Nonperturbative heavy-quark interactions in the QGP

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The properties of heavy quarkonia (charmonium and bottomonium) have long been recognized as a useful messenger of quark deconfinement in the Quark-Gluon Plasma (QGP) [1]. More recently, open heavy-flavor particles are utilized to extract transport properties of the QGP by computing their diffusion coefficient [1]. Both phenomena may be closely related [2,3]. The key connection is the large heavy-quark mass, m_Q, implying that for both quarkonia and individual heavy quarks the interactions are dominantly elastic with 3-momentum transfer dominating over energy transfer. This suggests that a potential-type picture is valid, at least for not too large temperatures and densities of the heat bath, T , μ_q $<<$ m_Q. If so, formidable simplifications in the theoretical description arise, allowing for more accurate predictions.

In the present work [2,3], we start from a relativistic Bethe-Salpeter equation which can be simplified into a 3-dimensional Lippmann-Schwinger equation by reducing the energy-transfer variable. A partial-wave expansion yields a 1-D integral equation for the thermodynamic T-matrix, $T = V+VG_2T$, where the input consists of the driving kernel (potential), V, and the intermediate 2-particle propagator, G_2, in the medium. Model-independent guidance for the in-medium potential can be extracted from finite-temperature lattice QCD (lQCD) calculations where the free energy of a heavy quark-antiquark pair is computed with good precision. In the vacuum this quantity coincides with the well-established phenomenological Cornell potential. As a first application of our approach, we use this potential to compute the vacuum spectrum [3]. Fixing the bare heavy-quark mass at $m^0_{c,b}$ ~ 1.3, 4.7 GeV and the constituent light-quark mass at m_q= 0.45 GeV, the empirical quarkonium and heavy-light meson spectra can be reproduced within an accuracy of ~0.1 GeV, which is comparable to the neglected hyperfine splittings (spin-spin interactions). In the medium a currently unresolved ambiguity arises as to whether the free (F) or internal energy (U) should be used as potential ($F=U-TS$; S: entropy). In Fig. 1 we

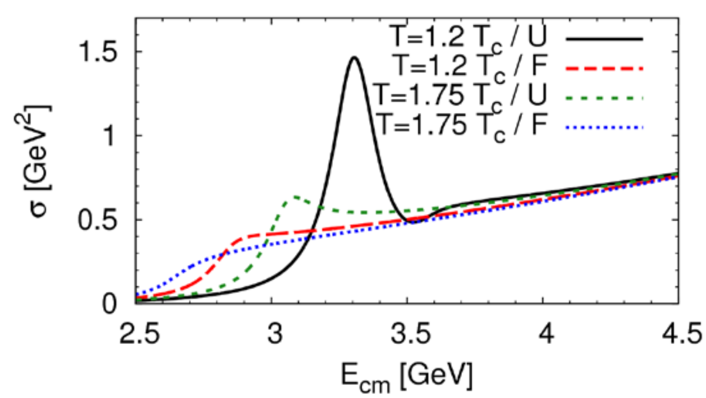

FIG. 1. Charmonium spectral functions calculated using either the internal (U) or the free energy (F).

summarize our results for the in-medium quarkonium spectral functions [3] for both choices and a quark width of 100 MeV (figuring into G_2). The spectral functions turn out to be quite different for the 2 potentials: for *F*, the ground-state charmonium dissolves at a temperature of ~1.2 T_c (T_c ~190MeV: critical temperature), compared to ~1.7 T_c for *U*. The results can be checked by calculating the corresponding correlator ratios in euclidean time and comparing them to lQCD results. For the latter only small variations around one (ca. 10 % at $T=2T_c$) have been found [4,5]. Surprisingly, this behavior is consistent with both our calculations, i.e. using *U* or *F* as potential (see Fig. 2): the rapid melting occurring for *F* is balanced by a smaller in-medium charm-quark mass. Within the same *T*-matrix approach, we can calculate heavy-quark transport properties. It turns out that the stronger interaction provided by *U* leads to a factor of ~2-3 faster thermalization time than for *F*.

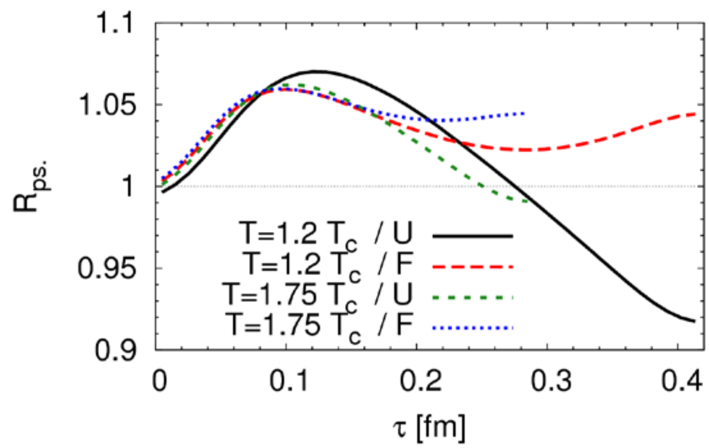

FIG. 2. Euclidian correlator ratios corresponding to the spectral functions shown in Fig. 1.

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