The single electron puzzle at RHIC

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We apply the DGLV theory of radiative energy loss to compute single electron suppression in Au+Au collisions at $\sqrt{s} = 200$ AGeV. We show that single electrons in the range $5 < p_T < 10$ GeV are dominated by bottom quark decays rather than the more strongly quenched charm quarks and cannot be neglected in the computation of single electron suppression.

1. Introduction

Recent data [1] from the Relativistic Heavy Ion Collider (RHIC) provide direct evidence that a novel form of strongly interacting Quark Gluon Plasma (sQGP) is created in central Au+Au collisions at $\sqrt{s} = 200$ AGeV [2]. In the near future, measurements of heavy quark jet quenching will provide further important tests of the transport properties of this new form of matter. In particular, heavy quarks are valuable independent probes of the intensity of color field fluctuations in the sQGP because their high mass ($m_c \approx 1.2$ GeV, $m_b \approx 4.75$ GeV) changes the sensitivity of both elastic and inelastic energy loss mechanisms to the medium in a well defined way [3]-[7] relative to those of light quark and gluon jets [8]-[10].

However, one disadvantage of heavy meson tomography is that direct measurements of identified high p_T D and B mesons are very difficult with current detectors and RHIC luminosities [11]. Therefore, the first experimental studies of heavy quark attenuation at RHIC have focused on the attenuation of their single (non-photonic) electron decay products [12]-[15].

A significant complication of heavy quark decay lepton measurements is that, according to estimates in Refs. [16,17], bottom decay leptons may, in fact, dominate those from charm for $p_T > 3$ GeV in pp collisions. Here, we show that jet quenching further amplifies the b contribution to the lepton spectrum and strongly limits the nuclear modification factor of electrons in AA collisions.

2. Theoretical framework

The calculation of the lepton spectrum includes initial heavy quark distributions from perturbative QCD, heavy flavor energy loss, heavy quark fragmentation into hadrons, H_Q, and H_Q decays to leptons (for more details see Ref. [18]).

The initial heavy quark p_T distributions were calculated as in Ref. [19]. We assume the same mass and factorization scales as in Ref. [20], employing the CTEQ6M parton densities [21] with no intrinsic k_T.

As in Ref. [6], we compute heavy flavor suppression using the DGLV generalization [4] of the GLV opacity expansion [8] to heavy quarks. We take multi-gluon fluctuations into account following Ref. [9].

The fragmentation functions, $D(c \to D)$ and $D(b \to B)$, are consistently extracted from e^+e^- data [22–24]. The leptonic decays of D and B mesons are obtained from Refs. [19,25, 26]. The uncertainty in our results due to fragmentation and decay schemes was studied using the corresponding PYTHIA [27] routines and assuming Peterson fragmentation [28] with a range of parameters. In Ref. [18] we showed that these results are robust with respect to the choice of fragmentation and decay schemes.

3. Bottom vs Charm quark suppression

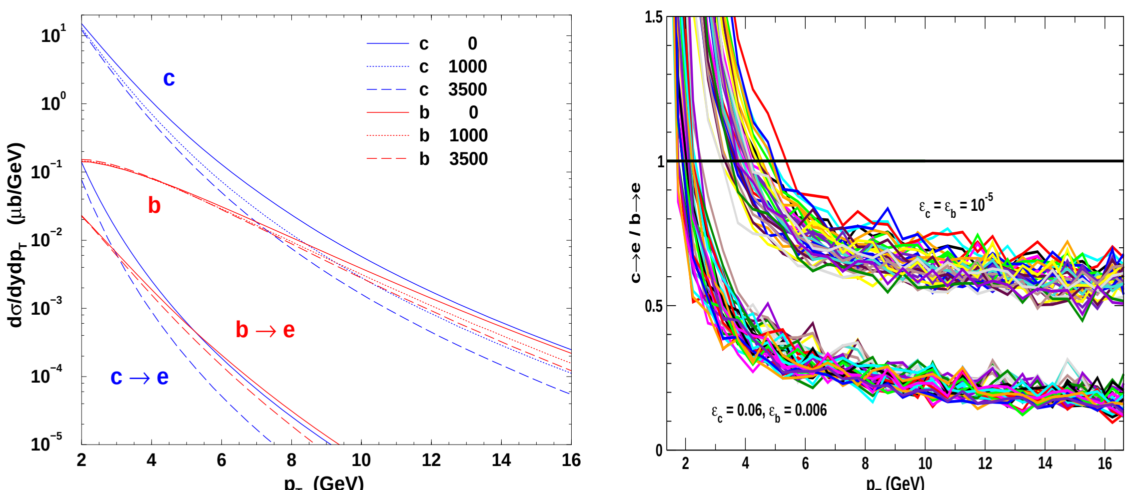

Figure 1. Left-hand side: The differential cross section (per nucleon pair) of charm and bottom quarks calculated to NLO in QCD [19] compared to single electron distributions calculated with the fragmentation and decay scheme of Ref. [19]. The solid, dotted and long dashed curves show the effects of DGLV heavy quark quenching with initial gluon rapidity densities of $dN_g/dy = 0, 1000,$ and 3500, respectively. Right-hand side: The ratio of charm to bottom decays to electrons obtained by varying the quark masses and scale factors. The effect of changing the Peterson function parameters from $\epsilon_c = 0.06$, $\epsilon_b = 0.006$ (lower band) to $\epsilon_c = \epsilon_b = 10^{-5}$ (upper band) is also illustrated.

The left-hand side of Fig. 1 compares the c and b distributions at midrapidity, as well as their contributions to single electrons. We see that single electrons from bottom dominate the single electron spectra at $p_T \sim 5$ GeV for all gluon rapidity densities. This conclusion is further supported by the right-hand side of Fig. 1, where the ratio of charm relative to bottom decays to electrons is shown. We see that, in all cases, the bottom contribution to single electrons is large and cannot be neglected in the computation of single electron suppression.

Within the radiative energy loss scenario we get that, to fit the central (0-10%) PHENIX

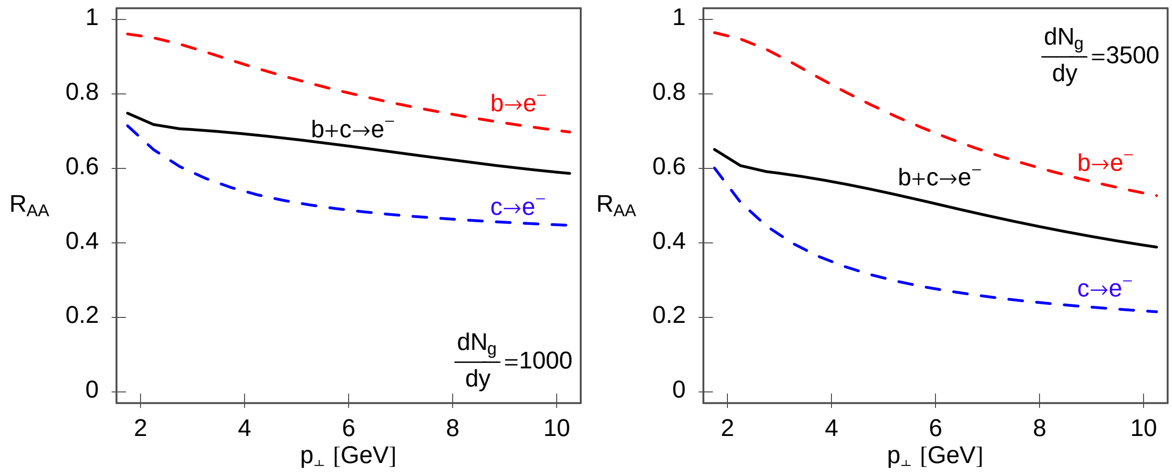

Figure 2. Single electron attenuation pattern for $dN_g/dy = 1000$, left, and $dN_g/dy = 3500$, right. The solid curves employ the fragmentation scheme and lepton decay parameterizations of Ref. [19]. Even for the extreme case on the right, the less quenched b quarks dilute R_{AA} so much that the modification of the combined electron yield from both c and b decays does not fall below $\sim 0.5 - 0.6$ near $p_T \sim 5$ GeV.

data [29], we need a gluon rapidity density in the range $1000 < dN_g/dy < 3500$ (for more details see Ref. [18]). We compute the single electron suppression for the upper and lower limits of this range, shown in Fig. 2. Our primary new observation is that since bottom quenching is greatly reduced relative to charm quenching [18], if heavy quark tomography is performed via single electron suppression patterns, the smaller b quenching strongly limits the possible electron quenching. We also note that taking only the charm contribution to the single electrons with $1000 < dN_g/dy < 3500$, we obtain results similar to Ref. [7], using an effective transport coefficient, $4 \leq \hat{q} \leq 14$ GeV^2/fm. However, the electrons arising from b decay, where there is only a modest amount of quenching, significantly reduce the single electron suppression, leading to $R_{AA}(p_T < 6 \text{ GeV}; e) > 0.5 \pm 0.1$.

4. Conclusions

In these proceedings, we predict the nuclear modification factor of single electrons, $R_{AA}(p_T, m_Q, dN_g/dy)$, produced by fragmentation of quenched charm and bottom quarks in central Au+Au collisions with $\sqrt{s} = 200$ AGeV. We found that within the DGLV theory of radiative energy loss, b quarks give the dominant contribution to $p_T \sim 5$ GeV electrons so that $R_{AA}(e) > 0.5 \pm 0.1$.

We also note that the unrealistically high gluon rapidity density, $dN_g/dy = 3500$, which seem to provide the best fit to the latest preliminary PHENIX π^0 data, suggests that other energy loss mechanisms, such as elastic energy loss, have to be taken into account. Including both radiative and elastic energy loss to obtain the pion and single electron suppression is addressed in Ref. [33].

Acknowledgments: Valuable discussions with Azfar Adil, Brian Cole, John Harris, Barbara Jacak, William Horowitz, Denes Molnar, Thomas Ullrich, Ivan Vitev and Nu Xu are gratefully acknowledged. This work is supported by the Director, Office of Science, Office of High Energy and Nuclear Physics, Division of Nuclear Physics, of the U.S. Department of Energy under Grants No. DE-FG02-93ER40764, DE-AC02-05CH11231.

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