

Charmonium suppression in PbPb collisions with CMS

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Rencontres QGP France 2017

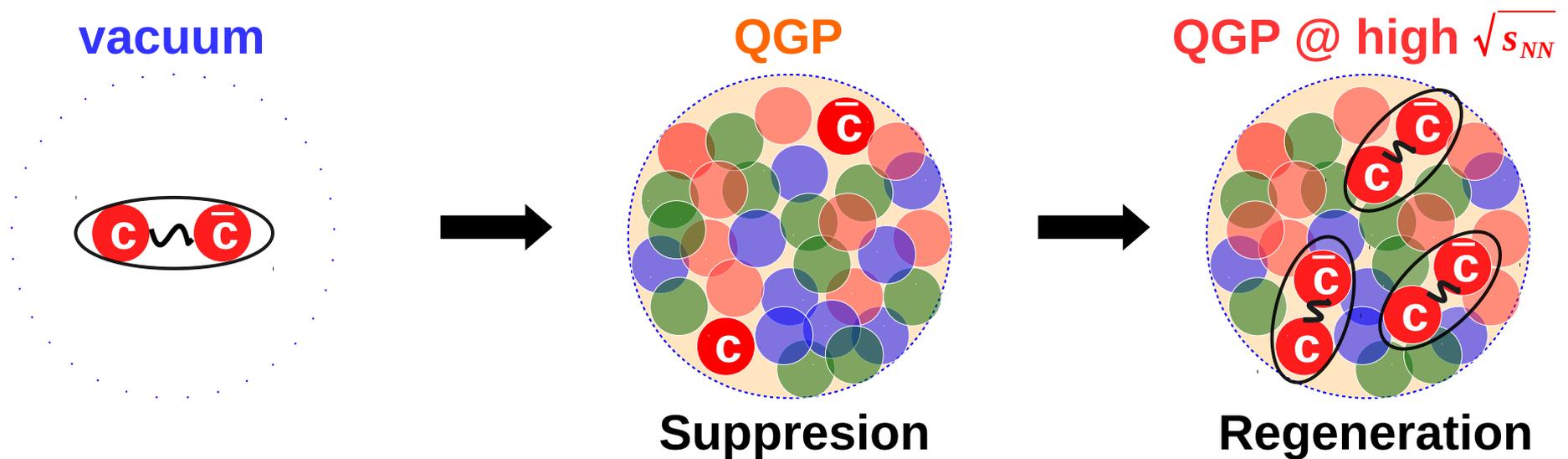


Charmonia in Pb-Pb Collisions

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

$$\tau_{\text{formation}}^{\text{Charmonia}} \lesssim \tau_{\text{formation}}^{\text{QGP}} < \tau_{\text{lifetime}}^{\text{QGP}} < \tau_{\text{decay}}^{\text{Charmonia}}$$

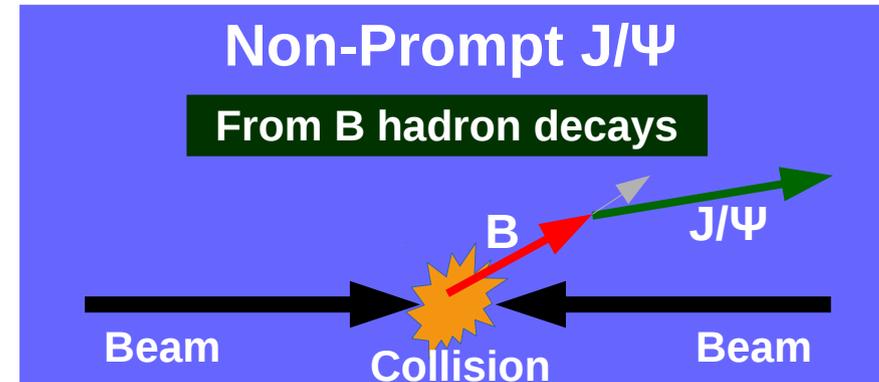
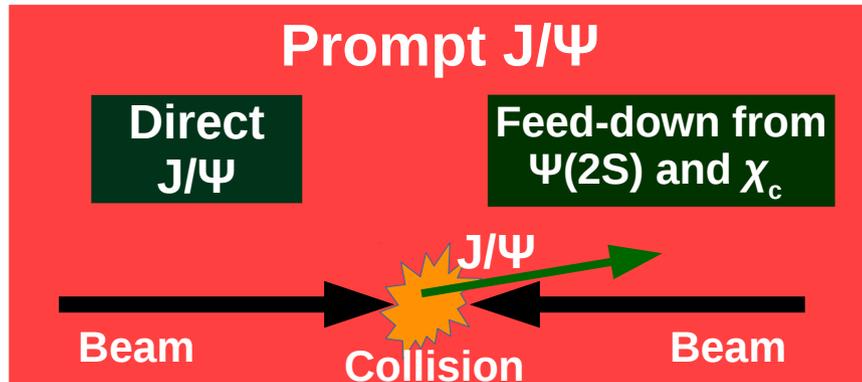
The Quark-Gluon Plasma is expected to modify the charmonia production



Charmonia are good probes of the medium evolution

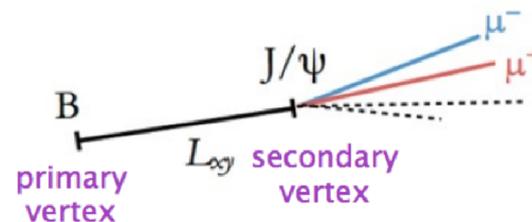
Prompt and Non-Prompt Charmonia

Inclusive J/ψ



- **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** ($L_{J/\psi}$)



LHC Runs: Recorded by CMS

Run 1 (2011-2013)

p-p	$\sqrt{s_{NN}} = 2.76 \text{ TeV}$	$L = 5 \text{ pb}^{-1}$
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Pb-Pb	$\sqrt{s_{NN}} = 2.76 \text{ TeV}$	$L = 150 \text{ } \mu\text{b}^{-1}$
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Run 2 (2015)

p-p	$\sqrt{s_{NN}} = 5.02 \text{ TeV}$	$L = 28 \text{ pb}^{-1}$
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Pb-Pb	$\sqrt{s_{NN}} = 5.02 \text{ TeV}$	$L = 460 \text{ } \mu\text{b}^{-1}$
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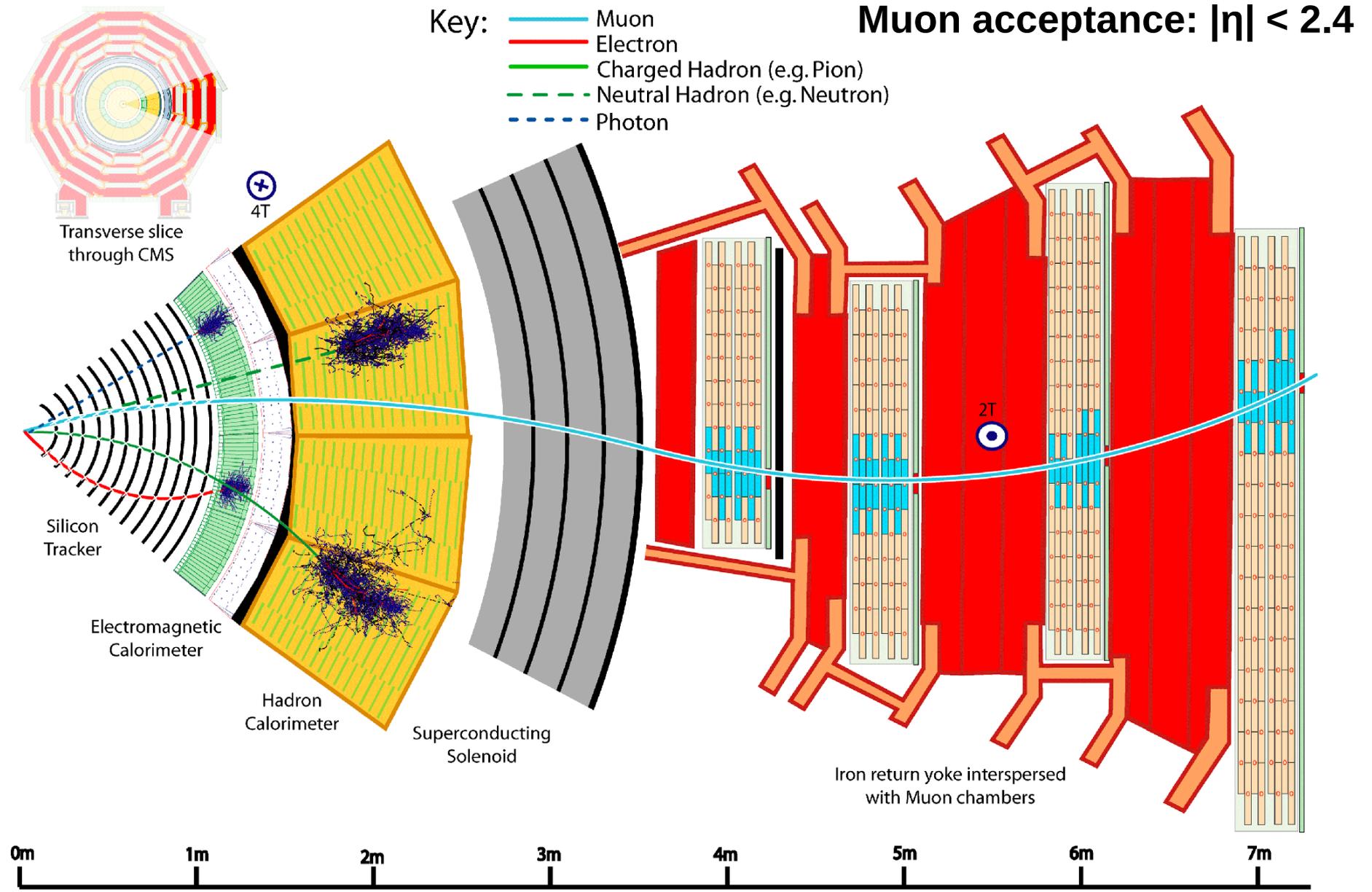
Run 1



Run 2

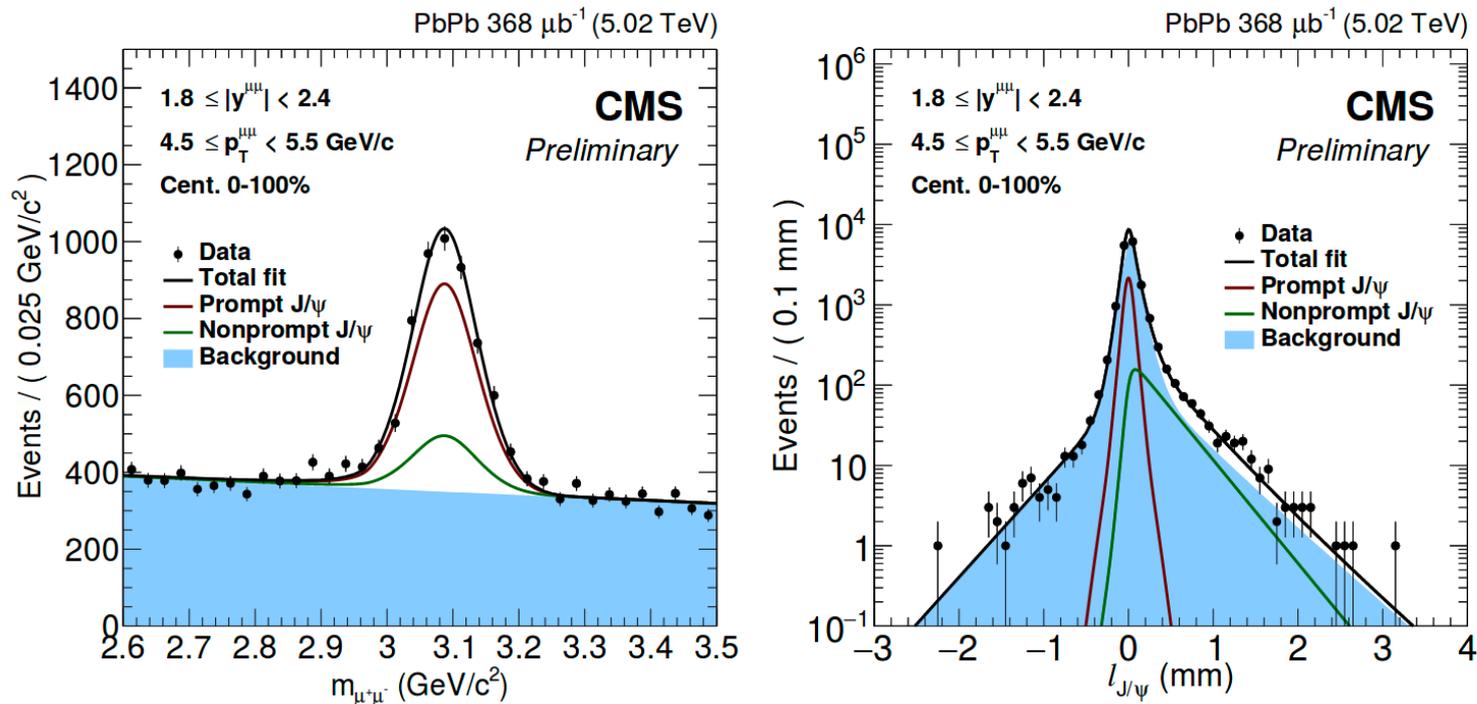
- **~2x increase in Energy**
- **~3x increase in Pb-Pb Luminosity**

CMS Detector



Prompt and Non-Prompt Charmonia

2D fits of the dimuon mass and pseudo-proper decay length

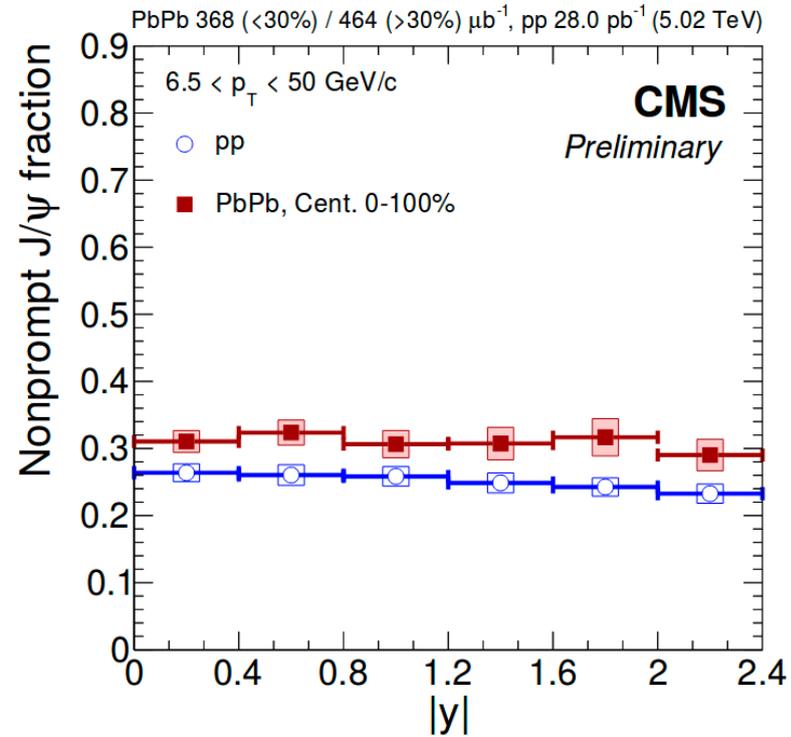
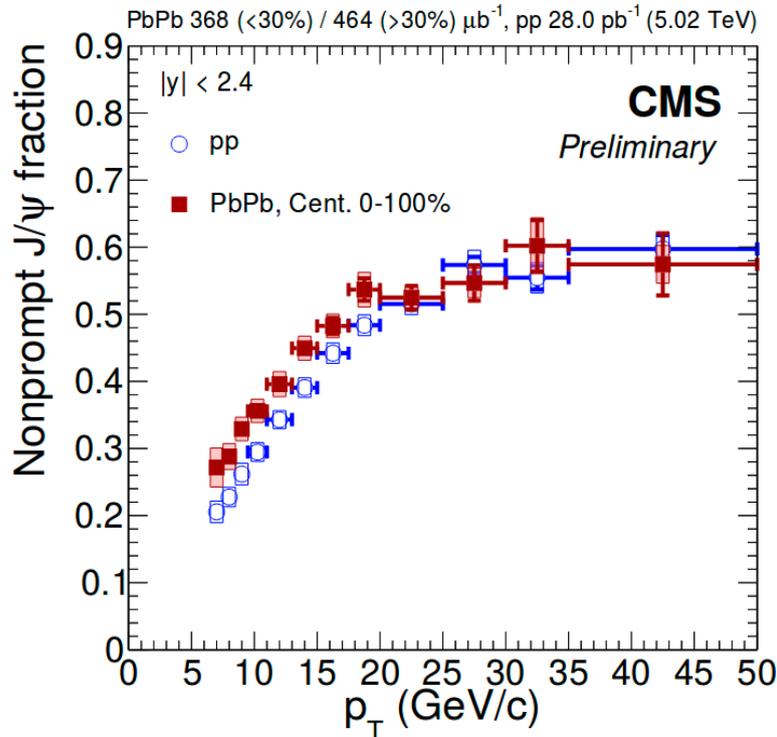


CMS-PAS-HIN-16-025

- Signal:
 - Mass: Two Crystal Ball Functions (Gaussian with power like tail)
 - Decay Length: Exponential Function
- Background:
 - Mass: Polynomial function (between order 1-3)
 - Decay Length: 3 Exponential Functions

Prompt and Non-Prompt Charmonia

2D fits of the dimuon mass and pseudo-proper decay length



CMS-PAS-HIN-16-025

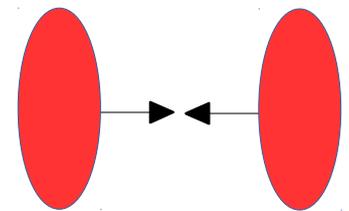
- From the fits we get:
 - Inclusive J/ ψ Yields
 - Nonprompt J/ ψ fraction (also called b fraction)
- Combining the inclusive yields and the b-fractions, we extract the Prompt and Nonprompt J/ ψ yields

Outline:

“Measurement of prompt and nonprompt charmonium suppression in PbPb collisions at 5.02 TeV”

CMS-PAS-HIN-16-025

- Prompt J/ψ in PbPb at 5.02 TeV
- Prompt $\psi(2S)$ PbPb at 5.02 TeV
- Nonprompt J/ψ in PbPb at 5.02 TeV

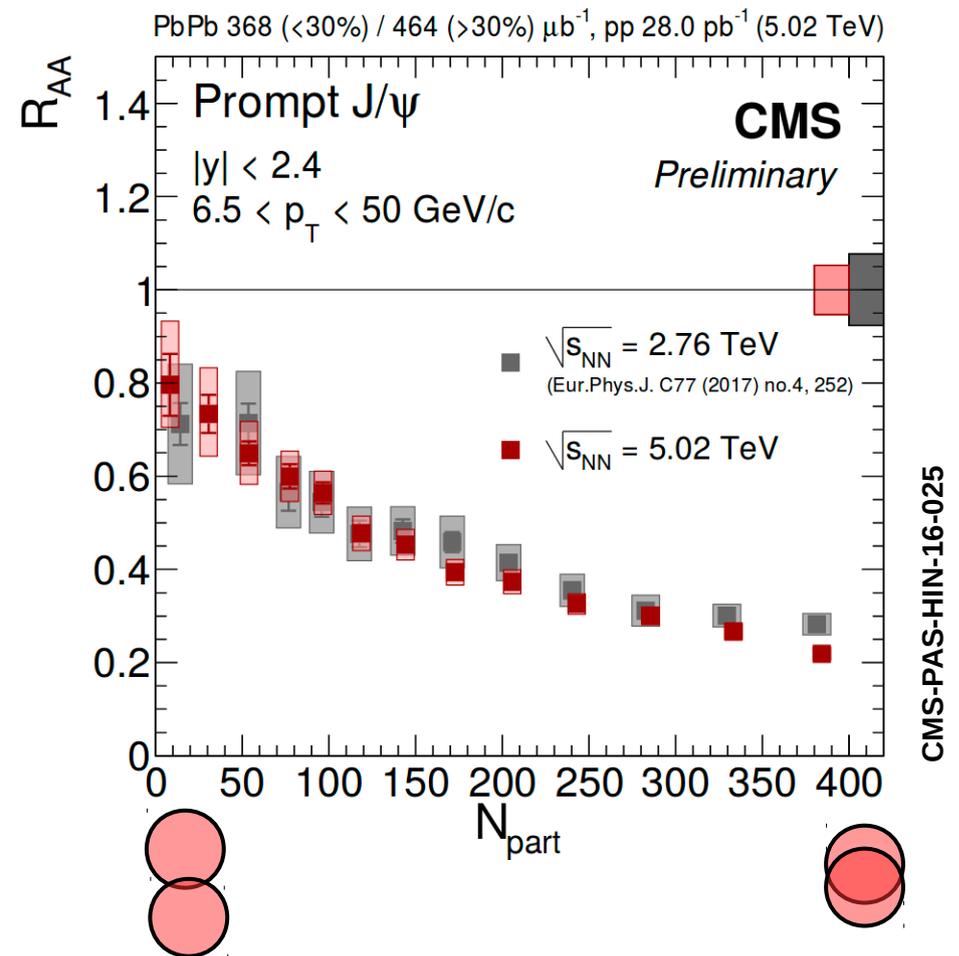
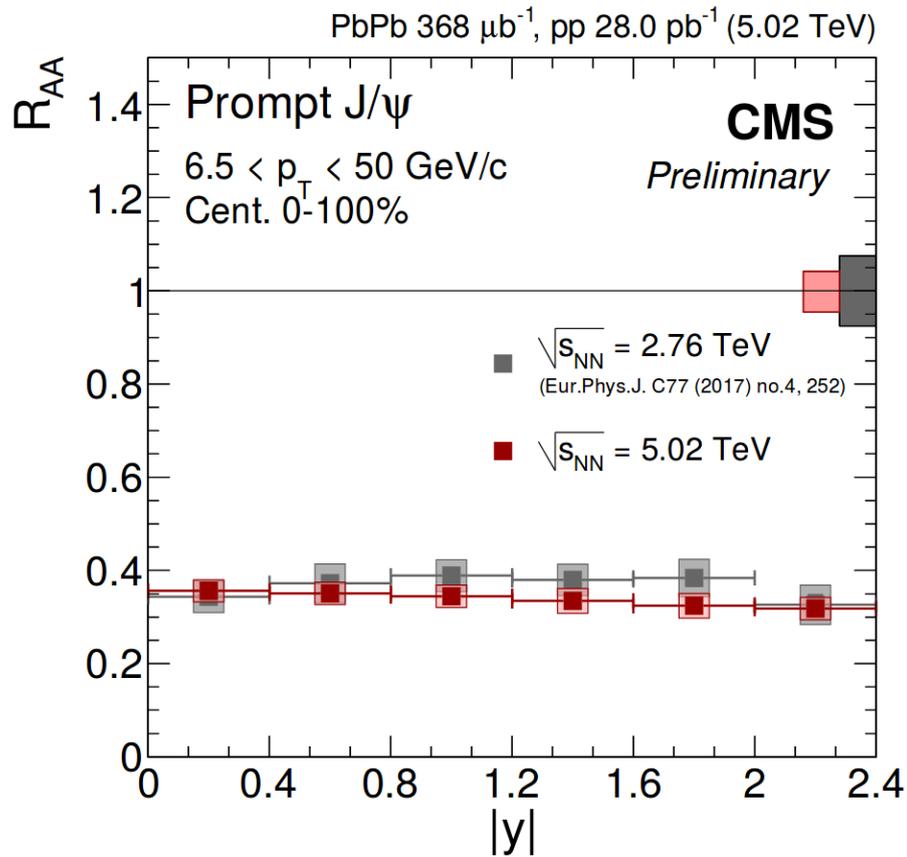


OUTLINE

Prompt J/ψ in PbPb at 5 TeV

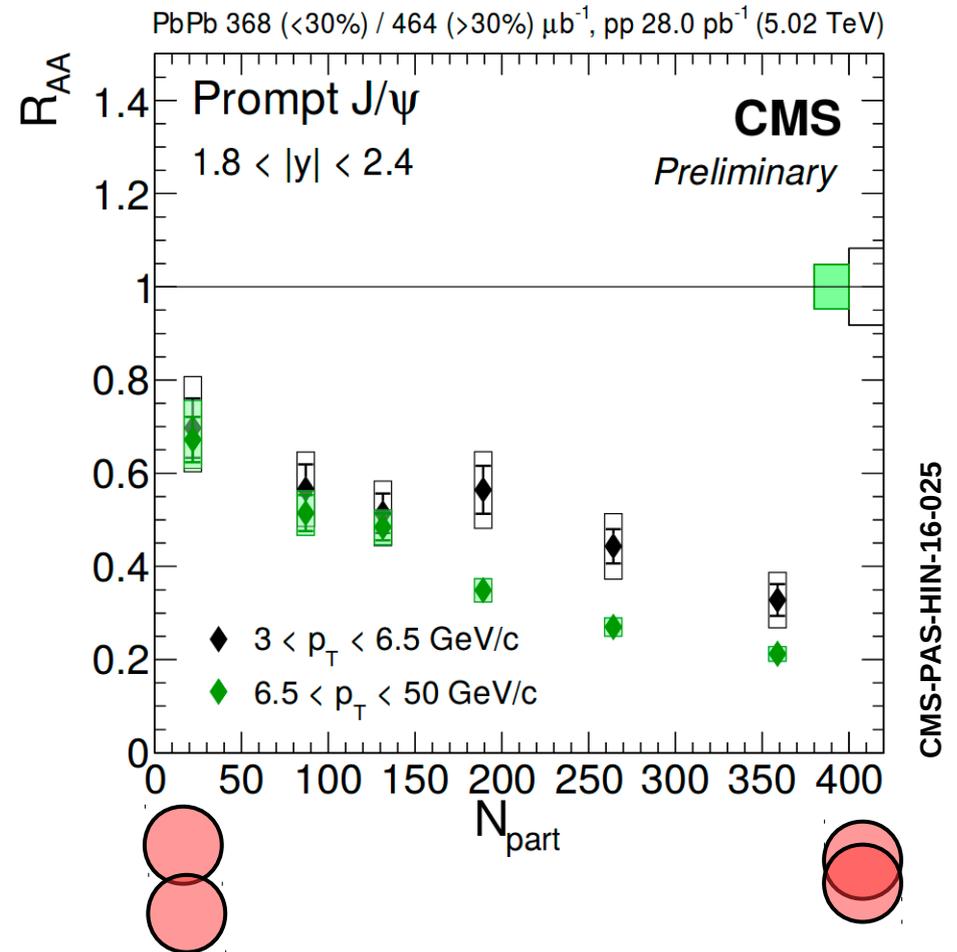
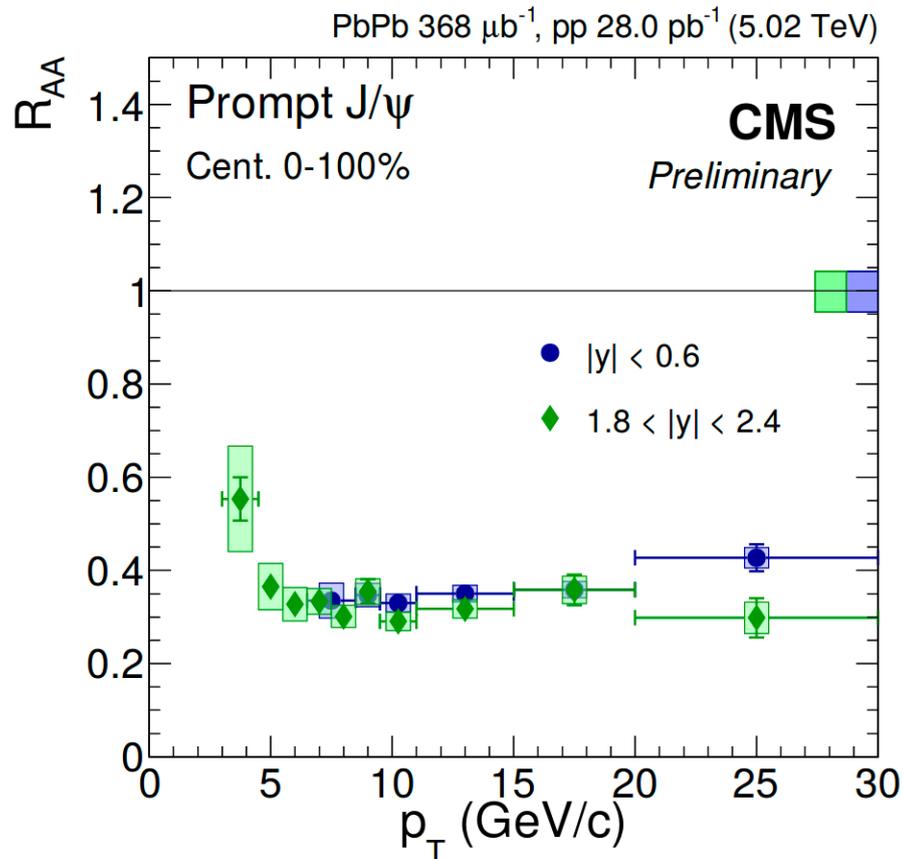


Prompt J/ψ R_{AA}



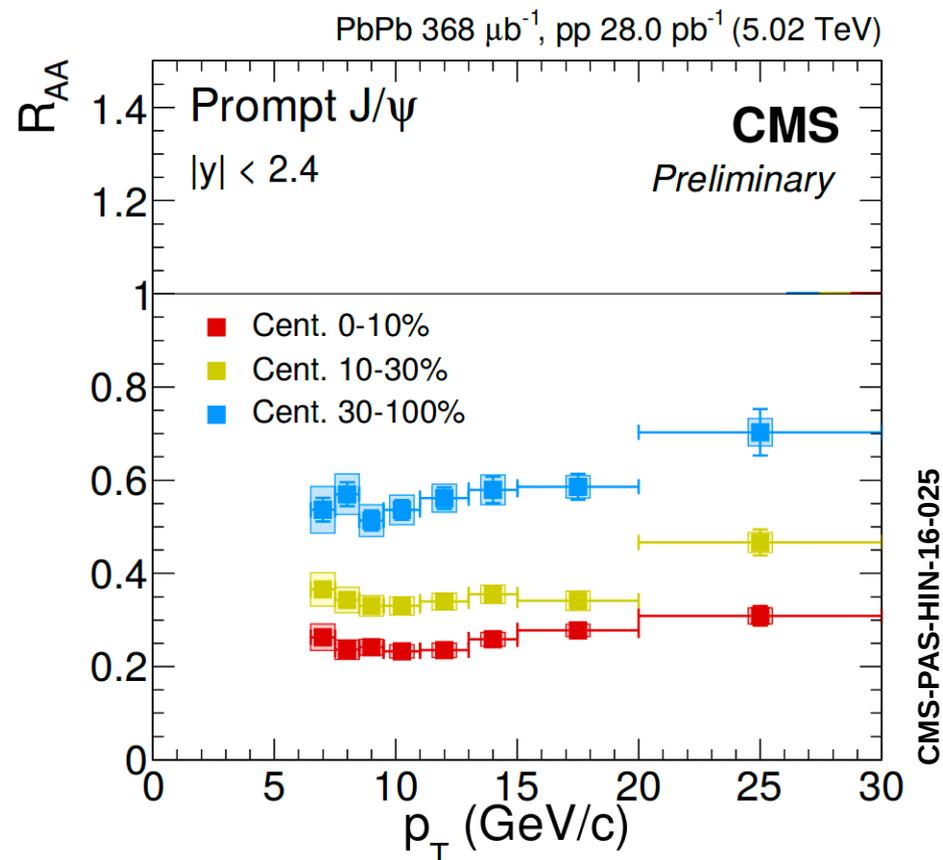
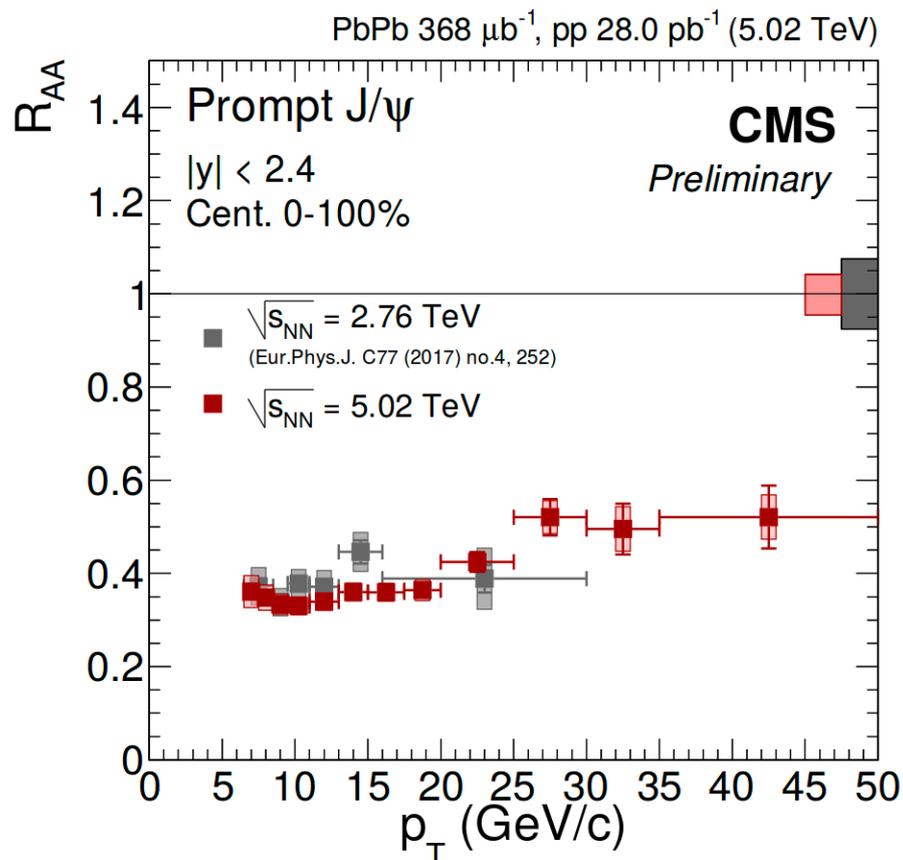
- Similar suppression between 5.02 TeV and 2.76 TeV
- No strong rapidity dependence
- Suppression increases when going to more central events

Prompt J/ψ R_{AA} : Low p_T



- Similar p_T trend for different rapidities bins
- Less suppression at lowest p_T
- Less suppression at lowest p_T for the most central events (cent < 30%)

Prompt J/ψ R_{AA} : High p_T



- Less suppression at high p_T
- Similar p_T trend between different centrality bins

OUTLINE

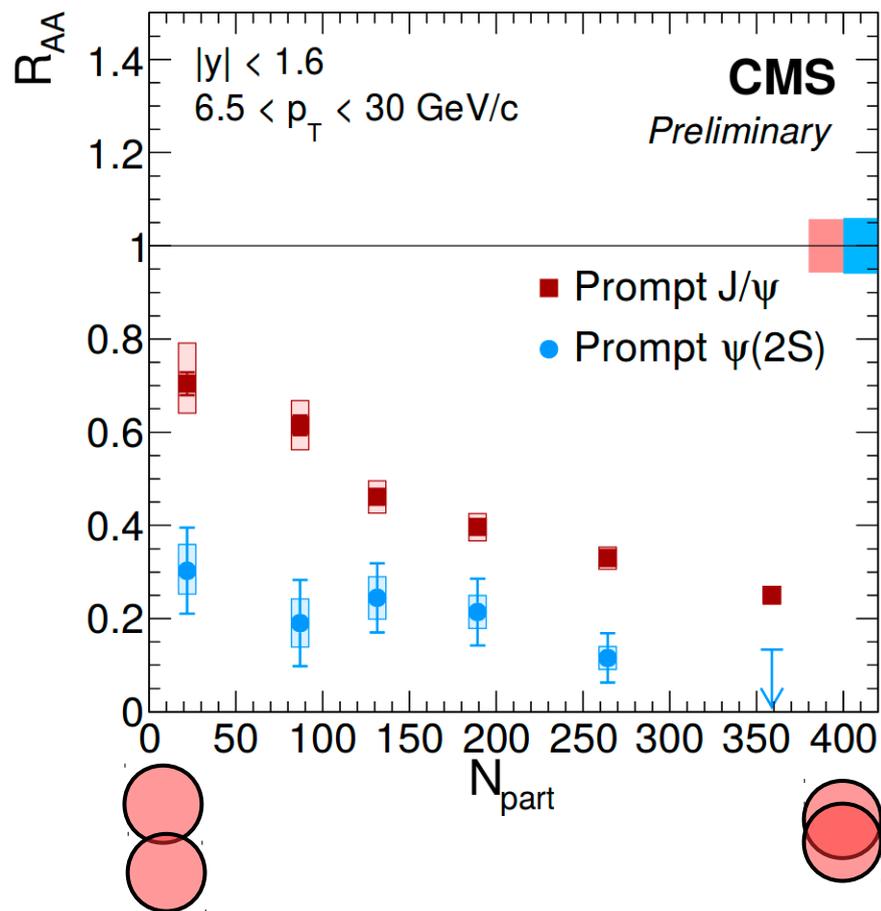
Prompt $\psi(2S)$ in PbPb at 5 TeV



Prompt $\psi(2S)$ R_{AA}

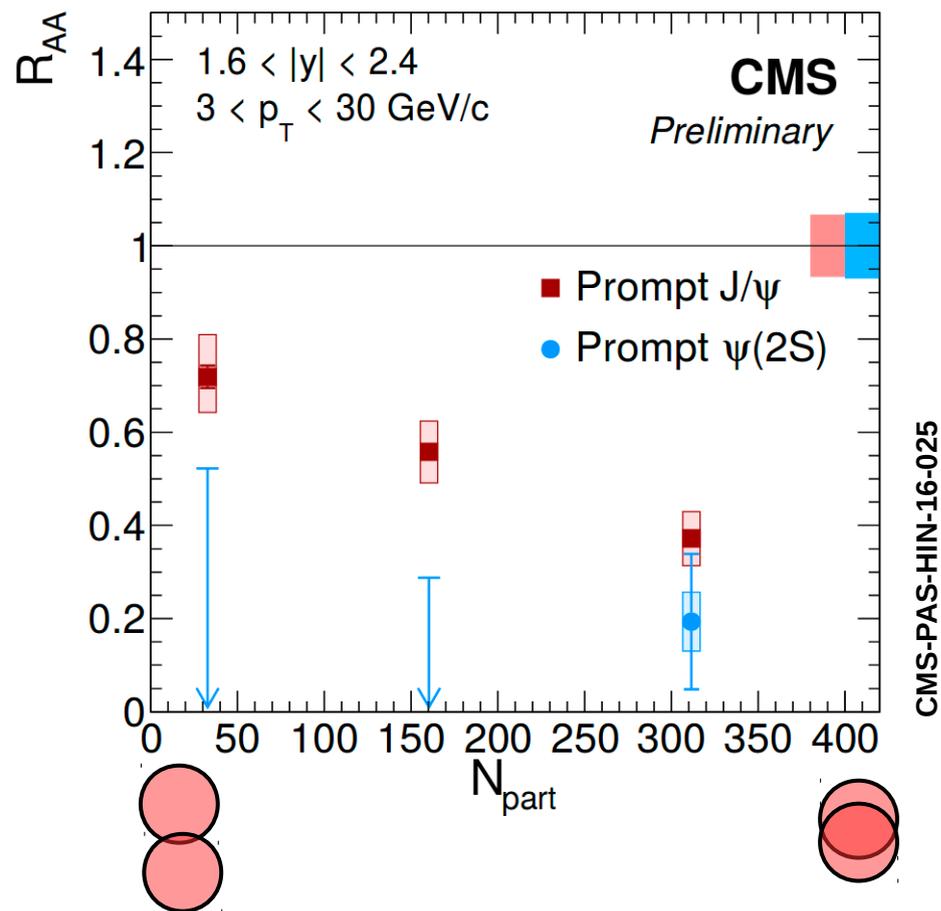
$|y| < 1.6$; $6.5 < p_T < 30$ GeV/c

PbPb 368 μb^{-1} , pp 28.0 pb^{-1} (5.02 TeV)



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

PbPb 368 μb^{-1} , pp 28.0 pb^{-1} (5.02 TeV)



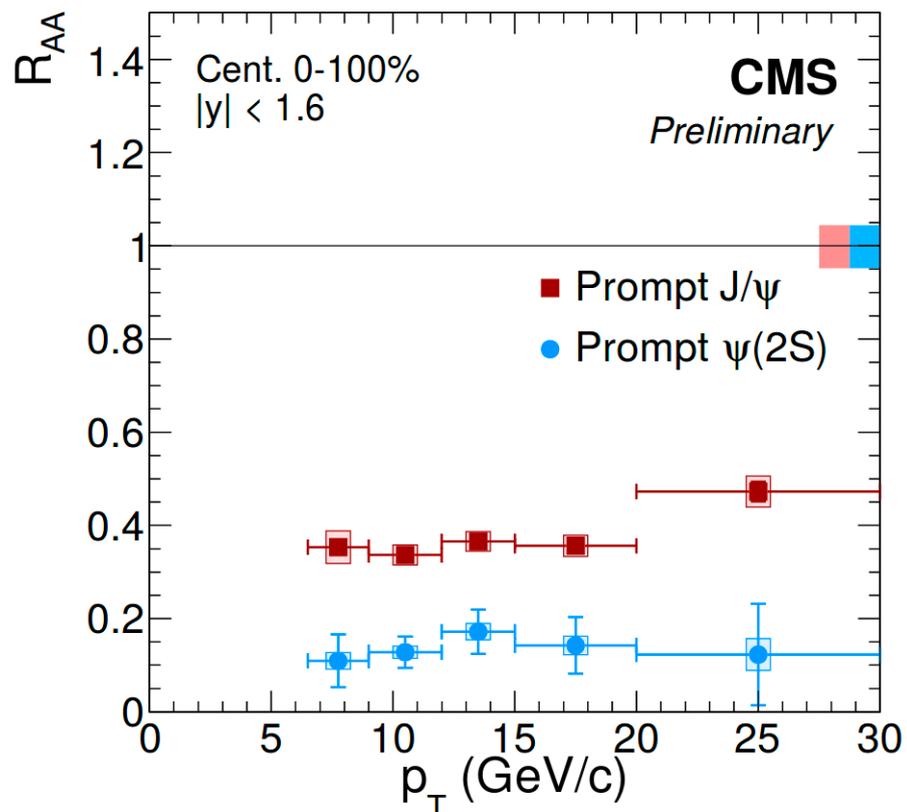
CMS-PAS-HIN-16-025

- Increasing suppression of $\psi(2S)$ towards more central events at high p_T
- Stronger suppression of $\psi(2S)$ than J/ψ in all centrality bins

Prompt $\psi(2S)$ R_{AA}

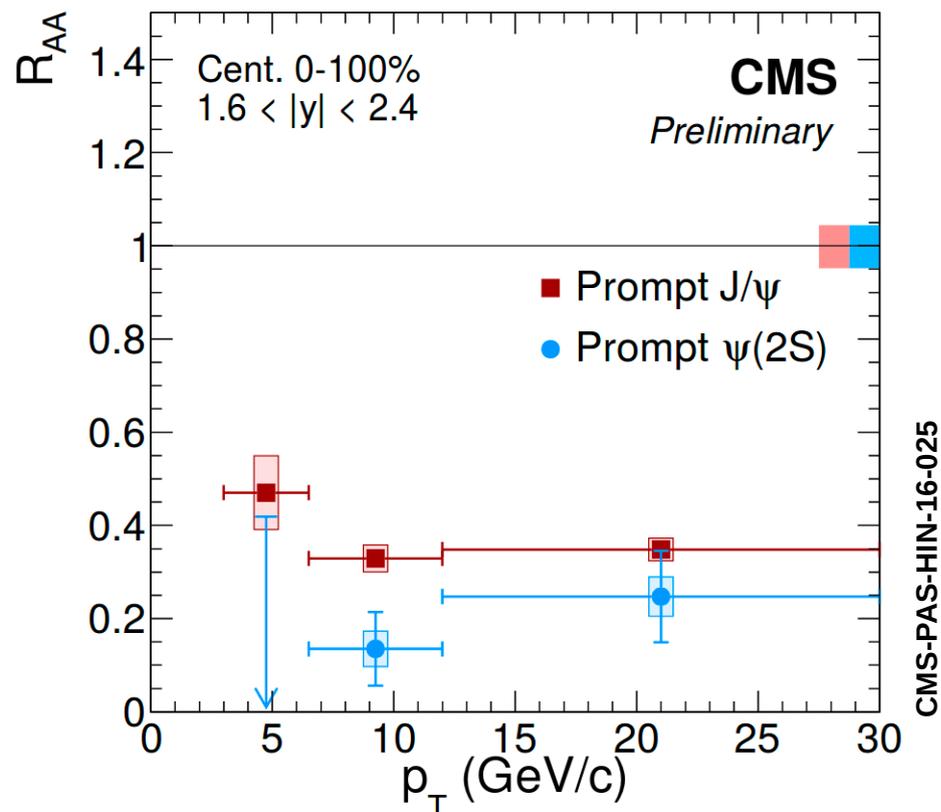
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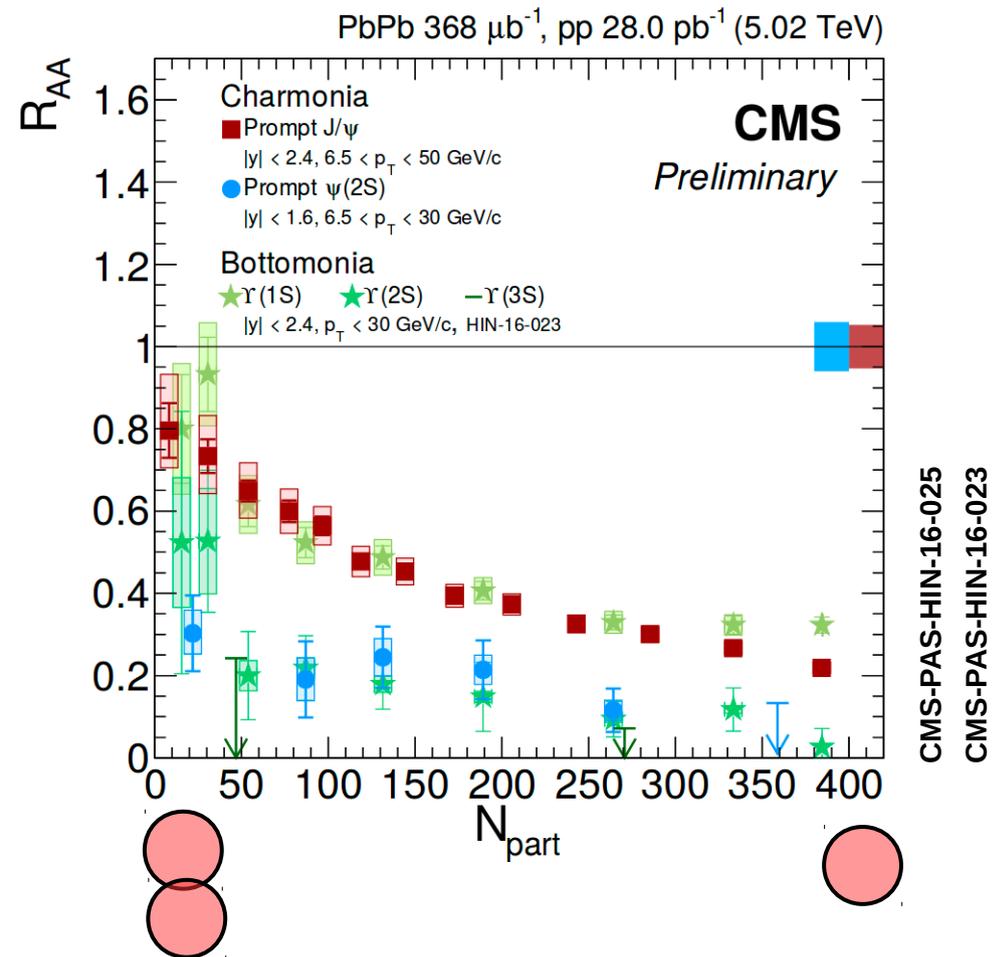
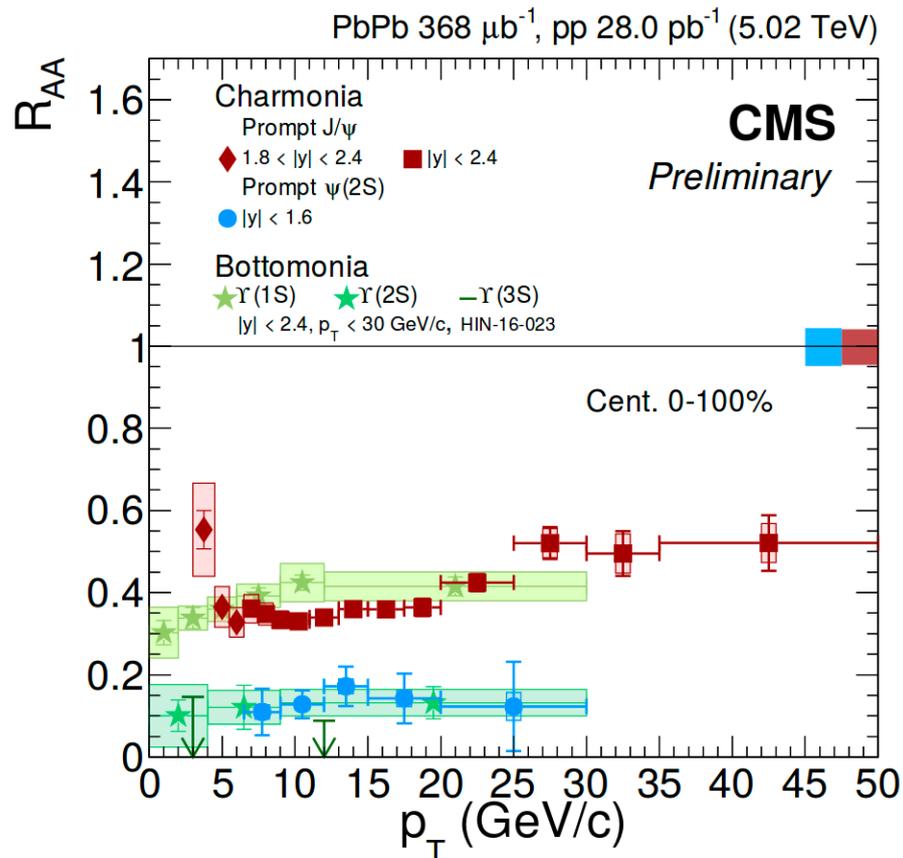
PbPb 368 μb^{-1} , pp 28.0 pb^{-1} (5.02 TeV)



CMS-PAS-HIN-16-025

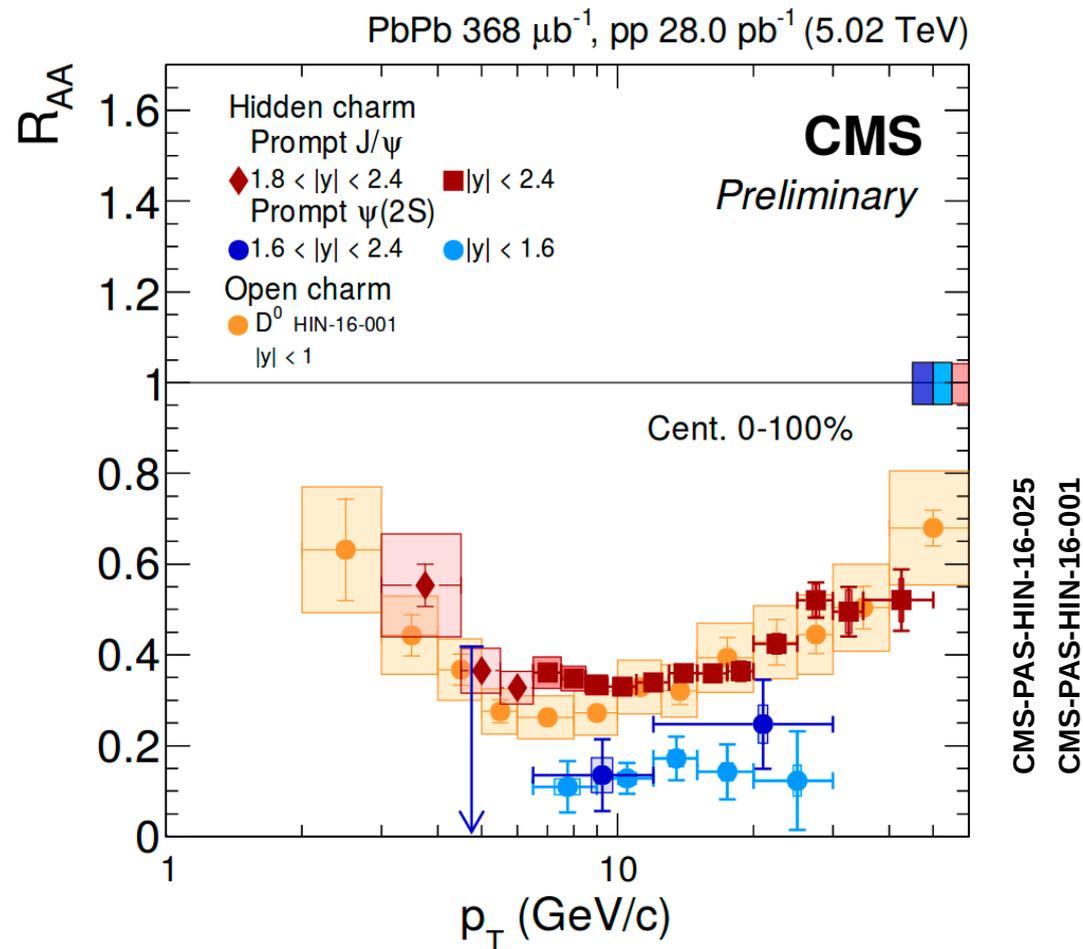
- No strong p_T dependence of $\psi(2S)$ suppression
- Stronger suppression of $\psi(2S)$ than J/ψ in all p_T bins

Charmonium vs Bottomonium



- Similar suppression between $\psi(2S)$ and $\Upsilon(2S)$, versus p_T and centrality
- Hint of less suppression of J/ψ compared to $\Upsilon(1S)$ at lowest p_T

Open vs Hidden Charm



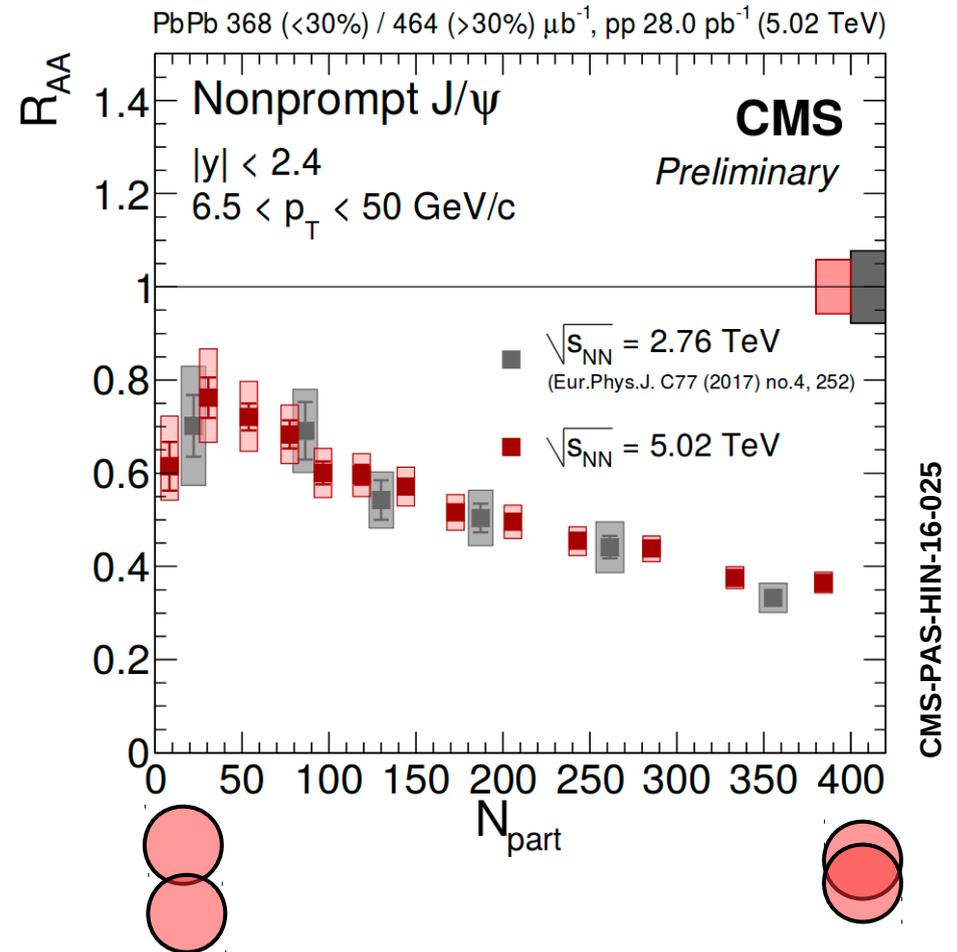
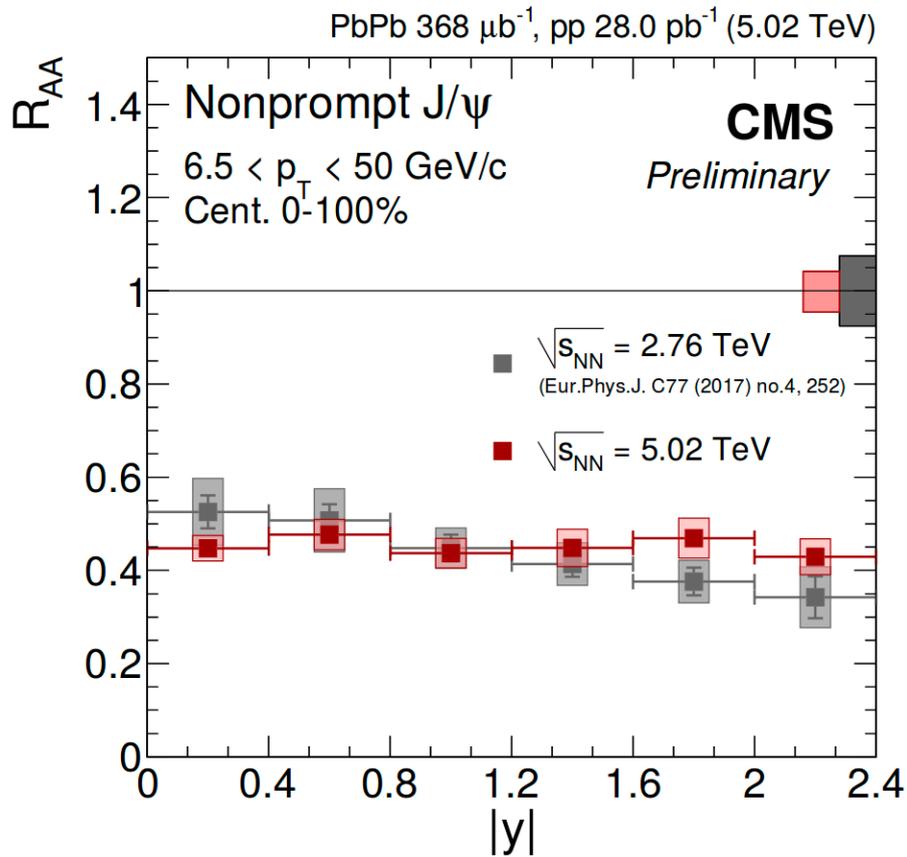
- Similar R_{AA} trend between prompt J/ψ and D^0 R_{AA}
 - E_{loss} contribution to charmonium suppression?
- $\psi(2S)$ still more suppressed up to $p_T = 30$ GeV/c

OUTLINE

Nonprompt J/ψ in PbPb at 5 TeV

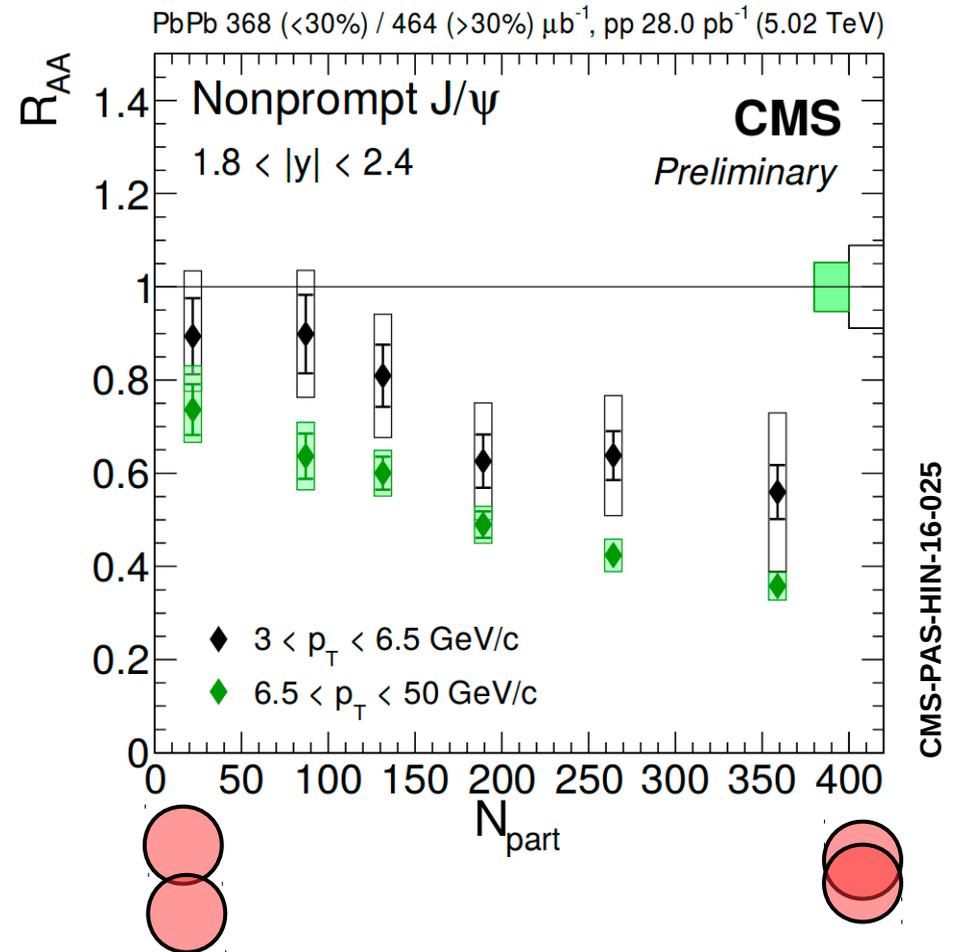
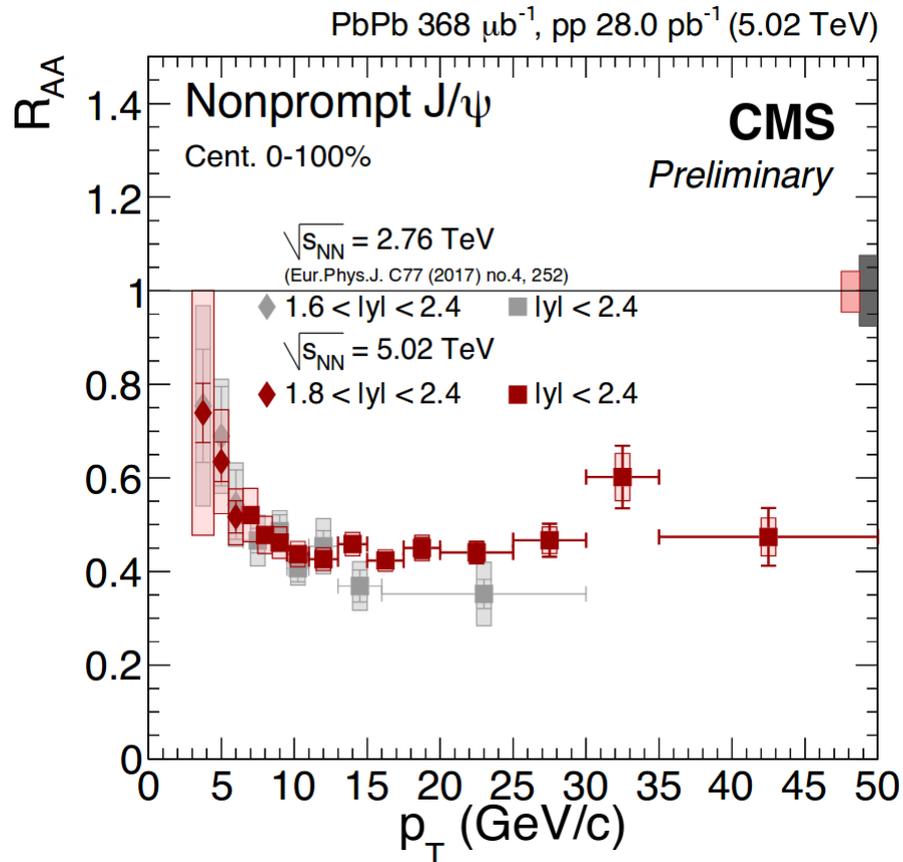


Nonprompt J/ψ R_{AA}



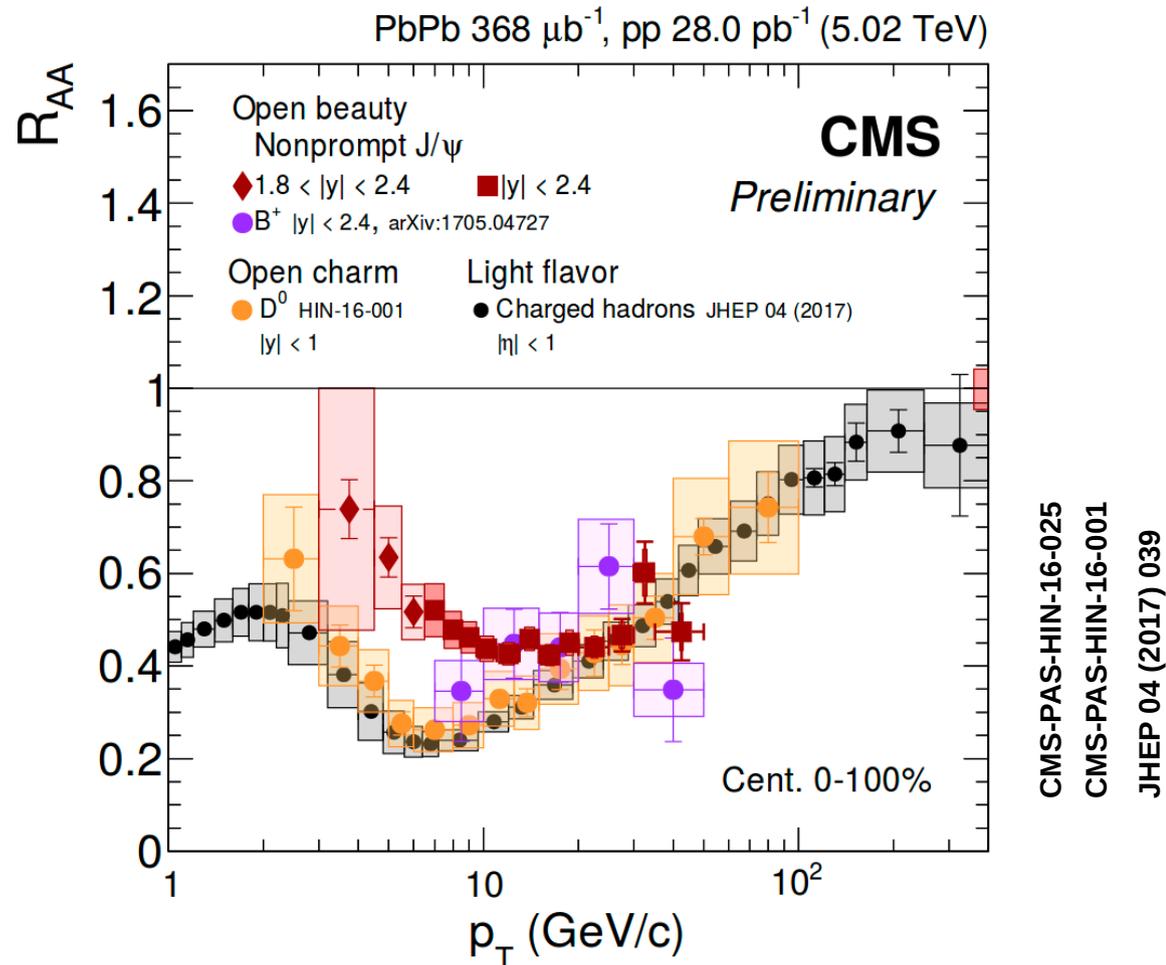
- Similar suppression between 2.76 TeV and 5.02 TeV
- No strong rapidity dependence at 5.02 TeV
- Increasing suppression towards more central events

Nonprompt J/ψ R_{AA}



- Similar suppression between 2.76 TeV and 5.02 TeV
- Hint of less suppression at lowest p_T , while no clear p_T dependence at high p_T
- Slight less suppression at the lowest p_T in all centrality bins

Flavour Dependence of E_{loss}

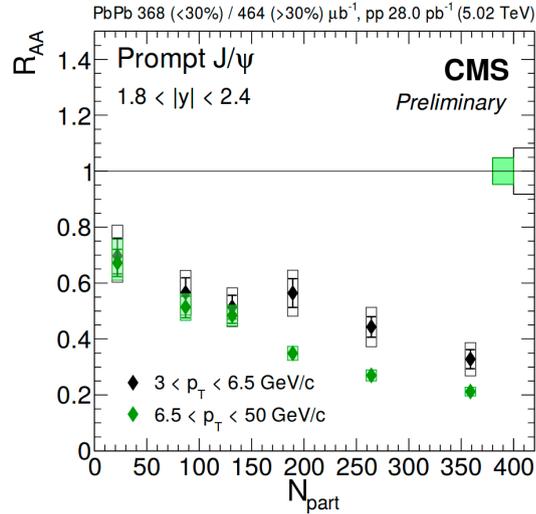


- **High p_T :** Similar suppression between D^0 , light hadrons and nonprompt J/ψ
 - **Universal trend of E_{loss} at high p_T ?**
- **Low p_T :** hints of $R_{AA}(B \rightarrow J/\psi) > R_{AA}(D^0) \sim R_{AA}(\text{light hadrons})$
 - **Smaller E_{loss} of b quarks at low p_T ?**

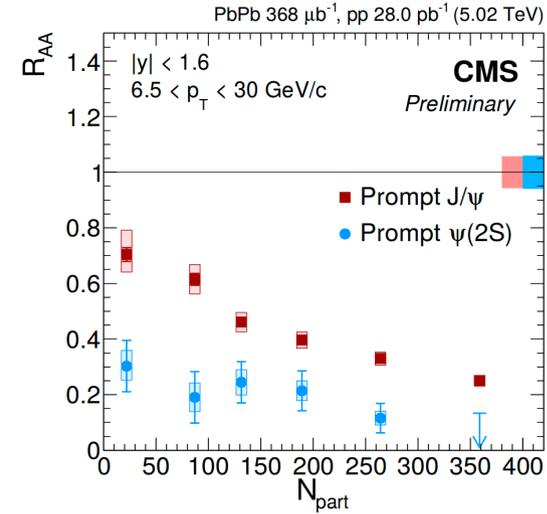
SUMMARY

Probing Hot Nuclear Matter Effects:

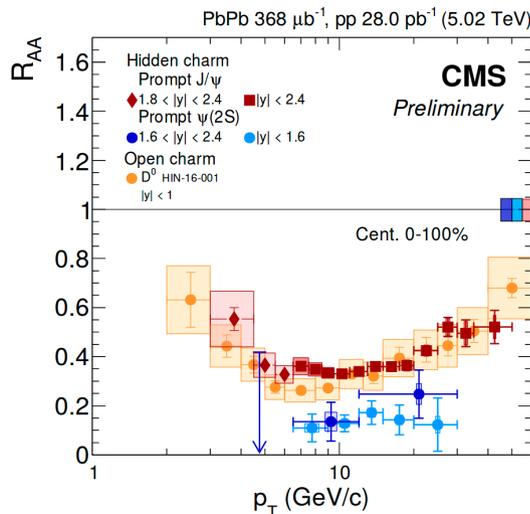
Less prompt J/ψ suppression at lowest p_T



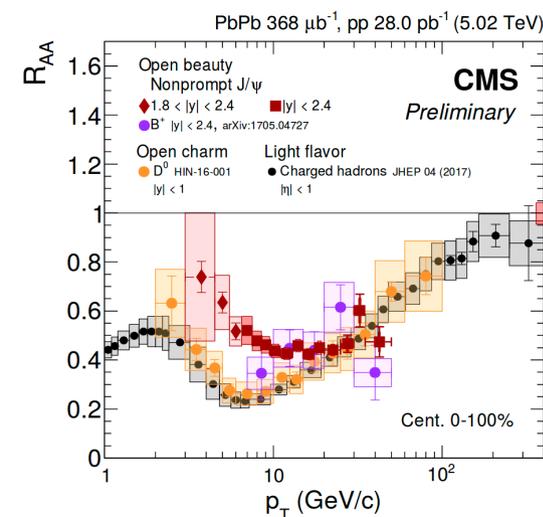
Prompt ψ(2S) more suppressed than J/ψ



E_{loss} in charmonium suppression?



Flavour dependence of E_{loss}?



Stay tuned for more future CMS results!

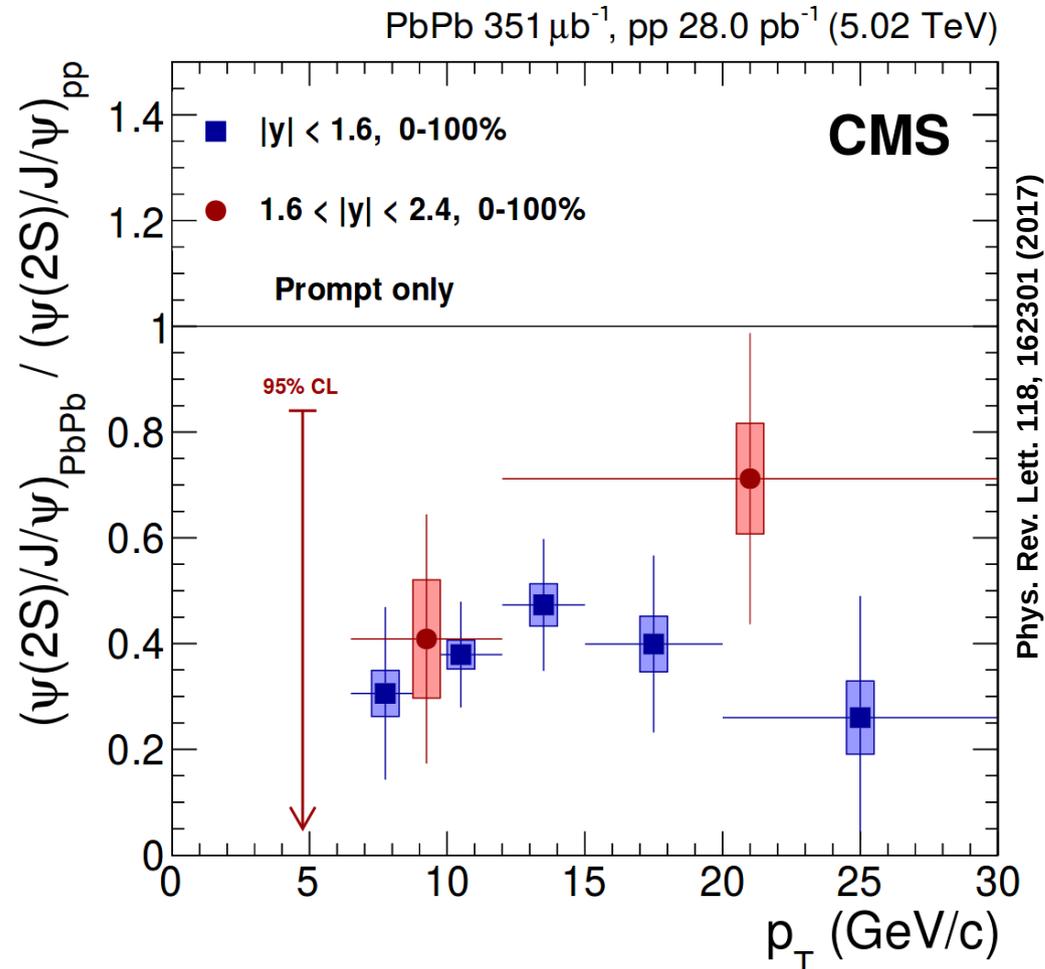
Thank you for your attention!



BACKUP



Ratio of $\psi(2S) / J/\psi R_{AA}$ vs p_T



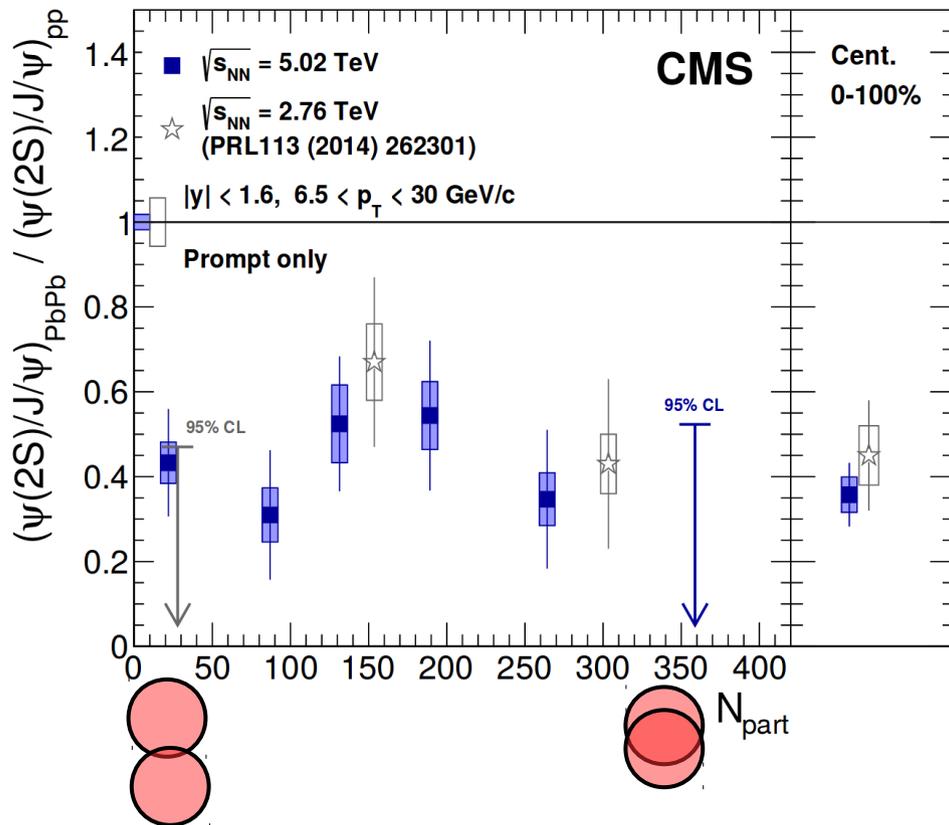
- $R_{AA}(\psi(2S)) / R_{AA}(J/\psi) < 1$ in all bins \rightarrow **$\psi(2S)$ is more suppressed than J/ψ**
- No p_T dependence within uncertainties

$\psi(2S) / J/\psi$ vs Centrality

2.76 vs. 5.02 TeV

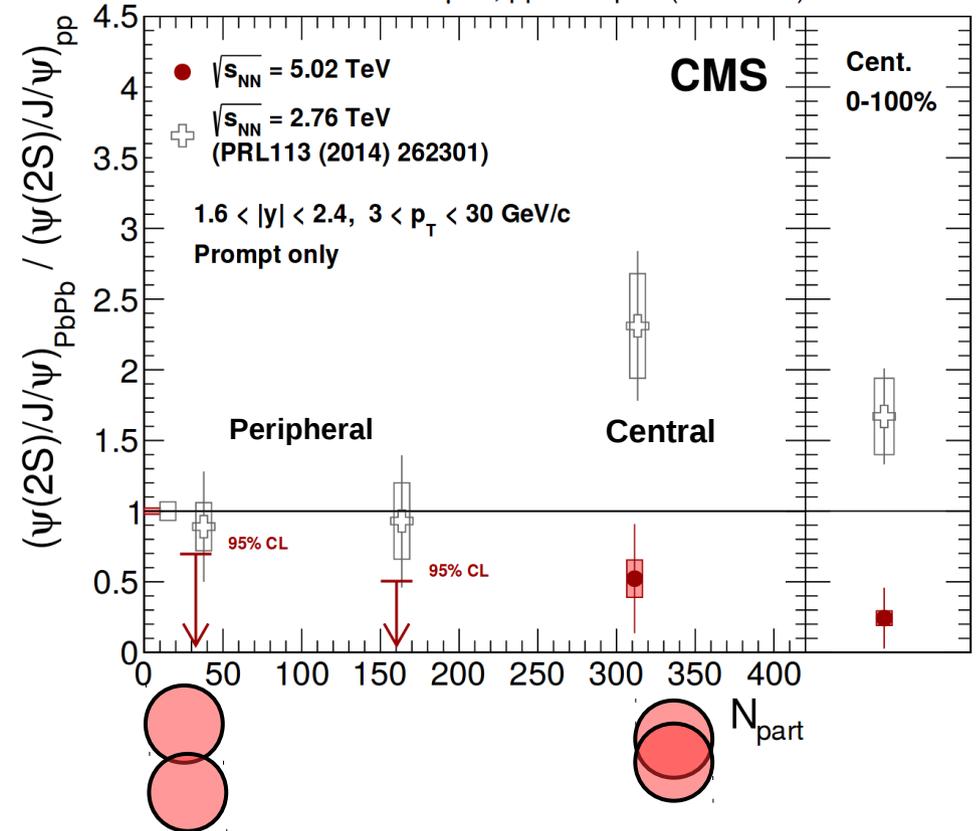
$|y| < 1.6 ; 6.5 < p_T < 30 \text{ GeV}/c$

PbPb $351 \mu\text{b}^{-1}$, pp 28.0 pb^{-1} (5.02 TeV)



$1.6 < |y| < 2.4 ; 3 < p_T < 30 \text{ GeV}/c$

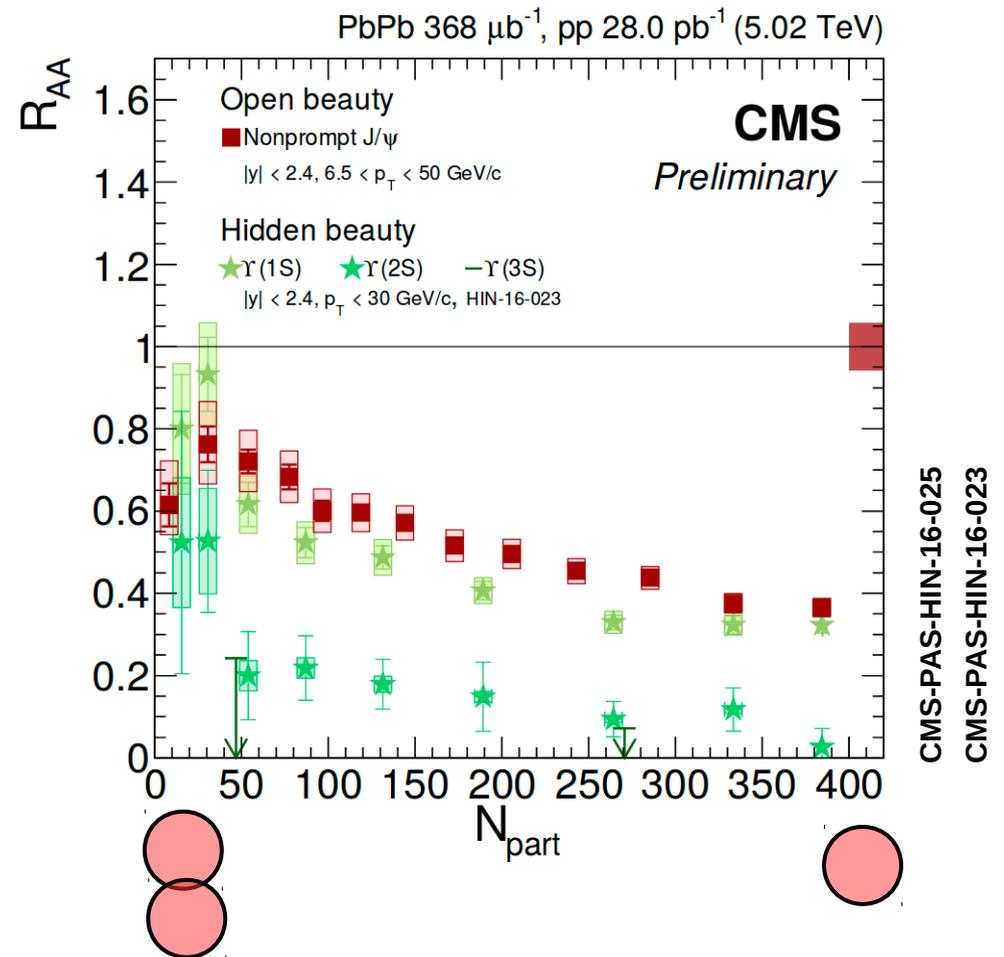
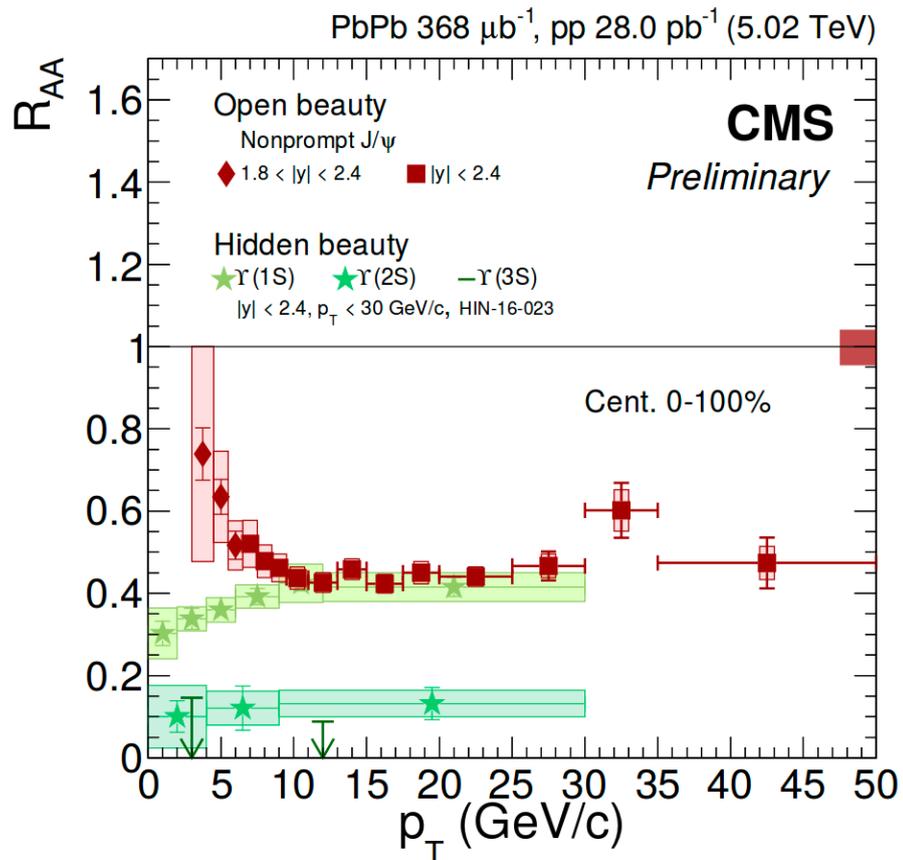
PbPb $351 \mu\text{b}^{-1}$, pp 28.0 pb^{-1} (5.02 TeV)



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

- $\psi(2S)$ 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 $1.6 < y < 2.4$, $3 < p_T < 30 \text{ GeV}/c$, especially for most central collisions (~ 3 s.d. in 0-100%)

Open vs Hidden Beauty



- Similar suppression between $\psi(2S)$ and $\Upsilon(2S)$, versus p_T and centrality
- Hint of less suppression of J/ ψ compared to $\Upsilon(1S)$ at lowest p_T