A Large Ion Collider Experiment

ALICE

Quarkonium measurements in nucleus-nucleus collisions with ALICE

Pascal Dillenseger
for the ALICE Collaboration

Venezia 2018 Quark Matter

HGS-HIRe for FAIR
Helmholtz Graduate School for Hadron and Ion Research

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

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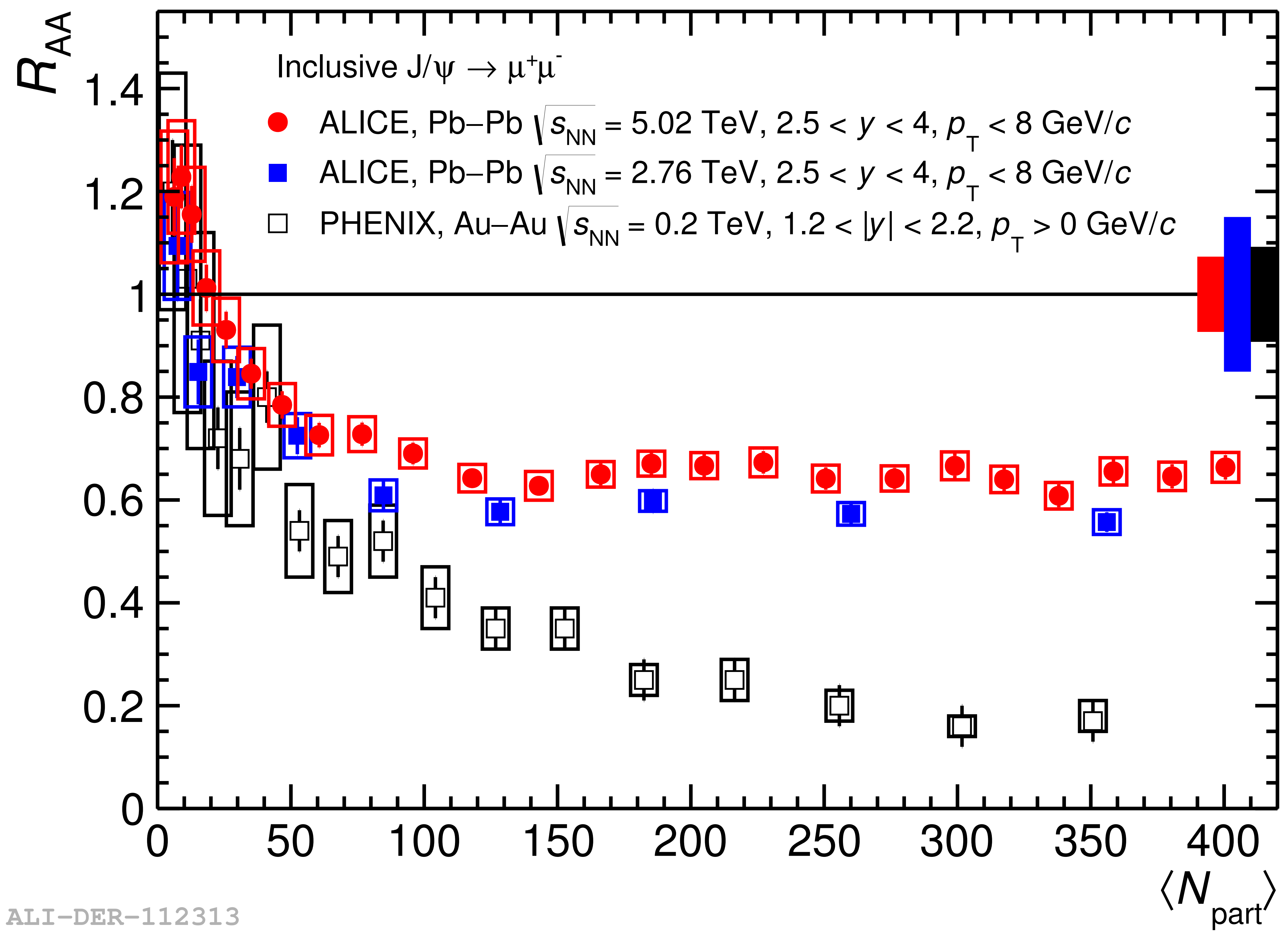
J/ψ suppression as a QGP signature



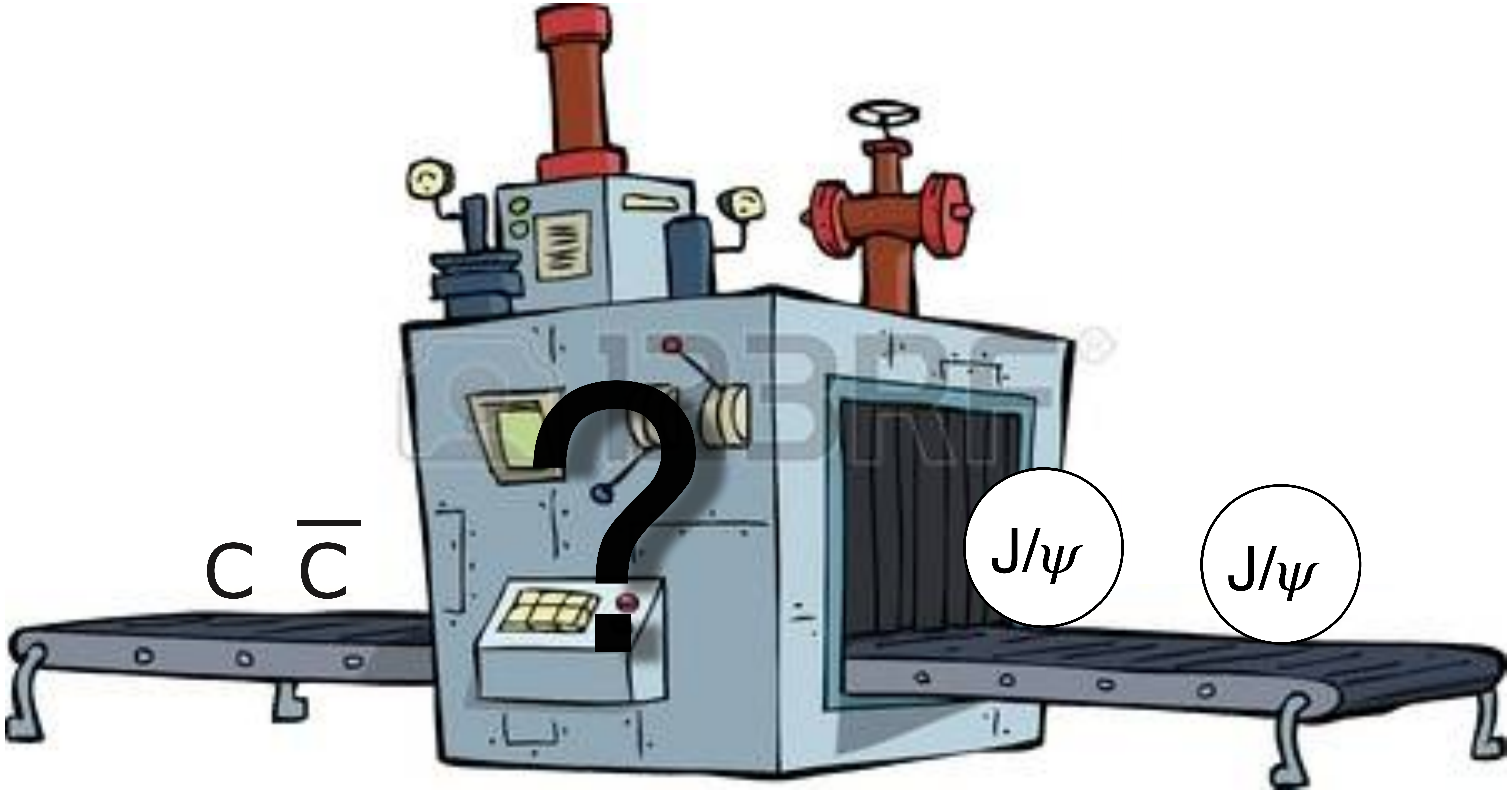
ALICE Collaboration PLB 766 (2017) 212
PHENIX Collaboration PRL 98 (2007) 232301

Matsui & Satz PLB 178 (1986) 416:

"J/ψ suppression as signature of a QGP formation"

- At SPS and RHIC energies:
  - suppression in R_{AA} clearly visible
  - increases with collision centrality
- At LHC energies
  - less suppression is visible
  - not nearly as strong as expected from color screening mechanism
  - saturation instead of ongoing decrease

So where do the J/ψ come from?



Quarkonium production via quark coalescence

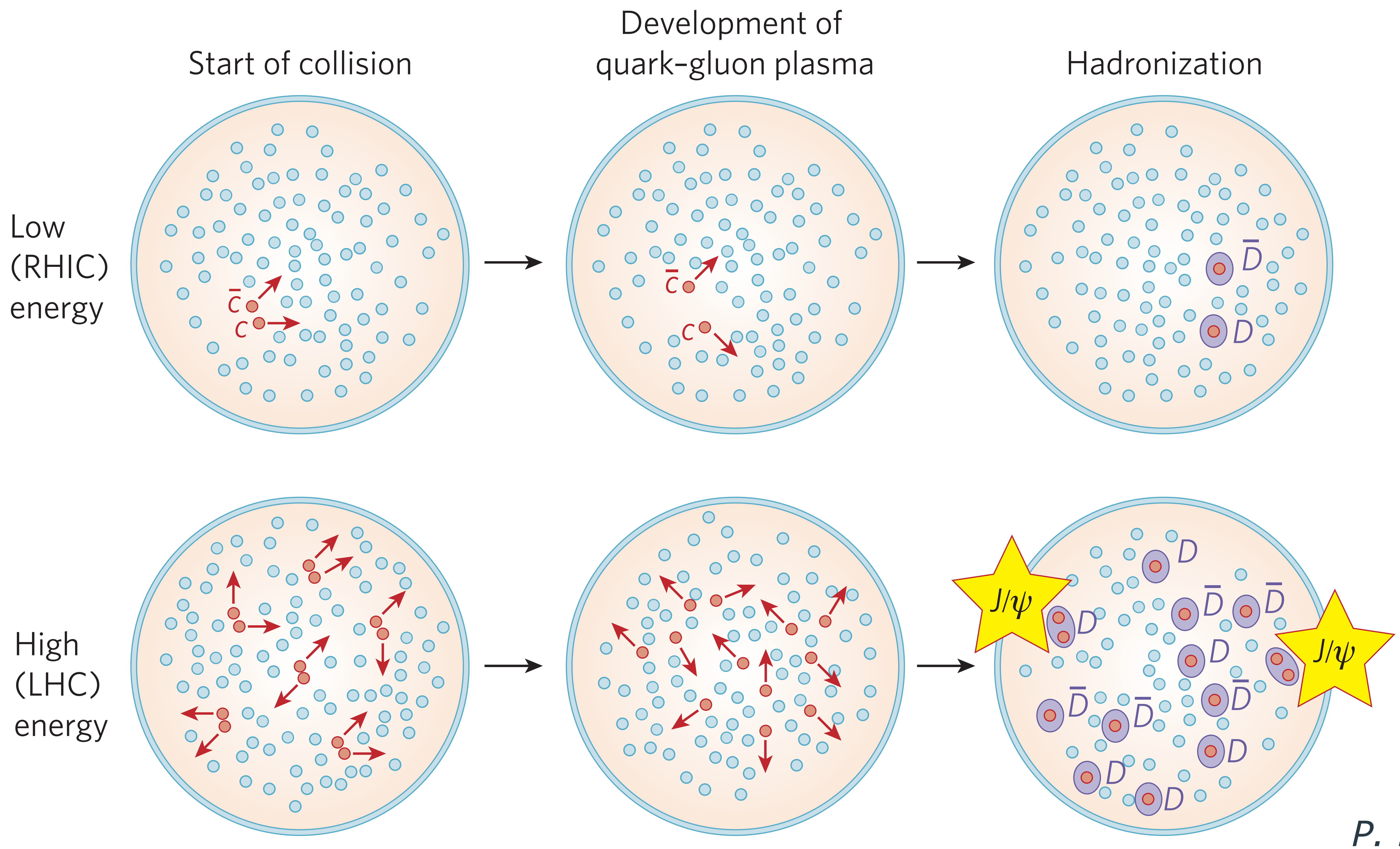


Figure: P. Braun-Munzinger, J. Stachel, Nature 448 (2007) 302

Some remarks:

the measured yields are influenced by:

- cold nuclear matter effects
  - see presentation by B. Paul 16 May 2018, 16:50 (Contribution ID 143)
- suppression and regeneration of quarkonia
  - strongly coupled to QGP properties
  - relative contributions should differ between $b\bar{b}$ and $c\bar{c}$

Matsui & Satz PLB 178 (1986) 416
P. Braun-Muzinger,J. Stachel, PLB 490(2000)196
R. Thews et al,Phys.Rev.C63:054905(2001)

Quarkonium measurements in nucleus-nucleus collisions

What you will see in the next ~ 10 min:

New Results!

- how ALICE measures quarkonia
  - at forward and mid-rapidity
- J/ψ R_{AA} versus:
  - centrality
    - in Pb–Pb collisions at 5.02 TeV and **Xe–Xe collisions at 5.44 TeV**
- J/ψ yield versus rapidity in Pb–Pb collisions at 5.02 TeV
  - **in bins of p_T and centrality in the forward rapidity range**
- J/ψ elliptic flow in Pb–Pb collisions at 5.02 TeV
- **ϒ(1S) and ϒ(2S) R_{AA} at forward rapidity in Pb–Pb collisions at 5.02 TeV**
  - **ϒ(1S) R_{AA} versus p_T and y**

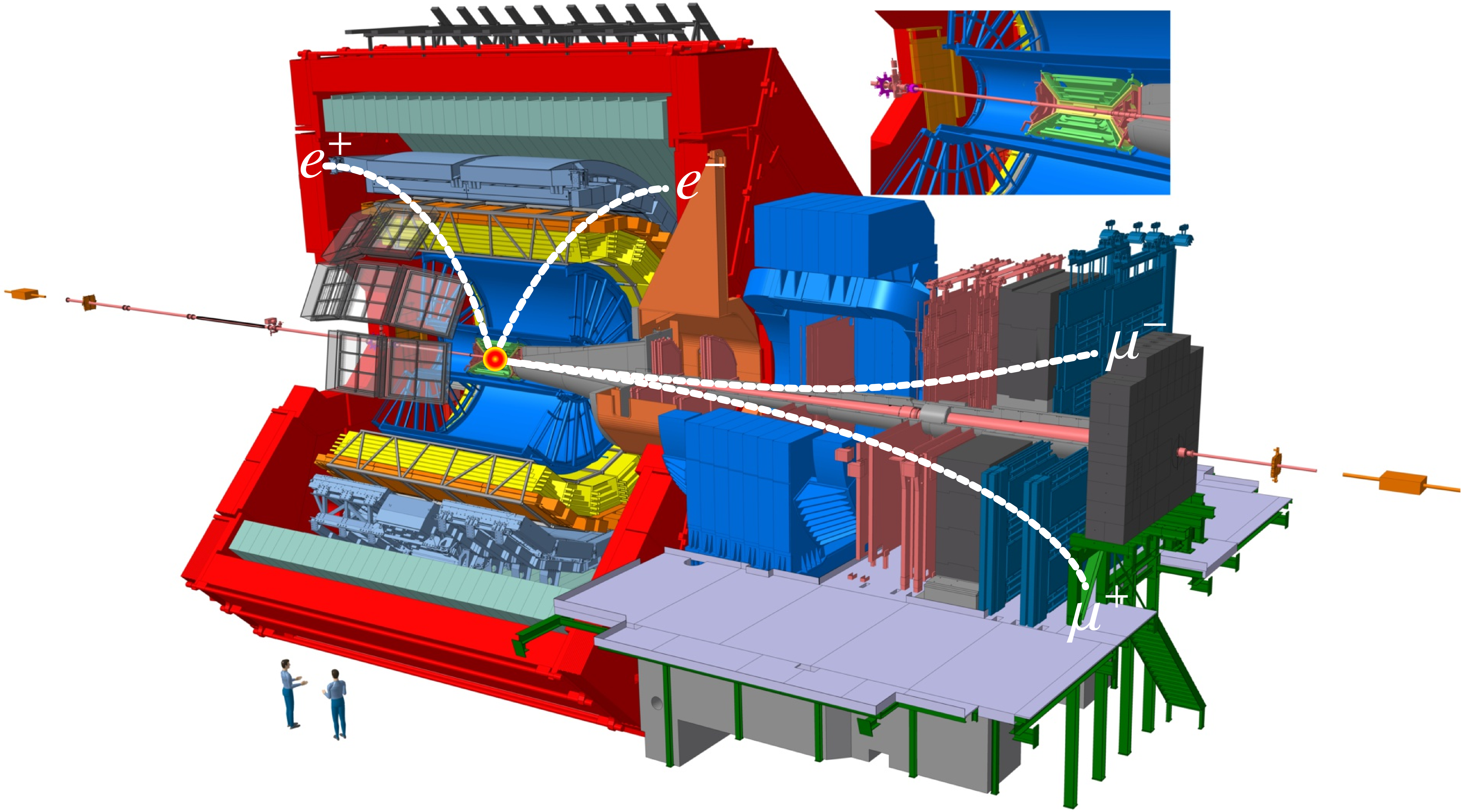
Quarkonium measurements with ALICE

<u>Mid-rapidity:</u>

- $Q\overline{Q} \rightarrow e^{+}e^{-}$
- $|y_{\mathrm{Lab}}| < 0.9$
- tracking + PID
  - ITS, TPC, TOF, TRD

<u>Forward rapidity:</u>

- $Q\overline{Q} \rightarrow \mu^{+}\mu^{-}$
- $2.5 < y_{\mathrm{Lab}} < 4$
- tracking + trigger
  - muon spectrometer



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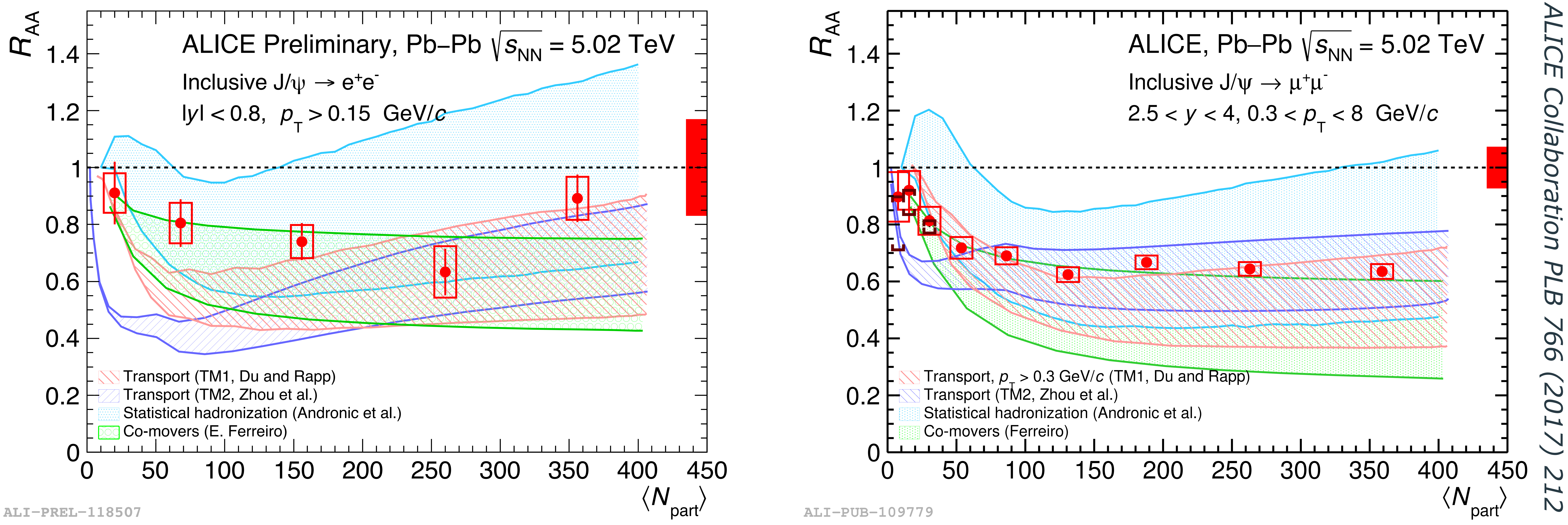
J/ψ R_{AA} versus centrality in Pb–Pb collisions at 5.02 TeV



All models describe the data — but the uncertainties of the models do not allow any discrimination between them

➔ Precise charm cross section measurement and more differential analyses needed

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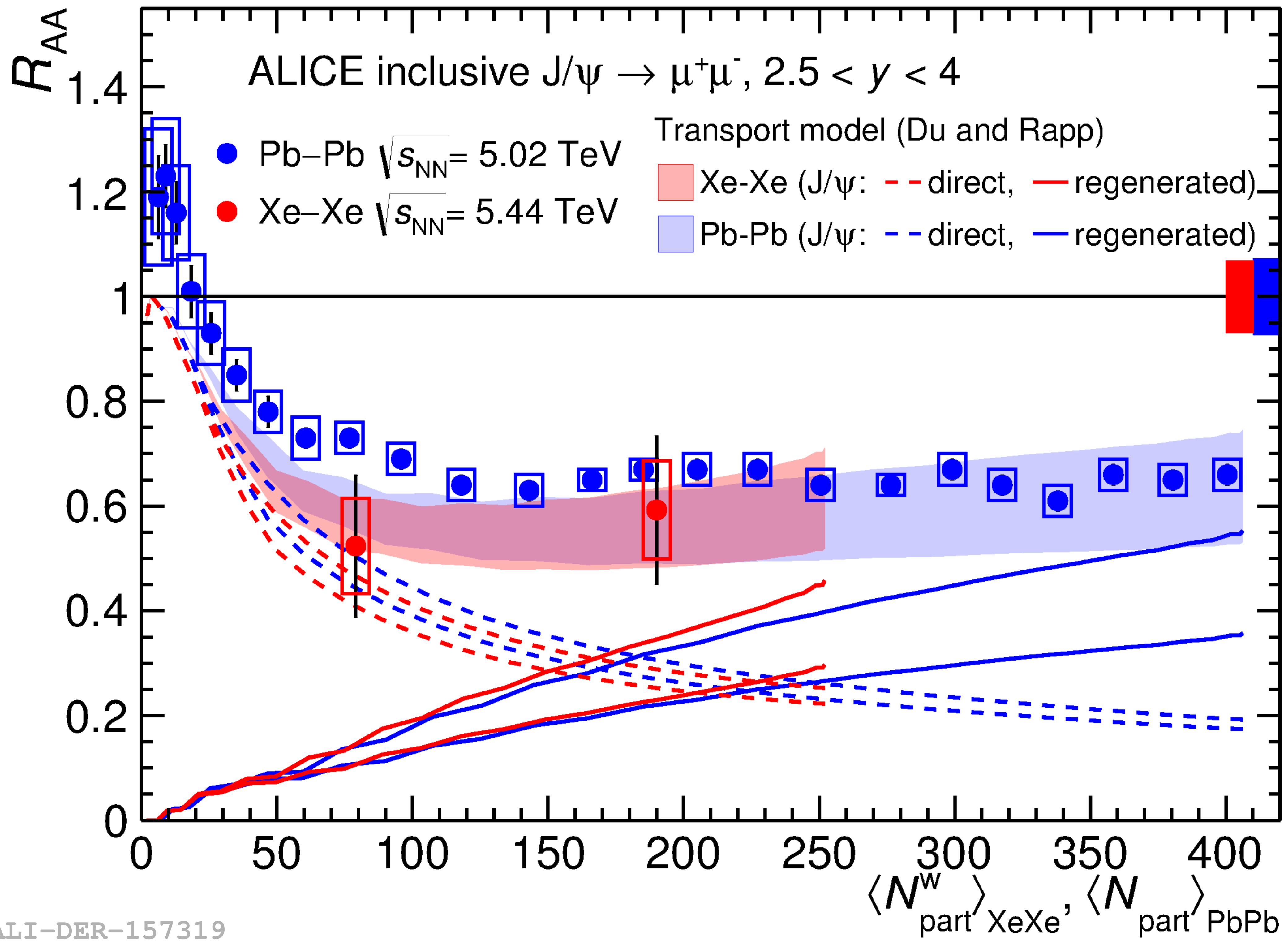
J/ψ R_{AA} versus centrality in Xe–Xe collisions at 5.44 TeV

New publication!



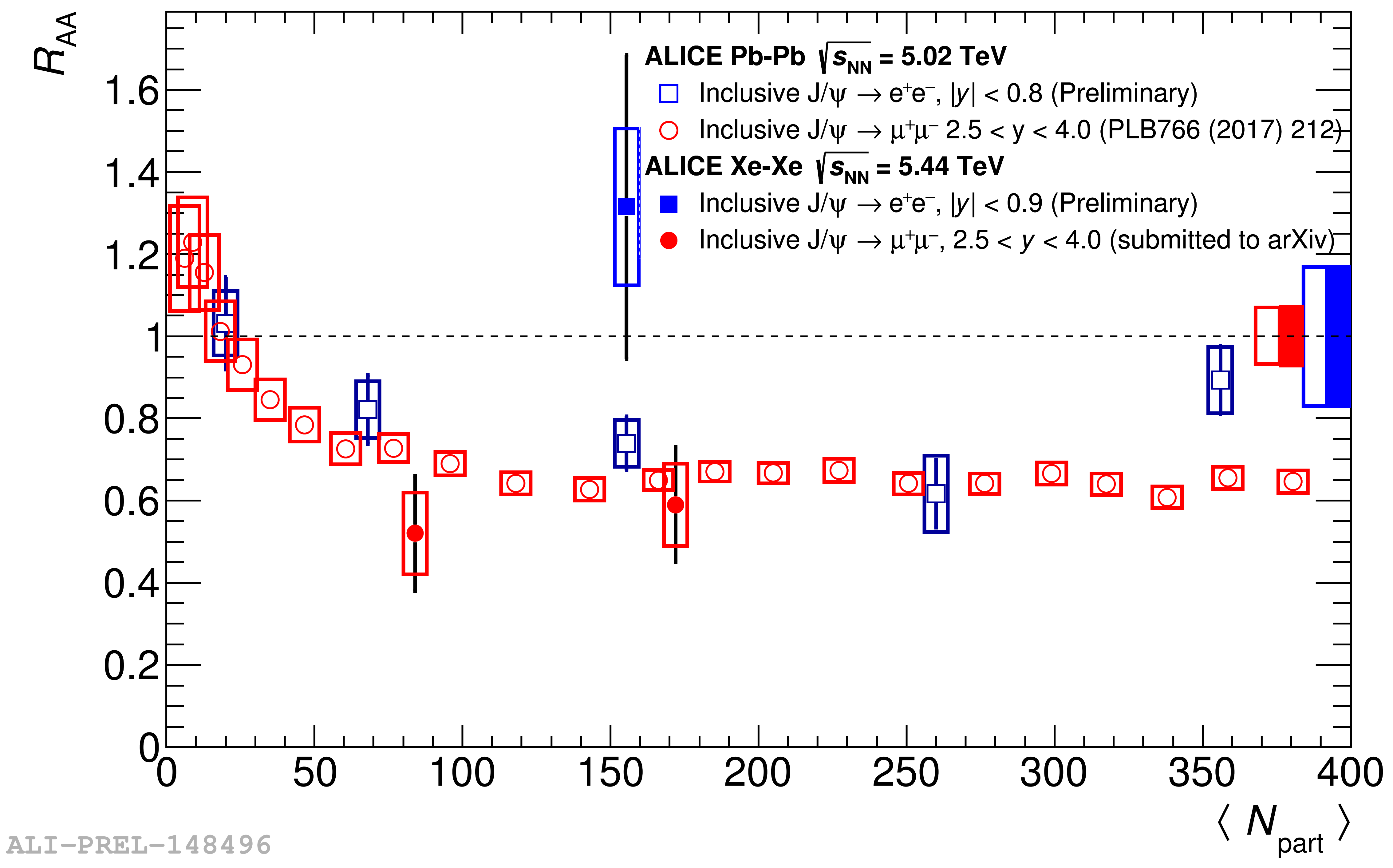
ALICE Collaboration arXiv:1805.04383

At forward rapidity:

- A_{Xe} = 129, $\mathscr{L}_{int} \approx 0.34\ \mu b^{-1}$
- A_{Pb} = 208 , $\mathscr{L}_{int} \approx 225\ \mu b^{-1}$
- $N_{J/\psi}$ = 241 ± 47(stat.) ± 26(syst.)
- 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/regeneration

J/ψ R_{AA} versus centrality in Xe–Xe collisions at 5.44 TeV



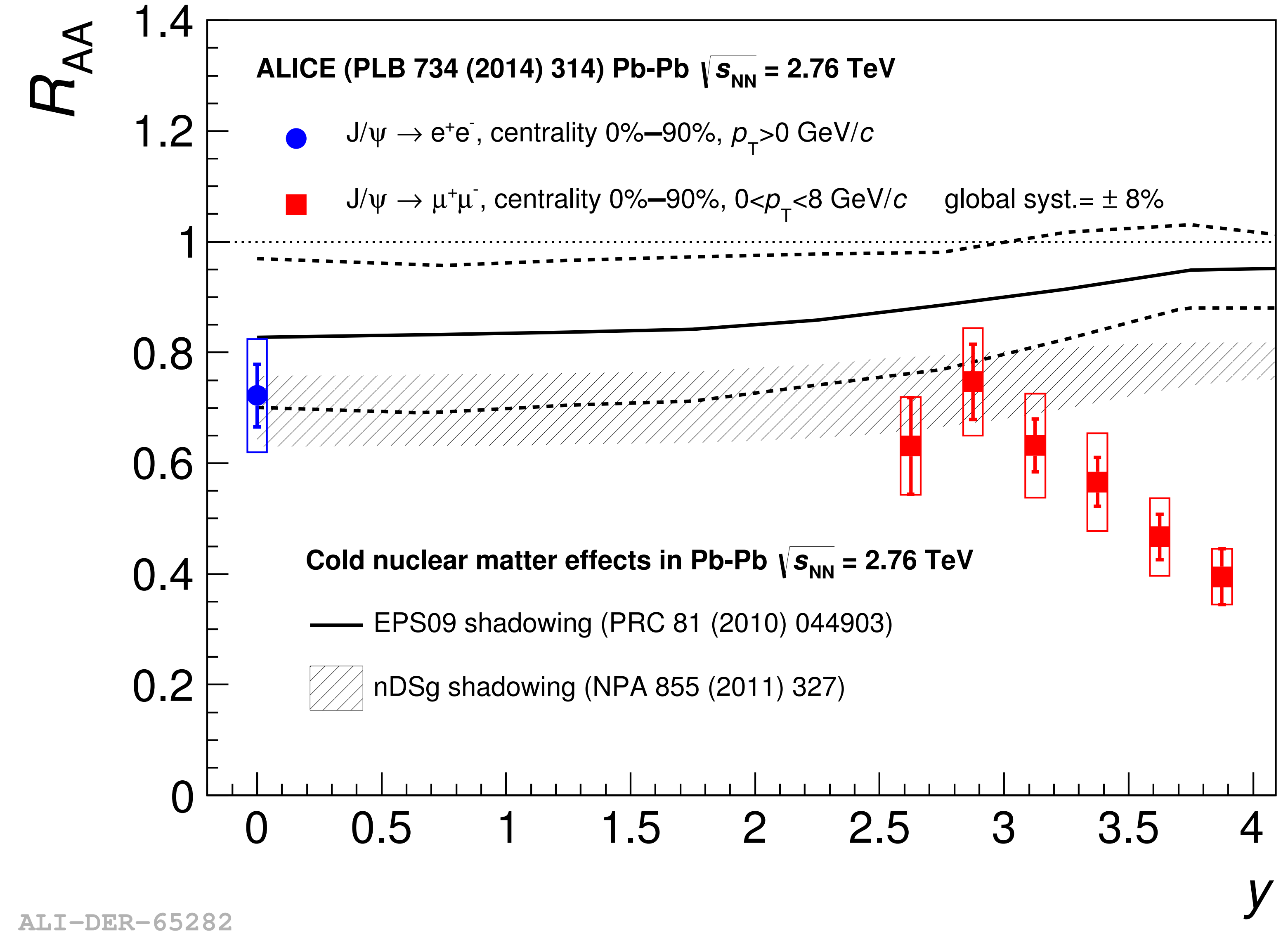
At mid-rapidity:

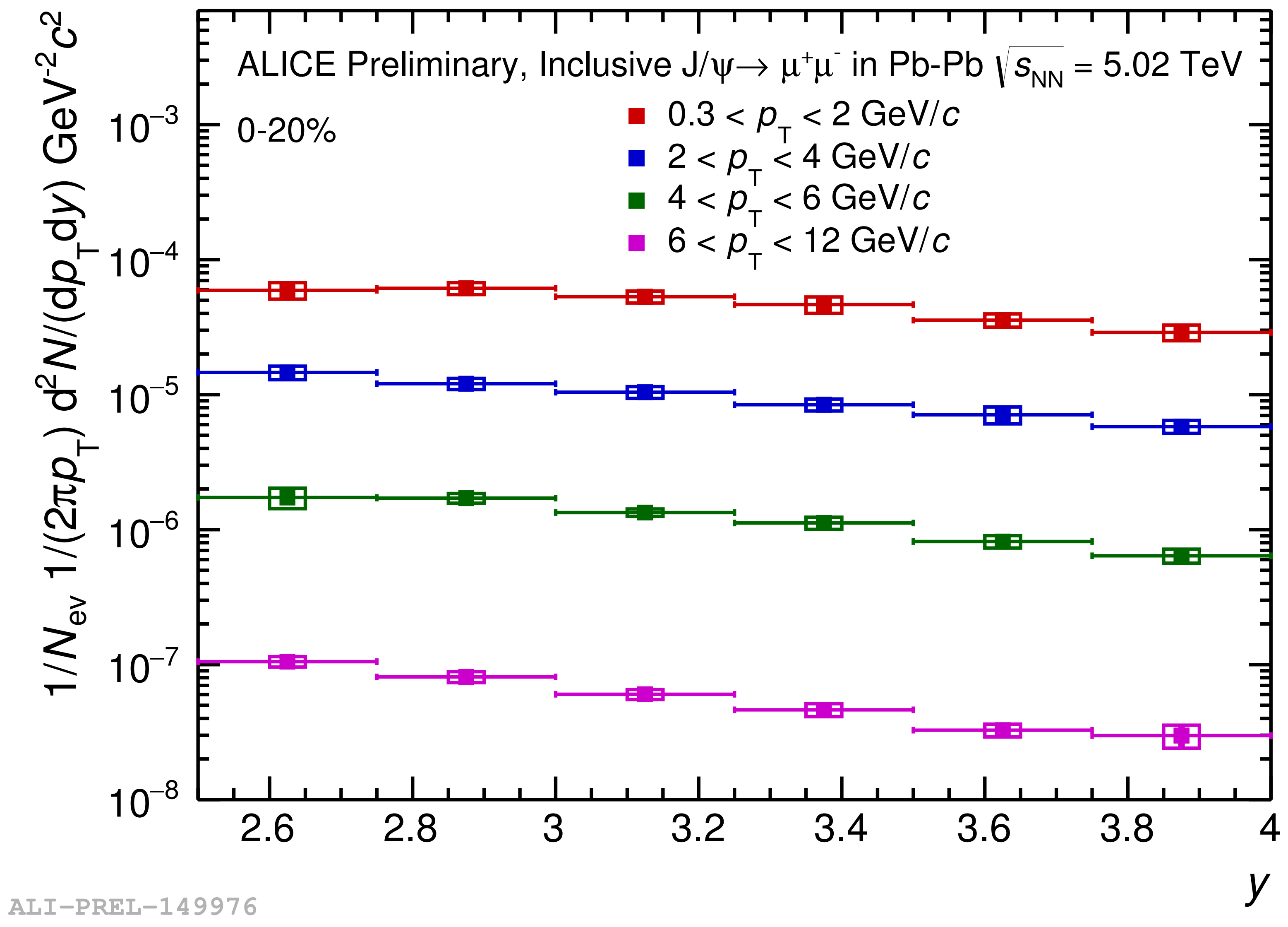
- A_{Xe} = 129 , $\mathscr{L}_{int} \approx 0.25\ \mu b^{-1}$
- A_{Pb} = 208 , $\mathscr{L}_{int} \approx 13\ \mu b^{-1}$
- $N_{J/\psi}$ = 340 ± 89(stat.) ± 14(syst.)
- R_{AA} consistent with unity within large stat. and syst. uncertainties

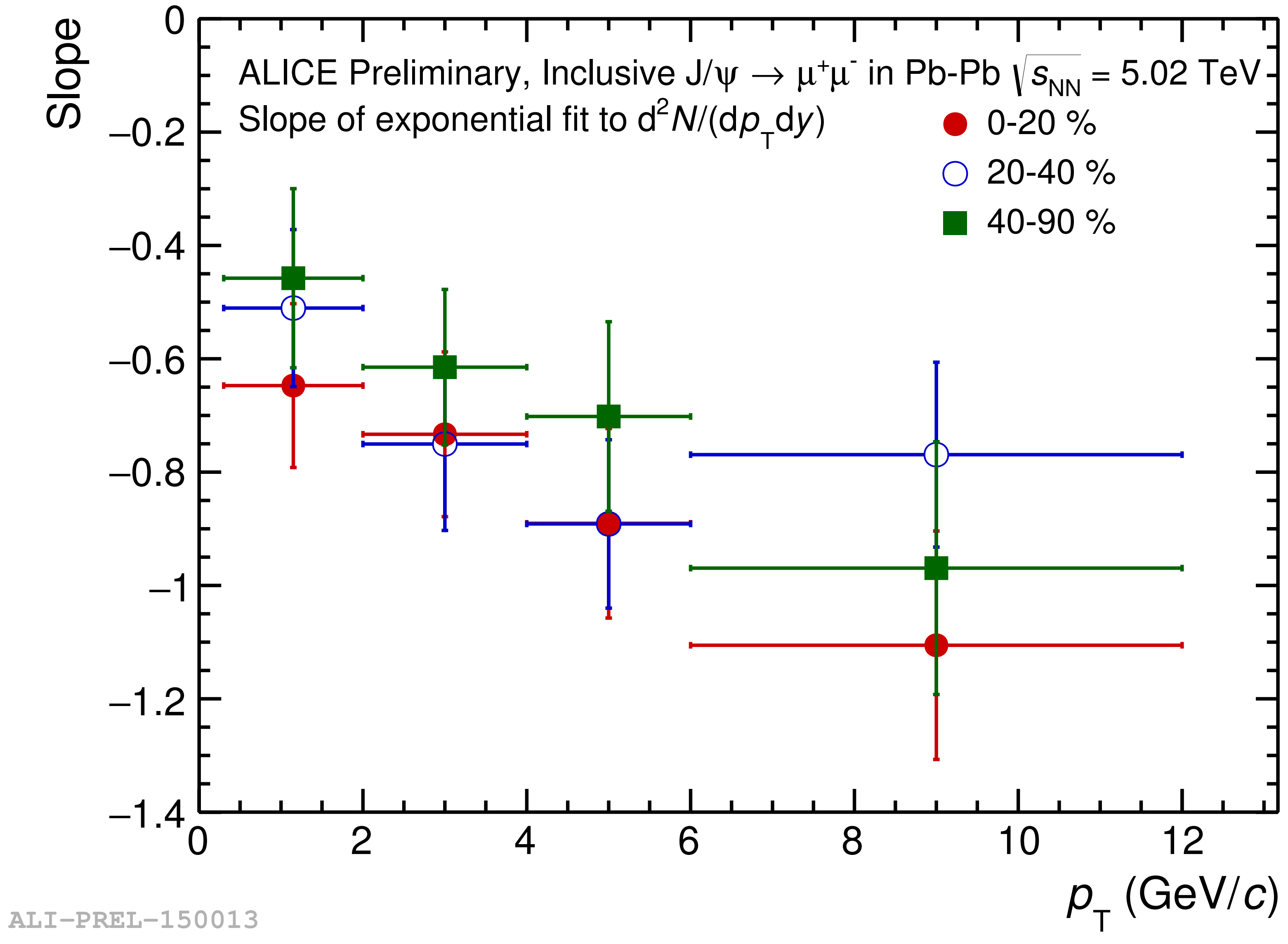
New preliminary results!

Multi-differential J/ψ measurement in Pb–Pb collisions at 5.02 TeV collisions

J/ψ R_{AA} versus rapidity in bins of centrality and momentum







New preliminary results!

See Poster by H. Hushnud (Contribution ID 60)

J/ψ elliptic flow in Pb–Pb collisions at 5.02 TeV

The idea:

- J/ψ from (re)combined $c\bar{c}$ quarks should inherit the charm flow

➔ positive v_2 signal

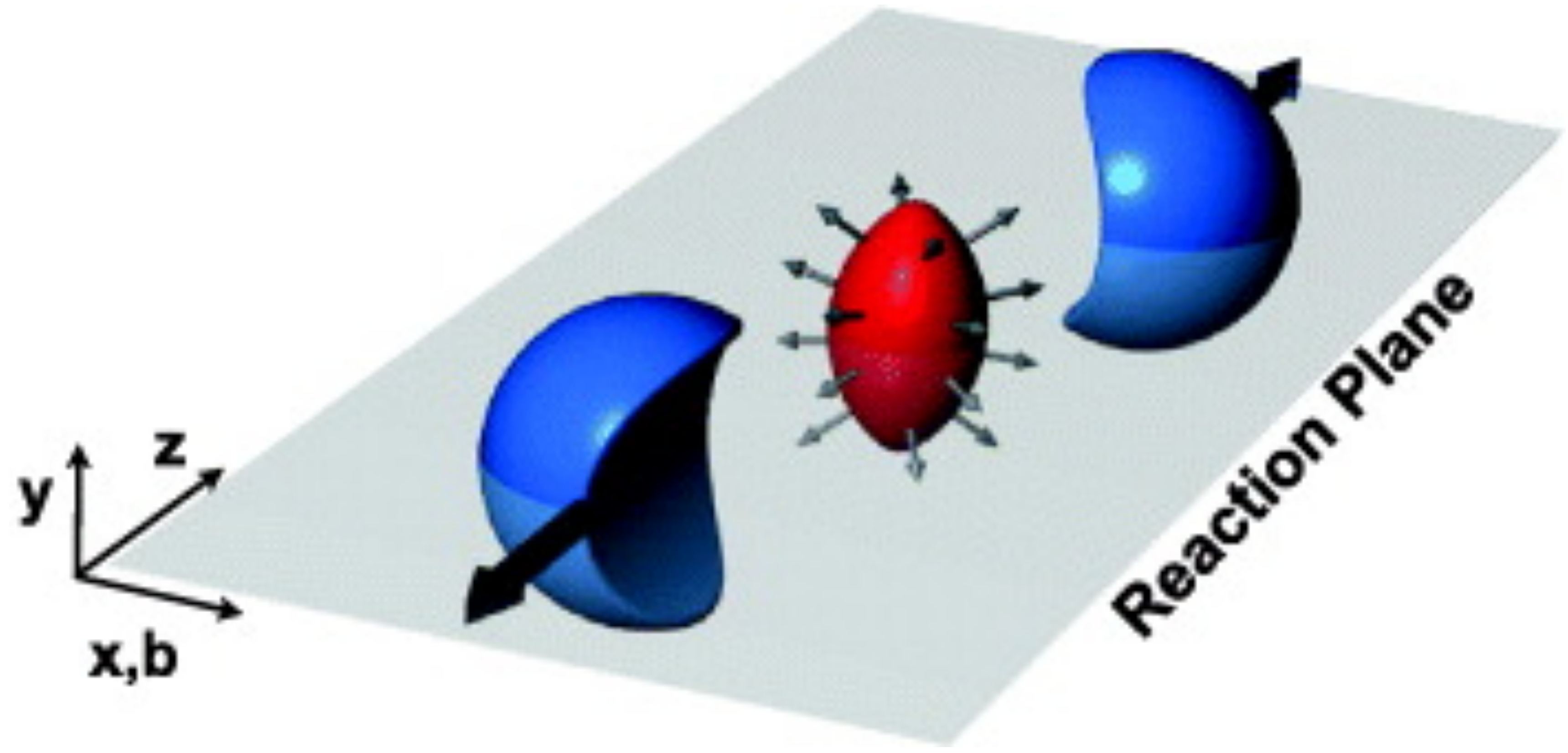


Figure: Raimond Snellings New J. Phys. 13 (2011) 055008

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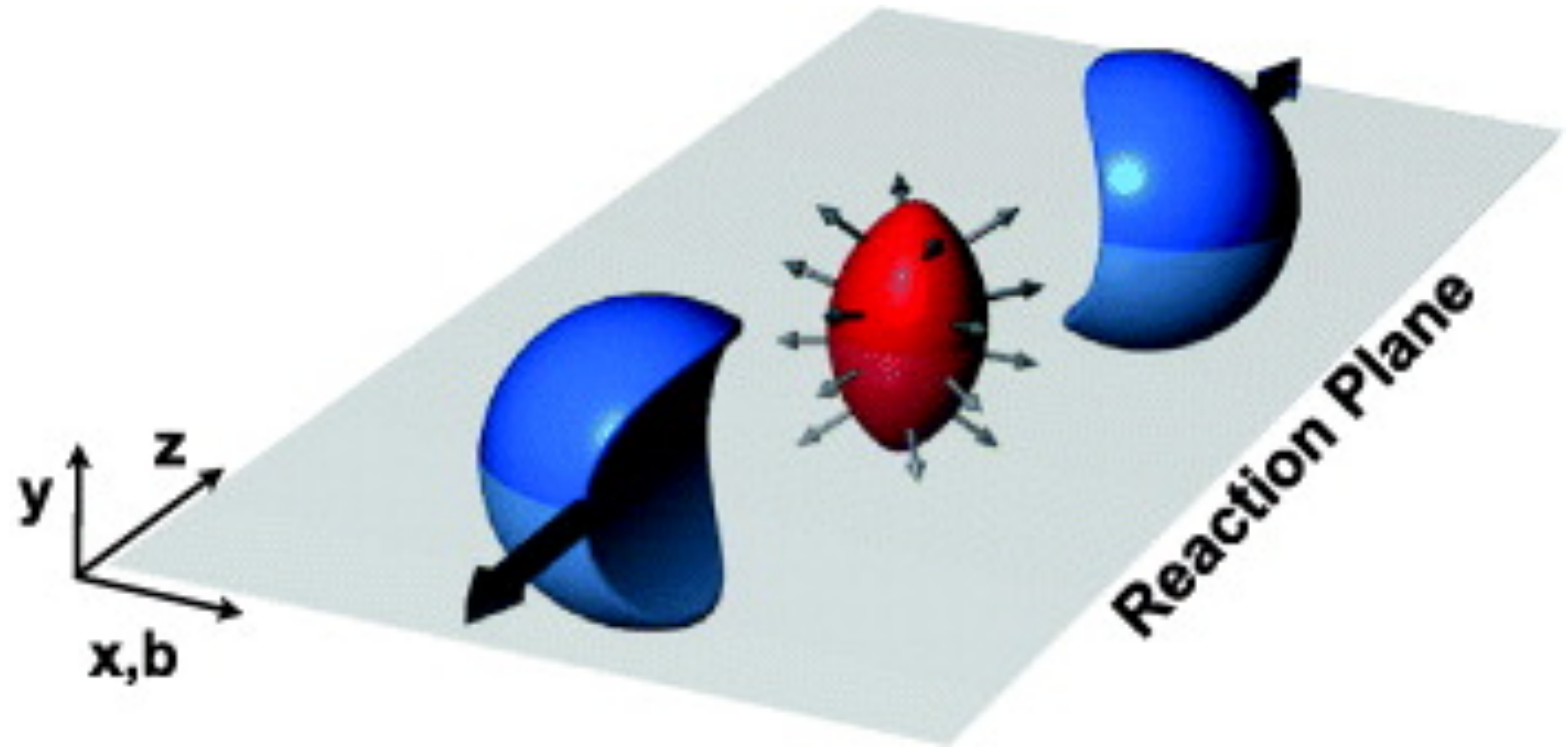

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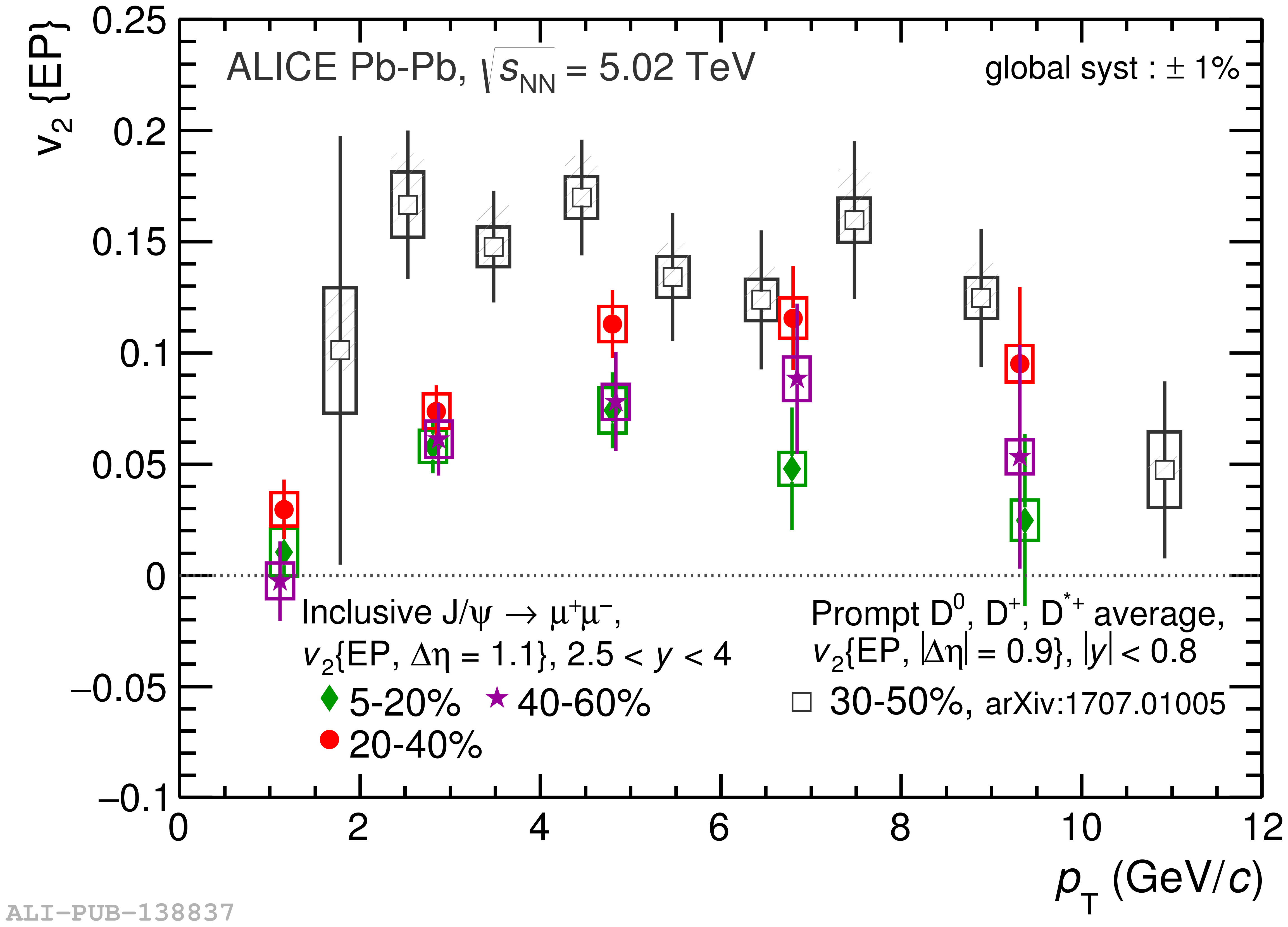
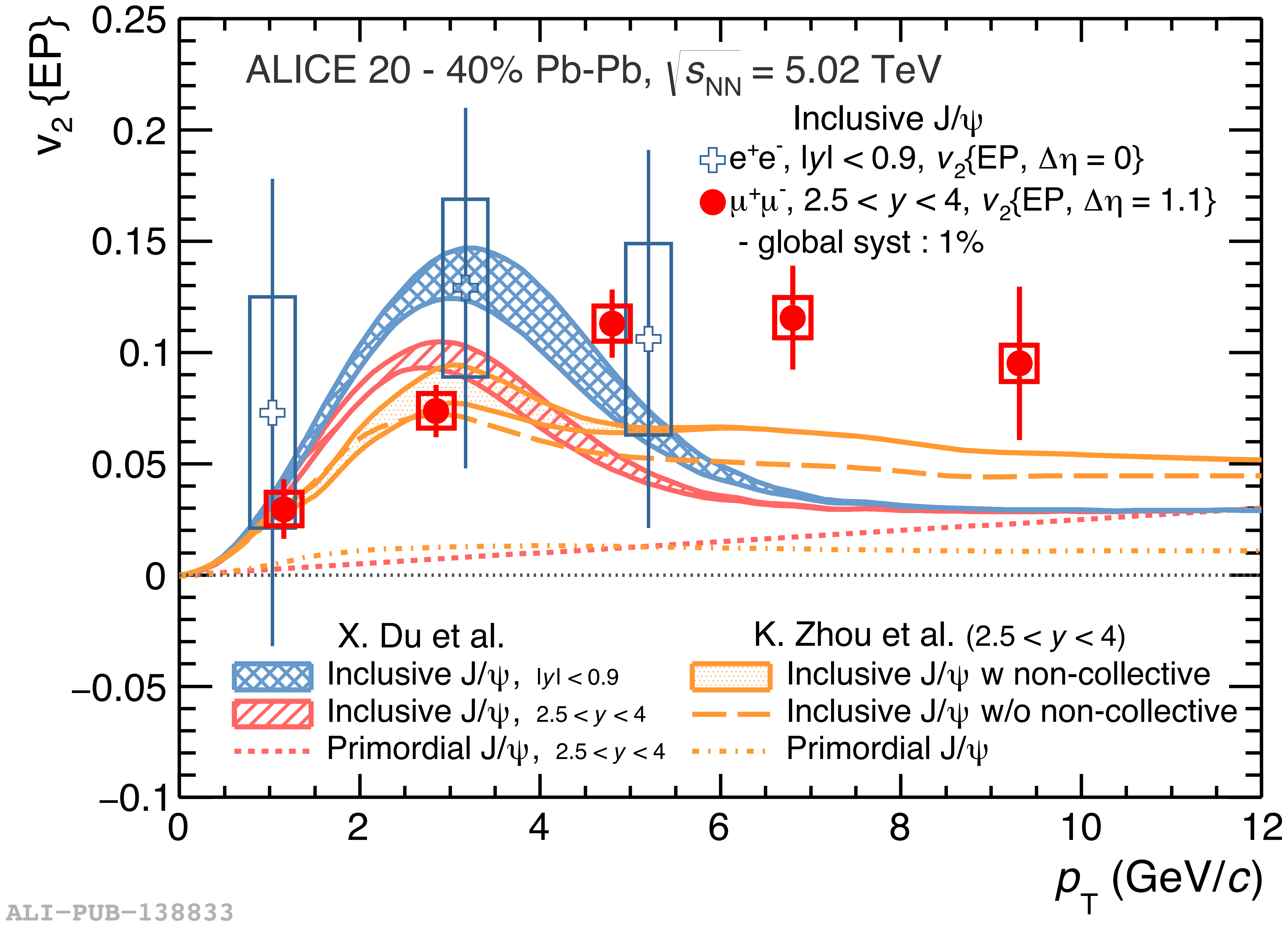


ALICE Collaboration PRL 119 (2017) 242301
ALICE Collaboration PRL 120 (2018) 102301

J/ψ elliptic flow in Pb–Pb collisions at 5.02 TeV

- forward and mid-rapidity results agree within uncertainties
- at low p_T models including regeneration agree with the data
- at high p_T the elliptic flow is underestimated by the models

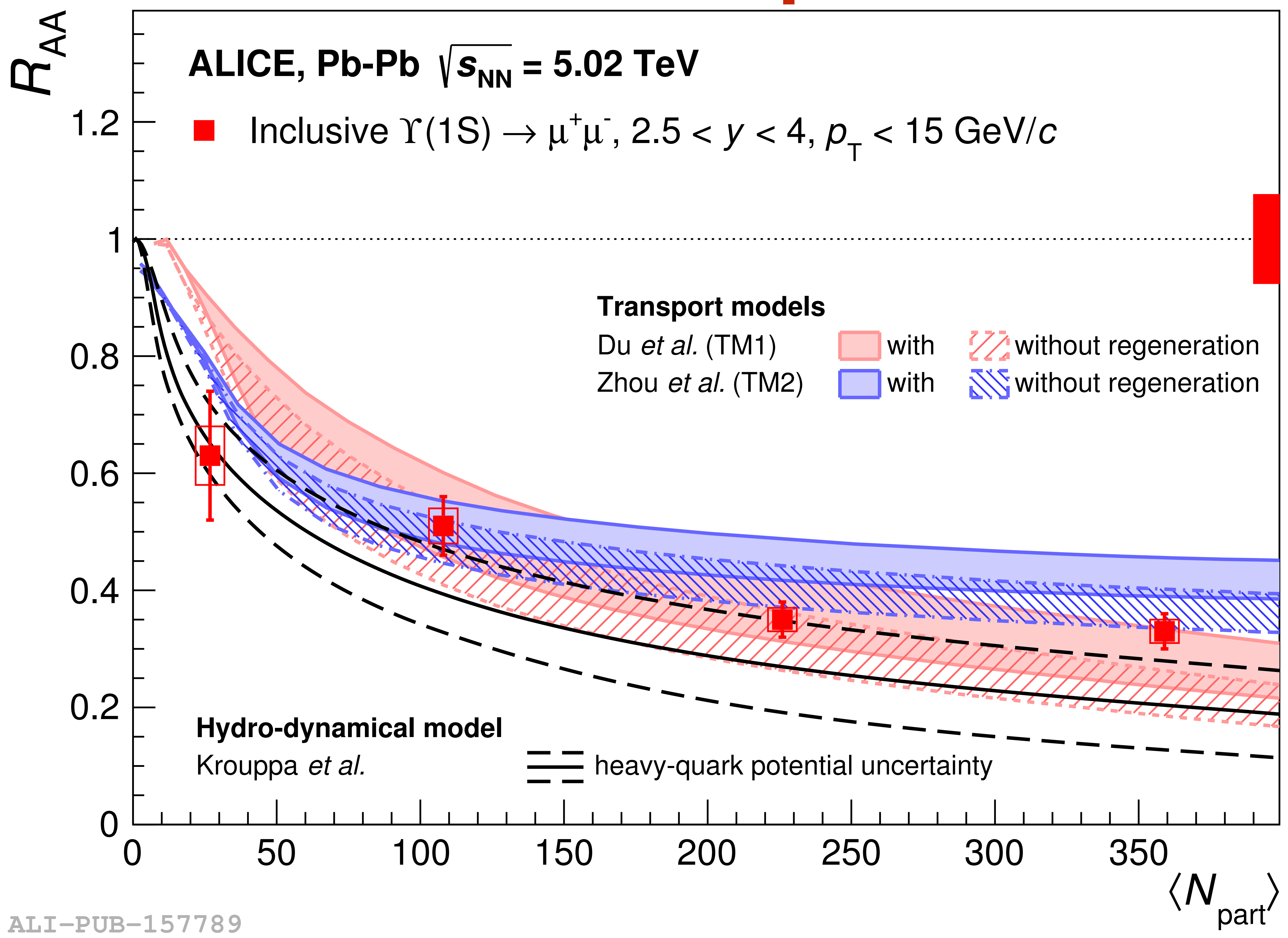


ALICE Collaboration PRL 119 (2017) 242301

$\Upsilon(1S)$ and $\Upsilon(2S)$ R_{AA} in Pb–Pb collisions at 5.02 TeV

New publication!

- stronger $\Upsilon(1S)$ suppression with increasing $\langle N_{part} \rangle$
  - feed-down fraction to $\Upsilon(1S)$ not precisely known
  - ➔ amount of direct $\Upsilon(1S)$ suppression is an open question
- models agree with the data within uncertainties
  - with and without a regeneration component
  - data on upper edge of hydro-dynamical model for $\langle N_{part} \rangle > 70$



- $R_{AA}^{\Upsilon(2S)} / R_{AA}^{\Upsilon(1S)} = 0.28 \pm 0.12(\text{stat.}) \pm 0.06(\text{syst.})$

ALICE Collaboration arXiv:1805.04387

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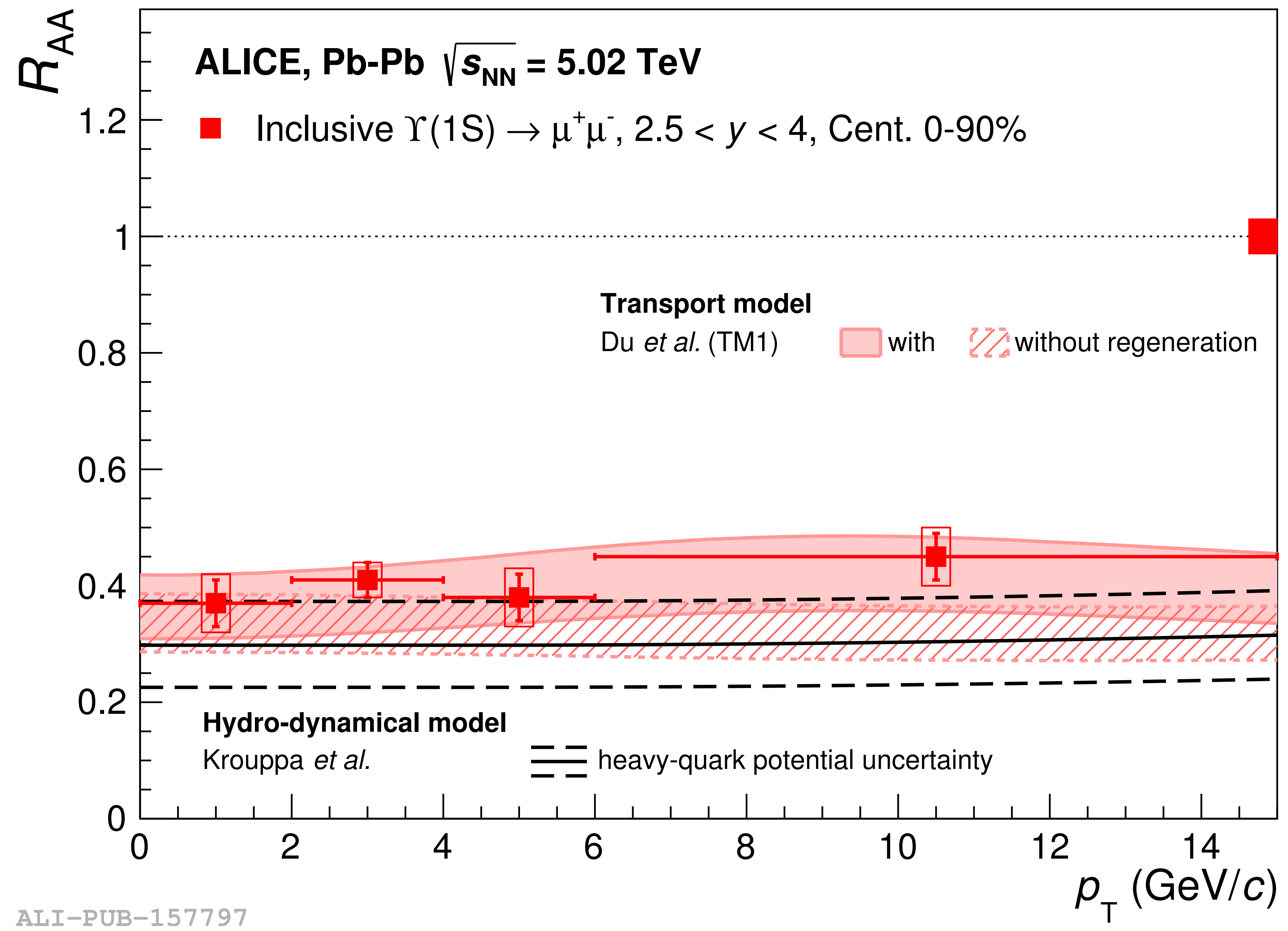
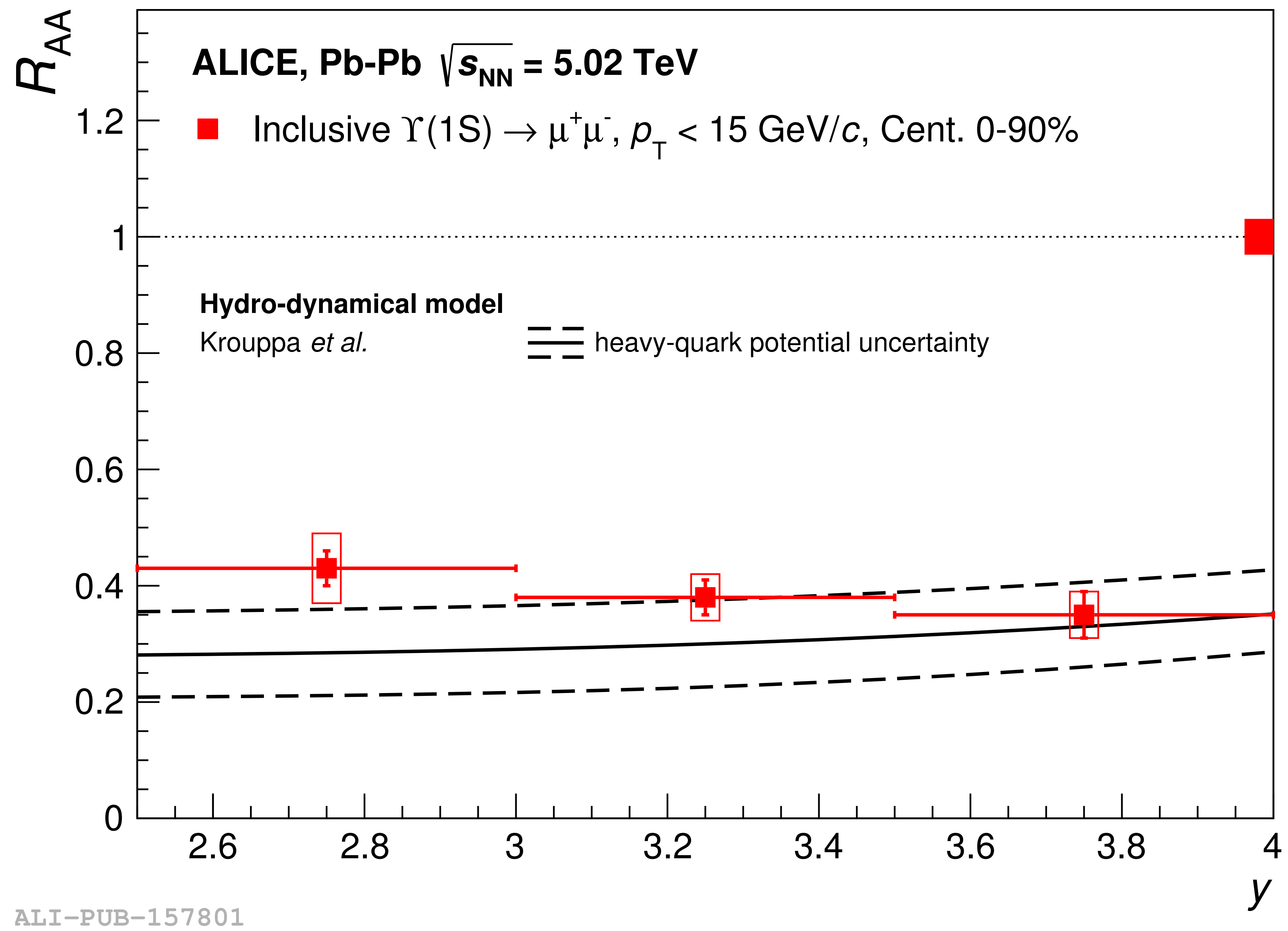
Υ(1S) R_{AA} versus p_T and y in Pb–Pb collisions at 5.02 TeV

New publication!





Υ(1S) R_{AA} does not show a significant dependence on p_T or y

ALICE Collaboration arXiv:1805.04387

2018 Quark Matter Venezia

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Summary

- Charmonium measurements indicate a competition between suppression and regeneration at LHC energies
  - J/ψ R_{AA} in Xe–Xe and Pb–Pb collisions compatible
  - differential R_{AA} analyses should be able to put stronger constraints on the models
  - J/ψ elliptic flow agrees with regeneration picture, for $p_T > 5$ GeV/c models significantly undershoot the data at forward rapidity

- Bottomonium production is clearly suppressed in Pb–Pb collisions at LHC energies
  - no indication for a significant regeneration component
  - ϒ(1S) R_{AA} in the forward rapidity range does not show a significant dependence on p_T or y
  - amount of direct ϒ(1S) suppression not known, more precise CNM measurements can help