QUARK MATTER 2015

October 2nd 2015

Experimental overview on quarkonium production

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INFN Torino

Outlook

Overview of recent/new results on charmonium and bottomonium production in pp, p-A and A-A collisions from RHIC to LHC energies

11 talks + 10 posters on quarkonium experimental results

Apologize for all the results which could not fit in this talk!!!

Quarkonium at RHIC and LHC

Facility	Experiment	System	$\sqrt{s_{NN}}$ (GeV)	Data taking
RHIC	PHENIX/STAR	Au-Au, Cu-Cu, Cu-Au, U-U	200, 193, 62, 39	2000-2015
		p-A, d-Au	200	
		pp	200-500	
LHC	ALICE/ATLAS /CMS/LHCb	Pb-Pb	2760	2010-2012
		p-Pb	5020	2013
		pp	2760, 7000, 8000, 13000	2010-2015

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		p-Pb	5020	2013
				2010-2015

Quarkonium production investigated via collisions:
- with different beam species
- at various energies

Quarkonium at RHIC and LHC

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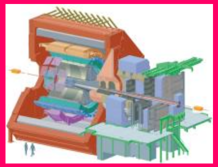
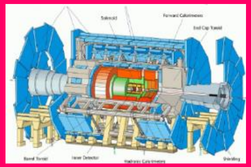
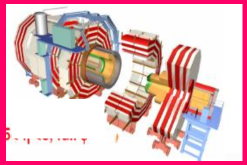
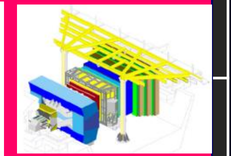
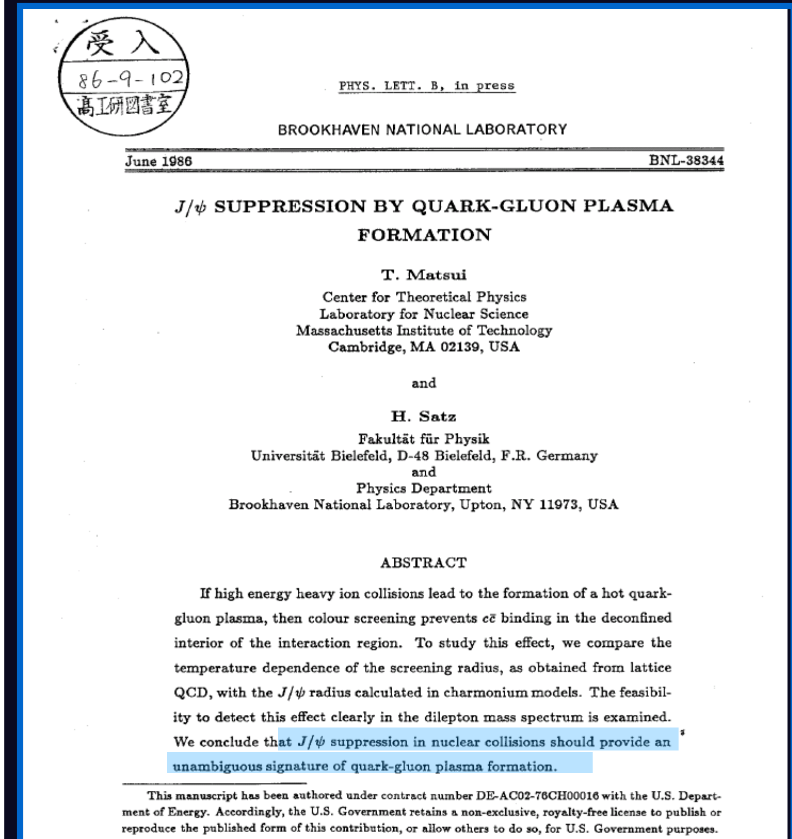
LHC	ALICE/ATLAS /CMS/LHCb			

All LHC experiments investigate quarkonium production

- high luminosity and energies
- complementary results due to different kinematic coverages of the experiments

AA: from suppression...



PHYS. LETT. B, in press

BROOKHAVEN NATIONAL LABORATORY

June 1986 BNL-38344

J/ψ SUPPRESSION BY QUARK-GLUON PLASMA FORMATION

T. Matsui
Center for Theoretical Physics
Laboratory for Nuclear Science
Massachusetts Institute of Technology
Cambridge, MA 02139, USA

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H. Satz
Fakultät für Physik
Universität Bielefeld, D-48 Bielefeld, F.R. Germany
and
Physics Department
Brookhaven National Laboratory, Upton, NY 11973, USA

ABSTRACT

If high energy heavy ion collisions lead to the formation of a hot quark-gluon plasma, then colour screening prevents $c\bar{c}$ binding in the deconfined interior of the interaction region. To study this effect, we compare the temperature dependence of the screening radius, as obtained from lattice QCD, with the J/ψ radius calculated in charmonium models. The feasibility to detect this effect clearly in the dilepton mass spectrum is examined. We conclude that J/ψ suppression in nuclear collisions should provide an unambiguous signature of quark-gluon plasma formation.

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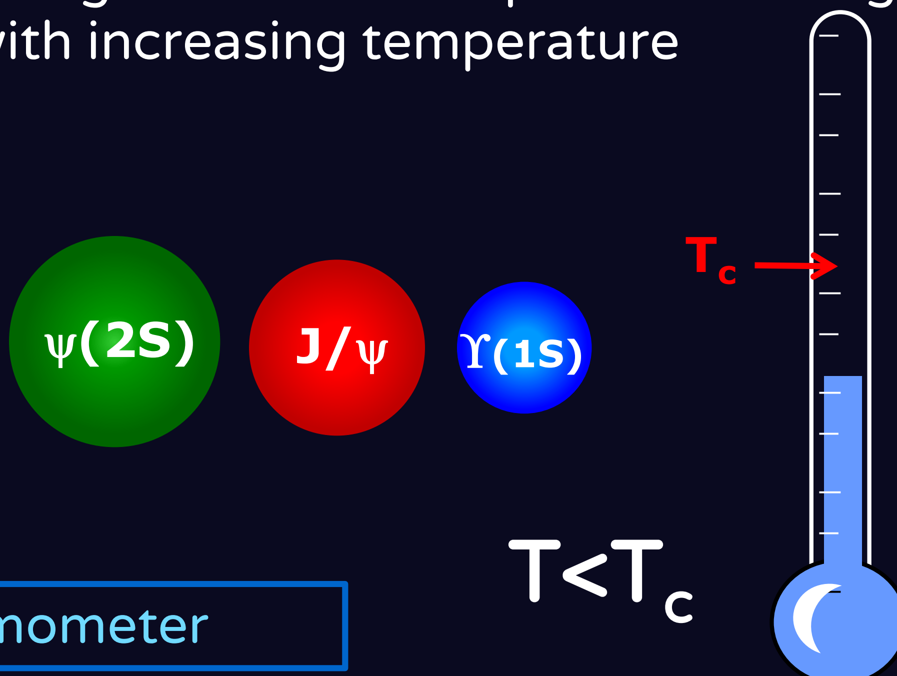
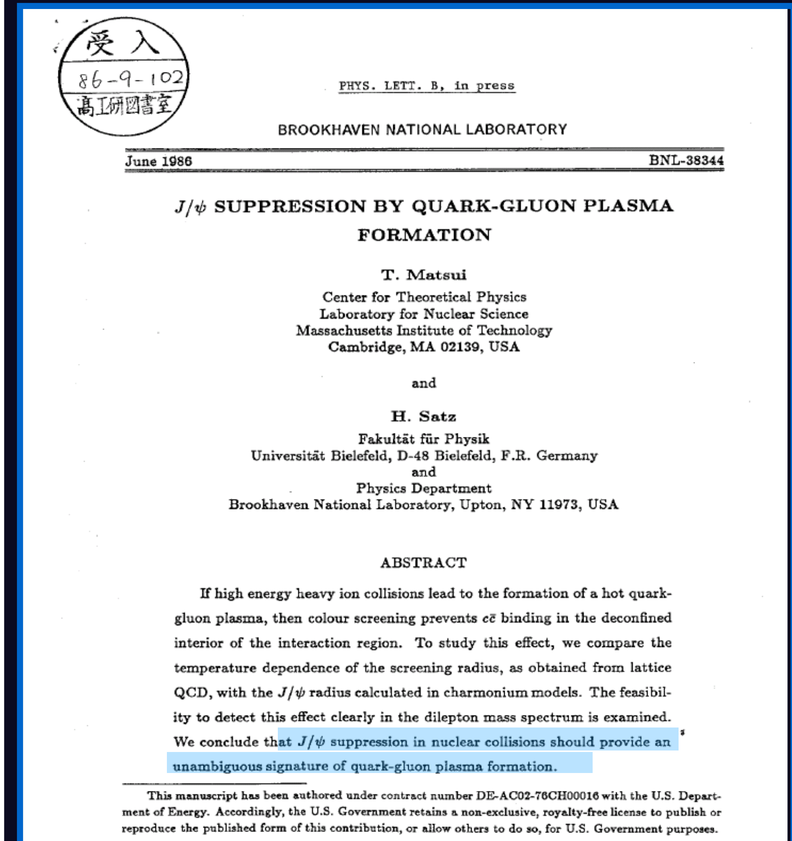
T.Matsui and H.Satz, Phys.Lett.B178 (1986) 416

- **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 is a QGP thermometer

AA: from suppression…



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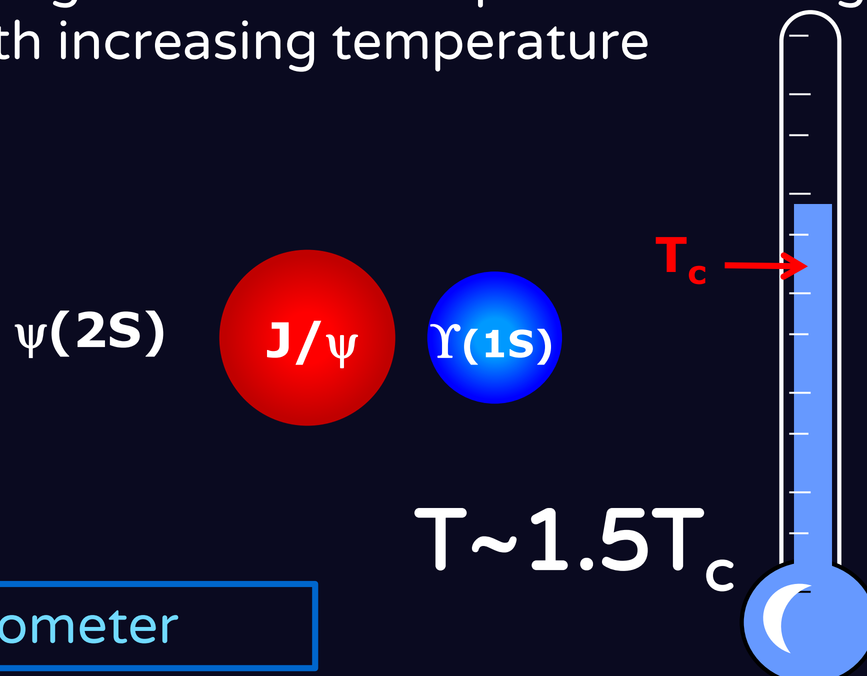

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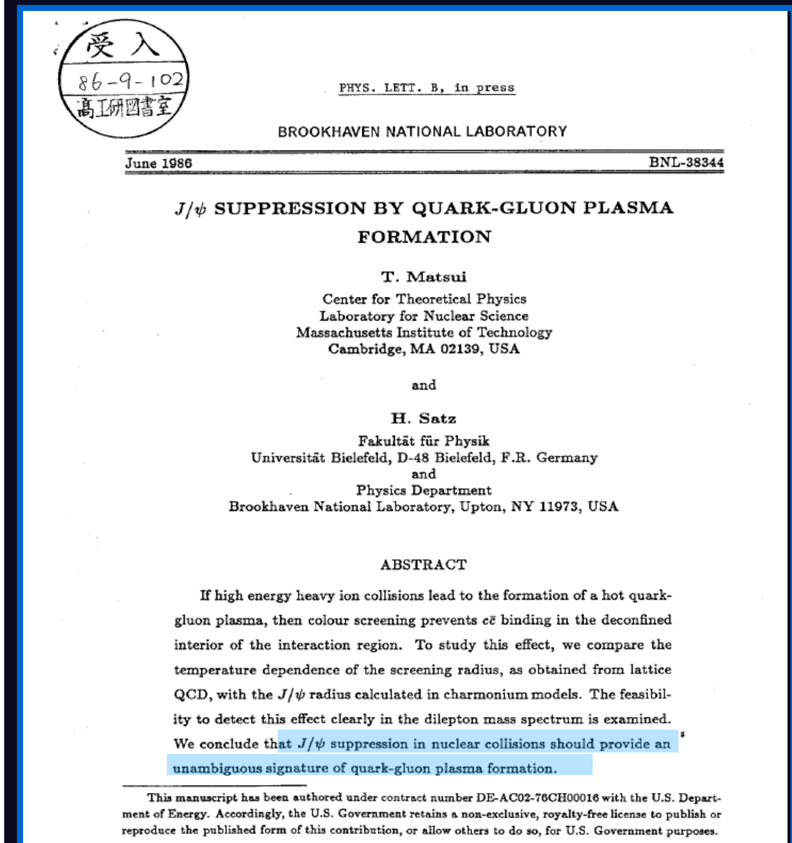

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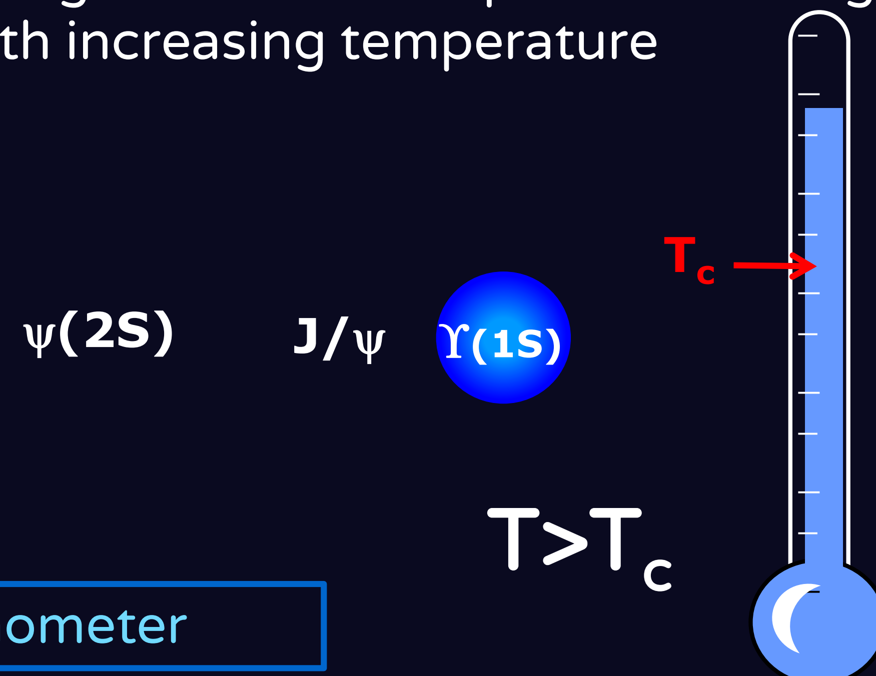

Quarkonium is a QGP thermometer

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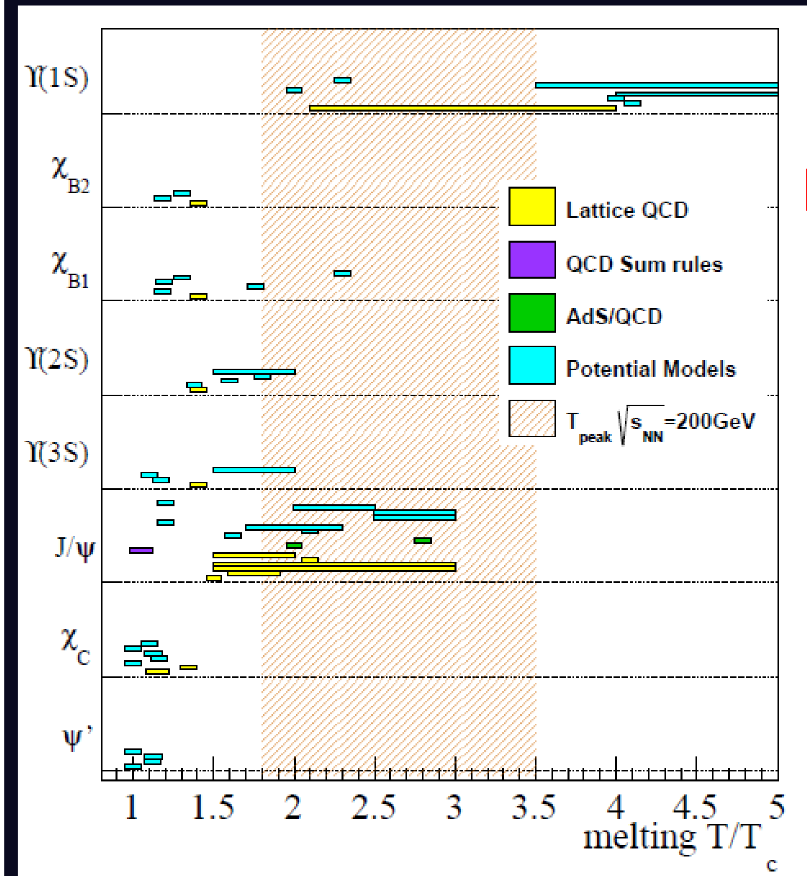

PHENIX, Phys.Rev C91, 024913

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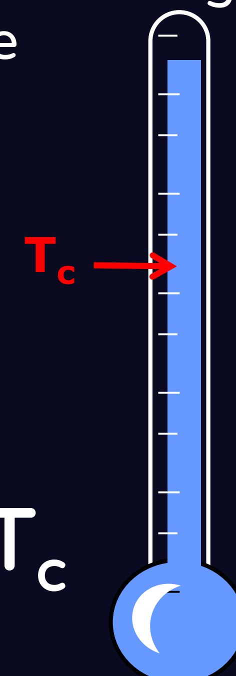
ψ(2S) J/ψ ϒ(1S)



$T >> T_c$

Quarkonium is a QGP thermometer

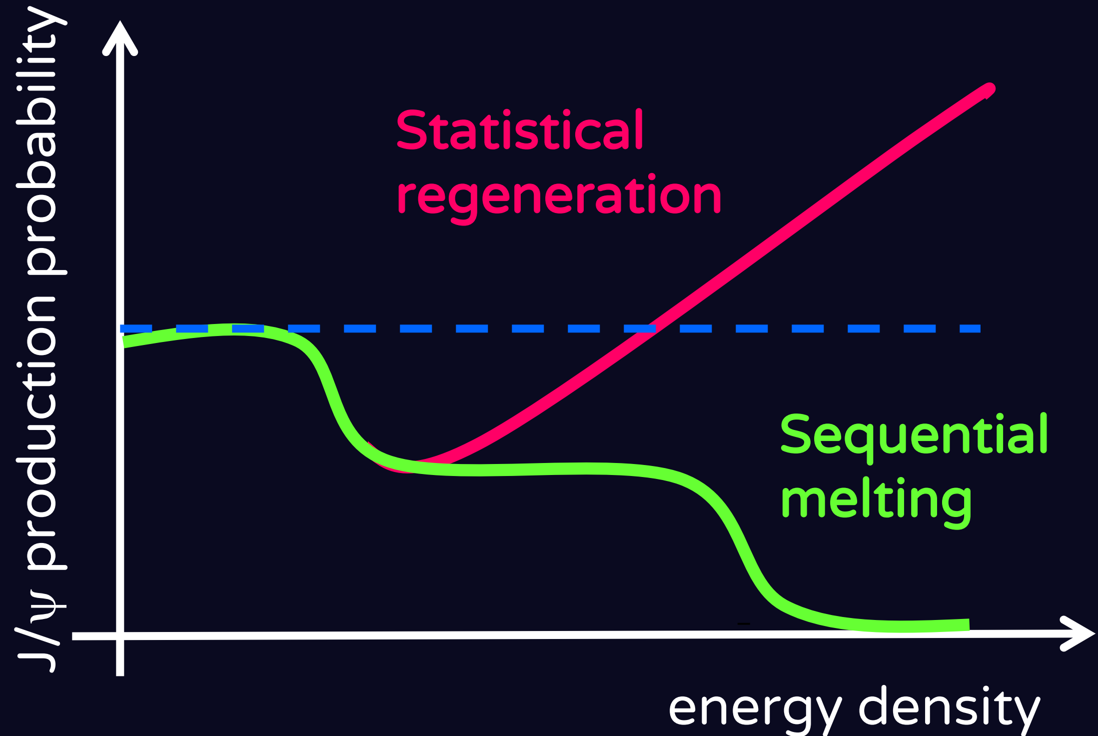
...to recombination

(Re)combination

increasing the collision energy the $c\bar{c}$ pair multiplicity increases

Central AA collisions	SPS 20 GeV	RHIC 200 GeV	LHC 2.76TeV
N_{ccbar}/event	~0.2	~10	~85

enhanced quarkonia production via (re)combination at hadronization or during QGP phase



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

pA: CNM effects

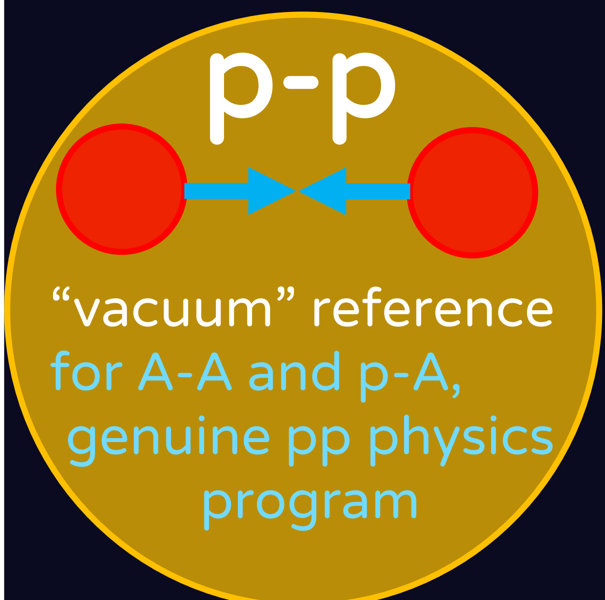
- on top of mechanisms related to hot matter, other cold matter effects might affect quarkonium production

  - nuclear parton shadowing/color glass condensate
  - energy loss
  - $c\bar{c}$ in medium break-up

  } investigated in p-A (d-A) collisions

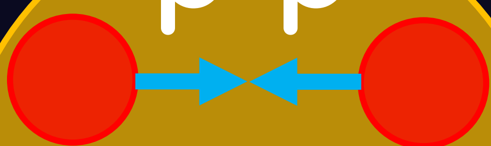
- The assessment of the size of these effects is fundamental to interpret quarkonium A-A results

Summarizing quarkonium in HI



Summarizing quarkonium in HI

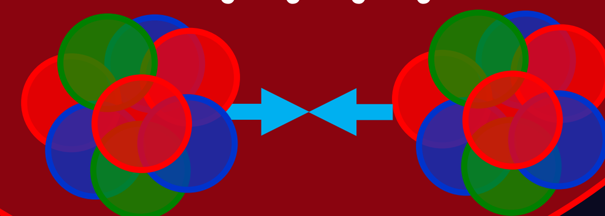
p-p



"vacuum" reference
for A-A and p-A,
genuine pp physics
program

hot matter
effects:
regeneration vs
suppression

A-A



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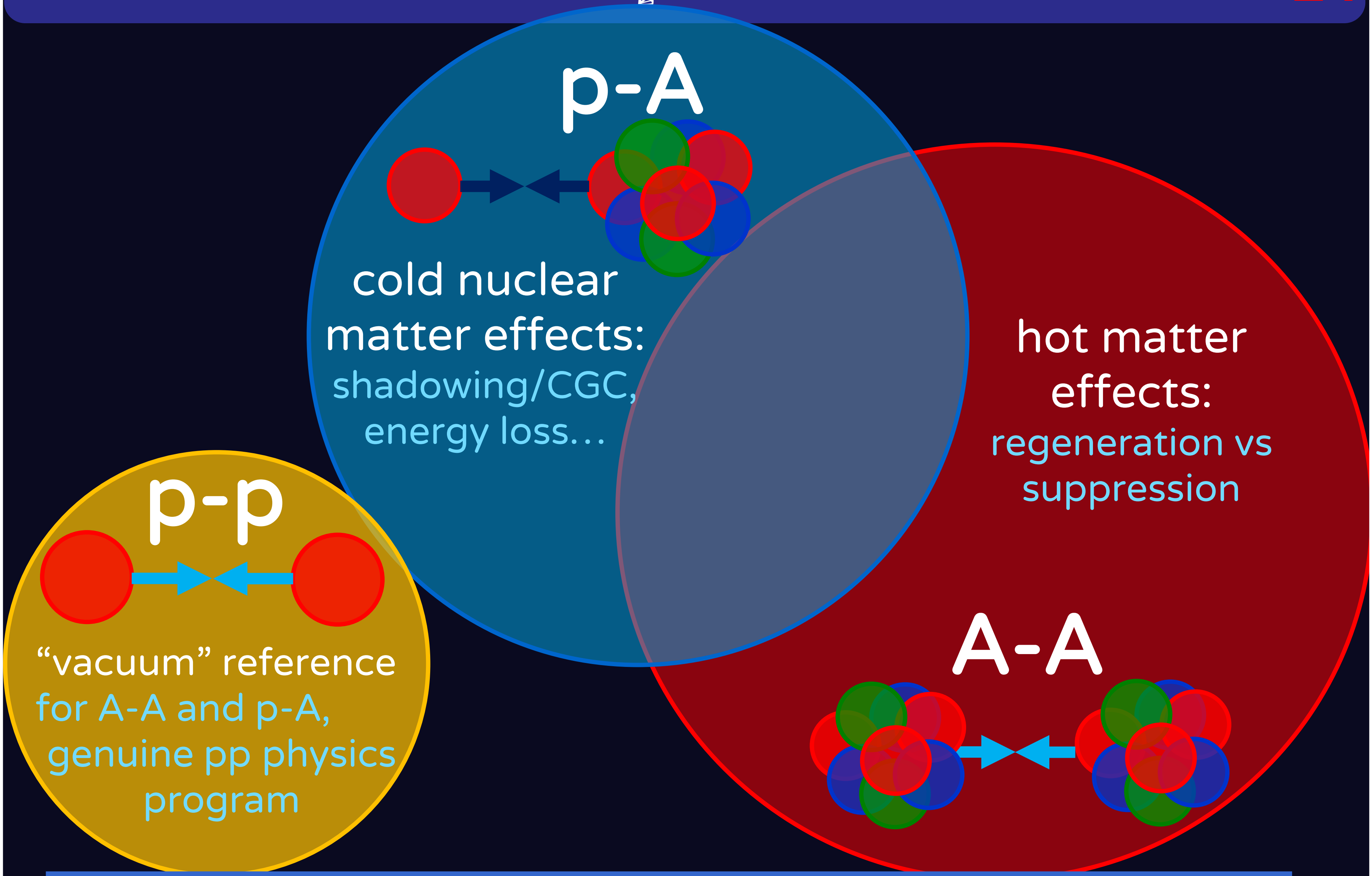

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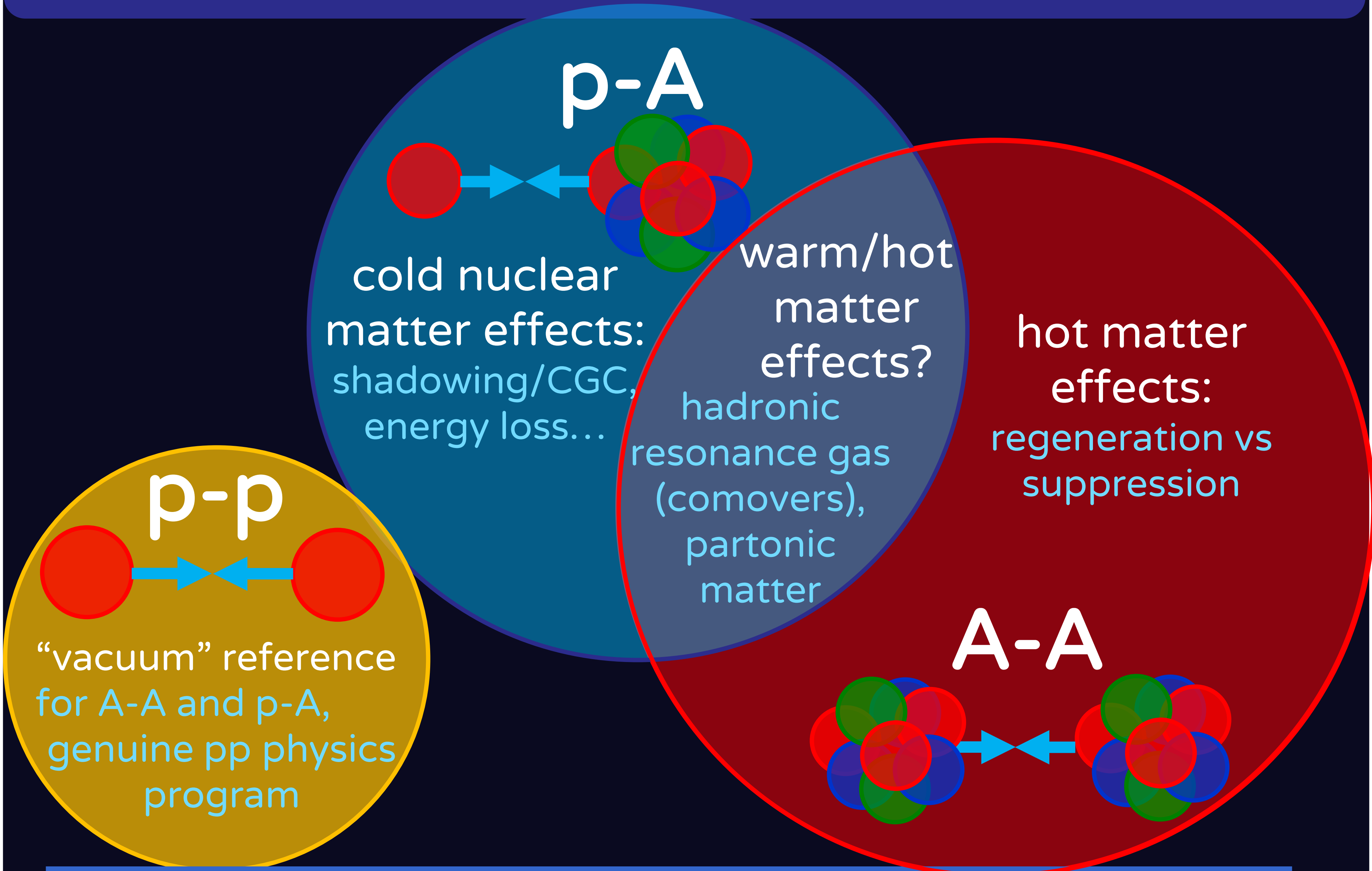
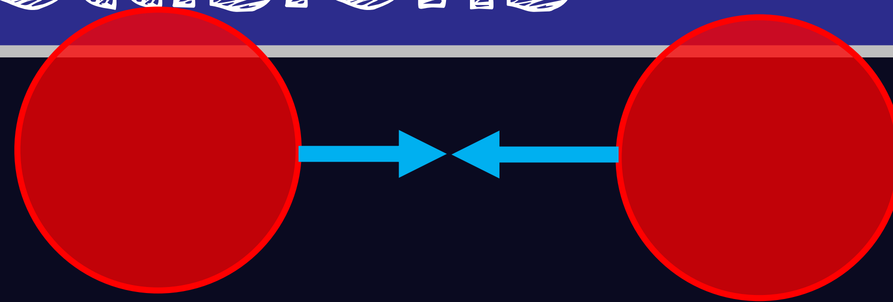


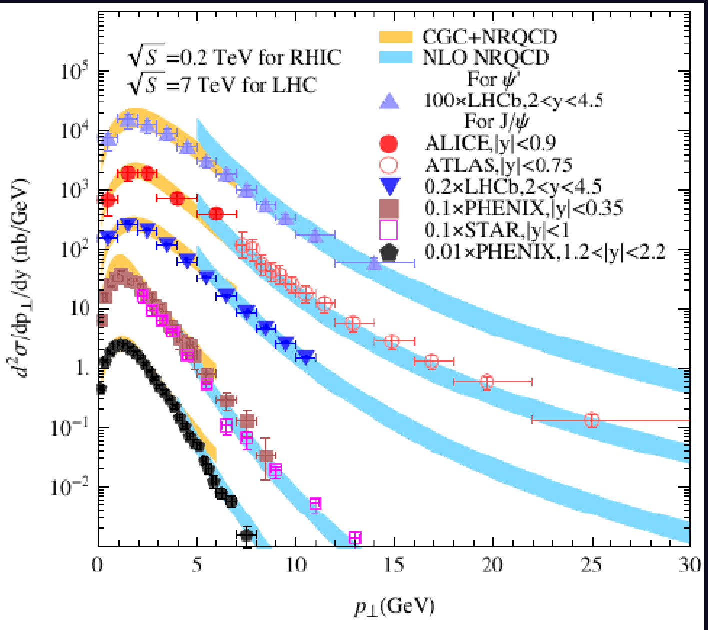
Quarkonium in pp collisions



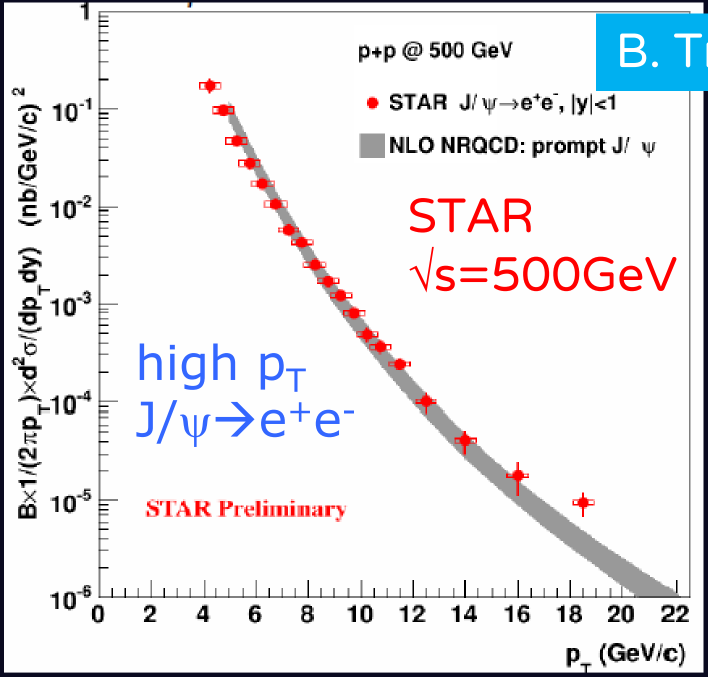
Recent news on J/ψ in pp

- pp as testing ground for quarkonium production mechanisms
  - results now cover a large √s range
  - very high p_T reached (ATLAS and CMS up to ~100GeV/c)

CMS, PRL 114,191802(2015)



Ma et al. PRL 113 (2014)192301



NLO NRQCD
→ describes production for p_T>4GeV/c
CGC+NRQCD
→ description of the low p_T range

NLO NRQCD describes STAR results @ √s= 500 GeV (p_T>4GeV/c)

Shao et al. JHEP 1505 (2015) 103

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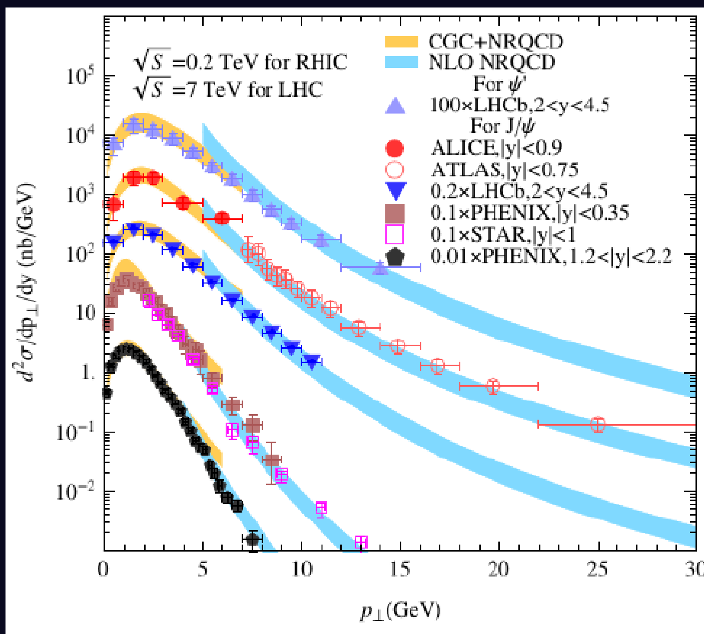
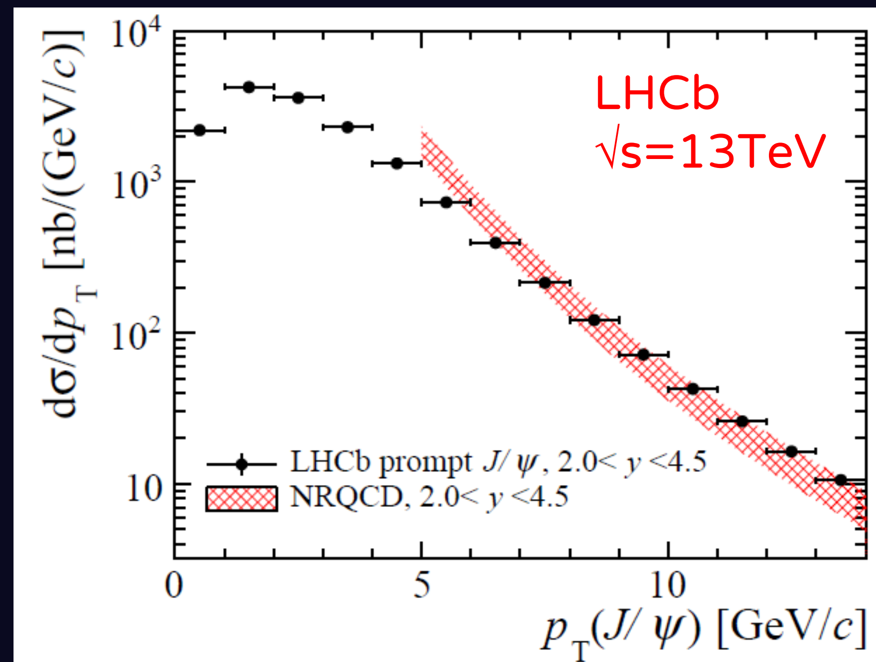


Ma et al. PRL 113 (2014)192301

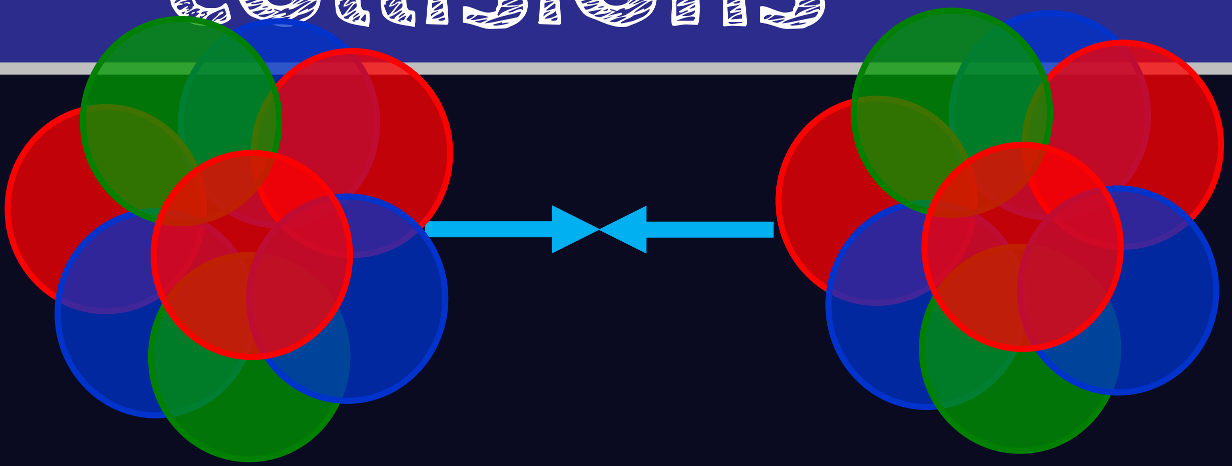


NLO NRQCD
→ describes production for p_T>4GeV/c
CGC+NRQCD
→ description of the low p_T range

NLO NRQCD describes high p_T data up to the LHC top energy (√s= 13 TeV)

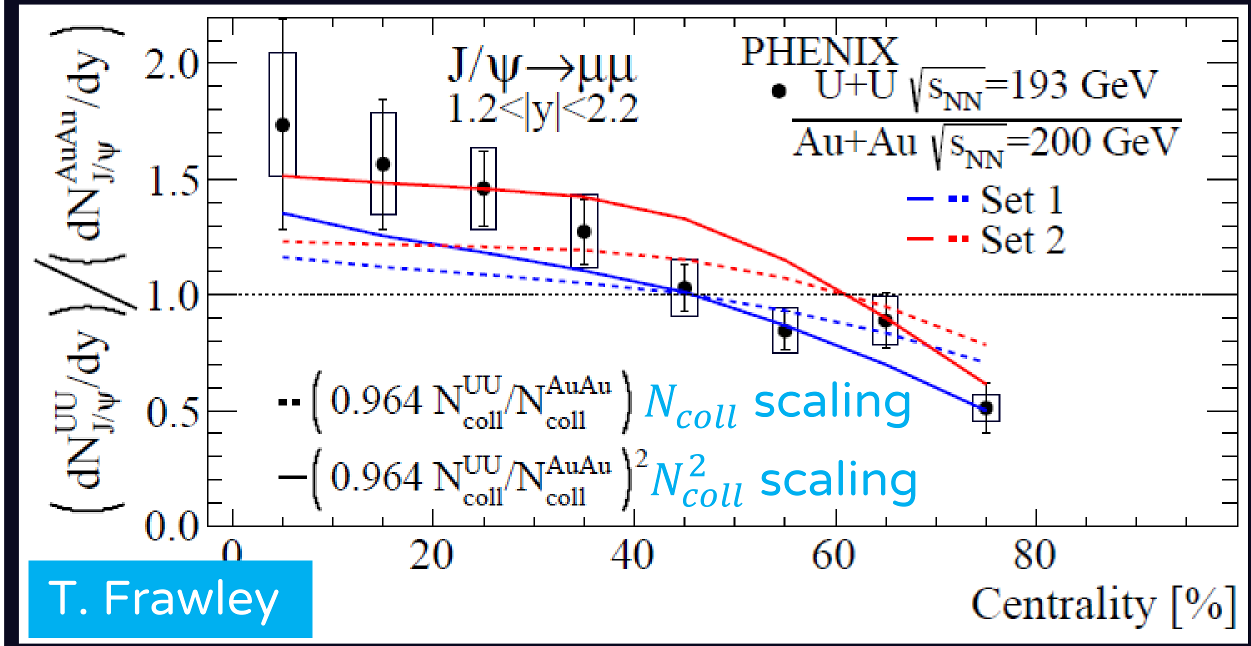
LHCb, arXiv:1509.00771

Quarkonium in AA collisions



J/ψ production at RHIC

(re)combination/suppression role investigated comparing U-U and AuAu



in central U-U collisions:

1) stronger suppression due to color screening

$\varepsilon_{AuAu} \sim$ 80-85% ε_{UU}

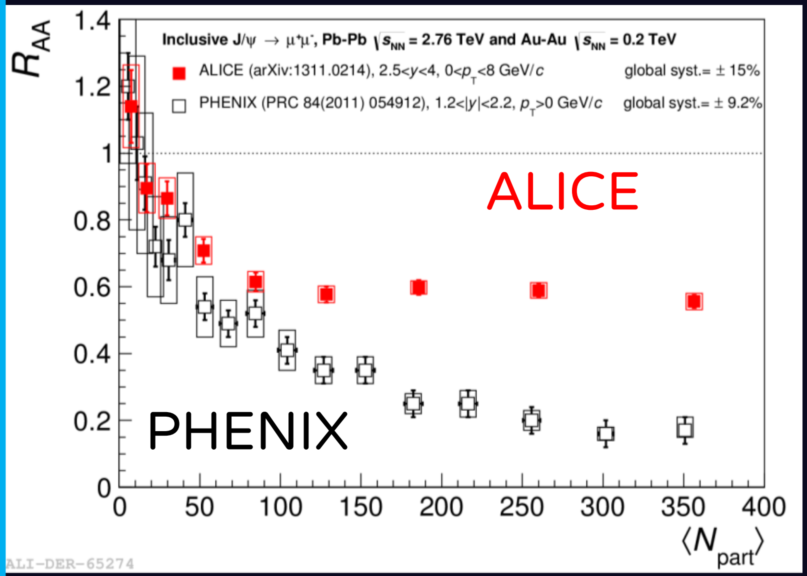
2) J/ψ recombination favoured by 25% larger N_{coll} in UU

$N_{J/\psi}^{stat} \sim N_c^2 \sim N_{coll}^2$

- results slightly favour N_{coll}^2 scaling → dominant (re)combination over suppression when going from central U-U to Au-Au collisions
- quantitative comparison depends on the choice of the uranium Woods-Saxon parametrizations

PHENIX, arXiv:1509.05380

evidence for recombination



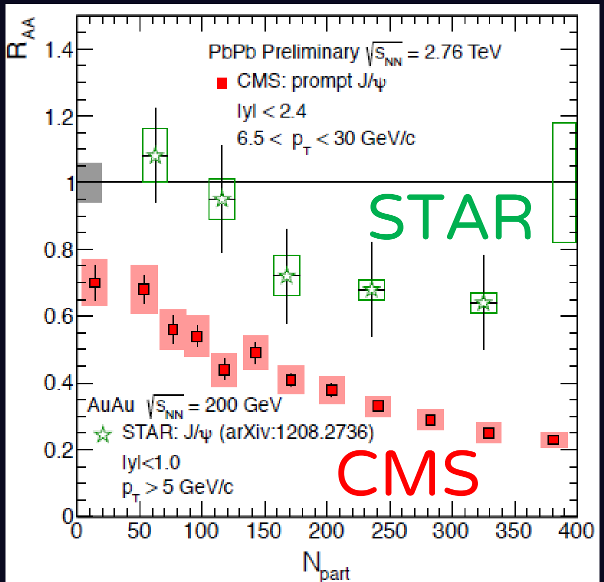
low p_T J/ψ

➡ **PHENIX vs. ALICE**

in spite of LHC larger energy densities, stronger J/ψ suppression, vs centrality, in PHENIX, with respect to ALICE,

similar trend observed both at forward at mid rapidity

ALICE PLB 734 (2014) 314,arXiv:1505.08804



high p_T J/ψ

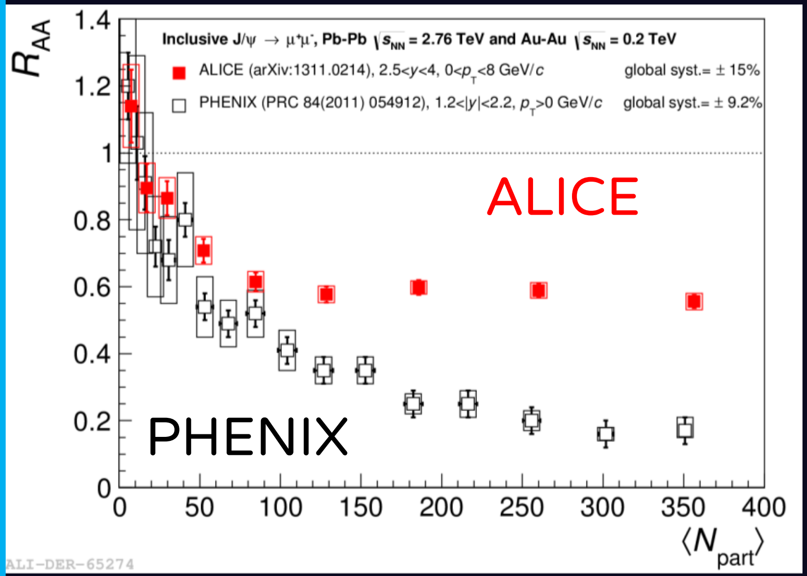
➡ **STAR vs. CMS**

opposite J/ψ behavior compared to low-p_T results

→ suppression stronger at higher √s, as expected from QGP dissociation

CMS PAS-HIN-12-014

evidence for recombination



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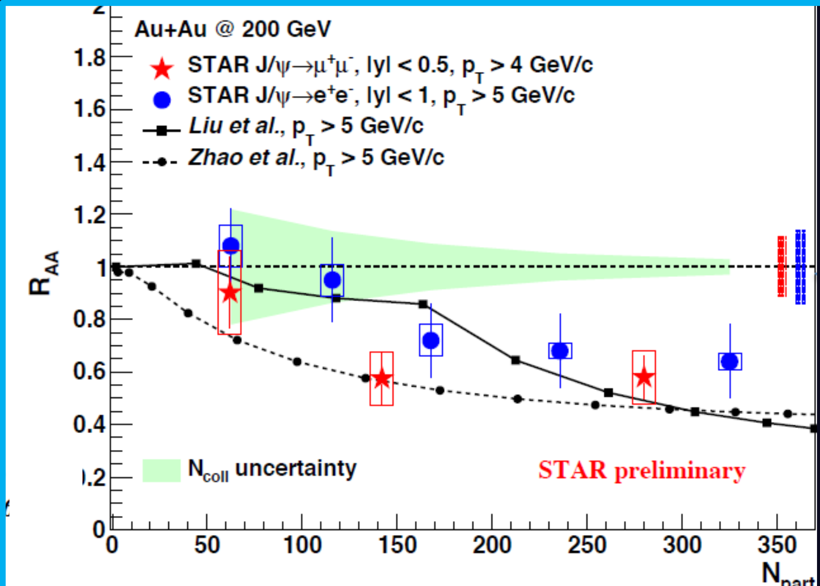


high p_T J/ψ

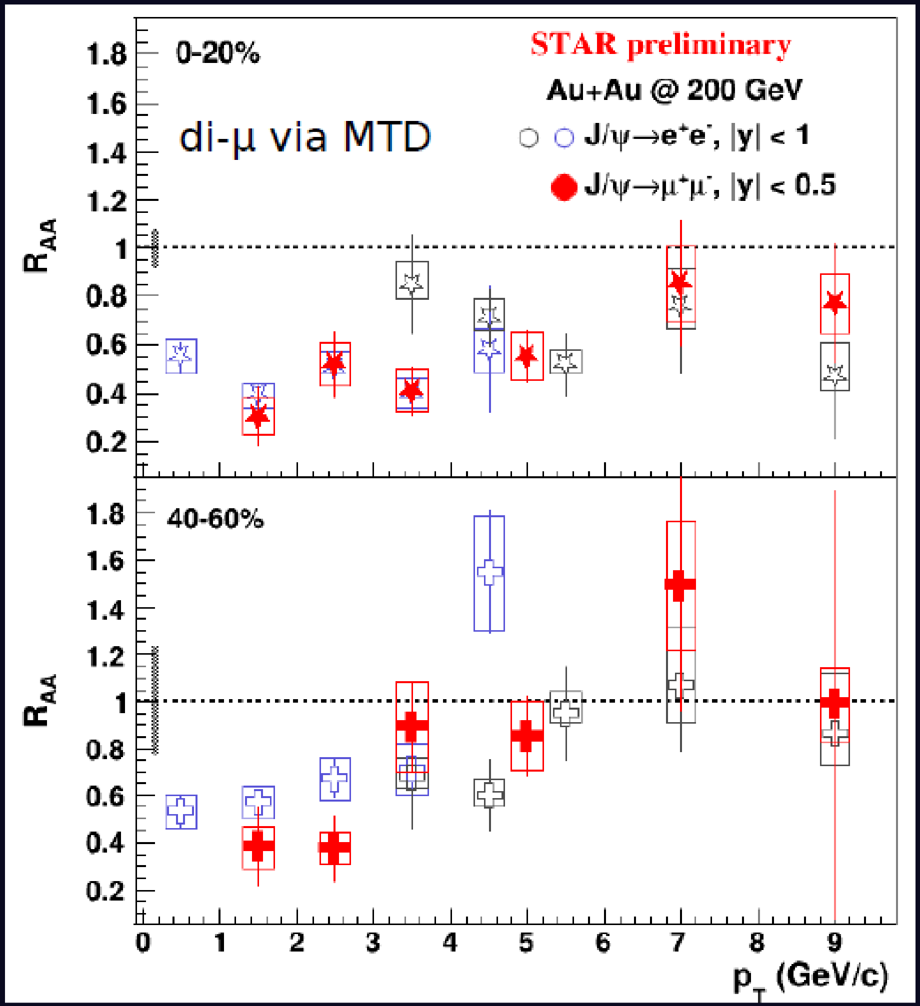
➡ **STAR vs. CMS**

New STAR results based on MTD (J/ψ → μμ) confirm suppression in central collisions observed in the dielectron channel

R.Ma

J/ψ R_{AA} vs p_T at RHIC

R.Ma



- J/ψ suppression stronger at low p_T
- similar p_T dependence observed in the dimuon and dielectron decay channels

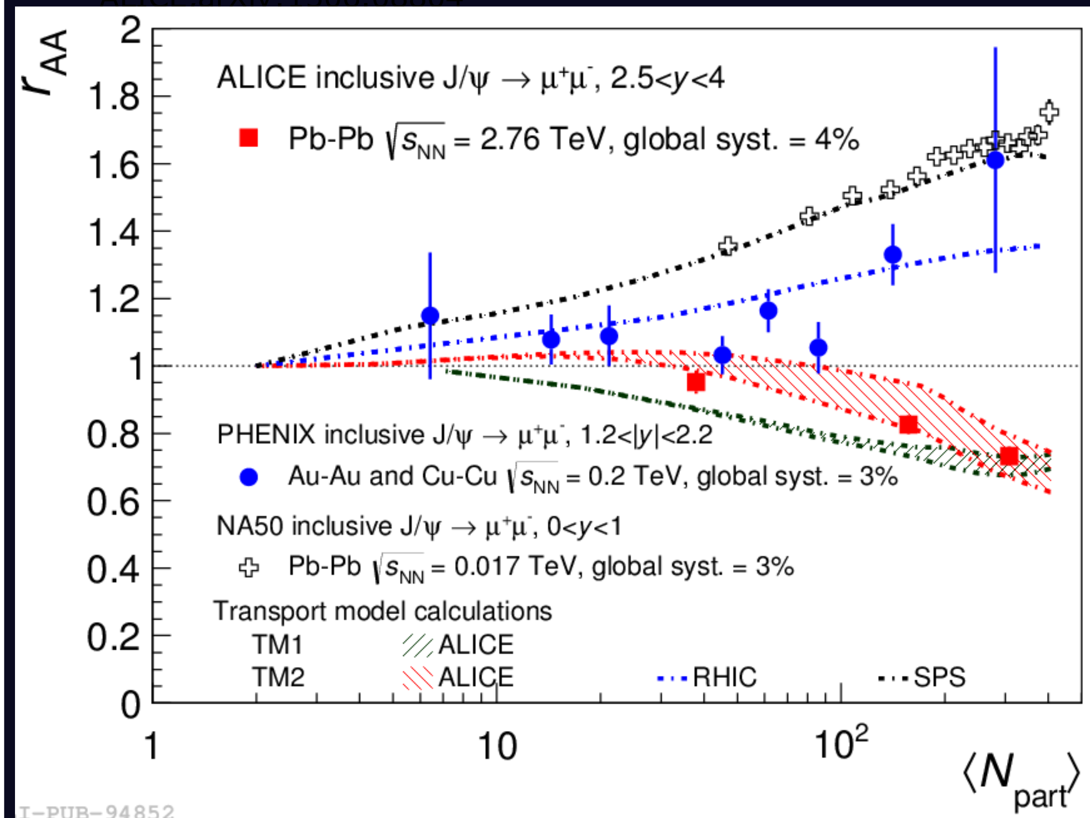
STAR PLB722(2013)55
STAR PR90(2014)024906
Liu et al. PLB678(2009)72
Zhao et al. PRC 82(2010) 064905

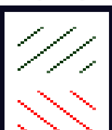
<p_T> increases from pp to AuAu

Evolution of J/ψ $\langle p_T^2 \rangle$

H. Pereira da Costa

ALICE arXiv:1506.08804





TM1: Zhao et al., Nucl.Phys.A859 (2011) 114
TM2: Zhou et al. Phys.Rev.C89 (2014)054911

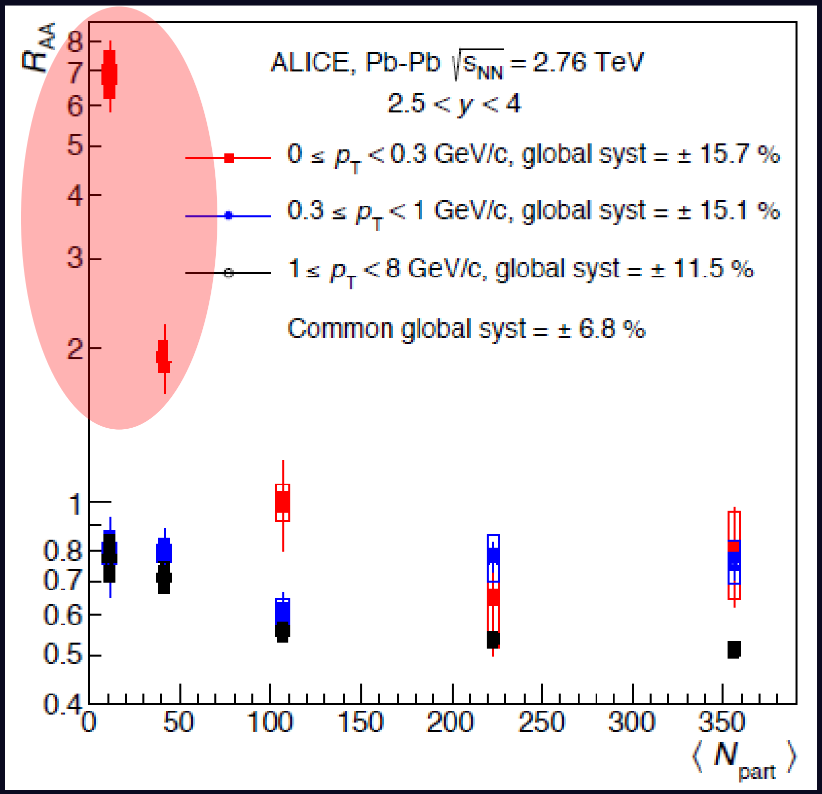
$$r_{AA} = \frac{\langle p_T^2 \rangle_{AA}}{\langle p_T^2 \rangle_{pp}}$$

- r_{AA} centrality evolution strongly depends on √s
- decreasing r_{AA} trend, observed at LHC
  → due to (re)combination, which dominates J/ψ production at low p_T
- transport models, already describing J/ψ R_{AA}, also reproduce the r_{AA} evolution

J/ψ at very low p_T

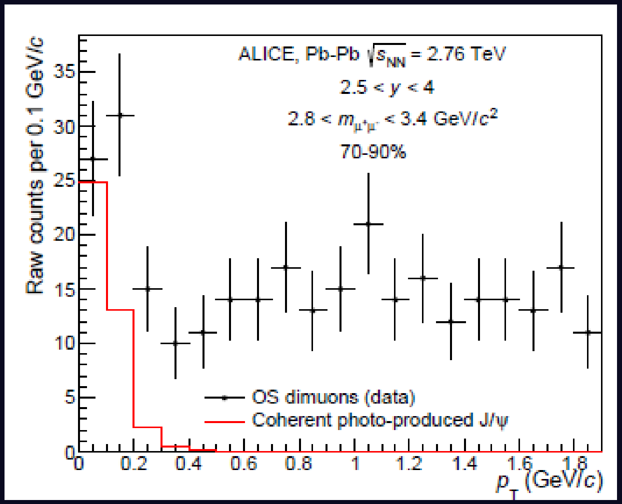
- Strong R_{AA} enhancement in peripheral collisions for $0<p_T<0.3$ GeV/c

G. Martinez



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

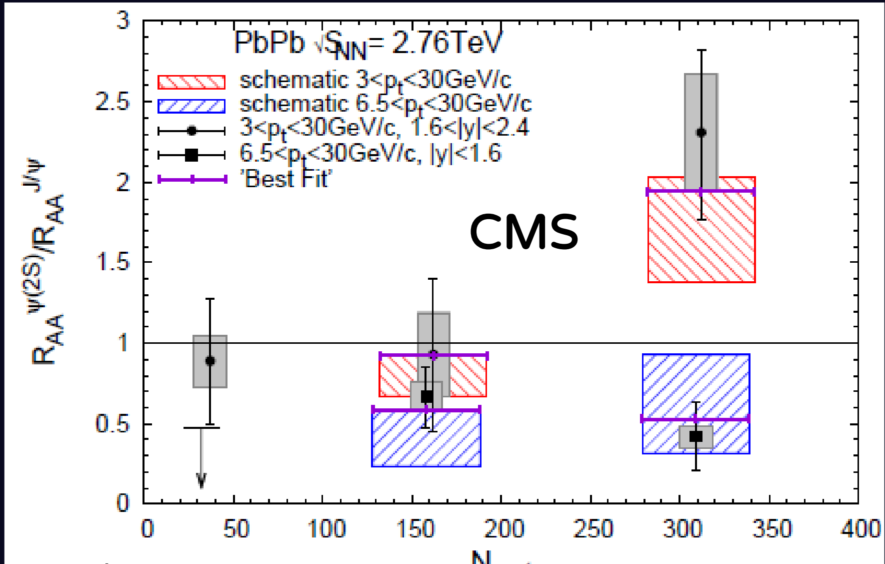
- excess might be due to coherent J/ψ photoproduction in PbPb (as measured also in UPC)



- 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)

ψ(2S) in AA collisions

➡ ψ(2S) production modified in AA with a strong kinematic dependence



Du and Rapp arXiv:1504.00670

Fw-y, 3<p_T<30GeV/c → $R_{AA}^{J/\psi} < R_{AA}^{\psi(2S)}$

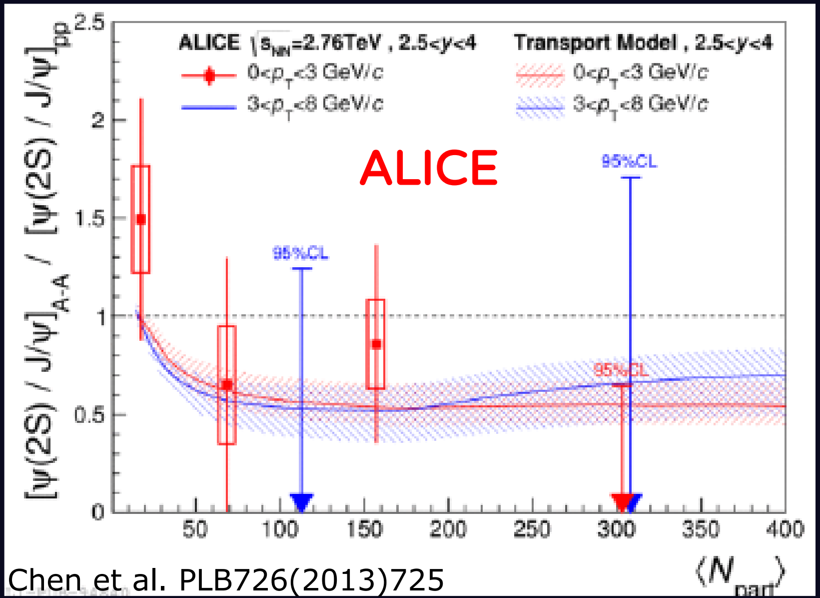
➡ later ψ(2S) regeneration, when radial flow is stronger, might explain the rise

Mid-y 6.5<p_T<30GeV/c → $R_{AA}^{J/\psi} > R_{AA}^{\psi(2S)}$

➡ stronger suppression of weakly bound ψ(2S) with respect to J/ψ

CMS, PRL 113(2014) 262301

Y. Kim



Chen et al. PLB726(2013)725

Fw-y, 0<p_T<3GeV/c → $R_{AA}^{J/\psi} > R_{AA}^{\psi(2S)}$

➡ ALICE trend in agreement with transport models and with statistical hadronization approach

H. Pereira da Costa

ALICE arXiv:1506.08804

Υ(ns) production in AA

M. Jo

Reanalysis of 2011 CMS data:

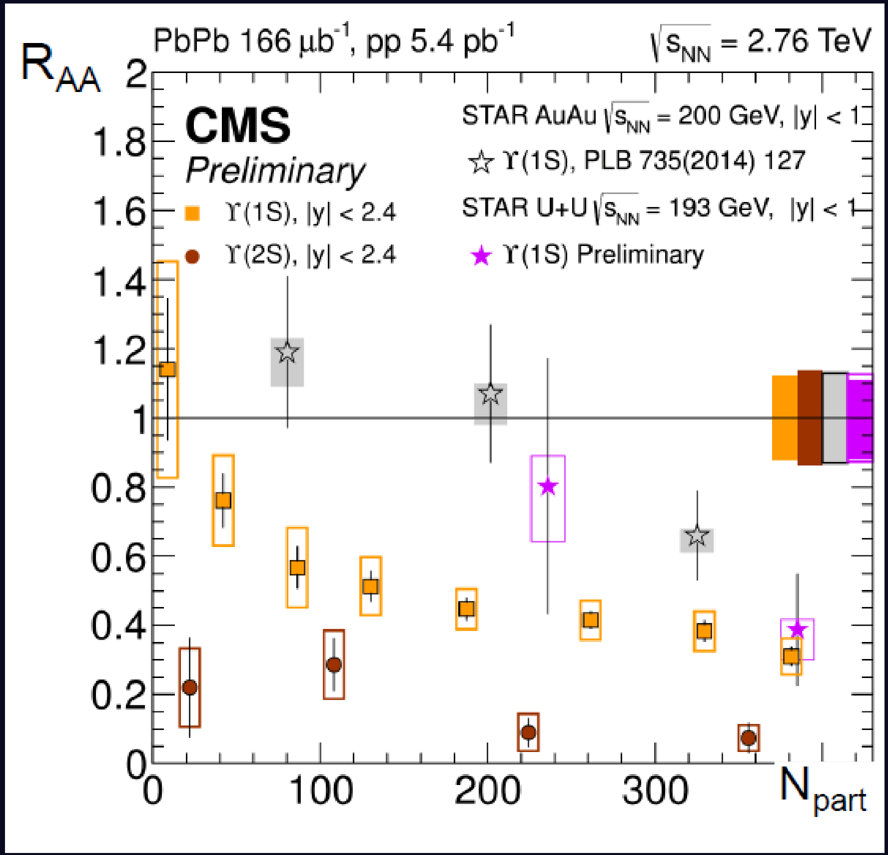
- improved reconstruction
- high statistics pp reference (x20)

➡ confirm the centrality dependent suppression for Υ(1S) and Υ(2S)

➡ Sequential suppression observed at LHC:

$$R_{AA}^{\Upsilon(3S)} < R_{AA}^{\Upsilon(2S)} < R_{AA}^{\Upsilon(1S)}$$

$R_{AA}(\Upsilon(1S)) = 0.43 \pm 0.03 \pm 0.07$
$R_{AA}(\Upsilon(2S)) = 0.13 \pm 0.03 \pm 0.02$
$R_{AA}(\Upsilon(3S)) < 0.14$ at 95% CL



CMS, PRL109 (2012) 222301 and HIN-15-001
STAR, PLB735 (2014) 127 and preliminary U+U

➡ Υ(1S) suppressed also in central Au-Au and U-U collisions at RHIC

Υ(ns) production in AA

M. Jo

Reanalysis of 2011 CMS data:

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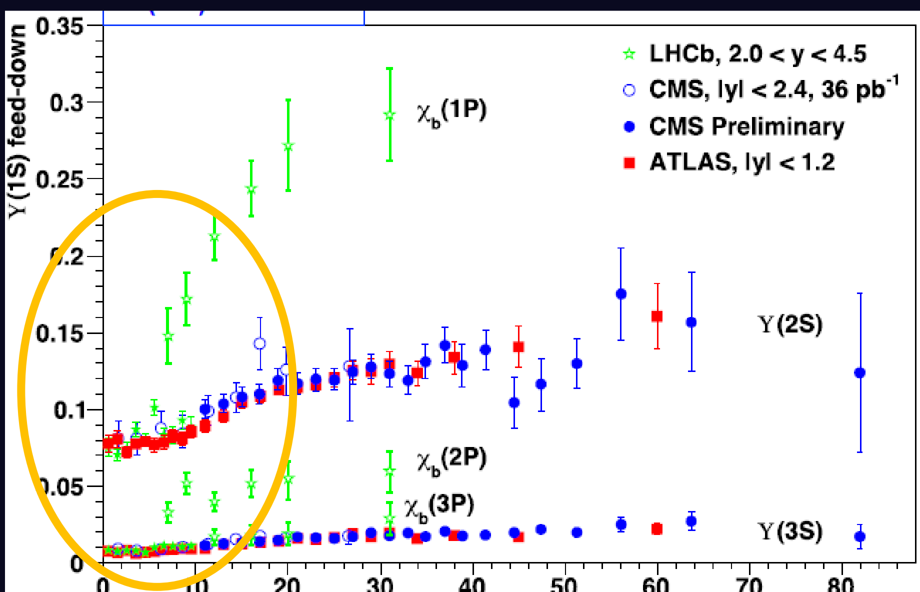
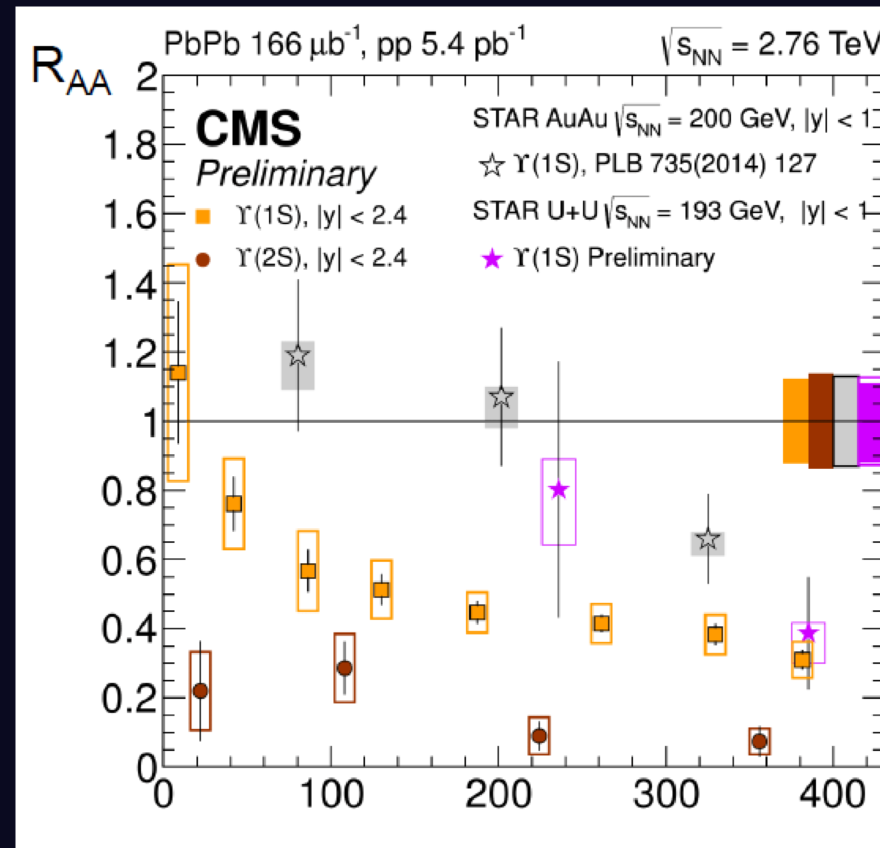
➡ Feed-down from excited states seems not enough to explain the observed Υ(1S) suppression



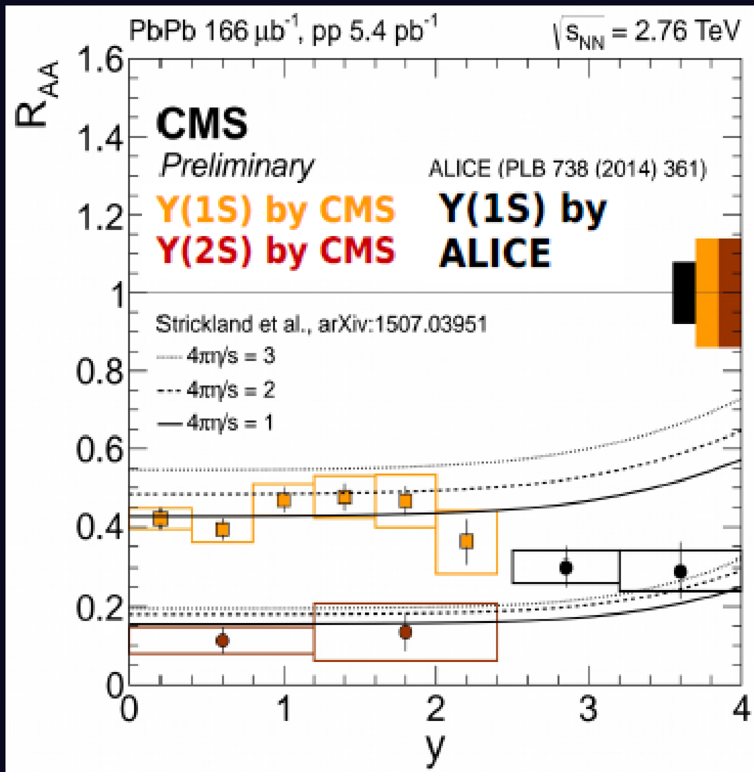
H. Wöhri, QWG2014

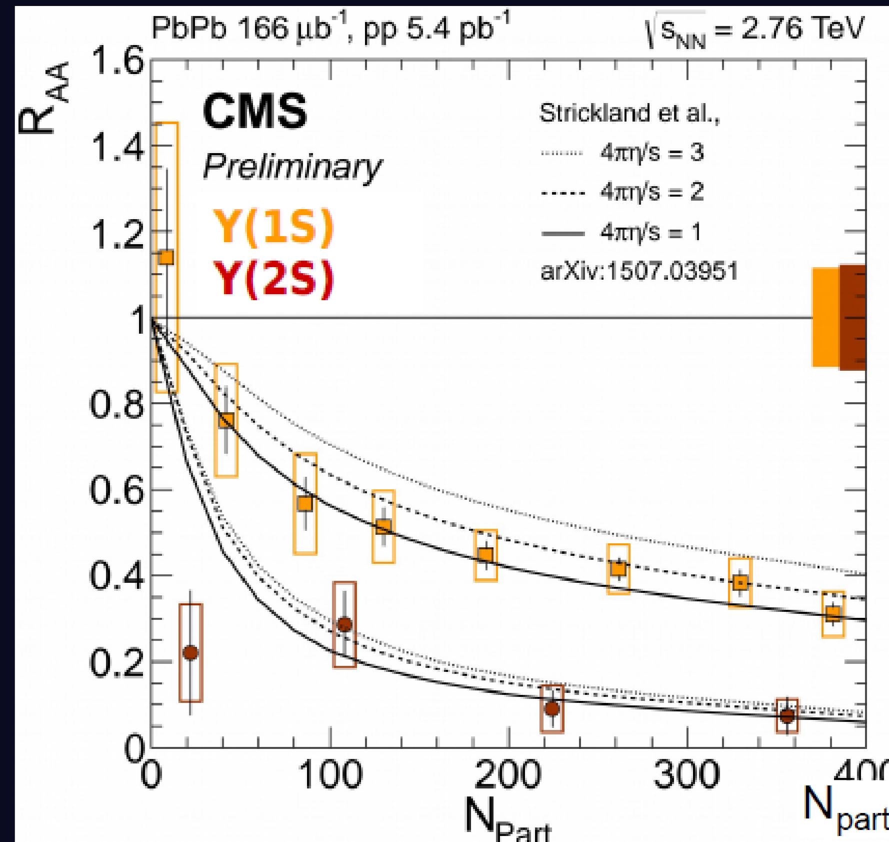


CMS, PRL109 (2012) 222301 and HIN-15-001
STAR, PLB735 (2014) 127 and preliminary U+U

ϒ(ns) production in AA

I. Das, M. Jo

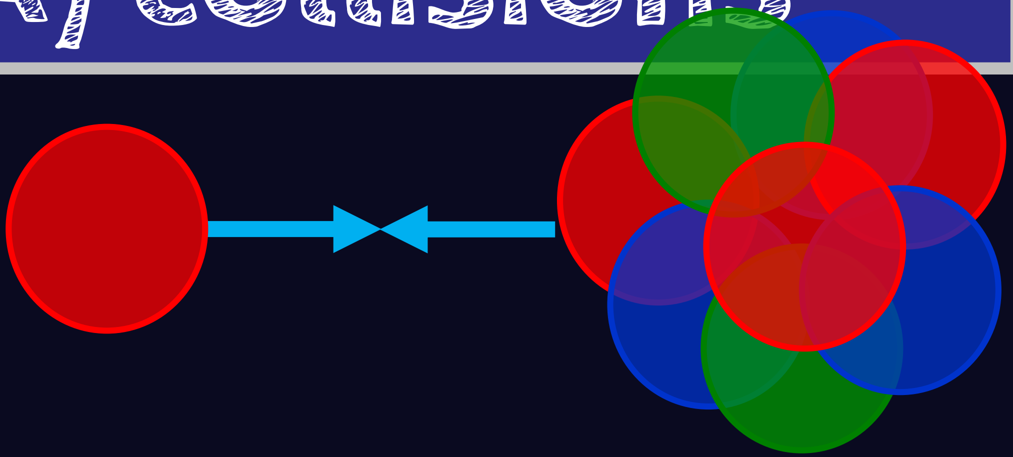




- no p_T or y dependence of the ϒ(1S) and ϒ(2S) suppressions
- new CMS R_{AA} closer to ALICE forward-y results

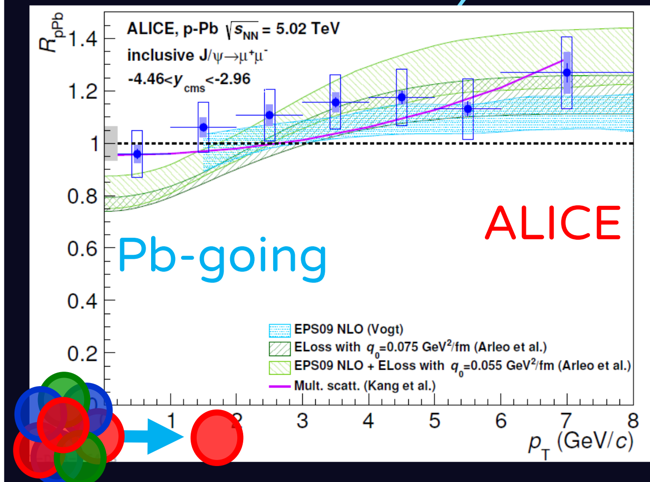
- models reproduce the p_T and centrality dependence. Rapidity description still needs tuning

Quarkonium in p-A (d-A) collisions

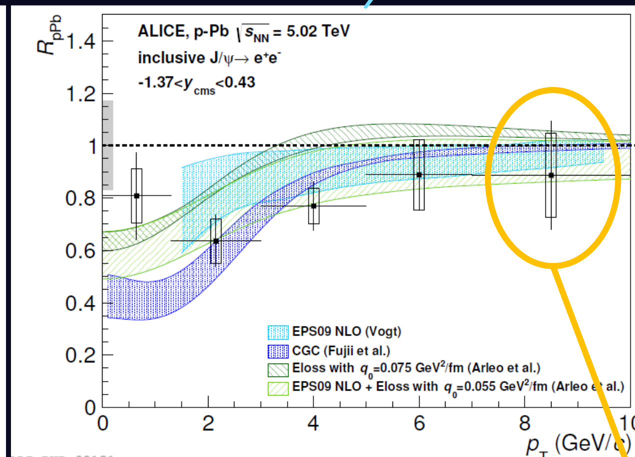


J/ψ R_{pA} vs p_T

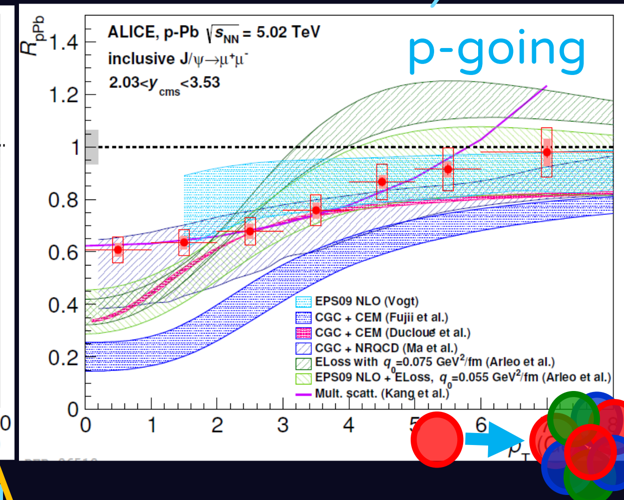
backward-y



mid-y



forward-y

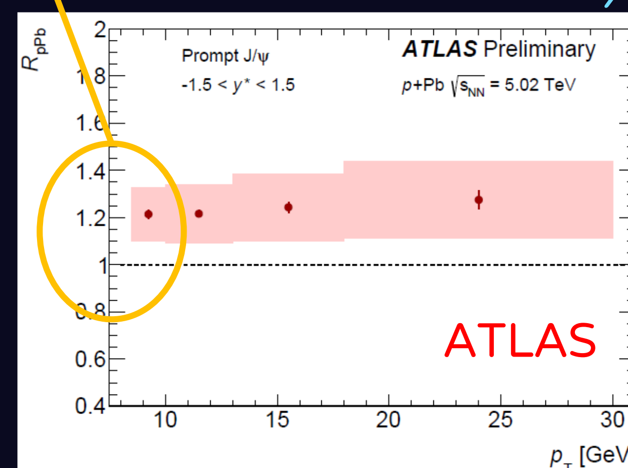


J/ψ production strongly depends of on y and p_T

- backward-y: R_{pA} ~1, negligible p_T dependence
- forward-y: R_{pA} increases with p_T
- mid-y: small p_T dependence, R_{pA} ~1 for p_T>3GeV/c (ALICE) and slightly larger for p_T>8GeV/c (ATLAS)

~0.7σ difference

mid-y

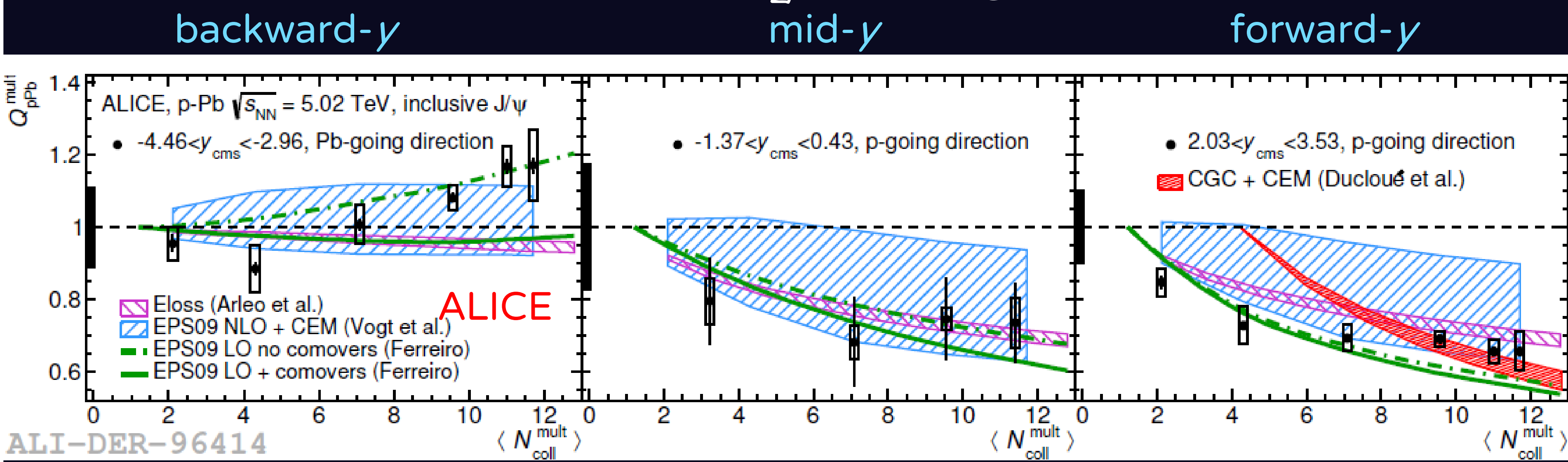


➡ shadowing and coherent parton energy loss models reasonably describe the data

➡ agreement with CGC depends on implementation

Q. Hu, M. Leoncino

J/ψ centrality dependence



➡ J/ψ production is investigated vs. centrality

ALICE:

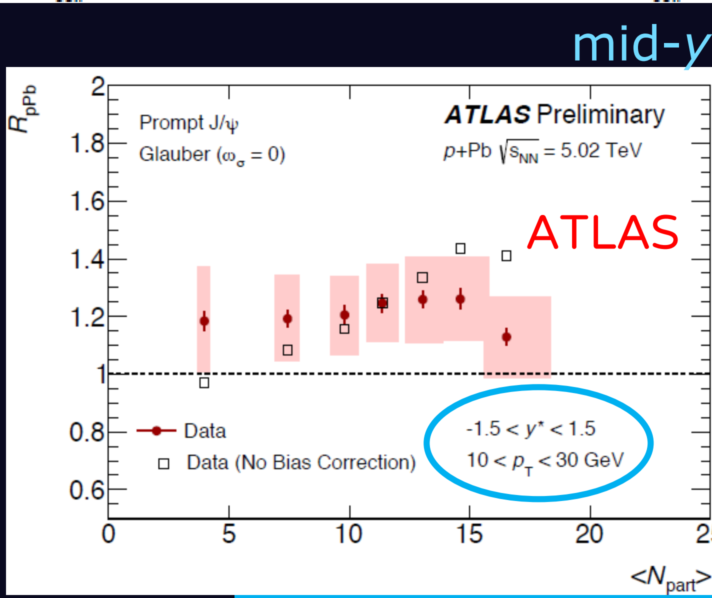
mid and fw-y: suppression increases with centrality

backward-y: hint for increasing Q_{pA} with centrality

Shadowing and coherent energy loss models in fair agreement with data

ATLAS

Flat centrality dependence in the high p_T range



Q. Hu, M. Leoncino

ψ(2S) production in pA

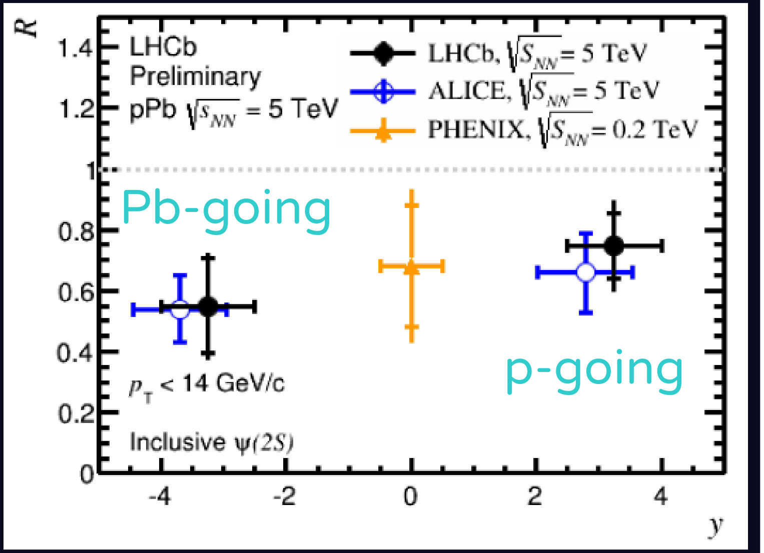
- Being more weakly bound than the J/ψ, the ψ(2S) is an interesting probe to have further insight on the charmonium behaviour in pA

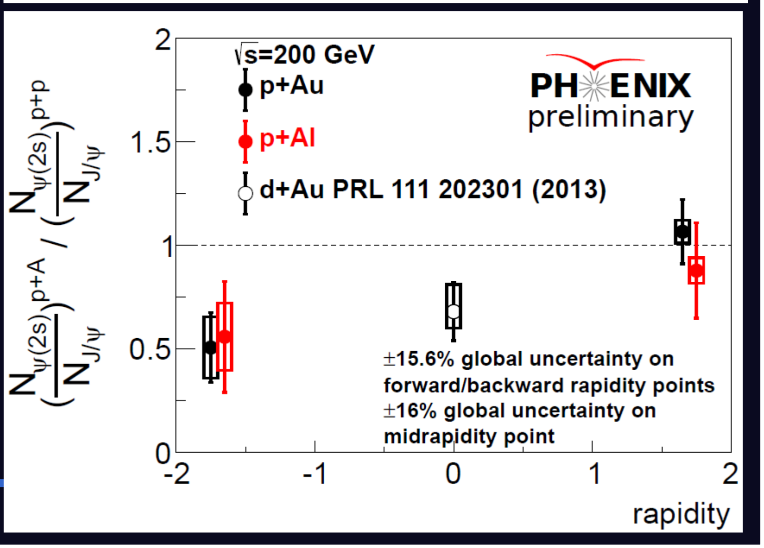
- ψ(2S) suppression stronger than the J/ψ one at RHIC and LHC

→ 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

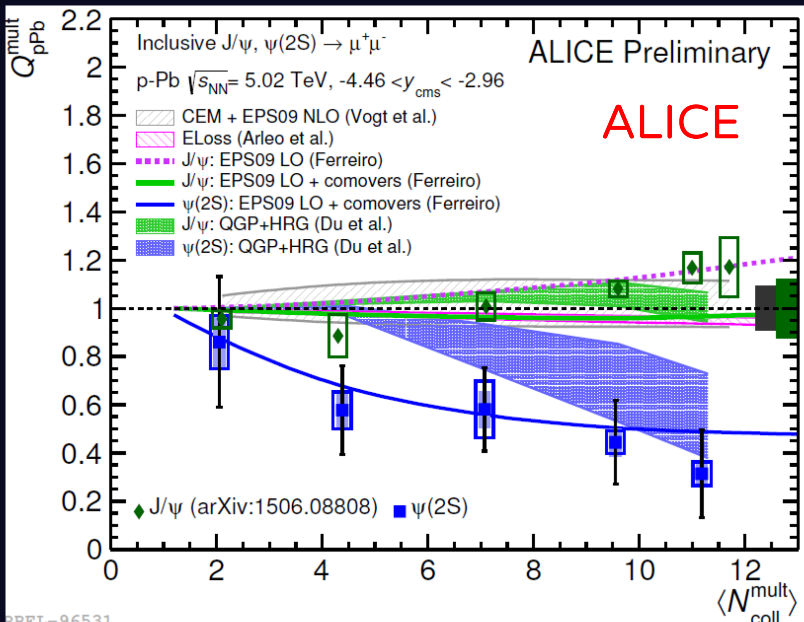
M.Brooks T. Frawley, M. Leoncino, Z. Yang



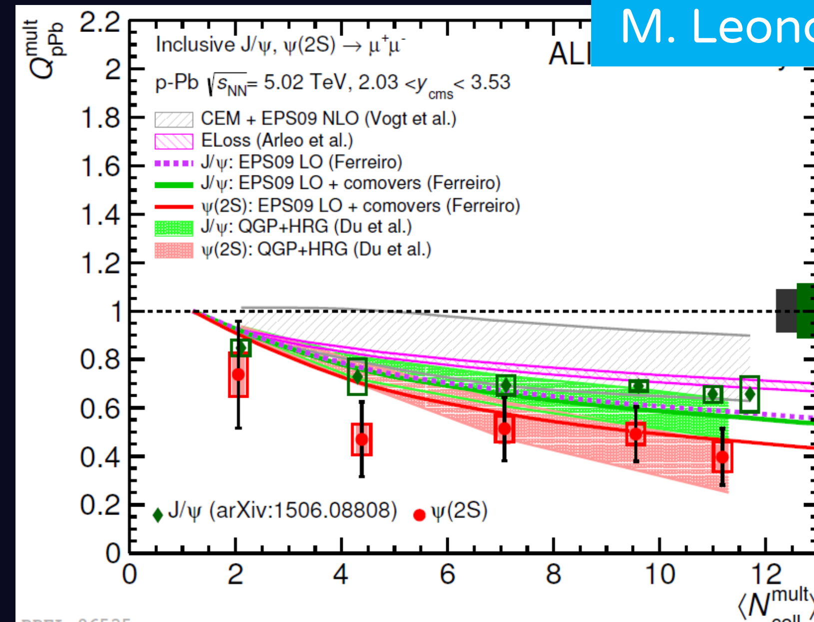


ALICE, JHEP 1412(2014)073, LHCb-conf-2015-005,PHENIX, PRL 111 (2013) 202301

ψ(2S) production vs centrality

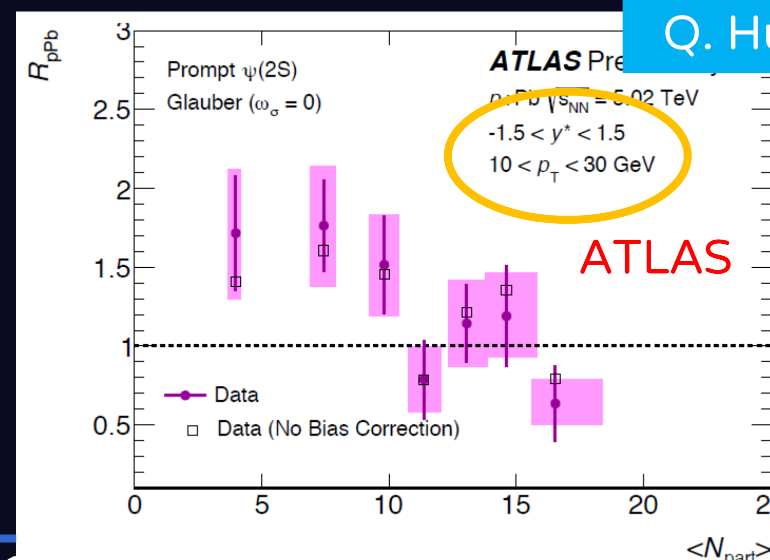


M. Leoncino

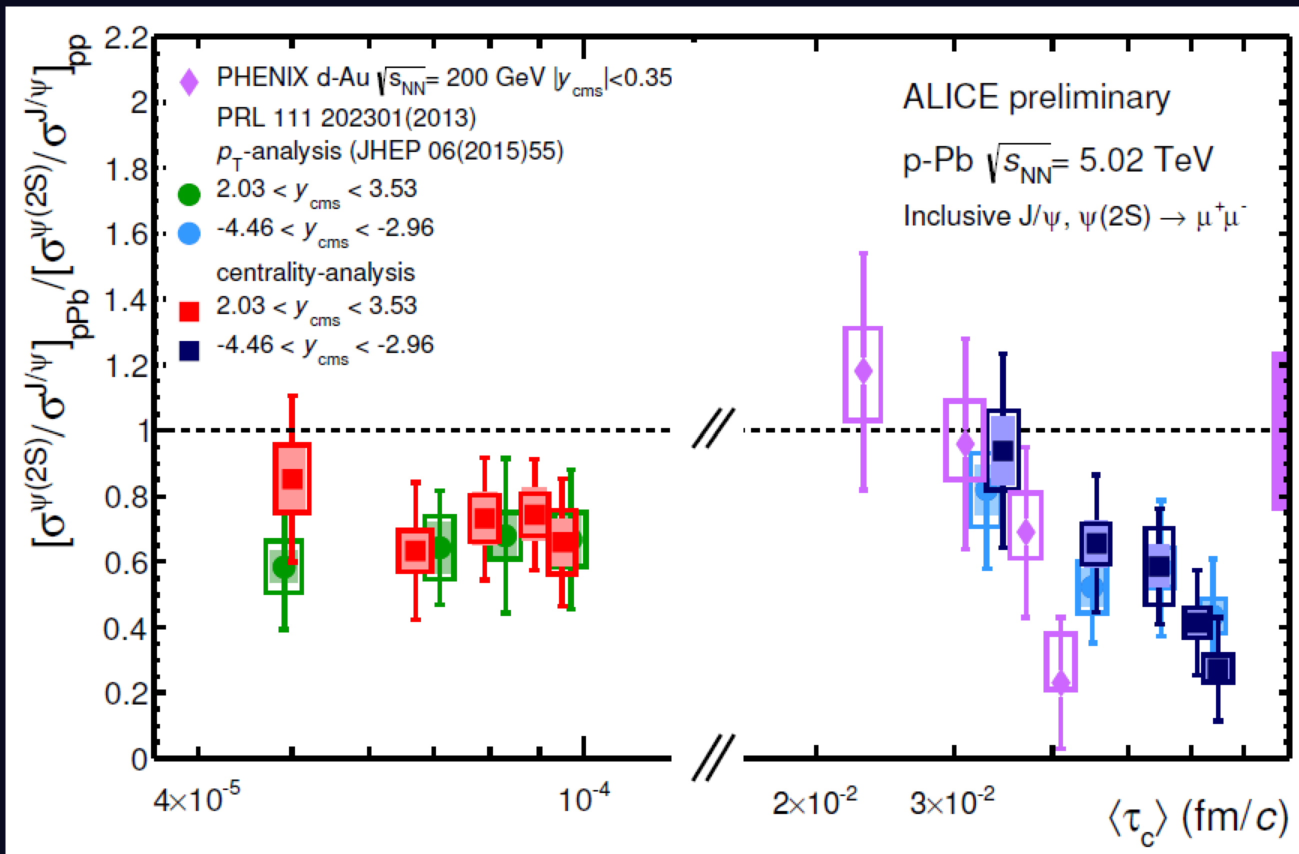


- QGP+hadron resonance gas (Rapp) or comovers (Ferreiro) models describe the stronger ψ(2S) suppression
- Consistency between ALICE and ATLAS results?
  It would be useful to have theory prediction for the higher p_T range

Q. Hu



ψ(2S) versus crossing time

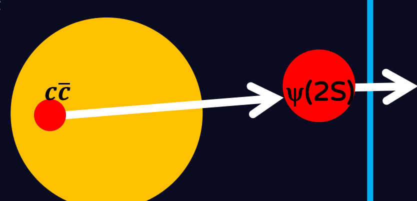


$$\tau_c = \frac{\langle L\rangle}{(\beta_z\gamma)}$$

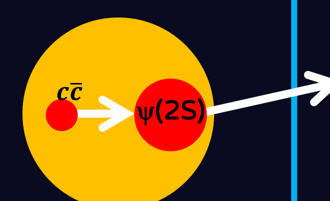
D. McGlinchey, A. Frawley and R.Vogt, PRC 87,054910 (2013)

M. Leoncino

Forward-y: $\tau_c << \tau_f$
interaction with nuclear matter cannot play a role

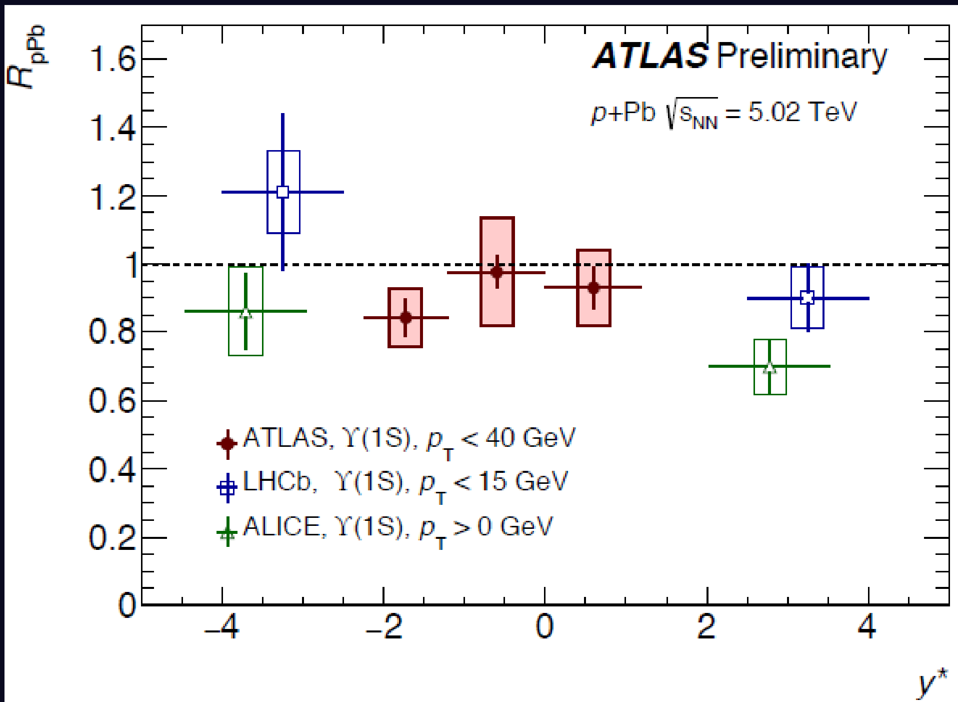


Backward-y: $\tau_c \lesssim \tau_f$
indication of effects related to break-up in the nucleus?

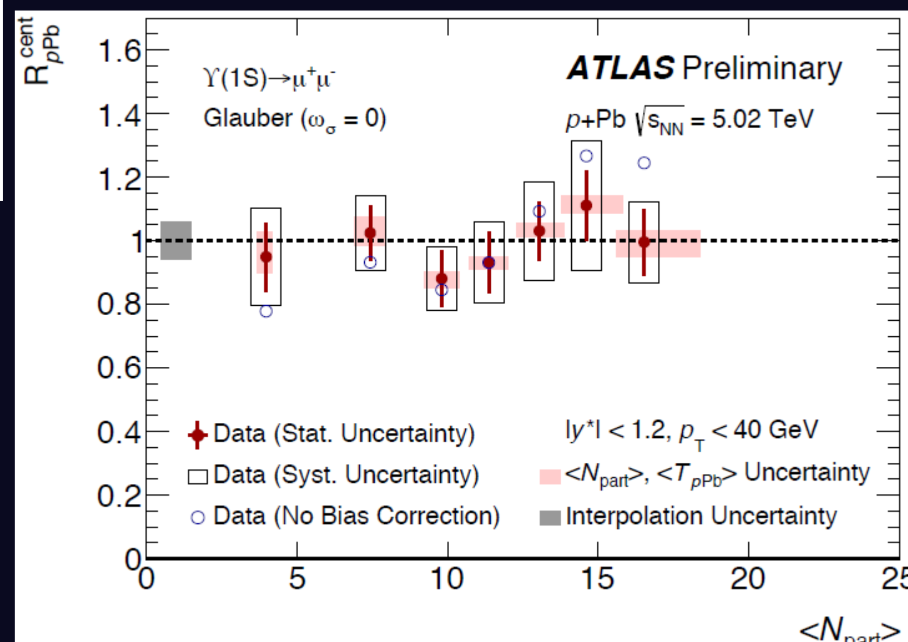


Υ(1s) in pA collisions

Q. Hu

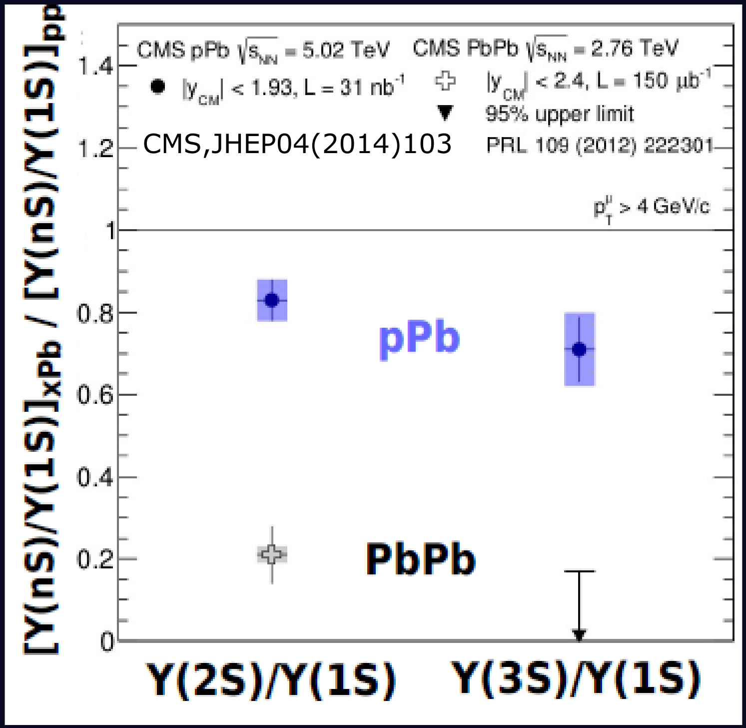


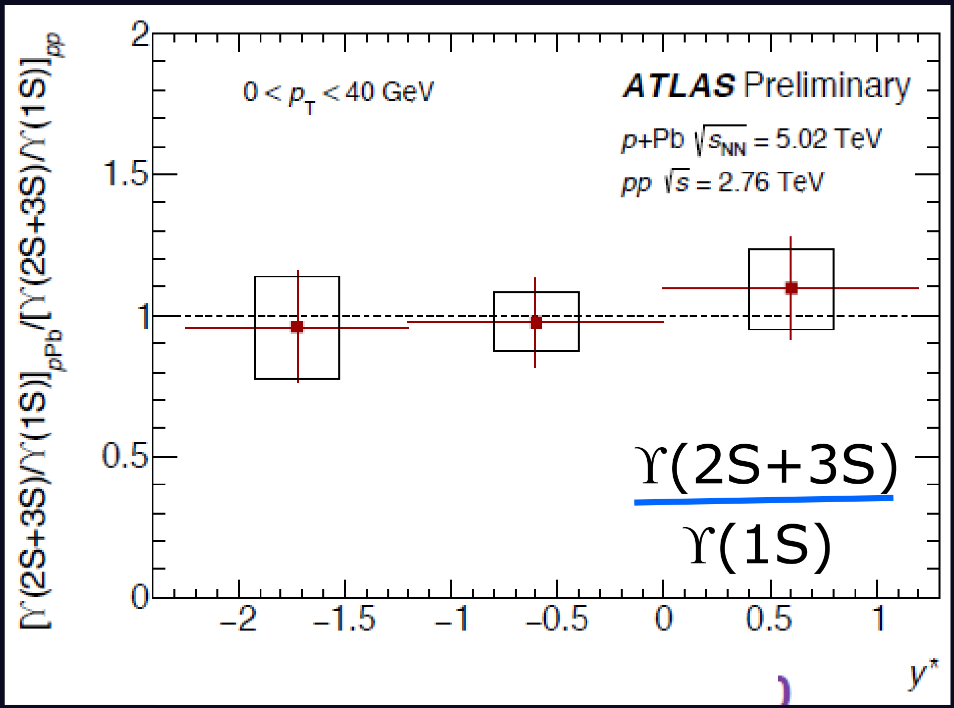
- No significant rapidity dependence of Υ(1S) R_{pA}
- Weak CNM effects on Υ(1S)
- Υ(1S) R_{pA} consistent with unity and rather flat versus centrality



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

Υ(ns) in pA collisions





CMS:

- excited states suppressed with respect to Υ(1S)
- Initial state effects similar for the Υ(ns) states
  → Final states effects at play?

ATLAS:

- no strong y (and p_T) dependence
- agreement with CMS within uncertainties

M. Jo, Q. Hu

Conclusions

New results on quarkonium in pp, pA and AA shown in QM:

pp

New differential J/ψ cross-section results at RHIC and LHC top energies will help constraining production models

AA

New results confirm the role of suppression and recombination mechanisms at play on the various quarkonium states

pA

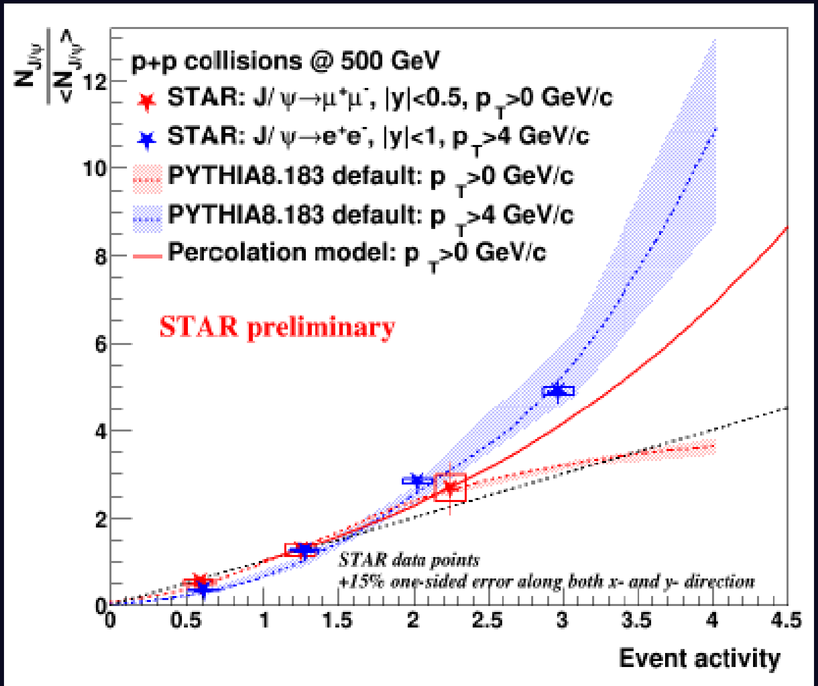
Interplay of shadowing and energy loss describes J/ψ production. Comover-like effects seem to affect excited quarkonium states

Thanks!

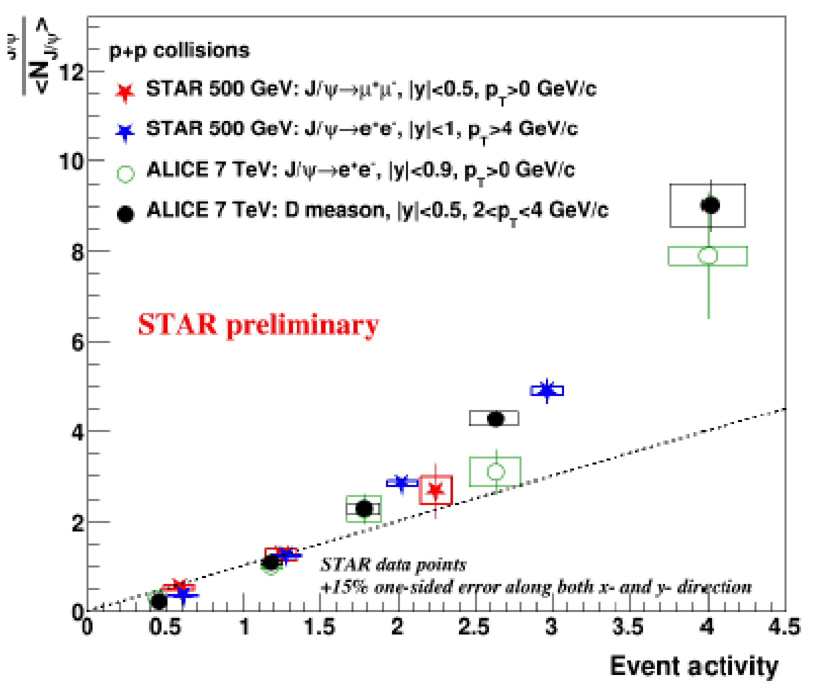
Backup slides pp

J/ψ production in pp

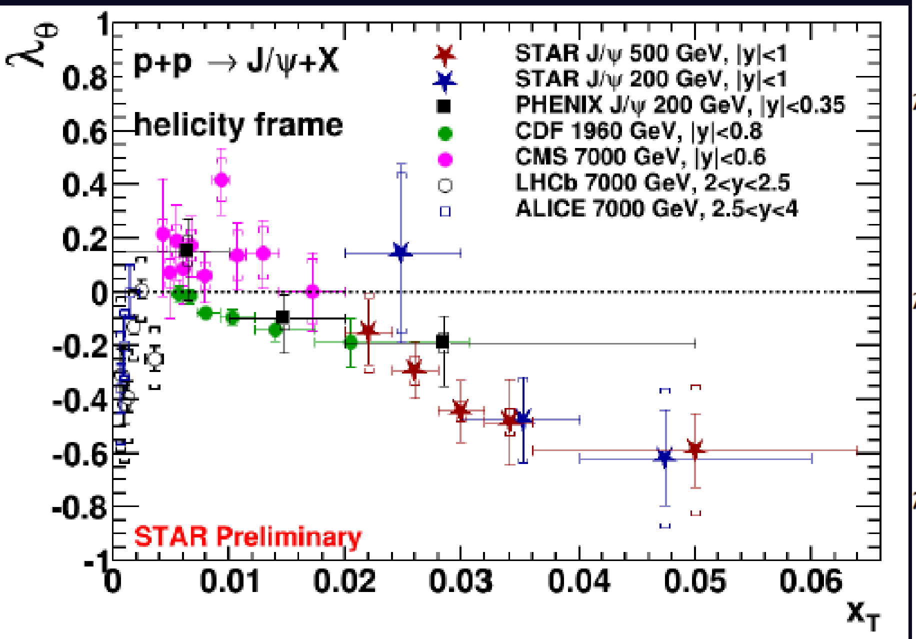
Correlation between J/ψ yields and multiplicity

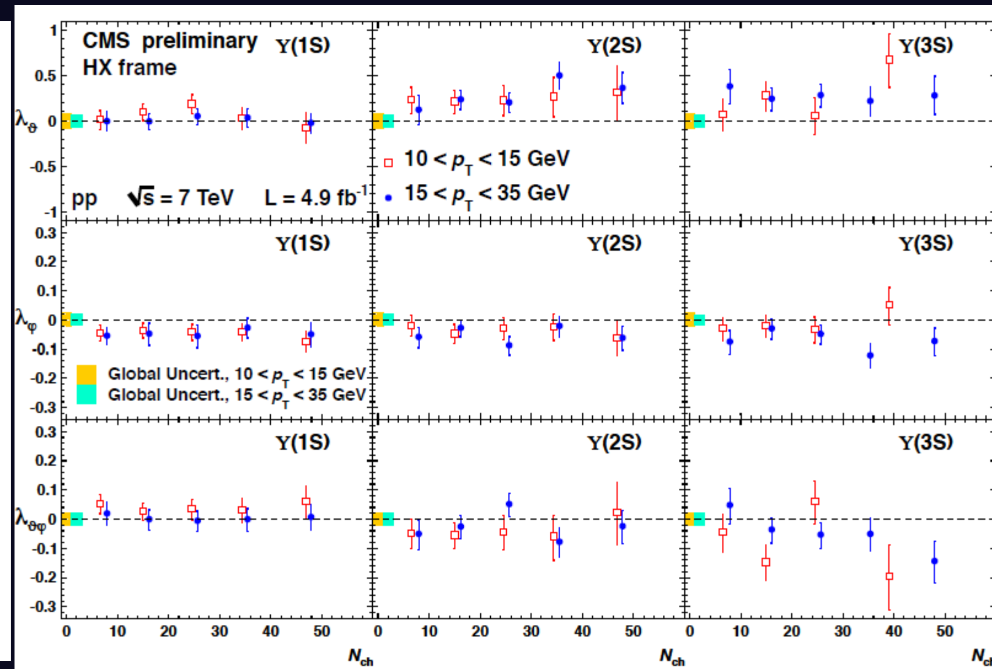


- Stronger than linear increase for pT>4GeV
- Possible interpretations: multi parton interactions (MPI) or percolation
- Similar trend observed in pp at √s=7TeV



J/ψ and ϒ(ns) polarization





CMS PAS HIN-15-003

- Same trend in √s=200 and new STAR 500 GeV results

- Common xT scaling towards negative λθ

  xT = 2pT/√s

- ϒ polarization in pp at √s= 7TeV: no trend observed as a function of the charged particle multiplicity

  No changes in the production process between low and high multiplicity

Backup slides AA

Uranium parametrization

Effect of U deformation model

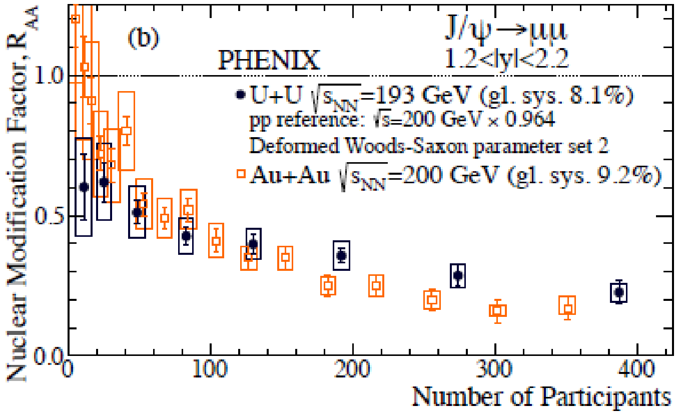
8

The parameters for set I are significantly different in their surface diffuseness:

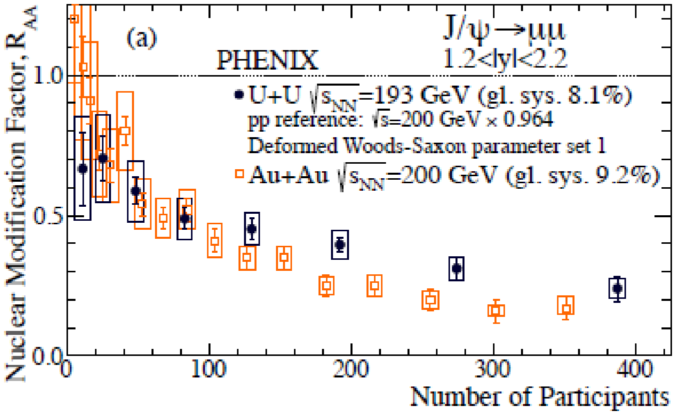
Parameter	set 1	set 2
$R\ (fm)$	6.81	6.86
$a\ (fm)$	0.6	0.42
β_2	0.28	0.265
β_4	0.093	0

Larger surface diffuseness for set I results in a less compact nucleus, a larger reaction cross section by 12%, and N_{coll} values that are smaller by 6 - 15%

Set 2

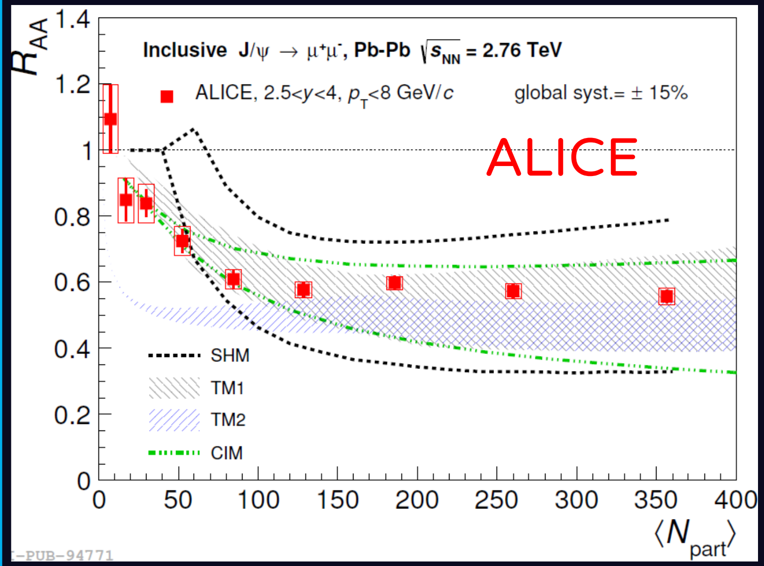


Set I



evidence for recombination

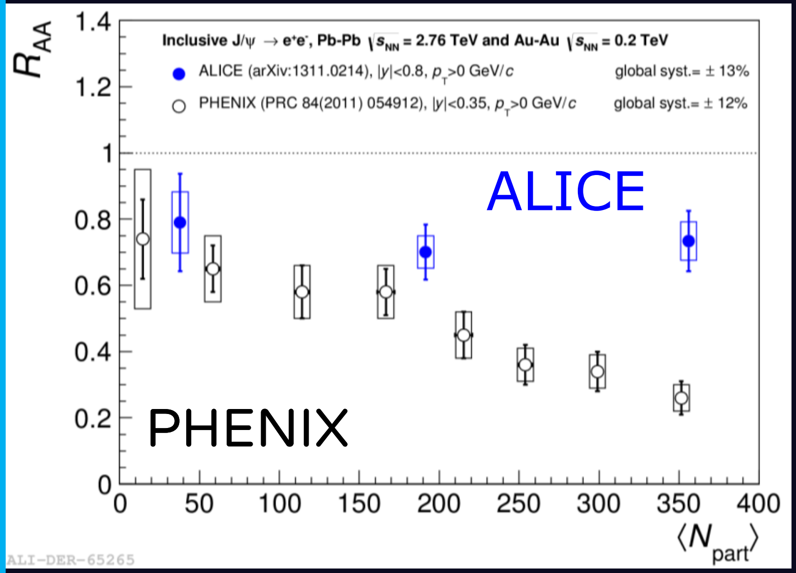
PHENIX vs. ALICE — low p_T J/ψ



agreement with models including J/ψ (re)combination in QGP or in the hadronic phase

ALICE PLB 734 (2014) 314,arXiv:1505.08804

PHENIX vs. ALICE — low p_T J/ψ



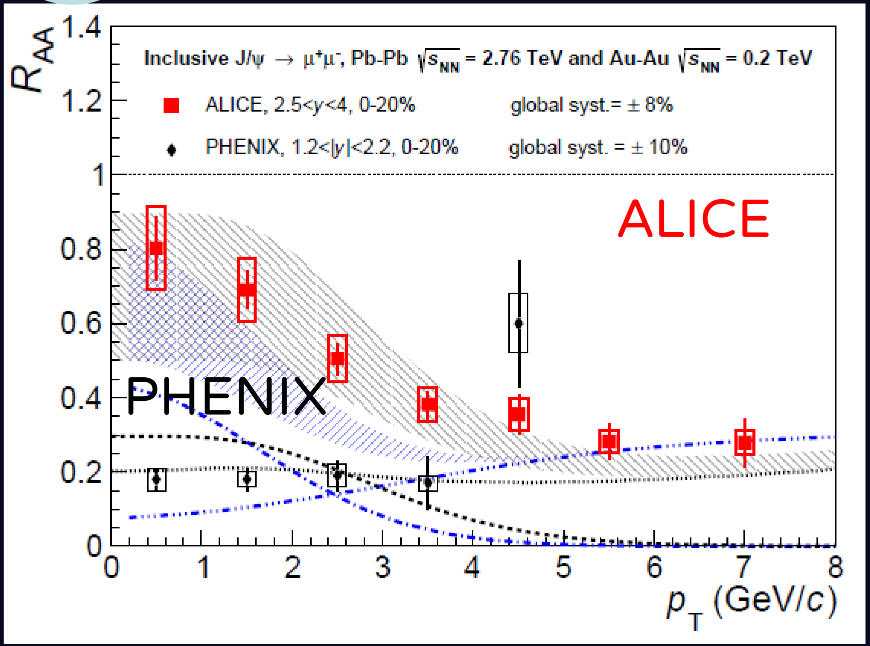
similar trend observed both at forward at mid rapidity

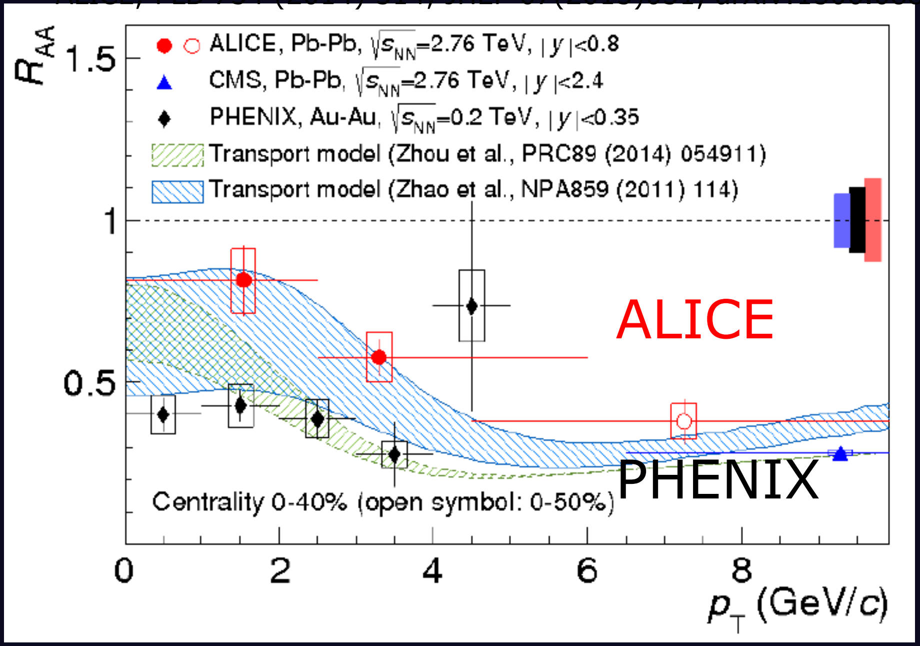
ALICE PLB 734 (2014) 314,arXiv:1505.08804

evidence for recombination

2 Comparison LHC vs RHIC (R_{AA} p_T dependence)

ALICE, PLB 734 (2014) 314, JHEP 07(2015)051, arXiv:1506.08804



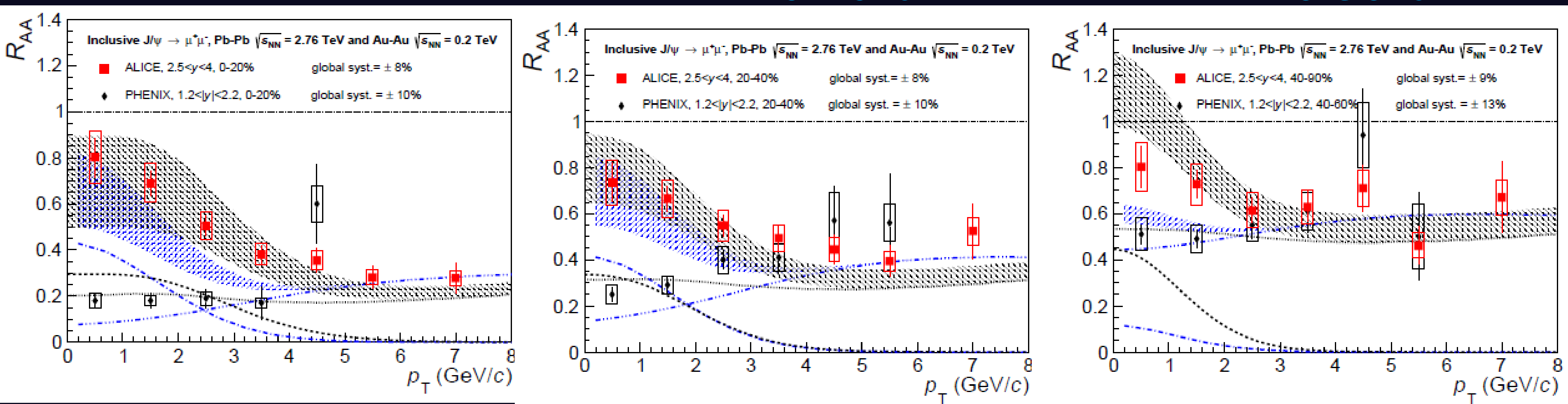


- weaker J/ψ suppression at low pT in agreement with models including J/ψ (re)combination in QGP or in the hadronic phase

Multi-differential J/ψ studies

- p_T-centrality multi-differential studies allows detailed comparison with theory models

0-20% 20-40% 40-90%



TM1 Zhao et al., Nucl.Phys.A859 (2011) 114

TM2 Zhou et al. Phys.Rev.C89 (2014)054911

ALICE, arXiv:1506.08804

Primordial J/ψ	(TM1)
Regenerated J/ψ	(TM1)
Primordial J/ψ	(TM2)
Regeneration J/ψ	(TM2)

- Model provide a fair description of the data, even if with different balance of primordial/regeneration components

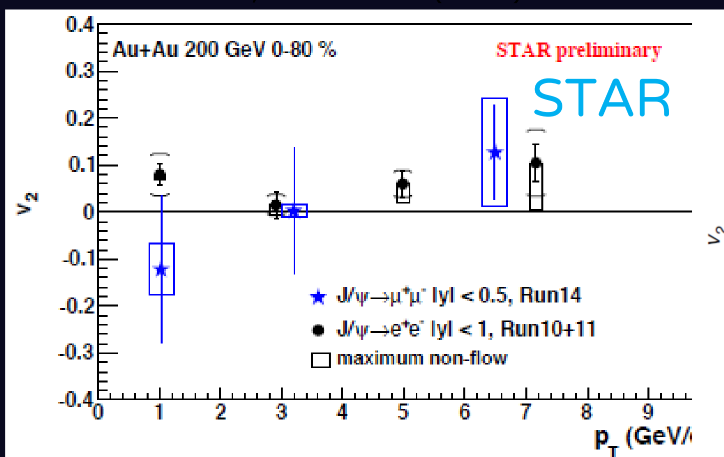
Still rather large theory uncertainties: models will benefit from precise measurement of σ_{cc} and CNM effects

J/ψ flow

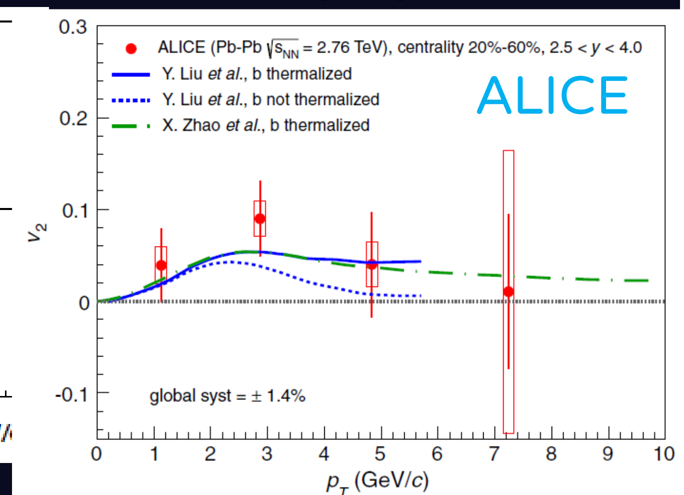
4 J/ψ elliptic flow

➡ The contribution of J/ψ from (re)combination should lead to a significant elliptic flow

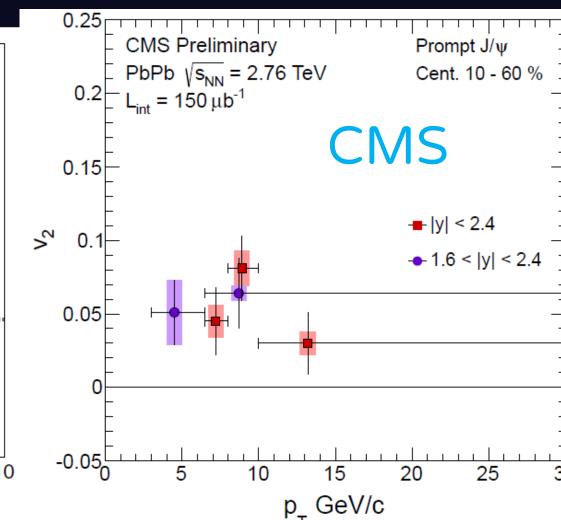
STAR, PRL 052301(2013)



ALICE, PRL 111(2013) 162301



CMS-PAS-HIN-12-001



➡ Hint for J/ψ flow at LHC, contrary to v_2~0 observed at RHIC!

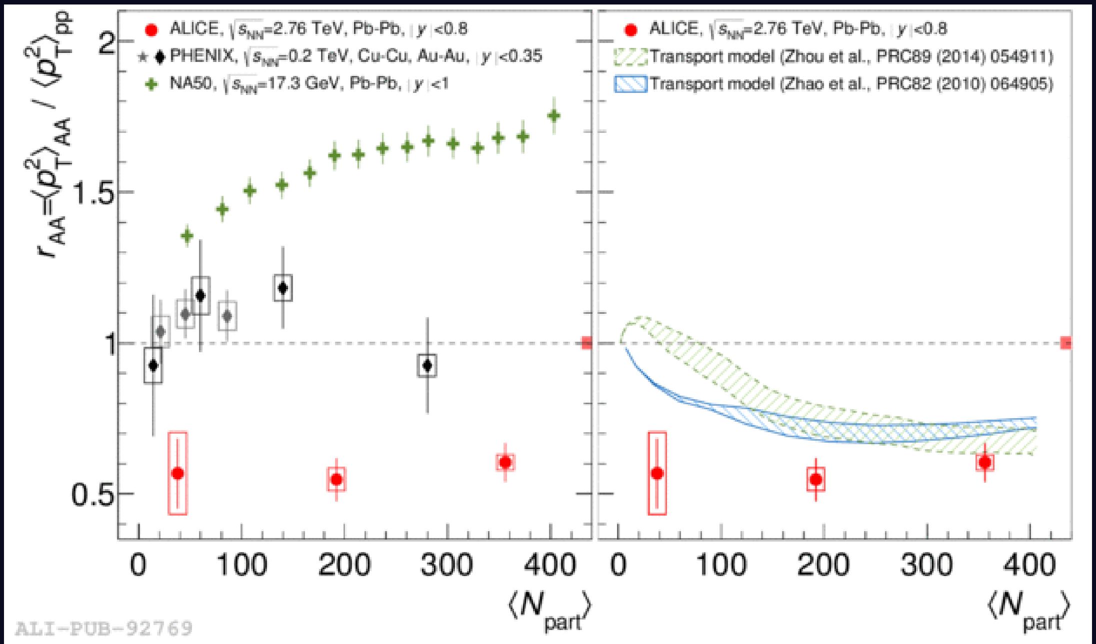
ALICE: qualitative agreement with transport models including regeneration

CMS: path-length dependence suppression effect?

J/ψ <pT>

$$r_{AA} = \frac{\langle p_T^2 \rangle_{AA}}{\langle p_T^2 \rangle_{pp}}$$

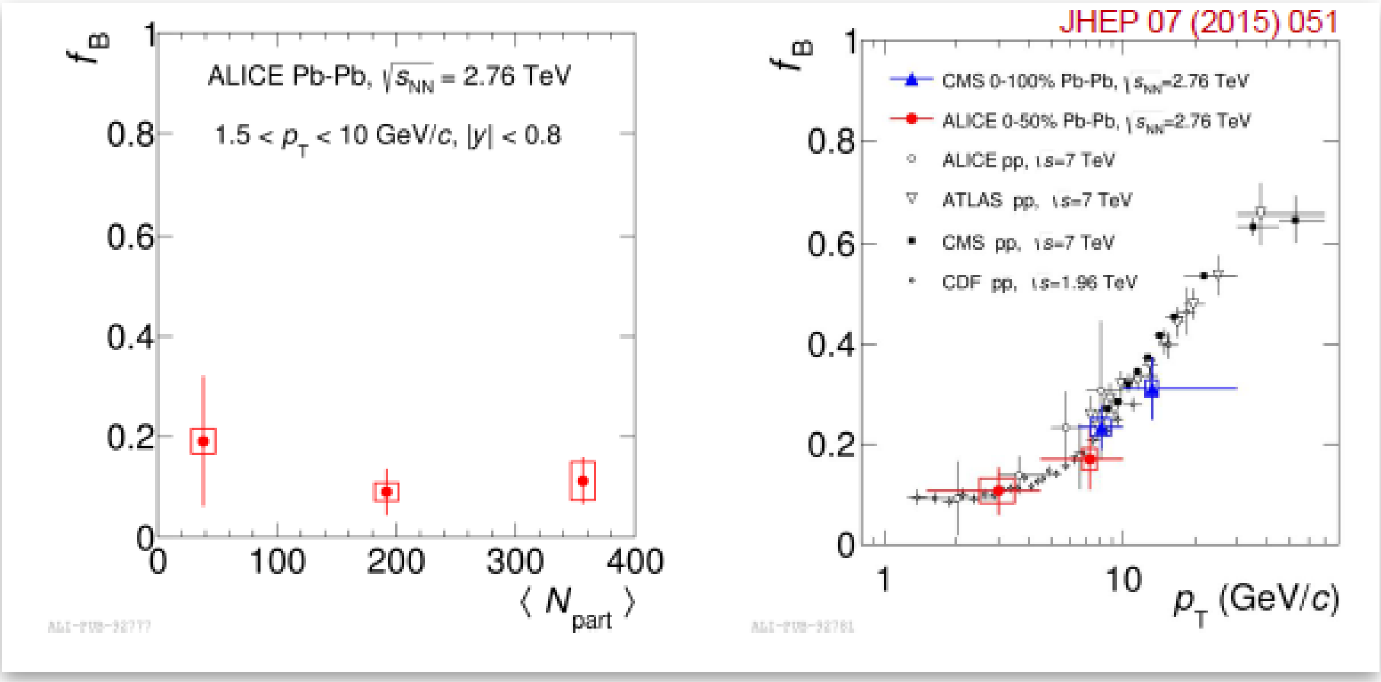
ALICE,JHEP07(2015)051



- Strong √s-dependence as at forward-y but less pronounced centrality dependence observed by ALICE at mid-rapidity
- Transport models, predicts a larger rAA, with a stronger centrality dependence

J/ψ fB

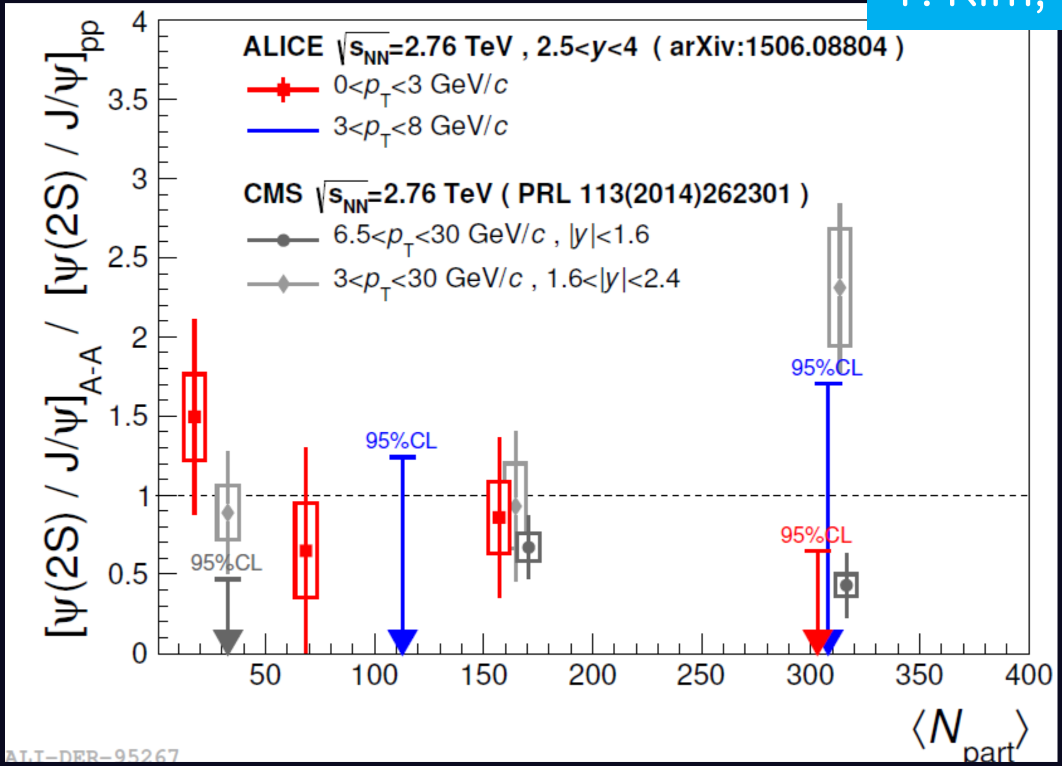
f_B = non-prompt / inclusive



ψ(2S) in AA collisions

- ψ(2S) production modified in AA with a strong kinematic dependence

Y. Kim, H. Pereira da Costa

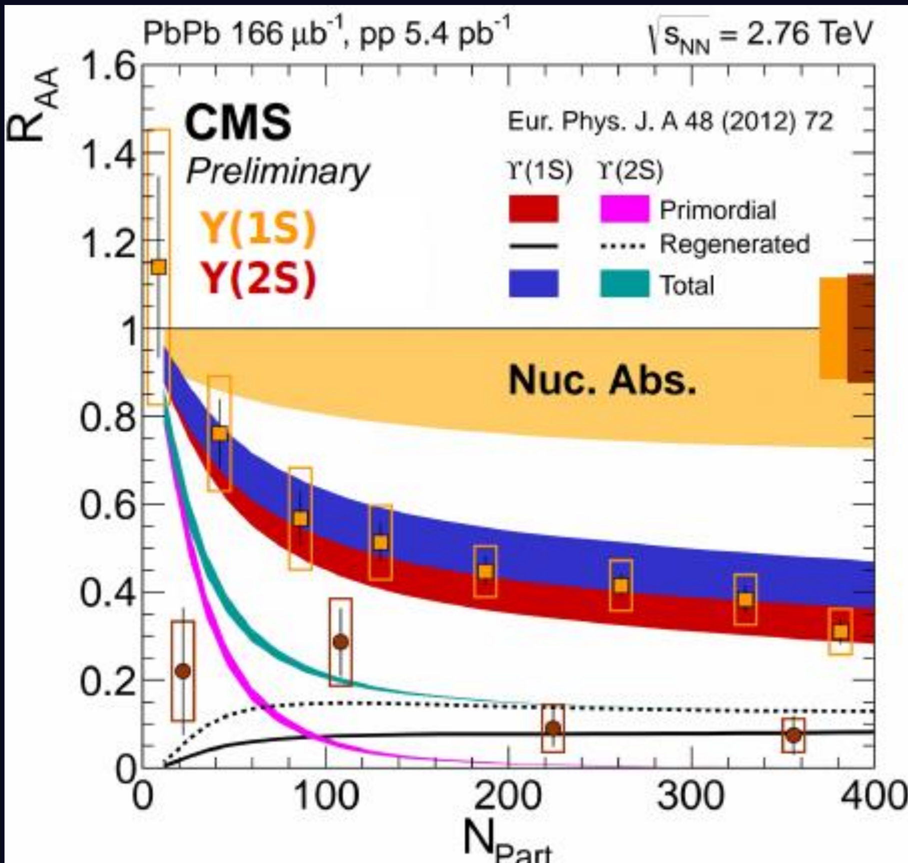


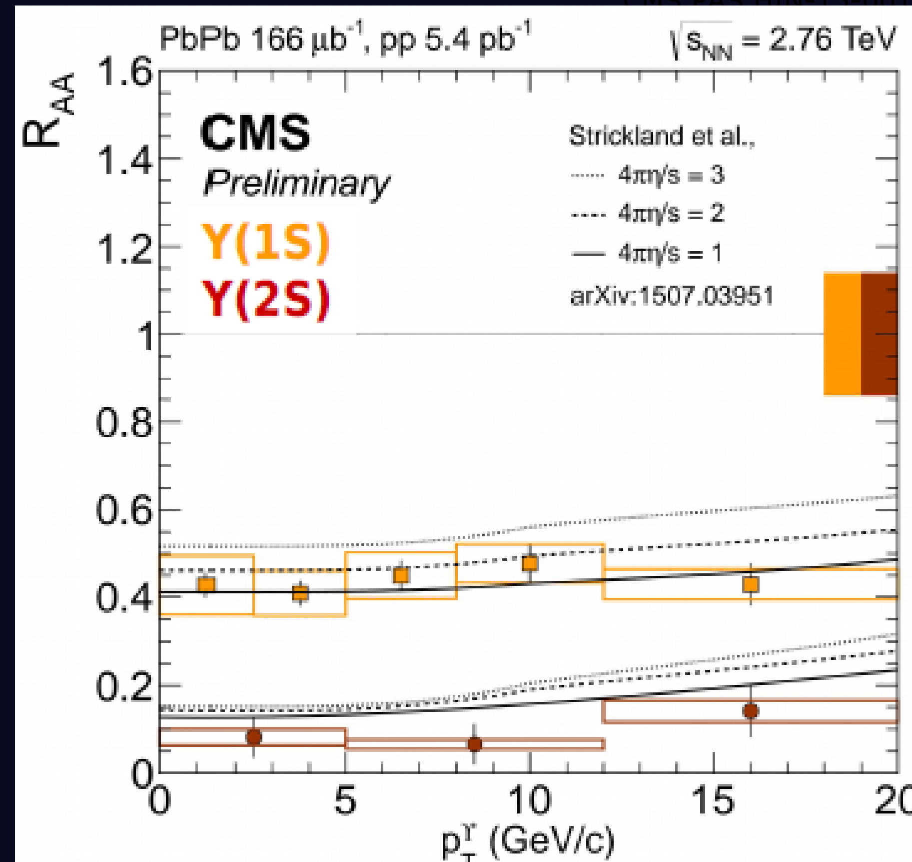
- small tension, between ALICE and CMS, in the most central bin?
- behaviour sensitive to the involved kinematic ranges?
- Run-II will help to clarify this issue!

CMS, PRL 113(2014) 262301, ALICE arXiv:1506.08804

ϒ(ns) production in AA

CMS PAS HIN-15-001





J/ψ at very low pT

Coherent photoproduction

$N_{AA}^{excess\ J/\psi} / (1+f_D+f_I)$ ➔ $d\sigma^{coh}_{J/\psi}/dy$

Cent. (%)	$N_{AA}^{J/\psi}$	$N_{AA}^{excess\ J/\psi}$	$d\sigma^{coh}_{J/\psi}/dy$ (μb)
0–10	$339 \pm 85 \pm 78$	< 251	< 318
10–30	$373 \pm 87 \pm 75$	< 237	< 290
30–50	$187 \pm 37 \pm 15$	$62 \pm 37 \pm 21$	$73 \pm 44 ^{+26}_{-27} \pm 10$
50–70	$89 \pm 13 \pm 2$	$50 \pm 14 \pm 5$	$58 \pm 16 ^{+8}_{-10} \pm 8$
70–90	$59 \pm 9 \pm 3$	$51 \pm 9 \pm 3$	$59 \pm 11 ^{+7}_{-10} \pm 8$

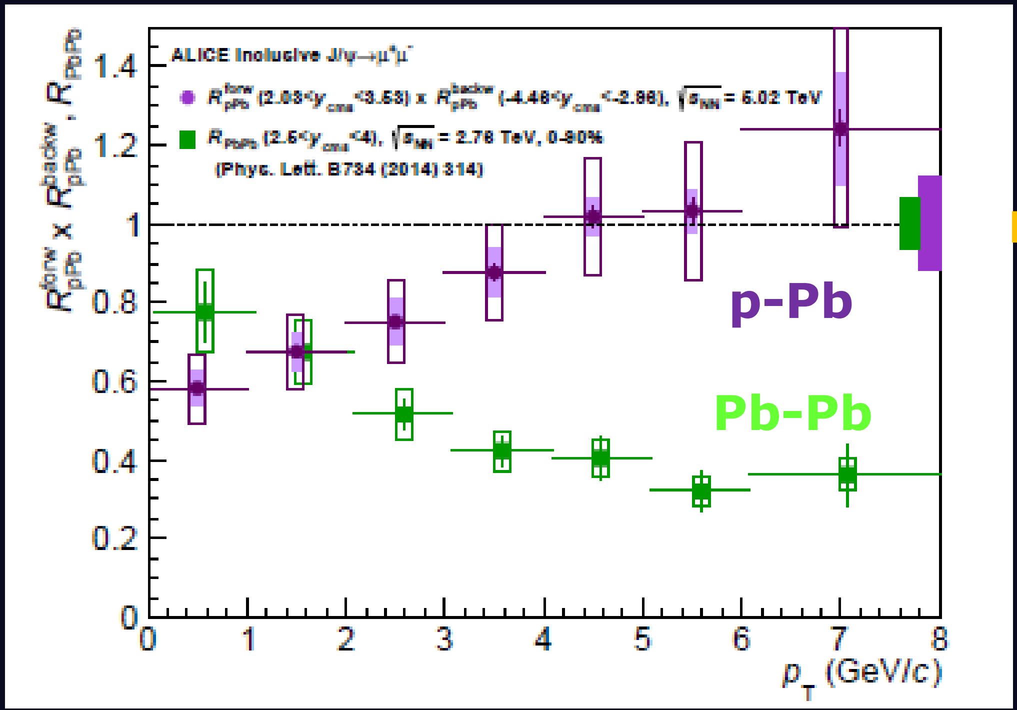
Photon from the Pb EM field interacts with the Pb nucleus (coherent) or with a nucleon (incoherent).

An extrapolation of measured J/ψ in UPC ($b_1=2R_{Pb}, b_2=\infty$) to 70-90% (N_{part}~11) centrality class ($b_1^{70\text{-}90\%}, b_2^{70\text{-}90\%}$), provides a cross section of ~40 μb. Good qualitative agreement with the measured value 59±16 μb.

From pA to AA

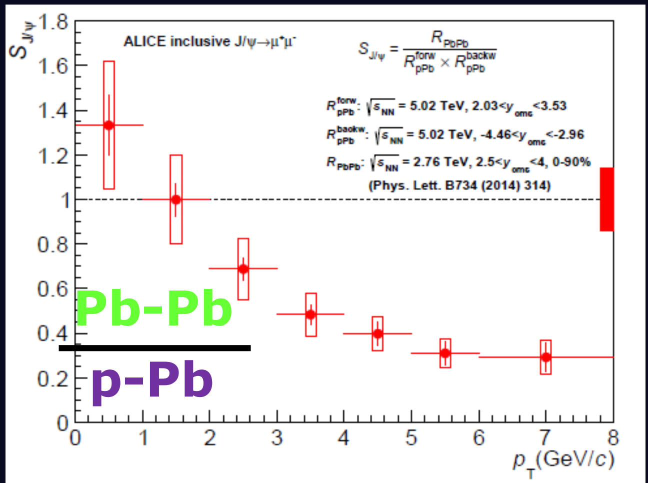
- Once CNM effects are measured in pA, what can we learn on J/ψ production in PbPb?

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

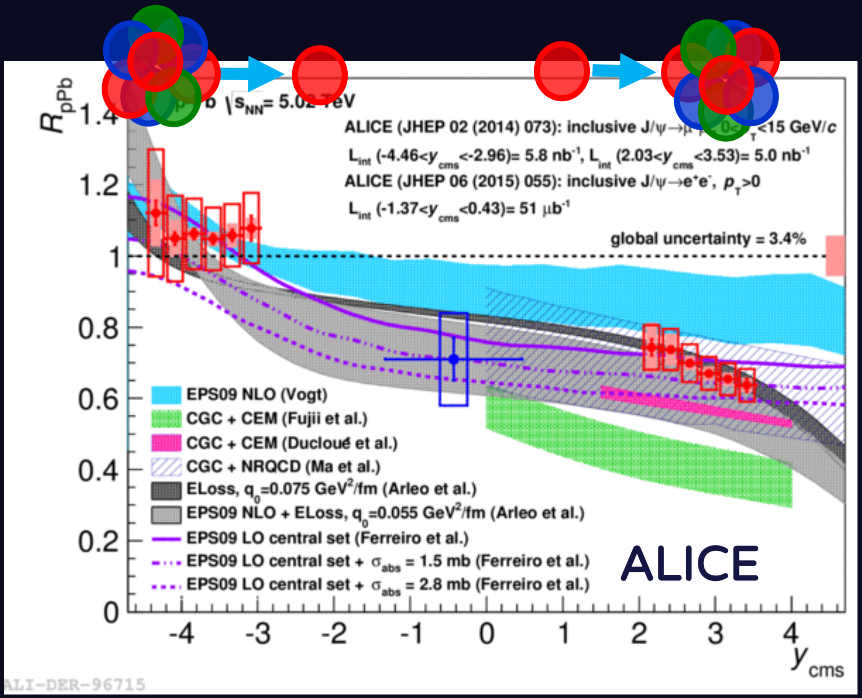


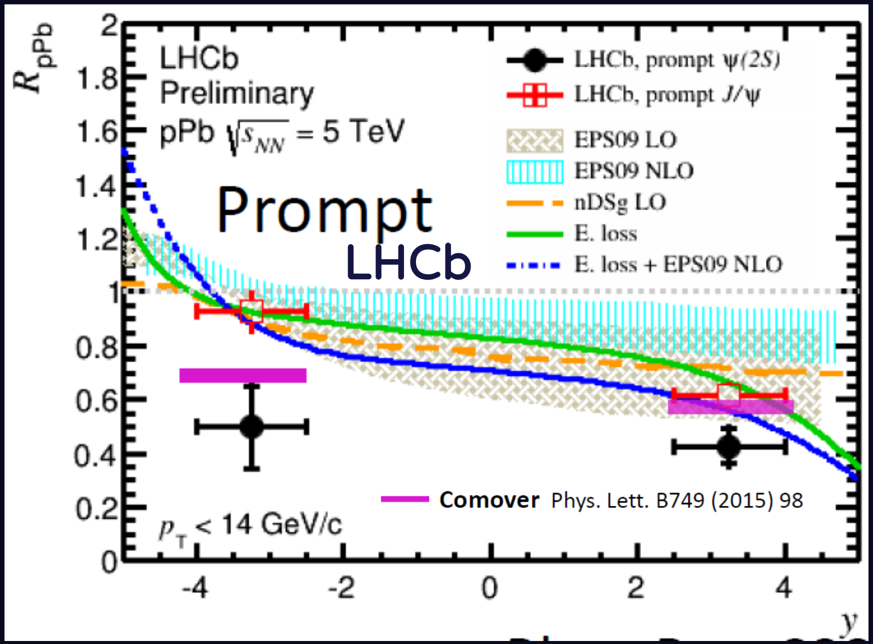
Backup slides pA

J/ψ production in pA

Pb-going p-going

M. Leoncino, Z. Yang





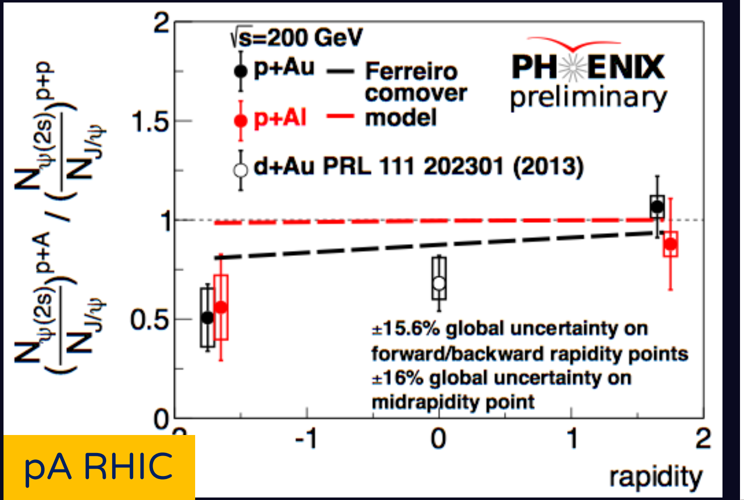
J/ψ production modified by CNM effects → R_{pA} decreases at forward *y*

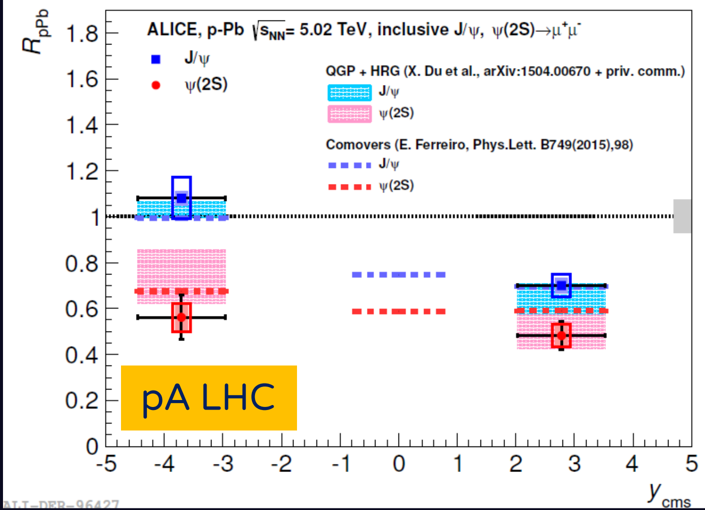
➡ Theoretical predictions:

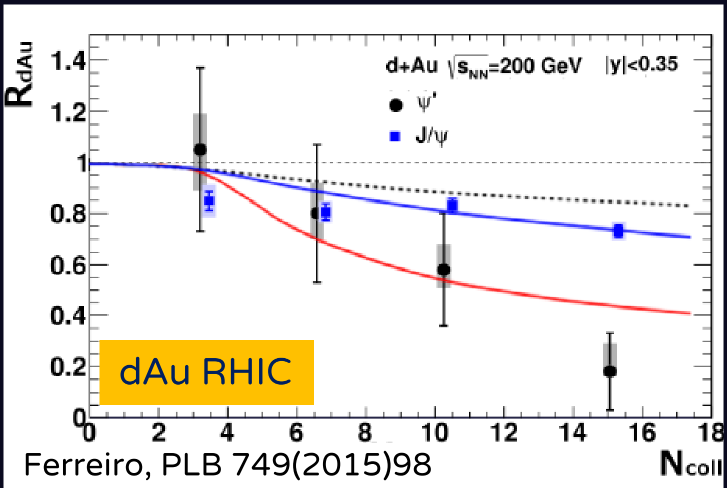
- shadowing calculations and models including coherent parton energy loss reasonably describe the data
- agreement with CGC depends on the implementation

Comparison to theoretical models

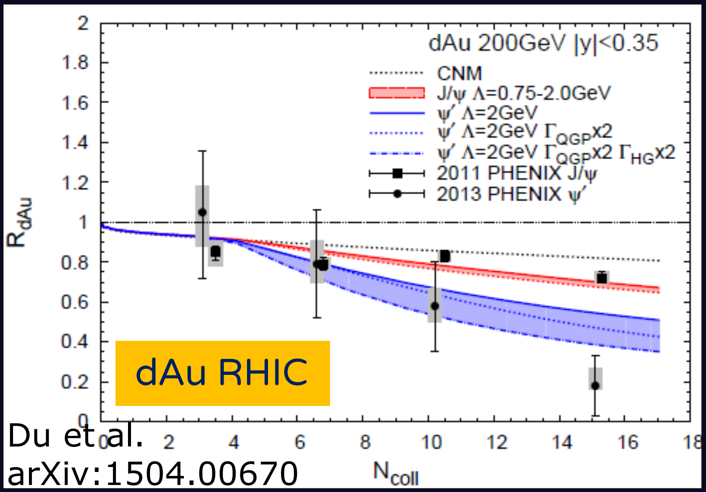
QGP+hadron resonance gas (Rapp) or comovers models (Ferreiro) reasonably describe both J/ψ and ψ(2S) suppression at RHIC and LHC







Ferreiro, PLB 749(2015)98

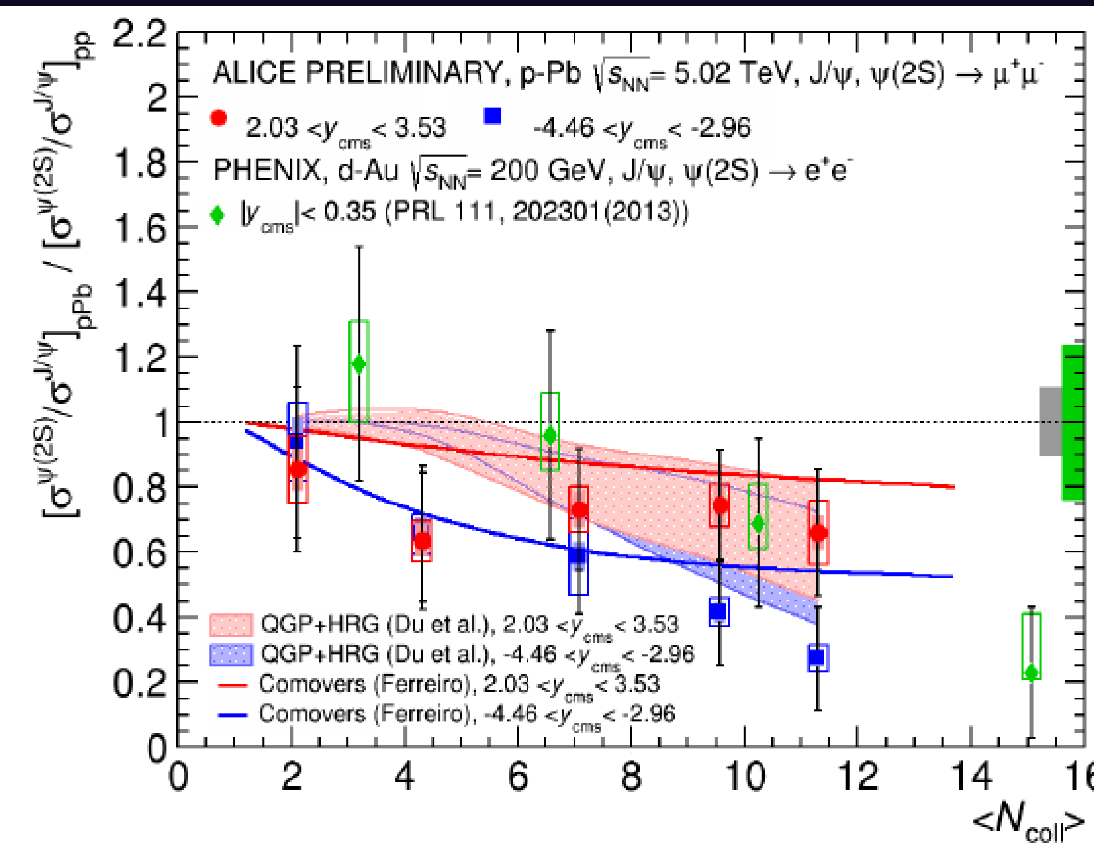


Du et al. arXiv:1504.00670

J/ψ
→ small suppression beyond CNM effects

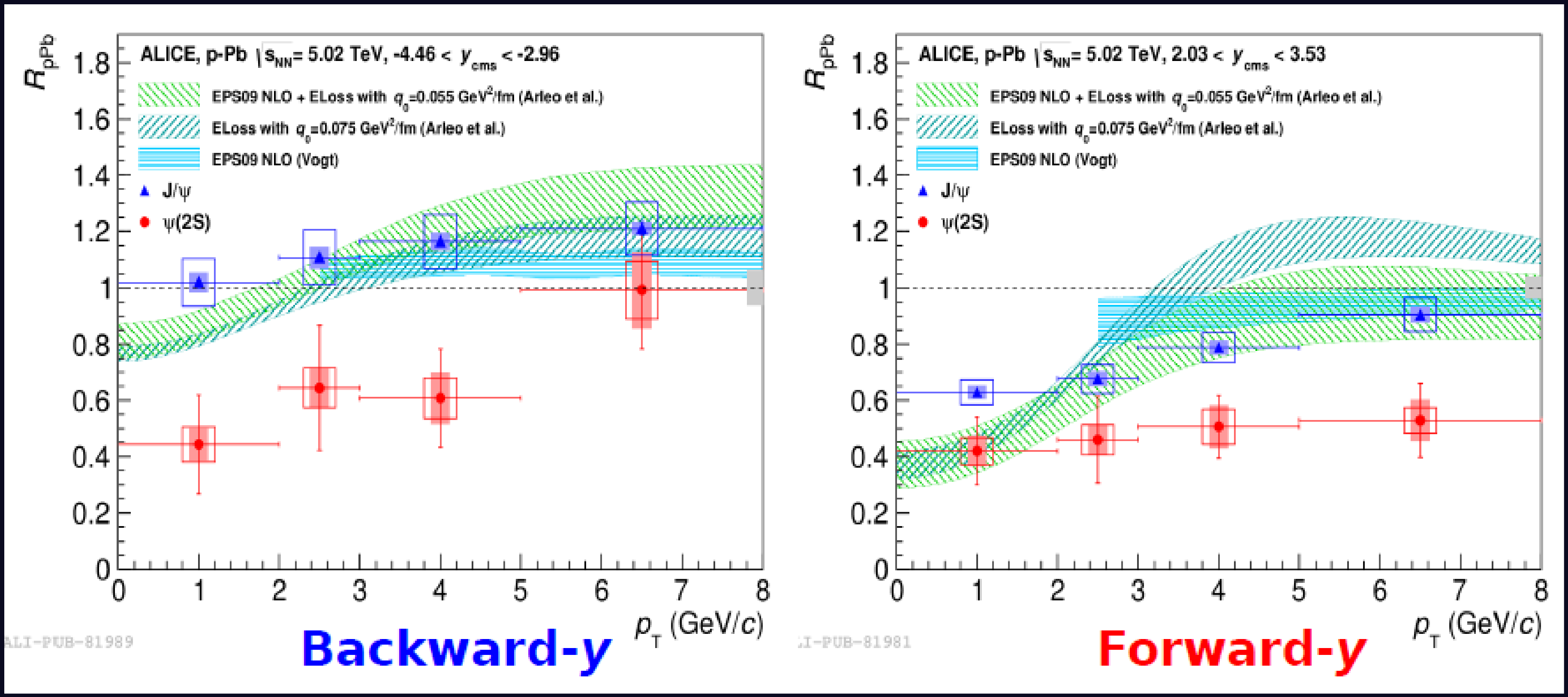
ψ(2S)
→ strongly affected by comovers due to its larger size
→ comovers more important in the A-going direction

ψ(2S) / J/ψ double ratio



Similar suppression trend observed versus centrality, by both ALICE and PHENIX

➡ QGP+hadron resonance gas (Rapp) or comovers models (Ferreiro) describe the observed suppression

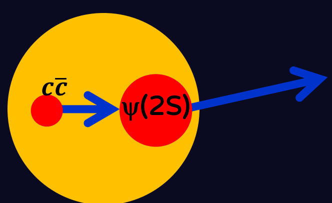


ALICE, p-Pb √s_NN = 5.02 TeV, -4.46 < y_cms < -2.96
EPS09 NLO + ELoss with q_0=0.055 GeV²/fm (Arleo et al.)
ELoss with q_0=0.075 GeV²/fm (Arleo et al.)
EPS09 NLO (Vogt)
J/ψ
ψ(2S)
R_pPb
p_T (GeV/c)
ALI-PUB-81989
Backward-y
ALICE, p-Pb √s_NN = 5.02 TeV, 2.03 < y_cms < 3.53
EPS09 NLO + ELoss with q_0=0.055 GeV²/fm (Arleo et al.)
ELoss with q_0=0.075 GeV²/fm (Arleo et al.)
EPS09 NLO (Vogt)
J/ψ
ψ(2S)
R_pPb
p_T (GeV/c)
ALI-PUB-81981
Forward-y

ψ(2S) production in pA

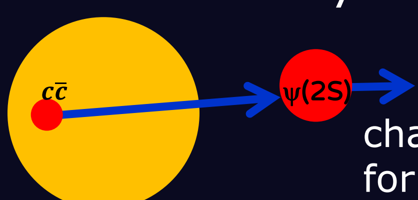
- Being more weakly bound than the J/ψ, the ψ(2S) is an interesting probe to have further insight on the charmonium behaviour in pA
- Low energy ψ(2S) p-A results from NA50, E866 and HERA-B:

<u>mid-*y* (x_F~0)</u>:
ψ(2S) suppression stronger than J/ψ one, interpreted via pair break-up
→ fully formed resonances traversing the nucleus



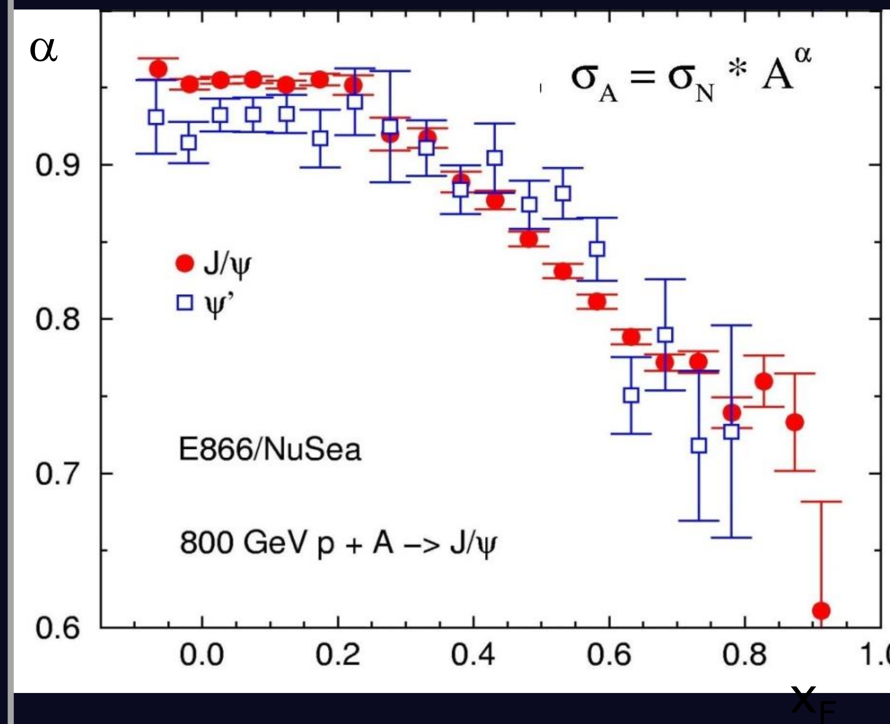
charmonium
formation time<crossing time

<u>forward-*y* (high x_F)</u>:
suppression becomes identical
→ dominated by energy loss



charmonium
formation time>crossing time

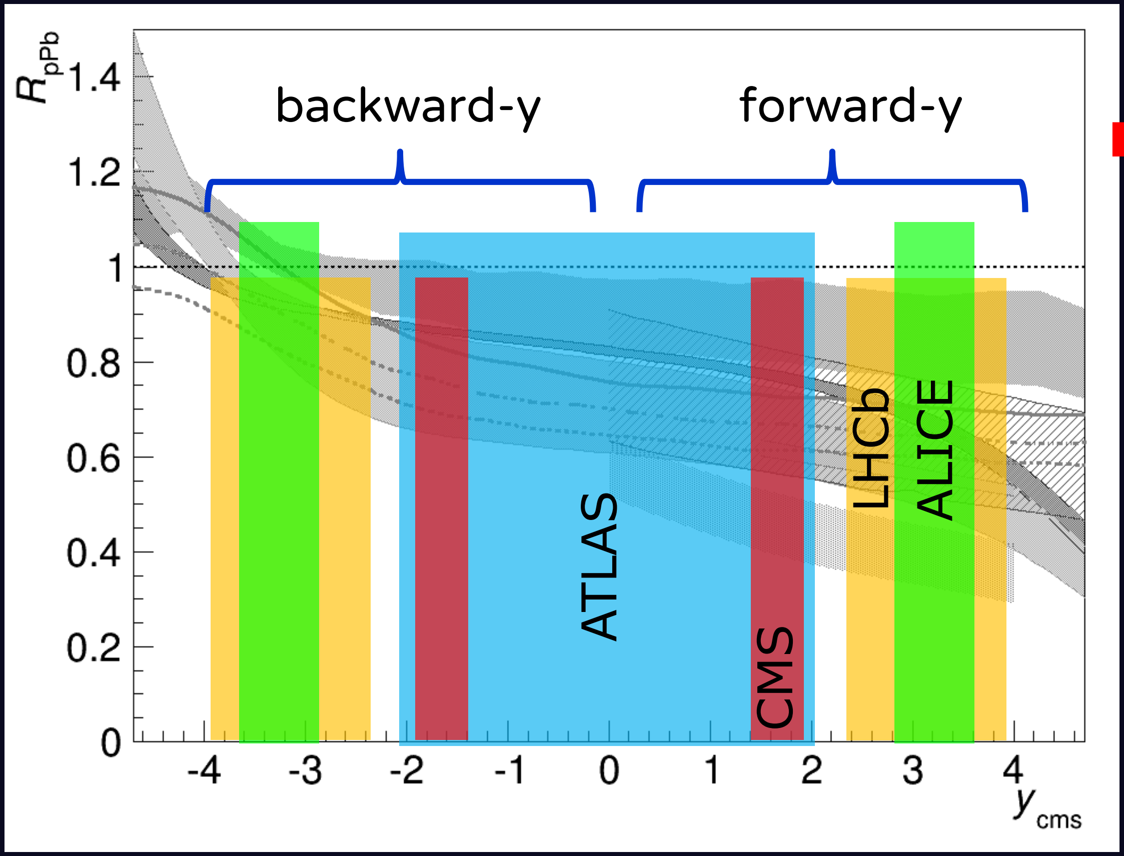
E866 Collab., PRL 84 (2000) 3256



J/ψ forward-to-backward ratio

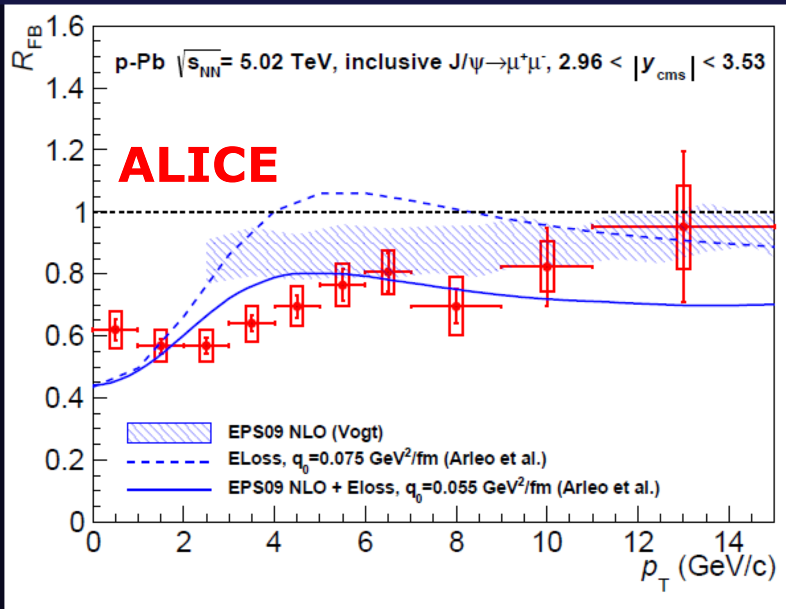
- Forward to backward ratio R_{FB} in a common y range
  → easier to evaluate wrt RpA, since no pp reference is needed
  → but less straightforward to interpret

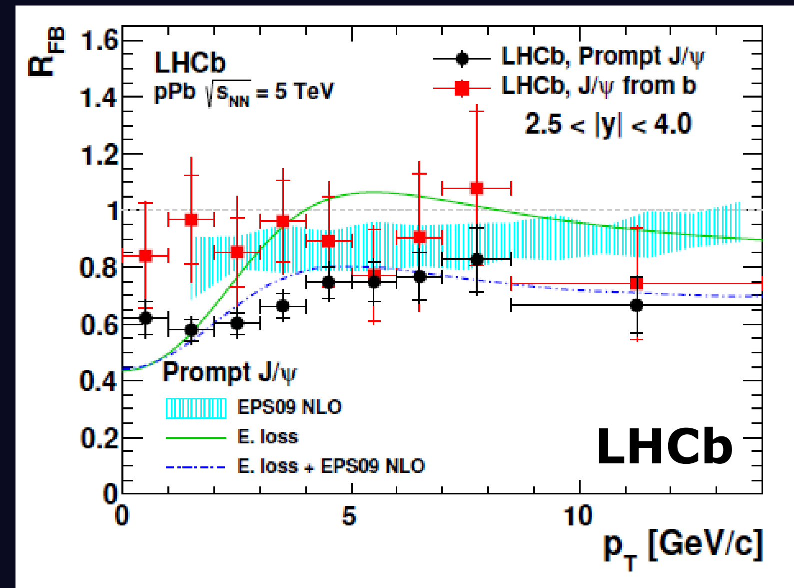
$$R_{FB} = \frac{Y_{J/\psi}^{forward}}{Y_{J/\psi}^{backward}}$$

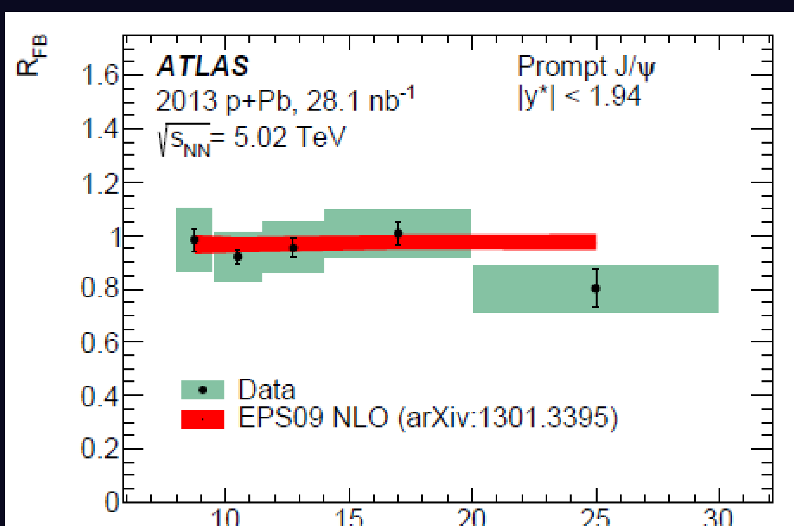


- Comparison of RFB results between experiments is not straightforward:
  1) CNM effects have a strong rapidity dependence
  2) kinematic ranges explored by the experiments are rather different

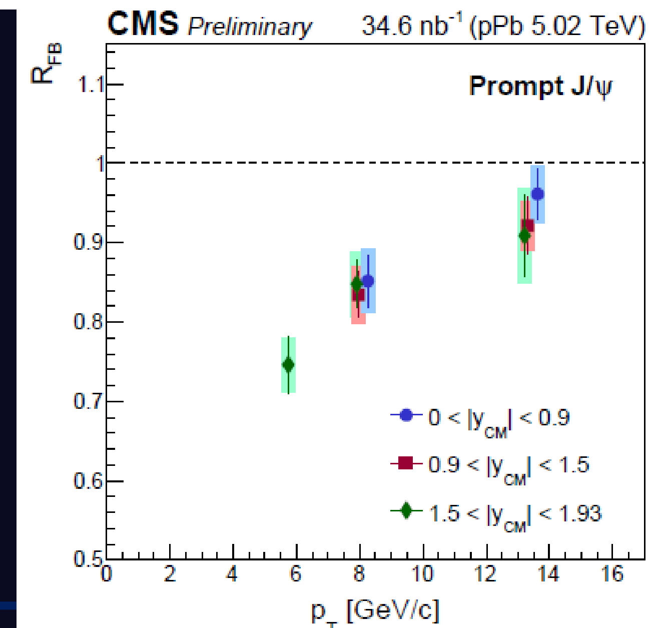
J/ψ forward-to-backward ratio



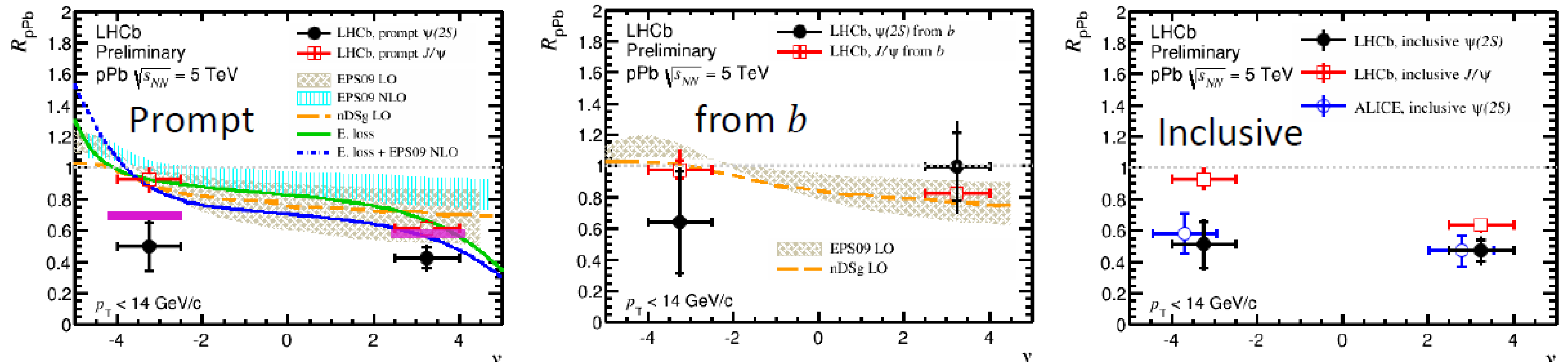




ATLAS, PRC 92(2015)034904



J/ψ RpA inclusive and prompt



EPS09 LO — Phys. Rev. C88 (2013) 047901

EPS09 NLO — Int. J. Mod. Phys. E22 (2013) 1330007

nDSg LO — Phys. Rev. C88 (2013) 047901

E. loss — JHEP 03 (2013) 122

E. loss + EPS09 NLO — JHEP 03 (2013) 122

EPS09 LO, nDSg LO — Nucl.Phys.A926 (2014) 236

Comover — Phys. Lett. B749 (2015) 98

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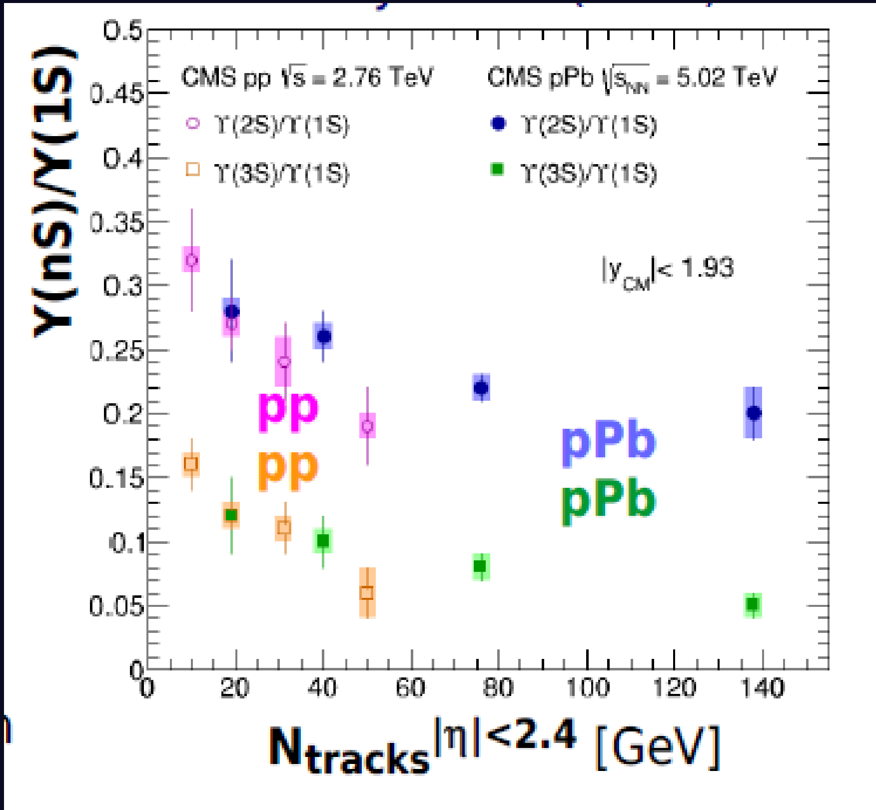
Υ vs ev. activity



- Υ(nS)/Υ(1S) ratios fall with event-activity
  - Is the multiplicity affecting the Υ(nS)?
  - Are the Υ(nS) produced differently with multiplicity?

CMS

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