J/ψ production at forward rapidity in Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV, measured with the ALICE detector

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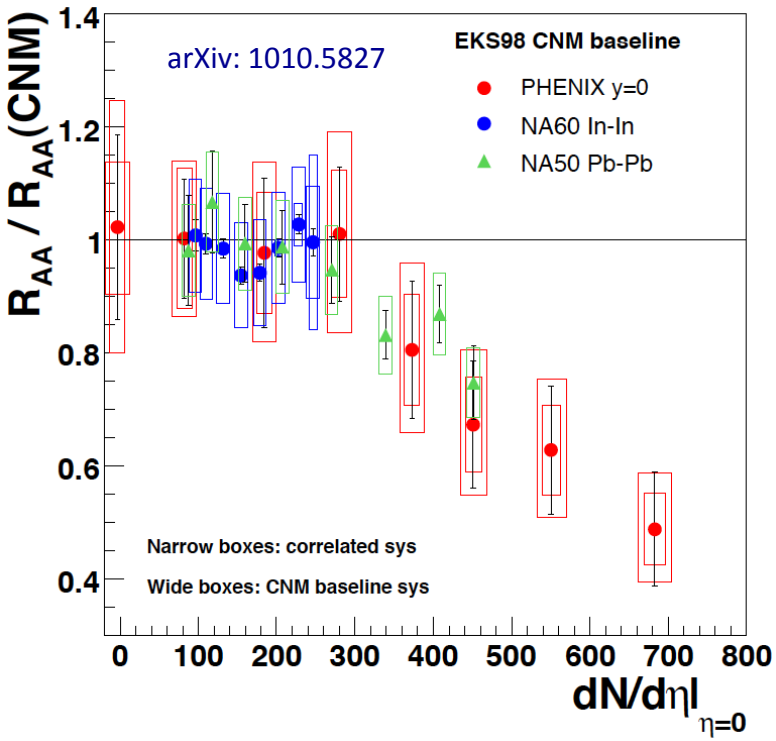
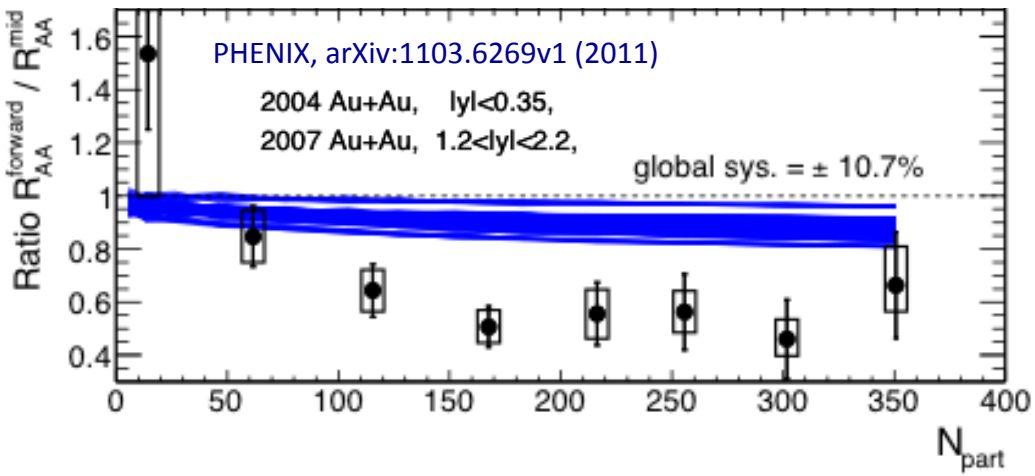
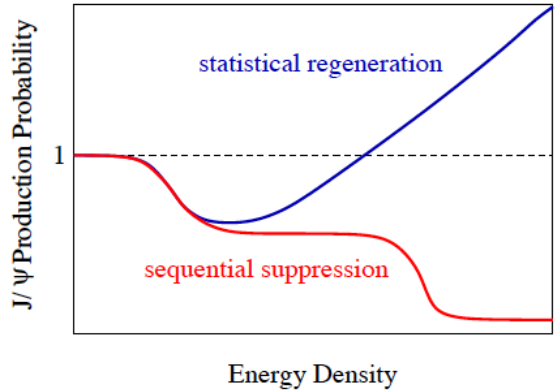
QUARK MATTER ANNECY 2011

Motivations

- J/ψ measurement: probe of deconfinement
- Puzzles:
  - Suppression above cold nuclear matter effects is not so large at RHIC. Does quarkonium regeneration play a role?
  - RHIC measures higher suppression at forward than at central rapidities





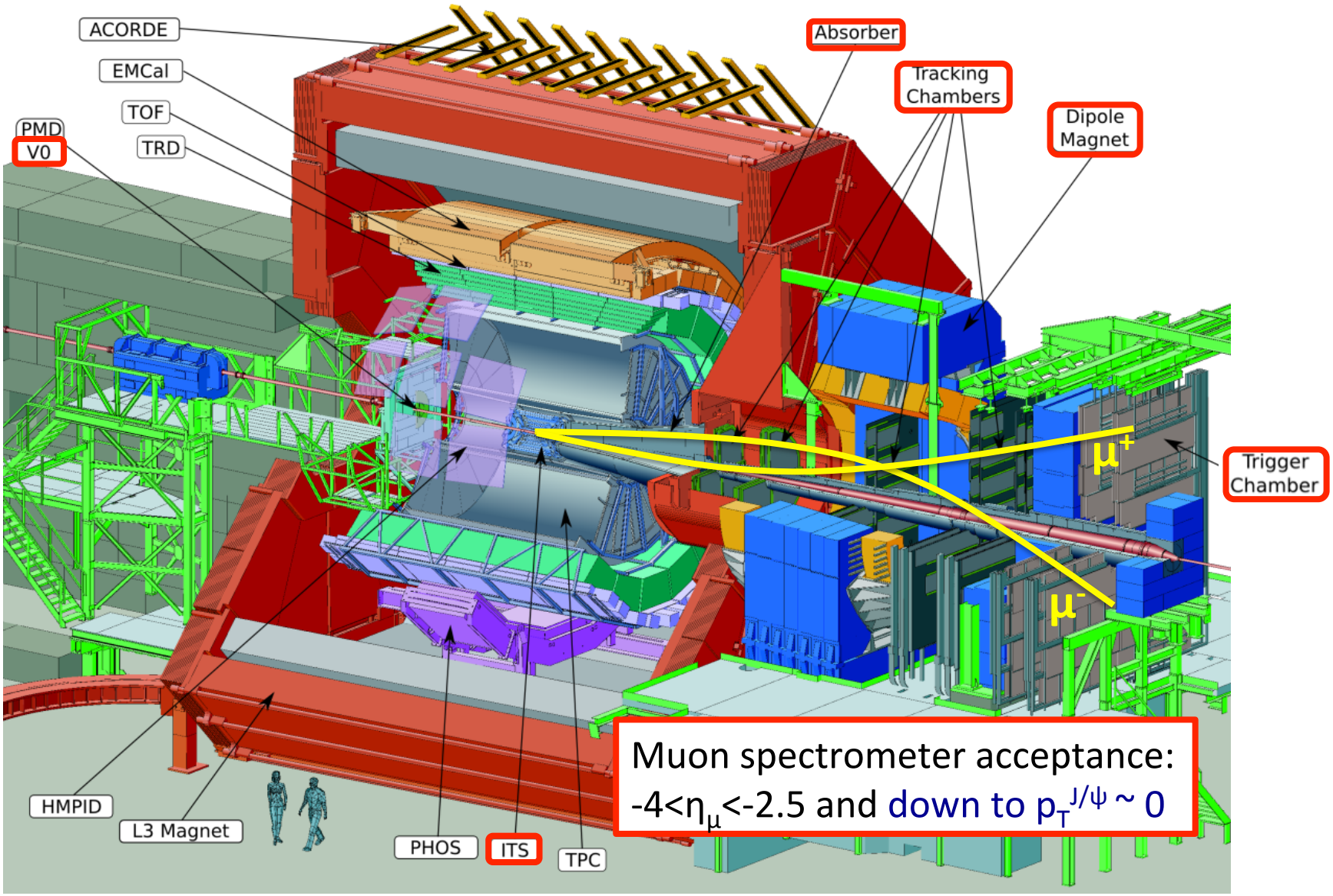


→ Need measurement at central and forward rapidities in higher energy collisions

Plan of the talk

- Brief reminder of the apparatus
- Main steps of the analysis
- Inclusive J/ψ R_{AA} and R_{CP} versus centrality
- Comparison with other experiments and model
- Conclusions

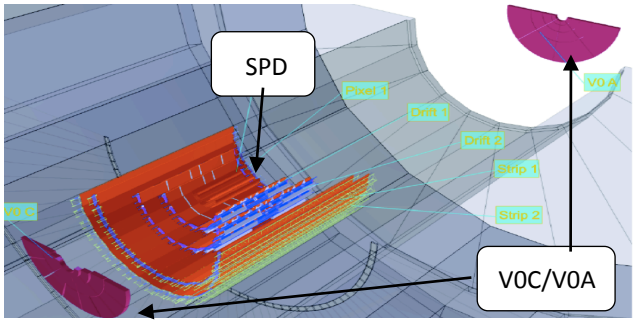
ALICE layout



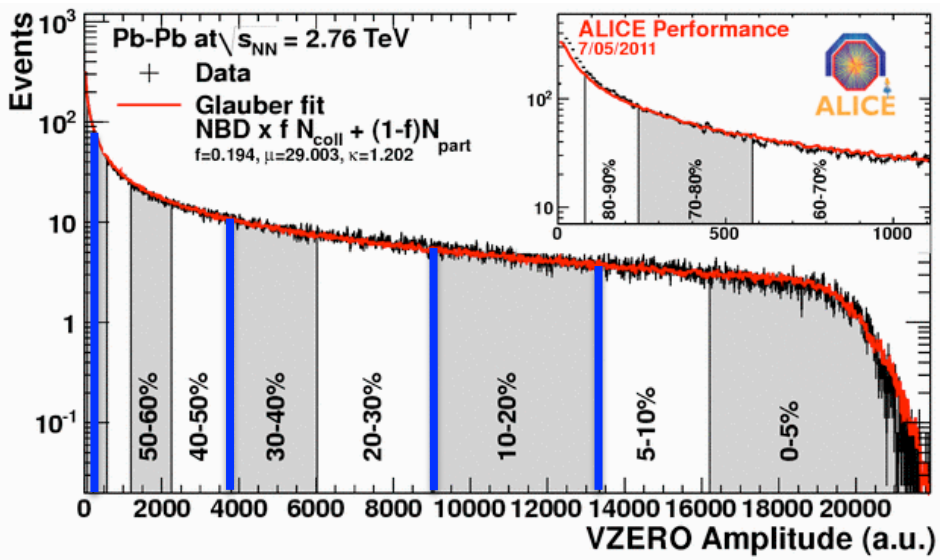
Muon spectrometer acceptance:
$-4<\eta_\mu<-2.5$ and down to $p_T^{J/\psi} \sim 0$

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

- Data sample:
  - Minimum bias trigger (V0A && V0C && SPD)
  - Cuts for beam-gas or electromagnetic interactions
  - Run selection based on the stability of the muon spectrometer tracking and triggering performance



→ Integrated luminosity after data selection: 2.7 μb^{-1}



- Track selection:
  - Muon trigger matching
  - $-4<\eta_\mu<-2.5$ and $17.6<R_{abs}<89$ cm (R_{abs} = track position at the absorber end)
  - $-4<y_{\mu\mu}<-2.5$

- Centrality selection:
  - Based on a geometrical-Glauber model fit of the V0 amplitude

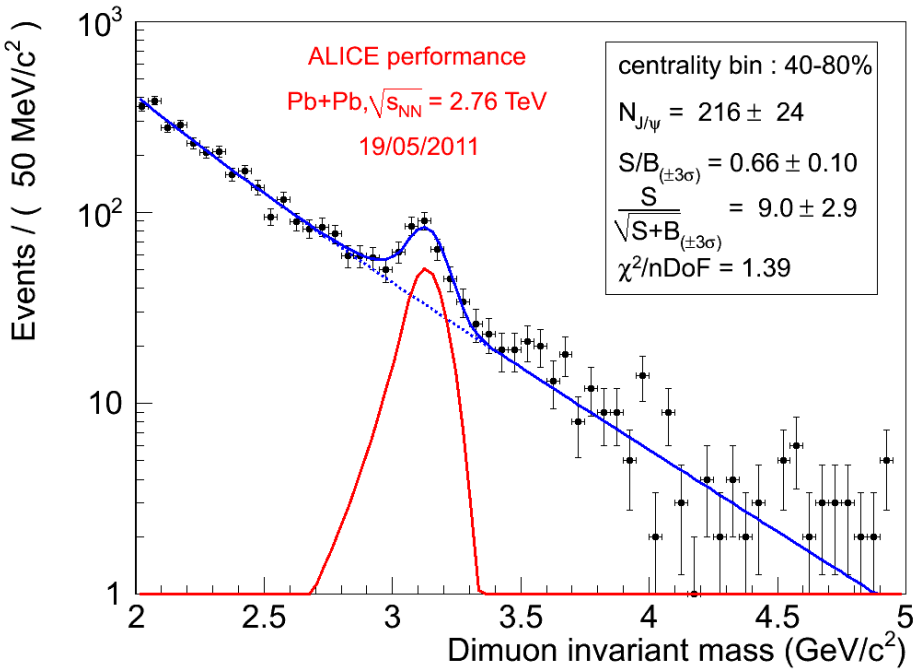
→ talk of C. Loizides on Mon.
→ Talk A. Toia in Tue.

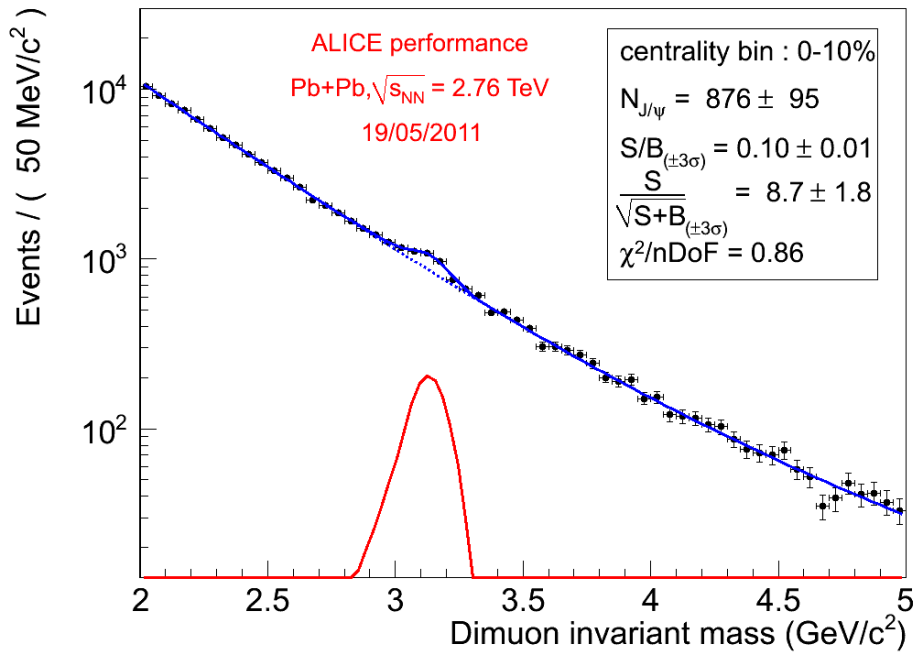
  - Centrality bins used in this analysis: [0, 10], [10, 20], [20-40] & [40-80]%

Signal extraction (1)

Fit the mass distribution in the range [2, 5] GeV/c^2:

- Background: a sum of 2 exponentials
- Signal: a Crystal Ball (CB) function with 1 or 2 tails
  - Shape fixed for the 4 centrality bins
  - Several parameterization (tails/position/width) tested





On the plots: J/ψ curve alone (red), background (dash, blue) and the sum (blue)

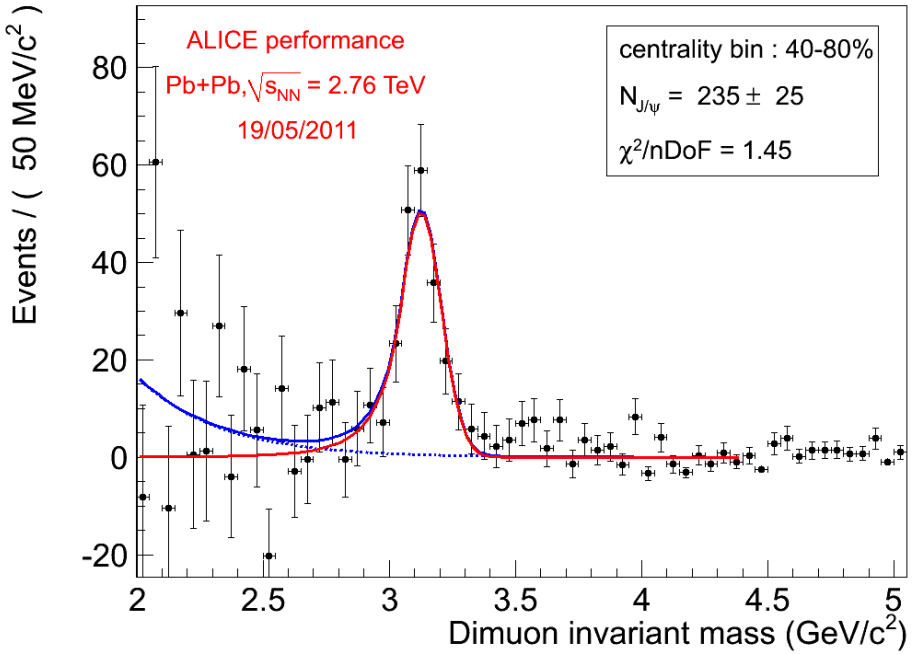
Signal extraction (2)

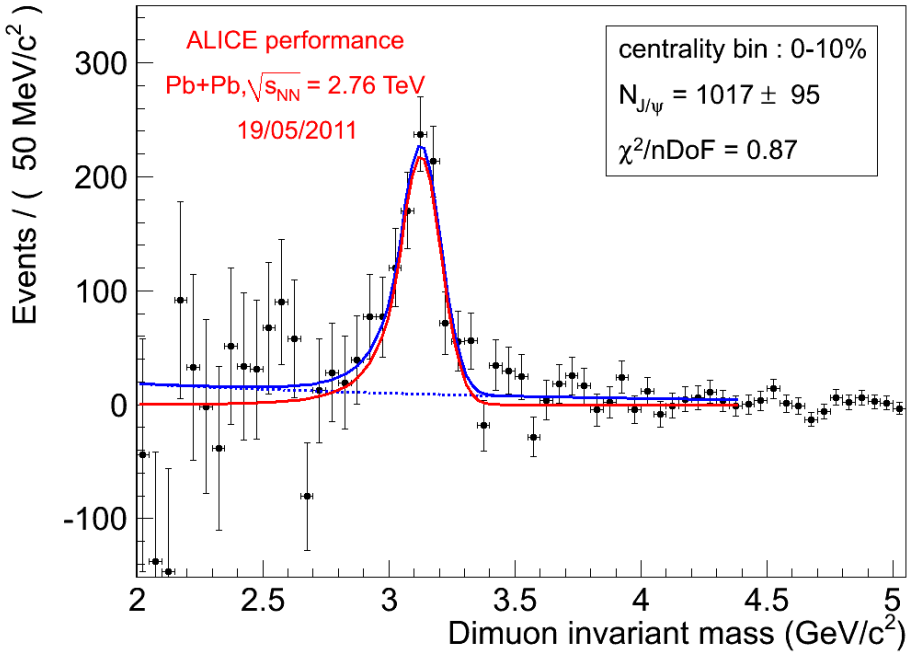
Subtract the background using event mixing technique:

- Mixed pair invariant mass distribution normalized to data in [1.5, 2.5] GeV/c^2

Fit the background subtracted mass distribution in the range [2, 4.5] GeV/c^2:

- Residual background: an exponential or a straight line
- Signal: the various CB shapes used in the first method





On the plots: J/ψ curve alone (red), background (dash, blue) and the sum (blue)

→ Results obtained with different techniques combined to extract <$N_{J/\psi}$> and systematics

Acceptance × efficiency correction

- Based on simulations that accounts for the detector conditions and their time dependence

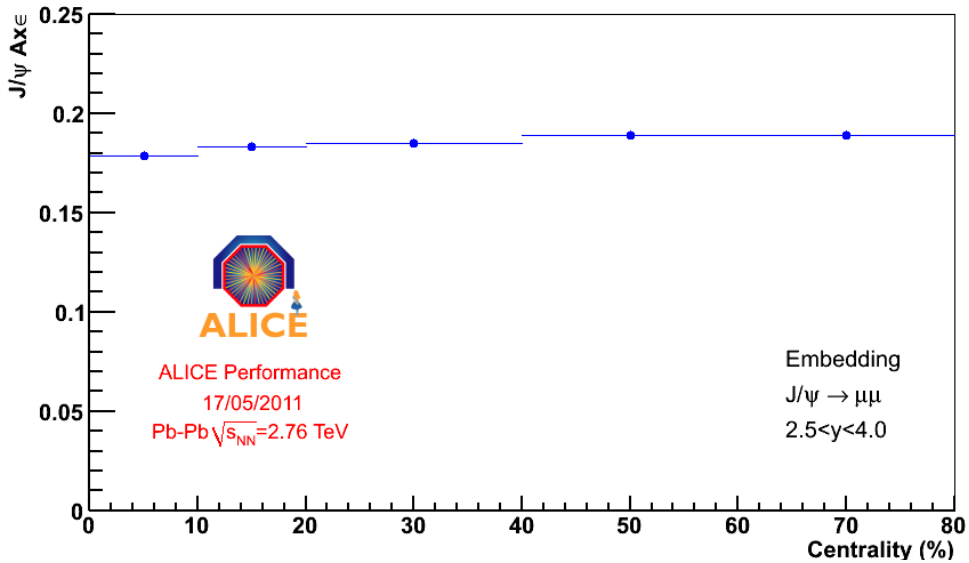
- Realistic J/ψ parameterization:
  - p_T and y interpolated from data (Phenix, CDF, LHC) F. Bossu *et al.*, arXiv:1103.2394
  - Shadowing from EKS98 calculations K.J.Eskola *et al.*, Eur. Phys. J. C9, 61, 1999

→ Integrated Acc×Eff correction with the current track selection = 19.44 ± 0.04 %

- Reconstruction efficiency also measured directly from data:
  → Poster of A. Lardeux and L. Valencia (#58)
  → Comparison with simulations gives the systematic uncertainty of Acc×Eff correction
  → Only 2% decrease in the most central events. Also added in the systematics

Embedding

One J/ψ embedded into each real event. Same reconstruction/selections as for data



- Acc×Eff correction versus centrality

→ Small decreasing of the reconstruction efficiency when increasing centrality

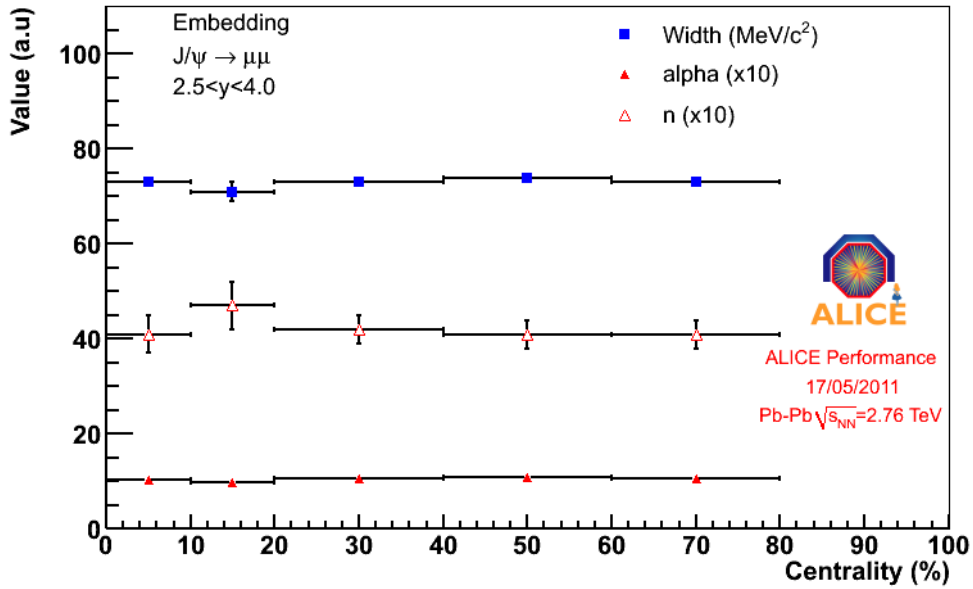
→ Good agreement with the direct measurement from data

→ included in the systematics

- Resolution of the J/ψ (fitted with a Crystal Ball func.) versus centrality

→ No sizable evolution of the parameters versus centrality

→ Good agreement with the measured spectrometer resolution from data



Normalization

For each centrality bin *i*:

- $$Y^i_{J/\psi} = \frac{N^i_{J/\psi}}{B.R. \times AccEff \times N^i_{MB}}$$

→ $$R^i_{AA} = \frac{Y^i_{J/\psi}}{< T^i_{AA} > \times \sigma^{inclusive}_{J/\psi}(2.76TeV)}$$

J/ψ inclusive cross-section in 2.5<y<4 measured in p-p at 2.76TeV:

$$\sigma^{inclusive}_{J/\psi}(2.76TeV) = 3.46 \pm 0.13(stat) \pm 0.32(syst) \pm 0.28(syst.lumi)\mu b$$

→ presented by R. Arnaldi

→ $$R^i_{CP} = \frac{Y^i_{J/\psi} \times < T^{40-80\%}_{AA} >}{< T^i_{AA} > \times Y^{40-80\%}_{J/\psi}}$$

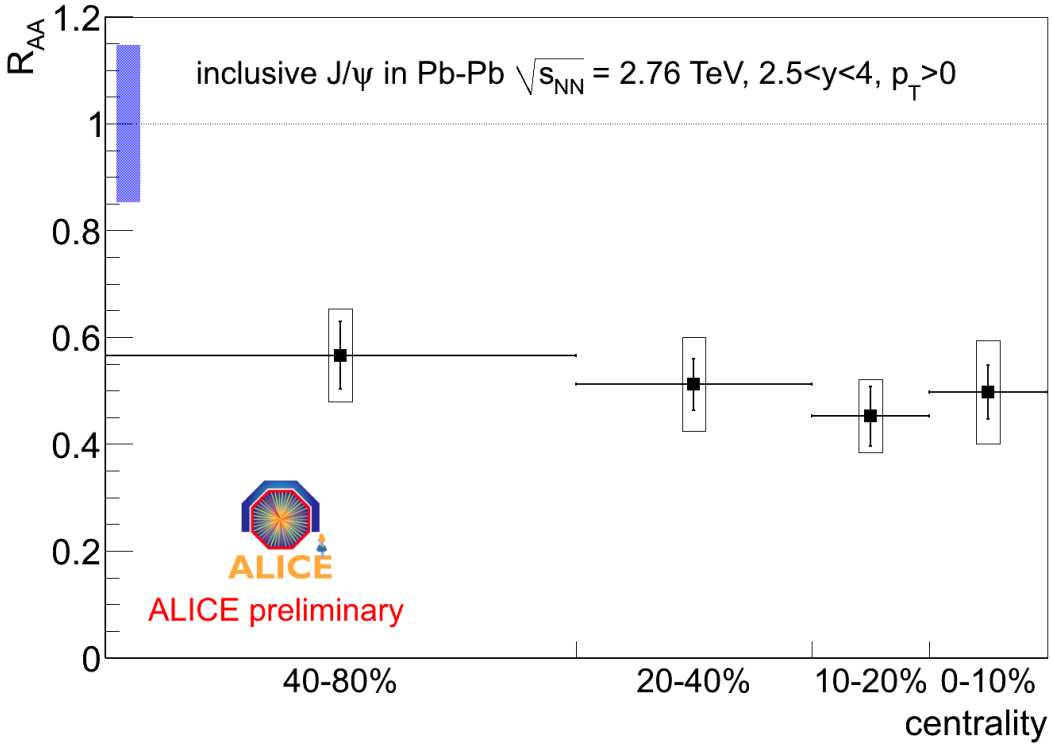
Systematic uncertainties

Systematic uncertainties depending on the centrality have been separated from the common systematics

centrality	0-10%	10-20%	20-40%	40-80%	Common
$N_{J/\psi}$	19%	14%	17%	14%	-
$N_{J/\psi} / N_{J/\psi}^{40\text{-}80\%}$	12%	8%	7%	-	-
Acceptance	-	-	-	-	3%
Eff. Tracker	4%	2%	1%	0%	5%
Eff. Trigger	-	-	-	-	4%
Reco.	-	-	-	-	2%
B.R.	-	-	-	-	1%
X-section	-	-	-	-	13%
$\langle T_{AA} \rangle$	4%	4%	4%	6%	-
$\langle T_{AA} \rangle^{i} / \langle T_{AA} \rangle^{40\text{-}80\%}$	6%	5%	4%	-	-
Total for R_{AA}	**20%**	**15%**	**17%**	**15%**	**15%**
Total for R_{CP}	**14%**	**10%**	**8%**	**-**	**-**

R_{AA} versus centrality

Inclusive J/ψ $R_{AA}^{0\text{-}80\%}$ = 0.49 ± 0.03 (stat.) ± 0.11 (sys.)



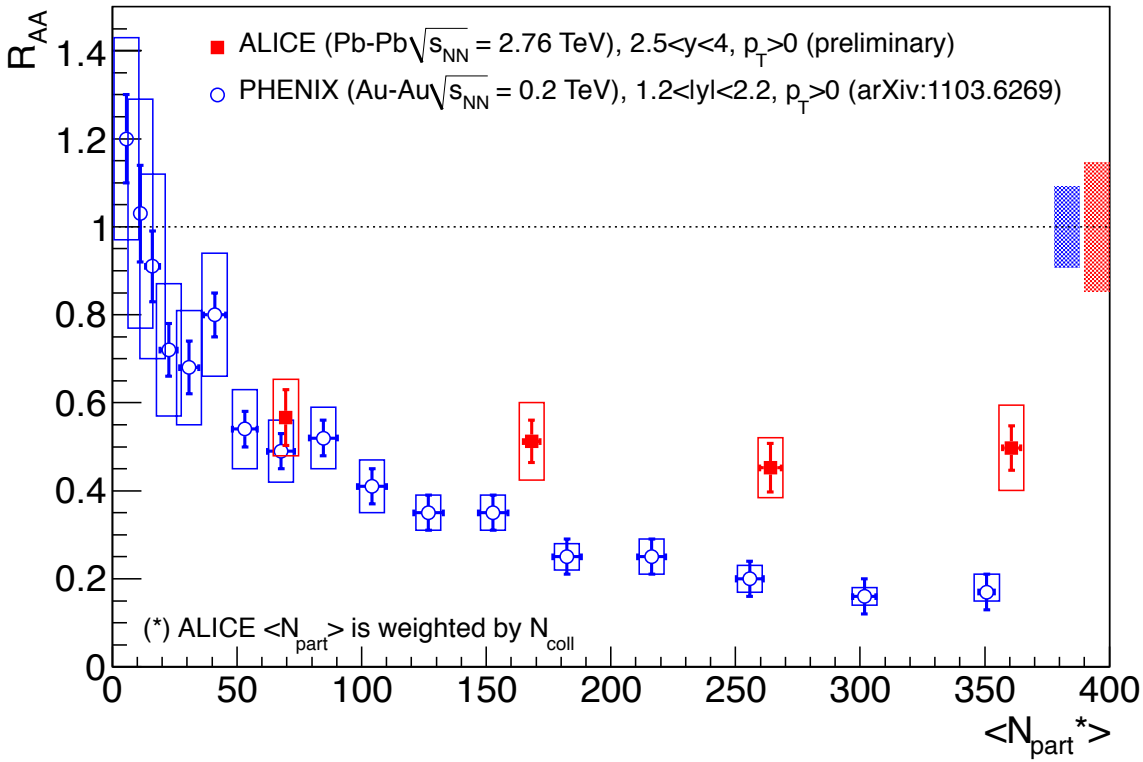
- Error bars:
  Statistical uncertainties
- Empty boxes:
  Centrality-dependent systematic uncertainties
- Blue box:
  Common systematic uncertainties

- Contribution from B feed-down:
  - ~ 10% from p-p measurement (LHCb Coll., arXiv:1103.0423)

  → Rough estimation assuming simple scaling with N_{coll}: ~ 11% reduction of $R_{AA}^{0\text{-}80\%}$

Comparison with PHENIX

Given the size of our centrality bins, and in order to ease the comparison with PHENIX, the calculation of $\langle N_{part} \rangle$ for ALICE has been weighted by N_{coll}



→ J/ψ R_{AA} in central collisions is larger at LHC in 2.5<y<4 than at RHIC in 1.2<|y|<2.2

Comparison with PHENIX

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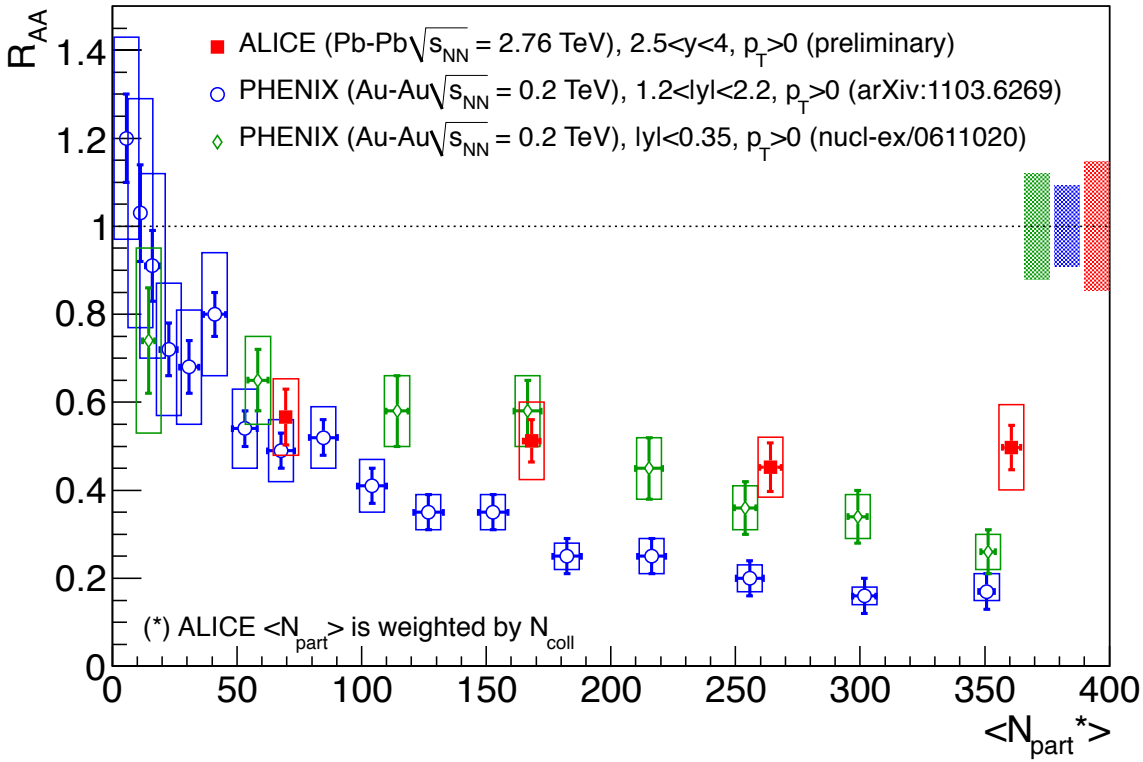
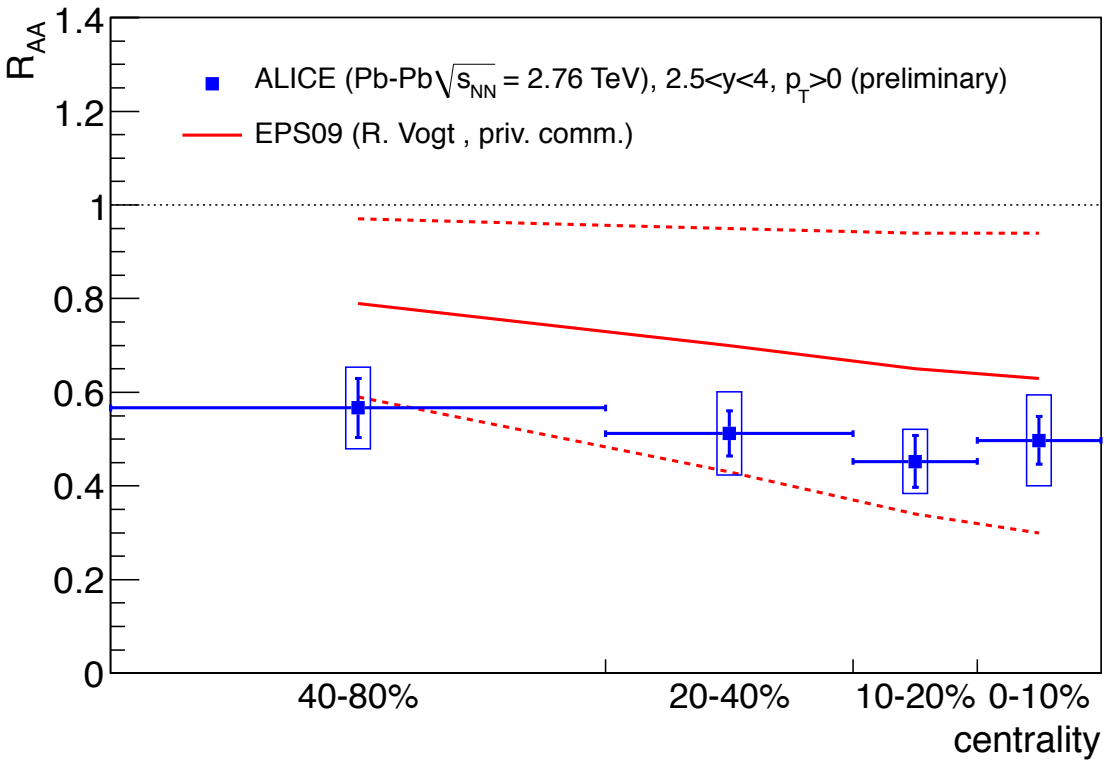


→ J/ψ R_{AA} similar at LHC in 2.5<y<4 and at RHIC in |y|<0.35, Except for the most central collisions

- Shadowing is expected to be larger at LHC…

Comparison with EPS09

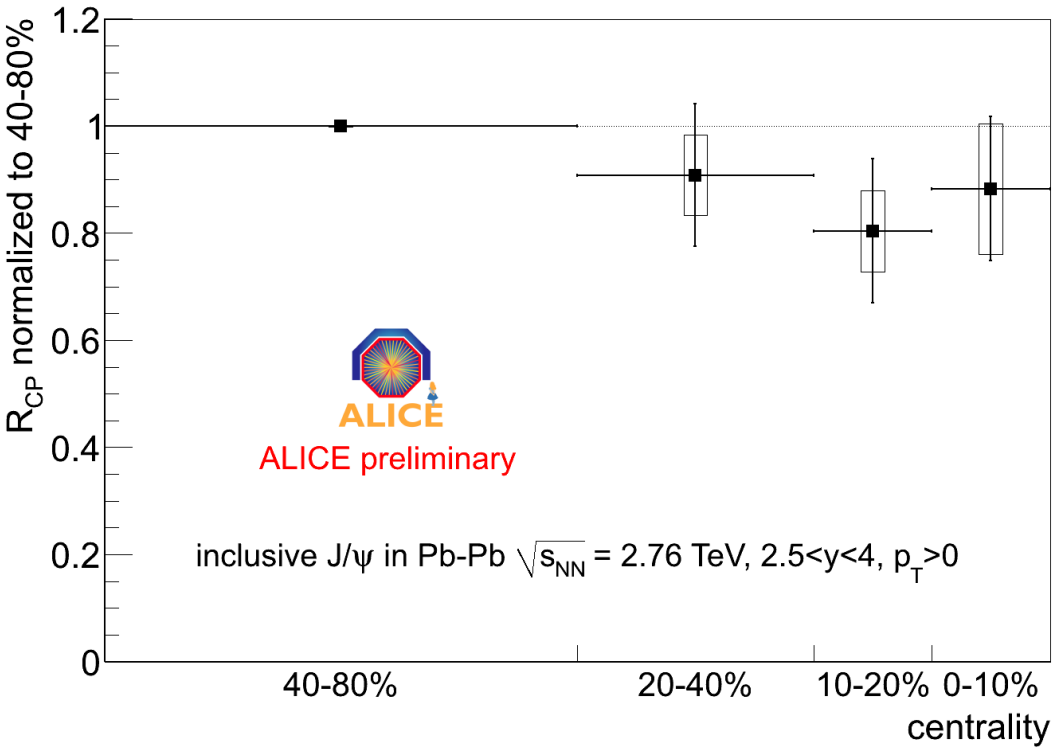
K.J.Eskola *et al.*, JHEP 0904:065, 2009
R. Vogt, Phys.Rev.C81:044903, 2010



- If shadowing is considered, it could even lead to an enhancement of the J/ψ in central Pb-Pb with respect to cold nuclear matter effects
- Large uncertainties for shadowing prediction, p-A is then imperative at LHC

R_{CP} versus centrality

R_{CP} is normalized to the centrality bin 40-80%

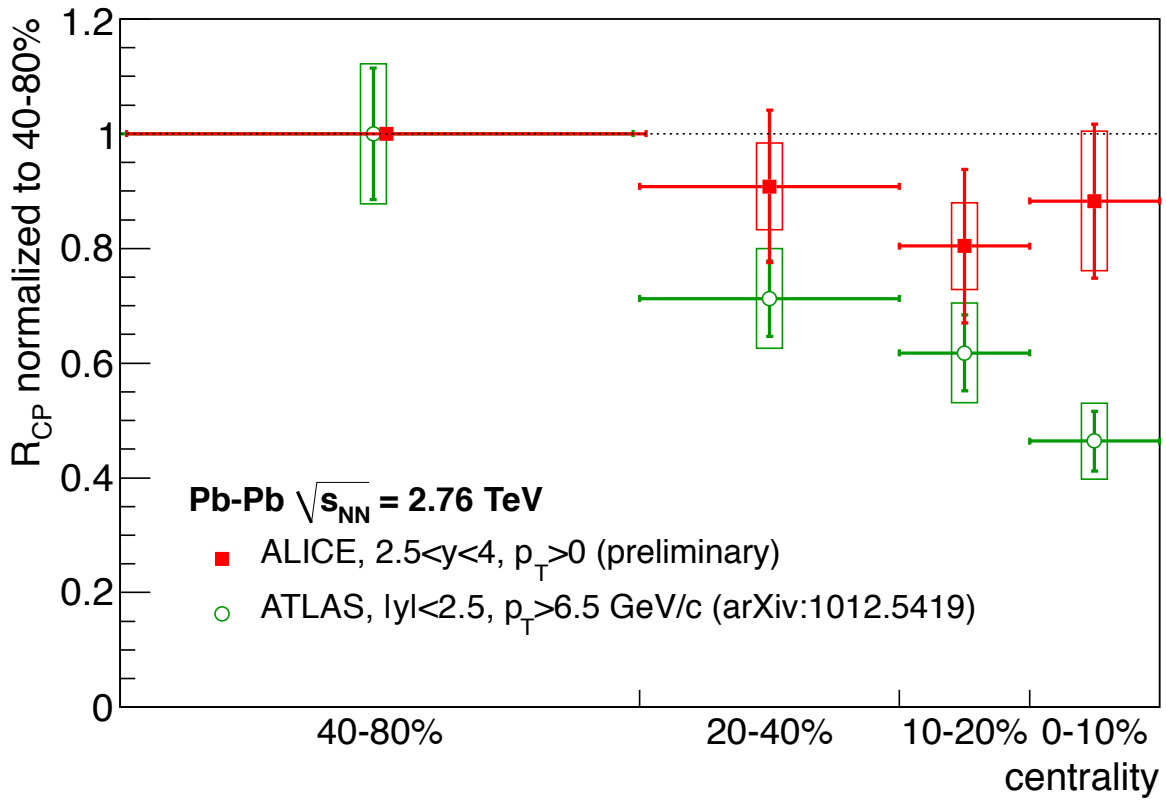


- Error bars: Statistical uncertainties
- Empty boxes: Centrality-dependent systematic uncertainties

- Statistical uncertainty of the reference are propagated to the ratio
- Systematic uncertainties of signal extraction and T_{AA} are have been calculated taking into account the correlations. Common systematic uncertainties vanish

Comparison with ATLAS

Statistical and systematic uncertainties have not been propagated for ATLAS



ALICE:

- 2.5<y<4
- $p_T > 0$

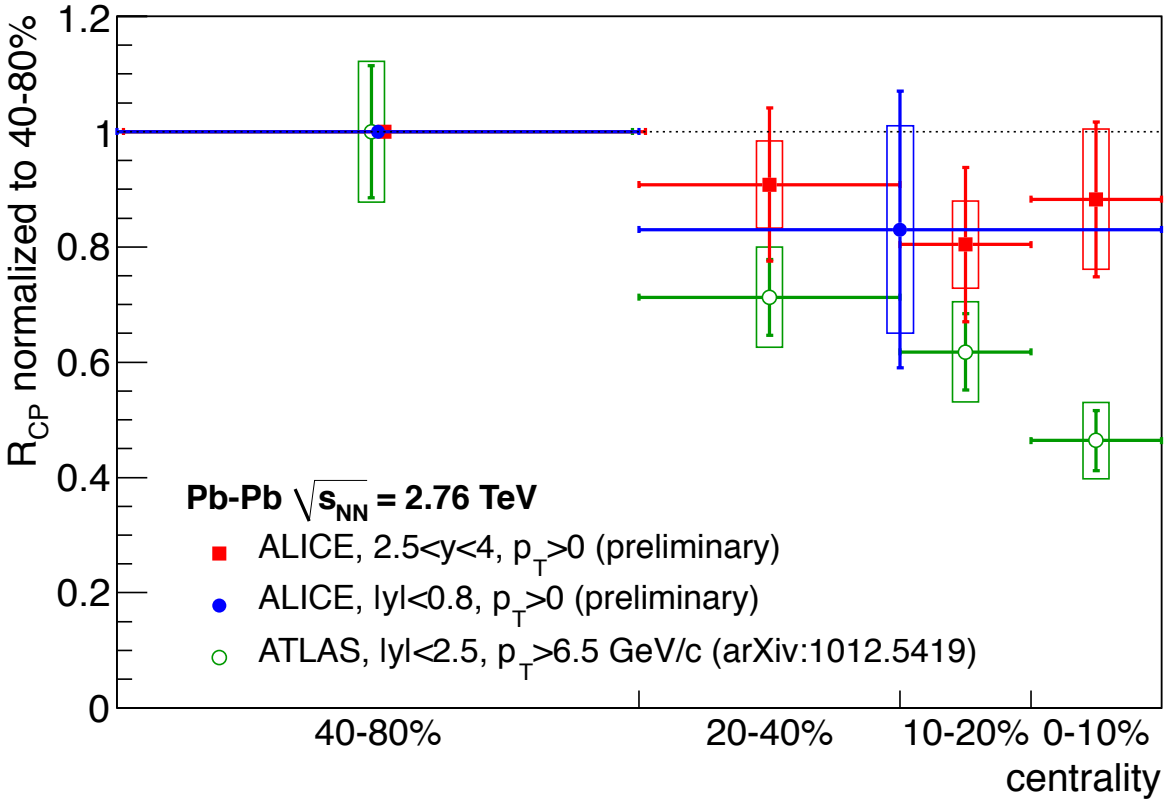
ATLAS:

- |y|<2.5
- 80% of J/ψ with $p_T > 6.5$ GeV/c

J/ψ R_{CP} larger for ALICE than for ATLAS in the most central collisions…
… But different rapidity and p_T coverage

Comparison with ALICE at mid-rapidity

Inclusive J/ψ R_{CP} can be also measured in ALICE at mid-rapidity in the dielectron channel



Very challenging analysis… error bars are still large

→ poster of J. Book and J. Wiechula (#75)

Summary

- Inclusive J/ψ measurement at forward rapidity (2.5<y<4) down to p_T = 0 in Pb-Pb collisions at 2.76 TeV

- R_{AA} (normalized to J/ψ cross-section in p-p at the same energy) and R_{CP} have been shown as a function of the centrality of the collision

→ J/ψ R_{CP} measured down to p_T = 0 at forward rapidity (ALICE) larger than high-p_T J/ψ R_{CP} at mid-rapidity (ATLAS) in central collisions

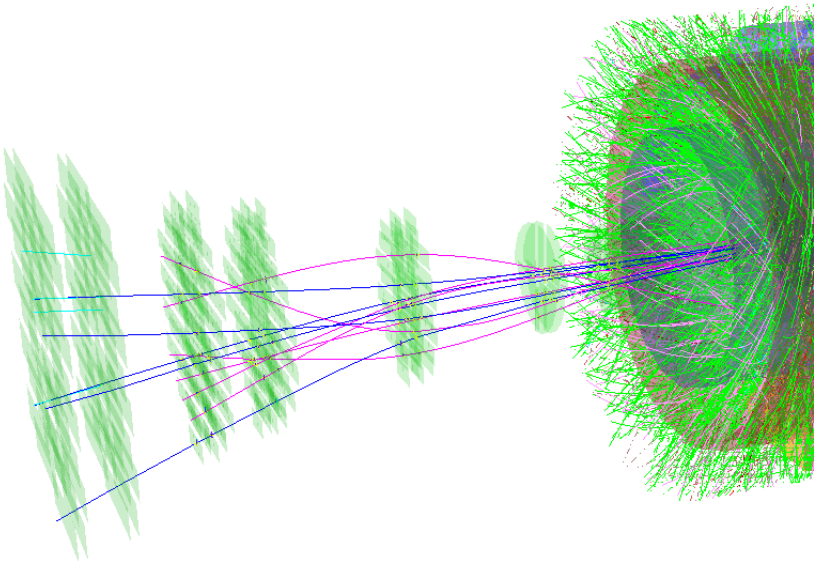
→ J/ψ R_{AA} larger at LHC in 2.5<y<4 than at RHIC in 1.2<|y|<2.2 in central collisions. Closer to the R_{AA} measured at RHIC in |y|<0.35

→ Cold nuclear matter effects have to be measured at LHC!

- Related posters:
  - A. Lardeux and L. Valencia (#58)
  - J. Book and J. Wiechula (#75)

backup

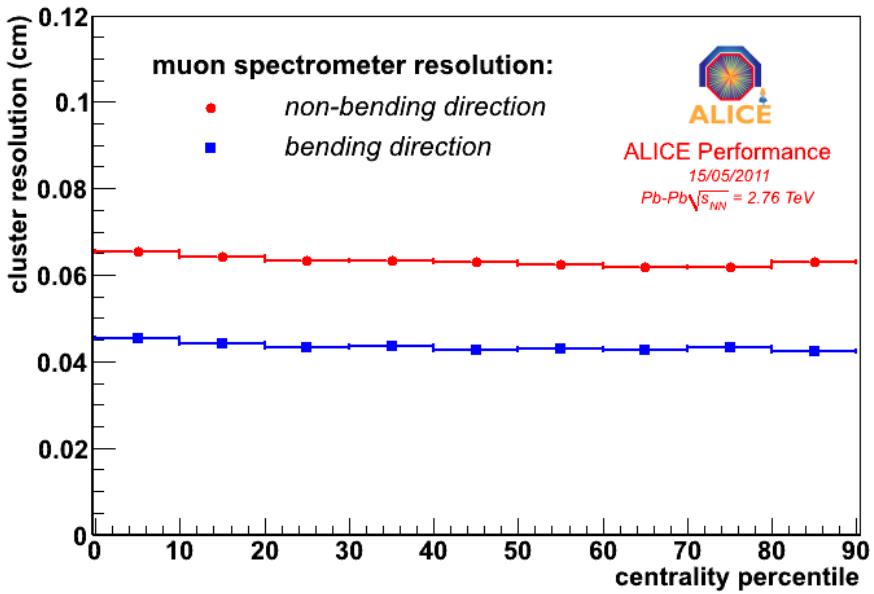
Muon Tracking in Pb-Pb collisions



- Reconstruction parameters specifically tuned on Pb-Pb data to minimize the number of fake tracks while maximizing the efficiency
- Remaining contamination: ~5-10% in the centrality bin 0-10%, mainly at low p_T
- No effect on the J/ψ analysis (checked with additional cut used in single-μ analysis)

- Spectrometer resolution measured directly from data using reconstructed tracks
- 5% loss of resolution in most central events

→ 1-2MeV/c^2 increase of the J/ψ width at most



Crystal Ball function

$$f(x;\alpha,n,\bar{x},\sigma) = N \cdot \begin{cases} \exp(-\frac{(x-\bar{x})^2}{2\sigma^2}), & \text{for } \frac{x-\bar{x}}{\sigma} > -\alpha \\ A \cdot (B - \frac{x-\bar{x}}{\sigma})^{-n}, & \text{for } \frac{x-\bar{x}}{\sigma} \leqslant -\alpha \end{cases}$$

$$A = \left(\frac{n}{|\alpha|}\right)^n \cdot \exp\left(-\frac{|\alpha|^2}{2}\right)$$

$$B = \frac{n}{|\alpha|} - |\alpha|$$

α sets the onset of the tail

n sets the size of the tail

Signal extraction results

- Several tests have been performed, w/ and w/o background subtraction, varying the (residual) background and signal shapes

→ The weighted average gives the number of J/ψ for the R_{AA}

→ The weighted RMS is used to assess the systematics

- For each test, the ratio of the number of J/ψ in the centrality bin *i* over the centrality bin 40-80% is computed

→ The weighted average gives the ratio used for R_{CP}

→ The weighted RMS is used to assess the systematics (the correlations vanish)

Acceptance × efficiency correction

- Based on simulations that accounts for the detector conditions and their time dependence

- Realistic J/ψ parameterization:
  - p_T and y interpolated from data (Phenix, CDF, LHC) ← F. Bossu et al., arXiv:1103.2394
  - Shadowing from EKS98 calculations

→ Integrated Acc×Eff correction with the current track selection = 19.44 ± 0.04 %

- Centrality dependence of reconstruction efficiency not included in the simulations
  - Measured directly from real data

    → Poster of Antoine Lardeux and Lizardo Valencia (#58)

  → 2% added in the systematics