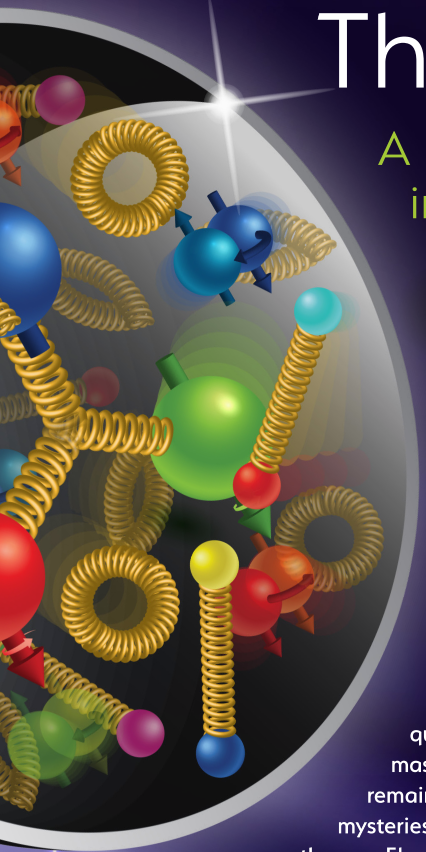
The Electron-Ion Collider

A machine for delving deeper than ever before into the building blocks of matter



Protons and neutrons constitute about 99.9 percent of the mass of the matter we see in the universe, everything from people to planets to stars. Yet nearly a century following their discoveries and after decades of study using particle accelerators and colliders, we still know little about how the internal constituents of protons and neutrons, i.e., quarks and gluons, combine to produce the well-known properties of mass and spin. The role of quarks, antiquarks, and gluons in determining the mass and spin of protons and neutrons remains one of the greatest unsolved mysteries in physics, and for this we need the new Electron-Ion Collider facility.

Quarks themselves have mass and spin but not nearly enough to account for the observed properties in protons or neutrons. Previous experiments suggest that quarks account for a tiny fraction of the mass of a proton and about one third of its spin. These experiments also suggest that gluons, which have no mass themselves, make an outsized contribution to these properties. This is stunning. How do particles of zero mass, when interacting with each other and with the quarks inside a proton, give rise to most of the mass of the visible matter in the universe today?

By observing precisely defined and controlled collisions of very-high-energy ion and electron beams, the proposed Electron-Ion Collider (EIC) will take three-dimensional pictures of the quarks, antiquarks, and the gluons inside individual protons and within atomic nuclei. The EIC also will be able to explore the new frontier of ultra-densely packed gluons inside these particles, with the potential to discover a new form of matter. The proposed EIC would be distinguished from all past, current, and contemplated facilities around the world by enabling high interaction rates with a versatile range of kinematics (particle motion), beam polarizations (alignment of particle spin), and beam species (types of particles collided).

Building an EIC and its research program in the U.S. would strengthen and expand U.S. leadership in physics and stimulate economic benefits well into the future. Just as studies of fundamental particles and forces have driven scientific, technological, and economic advances for the past century—from the discovery of the electrons that power computing and communications devices to the understanding of the structure of the cosmos—the new EIC research will spark innovation and enable widespread technological advances.

Overall, the EIC will:

- Drive development of innovative accelerator, particle detector, and computational technologies, advancing both known and yet-to-be-invented technologies;
- Leverage investments in infrastructure and core expertise at Brookhaven National Laboratory (BNL), Thomas Jefferson National Accelerator Facility (Jefferson Lab), and other DOE National Laboratories, building on decades of pioneering particle accelerator experience; and
- Inspire the next generation of scientific explorers, engineers, and tech-savvy workers needed to address some of our nation's greatest challenges.

In 2015, the Nuclear Science Advisory Committee (NSAC), in its Long Range Plan to advise the Department of Energy and the National Science Foundation, recommended an EIC as the highest priority for new facility construction. A National Academy of Sciences panel is reviewing the scientific opportunities enabled by an EIC and is expected to issue its findings and conclusions in the first half of 2018. Simultaneously, a large physics community—some 700 members from 150 institutions in 28 countries on 6 continents—is energized and working on the scientific and technical challenges. Finally, scientists at BNL and Jefferson Lab are collaborating on strategies and designs for a new facility while optimizing the use of existing infrastructure.

Benefits Beyond Physics

Nuclear physics has produced significant tangential benefits for society:

- Accelerators that deliver particle beams with cell-killing energy directly to tumors
- Radioisotopes for diagnosing heart disease and tracking and treating cancer
- Detector technologies that screen for dangerous substances at borders and ports and for cancers deep inside the human body
- Accelerator technology for manufacturing and studying new materials, including computer chips, electronics, batteries, and pharmaceuticals
- New methods for inspecting and protecting our food supply
- Computational tools for managing "big data" with widespread application
- Facilities for exploring the effects of space radiation to protect future astronauts and spacecraft

Building an EIC will push this field to the next frontier, expanding opportunities for scientific discovery and technological advances.