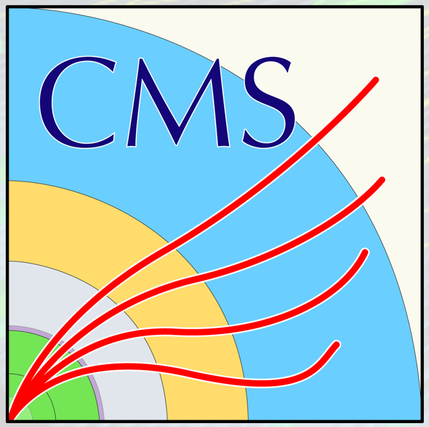
Measurement of the multiplicity dependence of charm hadron production in pPb collisions with CMS



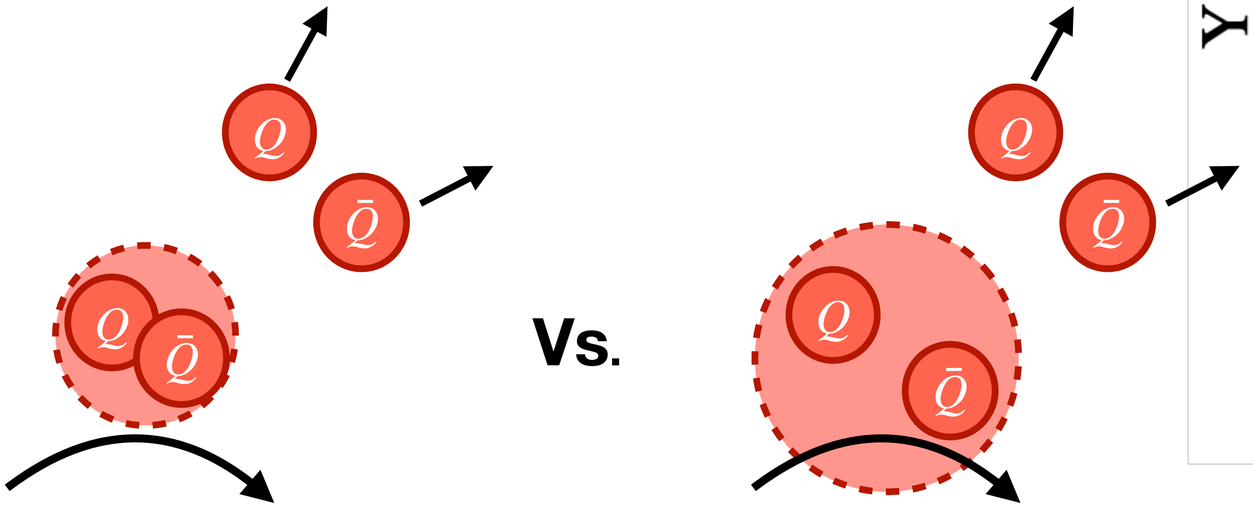
Austin Baty
for the CMS Collaboration

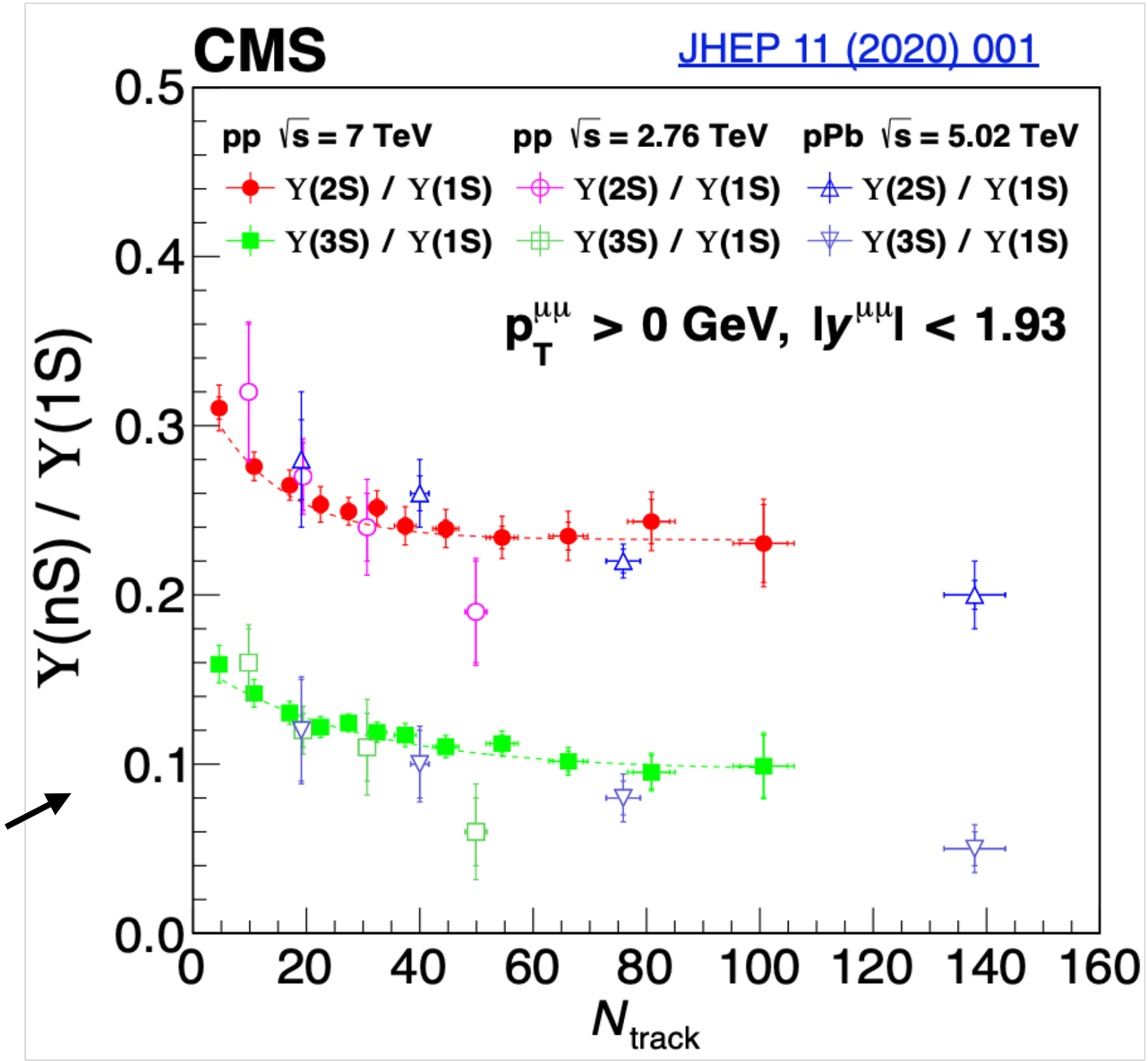
June 4, 2024
SQM 2024
Strasbourg, France

UNIVERSITY OF
ILLINOIS CHICAGO

Suppression of quarkonia excited states

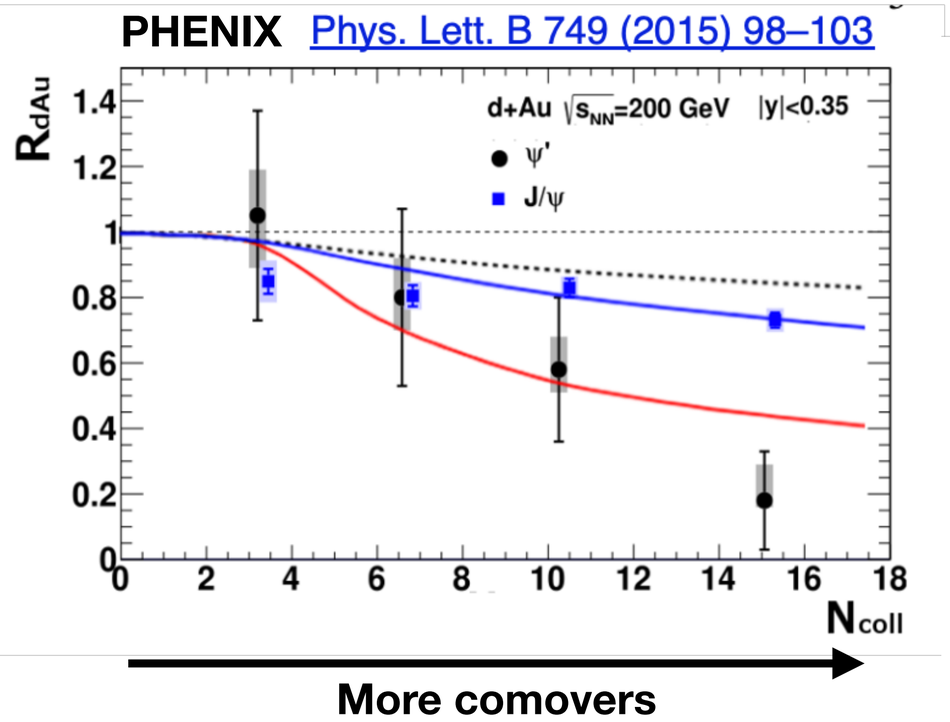
- Quarkonia suppressed in AA collisions
- Suppression of excited states also seen in small systems
- Co-moving particles break up excited states more easily than ground states?
  - Studies of Υ(nS) support this picture
  - Suppression should scale with comover density





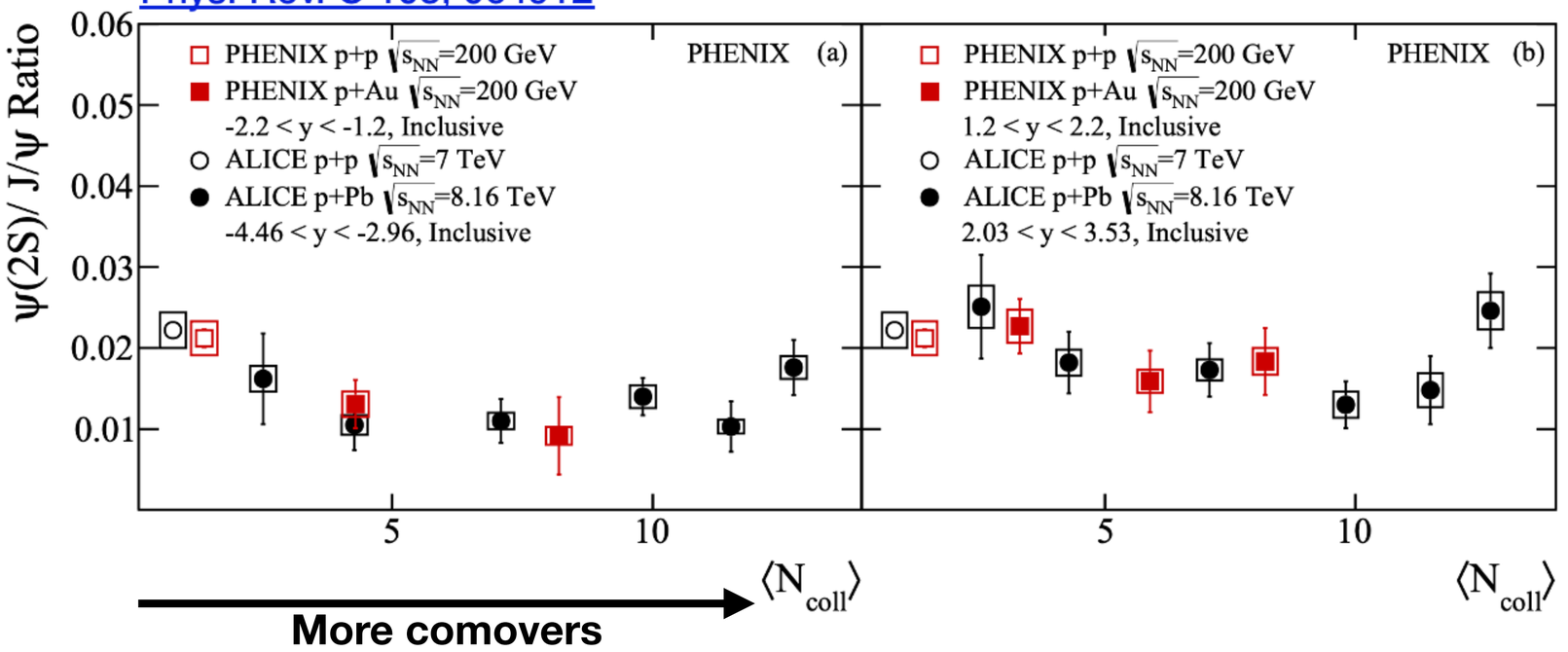
Studies of charmonia

PHENIX Phys. Lett. B 749 (2015) 98–103



More comovers

Phys. Rev. C 105, 064912



More comovers

- **What about charmonia? - weakly bound excited state**
  - **Should be more sensitive to comover effects**

- **Initial studies performed in pAu, dAu, pPb vs N_{col} inconclusive**

Recent measurements

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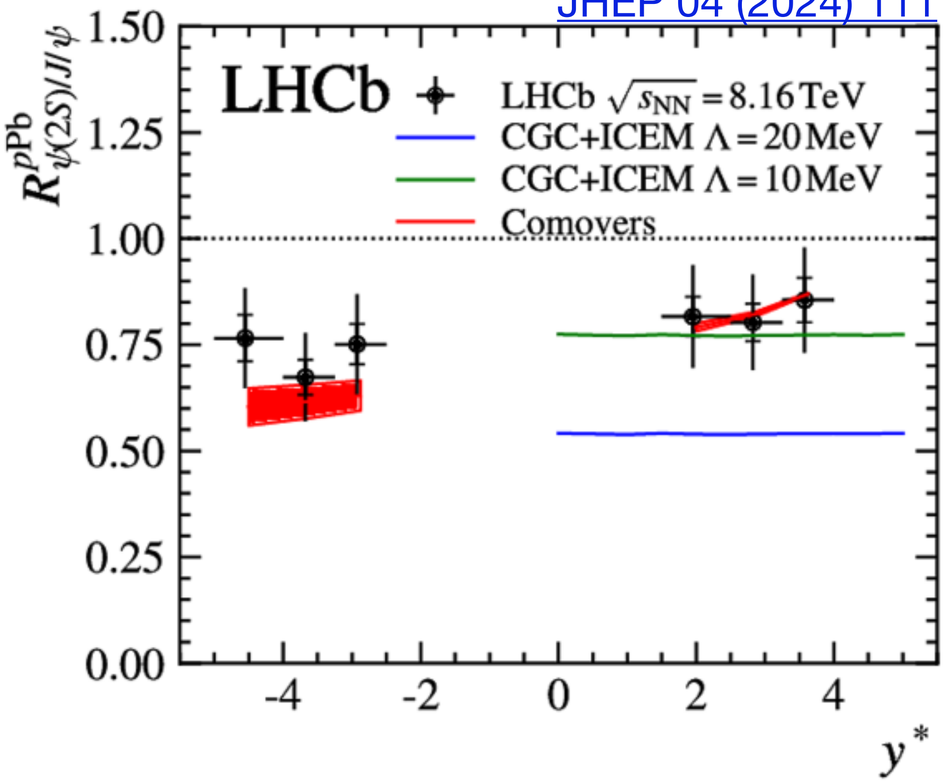

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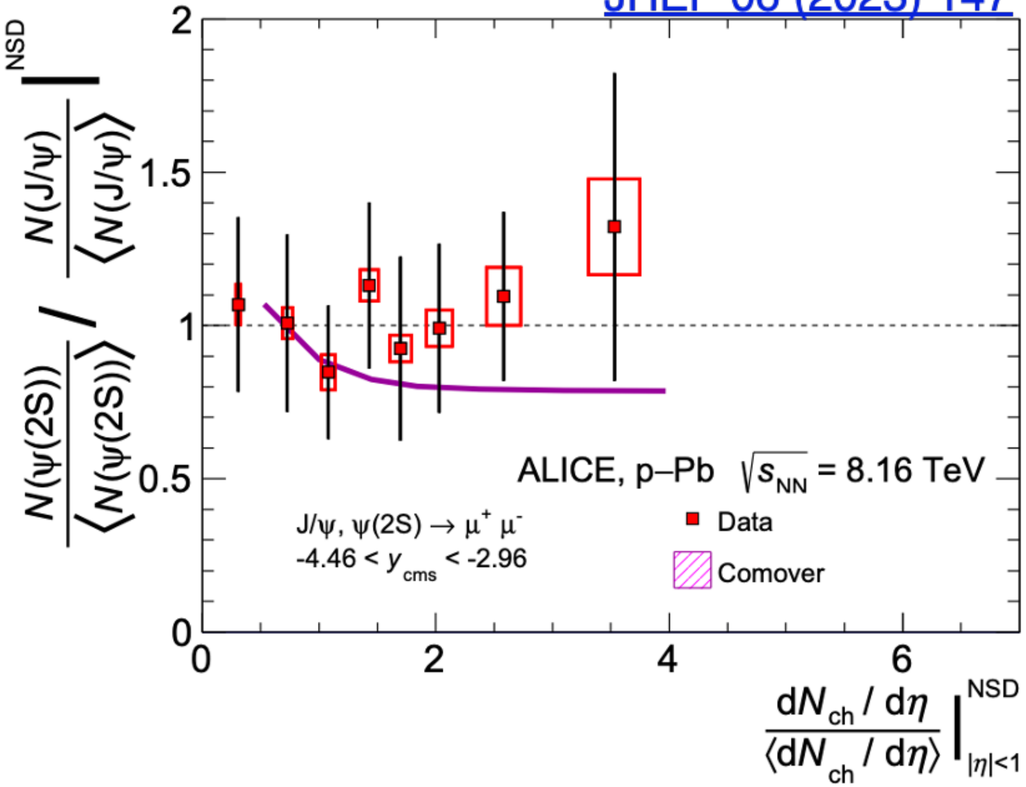
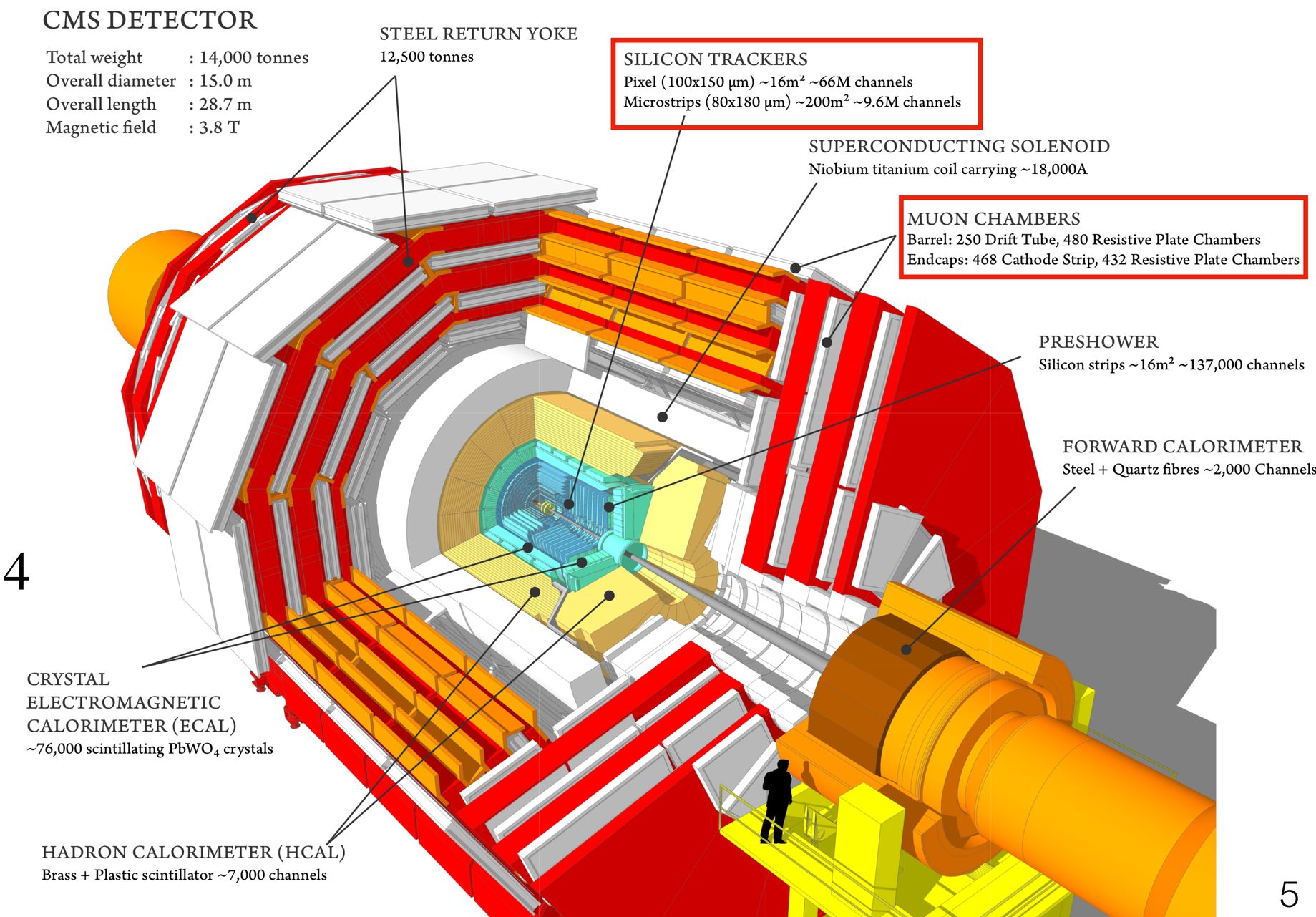


- **LHCb measurements - rapidity dependence of excited state suppression?**
- **ALICE measurements - study dependence on comover density directly**
- **Interpretation limited by large uncertainties in both cases**
  - **Comover effect expected only for prompt charmonia**
  - **Need prompt/non-prompt separation!**

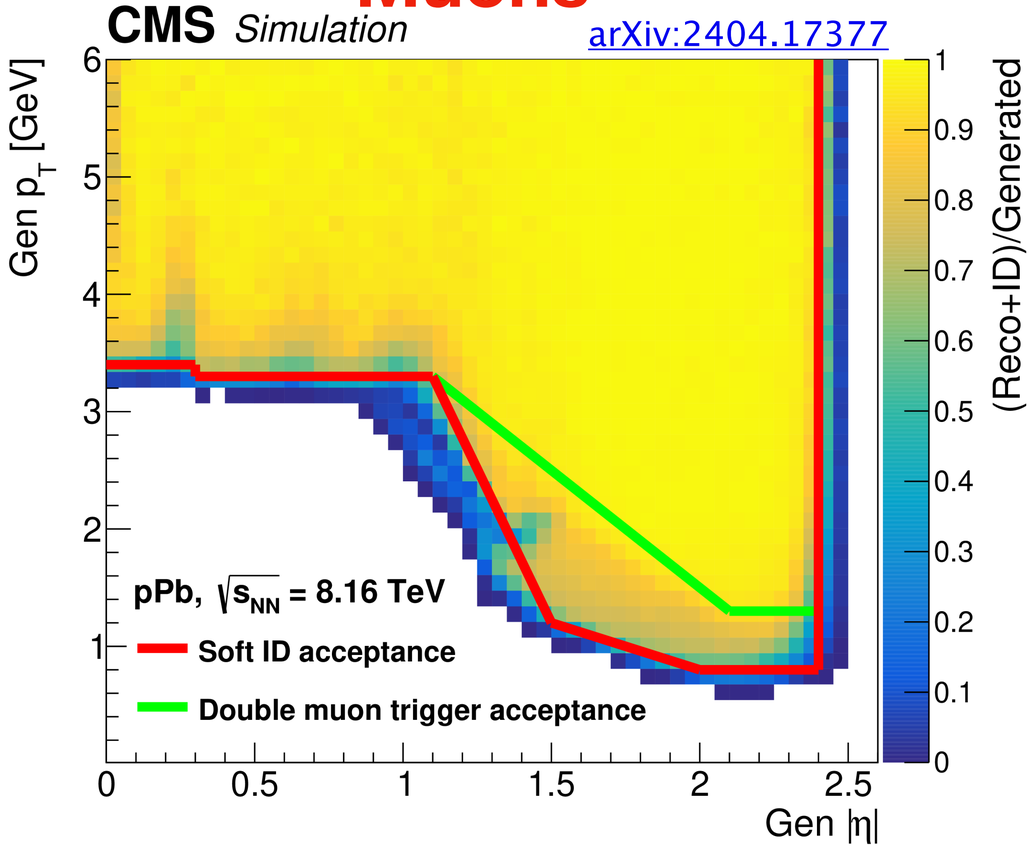
Detector and dataset

- **8.16 TeV pPb data**
- **175 nb^{-1}**
- **Dimuon trigger**
- **Charged hadron multiplicity, N_{trk}^{corr} measured in $|\eta| < 2.4$ and $p_T > 0.4$ GeV**

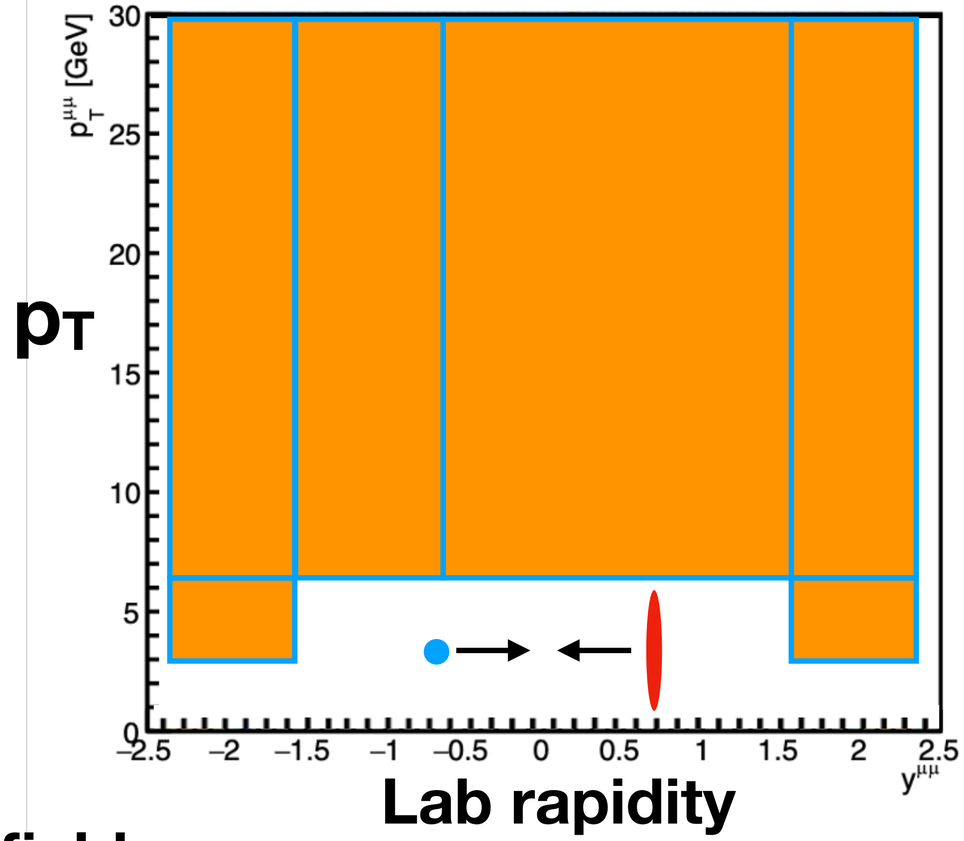


Muon and dimuon acceptance

Muons

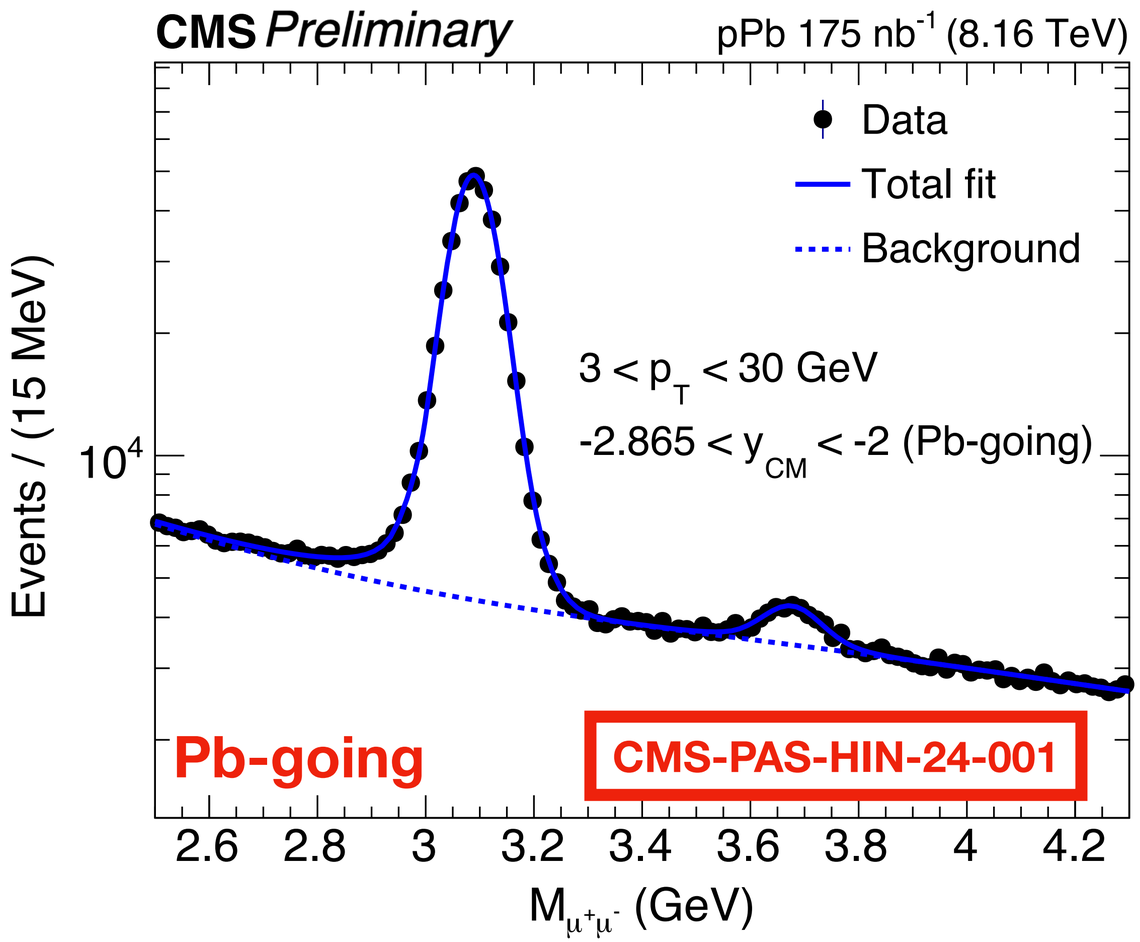


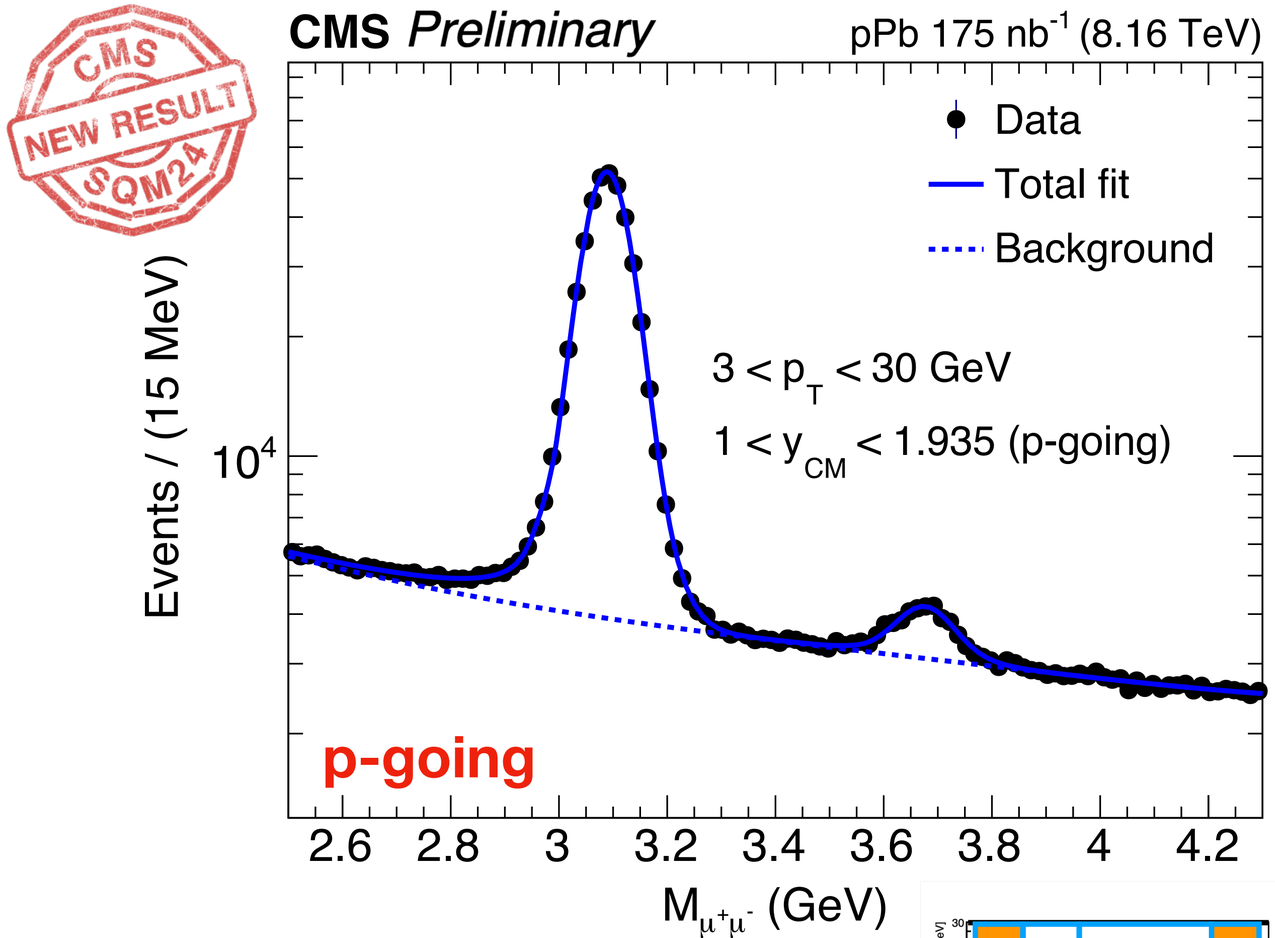
Dimuons



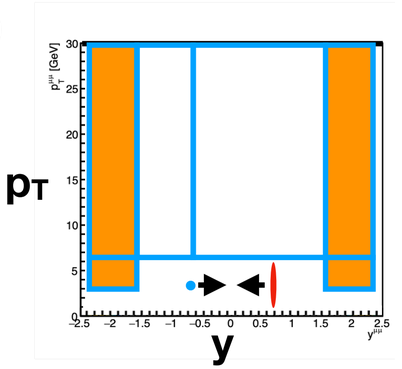
- **Midrapidity muon acceptance limited by B field**
- **Analysis performed in 6 bins within dimuon acceptance**
  - **High-p_T (6.5-30 GeV) across all rapidity**
  - **Low-p_T (3-6.5 GeV) only in endcaps**

Invariant mass peaks





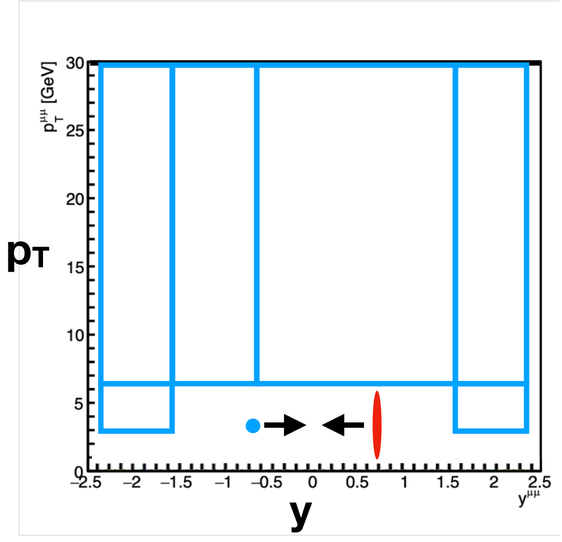
- **Clear J/ψ and $\psi(2S)$ peaks in both forward/backward regions**
- **Analysis mainly limited by $\psi(2S)$ statistics**
  - **Prompt/non-prompt components separated w/ decay length cuts**

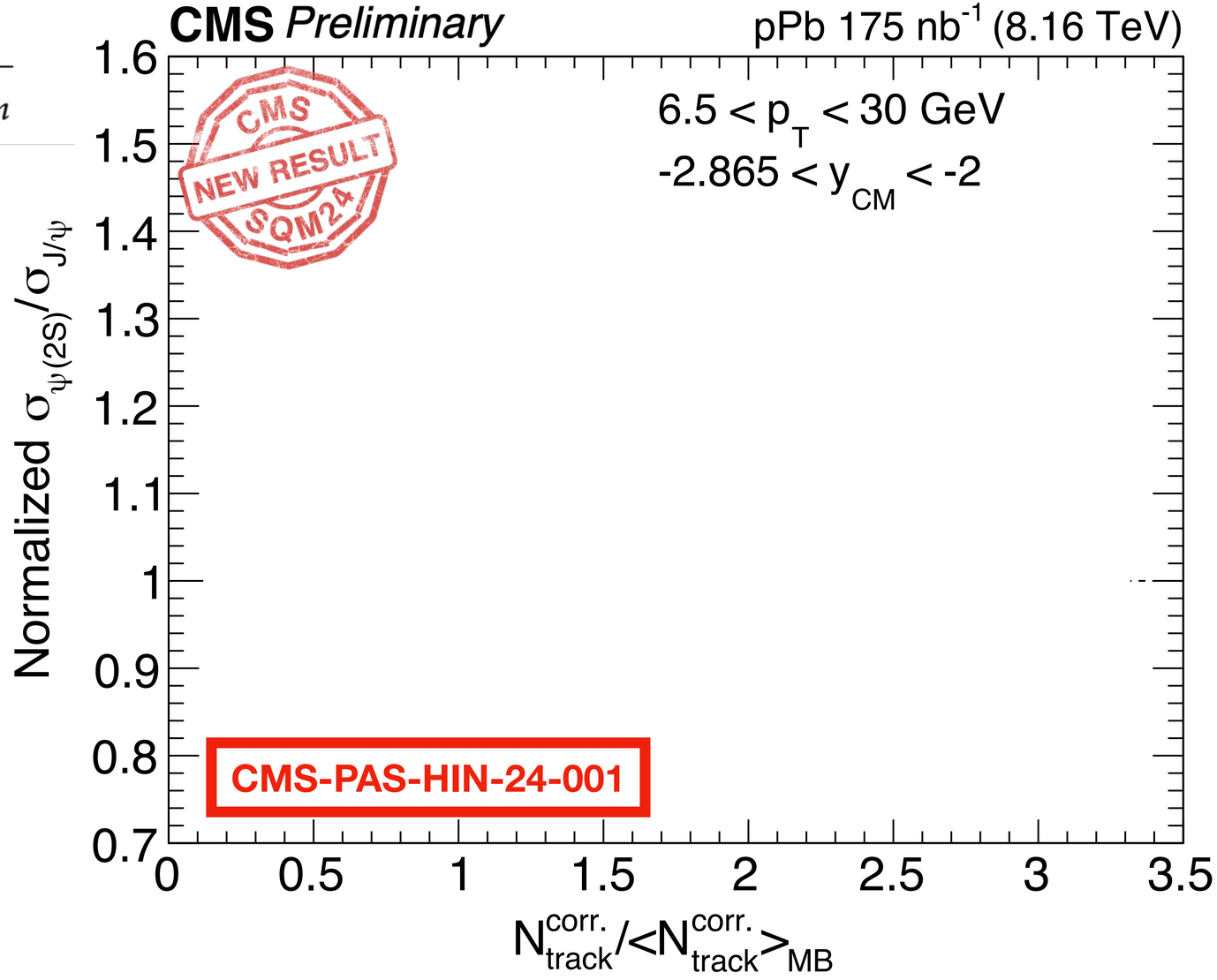


Observable of interest

$$\text{Normalised } \sigma_{\psi(2S),n}/\sigma_{J/\psi,n} = \frac{\sigma_{\psi(2S),n}/\sigma_{J/\psi,n}}{\sum_n \sigma_{\psi(2S),n}/\sum_n \sigma_{J/\psi,n}}$$

- **Normalized ratio cancels acceptance, shadowing effects**

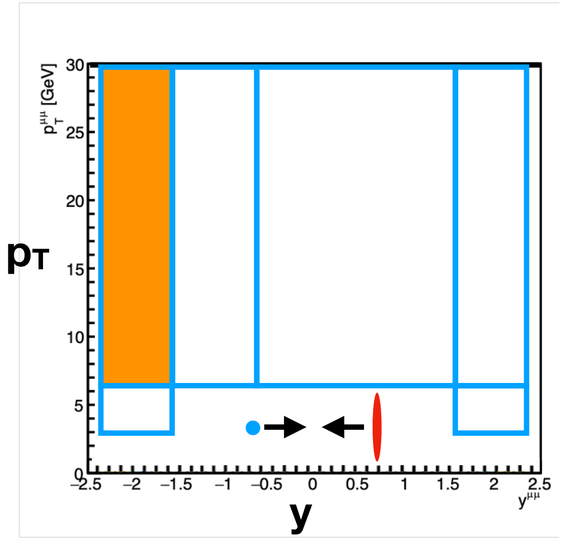


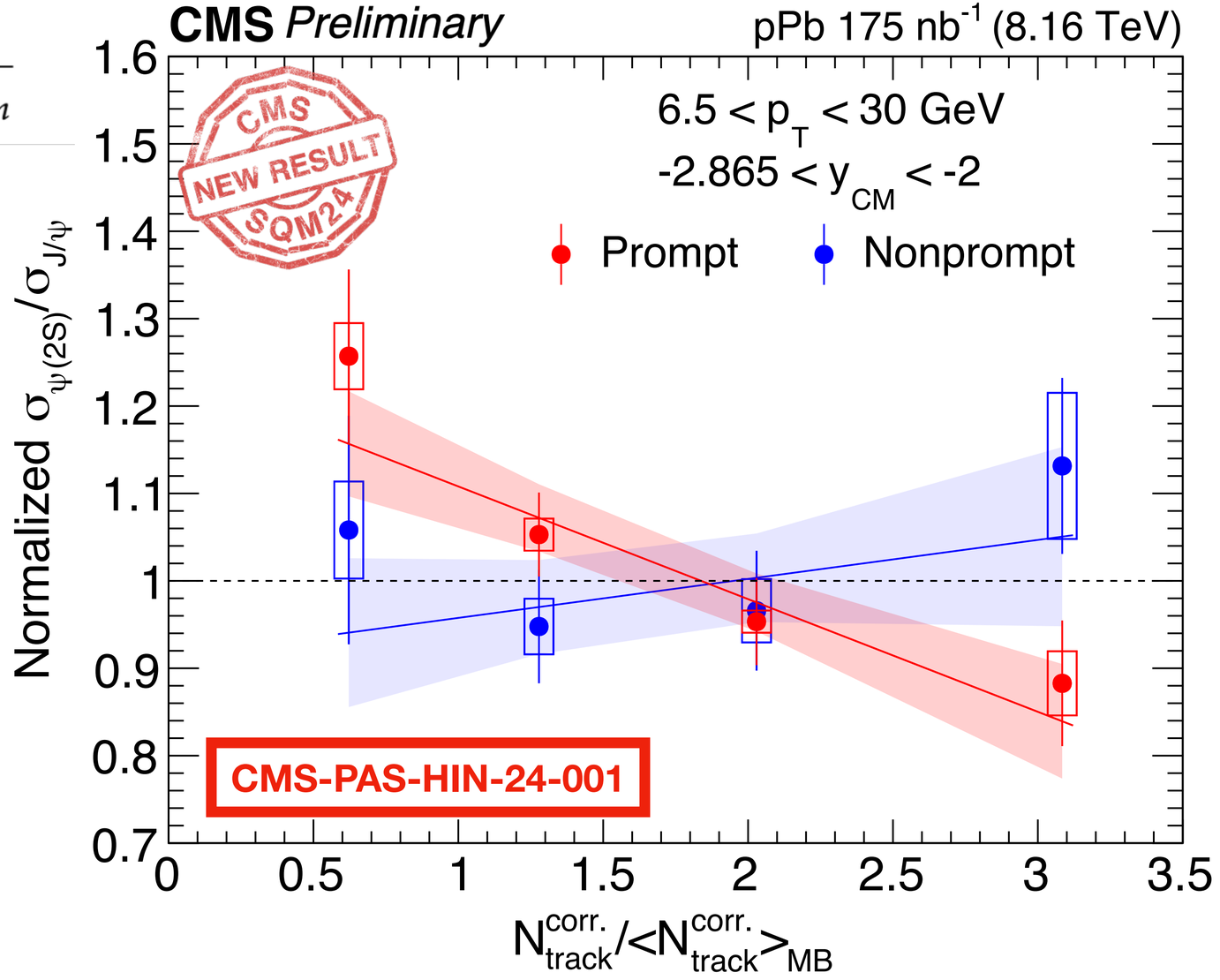


Far-backward results

$$\text{Normalised } \sigma_{\psi(2S),n}/\sigma_{J/\psi,n} = \frac{\sigma_{\psi(2S),n}/\sigma_{J/\psi,n}}{\sum_n \sigma_{\psi(2S),n}/\sum_n \sigma_{J/\psi,n}}$$

- **Normalized ratio cancels acceptance, shadowing effects**
- **Clear slope vs. N_{trk}^{corr} for prompt data**
- **No slope for non-prompt data**

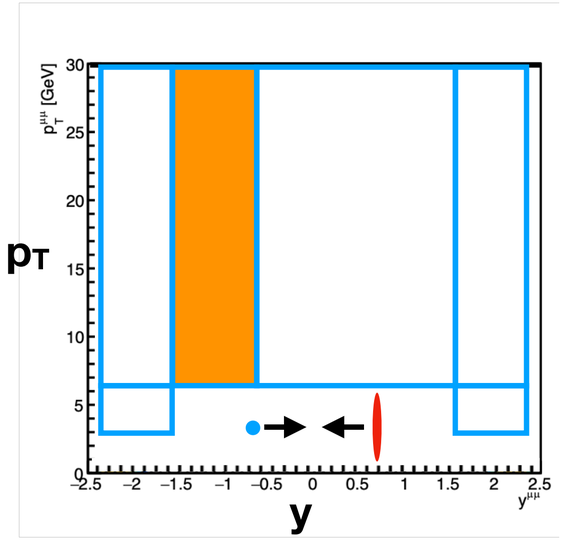


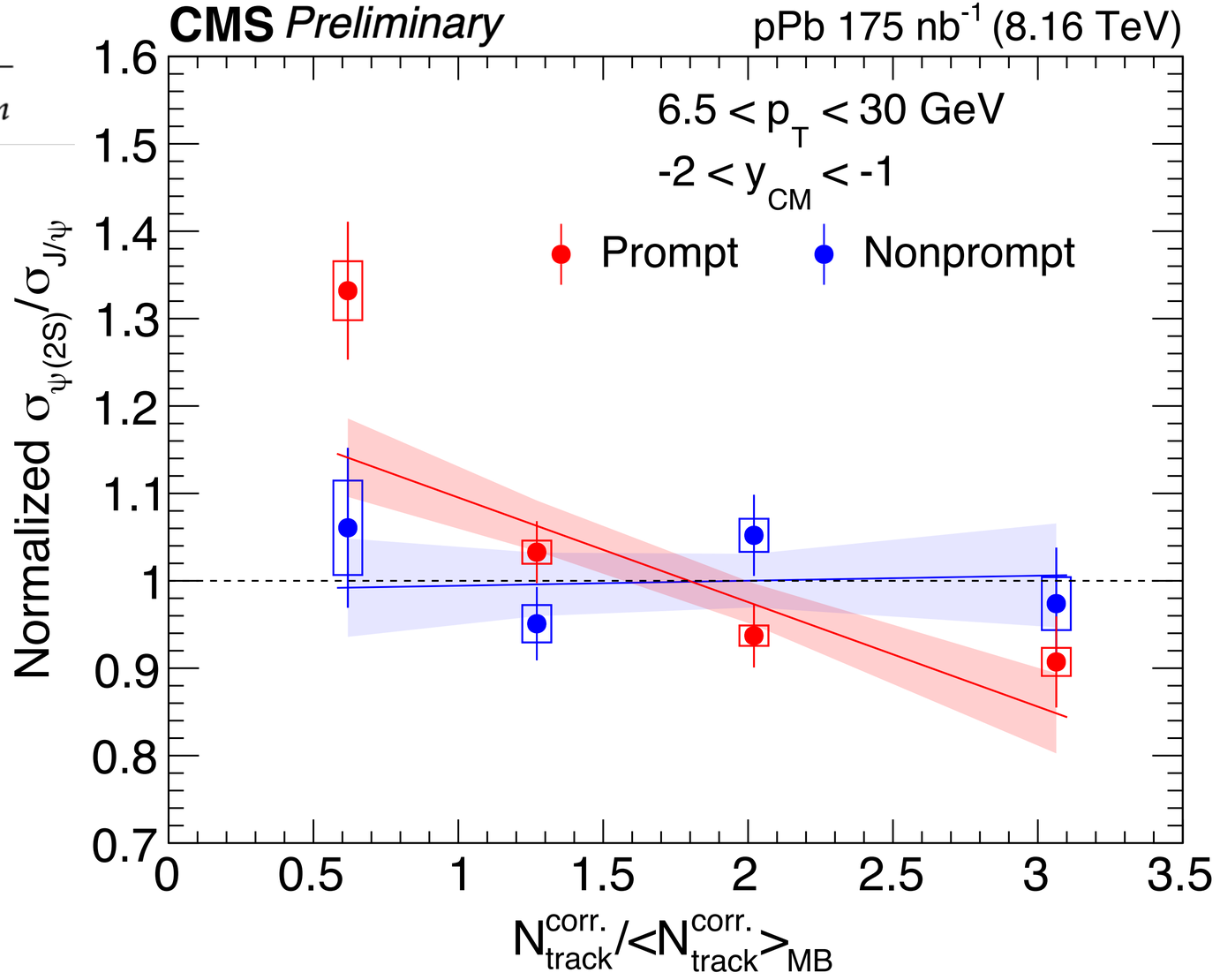


Backward results

$$\text{Normalised } \sigma_{\psi(2S),n}/\sigma_{J/\psi,n} = \frac{\sigma_{\psi(2S),n}/\sigma_{J/\psi,n}}{\sum_n \sigma_{\psi(2S),n}/\sum_n \sigma_{J/\psi,n}}$$

- **Normalized ratio cancels acceptance, shadowing effects**
- **Clear slope vs. N_{trk}^{corr} for prompt data**
- **No slope for non-prompt data**

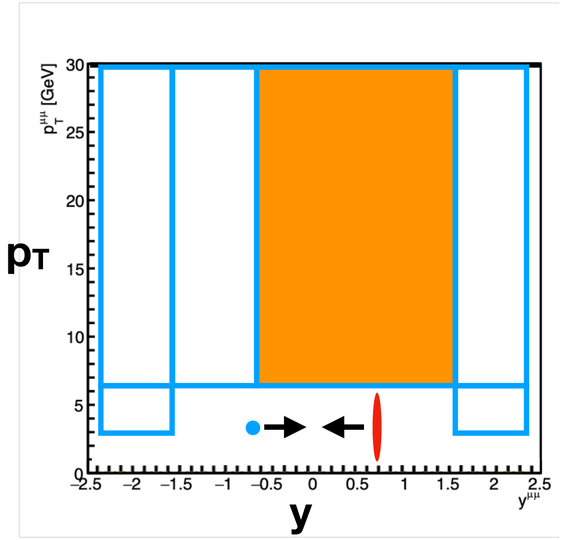


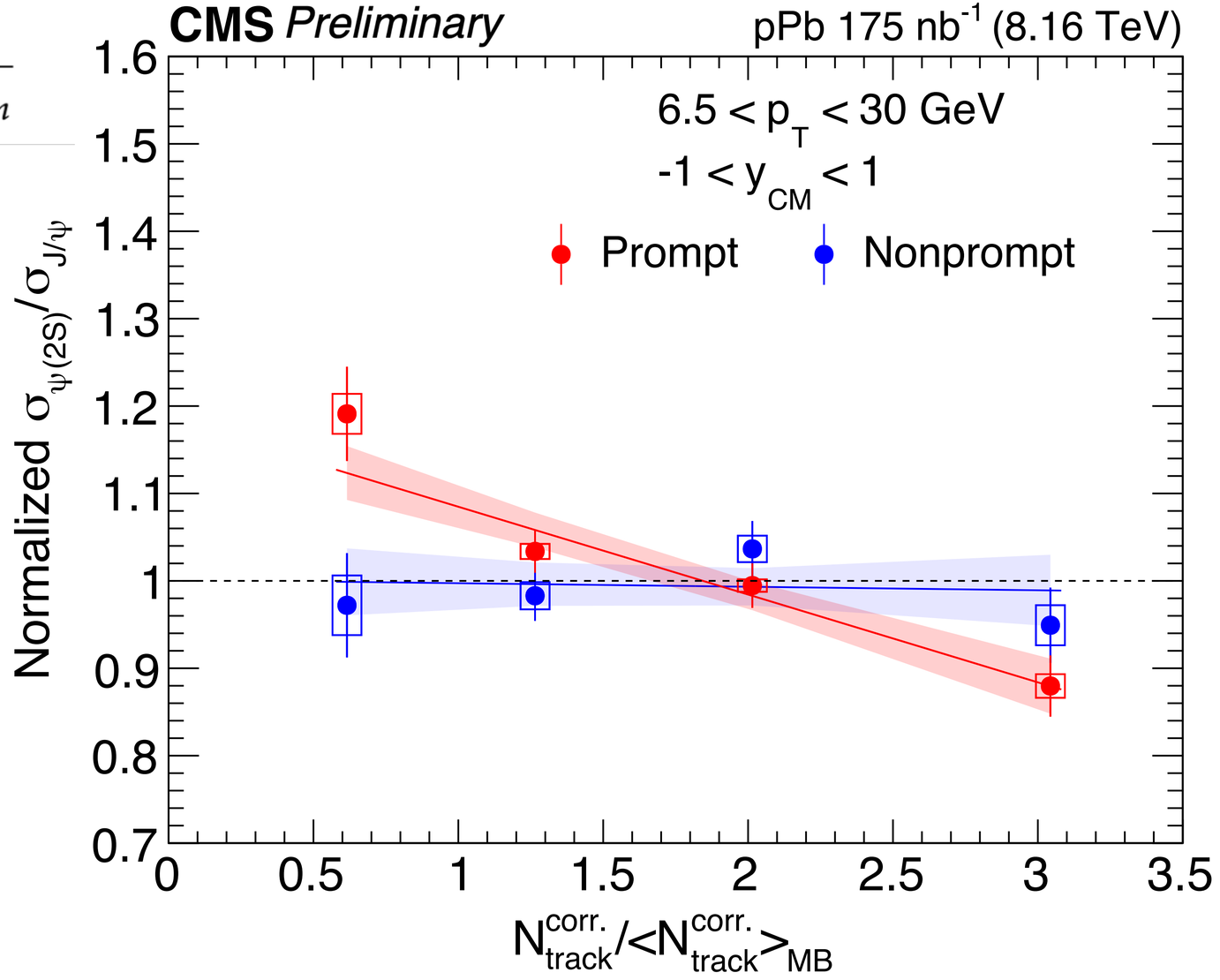


Midrapidity results

$$\text{Normalised } \sigma_{\psi(2S),n}/\sigma_{J/\psi,n} = \frac{\sigma_{\psi(2S),n}/\sigma_{J/\psi,n}}{\sum_n \sigma_{\psi(2S),n}/\sum_n \sigma_{J/\psi,n}}$$

- **Normalized ratio cancels acceptance, shadowing effects**
- **Clear slope vs. N_{trk}^{corr} for prompt data**
- **No slope for non-prompt data**

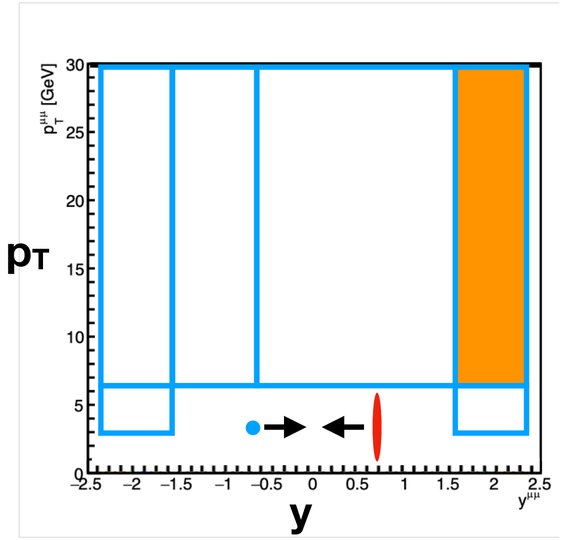


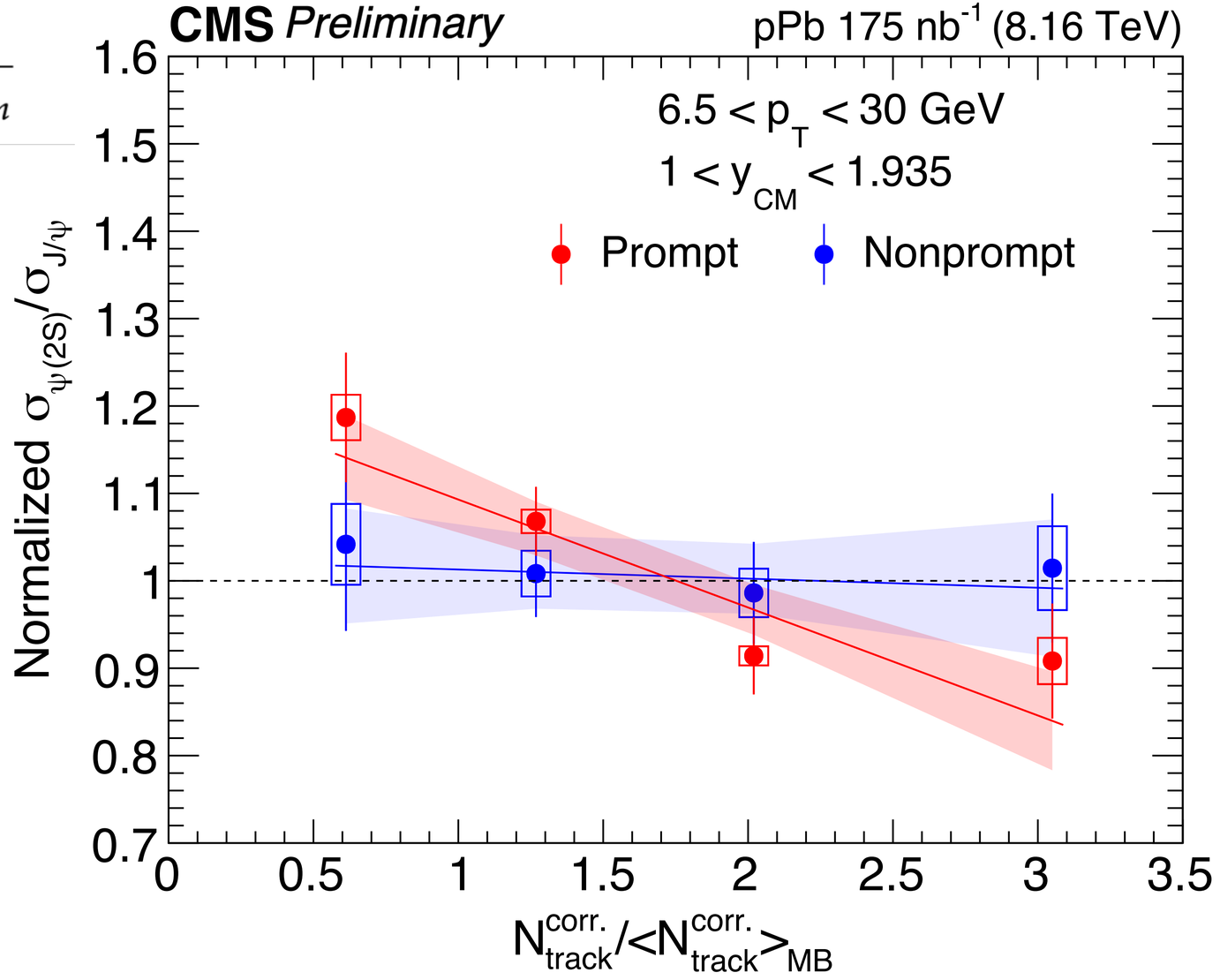


Forward results

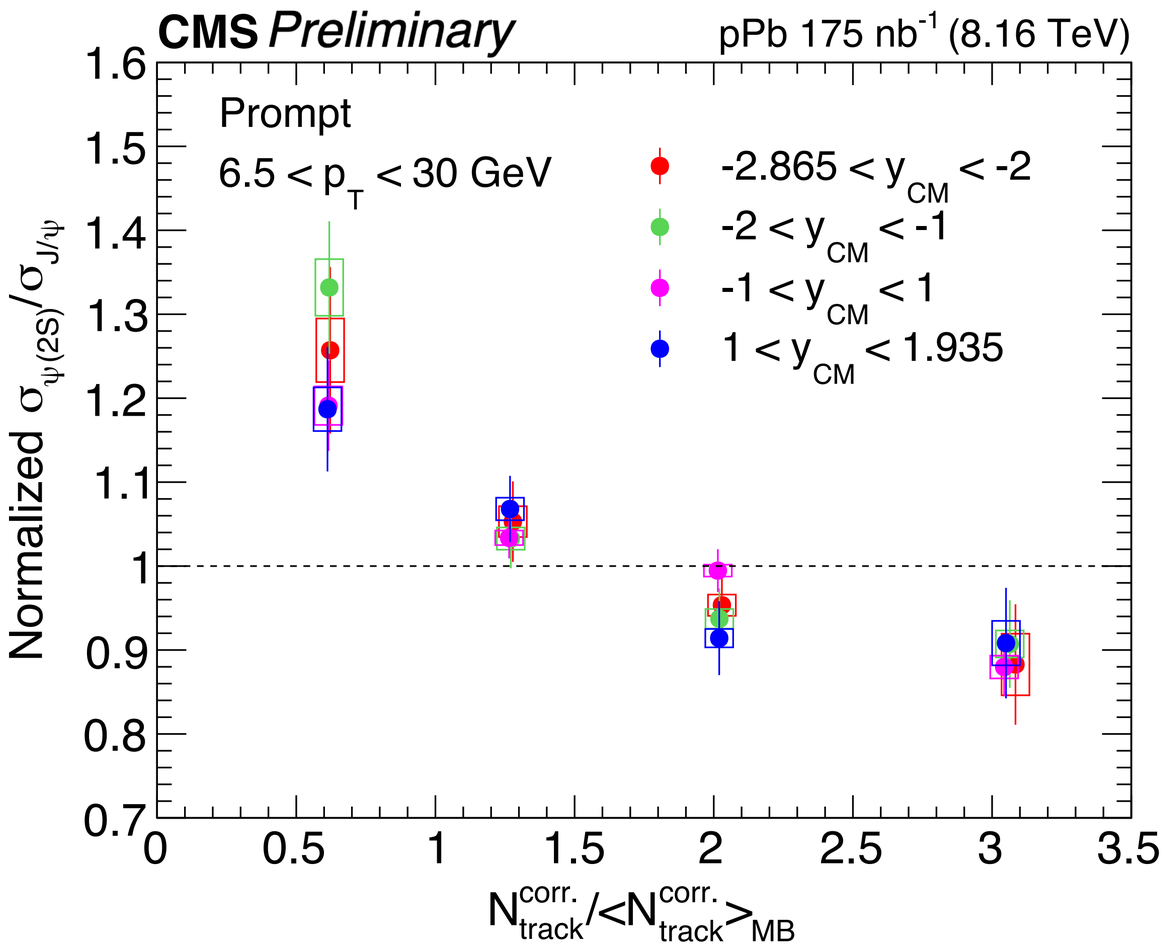
$$\text{Normalised } \sigma_{\psi(2S),n}/\sigma_{J/\psi,n} = \frac{\sigma_{\psi(2S),n}/\sigma_{J/\psi,n}}{\sum_n \sigma_{\psi(2S),n}/\sum_n \sigma_{J/\psi,n}}$$

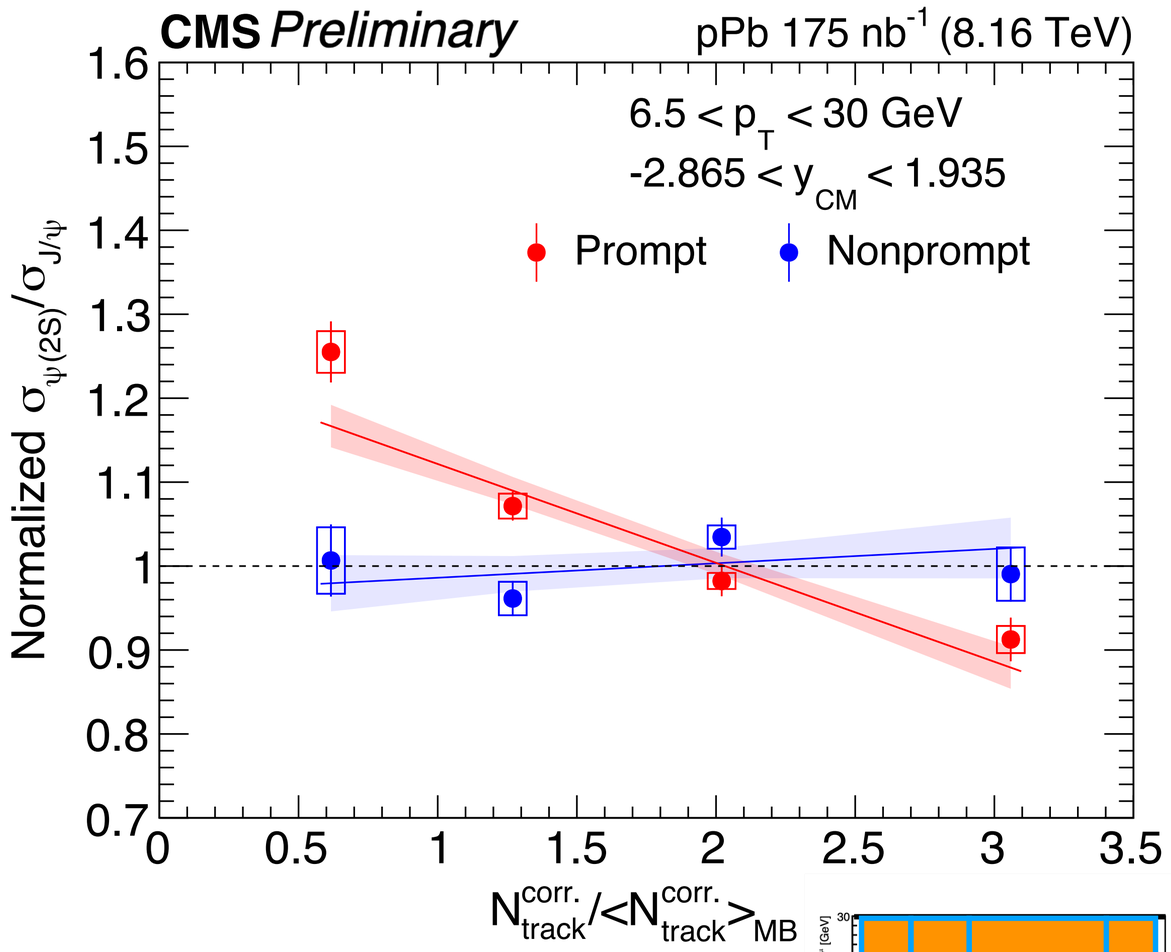
- **Normalized ratio cancels acceptance, shadowing effects**
- **Clear slope vs. N_{trk}^{corr} for prompt data**
- **No slope for non-prompt data**



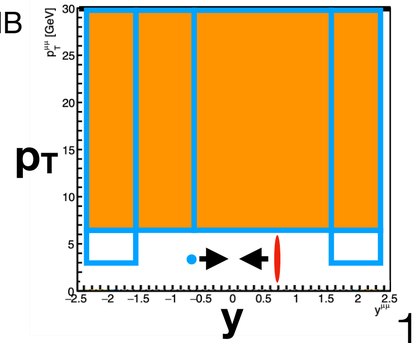


Summary of high-p_T results



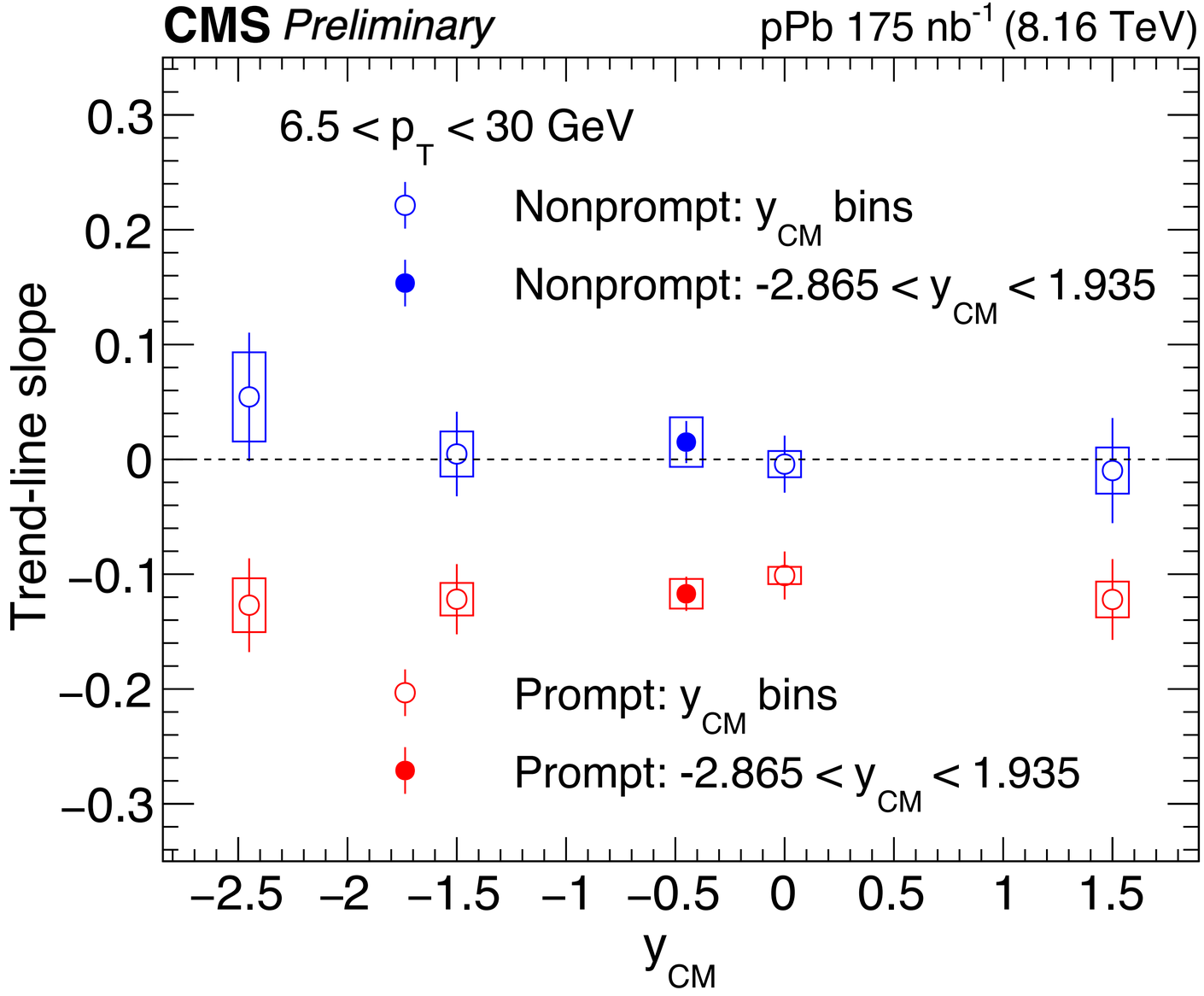


- N_{trk}^{corr} **dependence similar for all rapidities → combine**
  - **5.9σ deviation from flat line for prompt**
  - **Observation of multiplicity dependence of $\sigma_{\psi(2S)}/\sigma_{J/\psi}$ in pPb**

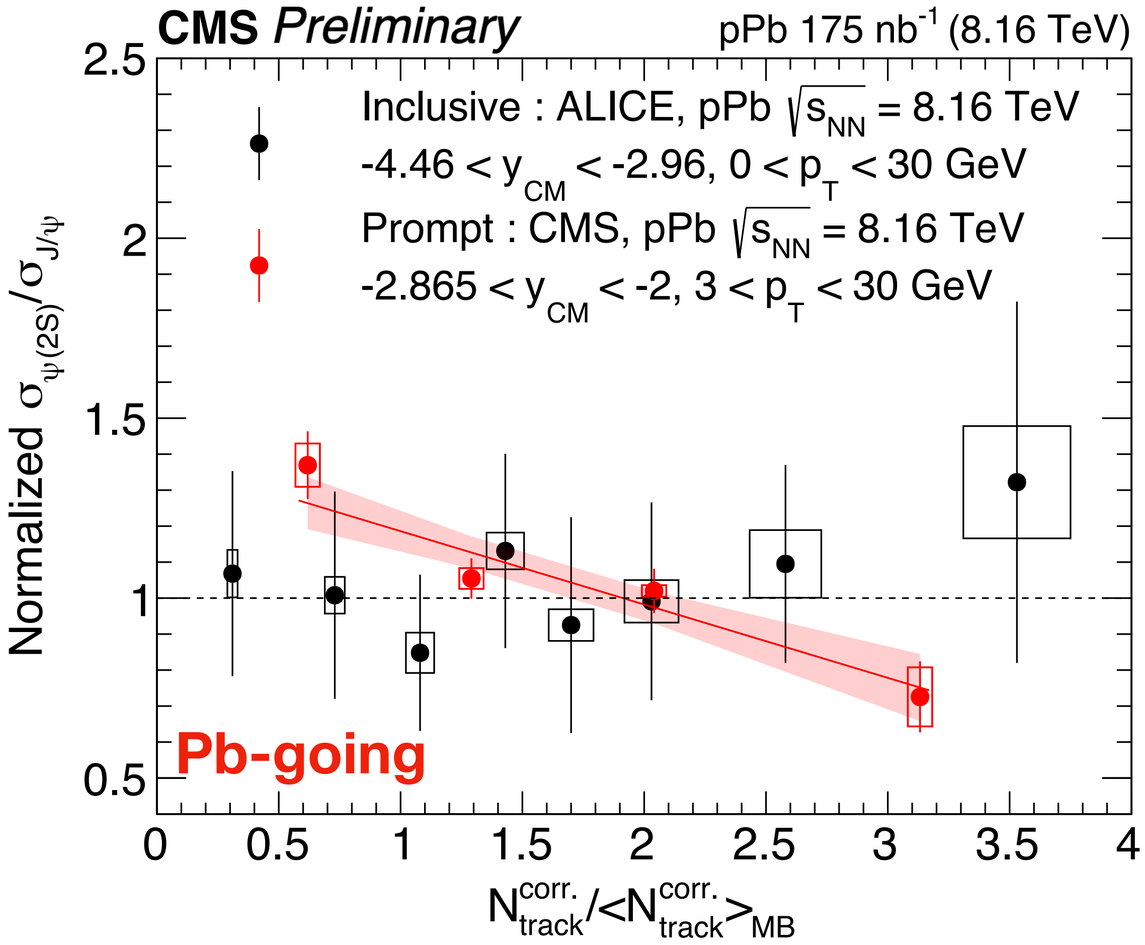


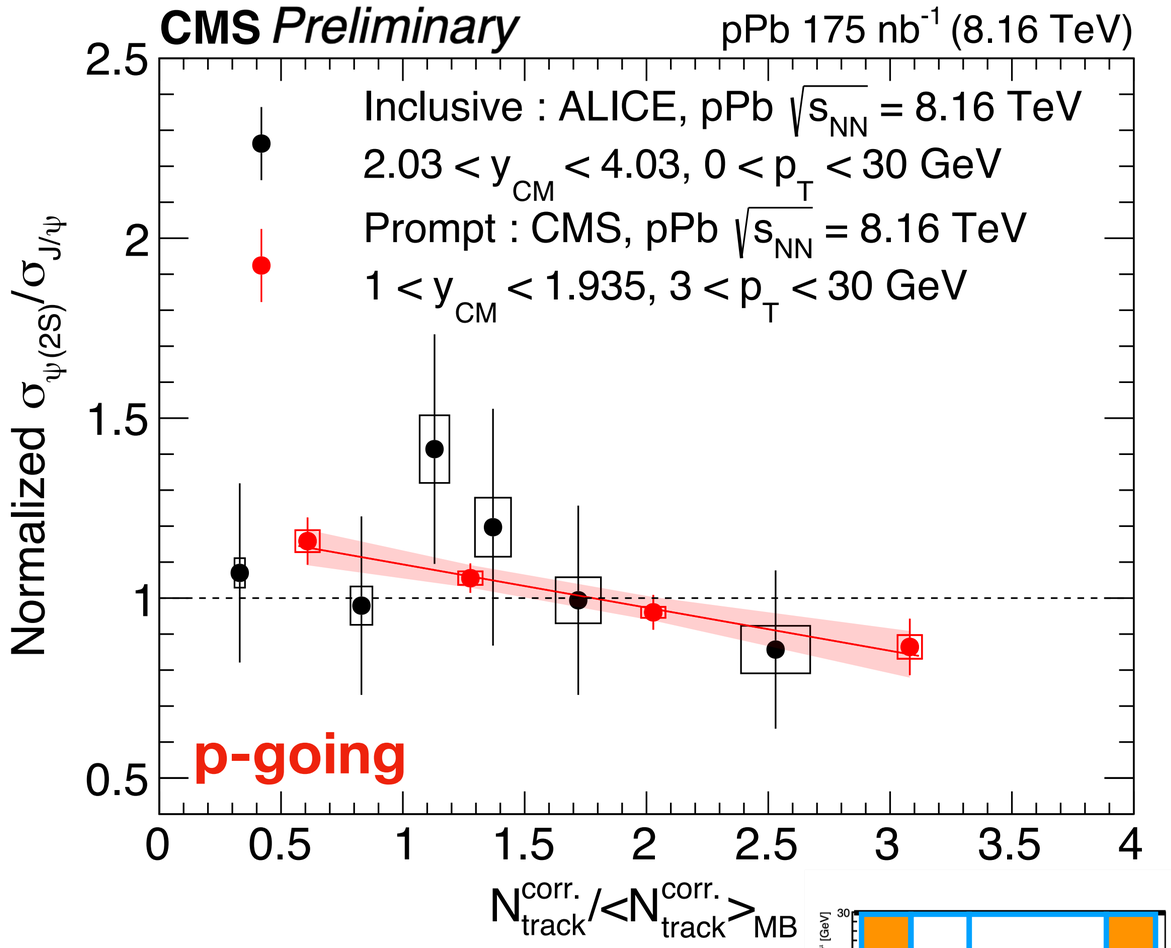
Rapidity dependence of slope

- **Slope of linear fits vs rapidity**
  - **Correlations between points in N_{trk}^{corr} accounted for**
- **No clear rapidity dependence**
  - **Average p_T is ~10 GeV**
- **All non-prompt measurements consistent with 0**

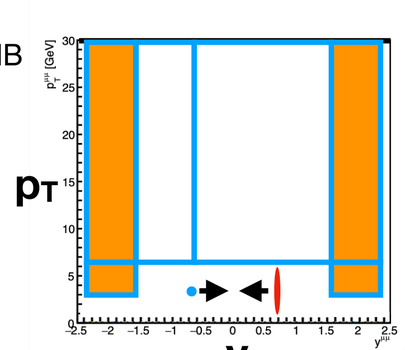


Comparison to ALICE results





- **CMS prompt data vs. ALICE inclusive data***
- **y_{cm} and p_T ranges slightly different but results are consistent**



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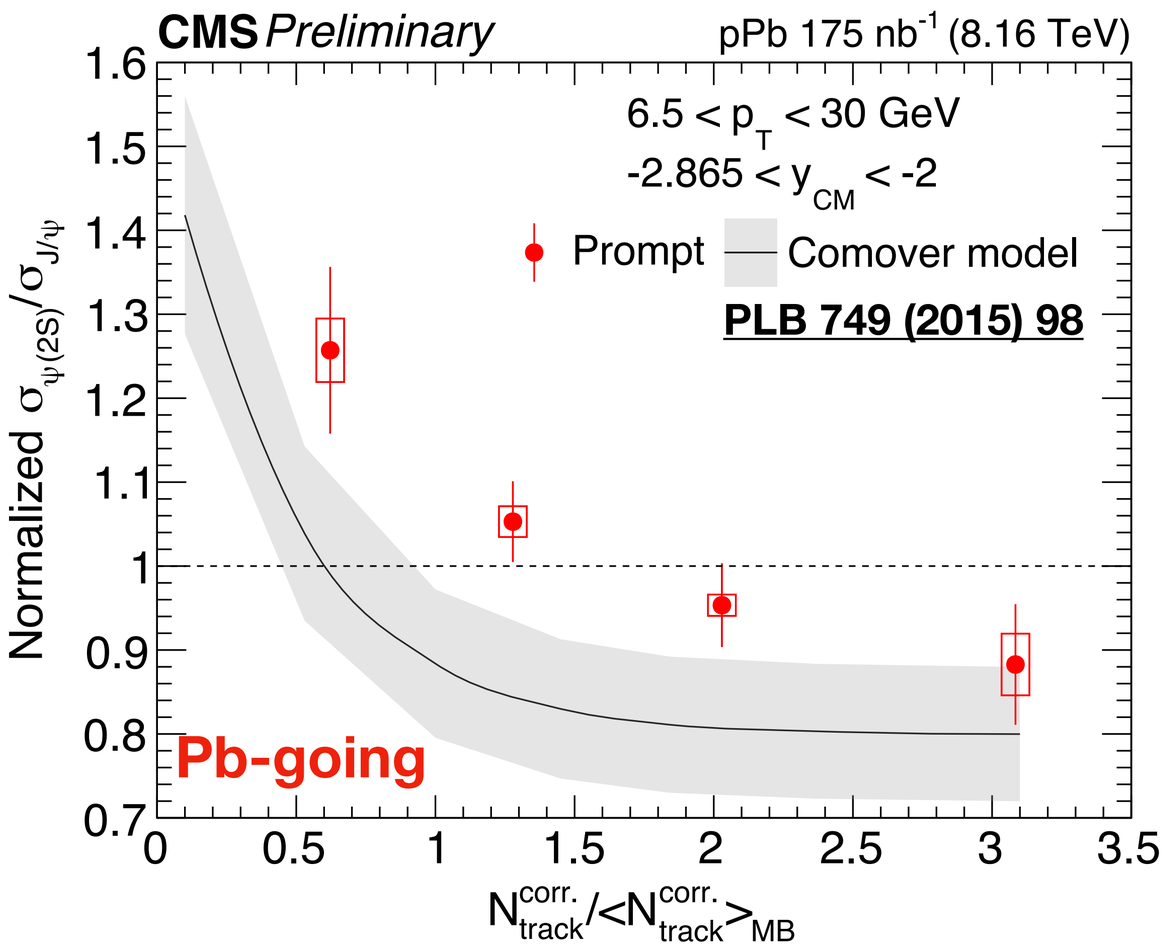
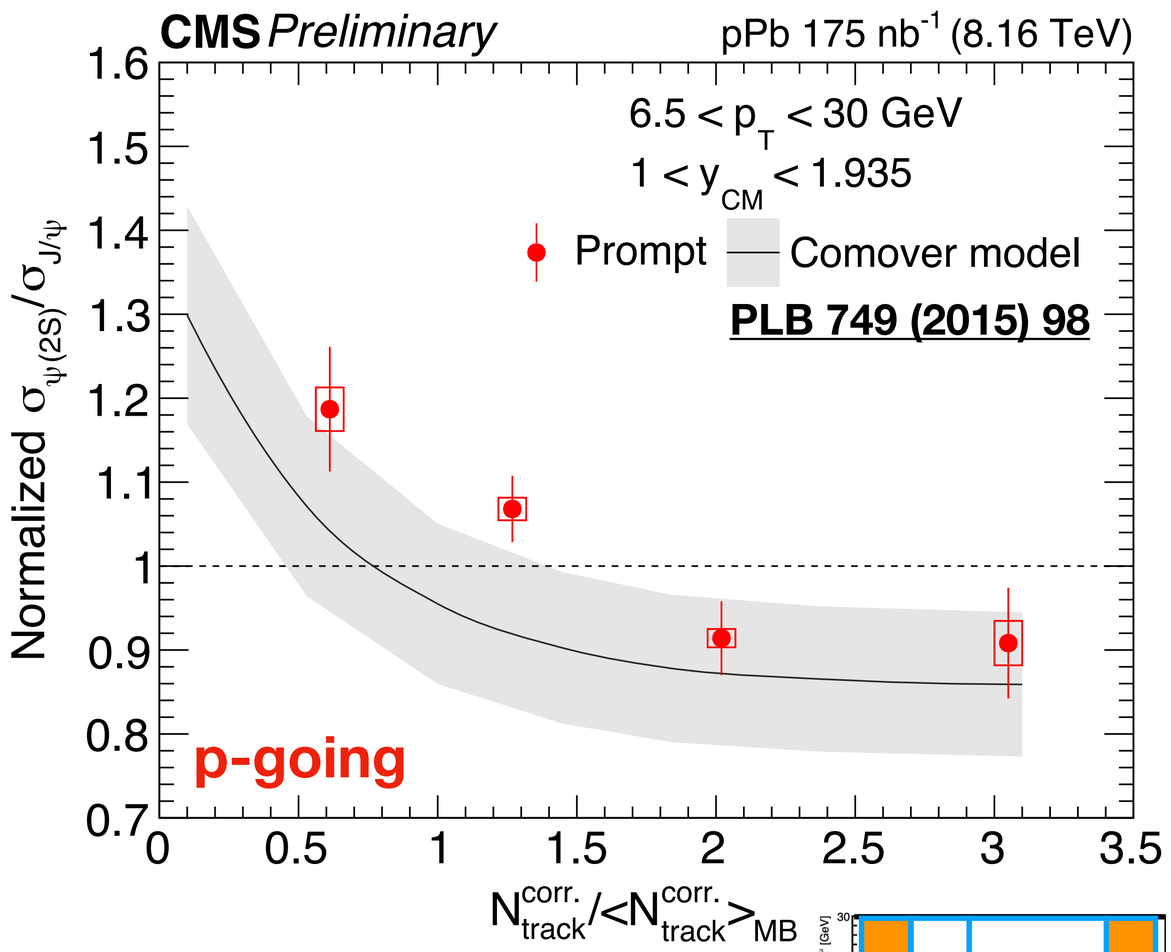
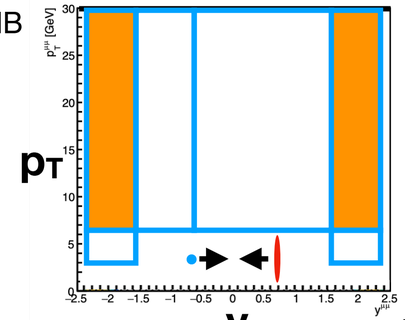
Comparison to Theory

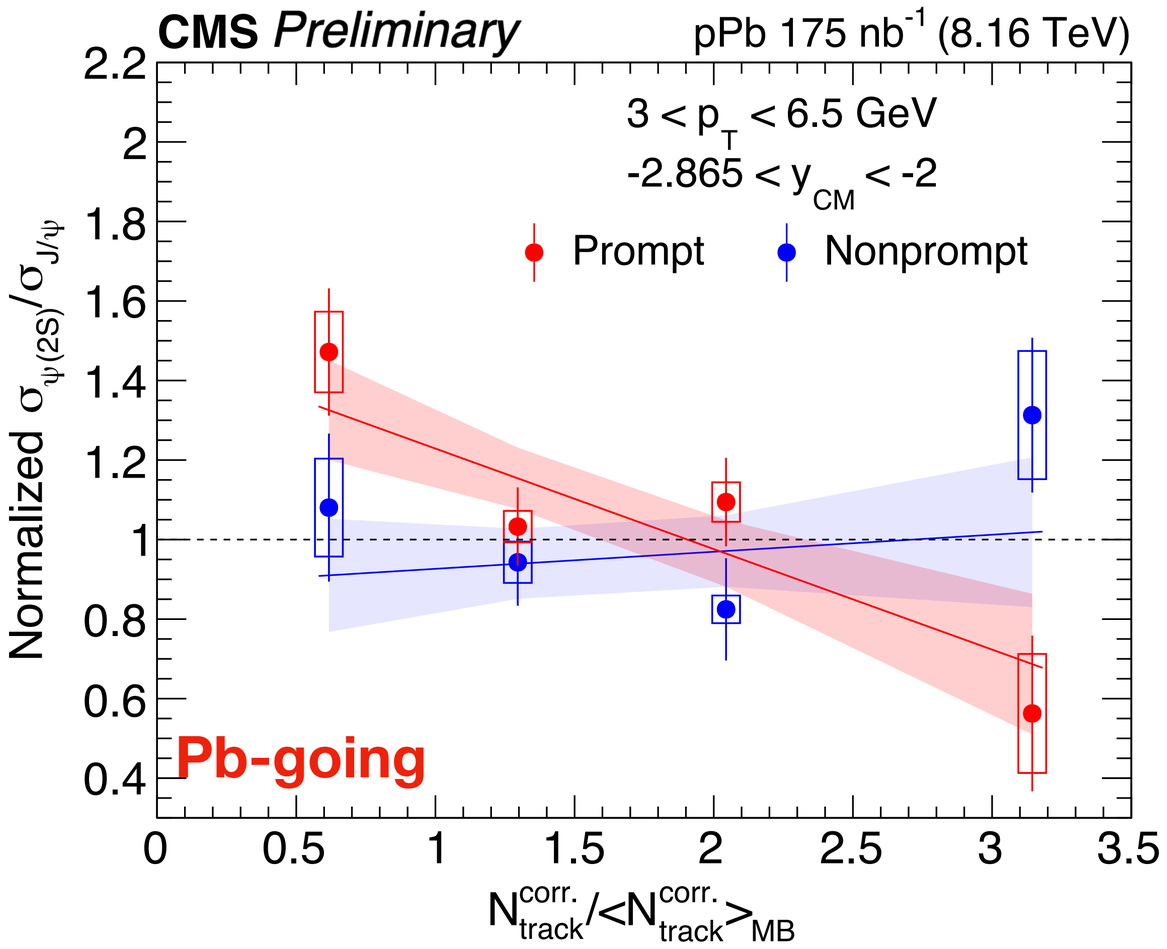


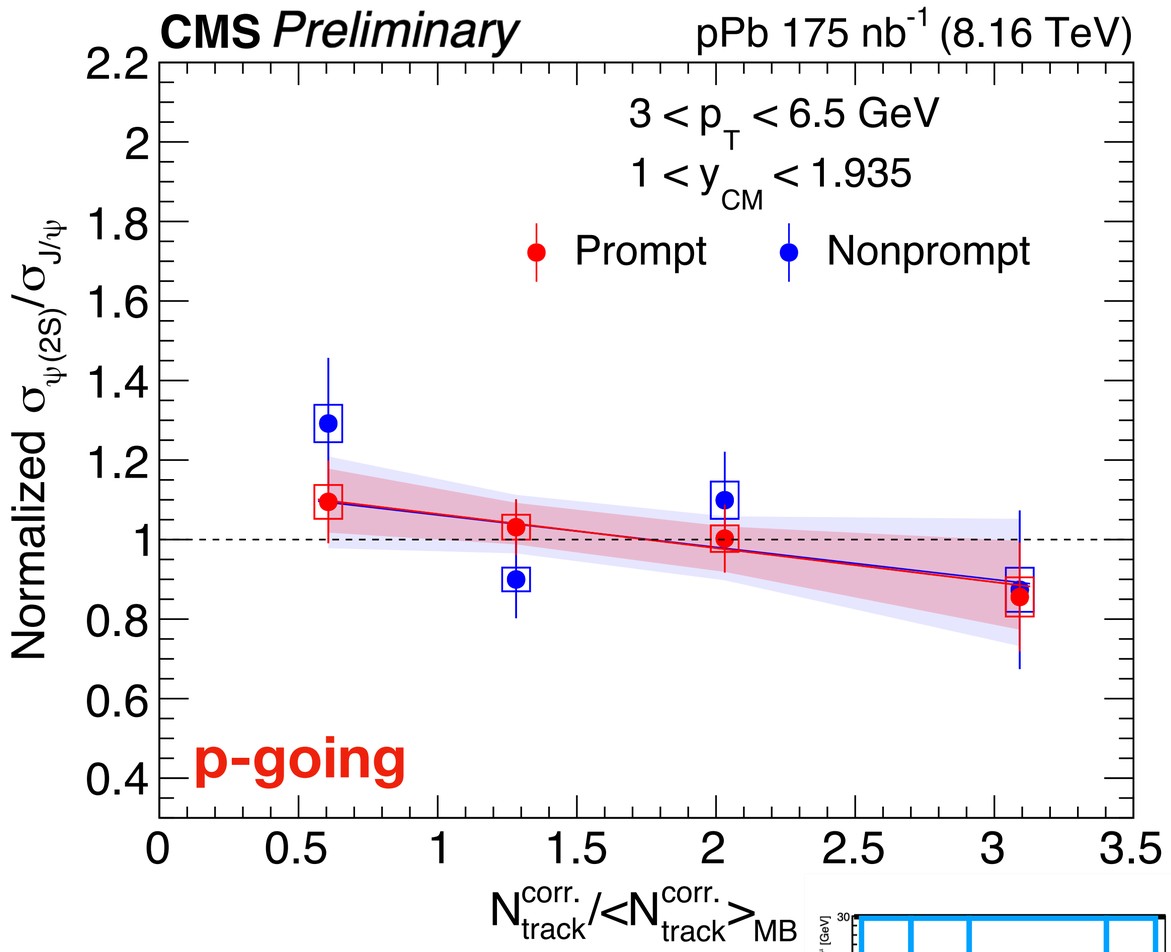


- **Model includes comover interactions**
- **Reasonable agreement in p-going side**
- **Less suppression in Pb-going side compared to model**

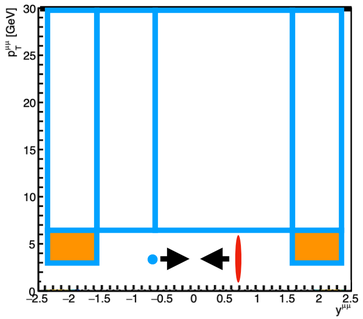


Low-p_T results



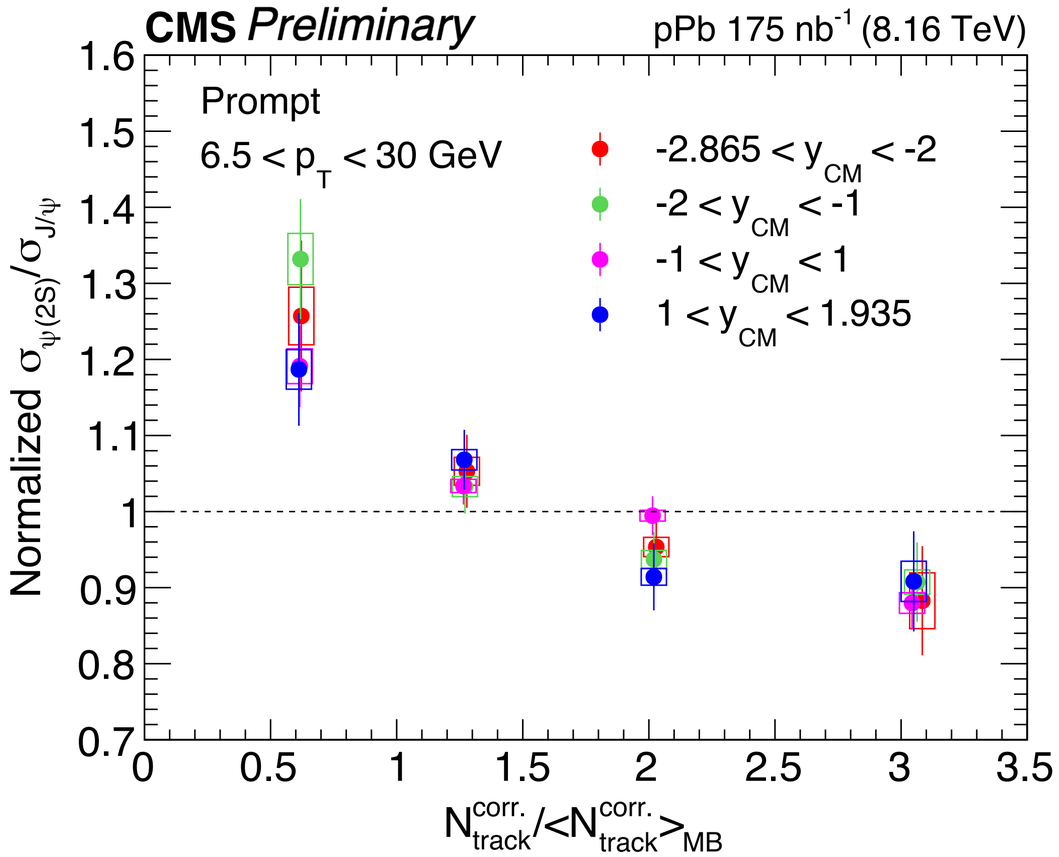


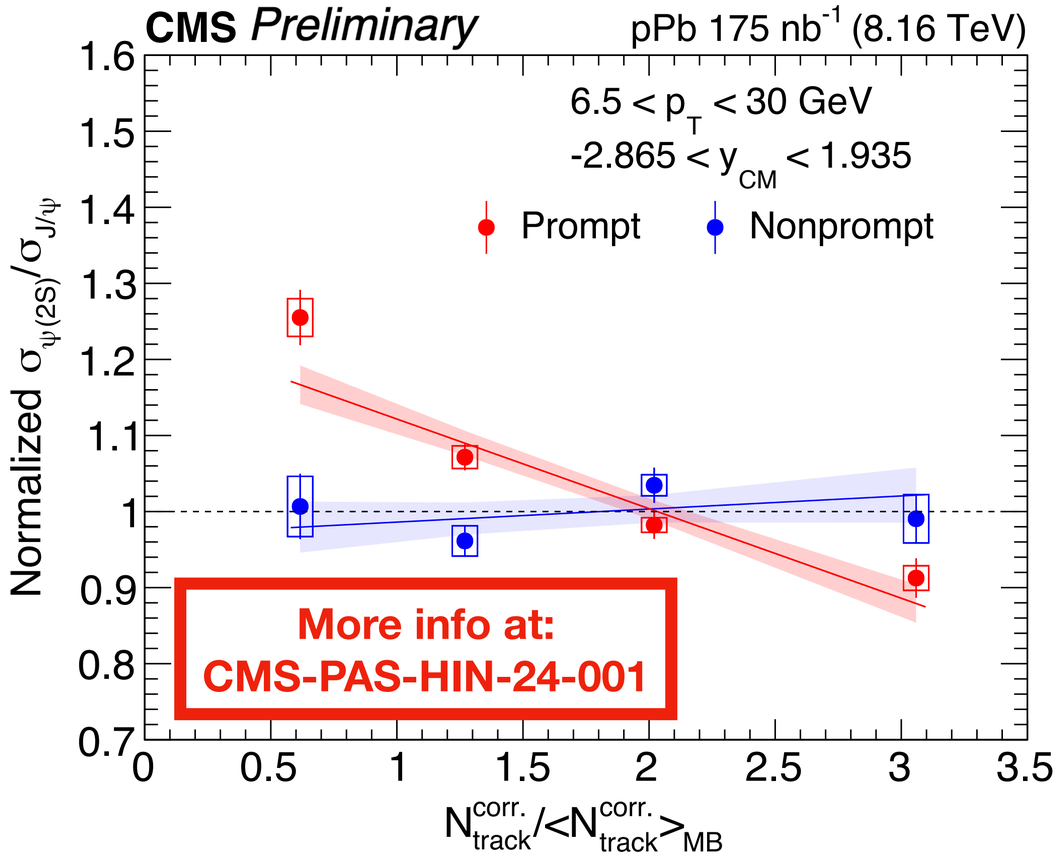
- **Far-backward and forward results at lower p_T**
- **Hint of stronger N_{trk}^{corr} dependence for prompt in Pb-going side (2.4σ)**
  - **Limited by statistical precision**



Summary

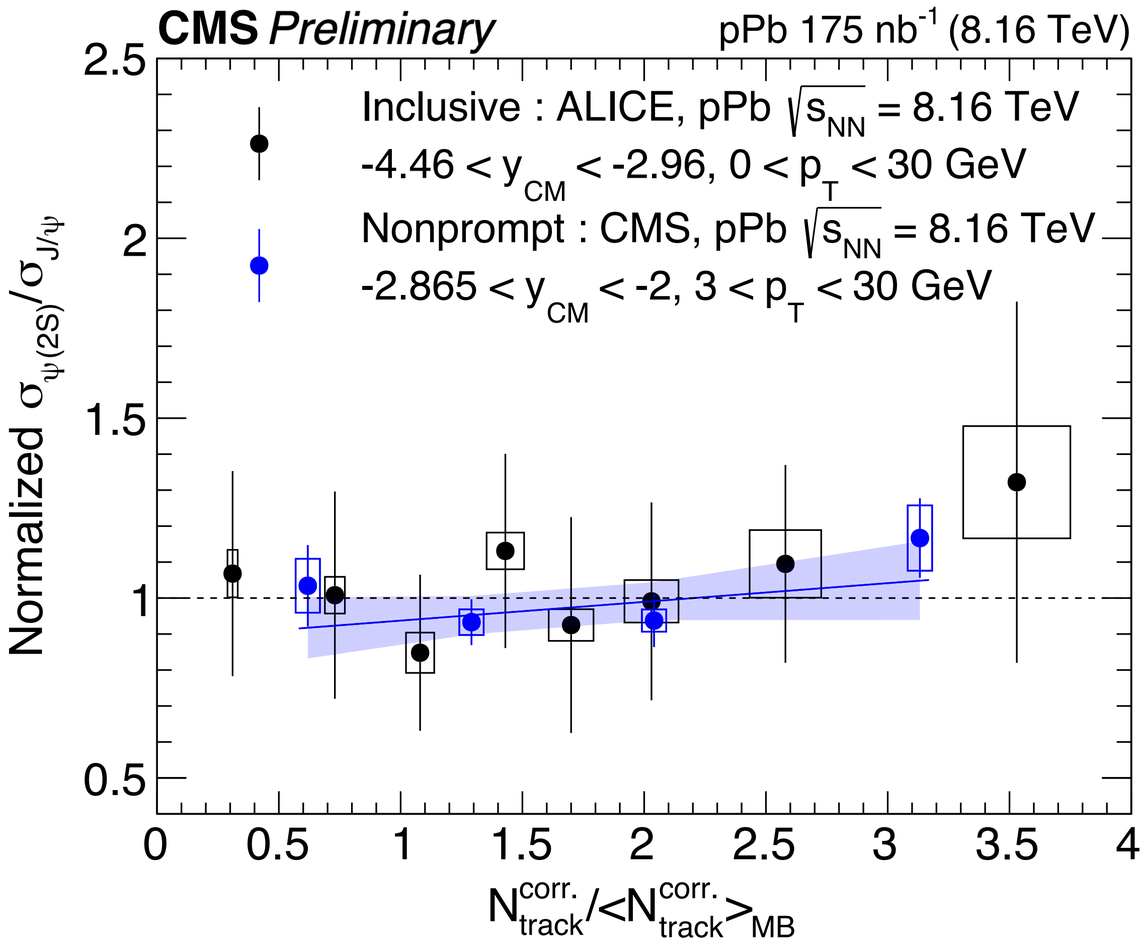
- **First observation of multiplicity-dependence of prompt $\sigma_{\psi(2S)}/\sigma_{J/\psi}$ in pPb**
- **Non-prompt ratio consistent with unity**
- **Hint of rapidity dependence at lower p_T**
- **Supports picture where suppression increases with comover density**
  - **Data constrain hadronization models of charm hadrons in small systems**

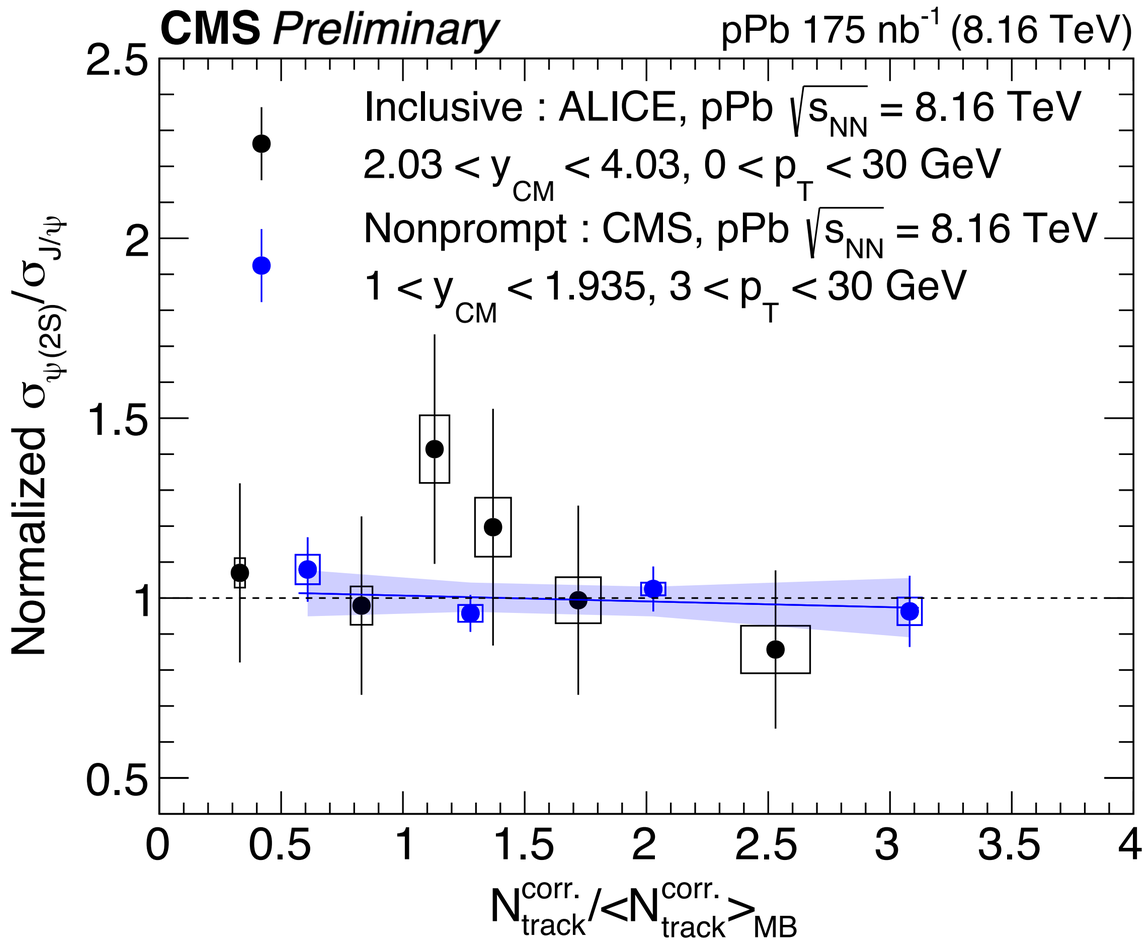




Backup

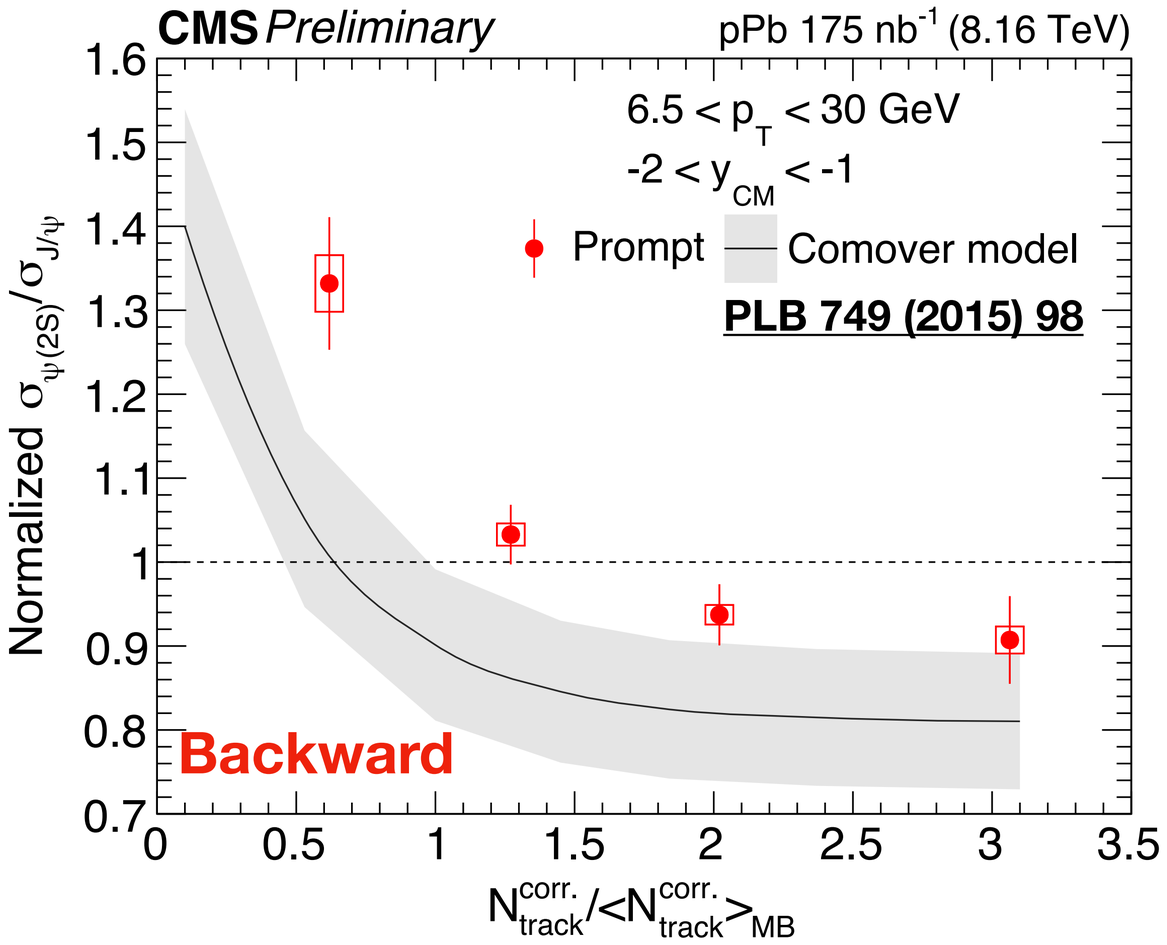
Non-Prompt vs ALICE

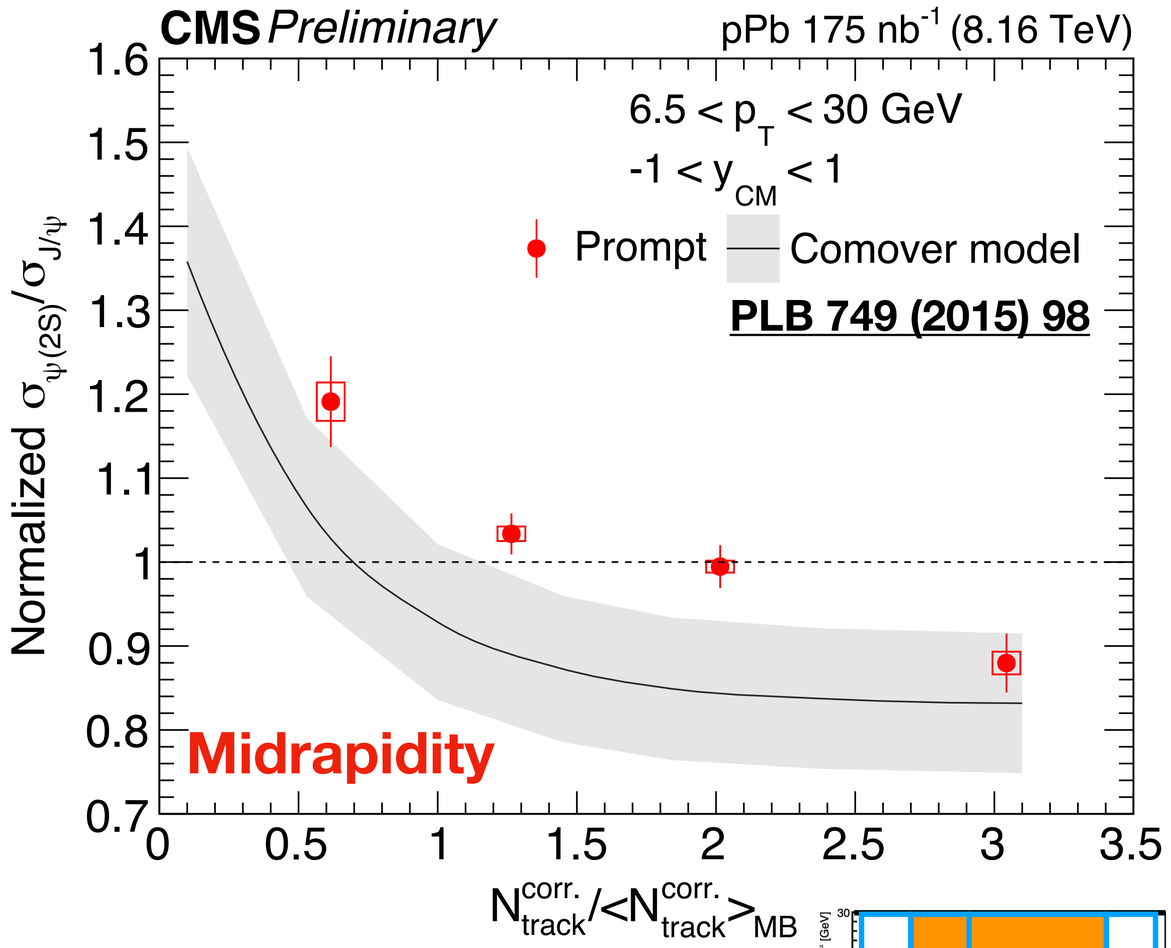




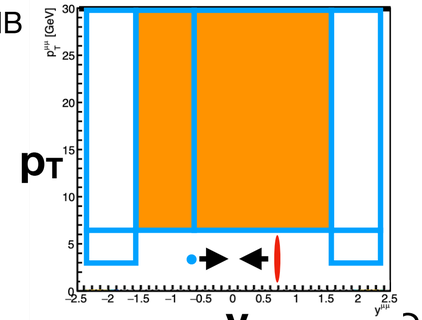
- **ALICE data also compatible with non-prompt CMS results**

Comparison to Theory - midrapidities

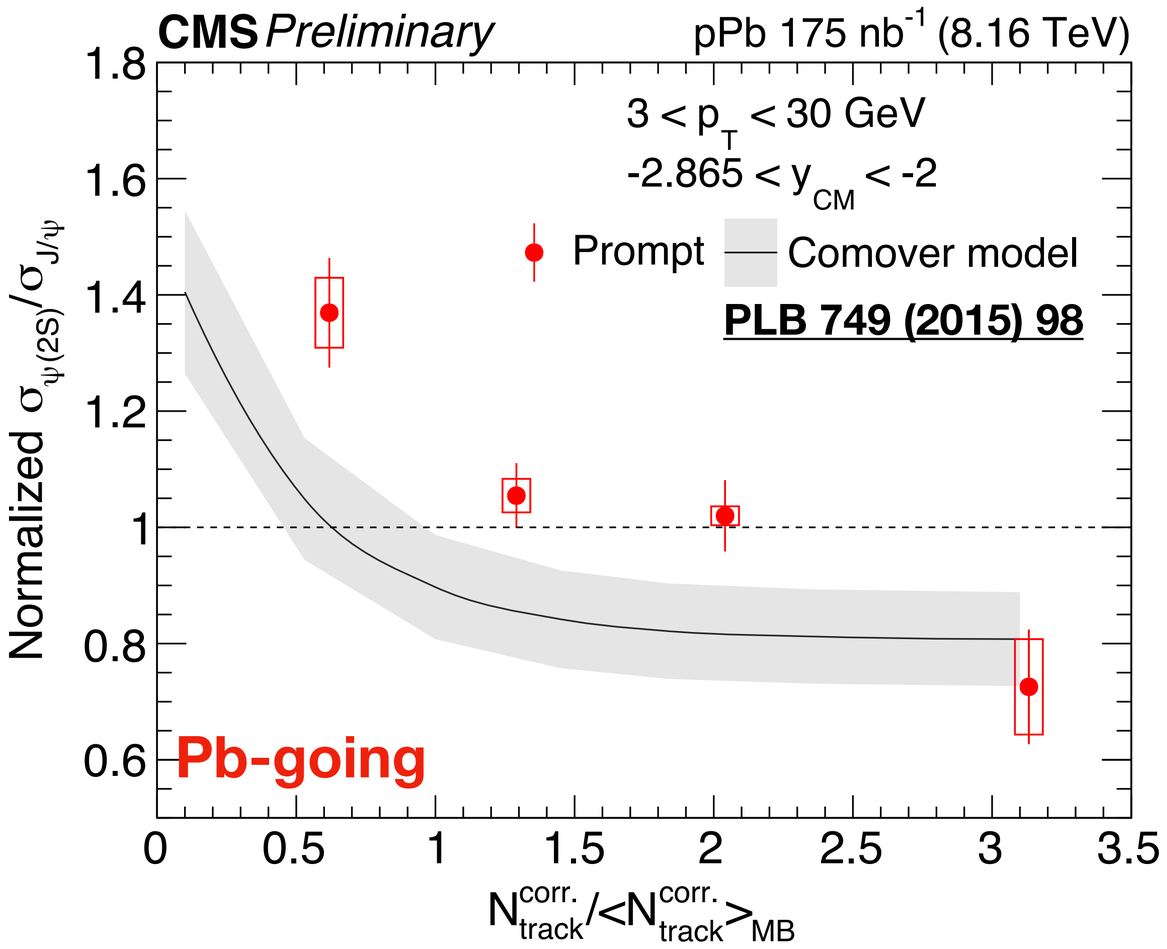


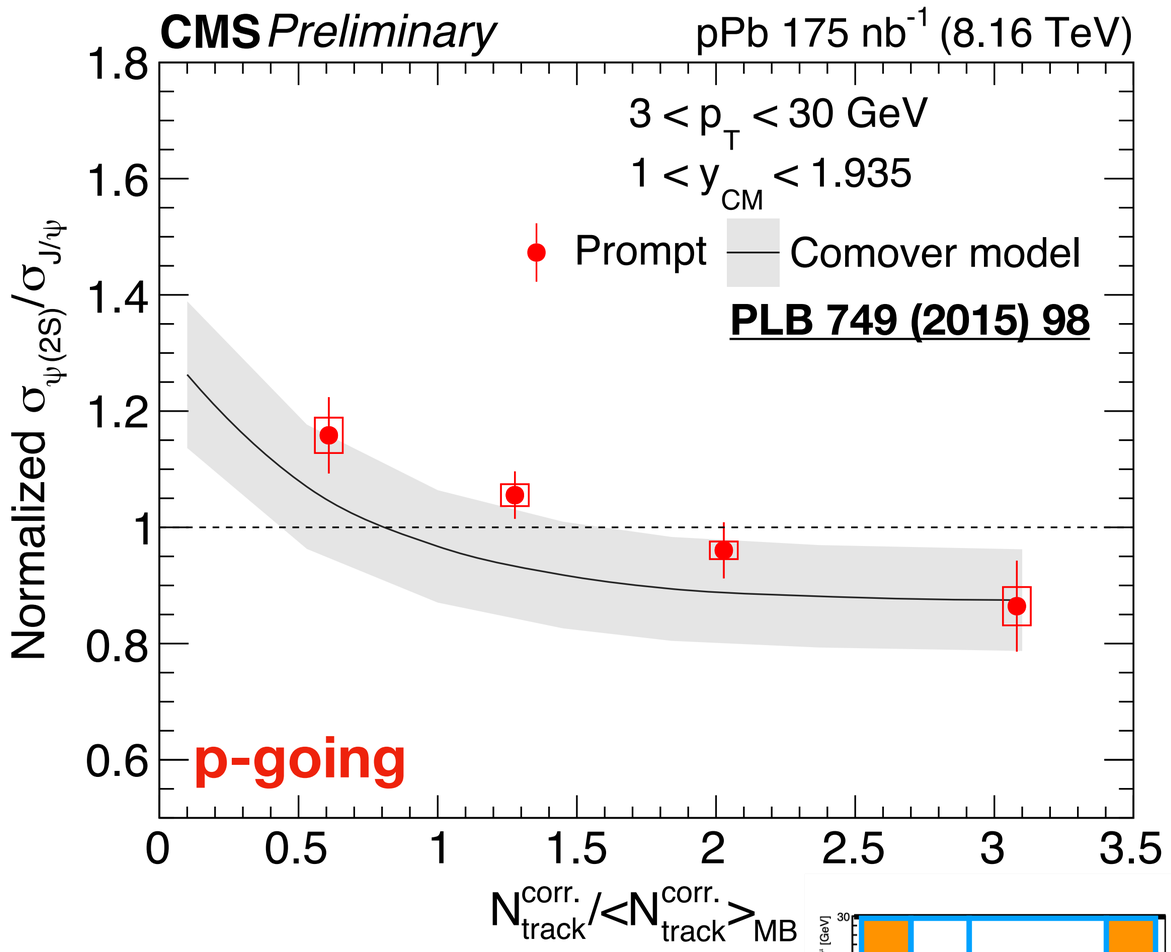


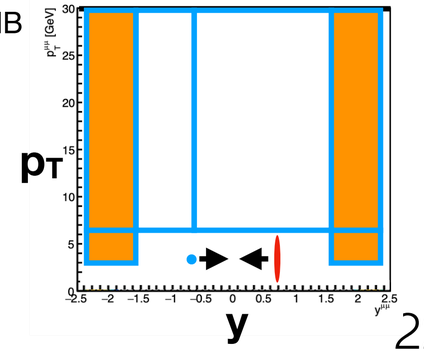
- **Theory predicts more suppression than data**



Comparison to Theory - with low p_T

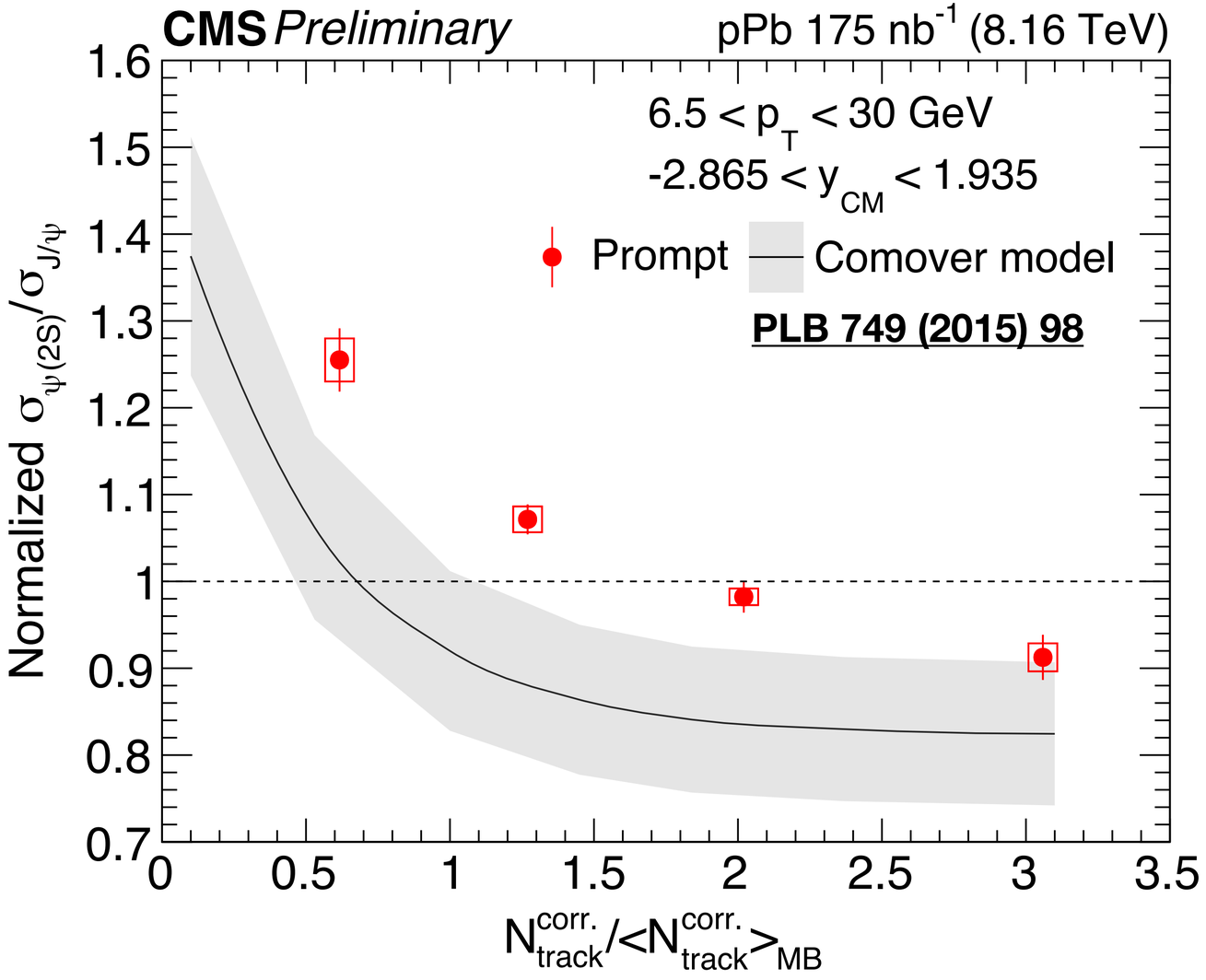




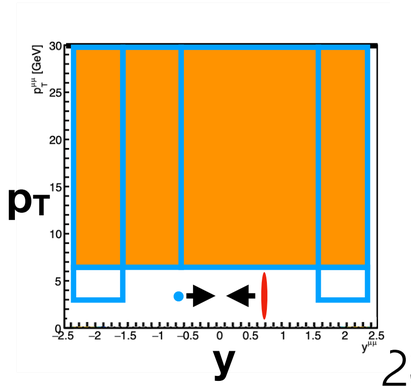


- **Similar conclusions as with 6.5-30 GeV selection**

Comparison to Theory - inclusive



- **Shape seems similar but scale of suppression is larger in model**



13 TeV pp results

- **Clear suppression of prompt charmonia vs N_{trk} observed by LHCb in pp**
  - **Supported by co-mover model**
- **ALICE data also suggestive of co-mover suppression but less clear**

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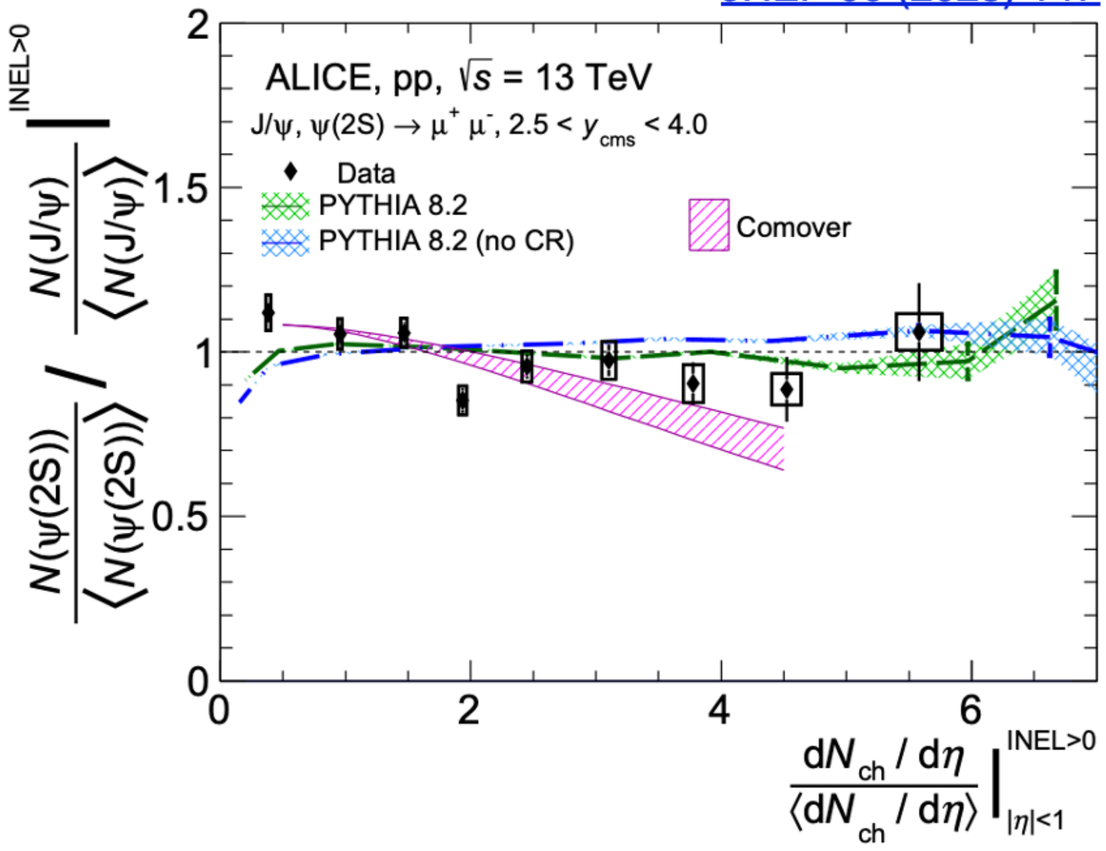

arXiv:2312.15201