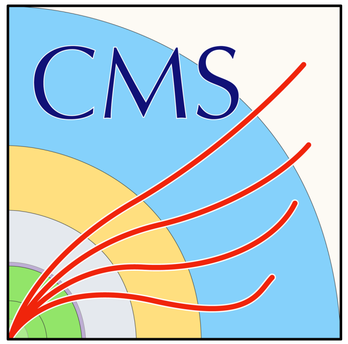
Investigation of in-medium effects of charmonia using azimuthal anisotropy in PbPb at 5.02 TeV with CMS

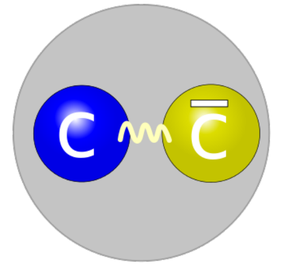


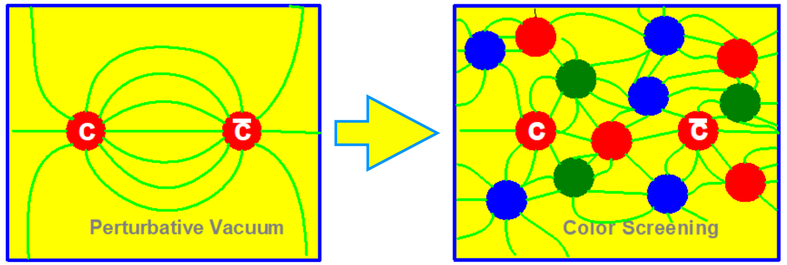
Gyeonghwan Bak (CNU)
on behalf of the CMS Collaboration

Introduction

- **Quarkonia** : Golden probes in heavy ion collisions
  - Produced via hard scattering : experience whole medium evolution
- **Various in-medium effects inside QGP**
  - Debye screening + Dissociation
  - Recombination
- **Azimuthal anisotropy (Flow)**
  - Collectivity (low-p_T), path-length E. loss (high p_T)
  - Sensitive to initial collision geometry

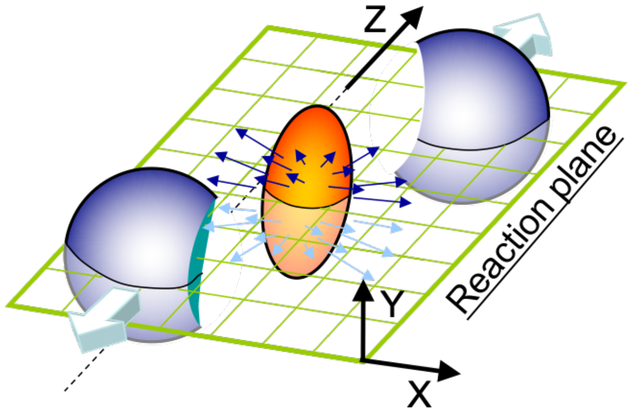
$J/\psi,\ \psi(2S)$



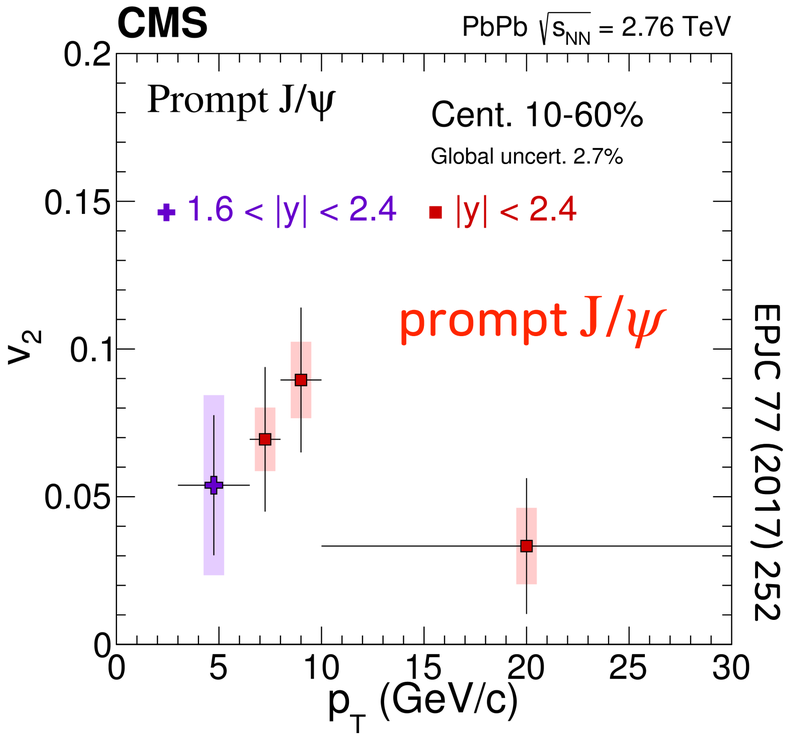


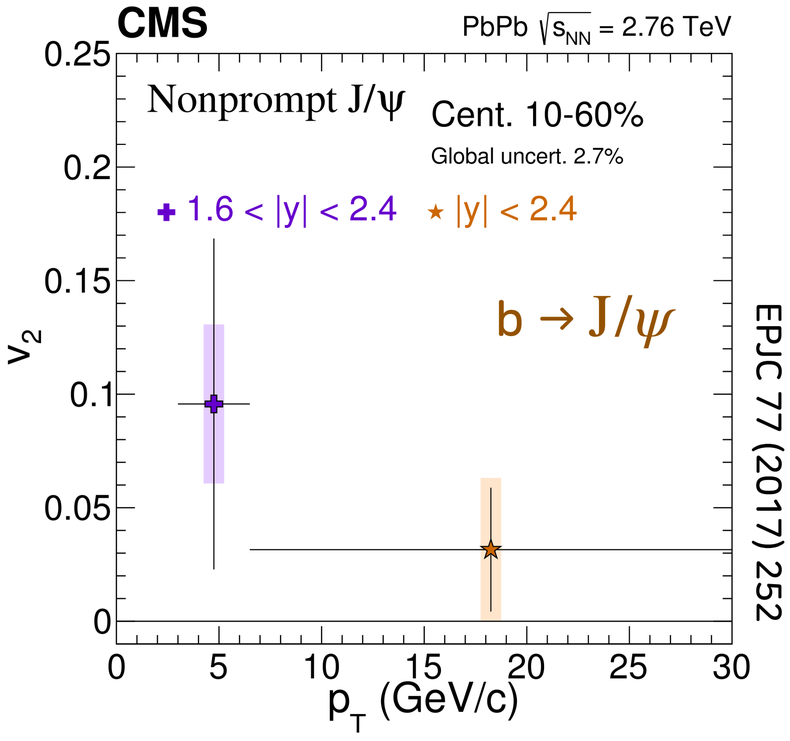
$$\frac{dN}{d\phi} \sim [1 + 2v_2 cos(2(\phi - \psi_2)) + 2v_3 cos(3(\phi - \psi_3))\ldots]$$

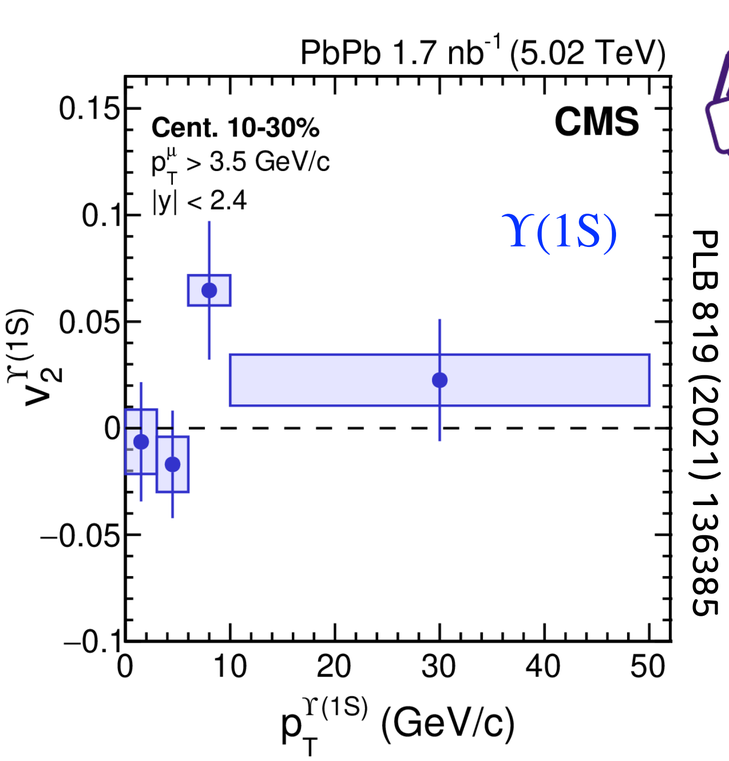
v_2 : Elliptic flow v_3 : Triangular flow



Motivation



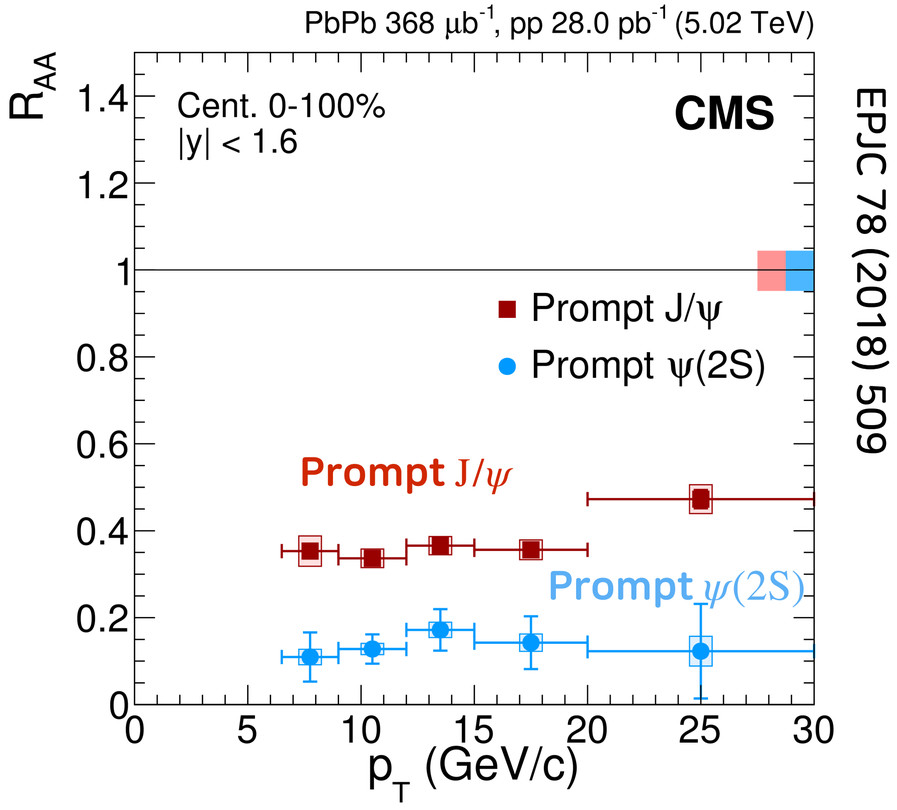




- J/ψ flow
  - Wide p_T coverage with CMS
  - Contribution from b hadron decays (b → J/ψ)
  - J/ψ $v_2 > 0 \Leftrightarrow \Upsilon(1S)$ $v_2 \approx 0$

→ Need to reveal 1) prompt vs b hadron decay J/ψ 2) p_T dependence

Motivation



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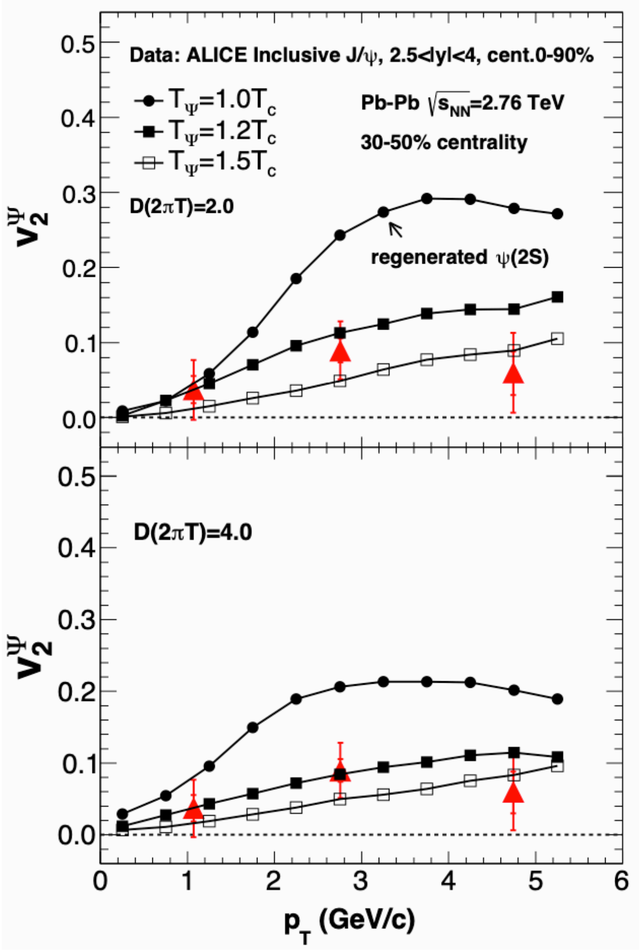

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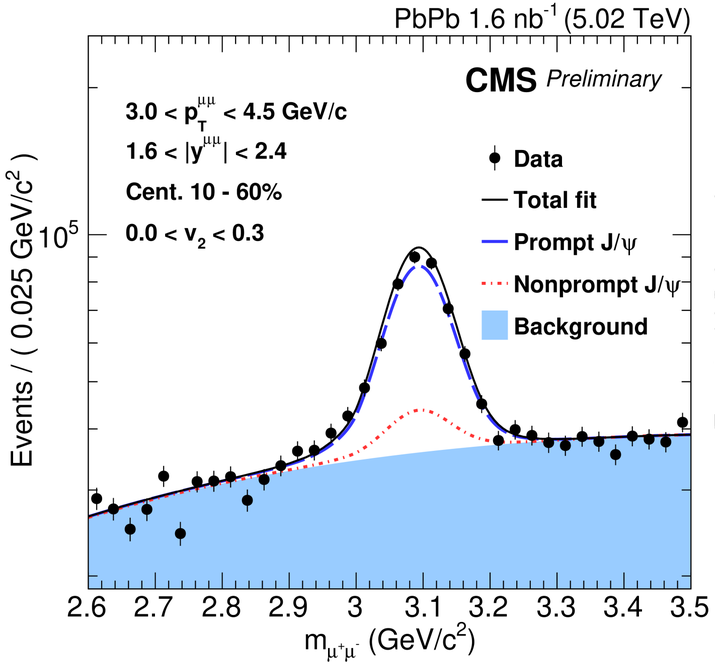
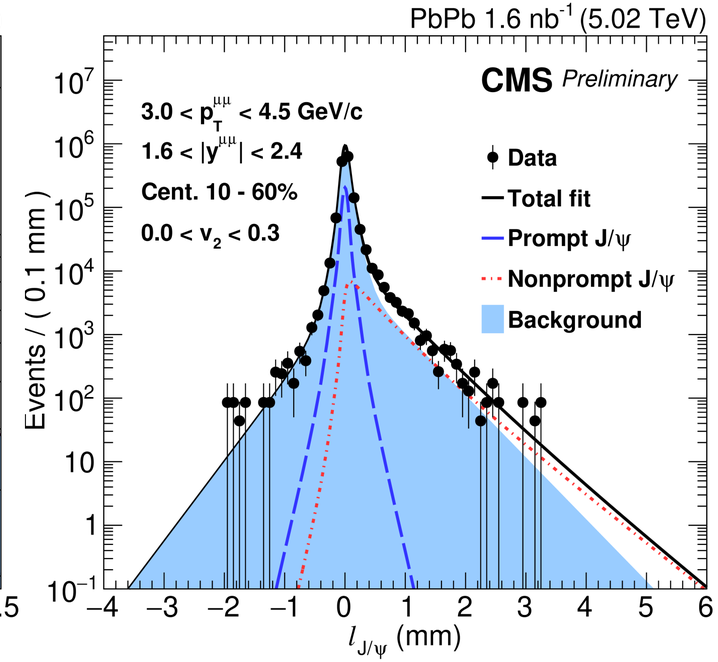
- $\psi(2S)$ flow
  - Not been measured yet in any collision system
  - Different amount of recombination for excited state?

Prompt and b hadron decay Charmonia

J/ψ : 2D fit on mass & decay length





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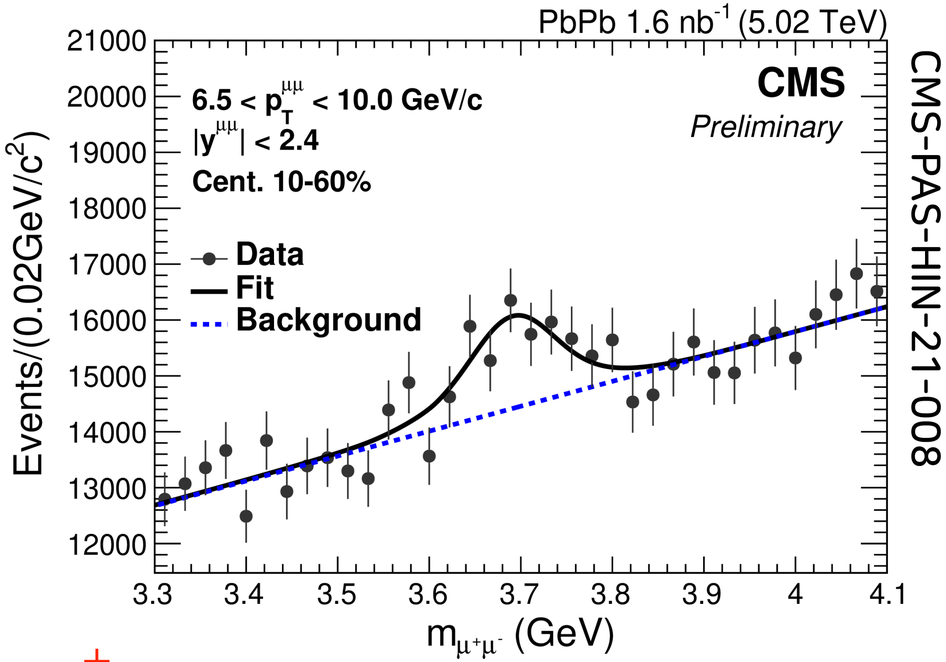
prompt J/ψ, b → J/ψ

$\psi(2S)$: Cut on decay length



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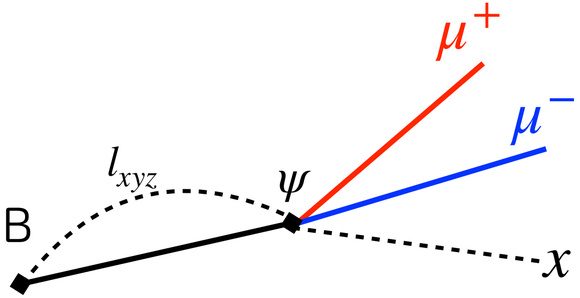
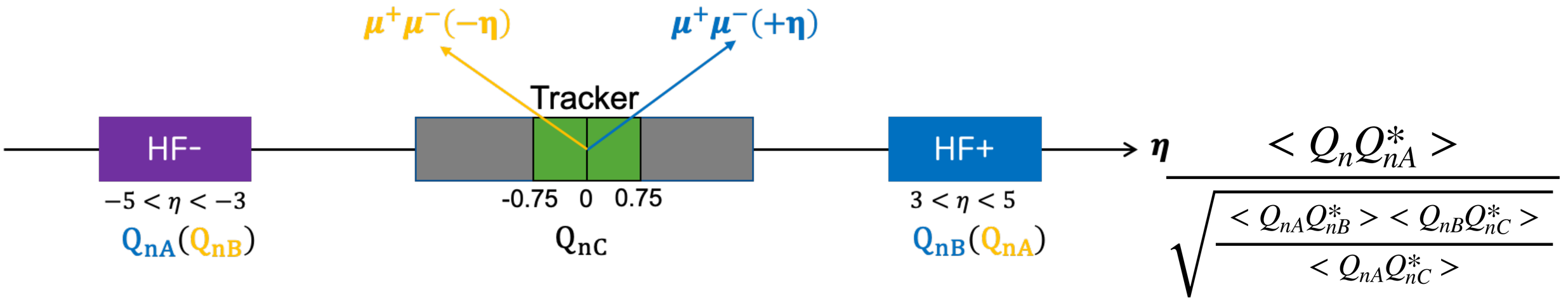
Prompt $\psi(2S)$



$$l_\psi = l_{xyz} \cdot m_\psi \cdot c / |p_{\mu\mu}|$$

v_n extraction : Scalar product method



$$\frac{< Q_n Q_{nA}^* >}{\sqrt{\frac{< Q_{nA} Q_{nB}^* > < Q_{nB} Q_{nC}^* >}{< Q_{nA} Q_{nC}^* >}}}$$

Scalar product method using Q-vectors

Q_n : Dimuon flow vector

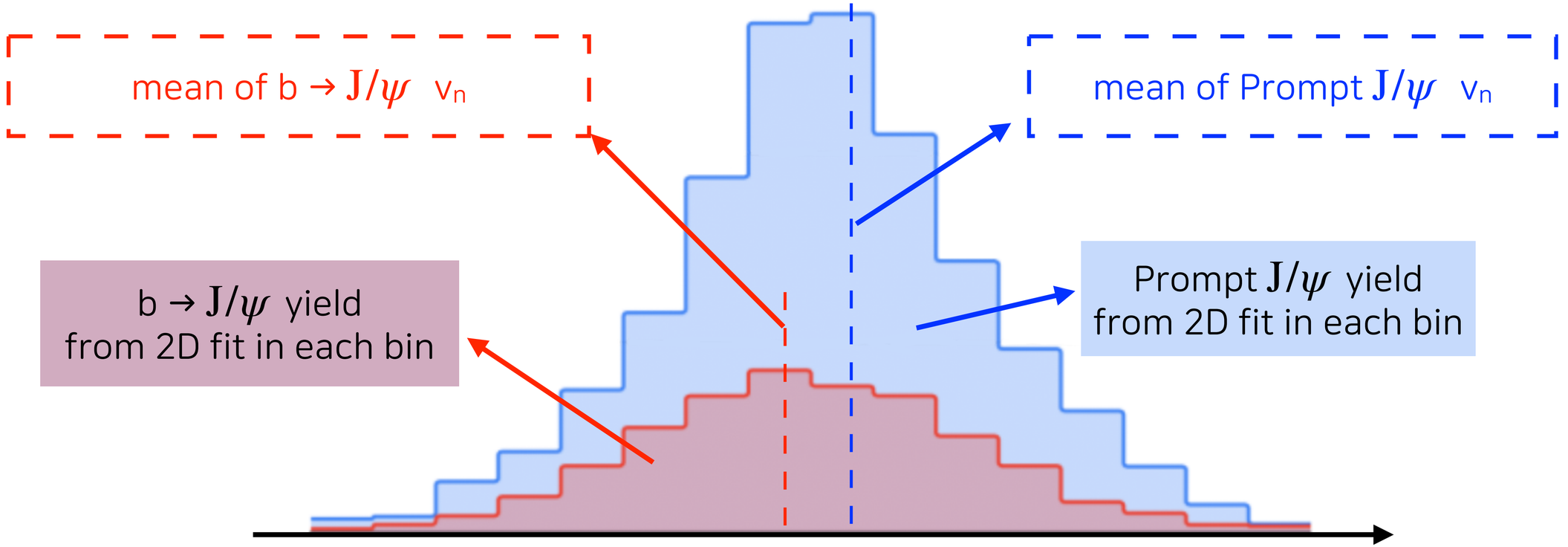
Q_{nA} (Q_{nB}) : Event plane vector for the opposite (same) side HF

Q_{nC} : Event plane vector in the tracker for $|\eta| < 0.75$

v_n extraction for J/ψ

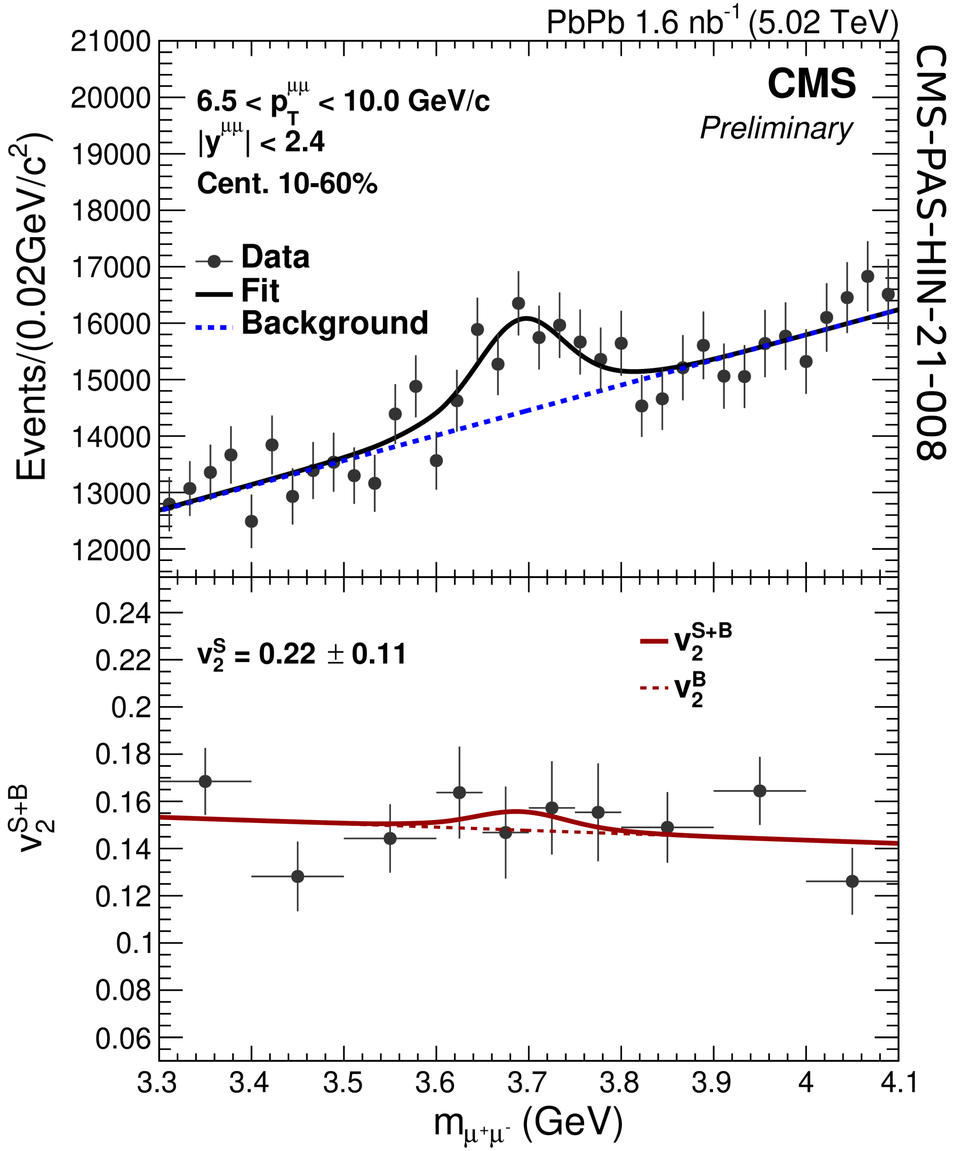
v_n profiling method

- no description needed for v_n background



$$\frac{Q_n Q_{nA}^*}{\sqrt{\frac{< Q_{nA} Q_{nB}^* > < Q_{nB} Q_{nC}^* >}{< Q_{nA} Q_{nC}^* >}}}$$

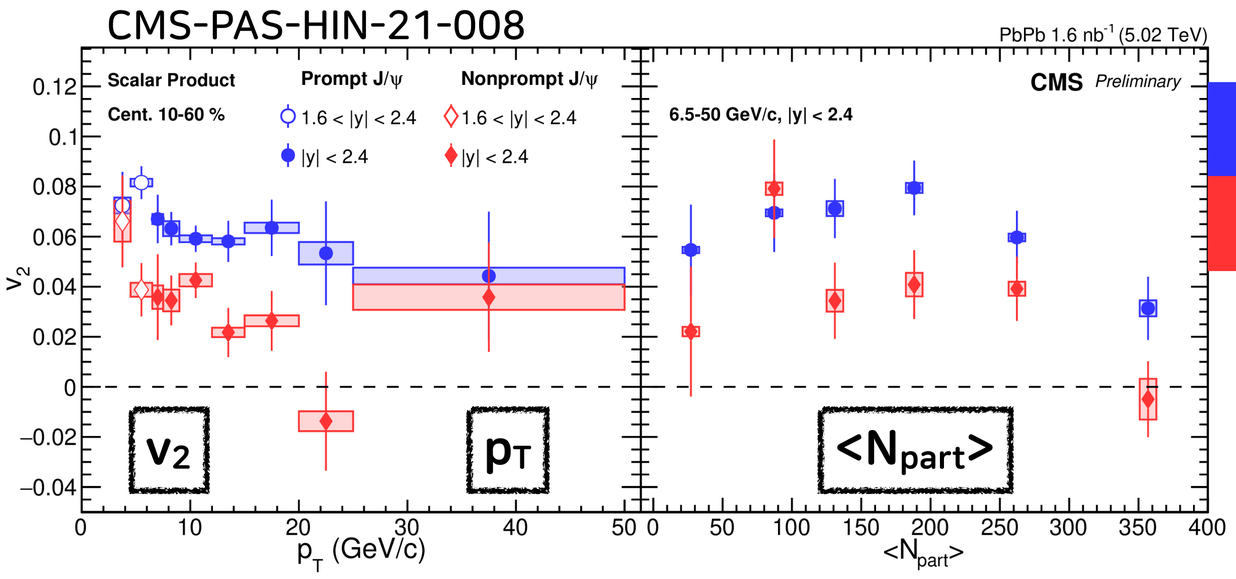
v_n extraction for prompt $\psi(2S)$



- Prompt enriched sample by decay length cut
- Mass and v_n simultaneous fit

- $v_n^{Sig+Bkg}(m_{inv}) = \alpha(m_{inv})v_n^{Sig} + (1-\alpha(m_{inv}))v_n^{Bkg}(m_{inv})$
- $\alpha(m_{inv}) = \dfrac{Sig(m_{inv})}{Sig(m_{inv}) + Bkg(m_{inv})}$

Result J/ψ v_n

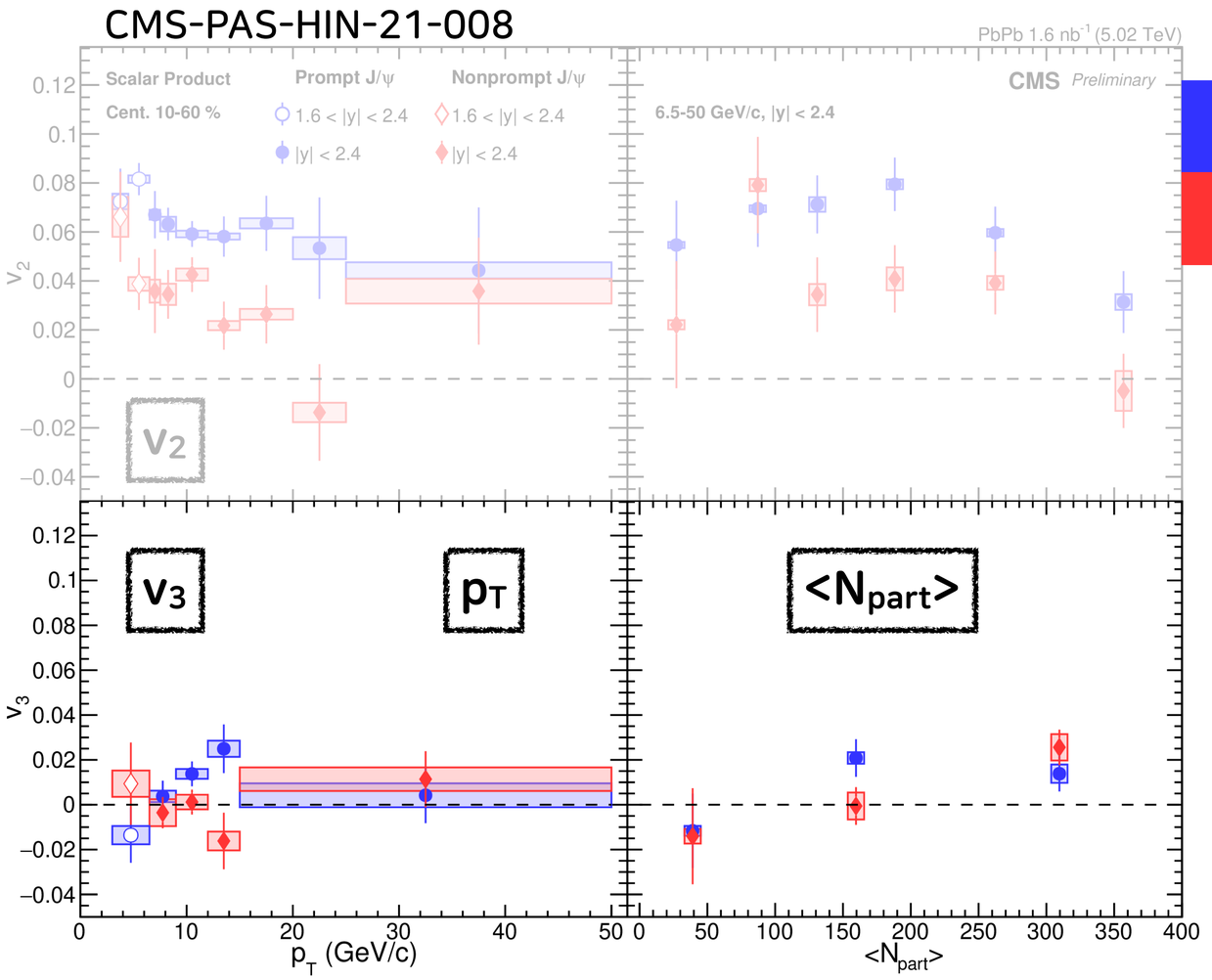


Prompt J/ψ

b → J/ψ

- Sizable v_2 up to 50 GeV/c
- b → J/ψ < prompt J/ψ v_2
  - different dynamics for c and b quark

Result J/ψ v_n



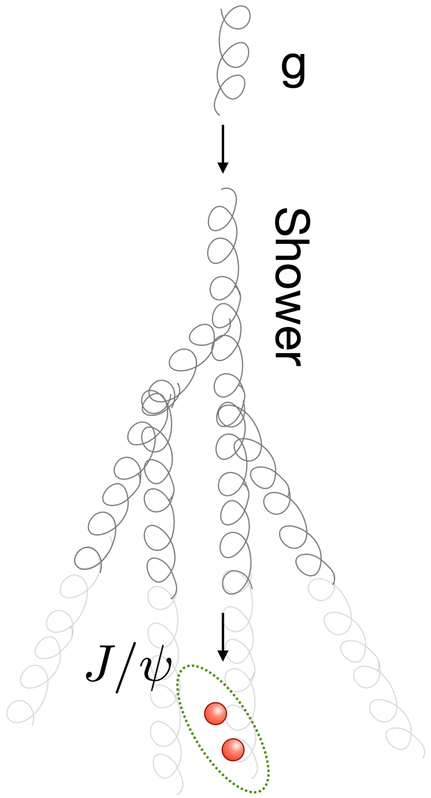
Prompt J/ψ

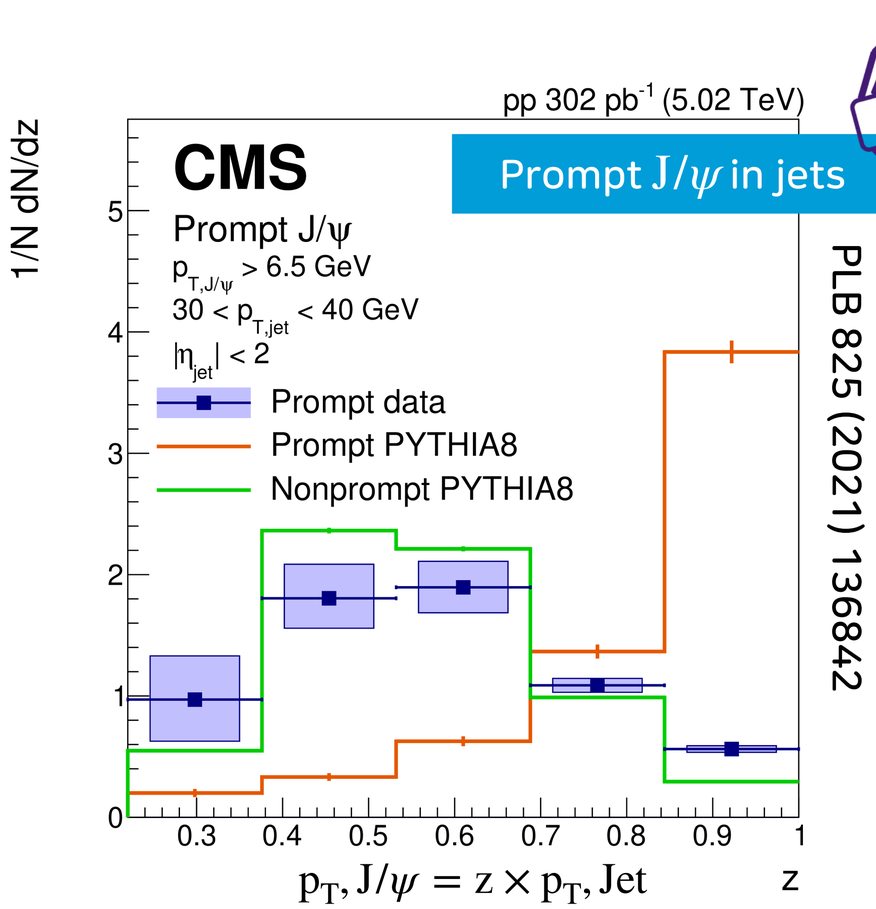
b → J/ψ

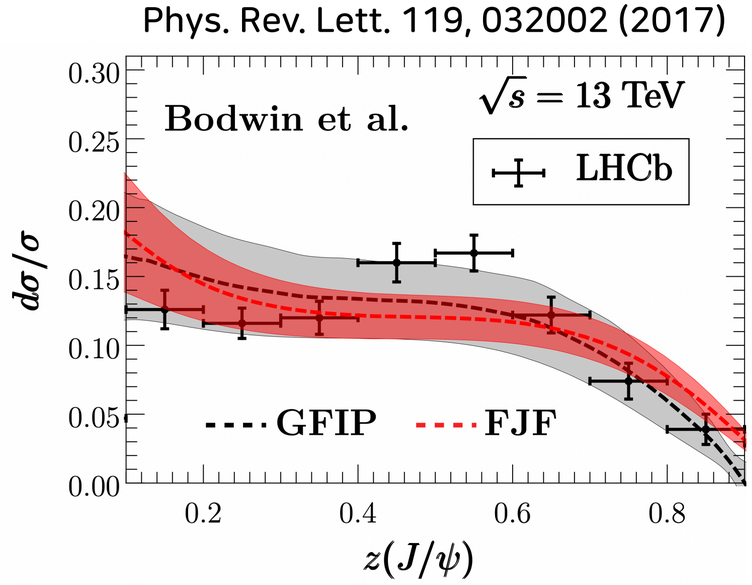
- Sizable v_2 up to 50 GeV/c
- b → J/ψ < prompt J/ψ v_2
  - different dynamics for c and b quark

- First separation of v_3 for prompt J/ψ and b → J/ψ
  - no significant non-zero v_3

Reminder : J/ψ in jets

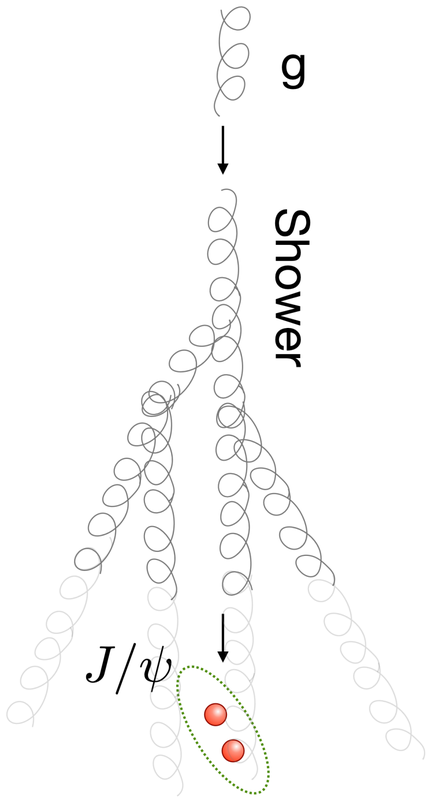


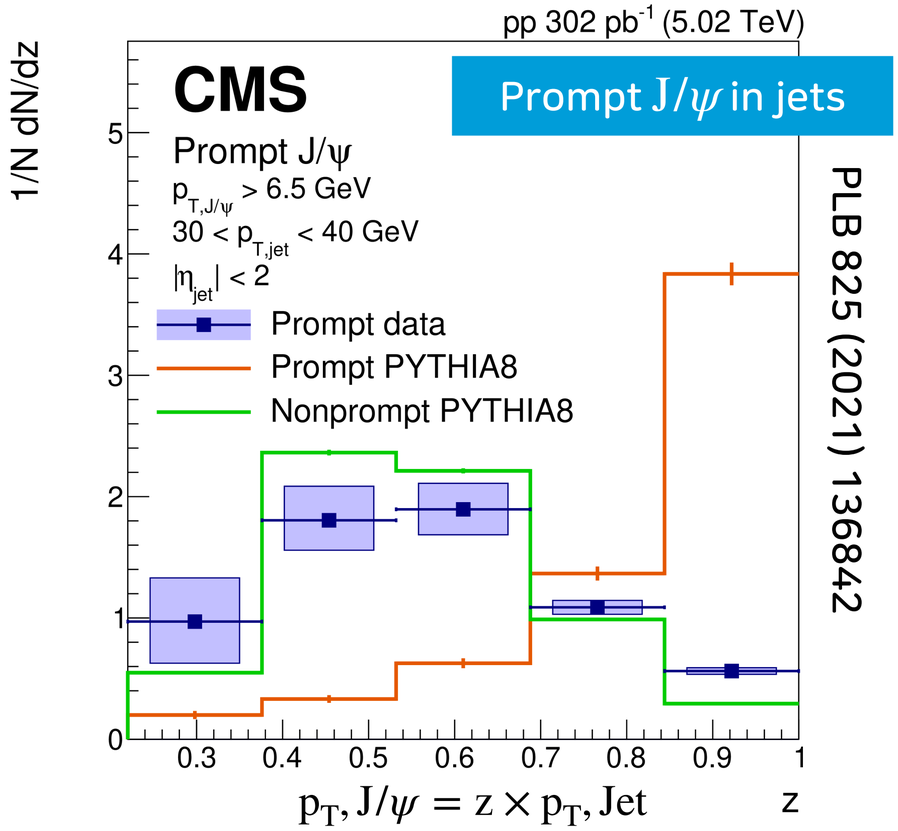


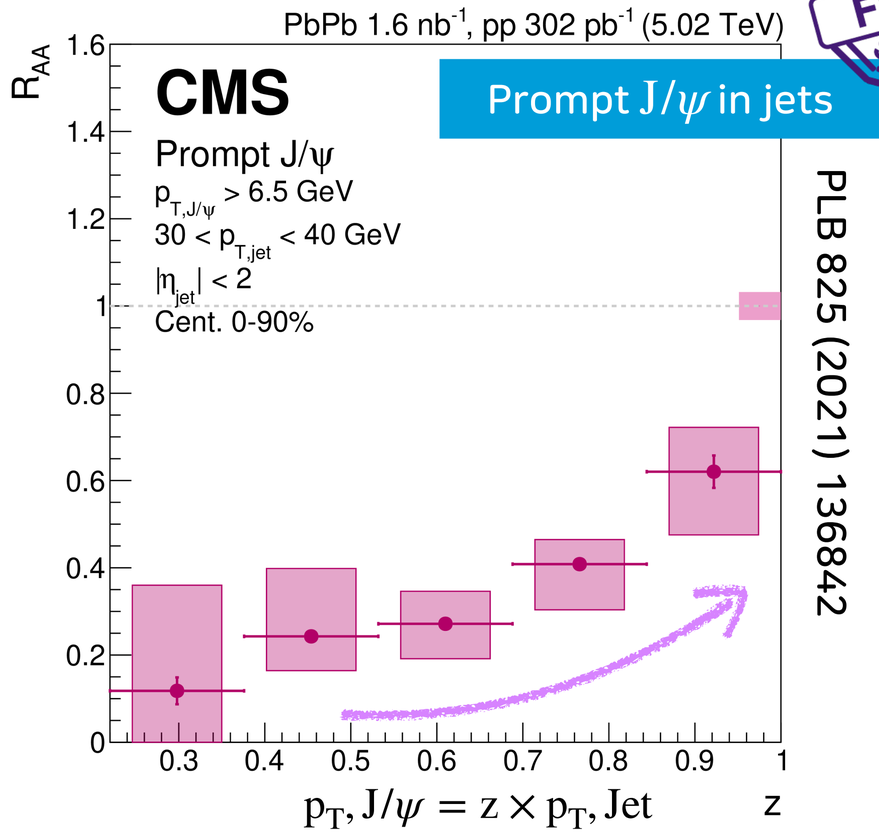


- Prompt J/ψ much more produced in jets than predicted by PYTHIA
  - Suggested to be produced at later stages by parton shower

Reminder : J/ψ in jets

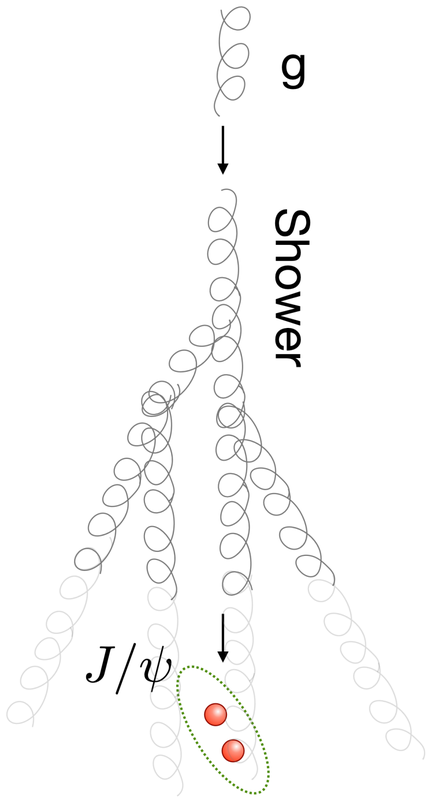


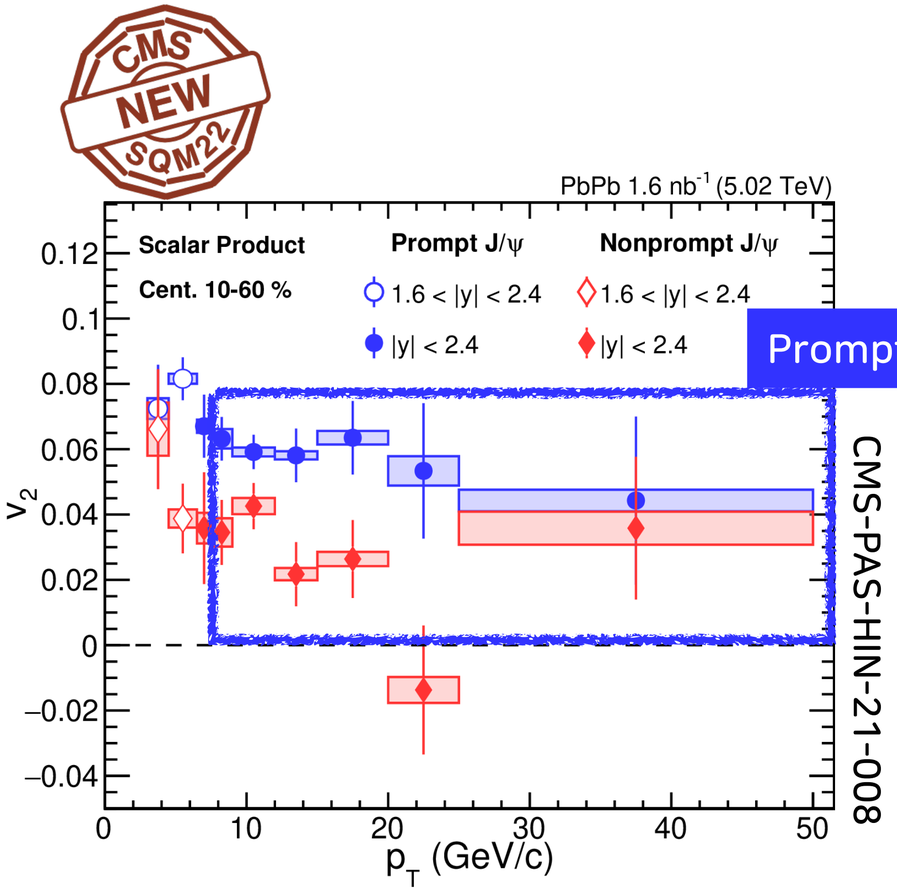


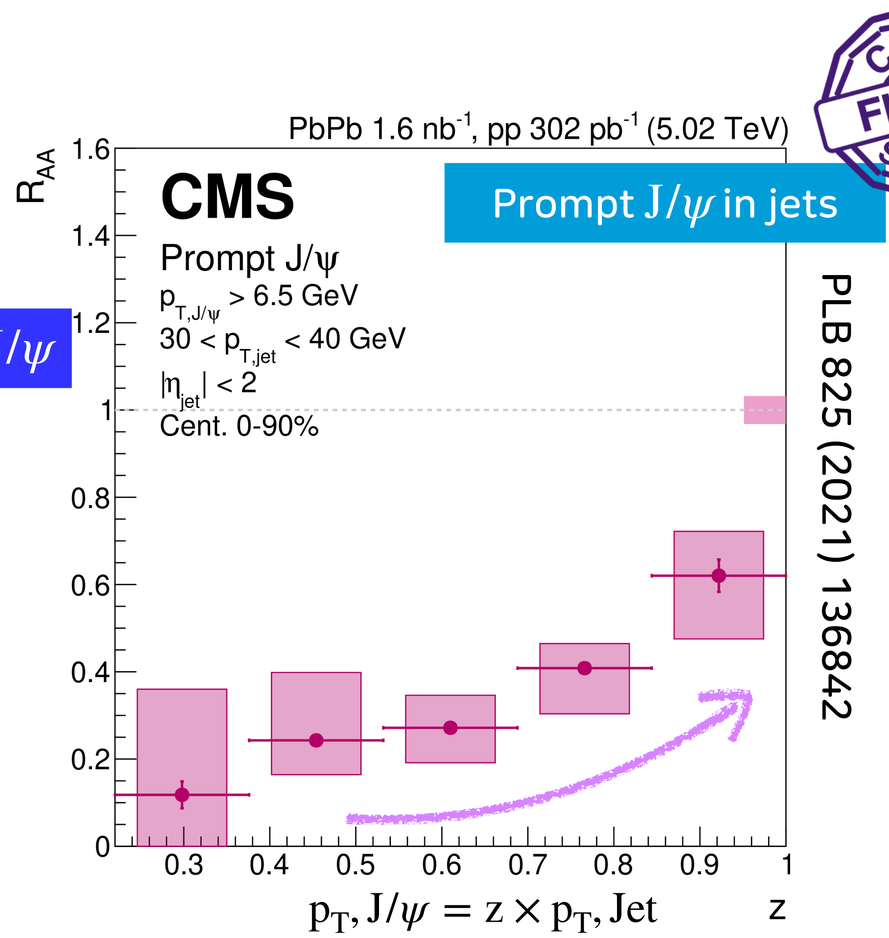


- Prompt J/ψ much more produced in jets than predicted by PYTHIA
  - Suggested to be produced at later stages by parton shower
- Less suppression for isolated J/ψ compared to J/ψ produced in jets
- Importance of jet quenching for Prompt J/ψ suppression at high-p_T

J/ψ v_2 ↔ J/ψ in jets

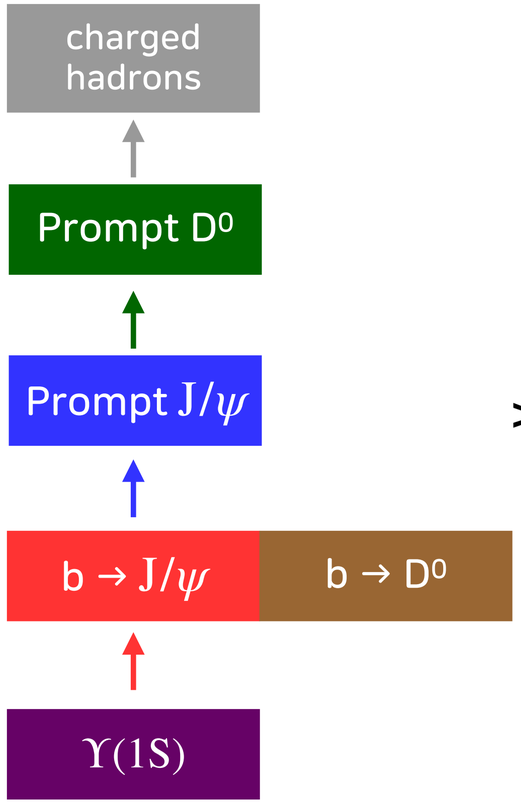


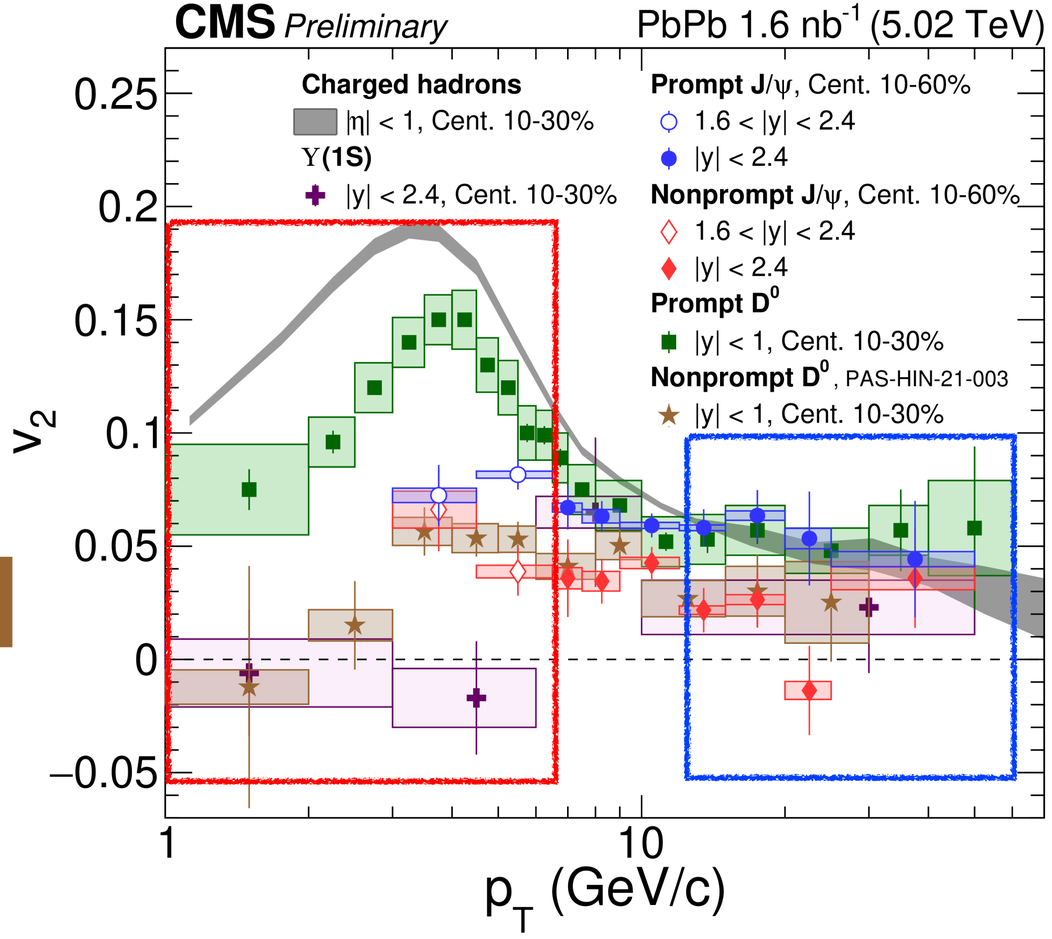




- Sizable v_2 up to 50 GeV/c → Connection to jet quenching?

Comparisons for v_2





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PLB 816 (2021) 136253

PLB 819 (2021) 136385

PLB 776 (2017) 195

charged hadrons ≈ Prompt D⁰ ≈ Prompt J/ψ

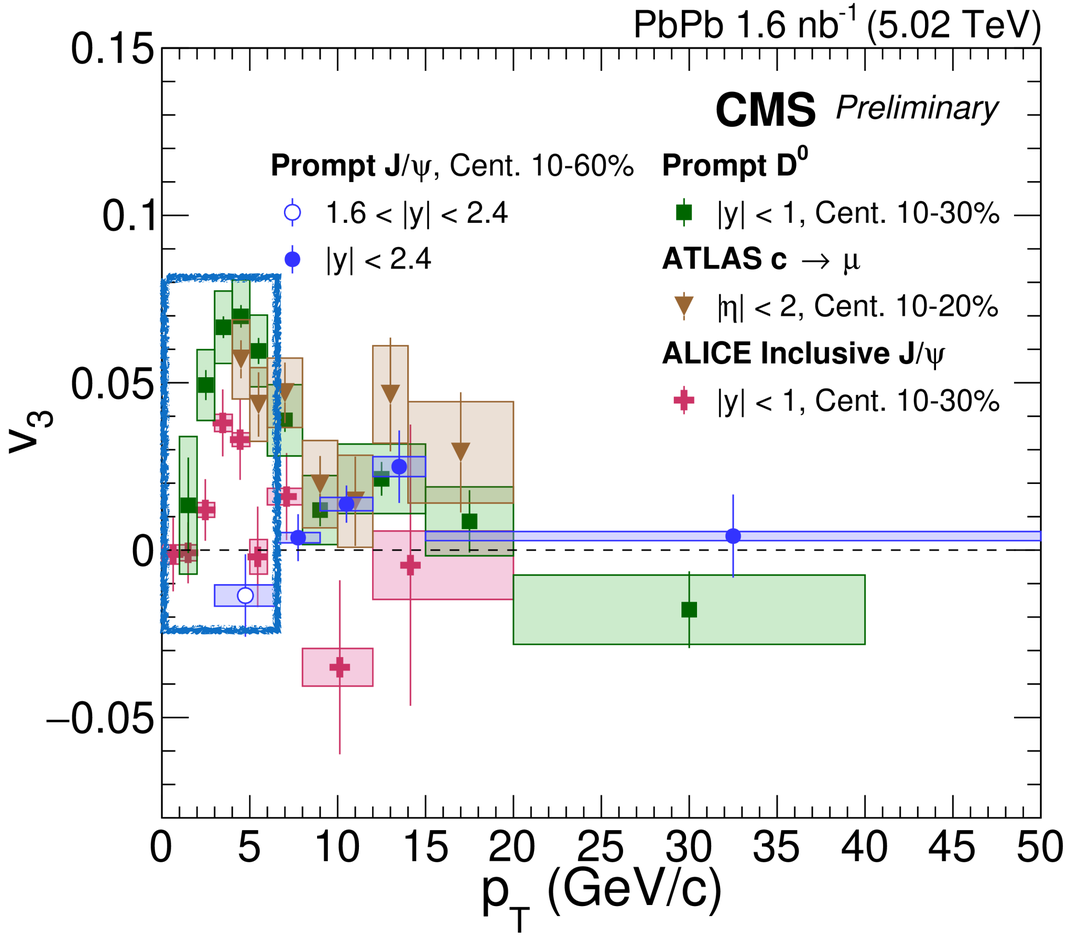
≈ b → J/ψ ≈ b → D⁰ ≈ ϒ(1S)

- **Low p_T : light > charm > beauty (mass ordering)**
- **High p_T : converge for all hadron species**

Comparisons for v_3

Prompt D^0 ≈ $c \rightarrow \mu$

Prompt J/ψ ≈ Inclusive J/ψ



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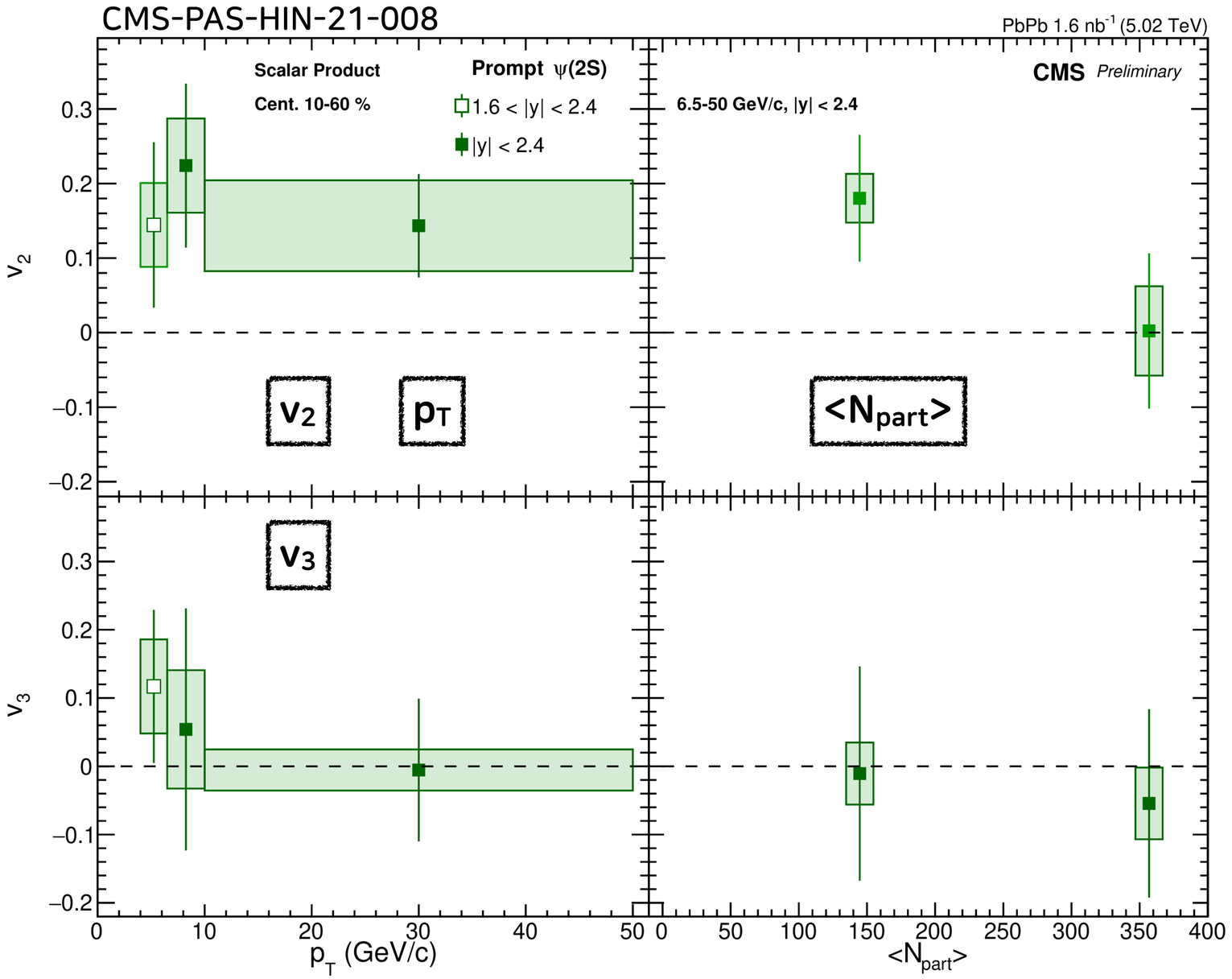
JHEP 10 (2020) 141

PLB 807 (2020) 135595

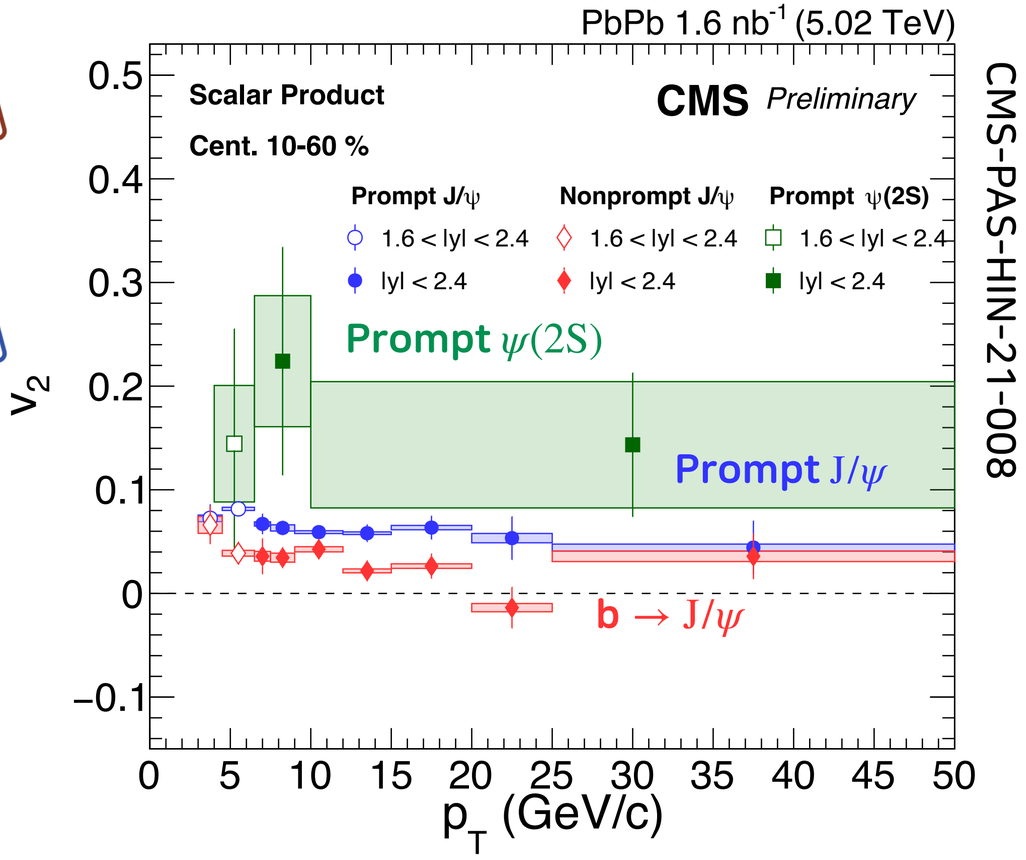
- Low p_T : Prompt D^0 v_3 > Prompt J/ψ / Inclusive J/ψ v_3
- Open charm is more sensitive to initial geometry than hidden charm

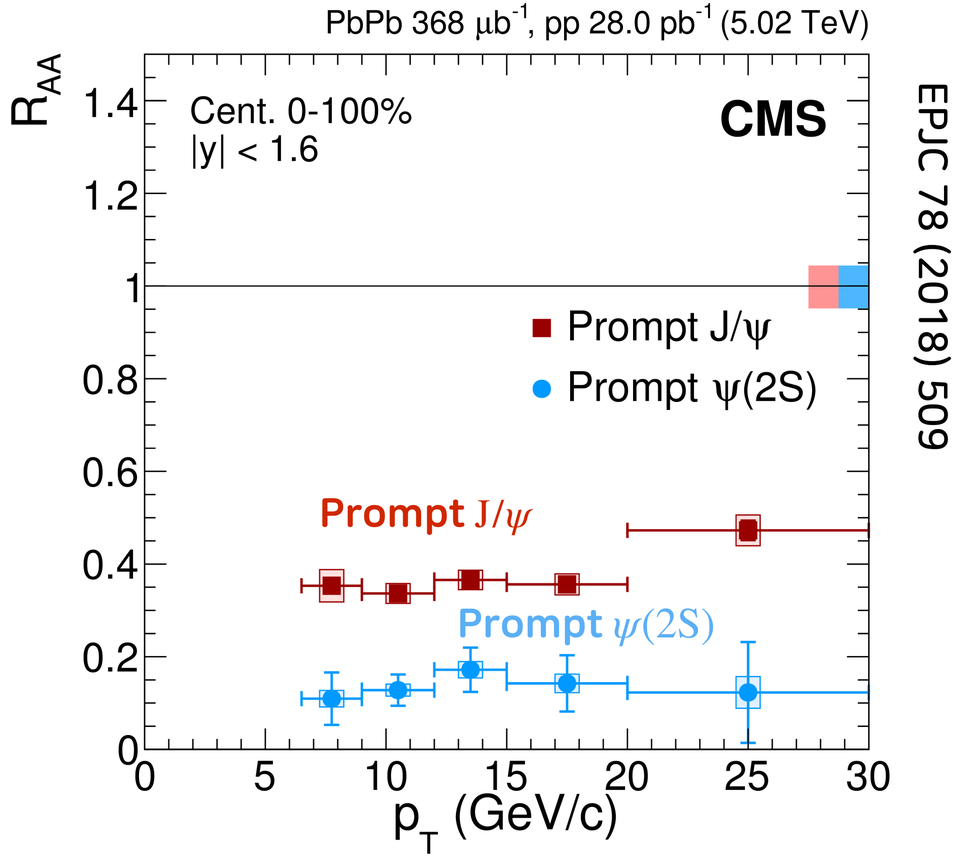
Result $\psi(2S)$ v_n



- First measurement in heavy ion!!
  - $v_2 > 0$ in p_T 4-50 GeV/c
  - v_3 consistent with zero

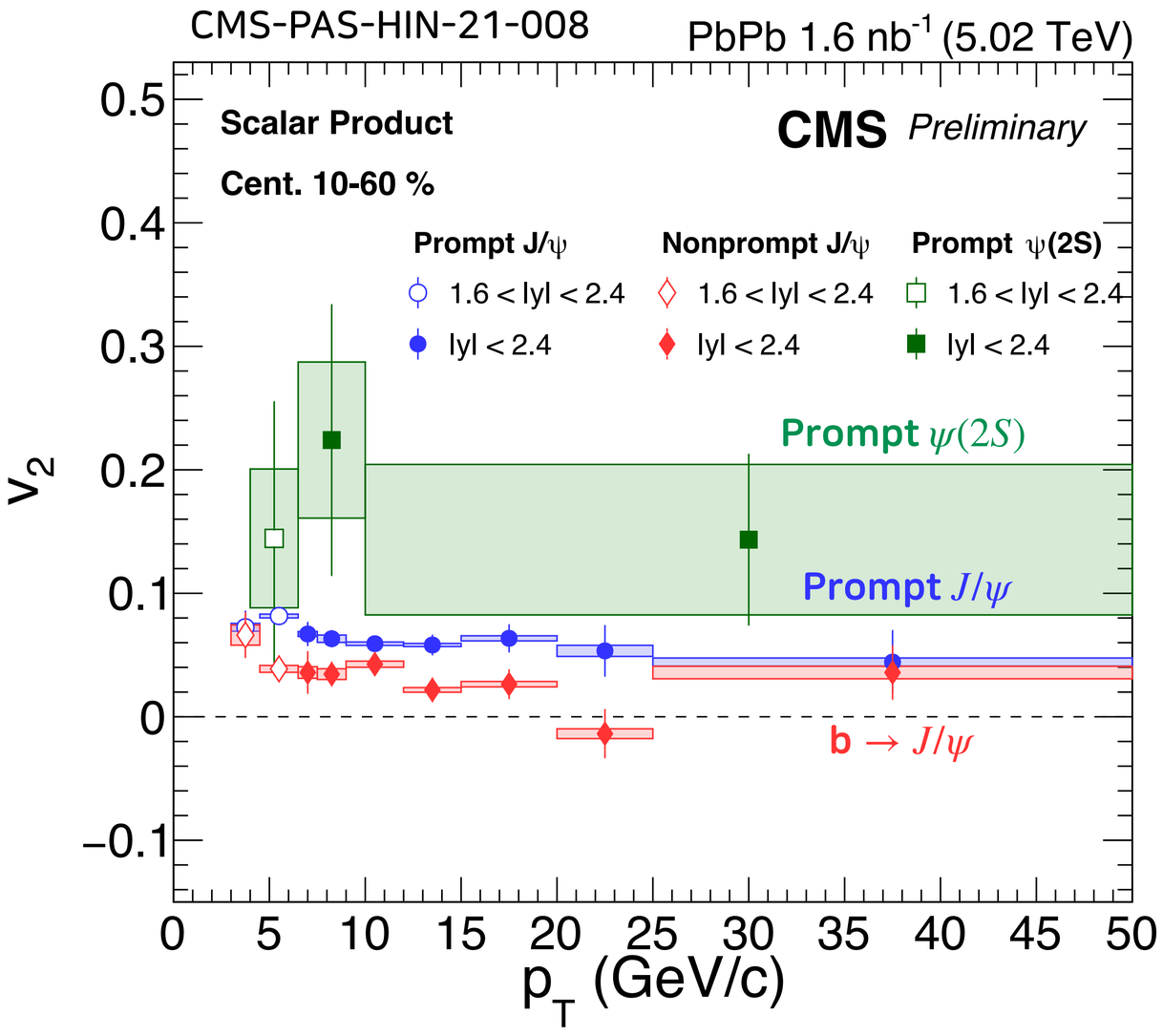
Result $\psi(2S)$ v_2 vs J/ψ v_2





- $\psi(2S)$ v_2 ≥ Prompt J/ψ v_2
  - Larger recombination effect? Path-length dependent E.Loss? etc?
    —> Need to be revealed with precision data in the future

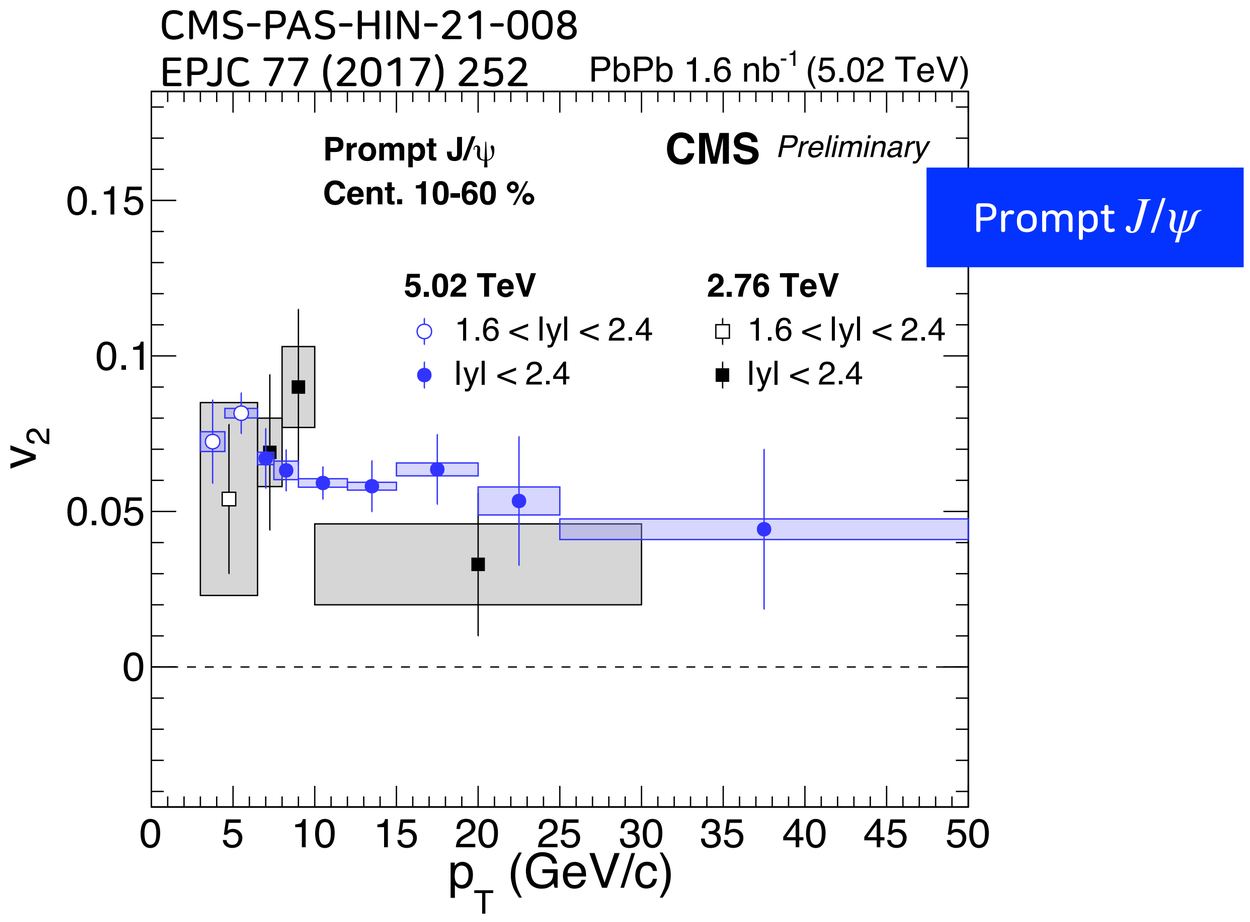
Summary



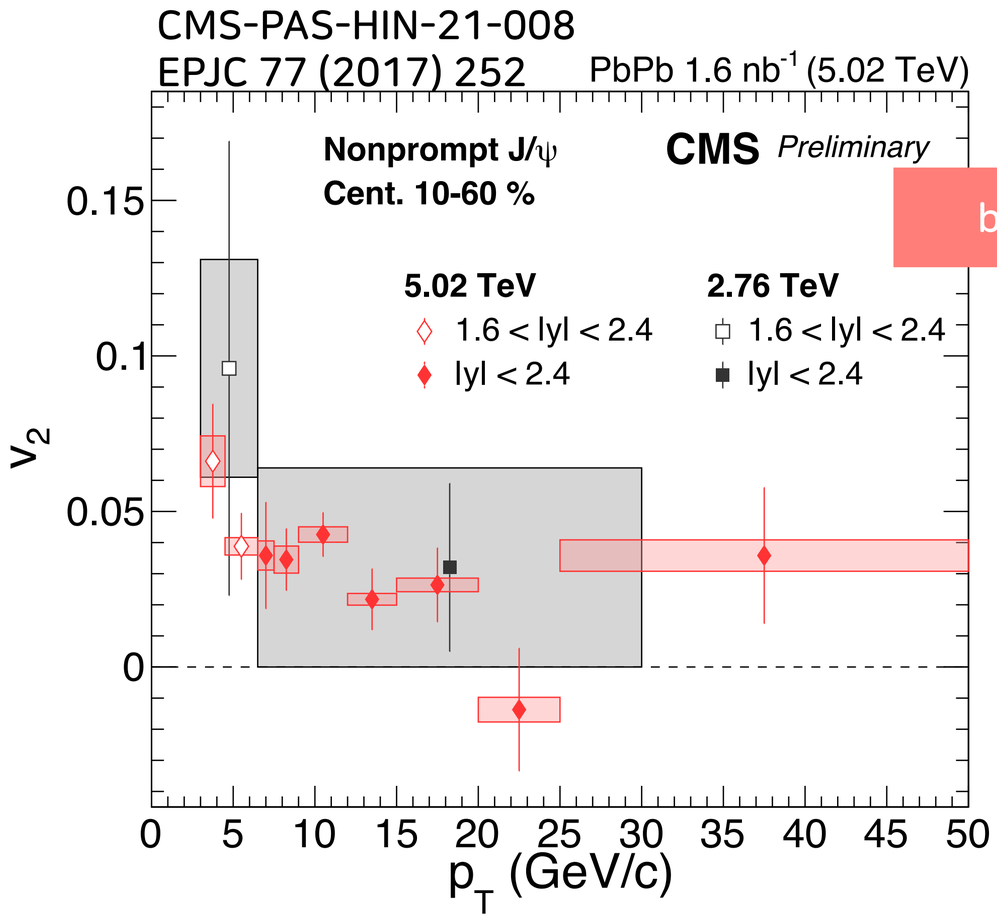
- Azimuthal anisotropy studied with charmonia in PbPb
- Prompt J/ψ v_2 > b → J/ψ v_2
- Sizable prompt J/ψ v_2 at high-p_T
- $\psi(2S)$ v_n first measured!
- $\psi(2S)$ v_2 $\geq$ J/ψ v_2

Thank you for your attention!

CMS 2.76 TeV vs 5.02 TeV



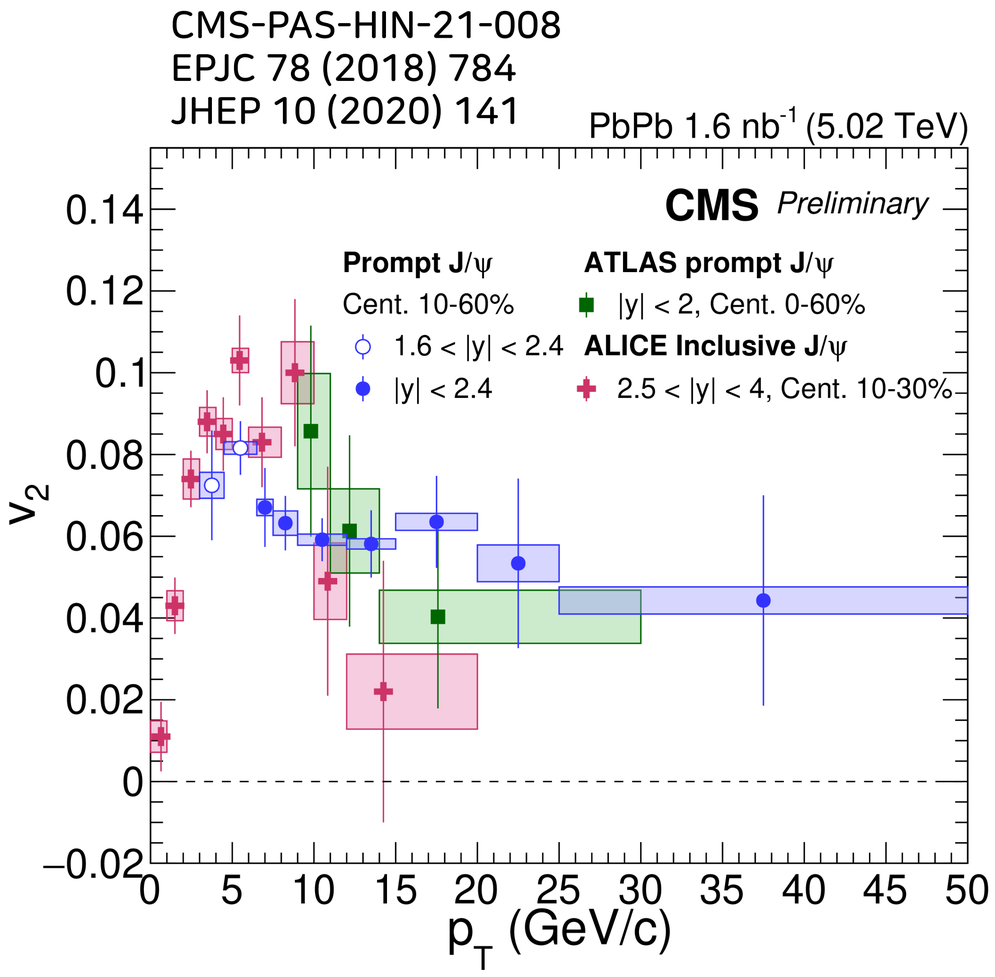
Prompt J/ψ



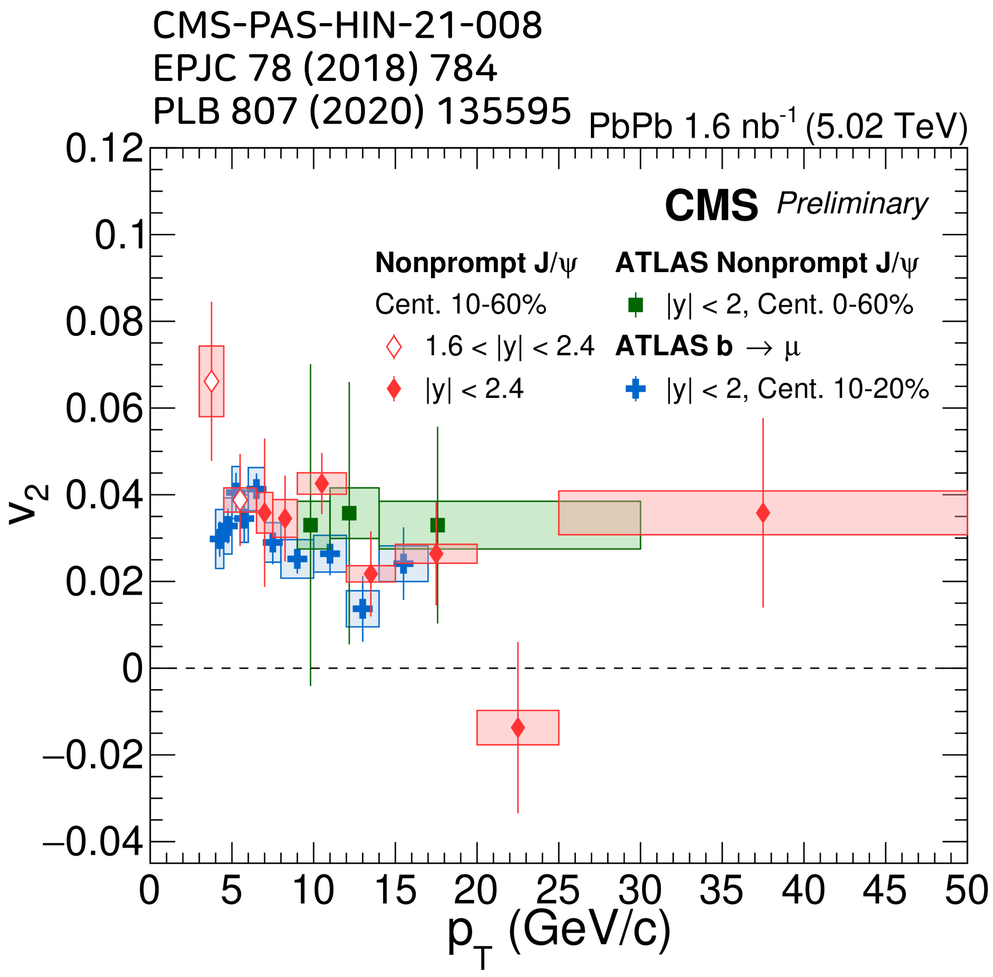
b → J/ψ

- Prompt and b → J/ψ at 2.76 vs 5.02 TeV
- High-precision with larger samples (x10)

Comparison v_2 with ATLAS, ALICE

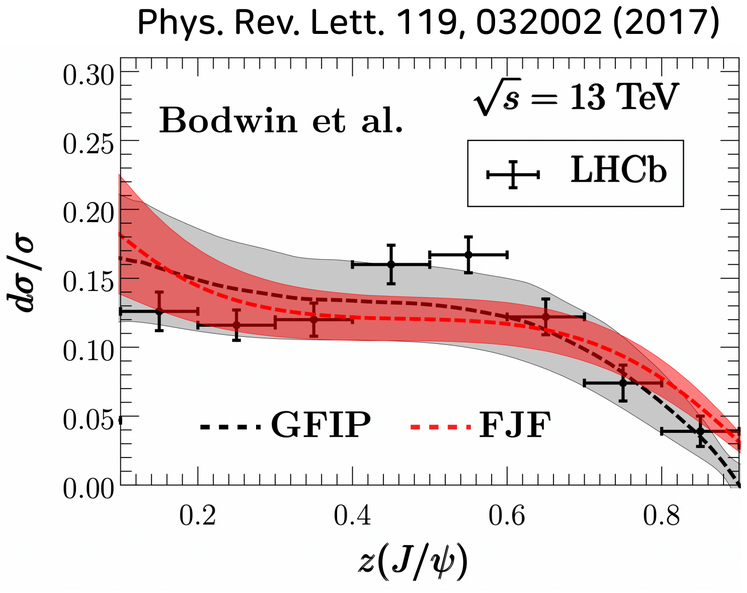


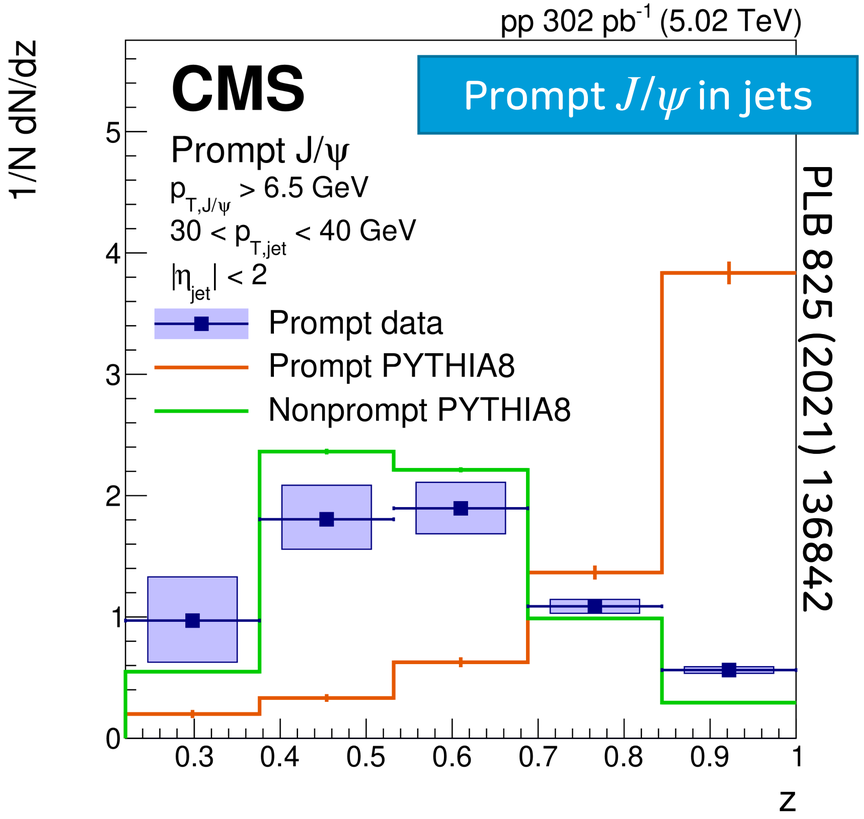
- Flow of inclusive and prompt J/ψ
- Flat to high p_T

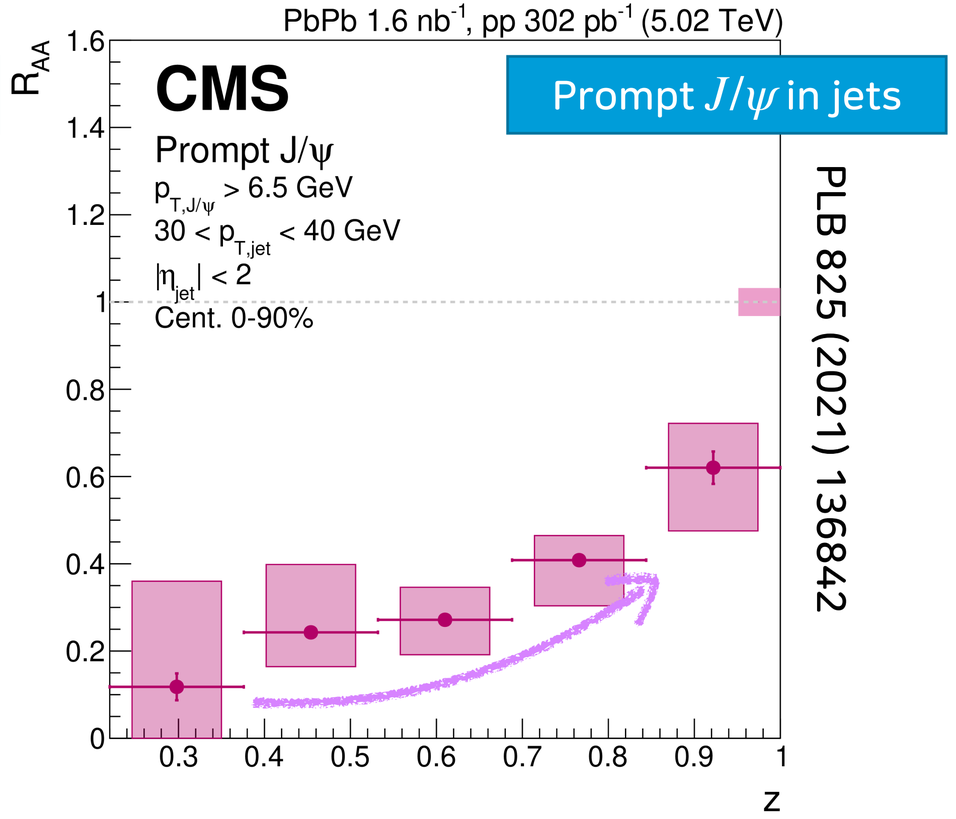


- Flow of b quark
- Compatible within uncertainty

J/ψ in jets


Phys. Rev. Lett. 119, 032002 (2017)
Bodwin et al.
$\sqrt{s} = 13$ TeV
LHCb
GFIP
FJF
$d\sigma/\sigma$
$z(J/\psi)$


pp 302 pb^{-1} (5.02 TeV)
CMS
Prompt J/ψ in jets
Prompt J/ψ
$p_{T,J/\psi}$ > 6.5 GeV
30 < $p_{T,jet}$ < 40 GeV
$|\eta_{jet}|$ < 2
Prompt data
Prompt PYTHIA8
Nonprompt PYTHIA8
1/N dN/dz
z
PLB 825 (2021) 136842


PbPb 1.6 nb^{-1}, pp 302 pb^{-1} (5.02 TeV)
CMS
Prompt J/ψ in jets
Prompt J/ψ
$p_{T,J/\psi}$ > 6.5 GeV
30 < $p_{T,jet}$ < 40 GeV
$|\eta_{jet}|$ < 2
Cent. 0-90%
R_{AA}
z
PLB 825 (2021) 136842

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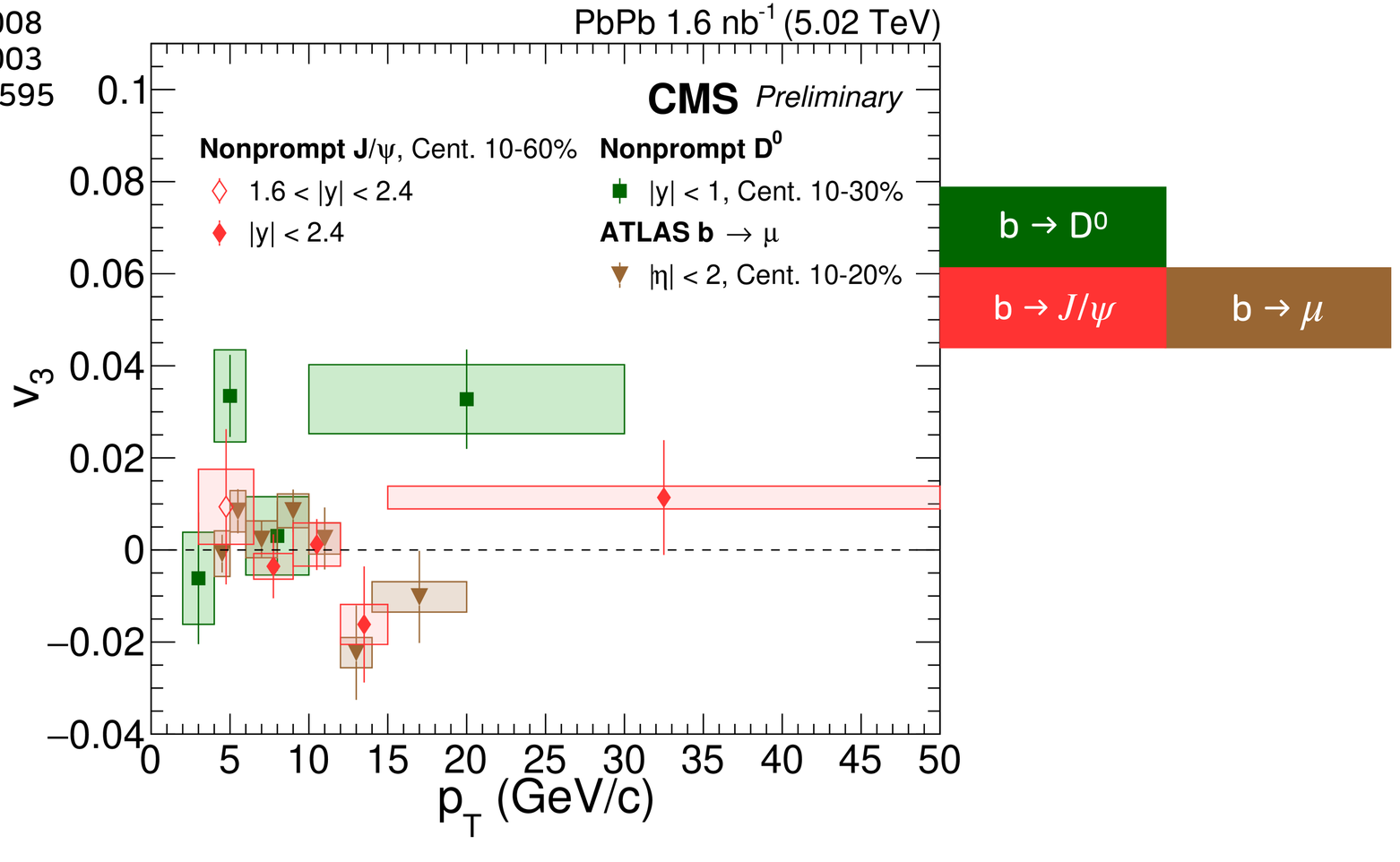
CMS-PAS-HIN-21-003
PLB 807 (2020) 135595



- v_3 of b hadrons are consistent