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Data-driven analysis of the temperature and momentum dependence of the heavy-quark transport coefficient

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Heavy quarks are considered as valuable probes of the quark-gluon plasma (QGP) created in ultra-realistic heavy-ion collisions. However, the simultaneous description of the heavy meson nuclear modification factor R_{AA} and the elliptic flow v_2 poses a significant challenge for most commonly used transport modes, especially those based on Langevin transport. We propose a generalized ansatz for the temperature and momentum dependence of the heavy quark diffusion coefficient and subsequently extract its functional form by calibrating against RHIC and LHC data utilizing a Bayesian model-to-data analysis. Using the extracted transport coefficient, our improved Langevin framework is able to simultaneously reproduce the measured R_{AA} and v_2 at both RHIC and LHC energies.

The Bayesian analysis used to extract the transport coefficient is set up as follows: a set of input parameters, in which the temperature and momentum dependence of the transport coefficient D_s is encapsulated, are evaluated via an event-by-event heavy flavor transport model. In a (2+1)-dimensional viscous hydrodynamical model describes the QCD medium, heavy quarks propagate according to an improved Langevin equation that incorporates both radiative and collisional energy loss. Hadronization of heavy quarks occurs via a hybrid model of fragmentation and recombination. Those model outputs are used to train Gaussian process emulators that mimic the behavior the heavy quark transport model, and act as a fast surrogate of the transport model to interpolate across the full model parameter space. We then calibrate the model parameters on experimental data via a Markov chain Monte Carlo (MCMC) using Bayes' Theorem. The final results of the analysis are the posterior probability distribution of all the model parameters that contain the high likelihood parameters range in which the model describes the data optimally. We find that the transport coefficient D_s has a minimum value around critical temperature, and is comparable to lattice QCD calculation. A non-trivial momentum dependence of D_s is observed as well. With the extracted functional form of the transport coefficients, the R_{AA} and v_2 of heavy quarks in different centralities at 200 GeV AuAu collisions and 2.76/5.02 TeV PbPb collisions are calculated, and observed to be consistent with the experimental data. The result of p-Pb collisions at 5.02 TeV is calculated and compared with experimental data.

Preferred Track

Open Heavy Flavors

Collaboration

Not applicable

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