The measurement of non-photonic electrons in STAR

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The measurements of non-photonic electrons, produced by semileptonic decays of D and B mesons, provide information on heavy quarks production as well as hot and dense nuclear matter created in relativistic in heavy ion collisions. In this proceedings we present the recent measurements of non-photonic production in p+p collisions at $\sqrt{s} = 200$ GeV and its suppression in Au+Au at $\sqrt{s_{NN}} = 200$ GeV, and azimuthal anisotropy at $\sqrt{s_{NN}} = 200$ GeV.

International Winter Meeting on Nuclear Physics,
21-25 January 2013
Bormio, Italy

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1. Introduction

Due to their large masses, heavy quarks are produced mainly during initial parton-parton interaction at RHIC, and they are good probes to study QCD matter. Study of heavy flavor production in p+p collisions is a test of the validity of the perturbative QCD. It is also used as a baseline to study the effects of hot and dense nuclear matter on the production of heavy quarks in heavy ion collisions [1]. These hot nuclear matter effects, as well as cold nuclear matter effects, are quantified with nuclear modification factor (R_{AA}). R_{AA} is defined as a ratio of the particle production in nucleus-nucleus collisions to the production in proton-proton collisions, scaled by the average number of binary collisions for a given centrality. R_{AA} can provide information about heavy quark energy loss

At RHIC, heavy quarks could be studied by non-photonic electrons (NPE) measurement, products of semi-leptonic heavy flavor decays or by study of D mesons production [2] [3]. For better understanding of the heavy quark interaction with the medium, it is important to have separate measurements on charm and bottom production. This could be done in p+p collisions via non-photonic electrons and charged hadrons azimuthal correlations, taking into account the fact that near side correlations have different shape for electrons from D and B decays [4]. Measurement of NPE azimuthal anisotropy, especially elliptic flow (v_2), is necessary to distinguish between different energy loss scenarios and can be a good proxy to reveal heavy flavor collectivity, which can improve our understanding of the medium thermalization. In this proceedings we present the recent measurements of NPE production in p+p collisions at $\sqrt{s} = 200$ GeV and its suppression in Au+Au $\sqrt{s} = 200$ GeV, and azimuthal anisotropy at $\sqrt{s_{NN}} = 200$ GeV.

2. Analysis

Data reported in this proceedings were collected in p+p collisions at $\sqrt{s} = 200$, and 500 GeV in the years 2005, 2008, and 2009 with High Tower Triggers (high-pT electron triggers), and in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV in the year 2010 with Minimum Bias Trigger and High Tower Triggers, where Minimum Bias Triggered data were used for $p_T < 2$ GeV/c results while High Tower Triggered data were used for $p_T > 2$ GeV results.

Main detectors used in presented measurements are the Time Projection Chamber (TPC), the main charged particle tracking device in the STAR detector used for particle identification and momentum determination, the Barrel Electromagnetic Calorimeter (BEMC), used for deposited energy measurement, and also as a trigger detector, and the Barrel Shower Maximum Detector (BSMD). Hadron contamination at low p_T was minimized using information from Time Of Flight (ToF) detector. At low-pT, Electron candidates were identified via specific ionization energy loss from the TPC combined with ToF information. Electrons at high-pT are selected using the ratio of track momentum to the energy deposited in the BEMC, the BSMD shower profile, and the distance between TPC track projected position at BEMC and reconstructed BEMC cluster position. The obtained inclusive electron sample includes non-photonic electrons, photonic electrons background, and hadron contamination. Non-photonic electrons yield is calculated as: $N_{NPE} = N_{Inclusive} * \varepsilon_{purity} - N_{PHE}/\varepsilon_{photonic}$, where N_{NPE} is non-photonic electrons yield, $N_{Inclusive}$ represents all electron candidates yield, ε_{purity} is a purity of inclusive electron sample, N_{PHE} is
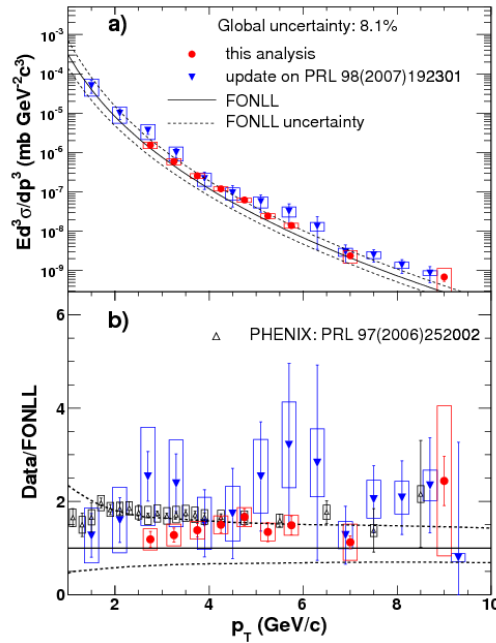
Figure 1: Top: Invariant cross section of non-photonic electrons after combining results from the years 2005 and 2008 (red circles). Taken from [5]. Bottom: The combined data results over FONLL ratio [5] [7].

yield of reconstructed photonic electron background, which mainly comes from photon conversion in the detector material and from Dalitz decay of π^0 and η mesons, and $\varepsilon_{photonic}$ is photonic electron reconstruction efficiency. This efficiency is determined by embedding simulated gammas and pi^0 into real data. The photonic electron reconstruction efficiency is found to be 0.3 - 0.7 and increases with p_T [5].

3. Non-photonic electrons in p+p collisions

Non-photonic electrons spectra were measured in the years 2005 and 2008. In the year 2005 the STAR detector setup included the silicon vertex detector in front of the TPC that led to much more gamma conversion background, and consequently to significantly lower NPE/PHE ratio, where PHE is photonic electron background. Despite of the large difference in photonic background, results from the years 2005 and 2008 agree with each other. After combining both results, the invariant cross section of non-photonic electron production in p+p collisions was obtained and compared with the FONLL calculation [7] - see Figure 1 (up). In Figure 1 (down) the data over FONLL ratio are shown. Data from PHENIX and corrected results from the year 2003 are shown there as well. All these results agree with each other [5] [6].

Non-photonic electrons originate dominantly from semi-leptonic decays of D and B mesons. Due to the different charm and bottom quark mass and consequently different decay kinematics, NPE from these two sources could be separated via charged hadron-NPE azimuthal correlations study. Relative B meson contribution to NPE could be obtained by comparing NPE-hadron correlations from data with PYTHIA calculation (Figure 2 left). Data results were fitted with PYTHIA templates for the charm and bottom part and with combined shape. In Figure 2 (right) the relative

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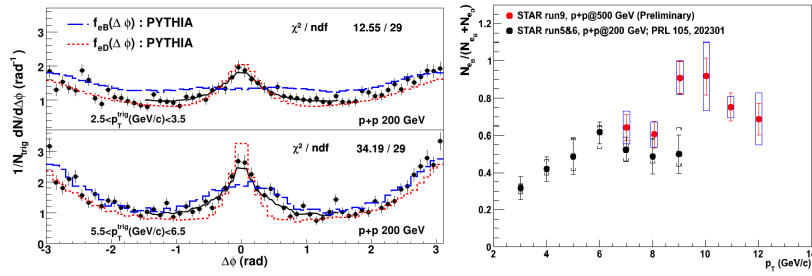
Figure 2: Left: Non-photonic-hadron azimuthal correlations from data in p+p collisions at $\sqrt{s}$=200 GeV (black) compared with PYTHIA simulations of electron(from B/D mesons decays)-hadron correlations (blue dashed and red dotted lines respectively). The black lines are combined fits to the data. Taken from [8]. Right: The relative bottom contribution to NPE electrons in p+p collisions at $\sqrt{s}$=200 GeV (black points), and at $\sqrt{s}$=500 GeV (red points)[8].

B contribution as a function of p_T at $\sqrt{s}$=200 GeV and $\sqrt{s}$=500 GeV is shown. The B decay contribution increases with p_T, and is comparable with the contribution from the D meson decay at p_T higher than 5 GeV/c at $\sqrt{s}$=200 GeV. The ratio of the B contribution to NPE is about 60% for p+p collisions at 500GeV at high p_T. The B contribution is systematically higher at 500 GeV than at 200 GeV in the overlap p_T region.

Using the information of the relative contribution of the bottom to NPE spectra, it is possible to compare the charm as well as the bottom NPE spectra to FONLL calculations. The measured spectra and calculations are consistent [5].
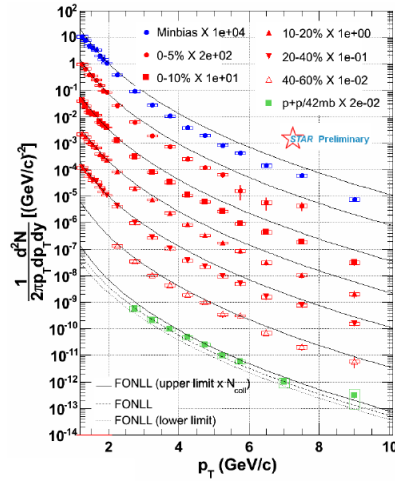
4. Non-photonic electrons in Au+Au collisions

The recent results of non-photonic electron measurements in Au+Au collisions at $\sqrt{s_{NN}}$=200 GeV from the year 2010 are shown in Figures 3 and 4. Figure 3 shows NPE invariant yield in five centrality bins compared with scaled FONLL calculation. The p_T range of results was extended up to 10 GeV/c [10]. The nuclear modification factor (R_{AA}) for 0-10% most central collisions is plotted in Figure 4. For R_{AA} calculation we used p+p results which have been discussed above. Results are compared to a number of theoretical models of energy loss mechanisms [11]-[15]. It is seen that gluon radiation scenario alone (dashed green line) fails to explain large NPE suppression which was observed at high p_T.

Measurements of NPE v_2 in Au+Au collisions at $\sqrt{s_{NN}}$=200 GeV is shown in Figure 5. These results are obtained using 2- ($v_2\{2\}$) and 4- ($v_2\{4\}$) particles correlations and event plane method ($v_2\{EP\}$). All these results are consistent with each other for $p_T < 3$ GeV/c. Finite v_2 at low p_T indicates strong charm-medium interaction. At high p_T we observe increase of v_2 which can arise from jet-like correlations or from path length dependence of heavy quark energy loss.

5. Summary and Outlook

In this proceedings, results of non-photonic electrons measurements in p+p collisions at $\sqrt{s}$=200 GeV and $\sqrt{s_{NN}}$=500 GeV and results of the NPE analysis in Au+Au collisions at $\sqrt{s_{NN}}$=200 GeV from STAR are presented. The preliminary results show large suppression of NPE production

Figure 3: Non-photonic electrons p_T spectra in Au+Au collisions at $\sqrt{s_{NN}}$=200 GeV. Spectrum was divided into 5 centrality bins which are plotted separately. Solid lines represent FONLL calculations scaled by number of binary collisions [10].
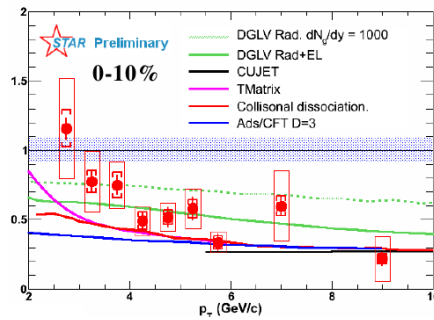
Figure 4: Nuclear modification factor for 0-10% most central collisions compared to theoretical models [11]-[15].
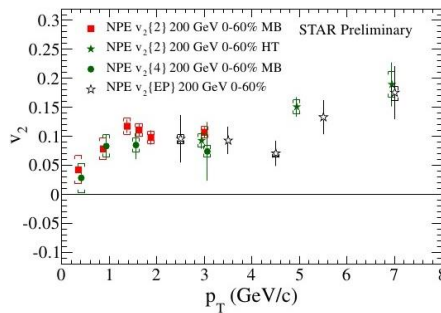
Figure 5: NPE azimuthal anisotropy in Au+Au collisions at $\sqrt{s_{NN}}$=200 GeV [10].

in central Au+Au collisions. This suppression cannnot be explained by gluon radiation scenario alone. Large NPE v_2 was observed at low p_T which indicates a strong charm-medium interaction.

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