Steffen Weber for the ALICE collaboration

July 09, 2015

Charmonium production at mid-rapidity in Pb-Pb and p-Pb collisions with ALICE

Outline

- Motivation
- Analysis method
- Results from Pb-Pb collisions and interpretation
- Results from p-Pb collisions and interpretation
- Summary and outlook

Motivation for Pb-Pb measurements

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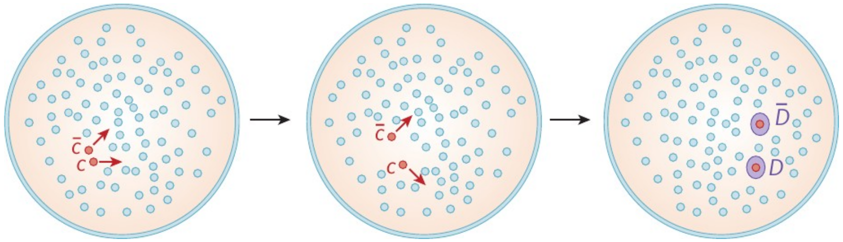
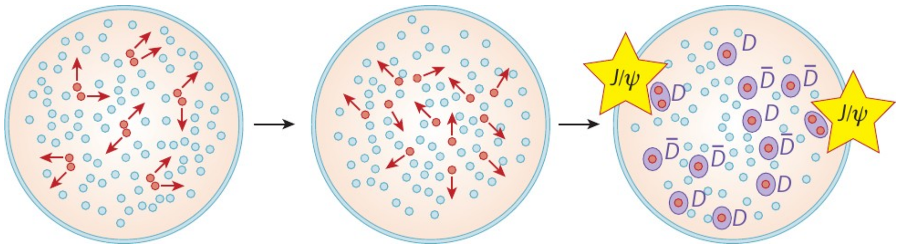
J/ψ is a unique probe for the hot medium created in AA collisions:

- Suppression due to colour screening T. Matsui, H. Satz: PLB 178 (1986) 416



- At LHC energies: abundant production of $c\bar{c}$ quark pairs → high chance of (re)combination into charmonia
  - At hadronization P. Braun-Munzinger , J. Stachel: PLB 490 (2000) 196
  - Continuous creation and dissociation in deconfined medium
    R. L. Thews et al.: Phys.Rev.C 63,054905 (2001)

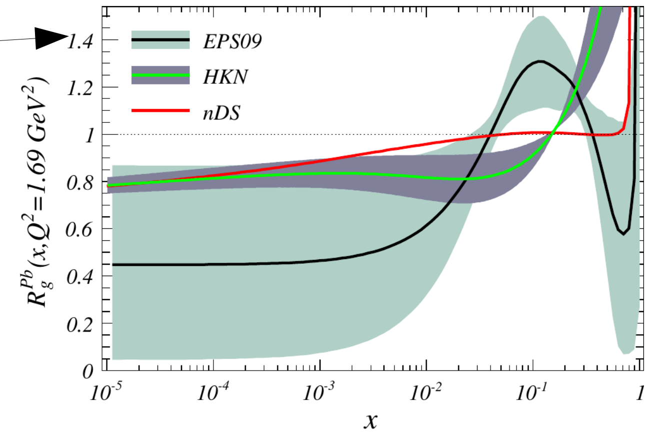


P. Braun-Munzinger, J. Stachel: Nature, 448:302–309 (2007)

Motivation for p-Pb measurements

Besides hot medium effects, also cold nuclear matter (CNM) effects (initial and final state) influence charmonium production:

- Gluon saturation (Colour Glass Condensate)
  François Gelis, Edmond Iancu: Ann.Rev.Nucl.Part.Sci.60:463-489 (2010)
- Nuclear shadowing
  K. J. Eskola et al.: JHEP 0904:065 (2009)
- Partonic energy loss
  Rishi Sharma, Ivan Vitev:
  Phys. Rev. C 87, 044905 (2013)



C. A. Salgado et al.: J.Phys. G39 (2012) 015010

- Nuclear absorption (negligible at LHC energy)

These effects are studied in p-A collisions.
→ provide a baseline for hot medium effects

Analysis Method

The ALICE detector

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$J/\psi \rightarrow e^+e^-$ reconstructed in ALICE central barrel down to $p_T=0$

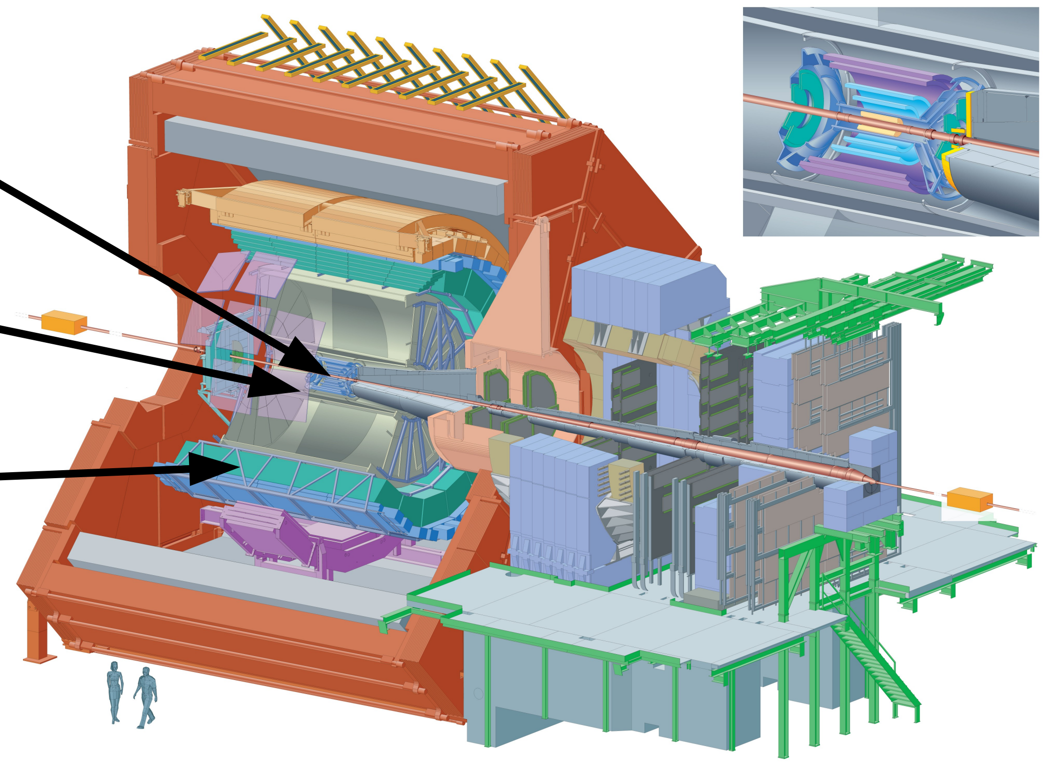
Pb-Pb : $|\eta| < 0.9$

p-Pb: $-1.37 < \eta_{cms} < 0.43$

ITS
vertexing, tracking

TPC
tracking, PID

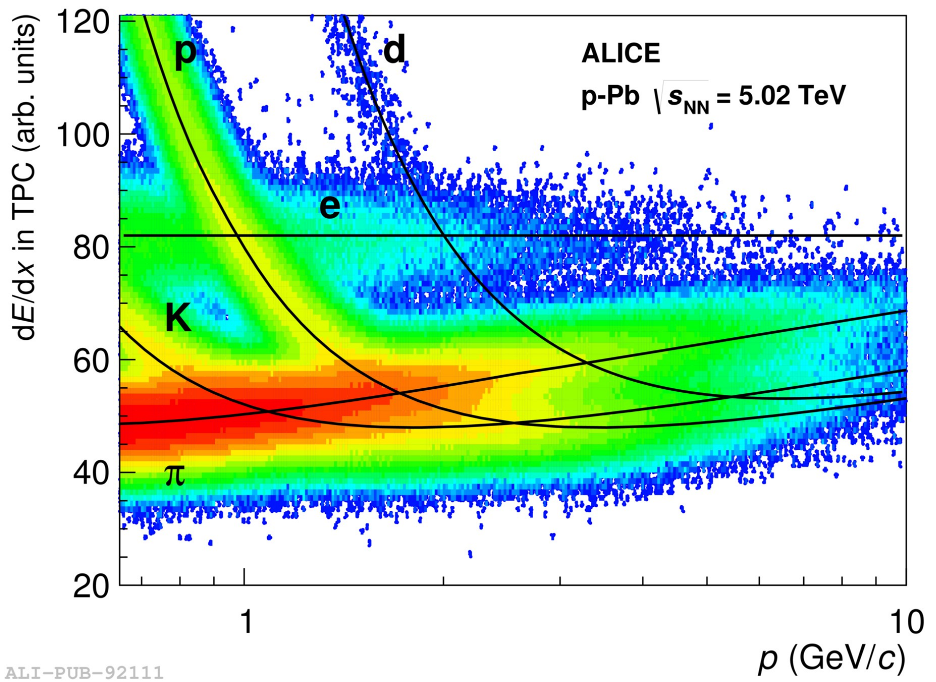
TRD
PID, trigger



V0, ZDC
centrality determination

Particle identification

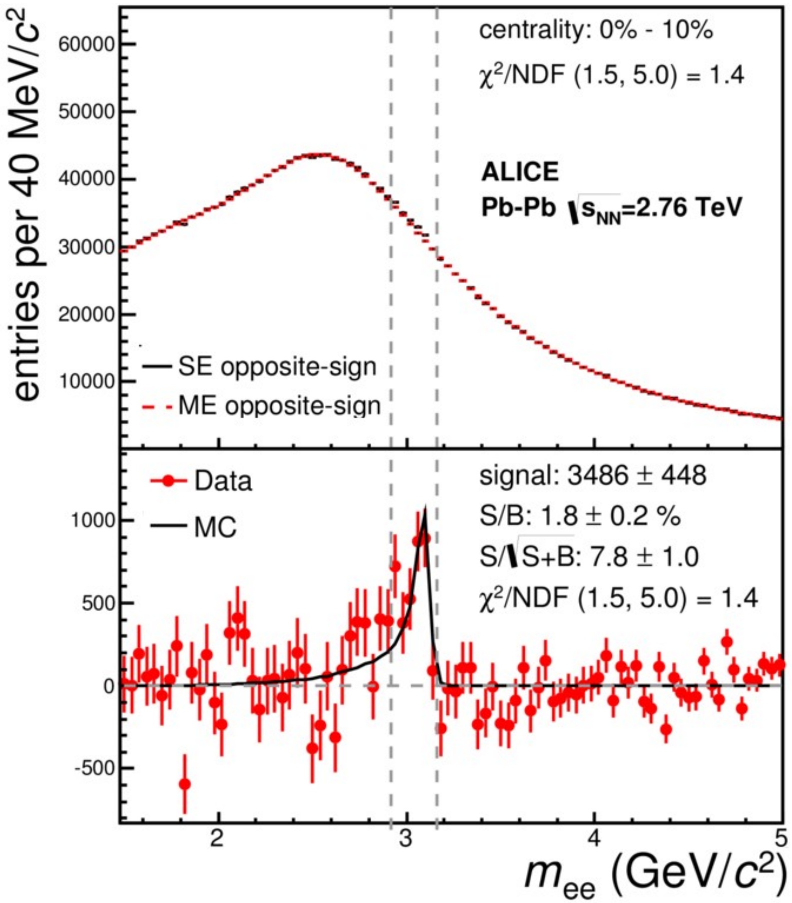
Electron identification via specific energy loss in TPC



ALICE coll.: JHEP 1506 (2015) 055

- Tracks within 3σ of electron band
- Tracks in pion and proton bands excluded
- Hit in innermost layer of ITS required to remove secondary particles
- p_T > 1 GeV/c required to remove background

Signal extraction

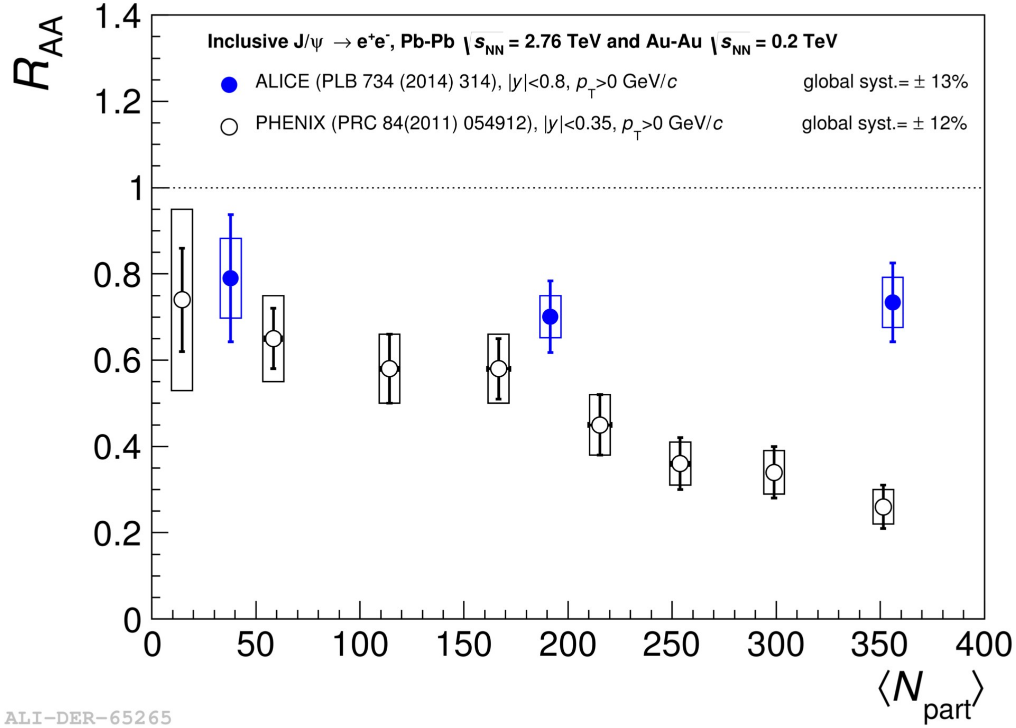


ALICE coll.: Phys. Lett. B 734 (2014) 314-327

- Electron-positron invariant mass distribution
- Several background estimators:
  - Like-sign pairs
  - Track rotation
  - Event mixing (shown here)
- Signal is counted in mass range $2.92 < m_{ee} < 3.16$ GeV/c^2 (correction from Monte Carlo line shape)

Results from Pb-Pb collisions

Nuclear modification factor vs centrality

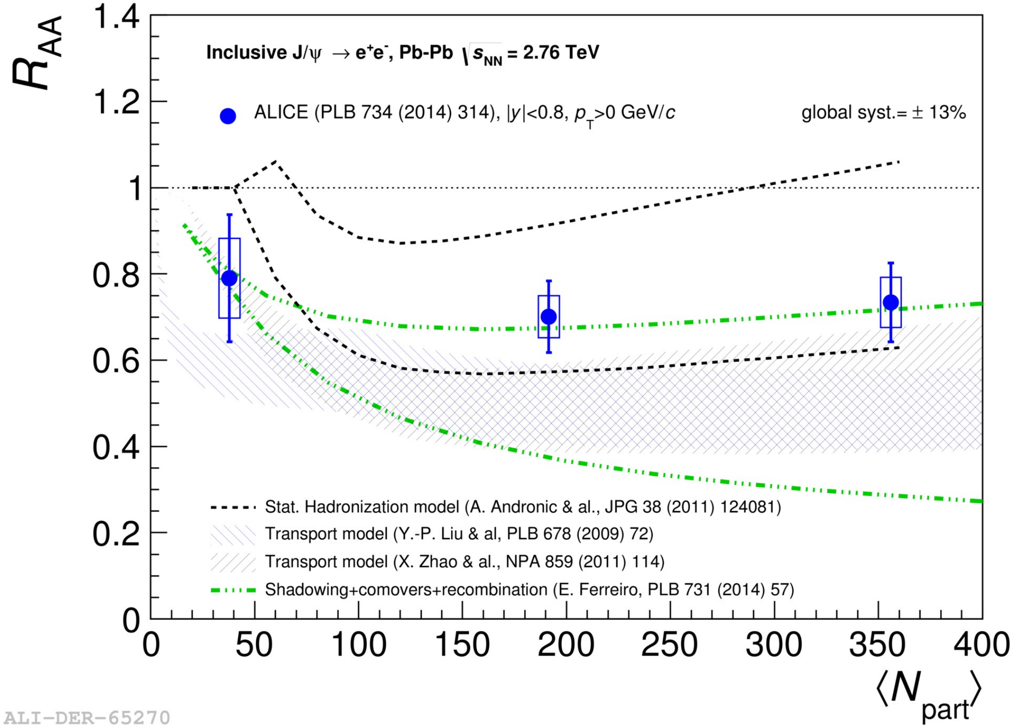


Nuclear modification can be quantified by

$$R_{AA} = \frac{Y_{J/\psi}^{Pb-Pb}}{\langle T_{AA} \rangle \times \sigma_{J/\psi}^{pp}}$$

- Suppression independent of centrality
- Less suppression than at RHIC energies, especially for central events

Comparison to models



- Good agreement with (re)combination models
- Statistical Hadronization Model and Transport Models describe data similarly well → no discrimination among the models possible yet
- Large theoretical uncertainties due to limited knowledge of charm cross section and nuclear shadowing

Nuclear modification factor vs p_T

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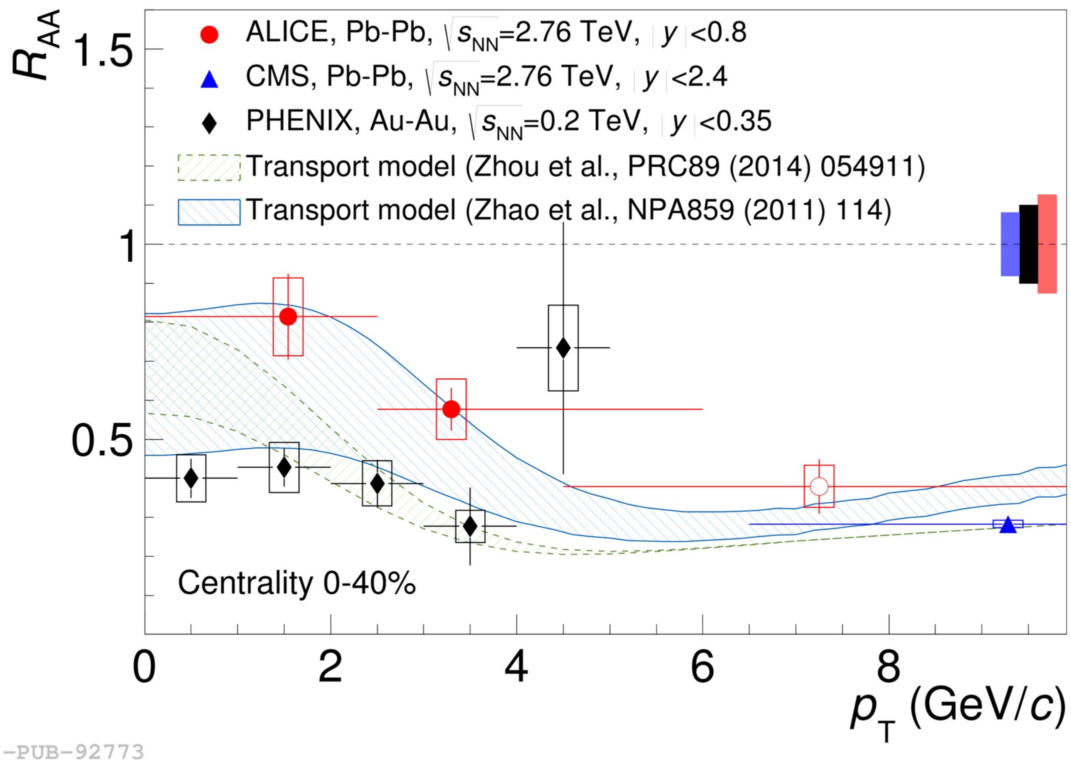
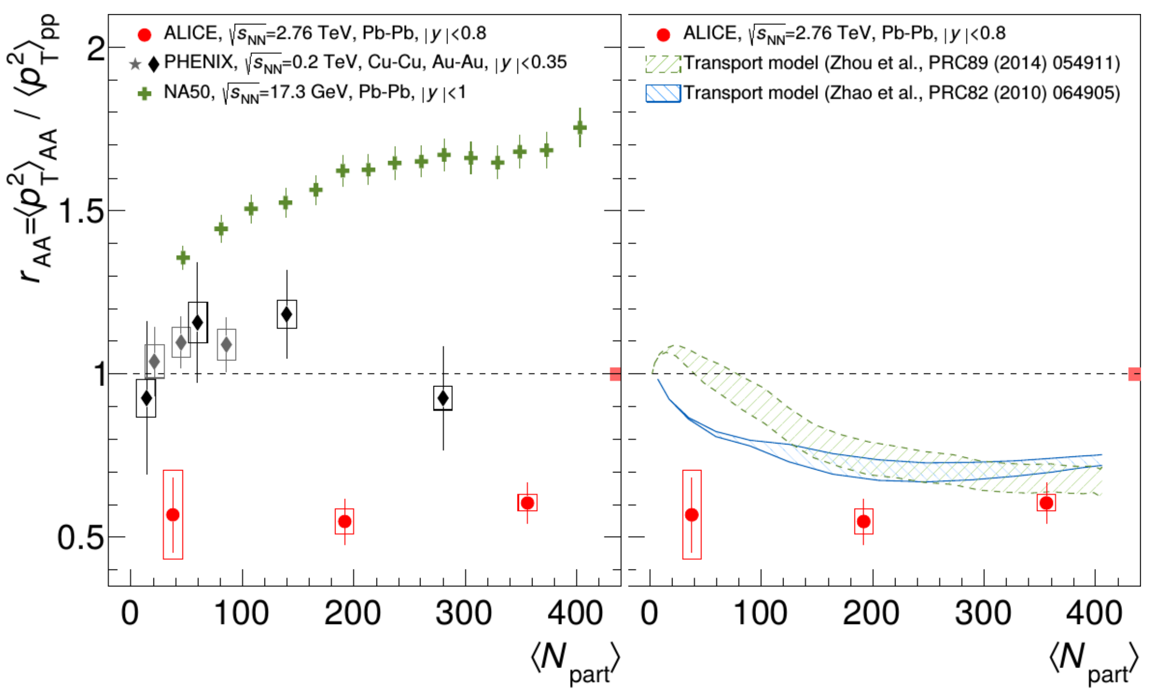


ALICE coll.: arXiv:1504.07151

- At high p_T: agreement with CMS measurement
- At low p_T: striking difference to behaviour at RHIC energies
- Data in agreement with models which include (re)combination

Mean transverse momentum

$r_{AA} = \langle p_T^2 \rangle_{AA} / \langle p_T^2 \rangle_{pp}$: Particularly sensitive to medium modifications affecting the transverse momentum distribution

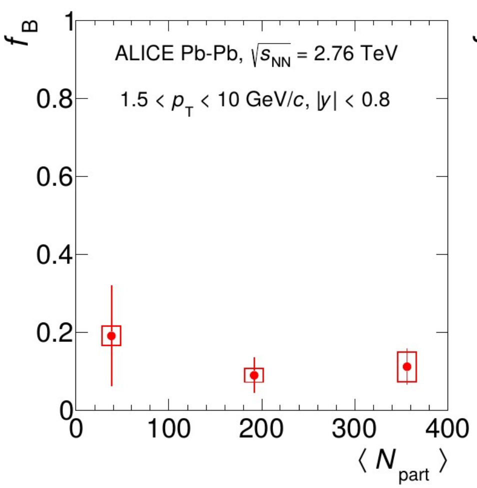


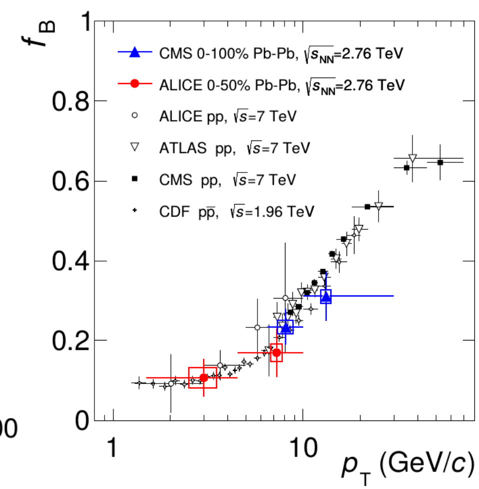
ALICE coll.: arXiv:1504.07151

Significantly below unity

- In contrast to experiments at lower energies
- Predicted by transport models
- Model agreement poor for non-central events

J/ψ from B hadron decays





p_T(GeV/c)	R_{AA}(inclusive J/ψ)	R_{AA}(prompt J/ψ)
0.0 – 1.5	0.89±0.20±0.21	–
1.5 – 4.5	0.76±0.09±0.08	0.76±0.10±0.08
4.5 – 10.0	0.38±0.07±0.06	0.38±0.07±0.06

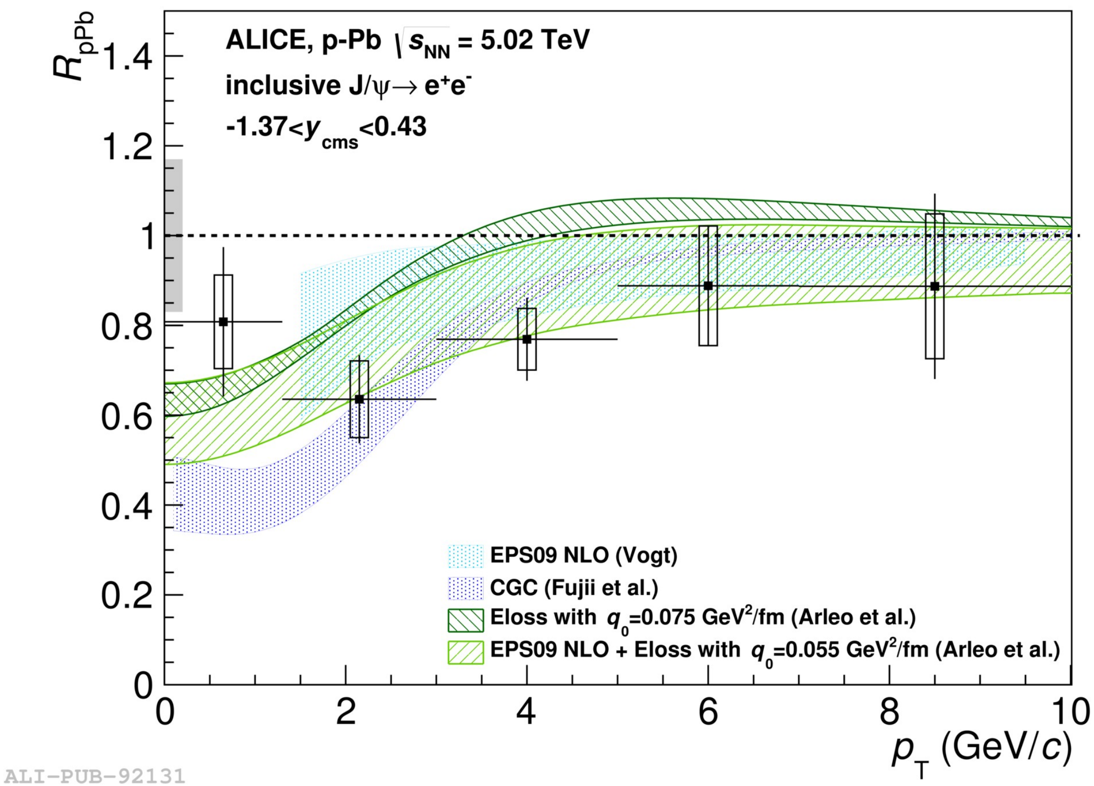
ALICE coll.: arXiv:1504.07151

- Identification of J/ψ from B hadron decays via decay length
- Fraction around 15%
  - independent of centrality
  - strong p_T dependence
- Influence on inclusive J/ψ R_{AA} negligible
- Non-prompt R_{AA}: different physical effects, not covered here → see talk by R. Bailhache

Heavy flavor production with ALICE
Thursday 10:00

Results from p-Pb collisions

Nuclear modification factor vs p_T



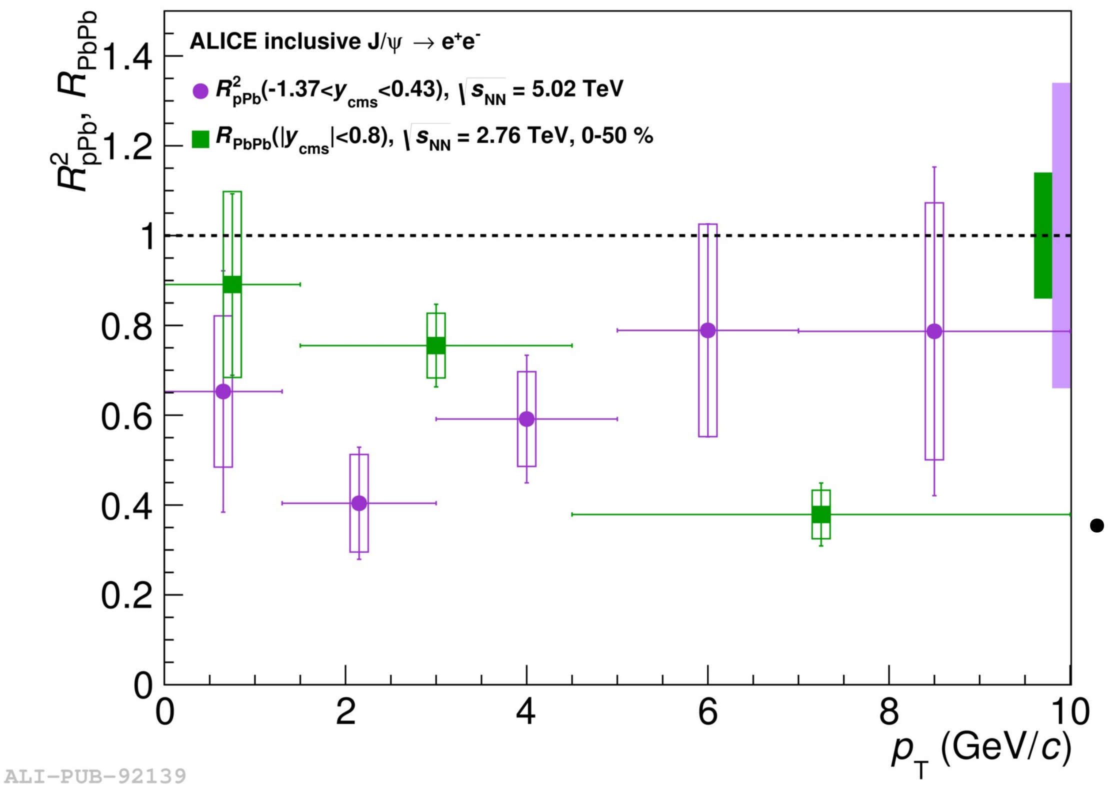
ALICE coll.: JHEP 1506 (2015) 055

Suppression at low p_T, vanishing at high p_T

Fair agreement with models based on

- Shadowing (EPS09 NLO)
- Gluon saturation (CGC)
- Energy loss (Eloss)

Comparing p-Pb and Pb-Pb



ALICE coll.: JHEP 1506 (2015) 055

- p-Pb and Pb-Pb collisions probe approx. the same x_{Bj} range:
  p-Pb: $6.1\times10^{-4}<x_{Bj}<3.0\times10^{-3}$
  Pb-Pb: $7.0\times10^{-4}<x_{Bj}<3.5\times10^{-3}$

  → R^2_{pPb} can be used as estimate for CNM in Pb-Pb

- p_T dependence different than for R_{PbPb}

  → Additional effect in Pb-Pb collisions beyond CNM → (re)combination

Summary

- Reduced J/ψ suppression in Pb-Pb collisions at low transverse momenta compared to lower collision energies suggests different production mechanism
- Models taking into account (re)combination show good agreement with measurements
- Results from p-Pb collisions show strongest influence of CNM at low p_T, different from Pb-Pb results

→ Pb-Pb suppression cannot be explained by CNM alone

Outlook

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LHC Run 2 started last month, Pb-Pb collisions foreseen for November this year with $\sqrt{s_{NN}} = 5$ TeV

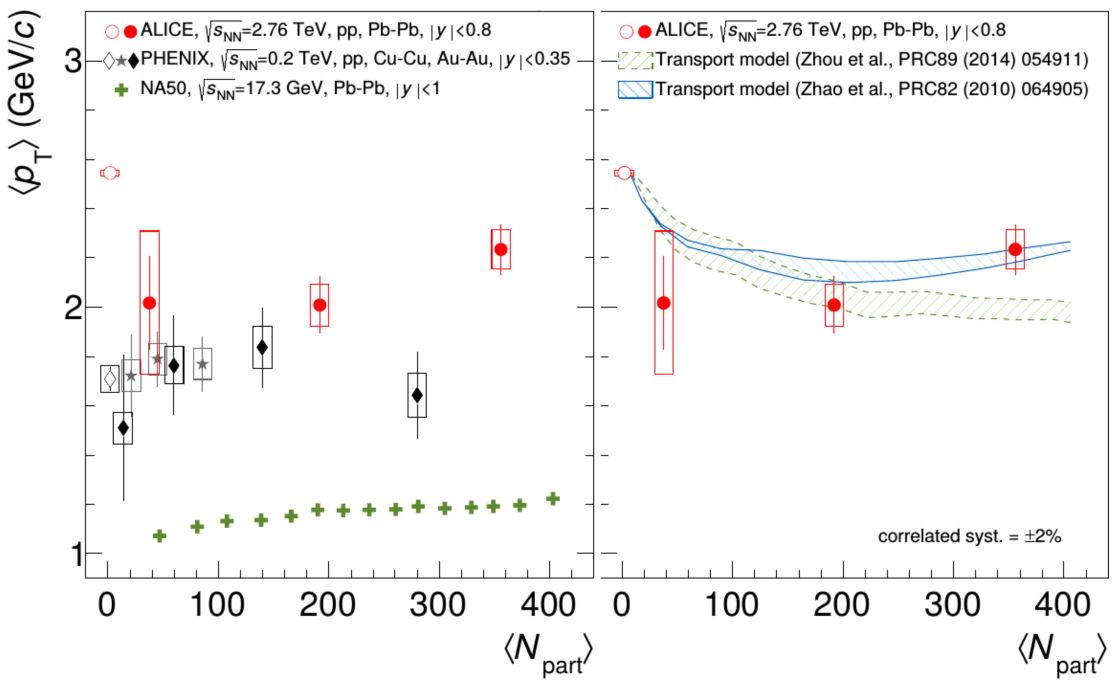
- Higher collision energy
  - Higher charm cross section → statistically higher chance of combination of c and $\bar{c}$ quarks to charmonia
  - Longer living hot medium → effects on charmonium production even more pronounced
- Usage of TRD PID capabilities and higher statistics will reduce uncertainties and open door for new insights

Thank you for your attention!

BACKUP

Mean transverse momentum

Alternative way to quantify nuclear suppression



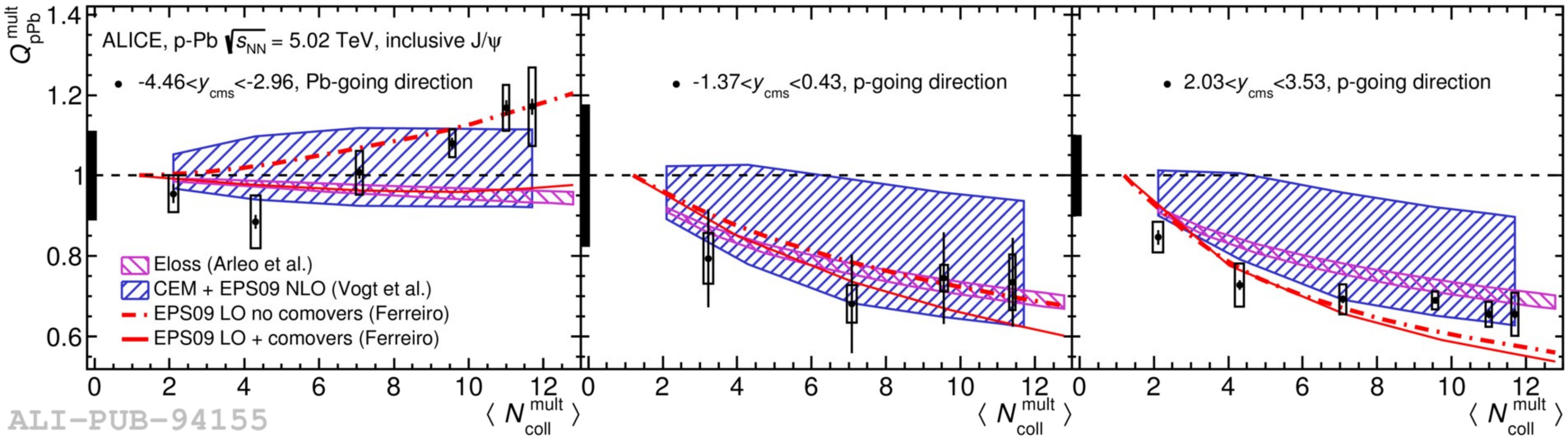
ALICE coll.: arXiv:1504.07151

- Significantly smaller than in pp collisions
- Effect not seen in data at lower collision energy

  → Either depletion of high p_T region or enhancement of low p_T production
- Good agreement with transport models

J/ψ Q_{pPb} as a function of centrality

(Q_{pPb} is used instead of R_{pPb} due to possible bias in centrality estimation)



ALICE coll.: arXiv:1506.08804

- Data is well reproduced when assuming strong shadowing
- Effect of comovers increases with centrality
- Energy loss model describes well the data