Charmonium production in p-Pb collisions at $\sqrt{s_{NN}}$ =8.16 TeV with the ALICE Muon Spectrometer

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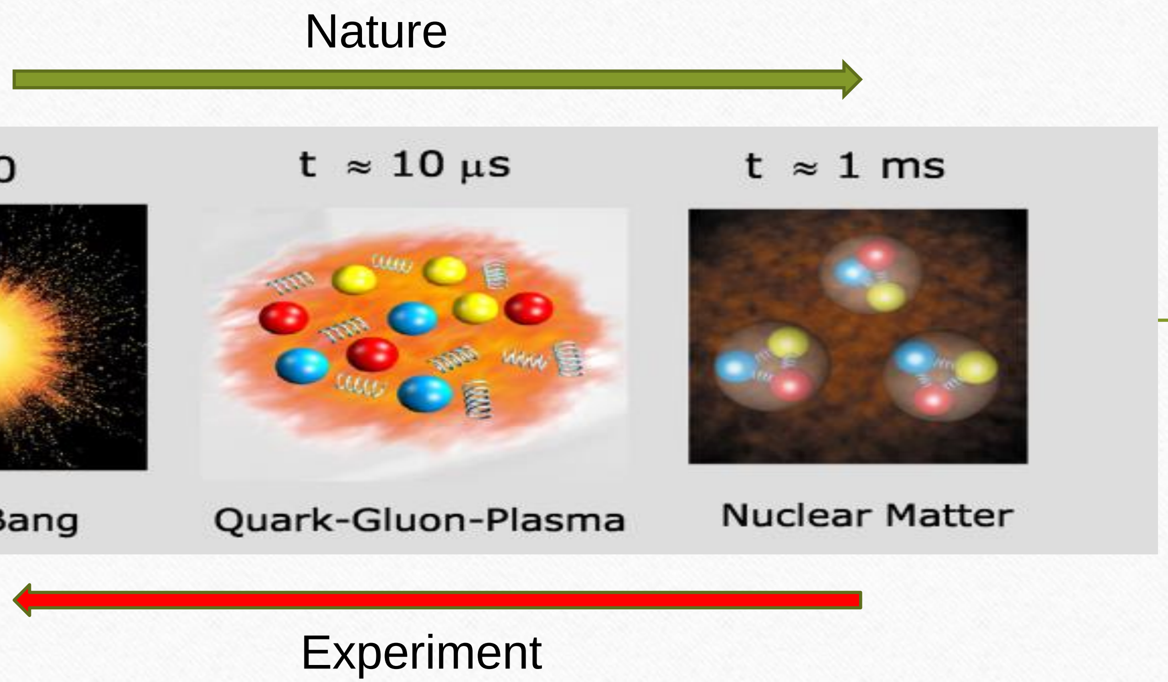
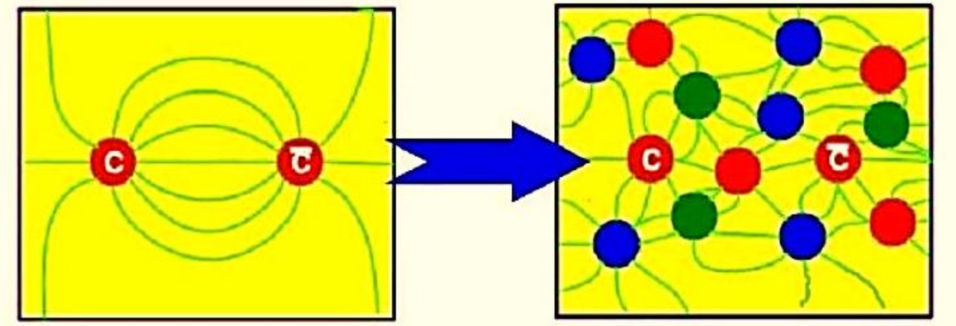
3rd Heavy Flavour Meet 2019

Goal of heavy-ion collisions ?



At high energy density (> 1 GeV/fm^3) hadronic matter undergoes a phase transition from confined state to a deconfined state of quarks and gluons, called Quark-Gluon Plasma (QGP).

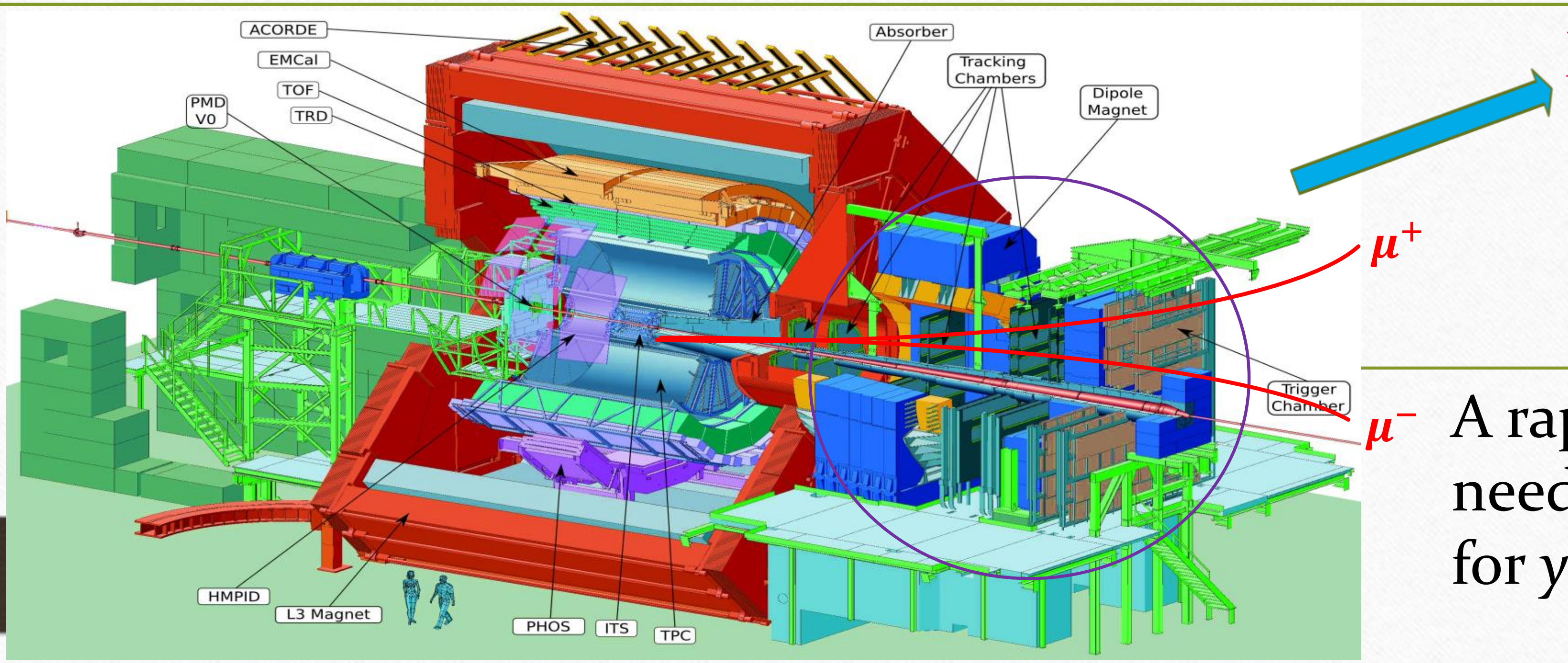
Why do we study p-Pb collisions ?



Charmonium is a bound state of charm (c) and anti-charm ($\bar{c}$) quarks.
Colour screening of binding potential prevents charmonium formation in QGP.
Cold Nuclear Matter (CNM) effects like energy loss, shadowing or anti-shadowing (modification of the Parton Distribution Function) and comovers absorption modify the charmonium yields in p-Pb collisions, where no QGP is expected. In addition to those effects, there are regeneration or recombination of charmonium which can enhance charmonium yield.

- The precise assessment of the mechanisms which affect charmonium yield in p-Pb collisions is important to correctly disentangle the QGP effects in Pb-Pb collisions.

The ALICE detectors



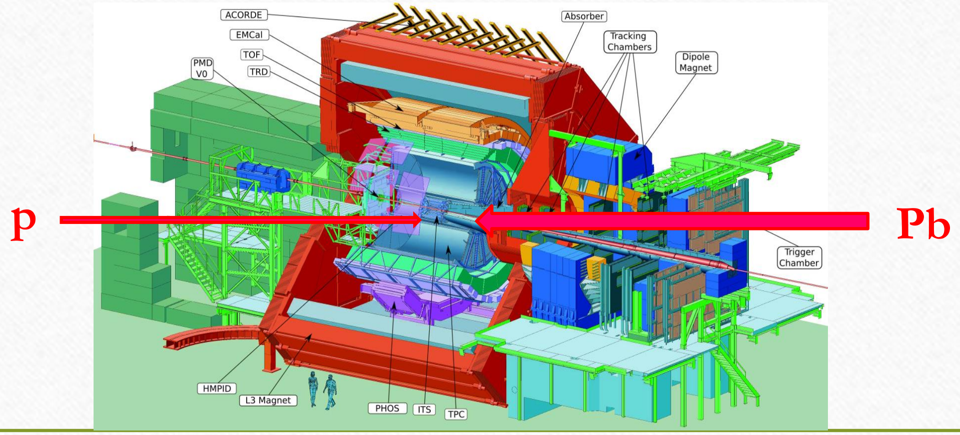
Muon Spectrometer

$J/\psi \rightarrow \mu^+\mu^-$

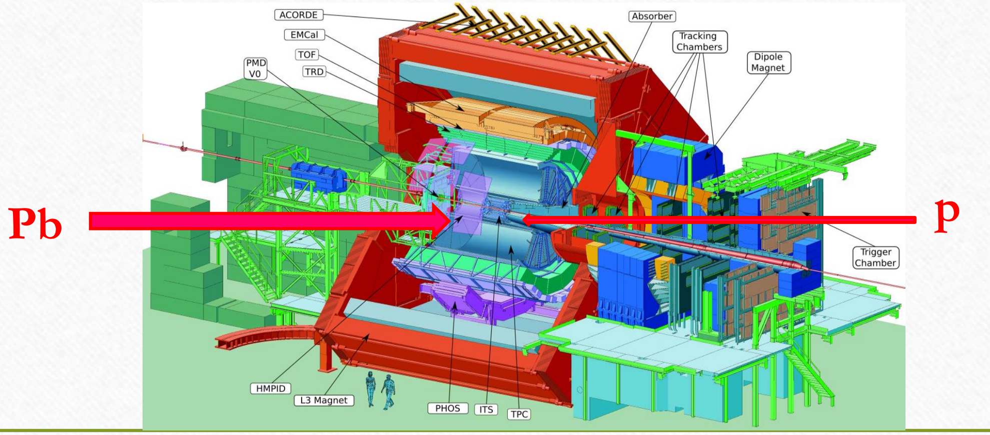
$-4 < \eta <$-2.5

A rapidity shift of 0.465 needs to be accounted for $y_{lab} \longrightarrow y_{cms}$ conversion

p-Pb $(2.03 < y_{cms} < 3.53)$



Pb-p $(-4.46 < y_{cms} <$ -2.96)

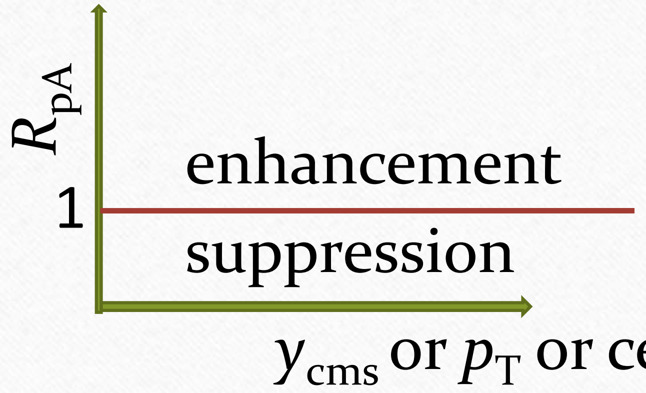


Observable

Nuclear modification factor : $$R^{J/\psi}_{pPb} = \frac{N^{corr}_{J/\psi}}{< T_{pPb} > N_{MB}.BR.\sigma^{pp}_{J/\psi}}$$

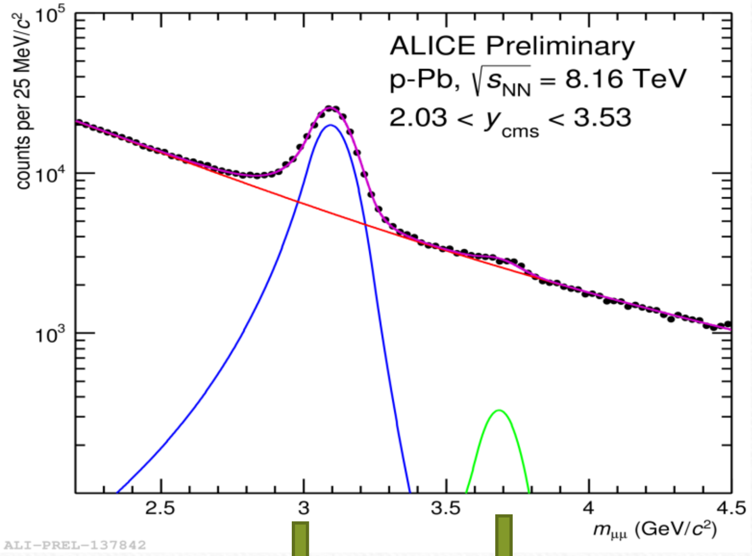
$N^{corr}_{J/\psi}$ is $N_{J/\psi}/A\times\varepsilon$, N_{MB} is the number of minimum bias events, T_{pPb} is the thickness function and $<T_{pPb}> = <N_{coll}>/\sigma^{pp\_inel}$

Centrality definition in p-A collisions: centrality selection is based on the energy measured with the ZDC (Zero Degree Calorimeter) in the Pb-going direction, deposited by the nucleons produced in the collision. The average number of binary nucleon collisions ($<N_{coll}>$) in a given centrality range is estimated using a Glauber model of the collisions.



No change with respect to the pp collisions scaled by nuclear thickness function

Ingredients of data analysis

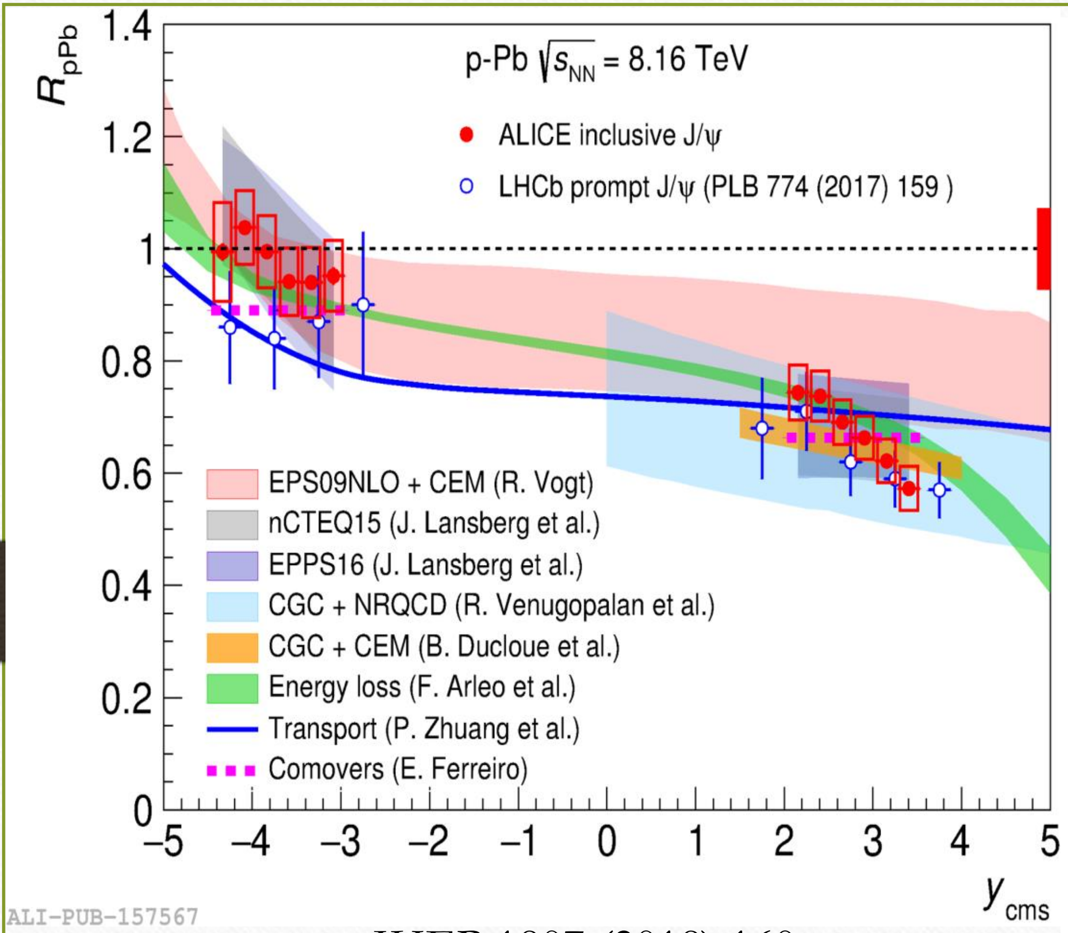


$\boldsymbol{N}_{J/\psi}$ and $\boldsymbol{N}_{\psi(2S)}$ are obtained from the invariant mass spectra

The $\boldsymbol{N}_{J/\psi}$ and $\boldsymbol{N}_{\psi(2S)}$ are then corrected by **Axε** of the detector.
To calculate the **Axε** a realistic MC is done using as input shapes of p_T and rapidity distributions tuned on data.

pp reference is obtained from the study of J/ψ and ψ(2S) cross sections in pp collisions at the same energy.

J/ψ R_{pPb} vs rapidity



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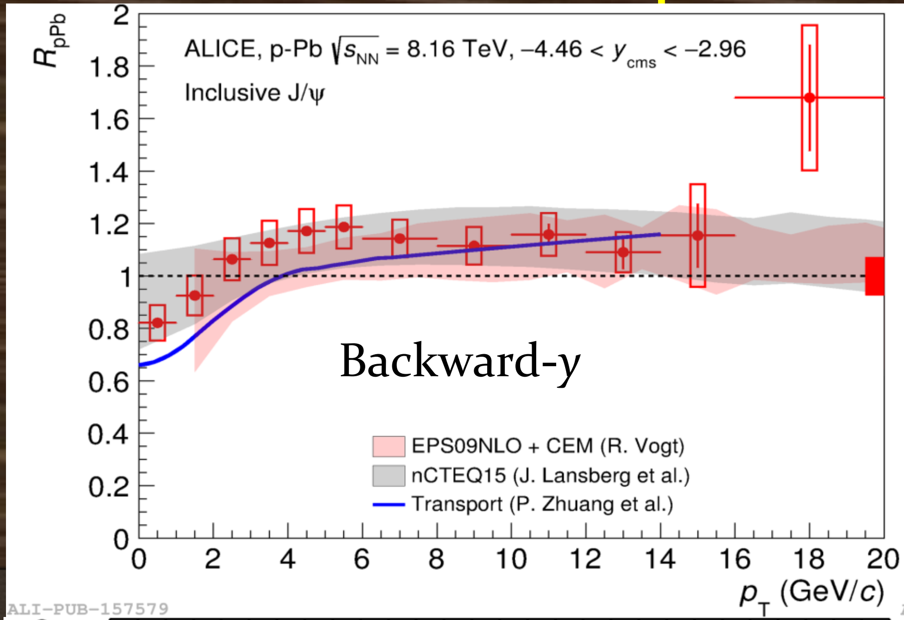
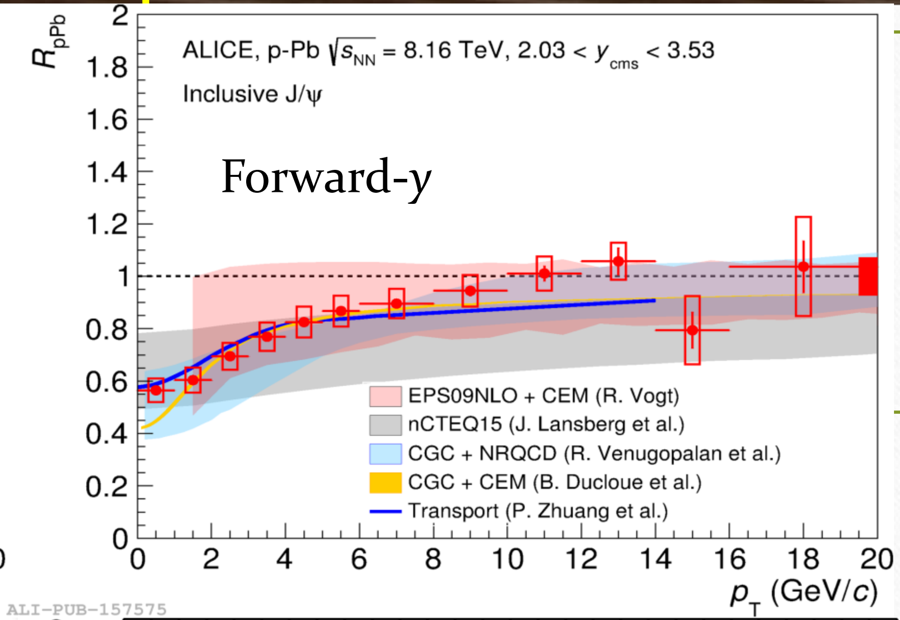
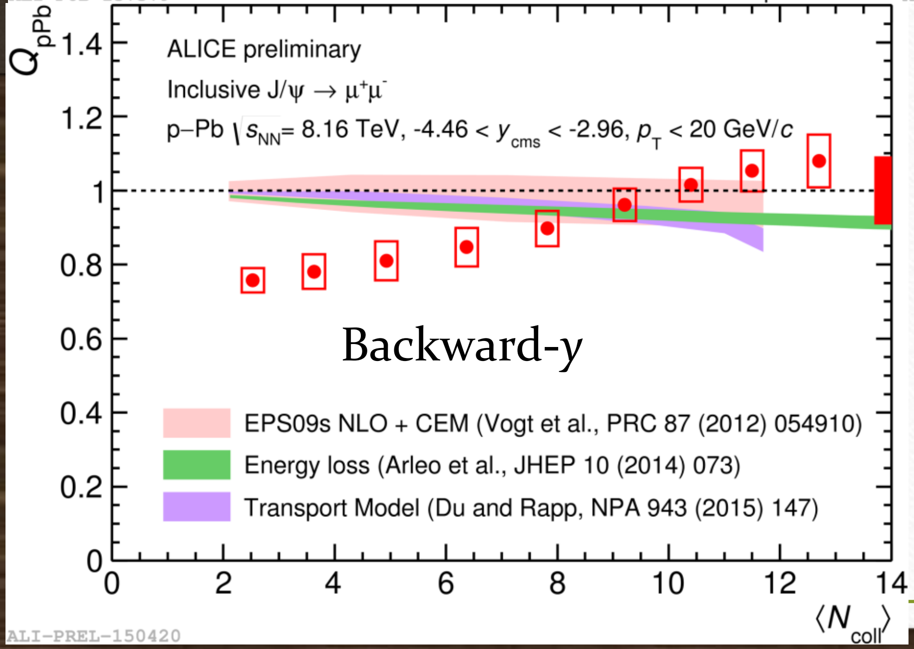
- Stronger suppression is observed at forward rapidity, while R_{pPb} is compatible with unity at backward rapidity
- ALICE and LHCb results are in agreement at the same energy
- Models based on different shadowing implementations, CGC, energy loss, transport models and comovers well describe the data.

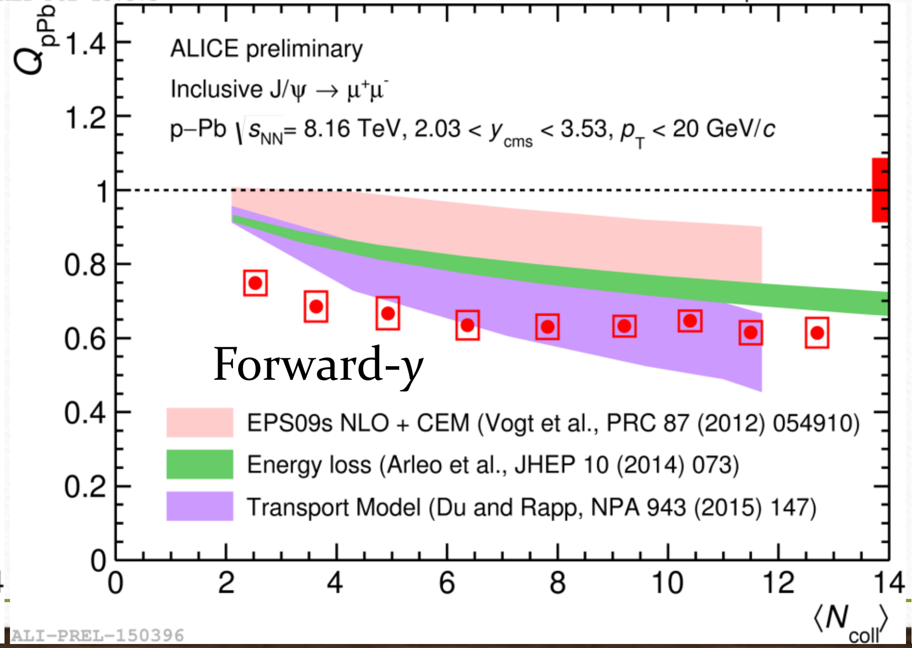
J/ψ R_{pPb} and Q_{pPb} vs p_T and centrality





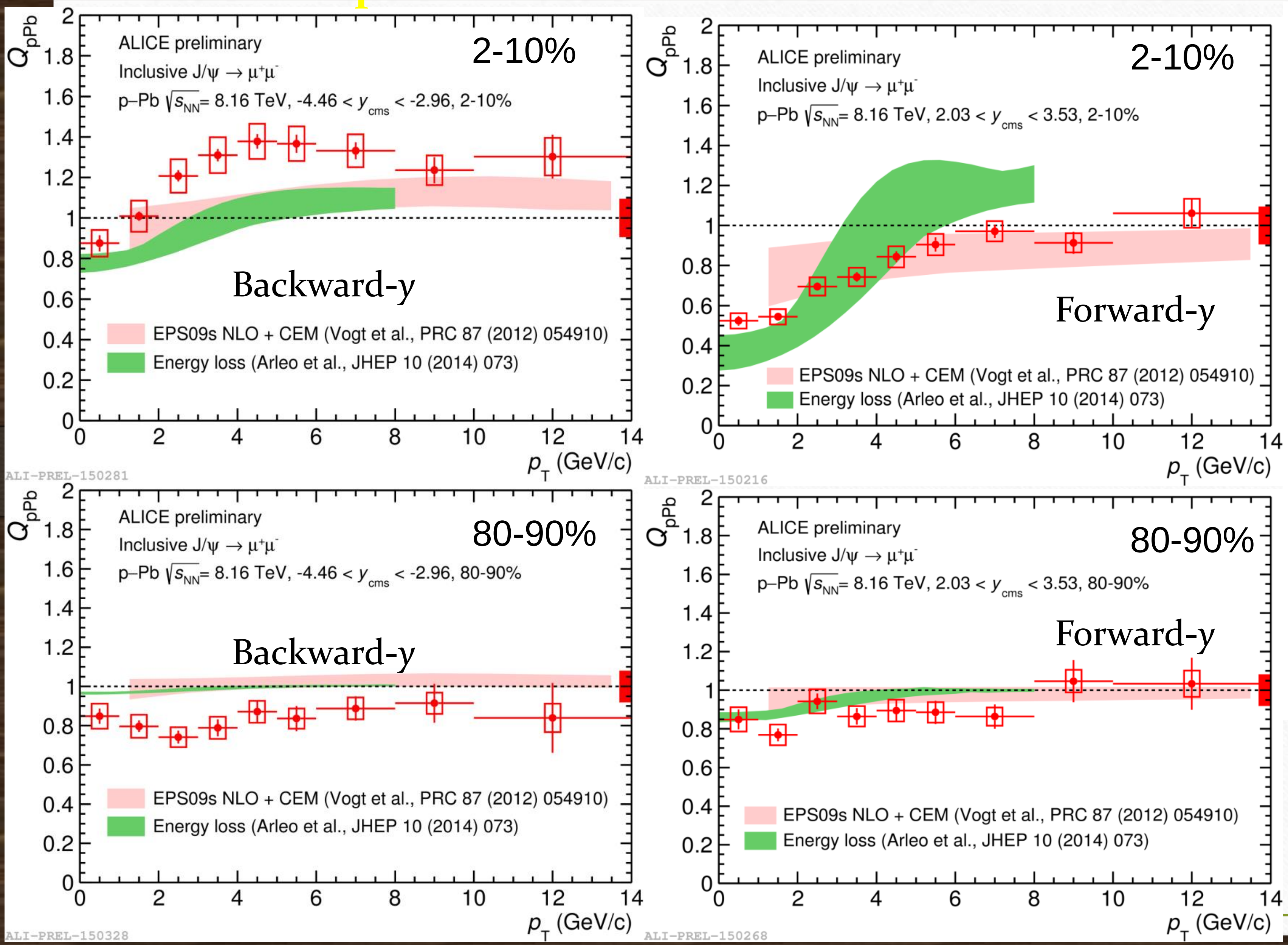
R_{pPb} shows a p_T dependence , with an increase from low to high p_T at both backward and forward rapidity





Q_{pPb} shows an increase from peripheral to central collisions at backward rapidity, whereas no strong centrality dependence is observed at forward rapidity.

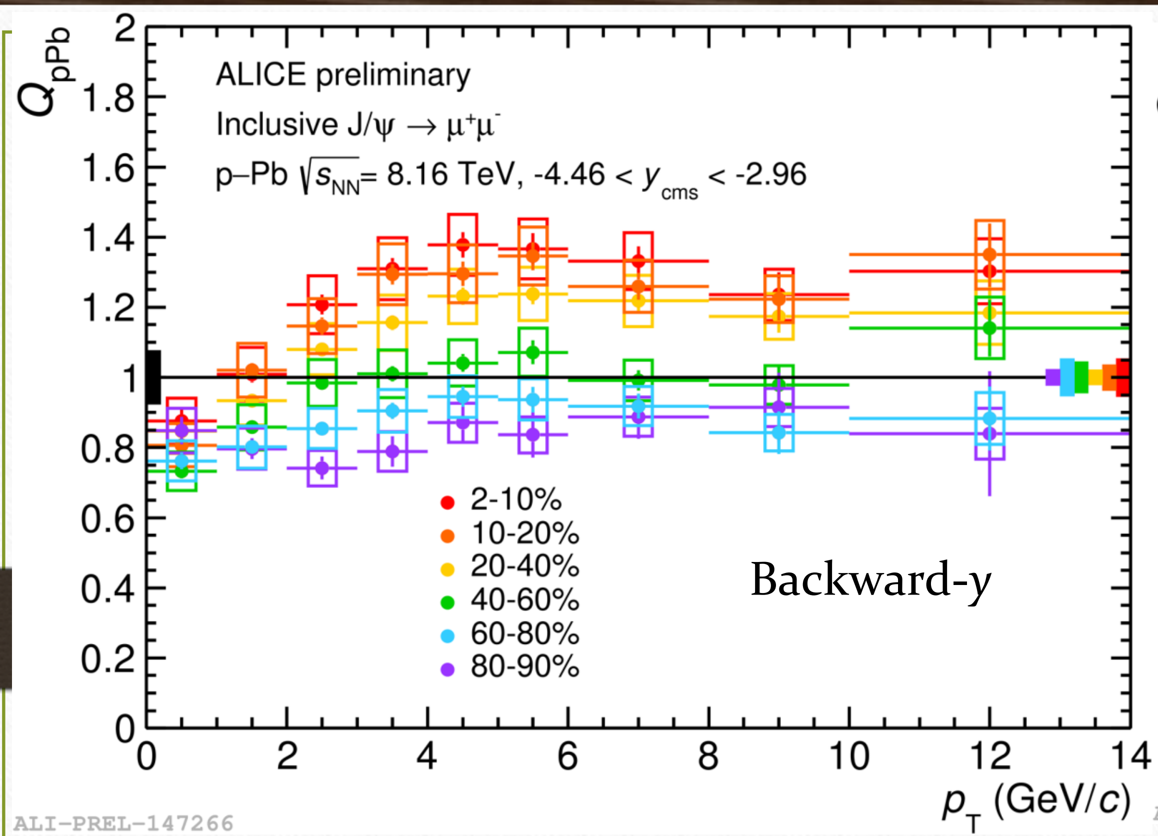
J/ψ Q_{pPb} vs p_T in central and peripheral collisions

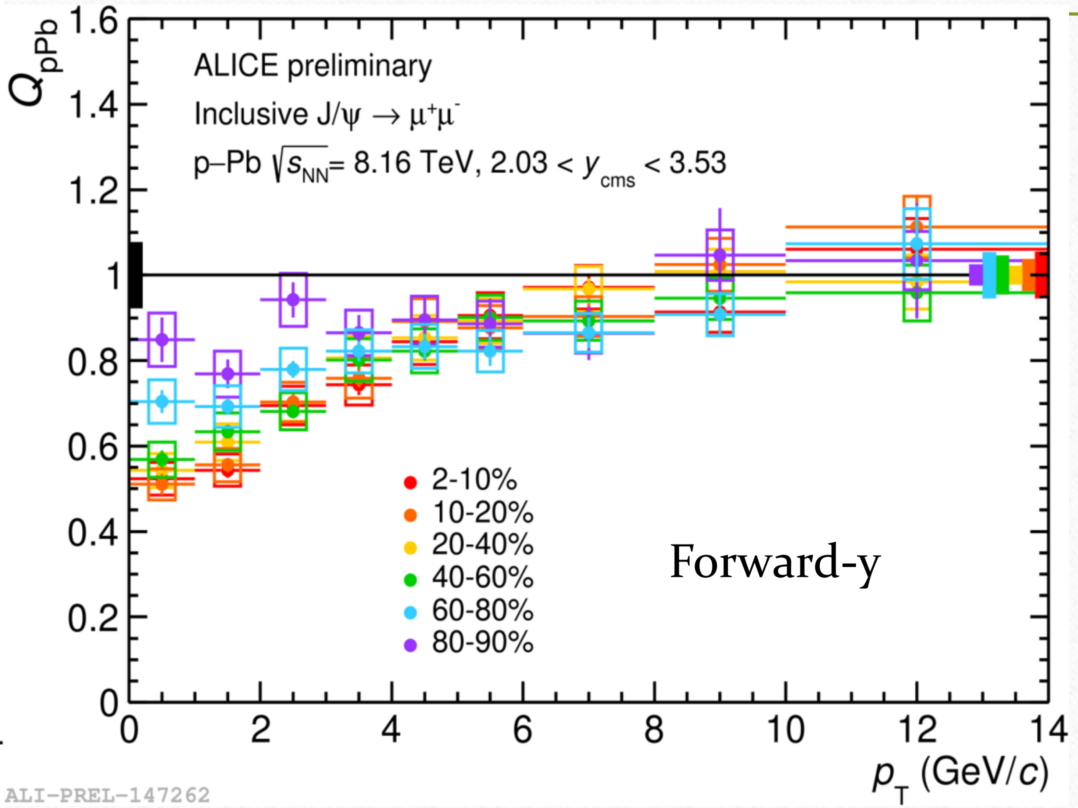


In central collisions, shadowing predicts a weaker p_T dependence w.r.t. the data whereas energy loss predicts a faster increase of Q_{pPb}.

In peripheral collisions, theoretical models show no p_T dependence, consistent with the Q_{pPb} measurement

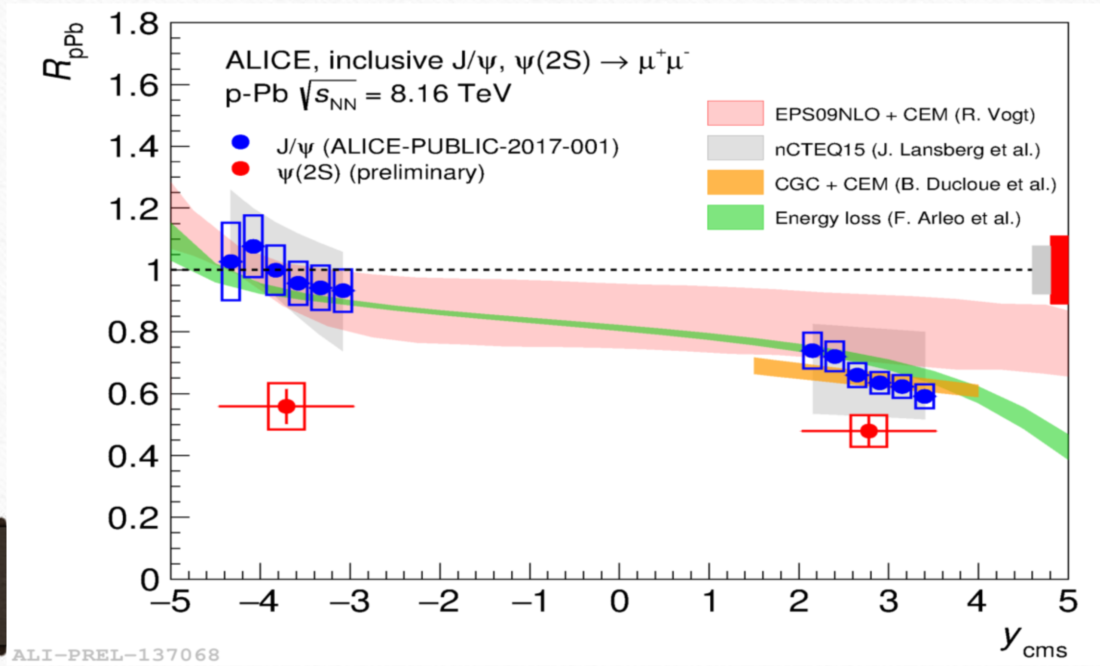
Multi-differential study of J/ψ

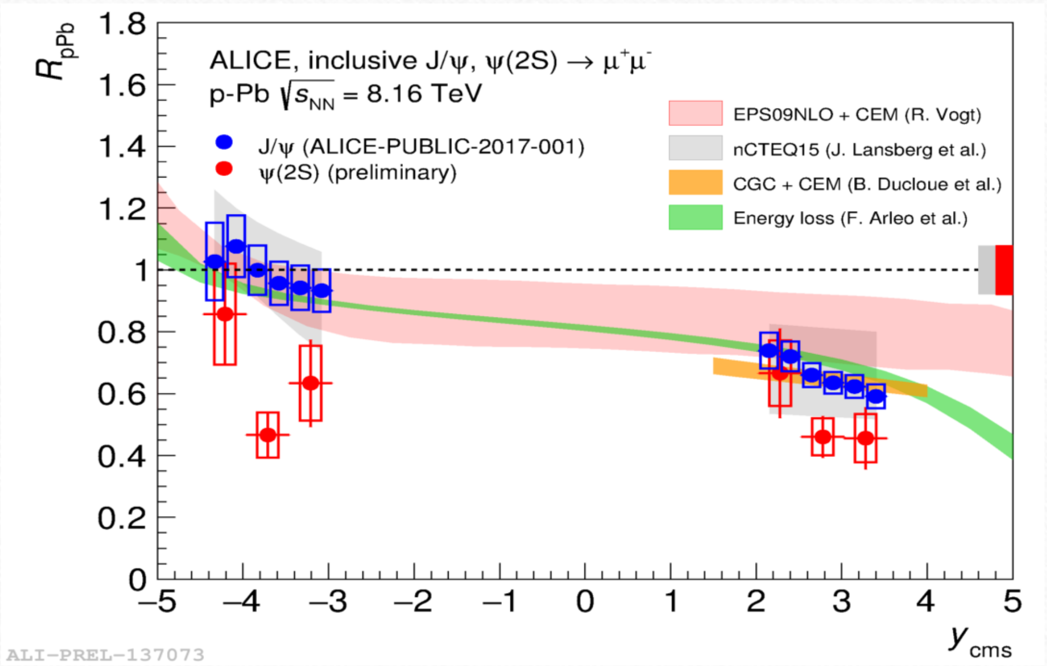




- ❑ Clear evolution of Q_{pPb} vs p_T in different centrality intervals
- ❑ At backward rapidity, enhancement in most central collisions for $p_T > 3$ GeV/c
- ❑ At forward rapidity, stronger suppression at low p_T in most central collisions and Q_{pPb} is compatible with unity for $p_T > 7$ GeV/c within uncertainties for all centrality intervals.

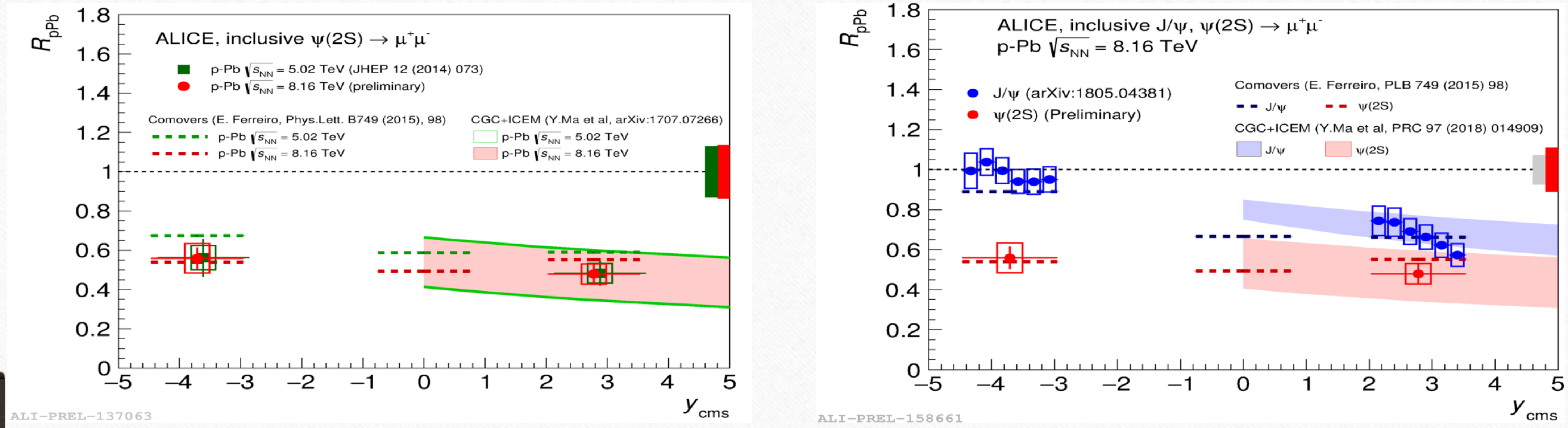
R_{pPb} of ψ(2S) vs *y* compared to J/ψ and CNM models





- Comparison of ψ(2S) and J/ψ results with shadowing and energy loss models
- Calculations tuned on J/ψ, but the effects included in the models are largely independent on the specific resonance, so the same behaviour is expected for ψ(2S)
- Shadowing and energy loss effects are not enough to explain ψ(2S) suppression, especially at backward rapidity

R_{pPb} of ψ(2S) vs y compared to final-state effects models

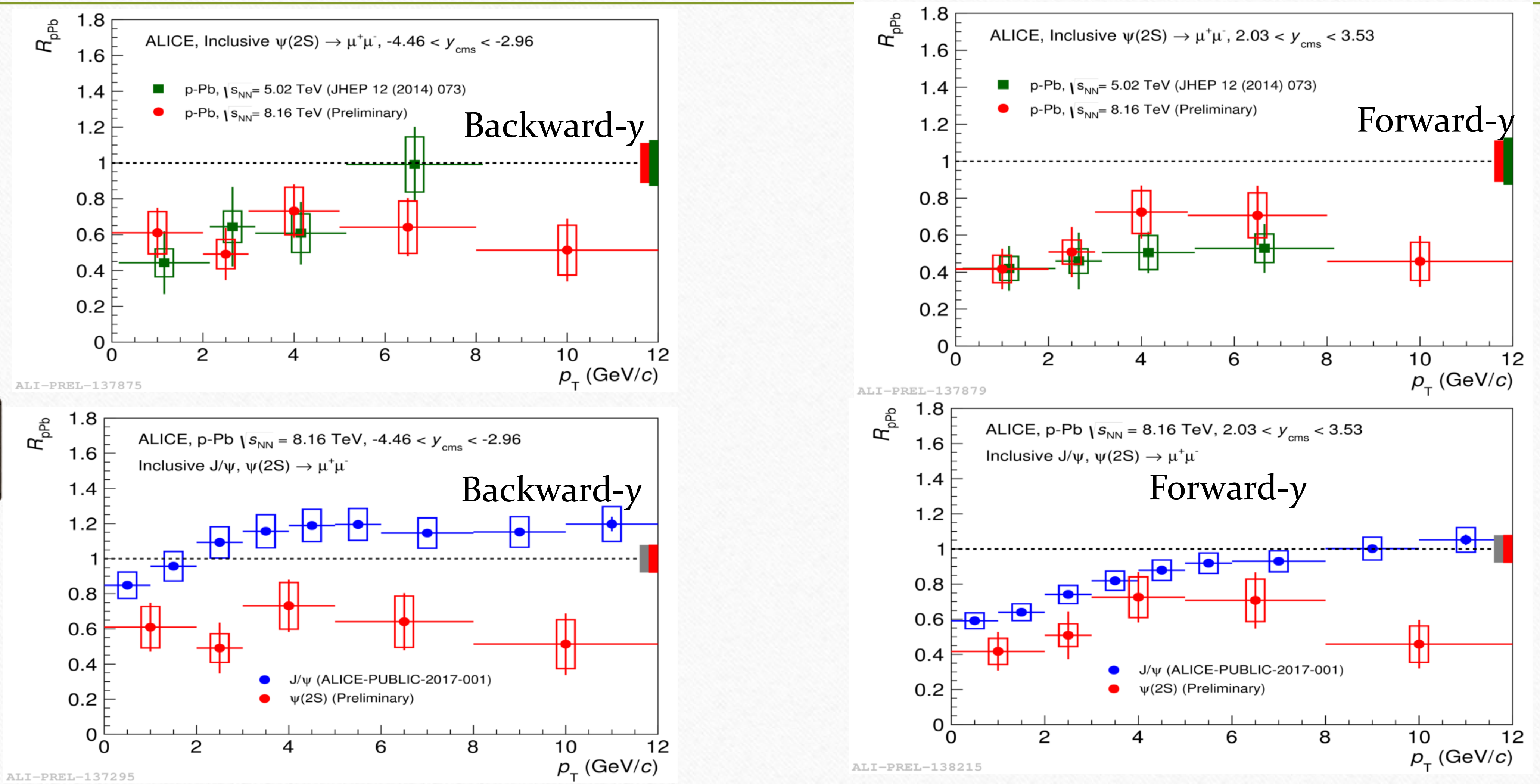


Two models compared to data :

1. "CGC + ICEM, Y. Ma et al." : soft color exchanges between $c\bar{c}$ hadronizing pair and comoving partons
2. "COMOVERS, E. Ferreiro" : final-state interactions with the comoving medium

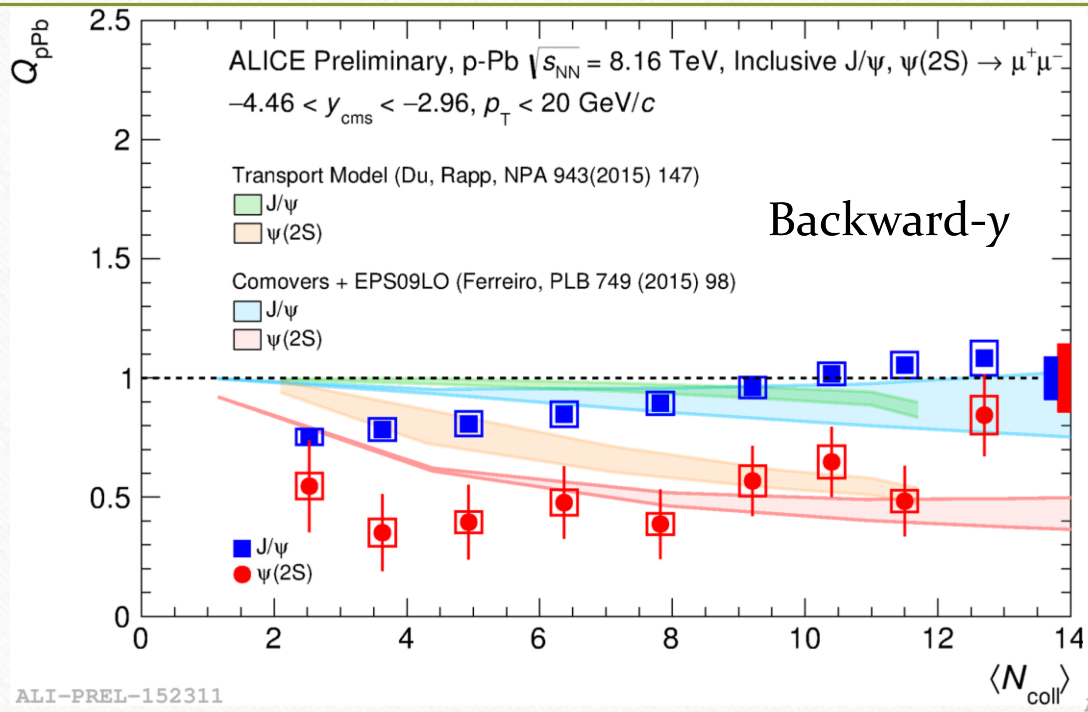
Models including final-state effects, together reproduce the ψ(2S) behaviour at backward and forward rapidities at both $\sqrt{s_{NN}} = 5.02$ and 8.16 TeV.

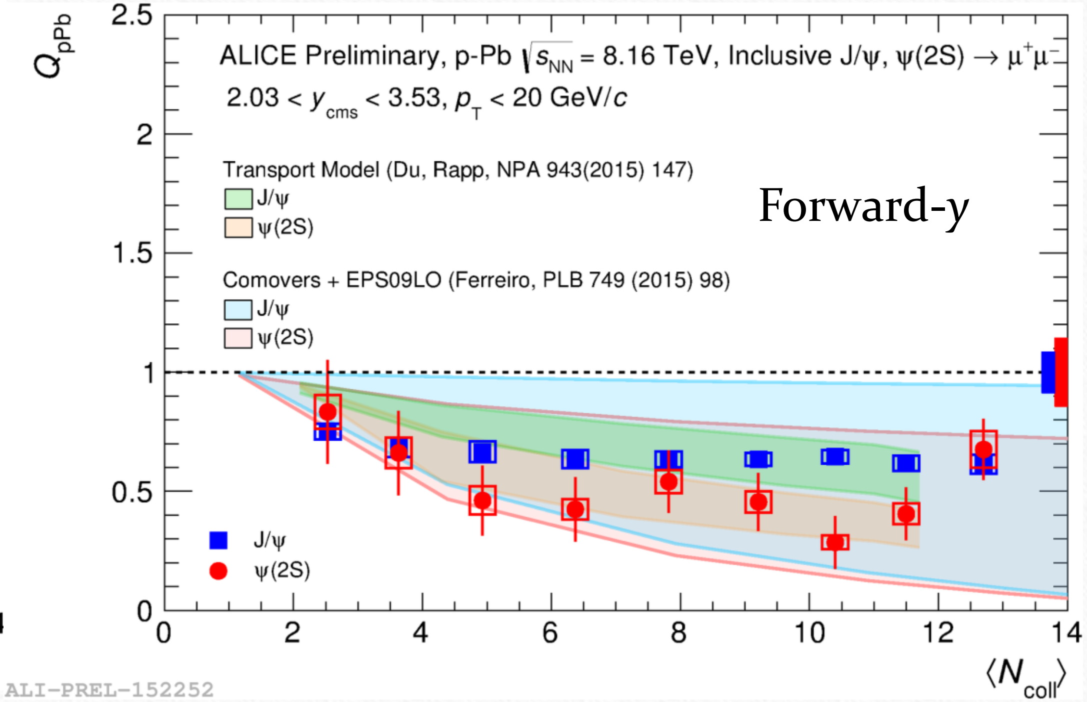
R_{pPb} of ψ(2S) vs. p_{T}



- ✓ No significant energy and p_{T} dependence is observed
- ✓ Stronger suppression of ψ(2S) visible over the full p_{T} range

R_{pPb} of ψ(2S) vs. centrality





The $\psi(2S)$ suppression is found to follow the same trend as in case of the J/ψ at forward rapidity.

At backward rapidity, stronger $\psi(2S)$ suppression compared to the J/ψ, is also visible as a function of centrality

Summary

- J/ψ
  - J/ψ shows a stronger suppression at forward rapidity than at backward rapidity, where R_{pPb} is compatible with unity.
  - At backward rapidity, high p_{T} J/ψ are enhanced for more central collisions, whereas at forward rapidity, low p_{T} J/ψ gets more suppressed for more central collisions.
  - Theoretical models qualitatively describe the J/ψ data.

- ψ(2S)
  - ψ(2S) shows a stronger suppression than J/ψ especially at backward rapidity.
  - Models including final-state effects needed to explain the ψ(2S) behaviour at backward rapidity.
  - R_{pPb} of ψ(2S) is found to be independent of energy for p-Pb collisions at $\sqrt{s_{NN}}$= 5.02 TeV and $\sqrt{s_{NN}}$ = 8.16 TeV.


THANK YOU