FACTS

The Relativistic Heavy Ion Collider

BROOKHAVEN NATIONAL LABORATORY

Purpose

To move from proof of the existence of quark-gluon plasma to the characterization of this post-Big Bang state of matter and its relationship to the fundamental features of the universe at present

Sponsor

Office of Nuclear Physics, Office of Science, U.S. Department of Energy

Facility-Users

More than 1,000 facility-users from universities, research institutions, and government laboratories in the U.S. and abroad, including:

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Web Address

www.bnl.gov/physics/rhicIIscience

The STAR dector at the Relativistic Heavy Ion Collider, one of two major experiments to be upgraded

RHIC Luminosity Upgrade (RHIC II)

New Capabilities for Studying Matter As It Existed Immediately After the Big Bang

Today, the ultra-high temperatures of the early universe are approachable on Earth — but only inside the largest, highest energy particle accelerators. That is why the Relativistic Heavy Ion Collider (RHIC) was constructed at the U.S. Department of Energy's (DOE's) Brookhaven National Laboratory: to attempt to recreate "quark-gluon plasma," a state of matter that is thought to have existed immediately after the Big Bang.

The Relativistic Heavy Ion Collider at Brookhaven National Laboratory

Following the accelerator-based discovery of quark-gluon plasma, RHIC nuclear physicists will be positioned to look deeply into quark-gluon plasma, to define its characteristics and phase transitions precisely. That is why Brookhaven Lab has proposed upgrading RHIC.

Once the existence of quark-gluon plasma is proven in the lab, the next challenge will be to experiment with this primordial state of matter, with the goal of understanding the fundamental interactions of unbound quarks and gluons.

Quark-Gluon Plasma and the Big Bang

When the universe was less than 10 microseconds old, the constituents of protons and neutrons — called quarks and gluons — did exist, but in a super hot and dense state that physicists call a plasma. At 10 microseconds, the universe became too cold for quarks and gluons to remain in a plasma. Just as water turns to ice as the temperature gets colder, quarks and gluons then combined to form familiar particles such as protons and neutrons, as well as other, more exotic particles.

Since then, quarks and gluons have been inseparable, confined within protons and neutrons of nuclei of atoms. Discovering quark-gluon plasma will not only provide insight into the beginnings of our universe, but will also open a window into the inner workings of the atomic nucleus.

Why Study Quark-Gluon Plasma?

Confirming the existence of quark-gluon plasma will have consequences for our understanding of the universe's evolution, as well as for the origin of elementary matter. While nuclear physicists are looking for evidence of quark-gluon plasma at RHIC, astronomers are hoping to see signs of it in space, for instance, within neutron stars.

More Collisions

To create the environment necessary for quark-gluon plasma, two gold-ion beams traveling in opposite directions at near light speed are collided within RHIC. In doing so, physicists are attempting to "melt" the protons and neutrons within gold-ion nuclei, thereby freeing the quarks and gluons to form the hot, dense matter.

Although RHIC's gold-ion beams are energetic and intense enough for the plasma's discovery and initial exploration, beams of even higher intensity are needed for a detailed examination of rare processes. Increasing the collider's luminosity by a factor of 10 will increase the rate of plasma production and the ability to study rare processes associated with the substance.

Science Endorsements

This year, after examining the science intersecting physics and astronomy, the National Research Council of the National Academy of Science identified the existence of quark-gluon plasma as one of the most pressing research questions to be addressed in this field.

In addition, the science underlying this upgrade received the highest ranking from a future-facilities subcommittee of the Nuclear Science Advisory Committee (NSAC), which reports to DOE's Office of Science and to the National Science Foundation. As NSAC noted in its long-range plan, the cost of the upgrade is incremental compared to the large investment already made in RHIC — while the benefits to science, technology, education, and the nation are significant.

One of the Office of Science's ten national laboratories, Brookhaven National Laboratory is managed and operated for the U.S. Department of Energy, by Brookhaven Science Associates, a company founded by Stony Brook University and Battelle.

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