Spin-induced interactions and heavy-quark transport in the QGP

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Heavy quarks play an important role in the spectroscopy of hadrons in vacuum and in the study of the quark-gluon plasma (QGP) in ultra-relativistic heavy-ion collisions (URHICs). The former has enabled critical tests of the fundamental potential between a heavy quark and its antiquark. In the latter, open heavy-flavor (HF) particles are a powerful probe of the transport properties of the QGP [1,2], which can be further utilized to investigate the microscopic in-medium force on heavy quarks [3]. In this work, we continue to combine these two areas.

Toward this end we have extended the thermodynamic T-matrix approach [4] to incorporate spin-dependent interactions between heavy quarks, representing $1/M_Q$ corrections (M_Q: heavy-quark mass) [6] which generate hyper/-fine splittings in the vacuum quarkonium spectra. In addition, an admixture of a Lorentz-vector component in the confining potential [5,6] (previously assumed to be scalar), further improved the description of the experimental mass splittings of in S- and P-wave states, especially for the charmonium, see Fig. 1.

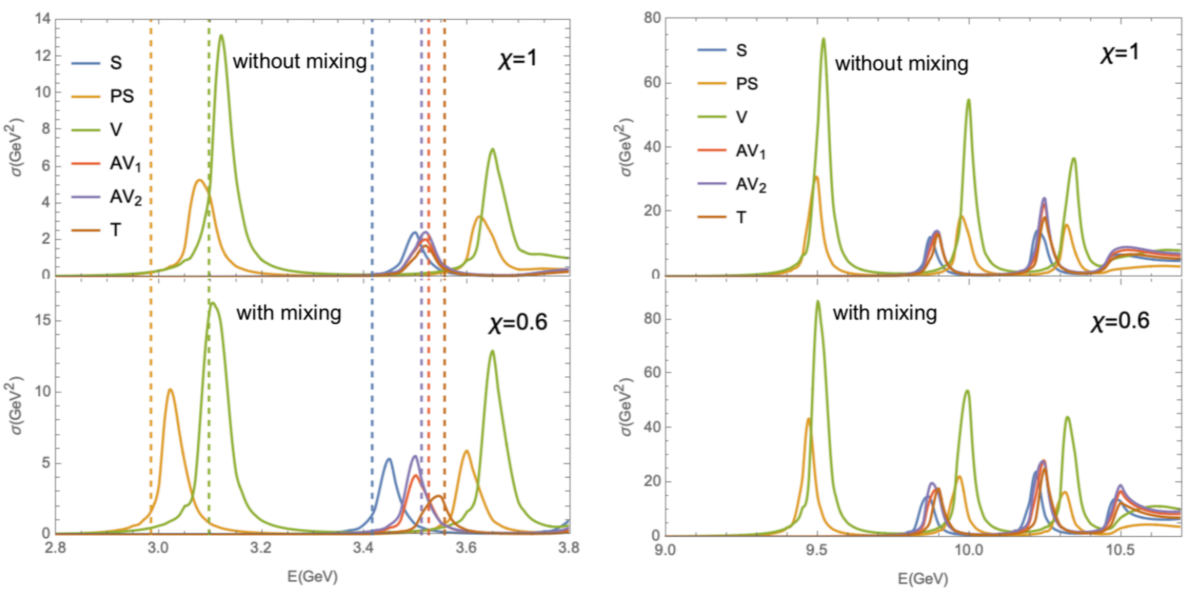

Fig. 1. Left panels: Vacuum charmonium spectral functions in scalar (S), pseudoscalar (PS), vector (V), axial-vector (AV) and tensor (T) channels computed with scalar confining potential ($\chi = 1$) and with mixed confining potential ($\chi = 0.6$). Right panels: Same as in the left panels but for bottomonium. Dashed lines indicate the observed masses.

We then employed the modified interaction to compute the thermal relaxation rate of charm quarks in the QGP. Comparing to the results with a purely scalar confining potential, we find a slightly higher rate at low momenta (which generates a smaller spatial diffusion coefficient, $\mathcal{D}_s$). At larger momenta the relativistic corrections generated by the vector-component of the string interaction produce a substantially larger increase, by a factor of 2-3 or even more, see Fig. 2.

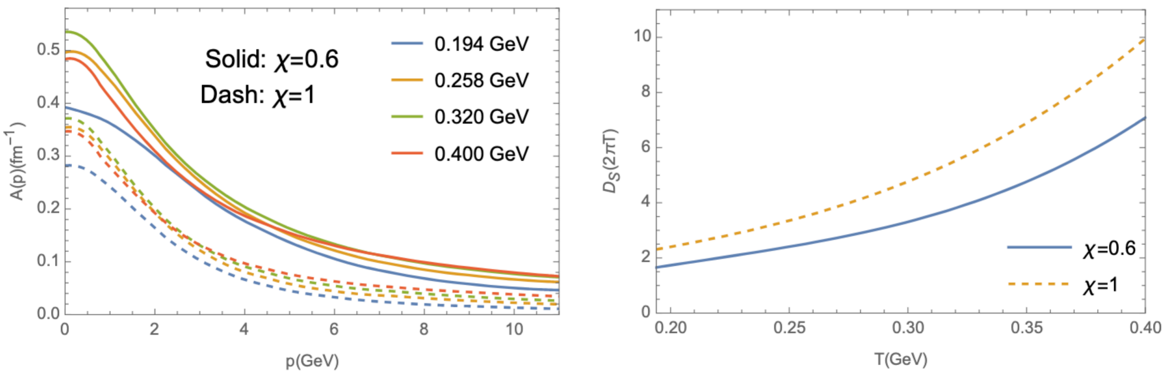

Fig. 2. Thermal relaxation rate of charm quarks vs. 3-momentum at different temperatures (left panel) and spatial diffusion coefficient vs. temperature (right panel); the parameter χ controls the vector admixture in the HQ potential which vanishes for χ=1 (dashed lines) and amounts to 40% for our new results with χ=0.6 (solid lines).

In the future, we plan to deploy our results in relativistic Langevin simulations of HF particles in URHICs. Combining our findings with radiative HQ scattering processes [7] yields transport coefficients that are quite comparable to the ones employed in Ref. [8] where a good description of D, D_s and Λ_c observables at the Relativistic Heavy-Ion Collider (RHIC) and the Large Hadron Collider (LHC) has been achieved. Our results could therefore play an important role in achieving a quantitative description of HF data in URHICs based on microscopically and non-perturbatively calculated transport coefficients.

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