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The Emergence of Hadrons and the Nuclear Force from Color at an EIC[1]

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The formation of hadrons has been successfully parameterized for decades via fragmentation functions, but thus far we have a limited understanding of the non-perturbative physics that gives rise to these functions, and how this physics is connected to QCD confinement. String models and cluster models of the underlying processes have been constrained by hadron distributions measured in a variety of hard collisions, however, little insight has been gained into the femtometer-scale dynamics at play. With the advent of new particle identification technologies, new information about hadronization can now be obtained from semi-inclusive deep inelastic scattering on nuclei by studying the interactions of the struck quark with the nuclear medium, allowing femtometer-scale measurements of the fundamental processes involved to be made for the first time. The modifications of the distributions of the identified hadrons emerging from nuclei of different sizes reveal a rich variety of spatial and temporal characteristics of the hadronization process, including its dependence on spin, flavor, energy, and hadron mass and structure. Fixed-target experiments of this kind at lower energies, pioneered by the HERMES experiment at DESY and now being extended at Jefferson Lab, are laying an important foundation of understanding of the issues involved, however, the ultimate program for exploring the high-energy domain of hadronization will come from the Electron-Ion Collider (EIC). The EIC will feature a wide range of kinematics, allowing a complete investigation of the effective lifetime of the propagation of QCD color charge. The EIC detectors are planned to have excellent particle identification, crucial for studying the flavor dependence of hadron formation. A fundamental process accessed by these studies is medium-induced gluon bremsstrahlung by the propagating quarks, leading to partonic energy loss. This fundamental process, which is also at the heart of jet quenching in heavy ion collisions, can be studied in detail for light quarks and heavy quarks at the EIC through observables quantifying hadron "attenuation" for a variety of hadron species. Fluctuations in the gluonic field of the nucleus may be accessible through the study of the broadening of the transverse momentum of produced hadrons, which has its origin in the quark-gluon interactions in the medium. The evolution of the forming hadrons in the medium may shed new light on the dynamical origins of the forces between hadrons. In this talk, a brief review of the status of this emerging sub-field will be followed by a description of the opportunities for advancement at the EIC.

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