Measurement of nonprompt and prompt D^0 azimuthal anisotropy in Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV

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Abstract. Heavy quarks are primarily produced via initial hard scatterings, and thus carry information about the early stages of the Quark-Gluon Plasma (QGP). Measurements of the azimuthal anisotropy of the final-state heavy flavor hadrons provide information about the initial collision geometry, its fluctuation, and more importantly, the mass dependence of energy loss in QGP. Due to the larger bottom quark mass as compared to the charm quark mass, separate measurements of charm and bottom hadron azimuthal anisotropy can shed new light on understanding the dependence of the heavy quark and medium interaction. Because of the high branching ratio and large D^0 mass, measurements of D^0 meson coming from bottom hadron decay (nonprompt D^0) can cover a broad kinematic range and be a good proxy of the parent bottom hadrons results. In this talk, we report on the prompt D^0 and the first nonprompt D^0 measurements of the azimuthal anisotropy elliptic (v_2) and triangular (v_3) coefficients of nonprompt D^0 in PbPb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV. The measurements are performed as functions of transverse momentum p_{T}, in three centrality classes, from central to midcentral collisions. Compared to the prompt D^0 results, the nonprompt D^0 v_2 flow coefficients are systematically lower but have a similar dependence on p_{T} and centrality. A non-zero v_3 coefficient of the nonprompt D^0 is observed. The obtained results are compared with theoretical predictions. The comparison could provide new constraints on the theoretical description of the interaction between heavy quarks and the medium.

1 Introduction

Azimuthal angle distribution of particles emitted in heavy ion collisions can be described via Fourier decomposition, where Fourier harmonics, v_n, represent the magnitude of the n-th order azimuthal anisotropy. Thermally produced particle anisotropy can be successfully described with relativistic hydrodynamics [1]. Unlike light quarks, heavy quarks are dominantly produced in the initial hard scattering [2], and their azimuthal anisotropy is expected to arise from the interaction with the medium. Indeed, significant positive charm (c) quark values of v_2 and v_3 have been measured and remarkable similarity is observed in transverse momentum (p_{T}) and centrality dependence compared to light hadrons [3]. The magnitude of flow coefficients, however, is smaller in the case of c quarks, particularly in the low- and intermediate-p_{T} range ($p_{\mathrm{T}} < 15$ GeV/c). The bottom (b) quark mass is even larger than the c quark mass, hence b hadron azimuthal anisotropy measurement is the next step in understanding the dependence of the heavy quark and medium interaction.

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In this proceedings we report the first measurement of the second, v_2, and third, v_3, azimuthal anisotropy coefficients of D^0 mesons that come from b hadron decays, in lead-lead (PbPb) collisions. Results are shown as a function of D^0 meson transverse momentum, in three centrality intervals.

2 Dataset and analysis details

This analysis uses PbPb collision data at a center-of-mass energy per nucleon pair of $\sqrt{s_{NN}}$ = 5.02 TeV collected with the CMS detector [4] in 2018 with a total integrated luminosity of 0.58 pb^{-1}. Inclusive D^0 ($\overline{D}^0$) meson candidates are reconstructed via decay channel $D^0 \rightarrow \pi^+ + K^-$ ($\overline{D}^0 \rightarrow \pi^- + K^+$). No particle identification is applied and the D^0 meson candidates are formed by combining pairs of oppositely charged detected particles in the event where both possible particle assignments are considered for each pair. The background is partially suppressed (both combinatorial background and prompt D^0 component) by applying a boosted decision tree (BDT) algorithm from the TMVA package [5].

Inclusive D^0 meson yield, in each bin of scalar product (v_n^i), is extracted from the fit of the invariant mass spectrum [6]. Nonprompt fraction is further obtained by fitting the distributions of the distance of closest approach (DCA) between the D^0 meson momentum vector and the collision point with a linear combination of prompt and nonprompt D^0 DCA simulated distributions. Finally, the v_n coefficients are measured by taking the mean of the nonprompt D^0 mesons scalar product distribution in each bin of p_T and centrality.

3 Results

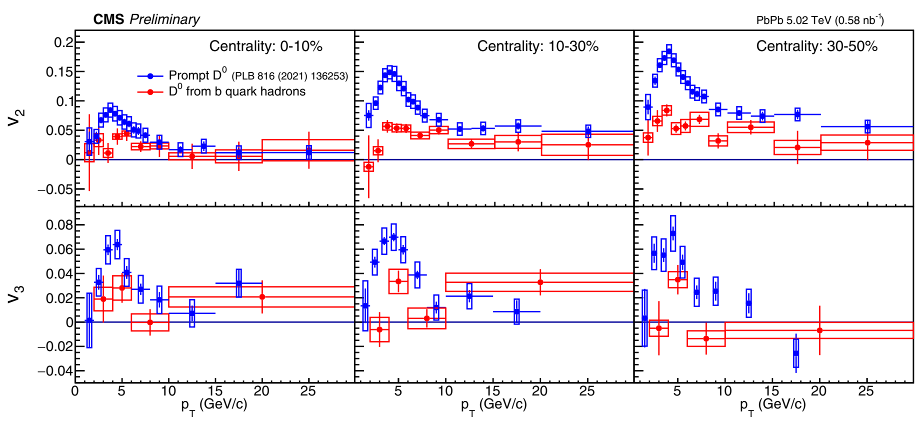

Figure 1. The elliptic, v_2 (top panel), and the triangular, v_3 (bottom panel), flow coefficients of non-prompt and prompt D^0 mesons as functions of p_T and in three bins of centrality. The bars and the boxes represent statistical and systematic uncertainties, respectively. The figure is taken from Ref. [6].

Figure 1 shows the results of v_2 and v_3 azimuthal anisotropy coefficients for nonprompt D^0 mesons, compared with previously published values for prompt D^0 from Ref. [7]. The results show non-zero values of the elliptic flow of b hadron daughters, although the flow magnitude is significantly smaller than for the prompt D^0 case. This is particularly evident in the low- and mid-p_T range ($p_T < 15$ GeV/c) and it is consistent with the mass ordering observed in pPb collisions [8], as well as mass ordering observed in leptonic channels in PbPb collisions [9, 10]. At larger D^0 transverse momentum, v_2 values from charm and bottom quarks start converging. Elliptic flow of nonprompt D^0 mesons exhibits very weak centrality and transverse momentum dependence, unlike flow of prompt D^0 mesons. The v_3 Fourier coefficients are strongly affected by statistical fluctuations so that neither the p_T, nor the centrality dependence can be determined. However, results indicate a non-zero value in the $4 < p_T < 6$ GeV/c range for all centralities. Similar as in the case of elliptic flow, the magnitude of v_3 is lower for nonprompt than for prompt D^0.

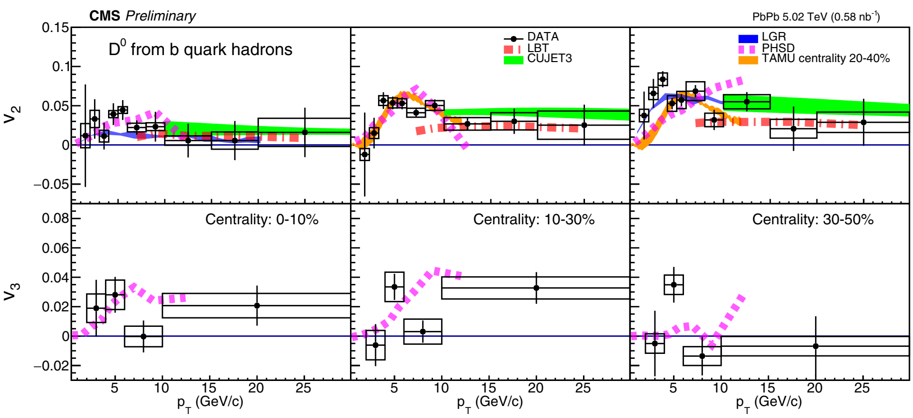

Figure 2. The elliptic, v_2 (top panel), and the triangular, v_3 (bottom panel), flow coefficients of non-prompt D^0 mesons as functions of transverse momentum and in three bins of centrality. The bars and the boxes represent statistical and systematic uncertainties, respectively. The colored bands show theoretical predictions [11–18]. The figure is taken from Ref. [6].

Figure 2 shows the measured nonprompt D^0 v_n coefficients compared with theoretical calculations that have different modeling of the b quark flow. All models show qualitative agreement with the measured p_T dependence of the elliptic flow, but there are quantitative discrepancies which could provide constraints on the description of bottom quark interactions with the medium. In the low- and mid- p_T regime, for the centrality range 30–50%, the measurements favor the LGR model [11, 12], while for the most central events (0–10%) the same model does not predict a peak structure seen in data. The PHSD model [13] provides a good description of the data, for more central collisions, 0–10% and 10–30%, but shows higher discrepancies in the 30–50% range. The TAMU model [14] provides predictions in the centrality range 20–40% only, so, direct comparison with data is not possible, but the model describe well the measurement performed in the centrality range 10–30%. At higher p_T, where anisotropy is driven by the path-length dependence of parton energy loss, the LBT [15, 16] model appears to be slightly closer to the data than CUJET3.0 [17, 18], which is systematically above the experimental results, however still within uncertainties. The PHSD is the only model that has predictions for v_3 coefficients. While uncertainties are rather large, both model and data reach similar maximal values in all centralities.

4 Summary

In summary, the second (v_2) and third (v_3) Fourier harmonics of D^0 mesons that come from b hadron decays (nonprompt D^0) are measured in PbPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV. The

v_2 results exhibit a weak transverse momentum dependence and increase from central to midcentral collisions. The measured flow magnitudes are lower compared to the prompt D^0 mesons. The v_3 coefficient shows no centrality dependence, but an indication of non-zero triangular flow is found in the transverse momentum range $4 < p_T < 6$ GeV/c. The new measurements place additional constraints on theoretical understanding of heavy quark interactions with the medium.

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