2012-089	-		-	150/ub
Azimuthal anisotropy at high pT (submitted to PRL)	CMS-HIN-11-012 arXiv:1204.1850 CERN-PH-EP-2012-096	-	 	-	150/ub
Elliptic flow (submitted to PRC)	CMS-HIN-10-002 arXiv:1204.1409 CERN-PH-EP-2012-095	-	 		3/ub
Jet momentum dependence of jet quenching (accepted by PLB)	CMS-HIN-11-013 arXiv:1202.5022 CERN-PH-EP-2012-042	-	 	-	150/ub
Charged particle RAA	CMS-HIN-10-005 arXiv:1202.2554 CERN-PH-EP-2012-043	EPJC 72 (2012) 1945	 		150/ub