

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

Milan Stojanovic

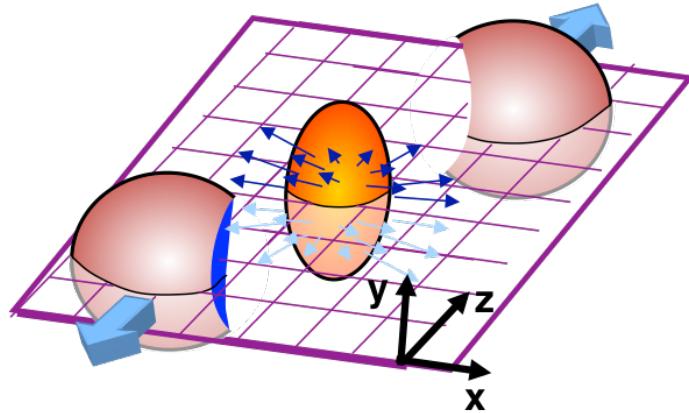
Purdue University
on behalf of the CMS collaboration



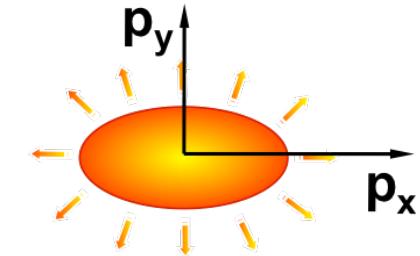
International Conference on High Energy Physics 2022
Bologna, Italy



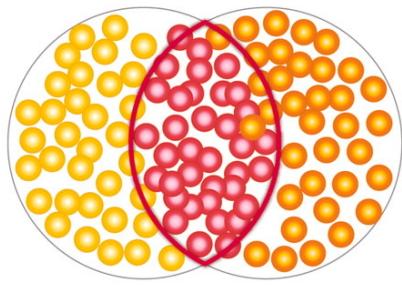
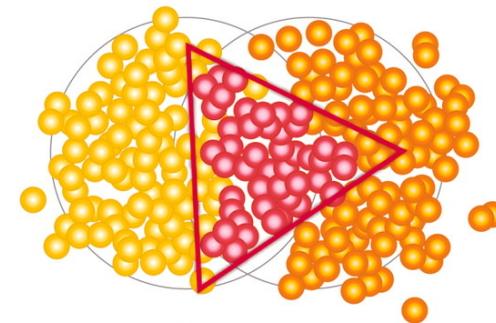
**ICHEP
2022**



Space anisotropy



momentum space anisotropy

System symmetry → elliptic flow, v_2 Fluctuations → triangular flow, v_3

Light hadron anisotropy

- Particle distribution over azimuthal angle:

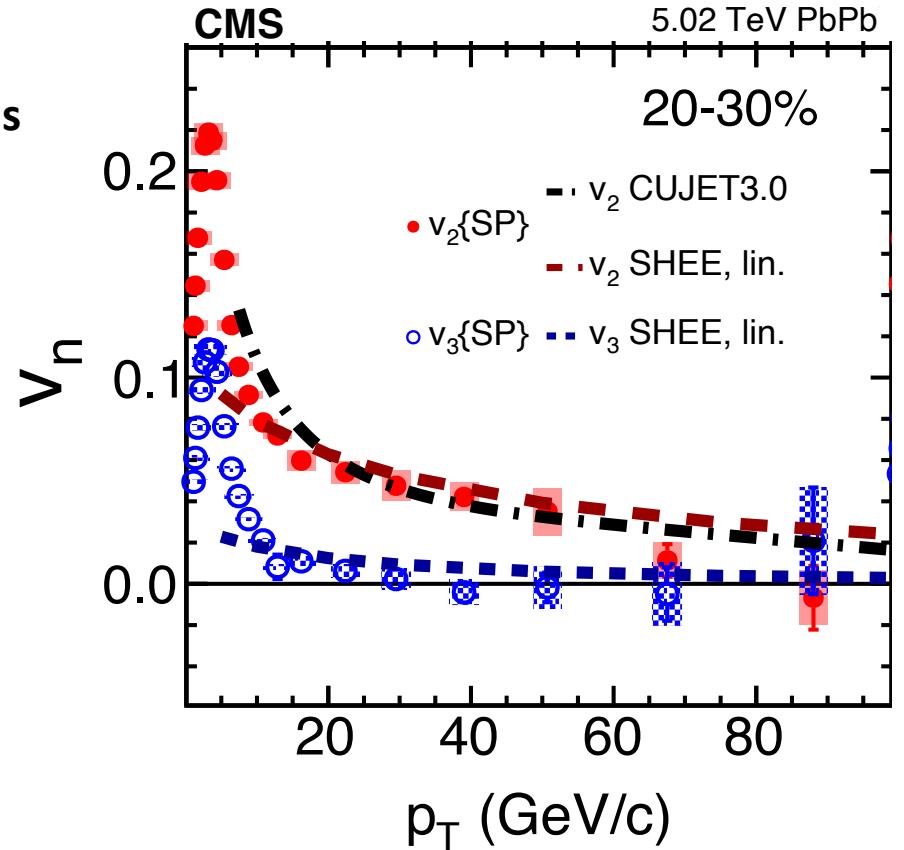
$$\frac{dN}{d\phi} \propto 1 + \sum_n 2v_n \cos[n(\phi - \Psi_n)]$$

- v_n coefficients driven by
 - ❖ Initial geometry
 - ❖ Medium evolution

Flow mechanism (light hadrons):

- low $p_T \rightarrow$ hydrodynamics
- medium $p_T \rightarrow$ coalescence
- high $p_T \rightarrow$ path-dependent parton energy loss

PbPb @ 5 TeV
Charged hadrons



Heavy quark anisotropy

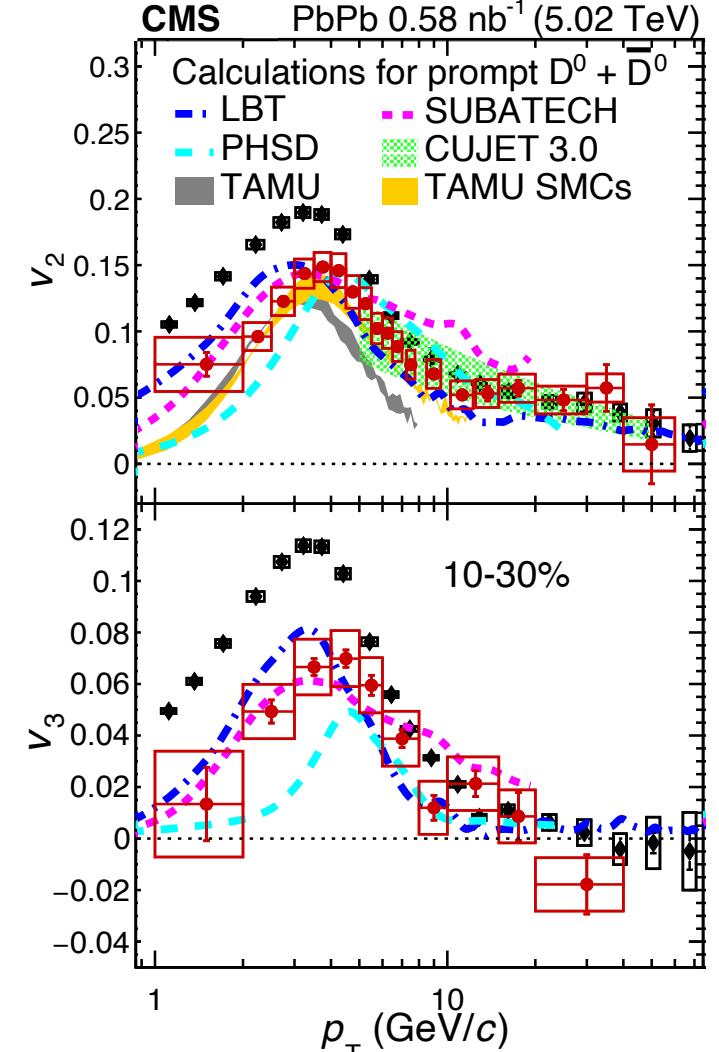
Traveling light carrying heavy luggage



vs



PbPb @ 5 TeV
Charged hadrons
Prompt D^0



Flow mechanism (heavy quarks):

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

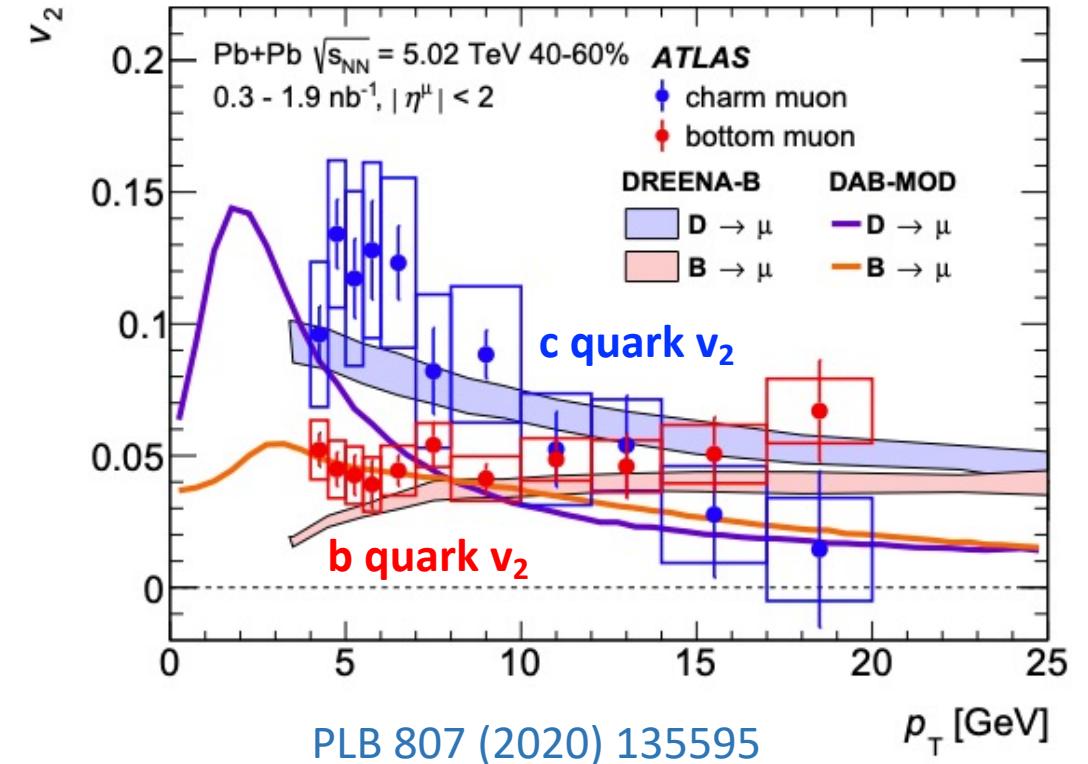
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Phys. Lett. B 816 (2021) 136253

b quark anisotropy



ATLAS ALICE CMS
 $b \rightarrow \mu$ $b \rightarrow e$ $b \rightarrow J/\psi$
❖ Non-zero v_2 !



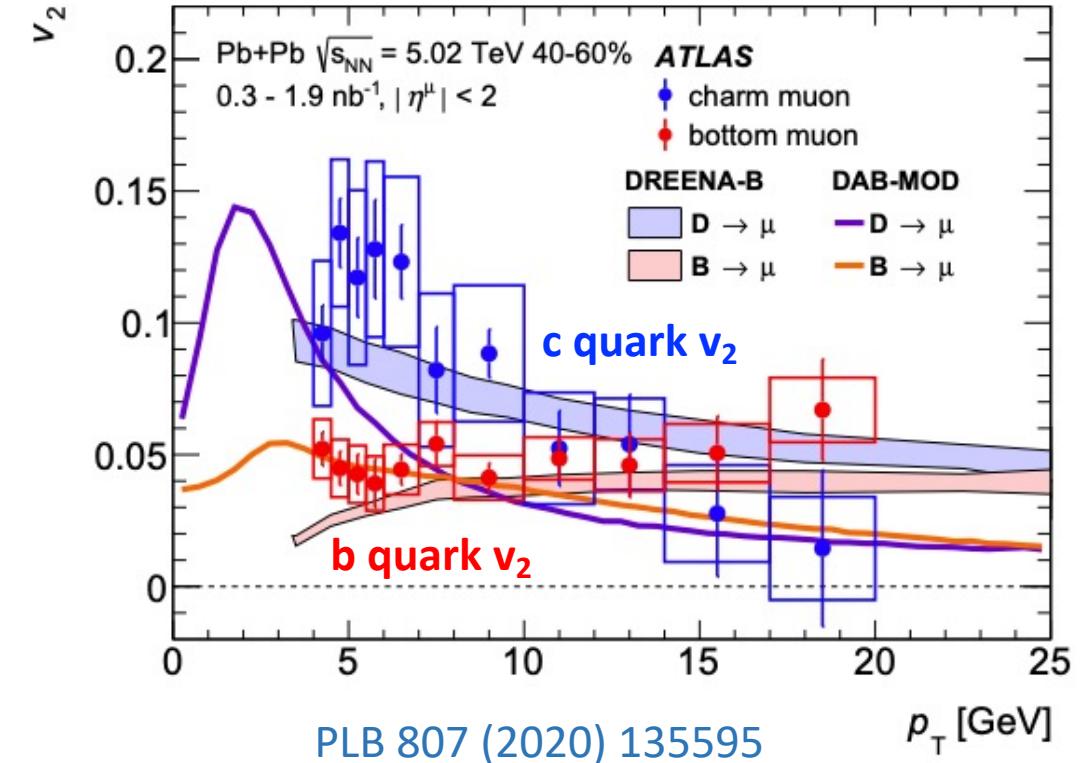
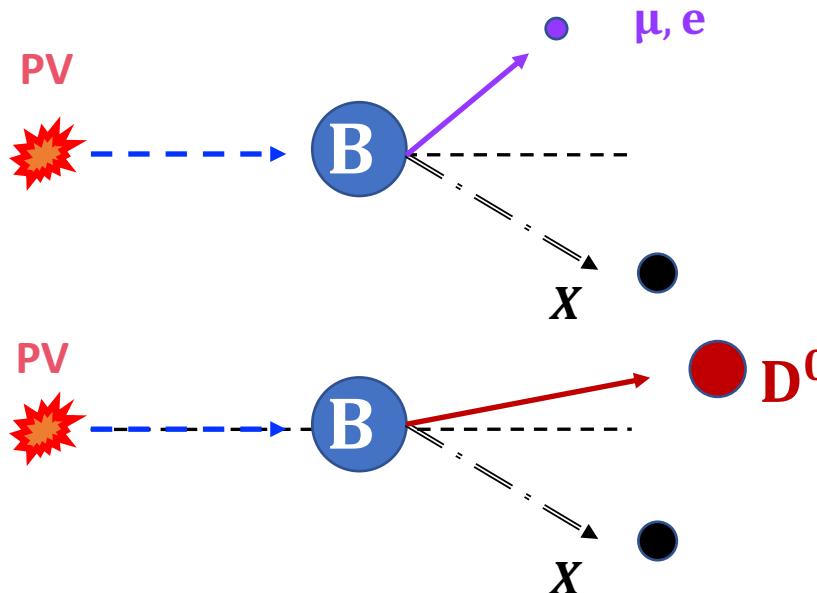
b quark anisotropy



- ATLAS ALICE CMS
- $b \rightarrow \mu$ $b \rightarrow e$ $b \rightarrow J/\psi$

❖ Non-zero v_2 !

- Advantages of $b \rightarrow D^0$ channel
 - ✓ Larger branching ratio wrt $b \rightarrow J/\psi$
 - ✓ Higher D^0 mass than leptons:
higher correlation between D^0 and b direction

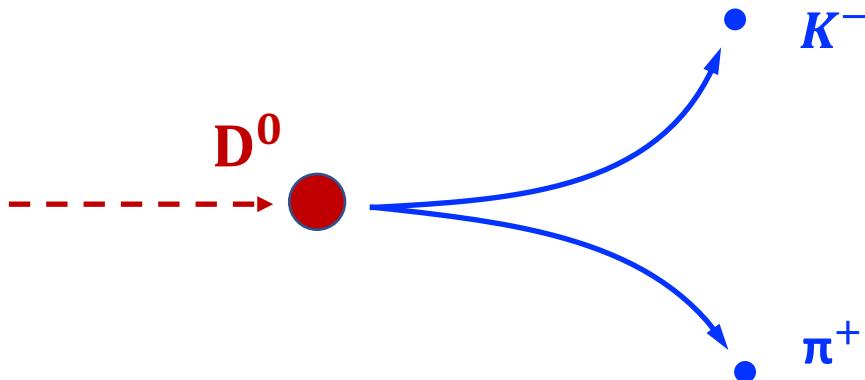


Potential for precise measurement in wide kinematic range!

Analysis technique

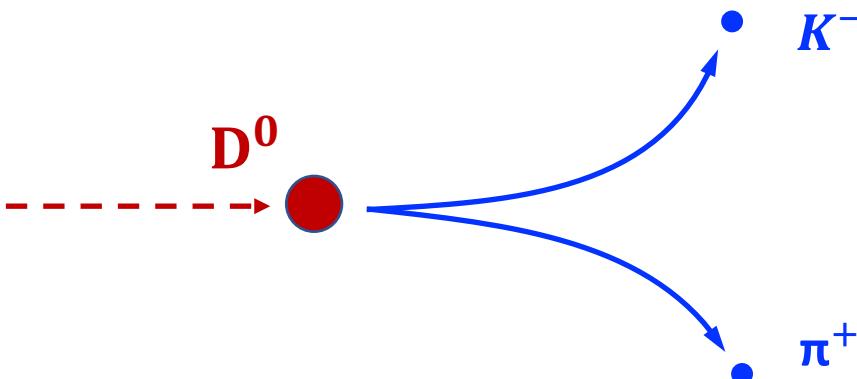
Reconstruction

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



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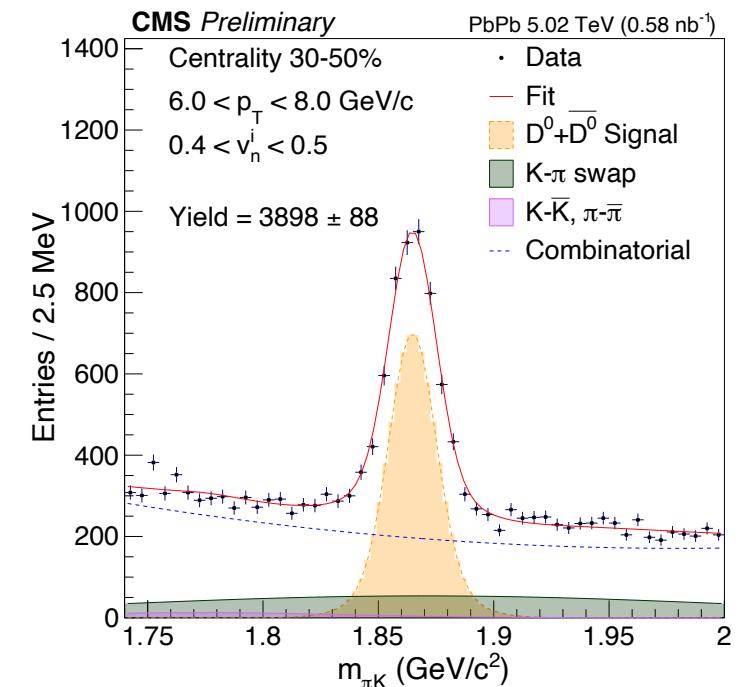


CMS-PAS-HIN-21-003

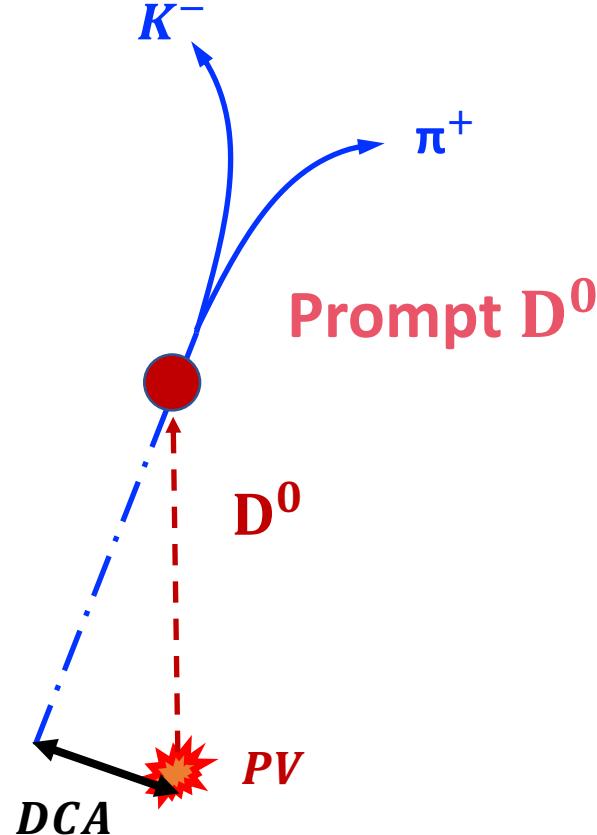
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Inclusive D^0 Yield

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

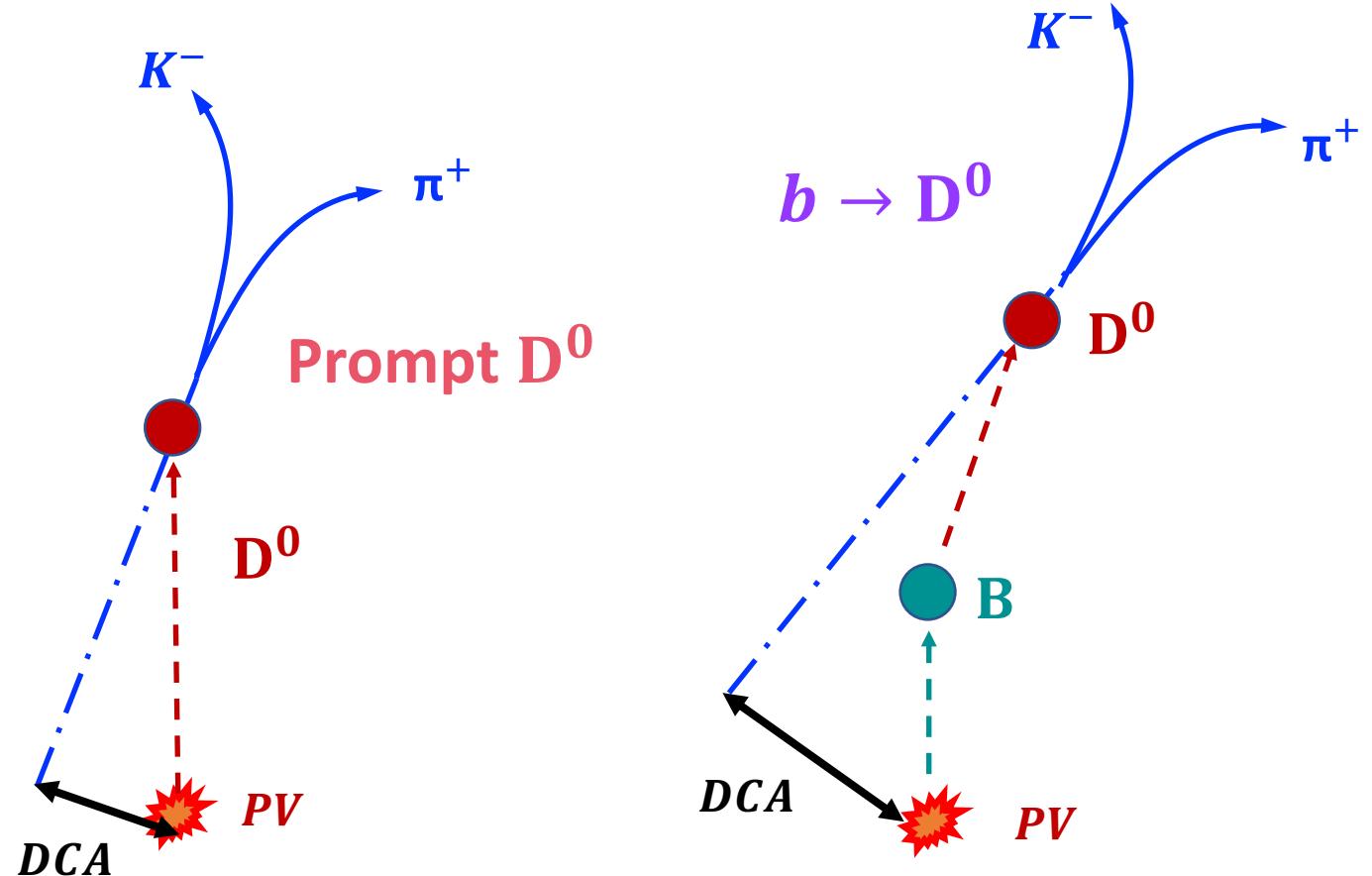


Two component template fit to extract $b \rightarrow D^0$ fraction



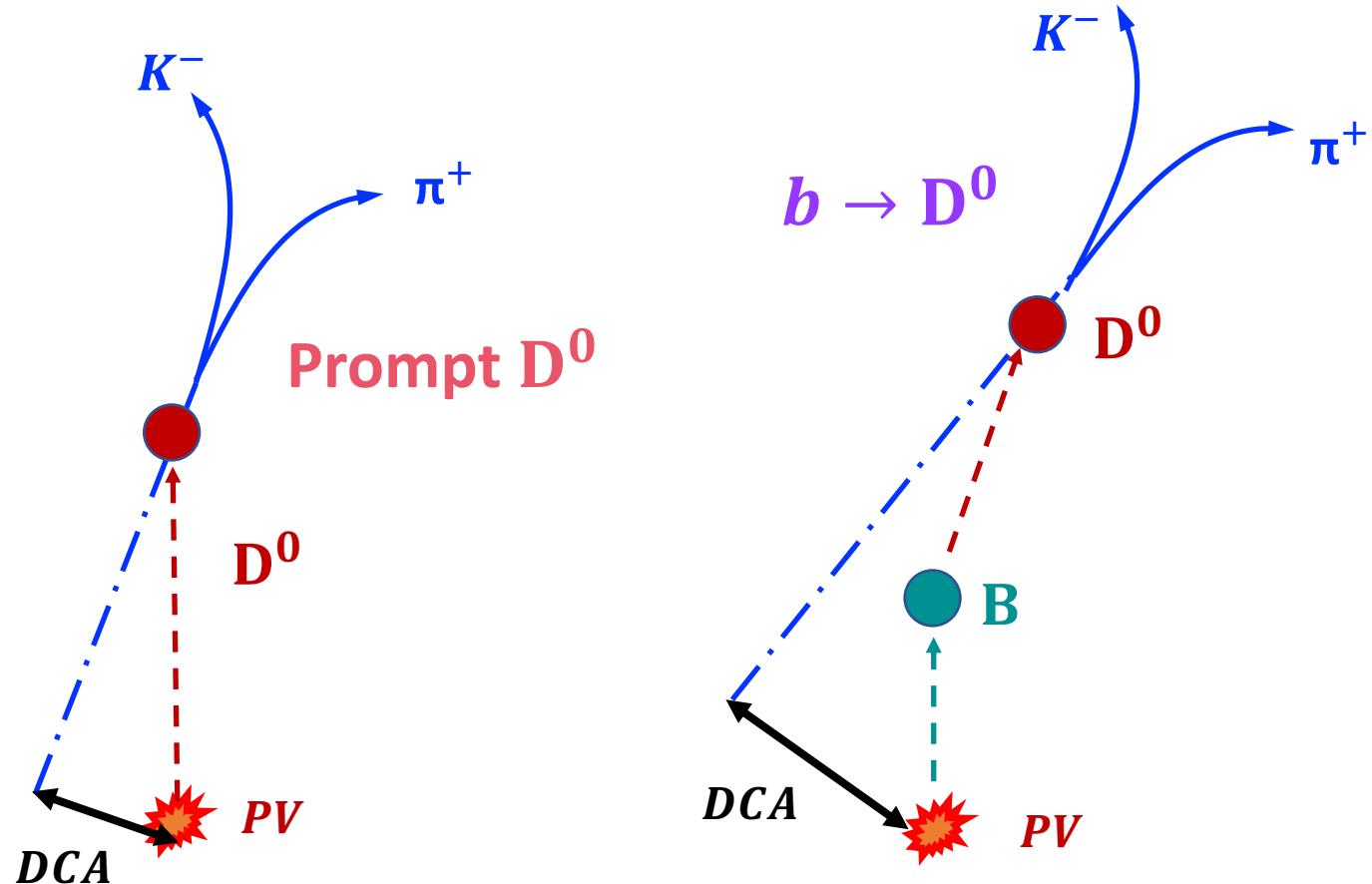
DCA (distance of closest approach)

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

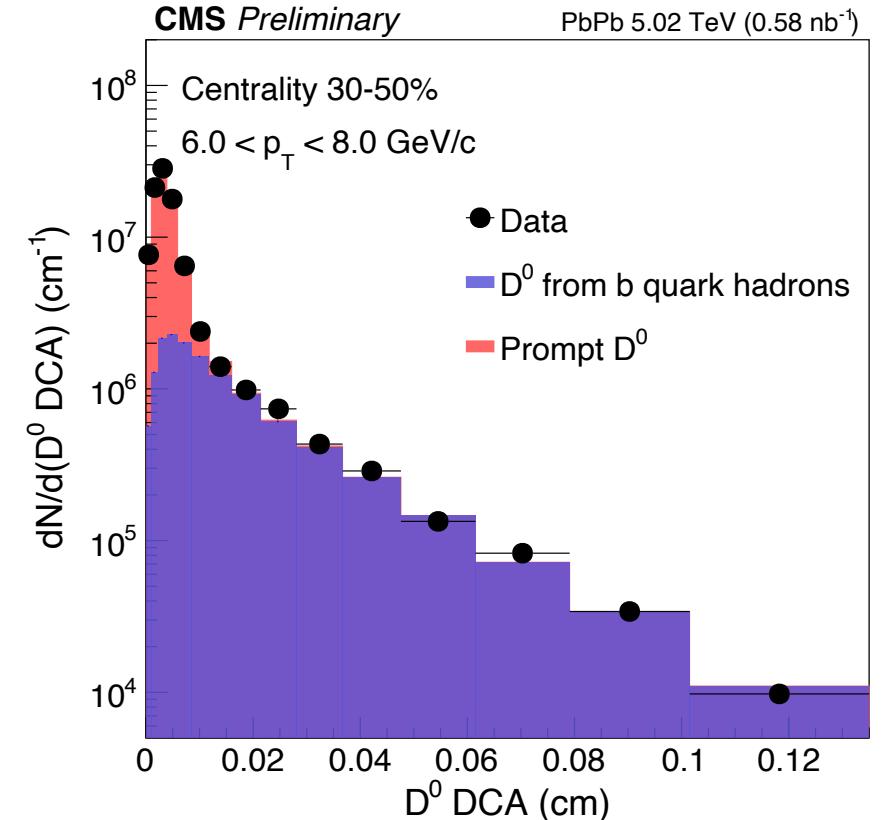


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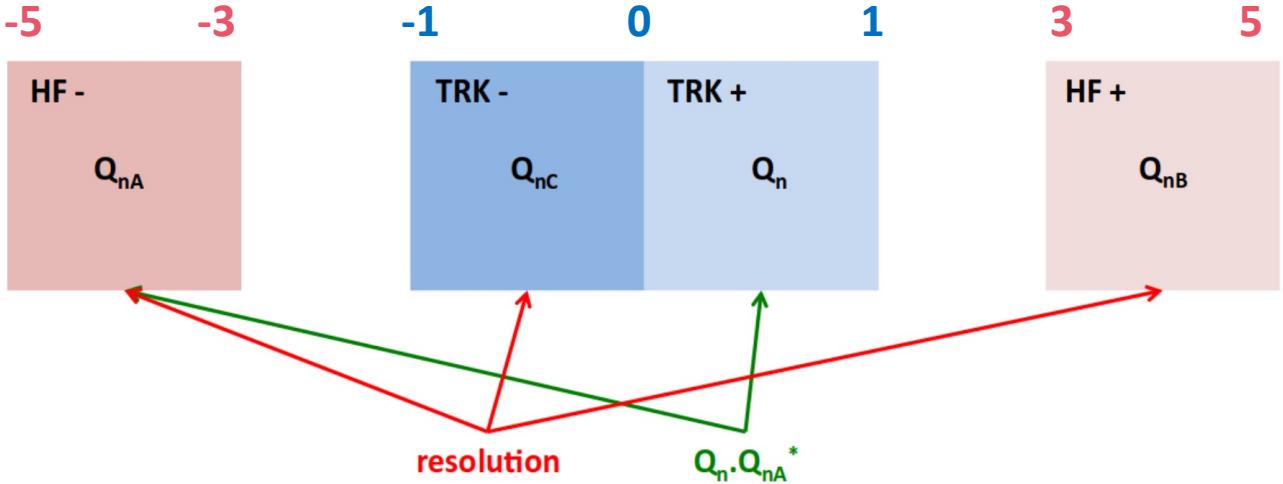
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CMS-PAS-HIN-21-003

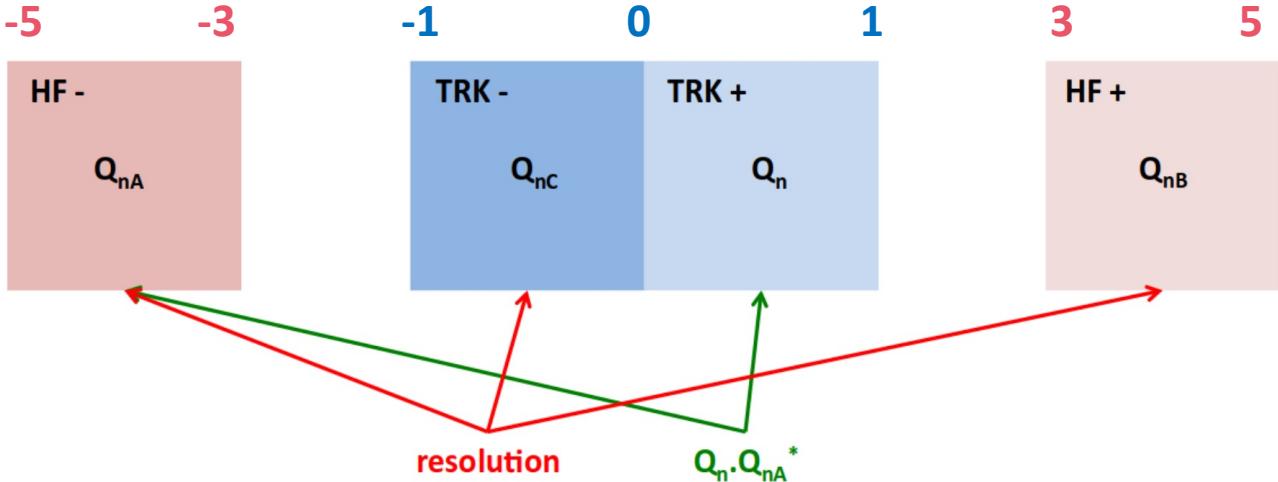


Q_n – D^0 candidate flow vector

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

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

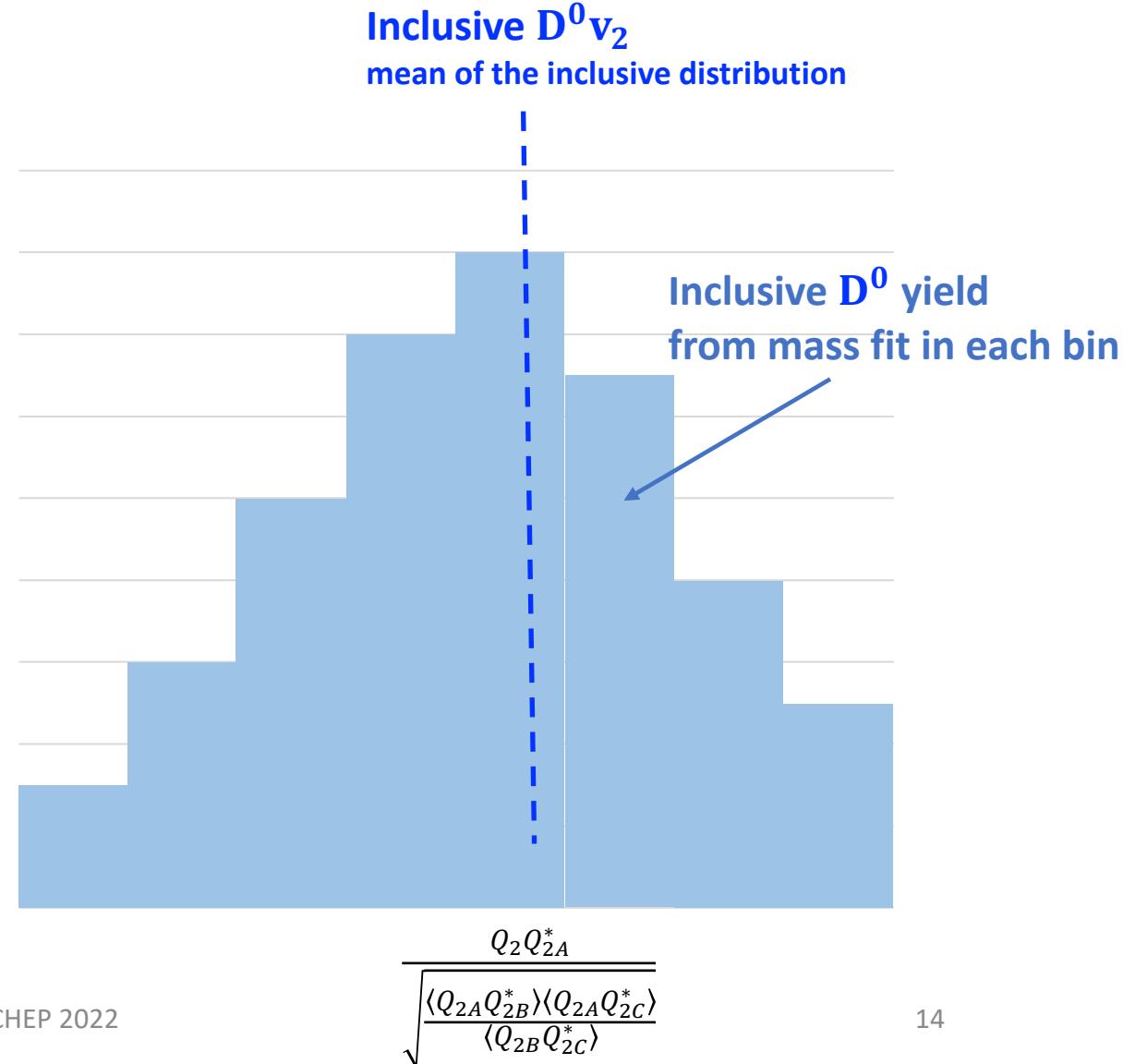
Scalar product method

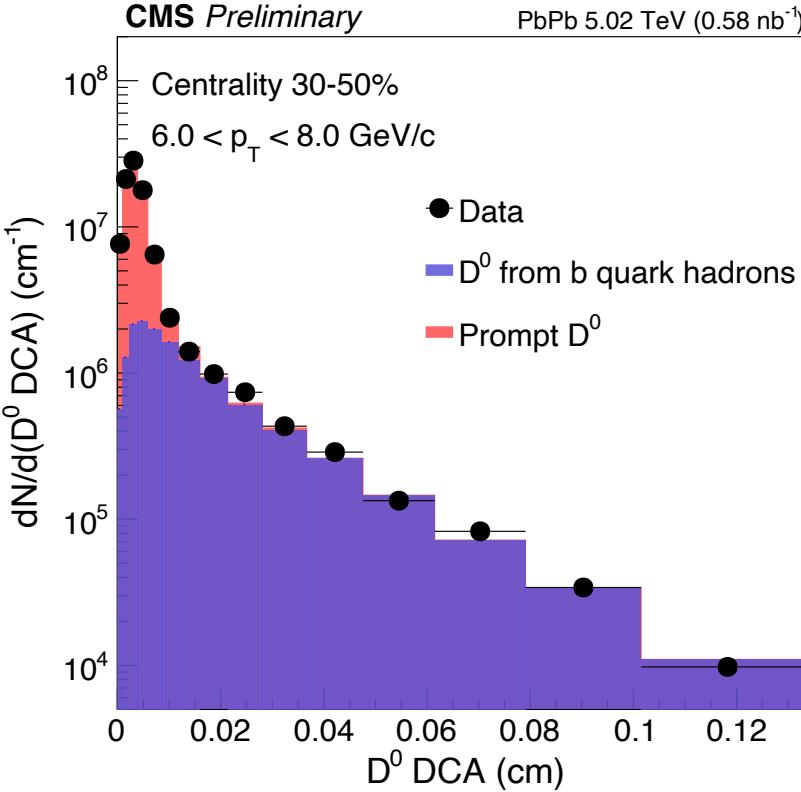


Q_n – D^0 candidate flow vector

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

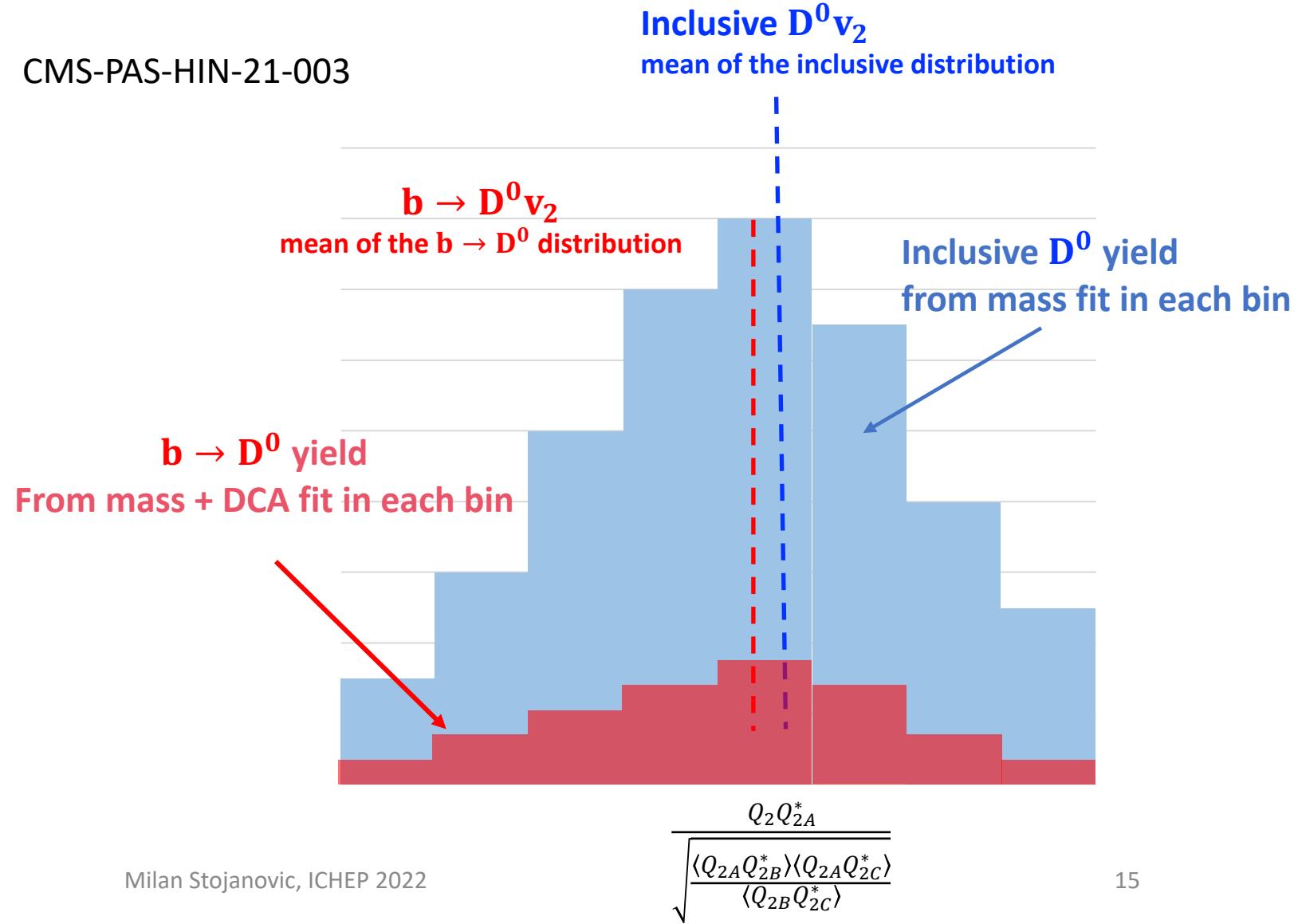
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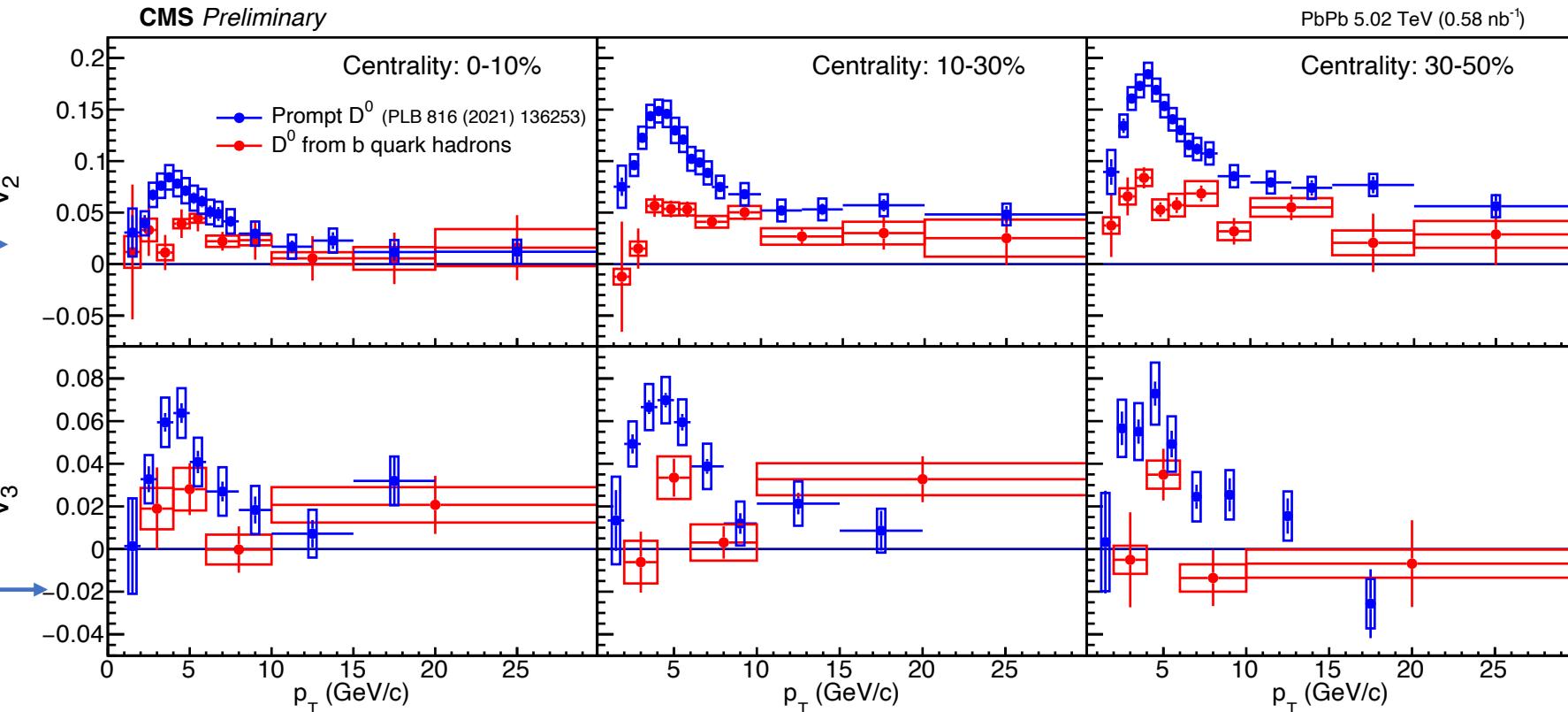
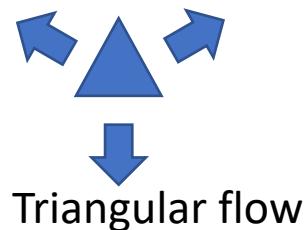
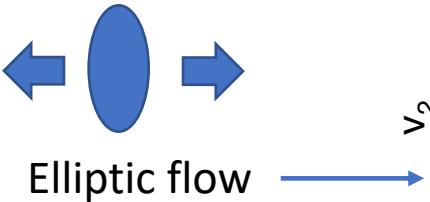


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CMS-PAS-HIN-21-003



Results



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

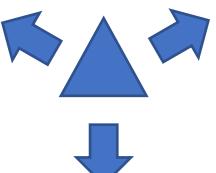
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Mass ordering of flow magnitudes

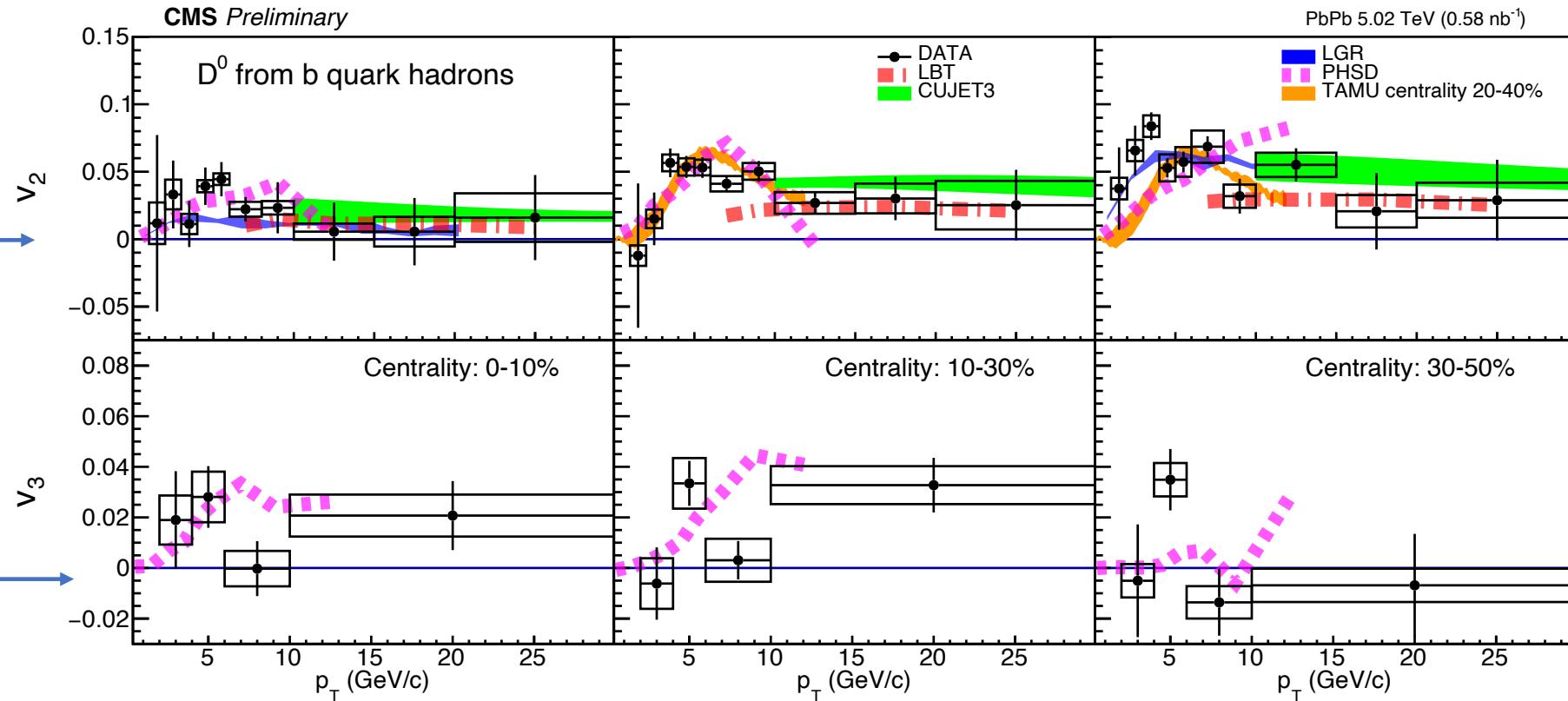
Weak p_T and centrality dependence
 Nonzero **both** v_2 & v_3



Elliptic flow



Triangular flow



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

CMS-PAS-HIN-21-003

- Qualitatively good agreement between theory and data

- PHSD magnitude of v_3 similar as in data
 - Maximum position shifted towards higher p_T

PHSD: PRC **92** (2015) 014910

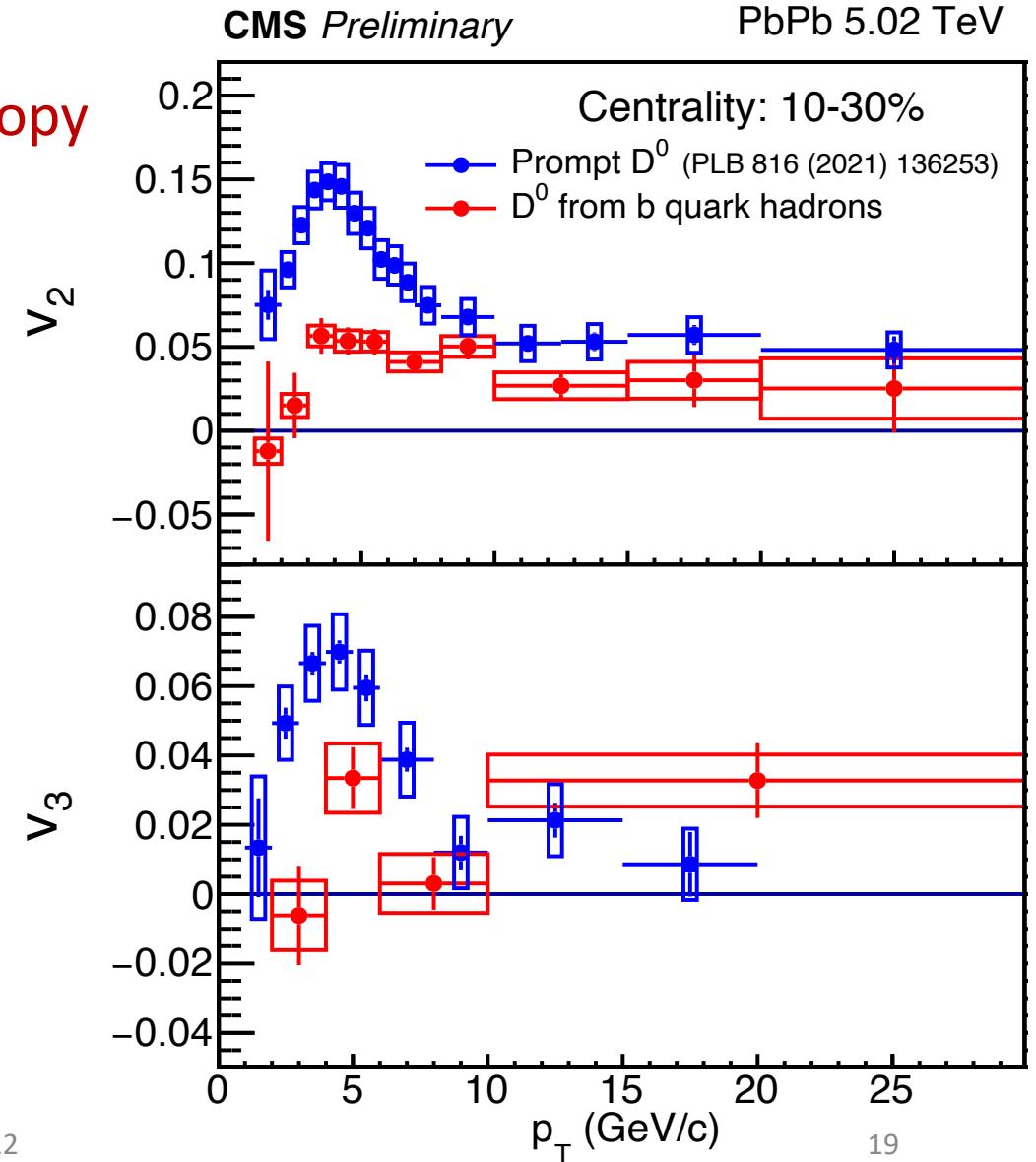
TAMU PLB **735** (2014) 445

LGR EPJ C **80** 7 (2020) 671

CUJET3 CPC **43** 4 (2019) 044101

LBT PRC **94** (2016) 014909

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



Backup

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

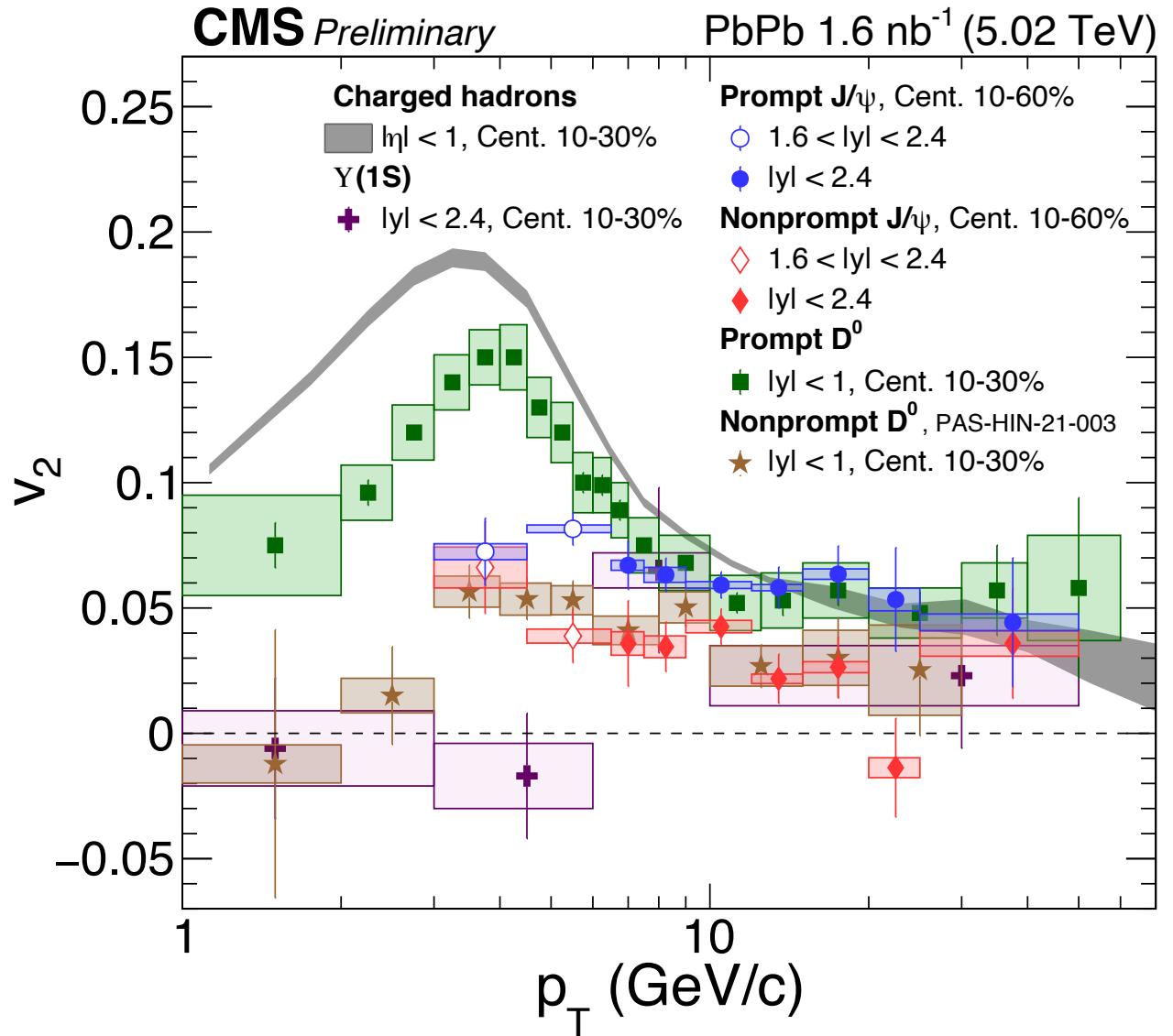
CMS-PAS-HIN-21-008

Nonprompt J/ψ

CMS-PAS-HIN-21-008

$\Upsilon(1S)$

CMS-PAS-HIN-21-008



Variables used for BDT training

D⁰ variables:

- χ^2 probability for the D⁰ vertex fit
- The distance between the secondary and primary vertices and its significance
- The angle between the momentum of the D0 meson candidate and the line connecting the primary and the secondary vertices (pointing angle)

D0 daughters variables:

- The significance of the distances of closest approach to the primary vertex
 - both along and perpendicular to the beam direction