Search for strong electromagnetic fields in PbPb collisions at 5.02 TeV via azimuthal anisotropy of $D^0$ and $\bar{D}^0$ mesons

The CMS Collaboration

Abstract

Motivated by the search for strong electromagnetic fields created in PbPb collisions, the first measurement of the $v_2$ difference ($\Delta v_2$) between $D^0$ and $\bar{D}^0$ is presented as a function of rapidity. The result for the rapidity-averaged $v_2$ difference is found to be $\langle \Delta v_2 \rangle = 0.001 \pm 0.001\text{(stat)} \pm 0.003\text{(syst)}$, consistent with zero within experimental uncertainties. Comparisons with models may help to directly constrain the electric conductivity of the hot and dense medium formed in these collisions. Measurements of flow harmonics of $D^0$ ($\bar{u}c$) and $\bar{D}^0$ ($u\bar{c}$) mesons are presented as functions of rapidity ($y$), transverse momentum ($p_T$), and collision centrality, for PbPb collisions at 5.02 TeV, using data collected by the CMS experiment during the 2018 LHC run. The results improve previous ones published by CMS, by extending the $p_T$ coverage and providing more differential information. A clear centrality dependence of prompt $D^0$ $v_2$ is observed, while $v_3$ is largely independent of centrality. The trend is consistent with expectations of flow driven by the initial-state geometry. No significant rapidity dependence of prompt $\bar{D}^0$ $v_2$ and $v_3$ is observed.
1 Introduction

The long-range and near-side azimuthal correlations constitute an effective tool to probe the properties of the quark-gluon-plasma (QGP) formed in ultrarelativistic heavy ion collisions at the BNL RHIC [1–4] and at CERN LHC [5–7]. These anisotropic flow correlations are parameterized by a Fourier expansion [8–10],

$$ \frac{dN}{d\phi} = \frac{N}{2\pi} \left( 1 + \sum_{n=1}^{\infty} 2v_n \cos[n(\phi - \Psi_n)] \right) $$

(1)

where $dN/d\phi$ is the azimuthal particle density and $\phi$ is the particle azimuthal angle with respect to a reference angle $\Psi_n$. In this paper the measured anisotropies are expressed in terms of the event-plane reference angle, defined by the azimuthal angle of the direction of the maximum particle density in the transverse plane [10].

The magnitude of the azimuthal anisotropy Fourier coefficients, $v_n$, can provide information about the initial collision geometry and its fluctuations [10]. The second-order ($v_2$) and third-order ($v_3$) Fourier coefficients are referred to as “elliptic” and “triangular” flow harmonics, respectively. Measuring these coefficients for different particle species may bring additional information about this hot and dense medium. Due to their large mass, charm and bottom quarks are predicted to be produced earlier in the collisions than the light quarks (up and down) [11, 12]. Charm $D^0$ ($\bar{u}c$) and $\bar{D}^0$ ($u\bar{c}$) mesons (henceforth referred to as $D^0$ mesons, except if explicitly stated) have a longer period for interacting with the medium and can provide stronger signals from the particles interactions with the QGP than the lighter flavor mesons.

In ultrarelativistic heavy ion collisions, a very strong (approximately $10^{16}$ T [13]) and transient ($\sim 10^{-1}$ fm/c [13]) electromagnetic (EM) field is expected to be induced by the collision spectators and participants. Such an EM field is predicted to produce a difference in the $v_n$ harmonics for positive- and negative-charged particles. The magnetic field is mainly responsible for splitting the rapidity-odd directed flow ($v_1$). The Coulomb electric field leads to a charge-dependent splitting in the $v_2$ coefficient and in the average $p_T$ values of the emitted particles [13]. As charm quarks are expected to be created very early in the collision, they have a higher probability of interacting with this strong EM field than light flavor hadrons [14, 15].

In this note, measurements of the $v_2$ and $v_3$ as functions of $D^0$ meson rapidity ($y$), transverse momentum ($p_T$), and PbPb collision centrality are presented. The flow harmonics are measured using the scalar product method [16, 17], considering collision event planes measured with the CMS hadron forward calorimeter (HF), as well as the tracker information (more details in Section 4). For improving the performance of the selection of $D^0$ mesons in this analysis, multivariate methods [18] are employed for selecting $D^0$ candidates and their antiparticles. The contamination from nonprompt $D^0$ candidates from B meson decay is considered as a systematic uncertainty. Using the data recorded in PbPb collisions during the 2018 LHC run period, the flow coefficient measurements are extended much further (to $|y| < 2$) than in the previous CMS measurement, in which it was performed in the barrel region of the detector, within the rapidity range $|y| < 1$ [19]. The new results provide smaller statistical uncertainties in the barrel region of the detector, furnishing important inputs for a better understanding of the three-dimensional evolution of the QGP formed in heavy ion collisions. Measurements of the $v_2$ difference between $D^0$ and $\bar{D}^0$, $\Delta v_2$, as a function of rapidity are also presented as a method to probe possible effects originating from the EM fields.
2 Experimental apparatus and data sample

The central feature of the CMS apparatus is a superconducting solenoid of 6 m internal diameter, providing a magnetic field of 3.8 T. Within the solenoid volume, there are four primary subdetectors including a silicon pixel and strip tracker detector, a lead tungstate crystal electromagnetic calorimeter, and a brass and scintillator hadron calorimeter, each composed of a barrel and two endcap sections. Iron and quartz-fiber Cherenkov hadron forward calorimeters cover the range $2.9 < |\eta| < 5.2$. Muons are measured in gas-ionization detectors embedded in the steel flux-return yoke outside the solenoid. The silicon tracker measures charged particles within the range $|\eta| < 2.5$. For charged particles with $1.0 < p_T < 10.0 \text{ GeV/c}$ and $|\eta| < 1.4$, the track resolutions are typically 1.5% in $p_T$ and 25–90 (45–150) $\mu$m in the transverse (longitudinal) impact parameter [20]. A detailed description of the CMS detector, together with a definition of the coordinate system used and the relevant kinematic variables, can be found in Ref. [21].

The analysis presented in this note uses approximately $4.27 \times 10^9$ minimum-bias (MB) events from PbPb collision events collected by the CMS experiment during the 2018 LHC run. The MB events are triggered by requiring ADC signals above a certain threshold (in the range 12–15) in both sides of the HF calorimeters. Further selections are applied offline to reject events from background processes (beam-gas interactions and nonhadronic collisions), as described in Ref. [22]. Events are required to have at least one reconstructed primary interaction vertex with a distance of less than 15 cm from the center of the nominal interaction along the beam axis. In PbPb collisions, the shapes of the clusters in the pixel detector have to be compatible with those expected from particles produced at the primary vertex location. The PbPb collision events are also required to have at least two towers in each HF detector with energy deposits of more than 4 GeV per tower. These criteria select $(99 \pm 2\%)$ of inelastic hadronic PbPb collisions. The possibility to have values higher than 100% reflects the possible presence of ultra-peripheral (nonhadronic) collisions in the selected event sample.

Events from Monte Carlo (MC) simulations are used to study both prompt and nonprompt $D^0$ meson processes. The events are generated using an embedding procedure, in which $D^0$ mesons generated by PYTHIA 8 [23] (tune CP5 [24]) are embedded into MB events from HYDJET 1.8 [25]. The prompt $D^0$ MC simulation is employed to define signal selections and measure efficiency corrections, while the nonprompt $D^0$ MC sample is used to estimate systematic uncertainties coming from nonprompt $D^0$ contamination.

3 $D^0$ meson reconstruction and selection

The prompt $D^0$ mesons are reconstructed from the decay $D^0 \rightarrow \pi^+ \pi^- K^- K^+$ (branching fractions of 3.94 ± 0.04%) using selected tracks with $p_T > 1 \text{ GeV/c}$ and $|\eta| < 2.4$. Candidates are formed by combining pairs of oppositely charged tracks and requiring an invariant mass within a ±200 MeV/c$^2$ window on the nominal $D^0$ mass of 1864.83 MeV/c$^2$ [26]. For each pair of selected tracks, two possible candidates for $D^0$ and $D^0$ mesons are considered by assuming one of the tracks has the pion mass, while the other track has the kaon mass, and vice versa. Kinematic vertex fits are performed to reconstruct the secondary vertices of $D^0$ candidates.

After the $D^0$ candidate reconstruction, a selection using a Boosted Decision Tree (BDT) algorithm from the TMVA package [18] is employed. For the BDT training, $D^0$ candidates in data events with same-sign $\pi K$ are used to mimic the combinatorial background. The signal candidates are taken from MC simulations and required to match $D^0$ mesons at the generator level. The variables related to $D^0$ mesons used to discriminate the signal from the background are:
χ² probability for the D⁰ vertex fit, 3D distance between secondary and primary vertices and its significance, decay length significance projected in the xy-plane, and the angle in 2- and 3-dimensions between the momentum of the D⁰ and the line connecting the primary vertex to the secondary vertex of the D⁰. Related to the decay products of the D⁰ the variables used are: the uncertainty in p_T, the significance of the z and the xy distance of closest approach, and the number of hits in the tracker detector. Different boosting algorithms were tested and overtraining checks were done for all the analysis bins by comparing the BDT distributions from training and testing D⁰ samples. In addition, a BDT cut optimization is performed in bins of centrality, p_T and rapidity. Compared to a cut based procedure, this BDT selection almost doubled the signal significance for D⁰ mesons in the forward region of the detector.

4 Analysis technique

The elliptic (v_2) and triangular (v_3) flow coefficients of D⁰ mesons are extracted using the scalar product method, similarly to what was done in a previous CMS publication [19]. In this method, the v_n coefficient of D⁰ candidates (including backgrounds) is first measured using Q-vectors,

$$v_n\{SP\} \equiv \frac{\langle Q_n Q^*_n A \rangle}{\sqrt{\langle Q_n Q^*_n B \rangle \langle Q_n Q^*_n C \rangle}}$$

where the Q_nA and Q_nB are defined using the event planes measurements from negative (−5 < η < −3, HF−) and positive (3 < η < 5, HF+) sides of HF, and Q_nC is measured using the tracker information in the region of −0.75 < η < 0.75. The Q_n is defined for each D⁰ candidate. The averages ⟨Q_nA Q^*_nB⟩, ⟨Q_nA Q^*_nC⟩ and ⟨Q_nB Q^*_nC⟩ are made considering all events, while the average ⟨Q_n Q^*_nA⟩ is made considering all D⁰ candidates in all events. To avoid autocorrelations the term ⟨Q_n Q^*_nA⟩ uses A = HF− when the D⁰ candidate is in the positive side of the detector and A = HF+ when D⁰ candidate is in the negative side.

The Q-vectors can be expressed as Q_n = ∑_{j=1}^{M} w_j e^{-i n j η}, where the weights w_j are taken as energy deposition in the case of HF, track p_T in the case of tracker data, and equal to 1 in the case of D⁰ candidates. The Q-vectors related to HF and tracker are measured and corrected for detector irregularities by applying a flattening and a recentering procedure [10, 27].

One goal of this analysis is to measure the difference Δv_n between D⁰ and D⁰ mesons flow coefficients v_n as a function of rapidity, to probe effects from EM fields. The difference Δv_n is measured as

$$Δv_n\{SP\} \equiv \frac{\langle Q_n^{D^0} Q^*_n A \rangle - \langle Q_n^{D^0} Q^*_n A \rangle}{\sqrt{\langle Q_n Q^*_n B \rangle \langle Q_n Q^*_n C \rangle}}$$

The v_n and Δv_n of D⁰ candidates are first measured as a function of invariant mass. The extraction of the D⁰ signal v_n is performed via a simultaneous fit of the invariant mass distribution and of v_n/Δv_n as a function of invariant mass. The invariant mass distribution is fit with three components: a third order polynomial to model the combinatorial background, B(m_{inv}), two Gaussians with same mean but different widths for the D⁰ signal, S(m_{inv}), and one additional Gaussian distribution for the swap component corresponding to the incorrect mass assignment of πK, SW(m_{inv}). The width of SW(m_{inv}) and the ratio between the yields of SW(m_{inv}) and S(m_{inv}) are fixed by the values extracted from MC simulations. In this case the following
expressions can be used for extracting $v^\text{sig}_n$:

$$v^\text{sig+bkg}_n(m_{\text{inv}}) = \alpha(m_{\text{inv}})v^\text{sig}_n + (1 - \alpha(m_{\text{inv}}))v^\text{bkg}_n(m_{\text{inv}}),$$  \hspace{1cm} (4)

where $\alpha(m_{\text{inv}})$, which characterizes the signal fraction as a function of mass, is defined as follows:

$$\alpha(m_{\text{inv}}) = \frac{(S(m_{\text{inv}}) + SW(m_{\text{inv}}))}{(S(m_{\text{inv}}) + SW(m_{\text{inv}}) + B(m_{\text{inv}}))} = \alpha_{\text{signal}}(m_{\text{inv}}) + \alpha_{\text{swap}}(m_{\text{inv}}).$$  \hspace{1cm} (5)

For extracting the difference $\Delta v^\text{sig}_n$, the following expression is employed

$$\Delta v^\text{sig+bkg}_n = \Delta v^\text{sig}_n(\alpha_{\text{signal}}(m_{\text{inv}}) - \alpha_{\text{swap}}(m_{\text{inv}})) + \text{Const.} \hspace{1cm} (6)$$

The term $v^\text{bkg}_n(m_{\text{inv}})$ from Eq. (4) is modeled with a linear function, while the constant parameter Const in Eq. (6) is added for taking into account possible fluctuations in the background $v_n$ component. The relevance of this Const parameter was investigated by redoing $\Delta v_n$ measurements in MC simulation. Fig. 1 shows an example of a simultaneous fit for $v_2$ and $\Delta v_2$.

Figure 1: Simultaneous fit on mass spectrum and $v_2$ ($\Delta v_2$) as function of invariant mass for $3.0 < p_T < 3.5$ GeV/c, centrality 20–70% and $-0.6 < y < 0.0$.

After performing the fits for extracting the signal $v_n$ there is still a non-negligible fraction of nonprompt $D^0$ embedded in $v^\text{sig}_n$. The extracted $v_n$ can be written as

$$v^\text{sig}_n = f_{\text{prompt}}v^\text{prompt}_n + (1 - f_{\text{prompt}})v^\text{nonprompt}_n \hspace{1cm} (7)$$

The nonprompt $D^0$ contamination is taken into account as a systematic uncertainty, after estimating the prompt $D^0$ fraction. The prompt $D^0$ fraction can be obtained using the distance of closest approach to the primary vertex (DCA) variable, which is defined as the flight distance of the $D^0$ times the sine of the pointing angle in three dimensions. For prompt $D^0$, the DCA comes from the detector resolution, and is expected to be concentrated around zero. For nonprompt $D^0$, larger values of DCA are expected due to the $B$ meson decay. To extract the prompt $D^0$ fraction, a fit to the DCA distributions in data is performed considering DCA shapes from MC.
simulations for prompt and nonprompt $D^0$. The nonprompt $D^0 v_n$ is estimated by considering two regions in the DCA: one with very low fraction of nonprompt $D^0$ ($\text{DCA} < 0.012 \text{ cm}$), and another one with a high fraction of nonprompt $D^0$ ($\text{DCA} > 0.012 \text{ cm}$). Using this information together with Eq. (7), it is possible to estimate $v_n^{\text{nonprompt}}$. In the current analysis this procedure can only be done in wider $p_T$, centrality, and rapidity bins because of the limited amount of data available in the region with DCA $> 0.012 \text{ cm}$.

5 Systematic uncertainties

The sources of systematic uncertainties include the $D^0$ identification cuts (BDT selection); the probability distribution function (PDF) for modeling the background in the invariant mass fit; the impact of acceptance and efficiency of the $D^0$ meson yield; the variation of the PDF for modeling the background $v_n$; and the remaining nonprompt $D^0$ contamination. With the exception of the component associated to nonprompt $D^0$ contamination, the uncertainties are quoted as absolute values of $v_n$ and $\Delta v_n$ after comparing the default analysis configuration with the variations.

In order to take into account the systematic uncertainty associated with the BDT selection, the BDT cut is varied up and down by the maximal deviation between BDT selection optimizations based on the MC simulations and data. Regarding the effect of the background mass modeling, an exponential function and a second order polynomial are considered, instead of the default fit function using a third order polynomial. To fit $v_n$ as a function of mass, the default configuration using a linear function is replaced by a constant and a second order polynomial. The default measurements are not corrected by the $D^0$ efficiency. Instead, this is included as systematic uncertainty by comparing uncorrected measurements with corrected ones. The efficiency correction is applied on the $D^0$ yield in bins of $p_T$ and rapidity and considers $D^0$ selection and detector acceptance.

The systematic uncertainties regarding contamination by the nonprompt $D^0$ are estimated by measuring nonprompt $D^0 v_n$ in wider bins of $p_T$, rapidity and centrality. A relative systematic uncertainty is obtained by comparing $v_n$ from mixed prompt and nonprompt $D^0$ with $v_n$ from nonprompt $D^0$.

Tables 1, 2, 3 summarize the estimates of systematic uncertainties for $v_2$, $v_3$ and $\Delta v_2$, respectively. The ranges of variation of the uncertainties are presented for each binning.

Table 1: Summary of systematic uncertainties for $v_2$. Ranges of variation of uncertainties for each binning are presented. The cells filled with “−” refer to the cases where no estimate of uncertainty is required for the source or where the uncertainty cancels out.

<table>
<thead>
<tr>
<th>Systematic sources</th>
<th>$p_T$ bins</th>
<th>$y$ bins</th>
<th>centrality bins</th>
</tr>
</thead>
<tbody>
<tr>
<td>BDT selection</td>
<td>0.002 – 0.014</td>
<td>0.0065</td>
<td>0.005</td>
</tr>
<tr>
<td>Bkg. mass PDF</td>
<td>0.0002 – 0.0017</td>
<td>0.0007 – 0.0015</td>
<td>0.0007 – 0.0011</td>
</tr>
<tr>
<td>Bkg. $v_n$ PDF</td>
<td>0.01 – 0.05</td>
<td>0.004 – 0.007</td>
<td>0.003 – 0.005</td>
</tr>
<tr>
<td>$D^0$ efficiency correction</td>
<td>–</td>
<td>0.004 – 0.007</td>
<td>0.004 – 0.0045</td>
</tr>
<tr>
<td>Non-prompt $D^0$ contamination (rel. uncert.)</td>
<td>2 – 5%</td>
<td>2 – 3%</td>
<td>2 – 4%</td>
</tr>
</tbody>
</table>
Table 2: Summary of systematic uncertainties for $v_3$. Ranges of variation of uncertainties for each binning are presented. The cells filled with “−” refer to the cases where no estimate of uncertainty is required for the source or where the uncertainty cancels out.

<table>
<thead>
<tr>
<th>Systematic sources</th>
<th>$p_T$ bins</th>
<th>$y$ bins</th>
<th>centrality bins</th>
</tr>
</thead>
<tbody>
<tr>
<td>BDT selection</td>
<td>0.002 – 0.023</td>
<td>0.001 – 0.009</td>
<td>0.002 – 0.006</td>
</tr>
<tr>
<td>Bkg. mass PDF</td>
<td>0.0001 – 0.004</td>
<td>0.0005 – 0.0008</td>
<td>0.0012 – 0.004</td>
</tr>
<tr>
<td>Bkg. $v_n$ PDF</td>
<td>0.01 – 0.05</td>
<td>0.003 – 0.004</td>
<td>0.0011</td>
</tr>
<tr>
<td>$D^0$ efficiency correction</td>
<td>−</td>
<td>0.002 – 0.004</td>
<td>0.003 – 0.005</td>
</tr>
<tr>
<td>Non-prompt $D^0$ contamination (rel. uncert.)</td>
<td>5 – 12%</td>
<td>2%</td>
<td>0.1 – 1%</td>
</tr>
</tbody>
</table>

Table 3: Summary of systematic uncertainties for $\Delta v_2$. Ranges of variation of uncertainties for each binning are presented. The cells filled with “−” refer to the cases where no estimate of uncertainty is required for the source or where the uncertainty cancels out.

<table>
<thead>
<tr>
<th>Source</th>
<th>$\Delta v_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$y$ bins</td>
</tr>
<tr>
<td>BDT selection</td>
<td>0.001 – 0.009</td>
</tr>
<tr>
<td>Bkg. mass PDF</td>
<td>0.00015 – 0.0003</td>
</tr>
<tr>
<td>Bkg. $v_n$ PDF</td>
<td>−</td>
</tr>
<tr>
<td>$D^0$ efficiency correction</td>
<td>0.001 – 0.004</td>
</tr>
<tr>
<td>Non-prompt $D^0$ contamination (rel. uncert.)</td>
<td>2 – 3%</td>
</tr>
</tbody>
</table>

6 Results

New results for prompt $D^0$ $v_2$ and $v_3$ anisotropic flow coefficients, obtained with 2018 PbPb data as functions of $p_T$ and for $|y| < 1$, are shown in Figure 2 in three centrality ranges: 0–10%, 10–30% and 30–50%. The new results significantly improve previously published data from CMS [19], by extending the high-$p_T$ coverage to $\sim 60$ GeV/c and by providing more differential information on the $p_T$ dependence of $v_2$ and $v_3$ at low $p_T$. With these high precision data, a clear trend of rise and fall from low to high $p_T$ is observed for both $v_2$ and $v_3$ across the full centrality range, a behavior similar to that is observed for inclusive charged particles [28]. For noncentral collisions (i.e., centrality 10–50%), values of prompt $D^0$ $v_2$ remain positive up to $p_T \sim 30 – 40$ GeV/c, whereas the $v_3$ values become consistent with zero already at $p_T \sim 10$ GeV/c.

Calculations from theoretical models at midrapidity ($|y| < 1$) are also presented: results from LBT [29], CUJET 3.0 [30], and SUBATECH [31] include collisional and radiative energy losses, while those from TAMU [32] and PHSD [12] include only collisional energy loss. Initial-state fluctuations are included in the calculations by LBT, SUBATECH, and PHSD, and calculations for the $v_3$ coefficient are only available from these three models. While most models seem to capture the qualitative trend of the points, no model can quantitatively describe the data over the full centrality range, which puts new constraints on the development of the collective flow for charm hadrons in the QGP medium.

Results for the rapidity dependence of heavy flavor collective flow is explored for the first time for prompt $D^0$ meson $v_2$ and $v_3$ as functions of $p_T$, both at midrapidity ($|y| < 1$) and in the forward ($1 < |y| < 2$) region, as shown in Figure 3. Within the experimental uncertainties, no significant rapidity dependence of the collective flow signals for prompt $D^0$ mesons is ob-
Figure 2: Prompt D⁰ meson v₂ (top) and v₃ (bottom) coefficients at midrapidity (|y| < 1) for the centrality classes 0–10% (left), 10–30% (middle), and 30–50% (right). The vertical bars represent statistical uncertainties and open boxes represent the systematic uncertainties. Theoretical calculations for vₙ coefficient of prompt D⁰ mesons are also plotted for comparison.

In Fig. 4 (left), results for prompt D⁰ v₂ and v₃, averaged over 2.0 < p_T < 8.0 GeV/c, for |y| < 1 and 1 < |y| < 2, are presented as a function of collision centrality. For both mid- and forward rapidity regions, the v₂ results show a clear increase from most central to mid-central events, and then a declining trend toward most peripheral events. This trend is similar to that observed for inclusive charged particles, and can be understood in terms of collision geometry and viscosity effects, especially for smaller system sizes in peripheral events. The v₃ shows no centrality dependence, which is also consistent with expectation from collision geometry.

Figure 4 (right) presents results for the rapidity dependence of prompt D⁰ meson v₂ and v₃, for centrality 20–70%, averaged over 2.0 < p_T < 8.0 GeV/c. As indicated already in Fig. 3, a weak rapidity dependence of v₂ and v₃ is observed in the data, except for a slight tendency to lower values at large rapidities.

Finally, to search for effects of strong electromagnetic fields on charge-dependent v₂, the difference Δv₂ between the v₂ values of D⁰ and D̄⁰, are presented in Fig. 5 as a function of rapidity, averaged over 2.0 < p_T < 8.0 GeV/c and for centrality 20–70%. No significant nonzero Δv₂ is observed within experimental uncertainties. After averaging over the full rapidity range, this results in a value of the v₂ splitting ⟨Δv₂⟩ = 0.001 ± 0.001(stat.) ± 0.003(syst.). In Ref. [13], the predicted v₂ splitting for inclusive charged particles due to electric fields is ~0.001 at LHC energies. While qualitative predictions for v₂ splitting of D⁰ mesons are not yet available, they are expected to be much larger than those for inclusive charged particles. The main reason is that light flavor particles are predominantly produced at the freeze-out stage, while heavy flavor quarks are produced much earlier, soon after the collision takes place, when the electromagnetic field strength is several orders of magnitude stronger. The results presented here...
Figure 3: Prompt D⁰ meson $v_2$ (top) and $v_3$ (bottom) coefficients at midrapidity ($|y| < 1$) and forward rapidity ($1 < |y| < 2$) for the centrality classes 0–10% (left), 10–30% (middle), and 30–50% (right). The vertical bars represent statistical uncertainties and open boxes represent the systematic uncertainties.

Pose stringent constraints on possible electromagnetic effects on charm quarks. Through future comparisons to theoretical calculations, direct constraints could be obtained on the electric conductivity of the QGP medium.
Figure 4: Prompt $D^0$ meson $v_2$ and $v_3$ as functions of centrality, for $2.0 < p_T < 8.0$ GeV/c and for rapidity ranges $|y| < 1$ and $1 < |y| < 2$ (left). Prompt $D^0$ $v_2$ and $v_3$ as function of rapidity, for $2.0 < p_T < 8.0$ GeV/c and for centrality 20–70% (right). The vertical bars represent statistical uncertainties and open boxes represent the systematic uncertainties.

Figure 5: Prompt $D^0$ meson $\Delta v_2$ as a function of rapidity, for $2.0 < p_T < 8.0$ GeV/c and centrality 20–70%. The vertical bars represent statistical uncertainties and open boxes represent the systematic uncertainties.
7 Summary

New measurements of prompt D\textsuperscript{0} mesons elliptic (v\textsubscript{2}) and triangular (v\textsubscript{3}) flow are presented as a function of p\textsubscript{T}, rapidity and collision centrality, in PbPb collisions at \sqrt{s}\textsubscript{NN} = 5.02 TeV. The results improve previously published CMS data by extending the p\textsubscript{T} coverage and by providing more differential information. A clear centrality dependency of prompt D\textsuperscript{0} v\textsubscript{2} is observed, while v\textsubscript{3} is largely centrality independent. The trend is consistent with the expectation of a centrality dependency driven by initial-state geometry. No significant rapidity dependency of prompt D\textsuperscript{0} v\textsubscript{2} and v\textsubscript{3} is observed, although possible dependency on rapidity cannot be discarded. When comparing against various theoretical calculations at midrapidity, no model is able to describe the data over the full centrality and p\textsubscript{T} ranges. Motivated by the search for a strong electric field possibly created in PbPb collisions, a first measurement of the v\textsubscript{2} difference (\Delta v\textsubscript{2}) between D\textsuperscript{0} and \overline{D}\textsuperscript{0} as a function of rapidity is presented. The rapidity-averaged v\textsubscript{2} difference is measured to be \langle \Delta v\textsubscript{2} \rangle = 0.001 \pm 0.001 (\text{stat.}) \pm 0.003 (\text{syst.}), consistent with zero within the experimental uncertainties, indicating that no effect of electric field on charm hadron collective flow is observed. Future model comparisons may provide constraints on the electric conductivity of the QGP medium.

References


