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NON-PHOTONIC ELECTRON AND CHARGED HADRON AZIMUTHAL CORRELATION IN $p+p$ COLLISIONS AT $\sqrt{s}=500$ GeV IN STAR*

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We present the STAR preliminary results of non-photonic electron and charged hadron azimuthal correlation at midrapidity at $6.5 < p_{\mathrm{T}}^{\mathrm{NPE}} < 12.5\,\mathrm{GeV}/c$ in 500 GeV $p+p$ collisions. The correlation distributions are compared with PYTHIA simulations to extract the relative contribution of B mesons to non-photonic electrons. Our measurements indicate that the extracted B meson decay contribution is above 60% at $8.5 < p_{\mathrm{T}} < 12.5\,\mathrm{GeV}/c$. By comparing the results between 200 and 500 GeV energies, we find that $e_B/(e_B+e_D)$ ratio is higher at 500 GeV than 200 GeV at $6.5 < p_{\mathrm{T}} < 9.5\,\mathrm{GeV}/c$.

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1. Introduction

Models based on gluon radiative energy loss mechanism can describe the large suppression of light hadrons at RHIC quite well [1,2]. The nuclear modification factor (R_{AA}) of non-photonic electrons (NPE) from heavy quark semi-leptonic decays is comparable to that of light hadrons at high transverse momenta (approximately $p_{\mathrm{T}} > 5\,\mathrm{GeV}/c$) in central Au+Au collisions at $\sqrt{s}=200\,\mathrm{GeV}$, which indicates that heavy quarks may lose a substantial amount of energy in medium [3]. Theoretical calculations predicted that the energy loss of heavy quarks is much smaller compared to that of light quarks

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due to its large mass ("dead-cone effect") [4,5,6], thus the large suppression of non-photonic electron production challenges the understanding of parton energy loss mechanism via gluon bremsstrahlung. Additionally, the observed large non-photonic electron v_2 clearly indicates a strong coupling between the heavy mesons and the medium [3]. In order to understand the interactions between heavy quarks and the medium that lead to large energy loss and large flow, one needs to determine the B mesons contribution to non-photonic electron measurements. Right now, our current measurements of directly reconstructed heavy mesons do not allow a precise separation of D and B contribution directly at RHIC. It will be possible after the completion of the STAR Heavy Flavor Tracker (HFT) [7]. An indirect way has been used to disentangle D and B meson contribution to non-photonic electrons at STAR taking into account the fact that electrons from D and B decays have different correlation shapes with charged hadrons on near side [8,9]. STAR has published results on non-photonic electron and charged hadron azimuthal correlation in $p+p$ collisions at $\sqrt{s} = 200\,\mathrm{GeV}$. The extracted B mesons decay contribution is approximately 50% at $p_{\mathrm{T}} > 5\,\mathrm{GeV}/c$ in 200 GeV $p+p$ collisions [8]. In this work, we extend the correlation analysis to higher p_{T} region in 500 GeV $p+p$ collisions. Comparing the results between 200 GeV and 500 GeV will help to better understand the heavy flavor production at RHIC.

2. Analysis

The data used in this analysis are taken from STAR Run 2009 $p+p$ collisions at $\sqrt{s} = 500\,\mathrm{GeV}$. The main detectors used in this analysis are STAR Time Projection Chamber (TPC) [10], Barrel Electromagnetic Calorimeter (BEMC) and Barrel Shower Maximum Detector (BSMD) [11]. In order to obtain sufficient statistics at high p_{T}, we used high tower triggered events requiring transverse energy deposition in one tower to be larger than 7.4 GeV. About 5.4 million events were used in this analysis.

The electrons were identified by applying cuts on ionization energy loss (dE/dx) measured in the TPC, ratio of particle momentum to the energy deposited in the BEMC, shower size in the BSMD and projection distance between TPC track projection position and the reconstructed BEMC point position. For more details of the electron identification procedure, see [9,12]. We calculated the purity of identified inclusive electron sample which is about 83.5% at $6.5 < p_{\mathrm{T}} < 12.5\,\mathrm{GeV}/c$. The inclusive electron contains two parts: non-photonic electrons and photonic electrons. By subtracting the photonic electron background from inclusive electron, one can get non-photonic electron signal. The photonic electrons are mainly from photon conversion and π^0, η Dalitz decays whose electron pairs have a small invariant mass [12,13]. We plot the invariant mass distribution by pairing the electron candidates with partner tracks pass a loose cut on dE/dx around the electron ionization band in TPC. Due to the limited tracking resolution of TPC, the invariant mass has a broad distribution. We construct the 2-D invariant mass by ignoring the opening angle in ϕ plane to eliminate the resolution effect. The 2-D invariant mass cut is set to be $0.1\,\mathrm{GeV}/c^2$ to remove the photonic electron reconstruction background.

We start with the semi-inclusive electron sample (Semi-Inc) to construct the correlation between non-photonic electrons and charged hadrons, where semi-inclusive electron is obtained by removing the electrons that have an opposite-sign partner after mass cut (OppSign) from the inclusive electron sample. The correlation signal between non-photonic electron and charged hadron is calculated from the following equation

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

where SameSign is electrons that have a same-sign partner after mass cut which is considered as combinatorial background. Thus $\Delta\phi_{\mathrm{SameSign}}$ is the SameSign electron correlation with charged hadrons, $\Delta\phi_{\mathrm{Hadron}}$ is hadron–hadron correlation which is considered as the hadron contamination, and $\Delta\phi_{\mathrm{Not\_Reco\_Pho}}$ is the photonic electron correlation with charged hadrons, in which the photonic electrons are not from direct reconstruction and is obtained from the following equation

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

where $\Delta\phi_{\mathrm{Reco\_Pho}}$ is the photonic electron correlation with hadrons, in which the photonic electrons are from direct reconstruction, ϵ is photonic electron reconstruction efficiency which can be obtained from simulations. The photonic electron reconstruction efficiency is 65% used in this analysis based on estimation from previous 200 GeV embedding data, and we vary it by ± 5% to estimate the systematic uncertainties. The detailed analysis procedure can be found in [8, 9].

3. Result

Figure 1 shows the constructed azimuthal correlation between NPE and charged hadrons in $p+p$ collisions at $\sqrt{s} = 500\,\mathrm{GeV}$ for different trigger NPE p_{T} bins at $6.5 < p_{\mathrm{T}} < 12.5\,\mathrm{GeV}/c$ requiring $|\eta^{\mathrm{NPE}}| < 0.7$. The associated hadrons are required to have $p_{\mathrm{T}} > 0.3\,\mathrm{GeV}/c$ and $|\eta^{\mathrm{asso}}| < 1.0$. Clear azimuthal correlation can be seen on near side and the correlation increases with increasing trigger p_{T}. We use PYTHIA 8.1 combined with STAR-HF-Tune Version 1.1 to generate azimuthal correlations between electrons from $D(B)$ meson decay and charged hadrons in $p+p$ collision at

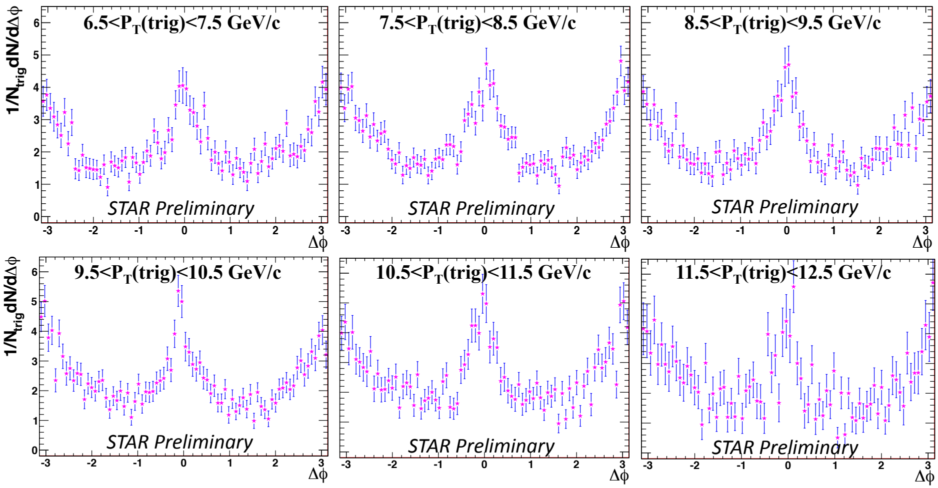

Fig. 1. (Color online) NPE-hadron azimuthal correlation in $p{+}p$ collisions at $\sqrt{s} = 500\,\mathrm{GeV}$ for different trigger electron p_{T} bin from STAR experiment.

$\sqrt{s} = 500\,\mathrm{GeV}$ [14]. STAR-HF Tune is a set of parameters that are optimized to describe the NPE and J/ψ measurements at RHIC. The p_{T} selection in PYTHIA simulation is the same as in data analysis. Figure 2 shows the constructed correlation from PYTHIA simulation for different trigger NPE p_{T} bins. The solid (red) line represents D meson decayed electron and hadron

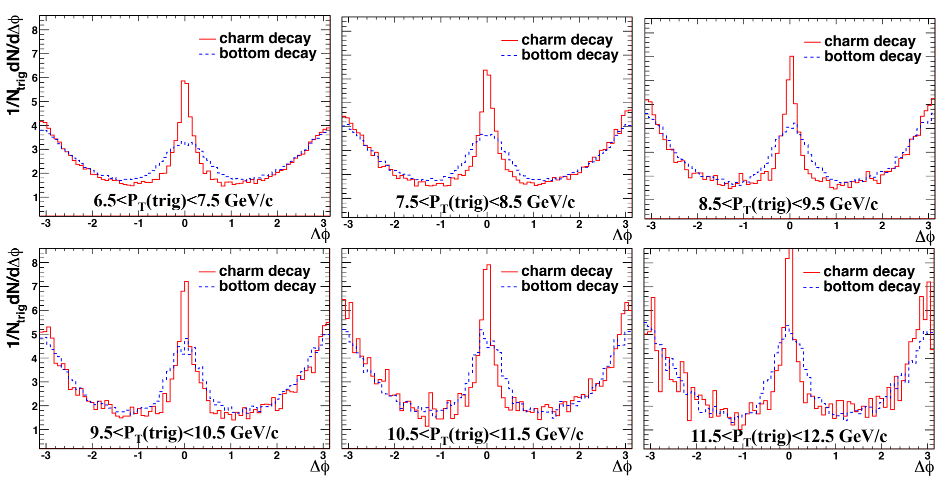

Fig. 2. (Color online) NPE-hadron azimuthal correlation in $p{+}p$ collisions at $\sqrt{s} = 500\,\mathrm{GeV}$ for different trigger electron p_{T} bin from PYTHIA simulation. Solid (red) curve is D meson decayed electron and hadron correlation, and dashed (blue) curve is B meson decayed electron and hadron correlation.

correlation, the dashed (blue) line represents B meson decayed electron and hadron correlation. Clear correlation peak can be seen on near side for D and B meson decayed electrons, and their correlation shape is different due to their different parent particle masses. As the trigger p_{T} increases, the near side correlation increases for both D and B decayed electrons, and the difference between the correlation shapes reduces.

Comparing the PYTHIA simulation results to experimental data, we can extract the B meson contribution ratio to non-photonic electrons, see panel (a) in figure 3. The fit function is: $\Delta\phi_{\mathrm{exp}} = R \times \Delta\phi_B + (1-R) \times \Delta\phi_D + C$, where R is the fit parameter which represents the B meson contribution ratio to non-photonic electrons, $\Delta\phi_B(\Delta\phi_D)$ is $B(D)$ meson decayed electron correlation with charged hadrons from PYTHIA simulation, C is the fitting constant. The light gray (green) curve is the fit results with fit range of -1.5 to 1.5 rad. Panel (b) shows the extracted B meson contribution ratio as a function of p_{T}. The error bars represent the statistical errors and the systematic uncertainties are shown as boxes. The systematic uncertainties are estimated by varying the photonic electron reconstruction efficiency, fit range and fit function in $\Delta\phi$ distribution. We also plot the results of 200 GeV energy as a comparison. The extracted $e_B/(e_B + e_D)$ ratio is above 60% at $8.5 < p_{\mathrm{T}} < 12.5\,\mathrm{GeV}/c$ with current uncertainties and is systematically higher at 500 GeV than 200 GeV for the overlap p_{T} region.

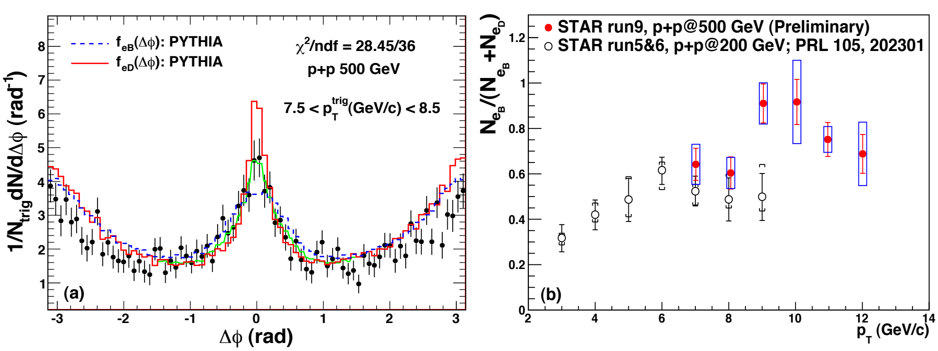

Fig. 3. (Color online) (a) NPE-hadron correlations from STAR data and the comparisons to PYTHIA simulation results. The data are shown as black dots, and the dashed (blue)/solid (red) curves represent $B(D)$ meson decayed electron correlation with charged hadrons from PYTHIA simulation, the light grey (green) curve is the fit results. (b) The extracted B mesons contribution to non-photonic electrons as a function of p_{T} in $p+p$ collisions at $\sqrt{s} = 500$ GeV depicted by solid (red) circles, the error bars is the statistical errors and the boxes represent the systematic uncertainty introduced by different fit range, fit function and photonic electron reconstruction efficiency; the open black circle represents the STAR published B meson decay contribution ratio to non-photonic electron for $\sqrt{s} = 200$ GeV.

4. Summary

In this work, we study the non-photonic electron and charged hadron azimuthal correlation in p+p collisions at $\sqrt{s} = 500$ GeV from STAR. Comparing the non-photonic electron and charged hadron azimuthal correlation with PYTHIA simulated D and B meson decayed electron and hadron correlation, we have extracted the B mesons contribution to non-photonic electron at $6.5 < p_{\mathrm{T}} < 12.5$ GeV/c. Our preliminary results based on PYTHIA simulation indicates that the extracted B meson decay contribution to non-photonic electron is above 60% at $8.5 < p_{\mathrm{T}}^{\mathrm{NPE}} < 12.5$ GeV/c, and the contribution ratio increases with increasing trigger NPE p_{T}. Compared with the results of 200 GeV, the $e_B/(e_B + e_D)$ ratio is systematically higher at 500 GeV than 200 GeV at $6.5 < p_{\mathrm{T}} < 9.5$ GeV/c.

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