Centrality dependence of charm and bottom quark suppression in Au + Au collisions at RHIC†

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Charm and bottom quarks, collectively referred as heavy flavor, are a clean probe to study the properties of quark-gluon plasma (QGP) produced in high-energy heavy-ion collisions. Because of their large mass, heavy quarks are predominantly produced at the initial stage of the collisions. Once produced, heavy flavors lose their energy as they propagate through the QGP. The energy loss of heavy quarks is expected to be suppressed by "dead cone" effect, where gluon radiation caused by bremsstrahlung is suppressed at an angle smaller than the mass-to-energy ratio of the quark.[1)] Thus, energy loss is expected to follow the mass ordering of quarks and gluons, $\Delta E_g > \Delta E_{u,d} > \Delta E_c > \Delta E_b$. The PHENIX experiment previously observed the different suppression of electrons from charm and bottom hadron decays in minimum bias Au + Au collisions at $\sqrt{s_{NN}} = 200$ GeV.[2)]

This article reports the centrality dependence of charm and bottom quark suppression measured at PHENIX. Using the high-statistics dataset recorded in 2014 and the updated $p + p$ reference from 2015,[3)] the nuclear modification factor, R_{AA} (a ratio of yields in Au + Au to $p + p$ after normalized by number of binary collisions) of the charm and bottom electrons in four centrality classes (0–10, 10–20, 20–40 and 40–60%) of Au + Au collisions can be measured with improved precision compared with our previous results.[2)]

Heavy flavor electrons are measured using the central arm PHENIX detector. An inner silicon tracker, VTX, measures the distance of closest approach of the electron track, DCA$_T$, to the collision vertex in the transverse plane. Using the different decay lengths of charm and bottom hadrons ($c\tau = 123$ μm for D^0 and 455 μm for B^0), electrons from these decays are statistically separated by the DCA$_T$. The measured electron samples contain not only heavy flavors but background electrons. The main background is photonic electrons which are photon conversions and Dalitz decays of light neutral mesons. The background is mostly rejected by the analysis cut with the hit-pair on VTX as the electron pairs from the photon conversions produce hits that are close to each other. The remaining backgrounds are estimated through the full GEANT detector simulation and subtracted from the measured electron samples. The electron samples are separated by the unfolding, which simultaneously fits the transverse momentum p_T spectrum and DCA$_T$ distributions.

Figure 1 shows R_{AA} in 0–10% central Au + Au collisions. The blue and green lines represent the bottom- and charm electrons with 1-sigma uncertainty bands, respectively. Significant suppression is seen for both charms and bottoms at high p_T. Charm suppression is stronger than bottom suppression for p_T = 2–5 GeV/c. The result was compared with the models that expect a mass ordering of energy loss in QGP. All models reproduce the data reasonably within large uncertainty.

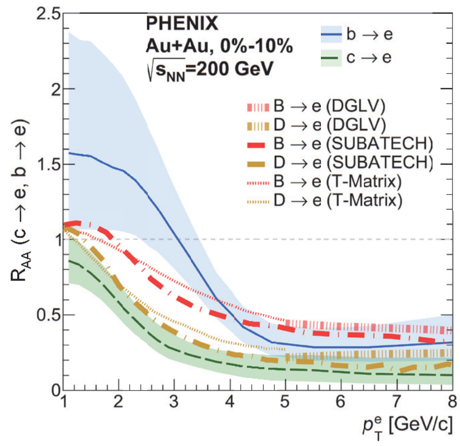

Fig. 1. R_{AA} for charm and bottom electrons compared with the theoretical models.

The centrality dependence of the suppression is studied using the number of nucleon participants in the collision ($N_{\rm part}$). Figure 2 shows R_{AA} vs $N_{\rm part}$ for three different p_T intervals. There is no suppression for both charms and bottoms in low p_T. The mid-p_T region shows a clear suppression of charm hadrons but no bottom suppression. The high-p_T region shows an increasing suppression of both charms and bottoms.

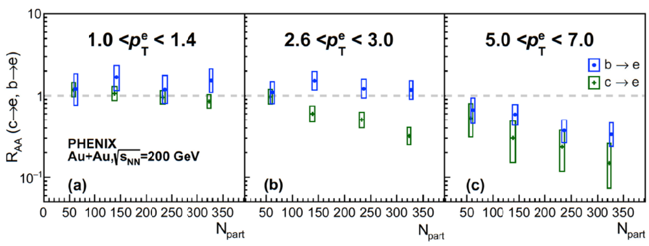

Fig. 2. R_{AA} charm and bottom electrons as a function of $N_{\rm part}$ for three p_T intervals.

In summary, PHENIX studied the centrality dependence of charm and bottom suppression. A clear different suppression was observed at p_T = 2.5 GeV/c. The suppression pattern is consistent with the models that expect mass ordering of energy loss.

References

1) Y. L. Dokshitzer *et al.*, Phys. Lett. B **519**, 199 (2001).
2) A. Adare *et al.*, Phys. Rev. C **93**, 034904 (2016).
3) C. Aidala *et al.*, Phys. Rev. D **99**, 10.1103 (2019).

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