Quarkonium production measurements in ALICE

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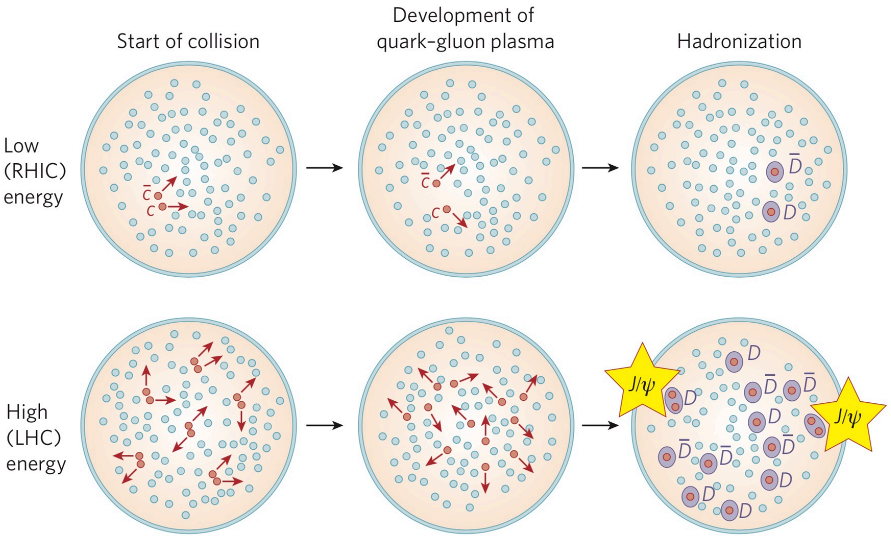
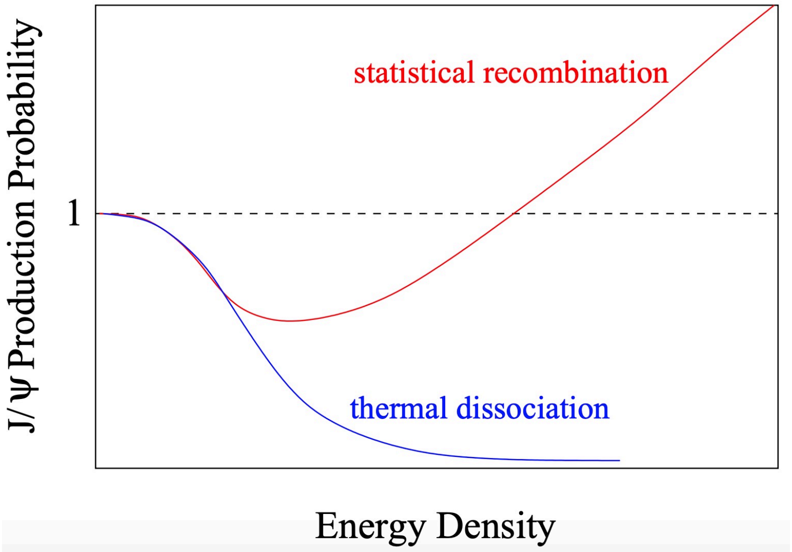
Outline

- **Motivation**
- **Quarkonia measurements in ALICE**
- **Results**
  - **Nuclear modification factor R_{AA}**
  - **Elliptic flow coefficient v_2**
- **Summary**

Quarkonium as a probe of the QGP

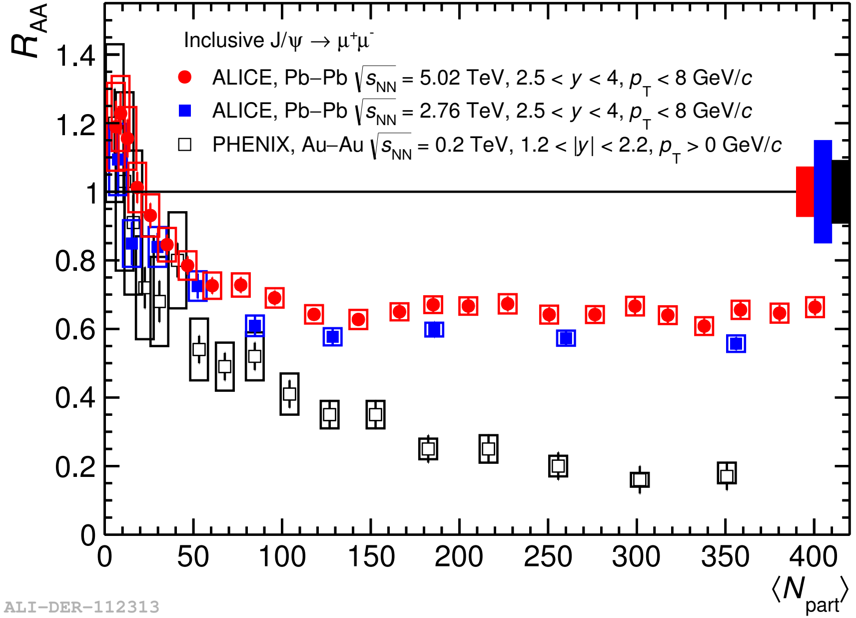


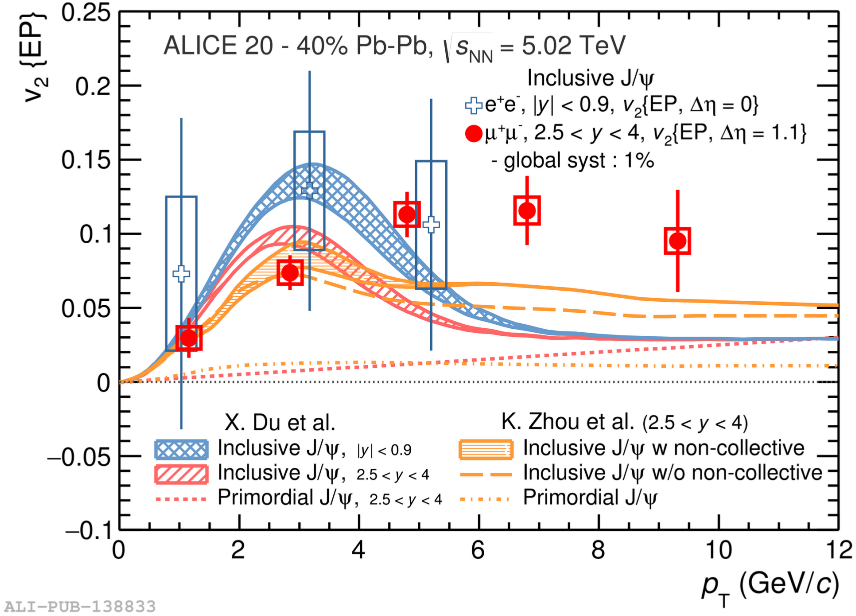


P. Braun-Munzinger, J. Stachel, Nature 448 (2007) 302
P. Braun Muzinger, J.Stachel, PLB 490 (2000) 196
R. Thews et al, Phys.Rev.C 63:054905 (2001)
Kluberg, Satz, arXiv:0901.3831

- Suppression of the direct charmonia due to color screening
- LHC: charm quark (c and $\bar{c}$) production cross section larger compared to RHIC energies
- Additional production mechanism: (re-)generation of quarkonium . Quarkonium can be used to study deconfinement in the QGP

Charmonia production in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV

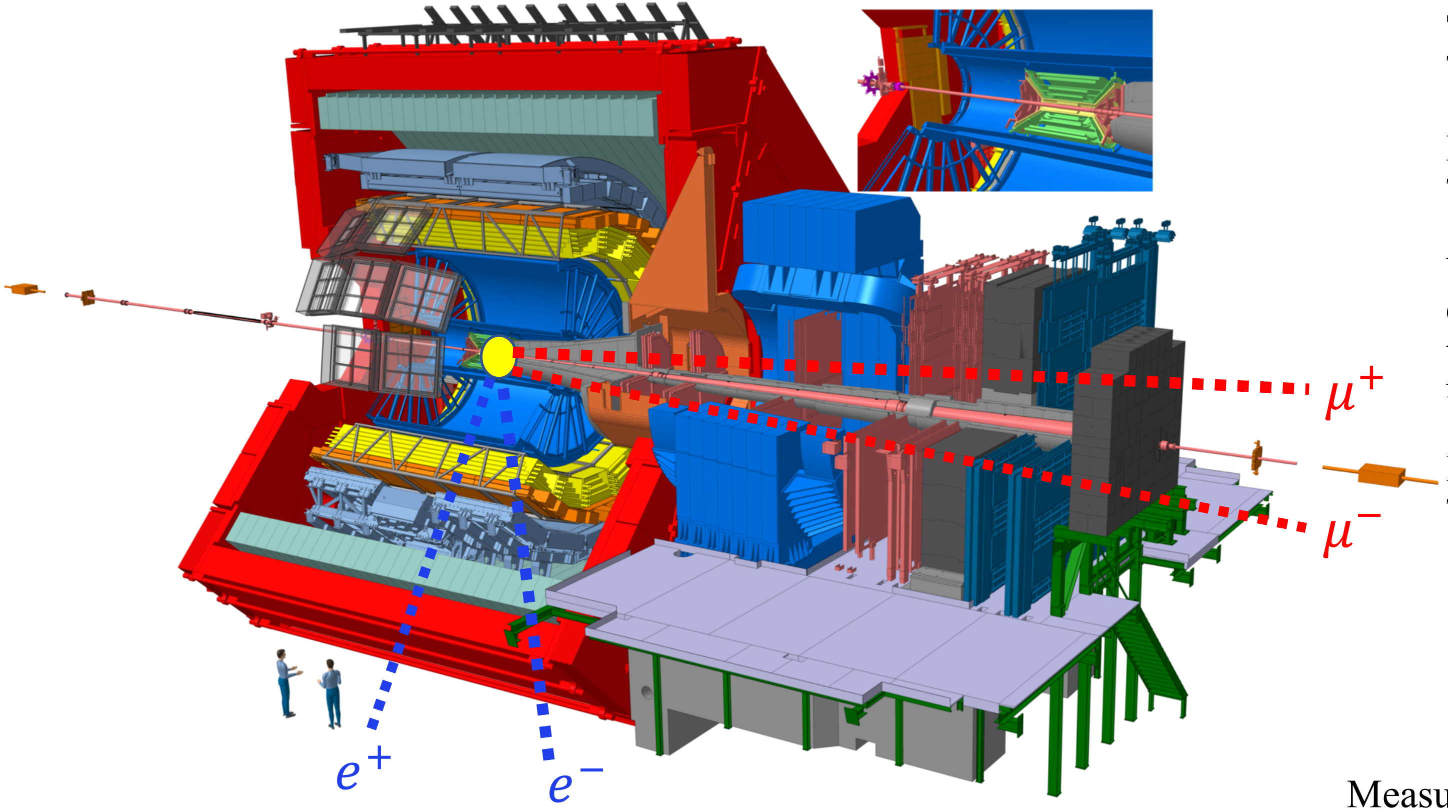




Matsui & Satz PLB 178 (1986) 416
PLB 766 (2017) 212 (ALICE)
PRL 98 (2007) 232301 (PHENIX)
PRL 119 (2017) 242301 (ALICE)

- Nuclear modification factor R_{AA}: suppression and (re-)generation of the quarkonia
- Charmonia elliptic flow v_2 : charm quark thermalization?

Quarkonia measurements with ALICE detector



Time Projection Chamber
Tracking, particle identification

Inner Tracking System
Tracking, vertex reconstruction

V0 Detector
Centrality determination triggering, and reaction plane measurement

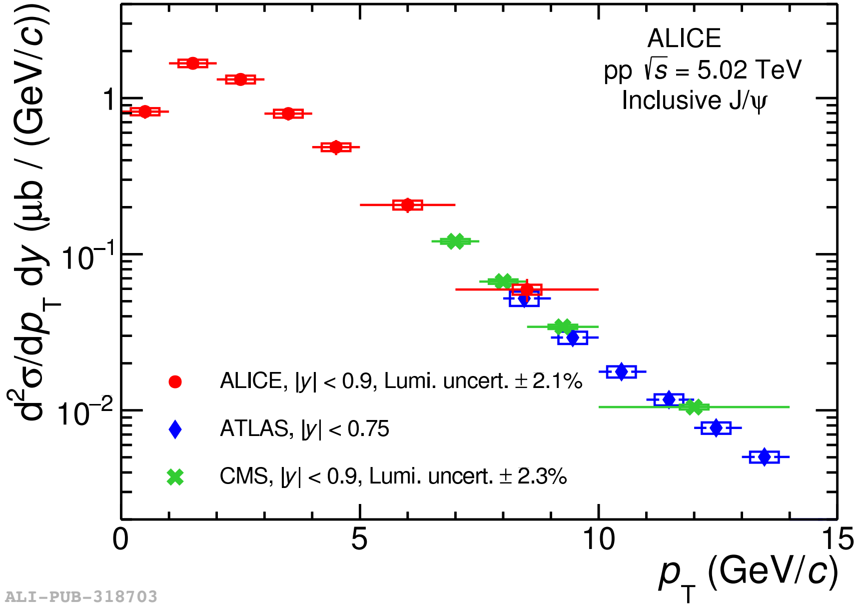
Muon spectrometer
Trigger and tracking for muons

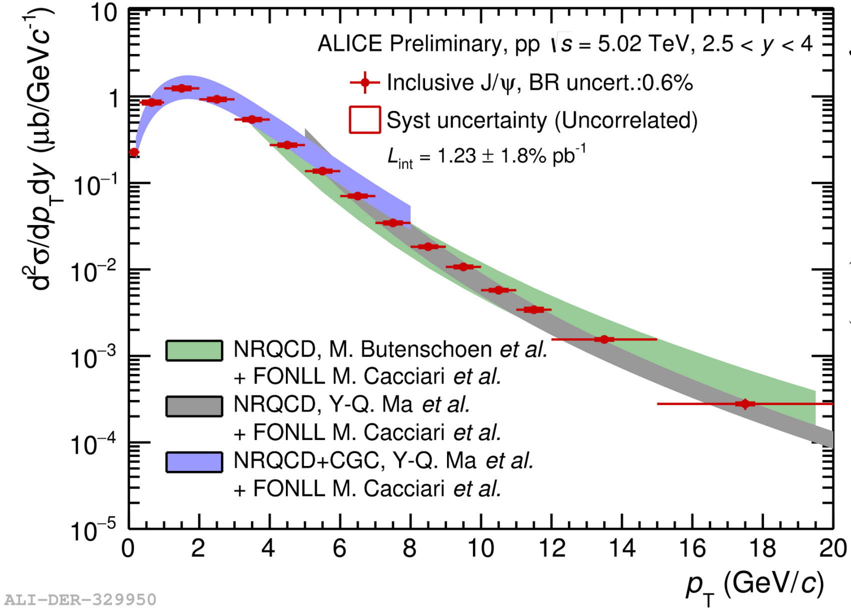
$J/\psi \rightarrow e^+e^-$

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

Measured p_T can be down to 0

pp reference for inclusive J/ψ production at $\sqrt{s}$ = 5.02 TeV

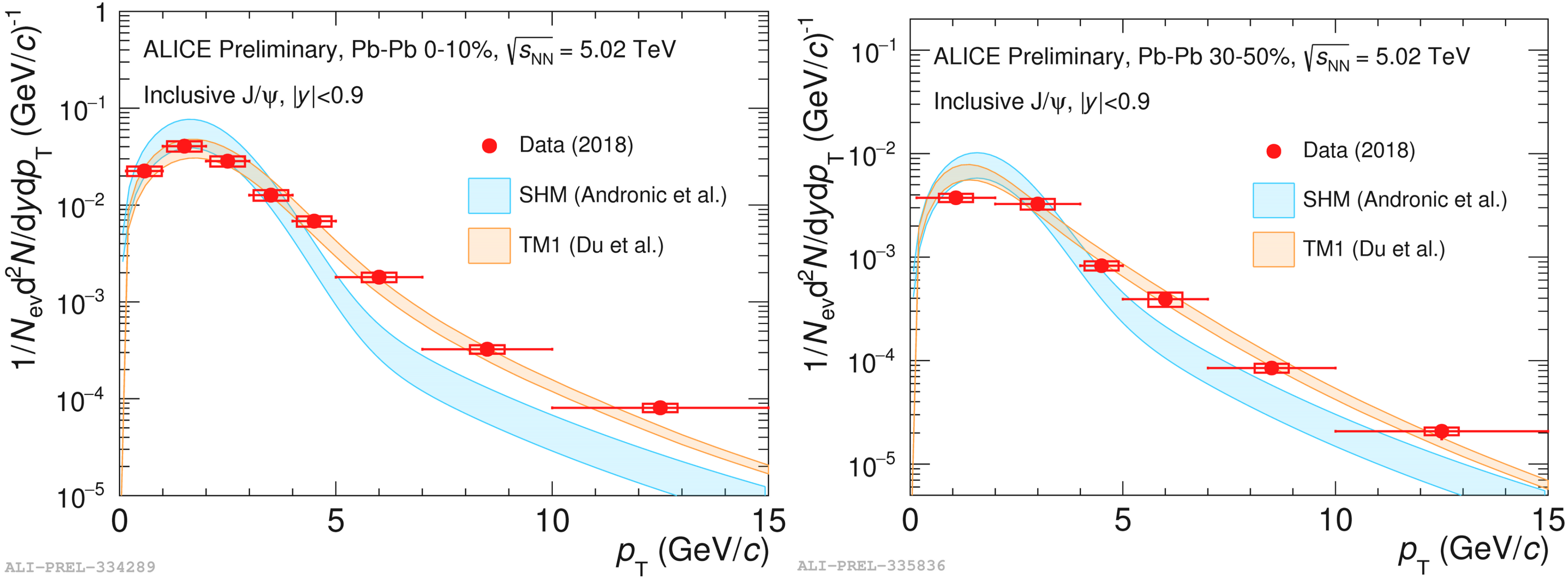




JHEP10 (2019) 084(ALICE)
Eur. Phys. J. C 78 (2018) 171(ATLAS)
Eur. Phys. J. C 77 (2017) 269(CMS)
Phys. Rev. Lett. 113 (2014) 192301

- First measurement of inclusive J/ψ production at pp 5.02 TeV, p_T down to 0
- New measurement consistent with ATLAS and CMS in overlapping p_T
- At forward-rapidity new measurement reach p_T to 20 GeV/c

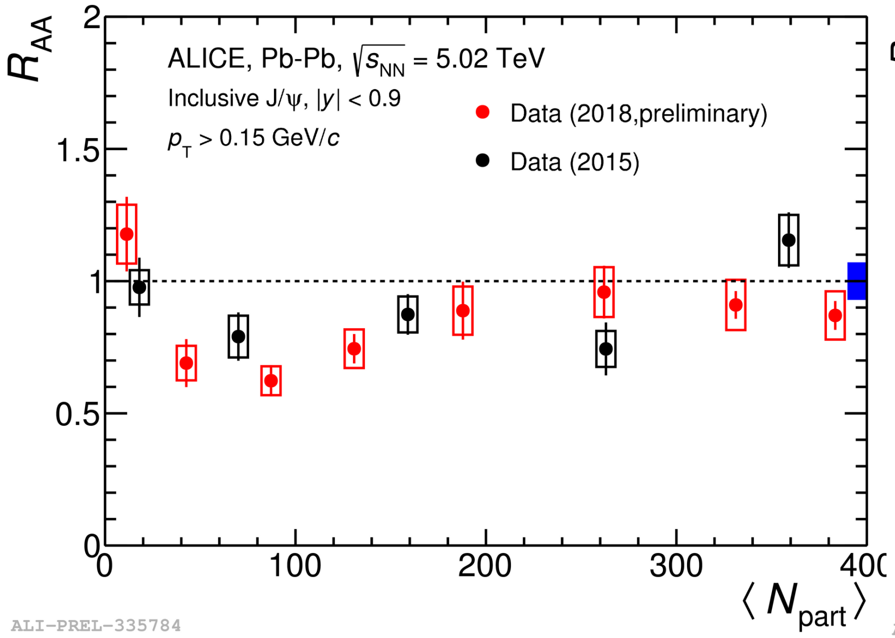
J/ψ p_T spectrum in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV

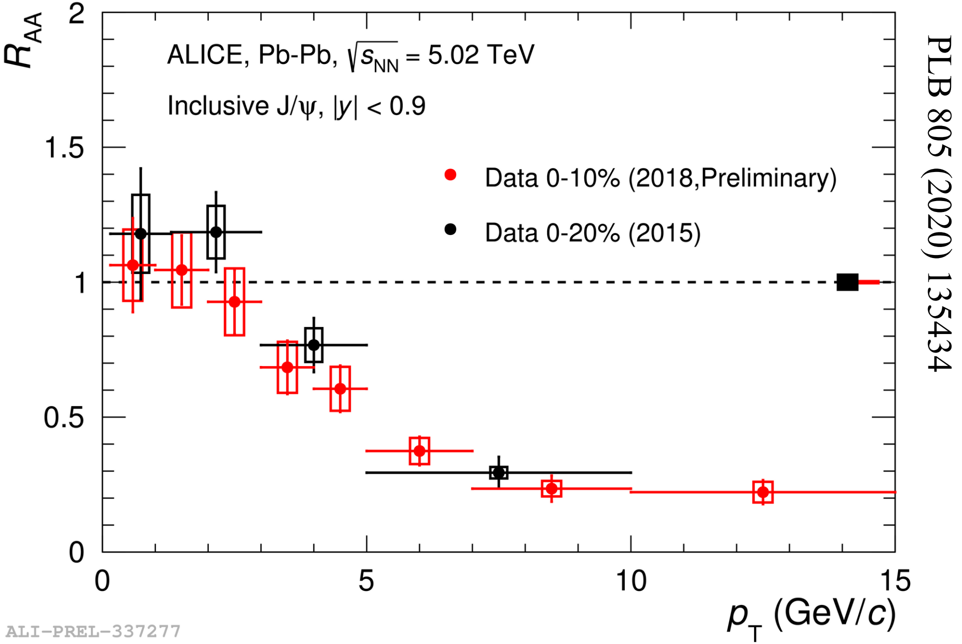


TM1: NPA943(2015)147
SHM: Phys.Lett. B797 (2019) 134836

Statistical hadronization model describes the data at low p_T, while the transport model agrees with data for all p_T

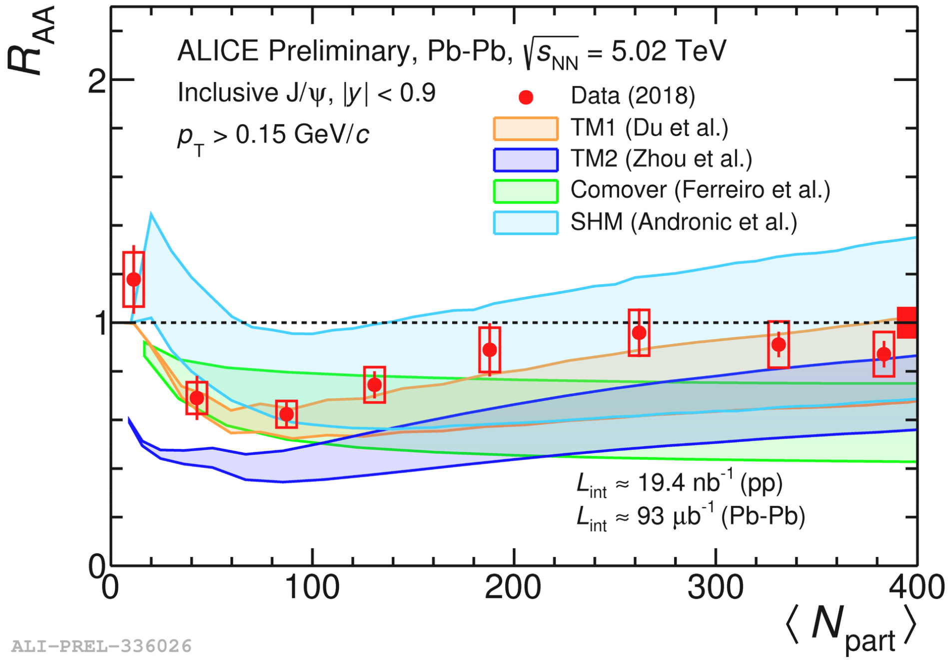
J/ψ R_{AA} in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV

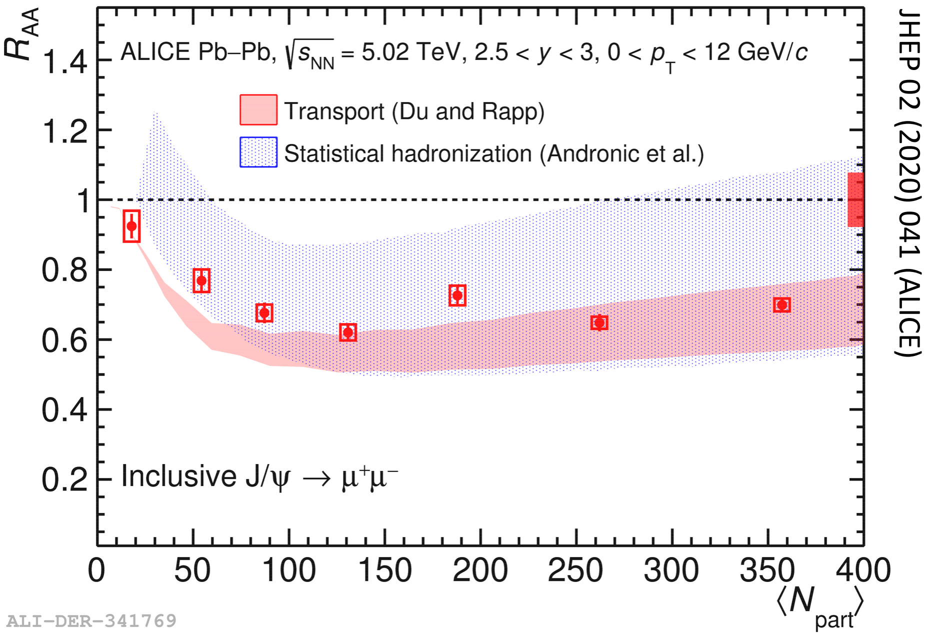




- New measurements based on high statistics data (~10 x for 0-10%, ~ 4 x for 30-50% compared to 2015)
- Significantly better precision and larger p_T coverage w.r.t the previous measurements

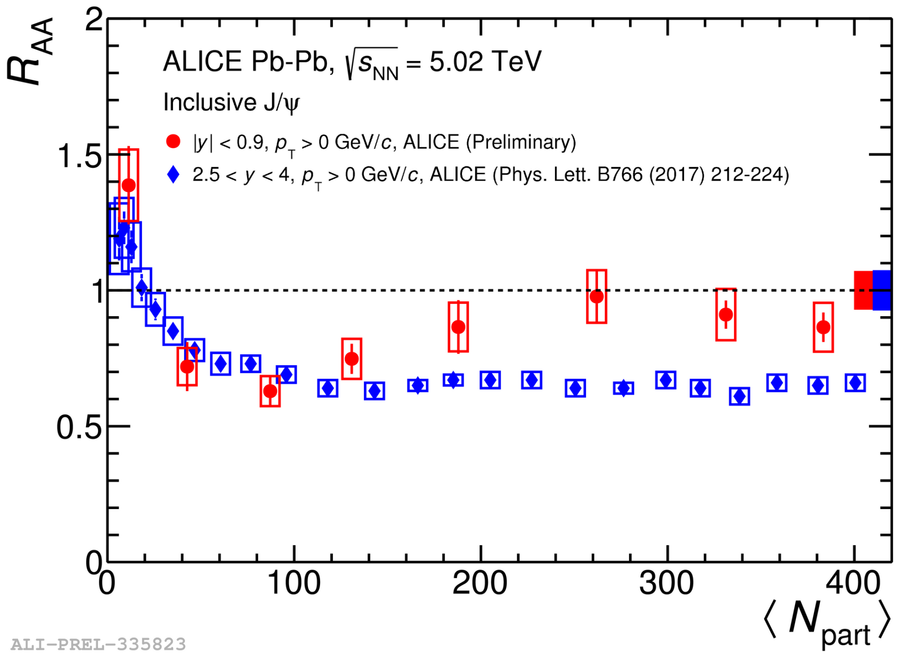
J/ψ R_{AA} in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV

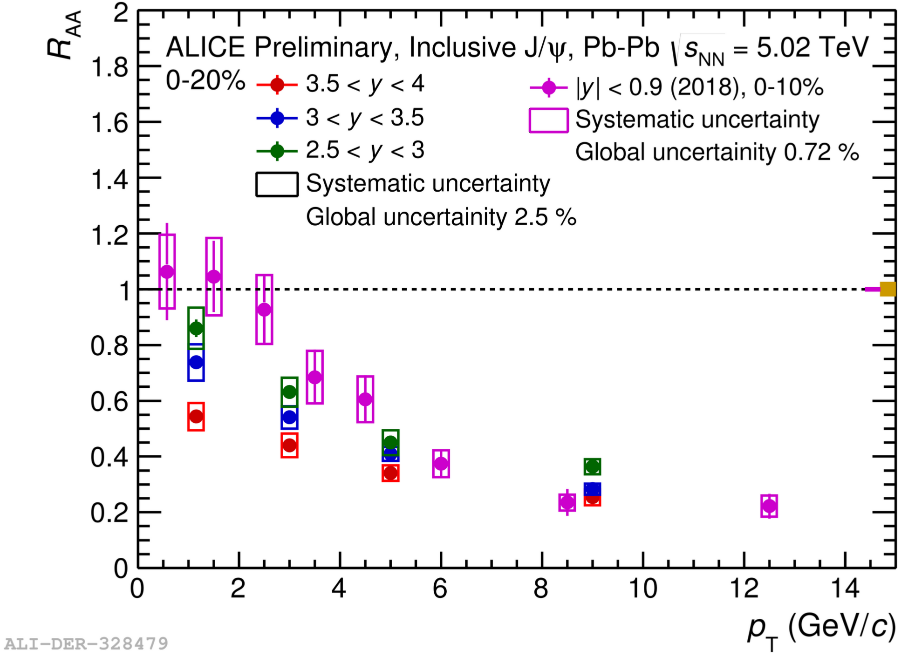




- The statistical hadronization model and transport model can describe the data within the uncertainties
- More precise experiment inputs (total charm cross-section/shadowing) are needed to constrain models

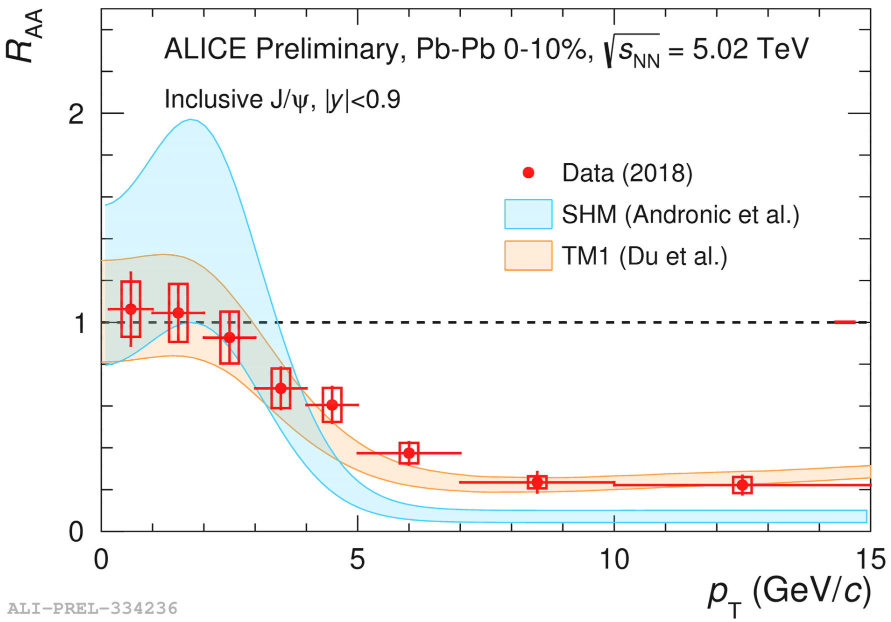
J/ψ R_{AA} in Pb-Pb collisions $\sqrt{s_{NN}} = 5.02$ TeV

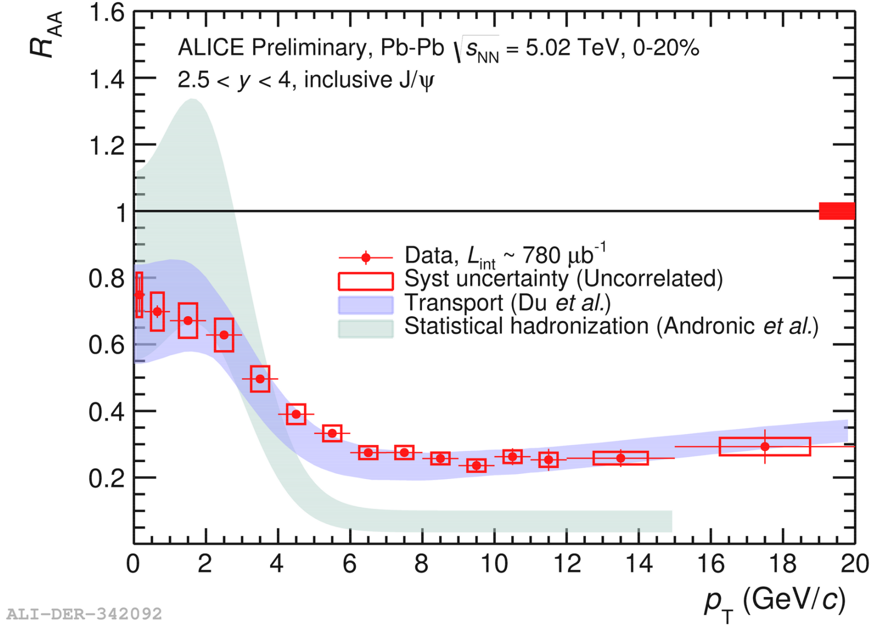




- Regeneration is the dominant process
- The charm quarks density increases towards midrapidity

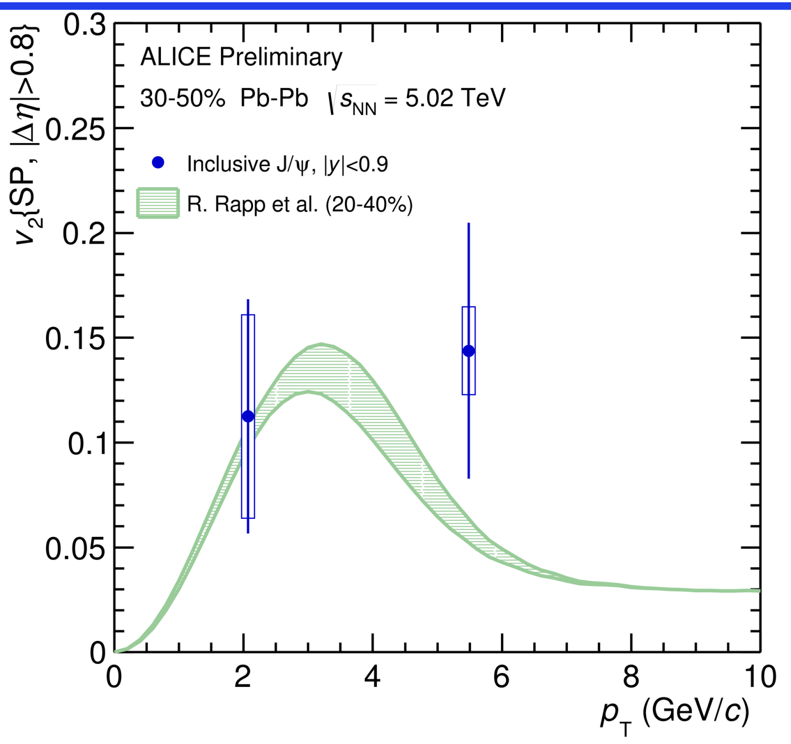
J/ψ R_{AA} in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV

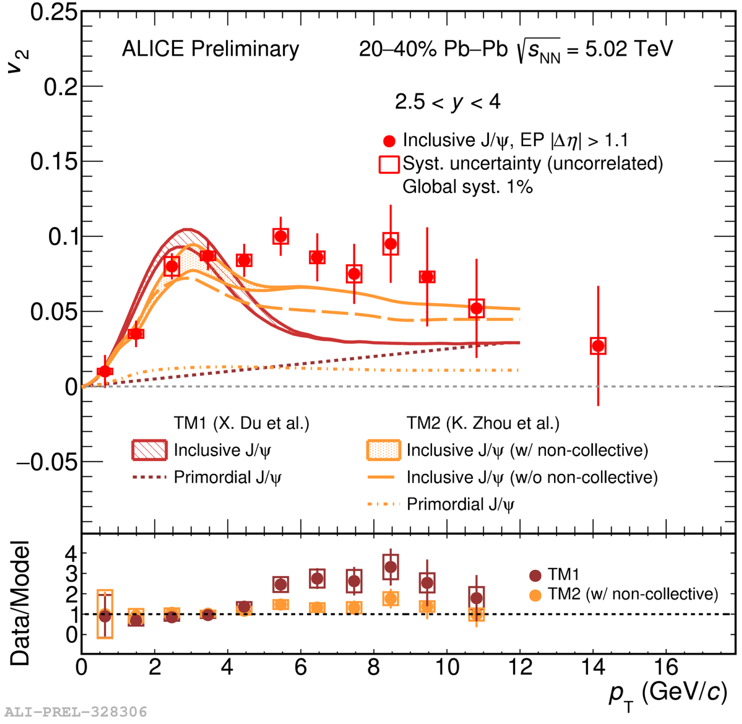




- Significant suppression for $p_T > 5$ GeV/c for both forward and midrapidity
- Statistical hadronization model describes data at low p_T, transport model agrees with the data for all the p_T

J/ψ v_2 in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV

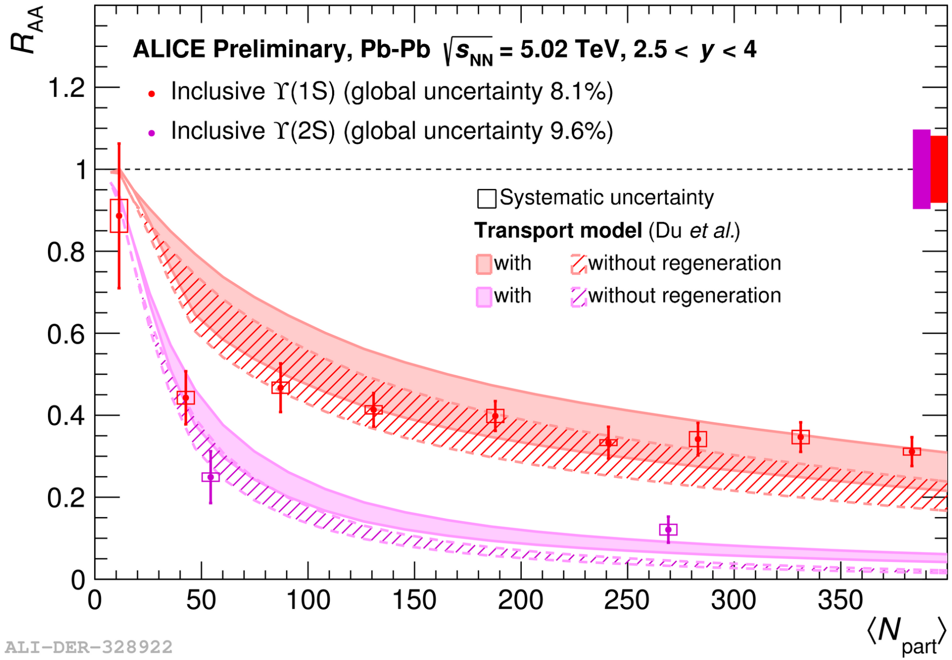




Phys. Rev. C 89, (2014) 054911
NPA 943 (2015)147

- Observation of positive J/ψ v_2 at both mid and forward rapidity
- Agreement with transport model at low p_T, indicates the charm quarks thermalization

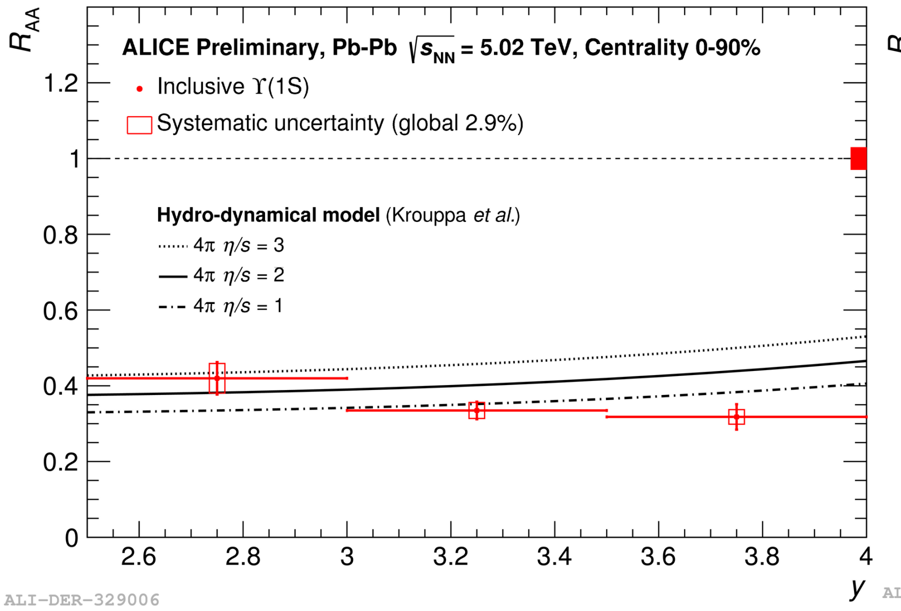
Υ(1S) and Υ(2S) R_{AA} in Pb-Pb collisions $\sqrt{s_{NN}}$ = 5.02 TeV

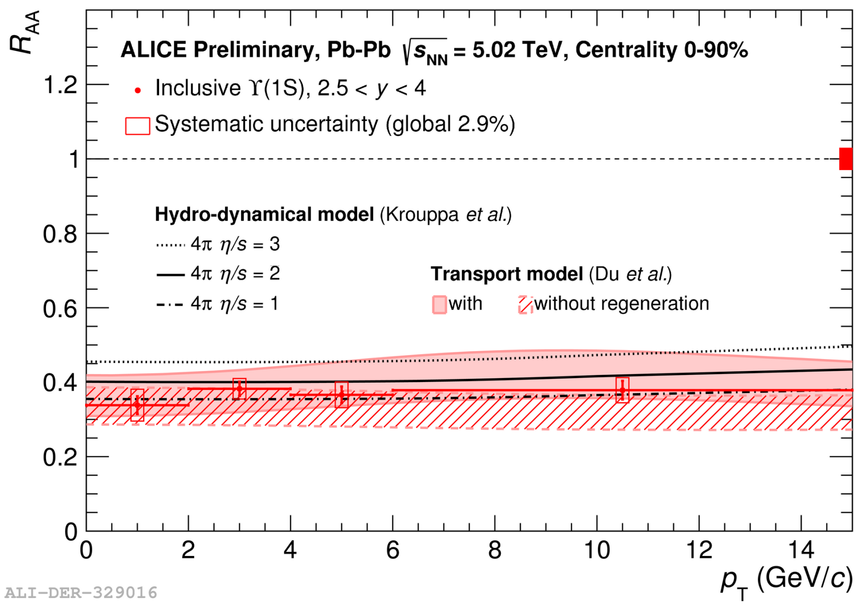


Phys. Rev. C **96**, 054901

- New measurement based on 2015+2018 data with high precision
- Slight centrality dependence for both Υ(1S) and Υ(2S) R_{AA}
- Stronger suppression of Υ(2S) compared to Υ(1S)

$\Upsilon(1S)$ R_{AA} in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV

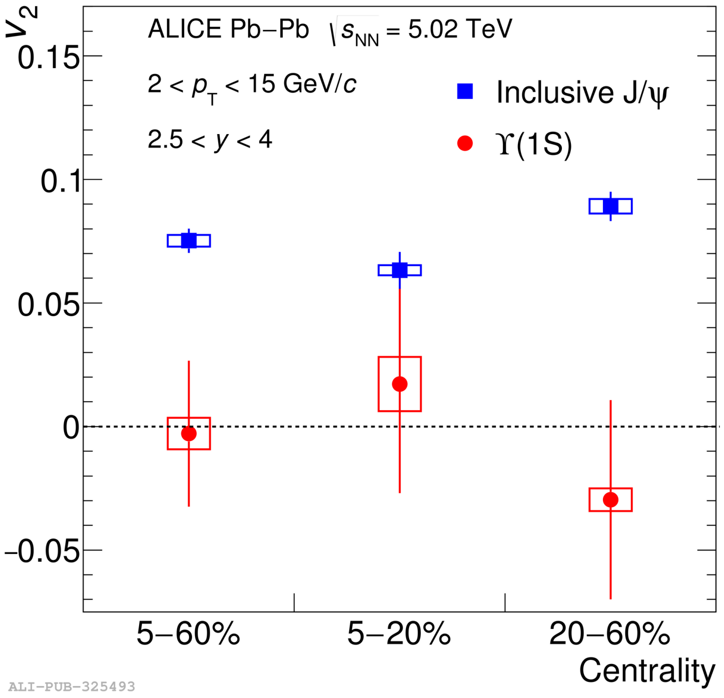


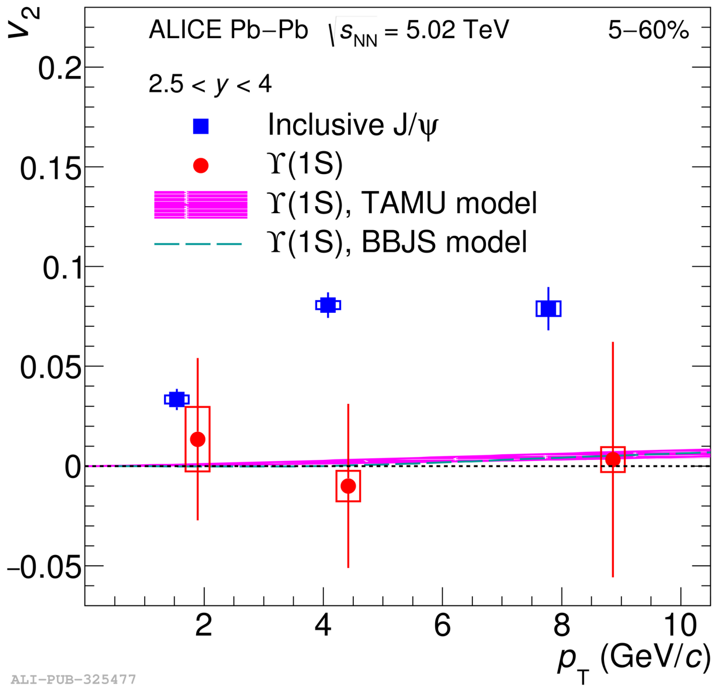


Tranport : Phys. Rev. C **96**, 054901
Hydro-dynamical:Universe 2 (2016) no.3, 16

- Slight rapidity dependence, the trend is different from the model calculation
- No p_T dependence which in strong contrast to the J/ψ R_{AA}

$\Upsilon(1S)$ v_2 in Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV





PRL 123 (2019) 19, 192301 (ALICE)
TAMU: Phys. Rev. C 96, (2017) 054901
BBJS: arXiv:1809.06235

- First measurement of the $\Upsilon(1S)$ elliptic flow coefficient v_2
- v_2 consistent with zero and lower than J/ψ v_2 by 2.6σ
- Beauty quarks thermalized? Phys.Rev.C 101 (2020) 6, 064905

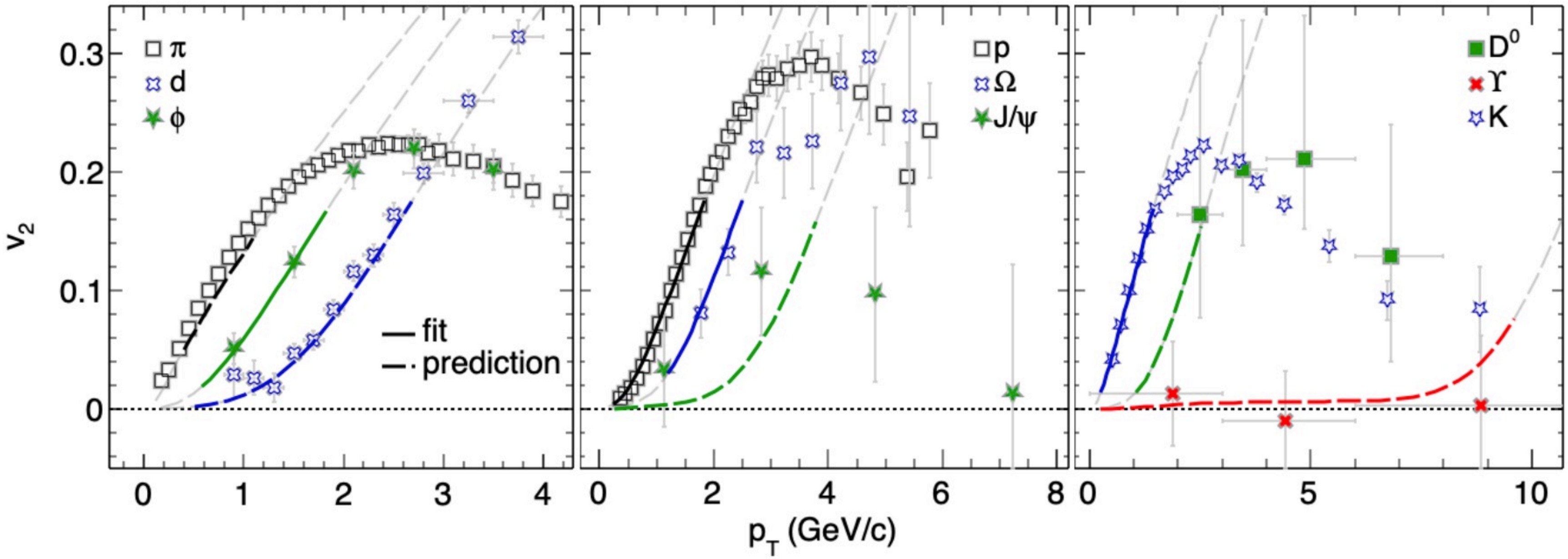
Summary

- **The quarkonia R_{AA} and v_2 are presented for both forward and midrapidity at $\sqrt{s_{NN}} = 5.02$ TeV**

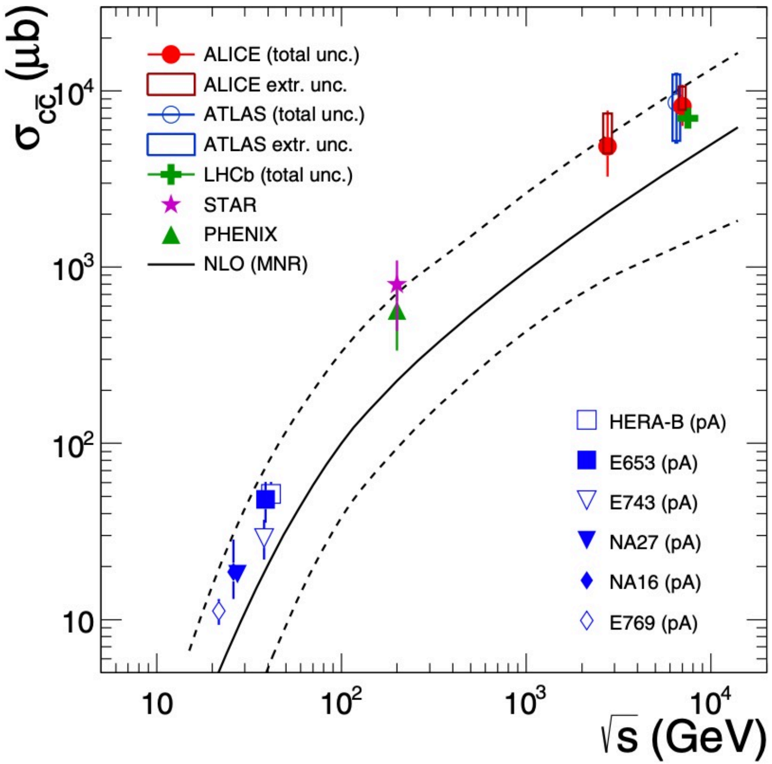
- **Charmonium**
  - Dominant contribution from (re-)generation in central collisions and low p_T
  - Observation of positive J/ψ v_2, indicates thermalization of charm quarks

- **Bottomonium**
  - Strong suppression for all centrality and p_T, stronger suppression of ϒ(2S) compared to the ϒ(1S)
  - The ϒ(1S) v_2 is consistent with zero ($2<p_T<15$ GeV/c) and lower than J/ψ v_2 by 2.6σ

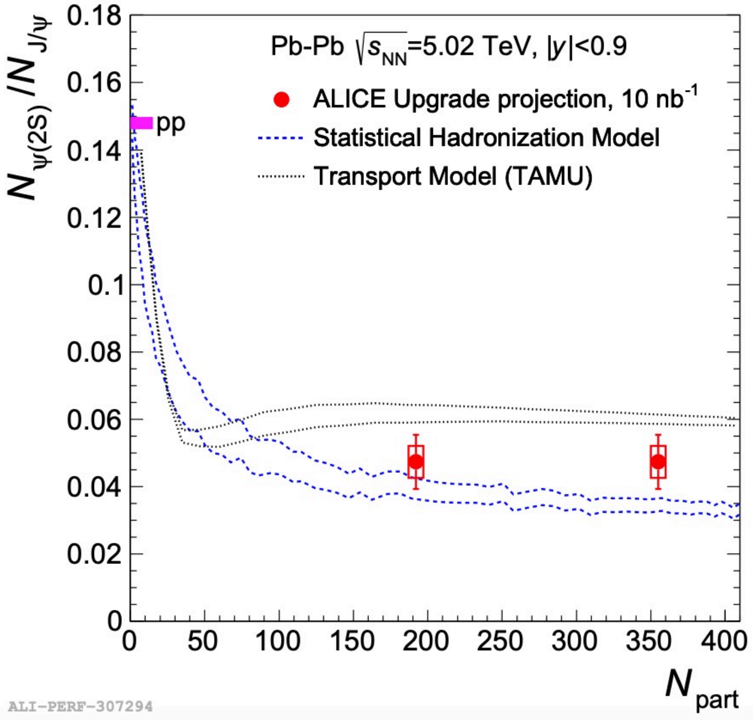
Thanks

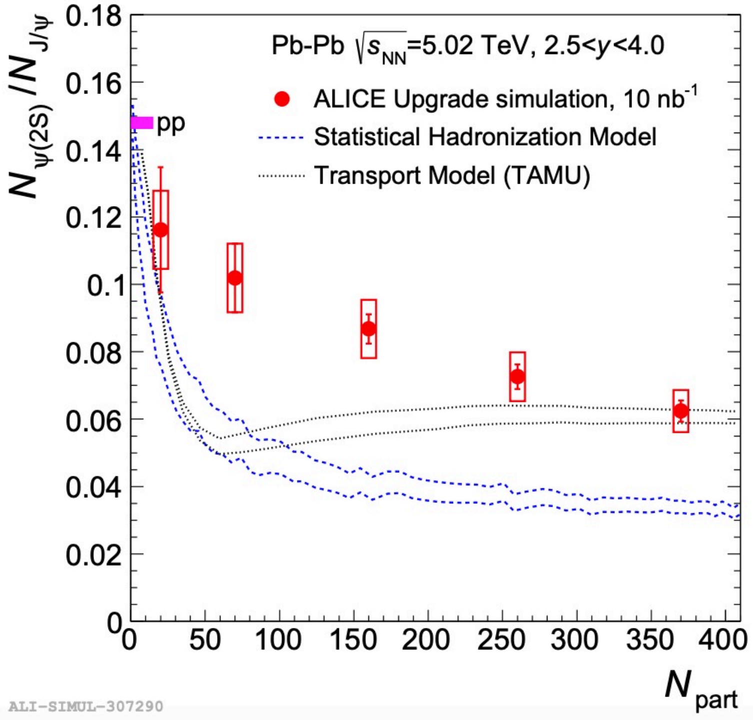


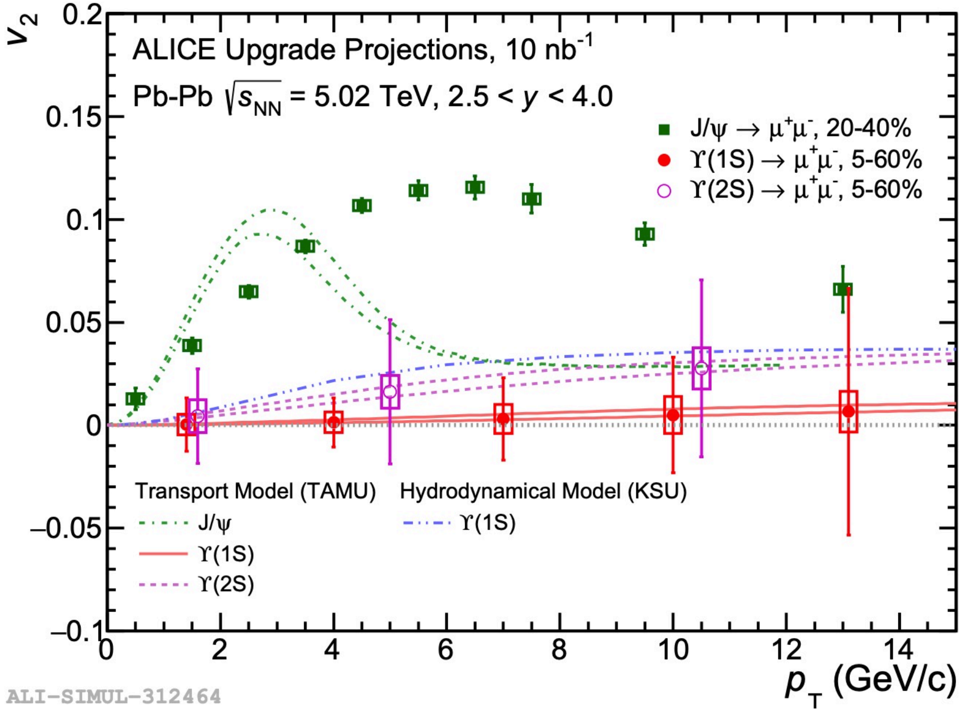
Phys.Rev.C 101 (2020) 6, 064905



PRC 94 (2016) 054908


Pb-Pb $\sqrt{s_{NN}}$=5.02 TeV, |y|<0.9
ALICE Upgrade projection, 10 nb^{-1}
Statistical Hadronization Model
Transport Model (TAMU)
pp
$N_{\psi(2S)}/N_{J/\psi}$
N_{part}
ALI-PERF-307294


Pb-Pb $\sqrt{s_{NN}}$=5.02 TeV, 2.5<y<4.0
ALICE Upgrade simulation, 10 nb^{-1}
Statistical Hadronization Model
Transport Model (TAMU)
pp
$N_{\psi(2S)}/N_{J/\psi}$
N_{part}
ALI-SIMUL-307290



ALICE Upgrade Projections, 10 nb-1
Pb-Pb √sNN = 5.02 TeV, 2.5 < y < 4.0
J/ψ → μ+μ-, 20-40%
ϒ(1S) → μ+μ-, 5-60%
ϒ(2S) → μ+μ-, 5-60%
Transport Model (TAMU)
J/ψ
ϒ(1S)
ϒ(2S)
Hydrodynamical Model (KSU)
ϒ(1S)
v2
pT (GeV/c)
ALI-SIMUL-312464