Υ production in p–Pb collisions at $\sqrt{s_{\rm NN}} = 8.16$ TeV with ALICE at the LHC

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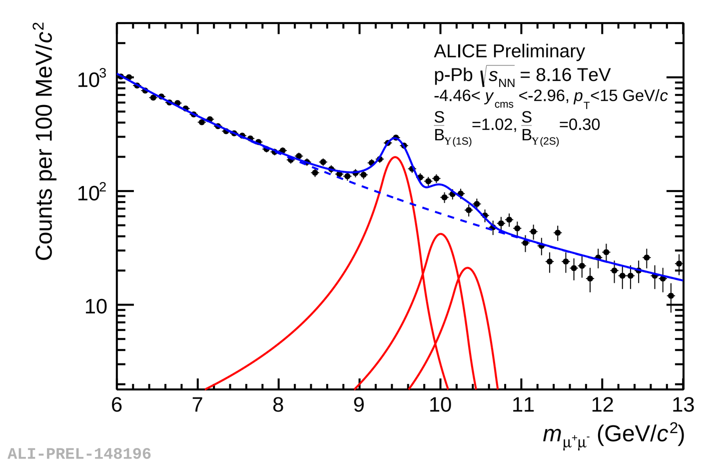
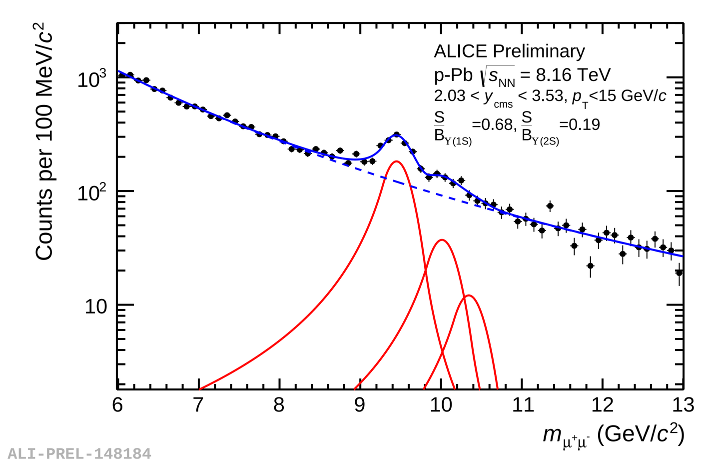
Physics motivation

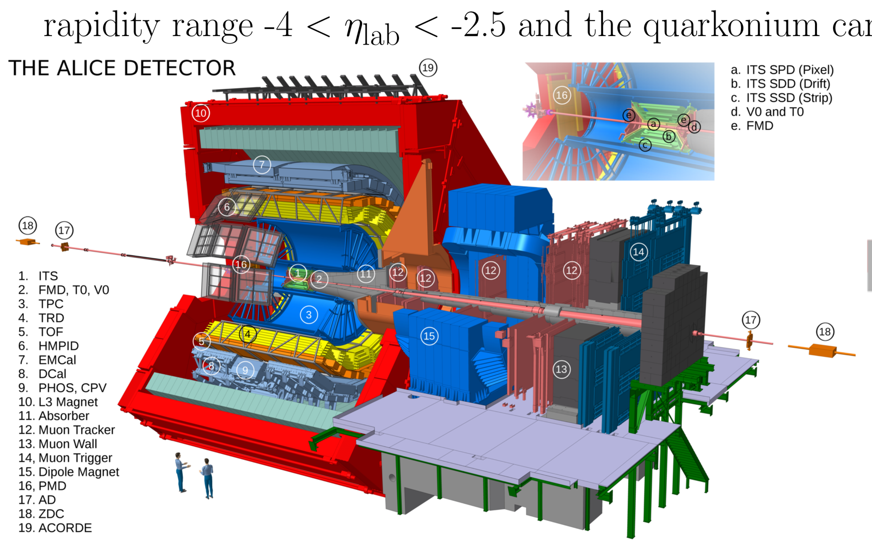
- Heavy quarkonia ($c\bar{c}$, $b\bar{b}$) produced at the early stage of relativistic heavy-ion collisions at the LHC energy are the striking probe to study the Quark-Gluon Plasma (QGP) i.e a hot and dense deconfined medium.
- Colour screening (suppression of $q\bar{q}$), sequential suppression [1] and regeneration phenomena (enhancement of $q\bar{q}$) influence quarkonium production due to QGP.
- Cold Nuclear Matter (CNM) effects which include shadowing or gluon saturation and energy loss can also lead to a modification of quarkonium production.
- In order to disentangle the CNM effects from the hot nuclear matter effect, quarkonium production is studied in p–Pb collisions where QGP is not expected to be formed.
- Bottomonia (Υ(nS)) are good candidates for the study of CNM effects in p-Pb collisions in order to properly understand the suppression in Pb–Pb collisions.
- Bottomonium production is studied with the ALICE forward spectrometer via its $\mu^+\mu^-$ decay channel.

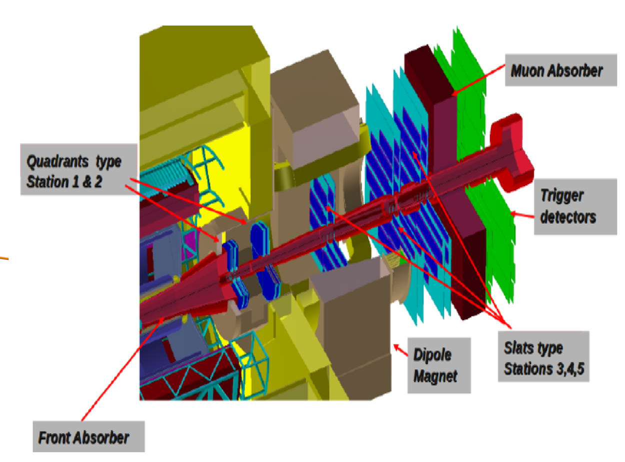




ALICE and the Muon Spectrometer

- The ALICE Muon Spectrometer is designed to measure the quarkonium states. It tracks muons in the pseudo-rapidity range -4 < $\eta_{\rm lab}$ < -2.5 and the quarkonium can be detected transverse momenta down to $p_{\rm T} = 0$.





- ALICE has taken p-Pb data at $\sqrt{s_{\rm NN}} = 5.02$ TeV (Run I and Run II) and at $\sqrt{s_{\rm NN}} = 8.16$ TeV (Run II).
- Due to energy asymmetry of LHC beams in p-Pb collisions, the nucleon-nucleon center of mass frame of the collisions is shifted by $\Delta y = 0.465$ w.r.t. laboratory frame in the direction of the proton beam
- In the center of mass frame, the muon spectrometer covers the forward rapidity region $2.03 < y_{\rm cms} < 3.53$ and backward rapidity region $-4.46 < y_{\rm cms} < -2.96$

Nuclear modification factor

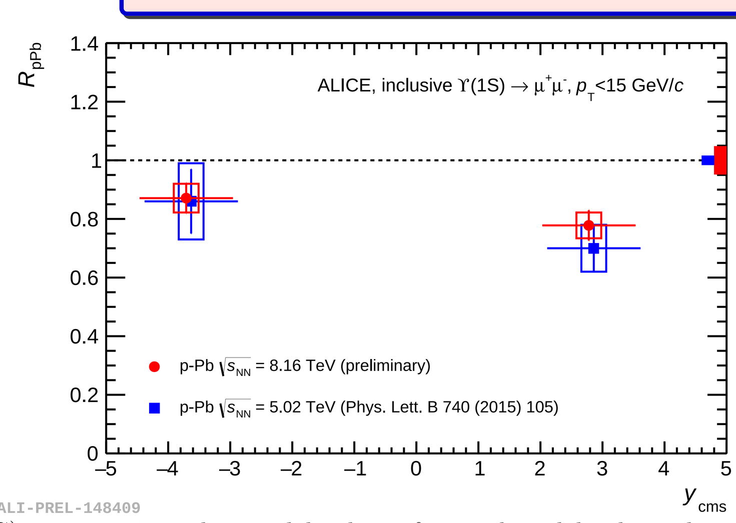
The nuclear modification factor is defined as:

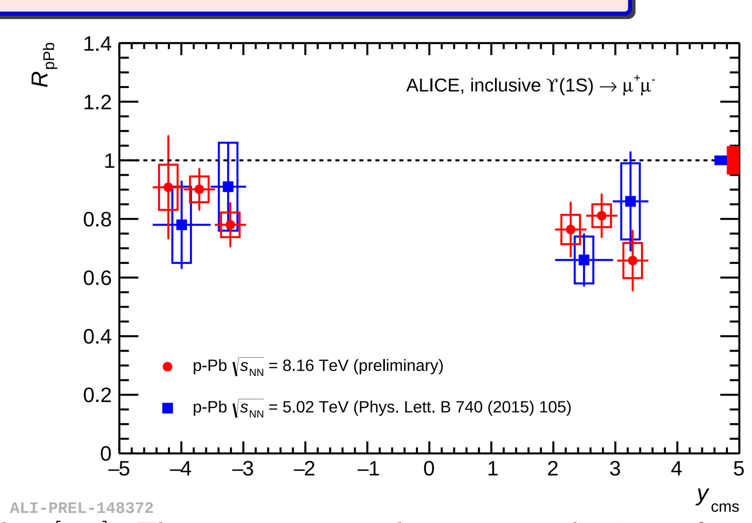
$$R_{\rm pPb} = \frac{N_\Upsilon}{\langle T_{\rm pPb}\rangle \cdot (A\times\epsilon) \cdot N_{\rm MB} \cdot {\rm BR}_{\Upsilon\to\mu^+\mu^-} \cdot \sigma_\Upsilon^{\rm pp}}$$

where:

- N_Υ is the number of Υ in a given $y_{\rm cms}$, $p_{\rm T}$ or centrality bin obtained from the signal extraction.
- $\langle T_{\rm pPb}\rangle$ is the centrality-dependent average nuclear overlap function.
- $A \times \epsilon$ is the product of the detector acceptance and the reconstruction efficiency.
- $N_{\rm MB}$ is the number of collected minimum-bias events.
- ${\rm BR}_{\Upsilon\to\mu^+\mu^-}$ is the branching ratio of Υ in dimuon decay channel (${\rm BR}_{\Upsilon(1S)\to\mu^+\mu^-}$=2.48±0.05%, ${\rm BR}_{\Upsilon(2S)\to\mu^+\mu^-}$=1.93±0.17%).
- $\sigma_\Upsilon^{\rm pp}$ is the inclusive Υ production cross section for pp collisions at the same energy, $y_{\rm cms}$ and $p_{\rm T}$ interval as for p–Pb collisions.

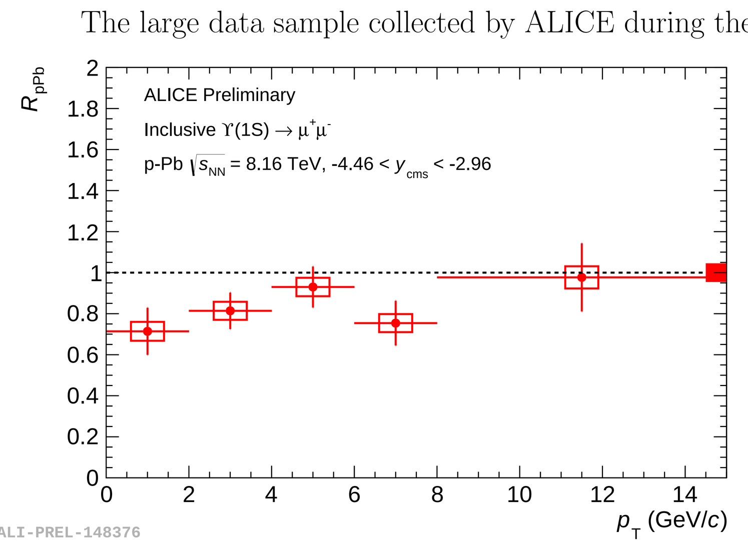
Υ(1S) $R_{\rm pPb}$ at $\sqrt{s_{\rm NN}} = 8.16$ TeV and 5.02 TeV

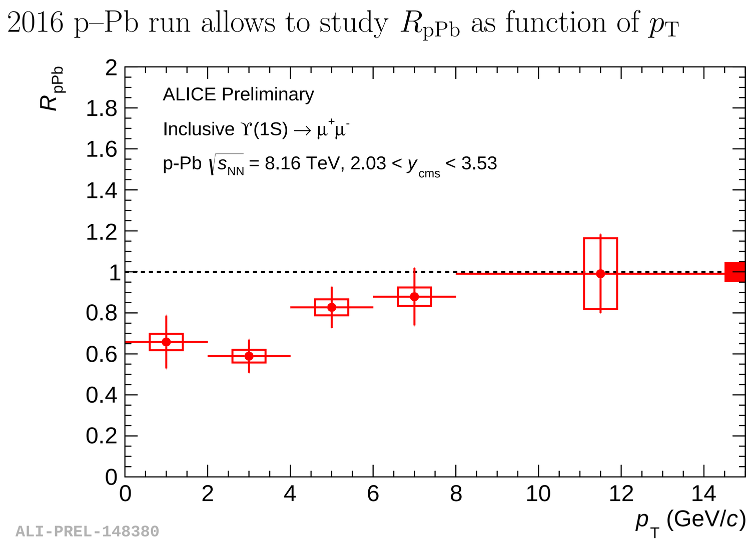




- Υ(1S) suppression observed both at forward and backward rapidity [2,3]. The suppression is about 2.8σ and 1.7σ at forward and backward rapidity, respectively.
- Compatible $R_{\rm pPb}$ at $\sqrt{s_{\rm NN}} = 5.02$ and 8.16 TeV [2,3]

The large data sample collected by ALICE during the 2016 p–Pb run allows to study $R_{\rm pPb}$ as function of $p_{\rm T}$

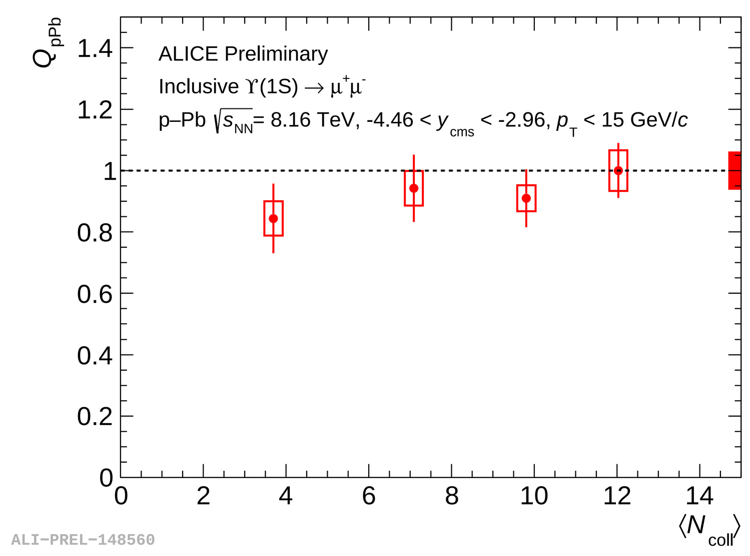


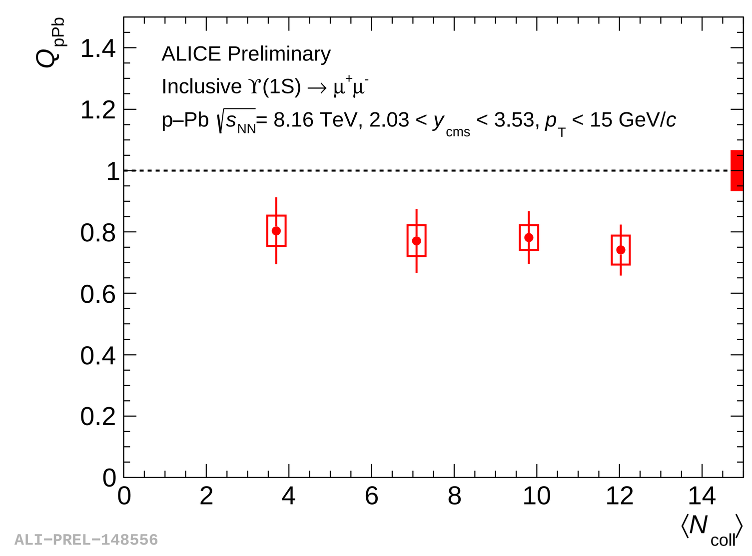


- Stronger Υ(1S) suppression observed at low $p_{\rm T}$ both at forward and backward rapidities [3]

Υ(1S) $Q_{\rm pPb}$ at $\sqrt{s_{\rm NN}} = 8.16$ TeV

- The Υ(1S) nuclear modification factor has been also studied as a function of the collision centrality
- We use $Q_{\rm pPb}$ instead of $R_{\rm pPb}$ due to a possible bias in the determination of centrality [4,5]

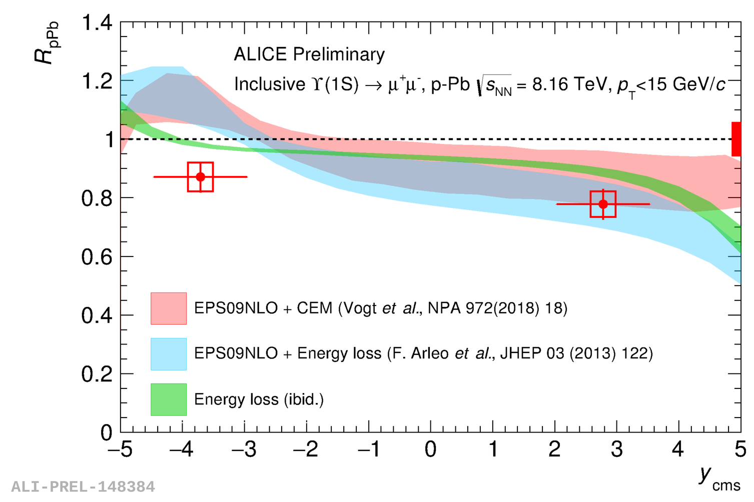


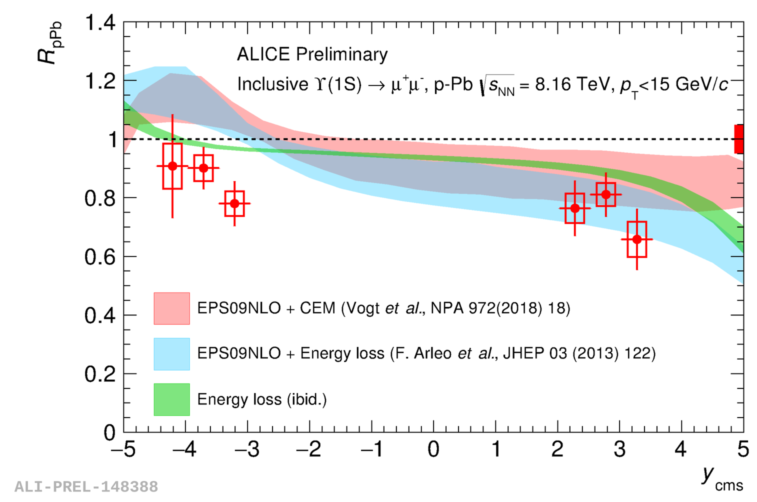


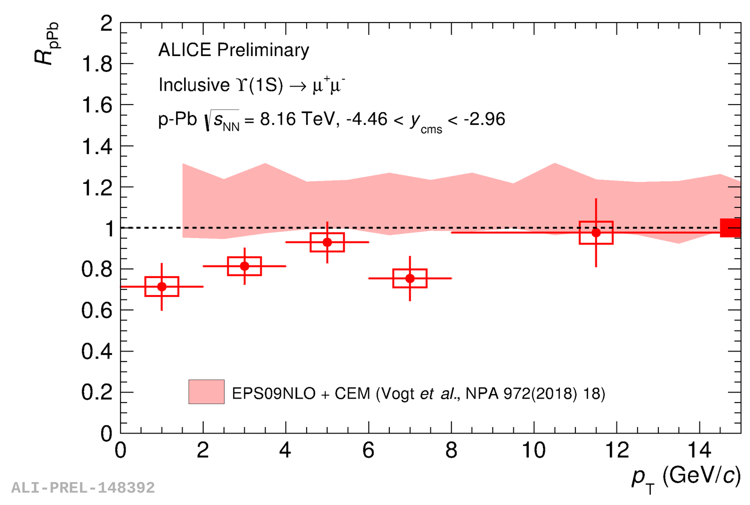
- No strong dependence of $Q_{\rm pPb}$ on centrality within uncertainties at both forward and backward rapidities
- $Q_{\rm pPb}$ suppression is larger at forward rapidity

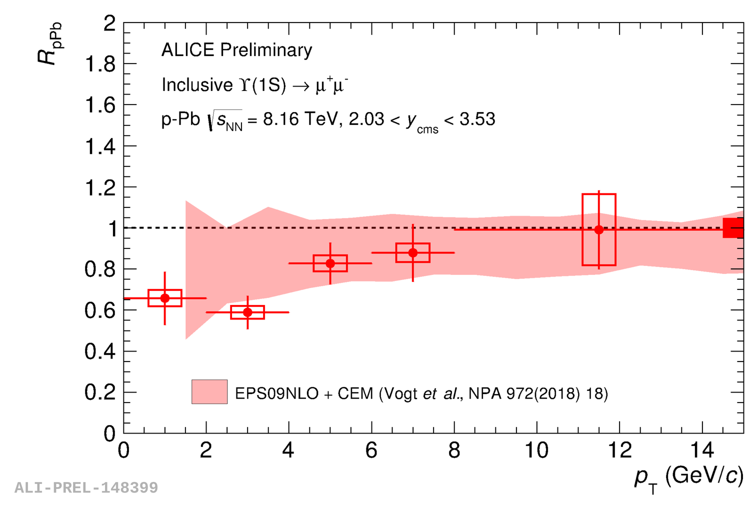
Υ(1S) $R_{\rm pPb}$ comparison with models prediction

- The rapidity and $p_{\rm T}$ dependence of the $R_{\rm pPb}$ are compared to the NLO CEM calculation using the EPS09 parameterization of the nuclear modification of the gluon PDF [6,7] and to a parton energy loss calculation [8] with and without EPS09 gluon shadowing at NLO





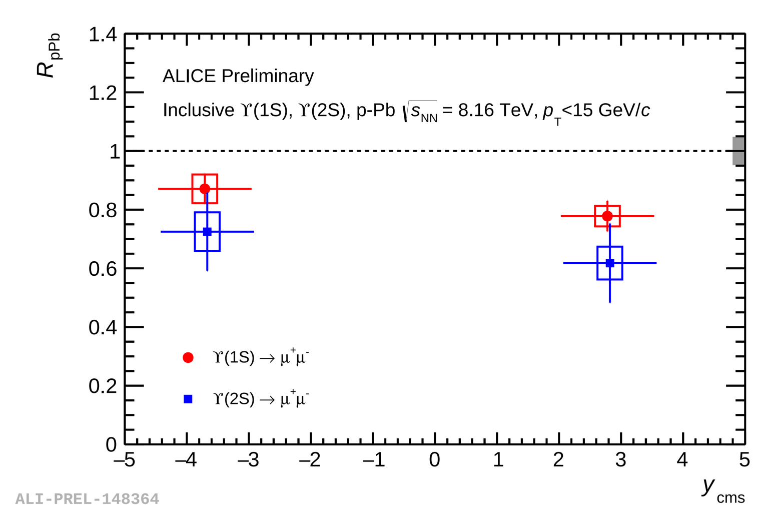




- The shadowing calculation and energy loss describes the $p_{\rm T}$ and rapidity dependent results at forward rapidity within uncertainties while they overestimate the data at backward rapidity

Υ(2S) $R_{\rm pPb}$

- The smaller Υ(2S) statistics does not allow differential studies, hence only results integrated over y and $p_{\rm T}$ are presented.



- The two resonances show similar suppression, slightly larger for Υ(2S)

Conclusions

- Suppression of the Υ(1S) yields in p–Pb collisions is observed at both forward and backward rapidities w.r.t binary-scaled pp collisions at the same center-of-mass energy of 8.16 TeV
- The $R_{\rm pPb}$ values are similar at forward and backward rapidities with a hint for a stronger suppression at low $p_{\rm T}$
- At both rapidity intervals there is no evidence for a centrality dependence of the Υ(1S) $Q_{\rm pPb}$
- The results obtained at $\sqrt{s_{\rm NN}} = 8.16$ TeV are compatible with those measured by ALICE in p–Pb collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV during LHC Run I
- Models based on nuclear shadowing and coherent parton energy loss fairly describe the data at forward rapidity, while they tend to overestimate the $R_{\rm pPb}$ at backward rapidity [2,3]
- Υ(2S) $R_{\rm pPb}$ shows a similar suppression in the two investigated rapidity ranges. The results for the two resonances are compatible within one sigma

ALICE Public Note: Inclusive Υ production in p–Pb collisions at $\sqrt{s_{\rm NN}} = 8.16$ TeV [ALICE-PUBLIC-2018-008] **NEW**

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