Measurement of Open Heavy Flavor Production in the STAR experiment at RHIC

Xin Li, for STAR Collarboration

Purdue University, West Lafayette, IN 47907, USA

Abstract. We present the STAR results of non-photonic electron measurements and direct reconstruction of charm mesons at $\sqrt{s_{NN}} = 200$ GeV. We also briefly outline the future perspectives of studying open heavy flavor production at RHIC.

Keywords: STAR, open heavy flavor mesons, non-photonic electrons, cross section
PACS: 13.20.Fc, 13.25.Ft, 24.85.+p, 25.75.Cj

INTRODUCTION

Heavy quarks are unique probes to study the strongly-coupled Quark-Gluon Plasma created at RHIC. Unlike light quarks, heavy quark masses come mostly from spontaneous symmetry breaking, which makes them ideal for studying the medium's QCD properties. Due to their large masses, they are produced early in the collisions and are expected to interact with the medium quite differently than light quarks. Detailed studies of the open heavy flavor meson productions in heavy-ion collisions and the baseline p+p and d+A collisions provide crucial information in understanding the medium's properties.

In STAR experiment, we can study open heavy flavor mesons indirectly through measuring non-photonic electron production, and directly through reconstructing charm mesons via their hadronic decay channels. The non-photonic electron, with the help of online triggers, allows studying heavy quark production at high p_T, while the direct measurements allow direct access of heavy quark kinematics and avoid the complication of disentangling charm and bottom quark components. In this paper, we report recent results from both fronts.

MEASUREMENTS OF NON-PHOTONIC ELECTRON PRODUCTION

The STAR experiment has measured open charm production through its semi-leptonic decay ($D,B \rightarrow l\nu_l X$) [1]. The dominant backgrounds are photonic electrons from photon conversion in the detector material and Dalitz decay of π^0 and η mesons. They can be partially identified through the reconstructed invariant mass distributions of electron-positron pairs. Not all photonic electrons can be identified this way since one of the electrons in a pair may escape the detector, or has a momentum too low to be reconstructed. This inefficiency in finding photonic electrons is estimated through simulation and is used to estimate the total photonic electron background.

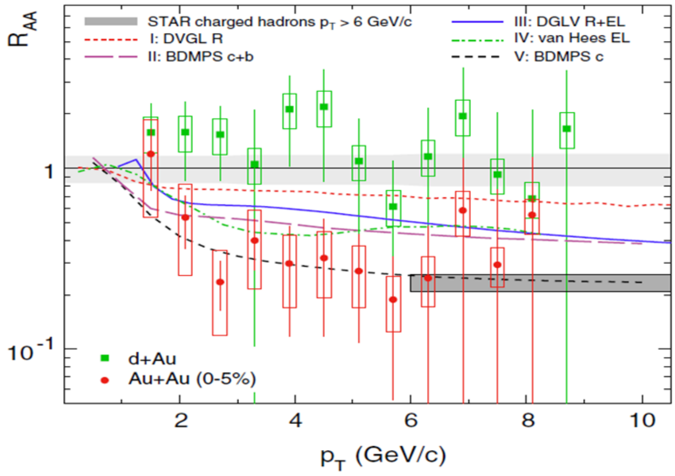

FIGURE 1. (Color online) The nuclear modification factor, R_{AA}, for d+Au and Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV, together with different theoretical model predictions. Look at Ref. [2] for details.

A long standing puzzle was that the measured high p_T non-photonic electron invariant yield in both $p+p$ and Au+Au collisions differ by about a factor of two between STAR and PHENIX. This was resolved by uncovering a mistake, similar in all of our published $p+p$, d+Au and Au+Au results, in applying the background finding efficiency when subtracting the photonic electron background [1]. Figure 1 shows the nuclear modification factor, R_{AA}, for d+Au and Au+Au collisions. Since the mistake has similar effects in all collision specifies, the corrected measurements are quite close to the original results in central values but with larger statistical errors. The results indicate substantial energy loss of heavy quarks in dense matter created at RHIC.

Electrons from bottom and charm meson decays are the two dominant components of the non-photonic electrons. The relative contribution to the non-photonic electrons from bottom and charm meson decays can be disentangled utilizing their different decay kinematics. In STAR, this is done though measuring the azimuthal correlation between non-photonic electrons and charged hadrons as well as the correlation between non-photonic electrons and D^0 [2]. The distribution of the azimuthal angle between non-photonic electrons and charged hadrons from bottom meson decays is much wider than that from charm meson decays. Through fitting the data using a function combining the two different distributions, we obtained the contribution of B-decay electron to the non-photonic electron yield $(e_B/(e_B+e_D))$. By using the measured $e_B/(e_B+e_D)$, together with the measured non-photonic electron cross section [3] with the electrons from J/ψ, γ decay and Drell-Yan processes subtracted, one can disentangle these two components. Figure 2 shows the invariant cross section of non-photonic electrons from bottom and charm mesons as a function of p_T [3] and the corresponding Fixed Order plus Next-to-Leading Logarithms predictions (FONLL) [4], along with the ratio of each measurement to the FONLL calculations. One can see the measurements are consistent with the FONLL prediction within its theoretical uncertainties. The integrated cross section of electrons at 3 GeV/$c < p_T <$ 10 GeV/c from bottom and charm meson decays

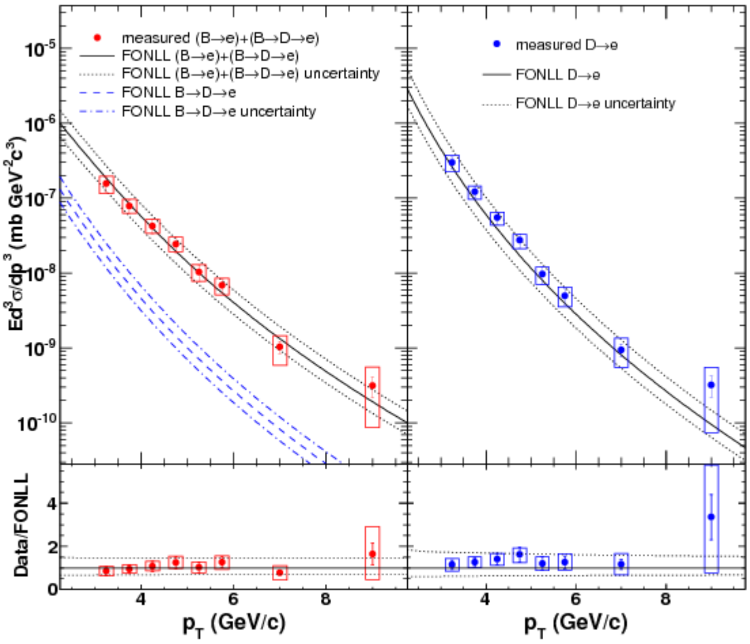

FIGURE 2. (Color online) Invariant cross section of electrons from bottom (upper-left) and charm meson (upper-right) decay, together with the ratio of the corresponding measurements to the FONLL predictions for bottom (lower-left) and charm electrons (lower-right), from Ref. [3].

are determined as

$$\frac{d\sigma_{(B\to e)+(B\to D\to e)}}{dy_e}|_{y_e=0} = 4.0 \pm 0.5(stat.) \pm 1.1(syst.)nb$$

$$\frac{d\sigma_{(D\to e)}}{dy_e}|_{y_e=0} = 6.2 \pm 0.7(stat.) \pm 1.5(syst.)nb$$

DIRECT RECONSTRUCTION OF OPEN CHARM MESONS

A direct reconstruction of the D meson was performed in Run2009 $p+p$ collisions at $\sqrt{s} = 200$ GeV. D^0 and $\overline{D^0}$ are reconstructed through the decay channel D^0 ($\overline{D^0}$) $\to K^{\mp}\pi^{\pm}$ with a branching ratio (BR) of 3.89%. $D^{*\pm}$ mesons are reconstructed through the decay channel $D^{*\pm} \to D^0\pi^{\pm}$ ($BR = 67.7\%$), $D^0 \to K^-\pi^+$ and its charge conjugate. Figure 3 shows the invariant mass distributions for the D^0 (left panel) and D^* meson (right panel) after background subtraction. Significant signal of directly reconstructed D^0 and D^* meson are observed.

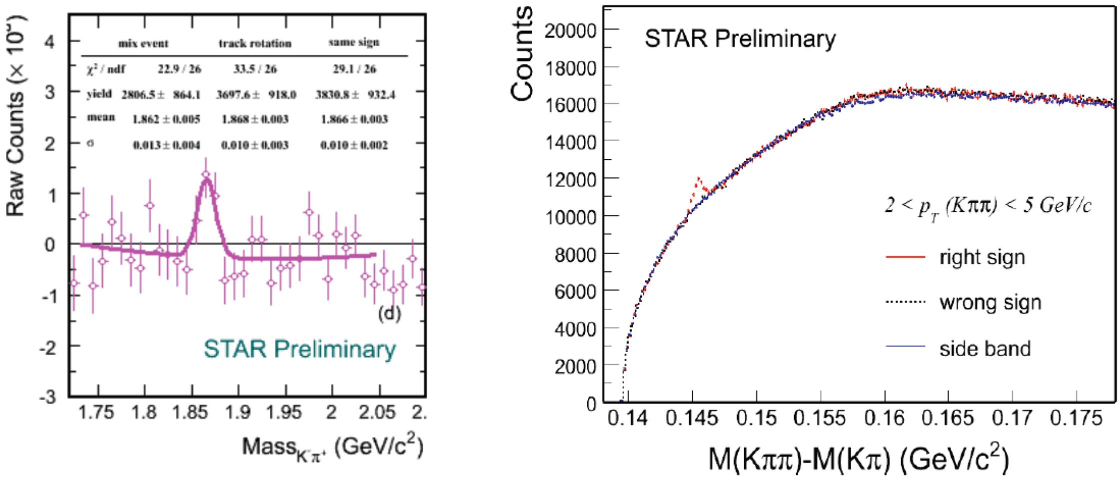

FIGURE 3. The invariant mass distributions after subtracting backgrounds. $M_{K\pi}$ for D^0, $M_{K\pi\pi} - M_{K\pi}$ for $D^{*\pm}$, respectively

SUMMARY AND OUTLOOK

In summary, we present the STAR non-photonic electron measurements at $\sqrt{s_{NN}} = 200$ GeV and report the status of the direct reconstruction of D mesons in 200 GeV $p+p$ collisions. The measurements of non-photonic electron production in $p+p$ collisions are consistent with the pQCD predictions. The R_{AA} in Au+Au collisions indicate substantial energy loss of heavy quark in the dense matter created at RHIC. In the future, with the STAR heavy flavor tracker (HFT) and Muon telescope detector (MTD) installed, the physics reach of STAR heavy flavor program will be significantly extended. HFT will determine precisely the secondary decay vertex of heavy flavor hadrons and improve the signal-to-background ratio of all heavy flavor measurements. MTD will allow studying heavy quark through muon decay channels. These detector upgrades, together with the RHIC-II luminosity upgrade, will open an opportunity for us to conduct the high precision measurements of heavy flavor hadrons at RHIC.

REFERENCES

1. J. Adams et al. [STAR Collaboration], *Phys. Rev. Lett.* 94, 062301 (2005); B. I. Abelev et al. [STAR Collaboration], *Phys. Rev. Lett.* 98, 192301 (2007); B. I. Abelev et al. [STAR Collaboration], *Phys. Rev. Lett.* 106, 159902 (2011).
2. M. M. Aggarwal et al. [STAR Collaboration], *Phys. Rev. Lett.* 105, 202301 (2010).
3. H. Agakishiev et al. [STAR Collaboration], *Phys. Rev. D* 83, 52006 (2011).
4. M. Cacciari, *Nucl. Phys. A* 783, 189 (2007); M. Cacciari, P. Nason and R. Vogt, *Phys. Rev. Lett.* 95, 122001 (2005); R. Vogt, private communication.