Heavy Ion Physics from the CMS Collaboration

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for

the CMS Collaboration

Google cms heavy ion public results

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PRL 109, 152303 (2012) Selected for a Viewpoint in *Physics* PHYSICAL REVIEW LETTERS week ending 12 OCTOBER 2012

Measurement of the Pseudorapidity and Centrality Dependence of the Transverse Energy Density in Pb-Pb Collisions at $\sqrt{s_{NN}} = 2.76$ TeV

S. Chatrchyan *et al.**
(CMS Collaboration)

(Received 12 May 2012; published 8 October 2012)

Final Results

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

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Measurement of jet fragmentation into charged particles in pp and PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV

CMS-HIN-12-015 CERN-PH-EP/ 2012/10/23

Observation of long-range, near-side angular correlations in pPb collisions at the LHC

CMS-HIN-11-011 CERN-PH-EP/2012-228 2012/08/15

Observation of sequential Upsilon suppression in PbPb collisions

The CMS Collaboration*

CMS-

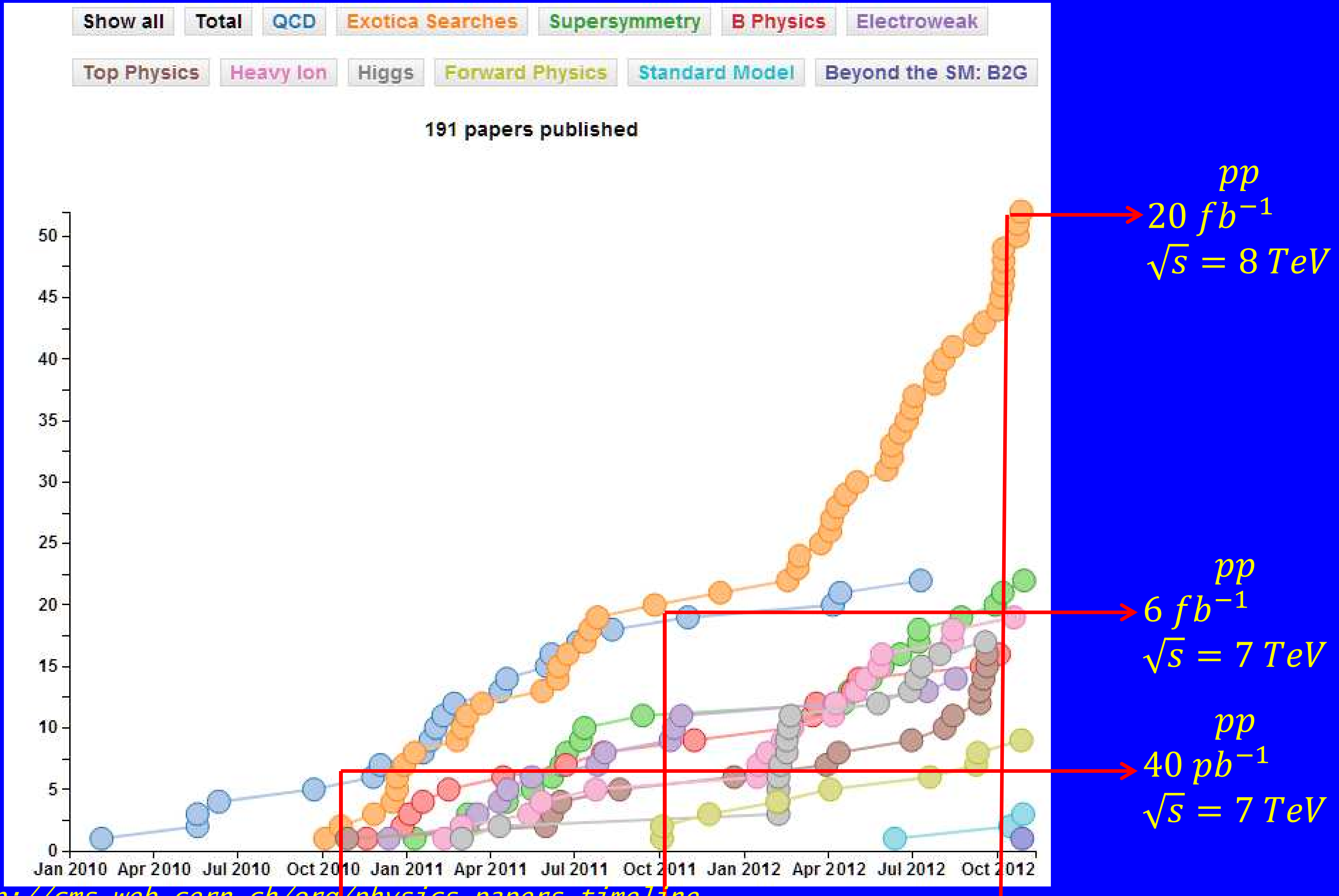
Measurement of the elliptic anisotropy of charged particles produced in PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV

The CMS Collaboration*

Measurement of the azimuthal anisotropy of neutral pions in PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV

The CMS Collaboration*

CMS Publication rate matches LHC Luminosity



http://cms.web.cern.ch/org/physics-papers-timeline

https://twiki.cern.ch/twiki/bin/view/CMSPublic/LumiPublicResults2011#LHC_Delivered_Luminosity_link

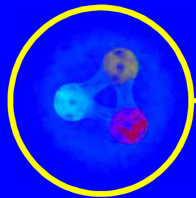
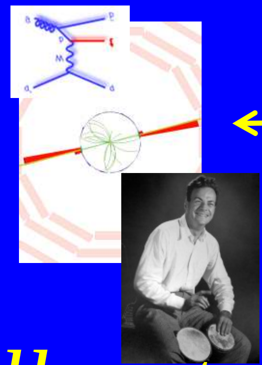
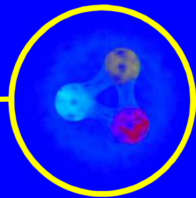
Heavy Ions are important to the CMS physics agenda

PbPb
$150\,\mu b^{-1}$
$\sqrt{s} = 2.76\,TeV/nucleon$

PbPb
$8\,\mu b^{-1}$
$\sqrt{s} = 2.76\,TeV/nucleon$

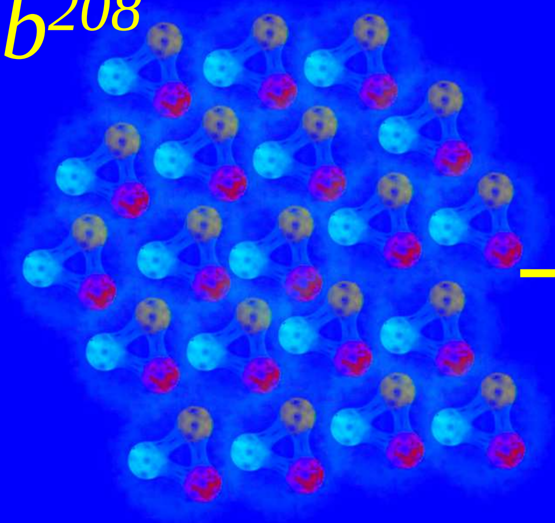
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsHIN

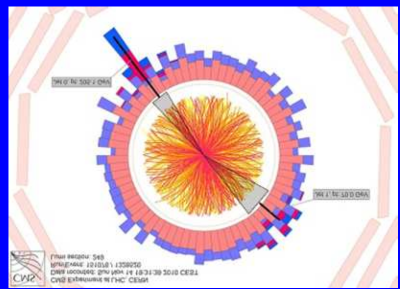
Why Heavy Ions ? Many body QCD!

p    *p*

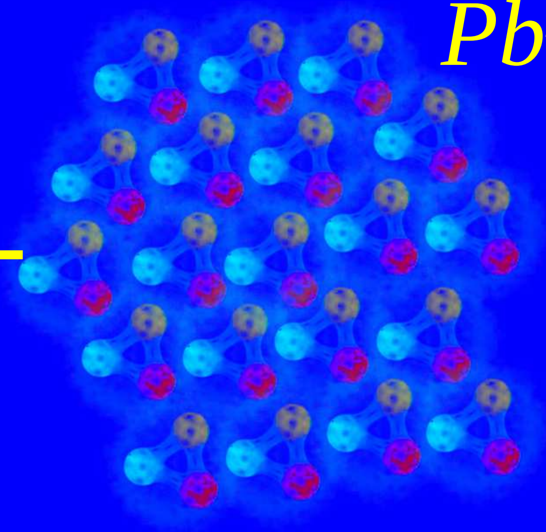
small system

Pb^{208}





Large System



Pb^{208}

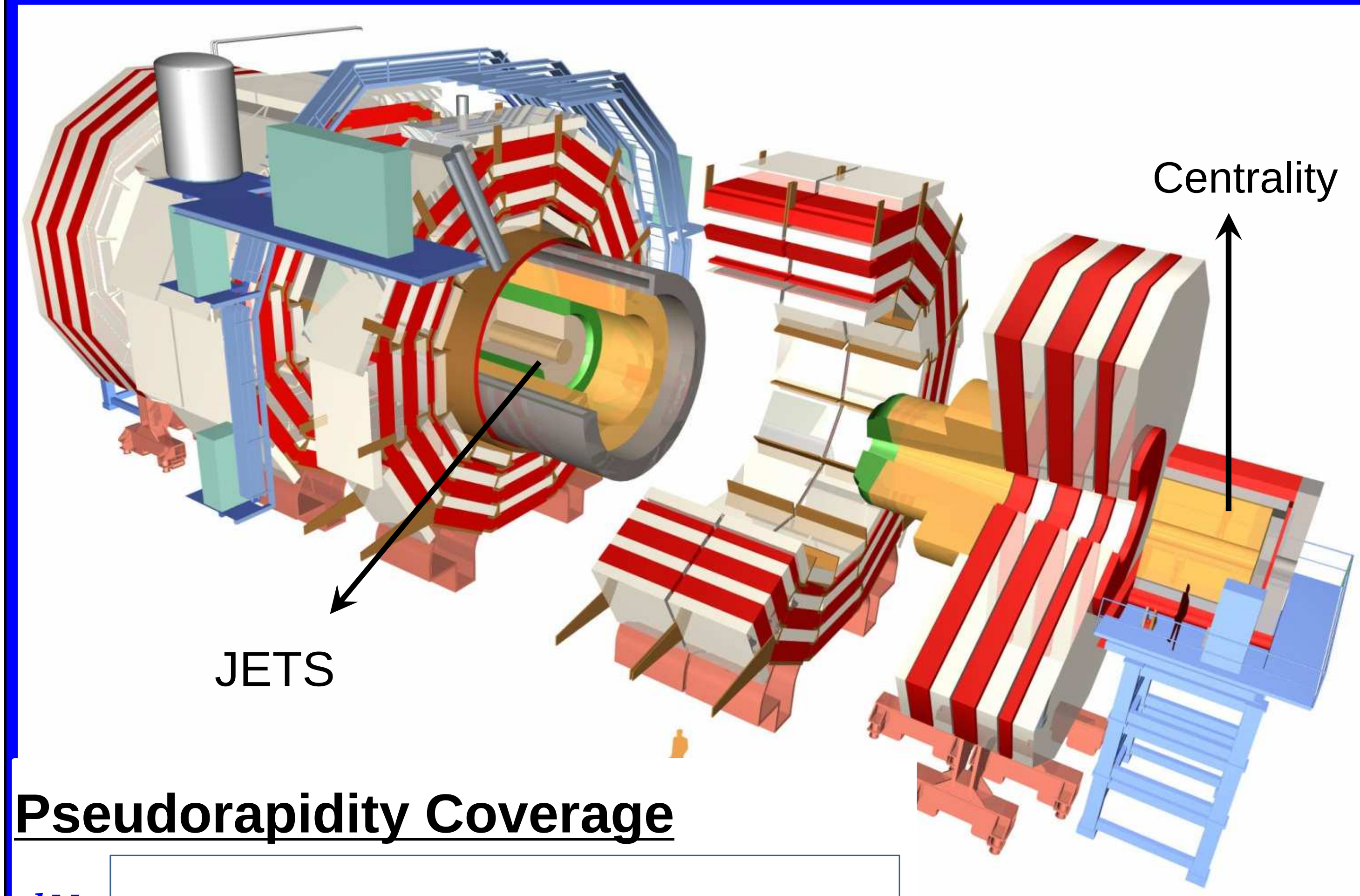
VERY Large System

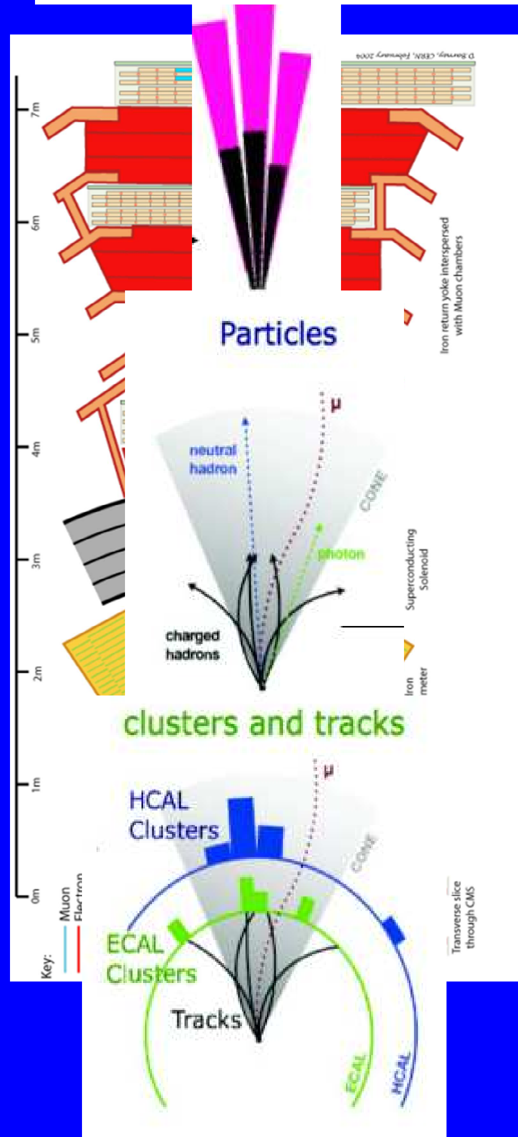
Universe at t =350,000 years

SDSS 2dF Survey: the most we will ever know about 'where we came from'

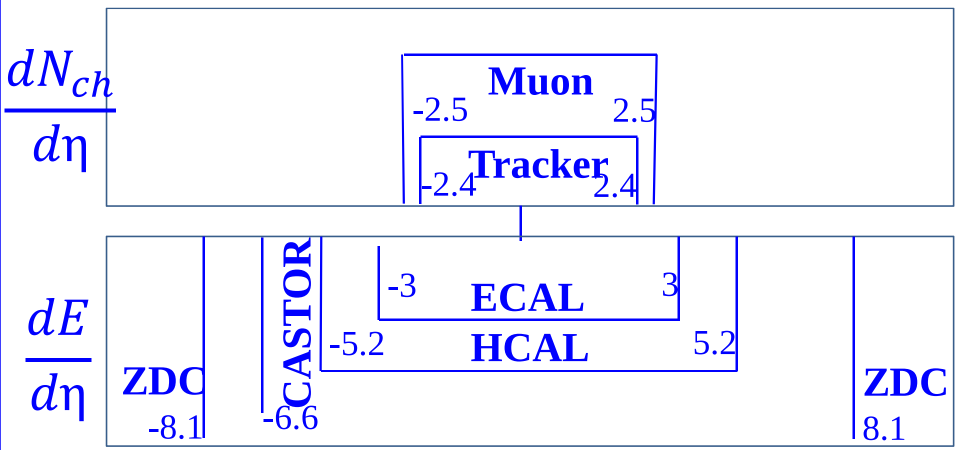
Why Heavy Ions in CMS ?

Hadron calorimetry
$\delta\eta \times \delta\varphi = 0.089 \times 0.089$





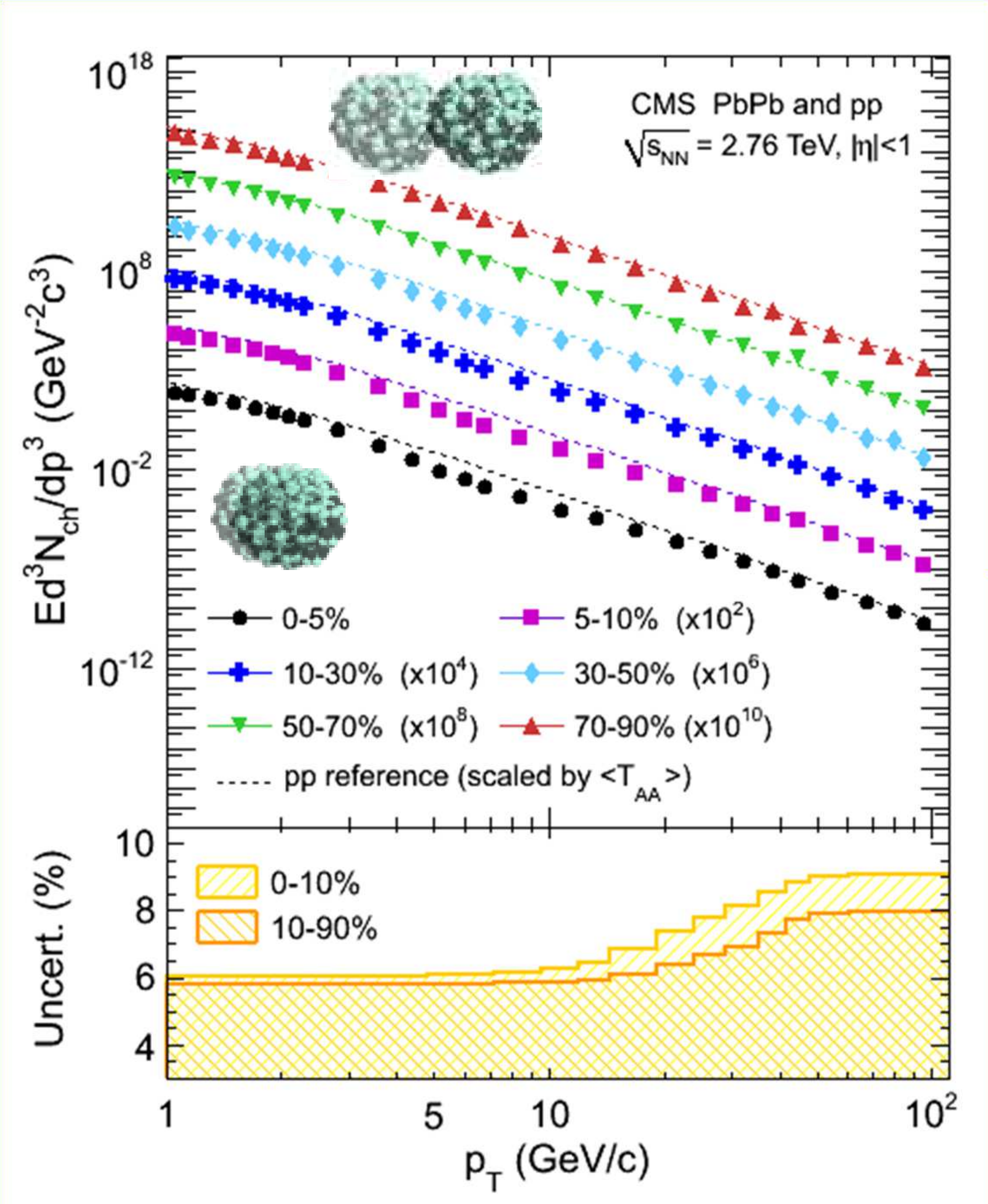
Pseudorapidity Coverage



Track p_T to ~ 100 GeV/c @ ~ 2% measurements up to ~ 500 GeV/c

R_{AA} : charged hadrons
What does the final state look like ?

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



R_{AA}

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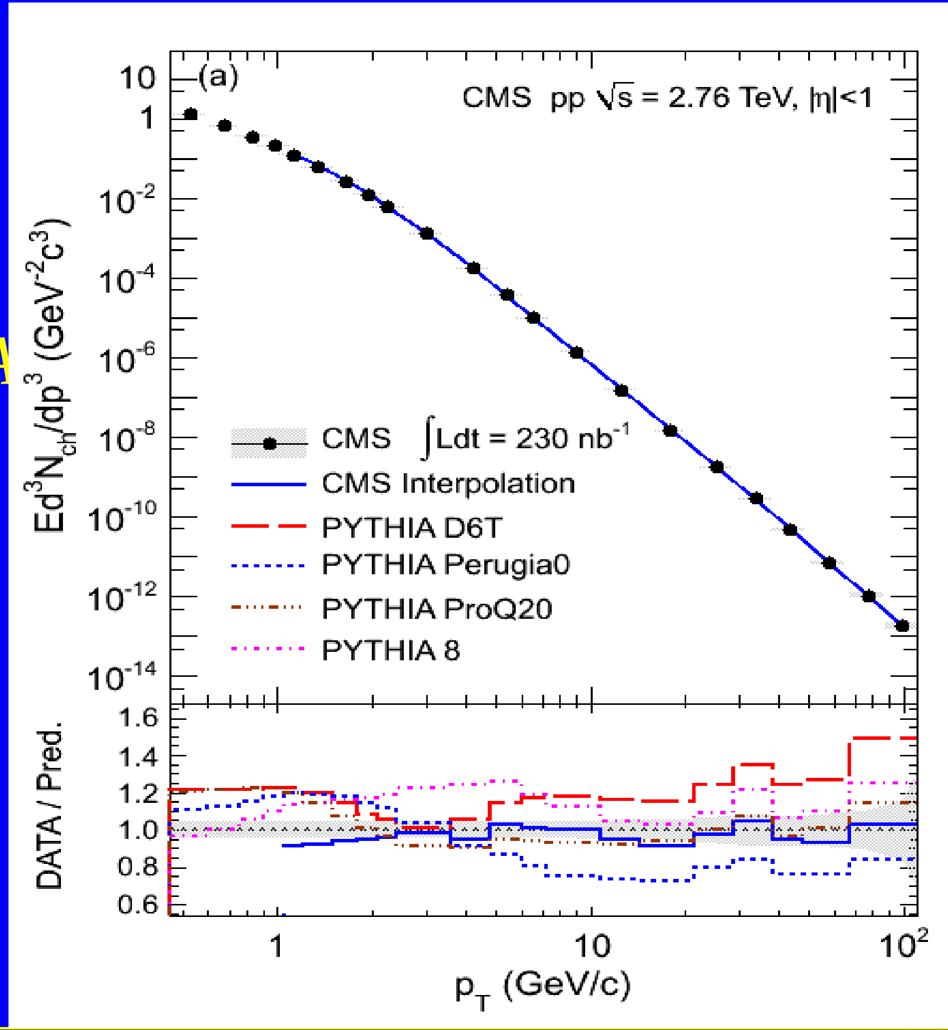
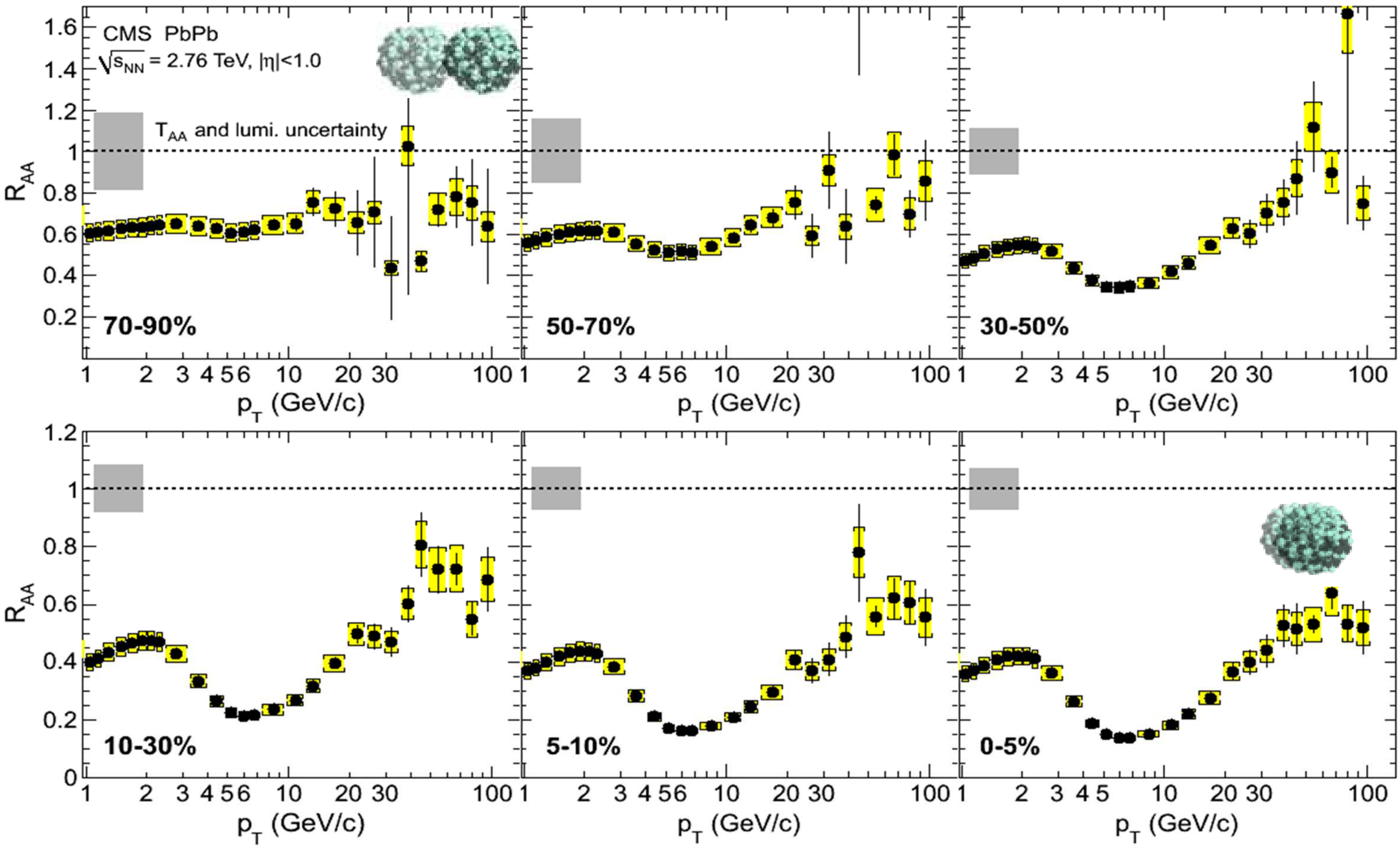
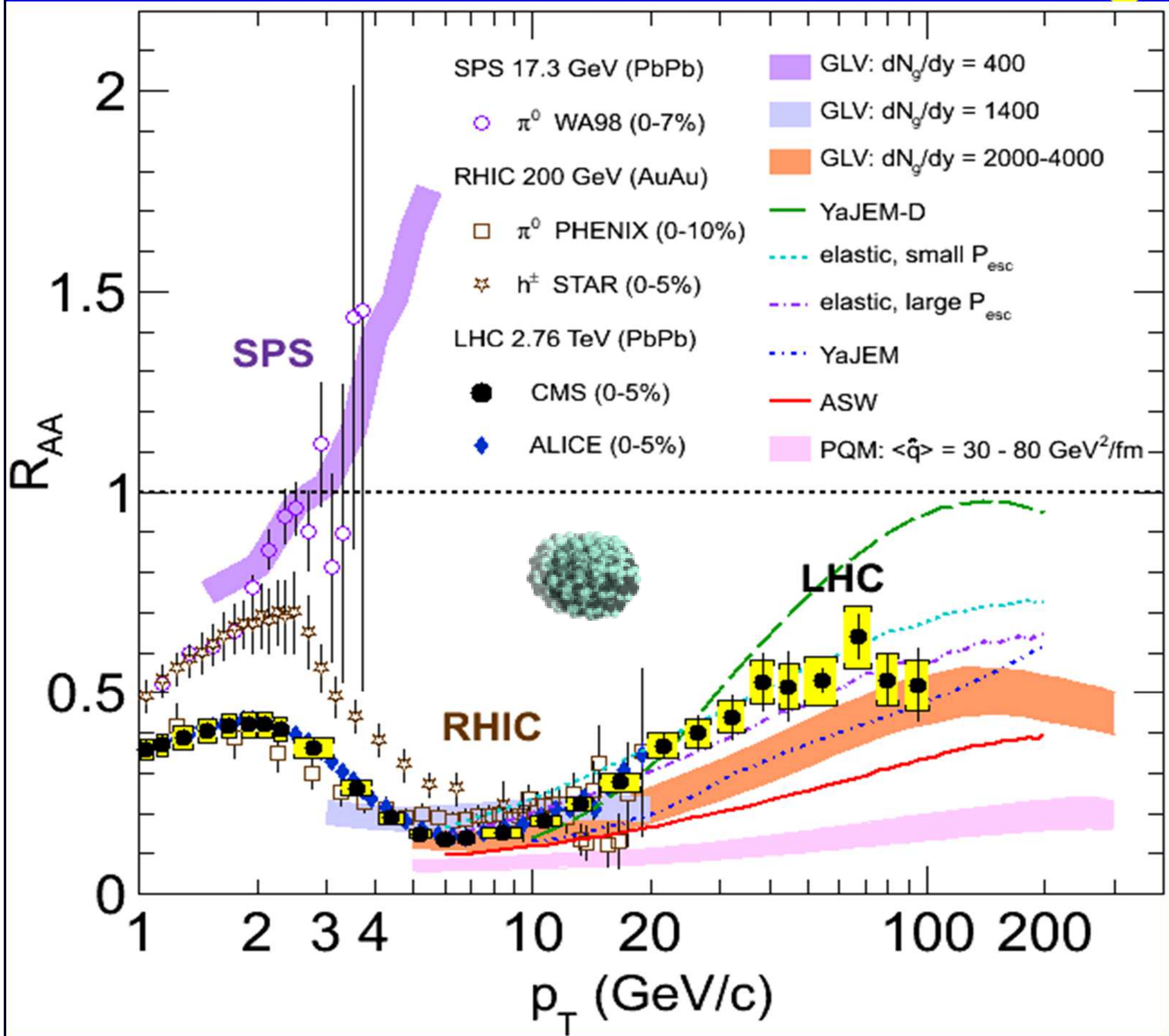


R_{AA} : charged hadrons are *suppressed*



CMS: Eur. Phys. J. C72 (2012) *1945* *CMS PAS HIN-12-004*

R_{AA} : high p_T hadron suppression *changes* with $\sqrt{s_{NN}}$

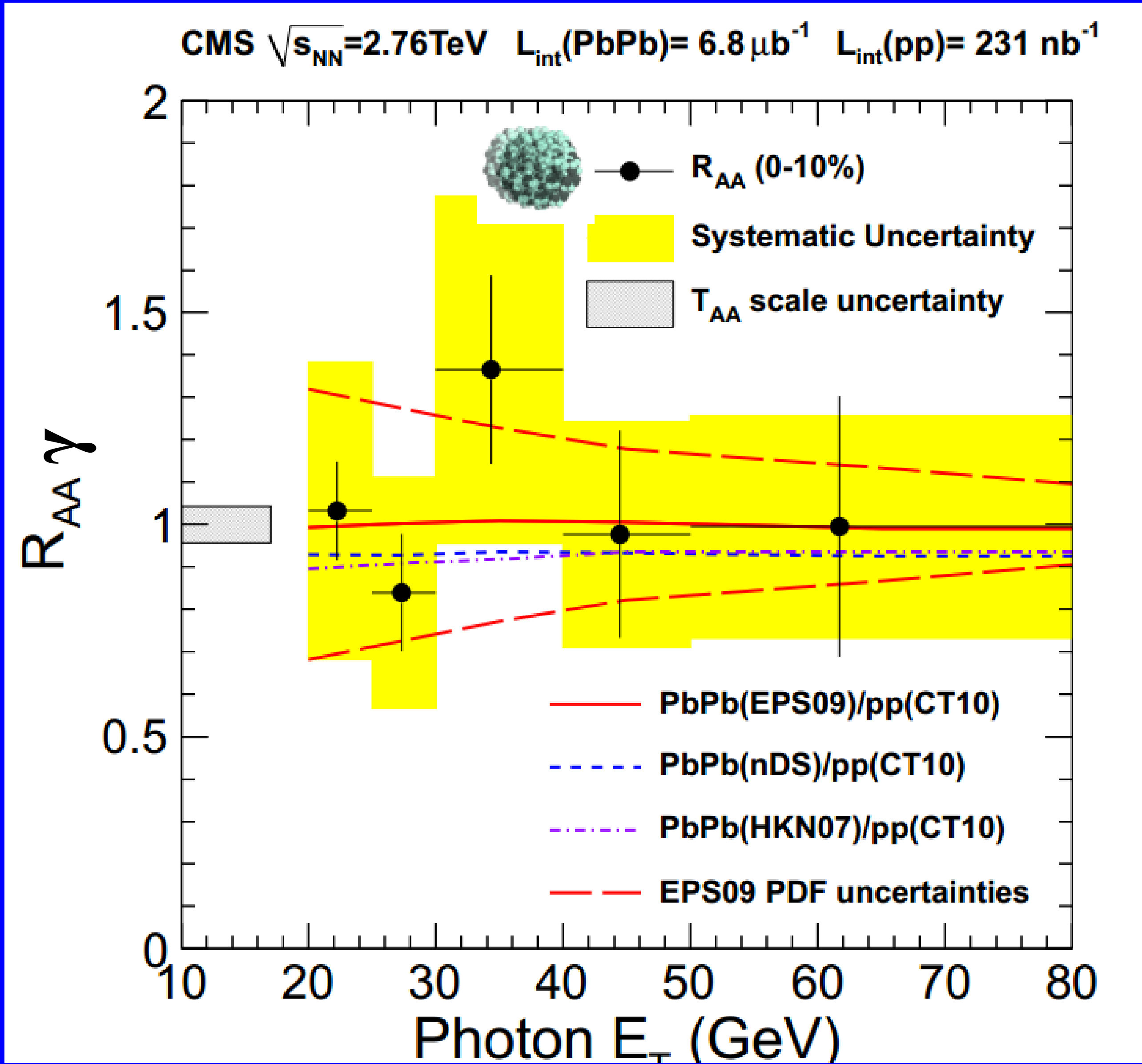


~ 1
nn interactions

< 1
QCD medium
greater number of
degrees of freedom

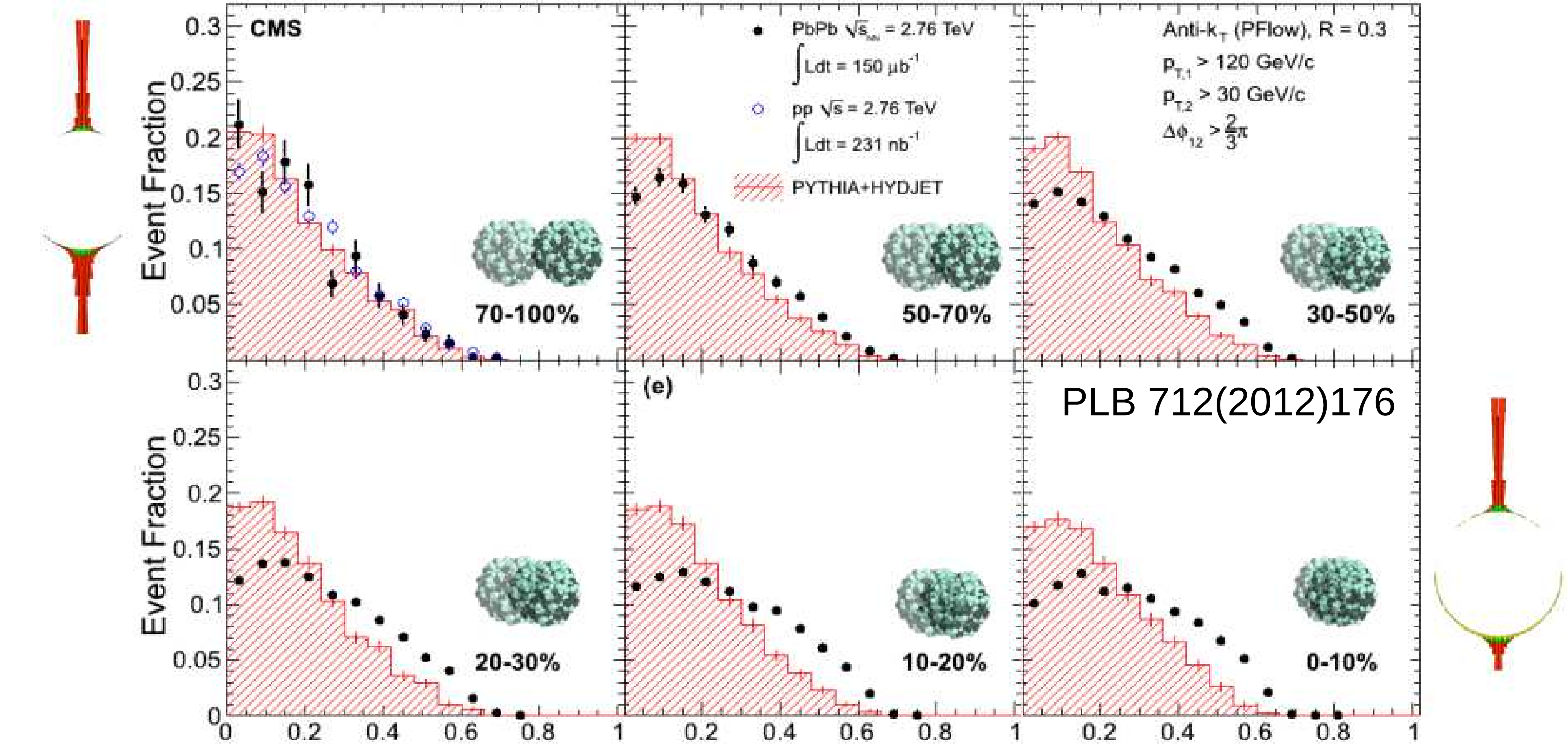
CMS: Eur. Phys. J C72(2012)

R_{AA} : Isolated photons are *not* suppressed



CMS: Physics Letters **B** 710(2012) 256-277

Jet Quenching: how does the initial state evolve through the QCD medium?



Jet Asymmetry $A_J = \dfrac{p_T^1 - p_T^2}{p_T^1 + p_T^2}$

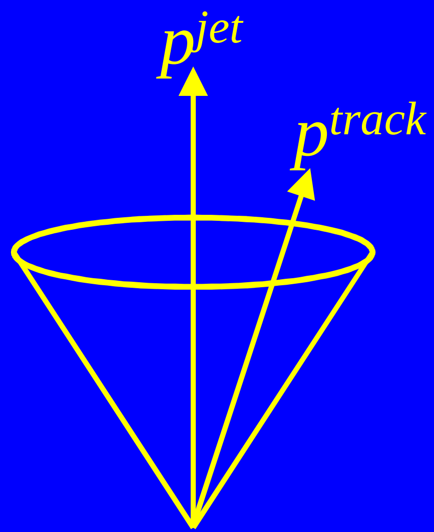
CMS: Phys. Lett B 712 (2012) 176

How is jet fragmentation affected by the QCD medium ?

1) Do partons first lose energy in the medium and then fragment into jets as they normally would in vacuum?

or

2) Does parton energy loss in the medium modify the fragmentation function itself?

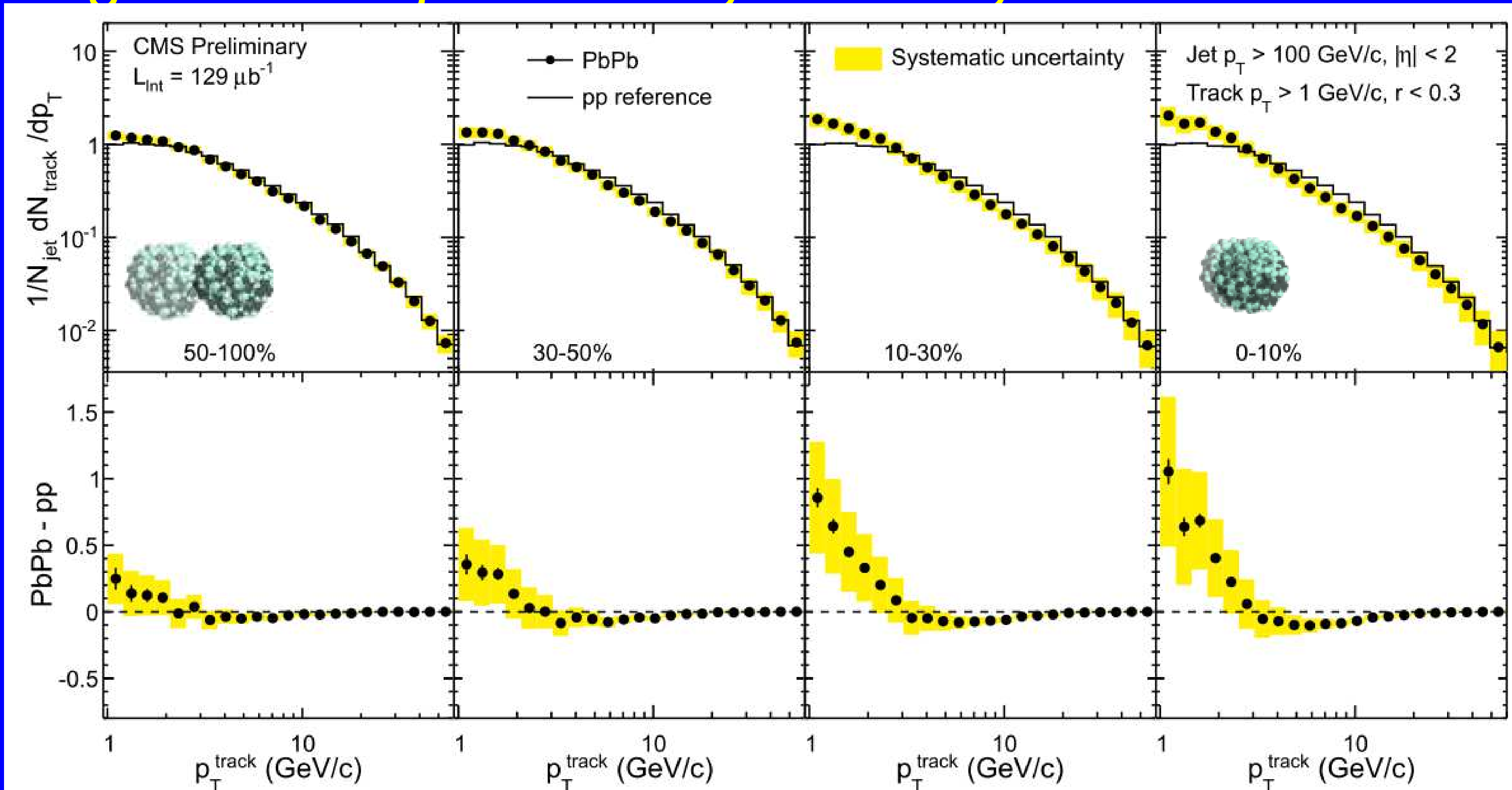


- Identify jets with high purity
- Reject background by reflection around η at same φ
- Look at the distribution of track p_T within the jet cone

CMS PAS HIN-12-013   Large statistics 2011 PbPb run $\int L = 150\ \mu b^{-1}$

How is jet fragmentation affected by the QCD medium ?

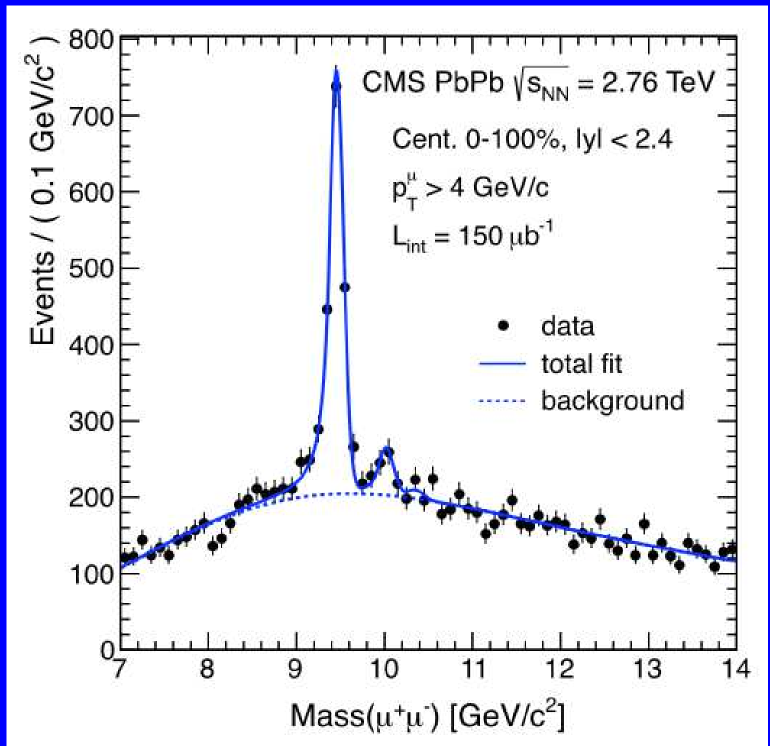
1) Partons first lose energy in the medium and then fragment into jets as they normally would in vacuum?



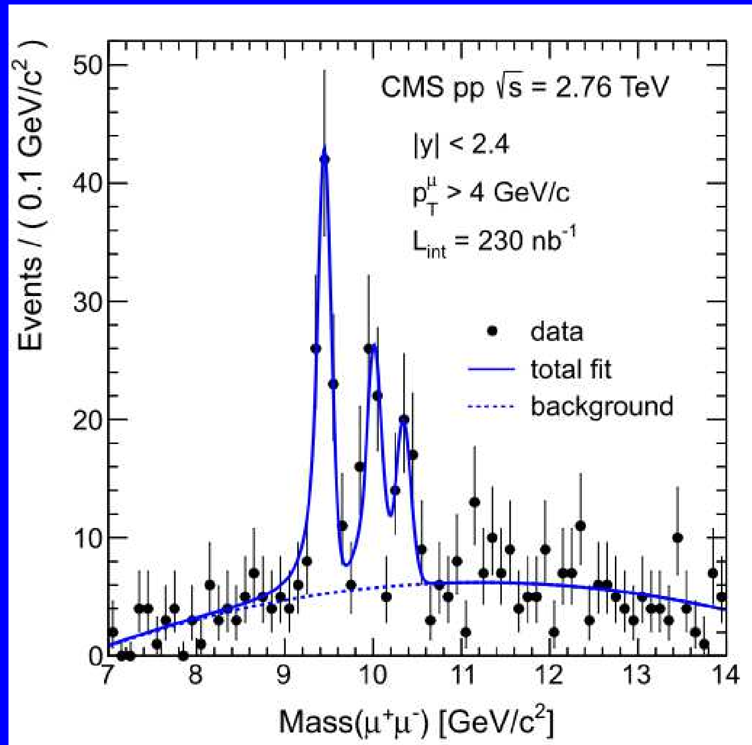
CMS PAS HIN-12-013   Large statistics 2011 PbPb run ∫ L = 150 μb^{-1}

Detailed chemistry of Upsilon states shows interesting dynamics in PbPb

CMuonS dimuon mass resolution is good enough for spectrometry of Υ excited states



$$\frac{\quad}{T_{AA}} \div$$

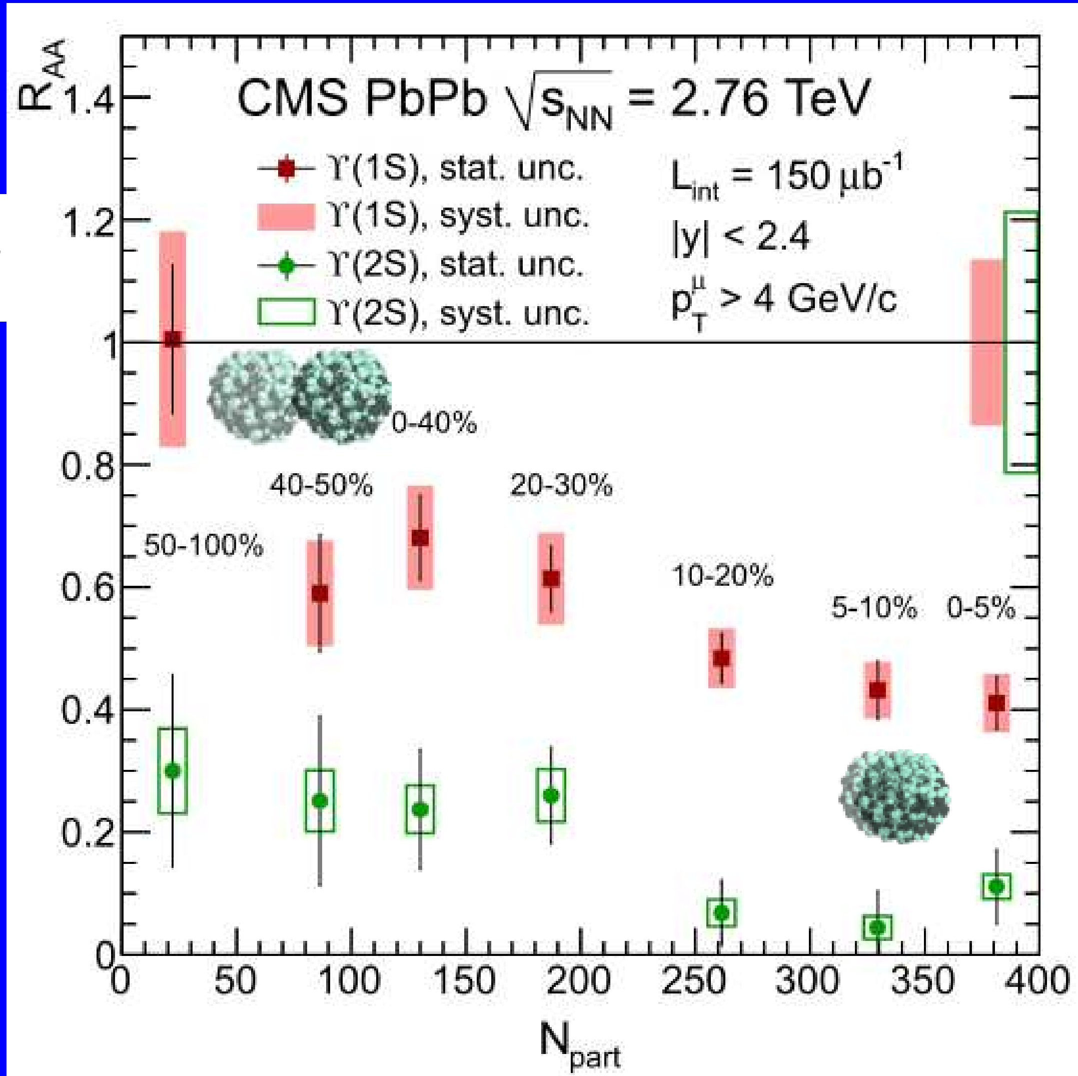


CMS :PRL 109 (2012) 222301

R_{AA} : *Absolute* suppression of Upsilon states is observed in PbPb

$$R_{AA} = \frac{\mathcal{L}_{pp}}{T_{AA} N_{MB}} \frac{\Upsilon(nS)|_{PbPb}}{\Upsilon(nS)|_{pp}} \frac{\varepsilon_{pp}}{\varepsilon_{PbPb}}$$

Identical reconstruction Algorithms used, so errors in efficiency cancel.

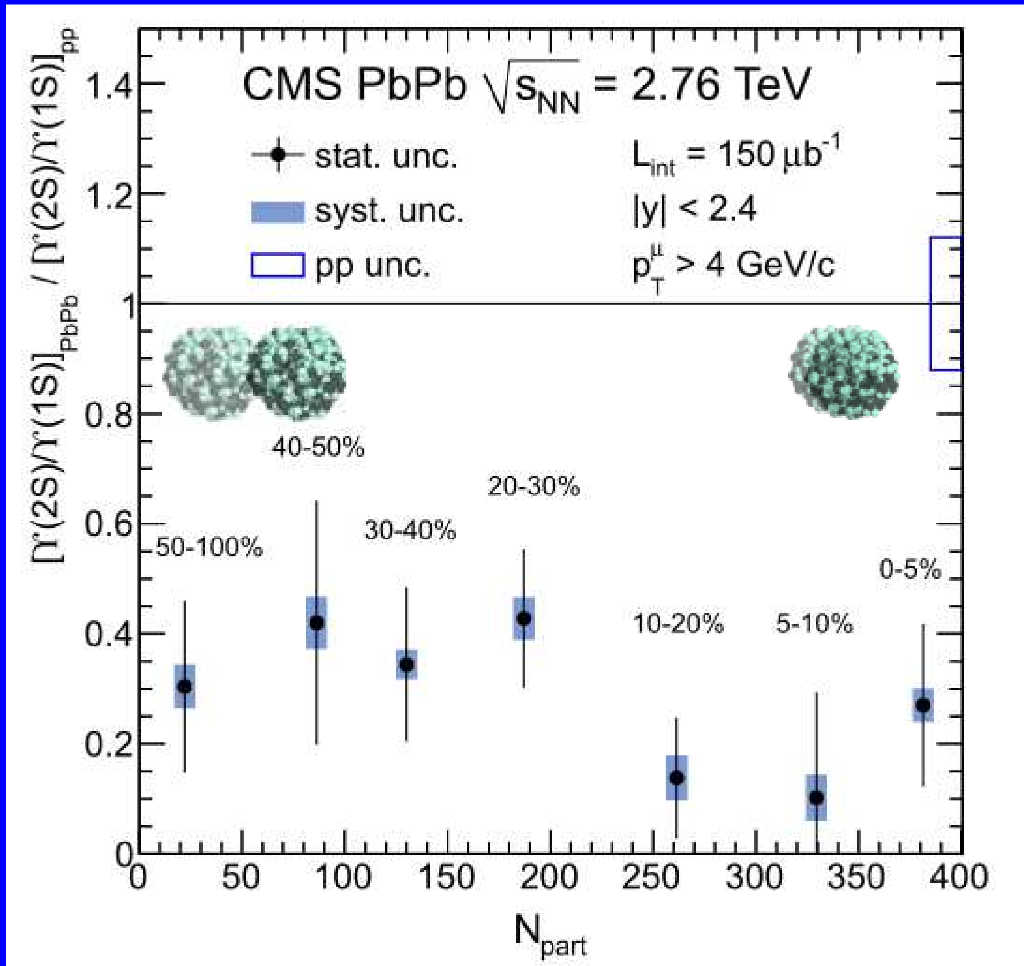


CMS :PRL 109 (2012) 222301

Relative suppression of higher excited Upsilon states is observed in PbPb

$$\frac{\Upsilon(2S)/\Upsilon(1S)|PbPb}{\Upsilon(2S)/\Upsilon(1S)|pp} = 0.21 \pm 0.07\,(stat) \pm 0.2\,(sys)$$

5σ result

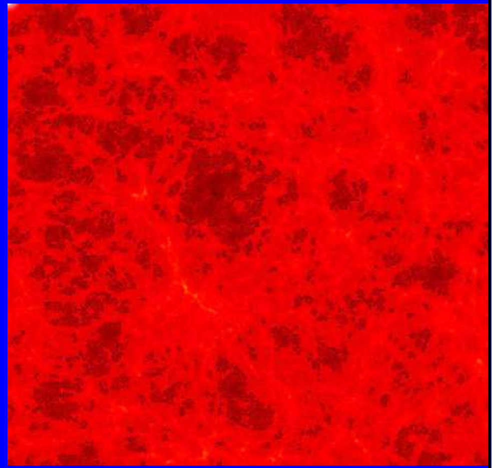


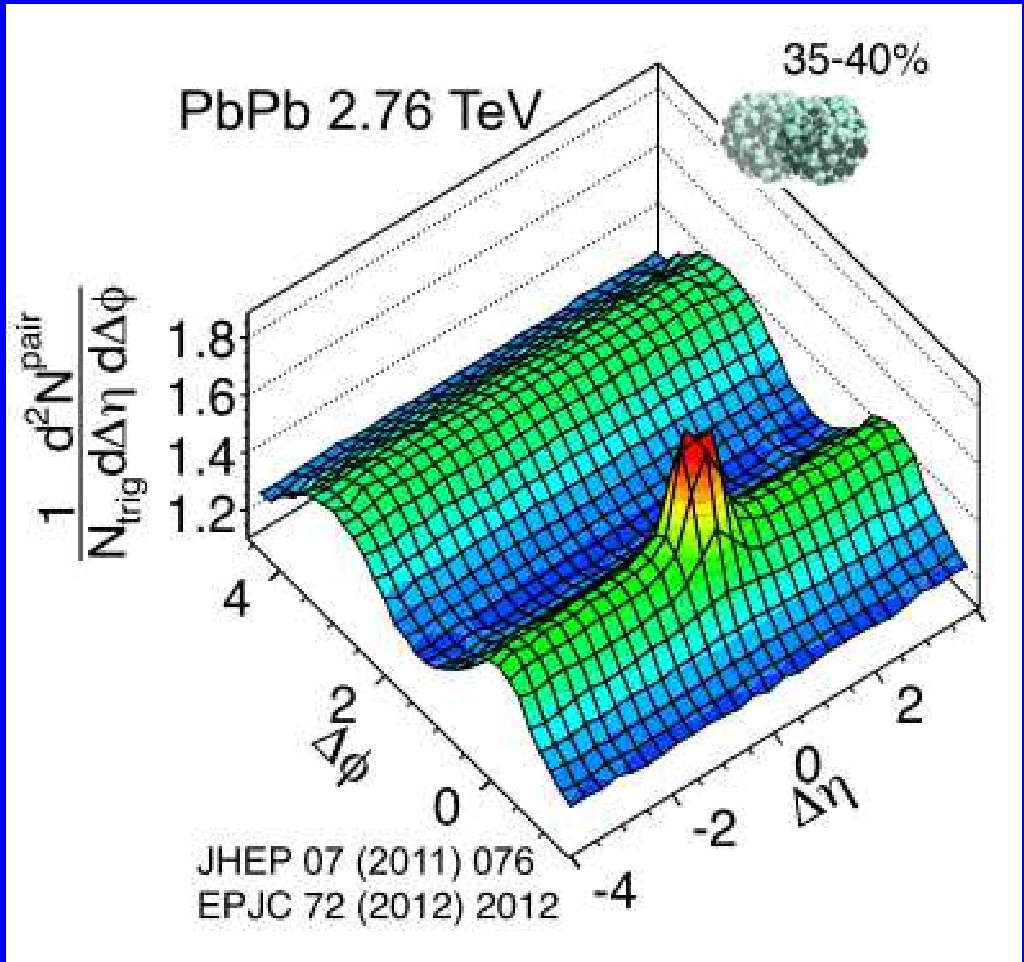
<0.17 @ 95% CL

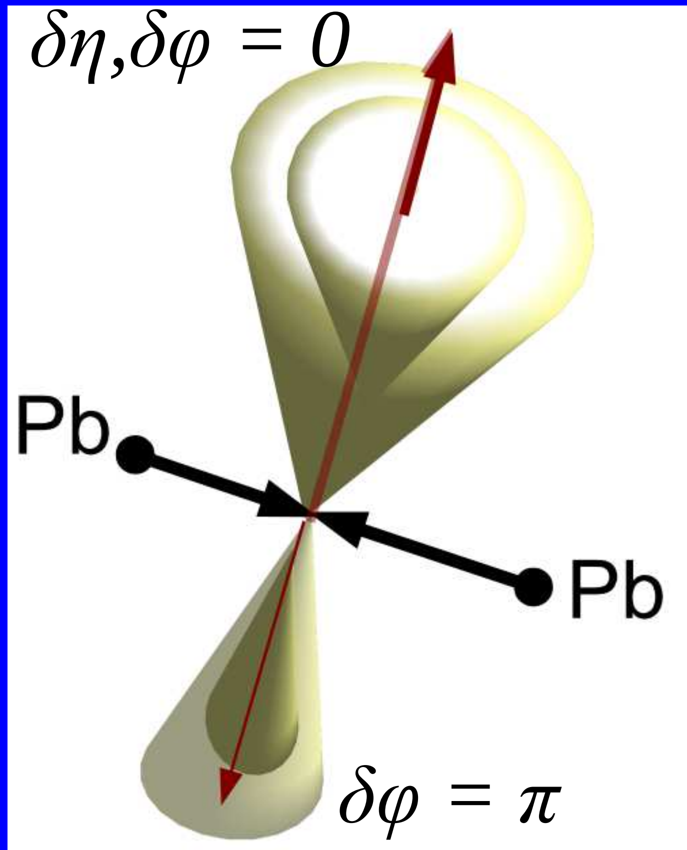
$$\frac{\Upsilon(3S)/\Upsilon(1S)|PbPb}{\Upsilon(3S)/\Upsilon(1S)|pp} = 0.06 \pm 0.06\,(stat) \pm 0.06\,(sys)$$

CMS :PRL 109 (2012) 222301

Track correlations across η,φ show interesting dynamics



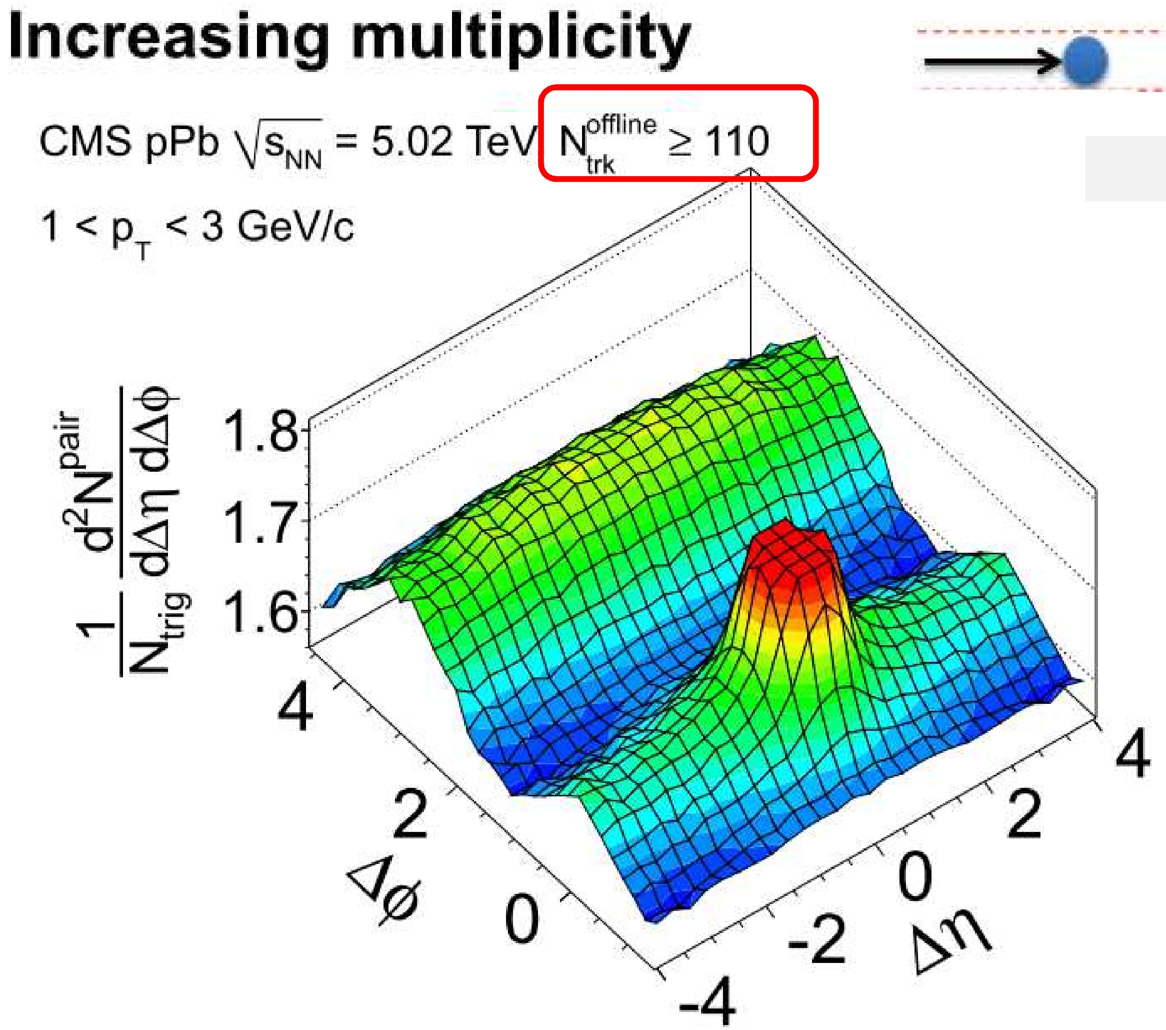


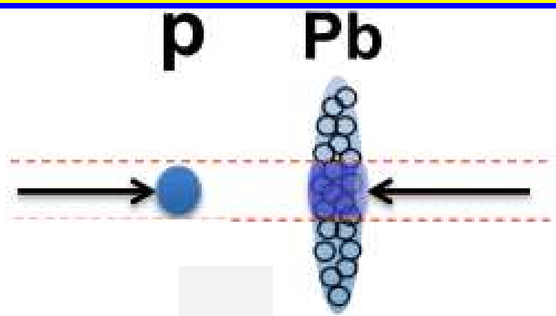


"Ridge" seen in *PbPb* collisions

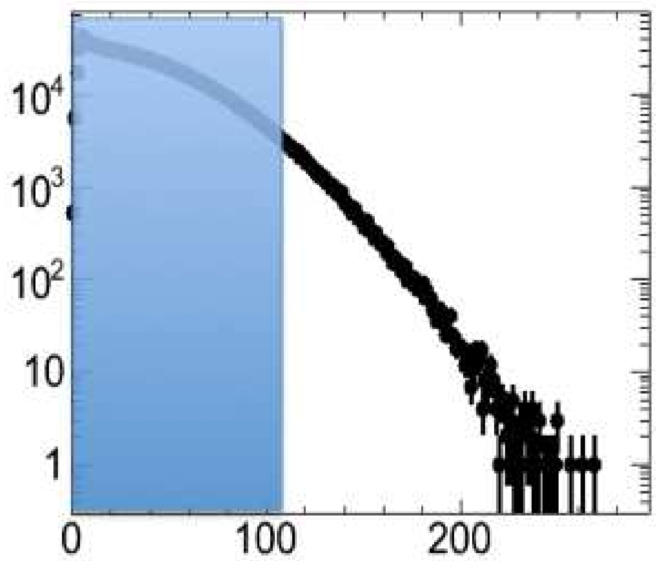
CMS: JHEP 07 (2011) 076 and EPJC 72 (2012) 2012

pPb collisions show some aspects of PbPb correlations!



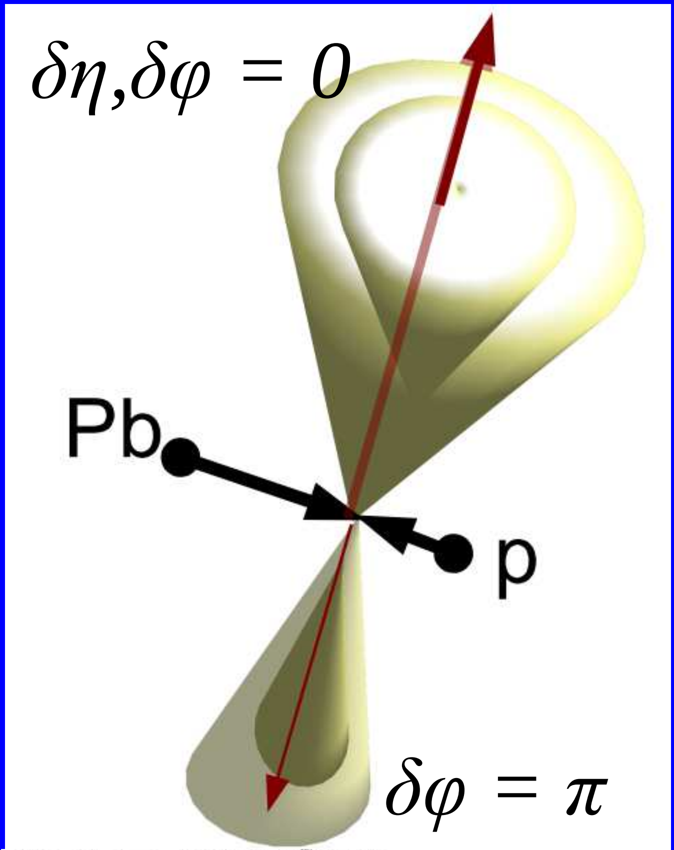


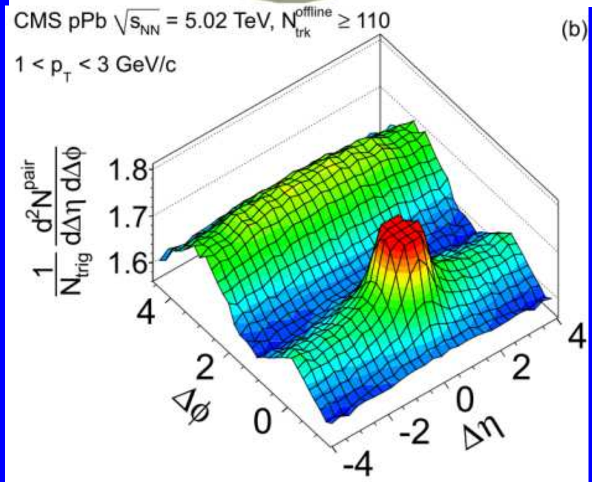
Divide into 4 multiplicity bins:

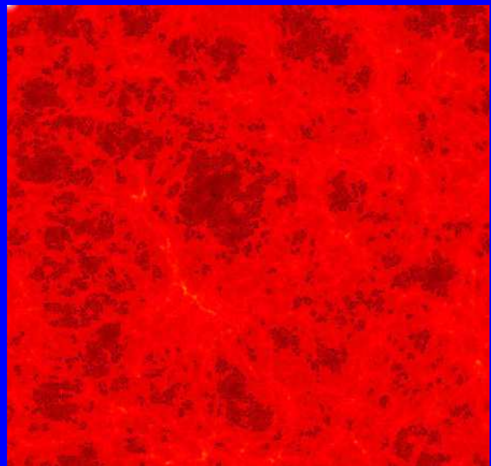


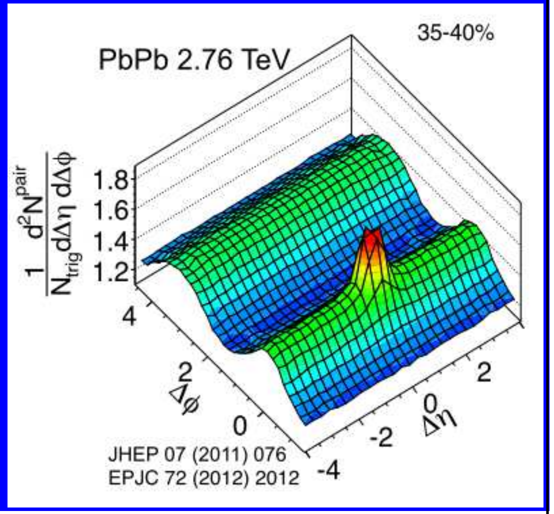
CMS PAS HIN-12-015 to appear in Phys. Lett. B

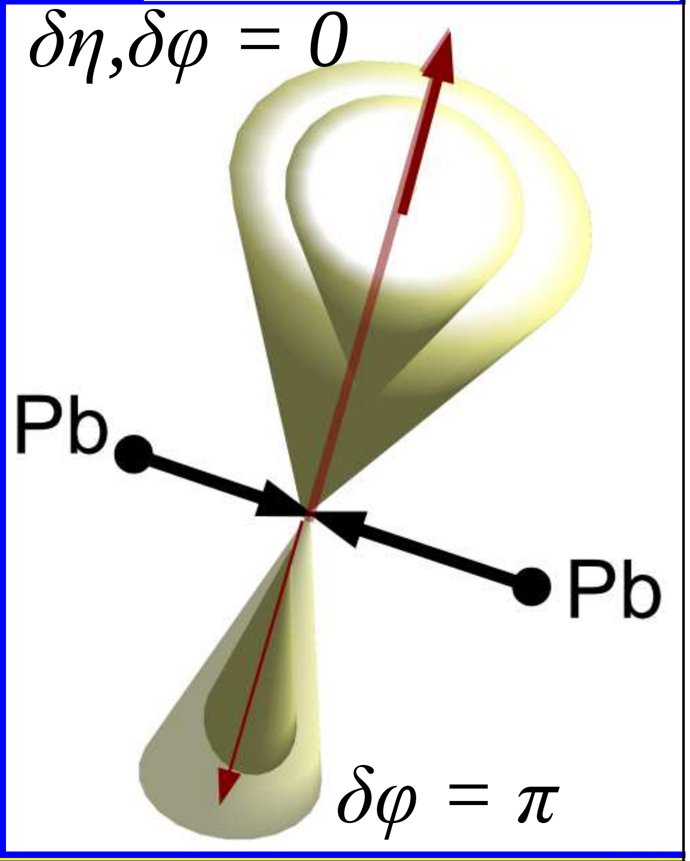
What do these correlations mean?











CMS has shown exciting results

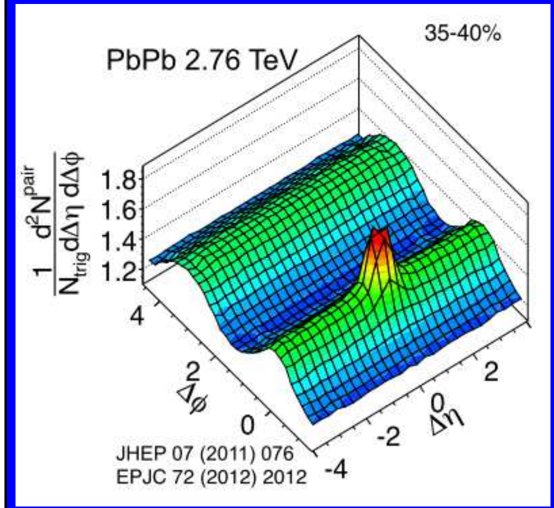
Detailed studies of many body QCD in heavy ion collisions at LHC

Highlights:

- **Suppresion of charged hadron production**
- **Jet quenching and fragmentation**
- **Chemistry of suppressed Upsilon states**
- ***Near* side η,φ correlations in PbPb and pPb**

Thank you CMS
Thank you LHC
Thank you Kruger2012

Backup



Associated hadron yield per trigger

$$\frac{1}{N_{trig}}\frac{d^2N^{pair}}{d\Delta\eta d\Delta\varphi} = B(0,0) \times \frac{S(\Delta\eta,\Delta\varphi)}{B(\Delta\eta,\Delta\varphi)}$$

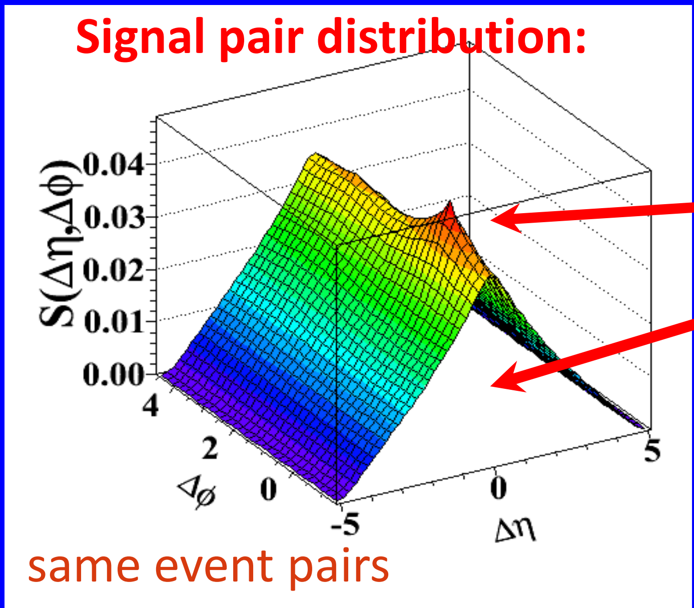
CMS: JHEP 09 (2010) 0

$$S(\Delta\eta,\Delta\varphi) = \frac{1}{N_{trig}}\frac{d^2N^{same}}{d\Delta\eta d\Delta\varphi}$$

$$B(\Delta\eta,\Delta\varphi) = \frac{1}{N_{trig}}\frac{d^2N^{mix}}{d\Delta\eta d\Delta\varphi}$$

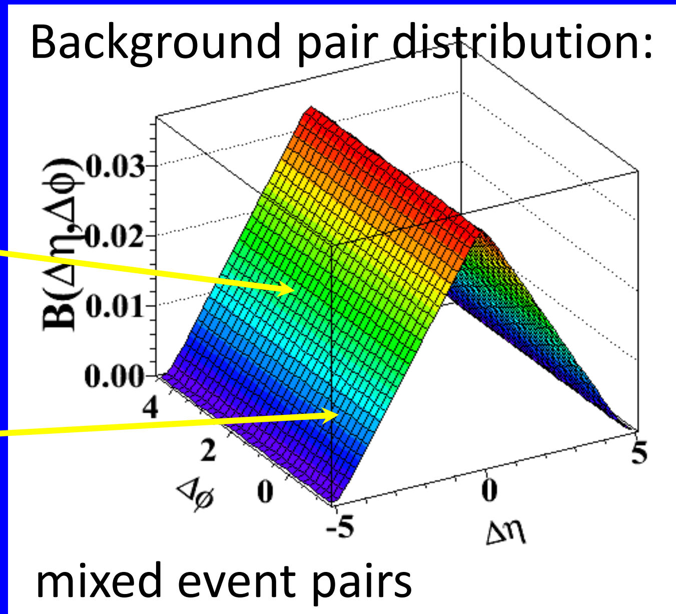
$\Delta\eta = \eta_1 - \eta_2$

$\Delta\varphi = \varphi_1 - \varphi_2$



Event 1

Event 2

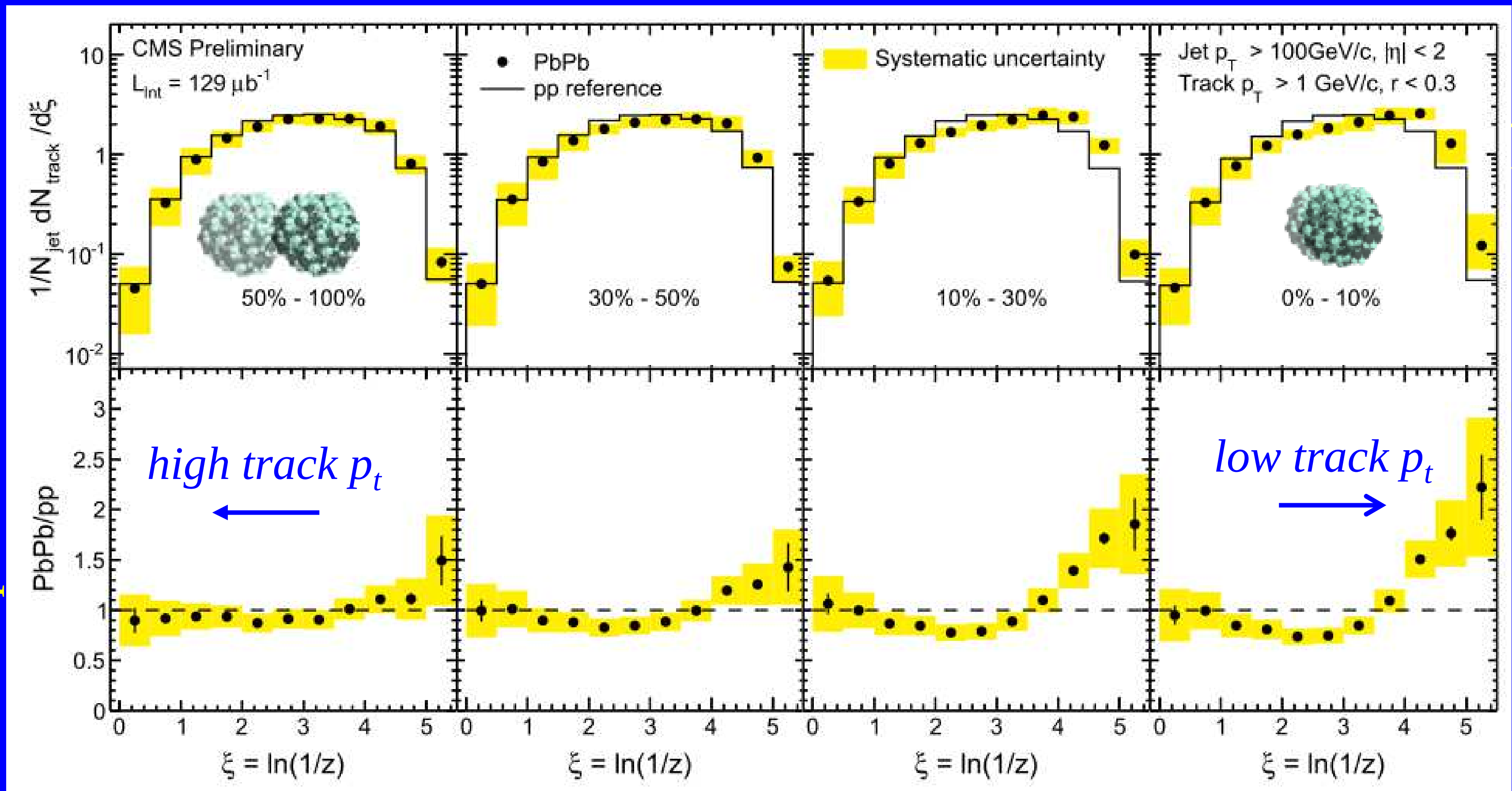


How is jet formation and fragmentation affected by the QGP ?

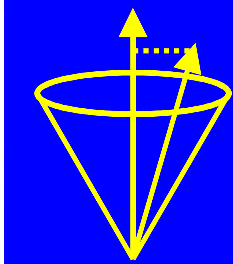
1) Do partons first lose energy in the QGP and then fragment into jets as they normally would in vacuum?

Jet fragmentation function

PbPb to pp comparison

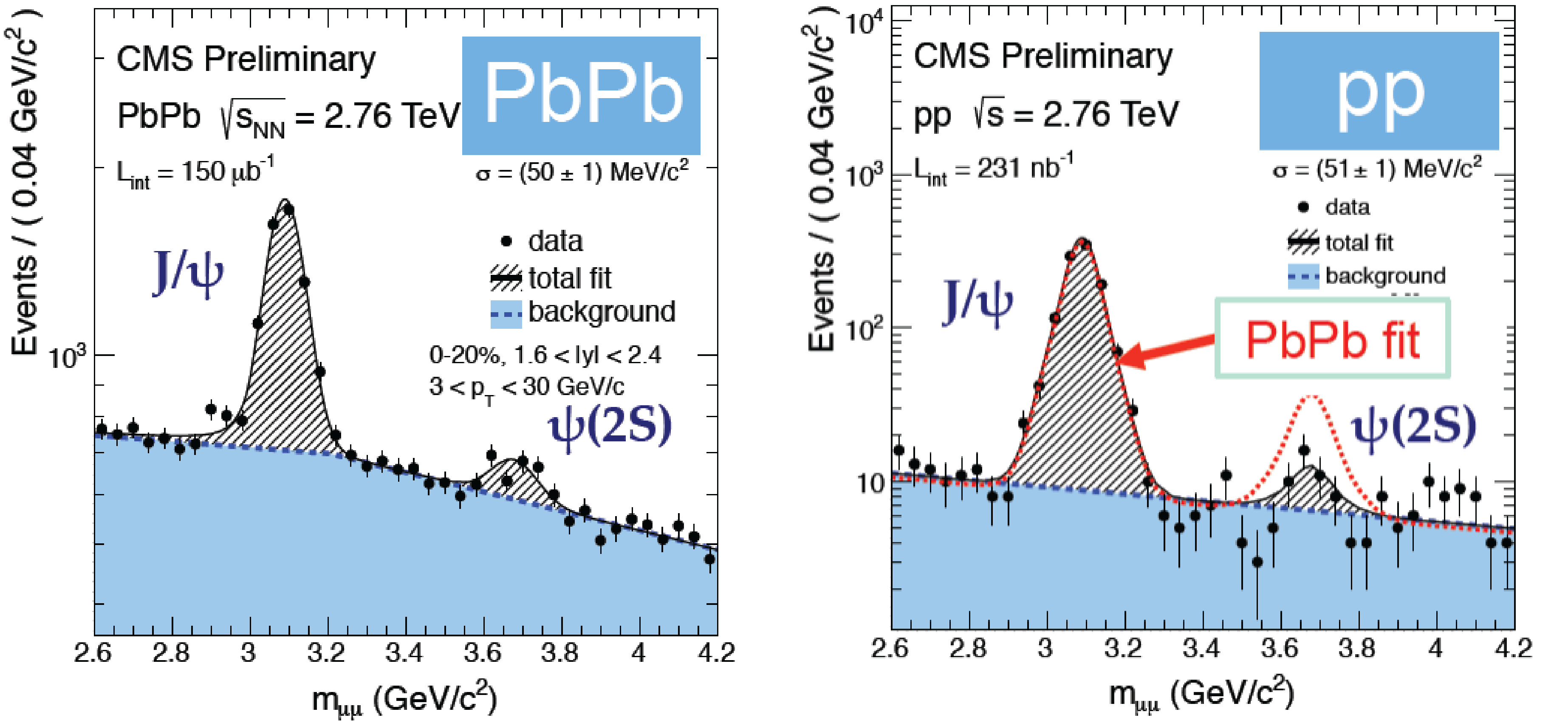


$$\frac{dN_{track}}{d\xi}$$



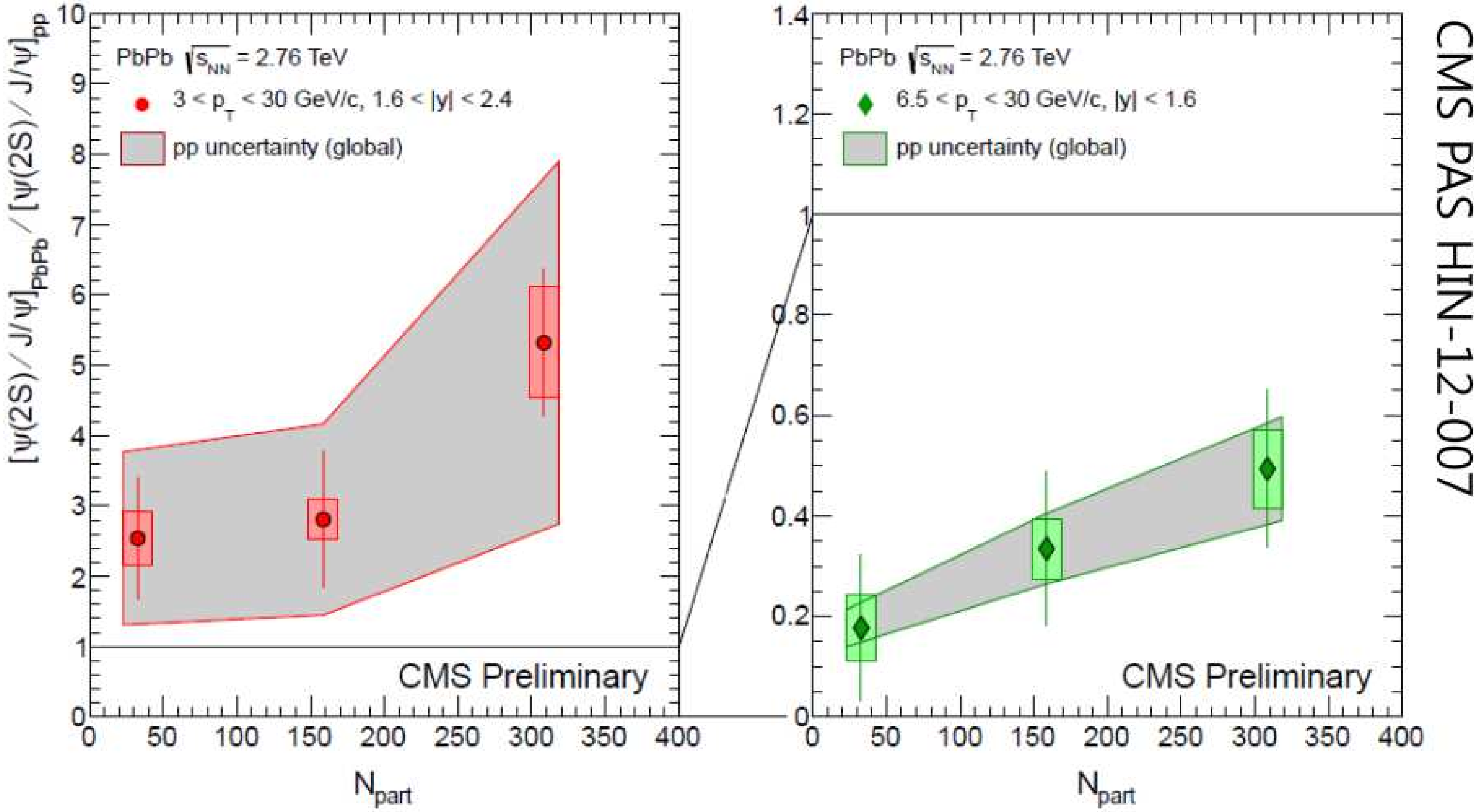
$$\left(\frac{p^{jet}}{p^{track}_{proj}}\right)$$

CMS PAS HIN-12-013 *Large statistics 2011 PbPb run ∫ L = 150 μb^{-1}*



- $R_{\psi(2S)}$: raw yield ratio of ψ(2S) / J/ψ
- For 3 < p_T < 30 GeV/c and 1.6 < |y| < 2.4
  $R_{\psi(2S)}$ in 0–20% PbPb ~ 5 times larger than in pp

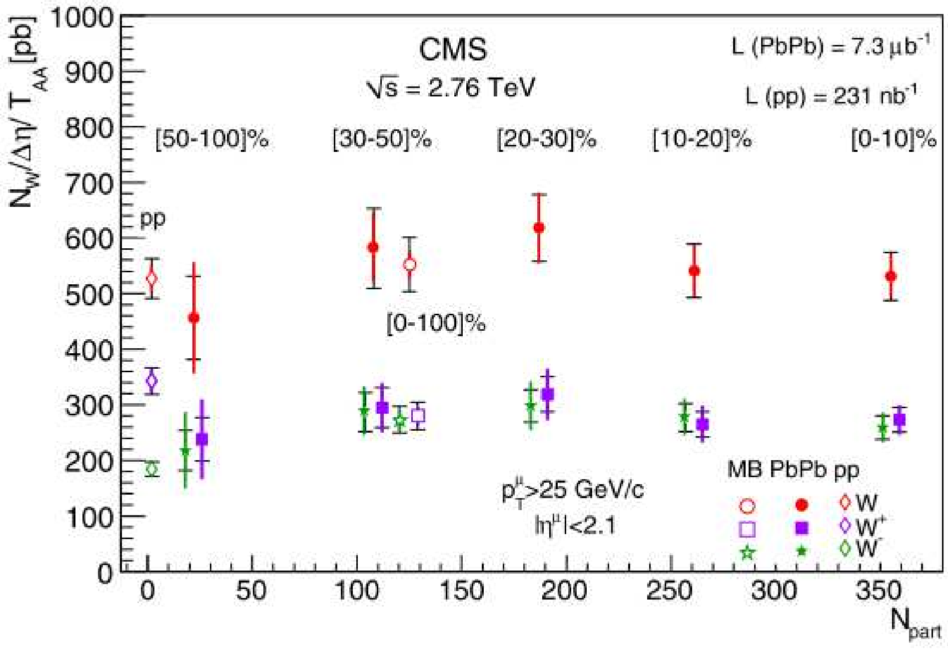
CMS PAS HIN-12-007



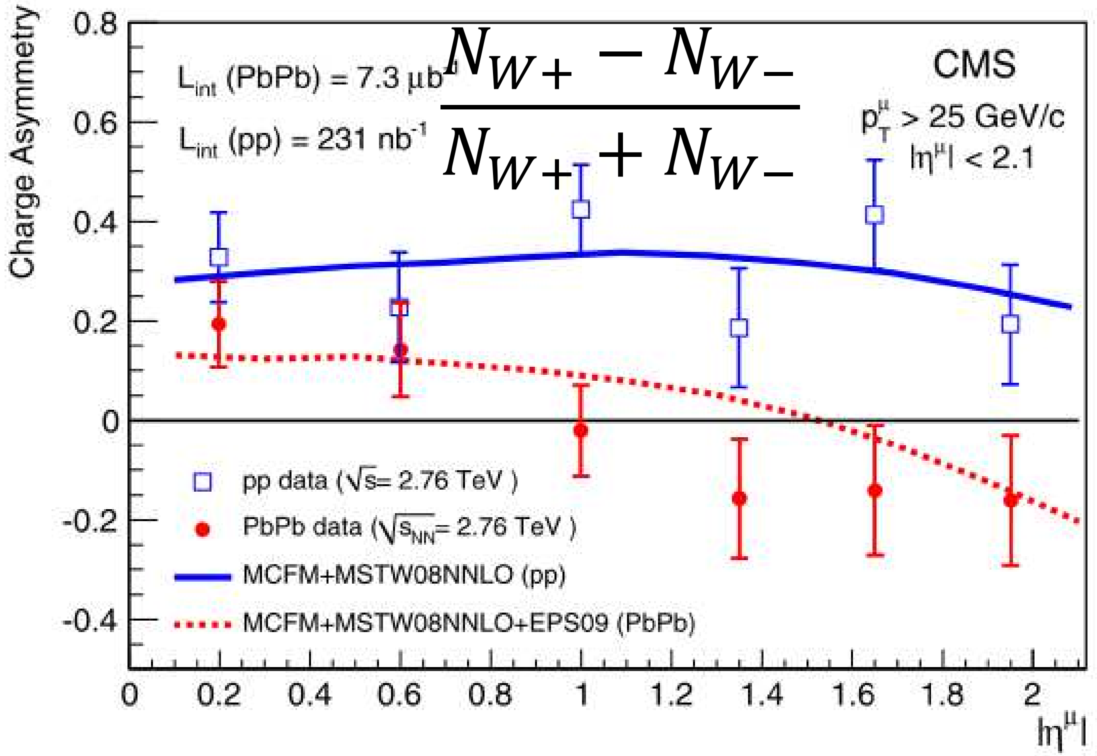
- For p_T>3 GeV/c and 1.6<|y|<2.4
  Indication of ψ(2S) being less suppressed than J/ψ (<2σ effect)
- For p_T>6.5 GeV/c and |y|<1.6
  ψ(2S) are more suppressed than J/ψ

CMS PAS HIN-12-007

Inclusive W is measured with W→μν$_{\mu}$ decays



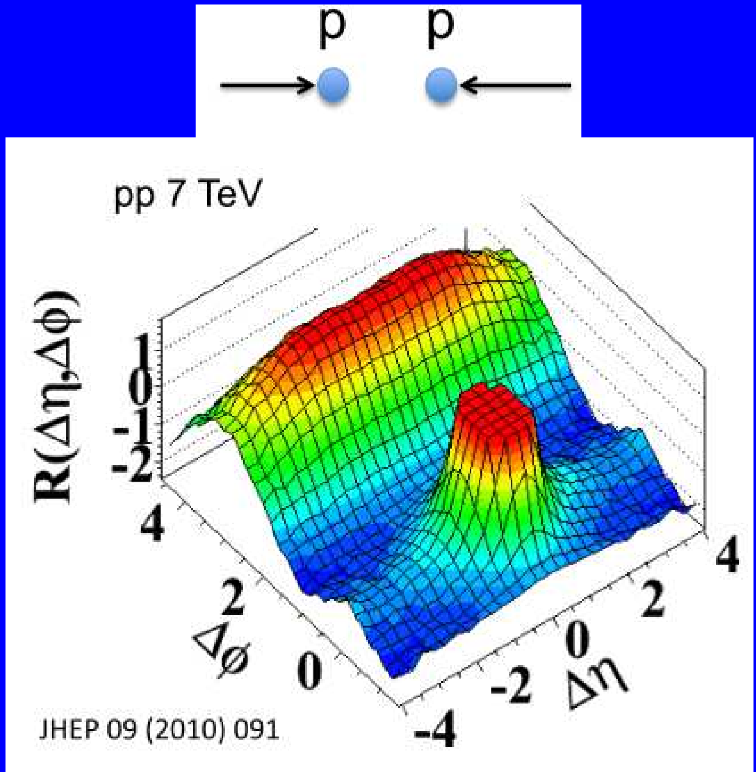
CMS : Phys. Lett. B 715 (2012) 66-87

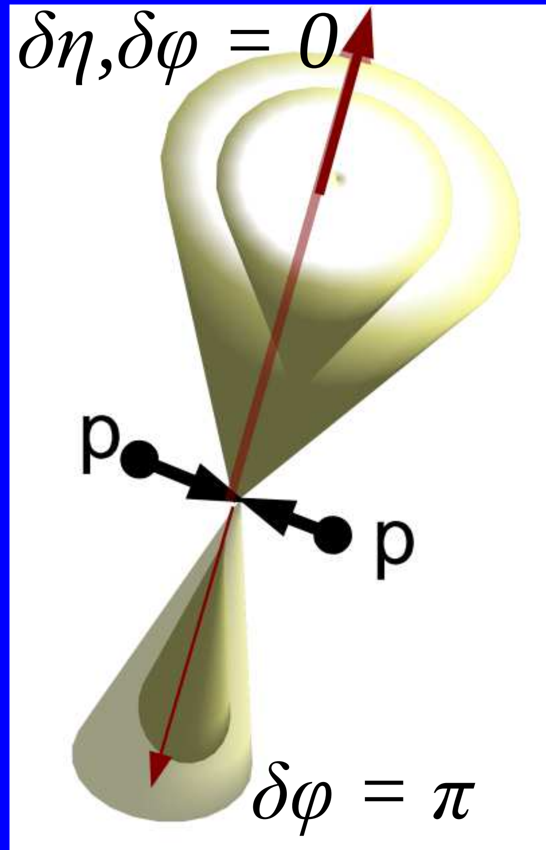


Conclusions:

- *Total W yield consistent with that in pp when scaled by <T_{AA}>*
- *Individual W^+ and W^- yields measured with μ^+ μ^- as a function of η show a charge asymmetry that is well explained by NNLO QCD*

High multiplicity pp collisions show similar η,φ correlations





High multiplicity *pp* collisions
show correlations across $\delta\eta$ *at* $\delta\varphi = 0$

CMS: JHEP 09 (2010) 091