Measurement of bottom contribution to the non-photonic electron production in p+p collisions at STAR

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Abstract.
We present the STAR preliminary results of the azimuthal correlations between non-photonic electrons and charged hadrons at mid-rapidity in p+p collisions at $\sqrt{s}$ = 200 GeV and 500 GeV. The correlation distributions are fitted with PYTHIA templates to extract the relative contribution from bottom decays to non-photonic electrons. This could provide a precise p+p reference for the study of bottom production in heavy-ion collisions at RHIC.

1. Introduction

Models based on radiative energy loss mechanism can describe the large suppression of light hadrons in central Au+Au collisions at RHIC quite well [1, 2]. However the large suppression of non-photonic electron (NPE) yields from semi-leptonic decays of B and D mesons challenges such models which predicted that the energy loss of heavy quarks should be much smaller compared to that of light quarks due to their larger masses ("dead-cone effect") [3, 4]. Various models have been proposed to explain the large suppression of NPE yields and such calculations are crucially dependent on the relative contributions from B/D meson decays to NPE [5, 6]. Thus separating the B/D meson contributions to NPE yield experimentally is important for constraining models, and thus understanding the energy loss mechanism of heavy flavor quarks in the medium. Separation of B/D meson contributions to NPE in p+p collisions serves as a reference for the study in heavy-ion collisions. By comparing results from 200 GeV and 500 GeV p+p collisions, we can check the collision energy dependence of bottom contribution to NPE. In this study, we utilize an indirect method to disentangle B and D meson contibutions to NPE, which relies on the fact that electrons decayed from B and D mesons have different azimuthal correlations with charged hadrons on the near side [7, 8].

2. Analysis

The data used in this analysis were recorded in p+p collisions at $\sqrt{s}$ = 200 GeV in 2012 and $\sqrt{s}$ = 500 GeV in 2011 by the STAR experiment. The main detectors used in this analysis are the Time Projection Chamber (TPC) [9], which is used for momentum determination and electron identification; Barrel Electromagnetic Calorimeter (BEMC) for electron identification as well as electron triggering at high transverse momenta (p_T) [10]; Barrel Shower Maximum Detector (BSMD) which is embedded in the BEMC and provides good shower size measurement for electron identification; Time Of Flight (TOF) which is used for low p_T electron identification [11]; and Vertex Position Detector (VPD) which provides the minimum bias trigger [12]. In order to obtain sufficient statistics at high p_T, we used BEMC triggered events, with single-tower energy thresholds of 2.6 and 4.3 GeV in p+p collisions at $\sqrt{s} = 200$ GeV; and 2.6, 4.3 and 6.0 GeV in p+p collisions at $\sqrt{s} = 500$ GeV.

We start with the semi-inclusive electron sample (Semi-Inc) to construct the correlation between non-photonic electrons and charged hadrons. The semi-inclusive electrons are obtained by removing the electrons that fall into the invariant mass cut after pairing with an opposite-sign partner (OppSign) from the inclusive electron sample. The invariant mass cut is set to be less than 0.24 GeV/c^2 to remove the background from photon conversions and π^0/η Dalitz decays. The correlation signal between non-photonic electrons and charged hadrons is calculated as following:

$$\Delta\phi_{Non\_Pho} = \Delta\phi_{Semi\_Inc} - \Delta\phi_{Not\_Reco\_Pho} + \Delta\phi_{SameSign} - \Delta\phi_{Hadron} \quad (1)$$

where $\Delta\phi_{SameSign}$ is an estimate of the combinatorial background using electrons that pass the invariant mass cut of 0.24 GeV/c^2 after pairing with a same-sign partner. $\Delta\phi_{Hadron}$ is the hadron-hadron correlation which is used to estimate the hadron contamination, and $\Delta\phi_{Not\_Reco\_Pho}$ is the correlation of photonic electrons with charged hadrons that was not captured by the invariant mass selection. It is calculated as:

$$\Delta\phi_{Not\_Reco\_Pho} = (\frac{1}{\varepsilon} - 1) \times \Delta\phi_{Reco\_Pho} \quad (2)$$

where $\Delta\phi_{Reco\_Pho}$ is the correlation between photonic electrons and hadrons, and ε is the efficiency for the photonic electron reconstruction which can be obtained from simulations. The detailed analysis procedure can be found in [7, 8].

3. Result

Panel (a) in Figure 1 shows the azimuthal correlation between NPE and charged hadrons in $p + p$ collisions at $\sqrt{s} = 200$ GeV for NPE with $5.5 < p_T < 6.5$ GeV/c and $|\eta^{NPE}| < 0.7$. The associated hadrons are required to have $p_T > 0.3$ GeV/c and $|\eta^{asso}| < 1.0$. Clear azimuthal correlation signals can be seen on the near side. We use PYTHIA 8.1 combined with STAR-HF-Tune Version 1.1 to generate azimuthal correlations between electrons from B and D meson decay and charged hadrons in $p + p$ collision at $\sqrt{s} = 200$ GeV [13]. STAR-HF Tune is a set of parameters that are tuned to describe the NPE and J/ψ measurements at RHIC. Clear correlation peak can also be seen on the near side for D and B meson decayed electrons, and the difference comes from the different decay kinematics. Fitting the experimental data with the NPE-h azimuthal correlations from PYTHIA, we can extract the B meson contribution to non-photonic electrons. The fit function is:

$$\Delta\phi_{exp} = (R \times \Delta\phi_B + (1 - R) \times \Delta\phi_D) \times Norm \quad (3)$$

where R is the fit parameter which represents the relative B meson contribution to non-photonic electrons, $\Delta\phi_B$ ($\Delta\phi_D$) is the correlation between B (D) meson decayed electrons and charged hadrons from PYTHIA simulation, and Norm is the normalization parameter.

Panel (b) shows the extracted B meson contribution as a function of p_T (red circles), together with published results from Run 6 $p+p$ collisions at $\sqrt{s} = 200$ GeV (black stars) for comparison. The error bars represent the statistical errors and the systematic uncertainties are shown as boxes. The preliminary results agree with STAR Run 6 analysis for $p_T < 8.5$ GeV/c, and the systematic uncertainties are significantly reduced. We also compare the results with Fixed

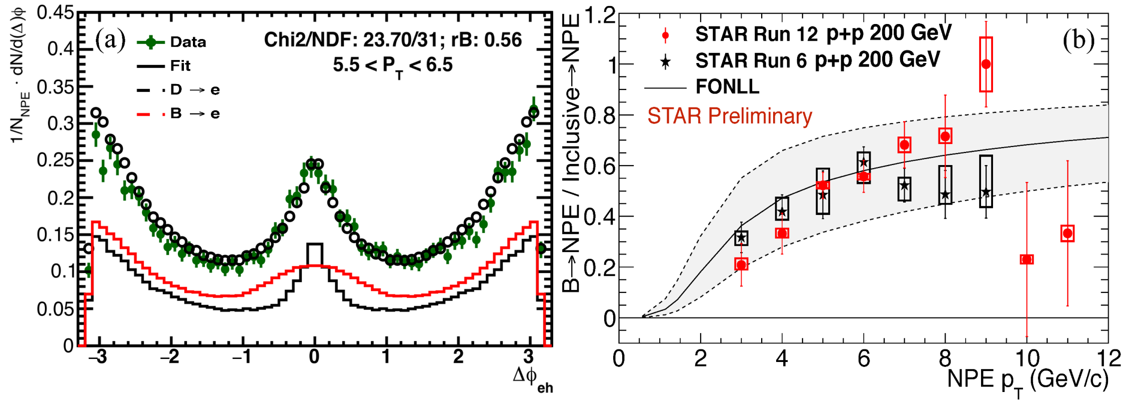

Figure 1. (Color online) (a) NPE-hadron azimuthal correlations from STAR fitted with PYTHIA templates in $p+p$ collisions at $\sqrt{s} = 200$ GeV. (b) The extracted B meson contribution to non-photonic electrons as a function of p_T in $p+p$ collisions at $\sqrt{s} = 200$ GeV.

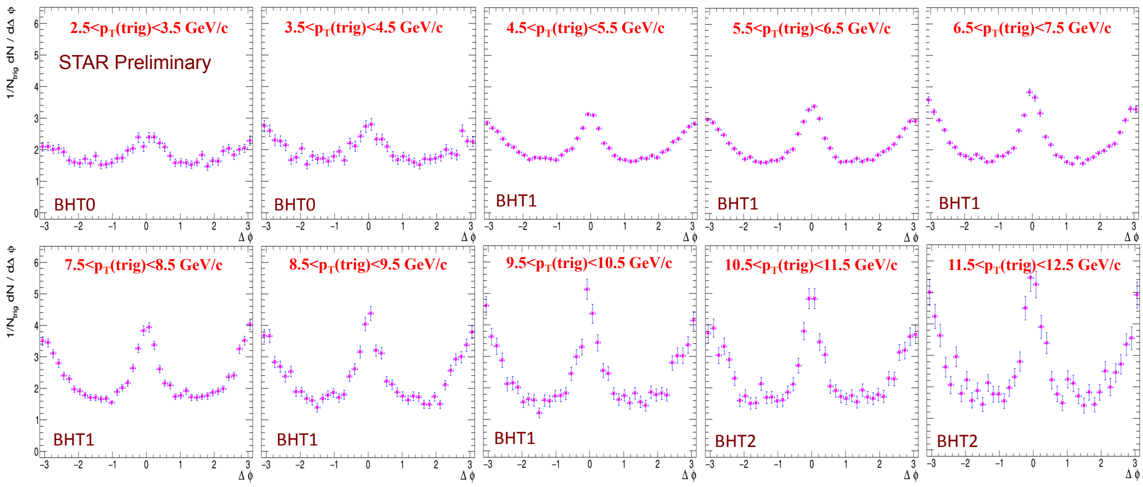

Figure 2. (Color online) NPE-hadron azimuthal correlations in $p+p$ collisions at $\sqrt{s} = 500$ GeV for different electron p_T bins from the STAR experiment.

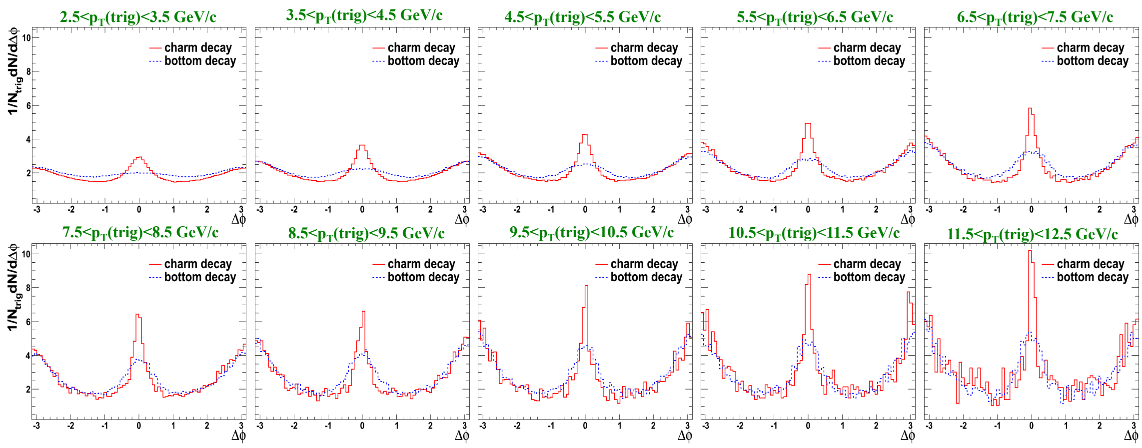

Figure 3. (Color online) NPE-hadron azimuthal correlation in $p+p$ collisions at $\sqrt{s} = 500$ GeV for different electron p_T bins from PYTHIA simulations.

Order Next to Leading Logarithm (FONLL) calculation, and find the results are consistent with FONLL calculation within uncertainties.

Figure 2 shows the raw azimuthal correlation between non-photonic electrons and charged hadrons in $p + p$ collisions at $\sqrt{s} = 500$ GeV for different trigger NPE p_T bins between $2.5 < p_T < 12.5$ GeV/c requiring $|\eta^{NPE}| < 0.7$. The associated hadrons are required to have $p_T > 0.3$ GeV/c and $|\eta^{asso}| < 1.0$. Clear azimuthal correlation can be seen on the near side and the correlation signal increases with increasing electron p_T. Figure 3 shows the correlations between B and D meson decayed electrons and charged hadrons from PYTHIA simulation for different electron p_T bins in $p + p$ collisions at $\sqrt{s} = 500$ GeV. A similar correlation structure is observed in $\sqrt{s} = 500$ GeV as in $\sqrt{s} = 200$ GeV. As the NPE p_T increases, the near side correlation signal increases for both B and D decayed electrons, but the difference between the correlation shapes reduces.

4. Summary

In this work, we study the azimuthal correlations bewteen non-photonic electrons and charged hadrons in $p + p$ collisions at $\sqrt{s} = 200$ GeV and $\sqrt{s} = 500$ GeV from the STAR experiment. By fitting the measured correlations with PYTHIA templates, we have extracted the B meson contribution to non-photonic electrons in the range of $2.5 < p_T < 11.5$ GeV/c for p+p collisions at $\sqrt{s} = 200$ GeV. The preliminary results agree with previous STAR Run 6 analysis for $p_T < 8.5$ GeV/c, and the systematic uncertainties are significantly reduced. The results are also consistent with FONLL calculation within uncertainties. For the analysis in p+p collisions at $\sqrt{s} = 500$ GeV, we have constructed the raw azimuthal correlation between non-photonic electrons and charged hadrons, and observed an increase to the near-side correlation signal as the electron p_T increases. We also used PYTHIA to simulate the azimuthal correlations between B and D meson decayed electrons and charged hadrons, and found that the correlation shapes are different on the near side for the two different species. This difference decreases as trigger electron p_T increases. Further study is under way to extract the B meson contribution to non-photonic electrons in p+p collisions at $\sqrt{s} = 500$ GeV.

Acknowledgments

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