Inclusive J/ψ production in pp and A-A collisions with ALICE

Raúl Tonatiuh Jiménez Bustamante
on behalf of the ALICE Collaboration

XIIIth Quark confinement and the Hadron Spectrum
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ALICE

UNIVERSITÄT HEIDELBERG
ZUKUNFT SEIT 1386

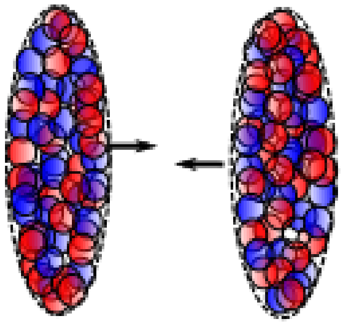
GSI

Outline

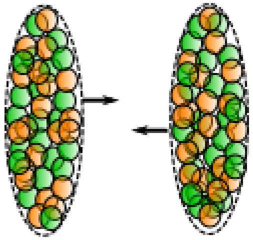
- Introduction and previous measurements

- Results: J/ψ production
  - vs multiplicity in pp collisions at $\sqrt{s}$= 13 TeV

  - in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV



  - in Xe-Xe collisions at $\sqrt{s_{NN}}$ = 5.44 TeV

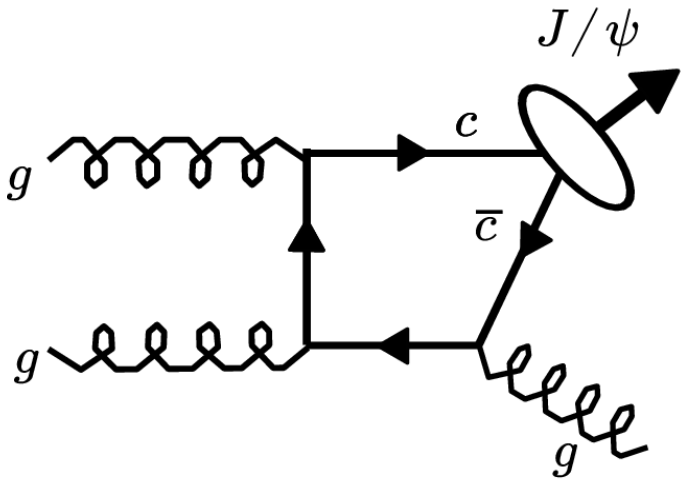


- Conclusions and outlook

J/ψ production in pp collisions

Hadronic J/ψ production can be factorized in 2 stages:

- $c\bar{c}$-quarks production via hard scattering
- Hadronization part **poorly understood**



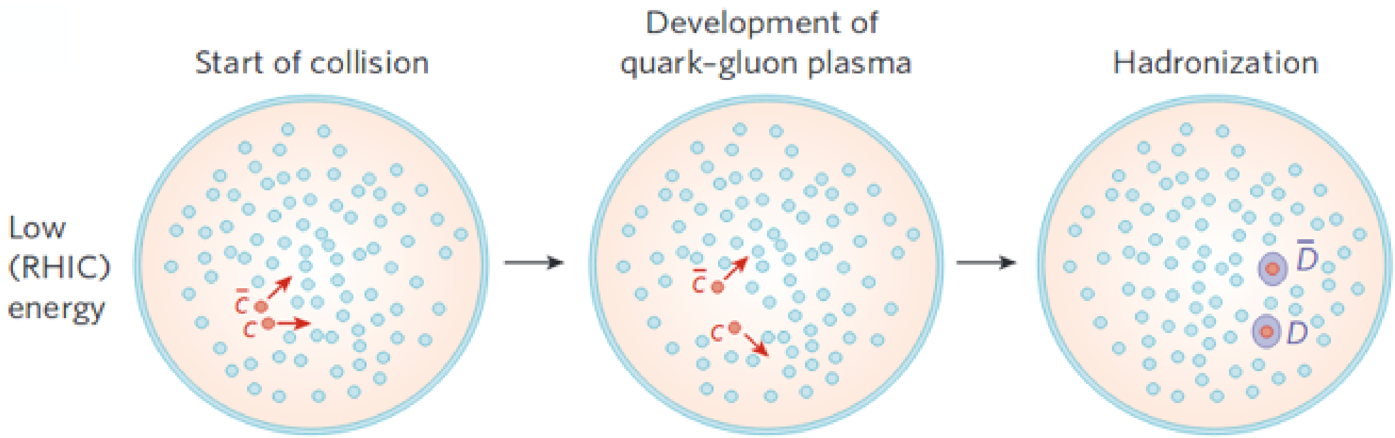
High multiplicity pp collisions:

- Multi-parton interactions (MPI) included in the models to describe high multiplicities
- Collective behaviour in pp collisions? PYTHIA → color reconnection mechanisms
  EPOS → hydro

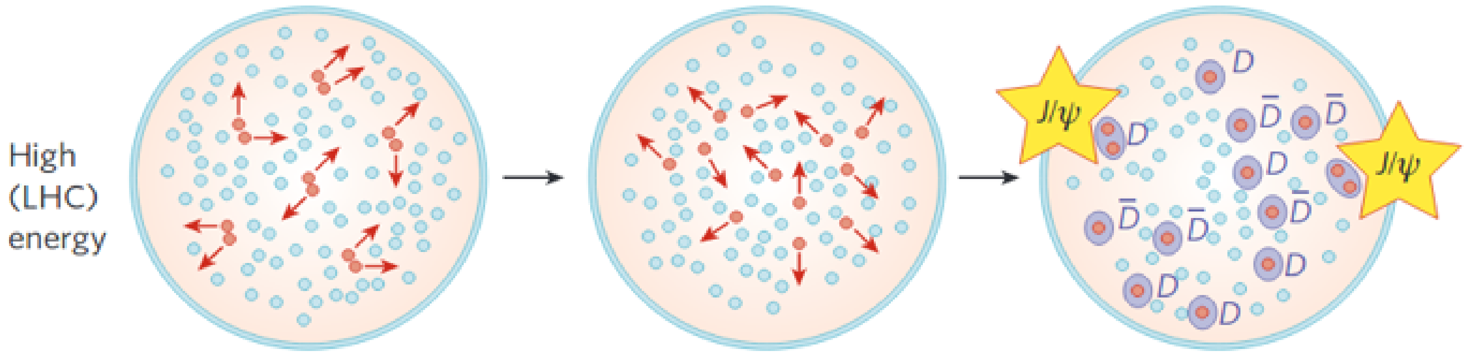
J/ψ production in A-A collisions

Initial idea: suppression of J/ψ production as a probe of deconfinement in heavy-ion collisions [1]

Temperature dependent **sequential suppression** of charmonium states due to the different binding energies [2]



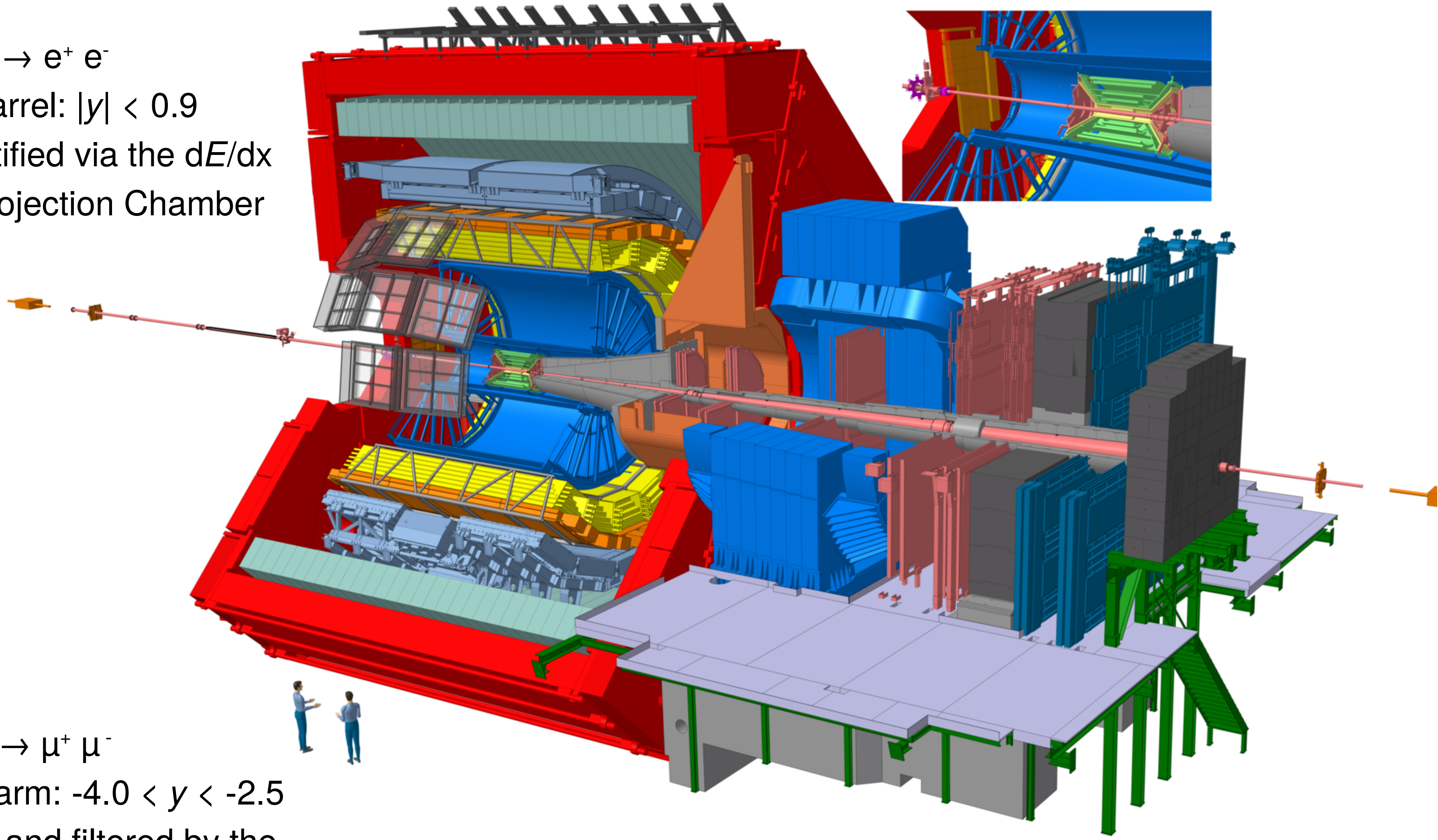
Large $c\bar{c}$-cross section at LHC energies → enhanced charmonium production via **(re-)generation** at hadronization or during the QGP phase [3],[4]



[1] T.Matsui, H.Satz, Phys Lett B.178 (1986) 416
[2] F.Karsch, H. Satz, Z.Phys. C51 (1991)
[3] P.Braun-Munzinger, J. Stachel, Phys. Lett. B490 (2000) 196
[4] R. Thews et al, Phys. Rev. C 63 054905 (2001)

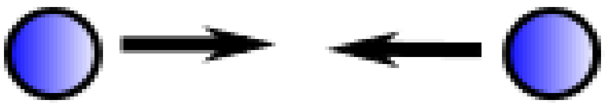
ALICE detector

$J/\psi \rightarrow e^+ e^-$
Central barrel: $|y| < 0.9$
Electrons identified via the dE/dx in the Time Projection Chamber



$J/\psi \rightarrow \mu^+ \mu^-$
Forward muon arm: $-4.0 < y < -2.5$
Muons tracked and filtered by the muon spectrometer

pp collisions at $\sqrt{s}$= 13 TeV

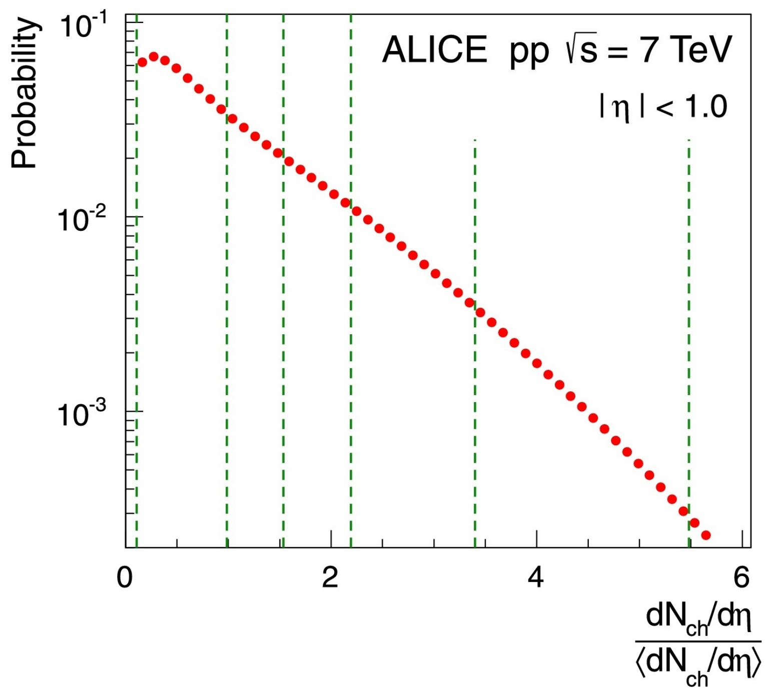


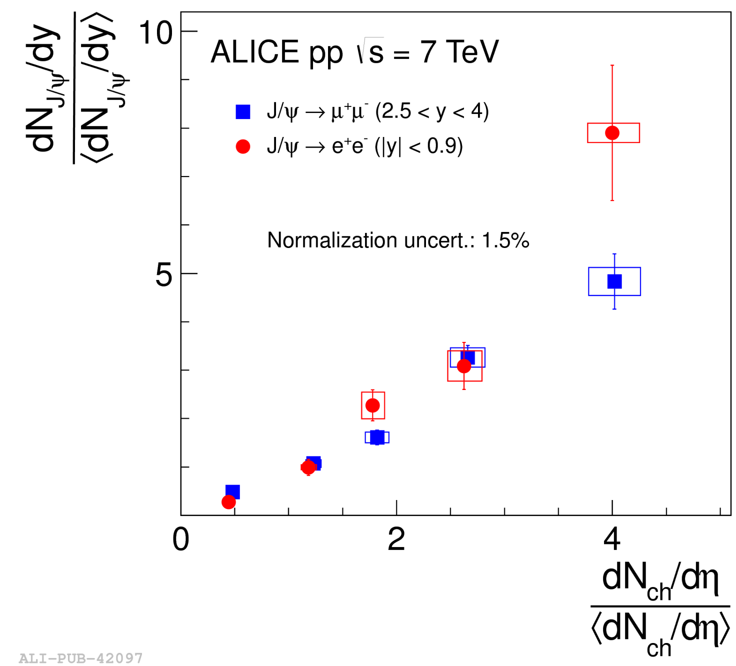
Results:

J/ψ vs multiplicity

Previous measurement at $\sqrt{s}$ = 7 TeV

The observable: relative J/ψ production vs relative charged-particle multiplicity





Advantages: full data driven analysis

Easier to compare at different energies and systems

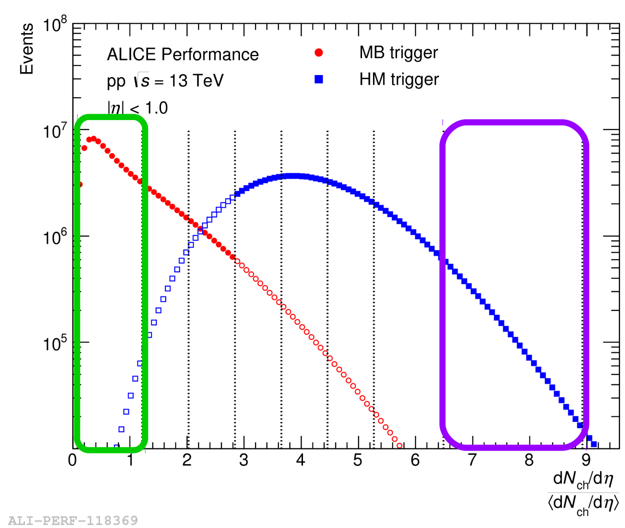
Approximately linear increase of the relative J/ψ yield as a function of relative multiplicity

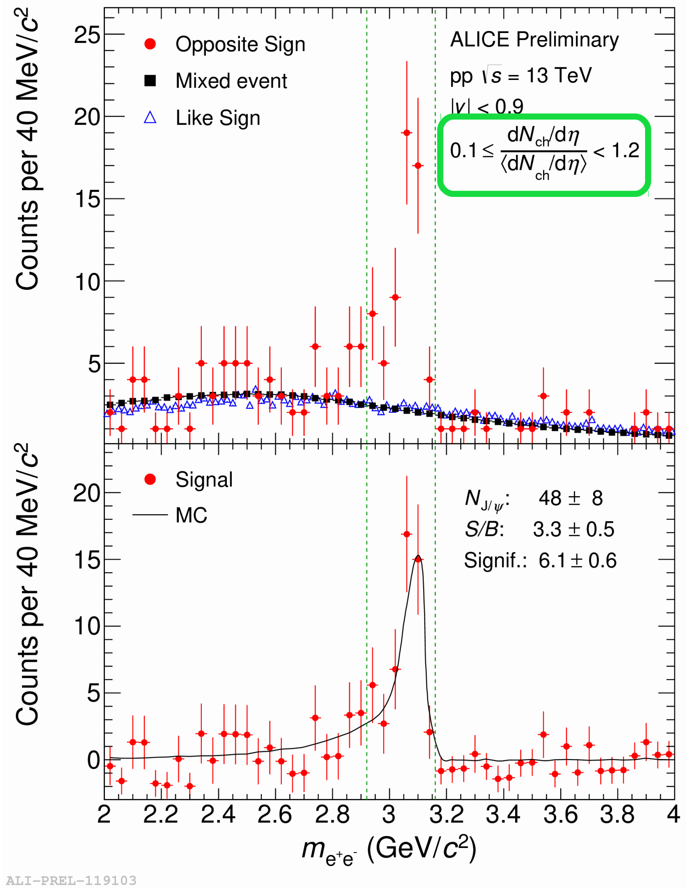
Similar increase at mid and forward-rapidity

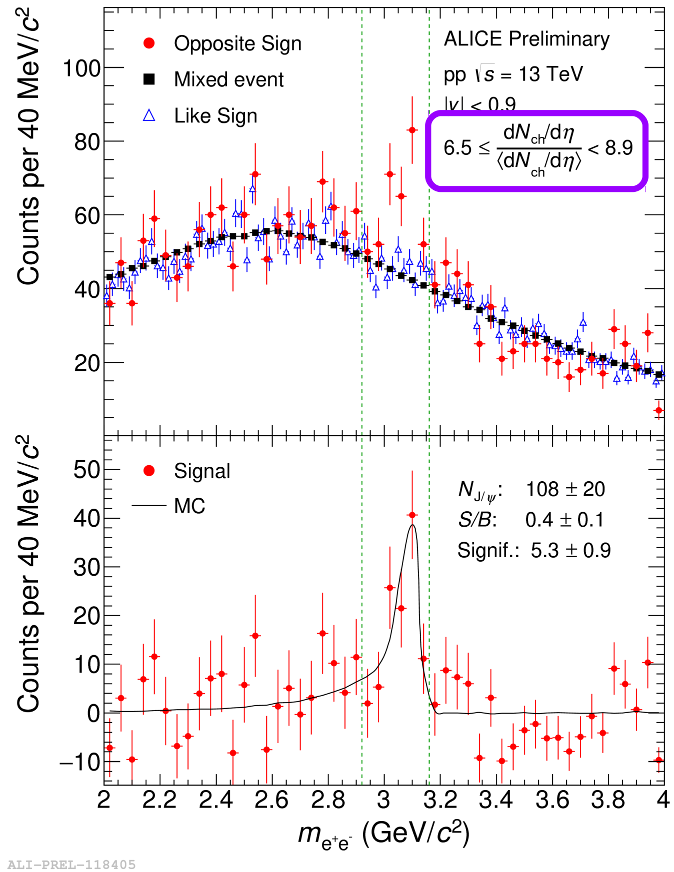
[1] ALICE,, Phys Lett B.712 (2012) 165-175

pp collisions at $\sqrt{s}$ = 13 TeV

Signal extaction in 8 different multiplicity intervals. Reaching up to $\frac{dN_{ch}/d\eta}{\langle dN_{ch}/d\eta \rangle} = 7$

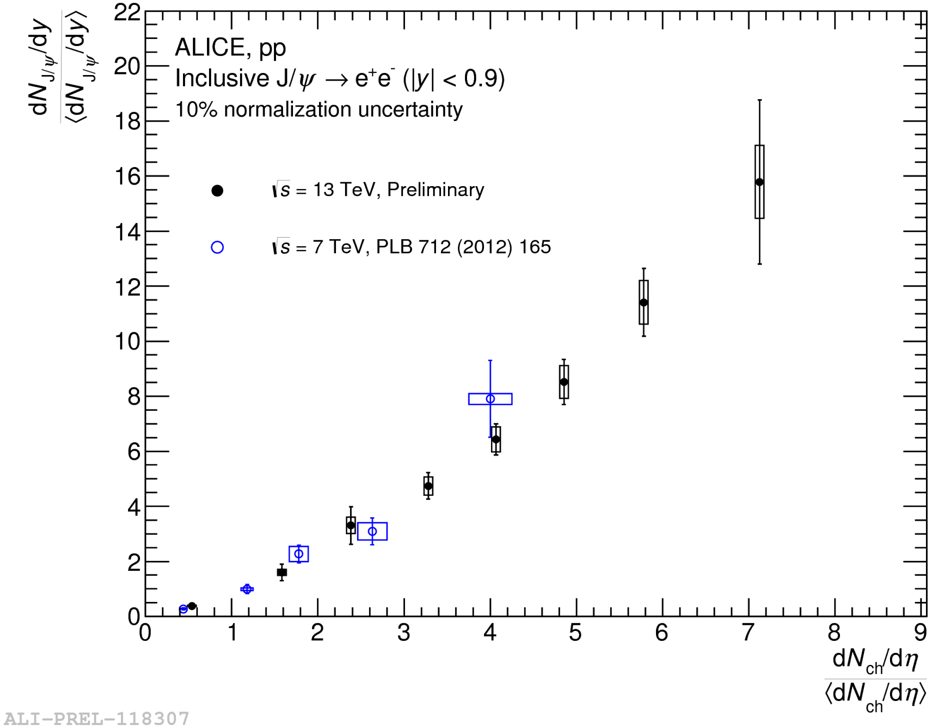






Background description with mixed event and like-sign methods

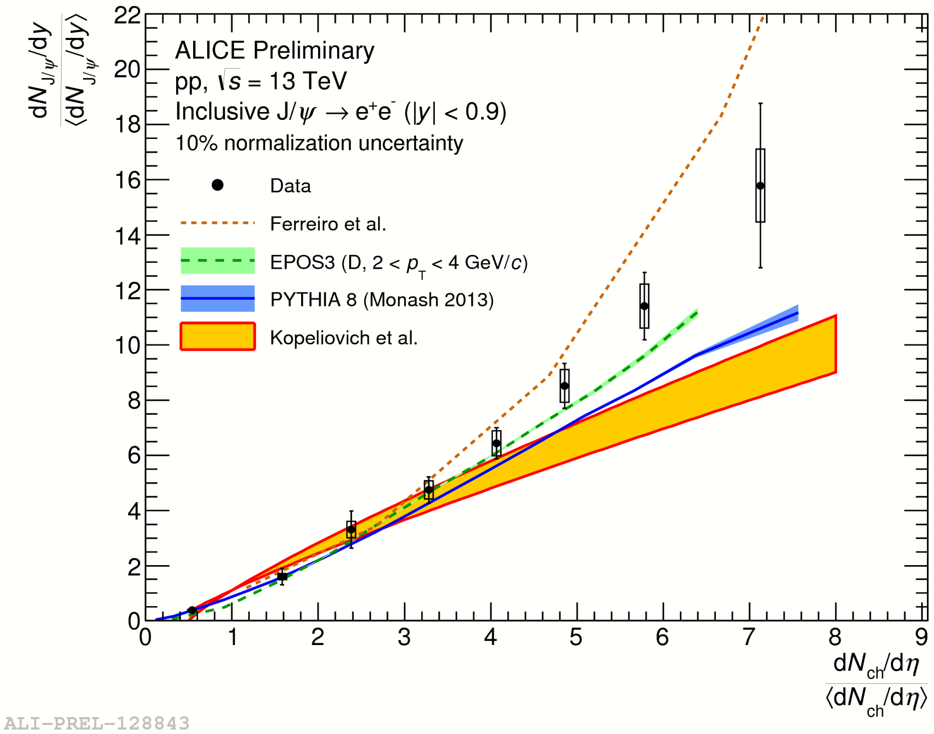
J/ψ vs multiplicity



Extended multiplicity up to 2 times w.r.t $\sqrt{s}$ = 7 TeV

Clear stronger than linear increase

J/ψ vs multiplicity



Extended multiplicity up to 2 times w.r.t $\sqrt{s}$ = 7 TeV

Clear stronger than linear increase

Models describe the enhancement with multiplicity:

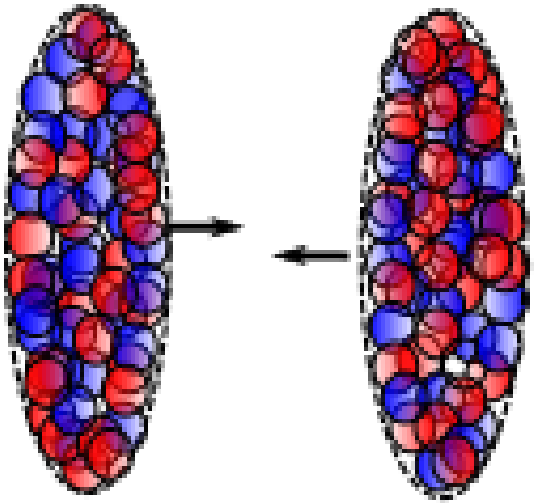
PYTHIA: Initial hard processes also in MPIs

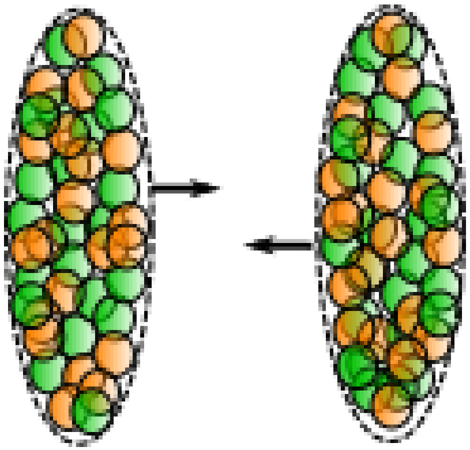
EPOS: Hydrodynamic evolution of the system

Kopeliovich: Contribution of higher Fock states to reach high multiplicities

Percolation : Overlapping strings → saturation of soft particle production, hard probes unaffected.

A-A collisions

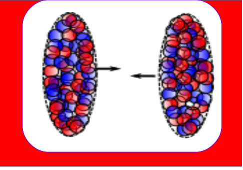




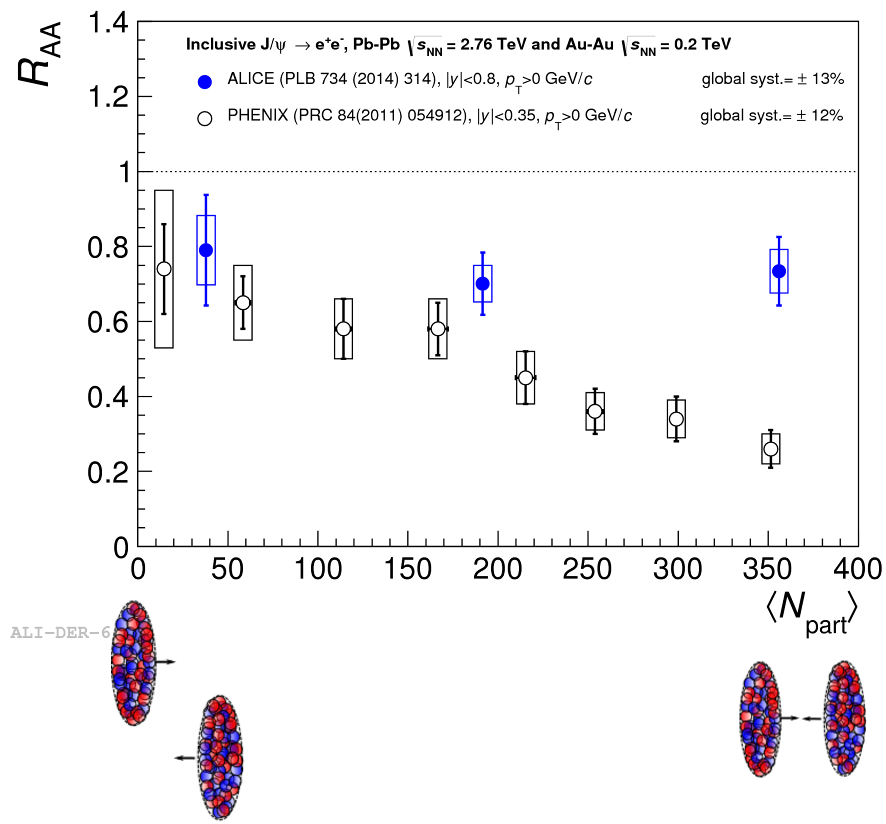
Results:

Inclusive J/ψ R_{AA} in Pb-Pb and Xe-Xe collisions

Previous results in A-A collisions



Nuclear modification factor $$R_{AA} = \frac{Y^{Pb-Pb}_{J/\psi}}{\langle T_{AA} \rangle \sigma^{pp}_{J/\psi}}$$



ALICE Pb-Pb at $\sqrt{s_{NN}}$ = 2.76 TeV

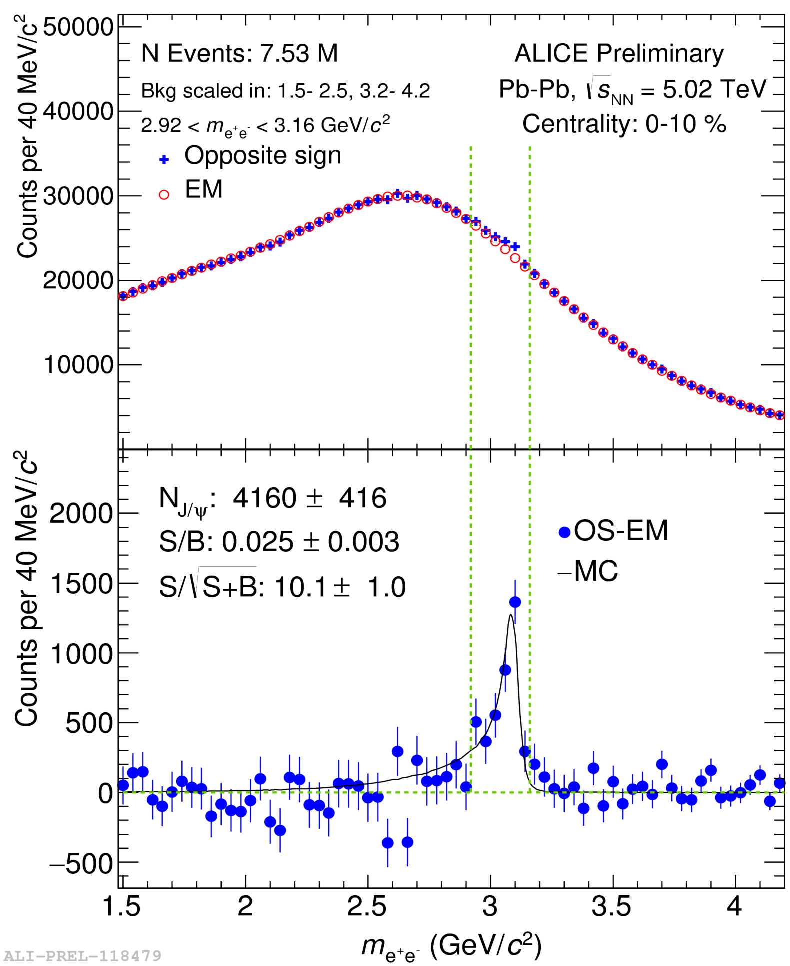
PHENIX Au-Au at $\sqrt{s_{NN}}$ = 0.2 TeV

Smaller suppression for central events in ALICE compared to PHENIX

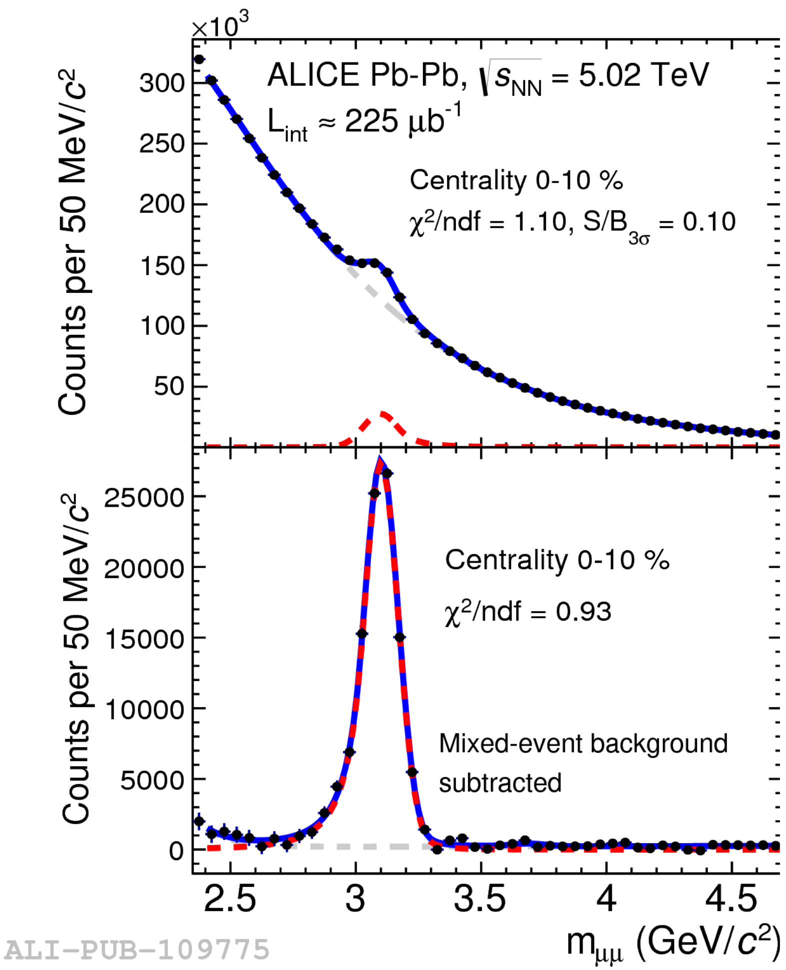
Indication of **new production mechanism→ (re)generation for charmonium** at LHC energies

Signal extraction in different centrality classes

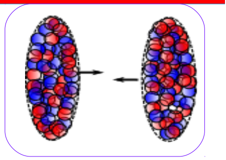
$|y| < 0.9$



$-4 < y < -2.5$



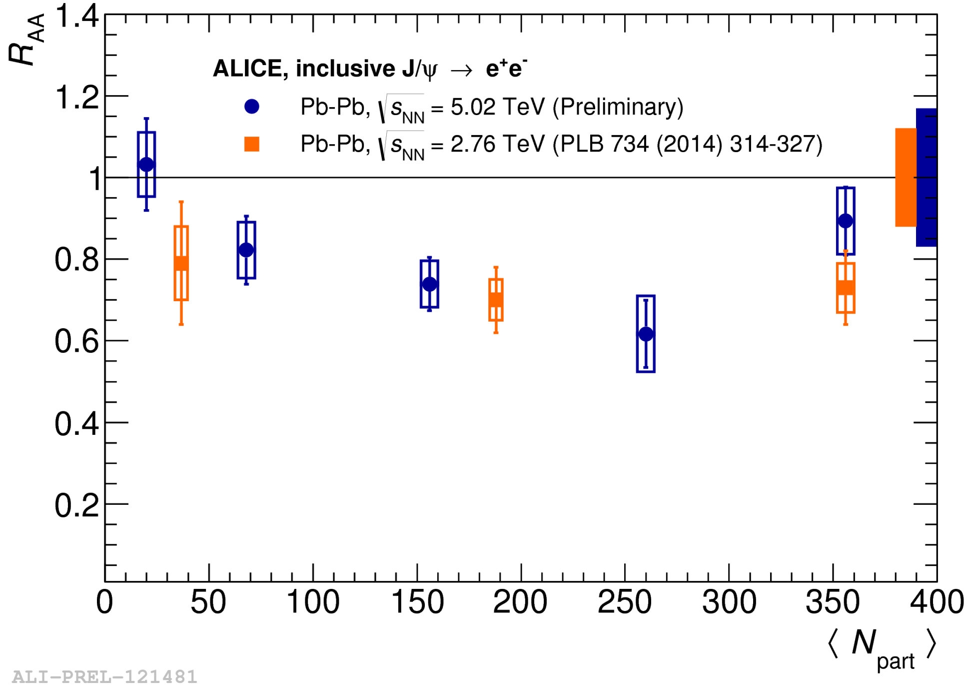
J/ψ R_{AA} versus centrality in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV



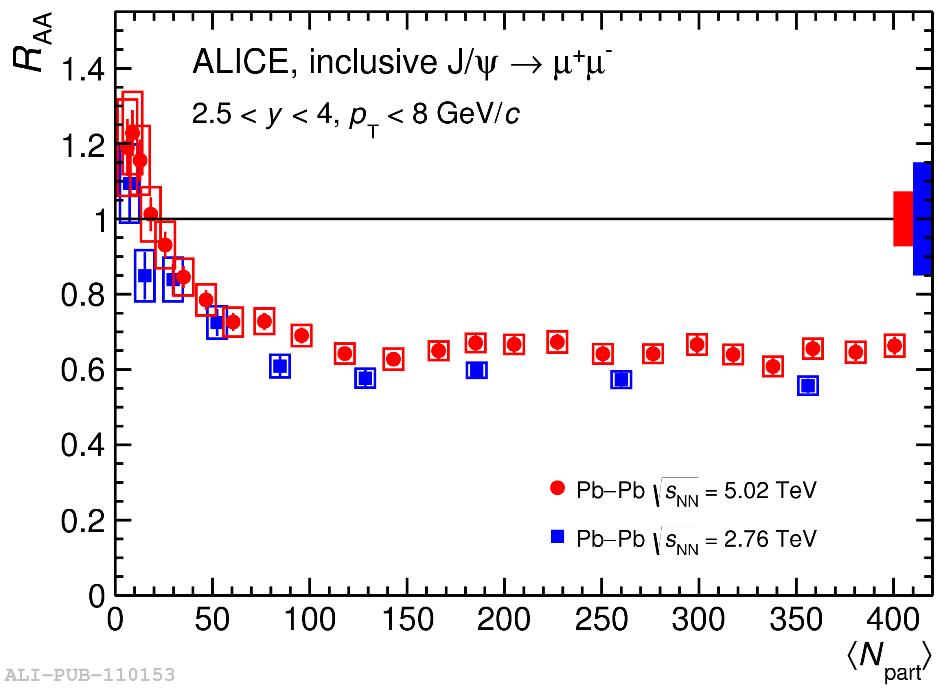
No significant dependence on centrality for $\langle N_{part} \rangle$ larger than 50

Slightly higher R_{AA} values at $\sqrt{s_{NN}}$= **5.02 TeV** compared to $\sqrt{s_{NN}}$= **2.76 TeV** measurement, compatible within uncertainties.

|y| < 0.9



-4 < y < -2.5



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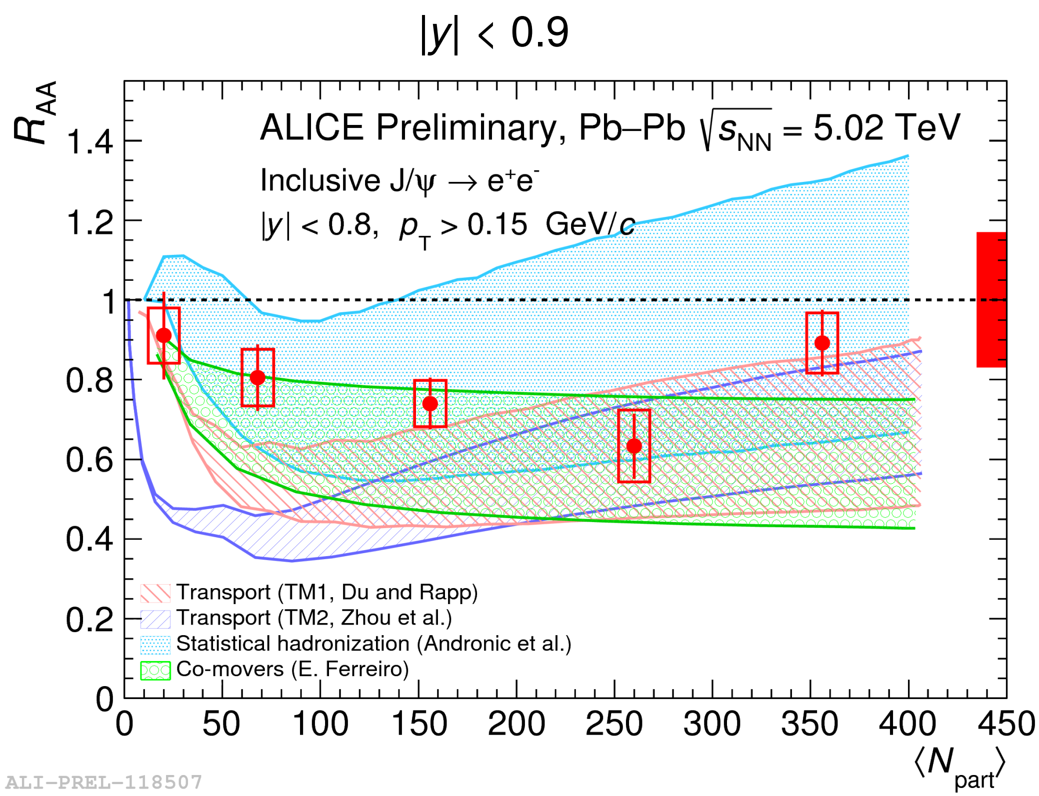
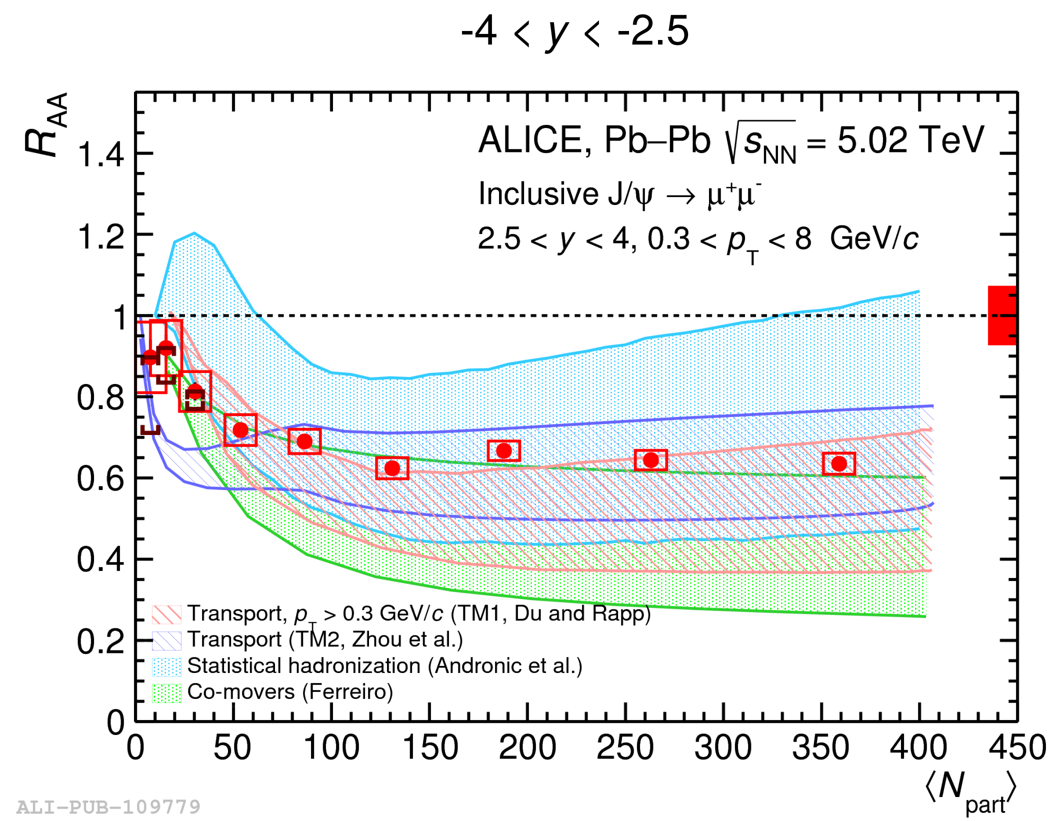
Comparison to models





Most of the models in agreement with the data within the large uncertainties

Uncertainties do not allow any discrimination between the statistical hadronization and transport models

Precise charm cross section measurement and more differential analyses needed

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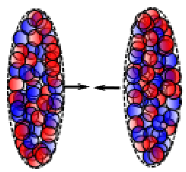
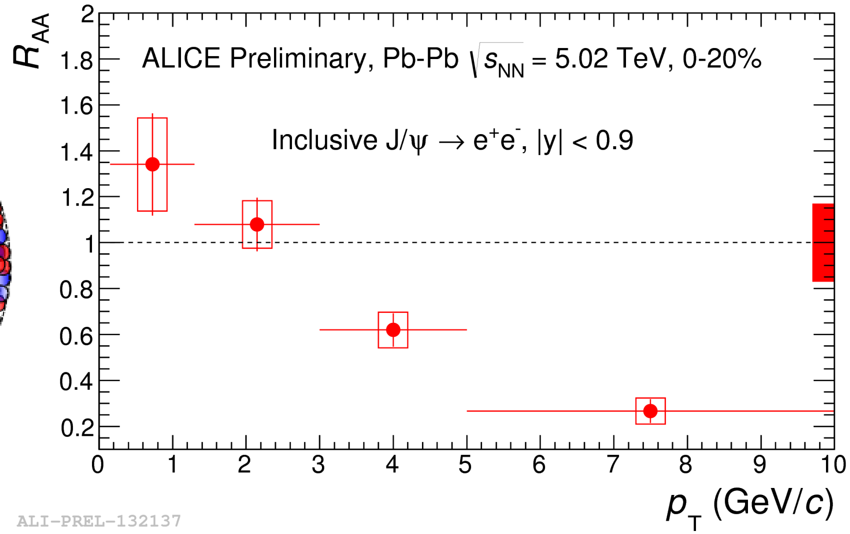
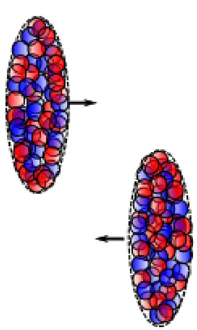
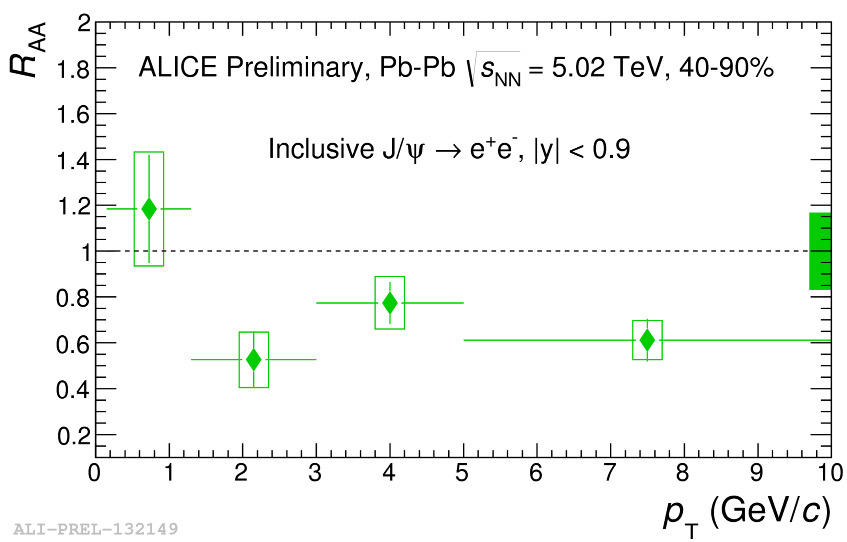
Increase of the R_{AA} at low p_T compatible with (re)generation scenario

Stronger **suppression at high p_T** in central collisions due to parton energy loss





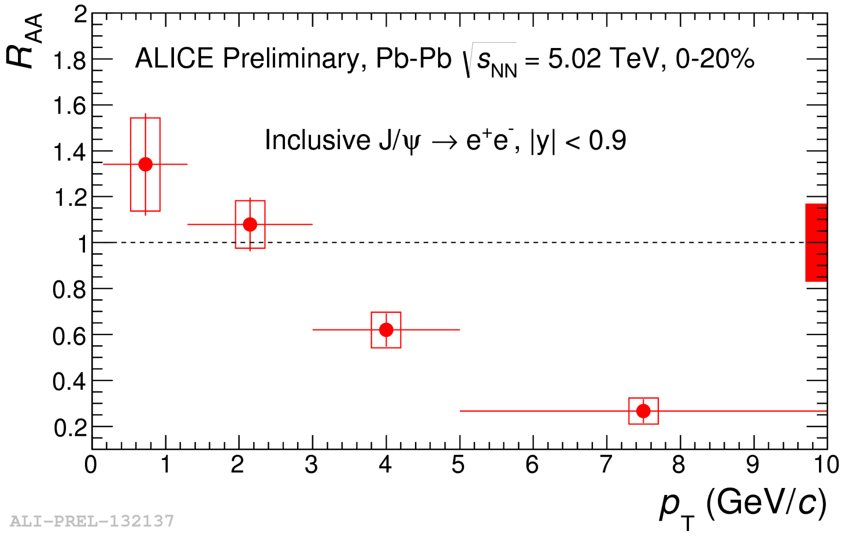


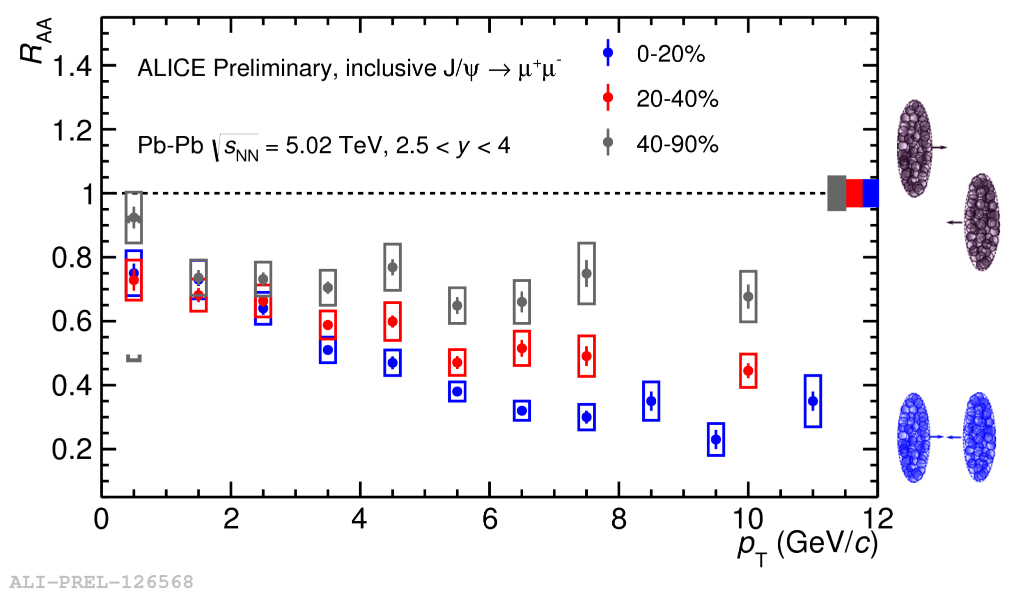


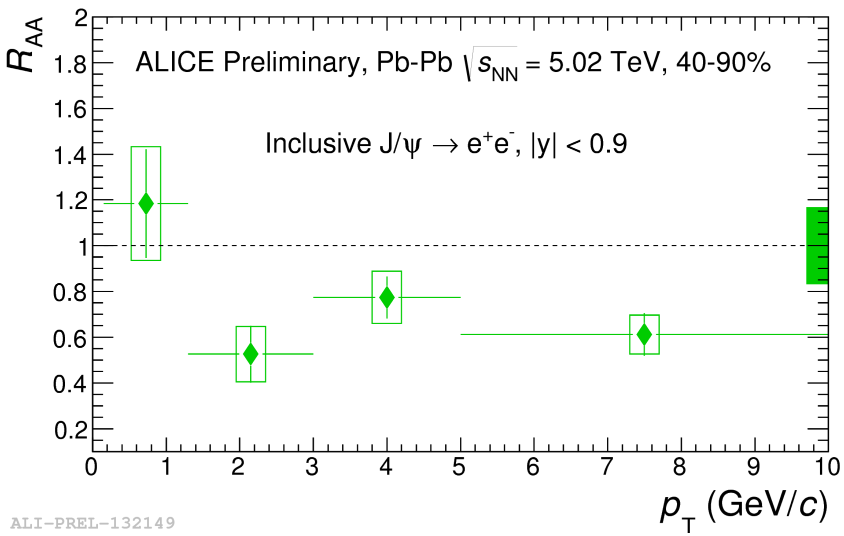
J/ψ R_{AA} versus transverse momentum

Increase of the R_{AA} at low p_T compatible with (re)generation scenario

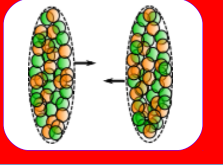
Stronger **suppression at high p_T** in central collisions due to parton energy loss



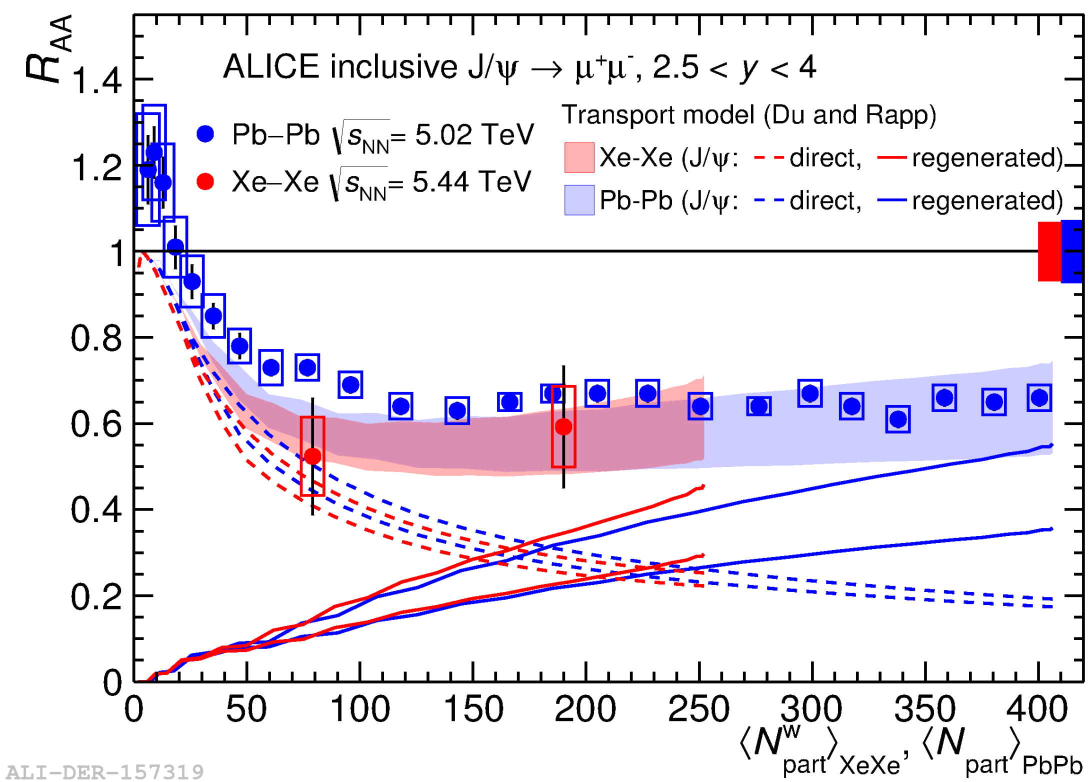




Xe-Xe collisions at $\sqrt{s_{NN}}$ = 5.44 TeV



J/ψ R_{AA} versus centrality at forward rapidity:



-A_{Xe} = 129, $L_{int} \approx 0.34\ \mu b^{-1}$

-A_{Pb} = 208, $L_{int} \approx 225\ \mu b^{-1}$

•R_{AA} results of Xe–Xe and Pb–Pb agree within uncertainties

➔ Similar $\sqrt{s_{NN}}$ and $\langle N_{part} \rangle$ lead to similar relative contributions of suppression and regeneration

ALICE Collaboration arXiv:1805.04383

Conclusions

J/ψ vs multiplicity in pp collisions

- Steep increase of relative J/ψ yield with event multiplicity
- Qualitatively **well described by different models**

J/ψ production in A-A collisions

- Similar R_{AA} values in Pb-Pb at $\sqrt{s_{NN}}$ = 2.76 and 5.02 TeV
- Compatible J/Ψ R_{AA} in Xe-Xe and Pb-Pb collisions
- Maximum of the R_{AA} towards low p_T (< 4 GeV/c) **in compatibility with (re)generation scenarios**

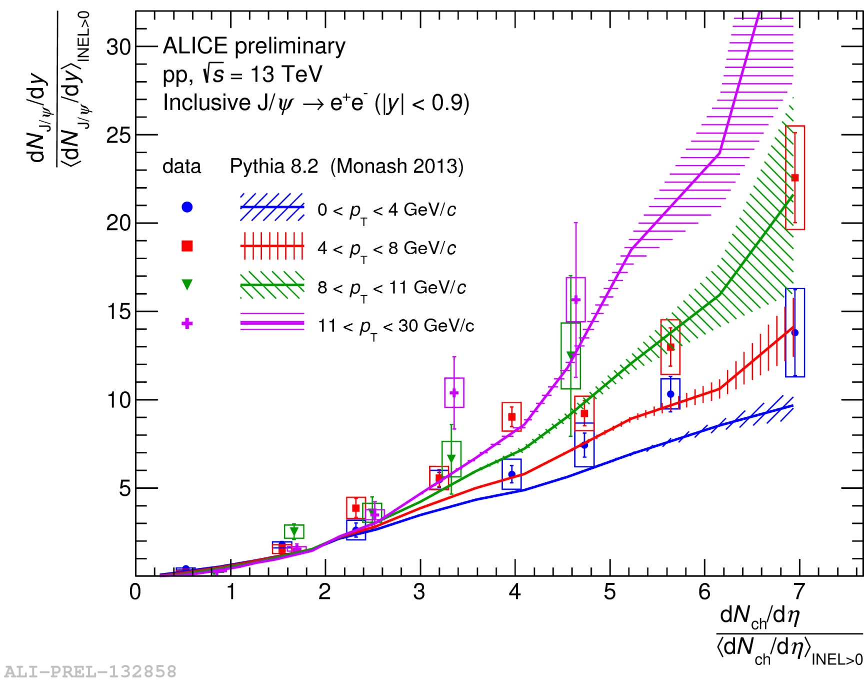
Outlook

Outlook:

- Study possible multiplicity estimator bias
- Improvement on the pp reference with 2017 data
- Higher statistics in Pb-Pb data at the end of the year
- Distinction among the different models will come in LHC-Run 3 $\rightarrow$ $\psi(2S)$ / J/ψ

Spares

J/ψ vs multiplicity



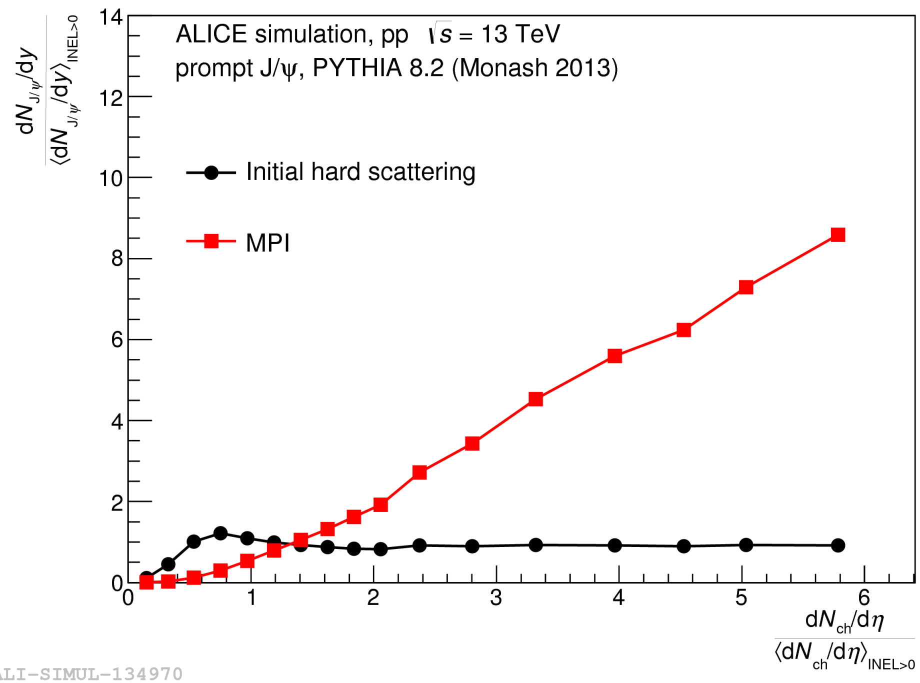
Relative J/ψ yields vs multiplicity in different p_{T} intervals.

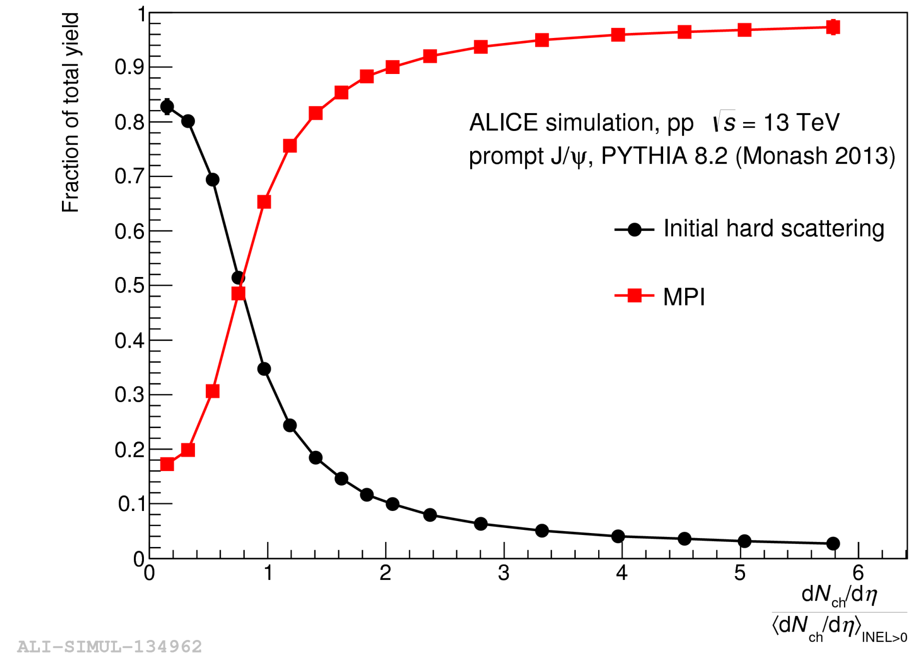
Extended high p_{T} (up to 30 GeV/*c*) using EMCAL

The steepness of the dependence increases strongly with the J/ψ p_{T}

PYTHIA 8 qualitatively describes the trend

PYTHIA: J/ψ production mechanisms





Contributions from initial hard scattering approximately multiplicity independent

MPI contributions dominate the high **multiplicity**

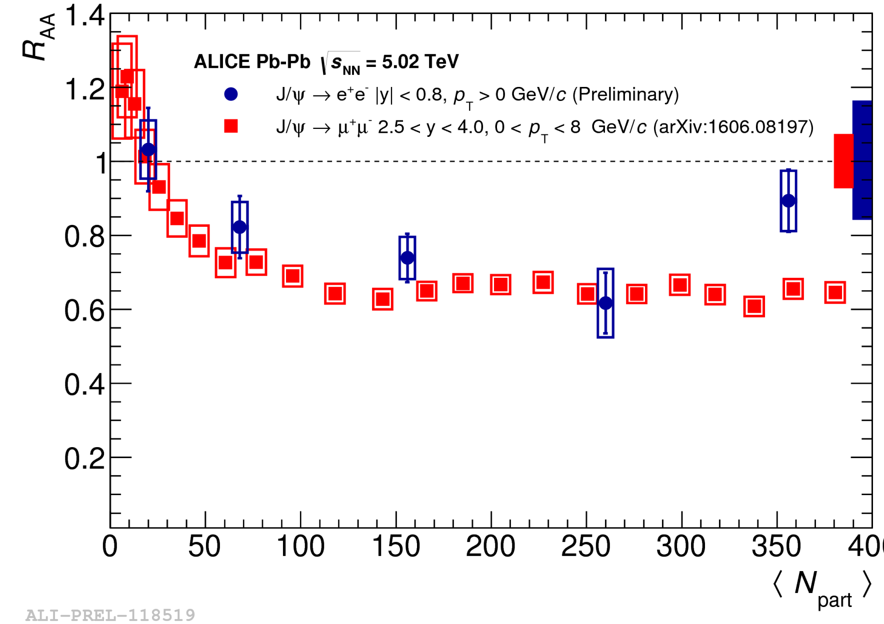
Inclusive R_{AA} vs rapidity

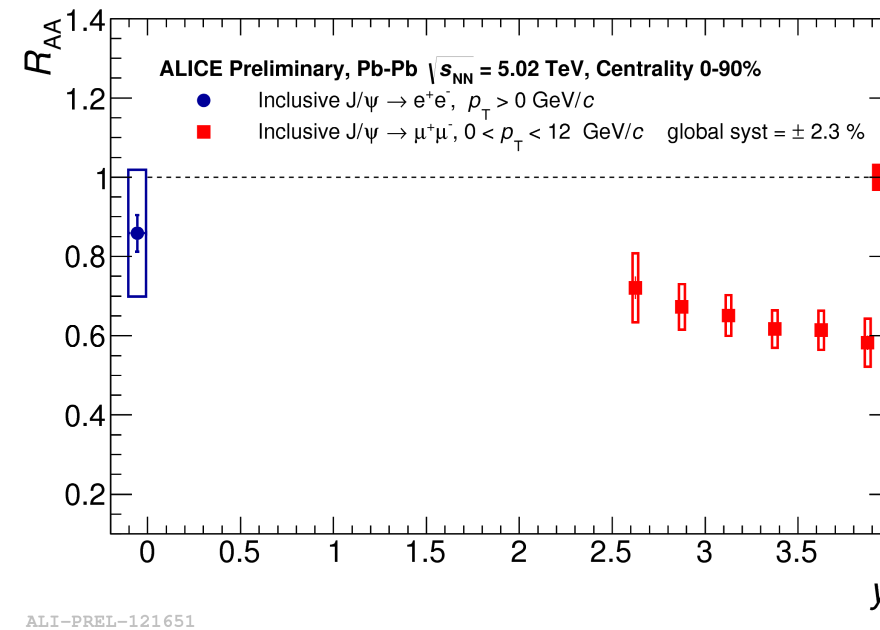
R_{AA} measurements vs centrality are consistent at mid- and forward-rapidity

Small increase of the R_{AA} in the most central collisions w.r.t forward rapidity

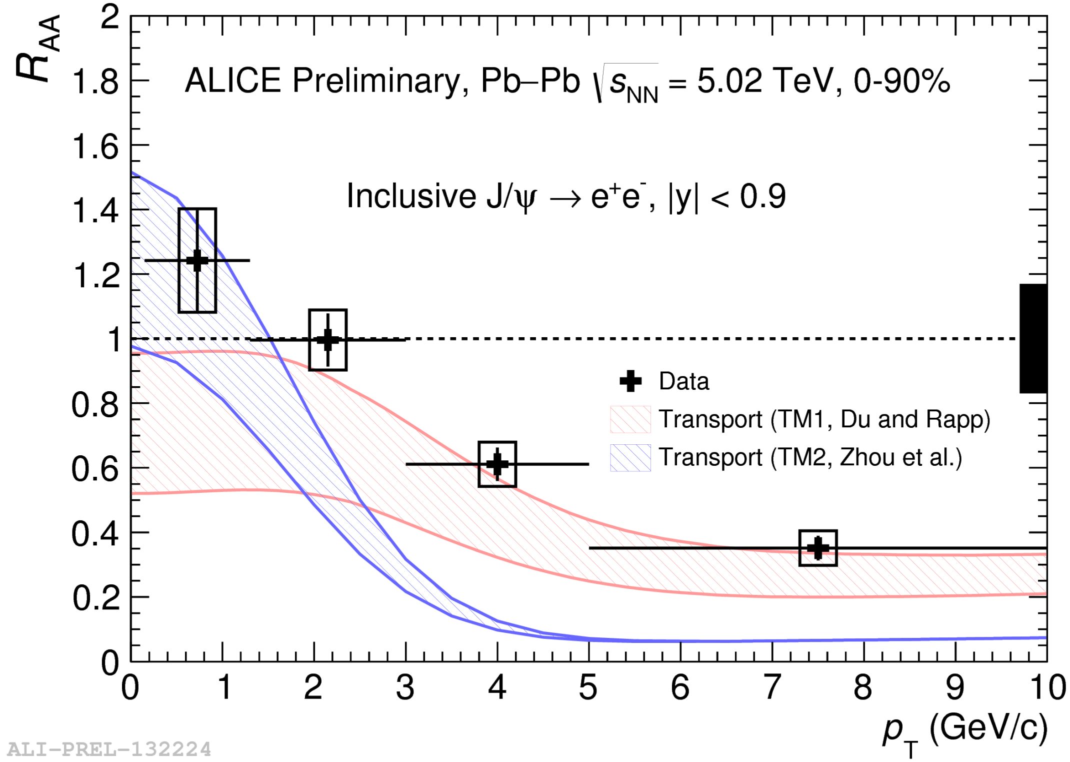
Still compatible with fluctuations

Hint of enhanced J/ψ production towards mid-rapidity





J/ψ p_T spectra vs models



Transport models describe the data with **TM1**[1] describe the data within uncertainties. **TM2**[2] at high p_T misses the quantitative description.

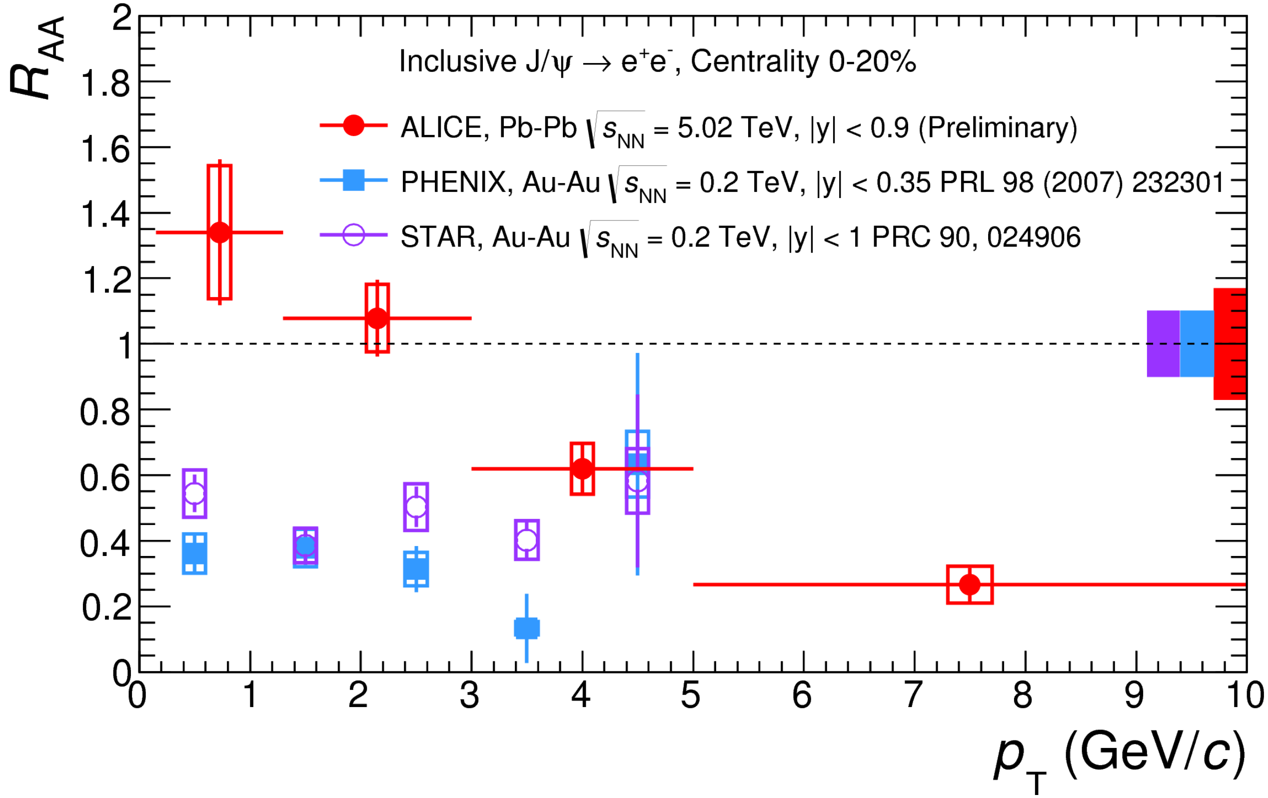
p_T spectra comparisson would be interesting to compare. ...

J/ψ p_T spectra at different energies

The J/ψ production due to (re)generation dominates at low p_T

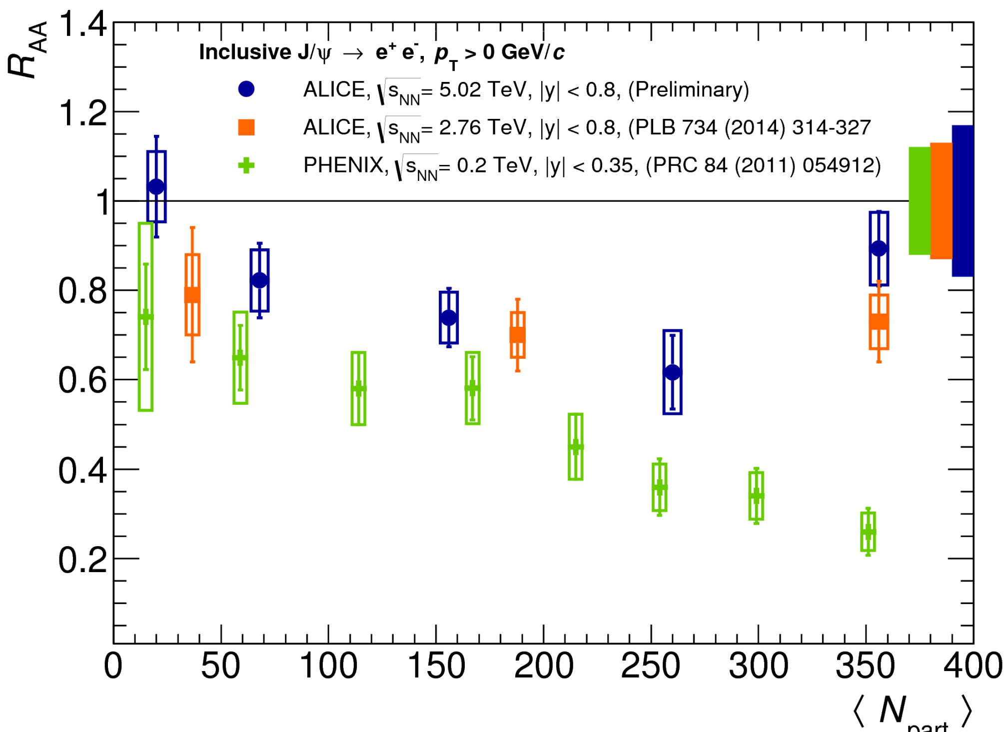
Striking difference at LHC energies in comparison to RHIC (STAR & PHENIX)

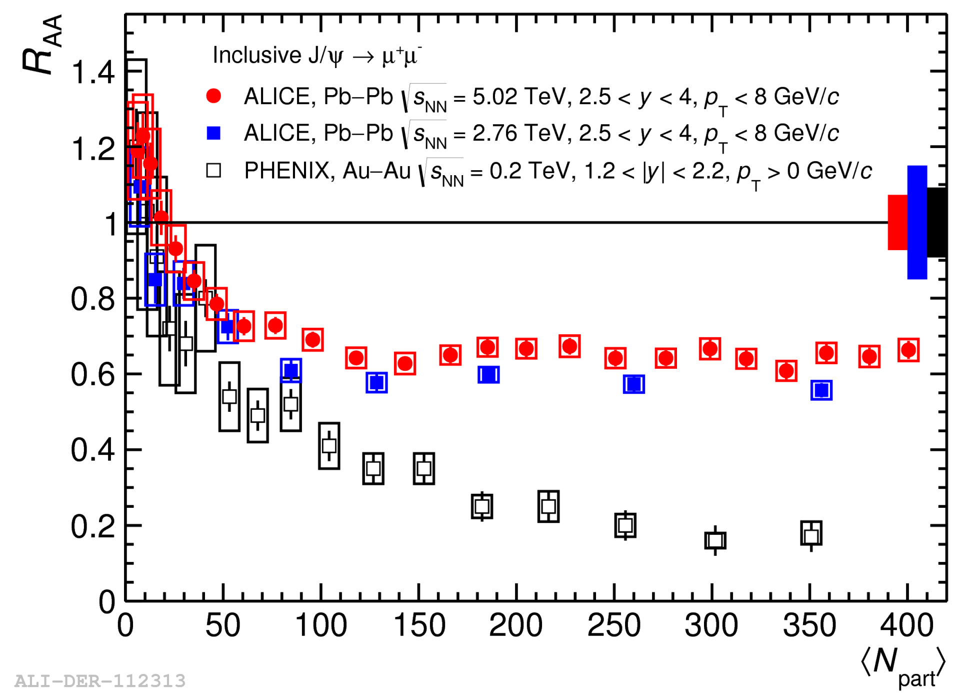
Suppression at high p_T attributed to charm energy loss in QGP



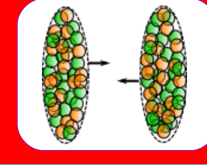
J/ψ R_{AA} versus centrality in Pb-Pb collisions at sNN 5.02 TeV

$\sigma^{pp}_{J/\psi}$: **Interpolation** of J/ψ measurements at mid-rapidity for different collision energies $\sqrt{s}$ = 0.2 [1], 1.96 [2], 2.76 [3] and 7 [4] TeV

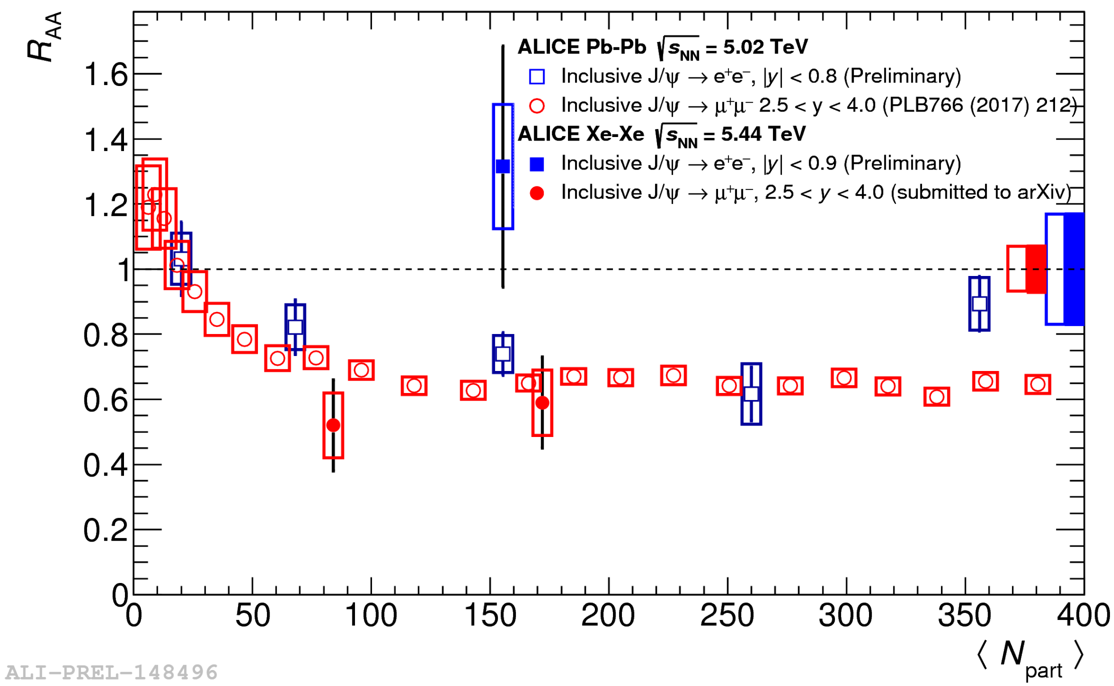




[1]PHENIX, Phys. Rev. Lett. 98, 232301 (2007)
[2]CDF, Phys. Rev. D 71, 032001 (2005)
[3]ALICE, Phys. Lett. B 718, 295 (2012)
[4]ALICE, Physics Lett. B 718, 692 (2012)



J/ψ R_{AA} versus centrality:



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