Recent quarkonium results in heavy-ion collisions from CMS

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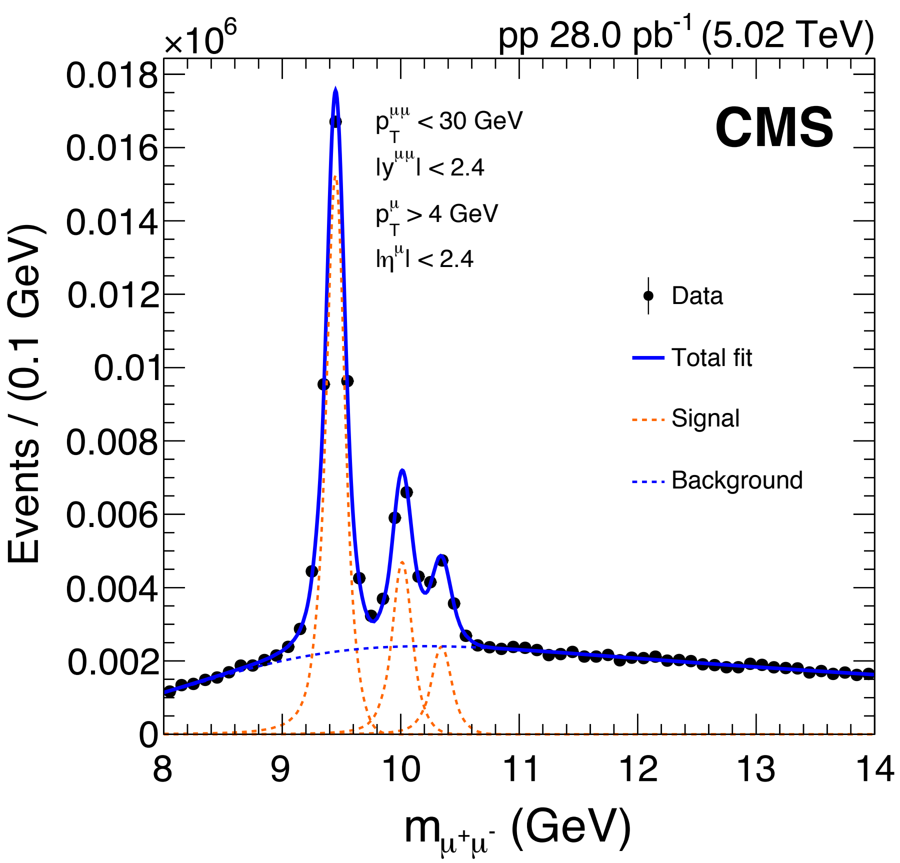
Bottomonia in CMS

- The CMS is an ideal experiment to reconstruct ϒ(nS) states ($b\bar{b}$) in their decays into μ+μ-:
  - Large detector acceptance for muons |η|<2.4
  - Very good dimuon resolution sets apart the 3 ϒ(nS) states



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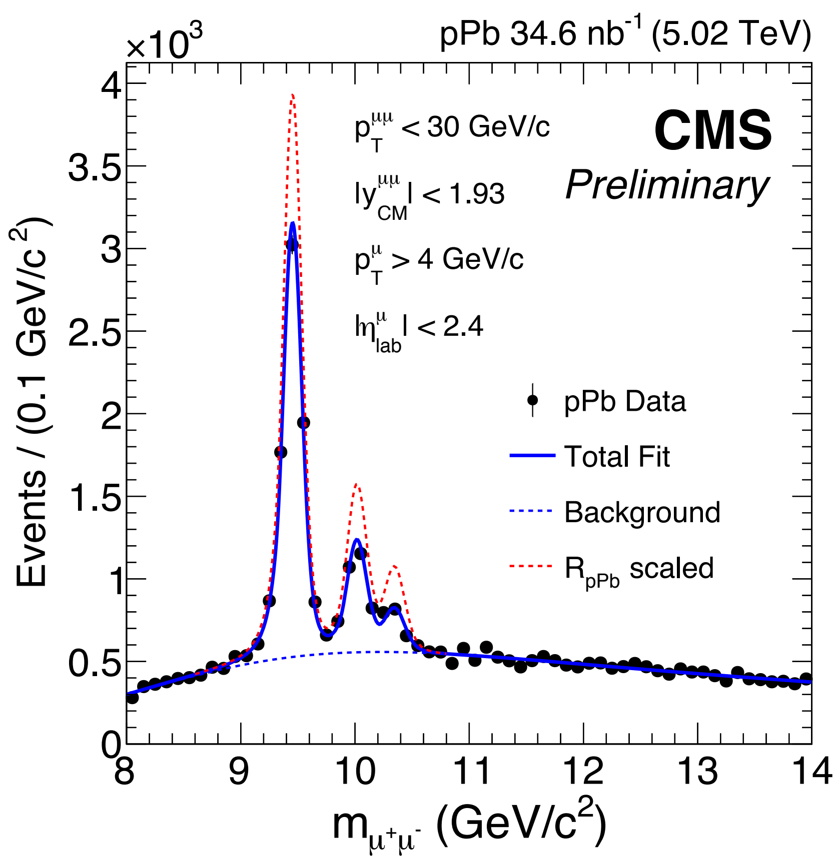

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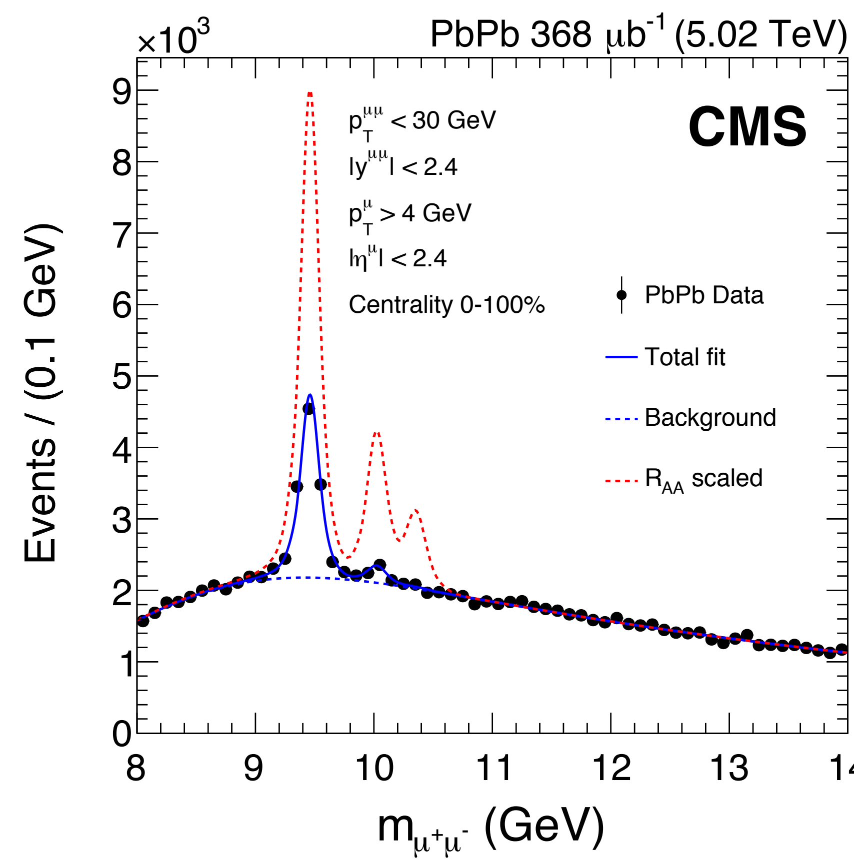

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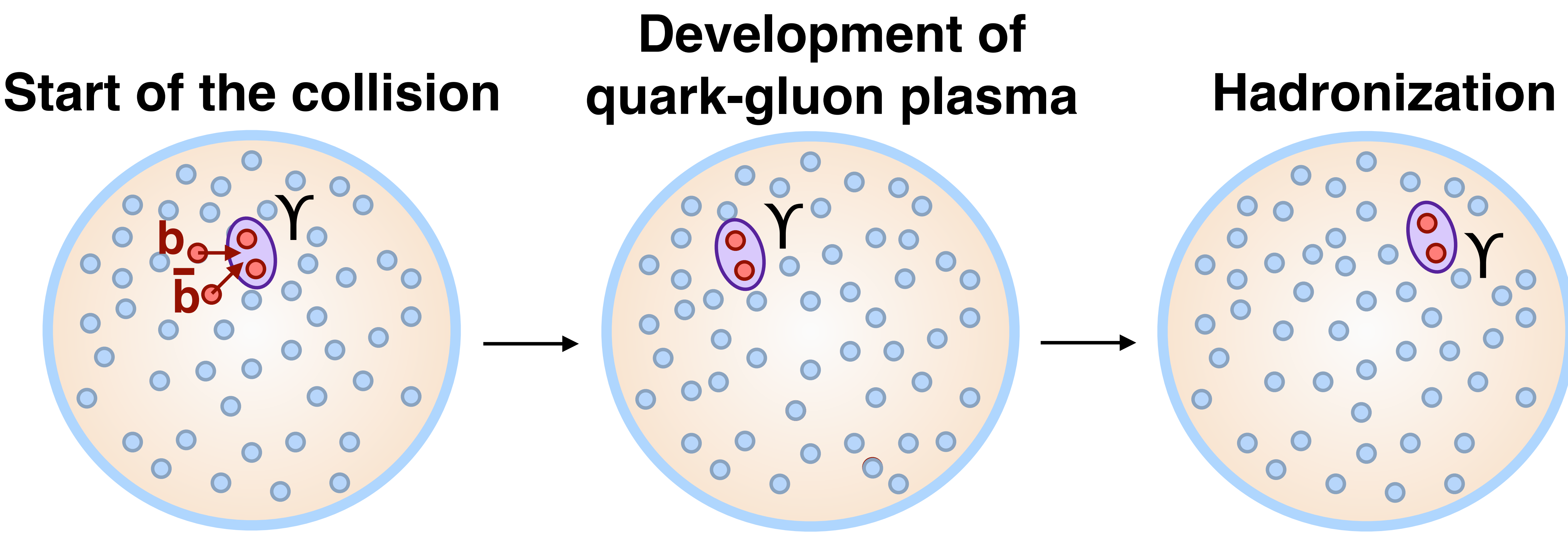
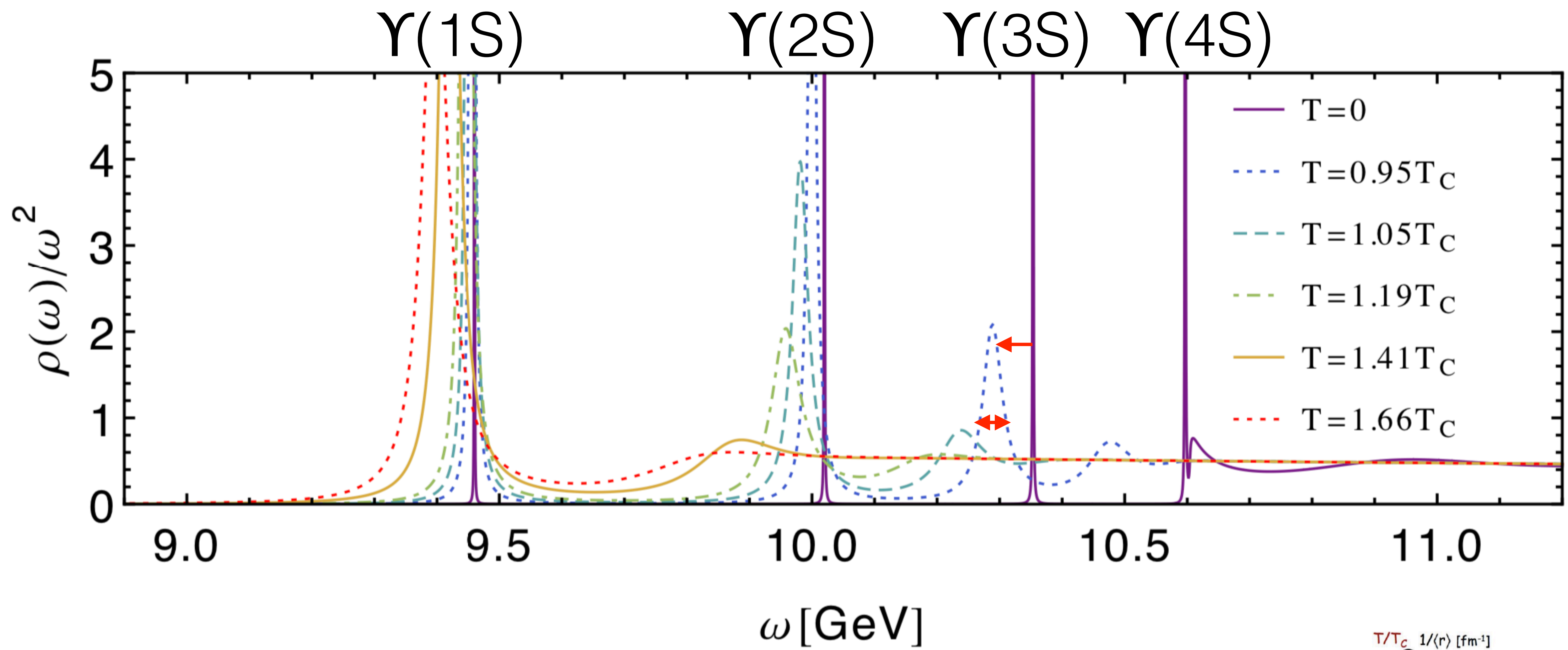
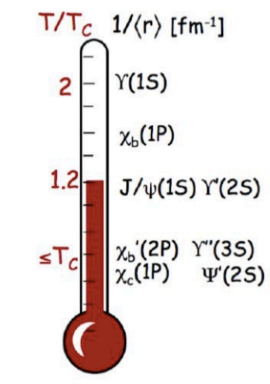
Bottomonia in Heavy Ion collisions



- Bottomonium states have high mass!
  - Early formation
  - Sensitive to color deconfinement!
  - Regeneration not significant
  - Outlives QGP

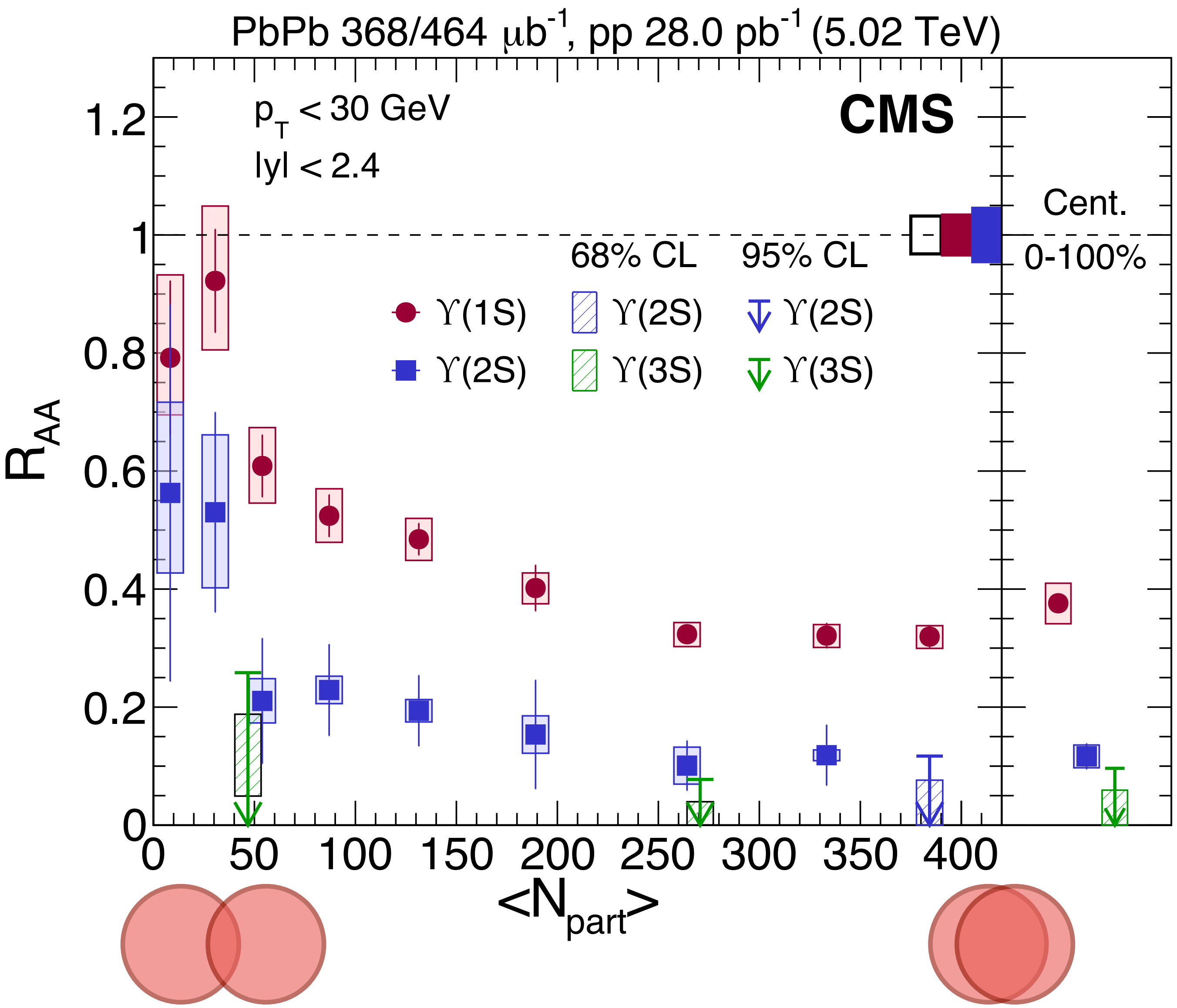
Sequential melting of bottomonia

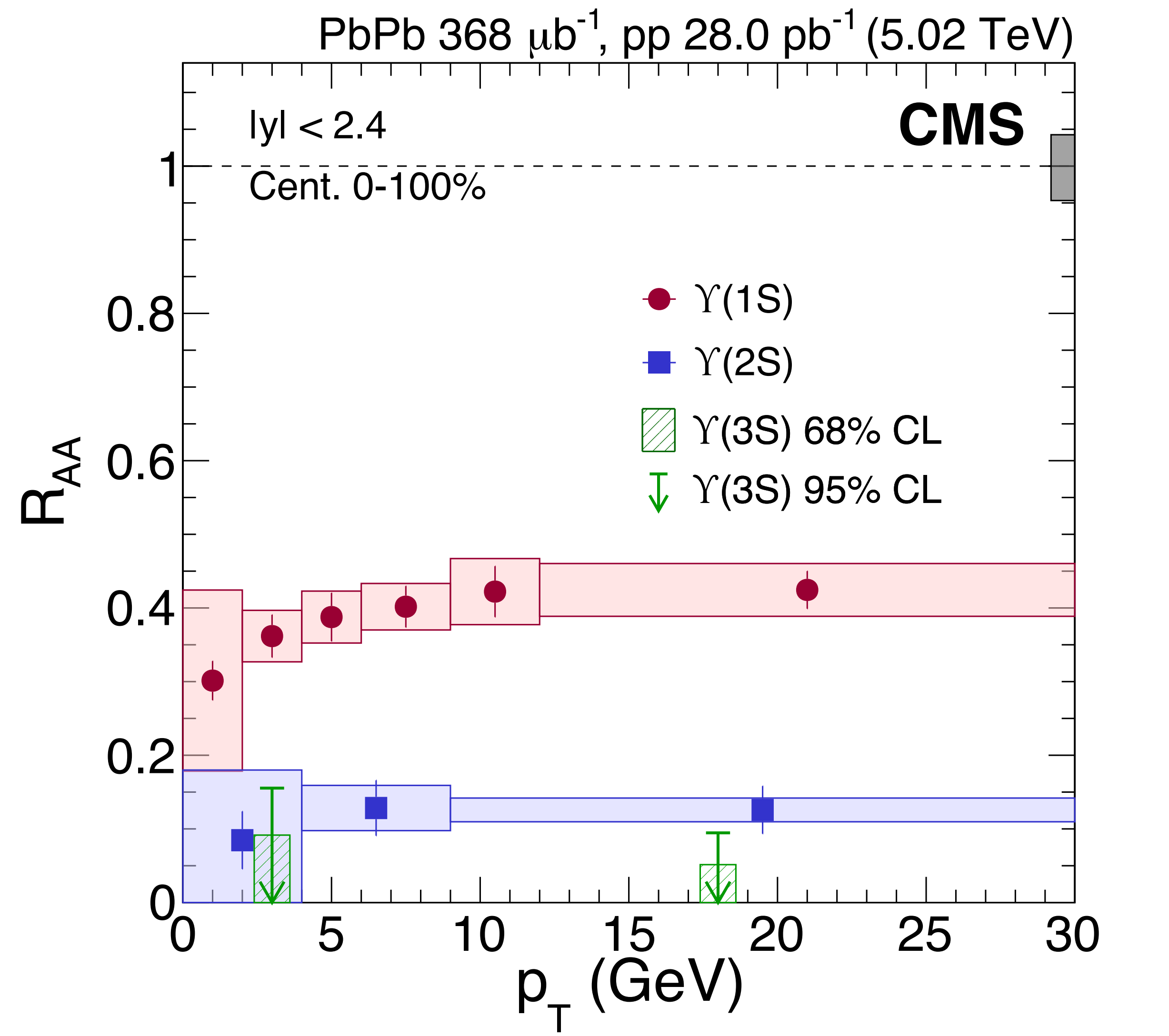




- As temperature increases:
  - The peaks broaden and their masses shift to lower values.
  - Highest states broaden and shift first, followed sequentially by lower states.
  - Peaks eventually disappear completely → States melt.

ϒ production in PbPb collisions





- Suppression of ϒ(1S) and ϒ(2S) have similar downward trend towards smaller centrality
- ϒ(3S) strongly suppressed
- Suppression slightly increasing in p_T for ϒ(1S)

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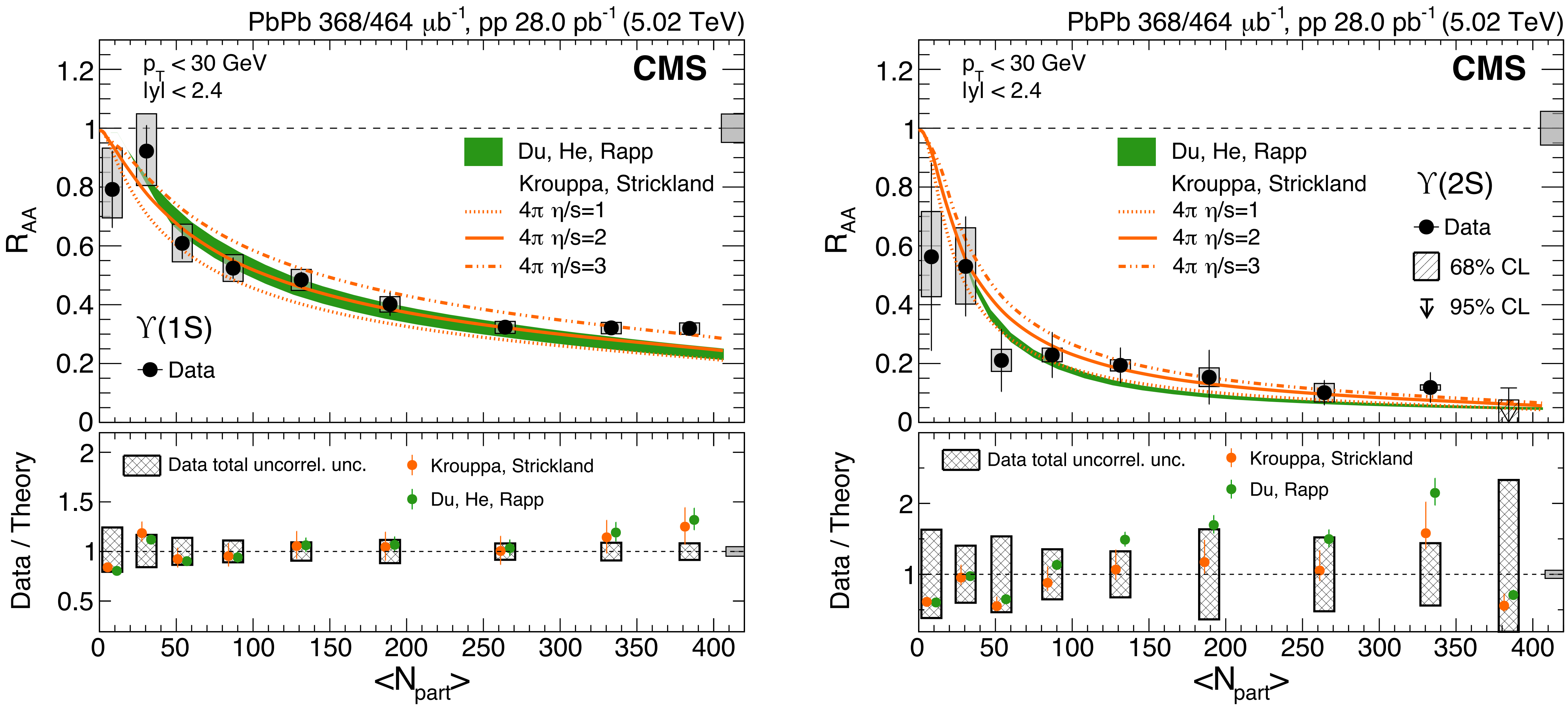
Υ production in PbPb collisions



- **Krouppa and Strickland model** uses anisotropic hydrodynamics evolution with different initial temperatures:
  - 4π η/s = {1,2,3} —> T_0={641, 632, 629} MeV
- **Du et al. model** contains a small component of regenerated bottomonia 550 ≤T_0 ≤ 800 MeV
- Results overlaps within the theoretical and experimental uncertainties

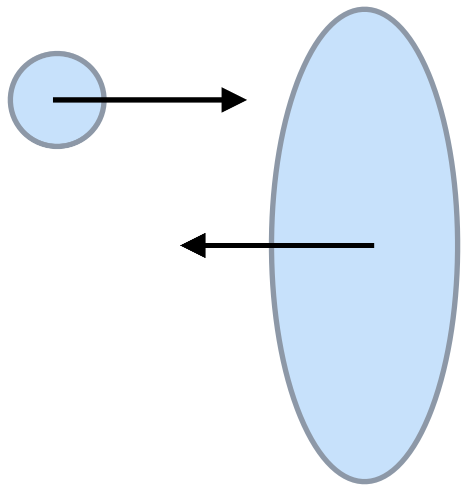
Cold nuclear matter effects

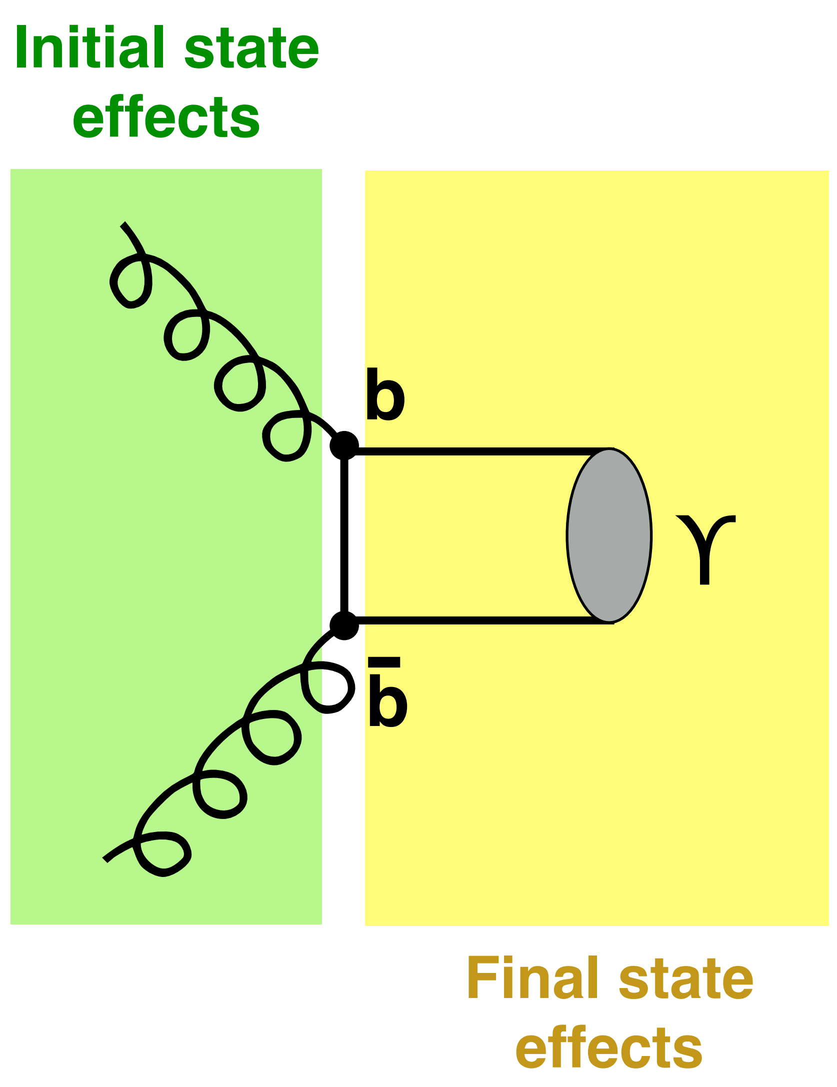
Initial state: Shadowing due to modification of nuclear PDFs

Initial-final: Energy loss due to parton propagation in medium

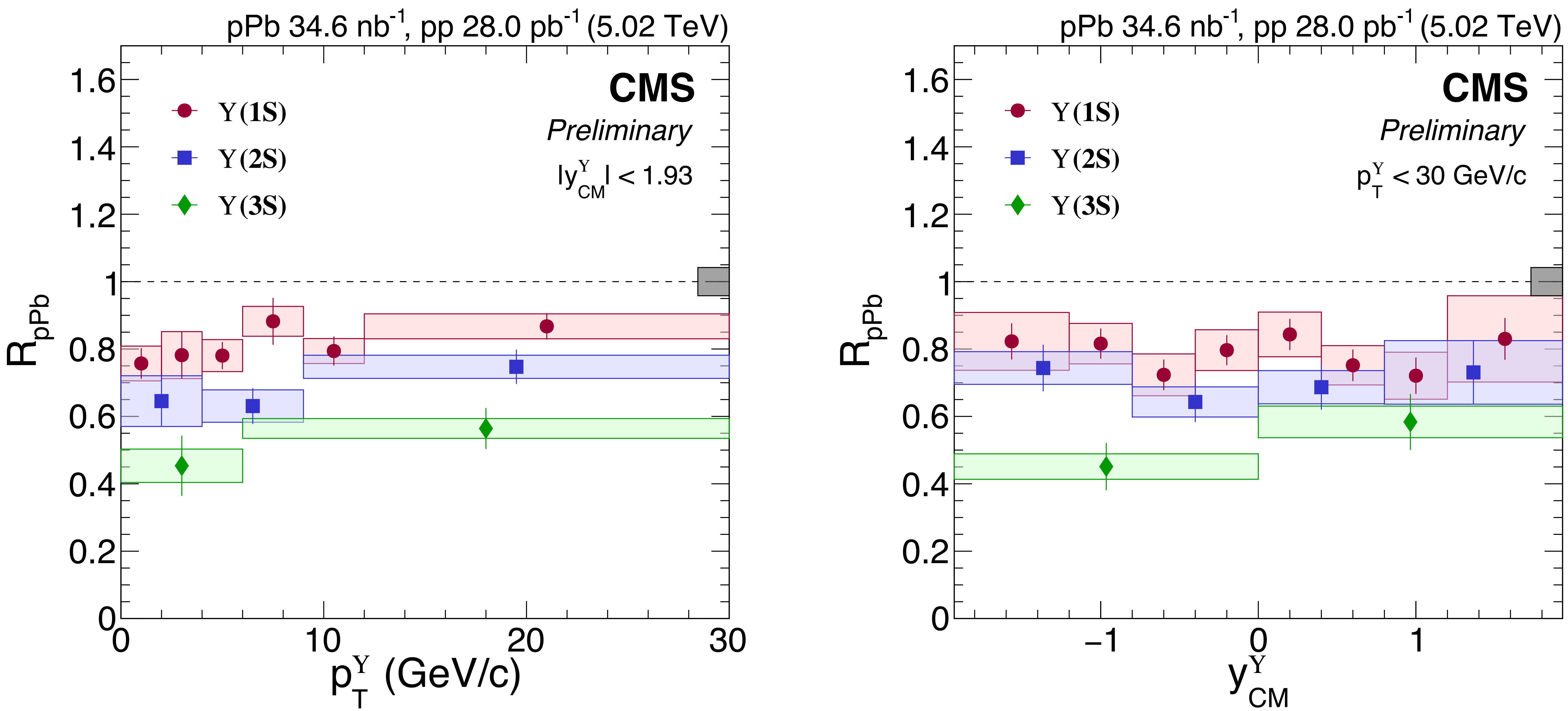
Final state: Interaction with comoving particles

pPb collisions





Υ production in pPb collisions



- All Υ states are suppressed in all kinematic region
- No significant pT dependance for all the 3 states

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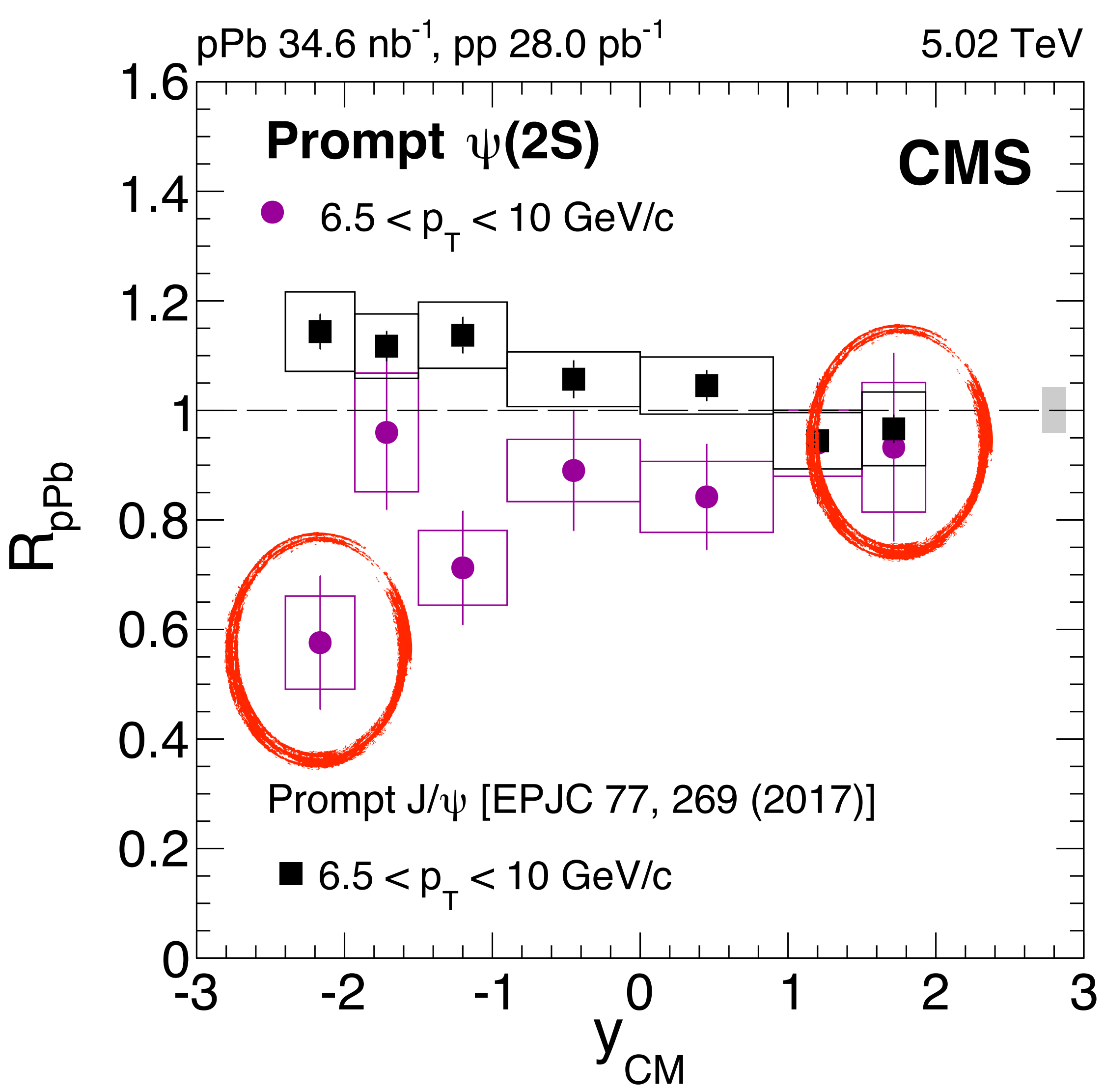
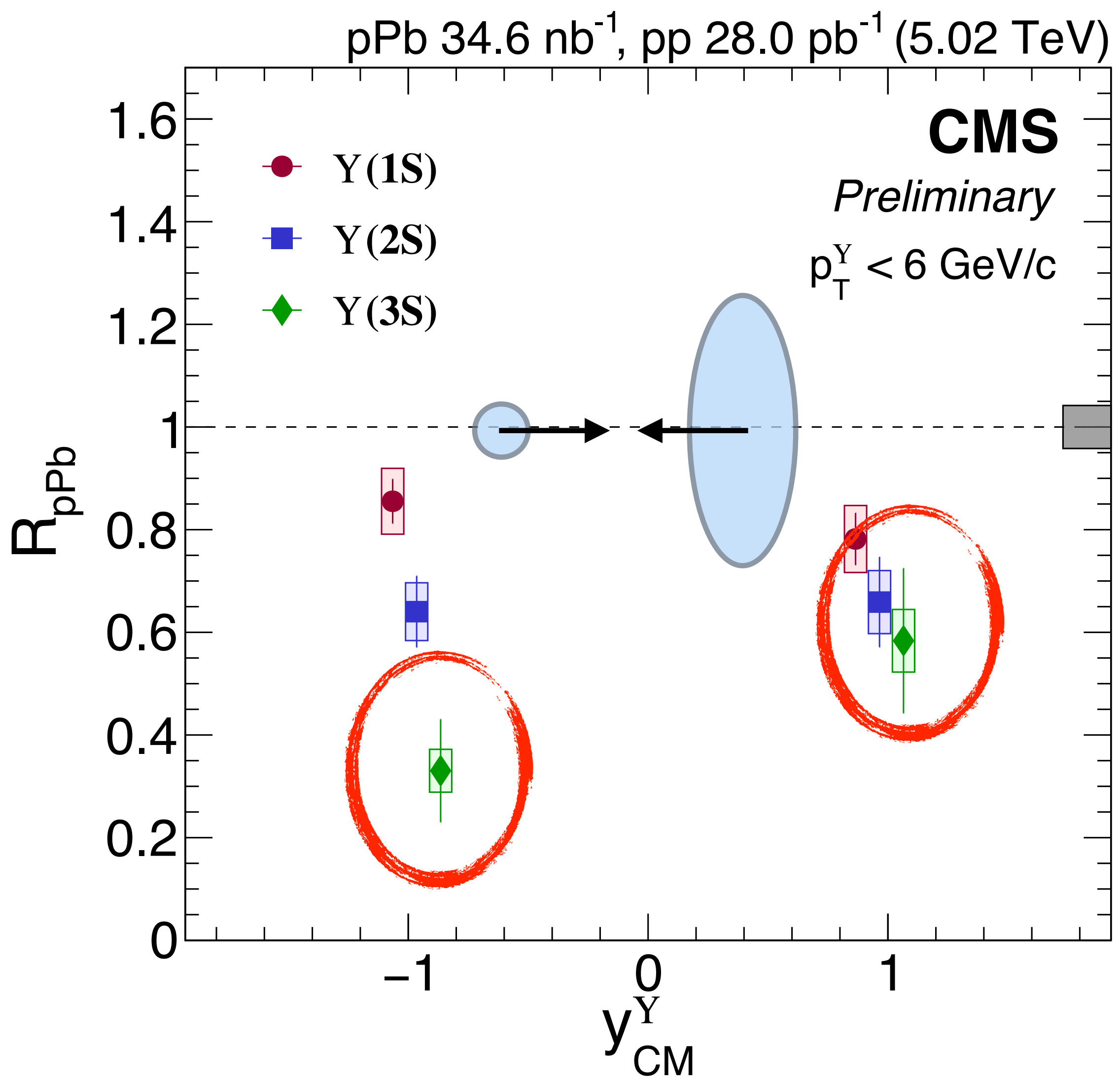
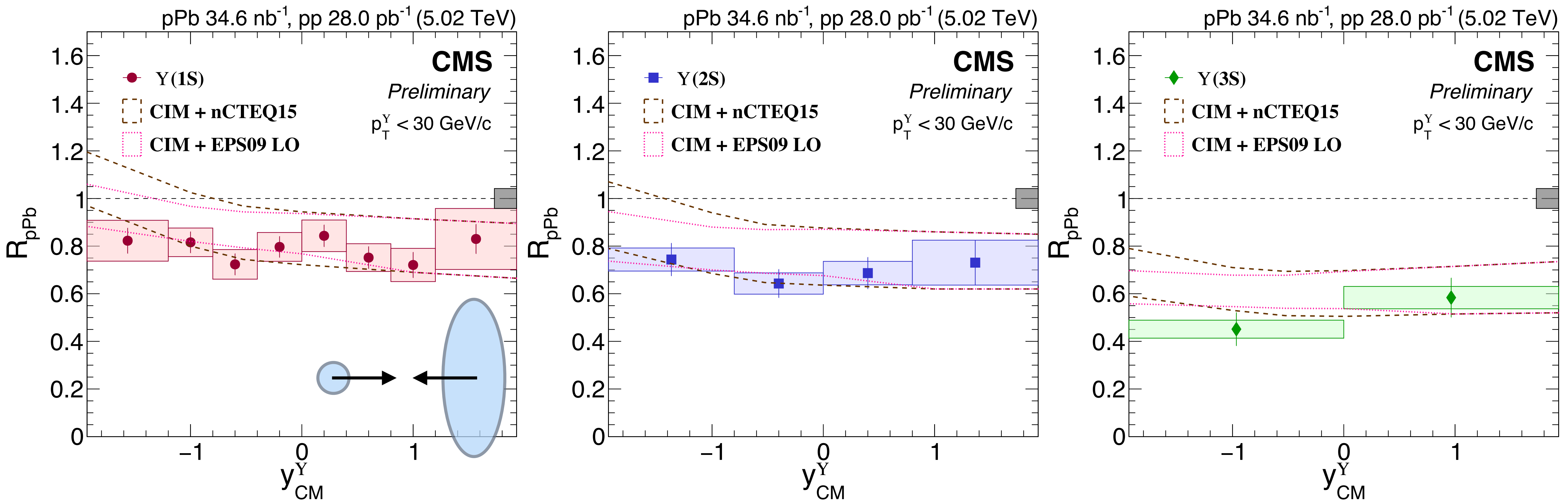
Υ production in pPb collisions





- Larger suppression of Υ(3S) at low pt in the Pb-going side
  - Similar behaviour as prompt ψ(2S)
  - Hint of final state effect on excited quarkonia states

Υ in pPb with model comparison



- Different R_{pPb} for each state in comover model (larger size)
- Larger comover effect for higher comover densities : Pb-going direction
- Model predictions are in agreement with data within uncertainties

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R_{pPb} at LHC

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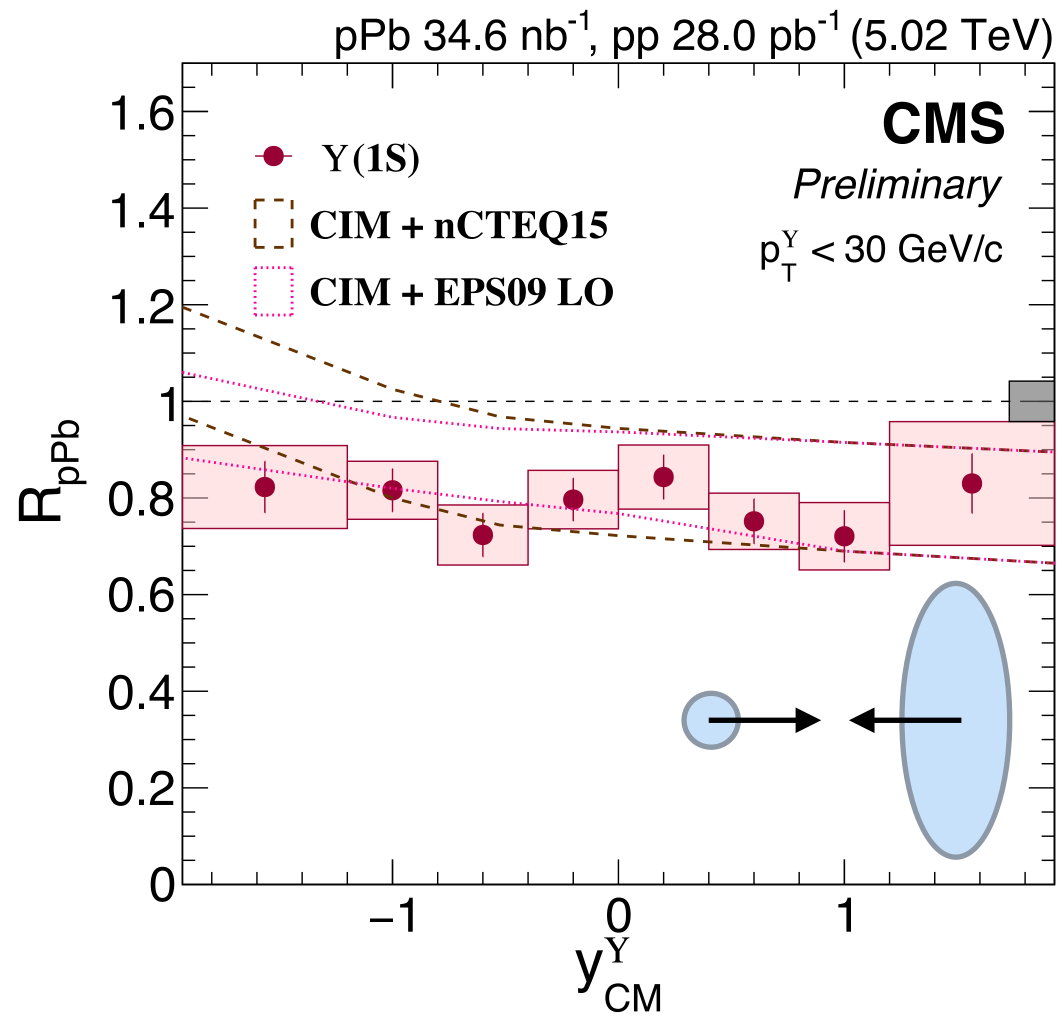
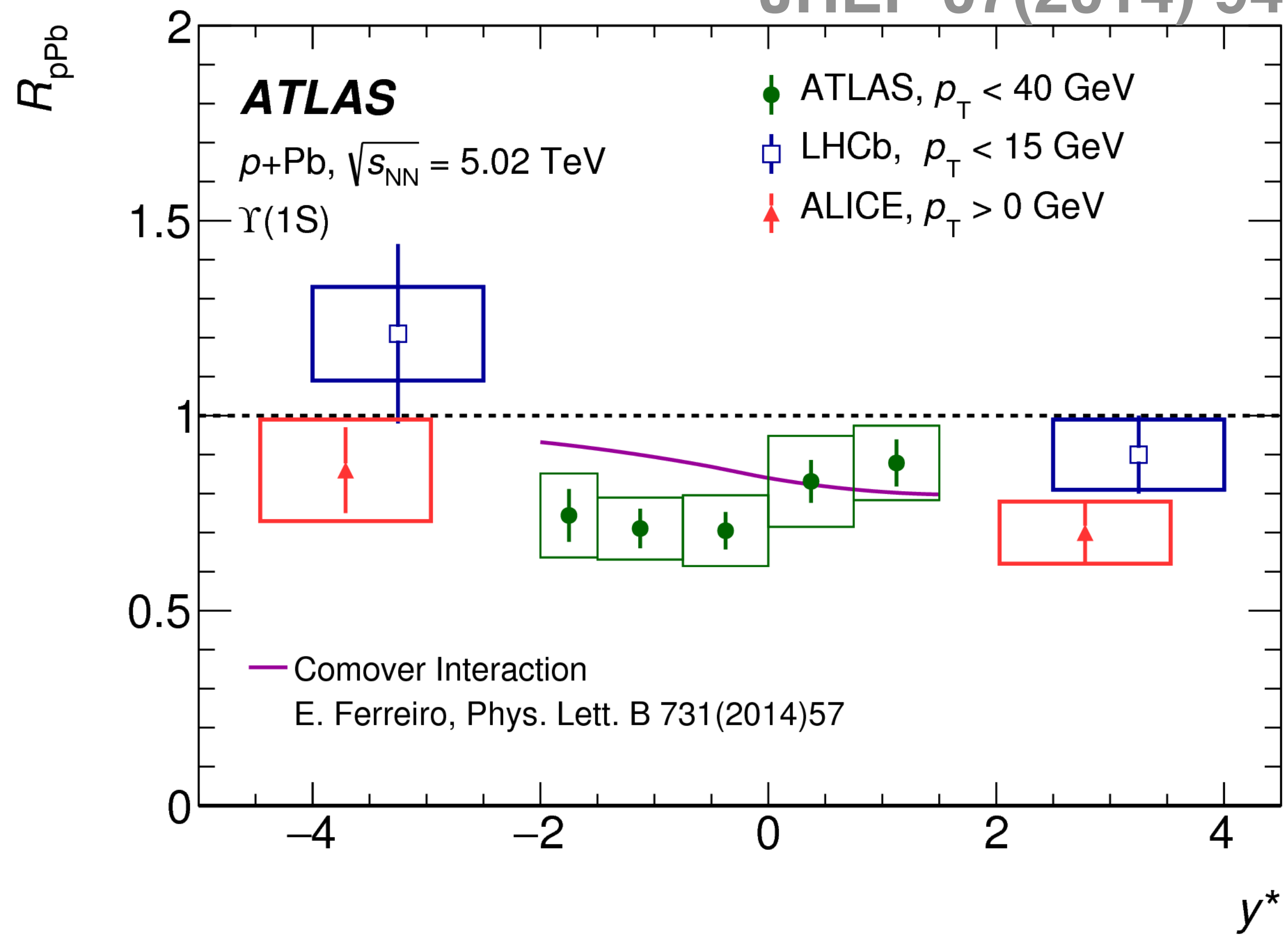
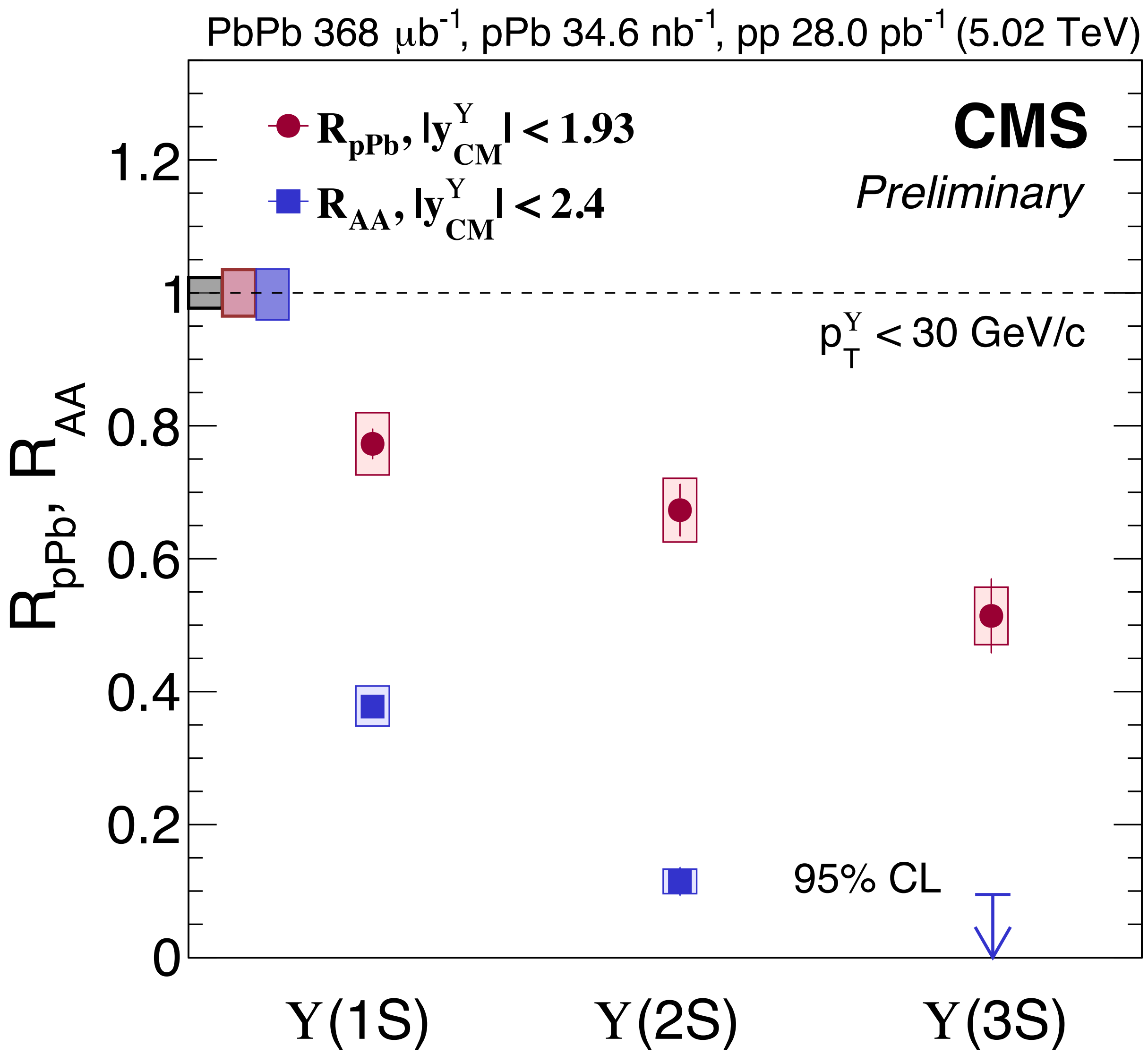


PLB 740(2015) 105
EPJC 78(2018) 171
JHEP 07(2014) 94



- ALICE, ATLAS, LHCb, CMS RpPb at 5.02 TeV
- Consistent results within uncertainties

pPb vs PbPb



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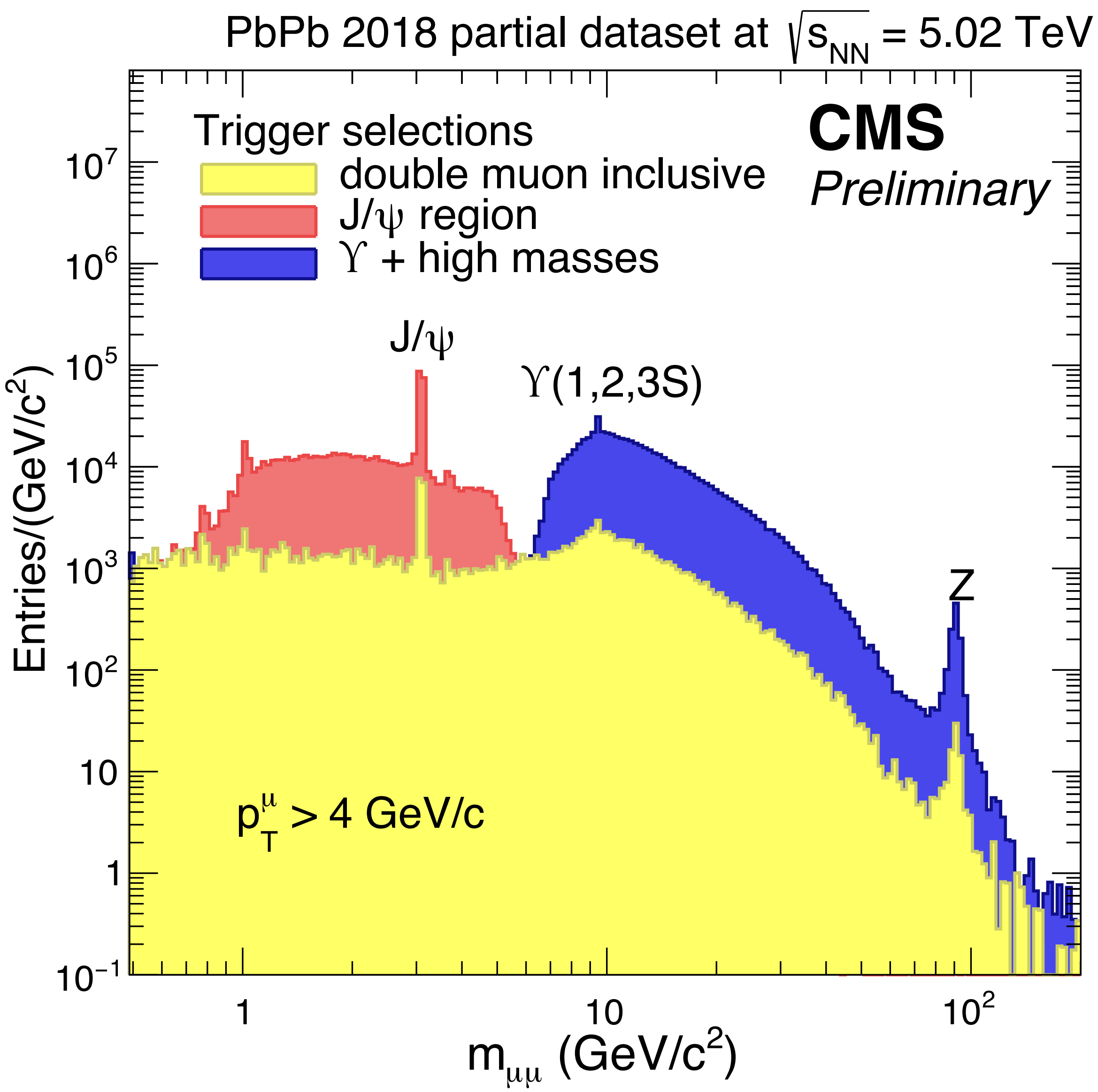
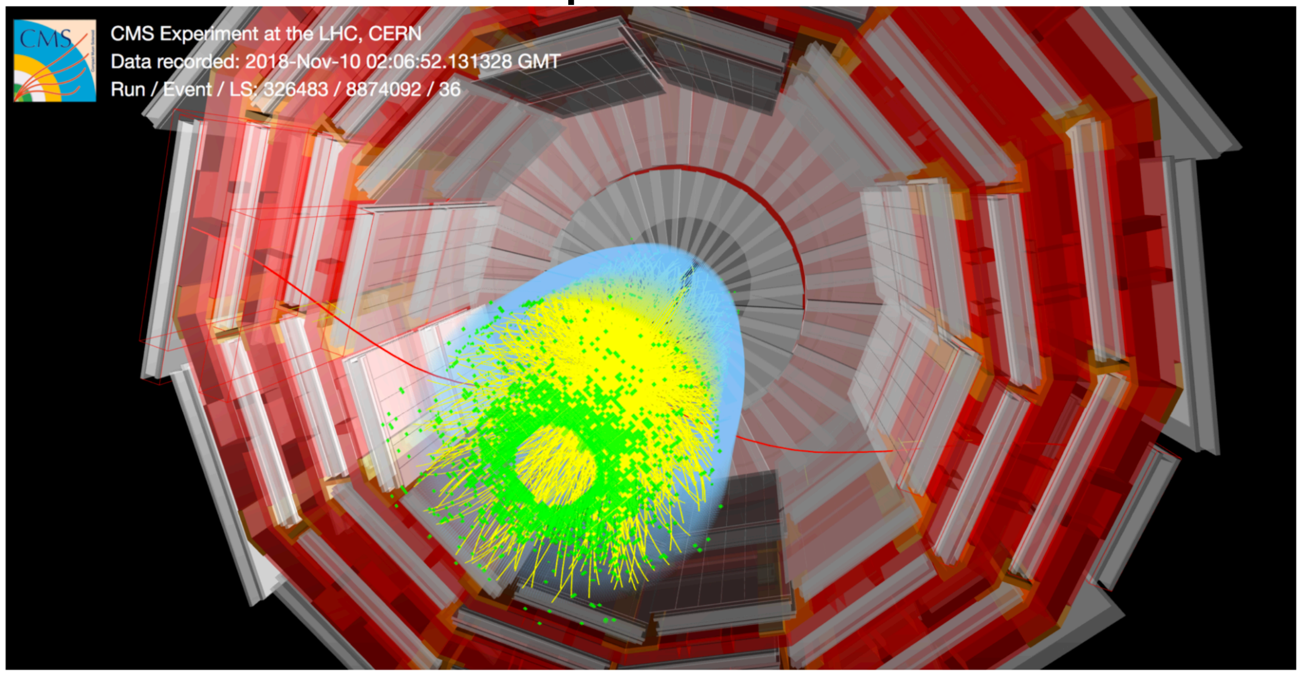
- Suppression in ordering of binding energy
  - $R_{pPb,PbPb}(\Upsilon(1S)) > R_{pPb,PbPb}(\Upsilon(2S)) > R_{pPb,PbPb}(\Upsilon(3S))$
- Larger suppression in PbPb than in pPb
  - $R_{pPb}(\Upsilon(nS)) > R_{PbPb}(\Upsilon(nS))$

PbPb in 2018

New PbPb data: $\sqrt{s_{NN}}$ = 5.02 TeV, L~1.7 nb-1

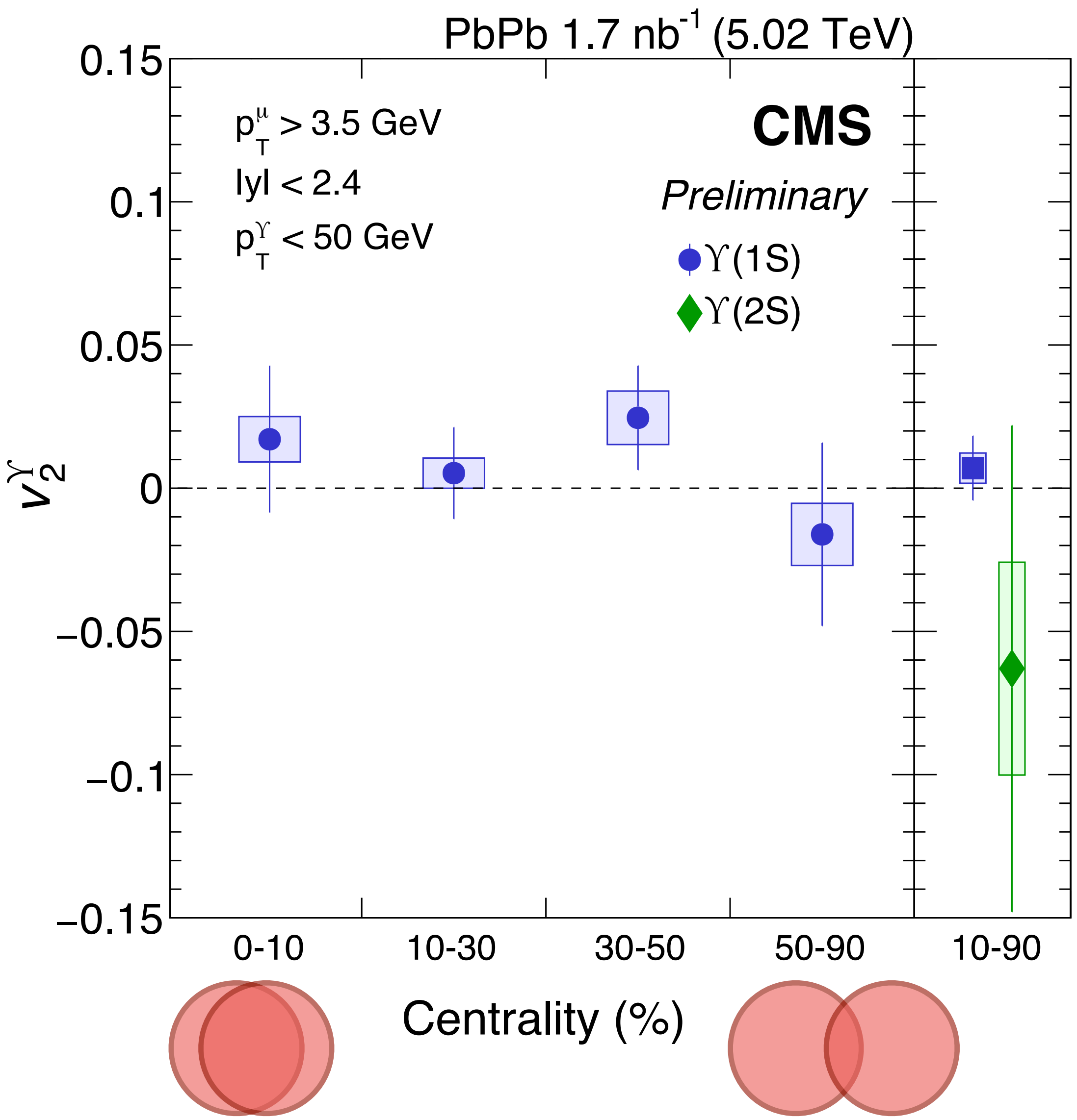


Upsilon candidate



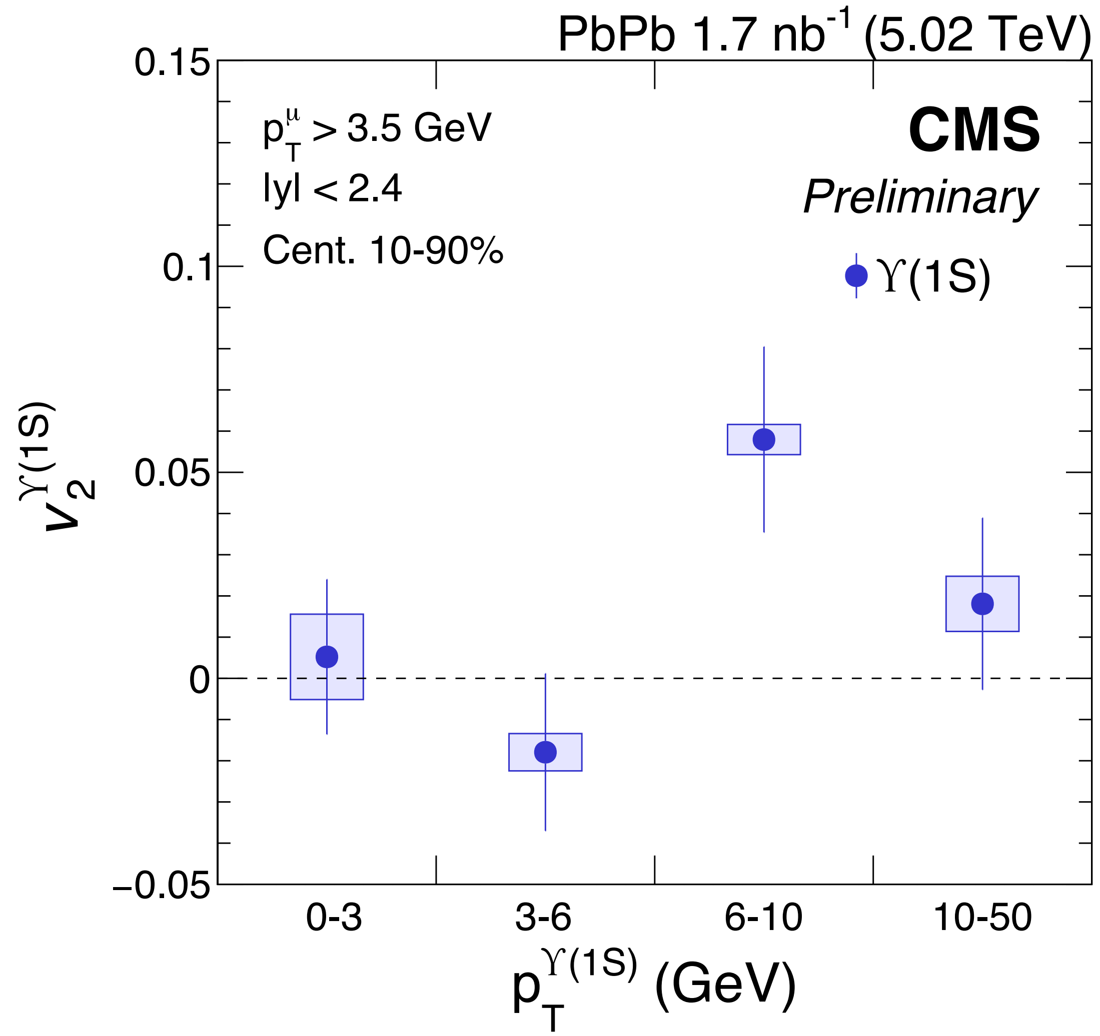
- ~x4.5 more statistics compared to 2015 data
- New first-time measurement in CMS HI : Elliptic flow (v_2) of ϒ

Elliptic flow (v_2) of ϒ in PbPb



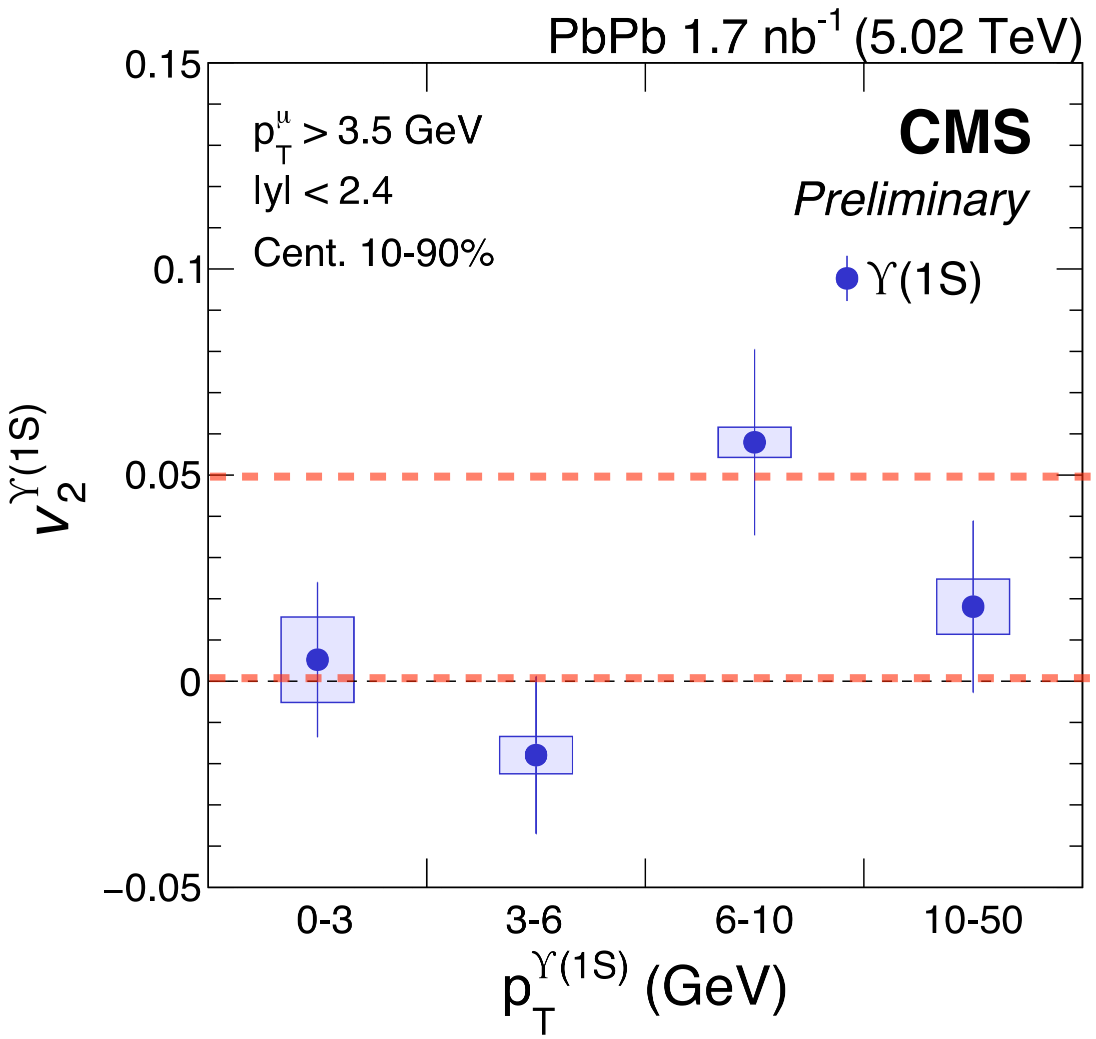
- Precise ϒ(1S) v_2 measurement
  - compatible with zero in all centrality intervals
- First measurement of ϒ(2S) v_2
  - provide new input to production mechanism

Elliptic flow of Υ(1S) in PbPb

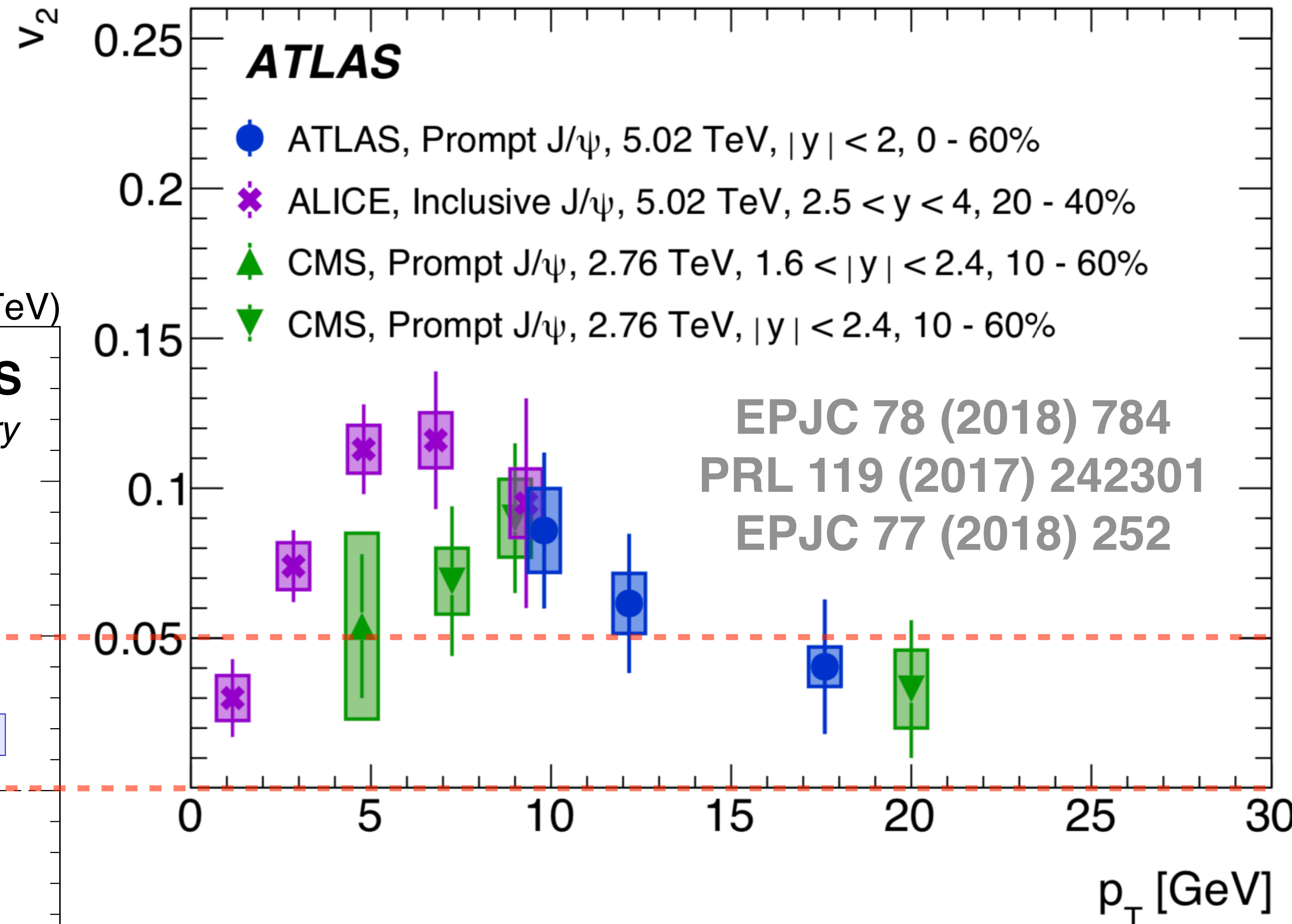


- v_2 measured with high precision as function of p_T
- Compatible with zero over all kinematic range: Max. ~2.5 standard dev. (p_T 6-10 GeV/c)

Υ(1S) vs J/ψ

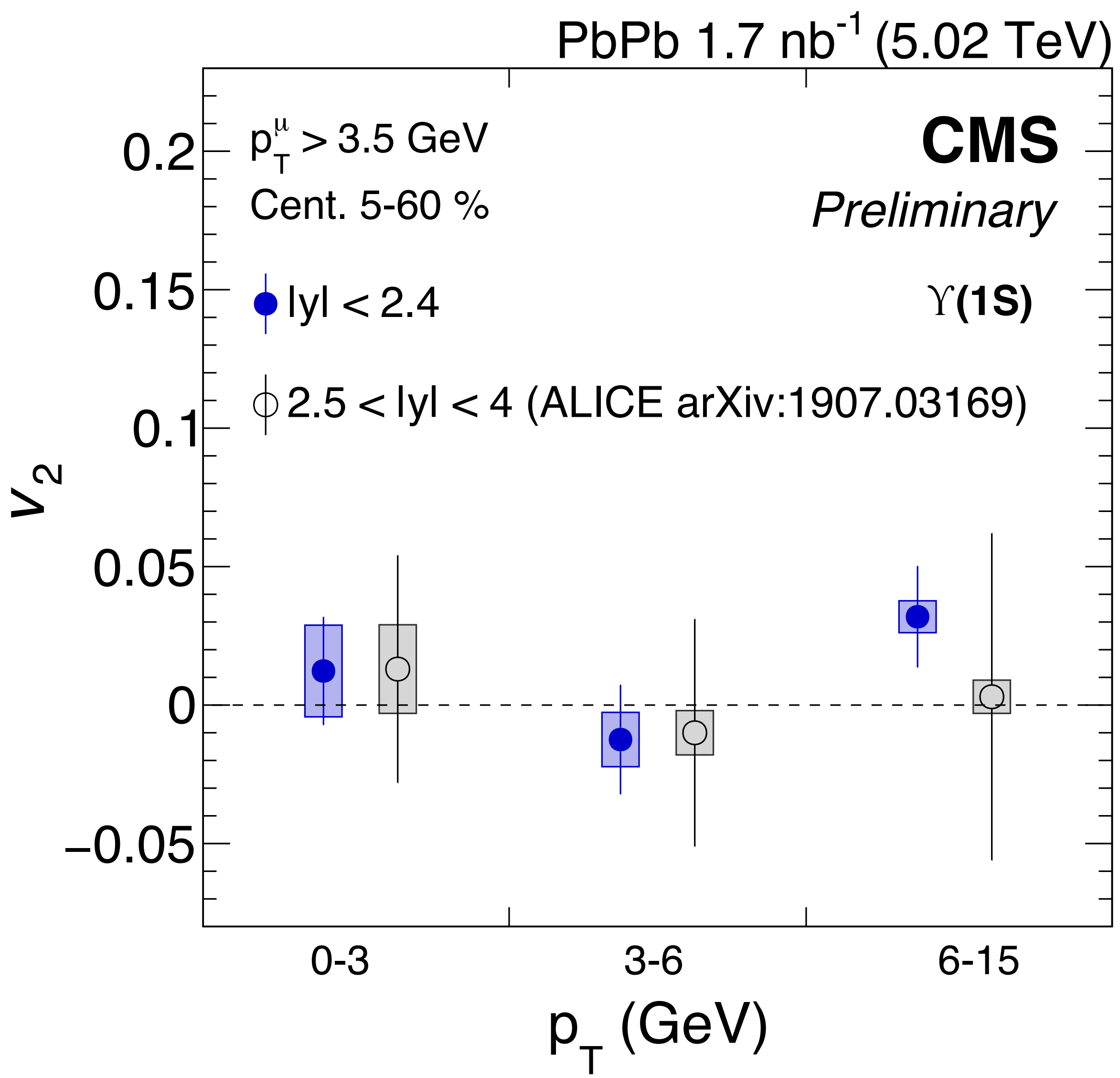


CMS-HIN-19-002



- Different v2 for Υ and J/ψ: different medium effect of charmonia and bottomonia

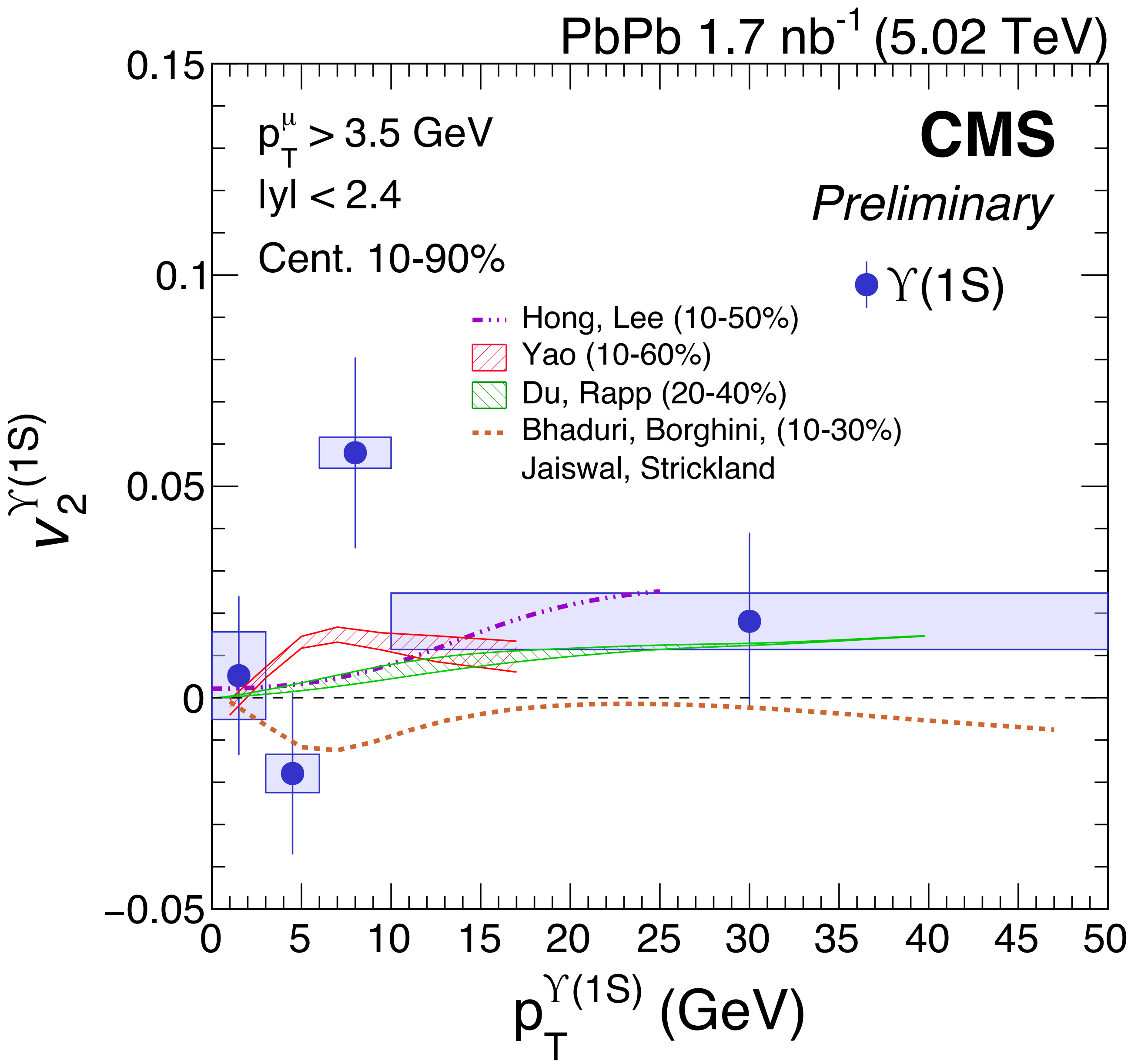
Comparison with ALICE



- $|y| < 2.4$ in CMS
- $2.5 < |y| < 4$ in ALICE

- Compatible results between CMS and ALICE
- Precise measurement in CMS with high lumi ~1.7 nb-1
- No |y| dependence found over wide rapidity range

Comparison with models



- Hong, Lee : potential NRQCD
  - Uses diffusion constant

  arXiv:1909.07696
- Yao : Boltzmann transport model
  - Real-time open heavy quark dist.

  arXiv:1812.02238
- Du, Rapp : kinetic-rate equation
  - T dependent binding energy
  - Medium effect from lattice-QCD based EOS

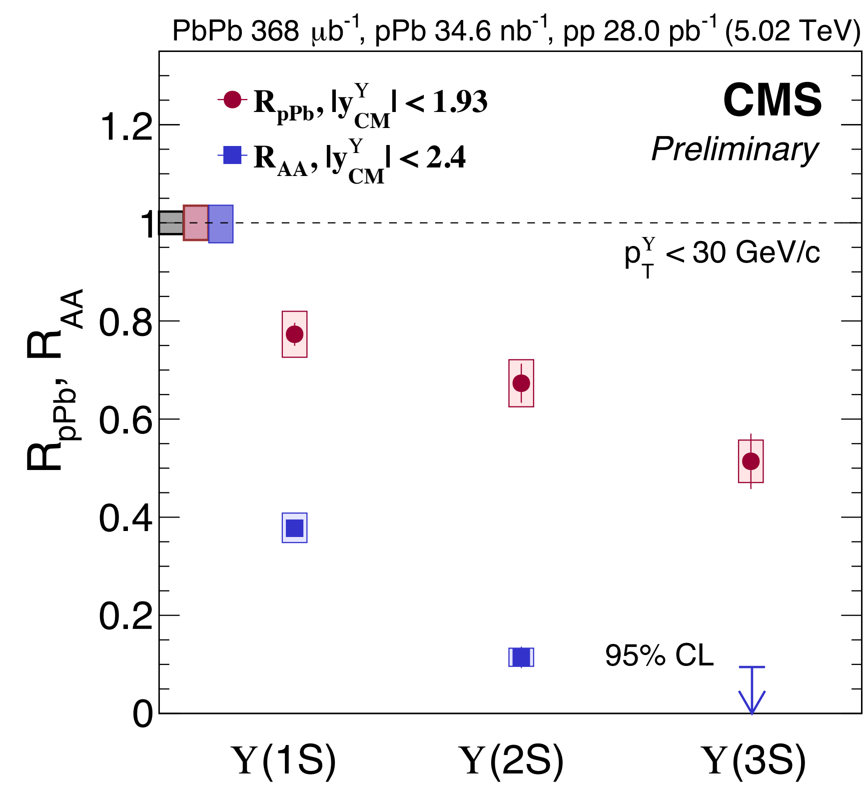
  PRC 96(2017) 054901
- Bhaduri et al : 3+1d aHydro model
  - Initial T & η/s tuned to LHC data
  - No recombination

  arXiv:1809.06235

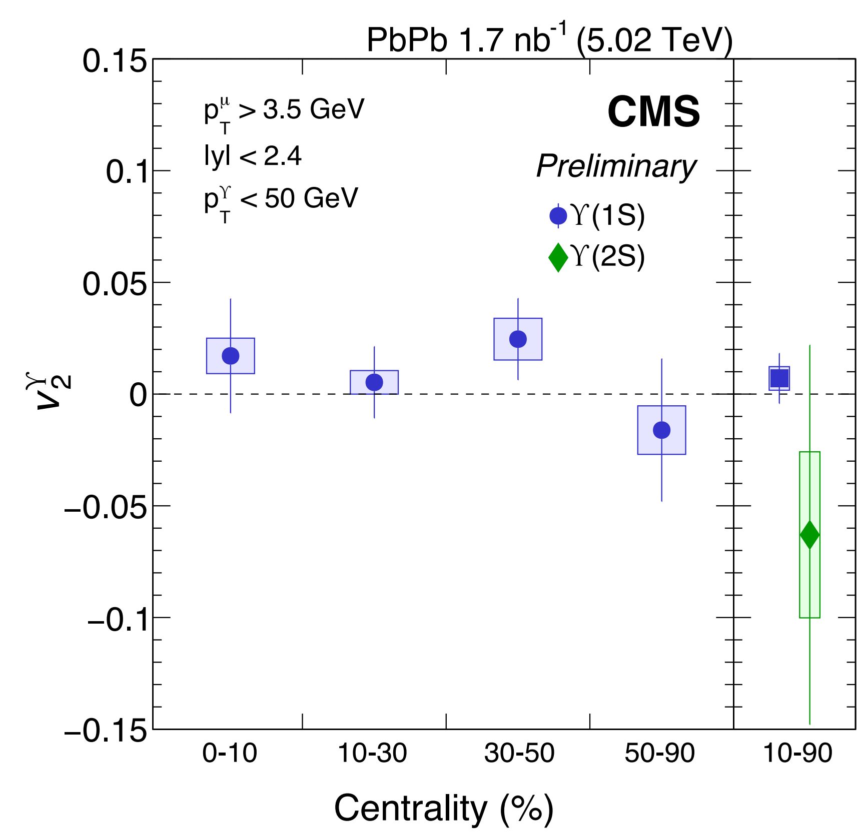
- Models in agreement with data
- Need more data to provide significant input to theory models

Summary

- All three upsilon states are in ordered suppression in PbPb and pPb
- Larger suppression in PbPb compared to pPb



- Precise measurement of v2 for ϒ(1S)
  - v2 = 0.007 +/- 0.011 (stat.) +/- 0.005 (syst.)
- First measurement of ϒ(2S) elliptic flow (v2) in heavy ion collisions



Backup