The Future at RHIC

Upgrades to Enable In-Depth Exploration of Matter, Fundamental Forces

Purpose:

To upgrade the Relativistic Heavy Ion Collider (RHIC) for the in-depth study of quantum chromodynamics (QCD), the theory that describes the interactions of the smallest known components of the atomic nucleus.

Sponsor:

The Office of Nuclear Physics within the U.S. Department of Energy's Office of Science

Total Upgrade Cost:

$ 700 million

Features:

- ten-fold increase in collider luminosity (RHIC II)
- new electron beam (eRHIC)
- upgrades to large-scale STAR and PHENIX detectors
- new detector to complement the ongoing capabilities of existing detectors
- high-end computing capabilities for QCD

Users:

RHIC serves a community of more than 1,000 scientists and students from national and international laboratories, universities, and other research institutions.

- PHENIX: 565 collaborators from 69 institutions and 13 countries
- STAR: 600 collaborators from 58 institutions and 12 countries

www.bnl.gov/rhic

The Relativistic Heavy Ion Collider (RHIC), the world's premiere nuclear physics research facility, has been delivering a steady stream of discoveries since it came online at Brookhaven National Laboratory in 2000. Built and operated with funding from the Office of Nuclear Physics within the U.S. Department of Energy's Office of Science, RHIC gives physicists from the U.S. and around the world a unique tool for exploring the most fundamental forces and properties of matter and the early universe.

Discoveries at RHIC, including the stunning finding that the early universe was a nearly "perfect" liquid, have captured worldwide attention and pointed to U.S. leadership in science. These discoveries have also led to compelling advances in the field of quantum chromodynamics (QCD), the theory that describes the interactions of the smallest known components of the atomic nucleus — the quarks and gluons that make up individual protons and neutrons.

To probe these questions, Brookhaven Lab proposes to upgrade RHIC in several stages. The first stage, enabling a science program known as RHIC-II, is an ongoing effort to increase RHIC's collision rate. Later stages will add a new electron beam, known as eRHIC, and a new detector.

These upgrades would capitalize on the large investment already made in RHIC. They would also exploit the use of new high-end computing facilities installed recently and planned for the future at Brookhaven — computers specifically designed for state-of-the-art QCD calculations. In addition, furthering the scientific program at RHIC will keep this facility at the forefront and complementary to research efforts at CERN, the European laboratory for nuclear and particle physics research.

Compelling science

RHIC's collisions of gold-ion beams have been energetic and intense enough to create, in microcosm, the hot, dense conditions scientists believe existed in the first microseconds of the early universe. Predicted to produce a gaseous plasma of liberated quarks and gluons, these collisions instead produced a nearly "perfect" *liquid*.

RHIC-II, a ten-fold increase in RHIC's luminosity, or collision rate, will enhance scientists' ability to study detailed properties of this perfect liquid.

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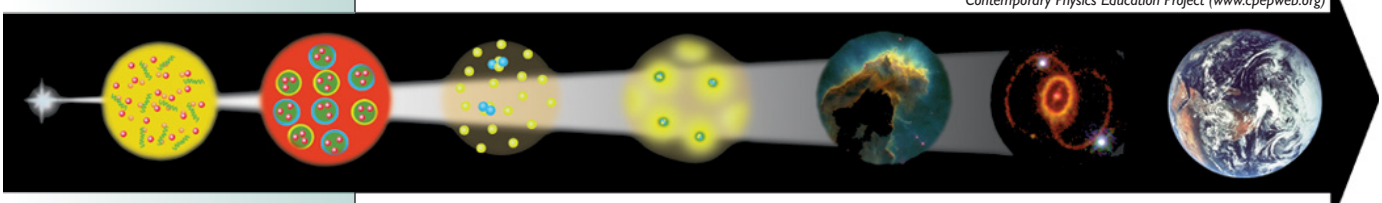
Contemporary Physics Education Project (www.cpepweb.org)



Big Bang | quark-gluon plasma | proton and neutron formation | formation of low-mass nuclei | formation of neutral atoms | dispersion of star formation | dispersion of massive elements | today

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The Future at RHIC (continued)

The RHIC-II luminosity improvement will be accomplished thanks to a technological breakthrough at RHIC that allows information about beam imperfections gathered at one location to beat the light-speed beam to a second location, where the imperfections can be corrected.

The addition of an electron beam, eRHIC, would make RHIC the world's only electron-heavy-ion collider. Smashing heavy nuclei head-on with electrons permits precise imaging of the nucleus at the maximum density attainable by particles subject to the "strong force" — the force that holds the quarks and gluons (and protons and neutrons) within atomic nuclei together. These collisions will give researchers a new window into the workings of this force.

Collision rates at eRHIC may also benefit from beam-correction techniques, including the use of free-electron-laser technology to amplify an image of the imperfections so they can be corrected more efficiently.

Another scientific spin

The RHIC-II and eRHIC upgrades will also benefit another scientific quest: the search for the source of proton spin. Spin is a magnetic property we routinely manipulate to look inside the body with magnetic resonance imaging (MRI), but scientists do not understand the origin of proton spin.

The quarks that make up the proton account for only a small portion of the total spin. So scientists are eager to probe the contributions from gluon spins and quark and gluon orbital motion, which may help account for the "missing" spin. By colliding beams of spin-aligned, or polarized, protons, RHIC allows researchers to probe these factors and gain further insight into the structure and interactions of subatomic particles.

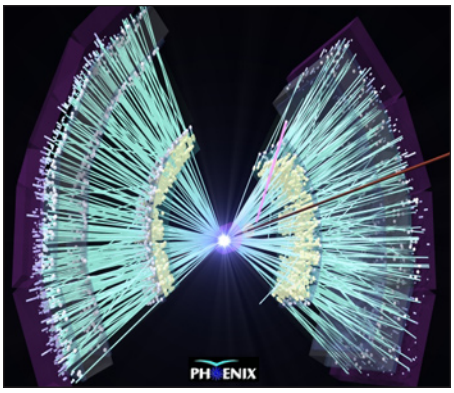
BROOKHAVEN NATIONAL LABORATORY

Sound investment

The U.S. Department of Energy has invested more than $1.1 billion in RHIC — including $600 million for construction of the collider and its detectors. Scientific organizations from 19 other countries have also made and continue to make significant contributions toward the program and operations at RHIC.

Historically, such investments in the scientific exploration of matter have taught us much about the universe. This research has also paid unexpected dividends — strengthening the development of future technologies and the economy. Every day, for example, we use modern technologies such as computers, diagnostic tools, and telecommunications devices that rely on such a basic understanding of matter.

In addition, by helping to train the next generation of physicists, the research at RHIC helps to maintain leadership in scientific endeavors. More than 200 students at the scientific undergraduate, masters, and doctoral levels have received or are now receiving their training at RHIC. This investment in intellectual capital will help the U.S. address current and future technological challenges and reap the economic benefits of these achievements for decades to come.



End view of particles emerging from a collision of two beams of gold ions in the PHENIX detector at the Relativistic Heavy Ion Collider at Brookhaven National Laboratory.