Measurement of nonprompt and prompt D^0 azimuthal anisotropy in Pb-Pb collisions at 5.02 TeV

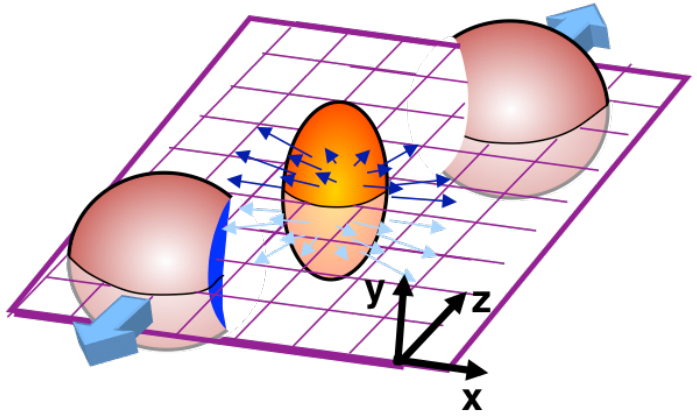
Milan Stojanovic

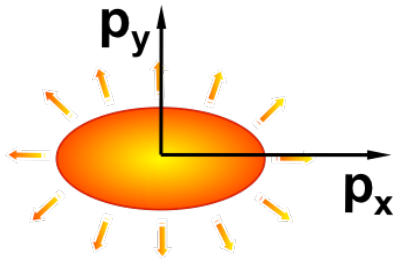
Purdue University

on behalf of the CMS collaboration

Strangeness in Quark Matter 2022, Busan, Republic of Korea

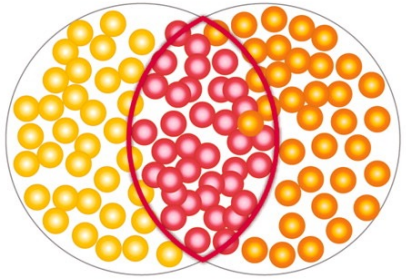
Anisotropy in heavy ion collisions

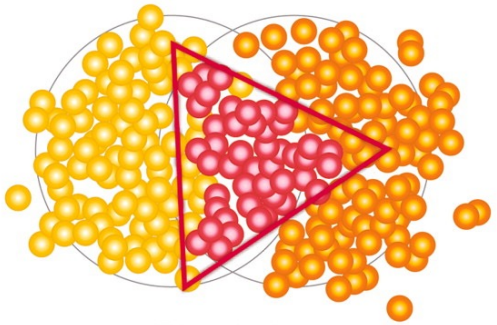




Space anisotropy

momentum space anisotropy





System symmetry → elliptic flow, v_2

Fluctuations → triangular flow, v_3

Light hadron anisotropy

- Particle distribution over azimuthal angle:

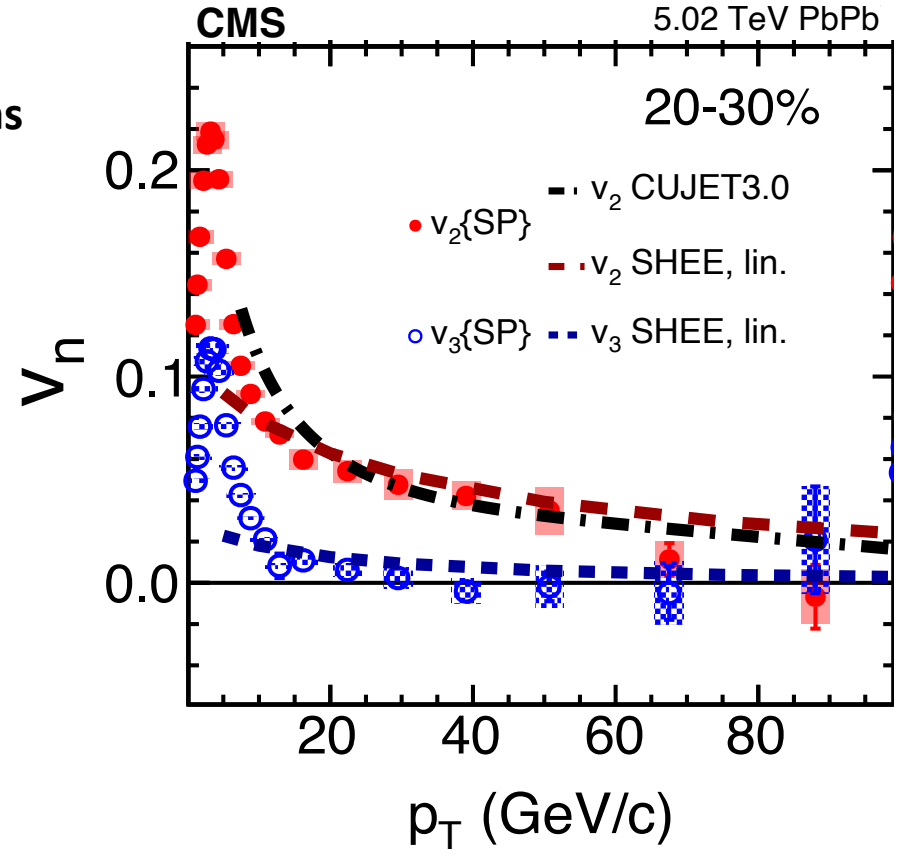
$$\frac{dN}{d\phi} \propto 1 + \sum_n 2v_n \cos[n(\phi - \Psi_n)]$$

- v_n coefficients driven by
  - Initial geometry
  - Medium evolution

Flow mechanism (light hadrons):

- **low p_T → hydrodynamics**
- **medium p_T → coalescence**
- **high p_T → path-dependent parton energy loss**

PbPb @ 5 TeV
Charged hadrons



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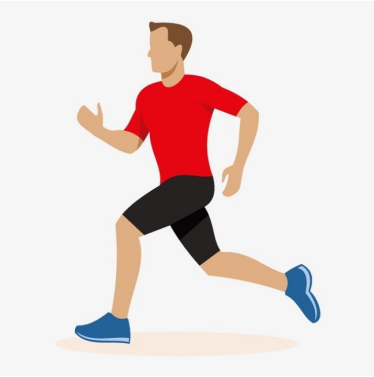
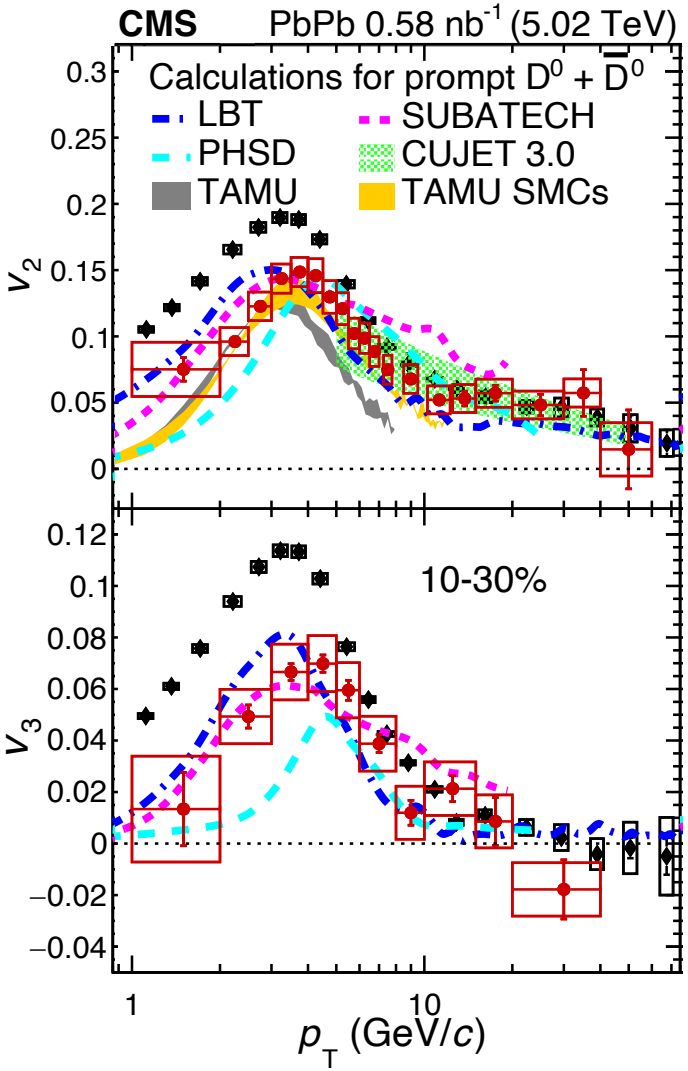
Heavy quark anisotropy

Traveling light **carrying heavy luggage**



vs

PbPb @ 5 TeV
Charged hadrons
Prompt D^0



Flow mechanism (heavy quarks):

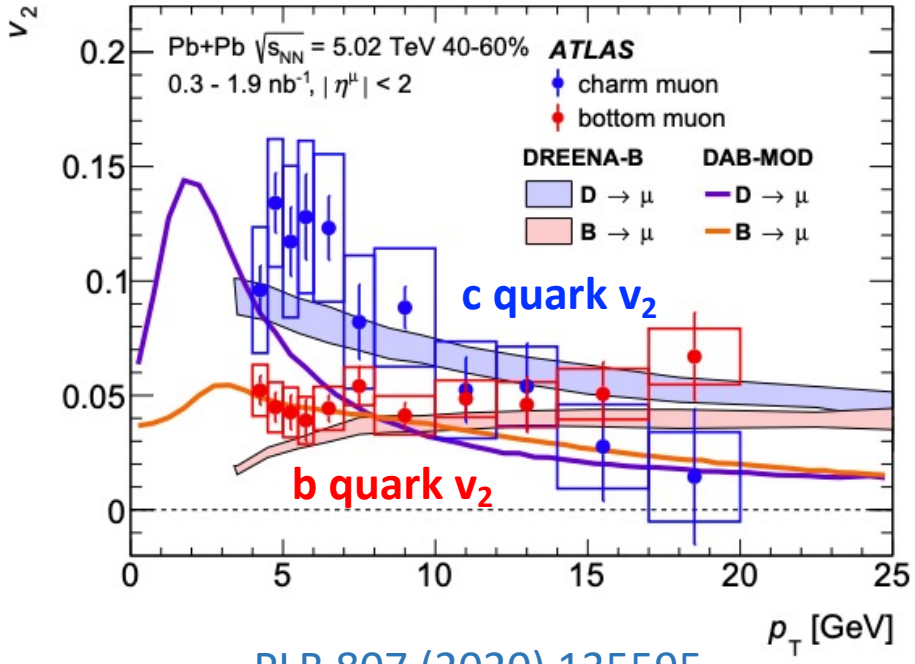
- low p_T → hydrodynamics
  + collisional energy loss
- ~~medium~~ all p_T → coalescence
- high p_T → path-dependent parton energy loss
  - Significant anisotropy of c quark is measured in PbPb events

Phys. Lett. B 816 (2021) 136253

b quark anisotropy

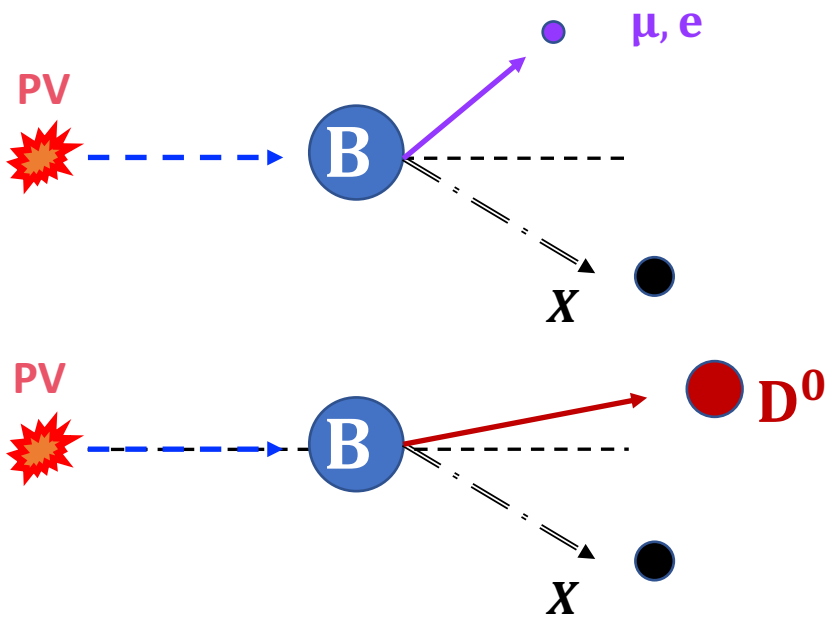
- ATLAS: $b \to \mu$
- ALICE: $b \to e$
- CMS: $b \to J/\psi$ ← Gyeonghwan PA-HF1

❖ Non-zero v_2!



PLB 807 (2020) 135595

- Advantages of $b \to D^0$ channel
  - ✓ Larger branching ratio wrt $b \to J/\psi$
  - ✓ Higher mass than leptons: less diluted signal



Potential for precise measurement in wide kinematic range!

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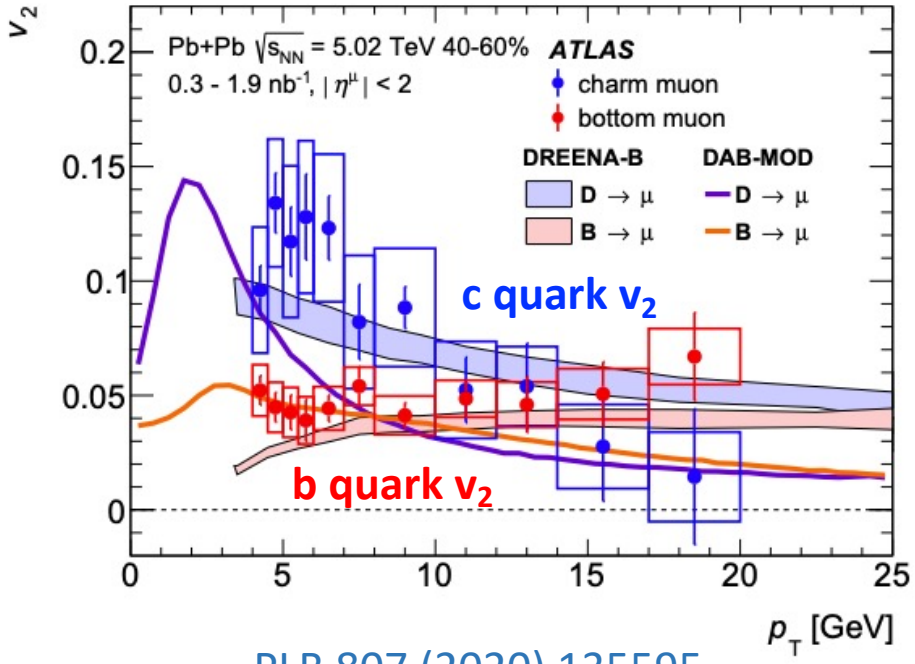

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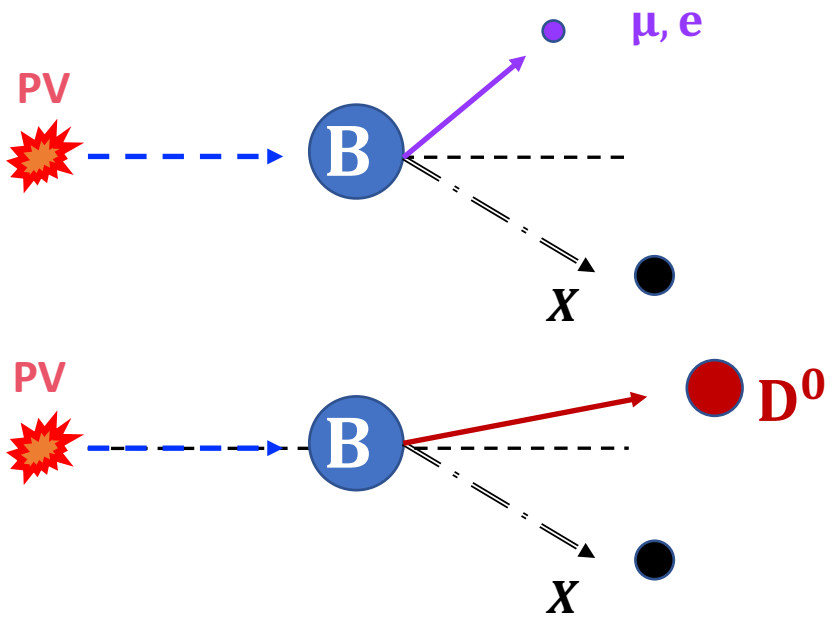


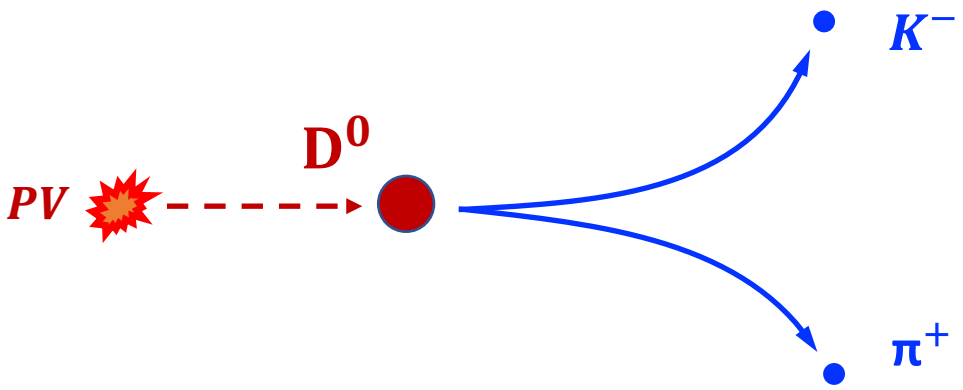
Potential for precise measurement in wide kinematic range!

Analysis technique

Inclusive D^0 signal extraction

Reconstruction

- Data from 2018 Run:
  - PbPb @ 5 TeV ~ 4B Minimum Bias events
- Inclusive D^0 reconstruction
  - $D^0 \rightarrow K^-\pi^+$
- No particle identification → All possible combinations of pairs with opposite charge track
- Additional selection performed with Boost Decision Tree



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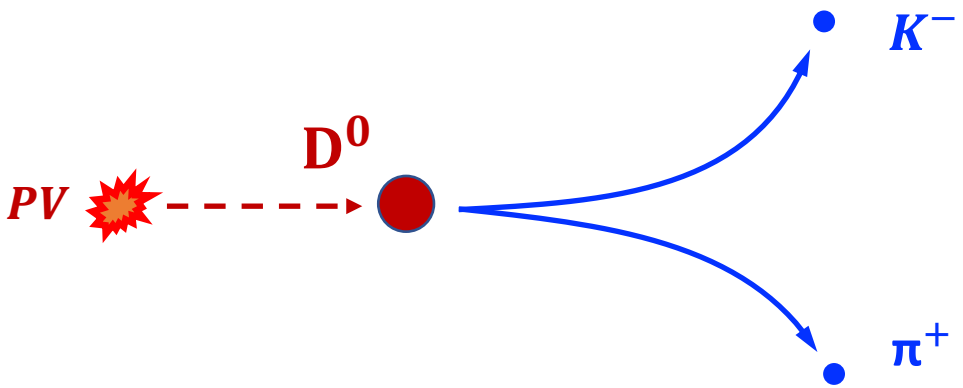
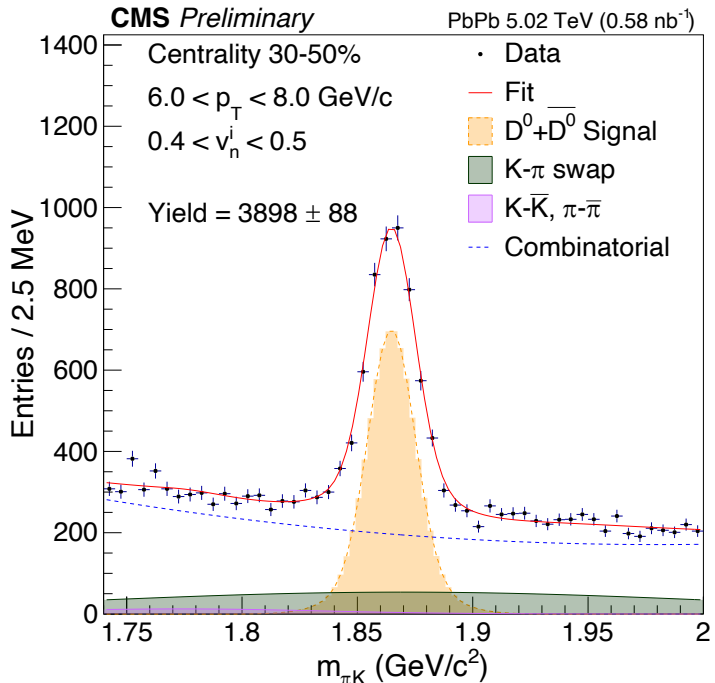


Inclusive D^0 Yield

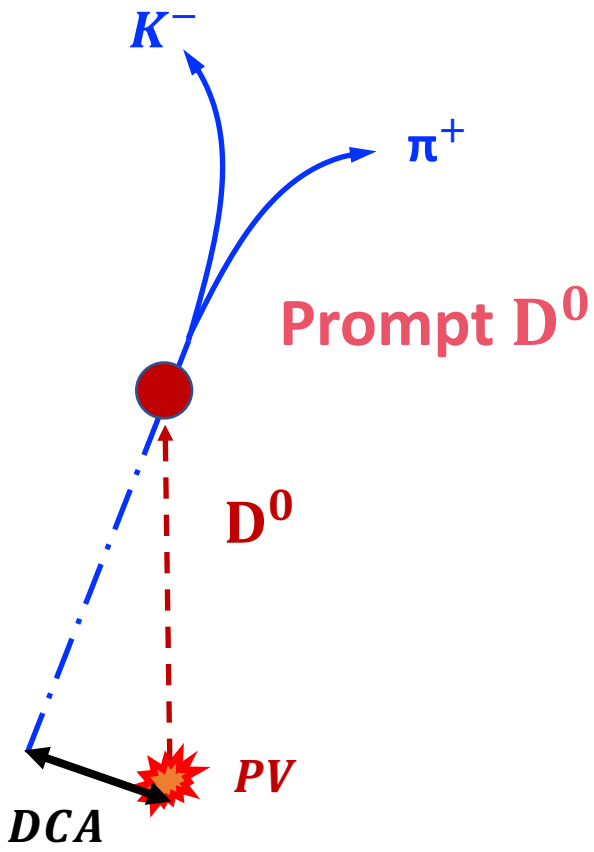
- Signal mass spectrum – double gaussian
- Swap component – gaussian
- K^+K^- & $\pi^+\pi^-$ – Crystal ball functions
- Combinatorial – polynomial 3rd order



CMS-PAS-HIN-21-003

$b \rightarrow \mathrm{D}^0$ fraction

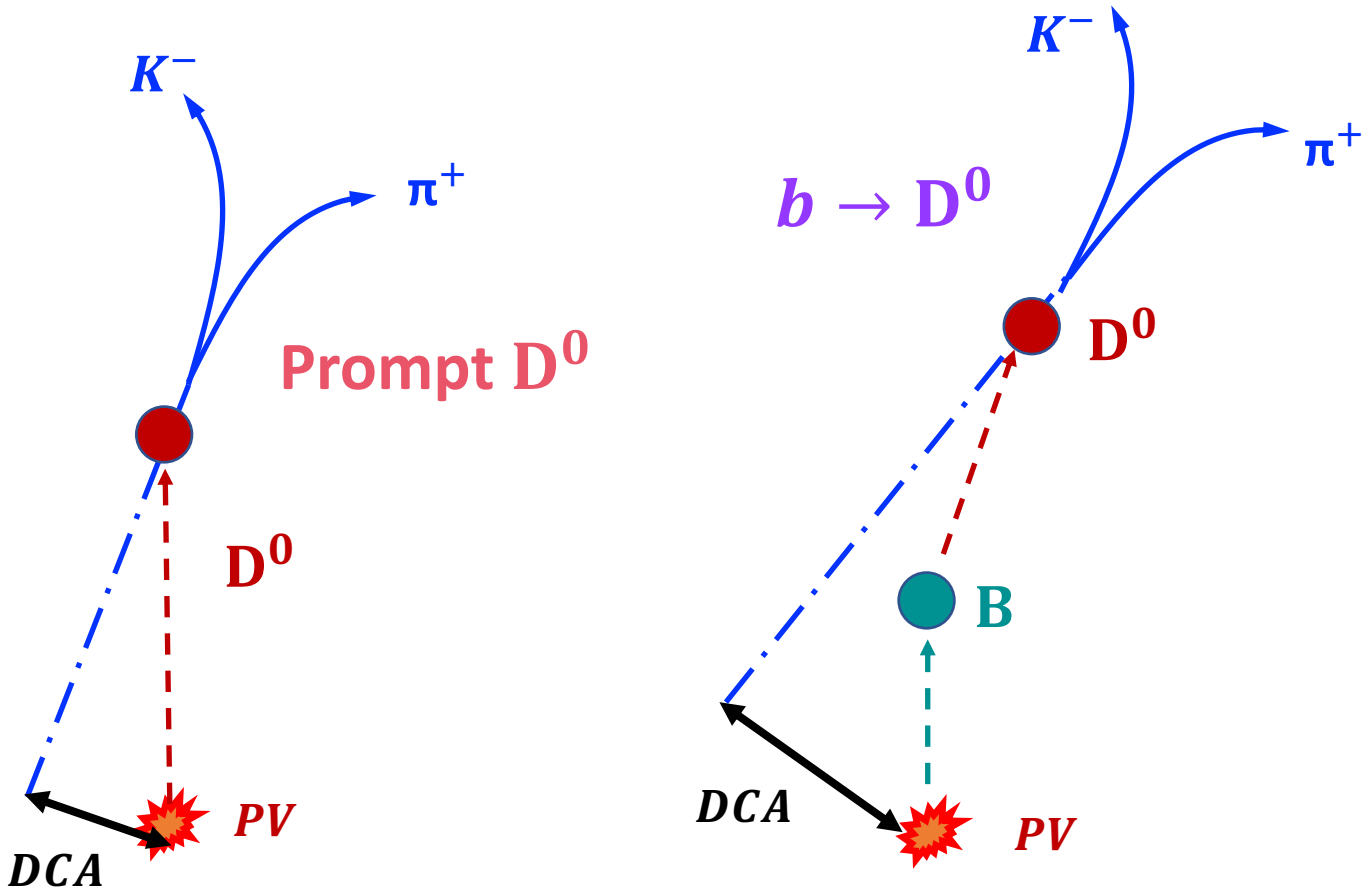
Two component template fit to extract $b \rightarrow \mathrm{D}^0$ fraction



DCA (distance of closest approach)

$b \rightarrow D^0$ fraction

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



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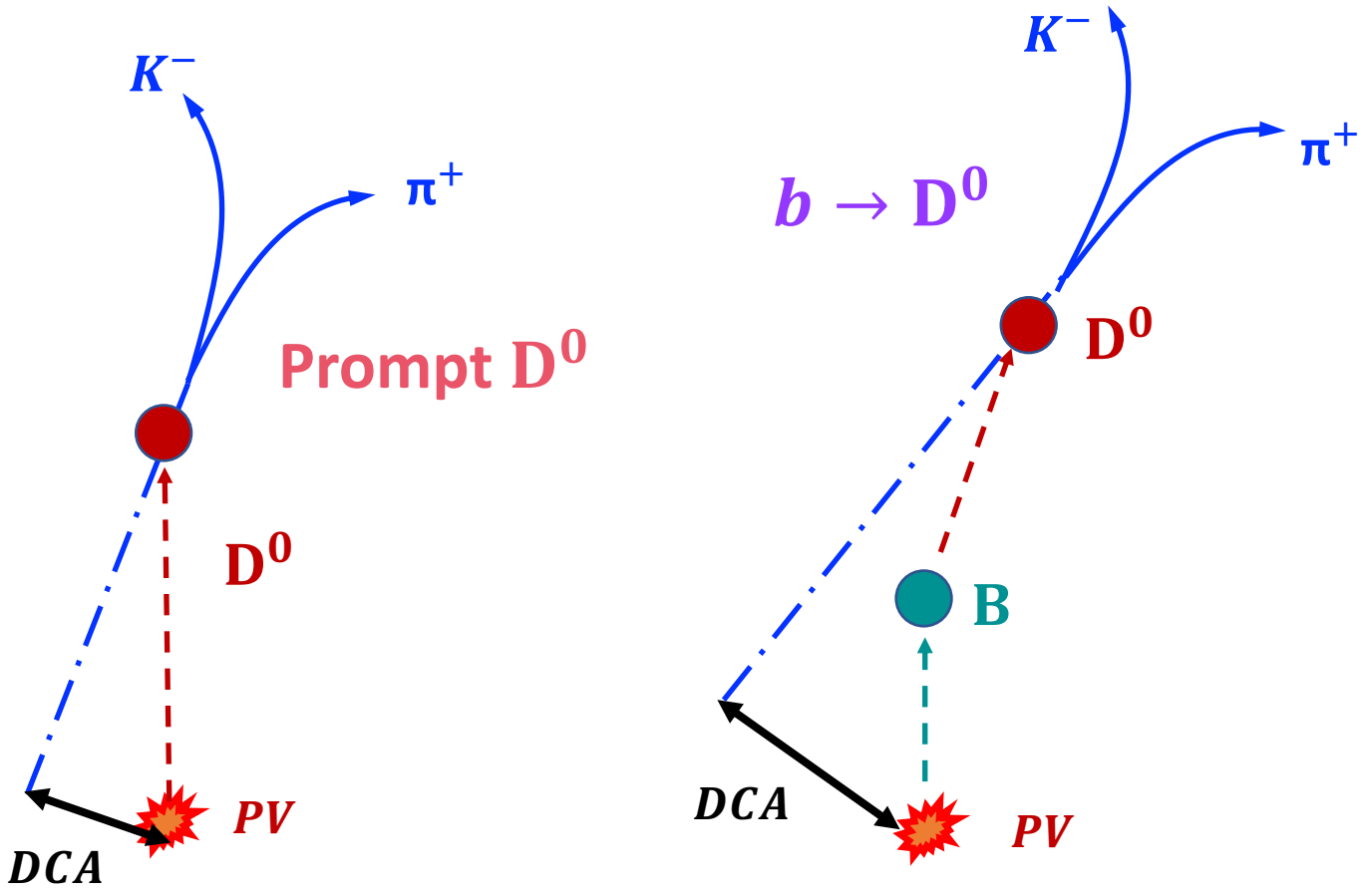

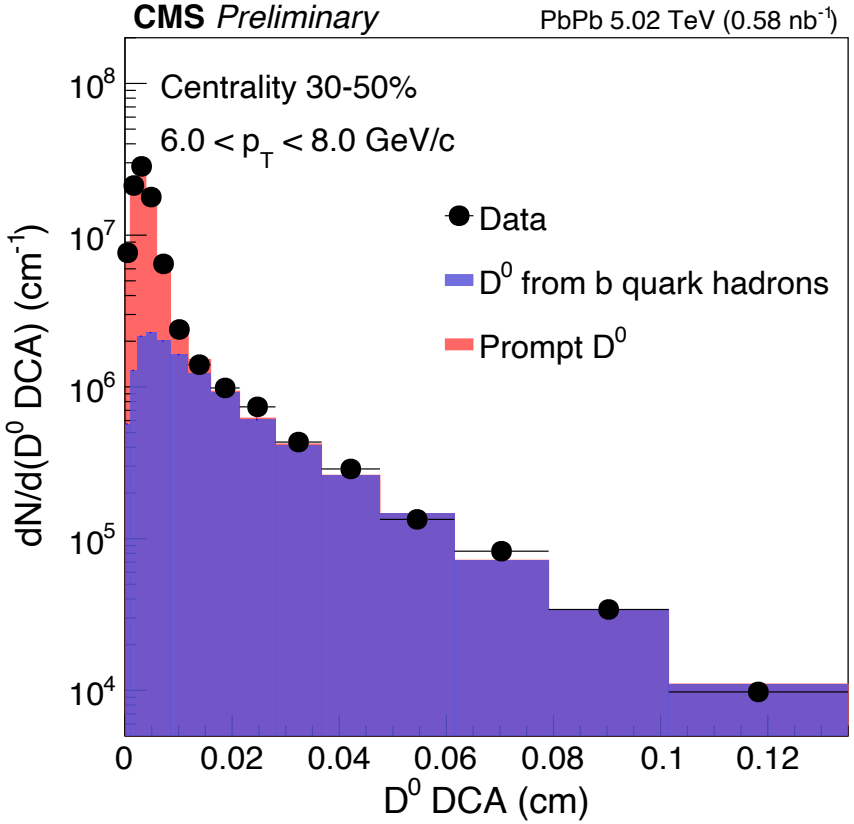

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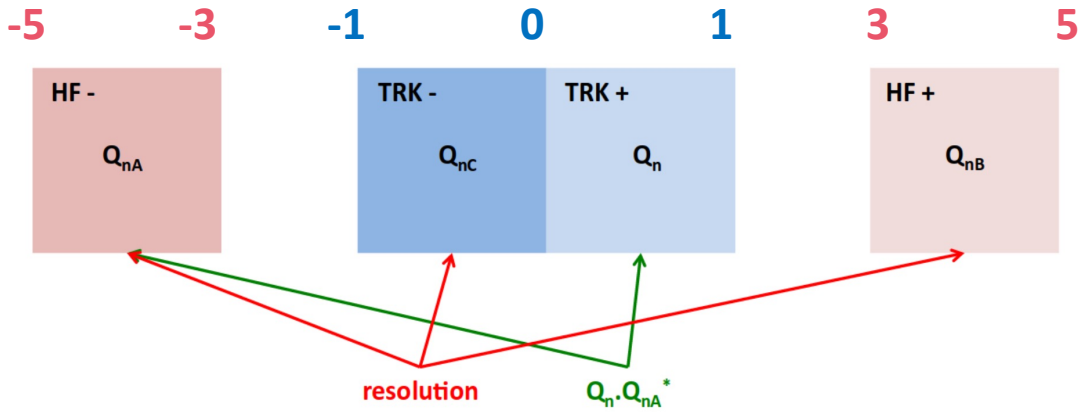
DCA (distance of closest approach)

Scalar product method

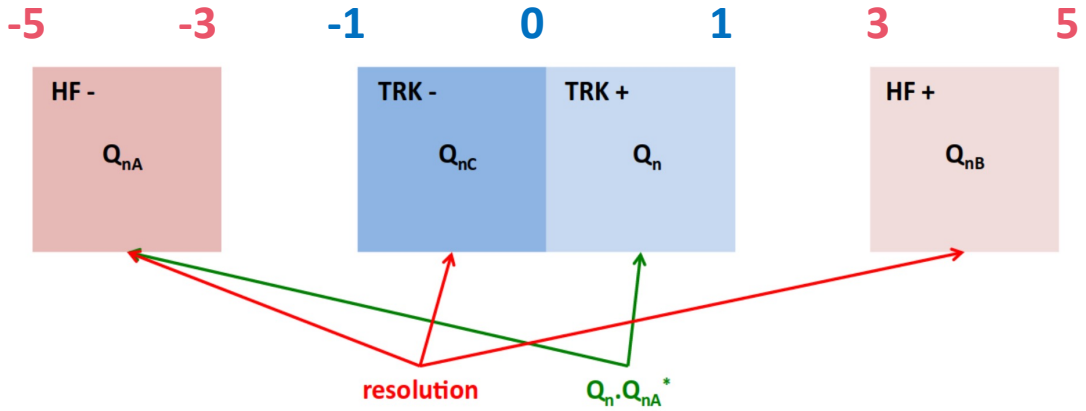


$$v_n\{\mathrm{SP}\} \equiv \frac{\langle Q_n Q_{nA}^* \rangle}{\sqrt{\frac{\langle Q_{nA} Q_{nB}^* \rangle \langle Q_{nA} Q_{nC}^* \rangle}{\langle Q_{nB} Q_{nC}^* \rangle}}}$$

$Q_n -$ D^0 candidate flow vector

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

Scalar product method



Q_n – D^0 candidate flow vector

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

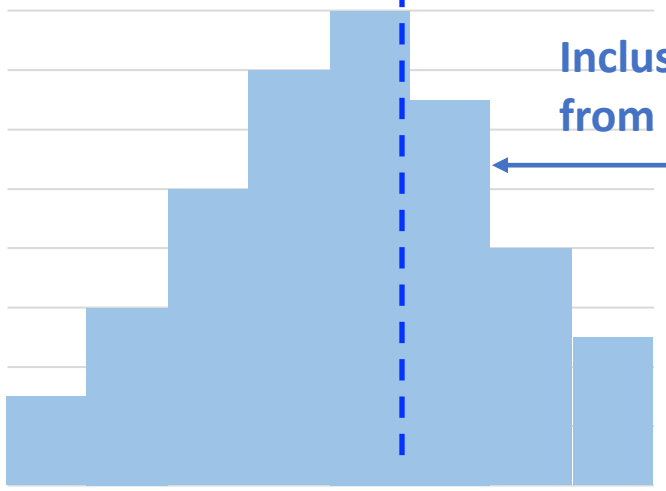
$$v_n\{\mathrm{SP}\} \equiv \frac{\langle Q_n Q_{nA}^* \rangle}{\sqrt{\frac{\langle Q_{nA} Q_{nB}^* \rangle \langle Q_{nA} Q_{nC}^* \rangle}{\langle Q_{nB} Q_{nC}^* \rangle}}}$$

mean value

Inclusive $D^0 v_2$

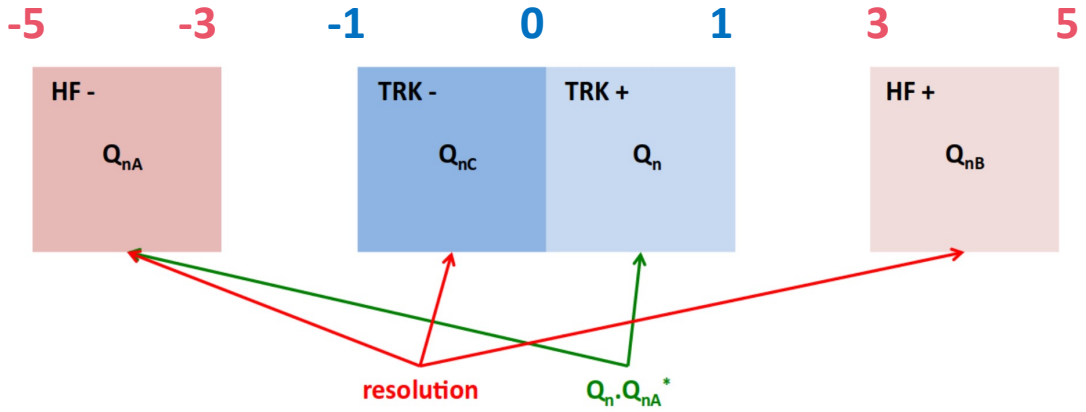
mean of the prompt distribution

Inclusive D^0 yield from mass fit in each bin



$$\frac{Q_2 Q_{2A}^*}{\sqrt{\frac{\langle Q_{2A} Q_{2B}^* \rangle \langle Q_{2A} Q_{2C}^* \rangle}{\langle Q_{2B} Q_{2C}^* \rangle}}}$$

Scalar product method



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mean value

Q_n – D^0 candidate flow vector

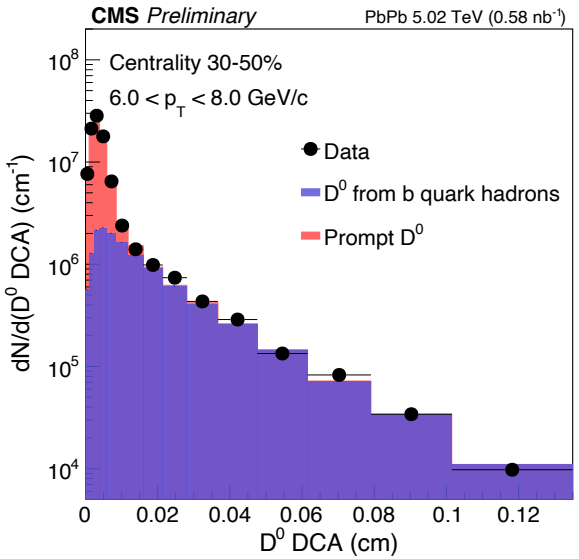
Q_{nA}, Q_{nB}, Q_{nC} – event plane vectors from subevent

$b \rightarrow D^0 v_2$
mean of the $b \rightarrow D^0$ distribution

Inclusive $D^0 v_2$
mean of the inclusive distribution

Inclusive D^0 yield
from mass fit in each bin

$b \rightarrow D^0$ yield
From mass + DCA fit in each bin



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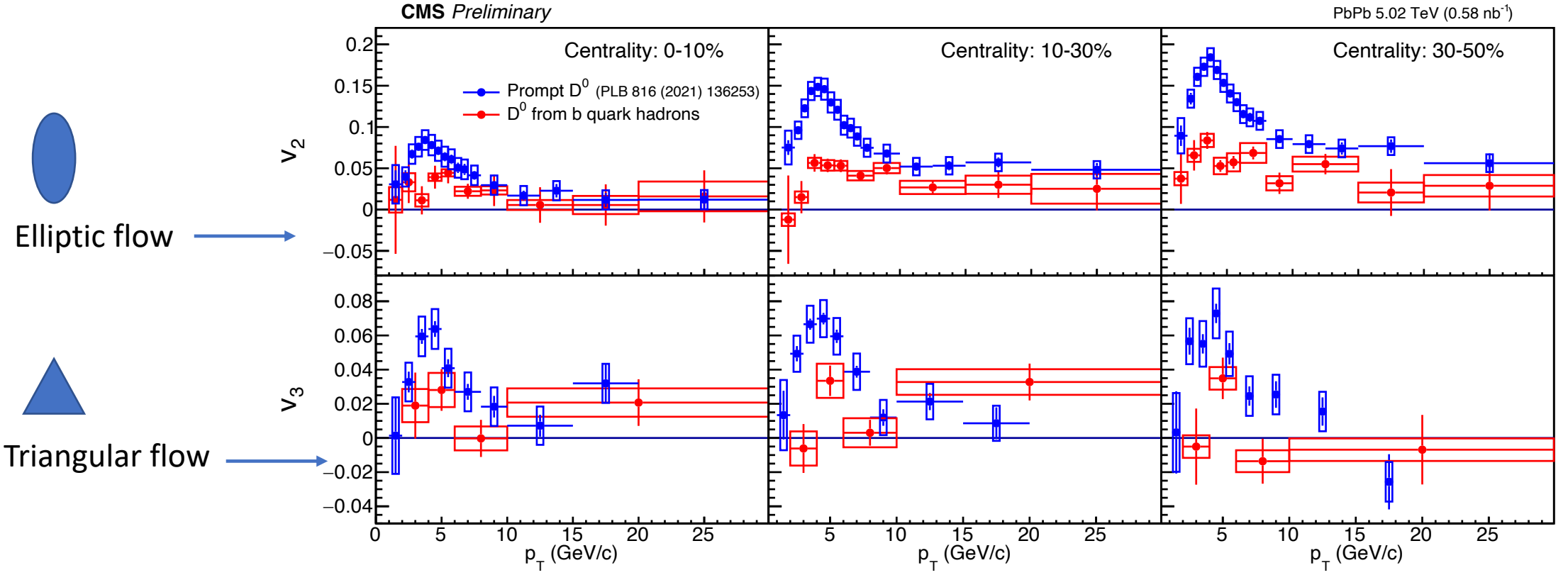
$$\frac{Q_2 Q_{2A}^*}{\sqrt{\frac{\langle Q_{2A} Q_{2B}^* \rangle \langle Q_{2A} Q_{2C}^* \rangle}{\langle Q_{2B} Q_{2C}^* \rangle}}}$$

Results

$b \rightarrow D^0$ anisotropy results



Elliptic flow

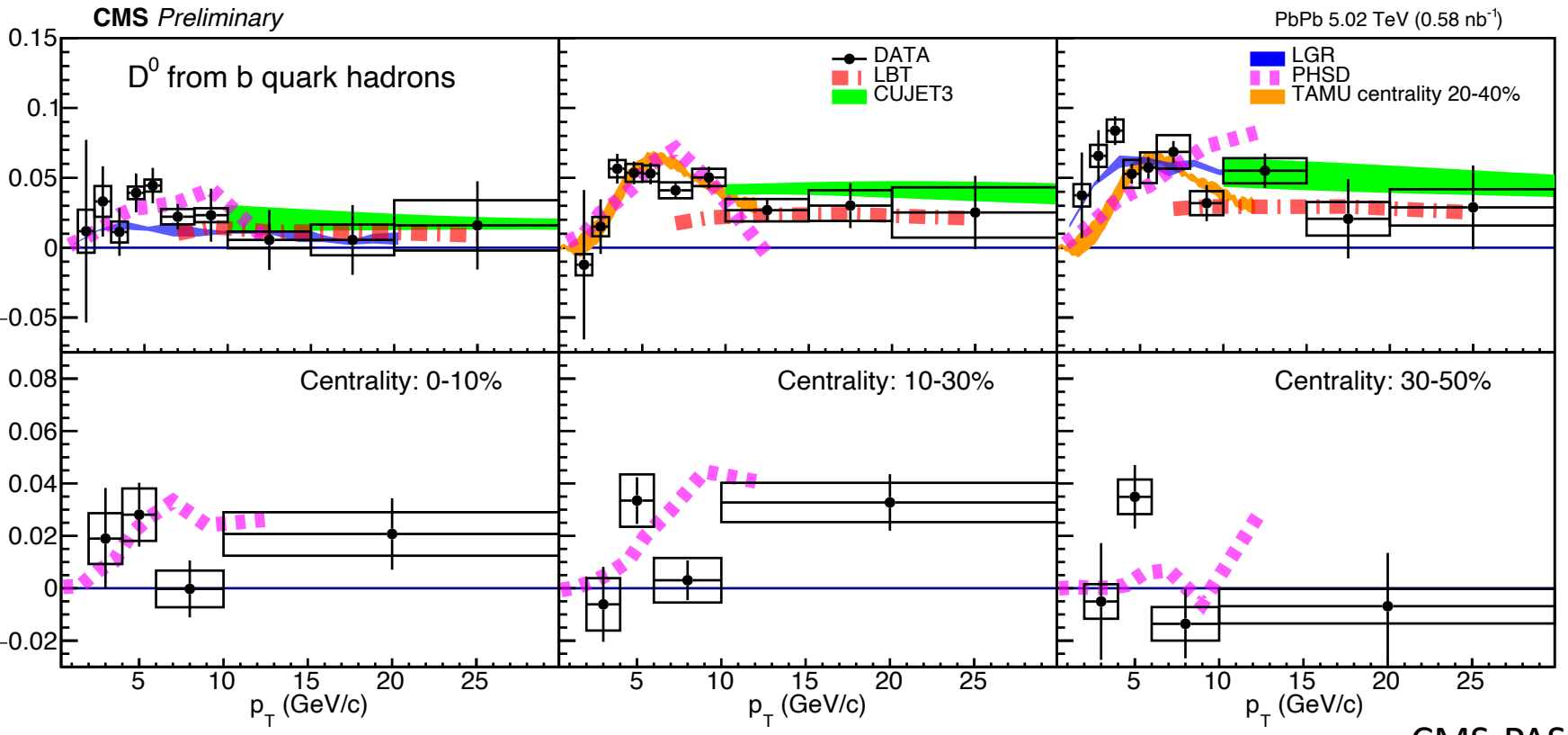
Triangular flow

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

CMS-PAS-HIN-21-003

- Mass ordering of flow magnitudes
- Weak p_T and centrality dependence
- Nonzero v_3

$b \rightarrow D^0$ anisotropy results



Elliptic flow

Triangular flow

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

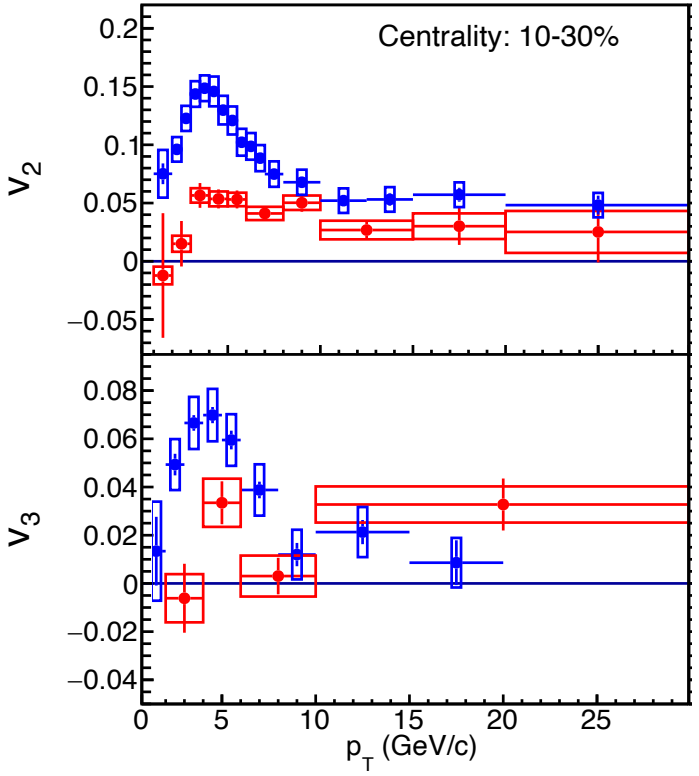
- Qualitatively good agreement between theory and data
- PHSD magnitude of v_3 similar as in data
  - Maximum position shifted towards higher p_T

CMS-PAS-HIN-21-003

PHSD: PRC **92** (2015) 014910
TAMU PLB **735** (2014) 445
LGR EPJ C **80 7** (2020) 671
CUJET3 CPC **43 4** (2019) 044101
LBT PRC **94** (2016) 014909

Summary

- First measurement of $b \rightarrow D^0$ azimuthal anisotropy in PbPb collisions
- Covered both high p_T and low p_T range
- Mass ordering of flow observed
- Qualitative agreement with expectations with additional constraint on models
- **Non-zero triangular flow**



Backup

Heavy flavor v_2 from CMS

Charged hadrons
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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

Y(1S)
CMS–PAS–HIN–21–008