Heavy-quark diffusion and hadronization in quark-gluon plasma

Min He, Rainer J. Fries, and Ralf Rapp

Heavy quarks (charm and bottom) in ultra-relativistic heavy-ion collisions (URHICs), produced in primordial nucleon-nucleon collisions, act as impurities in the subsequently formed quark-gluon plasma (QGP) and are not expected to fully equilibrate with the medium. Due to their large masses, a memory of their interaction history may be preserved, providing a direct probe of the medium properties [1].

In the present work [2], we calculate diffusion and hadronization of heavy quarks in URHICs by implementing the notion of a strongly coupled QGP in both micro- and macroscopic components. The diffusion process is simulated using relativistic Fokker-Planck dynamics for elastic scattering in a hydrodynamic background. The heavy-quark transport coefficients in the medium are obtained from non-perturbative T-matrix interactions which build up resonant correlations close to the transition temperature [3]. The latter also form the basis for hadronization of heavy quarks into heavy-flavor mesons via resonance recombination [4] with light quarks from the medium. This formalism satisfies energy conservation and provides an equilibrium mapping between quark and meson distributions.

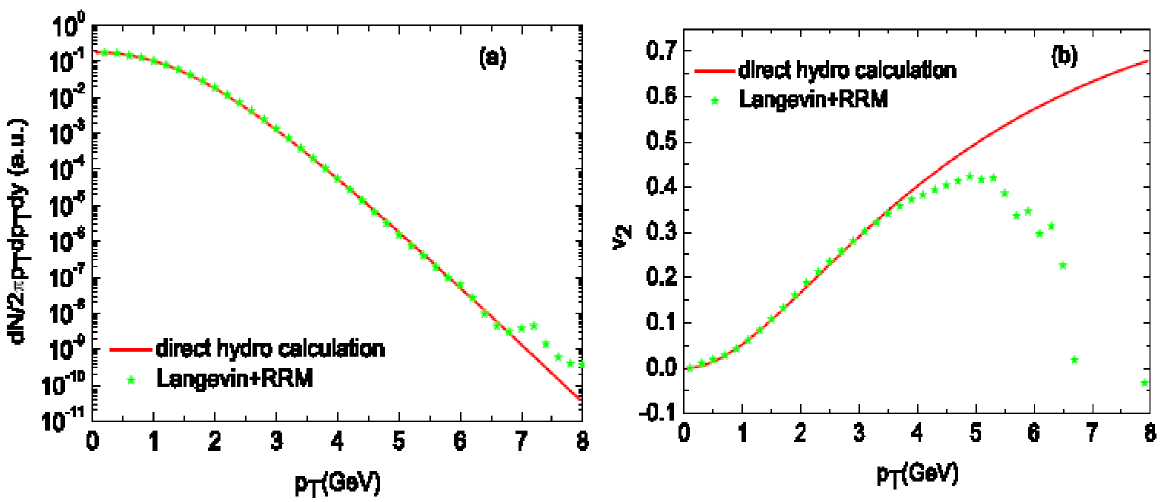

FIG. 1. (a) D-meson p_T -spectrum (stars) calculated from RRM on the hadronization hypersurface applied to charm-quark spectra from hydro+Langevin simulations in the large-drag coefficient limit. It is compared to the D-meson spectrum directly calculated from AZHYDRO on the same hypersurface. (b) Same as in panel (a) but for D-meson elliptic flow.

We first verified the equilibrium mapping (see Fig.1) using charm-quark Langevin diffusion simulations with an artificially large thermal relaxation rate, followed by resonance recombination with light quarks from the hydro medium. In realistic calculations, the relative partition of charm quark hadronization between recombination and independent fragmentation is determined by the coalescence probability based on the charm-quark reaction rate. Consequently, recombination dominates at low transverse momentum (p_T) and yields to fragmentation at high p_T (see Fig. 2). Our resonance recombination model respects kinetic equilibrium and drives D mesons closer to equilibrium as signaled

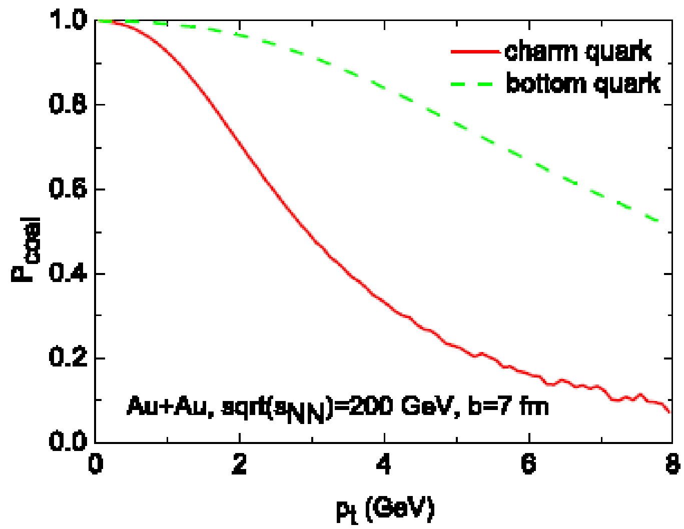

FIG. 2. Charm and bottom quark coalescence probability vs. lab frame transverse momentum.

by the flow bump developing in the nuclear modification factor (see Fig. 3) when going from charm quarks to D mesons.

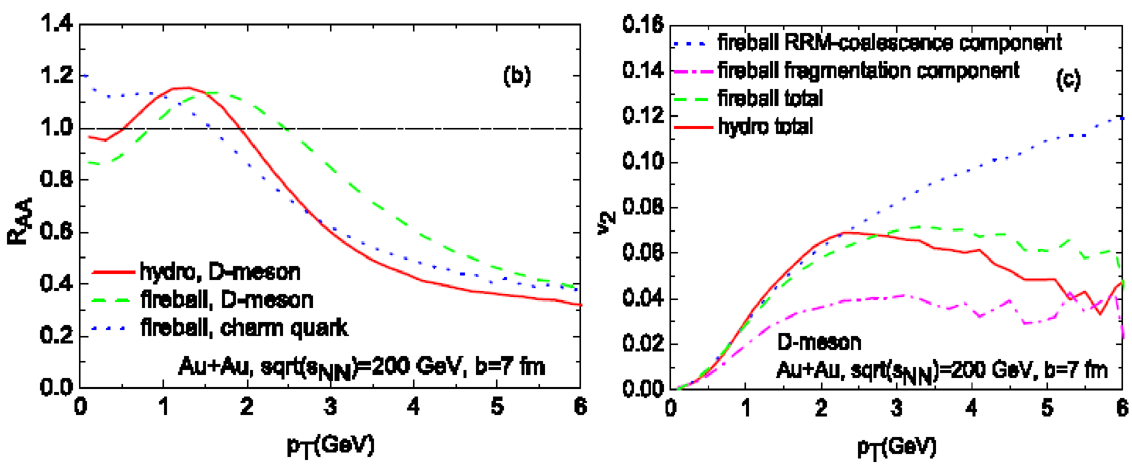

FIG. 3. Comparison of D-meson spectra and v_2 from AZHYDRO and an elliptic fireball with large flow in semi-central (b=7 fm) Au+Au collisions. Left panel: Nuclear modification factor for D-mesons (coalescence + fragmentation) and charm quarks. Right panel: Elliptic flow from coalescence, fragmentation and their weighted sum.

This work represents a further step toward a self-consistent and comprehensive description of open heavy flavor in a strong coupling framework of URHICs.

[1] R. Rapp and H. van Hees, in Quark-Gluon Plasma 4 (edited by R. Hwa and X.N. Wang), (World Scientific, Singapore, 2010), p.111; and LANL eprint arXiv:0903.1096 [hep-ph].

[2] M. He, R.J. Fries and R. Rapp, Phys. Rev. C (in press); arXiv:1106.6006[nucl-th].

[3] F. Riek and R. Rapp, Phys. Rev. C **82**, 035201 (2010).

[4] L. Ravagli anf R. Rapp, Phys. Lett. B **655**, 126 (2007).