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Parameterizing the Geometry of the QGP on an Event-by-Event Basis

Ultra-relativistic heavy-ion collisions create a nuclear fireball that serves as a powerful laboratory for probing the frontiers of Quantum Chromodynamics (QCD). In recent years, there has been growing interest in the study of small collision systems—such as proton-proton (pp) and proton-nucleus (pA) interactions—at facilities like RHIC and the LHC. Many of the assumptions underlying the energy loss formalism developed in the Djordjevic-Gyulassy-Levai-Vitev (DGLV) model, break down in these small systems. In this work, we present an extension of the DGLV formalism that specifically accounts for the unique features of small system dynamics. This is achieved by relaxing the large formation time approximation and introducing an additional correction term that accounts for short path lengths in the medium. By relaxing these assumptions, one encounters a more intricate analytic structure for the energy loss, and thus increased computational demands; we address this challenge by developing a novel numerical scheme. Our approach accurately parametrizes the geometry of the quark-gluon plasma (QGP), resulting in a dramatic computational speedup—improving efficiency by up to seven orders of magnitude.

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