Charm-Quark Thermalization in the Quark-Gluon Plasma

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Hadrons containing heavy quarks are believed to be valuable probes [1] for the investigation of the properties of the quark-gluon plasma (QGP), the hot and dense state of matter which is apparently created in ultrarelativistic heavy-ion collisions.

In this work [2] we address the interactions of anti-/charm quarks with thermal light anti-/quarks and gluons, which constitute the QGP. The *c*-quark p_T-distributions and elliptic flow, v_2, are believed to be reflected by the corresponding observables of *D*-mesons. Recent experimental data from the Relativistic Heavy-Ion Collider (RHIC) indicate that the v_2 of *D*-mesons is comparable to that of light hadrons [3,4].

As a non-perturbative mechanism for charm-quark thermalization, we have suggested rescattering off partons through mesonic resonances, whose survival in the QGP up to temperatures $T \cong 1-2T_c$ is motivated by pertinent findings from lattice-QCD calculations for light-light and heavy-heavy quark pairs, as well as from Nambu-Jona-Lasinio models for heavy-light mesonic systems.

Here, we use an effective heavy-quark model, which respects chiral and isospin symmetry for the light quarks and includes pseudoscalar *D*-mesons, their scalar chiral partners, D_0^*, and the vector and axialvector mesons, D^* and D_1^*. In the strange-quark sector we only include the pseudoscalar and the vector states since we expect the chiral s-$\bar{s}$ condensate to persist up to temperatures considerably higher than T_c. Within this model, we have calculated drag and diffusion coefficients for elastic *c*-*q* scattering, complemented by perturbative-QCD *c*-*q* and *c*-*g* cross sections, and assessed pertinent thermalization time scales employing a Fokker-Planck equation [5].

The resonance-scattering contribution leads to an equilibration time for charm quarks which is by a factor ~3 lower than with the pQCD cross sections alone, see Fig. 1. For the analogous case of bottom quarks the effect is much smaller due to their higher mass. The equilibration times for *c*-quarks are comparable to the typical lifetime of the QGP fireball, and thus (partial) thermalization becomes likely. Solving the time-dependent Fokker-Planck equation with an initial *c*-quark distribution from PYTHIA indeed shows that including the resonance scattering cross sections leads to a final distribution which is approximately thermal with a temperature of about 290 MeV.

In subsequent (ongoing) work, we use a Langevin simulation for a relativistic Fokker-Planck equation and include asymmetric flow for the QGP medium of light quarks and gluons, supplemented by a coalescence model for the formation of *D*-mesons. It seems that resonance scattering of *c*-quarks leads to p_T-distributions and an elliptic flow (v_2) for the electrons from *D*-meson decays which are compatible with current experimental data at RHIC.

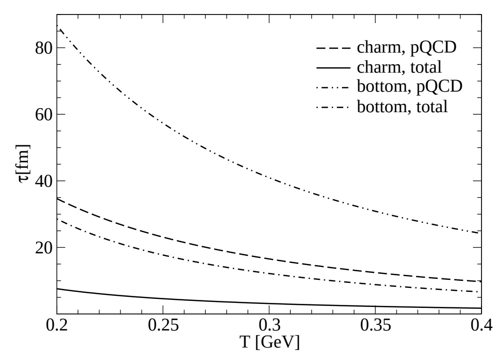

Figure 1: Equilibration times for charm and bottom quarks; the case of using only pQCD cross sections only is compared to a scenario including resonance scattering contributions.

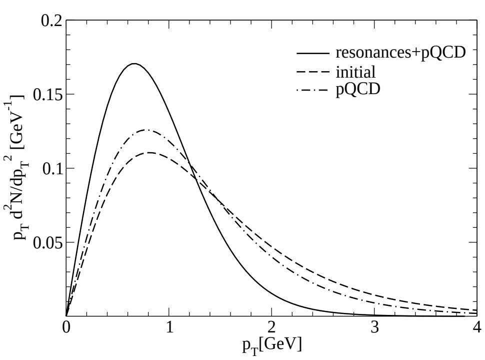

Figure 2: Charm-quark spectra, evaluated within a Fokker-Planck equation, using time-dependent drag and diffusion coefficients with and without resonance scattering contributions.

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