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Transport properties of the strongly interacting quark-gluon plasma

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An understanding of the properties of the quark-gluon plasma (QGP) is important for the interpretation of experimental data on the bulk observables, as well as on jet and heavy-quark attenuation in heavy-ion collisions. However, gaining this knowledge is a challenging task, since it pertains to the non-perturbative regime of QCD, for which only limited information from lattice QCD is currently available.

To overcome these difficulties, we employ the dynamical quasi-particle model (DQPM), which describes the non-perturbative nature of the strongly-interacting QGP at finite temperature and baryon chemical potential based on a propagator representation of massive off-shell quarks and gluons, the properties of which are adjusted to reproduce the lattice QCD equation of state for the QGP in thermodynamic equilibrium. From the DQPM propagators, we can explicitly derive the scattering amplitudes for both elastic ($2 \to 2$) and inelastic ($2 \to 3$) interactions (without resorting to additional approximations), allowing us to investigate not only the properties of the thermalized medium itself, but also jet and heavy-quark energy loss.

In this work, we present several key findings. First, we show how total elastic and radiative cross sections vary with energy and temperature, highlighting the dominance of elastic scattering at low energies and high temperatures, while radiative processes become increasingly relevant at high energies and low temperatures. Second, we obtain the interaction rate and relaxation time in the QGP and show that their values are primarily governed by elastic scatterings. Third, we evaluate the jet transport coefficient $\hat{q}$ and reveal its strong dependencies on the medium temperature, jet momentum and the choice of the strong coupling in thermal, jet-parton, and radiative vertices. We also examine the ratio of $\hat{q}$ to shear viscosity η, identifying regimes in which the commonly used scaling $\eta/s \approx 1.25T^3/\hat{q}$ either holds or is violated. Finally, we obtain the heavy-quark diffusion coefficient and explore its temperature and mass dependencies.

References:

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