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Heavy quark transport in a hybrid Boltzmann + Langevin approach

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Heavy quarks produced in relativistic heavy-ion collisions have proven to be sensitive to the properties of quark-gluon plasma (QGP) through which they propagate. Current measurements of open charm in heavy-ion collisions show unexpectedly large momentum anisotropies and small nuclear modification factors, posing a challenge for the theoretical understanding of the nature of coupling between heavy quark and the medium.

Linearized Boltzmann transport and Langevin diffusion are two popular kinetic models for heavy quark in-medium propagation. However, both of these approaches also suffer from shortcomings, i.e. Langevin diffusion is only fully applicable for heavy quarks experiencing small momenta transfer and vice versa a linearied Boltzmann transport approach with perturbative matrix elements works best in the high momentum transfer limit. In this work, we develop a hybrid heavy quark transport model that combines the strengths of each approach: heavy quarks are evolved with Langevin diffusion using an empirical diffusion constant, while rare but important scattering processes are described using linearized Boltzmann equations with perturbative matrix elements. This Langevin component is a complementary contribution to the Boltzmann component when perturbative calculation may be inadequate to describe all the interactions. Both elastic and inelastic scatterings are included in the Boltzmann component. The Landau-Pomeranchuk-Migdal effect is treated effectively via a gluon formation time and detailed balance is imposed between gluon emission and absorption. Finally, the QGP evolution is obtained by a state-of-the-art relativistic viscous hydrodynamic calculation.

With this hybrid model, we study heavy flavor momentum anisotropies, nuclear modification factor, and correlation observables in A-A collisions at RHIC and LHC energies. Comparing to available D and B meson data, we constrain the diffusion constant of the Langevin component.

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