Elliptic Flow of Charm in Pb-Pb Collisions from the LHC Run-2 measured with ALICE

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INTRODUCTION

Heavy-ion collisions at ultra-relativistic energies are aimed at exploring the structure of nuclear matter at extremely high temperatures and energy densities. Under these conditions, according to Quantum-Chromodynamics (QCD) calculations on the lattice, the confinement of quarks and gluons inside hadrons is no longer effective and a phase transition to a Quark-Gluon Plasma (QGP) occurs [1].

The measurement of anisotropy in the azimuthal distribution of particle momenta provides insight into the properties of the QGP medium. Anisotropic patterns originate from the initial anisotropy in the spatial distribution of the nucleons participating in the collision. The anisotropy of produced particles is characterized by the Fourier coefficients $v_n = \langle \cos[n(\phi - \Psi_n)] \rangle$, where $\phi$ is the azimuthal angle of the particle, and $\Psi_n$ is the azimuthal angle of the initial state symmetry plane for the $n$-th harmonic. For non-central collisions the overlap region of the colliding nuclei has a lenticular shape and the anisotropy is dominated by the second coefficient $v_2$, commonly denoted elliptic flow [2, 3].

The measurement of the elliptic flow of charmed hadrons provides further insight into the transport properties of the medium. Charmed hadron $v_2$ offers a unique opportunity to test whether also quarks with large mass ($m_c \approx 1.5 \text{ GeV}/c^2$) participate in the collective expansion dynamics and possibly thermalize in the medium [4, 5].

We present the measurement of $v_2$ for $D^0$ mesons and their anti-particles reconstructed in the $D^0 \to K^-\pi^+$ decay channel at rapidity $|y| < 0.8$ in non-central Pb–Pb collisions at $\sqrt{s_{\text{NN}}} = 5.02 \text{ TeV}$ recorded in 2015.

DATA ANALYSIS

The measurement was carried out with the ALICE detector at the LHC [6]. Particle reconstruction and identification for this analysis were based on the detectors of the central barrel, located inside a solenoid magnet, which generates a 0.5 T field parallel to the beam direction.

The detectors used for the reconstruction of the trajectories of candidate D meson decay particles were the Inner Tracking System (ITS), composed of six cylindrical layers of silicon detectors, and the Time Projection Chamber (TPC). The reconstructed particles were identified on the basis of their specific energy deposition $dE/dx$ in the TPC gas and of their time-of-flight from the interaction point to the Time Of Flight (TOF) detector. The ITS, TPC and TOF detectors provide full azimuthal coverage in the pseudorapidity interval $|\eta| < 0.9$.

The analysis was performed on a data sample of Pb–Pb collisions collected in 2015 with a minimum-bias trigger based on the requirement of coincident signal in the two scintillator hodoscopes at forward and backward rapidity. The measurement of $D$ meson $v_2$ was performed using non-central collisions in the centrality classes 30-50%. In this class, the initial geometrical anisotropy is largest. In this range, the trigger and event selection are fully efficient for hadronic interactions. The number of analysed events was $21 \times 10^6$. D meson candidates were selected using the displacement of the decay tracks from the interaction vertex, the separation between the secondary and primary vertices, and the pointing of the reconstructed $D$ meson momentum to the primary vertex. The pion and kaon identification in the TPC and TOF detectors was utilized by applying cuts in units of resolution (at $\pm 3\sigma$) around the expected mean values of $dE/dx$ and time-of-flight.

![Figure 1: Invariant mass distribution of $D^0$ meson candidates in the in-plane and out-of-plane sectors with respect to the estimated event plane.](image-url)
plane angle $\psi_2$ was determined from the second harmonic of the azimuthal distribution of the detected charged particles in the TPC. D meson candidates were classified in two groups according to their azimuthal angle relative to the event plane ($\Delta\phi = \phi_D - \psi_2$), see Fig. 1. The raw yields in the two $\Delta\phi$ intervals, $N_{\text{in-plane}}$ and $N_{\text{out-of-plane}}$, were obtained as the integrals over the corresponding Gaussian signal functions. $v_2$ was computed as:

$$v_2 = \frac{\pi}{(4R_2^2)} \left( N_{\text{in-plane}} - N_{\text{out-of-plane}} \right) / \left( N_{\text{in-plane}} + N_{\text{out-of-plane}} \right),$$

where $R_2$ is the event plane resolution correction factor.

RESULTS

Figure 2: $D^0 v_2$ in the centrality classes 30-50%.

Figure 3: average $v_2$ of D mesons at 2.76 TeV (Run-1 data) and at 5.02 TeV (Run-2 data).

Figure 4: comparison of the $v_2$ of D mesons and of pions.

Figure 2 shows the $D^0$ meson $v_2$ in the centrality classes 30-50% as a function of $p_T$. The measurement was carried out also for $D^+$ and $D^*$ mesons and the results were averaged with those of $D^0$ mesons. Figure 3 shows the average $v_2$ as a function of $p_T$, compared with the same measurement carried with Run-1 data at the centre-of-mass energy of 2.76 TeV. The measurements at the two energies are compatible within uncertainties and the new measurement has a better precision by a factor of about 2. The $D^0$ meson $v_2$ is compared with that of charged pions in Fig. 4. The magnitude of $v_2$ is similar for charmed hadrons and pions. The results indicate that, during the collective expansion of the QGP, charm quarks approach thermalisation in the system, as a consequence of multiple interactions with the plasma constituents. Comparison of these measurements with model calculations will provide information on the properties of the hot and dense QGP medium.


