17th France-China Particle Physics Network/Laboratory workshop

J/ψ measurements in the dimuon and dielectron channels with ALICE

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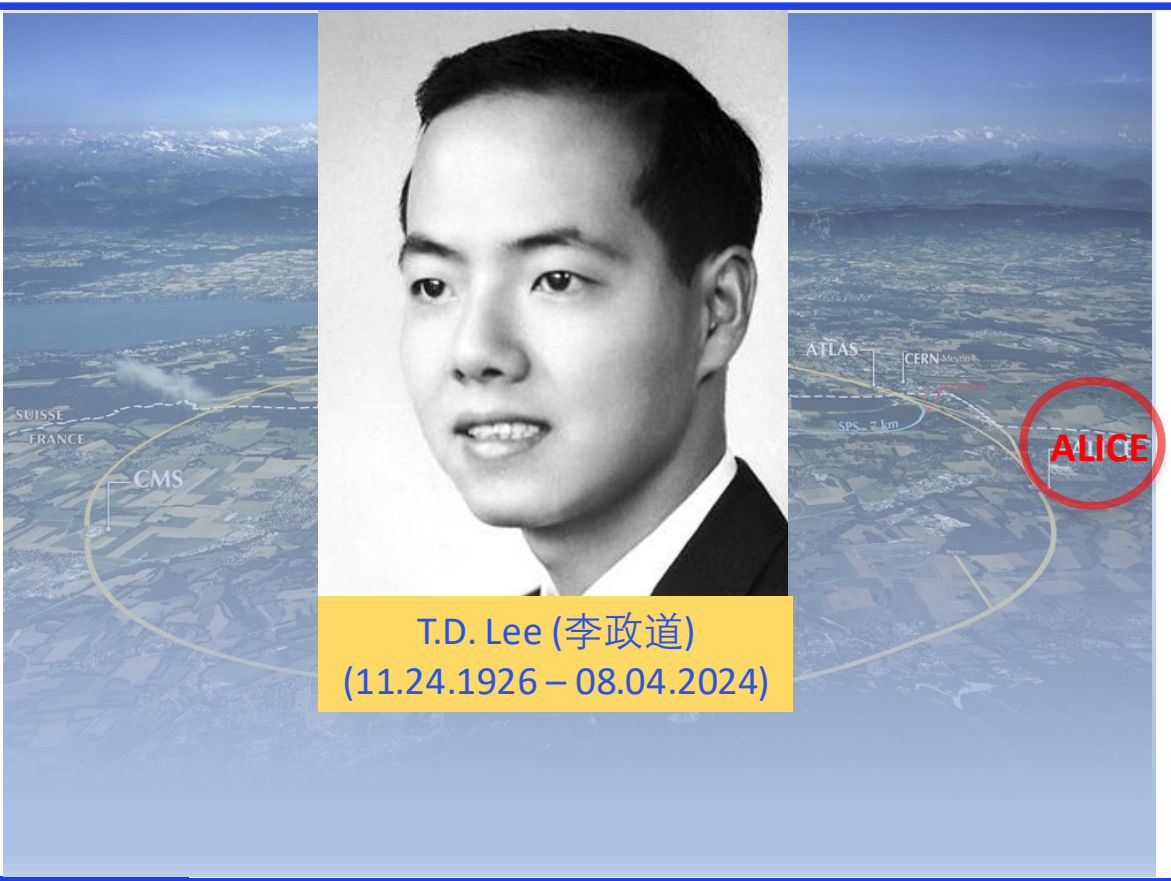
Villeurbanne, France, June 30, 2026

ALICE

CENTRAL CHINA NORMAL UNIVERSITY

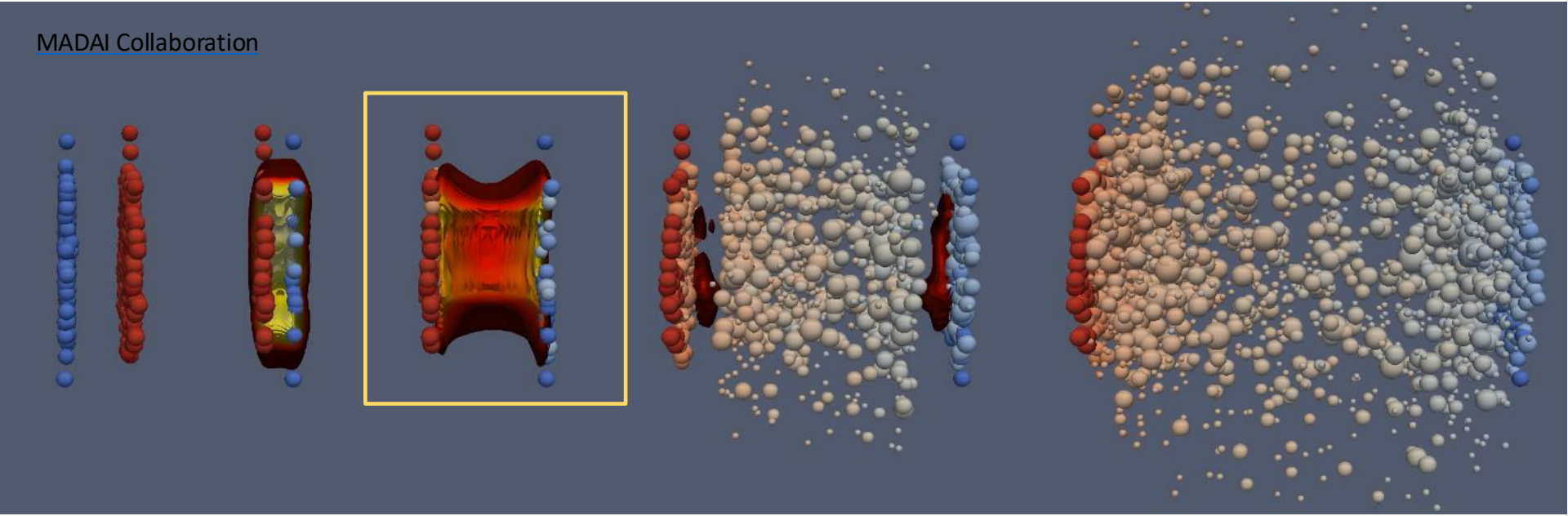
Motivation (some 50 years ago)



T.D. Lee (李政道)
(11.24.1926 – 08.04.2024)

"It would be **intriguing** to explore **new phenomena** by **distributing** high energy or high nuclear matter over a relatively large volume. , In this way, one could possibly **create abnormal states of nuclear matter**."

The history of the heavy-ion collision

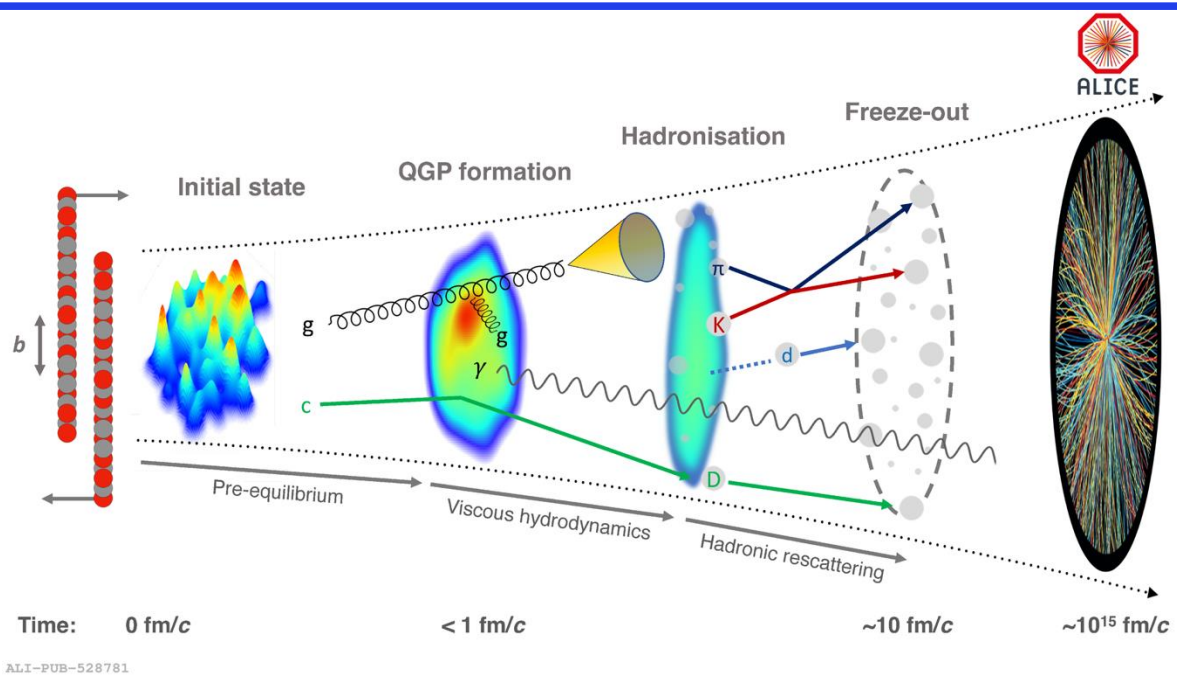


Initial stages

quark-gluon plasma (QGP)
fluid dynamic expansion

Final state: hadron scattering

Introduction to heavy-ion collisions



Early Proposed Signatures of QGP Formation:

- Strangeness enhancement （Rafelski & Müller, Phys. Rev. Lett. 48 (1982) 1066）
- J/ψ suppression （Matsui & Satz, Phys. Lett. B 178 (1986) 416–422）

Quarkonium suppression is the “smoking gun” of QGP

PHYS. LETT. B, in press

BROOKHAVEN NATIONAL LABORATORY

June 1986 BNL-38344

J/ψ SUPPRESSION BY QUARK-GLUON PLASMA FORMATION

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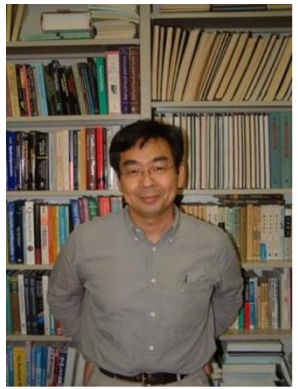
ABSTRACT

If high energy heavy ion collisions lead to the formation of a hot quark-gluon plasma, then colour screening prevents $c\bar{c}$ binding in the deconfined interior of the interaction region. To study this effect, we compare the temperature dependence of the screening radius, as obtained from lattice QCD, with the J/ψ radius calculated in charmonium models. The feasibility to detect this effect clearly in the dilepton mass spectrum is examined. We conclude that J/ψ suppression in nuclear collisions should provide an unambiguous signature of quark-gluon plasma formation.

- Heavy quarks produced in the early collision stages
- Quarkonium production is one of the “Smoking Guns” of QGP formation
- Quarkonium production suppressed sequentially via colour screening in QGP

T. Matsui, H. Satz, PLB178 (1986) 416

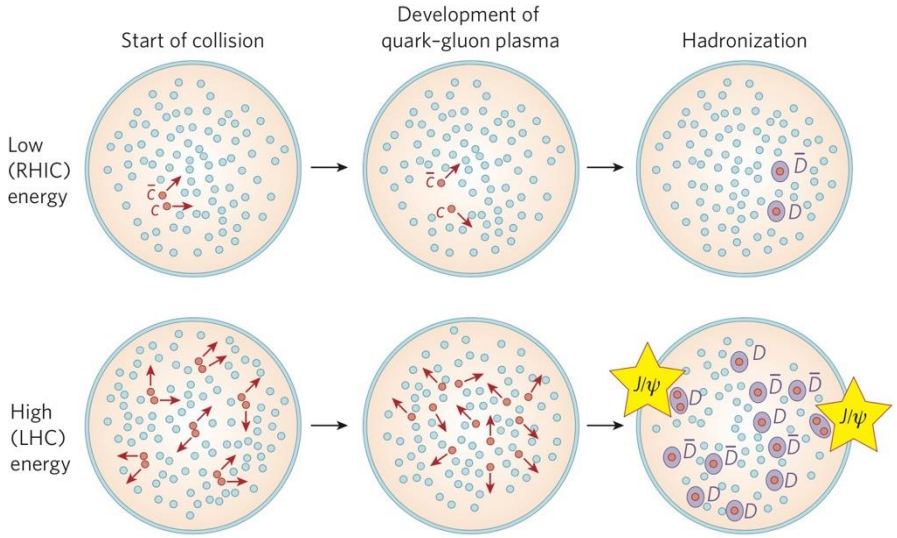
> 5700 citations



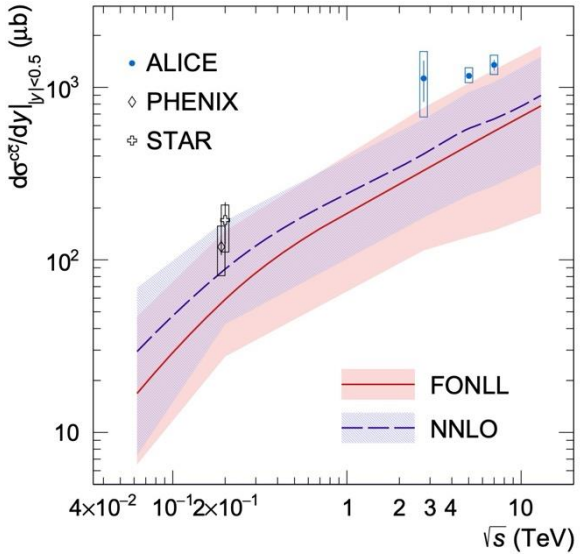
Tetsuo Matsui (1953-2025)

Charmonium (re)generation production

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



Phys. Rev. D 105, 011103 (2022)

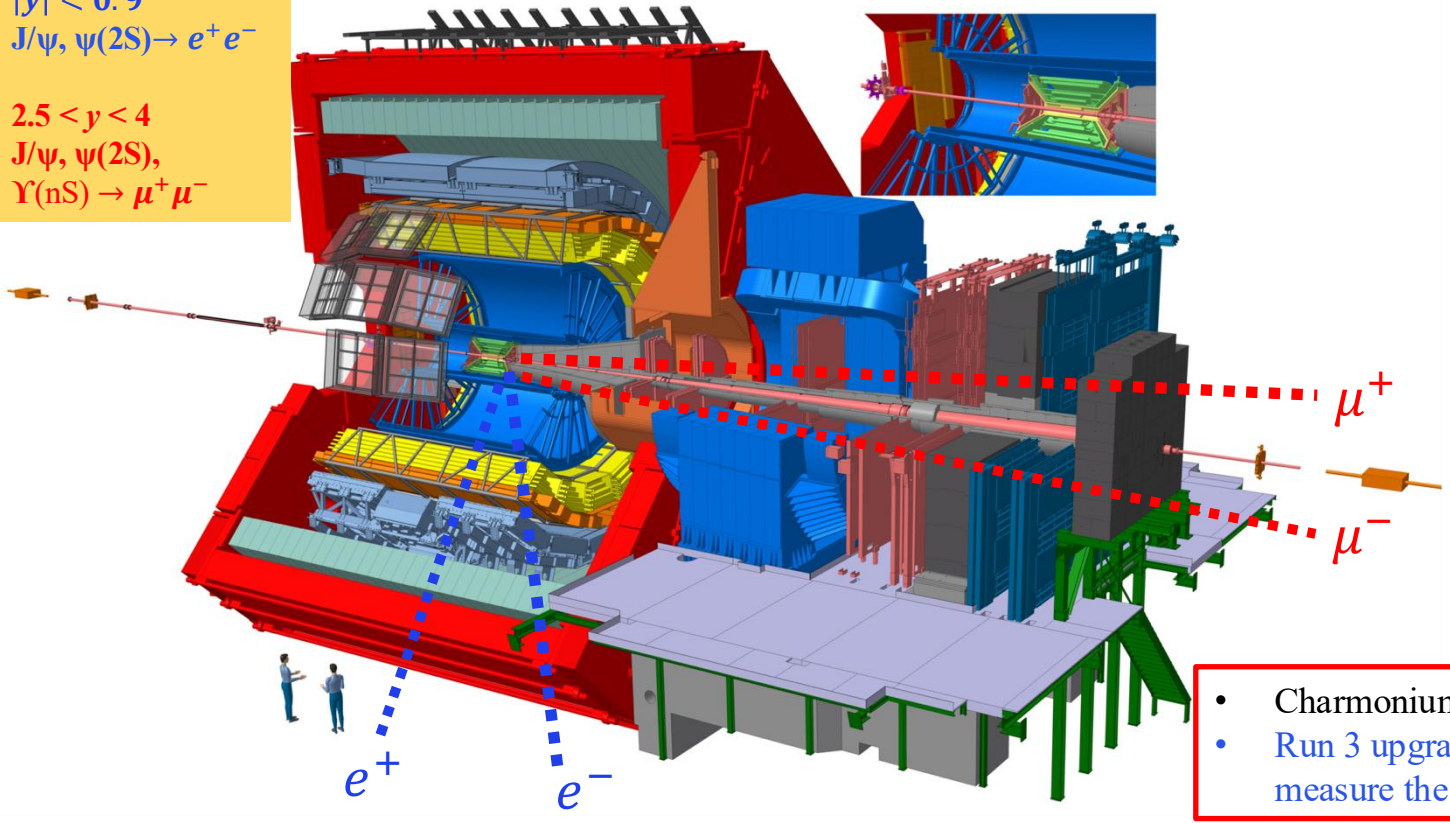


- Suppression of the charmonia due to colour screening and the dynamic dissociation
- Charm quark production cross section at the LHC is much larger compared to RHIC energies, and the **(re)generation** contribution to the J/ψ is significantly higher than at RHIC

Quarkonium measurements with the ALICE

$|y| < 0.9$
J/ψ, ψ(2S)→ e^+e^-

$2.5 < y < 4$
J/ψ, ψ(2S),
ϒ(nS) → $\mu^+\mu^-$



Time Projection Chamber
Tracking, particle identification

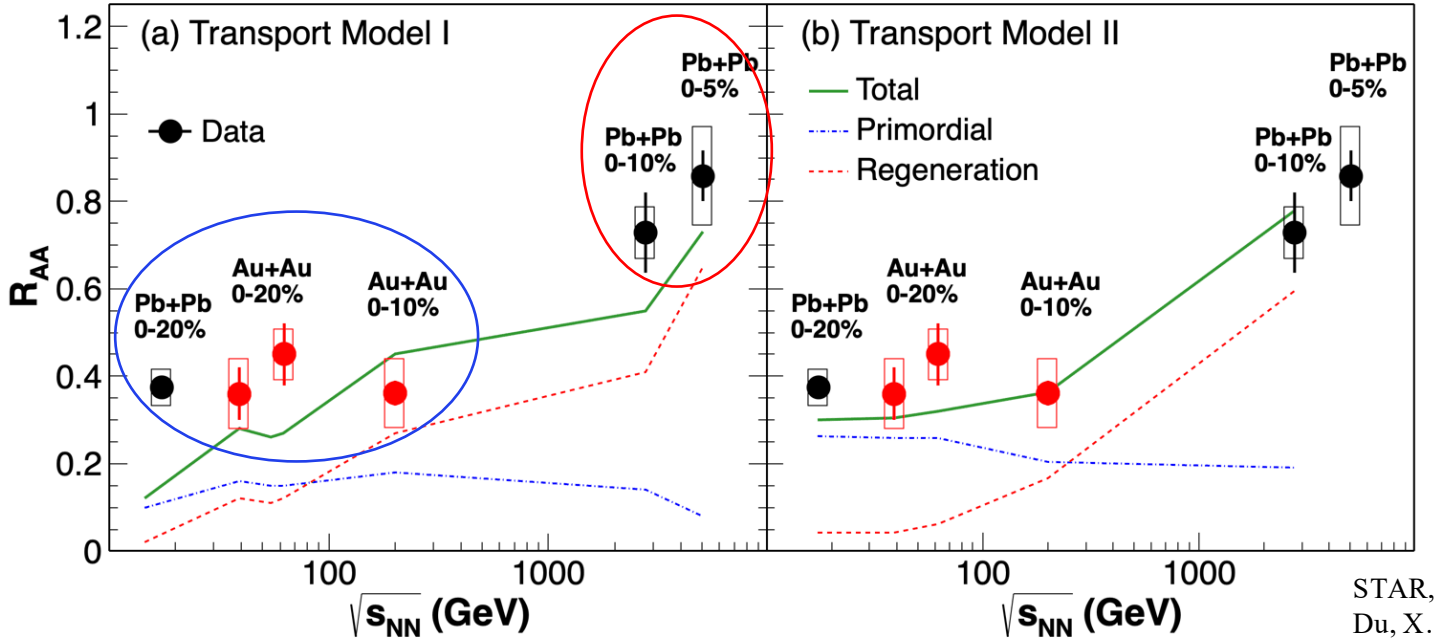
Inner Tracking System
Tracking, vertex reconstruction, Event plane determination

V0 Detector
Centrality determination, triggering, event plane determination, and background rejection

Muon spectrometer
Trigger and tracking for muons

- Charmonium measurement down to $p_T = 0$
- Run 3 upgraded detectors allow to measure the **ψ(2S)**, ϒ(nS) at midrapidty

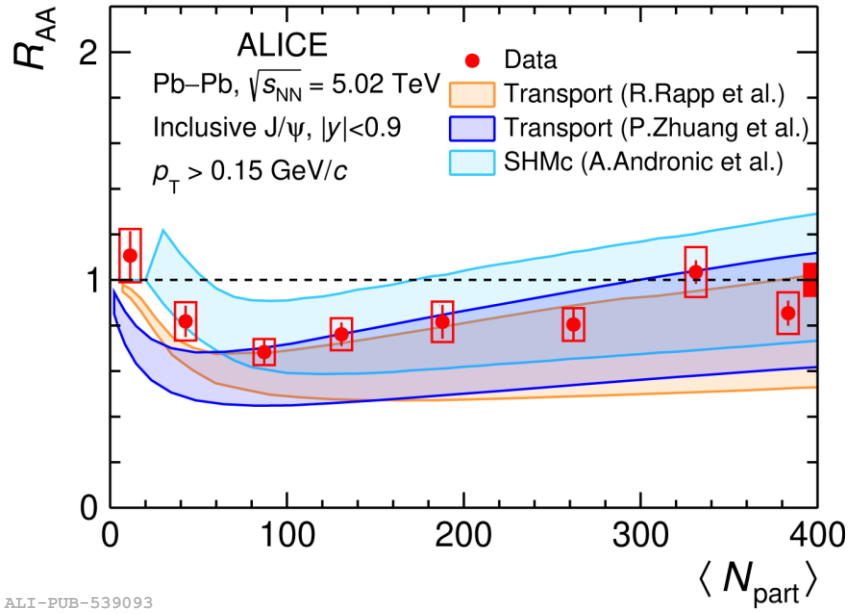
Charmonium production in RHIC and LHC

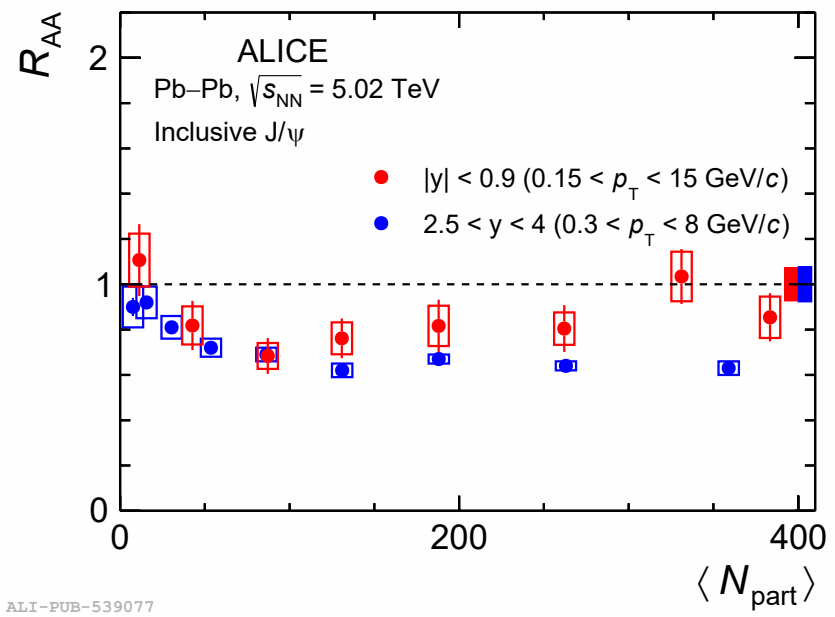


STAR, PLB 877 (2026) 140405
Du, X. et al., NPA 943, 147–158 (2015)
Zhou, K., et al., PRC 89, 054911 (2014)

- Suppression of the charmonia due to colour screening and the dynamic dissociation
- The **(re-)generation** contribution to the J/ψ is significantly higher than at RHIC

Inclusive J/ψ R_{AA} vs centrality



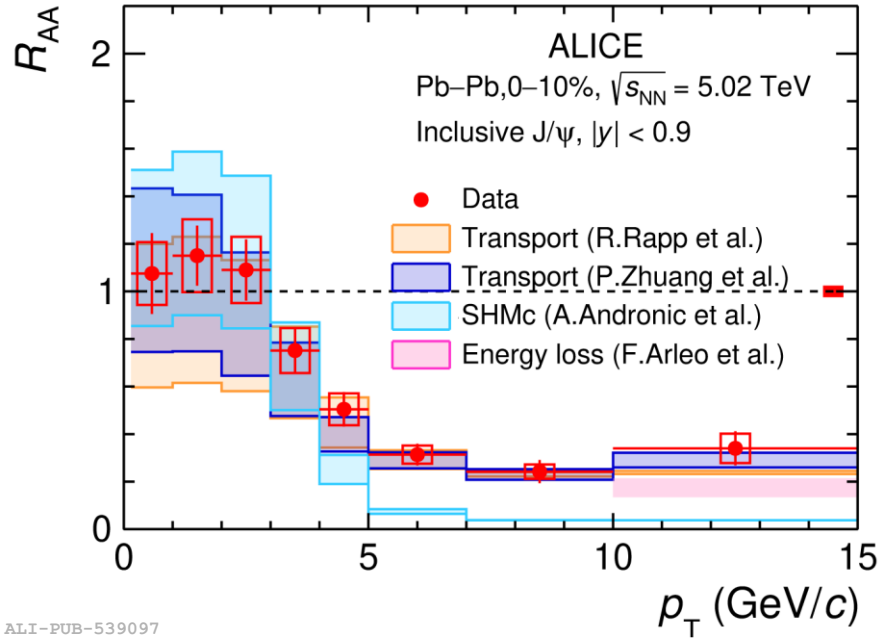


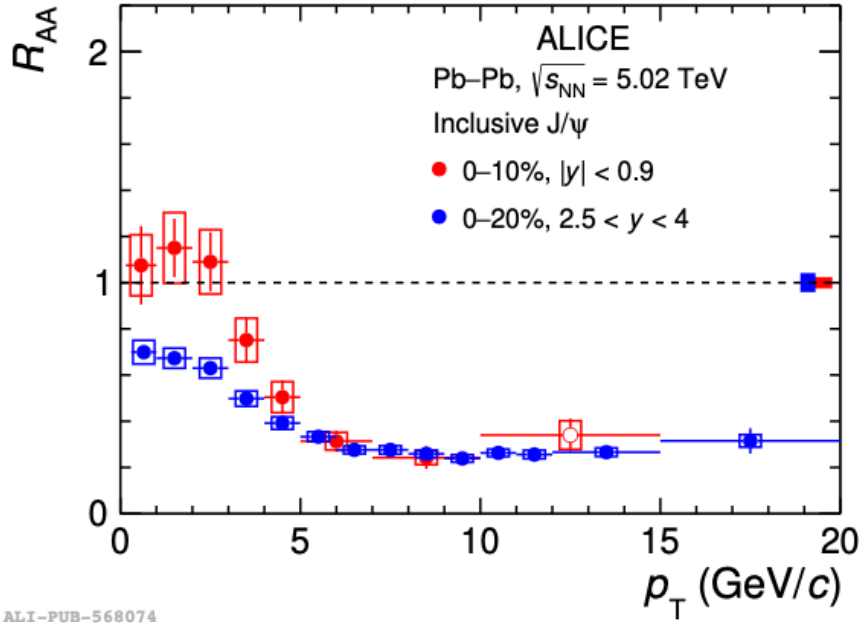
- **Evidence for J/ψ (re-)generation in central collisions, with a larger contribution at midrapidity compared to forward rapidity**
- All models can describe the data but suffer from large uncertainties related to inputs used in calculations (eg. charm cross section, shadowing)

Du, X. et al., NPA 943, 147–158 (2015)
Zhou, K., et al., PRC 89, 054911 (2014)
Andronic, A, et al, PLB 797, 134836 (2019)

Inclusive J/ψ R_{AA} vs p_T

ALICE, PLB 849 (2024) 138451



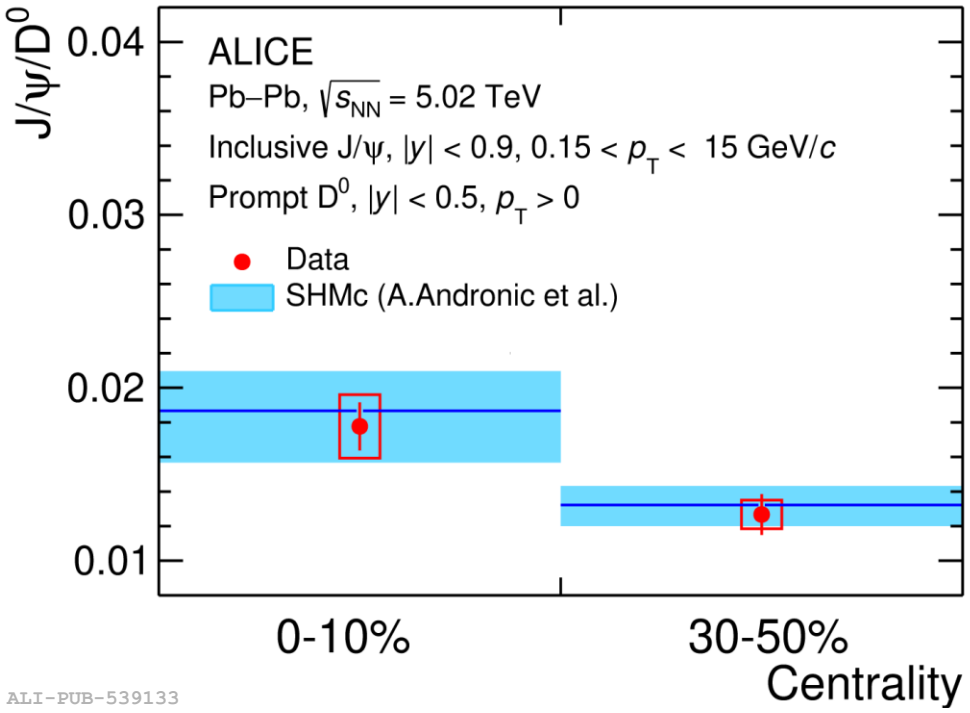


Transport and SHMc models describe data at low p_T, while SHMc underestimates the measurement at high p_T, the energy loss model agrees with data at high p_T

Du, X. et al., NPA 943, 147–158 (2015)
Zhou, K., et al., PRC 89, 054911 (2014)
Andronic, A, et al, PLB 797, 134836 (2019)

J/ψ-to-D^0 ratio in Pb–Pb collisions

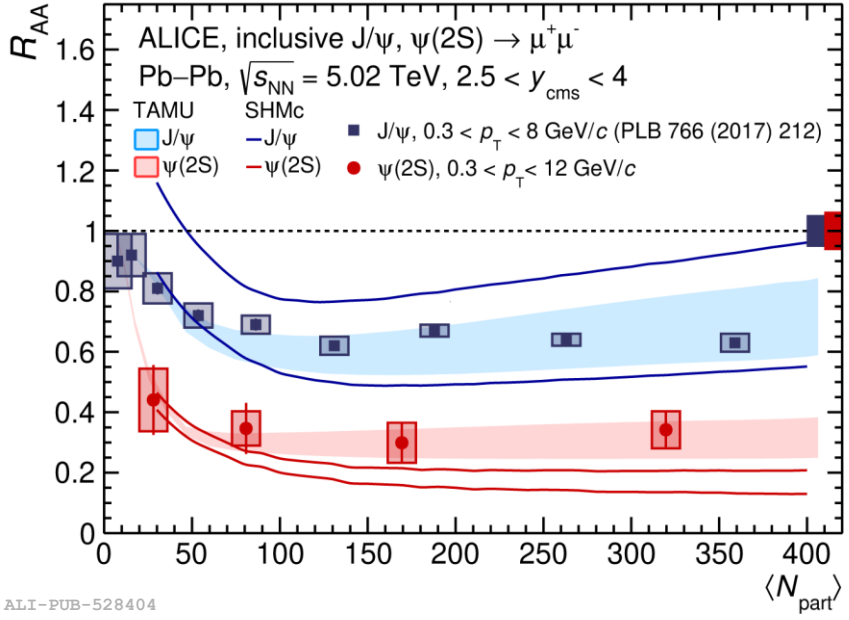
ALICE, PLB 849 (2024) 138451

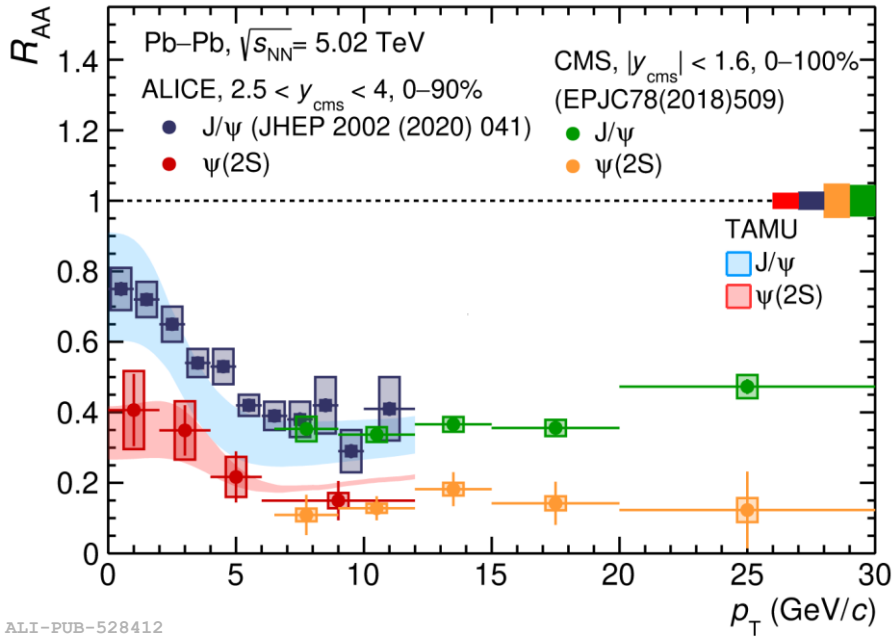


- Sensitive to hadronization mechanisms for open and hidden charm hadrons
- The centrality-dependent trend of the D^0 to J/ψ ratio can be explained by the increase of charm fugacity towards most central collisions
- **Evidence of charm deconfinement at LHC**

ψ(2S) R_{AA} in Pb−Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV

ALICE, PRL **132**, 042301(2024)

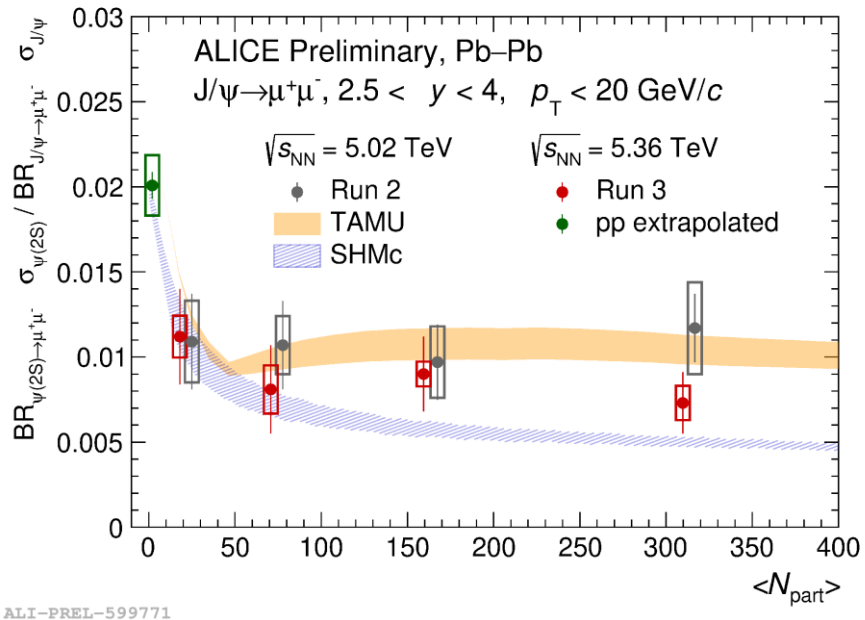


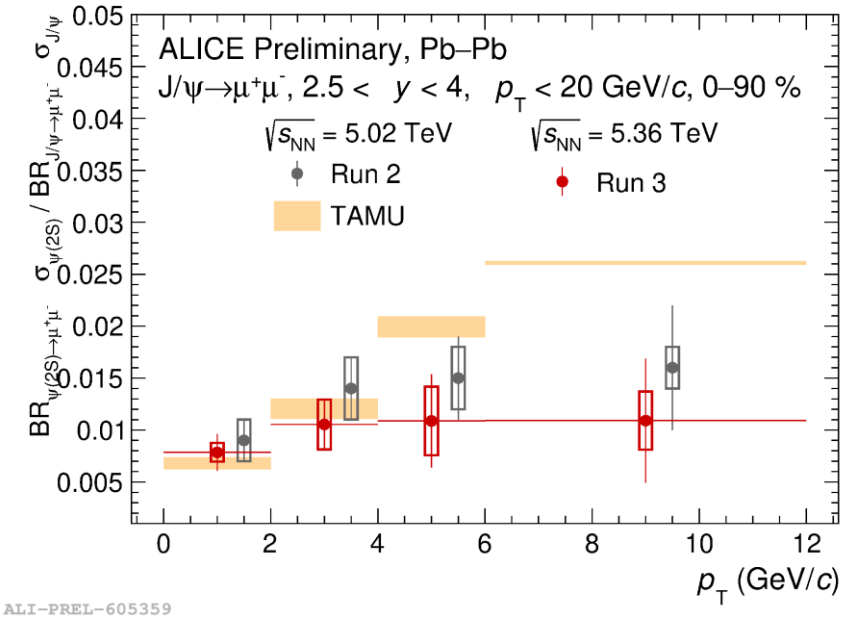


- A **larger suppression** of the ψ(2S) w.r.t the J/ψ is observed
- The ψ(2S) R_{AA} increases at low p_T , which is a hint of ψ(2S) regeneration
- The TAMU model describes data better than SHMc in central collisions

(TAMU) X. Du, et al.,NPA943,147-158(2015)
(SHMc) A. Andronic, et al.,PLB797,134836(2019)

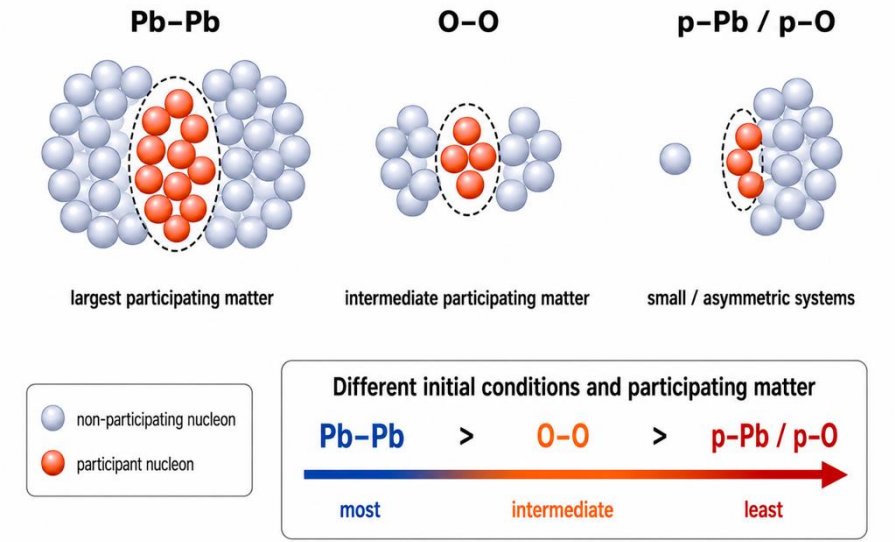
ψ(2S)-to-J/ψ ratio as a function of centrality and p_T





- ψ(2S) relative suppression observed to be a factor of 2 in Pb–Pb w.r.t. pp
- No significant dependence vs centrality and p_T within the uncertainties

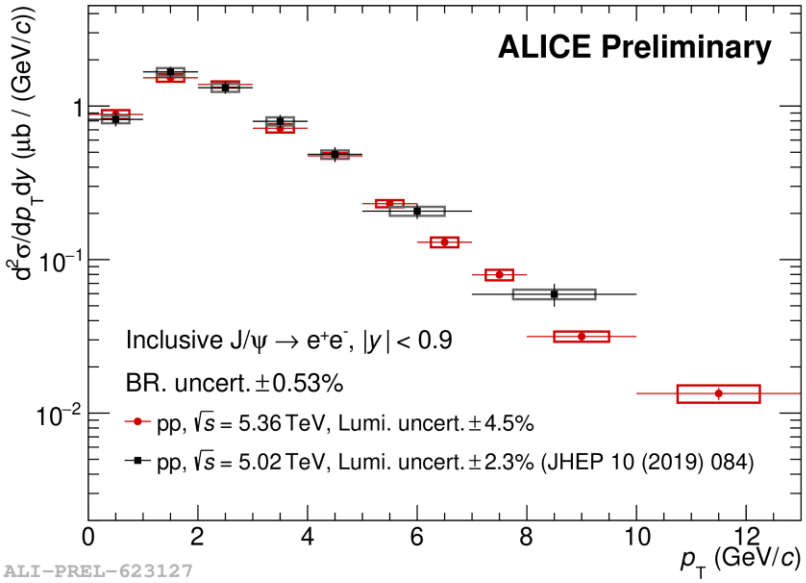
Motivation to study J/ψ in light-ion collisions

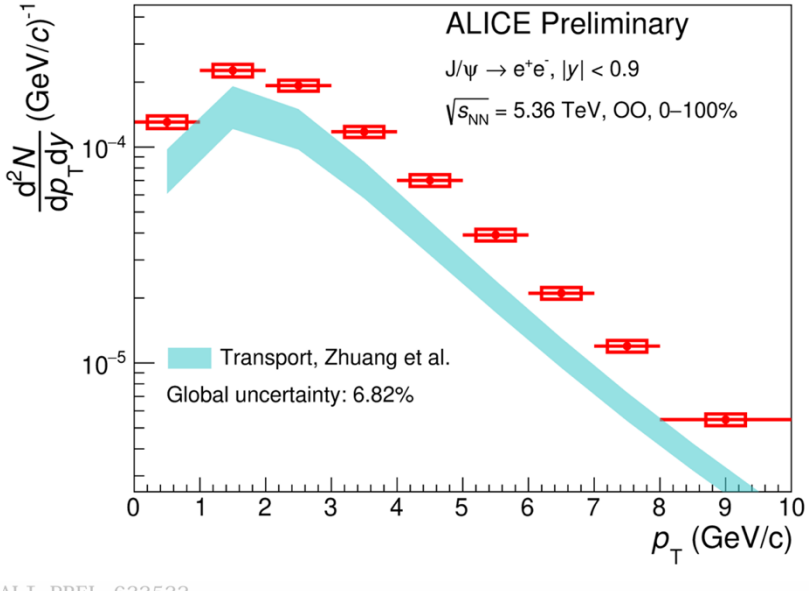


Why we want to study J/ψ in OO collisions (small and symmetric system, standing between Pb–Pb and p–Pb)?

- Investigate whether QGP is formed in this small system.
- Hope to better disentangle QGP effects and initial-state effects.
- Understand the system-size evolution of quarkonium production.

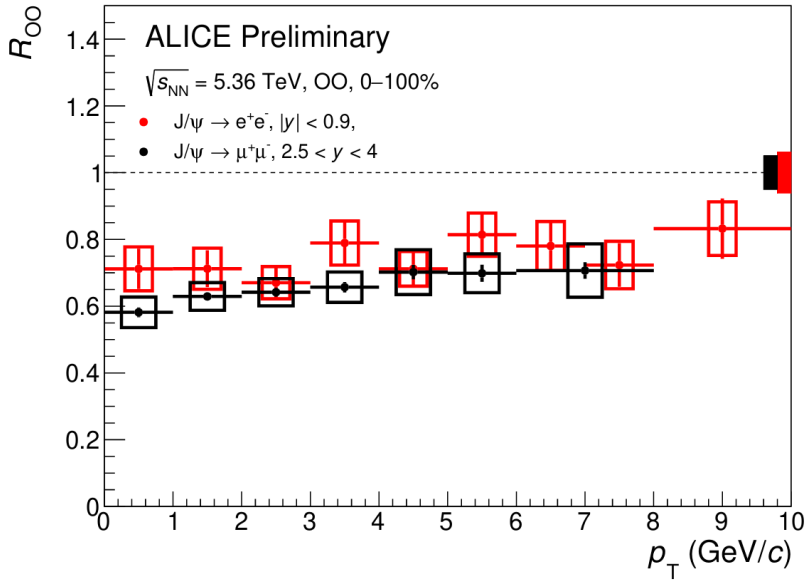
The J/ψ production as a function of p_T



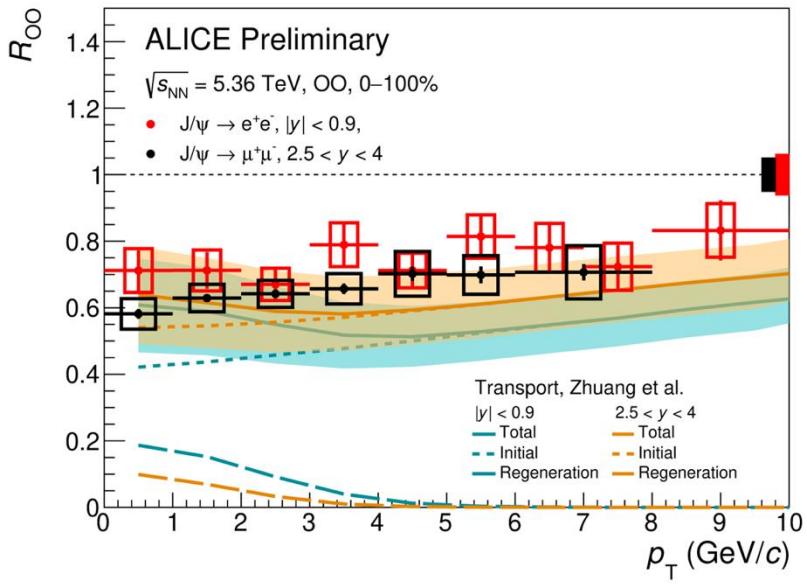


- The pp cross section at 5.36 TeV: consistent with the 5.02 TeV result, with extended p_T reach and improved statistical precision.
- The OO yield is higher than the current transport-model prediction.

R_{OO} results: forward rapidity vs. midrapidity



ALI-PREL-633548

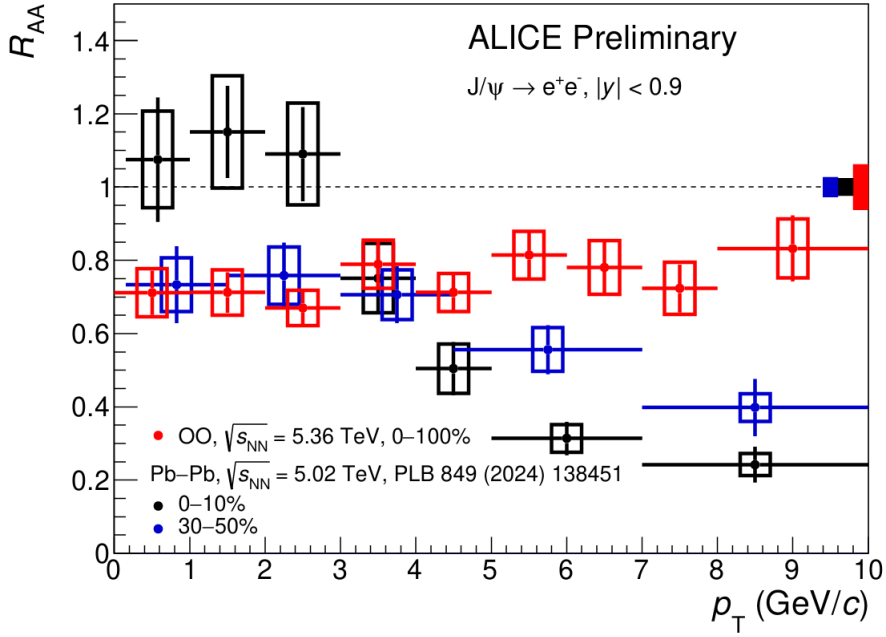


ALI-PREL-633552

- Mid- and forward-rapidity R_{OO} are consistent within uncertainties and below unity, indicating suppression.
- The midrapidity data are slightly higher than the model predictions; the forward rapidity data are consistent with the model within uncertainties.
- More model predictions are welcome to interpret the data.

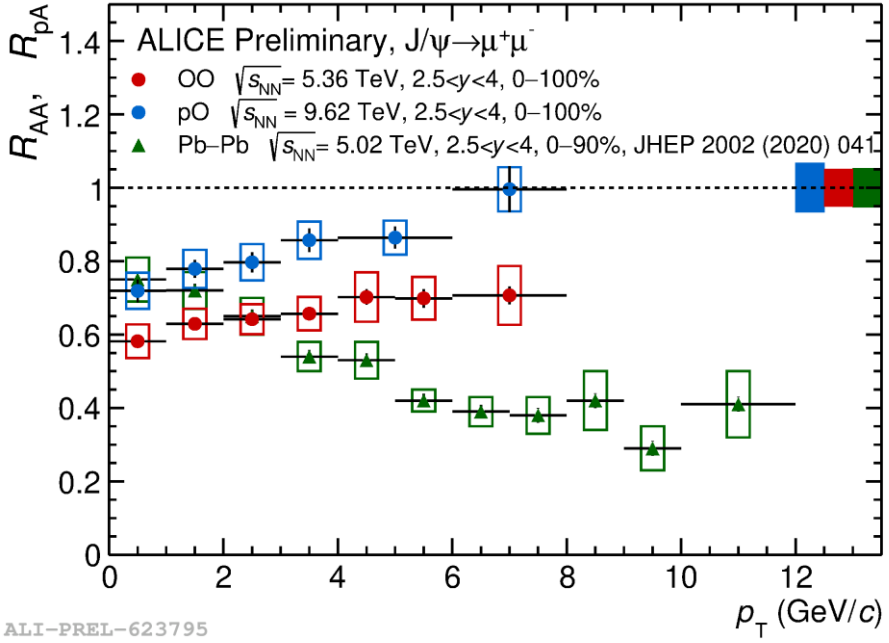
$$R_{OO} = \frac{\sigma_{OO}^{J/\psi}}{A^2 \cdot \sigma_{pp}^{J/\psi}}$$

R_{OO} system dependence — midrapidity



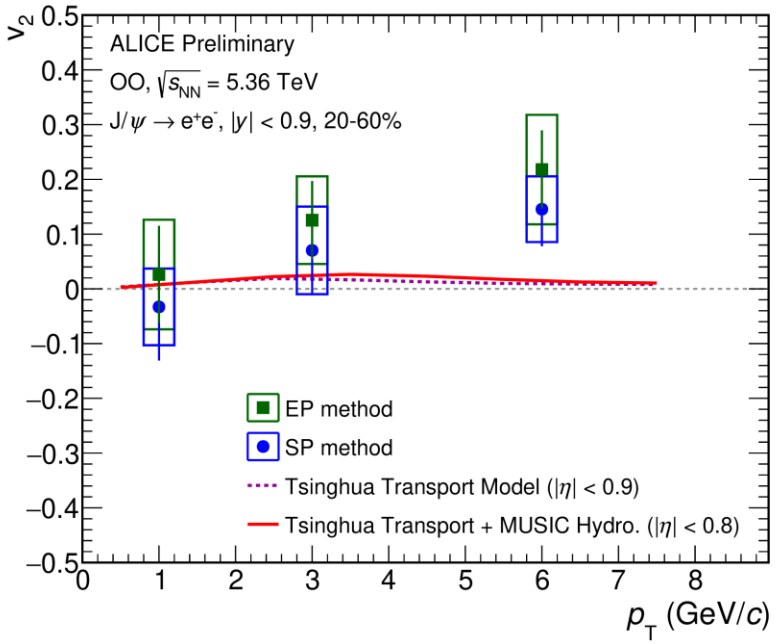
- Pb–Pb stronger p_T dependence than OO.
- Pb–Pb trend at low p_T is mainly driven by the regeneration.
- No clear low-p_T regeneration enhancement is observed in R_{OO}.

R_{OO} system dependence — forward rapidity



- $R_{OO} < R_{pO}$ along p_T bins, suggesting possible hot-medium effects in OO.
- Pb–Pb stronger p_T dependence than OO, trend at low p_T is mainly driven by the regeneration.
- No clear low-p_T regeneration enhancement is observed in R_{OO}.

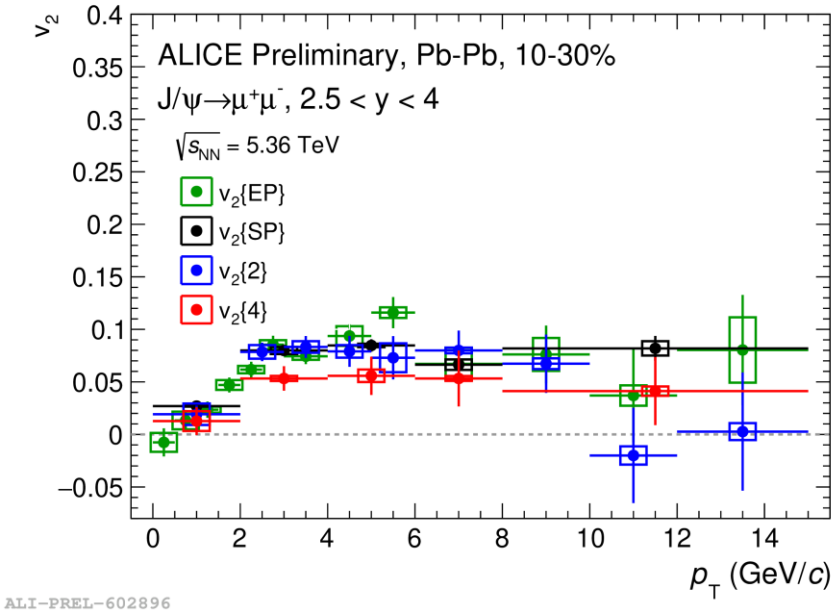
J/ψ v_2 vs p_T in OO — EP and SP

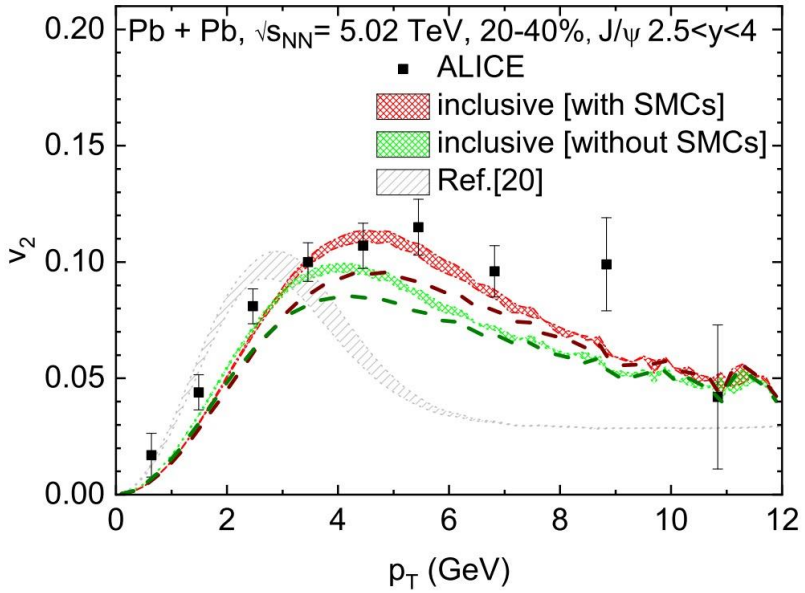


ALI-PREL-632813

- The results obtained with the EP and SP methods are all consistent with zero within uncertainties.
- Some deviations from the models are observed in low-p_T central and high-p_T semi-central bins. More model predictions are welcome to interpret the data.

J/ψ v_2 vs p_T in PbPb — EP and SP





M. He, et al., PRL.128, 162301 (2022)

- The new result is consistent with Run 2, with statistical precision improved at low p_T at forward rapidity
- A significant J/ψ v_2 is observed, consistent with the charm quark thermalization

Summary

- Dominant contribution from (re-)generation, **evidence of charm deconfinement at LHC**
- A larger suppression of the ψ(2S) with respect to the J/ψ is observed
- QGP-like signatures are observed in O–O collisions, suggesting possible hot-medium formation in a small collision system

Thanks