

Measurements of prompt and nonprompt D^0 mesons production and collective flow with CMS

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Purdue University
on behalf of the CMS collaboration



Quark Matter 2023, Houston, TX, USA



Why do we study D⁰ mesons?**Prompt D⁰**

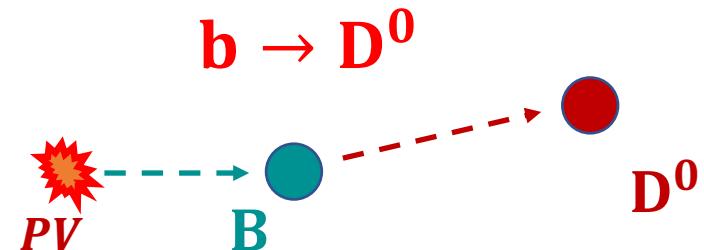
~40% of all prompt charm hadrons are D⁰ meson!

Best avenue for charm quark properties!

**Nonprompt D⁰**

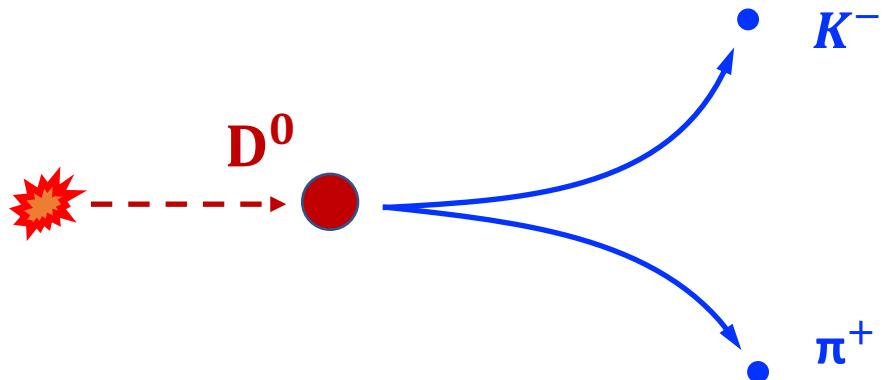
~70% of all b hadrons decay to D⁰ mesons!

Great possibilities for b quark studies!



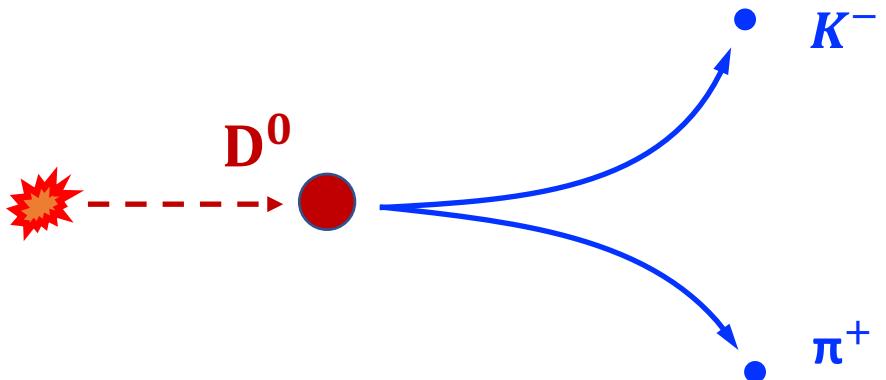
Reconstruction

- ❑ Inclusive D^0 reconstruction
 - ❖ $D^0 \rightarrow K^-\pi^+$
- ❑ No particle identification
 - ❖ All opposite charge track pairs combinations
- ❑ Boosted Decision Tree for background rejection



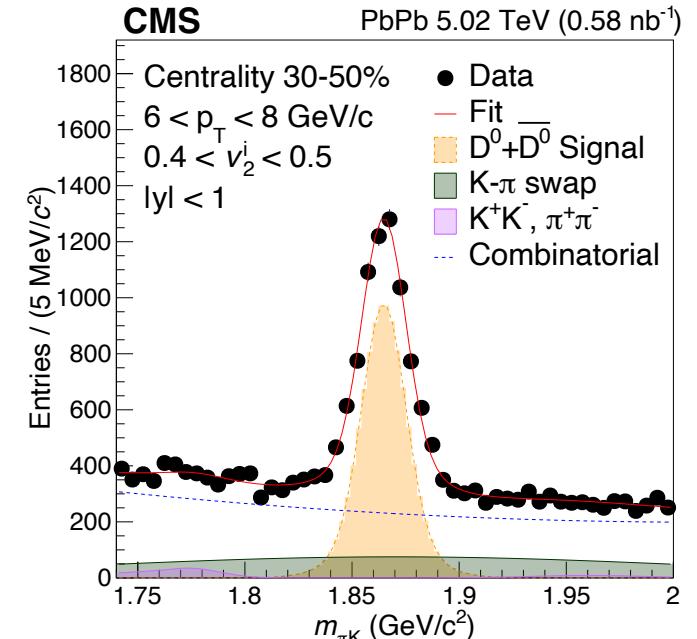
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Inclusive D⁰ Yield

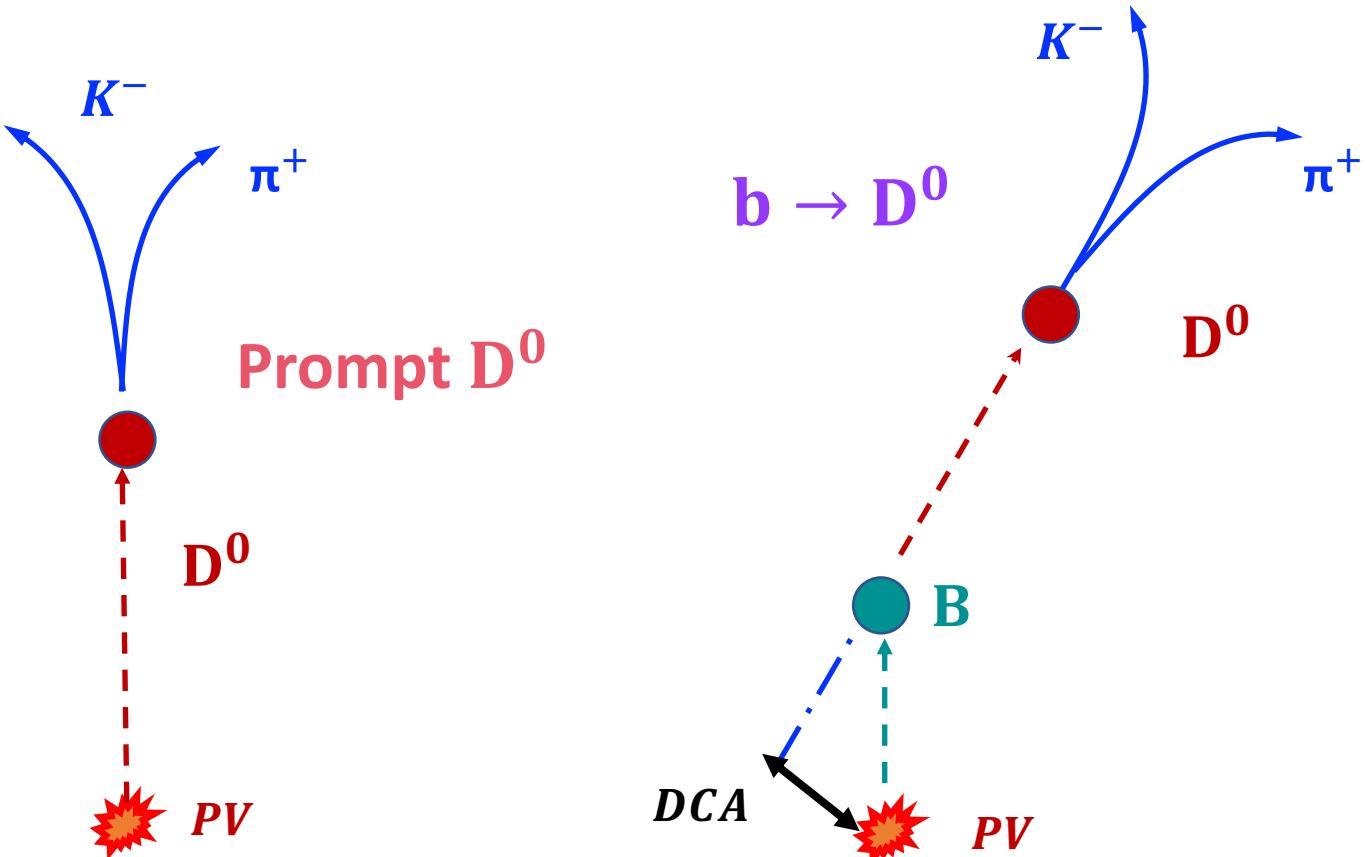
- ❑ Signal mass spectrum – double gaussian
- ❑ Swap component – gaussian
- ❑ K^+K^- & $\pi^+\pi^-$ – Crystal ball functions
- ❑ Combinatorial – polynomial 3rd order



arXiv:2212.01636
submitted to PLB

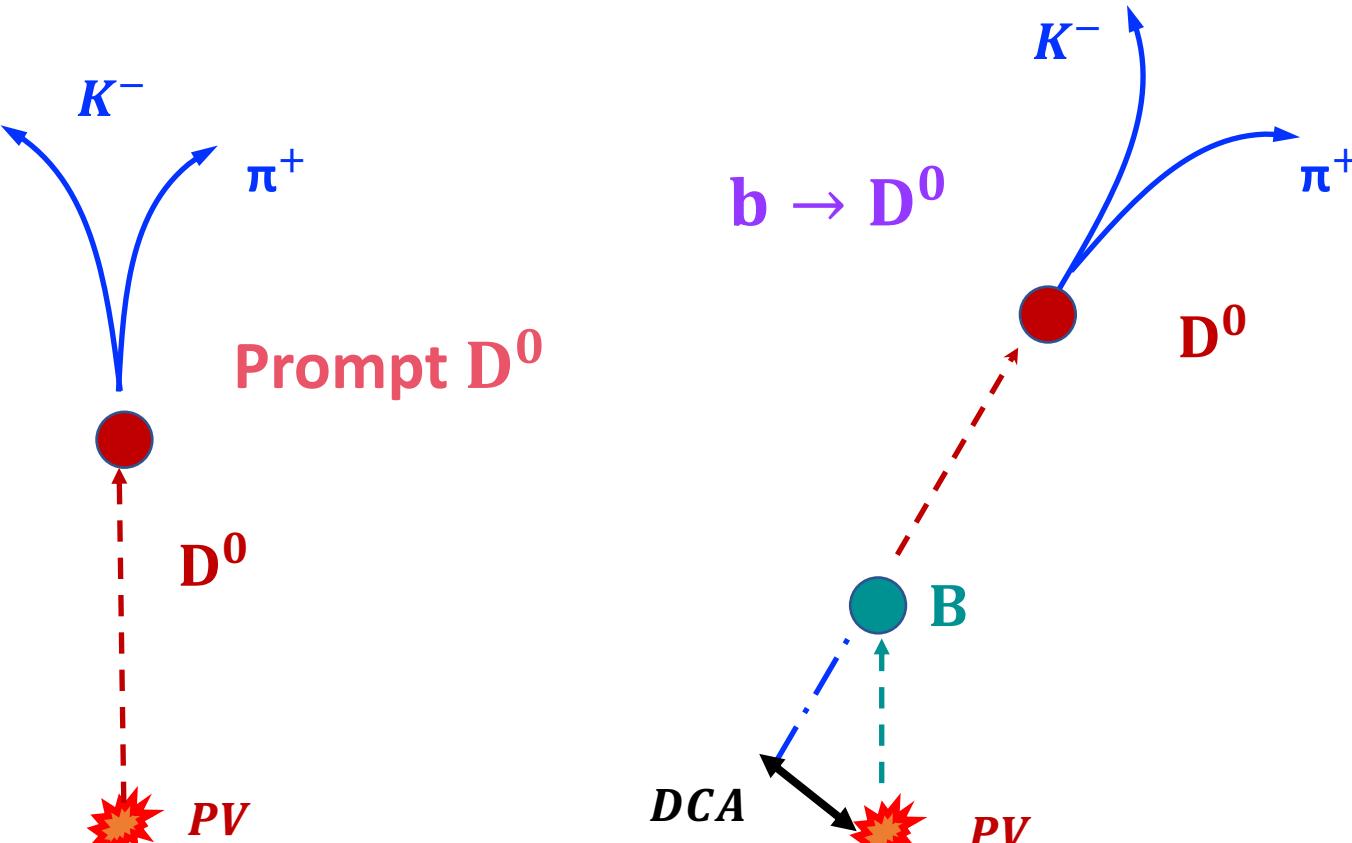
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Two component template fit to extract $b \rightarrow D^0$ fraction

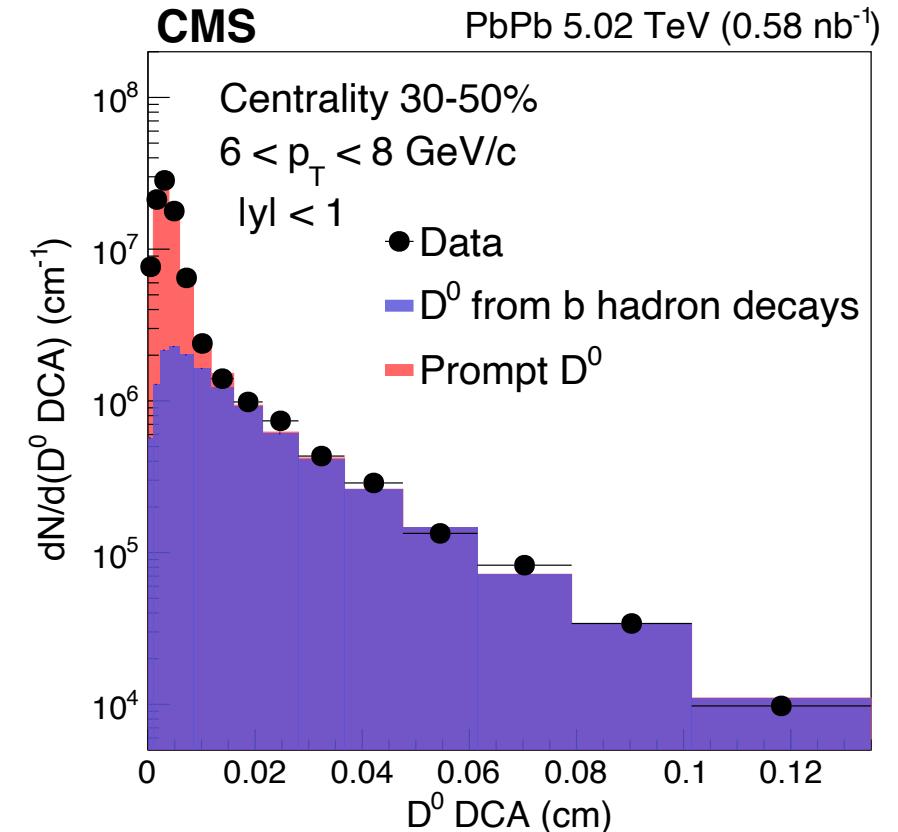


DCA (distance of closest approach)

Two component template fit to extract $b \rightarrow D^0$ fraction



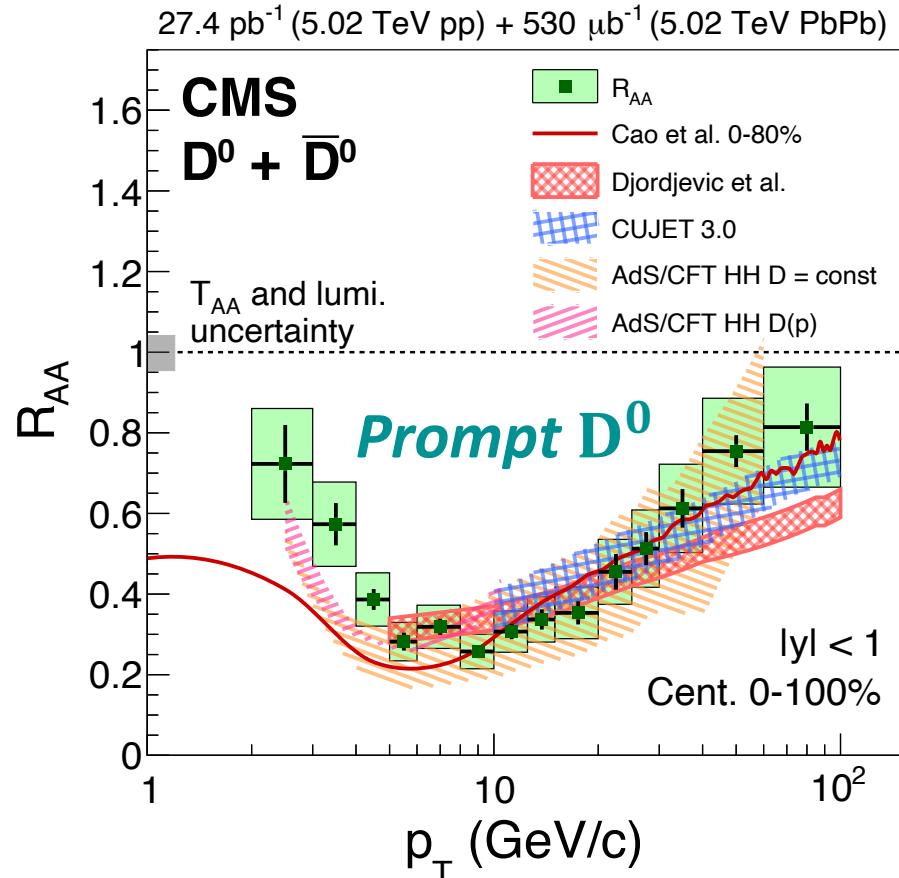
DCA (distance of closest approach)



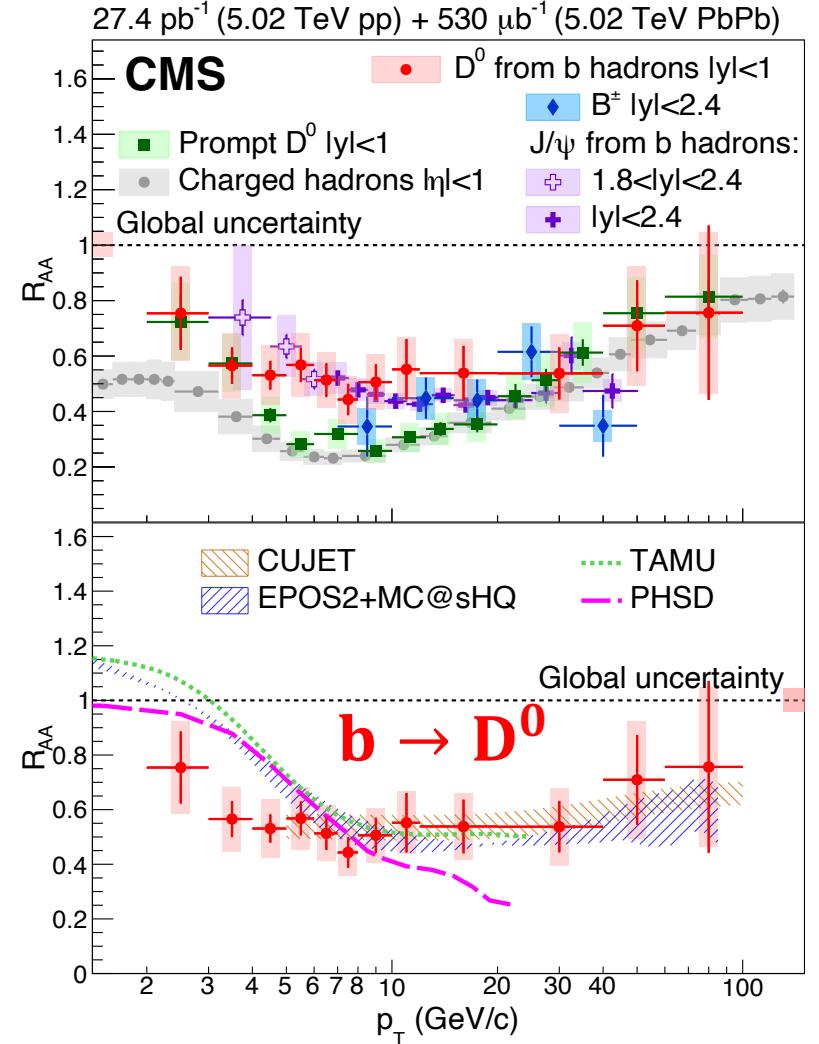
arXiv:2212.01636
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Results

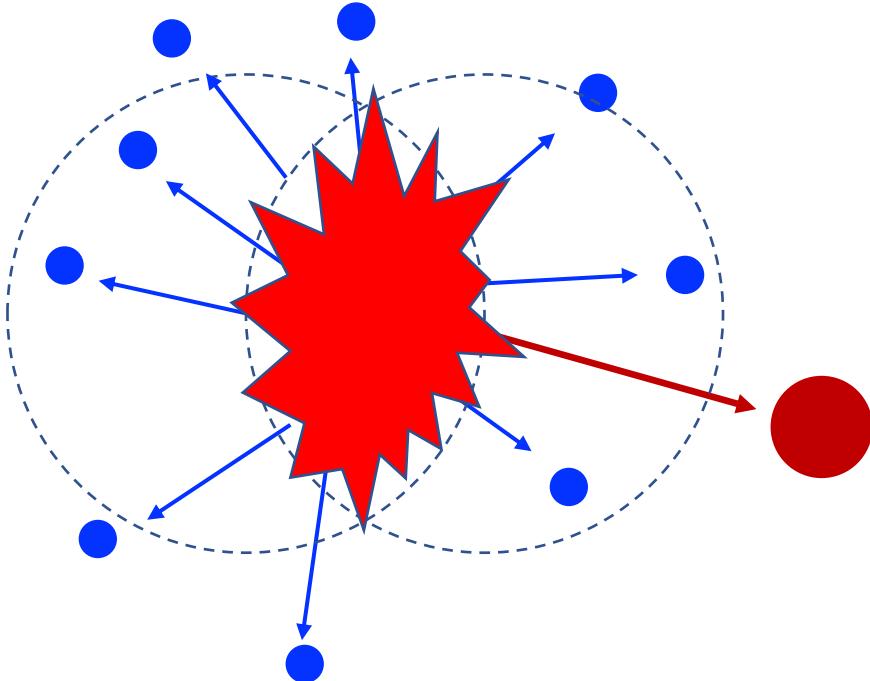
- Unexpected suppression at low p_T
- Hint of mass ordering at low p_T



PLB 782 (2018) 474



PRL 123 (2019) 022001



Azimuthal anisotropy:
correlation between D⁰ and bulk produced particles

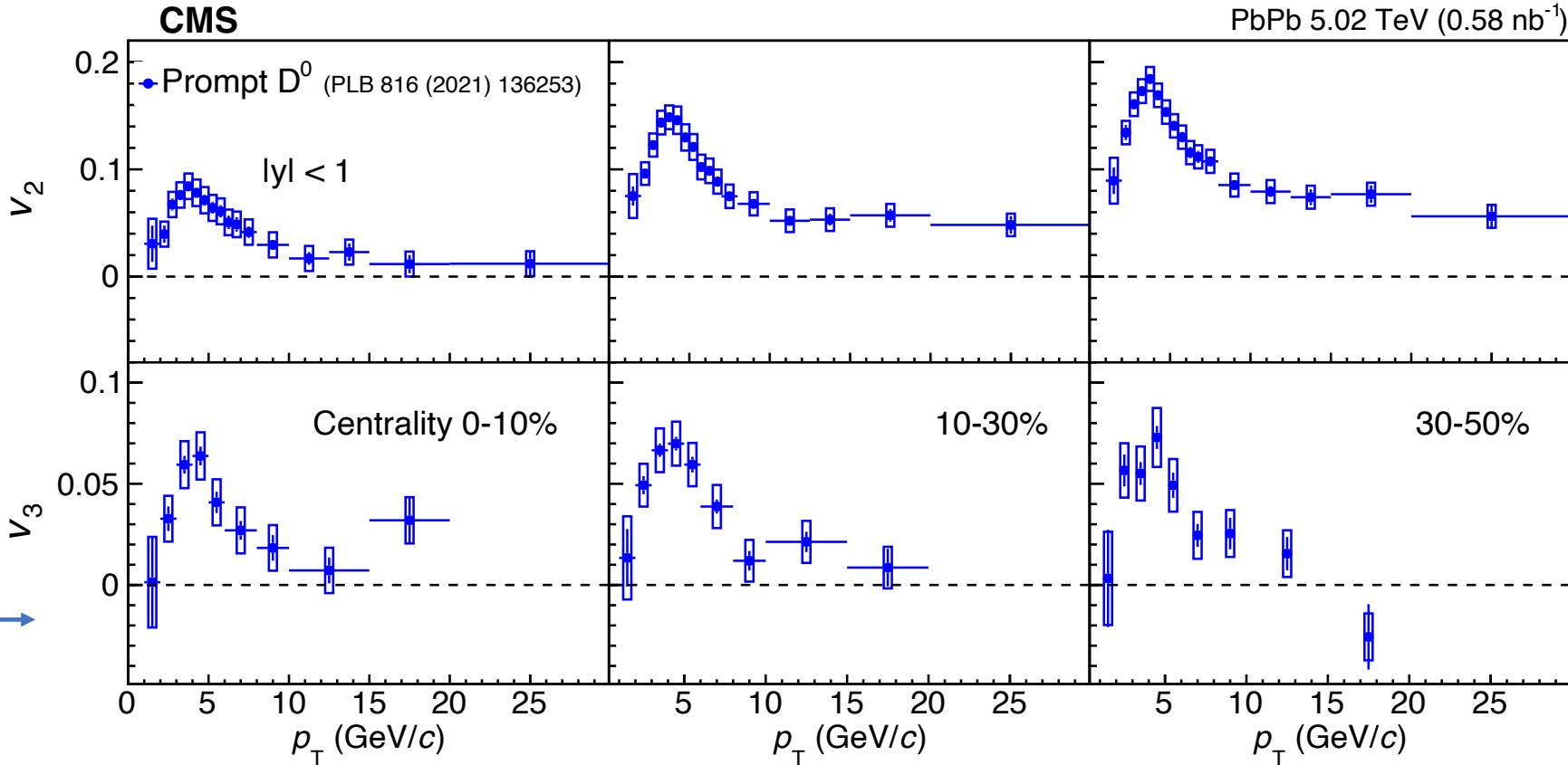
Anisotropy coefficients, v_n :

$$v_n = \langle 2 \cos n(\varphi - \Psi_n) \rangle$$

φ – D⁰ angle
 Ψ_n – symmetry plane

Probing:

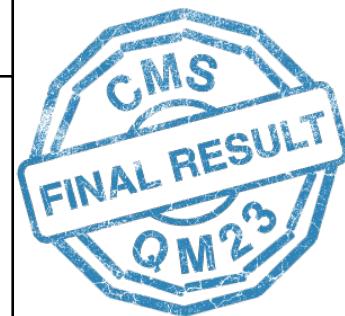
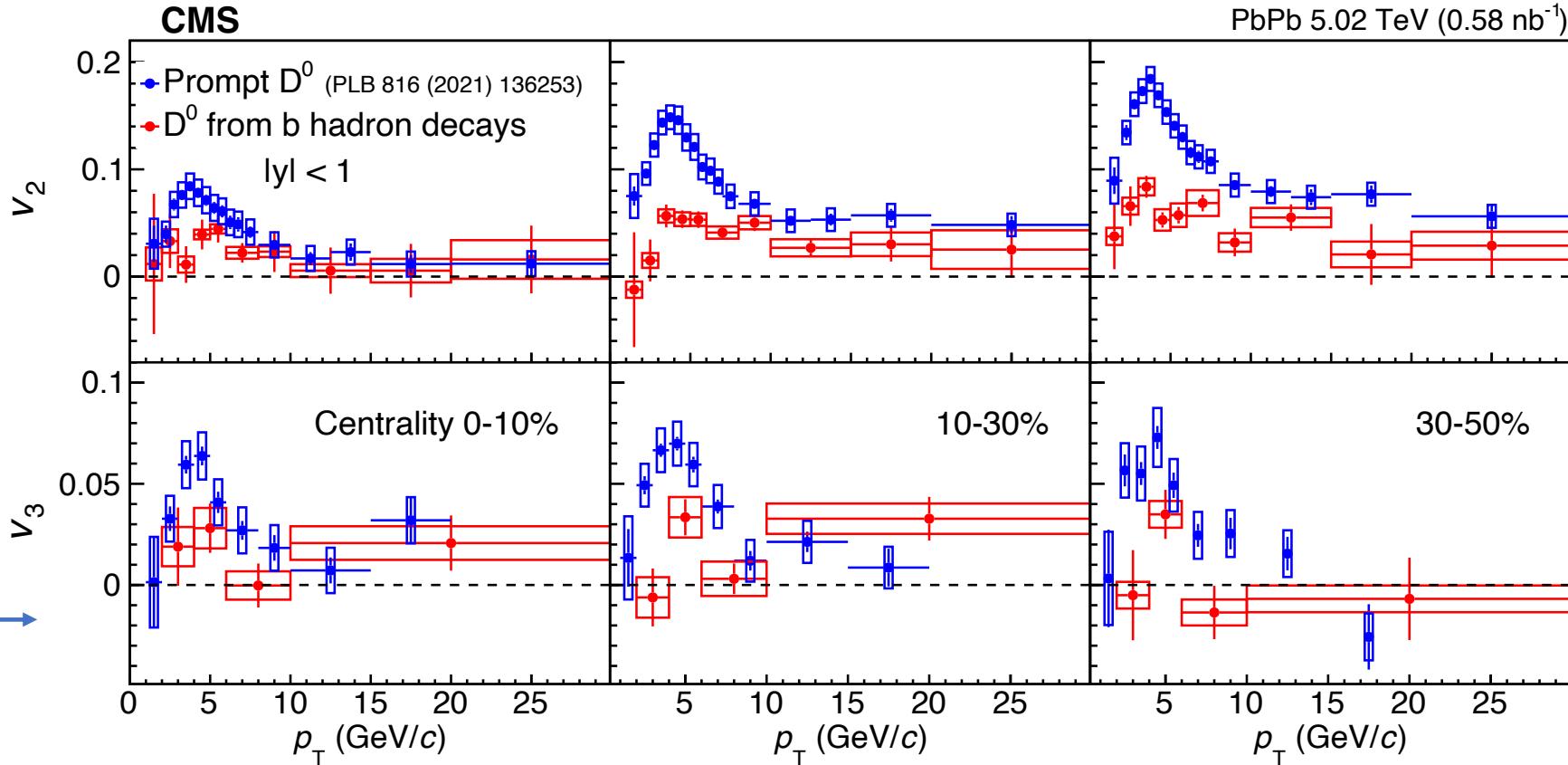
- Diffusion
- Path dependent parton energy loss
- Hadronization



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Prompt D⁰

- Strong p_T and centrality dependence
- Significant nonzero v_3 up to ~ 10 GeV

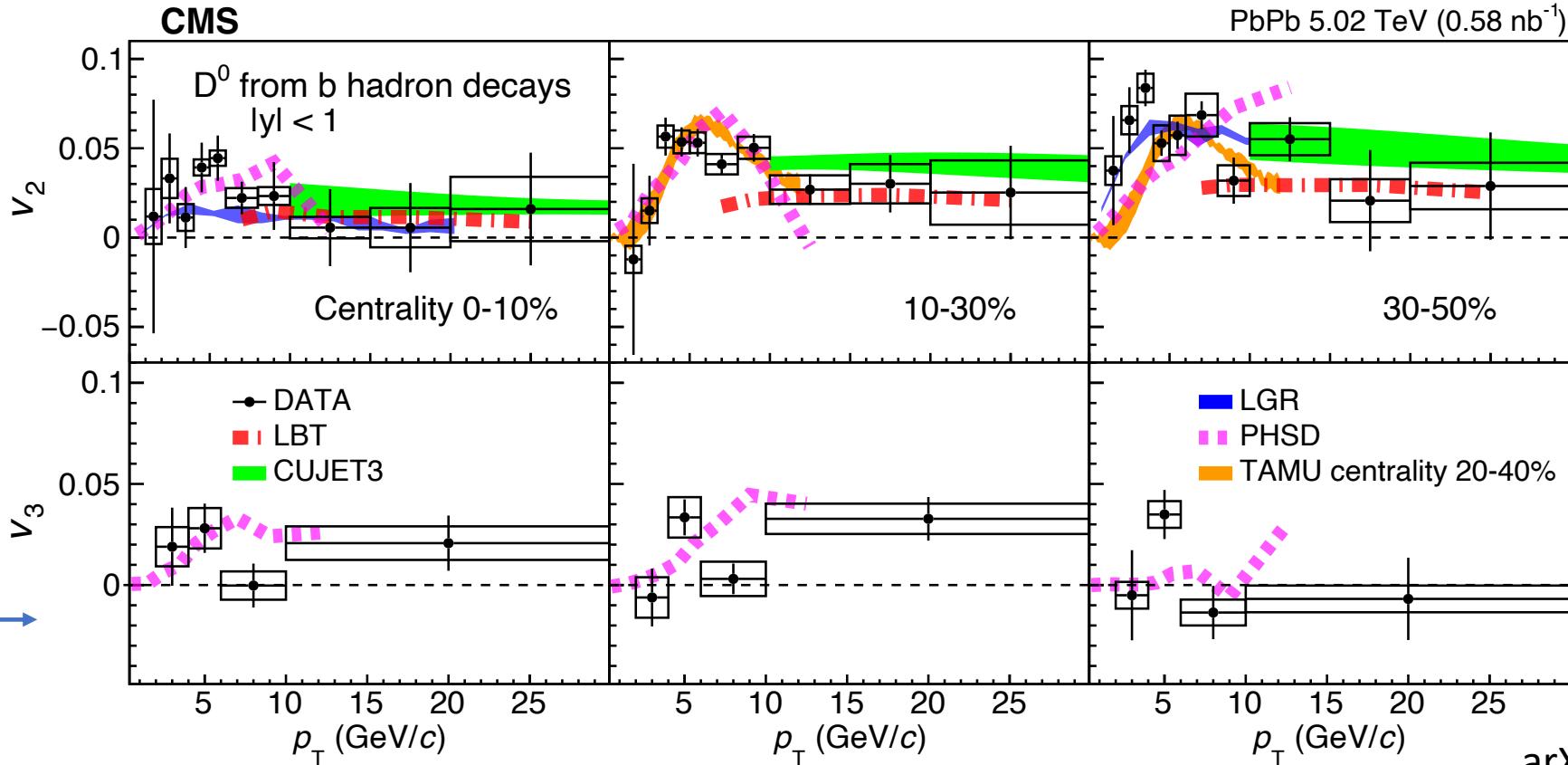


First measurement of $b \rightarrow D^0$ anisotropy in PbPb collisions

arXiv:2212.01636
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□ Mass ordering of flow magnitudes

□ Strong Weak p_T and centrality dependence
 □ Significant Indication of nonzero v_3



arXiv:2212.01636
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First measurement of $b \rightarrow D^0$ anisotropy in PbPb collisions

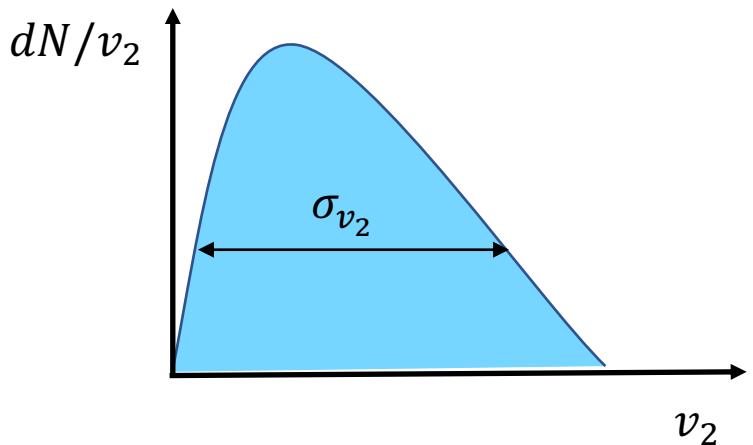
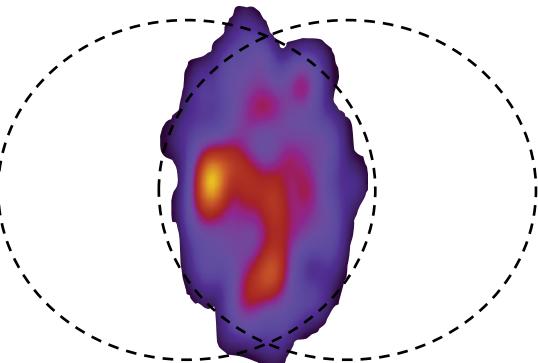
- Qualitatively good agreement between theory and data
- No model can describe whole p_T range

high- p_T
CUJET3 CPC 43 4 (2019) 044101
LBT PRC 94 (2016) 014909

low- p_T
PHSD: PRC 92 (2015) 014910
TAMU PLB 735 (2014) 445
LGR EPJ C 80 7 (2020) 671

Event by event fluctuations:

- ❑ Initial geometry fluctuations – event property
- ❑ Final state effects – particle dependent



➤ Two-particle correlations:

$$v_2\{2\} = \sqrt{\langle v_2 \rangle^2 + \sigma_{v_n}^2}$$

➤ Four-particle correlations:

$$v_2\{4\} \approx \sqrt{\langle v_2 \rangle^2 - \sigma_{v_n}^2}$$

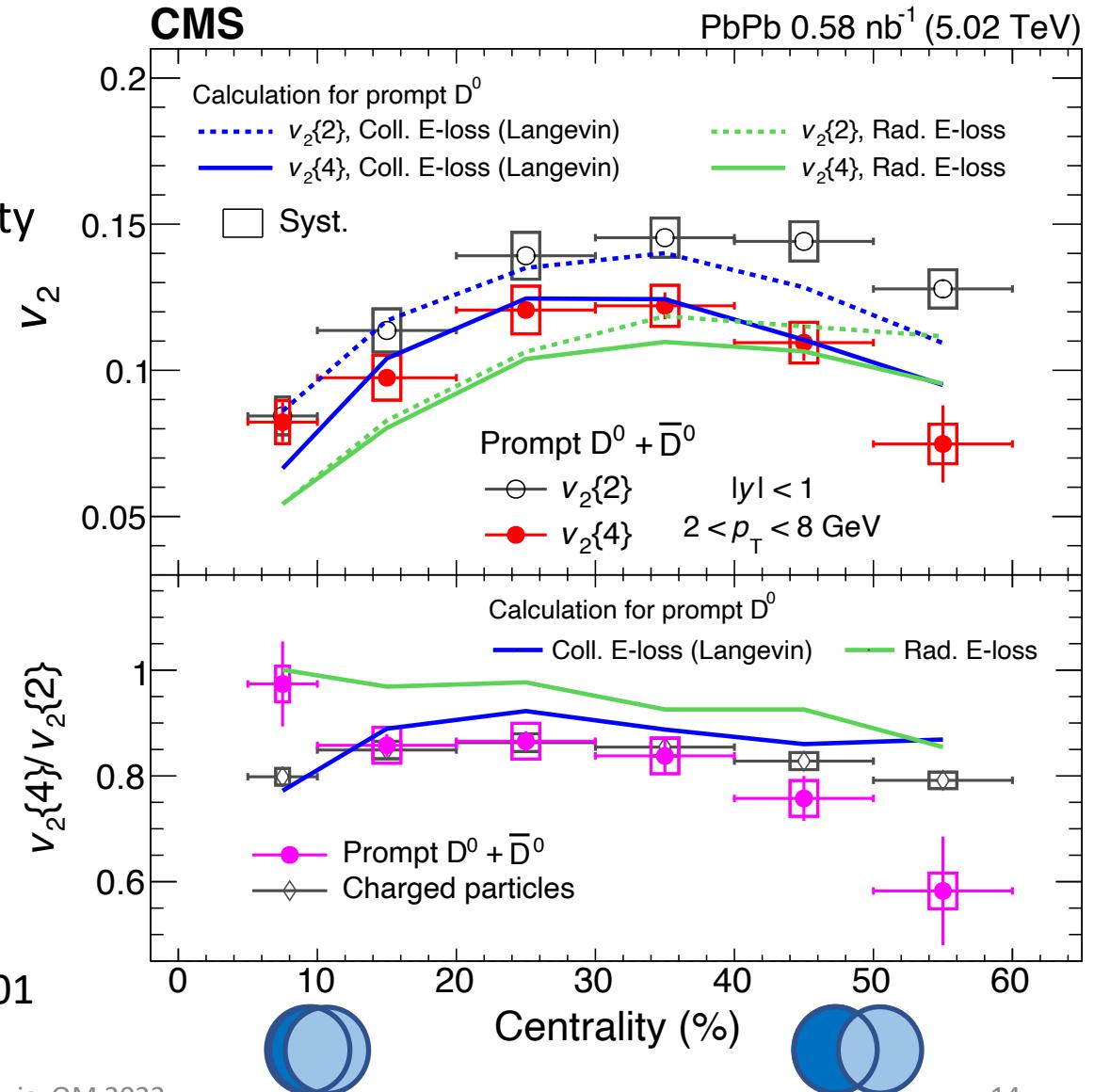
$v_2\{4\}/v_2\{2\}$

- D^0 compatible with charged hadrons in 10-40% centrality
 - Suggesting that initial fluctuations are dominant

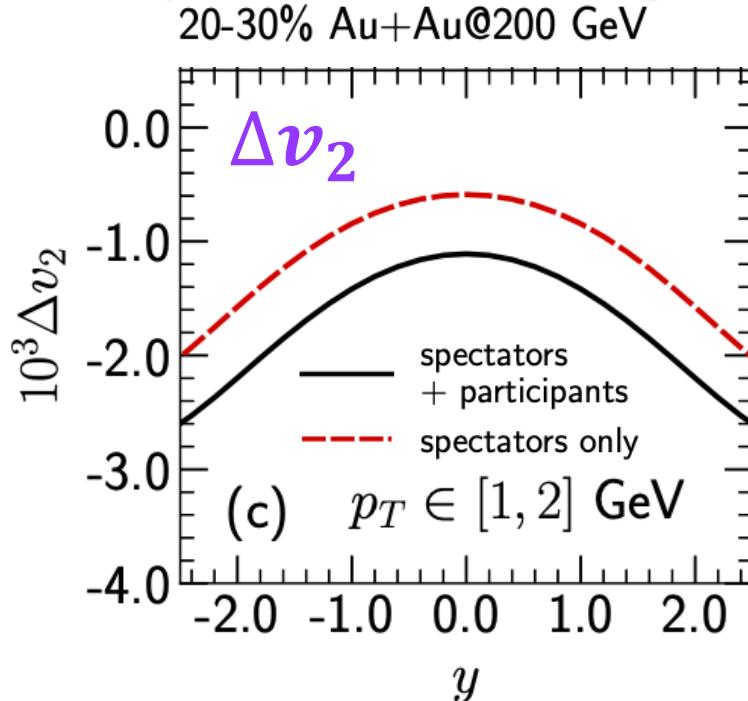
- Central and peripheral collisions:
 - Indication of discrepancies
 - potential final state effects

PRL 129 (2022) 022001

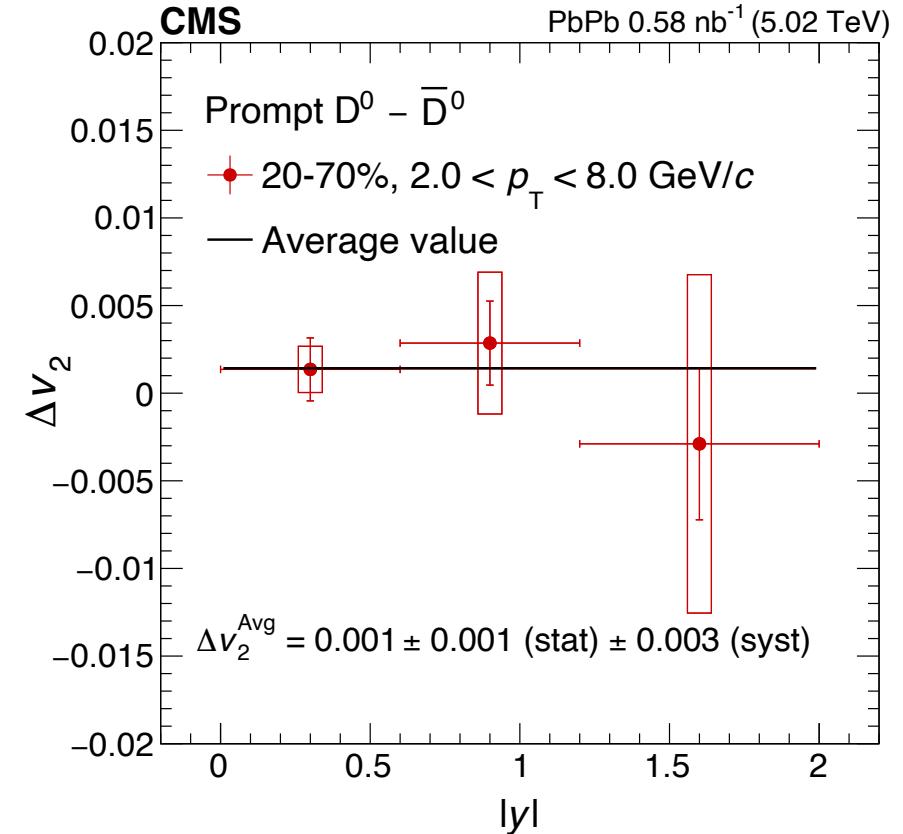
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EM field from participant can affect v2 signal



Predictions for pions

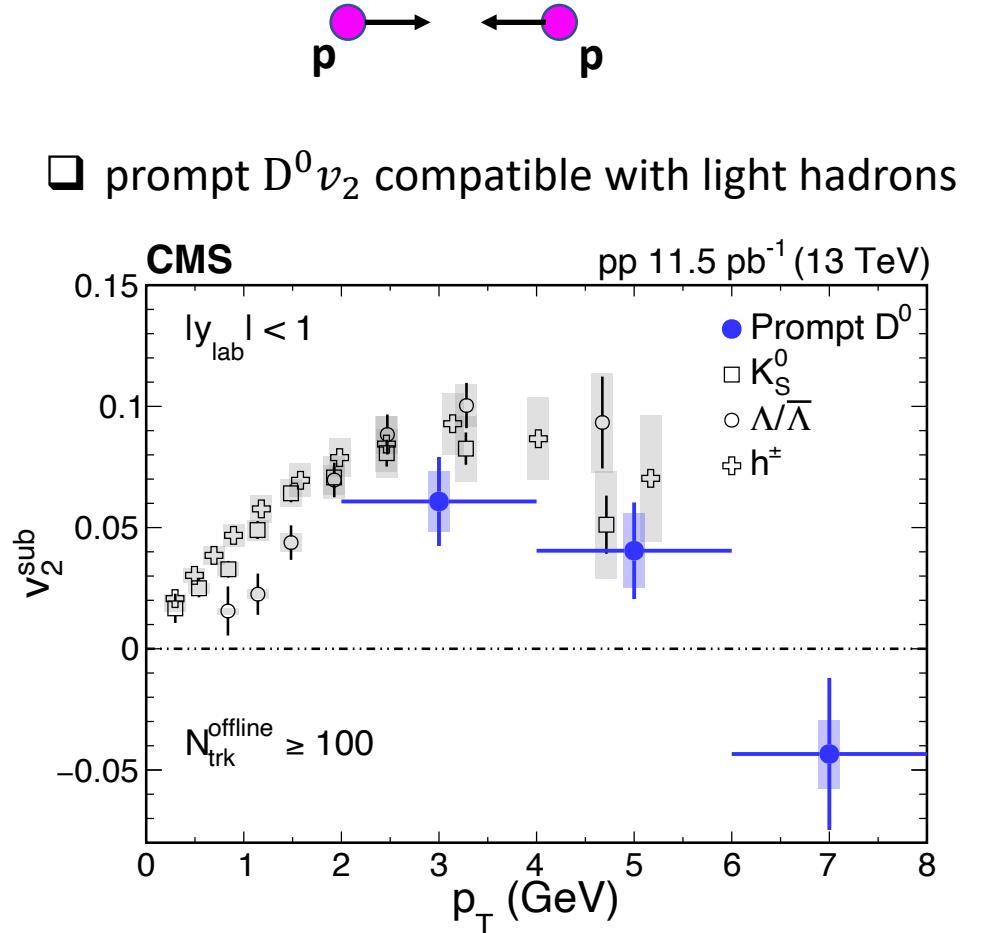
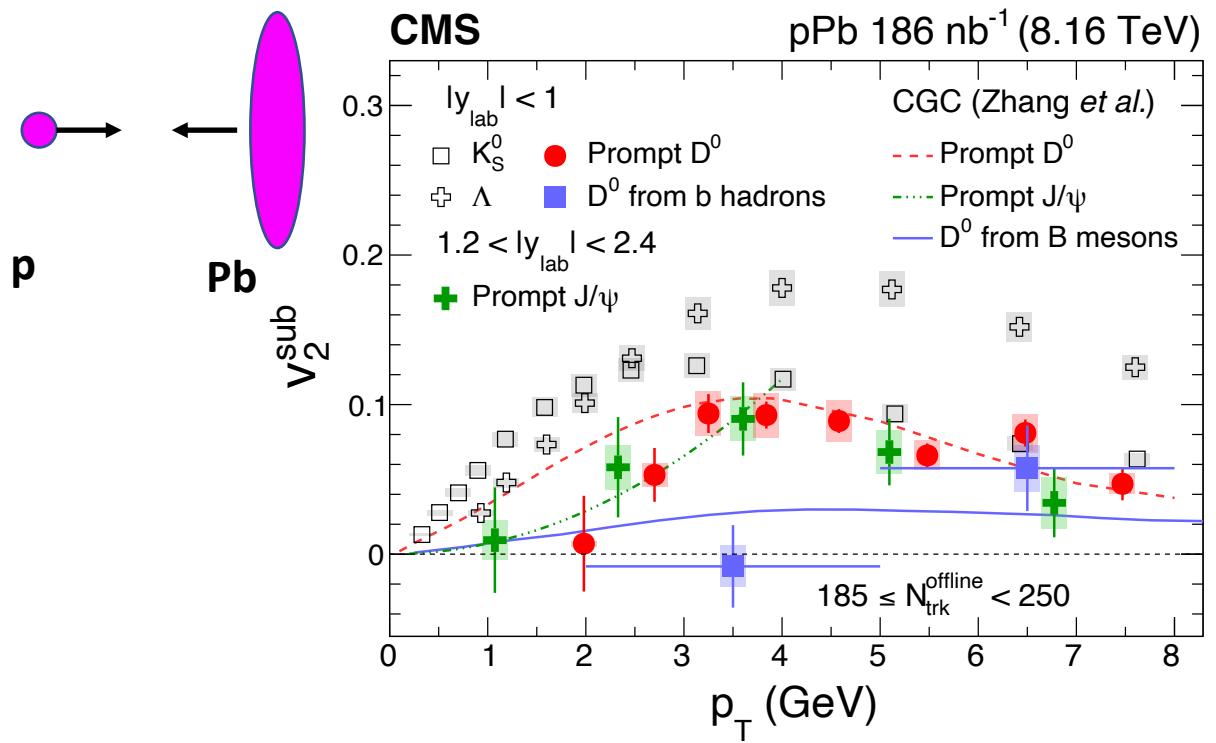


Average value extracted with a fit to data:

$$\Delta v_2 \equiv v_2(D^0) - v_2(\bar{D}^0) = 0.001 \pm 0.001 \text{ (stat)} \pm 0.003 \text{ (syst)}$$



- Open charm (prompt D⁰) $v_2 \approx$ hidden charm (prompt J/ ψ)
- Flavor hierarchy prompt D⁰ $v_2 > b \rightarrow D^0 v_2 \approx 0$
- In agreement with CGC model



PLB 813 (2021) 136036

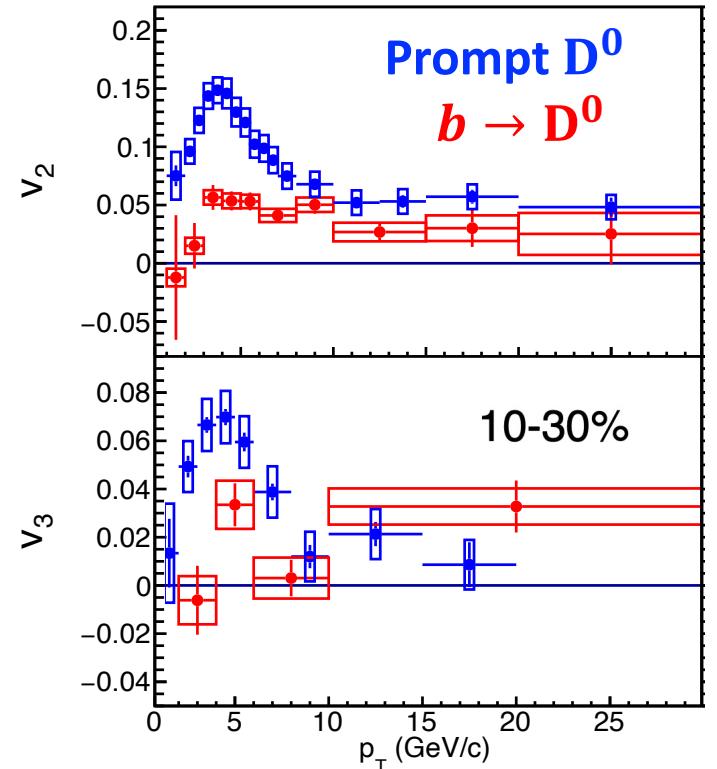
□ D^0 mesons demonstrates great potential for both charm and beauty measurements

- ❖ Significant R_{AA} and flow in PbPb
 - Significant prompt D^0 flow in small systems
- ❖ Mass ordering observed for $p_T < 10$ GeV
 - Both flow and R_{AA}
 - Both PbPb and pPb



□ Potential for statistically challenging analyses

- Indication of different E-by-E fluctuations between charm and light hadrons
- No sign of strong Coulomb field in PbPb



arXiv:2212.01636
submitted to PLB

Backup

CUJET 3CPC **43 4** (2019) 044101

PHSD PRC **92** (2015) 014910

TAMU PLB **735** (2014) 445

EPOS NPA 931 (2014) 581

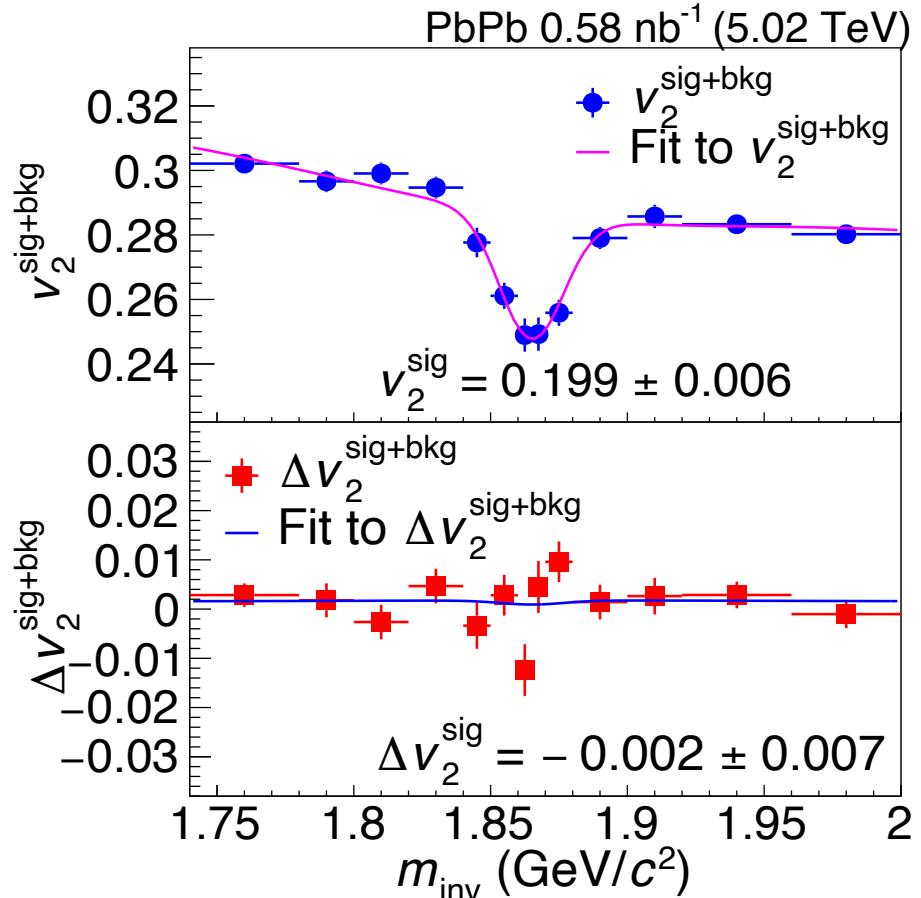
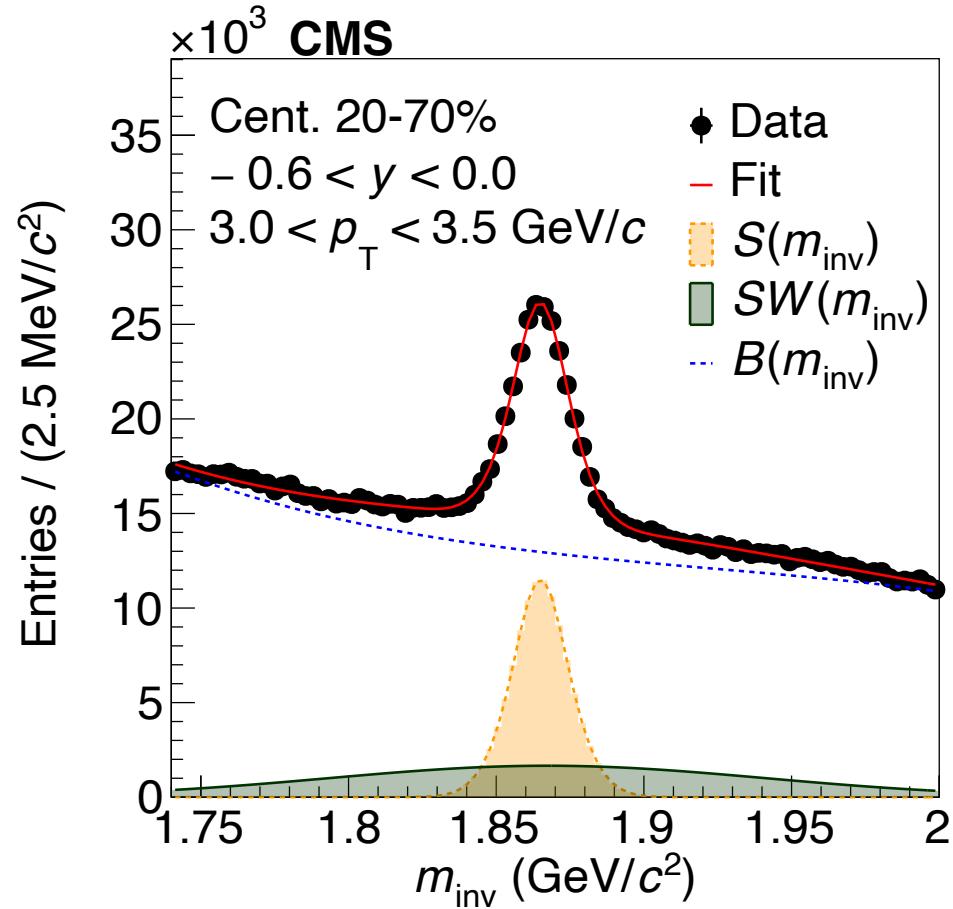
Cao at al. PRC 94 (2016)

AdS/CFT PRD 91 (2015) 085019

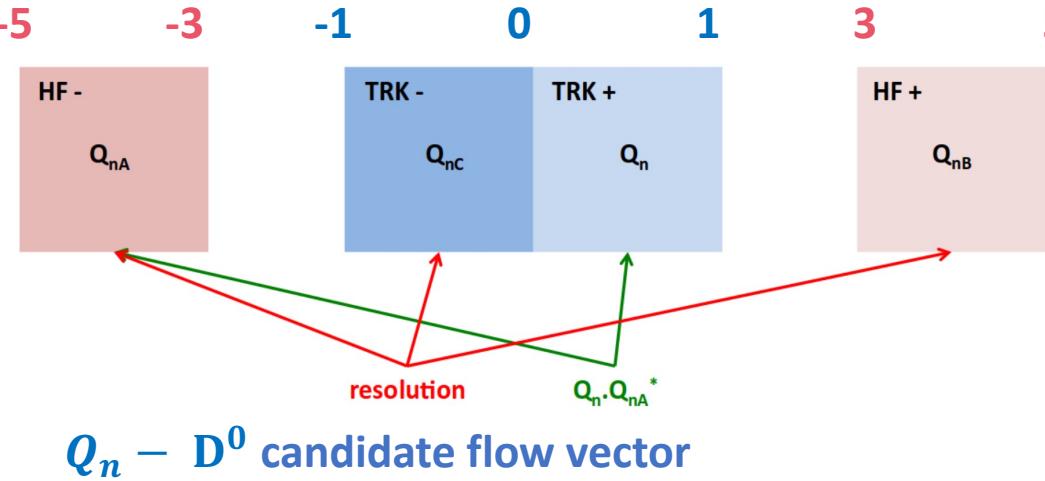
Djordjevic at al. PRC 92 (2015) 024918

LBT PRC 94 (2016) 014909

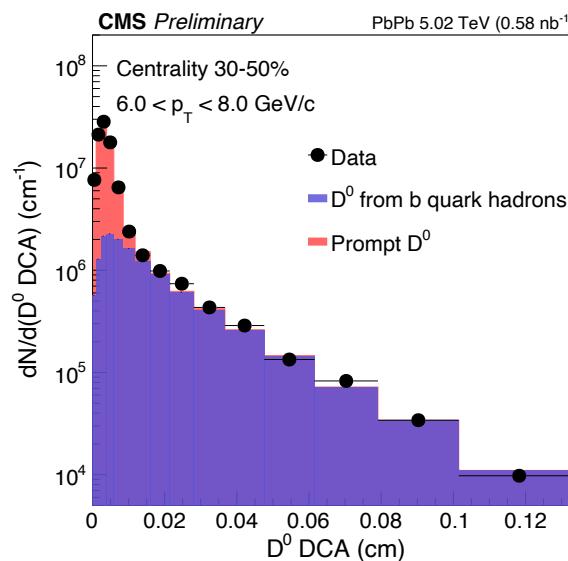
LGR EPJ C 80 7 (2020) 671

Simultaneous fit on invariant mass distribution and v_n (delta v_n) versus mass

PLB 816 (2021) 136253

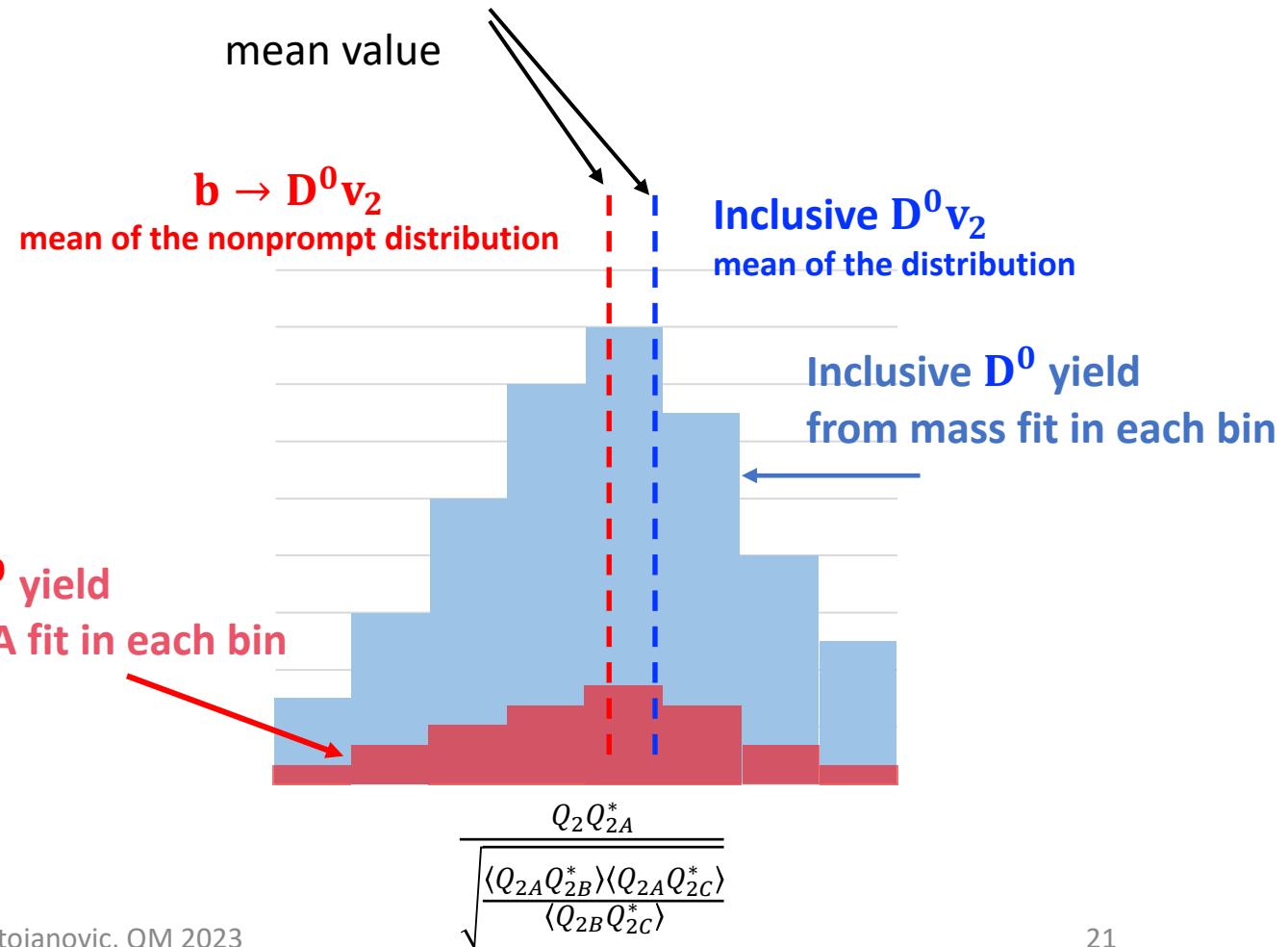


Q_{nA}, Q_{nB}, Q_{nC} – event plane vectors from subevent



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$$v_n \{\text{SP}\} \equiv \frac{\langle Q_n Q_{nA}^* \rangle}{\sqrt{\frac{\langle Q_{nA} Q_{nB}^* \rangle \langle Q_{nA} Q_{nC}^* \rangle}{\langle Q_{nB} Q_{nC}^* \rangle}}}$$



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Charged hadrons

Phys. Lett. B 776 (2017) 195

Prompt D^0

Phys. Lett. B 816 (2021) 136253

Nonprompt D^0

CMS-PAS-HIN-21-003

Prompt J/ψ

CMS-PAS-HIN-21-008

Nonprompt J/ψ

CMS-PAS-HIN-21-008

$\Upsilon(1S)$

CMS-PAS-HIN-21-008

