

# CMS bottomonia results in pp, pPb and PbPb at 2.76 TeV and 5.02 TeV

**Yongsun Kim (金容仙)**

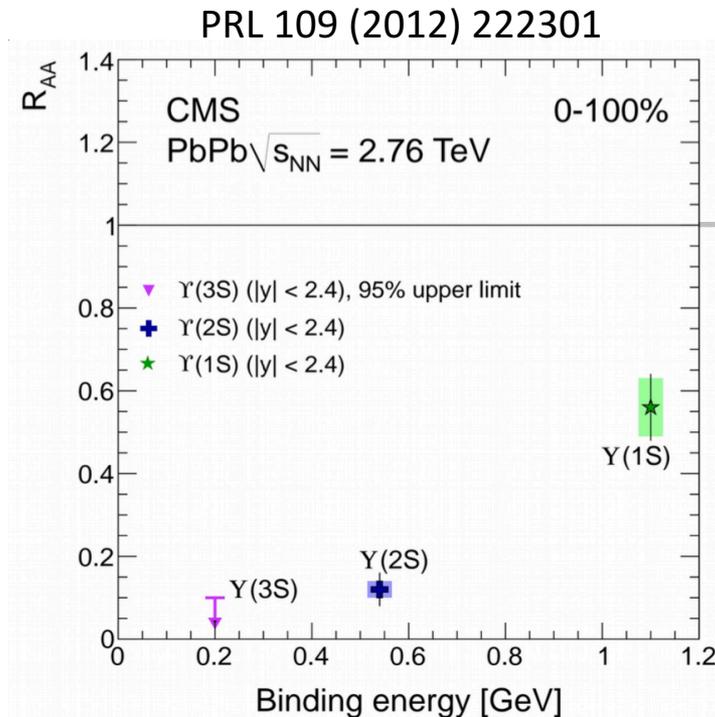
Korea University

On behalf of CMS collaboration

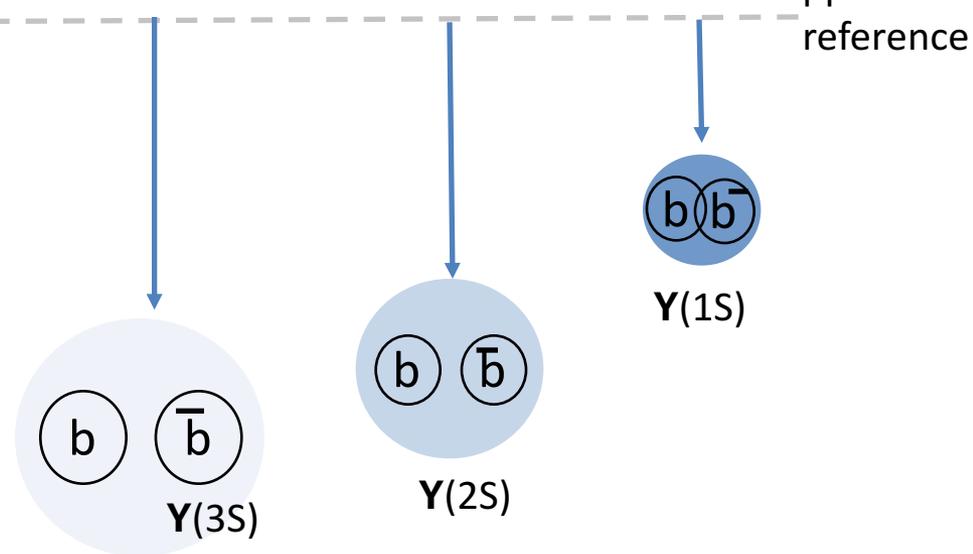
HardProbes, Wuhan, 2016.09.25



# Introduction

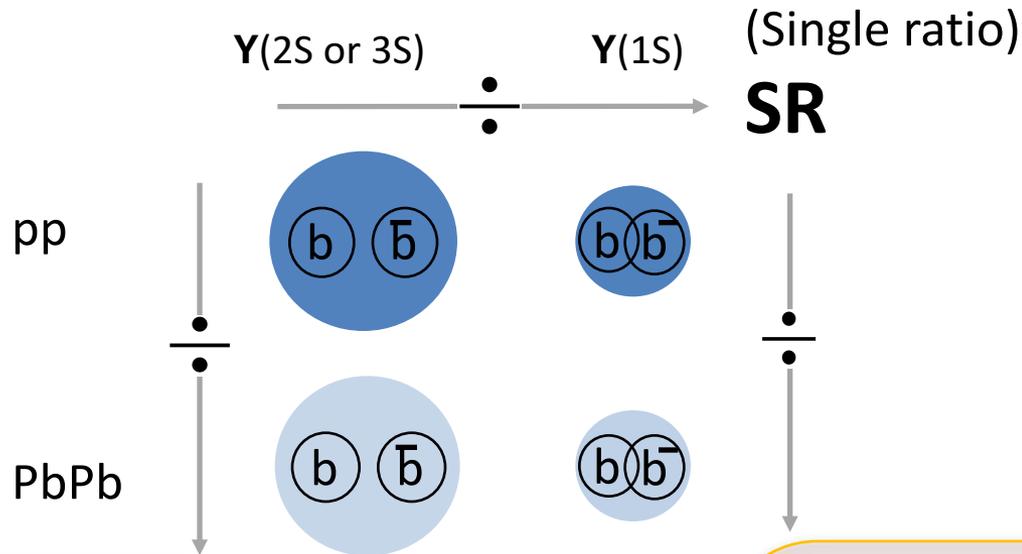


More tightly bound  $\rightarrow$  less suppressed



- **Upsilon** mesons provide evidence for quarkonia melting that is sequential w.r.t. binding energy by color charge screening
- This presentation reviews the recent observation of upsilon state modifications in pPb and PbPb collisions
- **New results** of 5.02 TeV PbPb and pp in Nov/Dec 2015

# $R_{AA}$ and Double Ratio as observables



**$R_{AA}$**

- Best constraints for theoretical models
- Several sources of experimental uncertainties exist

**DR**

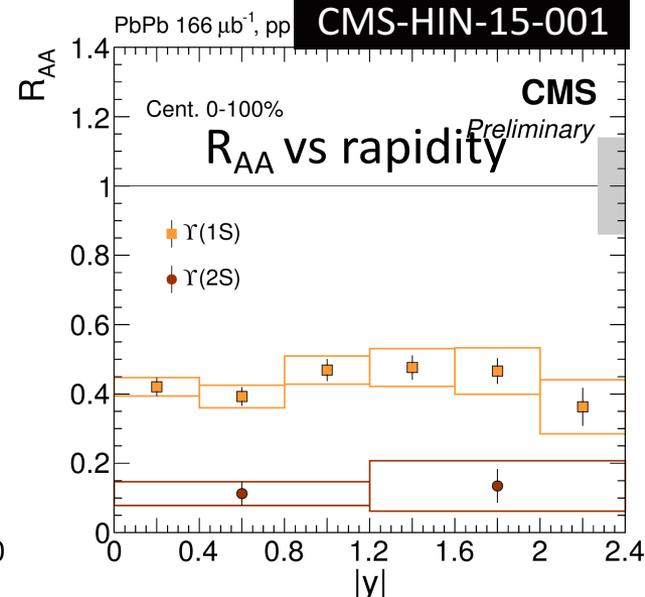
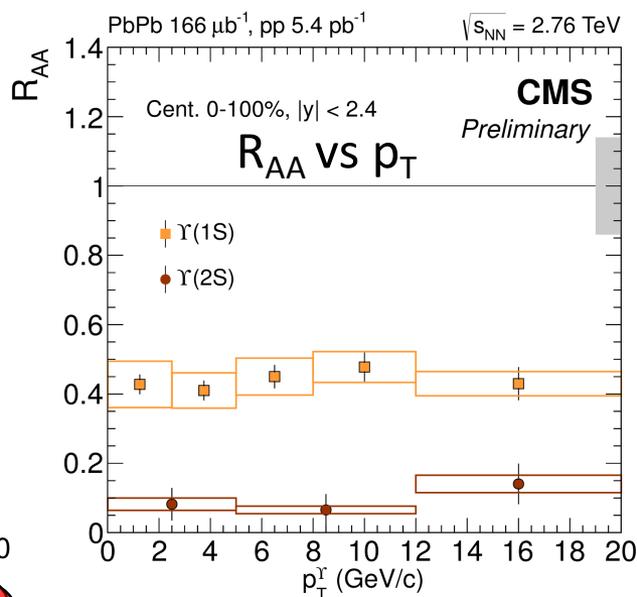
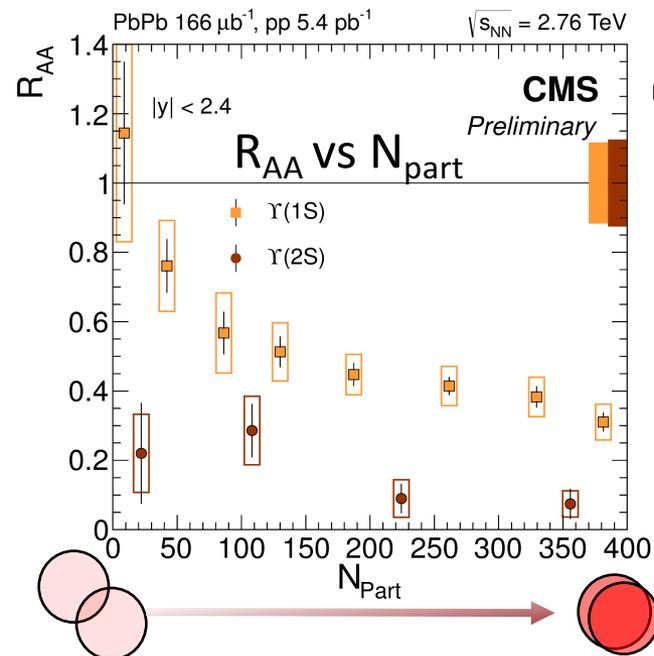
(double ratio)

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

- Isolates the final state effects from production mechanism
- Precision measurement for very few corrections beyond signal counting

# $Y(nS) R_{AA}$ at 2.76 TeV

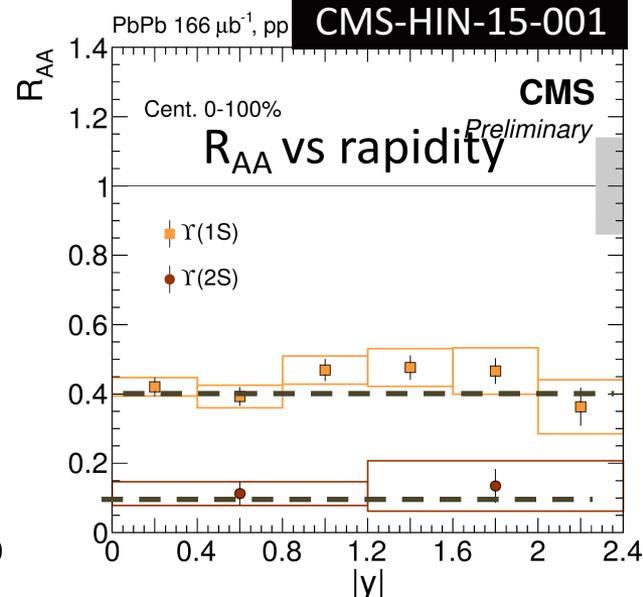
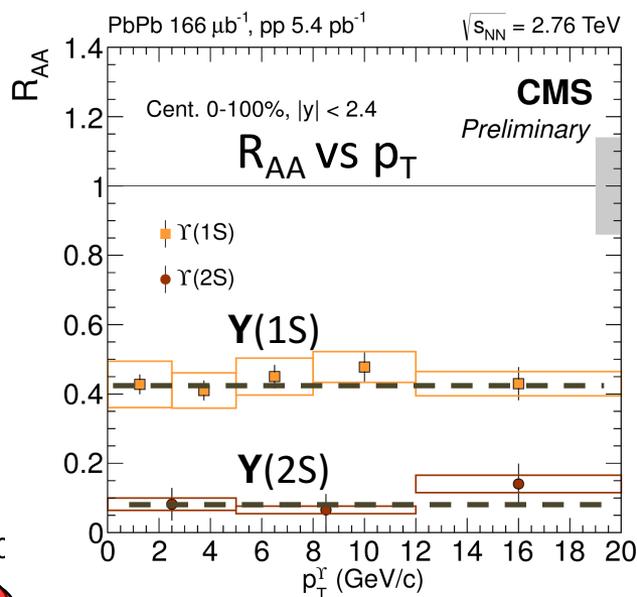
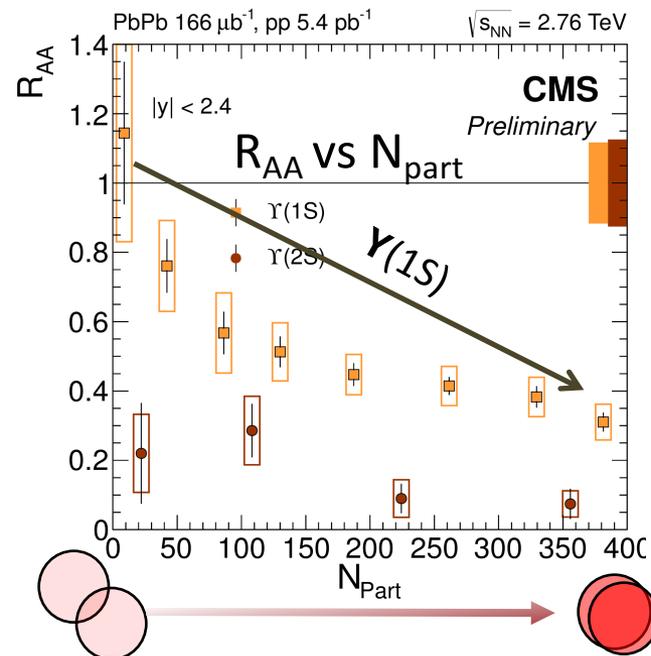
## 2.76 TeV



- $Y(1S)$  shows gradual centrality dependence
- $Y(2S)$  largely suppressed at all centralities
- Both  $R_{AA}$  are flat over  $|y| < 2.4$  and  $p_T < 20 \text{ GeV}/c$
- $Y(3S)$  not observed  $\rightarrow R_{AA}(3S) < 0.14$  at 95% confidence level

# $Y(nS) R_{AA}$ at 2.76 TeV

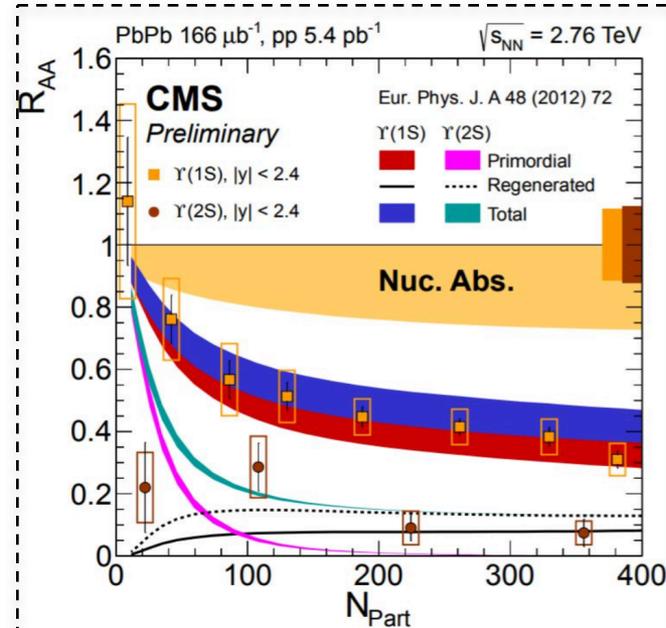
## 2.76 TeV



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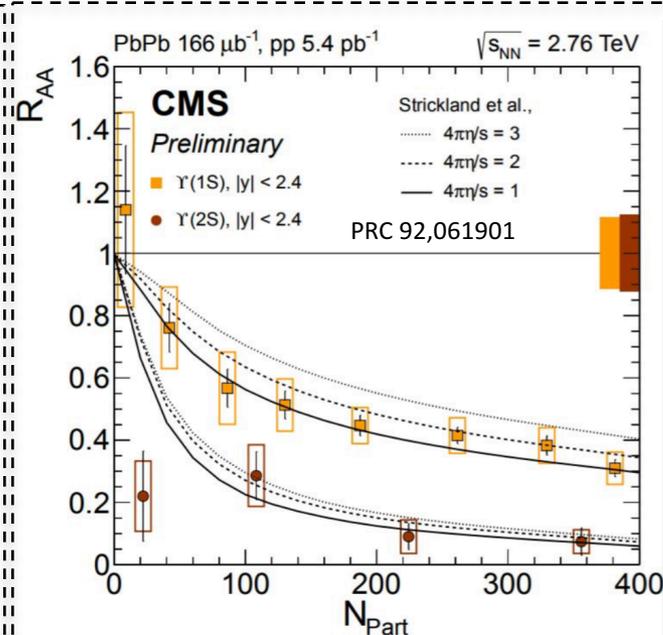
# $Y(nS) R_{AA}$ comparison with models

## 2.76 TeV



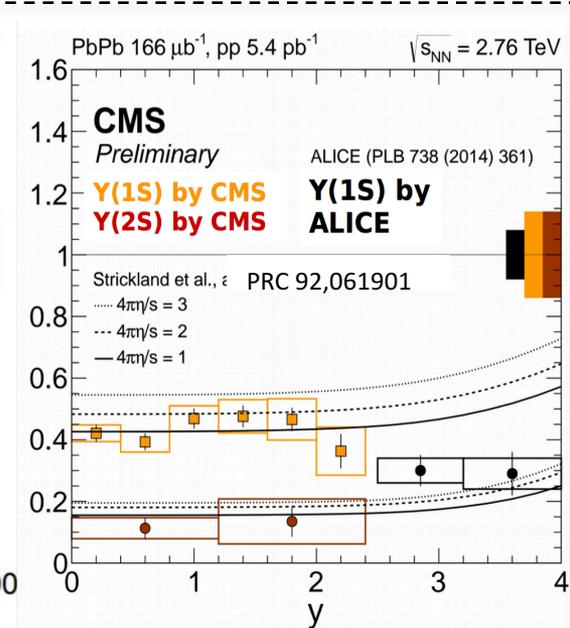
### Kinetic Theory Model

- Initial temperature  $\sim 600 \text{ MeV}$
- Most of  $Y(2S)$  in PbPb are produced by **regeneration**

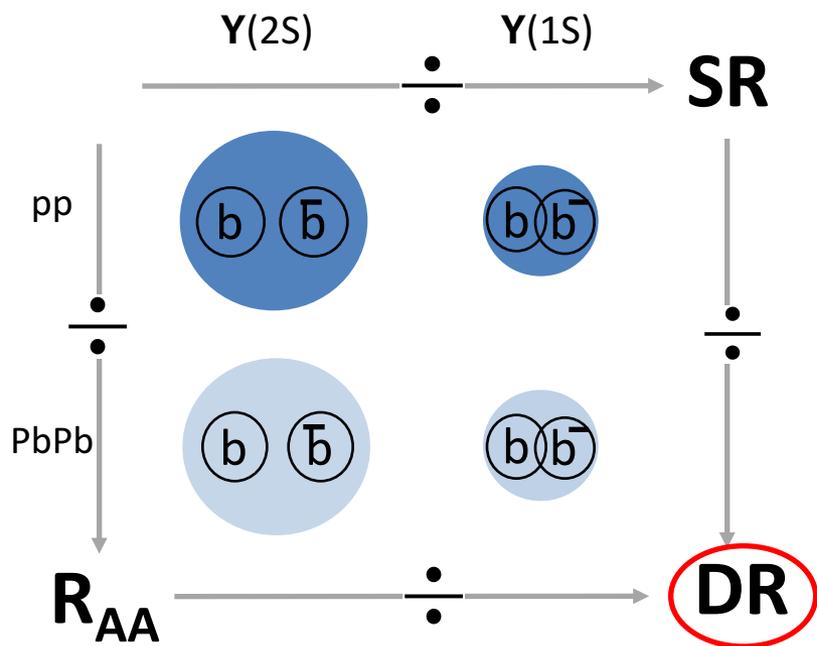


### Hydrodynamics model

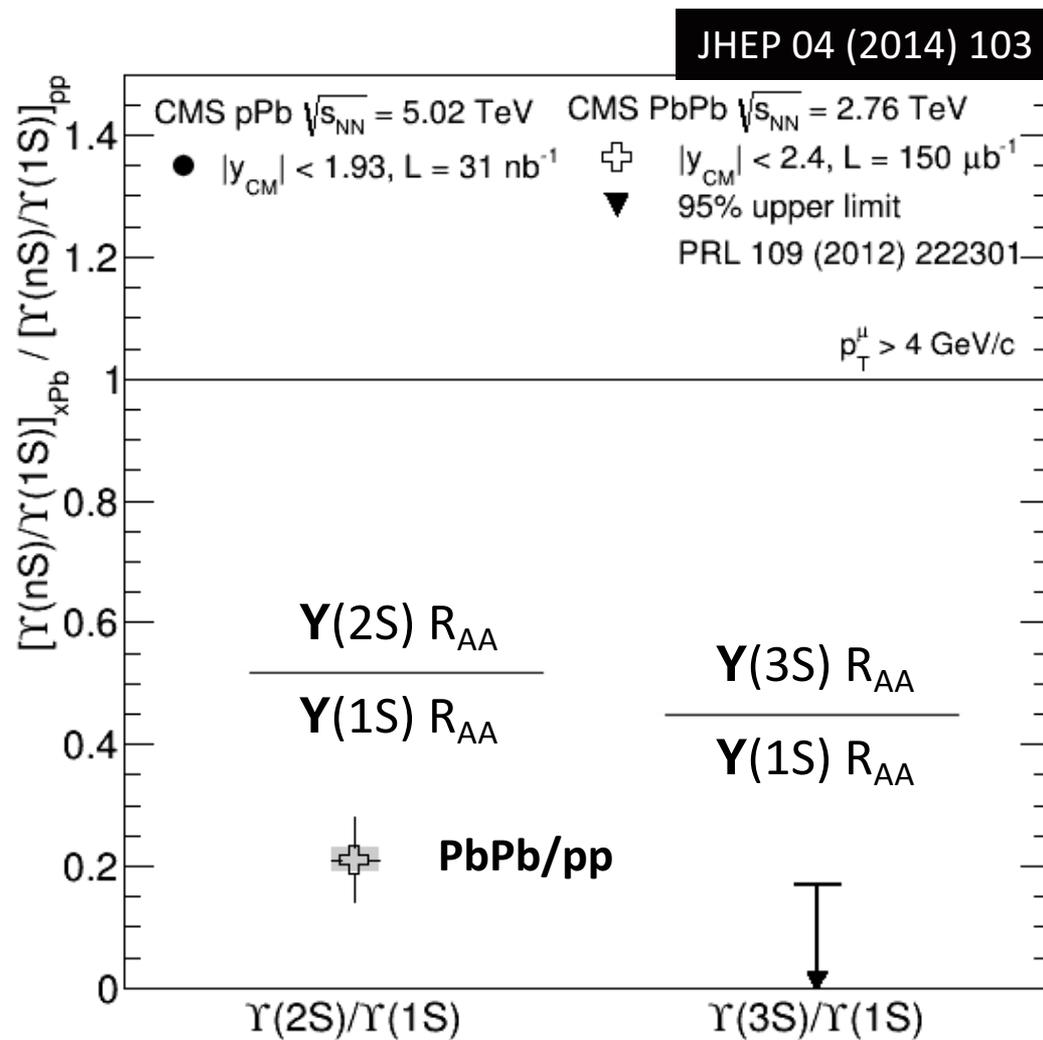
- Thermal parameters are constrained by data
- Agrees well with CMS data, but deviation from ALICE result at forward



# Y(2S) double ratio in PbPb

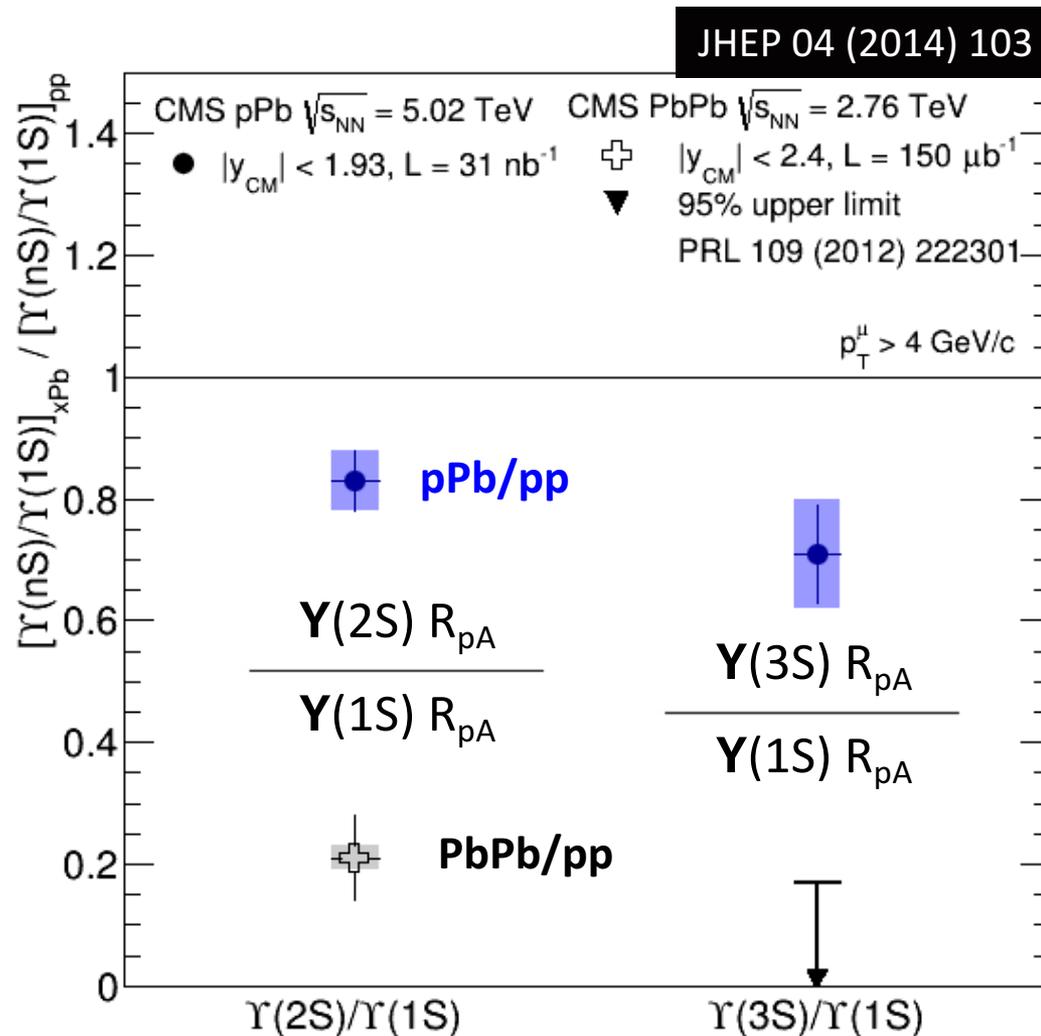


Double ratio of PbPb  
at 2.76TeV



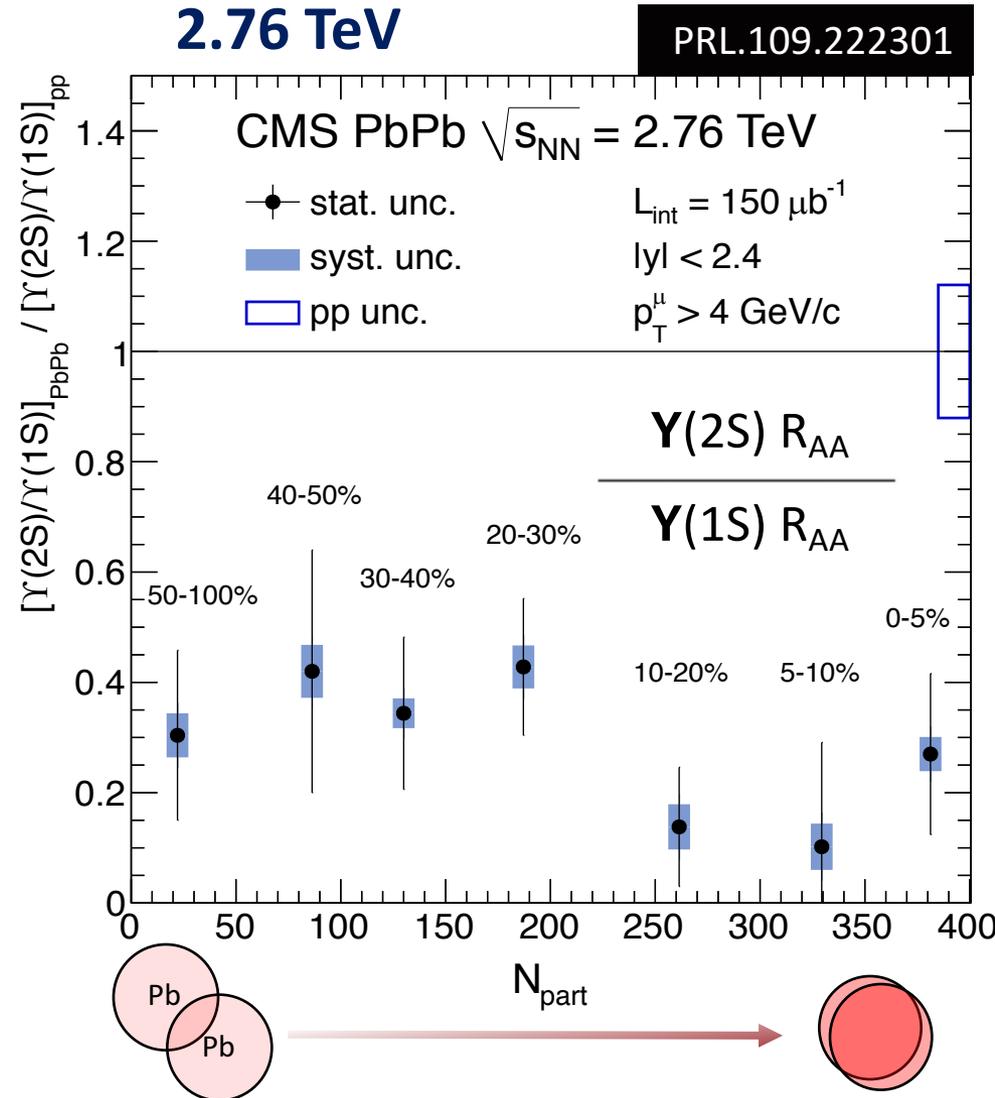
# Y(2S) double ratio in pPb

- pPb serves as cold nuclear baseline
- Drop of double ratios observed in pPb
  - less than PbPb but in the analogous manner
- Indicates final state effects from cold nuclear matter



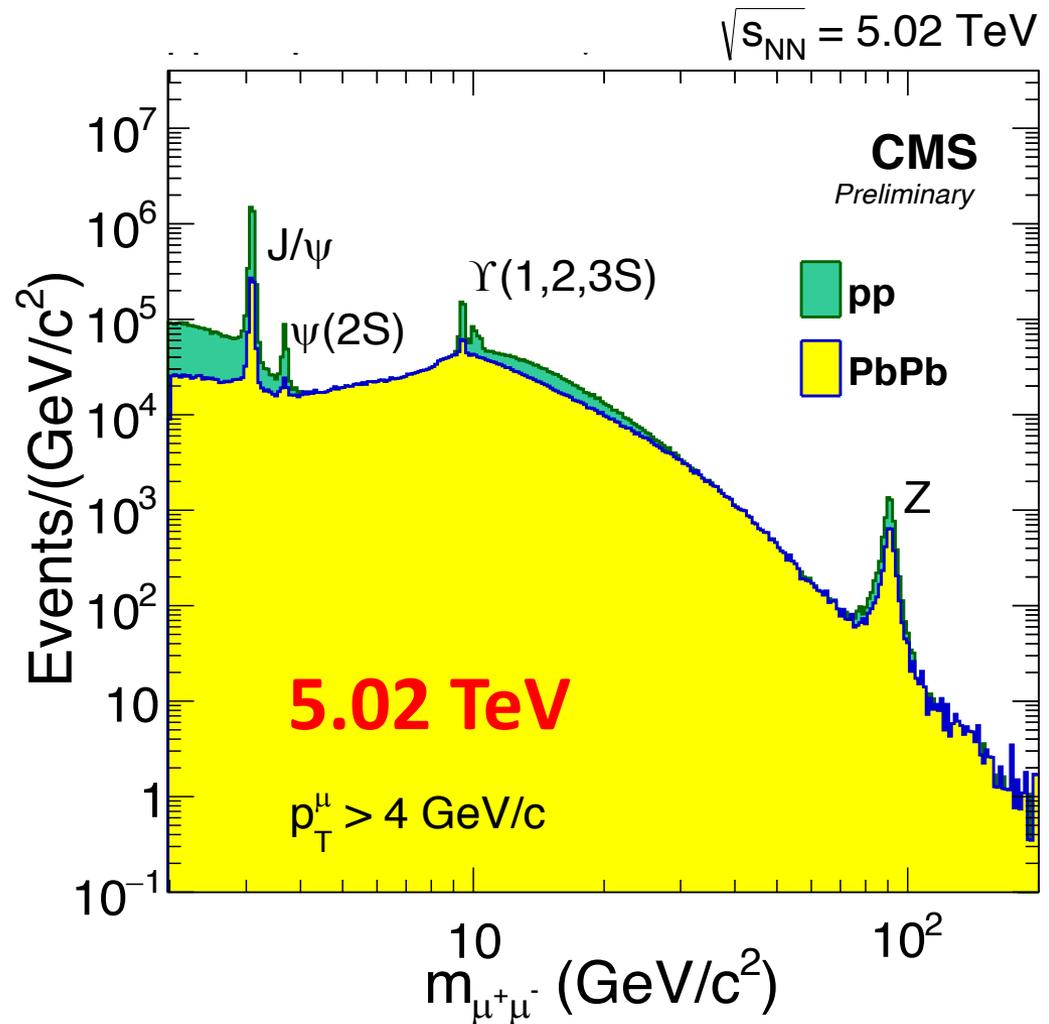
# Leftover Questions from 2.76 TeV PbPb

- At 2.76 TeV,  $Y(2S)$  is more suppressed than  $Y(1S)$  at all centralities
- Did it miss centrality dependence?
- Will DR approach unity at peripheral extremum?
- Maybe the **new data at 5.02 TeV** can be the answer!



# 5.02 TeV Data from 2015 Run

- **PbPb** and **pp** data collected in Nov, Dec 2015 **@5.02 TeV**
- Double muon trigger implemented at L1 (hardware based algorithm)
- pp luminosity  $\sim 26\text{pb}^{-1}$
- PbPb had two datasets
  - $350\ \mu\text{b}^{-1}$  for 0-30% interval
  - $460\ \mu\text{b}^{-1}$  for other intervals
- $\sim 3$  times more upsilons collected than from 2.76TeV

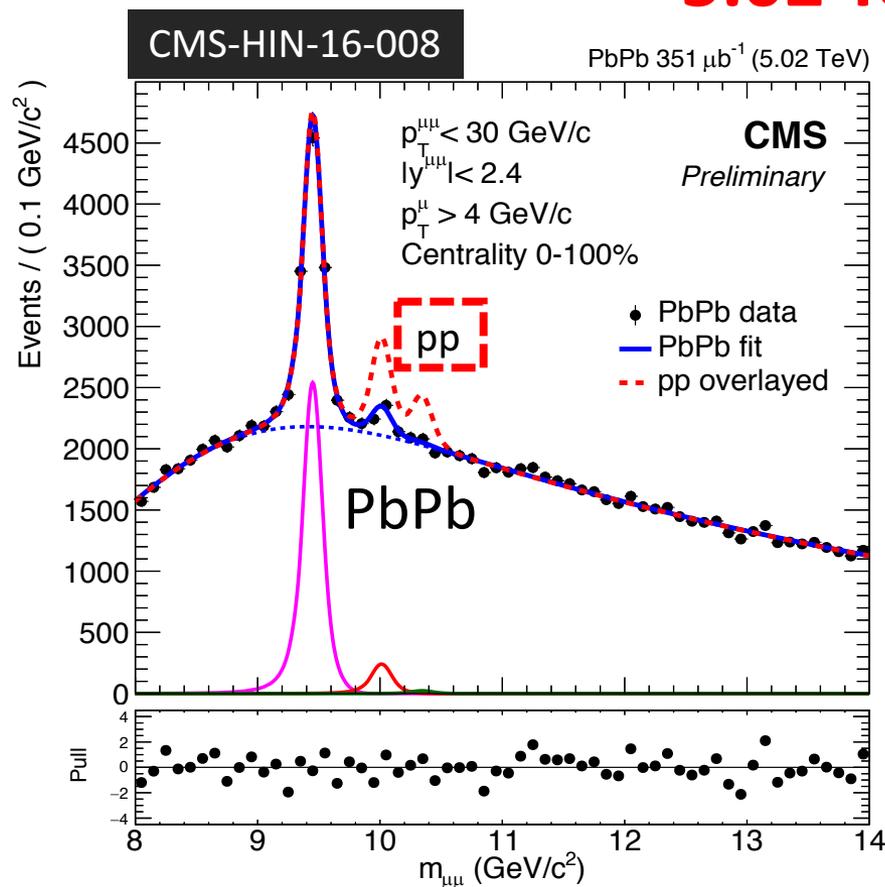
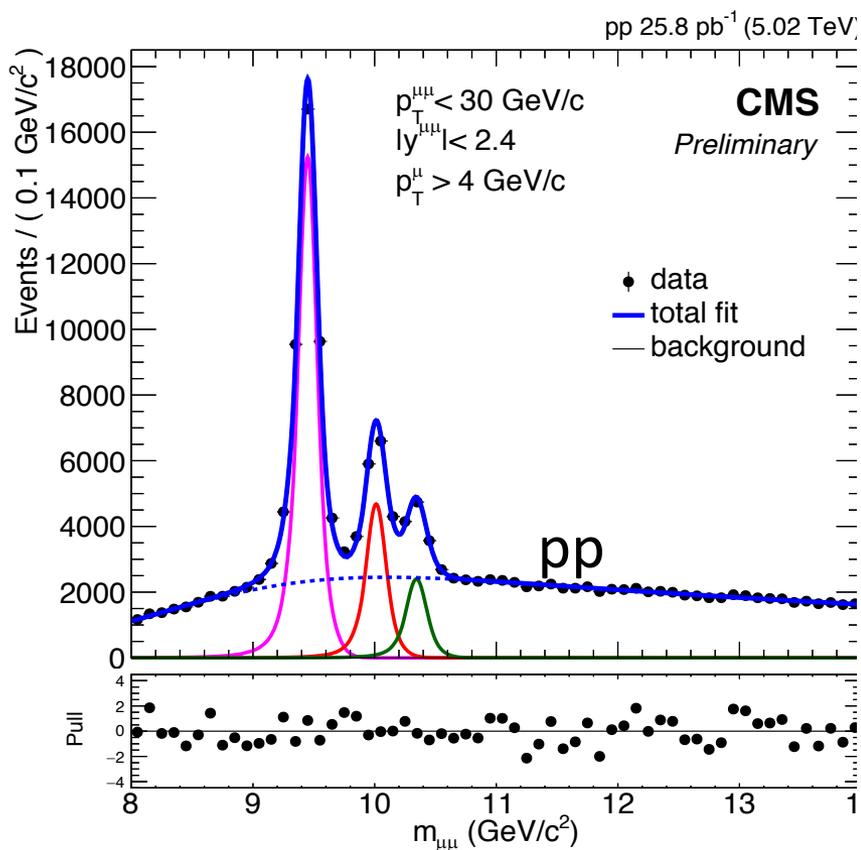


# New result at 5.02 TeV!



5.02 TeV

- $Y(1S)$  in pp collisions (red dashed line) normalized to PbPb  $Y(1S)$
- Discrepancy in  $Y(2S)$ ,  $Y(3S)$  graphically illustrates the definition of DR
- $Y(3S)$  in PbPb consistent with zero!



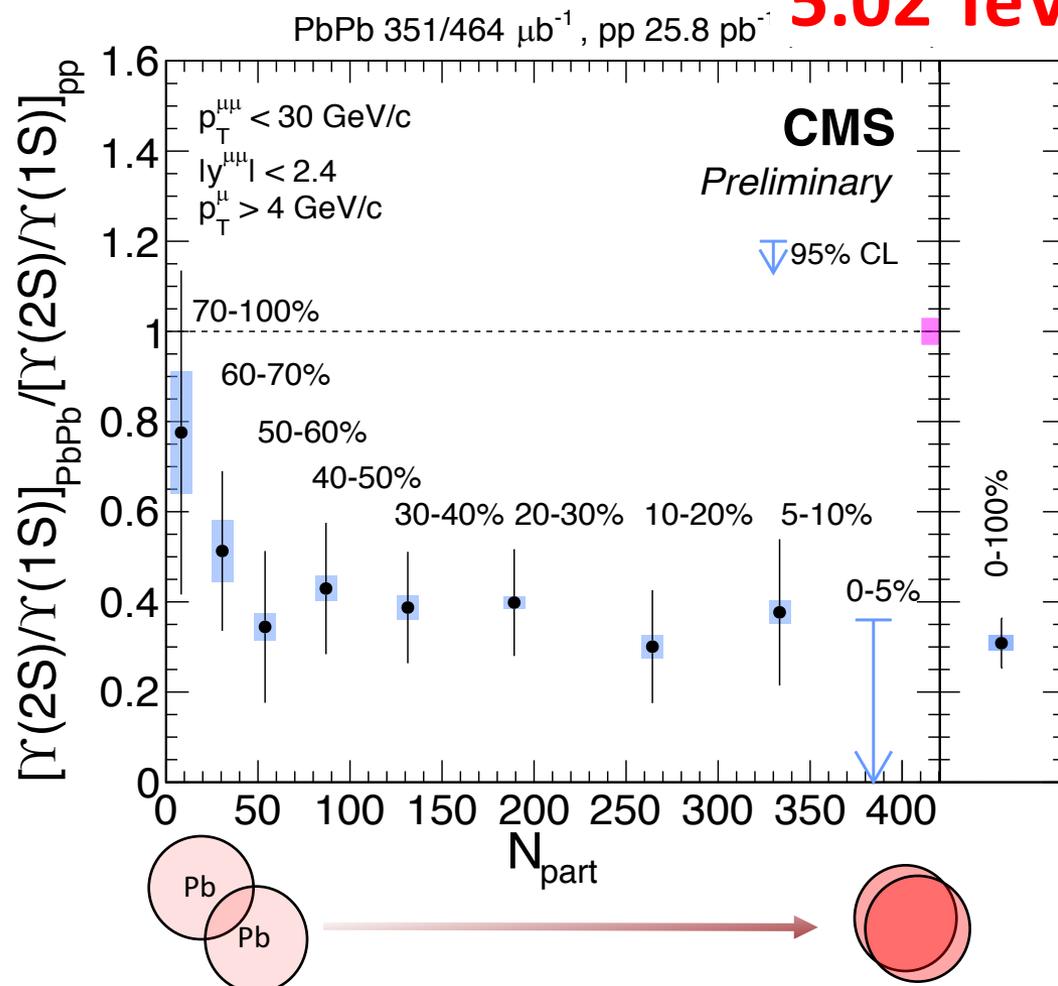
# Y(2S) double ratio vs centrality

$$\frac{Y(2S) R_{AA}}{Y(1S) R_{AA}} \text{ is } 0.308 \pm 0.055(\text{stat}) \pm 0.017(\text{syst})$$

CMS-HIN-16-008



5.02 TeV



# Y(2S) double ratio vs centrality

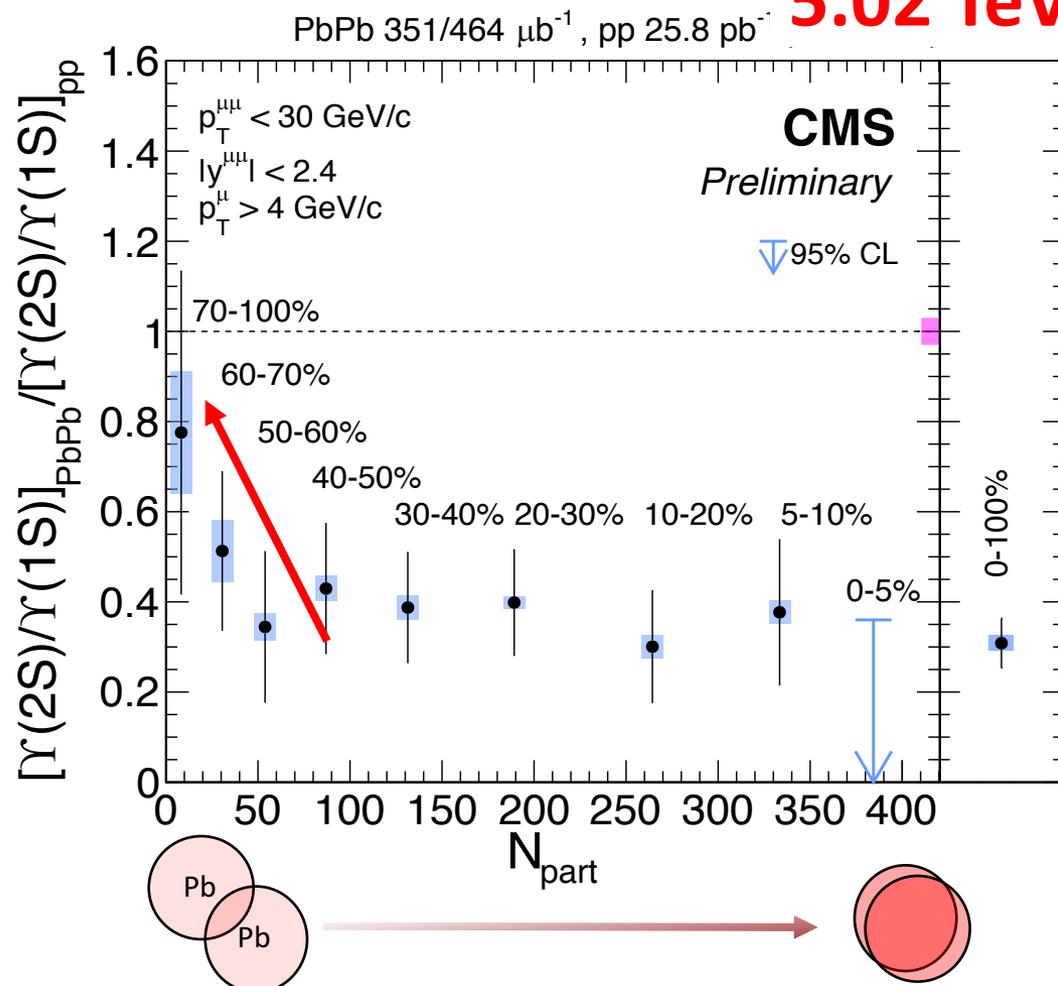
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CMS-HIN-16-008



5.02 TeV

- DR approaches to unity in the most peripheral bins



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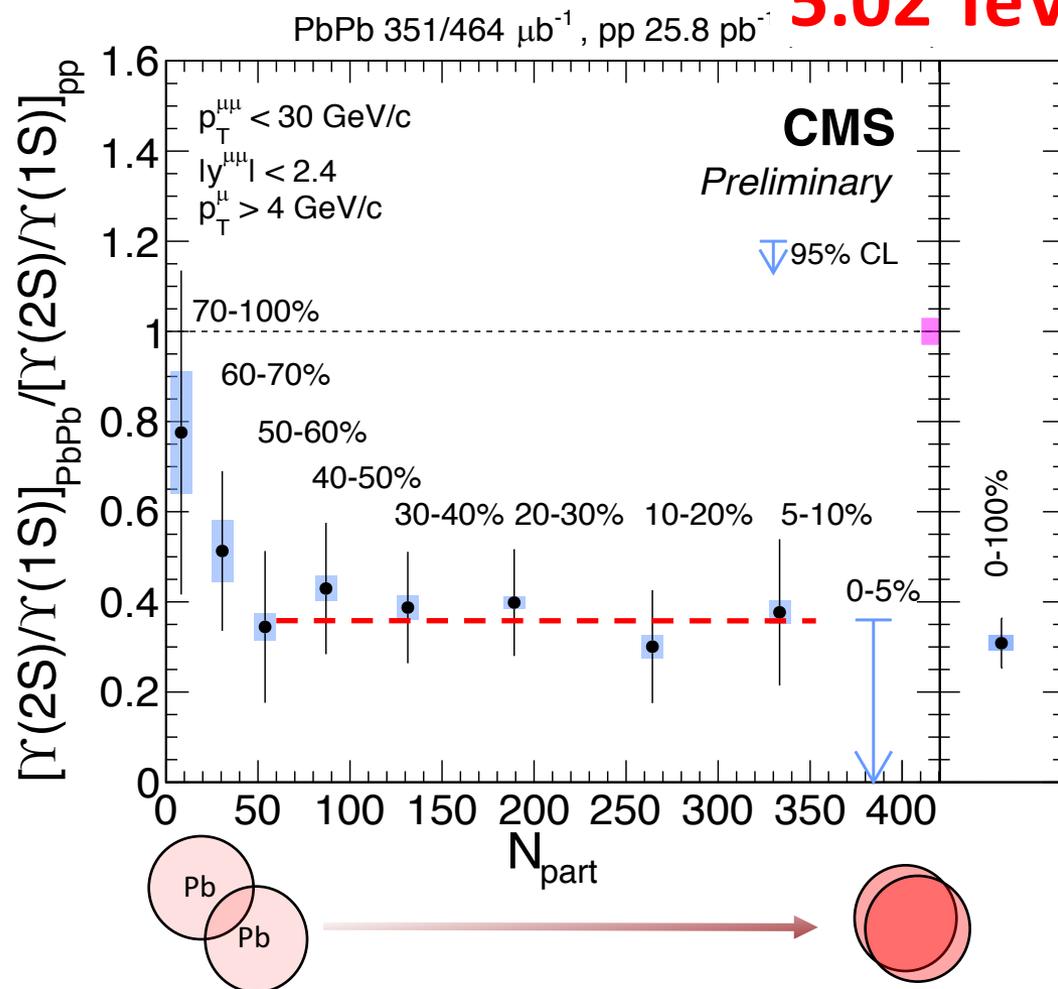
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CMS-HIN-16-008



5.02 TeV

- DR approaches to unity in the most peripheral bins
- Relatively flat across mid-central events



# Y(2S) double ratio vs centrality

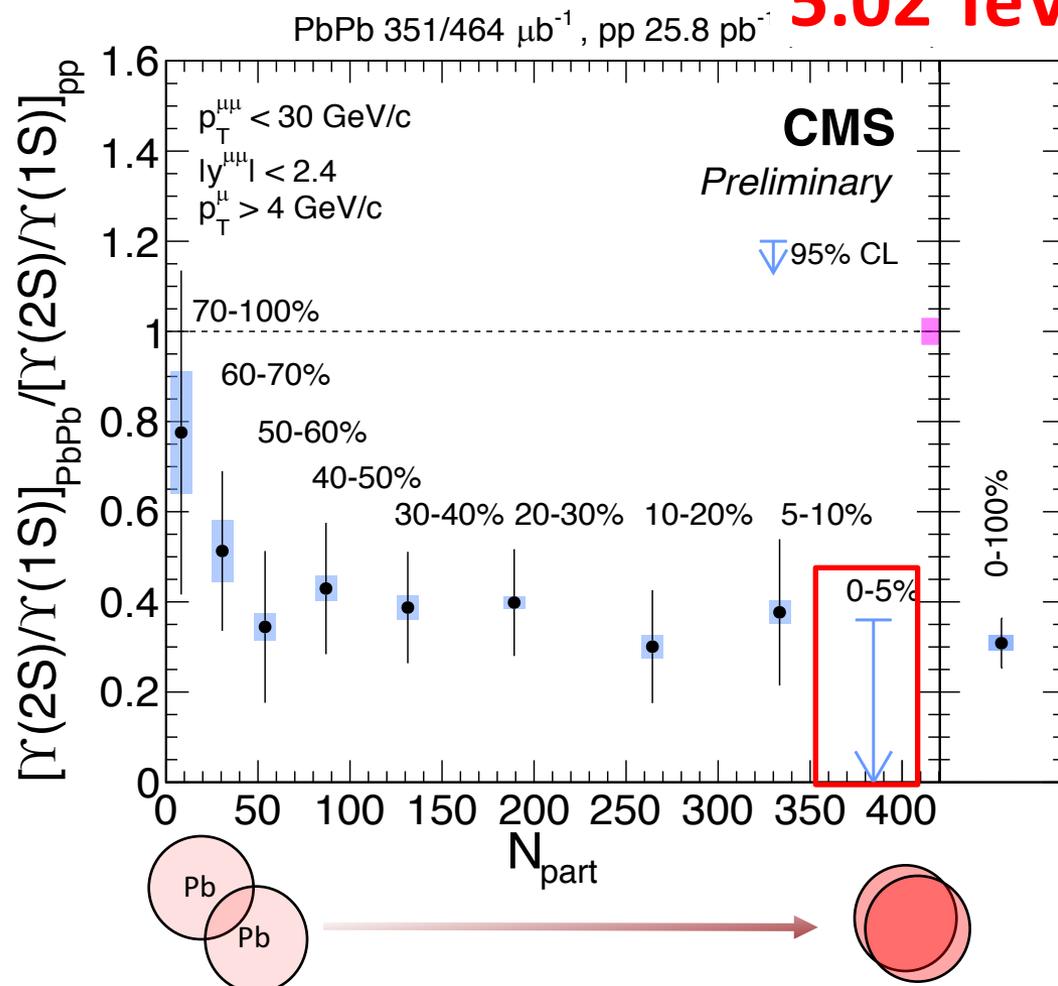
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CMS-HIN-16-008



5.02 TeV

- DR approaches to unity in the most peripheral bins
- Relatively flat across mid-central events
- In 0-5% bin, **Y(2S) signal is consistent to zero as well as Y(3S)**



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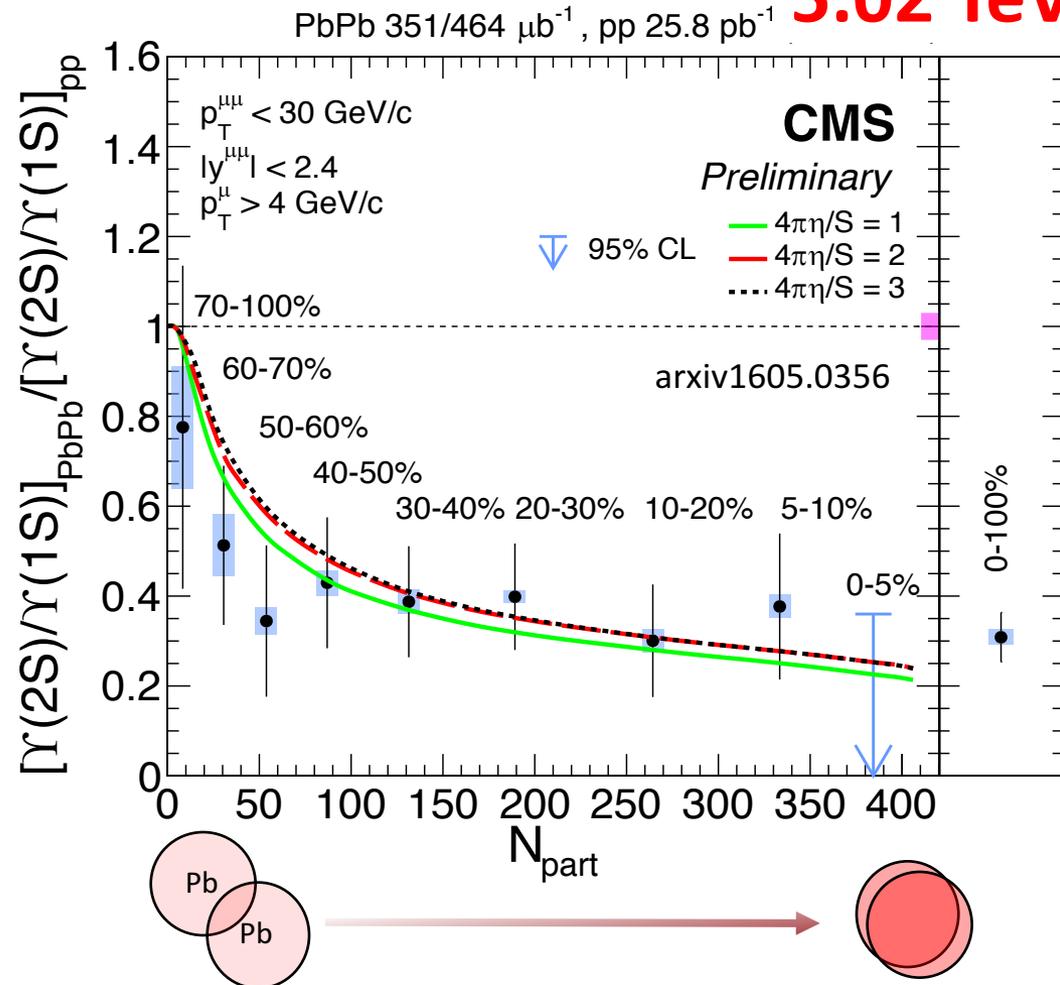
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CMS-HIN-16-008



5.02 TeV

- DR approaches to unity in the most peripheral bins
- Relatively flat across mid-central events
- In 0-5% bin, **Y(2S) signal is consistent to zero as well as Y(3S)**
- Theory curves use hydrodynamics and lattice-based potential
  - Obtained from the ratio of  $R_{AA}$  predictions of Y(1S) and Y(2S) in [Krouppa and Strickland]



# Y(3S) double ratio vs centrality

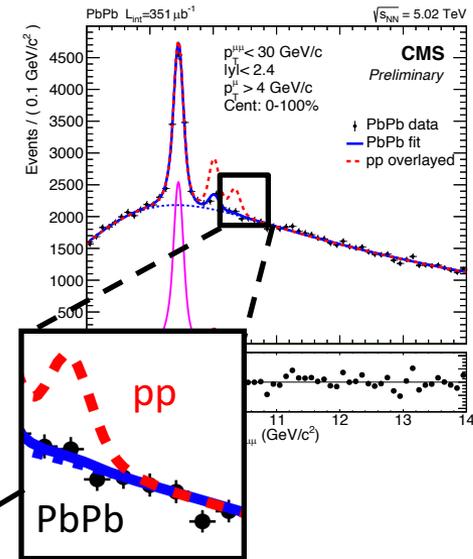
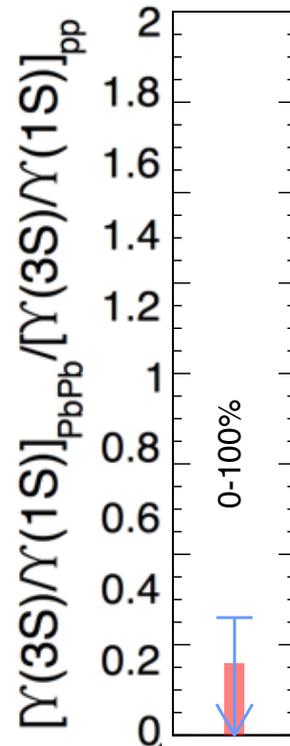


5.02 TeV

- Y(3S) is very small in all centrality bins → upper limits reported
- Arrows are 95% CL and boxes are 68% CL

Needed to inspect through centrality bins

Slide to unlock ←



Y(3S) not observed in centrality-integrated bin

CMS-HIN-16-008

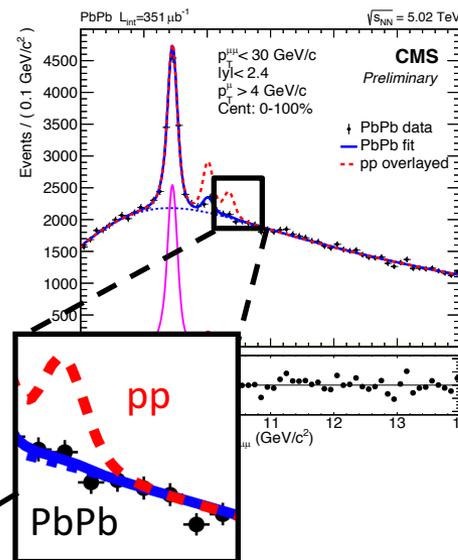
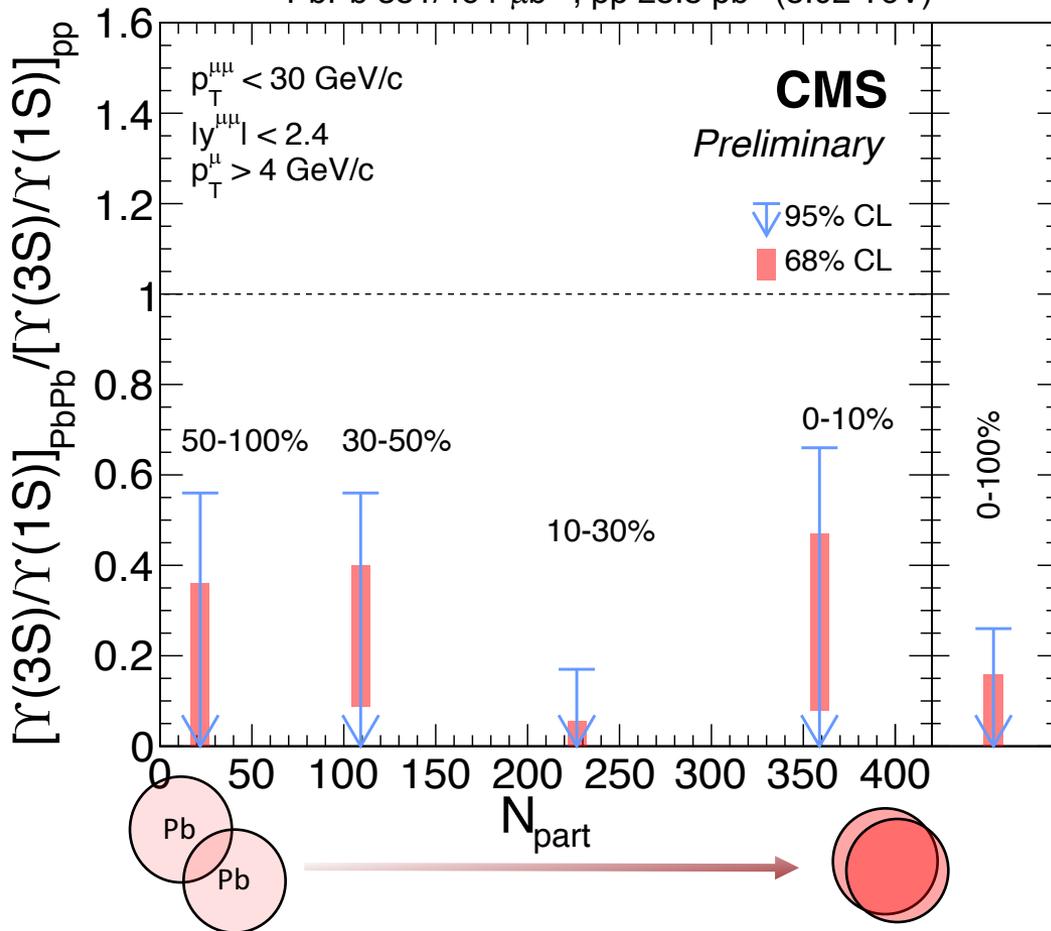
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5.02 TeV

PbPb 351/464  $\mu\text{b}^{-1}$ , pp 25.8  $\text{pb}^{-1}$  (5.02 TeV)



Y(3S) not observed in centrality-integrated bin

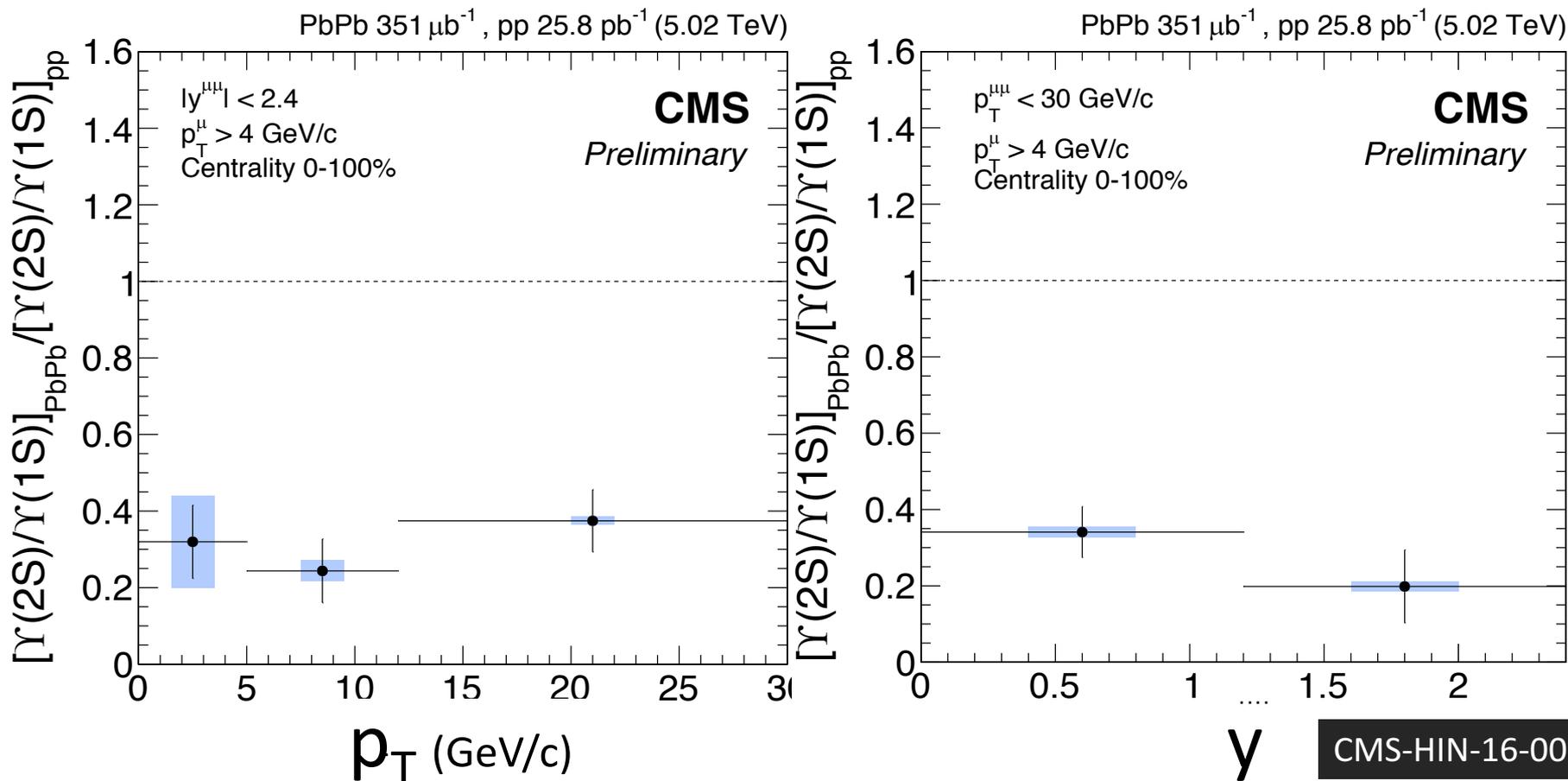
CMS-HIN-16-008

# Double ratio of $\Upsilon(2S)$ in $p_T$ and $y$ bins

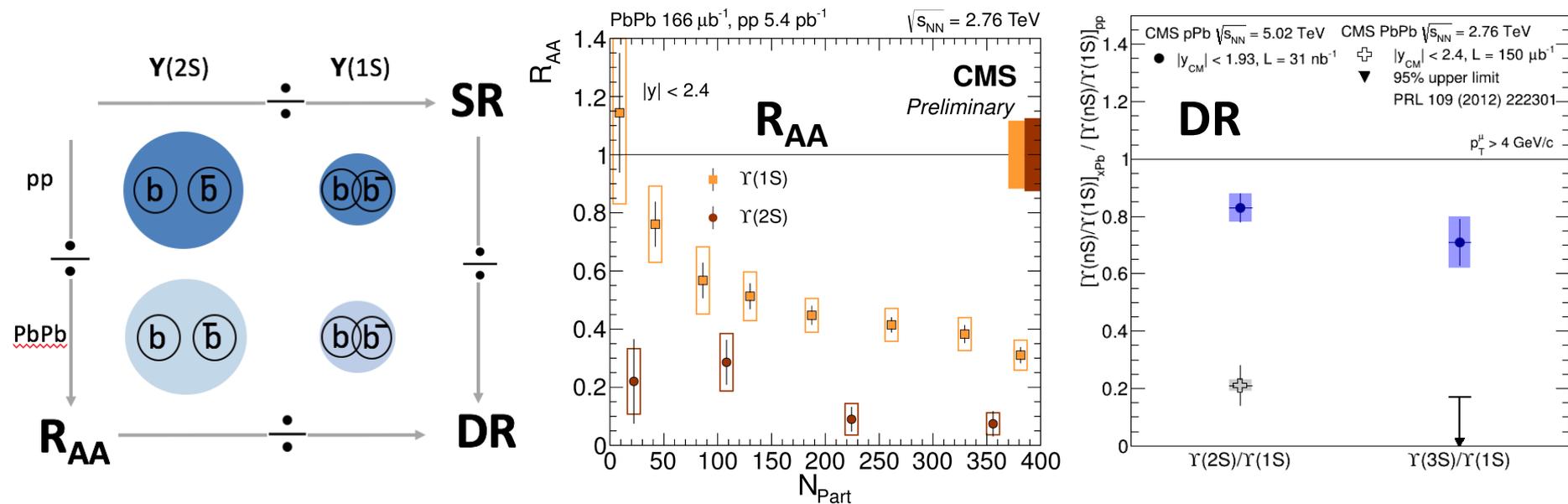


- DR has no clear dependence on  $p_T$  or rapidity
- similarly to 2.76TeV result

5.02 TeV

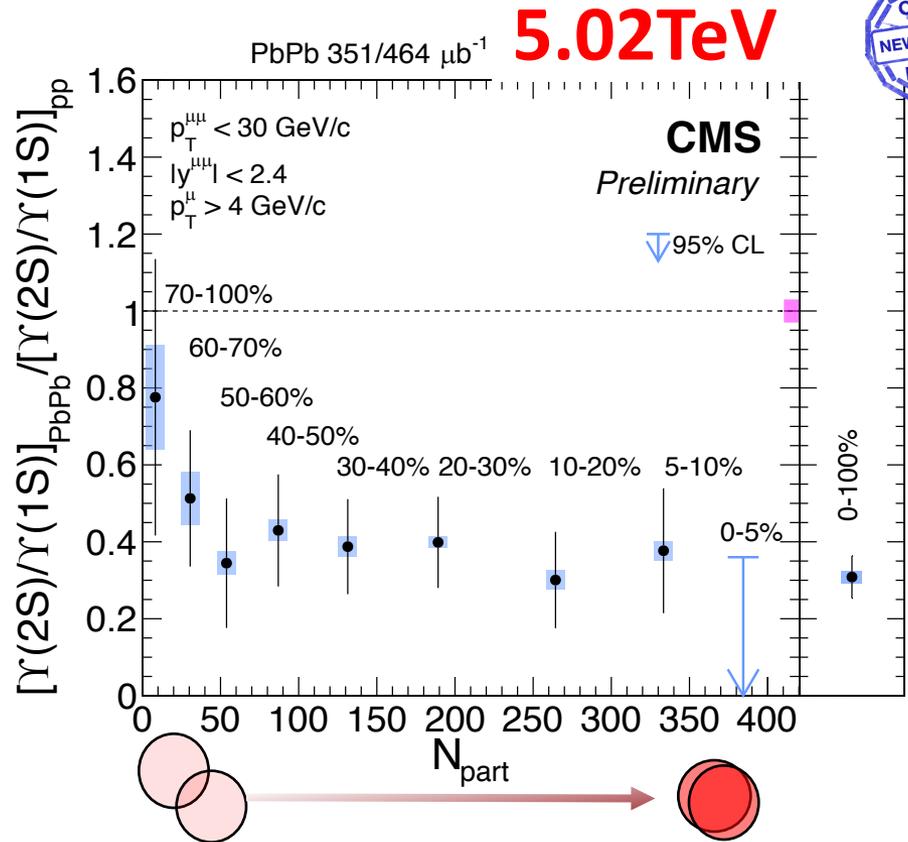
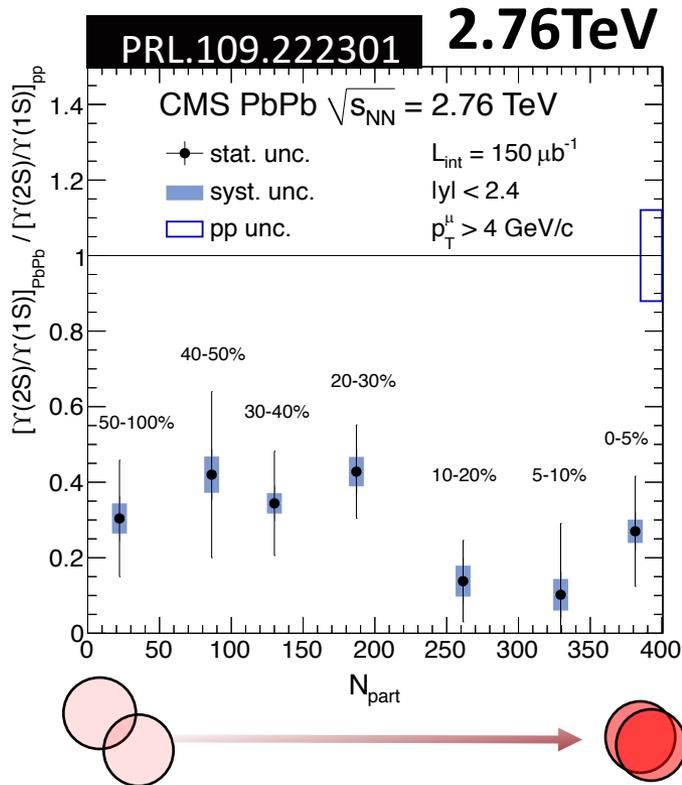


# Summary (1/2)



- $Y(1S)$ ,  $Y(2S)$  and  $Y(3S)$  states are measured in pp, pPb, PbPb collisional systems in forms of  $R_{AA}$  and DR
- Sequential ( $1S \rightarrow 2S \rightarrow 3S$ ) suppression illuminates thermal break-up and regeneration of quarkonia

# Summary (2/2)



## New 5.02 TeV results extend current heavy quarkonia picture

- $Y(2S)$  strongly suppressed from mid-central collisions
- Hints for turning point for  $Y(2S)$  suppression in the peripheral interval
- Is the  $Y(3S)$  completely dissolved?
- Analysis summary note  $\rightarrow$  <http://cds.cern.ch/record/2217909/files/HIN-16-008-pas.pdf>

# BACKUP