ALICE results on charmonia and bottomonia

Roberta Arnaldi
INFN Torino

for the ALICE Collaboration

ALICE

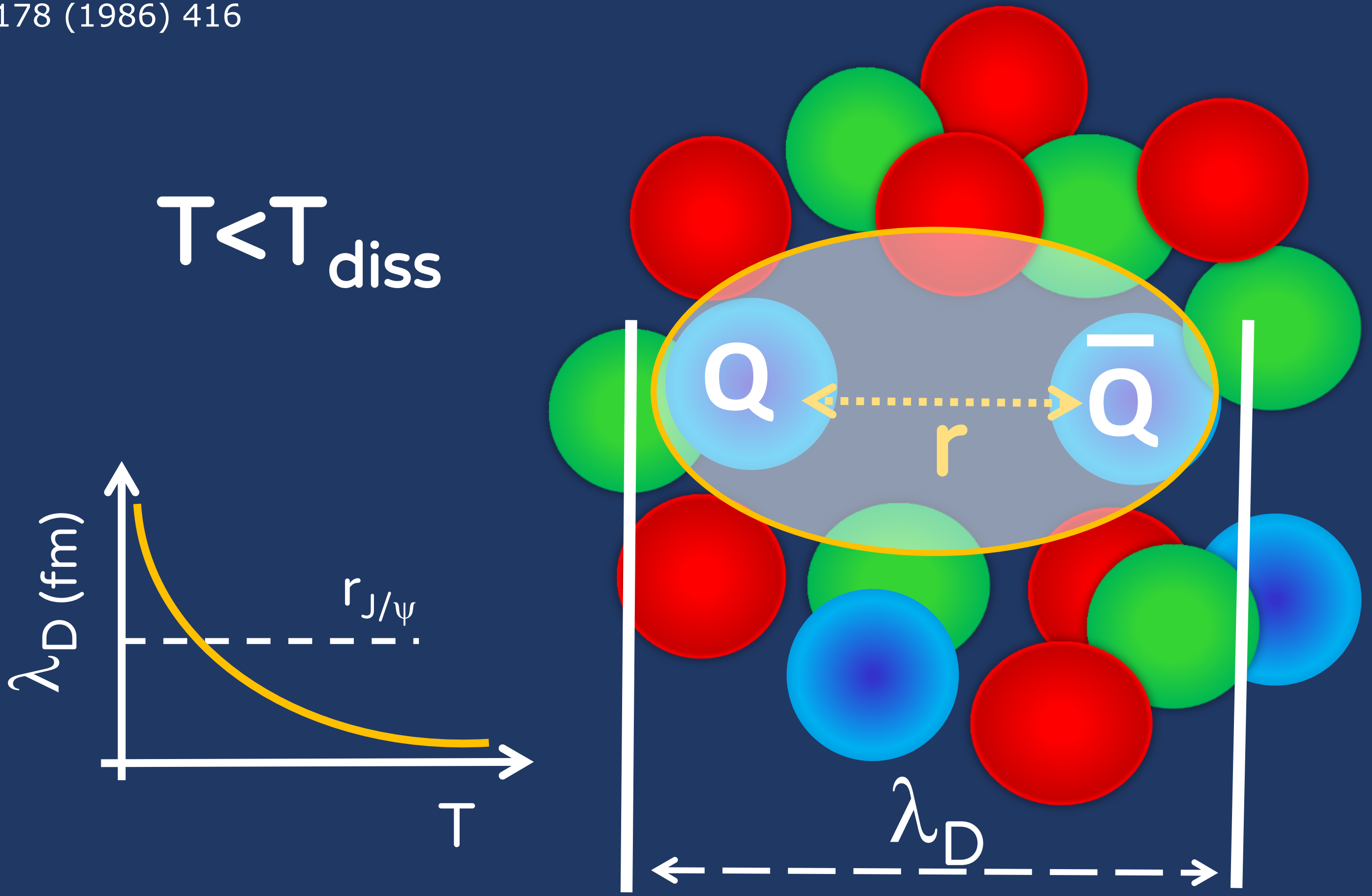
Quarkonium in AA collisions

the original idea:

quarkonium production suppressed via color screening in the QGP

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

$T<T_{diss}$



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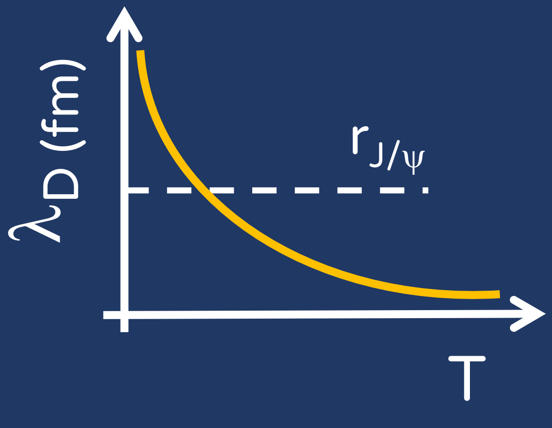

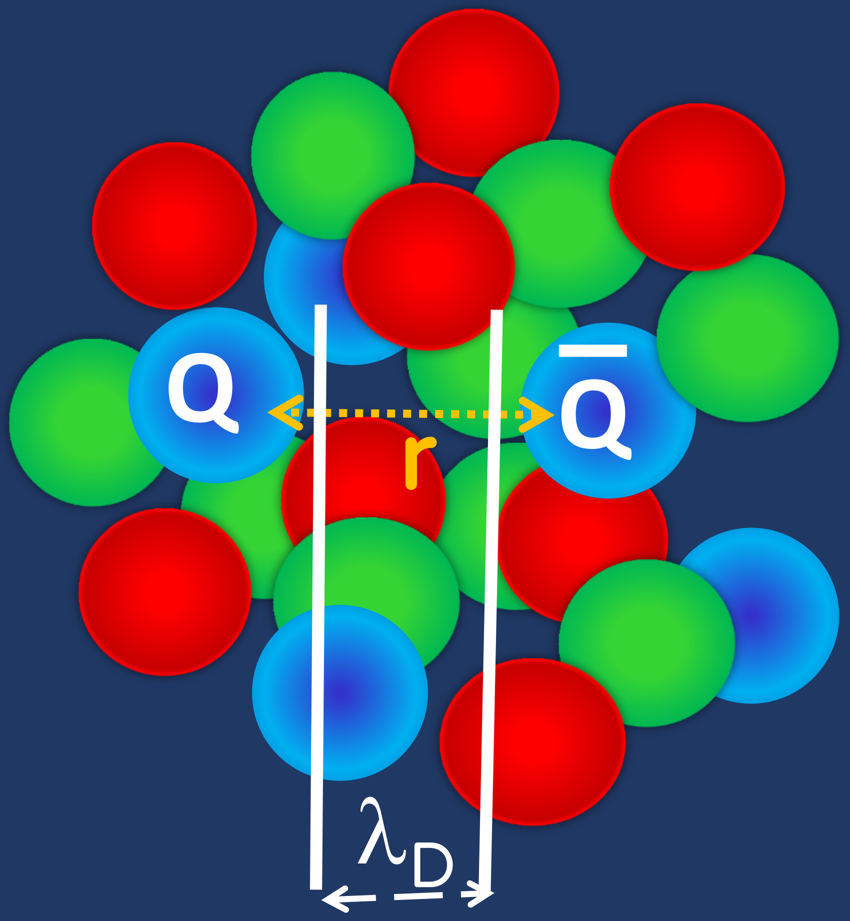

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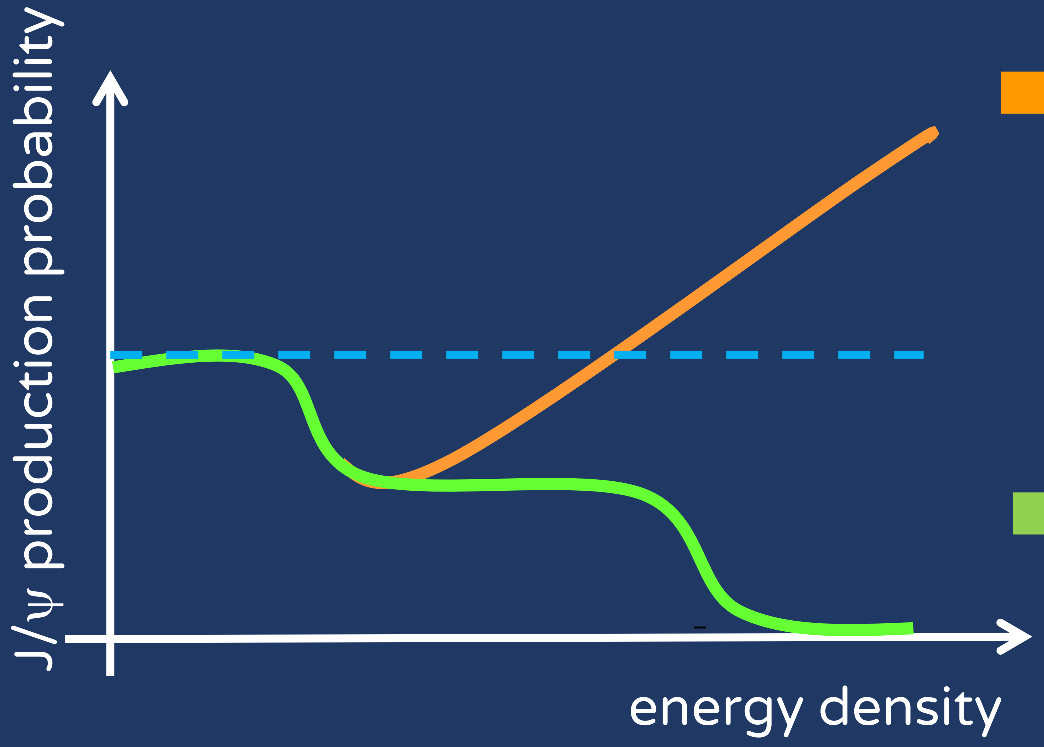


Statistical regeneration

cc multiplicity increases with collision energy
→ enhanced quarkonium production via (re)combination at hadronization or during QGP

P. Braun-Muzinger,J. Stachel, PLB 490(2000)196, R. Thews et al,Phys.Rev.C63:054905(2001)

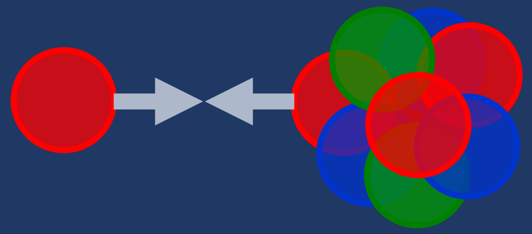
Sequential melting

differences in the quarkonium binding energies lead to a sequential melting with increasing temperature

Digal,Petrecki,Satz PRD 64(2001) 0940150

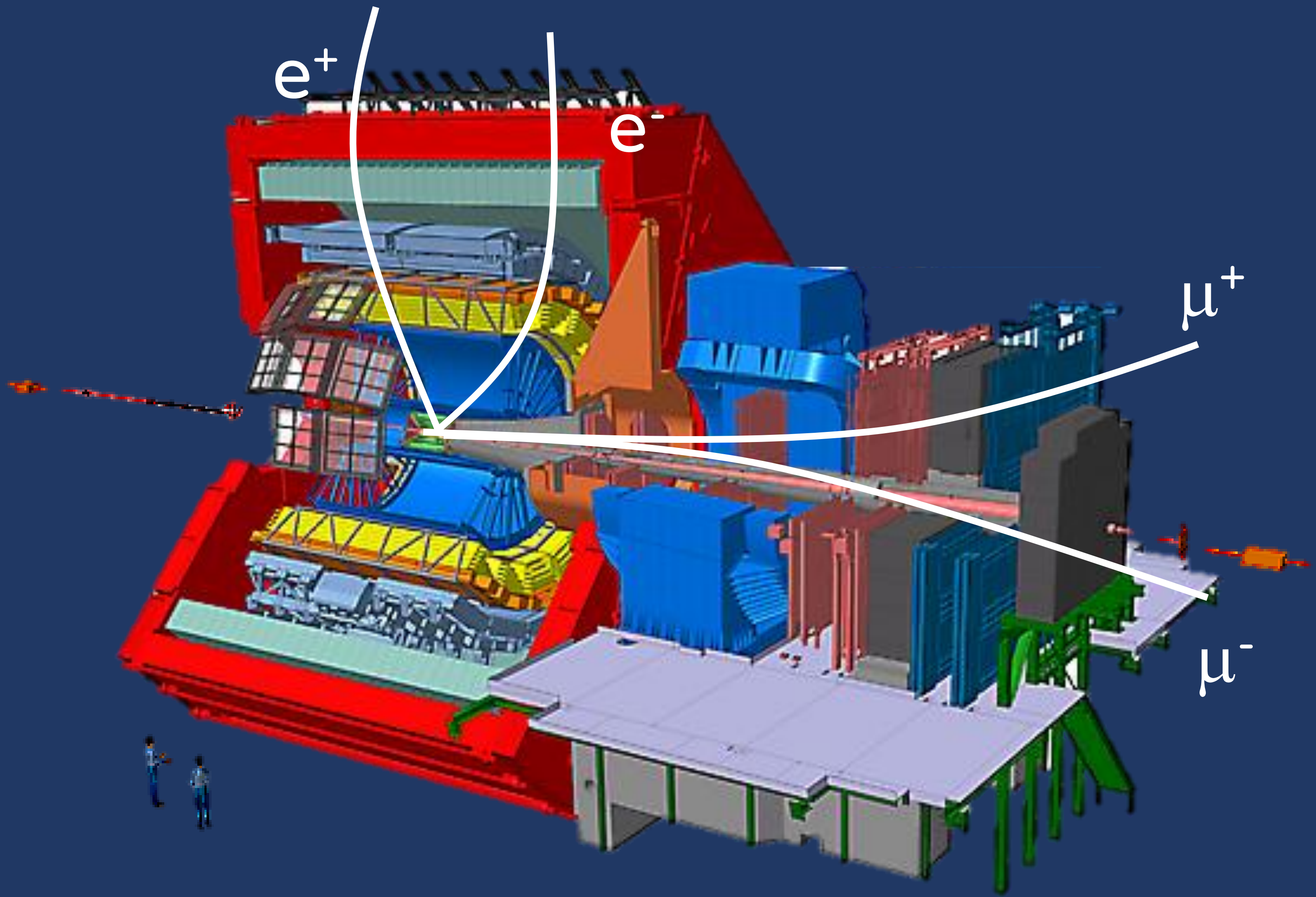
Cold nuclear matter effects

- **On top of the hot matter mechanisms, other effects, related to cold nuclear matter (CNM), might affect quarkonium production**
  - nuclear parton shadowing/color glass condensate
  - energy loss
  - $c\bar{c}$ break-up in nuclear matter
- CNM are investigated in pA collisions, addressing:



- Role of the various contributions, whose importance depends on kinematic and energy of the collisions
- Size of CNM effects, fundamental to interpret quarkonium AA results

Quarkonium measurements: ALICE



Central Barrel $J/\psi \rightarrow e^+e^-$
$|y_{LAB}|<0.9$
Electrons tracked using ITS and TPC
Particle id: ITS, TPC, TOF, TRD

Forward muon arm $J/\psi \rightarrow \mu^+\mu^-$
$2.5<y_{LAB}<4$
Muons identified and tracked in the muon spectrometer

- acceptance coverage in both y regions down to zero p_T
- ALICE measures inclusive J/ψ at mid and forward-y and prompt J/ψ at mid-y

Quarkonium at mid-rapidity

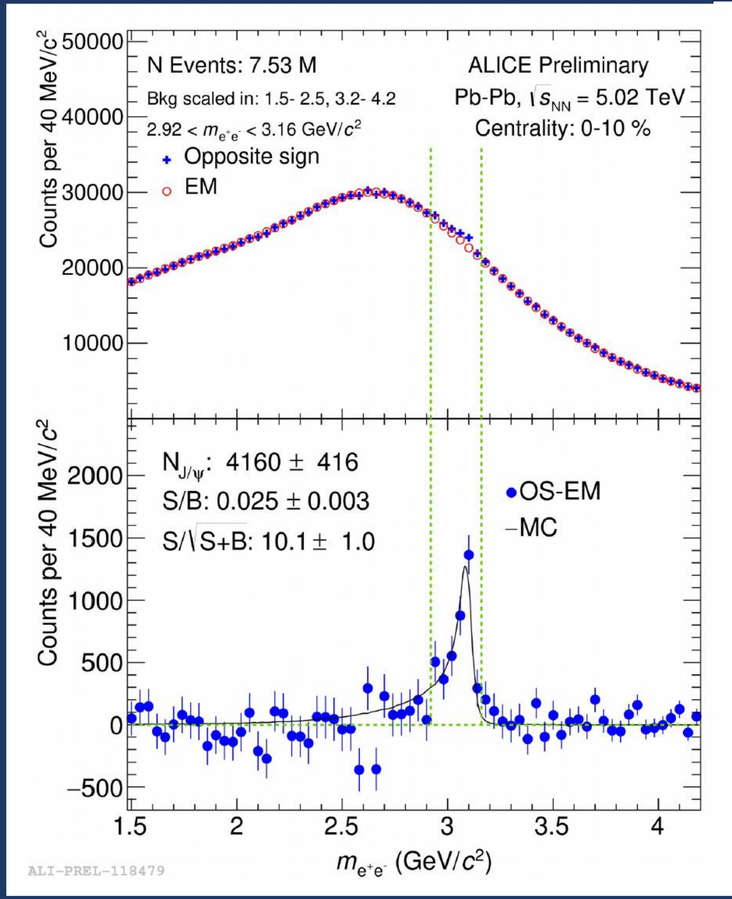
$J/\psi \rightarrow e^+e^-$

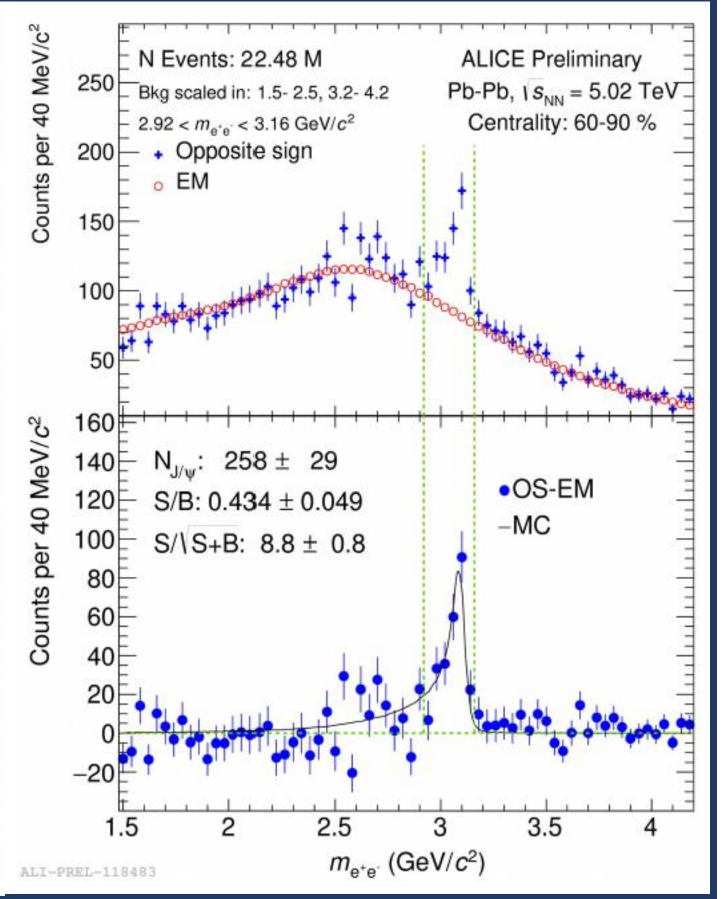
- Minimum bias trigger
- Good mass resolution, but low significance especially in Pb-Pb → only J/ψ analysis so far

Signal extraction:

- Combinatorial background subtracted via event mixing
- Signal obtained by counting technique

Pb-Pb: 0-10% J/ψ 60-90%





Quarkonium at forward-rapidity

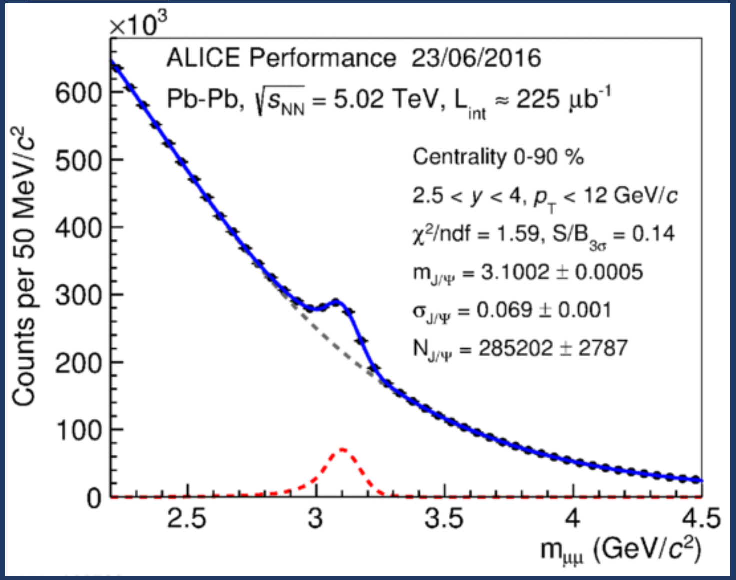
quarkonium → $\mu^+\mu^-$

- Dimuon trigger
- Good S/B for J/ψ and ϒ(1S)
  → study of excited resonances still limited in Pb-Pb

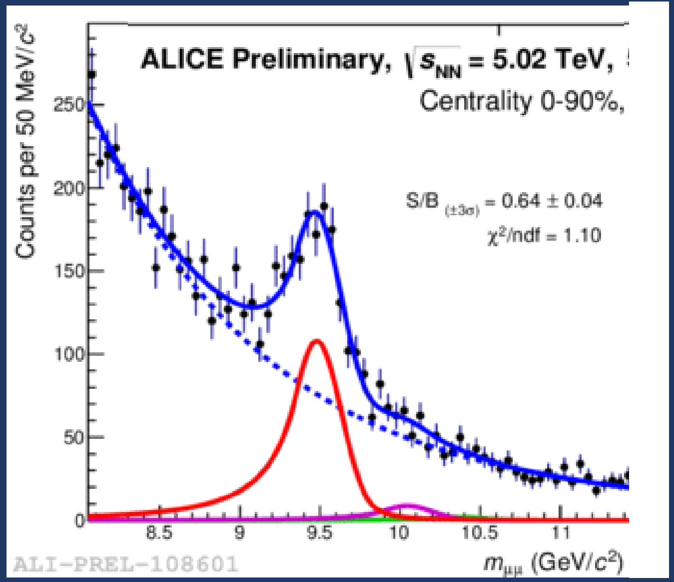
Signal extraction:

- Yields extracted from a fit with signal + background shapes
- In Pb-Pb, background subtracted also via mixed-events

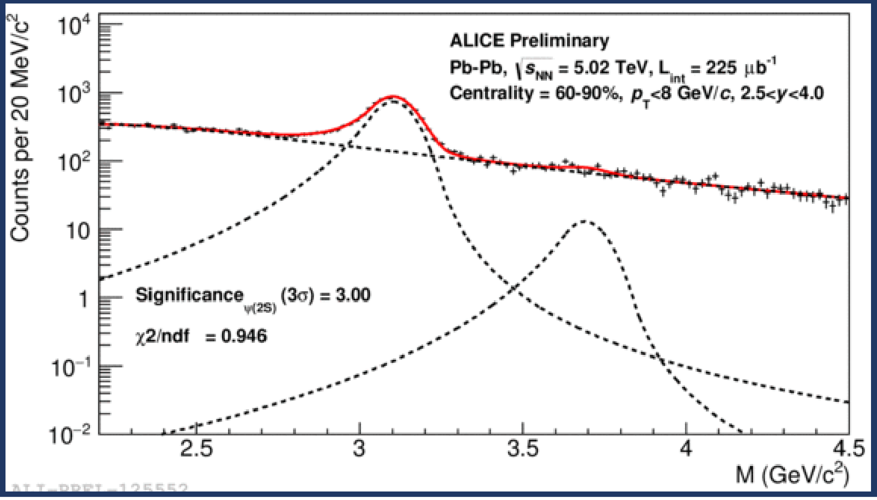
J/ψ



ϒ



ψ(2S)



Quarkonium measurements: data taking

	System	$\sqrt{s_{NN}}$ (TeV)	L (MB)	L (dimuon)
Run 1 2009-2013	pp	0.9, 2.76, 7, 8	1.1 nb^{-1} @2.76	19.9 nb^{-1} @2.76
	p-Pb	5.02	51 μb^{-1}	5-5.8 nb^{-1}
	Pb-Pb	2.76	26 μb^{-1}	69 μb^{-1}
Run 2 2015-2018	pp	5.02, 13	2nb^{-1} @5.02	106nb^{-1} @5.02
	p-Pb	5.02, 8.16	0.4 nb^{-1} @5.02	8.7-12.9 nb^{-1} @8.16
	Pb-Pb	5.02	19 μb^{-1}	225 μb^{-1}
	Xe-Xe	5.44	-	-

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pp

vacuum reference for AA - pA, genuine pp physics program

ALICE talks:

- Hugo Pereira da Costa → Nov 8th
- Cristiane Janke → Nov 9th

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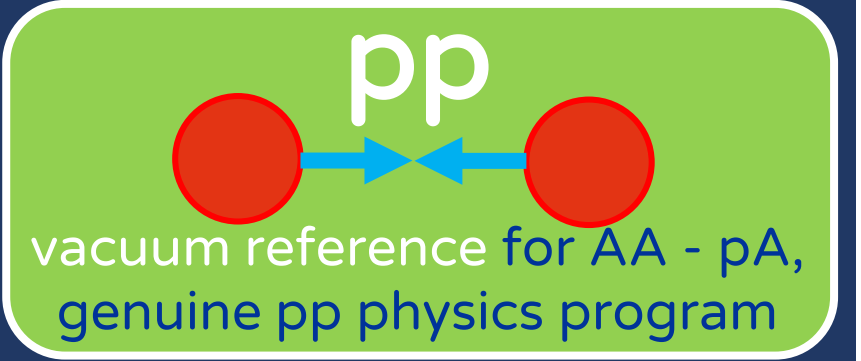

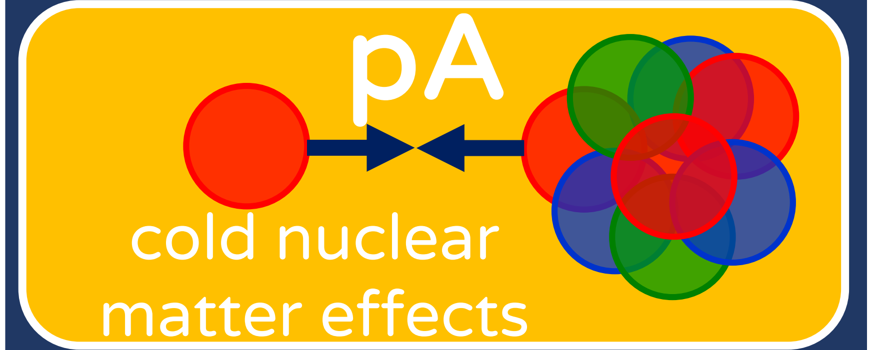

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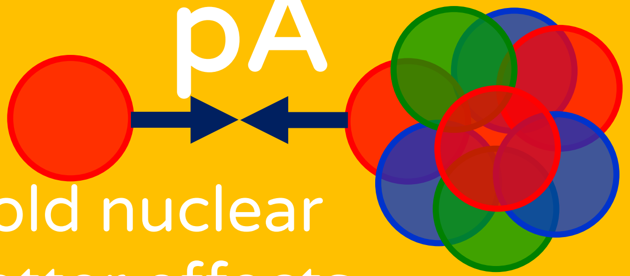
➡ Focus on pA and AA Run 2 results

pp

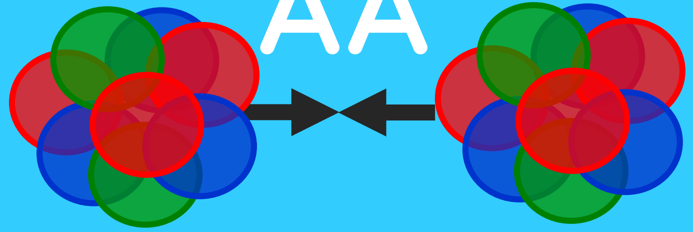
vacuum reference for AA - pA, genuine pp physics program

pA



cold nuclear matter effects

AA



hot matter effects

Observables

Nuclear modification factor R_{AA}

Medium effects quantified comparing AA particle yield with pp cross section, scaled by a geometrical factor ($\propto N_{coll}$)

$$R_{AA} = \frac{Y_{AA}}{\langle T_{AA}\rangle \sigma_{pp}}$$

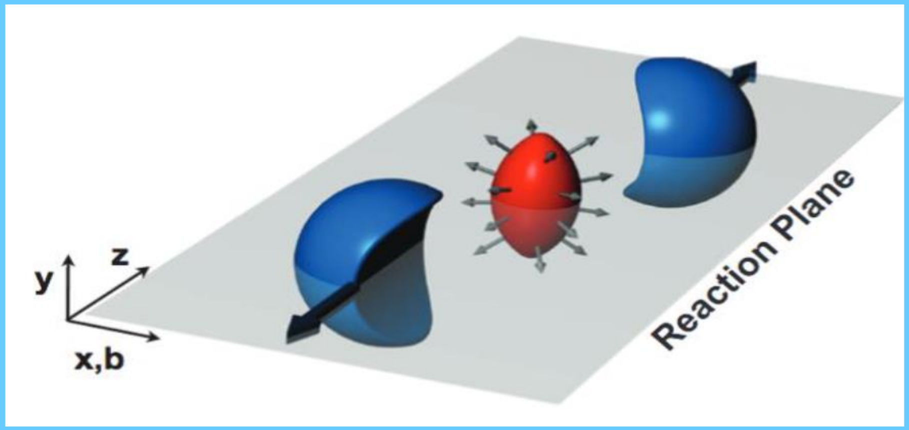
- no medium effects
  → $R_{AA} = 1$
- hot/cold matter effects
  → $R_{AA} \neq 1$

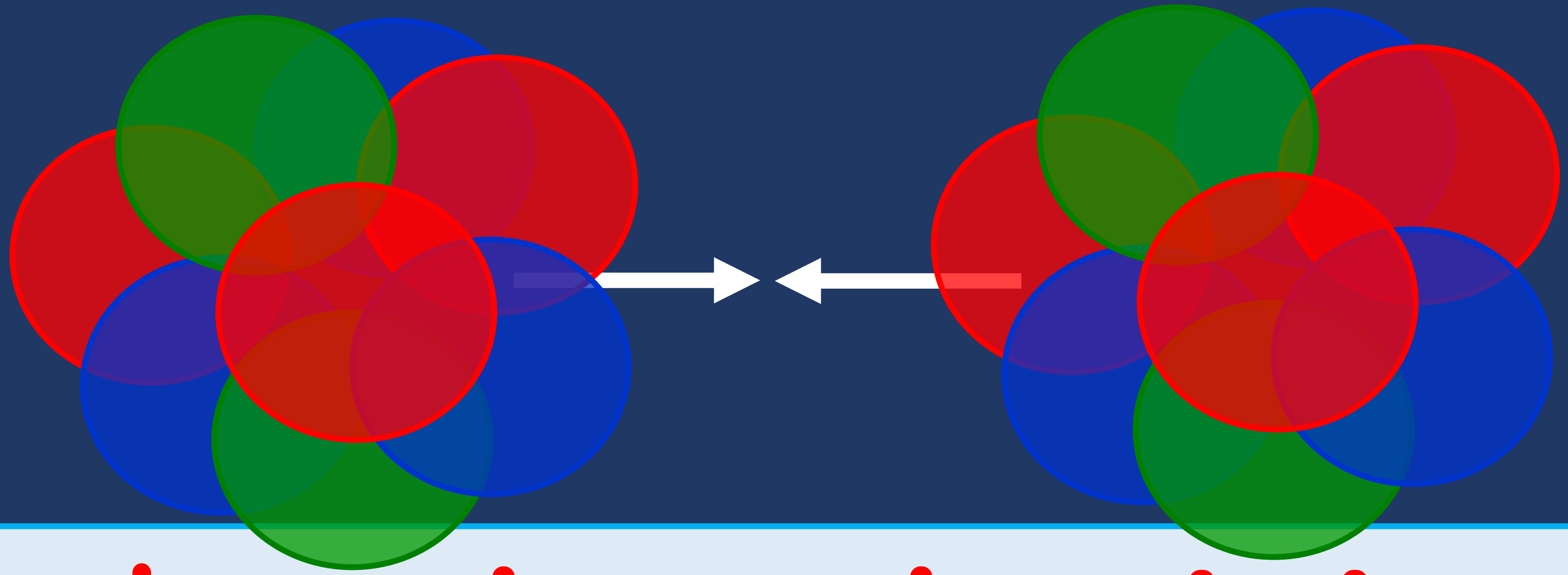
Azimuthal anisotropy v_2

Multiple interactions in the medium convert initial geometric anisotropy into particle momenta anisotropy

→ elliptic flow (v_2) is the 2nd coeff. of the Fourier expansion of the azimuthal distributions of the produced particles

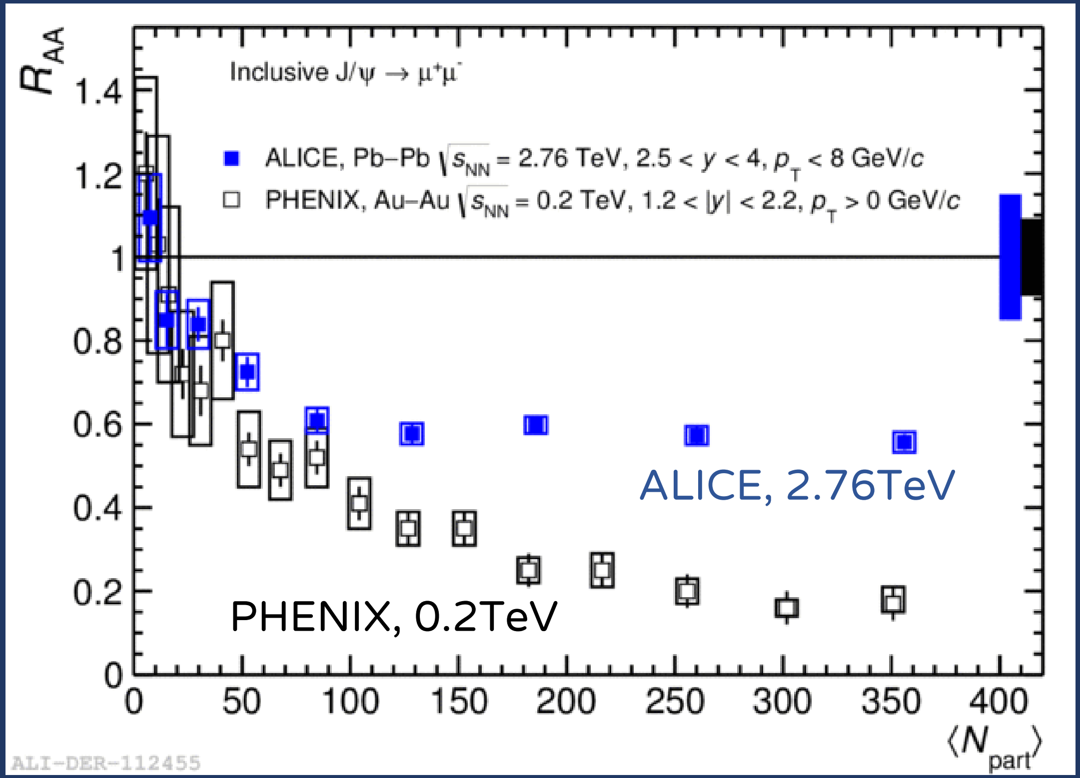
$$v_2 = \langle \cos 2(\phi_{particle} - \Psi_{EP}) \rangle$$

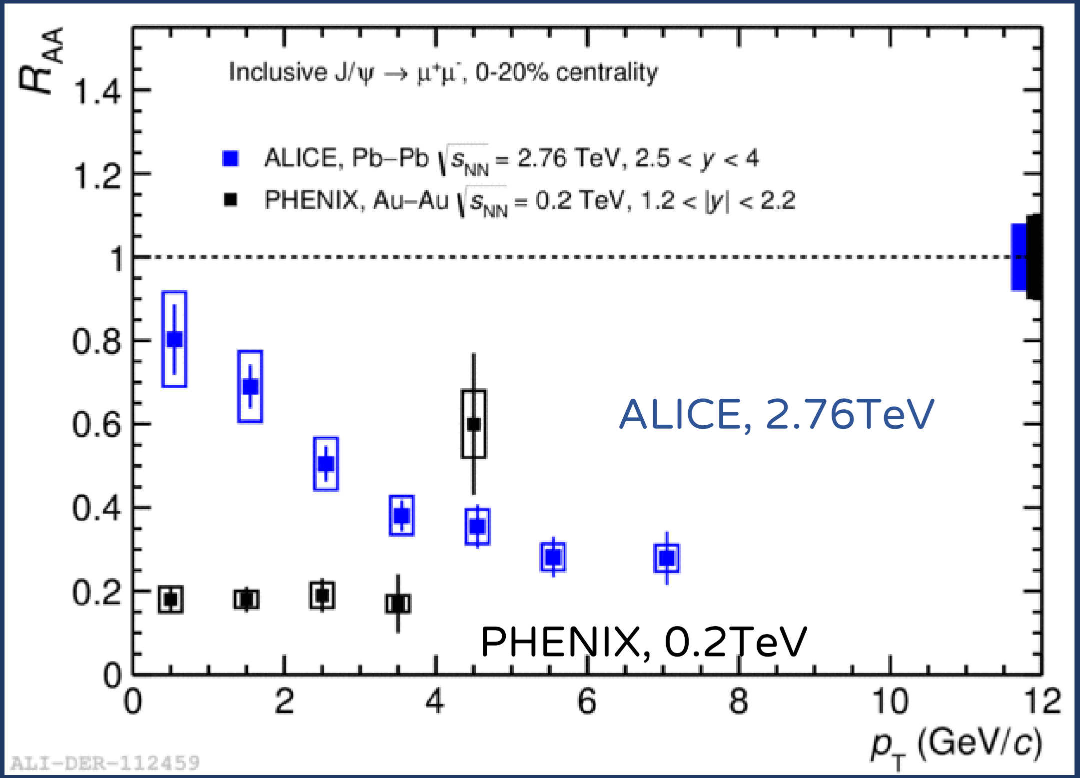




quarkonium in AA

J/ψ R_{AA} at forward-*y* - Run 1



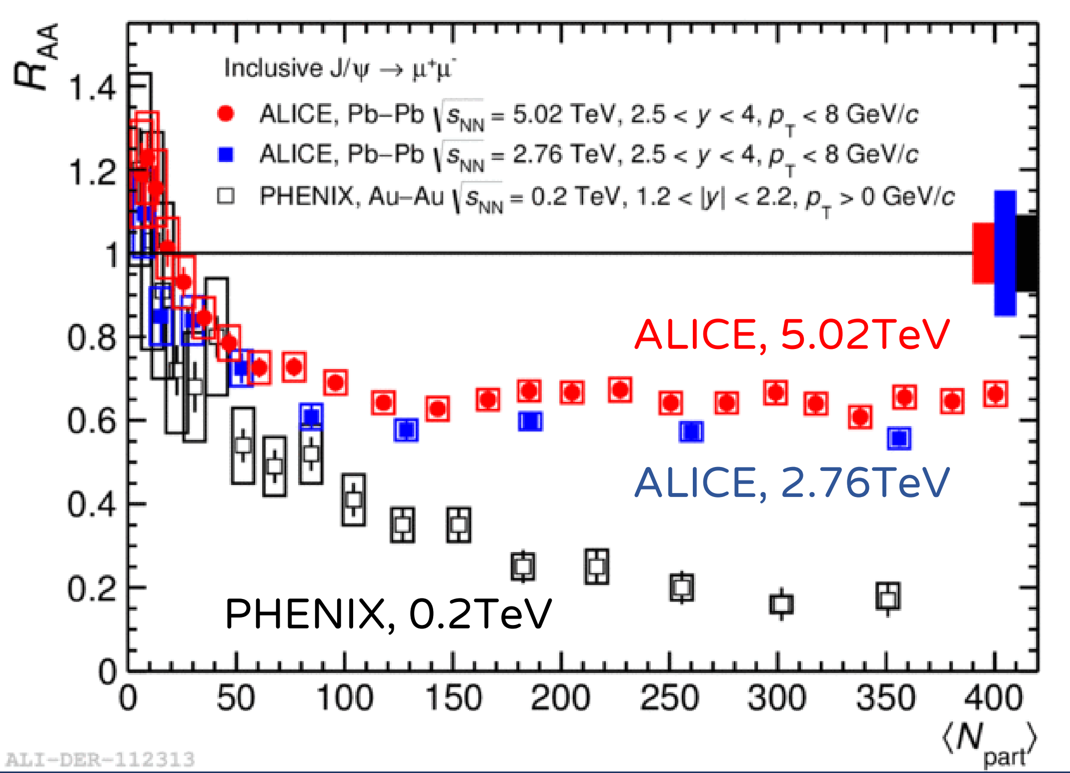


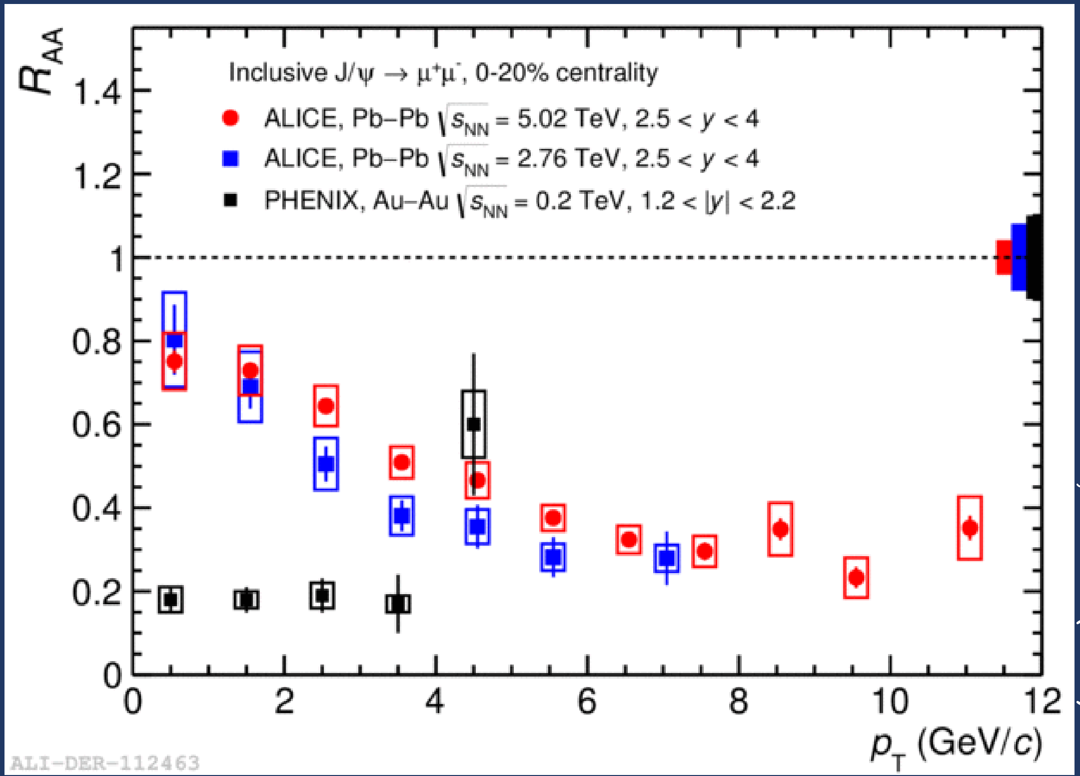
ALICE, JHEP 05 (2016) 179
ALICE, PLB 734 (2014) 314
ALICE, PRL 109 (2012) 072301

Low p_T J/ψ ➡
- Stronger centrality suppression at RHIC, in spite of LHC larger energy densities
- Very different p_T dependence

} suppression + regeneration mechanisms

J/ψ R_{AA} at forward-*y* - Run 2

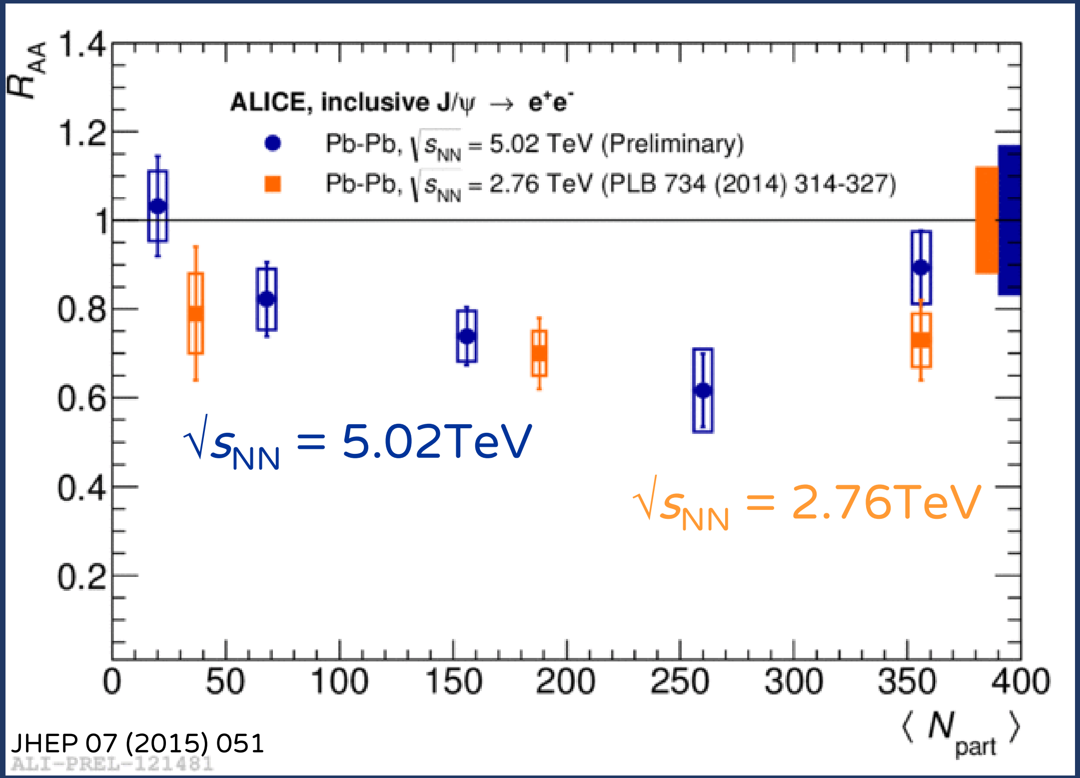


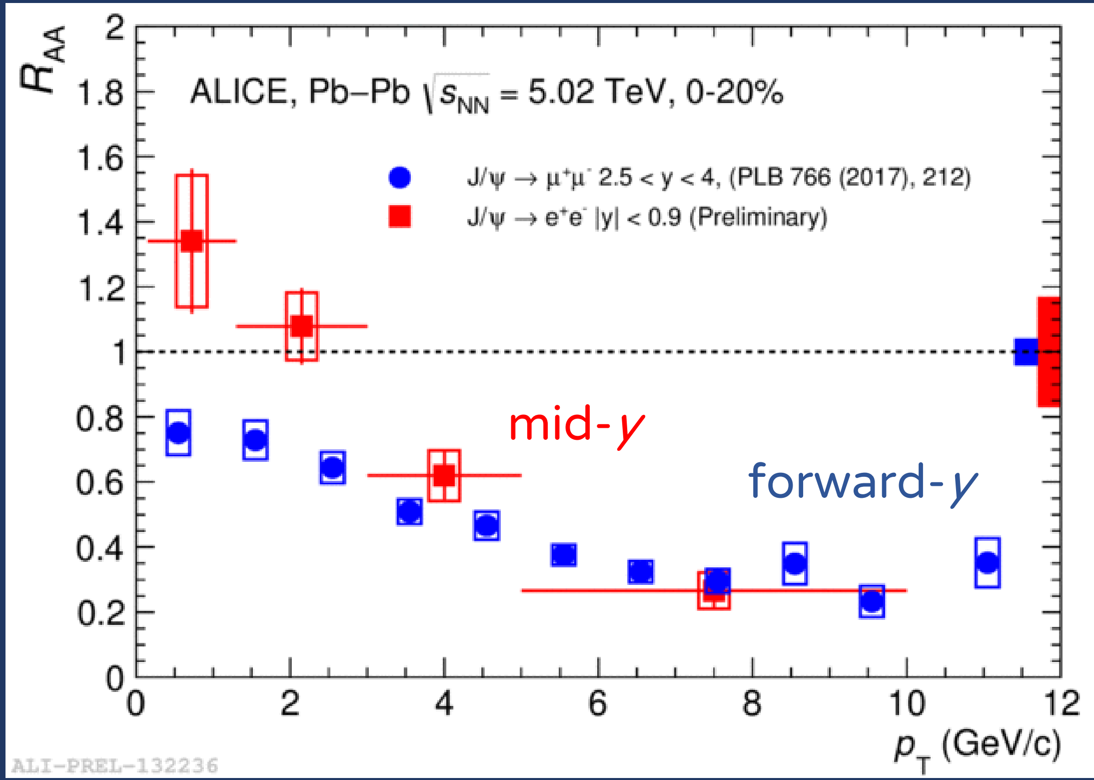


ALICE, PLB766 (2017) 212

➡ J/ψ suppression in Run2 confirms Run1 observation, with an increased precision

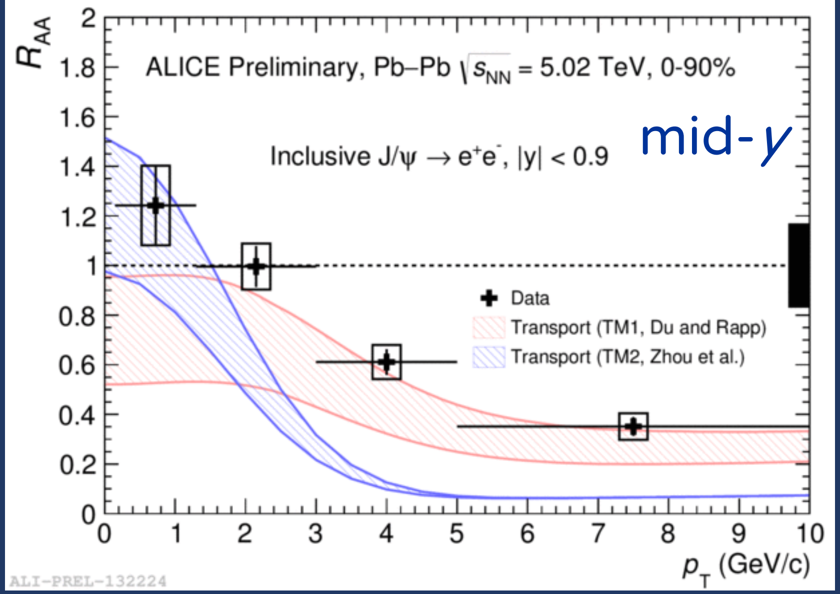
J/ψ R_{AA} at mid-y - Run 2

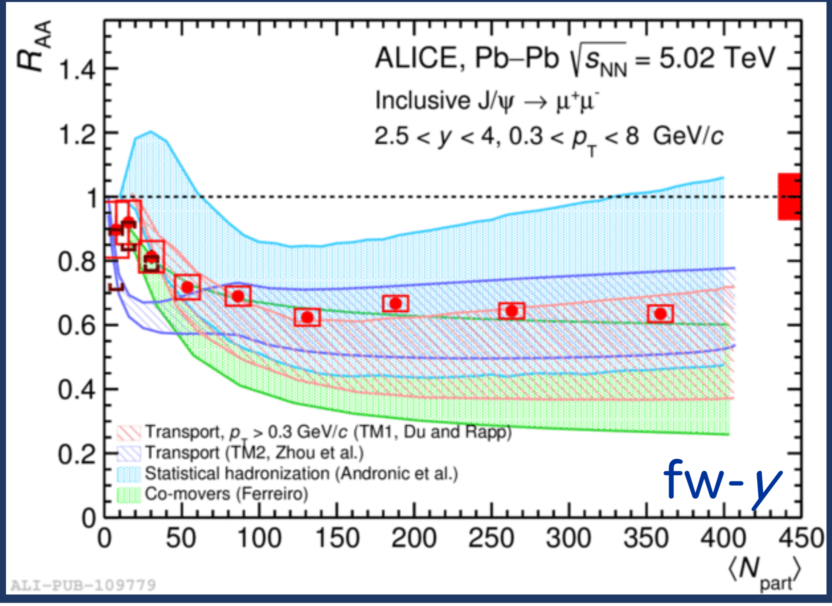




- No significant $\sqrt{s}$-dependence at mid-rapidity, confirming observation at forward-y
- Increase at low p_T compared to forward-y

Comparison with theoretical models





Transport models:
based on thermal rate eq. with continuous J/ψ dissociation and regeneration in QGP and hadronic phase

X. Zhao, R. Rapp NPA 859 (2011) 114, K. Zhou et al, PRC 89 (2011) 05491

Statistical hadronization:
J/ψ produced at chemical freeze-out according to their statistical weight

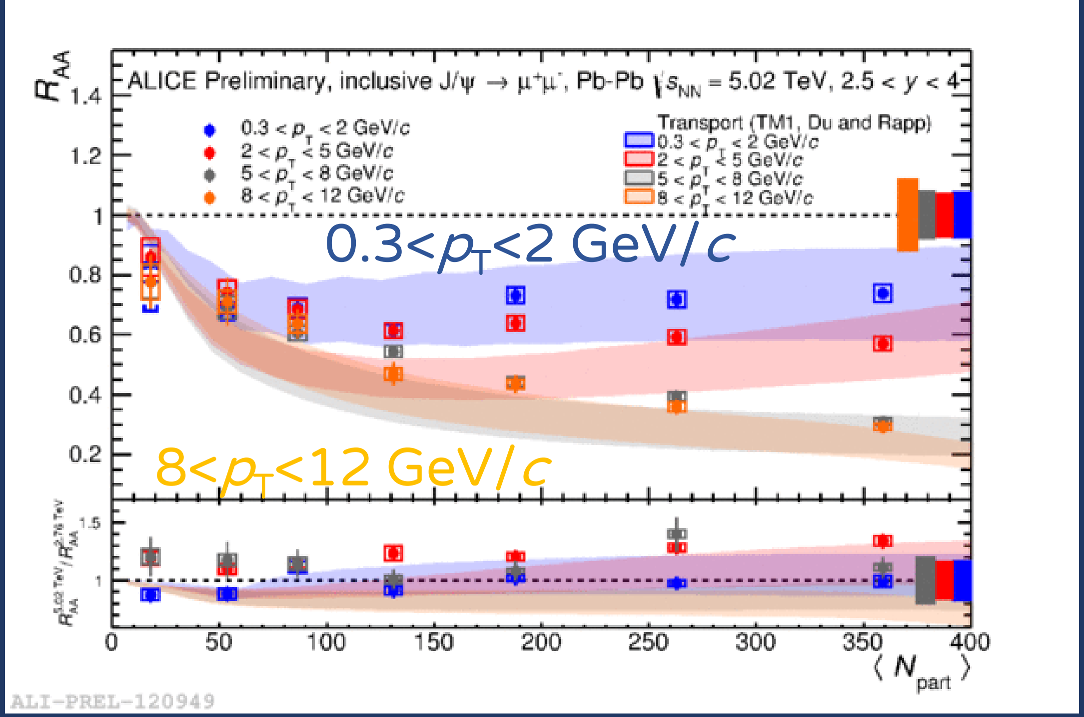
A. Andronic et al., NPA 904-905 (2013) 535

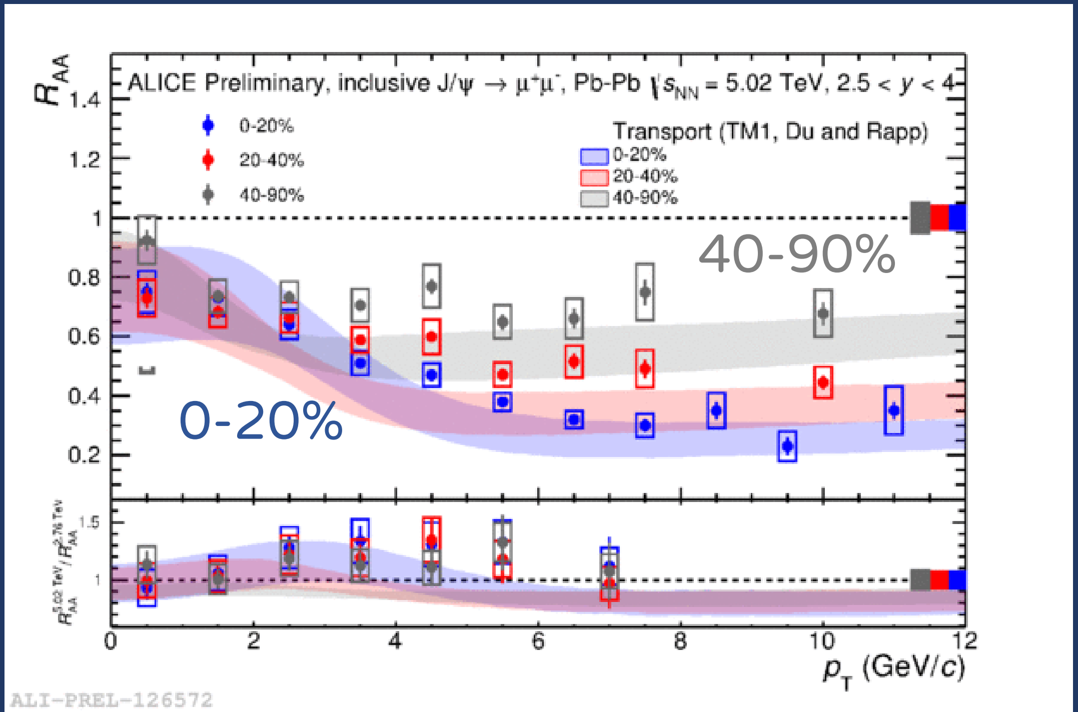
Comover model:
J/ψ dissociated via interactions with partons - hadrons + regeneration contribution

E. Ferreiro, PLB749 (2015) 98, PLB731 (2014) 57

- All models fairly describe the data, as already in Run1
- but large uncertainties associated to charm cross section and shadowing (data precision better than the theory one)

Multi-differential R_{AA} at forward-y





Zhao et al., NPA 859 (2011) 114

- R_{AA} vs p_T for different centrality bins (and vice-versa) at $\sqrt{s_{NN}}$=5.02 TeV

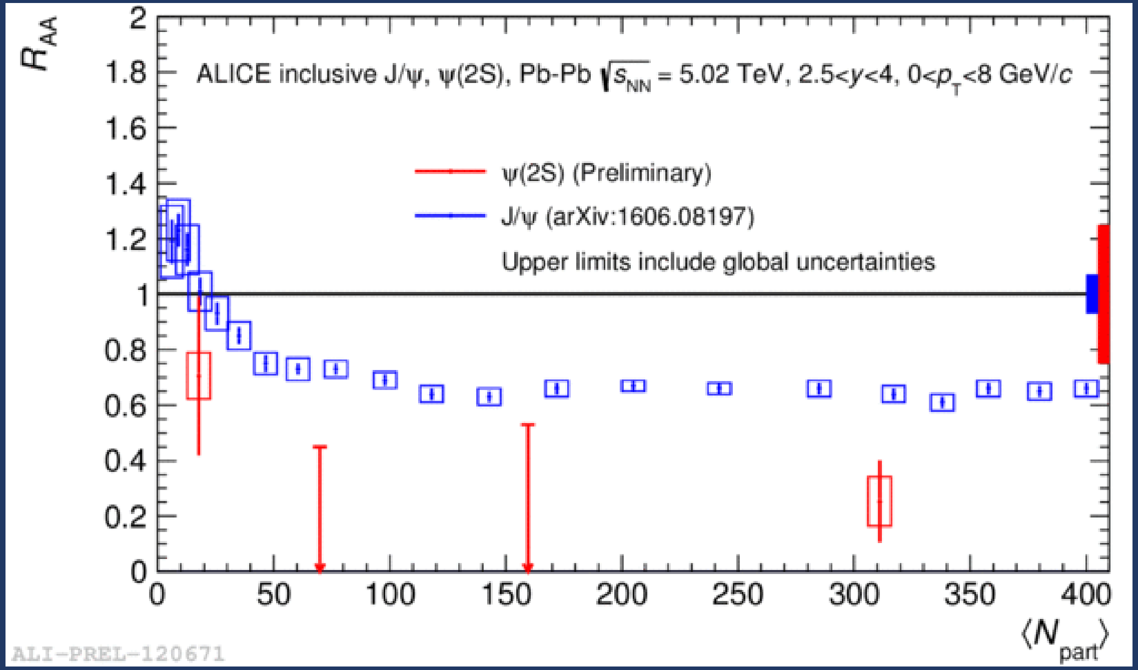
Striking features observed
→ no R_{AA} centrality dependence in 0.3<p_T<2 GeV/c
→ ~80% suppression for central events at p_T~10 GeV/c

- Increase in results precision opens up the way to precise model comparisons

$\psi(2S)$ R_{AA}

➡ $\psi(2S)$ shows a stronger suppression than the J/ψ, in semi-central and central collisions

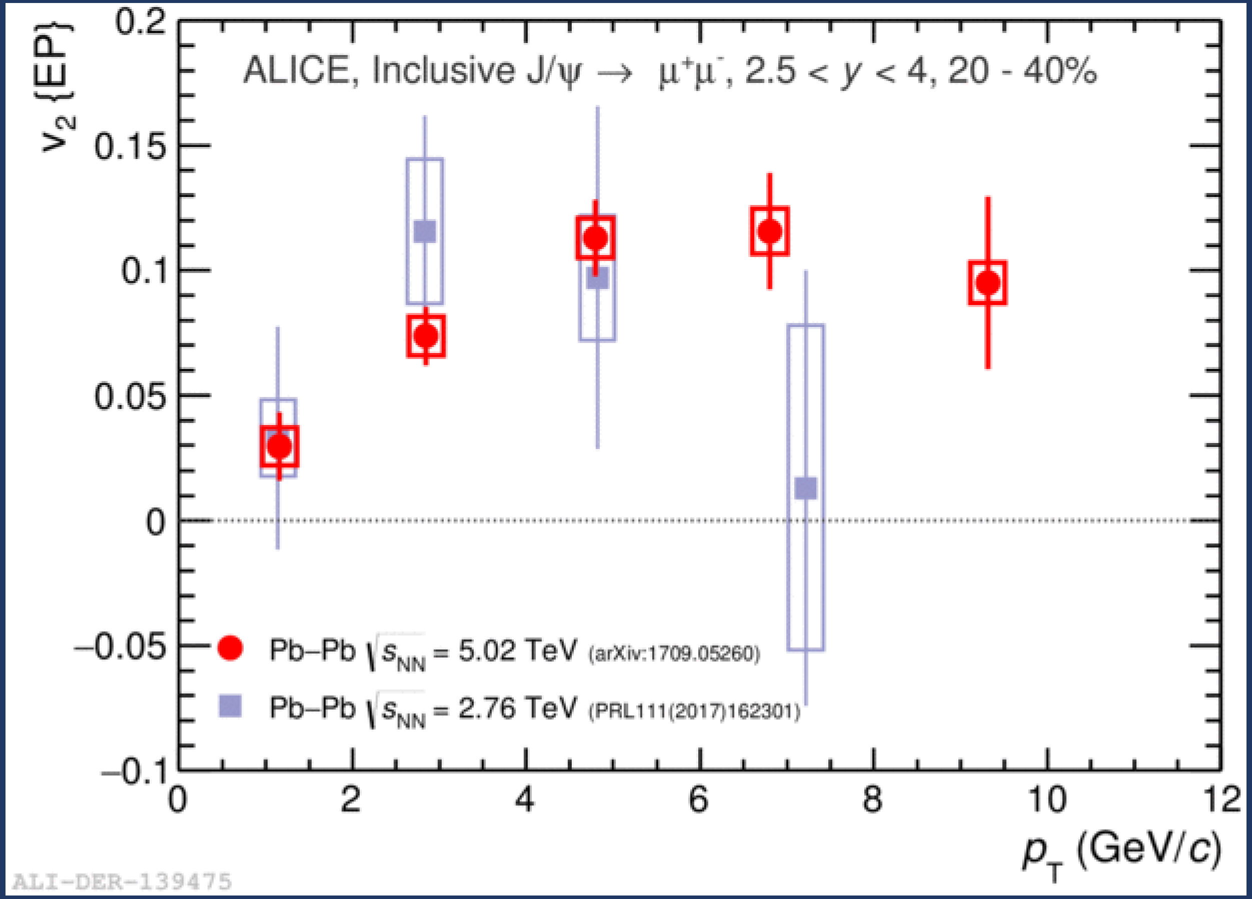
However, the low significance limits the precision of the measurements



➡ Results at $\sqrt{s_{NN}}$ = 5.02 TeV compatible with those at $\sqrt{s_{NN}}$ = 2.76 TeV

➡ Good agreement also with CMS results at $\sqrt{s_{NN}}$ = 5.02 TeV

J/ψ elliptic flow

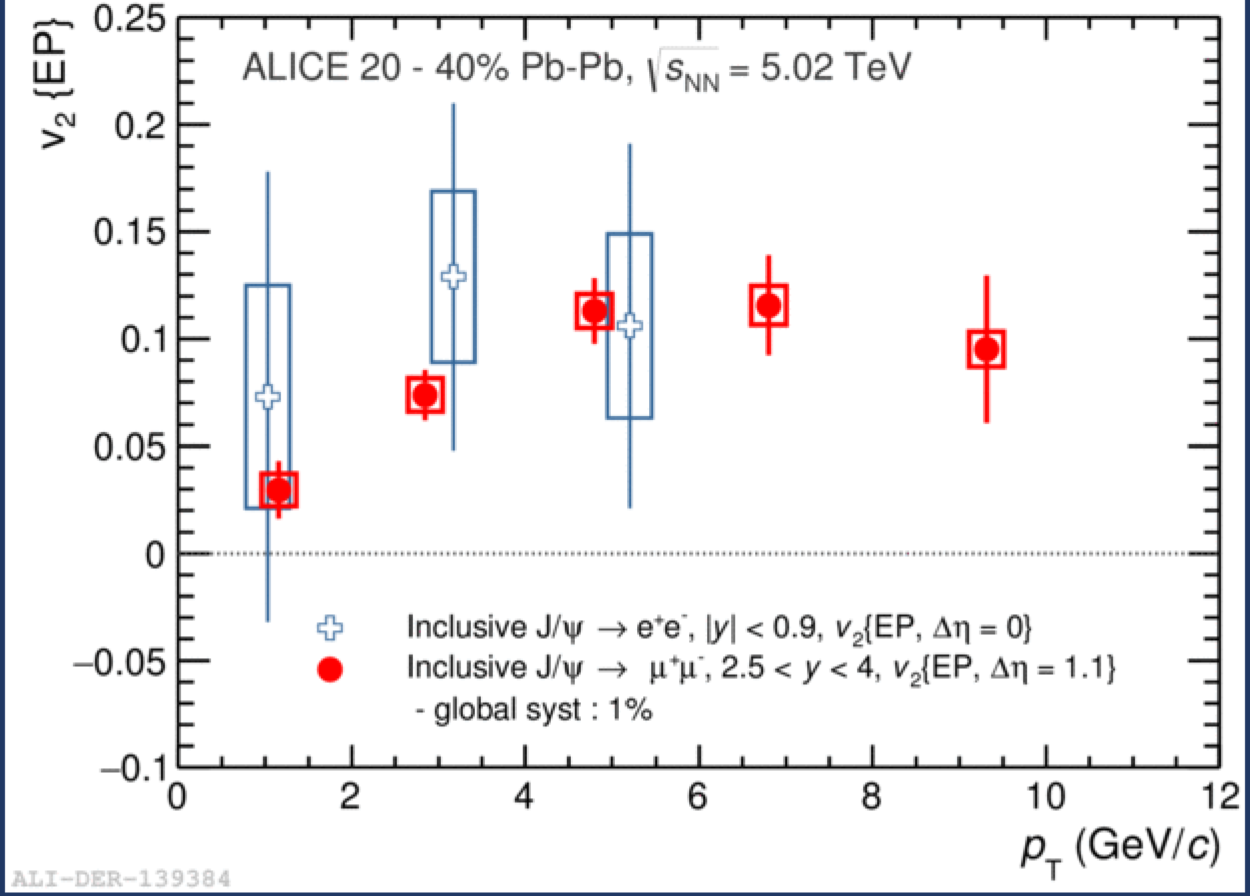


ALICE, arXiv:1709.05260

J/ψ from recombination should inherit the charm flow, leading to a v_2 signal

- ALICE Run 1 result
  → indication of non-zero flow (2.7σ)
- Higher Run2 precision
  → evidence for non-zero flow
  (7σ effect in $4<p_T<6$ GeV/c)

J/ψ elliptic flow: mid and forward-y



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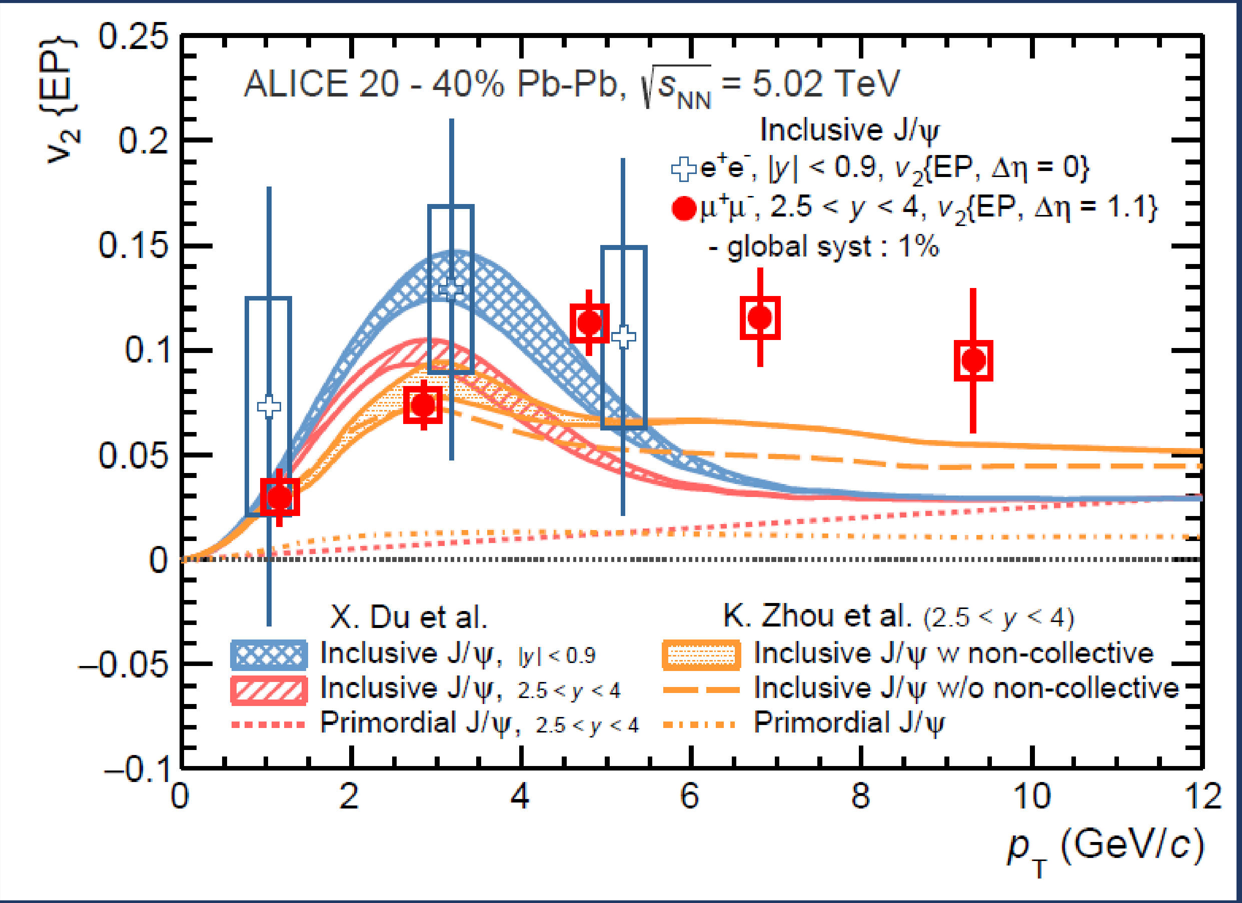
- First J/ψ v_2 measurement at mid-y
  → agreement with forward-y result

J/ψ elliptic flow: theory models



ALICE, arXiv:1709.05260
Zhou et al., PRC89(2014) 054911
Du et al., NPA943 (2015) 147

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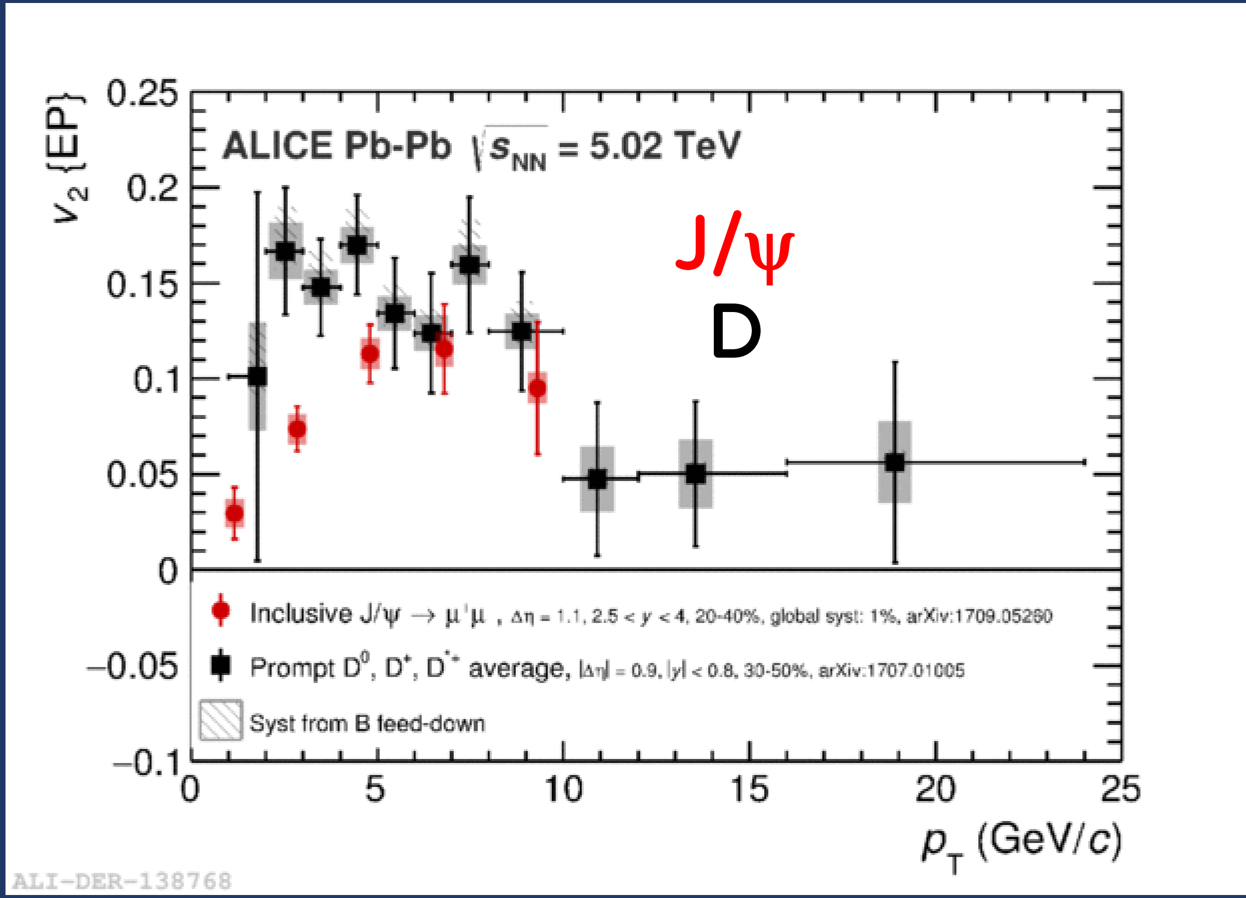
- First J/ψ v_2 measurement at mid-y
  → agreement with forward-y result
- Comparison with models:
  → **low p_T: v_2 reproduced** including a strong J/ψ regeneration component
  → **high p_T: v_2 underestimated** (prompt J/ψ from CMS also show $v_2 \neq 0$)

J/ψ elliptic flow: comparison with open charm



ALICE, arXiv:1707.01005

- Similar v_2 observed for open charm

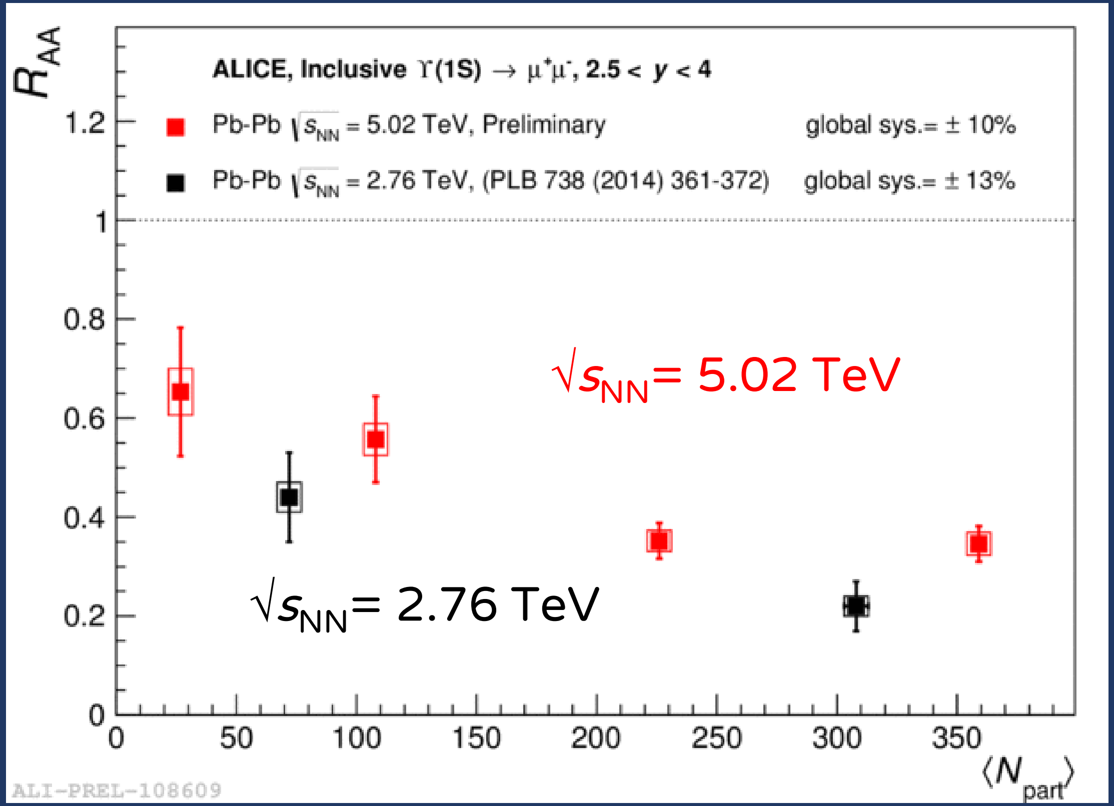
  → different kinematic range:

  J/ψ: 2.5 < y < 4, centrality= 20-40%
  D: $|y|$ < 0.8, centrality= 30-50%

  → Low p_T v_2 larger for D

- Charm quarks strongly interact in the medium
- Comparison between J/ψ and D flow can give insights on flow properties of heavy vs light quarks

Bottomonia in ALICE



- Strong Υ(1S) suppression vs centrality, similar, within uncertainties, to the $\sqrt{s_{NN}}$= 2.76TeV one

- bottomonium states accessible with higher precision in Run 2

- Hint for stronger Υ(2S) suppression vs Υ(1S), as observed by CMS

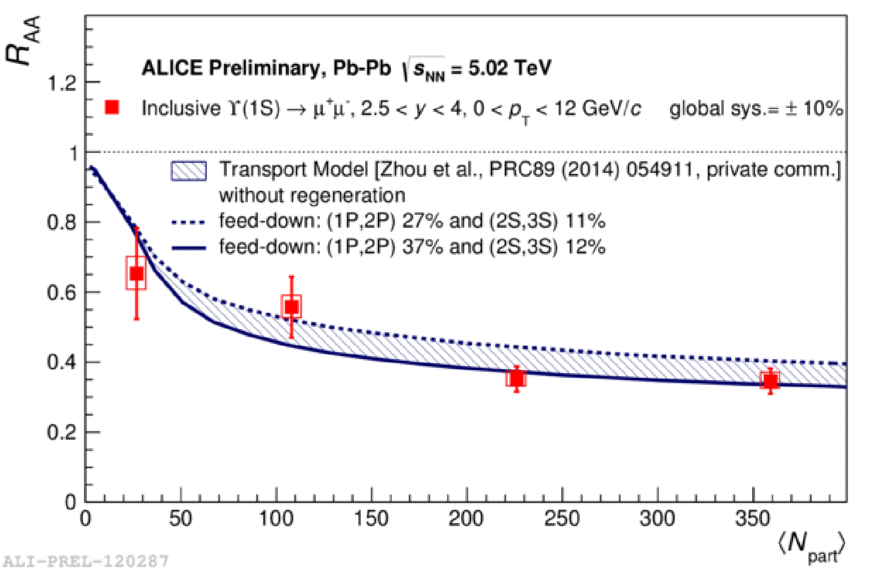
R_{AA} (Υ(2S)) = 0.26± 0.12 ± 0.06(sys.)

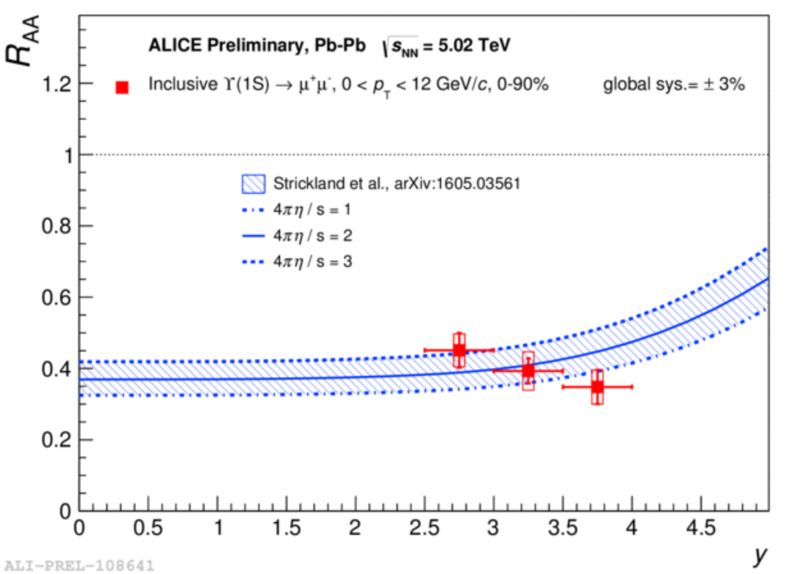
<

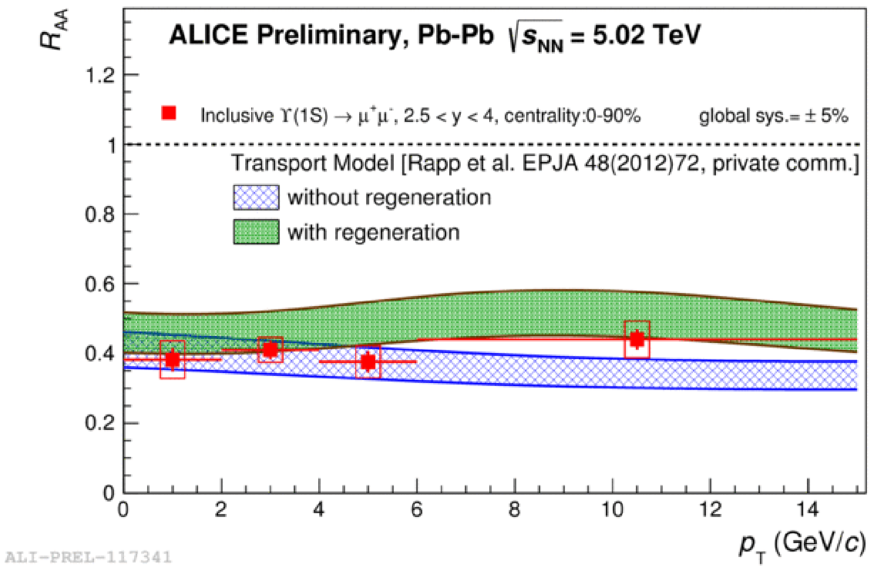
R_{AA} (Υ(1S)) = 0.40 ± 0.03 ± 0.04(sys.)

- suppression of directly produced Υ(1S)?
→ feed-down contribution~30%

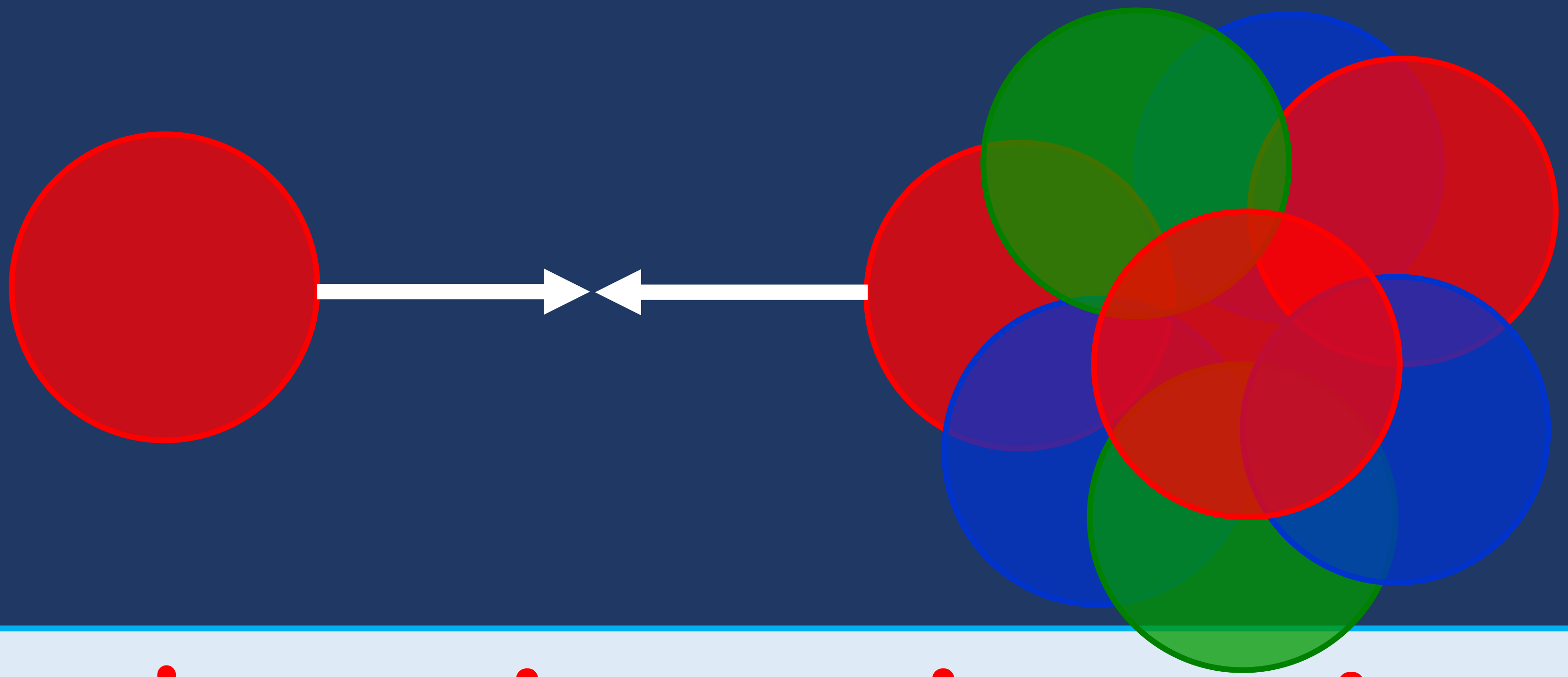
Υ(1S) in ALICE: theory comparison







- Transport and anisotropic hydrodynamical models qualitatively describe the centrality and the p_T evolution
- Some tension in the *y* dependence?
- No need for significant contribution of regenerated Υ(1S)

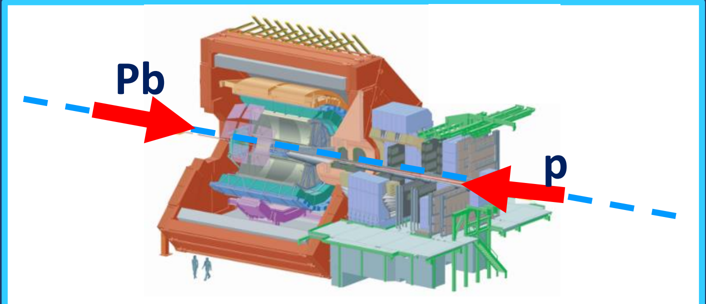


quarkonium in pA

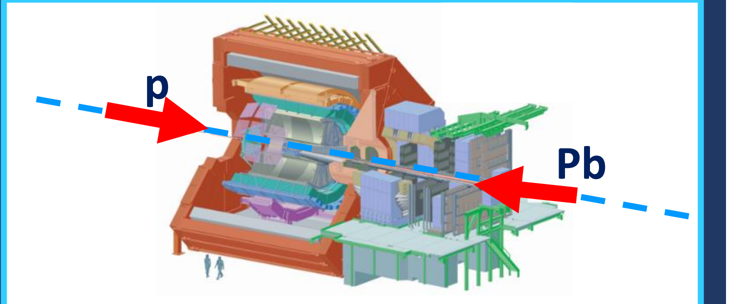
J/ψ in p-Pb collisions

pA collisions are a tool to:
- Disentangle among CNM effects
- Investigate role of CNM effects underlying AA collisions
- Search for possible hot matter effects?

➡ Two beam configurations: p-Pb and Pb-p



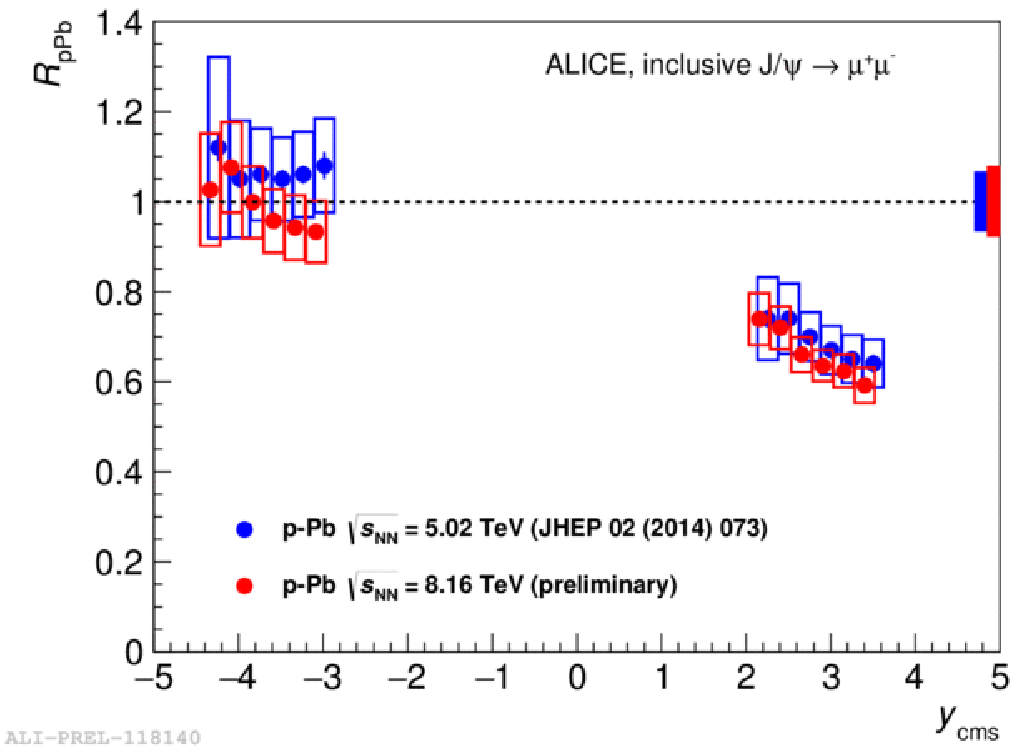
$-4.46<y_{CMS}<-2.96$



$2.03<y_{CMS}<3.53$

➡ Clear J/ψ suppression at forward-y, while R_{pA} is compatible with unity at backward-y

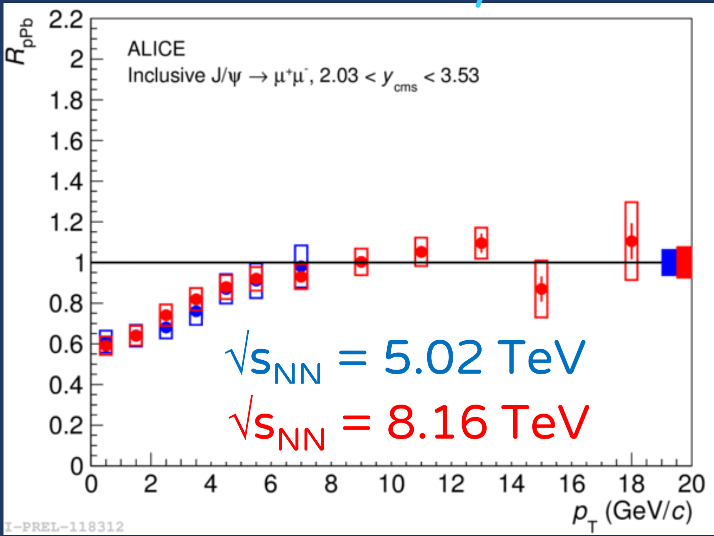
➡ Compatible R_{pPb} at $\sqrt{s_{NN}}$ = 5.02 and 8.16 TeV (slightly different x_F range)



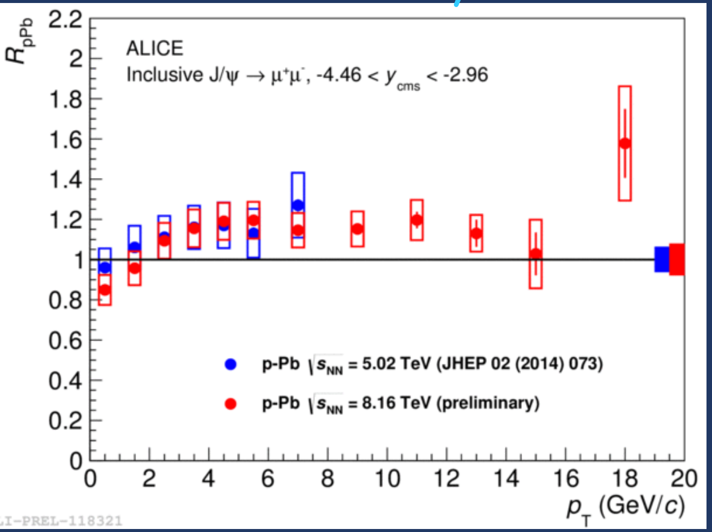
CERN-ALICE-PUBLIC-2017-001

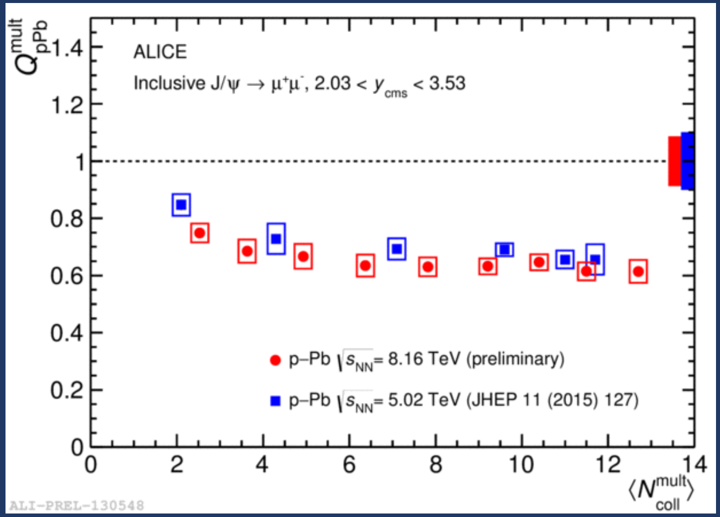
J/ψ in p-Pb collisions: Run1 vs Run2

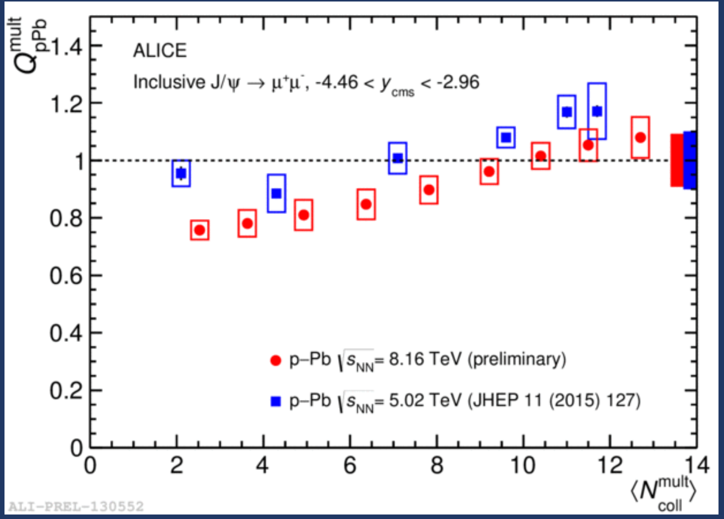
forward-y



backward-y







p_T dependence:

- p_T coverage extended to 20 GeV/c
- R_{pPb} increases with p_T at forward y
- weaker dependence at backward y

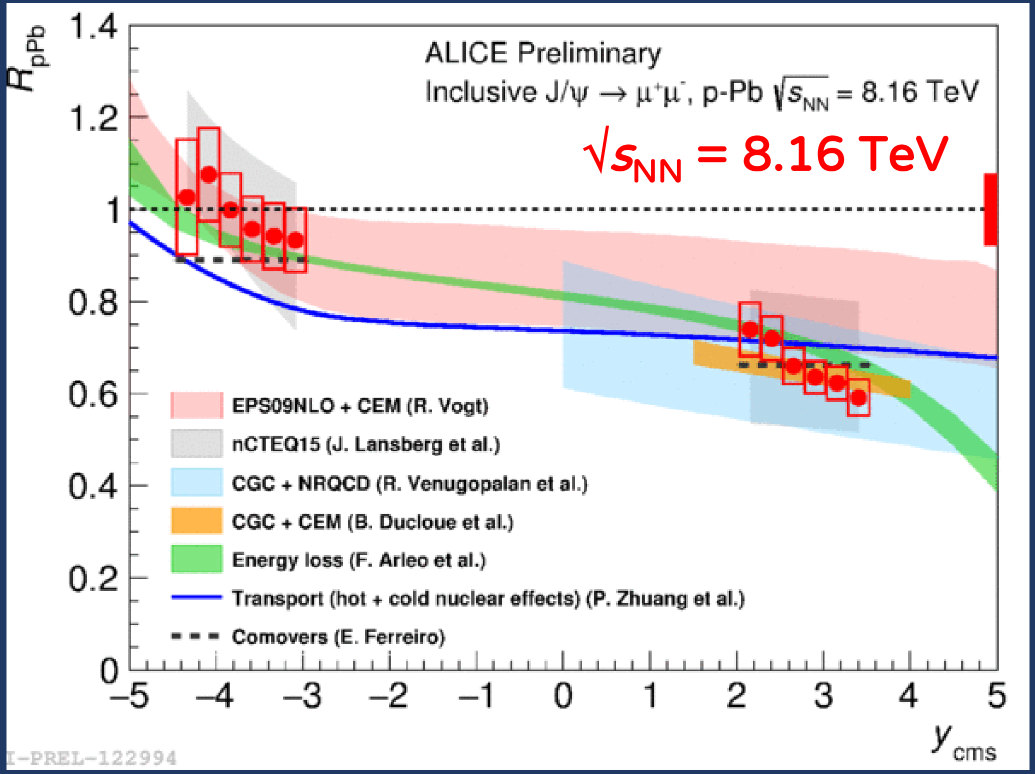
centrality dependence:

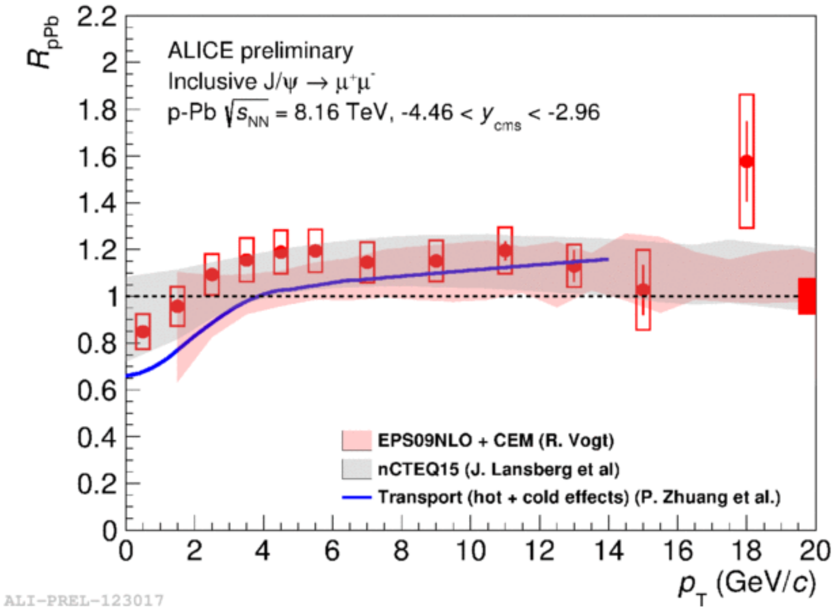
- finer binning at $\sqrt{s_{NN}}$ = 8.16TeV wrt 5.02 TeV
- **the nuclear modification factor decreases with N_{coll} at forward y while an opposite trend is observed at backward y**

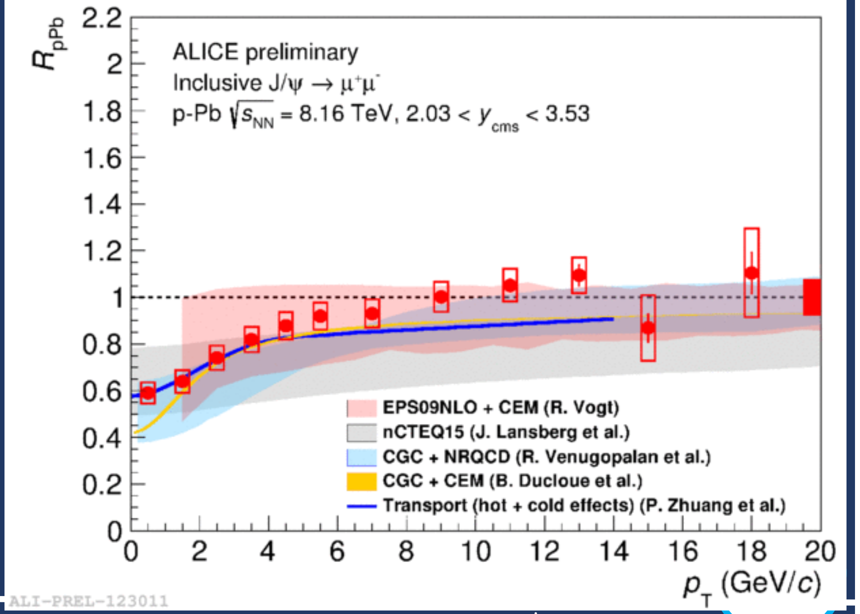
Comparison with theory models

- Good agreement between data and models based on shadowing and/or energy loss, as at $\sqrt{s_{NN}}$ = 5.02 TeV

CERN-ALICE-PUBLIC-2017-001





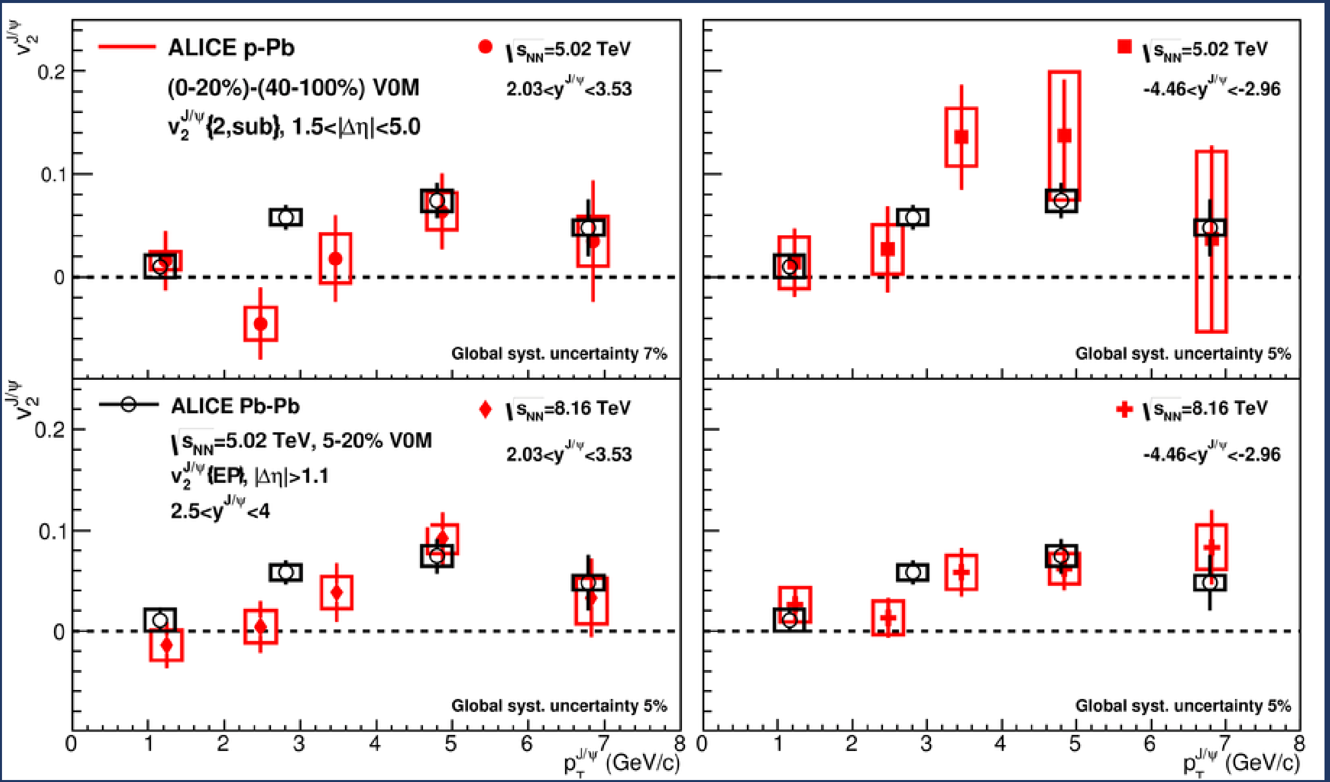


- Size of theory uncertainties (mainly shadowing) still limits a more quantitative comparison

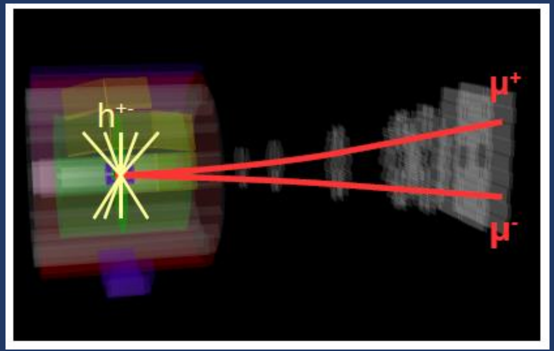
Ducloue et al,PRD91(2015)114005, Lansberg et al,EPJC77(2017)1,Ma et al,PRD92(2015)071901,Chen et al,PLB765(2017)323,Arleo,Vogt arXiv:1707.09973

J/ψ v_2 in p-Pb

Azimuthal correlations between forward / backward J/ψ and mid-*y* charged particles



ALICE, arXiv:1709.06807, ALICE, arXiv:1709.05260



- p_T<3 GeV/*c* → v_2 compatible with 0 (in line with expectation of no recombination)
- 3<p_T<6 GeV/*c* → v_2>0

v_2 >0 → suggests J/ψ participation to the collective flow of the medium

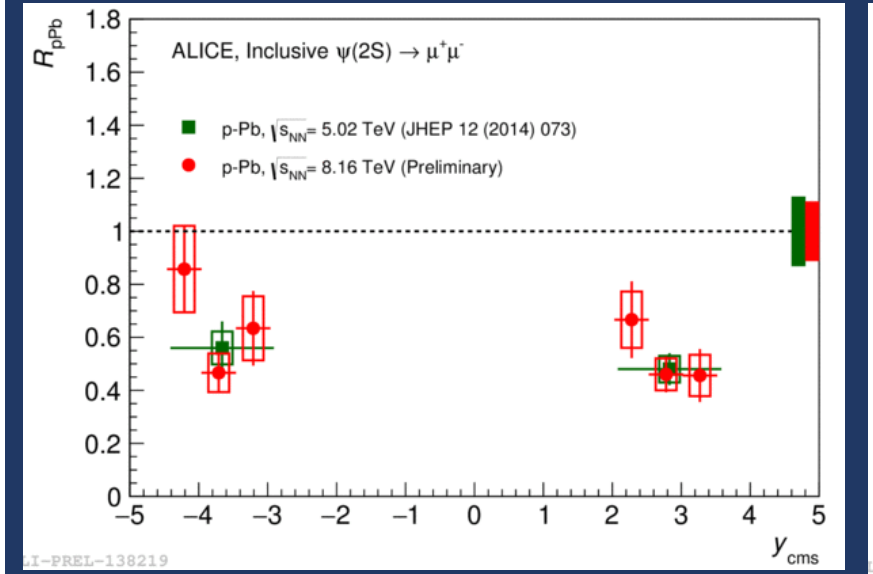
→ ~5σ total significance (forward + backward, 5.02+8.16 TeV)

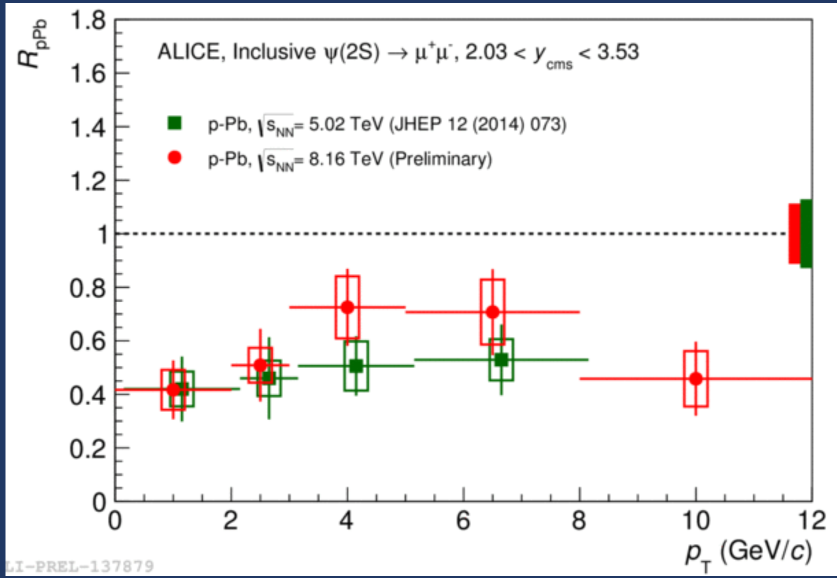
values comparable to J/ψ v_2 in central Pb-Pb collisions

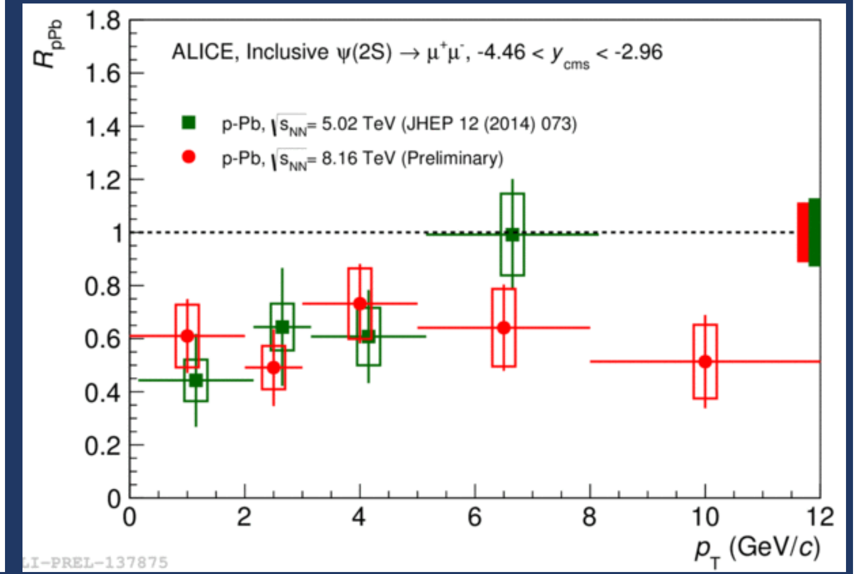
→ common mechanism at the origin of the J/ψ v_2?

ψ(2S) in pA collisions

Strong ψ(2S) suppression of at both forward and backward y



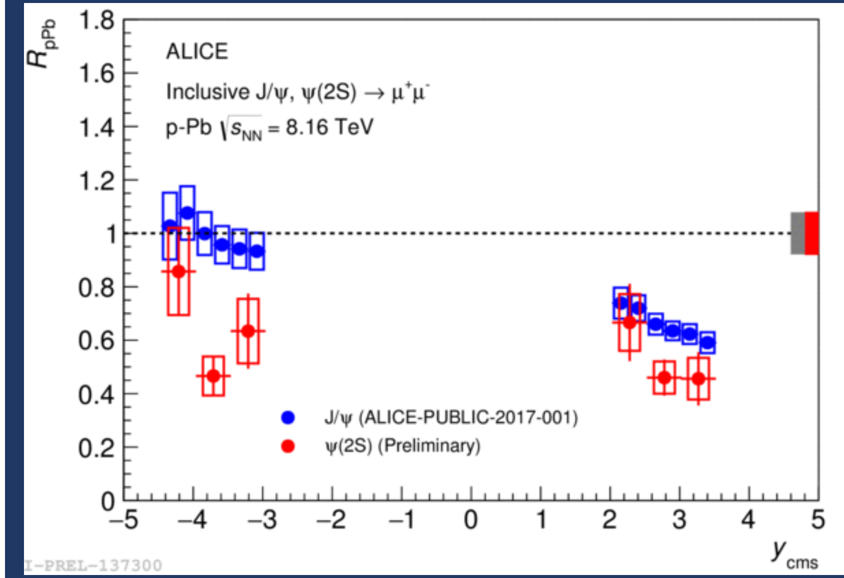


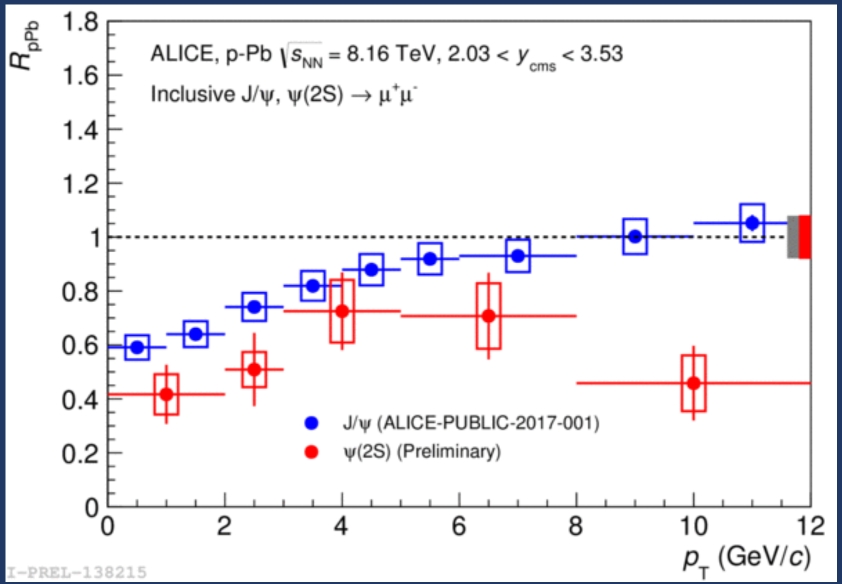


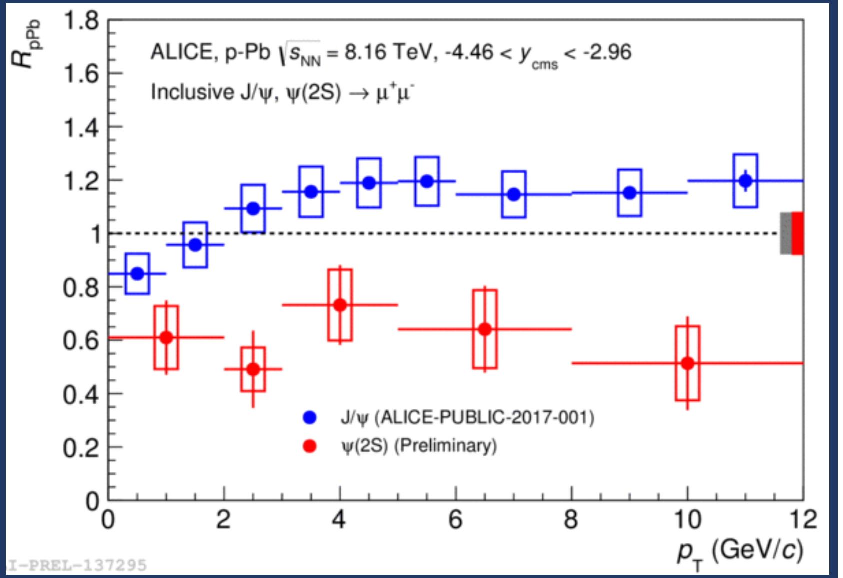
- Effect similar to the one observed at $\sqrt{s_{NN}}$ = 5.02 TeV
- No sizeable $\sqrt{s_{NN}}$ dependence, both in y and p_T

J/ψ and ψ(2S) comparison in pA

➡ Strong ψ(2S) suppression of at both forward and backward *y*



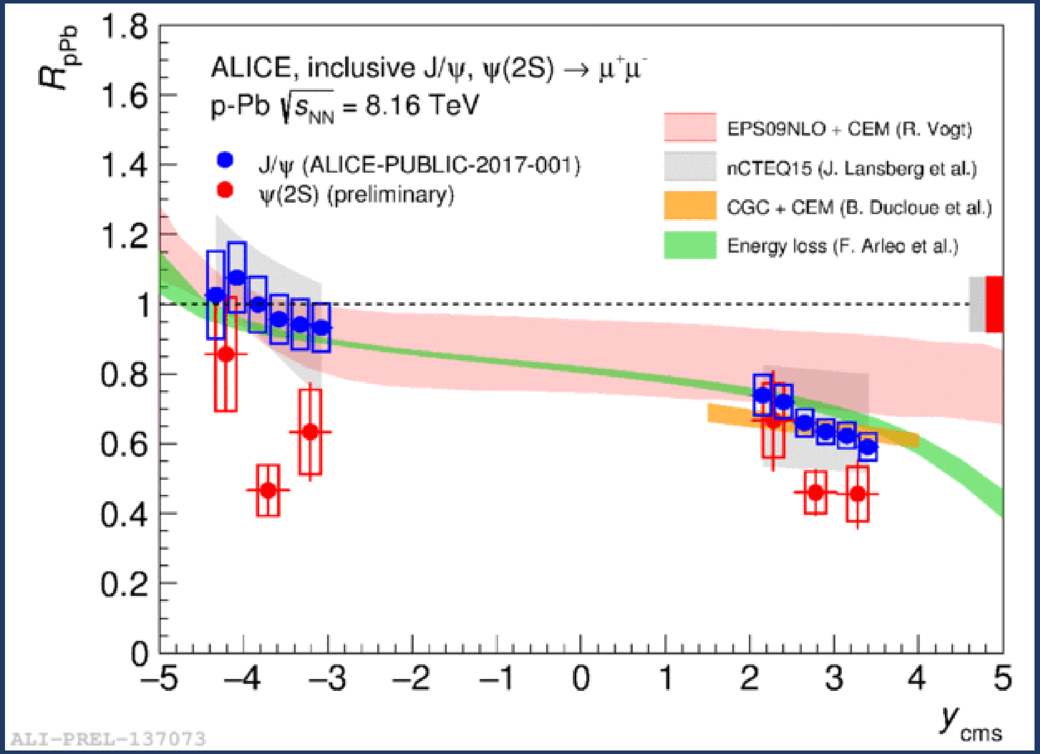


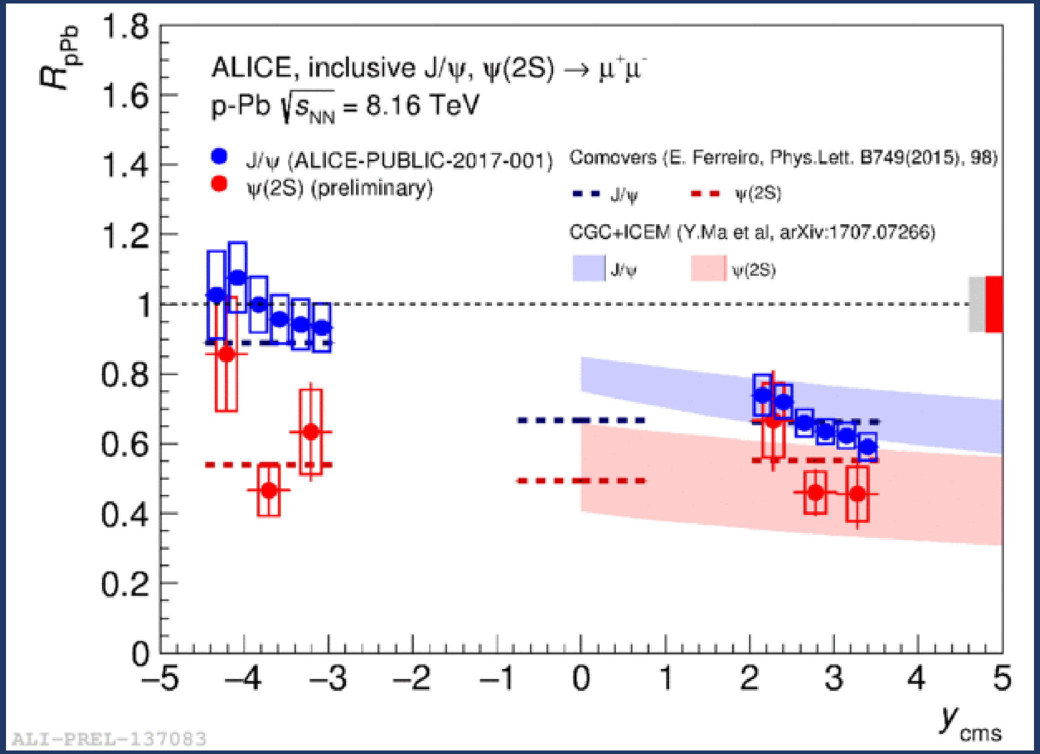


➡ ψ(2S) suppression is stronger than the J/ψ one, in particular at backward-*y*

➡ unexpected J/ψ and ψ (2S) different behavior since at LHC energies formation time > crossing time

J/ψ and ψ(2S) comparison with theory





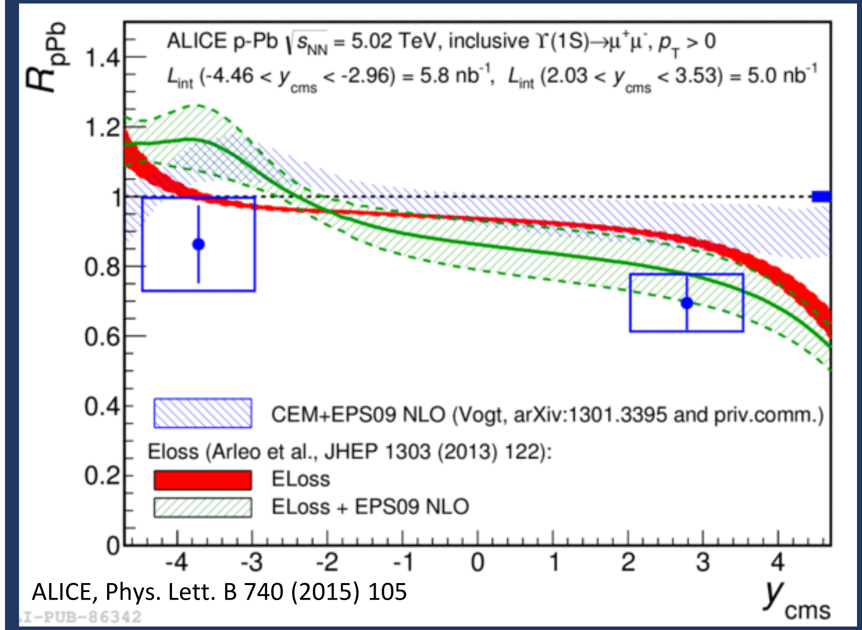
➡ shadowing/energy loss:

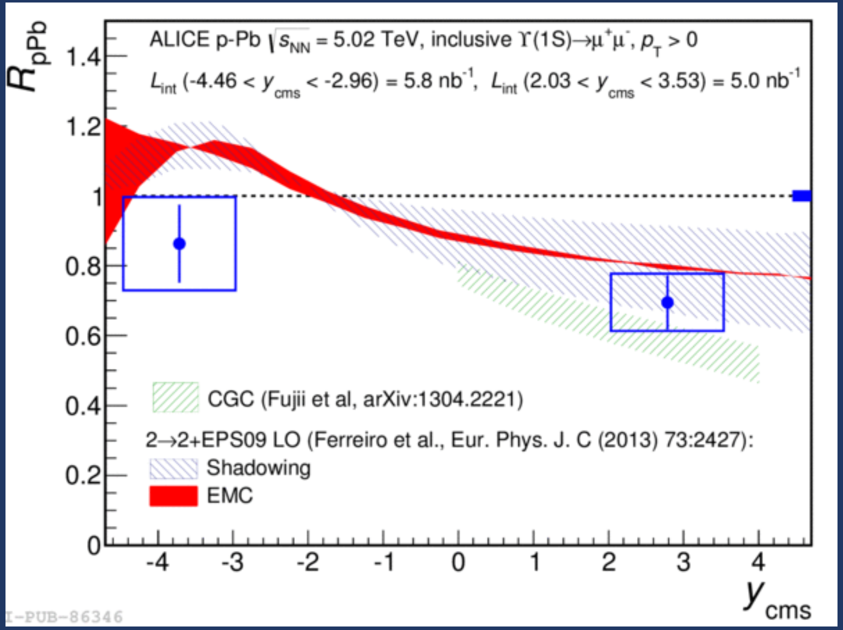
- similar for J/ψ and ψ(2S)
- not enough to describe the ψ(2S) suppression at backward-*y*

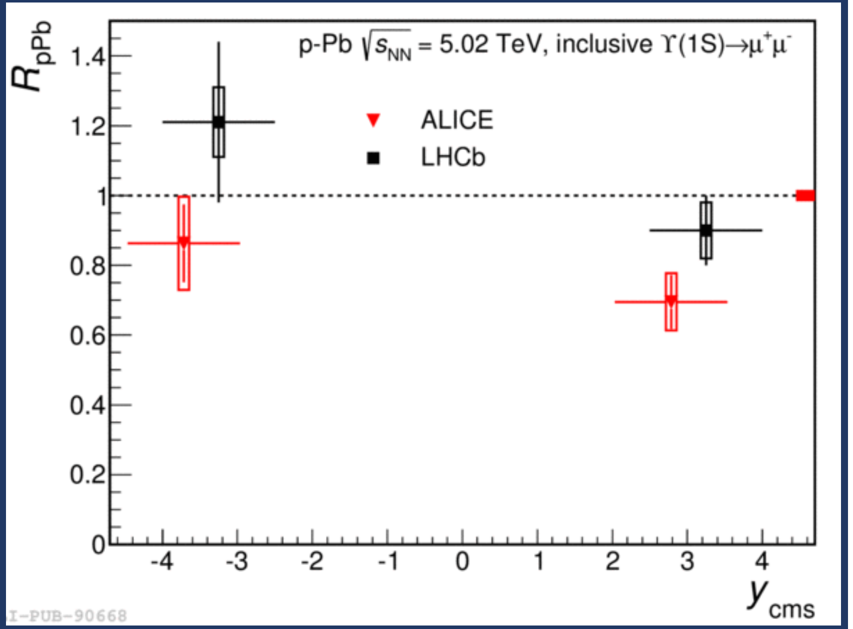
➡ need final state effects

- soft color exchanges between hadronizing cc and comoving partons (Ma and Venugopalan)
- "classical" comover model, with break-up σ tuned on low energy data (Ferreiro)

Υ in pA collisions – Run 1





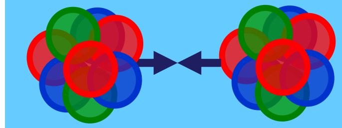


- Model predictions describe the measured R_{pPb} at forward y and tend to underestimate the suppression at backward y
- Compatible within (large) uncertainties with LHCb results
- Run 2 data will be soon available!

Conclusions

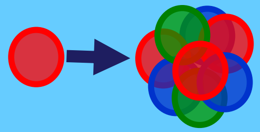
New high-precision results on flavor production in pA and AA collisions

AA



- J/ψ described by interplay of suppression and recombination mechanisms
- Significant J/ψ v_2 at intermediate p_T confirms formation by recombination
- Strong ψ(2S) suppression
- Hint for sequential suppression of bottomonium states

pA

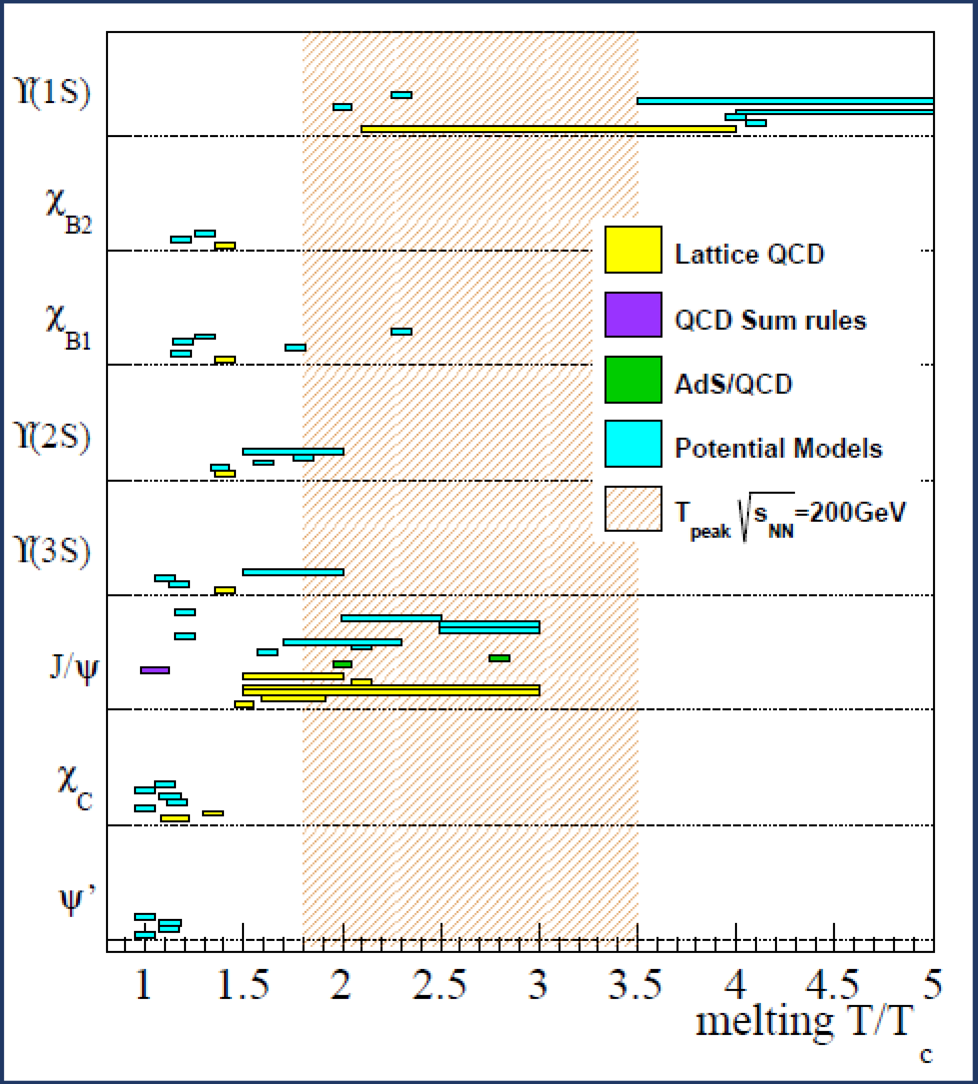


- Modification of J/ψ yields, with strong kinematic dependence, understood in terms of “standard” cold nuclear matter effects
- Size of J/ψ v_2 at intermediate p_T, reminiscent of the Pb-Pb one. Common mechanism at play?
- Strong ψ(2S) suppression due to final state effects?

Thanks!

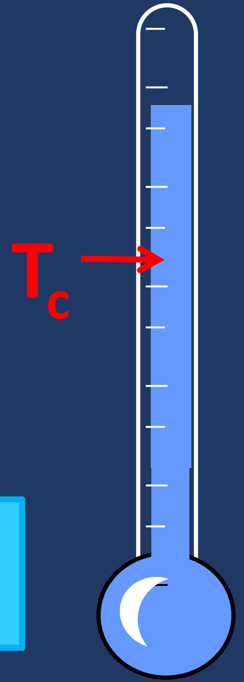
Backup slides

Quarkonium sequential melting



PHENIX, Phys.Rev C91, 024913

- **the original idea:**
  quarkonium production suppressed via color screening in the QGP
- **sequential melting:**
  differences in the quarkonium binding energies lead to a sequential melting with increasing temperature



Quarkonium as thermometer of the initial QGP temperature

Quarkonium sequential melting

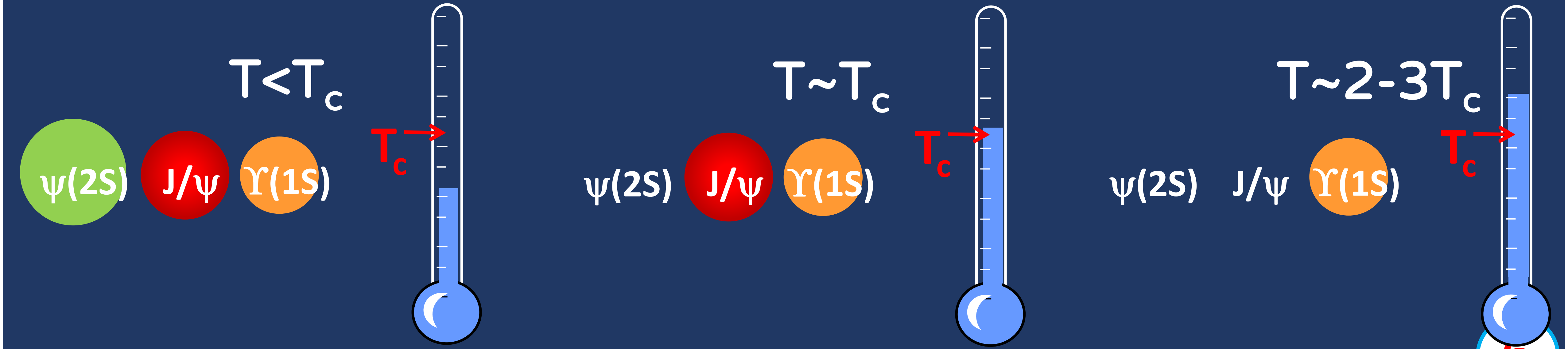
state	J/ψ	χ_c	ψ(2S)	ϒ(1S)	ϒ(2S)	ϒ(3S)
Mass(GeV)	3.10	3.51	3.69	9.46	10.0	10.36
ΔE (GeV)	0.64	0.22	0.05	1.10	0.54	0.20
r_o(fm)	0.50	0.72	0.90	0.28	0.56	0.78

(Digal,Petrecki,Satz PRD 64(2001) 0940150)

➡ **sequential melting:**

differences in the quarkonium binding energies lead to a sequential melting with increasing temperature

Quarkonium as thermometer of the initial QGP temperature



Caveat

Even if the “suppression-recombination” approach looks simple, a realistic description of the involved mechanisms is rather complex:

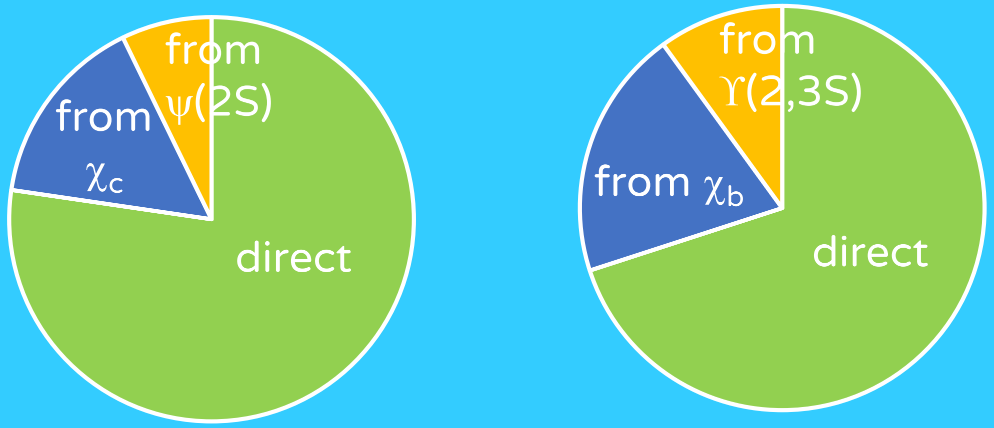
→ on the theory side:

- Link between suppression and critical temperature requires precise assessment of T_D, $M_\psi(T)$, $\Gamma_\psi(T)$ from QCD calculations using EFT/LQCD spectral functions

- Short QGP thermalization time at LHC might imply in-medium formation of quarkonia rather than suppression

→ on the experimental side:

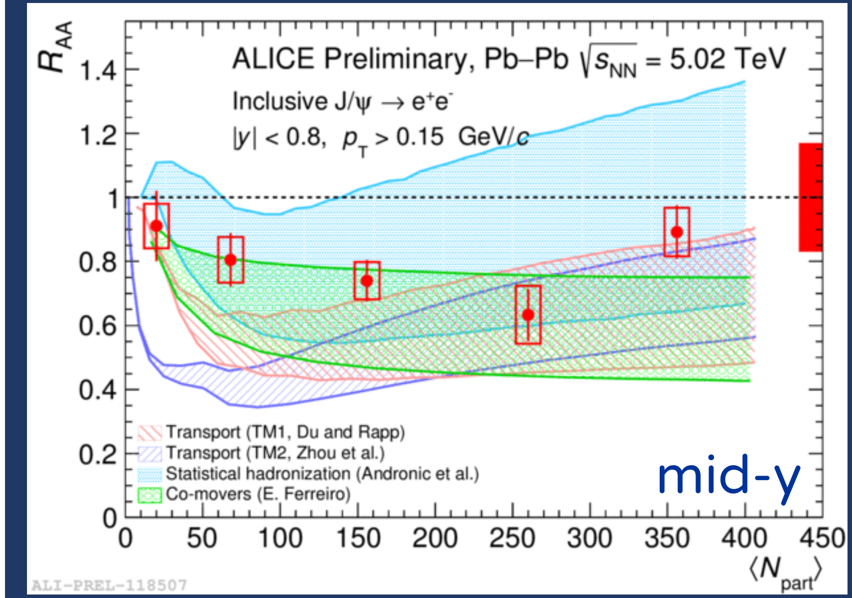
- Precise determination of open charm σ
- Assessment of quarkonium feed-down into lighter states

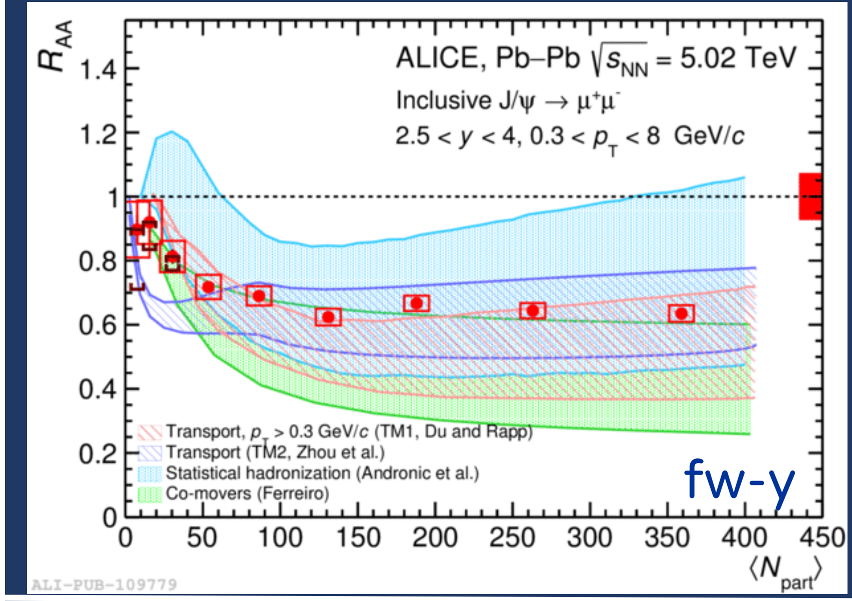


Low p_T J/ψ Low p_T $\Upsilon(1S)$

- Role of B feed down for charmonium

Comparison with theoretical models





Transport models: based on thermal rate eq. with continuous J/ψ dissociation and regeneration in QGP and hadronic phase

X. Zhao, R. Rapp NPA 859 (2011) 114, K. Zhou et al, PRC 89 (2011) 05491

Statistical hadronization: J/ψ produced at chemical freeze-out according to their statistical weight A. Andronic et al., NPA 904-905 (2013) 535

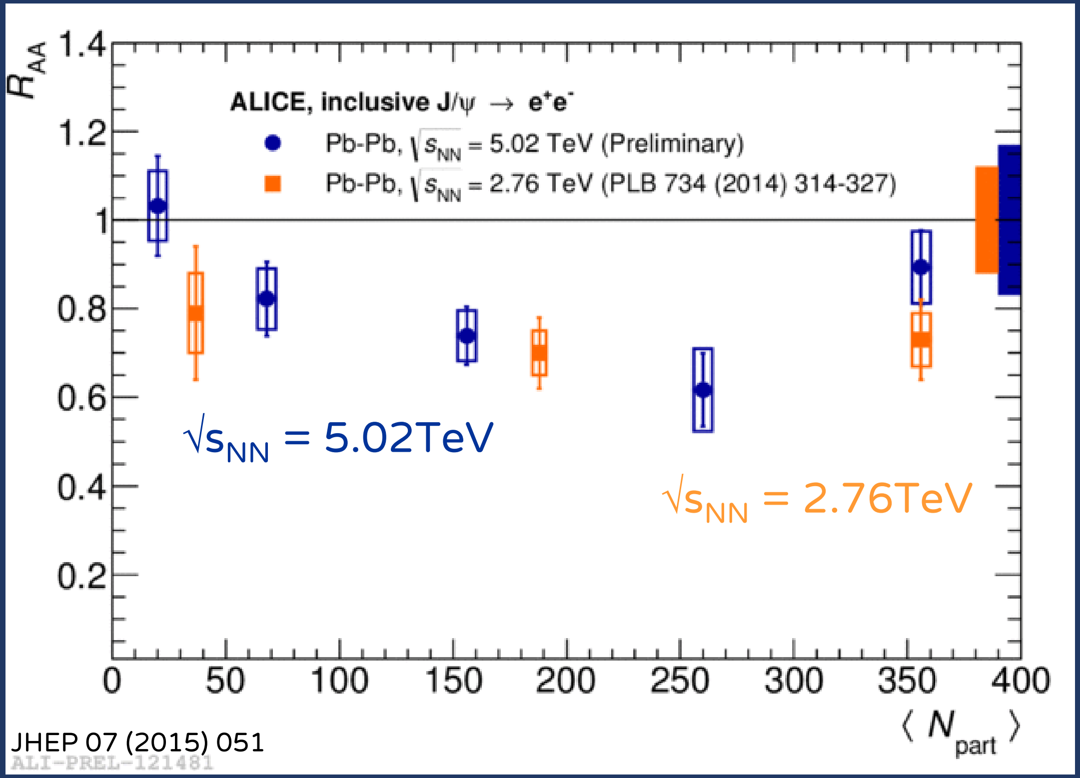
Comover model: J/ψ dissociated via interactions with partons - hadrons + regeneration contribution E. Ferreiro, PLB749 (2015) 98, PLB731 (2014) 57

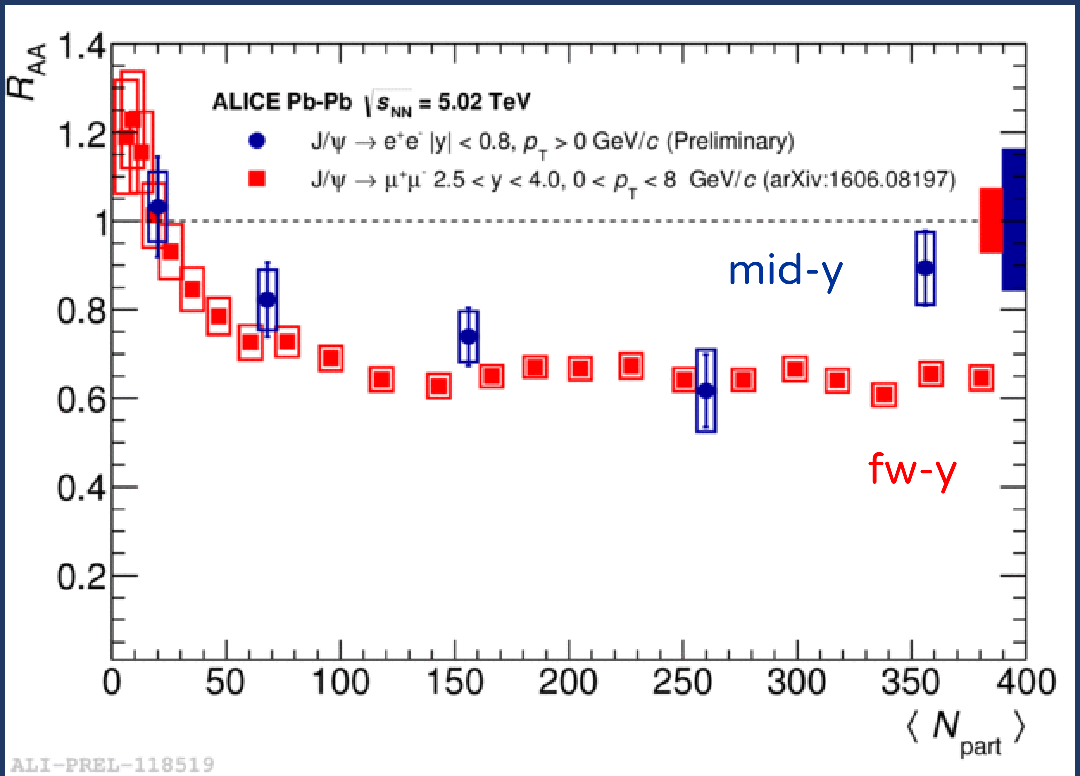
➡ All models fairly describe the data, as already in Run1

Model	$d\sigma_{J/\psi}/dy$ [mb] fw-y	shadowing
Transport, TM1	0.57	EPS09
Transport, TM2	0.82	EPS09
Stat. Hadroniz.	0.32	EPS09
Comovers	0.45-0.7	Glauber-Gribov

but large uncertainties associated to charm cross section and shadowing

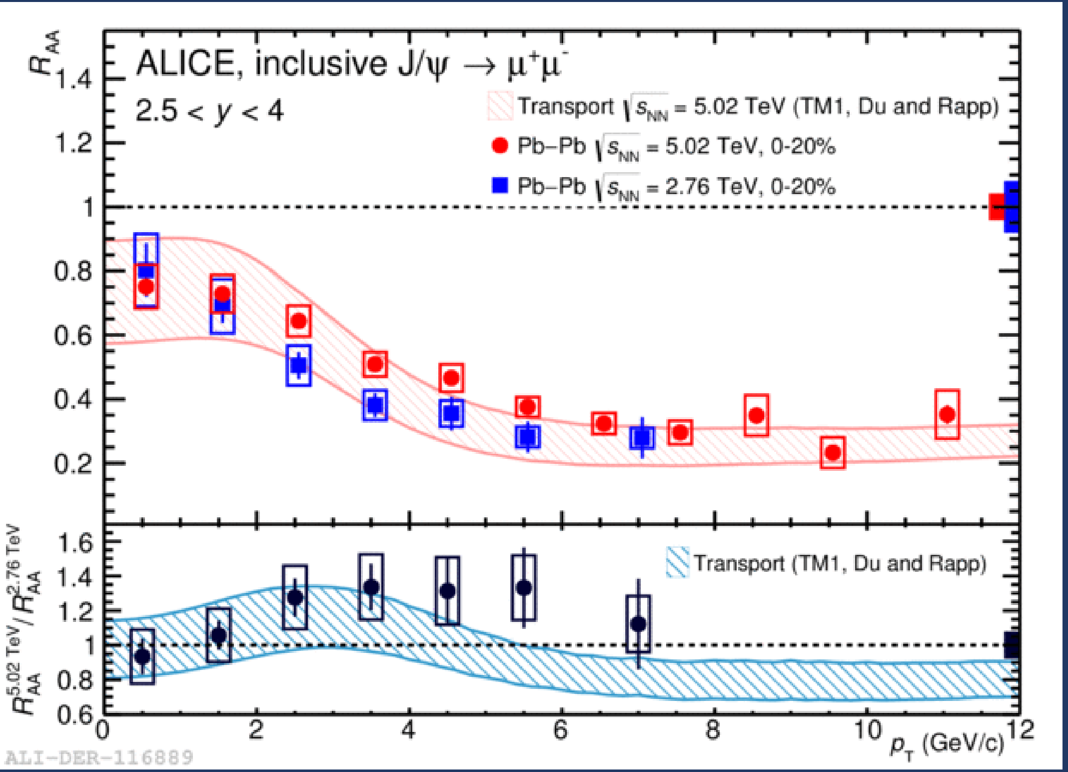
J/ψ R_{AA} at mid-y: Run 2



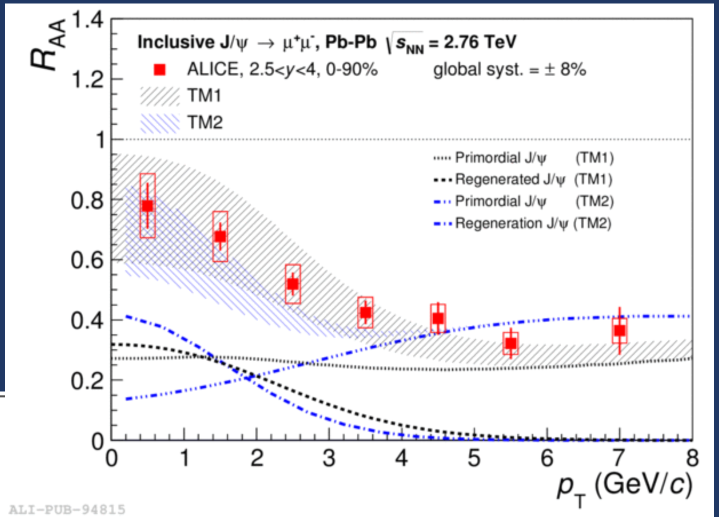


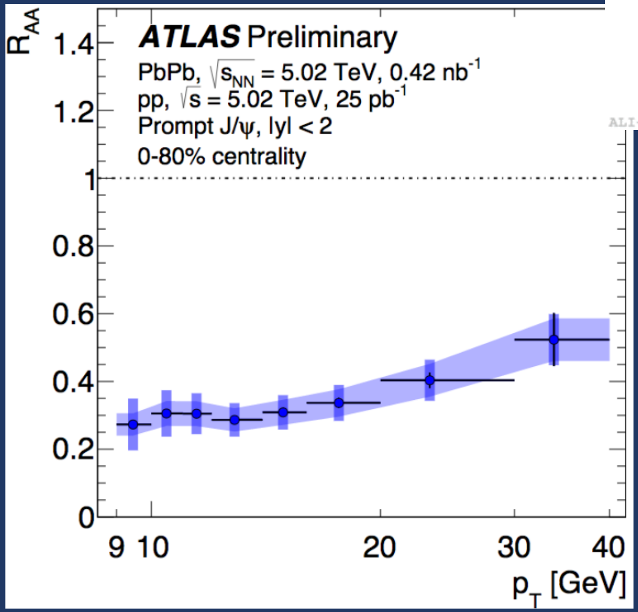
- No significant $\sqrt{s}$-dependence also at mid-rapidity, confirming observation at forward-y
- Small R_{AA} increase in most central collisions, wrt forward-y, as expected in a (re)generation scenario (but fluctuations cannot be yet excluded)

p_T dependence of R_{AA}



- J/ψ R_{AA} is higher at low p_T, where J/ψ from regeneration dominate



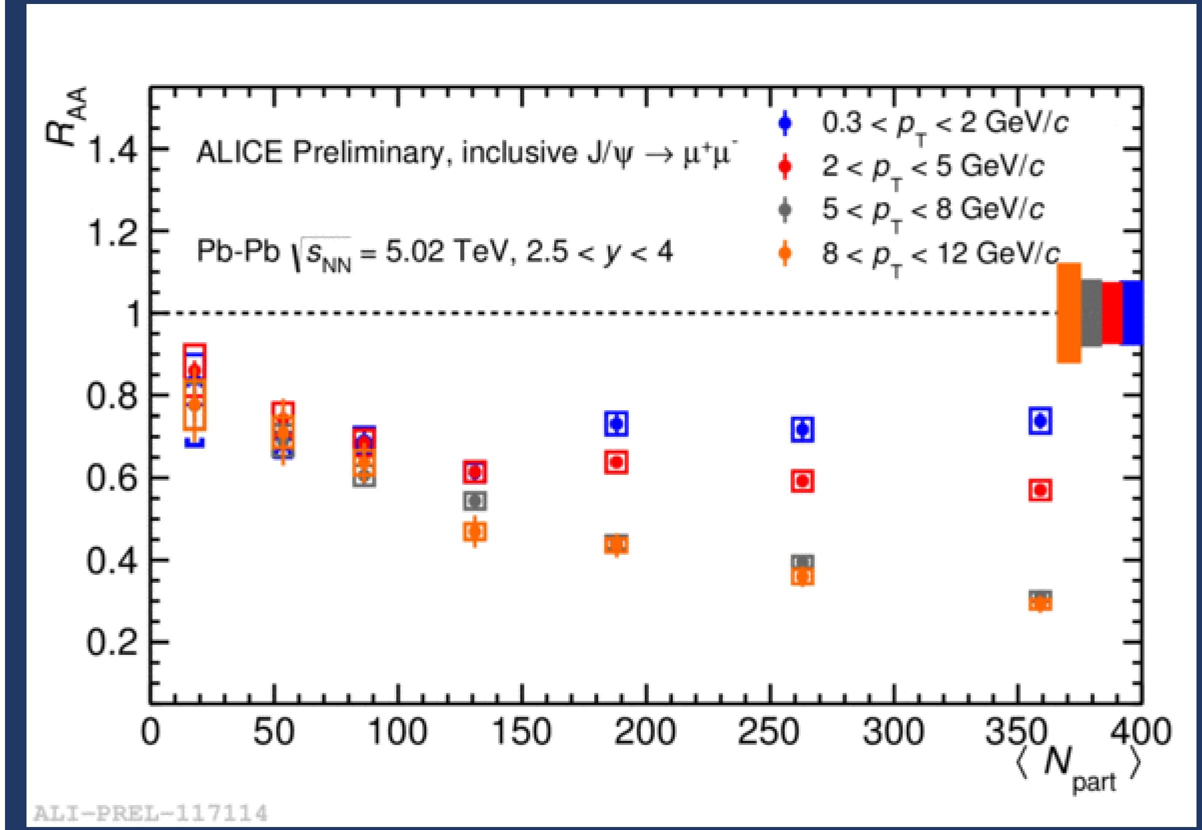


- Similar R_{AA} at $\sqrt{s_{NN}}$ = 2.76 and 5.02 TeV, with a hint for an increase in the range $2<p_T<6$ GeV/c

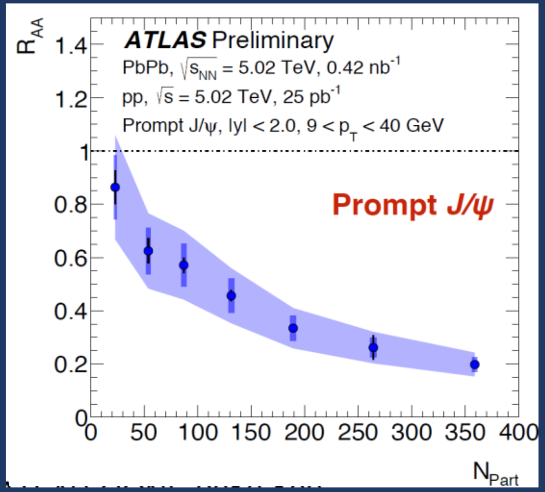
- Very different behavior wrt R_{AA} of high-p_T J/ψ as measured by ATLAS and CMS

More differential J/ψ R_{AA}: p_T

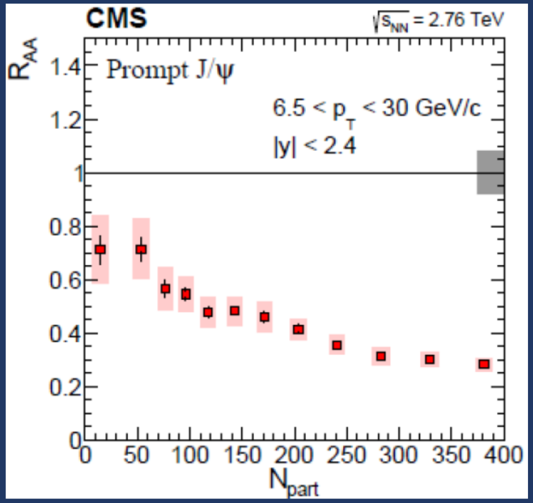
- Constraints to the theoretical models can be imposed by more differential R_{AA} studies



- no centrality dependence in $0.3<p_T<2$ GeV/c
- in central collisions, smaller suppression for low-p_T J/ψ, as expected by (re)generation



ATLAS-CONF-2016-109



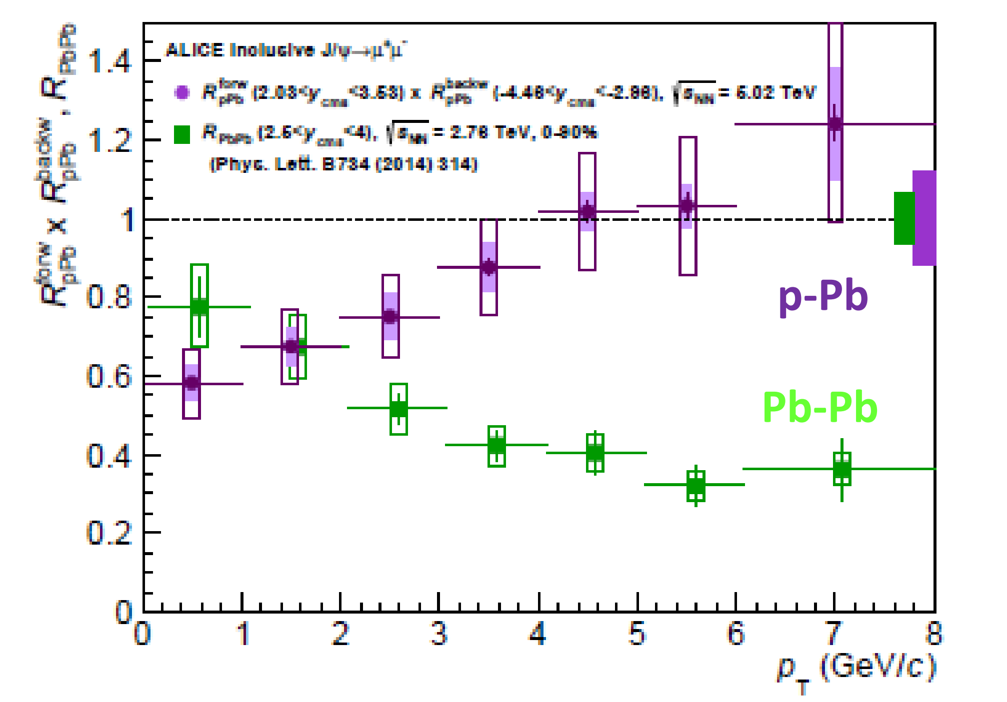
arXiv:1610.00613

- High-p_T J/ψ : pattern qualitatively similar to the one measured by ATLAS and CMS, reaching R_{AA}~0.2

From pA to AA

- Once CNM effects are measured in pA, what can we learn on J/ψ production in PbPb?

Hypothesis:
- 2→1 kinematics for J/ψ production
- CNM effects (dominated by shadowing) factorize in p-A
- CNM obtained as R_{pA} x R_{Ap} (R_{pA}^2), similar x-coverage as PbPb

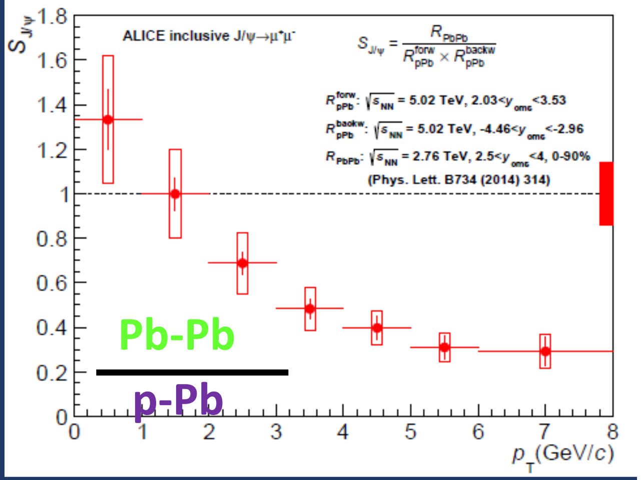


- Sizeable p_T dependent suppression still visible → CNM effects not enough to explain AA data at high p_T

- we get rid of CNM effects with

AA / pA

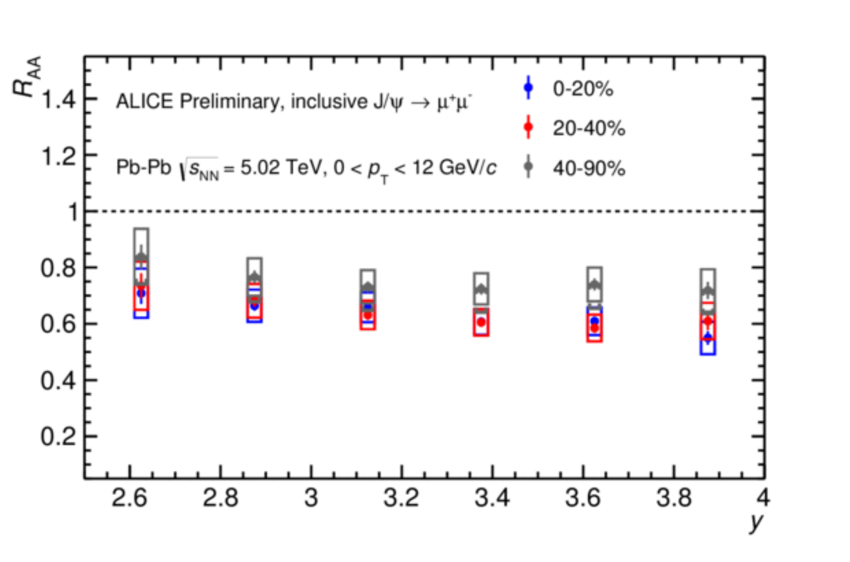
CNM effects not enough to explain PbPb data at high p_T

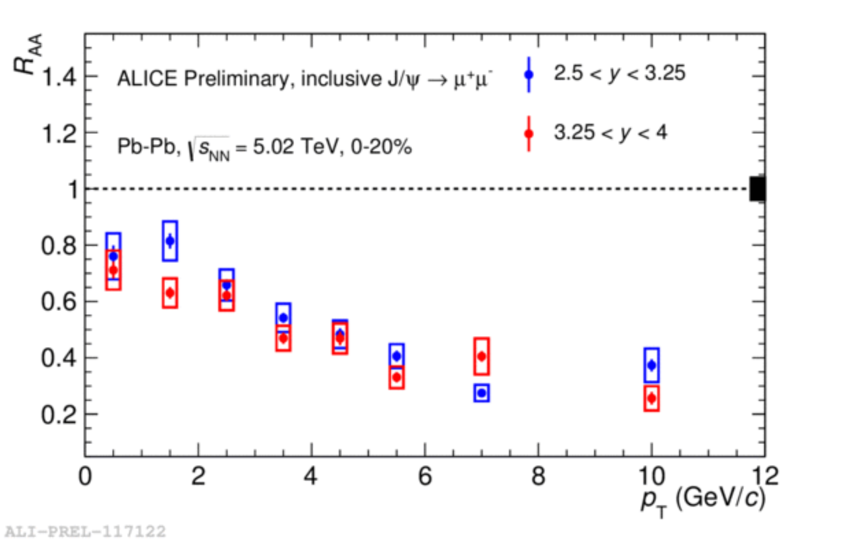


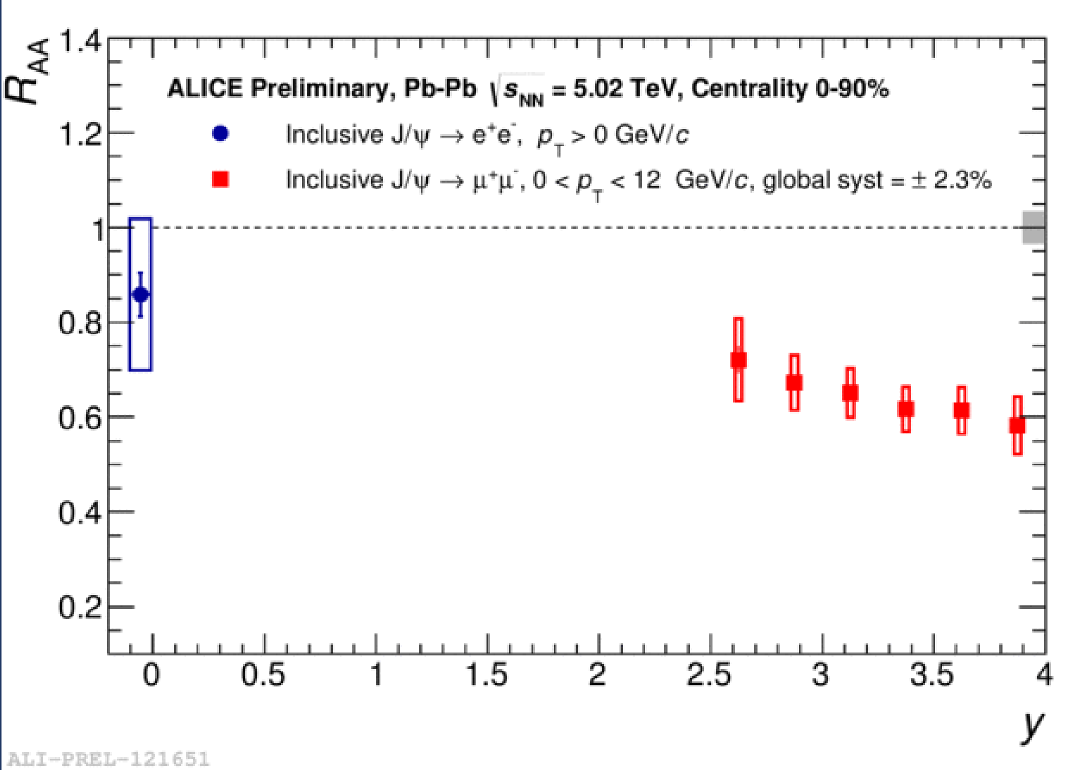
Evidence for hot matter effects in Pb-Pb!

RAA vs y

- Constraints to the theoretical models can be imposed by more differential RAA studies





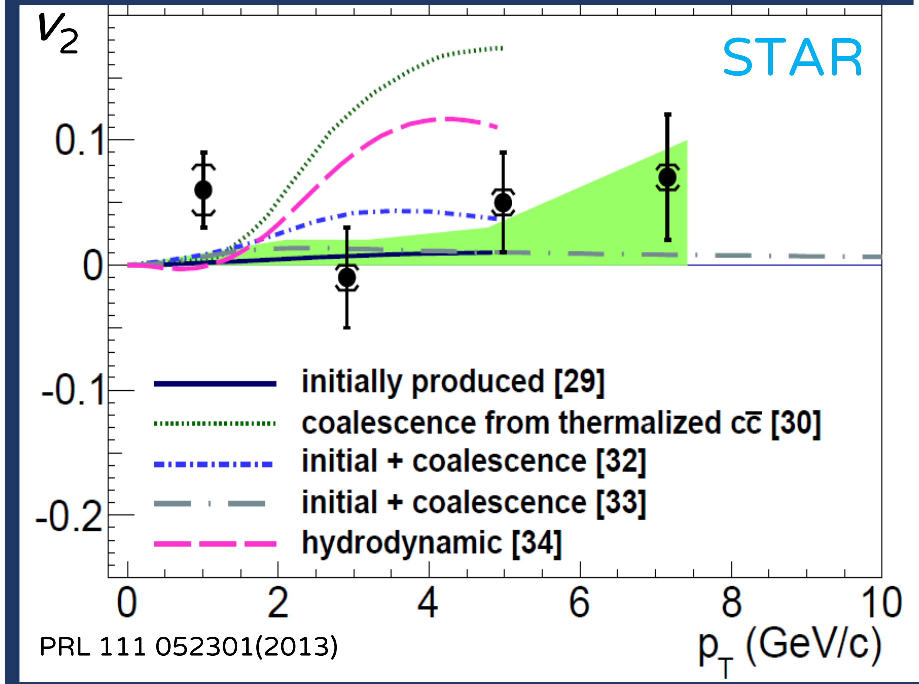


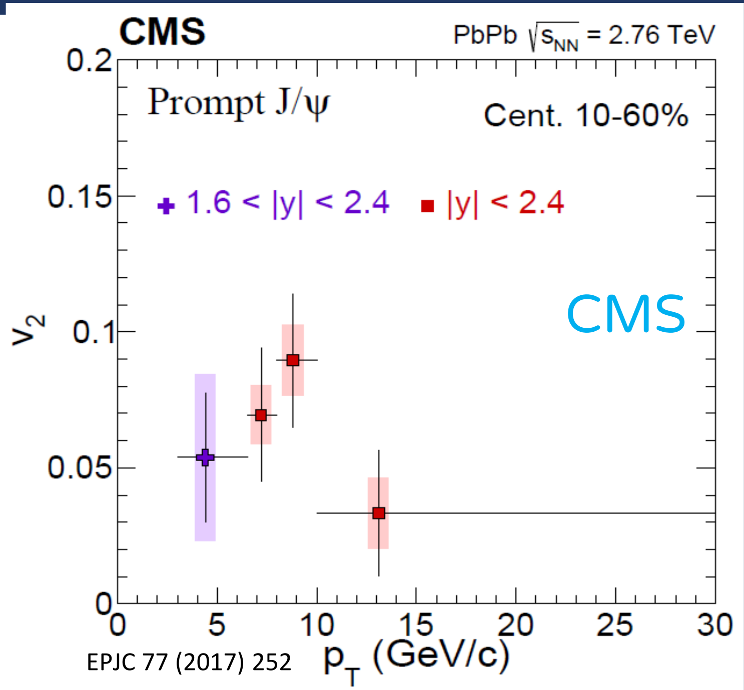
- Hint of enhanced production towards mid-*y*

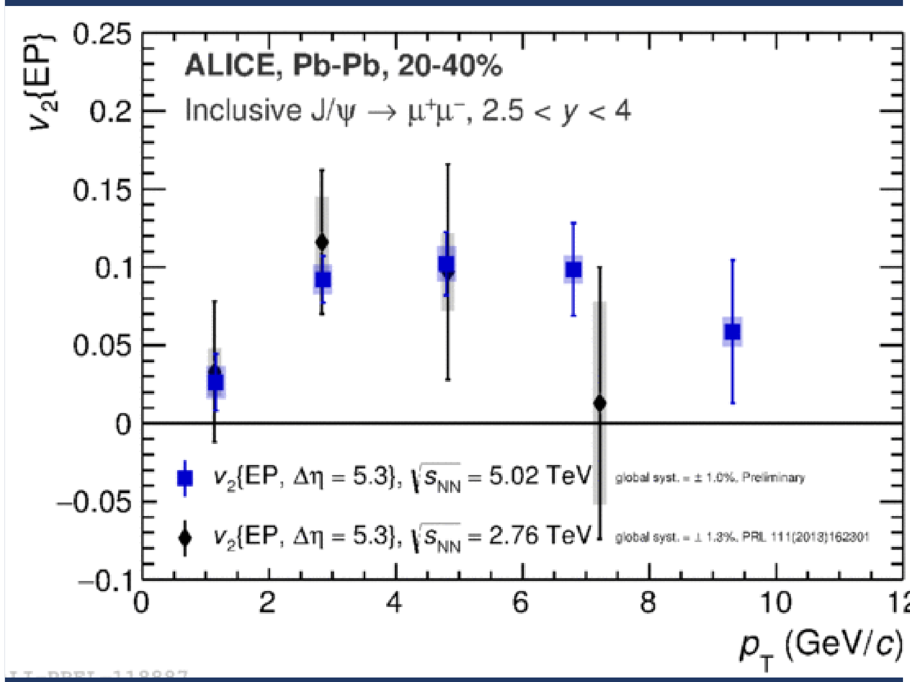
J/ψ elliptic flow

J/ψ from recombination should inherit the charm flow, leading to a v_2 signal

➡ Effect should be important at LHC energies, in kinematic regions where regeneration plays a role







➡ RHIC results favour v_2~0

➡ $v_2 \neq 0$ at high p_T
→ possibly due to the energy loss path-length dependence

➡ ALICE observes evidence for non-zero flow at intermediate pT (7σ effect)

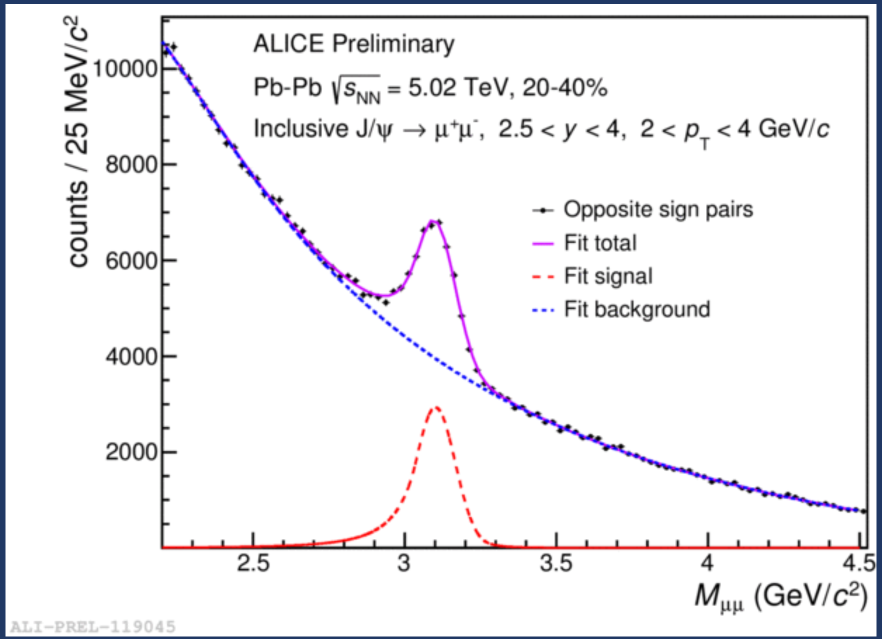
J/ψ elliptic flow: analysis technique

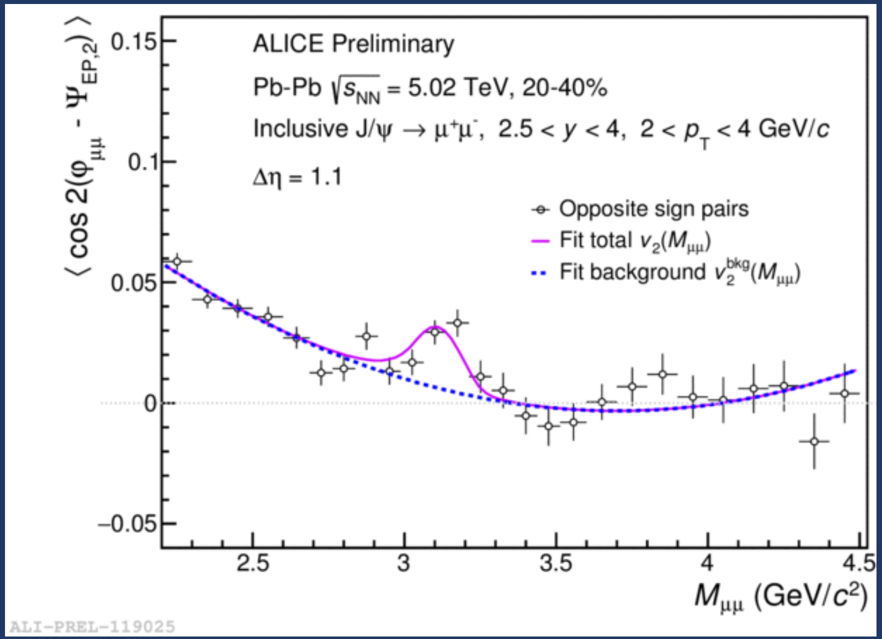
- J/ψ $v_2 = \langle\cos 2(\phi_{\mu\mu}-\Psi_{EP})\rangle$ is computed using the Event Plane from
  - SPD ($\Delta\eta$=1.1) at fw-y
  - TPC ($\Delta\eta$=0) at mid-y
- $v_2^{J/\psi}$ is obtained modeling $\langle\cos 2(\phi_{\mu\mu}-\Psi_{EP})\rangle$ vs inv. mass as

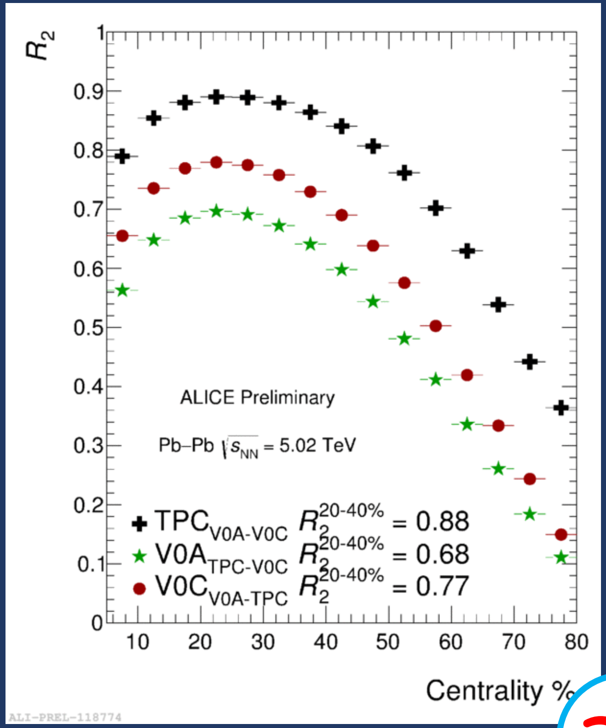
$$v_2(m_{\mu\mu}) = v_2^{J/\psi}\alpha(m_{\mu\mu}) + v_2^{bck}(1-\alpha(m_{\mu\mu}))$$

- $\alpha(m_{\mu\mu})$ is S/S+B from inv. mass fit
- v_2^{bck} background parametrized by several functions

- $v_2 = v_2^{obs}/\sigma_{EP}$





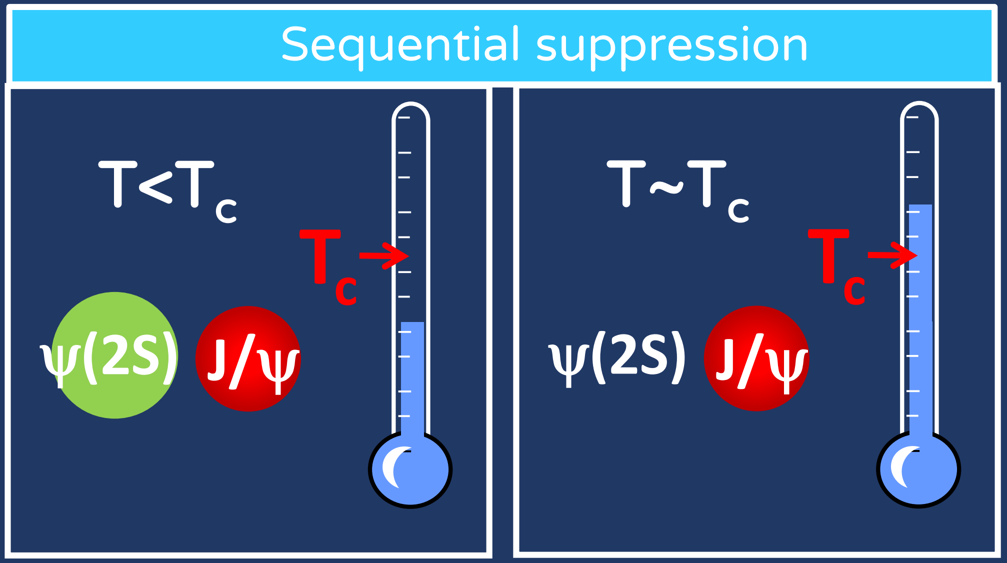


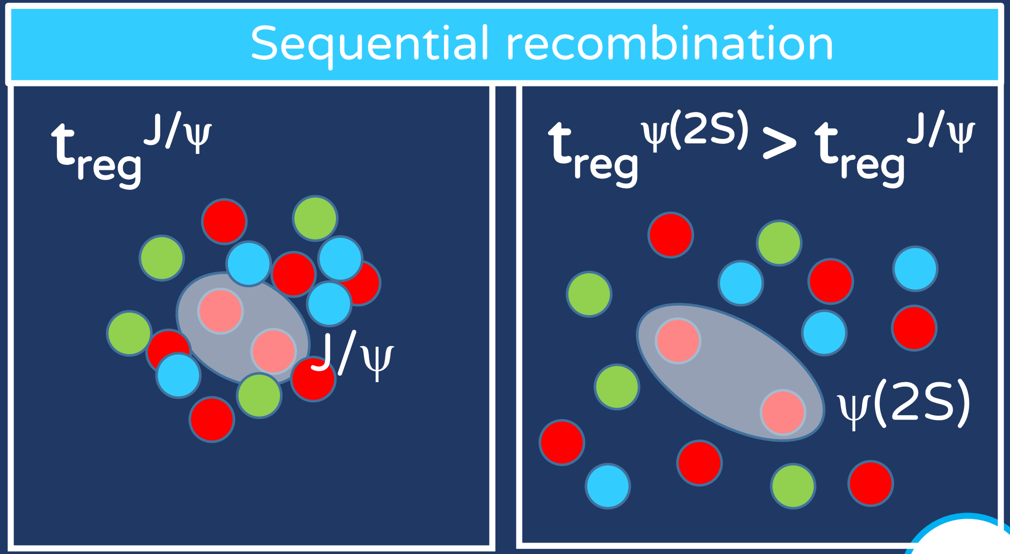
ψ(2S) in AA collisions

- ψ(2s) is a loosely bound state
  (binding energy ~60 MeV wrt to ~640 MeV for J/ψ)

- Expected to be more easily dissociated than J/ψ
  → sequential suppression scenario

- Less clear role played by recombination, taking place
  → at freeze-out, as for J/ψ in the statistical hadronization model
  → in later collision stages, when the system is more diluted (and radial flow is stronger) [sequential regeneration, Rapp, arXiv:1609.04868]

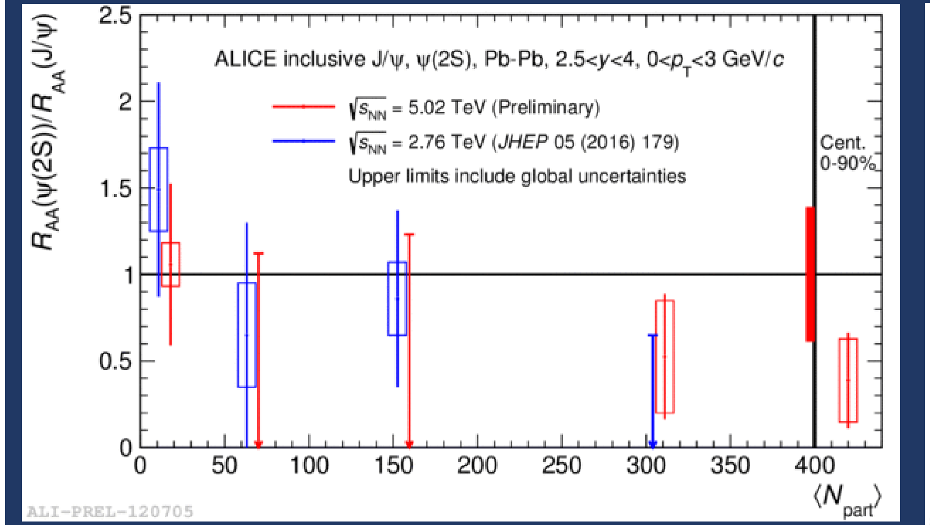


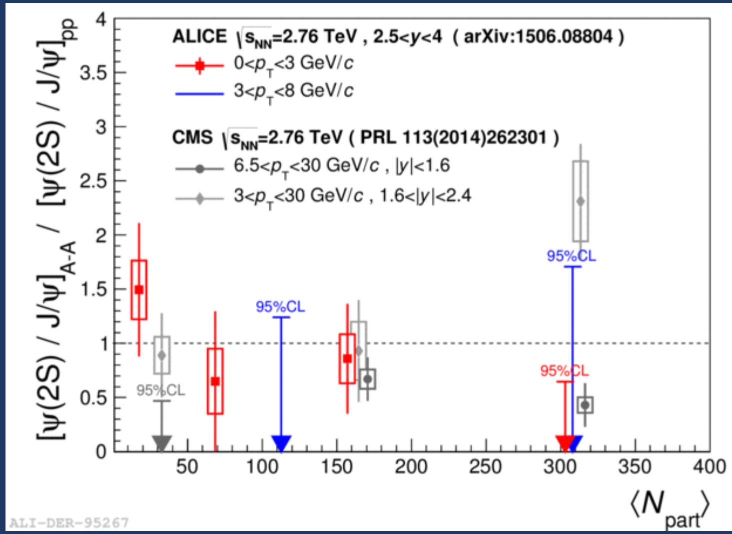


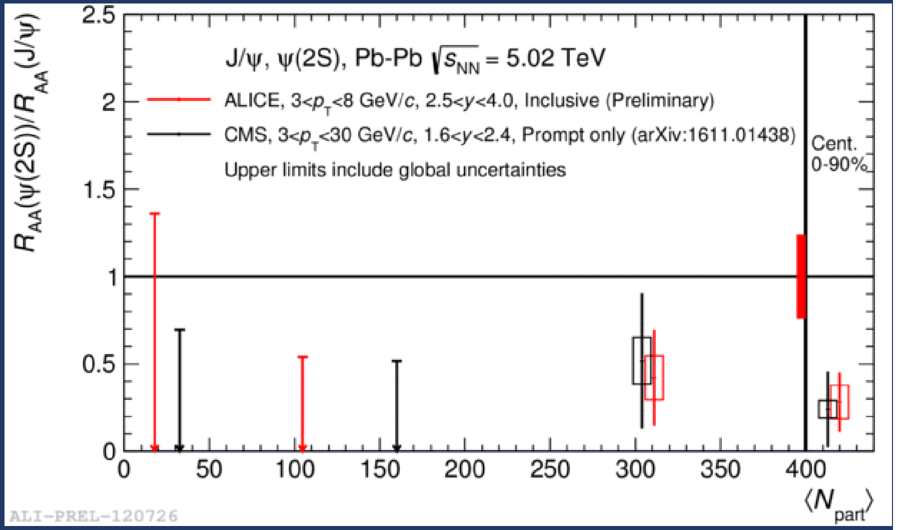
- Ratio of charmonium states vs. centrality and vs. p_T can give insight on quarkonium behaviour

ψ(2S) R_{AA}

- At $\sqrt{s_{NN}}$ = 5.02 TeV, results are compatible with CMS, in a similar kinematic range, while some tension exists at lower energy



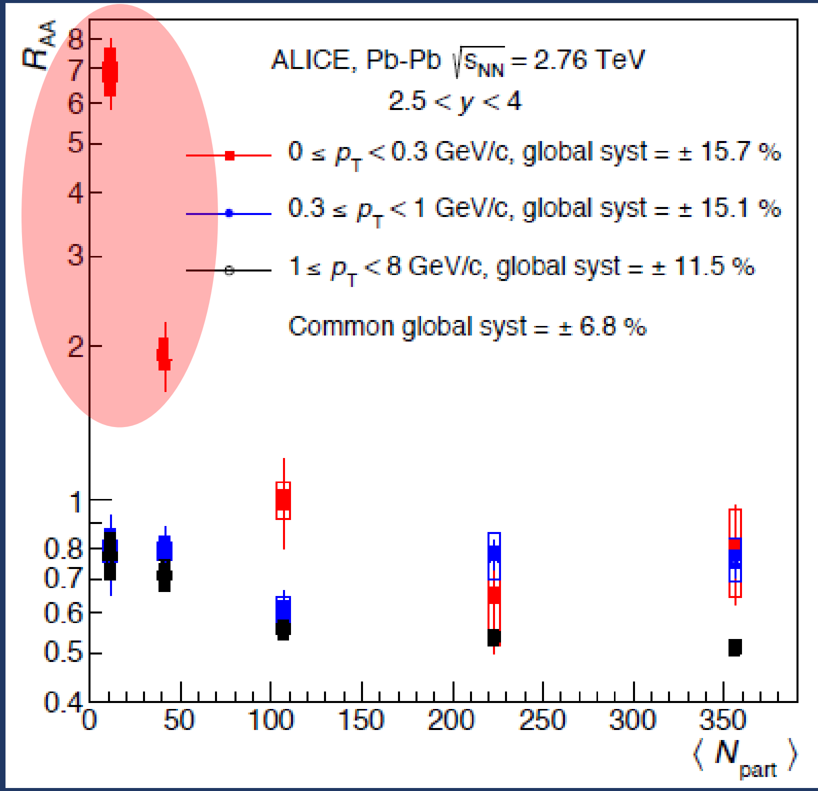




- Results in different kinematic ranges are sensitive to the fraction of primordial and regenerated charmonia, to different medium temperature and flow…

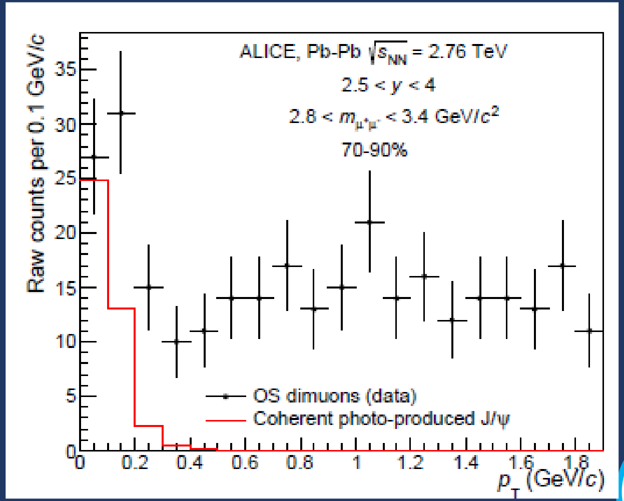
Low pT J/ψ at fw-y

- Strong R_{AA} enhancement in peripheral collisions for $0<p_T<0.3$ GeV/c



- significance of the excess is 5.4 (3.4)σ in 70-90% (50-70%)
- behaviour not predicted by transport models

- excess might be due to coherent J/ψ photoproduction in PbPb (as measured also in UPC)



- if excess is "removed" requiring $p_T^{J/\psi}$>0.3GeV/c → ALICE R_{AA} lowers by 20% at maximum (in the most peripheral bin)

Bottomonia in AA

Three states characterized by very different binding energies:

ϒ(1S): Eb~1100 MeV
ϒ(2S): Eb~500 MeV
ϒ(3S): Eb~200 MeV

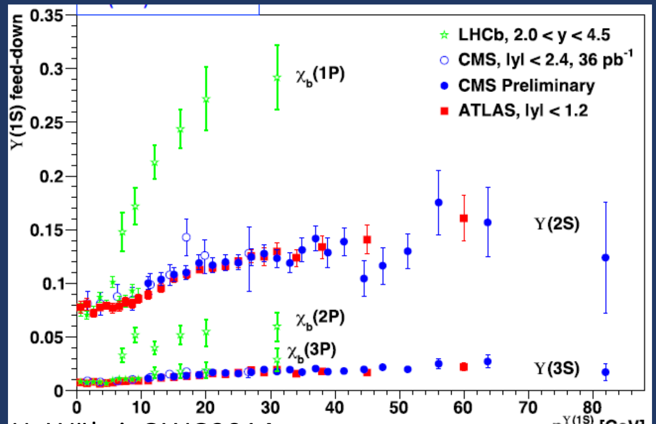
Sensitive in very different ways to the medium

With respect to charmonium:

- Limited recombination effects → interesting for sequential suppression studies
- More robust theoretical calculations, due to higher b quark mass
- No B hadron feed-down → simpler interpretation?

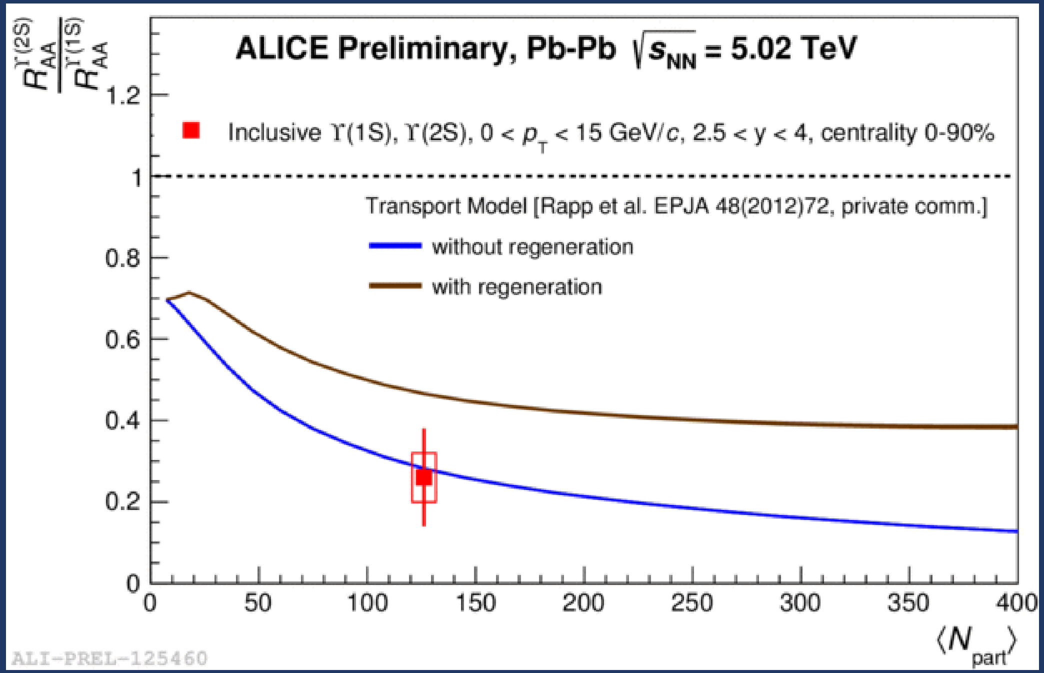
Some drawbacks

- Lower production cross sections
- Non negligible feed-down contributions from higher states



H. Wöhri, QWG2014

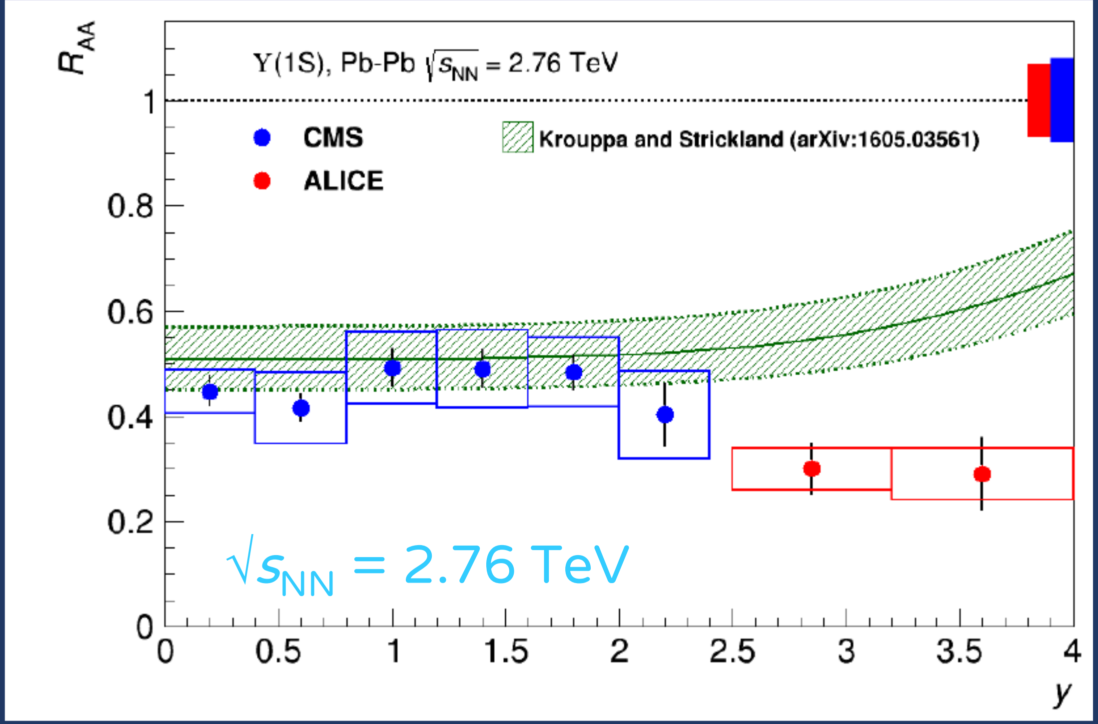
Υ(2S) in ALICE

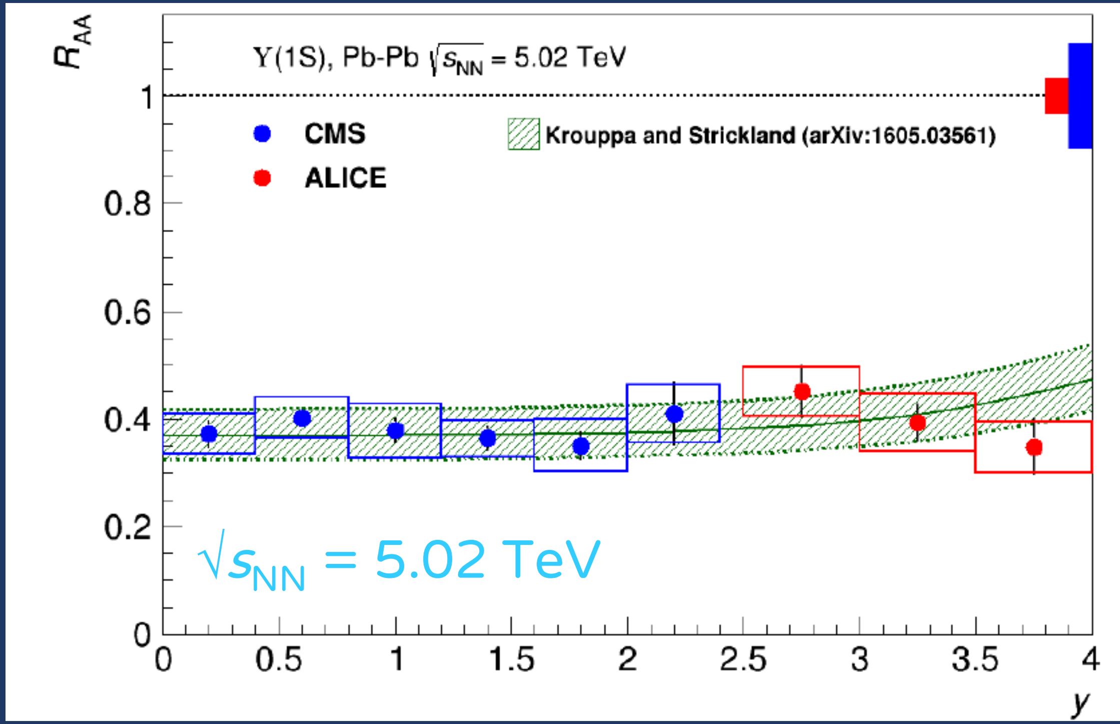


Stronger suppression has been observed for the Υ(2S) wrt Υ(1S)

- Theoretical models describe the R_{AA} ratio (no need for regeneration contribution)
- Result is consistent with the centrality-integrated CMS measurement

ϒ(1S) in ALICE: theory comparison





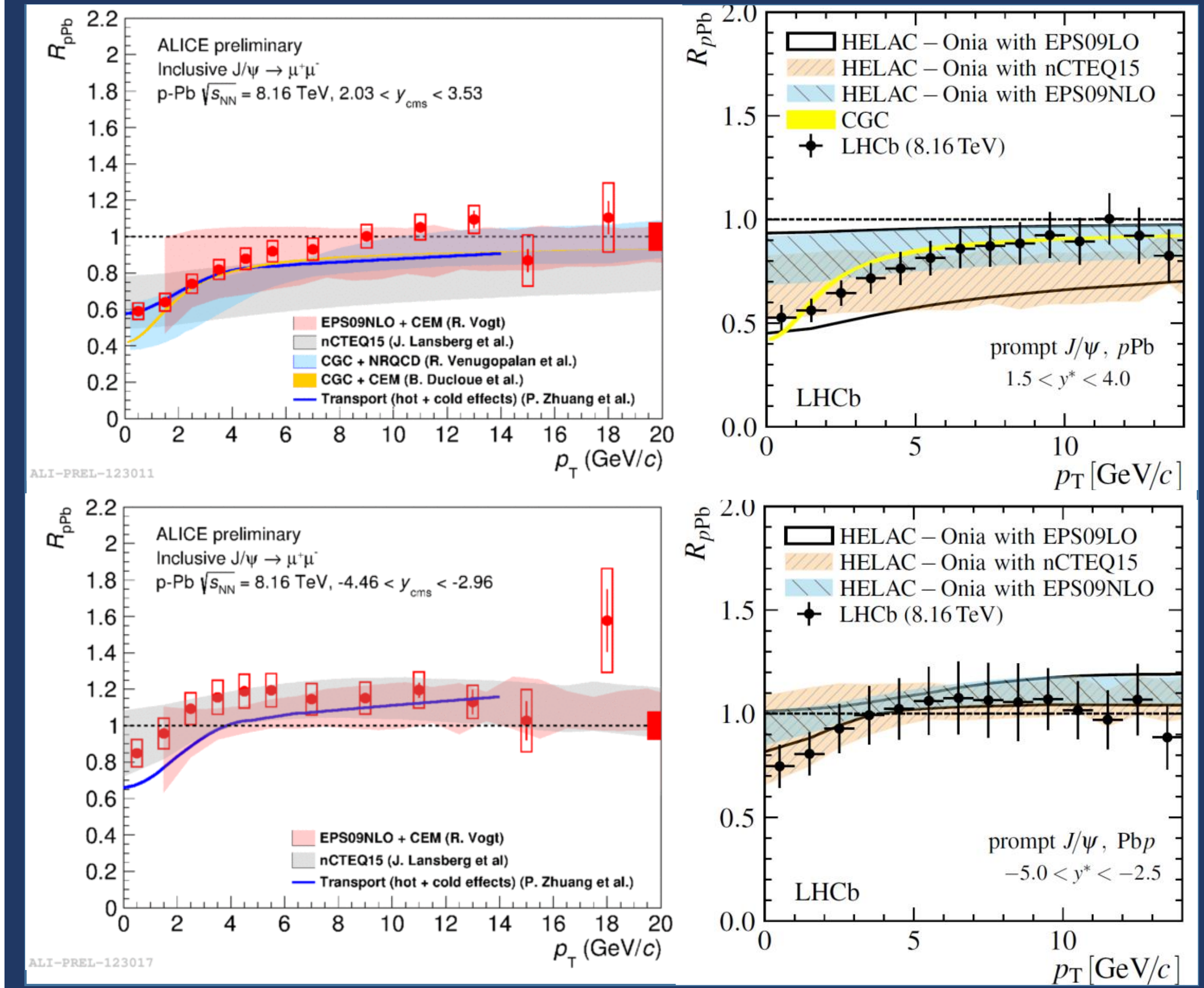
CMS-PAS-HIN16-023
CMS arXiv:1611.01510

E. Scomparin, QM17

- Suppression increases with y at $\sqrt{s_{NN}}$ = 2.76TeV
- Suppression is constant at $\sqrt{s_{NN}}$ = 5.02TeV

- Some tension in the R_{AA} evolution vs y with energy, but still large uncertainties

p_T dependence of J/ψ R_{pA}

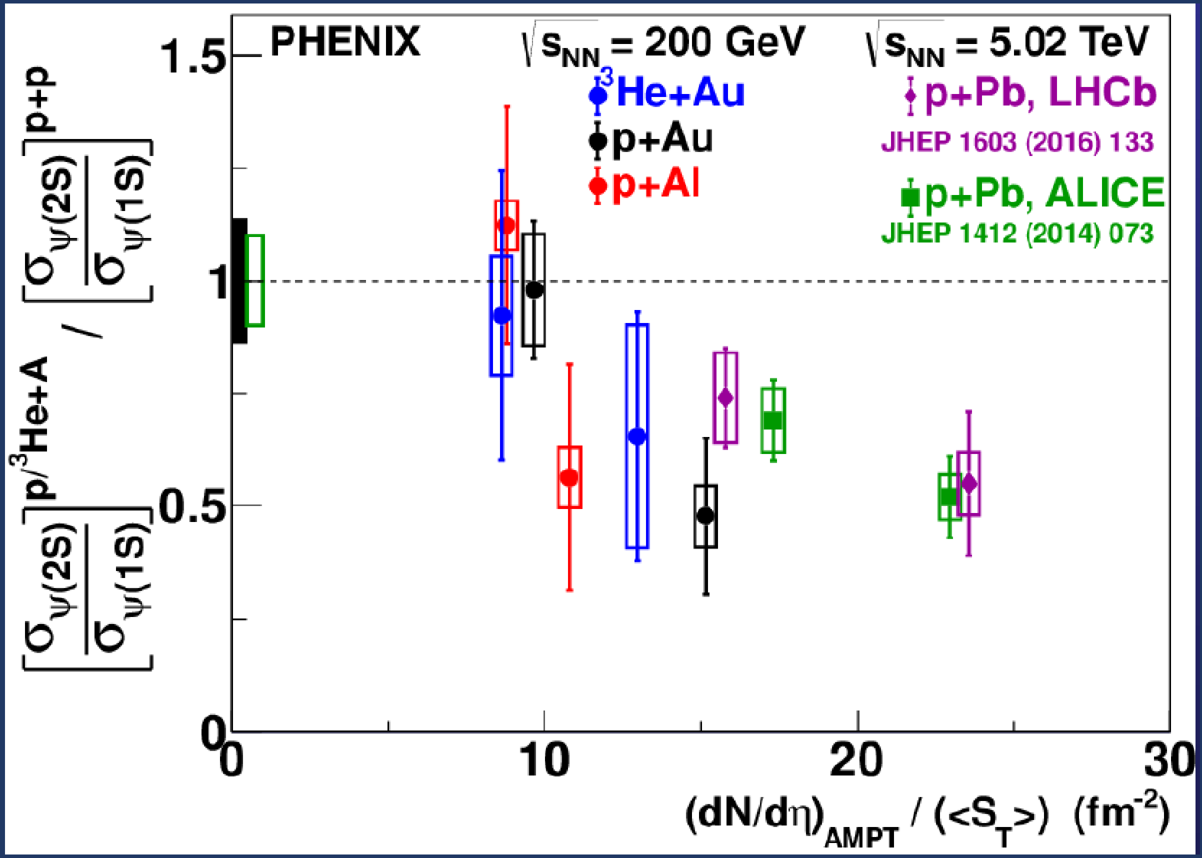


- Slightly different y coverage in ALICE and LHCb, but rather similar p_T dependences
- Shadowing and energy loss models describe R_{pA} vs p_T

ψ(2S) in pA collisions

Being more weakly bound than the J/ψ, the ψ(2S) is an interesting probe to have further insight on the charmonium behaviour in pA

PHENIX, PRC 95, 034904 (2017)



➡ ψ(2S) suppression stronger than the J/ψ one at RHIC and LHC

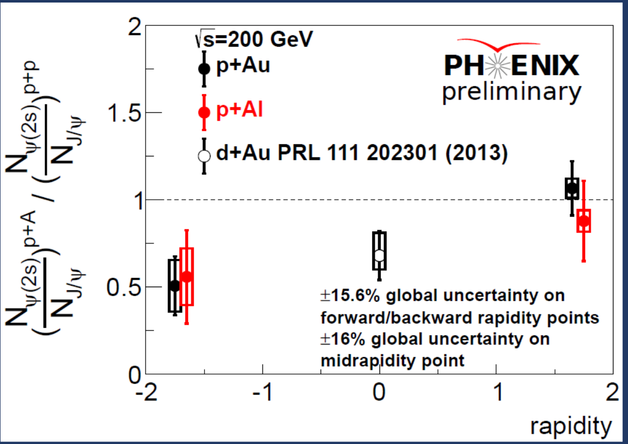
→ unexpected because time spent by the cc pair in the nucleus (τ_c) is shorter than charmonium formation time (τ_f)

→ shadowing and energy loss, almost identical for J/ψ and ψ(2S), do not account for the different suppression

➡ QGP+hadron resonance gas or comovers models describe the stronger ψ(2S) suppression

$\psi(2S)$ in p-Pb at $\sqrt{s_{NN}}$ = 5.02TeV

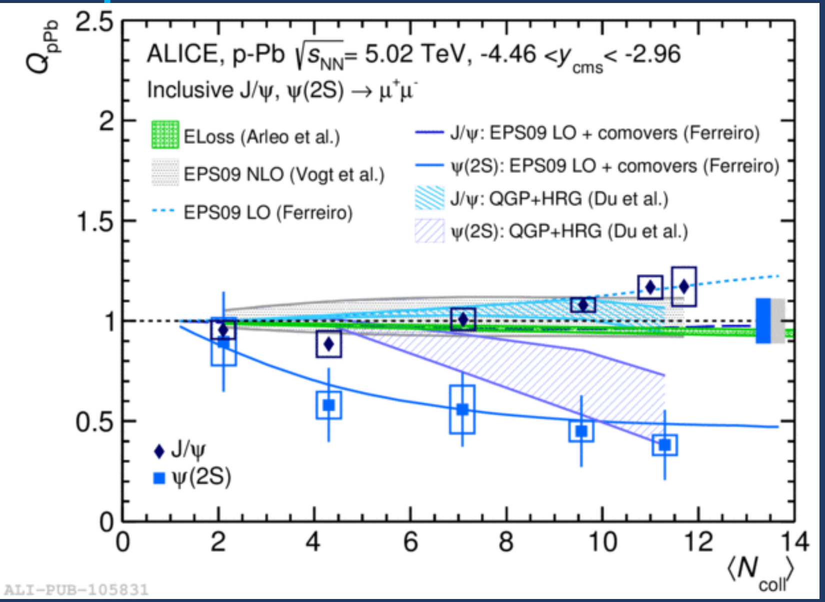
- Being more weakly bound than the J/ψ, the $\psi(2S)$ is an interesting probe to have further insight on the charmonium behaviour in pA

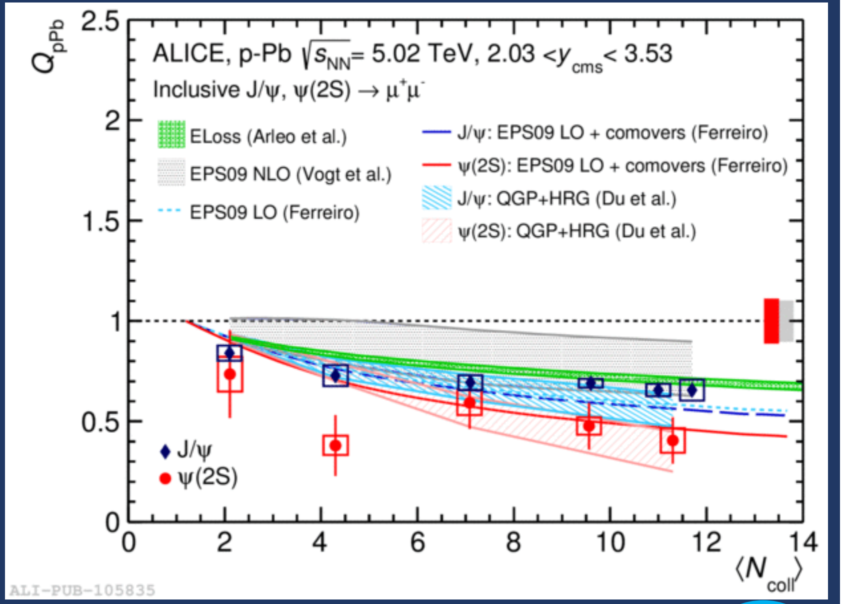


- $\psi(2S)$ suppression stronger than the J/ψ one at RHIC and LHC

→ unexpected because time spent by the cc pair in the nucleus (τ_c) is shorter than charmonium formation time (τ_f)

→ shadowing and energy loss, almost identical for J/ψ and $\psi(2S)$, do not account for the different suppression

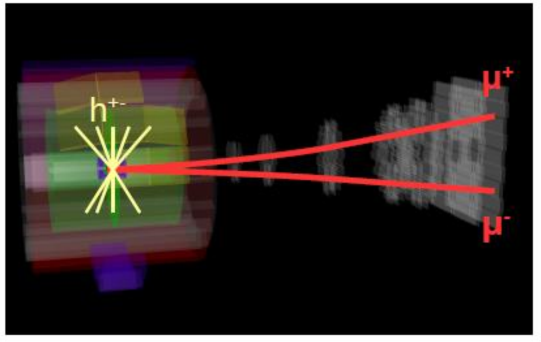




QGP+hadron resonance gas or comovers models describe the stronger $\psi(2S)$ suppression

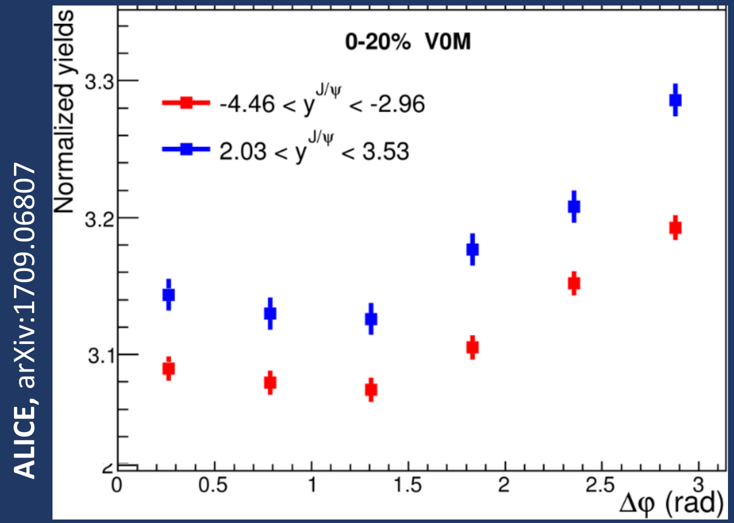
J/ψ v_2 in pPb

Azimuthal correlations between forward/backward J/ψ and mid-*y* charged particles



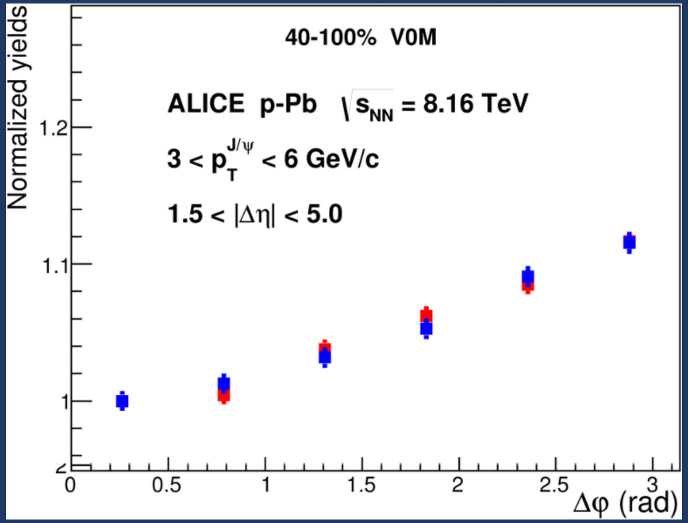
- Correlations expressed as associated SPD-tracklet yields per dimuon(J/ψ) trigger

High multiplicity

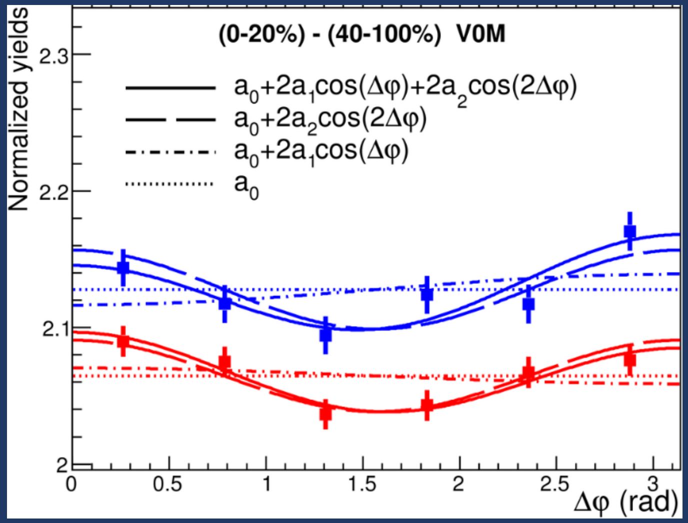


additional enhancement at both near and away sides

Low multiplicity



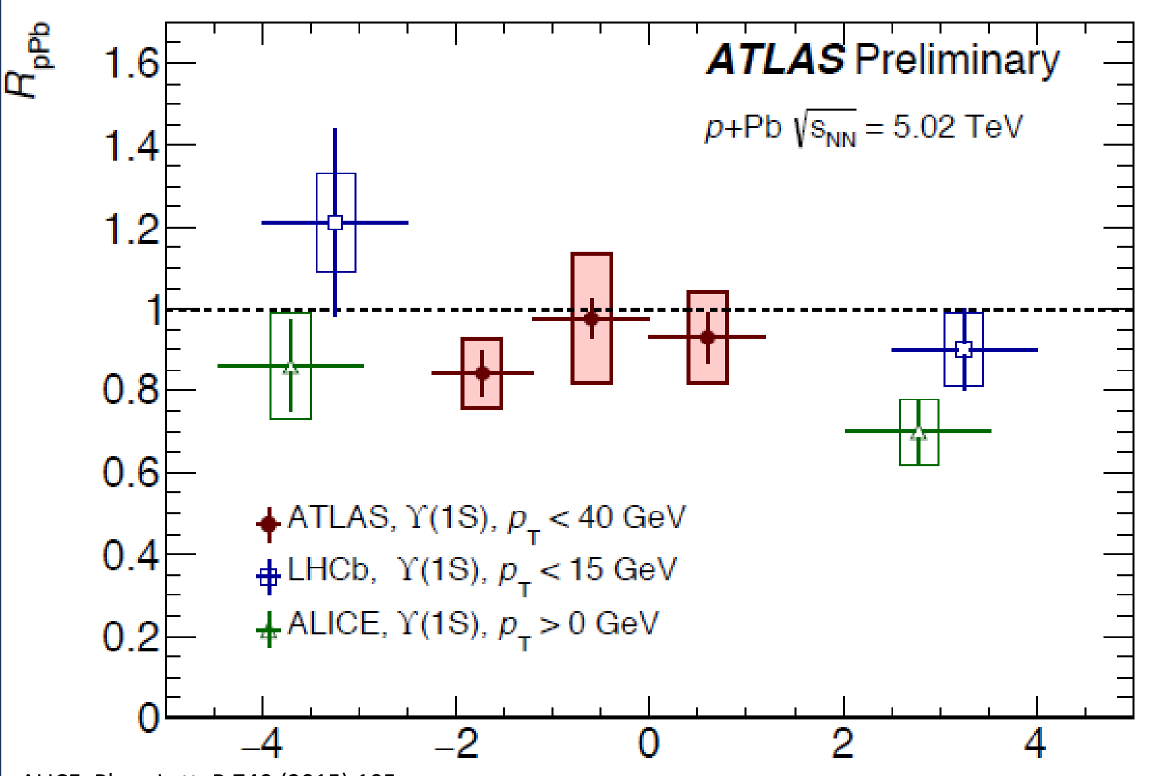
clear away-side correlation (jets?)



Jet correlations eliminated via subtraction

- J/ψ v_2 extracted assuming factorization of J/ψ and tracklet v_2

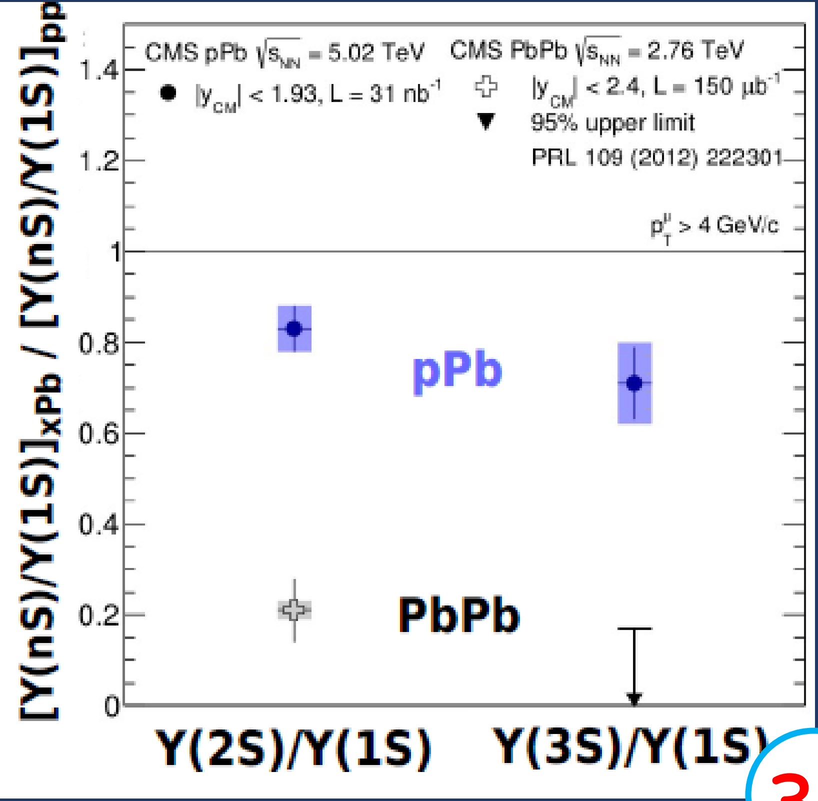
Υ in pA collisions



ALICE, Phys. Lett. B 740 (2015) 105
ATLAS-CONF-2015-050 ,LHCb, JHEP 07(2014)094

➡ no strong rapidity dependence of Υ(1S) R_{pA}

Υ(1S) R_{pA} described by shadowing and energy loss models



➡ Stronger excited states suppression with respect to Υ(1S)
Initial state effects similar for the three Υ states
→ Final states effects in p-Pb?