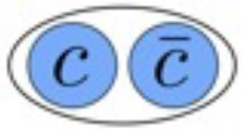
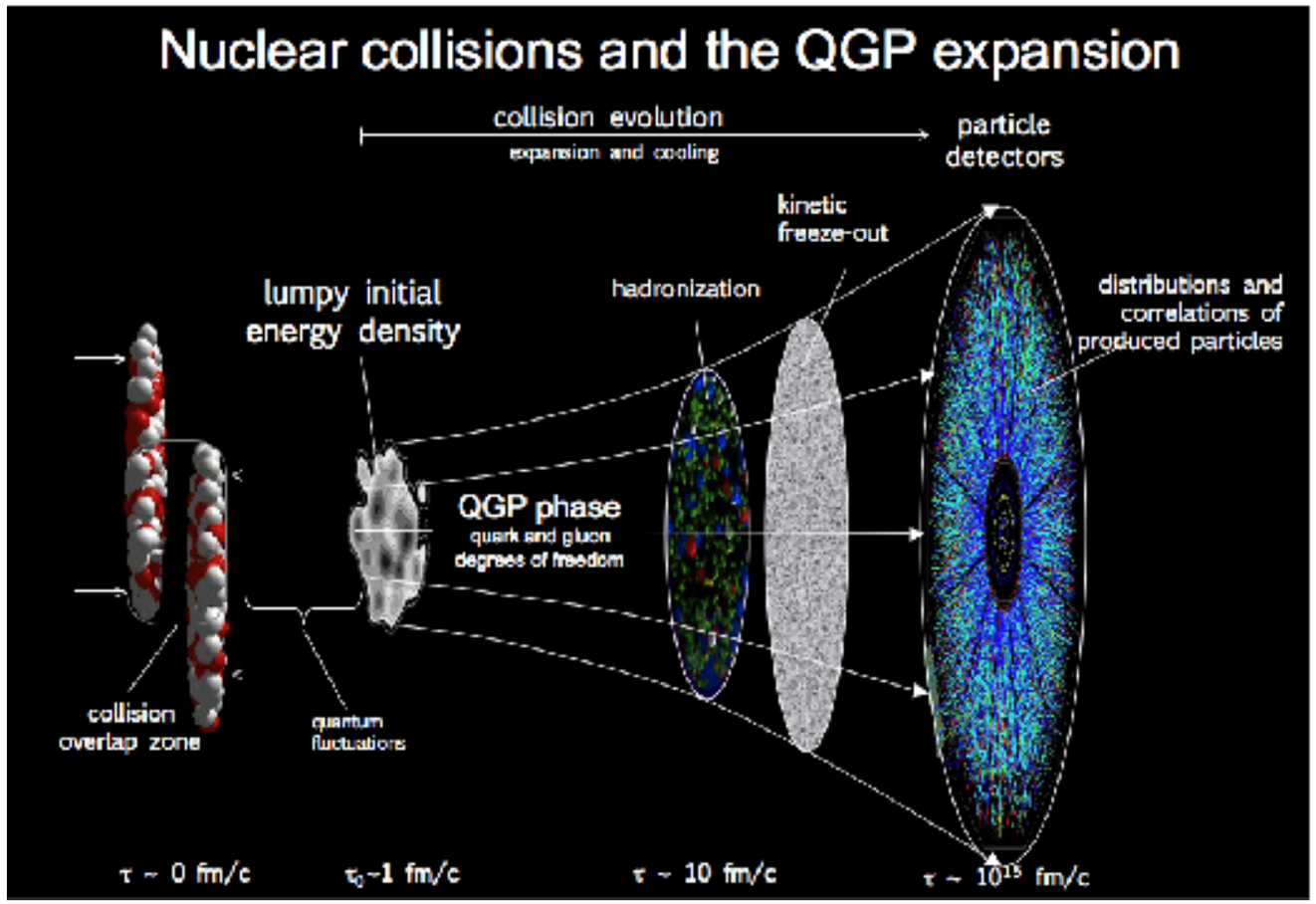
Charmonium measurement in pp, pPb and PbPb collisions at 5.02 TeV with CMS

JaeBeom Park, Korea University
on behalf of the CMS Collaboration

Motivation

- **Charmonia : Bound states of one charm quark and its anti quark**
  - One of the most important probes in heavy ion collisions
  - Produced by hard scattering at the early stage in the collision





$\tau_{formation}(c\bar{c}) \sim 0.08$ fm/c

$\tau_{life}(QGP) \sim 10$ fm/c

$\tau_{life}(charmonia) \sim 2000$ fm/c

$\tau_{formation}^{c\bar{c}} < \tau_{life}^{QGP} < \tau_{life}^{charmonia}$

⟶ experience the whole evolution of QGP medium

Outline

- **J/ψ in pPb at 5 TeV** [arXiv:1702.01462] EPJC accepted last week!
  - $R_{pPb} = \frac{1}{< N_{coll} >} \frac{N_{pPb}}{N_{pp}}$
  - $R_{FB}(y_{CM} > 0) = \frac{N_{pPb}(y_{CM})}{N_{pPb}(-y_{CM})}$
- **ψ(2S) in pPb at 5 TeV** [HIN-16-015]
  - $R_{pPb} = \frac{1}{< N_{coll} >} \frac{N_{pPb}}{N_{pp}}$

Cold Nuclear Matter Effect

- nPDF modification
- Energy loss
- Nuclear absorption

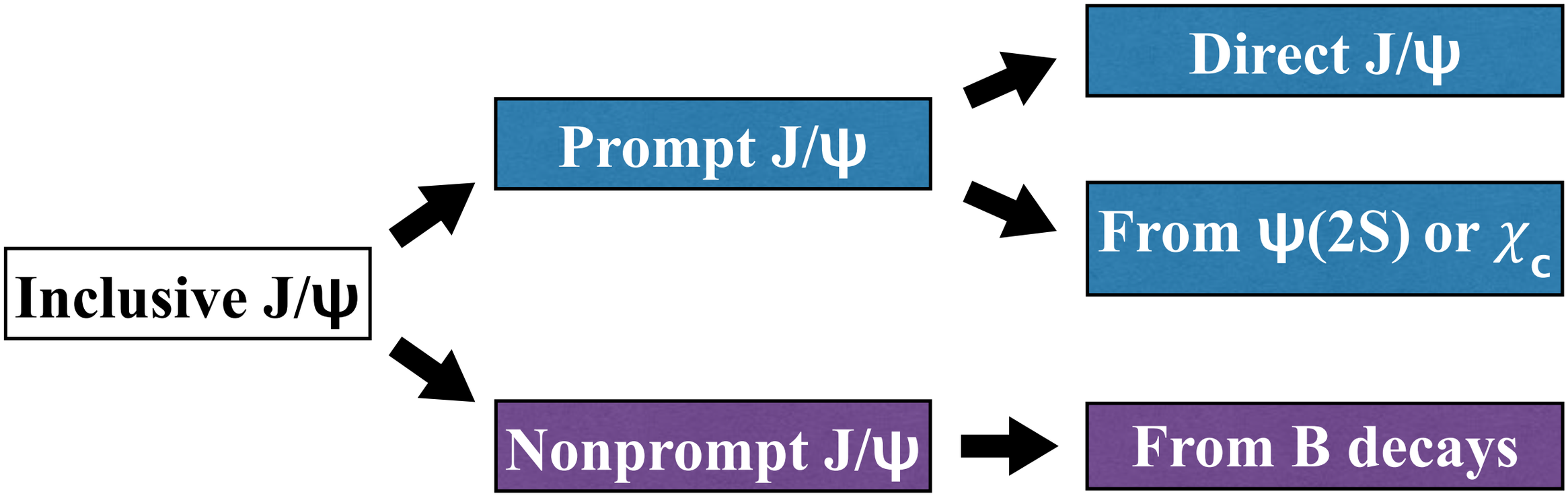
- **J/ψ & ψ(2S) in PbPb at 5 TeV**
  - $DR = \frac{(N_{\psi(2S)}/N_{J/\psi})_{PbPb}}{(N_{\psi(2S)}/N_{J/\psi})_{pp}} = \frac{R_{AA}(\psi(2S))}{R_{AA}(J/\psi)}$

[arXiv:1611.01438]

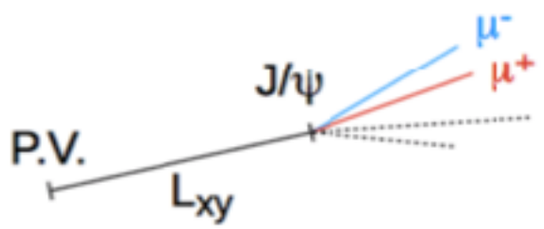
QGP Effect

- Debye Screening
- Regeneration

Prompt & Nonprompt J/ψ

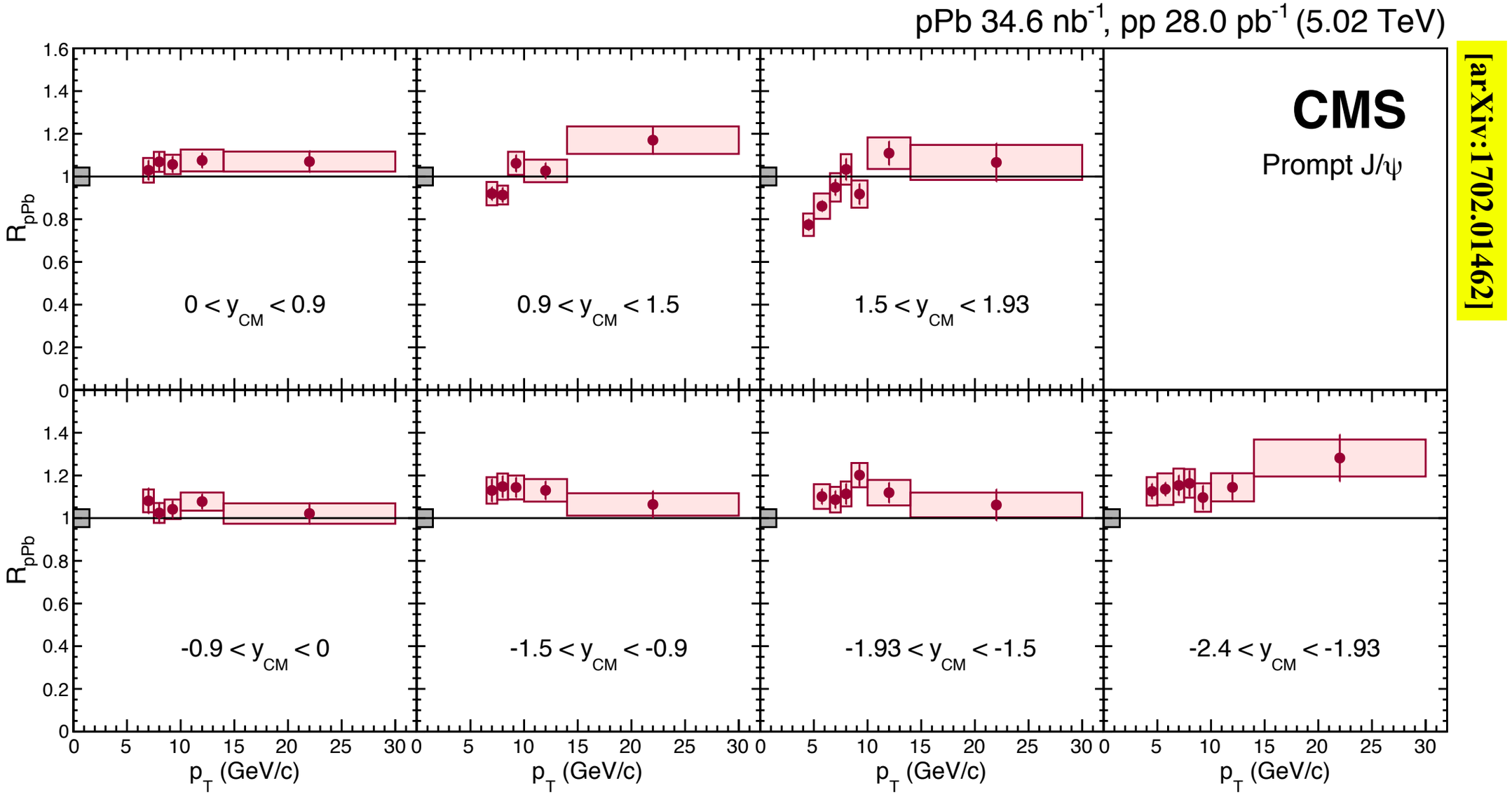


$$l_{J/\psi} = L_{xy} \frac{m_{J/\psi}}{p_T}$$

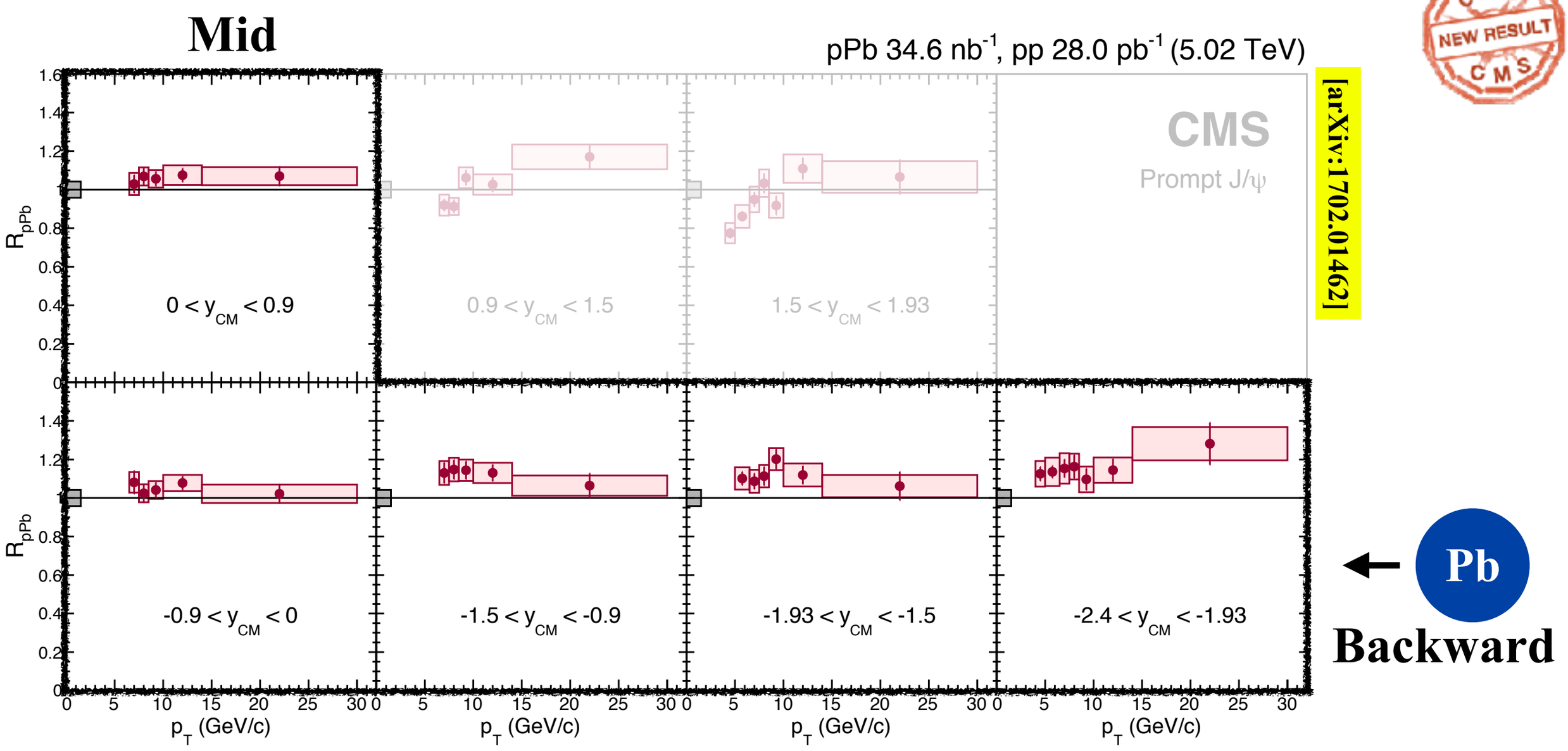


- **Prompt J/ψ : Nuclear effects on quarkonium production**
- **Nonprompt J/ψ : Information on open heavy flavor (b-quark)**

Prompt J/ψ R_{pPb}

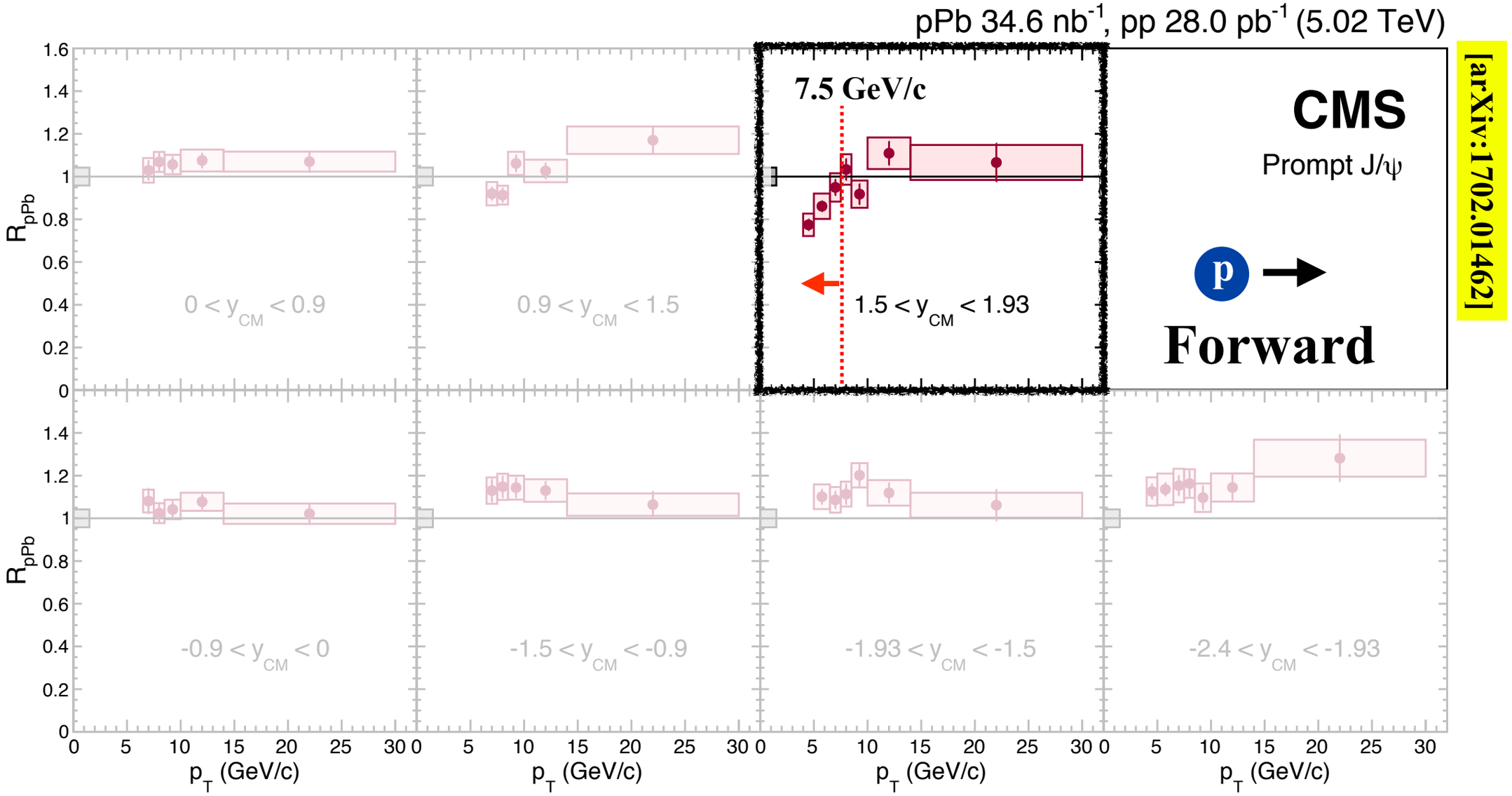


Prompt J/ψ R_{pPb}



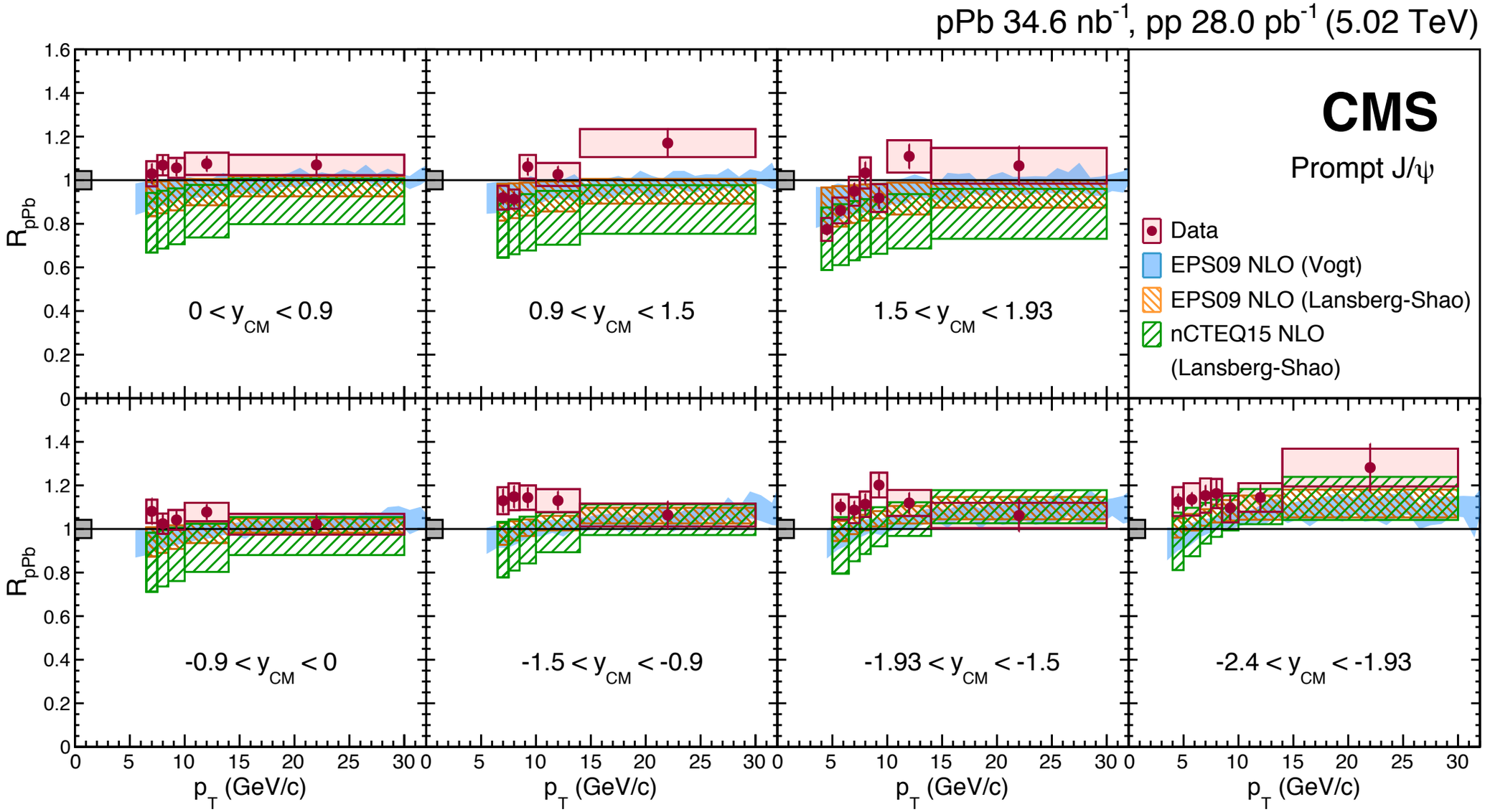
- **Above unity in mid-backward rapidity ($-2.4 < y_{CM} < 0.9$)**

Prompt J/ψ R_{pPb}



- **Above unity in mid-backward rapidity ($-2.4 < y_{CM} < 0.9$)**
- **Possible depletion in forward region $p_T \lesssim 7.5$ GeV/c**

Prompt J/ψ R_{pPb}

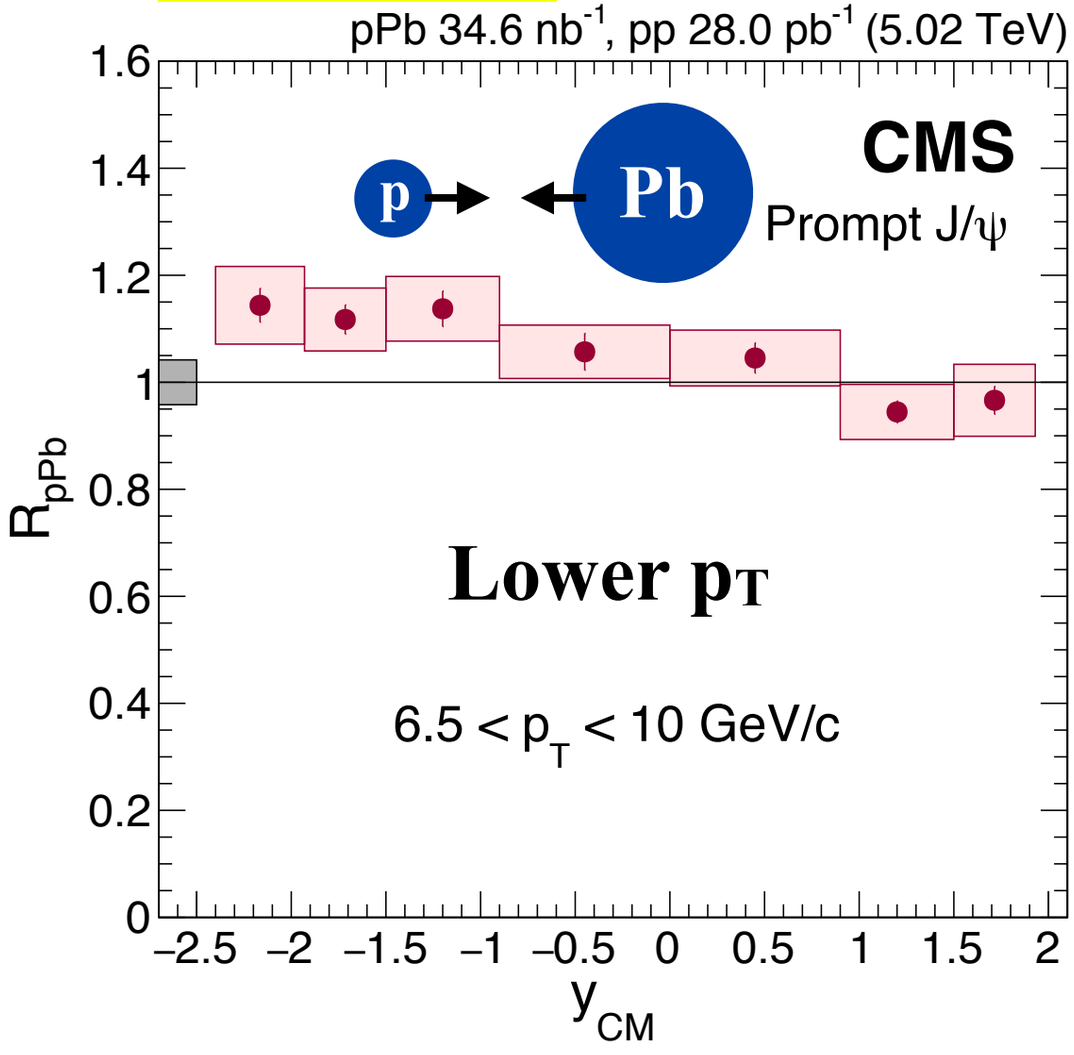


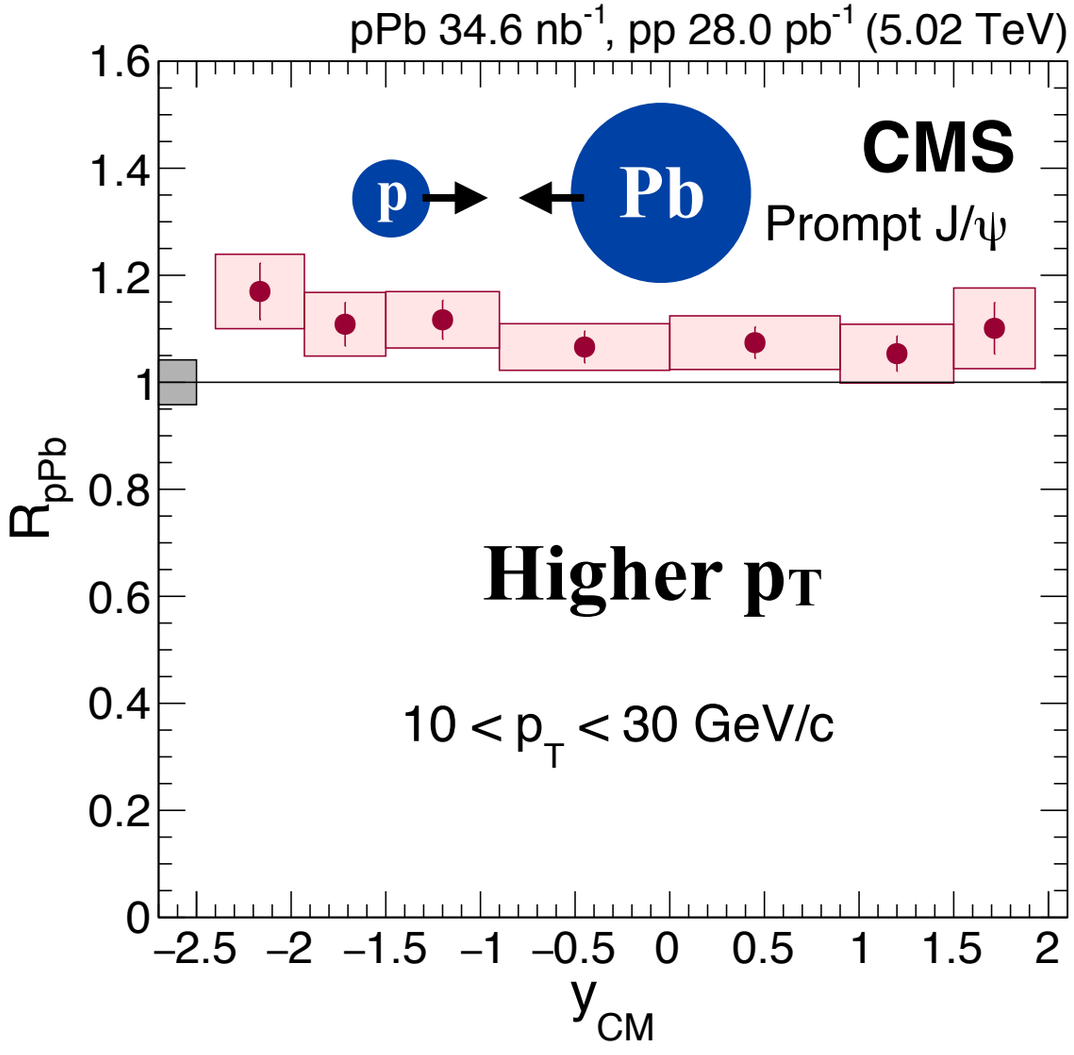
[arXiv:1702.01462]

- **Above unity in mid-backward rapidity ($-2.4 < y_{CM} < 0.9$)**
- **Possible depletion in forward region $p_T \lesssim 7.5$ GeV/c**
- **Shadowing models slightly below data, consistent in low p_T forward region**

Prompt J/ψ R_{pPb}

[arXiv:1702.01462]

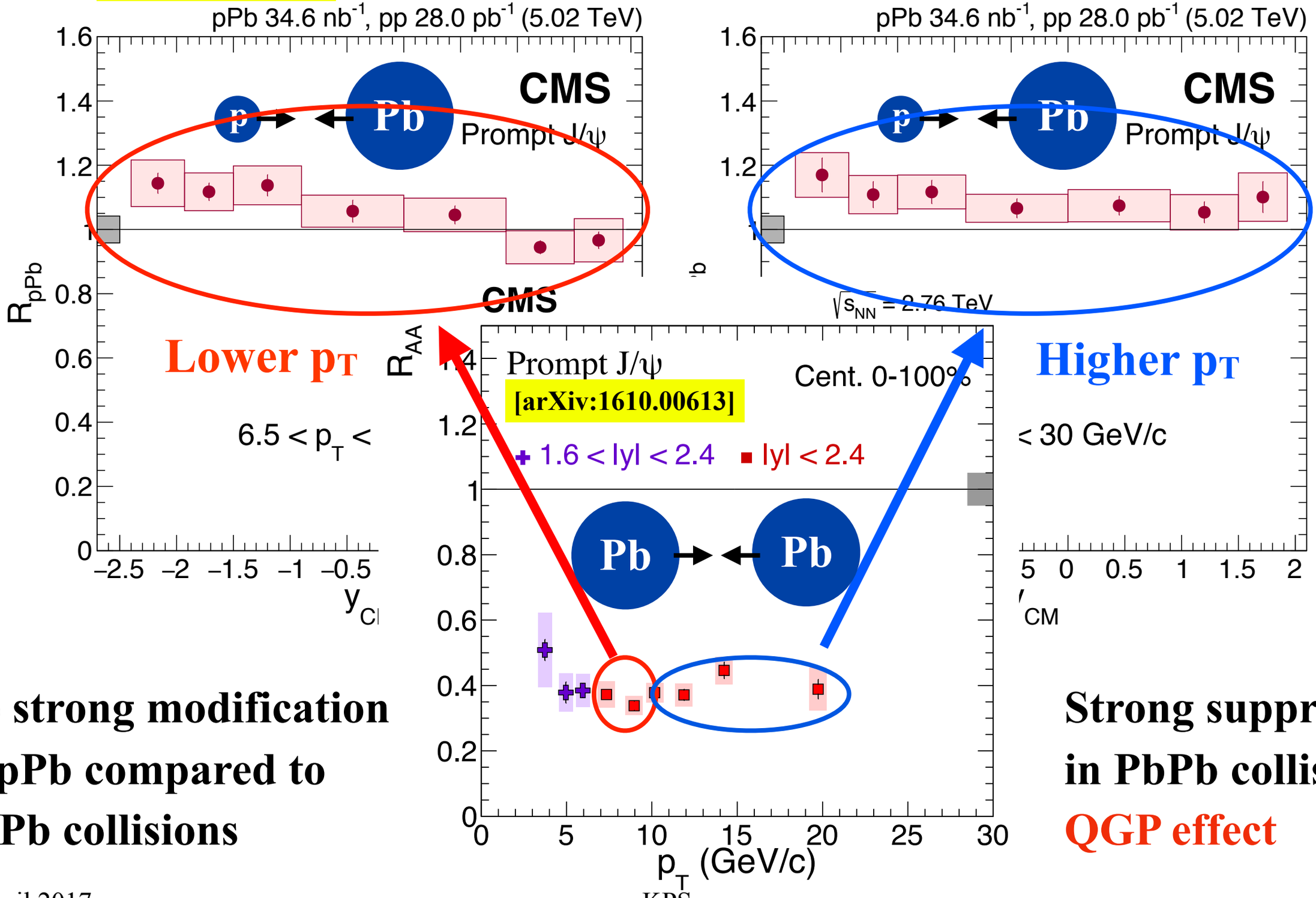




- **Lower p_T : Decrease with increasing y_{CM}**
- **Higher p_T : Above unity over whole rapidity range**

Prompt J/ψ R_{pPb}

[arXiv:1702.01462]

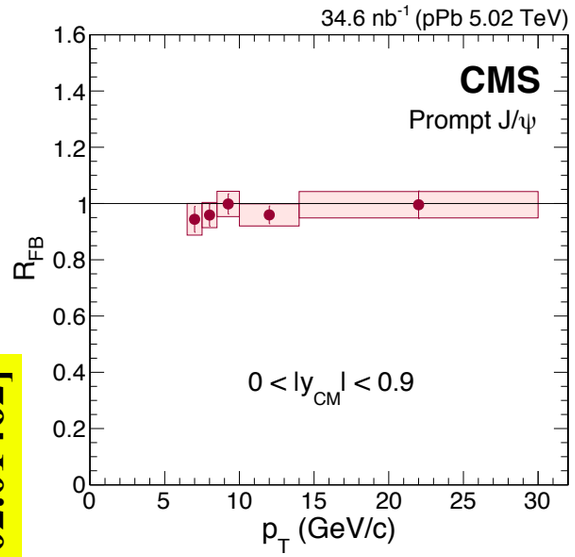


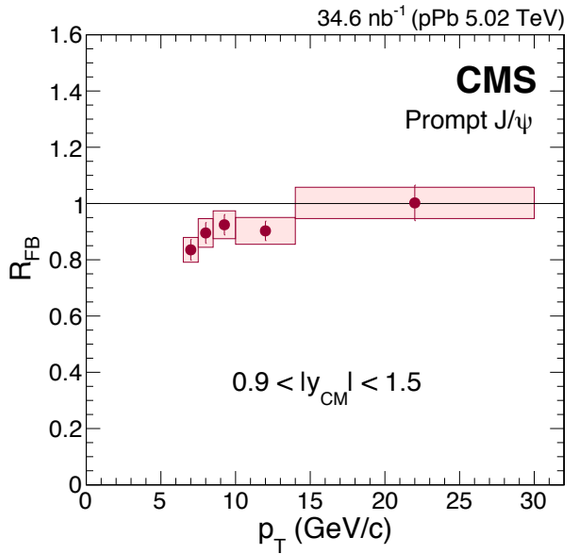
No strong modification in pPb compared to PbPb collisions

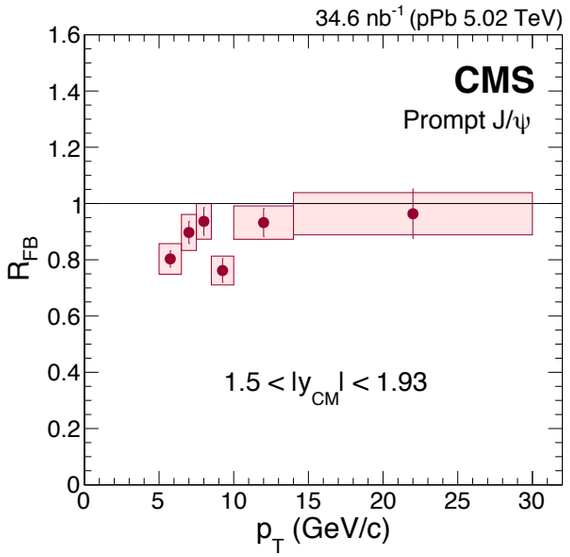
Strong suppression in PbPb collisions : QGP effect

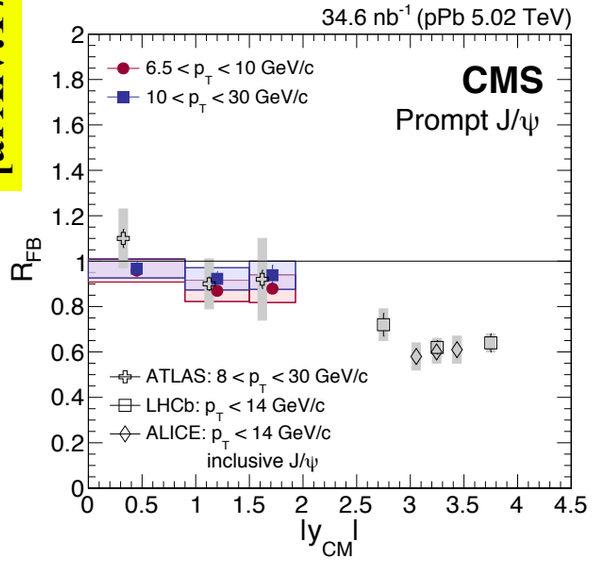
Prompt J/ψ R_{FB}

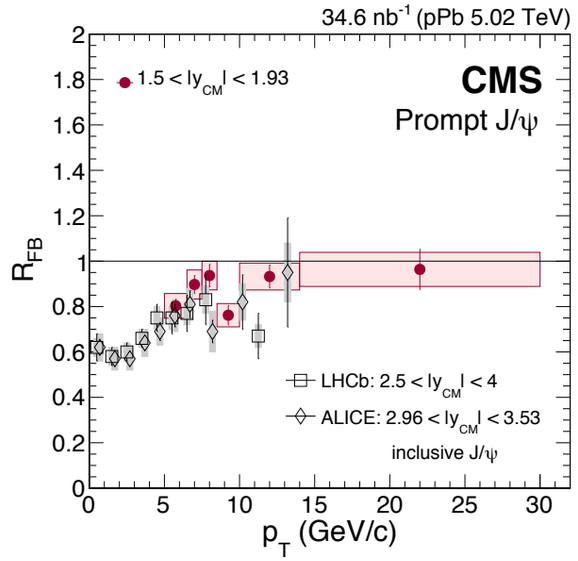
[arXiv:1702.01462]

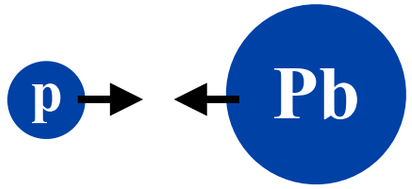






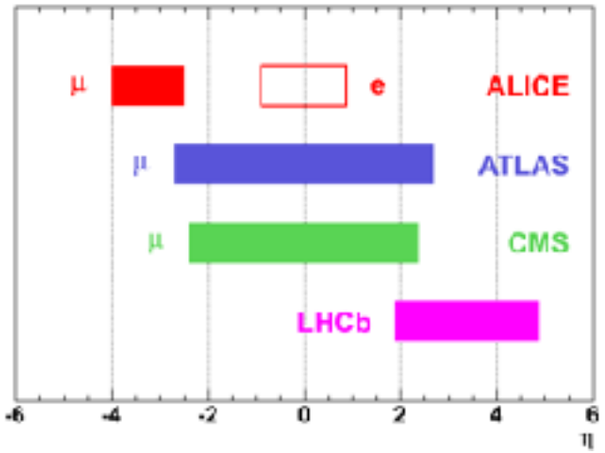






- **No need of pp reference**
- **Different x value of J/ψ in forward & backward**

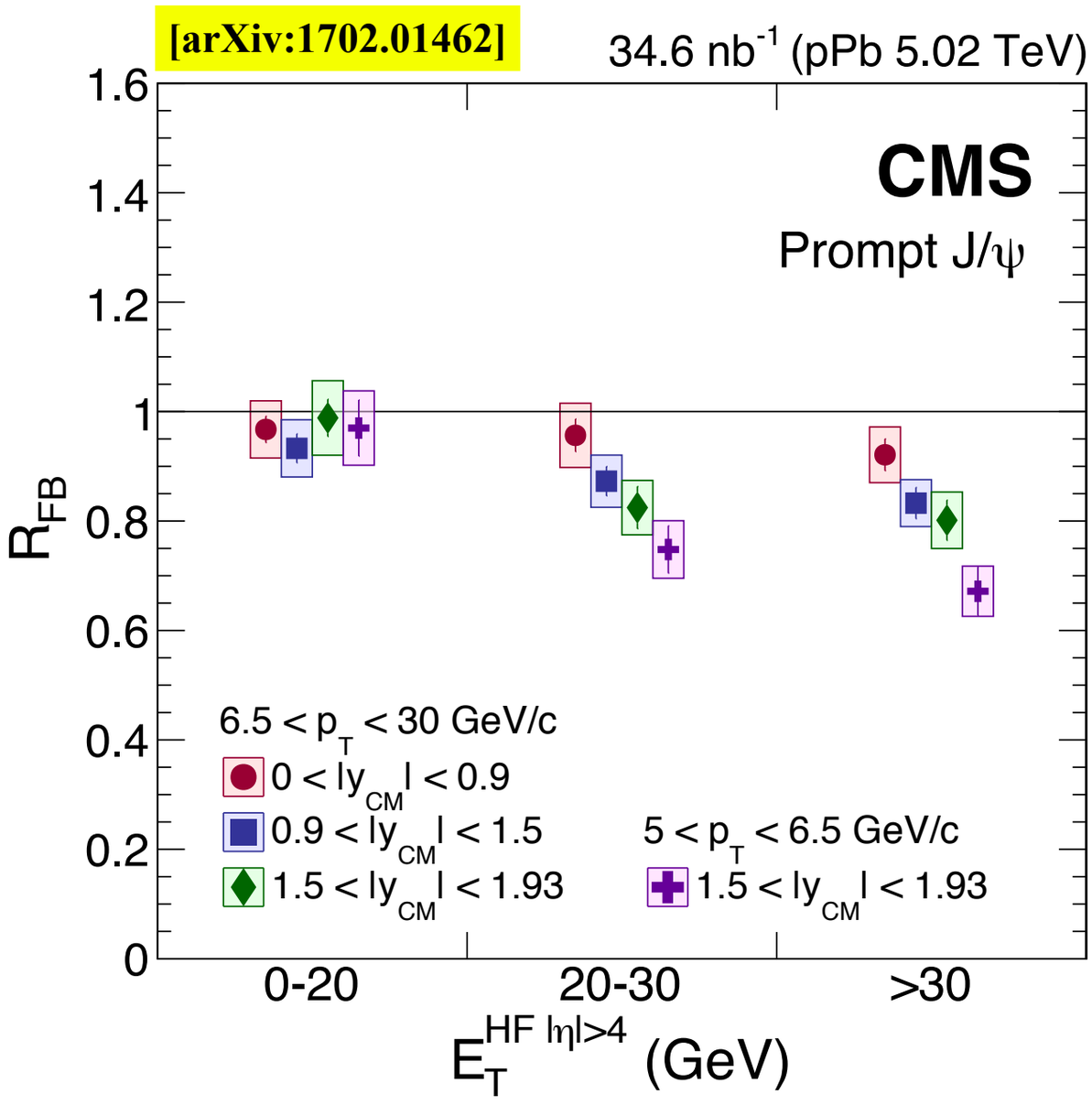
$$R_{FB} = \frac{N^{forward}_{J/\psi}}{N^{backward}_{J/\psi}}$$



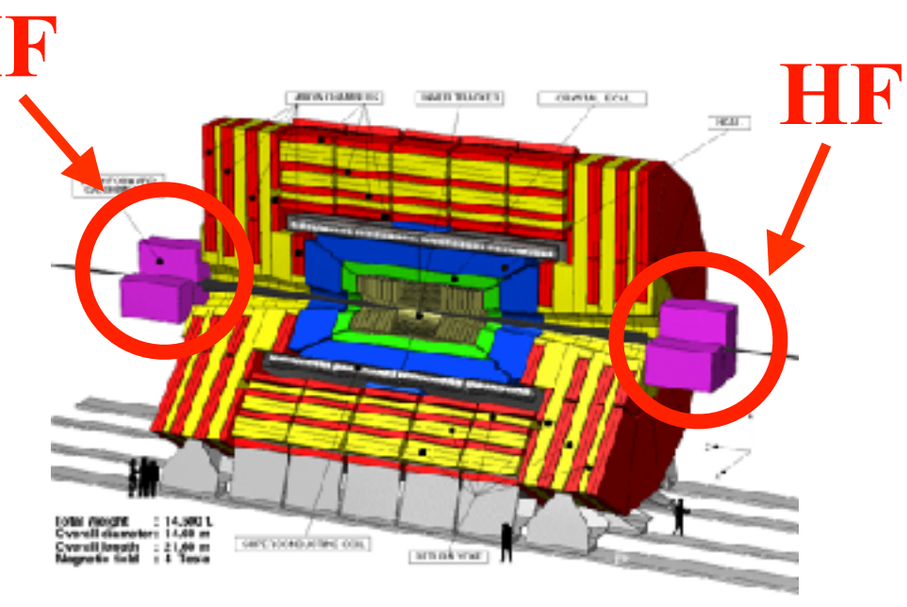
$10^{-4} < x < 10^{-2}$ (shadowing regime)

- **Below unity in $p_T \lesssim 7.5$ GeV/c and $|y_{CM}| > 0.9$**
- **Consistent with ATLAS data in $10 < p_T < 30$ GeV/c**
- **CMS measurement extends ALICE & LHCb points to higher p_T (Different rapidity, could be different effects)**

Prompt J/ψ R_{FB}



Event activity :
Transverse energy deposit in the Hadron Forward calorimeters in $4 < |\eta| < 5.2$ ($E_T^{HF|\eta|>4}$)

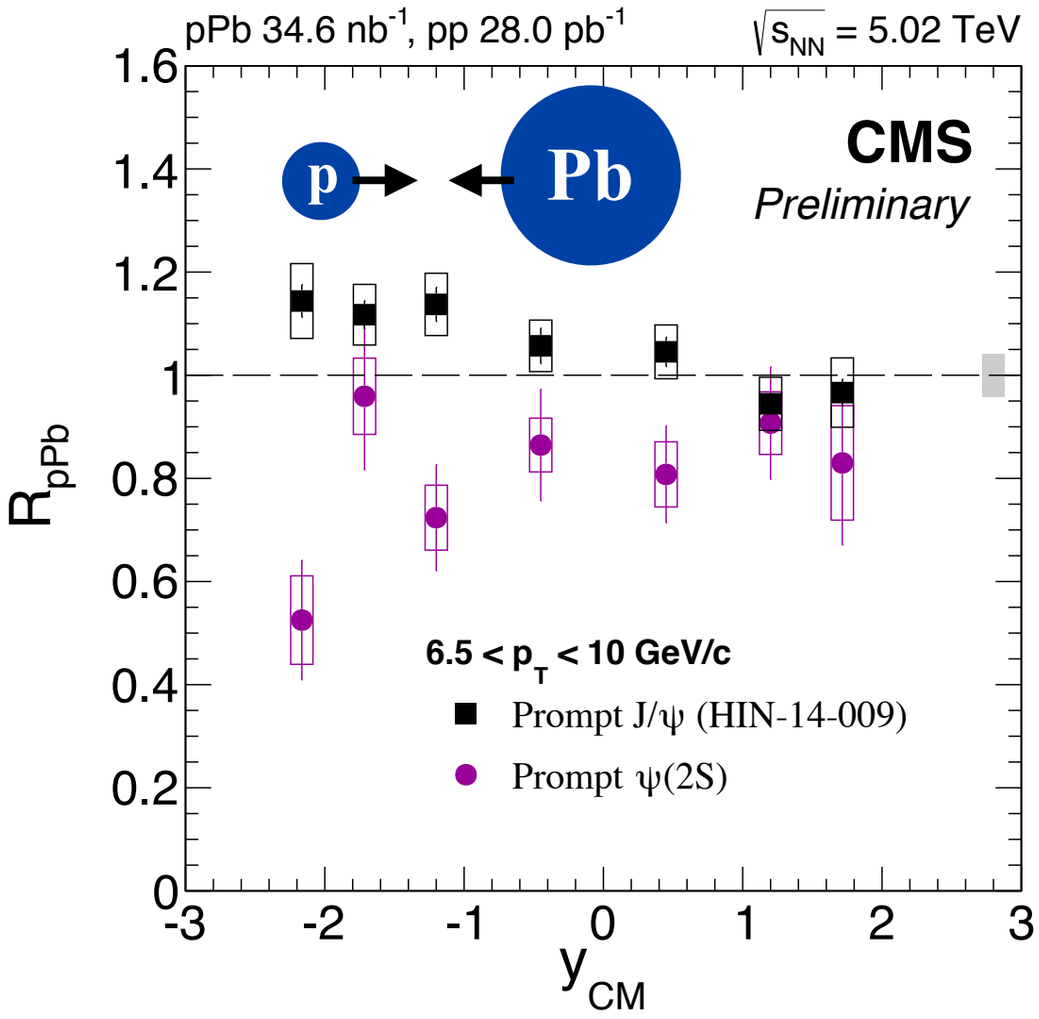


- **Decrease R_{FB} with increasing event activity**
- **Enhanced nuclear matter effects for increasingly central pPb collisions**

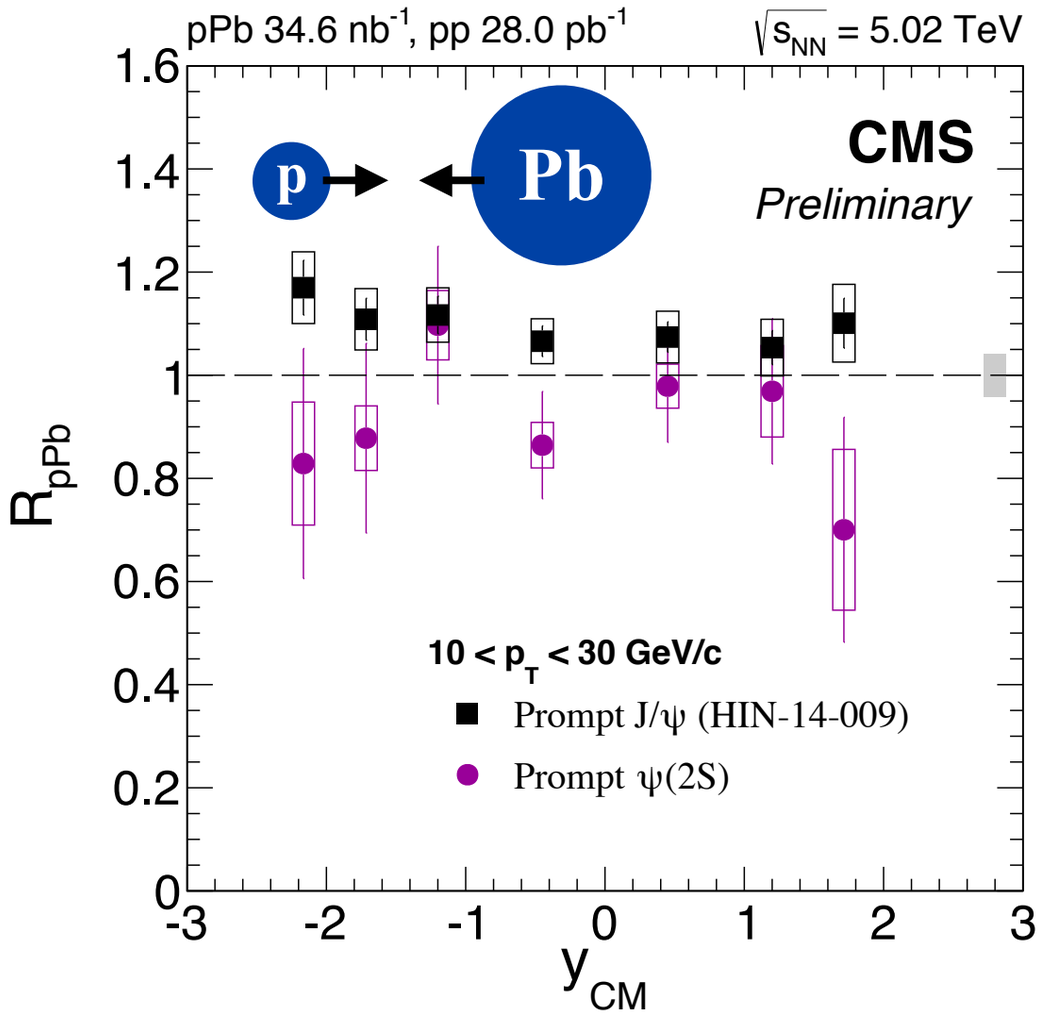
ψ(2S) R_{pPb}

[CMS-HIN-16-015]

Lower p_T



Higher p_T

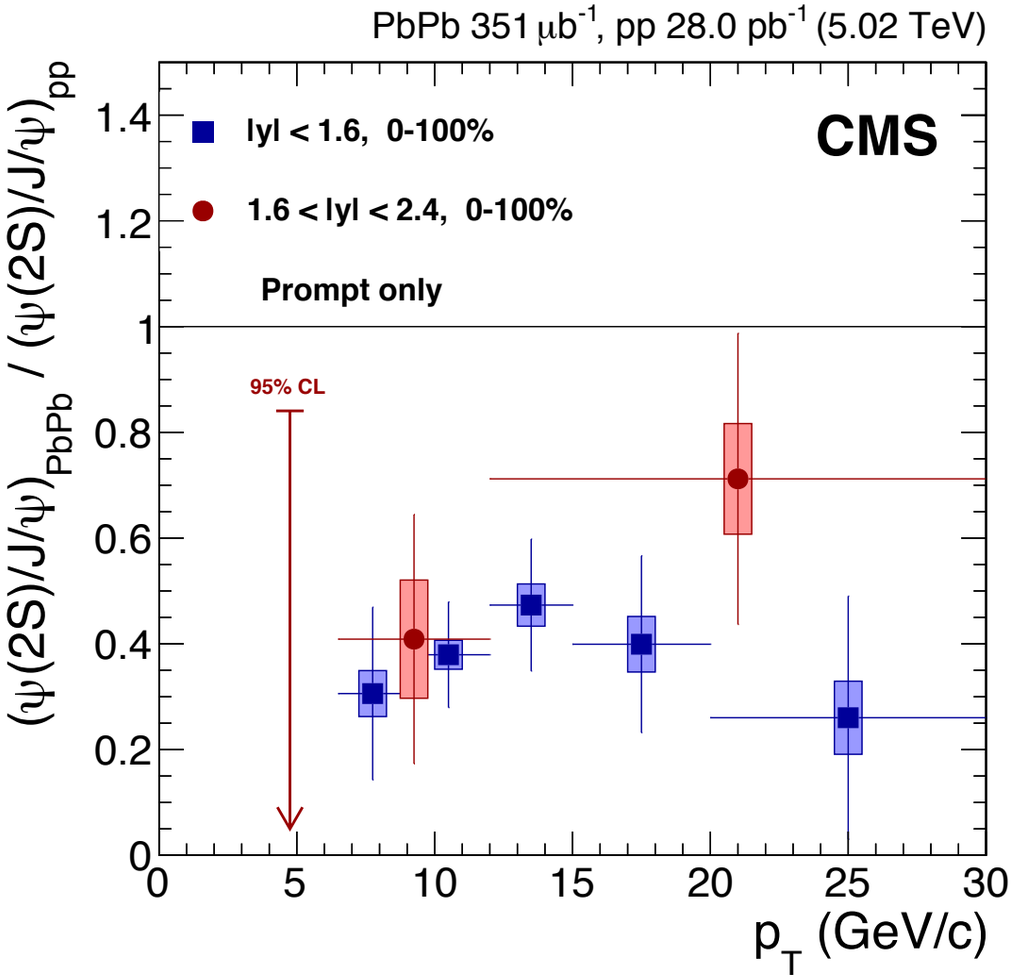


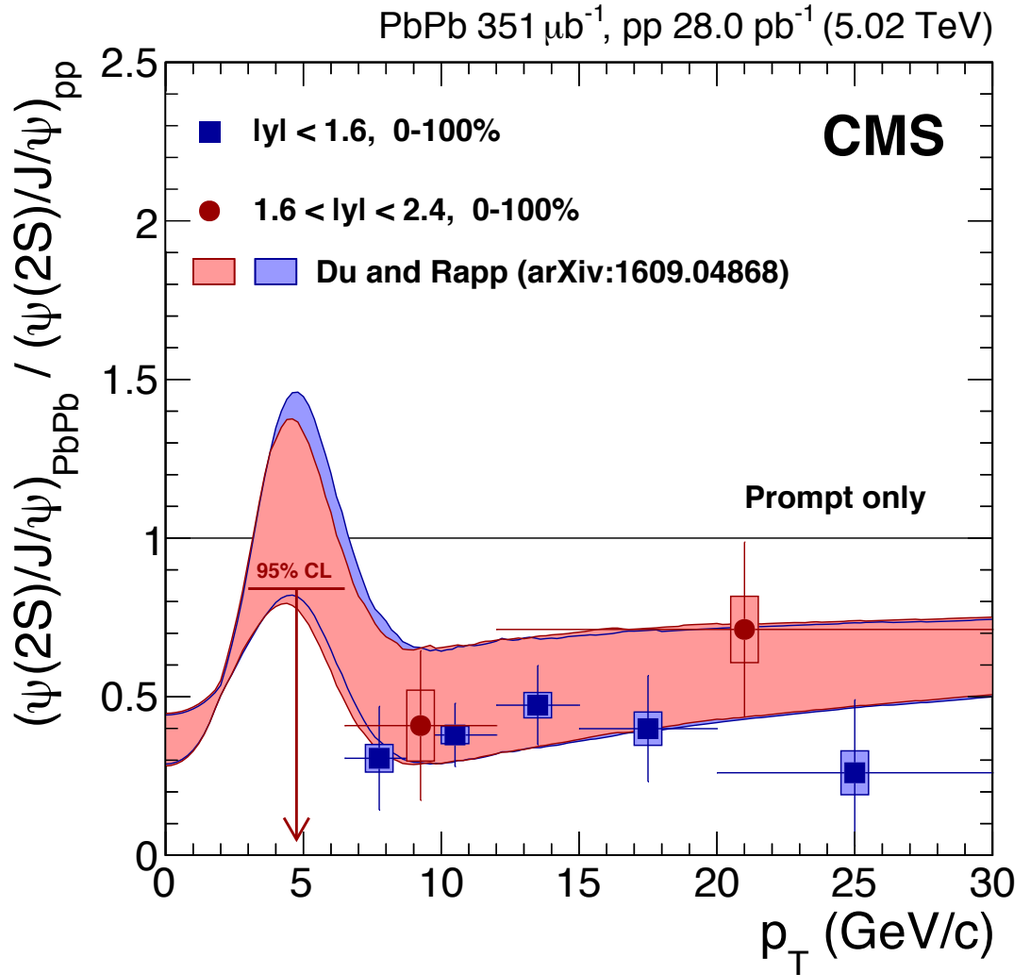
- **R_{pPb} of ψ(2S) stays mostly below R_{pPb} of J/ψ at backward (Pb-going)**
- **Large suppression at lowest p_T and backward rapidity :**

  Final state effects of co-mover breakup?

Double Ratio in PbPb

[arXiv:1611.01438]





- **ψ(2S) more suppressed over all p_T and rapidity regions**
- **Regeneration model calculation lies consistent within uncertainties :**
  → Hint for regeneration of charmonium states
- **No clear p_T and y dependence**

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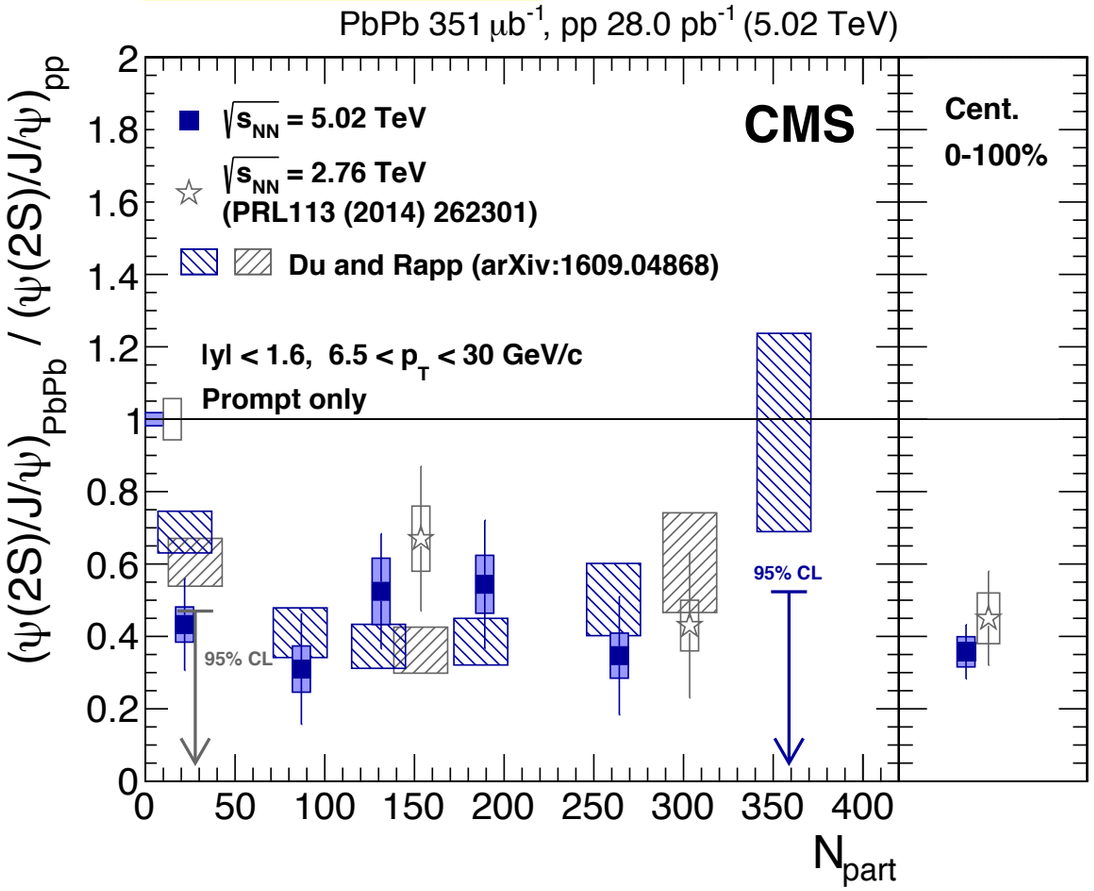
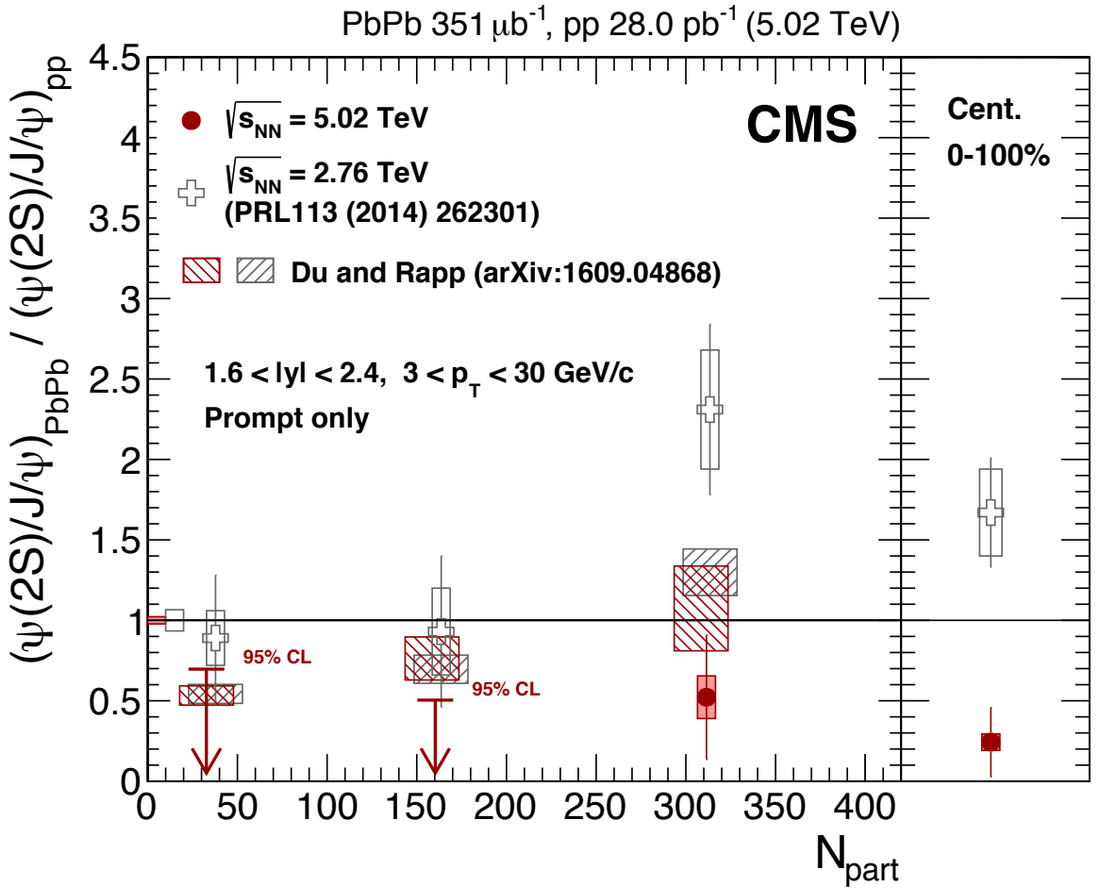
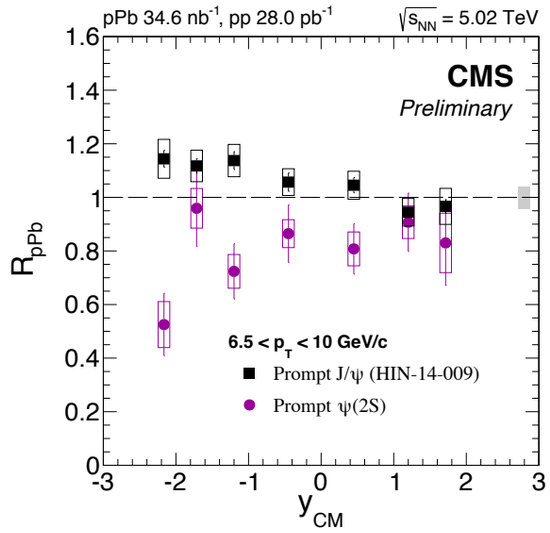




- **More suppression of ψ(2S) and no centrality dependence at 5.02 TeV**
- **Consistently lower in 1.6 < |y| <2.4 and 3 < p_T < 30 GeV/c than 2.76 TeV**
- **Provide information for model calculation such as of regeneration rate and regeneration temperature etc.**

Summary

- **R_{pPb} measurements of J/ψ & ψ(2S) :**
  - **No strong modification in pPb compared to PbPb :**
    ⟶ Dominant QGP effect in PbPb collisions
  - **ψ(2S) result : Indication of co-mover effects?**
    (final state effects)



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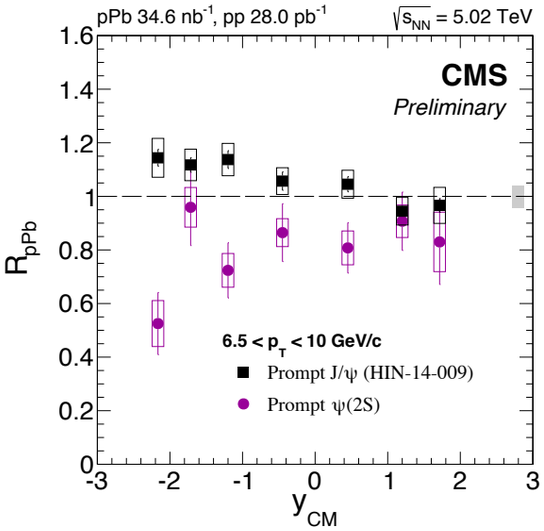
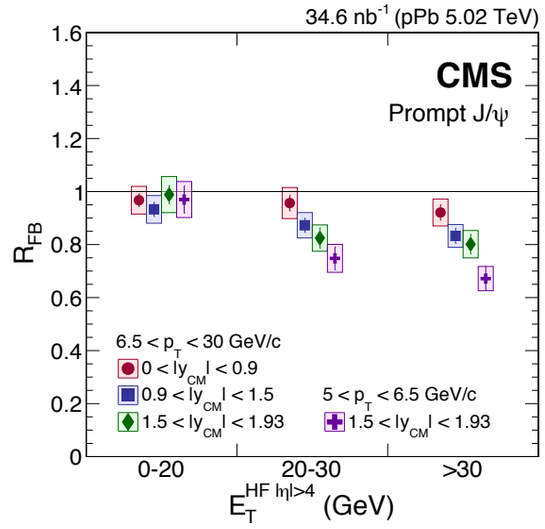
- **R_{FB} of J/ψ : Nuclear effect observed with increasing event activity**





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    (final state effects)

- **R_{FB} of J/ψ : Nuclear effect observed with increasing event activity**

- **More suppression of ψ(2S) than J/ψ at 5.02 TeV**

- **Looking forward the R_{AA} results of J/ψ at 5.02 TeV**