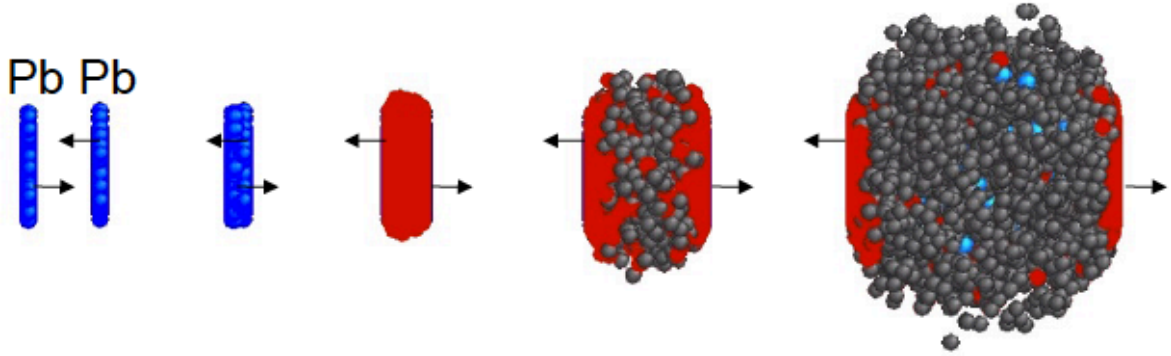
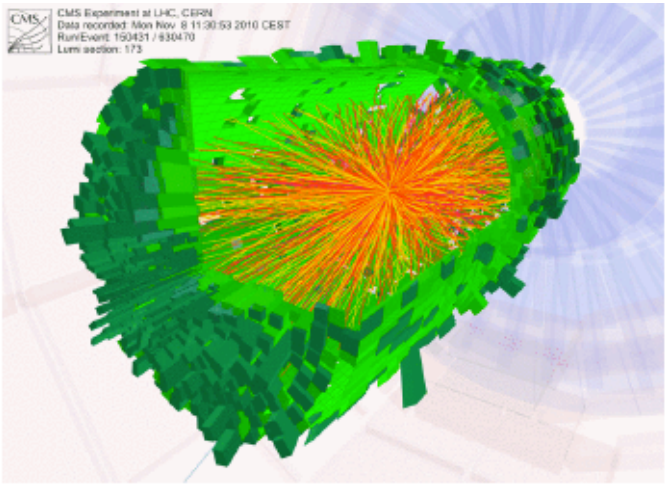
Heavy Ion Physics with ATLAS & CMS





Lamia Benhabib
On behalf of CMS and ATLAS collaborations

23rd Rencontres de Blois Particle Physics and Cosmology

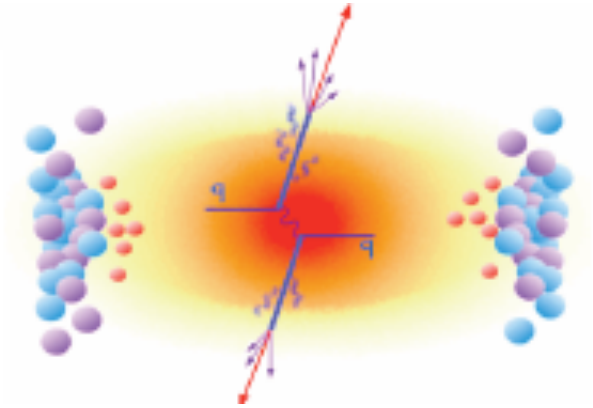
Both **ATLAS** and **CMS** collaborations provide impressive results in heavy ion physics after **PbPb** run 2010 at **$\sqrt{s}$ = 2.76TeV**

- ✓ Multiplicity and transverse energy CMS-PAS-HIN-11-006
- ✓ Di-hadron correlation arXiv:1105.2438; CMS-PAS-HIN-11-001
- ✓ Elliptic flow and higher harmonics CMS-PAS-HIN-11-003
- ✓ Nuclear modification factor CMS-PAS-HIN-10-005
- ✓ Electroweak bosons Z, W arXiv:1102.5435v1
- ✓ Isolated photons CMS-PAS-HIN-11-002
- ✓ Jet measurement
  - ✓ Dijet asymmetry Phys. Rev. Lett 105 (2010) 252303; arXiv:1102.1957
  - ✓ Fragmentation function
- ✓ Quarkonia
  - ✓ Jψ measurement Phys. Rev. Lett.B697:294-312 (2011); CMS-PAS-HIN-10-006

  and Υ suppression arXiv:1105.4894

Parton energy loss in the medium

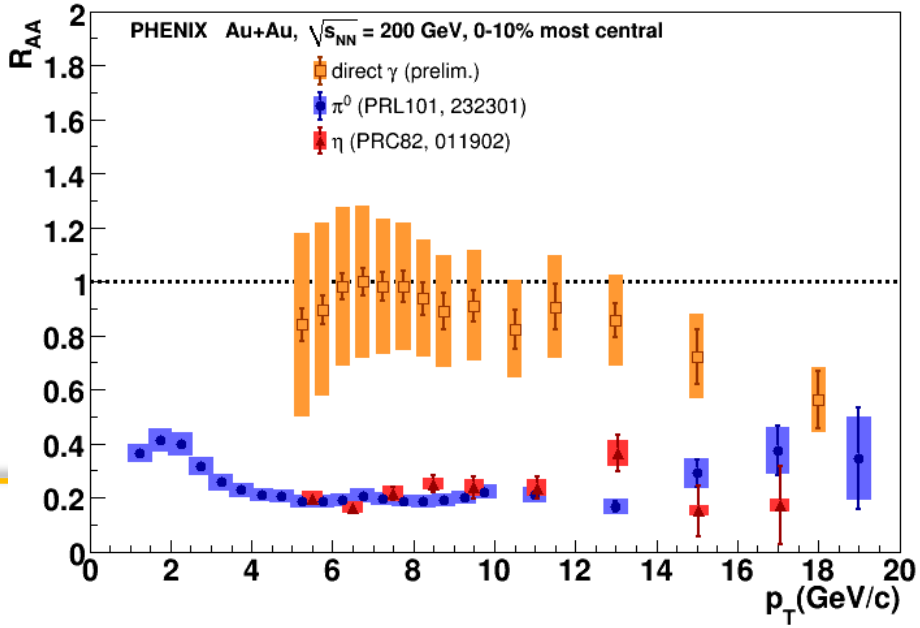
- At RHIC high p_T particle production is suppressed traversing a hot dense medium created in heavy ion collisions



- Nuclear modification factor R_{AA} is ratio of measured particle yields to what would have been measured if a Heavy -Ion collision was just a superposition of independent p-p collisions

$$R_{AA} = \frac{1/N_{evnts} d^2N_{PbPb}/dydp_T}{< T_{AB} > d^2\sigma_{pp}/dydp_T}$$

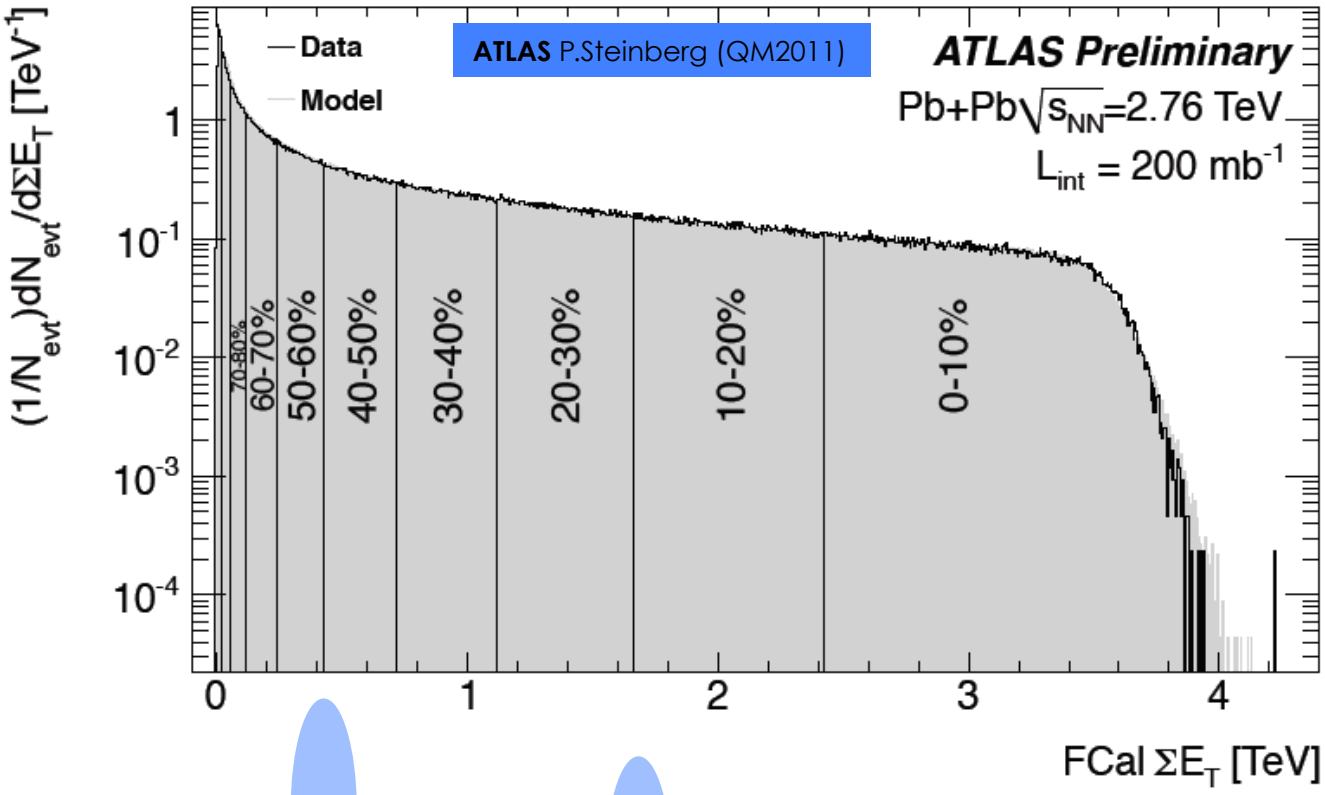
$$\frac{\text{medium like}}{\text{Vaccum like}}$$

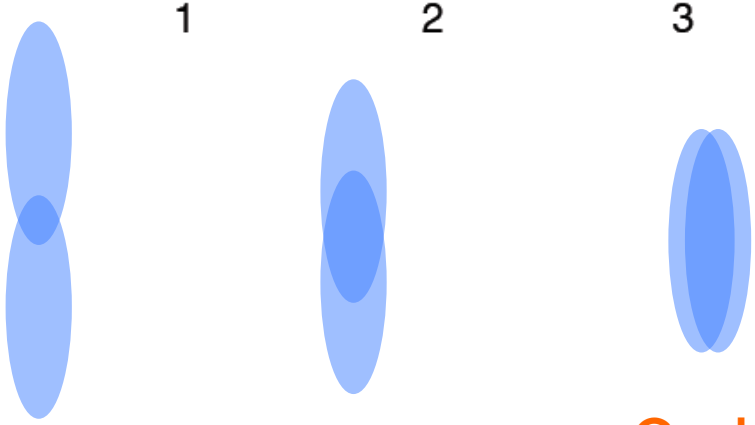


Clear **suppression** for high p_T particles (π^0 , η) in the most central event, however **direct photon** measurement is consistent with 1 (up to 14 GeV/c)

Centrality

- Centrality of a collision is determined from the energy deposit in forward calorimeters





Peripheral (pp like)

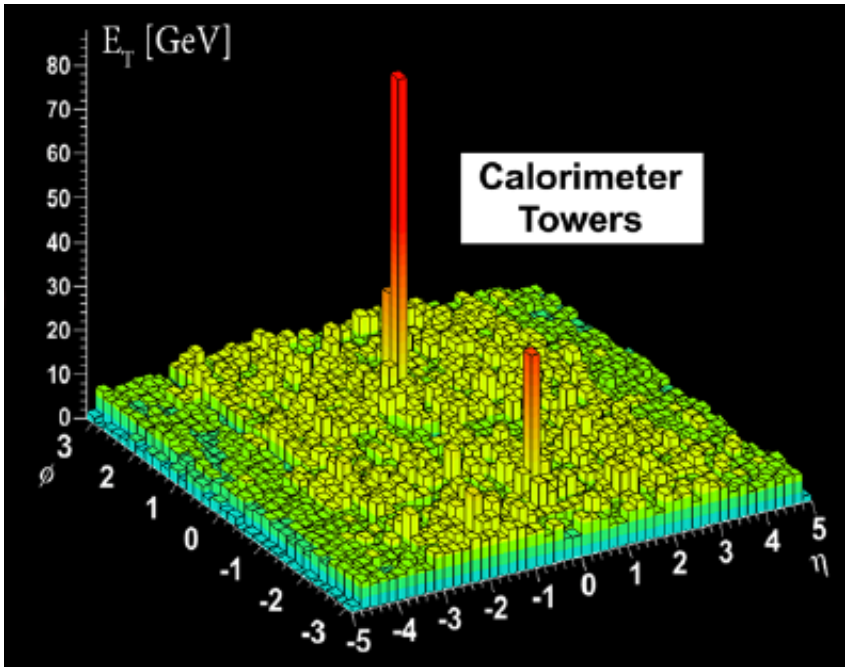
Central

Imbalance dijet

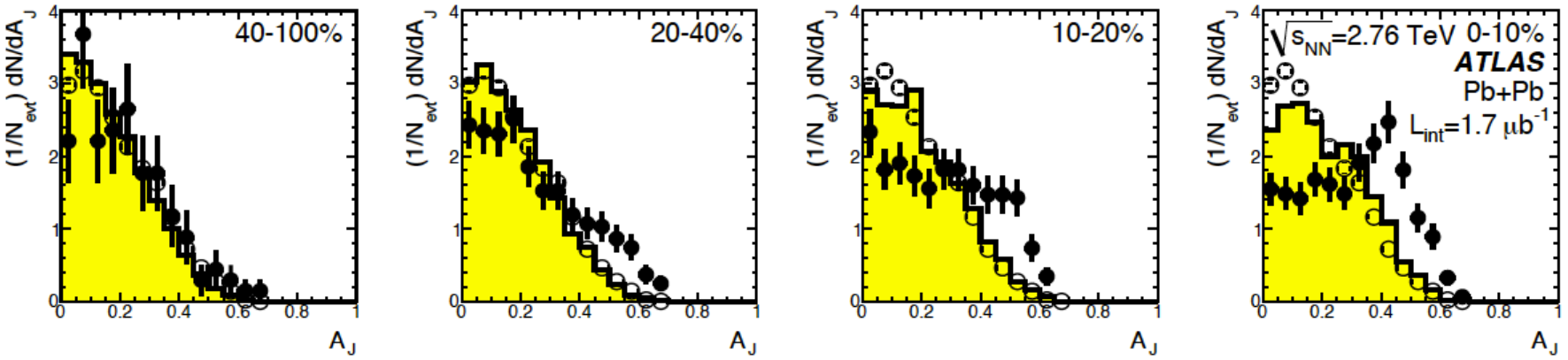
- Dijet selection
  - Leading jet p_T > 100 GeV/c
  - Subleading jet p_T > 25 GeV/c

- Quantify dijet imbalance by asymmetry ratio

$$A_j = \frac{E_{T1} - E_{T2}}{E_{T1} + E_{T2}}$$



Phys. Rev. Lett **105** (2010) 252303

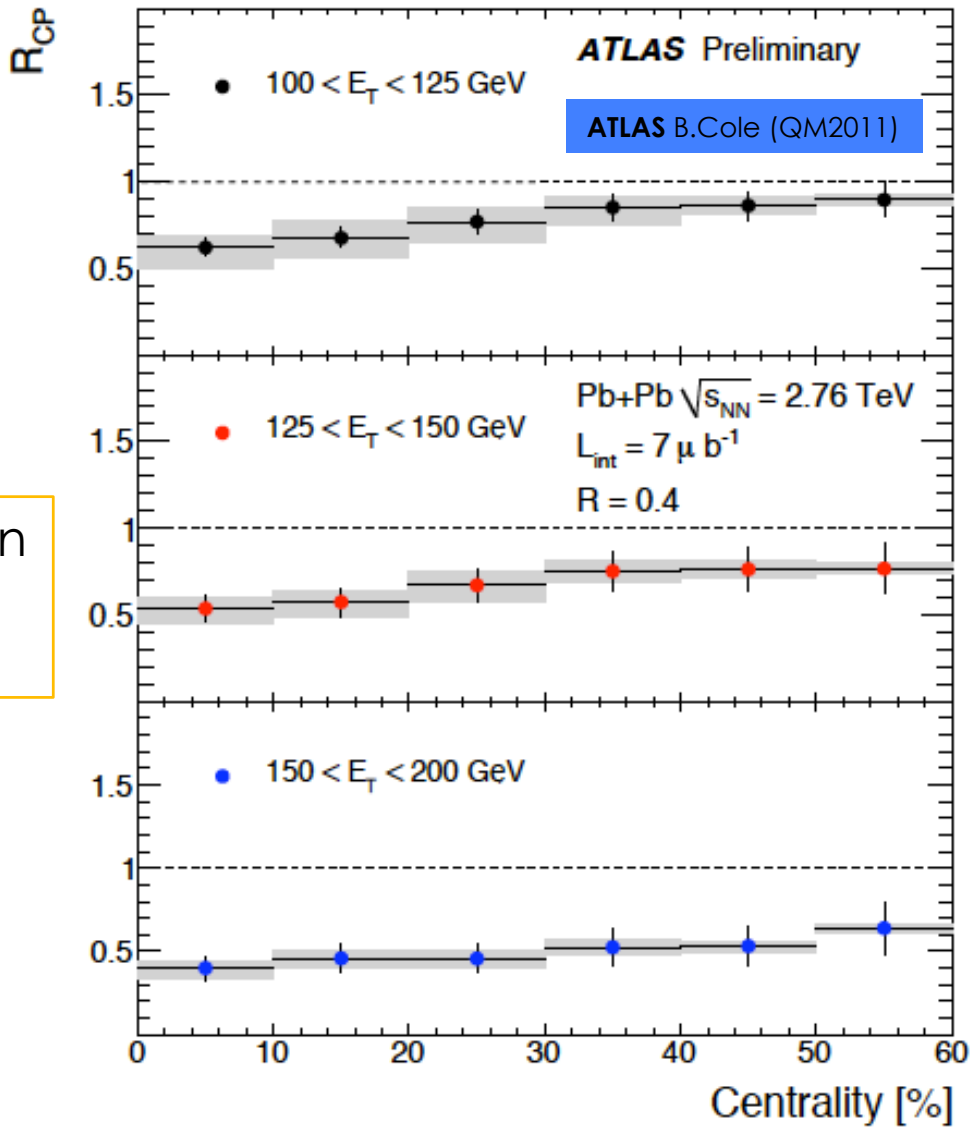


Parton energy loss is observed as pronounced energy imbalance in reconstructed dijets

Single jet central to peripheral ratio :R_{cp} vs centrality

$$R_{cp} = \frac{\frac{1}{N_{coll}^{cent}} \frac{1}{N_{evt}^{cent}} \frac{dN_{jet}^{cent}}{dE_T}}{\frac{1}{N_{coll}^{60-80}} \frac{1}{N_{evt}^{60-80}} \frac{dN_{jet}^{60-80}}{dE_T}}$$

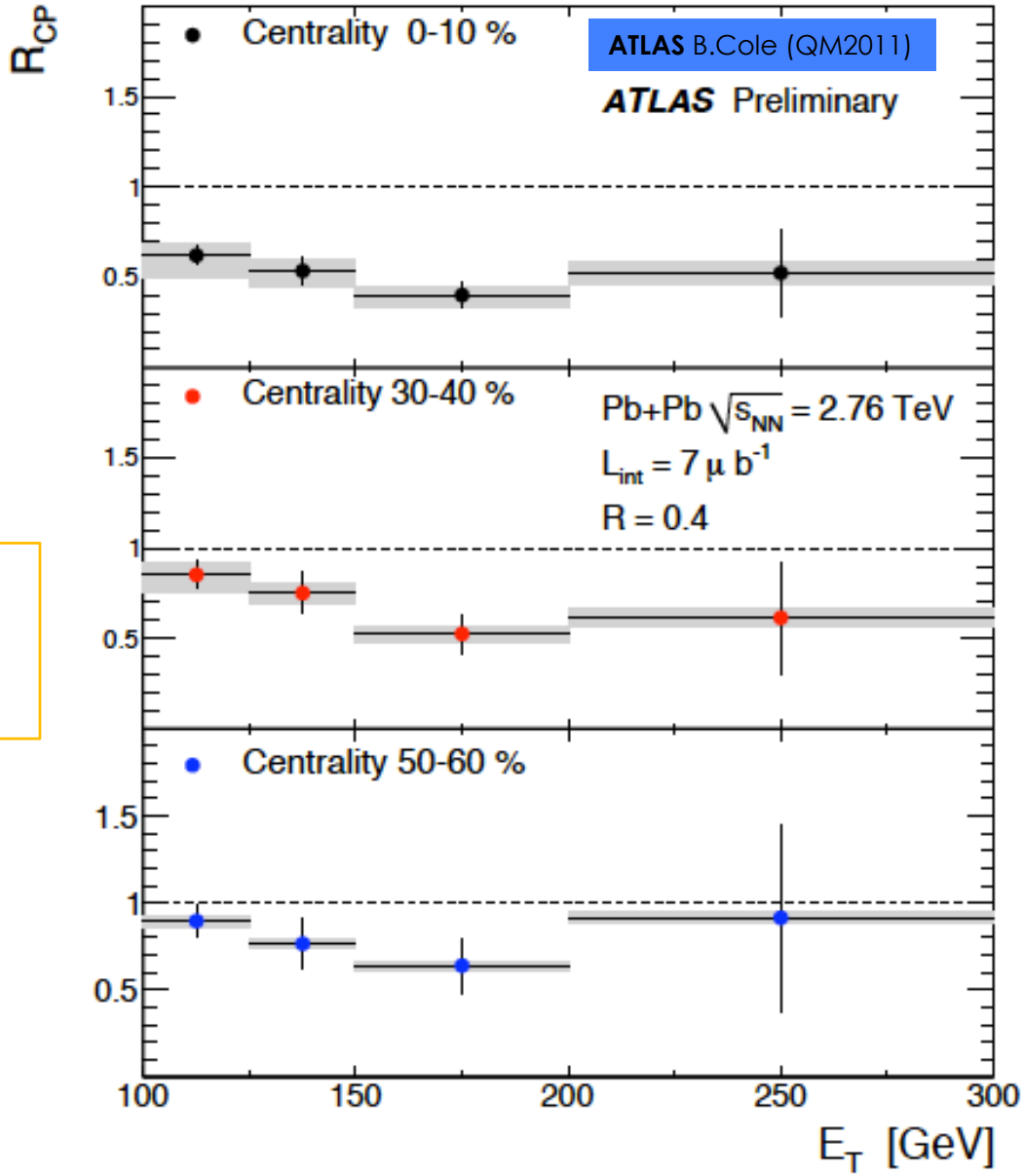
A factor 2 suppression is observed in central (0-10%) collisions relative to peripheral 60-80%



Single jet central to peripheral ratio R_{cp} vs E_T

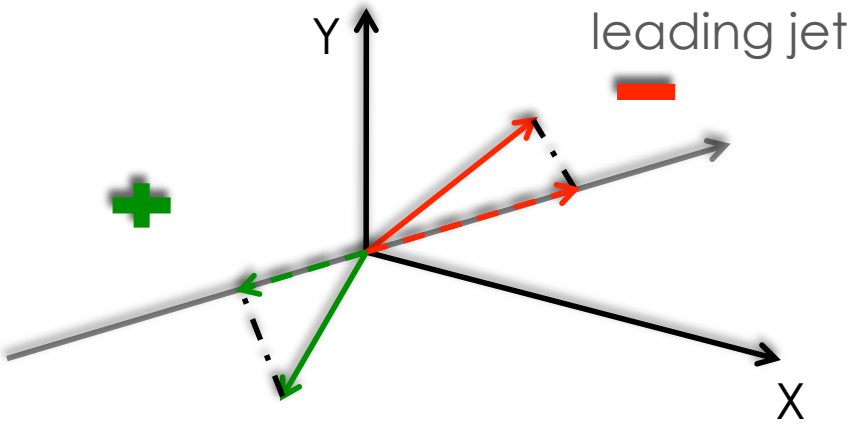
- $$R_{cp} = \frac{\frac{1}{N_{coll}^{cent}} \frac{1}{N_{evt}^{cent}} \frac{dN_{jet}^{cent}}{dE_T}}{\frac{1}{N_{coll}^{60-80}} \frac{1}{N_{evt}^{60-80}} \frac{dN_{jet}^{60-80}}{dE_T}}$$

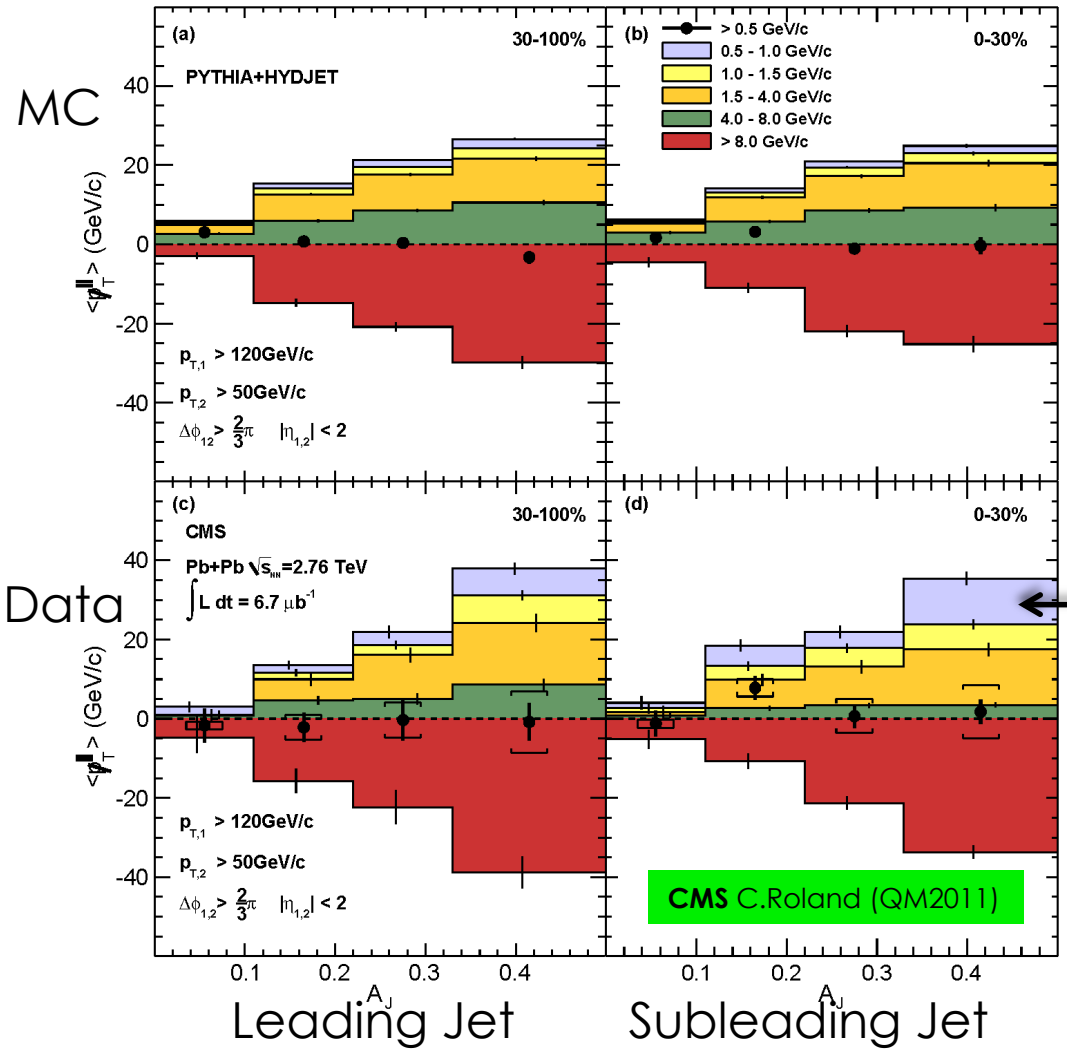
The suppression is independent of the E_T jets within the statistical and systematic errors



Where does the missing p_T goes?

$$\not{p}_{\mathrm{T}}^{\parallel} = \sum_{\mathrm{Tracks}} -p_{\mathrm{T}}^{\mathrm{Track}} \cos\left(\phi_{\mathrm{Track}} - \phi_{\mathrm{Leading\ Jet}}\right)$$





0.5 – 1.0 GeV/c

1.0 – 2.0 GeV/c

2.0 – 4.0 GeV/c

4.0 – 8.0 GeV/c

> 8.0 GeV/c

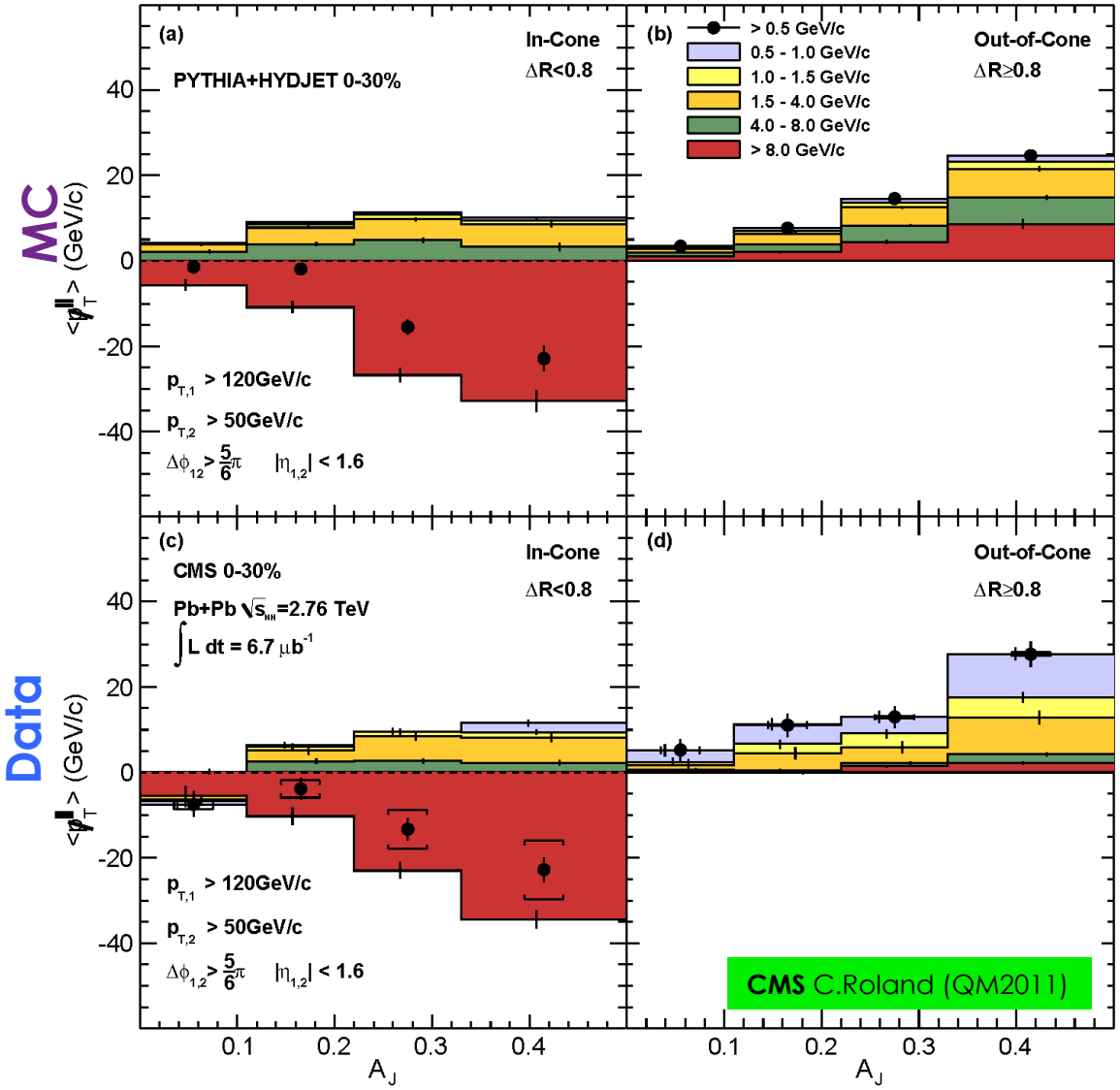
Excess of particles at low p_T

arXiv:1102.1957

Where does the missing p_T goes?

- In **PYTHIA**, balance is found out-of-cone as well, but at higher p_T (3^{rd} jets)

PbPb **Data**, in-cone excess of high-p_T tracks is balanced by out-of-cone low-p_T tracks

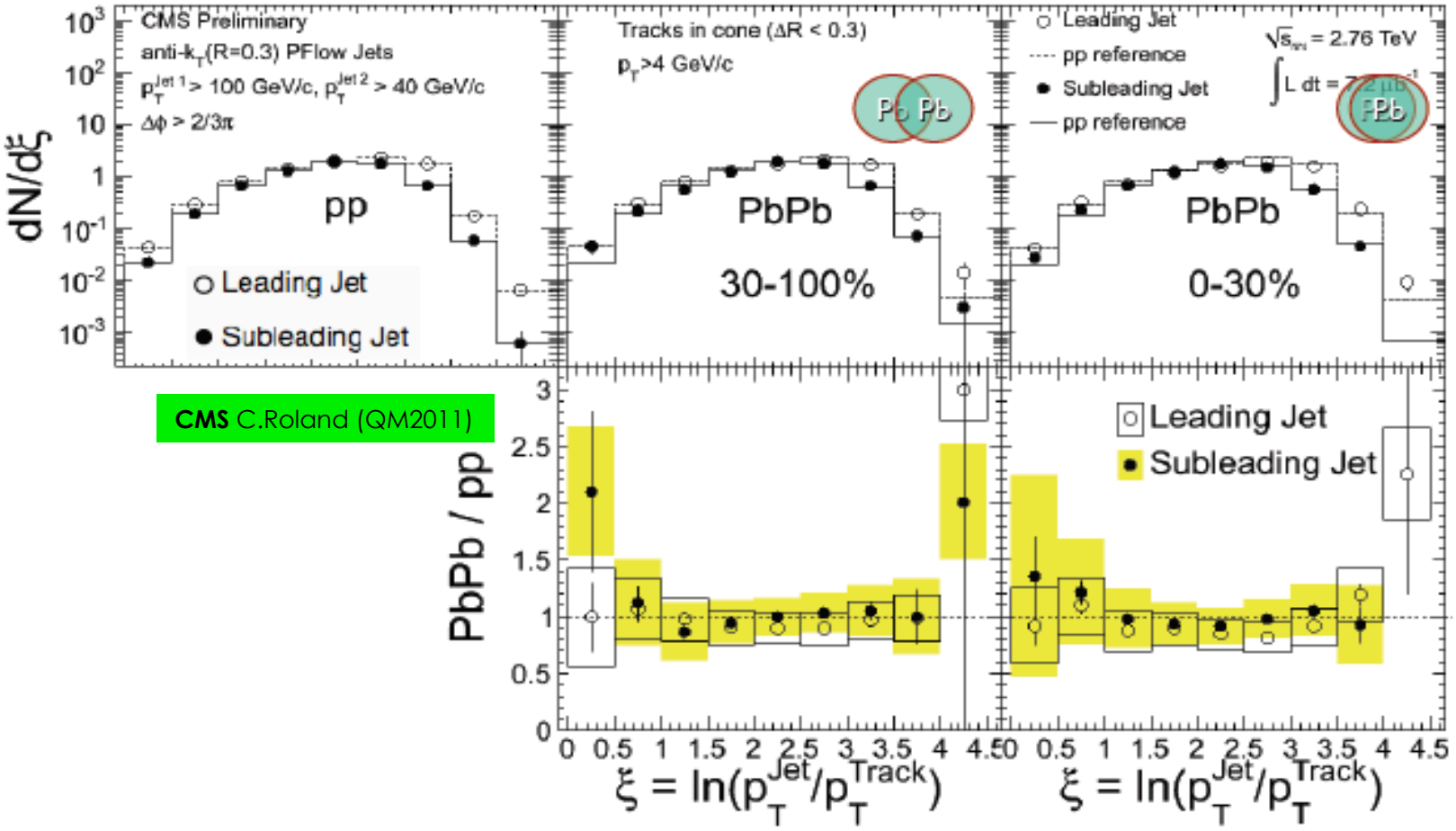


arXiv:1102.1957

Leading Jet Subleading Jet

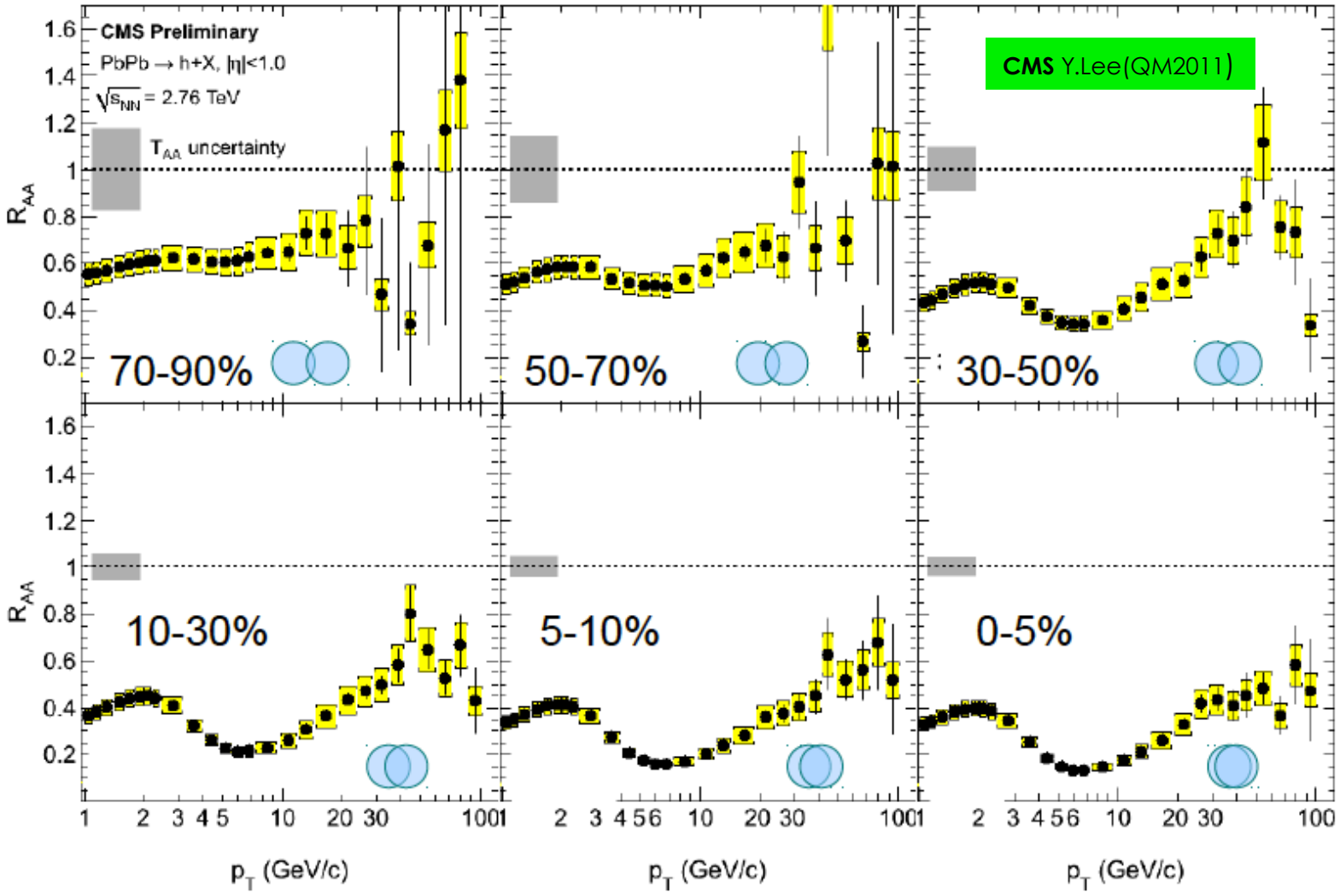
Fragmentation function

- Fragmentation function represent the fraction of energy that carry a particular hadron coming from a fragmentation of a parton



Leading and subleading jet in PbPb fragment like jets of a corresponding energy in pp collisions

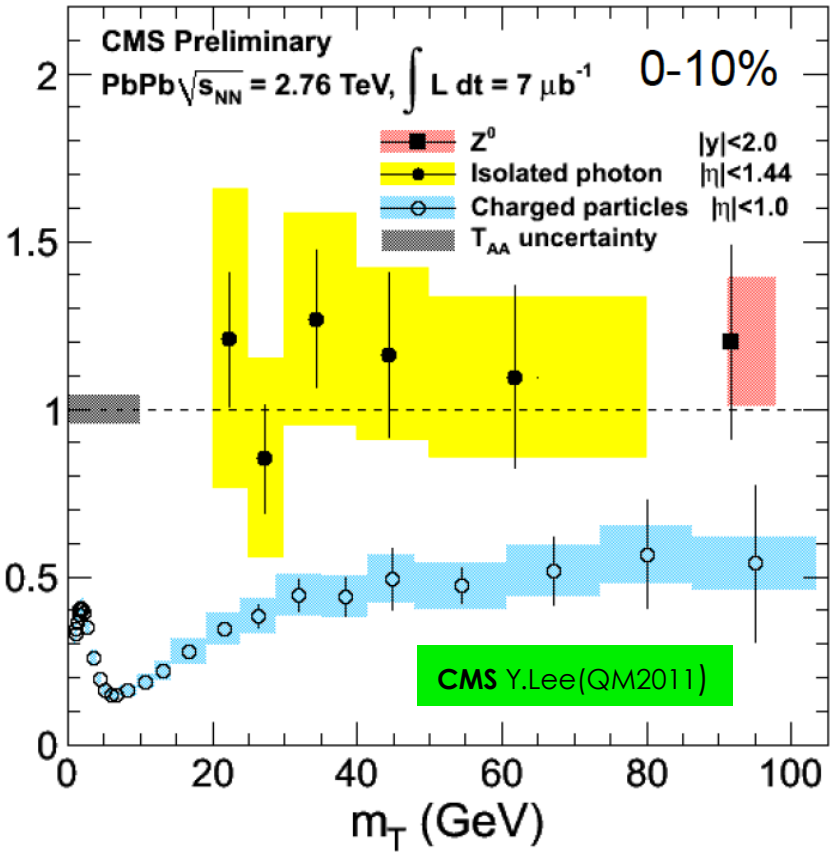
R_{AA} of charged particles

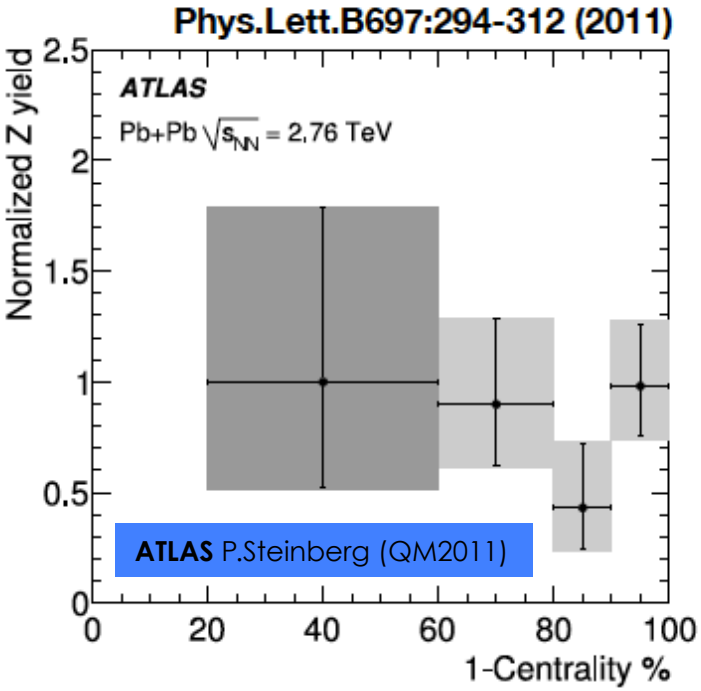


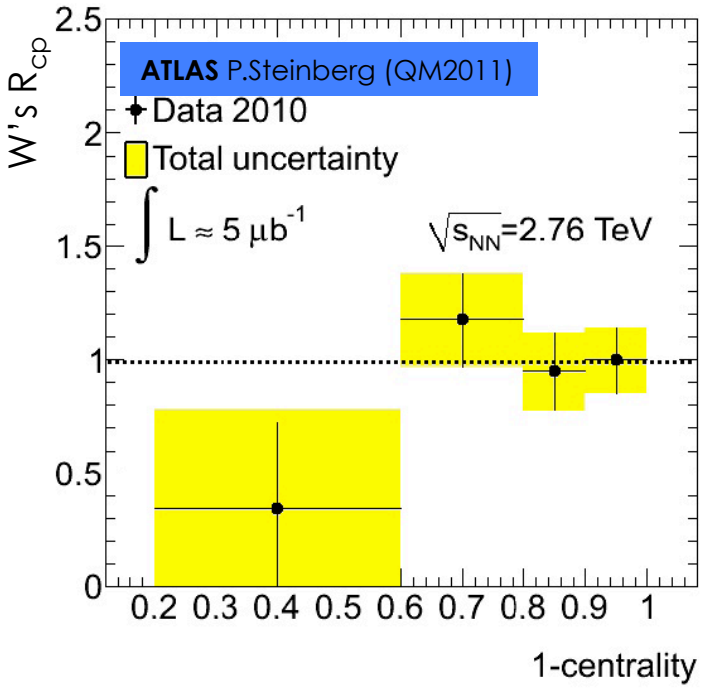
- R_{AA} increases as a function of p_T in the p_T >10GeV/c
- Strong constrain on the parton energy loss

W, Z bosons and Isolated photons

- First measurement of Z boson and isolated photons in heavy ion collisions
- No modification is observed in Z and isolated photon production
  - Confirmation of the N_{coll} scaling for the pQCD probe



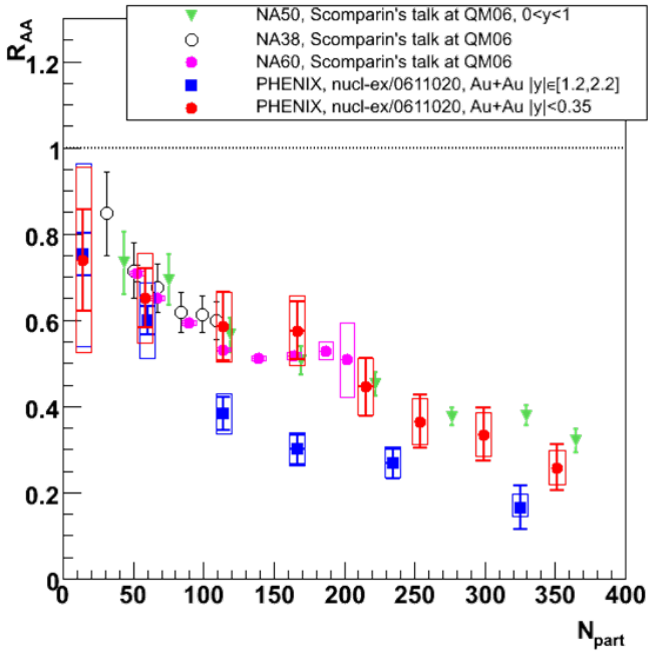




Quarkonia

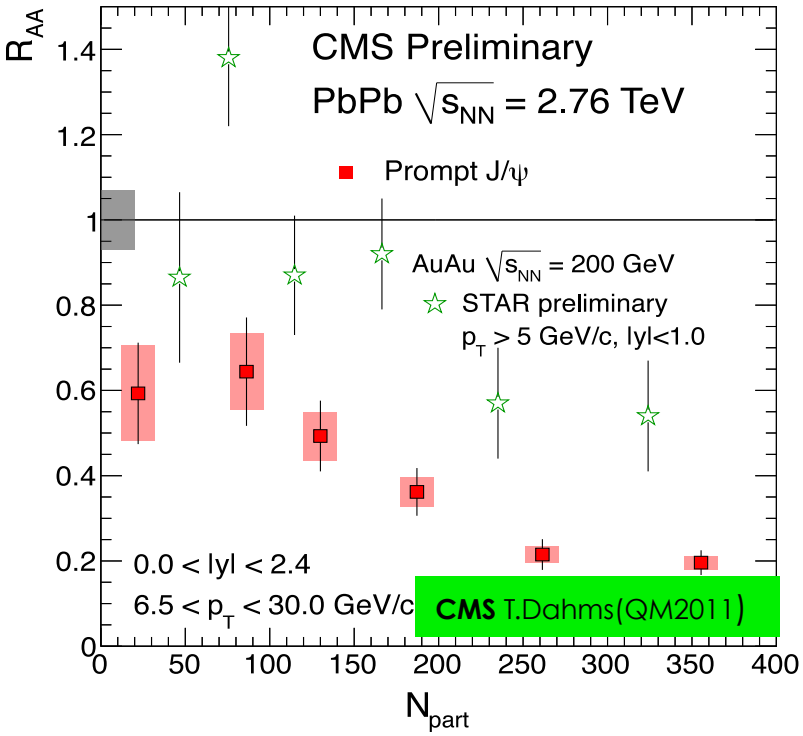
- T. Matsui & H. Satz PLB178, 416 (1986): quarkonia should melt in the QGP
- Good candidates to probe the QGP
  - Large masses and (dominantly) produced at the early stage of the collision via hard-scattering of gluons
  - Strongly bound resonances
- Quarkonia puzzle started at RHIC
  - No increase of the suppression with local density
  - R_{AA} ($|y|<0.35$) > R_{AA} ($1.2<|y|<2.2$
- Similar suppression at SPS and RHIC energies R_{AA} (RHIC, $|y|<0.35$) ≈ R_{AA} (SPS)

- Possible ingredients
  - Suppression (gluon diss.)
  - Sequential melting
  - Gluon saturation / shadowing
  - Regeneration
- What about Quarkonia at LHC ?

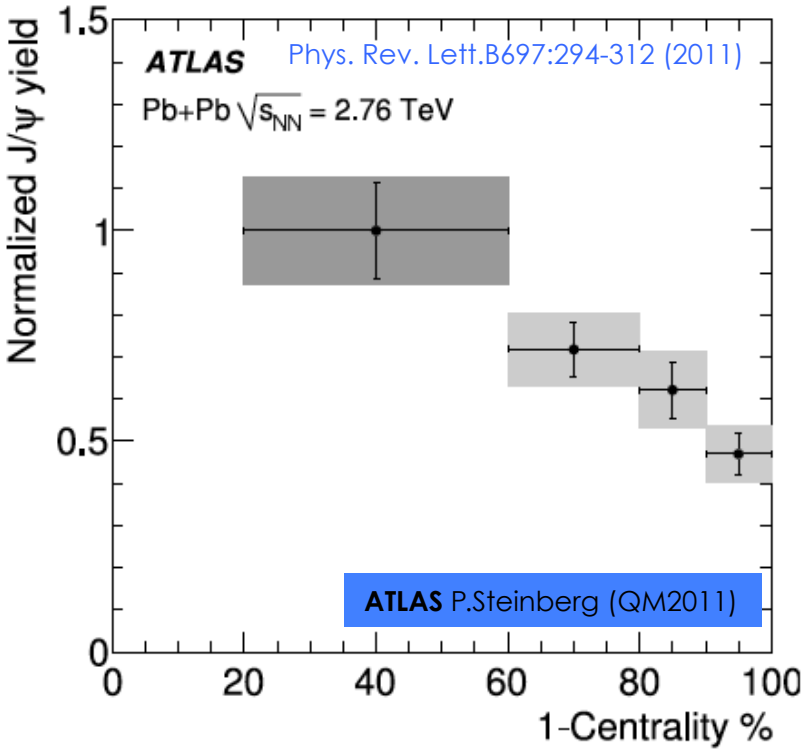


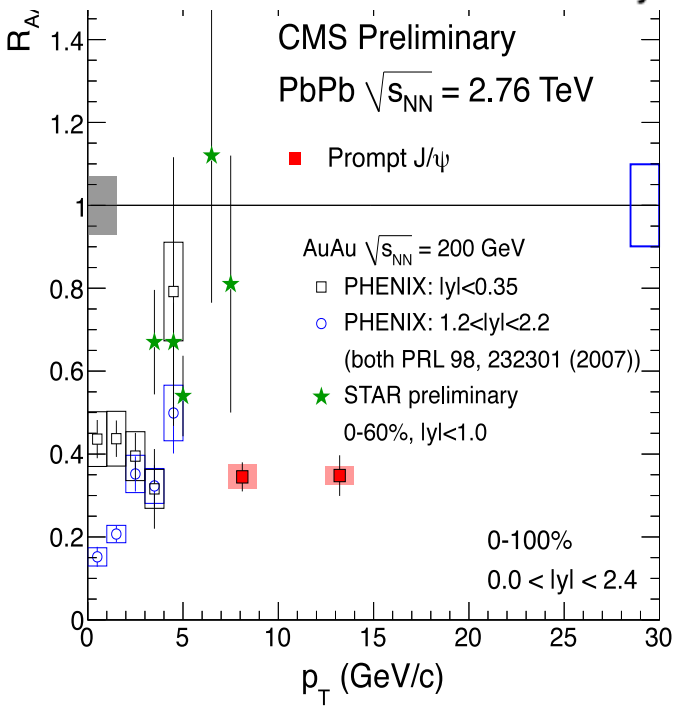
R_{AA} and R_{cp} of J/ψ

- ATLAS published a first measured suppression of J/ψ
- J/ψ production is more suppressed in central compare to peripheral events



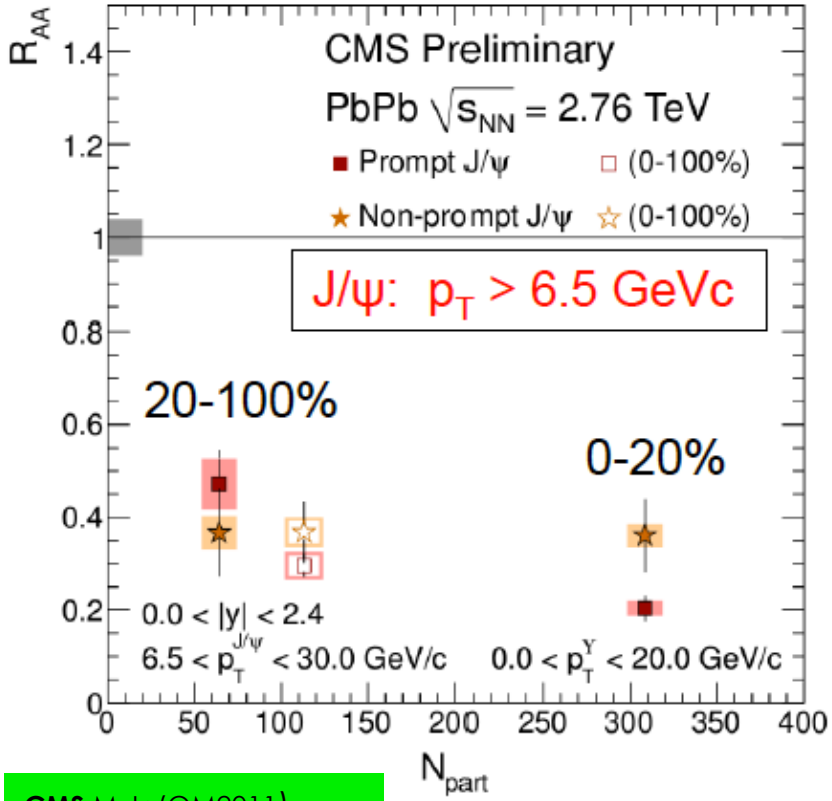
- Stronger suppression seen in CMS than at STAR
- High $p_T^{J/\psi}$ tendency to survive at RHIC (and SPS) is not seen at the LHC



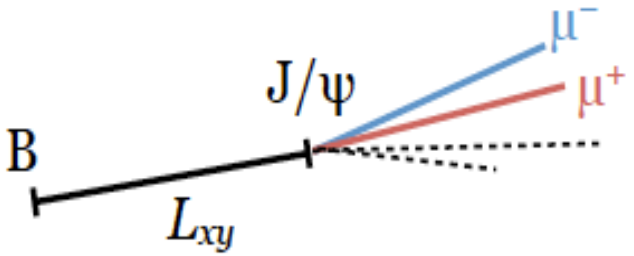


First B → J/ψ

Inclusive J/ψ → Prompt J/ψ → Direct J/ψ
Prompt J/ψ → Feed-down from ψ' and χ_c
Inclusive J/ψ → **Non-Prompt J/ψ from B decays**



CMS M.Jo(QM2011)



- b quark energy loss

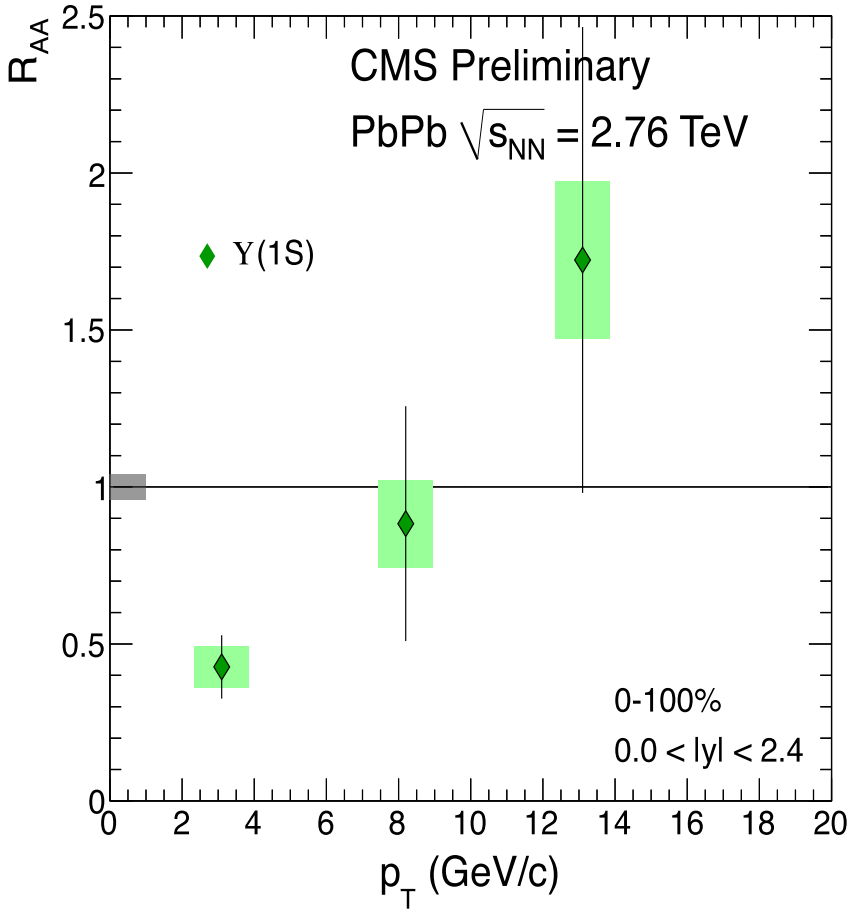
Min. bias R_{AA} = 0.37 ± 0.07(stat) ± 0.03(syst)

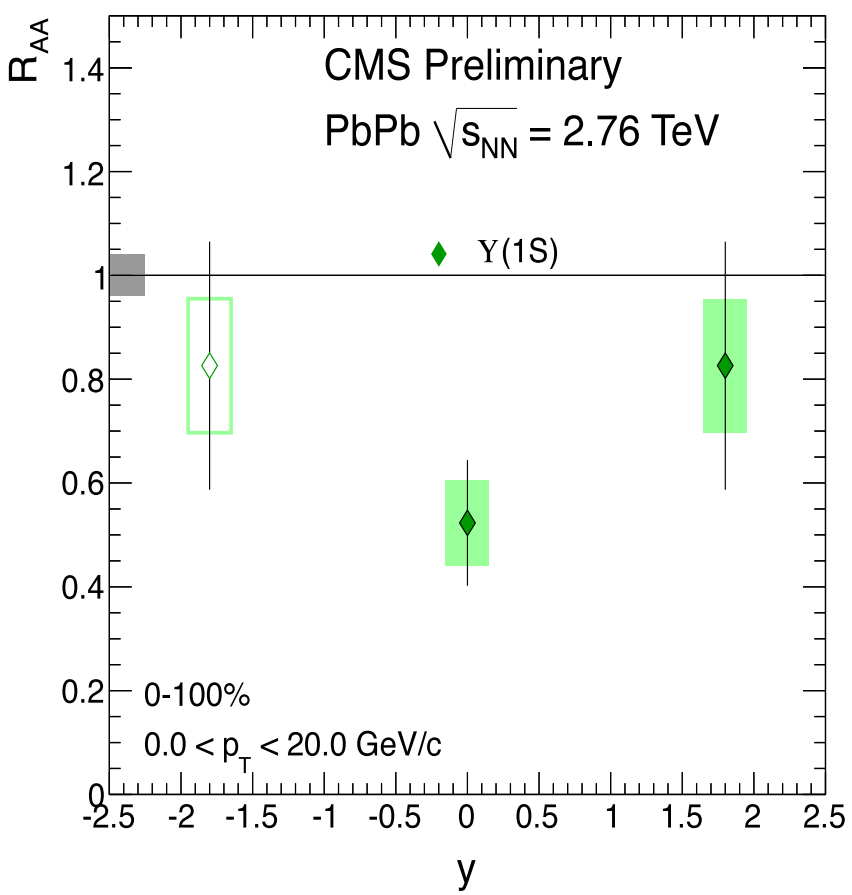
Central 0-20% R_{AA} = 0.36 ± 0.08(stat) ± 0.03(syst)

non-prompt J/ψ are less suppressed than prompt J/ψ
First indication of high-p_T-quark quenching

R_{AA} of Υ(1S)

CMS C.Silvestre(QM2011)

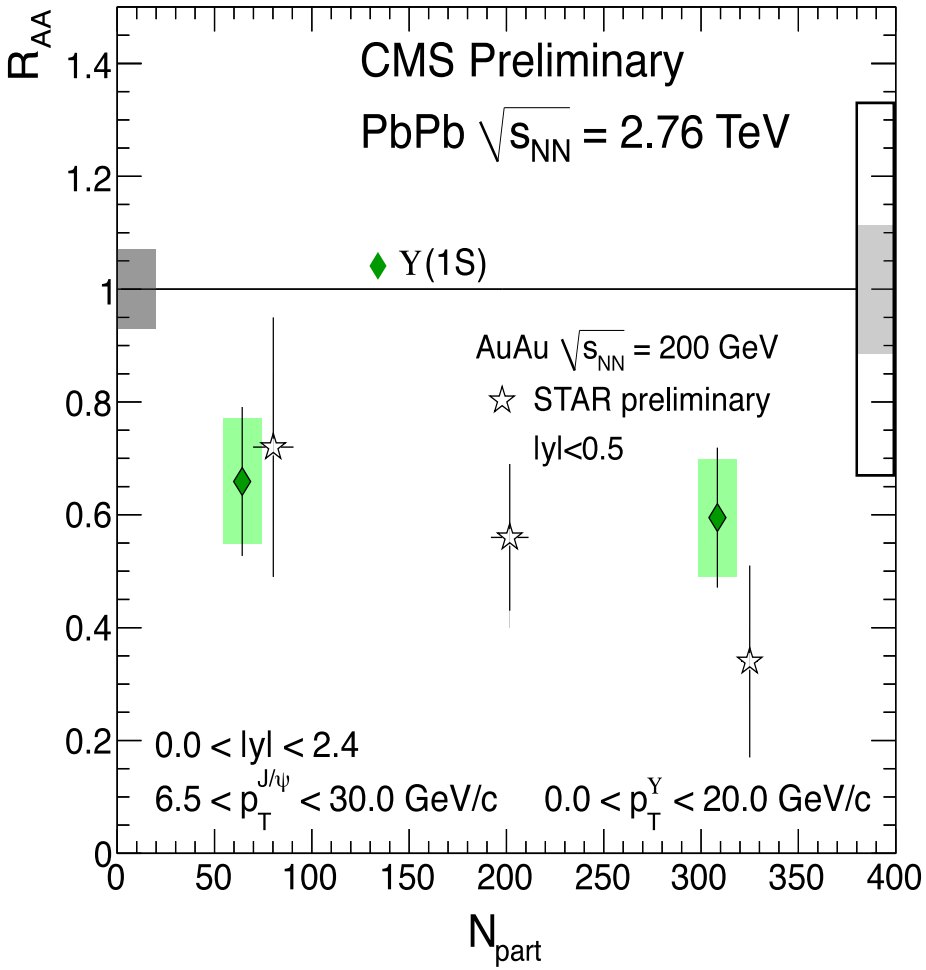




- Minimum bias R_{AA}= 0.62 ± 0.11(syst) ± 0.10(stat)
- Need more statistics to conclude if high p_T Υ are less suppressed

R_{AA} of Υ(1S) comparison to STAR

CMS C.Silvestre(QM2011)

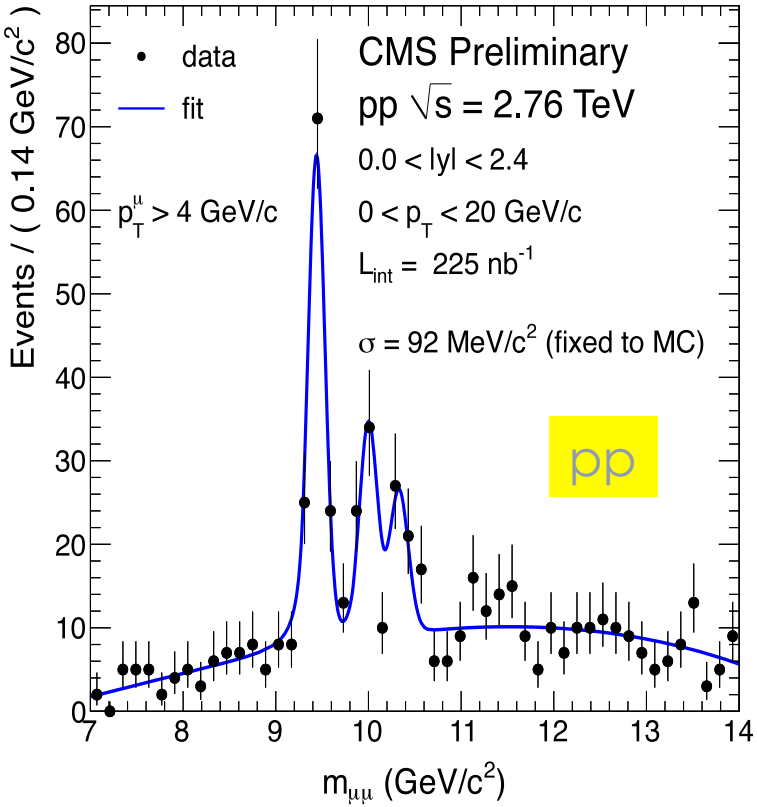


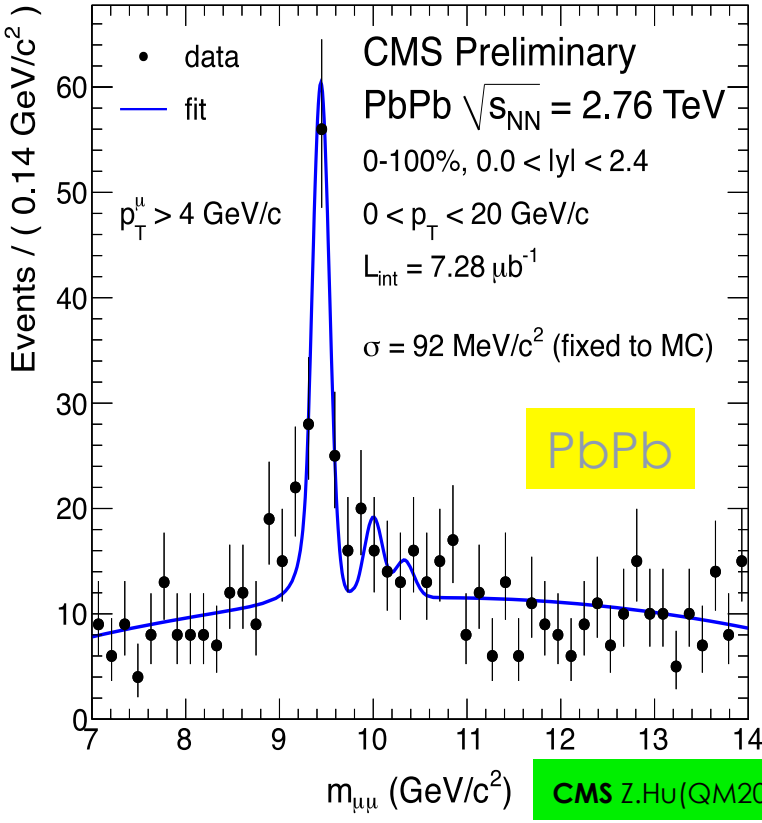
CMS : Υ(1S) R_{AA}(0-100) = 0.62 ± 0.11 ± 0.10

STAR : Υ(1S+2S+3S) R_{AA}(0-60) = 0.56 ± 0.11 $^{+0.02}_{-0.10}$ R. Reed (poster QM2011)

Υ (1S),(2S),(3S) in pp and PbPb @ 2.76TeV

- Compare Υ(2S+3S) production relative to Υ(1S) in pp and PbPb





$$\Upsilon(2S+3S)/\Upsilon(1S)\big|_{pp} = 0.78^{+0.16}_{-0.14} \pm 0.02$$

$$\Upsilon(2S+3S)/\Upsilon(1S)\big|_{PbPb} = 0.24^{+0.13}_{-0.12} \pm 0.02$$

Υ(2S+3S) Suppression

- A double ratio is performed in order to estimate the suppression

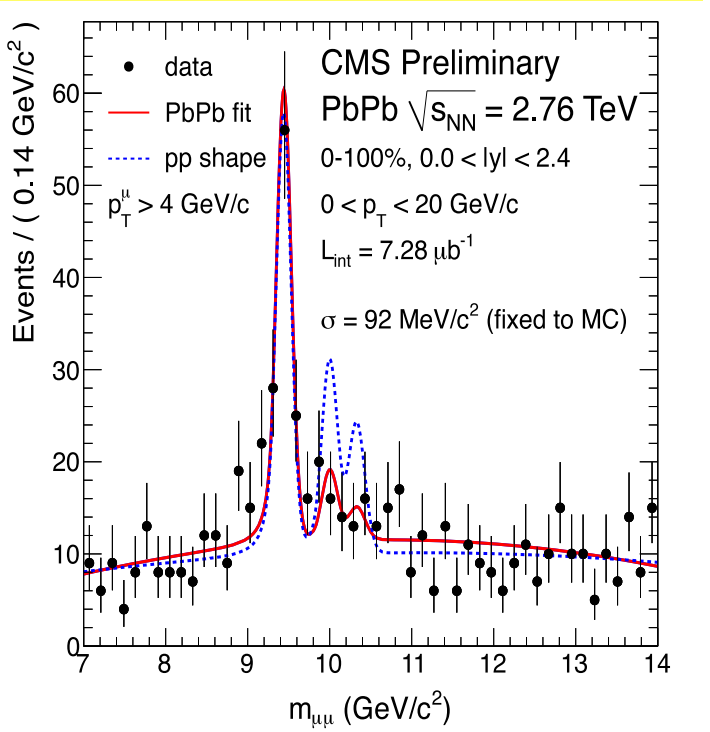
$$\frac{\Upsilon(2S+3S)/\Upsilon(1S)\big|_{PbPb}}{\Upsilon(2S+3S)/\Upsilon(1S)\big|_{pp}}$$

- Acceptance and efficiency cancel with a double ratio

- Potential differences remain in systematic 9%, from line shapes

$$\frac{\Upsilon(2S+3S)/\Upsilon(1S)\big|_{PbPb}}{\Upsilon(2S+3S)/\Upsilon(1S)\big|_{pp}} = 0.31^{+0.19}_{-0.15} \pm 0.03$$

Hypothesis: no suppression ⇒ p-value 1%
Significance of the suppression 2.4 σ



arXiv : 1105.4894 Sub. to PRL

Conclusion-1-

- There about a factor 2 suppression for jets from central to peripheral events in PbPb collisions
- The results with different cone size R=0.2 and R = 0.4 are quantitatively similar and there is no significant E_T dependence of the suppression
- The momentum difference in the dijet is balanced by low p_T particles at large angles relative to the away side jet axis
- Leading and subleading jet in PbPb fragment like jets of a corresponding energy in pp collisions and the fragmentation pattern independent of energy lost in the medium is consistent with parton fragmenting in vacuum
- No modification is observed in Z and isolated photon production and a large suppression is observed in PbPb charged particle spectra which is due to final state medium modification
- R_{AA} rises to about 0.R at high p_T in the most central events. Strong constrain on the parton energy loss models

Conclusion-2-

- Prompt J/ψ is significantly suppressed at LHC
- In CMS for $p_T^{J/\psi} > 3$ GeV/c and $|y| < 2.4$
  - In the 10% most central collisions $R_{AA} = 0.20 \pm 0.03(stat) \pm 0.01(syst)$
  - In the 50-100% peripheral collisions $R_{AA} = 0.59 \pm 0.12(stat) \pm 0.10(syst)$
- First non-prompt J/ψ in Heavy Ion
  - b-quark energy loss
  - Central 0-20% $R_{AA} = 0.36 \pm 0.08(stat) \pm 0.03(syst)$
- non-prompt J/ψ are less suppressed than prompt J/ψ

- $\Upsilon(2S)+\Upsilon(3S)$ excited states are suppressed (relative to $\Upsilon(1S)$) in PbPb colllisions at $\sqrt{s}$ =2.76TeV

ATLAS https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HeavyIonsPublicResults

CMS https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResults