Charmonium production in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 and 5.02 TeV with ALICE

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On behalf of the ALICE Collaboration

Strangeness in Quark Matter 2016, Berkeley, June 27th – July 1st 2016

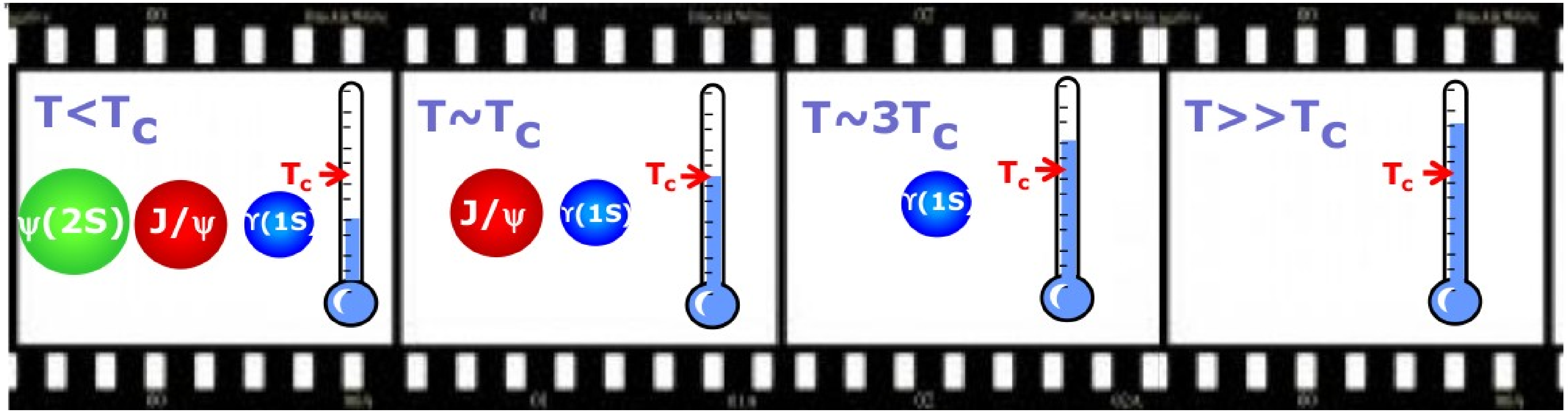
Outline

- Introduction
- ALICE detector
- Analysis technique
- Inclusive J/ψ R_{AA} at $\sqrt{s_{NN}}$ = 5.02 TeV in Pb-Pb collisions versus centrality and transverse momentum NEW!!
  - Using pp cross section at $\sqrt{s}$ = 5.02 TeV as R_{AA} reference
  - Comparison to the results at $\sqrt{s_{NN}}$ = 2.76 TeV
  - Comparison to the theoretical models NEW!!
- The results are available in CERN-EP-2016-162 and are published in arXiv:1606.08197

Quarkonium in a hot medium

→ Quarkonium suppression:

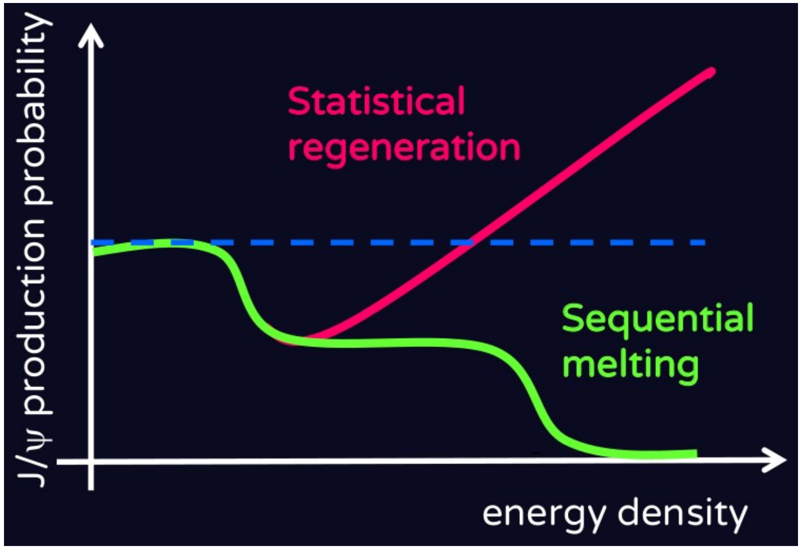
- Quarkonium states are expected to be dissociated in a hot medium by color screening.
- Differences in the binding energies lead to a sequential melting of the states with increasing temperature (T. Matsui and H. Satz, PLB 178 (1986) 416).



→ Quarkonium (re)combination:

- Increasing the collision energy, the $c\bar{c}$ pair multiplicity increases.
- Enhanced quarkonium production via (re)combination at hadronization or during QGP stage.

(P. Braun-Muzinger, J. Stachel, PLB 490 (2000) 196, R. Thews et al, Phys. Rev. C 63 (2001) 054905)



Quarkonium measurement in ALICE

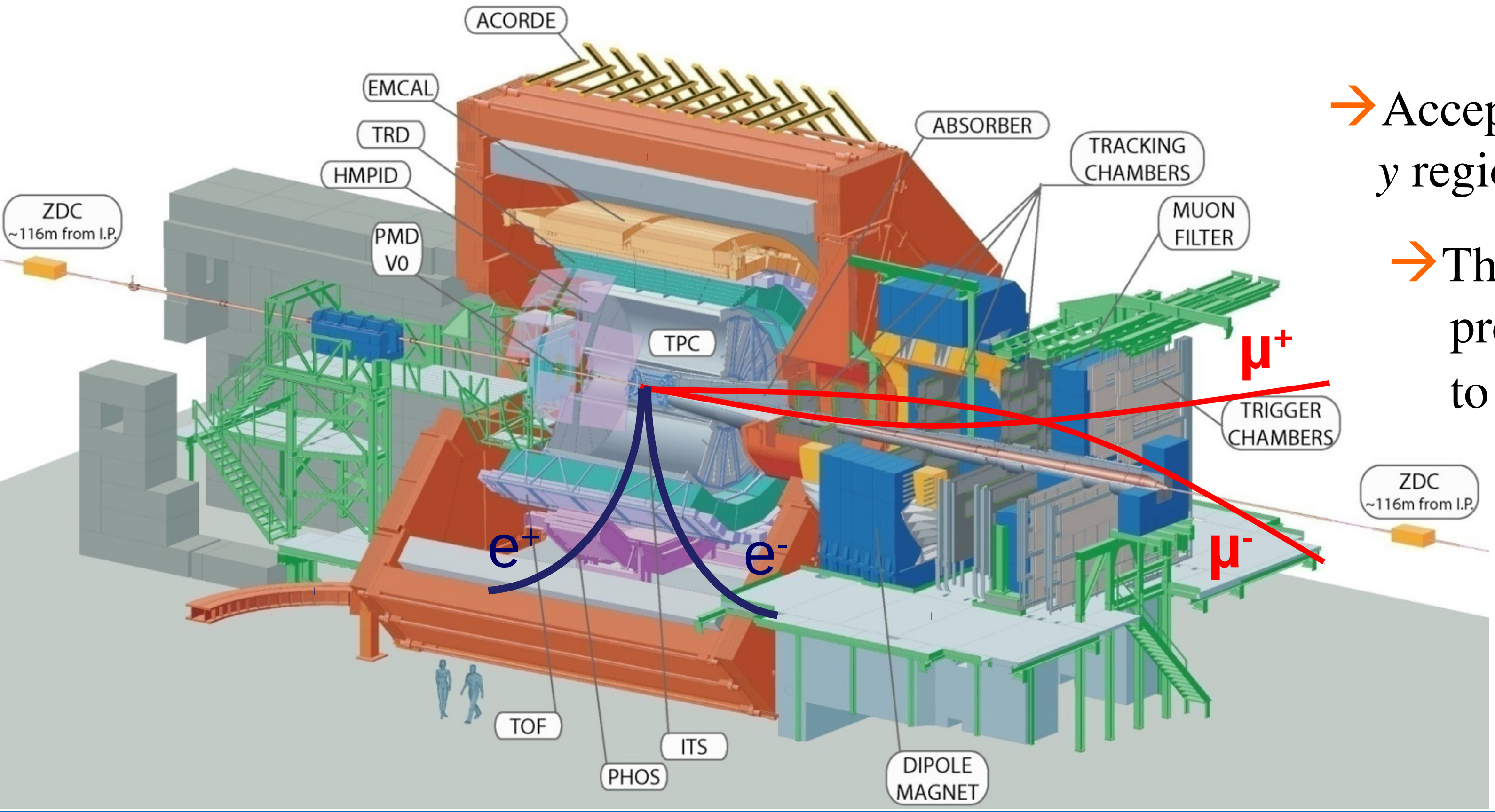
→ Quarkonium in ALICE can be measured in two ways:

Central Barrel: $J/\psi \rightarrow e^+e^-$
($|y| < 0.9$)

Electrons tracked using ITS and TPC
Particle identification: TPC (+TOF)

Forward muon arm: $J/\psi \rightarrow \mu^+\mu^-$
($2.5 < y < 4$)

Muons identified and tracked in the muon spectrometer



→ Acceptance coverage in both y regions down to zero p_T

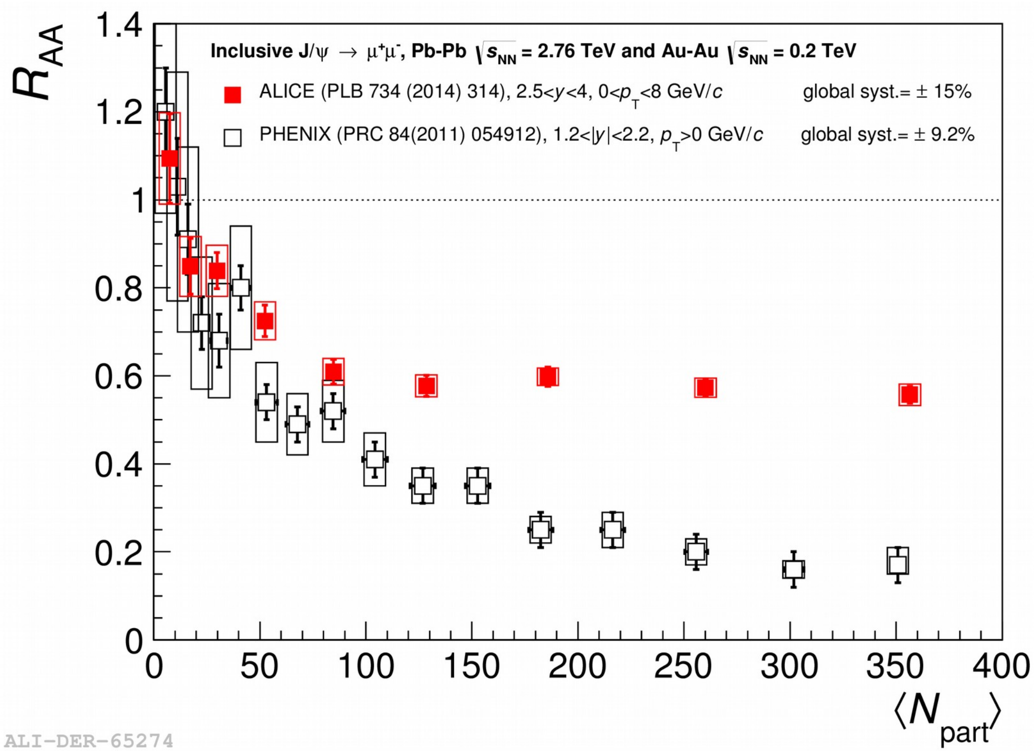
→ The ALICE results presented in this talk refer to inclusive J/ψ.

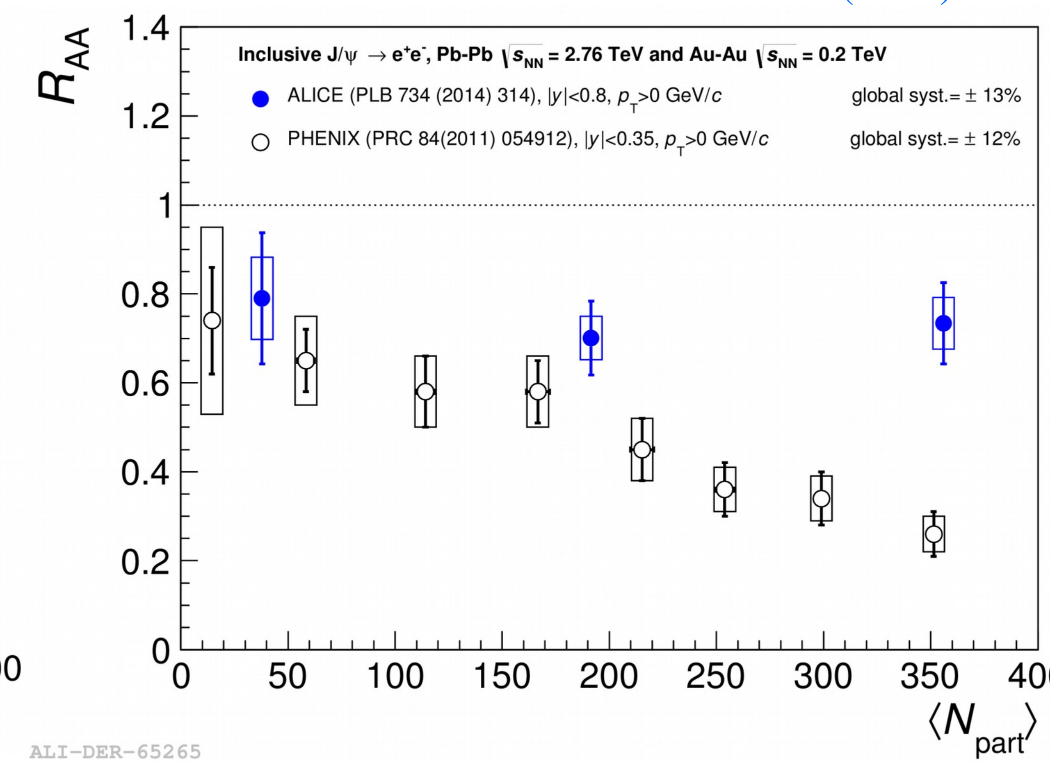
ALICE J/ψ Run-1 results in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV

J/ψ R_{AA} vs centrality: ALICE vs PHENIX

→ Centrality dependence of the J/ψ inclusive R_{AA} studied by ALICE at both central and forward rapidities down to zero p_T.

ALICE Coll. PLB 734 (2014) 314





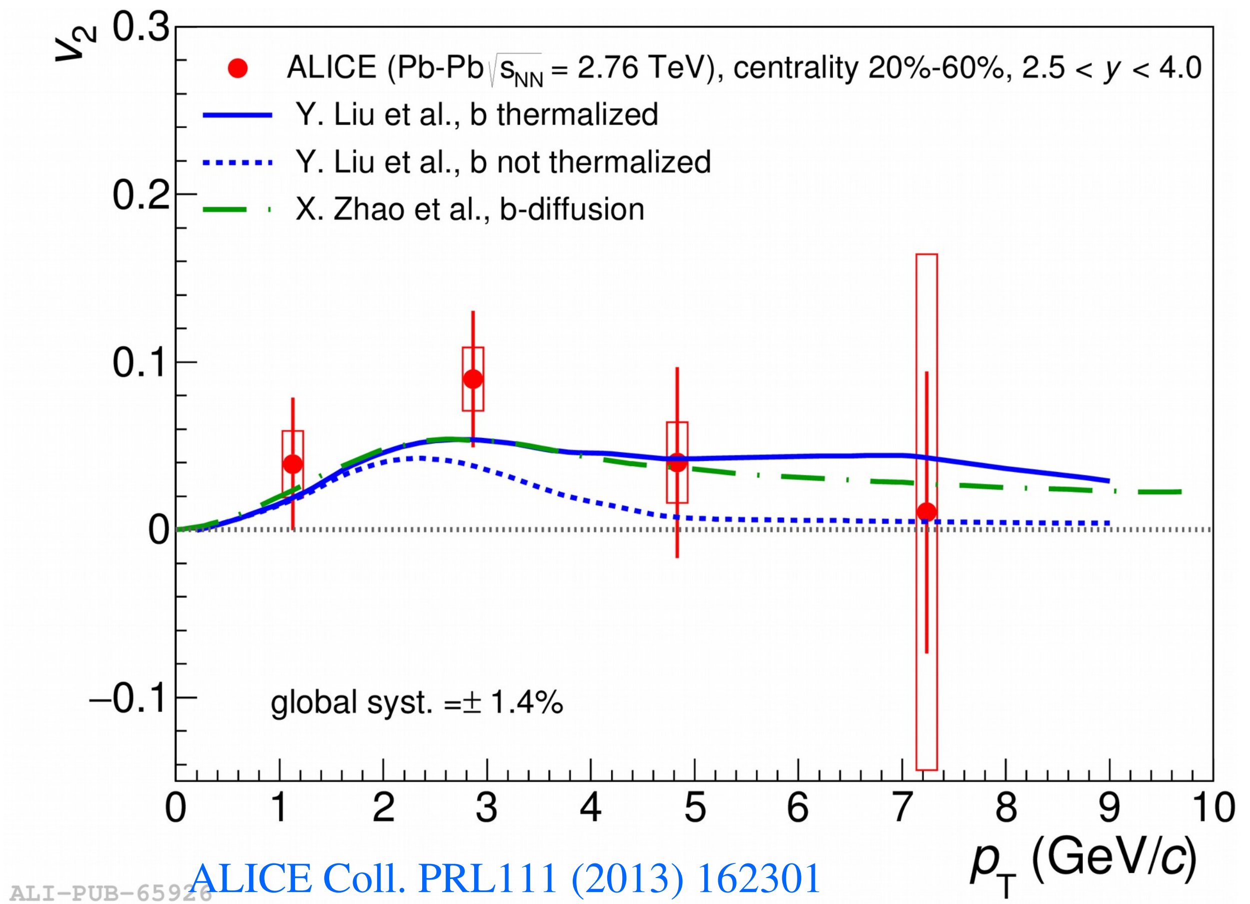
→ ALICE results:

clear J/ψ suppression with almost no centrality dependence for $N_{part} > 100$.

→ Comparison with PHENIX:

ALICE results show weaker centrality dependence and smaller suppression for central events, behaviour expected in a (re)combination scenario.

J/ψ flow



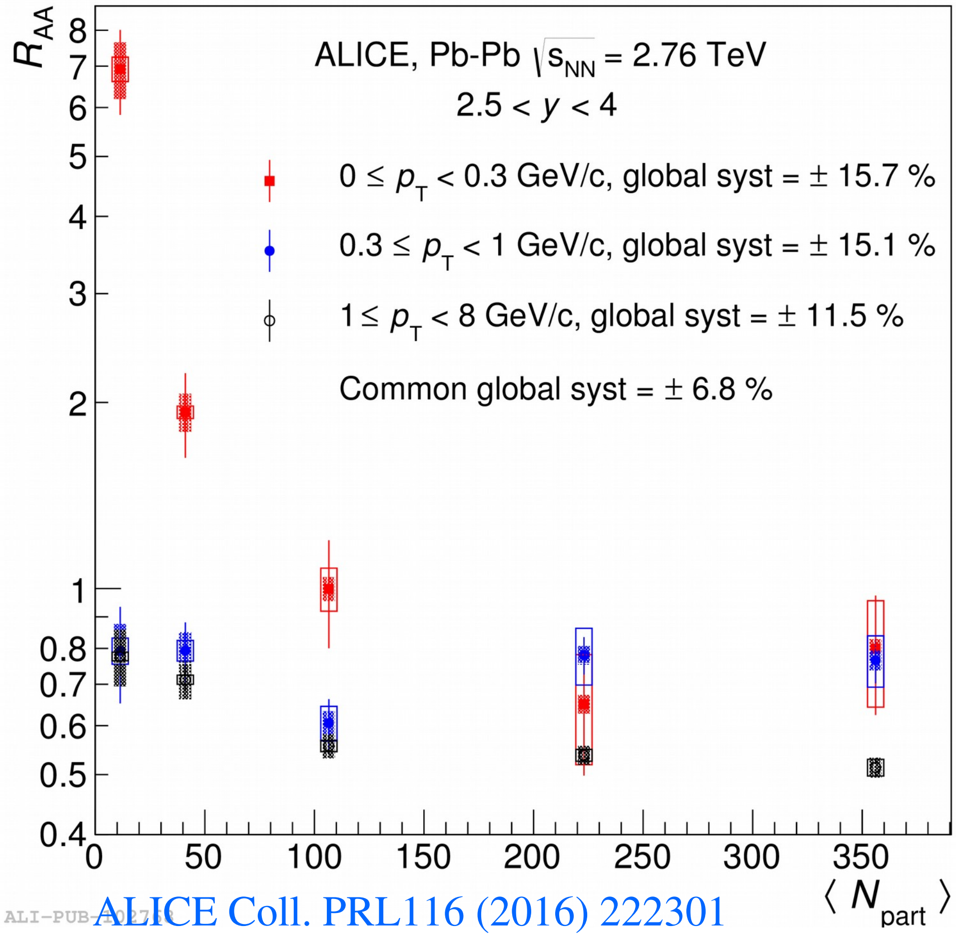
ALICE Coll. PRL111 (2013) 162301

→ The contribution of J/ψ from (re)combination should lead to a significant elliptic flow signal at LHC energy.

→ Hint for J/ψ flow at the LHC while $v_2 \sim 0$ at RHIC [PRL. 111, 052301 (2013)] (even if with large uncertainties).

→ Qualitative agreement with transport models including regeneration.

Low p_T J/ψ



ALICE Coll. PRL116 (2016) 222301

→ Excess of J/ψ at very low p_T observed in peripheral Pb-Pb collisions.

→ Photoproduction of J/ψ in Pb-Pb collisions with $b < 2R$ was proposed to be at the origin of this excess. The cut $p_T > 0.3$ GeV/c removes ~75% of photoproduced J/ψ.

ALICE J/ψ Run-2 results in Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV

NEW!!

CERN-EP-2016-162
arXiv:1606.08197

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

→ Results from 2015 data set, based on dimuon triggered events

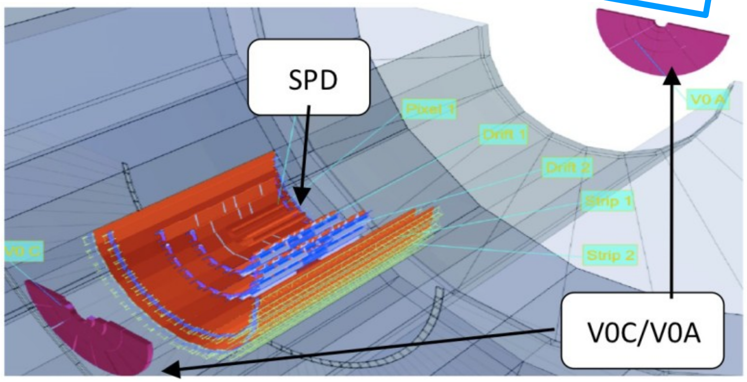
Integrated luminosity ~ 225 μb^{-1}

→ **Event selection:**

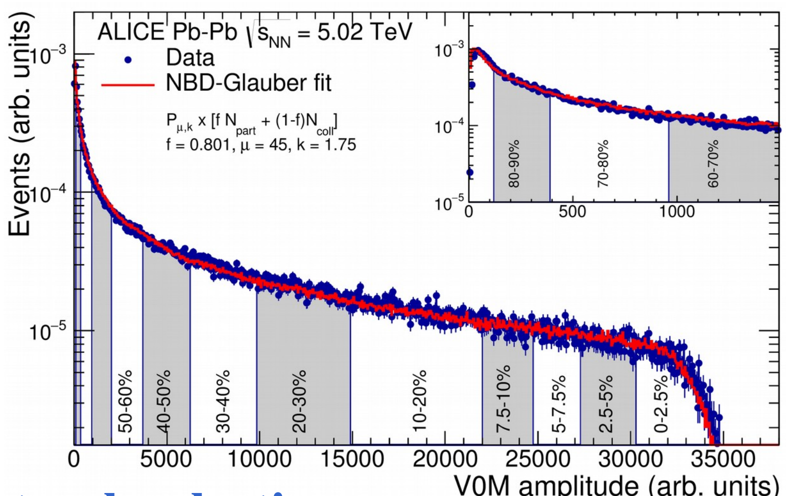
Rejection of beam gas and electromagnetic interactions (V0 and ZDC)
SPD used for vertex determination

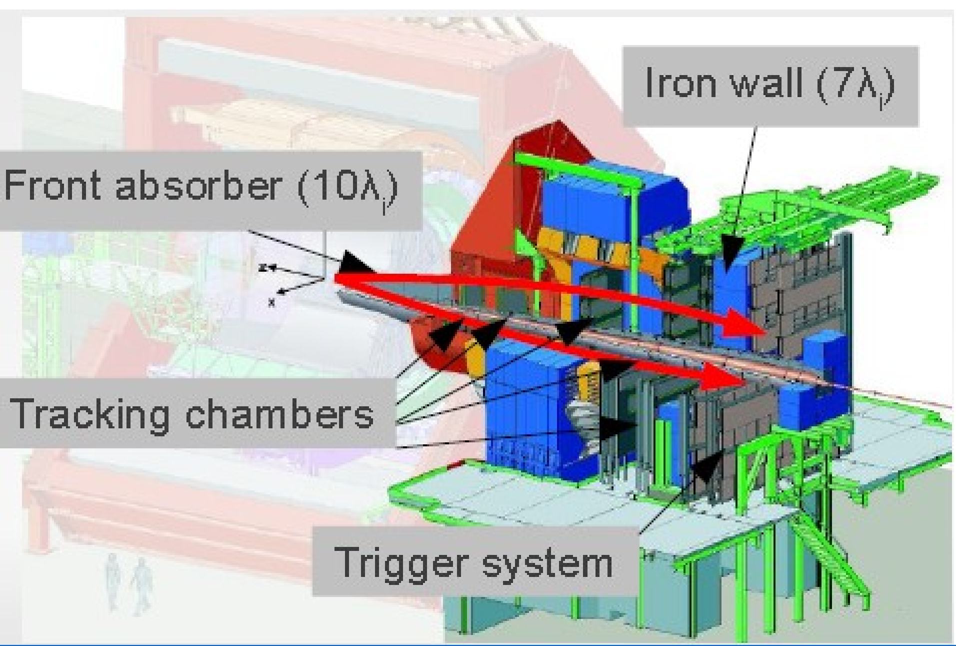
→ **Centrality selection:**

Estimate based on a Glauber model fit of the V0 amplitude



PRL. 116, 222302 (2016)





→ **Muon track selection:**

- Muon trigger matching
- $-4 < \eta_\mu < -2.5$
- $17.6 < R_{abs} < 89.5$ cm
  (R_{abs} = track position at the absorber end)
- $2.5 < y_{\mu\mu} < 4$

NEW!!

J/ψ -> $\mu^+\mu^-$ signal

→ The statistics is now ~ 7 times higher w.r.t. Run-1.

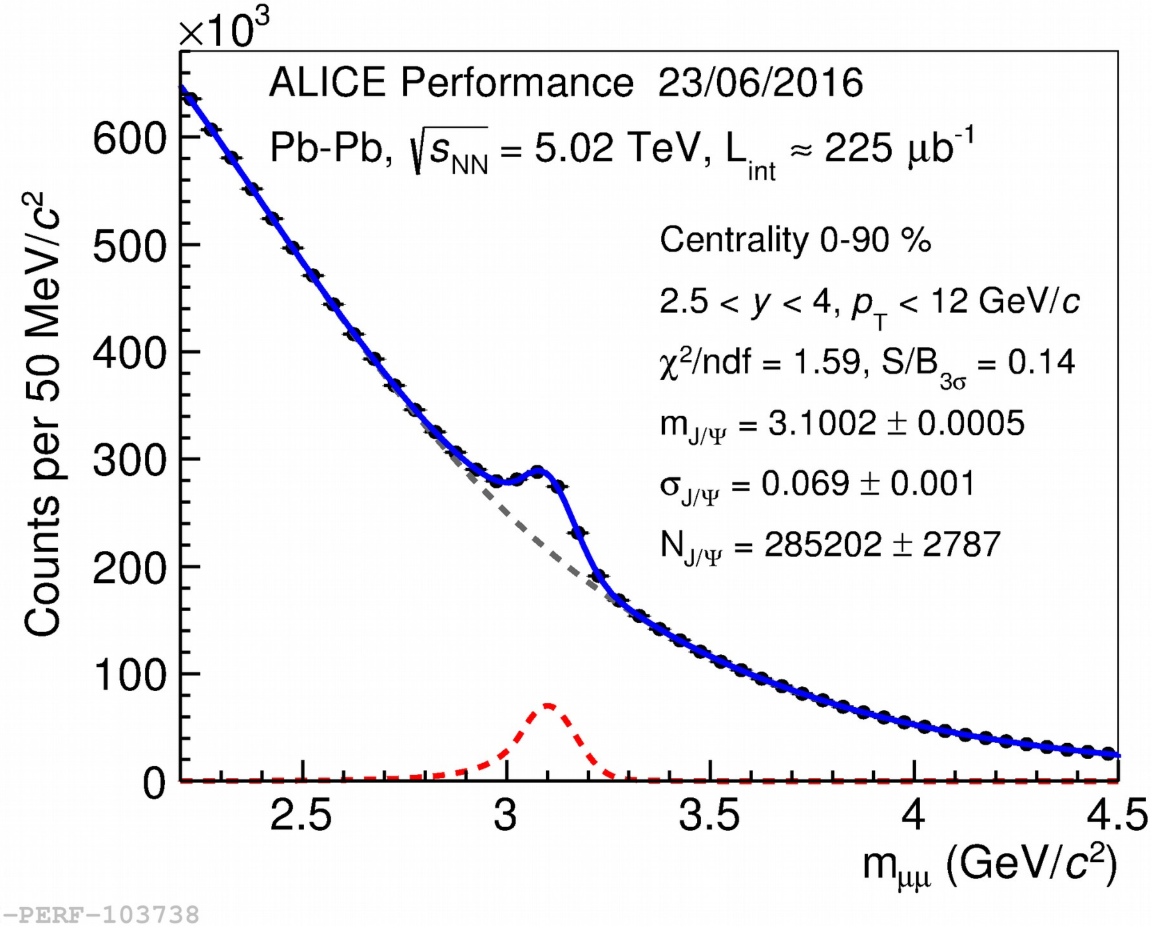
→ J/ψ yield extracted fitting the opposite sign dimuon invariant mass spectrum.

0-90% centrality, p_T < 12 GeV/c

→ Signal is extracted with a extended Crystal Ball function or a pseudo-Gaussian function

Background: phenomenological fits of the inv. mass spectrum or subtraction of the background evaluated from event mixing

→ Results obtained with different techniques are combined to extract $\langle N_{J/\psi}\rangle$ and to evaluate systematic uncertainties.



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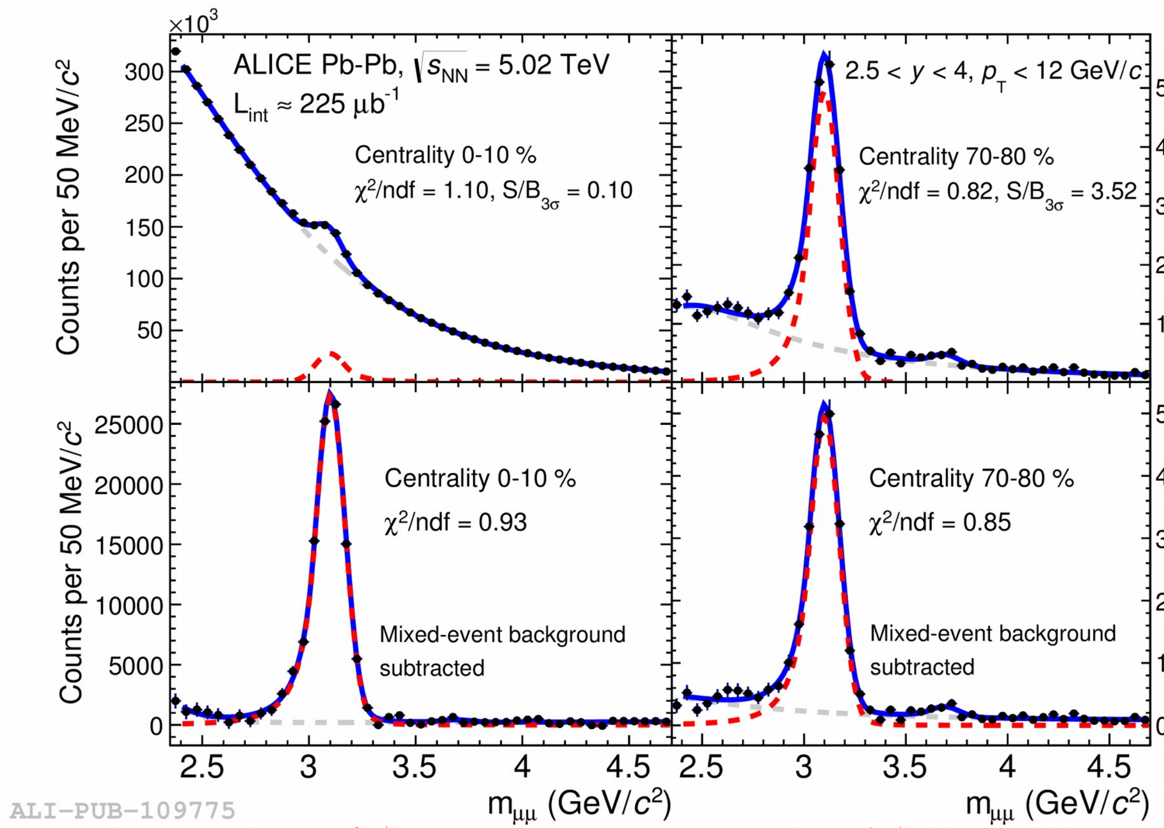
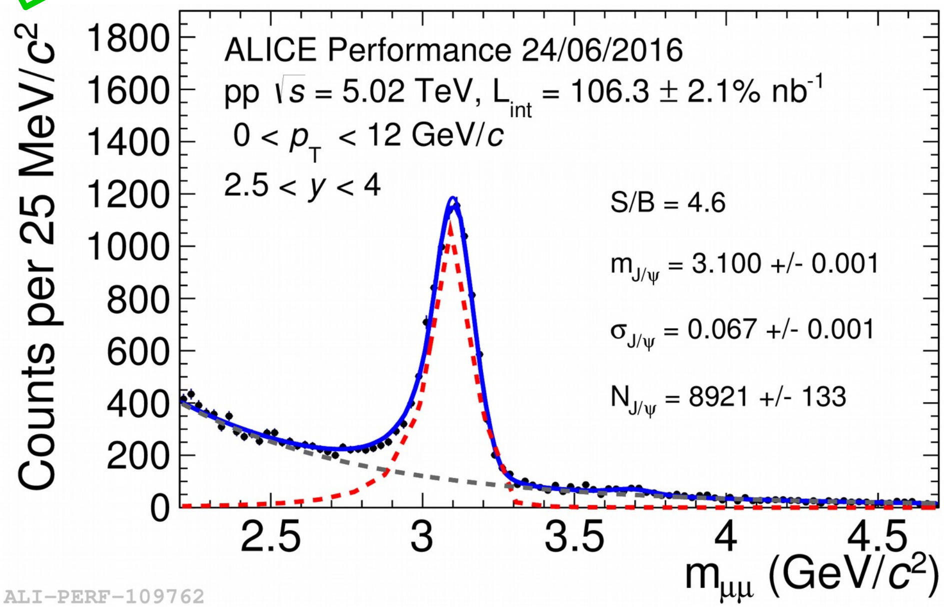


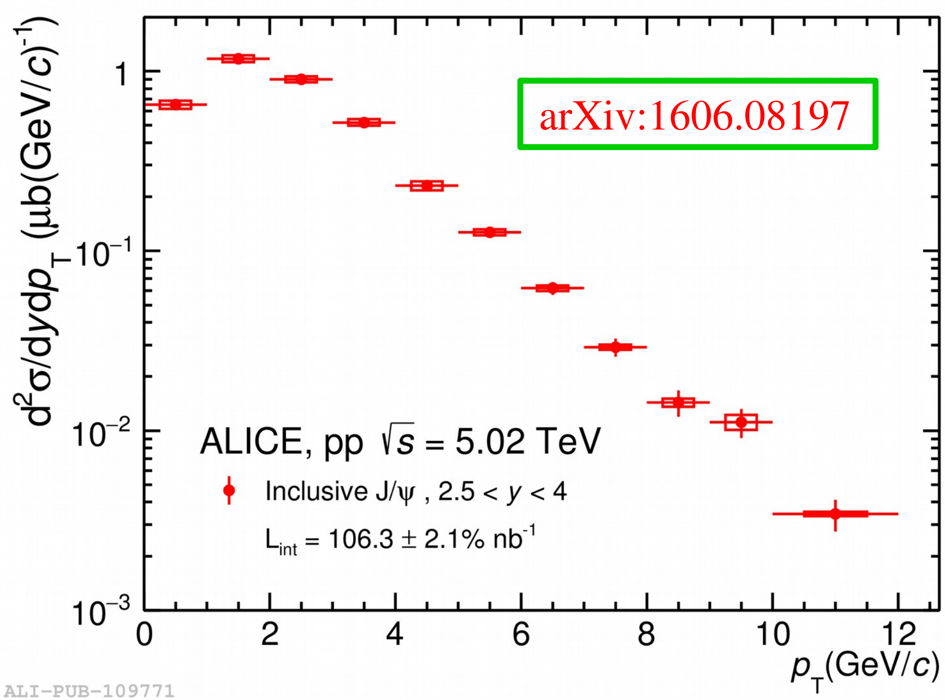
Central

Peripheral

pp cross section at $\sqrt{s}$ = 5.02 TeV

NEW!!





→ ALICE took data at $\sqrt{s}$ = 5.02 TeV during 4 days in November 2015.

→ We collected a luminosity of 106.3 nb^{-1}

→ The analysis technique adopted is similar to the one of Pb-Pb collisions.

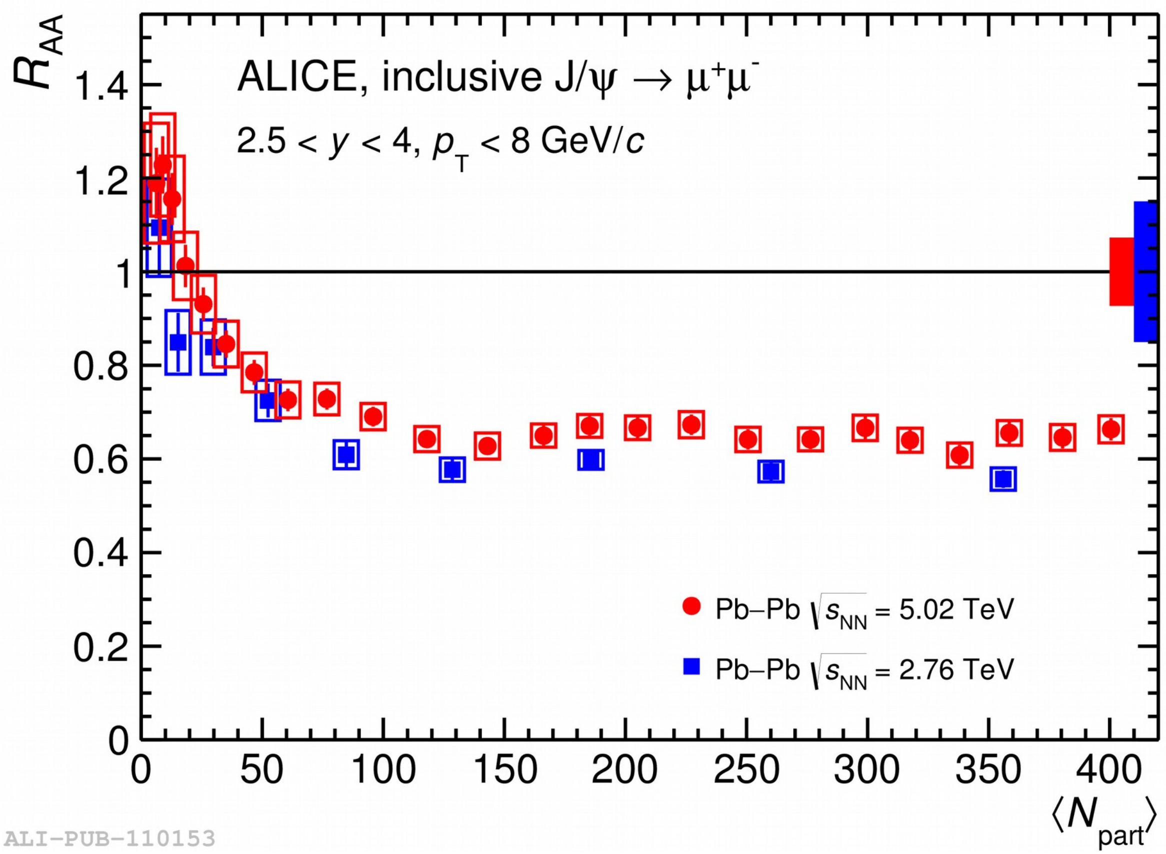
→ We use these data as reference for the J/ψ R_{AA} in Pb-Pb collisions.

→ Integrated cross section (p_T < 12 GeV/c): 5.61 ± 0.08 (stat.) ± 0.28 (syst.) μb.

→ The integrated and differential cross sections are in very good agreement with the interpolation values used for p-Pb results at $\sqrt{s_{NN}}$ = 5.02 TeV.

Inclusive J/ψ R_{AA} vs centrality

→ High statistics collected in 2015 allows the R_{AA} measurement in narrow centrality bins.



arXiv:1606.08197

→ Clear J/ψ suppression with almost no centrality dependence above N_{part}~100.

→ $R_{AA}^{0\text{-}90\%}$ ($0 < p_T < 8$ GeV/c) = 0.66 ± 0.01 (stat.) ± 0.05 (syst.).

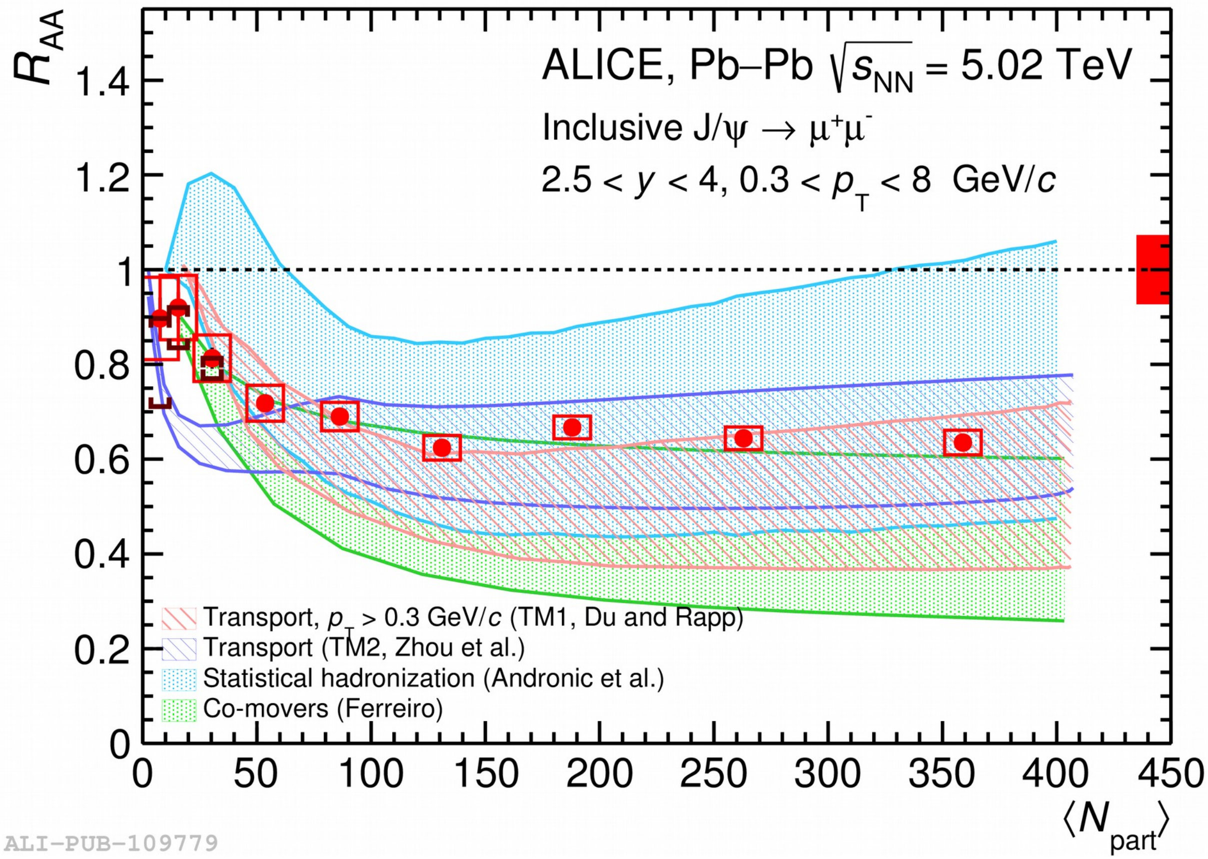
→ R_{AA} at $\sqrt{s_{NN}}$ = 2.76 TeV was 0.58 ± 0.01 (stat.) ± 0.09 (syst.).

→ A systematic difference of ~15% is visible w.r.t. R_{AA} at $\sqrt{s_{NN}}$ = 2.76 TeV. Effect is within the uncertainties of the measurement.

→ The R_{AA} of prompt J/ψ would be about 10% higher if $R_{AA(non\text{-}prompt)} = 0$ and about 5% (1%) smaller if $R_{AA(non\text{-}prompt)} = 1$ for central (peripheral) collisions.

NEW!!

Inclusive J/ψ R_{AA} vs centrality



arXiv:1606.08197

→ p_T > 0.3 GeV/c cut removes about 80% of photoproduced J/ψ.

→ R_{AA} is compared with the theoretical calculations: statistical, transport and comovers approaches.

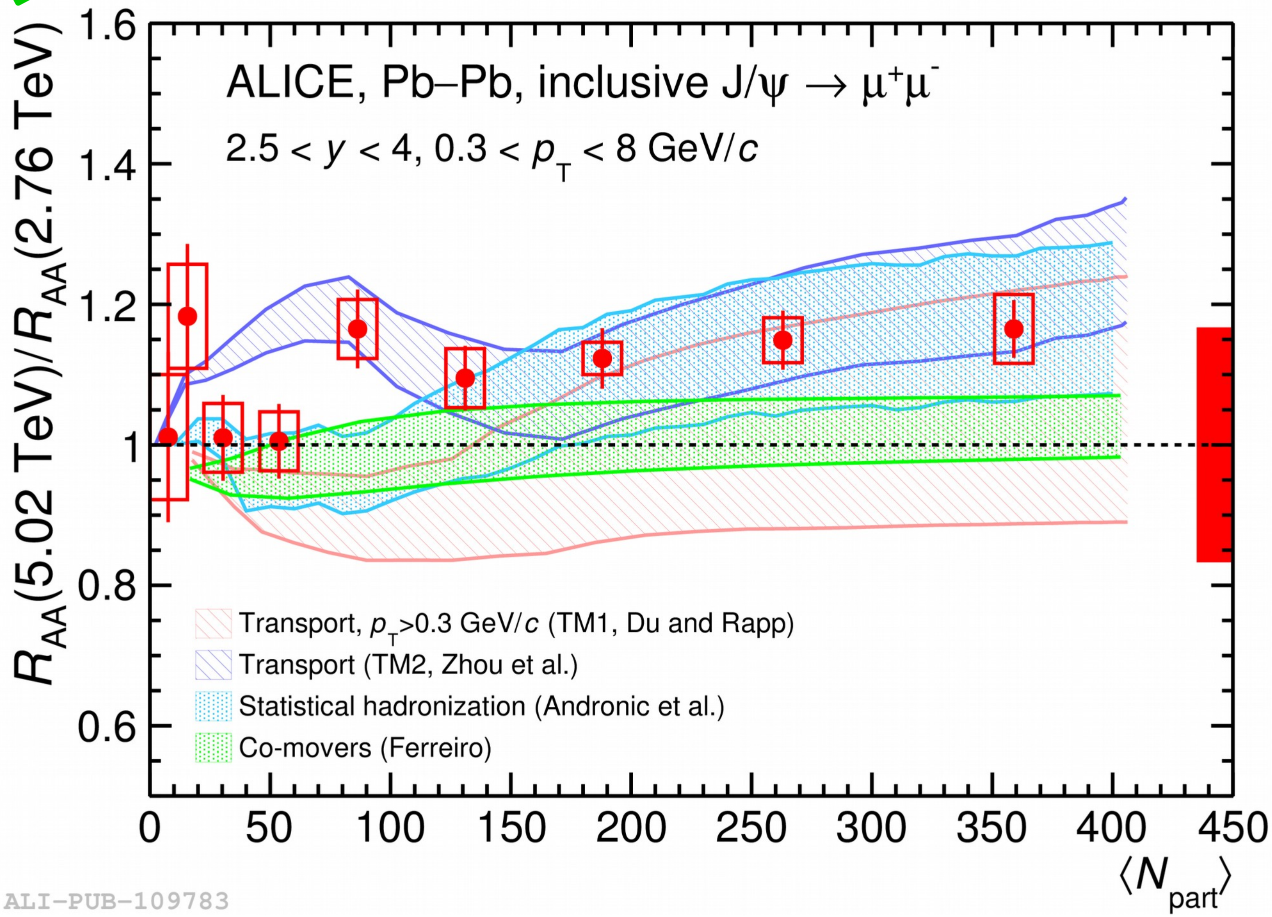
→ Large uncertainties due to the choice of input parameters in particular $\sigma_{c\bar{c}}$.

TM1: Nucl. Phys. A859 (2011) 114–125
TM2: Phys. Rev. C89 no. 5, 459 (2014) 054911
Stat. hadronization: NPA 904-905 (2013) 535c
Co-movers: Phys. Lett. B731 (2014) 57–63

→ For most calculations a better agreement with the data is found when considering their upper limit.

→ For transport models this corresponds to the absence of nuclear shadowing, which can be clearly considered as an extreme assumption.

Ratio of R_{AA} at $\sqrt{s_{NN}}$ = 5.02 and 2.76 TeV



arXiv:1606.08197

→ By doing the double ratio, some uncertainties on the models cancel out.

→ With the measurement, the T_{AA} uncertainty is cancelled.

→ The error bands on the models correspond to a variation by 5% of the $c\bar{c}$ cross section.

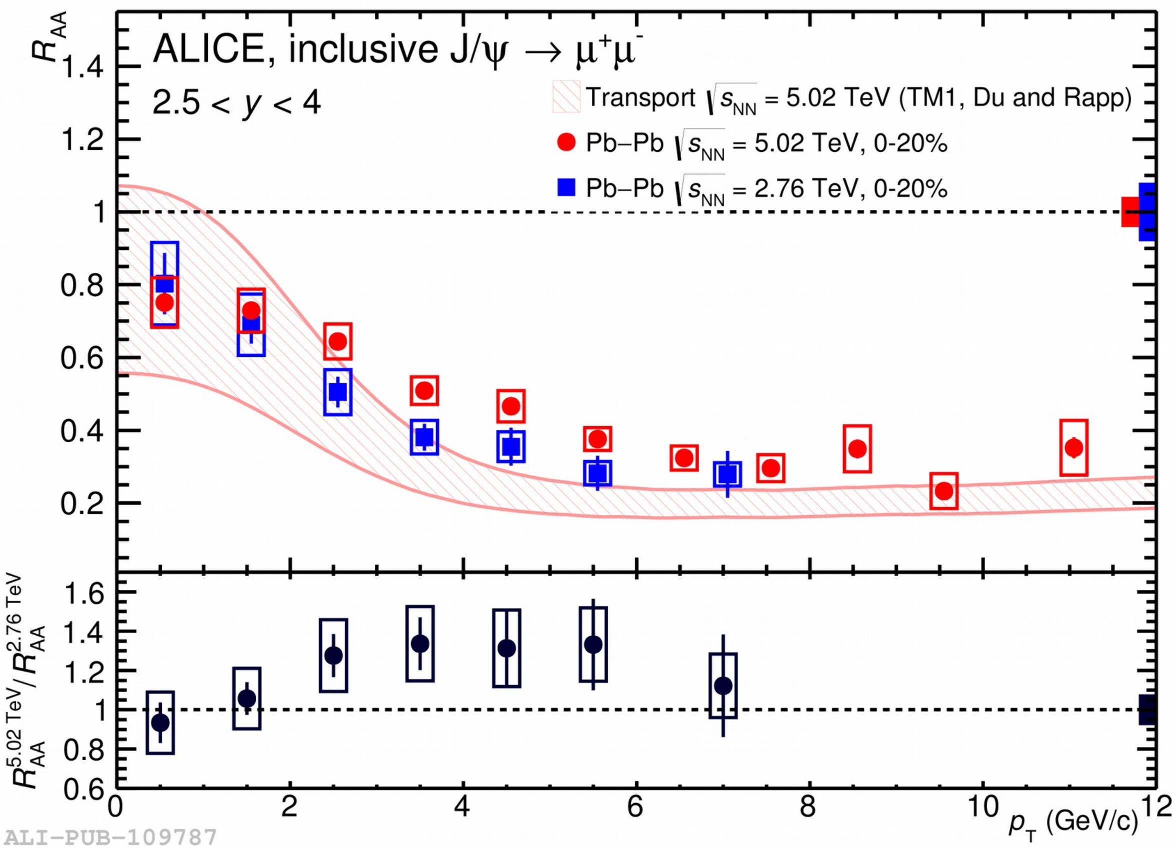
→ Contribution from non-prompt J/ψ varies the double ratio by 2%.

→ The double ratio for most central events is 1.17 ± 0.04 (stat.) ± 0.20 (syst.).

→ Data are, within uncertainties, compatible with the theoretical models, and show no clear centrality dependence.

NEW!!

Inclusive J/ψ R_{AA} vs p_T



arXiv:1606.08197

→ R_{AA} measurement now extended up to 12 GeV/c.

→ Less suppression at low with respect to high p_T, with stronger p_T dependence for central events as expected from models with strong regeneration component.

→ Hint for an increase of R_{AA} with $\sqrt{s_{NN}}$ is visible in $2 < p_T < 6$ GeV/c.

Conclusions

→ The J/ψ cross section has been measured both integrated and in p_T bins in pp collisions at $\sqrt{s}$ = 5.02 TeV.

→ The inclusive J/ψ nuclear modification factor has been measured in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV at forward rapidity, down to $p_T = 0$.

→ The centrality and p_T dependence of R_{AA} have been studied:

- R_{AA} shows an increase of the suppression with centrality up to $N_{part} \sim 100$ followed by a saturation.
- The p_T dependence of R_{AA} exhibits an increase at low p_T.

→ Comparing the R_{AA} at $\sqrt{s_{NN}}$ = 5.02 and 2.76 TeV:

- A difference by ~ 15% is observed, without a clear centrality dependence.
- As a function of p_T, a hint for an increase of R_{AA} is visible in $2 < p_T < 6$ GeV/c.

→ These results are described by theoretical calculations and they support a picture of J/ψ suppression and regeneration in a QGP.

Thank you

Summary of systematic uncertainties (Pb-Pb)

Source	0-90%, p_T<12GeV/c	0-20%, vs p_T	Vs centrality
Signal extraction	1.8%	1.2-3.1%	1.6-2.8%
MC input	2%	2%	2%*
Tracking efficiency	3%	3%+1%	3%*+1% (central)
Trigger efficiency	3.6%	1.5-4.8%+1%	3.6%*+1% (central)
Matching efficiency	1%	1%	1%*
$<T_{AA}>$	3.2%	3.2%*	3.1-7.6%
F_{norm}	0.5%	0.5%*	0.5%*
Centrality	0%	0.1%*	0-6.6%
pp reference (stat.)	1.5%	3-20%	1.5%*
pp reference (syst.)	5.0%	3-10% + 2.1%*	4.9%*

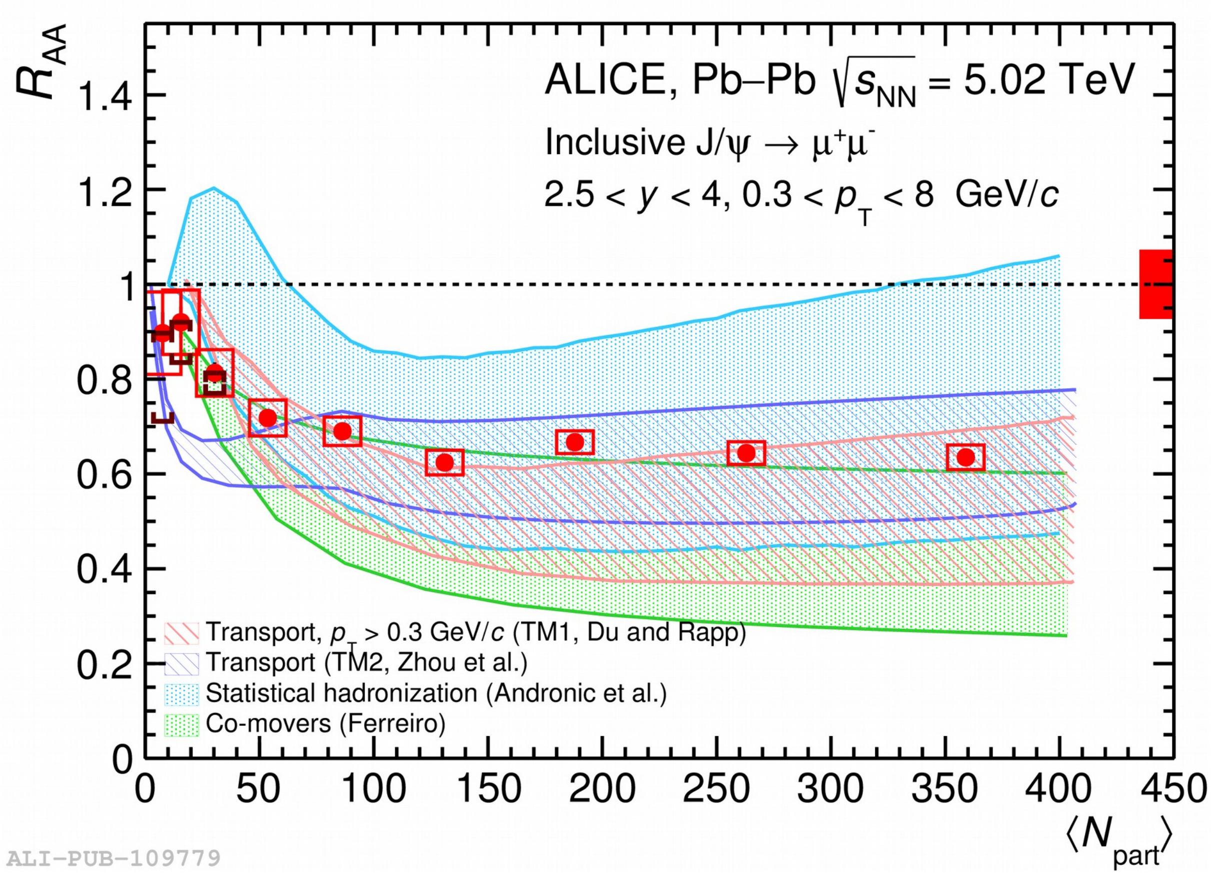
* correlated error

Summary of systematic uncertainties (pp)

Source	$0 < p_T < 12$ GeV/c	Vs p_T
Signal extraction	3%	1.5-9.3%
MC input	2%	0.7-1.5%
Tracking efficiency	1%	1%
Trigger efficiency	1.8%	1.5-1.8%
Matching efficiency	1%	1%
Luminosity	2.1%	2.1%*
BR	0.5%	0.5%*

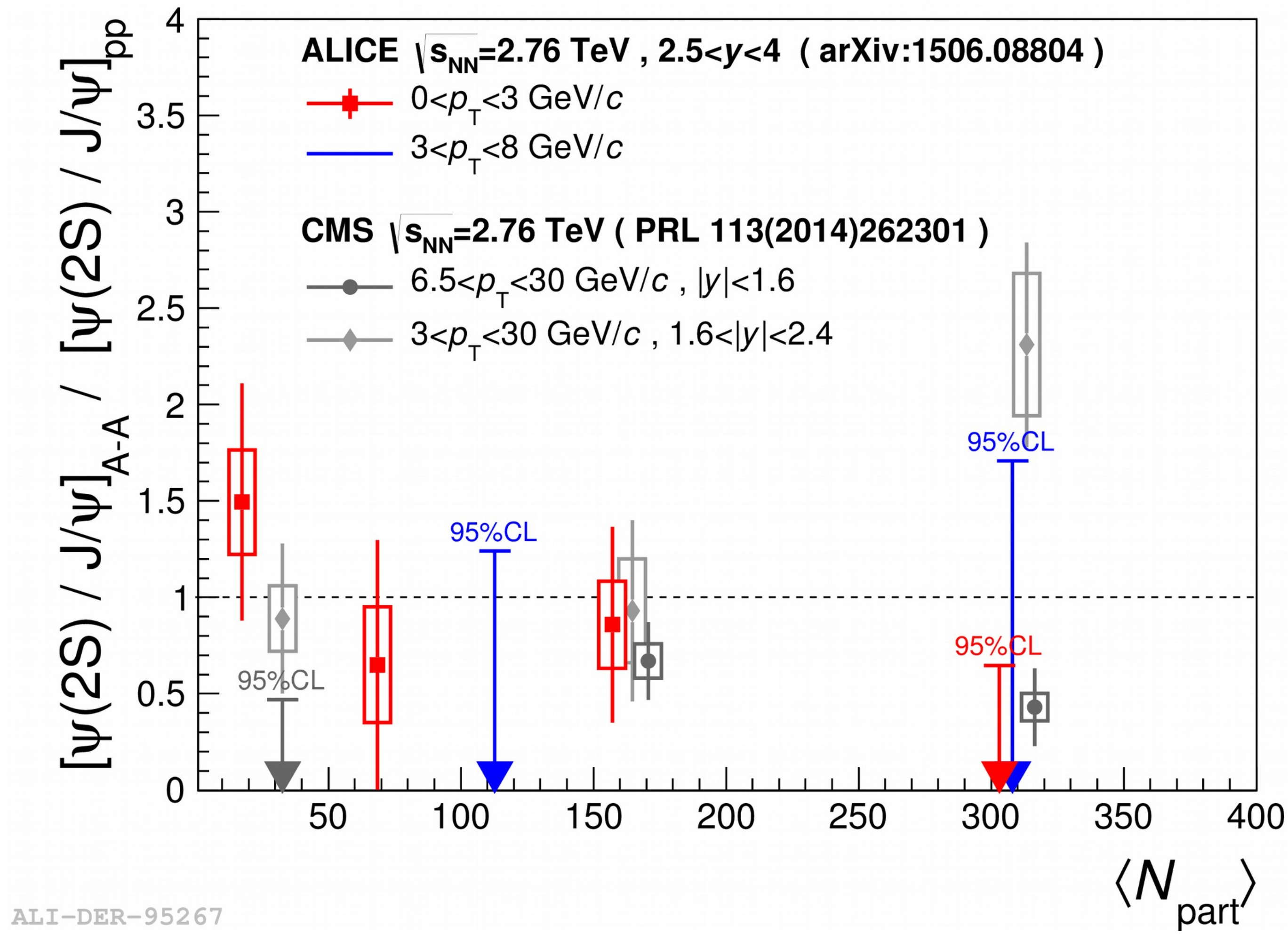
* correlated error

Inclusive J/ψ R_{AA} vs centrality



model	$\sigma_{c\bar{c}}$	N-N $\sigma_{J/\psi}$	comover $\sigma_{J/\psi}$	Shadowing
Transport(Rapp)	0.57 mb	3.14 μb	-	EPS09
Transport(Zhou)	0.82 mb	3.5 μb	-	EPS09
Stat. hadronization	0.45 mb	-	-	EPS09
Comovers	[0.45,0.7] mb	3.53 μb	0.65 mb	Glauber-Gribov theory

ψ(2S)/J/ψ ratio



→ Good agreement between ALICE and CMS data.

→ Large statistical and systematic uncertainties prevent a firm conclusion on the y ψ(2S) trend vs centrality.

R_{AA} of prompt and non-prompt J/ψ

→ The R_{AA} of prompt J/ψ would be about 10% higher if $R_{AA(non\text{-}prompt)} = 0$ and about 5% (1%) smaller if $R_{AA(non\text{-}prompt)} = 1$ for central (peripheral) collisions.

→ The prompt J/ψ R_{AA} is expected to be 7% larger (2% smaller) for $p_T < 1$ GeV/c and 30% larger (55% smaller) for $10 < p_T < 12$ GeV/c when the beauty contribution is fully (not) suppressed.