Quarkonium production in heavy ion collisions at the LHC

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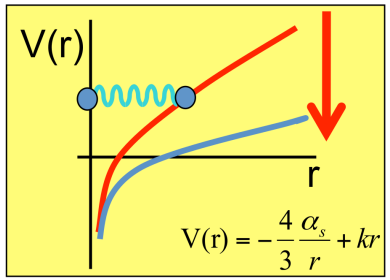
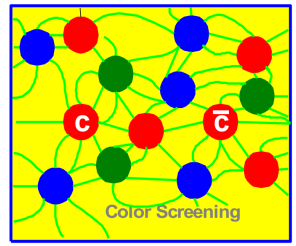
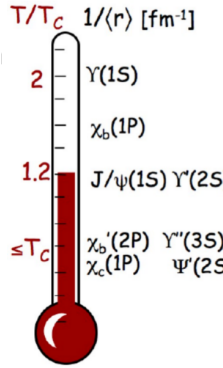
Torino, 10/10/2017

Why quarkonium in heavy ions (I)

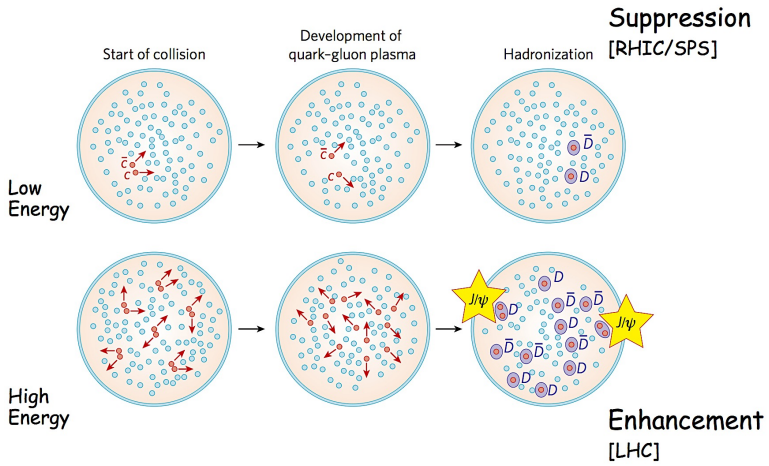
- Matsui and Satz: screening in the $q\bar{q}$ potential, J/ψ "melts" in the QGP.
- Different $q\bar{q}$ states may not form at different temperatures.







- At LHC, large charm (beauty) cross section: x10 (x60) more than at RHIC.
- About 100 $c\bar{c}$ pairs per PbPb collision.
- Possible statistical recombination of uncorrelated charm quarks.
- Charm may participate to collective motions of the medium.

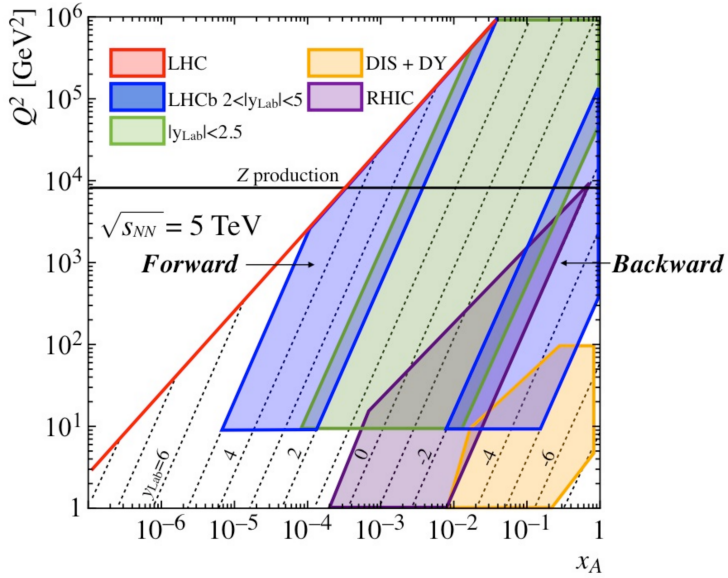


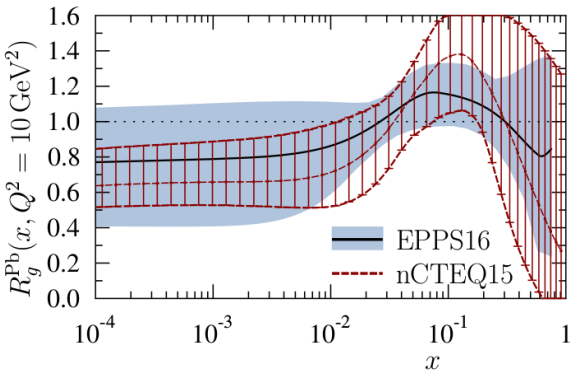
Why quarkonium in heavy ions (II)

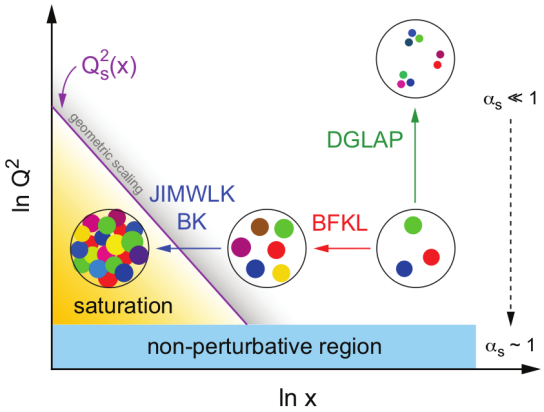
p-nucleus: just a control experiment?

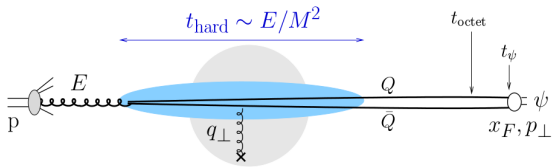
- At LHC, heavy flavours allow one to reach of very small x_B.
- Density of gluons increases.
- Does collinear factorization still hold?
- Which other processes can intervene in quarkonium production?
- Coherent energy loss? Comovers?
- Small deconfined systems?

And what about pp collisions?...

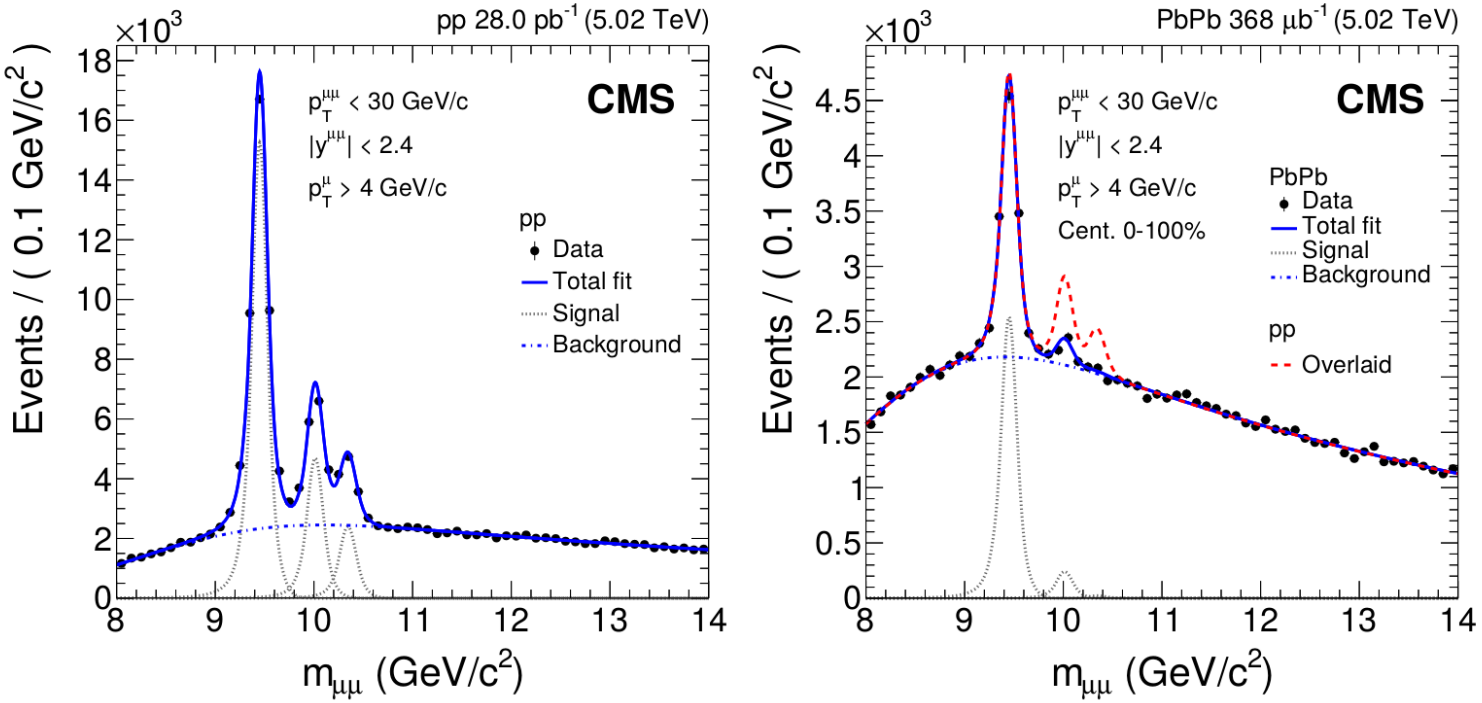








Bottomonium in PbPb

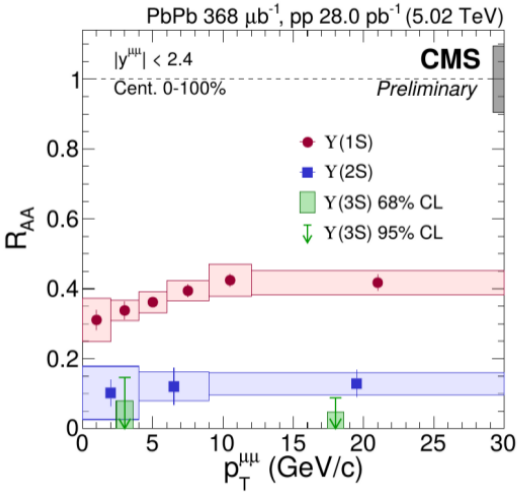


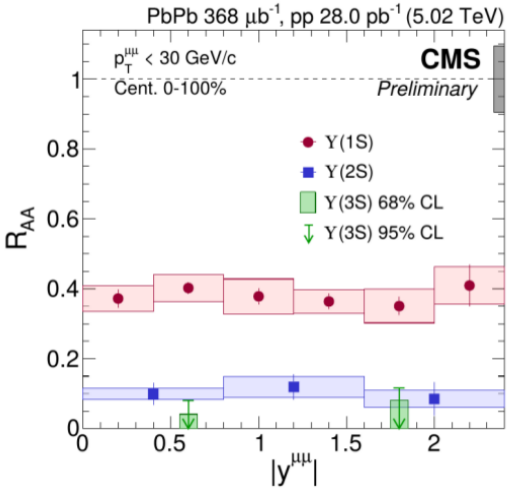
arXiv:1706.05984

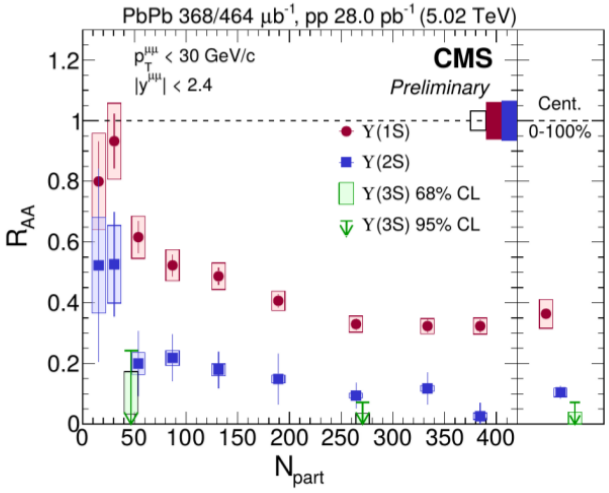
- Textbook like plot for quarkonium suppression in PbPb!

Bottomonium in PbPb

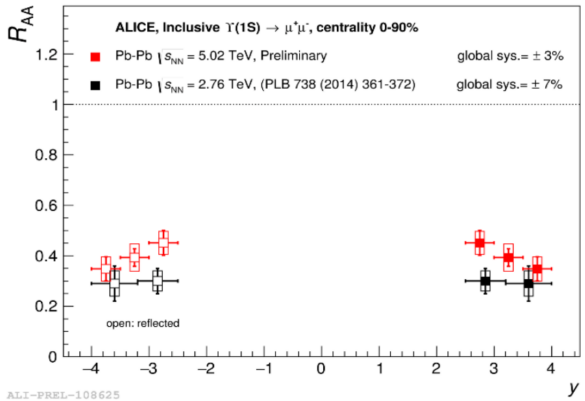
CMS-HIN-16-023





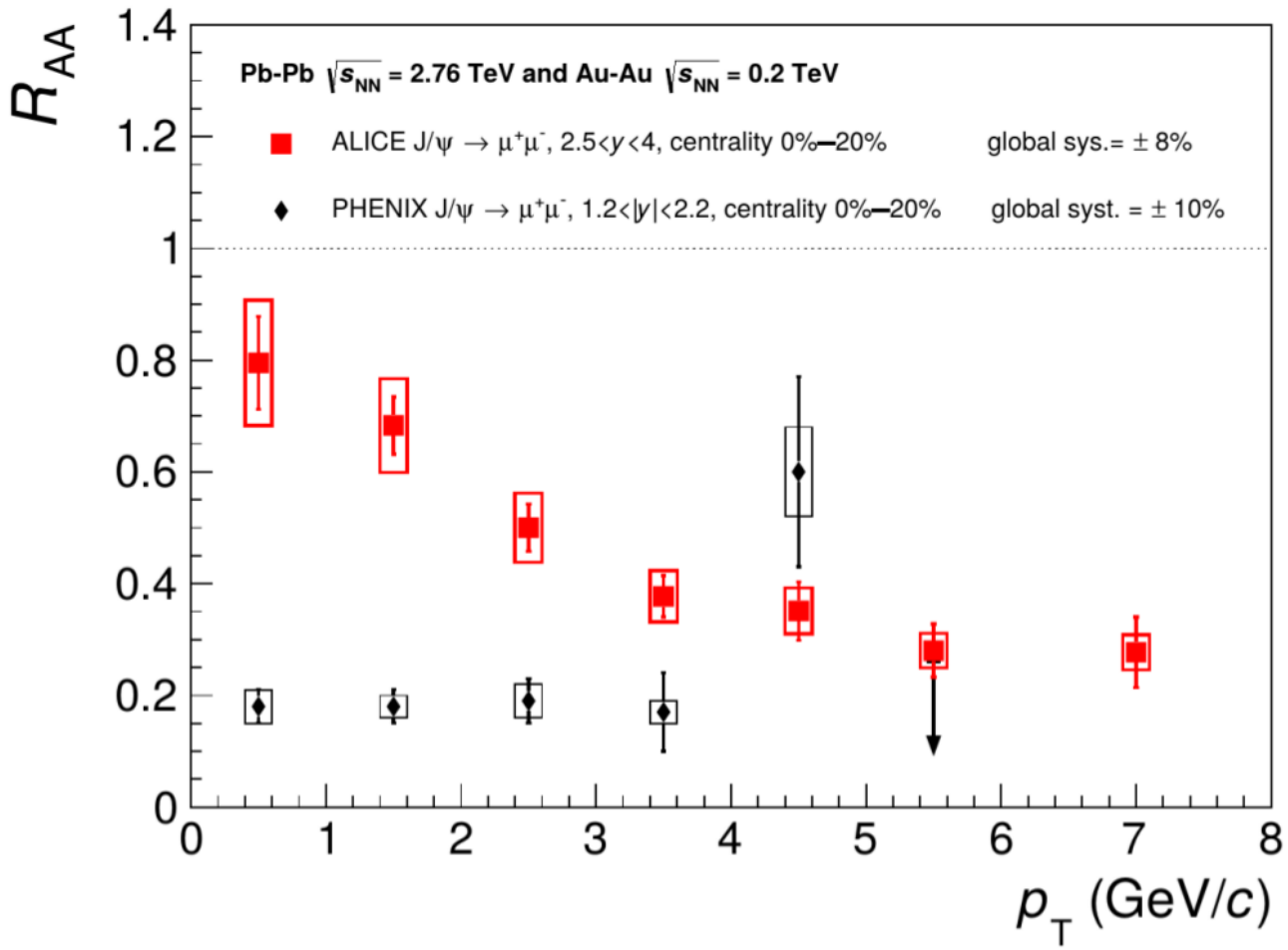


- $R_{AA}(\Upsilon(1S)) \approx 0.4$, $R_{AA}(\Upsilon(2S)) \approx 0.1$, $\Upsilon(3S)$ not seen.
- Results at $\sqrt{s_{NN}} = 5$TeV and 2.67 TeV consistent within uncertainties.
- y-dependence: at 2.76TeV, forward rapidity $R_{AA}(\Upsilon(1S))$ lower than mid-rapidity. At 5TeV less tension.
- No p_T-dependence.
- R_{AA} approaches unity in peripheral collisions.



J/ψ in PbPb

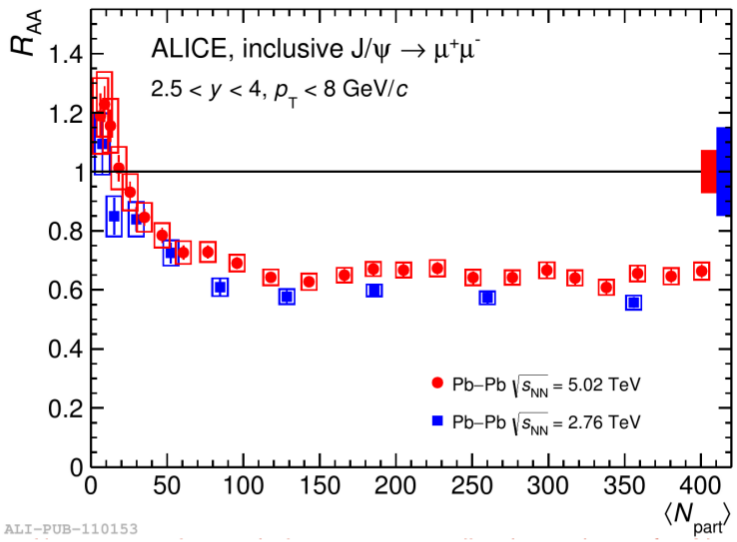
Phys. Lett. B 734 (2014) 314-327

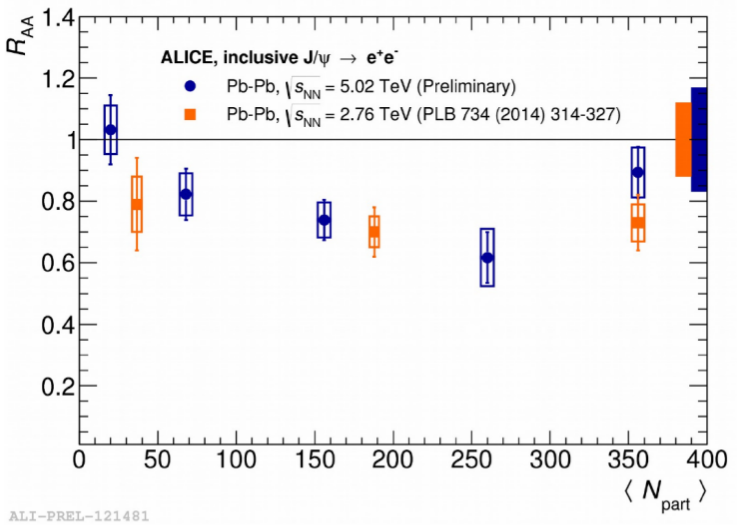


- ALICE measurement at 2.76TeV: striking difference with measurement at RHIC.
- R_{AA} larger at low-p_T, compatible with $c\bar{c}$ recombination at later stages of the evolution.

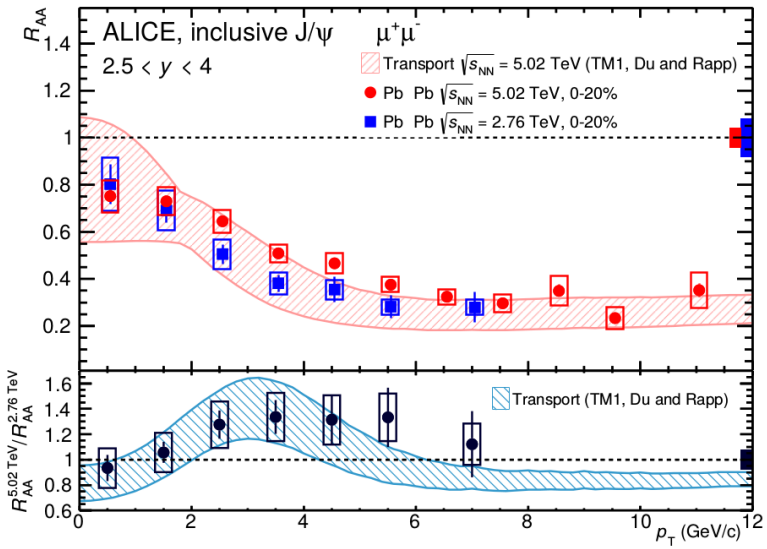
J/ψ in PbPb

Phys. Lett. B 766 (2017) 212-224





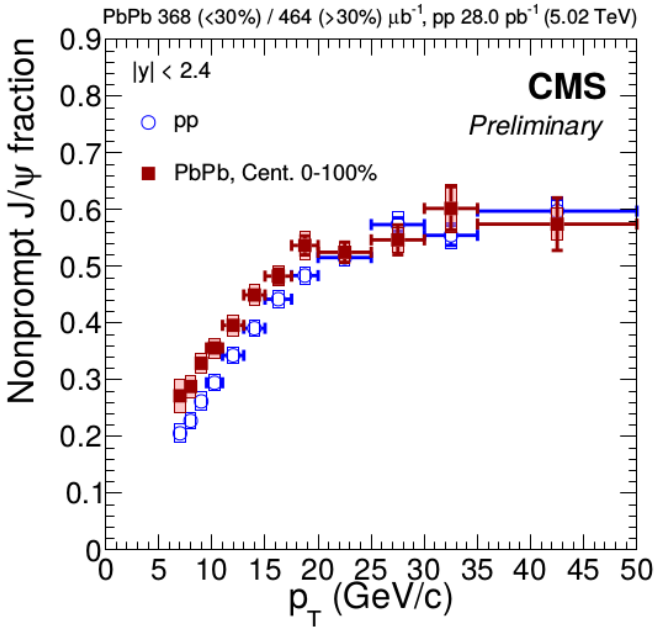
- Similar suppression at mid- and forward rapidities.
- Compatible results at two energies. Better statistical precision with 5TeV data.
- New results at 5TeV show of slightly larger R_{AA} than 2.76TeV results for $2 < p_T < 6$GeV/c

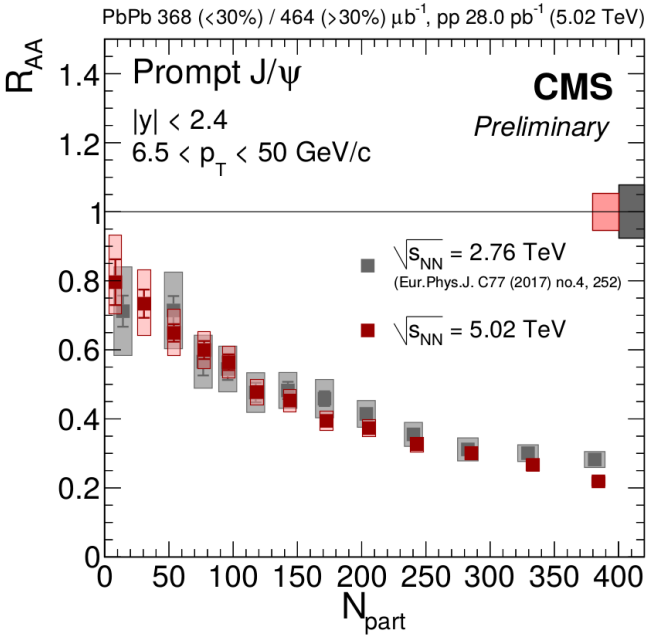


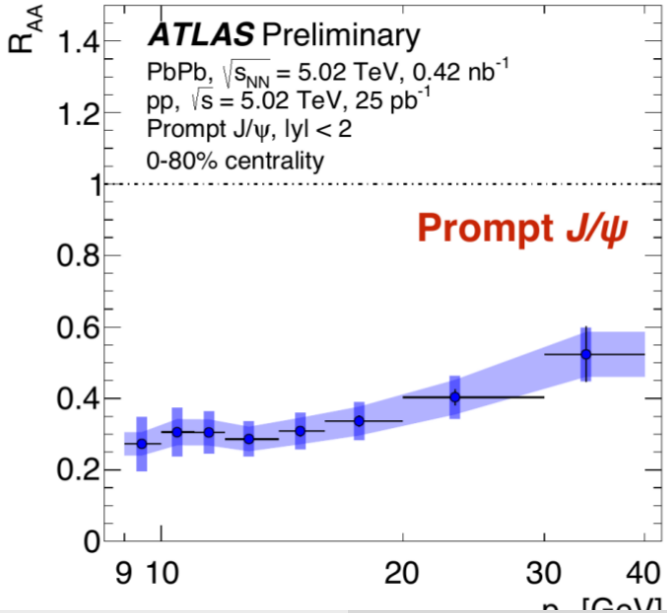
J/ψ in PbPb

CMS-HIN-16-025

ATLAS-CONF-2016-109





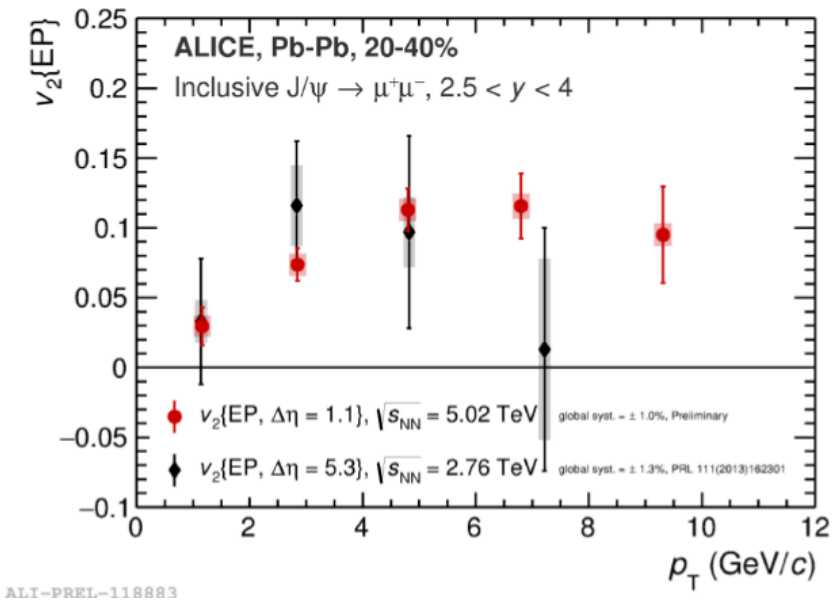


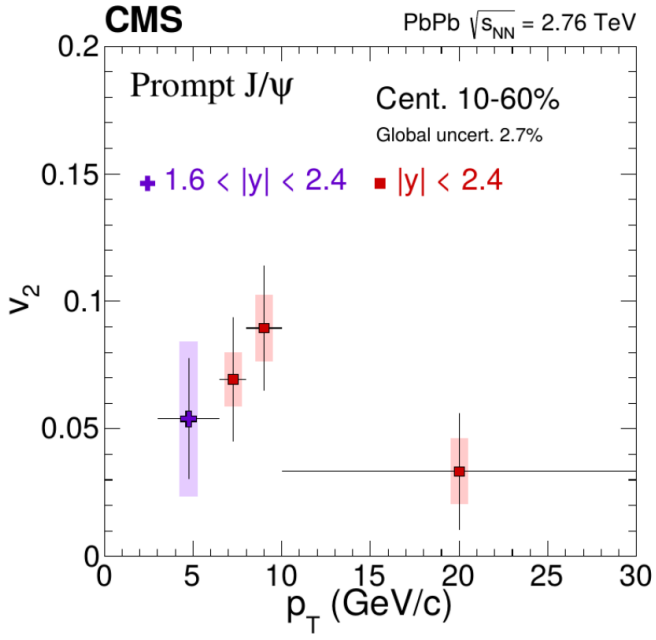
- CMS and ATLAS extend J/ψ measurements at high p_{T}.
- Nonprompt fraction similar to pp, then similar R_{AA} for prompt and nonprompt, but different mechanisms.
- 2.76TeV and 5TeV R_{AA} results compatible also at medium/high p_{T}.

J/ψ in PbPb

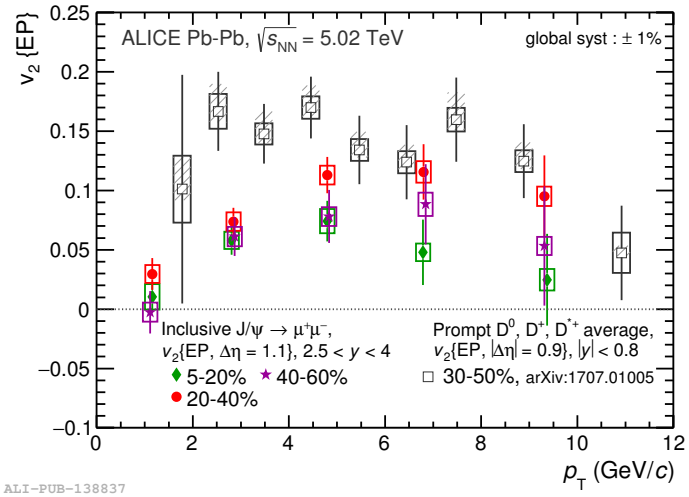
Phys. Rev. Lett. 111 (2013) 162301

Eur. Phys. J. C 77 (2017) 252





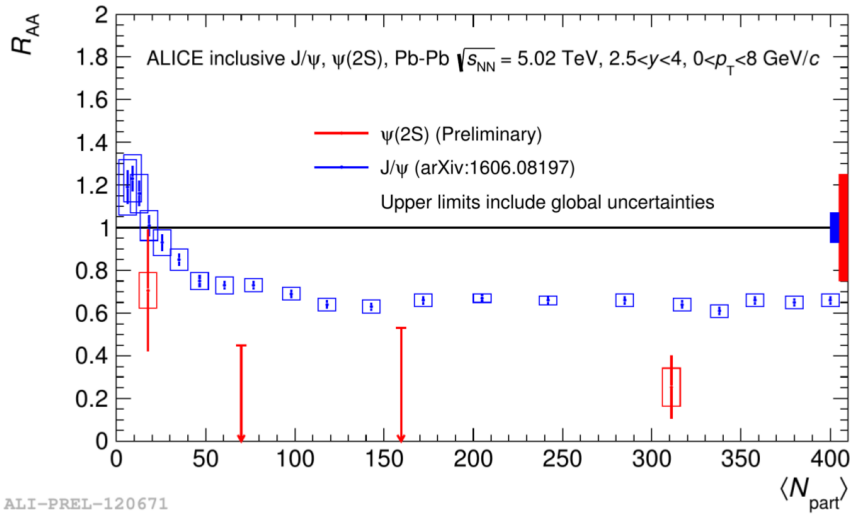
- Evidence of positive v_2 of J/ψ at 2.67TeV.
- Confirmation with better precision with 5TeV data.
- Similar v_2 for J/ψ and prompt charm mesons.
- CMS data extend ALICE measurement at higher p_T.

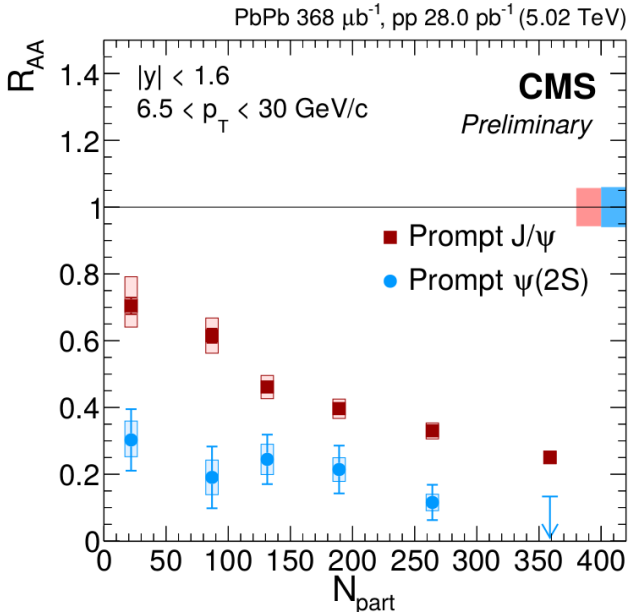


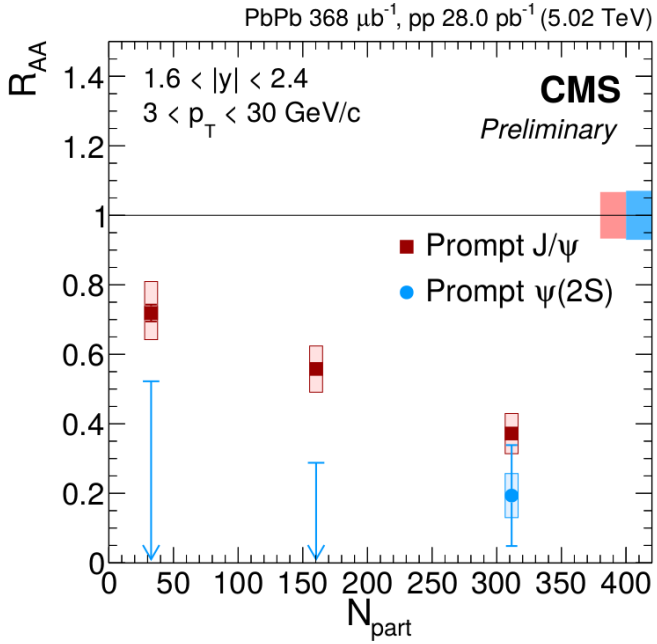
$\psi(2S)$ in PbPb

JHEP 05 (2016) 179

Phys. Rev. Lett. 113 (2014) 262301





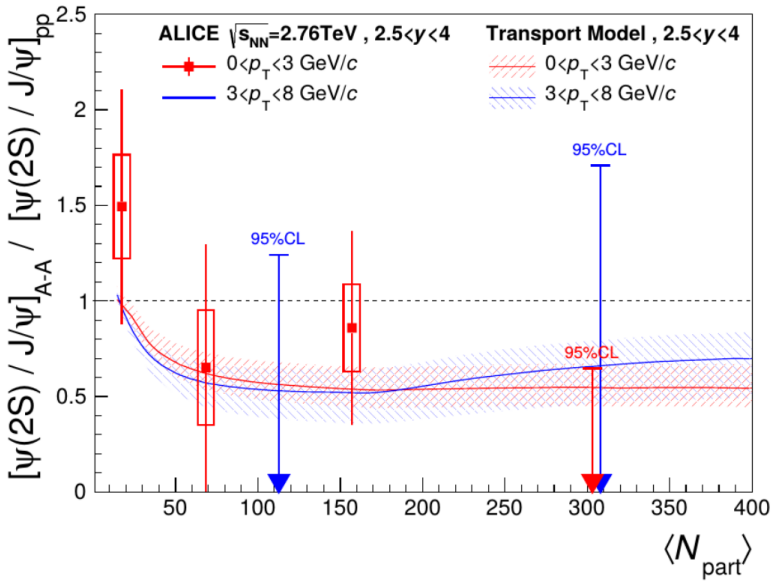


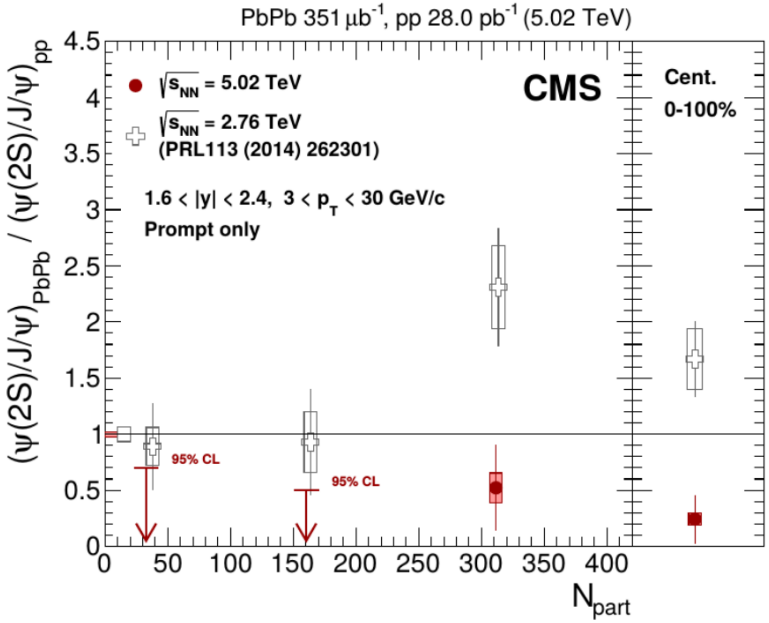
- $\psi(2S)$ production in PbPb: difficult measurement.
- Stronger suppression than J/ψ .
- Also at intermediate/high p_T.

$\psi(2S)$ in PbPb

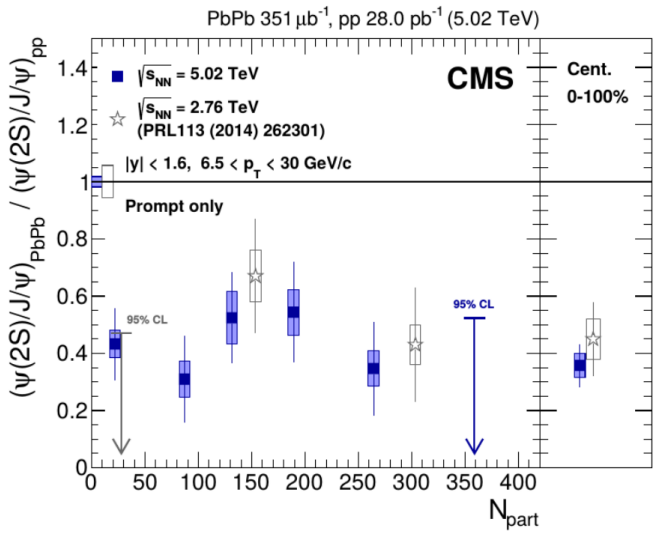
JHEP 05 (2016) 179

Phys. Rev. Lett. 118, 162301 (2017)



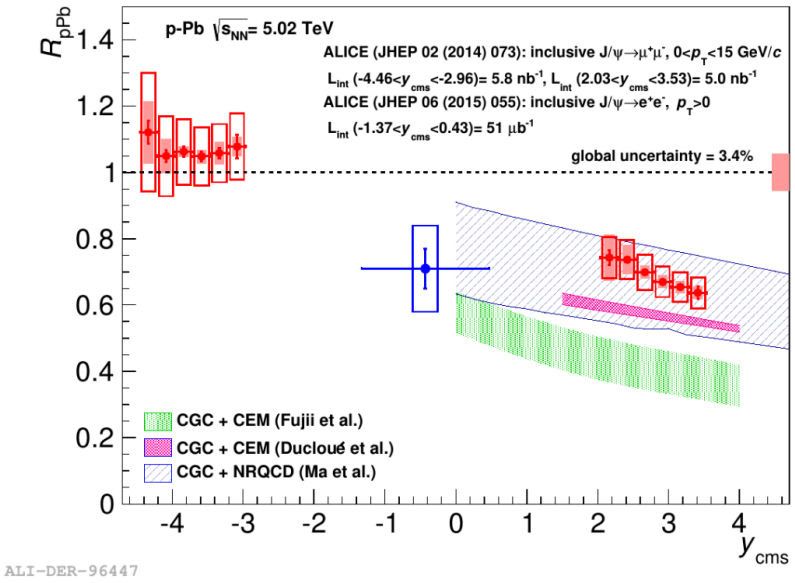


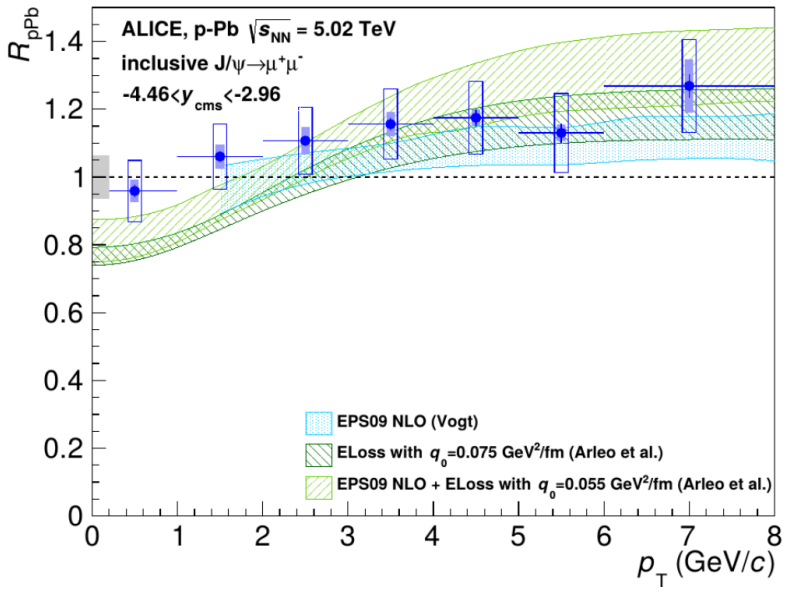
- Double ratio $[\psi(2S)/J/\psi]_{PbPb}/[\psi(2S)/J/\psi]_{pp}$: direct comparison of medium strength effects on J/ψ and $\psi(2S)$.
- Puzzling enhancement observed by CMS at 2.76TeV, not seen by ALICE and not present in the 5TeV dataset.
- Double ratio compatible with zero at forward rapidity. Lower than unity also at high p_T.

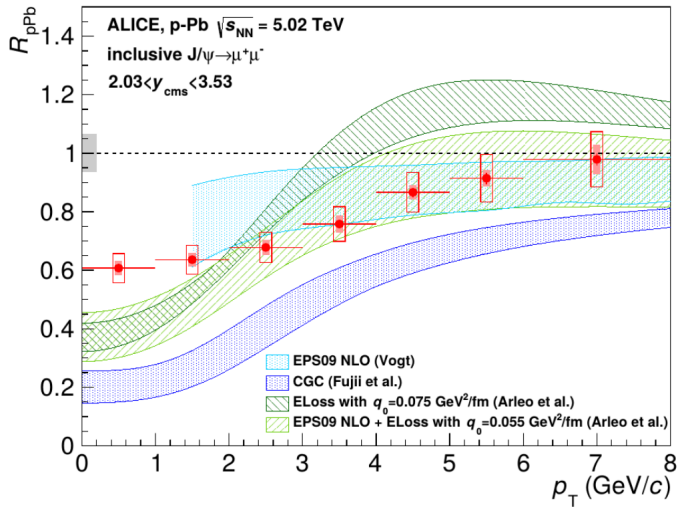


J/ψ in pPb

JHEP 06 (2015) 55





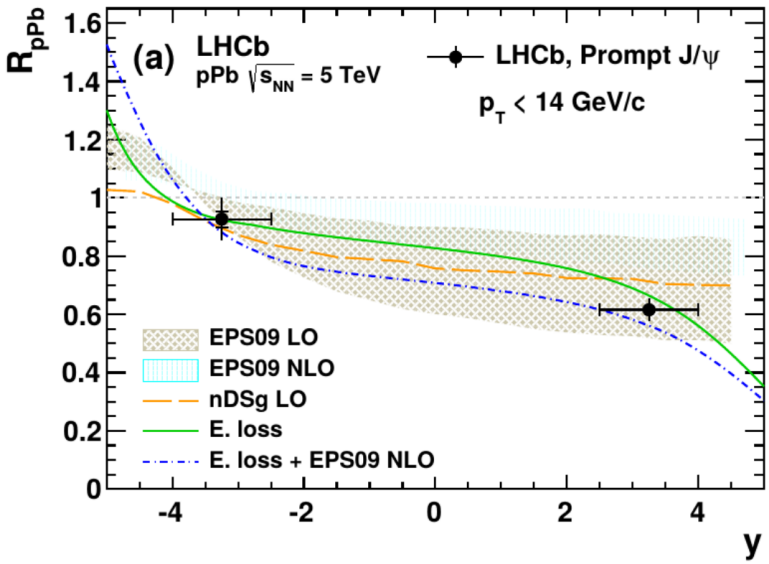


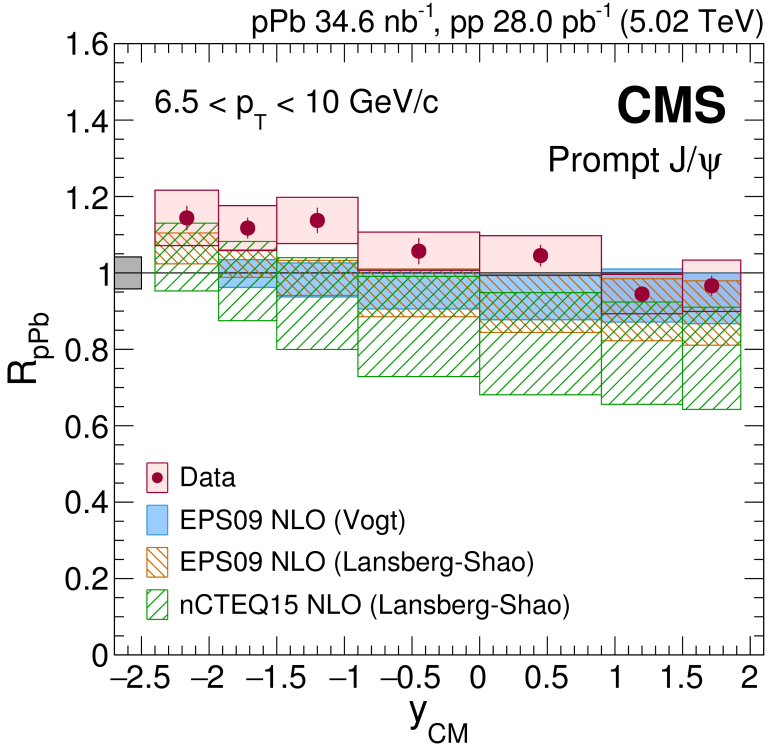
- Inclusive J/ψ production in pPb@5TeV
- Strong suppression at forward rapidity.
- At backward, R_{pPb} compatible with unity.
- Suppression at low p_T, approaching unity at high p_T.

J/ψ in pPb

JHEP 1402 (2014) 072

Eur. Phys. J. C 77 (2017) 269

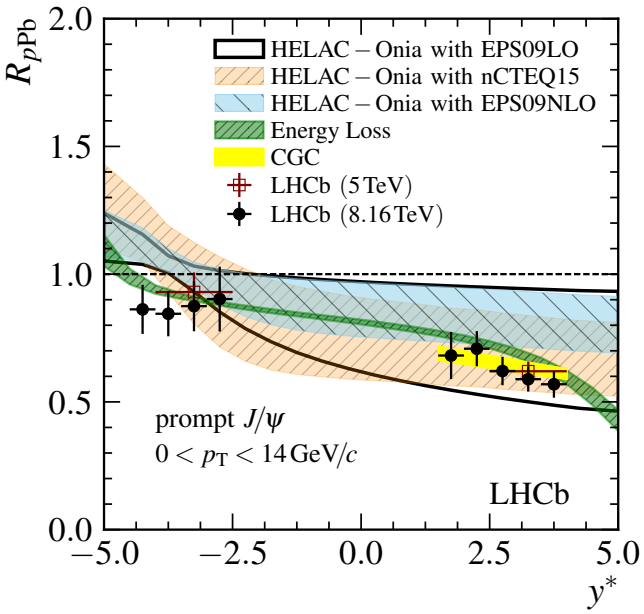


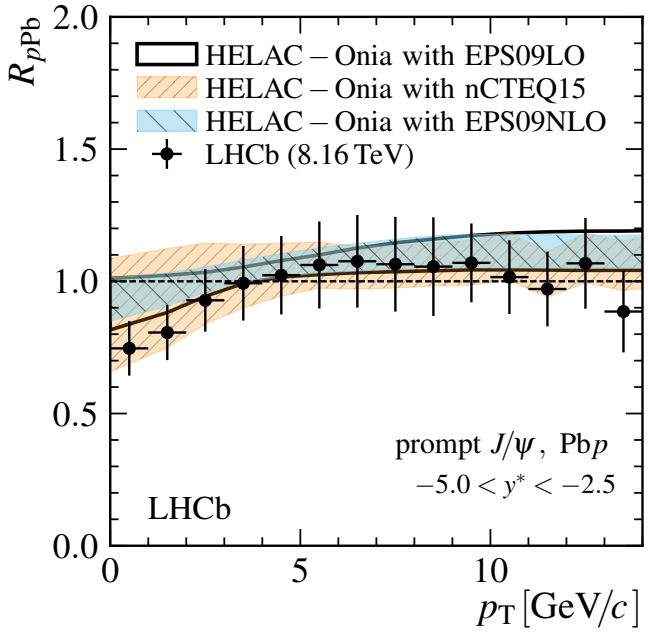


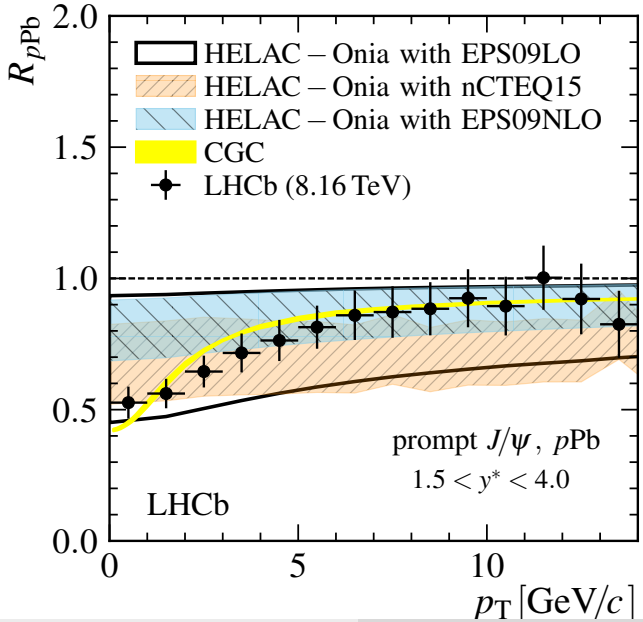
- Similar observations by LHCb and CMS for prompt J/ψ production in pPb@5TeV.

J/ψ in pPb

LHCb-PAPER-2017-014 (accepted by PLB)

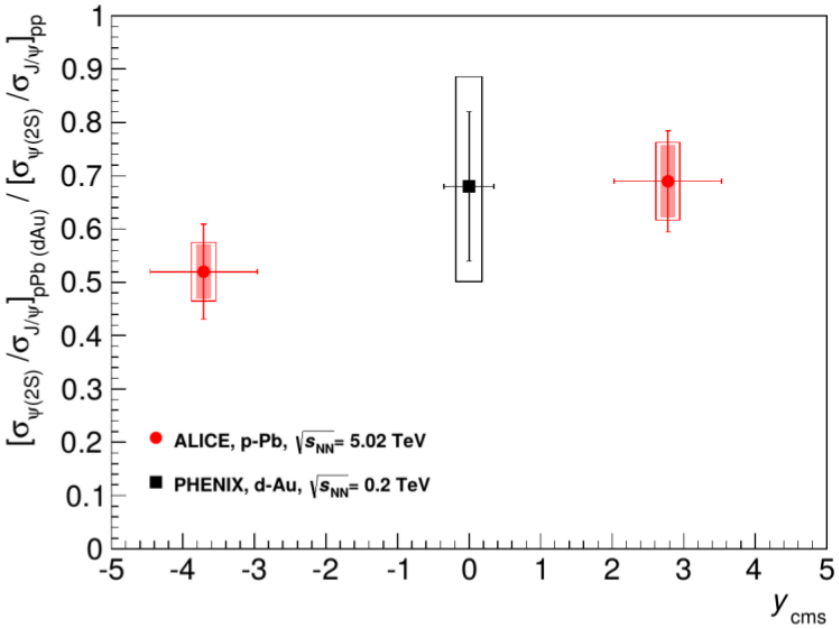


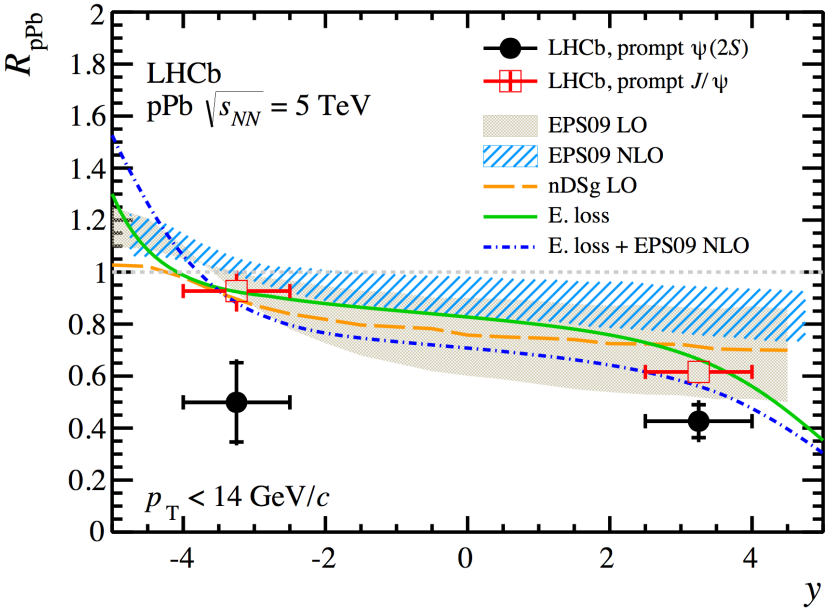




- Measurements of prompt and inclusive J/ψ production in pPb@8.16TeV confirm of 5TeV results.
- Strong suppression at forward rapidity.
- At backward, R_{pPb} compatible with unity, although interesting tensions with nPDF calculations.
- Suppression at low p_T, approaching unity at high p_T.

$\psi(2S)$ in pPb



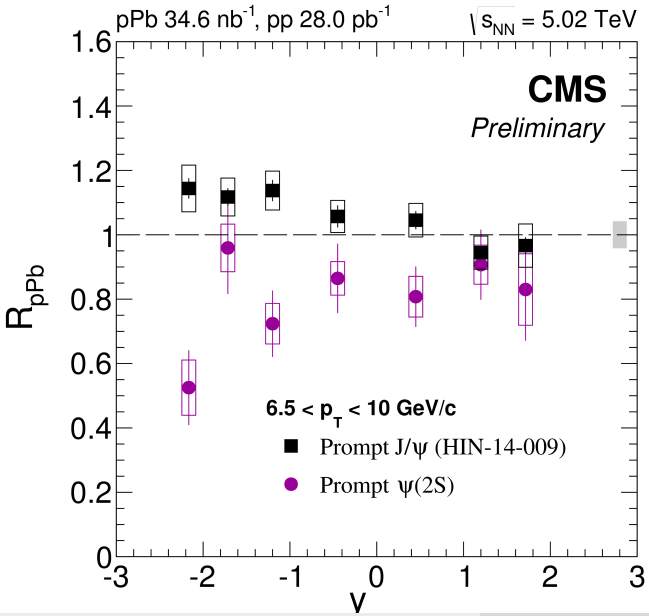


JHEP 1412 (2014) 073

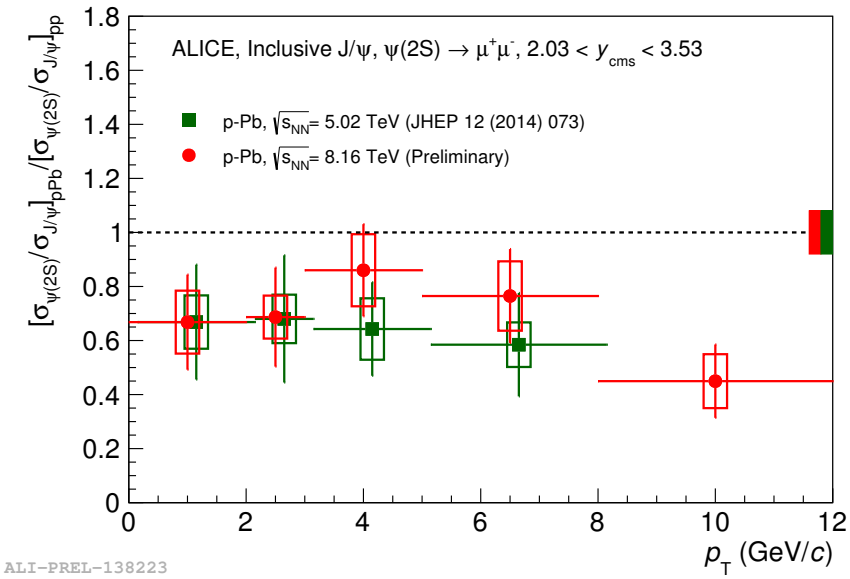
CMS-HIN16-015

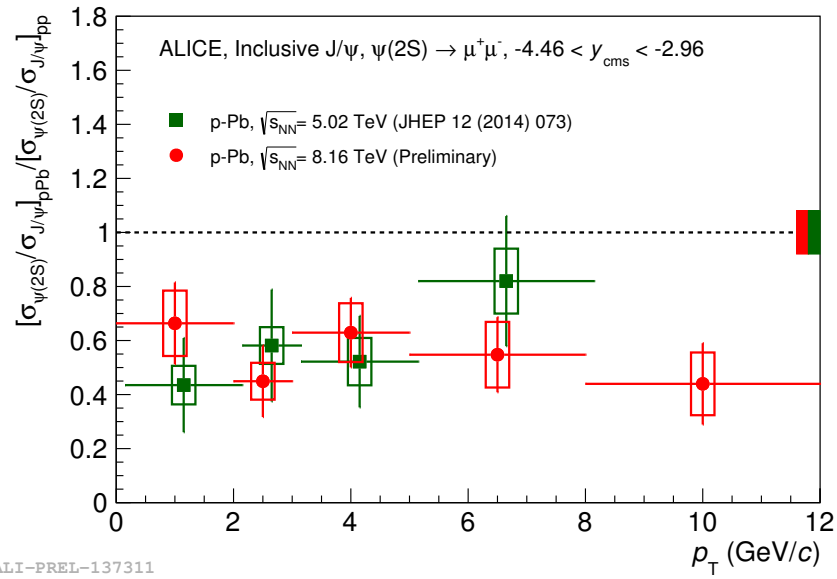
JHEP 1603 (2016) 133

- Suppression of $\psi(2S)$ stronger than J/ψ .
- Similar results already observed at RHIC.
- Weak rapidity and momentum dependence.
- pPb@5TeV sample is statistically limited.



$\psi(2S)$ in pPb



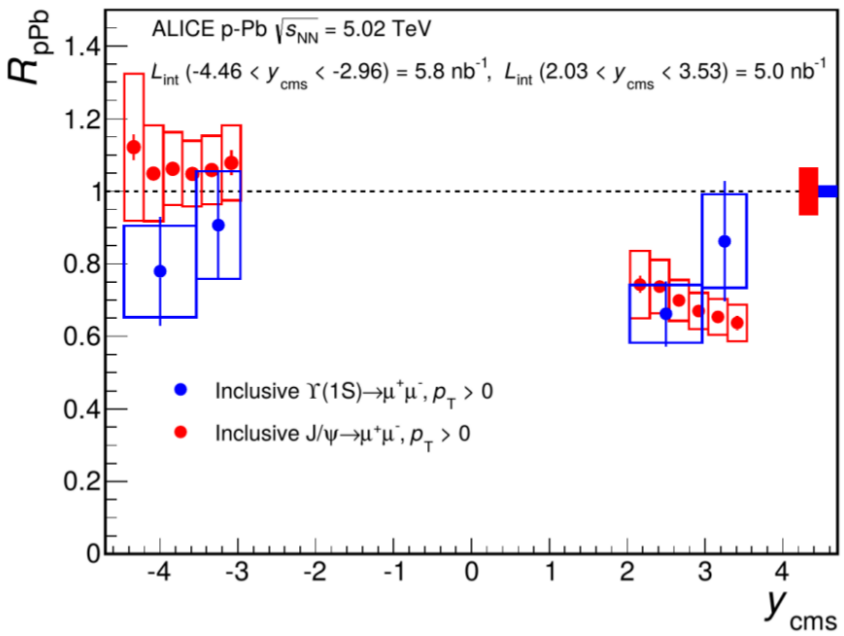


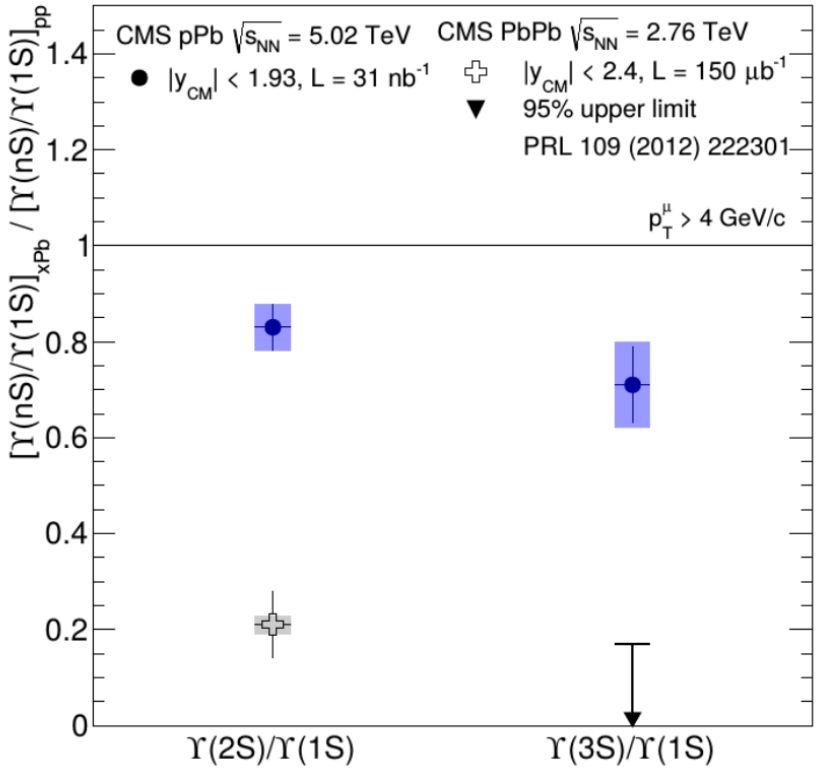
- Suppression of $\psi(2S)$ stronger than J/ψ .
- New results at 8.16 TeV are compatible with 5TeV findings,.
- Small/No p_T dependence.

Bottomonium in pPb

Phys. Lett. B 740 (2015) 105-117

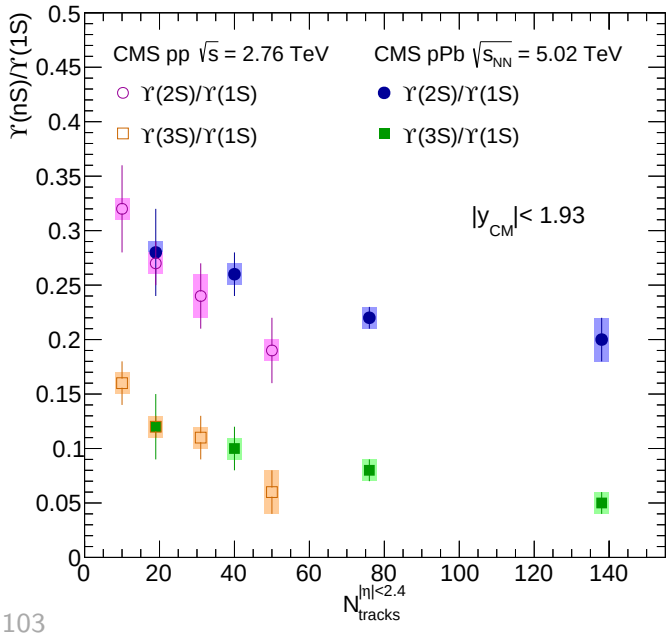
JHEP 04 (2014) 103





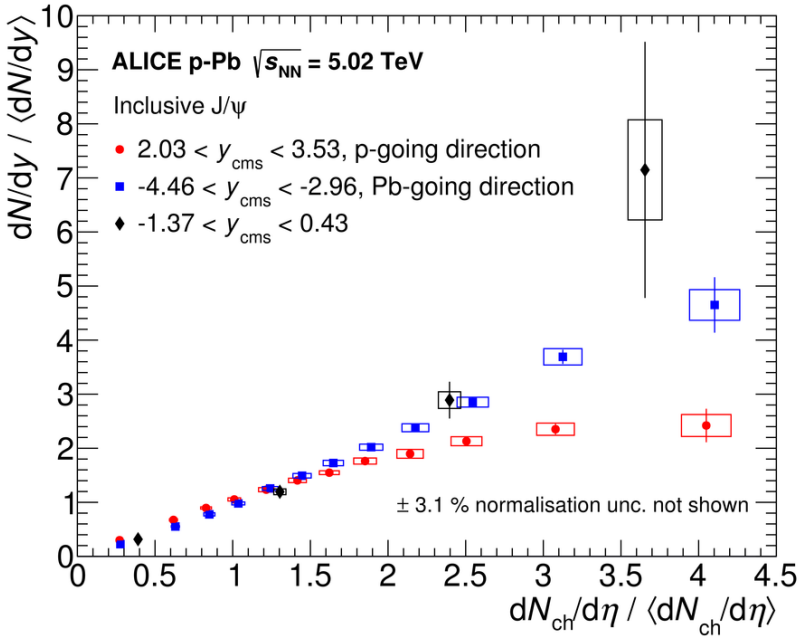
- $\Upsilon(1S)$ shows similar behaviour as J/ψ within uncertainties.
- Exited states are suppressed (like $\psi(2S)$), but not as much as in PbPb.
- pPb run at 5TeV statistically limited. Waiting for 8.16TeV results.

Quarkonium in pPb and pp

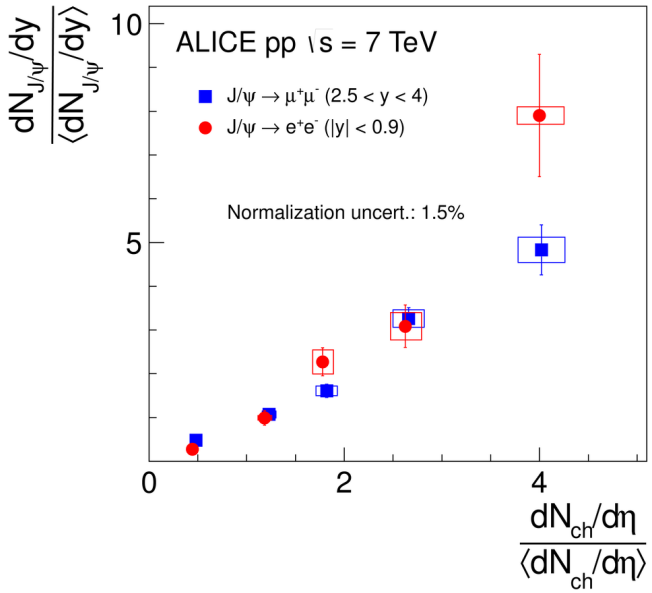


JHEP 04 (2014) 103

arXiv:1704.00274



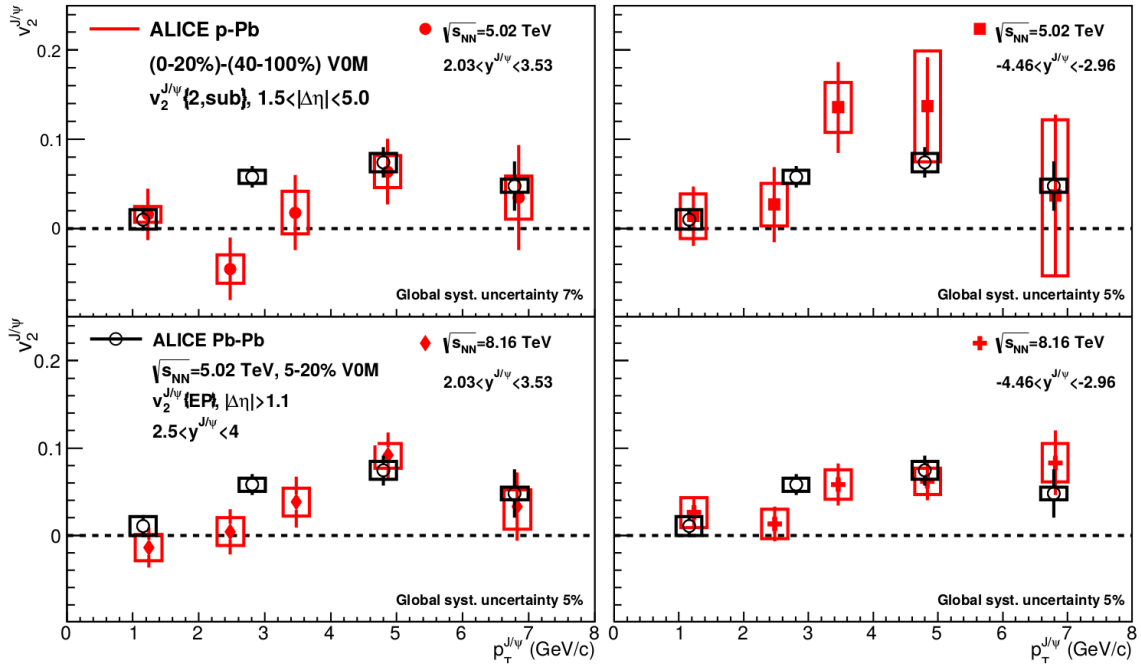
Phys.Lett. B712 (2012) 165-175



- Quarkonium production dependence on multiplicity.
- Similar results observed in pp and pPb.
- Forward-backward difference in high multiplicity events.
- Suppression of exited bottomonium states depend on event multiplicity.

v_2 in pPb

arXiv:1709.06807



- Correlations between hardons and J/ψ in pPb collisions used to extract v_2.
- $p_T < 3$ GeV/c: no deviation from zero.
- $p_T > 3$ GeV/c: positive v_2.
- Similar strength at forward and backward rapidities and at the two energies.
- Overlay with PbPb central collisions shows similar v_2.

Summary

PbPb

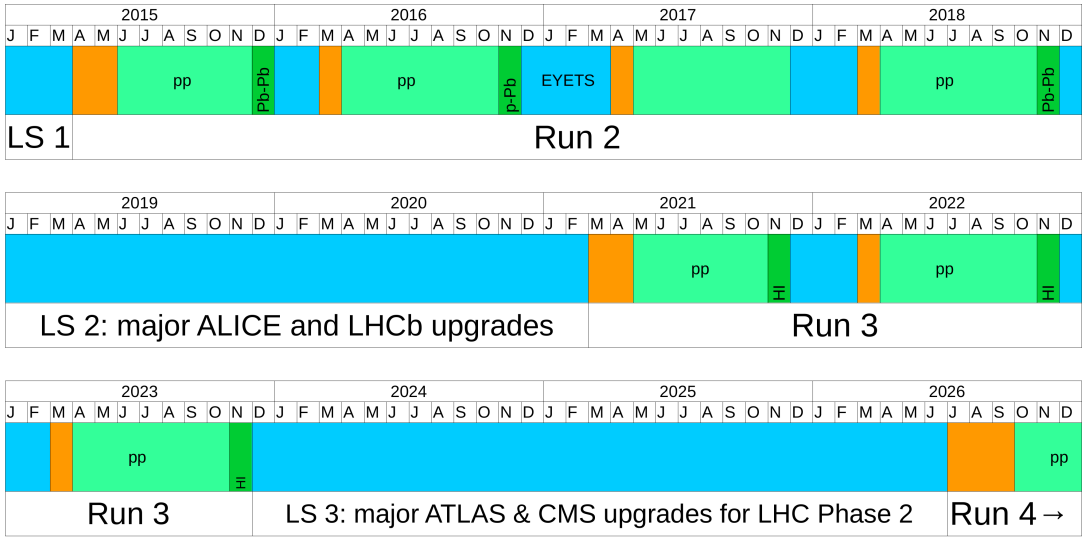
- Suppression of excited Υ states: iconic result for quarkonium suppression in QGP.
- Low-p_T J/ψ : enhancement with respect to RHIC, regeneration of bound states.
- Non zero v_2 for inclusive J/ψ over a large kinematic range.
- $\psi(2S)$ would benefit from larger samples.

pPb

- Quarkonia and heavy flavour hadrons allow one to test/constrain nPDF and gluon saturation.
- Stronger suppression of excited states: depends on event activity, but not much on kinematics.
- J/ψ shows positive v_2 for $p_T > 3$ GeV/c.

Outlook

arXiv:1609.01135



- Still Run 2 will provide more PbPb data. Increase in statistics allows one to explore more differential measurements, in particular for exited states.
- pPb data still to be fully exploited. More results are on the way, also possible measurements of χ_c.
- ALICE and LHCb will undergo major upgrades during LS2.
- ALICE central barrel will run at 50kHz PbPb collisions.
- ALICE muon arm will be equipped with a silicon tracker close to the interaction point: better resolution and measurements of $B \to J/\psi + X$
- LHCb will have a better centrality reach in PbPb.