Status of future prospect of recent bottomonium measurement in heavy-ion collisions with CMS

JaeBeom Park, Korea University

— 2nd CENUM Joint Workshop 2020 —

Outline

1. Motivation

2. Experimental Results and Future prospects

3. Summary

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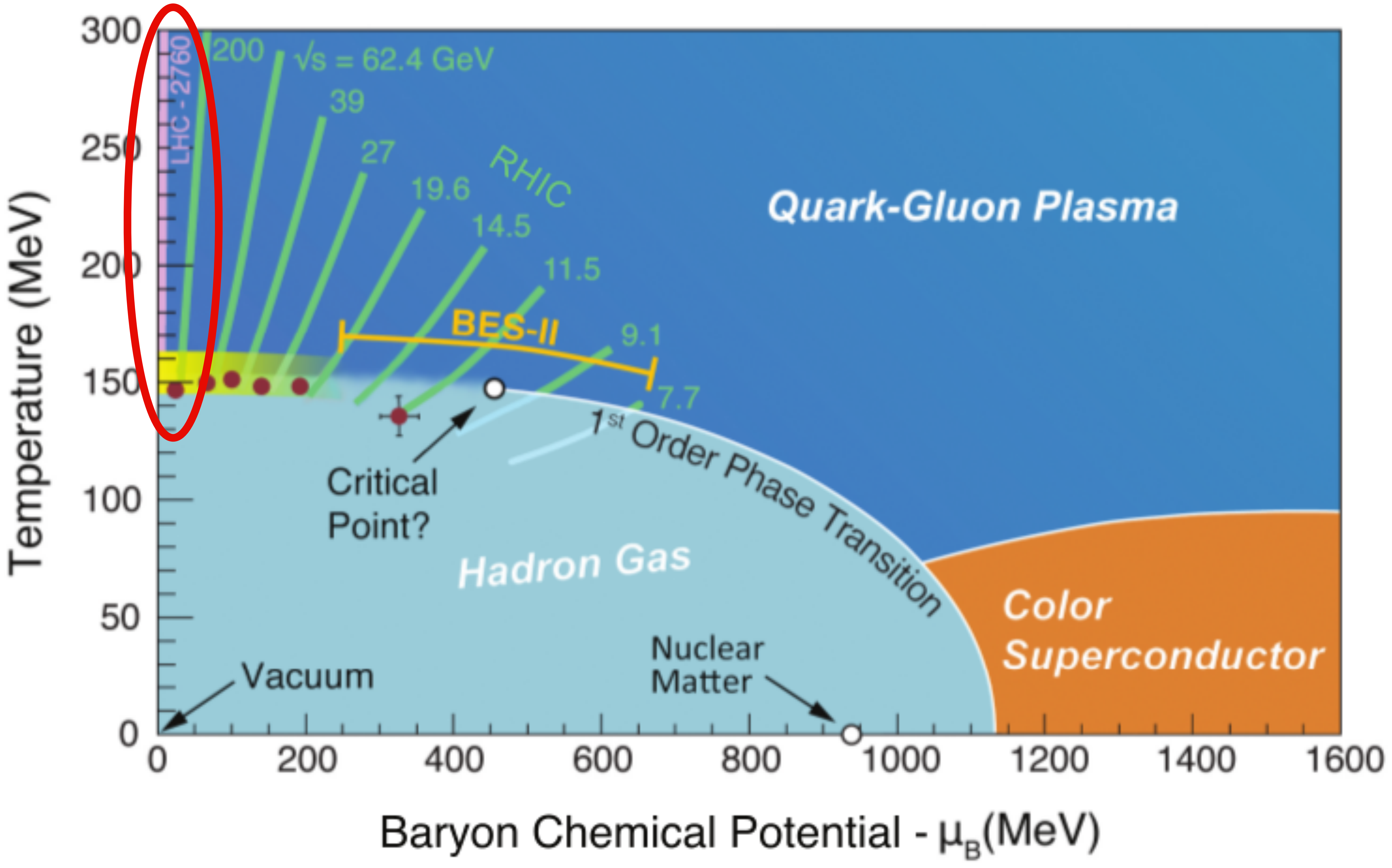
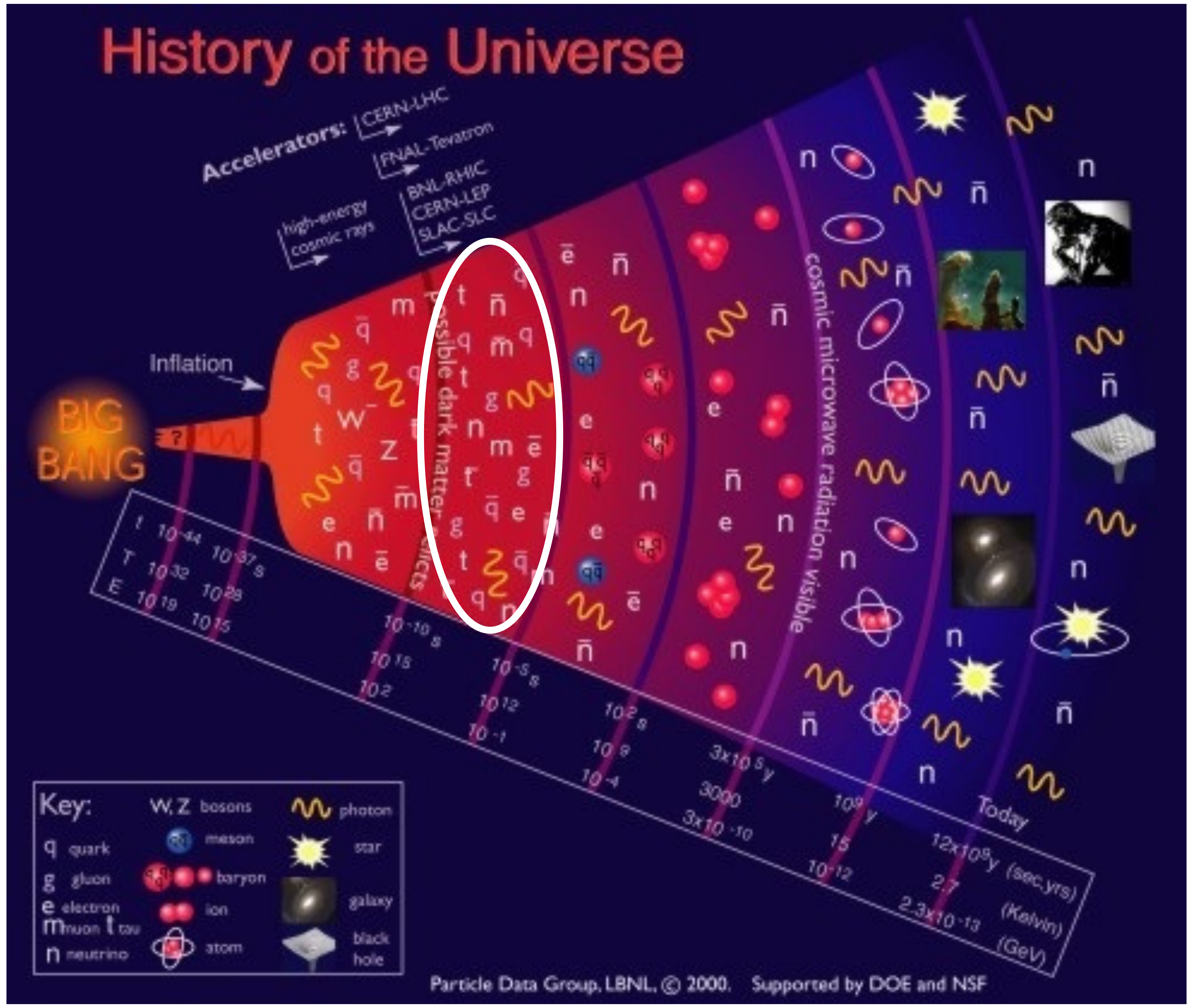
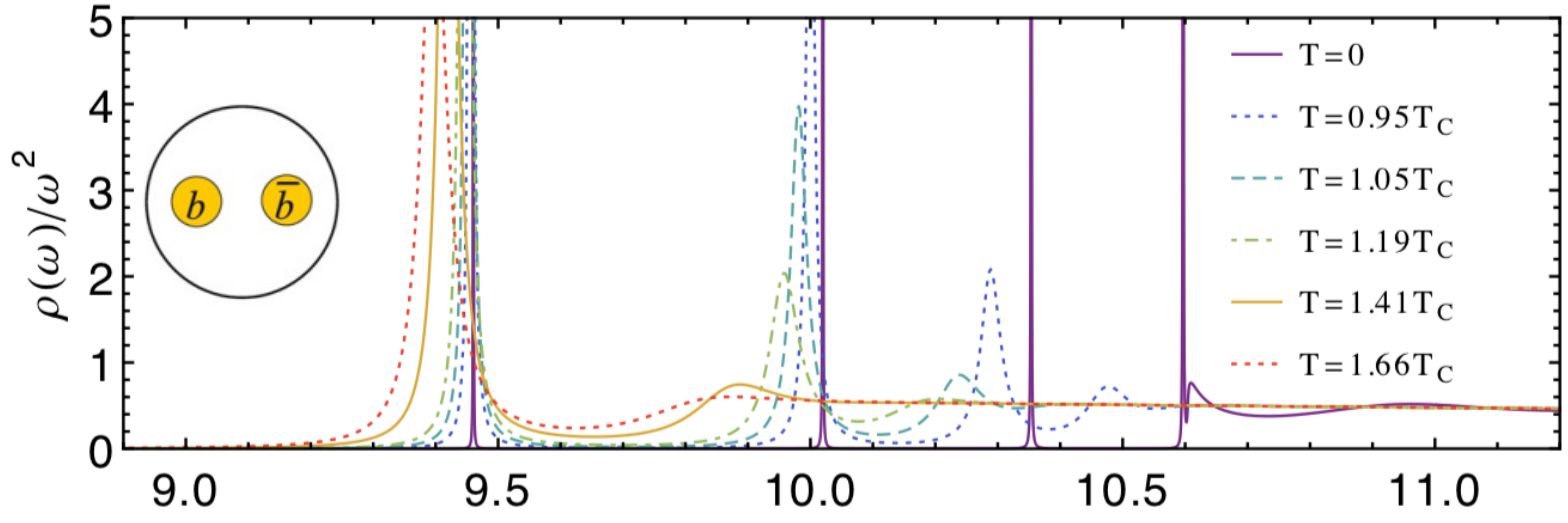
- Quark-Gluon Plasma (QGP) : Strongly interacting matter of deconfined quarks and gluons
  - Existed in early universe ~ 10^{-6} s



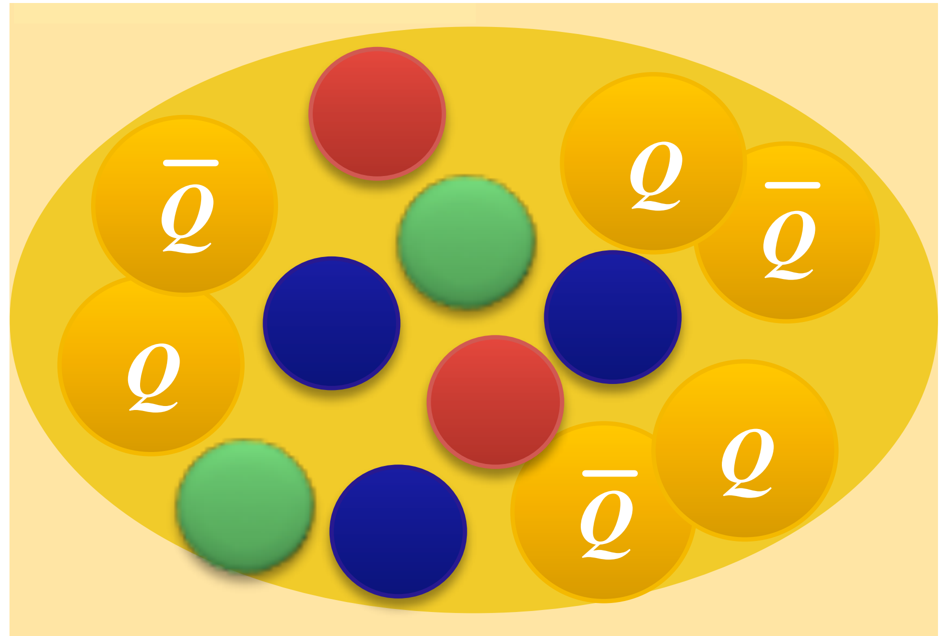


Motivation : Bottomonia

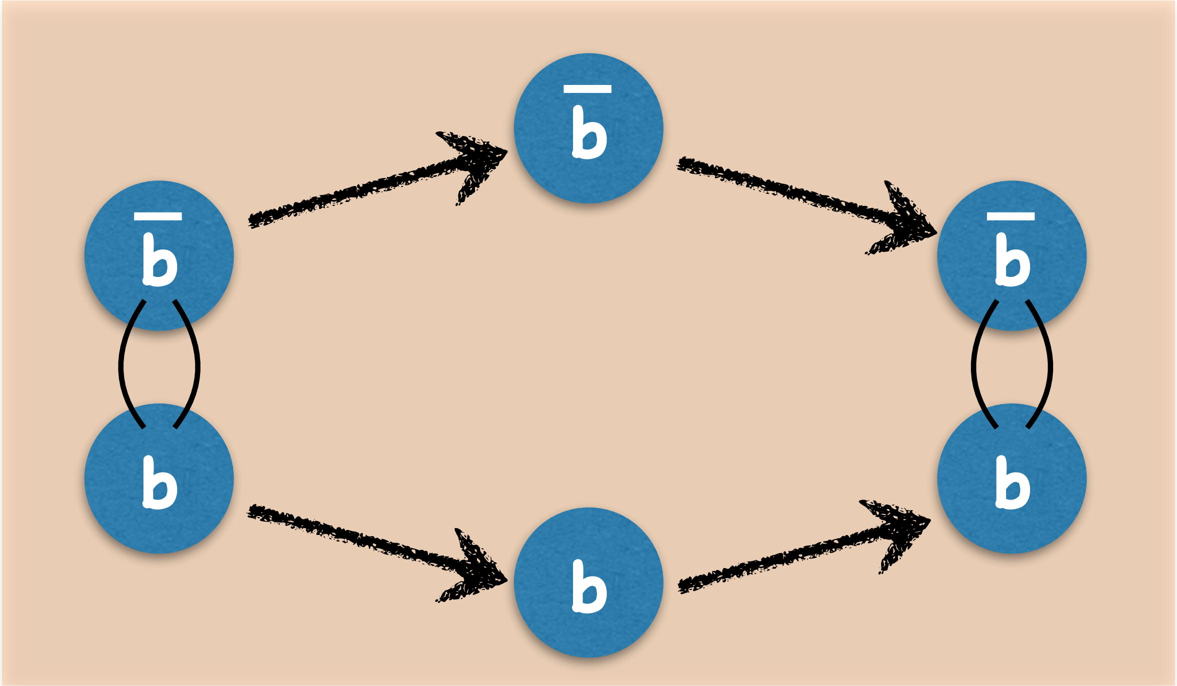
- **Spectral function modification**
  - Debye screening - real part
  - Dissociation - imaginary part



- **Recombination**
  - Uncorrelated recombination

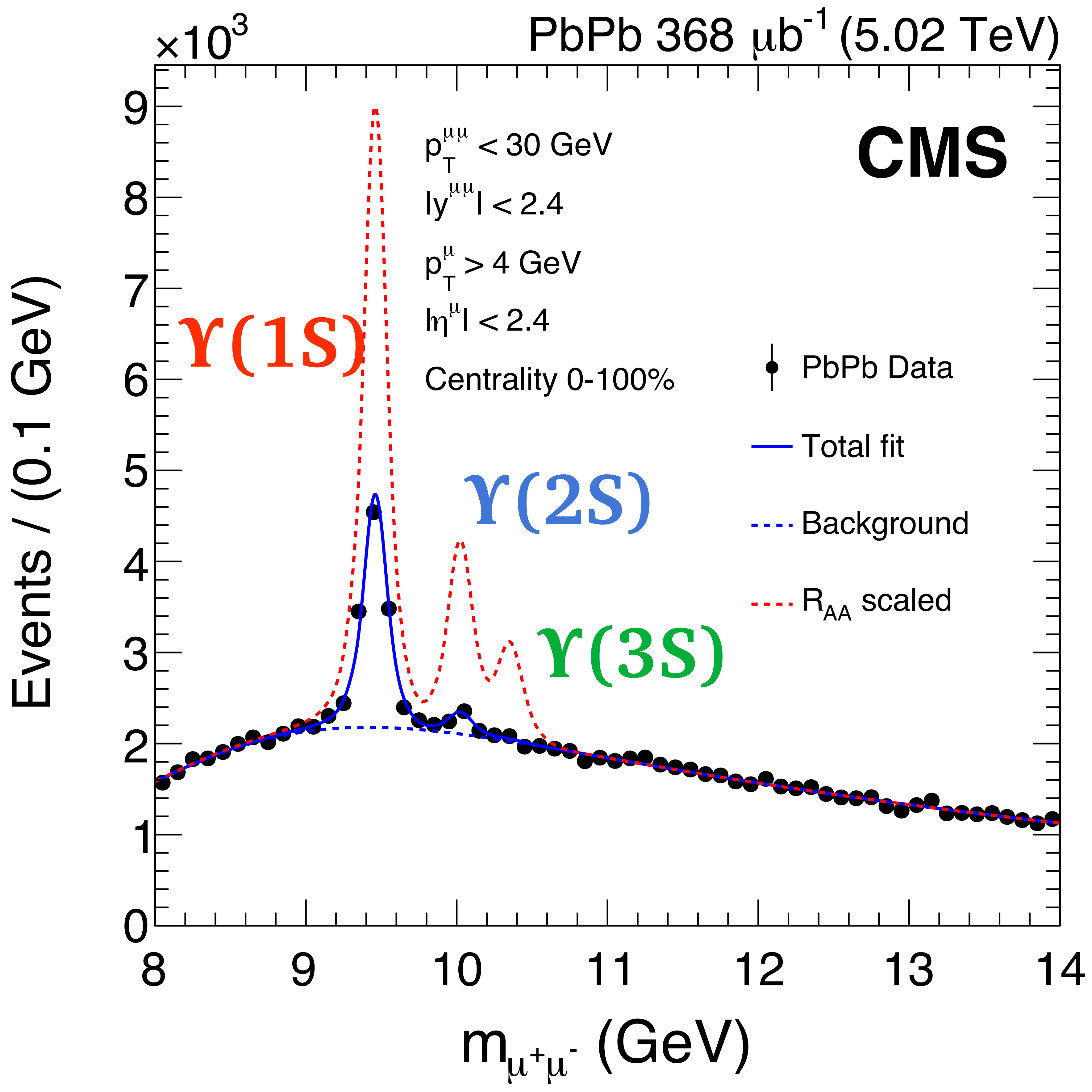


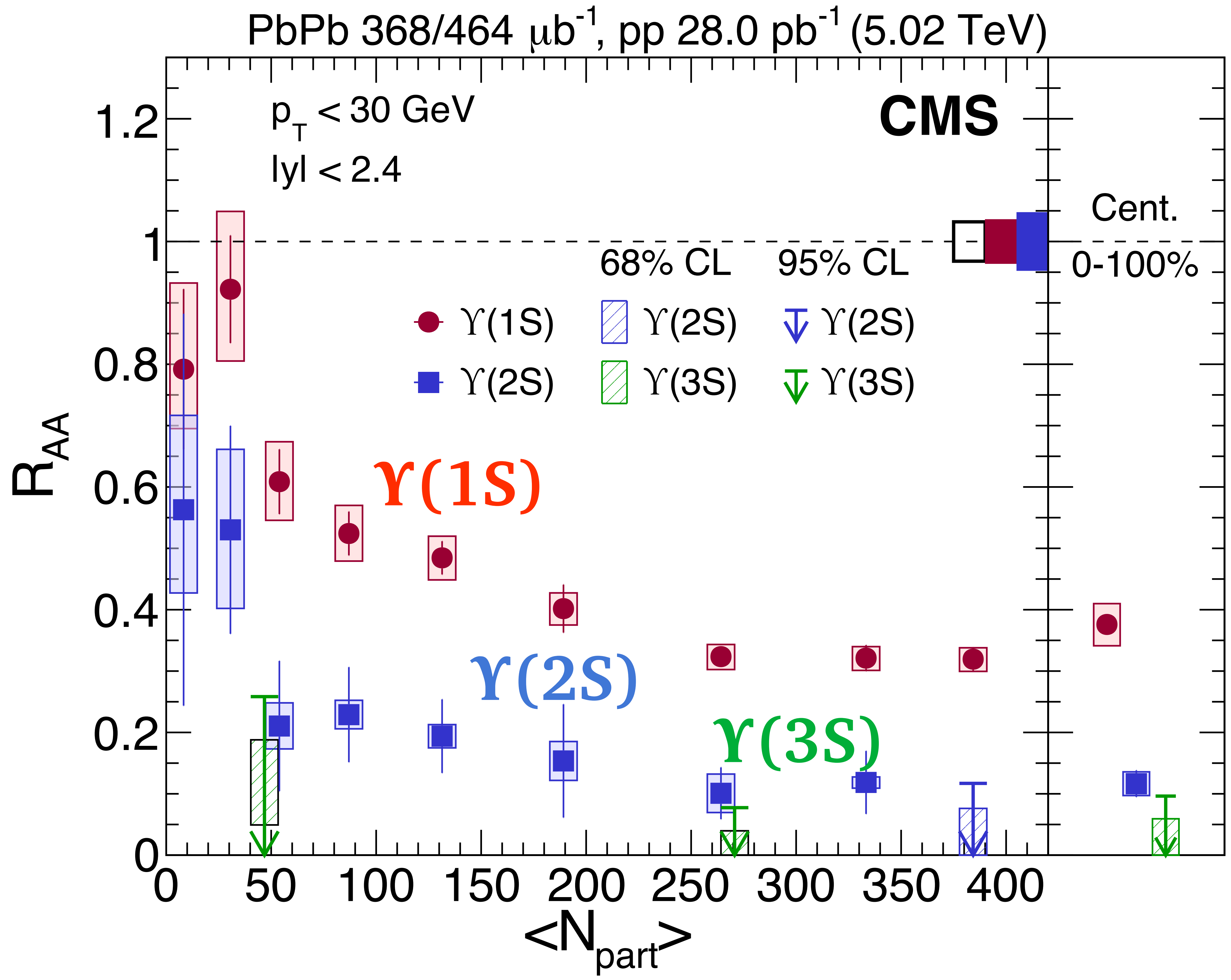
  - Correlated recombination



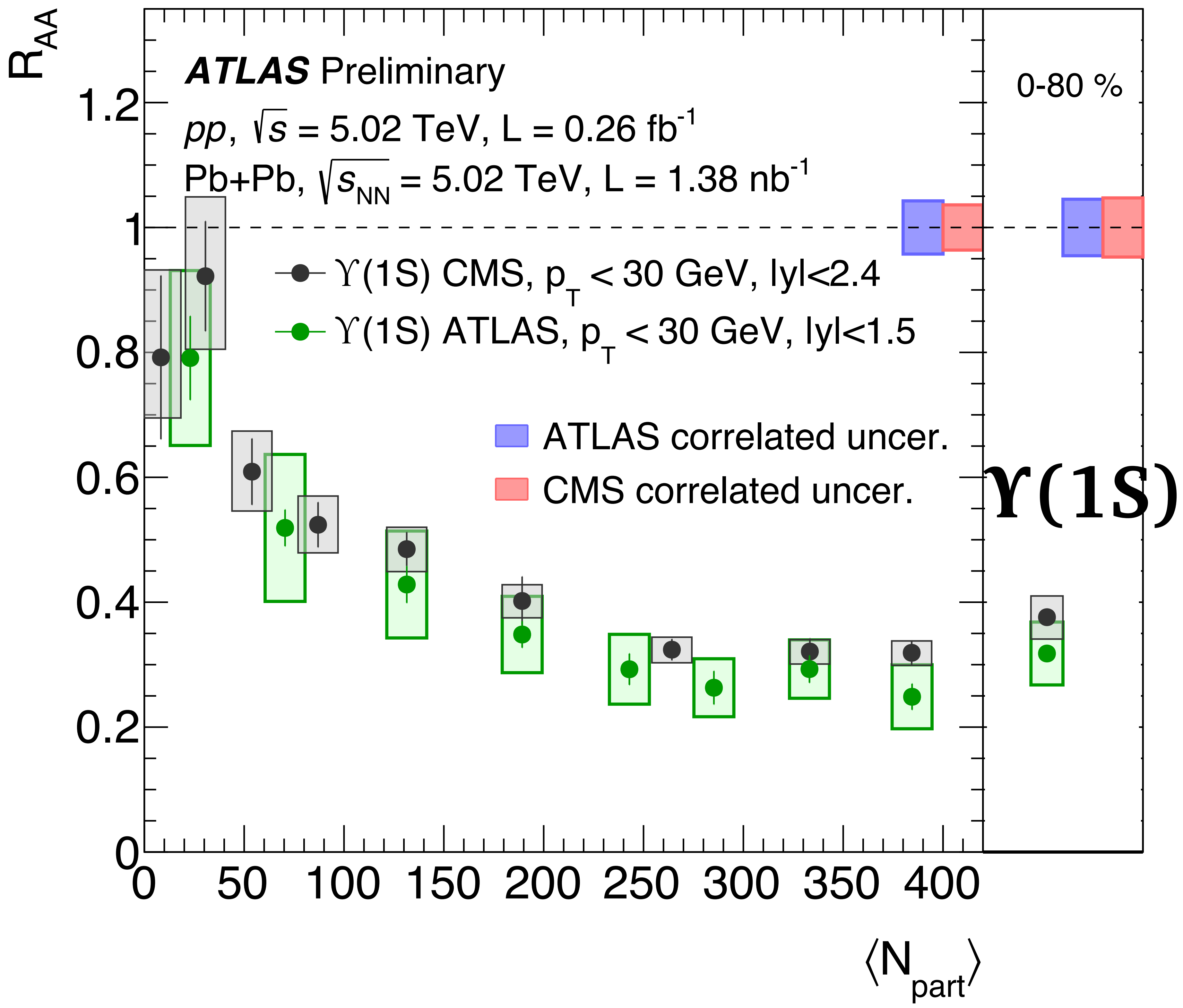
Motivation : Previous results

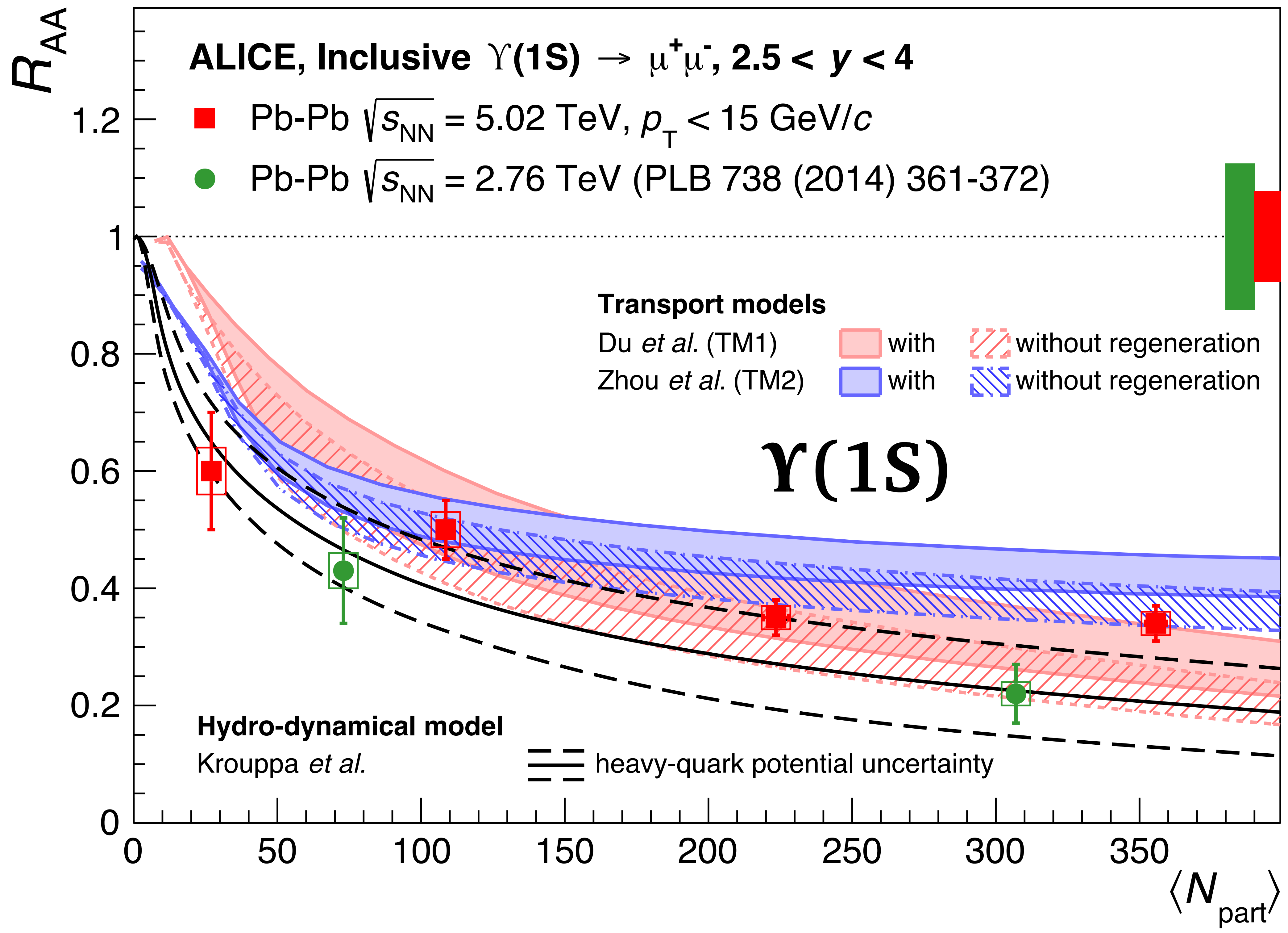
- **Sequential suppression of ϒ states**





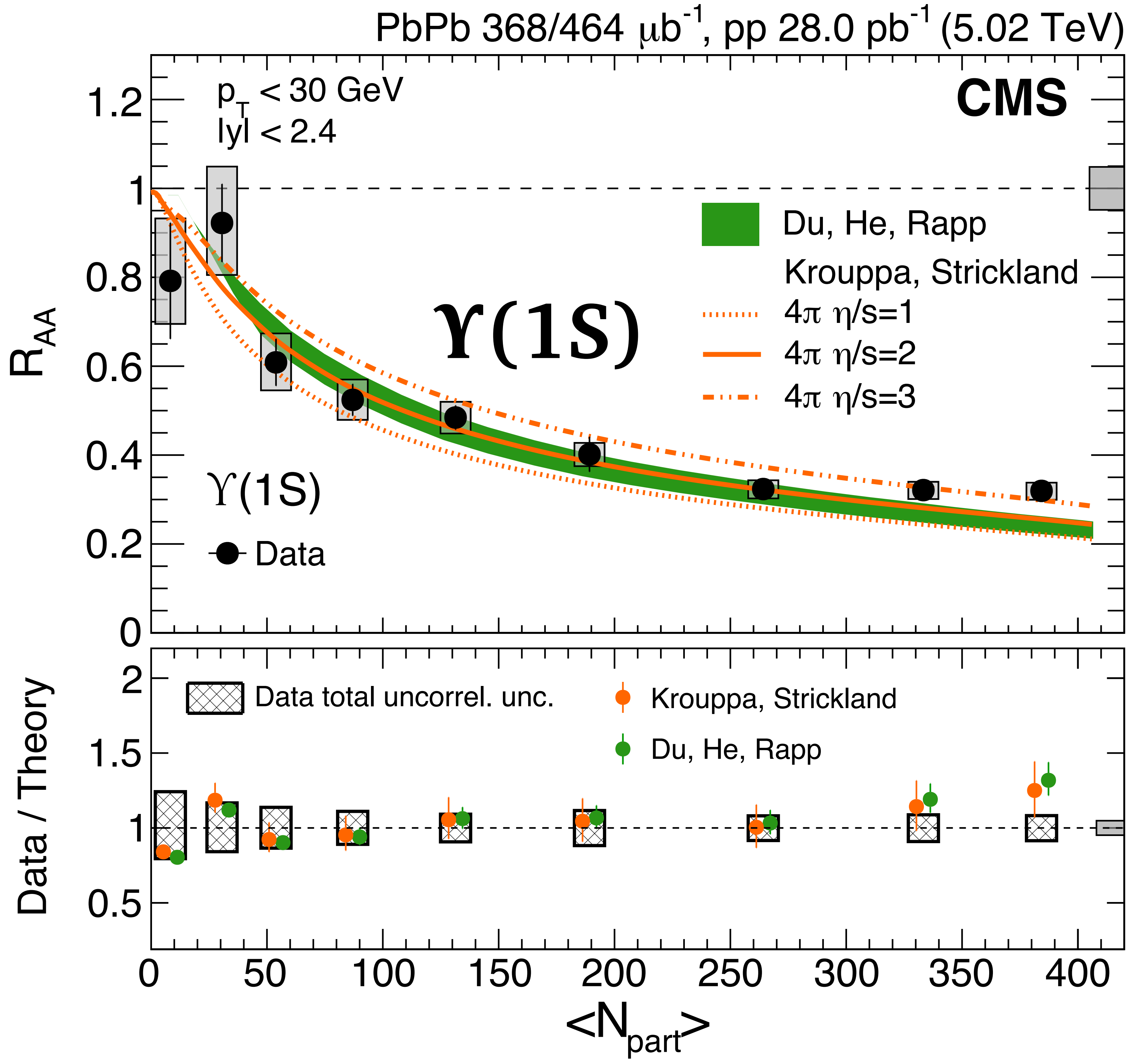
- Consistent among LHC experiments
  - ATLAS, ALICE, CMS similar Υ(1S) R_{AA}

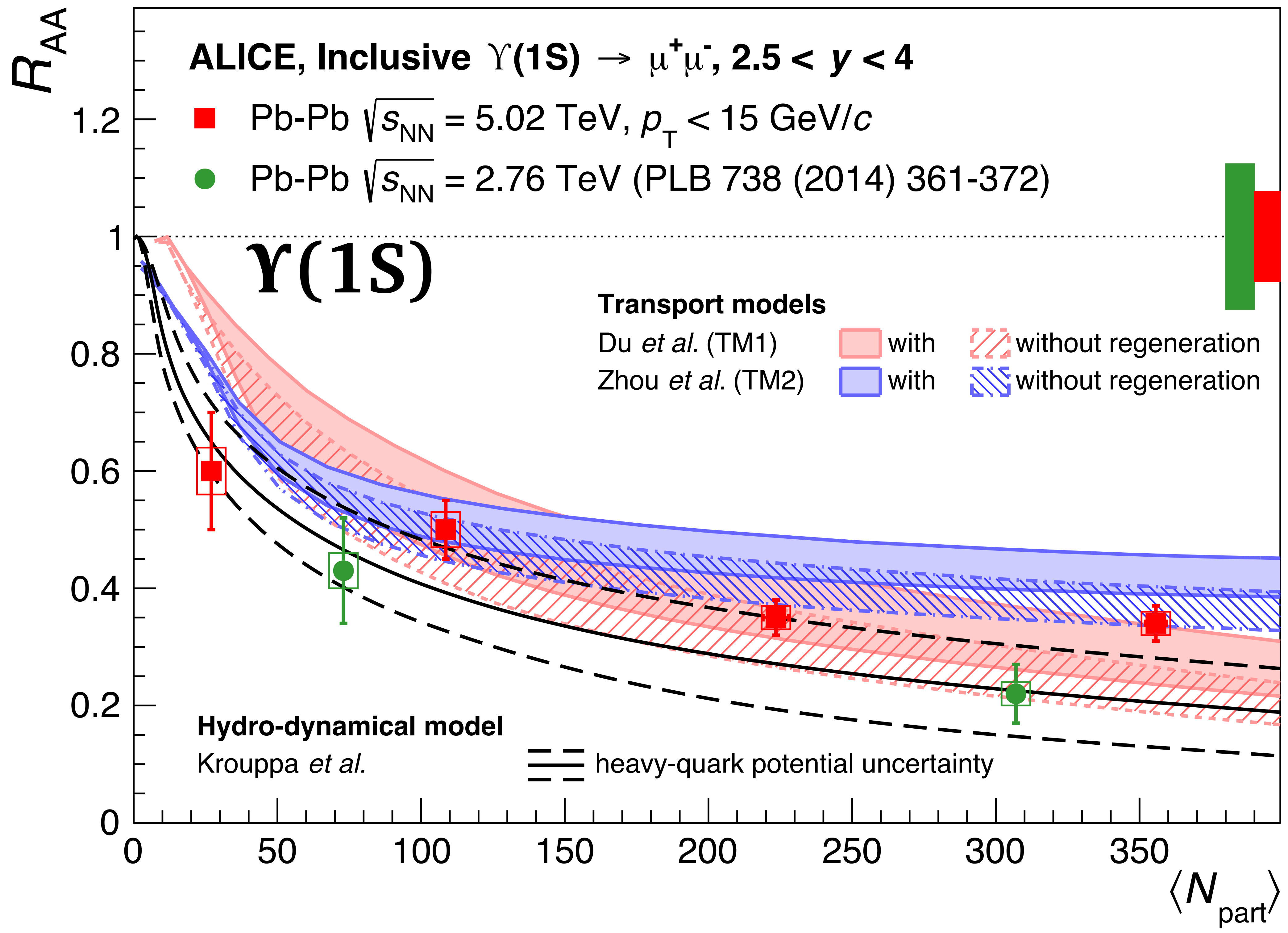




Motivation : Theory model

- Well described by models with different ingredients
  - Transport model : w/ recombination
  - Hydrodynamic model : w/o recombination

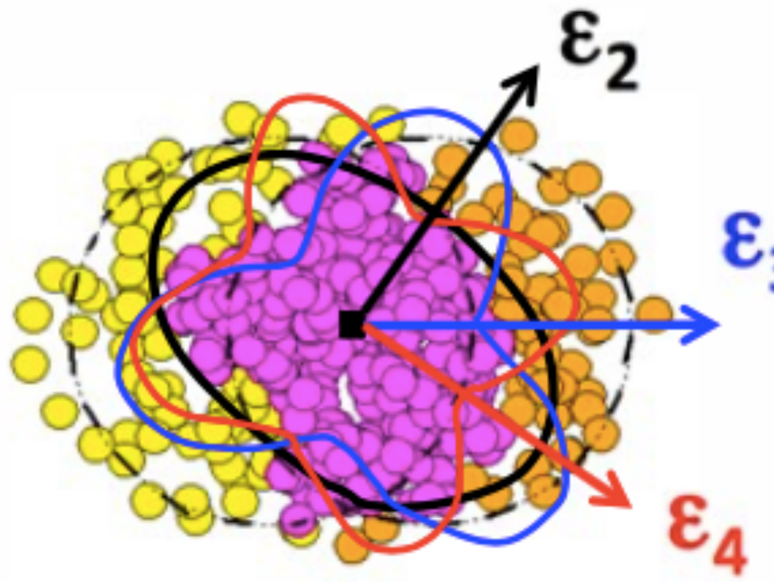


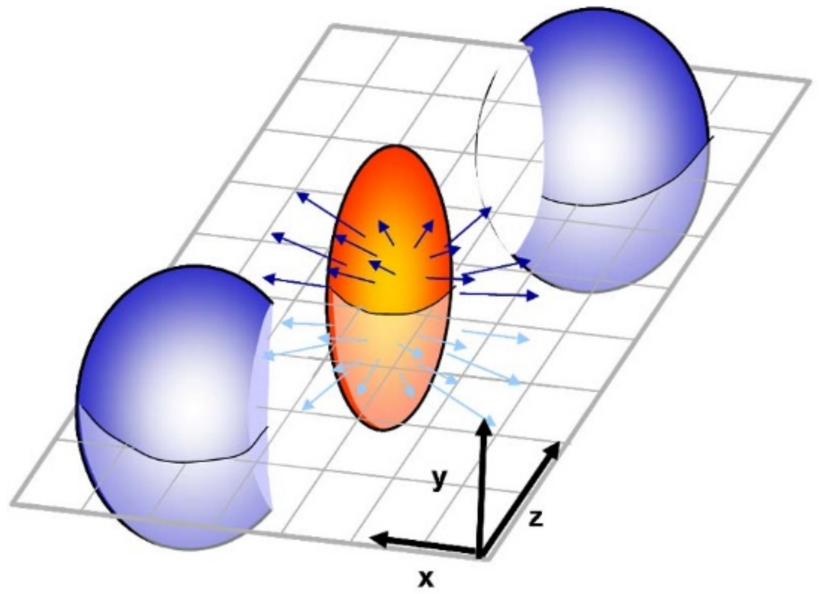


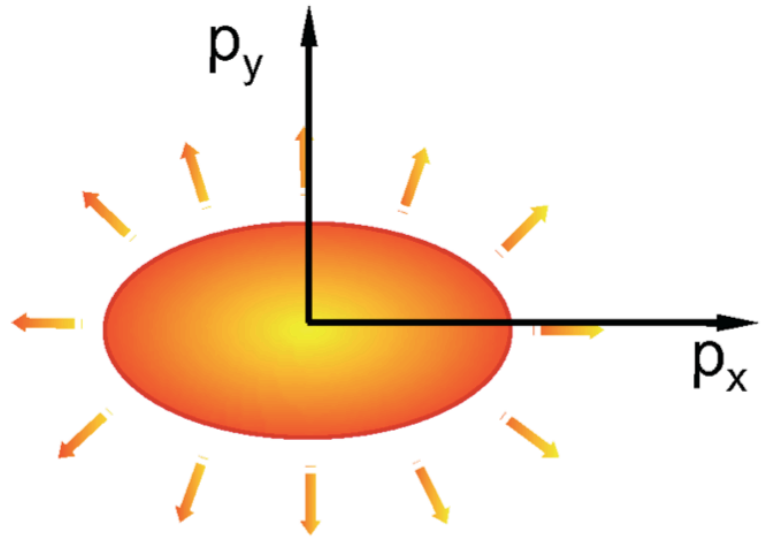
Motivation : Different probes

- Elliptic flow (v_2) measurement

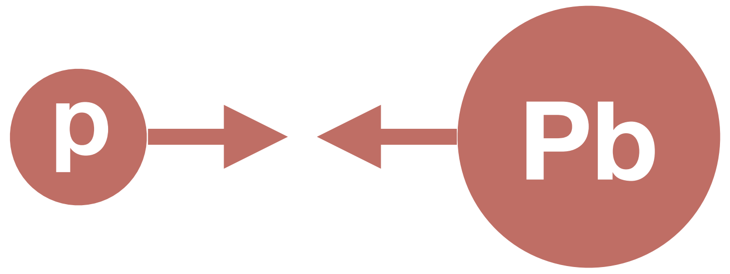
$$\frac{dN}{d\phi} \propto 1 + \sum_n 2v_n cosn(\phi - \Phi_n)$$

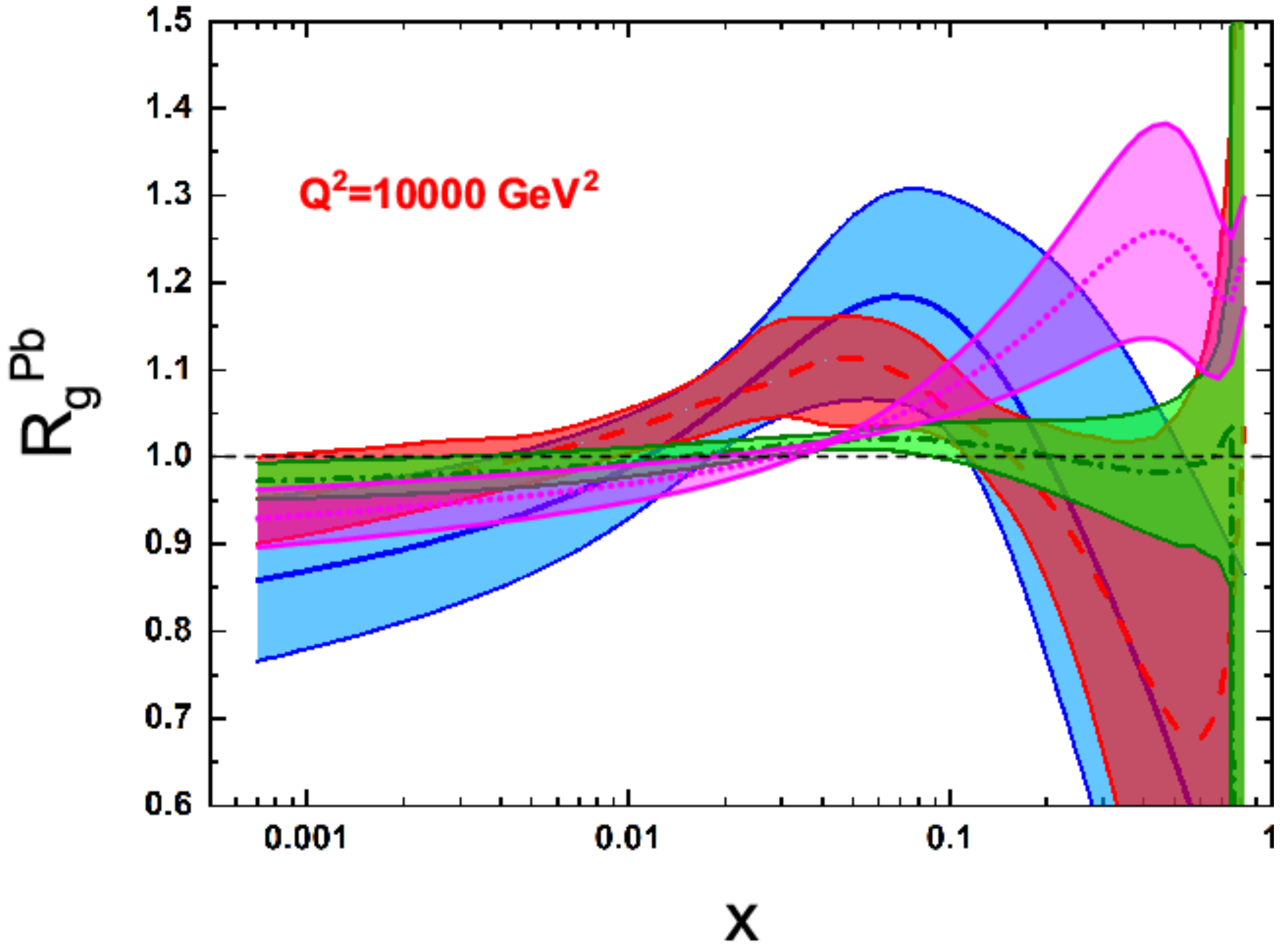


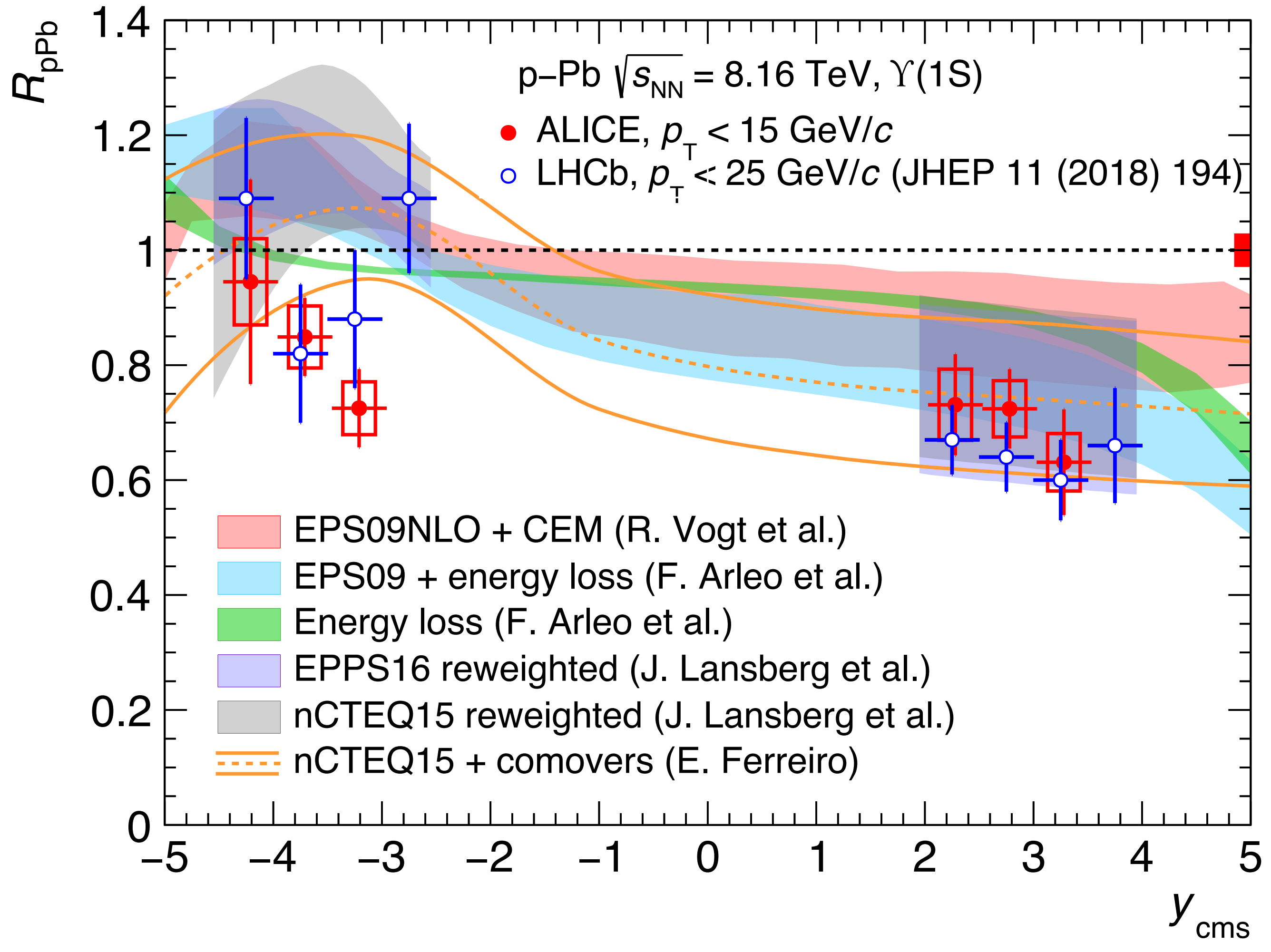




- Modification in pPb collisions







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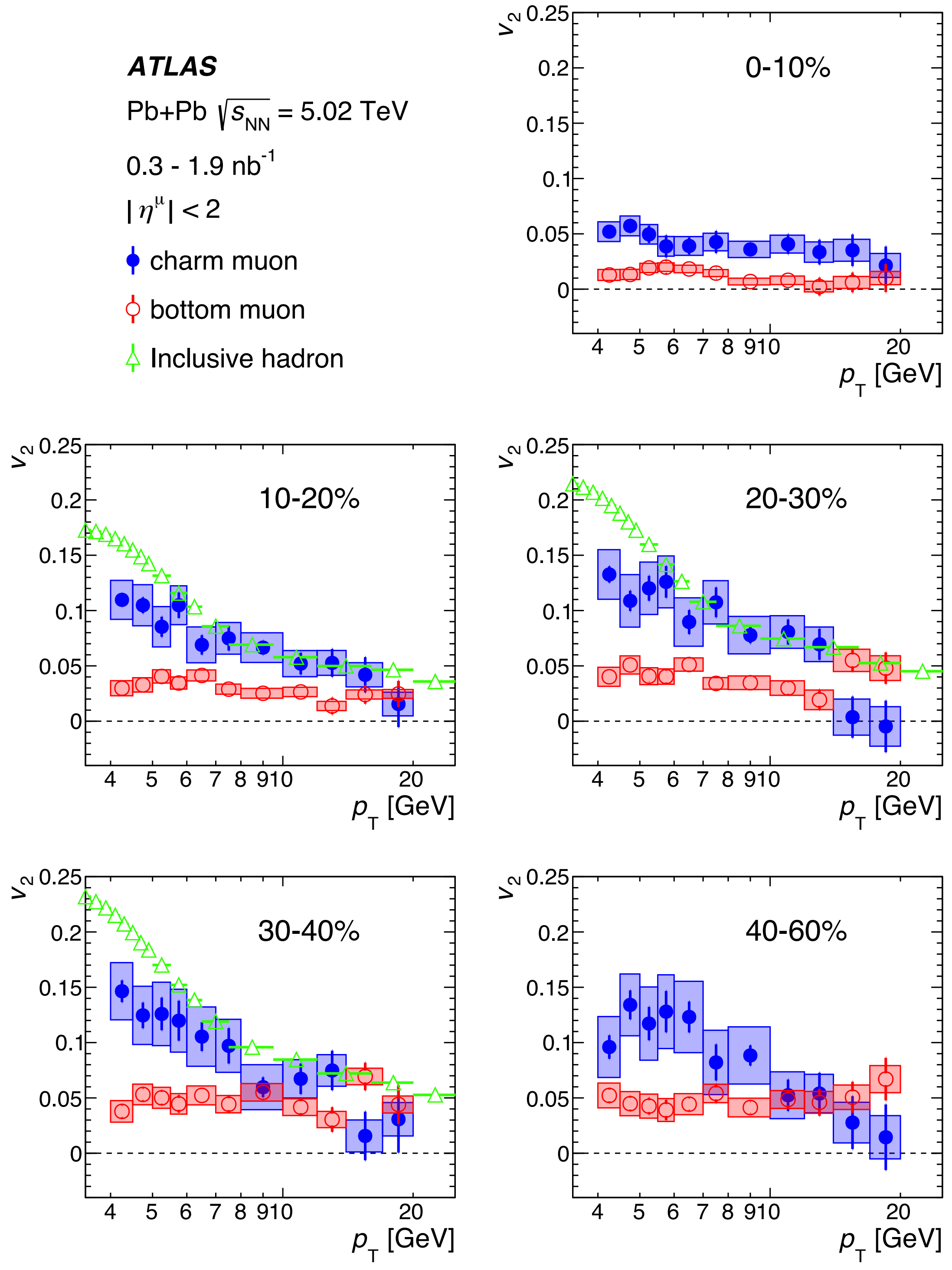
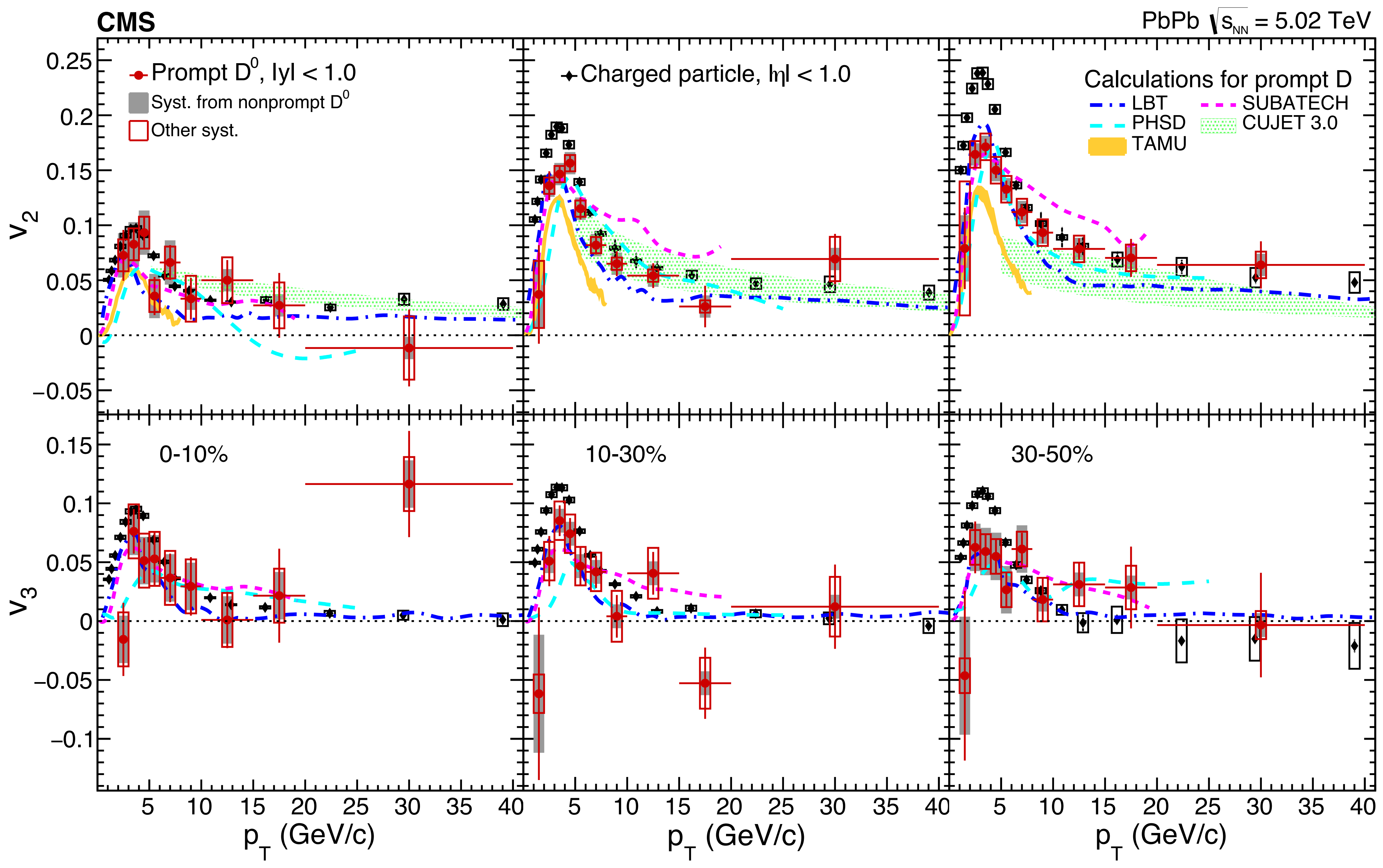
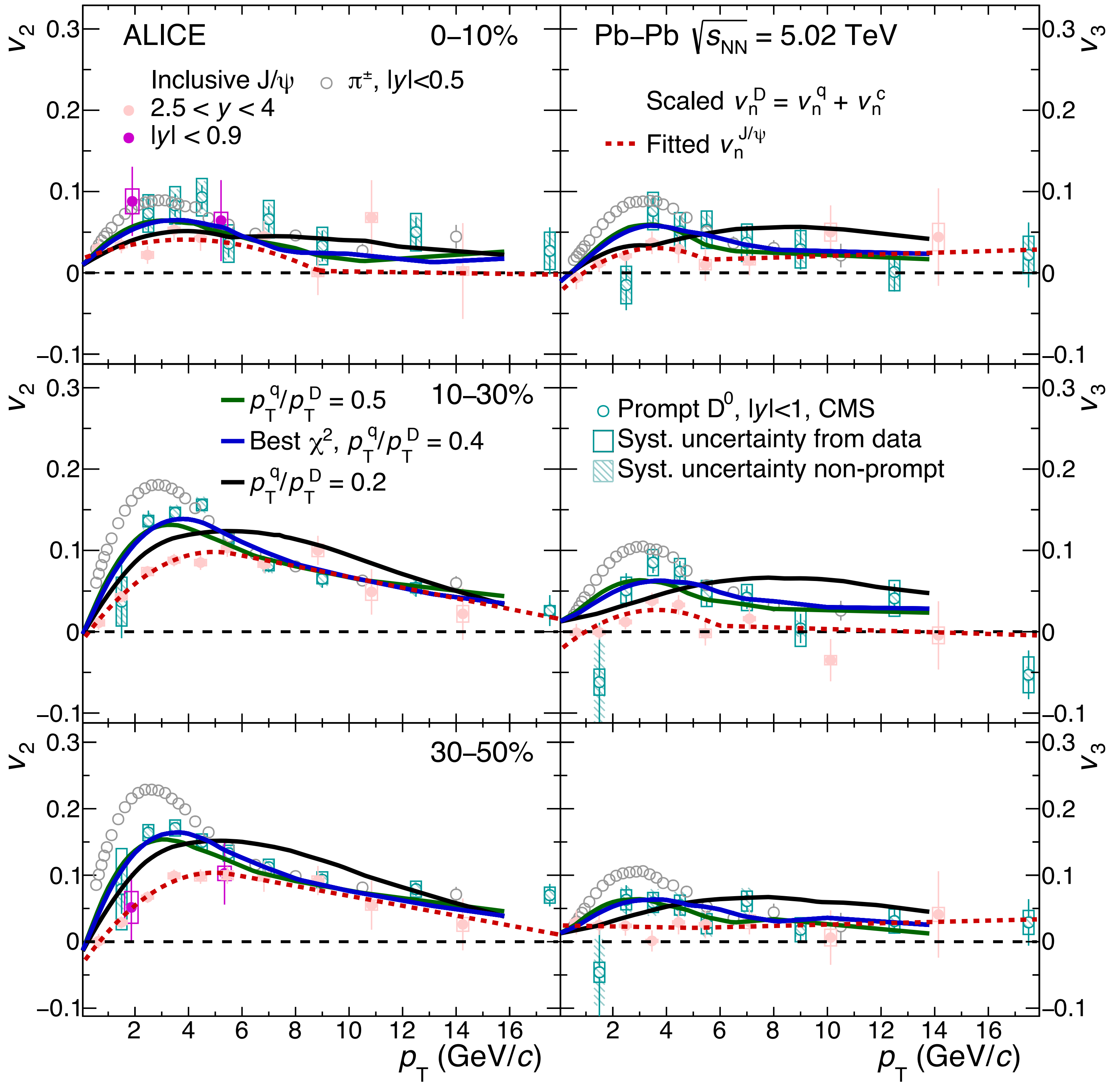
Results : Recent measurements

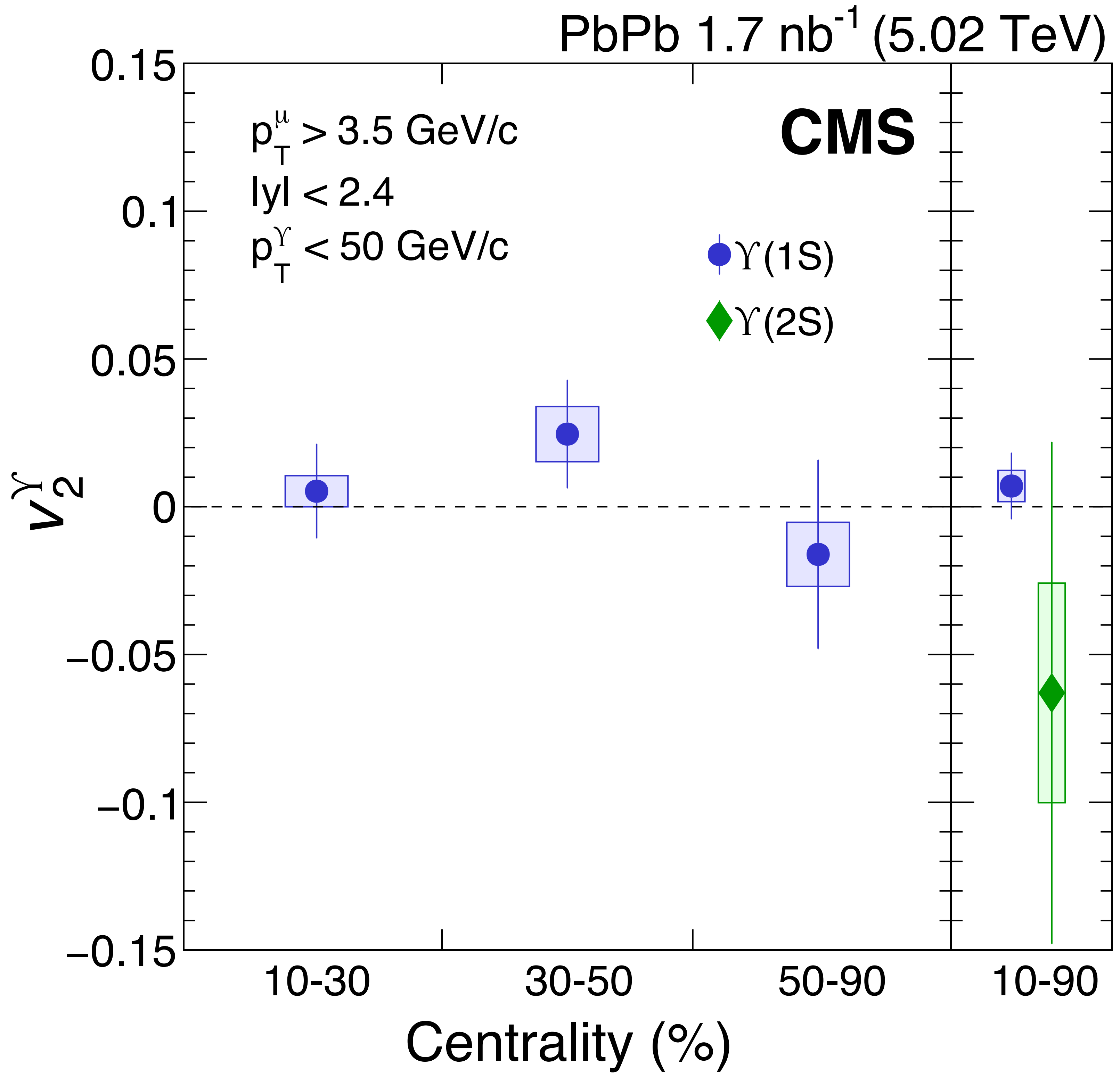
- **Various flow results of heavy-quark**
  - J/ψ, D0, Heavy Flavor muon : Quark hierarchy

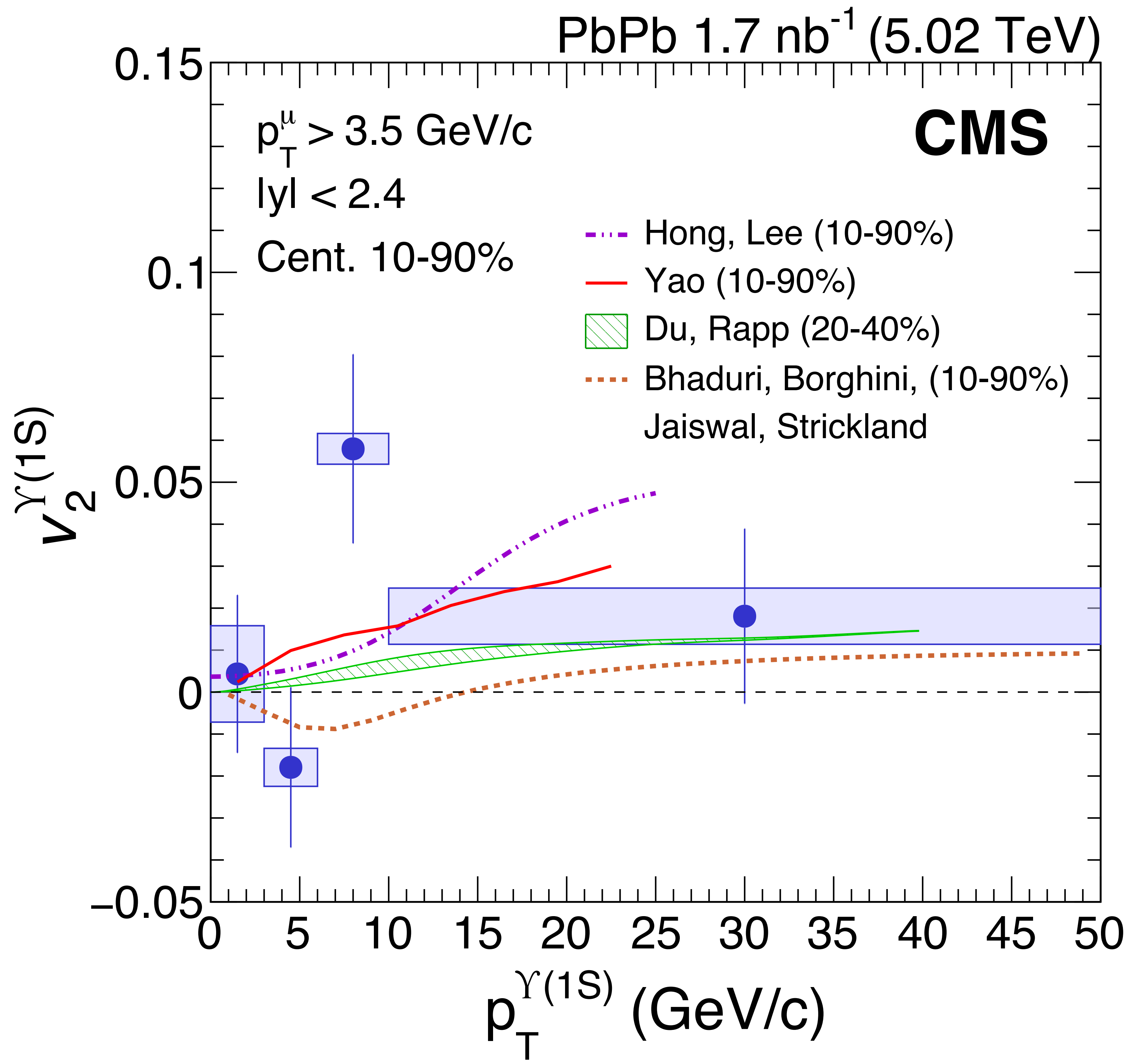






Results : Upsilon flow

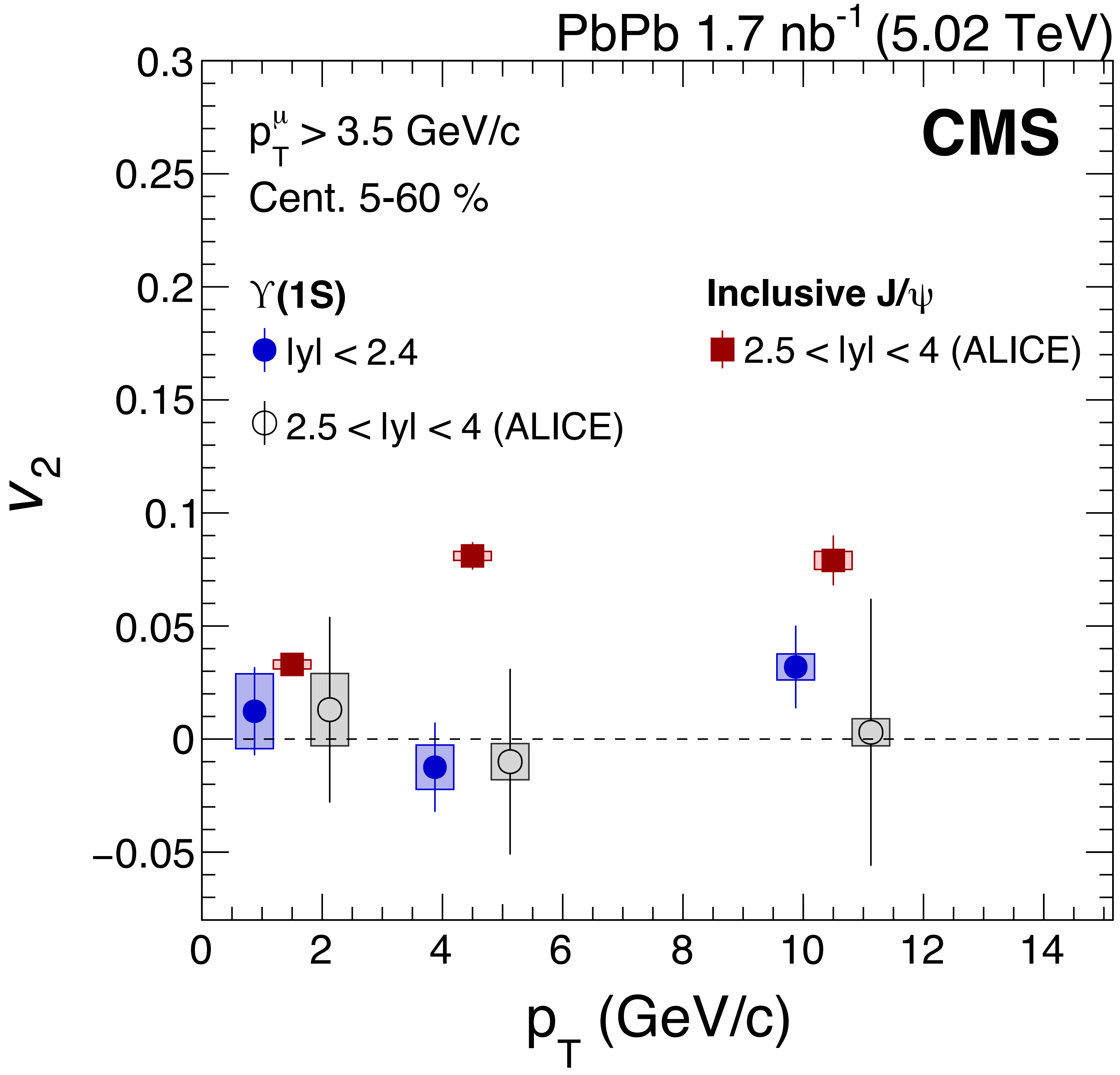




- v_2 measurement of upsilon states in PbPb collision
  - No significant v_2 observed in the overall kinematic range
  - Different model ingredients : recombination, coalescence etc.
  - Recently submitted to PLB : arXiv:2006.07707

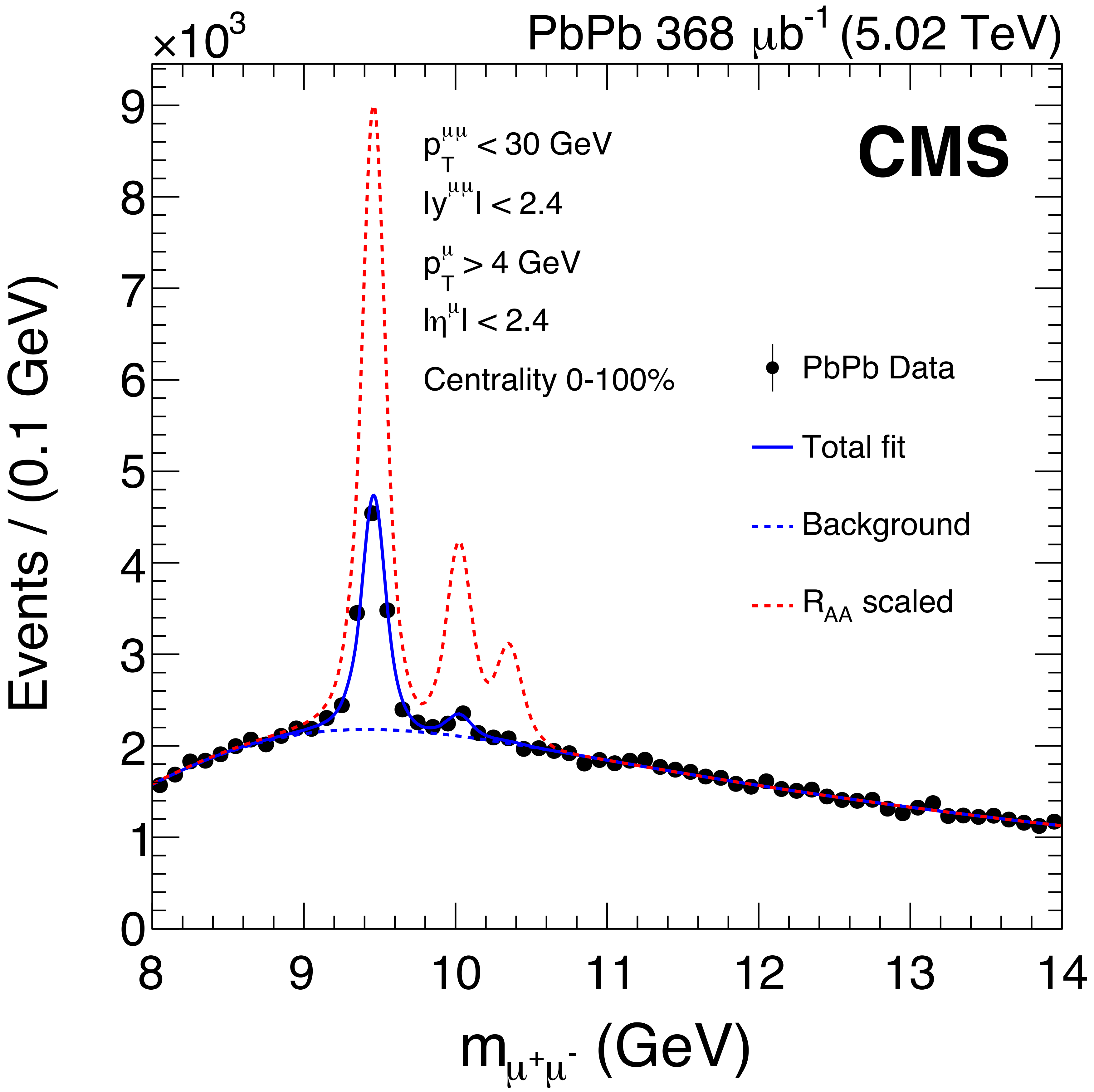
Results : Upsilon flow

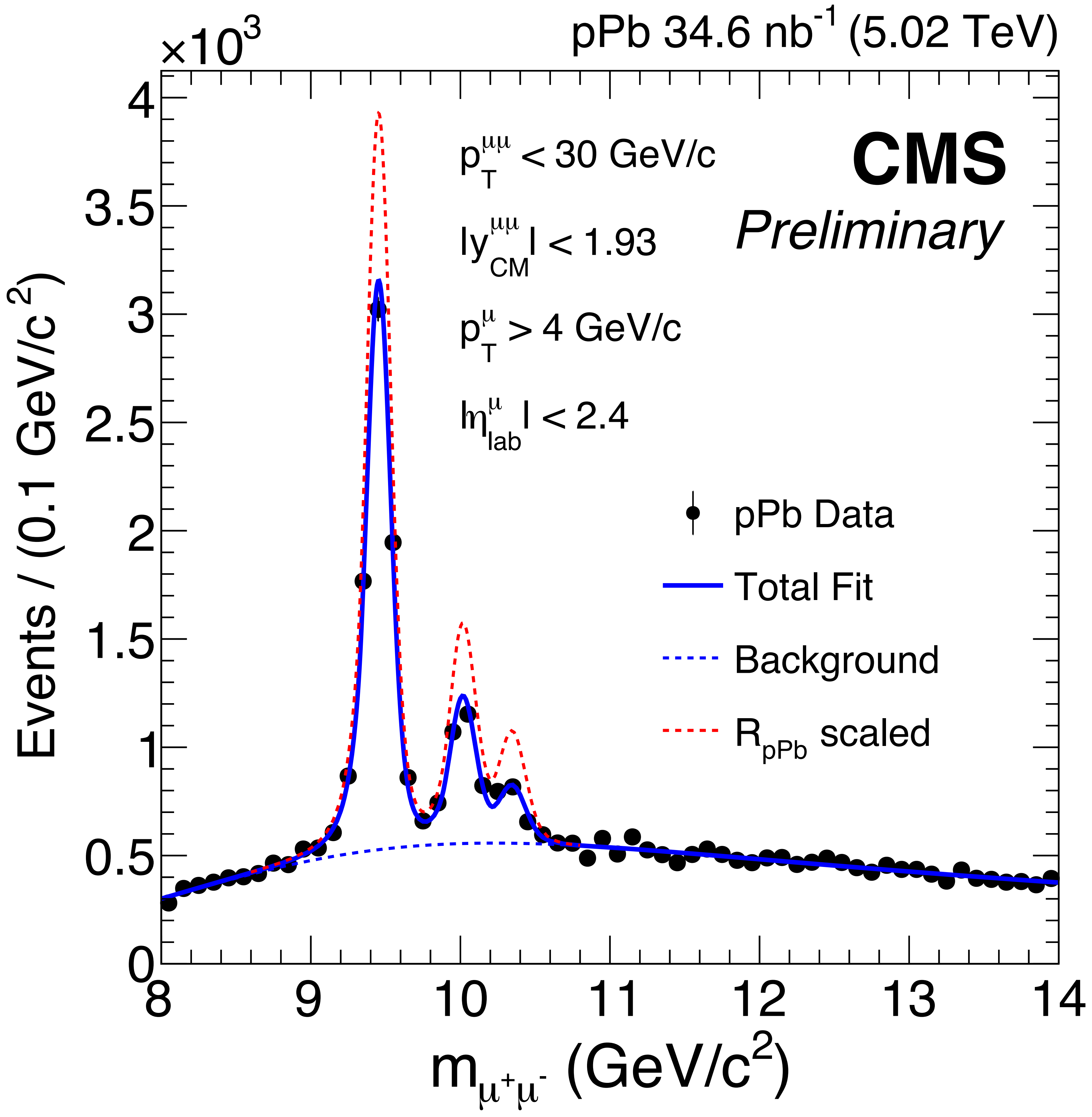
- **Comparison with previous results**
  - Compared to ALICE $\Upsilon(1S)$ v_2
    : More precision with more statistics
  - $\Upsilon(1S)$ v_2 consistent with zero in wide rapidity & p_T range
  - Clearly lower v_2 value compared to J/ψ
    : Different in-medium effect b/w charmonia & bottomonia



Results : Upsilon R_{pPb}

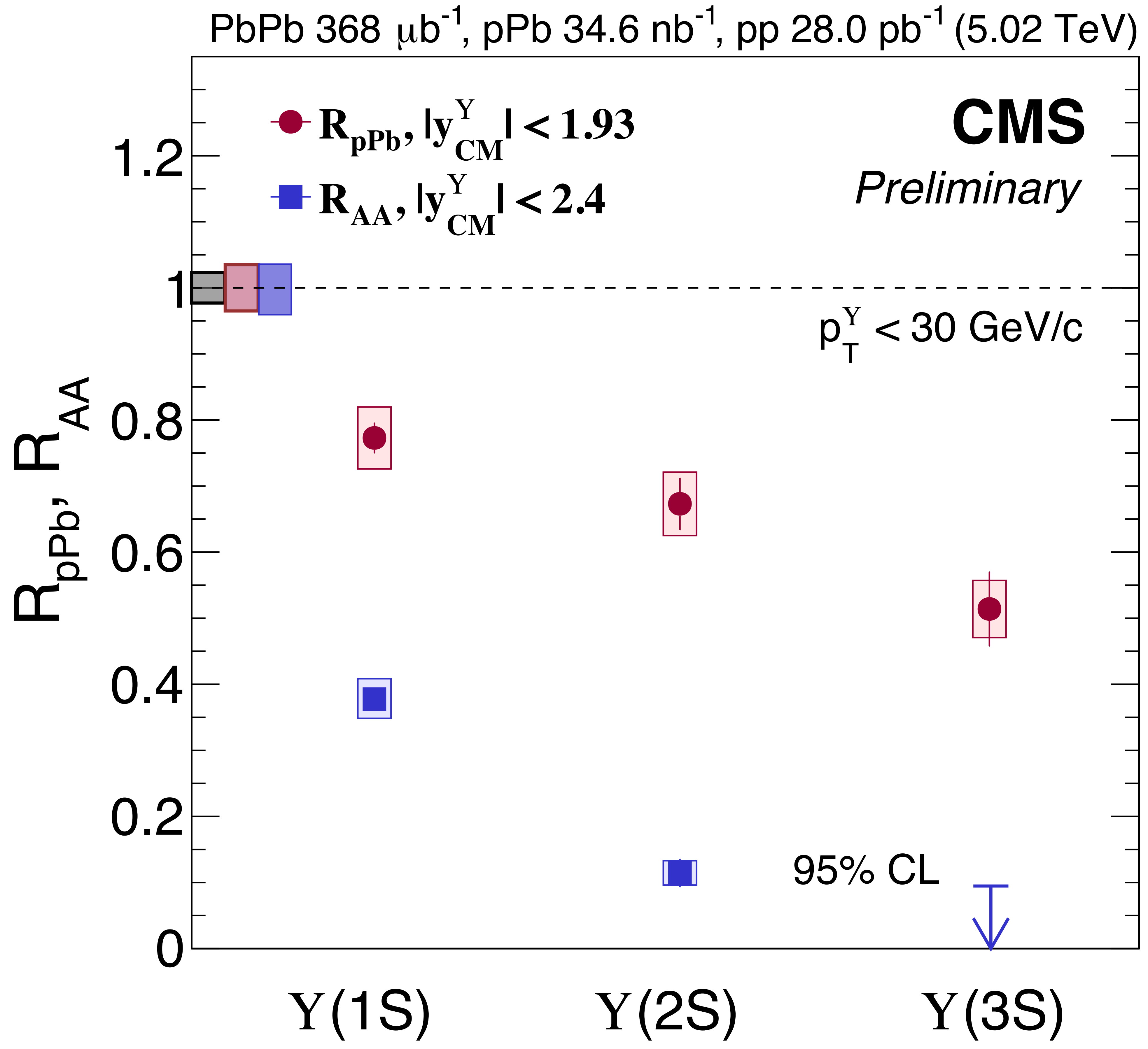
- Suppression of bottomonium states also found in pPb



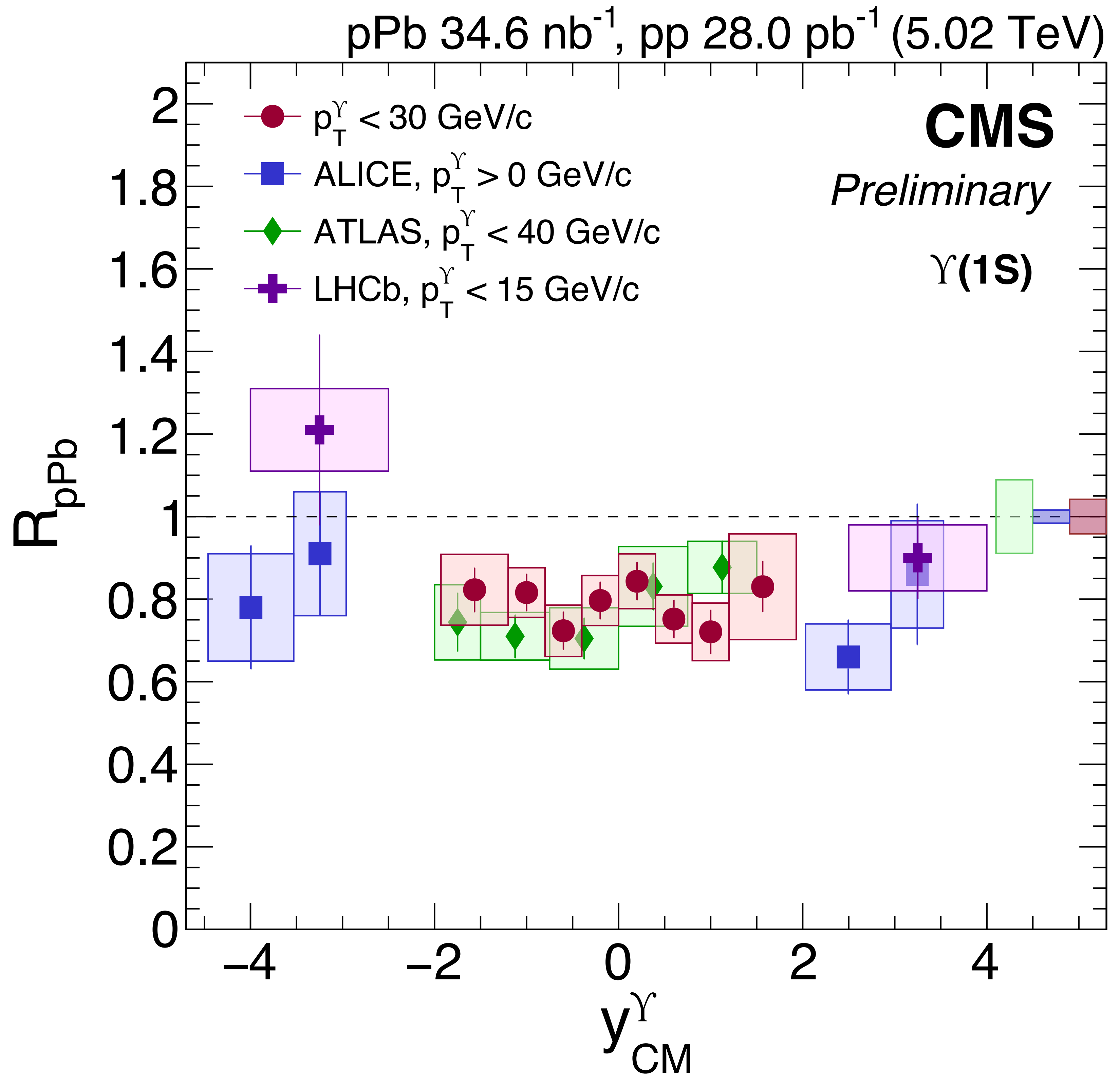


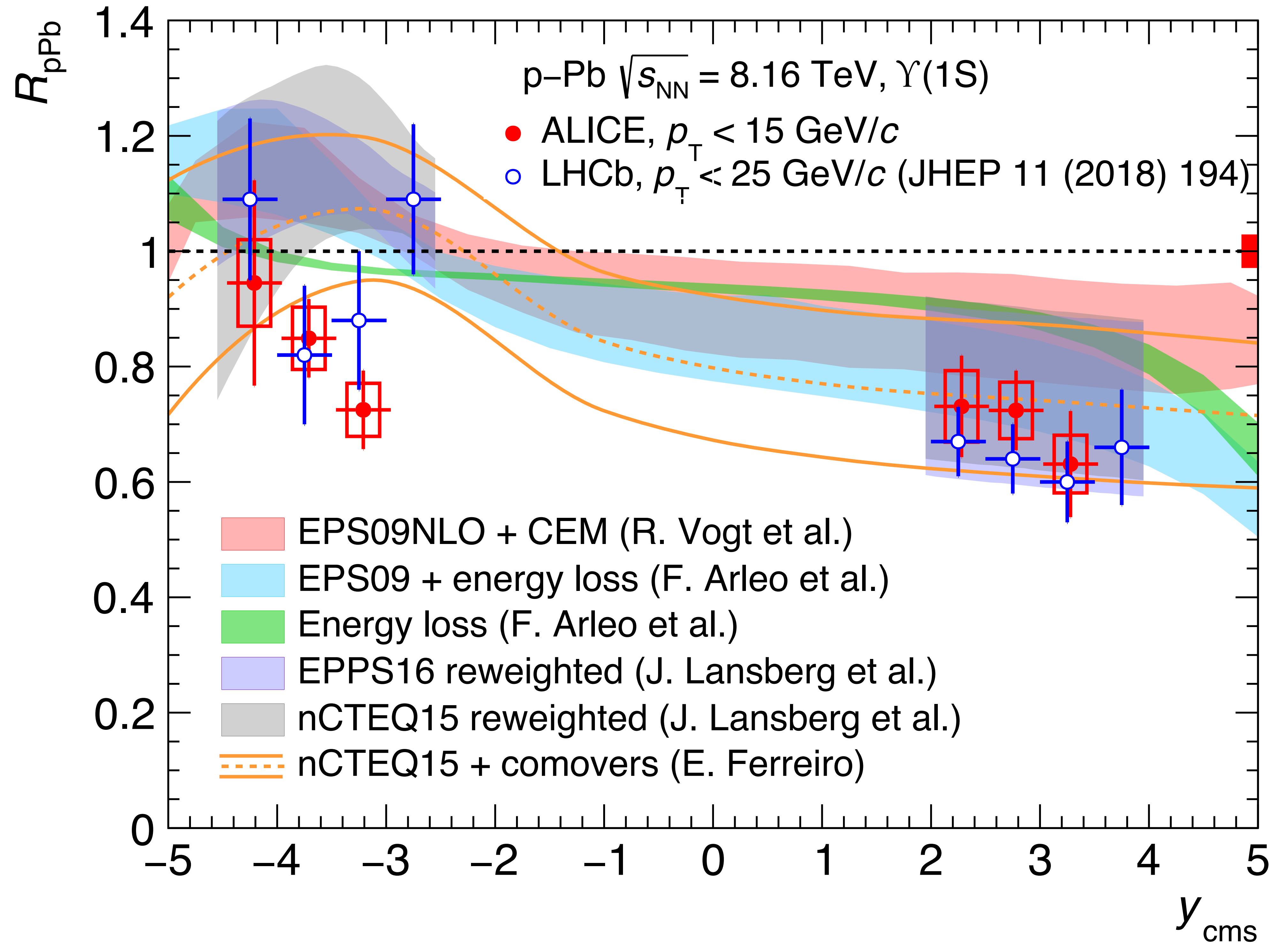
Results : Upsilon R_{pPb}

- Sequential suppression in pPb collisions
- Much larger suppression in PbPb



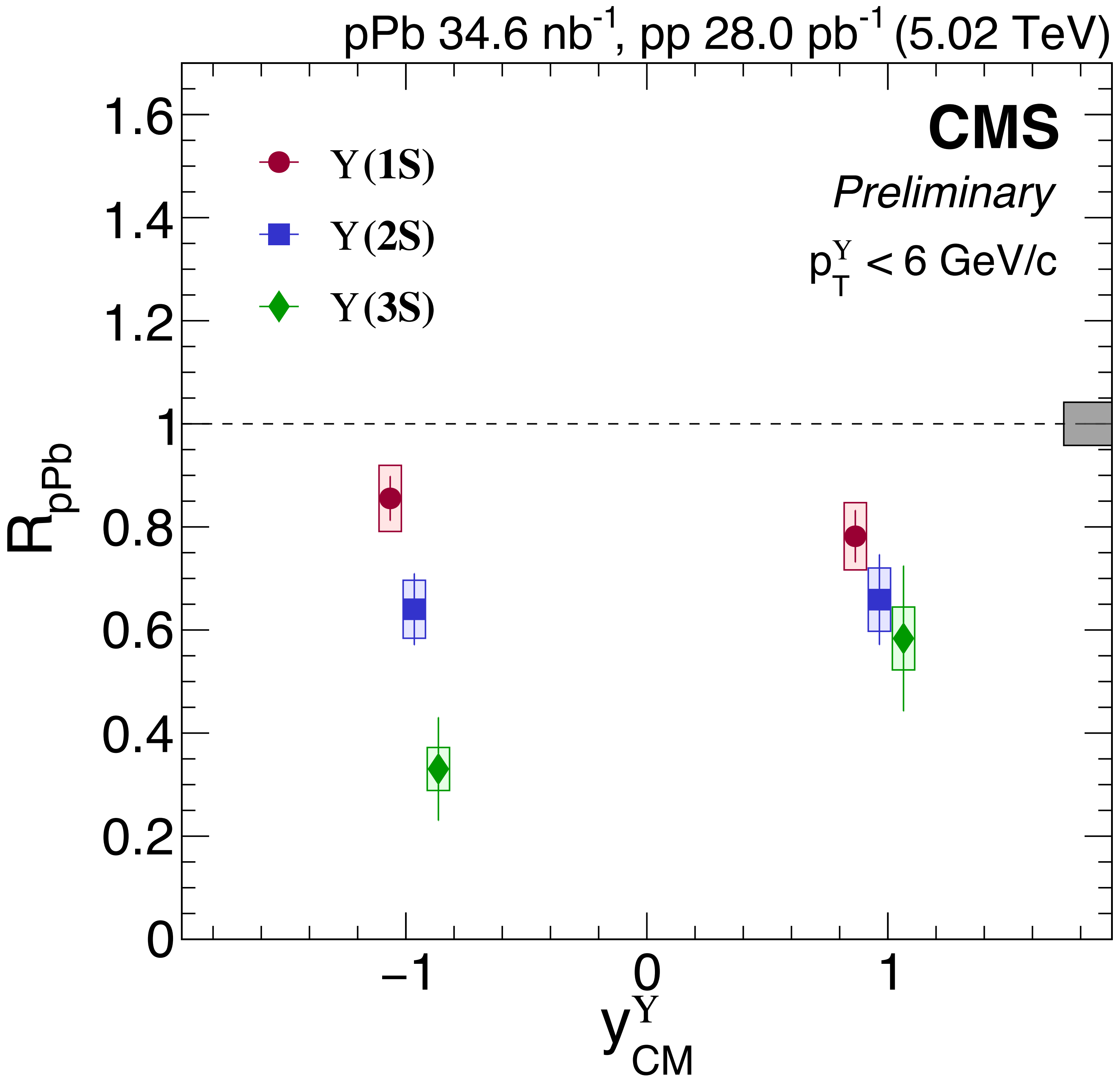
Results : Upsilon R_{pPb}

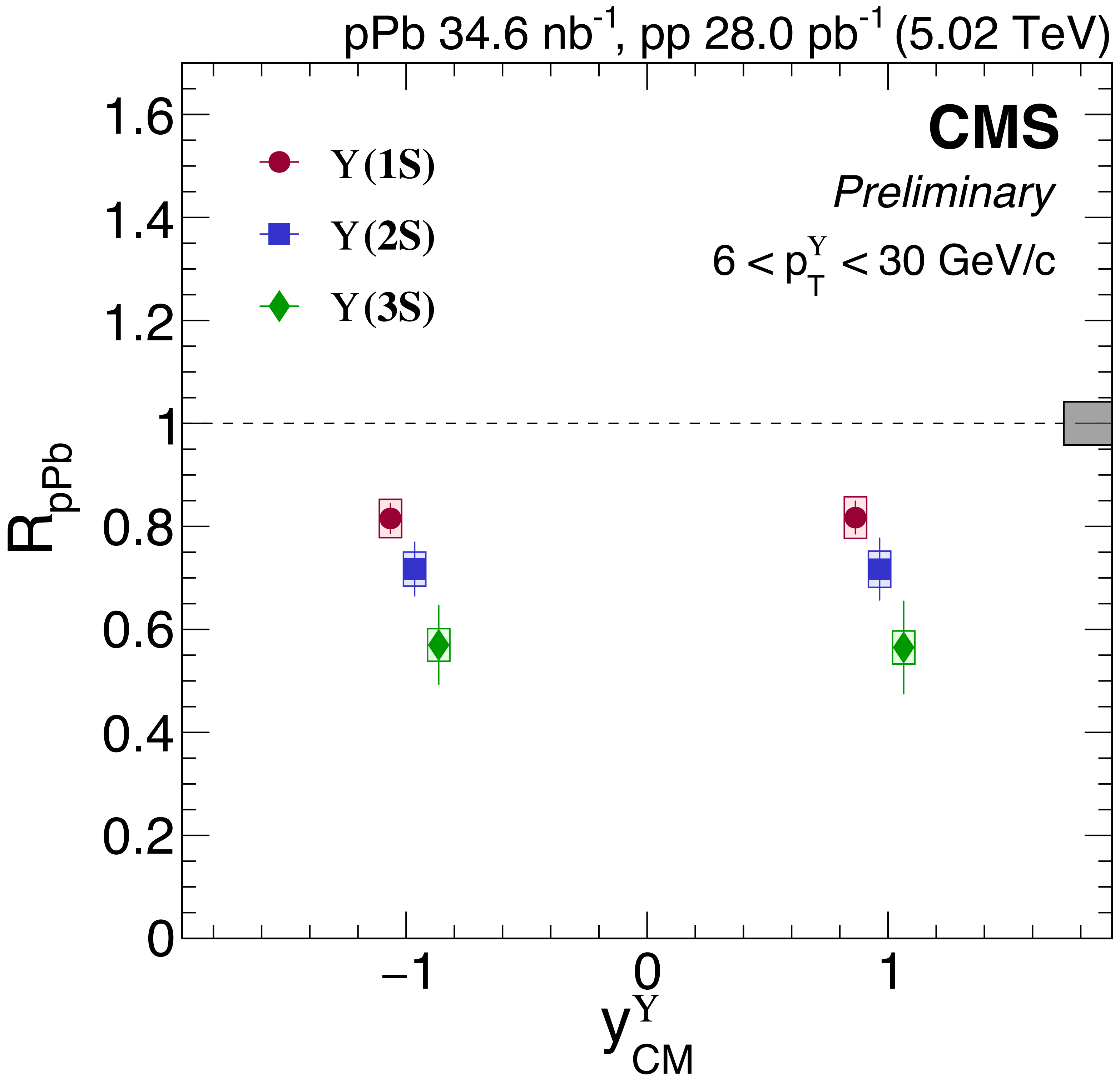


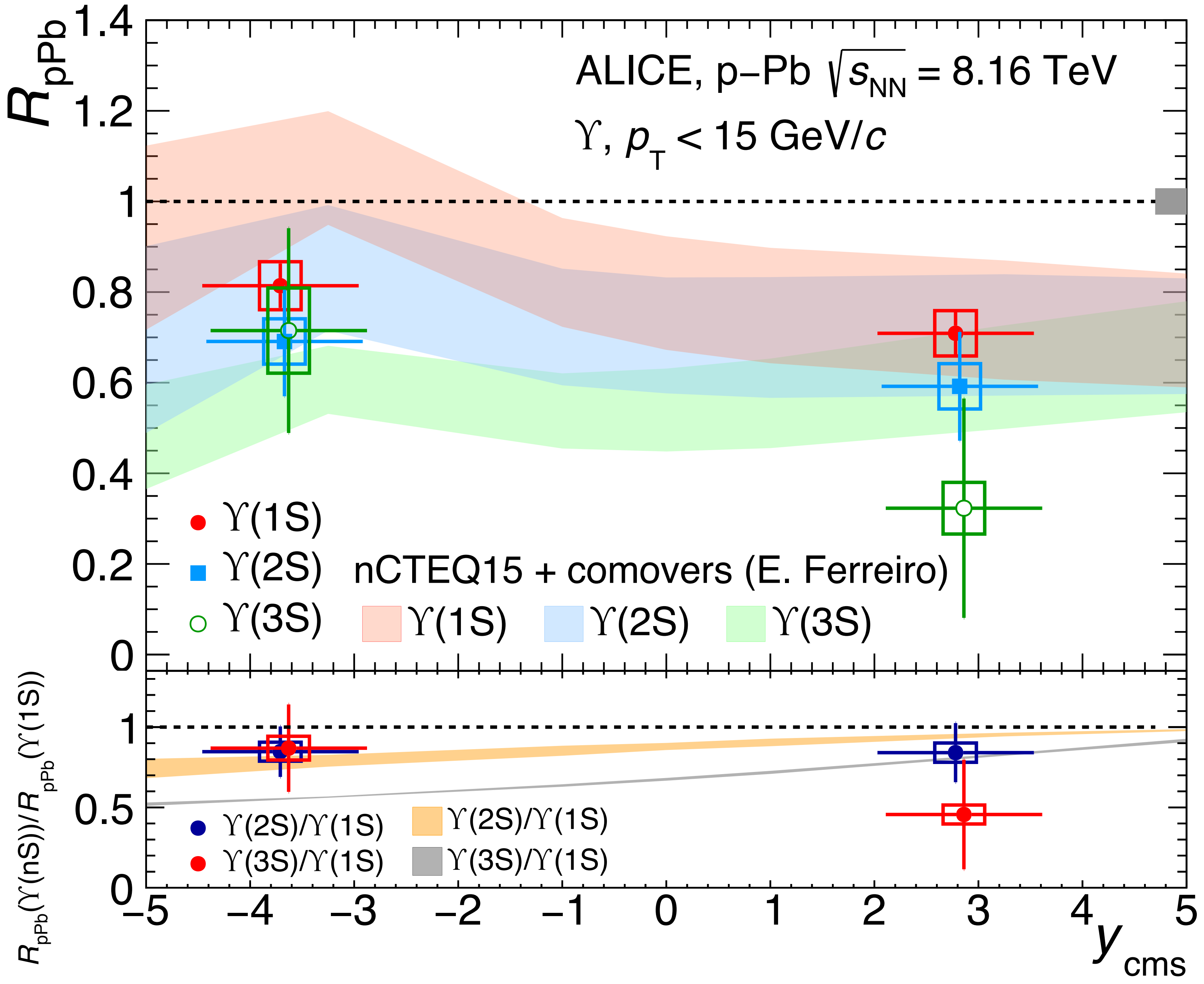


- In agreement with other experiments
- Υ(1S) R_{pPb} generally well described by nPDF calculations

Results : Upsilon R_{pPb}

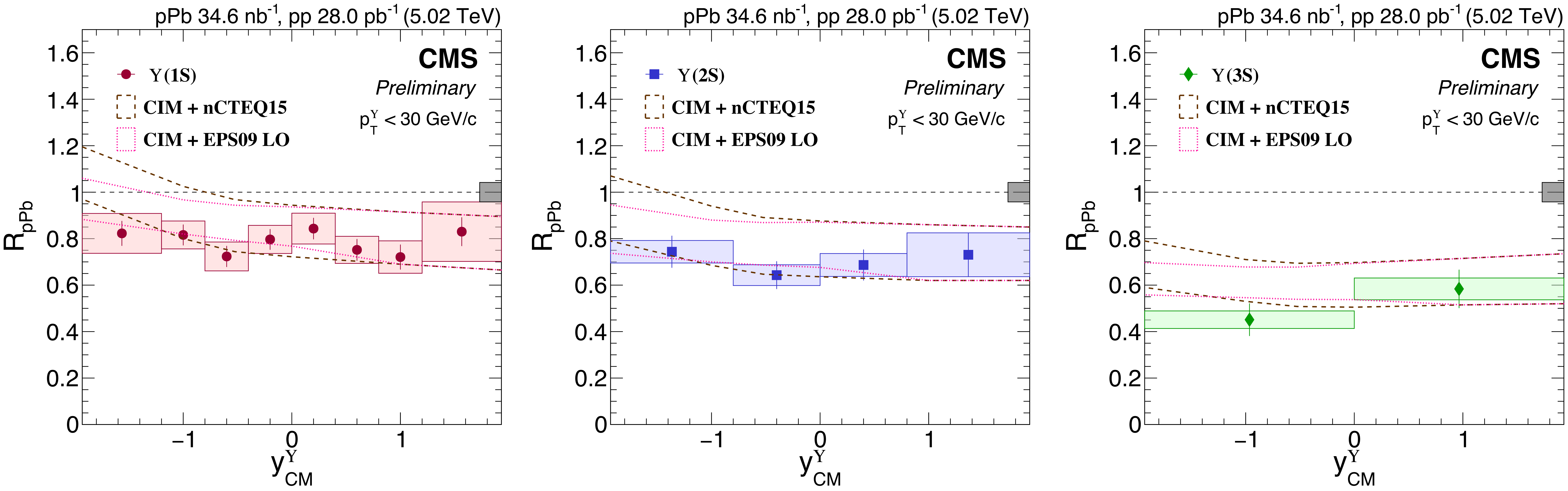






- **nPDF & energy loss model suggest similar R_{pPb} for all Υ(nS)**
  : Inconsistent with data —> Described by comover model
- **Slightly different trend b/w CMS & ALICE**

Results : Upsilon R_{pPb}

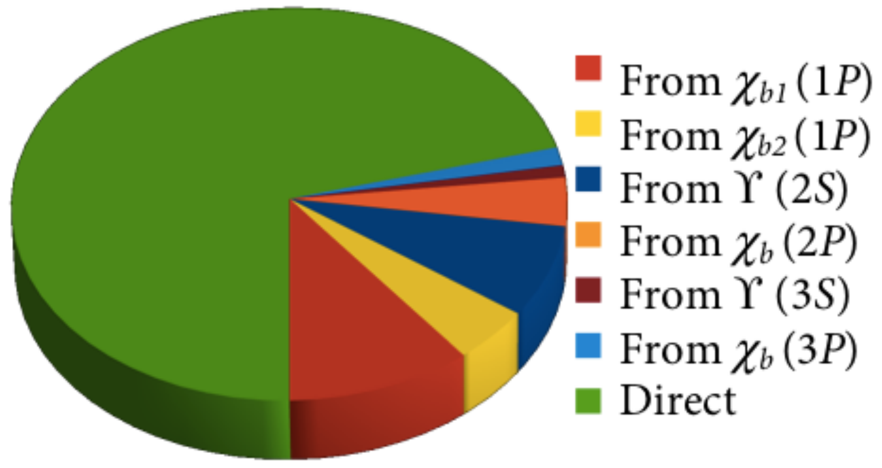


- Comover breakup model in agreement with data

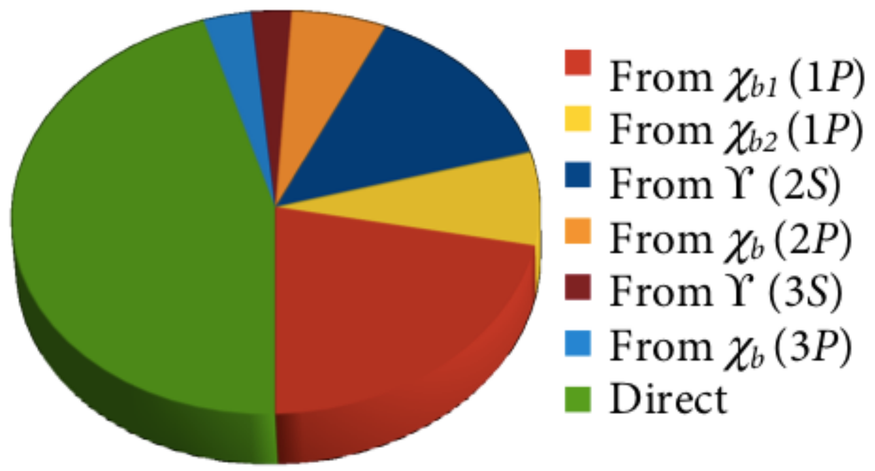
Future prospects

- Feed down fraction

[arXiv:1903.09185]



Low-p_T $\Upsilon(1S)$

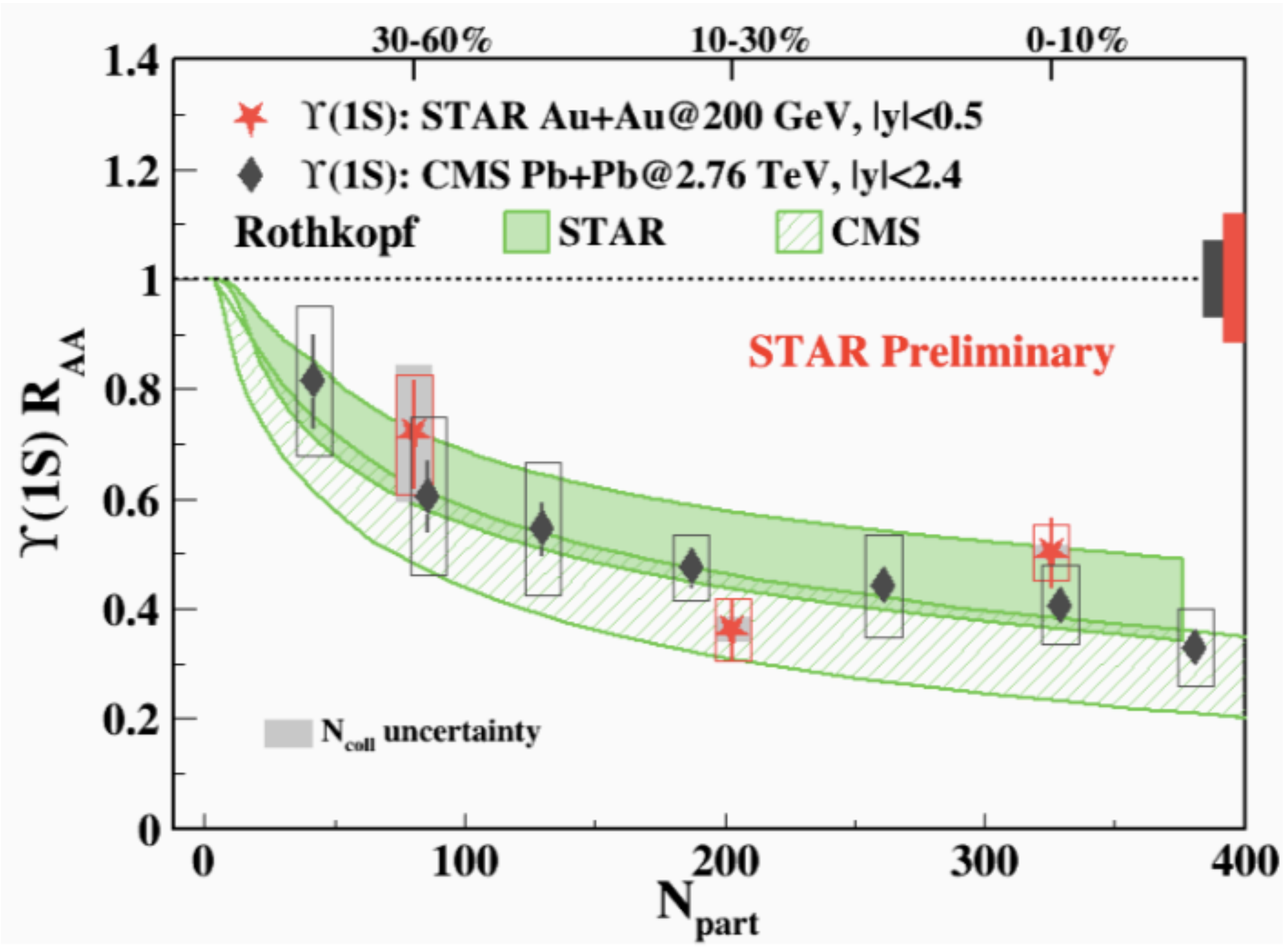


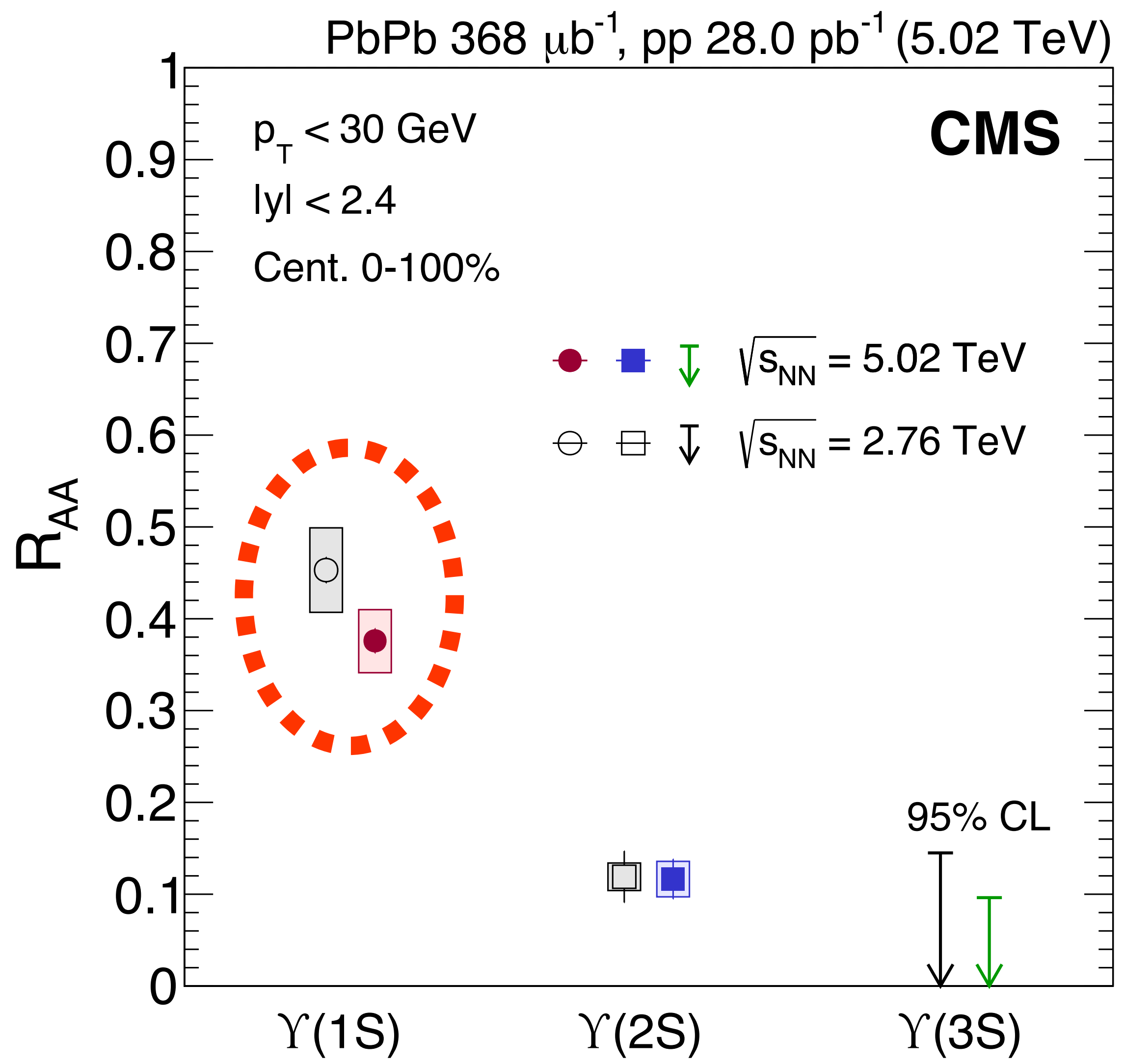
High-p_T $\Upsilon(1S)$

PRC 96 (2017) 054901 : link

$$\sigma_{1P} \simeq 1.08\sigma_{1S}^{tot}$$

- Cross section 1P > 1S

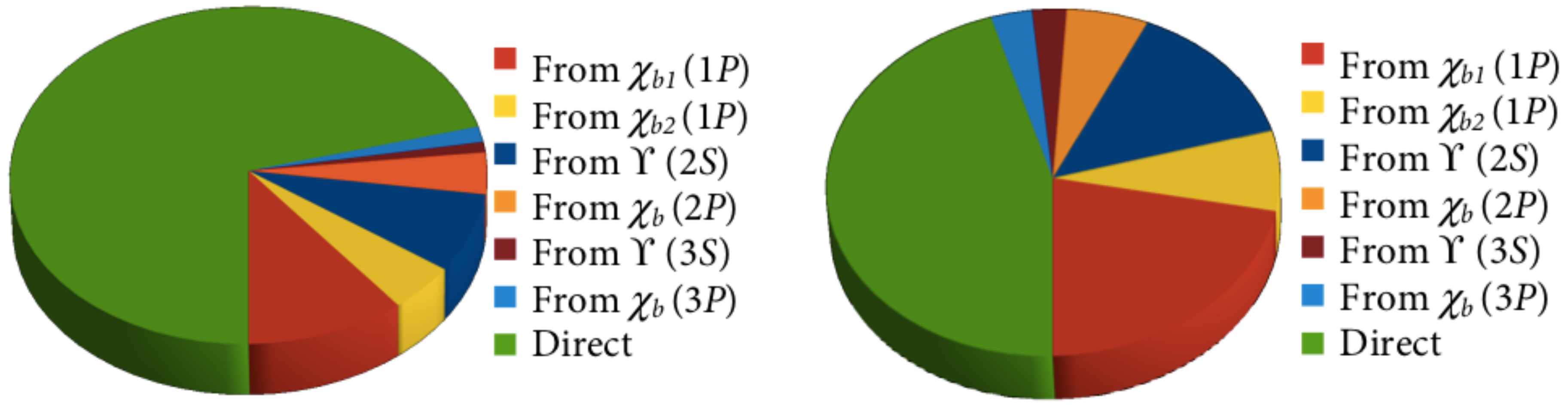




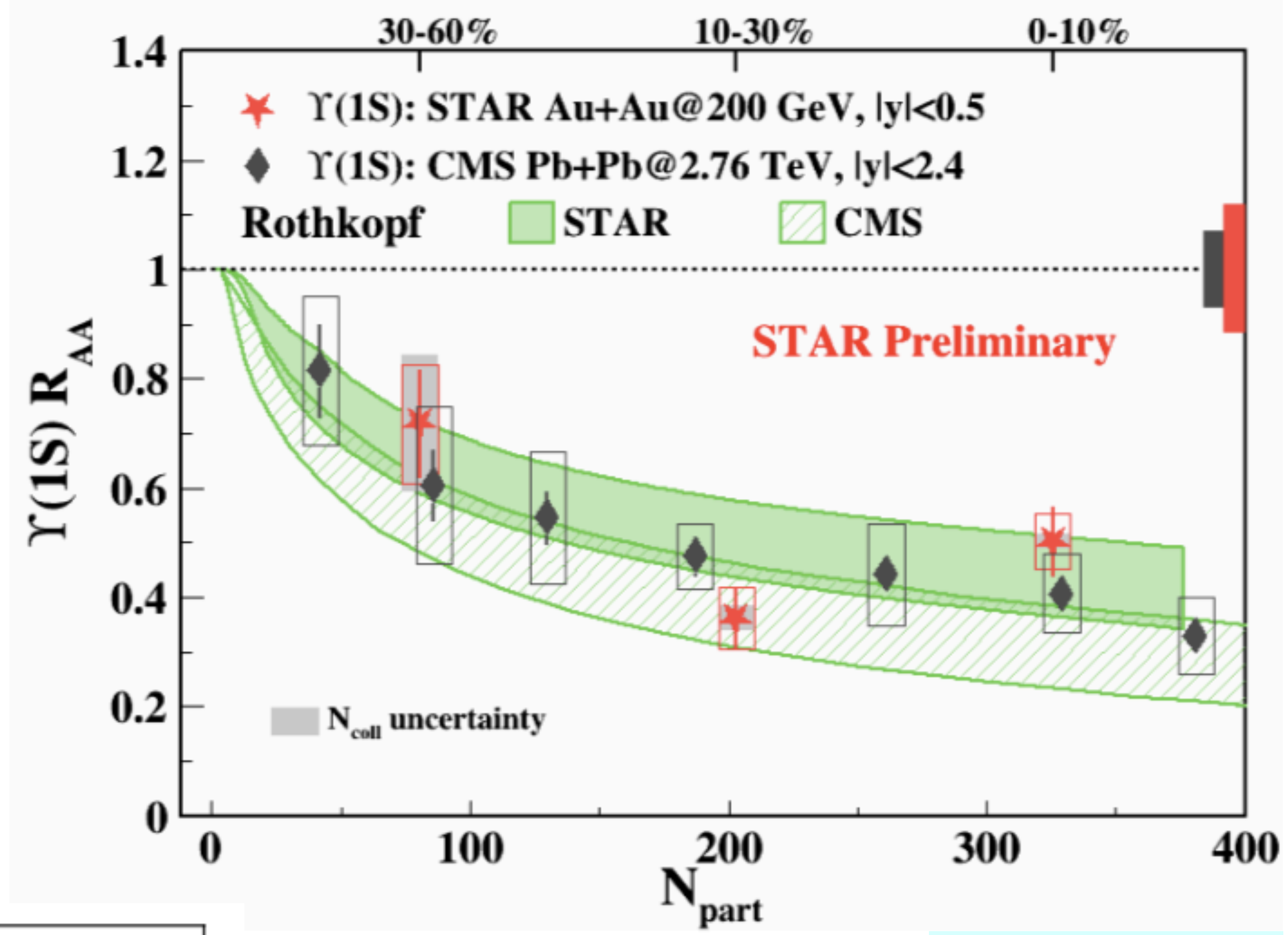
Future prospects

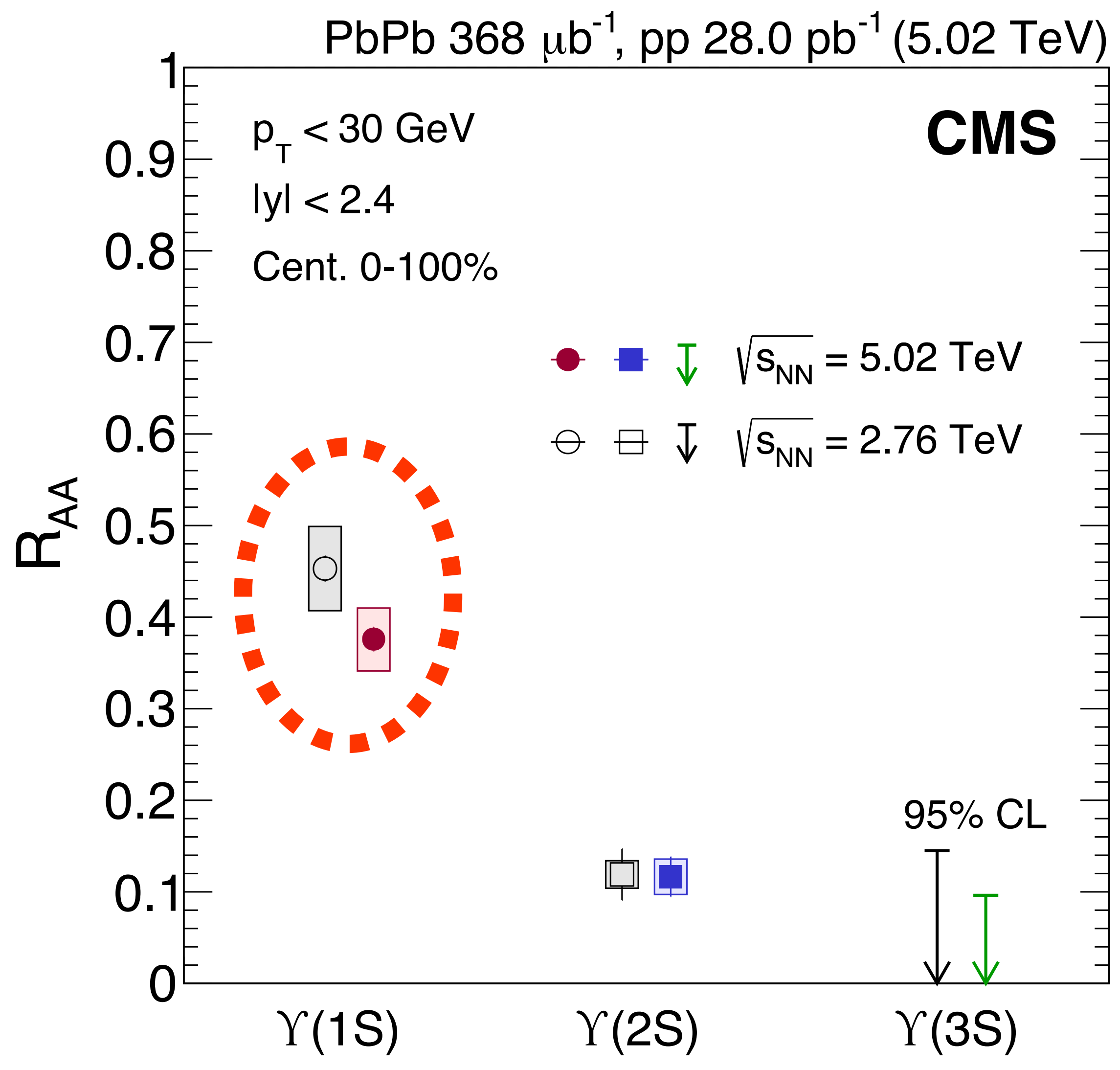
▸ Feed down fraction

[arXiv:1903.09185]



Low-p_T $\Upsilon(1S)$ High-p_T $\Upsilon(1S)$

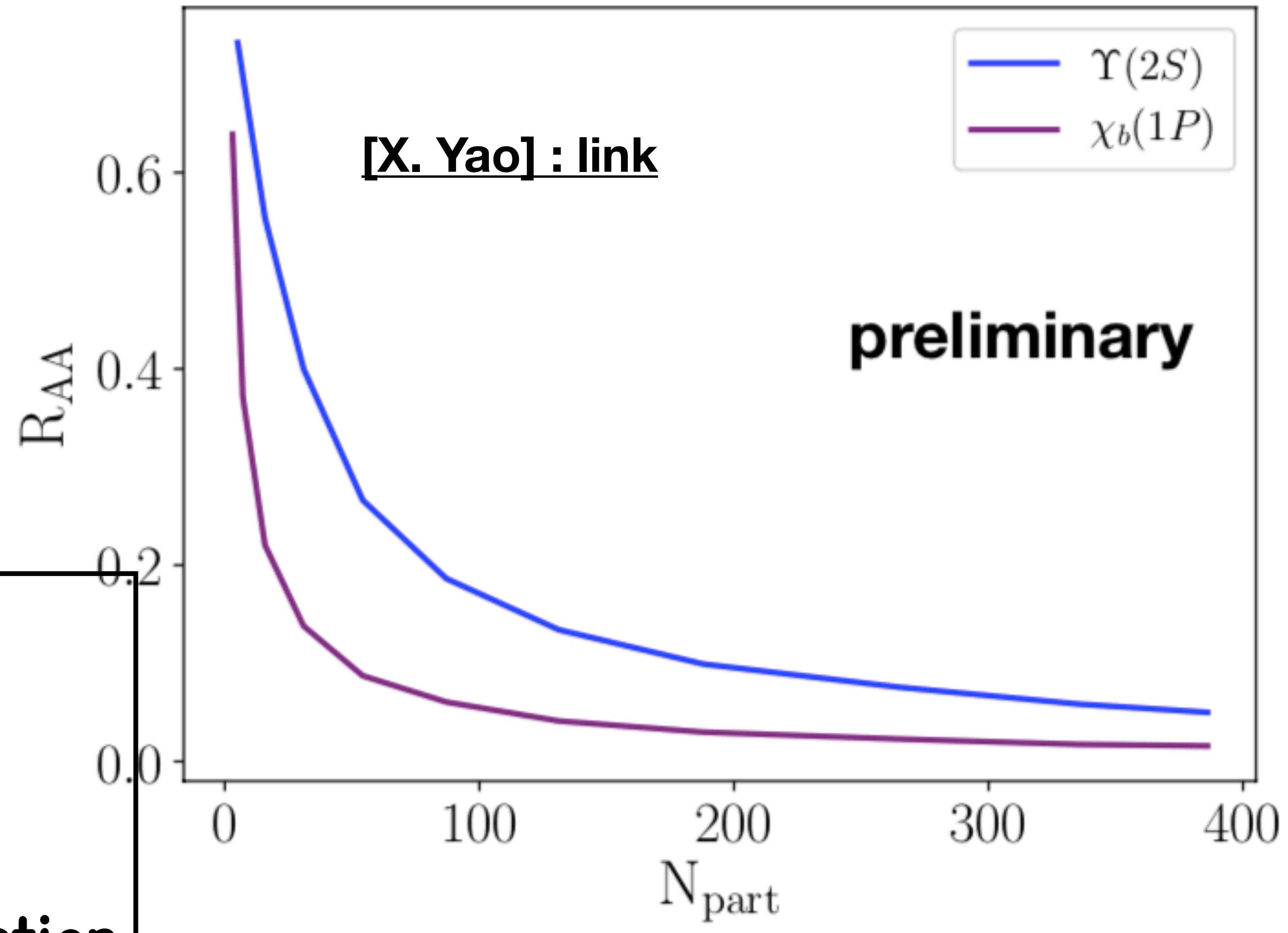




PRC 96 (2017) 054901 : link

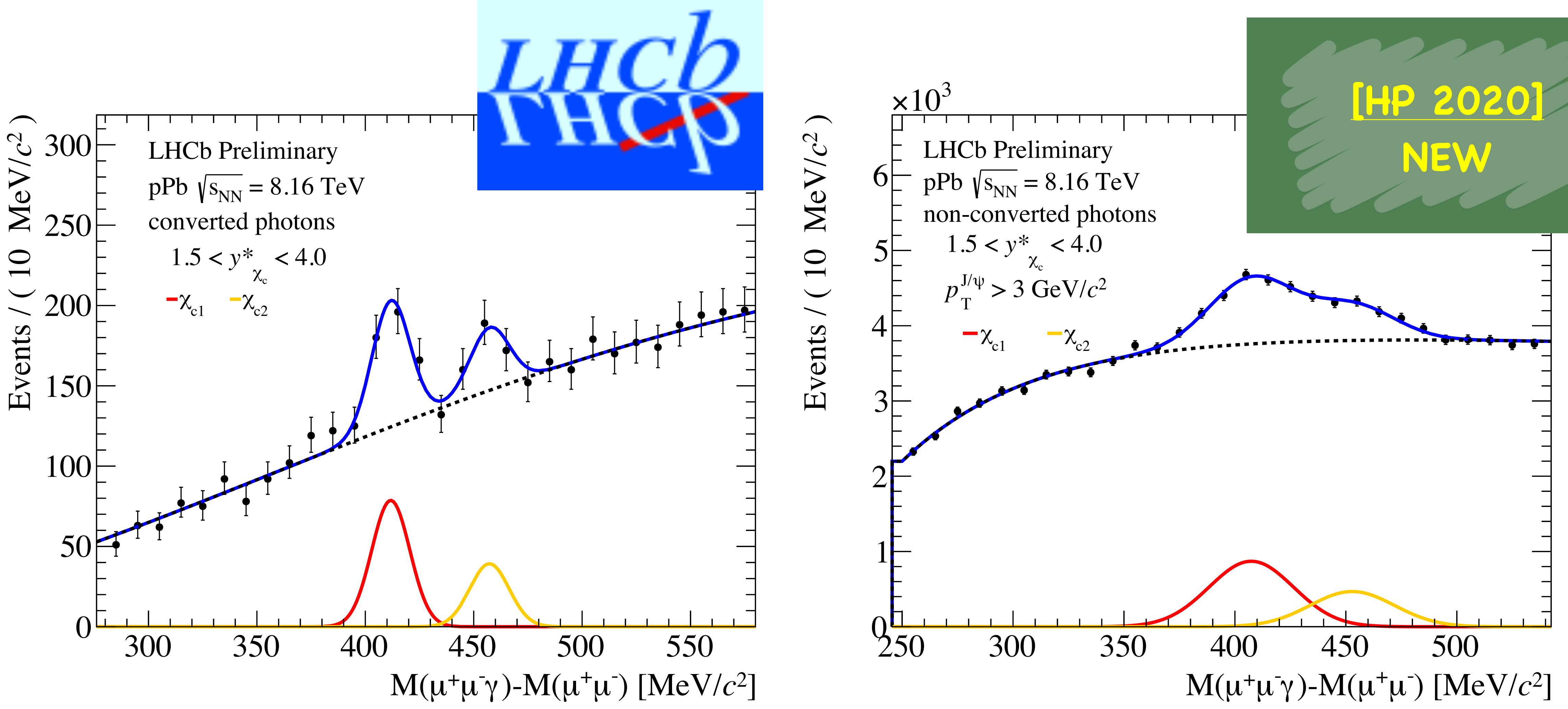
$\sigma_{1P} \simeq 1.08\sigma_{1S}^{tot}$

- Cross section 1P > 1S



[HP 2020]
NEW

- Similar binding energy
- Recombination for 1P->2S ≃ 2S->1P
- Larger 1P cross section
- R_{AA} not scale with cross section



[HP 2020]
NEW

- P-wave state measurement in near future

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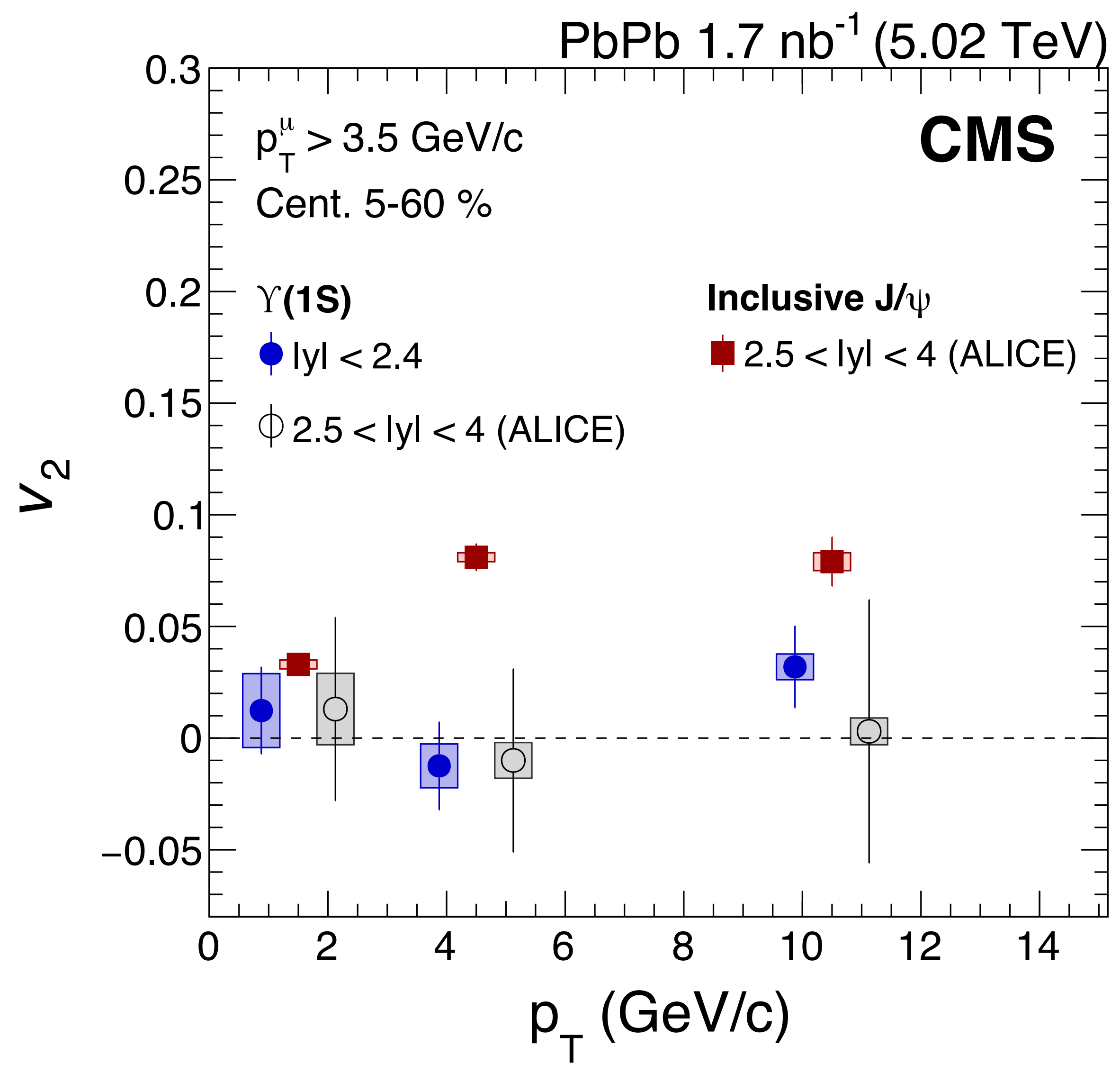
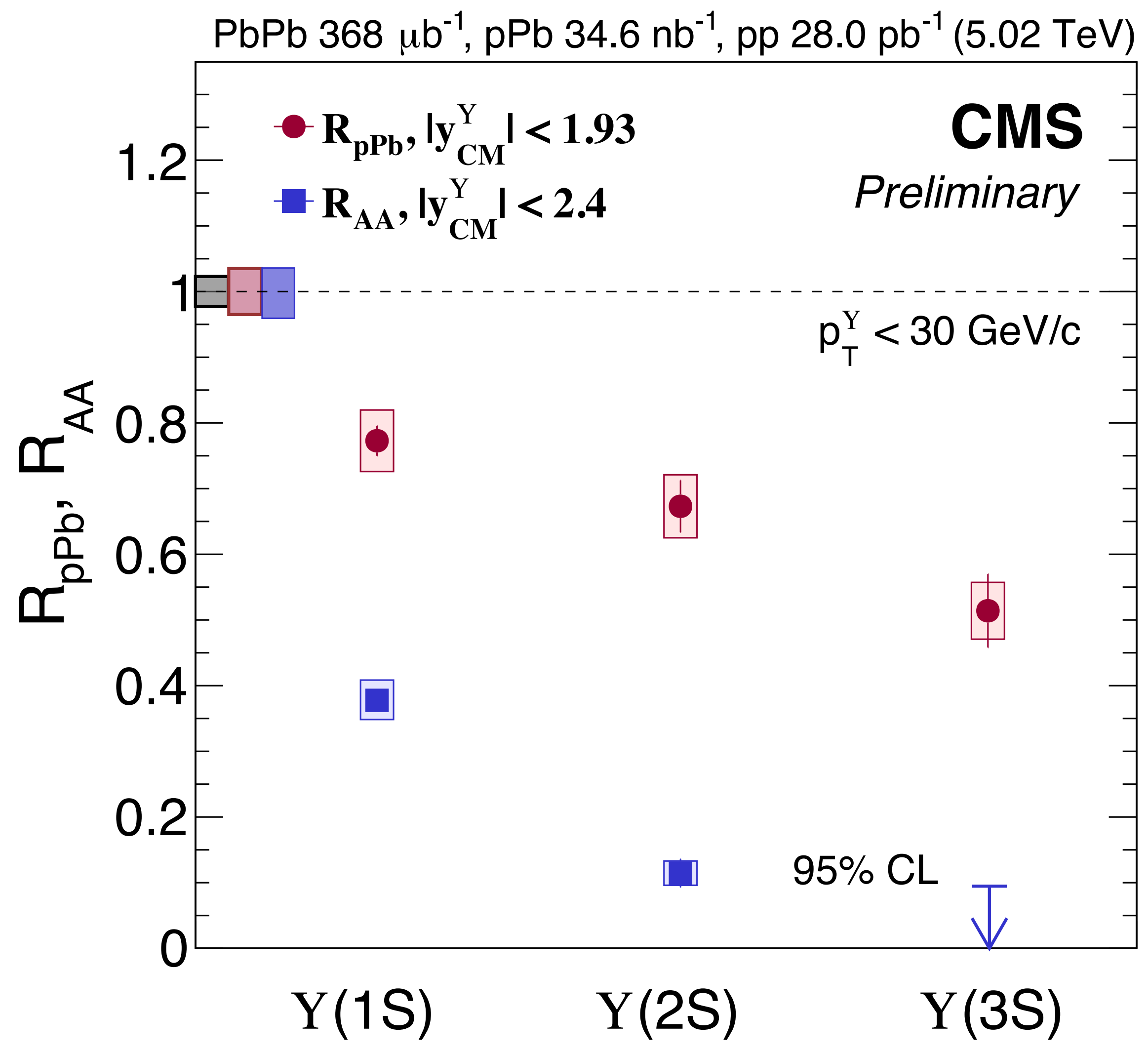
Summary

- Significant work done of Υ measurement in the past years
- No significant flow signal of Υ states observed in PbPb
- Sequential suppression found in pPb : much smaller than PbPb
  - Cannot explained by nPDF calculations — comover breakup as a suggestion
- Looking forward for future new measurements (χ_b)

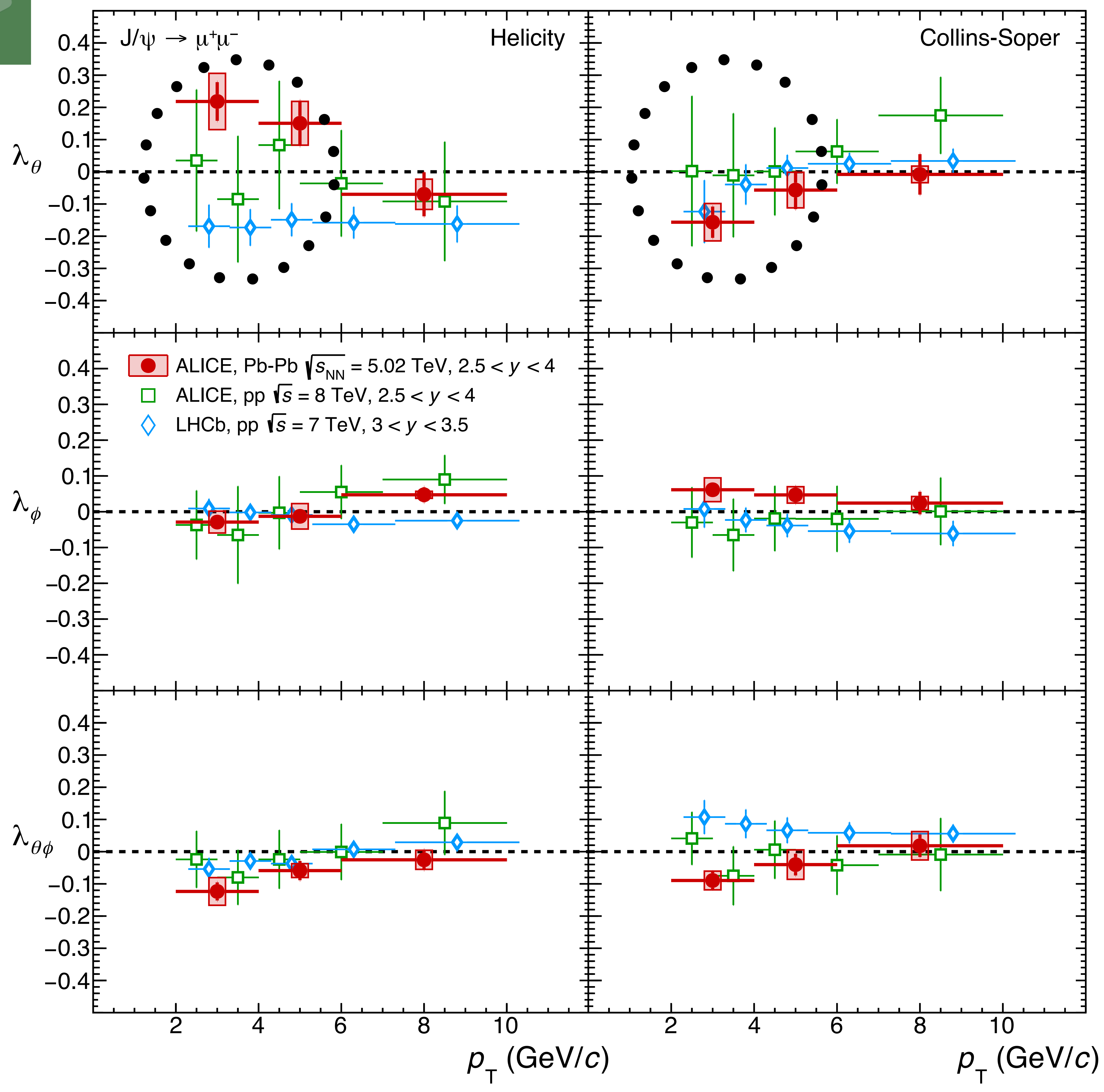


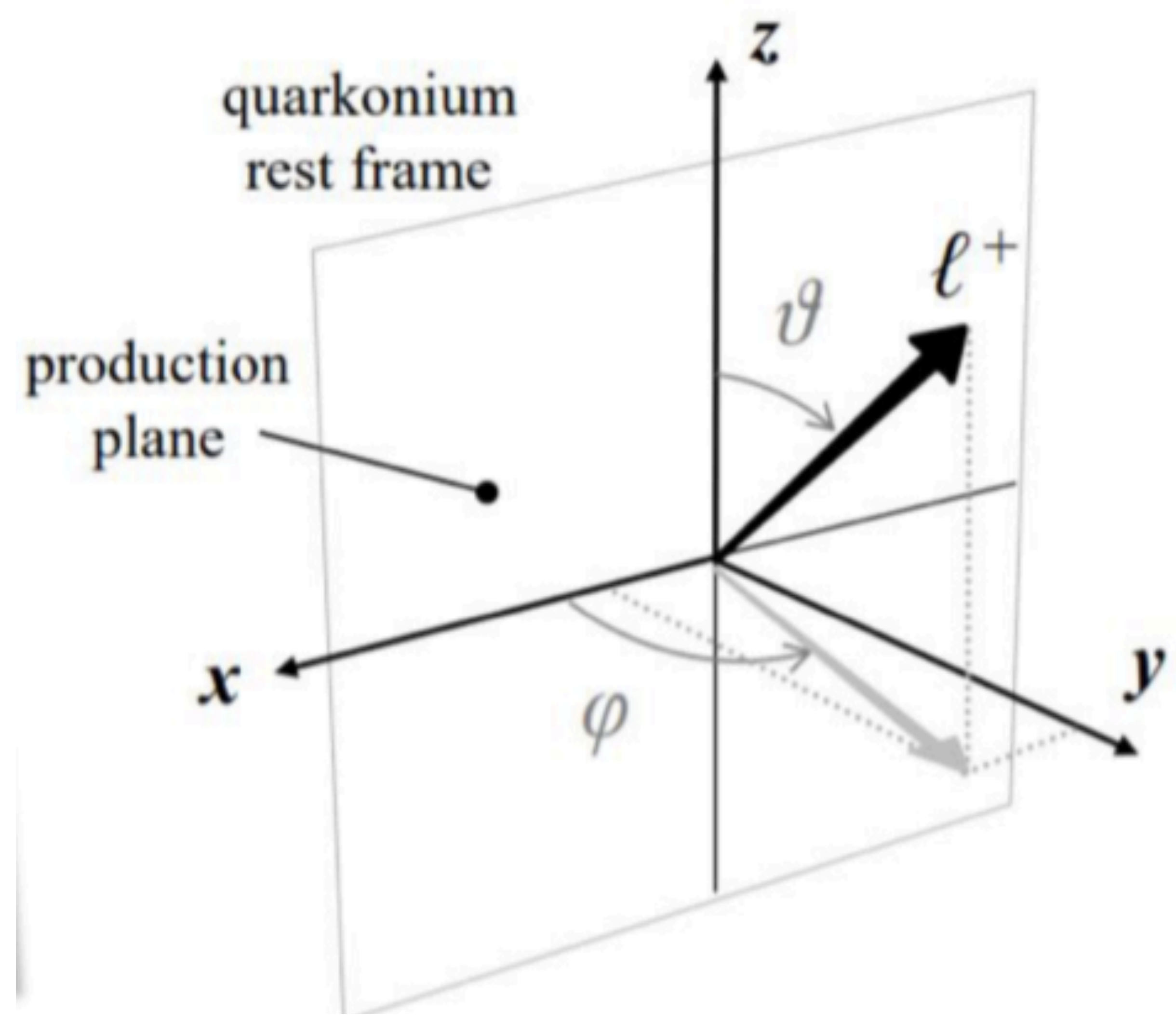


Back-Up

First J/ψ polarization in PbPb

[HP 2020] FINAL





$$W(\cos\theta,\varphi) \propto \frac{1}{3+\lambda_\theta} \cdot (1 + \lambda_\theta \cos^2\theta + \lambda_\varphi \sin^2\theta \cos 2\varphi + \lambda_{\theta\varphi} \sin 2\theta \cos\varphi)$$

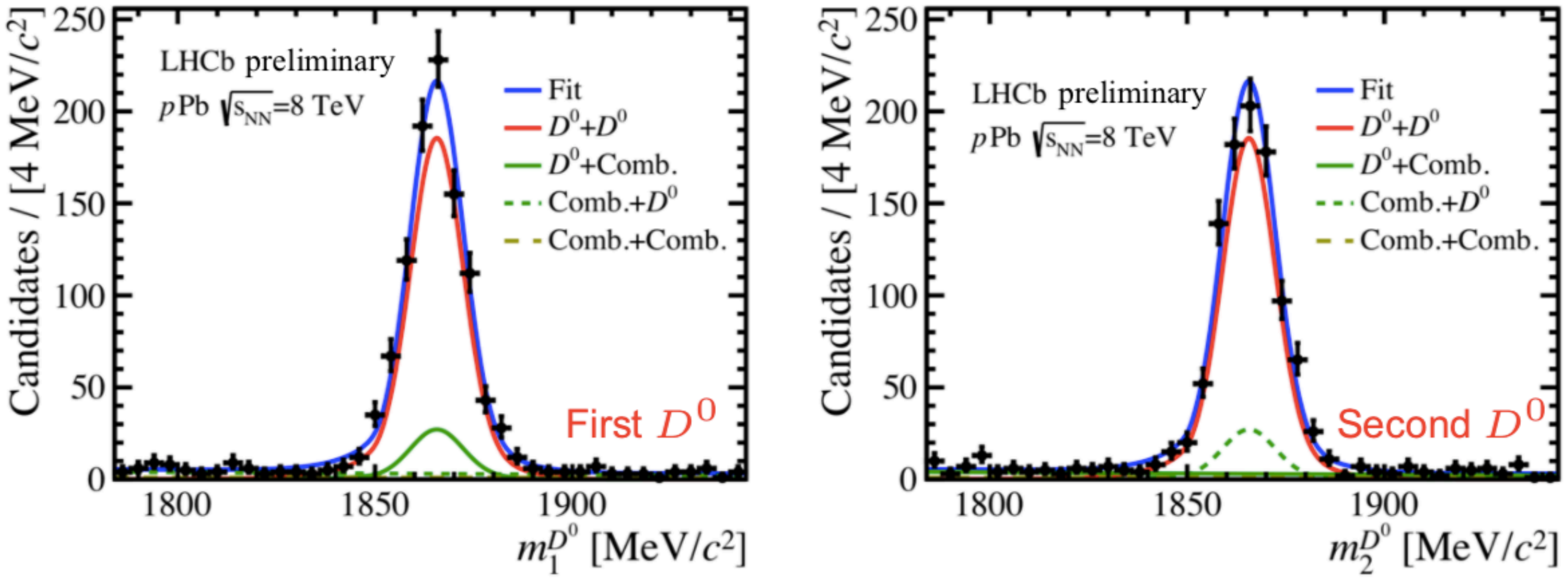
- $(\lambda_\theta, \lambda_\phi, \lambda_{\theta\phi})$ = (0,0,0) —> No polarization
- $(\lambda_\theta, \lambda_\phi, \lambda_{\theta\phi})$ = (-1,0,0) —> Longitudinal polarization
- $(\lambda_\theta, \lambda_\phi, \lambda_{\theta\phi})$ = (+1,0,0) —> Transverse polarization

- Possible polarization at low-p_T?
- Regneration? Feed-down? No model so far

First double charm measurement in pPb

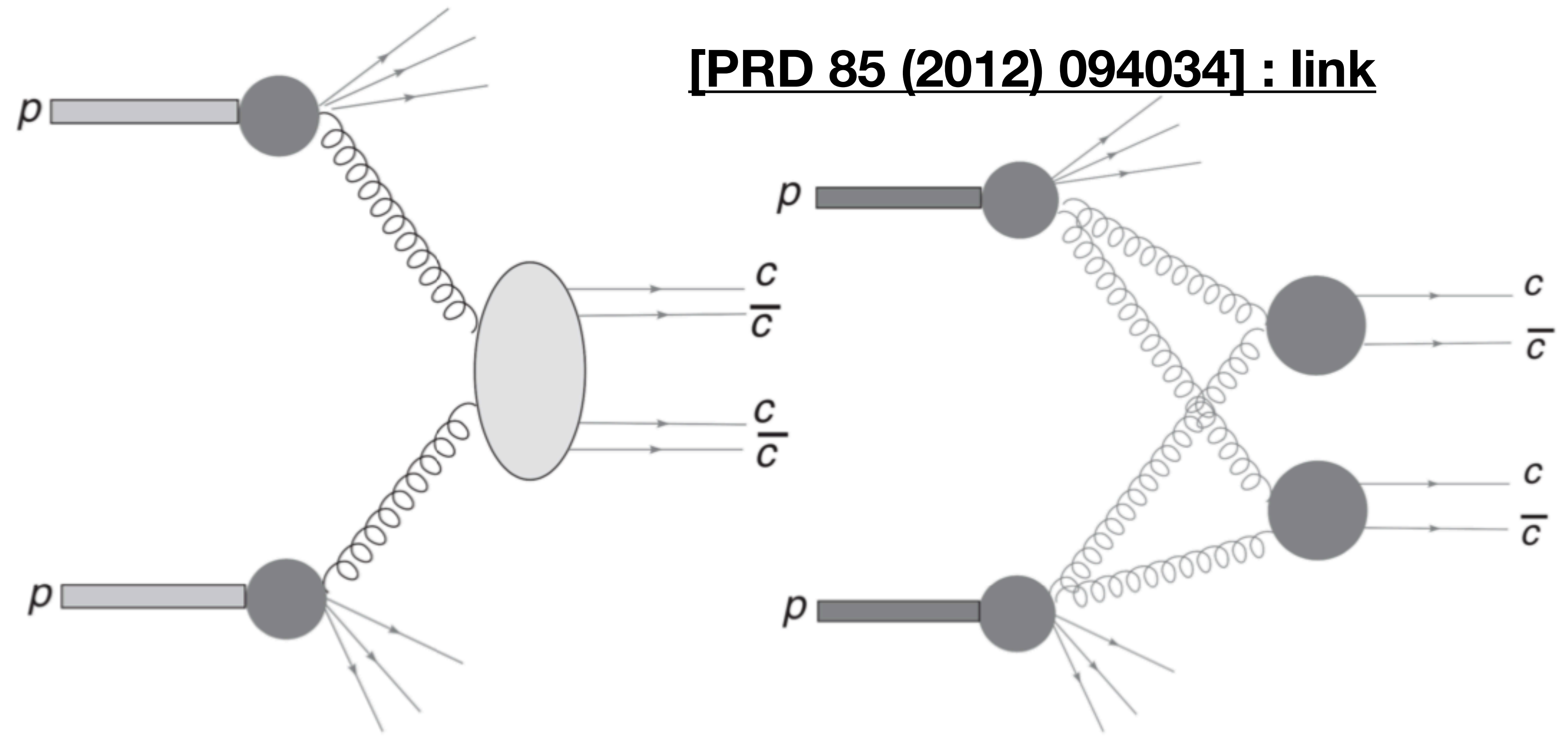
[HP 2020] NEW

[J. Wang] : link

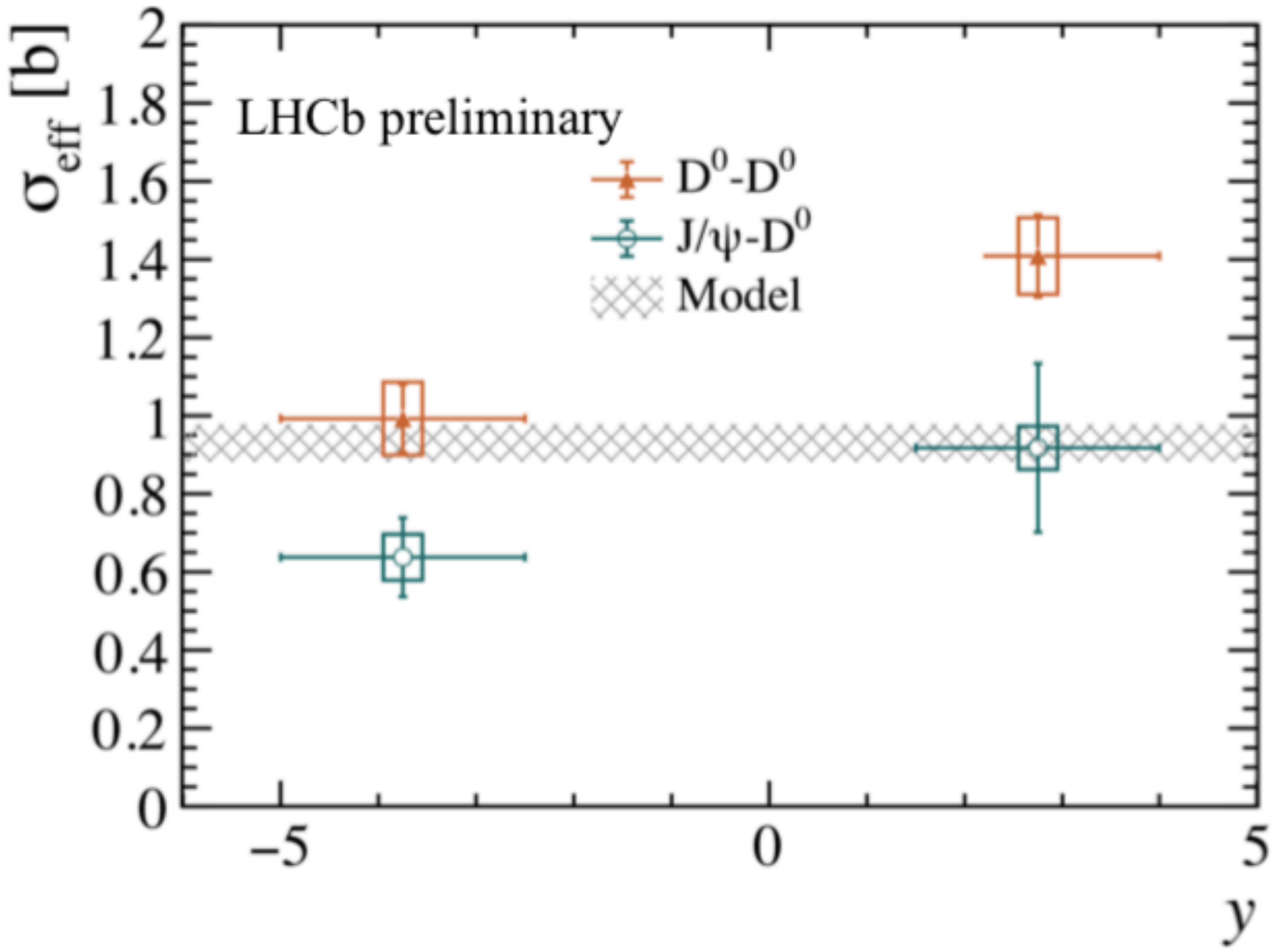


Simple parton scattering (SPS) vs Double parton scattering (DPS)

[PRD 85 (2012) 094034] : link



$$\sigma_{\text{eff}} = \frac{\sigma^A \sigma^B}{(1+\delta_{AB})\sigma^{AB}_{\text{DPS}}}$$



- Model suggest DPS/SPS enhancement by factor of 3
- J/ψ-D⁰ smaller than D⁰-D⁰ similar as pp
  - SPS contamination? DPS enhancement?
- pPb higher than Pbp : suppression of DPS in pPb
- R. Vogt : [R. Vogt] : link
  - Double J/ψ production in agreement with NLO $b\bar{b}$ production
  - $b\bar{b}$ angular and rapidity quantities as a tool to probe HNM & CNM effects