Abstract. In this article, we report the measurements of the nuclear modification factor (\(R_{AA}\)) and elliptic flow (\(v_2\)) for \(D^\pm\) in Au+Au collisions at \(\sqrt{s_{NN}} = 200\) GeV from the STAR experiment. These results are compared with the results of other open charm mesons to study the hadronization mechanism of the charm quarks and disentangle the transport properties of quark-gluon plasma and hadronic phase [1]. We found that the nuclear modification factor for \(D_s\) are systematically higher than unity and \(D_0 R_{AA}\). The ratio of \(D_s/D^0\) for 10-40% central Au+Au collisions is also higher than that in p+p collisions as predicted by PYTHIA. The \(D_s/D^0\) ratio is also compared to that in Pb+Pb collisions at \(\sqrt{s_{NN}} = 2.76\) TeV measured by the ALICE experiment. Our results indicate an enhancement of \(D_s\) meson production in Au+Au collisions.

1. Introduction

Heavy quarks are a unique probe to study the medium produced in ultra-relativistic heavy-ion collisions. Because of the large masses, their production is dominated by initial hard scatterings and is well described by perturbative QCD (pQCD) [2]. In particular the \(D_s(c\bar{s}/\bar{c}s)\) production in heavy-ion collisions is expected to be affected by both the strangeness enhancement and the primordial charm quark production. The modifications of \(D_s\) meson spectrum and its elliptic flow\((v_2)\) in ultra-relativistic heavy-ion collisions are identified as a quantitative probe of key properties of the hot nuclear medium [1]. Theoretical calculations predict a remarkable enhancement of the \(D_s\) meson production as the result of a strong charm quark coupling to the Quark-Gluon Plasma (QGP) and subsequent recombination with equilibrated strange quarks when compared to non-strange D mesons [1]. Like multi-strange hadrons, \(D_s\) mesons are expected to freeze out at pseudo-critical temperature (\(T_{pc}\)), while the non-strange D meson picks up significant additional \(v_2\) during the hadronic phase. Therefore, the elliptic flow of \(D_s\) meson is considered to be a better measure of the partonic contribution to the charm hadron \(v_2\) than that of \(D^0\) or \(D^\pm\) [1].

The Heavy Flavor Tracker (HFT), installed at the STAR experiment since 2014, is designed to extend STAR’s capability of measuring open charm mesons via the topological reconstruction of displaced decay vertices. The HFT detector consists of 4 layers of silicon detectors. The outer layer is the Silicon Strip Detector (SSD). The Intermediate Silicon Tracker (IST), consisting of one layer of single-sided strips, is located inside the SSD. Two layers of the Silicon Pixel Detector (PXL) are inside the IST. The PXL detectors have the resolution necessary for a precise measurement of the displaced vertices. The track pointing resolution of the HFT detector is about 46 \(\mu\)m for kaons at 750 MeV/c [3].
2. Data Analysis
About 750 million minimum bias events taken during the 2014 Au+Au run at $\sqrt{s_{NN}} = 200$ GeV by the STAR experiment were used in this analysis. The identification of daughter particles was done at mid-rapidity $|y| < 1$ using the Time Projection Chamber (TPC) and the Time-of-Flight (TOF) detector. The HFT detector is used to reconstruct the decay vertices. We reconstruct $D_s$ meson through the hadronic decay channel: $D_s \rightarrow \phi(1020) + \pi \rightarrow K^+ + K^- + \pi$, whose branching ratio is $(2.27 \pm 0.08)\%$. Topological and kinematic cuts are applied to reduce the combinatorial background. Figure 1 shows the reconstructed $D_s$ signal for 0-80% centrality.

![Figure 1](https://example.com/figure1.png)

Figure 1. (Color online) The invariant mass distribution for $D_s$ meson in 0-80% central Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV

3. Physics Results
The invariant yield of $D_s$ (average yield of $D_s^+$ and $D_s^-$) are calculated in two $p_T$ bins in 10-40% central Au+Au collisions. The results are depicted in Fig. 2, where the invariant yield of $D^0$ from the same centrality bin [4] is also shown. The $D_s/D^0$ ratio as a function of $p_T$ is shown in Fig. 3 for 10-40% central Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV, along with a similar ALICE measurement for 0-10% central Pb+Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV [6]. The two measurements follow the same trend within the large uncertainties. On the other hand, the Au+Au measurement is systematically higher than the ratio in p+p collisions predicted by PYTHIA [5].

Medium effects on $D_s$ meson production are quantified as the nuclear modification factor, i.e. $R_{AA}(p_T) = (dN_{AA}/dp_T)/(N_{coll}dN_{pp}/dp_T)$, where $dN_{AA}/dp_T$ is the differential yield in Au+Au collisions and $dN_{pp}/dp_T$ is the corresponding yield in p+p collisions. $N_{coll}$ is the number of binary collisions, derived from the Glauber model [15]. Since there is no measurement of $D_s$ spectrum in p+p collisions at $\sqrt{s} = 200$ GeV, the charm quark cross-section measured by the STAR experiment in p+p collisions at the same collision energy [7] was used to derive the $p_T$ spectrum for $D_s$ meson. The fragmentation factor ($c \rightarrow D_s$) used to convert the charm cross-section to $D_s$ cross-section is $0.09 \pm 0.01$ [8, 9, 10]. The $R_{AA}$ of $D_s$ at mid-rapidity ($|y| < 1.0$) in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV for 10-40% centrality bin is presented in Fig. 5. Model calculations of $R_{AA}$ for $D_s$(red band) and $D^0$(purple dashed-dotted lines) [1] are also shown in Fig. 5. STAR measurements are consistent with model calculations within uncertainties. The $R_{AA}$ of $D_s$ is systematically higher than that of $D^0$ [4] but the enhancement is not statistically significant.

The elliptic flow can be used to probe the dynamics of early stages of heavy-ion collisions [11]. In Fig. 6, the measurement of $D_s$ $v_2$ for 0-80% centrality bin in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV is shown. Within large uncertainties, the $D_s$ meson $v_2$ is consistent with $v_2$ of $D^0$ [13] and $\phi$ [14].
We present the first measurement of $D_s$ production in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV using the newly installed HFT at the STAR experiment. The $D_s/D^0$ ratio seems to be higher than that in p+p collisions predicted by PYTHIA at the intermediate $p_T$ range. The nuclear modification factor of $D_s$ is consistent with model calculations, and systematically higher than $D^0 R_{AA}$, indicating an enhancement of $D_s$ production in Au+Au collisions. The $R_{AA}$ of $D_s$ is equal to $2.1 \pm 0.5$ (stat.) $\pm 0.7$ (sys.) and $1.7 \pm 0.4$ (stat.) $\pm 0.7$ (sys.) at $p_T = 2.8$ and 3.9 GeV/c.
Figure 6. (Color online) Elliptic flow for $D_s$, $D^0$ [13] and $\phi$ [14] for 0-80% centrality bin in Au + Au collisions at $\sqrt{s_{NN}} = 200$ GeV. Open boxes and cap symbols are the systematic uncertainties on corresponding data points. Shaded grey band on $D^0 v_2$ is for non-flow estimation. Vertical lines are statistical errors.

GeV/$c$ respectively. We have also presented the first measurement of $D_s$ meson $v_2$ in heavy-ion collisions.

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