Bottomonium production in pp and Pb+Pb collisions with ATLAS

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on behalf of ATLAS collaboration

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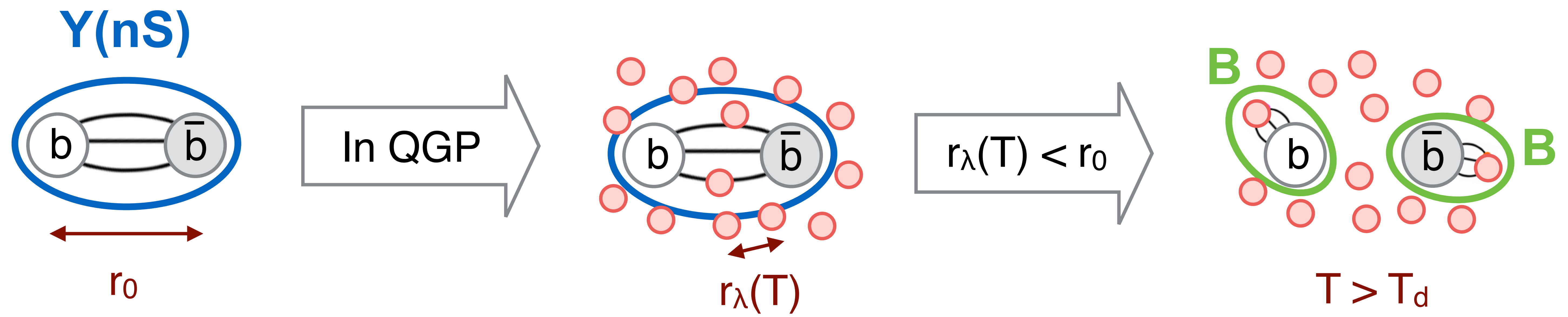
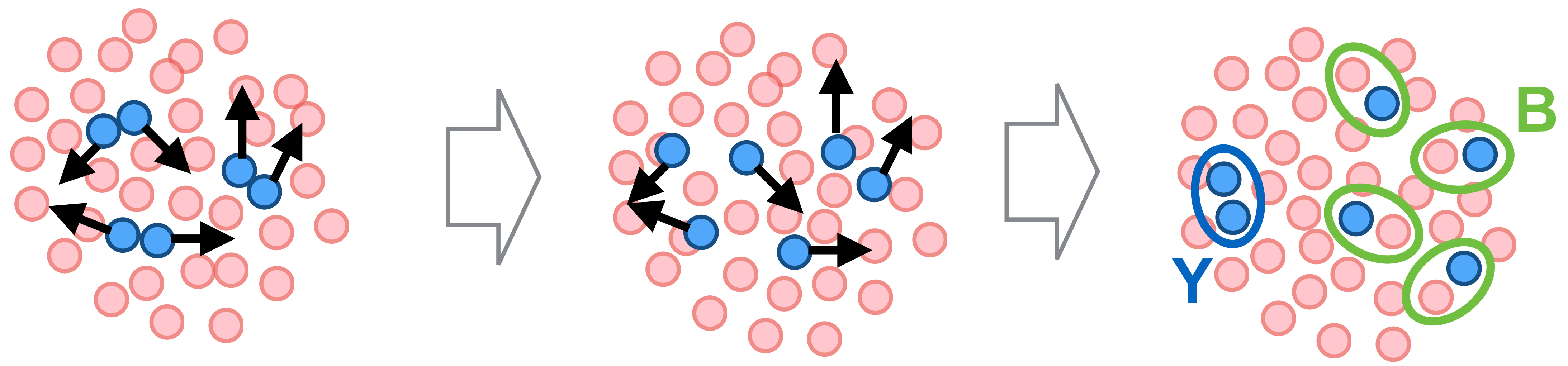
Motivation

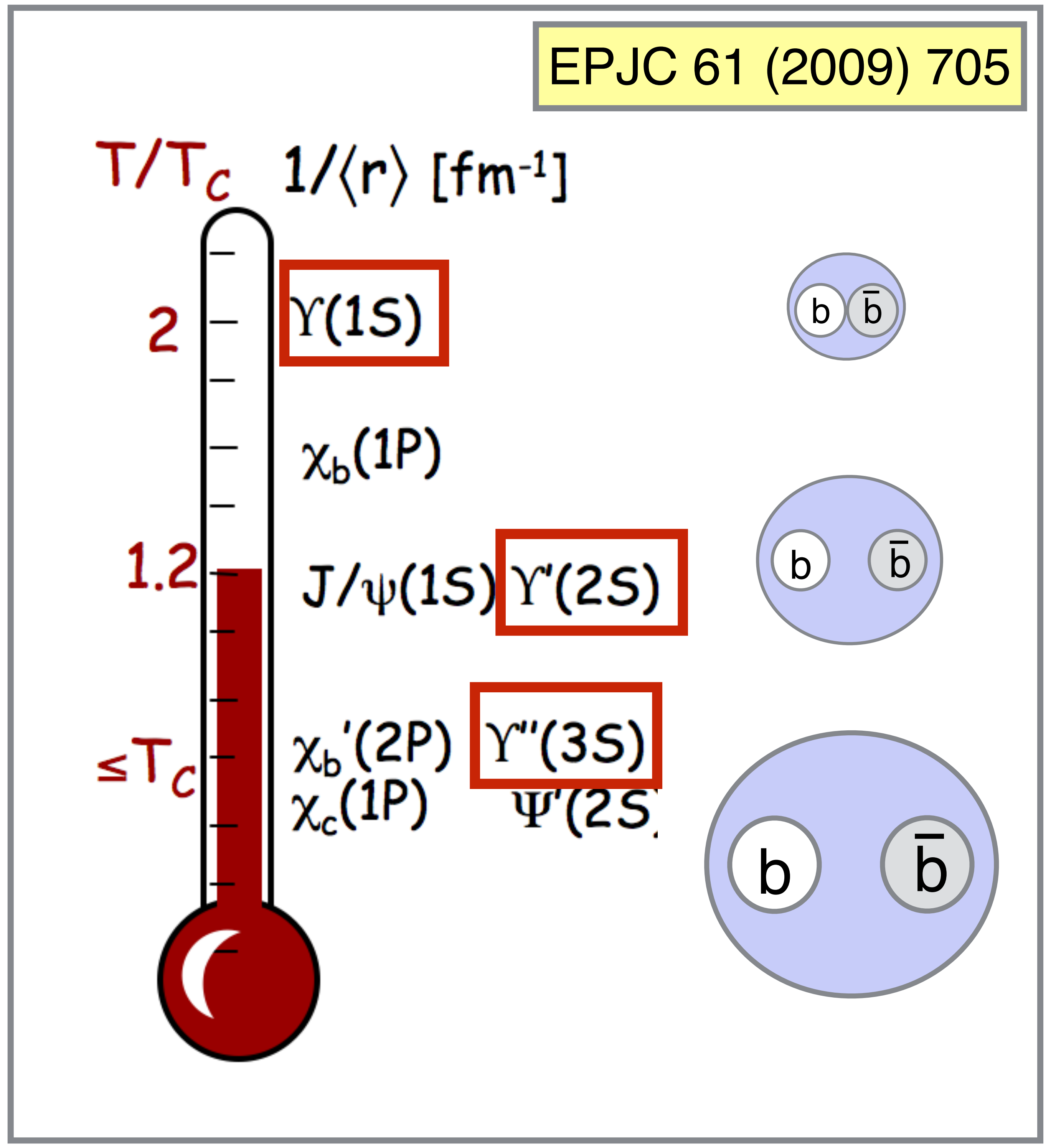
- Bottomonia are important probes of Quark-Gluon Plasma
  - Mainly produced at the early stage of the collisions
  - Negligible nonprompt fraction and less regeneration compared to charmonia
  - Three Υ(nS) states are characterized by similar kinematics but have different binding energies

[Color screening]



[Regeneration]

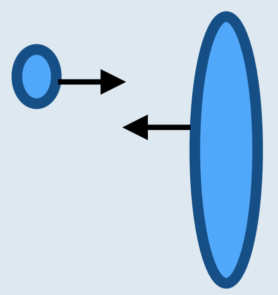




ATLAS quarkonium results

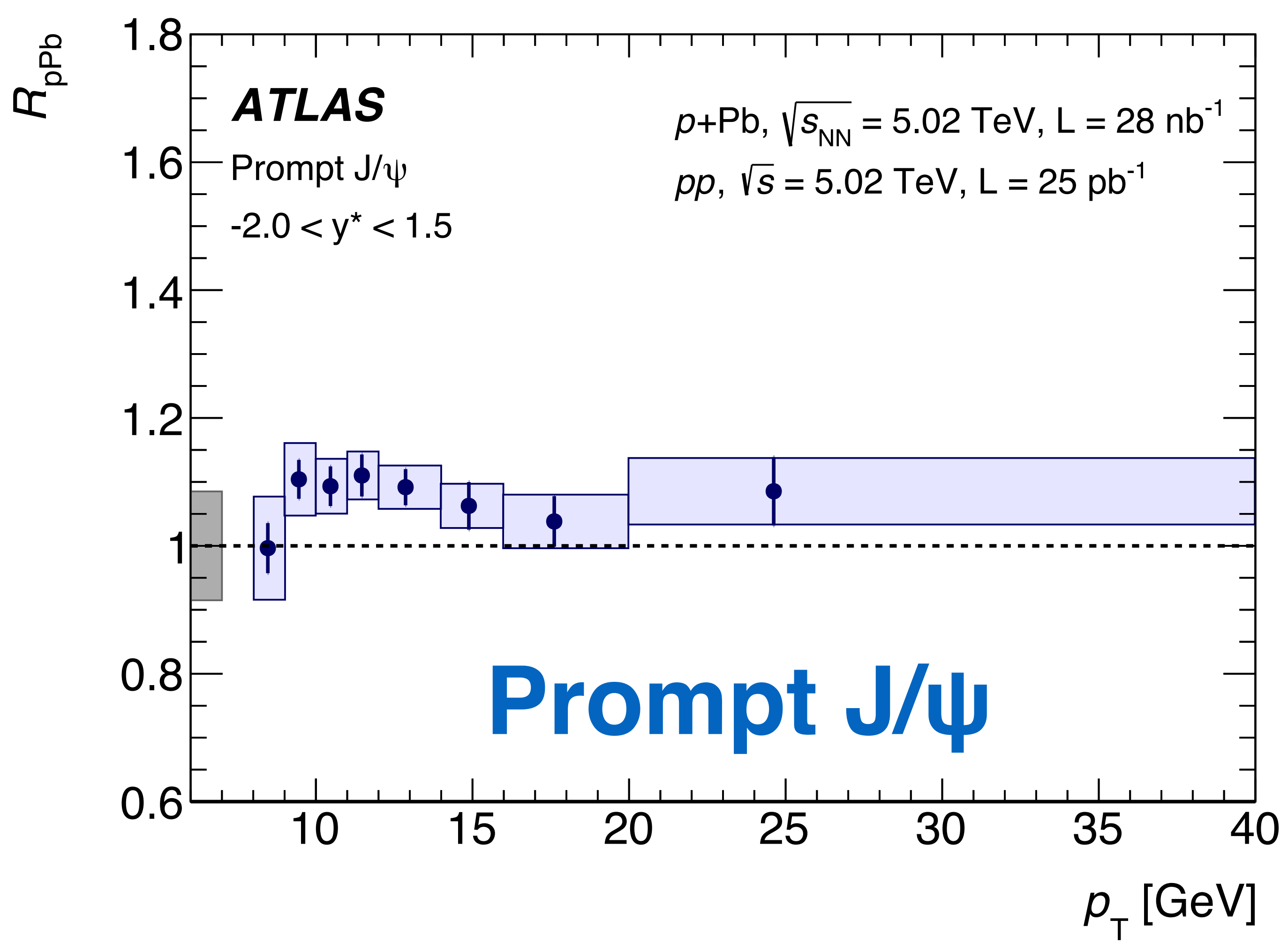
	Charmonia	Bottomonia
p+Pb	EPJC 78 (2018) 171	EPJC 78 (2018) 171
Pb+Pb	EPJC 78 (2018) 762	New

p+Pb



Charmonia

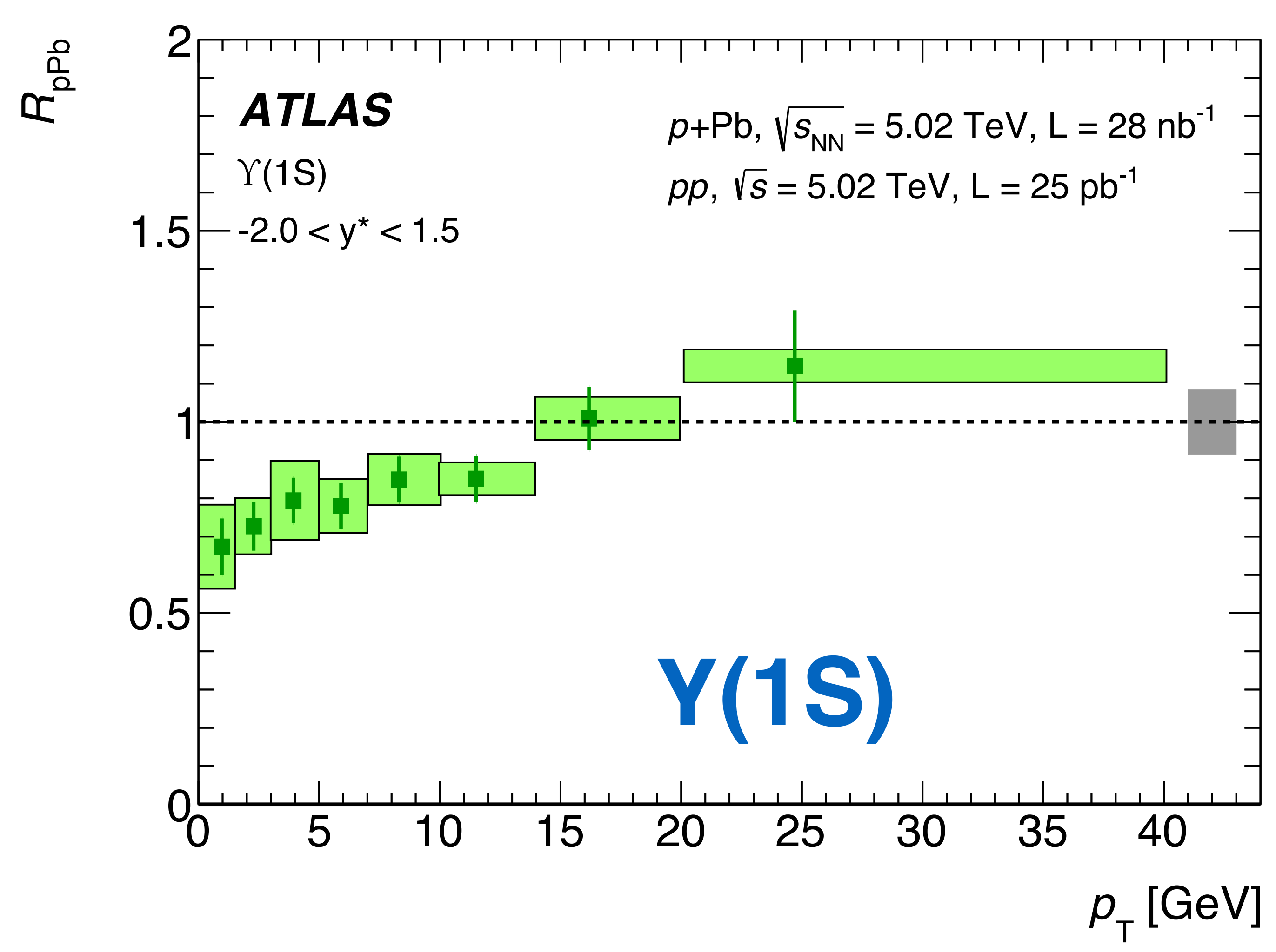
EPJC 78 (2018) 171



- $9 < p_T < 40$ GeV
- $R_{pPb} \sim 1$

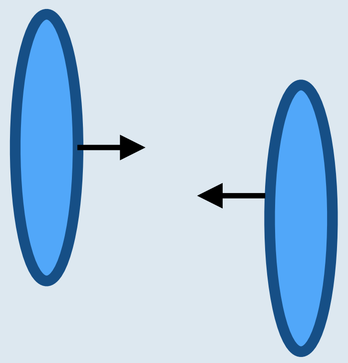
Bottomonia

EPJC 78 (2018) 171



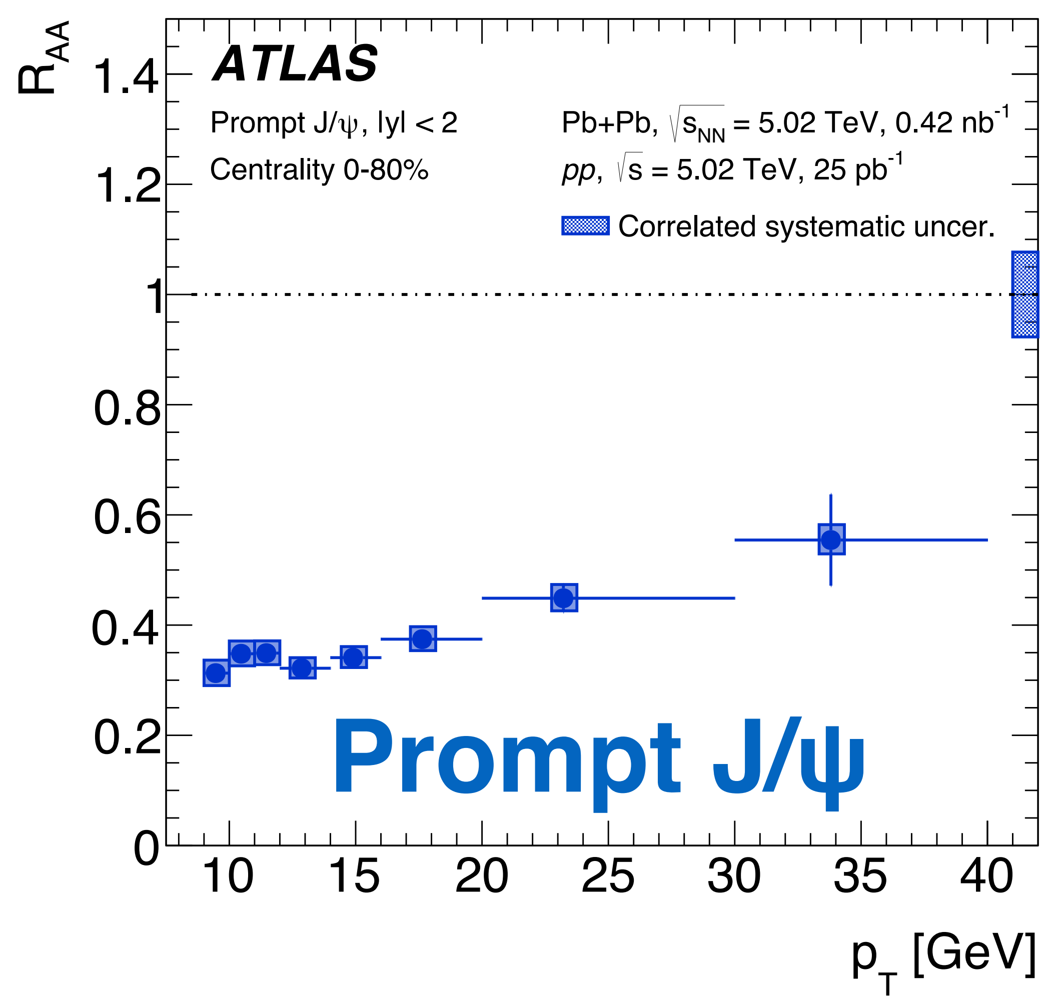
- $R_{pPb} \sim 1$ for $p_T > 15$ GeV

Pb+Pb



Charmonia

EPJC 78 (2018) 762



- Strong suppression
- $R_{AA} \sim 0.2$ for 0-5%

Bottomonia

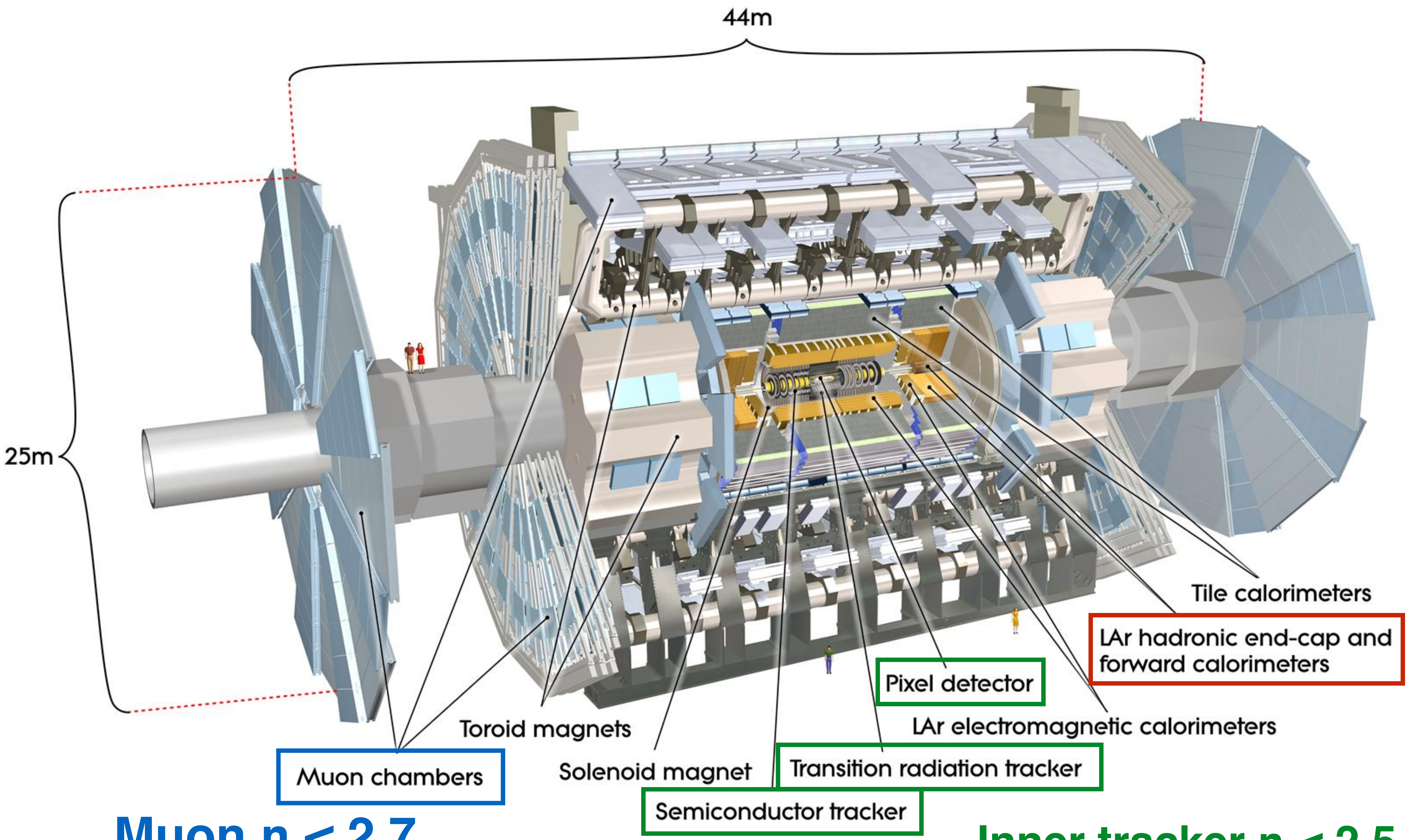
New

ATLAS-CONF-2019-054

- pp collisions in 2017: 0.26 fb^{-1}
- Pb+Pb collisions in 2018: 1.38 nb^{-1}

ATLAS detector

- Bottomonia are measured via the dimuon decay channel: $\Upsilon(nS) \rightarrow \mu^+\mu^-$



FCal 3.1 < η < 4.9 (for centrality)

Muon η < 2.7

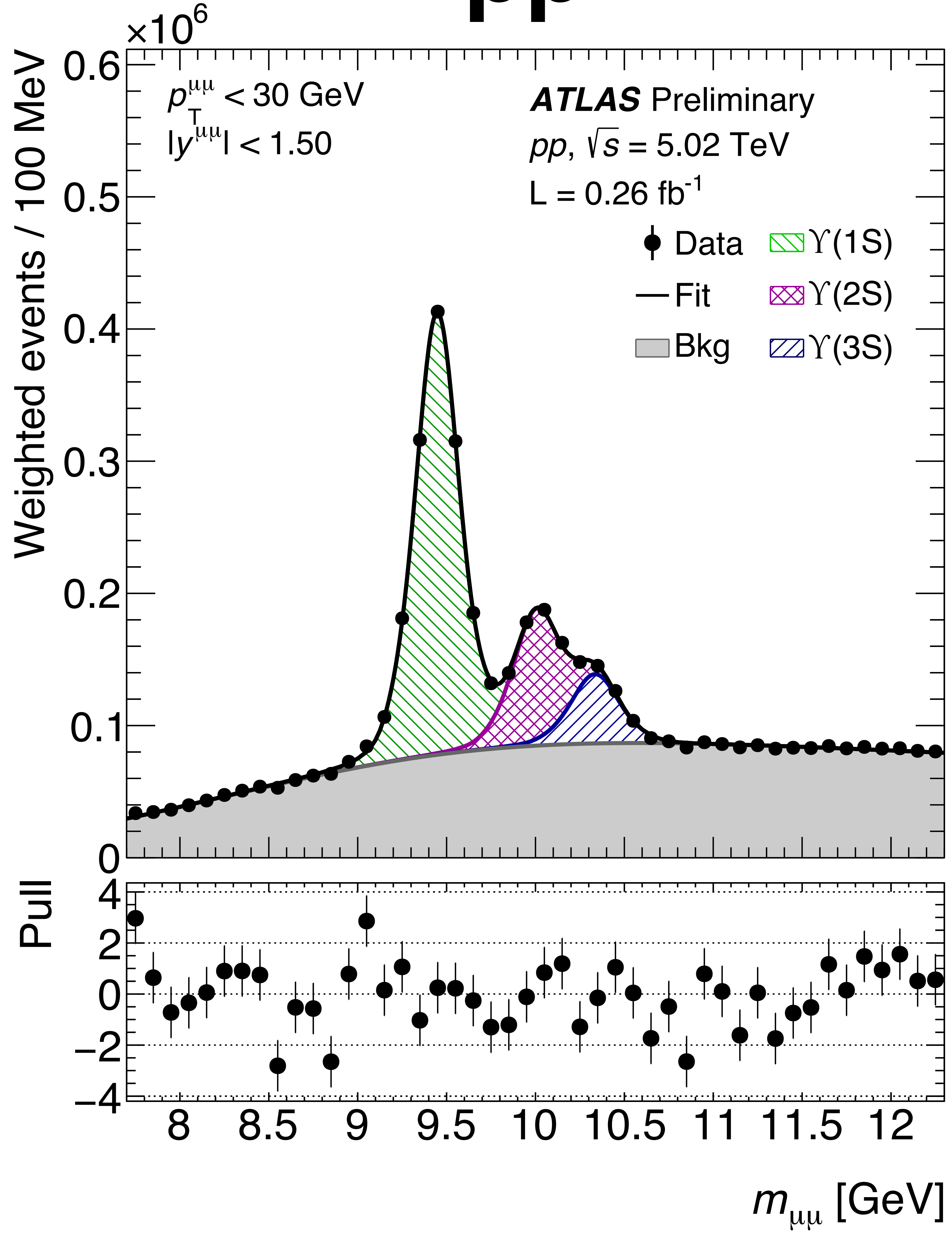
Inner tracker η < 2.5

Υ(nS) signal extraction

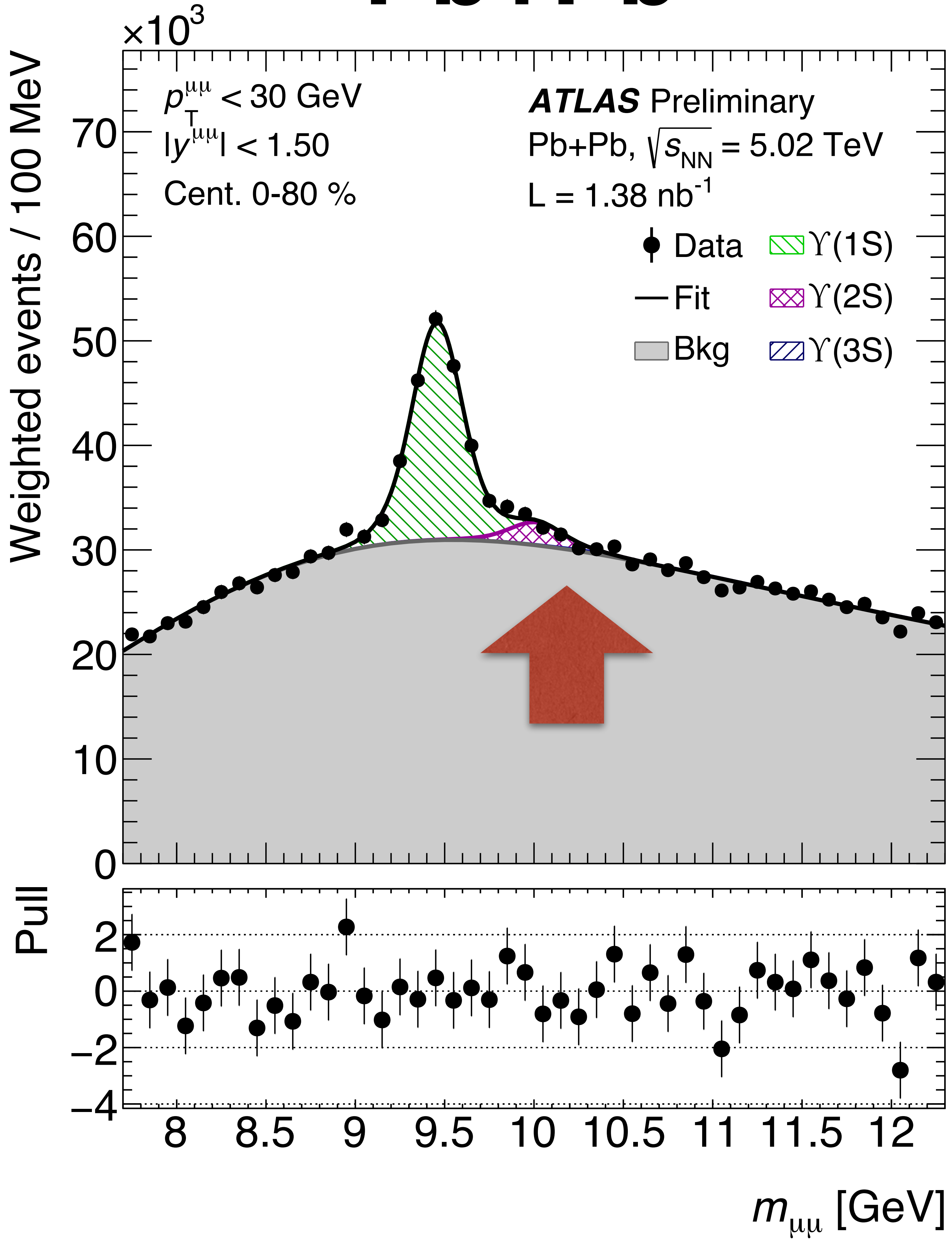
- $p_T^{\mu\mu} < 30$ GeV
- $|y^{\mu\mu}| < 1.5$
- Centrality 0-80 %

- Signal
  - Crystal ball + Gaussian
- Background
  - $p_T < 6$ GeV: Exponential x Error func.
  - $p_T > 6$ GeV: 2nd-order polynomial

pp

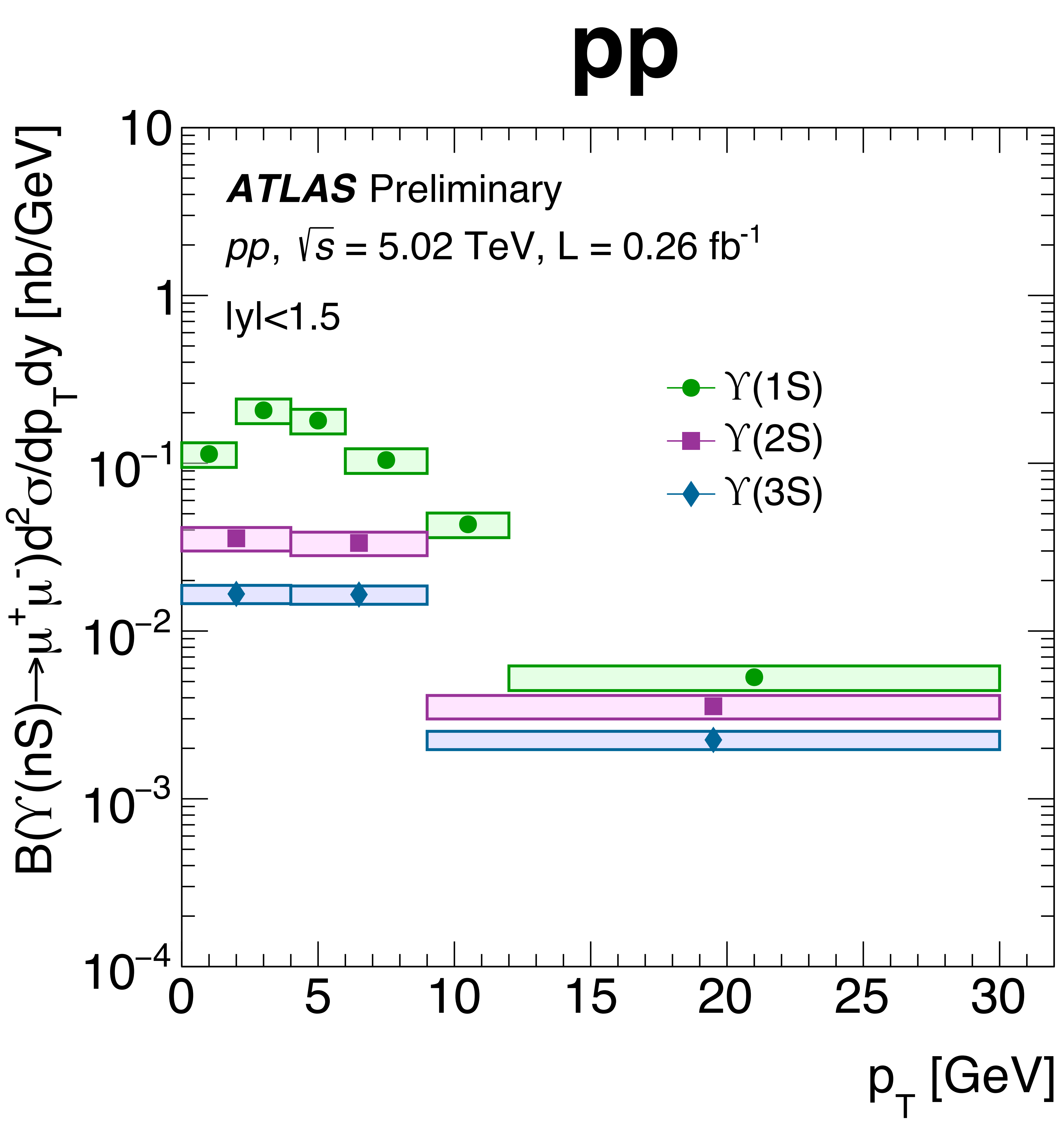


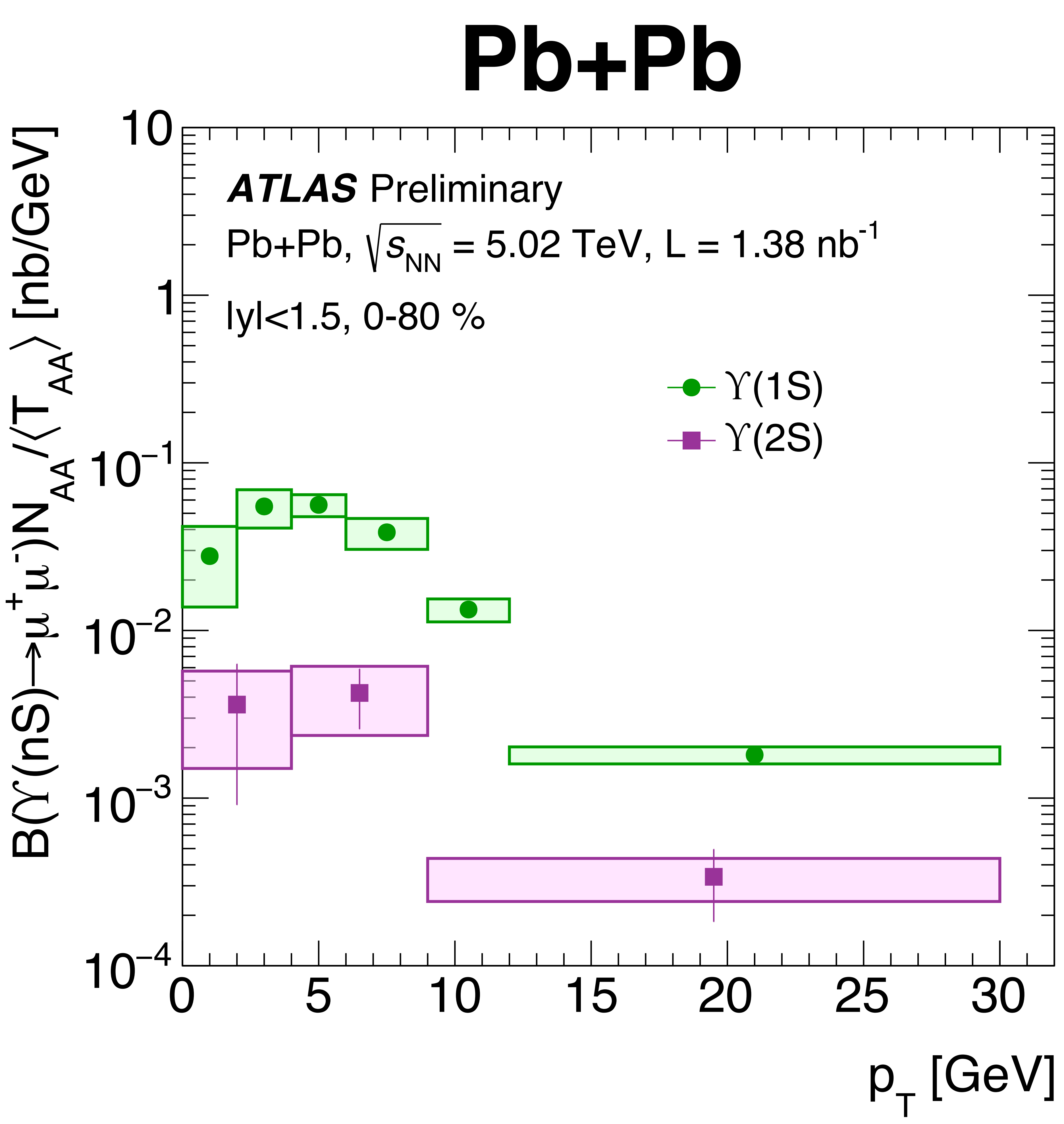
Pb+Pb



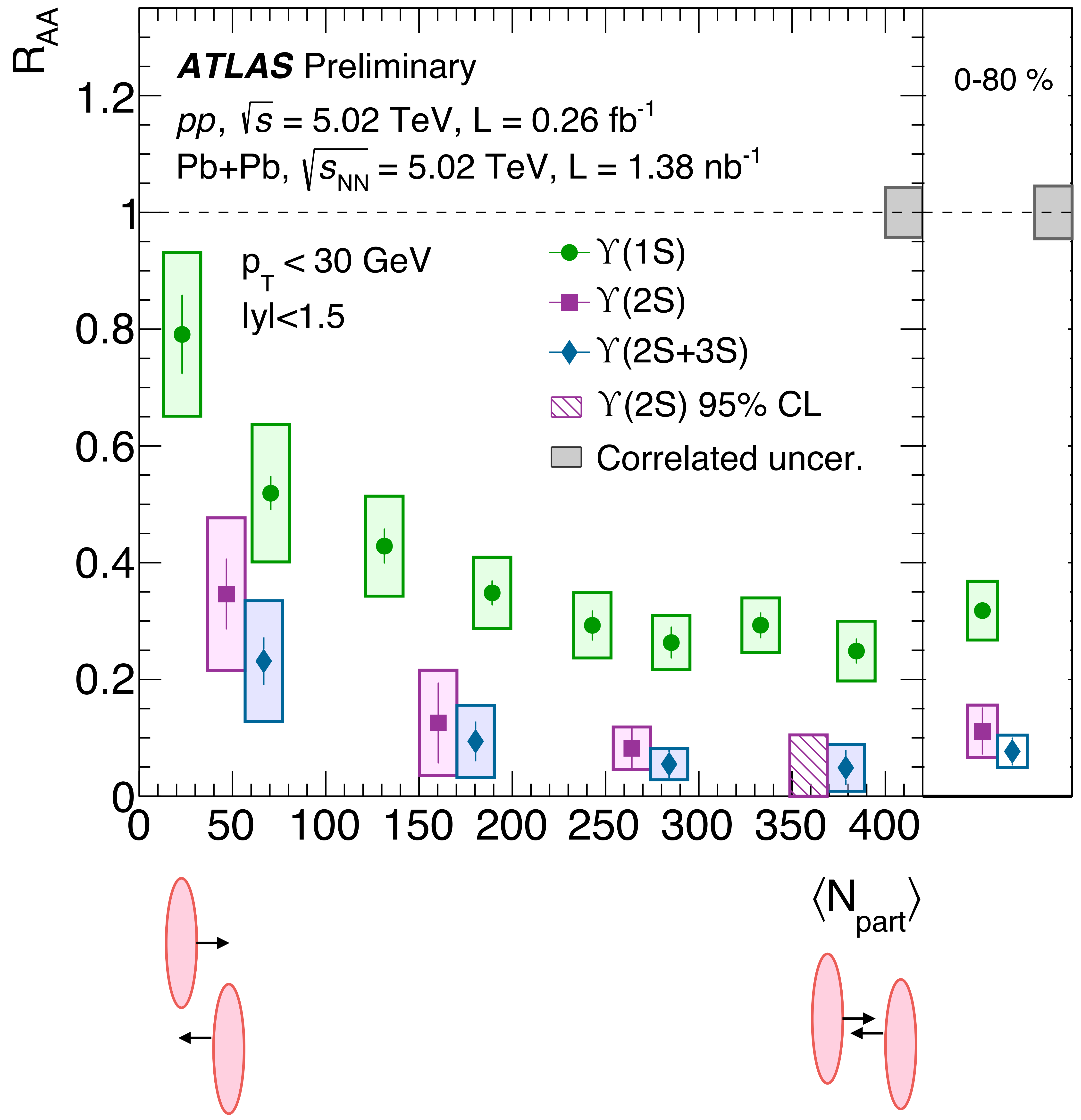
- Suppression of excited states in Pb+Pb: Υ(3S) is not identified

Production cross-sections





- For Pb+Pb, $\langle T_{AA} \rangle$ = nucleon-nucleon equivalent integrated luminosity per heavy-ion collisions
- Y(3S) in Pb+Pb collisions is not shown due to strong suppression



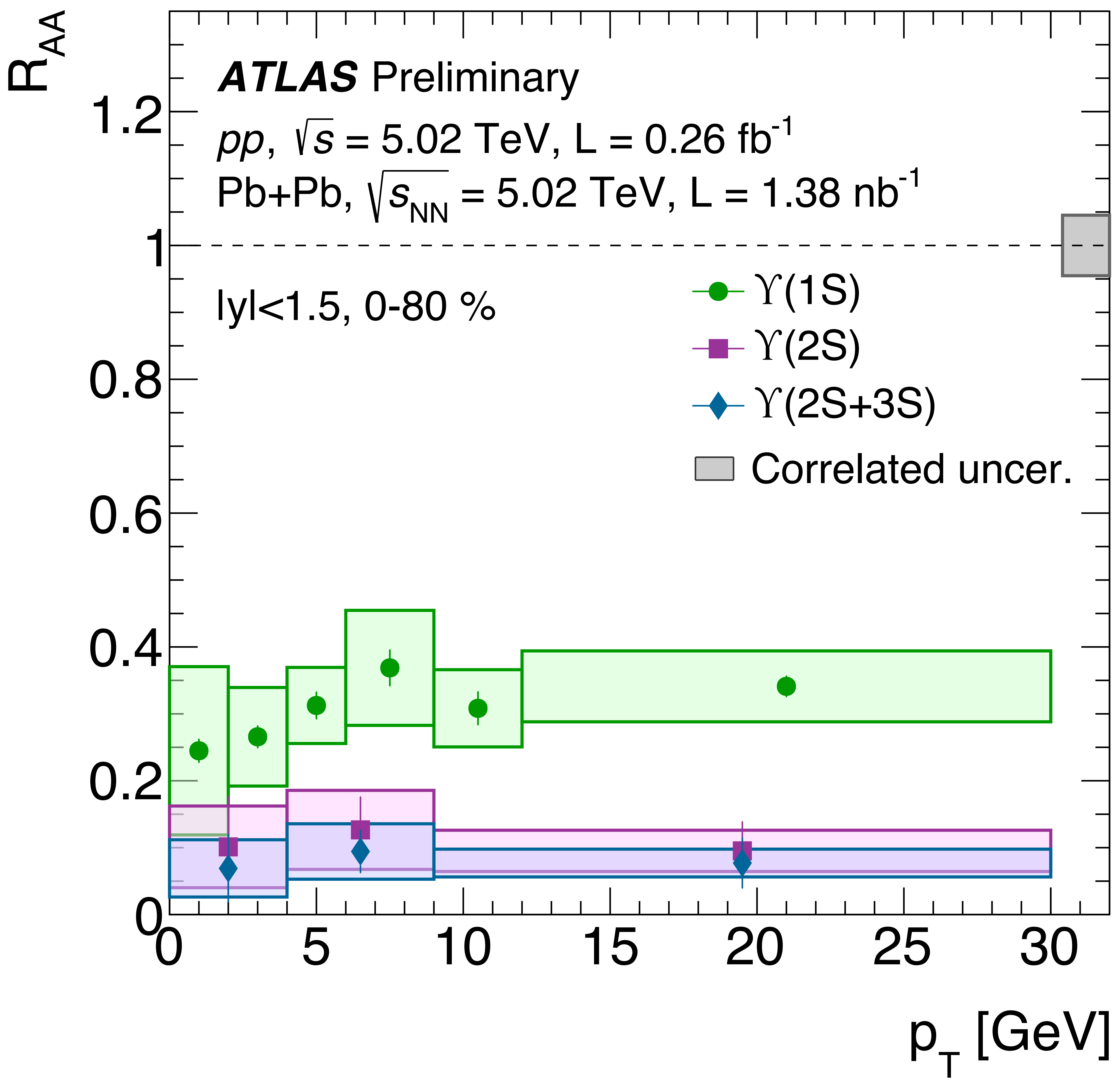
Nuclear modification factor

$$R_{AA} = \frac{N_{AA}}{\langle T_{AA} \rangle \times \sigma^{pp}}$$

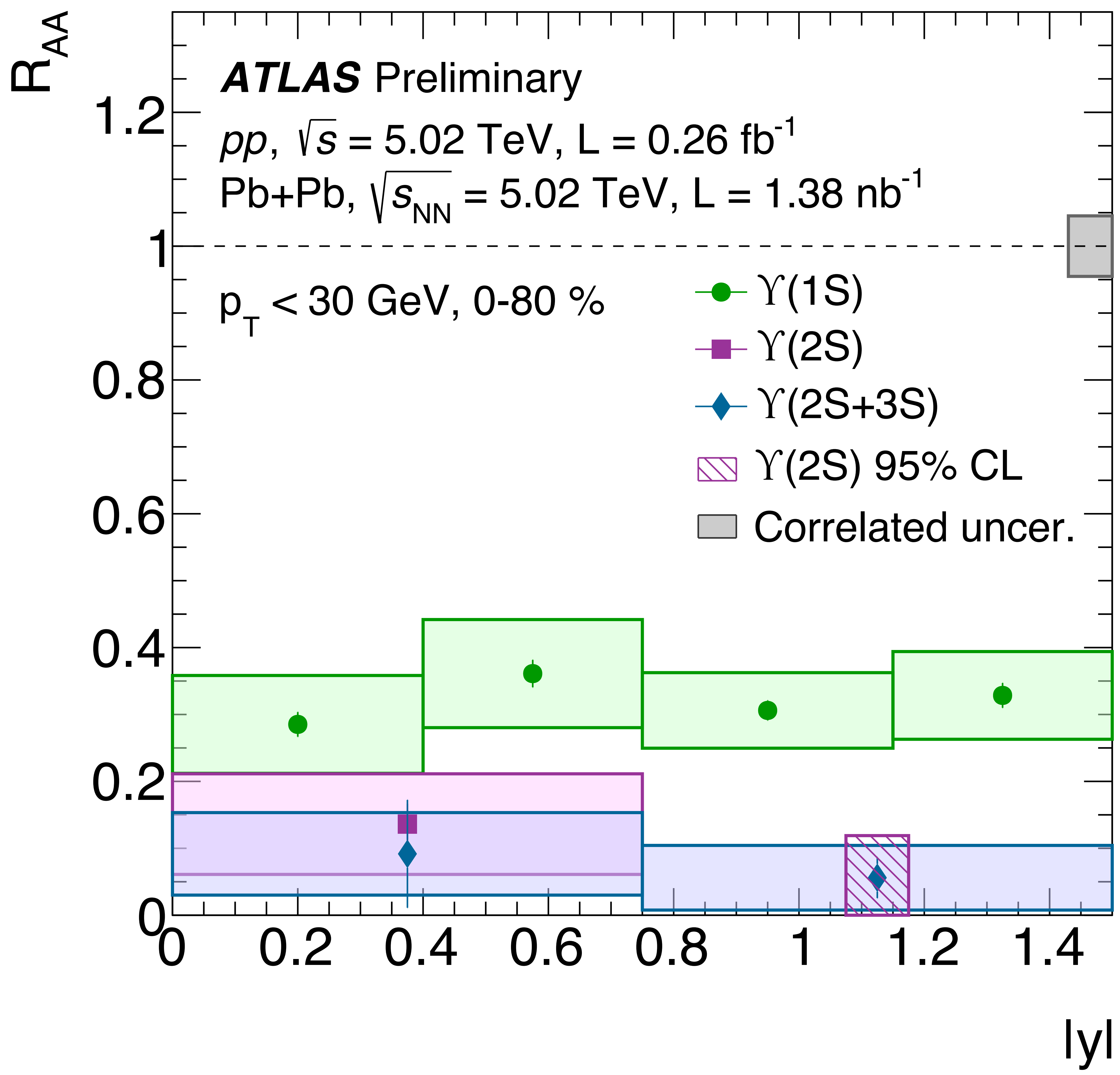
- **Y(2S+3S)** is also shown to constrain Y(3S)
- Upper limit is set for the point consistent with zero
- Ordering in R_{AA}: **Y(1S)** > **Y(2S)** > **Y(2S+3S)**
- More suppression in more central collisions

R_{AA} vs. p_T and |y|

vs. p_T



vs. |y|



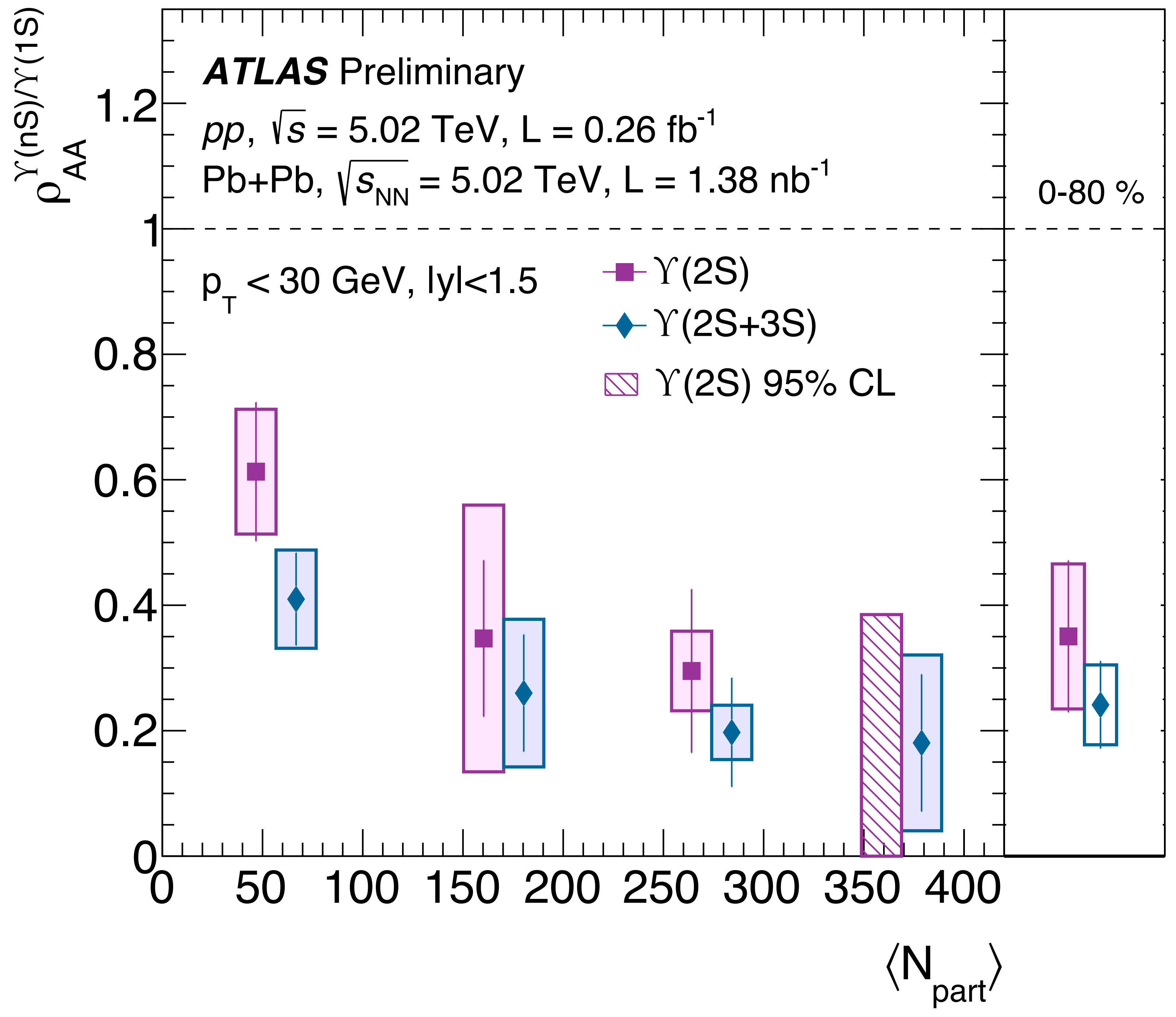
- No strong p_T or |y| dependence for all Y(nS) states

Double ratios ρ_{AA}

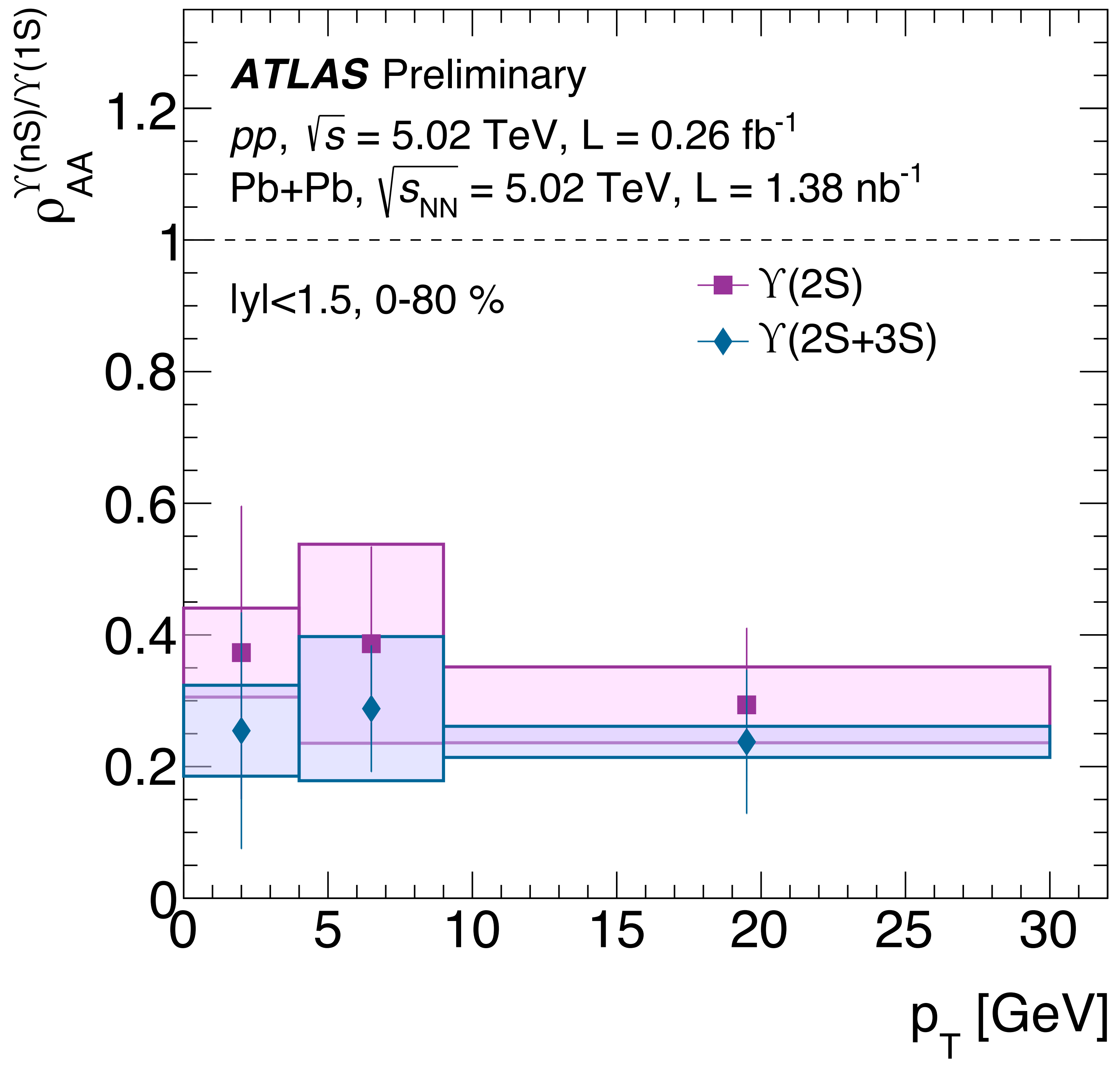
$$\rho_{\mathrm{AA}}^{\Upsilon(\mathrm{nS})/\Upsilon(\mathrm{1S})} = \frac{\sigma_{\mathrm{AA}}^{\Upsilon(\mathrm{nS})}/\sigma_{\mathrm{AA}}^{\Upsilon(\mathrm{1S})}}{\sigma_{pp}^{\Upsilon(\mathrm{nS})}/\sigma_{pp}^{\Upsilon(\mathrm{1S})}} = \frac{R_{\mathrm{AA}}(\Upsilon(\mathrm{nS}))}{R_{\mathrm{AA}}(\Upsilon(\mathrm{1S}))}$$

- Luminosity and $\langle T_{AA} \rangle$ corrections are cancelled
- Acceptance and efficiency corrections are partially cancelled

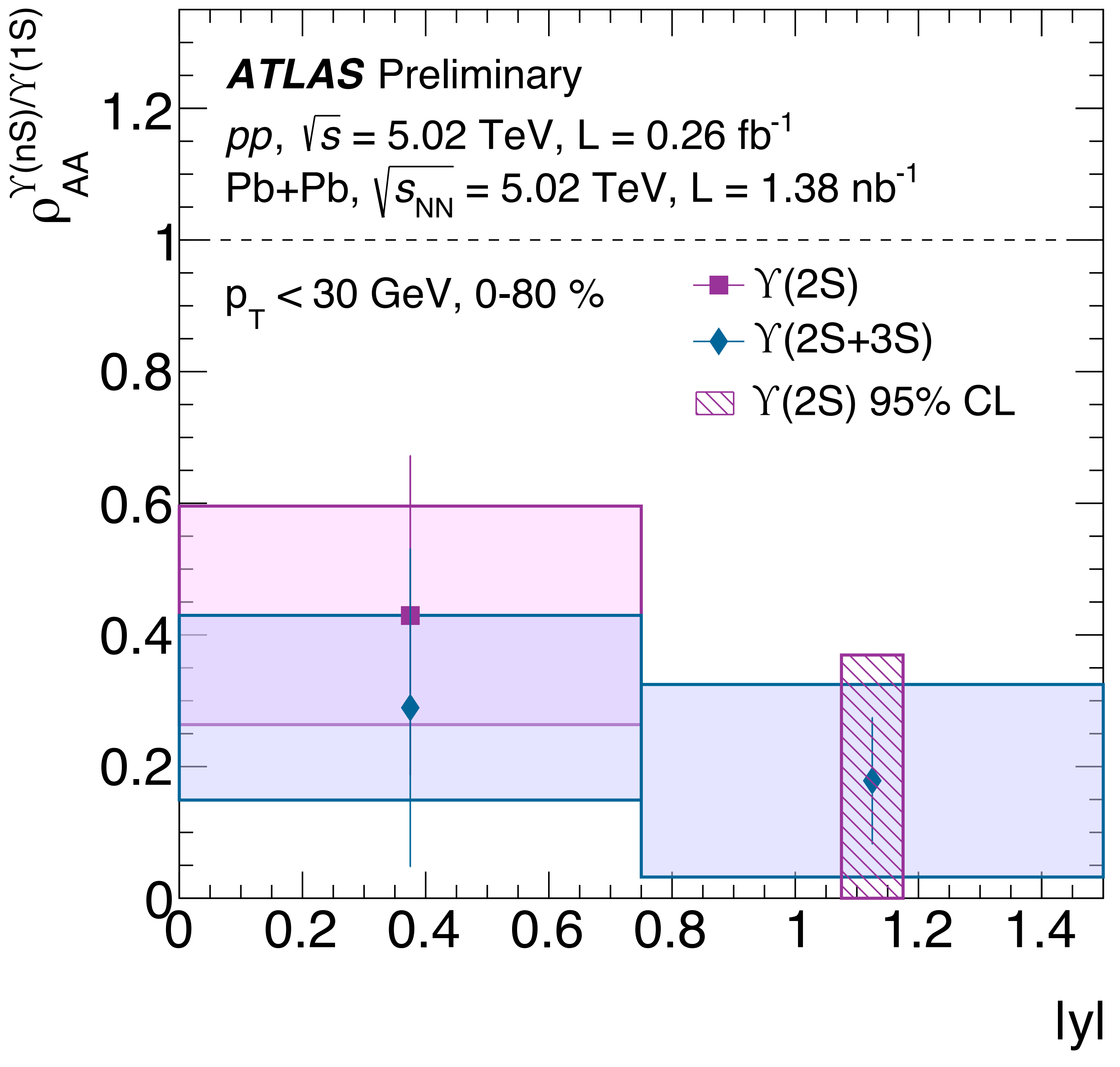
vs. centrality



vs. p_T



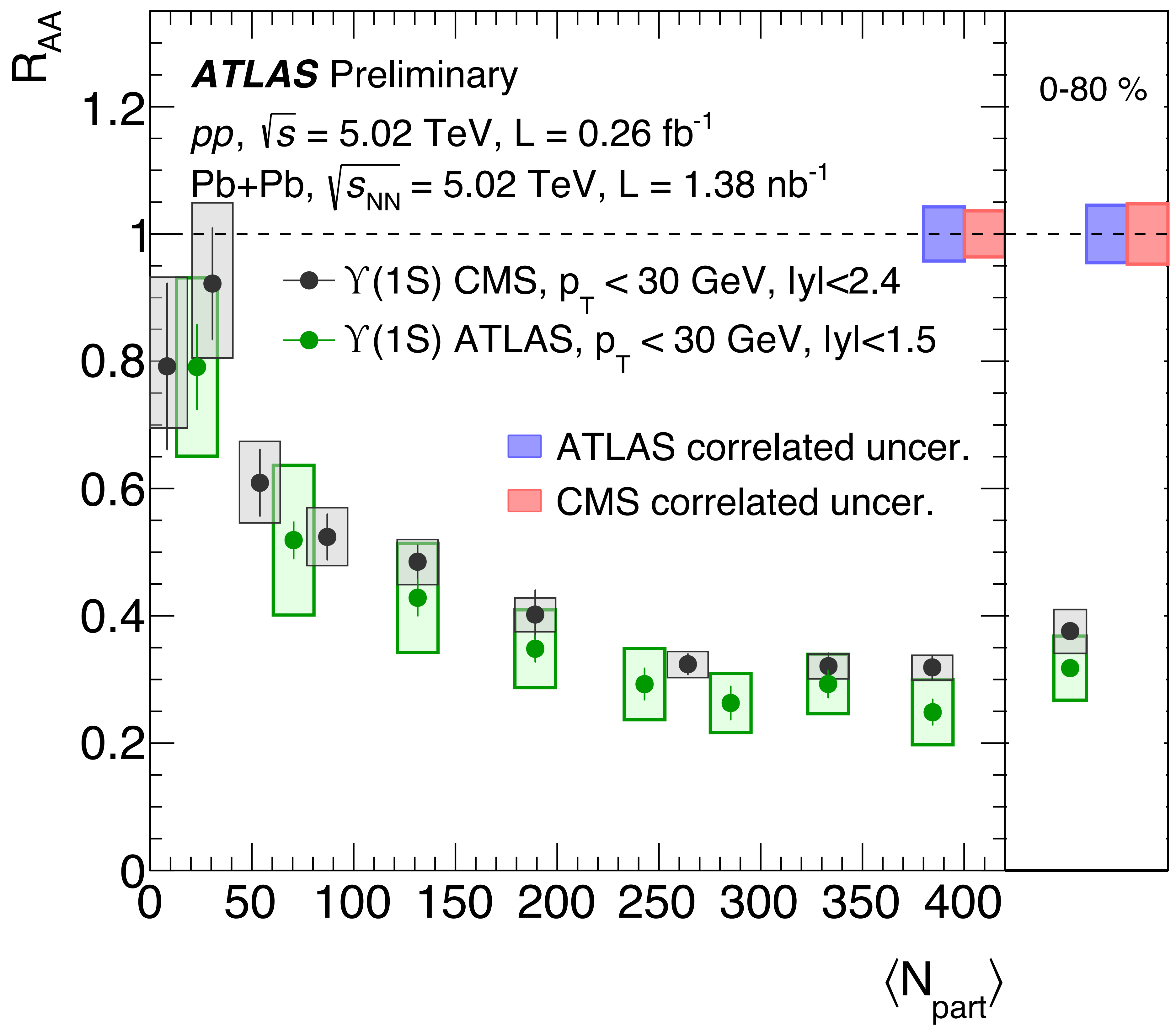
vs. |y|



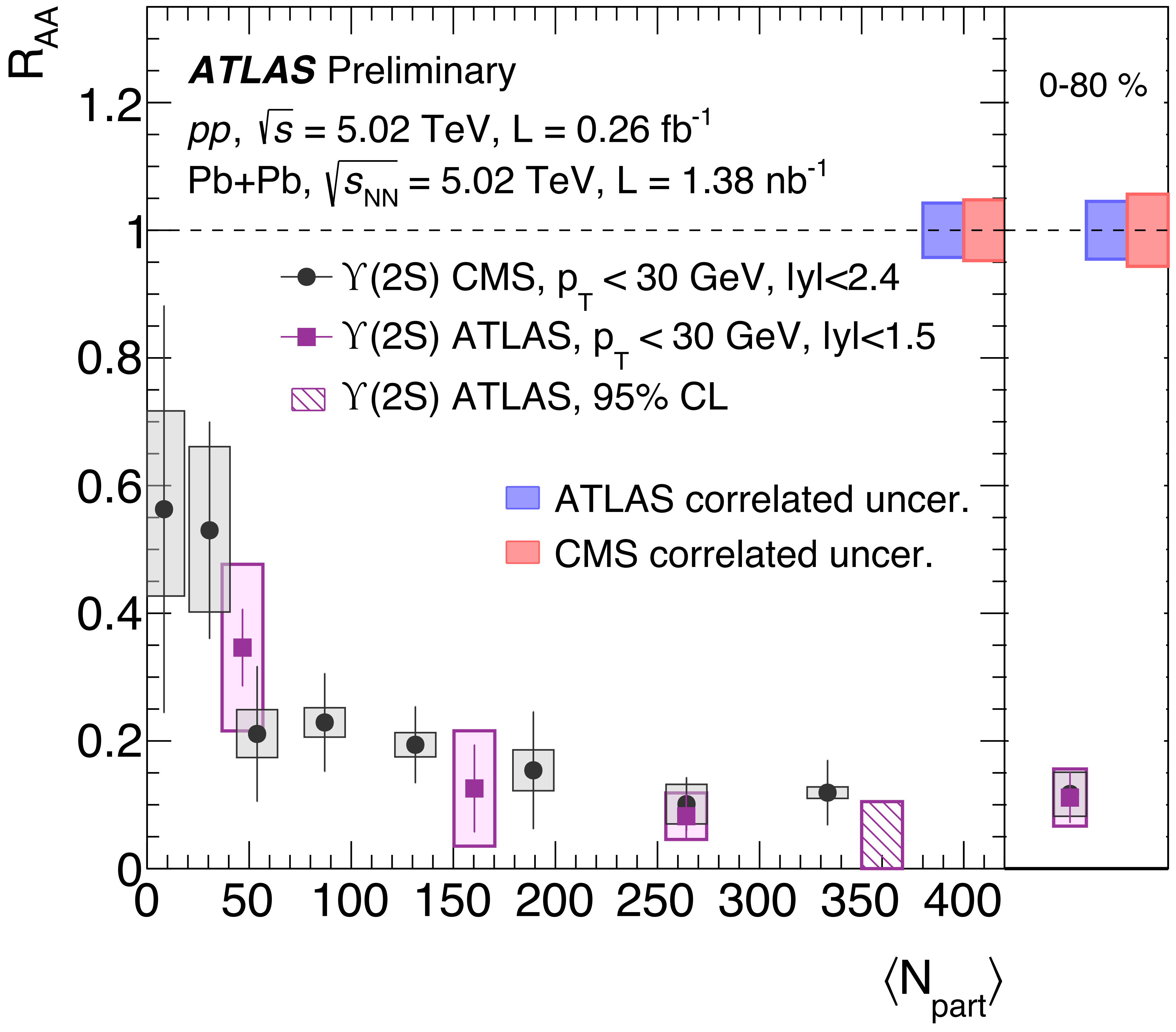
- Slight centrality dependence
- No strong p_T or |y| dependence

Comparison to CMS: R_{AA}

Y(1S)



Y(2S)



- For Y(1S), CMS results are slightly higher but compatible within uncertainties
- N.B. CMS: lyl<2.4, centrality = 0-100 %

  ATLAS: lyl<1.5, centrality = 0-80 %

CMS: PLB 790 (2019) 270

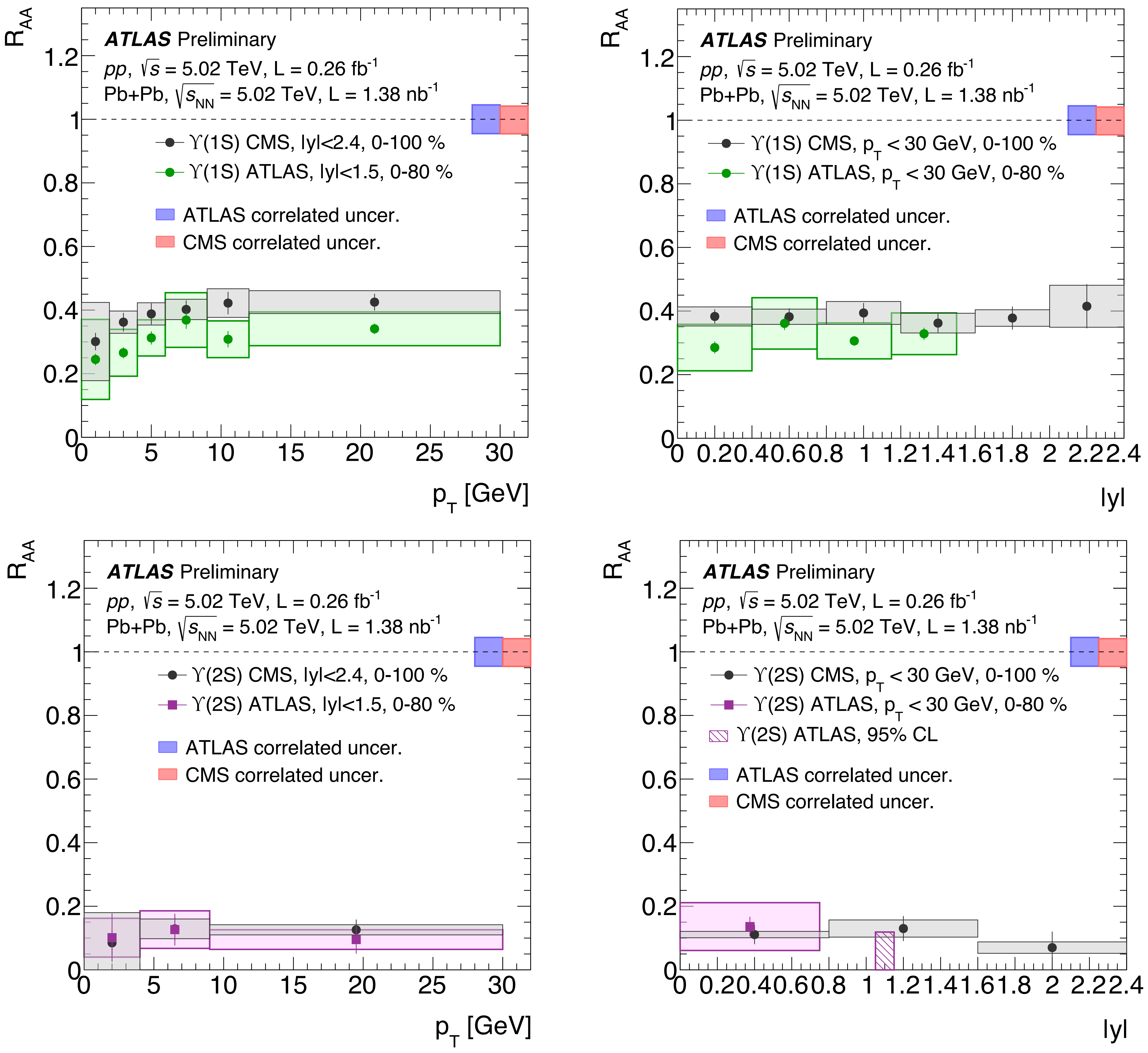
Comparison to CMS: R_{AA}

CMS: PLB 790 (2019) 270

vs. p_T vs. |y|

Υ(1S)

Υ(2S)



- Υ(1S) R_{AA} from CMS is slightly higher as observed in centrality-dependent results
- Both experiments show similar trend vs. p_T and |y|

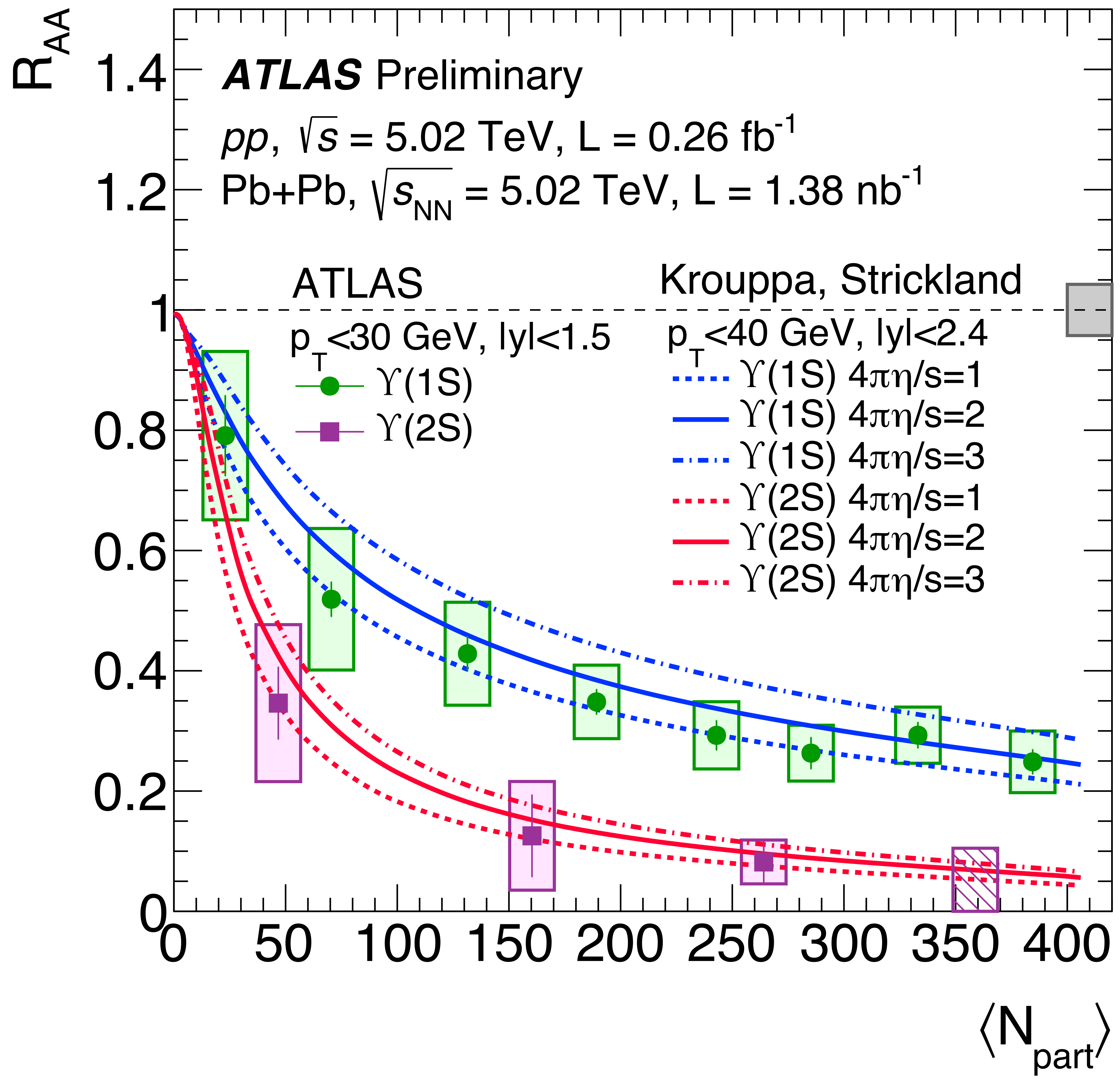
Comparison to CMS: double ratios

- Two experiments are in good agreement
- N.B. CMS: |y|<2.4, centrality = 0-100 %

  ATLAS: |y|<1.5, centrality = 0-80 %

CMS: PRL 120 (2018) 142301

Comparison to theoretical predictions



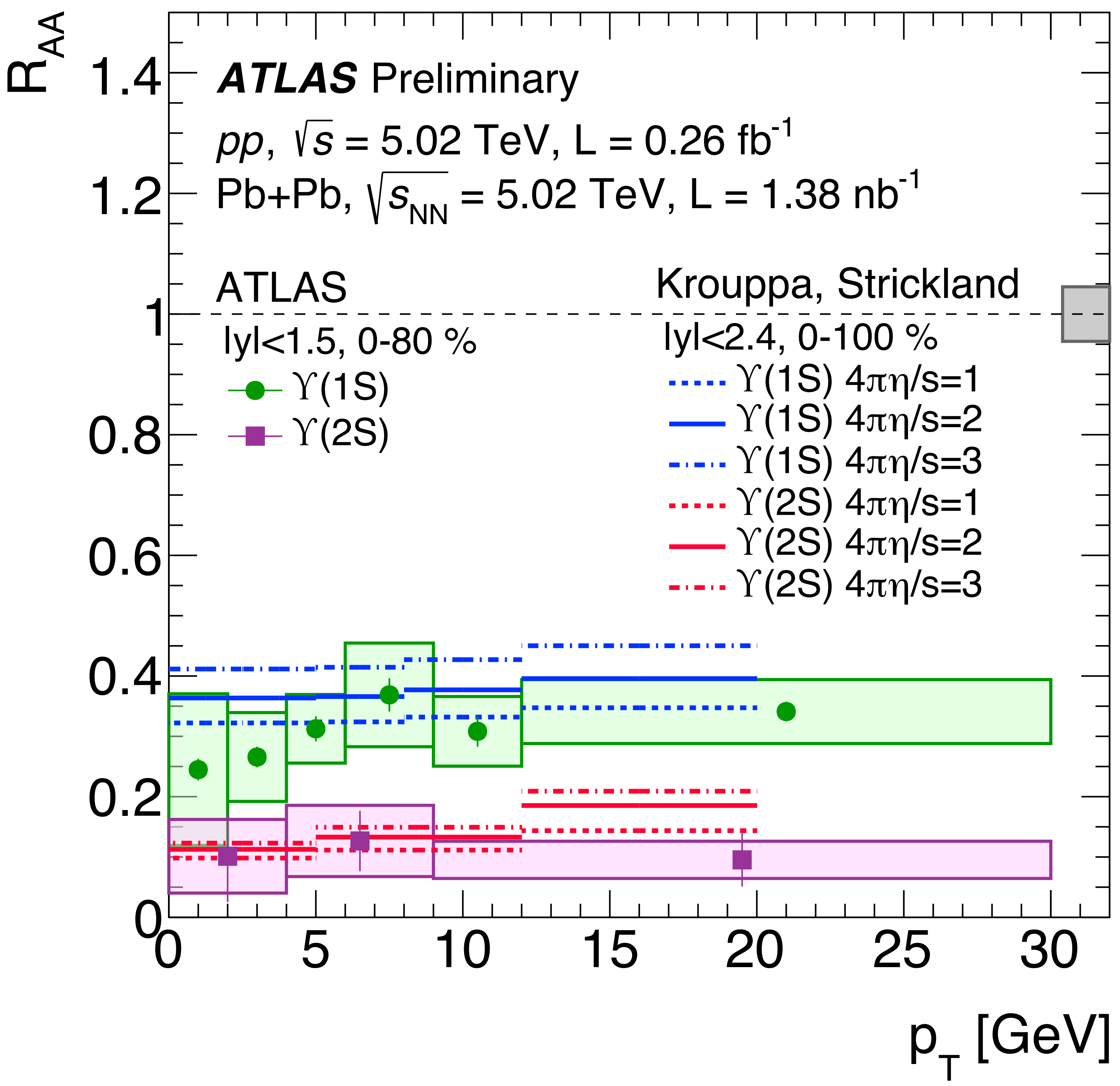
- The model includes the effect of in-medium dissociation, feed-down effects (30-40%), and uses anisotropic viscous hydrodynamic background
- No regeneration or cold nuclear matter effects
- N.B. calculation with p_T < 40 GeV, |y| < 2.4, 0-100%

Model: Universe 2 (2016) 16

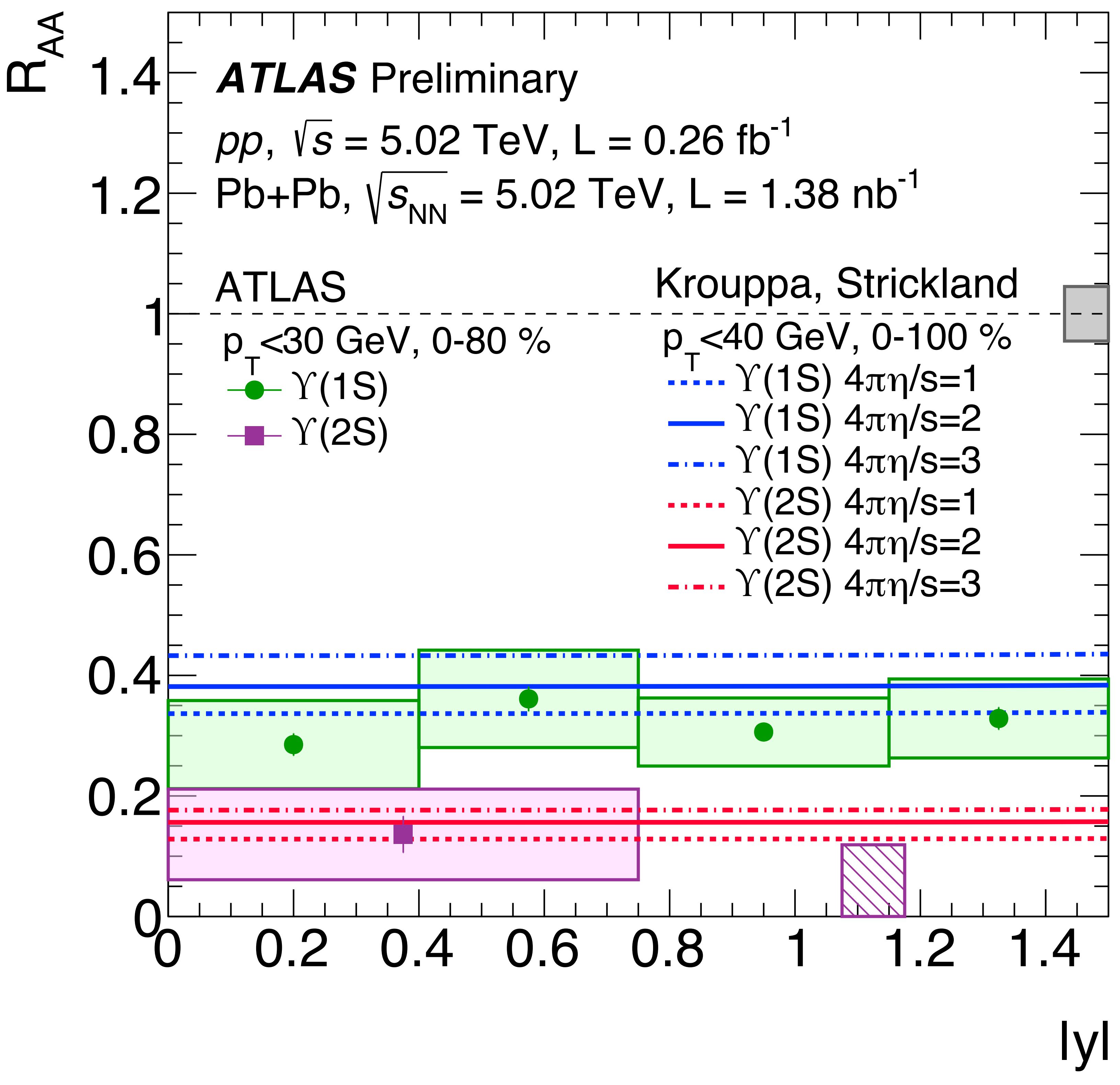
Comparison to theoretical predictions

Model: Universe 2 (2016) 16

vs. p_T

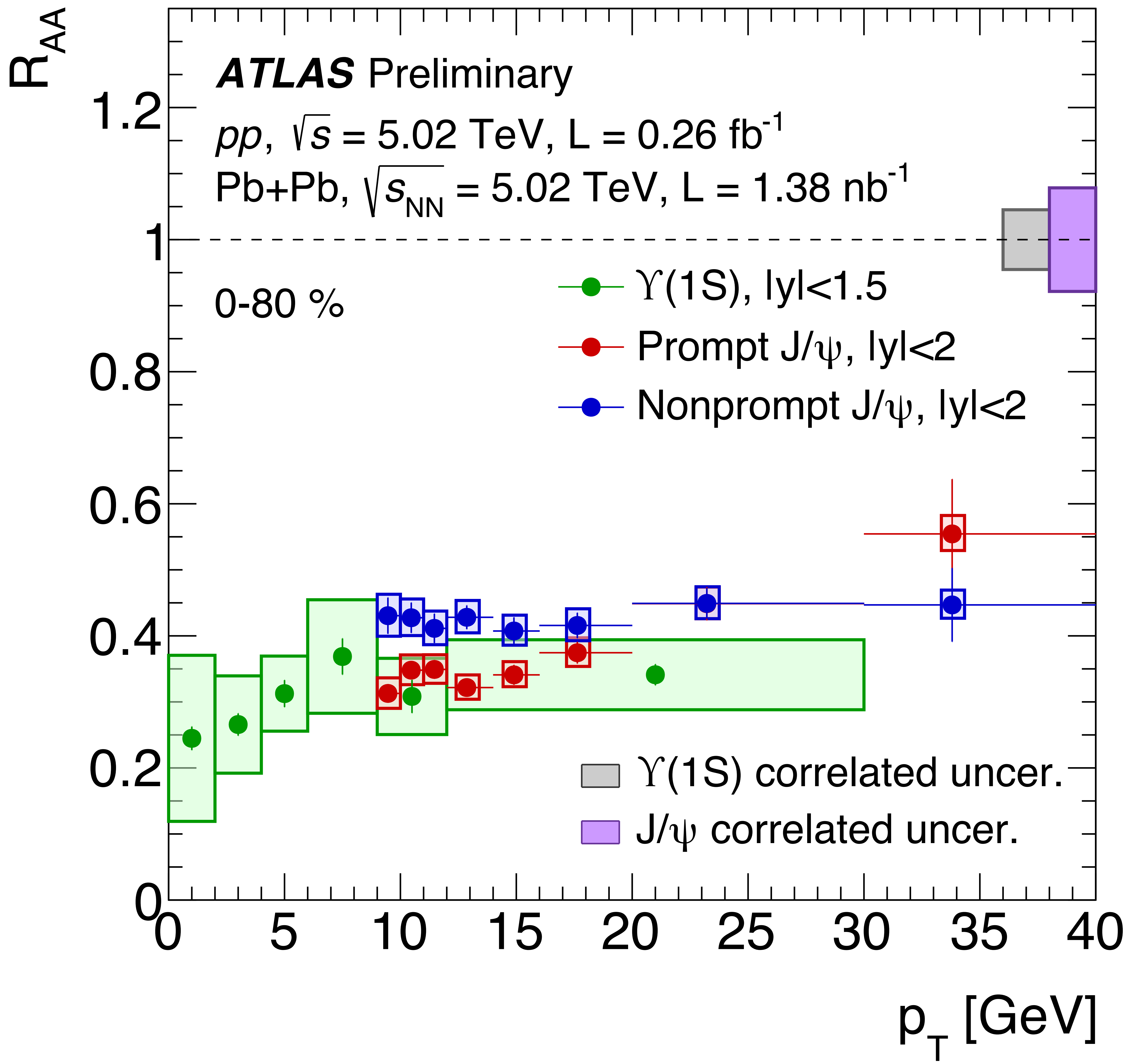


vs. |y|



- The model predicts slightly increasing R_{AA} with p_T and no clear |y| dependence
- N.B. Left: calculation up to 20 GeV in |y| <2.4, Right: calculation in $p_T < 40$ GeV
- Need the same centrality and kinematic requirements for an apple-to-apple comparison

Charmonia vs. Bottomonia



- J/ψ R_{AA}: $9 < p_T < 40$ GeV, |y| < 2
- Similar amount of suppression for Y(1S) and prompt J/ψ although Y(1S) is more tightly bound
- Hard to draw a firm conclusion due to different regenerations, feed-down effects, etc.
- Nonprompt J/ψ R_{AA} reflects b-quark energy loss

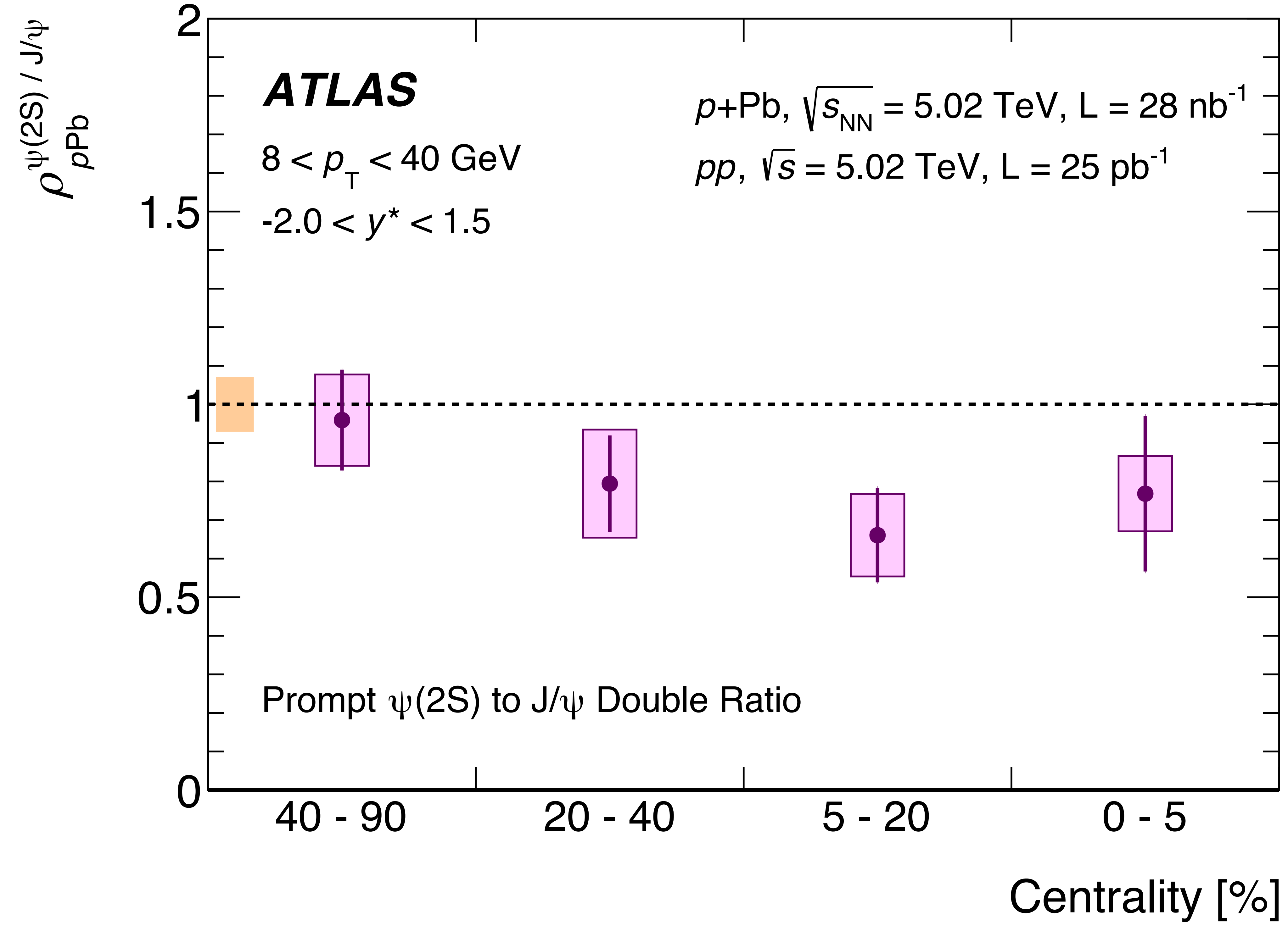
J/ψ :EPJC 78 (2018) 762

Double ratios: charmonia

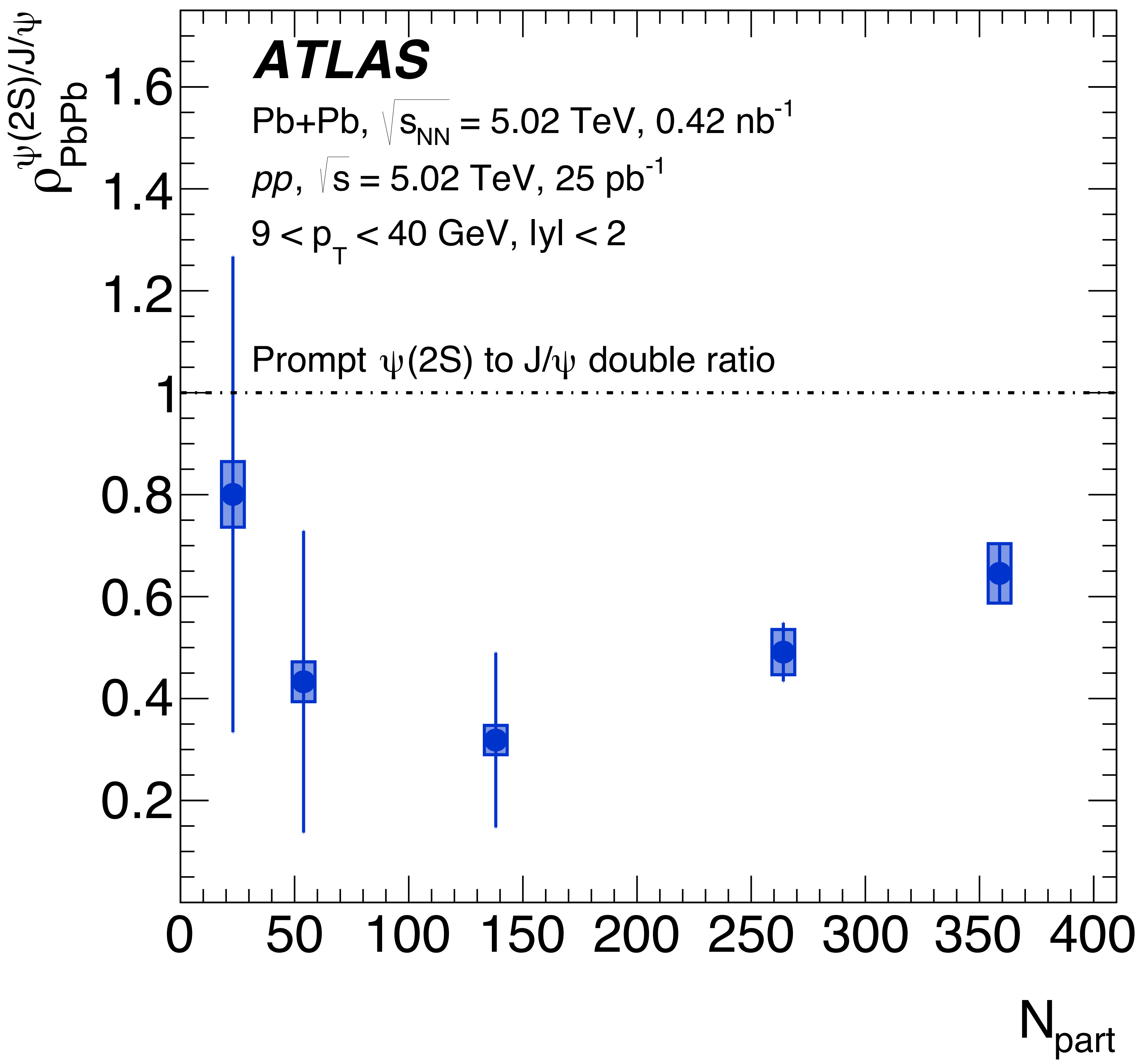
p+Pb: EPJC 78 (2018) 171

Pb+Pb: EPJC 78 (2018) 762

p+Pb



Pb+Pb

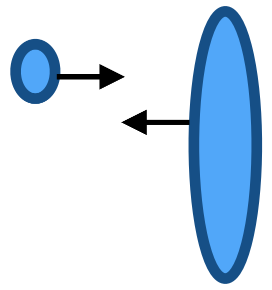


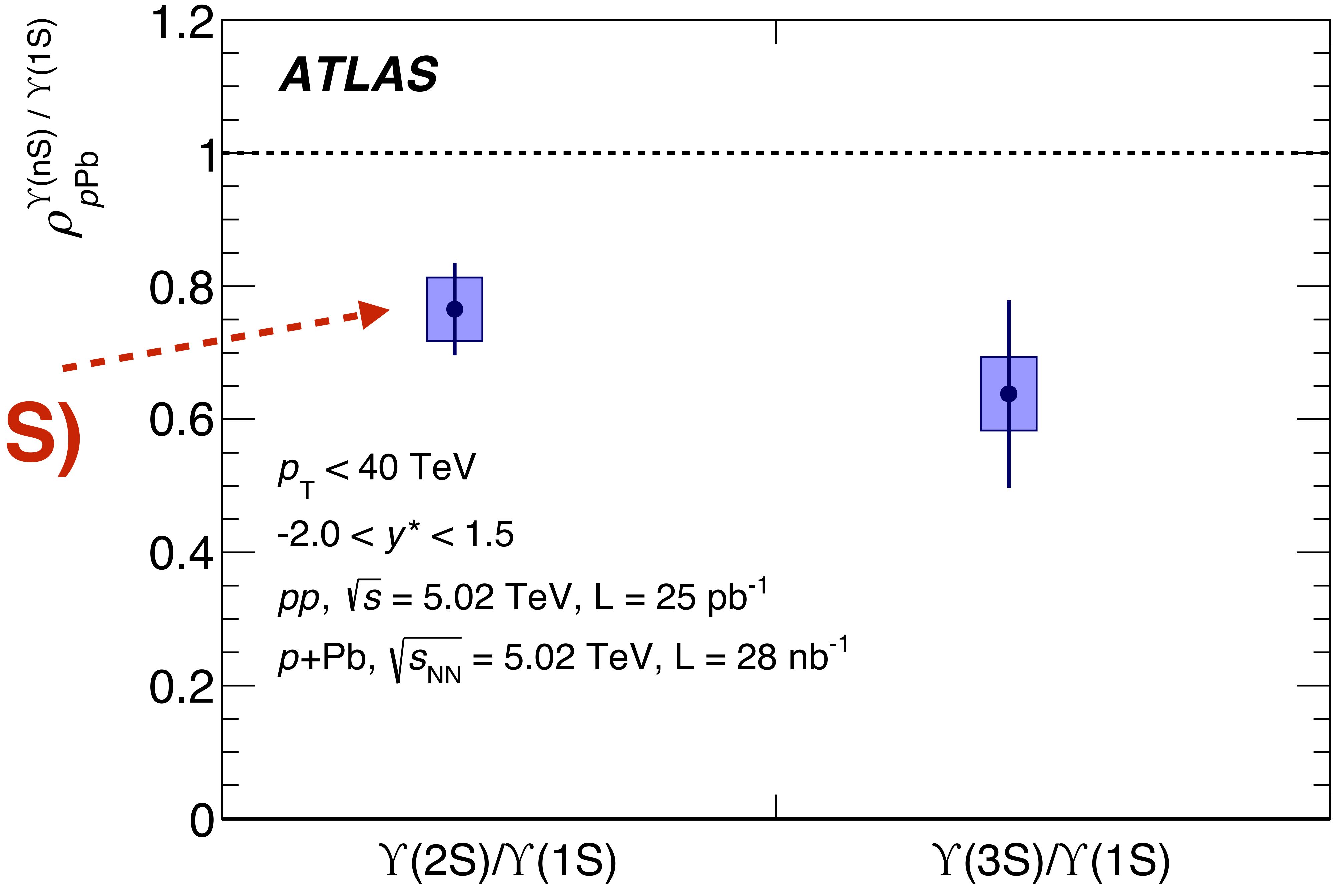
- Excited state is more suppressed than the ground state even in p+Pb collisions
- Relative suppression of excited state w.r.t. ground state is more prominent in Pb+Pb collisions
- Possible enhancement of ψ(2S) in central PbPb → a sequential regeneration?

Double ratios: bottomonia

p+Pb: EPJC 78 (2018) 171

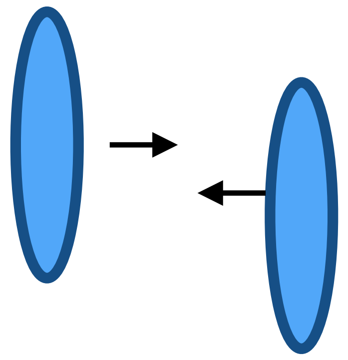
p+Pb

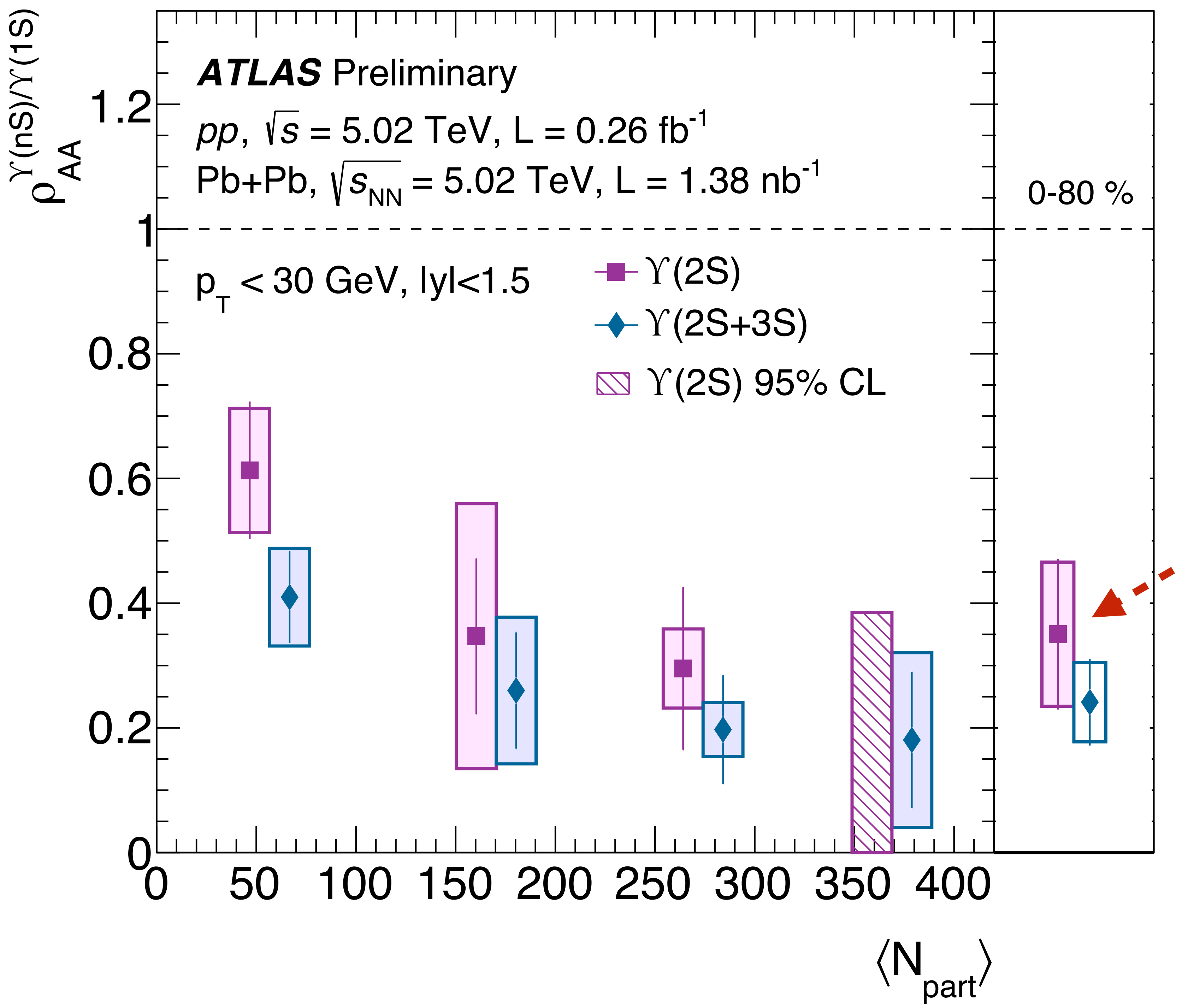




Y(2S)/Y(1S)
~0.8

Pb+Pb





Y(2S)/Y(1S)
~0.4

- $\rho^{(nS)/(1S)}_{pPb} > \rho^{(nS)/(1S)}_{pPbPb}$ for bottomonia as well as charmonia
- Medium effects in Pb+Pb are more sensitive to binding energies than those in p+Pb
- No increasing trend with centrality unlike charmonia results

Summary

- Production cross-sections, R_{AA}, and ρ_{AA} of Υ(nS) mesons are measured in pp and Pb+Pb collisions at 5.02 TeV
- R_{AA} and ρ_{AA} decrease with increasing centrality, and show no clear dependence on p_T or |y|
- More suppression for more excited states are observed which supports a sequential melting scenario
- Results agree with previous CMS results and theoretical model predictions

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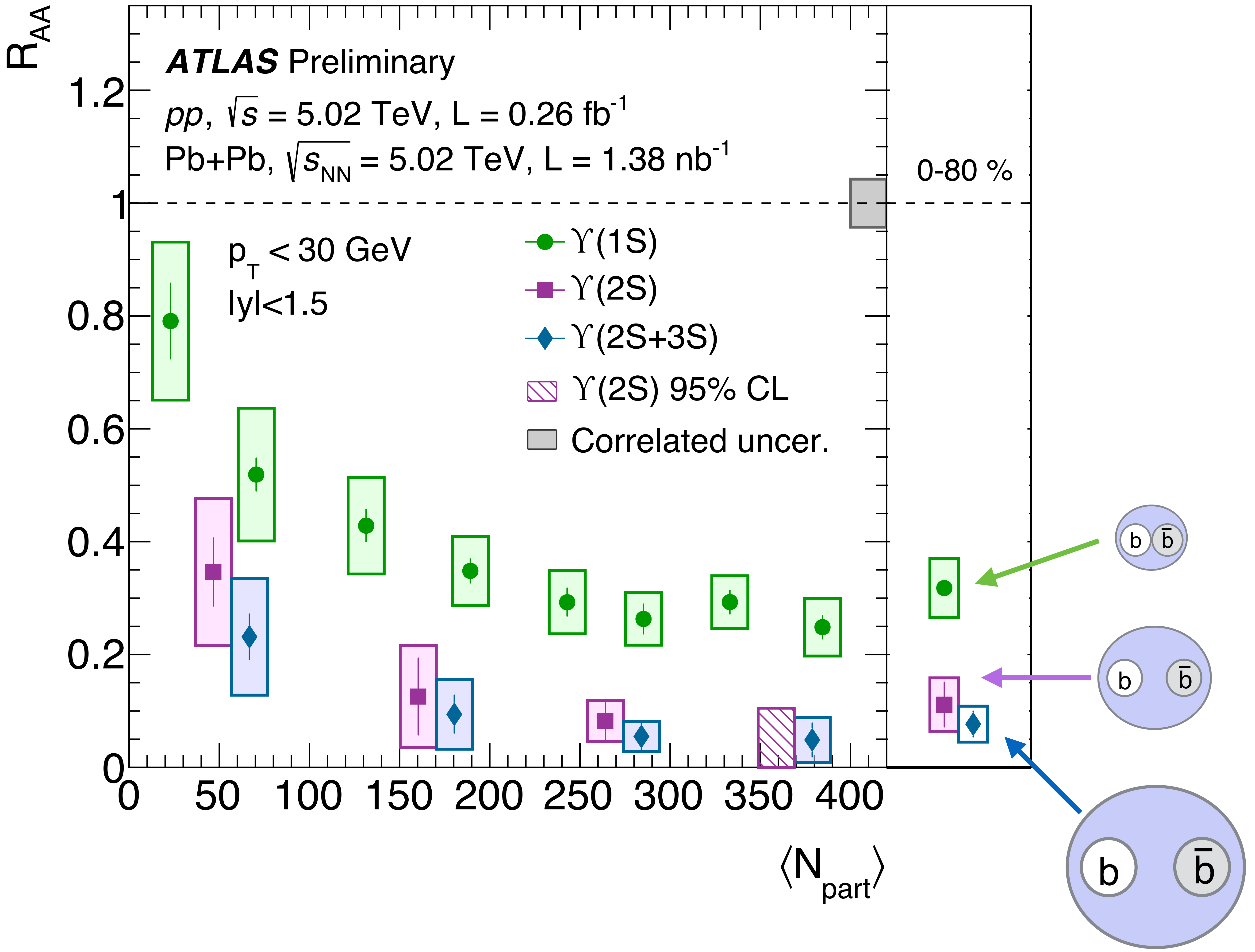
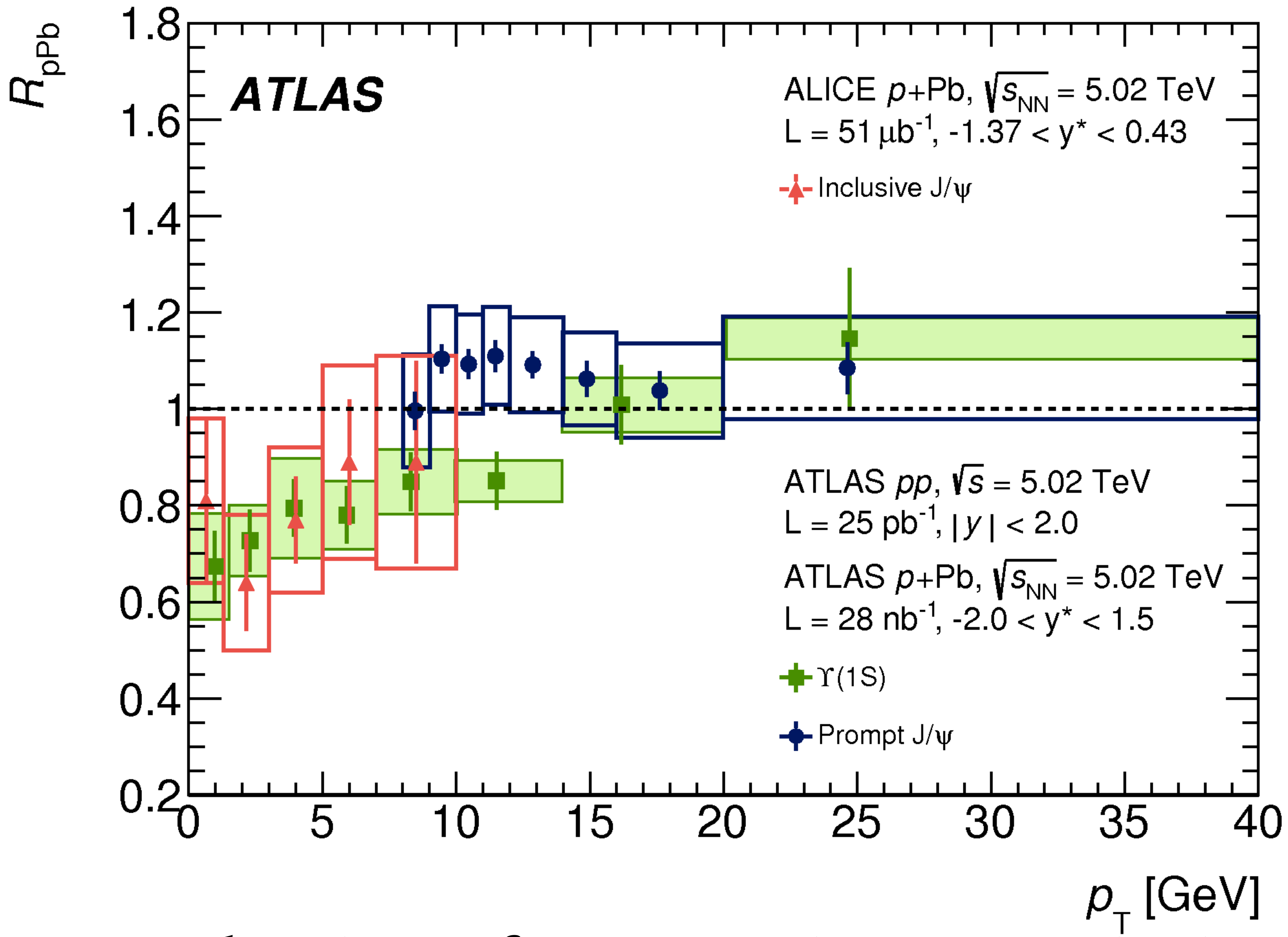


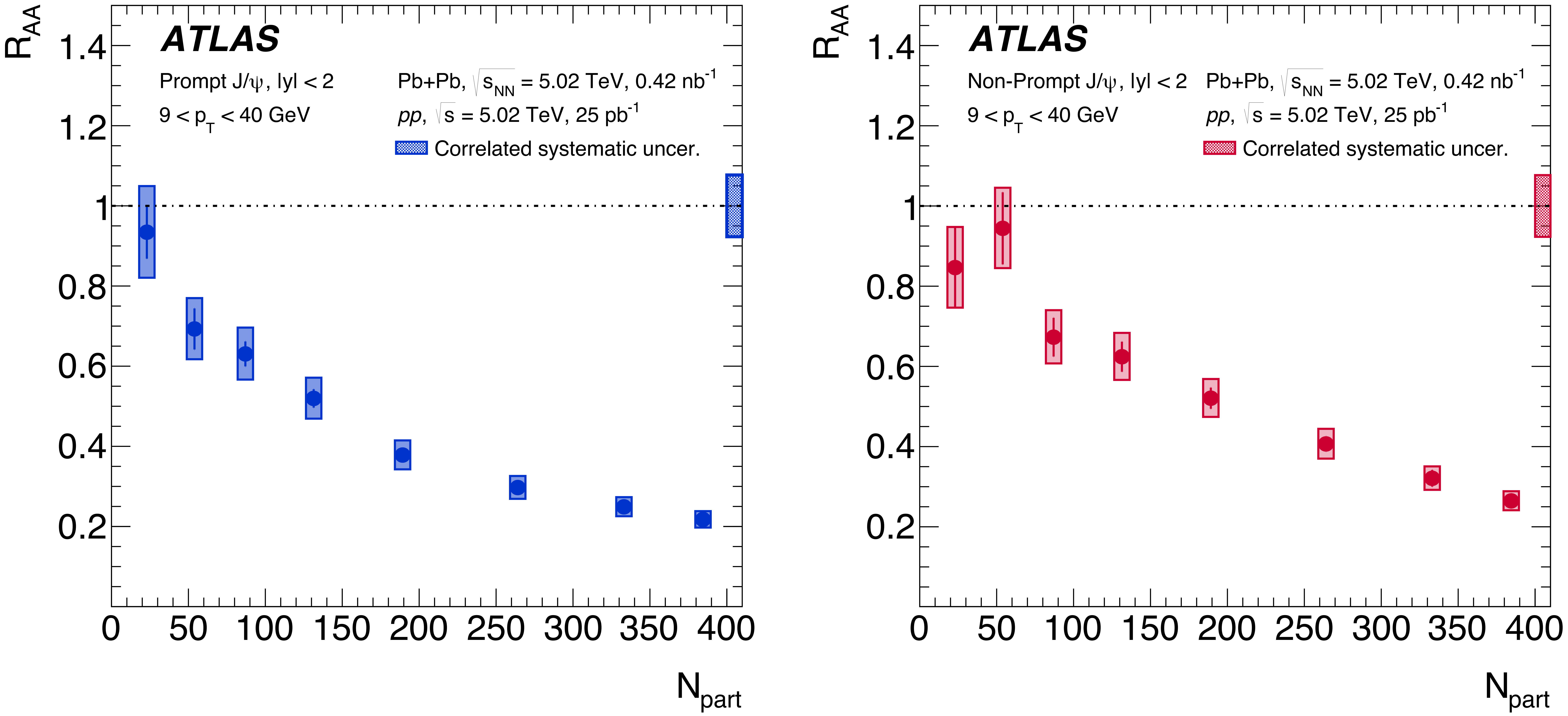
Backups

R_{pPb} comparison to ALICE

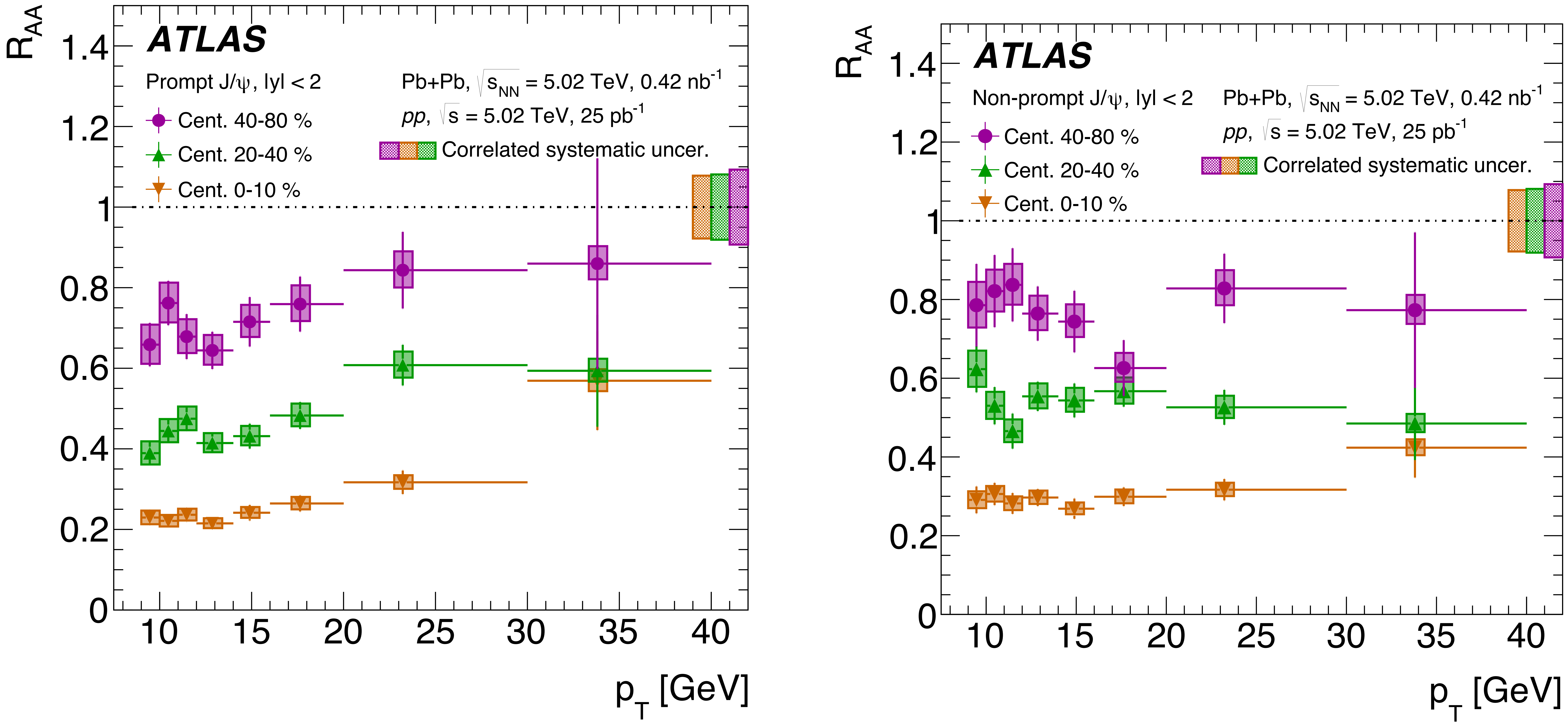


EPJC 78 (2018) 171

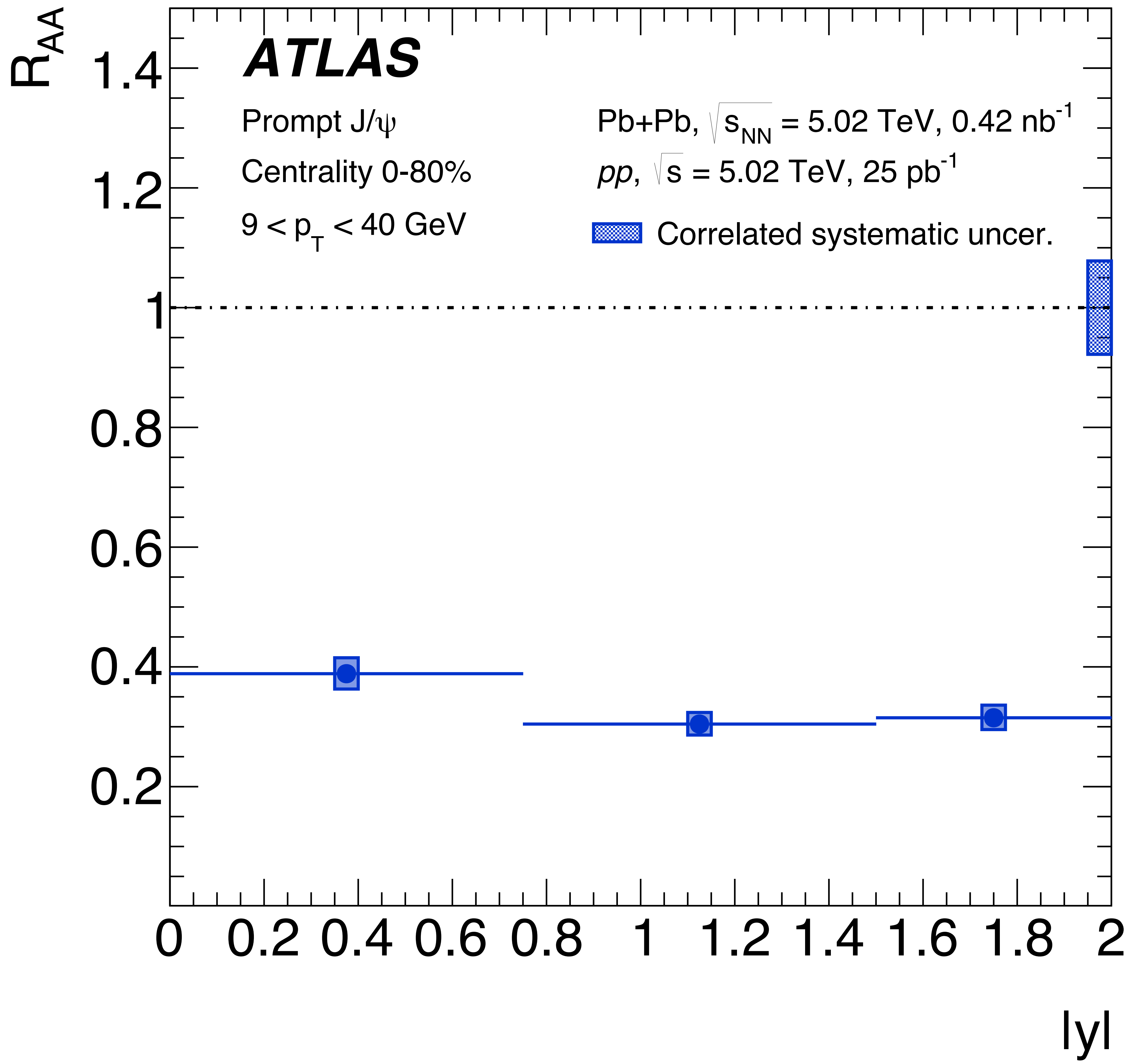
J/ψ R_{AA} in Pb+Pb

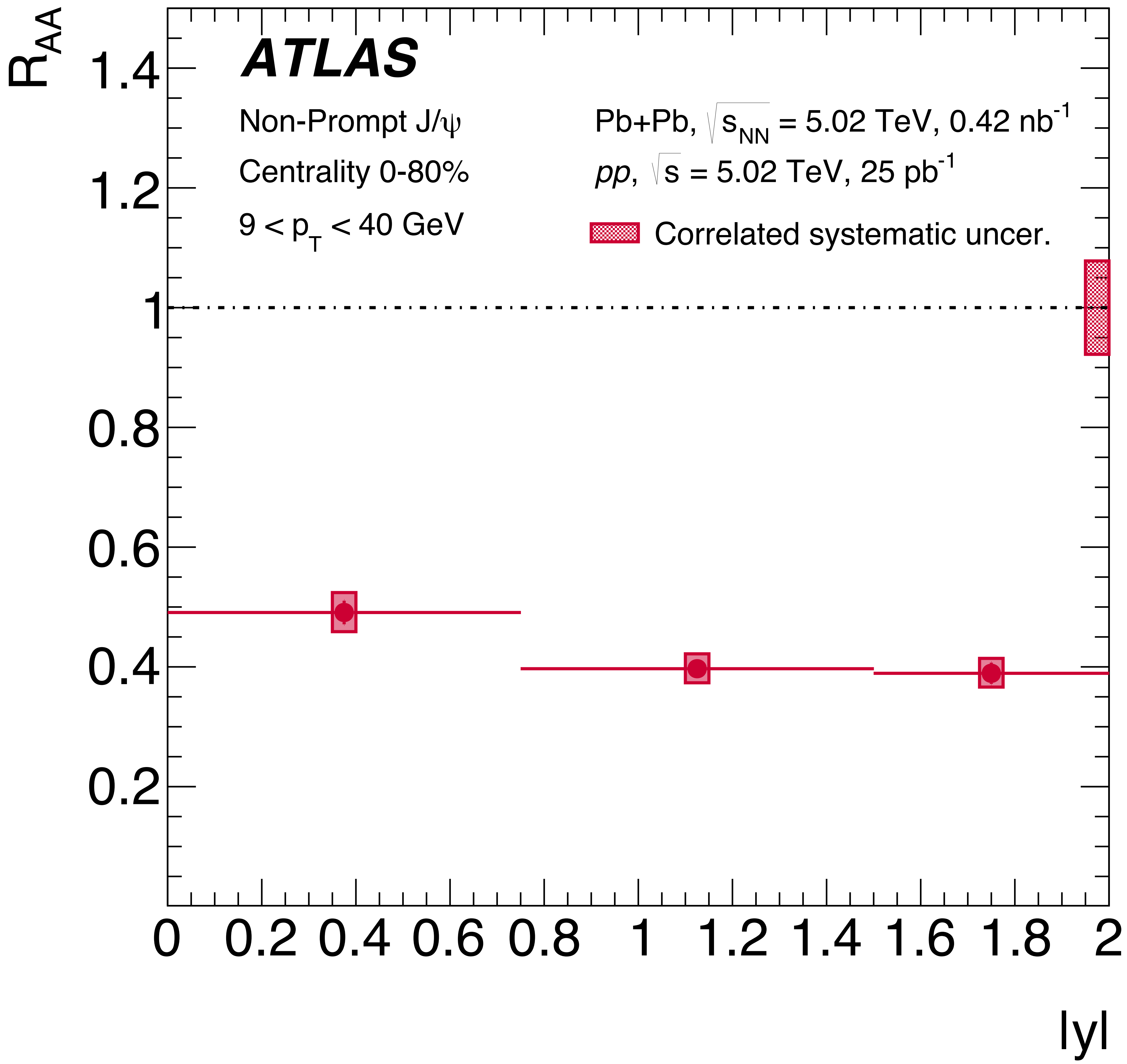


J/ψ R_{AA} in Pb+Pb

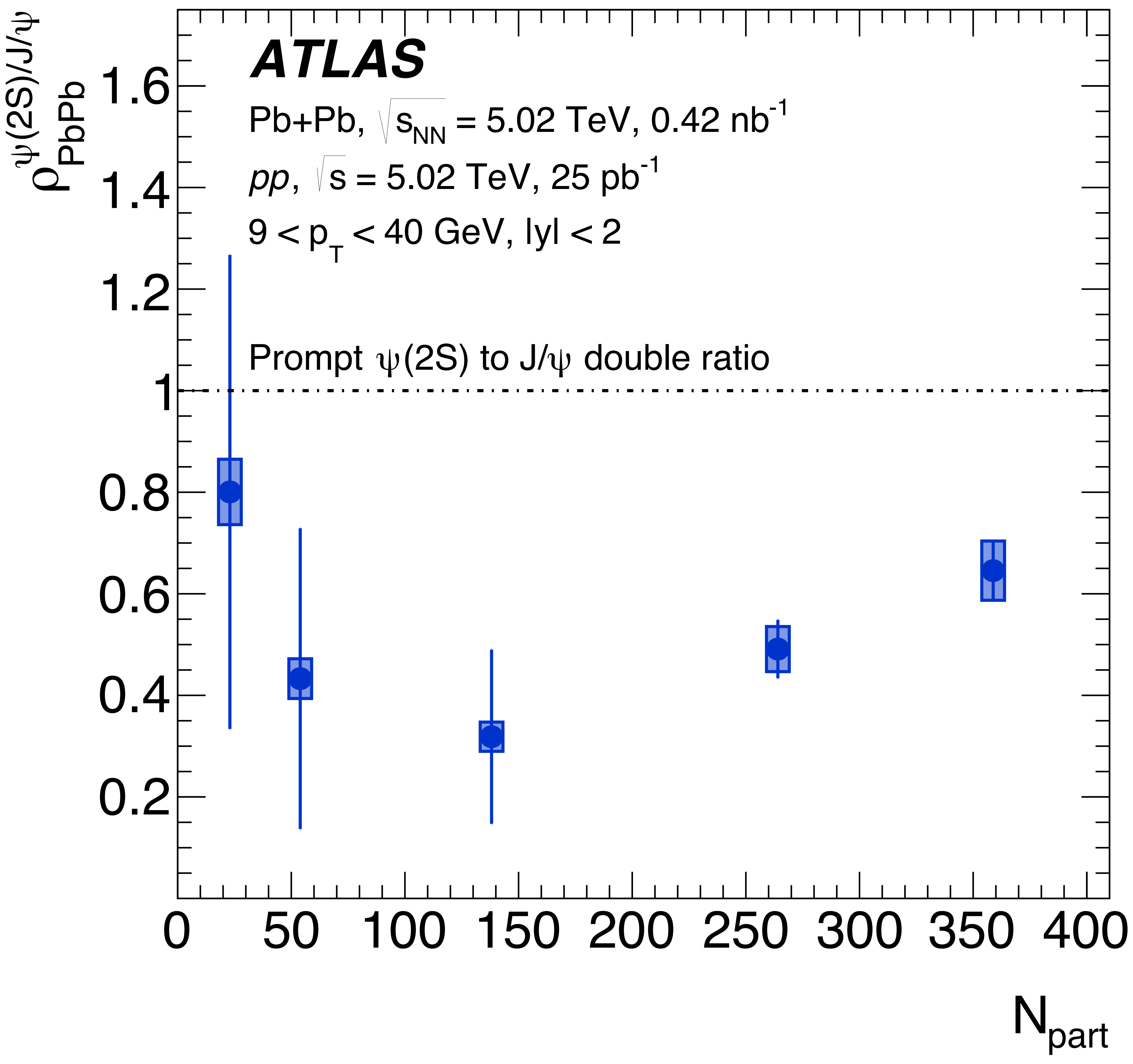


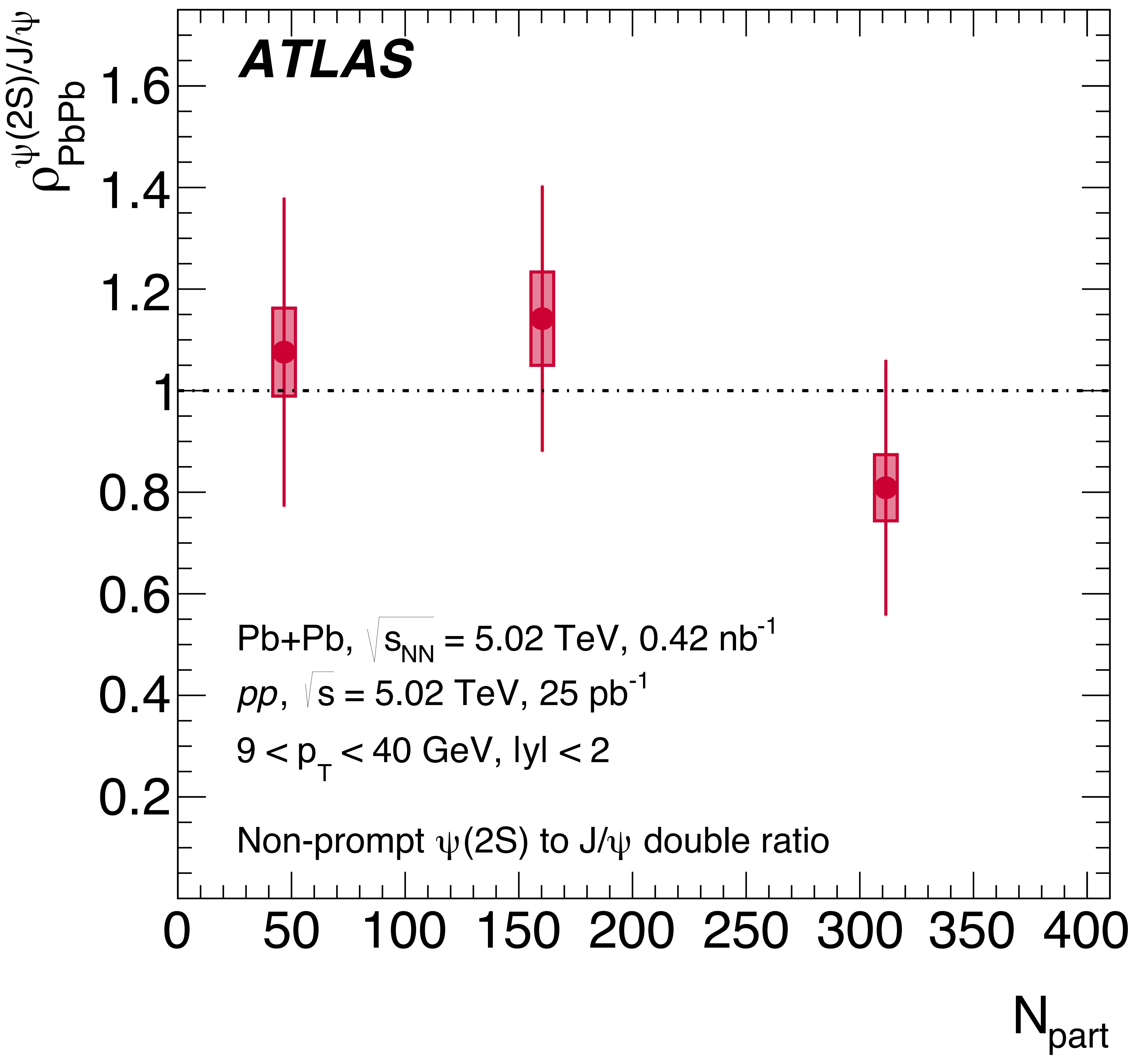
J/ψ R_{AA} in Pb+Pb



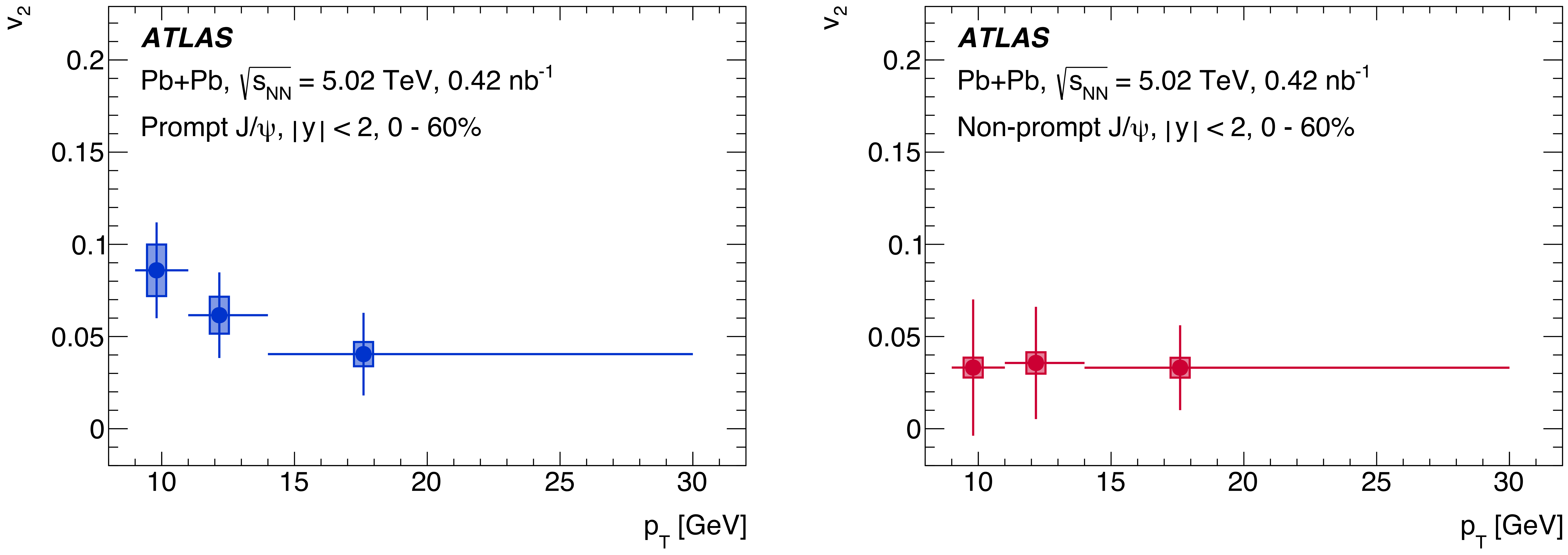


J/ψ double ratios in Pb+Pb



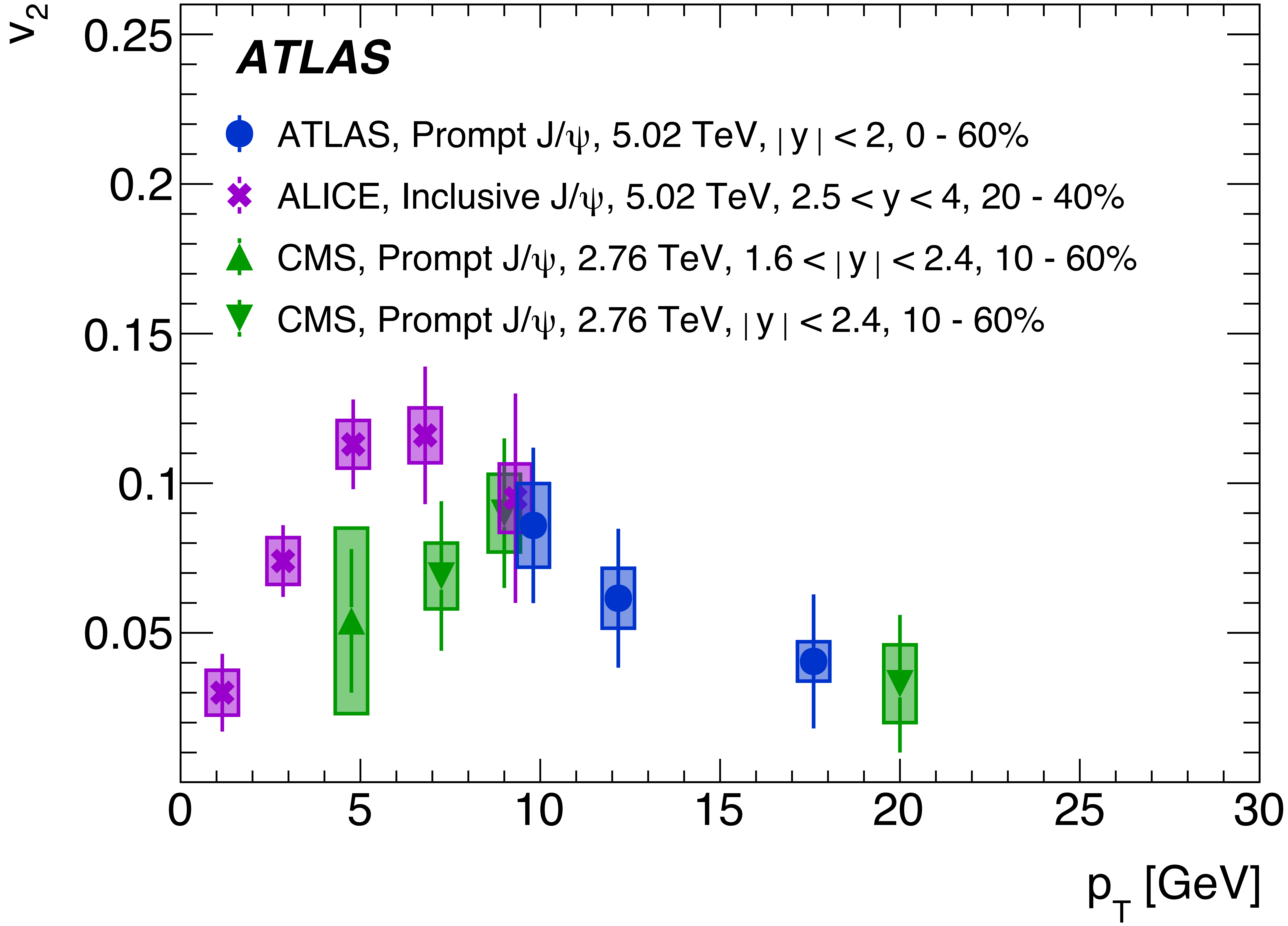


J/ψ v_2 in Pb+Pb



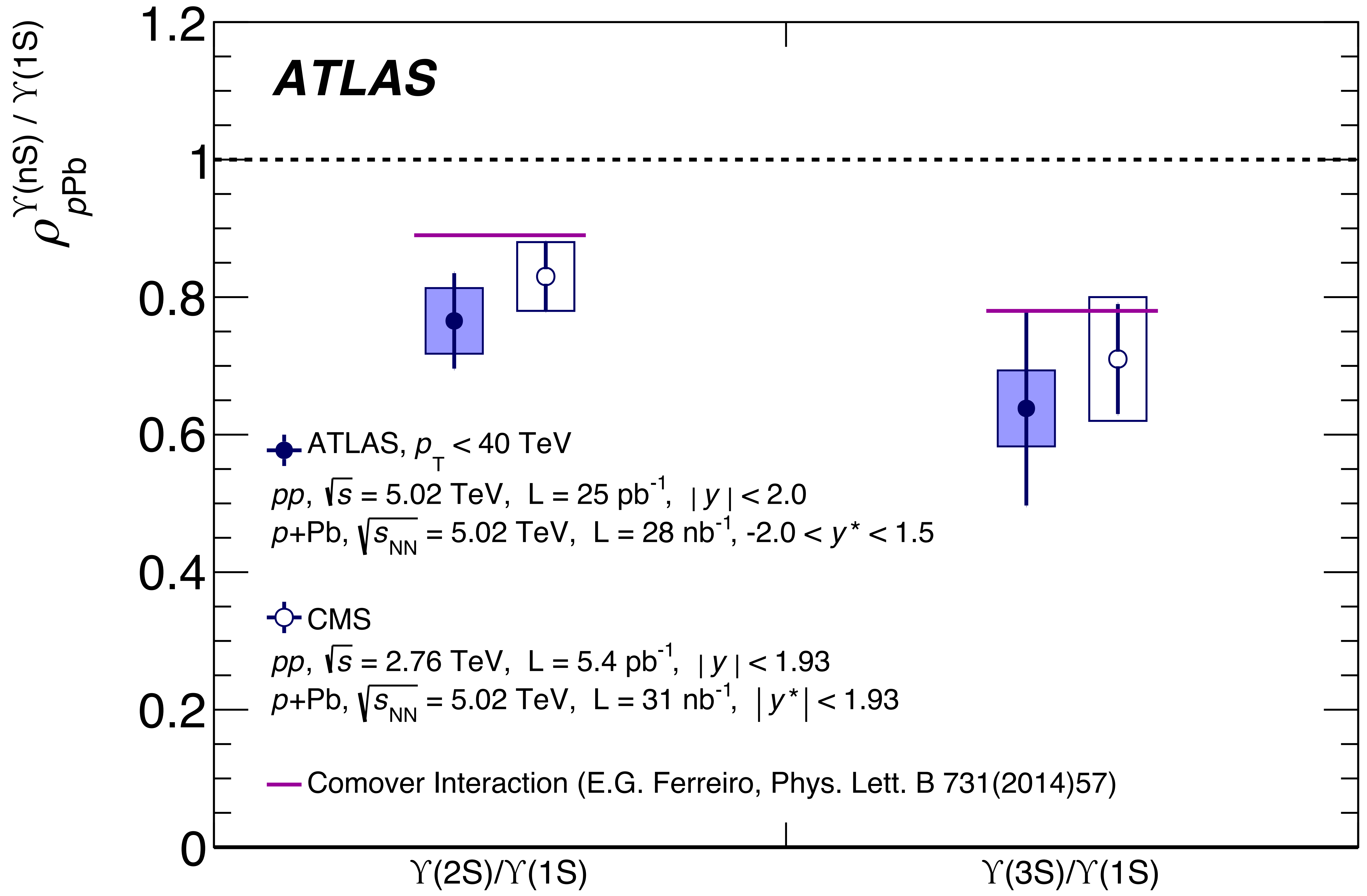
EPJC 78 (2018) 784

J/ψ v_2 in Pb+Pb



EPJC 78 (2018) 784

Υ(nS) double ratios in p+Pb



EPJC 78 (2018) 171

Comparison to CMS: cross-sections

CMS: PLB 790 (2019) 270