Quarkonium production measurement in Pb-Pb collisions at forward and mid rapidity with the ALICE experiment

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Rencontres QGP

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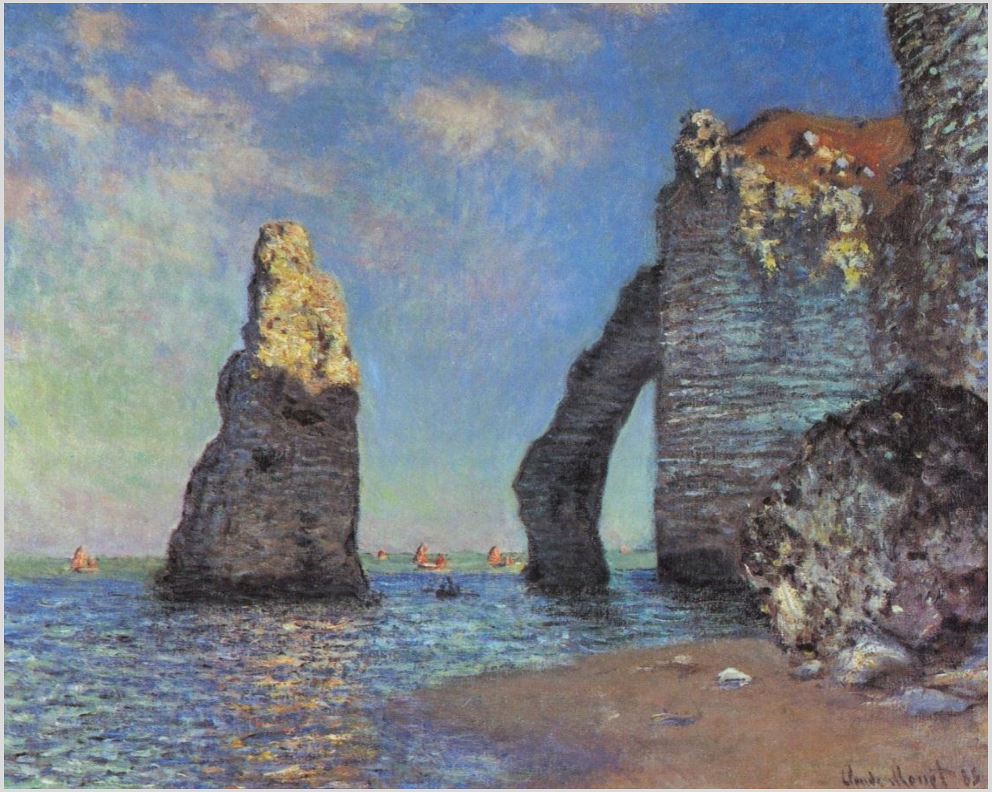
Outline

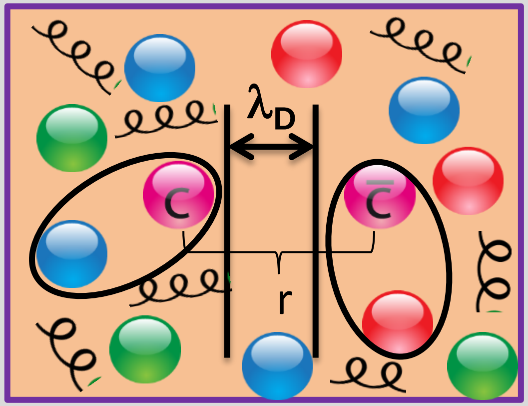
- Physics motivations.
- The ALICE experiment.
- Analysis:
  - $J/\psi \rightarrow ee$ ($|y| < 0.9$)
  - $J/\psi \rightarrow \mu\mu$ ($2.5 < y < 4.0$)
- Results
- Conclusions.



The Cliffs at Etretat, Claude Monet

Quarkonia in A-A

- Ultrarelativistic heavy-ion collisions → high energy densities.
- Quark Gluon Plasma: deconfined state of quarks and gluons.



Quarkonia as a probe of deconfinement:

✓ Created in the early stages of the collision.
✓ Suppressed by Debye screening.
✓ Different radii & bounding energies → sequential suppression.

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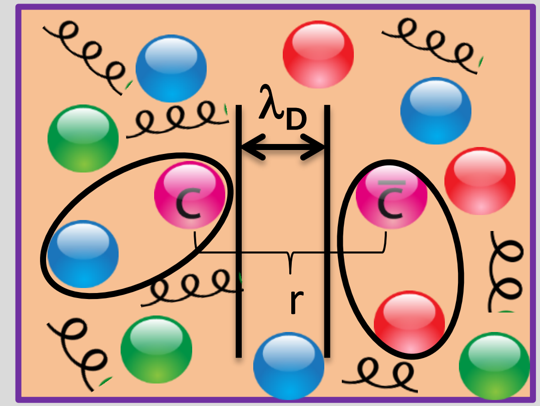

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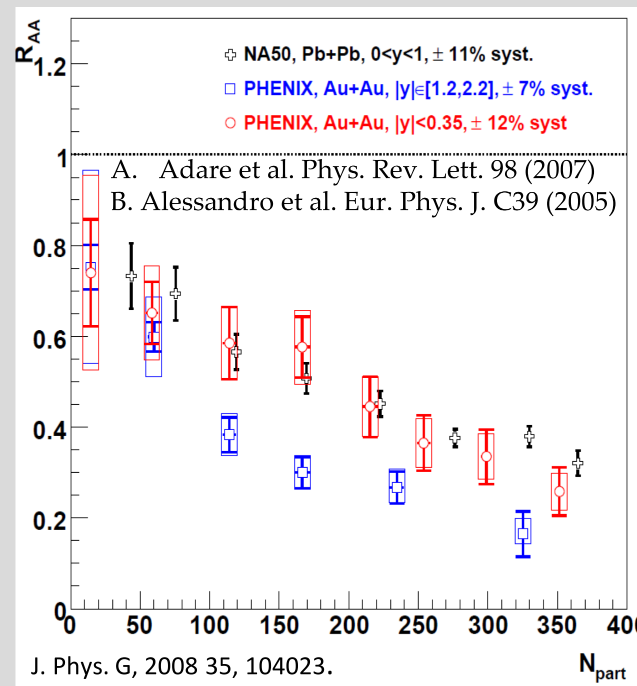
NA50: Fair description provided by both QGP (color screening) and no QGP (comovers interaction) hypothesis.

PHENIX: suppression still observed (larger at forward rapidity), regeneration might be needed to explain the data.



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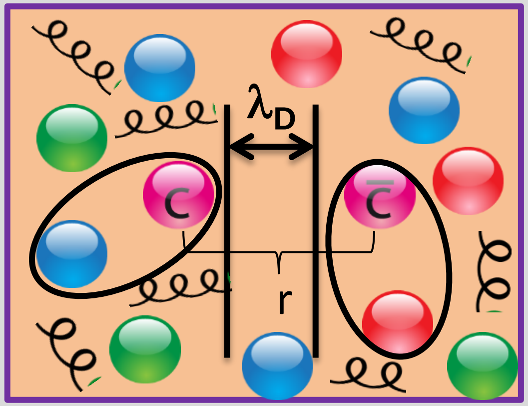

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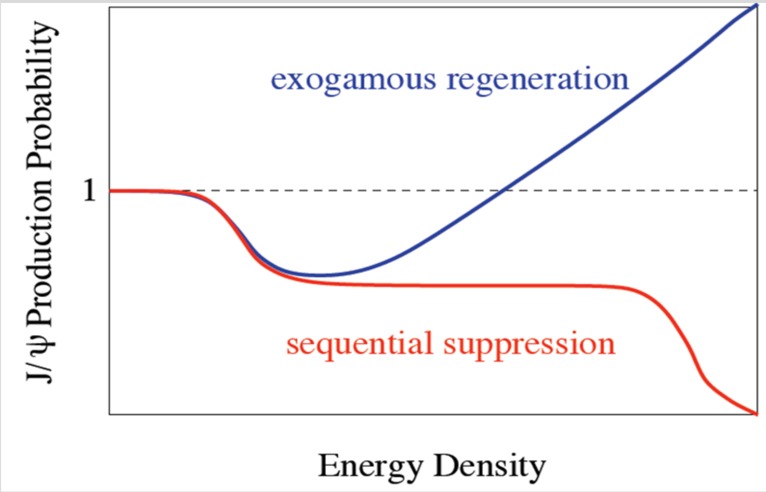
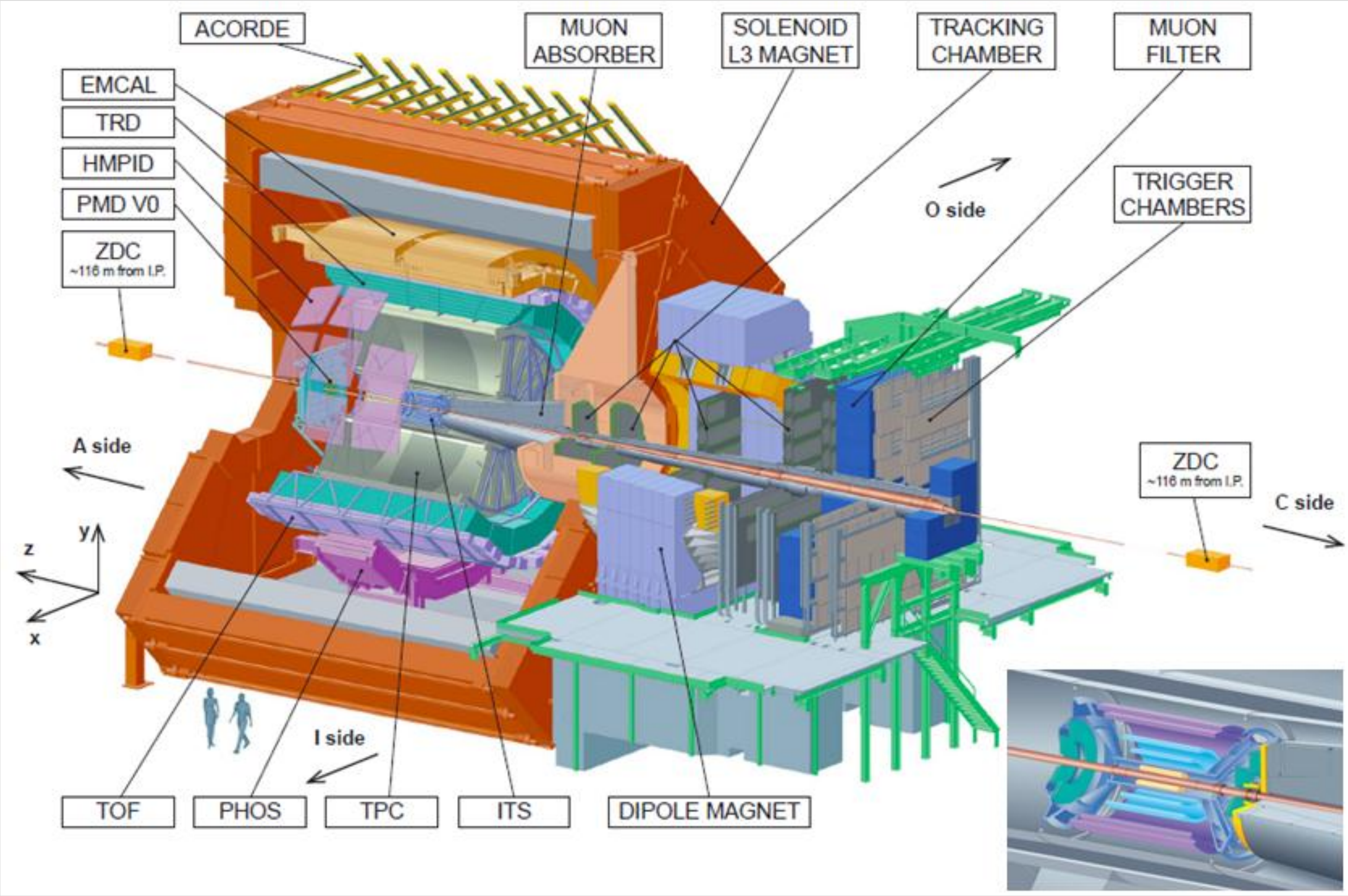
LHC:

1. Collision energy > RHIC & SPS ➔ larger suppression?
2. $\sigma_{c\bar{c}} \approx 10 \times \sigma_{c\bar{c}}$(RHIC) ➔ more regeneration?



The ALICE experiment



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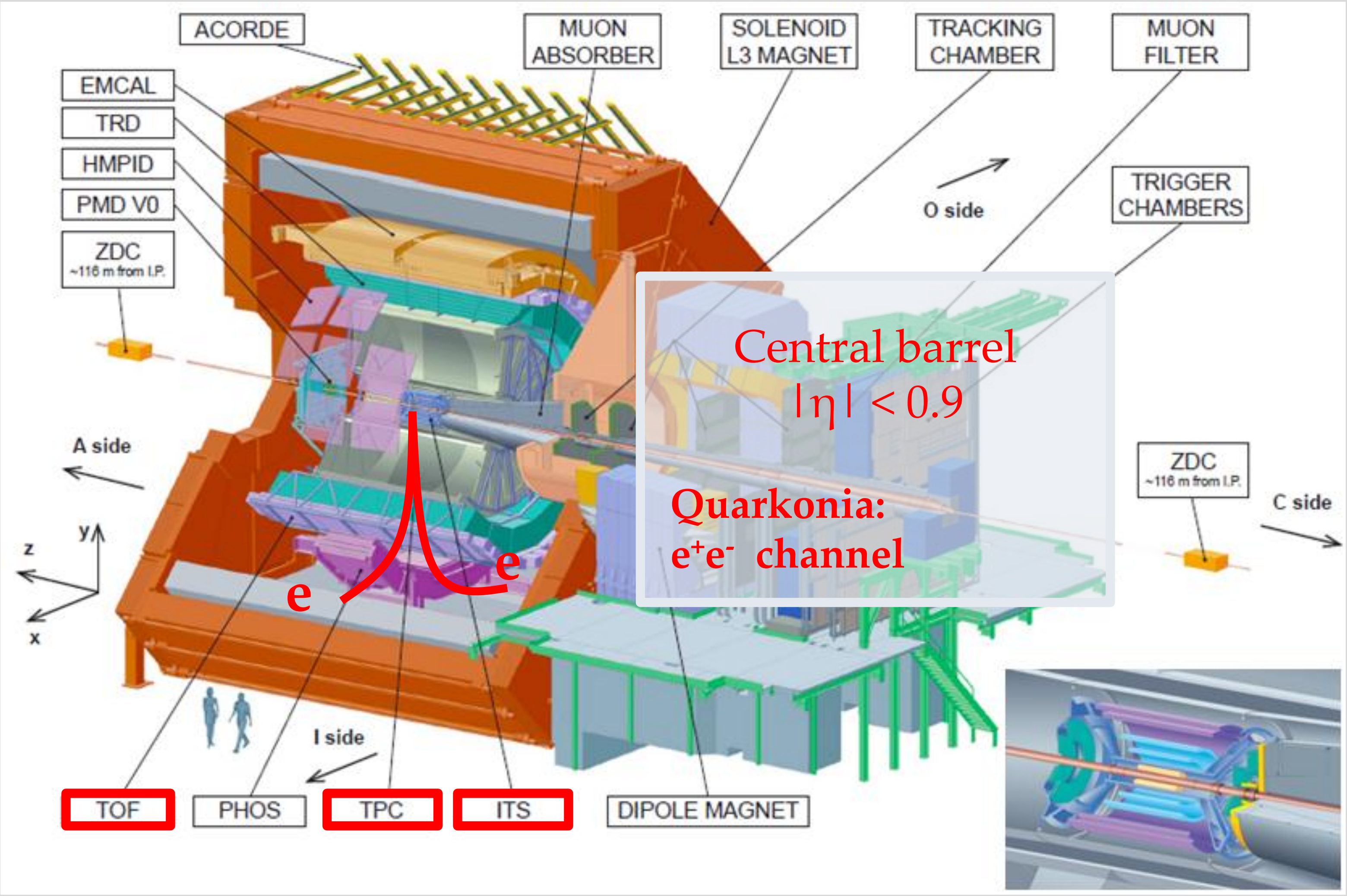

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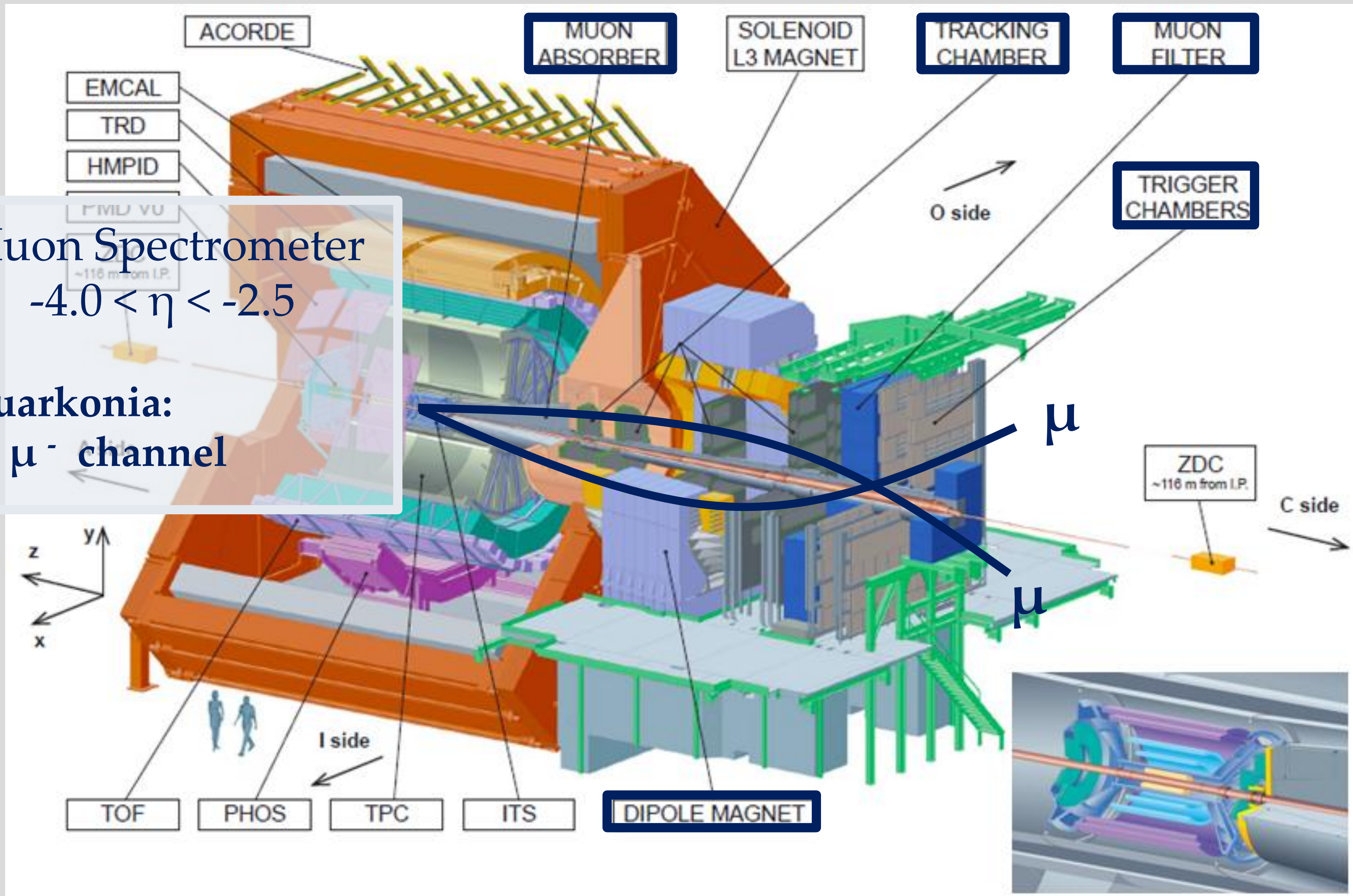


Muon Spectrometer
$-4.0 < \eta < -2.5$

Quarkonia:
$\mu^+ \mu^-$ channel

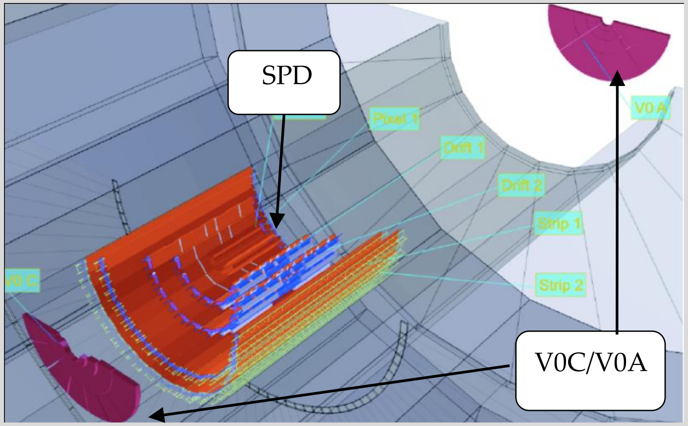
Trigger, event selection and centrality

➢ $J/\psi \rightarrow ee$:

2010 + 2011 data set: 11.6x10^{6} Minimum Bias (MB) events ~ L_{int} of 15 μb^{-1}.

2010 MB trigger: signal in two hodoscope scintillators (V0A and V0C) and in the outer layer of a pixel detector (SPD).

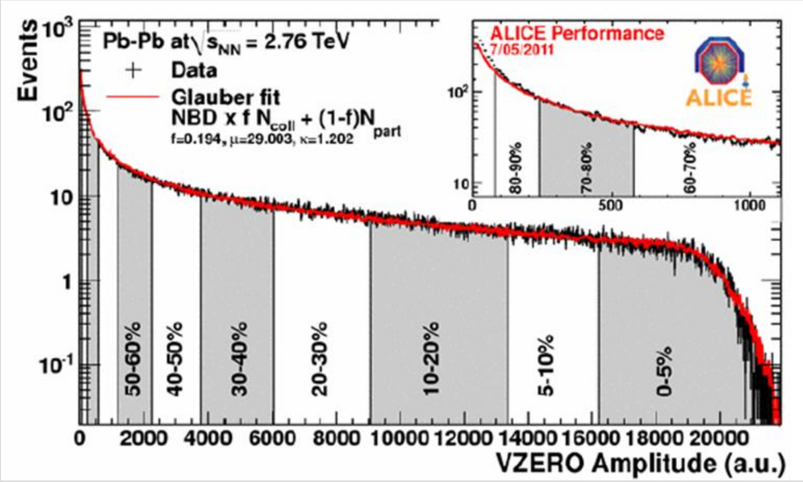
2011 MB trigger: signal in V0A and V0C.



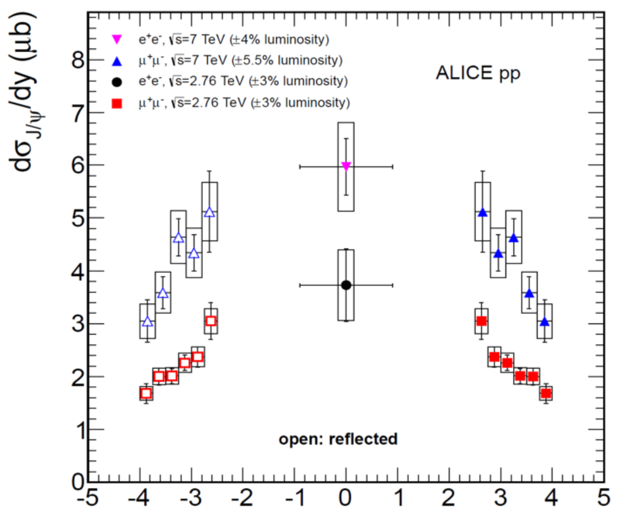
➢ $J/\psi \rightarrow \mu\mu$:

2011 data set: 17.7x10^{6} dimuon events ~ L_{int} of 70 μb^{-1}.

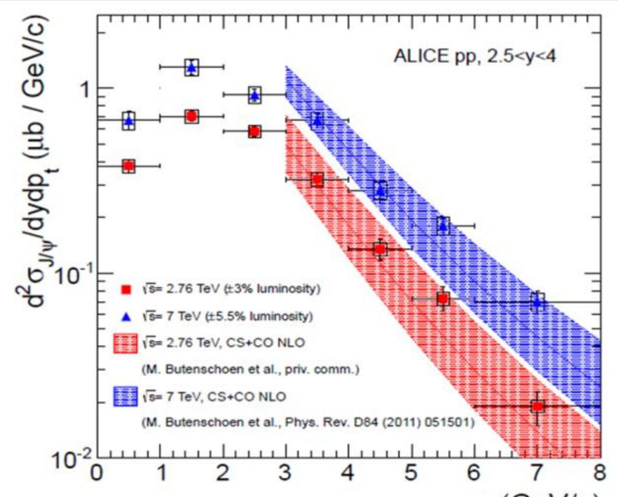
Centrality estimation is based on a Glauber model fit of the V0 amplitude.



pp measurements at $\sqrt{s_{NN}} = 2.76$ TeV



arXiv:1203.3641



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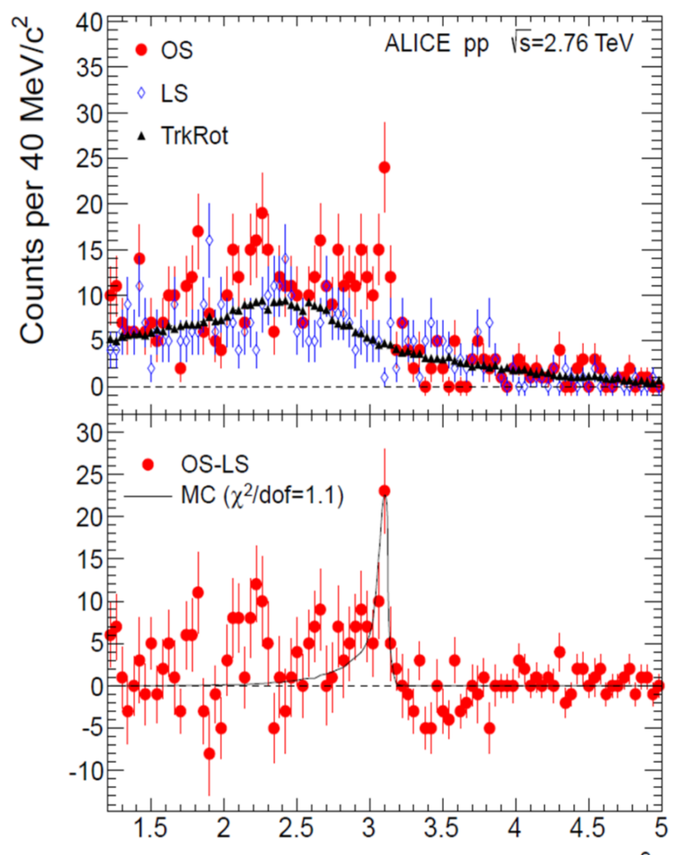
Reference from pp collisions is needed!

Both at forward and midrapity.

$2.5 < y < 4.0$: NRQCD calculations describe the measured $d^2\sigma/dydp_T$ at 7 and 2.76 TeV.

pp reference is the main source of systematics in the R_{AA}:

- 9% for $J/\psi \to \mu\mu$.
- 26% for $J/\psi \to ee$.



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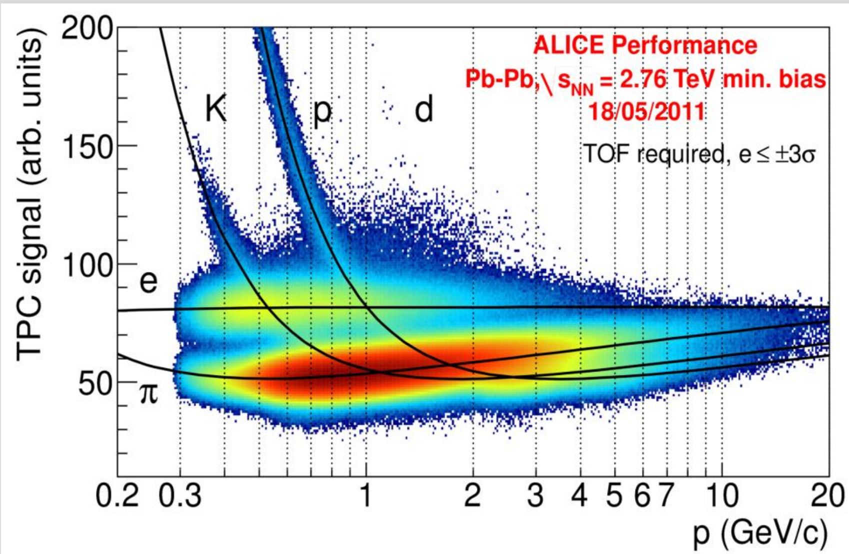
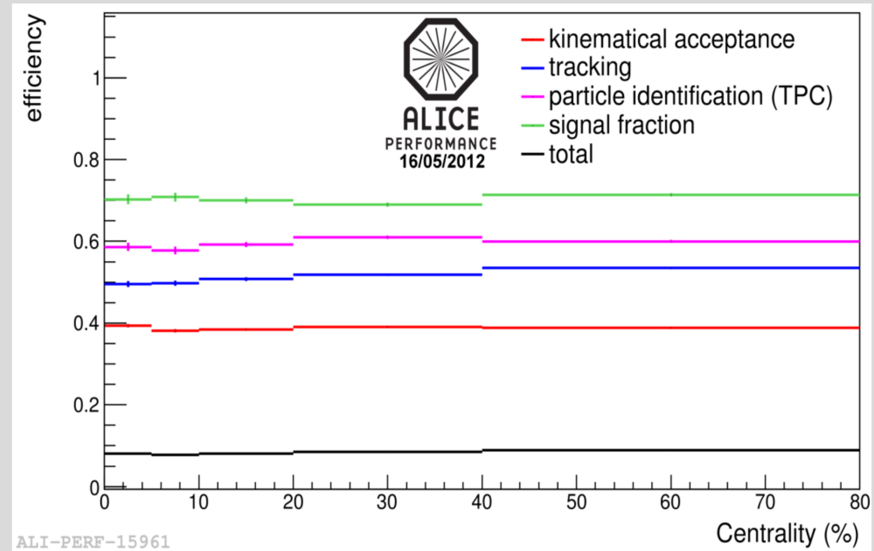
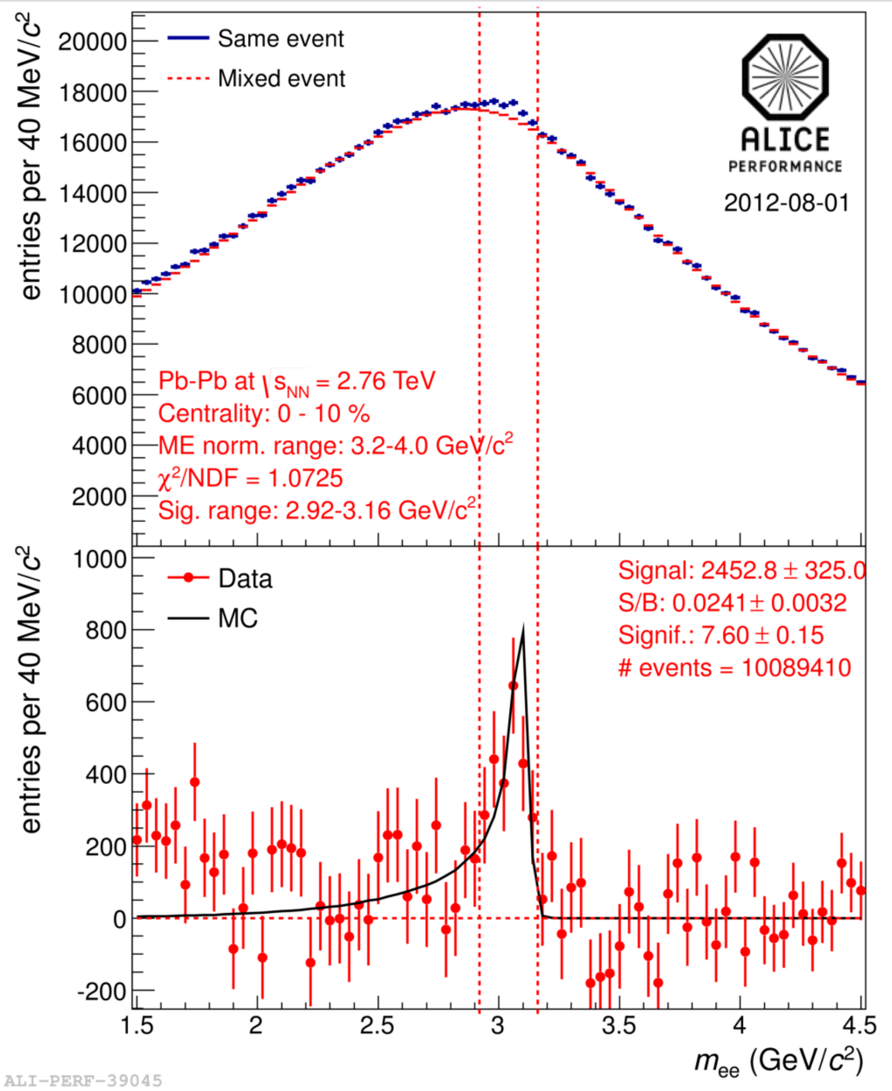
J/ψ → ee in Pb-Pb: Analysis





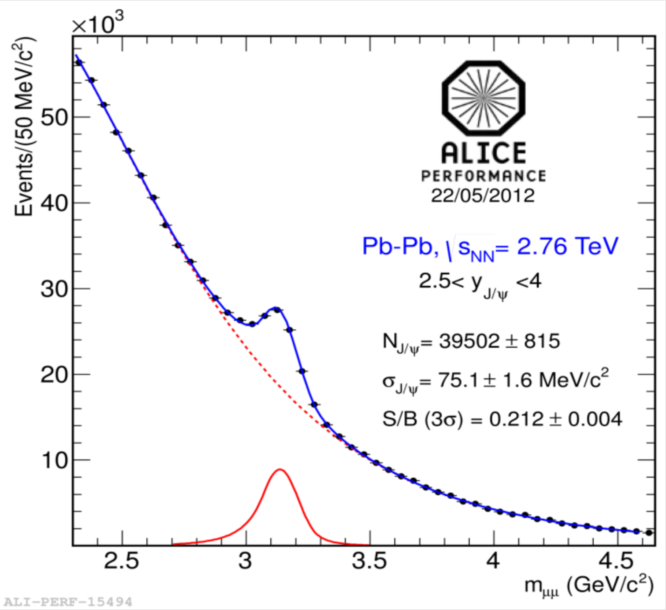
- ❑ Particle Identification: TPC + TOF.
- ❑ Electron from conversion rejected:
  - ITS cluster required on *e* candidates.
  - Removed tracks from reconstructed γ conversion V_0's.
- ❑ Efficiency computed with HIJING enriched with J/ψ.
- ❑ Little dependence on the centrality.

J/ψ → ee in Pb-Pb: Analysis



- ✓ J/ψ yield obtained by subtracting the background from the opposite sign dielectron invariant mass spectrum using the mixed event technique.
- ✓ Mixed event background is normalized to the unlike sign distribution in the invariant mass region of 3.2 to 4.0 GeV/c^2.
- ✓ The MC signal includes the bremsstrahlung of the electrons in the detector material.
- ✓ Signal extracted in three centrality bins: 0-10%, 10-40% and 40-80%.

J/ψ → μμ in Pb-Pb: analysis

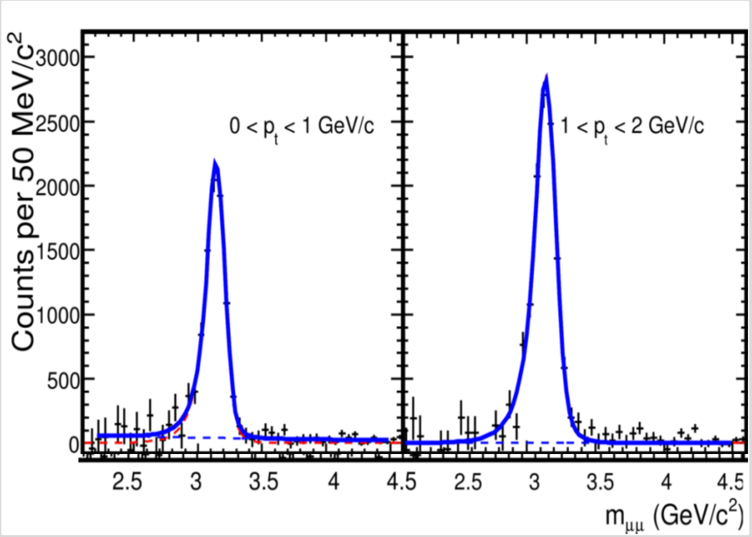


Yield extracted by fitting the unlike sign invariant dimuon mass spectrum:

- ✓ Signal: extended Crystal Ball.
- ✓ Background: different functions. Also subtracted using the event mixing technique.

Results are then combined to obtain a mean weighted $N_{J/\psi}$ and to extract systematic uncertainties on signal extraction.

J/ψ → μμ in Pb-Pb: analysis



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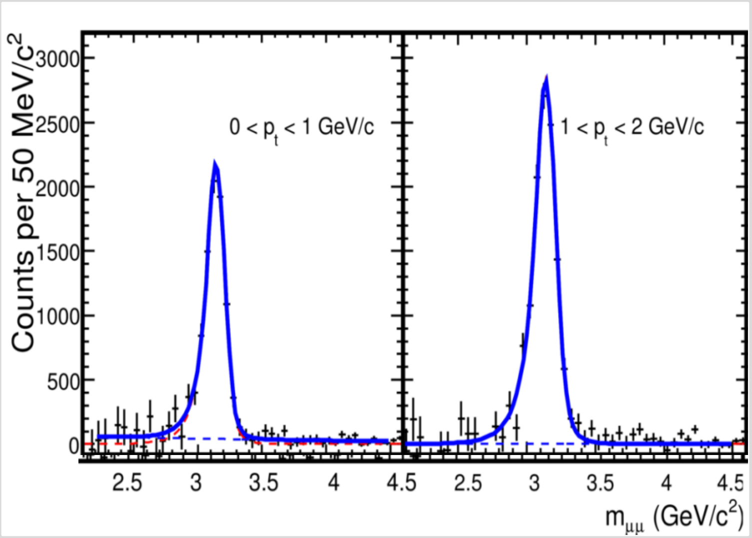

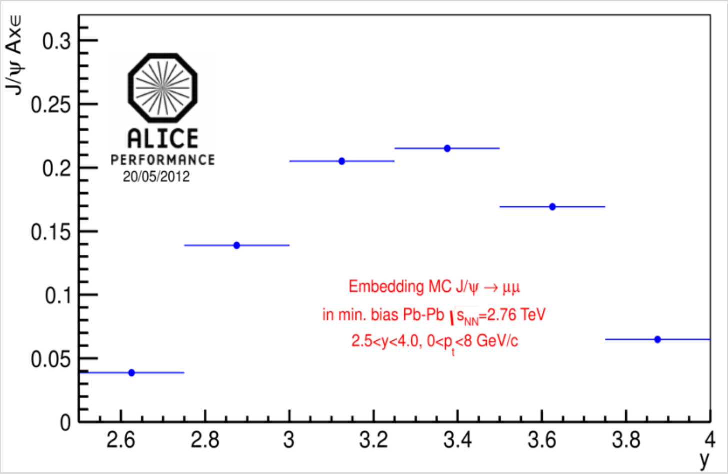

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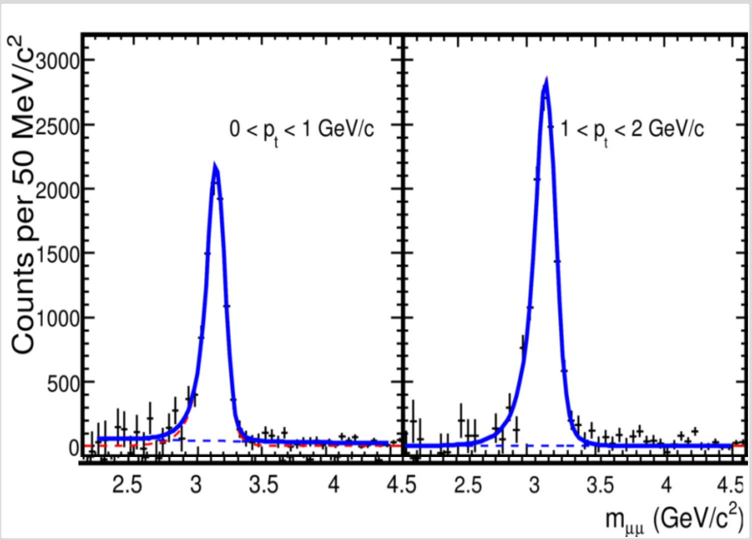
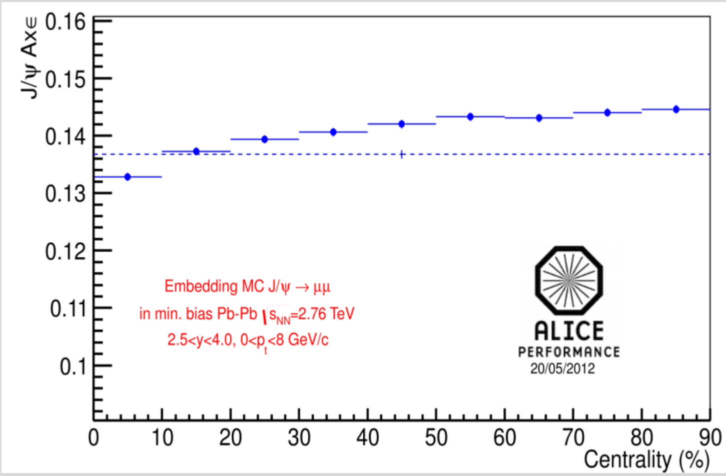
Acceptance x efficiency values obtained by embedding MC J/ψ's into real events.

Rapidity bins: detector acceptance.

$J/\psi \to \mu\mu$ in Pb-Pb: analysis





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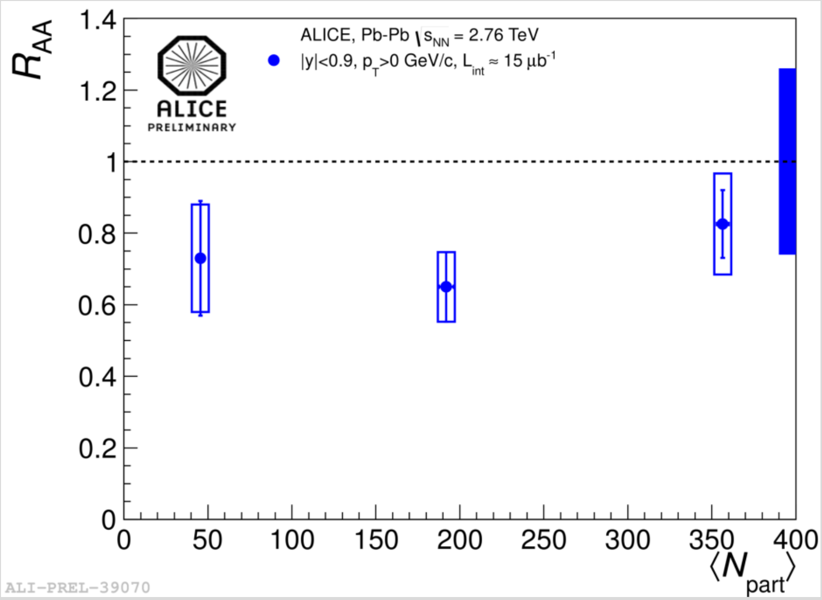
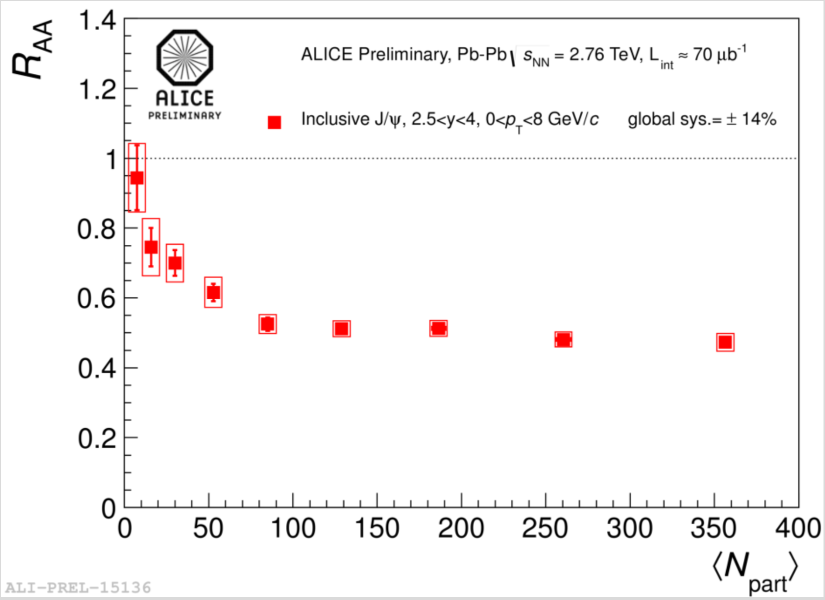
Acceptance x efficiency values obtained by embedding MC J/ψ's into real events.

Rapidity bins: detector acceptance.

Small centrality dependence.

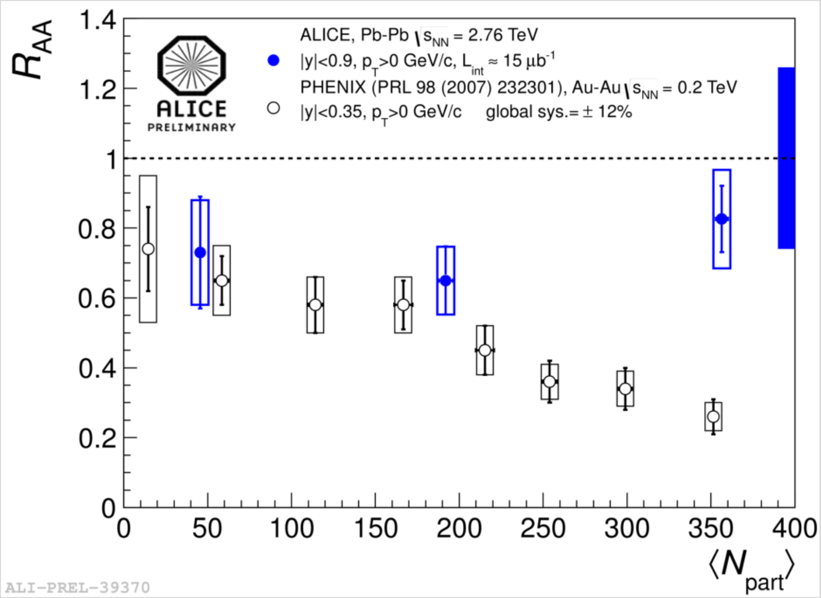
Results: R_{AA} vs centrality

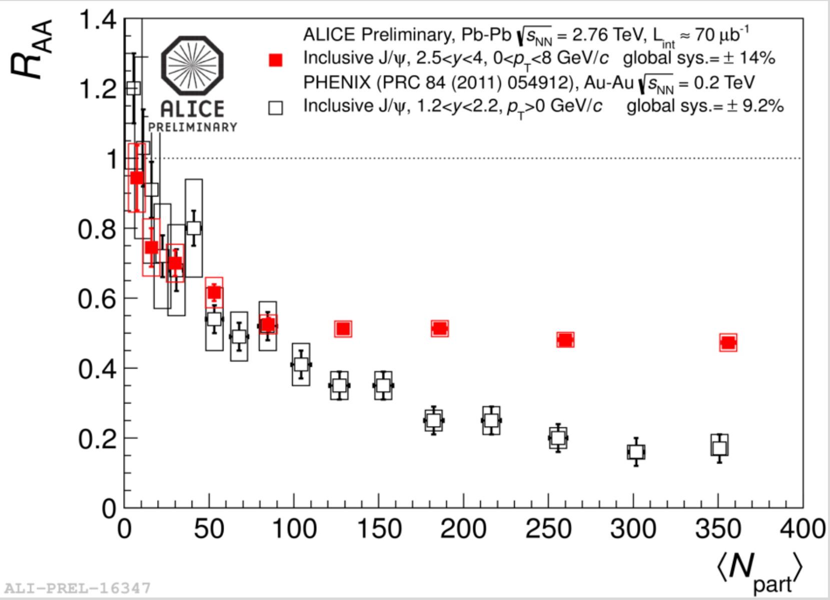




- No significant centrality dependence within errors.
- No significant centrality dependence for $N_{part} > 100$.

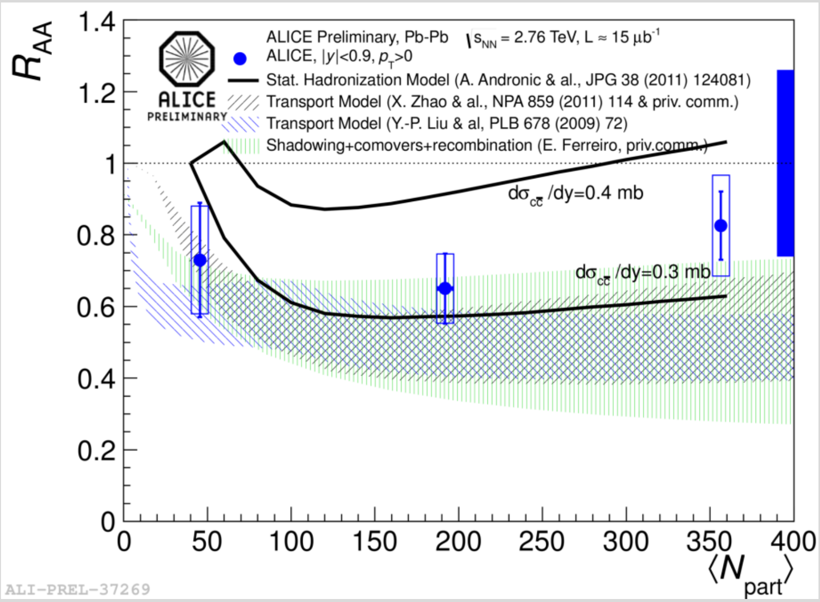
Results: R_{AA} vs centrality

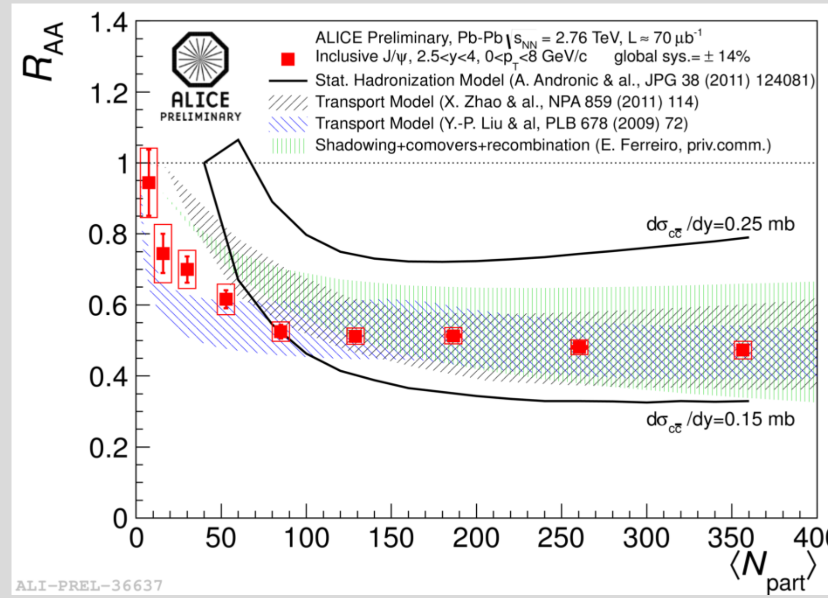




- No significant centrality dependence within errors.
- No significant centrality dependence for $N_{part} > 100$.
- R_{AA} in the most central collision from ALICE is ~3 times larger than at PHENIX.
- $R_{AA}^{ALICE} \sim 3 \times R_{AA}^{PHENIX}$ for $N_{part} > 200$.

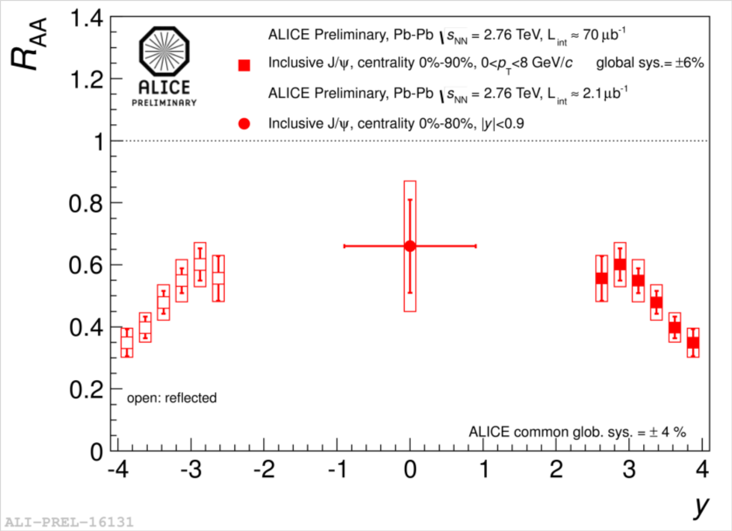
Results: R_{AA} vs centrality

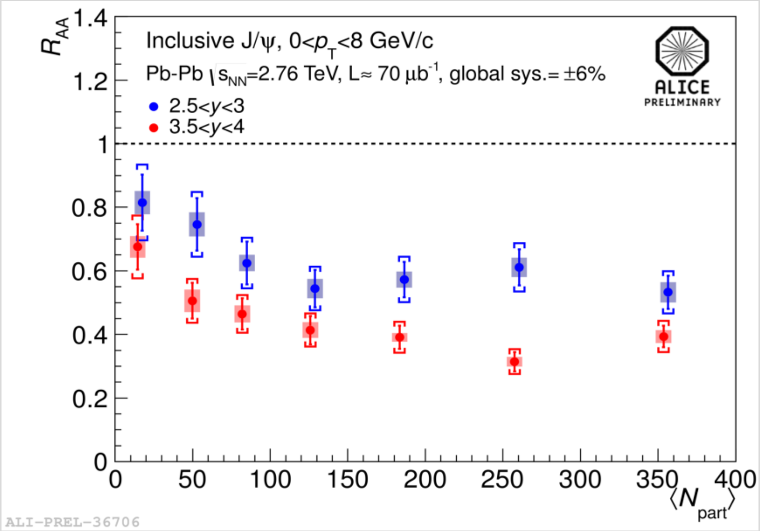




- Statistical Hadronisation Model: prediction for two $d\sigma_{c\bar{c}}/dy$ in Pb-Pb collisions.
- Transport Models: different rate equations of J/Ψ dissociation and regeneration in QGP, more than 50% of measured yield in the most central collisions due to J/Ψ regeneration.
- Green band: includes shadowing, comovers and recombination.
- How can we differentiate among the theoretical models?
  1. Precise measurement of $d\sigma_{c\bar{c}}/dy$.
  2. Measure Cold Nuclear Matter effects.

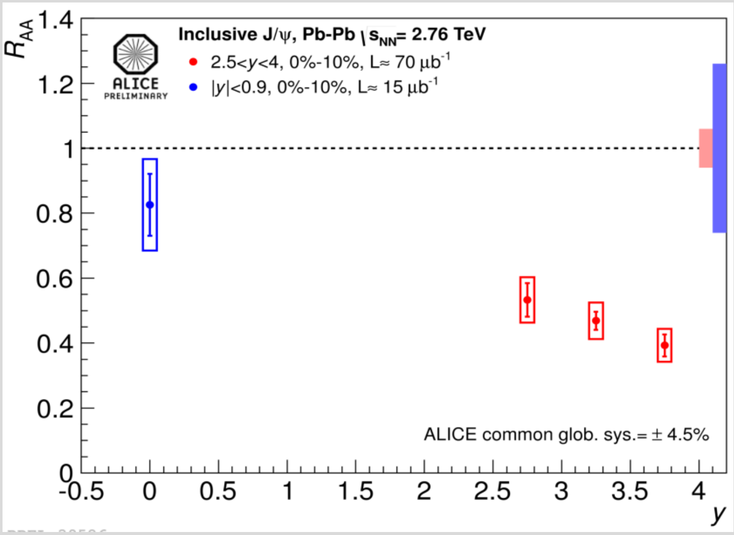
Results: R_{AA} vs centrality, *y* bins

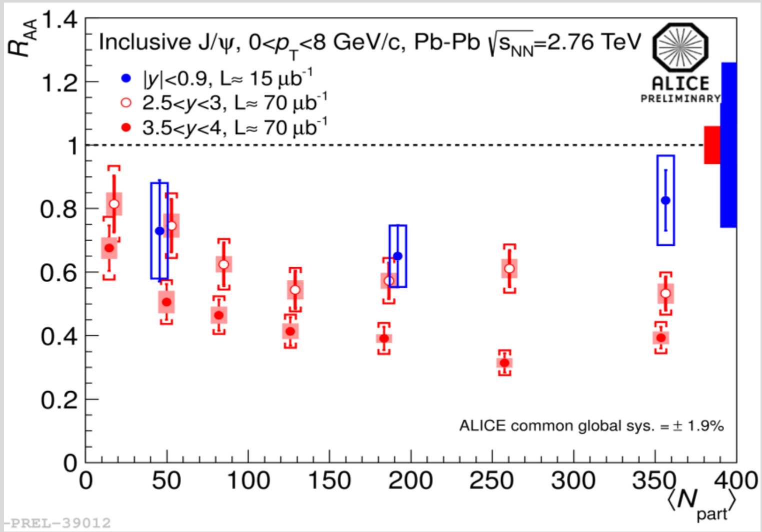




- R_{AA} decreases by 40% from *y* = 2.5 to *y* = 4.
- Same centrality behavior at forward *y*.

Results: R_{AA} vs centrality, *y* bins





- R_{AA} decreases by 40% from $y = 2.5$ to $y = 4$.
- Same centrality behavior at forward *y*.

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

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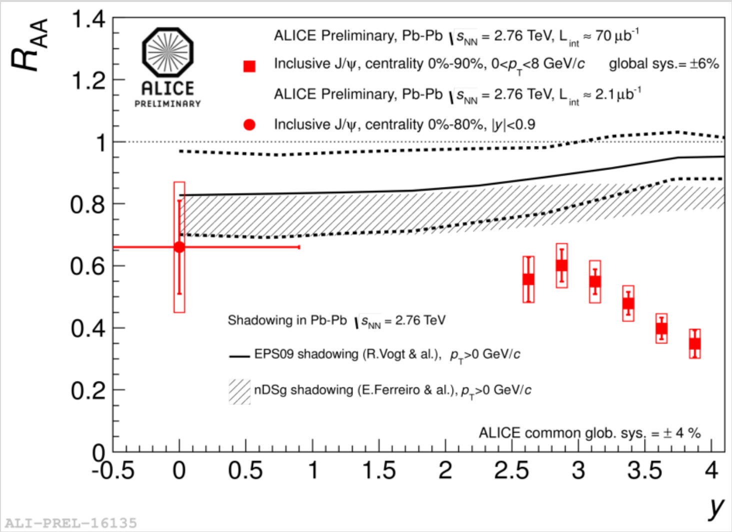
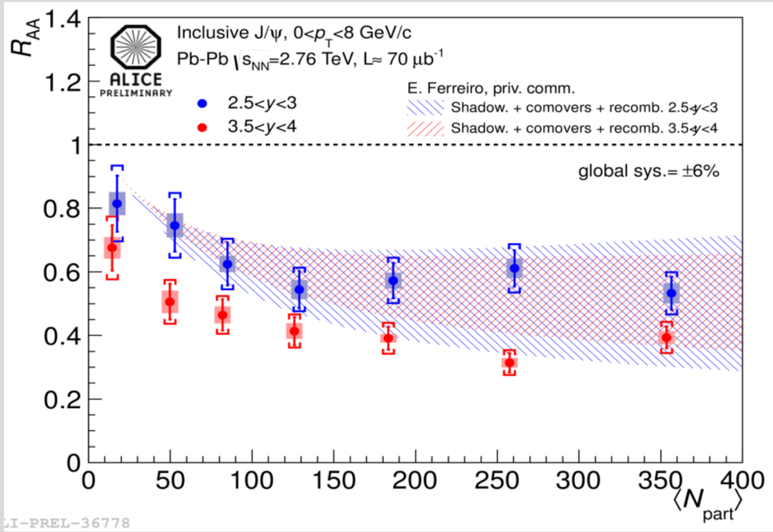




- R_{AA} decreases by 40% from $y = 2.5$ to $y = 4$.
- Same centrality behavior at forward *y*.

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

Mid rapidity J/ψ less suppressed if shadowing calculations are considered.

Weaker *y* dependence predicted by shadow. + comovers + recombination.

Cold Nuclear Matter effects need to be quantified!

Conclusions

- Inclusive J/ψ R_{AA}'s have been measured down to $p_T = 0$ by the ALICE experiment in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV.

- ALICE results vs N_{part} show a different behavior relative to PHENIX:
  - Flat centrality dependence in all rapidities ($N_{part} > 100$ at forward y).
    - $R_{AA}^{ALICE} \sim 3 \times R_{AA}^{PHENIX}$ for the most central collisions.

- Hint of smaller suppression at midrapidity than at forward rapidity in the most central collisions.

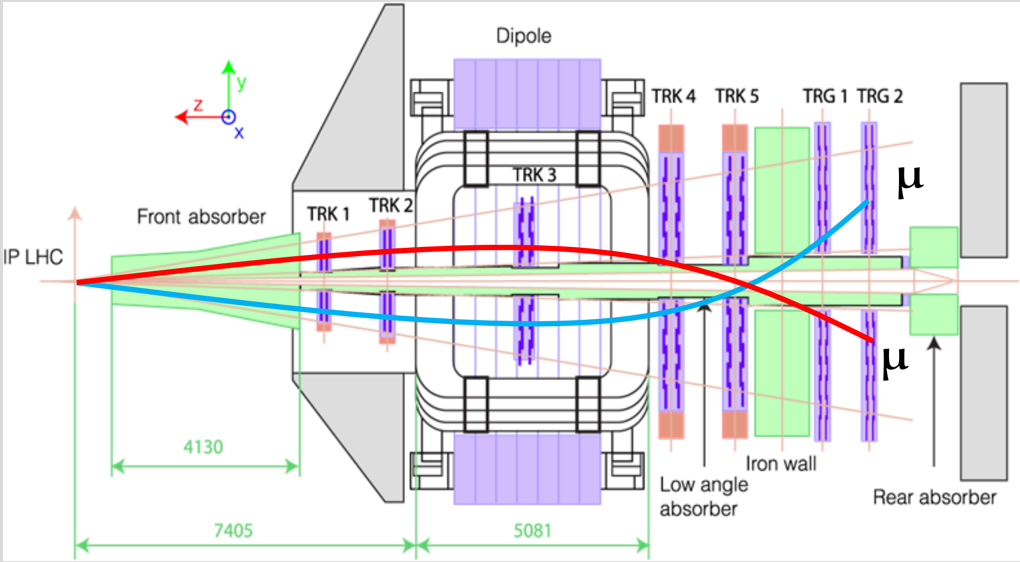
- Comparisons to models point to (re)generation.

- Important to measure Cold Nuclear Matter effects and $d\sigma_{c\bar{c}}/dy$.

Backup

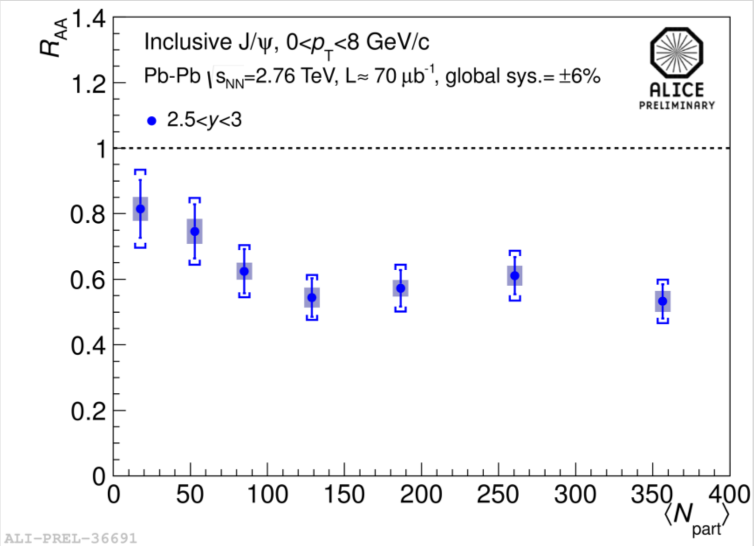
The ALICE Muon Spectrometer

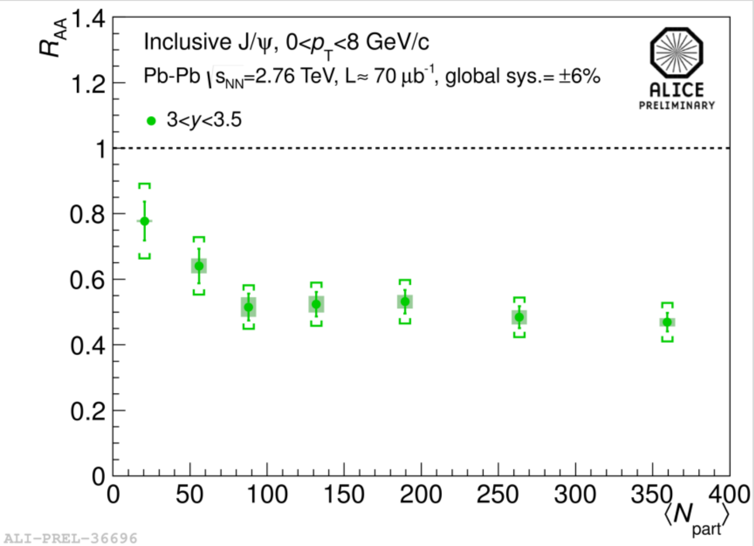
Located in the forward rapidity region and with a full azimuthal coverage, it is composed by:

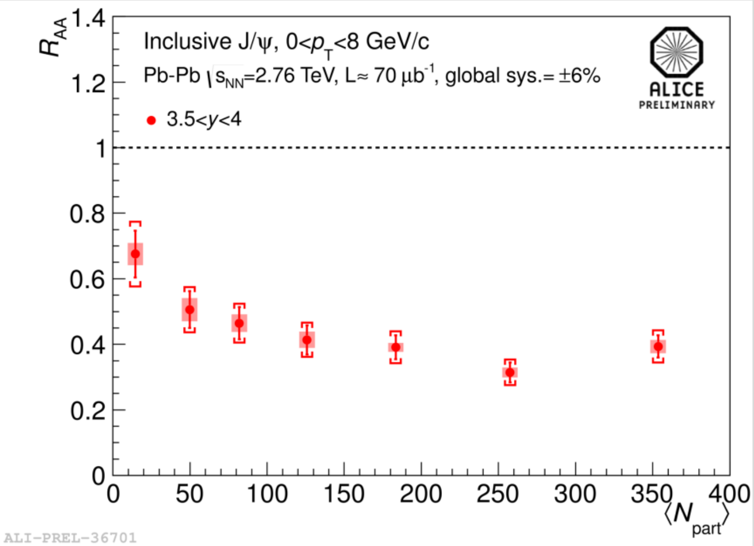


- Absorbers:
  a) Front absorber.- Absorbs hadrons, photons and electrons.
  b) Beam shield.- Protects from particles produced at large *y*.
  c) Iron wall.- Absorbs hadrons that punch-through the frontal absorber.
- Magnetic dipole.- 3 T·m integrated magnetic field, bends charged particles allowing to extract the sign of their electric charge and momentum.
- Tracking chambers.- Spatial resolution, in bending coordinate, better than 100 μm in order to identify and disentangle the ϒ family (100 MeV resolution).
- Trigger chambers.- Timing resolution of 1-2 ns and latency of 700 ns (LØ trigger), can trigger likesign and unlikesign events.

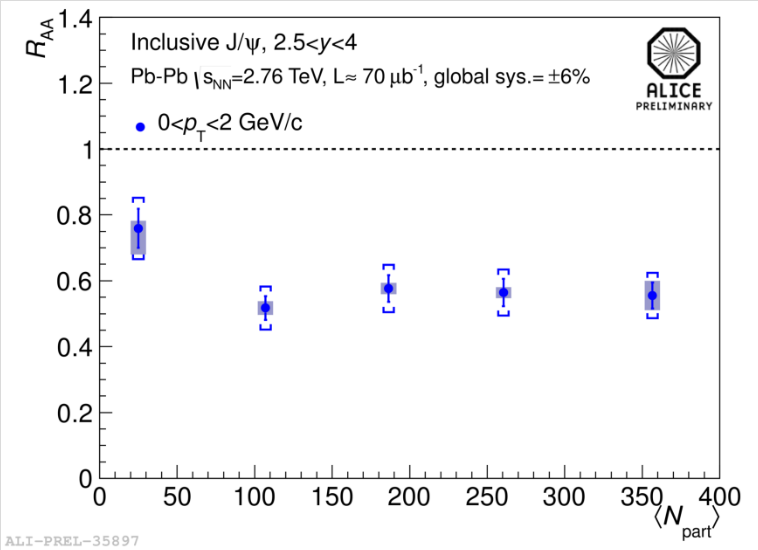
R_{AA} vs Centrality, y bins

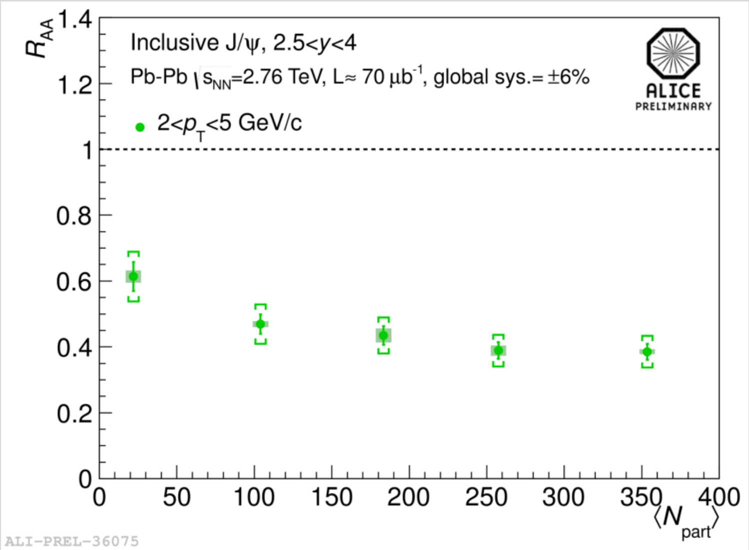


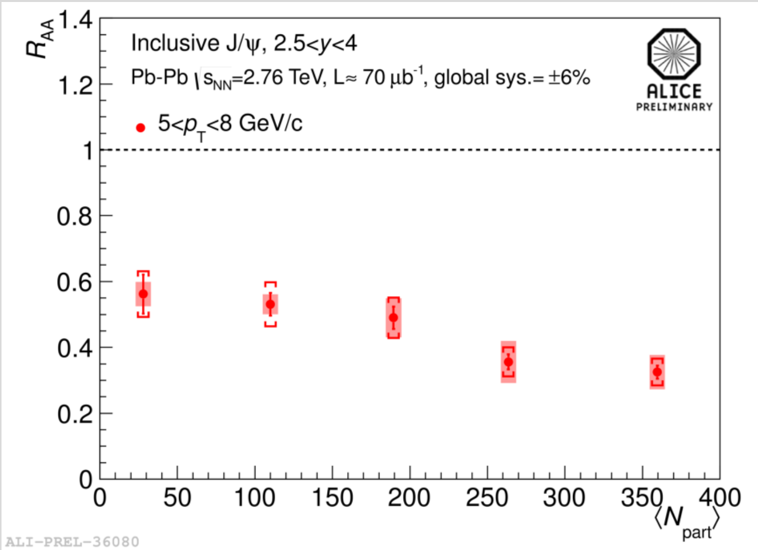




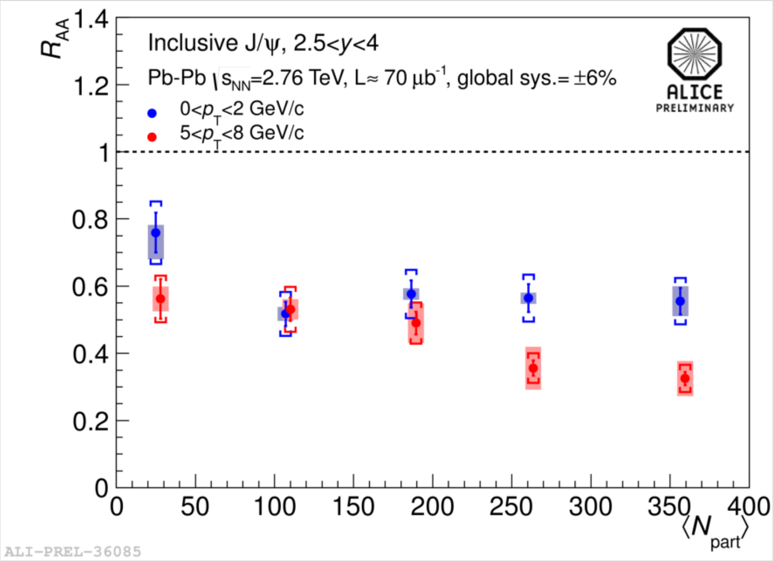
R_{AA} vs Centrality, p_T bins







Results: R_{AA} vs centrality, p_T bins



- Stronger suppression for high-p_T J/ψ's.
- No centrality dependence for low-p_T J/ψ's when $N_{part} > 100$.
- Consistent behavior with (re)combination.

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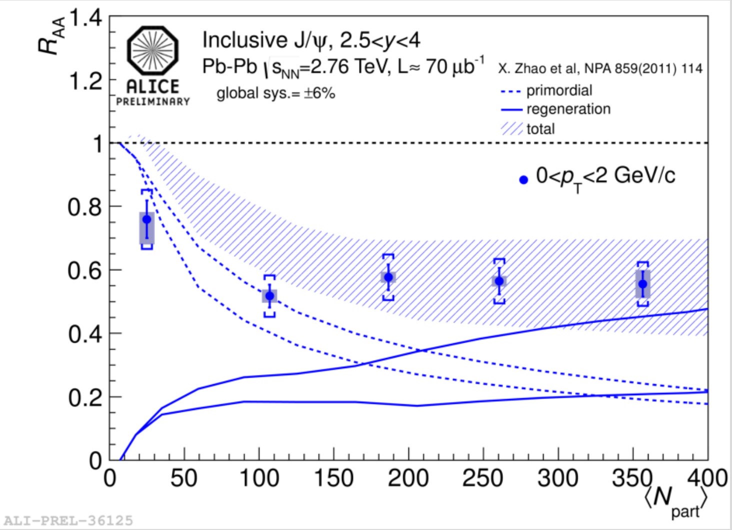

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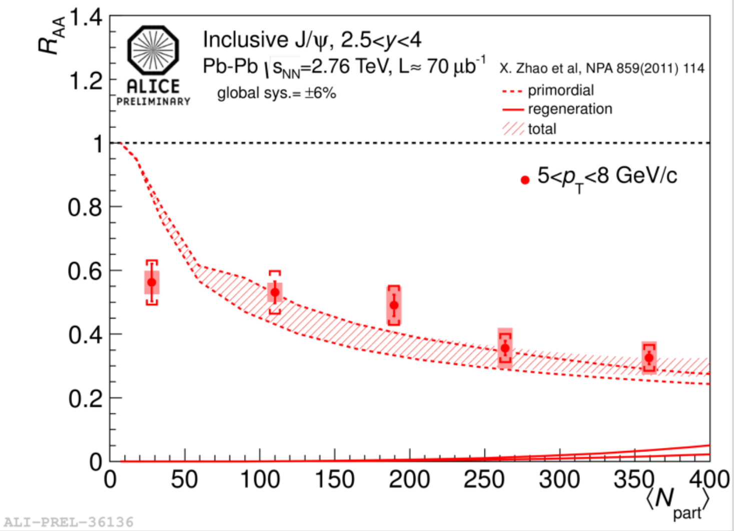

- Good agreement between data and theory.
- Around 50% of the low-p_T J/ψ's are produced by (re)combination.
- In the opposite way, for high-p_T J/ψ's this contribution is very small.