Measurements of the prompt and non-prompt J/ψ production in Pb-Pb collisions at 5.02 TeV with ALICE

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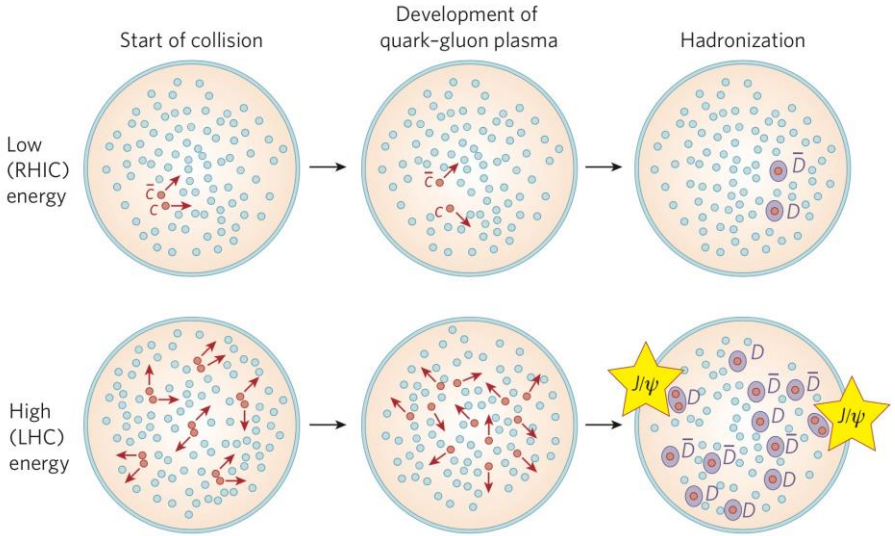
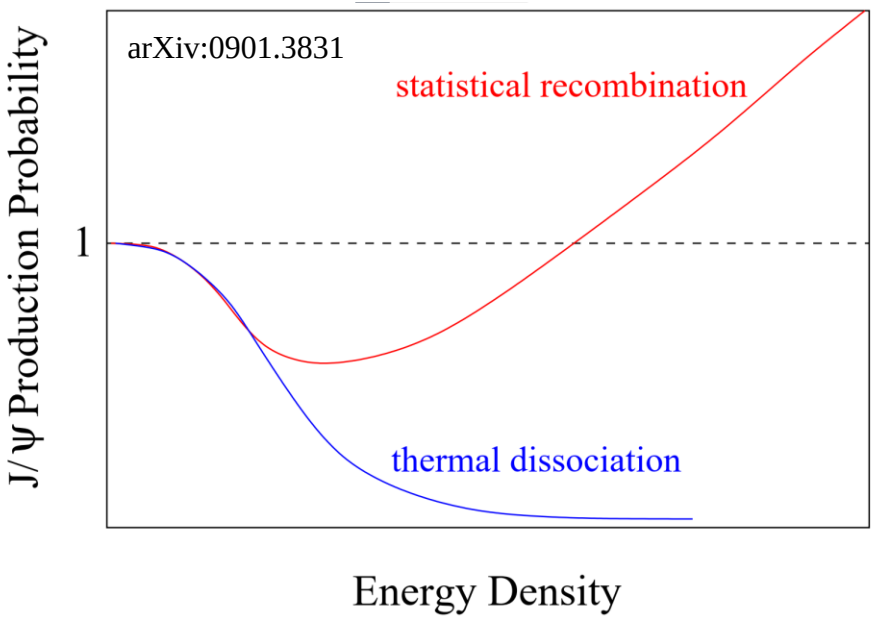
Prompt charmonium production

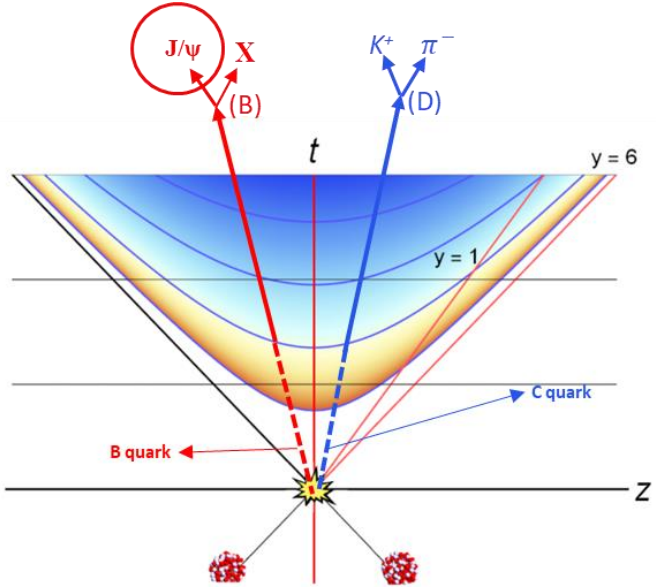
P. Braun-Munzinger, J. Stachel, Nature 448 (2007) 302

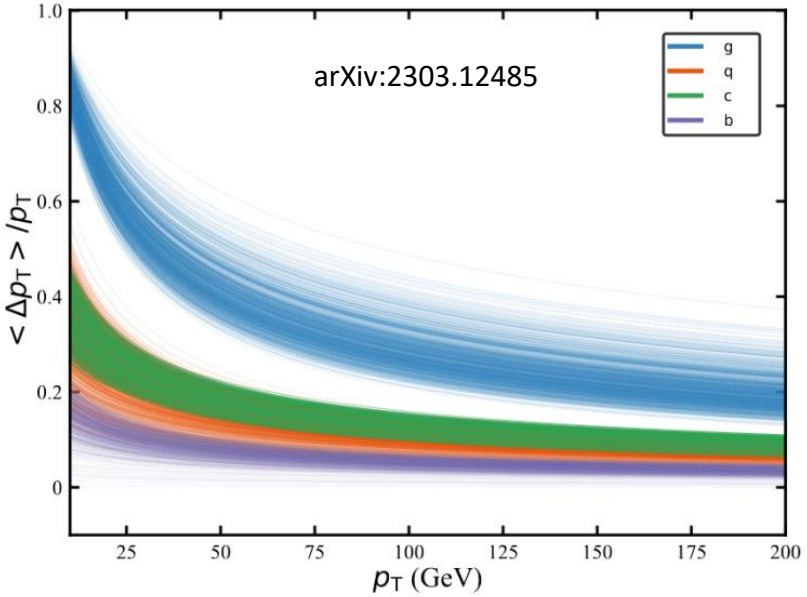




- Suppression of the direct charmonium due to color screening and the dynamic dissociation
- Charm quark production cross section at the LHC is very large, and the **(re)generation** contribution to the J/ψ is significant.

Mass dependent parton energy loss



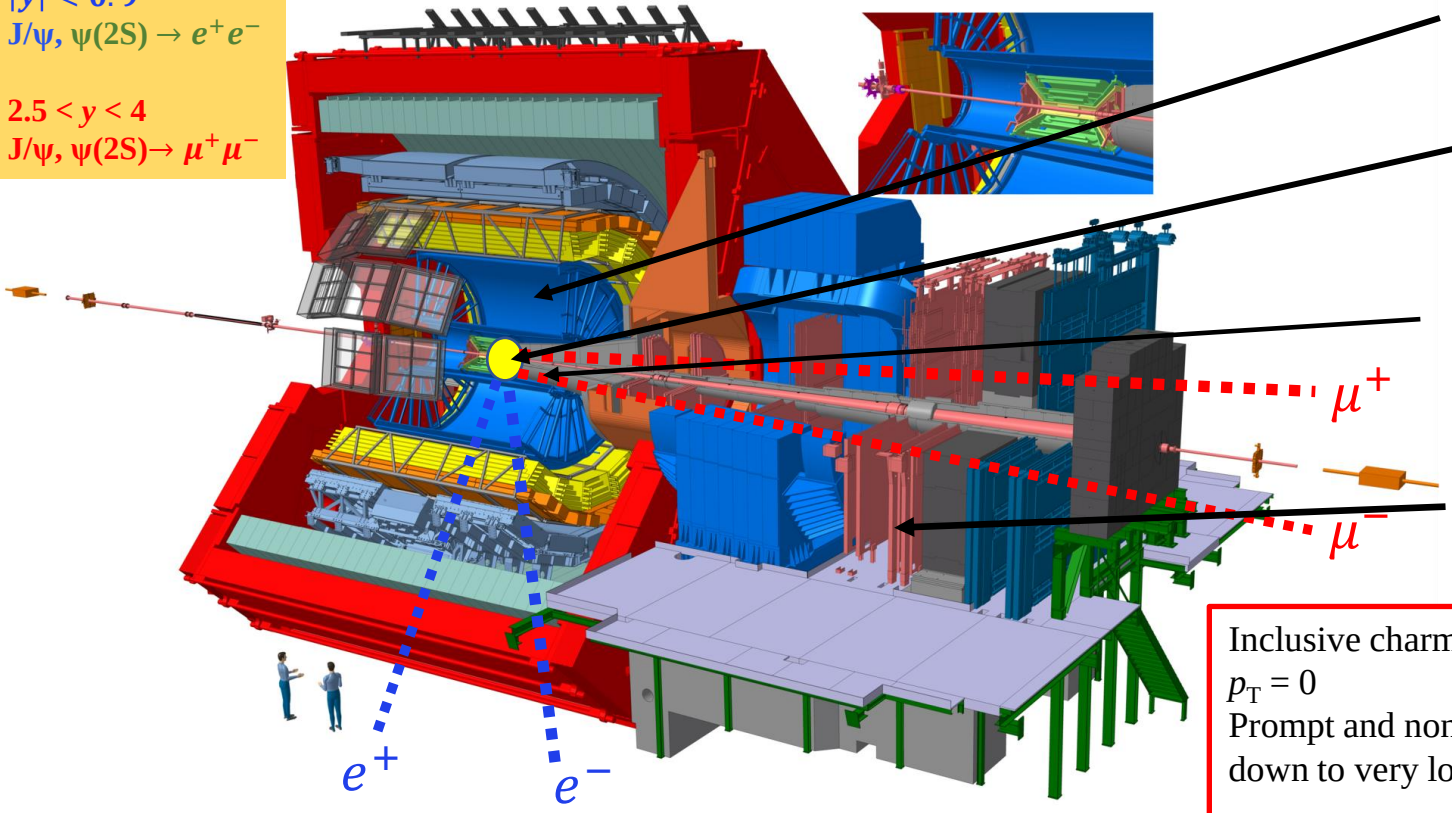


- The heavier parton losses less energy.
- Non-prompt charmonium is from the beauty hadron decays: corresponding measurements can contribute to the study of the **mass dependence of parton energy loss**.

Charmonium measurements with the ALICE detector (Run 2)

$|y| < 0.9$
$J/\psi, \psi(2S) \rightarrow e^+e^-$

$2.5 < y < 4$
$J/\psi, \psi(2S) \rightarrow \mu^+\mu^-$



Time Projection Chamber
Tracking, particle identification

Inner Tracking System
Tracking, vertex reconstruction, Event plane determination

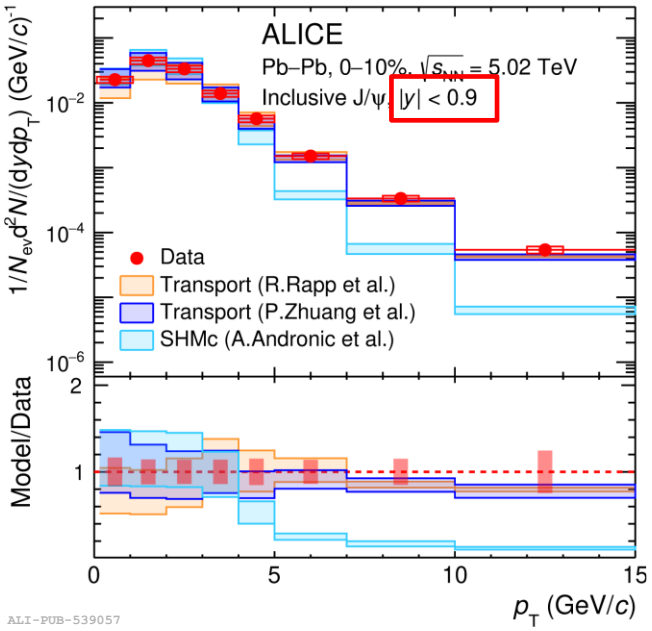
V0 Detector
Centrality determination, triggering, event plane determination, and background rejection

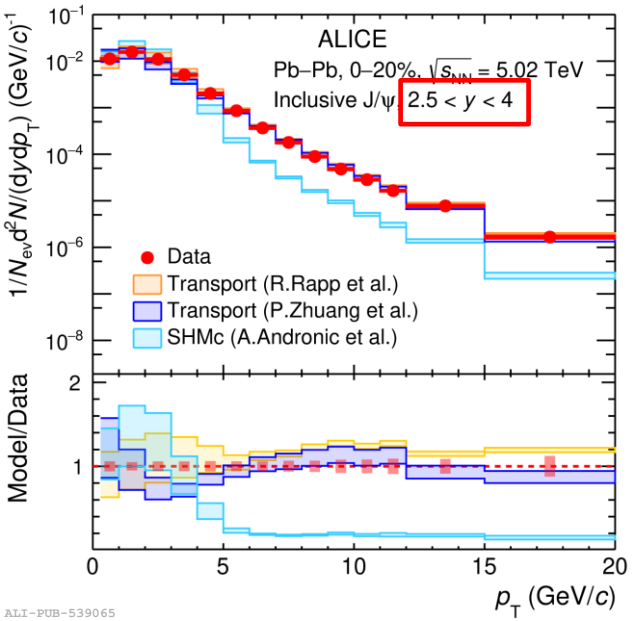
Muon spectrometer
Trigger and tracking for muons

Inclusive charmonium measurement down to $p_T = 0$
Prompt and non-prompt J/ψ can be separated down to very low p_T at midrapidity

Inclusive J/ψ yield in Pb−Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV

arXiv:2303.13361



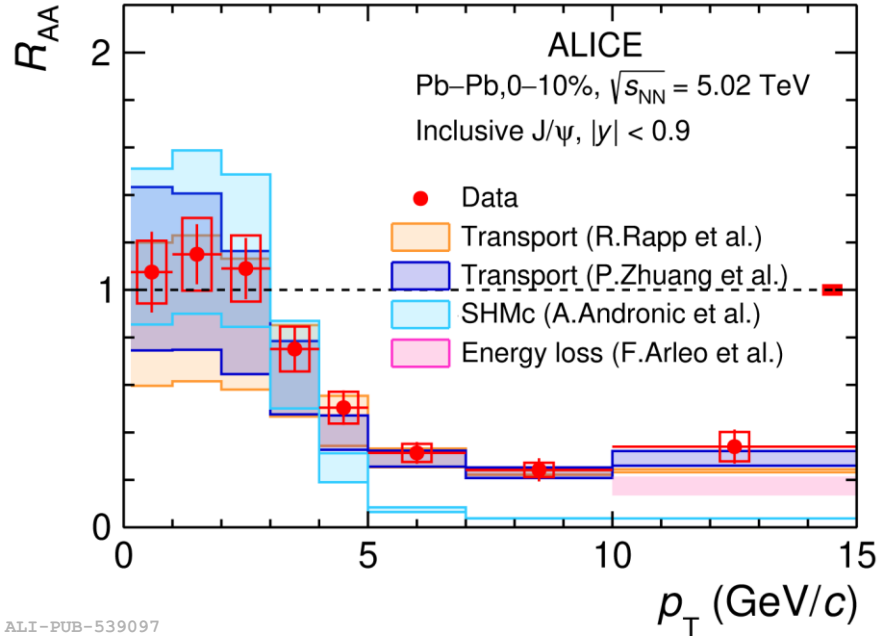


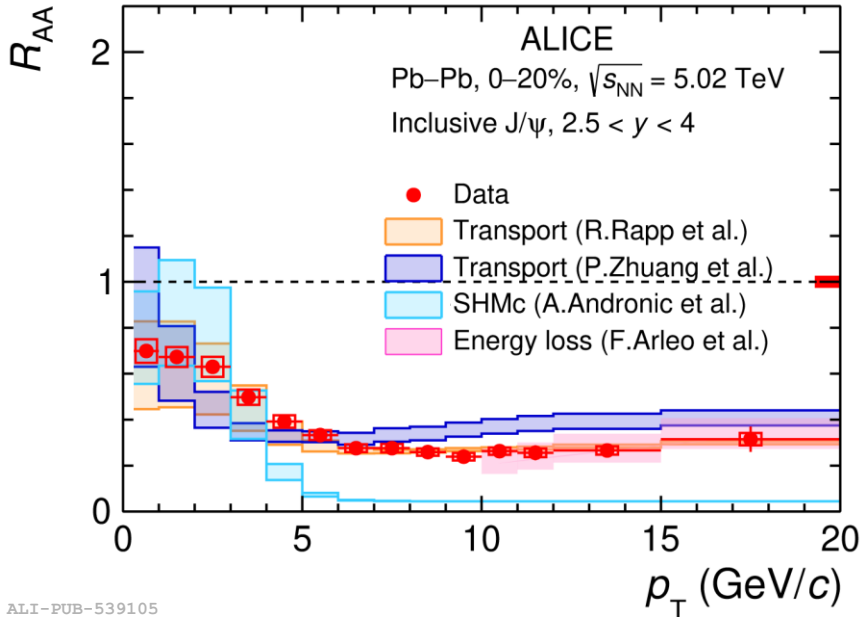
- Inclusive J/ψ yields are shown as a function of p_T at **mid- (left) and forward (right)** rapidity in central collisions
- Two transport models describe the data within uncertainties
- SHMc agrees with data at low p_T, and underestimates the measurement at high p_T

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)

Inclusive J/ψ R_{AA} vs p_T

arXiv:2303.13361



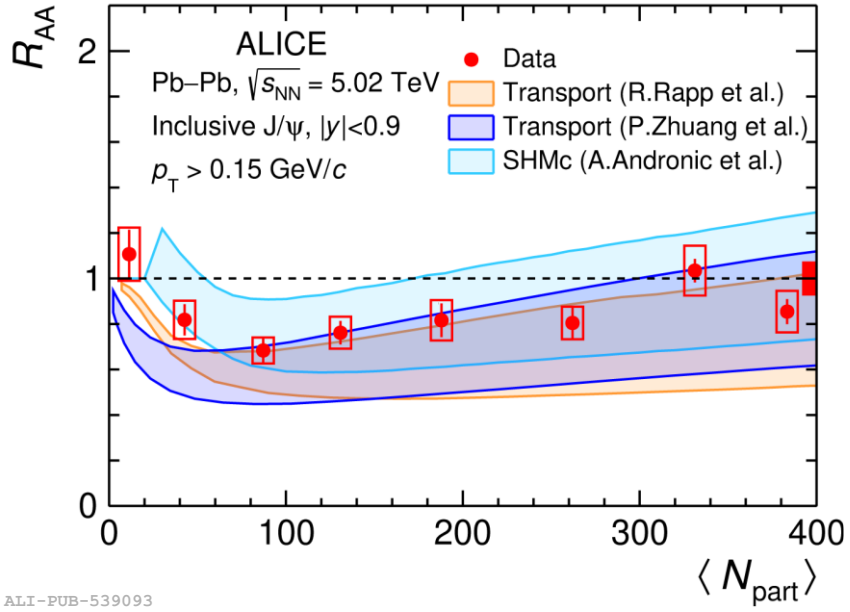


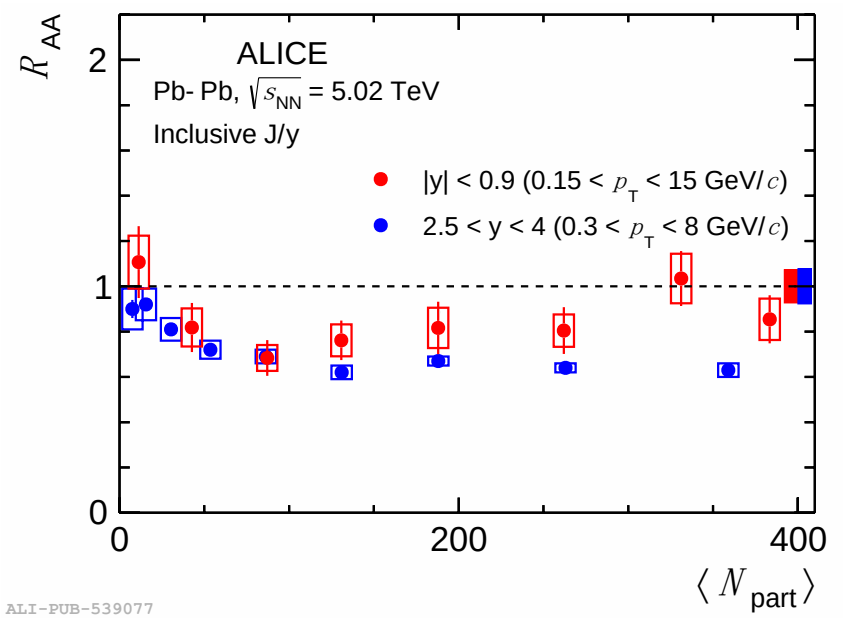
- **Evidence for J/ψ (re-)generation at low p_T**
- Transport and SHMc models describe data at low p_T, while SHMc underestimates the measurement at high p_T. The energy loss model agrees with data at high p_T

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)
Arleo. F, PRL119, 062302 (2017)

Inclusive J/ψ R_{AA} vs centrality

arXiv:2303.13361



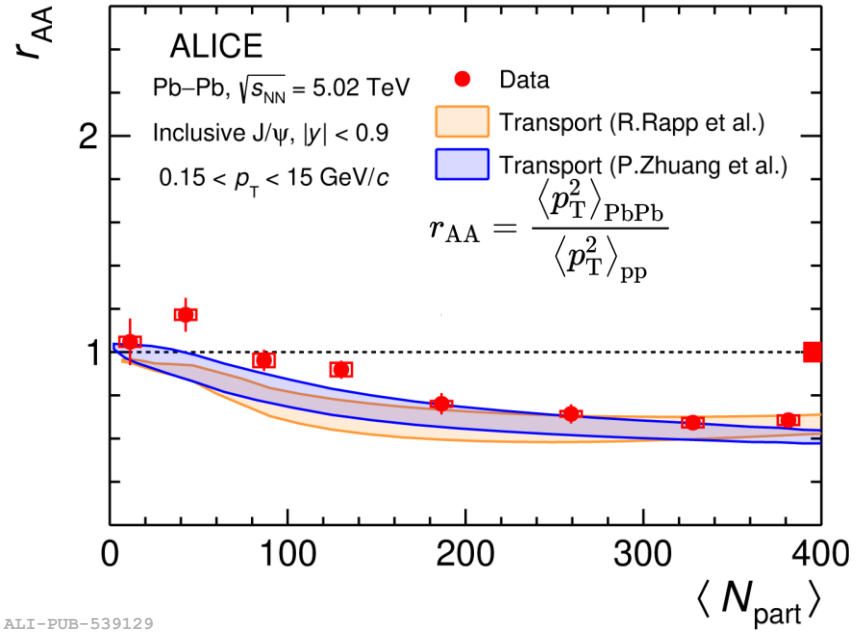


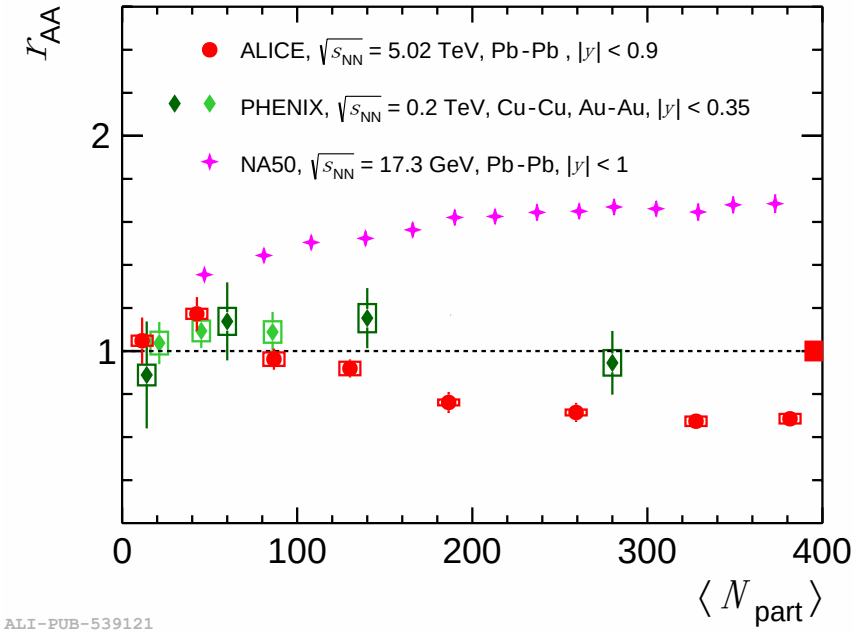
- **Evidence for J/ψ (re-)generation in central collisions, with a larger contribution at midrapidity compared to forward rapidity**
- All models can describe the data but suffer from large uncertainties related to inputs used in calculations (eg. charm cross section, shadowing).

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

arXiv:2303.13361



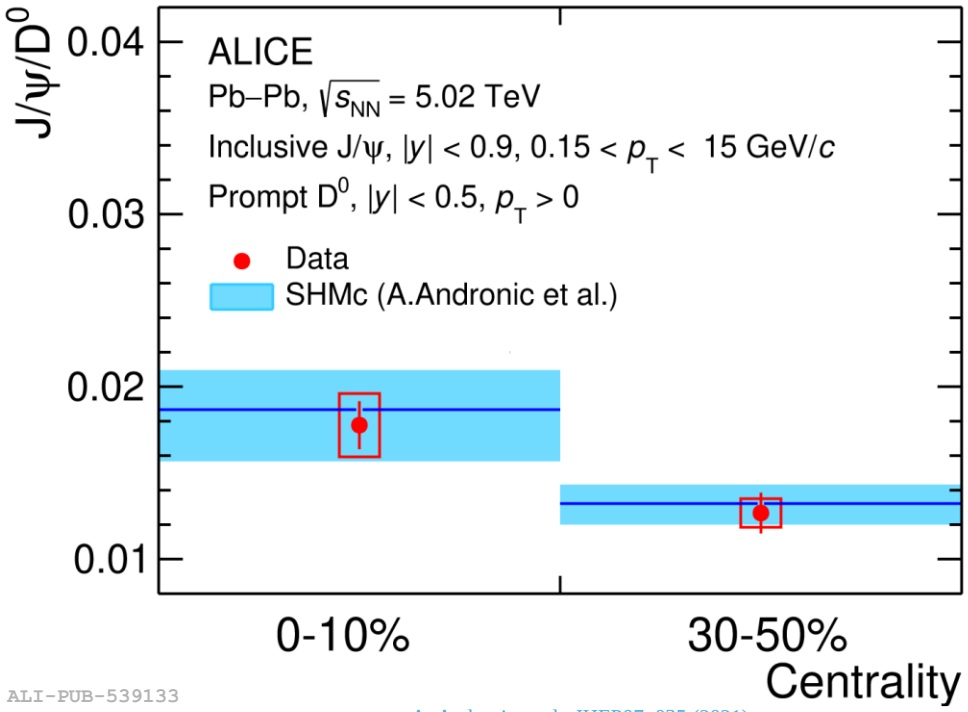


- Decreasing trend for r_{AA} from semicentral toward central collisions
- r_{AA} below unity indicates a softening of the J/ψ p_T shape in Pb−Pb collisions compared to pp collisions, the behavior is different from the lower center-of-mass energies

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

J/ψ-to-D^0 ratio in Pb–Pb collisions

arXiv:2303.13361

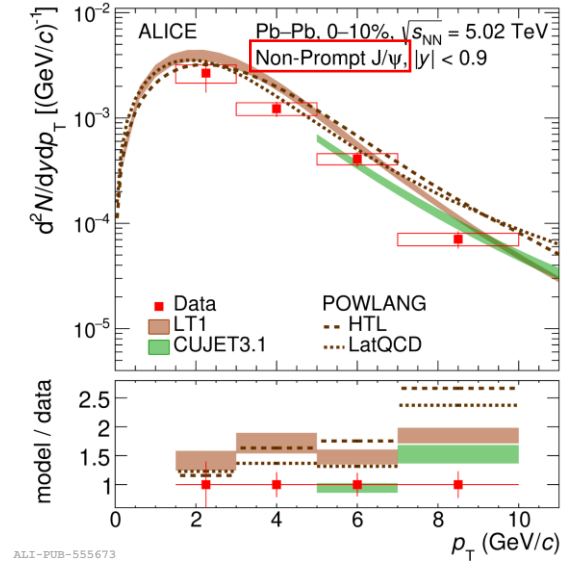


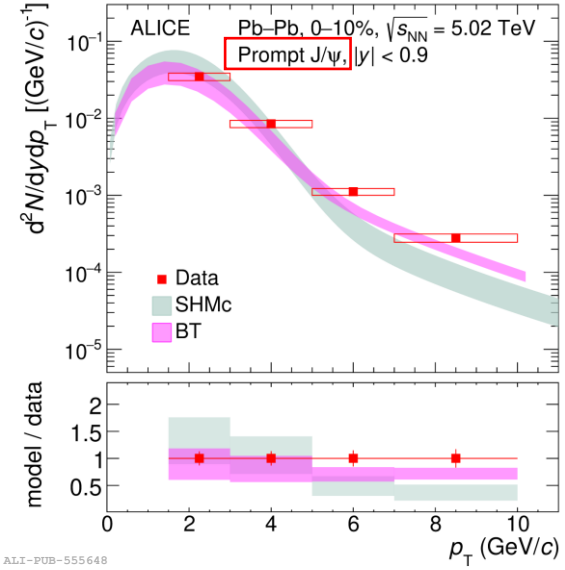
A. Andronic et al., JHEP07, 035 (2021)

- 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 according to SHMc prediction

Non-prompt and prompt J/ψ p_T spectrum

arXiv:2308.16125



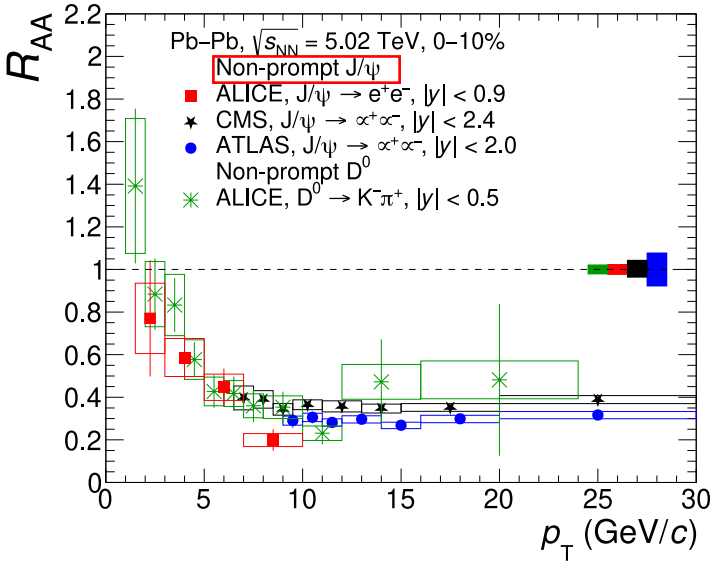


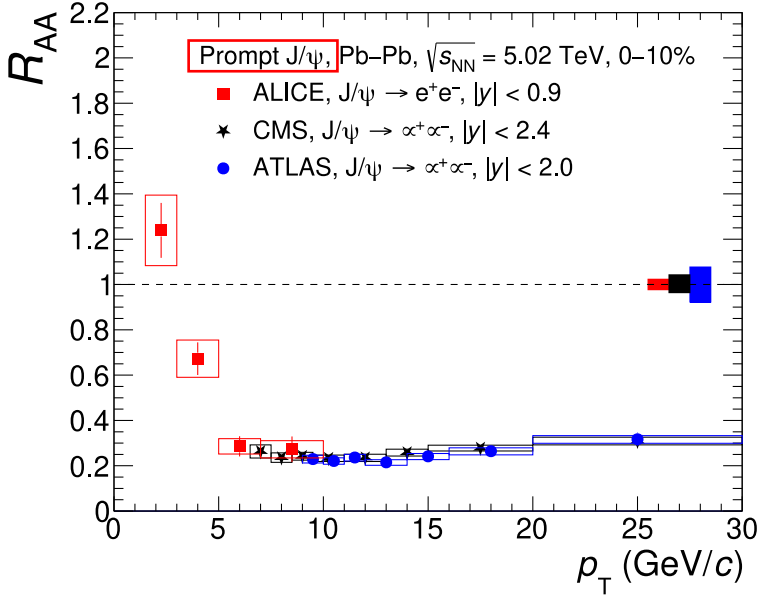
LT1: PRC107, 054917(2023)
POWLANG:
JHEP 05 (2021) 279,
EPJC 75 (2015) 121
CUJJET3.1: CPC 43 (2019) 044101
SHMc: PLB 797 (2019) 134836
BT: CPC43 (2019) 124101

- Non-prompt (left) and prompt (right) J/ψ p_T spectra are compared with models.
- All the models seem to overestimate data of non-prompt J/ψ, the SHMc and BT agree with data within uncertainties for the prompt J/ψ at low p_T

p_T dependence of prompt and non-prompt J/ψ R_{AA}

arXiv:2308.16125



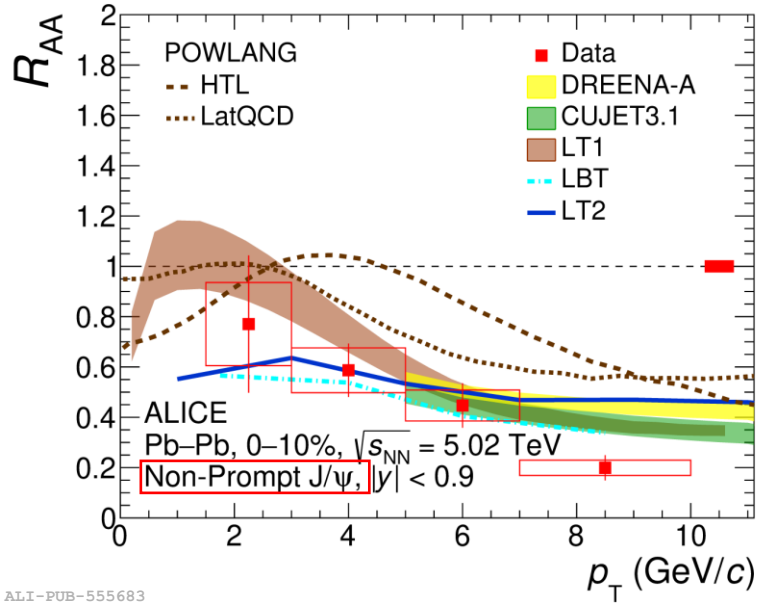


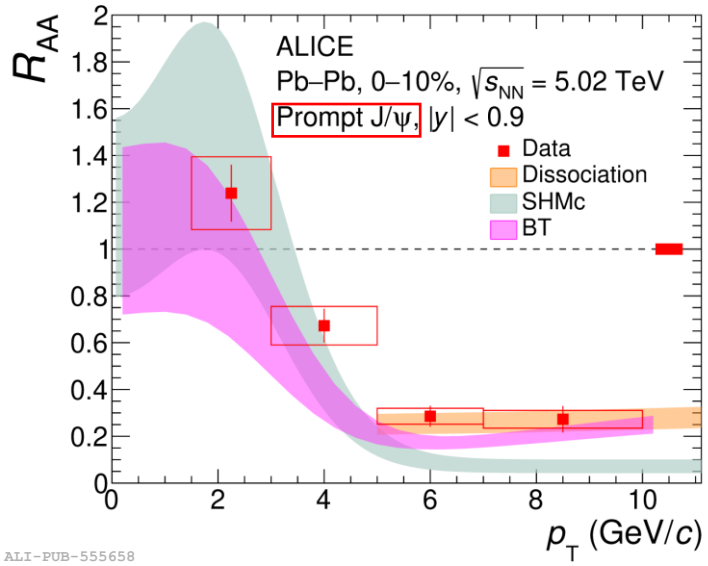
- R_{AA} extended down to p_T =1.5 GeV/c and compatible within uncertainties with ATLAS and CMS measurements in the common p_T range
- ALICE non-prompt J/ψ and D^0 are compatible within uncertainties

JHEP 12 (2022) 126
ATLAS, Eur. Phys. J. C 78 (2018) 762
CMS, Eur. Phys. J. C 78 (2018) 509

Non-prompt and prompt J/ψ R_{AA} :comparison with models

arXiv:2308.16125





DREENA-A:
Front. Phys. 10:957019 (2022),
Phys. Rev. C 105, L021901
CUJJET3.1: CPC 43 (2019) 044101
LT1: PRC107, 054917(2023)
LBT: PLB838(2023) 137733
LBT2: EPJC 81 848 (2021) 1035
Dissociation:
PLB 778 (2018) 384-391
SHMc: PLB 797 (2019) 134836
BT: CPC43 (2019) 124101

- **Non-prompt J/ψ R_{AA}** described within uncertainties by models implementing energy loss contributions **from collisional and radiative process**
- POWLANG calculations, which include only collisional contributions, overestimate the R_{AA} at intermediate and high p_T
- The SHMc model and transport microscopic calculations that include a contribution from **regeneration** are compatible with the measured **prompt J/ψ R_{AA} at low p_T**

Summary

- Inclusive J/ψ
  - Dominant contribution from (re-)generation in central collisions and low p_{T}
  - Softening of the J/ψ p_T shape in Pb−Pb collisions compared to pp collisions
- Prompt and non-prompt J/ψ
  - R_{AA} extended down to p_T =1.5 GeV/c
  - Strong suppression observed for non-prompt J/ψ

Thanks