Quark Propagation through Cold QCD Matter

Jefferson Lab Experiment 02-104
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Quantum Chromodynamics (QCD), the theory of the strong interaction, is believed to describe the interactions of quarks and gluons at all energy scales. While well-verified in high energy interactions, at lower energies QCD has not been thoroughly tested. In this regime the strong coupling of the elementary constituents does not permit solution of the QCD equations except through intensive numerical simulations on a grid of space-time points; these simulations are still in their infancy. A major theme of Jefferson Lab's scientific program is to explore systems composed of quarks and gluons in the strong coupling limit, making contact with quark-gluon degrees of freedom to the extent possible.

This experiment is an exploratory foray into understanding propagation of quarks through nuclear systems. Isolated quarks are not in general available for experimental study, since they are bound into multiquark systems through the poorly-understood mechanism of confinement. In electron scattering experiments, kinematic conditions can be selected so that the scattering is predominantly between a virtual photon and a single quark ('deep inelastic scattering,' or DIS). However, the struck quark does not emerge in an isolated condition; instead, it goes through a process called hadronization, where new systems of two and three quarks are created in the region of high energy density associated with the original scattered quark, and only bound systems of quarks ultimately emerge from the interaction point. Several characteristics of the hadronization process have been successfully modeled phenomenologically, such as the distribution of emerging particle types and their energy and angular distributions. However, the understanding of the *space-time characteristics of the hadronization process* is still at a primitive stage, since there are very few constraints provided by experimental data.

New information on the hadronization process can be obtained by implanting it within a nuclear system. The struck quark from a DIS event on a nucleus will evolve into a fully formed hadron after an interval of time. If the formation time is short compared to the time required to exit the nucleus, the hadron will be formed inside the nucleus and will strongly interact with the nuclear medium. If, however, the formation time is much longer than the nuclear transit time, the hadron will be formed outside the nucleus and will not interact with it. Thus, the transparency of nuclei to hadrons produced in DIS can be used to estimate the characteristic time scales of the hadronization process. This provides new information on confinement, a fundamental property of QCD.

A second fundamental property of QCD is *gluon emission from quarks*. Isolated quarks passing through nuclear systems are expected to lose energy through gluon bremsstrahlung as they multiple scatter. This process is predicted to depend strongly on the nuclear temperature and density. The energy loss has been predicted to be manifested by modifications to the energy spectrum of emitted hadrons, as well as by the broadening of the distribution of momentum of the outgoing hadrons. A correlation function between high energy quarks and low energy gluons has also been predicted to be accessible by the momentum broadening.

This experiment consists of a series of measurements comparing hadron production from four nuclei (^{14}N, ^{56}Fe, ^{84}Kr, ^{197}Au) in DIS kinematics to that from deuterium, using the CLAS in Hall B. The attenuation of pions and the broadening of their transverse momentum will be measured as a function of a number of kinematic variables, with very good statistical precision. These measurements will provide greater understanding of the space-time characteristics of hadronization, and the emission of gluons by energetic quarks.