Heavy-Quark Interactions in the Quark-Gluon Plasma and Single-Electron Spectra at RHIC

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Heavy quarks and quarkonia are believed to be valuable probes of the medium produced in ultrarelativistic heavy-ion collisions (URHICs). Recent spectra of semileptonic decay electrons associated with charm and bottom hadrons in Au-Au collisions at the Relativistic Heavy-Ion Collider (RHIC) have shown a surprisingly large suppression (small nuclear modification factor, R_{AA}) [1-3] and elliptic flow (v_2) [4-6], indicating significantly stronger interactions of heavy quarks in the quark-gluon plasma (QGP) than expected within perturbative QCD (pQCD).

To study microscopic reaction mechanisms underlying the behavior of heavy quarks in a strongly interacting QGP (sQGP), we have introduced *D*- and *B*-meson like resonance states [7] mediating elastic rescattering of *c*- and *b*-quarks. Here, we study the consequences of this conjecture for the thermalization and flow of the heavy quarks in the sQGP formed in Au-Au collisions at RHIC, employing a Fokker-Planck approach, followed by a combined quark-coalescence/fragmentation model for the hadronization of the heavy quarks. The resulting transverse-momentum (p_T) spectra and v_2 of the single decay-electrons are confronted with RHIC data [8].

The drag and diffusion coefficients for heavy-quarks, entering the Fokker-Planck equation, are calculated from elastic rescattering off light antiquarks in the sQGP via *D*- and *B*-meson resonances assumed to survive above the critical temperature. This is motivated by recent lattice QCD (lQCD) computations of hadronic correlators and lQCD-based potential models which indicate colorless resonances in both the light- and heavy-quark sector [9]. The resonant Q-$\bar{q}$ cross sections are supplemented with leading-order pQCD elastic scattering [10]. We find that the resulting drag coefficients imply thermalization times which are lower by a factor ~3 compared to pQCD scattering alone [7].

The coefficients are used in a relativistic Langevin simulation for heavy-quark interactions in an isentropically expanding, elliptic QGP fireball corresponding to impact parameter *b*=7fm 200 *A*GeV Au-Au collisions at RHIC. The expansion parameters are adjusted to resemble the time evolution of radial and elliptic flow of the bulk matter in hydrodynamic simulations [11]. The proper thermal equilibrium limit in the Langevin process is implemented via the Hänggi-Klimontovich realization [12], cf. also Ref. [13].

The initial heavy-quark p_T-distributions and the relative magnitude of *c*- and *b*-quark spectra are determined by fitting experimental *D*- and *D**- spectra in d-Au collisions [14] and attributing the missing yield of the corresponding semileptonic electrons [15] at higher p_T to *B*-meson decays. This leads to a cross-section ratio for *b*- and *c*-quark pair production of $4.9 \cdot 10^{-3}$ and a crossing of *D*- and *B*-decay electrons at p_T~5 GeV, in line with expectations from pQCD.

The *c*- and *b*-quark output spectra from the Langevin simulation are subjected to coalescence with light antiquarks following the model of Ref. [16]. Conservation of *c*- and *b*-quark number is ensured by hadronizing unpaired heavy quarks via δ-function fragmentation. Finally, the single-electron spectra are obtained from *D*- and *B*-meson three-body decays. Fig. 1 shows that resonance scattering leads to a substantial decrease in R_{AA} and increase in v_2 compared to elastic pQCD rescattering. While coalescence with light antiquarks amplifies v_2, it also leads to *harder* *D*- and *B*-meson momentum spectra, which increases the electron R_{AA}. The approach to thermalization of *c*-quarks leads to a strong quenching of their electron-decay spectra, entailing that *B*-meson decay contributions become prevalent for electron momenta of p_T >2.5 GeV. This substantially reduces the effects in the single-electron spectra, since *b*-quarks (due to their large mass) are much less affected in the sQGP than *c*-quarks.

In conclusion, resonance formation in the sQGP could play an essential role in understanding current observations on semileptonic single-electron spectra at RHIC. Future calculations should aim at a consistent inclusion of radiative energy-loss which is expected to become the dominant effect at (very) high p_T.

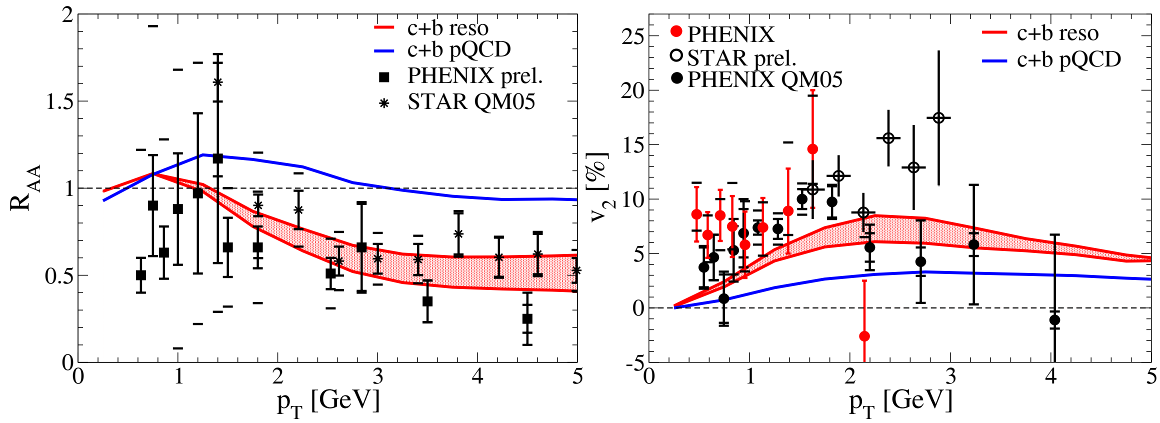

Figure 1. Nuclear Modification factor, R_{AA} (left panel), and elliptic flow, v_2 (right panel), of semileptonic *D*- and *B*-meson decay electrons in *b*=7 fm 200 *A*GeV Au-Au collisions assuming different elastic heavy-quark interactions in the QGP with subsequent hadronization via coalescence and fragmentation, compared to PHENIX and STAR data [1,2,5,6].

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