# Prompt $D^0$ $v_n$ harmonics in PbPb at 5.02 TeV with CMS

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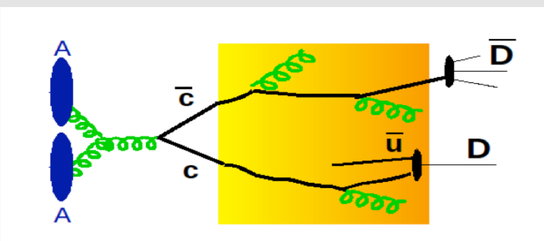
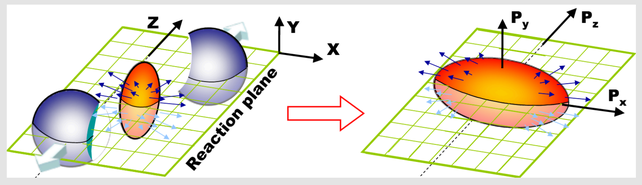
***Abstract***

**The Fourier coefficients $v_2$ and $v_3$, which reflect the azimuthal anisotropy of $D^0$ meson, is measured with scalar-product method in PbPb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV with CMS. It is the first measurement on $D^0$ $v_3$ and the uncertainties on $D^0$ $v_2$ are significantly improved compared with previous measurements. The measured positive prompt $D^0$ $v_n$ (n = 2, 3) at low $p_T$ shows strong charm collective motion in the medium, while the positive $v_2$ at high $p_T$ indicates path length dependence of charm energy loss. $D^0$ $v_n$ is consistent with charged particle $v_n$ in central collisions, and begins to be lower than charged particles $v_n$ at low $p_T$ for more peripheral collisions. These precise measurements give new constrains for model predictions.**

## Motivation

Heavy quarks are primarily produced at the early stages of the collisions. They experience the full evolution of the medium. So they are good probes of the medium.




final momentum anisotropy ($v_n$) from initial geometry and pressure gradient anisotropy

$D^0$ $v_n$ can probe the interaction strength between charm quarks and the medium.

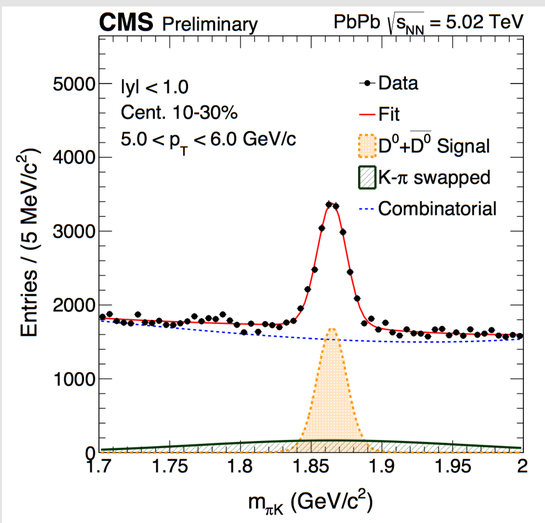
- $D^0$ $v_n$ at low $p_T$ ⟹ degree of charm thermalization in the medium
- $D^0$ $v_n$ at high $p_T$ ⟹ path length dependence of the heavy quark energy loss

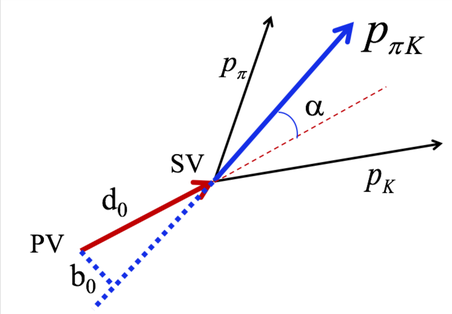
## $D^0$ reconstruction and signal

2015 PbPb run at 5.02 TeV

170M / 270M events for 0-100% / 30-100% centrality

$D^0 \to K\pi$, BR = 3.88±0.05%, $c\tau(D^0)$ = 122.9 μm




$D^0$ candidates reconstructed from oppositely charged tracks with topological selections:

- 3D decay length significance ($d_0/\sigma(d_0)$)
- Pointing angle α
- Secondary vertex probability
- Impact parameter of $D^0$ candidates ($b_0$)

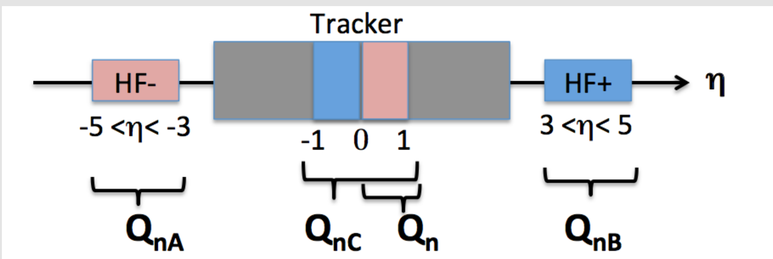
clear $D^0$ signal can be seen

## $D^0$ $v_n$ calculation

Large η gap (|Δη|>3) to suppress non-flow correlation

Scalar product method for $v_n$:

$$Q_n = \sum_j w_j e^{in\phi_j}$$



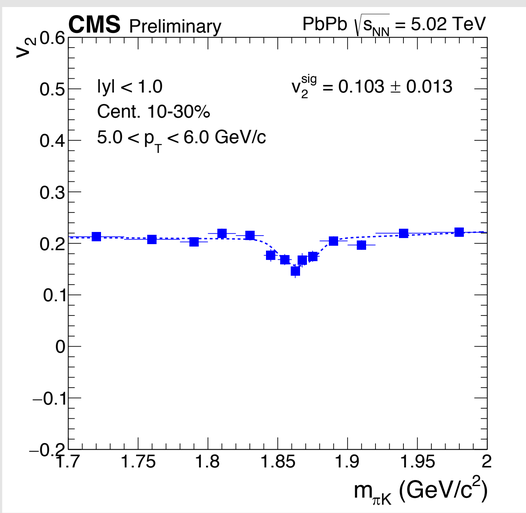

Sum over tracks (tracker) / towers (HF)

$w_j$: tower $E_T$ (HF) / track $p_T$ (tracker)

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

Scaling factor from 3 sub events

$D^0$ $v_n$ obtained by simultaneous fit on candidate $m_{inv}$ spectrum (plot above) and candidate $v_n\{SP\}$ vs. $m_{inv}$ (plot on the right):




candidate $v_n$ vs. $m_{inv}$ to be fit

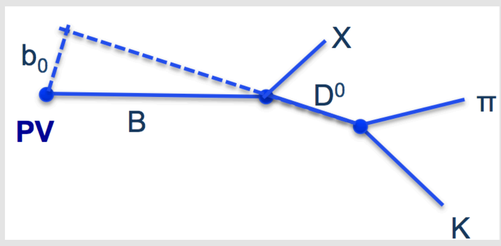
result signal $v_n$

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

signal / candidate fraction vs. $m_{inv}$

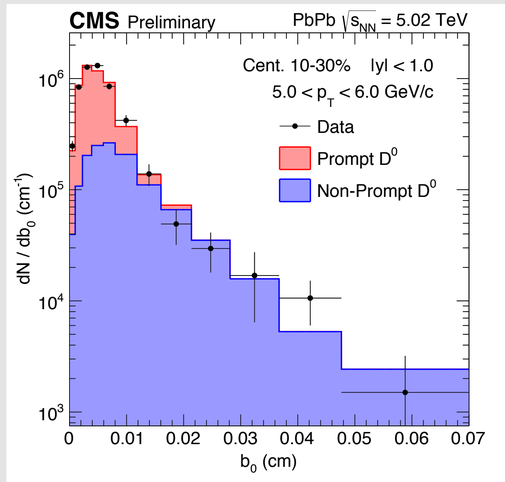
background $v_n$ vs. $m_{inv}$, first order polynomial

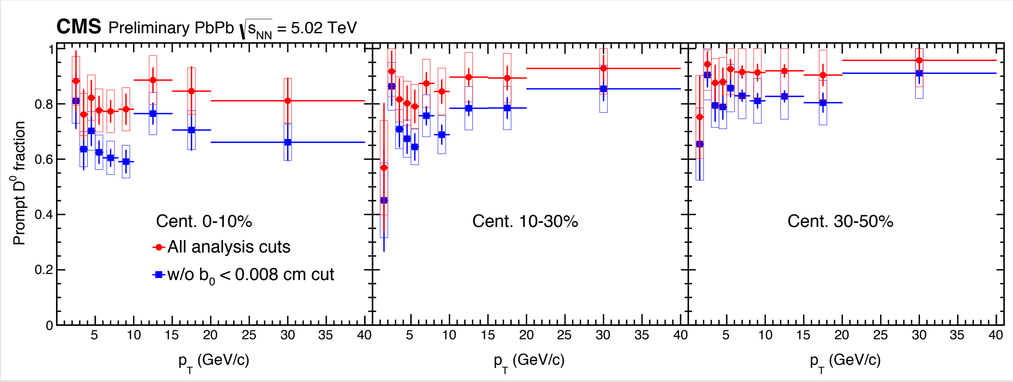
## Nonprompt $D^0$ contamination




Nonprompt $D^0$ has finite impact parameter $b_0$ from B->$D^0$+X decay.

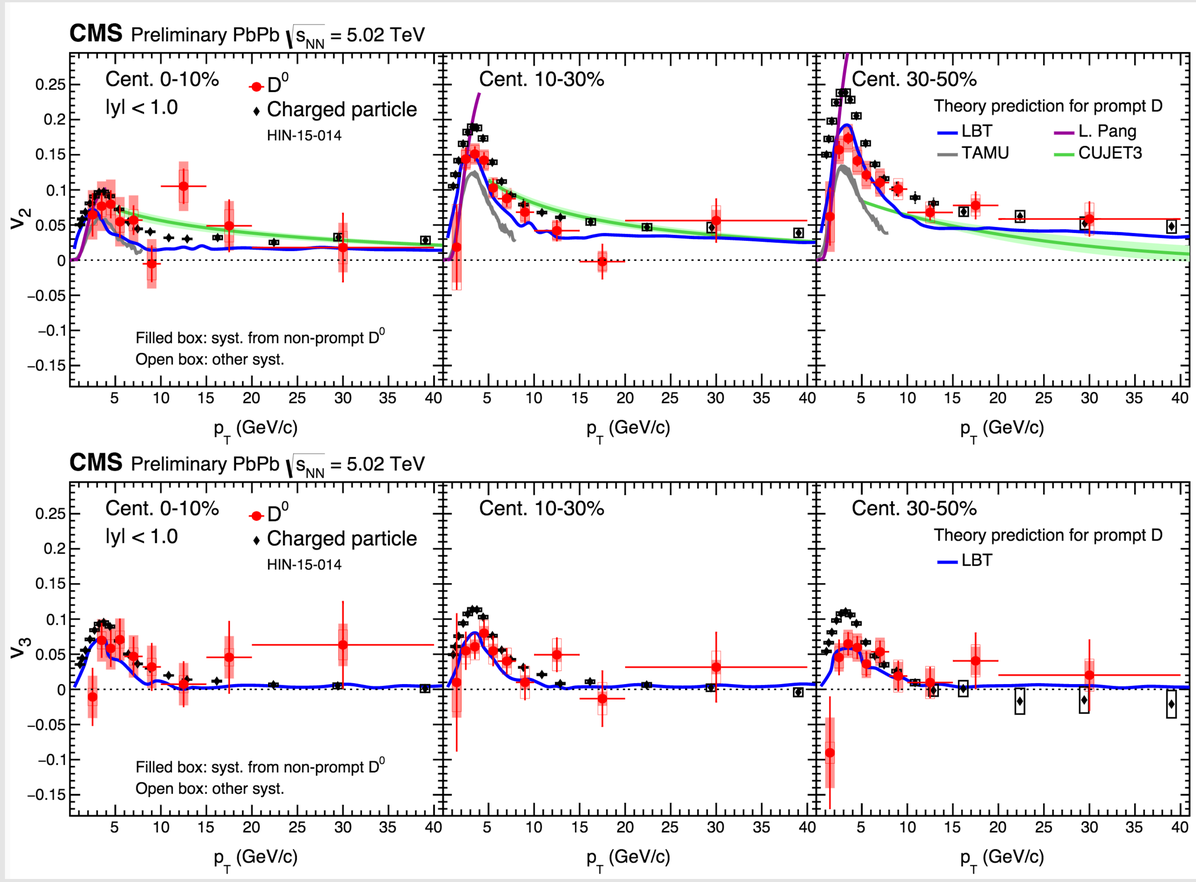
Its contamination can be estimated by template fit on $b_0$ distribution.




With $b_0$ < 80 μm cut, nonprompt component < 20% for most bins.

## Results




- First prompt $D^0$ $v_3$ and more precise $D^0$ $v_2$ measurements than previous results
- Prompt $D^0$ $v_2$ > 0 at both low and high $p_T$ $v_3$ > 0 at low $p_T$
  - Low $p_T$: charm quarks take part in the collective motion of the system
  - High $p_T$: indicates path length dependence of energy loss
- $v_n$ peaks around 3 GeV, then decrease vs $p_T$.
- Low $p_T$: $v_2$ (0-10%) < $v_2$ (10-30%) ≈ $v_2$ (30-50%) $v_3$ has little centrality dependence.
- In 0-10%, consistent with $v_n$ of charged particles
- In 10-30% and 30-50%, $v_n$ (prompt $D^0$) < $v_n$ (charged particle) at low $p_T$

These precise measurements give new constrains for model predictions.

- **LBT:** linearized Boltzmann transport model for jet propagation in QGP.
  *Cao, Luo, Qin, Wang PRC 94 014909 (2016)*
- **TAMU:** non-perturbative transport model with thermodynamic T-matrix approach.
  *He, Fries, Rapp PLB 735 (2014) 445*
- **CUJET3:** jet quenching model based on DGLV.
  *Xu, Liao, Gyulassy JHEP 1602 (2016) 169*
- **L. Pang:** second order viscosity hydrodynamic model.
  *Pang, Hatta, Wang, Xiao PRD 91, 074027 (2015)*

*The CMS Collaboration: CMS PAS HIN-16-007*