Bottomonium properties in QGP from a Lattice-QCD informed T-Matrix approach

Zhanduo Tang, Swagato Mukherjee, Peter Petreczky and Ralf Rapp

Introduction

The microscopic description of the quark-gluon plasma (QGP) as a strongly coupled medium governed by Quantum Chromodynamics (QCD) poses significant theoretical challenges. Heavy-flavor (HF) quarks, i.e., charm and bottom, are ideal probes of the QGP's dynamical properties [1,2]. Quarkonia, bound states of a heavy quark and antiquark, are especially sensitive to the in-medium QCD force, making them key to studying deconfinement and color screening effects [3-6]. Recent lattice-QCD (lQCD) studies using extended meson operators, compared to traditional point operators, have an enhanced sensitivity to in-medium bottomonium modifications [7], providing new opportunities to constrain theoretical approaches. These developments motivate the application of non-perturbative methods such as the thermodynamic T-matrix framework, which self-consistently incorporates realistic interaction potentials and broad spectral functions to describe heavy-quark dynamics in the QGP.

Methods

The T-matrix approach provides a quantum many-body framework for self-consistent calculations of 1- and 2-body correlations in the strongly-coupled QGP [8-10]. Building on previous constraints from the equation of state (EoS) and static Wilson line correlators (WLCs) [11], we now incorporate lQCD results for bottomonium extended-operator correlators (EOCs) to further refine the in-medium potential.

Results

A fair agreement with lQCD data could be achieved for the effective masses of S- and P -wave bottomonia from the EOCs, cf. Fig.1. The inferred in-medium potentials are quite similar to those in our

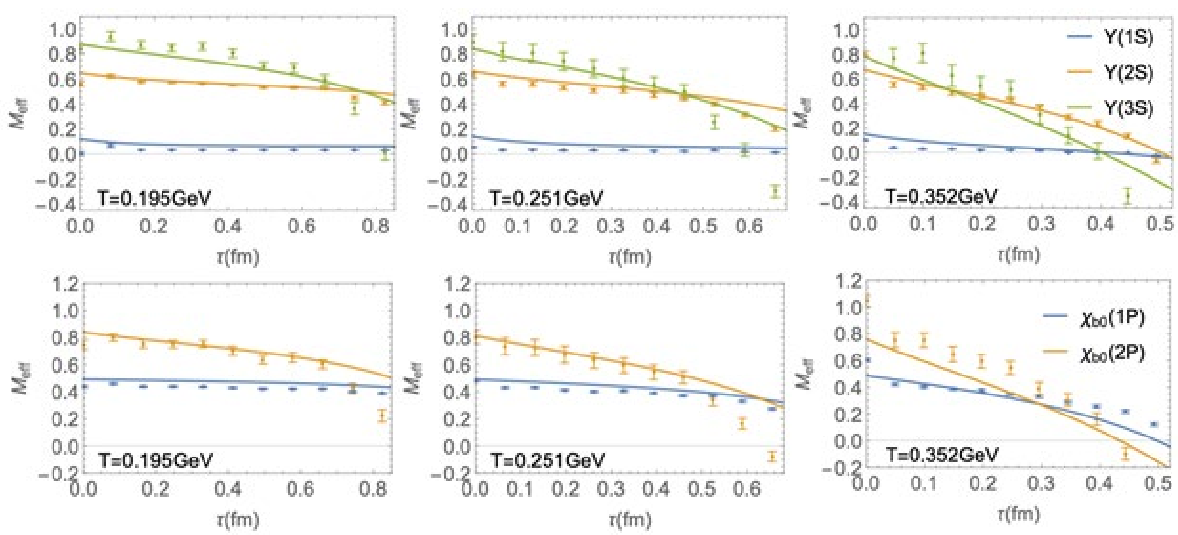

Fig. 1. Effective masses from bottomonia EOCs from the selfconsistent T-matrix (lines) as a function of imaginary time at different temperature for S- (upper) and P-wave (lower) states, compared to 2+1-flavor lQCD data [7] (dots).

previous study where they have been constrained by the QGP EoS and static WLCs only, but interference effects turn out to be more significant when also including the constraints from EOCs, cf. Fig.2. The main

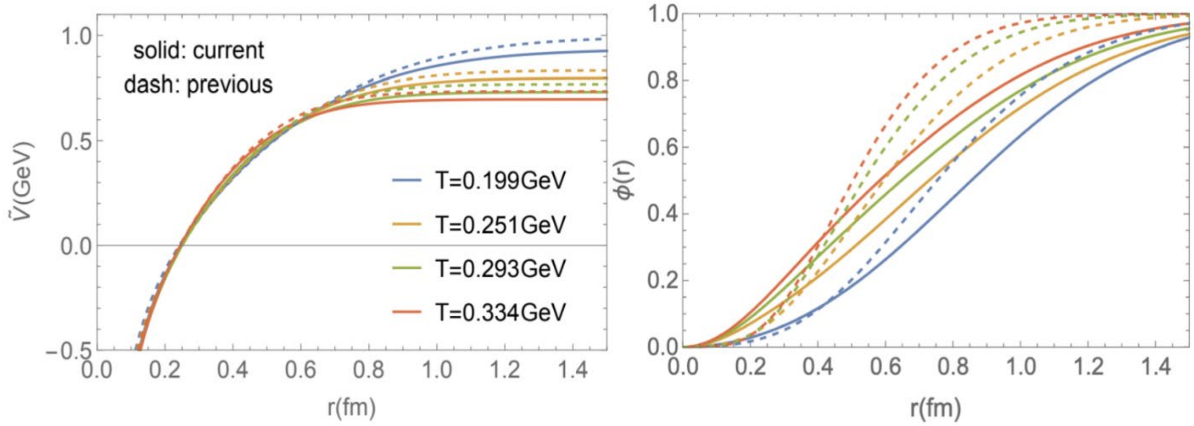

Fig. 2. Left panel: The in-medium potentials used in the T -matrix approach as a function of distance at different temperatures. Right panel: The interference function vs. distance at different temperatures. The free energy-based results (dashed) are from previous study [11].

features for the transport properties from our previous and current studies remain intact: a weak temperature dependence of the predicted spatial diffusion coefficient in fair agreement with recent 2+1-flavor lQCD results, cf. right panel of Fig.3. The thermal relaxation rate (friction coefficient) in the present work is slightly larger at higher temperatures but closely agrees with our previous study at lower ones, cf. left panel of Fig.3.

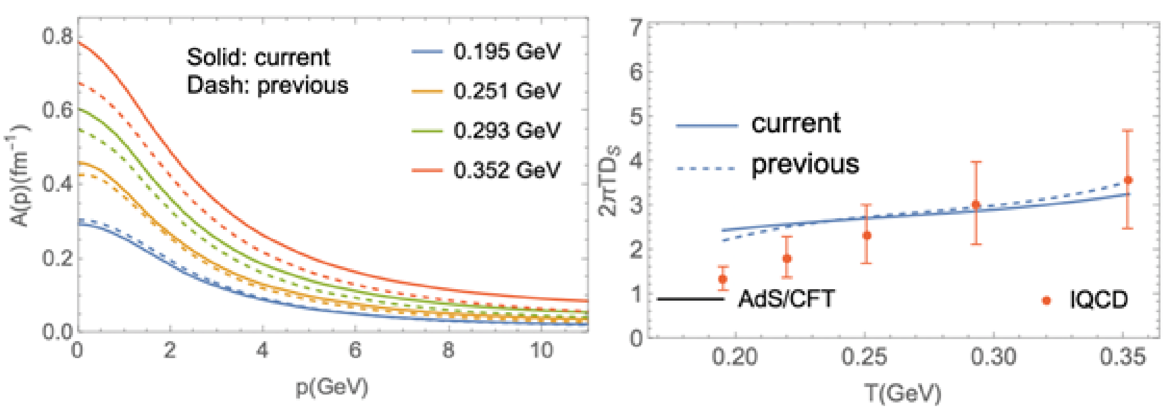

Fig. 3. Left panel: The charm-quark friction coefficients in this and previous studies as a function of 3- momentum at different temperatures. Right panel: The spatial diffusion coefficient for charm quarks as a function of temperature compared to the 2+1-flavor lQCD data [12] (dots). The free energy-based results (dashed) are from previous study [11].

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