Non-photonic electron-hadron azimuthal correlation for AuAu, CuCu and pp collisions at $\sqrt{s_{NN}} = 200$ GeV

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Abstract

We present preliminary STAR results of azimuthal correlations between non-photonic electrons and hadrons in AuAu, CuCu and pp at $\sqrt{s_{NN}} = 200$ GeV. Comparison of the e-h correlations from these colliding systems allows one to study the system-size dependence of heavy quark jet-medium interactions. We also report on the relative charm and bottom contributions to non-photonic electrons extracted from correlations measured in pp collisions. Our results, when combined with $R_{AA}$ measurements of non-photonic electrons, constrain the charm and bottom energy loss in the dense medium.

1. Introduction

Data for di-hadron correlations in AuAu and dAu using the STAR detector show a suppression of high-$p_t$ hadron yields and modifications in the azimuthal correlation in central AuAu collisions [1, 2]. On the away-side of the trigger particles, the observed broadening in the correlations reflects the presence of strong jet-medium interactions, possibly a Mach cone effect [3, 4]. Non-photonic electron triggered particle correlations probe heavy quark jet-medium interactions. Electron-hadron (e-h) correlations on the near side, triggered by non-photonic electrons from charm and bottom decays, have different patterns due to the large mass difference between $D$ and $B$ mesons. Using e-h correlations from pp collisions in comparison with PYTHIA calculations, we can estimate the relative $D$ and $B$ contributions to the non-photonic electrons.

2. Analysis Technique

The data sets used were collected by STAR at RHIC in 2007 for AuAu, 2006 for CuCu and 2005 ($3 < p_t < 6$ GeV/c) and 2006 ($6 < p_t < 9$ GeV/c) for pp. The Time Projection Chamber (TPC) [5], the heart of STAR, was used to reconstruct the tracks of charged particles. Additionally the Barrel Electromagnetic Calorimeter (BEMC) and Shower Maximum Detector (SMD) [6], the electromagnetic calorimeters which surround the TPC in full 2$\pi$ azimuth, were required to have a least one track projected from the TPC onto it and also have an energy deposition greater than a predetermined minimum (i.e. high-tower threshold). This is to increase the number and purity of high $p_t$ electrons. For CuCu the threshold was at 3.75 GeV, 5.5 GeV for AuAu and 5.4 GeV for pp. For pp and AuAu the pseudorapidity used was $|\eta| < 0.7$, while for CuCu it was $0 < \eta < 0.7$ due to the partial installation of the BEMC/SMD. For the AA collisions we used a 0-20% centrality cut, the definition of which is explained in [7].
To identify electron candidates one used a combination of measurements: ionization energy loss (dE/dx) in the TPC, ratio of particle momentum to energy deposited in the BEMC and lastly the electromagnetic shower size in the SMD—see [8, 9] for more detail.

The primary background are photonic electrons either coming from photon conversions inside STAR or the Dalitz decays of π⁰ and η. In both cases the electron pairs have a small invariant mass. This background is removed by pairing electron candidates with a track having passed a loose dE/dx cut around the electron ionization band. The distribution of 2D invariant masses (Δφ is ignored to minimize tracking resolution effects) for opposite sign (OppSign) pairs is obtained upon which a cut of < 0.1 GeV/c² is applied to reject most photonic pairs. The combinatorial background is estimated using the 2D invariant mass distribution of same sign (SameSign) pairs.

The azimuthal correlation of non-photonic electrons and hadrons begins with a semi-inclusive (semi-inc.) electron sample, which is the inclusive electron sample minus the OppSign background (after having applied the mass cut).

The correlation is done via the following method:

\[ \Delta \Phi_{\text{non-photonic}} = \Delta \Phi_{\text{semi-inc}} - \Delta \Phi_{\text{not reco. photonic}} + \Delta \Phi_{\text{comb}} \]  
\[ \Delta \Phi_{\text{not reco. photonic}} = \left( \frac{1}{\epsilon} - 1 \right) \Delta \Phi_{\text{reco. photonic}} \]

\( \Delta \Phi_{\text{comb}} \) is the same sign combinatorial background, while \( \Delta \Phi_{\text{not reco. photonic}} \) are the photonic electrons which weren’t reconstructed due to inefficiencies \( \epsilon \), which is the photonic electron reconstruction efficiency estimated via simulations and found to be ~ 60% for AuAu, ~ 66% for CuCu and ~ 70% for pp. There is only a minor transverse momentum dependence of the efficiency in the momentum range being looked at. More details on this method using a semi-inclusive electron sample are in [10, 11].

3. Results

Figures 1 and 2 plot the e-h azimuthal correlation for AuAu and CuCu at 200 GeV. The left panels show the raw correlations along with dashed curves for elliptic flow (\( v_2 \)) and zero yield at minimum (ZYAM) [3]. Systematic uncertainty of \( v_2 \) is determined by using a lower limit of zero and upper limit of 80% for AuAu or 60% for CuCu of charged hadron \( v_2 \). The momentum ranges used are 3 GeV/c < \( p_T \) < 6.0 GeV/c for trigger electrons and 0.15 GeV/c < \( p_T \) < 0.5 GeV/c for hadrons in AA collisions. To decrease the error bars, the correlation is folded into [0, \( \pi \)] and the data points beyond are reflections. One clearly already sees a modification of the away-side. The right panels plot the correlation after the \( v_2 \) subtraction and ZYAM application.

On the away-side (around \( \pi \)) instead of a single peak there is a broadening (AuAu) or possible double-peak (CuCu) structure. Using a PYTHIA calculation for pp to fit this one sees the \( \chi^2/\text{ndf} \) is rather poor. This modification of the away-side is similar to the di-hadron case in AuAu [4] and probably indicates heavy quark interaction with the dense medium.

Fitting the near-side of the e-h correlation over various trigger \( p_T \) ranges with a PYTHIA simulation (fitting method is described in [10, 11]) one sees equal charm and bottom contribution above 5 GeV/c, Figure 3(a). Combining this with the previously measured \( R_{AA} \) for non-photonic electrons [8, Figure 3(c)] one has

\[ R_{AA}^{\text{non-photonic}} = (1 - r_B) R_{AA}^{e_B} + r_B R_{AA}^{e_D} \]

\[ r_B = \frac{e_B}{e_B + e_D} = \frac{e_B}{e_{\text{non-\gamma}}} \]  

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Figure 1: Non-photonic e-h correlation in AuAu collisions at 200 GeV. Panel (a) shows the correlation before $v_2$ background subtraction and panel (b) after the subtraction, with a dashed fitting curve from PYTHIA pp expectations on the away side. The error bars are statistical, and the error band around zero shows the systematical uncertainty from ZYAM.

Figure 2: Non-photonic e-h correlation in CuCu collisions at 200 GeV. Panel (a) shows the correlation before $v_2$ background subtraction and panel (b) after the subtraction, with a dashed fitting curve from PYTHIA pp expectations on the away side. The error bars are statistical, and the error band around zero shows the systematical uncertainty from ZYAM.

Figure 3 (b) shows the most probable values for $R_{ AA}^{eD}$ and $R_{ AA}^{eB}$ with the dashed line being the 90% confidence limit (taking $R_{ AA}^{eD}$ and $r_{ B}$ uncertainties into consideration). Even if D decay electrons are fully suppressed $R_{ AA}^{eB} < 1$. This indicates B meson yields are suppressed at high $p_t$ in heavy ion collisions presumably due to $b$ quark energy loss in the dense matter [13], modification of the fragmentation process due to the dense medium and/or dissociation/absorption of heavy flavor hadrons in the dense medium during the evolution [14]. From it one can see that electrons
coming from B decays are as suppressed as those from D decays. Models I, II and III are described in [13], [14] and [15] respectively.

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