Azimuthal Correlations between Non-Photonic Electrons and Charged Hadrons in p+p Collisions from STAR

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Abstract

We present the preliminary measurement of azimuthal correlations between non-photonic electrons and charged hadrons in p+p collisions at $\sqrt{s_{NN}} = 200$ GeV from STAR. The results are compared to PYTHIA simulations to estimate the relative contributions of $D$ and $B$ meson semi-leptonic decays to the non-photonic electrons.

Key words: non-photonic electrons, electron-hadron correlations, charm and bottom contributions to electron spectra

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Heavy quarks are valuable probes of the dense medium created in heavy-ion collisions. Their transport dynamics such as flow and energy loss reflect QCD properties of the dense matter. Recently, the STAR and PHENIX collaborations have observed a suppression of non-photonic electrons much larger than predicted in the $p_T \sim 4 - 8$ GeV/c region [1][2]. This observation challenges theoretical predictions based on energy loss via induced gluon radiation for heavy quarks [3][4]. The fact that the relative contributions from semi-leptonic decays of $D$ and $B$ mesons to the measured non-photonic electron spectrum is currently unknown at RHIC severely restricts the understanding of the heavy quark energy loss. A nonzero non-photonic electron $v_2$ has been measured for $p_T < 2.0$ GeV/c, while at higher $p_T$ the $v_2$ is observed to decrease with $p_T$ [5]. The quantitative understanding of this feature in heavy quark measurements requires the knowledge of the relative charm and bottom contributions to non-photonic electrons.

In this paper we will present preliminary results on the measurement of azimuthal correlations between high-$p_T$ non-photonic electrons and charged hadrons in p+p collisions at 200 GeV from STAR. This measurement will
help distinguish relative $B$ and $D$ decay contributions to non-photonic electrons because of their different decay kinematics [6]. We will compare the results to PYTHIA simulations in order to estimate $B$ and $D$ decay contributions to non-photonic electrons as a function of $p_T$ for $p_T > 2.0$ GeV/c.

For this analysis we used about 23.4 million p+p events at $\sqrt{s_{NN}} = 200$ GeV with a cut of $-40 \, \text{cm} < \text{primary vertex } z < +30 \, \text{cm}$ in order to maximize the statistics while keeping the amount of material in a reasonable level to minimize photon conversions. To obtain sufficient statistics at high-$p_T$, we developed high tower triggers corresponding to an energy deposition of at least 2.6 GeV (HT1) and 3.5 GeV (HT2) in a single tower of the STAR Barrel Electromagnetic Calorimeter (BEMC) [7]. Around 3.32 million HT1 events and 2.27 million HT2 events were used in this analysis.

Electron identification uses the information from two of the STAR subsystems, the TPC [8] and the BEMC. The measurement of the ionization energy loss, $dE/dx$, for charged tracks in the TPC gas is used to identify electrons in the first stage. Requiring the $dE/dx$ values of the selected tracks to be near the expected electron band in the region $p_T > 2.0$ GeV/c rejects a significant fraction of the hadron background. After extrapolating the TPC tracks to the BEMC, we require the $p/E$ to be less than 1.5 using the momentum information from the TPC, $p$, and the tower energy information from the BEMC, $E$. Electrons will deposit almost all of their energy in the BEMC while this is not true for hadrons. Further hadron rejection is provided by the shower maximum detector (SMD) [7], which allows us to cut on the shower size with high spatial resolution. We require the profile of the electro-magnetic shower to be within the expectation for electrons. Combining the power of TPC and BEMC, we can achieve an inclusive electron sample with purity $> 99\%$ in the $p_T$ region up to 5.5 GeV/c. The details of the electron identification technique can be found in reference [1] [9].

The physics signal in this analysis is the angular correlation of charged hadrons and non-photonic electrons. The background is the angular correlation of charged hadrons and photonic electrons. There are primarily two types of photonic electron background. One is from photon conversion in the detector material and the other is from scalar meson Dalitz decay [10]. The contributions from photon conversions and $\pi^0, \eta$ Dalitz decays can be reconstructed from an invariant mass calculation of electron pairs. The electron candidates are combined with tracks passing a very loose cut on $dE/dx$ around the electron band. A cut of mass $< 0.1$ GeV/c$^2$ rejects around 70\% of the photon conversion and $\pi^0, \eta$ Dalitz decay electrons. The fraction of background electrons from other sources is negligible [1].

In order to extract the angular correlation of charged hadrons and non-photonic electrons, we start with the semi-inclusive electron sample. The inclusive elec-
Fig. 1. $\Delta \varphi_{\text{non-pho}}$ distributions and the comparison to PYTHIA simulations for three electron trigger cuts with associated hadron $p_T(\text{asso}) > 0.1$ GeV/c. The data is shown as dots, the simulation is depicted by lines. Dashed lines show electrons from $D$ meson decays, solid lines show electrons from $B$ meson decays.

electron sample includes all tracks that pass our electron identification cuts. From this sample, we remove those electrons which satisfy the invariant mass cut where the charges of the electron pair are opposite (Opp-Sign). The remaining electrons form the ”semi-inclusive” electron sample. The Opp-Sign contains reconstructed-photonic electrons and also combinatorial background, since non-photonic electrons can be falsely identified as photonic electrons. This background can be estimated by the Same-Sign calculation, which means electrons satisfy the invariant mass cut where the charges of the electron pair are the same. The relationship of these samples is: $\text{semi-inc} = \text{inc} - (\text{reco-pho} + \text{combinatorics}) = \text{inc} - (\text{pho} - \text{not-reco-pho} + \text{combinatorics}) = \text{non-pho + not-reco-pho} - \text{combinatorics}$. Therefore the signal can be obtained by the equation: $\Delta \varphi_{\text{non-pho}} = \Delta \varphi_{\text{semi-inc}} - \Delta \varphi_{\text{not-reco-pho}} + \Delta \varphi_{\text{combinatorics}}$. $\Delta \varphi_{\text{not-reco-pho}}$ can be calculated using $\Delta \varphi_{\text{reco-pho}}$ by an efficiency correction after removing the photonic partner of the reconstructed-photonic electron.

The reason to remove the photonic partner is that for the reconstructed-photonic electron the photonic partner is found while for not-reconstructed-photonic electron the partner is missing. The resulting e-h correlations for reconstructed photonic electrons and not reconstructed photonic electrons cannot be related to each other by an efficiency correction factor. Therefore $\Delta \varphi_{\text{not-reco-pho}}$ can be obtained by the equation: $\Delta \varphi_{\text{not-reco-pho}} = (1/\varepsilon -$
1) $\Delta \varphi_{\text{reco-pho-no-partner}}$, where $\varepsilon$ is the photonic electron reconstruction efficiency and $\text{reco-pho-no-partner}$ means reconstructed photonic electrons after removing the photonic partner. The corresponding efficiency can be calculated from simulations. For simplicity we assume 70% here, based on previous analyses [1]. We still can see a signal even if the efficiency decreases to $\sim 60\%$. A more detailed re-evaluation is on progress.

Figure 1 shows $\Delta \varphi_{\text{non-pho}}$ distributions and the comparison to PYTHIA simulations for $2.5 < p_T^{(\text{trig})} < 3.5$ GeV/c, $3.5 < p_T^{(\text{trig})} < 4.5$ GeV/c, and $4.5 < p_T^{(\text{trig})} < 5.5$ GeV/c with associated hadron $p_T > 0.1$ GeV/c. The data is shown as dots, the curves are from PYTHIA simulations. The dashed lines are for electrons from $D$ decays and the solid lines are for electrons from $B$ decays. Preliminary results can match the electron-hadron $\Delta \varphi$ distributions from PYTHIA simulations where electrons come from heavy quark decays only. Our data indicate that $D$ meson decays are the dominant contribution to the non-photonic electrons at $p_T \sim 2.5 - 3.5$ GeV/c, and even at higher $p_T$, $p_T \sim 4.5 - 5.5$ GeV/c, $D$ meson decay contribution is still favored.

In conclusion, the azimuthal correlations between non-photonic electrons and charged hadrons are a promising tool to distinguish between $D$ and $B$ decay contributions to non-photonic electrons. The electron-hadron correlations have been measured in p+p collisions at $\sqrt{s_{NN}} = 200$ GeV from STAR. Preliminary results show that the $B$ meson decay contribution does not dominate the measured non-photonic electron yield up to electron $p_T$ of 5.5 GeV/c. More quantitative analysis in the future may provide insight to the puzzle of heavy quark energy loss.

References

[1] J. Adams et al., STAR Collaboration, [nucl-ex/0607012]
[2] S.S. Adler et al., PHENIX Collaboration, Phys. Rev. Lett. 96, 032301 (2006).
[3] N. Armesto et al., Phys. Rev. D 71, 054027 (2005) 054027.
[4] M. Djordjevic et al., Phys. Lett. B 632, 81 (2006).
[5] Y. Akiba (for the PHENIX Collaboration), [nucl-ex/0510008]
[6] X.Y. Lin, [hep-ph/0602067]
[7] M. Beddo et al., Nucl. Instr. Meth. A 499 (2003) 725.
[8] M. Anderson et al., Nucl. Instr. Meth. A 499 (2003) 659.
[9] W.J. Dong, Ph.D. thesis, UCLA (2006).
[10] S. Eidelman et al., Phys. Lett. B 592 (2004) 1+.