EIC Recommendation Text For The QCD Town Meeting

A high luminosity, high-energy polarized Electron Ion Collider (EIC) is the highest priority of the U.S. QCD community for new construction.

The EIC will, for the first time, precisely image the gluons and sea quarks in the proton and nuclei, resolve completely the proton’s internal structure including the origin of its spin, and explore a new QCD frontier of ultra-dense gluon fields in nuclei at high energy. These advances are made possible by the EIC’s unique capability to collide polarized electrons with polarized protons and light ions at unprecedented luminosity and with heavy nuclei at high energy. EIC will be absolutely essential to maintain U.S. leadership in fundamental nuclear physics research in the coming decades.
EIC: The Two Page Narrative

Atomic nuclei are built from protons and neutrons, which themselves are composed of quarks that are bound together by gluons. Neither quarks nor gluons appear in isolation. Unlike quarks, gluons do not carry an electric charge and are thus not directly visible to electrons, photons, and other common probes of the structure of matter. Gluons’ role in forming the visible matter in the universe remains largely un-understood.

The Electron Ion Collide (EIC) with its unique capability to collide polarized electrons with polarized protons and light ions at unprecedented luminosity, and with heavy nuclei at high energy, will be the first precision microscope to explore how gluons bind quarks to form protons and nuclei at the heart of the visible matter. By precisely imaging gluons and sea quarks inside the proton and nuclei, the EIC will address some of the deepest and most puzzling questions nuclear physicists ask:

- Where are the gluons and sea quarks, and their spins, distributed in space and momentum inside the nucleon? What is the role of the orbital motion of sea quarks and gluons in building the nucleon spin?
- What happens when gluons are packed densely inside a large nucleus? Does the gluon density saturate? Does this mechanism give rise to a universal component of matter in all nuclei, even the proton, when viewed at close to the speed of light?
- How does the nuclear environment affect the distributions of quarks and gluons and their interactions in nuclei? How does nuclear matter respond to a fast moving color charge passing through it? How do quarks dress themselves to become hadrons?

Quantum Chromo-Dynamics (QCD), the gauge theory of the strong interaction, not only determines the structure of hadrons but also provides the fundamental framework to understand the properties and structure of atomic nuclei at all energy scales in the universe. QCD is based on the exchange of massless gauge bosons called gluons between the constituents of hadrons, quarks. Without gluons there would be no protons, no neutrons, and no atomic nuclei. The interactions between gluons and quarks, and among gluons themselves, determine the unique features of the strong interactions. Understanding the interior structure and interactions of nucleons and nuclei in terms of the properties and dynamics of the quarks and gluons as dictated by QCD is thus a fundamental and central goal of modern nuclear physics.

A full understanding of QCD, especially in the regime relevant to the structure and properties of hadrons and nuclei, demands a new era of precision measurements that are capable of probing the structure of these particles in its full complexity. Theoretical advances over the past decade have resulted in the development of a powerful formalism that provides quantitative links between such measurements
and the questions QCD physicists are trying to answer, such as the gluon distribution in the proton, the fraction of the proton spin carried by sea quarks, or the scale at which the gluon density in a heavy nucleus saturates. A second important advance in recent years is the increasing precision and reach of \textit{ab initio} calculations performed with lattice QCD techniques. Using the experimental data from an EIC, physicists will, for the first time, be able to undertake the detailed comparative study between experimental measurements and the predictions made by lattice QCD, as well as elucidate aspects of the structure of hadrons and nuclei that are still beyond the reach of lattice calculations.

The experimental study of how hadrons and nuclei emerge from the laws of QCD is a high scientific priority. Two world-leading facilities in the U.S., CEBAF at Jefferson Lab and RHIC at BNL, are international centers for the study of nuclear QCD. With the increase of its beam energy to 12 GeV, Jefferson Lab operates a unique electron microscope which will precisely and systematically map the structure of protons and other nuclei in the valence quark region, and search for new types of hadrons with yet unobserved structure. In addition to its discovery and continuing exploration of the strongly coupled quark gluon plasma (QGP), RHIC has used its unique capability as a polarized proton collider to make a first direct determination of the contribution of the gluons to the proton’s spin.

A high energy, high luminosity polarized EIC will extend these capabilities to image the transverse momentum and position distributions of quarks and gluons inside fast moving hadrons. The EIC will be a true “QCD Laboratory”, unique of its kind in the world. In addition to providing three-dimensional images of the confined motion of quarks and gluons and their spatial distribution, the EIC will study the way in which gluons interact with each other by splitting and fusing. When hadrons move at nearly the speed of light, the soft gluons contained in their wave functions become experimentally accessible. By colliding electrons with heavy nuclei, the EIC provide access to a conjectured, but so far unconfirmed, regime of matter where abundant gluons dominate its behavior. Such universal cold gluon matter is an emergent phenomenon of QCD dynamics. Its properties and its underlying QCD dynamics are critically important for understanding the dynamical origin of the creation of the QGP from colliding two relativistic heavy ions, and the QGP’s almost perfect liquid behavior.

The EIC was designated in the 2007 Nuclear Physics Long Range Plan as \textit{"embodying the vision for reaching the next QCD frontier"}. In 2013 the NSAC Subcommittee report on Future Scientific Facilities declared an EIC to be \textit{"absolutely essential in its ability to contribute to the world-leading science in the next decade"}. The EIC will extend the current scientific programs at the CEBAF and RHIC in dramatic and fundamentally important ways. Its versatile range of kinematics, beam species and polarization will allow the most central questions to be addressed at a single facility, thereby maintaining U. S. leadership in a central area of fundamental physics research.