Quarkonia in heavy-ion collisions

Introduction

- Quarkonia (Q-Qbar)
- c-cbar family
  - η_c, J/ψ, ψ(2S), χ_c…
- b-bbar family
  - Y(1S) Y(2S), Y(3S) and χ_b

- In heavy-ion collisions, QGP is expected to screen the confining potential of Q-Qbar.

- Leads to melting of charmonium and bottomonium states, J/ψ, ψ(2S), χc, Y(1S), Y(2S), Y(3S), and χb.

- The melting temperature depends on the binding energy of the quarkonia state.

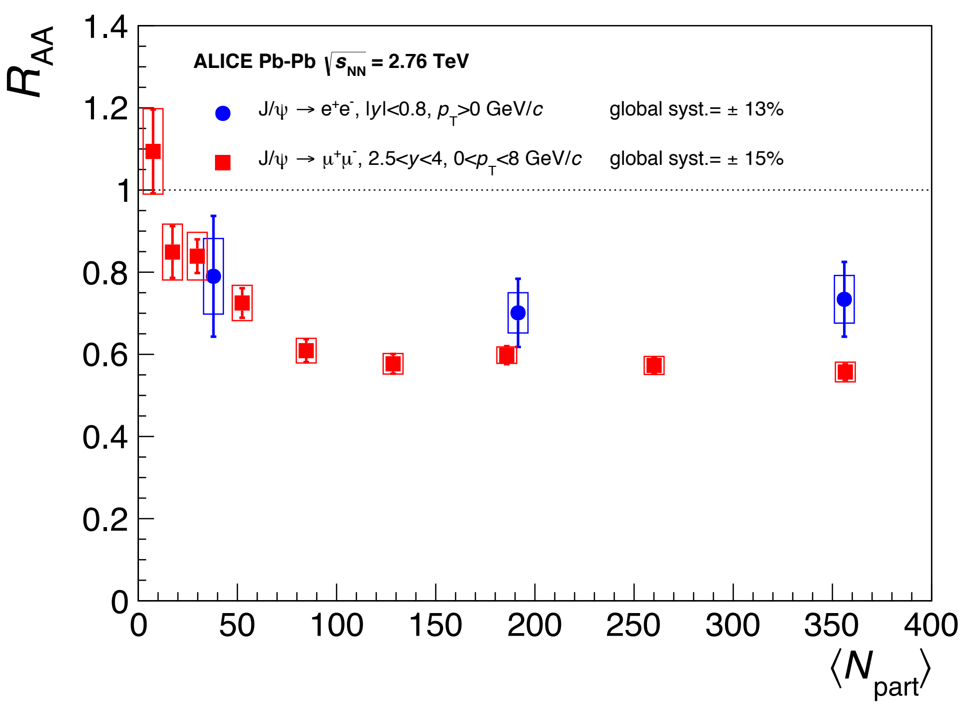
Bound state	χ_c	ψ'	J/ψ	$\Upsilon(2S)$	χ_b	$\Upsilon(1S)$
T_d	$\lesssim T_c$	$\lesssim T_c$	$\sim 1.2T_c$	$\sim 1.2T_c$	$\sim 1.3T_c$	$\sim 2.0T_c$

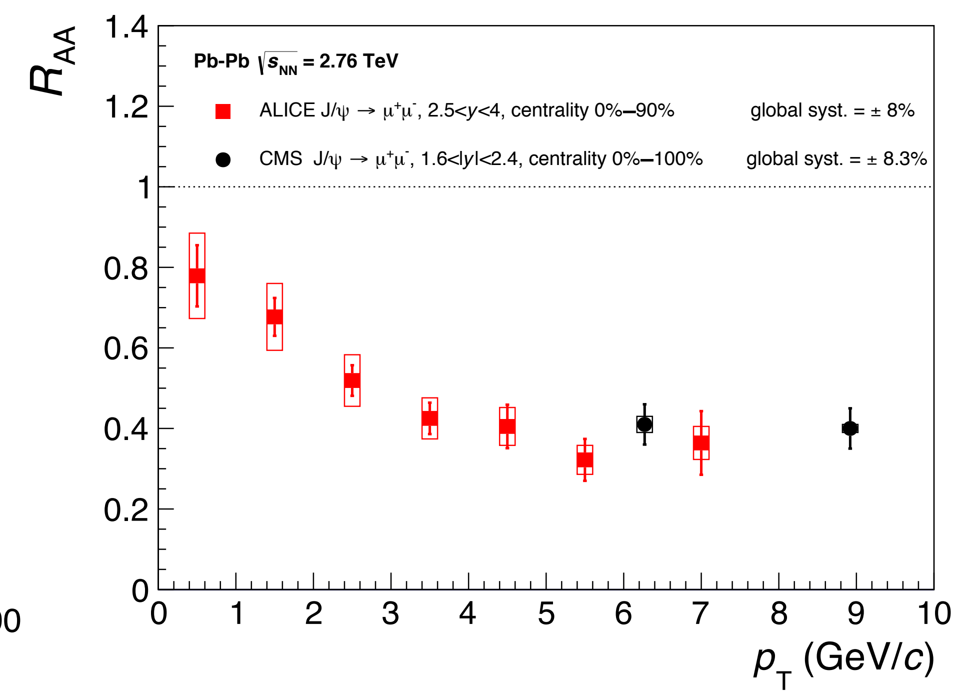
Introduction

- At high $\sqrt{s_{NN}}$, many c-cbar pairs created.
- At the end of the evolution of the QGP, the uncorrelated c-cbar can combine together (regeneration)
- This leads to higher quarkonia yields.
- Last class:
  - Measurements at RHIC showed that the suppression is similar to SPS
  - Suppression in forward rapidity higher than mid rapidity → puzzle not understood.

Measurements at LHC (Inclusive J/Ψ)

- Include J/Ψ (prompt and non-prompt) measurement in ALICE.
- Use muons at forward rapidity and electron in mid-rapidity.
- R_{AA} vs centrality (forward rapidity) : suppression shows no dependence on centrality for N_{part} > 70.
- R_{AA} vs. centrality (mid rapidity) : suppression constant w.r.t. centrality.
- R_{AA} vs p_T (forward rapidity) : suppression increases with increase in p_T → regeneration happens at low p_T

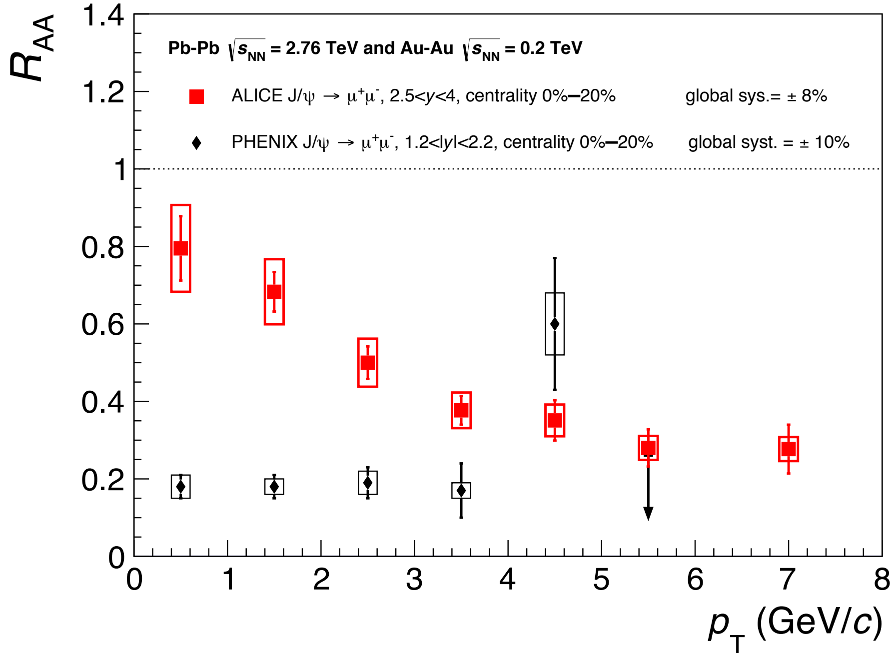


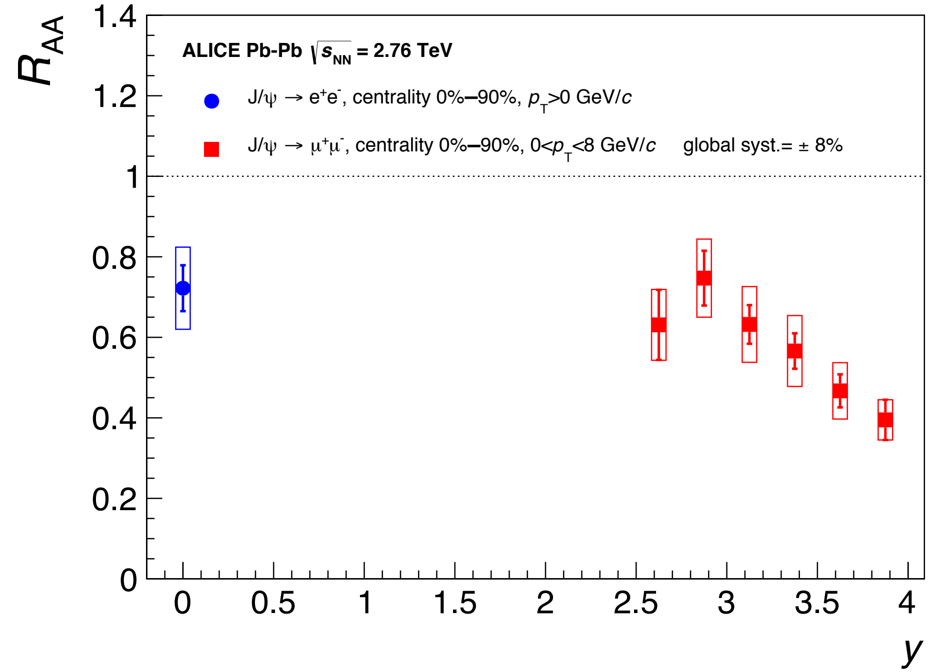


Measurements at LHC (Inclusive J/Ψ)

Suppression at LHC much lower than at RHIC →Regeneration could be the answer.

Suppression slightly larger at forward rapidity than at mid rapidity.





Measurements at LHC (Separate prompt and non-prompt J/Ψ)

Suppression of J/Ψ could be

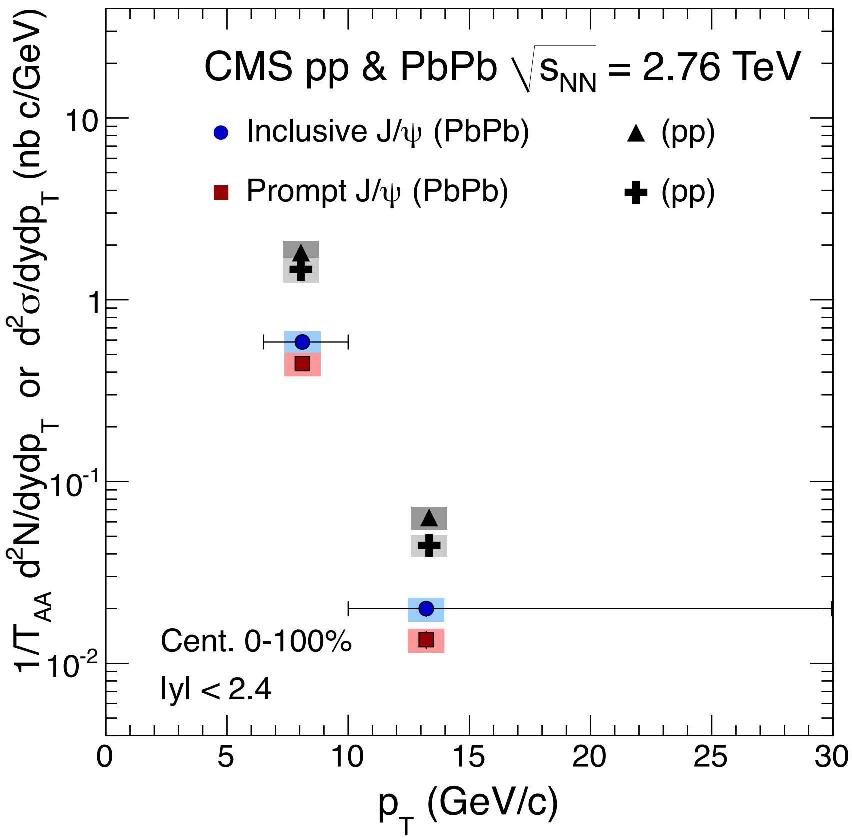
1. Melting of c-cabr pairs (prompt)
2. Energy loss of b quark : b →J/Ψ (non-prompt)

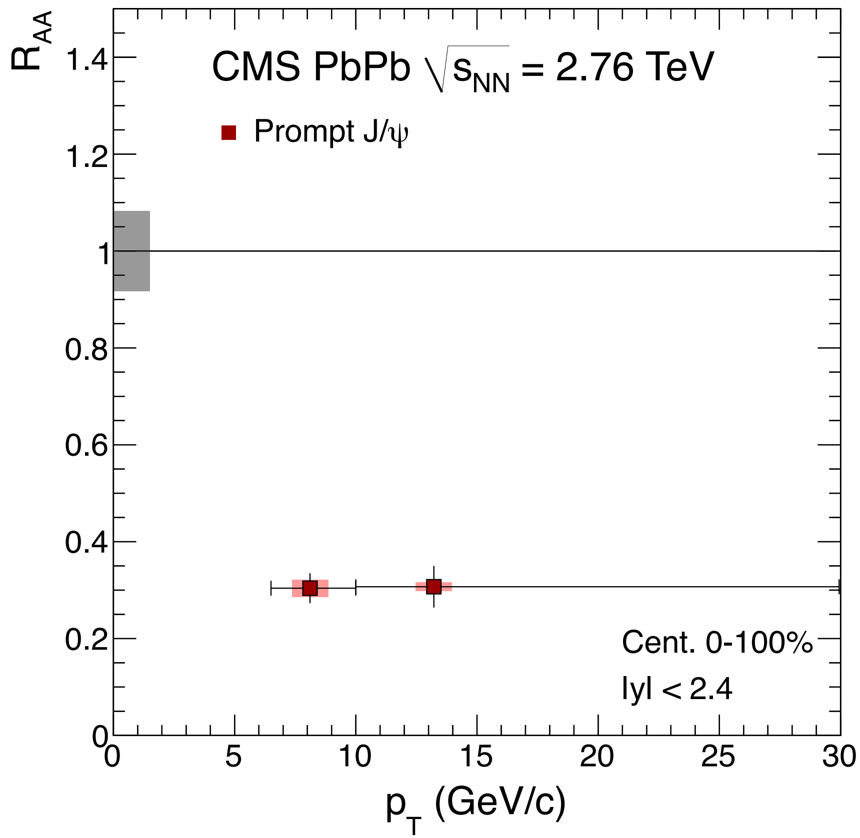
- Lifetime of b hadrons (~ 500 μm/c) longer than lifetime of QGP (~ 10 fm/c).
- This contribution should not suffer from colour screening, but instead reflect b-quark energy loss in the medium.

To understand quarkonia melting, we look at prompt J/Ψ (CMS).

Measurements at LHC (prompt J/Ψ)

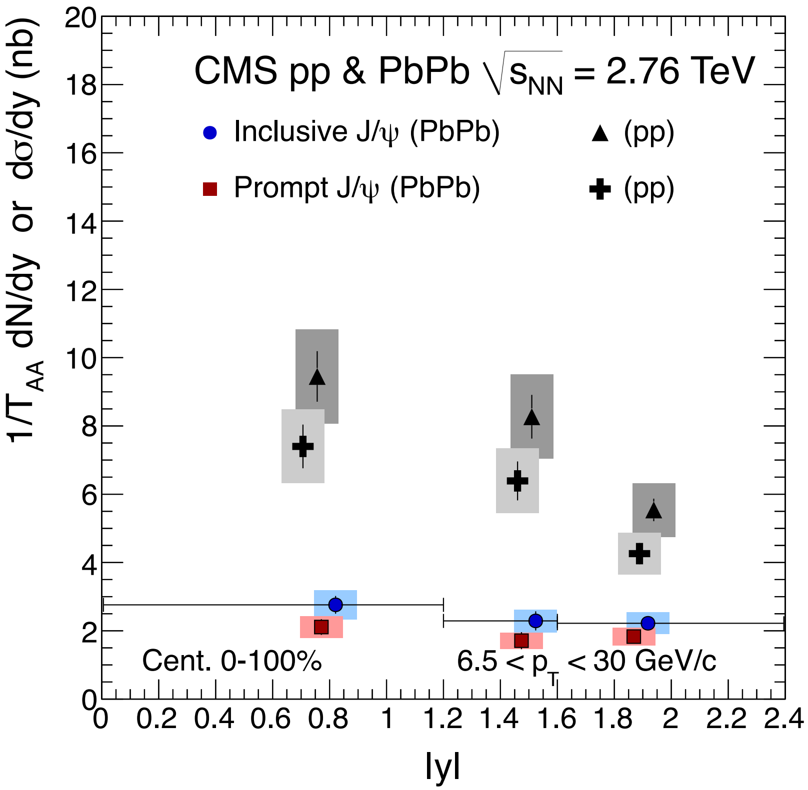
R_{AA} : do not exhibit p_T dependence.

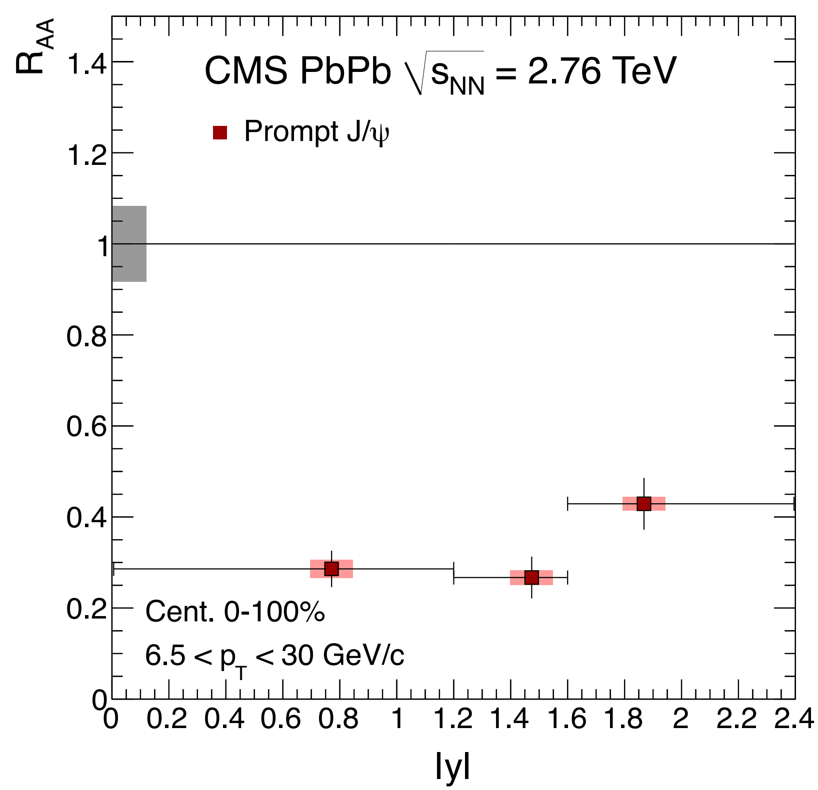




Measurements at LHC (prompt J/Ψ)

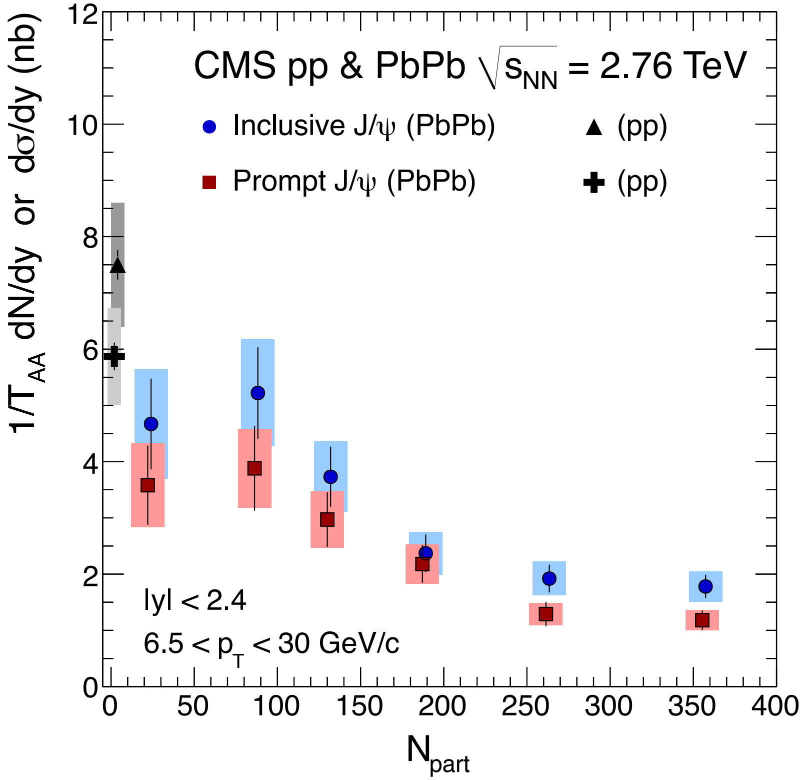
R_{AA} vs. rapidity : indication of less suppression in the most forward rapidity bin in comparison to mid rapidity.

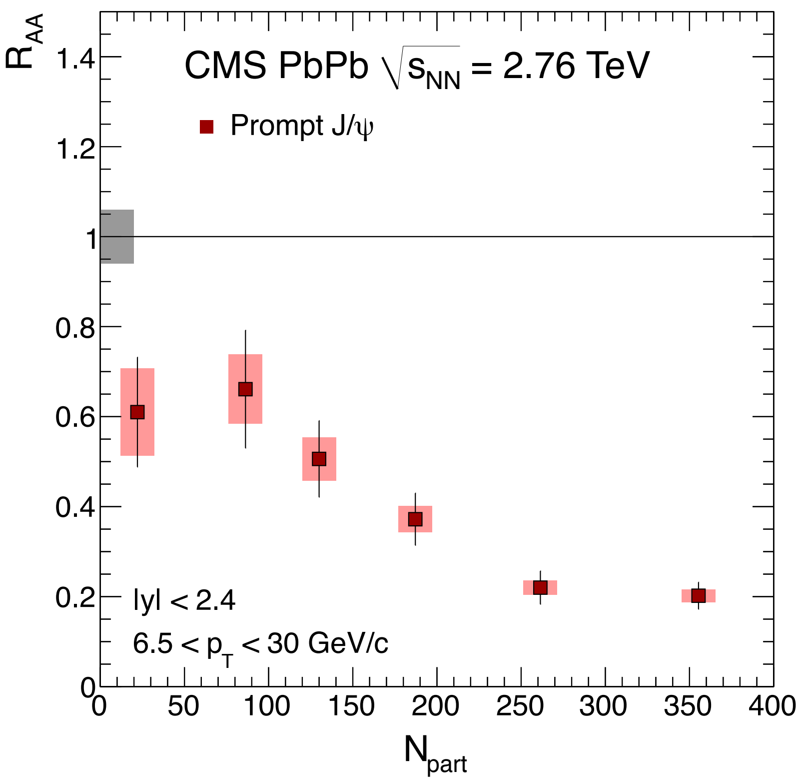




Measurements at LHC (prompt J/Ψ)

- R_{AA} vs. N_{part} : Same centrality dependence as the inclusive J/Ψ.
- Suppressing increases with increase in centrality
  - Different from ALICE measurement, but ALICE measurement is in forward rapidity.





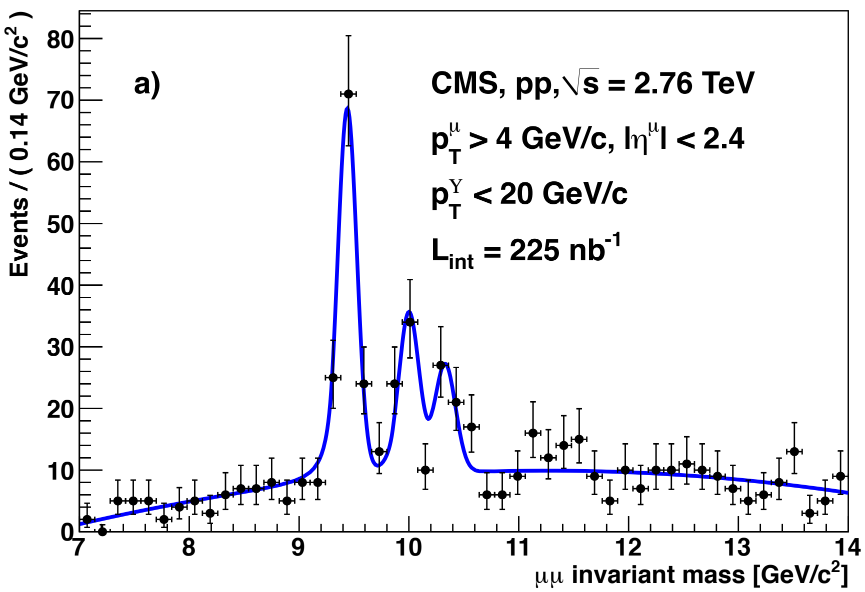
Measurement of Υ states

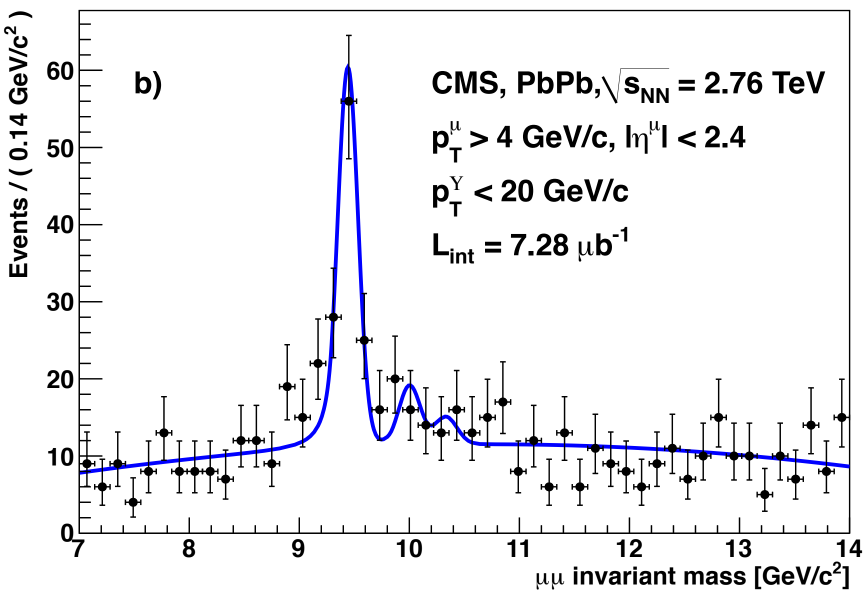
Υ states : Υ(1S), Υ(2S), Υ(3S)

$$\Upsilon(2S+3S)/\Upsilon(1S)|_{pp} = 0.78(+0.18-0.16)$$

$$\Upsilon(2S+3S)/\Upsilon(1S)|_{Pb-Pb} = 0.24(+0.15-0.14)$$

$$\frac{\Upsilon(2S+3S)/\Upsilon(1S)|_{Pb-Pb}}{\Upsilon(2S+3S)/\Upsilon(1S)|_{pp}} = 0.31(+0.21-0.18)$$





Measurement of Y states

Large fraction of Y(1S) states come from decays of heavier bottomonium states.

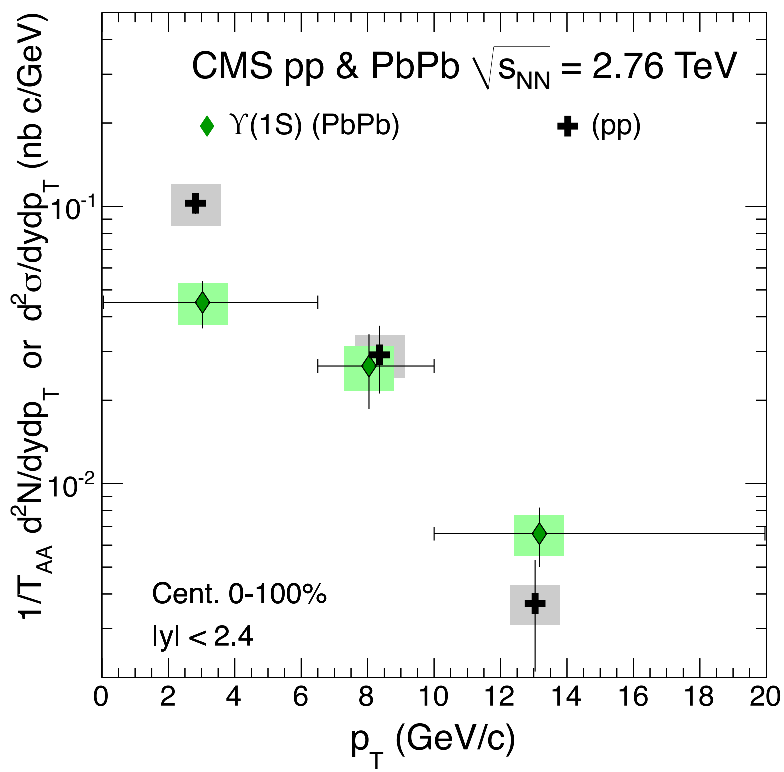
Does this effect Y(1S) suppression??

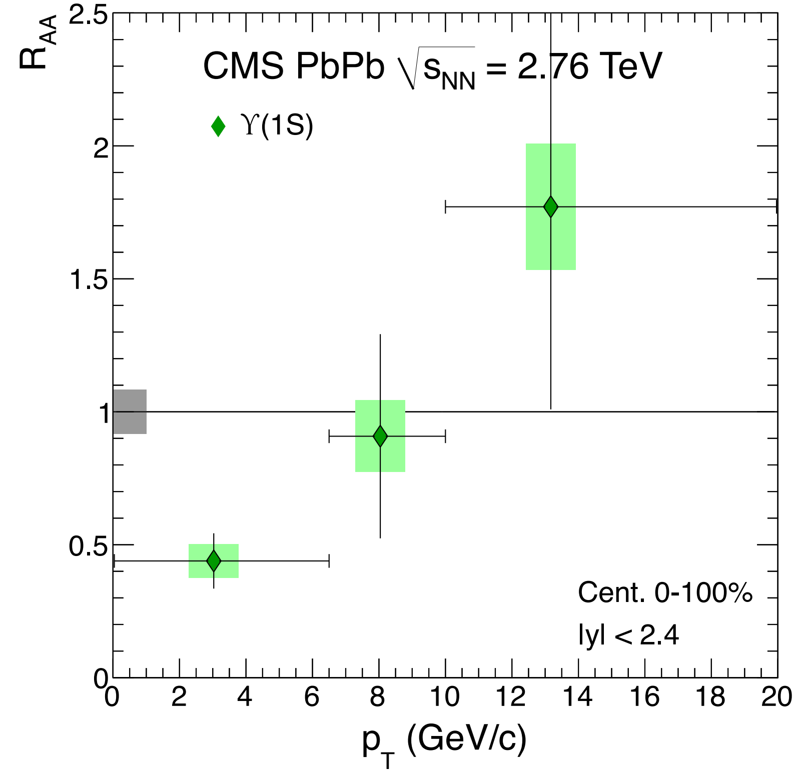
Measurement of Υ(1S) states

R_{AA} vs p_T : Significant suppression at low p_T.

Disappears for p_T > 6.5 GeV/c.

Low p_T Υ(1S) could come from excited states, hence suppressed.

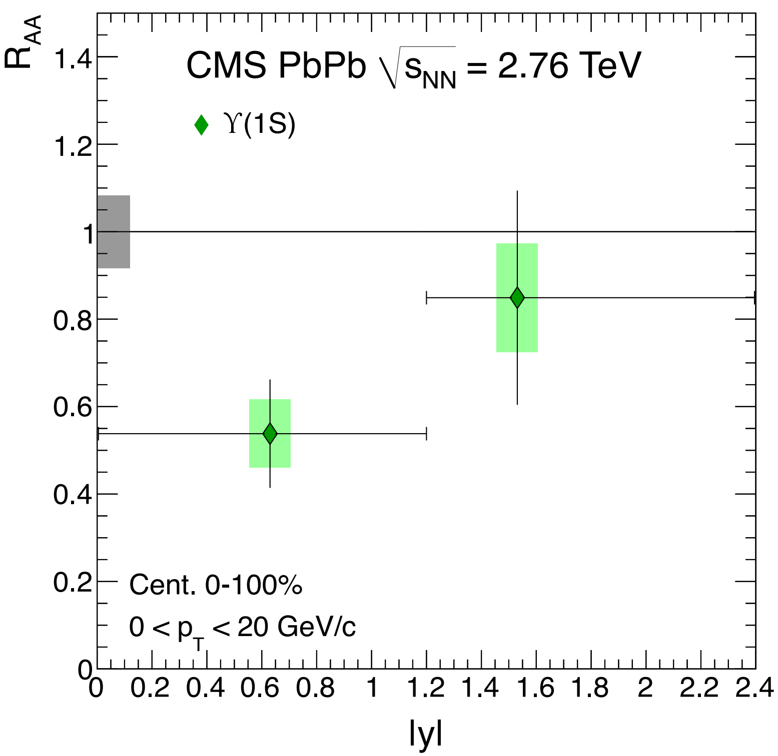


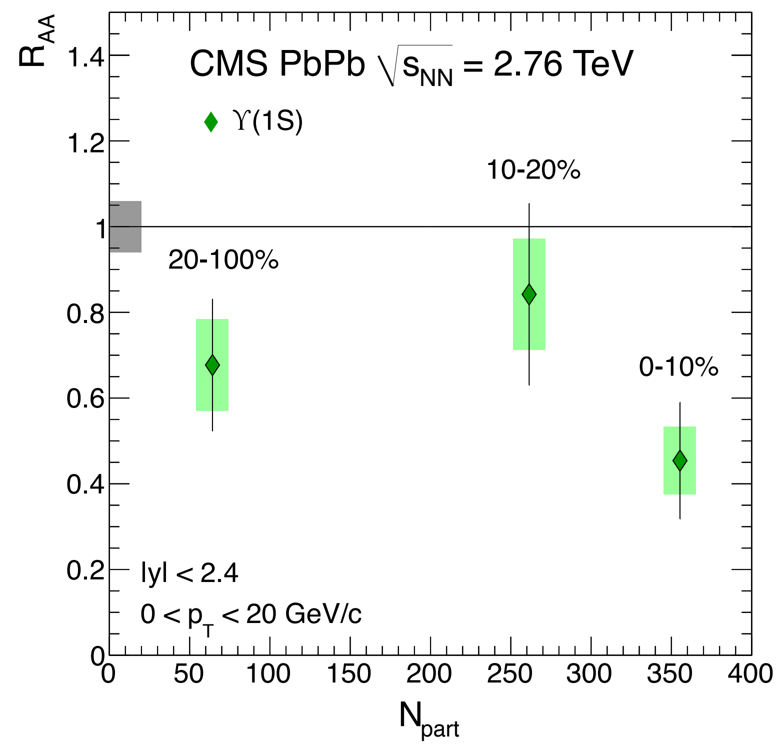


Measurement of Υ(1S) states

R_{AA} vs. rapidity: Large statistical error to conclude on rapidity dependence.

R_{AA} vs. N_{part} : No centrality dependence within uncertainties.





Back up

Measurements at LHC (Non-prompt J/Ψ)