Self-consistent evaluation of charm and charmonium properties in the quark-gluon plasma

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Heavy quarks are versatile probes of the medium created in ultrarelativistic heavy-ion collisions. The diffusion of a single heavy quark is sensitive to the transport properties of the medium and the spectrum of heavy quarkonia to Debye screening of the color force in bound-state formation. The large heavy-quark (HQ) mass, $m_Q >> T$, implies that the 4-momentum transfers in these interactions are dominantly spacelike, i.e., potential-like. In Ref. [1] we have constructed a potential-based thermodynamic T-matrix approach to describe HQ diffusion and quarkonia in the quark-gluon plasma (QGP) in a common framework. With input potentials taken from lattice-QCD (lQCD) computations of the HQ free energy and relativistic (kinematic) corrections, a fair description of the vacuum quarkonium and heavy-light meson spectrum can be obtained. Using in-medium HQ free (or internal) energies to calculate heavy-heavy and heavy-light quark T-matrices, one finds that (i) the resulting quarkonium spectral functions are approximately compatible with Euclidean correlation functions computed in lQCD, and (ii) the thermal HQ relaxation time is substantially reduced compared to perturbative calculations.

In the present work [2] we have gone beyond Ref. [1], treating the HQ sector self-consistently by calculating the HQ self-energy from the heavy-light T-matrix and vice versa via numerical iteration. Going beyond the quasiparticle approximation, we also obtain the quarkonium zero modes from applying the Matsubara formalism to the 2-body Q-Qbar Greens function in the T-matrix equation. This enables a parameter-free inclusion of the zero-mode contribution in the Euclidean quarkonium correlators as well as a calculation of the HQ susceptibility which for the first time includes finite-width effects.

In Fig. 1 we compare our result for the correlator ratio in the S-wave charmonium channel (using the internal energy as potential) to unquenched lQCD data, showing fair (albeit not perfect) agreement. The underlying spectral function is characterized by a "melting" of the J/ψ peak at ca. 1.5 T_c. This is somewhat lower than in previous calculations, mostly due to the rather large charm-quarks widths of ca. 200 MeV (the single HQ transport properties are essentially unchanged, with a thermalization time of

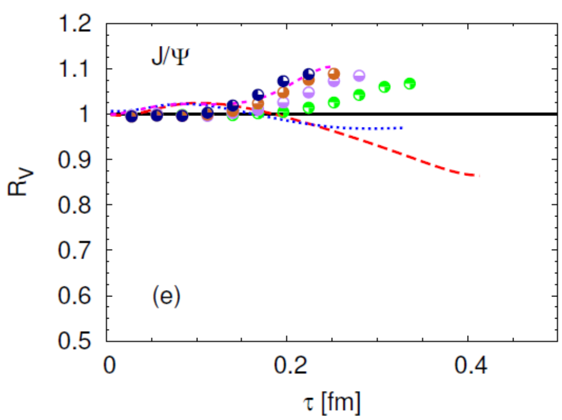

FIG. 1. Euclidean *J/ψ* correlator ratios calculated using the internal energy (U), compared to lQCD "data" [3].

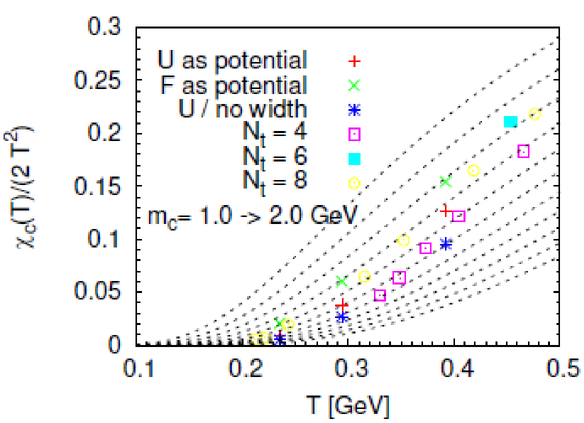

FIG. 2. Heavy-quark susceptibility calculated from the quarkonium zero modes, compared to lQCD computations with different number of Euclidean-fine points, N_t [4].

around 5fm/c). The extraction of the HQ susceptibility, shown in Fig. 2, reiterates the importance of width effects which can compensate for an increase in the HQ mass. Again, the self-consistent results are in fair agreement with thermal lQCD computations.

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

[2] F. Riek and R. Rapp, New J. Phys. **13**, 045007 (2011).

[3] G. Aarts et al., Phys. Rev. D **76**, 094513 (2007).

[4] P. Petreczky, P. Hegde and A. Velytsky, PoS **LAT2009**, 159 (2009).