Measurement of elliptic flow of single electrons from semi-leptonic decay of charm and bottom hadrons in Au + Au collisions at $\sqrt{s_{NN}} = 200$ GeV

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Heavy flavors (HFs), charm (c) and bottom (b) quarks, are suitable probes for the study of quark gluon plasma (QGP). HFs are mainly produced from the hard scattering at the early stage of collisions because they have large masses ($M_c \approx 1.3$ GeV$/c^2$, $M_b \approx 4.2$ GeV$/c^2$). HFs reflect the space-time evolution of the QGP well. The perturbative QCD calculations can be applied to the c and b quarks at the initial hard scattering in the collisions. It means that the yield of the c and b quarks is calculated precisely. Also, the b quark mass is about three times as heavy as the c quark mass. The measurement with c and b quark separation shows the quark mass dependence of their quantities and behaviors in the QGP. Therefore, the c and b quark measurement is essential for QGP research. The modification of c and b quarks provides information about QGP.

A Silicon Vertex Tracker (VTX) consisting of 4 layers of silicon detectors was installed at the RHIC-PHENIX experiment in 2011 to reconstruct charged particle trajectories and their Distances of Closest Approach (DCA) to the primary collision vertex. The DCA is related to the decay length of the particles. As the decay lengths of c and b hadrons are different enough ($D^0 \sim 123$ μm, $B^0 \sim 455$ μm), we can statistically separate electrons from the semileptonic decays of c and b hadrons using the DCA, even with a lower integrated luminosity. In 2014, the PHENIX collected about 15 billion minimum bias events from Au + Au collisions at $\sqrt{s_{NN}} = 200$ GeV, which is 10 times larger than the previous dataset obtained in 2011. Additionally, the systematic uncertainties are reduced because the photonic background estimation and the VTX are improved.

For the HF study, we measure the centrality dependence of the nuclear modification factors$^{1)}$ and the azimuthal anisotropy (v_2) of the c and b electrons. v_2 is originated from the initial geometry of the QGP. It then expands the pressure gradient with the QGP evolution. v_2 reflects the hydrodynamic property of the QGP, *e.g.*, η/s, well. Therefore, the c and b electron separation measurement of v_2 is essential for the study of the flow effect. We installed the high-resolution detector FVTX at the RHIC-PHENIX experiment in 2012 for the c and b electron v_2 separation measurement. The FVTX detector precisely measures the reaction plane, which is the reference of the v_2 measurement. We measure the c and b electron v_2 with smaller uncertainties using this detector.

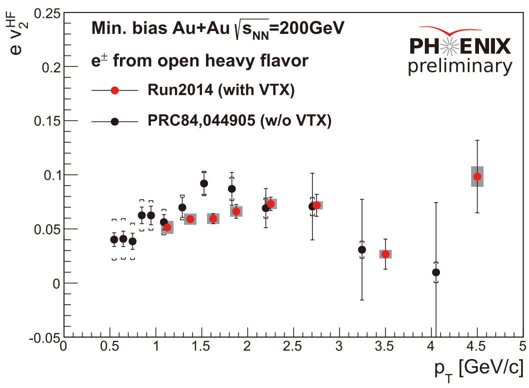

Fig. 1. Comparison of HF v_2 using 2007 dataset and 2014 dataset.

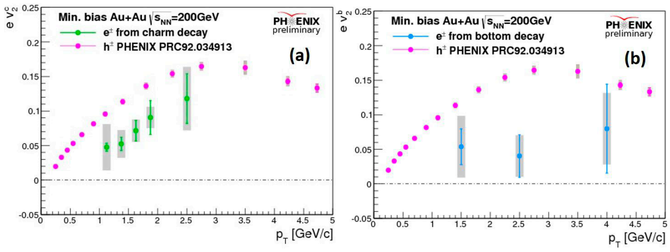

Fig. 2. Compared of charged hadron v_2 with (a) charm and (b) bottom electron v_2.

A comparison of HF electron v_2 using the 2014 dataset (black point) and the 2004 dataset (red point) is shown in Fig. 1. The new result is consistent with the previous result. On the other hand, the uncertainties became smaller because of the higher statistics in the 2014 dataset and the higher resolution provided by the FVTX detector.

The HF v_2 is statistically separated into $c \to e\ v_2$ and $b \to e\ v_2$ using the DCA information. The DCA region is separated into 2 DCA regions: c and b rich regions. The c/b electron v_2 ($v_2^{c/b}$) is described with the calculated b fraction $f_b(c/b)$ and background (BG) fraction $f_{\rm BG}(c/b)$ for the c/b rich region using the following formulas.

$$v_2^{\rm meas}(c) = f_b(c) \cdot v_2^b + (1 - f_b(c)) \cdot v_2^c + f_{\rm BG}(c) \cdot v_2^{\rm BG}(c)$$

$$v_2^{\rm meas}(b) = f_b(b) \cdot v_2^b + (1 - f_b(b)) \cdot v_2^c + f_{\rm BG}(b) \cdot v_2^{\rm BG}(b)$$

Here, $v_2^{\rm meas}(c/b)$ and $v_2^{\rm BG}(c/b)$ are the measured inclusive electron v_2 and BG v_2 for the c/b rich region, respectively. The c and b electron v_2 are separately calculated by solving these equations.

A comparison of (a) c electron v_2 (red point) and (b) b electron v_2 (blue point) with the charged hadron v_2 (pink point) is shown in Fig. 2. It is the first measurement of b electron v_2 at RHIC. The c and b electron v_2 are smaller than the charged hadron v_2. Also, the c electron v_2 seems to be larger than the b electron v_2. Unfortunately, the large uncertainty makes b electron v_2 consistent with zero. We will improve the method for the c and b electron v_2 separation measurement.

Reference

1) K. Nagashima for the PHENIX Collaboration., Nucl. Phys. A **967**, pp. 644–647 (2017).

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