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Measurement of D^0 Meson Production and Azimuthal Anisotropy in Au+Au Collisions at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV

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Abstract

Due to the large masses, heavy-flavor quarks are dominantly produced in initial hard scattering processes and experience the whole evolution of the medium produced in heavy-ion collisions at RHIC energies. They are also expected to thermalize slower than light-flavor quarks. Thus the measurement of heavy quark production and azimuthal anisotropy can provide important insights into the medium properties through their interactions with the medium.

In these proceedings, we report measurements of D^0 production and elliptic flow (v_2) via topological reconstruction using STAR's recently installed Heavy Flavor Tracker (HFT). The new measurement of the nuclear modification factor (R_{AA}) of D^0 mesons in central Au+Au collisions at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV confirms the strong suppression at high transverse momenta (p_T) reported in the previous publication with much improved precision. We also report the measurement of elliptic flow for D^0 mesons in a wide transverse momentum range in 0-80% minimum-bias Au+Au collisions. The D^0 elliptic flow is finite for $p_T > 2$ GeV/c and is systematically below that of light hadrons in the same centrality interval. Furthermore, several theoretical calculations are compared to both R_{AA} and v_2 measurements, and the charm quark diffusion coefficient is inferred to be between 2 and ∼12.

Keywords: Quark-gluon plasma, Nuclear modification factor, Elliptic flow, Heavy Flavor Tracker

1. Introduction

The mass of the charm quark is significantly larger than those of light quarks, the QCD scale, and the temperature of the quark-gluon plasma (QGP) created at RHIC energies. The charm quark mass is mostly unaffected by the QCD medium, and the charm quarks are dominantly produced at the early stage of heavy-ion collisions through hard scattering processes at RHIC. They experience the whole evolution of the system. Therefore, charm quarks provide unique information on the properties of hot and dense strongly-coupled QGP.

The charm quark production has been systematically studied in p+p ($\overline{\mathrm{p}}$) collisions at various experiments. Figure 1 shows the charm quark differential cross-section versus transverse momentum (p_T) in p+p collisions at $\sqrt{s}$ = 200 GeV-7 TeV [1, 2, 3, 4]. Experimental data are compared with Fixed-Order Next-to-Leading-Log (FONLL) pQCD calculations shown as grey bands [5]. Within uncertainties, FONLL calculations describe the data over a broad range of collision energies. At RHIC energies, charm quarks are produced mostly via initial hard scatterings. This is confirmed in Figure 2 where the total charm quark cross sections in p+p, d+Au and Au+Au collisions are shown to scale with the number of binary nucleon-nucleon collisions (N_{coll}) [1, 5, 6, 7, 8].

Recent measurements at both the RHIC and the LHC show that high p_T charmed meson production is considerably suppressed in the central heavy-ion collisions, which indicates strong interactions between charm quarks and the medium. It is also found that the

[1] A list of members of the STAR Collaboration and acknowledgments can be found at the end of this issue.

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D-meson elliptic flow measured at the LHC is comparable with that of light hadrons [9].

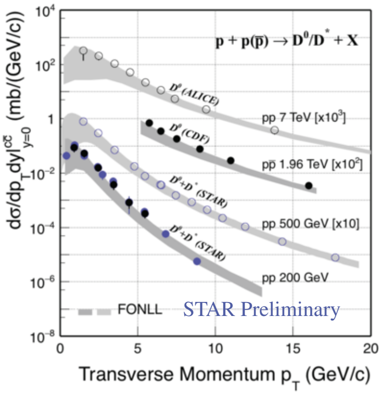

Figure 1: Charm quark pair production cross section vs. p_T at mid-rapidity in p+p ($\bar{p}$) collisions [1, 2, 3, 4].

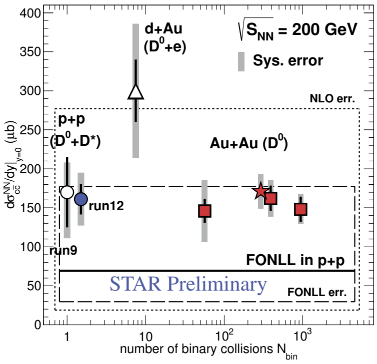

Figure 2: Charm quark cross sections at mid-rapidity in p+p, d+Au and Au+Au collisions measured by the STAR experiment.

2. Experiment and Analysis

The STAR experiment is a large-acceptance detector covering full azimuth and pseudorapidity of $|\eta| < 1$ at the RHIC. Data were taken by the STAR experiment using the newly installed Heavy Flavor Tracker (HFT) in the year 2014. The HFT is a high resolution silicon detector which provides a track pointing resolution of less than 50 μm for kaons with p_T = 750 MeV/c.

About 780M minimum bias Au+Au events are used in this analysis. These events are selected to contain primary vertices within 6 cm to the center of the STAR detector along the beam direction for uniform HFT acceptance. D^0 and $\overline{D^0}$ are reconstructed through the hadronic decay channel, with a branching ratio of $\sim$ 3.9% and a lifetime of $c\tau \sim 123$ μm. The kaons and pions are identified using the energy loss (dE/dx) measured by the Time Projection Chamber (TPC) and the time of flight measured by the Time-Of-Flight (TOF) detector [10]. The secondary vertices are reconstructed as the middle points at the Distance of the Closest Approach (DCA) between the two daughter particles. With the HFT, the following topological cuts are applied to greatly reduce the combinational background: decay length (distance between primary and decay vertices), DCA between daughter tracks, DCA between reconstructed D^0 and the primary vertex, DCA between daughter tracks and the primary vertex. Topological cuts are optimized in each D^0 p_T bins using the Toolkit for Multivariate Data Analysis (TMVA) package to achieve the best D^0 signal significance.

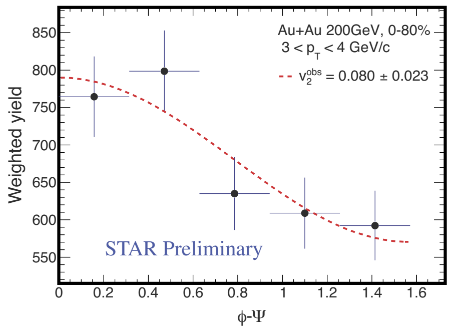

Figure 3: D^0 yield as a function of the angle relative to the event plane ($\phi - \Psi$) for $3 < p_T < 4$ GeV/c, in 0-80% Au+Au collisions.

The event plane method is used to extract the second-order azimuthal anisotropy (v_2) for D^0. The second-order event plane (Ψ) is reconstructed using TPC tracks excluding decay products of D^0 mesons and corrected for non-uniform detector efficiency. In order to reduce the non-flow contribution, a η-gap of $|\Delta\eta| > 0.15$ between D^0 mesons and charged tracks used for event plane reconstruction is required. The azimuthal distribution of D^0 mesons with respect to the event plane ($\phi - \Psi$) is then obtained and weighted by 1/(ϵ*R) for each centrality, where ϵ is the D^0 reconstruction efficiency and R the event plane resolution. The observed v_2 (v_2^{obs}) is obtained by fitting the distribution of D^0 yield versus ($\phi - \Psi$) with a functional form of $A(1 + 2v_2^{obs}\cos(2(\phi - \Psi)))$ taking into account the finite bin width effect. Finally, the true v_2 is obtained by scaling v_2^{obs} with $1/R$ to correct for the event plane resolution. Figure 3 shows the weighted yield as a function of ($\phi-\Psi$) for D^0 candidates with $3 < p_T < 4$ GeV/c. The