SQM 2016

UC Berkeley

Upsilon production measurements in p-Pb and Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV with ALICE

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On behalf of the ALICE collaboration

Outline:

- ✓ p–Pb results
- ✓ Pb–Pb results

$Q\bar{Q}$ pairs are produced in the initial stage of the collision by hard scatterings.

↳ sensitive to the evolution of the Quark-Gluon Plasma (QGP).

Quarkonium suppression as a probe of de-confinement:

↳ Color screening mechanism induced by the high density of color charges in the QGP,

↳ Sequential suppression (feed-down) [hep-ph/0602245].

Why to look at bottomonia?

- Bottom-quark effective theory is more reliable than for charmonia (more perturbative process),
- Regeneration of bottomonia through statistical recombination is much smaller than for charmonia ($N_{\mathrm{c\bar{c}}} \gg N_{\mathrm{b\bar{b}}}$),
- No feed-down from higher-mass open heavy flavors,
- Cold Nuclear Matter (CNM) effects are expected to be smaller than for the charmonia,
- Different kinematics (Bjorken-x) ranges probed with respect to charmonia.

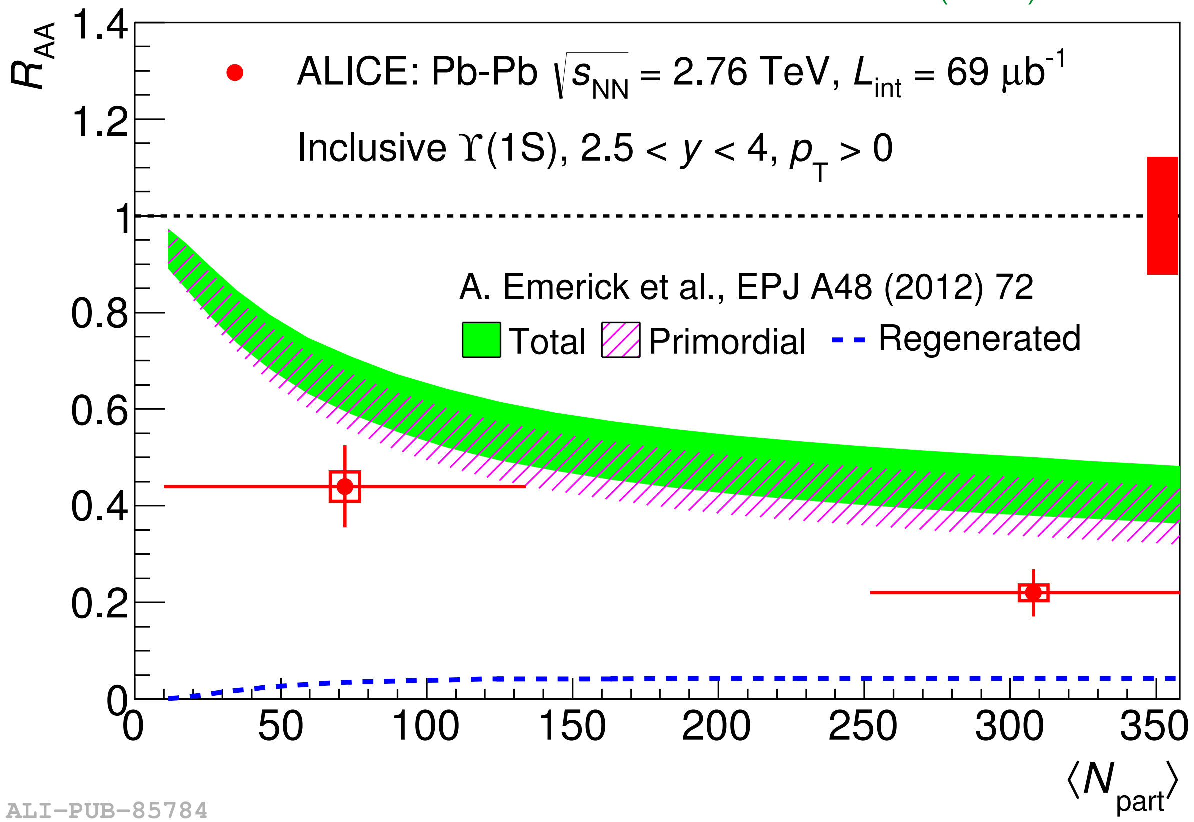
Previous ϒ(1S) results

Nuclear modification factor:

2.76 TeV
Pb-Pb data

Note: σ_{pp} at 2.76 TeV is taken from LHCb Collaboration
EPJ C74 (2014) 2835

PLB 738 (2014) 361–372



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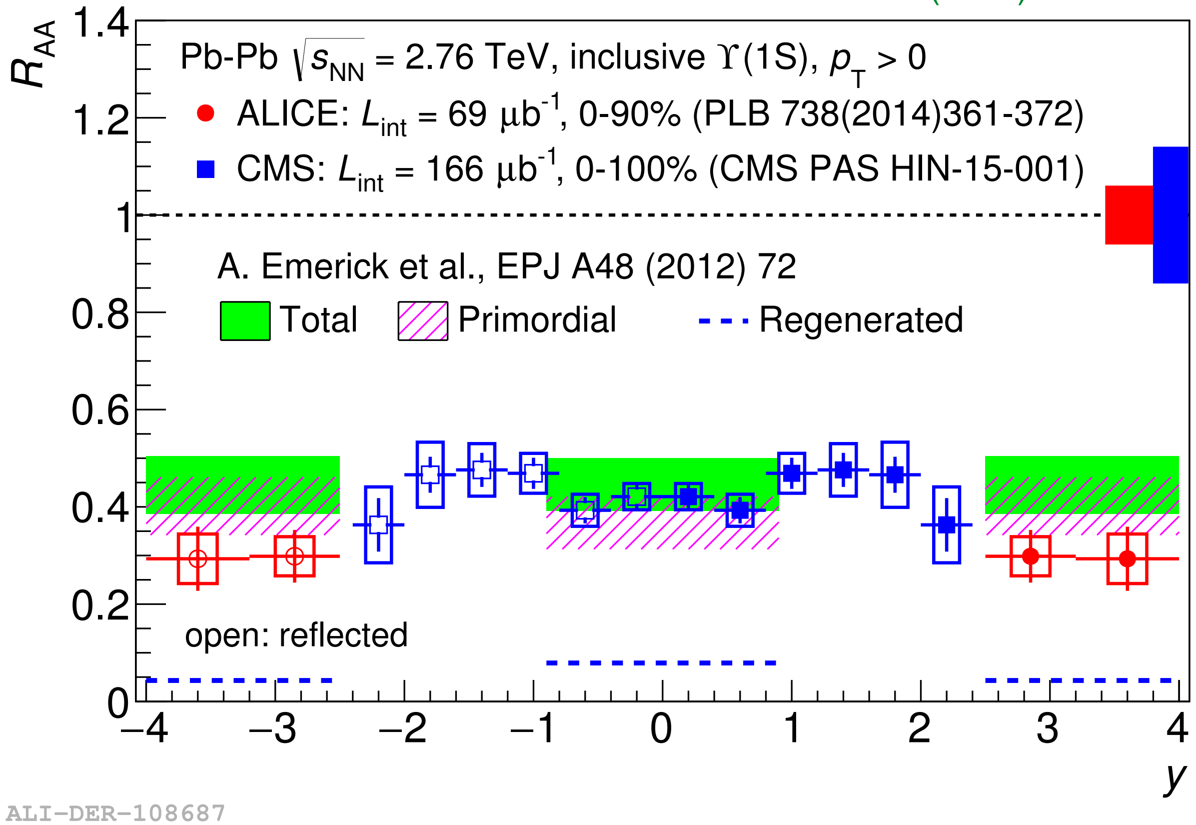
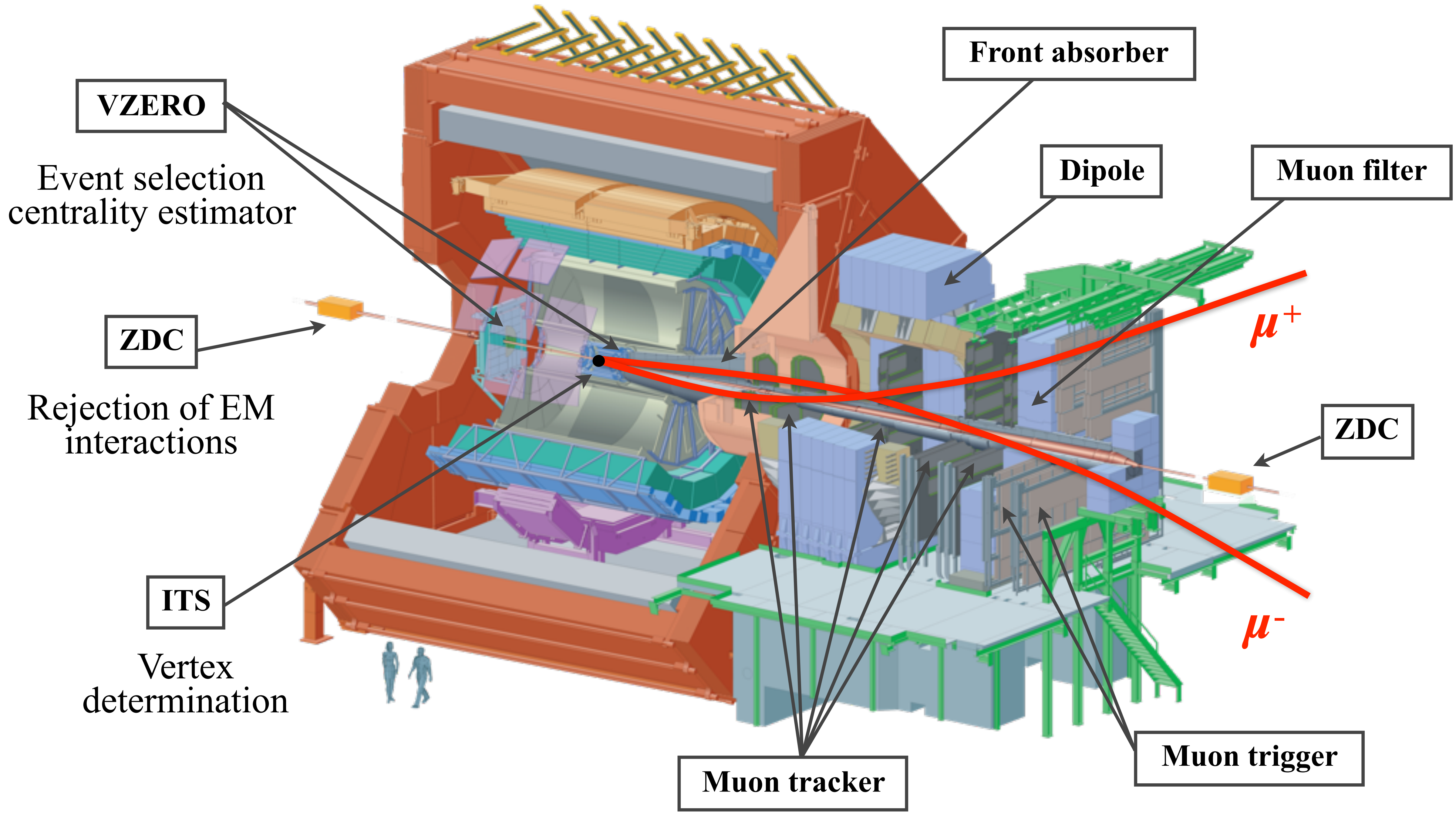


Clear ϒ(1S) suppression, increasing from peripheral to central Pb-Pb collisions.

Similar suppression at forward (ALICE) and mid rapidity regarding the CMS results.

What is going on at higher energy density?

ALICE apparatus



Inclusive quarkonium production measured down to zero transverse momentum

pp reference for R_{pPb} and R_{AA}

pp reference at 5.02 TeV

Extrapolation method (not enough statistics in pp data at 5.02 TeV)

Based on fits to LHCb data with different shapes:

- two-parameter functions: linear, power law and exponential,
- a Leading Order Color Evaporation Model (LO-CEM) calculation,
- the energy and rapidity dependence of the total $\sigma_{b\bar{b}}$ cross section, computed in the FONLL approach with the CTEQ6.6 set of parton distribution functions.

Both R_{pPb} and R_{AA} computations reported in this talk are based on this σ_{pp} interpolation

$$\rightarrow \quad \sigma_{\Upsilon(1S)}\ \mathbf{(pp@5.02\ TeV,\ 2.5 < \mathit{y} < 4) = 1.14 \pm 0.10\ (syst)\ nb}$$

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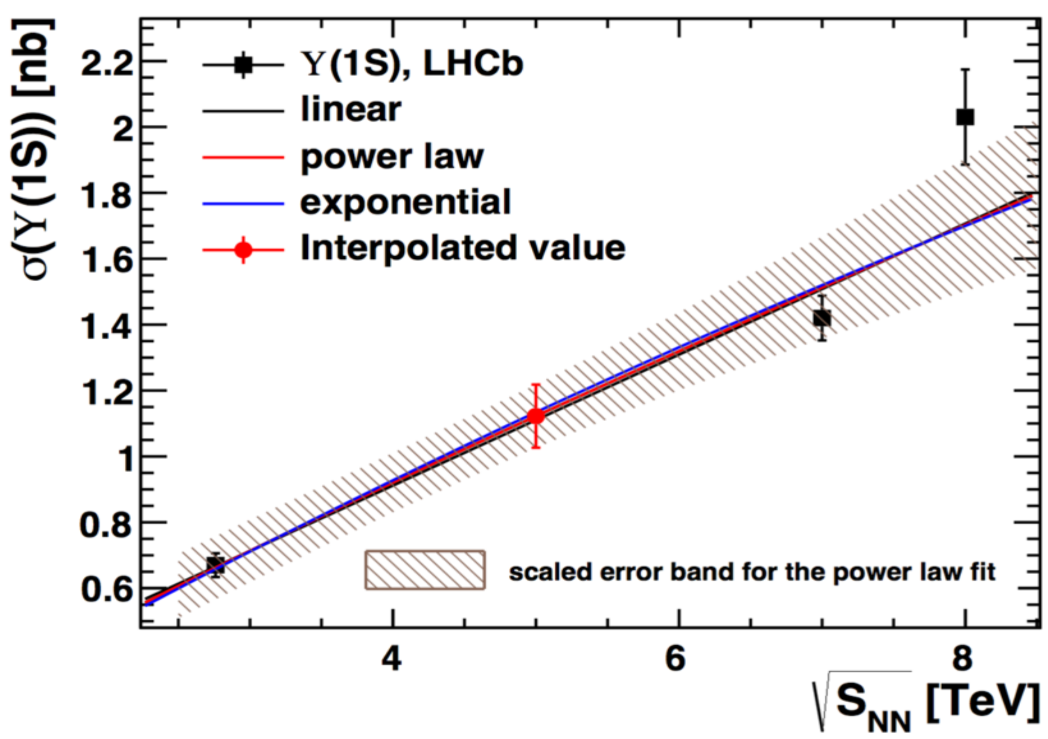

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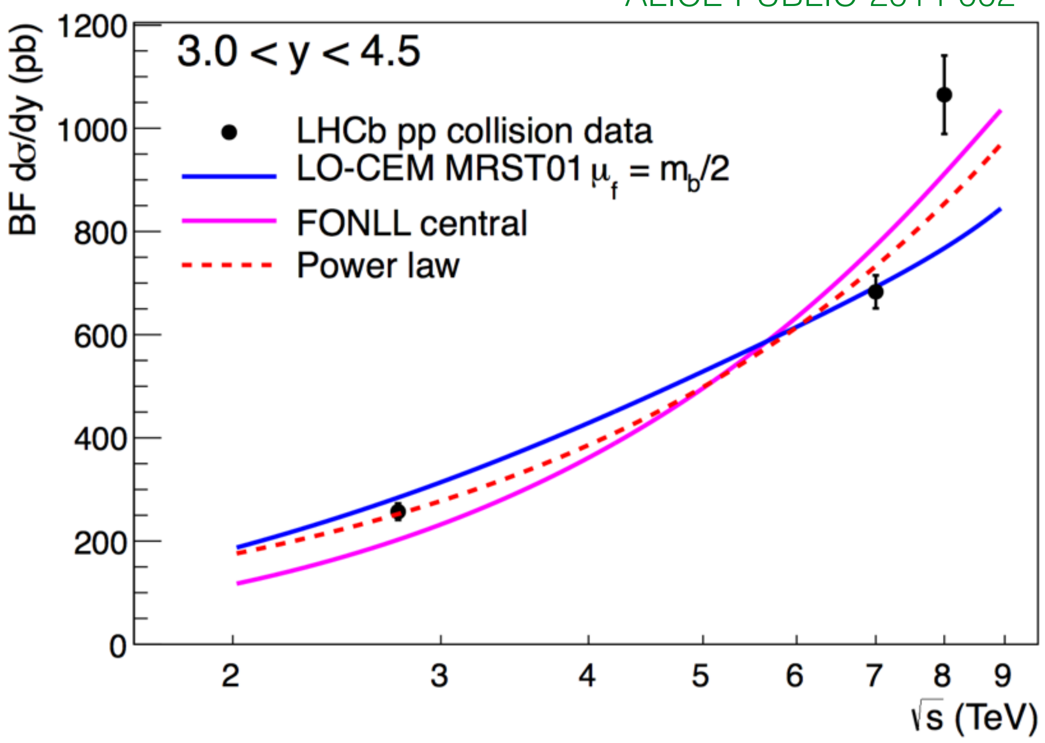


p-Pb collisions

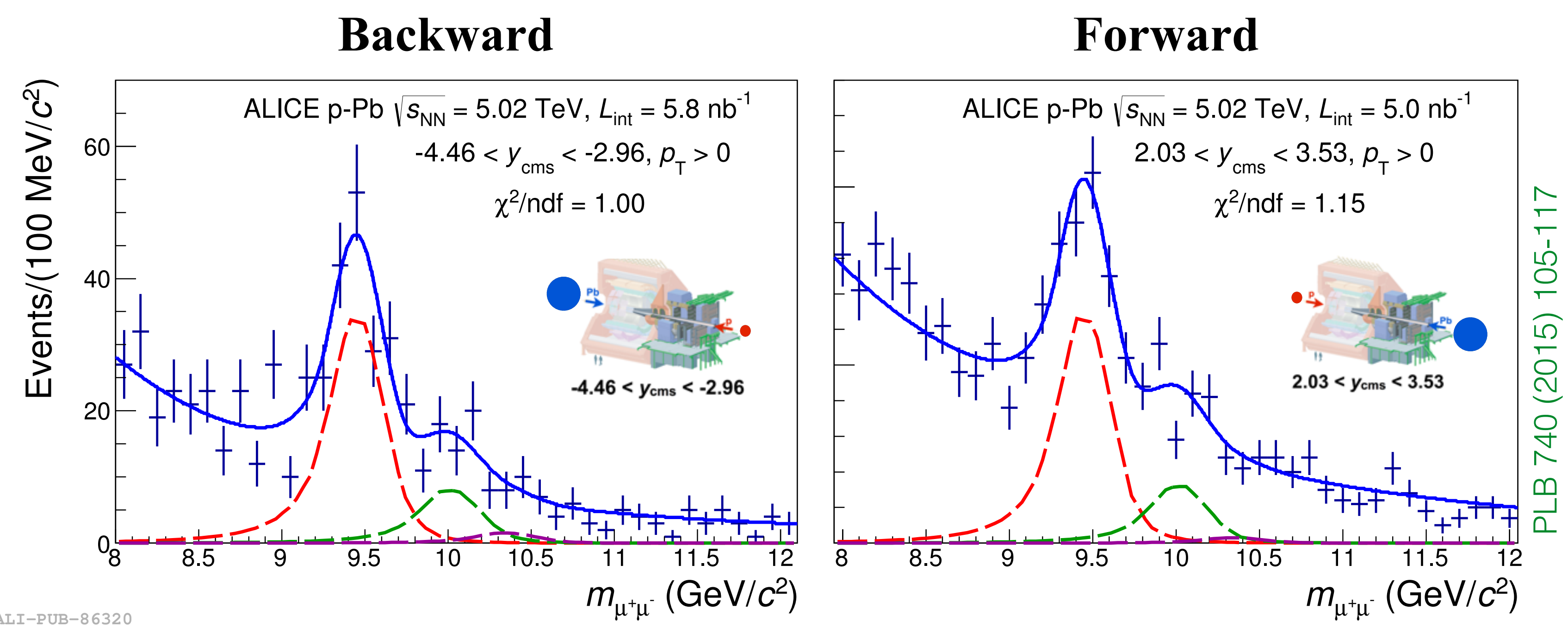
ϒ(1S) in p-Pb collisions at 5.02 TeV

Upsilon measurement:

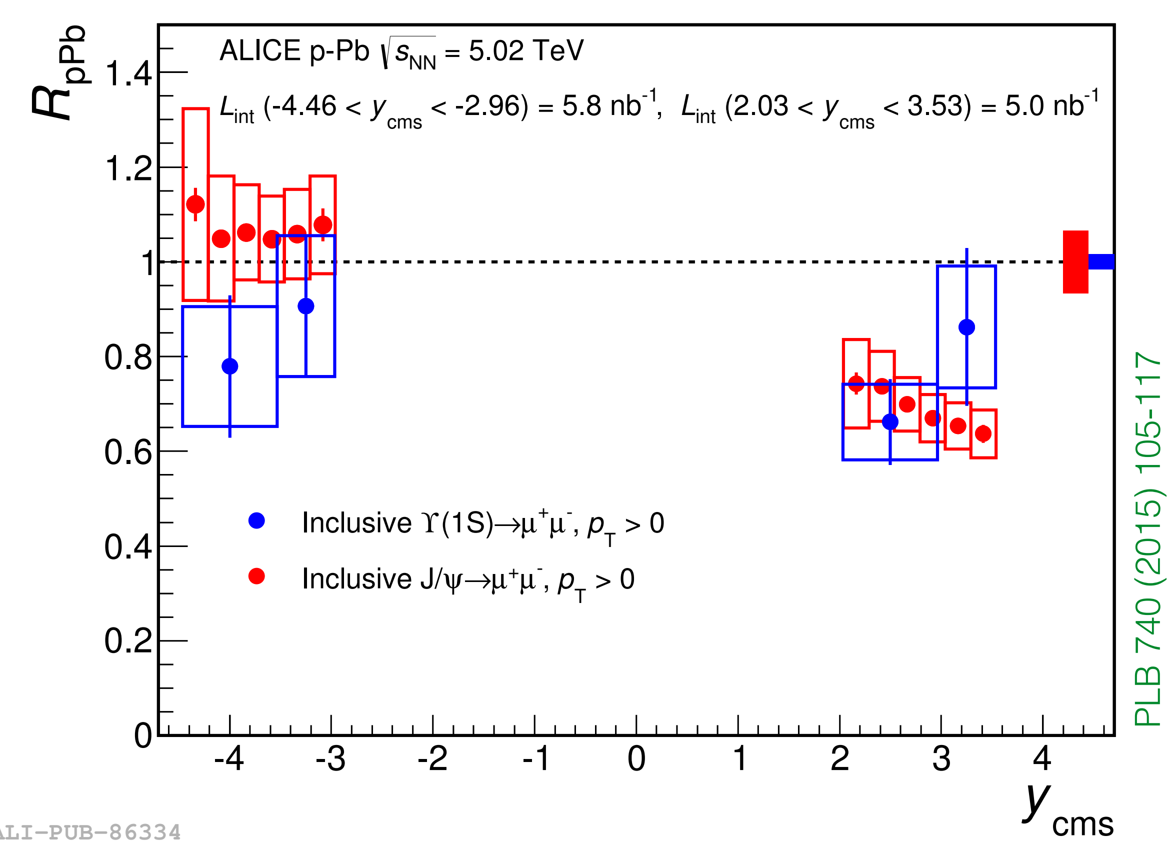
Use of fits to the invariant mass distribution of opposite sign muon pairs detected in the muon spectrometer

L_{int} (p-Pb) ≈ 5.8 nb^{-1}

L_{int} (Pb-p) ≈ 5 nb^{-1}



R_{pPb} as a function of rapidity:

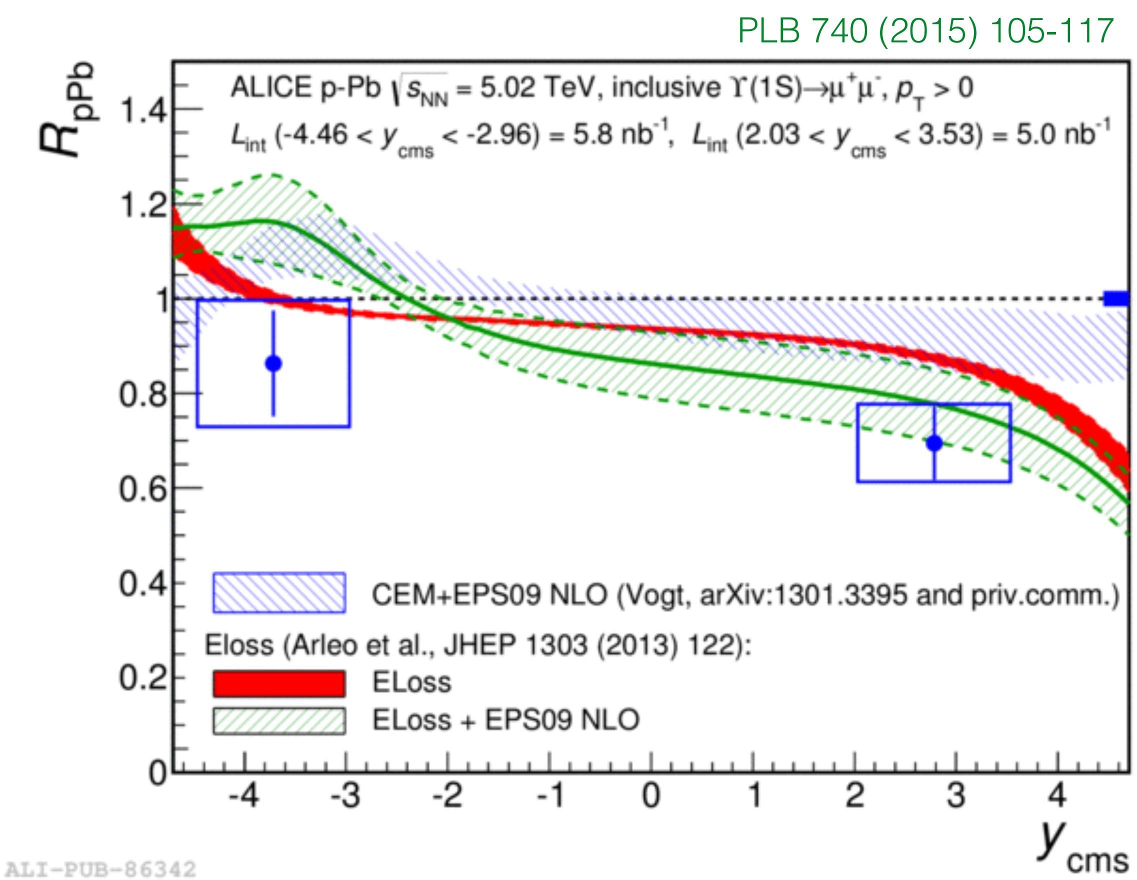


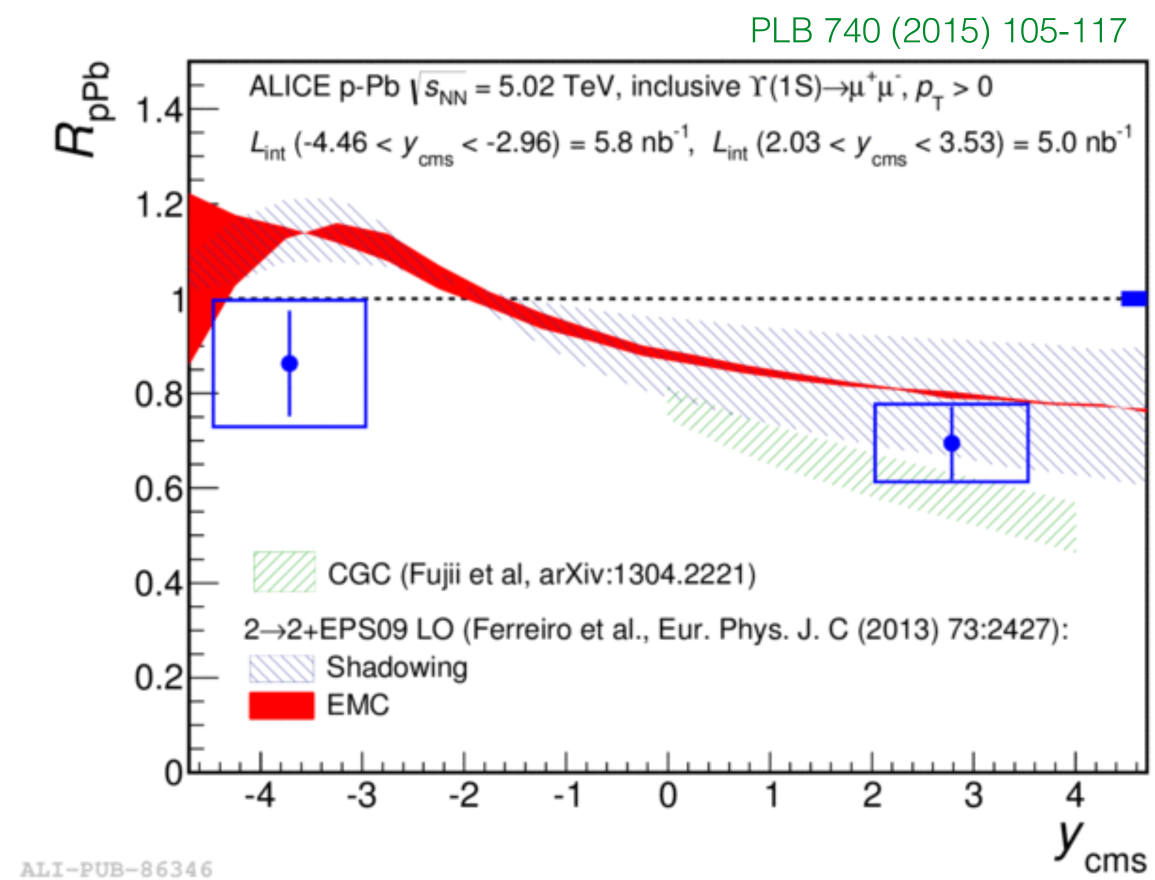
Consistent with no suppression at backward rapidity

Indication of suppression at forward rapidity, similar to the J/ψ one within uncertainties

$\Upsilon(1S)$ R_{pPb} at 5.02 TeV

Comparison to models:





Forward: better agreement with E_{loss} and shadowing,
Backward: slightly better agreement with E_{loss} only.

All models are compatible at forward rapidity, Model comparisons suggest smaller anti-shadowing than assumed (backward rapidity)

$[\Upsilon(2S)/\Upsilon(1S)]_{pPb\ (bwd)} = 25.8 \pm 9.1 \pm 3.9$ %,
$[\Upsilon(2S)/\Upsilon(1S)]_{pPb\ (fwd)} = 27.3 \pm 8.1 \pm 4.0$ %
Consistent with the pp ratios measured by LHCb at 2.76, 7 and 8 TeV. [PLB 740 (2015) 105-117]

No evidence for different CNM effects on the $\Upsilon(1S)$ and $\Upsilon(2S)$ within uncertainties

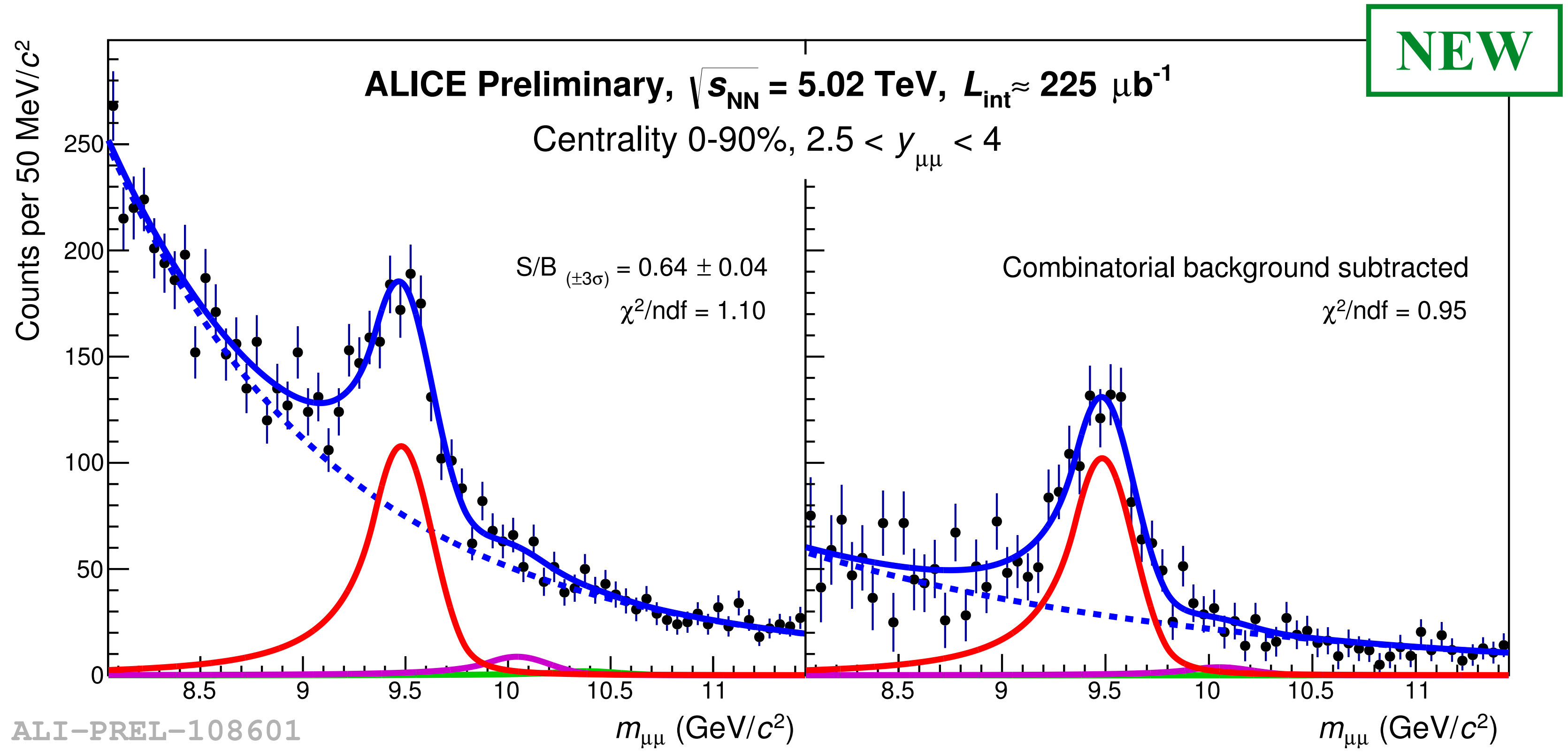
Pb-Pb collisions

ϒ(1S) in Pb-Pb collisions at 5.02 TeV

Upsilon measurement:

Use of fits to the invariant mass distribution of opposite sign muon pairs detected in the muon spectrometer

$L_{int} \approx 225\ \mu b^{-1}$



Various fits are performed by changing the background and signal shapes, the fitting range, etc.

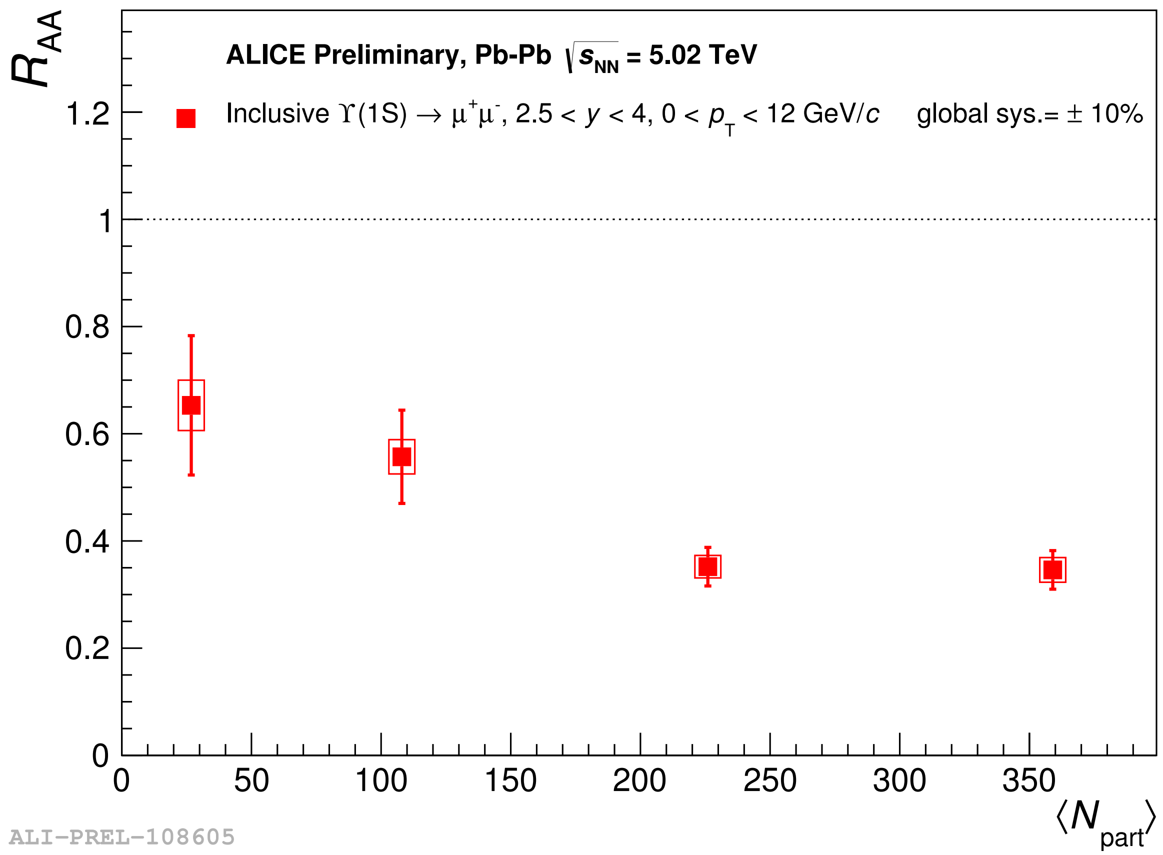
$N_{\Upsilon(1S)}$ = 1107 ± 70 (stat.) ± 43 (syst.)

Acceptance x efficiency correction evaluated by using embedded ϒ(1S) MC in data.

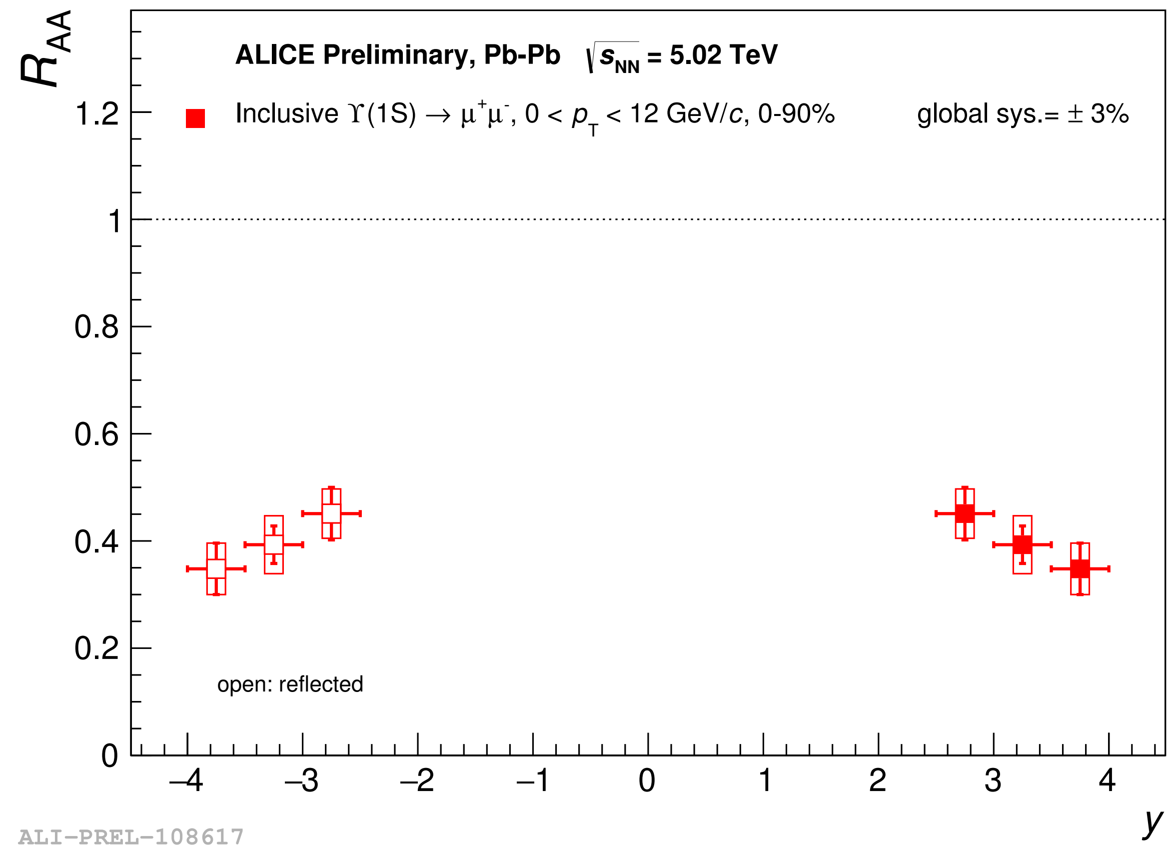
The dominant sources of systematic uncertainty entering in the R_{AA} are:
the signal extraction (4-7%) and the interpolated pp cross section (8-12%).

Υ(1S) R_{AA} at 5.02 TeV

R_{AA} as a function of centrality:



R_{AA} as a function of rapidity: NEW



R_{AA} (5.02 TeV, 0-90%) = 0.40 ± 0.03 (stat.) ± 0.04 (syst.)

Clear Υ(1S) suppression,

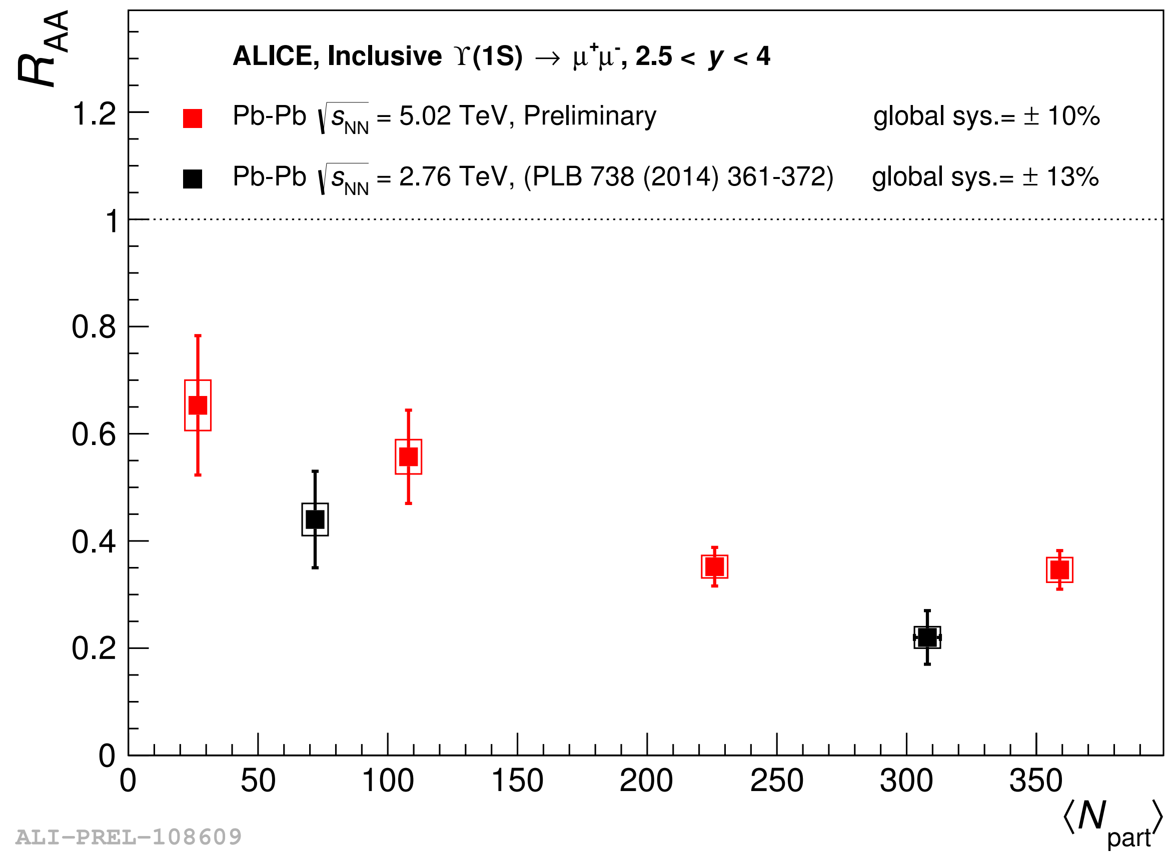
Decrease of R_{AA} from peripheral to central Pb-Pb collisions.

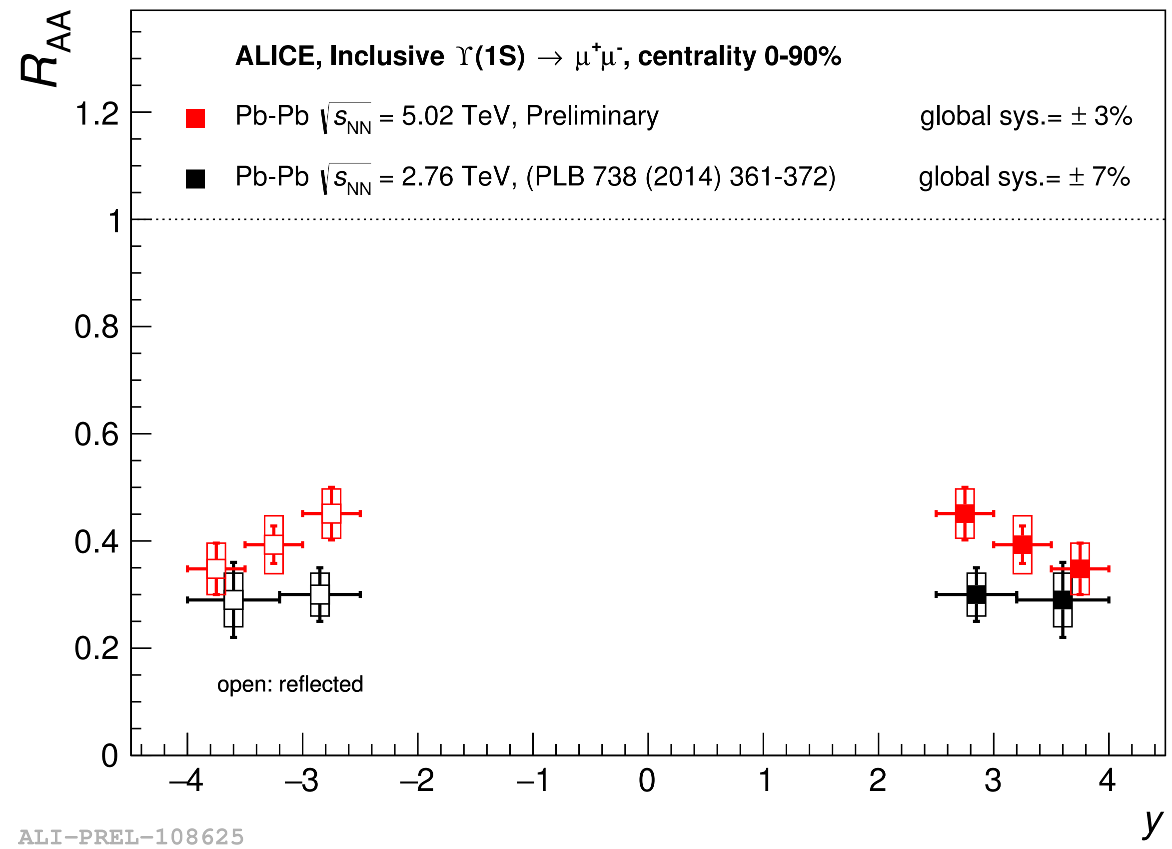
Hint for a decreasing trend from most central to forward rapidity but remains compatible within uncertainties.

Υ(1S) R_{AA} at 5.02 TeV

Collision energy comparison:

NEW





R_{AA} (5.02 TeV, 0-90%) = 0.40 ± 0.03 (stat.) ± 0.04 (syst.)

R_{AA} (2.76 TeV, 0-90%) = 0.30 ± 0.05 (stat.) ± 0.04 (syst.)

Larger R_{AA} values at 5.02 TeV than at 2.76 TeV but remain compatible within uncertainties.

Υ(1S) R_{AA} at 5.02 TeV

Collision energy comparison:

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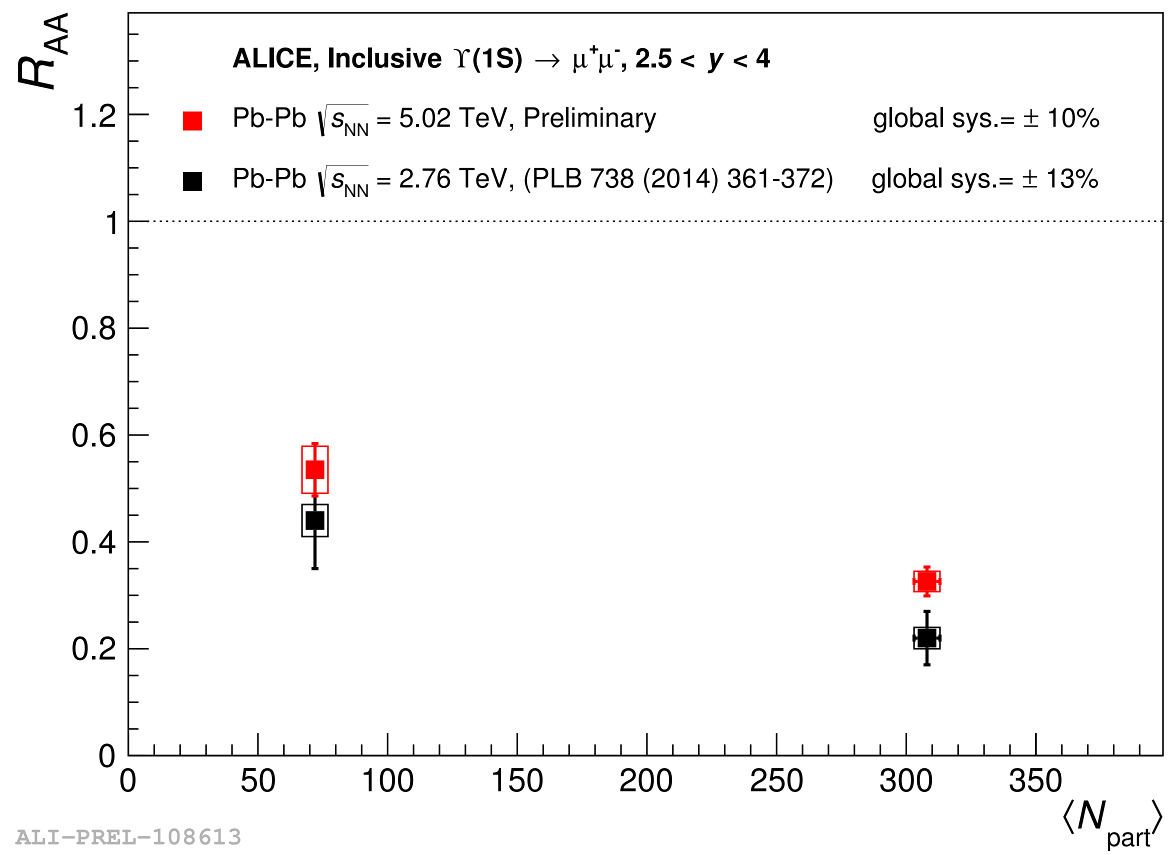
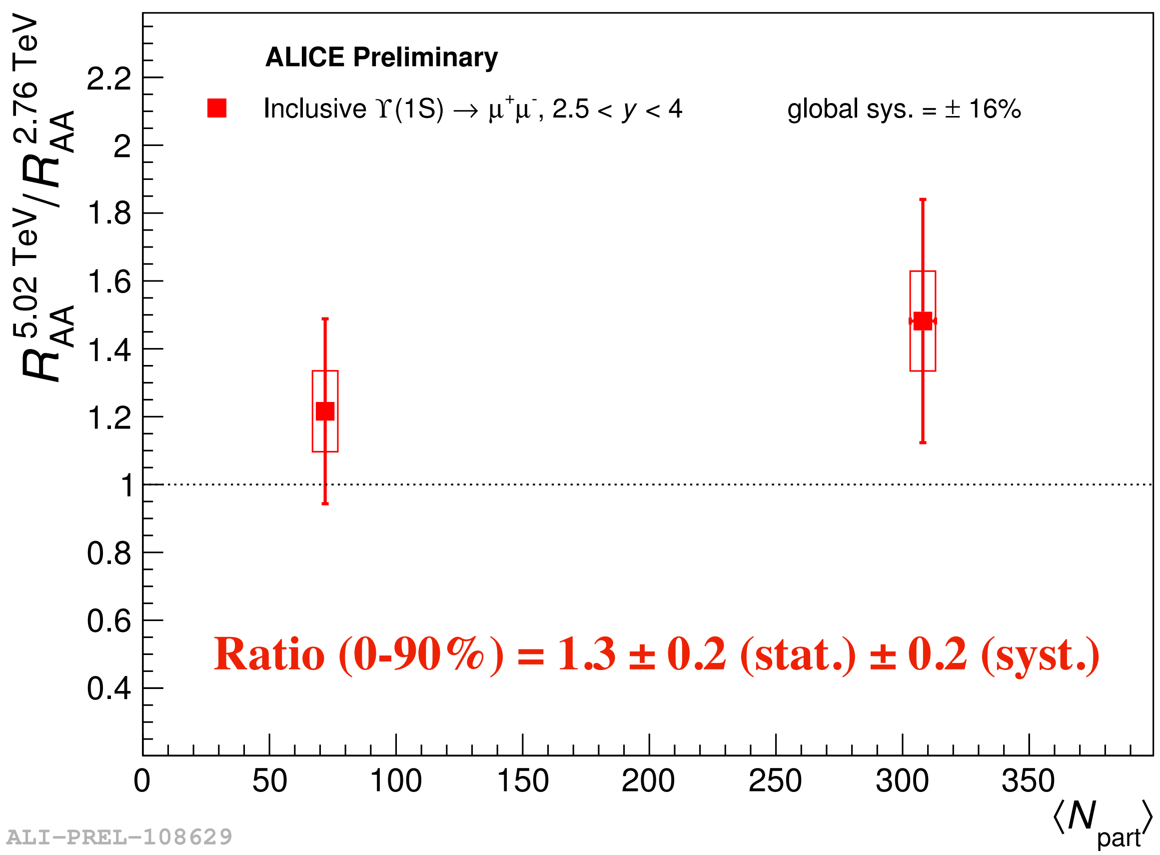




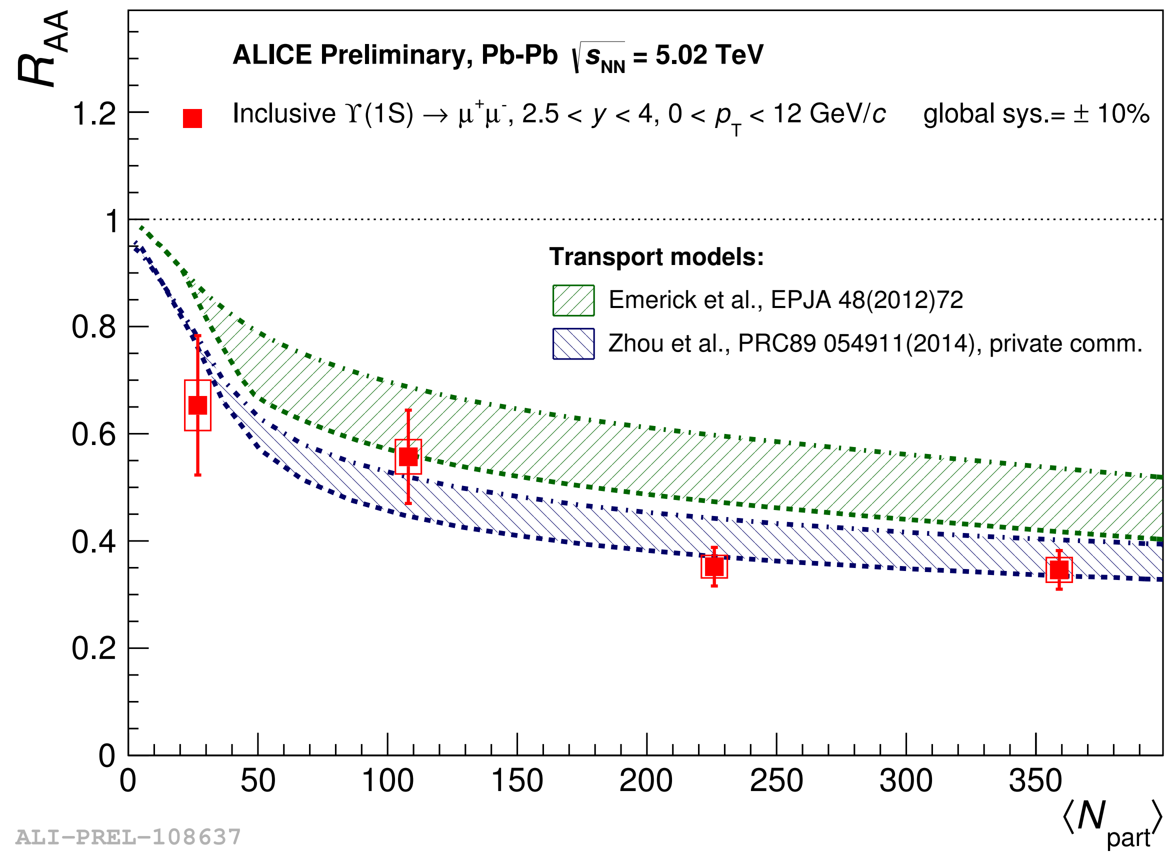
Data comparison by using the same centrality classes at both energies.

Results are compatible within uncertainties

Note that transport model (Emerick et al.) predicts a small decrease (up to 5%) of this R_{AA} ratio moving from peripheral to central collisions.

Υ(1S) R_{AA} at 5.02 TeV

Model comparison:



NEW

Transport models:

- A. Emerick, X. Zhao and R. Rapp:
  EPJA48 (2012) 72
  - Band: upper limit no shadowing, lower limit shadowing (up to a reduction of 25%),
  - Feed-down taken from ALICE and LHCb Collaborations,
  - **Regeneration component include.**
- K. Zhou, N. Xu, Z. Xu and P. Zhuang:
  PRC 89 05911 (2014)
  - Band: different sets of feed-down fractions,
  - CNM: shadowing from EKS98
  - **No regeneration component.**

Transport models reproduce qualitatively the centrality dependence.
Emerick et al. model underestimates the suppression for most central collisions.

No strong indication of direct Υ(1S) suppression in most central collisions (considering a suppression of ~30% from feed-down and ~30% from CNM effects)

Model comparison:

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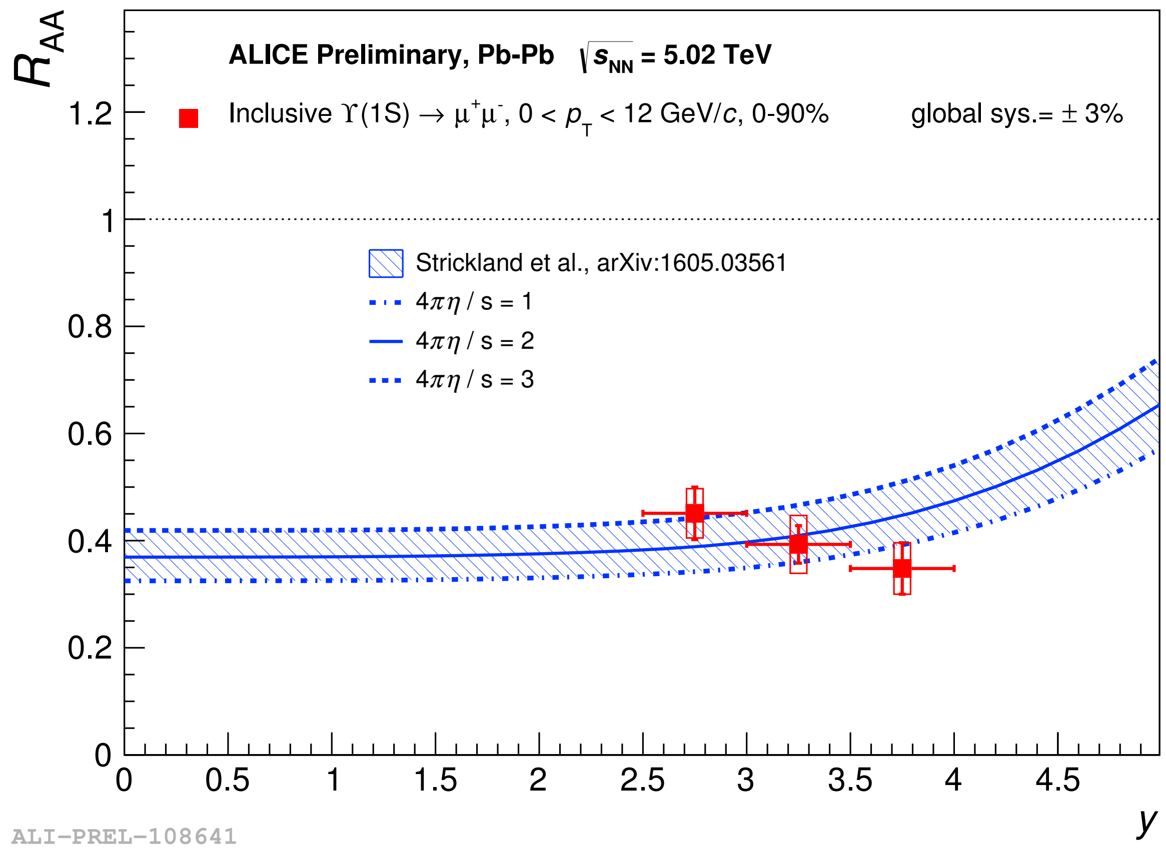

Hydrodynamic model:

- M. Strickland et al.: arXiv:1605.03561
  - Thermal suppression in hydrodynamic + anisotropic screening model,
  - Band: different values of η/s ratio
  - Initial momentum-space anisotropy $\xi_0 = 0$
  - No regeneration component
  - No CNM effects

The model can reproduce the data within uncertainties.

The predicted shape in the most forward rapidity region goes in the opposite way with respect to the data.

Conclusion

ALICE has measured the $\Upsilon(1S)$ production both in p-Pb and Pb-Pb collisions at 5.02 TeV with the Muon Spectrometer.

p-Pb collisions:

- Indication of $\Upsilon(1S)$ suppression at forward rapidity,
- Indication of smaller anti-shadowing than suggested by the models at backward rapidity,
- All models can reproduce the data within uncertainties.

Pb-Pb collisions:

- $\Upsilon(1S)$ R_{AA} shows a stronger suppression with increasing centrality at forward rapidity,
- Results at 2.76 and 5.02 TeV are compatible within uncertainties,
- No strong indication of direct $\Upsilon(1S)$ suppression in the most central collisions,
- Models including CNM effects are able to reproduce the data at 5 TeV.

Outlooks:

More statistics and higher luminosity coming soon during LHC run-2:

- p-Pb data at the end of this year $\rightarrow$ constrain the models,
- Pb-Pb data at the end of the LHC run 2 (up to $L_{int} = 1\ nb^{-1}$ expected).

Thank you for your attention