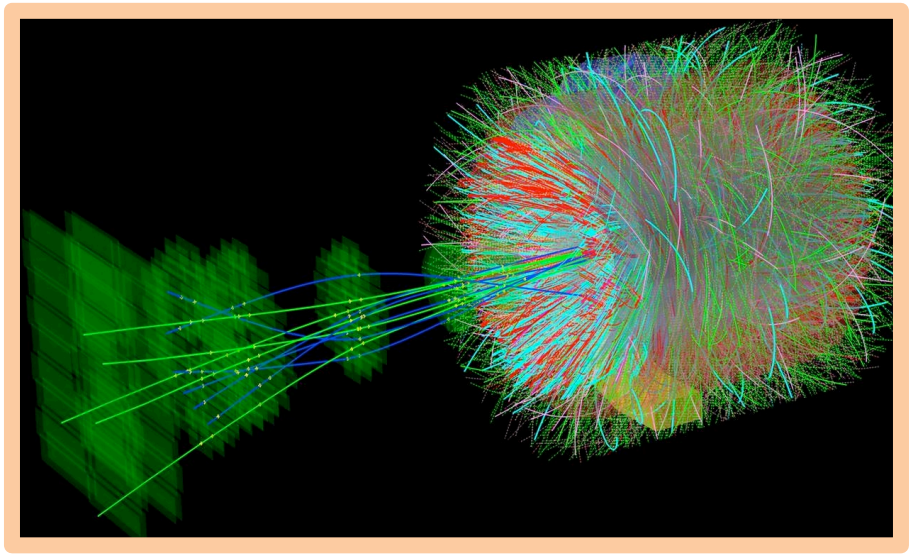
J/ψ production in Pb-Pb collisions at $\sqrt{s_{NN}}$ = *2.76 TeV* in the ALICE experiment



LARDEUX Antoine

SUBATECH - Nantes (France)

On behalf of the ALICE collaboration

Hot Quarks 2012 - Copamarina
October 14th-20th 2012

Outline

J/ψ production in Pb-Pb collisions at $\sqrt{s_{NN}}$ = *2.76 TeV* in the ALICE experiment

- Physics motivations
- ALICE setup
- *J/Ψ* R_{AA}
- *J/Ψ* $\langle p_T \rangle$
- *J/Ψ* low p_T excess
- Conclusions and perspectives

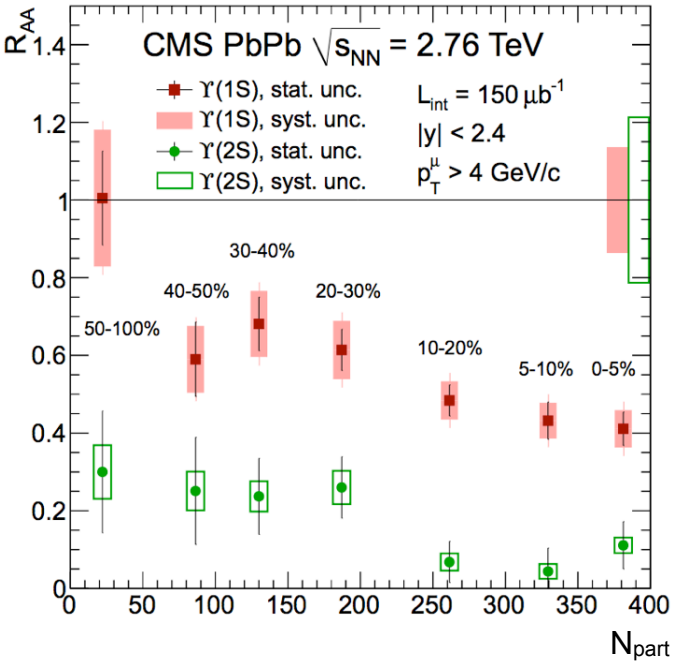
Charmonium production mechanisms

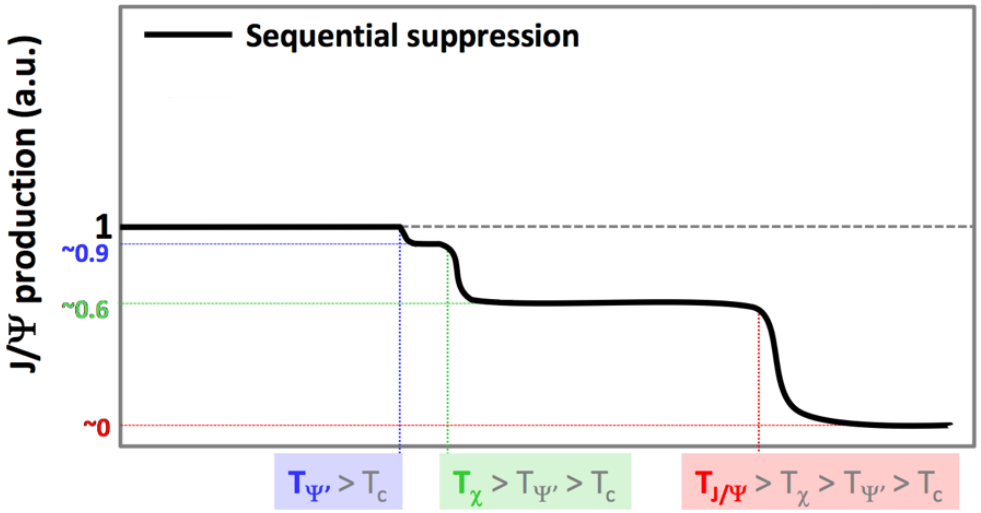
J/Ψ suppression in heavy-ion collision is a promising probe of QGP

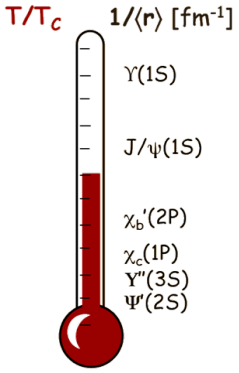
✓ Quarkonia dissociation due to the color screening **[T. Matsui, H. Satz, Phys. Lett. B178 (1986) 416]**

- Suppression behaviour → Access to properties of the system : Temperature
- LHC: huge energy density available
- CMS : «Observation of sequential Upsilon suppression in PbPb collisions»
  [CMS collaboration arXiv 1208.2826]

  => J/Ψ dissociation temperature reached?







Charmonium production mechanisms

J/Ψ suppression in heavy-ion collision is a promising probe of QGP

✓ Quarkonia dissociation due to color screening **[T. Matsui, H. Satz, Phys. Lett. B178 (1986) 416]**

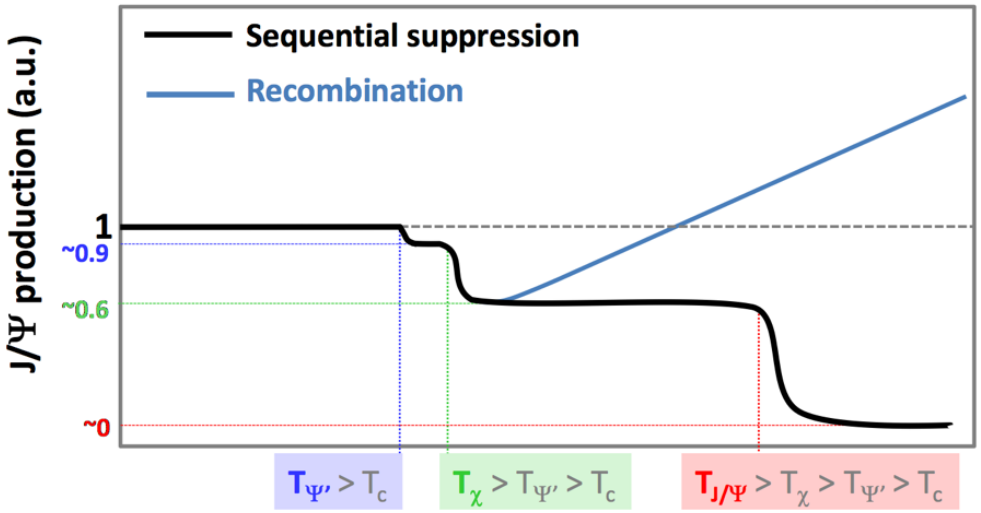
- Suppression behaviour → Access to properties of the system : Temperature
- LHC: huge energy density available
- CMS : «Observation of sequential Upsilon suppression in PbPb collisions»
  [CMS collaboration arXiv 1208.2826]

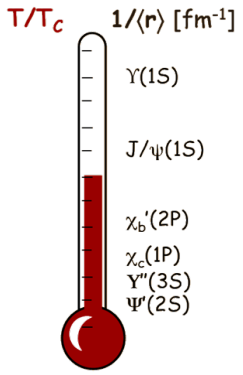
  => J/Ψ dissociation temperature reached?

✓ Alternative quarkonia production mechanism: (re)combination

- LHC: Large number of charm quark pairs created $\sigma(c\bar{c})_{LHC} \approx 10 \times \sigma(c\bar{c})_{RHIC}$

  => Non-negligible contribution expected





Charmonium production mechanisms

J/Ψ suppression in heavy-ion collision is a promising probe of QGP

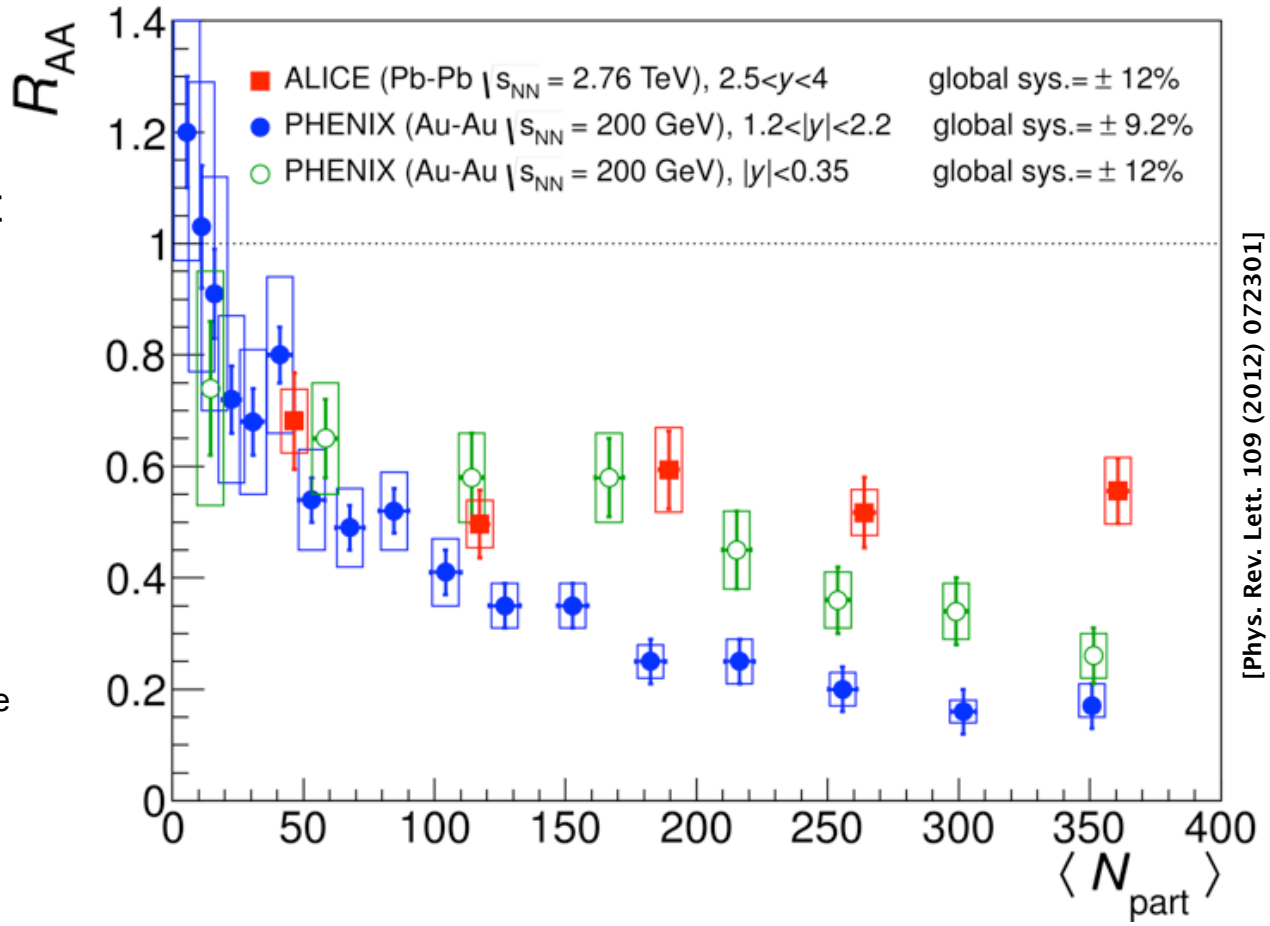
✓ Quarkonia dissociation due to color screening [T. Matsui, H. Satz, Phys. Lett. B178 (1986) 416]

✓ Alternative quarkonia production mechanism: (re)combination

✓ Weaker suppression at LHC compared to RHIC

✓ Almost flat centrality dependence of R_{AA} at LHC in contrast with the stronger variation observed by RHIC.

Caveat: cold nuclear matter effects are not taken into account however they could hardly explain these results



Charmonium production mechanisms

J/Ψ suppression in heavy-ion collision is a promising probe of QGP

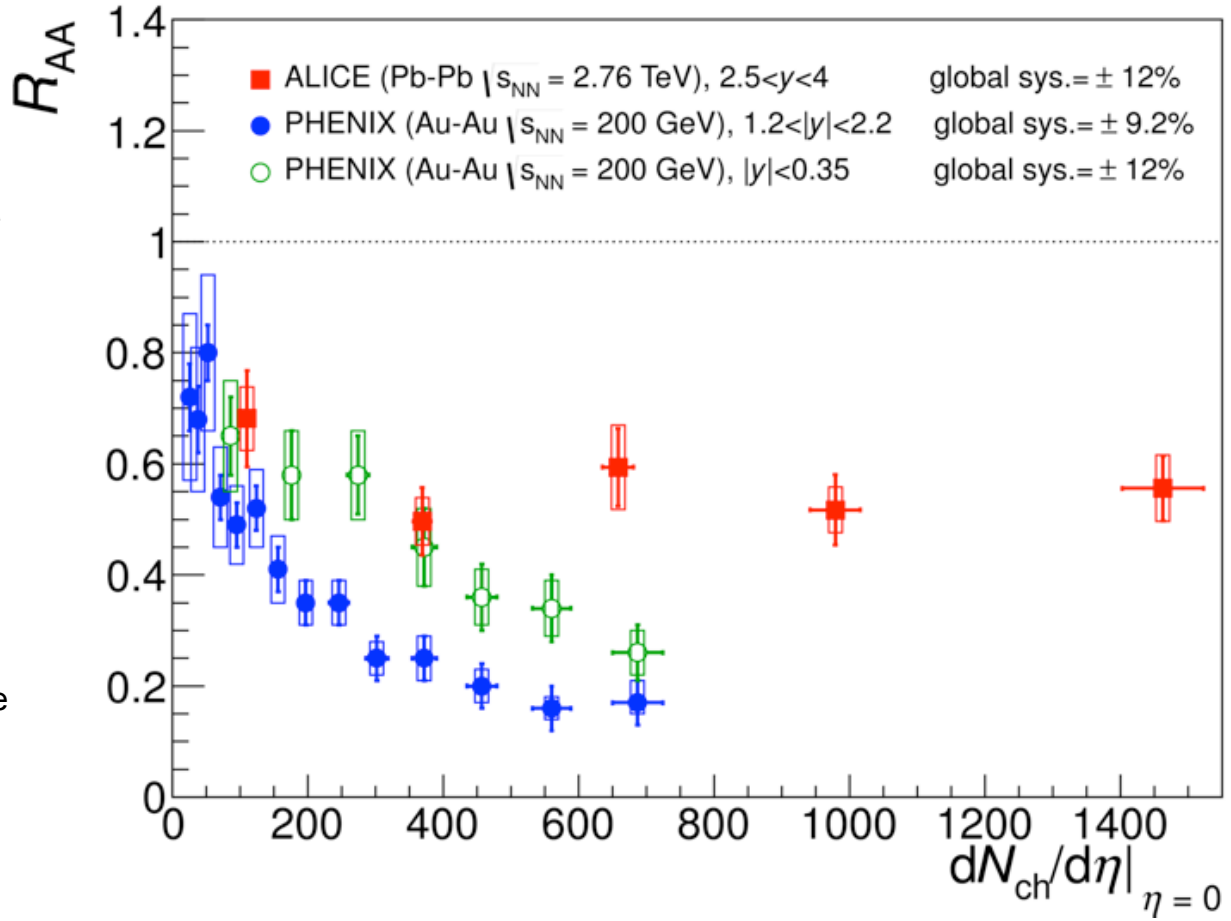
✓ Quarkonia dissociation due to color screening [T. Matsui, H. Satz, Phys. Lett. B178 (1986) 416]

✓ Alternative quarkonia production mechanism: (re)combination

✓ Weaker suppression at LHC compared to RHIC

✓ Almost flat centrality dependence of R_{AA} at LHC in contrast with the stronger variation observed by RHIC.

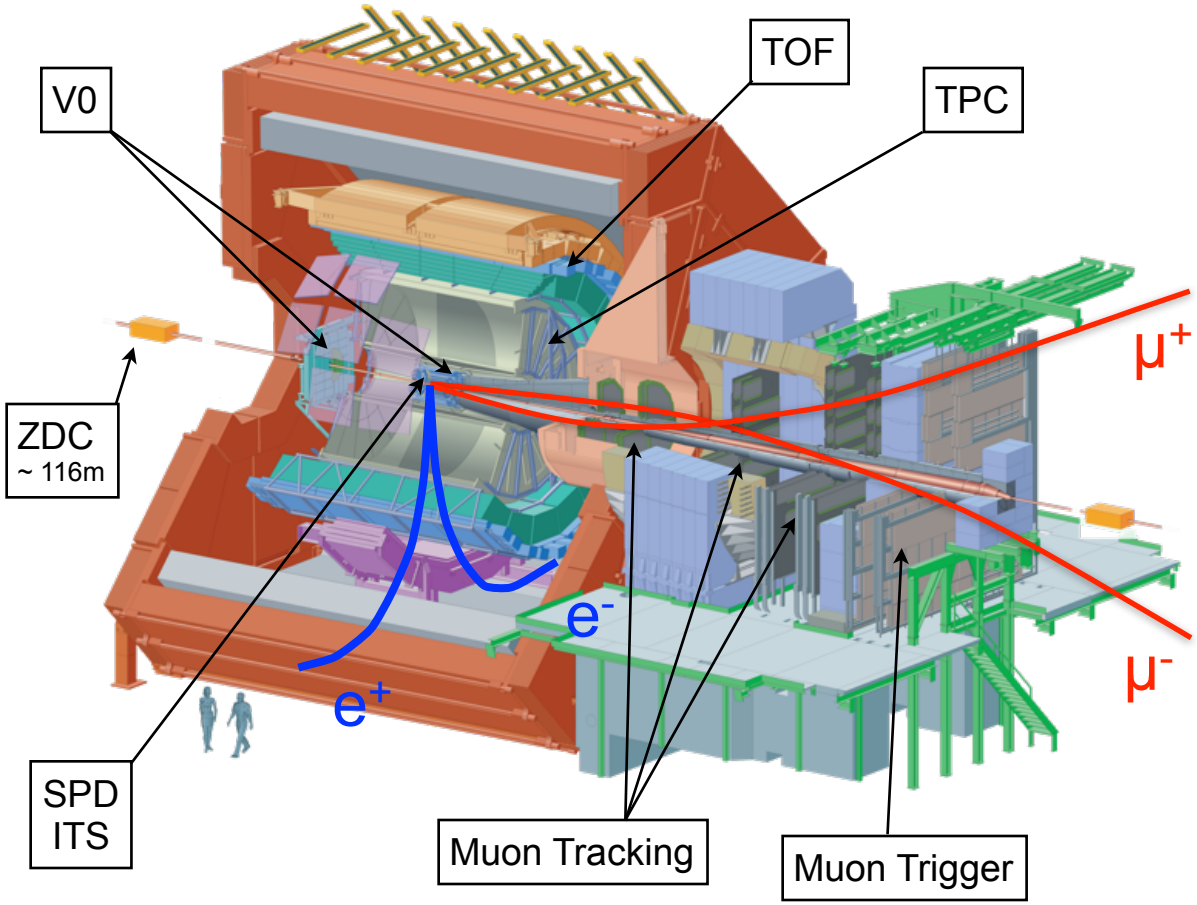
Caveat: cold nuclear matter effects are not taken into account however they could hardly explain these results



ALICE setup

Central Barrel: $J/\Psi \rightarrow e^+e^-$ ($|y|<0.9$)
Electrons tracked using ITS and TPC
Particle identification: TPC (+TOF)
Integrated luminosity ~ **15 μb^{-1}**

Forward muon arm: $J/\Psi \rightarrow \mu^+\mu^-$ ($2.5<y<4$)
Muons identified and tracked in the muon spectrometer
Integrated luminosity ~ **70 μb^{-1}**



Event selection:

Rejection of beam gas and electromagnetic interactions (VZERO and Zero Degree Calorimeters ZDC). Silicon Pixel Detector (SPD) used for vertex determination.

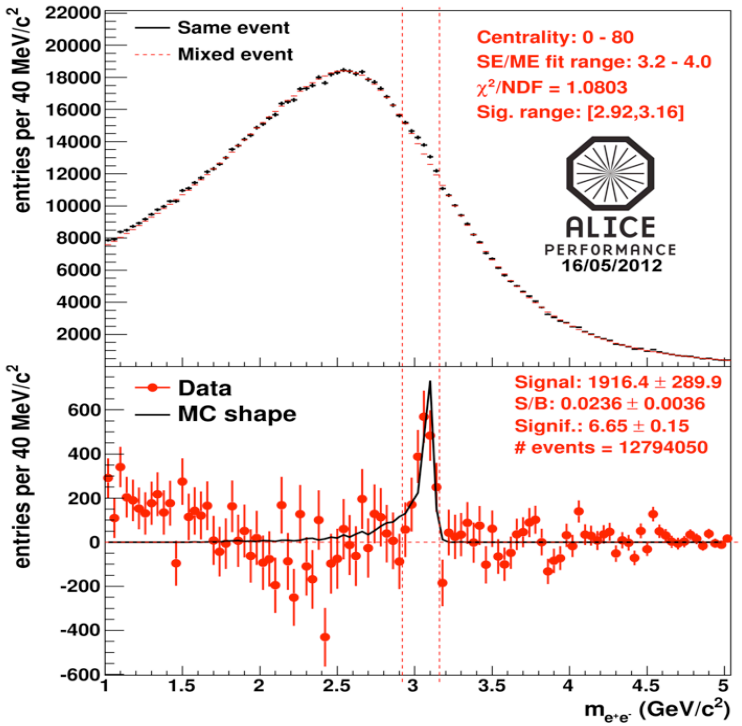
Centrality selection:

Estimate from a fit to the VZERO amplitude distribution with a Glauber model.

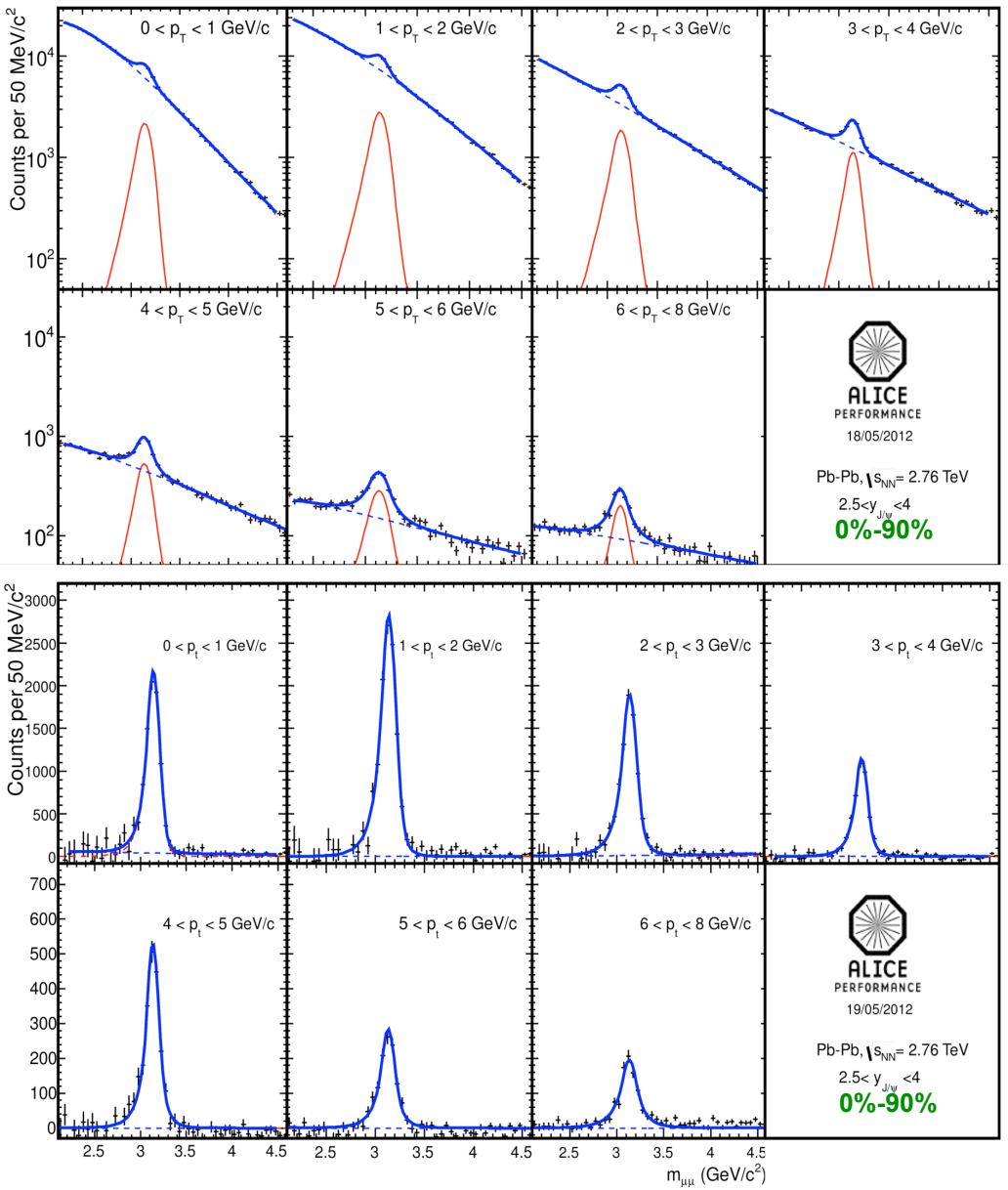
➙ ALICE results refer to **inclusive J/Ψ production down to $p_T = 0$**

J/Ψ signal extraction

$J/\Psi \rightarrow e^+e^-$ ($|y|<0.9$)



$J/\Psi \rightarrow \mu^+\mu^-$ ($2.5<y<4$)



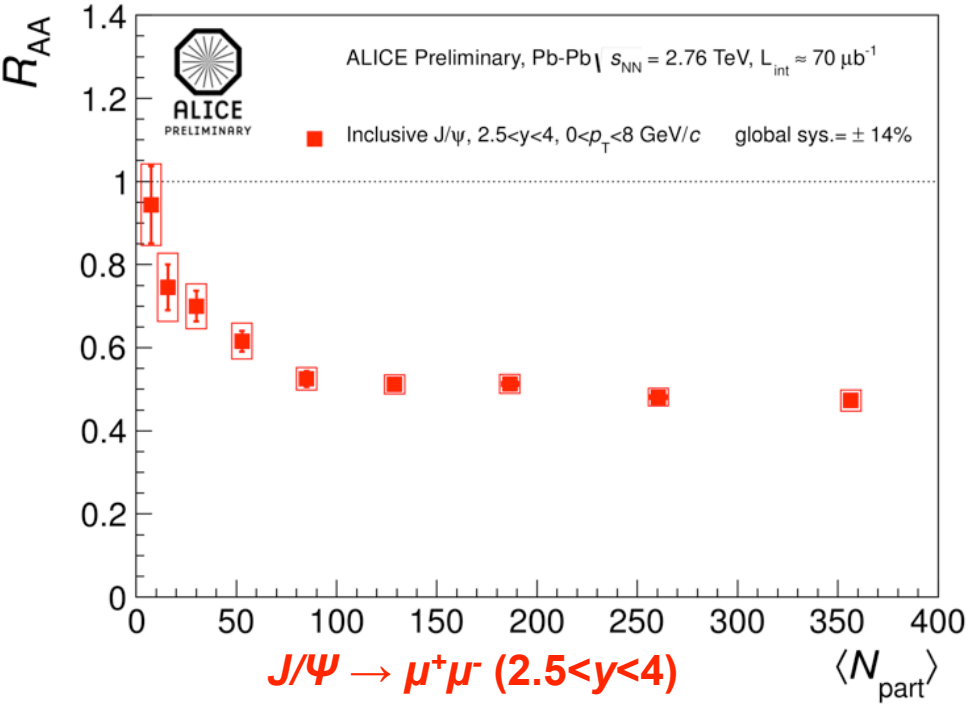
✓ $\langle N_{J/\Psi} \rangle$ and associated uncertainties are extracted by combining different techniques.

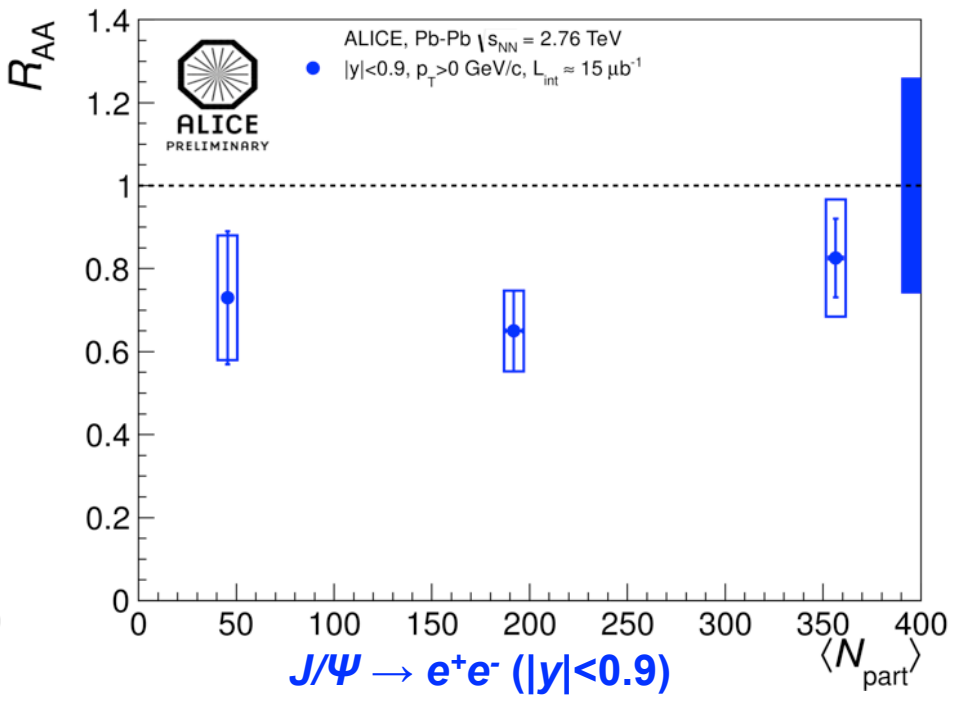
✓ J/Ψ $A\varepsilon$ correction computed by embedding simulated J/Ψ into:

- real Pb-Pb events for $J/\psi \rightarrow \mu^+\mu^-$
- HIJING events for $J/\psi \rightarrow e^+e^-$

➙ $A\varepsilon$ are high [9;14]% and weakly dependent on the collision centrality.

J/Ψ R_{AA} results vs Centrality

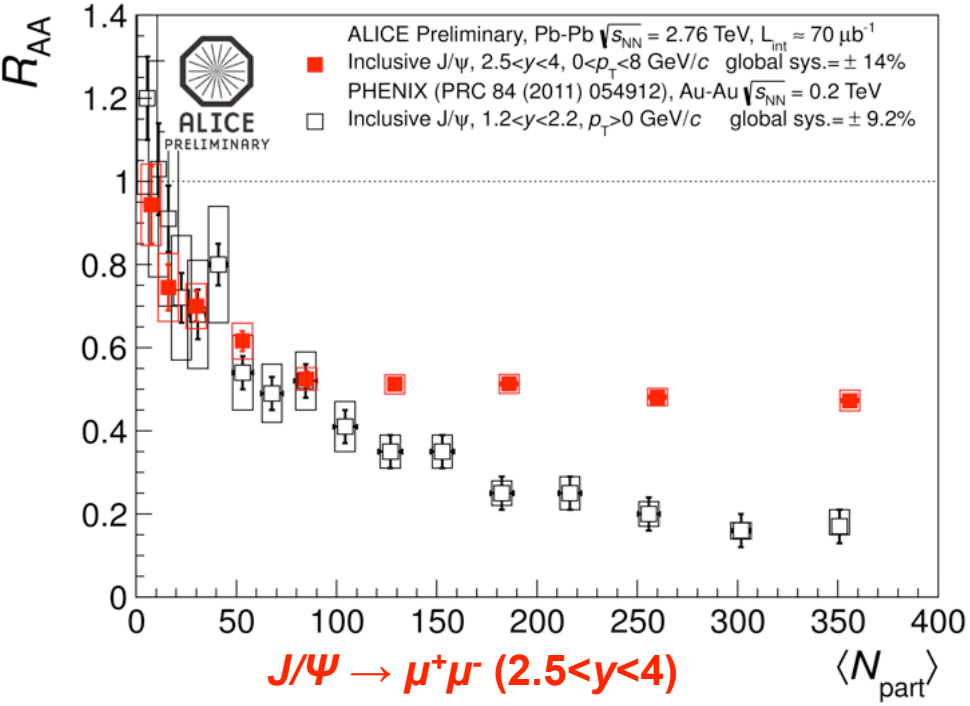


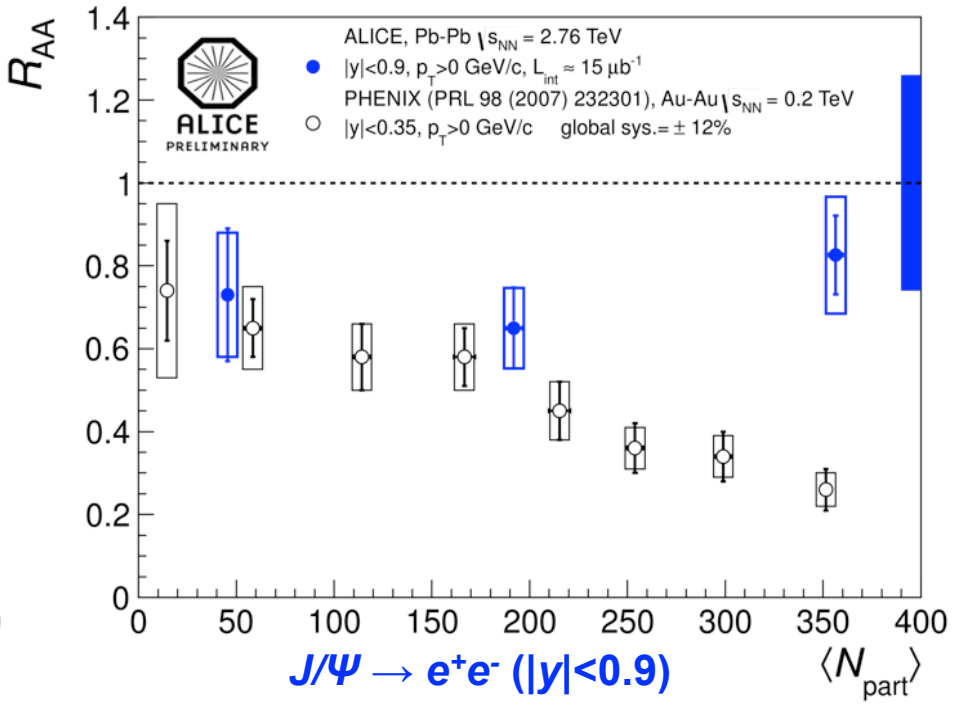


Clear J/Ψ suppression at forward rapidity with almost no centrality dependence above N_{part} ~ 100.

Hint of smaller suppression at mid than at forward rapidity in central collisions.

J/Ψ R_{AA} results vs Centrality



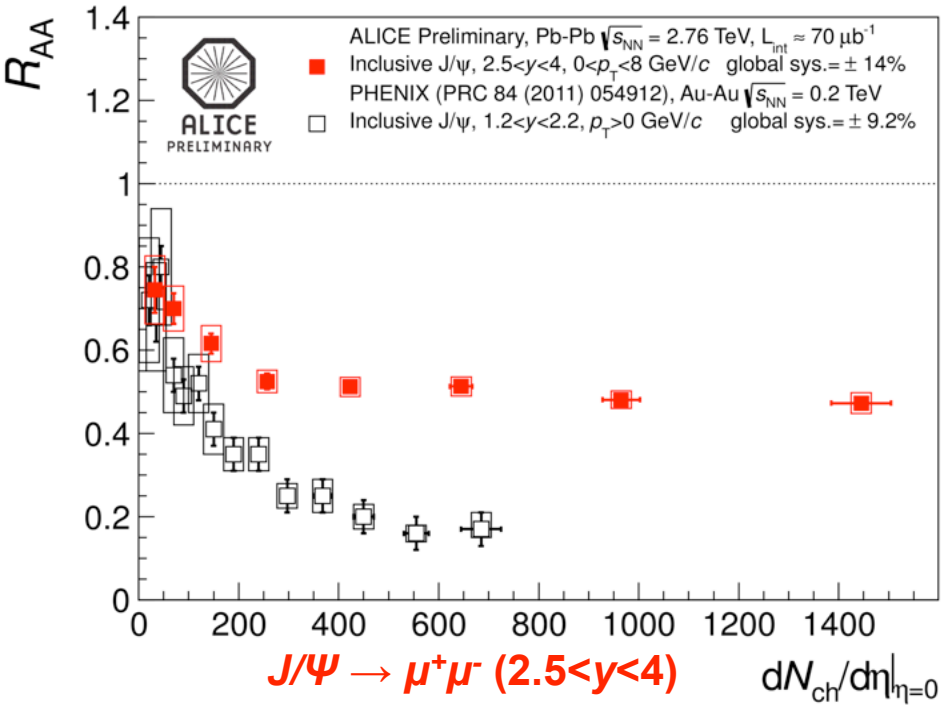


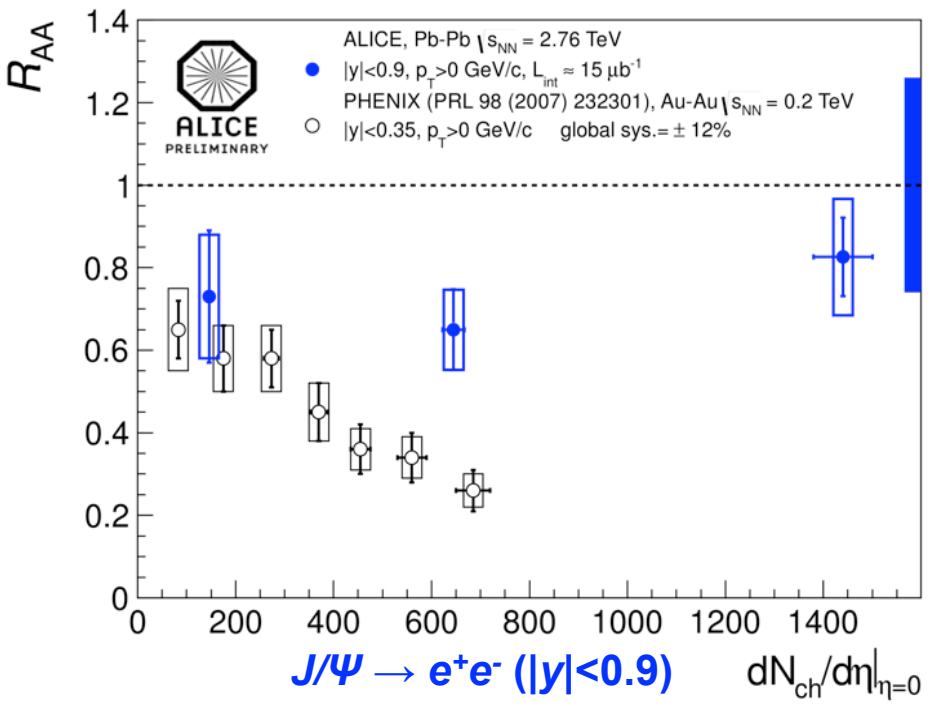
Clear J/Ψ suppression at forward rapidity with almost no centrality dependence above N_{part} ~ 100.

Hint of smaller suppression at mid than at forward rapidity in central collisions

ALICE vs PHENIX: weaker centrality dependence and smaller suppression for central events in both cases

J/Ψ R_{AA} results vs Centrality



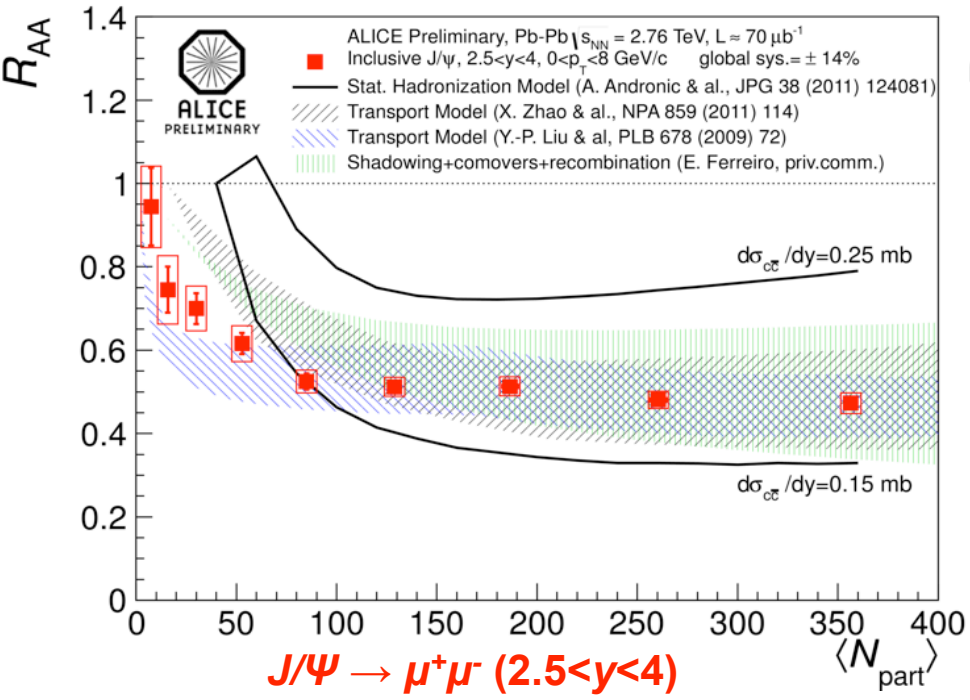


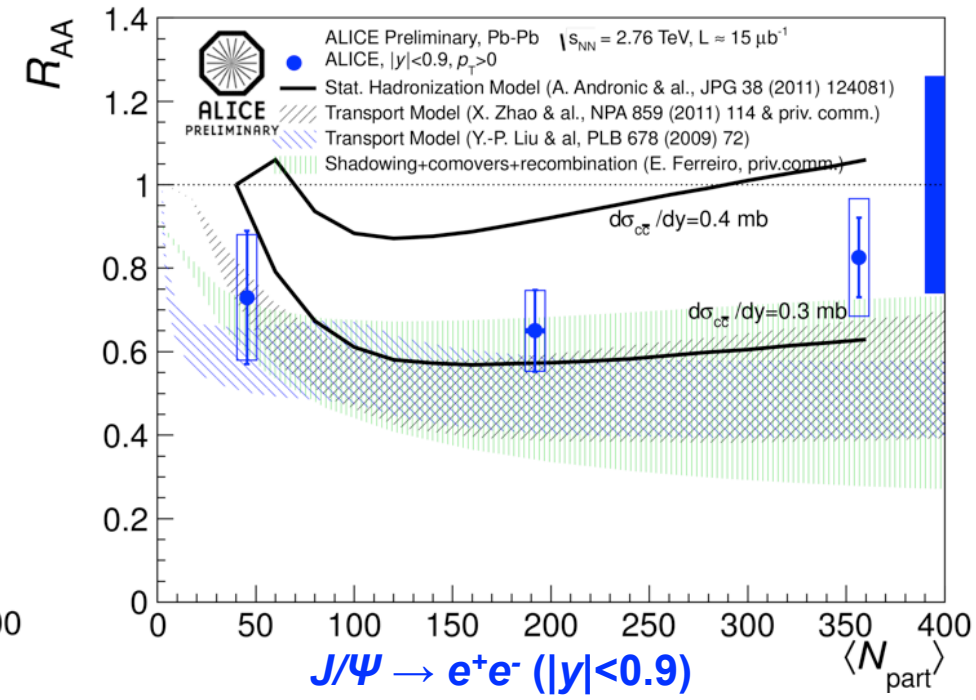
Clear J/Ψ suppression at forward rapidity with almost no centrality dependence above N_{part} ~ 100.

Hint of smaller suppression at mid than at forward rapidity in central collisions

ALICE vs PHENIX: weaker centrality dependence and smaller suppression for central events in both cases

J/Ψ R_{AA} results vs Centrality





Clear J/Ψ suppression at forward rapidity with almost no centrality dependence above N_{part} ~ 100.

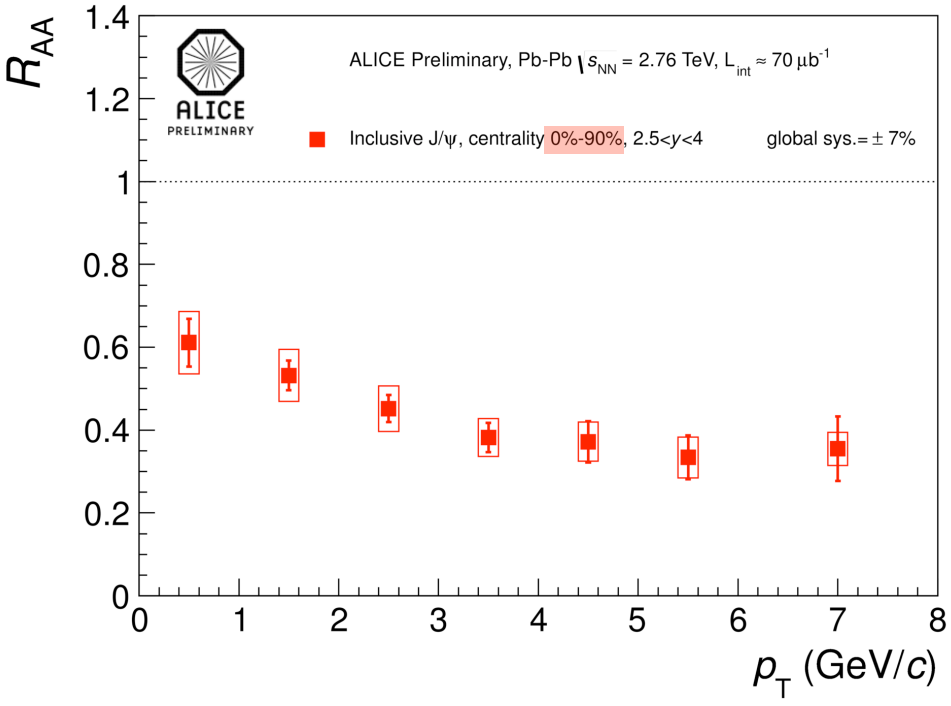
Hint of smaller suppression at mid than at forward rapidity in central collisions

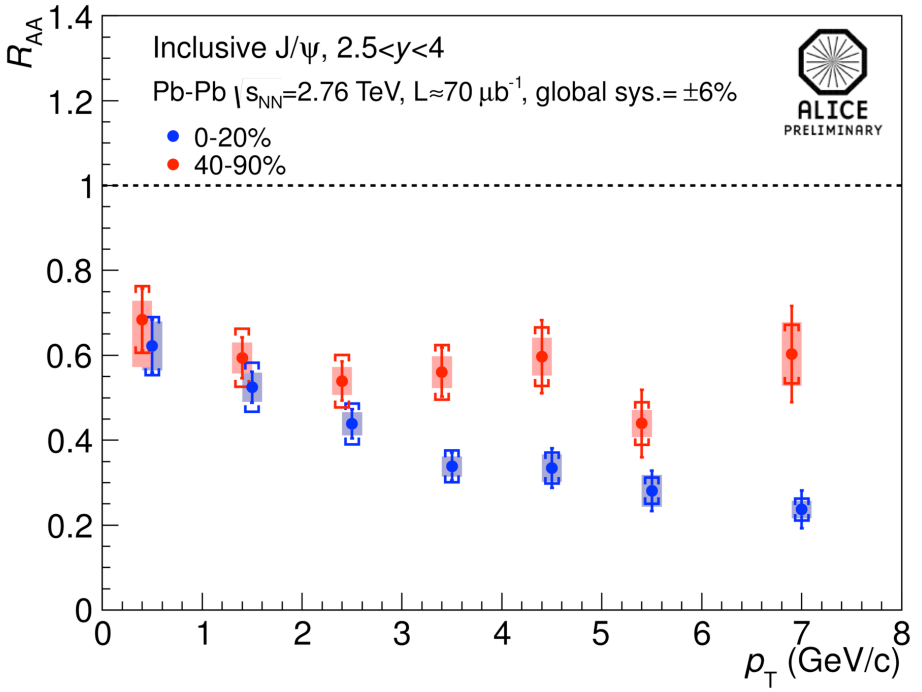
ALICE vs PHENIX: weaker centrality dependence and smaller suppression for central events in both cases

Models including hot and cold nuclear matter suppression, regeneration, b feed-down, ... can describe ALICE results in central collisions.

In both transport models, the amount of J/ψ produced from regeneration is ≥ 50% in the most central collisions.
In Statistical Hadronisation model, all J/ψ are formed at hadronization by (re)combination of $c\bar{c}$ pairs.

J/Ψ R_{AA} as a function of p_T at forward rapidity

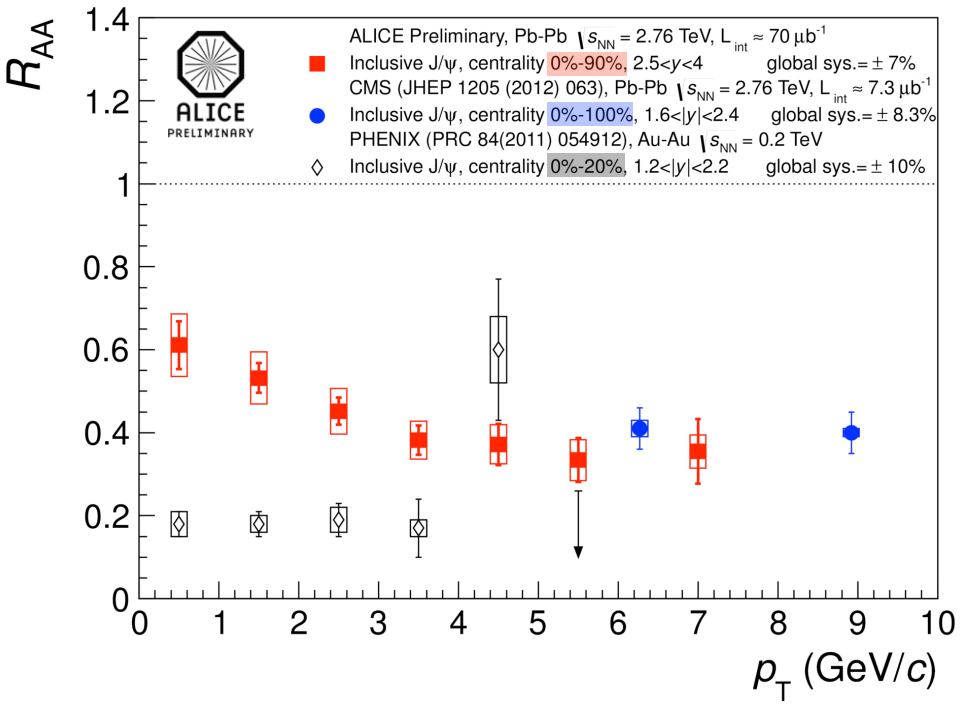


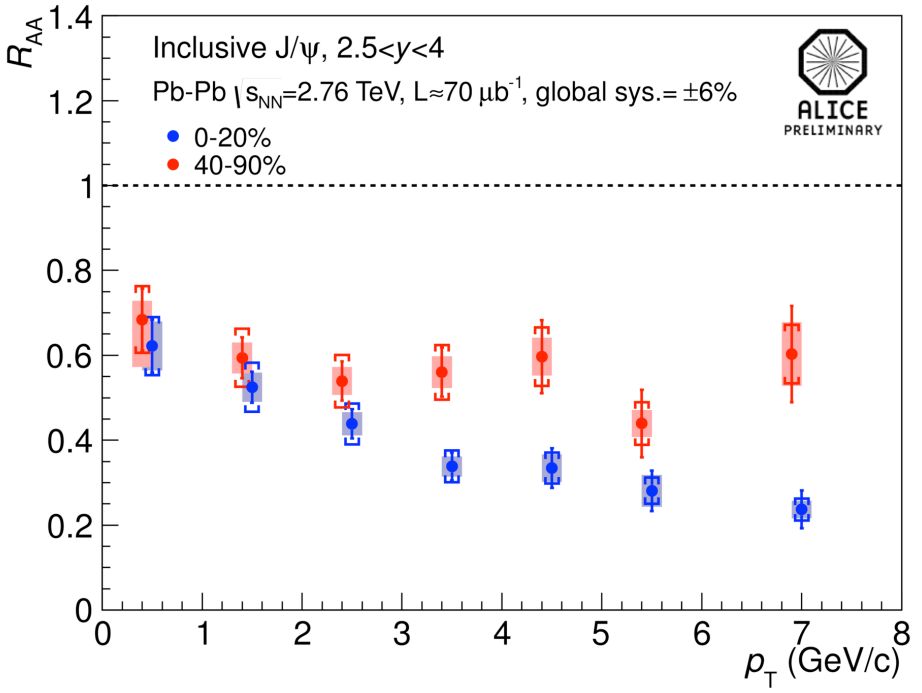


Suppression is stronger for high p_T J/Ψ ($R_{AA} \approx 0.6$ at low p_T and ≈ 0.35 at high p_T)

J/Ψ suppression is stronger at high p_T for central collisions (0-20%) compared to peripheral (40-90%)

J/Ψ R_{AA} as a function of p_T at forward rapidity



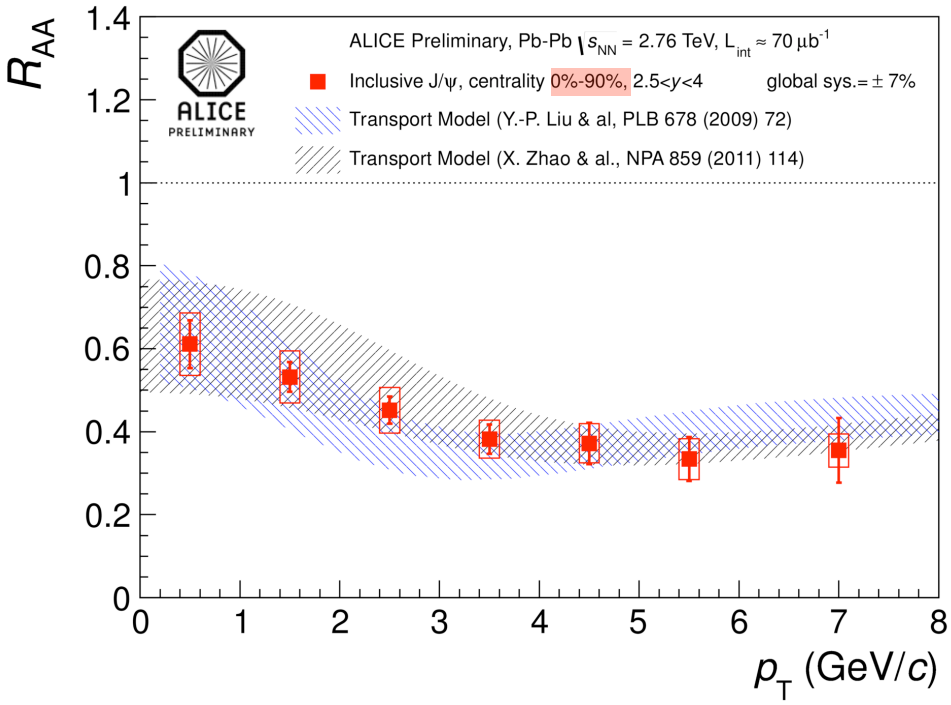


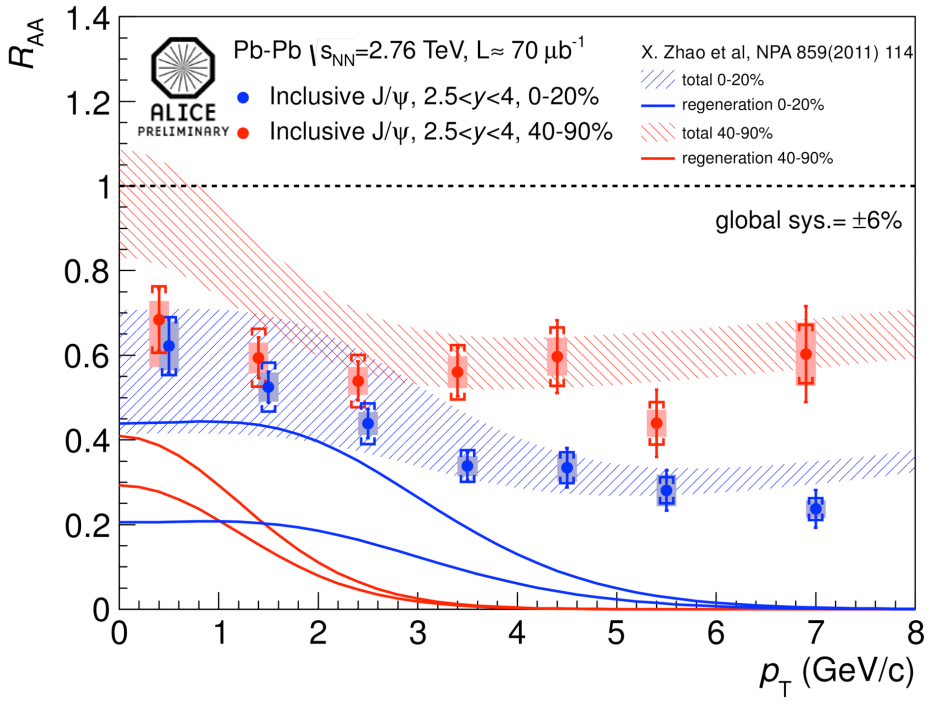
Suppression is stronger for high p_T J/Ψ ($R_{AA} \approx 0.6$ at low p_T and ≈ 0.35 at high p_T)

J/Ψ suppression is stronger at high p_T for central collisions (0-20%) compared to peripheral (40-90%)

- Good agreement with CMS data at high p_T (1.6<|y|<2.4) .
- PHENIX measured larger suppression at low p_T (0-20% central, 1.2<|y|<2.2)

J/Ψ R_{AA} as a function of p_T at forward rapidity





Suppression is stronger for high p_T J/Ψ ($R_{AA} \approx 0.6$ at low p_T and ≈ 0.35 at high p_T)

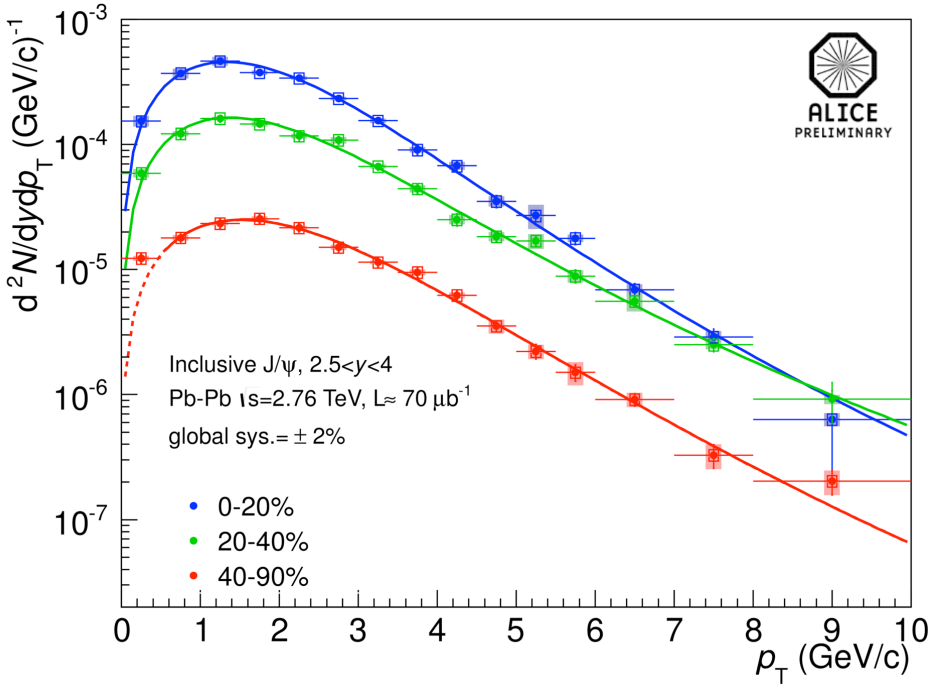
J/Ψ suppression is stronger at high p_T for central collisions (0-20%) compared to peripheral (40-90%)

- Good agreement with CMS data at high p_T (1.6<|y|<2.4) .
- PHENIX measured larger suppression at low p_T (0-20% central, 1.2<|y|<2.2)

Fair agreement between data and model including a large contribution from (re)combination.
(≈ 50% in central and ≈ 30% in peripheral collisions)
Shadowing effect to be measured with future pPb and Pbp data.

J/Ψ p_T distribution and $\langle p_T \rangle$ vs centrality

Comparison with lower energy results can be carried out by comparing $\langle p_T \rangle$ vs centrality.

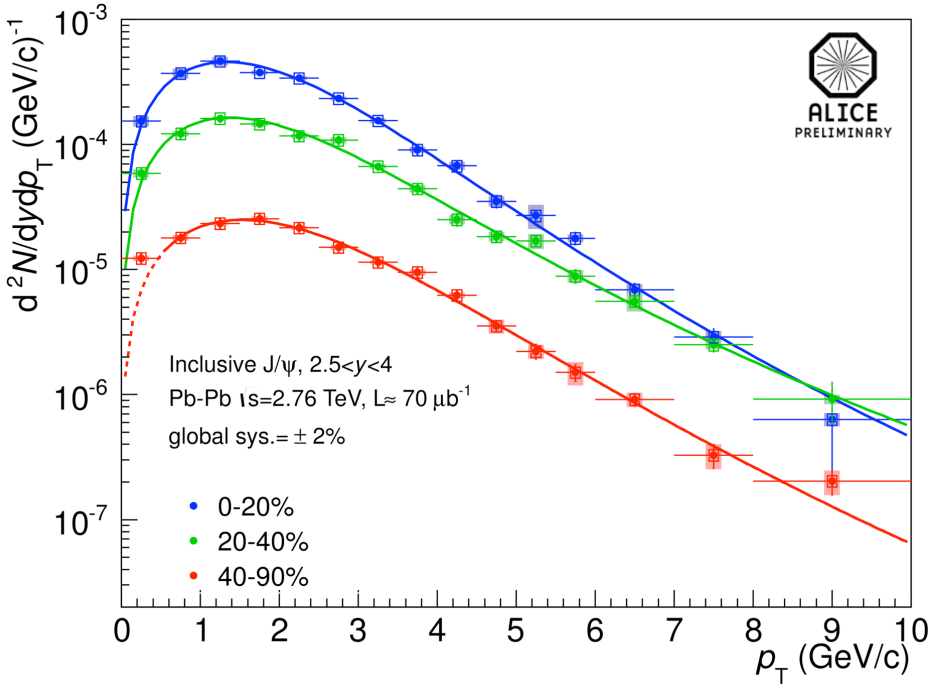


J/Ψ $\langle p_T \rangle$ values are extracted from fits to $d^2N/dydp_T$ distribution by using this formula:

$$\frac{dN}{dydp_\perp} \propto \frac{p_\perp}{\left(1+\left(\frac{p_\perp}{p_0}\right)^2\right)^n}$$

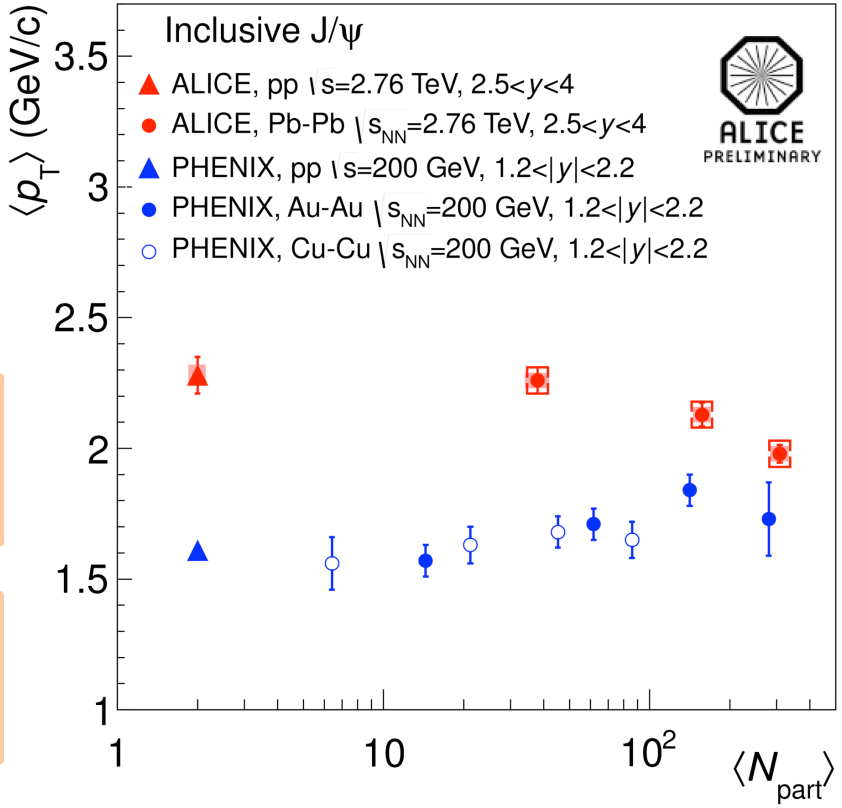
J/Ψ p_T distribution and $\langle p_T \rangle$ vs centrality

Comparison with lower energy results can be carried out by comparing $\langle p_T \rangle$ vs centrality.



J/Ψ $\langle p_T \rangle$ values are extracted from fits to $d^2N/dydp_T$ distribution by using this formula:

$$\frac{dN}{dydp_\perp} \propto \frac{p_\perp}{\left(1+\left(\frac{p_\perp}{p_0}\right)^2\right)^n}$$

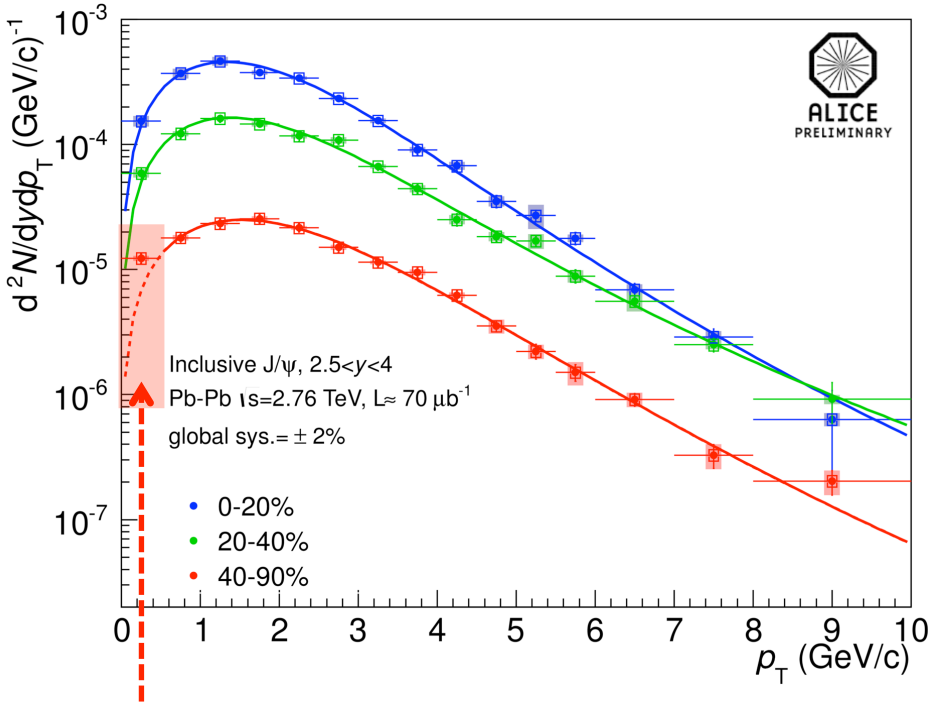


J/Ψ $\langle p_T \rangle$ from ALICE results decreases as a function of centrality while it is the contrary at lower energies.

Confirms that low p_T J/Ψ are less suppressed in central collisions
→ (re)combination ?

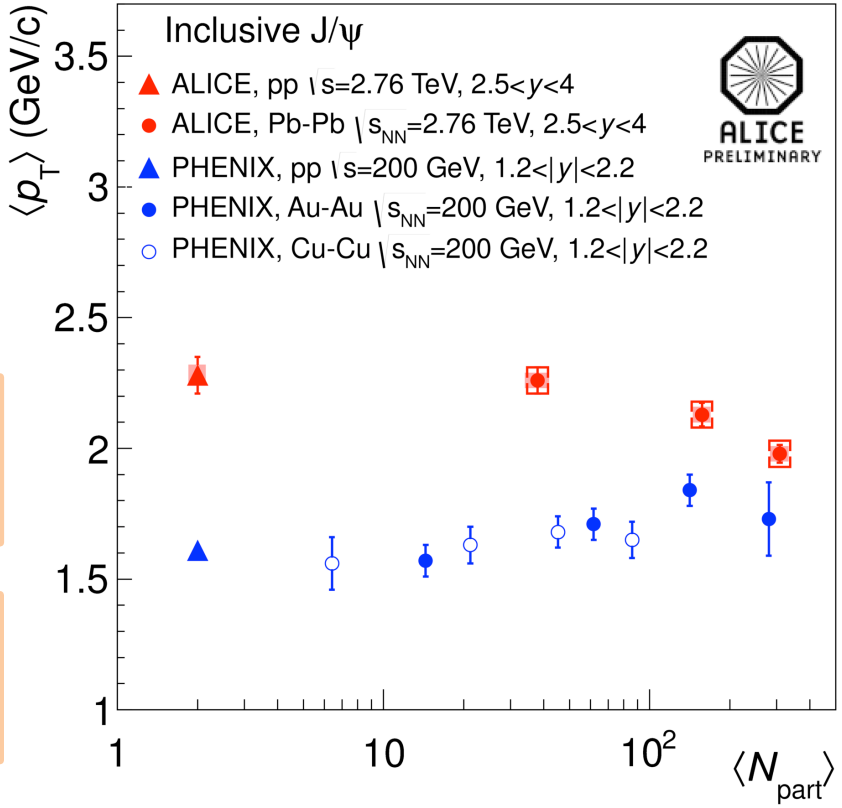
J/Ψ p_T distribution and $\langle p_T \rangle$ vs centrality

Comparison with lower energy results can be carried out by comparing $\langle p_T \rangle$ vs centrality.



J/Ψ $\langle p_T \rangle$ values are extracted from fits to $d^2N/dydp_T$ distribution by using this formula:

$$\frac{dN}{dydp_\perp} \propto \frac{p_\perp}{\left(1+\left(\frac{p_\perp}{p_0}\right)^2\right)^n}$$



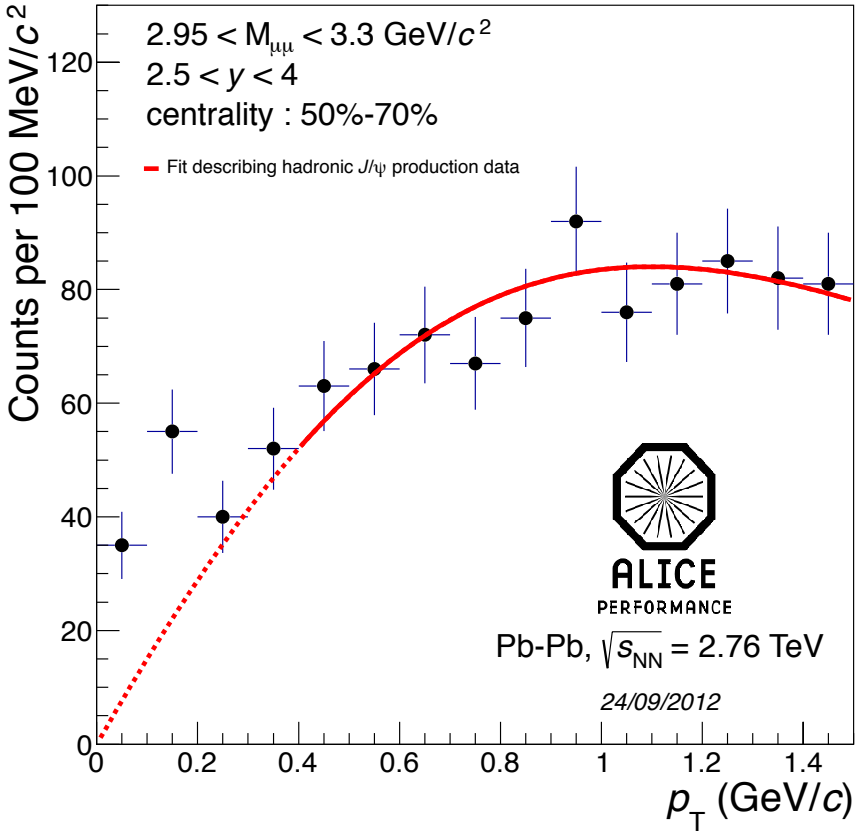
J/Ψ $\langle p_T \rangle$ from ALICE results decreases as a function of centrality while it is the contrary at lower energies.

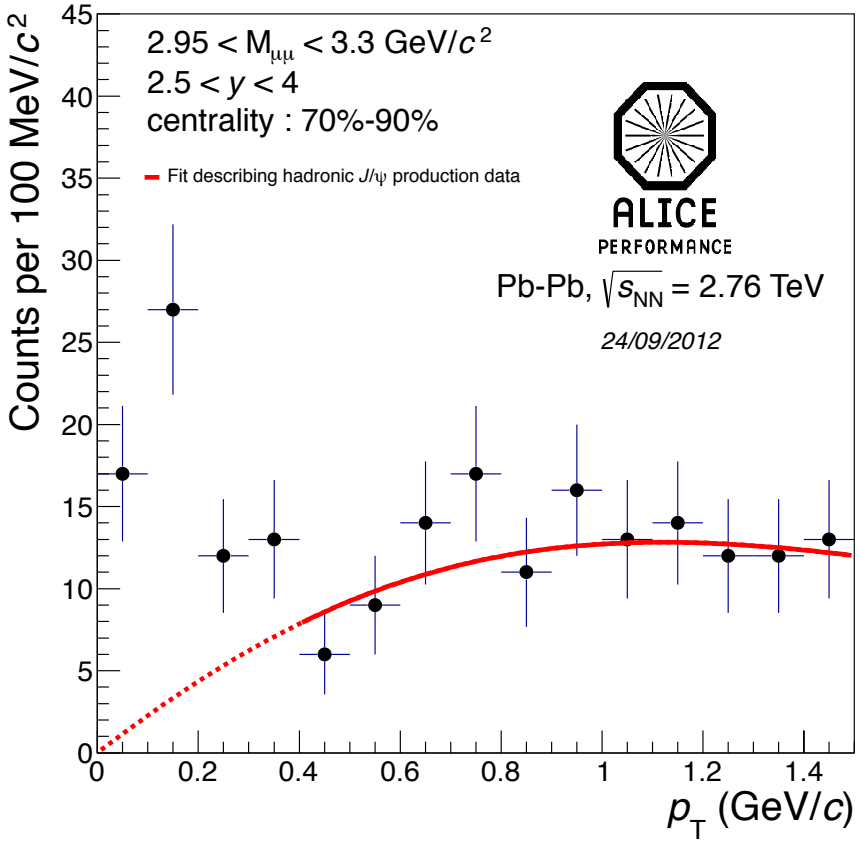
Discrepancy at very low p_T in peripheral collisions.

Confirms that low p_T J/Ψ are less suppressed in central collisions
→ (re)combination ?

Low p_T J/Ψ excess in nuclear collisions

Dimuon p_T distribution ($M_{\mu\mu}$ within $M_{J/\Psi} \pm 3\sigma$)



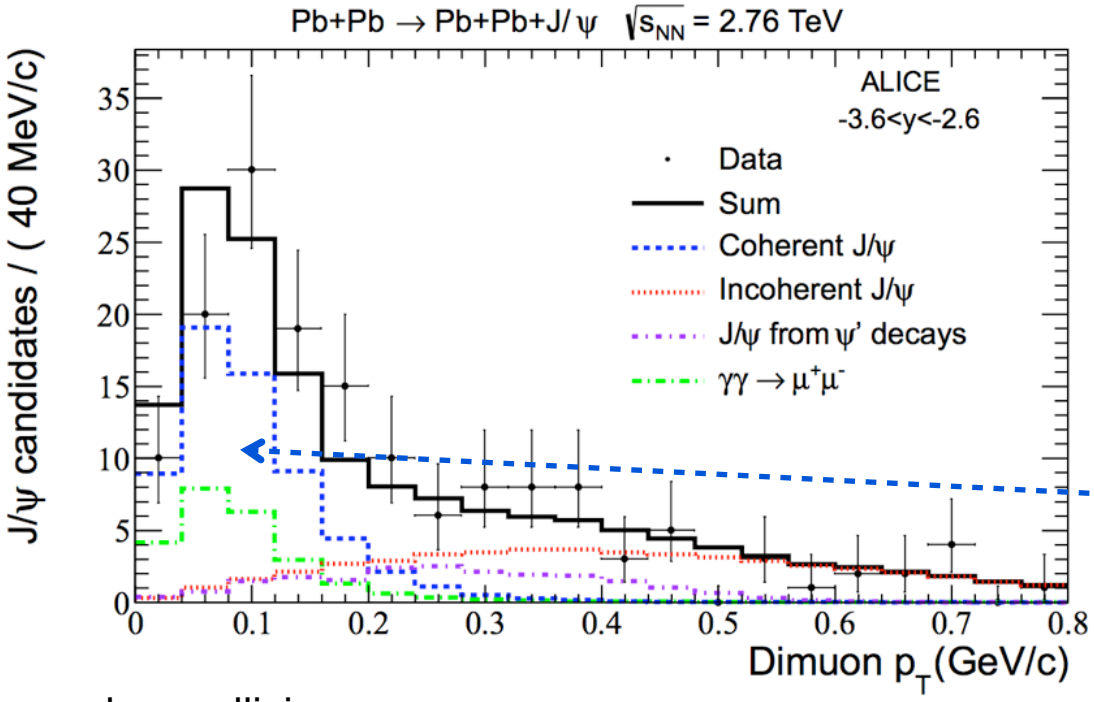


Compared to expected shape from J/Ψ hadro-production, an excess of *J/Ψ* is clearly visible at low p_T in semi-peripheral and peripheral collisions

→ *J/Ψ* photo-production could be at the origin

Caveat: At the moment a counting technique is used to extract the *J/Ψ* (quite reasonable approach, given the S/B).
However, we plan to perform a more detailed study, evaluating the *J/Ψ* yield after the background subtraction.

J/Ψ Photo-production in UPC



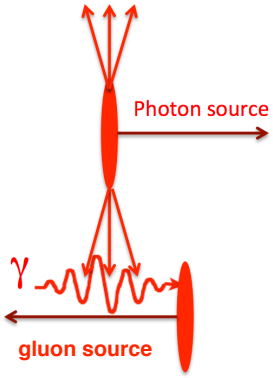
← J/Ψ production in Ultra-Peripheral Pb-Pb Collisions **[arXiv:1209.3715]**

Jaroslav ADAM
Saturday [148]

Coherent:
$\langle p_T^{J/\psi} \rangle$ ~ 60 MeV/c

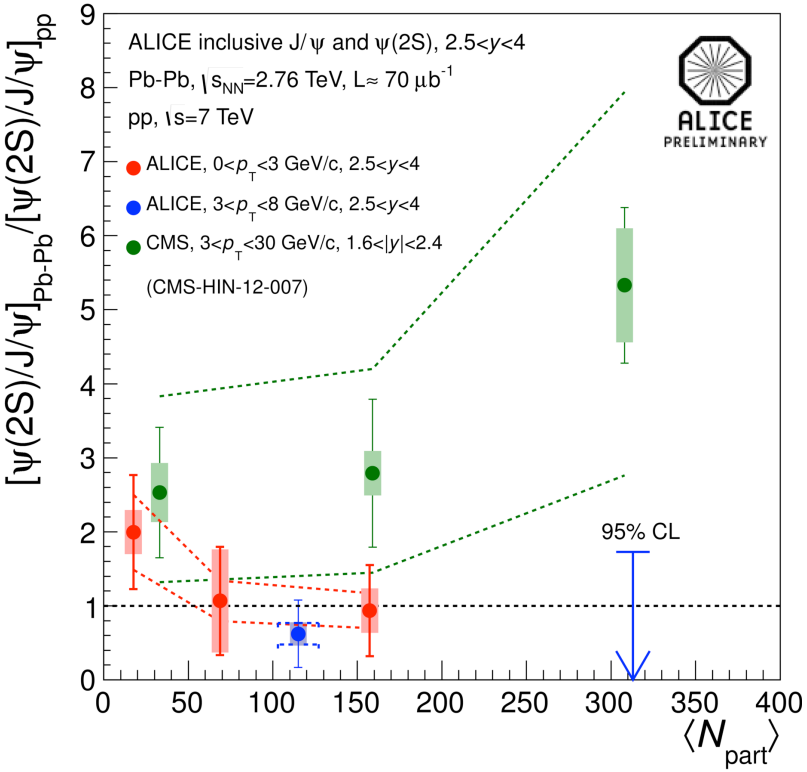
<u>In nuclear collisions:</u>

- ✓ Photo-production arise in the early stages of heavy-ion collision
- ✓ Coherent J/Ψ produced by photo-production mechanism have a very different p_T distribution compared to the otherwise produced J/Ψ
- ✓ The contribution from incoherently produced ψ′ is expected to give a negligible contribution for p_T < 0.3 GeV/c
- ✓ No X_c are photo-produced.

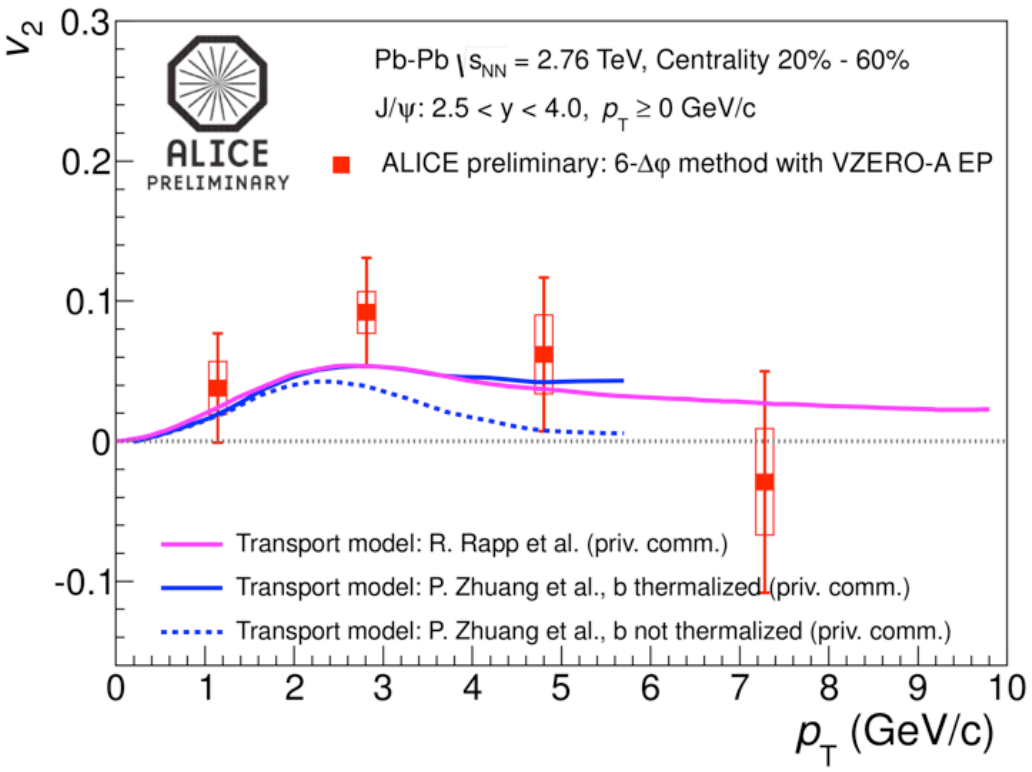


A suppression of the coherent photo-production in nuclear collisions could be a direct probe of color screening of this charmonium state at LHC.

Other very interesting ALICE measurements



Ψ(2S) over J/Ψ ratio from ALICE in central PbPb collisions does not show a large Ψ(2S) enhancement compared to pp.



Hint of non zero flow in semi-central collisions in p_T range [2;4] GeV/c with a significance of 2.2 σ.

Conclusions and perspectives

• The J/Ψ nuclear modification factor has been studied in detail in Pb-Pb collisions at mid and forward rapidity, down to p_T=0 :

- Lower suppression at low with respect to high p_T, with stronger p_T dependence for central events
- Models including *J/Ψ* production via (re)combination succeed in describing ALICE results in central collisions
- $\langle p_T \rangle$ vs $\langle N_{part} \rangle$ measured in ALICE shows an opposite behaviour with respect to lower energy measurements: a decrease is observed.

• Clear excess of low p_T *J/Ψ* in peripheral and semi-peripheral collisions is observed.

- It seems that photo-production at LHC could be at the origin.
- Could be a probe to study color-screening suppression of the *J/Ψ.*

• A deeper understanding requires a precise knowledge of cold nuclear matter effects:

- Looking for pA at LHC in 2013!

Thanks