J/ψ nuclear modification factor in Pb–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV with ALICE

Alena Gromada for the ALICE Collaboration

UNIVERSITÄT
HEIDELBERG
ZUKUNFT
SEIT 1386

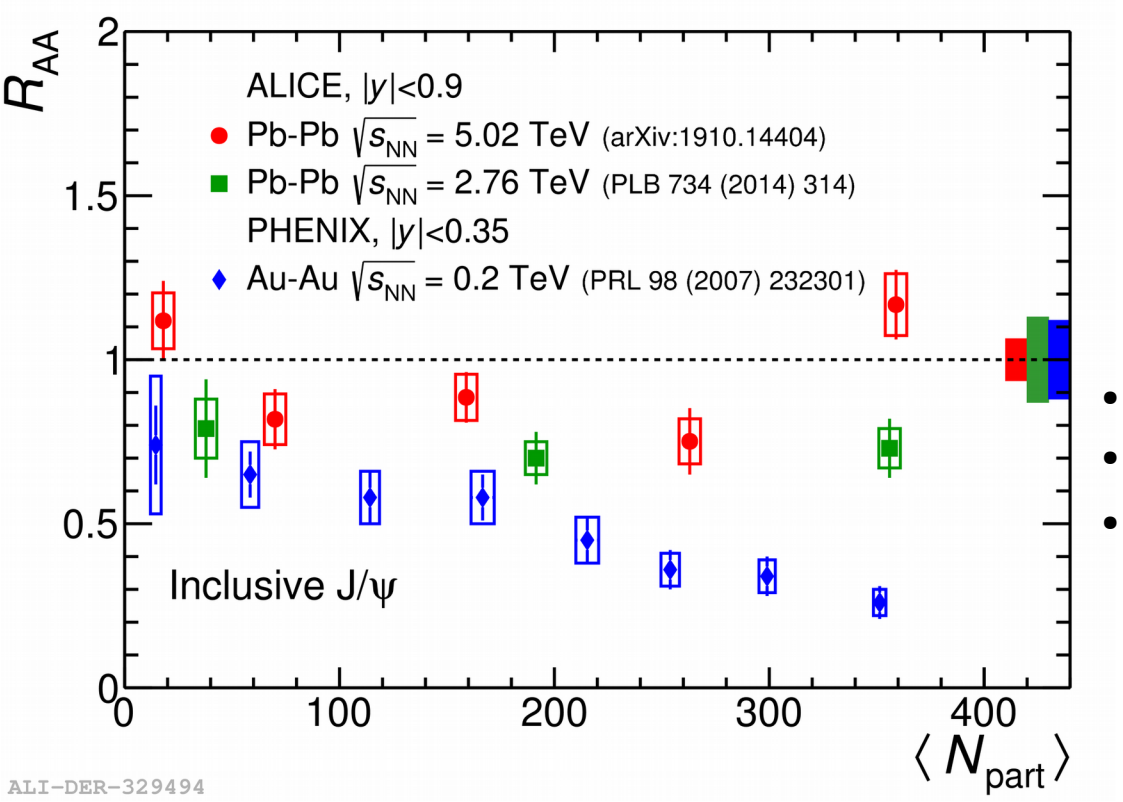
19. Zimányi School
4.12.2019

GSI

ALICE

J/ψ in heavy-ion collisions

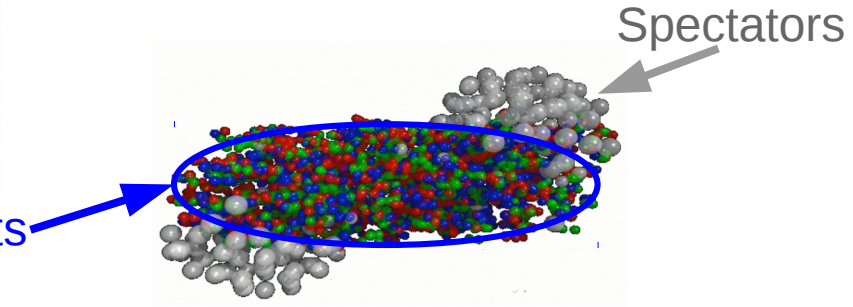
- J/ψ suppression in heavy-ion collisions → Quark-Gluon Plasma (QGP) presence
  - Color screening of $c\bar{c}$ in deconfined medium
    Matsui and Satz in 1986, Phys. Lett. B178 (1986) 416 422
  - Suppression observed at SPS, RHIC and LHC energies



Nuclear modification factor

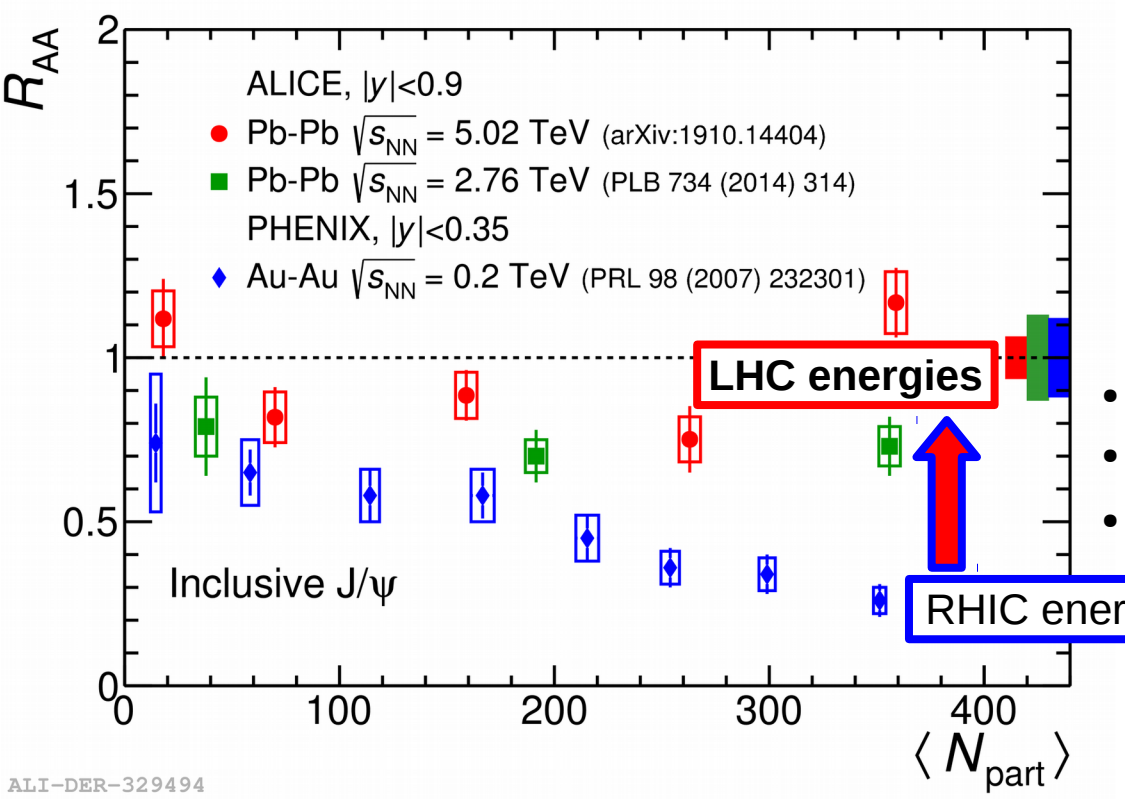
$$R_{AA} = \frac{\mathrm{d}N_{J/\psi}/\mathrm{d}y}{\langle T_{AA} \rangle \mathrm{d}\sigma^{pp}_{J/\psi}/\mathrm{d}y}$$

- Sensitive to medium effects
- $R_{AA} < 1$ → suppression with respect to pp
- $R_{AA} > 1$ → enhancement



J/ψ in heavy-ion collisions

- J/ψ suppression in heavy-ion collisions → Quark-Gluon Plasma (QGP) presence
  - Color screening of $c\bar{c}$ in deconfined medium
    Matsui and Satz in 1986, Phys. Lett. B178 (1986) 416 422
  - Suppression observed at SPS, RHIC and LHC energies



Nuclear modification factor

$$R_{AA} = \frac{\mathrm{d}N_{J/\psi}/\mathrm{d}y}{\langle T_{AA} \rangle \mathrm{d}\sigma^{pp}_{J/\psi}/\mathrm{d}y}$$

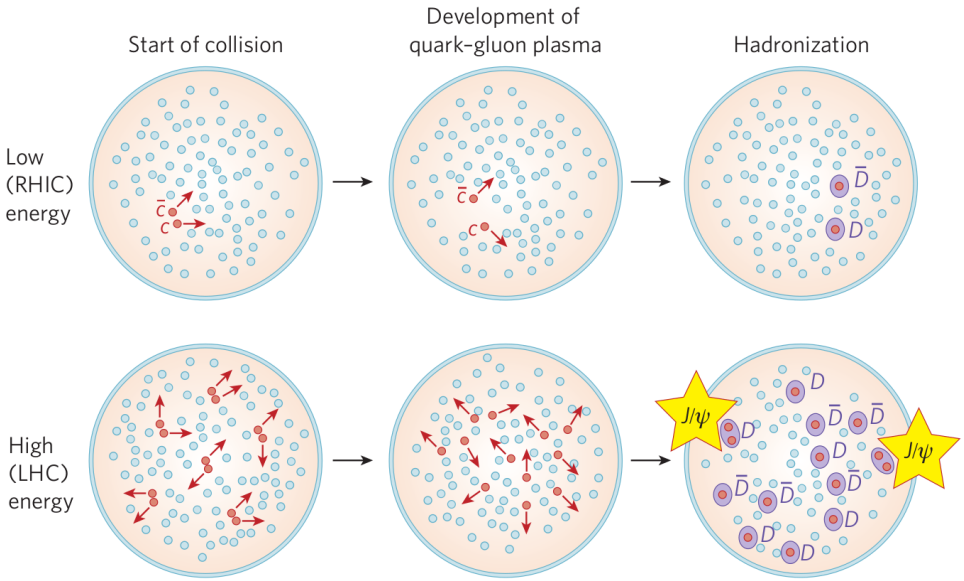
- Sensitive to medium effects
- $R_{AA} < 1$ → suppression with respect to pp
- $R_{AA} > 1$ → enhancement

- Less suppression at higher LHC energies

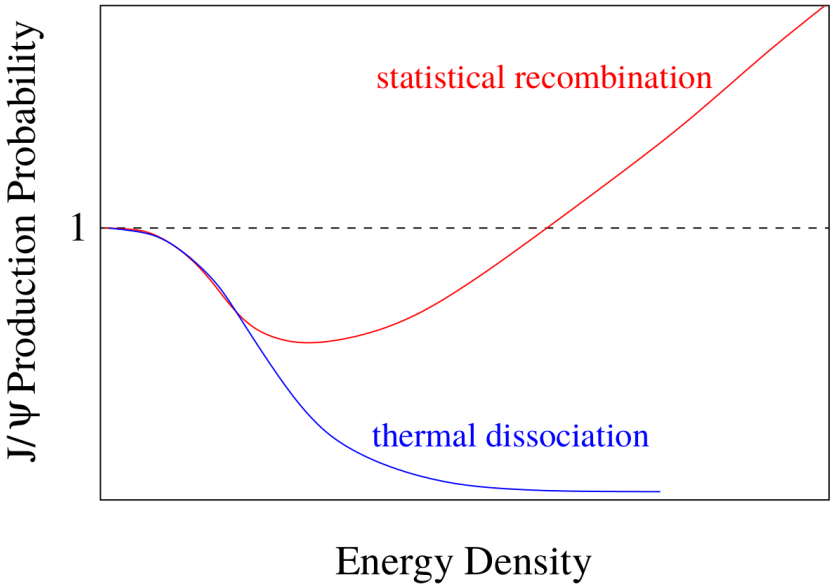
(Re)generation mechanism

- (Re)generation

  Braun-Munzinger, Stachel, Phys. Lett. B490 (2000) 196; Thews, Schroedler, Rafelski, Phys. Rev. C 63 (2001) 054905
  - Only possible in deconfined medium
  - J/ψ formation at hadronization or continuously during QGP phase
  - High collision energy → large $c\bar{c}$ density → higher probability of (re)generation



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



L. Kluberg, H. Satz, arXiv:0901.3831

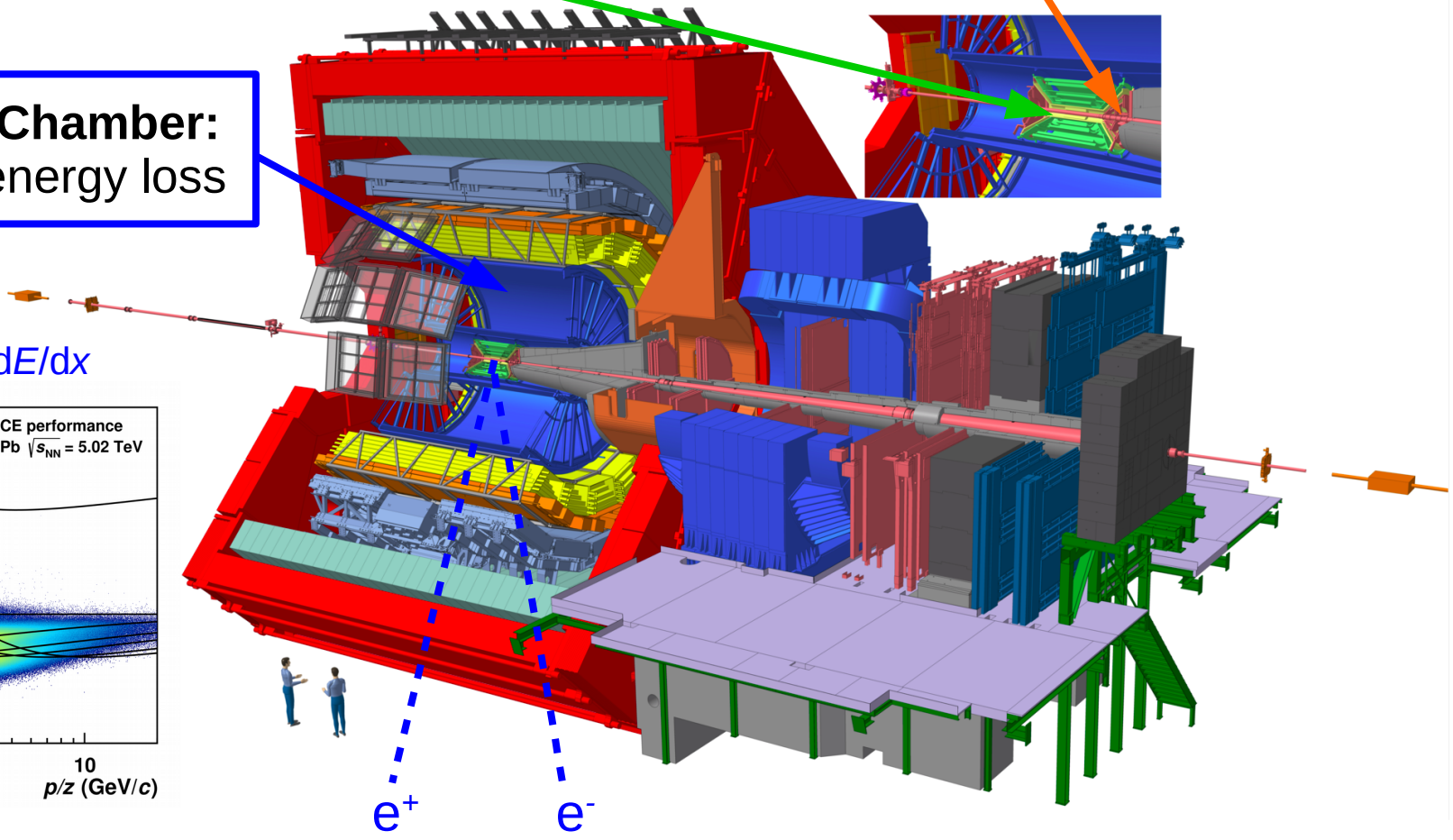
J/ψ reconstruction at midrapidity

- **Dielectron decay channel: $J/\psi \rightarrow e^+e^-$**

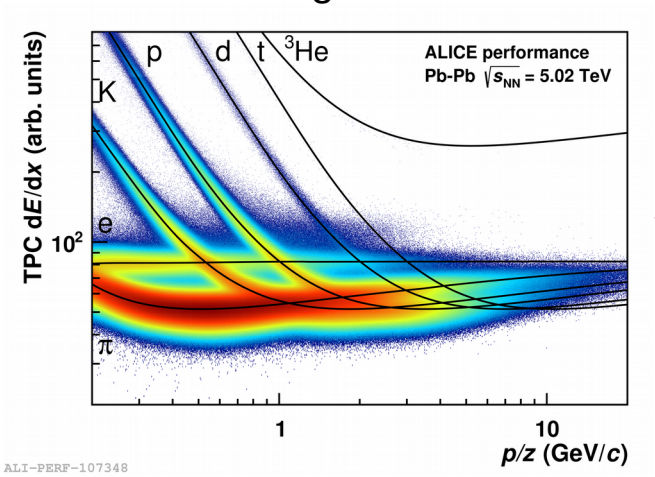
Inner Tracking System: vertexing, tracking

V0 Detector: minimum-bias and centrality trigger

Time Projection Chamber: tracking, PID via energy loss



PID using TPC d*E*/d*x*



J/ψ reconstruction at forward rapidity

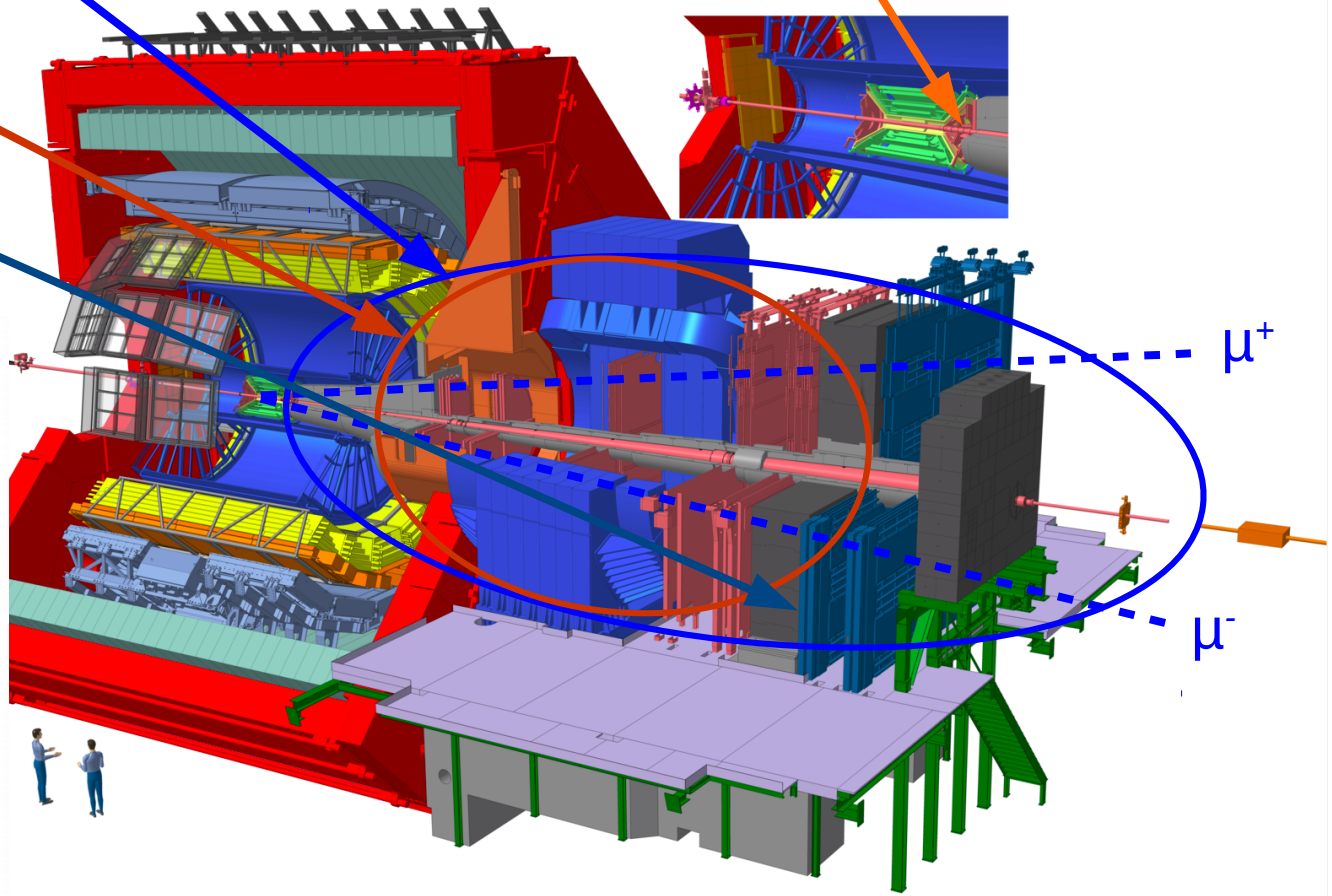
- **Dimuon decay channel: $J/\psi \rightarrow \mu^+\mu^-$**

Dimuon Spectrometer: triggering and tracking for muons

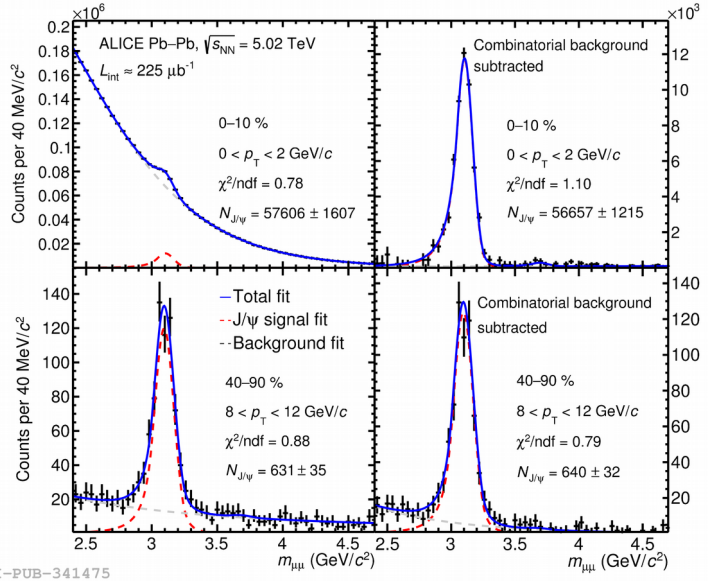
V0 Detector: minimum-bias and centrality trigger

Tracking Chambers

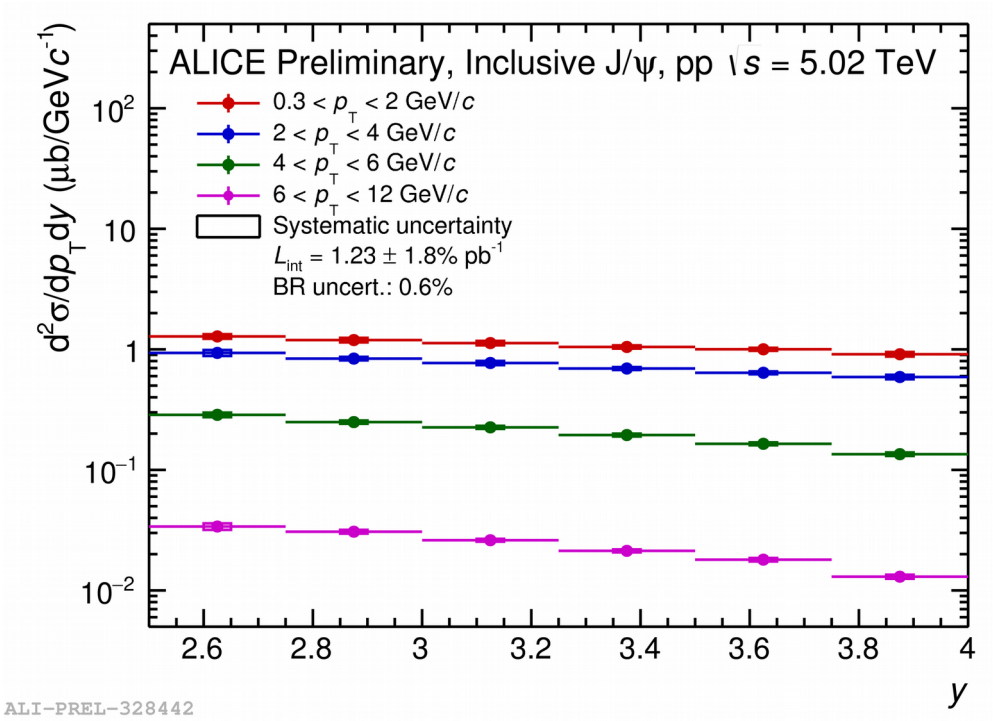
Trigger Chambers

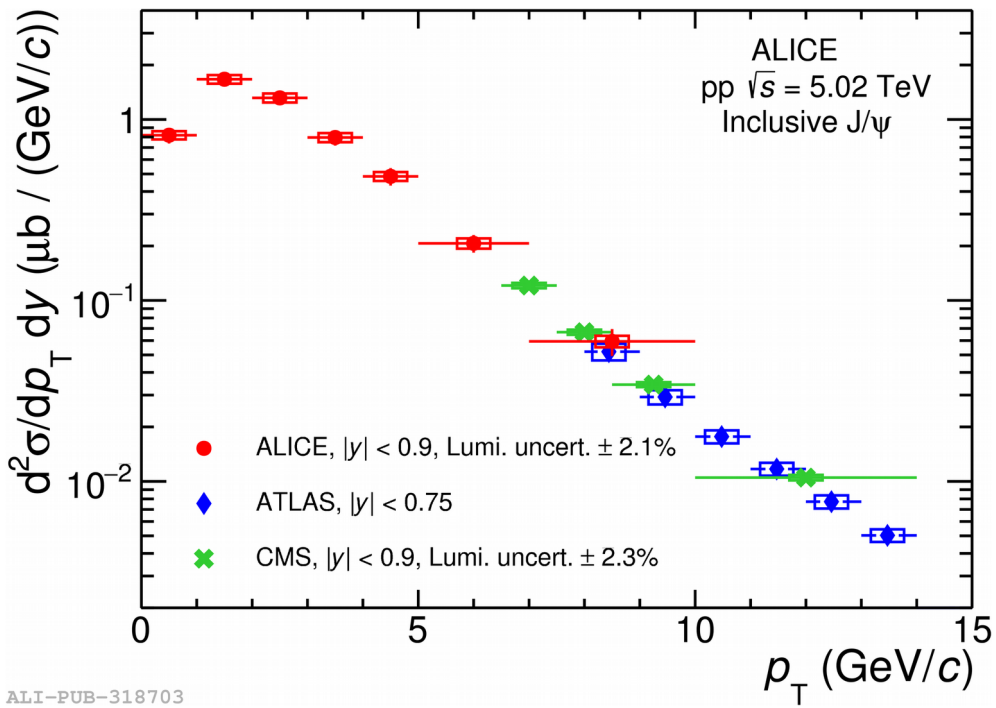


Invariant mass distribution



Inclusive J/ψ pp reference at $\sqrt{s_{NN}}$ = 5.02 TeV

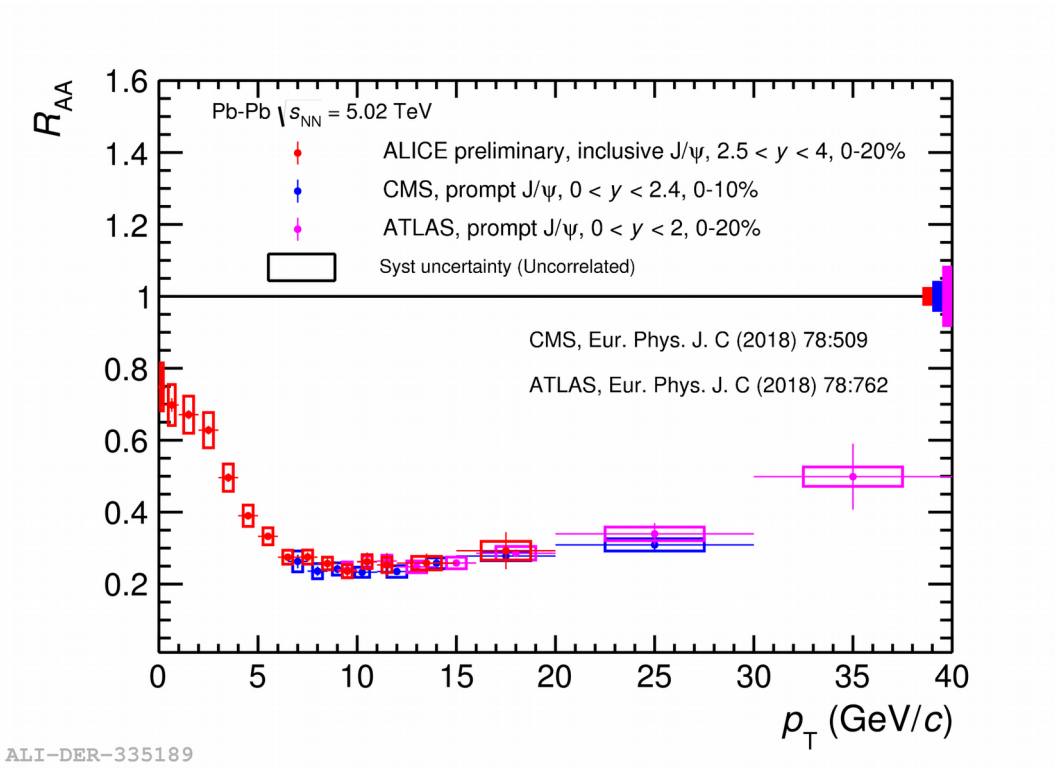


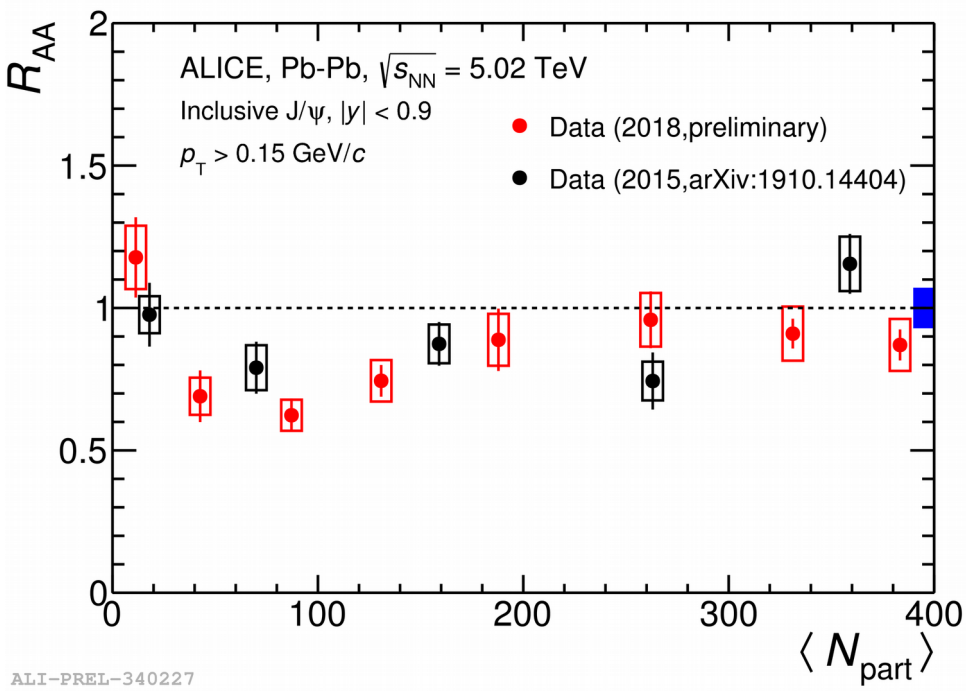


ALICE, JHEP10 (2019) 084
ATLAS, Eur. Phys. J. C 78 (2018) 171
CMS, Eur. Phys. J. C 77 (2017) 269

- pp measurements serve as important baseline for Pb–Pb
- Forward rapidity: pp reference split in 6 rapidity times 4 p_T bins allowing more differential measurements also in Pb–Pb collisions
- Midrapidity: consistent with other experiments in overlapping regions

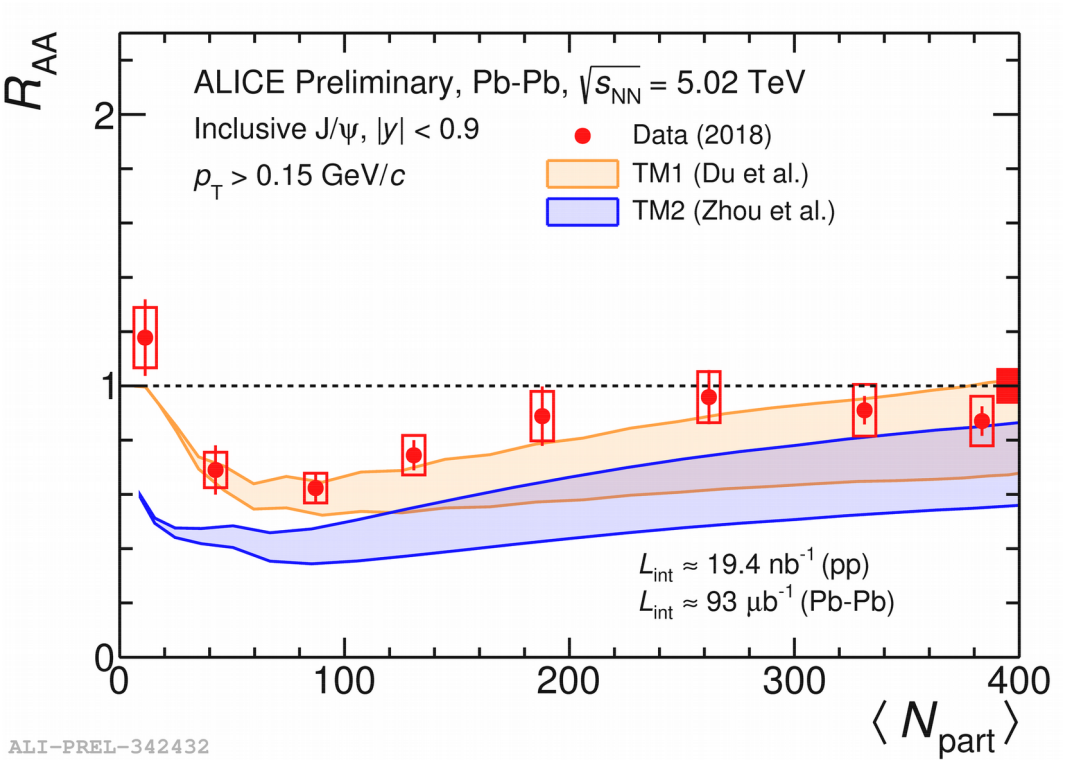
Inclusive J/ψ R_{AA} as function of centrality





- ALICE has a unique capability at the LHC to measure J/ψ production down to p_T = 0 GeV/c in Pb–Pb
- High statistics data taken in 2018 allow more precise and more differential measurements
  - Forward rapidity
    - 0-90%: ~ 3 x more than in 2015
  - Midrapidity
    - 0-10%: ~ 10 x more
    - 30-50%: ~ 4 x more

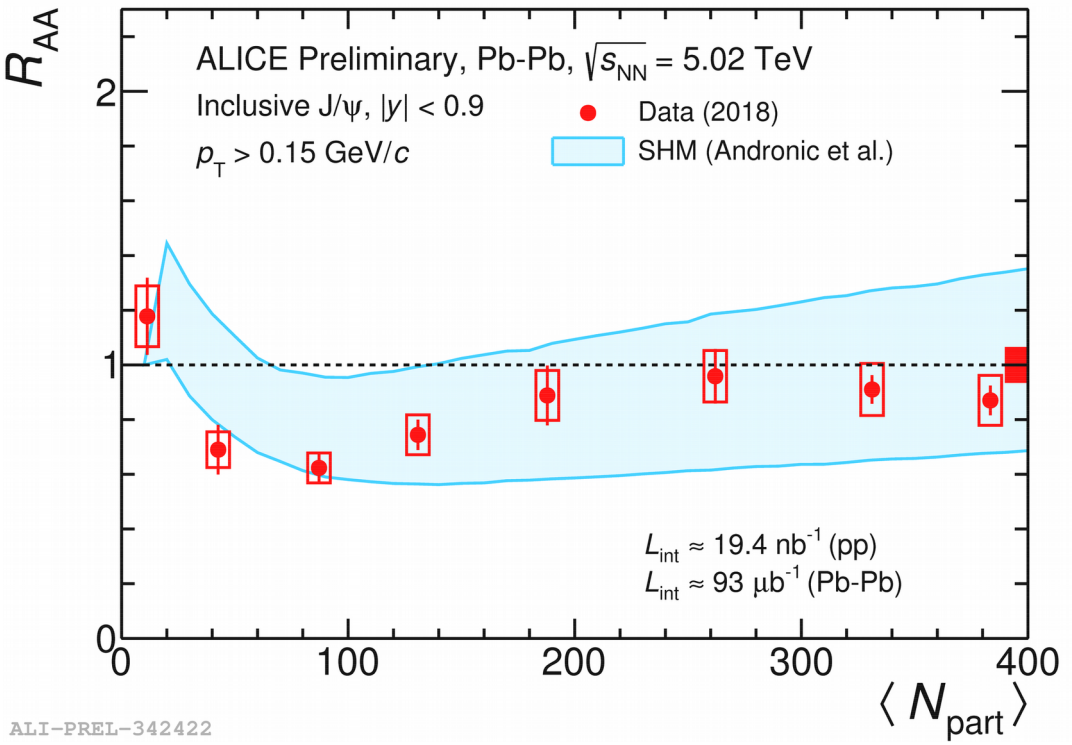
Model comparison



- **Transport model 1 and 2 (TM1, TM2)**
  - J/ψ production during hard parton scattering, dynamically generated in QGP and at hadronization

TM1: Du, Rapp, *Nucl. Phys.* A943 (2015) 147-158
TM2: Zhou, Xu, Zhuang, *Phys. Rev.* C89 no. 5, (2014) 054911
Comover: Ferreiro, *Phys. Lett.* B731 (2014) 57-63
SHM: Andronic, Braun-Munzinger, Köhler, Redlich, Stachel, *Phys. Lett.* B797 (2019) 134836

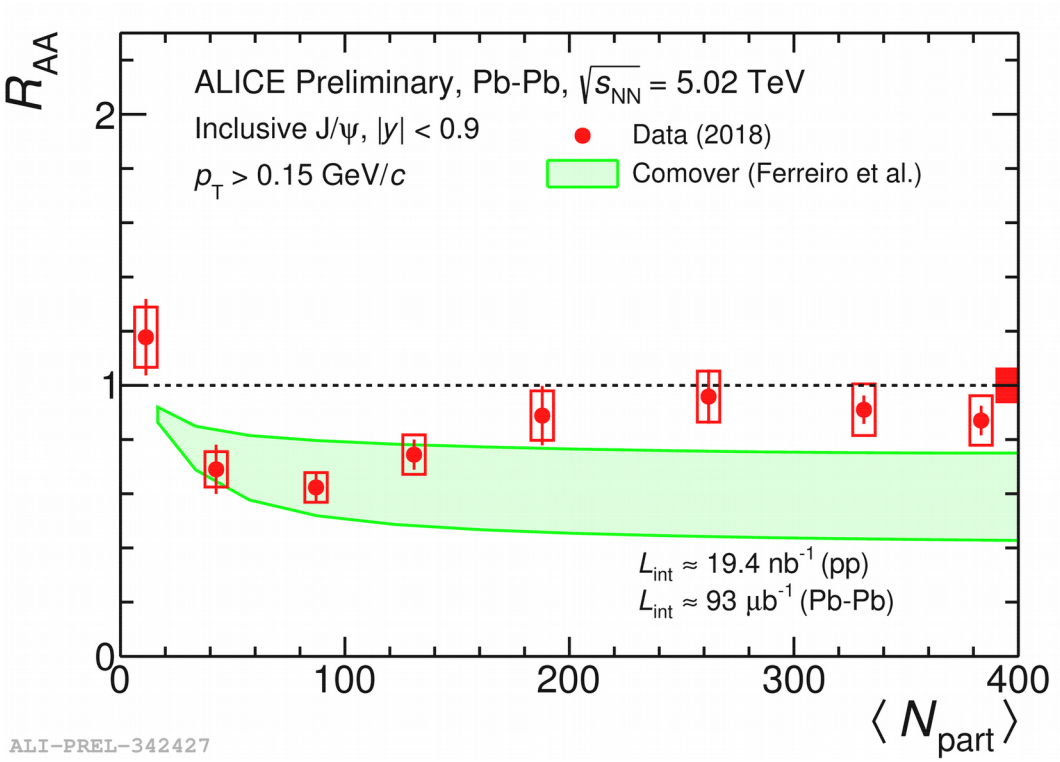
Model comparison



- **Transport model 1 and 2 (TM1, TM2)**
  - J/ψ production during hard parton scattering, dynamically generated in QGP and at hadronization
- **Statistical Hadronization Model (SHM)**
  - J/ψ production during hard parton scattering and at chemical freezeout
  - Charm hadrons thermalized at the phase boundary

TM1: Du, Rapp, *Nucl. Phys.* A943 (2015) 147-158
TM2: Zhou, Xu, Zhuang, *Phys. Rev.* C89 no. 5, (2014) 054911
Comover: Ferreiro, *Phys. Lett.* B731 (2014) 57-63
SHM: Andronic, Braun-Munzinger, Köhler, Redlich, Stachel, *Phys. Lett.* B797 (2019) 134836

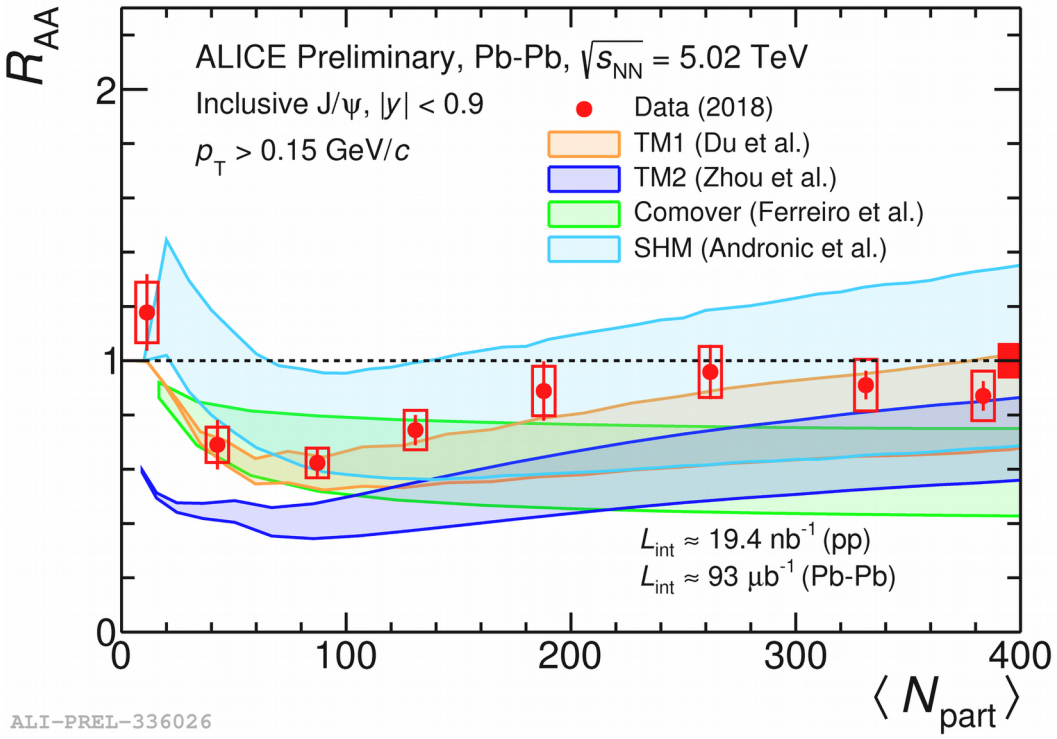
Model comparison

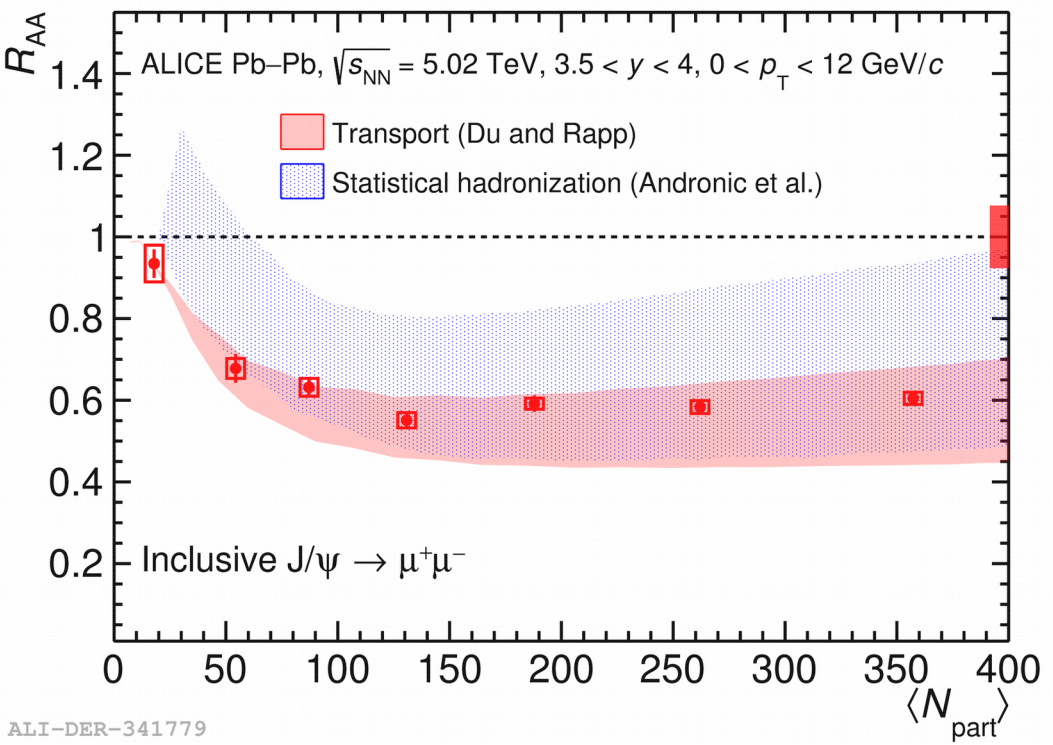


- **Transport Model 1 and 2 (TM1, TM2)**
  - J/ψ production during hard parton scattering, dynamically generated in QGP and at hadronization
- **Statistical Hadronization Model (SHM)**
  - J/ψ production during hard parton scattering and at chemical freezeout
  - Charm hadrons thermalized at the phase boundary
- **Comover interaction model**
  - J/ψ dissociated by co-movers, regeneration implemented
  - No thermalisation

TM1: Du, Rapp, *Nucl. Phys.* A943 (2015) 147-158
TM2: Zhou, Xu, Zhuang, *Phys. Rev.* C89 no. 5, (2014) 054911
Comover: Ferreiro, *Phys. Lett.* B731 (2014) 57-63
SHM: Andronic, Braun-Munzinger, Köhler, Redlich, Stachel, *Phys. Lett.* B797 (2019) 134836

Model comparison

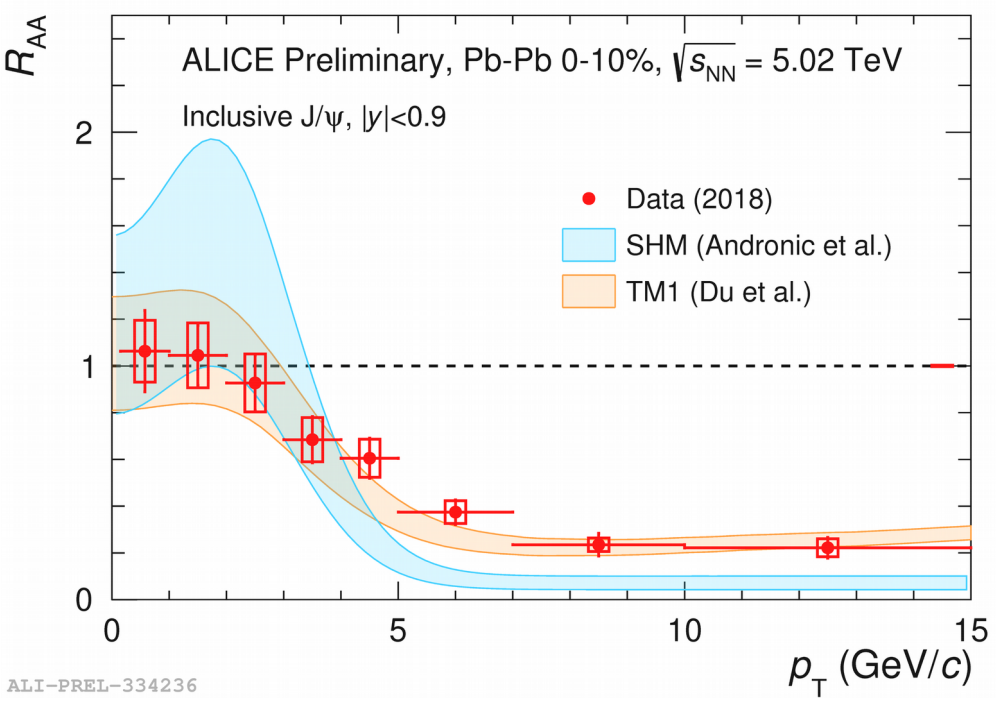


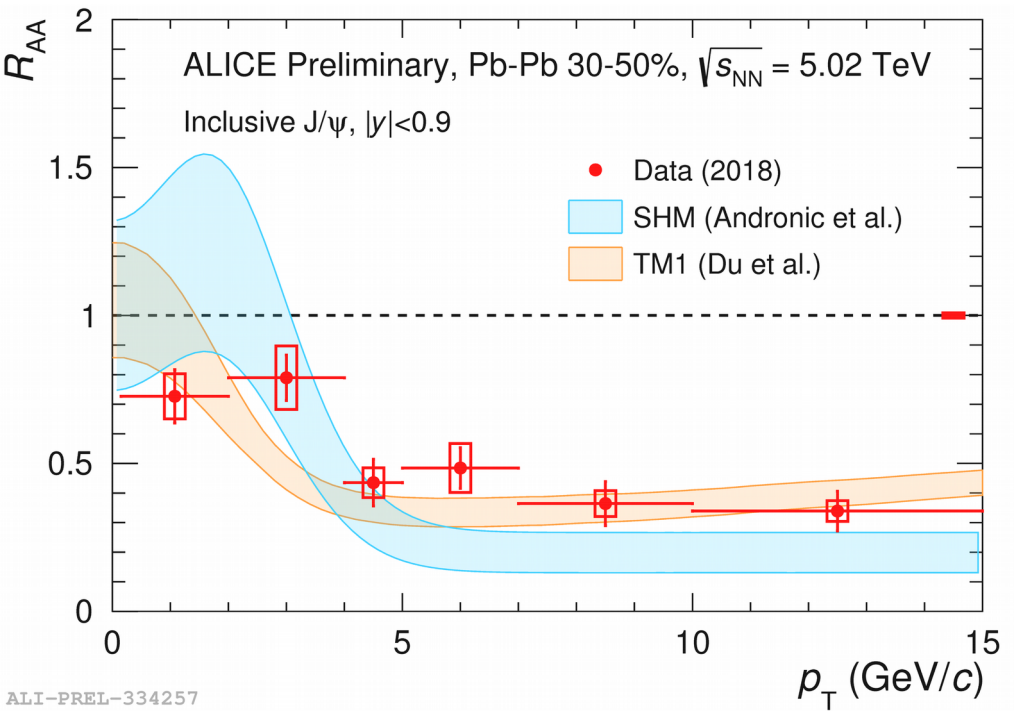


ALICE, arXiv:1909:03158

- SHM and transport model TM1 describe data at mid and forward rapidity
- To draw more conclusions we need:
  - More precise experiment inputs to constrain models (total charm cross section, shadowing)
  - More differential measurements

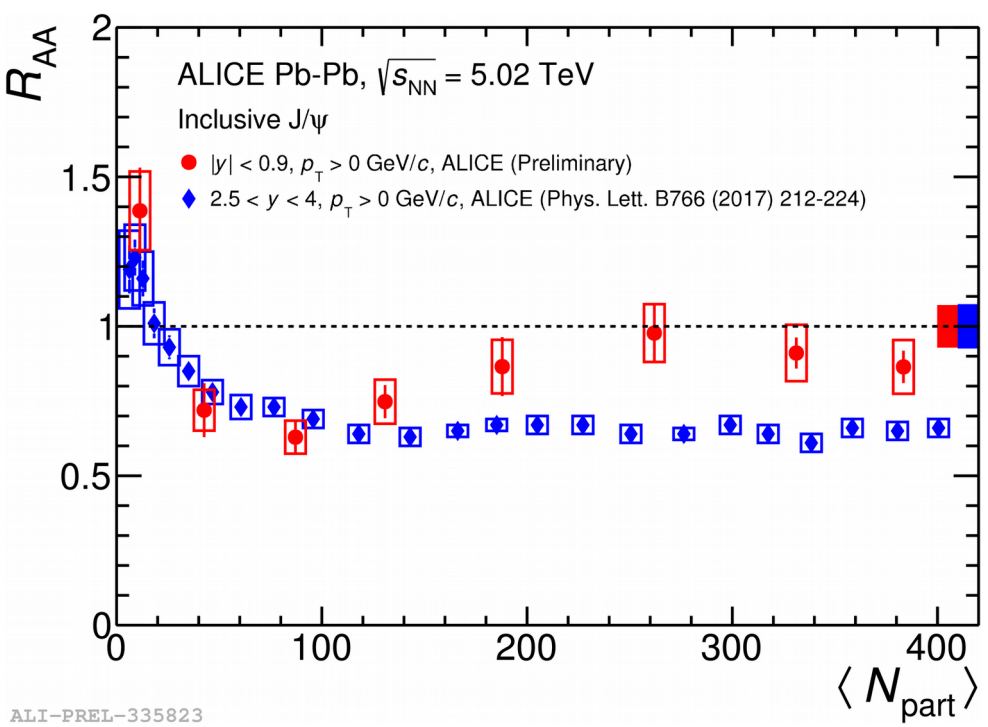
Inclusive J/ψ R_{AA} as function of p_T

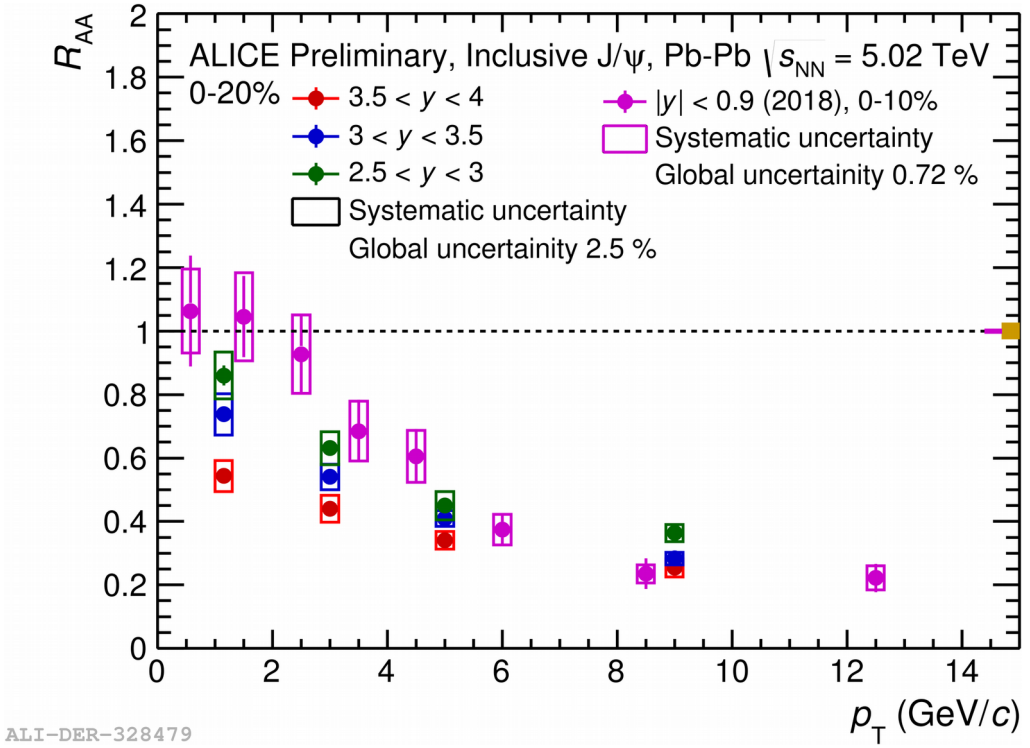




- Data are described by TM1 at all p_T and by SHM below 5 GeV/c
- (Re)generation plays important role at low momentum, especially in most central events
  - 0-10%: R_{AA} consistent with unity below 3 GeV/c
  - 30-50%: R_{AA} below unity

Inclusive J/ψ R_{AA} and rapidity





- Less suppression at midrapidity w.r.t. forward rapidity in central and semi-central events
  - Charm-quark density increases towards midrapidity

Summary and conclusions

- J/ψ suppression in heavy-ion collisions → QGP presence
- (Re)generation is an important production mechanism at LHC energies

- R_{AA} as function of centrality:
  - SHM and transport model describe data well

- R_{AA} as function of p_T:
  - Suppression increases with p_T
  - (Re)generation plays important role at low p_T

- R_{AA} and rapidity:
  - Less suppression at midrapidity
  - Charm quark density increases towards midrapidity

Thank you for your attention!

https://cds.cern.ch/record/1477949