Quarkonia: experiment

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for the LHC experiments

CERN

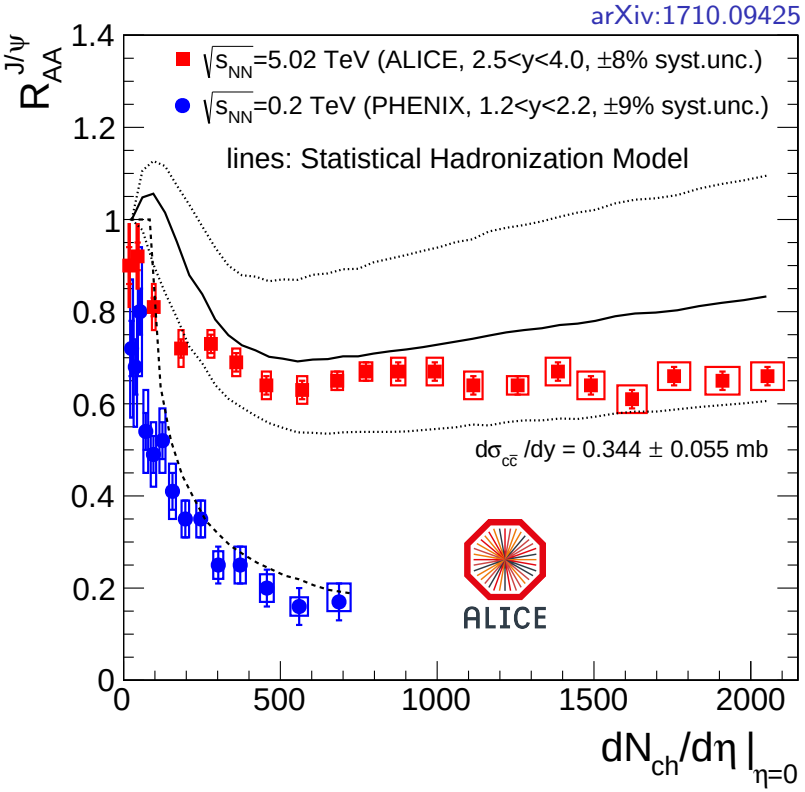
HL-LHC workshop

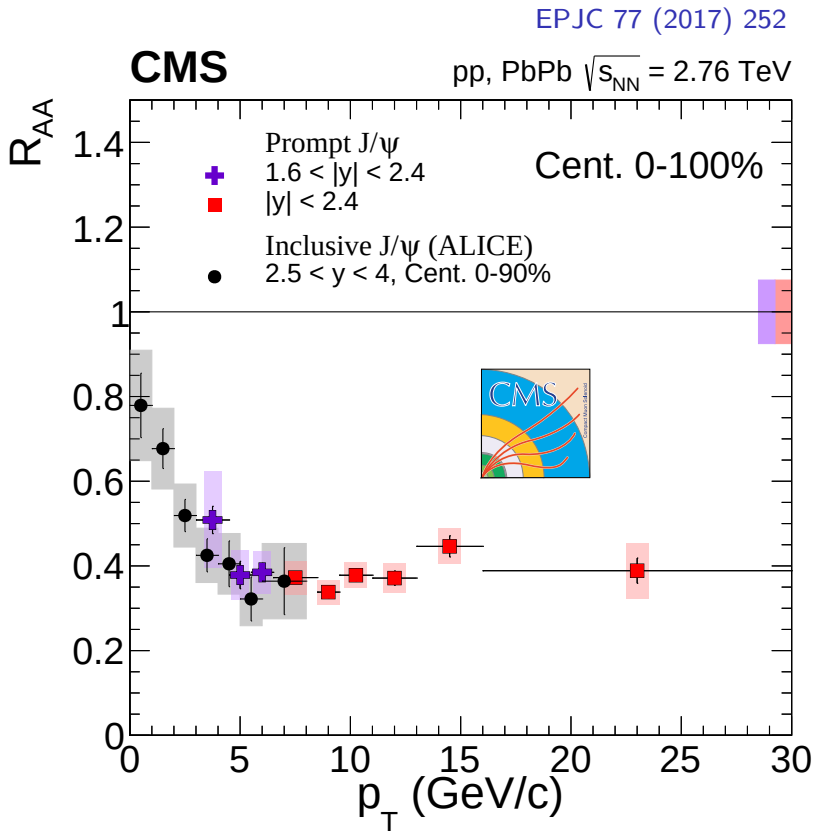
Open questions regarding quarkonium production in heavy ion collisions

- Do we understand the different ingredients for quarkonium suppression?
  - contribution from feed-down
  - cold nuclear matter effects
  - low p_T: transport vs statistical models
  - high p_T: energy loss, importance of gluon fragmentation
- Ground vs excited states in pp, pPb, PbPb?
- What is the impact of multiplicity? Does polarisation depend on multiplicity?
- What is the R_{AA} in very peripheral PbPb? Importance of EM production?
- What is the flow of heavy quarks (c, b)? Is it implying their complete thermalisation?

Understanding quarkonium suppression in AA

Quarkonium is a crucial observable for QGP studies





- SHM (J/ψ newly-generated at $T = 156\,\mathrm{MeV}$) *and* transport models both describe J/ψ data
- As expected (transport models): increase of J/ψ R_{AA} at the LHC at low p_T

High p_T quarkonium suppression

- Strong J/ψ suppression is observed at high p_T
- For $p_T \gg M_Q$, expected to be similar to light partons.
- True for J/ψ but not for B-hadrons? Hint of different behaviour between prompt and nonprompt J/ψ

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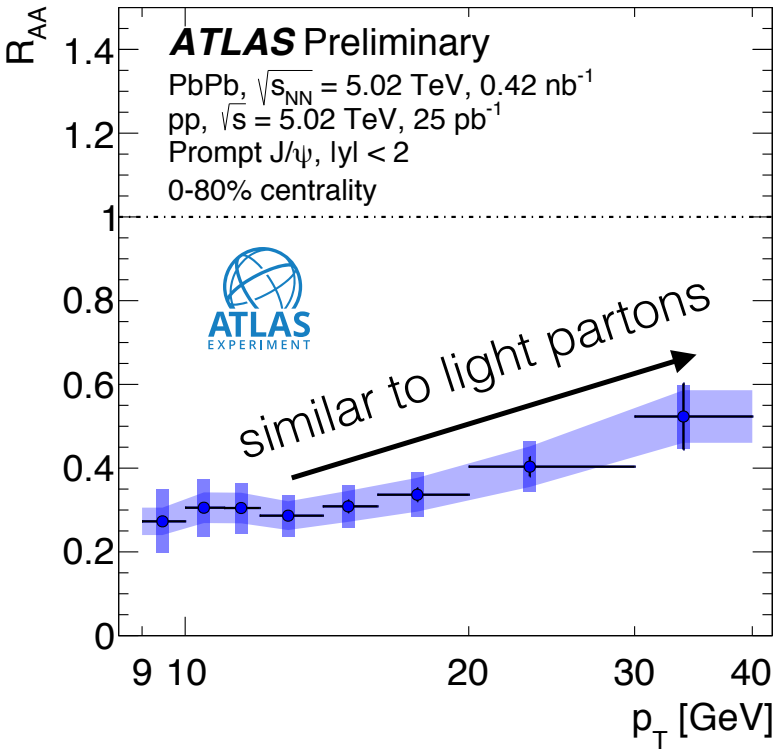

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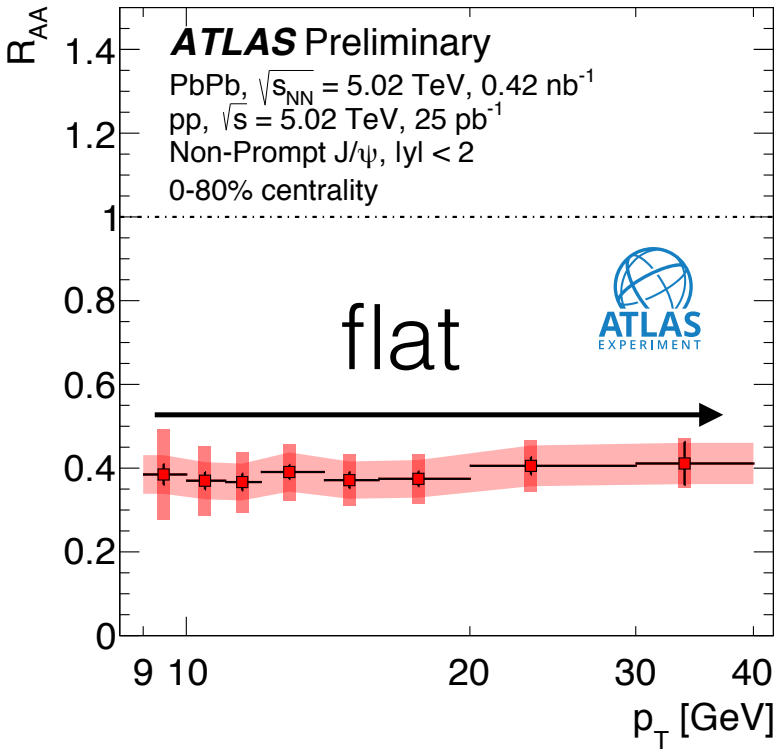

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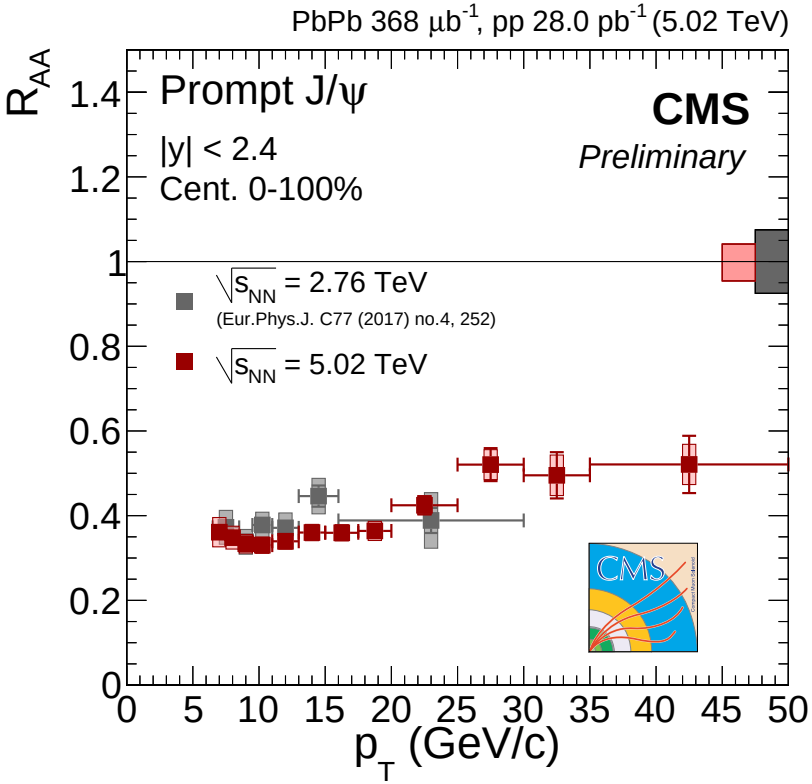
CMS-PAS-HIN-16-025



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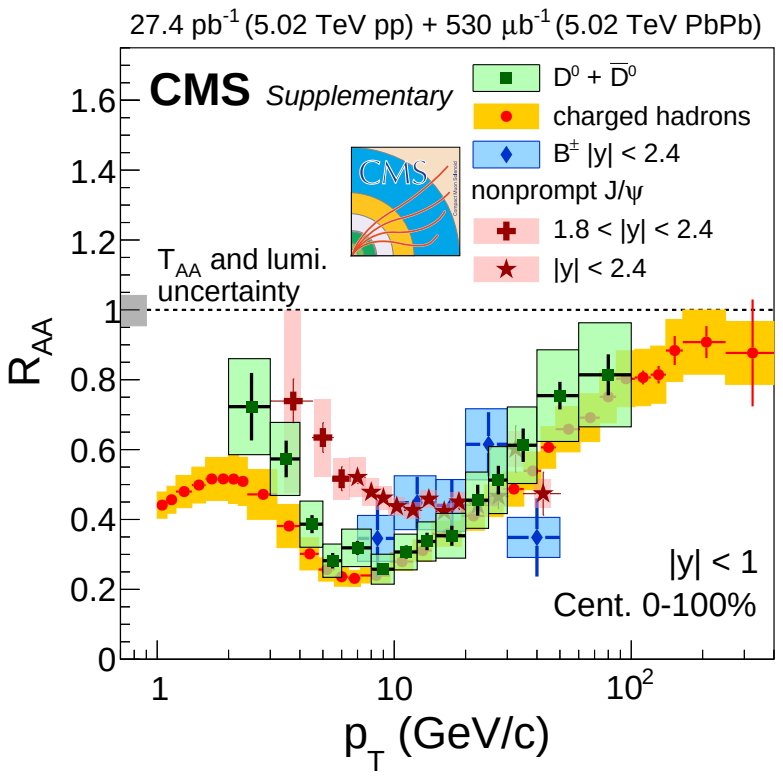
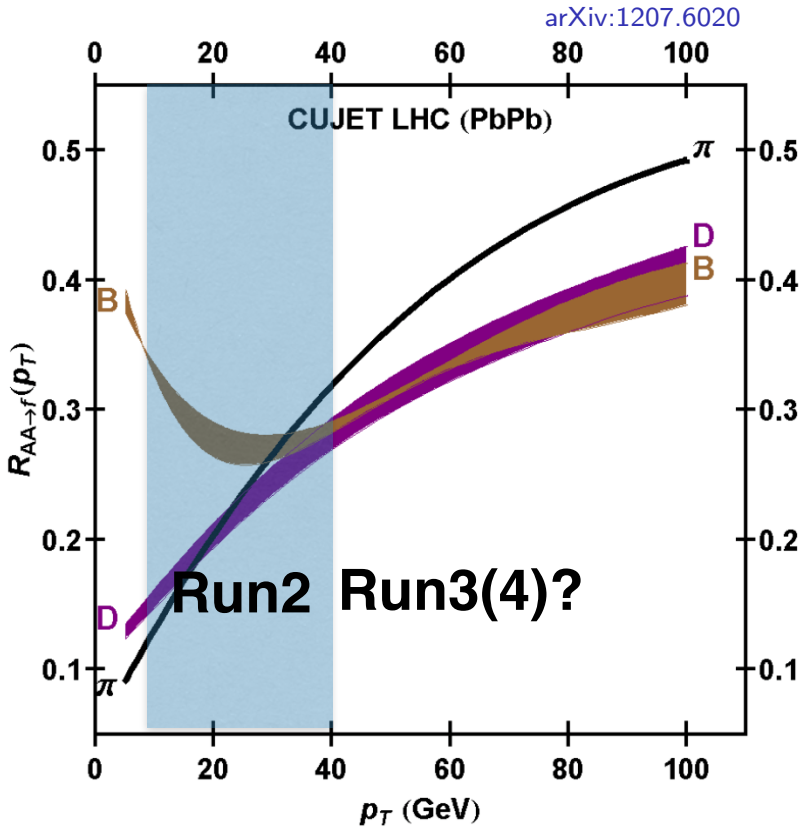
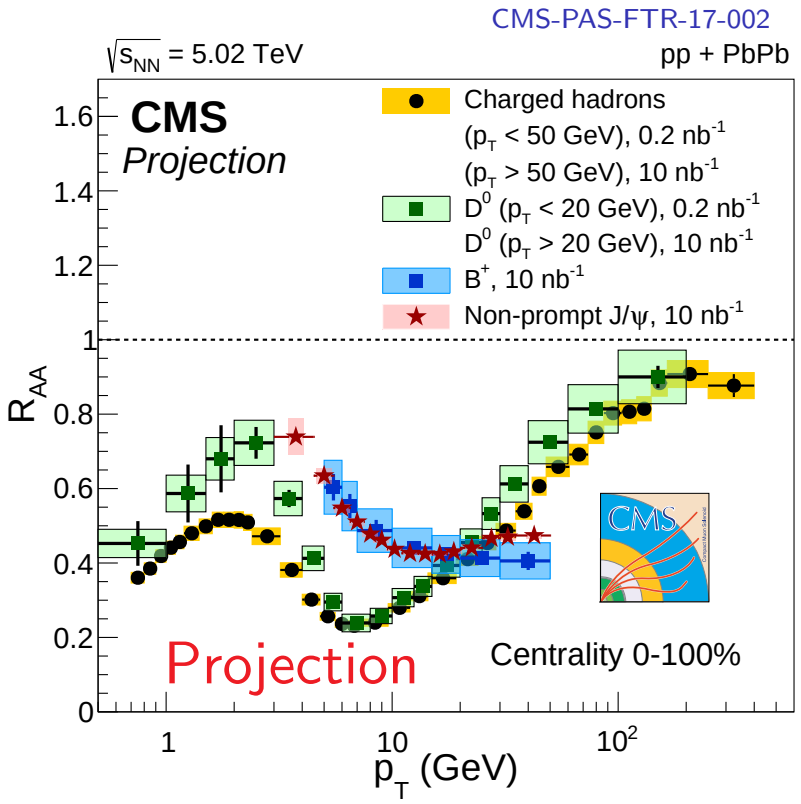


High p_T quarkonium suppression

More data will allow us to reach higher p_T and with higher precision

- Test energy loss models:
  - collisional vs radiative?
  - coherent energy loss $\rightarrow$ jet quenching?
- Hadronisation via (medium modified) fragmentation?





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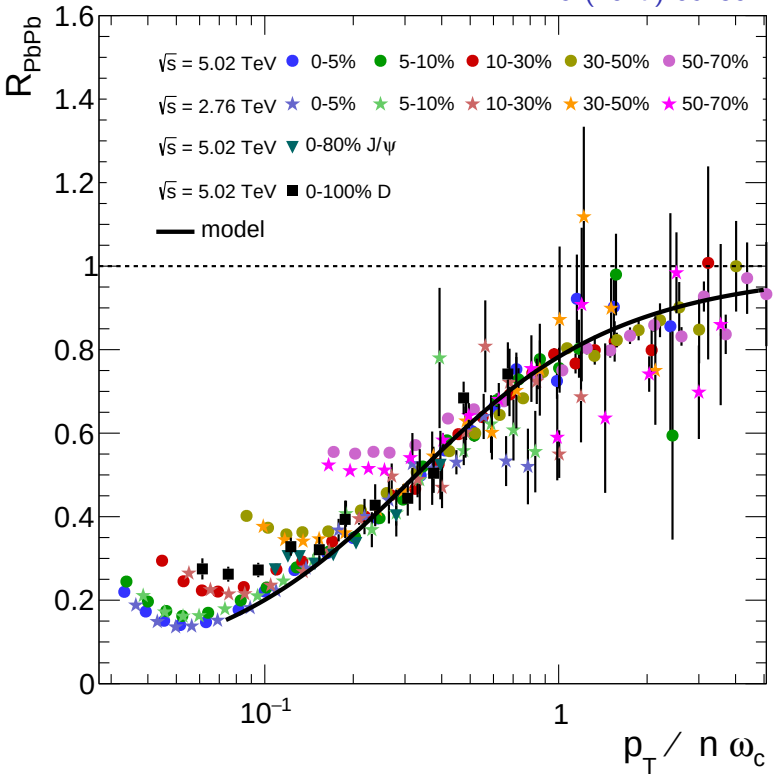
PRL 119 (2017) 062302



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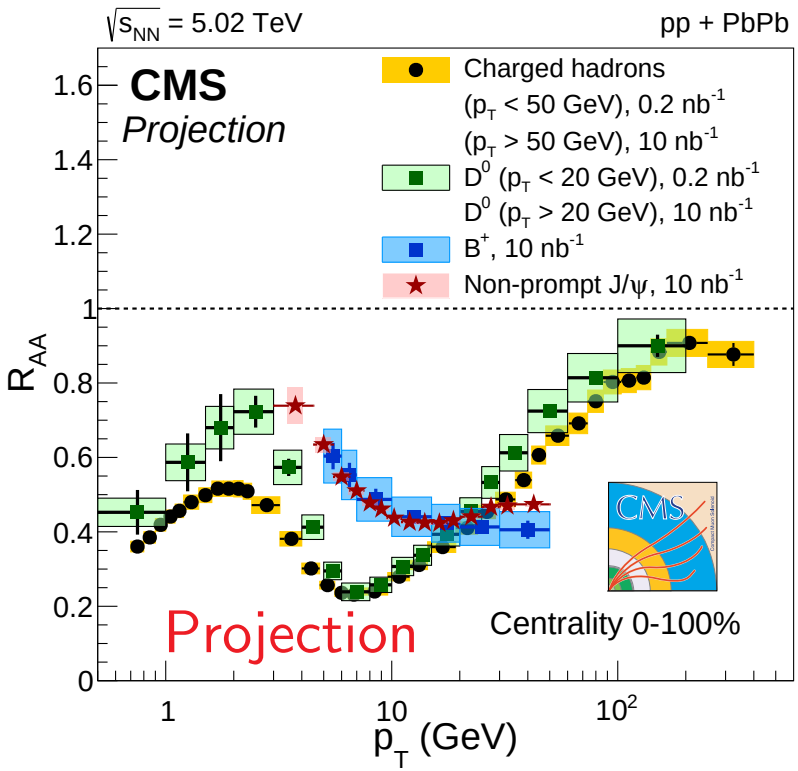

What about bottomonia?

More data also needed for the high p_T behaviour of bottomonium suppression

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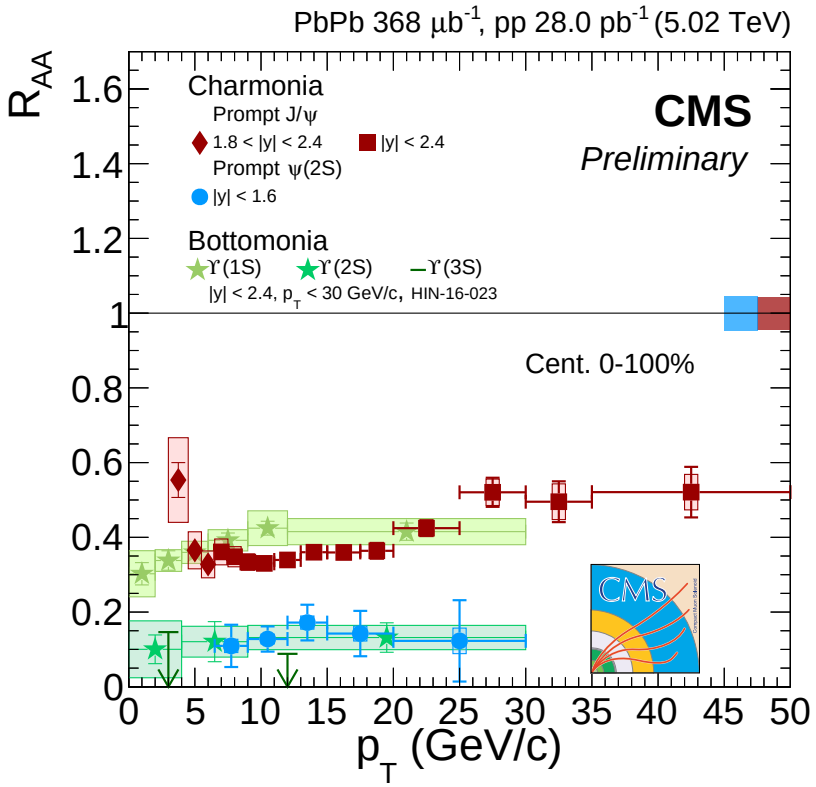
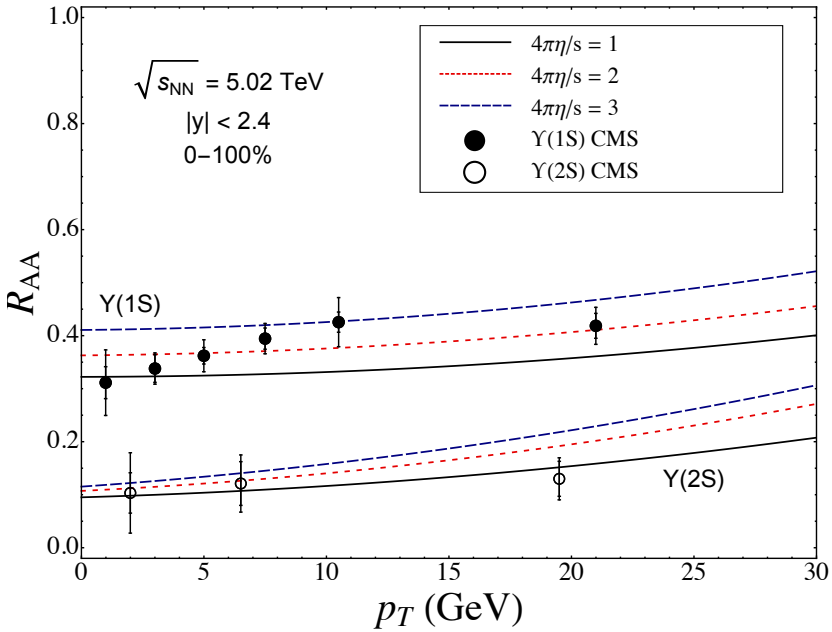
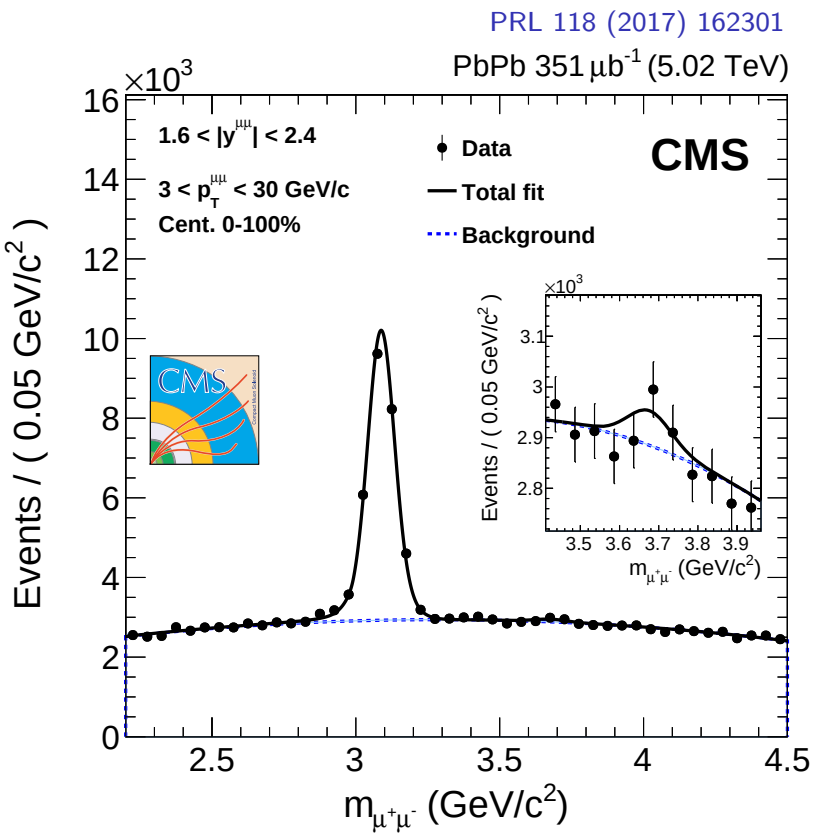


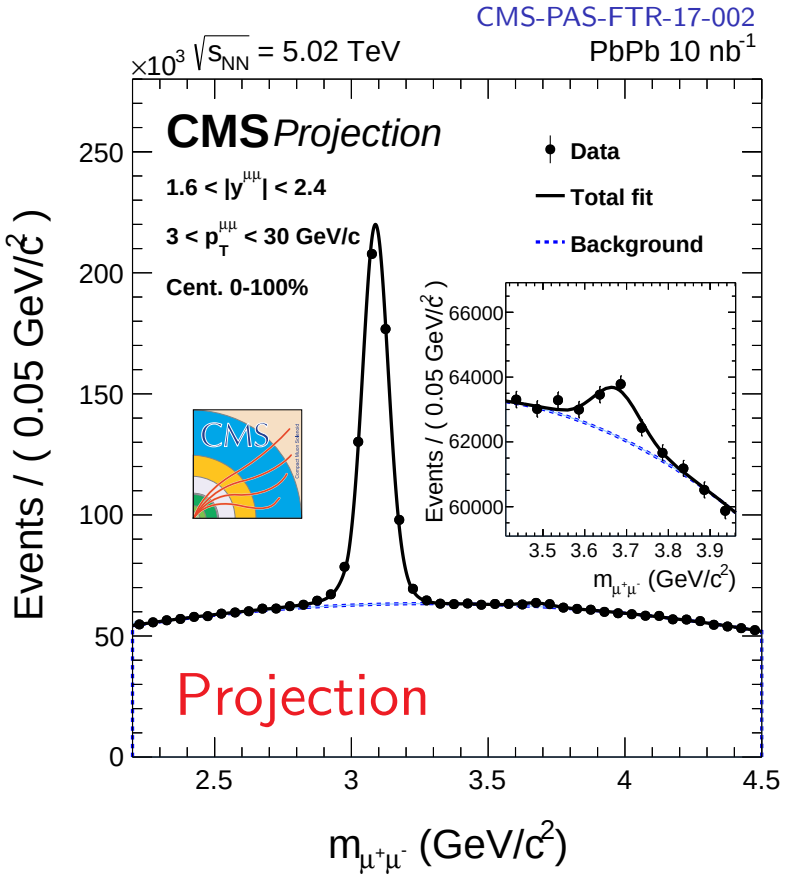
NPA 967 (2017) 604



Excited charmonium production: PbPb

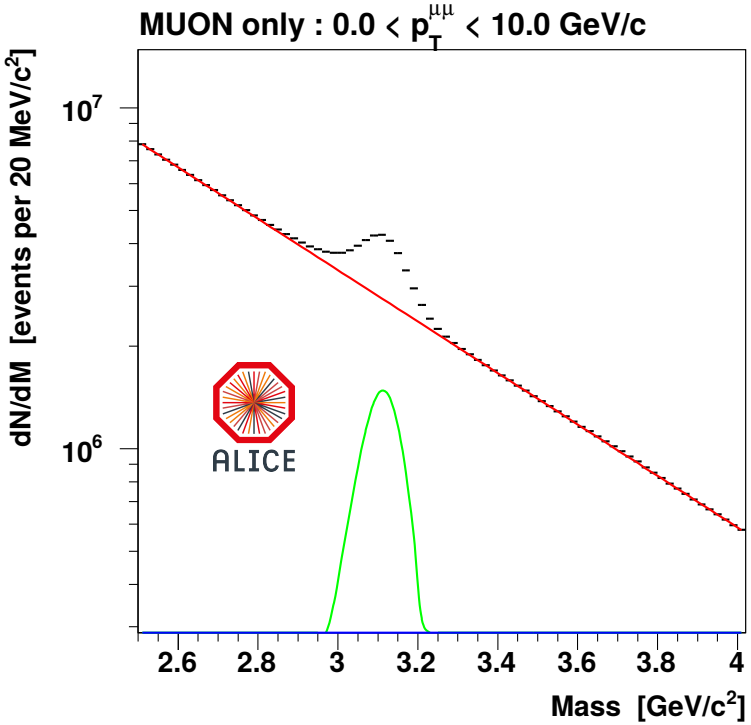
- Very low S/B ratio: limited precision with current data



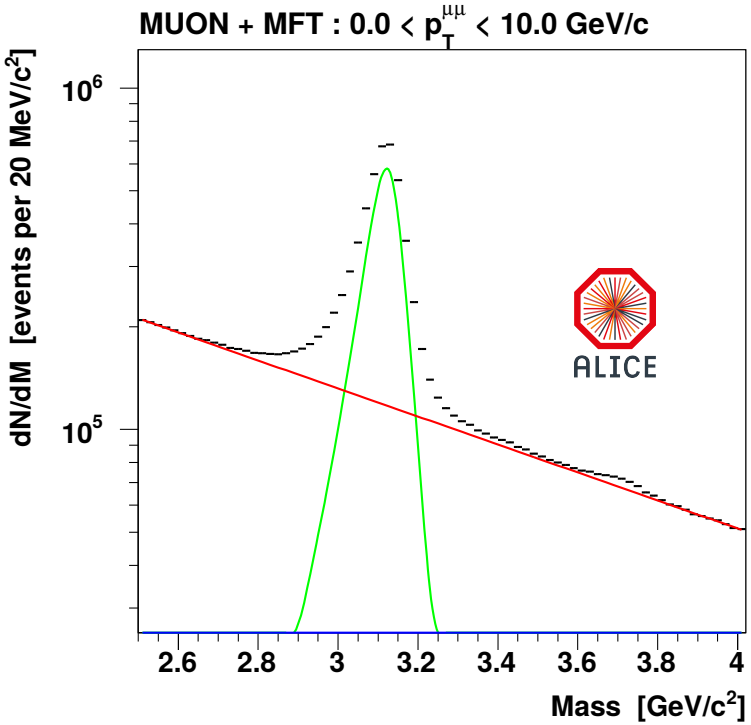


Excited charmonium production: PbPb

- Very low S/B ratio: limited precision with current data
- ALICE will also benefit from the MFT

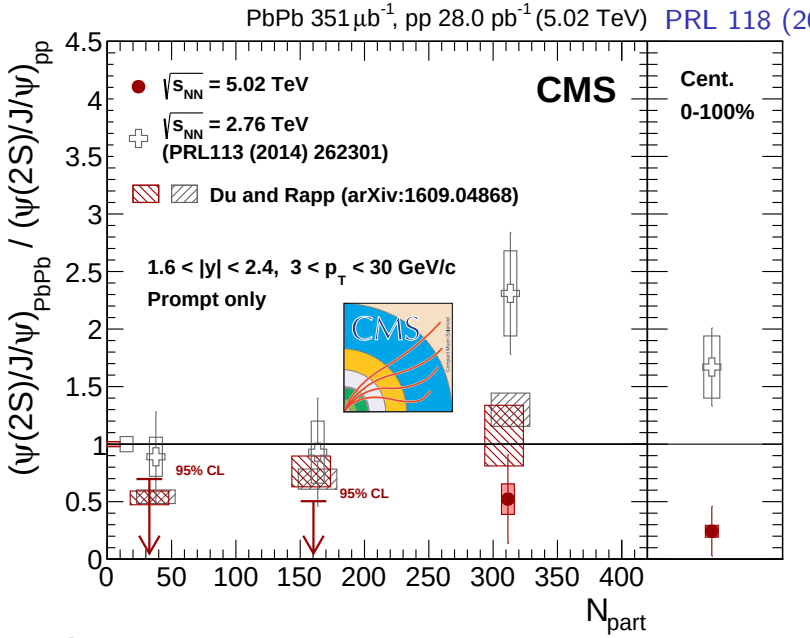


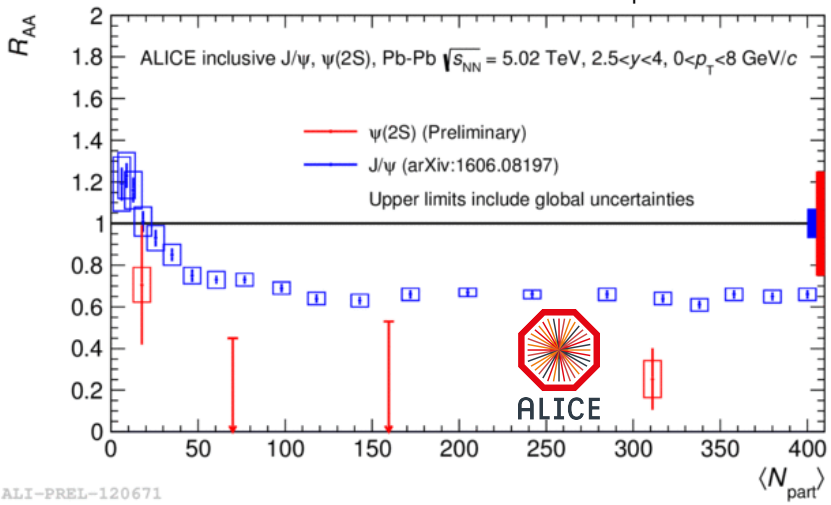
ALICE Upgrade LOI: MFT (Projections)

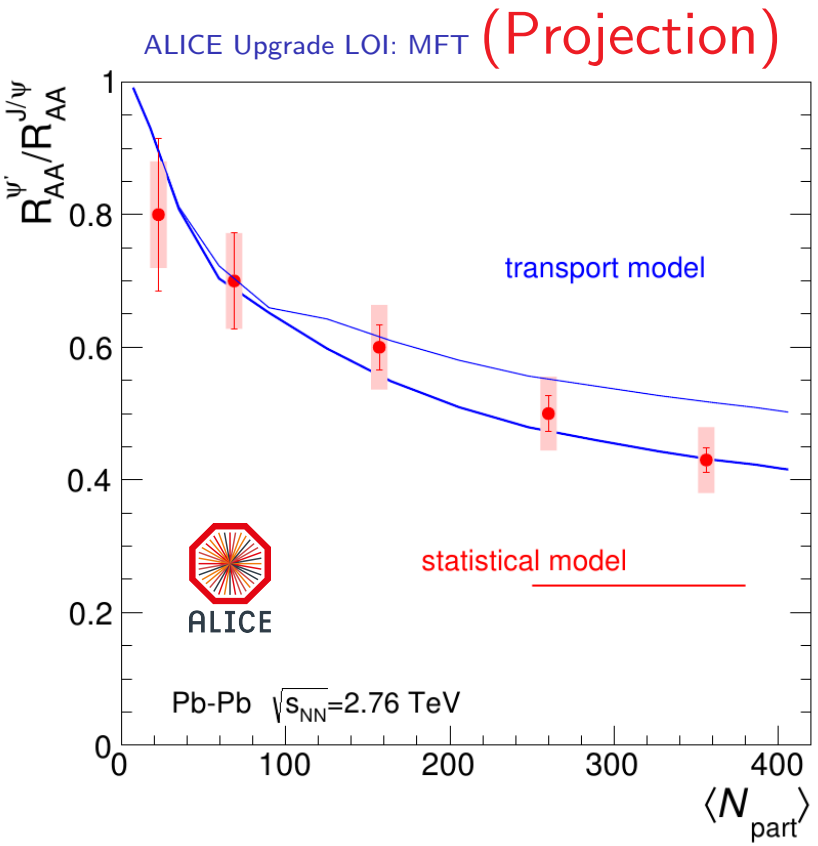


Excited charmonium production: PbPb

Excited charmonium production in PbPb: distinguish between transport and statistical models

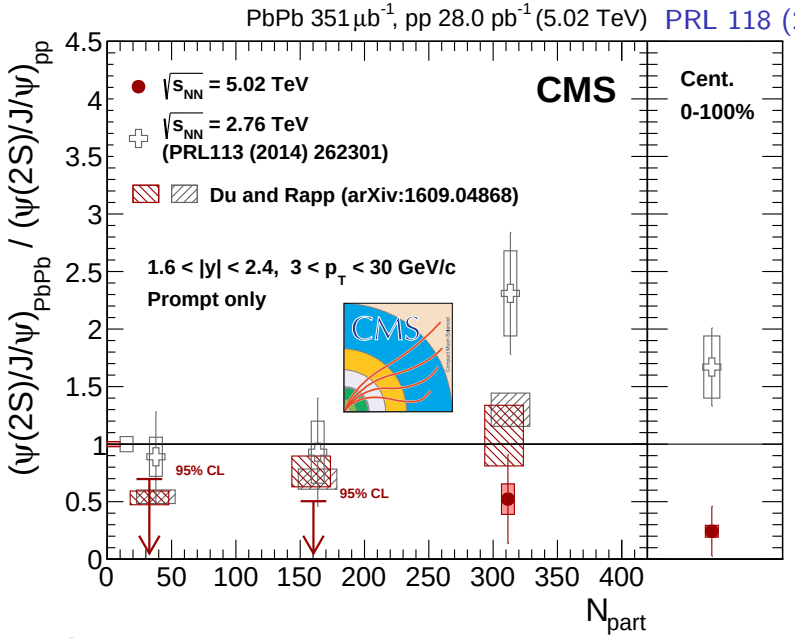


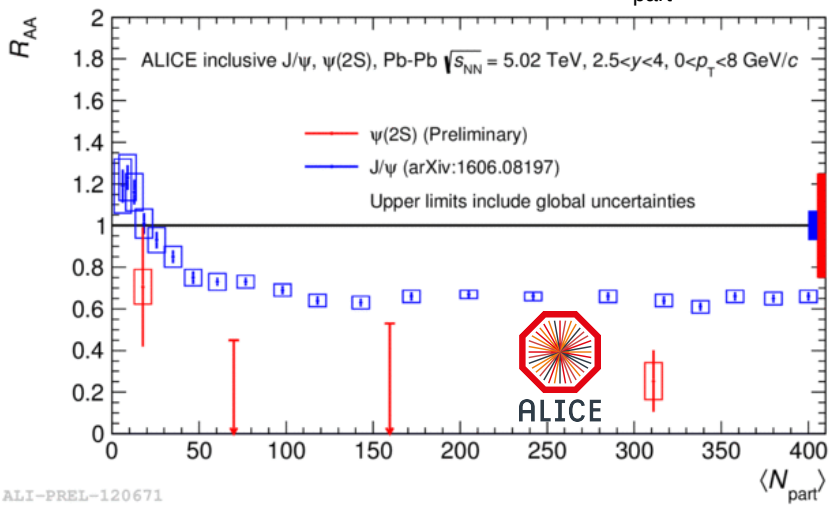


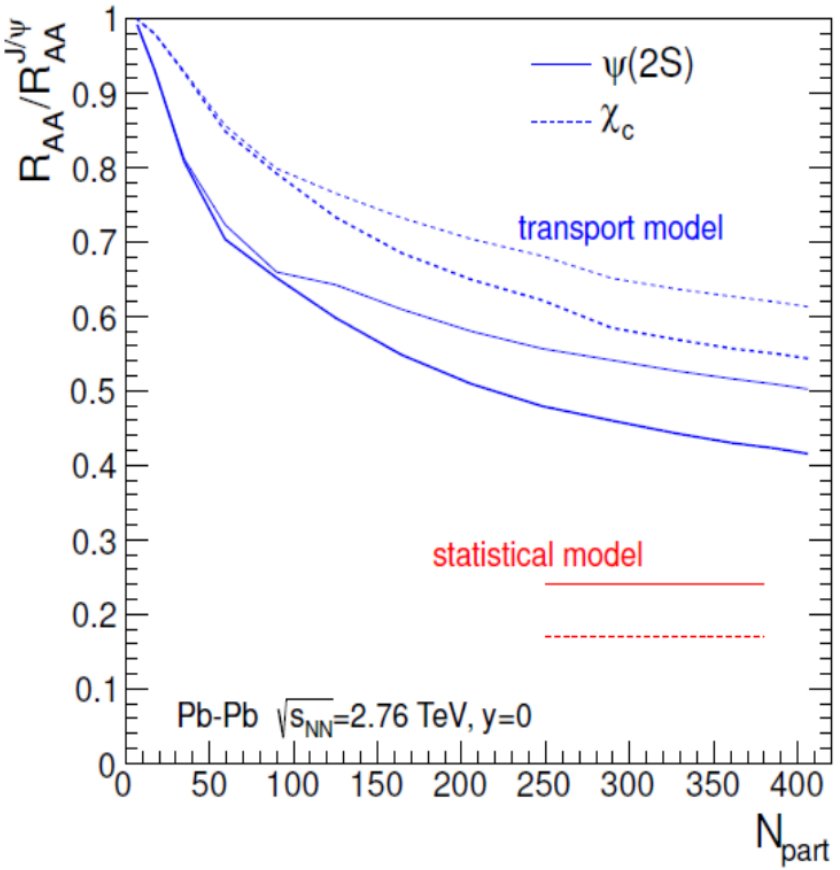


Excited charmonium production: PbPb

Excited charmonium production in PbPb: distinguish between transport and statistical models (χ_c would also help)



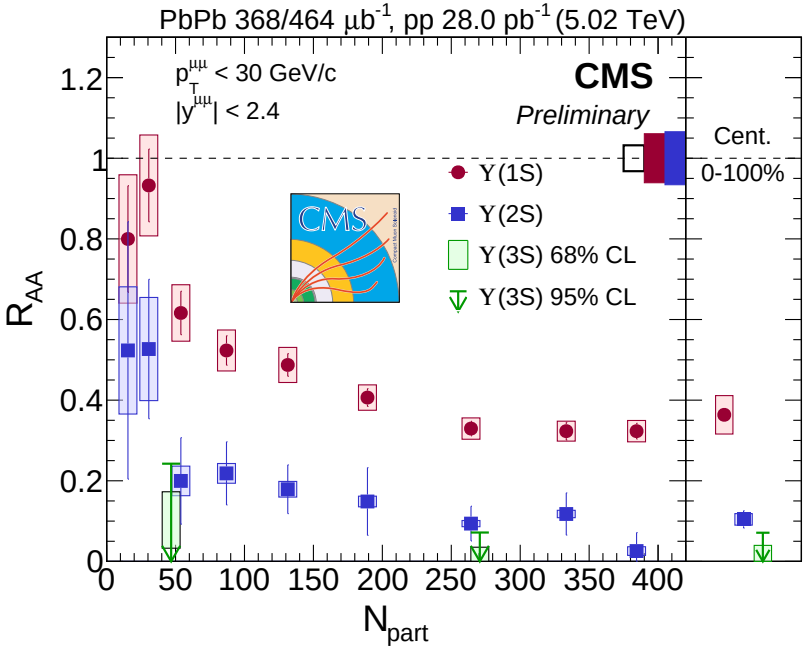




Excited bottomonium production: PbPb

- What is the R_{AA} of Υ(3S)?
- What is the R_{AA} of Υ(1S,2S,3S) in peripheral events?
- Sensitivity to η/s with $10\,\mathrm{nb}^{-1}$

CMS-PAS-HIN-16-023



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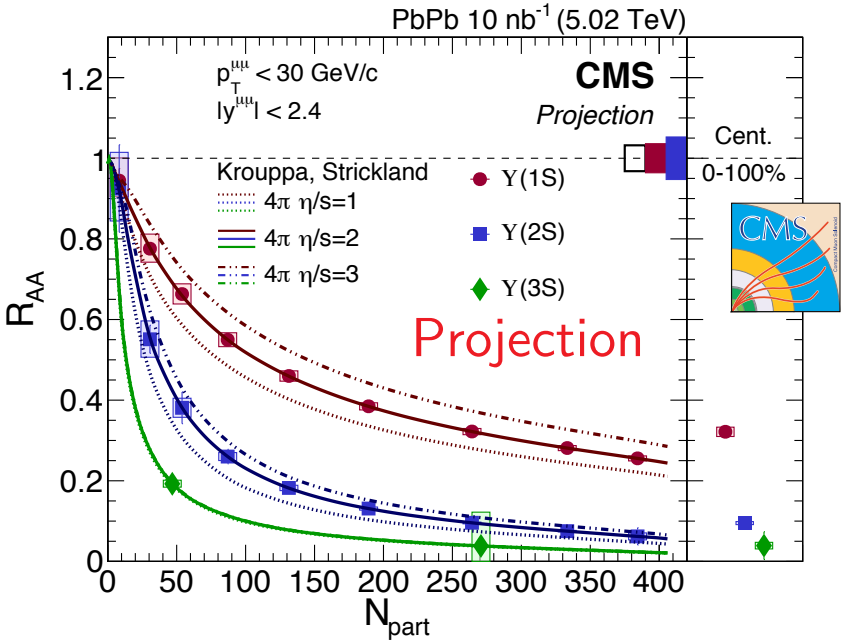
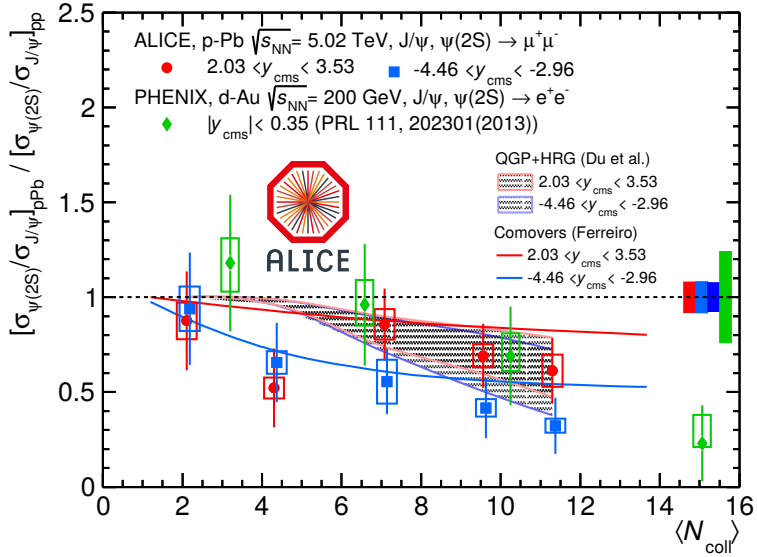


Excited quarkonia: what about pPb?

Excited quarkonium production in pPb requires further studies and understanding (also needed to understand PbPb)

arXiv:1704.00274



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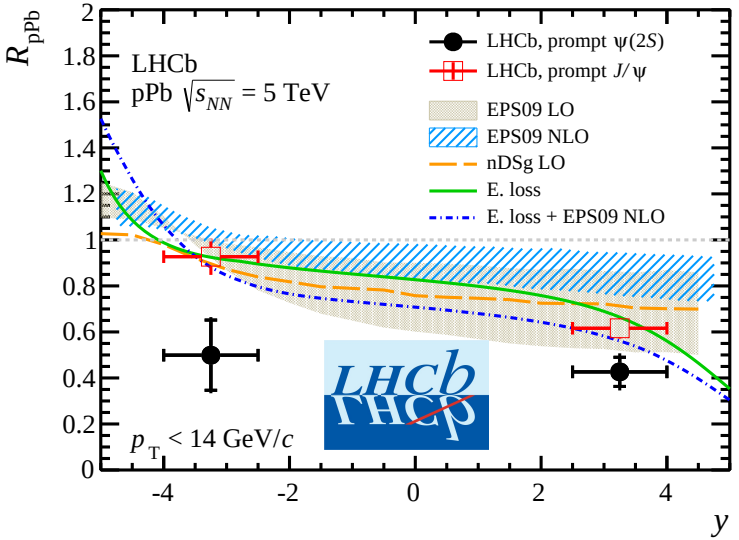

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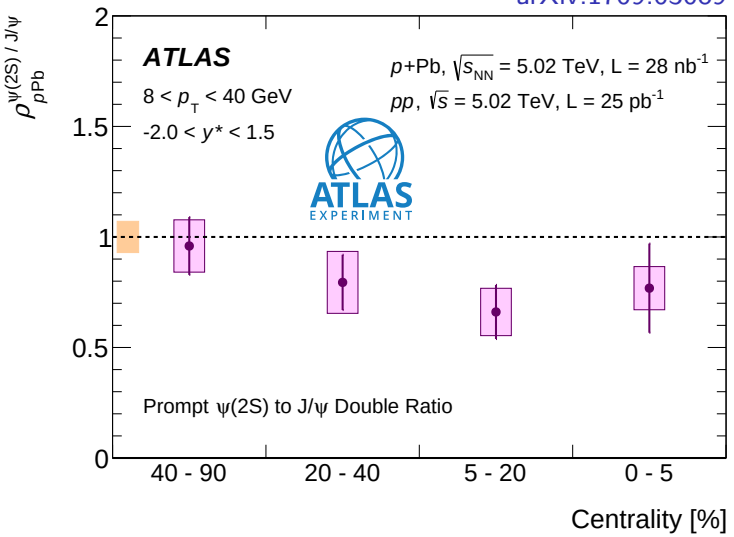

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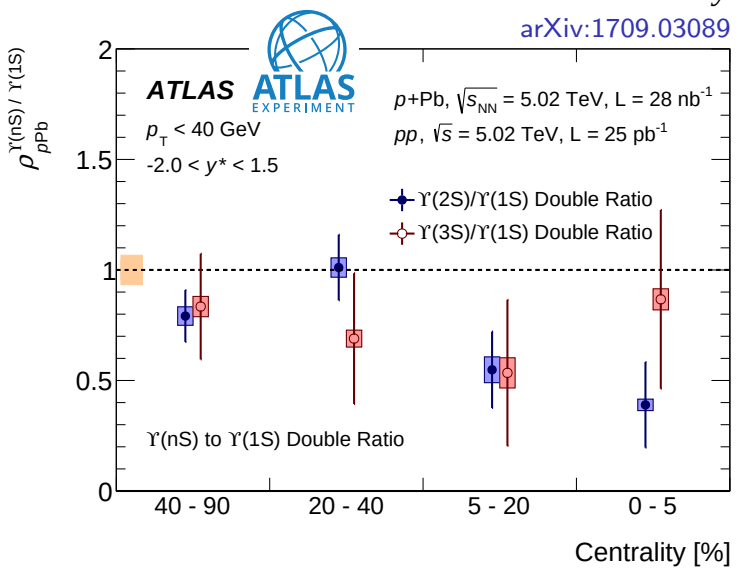
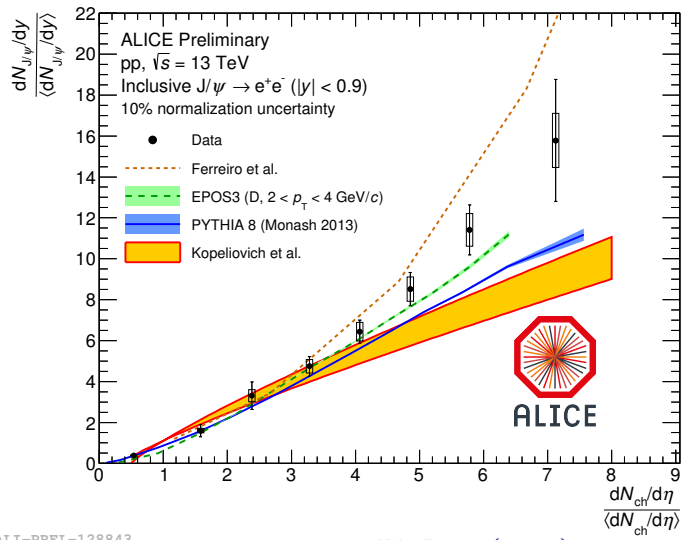


Studies as a function of multiplicity

Impact of multiplicity on quarkonium production and polarisation in pp and pPb? More data needed for further studies



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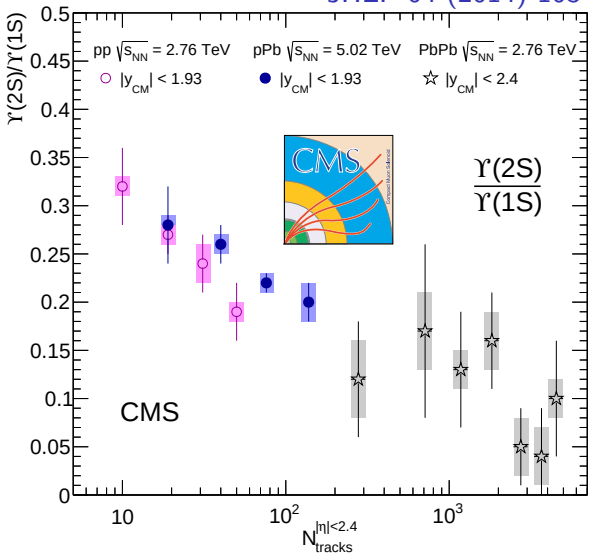
JHEP 04 (2014) 103



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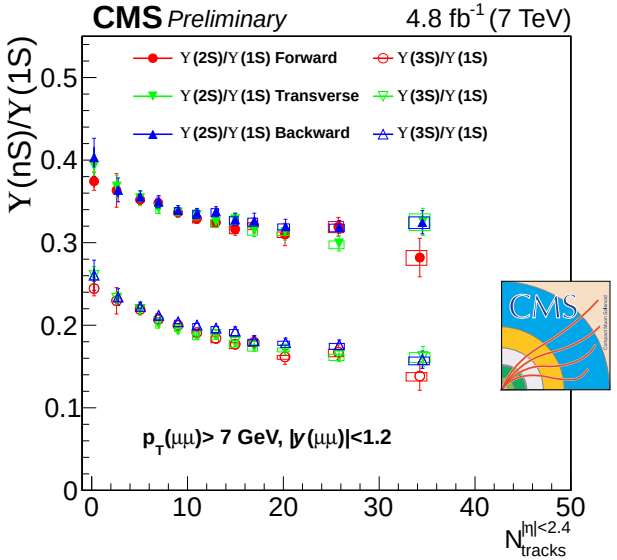
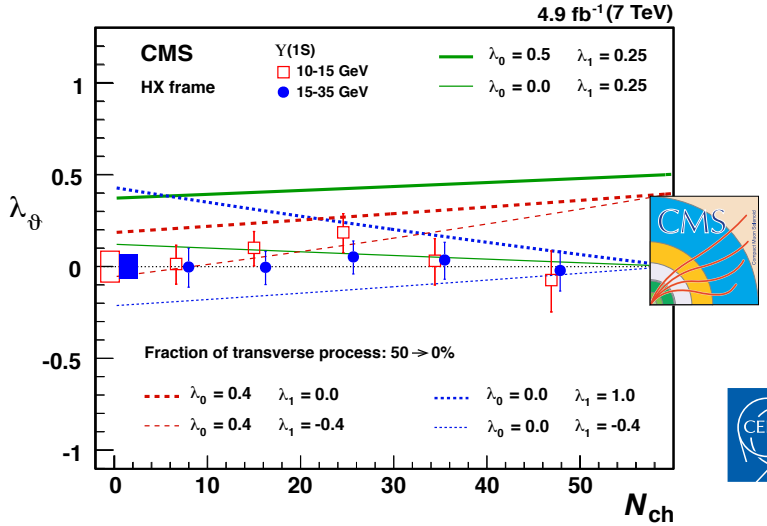
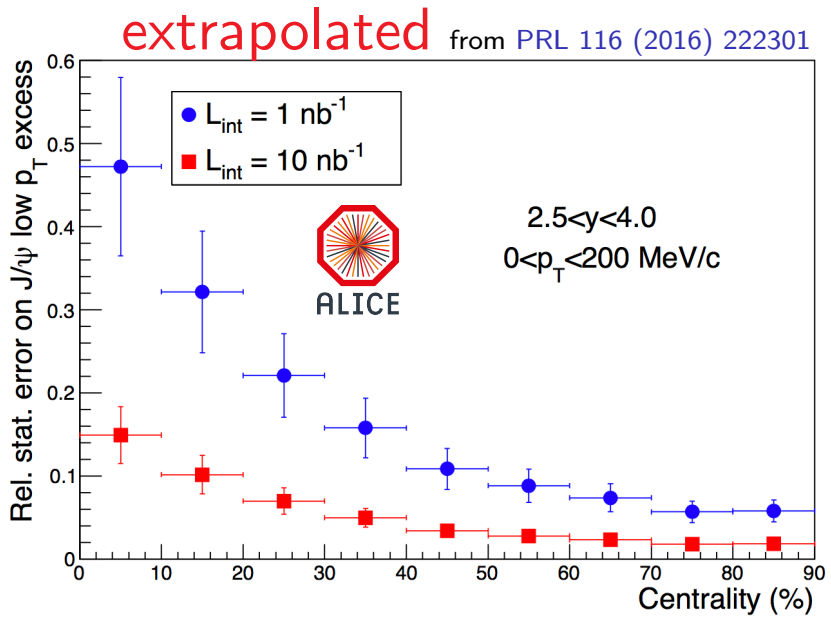


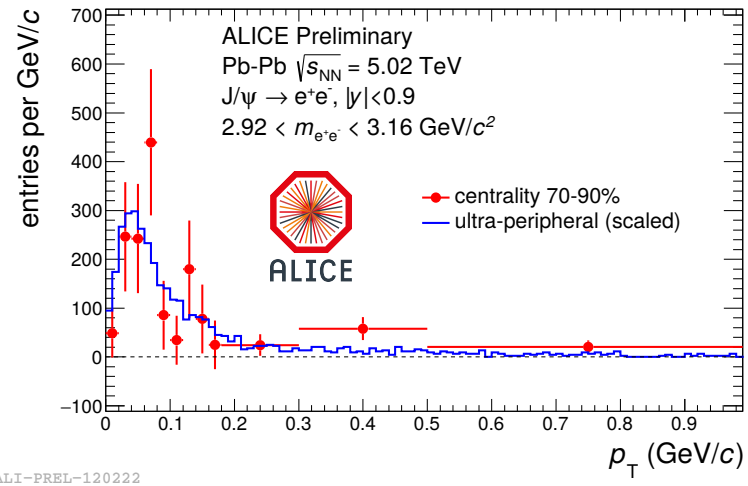
PLB 761 (2016) 31



Photoproduction

- J/ψ photoproduction in very peripheral events
- Currently strongly statistically limited in ALICE at midrapidity $\rightarrow$ TPC upgrade





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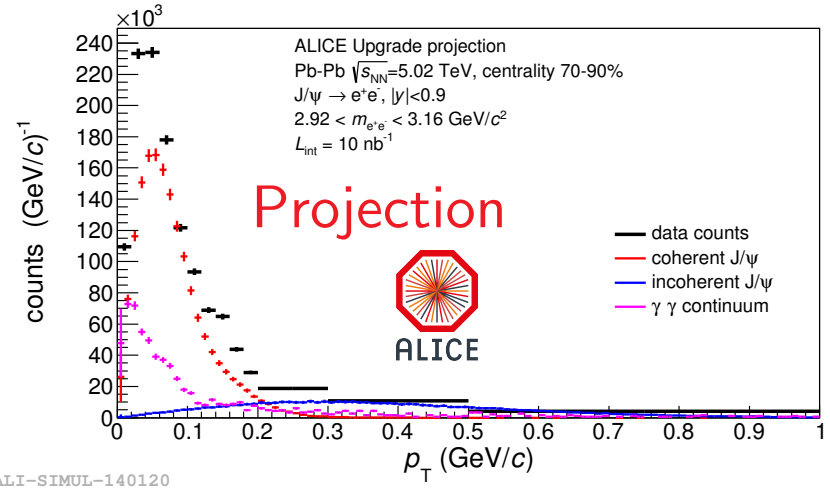
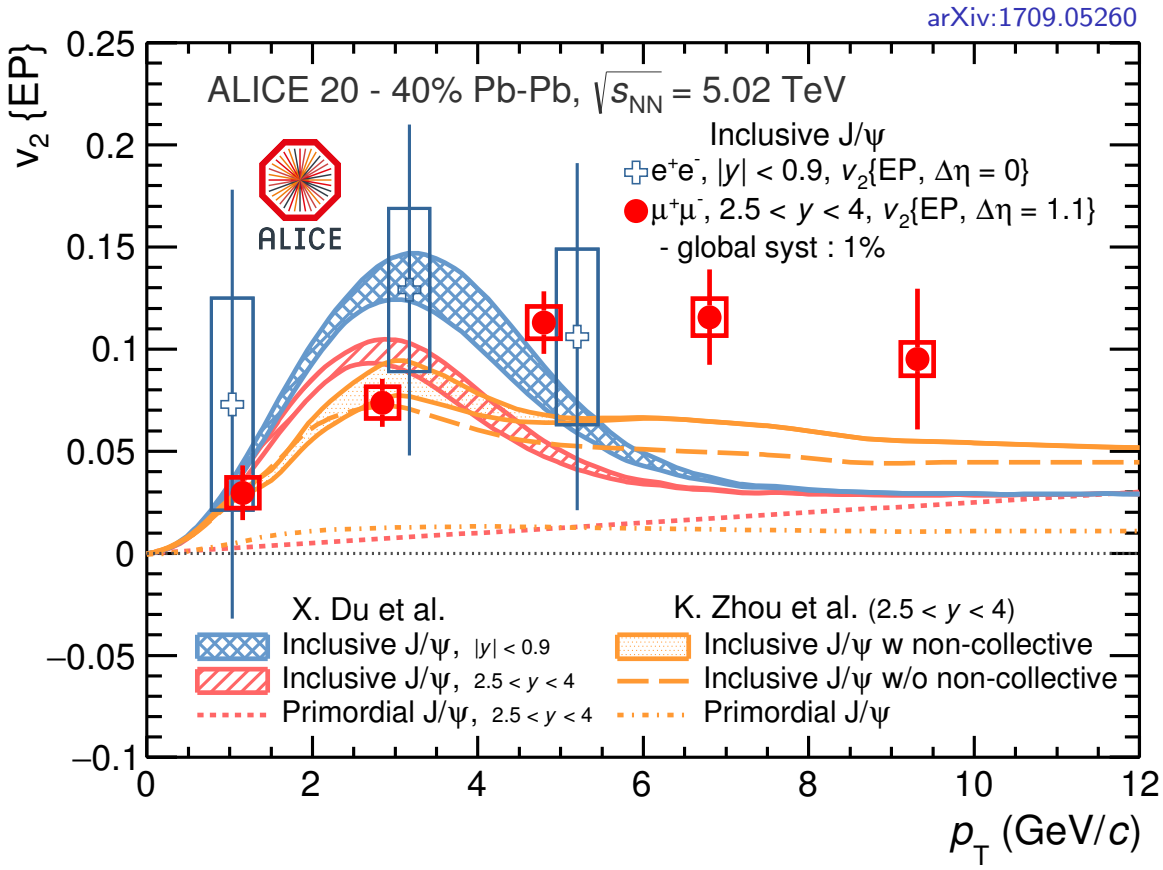


ALI-SIMUL-140120

J/ψ v_2

Clear flow of J/ψ in PbPb

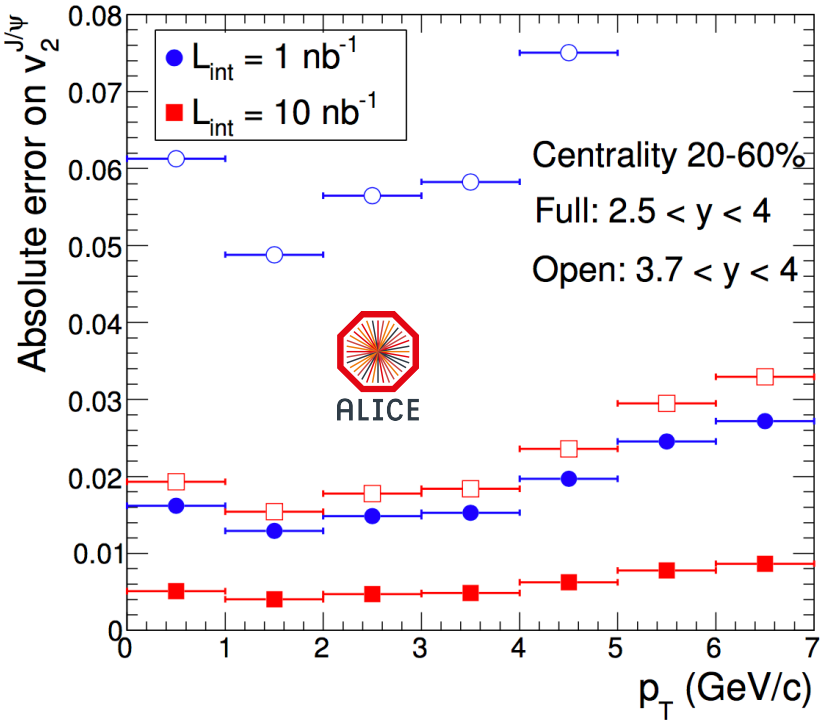


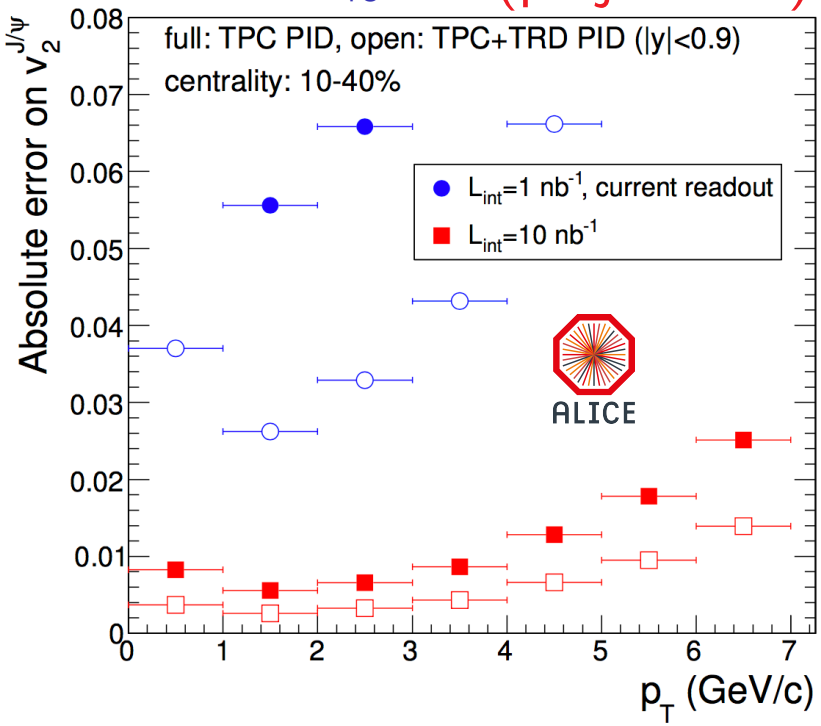
J/ψ v_2

Can reach very high precision with $10\,\mathrm{nb}^{-1}$:

- what is the high p_T v_2 of J/ψ?
- also precise measurement at midrapidity (where the v_2 is predicted to be maximum)

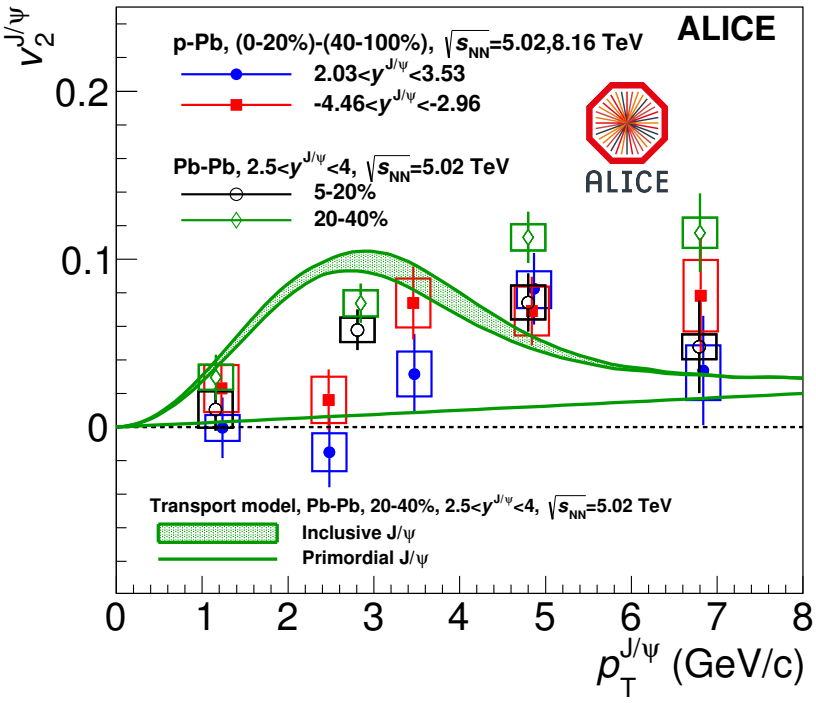
ALICE upgrade LOI (projections)

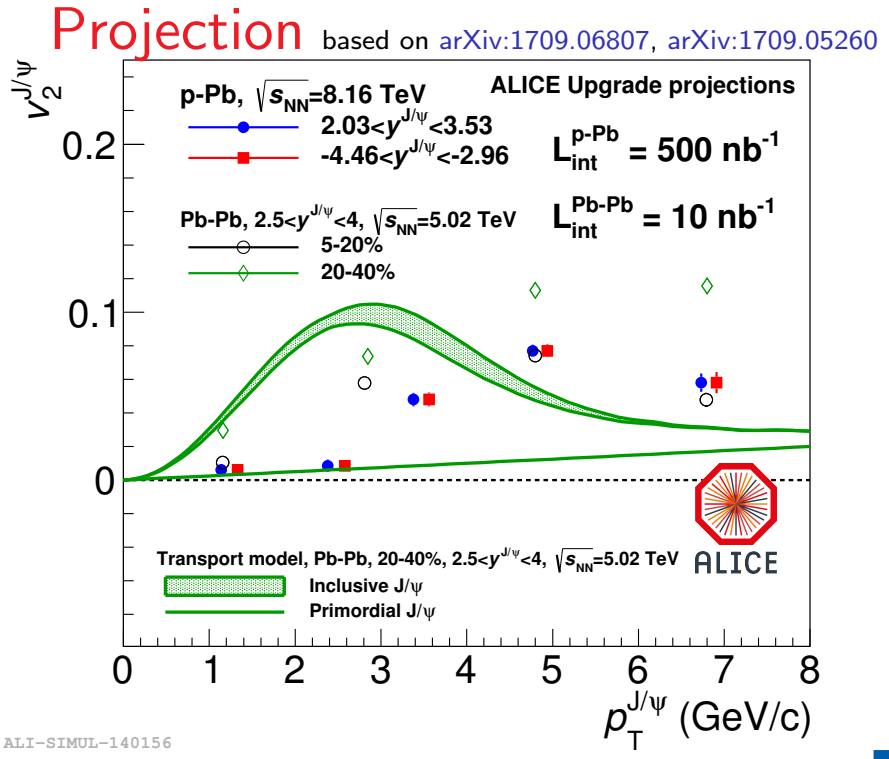




J/ψ v_2

- In PbPb: primordial vs regenerated J/ψ, complementary to R_{AA}. Also Eloss information
- Origin of v_2 in pPb? Similar with PbPb?



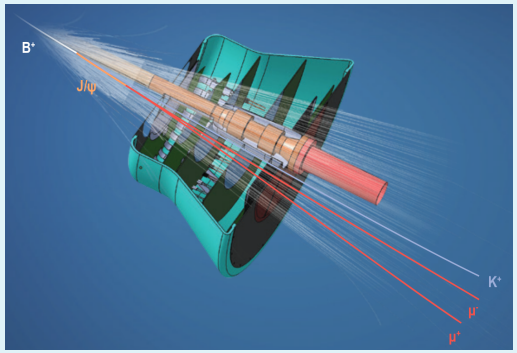


Expected improvements from the experiments

ALICE

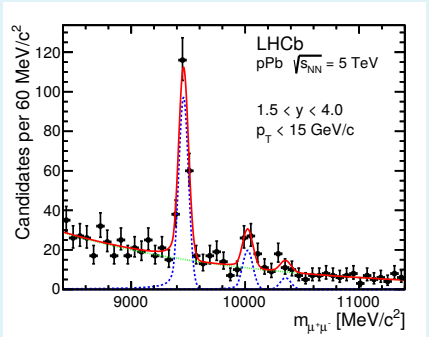
Phase-I upgrades with major impact on quarkonium measurements (improved tracking, higher readout rate):

- Midrapidity (electrons): ITS, TPC, TRD
- Forward rapidity (muons): MFT



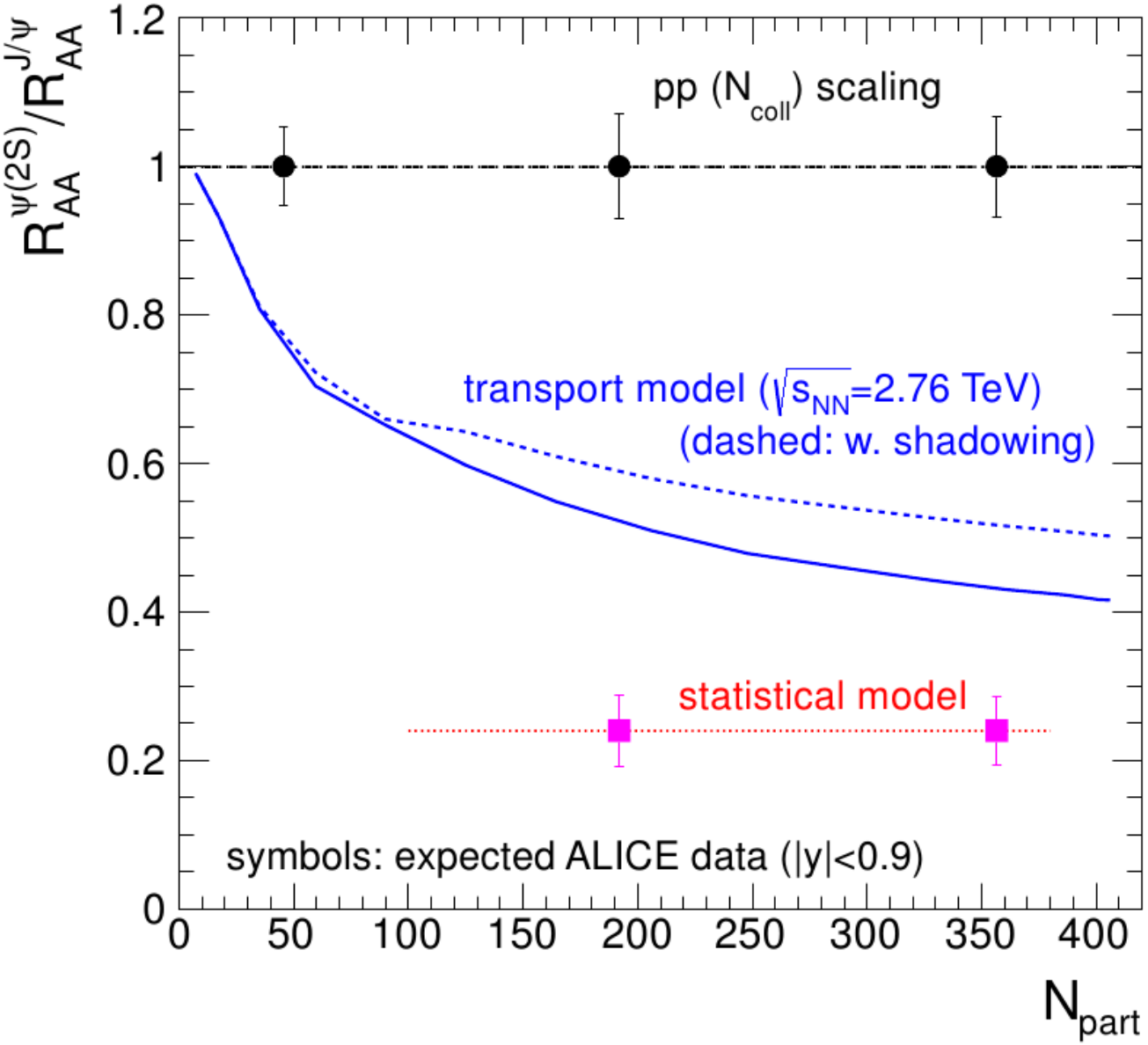
LHCb

- Triggerless readout and full software trigger at 30 MHz in pp collisions
- pPb and pA fixed target below pp occupancy
  - Limitation in fixed target mode: luminosity
- AA collisions: preferred running condition to be defined
  - collider mode: can central collisions can be analysed with the upgrade detector (pixel VELO, ...)?
  - fixed target mode: maximal occupancy in central PbAr about a factor 5 below central PbPb

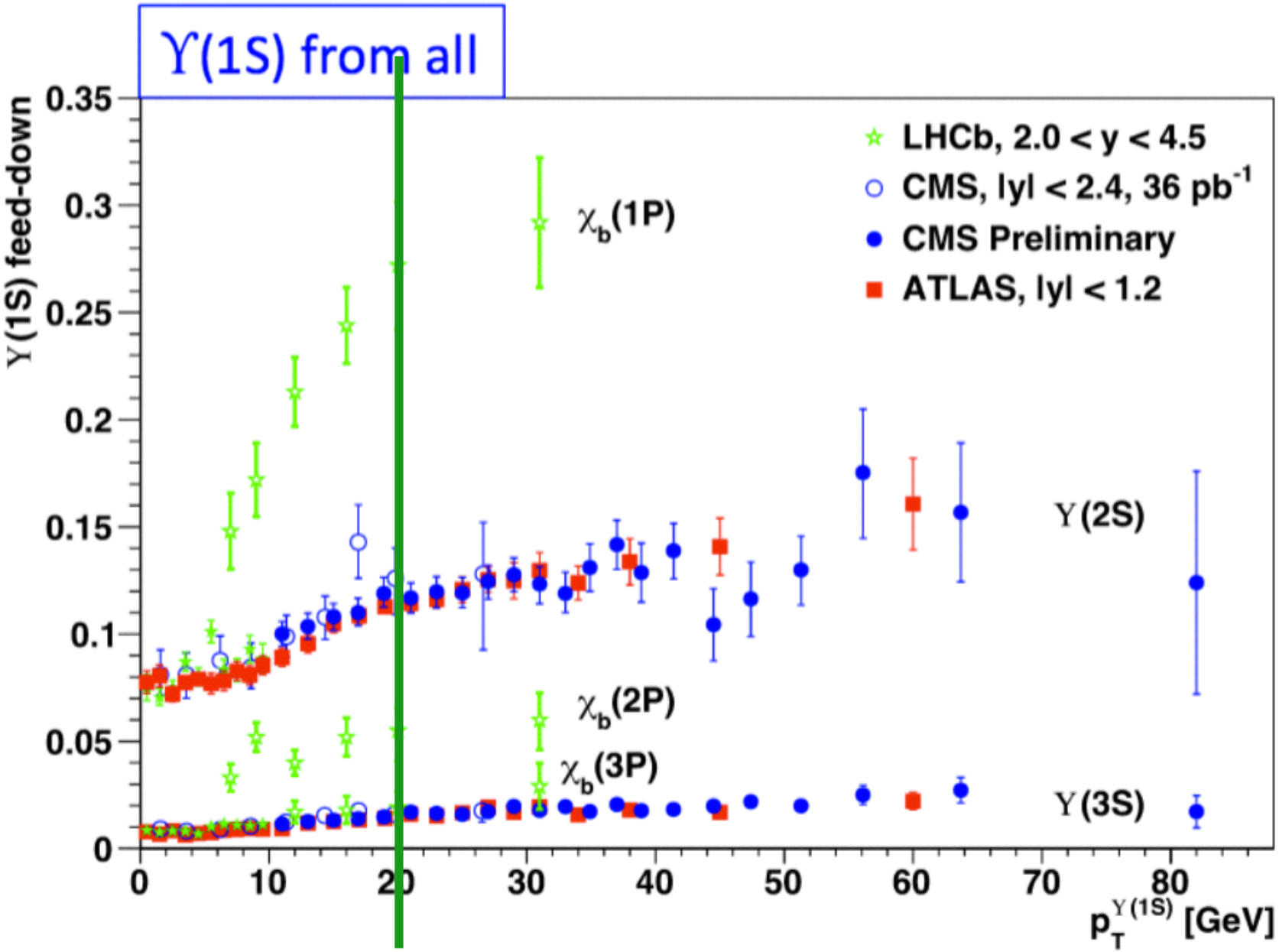


Supplementary material

ψ(2S) in ALICE at midrapidity



Feeddown


Υ(1S) from all
Υ(1S) feed-down
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
10
20
30
40
50
60
70
80
$p_T^{\Upsilon(1S)}$ [GeV]
LHCb, 2.0 < y < 4.5
CMS, |y| < 2.4, 36 pb^{-1}
CMS Preliminary
ATLAS, |y| < 1.2
χ_b(1P)
χ_b(2P)
χ_b(3P)
Υ(2S)
Υ(3S)