Quarkonium measurements in Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV

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for the ALICE Collaboration

- Introduction
- J/ψ measurements
- A first look at ψ'

QWG9, Beijing, 22-26 april 2013

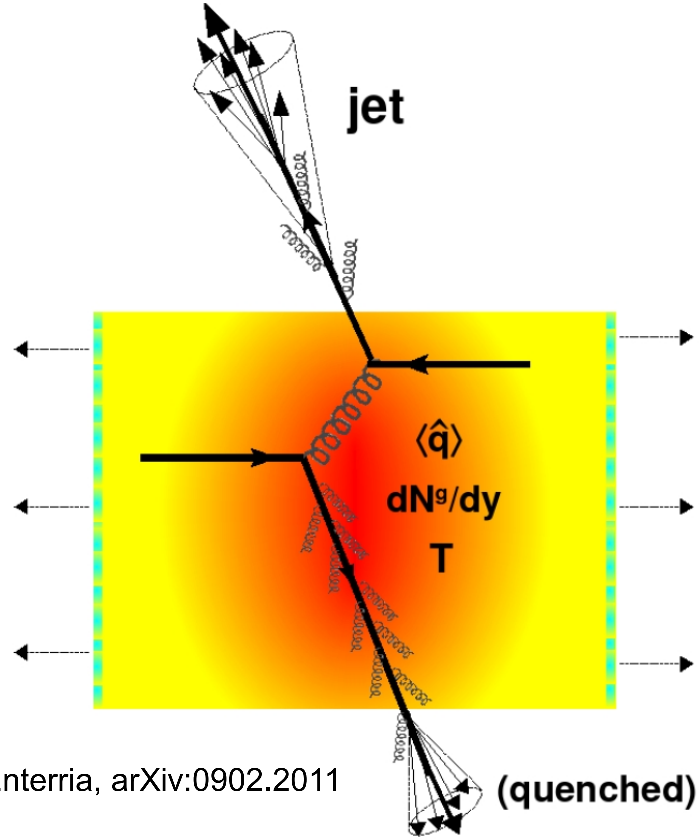
FIAS Frankfurt Institute for Advanced Studies

EMMI

Charmonia in medium

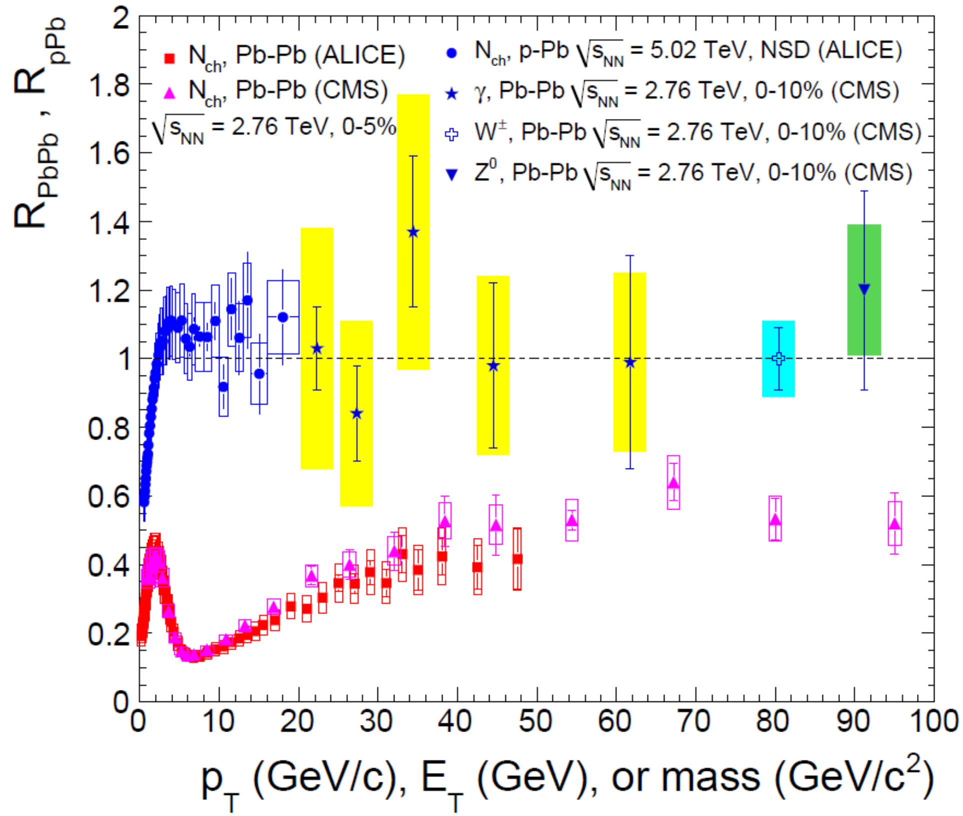
- Charm quark pairs are created early, during the initial hard scatterings
- How is the charmonia affected by the hot and dense medium?
  - Debye screening (T.Matsui, H.Satz 1986)
  - Production at the chemical freeze-out (P.Braun-Munzinger, J.Stachel, 2000)
  - In medium (re)combination (Thews et al.)
- Not so simple to answer, many effects need to be understood
  - Cold nuclear matter effects (nuclear absorbtion, formation time, shadowing)
  - Feed-down from higher charmonium states and beauty

Quantifying medium effects



D.d'Enterria, arXiv:0902.2011

$$R_{AA} = \frac{d^2N_{AA}/dp_T dy}{N_{coll} \times d^2N_{pp}/dp_T dy}$$

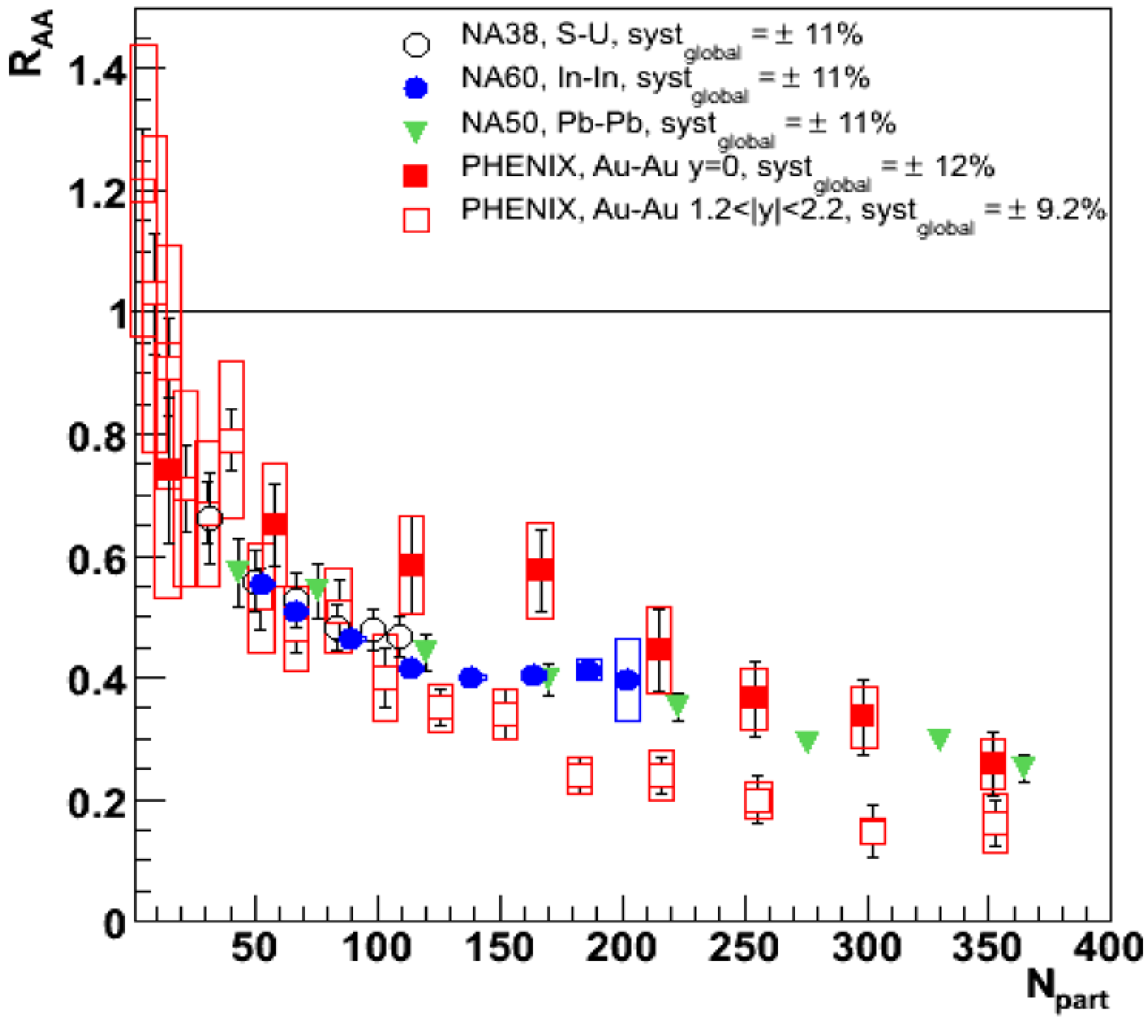


p-Pb, ALICE PRL110(2013)082302
Pb-Pb, ALICE, Phys.Lett.B720 (2013)52
Pb-Pb, CMS, EPJC (2012) 72

γ, CMS, PLB 710 (2012) 256
$W^{\pm}$, CMS, PLB715 (2012) 66
Z^0, CMS, PRL106 (2011) 212301

- Strong hadron suppression seen in Pb-Pb collisions at the LHC even above 50 GeV

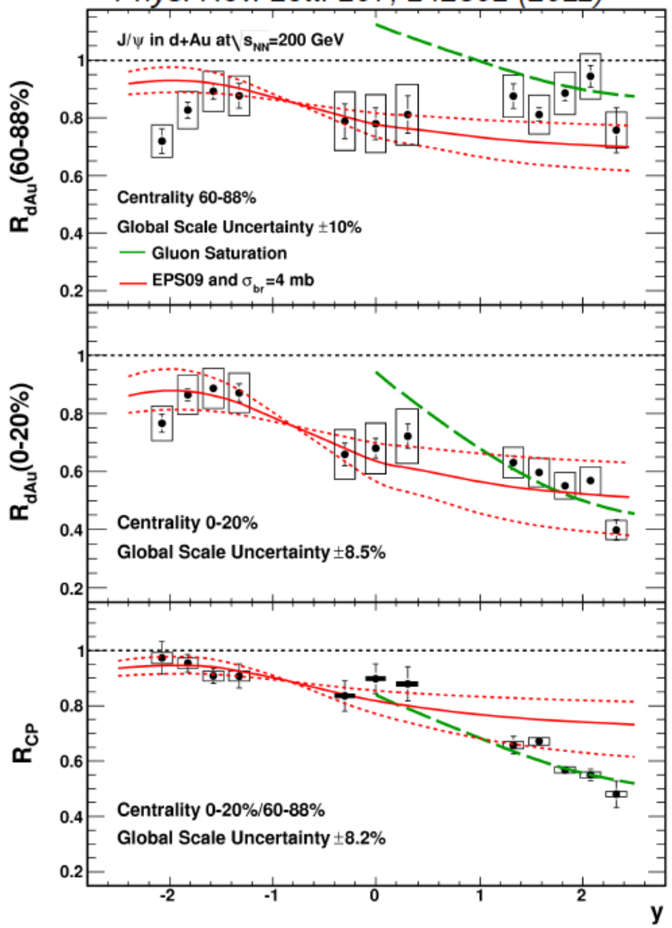
J/ψ measurements at lower energies

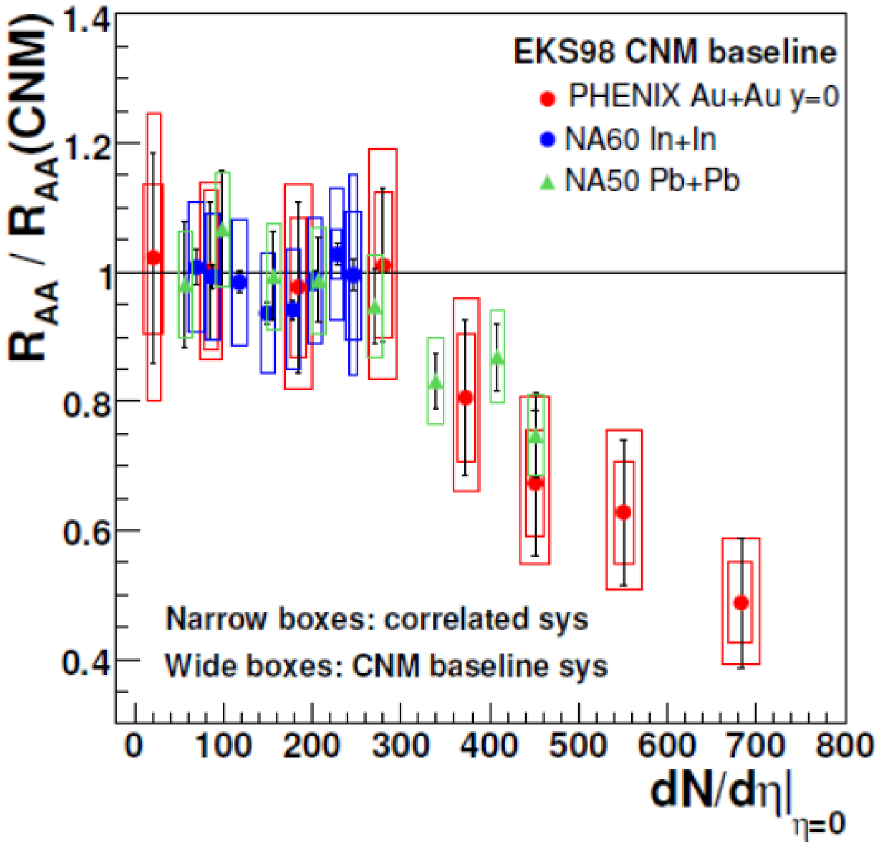


- Strong J/ψ suppression seen at RHIC and at SPS energies
- Competing effects having different dependence on collision energy

Cold nuclear matter (CNM) effects

Phys. Rev. Lett. 107, 142301 (2011)

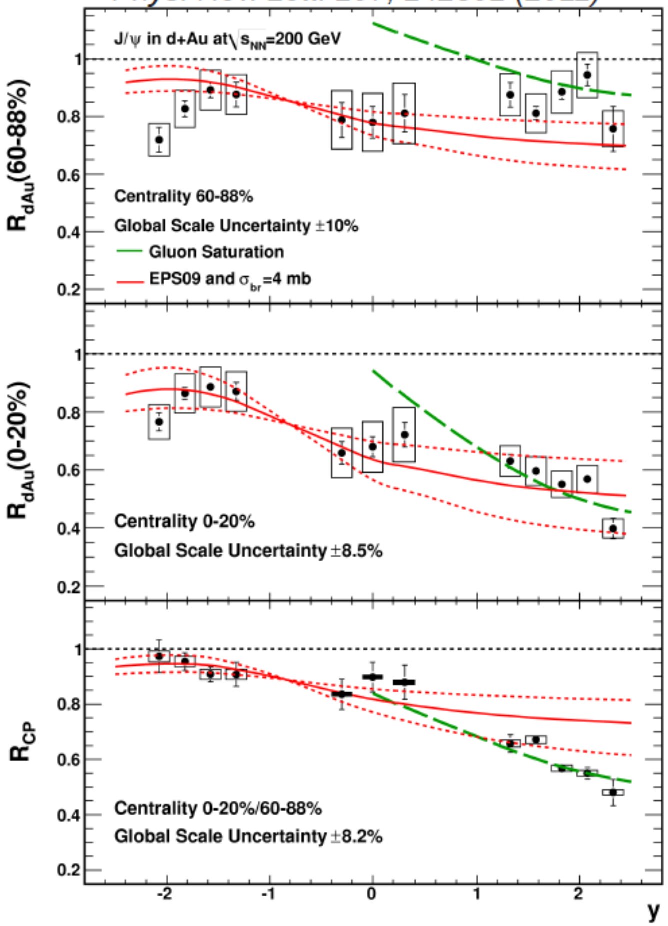




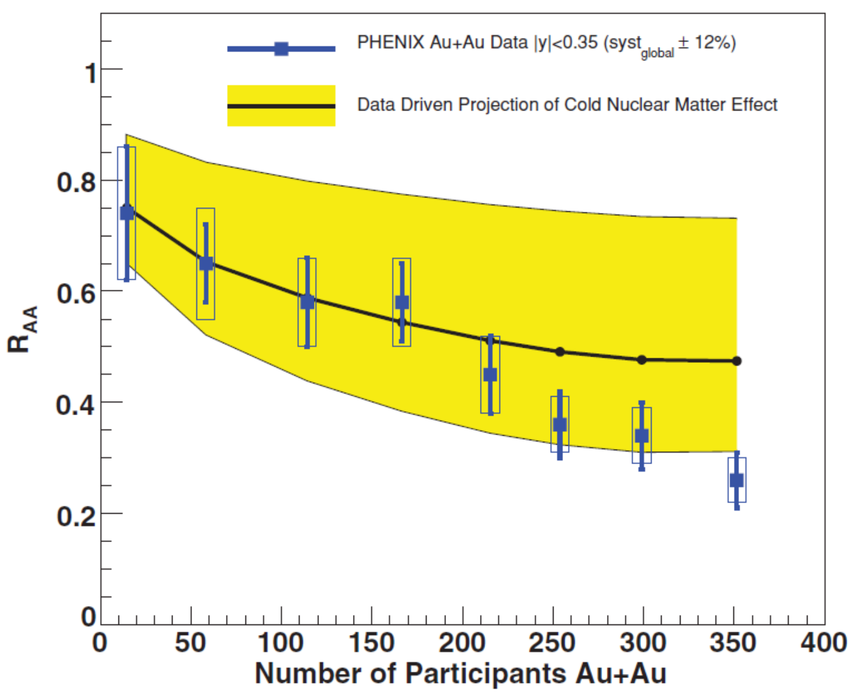
- CNM effects strong at RHIC energies → need to be disentangled in order to understand final state effects

Cold nuclear matter (CNM) effects

Phys. Rev. Lett. 107, 142301 (2011)

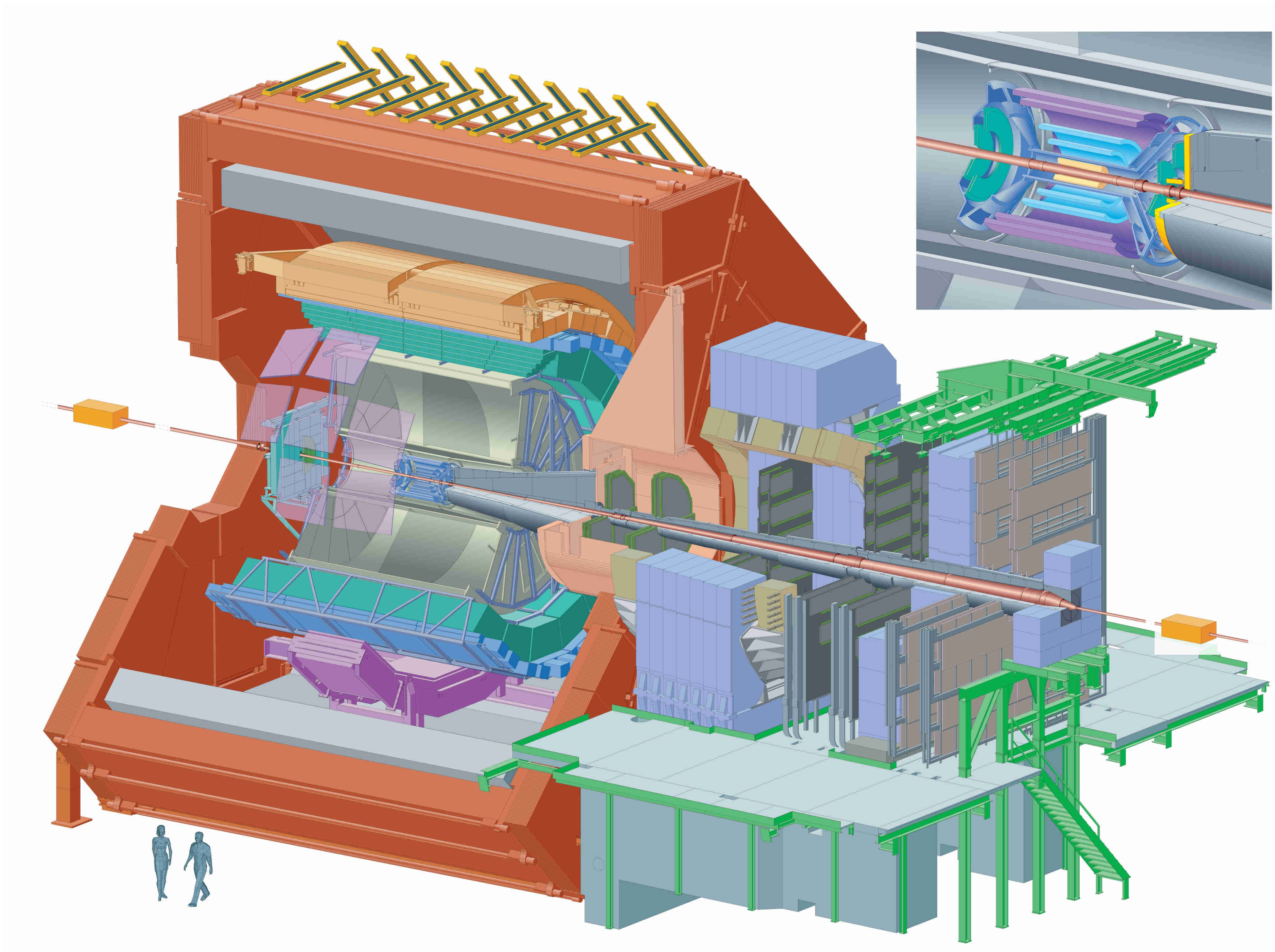


PHENIX, Phys. Rev. C77 (2008), 024912

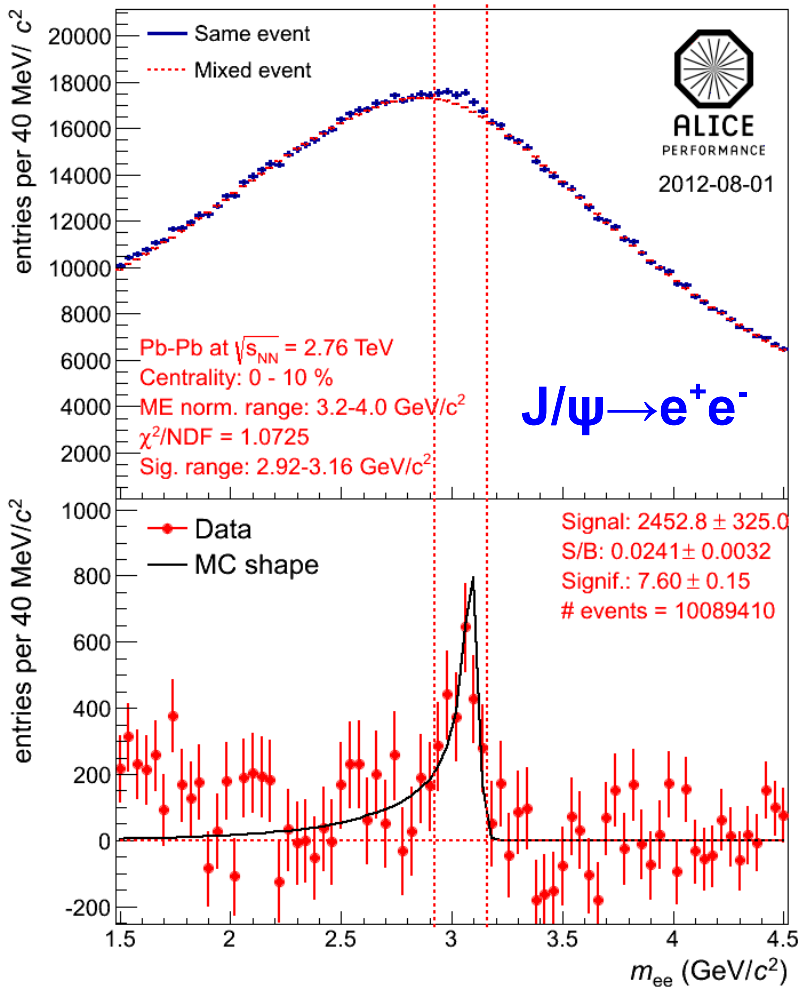


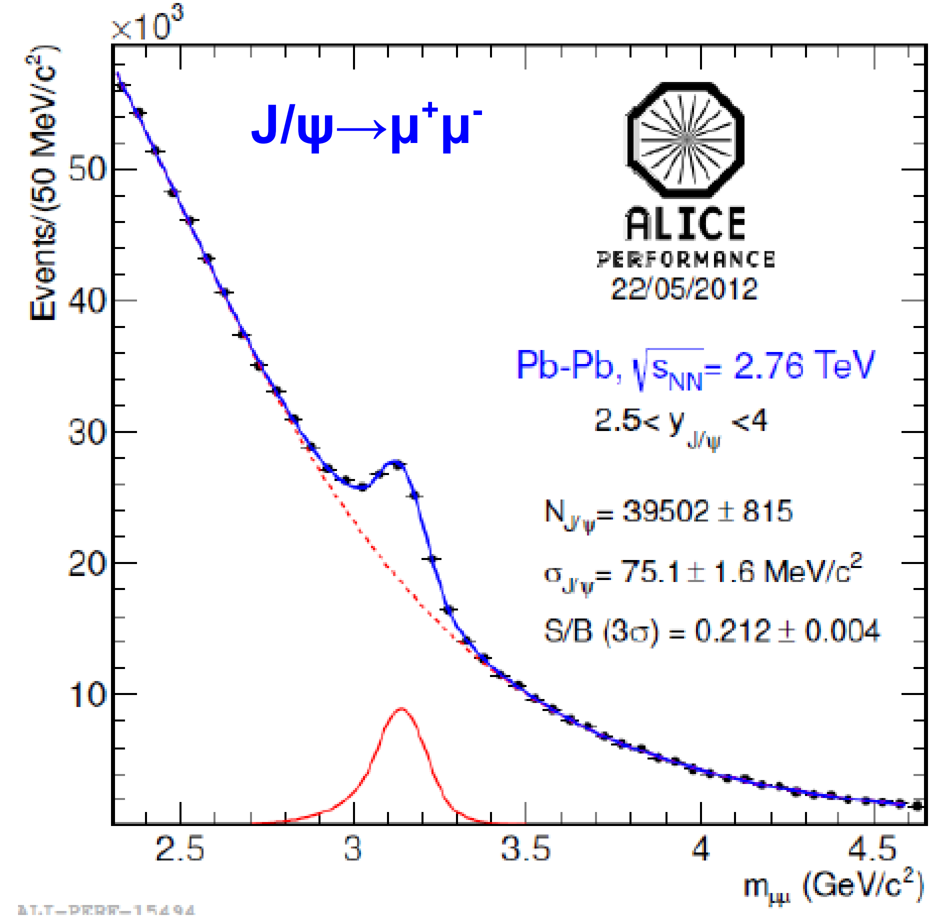
- Some interpretations suggest supression at mid-rapidity could be explained by CNM alone
- CNM effects are also studied at LHC and results will be available soon

The ALICE setup



The J/ψ in ALICE





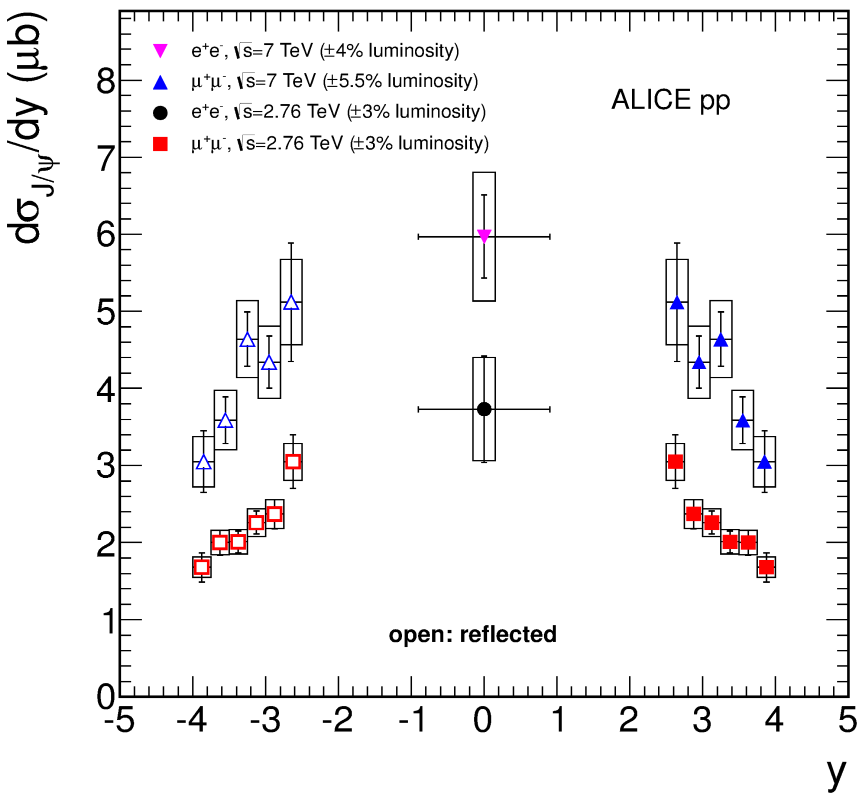
Phase space coverage

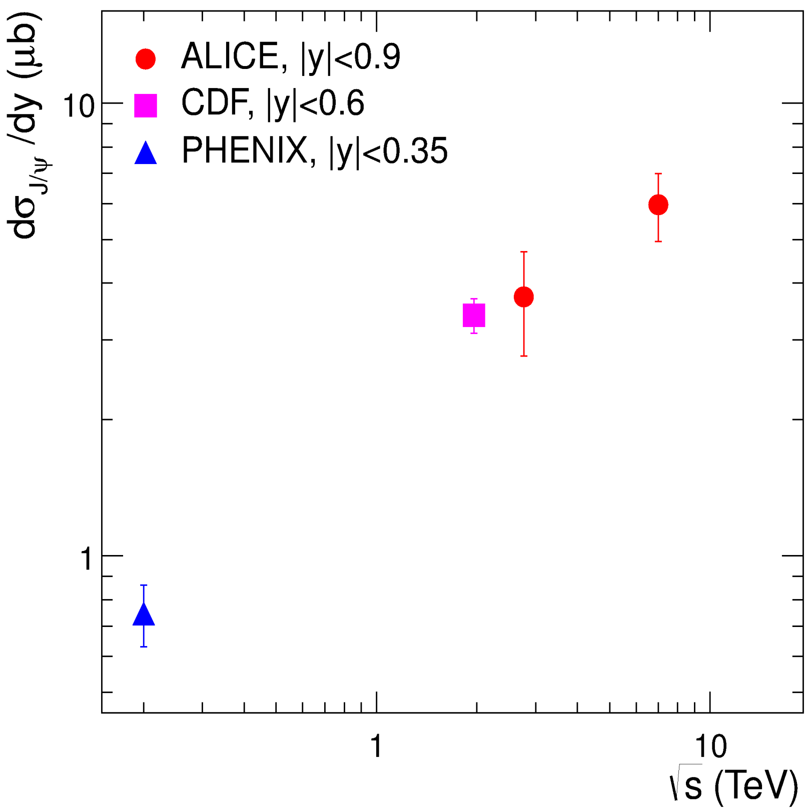
- $|y|<0.9$ (J/ψ→e^+e^-)
- $2.5<y<4$ (J/ψ→$\mu^+\mu^-$)
- $p_T>0$ GeV/c

The pp reference

L.Bianchi, Monday

ALICE Collaboration, arXiv:1203.3641

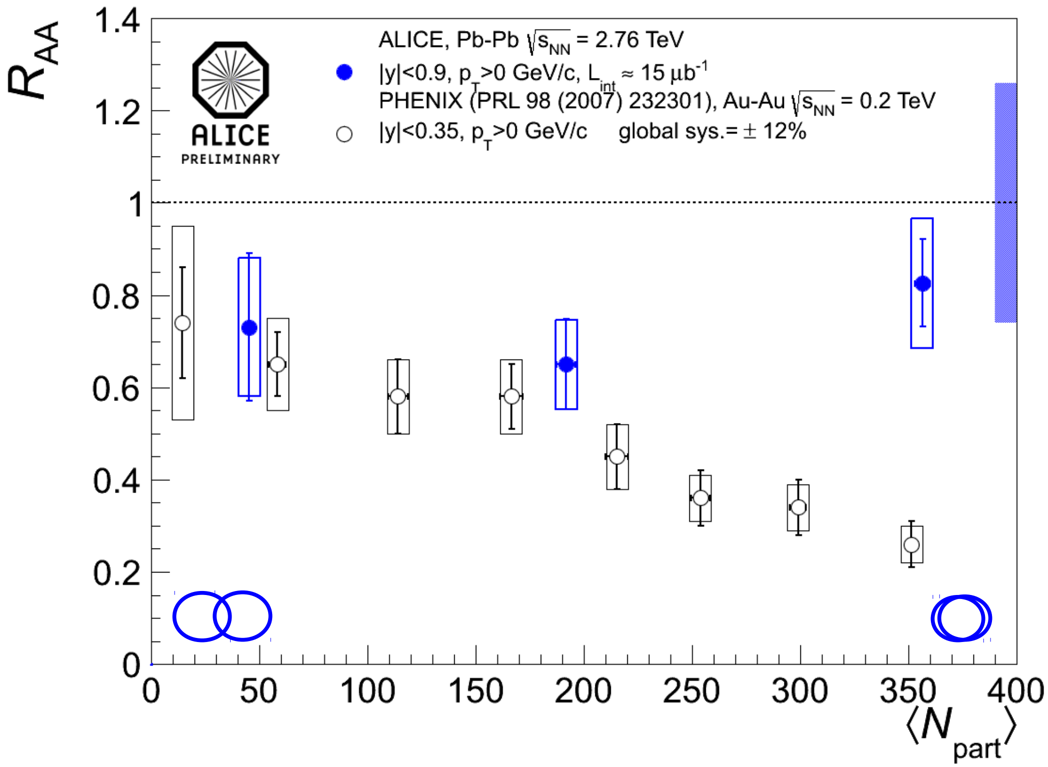


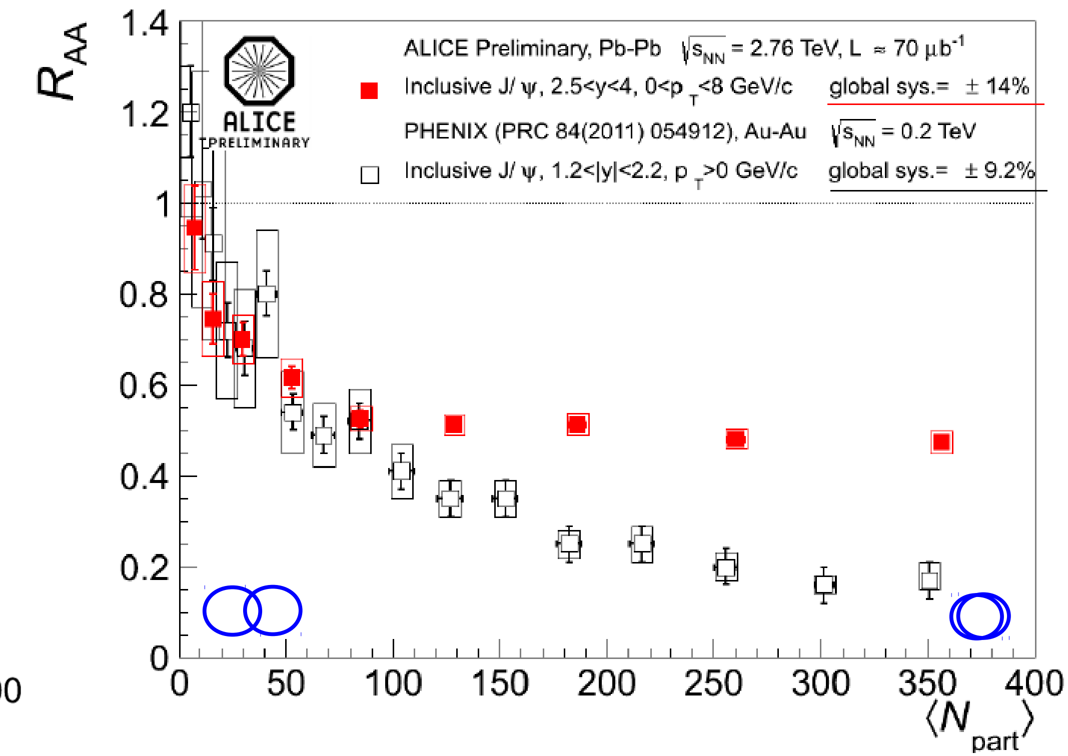


$$\sigma_{J/\psi}(|y|<0.9) = 6.71 \pm 1.24\,(stat.) \pm 1.22\,(syst.)\,\mu b$$

$$\sigma_{J/\psi}(2.5<y<4.0) = 3.34 \pm 0.13\,(stat.) \pm 0.27\,(syst.)\,\mu b$$

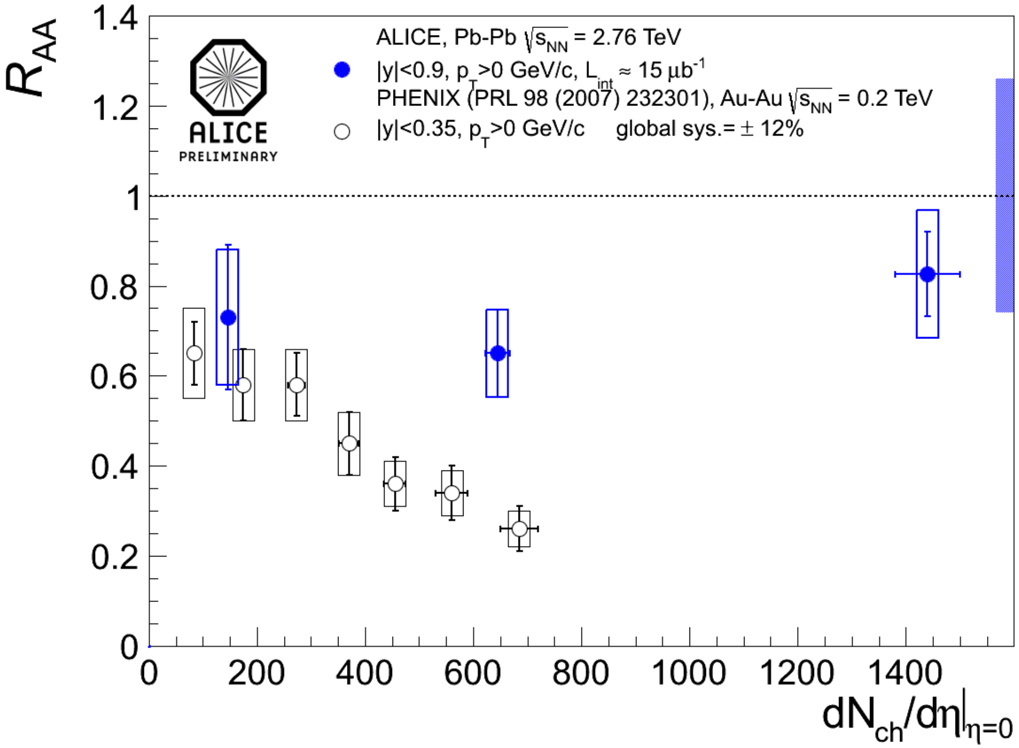
Inclusive J/ψ R_{AA} vs. centrality

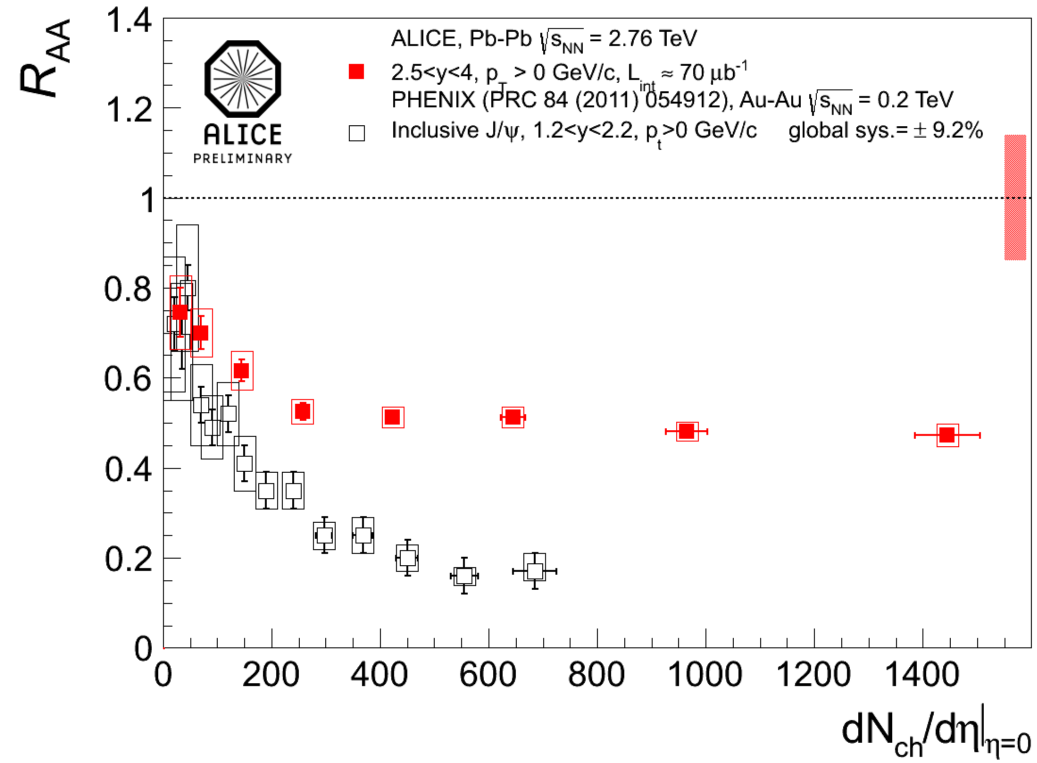




- Higher R_{AA} seen in central collisions by ALICE at both mid- and forward rapidity

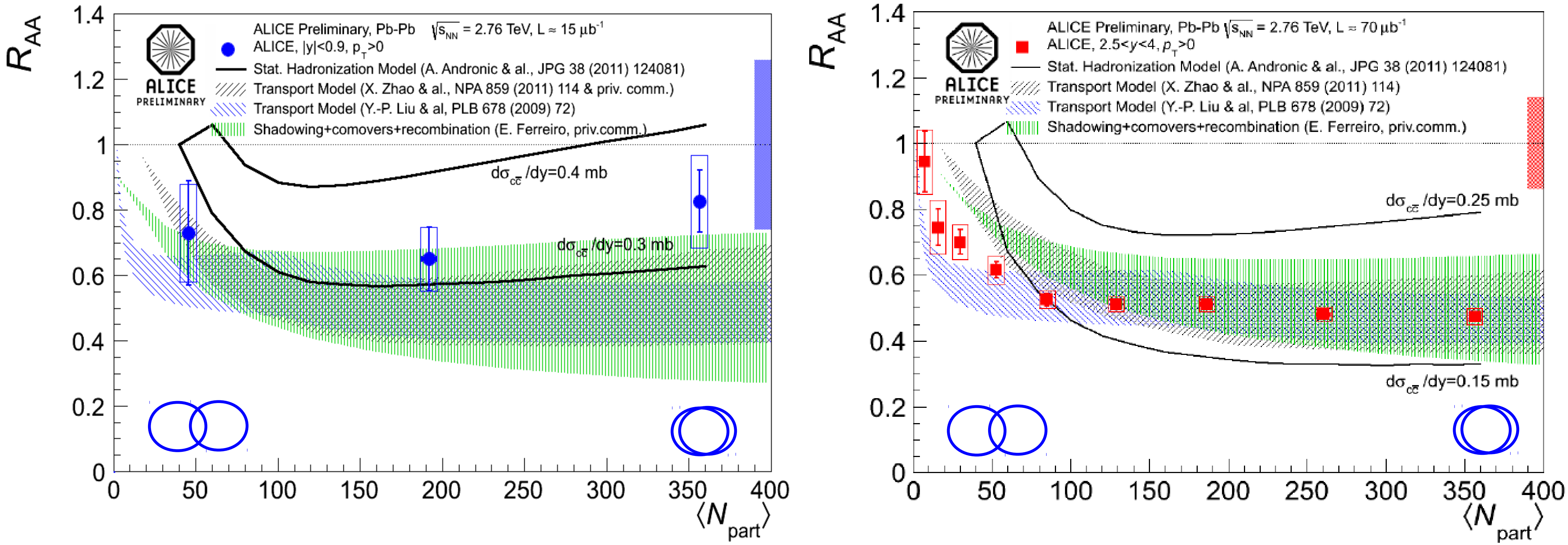
Inclusive J/ψ R_{AA} vs. particle density





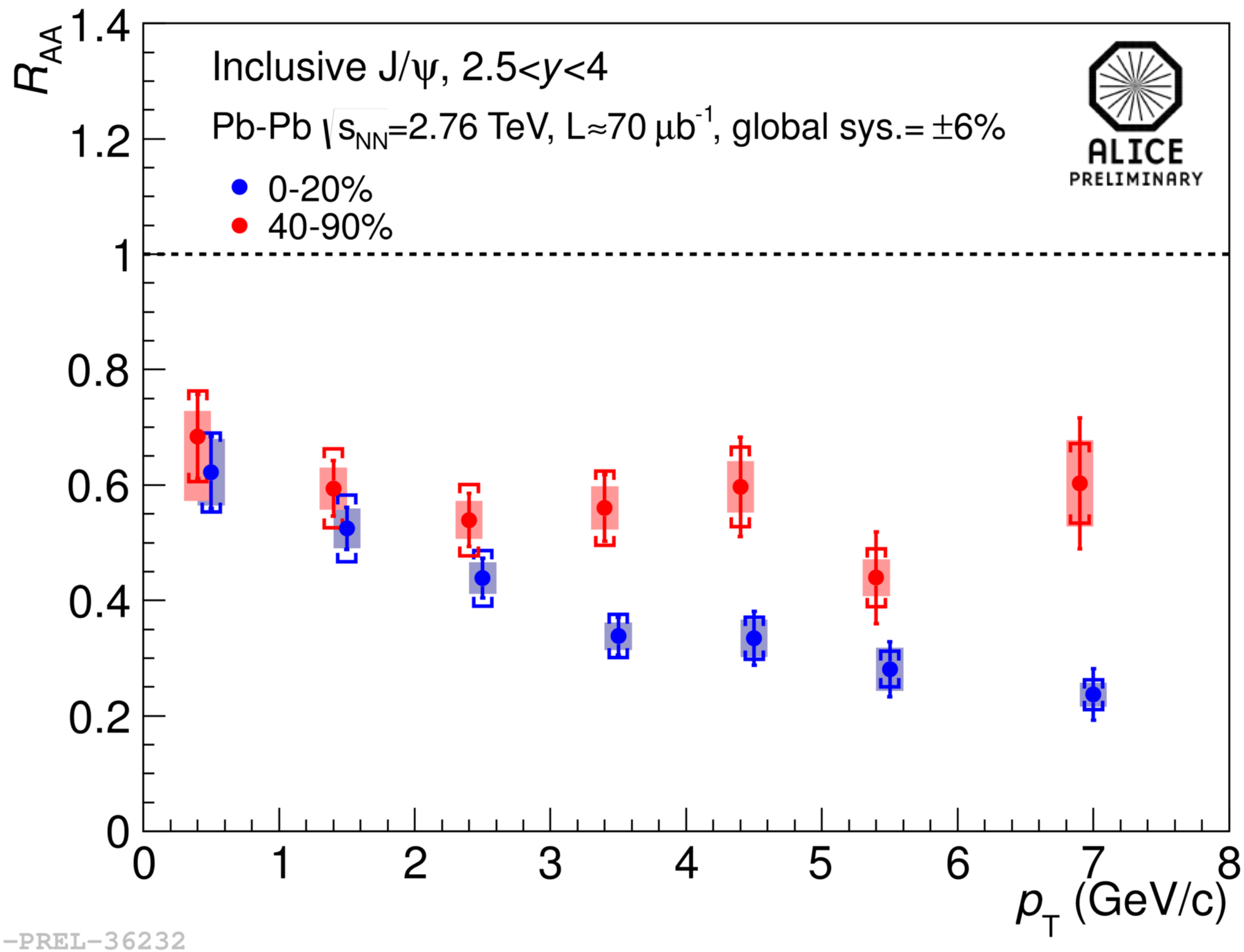
- R_{AA} at the same charged particle density grows with the collision energy

J/ψ suppression in models



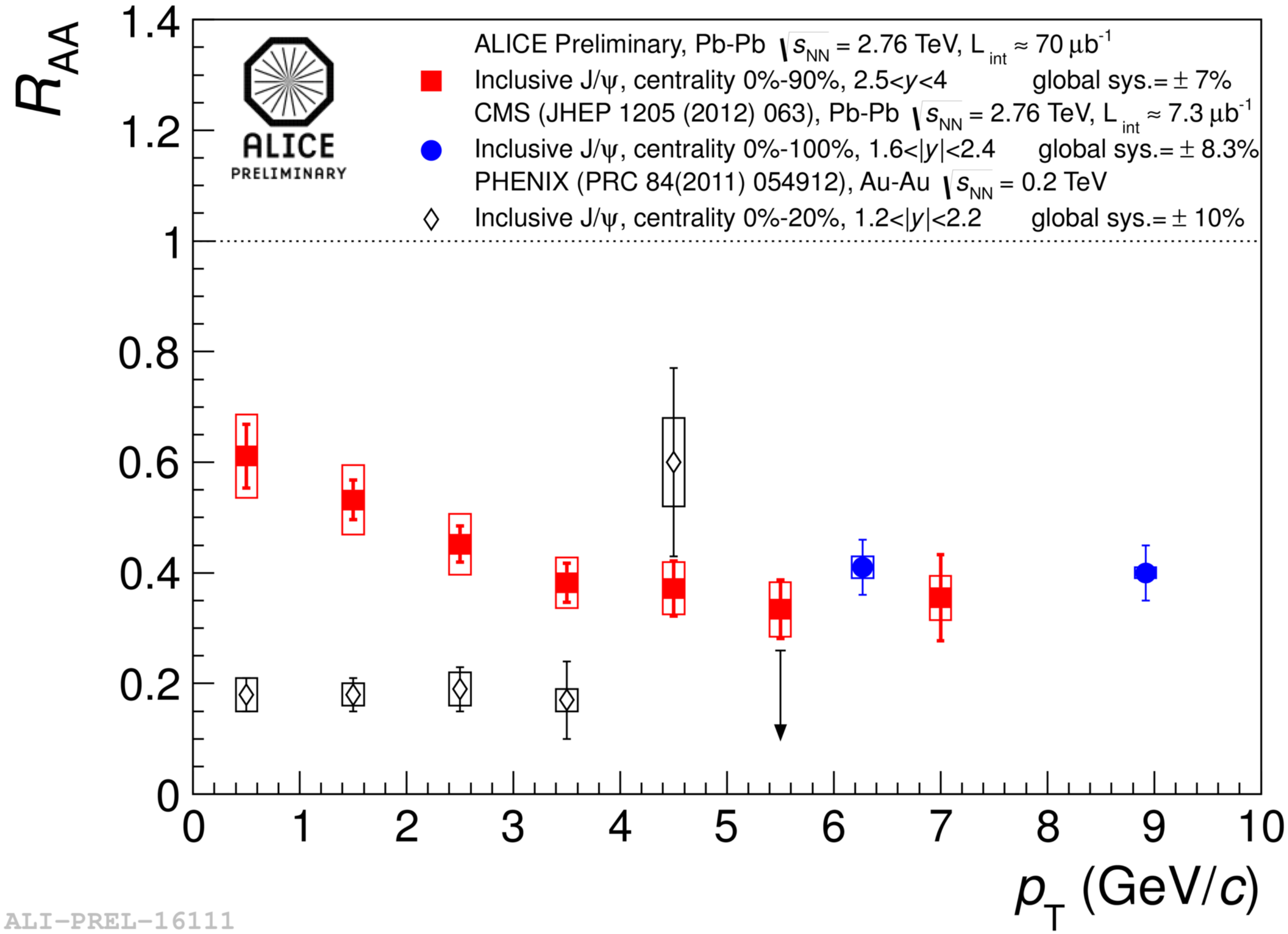
- Models which consider the (re)combination of charm pairs from the QGP are in qualitative agreement with the data
- Theoretical calculations limited by the unknown integrated cc-bar cross-section

Inclusive J/ψ R_{AA} vs. p_T



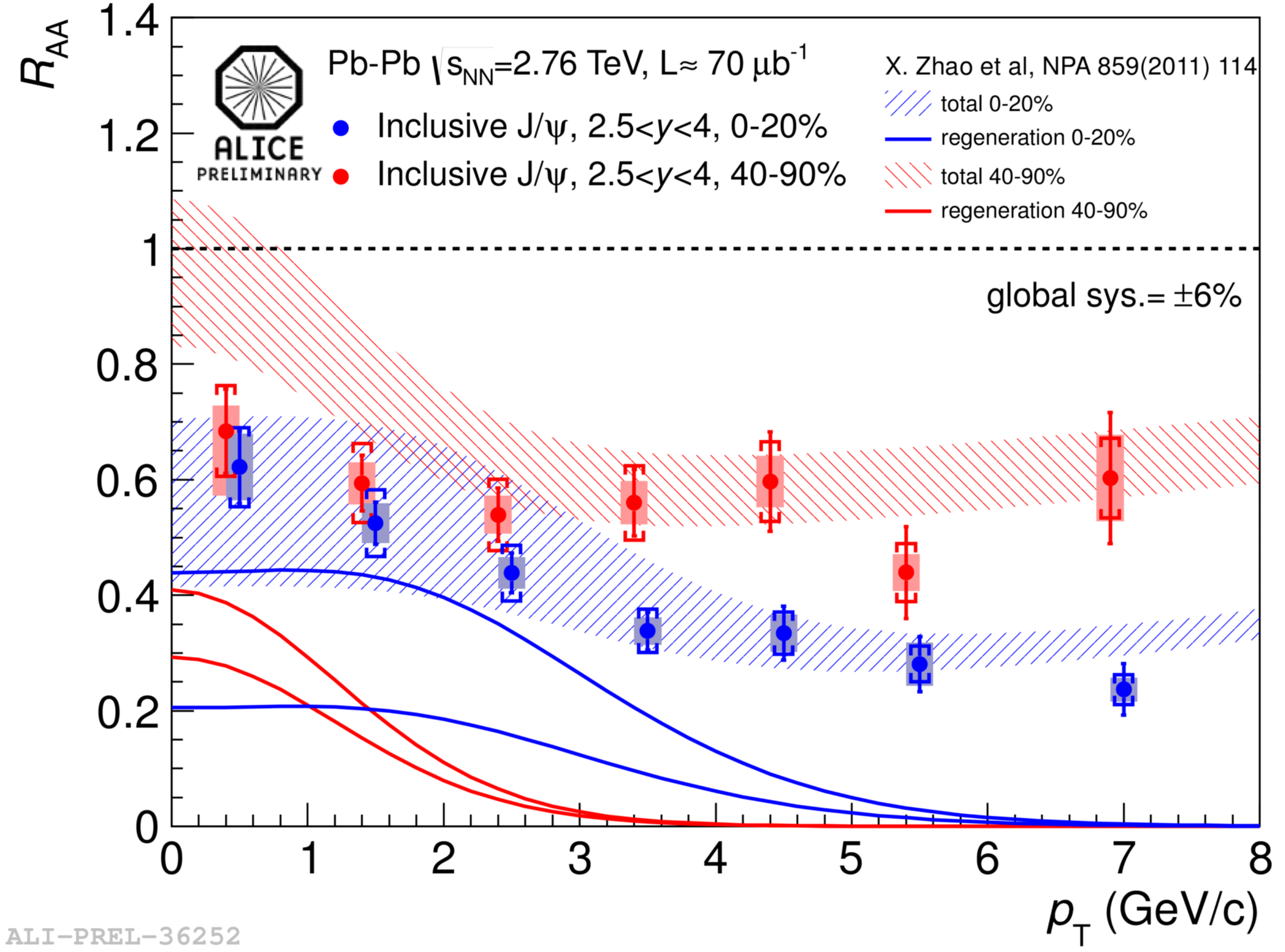
- Less suppression seen at low p_T compared to high p_T in central collisions

Inclusive J/ψ R_{AA} vs. p_T



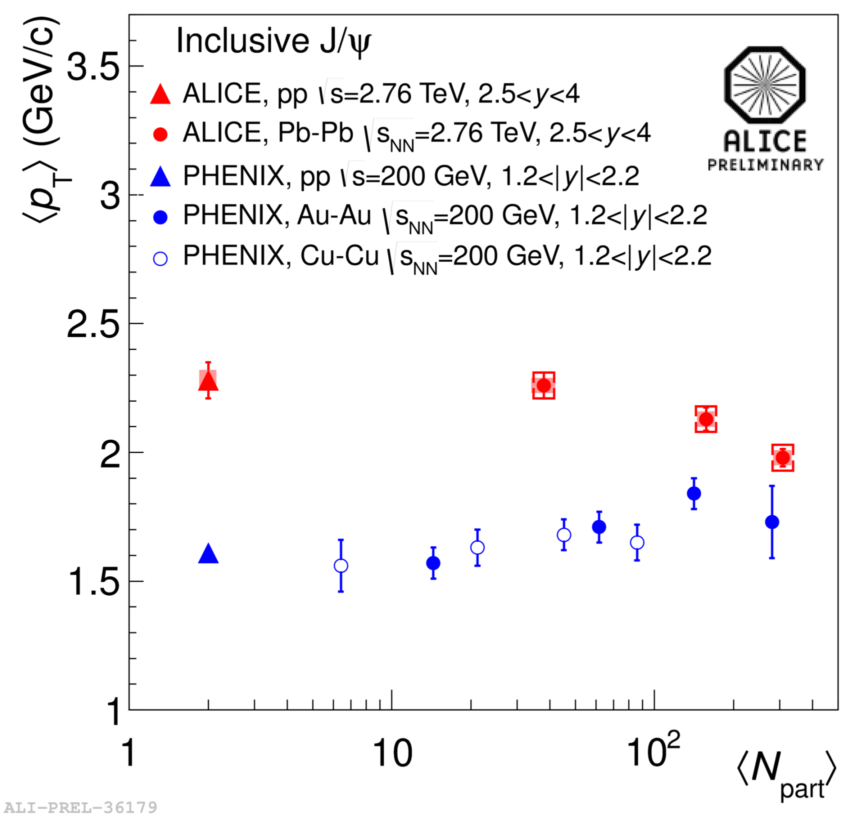
- Low p_T R_{AA} is 3 times higher at LHC than at RHIC

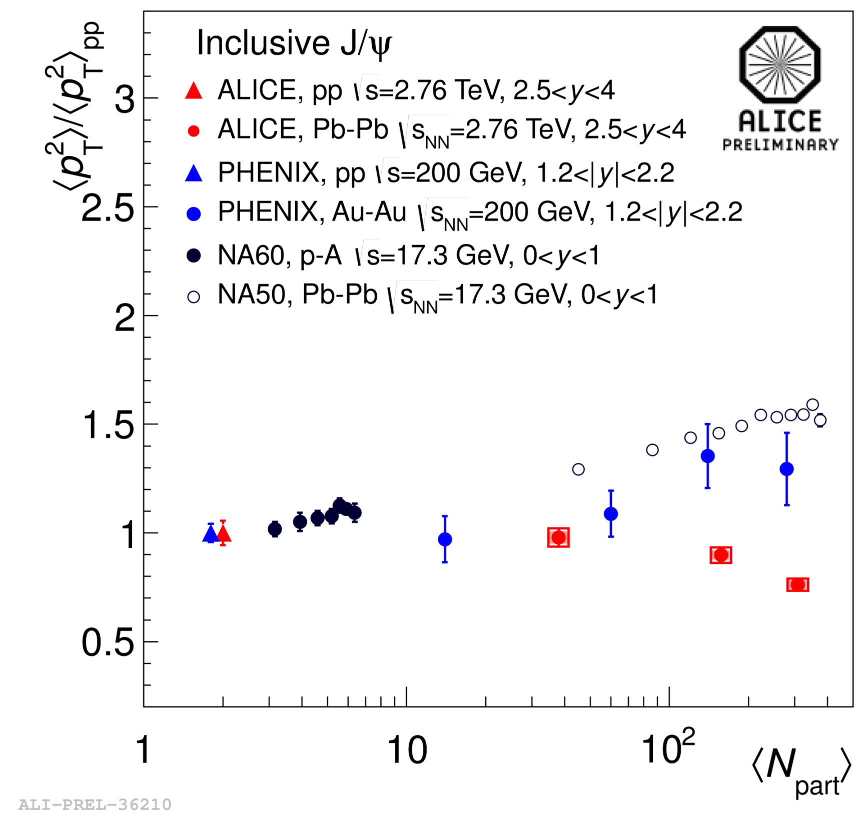
Inclusive J/ψ R_{AA} vs. p_T



- Calculations from *Zhao et al.* in agreement with data in central collisions but overestimate the yield at low p_T in peripheral collisions.

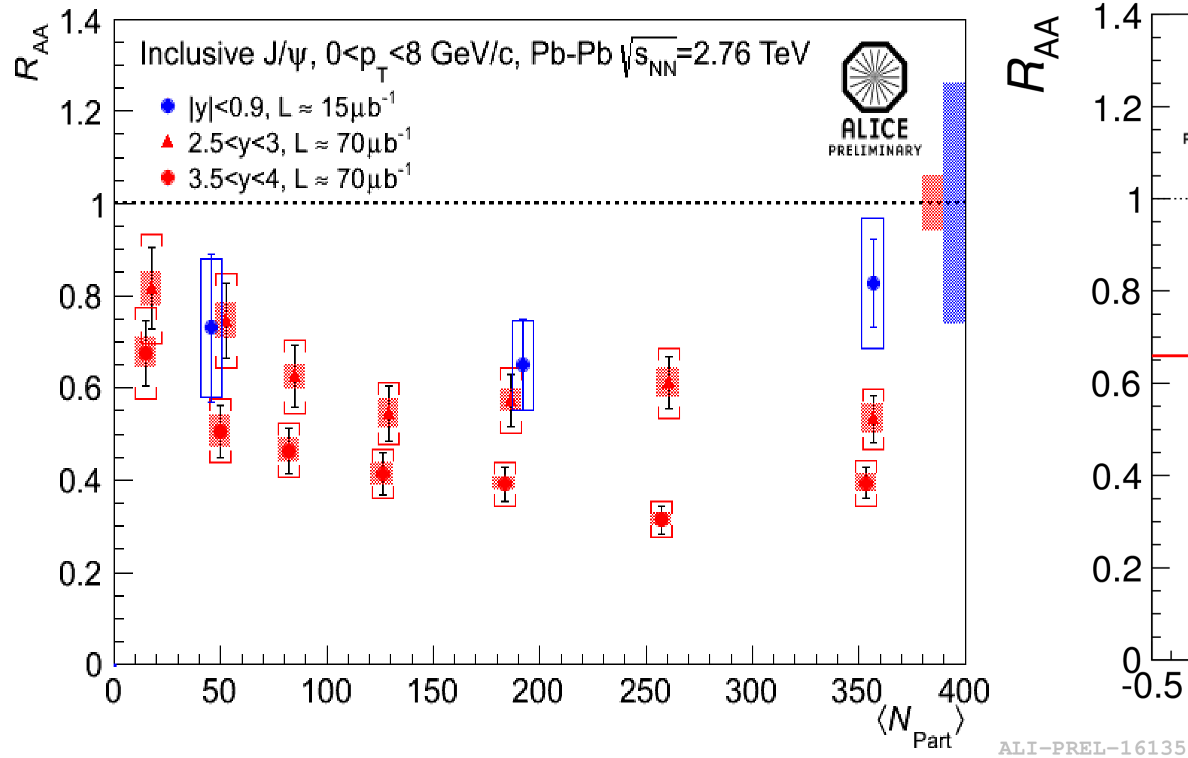
J/ψ p_T distributions

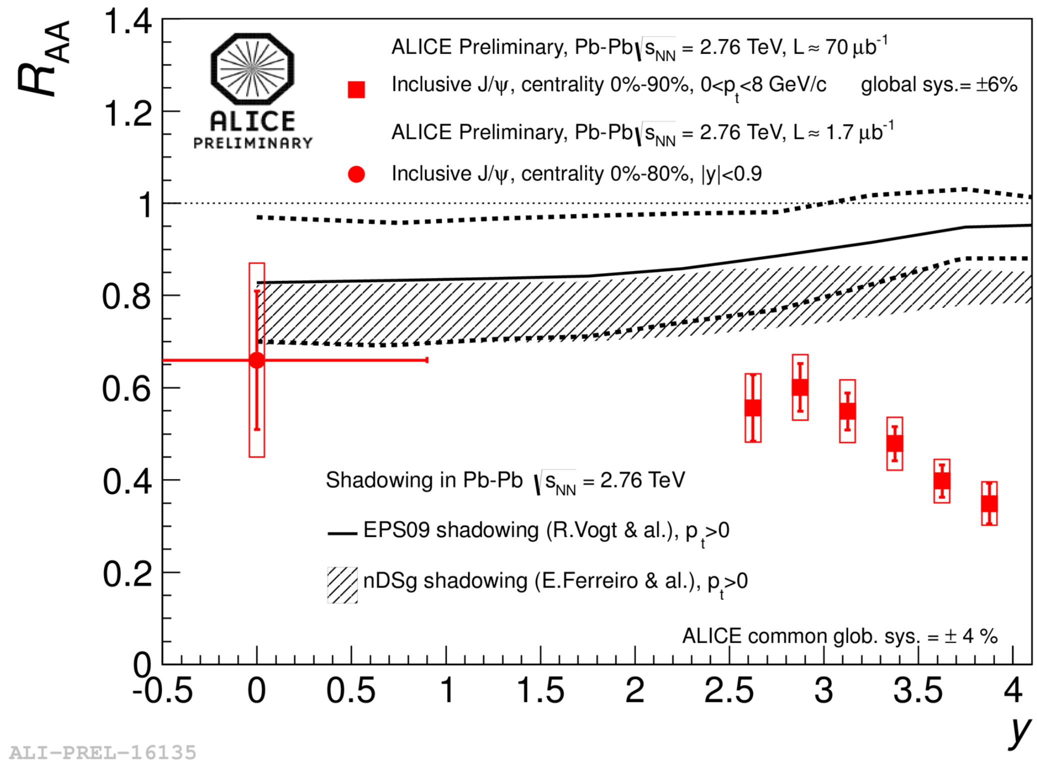




- The J/ψ p_T spectrum in Pb-Pb at LHC is softer than in pp at all centralities.
- An opposite behaviour is observed at lower energies

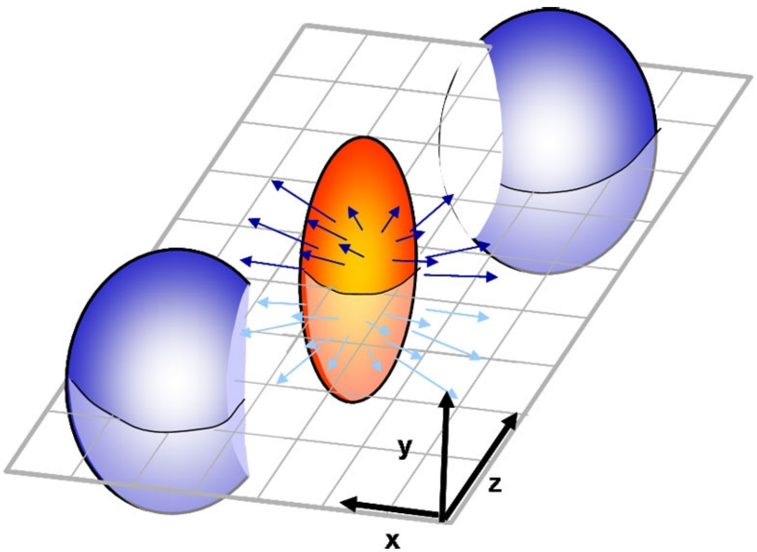
Inclusive J/ψ R_{AA} vs. rapidity



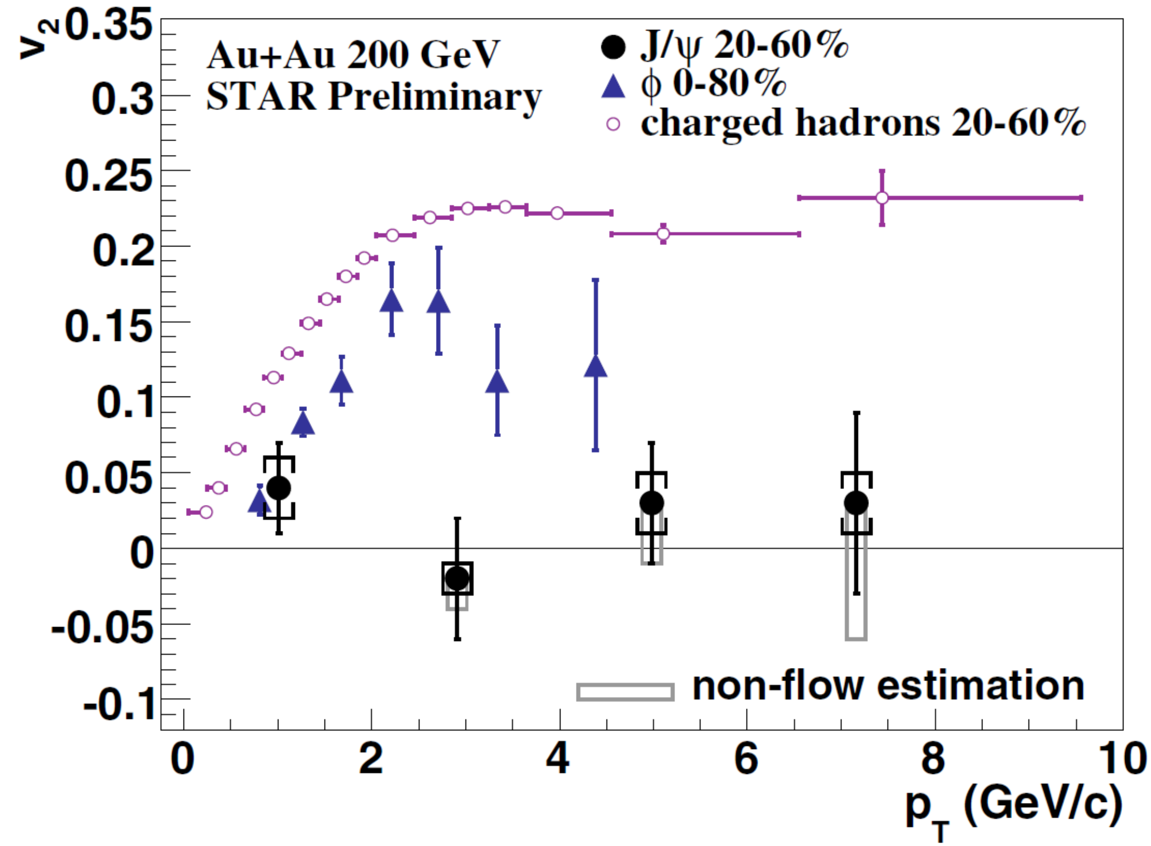


- Suppression becomes stronger with increasing rapidity
- This dependence seems not to be explained by shadowing calculations

Elliptic flow

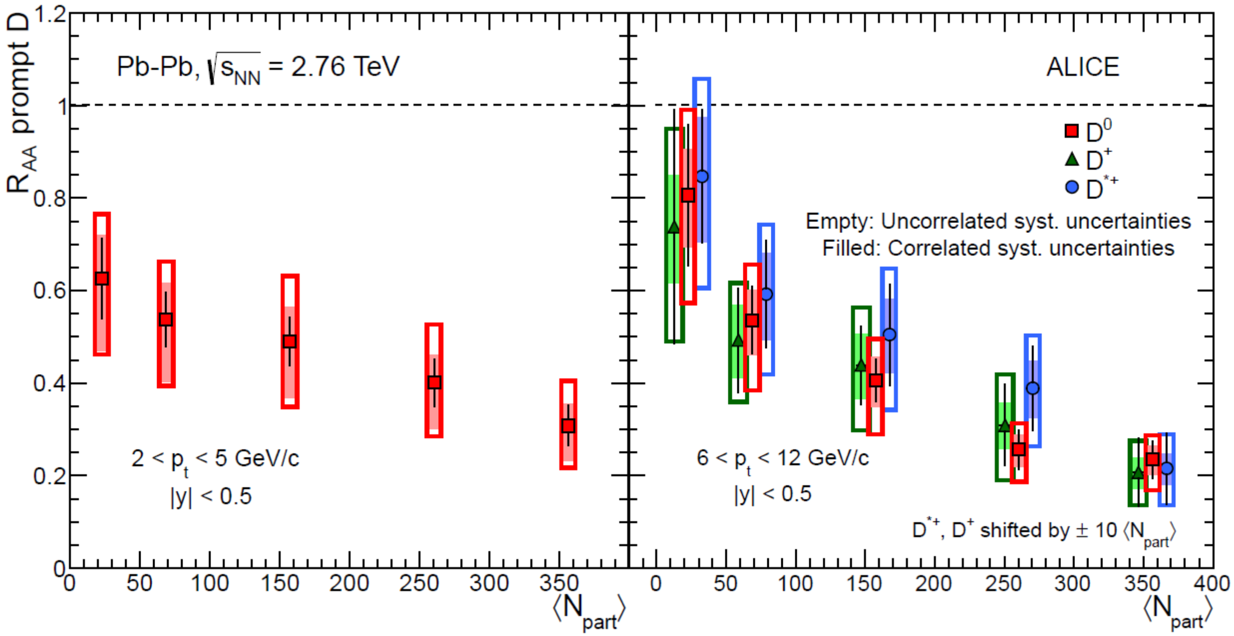


J.Phys.G38 124107 (STAR Collaboration)

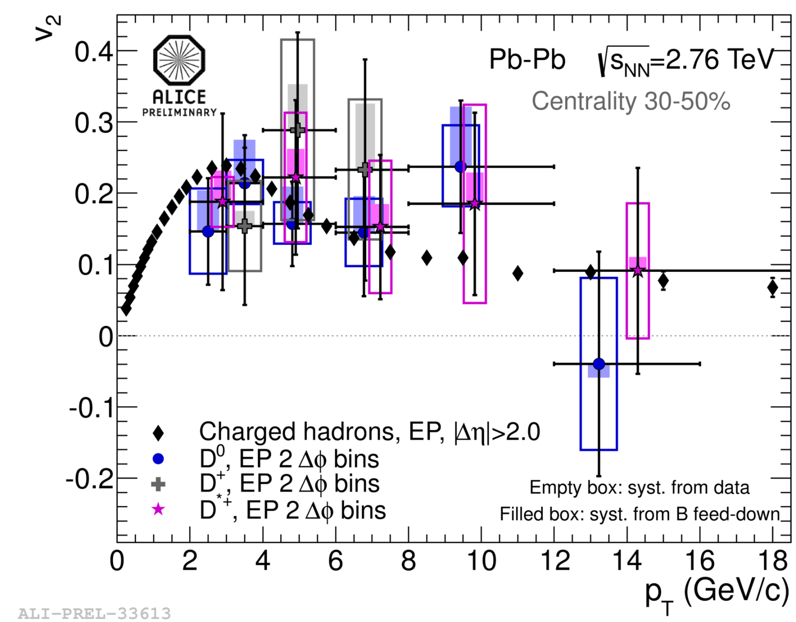


- Flow measurements at RHIC are compatible with zero
- J/ψ expected to inherit some elliptic flow from the medium via the (re)combination mechanism ?

Open heavy flavour at LHC

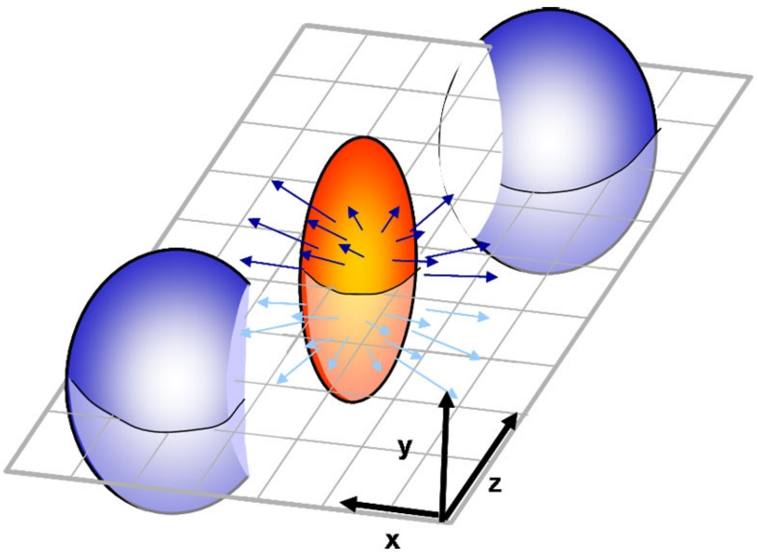


JHEP 1209 (2012) 112 (ALICE Collaboration)

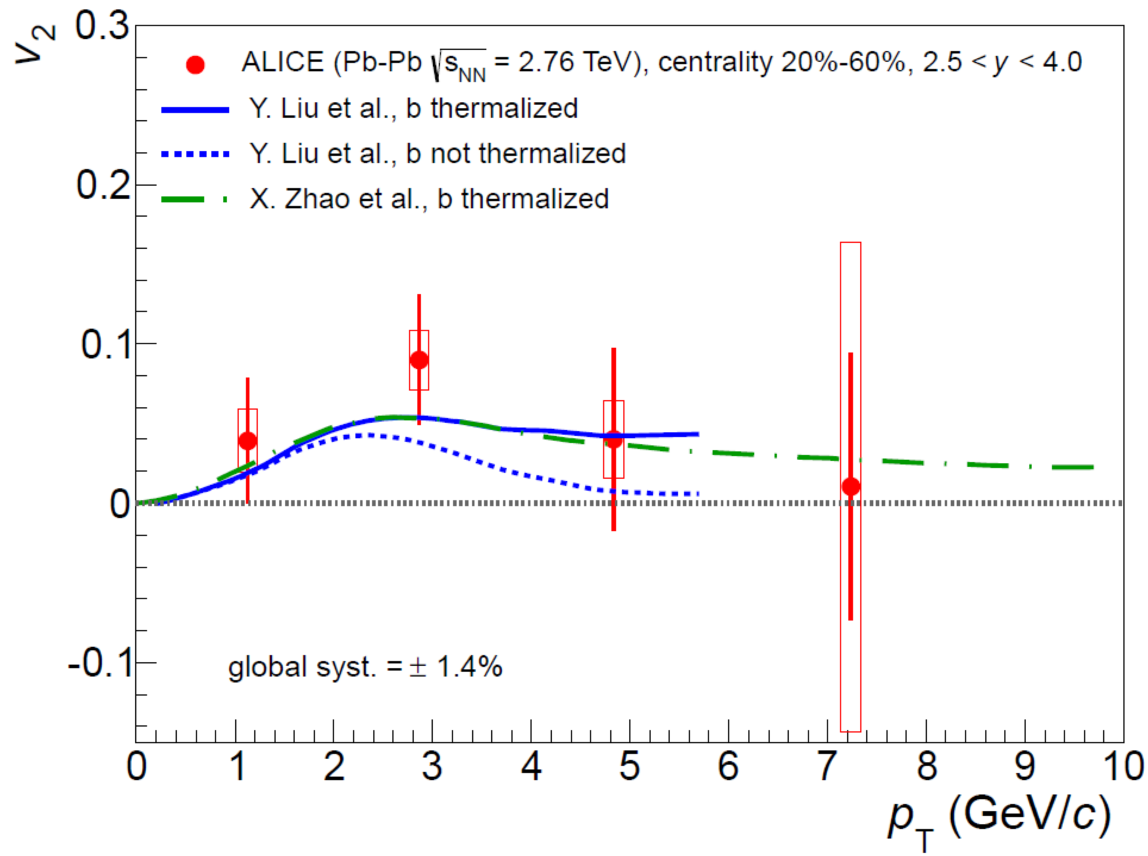


- Open charm shows high suppression towards central collisions
- Strong flow measured, as for the charged hadrons
- Charm quarks are thermalized

Elliptic flow of J/ψ at LHC



arXiv:1303.5880 (ALICE Collaboration)

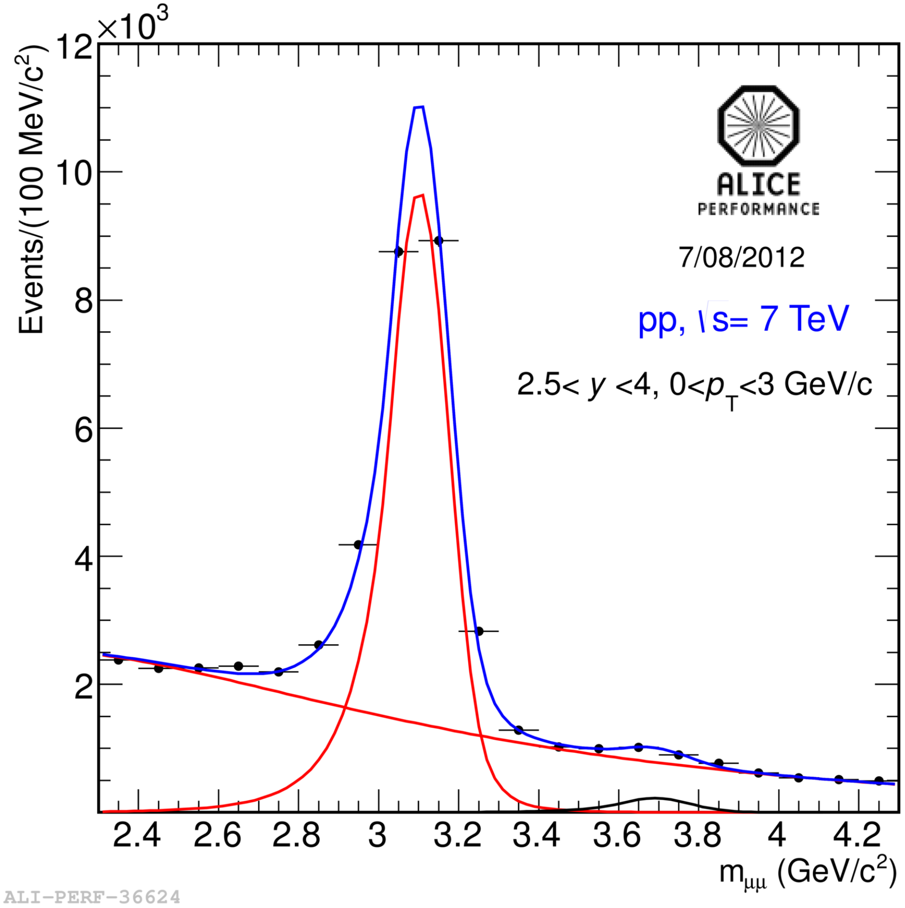


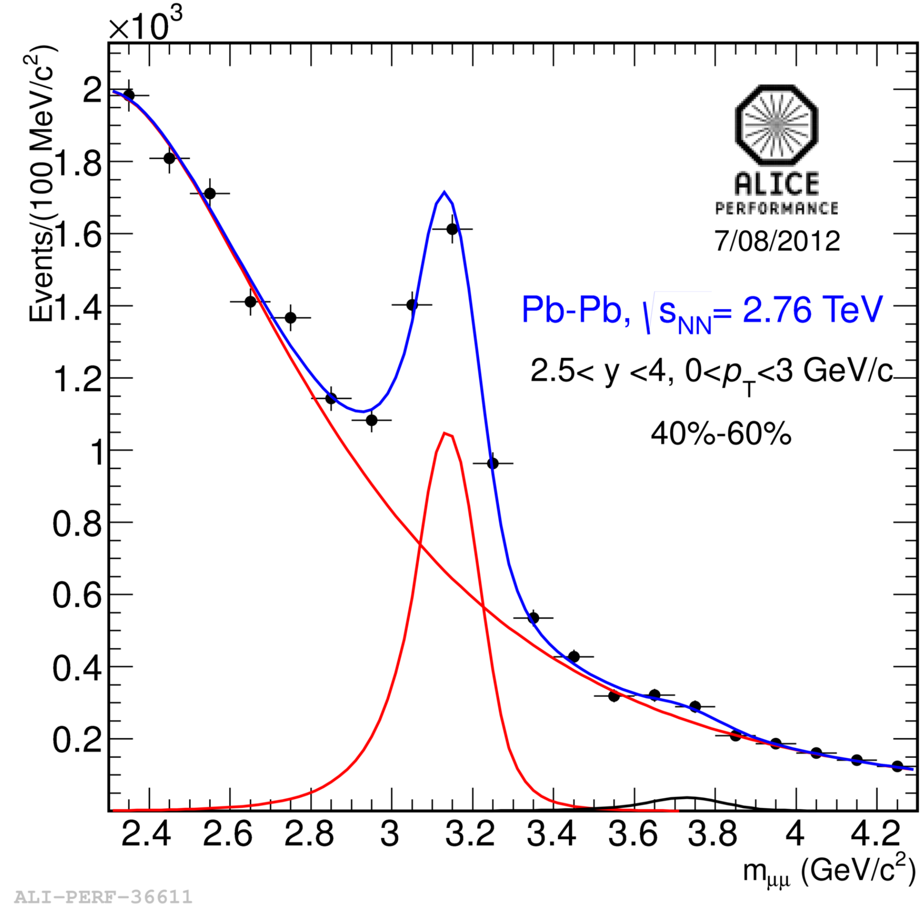
- Hint of non-zero v_2 in the intermediate p_T region seen in ALICE?
- Transport models with (re)combination in agreement with data.

So what do we observe?

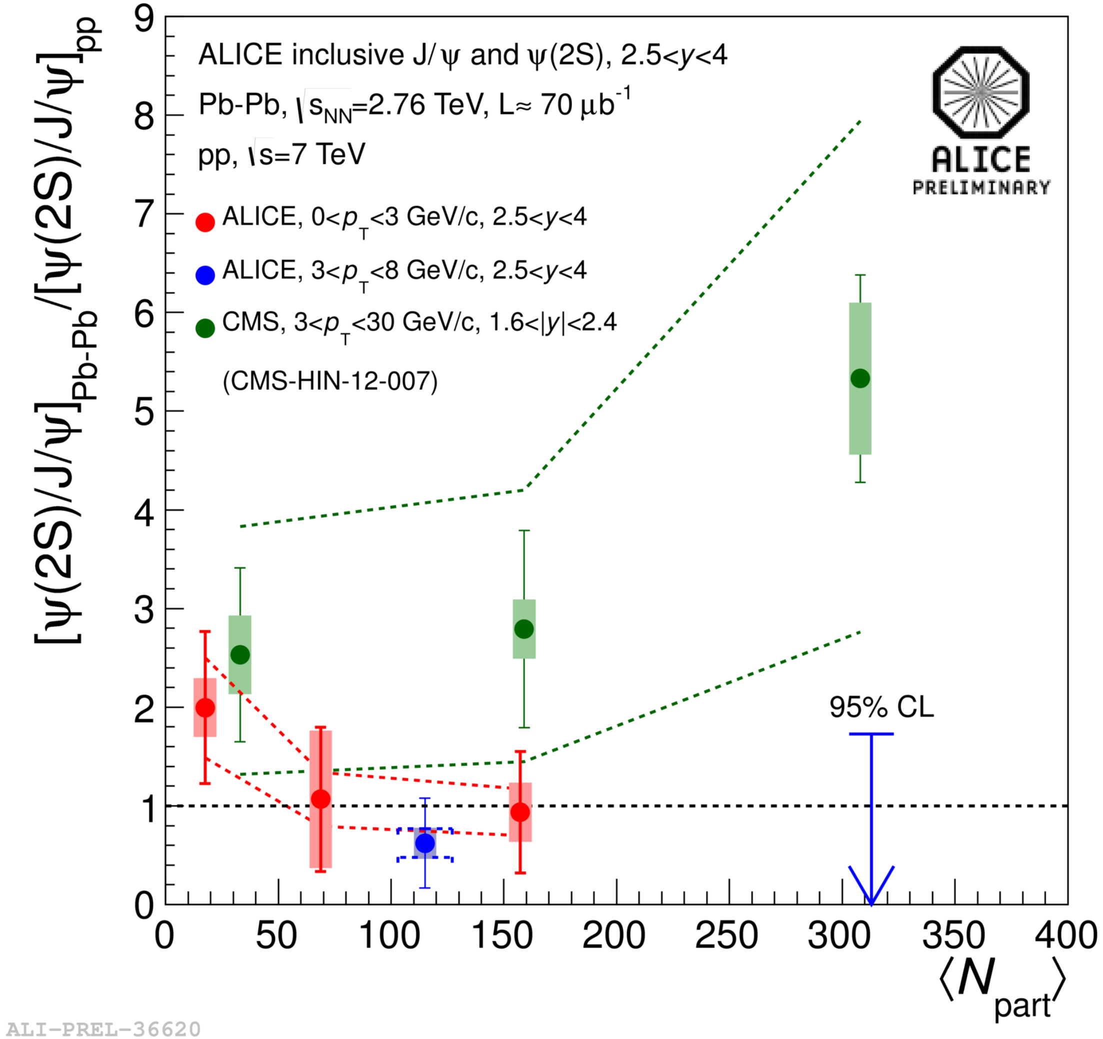
- Higher R_{AA} compared to RHIC, concentrated at low p_T
- The p_T spectrum becomes softer from pp towards central collisions, opposite to low energy results
- The amount of suppression decreases when going from forward towards mid-rapidity
- ALICE data may indicate non-zero elliptic flow
- (Re)combination models agree with the data
- Looking forward for the pPb results !

ψ(2S)


×10³
Events/(100 MeV/c²)
ALICE
PERFORMANCE
7/08/2012
pp, √s= 7 TeV
2.5< y <4, 0<p_T<3 GeV/c
m_μμ (GeV/c²)
ALI-PERF-36624


×10³
Events/(100 MeV/c²)
ALICE
PERFORMANCE
7/08/2012
Pb-Pb, √s_NN= 2.76 TeV
2.5< y <4, 0<p_T<3 GeV/c
40%-60%
m_μμ (GeV/c²)
ALI-PERF-36611

ψ(2S)/ψ(1S)



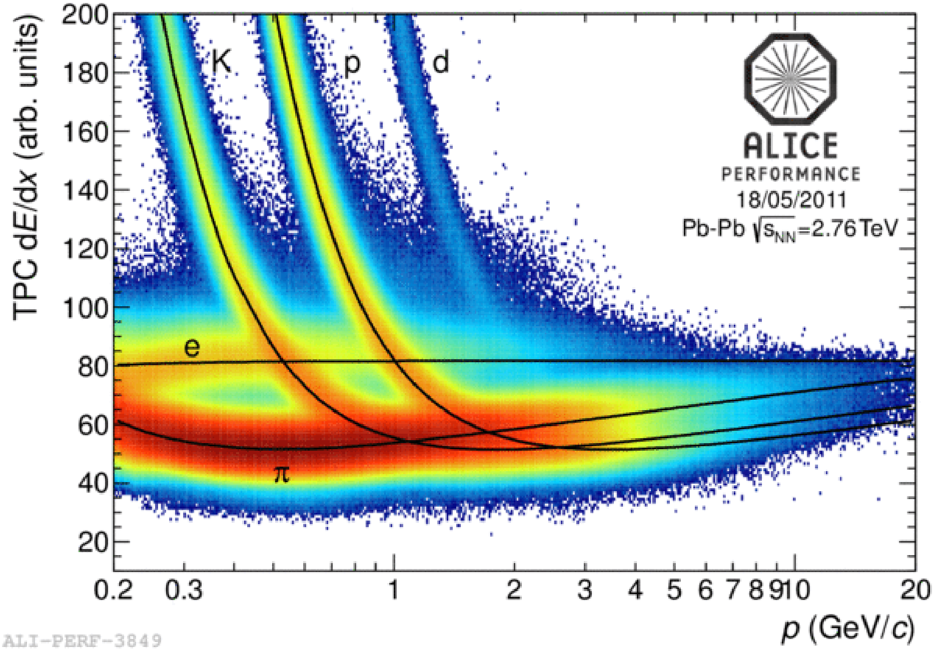
- ALICE uses the pp reference measured at √s=7 TeV
- CMS had measured pp reference at √s=2.76 TeV
- No final conclusion yet due to large uncertainties but a large ψ(2S) enhancement seem to be excluded in central collisions in ALICE data

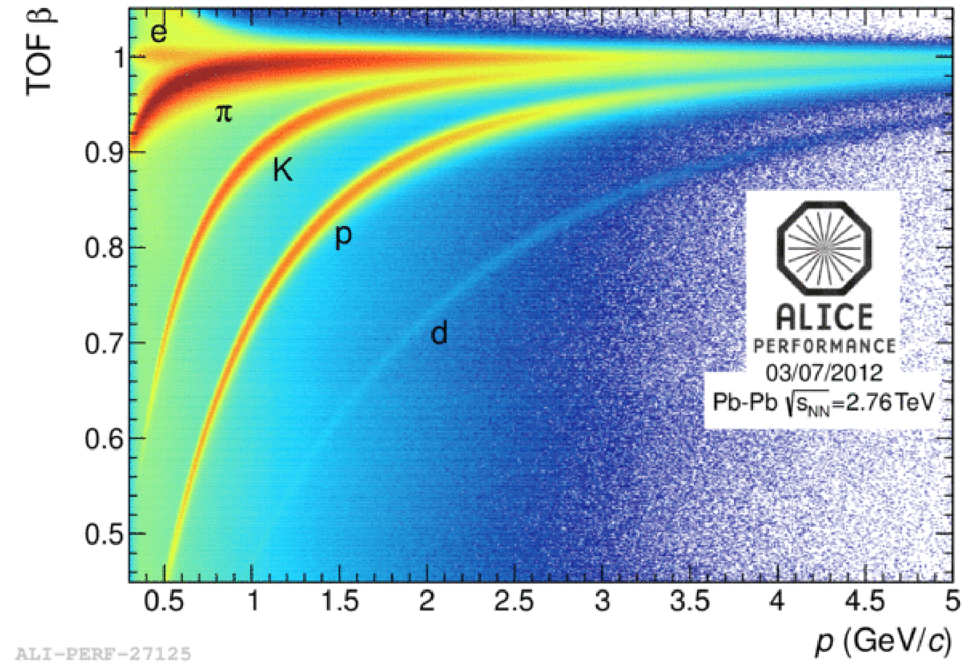
Summary

- The nuclear modification factor for inclusive J/ψ in Pb-Pb collisions
  - R_{AA} measured by ALICE is significantly higher than the one measured at RHIC both at mid- and forward-rapidity.
  - The J/ψ p_T distributions become softer with increasing centrality. This trend is opposite to what is measured at lower energies
  - The amount of suppression increases when going to forward rapidity
  - Data indicates non-zero elliptic flow as generically expected if the charm quarks thermalize in the plasma
  - The results are qualitatively described in models which include the formation of charmonium in the medium or at the chemical freeze-out.
  - Results from pPb collisions will be available and help disentangling the CNM effects
- The ψ(2S)/ψ(1S) ratio was measured at forward rapidity in ALICE. The large error bars prevent a firm conclusion but a large ψ(2S) enhancement in central collisions is unlikely.
- Results for ϒ(1S) will be available within the next weeks

Backup slides

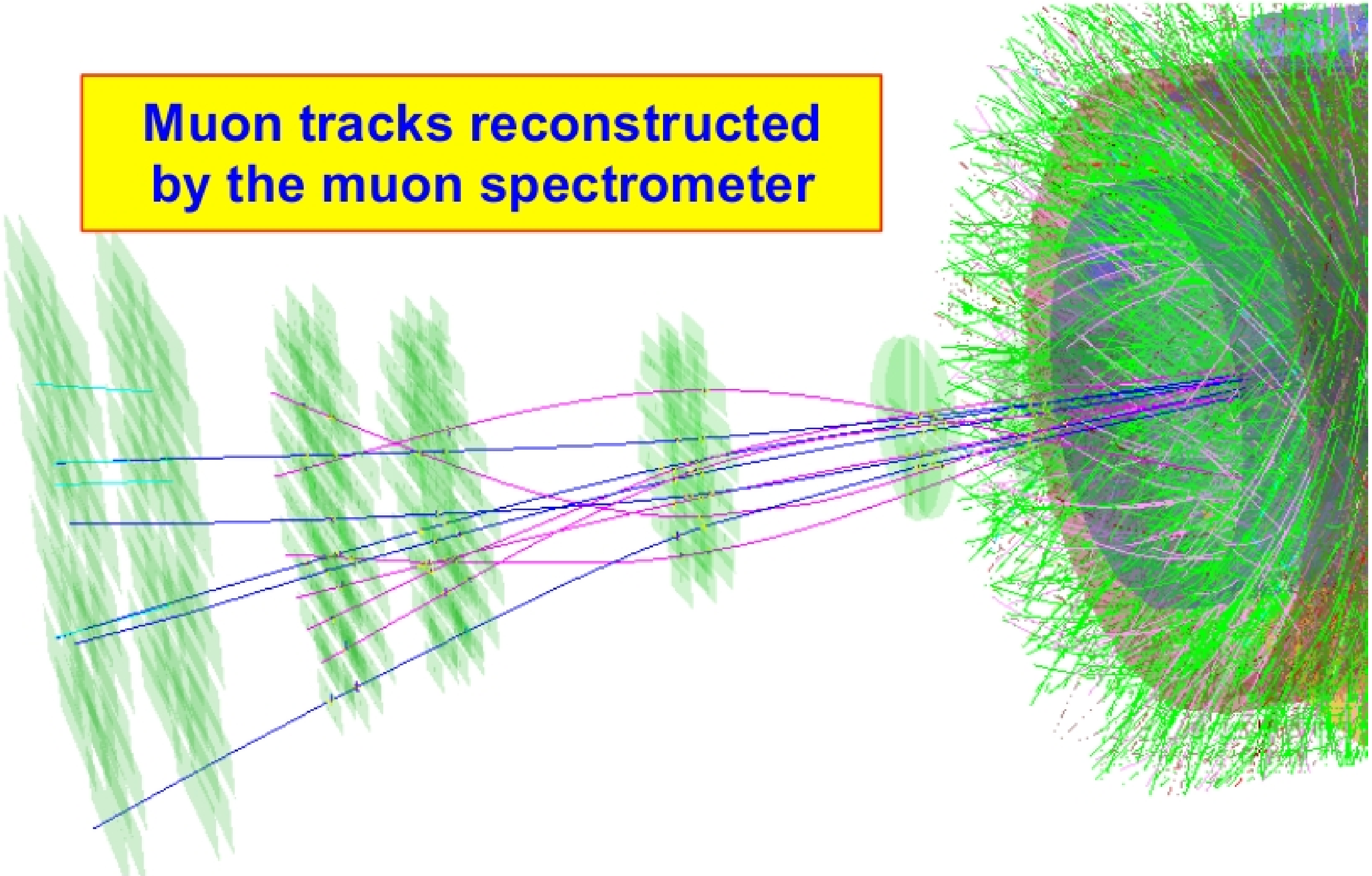
J/ψ→e^+e^- reconstruction





- Kinematics
  - $|y^{J/\psi}|<0.9$, $p_T^{J/\psi}>0$ GeV/c
  - $|\eta_e|<0.9$, $p_T^{e}>0.85$ GeV/c
- Tracking
  - Primary track requirements using ITS and TPC
- Particle identification
  - TPC+TOF
- Conversion electrons rejection
  - ITS cluster requirements on electron candidates
  - Removal of tracks from reconstructed γ-conversion V_0 's

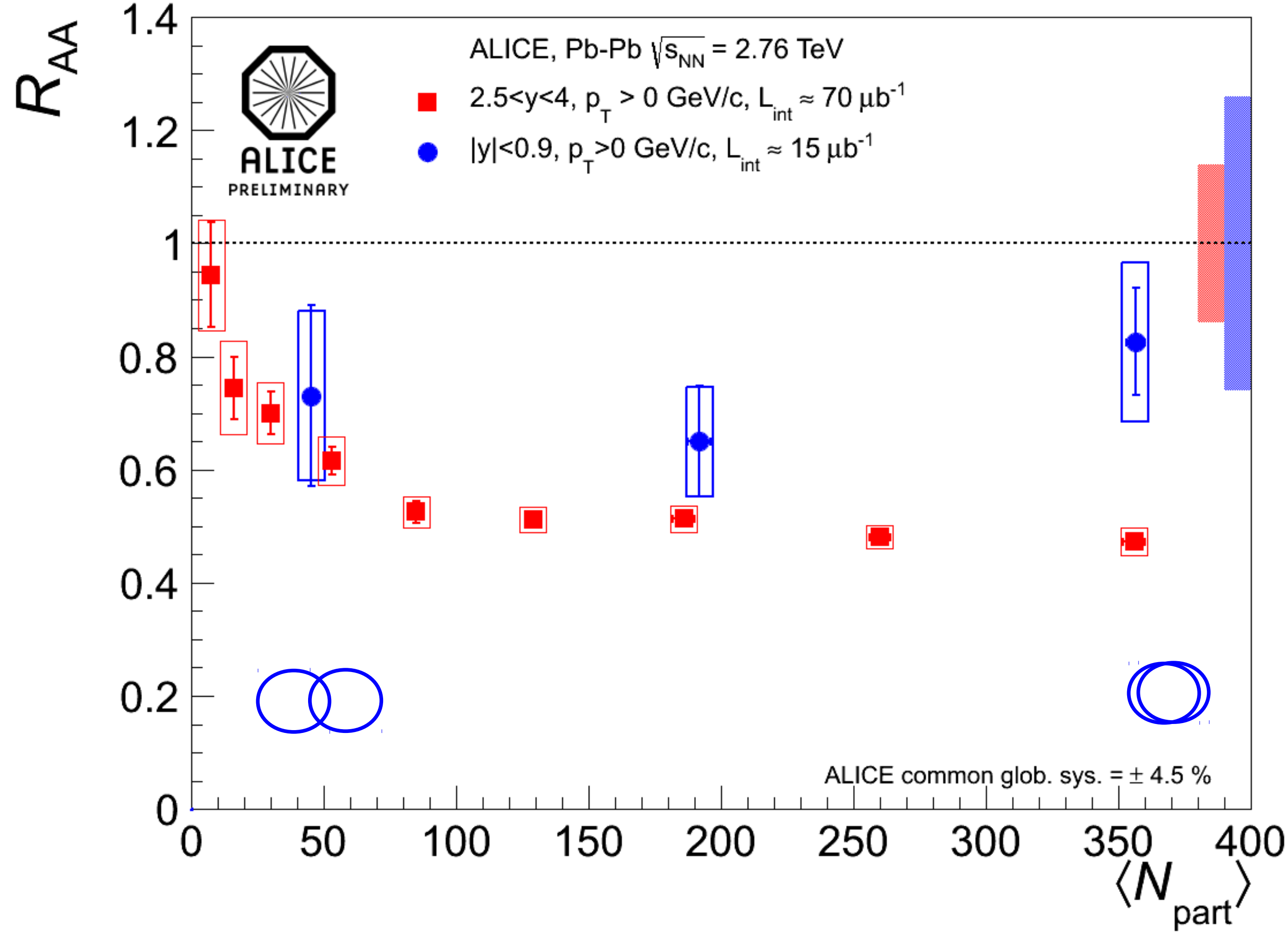
J/ψ→$\mu^+\mu^-$ reconstruction



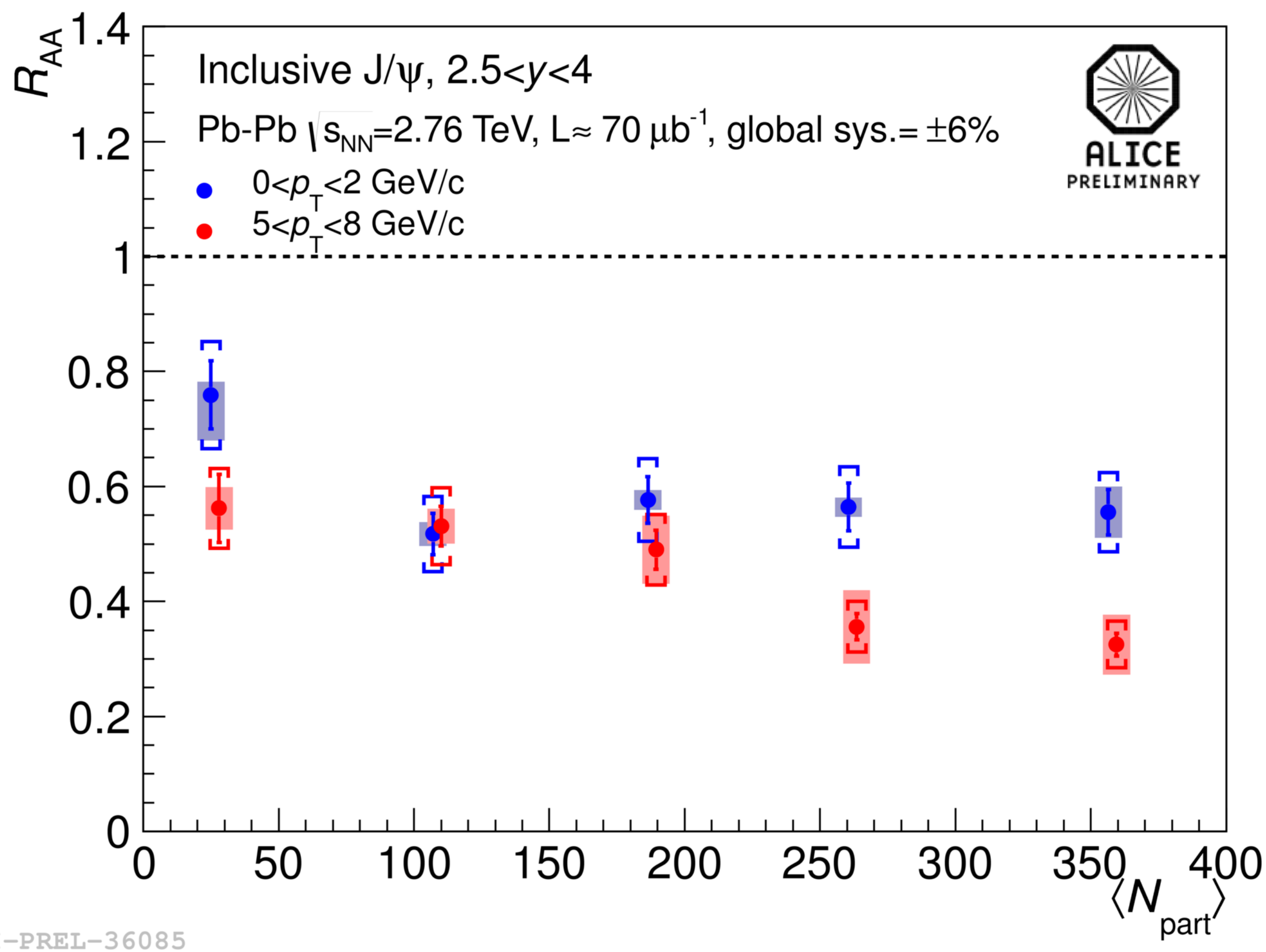
- Muons are reconstructed using tracking chambers placed behind a thick hadron absorber

- Kinematics:
  - Trigger on p_T^{μ}>1 GeV/c
  - 2.5<$y^{J/\psi}$<4
  - $p_T^{J/\psi}$>0 GeV/c

Inclusive J/ψ R_{AA} vs. centrality

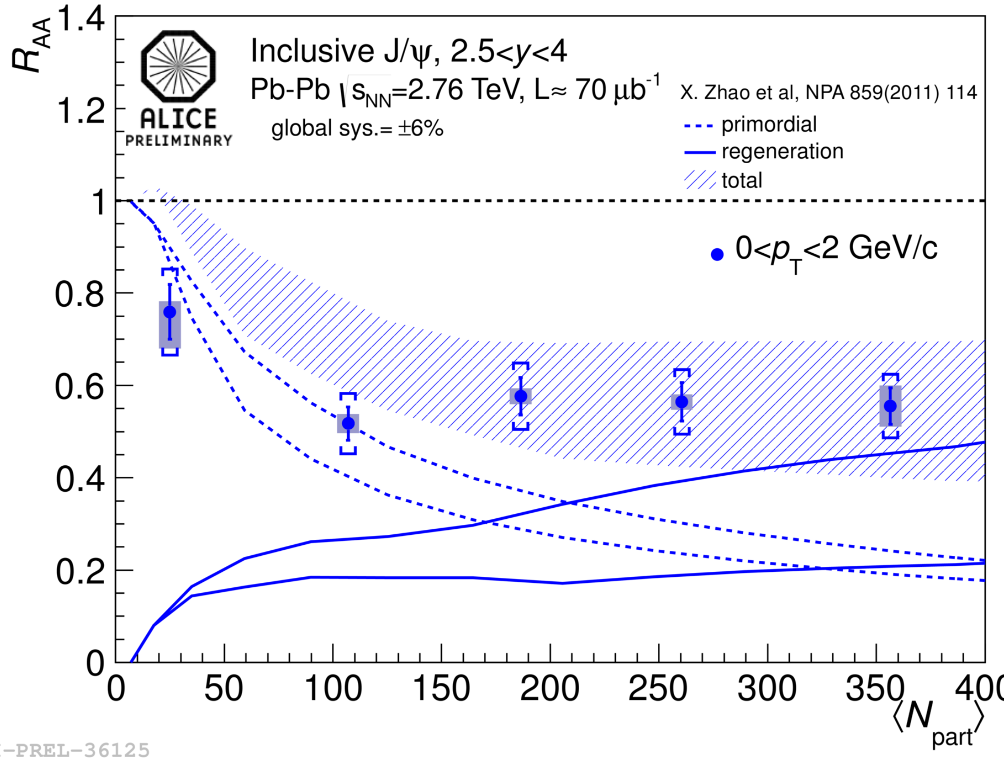


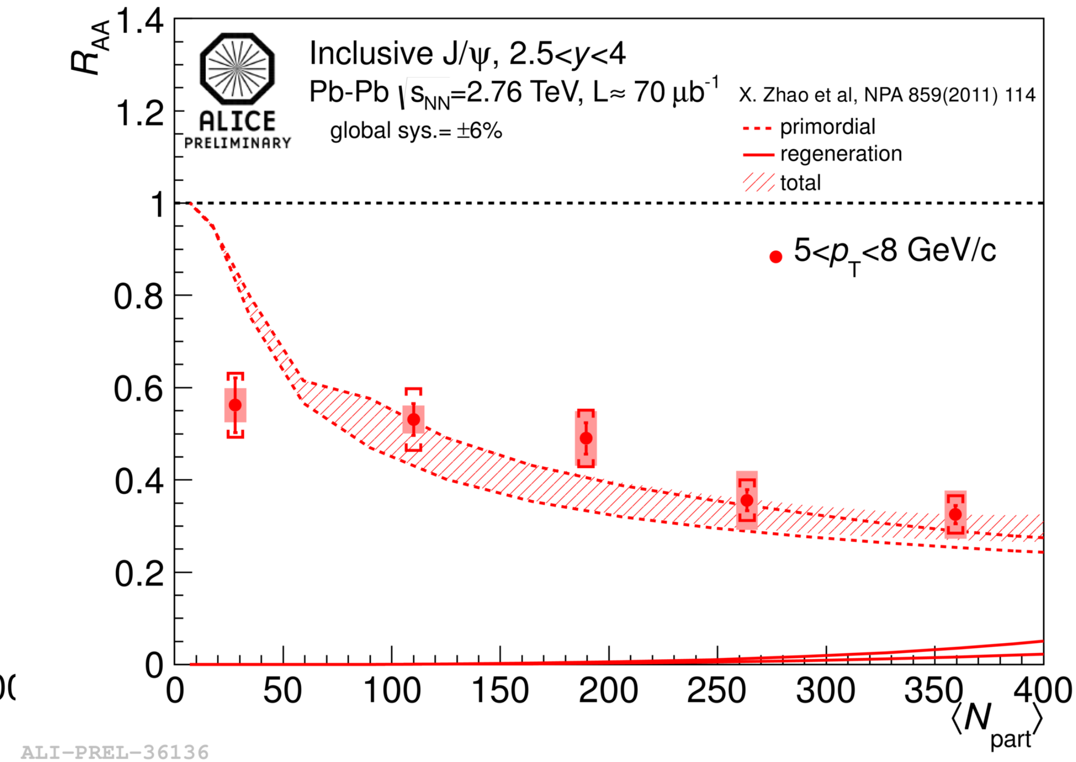
Inclusive J/ψ R_{AA} vs. centrality in p_T bins



- Low p_T J/ψ less suppressed in central collisions

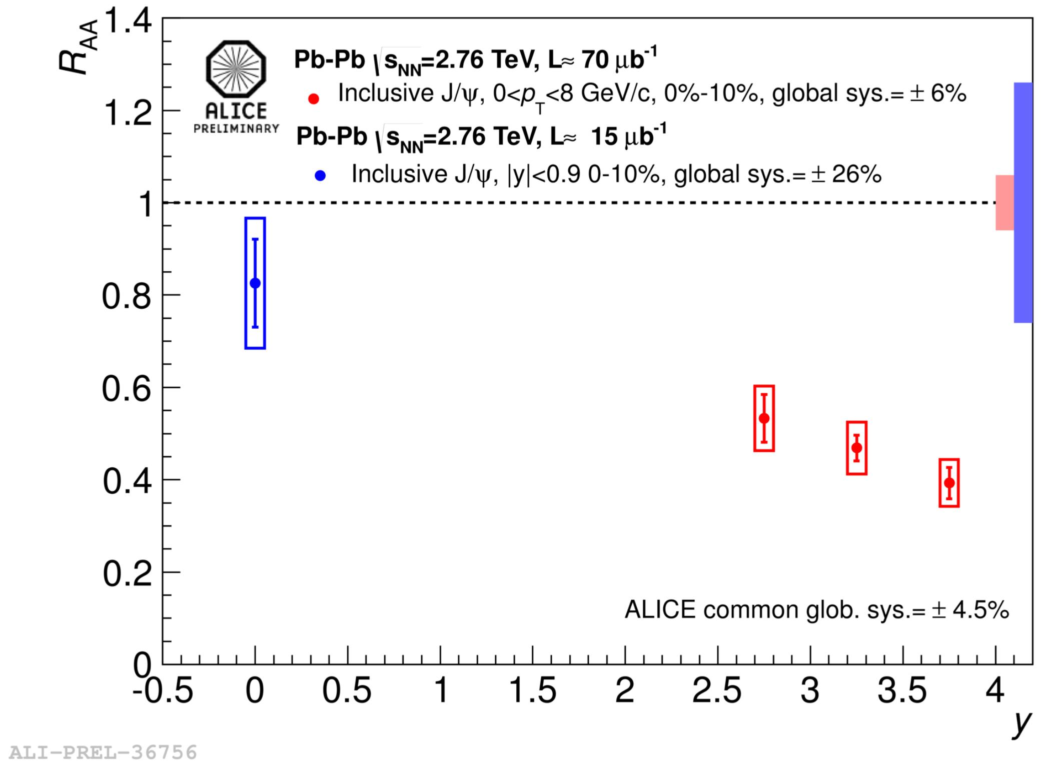
Inclusive J/ψ R_{AA} vs. centrality in p_T bins





- Transport models (e.g. *Zhao et. al*) suggest that ~50% of the J/ψ yield at low p_T is produced via (re)combination of charm quarks

Raa vs rapidity in central collisions



Heavy flavour electrons