Charmonium production in pPb and PbPb collisions at 5.02 TeV with CMS

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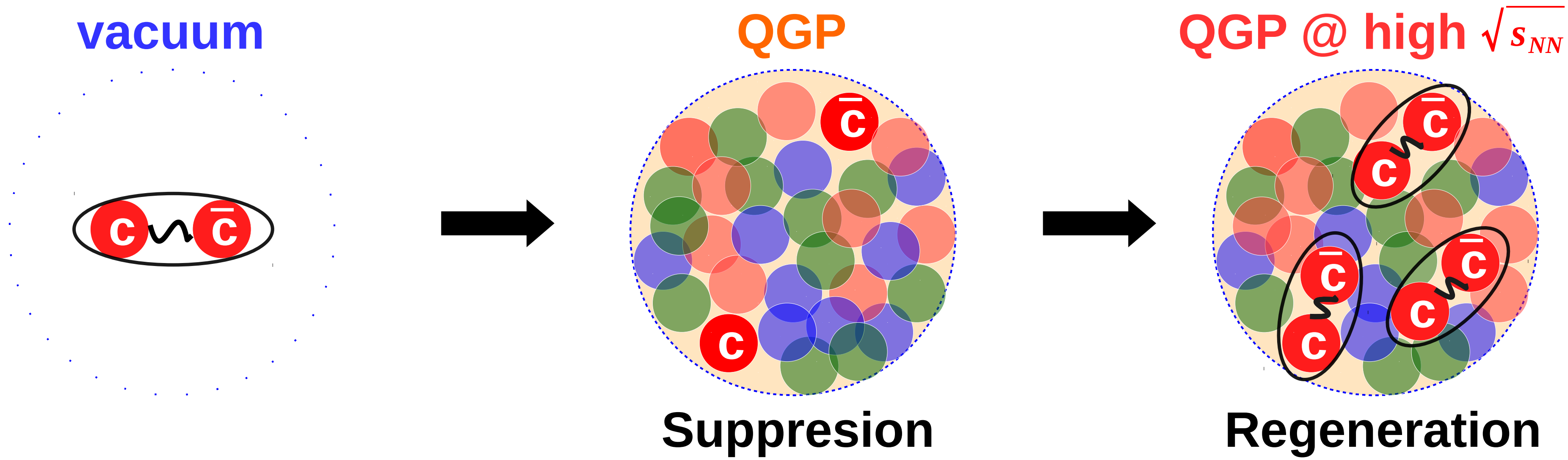
Charmonia in Pb-Pb Collisions

Charmonia ($c\bar{c}$ mesons) are produced in the early stages of the collision

$$\tau^{Charmonia}_{formation} \lesssim \tau^{QGP}_{formation} < \tau^{QGP}_{lifetime} < \tau^{Charmonia}_{decay}$$

The Quark-Gluon Plasma is expected to modify the charmonia production

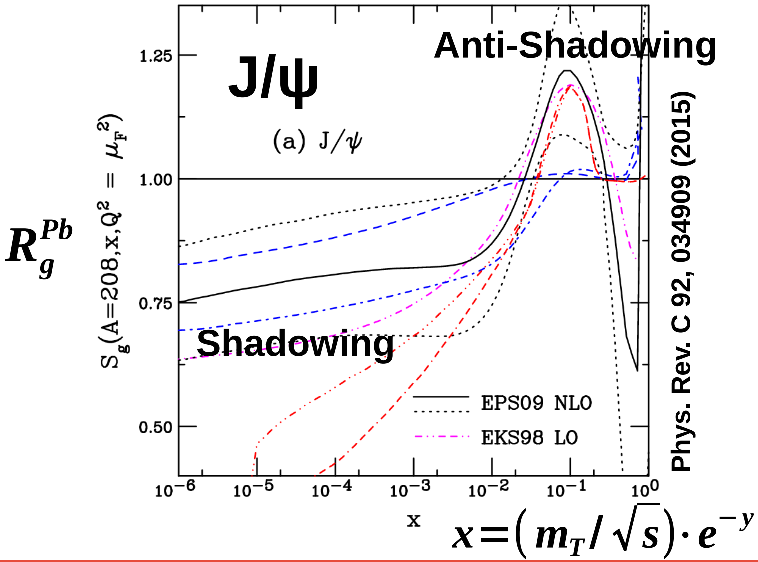


Charmonia are good probes of the medium evolution

Besides **Hot Nuclear Matter effects**, we also need to consider **Cold Nuclear Matter effects**

Charmonia in p-Pb Collisions

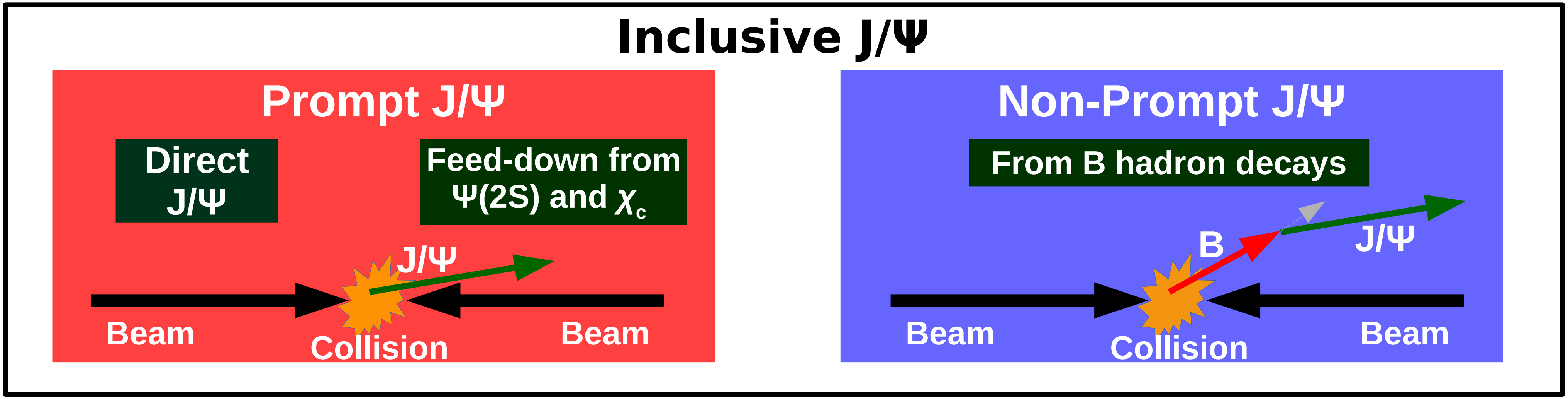
- Study of J/ψ in pPb allows to probe Cold Nuclear Matter effects:
  - Initial state energy loss
  - Nuclear PDF modifications
  - Nuclear absorption



Excited States in HI Collisions

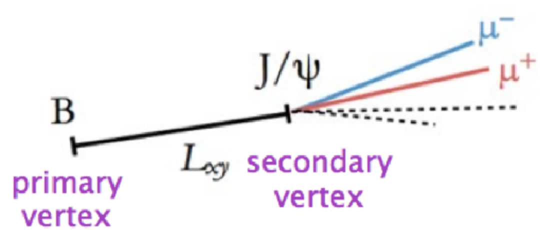
- The study of ψ(2S) brings additional information:
  - Excited states are **less tightly bounded** than the 1S state (J/ψ)
    - More suppressed in the QGP compared to J/ψ
  - Models including Cold Nuclear Matter effects **predict similar suppression** as for J/ψ

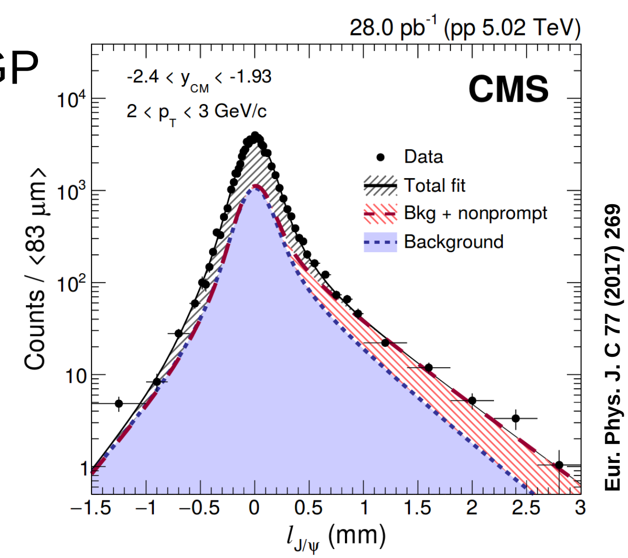
Prompt and Non-Prompt Charmonia



- **Prompt Charmonia:**
  Directly affected by the QGP
- **Non-Prompt Charmonia:**
  Reflects energy loss of b quarks in the QGP

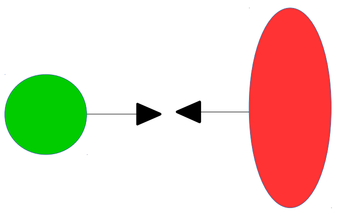
Separation based on **pseudo-proper decay length** ($\ell_{J/\Psi}$)





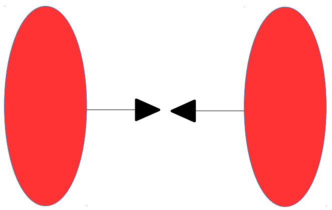
Outline

- **J/ψ in pPb at 5 TeV**
  - Eur. Phys. J. C 77 (2017) 269



- **ψ(2S) from pp to pPb at 5 TeV**
  - HIN-16-015

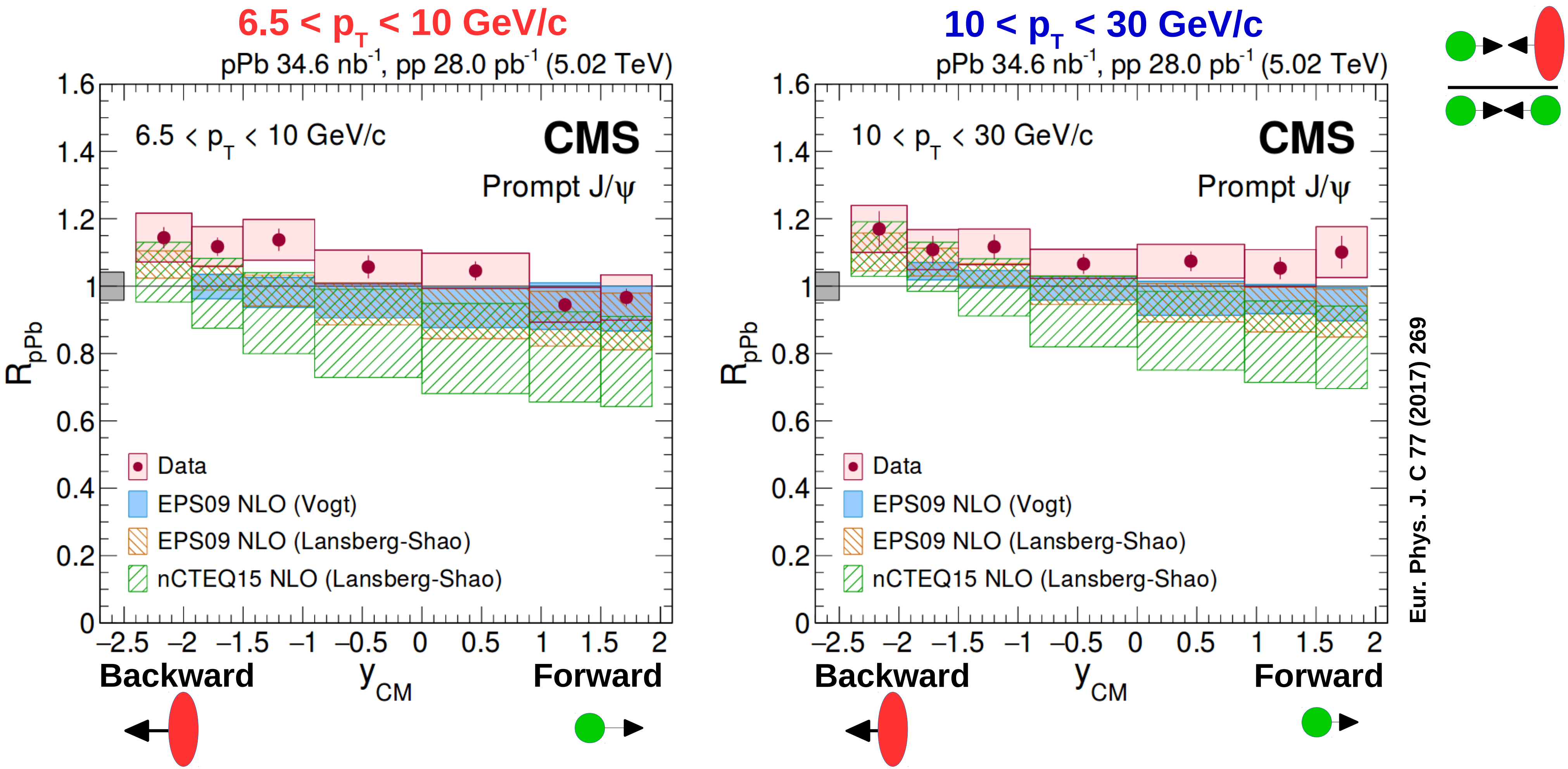
- **Relative modification of prompt J/ψ and ψ(2S) from pp to PbPb at 5 TeV**
  - Phys. Rev. Lett. 118, 162301 (2017)



Outline

J/ψ in pPb at 5 TeV

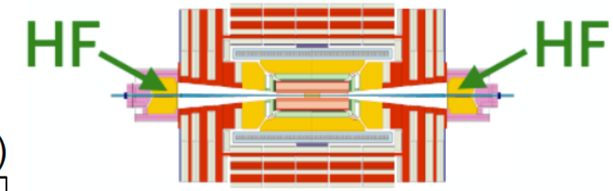
Prompt J/ψ R_{pPb}

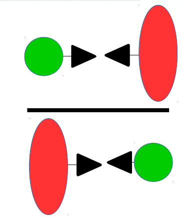


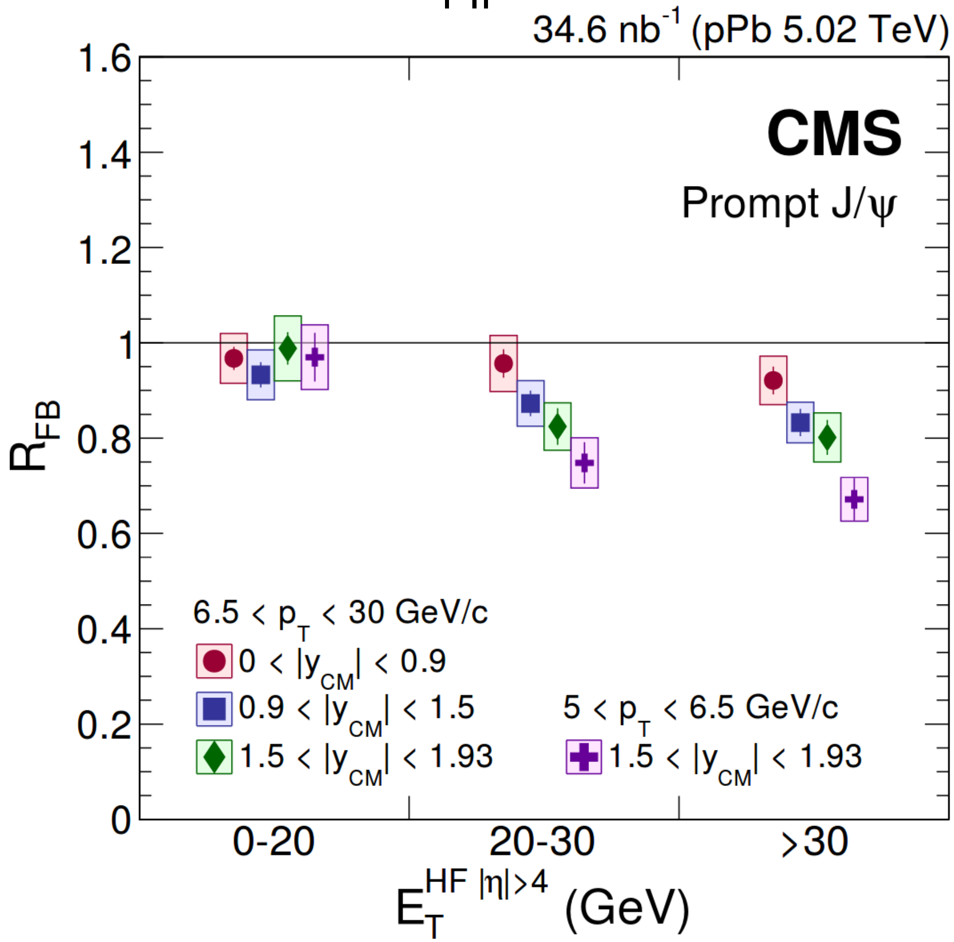
- Lower p_T : R_{pPb} decreases with y_{CM}
- Higher p_T : R_{pPb} above unity for the whole y_{CM} range
- nPDF theory predictions slightly lower than data

Forward-Backward J/ψ in pPb

Event activity determined using the **transverse energy deposited** in the **Hadron Forward calorimeters** in $4 < |\eta| < 5.2$







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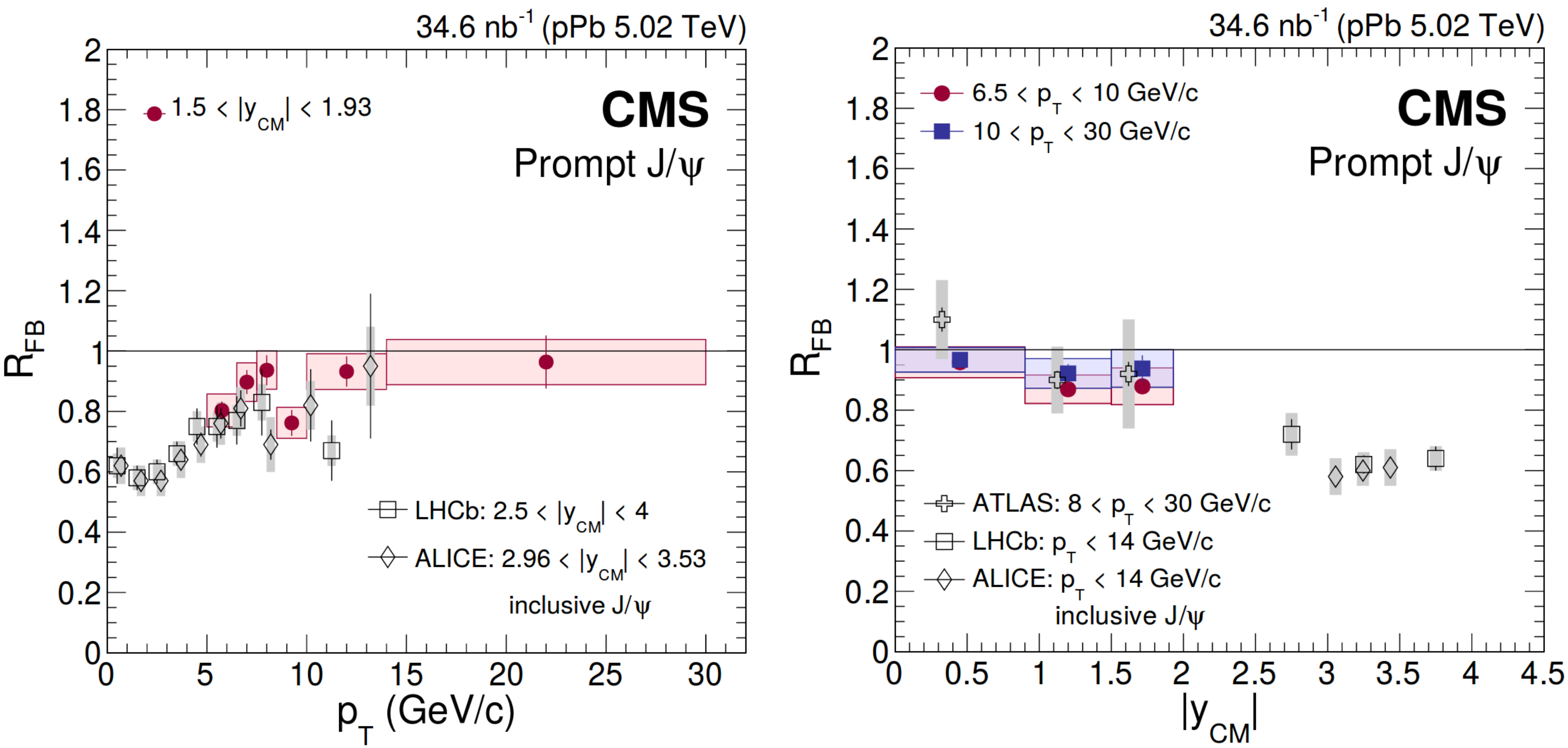
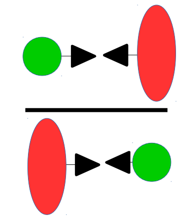
- Decrease of R_{FB} for increasing event activity
- Nuclear matter effects enhanced at larger event activity

Forward-Backward J/ψ in pPb

CMS: Eur. Phys. J. C 77 (2017) 269
LHCb: High Energ. Phys. (2014) 2014: 72.





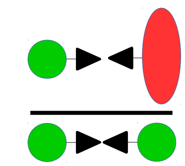
ATLAS: Nucl.Part.Phys.Proc. 276-278 (2016) 149-152
ALICE: Nucl.Phys.A 956 (2016) 689-692

- CMS measurements extend ALICE and LHCb ones to higher p_T
- Results consistent with ATLAS

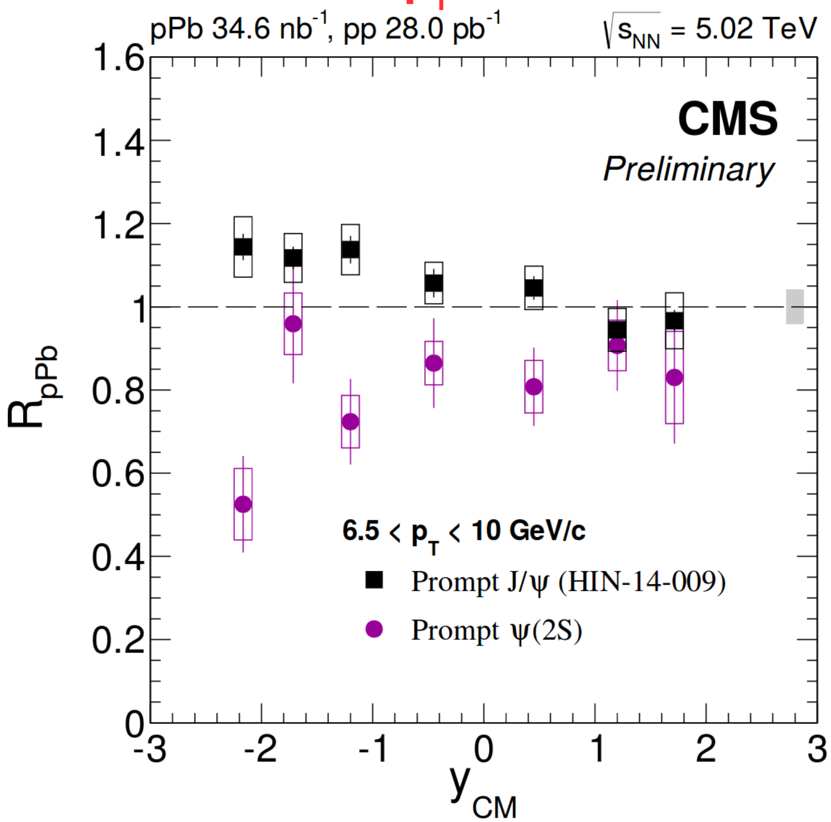
Outline

ψ(2S) from pp to pPb at 5 TeV

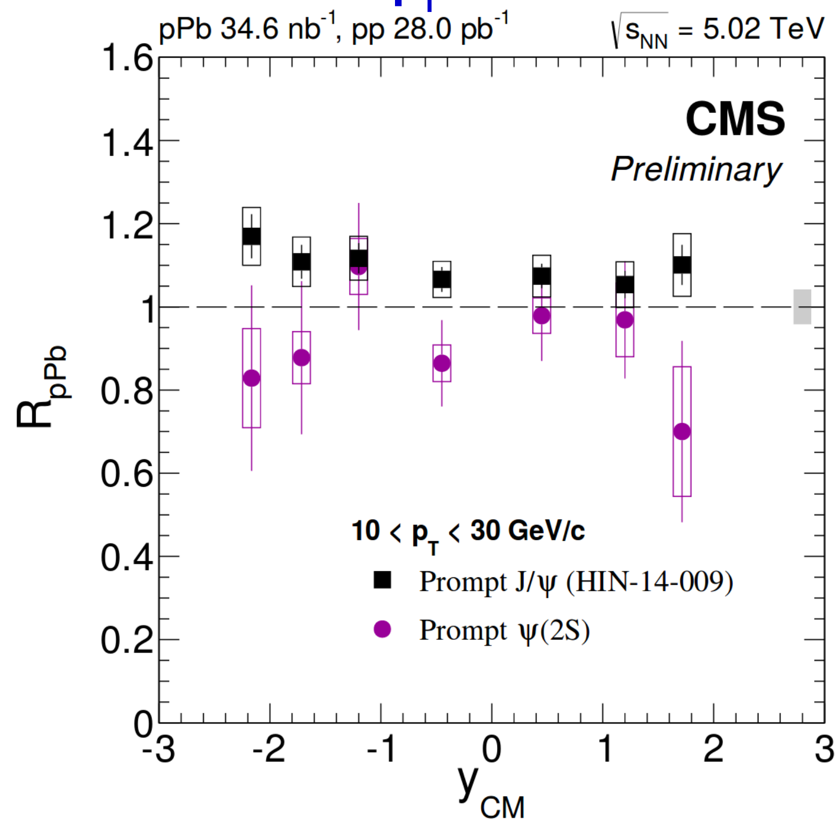
Prompt ψ(2S) in pPb



6.5 < p_T < 10 GeV/c



10 < p_T < 30 GeV/c



CMS-PAS-HIN-16-015

- **Ratio: R_{pPb} (ψ(2S)) < R_{pPb} (J/ψ) especially at backward** (Pb-going direction)
- Different suppression between J/ψ and ψ(2S) could be consistent with final state inelastic interactions of ψ(2S) mesons with comoving particles in the medium
- CMS measurements bring stringent constraints to the origin of charmonium suppression in pPb collisions at LHC

Prompt J/ψ vs ψ(2S) from pp to PbPb at 5 TeV

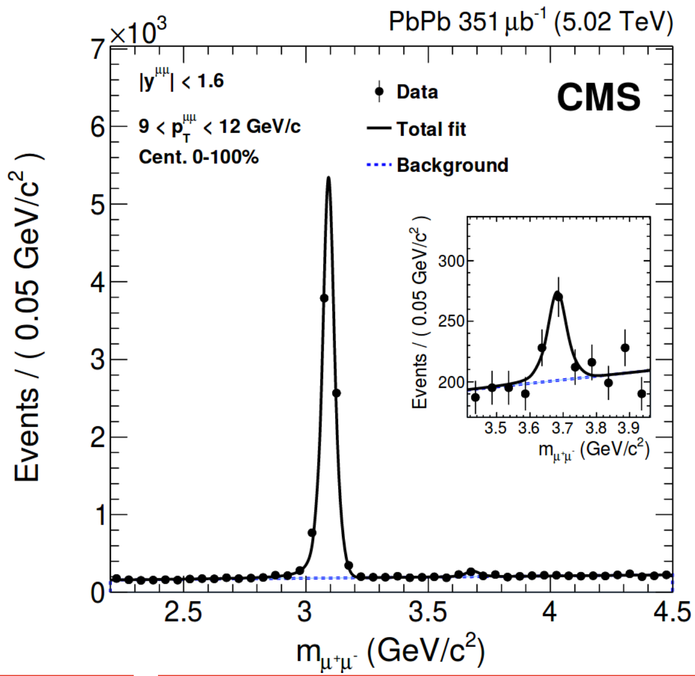
ψ(2S) vs J/ψ modification in PbPb

Double ratio of Charmonia in PbPb and pp at 5 TeV:

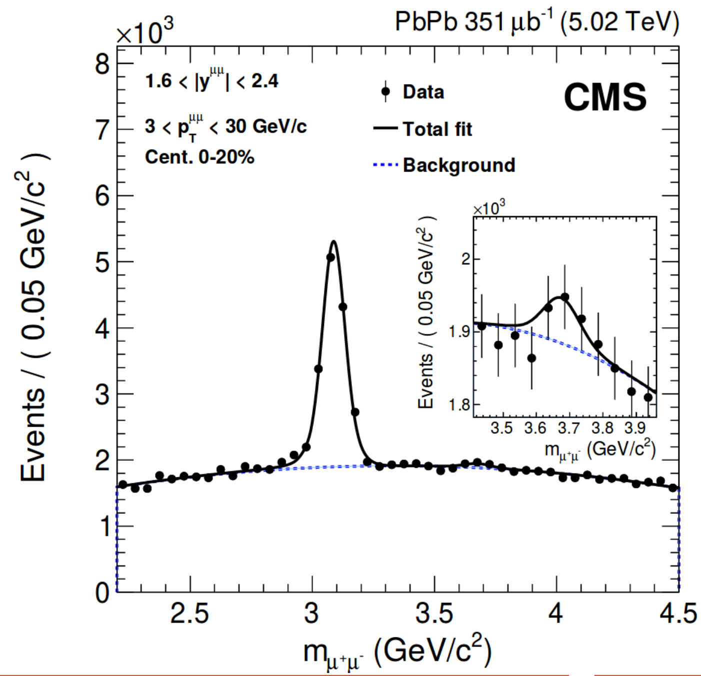
$$\frac{\left[\frac{\psi(2S)}{J/\psi}\right]_{PbPb}}{\left[\frac{\psi(2S)}{J/\psi}\right]_{pp}} = \frac{R_{AA}(\psi(2S))}{R_{AA}(J/\psi)}$$

- Many corrections and uncertainties cancel (experimental and theoretical)
- Relative modification of ψ(2S) and J/ψ in PbPb

$|y| < 1.6$; $9 < p_T < 12$ GeV/c
Cent: 0-100%

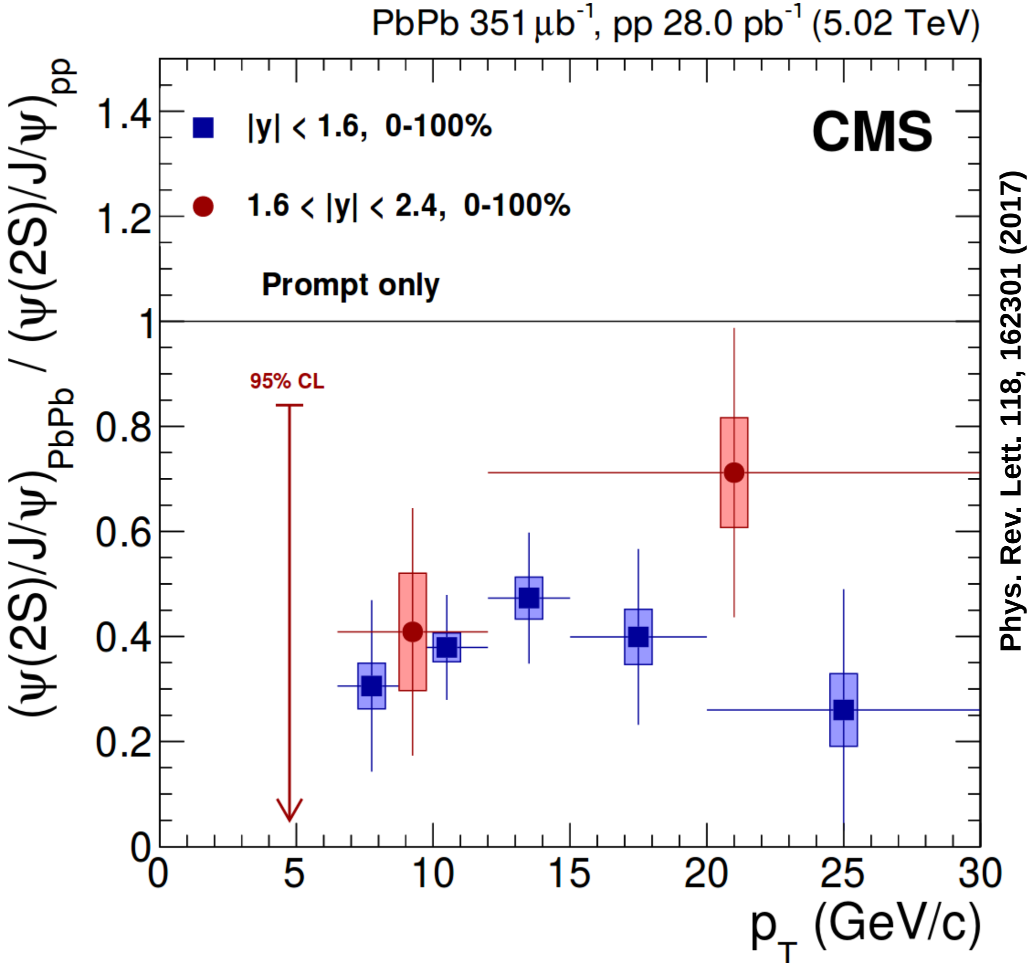


$1.6 < |y| < 2.4$; $3 < p_T < 30$ GeV/c
Cent: 0-20%



Phys. Rev. Lett. 118, 162301 (2017)

Ratio of ψ(2S) / J/ψ R_{AA} vs p_T

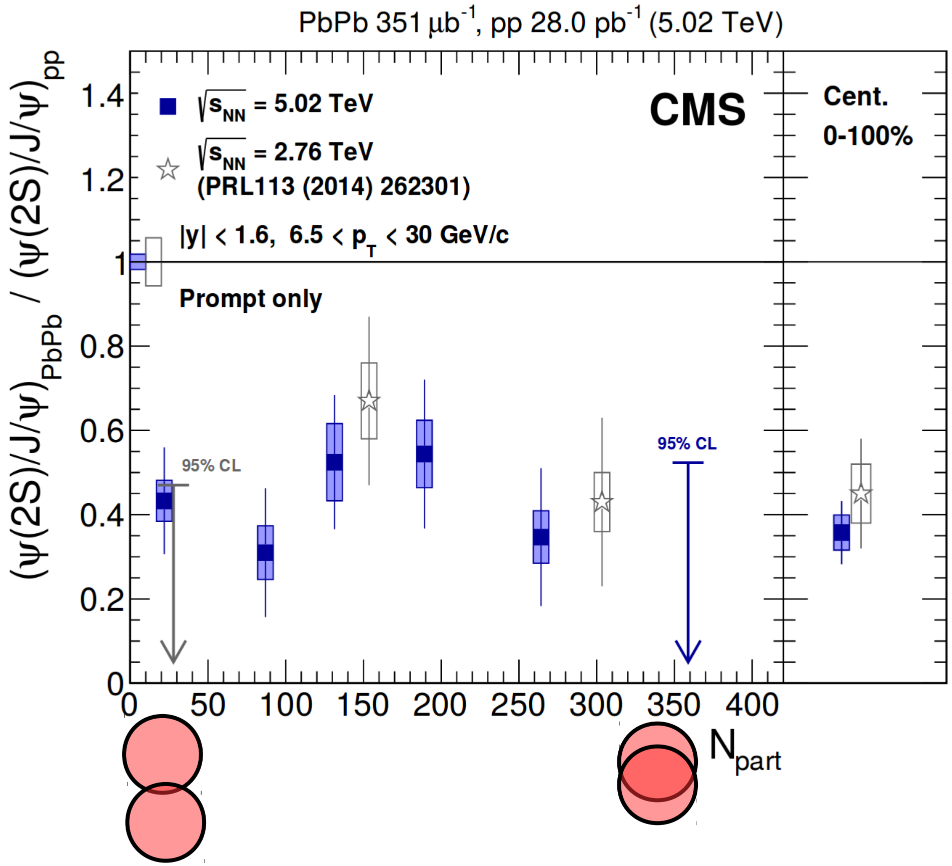


- $R_{AA}(\psi(2S))$ / $R_{AA}(J/\psi)$ < 1 in all bins → **ψ(2S) is more suppressed than J/ψ**
- No p_T dependence within uncertainties

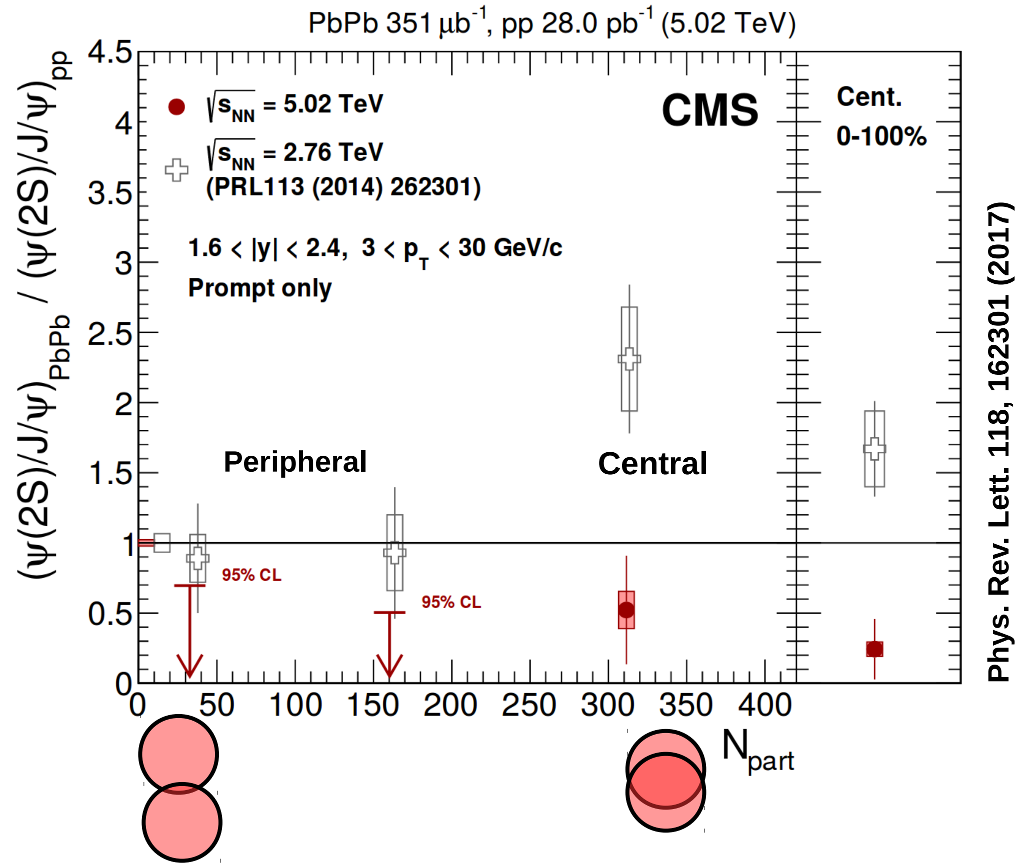
ψ(2S) / J/ψ vs Centrality

2.76 vs. 5.02 TeV

$|y| < 1.6$; $6.5 < p_T < 30$ GeV/c



$1.6 < |y| < 2.4$; $3 < p_T < 30$ GeV/c



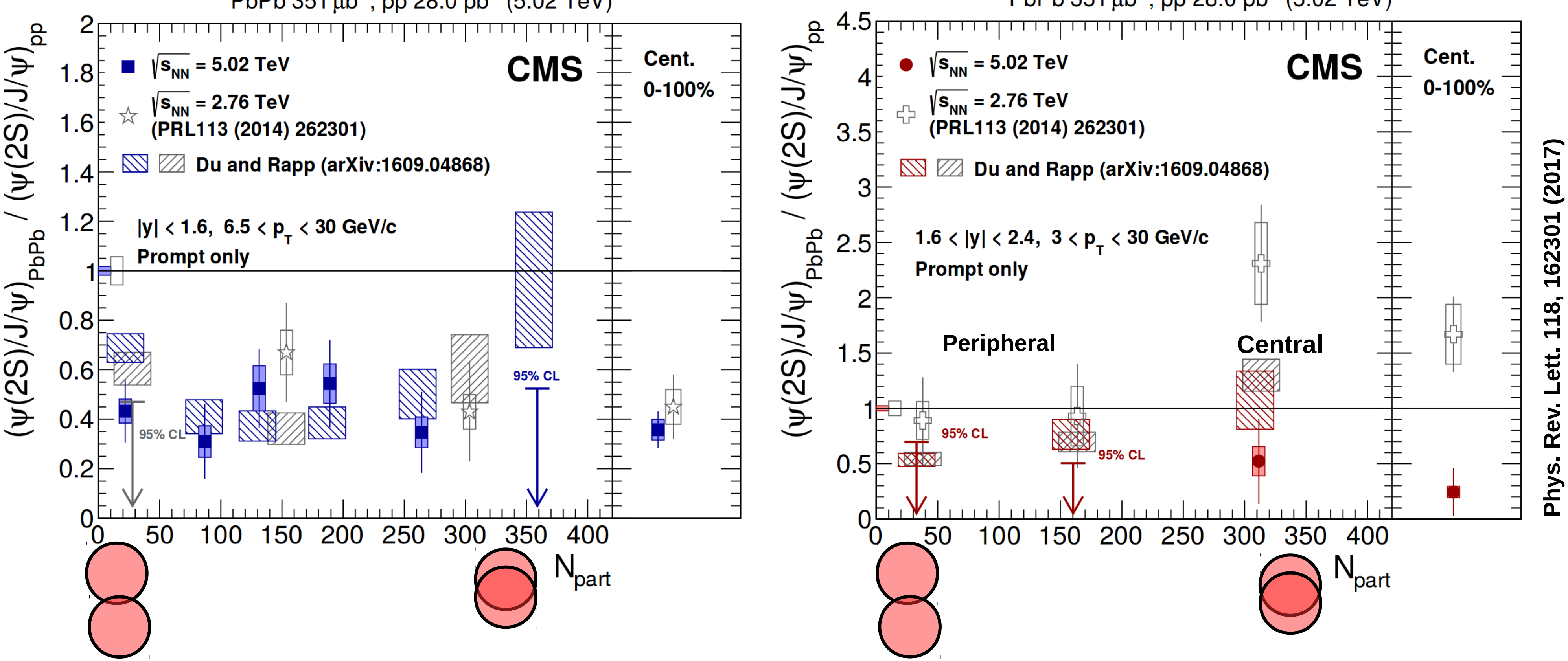
Phys. Rev. Lett. 118, 162301 (2017)

- **ψ(2S) is more suppressed than J/ψ** at 5.02 TeV
- No strong N_{part} dependence at 5.02 TeV
- Double ratio at 5.02 TeV consistently lower than at 2.76 TeV in $1.6 < y < 2.4$, $3 < p_T < 30$ GeV/c, especially for most central collisions (~3 s.d. in 0-100%)

ψ(2S) / J/ψ vs Centrality

2.76 vs. 5.02 TeV

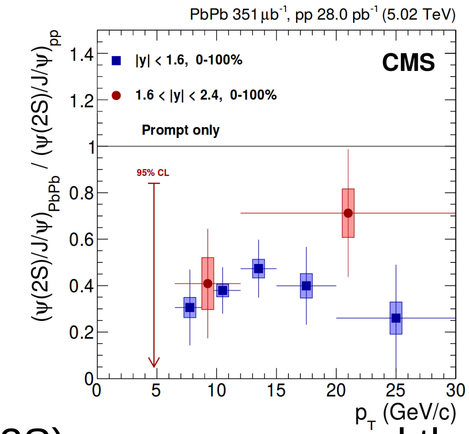
$|y| < 1.6$; $6.5 < p_T < 30$ GeV/c — **$1.6 < |y| < 2.4$; $3 < p_T < 30$ GeV/c**



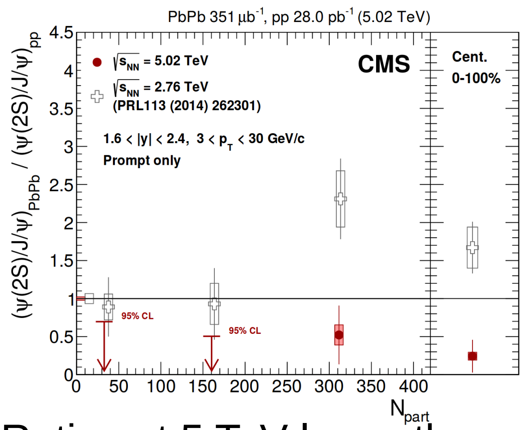
- A sequential regeneration model of charmonia states in the fireball evolution might explain the smaller suppression of ψ(2S) compared to J/ψ observed by CMS in PbPb at 2.76 TeV
- Due to the increase in transverse flow from 2.76 TeV to 5.02 TeV, the model predicts that more regenerated J/ψ are produced at $p_T > 3$ GeV/c, thus suppressing the double ratio at $3 < p_T < 30$ GeV/c, in agreement with the CMS measurements

SUMMARY

Probing Hot Nuclear Matter Effects:

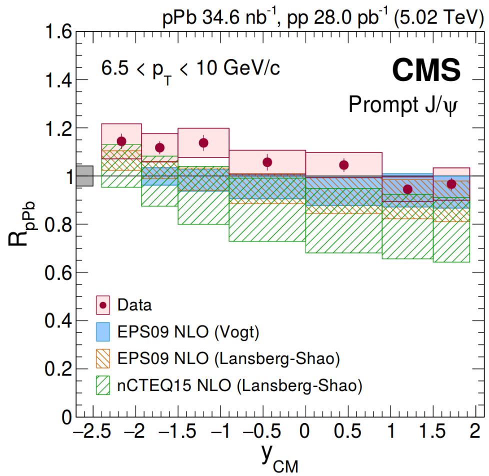


ψ(2S) more suppressed than J/ψ

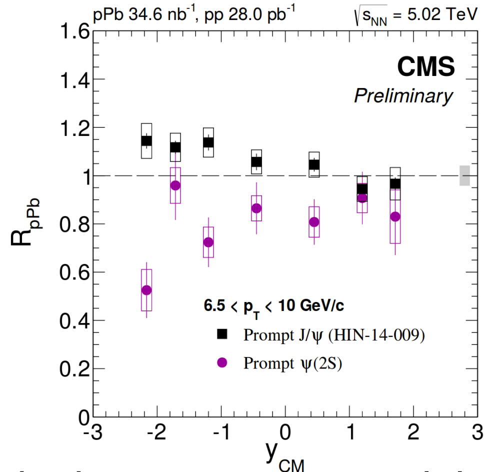


Double Ratios at 5 TeV lower than at 2.76 TeV

Probing Cold Nuclear Matter Effects:



J/ψ R_{pPb} slightly above nPDF predictions



ψ(2S) more suppressed than J/ψ

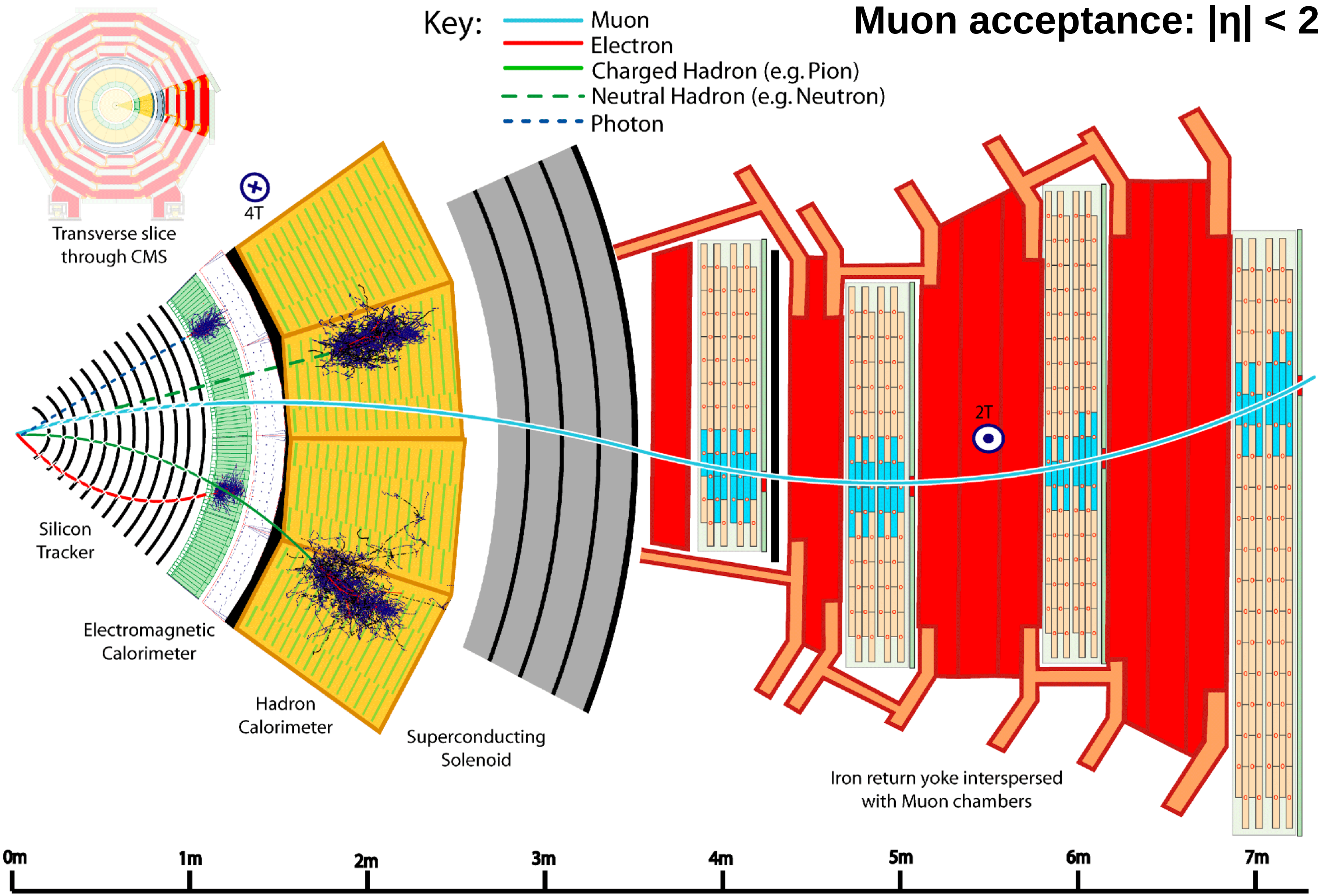
Stay tuned for more CMS results!

Thank you for your attention!

BACKUP

CMS Detector

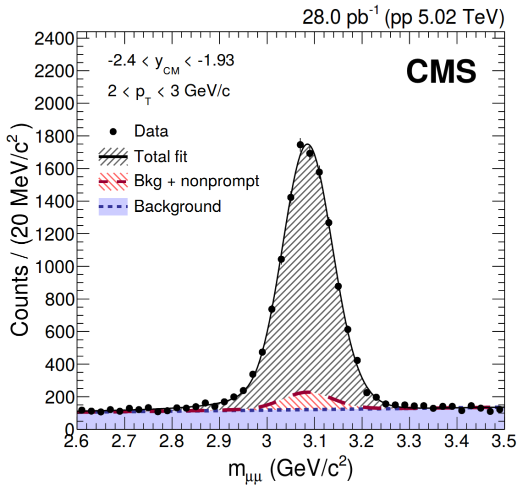
Muon acceptance: |η| < 2.4

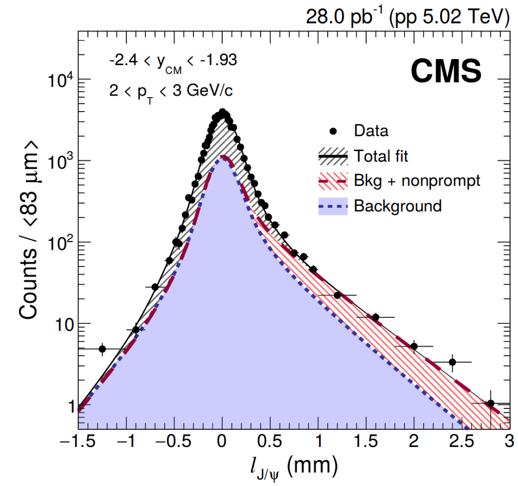


Prompt and Non-Prompt Charmonia

Two techniques to separate components:

1. **2D fits of dimuon mass and pseudo-proper decay length**





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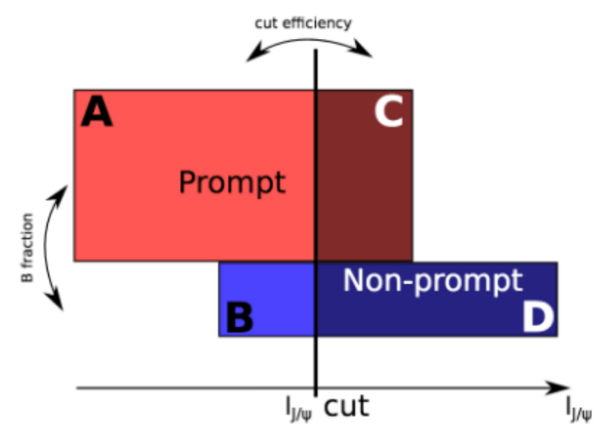
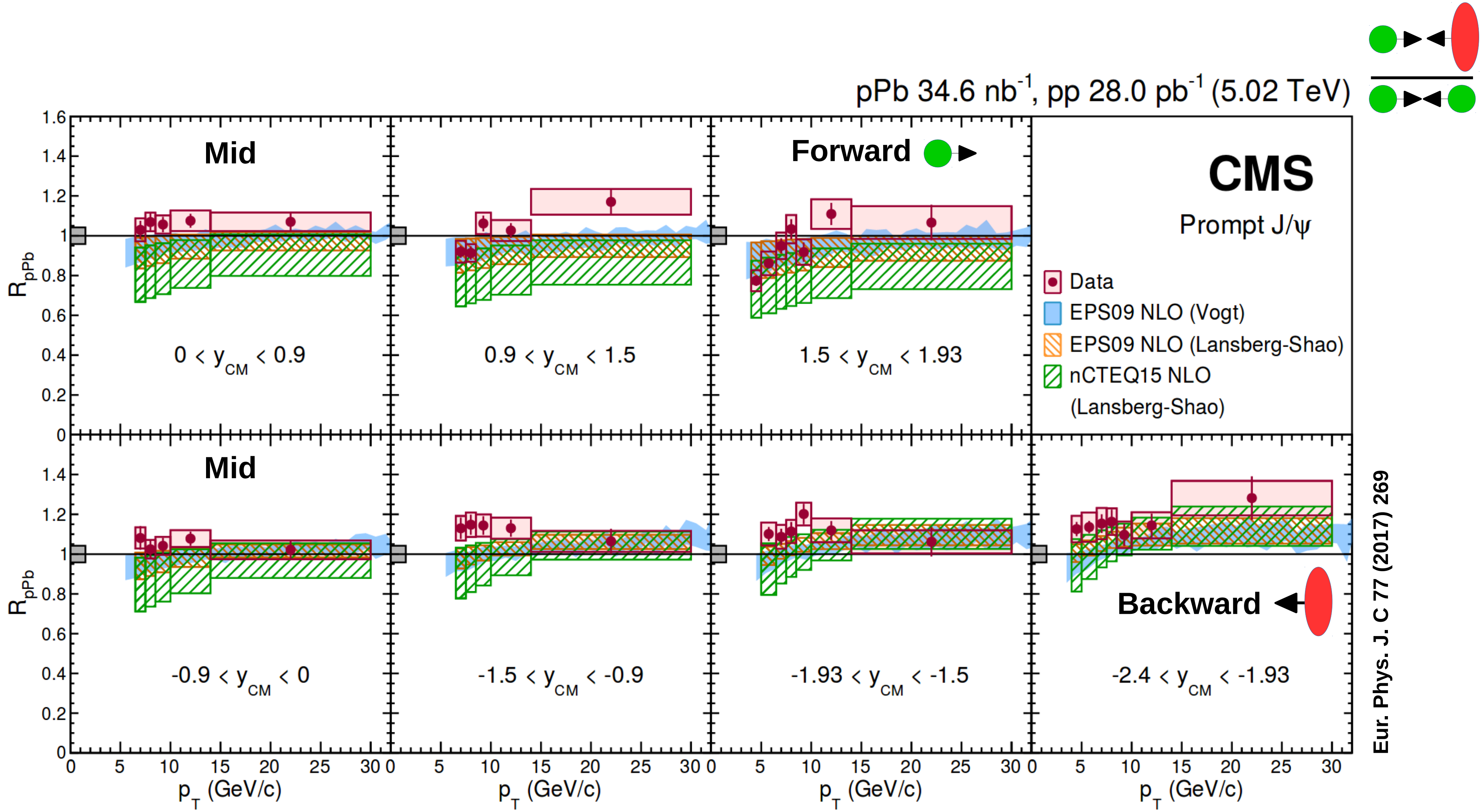
2. **Rejecting non-prompt applying a cut on pseudo-proper decay length**

Data-based corrections applied to remove non-prompt contamination

- Using reverted $\ell_{J/\Psi}$ cut
- MC efficiency of $\ell_{J/\Psi}$ cut



Prompt J/ψ in pPb



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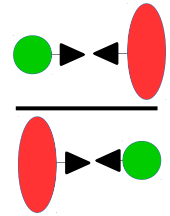
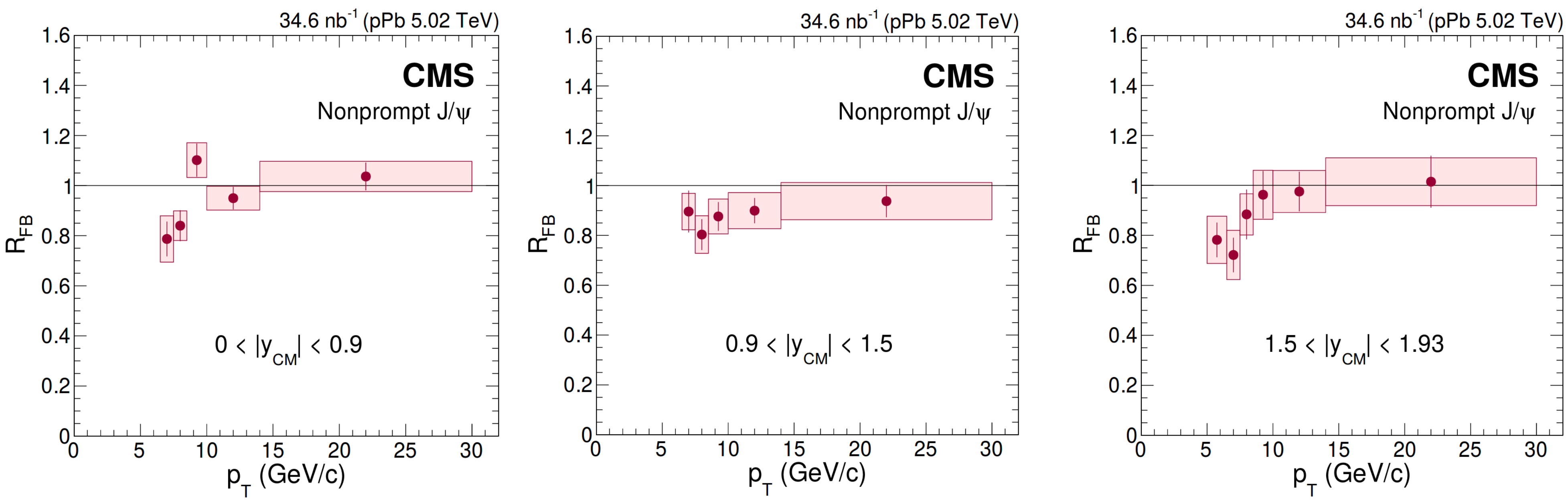
Prompt J/ψ in pPb





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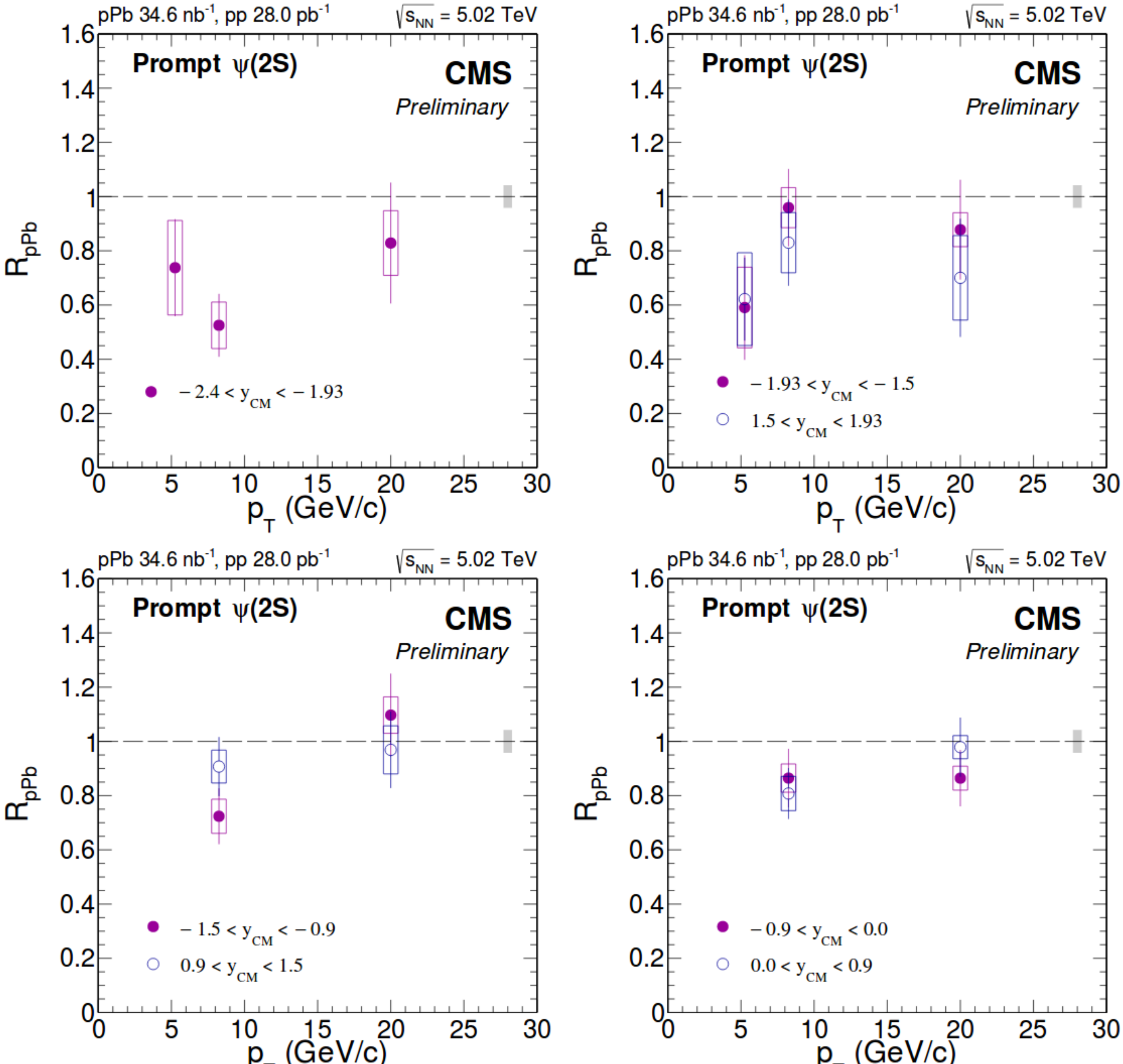
Prompt ψ(2S) in pPb



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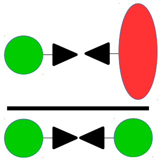
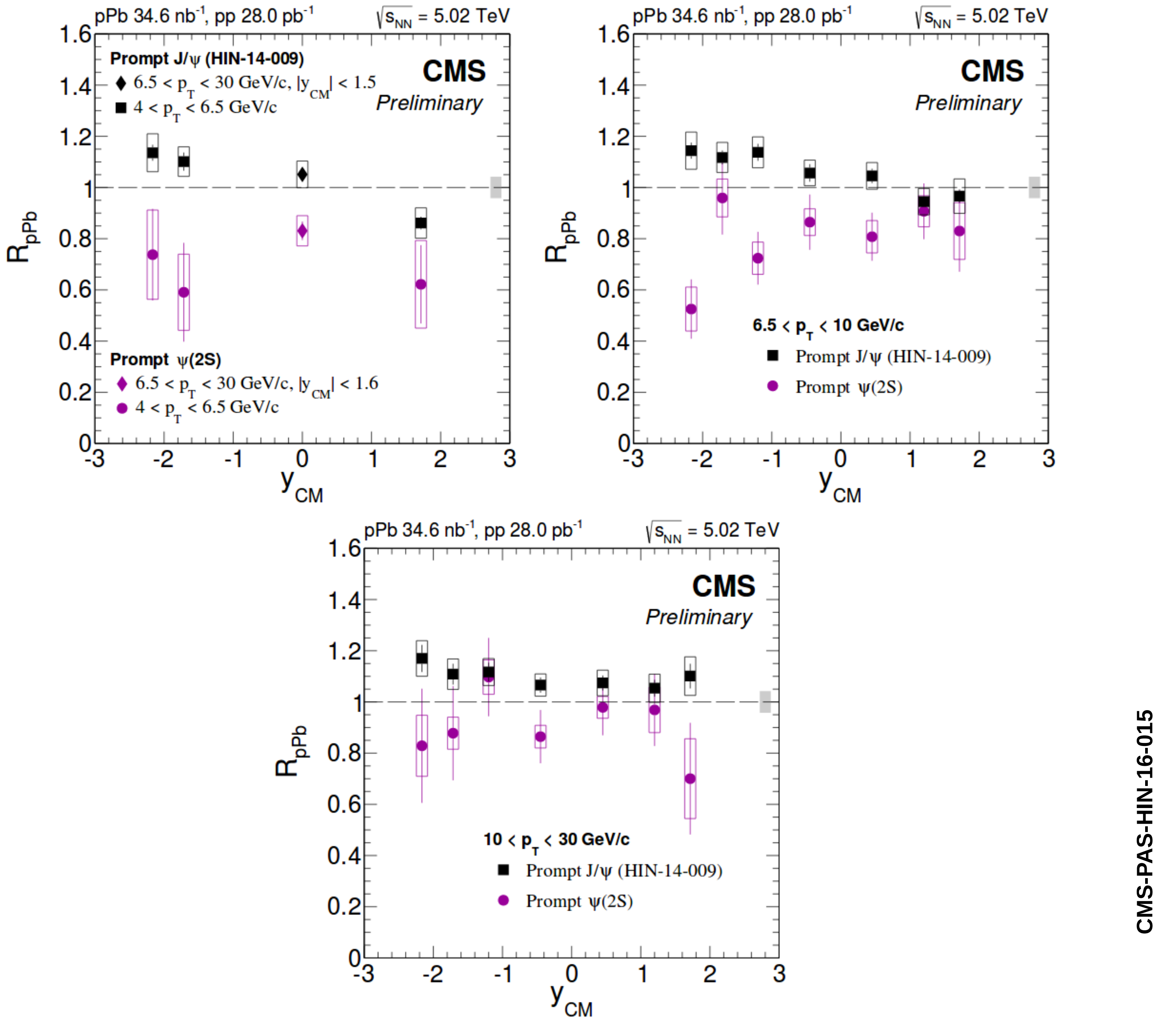
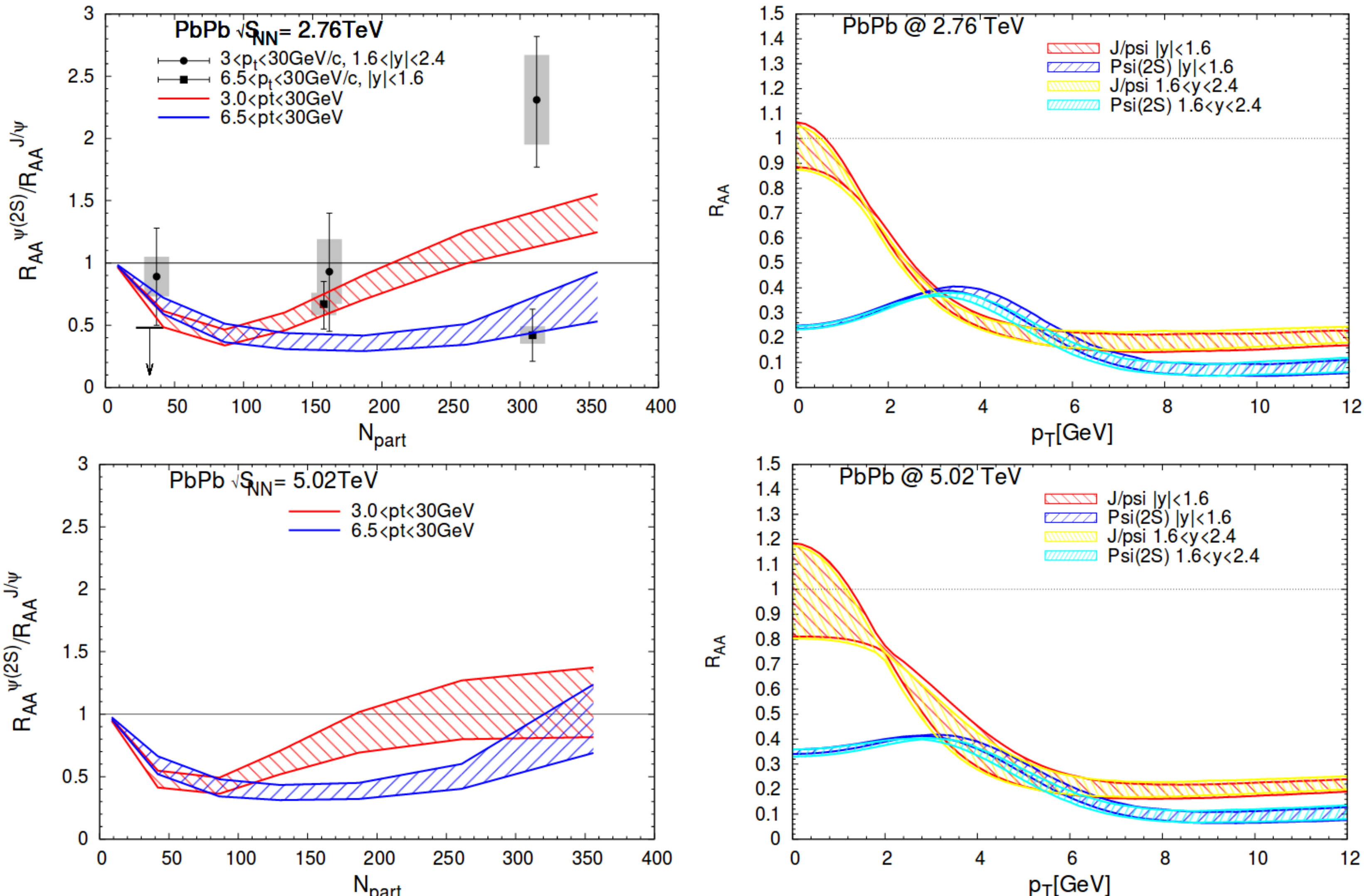


Prompt ψ(2S) in pPb



Sequential Regeneration

J. Phys. Conf. Series, Vol. 779, Conf. 1



T_0 ~ 600 MeV

T_0 ~ 640 MeV

2.76 TeV → 5.02 TeV

- ~7% increase of initial temperature
- ~10% more shadowing
- ~40% increase of charm cross section