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Energy Loss as a Probe of Quark-Gluon Plasma Formation Across Collision System Size

The quark-gluon plasma (QGP) is formed when protons and neutrons melt at temperatures over 100,000 times hotter than the Sun's core. These conditions are achieved in high-energy heavy-ion collisions, such as those involving lead or gold nuclei at the Large Hadron Collider (LHC) and the Relativistic Heavy Ion Collider (RHIC). More recently, signs suggest that small droplets of QGP may also form in rare, high-activity proton-proton and proton-lead collisions. One way to study the QGP is by measuring how much energy high-momentum particles—produced early in the collision—lose to the medium. If QGP forms in small systems, a suppression of high-momentum particles should also be observed; however, there is currently no conclusive evidence of energy loss in small systems. In this work, we use a statistically driven analysis of R_{AA} data from heavy-ion collisions to constrain the effective strong coupling in our energy loss model, which includes corrections for small system sizes. We also quantitatively estimate various theoretical uncertainties to evaluate the robustness of our conclusions. With the model constrained using only large-system data, we make predictions for small systems with no further tuning and compare them to experimental results at RHIC and LHC. We find that high-momentum particle suppression in central small systems is comparable to that in peripheral heavy-ion collisions, consistent with RHIC data and with LHC heavy-ion results—but in stark disagreement with LHC small-system measurements. We show that this equal suppression in peripheral large systems and central small systems holds across a variety of simple energy loss models. We argue that the LHC small-system discrepancy is likely due to event selection biases in the measurements, to which RHIC data are less sensitive.

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