Non Photonic $e - D^0$ correlations in $p + p$ and $Au + Au$ collisions at $\sqrt{s_{NN}} = 200$ GeV

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Abstract. The sum of charm and beauty in $Au+Au$ collisions at 200 GeV measured through non-photonic electrons, show similar suppression at high $p_T$ as light hadrons, in contrast to expectations based on the dead cone effect. To understand this observation, it is important to separate the charm and beauty components. Non-photonic electron-$D^0$ and electron-hadron azimuthal angular correlations are used to disentangle the contributions from charm and beauty decays. The beauty contribution in $p+p$ collisions at 200 GeV is found to be comparable to charm at $p_T \sim 5.5$ GeV, indicating that beauty may contribute significantly to the non photonic electrons from heavy flavour decays in $Au+Au$ data at high $p_T$. Furthermore, in $Au+Au$ collisions we present the status of $D^0$ meson reconstruction using microvertexing techniques made possible with the addition of the silicon detectors.

Keywords: Relativistic Heavy Ions Collisions, STAR Experiment, Heavy Quark, Energy Loss

PACS: 25.75-q

INTRODUCTION

One of the most important discoveries at RHIC is the quenching of jets traversing the hot and dense matter created in heavy ion collisions. Jet quenching allows for an estimate of the gluon density of the medium. One of the current puzzles at RHIC is the suppression of heavy flavors measured through non-photonic electrons, which is found to be similar to that observed for charged hadrons [1] in contrast to theoretical expectations based on the dead cone effect [2]. Therefore, it is of interest to determine separately the relative contributions from charm and beauty. STAR uses non-photonic electron-$D^0$ and electron-hadron azimuthal angular correlations in order to disentangle the contributions from charm and bottom decays.

ANALYSIS AND RESULTS

One method to disentangle charm and beauty is the measurement of azimuthal angular correlations between non-photonic electrons and charged hadrons in $p+p$ collisions [3]. The width of the near-side correlation function is expected to be larger for the semileptonic decay of beauty compared to charm, due to the larger mass of the $b$ quark. The distributions for charm and beauty meson decays have been obtained from PYTHIA and then simultaneously fitted to the experimental correlation function to obtain the relative contribution of bottom decay as a function of $p_T$ up to $p_T$ of 9 GeV [3].

A second method concerns $e-D^0$ correlations resulting from $c-\overline{c}$ and $b-\overline{b}$ production and decay as shown in fig. 1 (a) and (b) [4]. The branching fraction of charm and beauty
decaying into electrons is about 10%. The electrons from these decays can be selected by the online trigger through their energy deposition in the STAR electromagnetic calorimeter, while the hadronic decay of the $D^0 \rightarrow K^- \pi^+$ can be reconstructed through the $K^- \pi^+$ invariant mass.

Figure 1 illustrates the azimuthal angular correlation of electron and $D^0$ for the unlike-sign electron-kaon (fig. 1, d), and the like sign electron-kaon (fig. 1, c), from a PYTHIA simulation [4]. It is shown that the near-side peak of the like-sign e-K case is dominated by $D^0$ from beauty, while the away-side peak of the like-sign e-K case is dominated by $D^0$ from charm decay (fig. 1, c). The away-side peak of the unlike-sign e-K case is dominated by $D^0$ from beauty (fig. 1, d). Therefore, the azimuthal correlation of $e-D^0$ in combination with the charge-sign requirement allows the separation of charm and beauty components.

Electron identification uses the combined information from the Time Projection Chamber (TPC) the Barrel Electromagnetic calorimeter (BEMC) and the Shower Maximum Detector (SMD). The STAR TPC and the BEMC cover midrapidity ($|\eta| < 1$) and full azimuthal angle. Electrons are identified by applying a momentum dependent cut on the ionization energy loss within the range $3.5 < dE/dx < 5.0$(keV/cm), a cut in the shower profile size, and by requiring the (TPC) momentum to (BEMC) energy ratio to be $0 < p/E < 2$. The electrons have contributions from the signal heavy-flavour decays,
while the main background is electrons from photon conversions, $\pi^0$ and $\eta$ Dalitz decays. To reject the 'photonic electrons' the invariant mass of all $e^+$ and $e^-$ candidates in each event is formed (figure 2 left). The like-sign electron (positron) candidate (red) is superimposed to the unlike-sign pair (black) invariant mass. The crossing point at 150 MeV/$c^2$ indicates the corresponding cut choosen, excluding the electron candidates that form invariant mass below this value. The partner finding efficiency was estimated to be 50% at low $p_T$ and increases to 80% at high $p_T$.

$D^0$ mesons are reconstructed through their hadronic decay $D^0 \rightarrow K^-\pi^+$ (BR=3.89%) (fig. 2 right). Kaons are required to have a $dE/dx$ within $\pm 3\sigma$ from the expected kaon $dE/dx$. The combinatorial background is being calculated by taking into account the like sign pairs invariant mass yield $\sqrt{(K^+\pi^+)\times(K^-\pi^-)}$.

FIGURE 3. Left: $e^-D^0$ azimuthal angular correlations in p+p collisions at 200 GeV (for the like-sign e-K pairs) compared to PYTHIA, scaled by a factor 2.86. Right: Ratio of beauty to the sum of beauty and charm as a function of $p_T$ in p+p collisions at 200 GeV, compared to FONLL calculations. In this analysis no microvertexing technique was used.

Measurements in $p+p$ collisions without micro-vertexing techniques provide a baseline from which to search in Au+Au collisions. Figure 5 left, shows the azimuthal correlation distribution of electrons and $D^0$ mesons in $p+p$ collisions, which exhibit a near- and a away-side correlation peak with similar yields and is compared to a PYTHIA simulation [3].

The relative contribution of beauty to the sum of beauty and charm estimated by the methods of $e^-h$ and $e^-D^0$ azimuthal correlations is shown in figure 3 [3]. The contribution of beauty increases with $p_T$ and becomes 50% at $p_T$ around 5.5 GeV. The data are found to be compatible with FONLL estimates.

In the analysis of Au+Au collisions at 200 GeV we are employing microvertexing techniques, taking advantage of the STAR silicon detectors to improve the S/B ratio for the $D^0$ inv. mass. The Silicon tracker consist of 3 layers of silicon drift detector (SVT) at 6.85, 10.8 and 14.5 cm and one layer of silicon strip detector (SSD) at 23 cm from the beam. The silicon inner tracker of STAR leads to an improvement by an order of magnitude of the resolution of the Distance to Closest Approach (DCA) of charged particles to the Primary Vertex for momentum 1 GeV (figure 4 left) [5].

As a check of the micro-vertexing technique, figure 4 right, shows a preliminary invariant mass plot $K^-\pi^+$ from peripheral Au+Au collisions at 200 GeV. There is a hint of a signal peak in the $D^0$ mass region, after requiring at least one hit in the Silicon inner
SUMMARY AND CONCLUSION

Heavy quarks measured through non photonic electron yields show a larger suppression than expected. To understand this puzzle and understand better the flavour dependence of jet quenching, separation of charm and beauty contributions is important. STAR is using two methods for this purpose, electron-hadron and electron-$D^0$ azimuthal angular distributions. Using these methods it is found that the beauty contribution increases with $p_T$ and becomes comparable to the charm contribution around $p_T \approx 5.5$ GeV in p+p collisions at 200 GeV. The beauty contribution is found to be compatible to FONLL calculations within the uncertainties. The analysis of $D^0$ identification in Au+Au collisions at 200 GeV using microvertexing techniques based on the STAR silicon inner tracker is underway. In the near future the full TOF detector installation in STAR will allow for better particle identification from which charm and beauty searches will benefit considerably. In addition, the future STAR Heavy Flavour Tracker under development is going to improve significantly the momentum resolution and the application of microvertexing techniques for charm and beauty identification and studies.

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