Investigation of azimuthal anisotropy of charmonium with the CMS experiment

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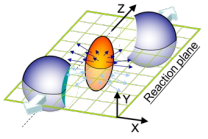
Abstract : The quark-gluon plasma(QGP) is considered the state of the early universe. The azimuthal anisotropy for charmonium states has been researched as one of the probes to understand the nature of the QGP. In this poster, we will report recent progress regarding the study of the elliptic and triangular flow for prompt and nonprompt J/ψ and prompt $\psi(2S)$ states in lead-lead collisions at the center-mass-energy per nucleon $\sqrt{s_{NN}}$ = 5.02 TeV with the CMS detector in 2018.

Motivation of flow analysis

❑ Azimuthal anisotropy (flow)



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

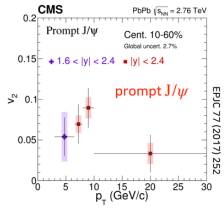
Elliptic flow — Triangular flow

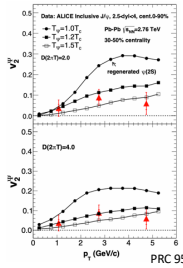
- Sensitive to initial collision geometry
- Collectivity (low-p_T), path-length energy loss (high p_T)

❑ Charmonia : bound state of charm quark pair

- Produced via hard scattering
- Reflect the various in-medium effects inside QGP
  - Debye screening + Dissociation
  - Recombination

❑ Previous results





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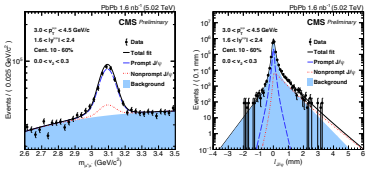
- J/ψ flow
  - Wide p_T coverage with the CMS detector
  - Contribution from b hadron decays (b->J/ψ)
- $\psi(2S)$ flow
  - Not been measured yet
  - Different amount of recombination for excited states?

Analysis procedure

J/ψ

❑ Prompt and b → J/ψ separation :

2D fit on mass and decay length



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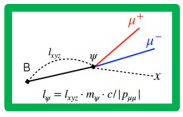
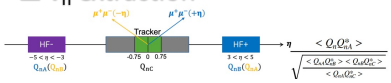


❑ v_n extraction



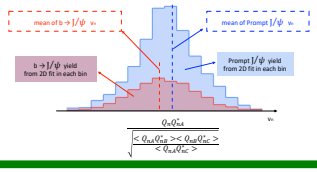
Scalar product method using Q-vectors

Q_n : Dimuon flow vector

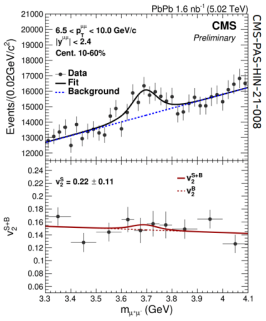
Q_{nA} (Q_{nB}) : Event plane vector for the opposite (same) side HF

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

v_n profiling method



$\psi(2S)$



❑ Prompt and b → J/ψ separation

- Cut on decay length

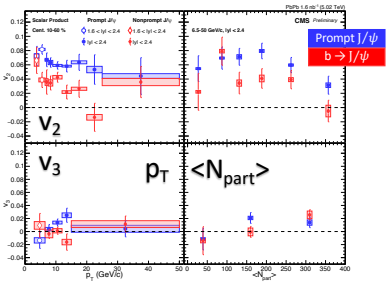
❑ v_n extraction

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

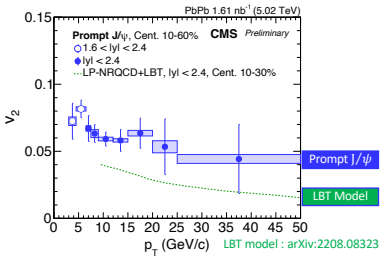
- $v_n^{Sig+Bkg}(m_{inv}) = \alpha(m_{inv}) v_n^{Sig} + (1 - \alpha(m_{inv})) v_n^{Bkg}(m_{inv})$
- $\alpha(m_{inv}) = \frac{Sig(m_{inv})}{Sig(m_{inv}) + Bkg(m_{inv})}$

Results : CMS-PAS-HIN-21-008

J/ψ



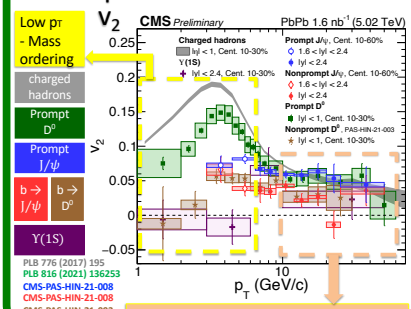
- Sizable v_2 up to 50 GeV/c
- b → J/ψ < Prompt J/ψ v_2
  - different dynamics for c and b quark
- First separation of v_3 for b → J/ψ and Prompt J/ψ
  - compatible with zero v_3



LBT model : arXiv:2208.08323

- LBT is used for the medium response of jets in PbPb collisions
- Model overpredicts v_2 in the data
- This discrepancy indicates additional effects are required to describe the observed sizable v_2 at high p_T for Prompt J/ψ

❑ Comparison with other hadron species



PLB 776 (2017) 195
PLB 816 (2021) 136253
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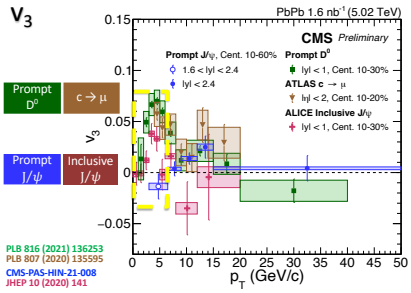
PLB 819 (2021) 136385

High p_T : Converge for all hadron species



PLB 816 (2021) 136253
PLB 807 (2020) 135595
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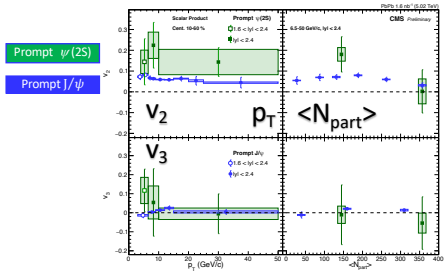
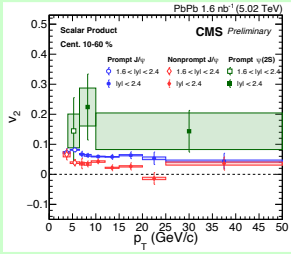
Suggestion of less sensitivity to initial geometry for hidden charm than open charm

$\psi(2S)$



- v_2 : slightly larger for Prompt $\psi(2S)$
- v_3 : consistent with zero

Summary



- First measurement
  - Prompt J/ψ and b → J/ψ v_3
  - Prompt $\psi(2S)$ v_n

v_2
- Prompt J/ψ and b → J/ψ : indicate a decreasing trend from mid-central towards central collision events
- no clear p_T dependence between 3 to 50 GeV/c
- Prompt J/ψ > b → J/ψ : suggest different in-medium effects for charm and bottom quarks
- Prompt $\psi(2S)$ > Prompt J/ψ

v_3
- Prompt J/ψ and b → J/ψ : consistent with zero
- Prompt $\psi(2S)$ > Prompt J/ψ