Quarkonia production in **light-ion collisions** with ALICE

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On behalf of the ALICE Collaboration

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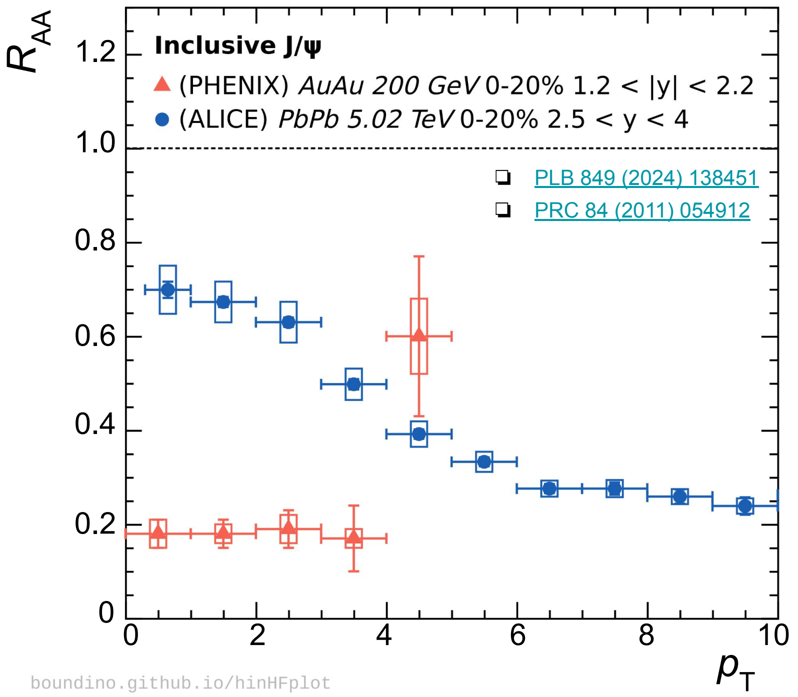
SQM26, 25/03/2026

Physics motivations: hot matter effects

Quarkonium serves as a key observable for studying heavy-ion collisions:

- At RHIC energies: suppression dominates due to the strongly interacting medium created in the collision
- At LHC energies: in addition to suppression, regeneration becomes significant especially at low p_T

- T. Matsui, H. Satz, Phys. Lett. B 178 (1986) 416
- A. Andronic, P. Braun-Munzinger, K. Redlich, J. Stachel, Nucl. Phys. A 789 (2007) 334
- L. Grandchamp, R. Rapp, G.E. Brown, Phys. Rev. Lett. 92 (2004) 212301

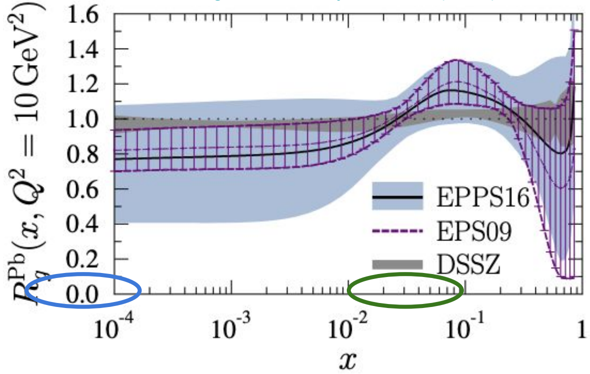


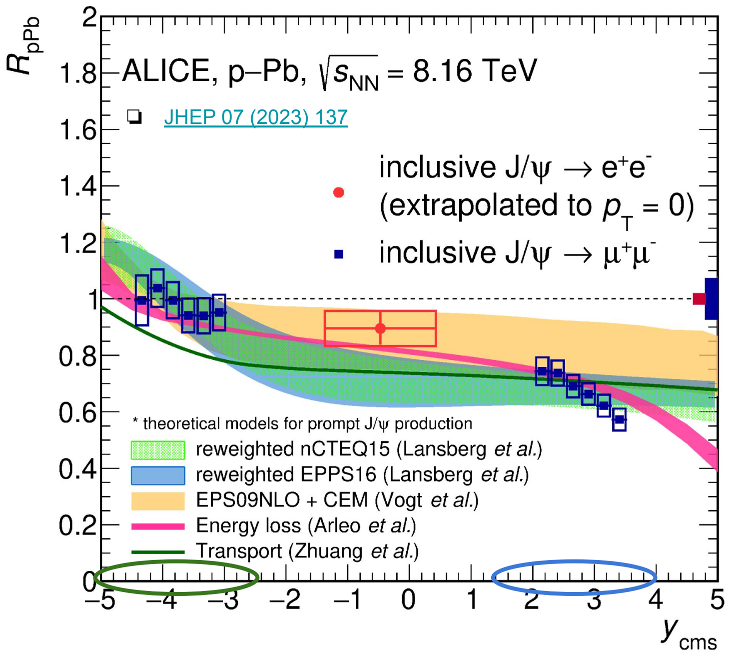
Physics motivations: cold matter effects

Cold nuclear matter effects can be explored in small systems such as p–Pb collisions:

- $R_{\text{p–Pb}}$ consistent with shadowing, additional CNM effects may also be present

❏ K. J. Eskola, P. Paakkinen, H. Paukkunen, C. A. Salgado, Eur. Phys. J. C 77 (2017) 163





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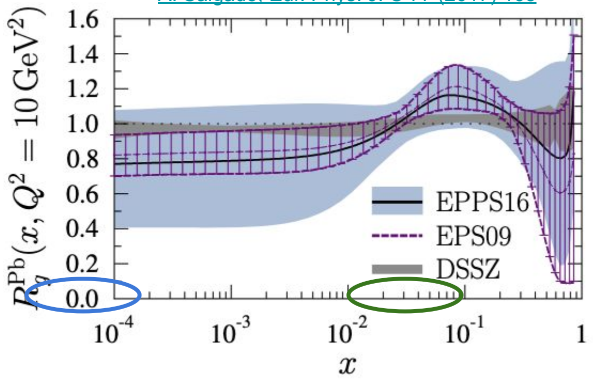

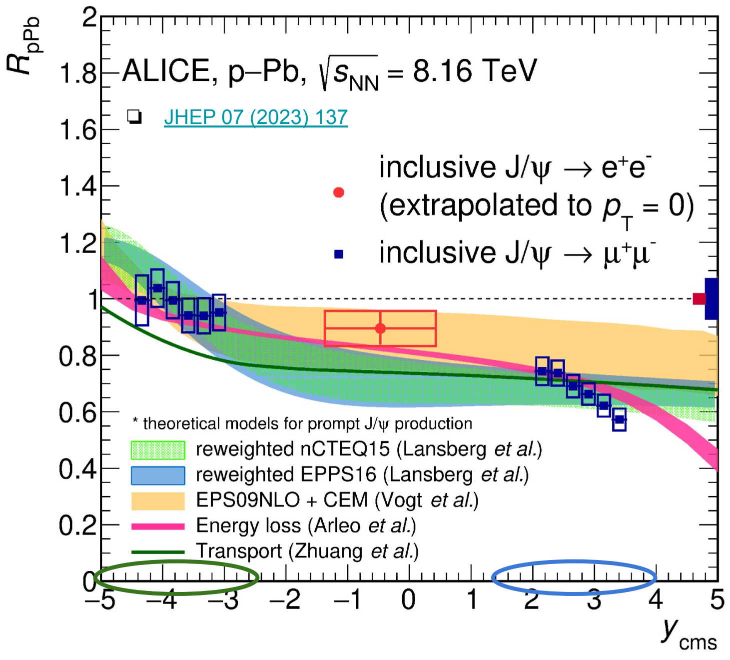

What happens with OO and pO collisions?

Light ion collisions

- What changes for **lighter systems** at the **same LHC** collision **energy**?
- Are we observing effects due to hot nuclear matter, or mainly cold nuclear matter?

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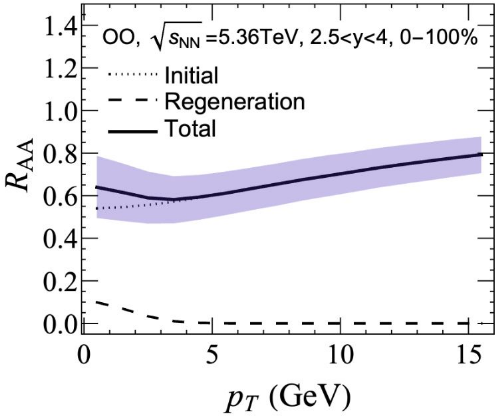
OO

Transport model

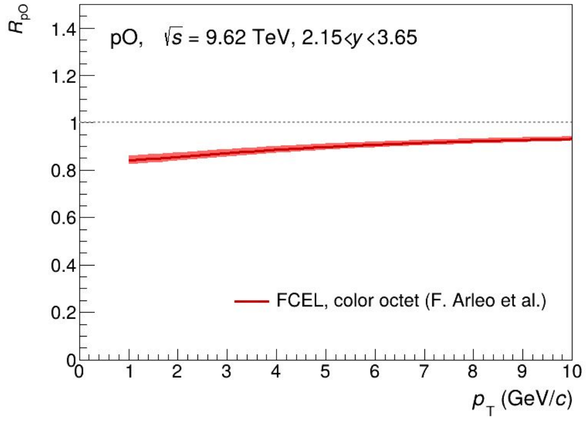
- J. Zhao, K. Zhou, S. Chen, and P. Zhuang, Prog. Part. Nucl. Phys. 114, 103801 (2020)
- J. Zhao, B. Chen, and P. Zhuang, Phys. Rev. C 105, 034902 (2022)



pO

Fully coherent energy loss (FCEL) model

- F. Arleo and S. Peigné, JHEP 03, 122 (2013)



ALICE: Light ions data taking

OO:

- $\sqrt{s_{NN}}$ = 5.36 TeV
- 2 days of data taking: 07/2025
- Recorded luminosity = 5.01 nb^{-1}

pO:

- $\sqrt{s_{NN}}$ = 9.62 TeV
- 2 days of data taking: 07/2025
- Recorded luminosity = 7.27 nb^{-1}

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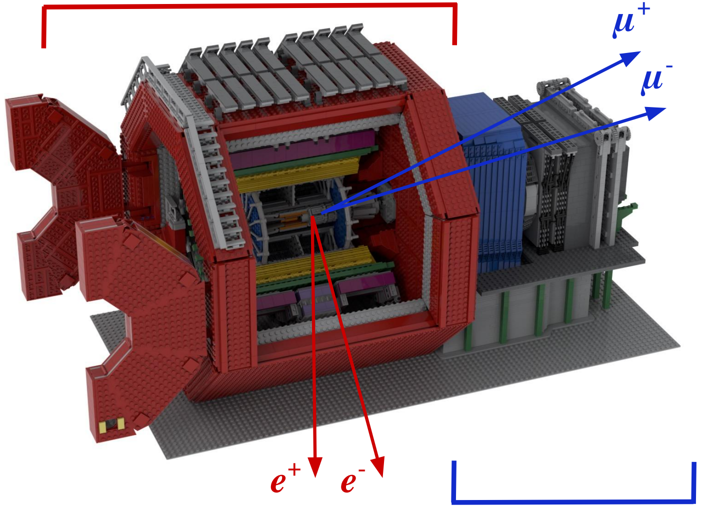
$J/\psi \rightarrow e^+ e^-$

- Inner Tracking System (ITS)
- Time Projection Chamber (TPC)
- Fast Interaction Triggers (FITs)

Central barrel, Midrapidity: $|y| < 0.9$



Muon spectrometer, Forward rapidity: $2.5 < y < 4$

$J/\psi \rightarrow \mu^+ \mu^-$

- Muon tracking (MCH)
- Muon identification (MID)

Nuclear modification factors: R_{OO} and R_{pO}

$$R_{xO} = \frac{\sigma_{xO}^{J/\psi}}{xO \cdot \sigma_{pp}^{J/\psi}}$$

The main steps involved in the calculation of R_{xO} are:

- signal extraction
- pp reference

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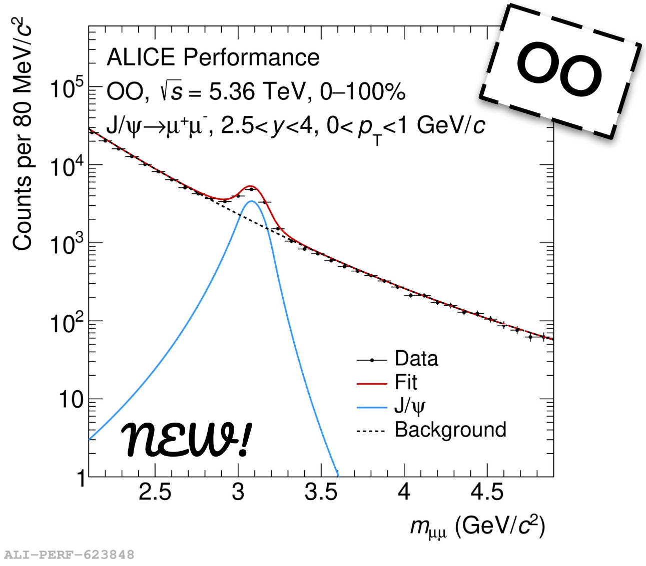
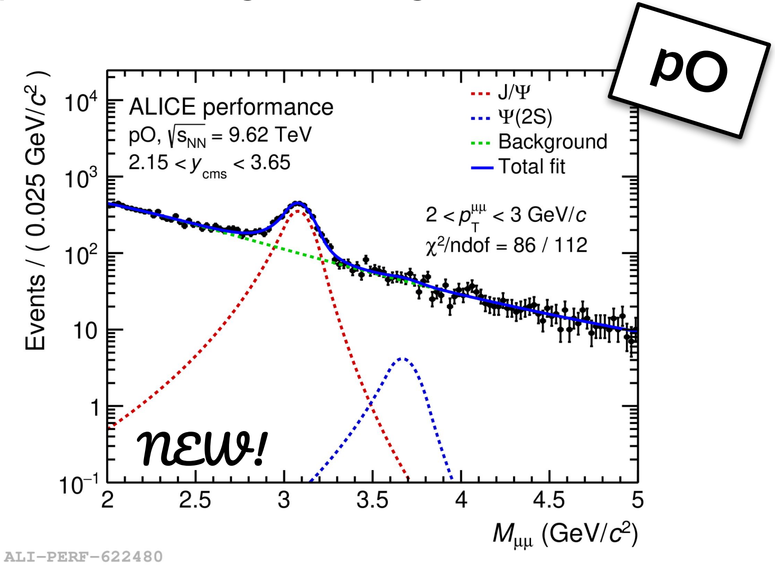
Gaussian with variable tails, phenomenological background





$N^{J/\psi}$ (0-100%, 0-20 GeV/*c*) ~ 6×10^4

$N^{J/\psi}$ (0-100%, 0-20 GeV/*c*) ~ 2×10^4

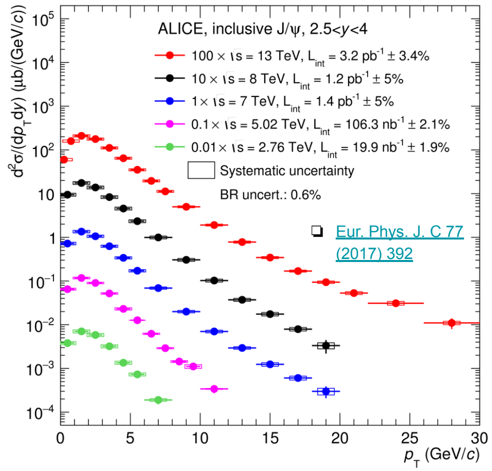
Nuclear modification factors: R_{OO} and R_{pO}

$$R_{xO} = \frac{\sigma^{J/\psi}_{xO}}{xO \cdot \sigma^{J/\psi}_{pp}}$$

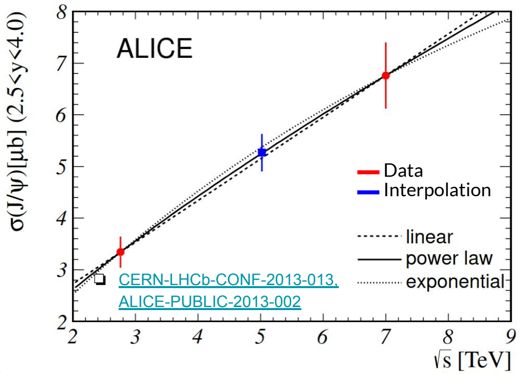
The main steps involved in the calculation of R_{xO} are:

- signal extraction
- **pp reference**: cross-section interpolation

1. Based on previous results at different energies
2. Interpolation of the point using three different functions



$$\sigma(\sqrt{s}) = \begin{cases} p_0 + \sqrt{s}\, p_1 \\ (\sqrt{s}/p_0)^{p_1} \\ p_0(1 - \exp(-\sqrt{s}/p_1)) \end{cases}$$

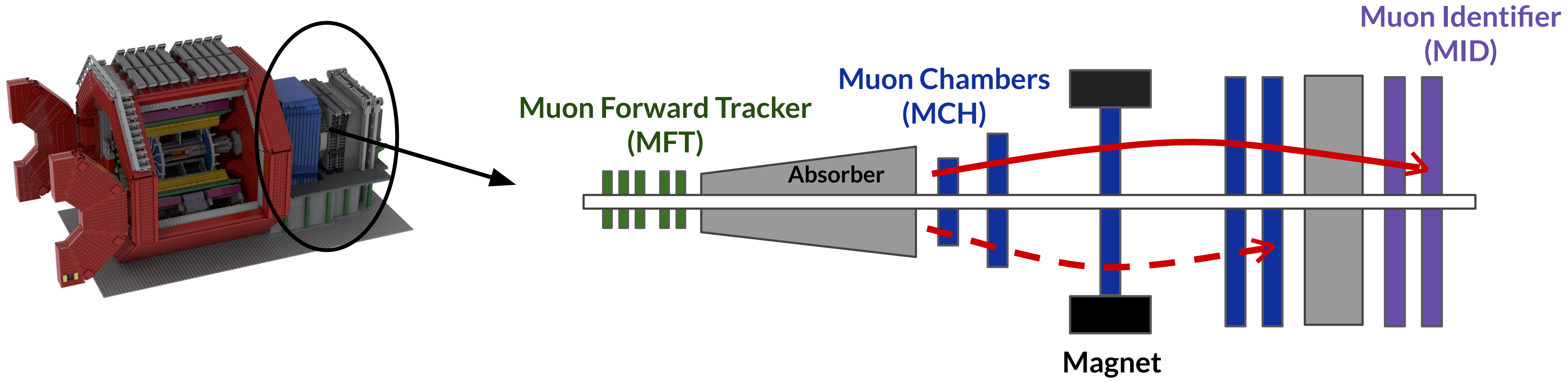


Systematics uncertainties

Summary of the primary systematics calculated for R_{OO} and R_{pO}:

- Main contribution: pp reference

System	signal extraction	pp reference	MC	Matching Efficiency MCH-MID	Tracking Efficiency MCH	BR	luminosity	Others (e.g. rapidity extension)
OO	[2.5,5.0]%	[5.0,9.0]%	2.5%	2.0%	2.5%	0.5%	3%	//
pO	[3.0,5.0]%	[5.5,6.5]%	2 %	2.0%	2.5%	0.5%	3.5%	3 %

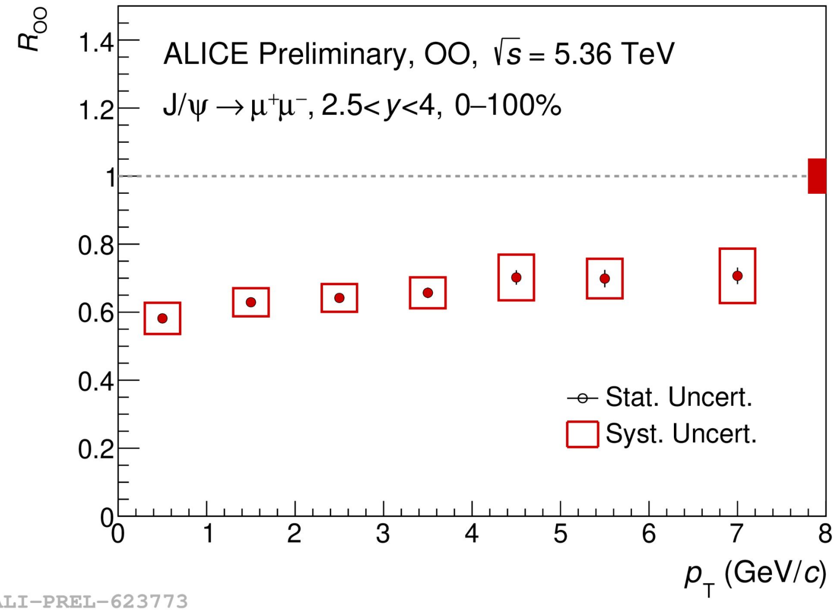


OO: results

R_{OO}:

- exhibits a **suppression** of about **40%** at low p_T
- weak dependence as a function of p_T

NEW!



ALI-PREL-623773

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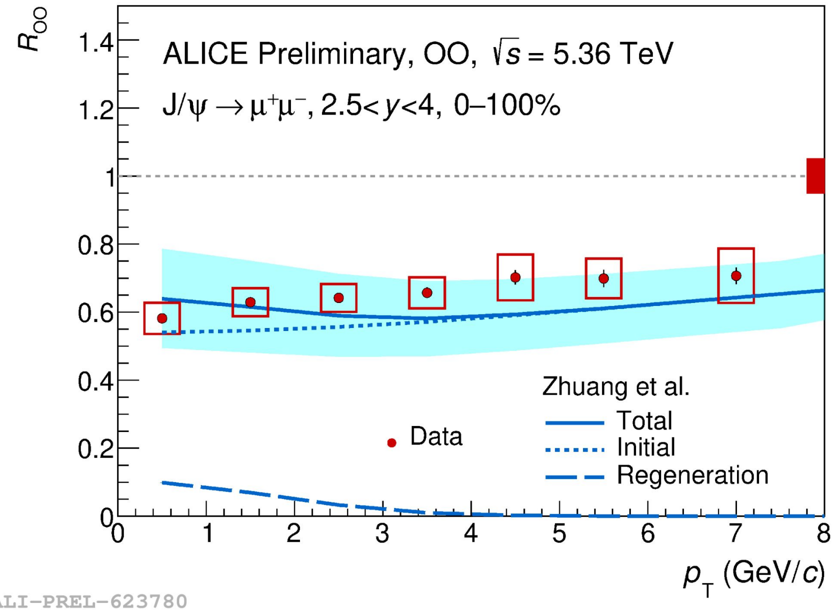


ALI-PREL-623780

Transport model

Cold Nuclear Matter effects:

- Shadowing (EPS09)
- Cronin Effect

Hot Nuclear Matter effects:

- Dissociation in the medium
- Regeneration

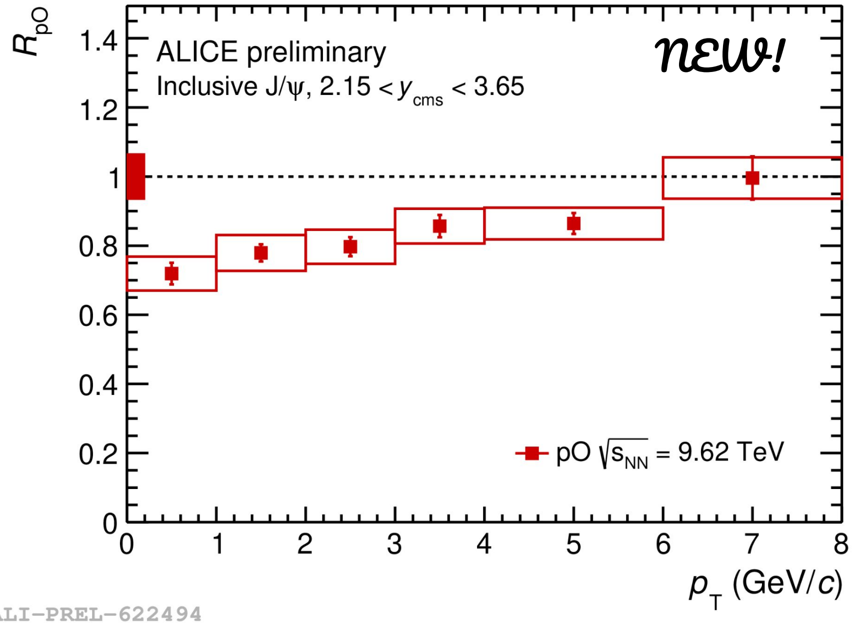
Comparison between OO and model:

- Data in agreement with theoretical predictions
- No sign of R_{OO} increasing trend at p_T 0-1 GeV/c in data

pO: results

R_{pO}:

- exhibits a **suppression** of about **30%** at low p_T
- **increase** towards higher p_T



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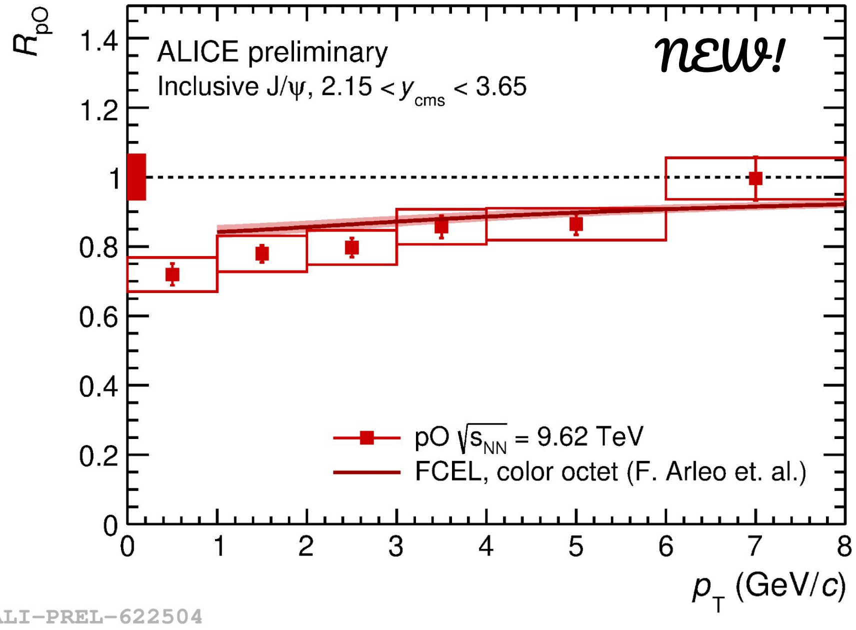


❑ F. Arleo and S. Peigné, JHEP 03, 122 (2013)

FCEL model

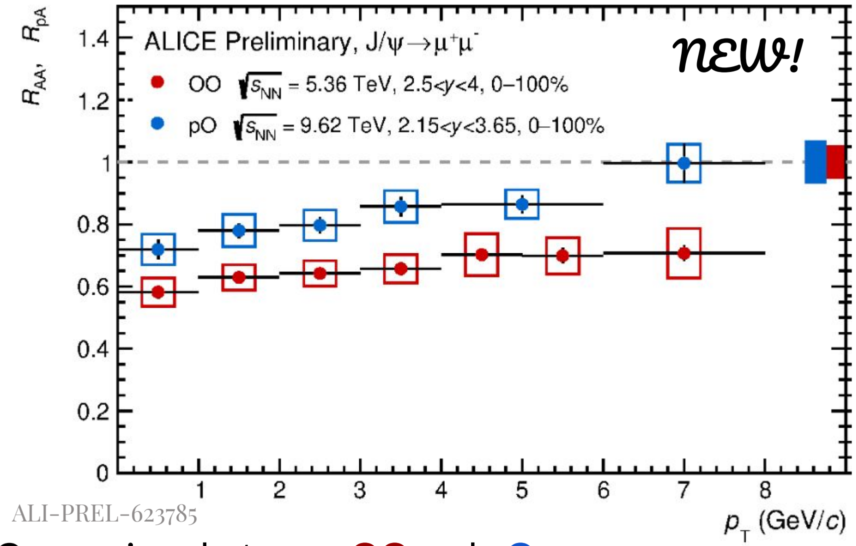
➢ Constructive interference of radiative emission amplitude between initial and final state

➢ Assumes $c\bar{c}$ pair is in color octet state, does not include any nPDF effects

Comparison between pO and FCEL:

- Data in agreement with theoretical predictions

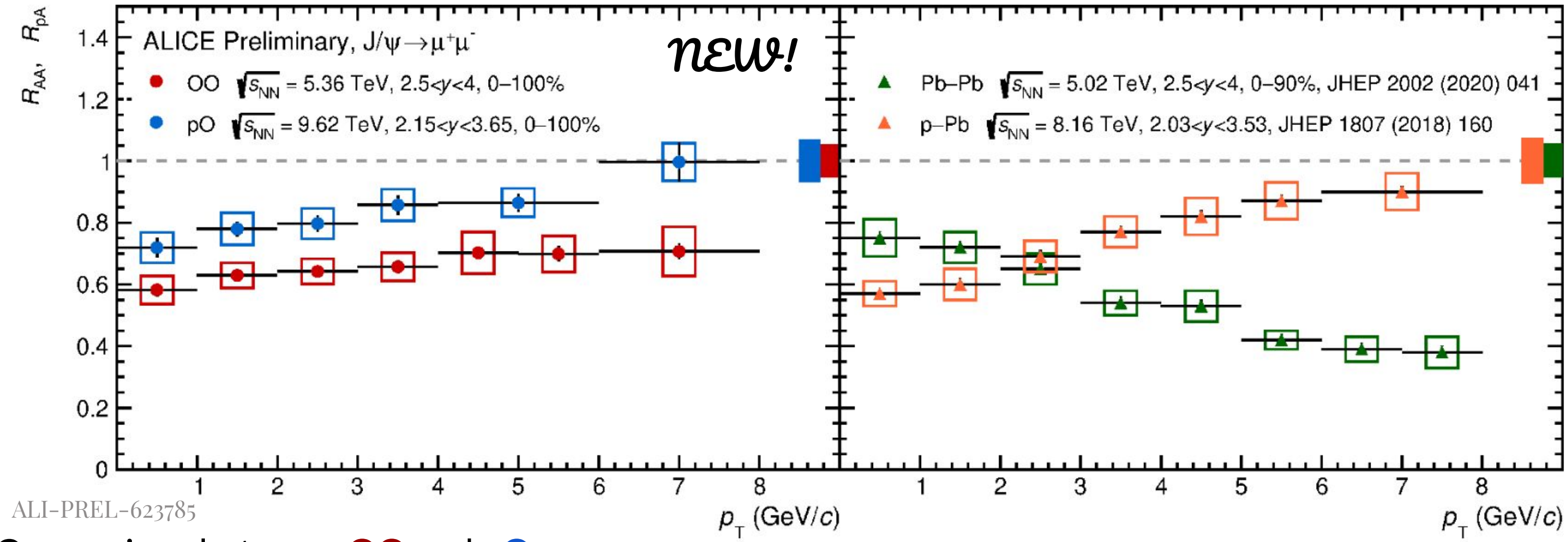
Comparisons: OO and pO



Comparison between **OO** and **pO**:

- $R_{OO} < R_{pO}$ along p_T bins
- pO: smaller system, trend mainly driven by cold matter effects
- OO: hot matter effects can start to play a role

Comparisons: OO and pO



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Comparison between **OO** and **Pb–Pb**:

- Pb–Pb stronger p_T dependence than OO
- Pb–Pb trend at low p_T is mainly driven by the regeneration

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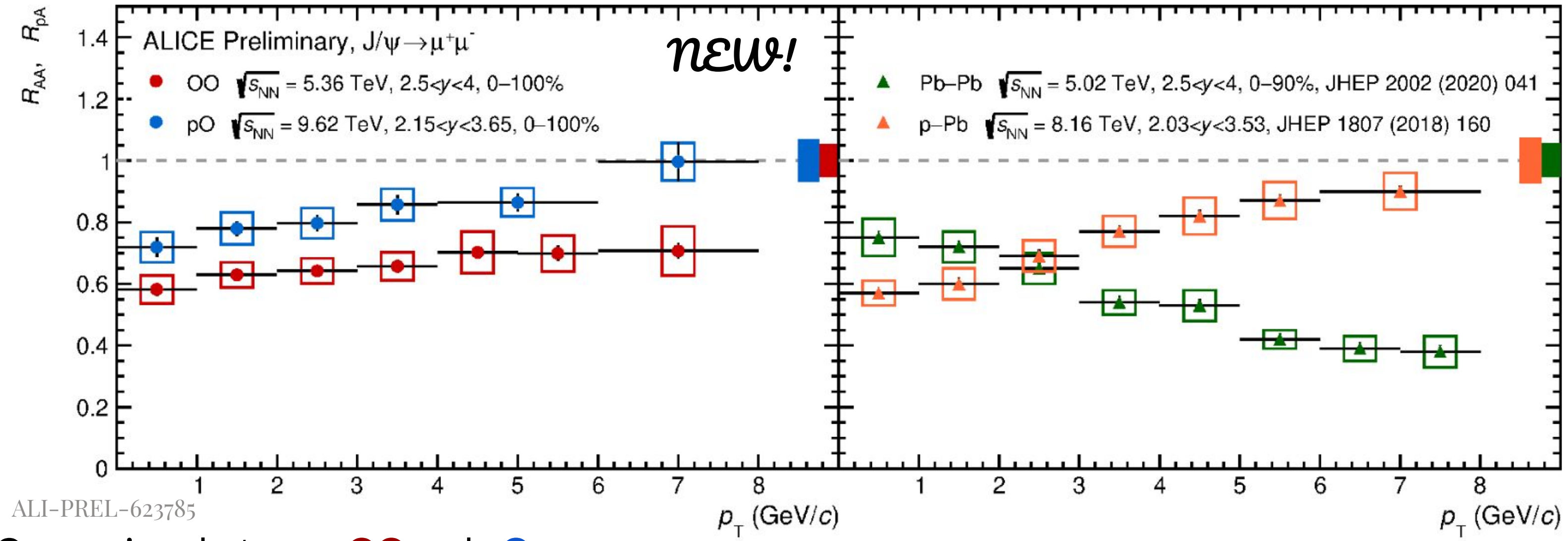

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Comparison between **pO** and **p–Pb**:

- Similar trend with different magnitude

Conclusions

- Studied OO and pO data collected in early July 2025
- The **first J/ψ R_{OO} and R_{pO}** values measured by ALICE have been calculated
- **OO** exhibits **stronger suppression** than **pO**
- **Both systems** are **consistent with** theoretical **models**
- OO data point to reduced/absent regeneration?
- pO trend is similar to p–Pb, but with reduced magnitude

Future work:

- Extend the analysis at forward vs centrality and rapidity, to further explore the J/ψ R_{OO} and R_{pO} dependence on other relevant variables
- Extend the analysis at mid-rapidity, providing a broader picture

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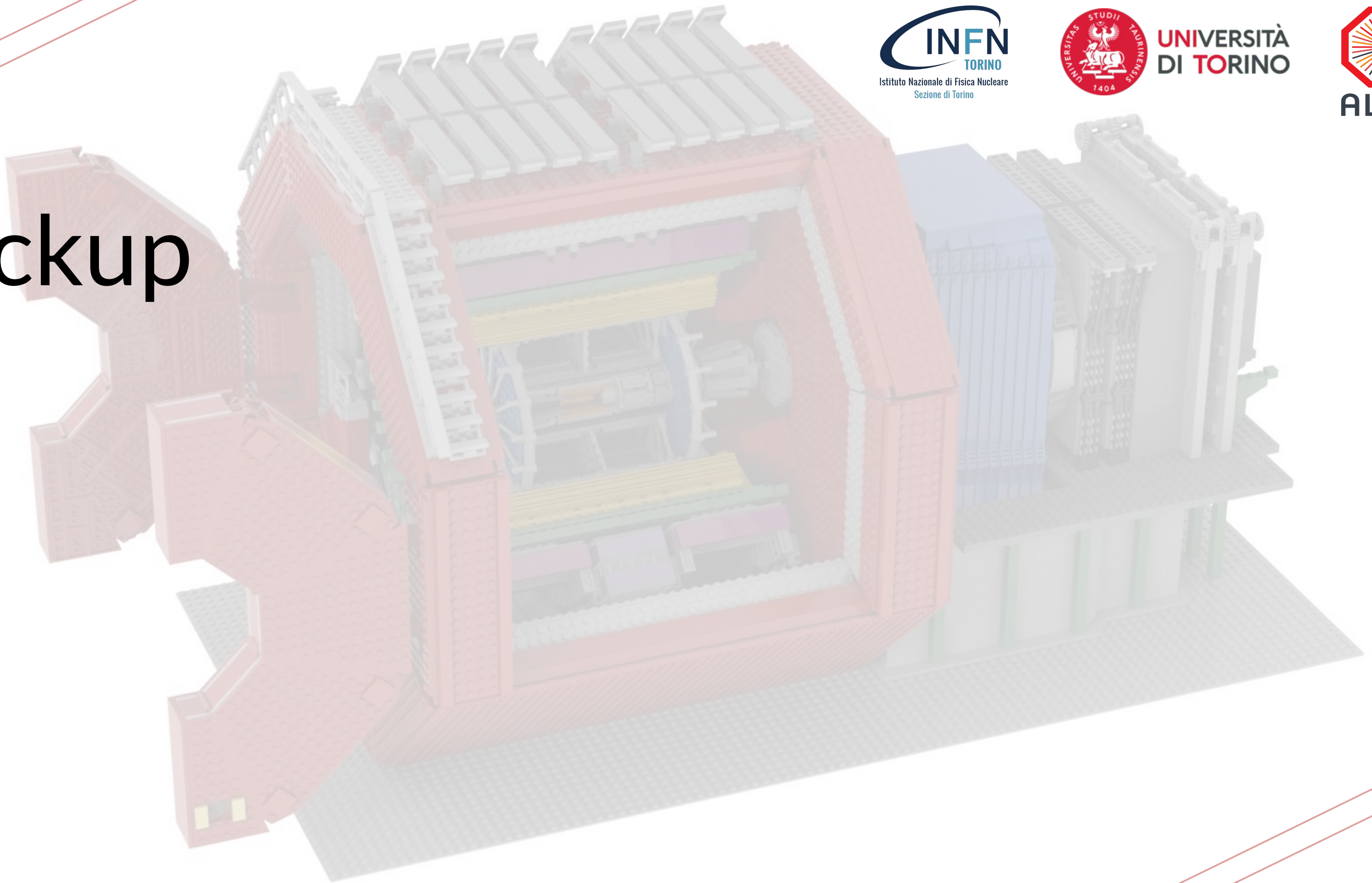
Thank you!

Backup



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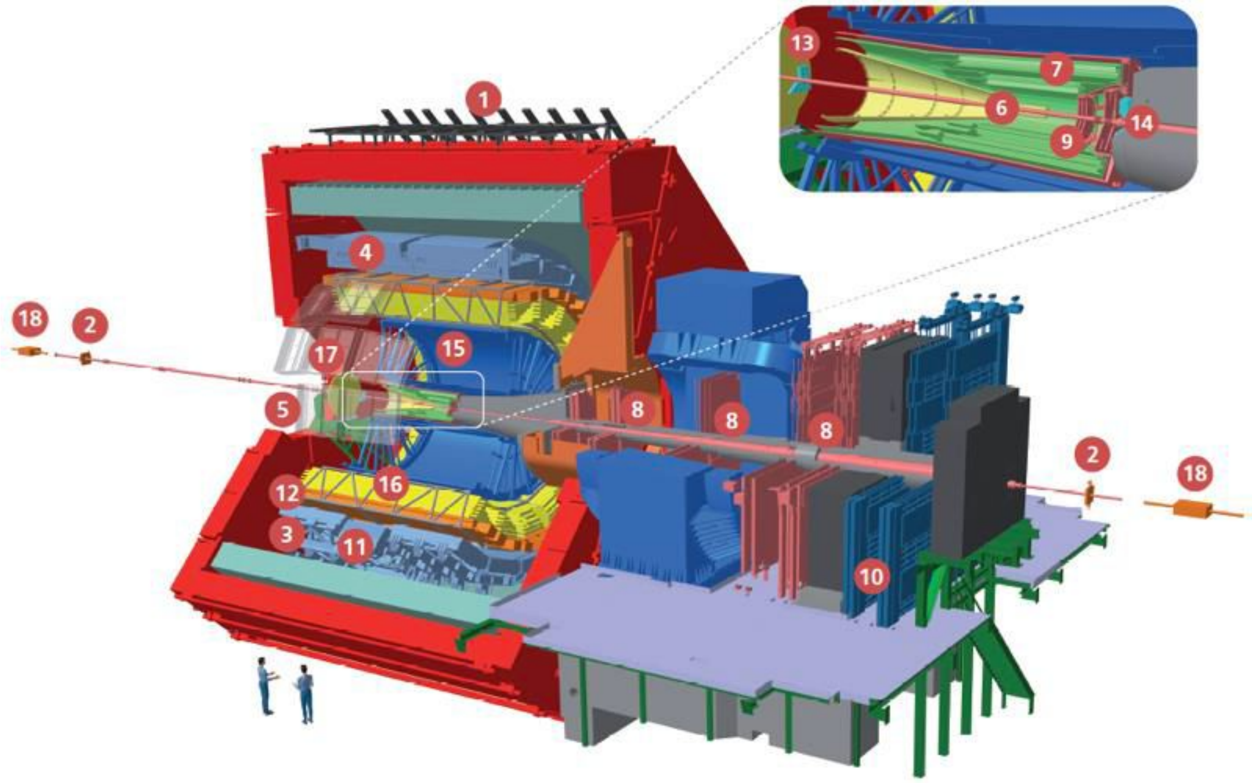
ALICE

ALICE detector



1. **ACORDE** | ALICE Cosmic Rays Detector
2. **AD** | ALICE Diffractive Detector
3. **DCal** | Di-jet Calorimeter
4. **EMCal** | Electromagnetic Calorimeter
5. **HMPID** | High Momentum Particle Identification Detector
6. **ITS-IB** | Inner Tracking System - Inner Barrel
7. **ITS-OB** | Inner Tracking System - Outer Barrel
8. **MCH** | Muon Tracking Chambers
9. **MFT** | Muon Forward Tracker
10. **MID** | Muon Identifier
11. **PHOS / CPV** | Photon Spectrometer
12. **TOF** | Time Of Flight
13. **T0+A** | Tzero + A
14. **T0+C** | Tzero + C
15. **TPC** | Time Projection Chamber
16. **TRD** | Transition Radiation Detector
17. **V0+** | Vzero + Detector
18. **ZDC** | Zero Degree Calorimeter