Measurement of Bottomonia in pp, pPb and PbPb collisions at 5.02 TeV

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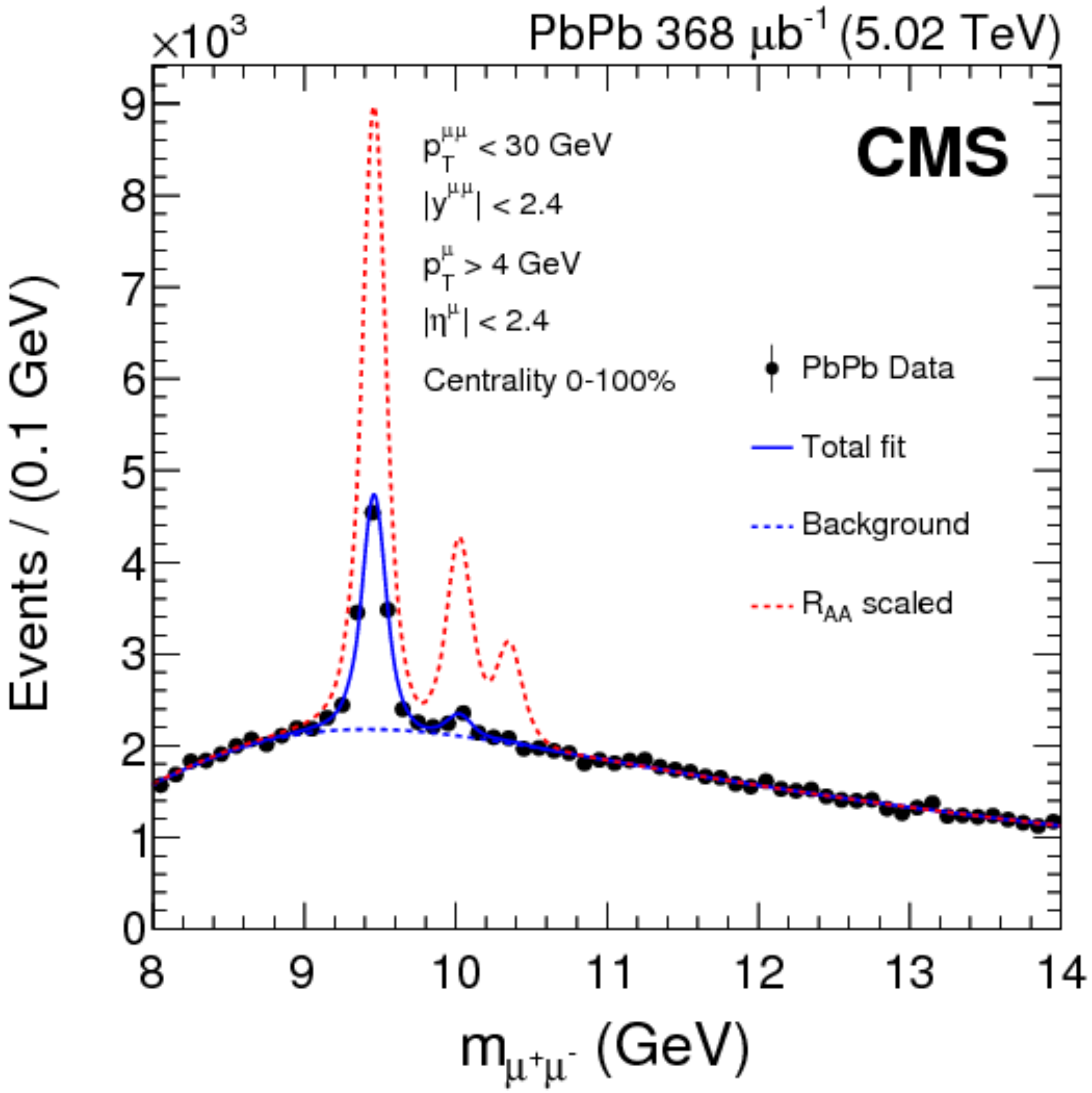
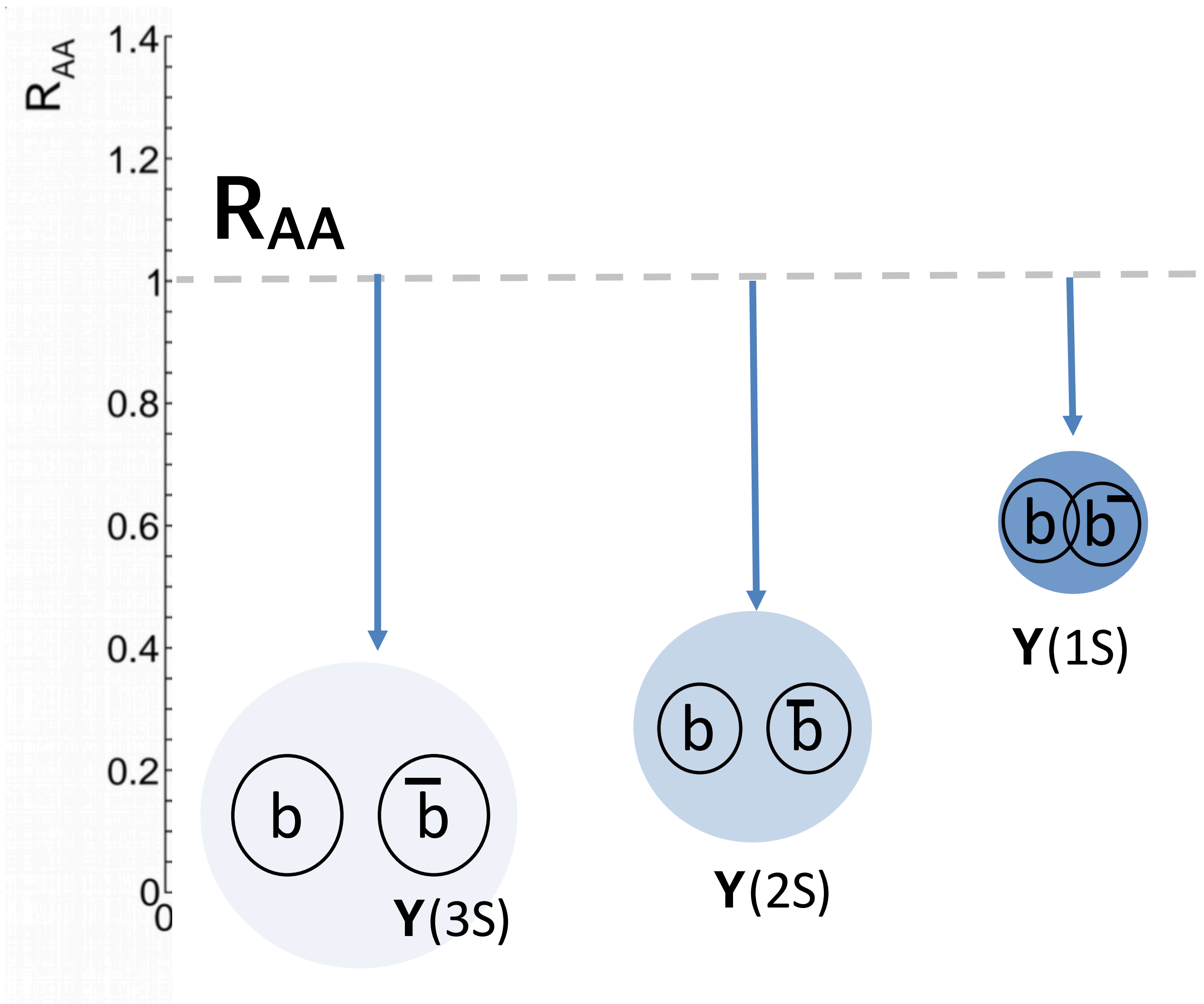
CMS Collaboration
IS2019, NY

Universe, Whanki Kim (1913-1973)

Upsilon states in Heavy ion collision





- **Υ(nS)** mesons provide evidence for color charge screening that sequentially increases w.r.t. binding energy
- This presentation reviews the recent observation of upsilon state modifications in pPb and PbPb collisions at 5.02 TeV

Upsilon states in Heavy ion collision

- Suppression of excited Υ(nS) in PbPb at 2.76 TeV
  [PRL 107 (2011) 052302]
- Quarkonium production in PbPb collisions at 2.76 TeV
  [JHEP 1205 (2012) 063]
- Observation of Υ(nS) suppression at 2.76 TeV
  [PRL 109 (2012) 222301]
- Suppression of Υ(nS) in PbPb at 2.76 TeV
  [PLB 770, 357(2017)]
- Event activity of Υ(nS) in pPb at 5.02 TeV
  [JHEP 04 (2014) 103]
- Suppression of Υ(nS) in PbPb at 5.02 TeV
  [PRL 120 (2018) 142301]
- Nuclear modification of Υ(nS) in PbPb at 5.02 TeV
  [PLB 790 (2019) 270]

2011-2013

PbPb : $\sqrt{s_{NN}}$ = 2.76 TeV, L = 166 μb^{-1}

pPb : $\sqrt{s_{NN}}$ = 5.02 TeV, L = 34.6 nb^{-1}

pp : $\sqrt{s_{NN}}$ = 2.76 TeV, L = 5.4 pb^{-1}

Run1

Run2

2015

PbPb : $\sqrt{s_{NN}}$ = 5.02 TeV, L = 368 μb^{-1}

pp : $\sqrt{s_{NN}}$ = 5.02 TeV, L = 28 pb^{-1}

New data 2017-2018 PbPb : $\sqrt{s_{NN}}$ = 5.02 TeV, L ~ 1.6 nb^{-1} , pp : $\sqrt{s_{NN}}$ = 5.02 TeV, L ~ 300 pb^{-1}

Upsilon states in Heavy ion collision

- **Suspension of excited Υ(nS) in PbPb at 2.76 TeV**

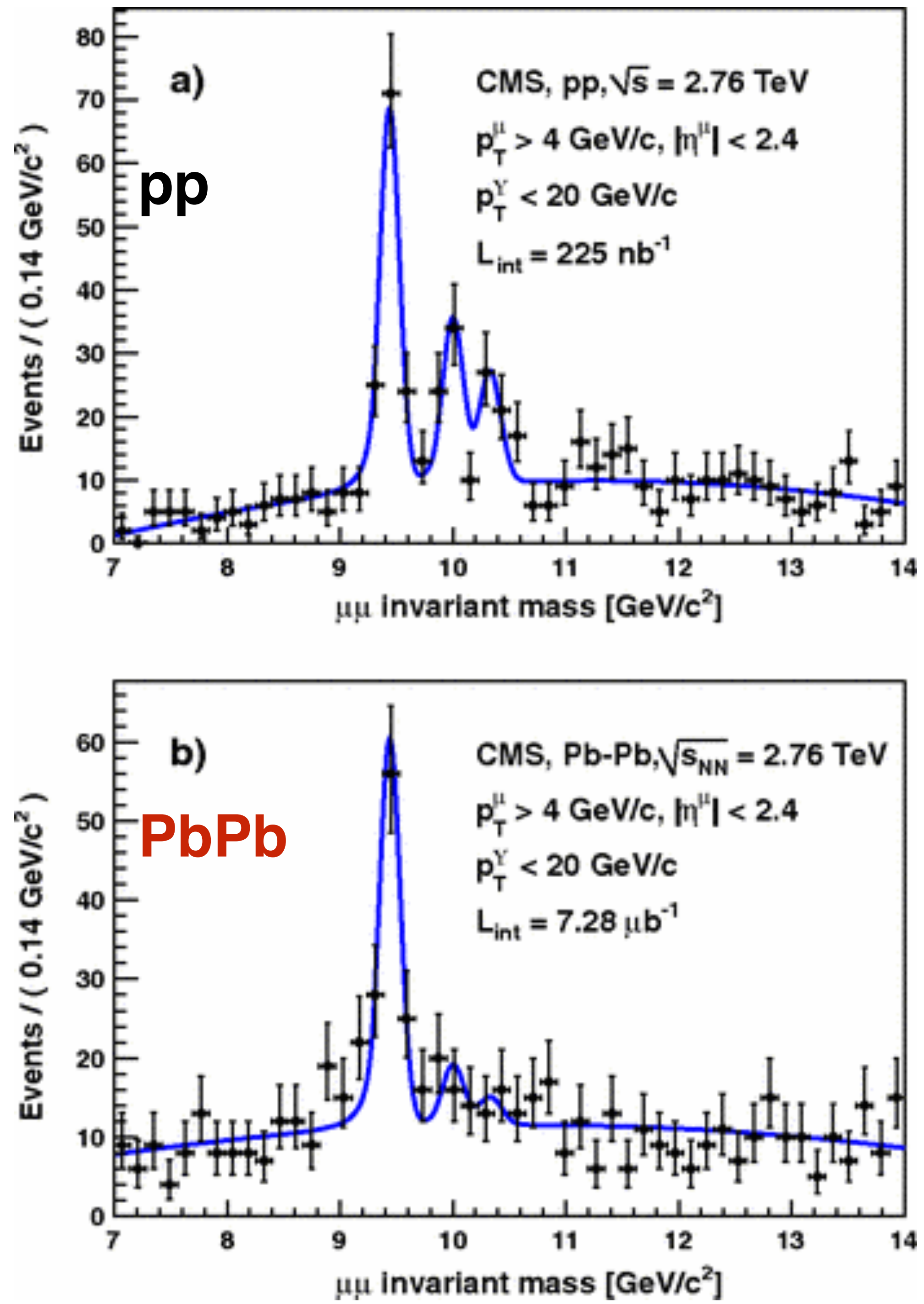
  [PRL 107 (2011)]

From the first PbPb run at LHC, we observed different ratio of Y(nS)/Y(1S) between pp and PbPb.
Sequential melting?

The observation led us to measure the

double ratio $\frac{R_{AA} \text{ of } \mathbf{Y}(nS)}{R_{AA} \text{ of } \mathbf{Y}(1S)}$

- Precision measurement for very few corrections beyond signal counting
- Isolates the final state effects from production mechanism
- Used 7.3 μb^{-1}



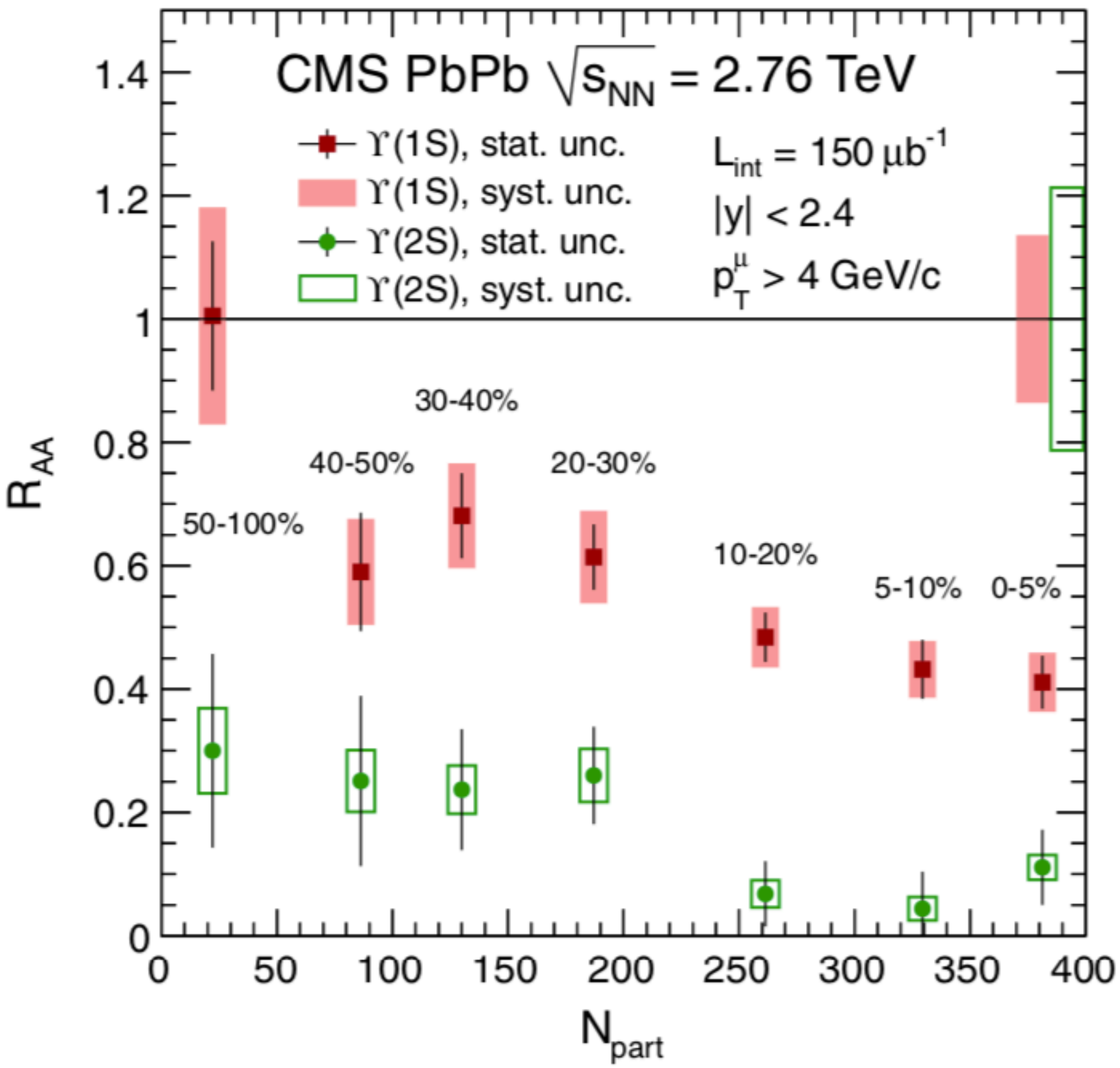
Upsilon states in Heavy ion collision

- **Observation of ϒ(nS) suppression at 2.76 TeV**

  [PRL 109 (2012) 222301]

In the following year, we got 20 times more data

- First measurement of R_{AA} vs centrality
- Not enough statistics for Y(3S) measurement
- Used 150 μb^{-1} (x20 than 2010)

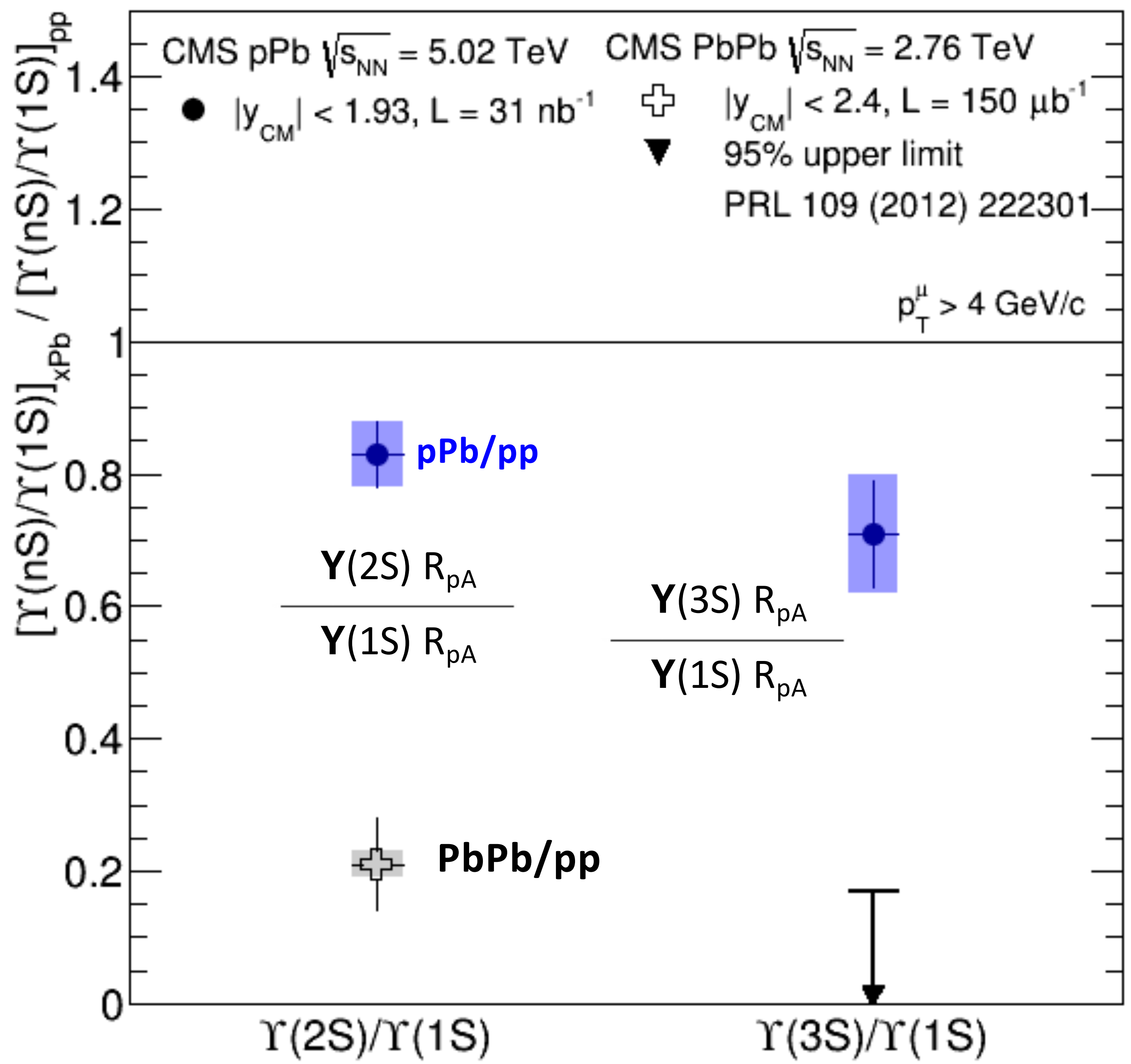


Upsilon states in Heavy ion collision

- **Event activity of Υ(nS) in pPb at 5.02 TeV**
  [JHEP 04 (2014) 103]

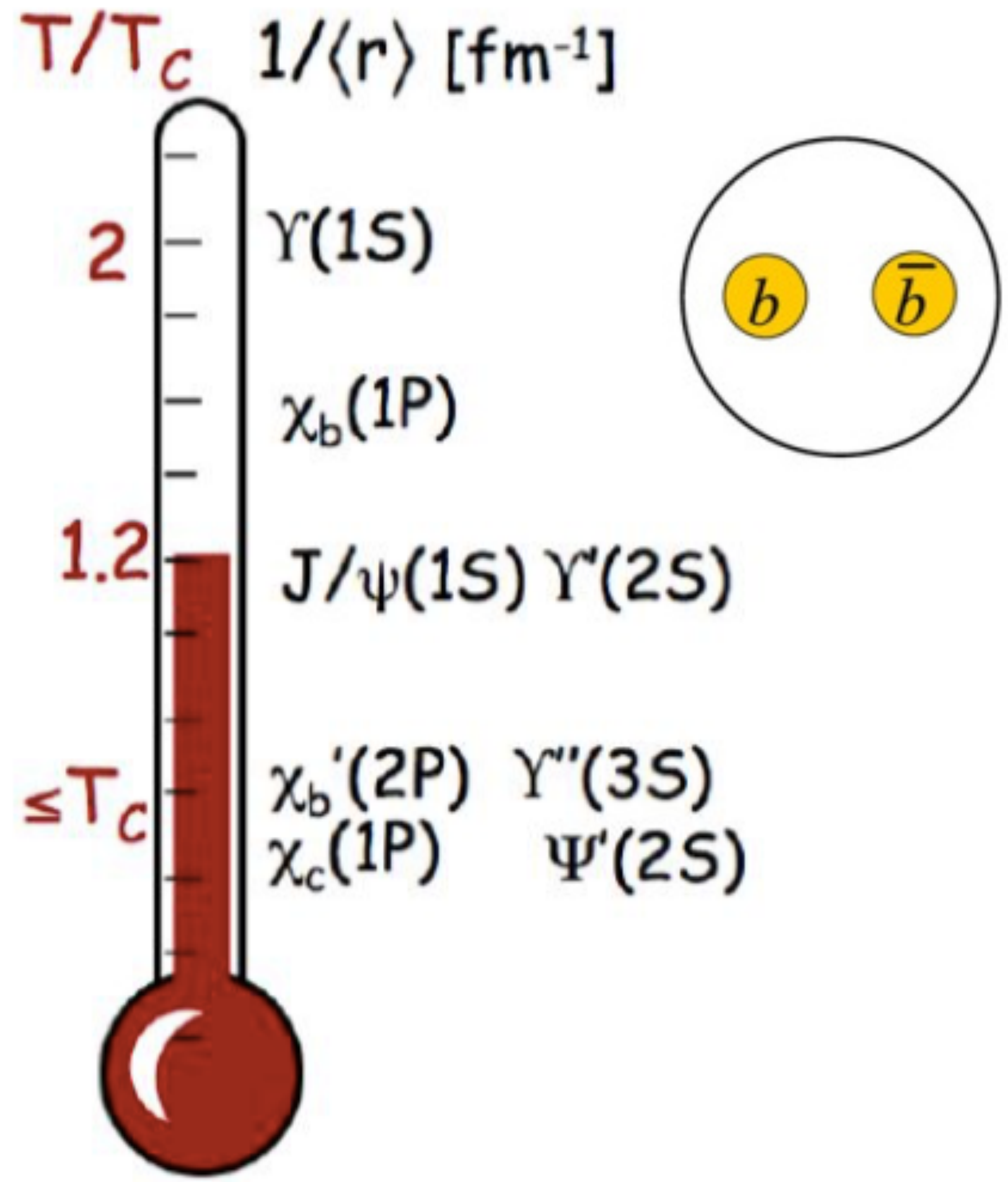
In 2013, we took pPb data at 5.02 TeV

- pPb serves as cold nuclear baseline
- Drop of double ratios observed in pPb less than PbPb but in the analogous manner
- confirmed that large suppression of excited states is primarily due to hot medium (QGP)



Lessons from Run I result

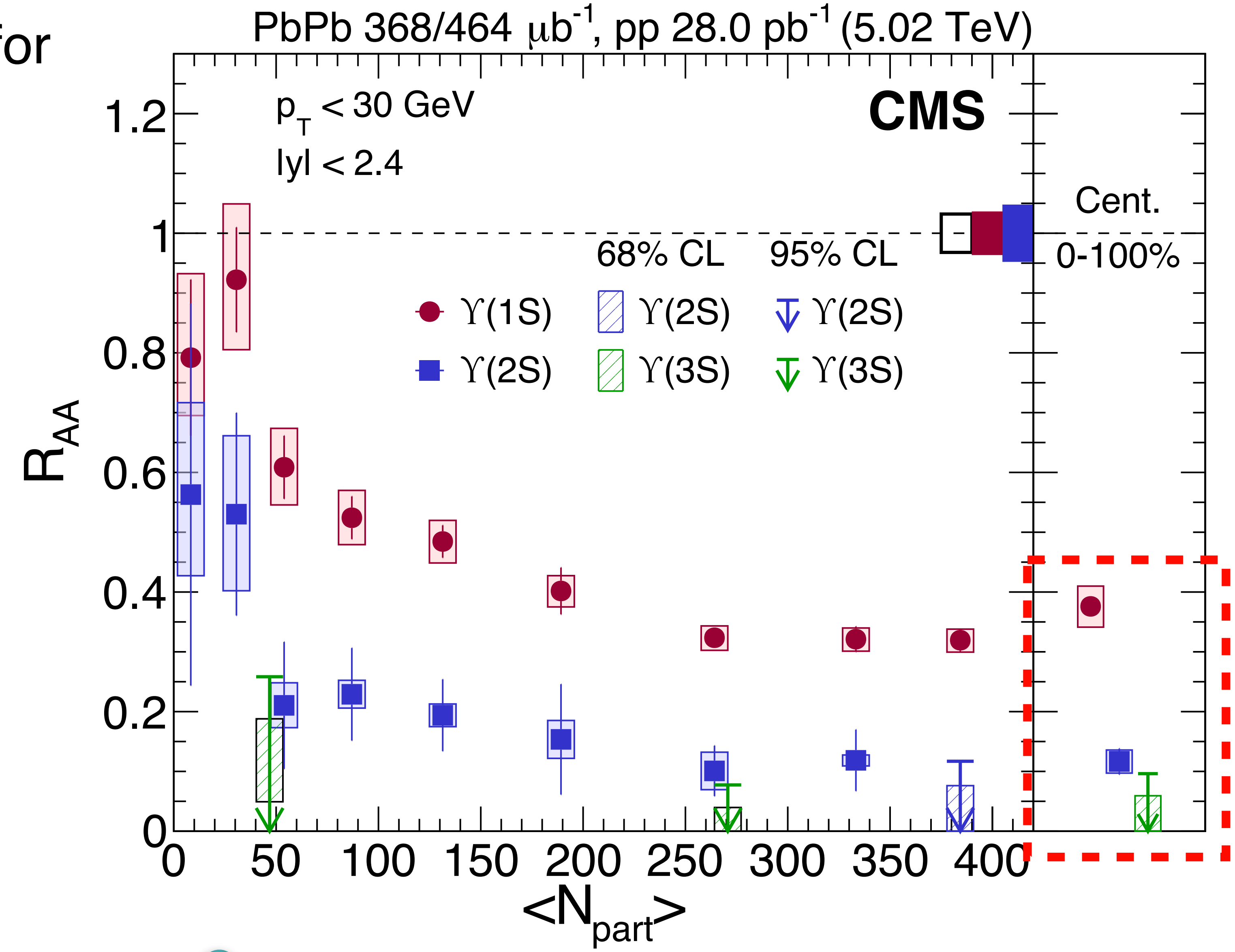
- Y(nS) is suppressed by interaction with medium, but not exactly as predicted by the classical sequential melting picture All-or-nothing switch by temperature threshold
- Yet, suppression is higher for more excited states
- Suppression smoothly depends on the centrality
- Results with more statistics and in different collision energy would be useful to comprehend the thermal property of QGP, as a function of space and time

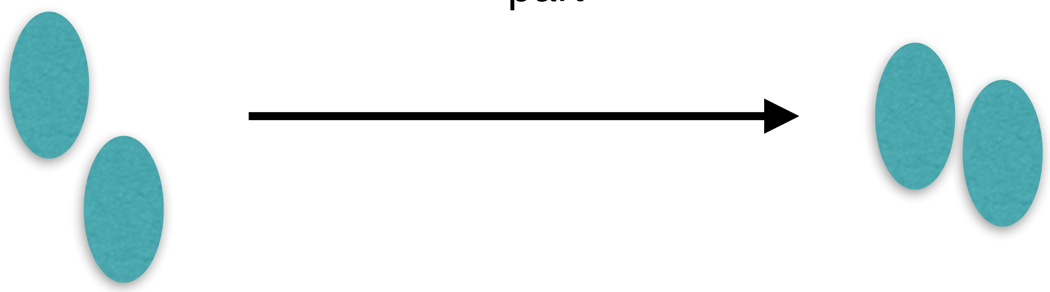


Upsilon results with Run II data

- Nuclear modification measured for all three states

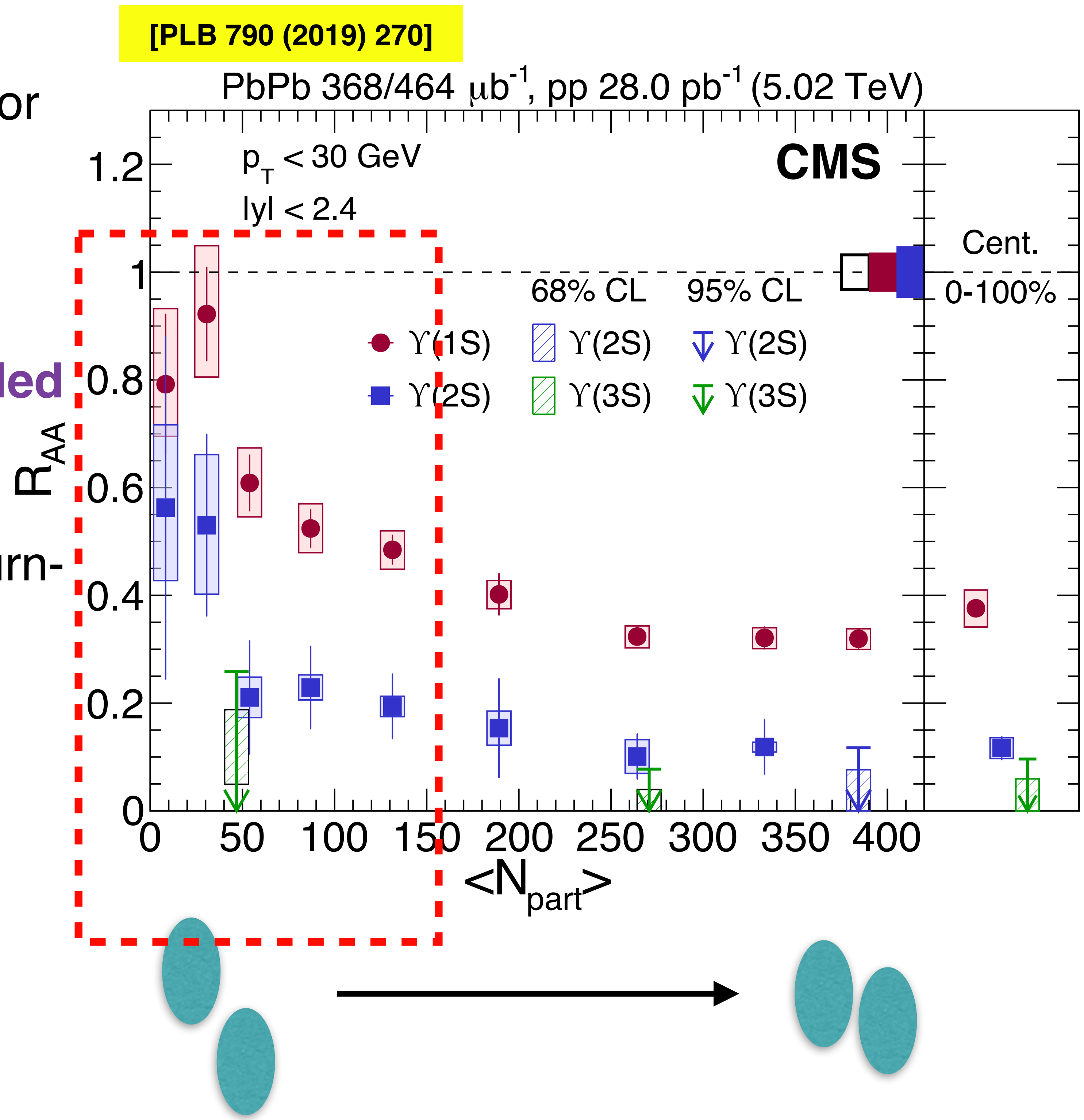
[PLB 790 (2019) 270]





Upsilon results with Run II data

- Nuclear modification measured for all three states
- Dedicated trigger **for un-prescaled peripheral** collision
  - to illuminate the moment of turn-R_{AA} of excited state



Upsilon results with Run II data

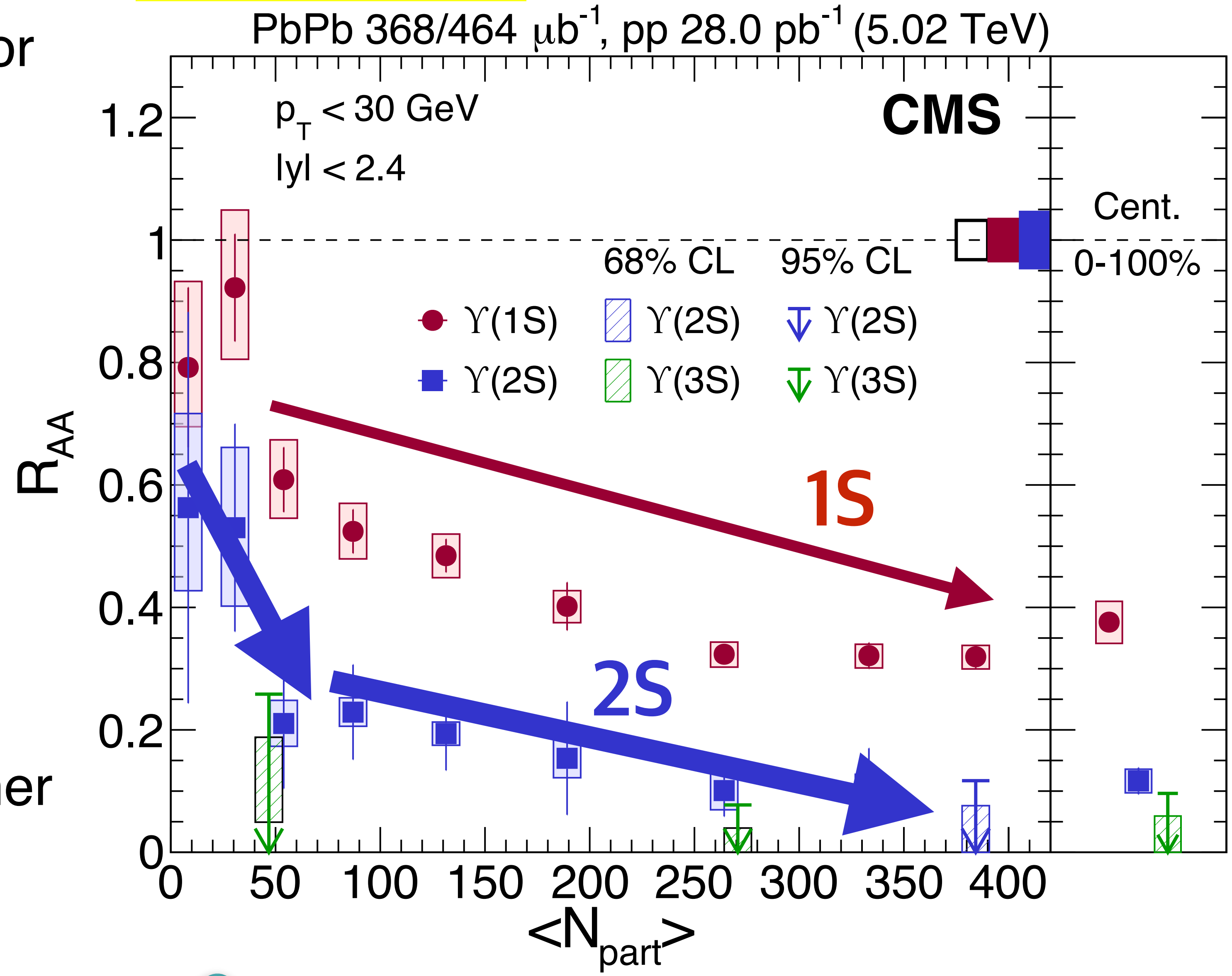
- Nuclear modification measured for all three states

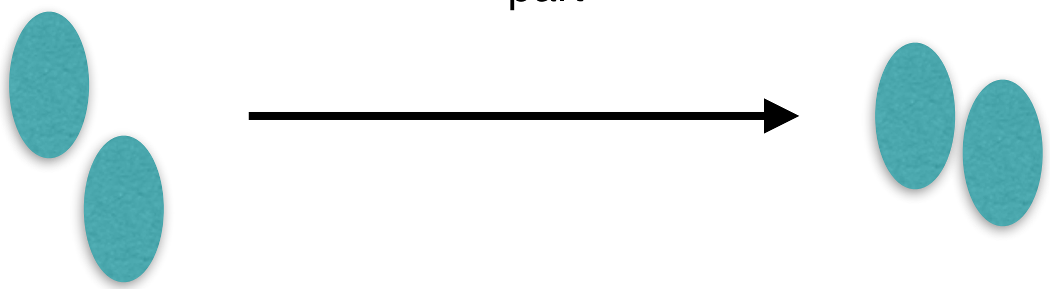
- Same ordering of suppression in 2.76 TeV

R_{AA}(ϒ(1S)) : 0.376 ± 0.013 (stat) ± 0.035 (syst)
R_{AA}(ϒ(2S)) : 0.117 ± 0.022 (stat) ± 0.019 (syst)
R_{AA}(ϒ(3S)) < 0.096 in 95% C.L.

- R_{AA} Gradually decreases for higher centrality for 1S and 2S
  - Hints for rapid turn-on at very peripheral collision (> 70%)

[PLB 790 (2019) 270]





Upsilon results with Run II data

- Nuclear modification measured for all three states

- Same ordering of suppression in 2.76 TeV

  $R_{AA}(\Upsilon(1S))$: 0.376 ± 0.013 (stat) ± 0.035 (syst)

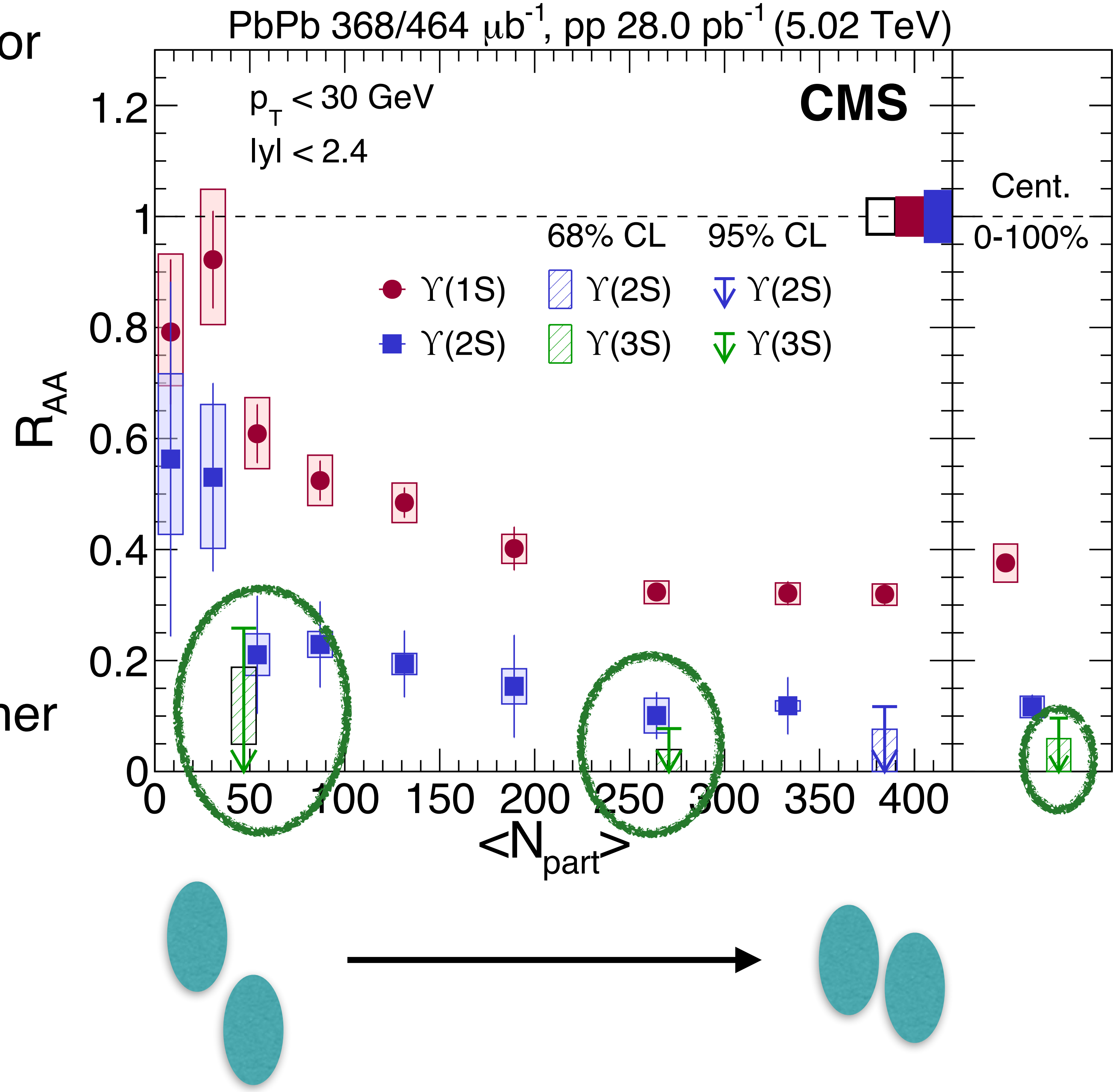
  $R_{AA}(\Upsilon(2S))$: 0.117 ± 0.022 (stat) ± 0.019 (syst)

  $R_{AA}(\Upsilon(3S))$ < 0.096 in 95% C.L.

- R_{AA} Gradually decreases for higher centrality for 1S and 2S

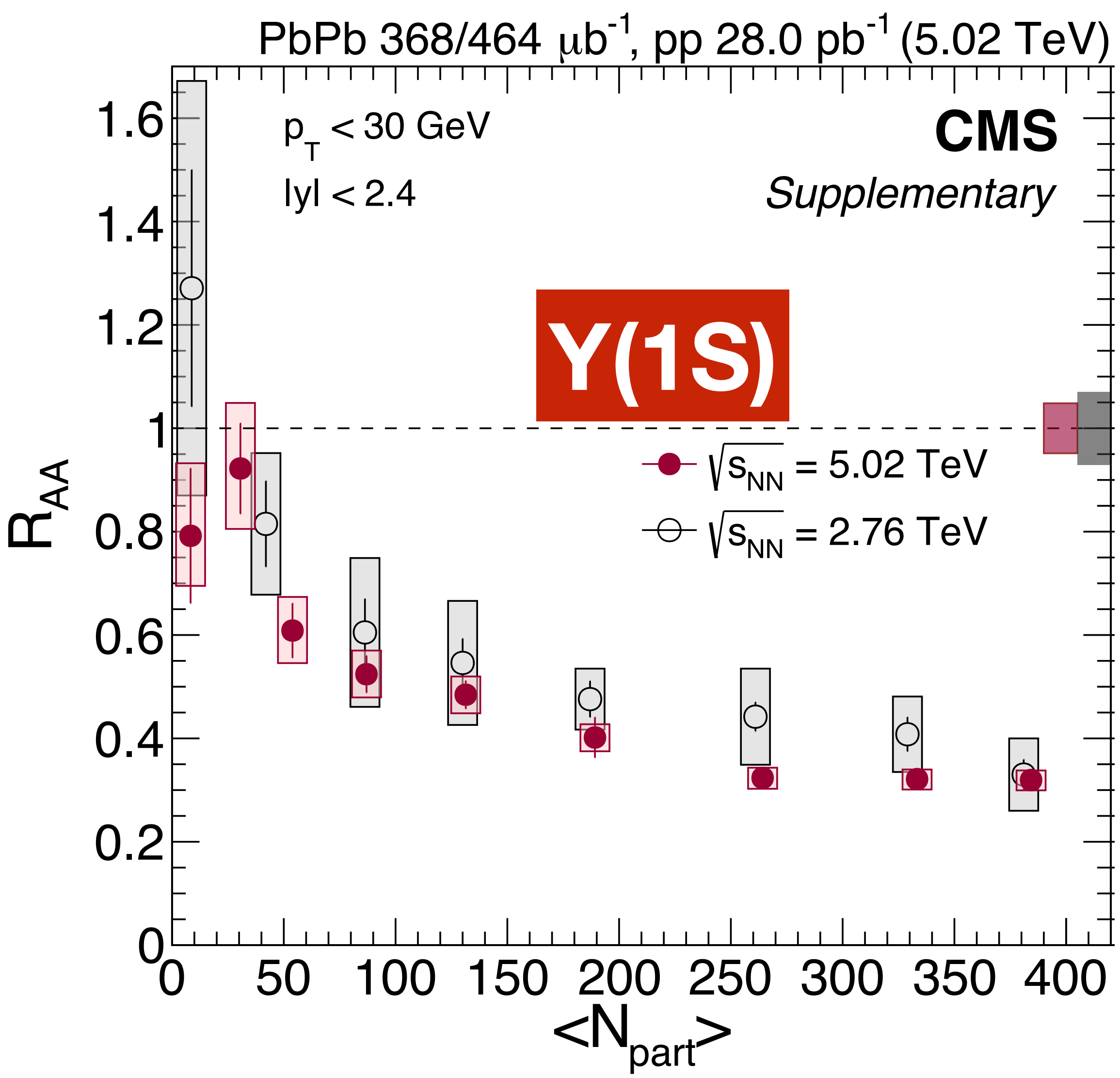
- Strong suppression of 3S

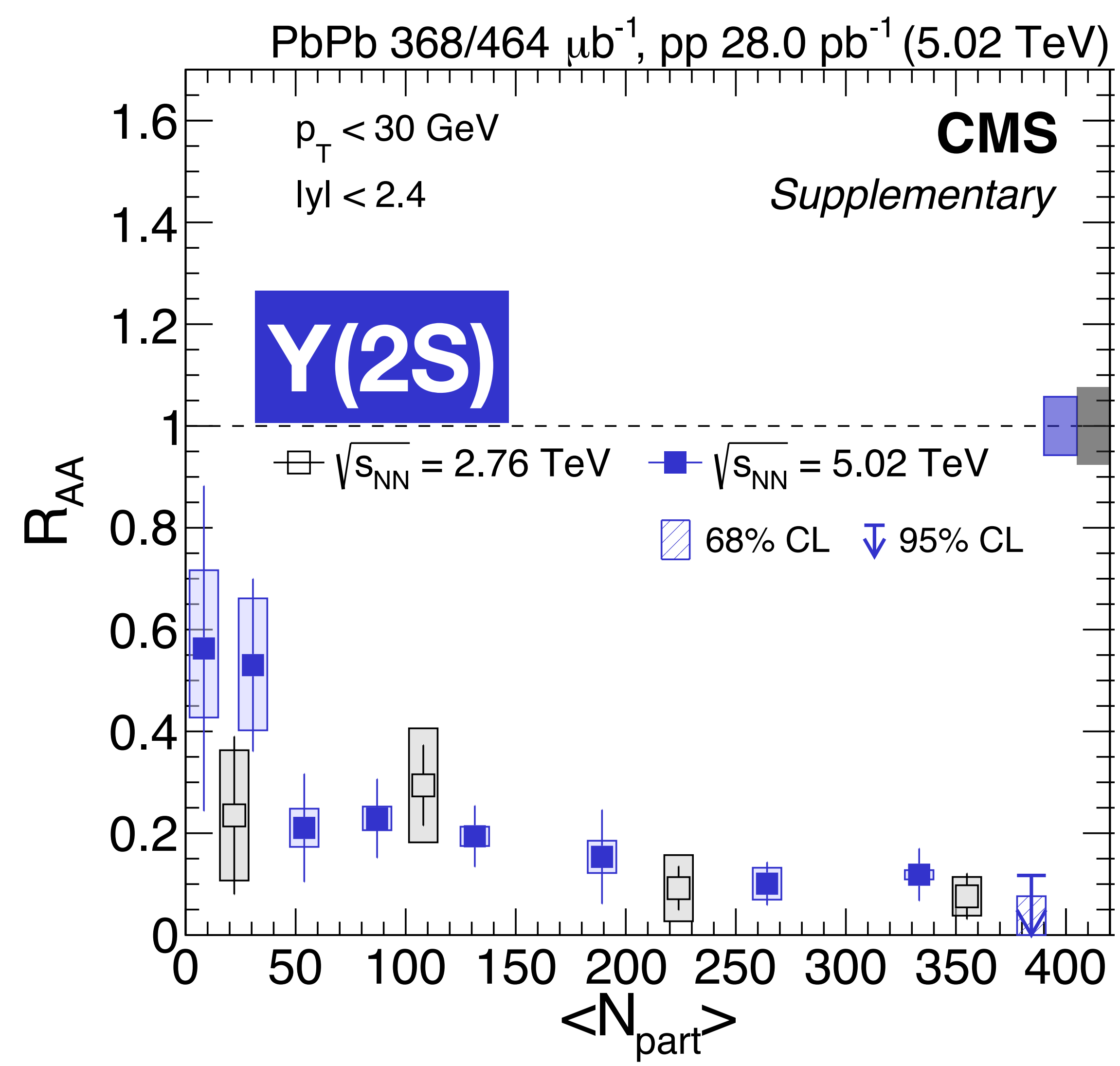
[PLB 790 (2019) 270]



[Comparison with 2.76 TeV] R_{AA} vs centrality

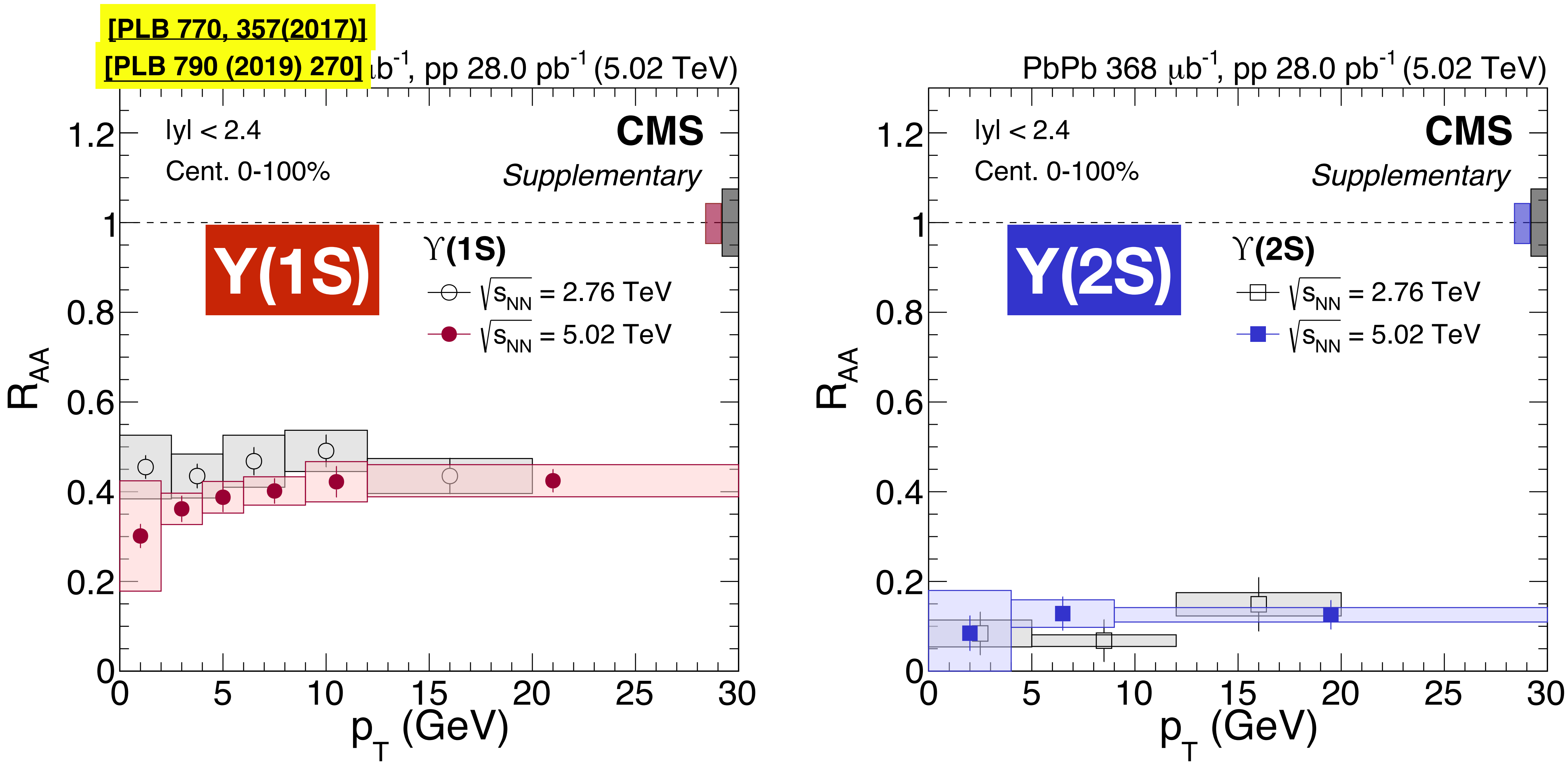
[PLB 790 (2019) 270] [PLB 770, 357(2017)]





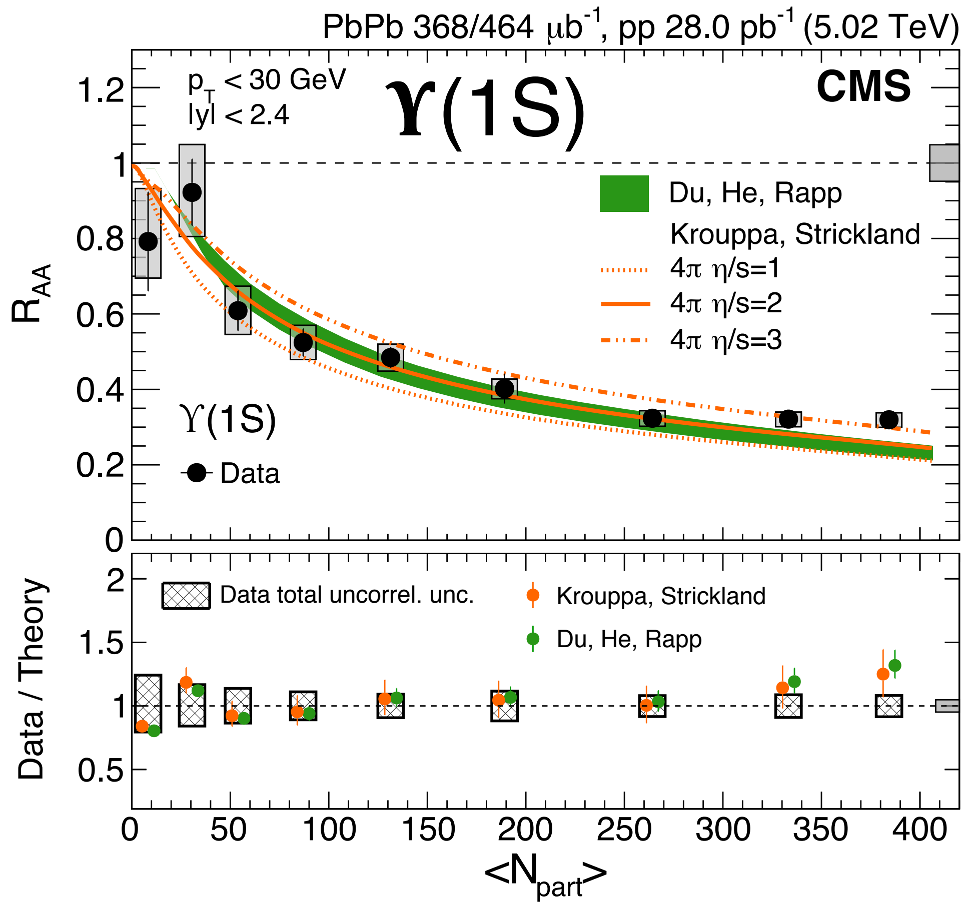
- ϒ(1S)
  - ➡ **R_{AA}(5.02) / R_{AA}(2.76) = 1.2 ± 0.15**
  - ➡ compatible within uncertainties
- ϒ(2S)
  - ➡ Monotonic dependence on centrality is clearer in 5.02 TeV
  - ➡ Similar suppression in both energies

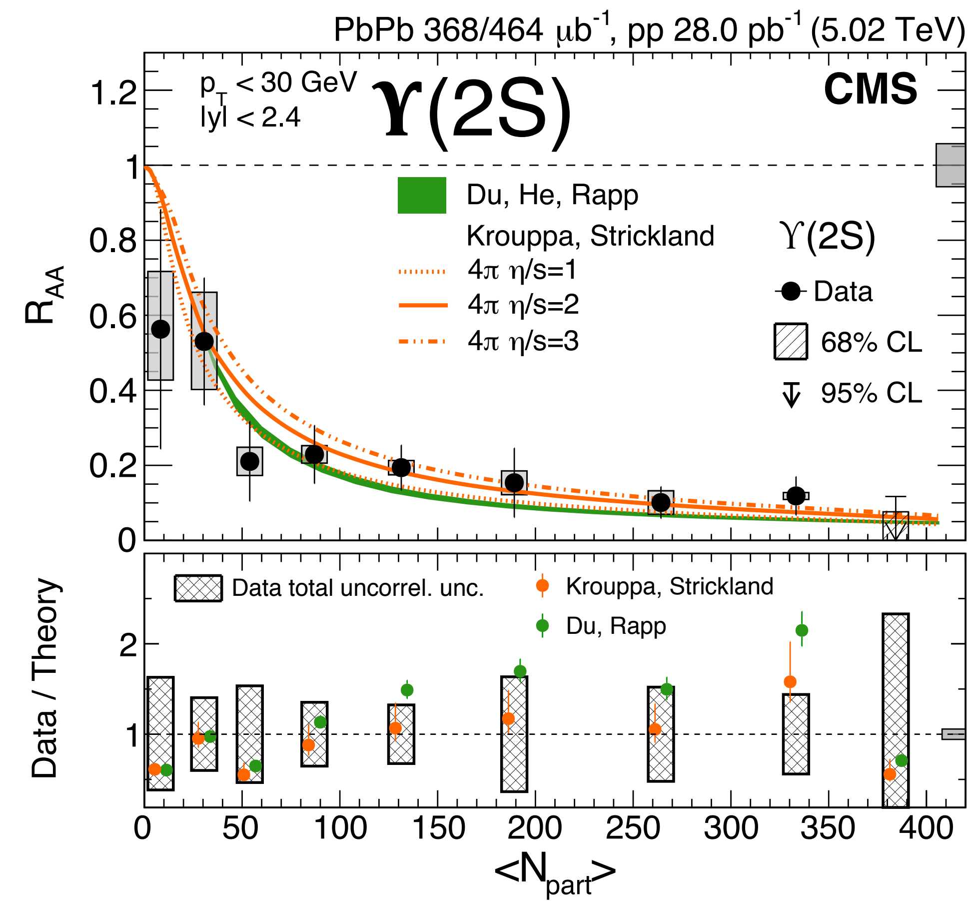
[Comparison with 2.76 TeV] R_{AA} vs p_T



- Extended high-p_T reach by 10 GeV for 5.02 TeV
- No significant p_T dependence for Y(1S) and Y(2S) in both energy
- Compatible suppression for both energies

Comparison with models at 5.02 TeV





Melting temperature →

Initial temperature →

<Krouppa & Strickland>

- **Υ(1S) : 600 MeV**
- **Υ(2S) : 230 MeV**
- **Υ(3S) : 170 MeV**
- **T_0 = {641,632,629} MeV**
- **No regeneration**

Universe 2 (2016) 16

<Du, He & Rapp>

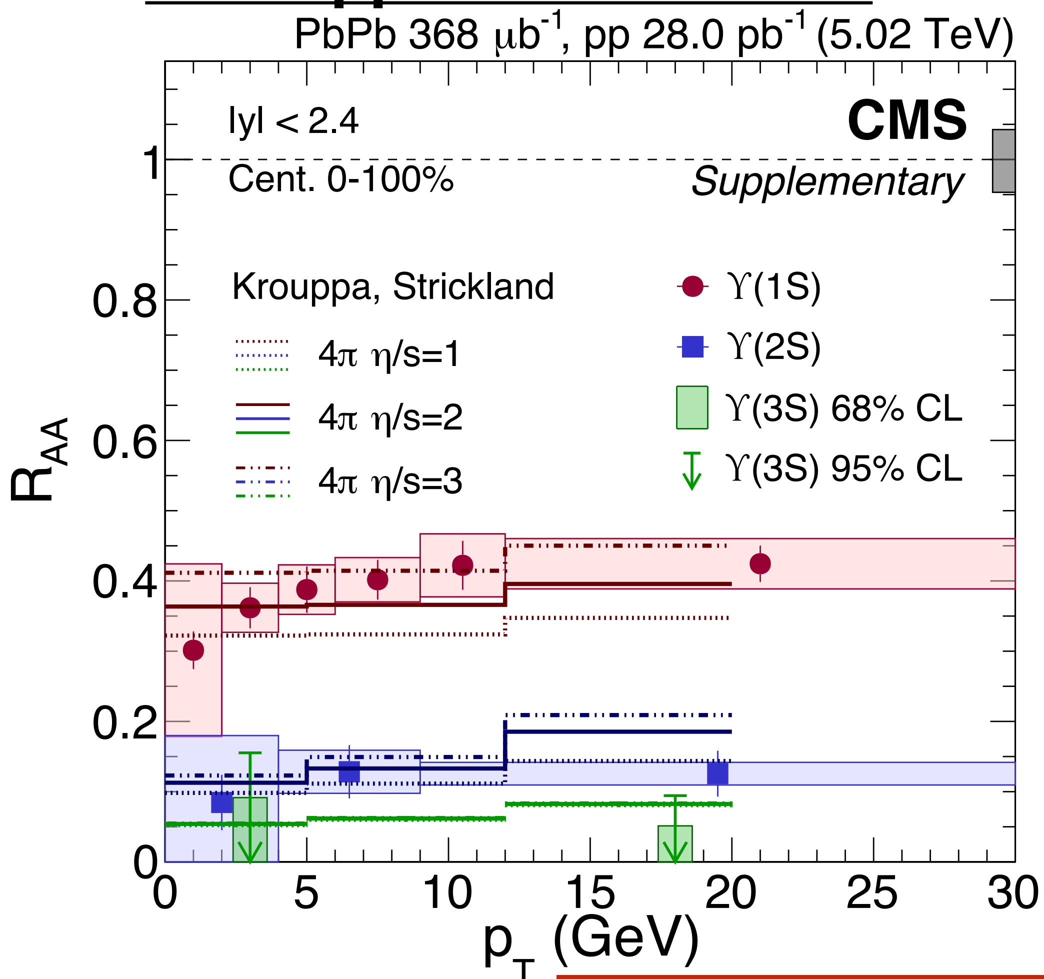
- **Υ(1S) : 500 MeV**
- **Υ(2S) : 240 MeV**
- **Υ(3S) : 190 MeV**
- **T_0= 550 - 800 MeV**
- **Regeneration included**

Phys. Rev. C 96, 054901

~67% direct production of Υ(1S) for both model

p_T dependence

<Krouppa & Strickland>



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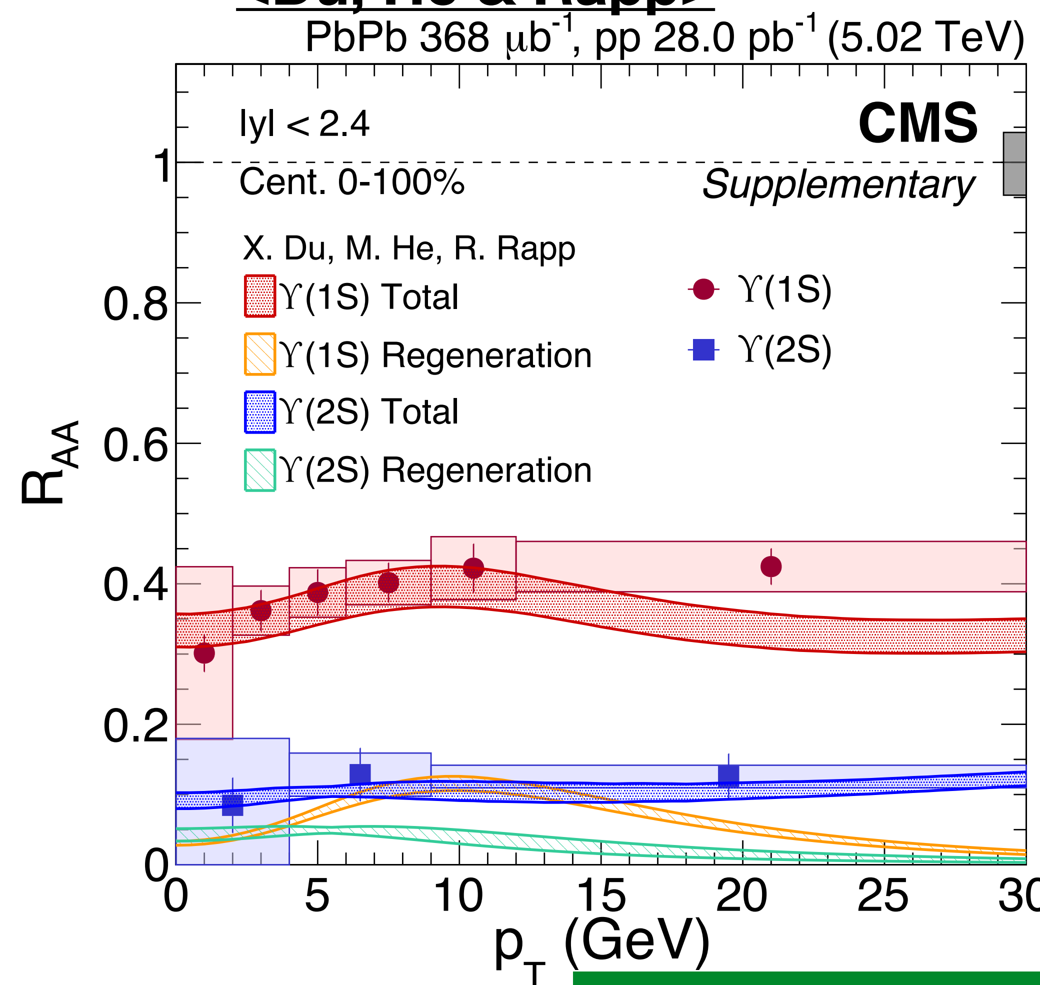


Phys. Rev. C 96, 054901

High speed upsilon can escape QGP

—> Smooth increase R_{AA} for p_T

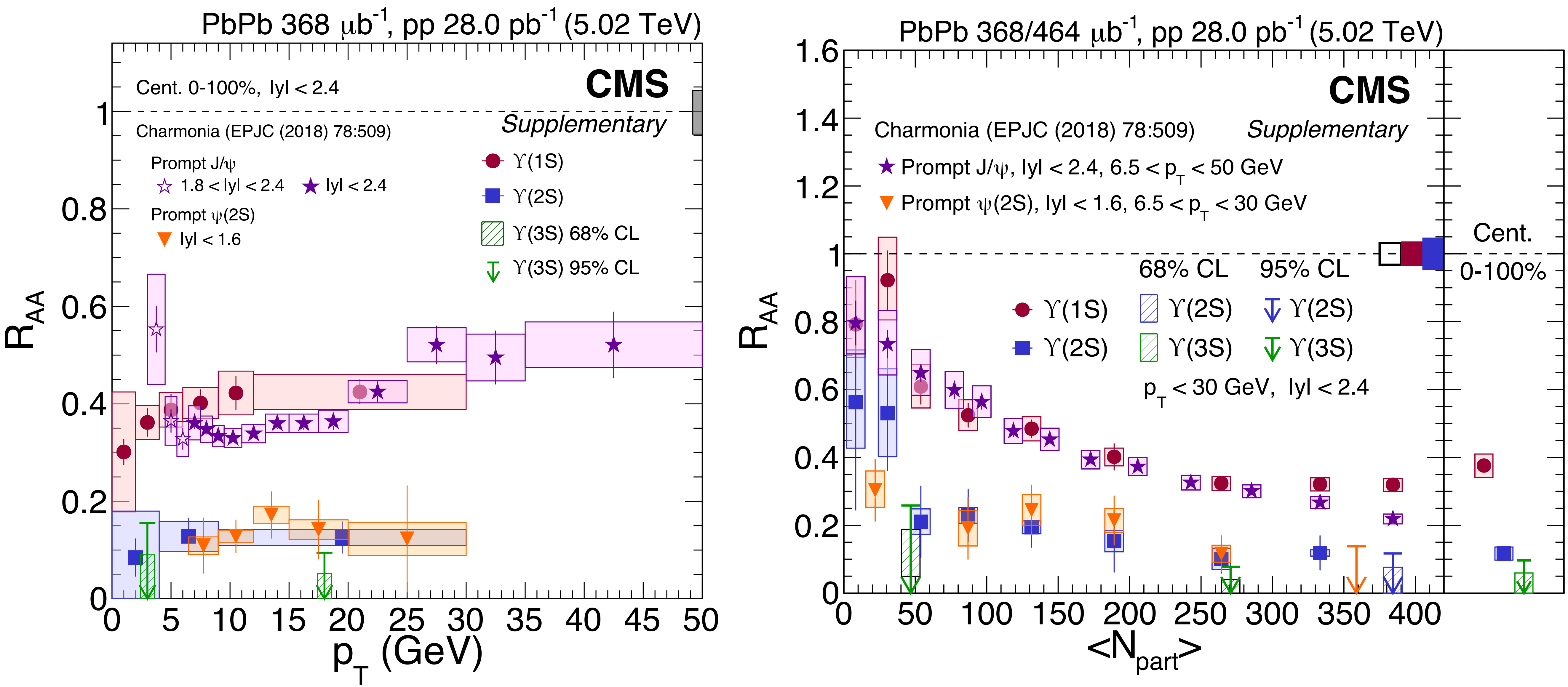
p_T dependent regeneration competes with suppression

—> Predicts broad bump near p_T =10 GeV

Yet, both models are compatible with data within statistical uncertainty.

Have to check high p_T > 20 GeV —> Need more data

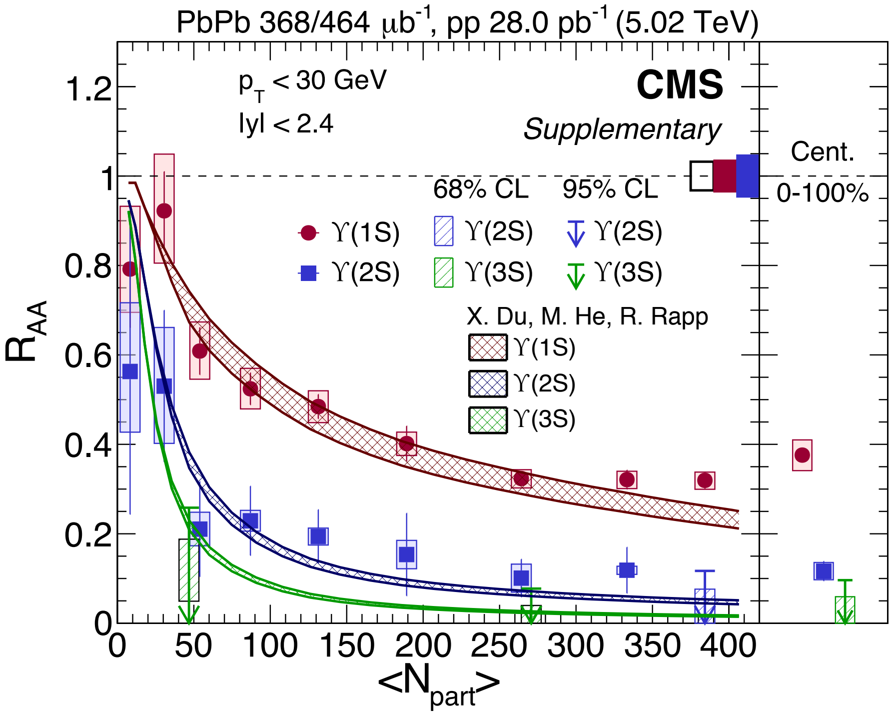
Comparison with Charmonia results

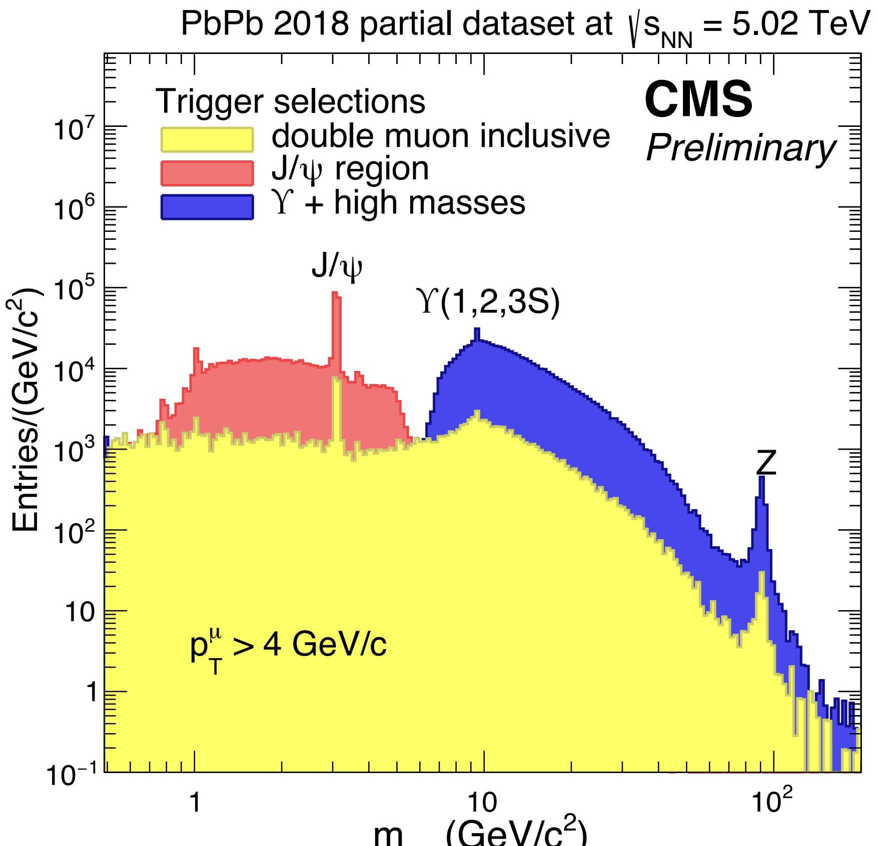


- Very similar behavior between Charmonia and Bottomonia
  - **ϒ**(1S) aligns with J/psi(1S)
  - **ϒ**(2S) aligns with psi(2S)
- Any geometrical indication?

Remarks and plan

- R_{AA} of Υ(1S), Υ(2S) and Υ(3S) were measured as a function of p_T, rapidity and centrality, improving the previous results at 2.76 TeV
  - Consistent with 2.76 TeV data within uncertainty (Models predicted -16%)
  - Clearer dependence on centrality, yet we need more data for peripheral collisions to find the turn-on curve of R_{AA}
- The Υ(3S) peak is not visible yet
- Compatible with both two different models
  - p_T dependence study with higher statistics may help to resolve
- New data with **~4 times** more statistics was taken in 2018. It will lead us to much more interesting physics, so stay tuned!

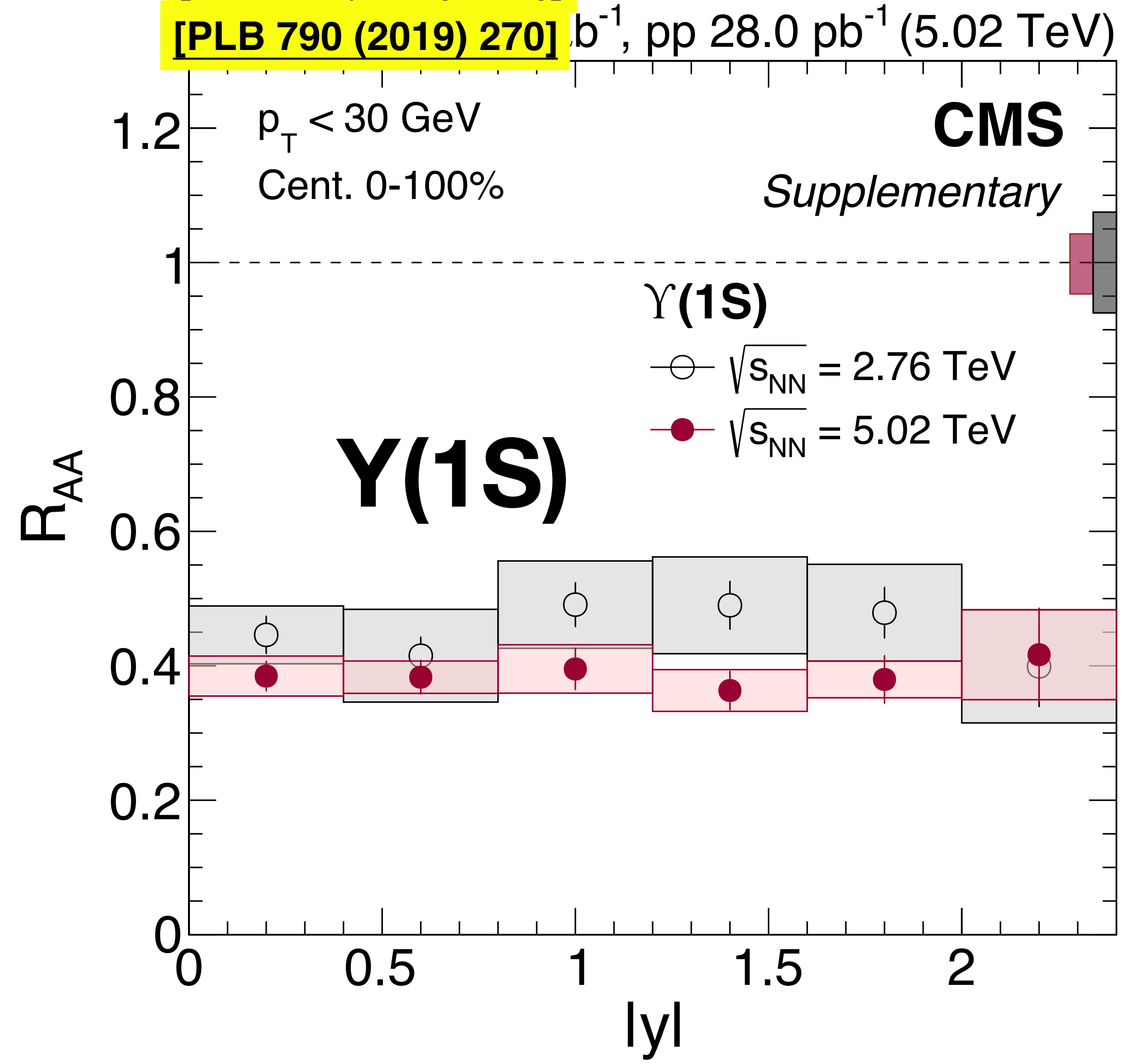


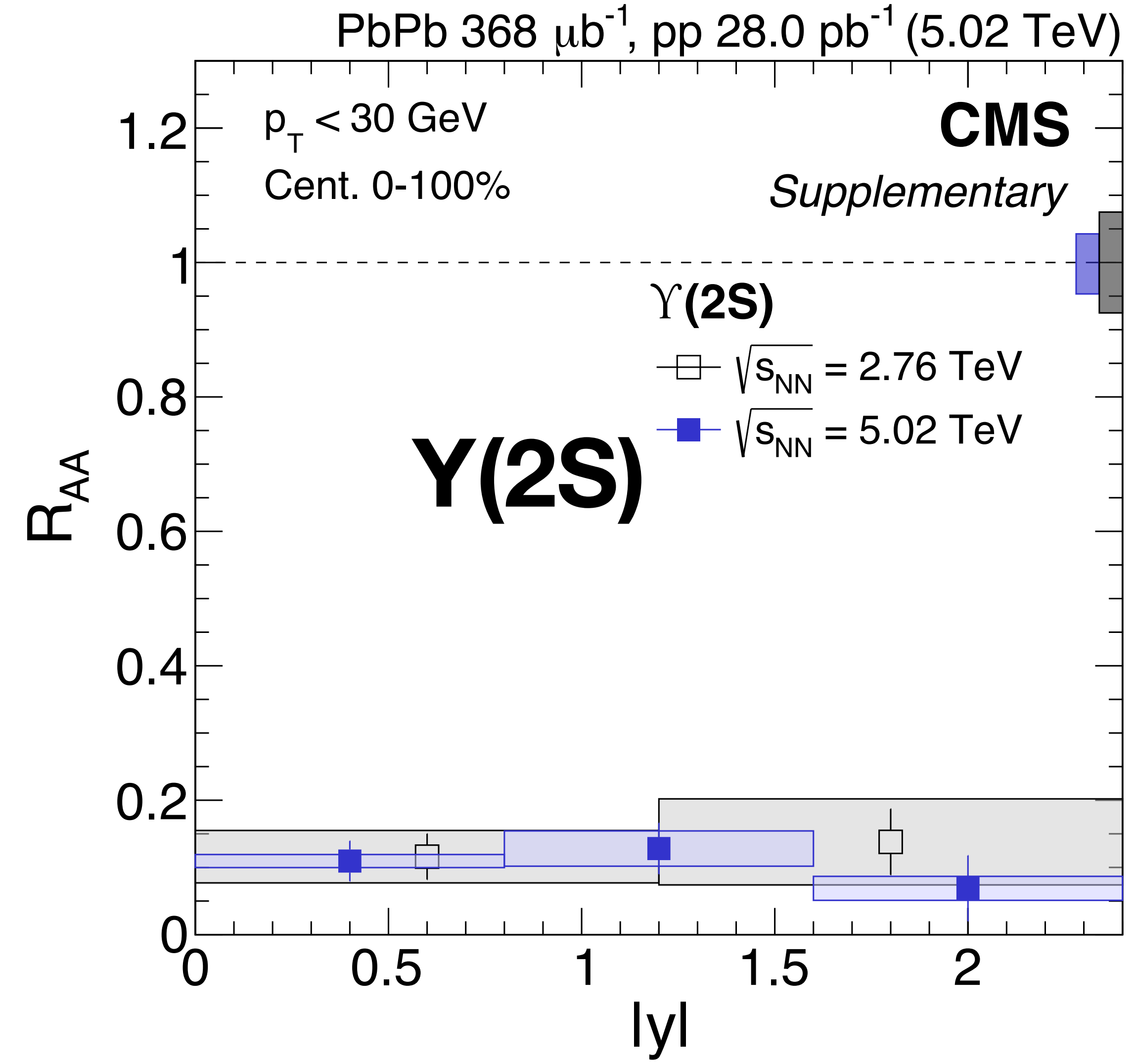


BACKUP

Comparison with 2.76 TeV

[PLB 770, 357(2017)]
[PLB 790 (2019) 270]





- No dependence on rapidity