T-matrix analysis of static Wilson line correlators from lattice QCD at finite temperature

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The microscopic description of quark-gluon plasma (QGP), a strongly interacting medium where quarks and gluons are deconfined, is a fundamental objective in studying the phases of matter emerging from Quantum Chromodynamics (QCD). Heavy-flavor (HF) particles, i.e., charm and bottom quarks, are excellent probes for investigating the properties of QGP in ultrarelativistic heavy-ion collisions [1-3]. In particular, the in-medium properties of quarkonia, bound states of heavy quarks and antiquarks, offer unique insights into the QGP because they are closely related to the QCD force [4-6]. Toward this end, recent lattice-QCD (lQCD) studies have provided novel data on the Wilson line correlators (WLCs) (correlation functions of a static quark-antiquark pair) at finite temperature [7], which can be analyzed using theoretical models for the interactions between particles in QGP. It turns out that these lQCD results cannot be described by perturbative approaches [7], calling for non-perturbative methods like the thermodynamic T-matrix approach.

The T-matrix approach is a quantum many-body formalism that enables a self-consistent calculation of 1- and 2-body correlation functions in a strongly coupled QGP [8-10], encompassing both

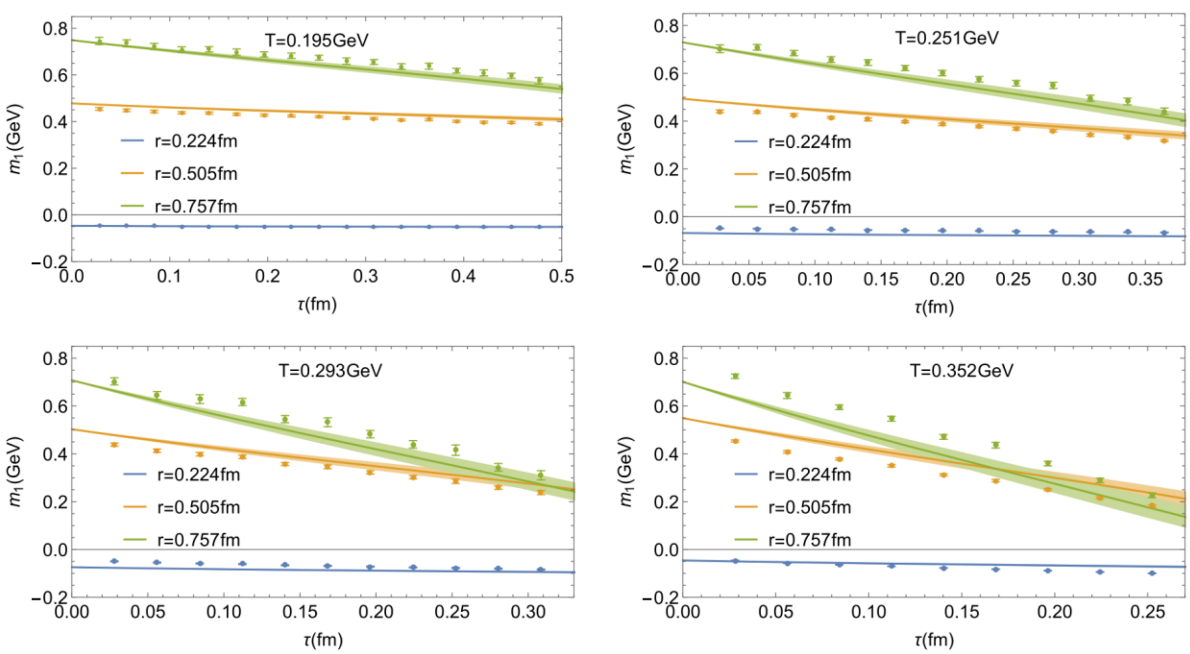

FIG. 1. The first cumulant of WLCs from the self-consistent T-matrix calculations (lines) as a function of imaginary time at different temperatures and distances, compared to the 2+1-flavor lQCD data [7].

bound states and scattering processes. The key input to this approach is the in-medium potential which has been constrained by static heavy-quark (HQ) free energies and Euclidean correlators in previous work [11]. Here we revisit these results using constraints from lQCD data on WLCs and the QGP equation of state [12].

We have found that with an in-medium Cornell potential that is less screened at higher temperatures than previously (specifically for the long-range confining force), one can achieve a good agreement with lQCD data, cf. Fig.1. The underlying in-medium potential, displayed in the left panel of Fig. 2, features remnants of the confining force up to rather large distances. This has significant consequences for the

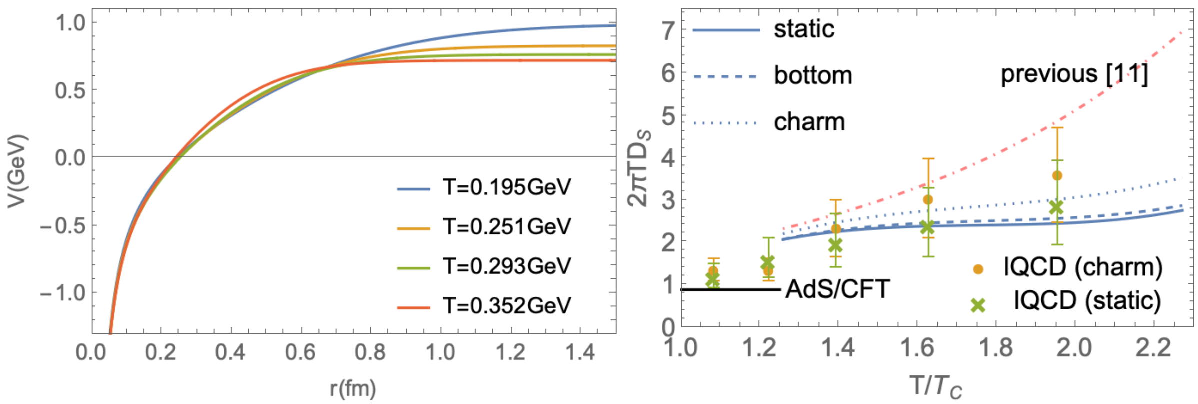

FIG. 2. Left panel: The in-medium potentials used in the T-matrix as a function of distance at different temperatures. Right panel: The spatial diffusion coefficients for charm, bottom and static quarks in comparison with 2+1-flavor lattice data [13,14]. The free energy-based results are from Ref. [11].

thermal relaxation rate, A(ρ,T) of heavy quarks, which shows a stronger temperature dependence than in our previous results based on HQ free energies. On the other hand, the predicted HQ spatial diffusion coefficient, which relates to the zero-momentum limit of the relaxation rate as $D_S = T/(M_Q A(0))$, exhibits a weaker T-dependence, in good agreement with recent lQCD results, cf. right panel in Fig. 2. Applications of these results to phenomenological studies in heavy-ion collisions are underway.

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