The Relativistic Heavy Ion Collider

The Relativistic Heavy Ion Collider (RHIC) is a world-class particle accelerator at Brookhaven National Laboratory. At RHIC, physicists are exploring the most fundamental forces and properties of matter and the early universe, with important implications for our understanding of the world around us — from the subatomic to the cosmic, and from the beginning of time to the present and beyond.

Operated with funding from the U.S. Department of Energy's Office of Science, RHIC was designed to recreate a state of matter thought to have existed immediately after the Big Bang, some 13 billion years ago, and to investigate how the proton gets its spin and intrinsic magnetism from its quark and gluon constituents. Large detectors located around the 2.4-mile-circumference accelerator take "snapshots" of collisions between beams of particles — from protons to the nuclei of heavy atoms such as gold — to get a glimpse of the basic constituents of matter.

The promise of RHIC

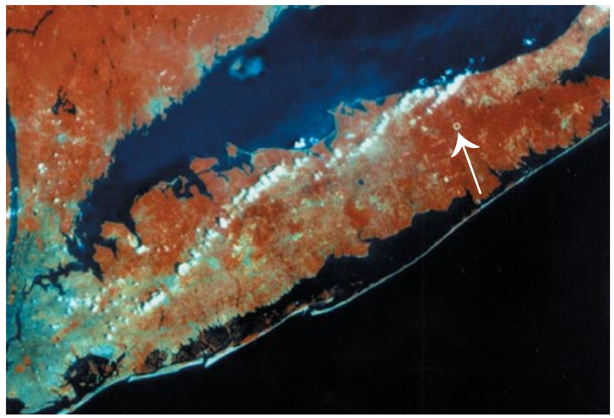
Understanding matter at such a fundamental level will teach us about the forces that hold the universe and everything in it together.

While no one can predict what, if any, practical applications that knowledge will yield, other, earlier physics studies on the basic structure and properties of matter have yielded countless, unforeseen advances and technologies we now take for granted — things like personal computers, medical instruments, and tiny hand-held cellular phones.

The idea behind RHIC is to delve deeper into the mysteries of matter. And in so doing, RHIC has become one of the world's premiere training grounds for young physicists and shone a spotlight on U.S. leadership in science.

Brookhaven National Laboratory

Funded by the U.S. Department of Energy, Brookhaven National Laboratory is a multipurpose research institution located on a 5,300-acre site on Long Island, New York. Six Nobel Prize-winning discoveries have been made at Brookhaven Lab. The Laboratory operates large-scale scientific facilities and performs research in physics, chemistry, biology, medicine, applied science, and advanced technology. Each year, some 5,000 visiting researchers from universities, industry, and other laboratories worldwide take advantage of Brookhaven's unique scientific facilities. Supporting them, and doing their own research in many scientific disciplines, are Brookhaven's core staff of some 2,600 scientists, engineers, technicians, and support personnel.



Satellite photo of Long Island, showing the RHIC ring

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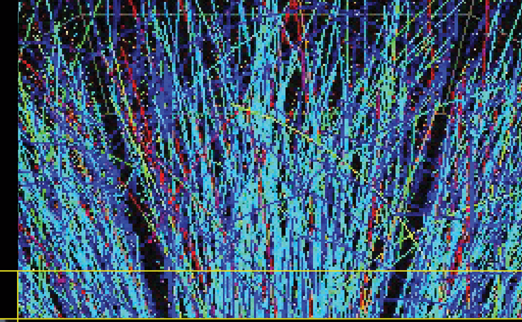
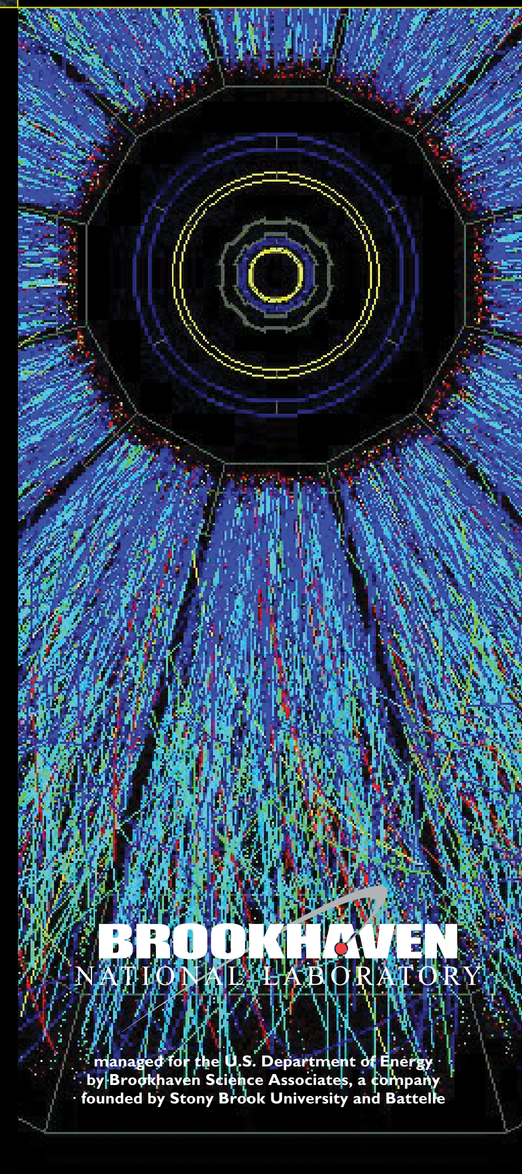
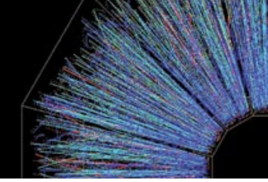


Relativistic Heavy Ion Collider



RHIC

Brookhaven's Relativistic Heavy Ion Collider



A Look Inside RHIC

RHIC's 2.4-mile-circumference tunnel dominates Brookhaven National Laboratory's 5,300-acre campus. Inside the tunnel, two rings of supercold, superpowerful, superconducting magnets guide and focus high-speed packets of "heavy ions" — the nuclei of atoms as heavy as gold — into collisions with one another. The ions travel at energies called "relativistic," because they approach the speed of light.

Superconducting magnets

RHIC's magnets steer the speeding ions into collision at points where the two rings intersect. The temperatures and densities resulting from these collisions are so extreme that they mimic conditions that existed in the first few microseconds of the universe — but only at the scale of a single atomic nucleus.

RHIC's two rings are made of 1,740 superconducting magnets, which focus and steer the beams.

The process of steering beams at such high energy takes a lot of electricity. But the cost of the electricity at RHIC has been greatly reduced because the magnets are made of superconducting materials. When cooled to extremely cold temperatures — just above absolute zero — superconducting materials lose all resistance to electricity, so electricity flows freely.

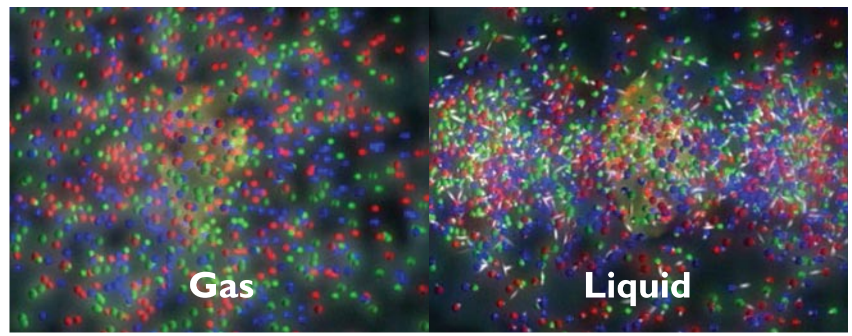
A Perfect Surprise

Already, RHIC research has captured worldwide attention with an astonishing surprise: Scientists at RHIC had expected collisions between two beams of gold nuclei to pack enough energy and matter into a tiny space to produce a *gas* of free quarks and gluons. But instead of behaving like a gas, the matter created in RHIC's energetic gold-gold collisions appears to be more like a *liquid* — a "perfect" liquid with virtually no viscosity, or frictional resistance to flow.

Moving forward

The stunning surprise that the early-universe matter created at RHIC behaves more like a liquid than a gas has enriched physicists' understanding of quantum chromodynamics (QCD), the theory that describes the interactions of the smallest known components of the atomic nucleus. But it has also raised compelling new questions.

These questions have prompted the need for the enhancement of RHIC to further the study of QCD. To address these questions, key improvements are planned for the RHIC facility. As part of a symbiotic research program using Brookhaven's supercomputers, these upgrades will create a new QCD laboratory at RHIC unlike any research center in the world.



RHIC scientists had expected a uniformly expanding gas of particles, with little or no interactions (left). Instead they observed asymmetric expansion and very strong interactions - suggesting that the early universe was a nearly frictionless liquid (right).

RHIC-II and eRHIC

A near-term upgrade, known as RHIC-II, will increase the machine's collision rate and improve the sensitivity of the detectors to reveal detailed characteristics of the new form of matter.

A longer-term upgrade, known as eRHIC, would add a high-energy electron beam to collide with polarized proton beams or heavy ion beams at RHIC. With this powerful added dimension, physicists expect to probe another new form of matter locked deep inside ordinary nuclei, and further expand our ability to explore the newest and most intriguing questions about the substructure of the world around us.

Detectors — The Eyes of RHIC

Four very different detectors — STAR, PHENIX, PHOBOS, and BRAHMS — have helped physicists analyze the particle collisions at RHIC. STAR and PHENIX remain operational. Like giant 3-D digital cameras, these detectors electronically record the results of collisions at RHIC, seeking insight into what happens when the quarks that make up ordinary protons and neutrons — and the gluons that hold them together— are liberated from their confinement inside atomic nuclei.

The STAR detector tracks and analyzes thousands of particles, such as protons, neutrons, and pions, that may be produced in each collision inside the detector — as seen in the cover image. STAR stands for Solenoidal Tracker at RHIC.

The PHENIX detector examines entities such as photons, electrons, and muons, in addition to the particles tracked by STAR. PHENIX stands for Pioneering High-Energy Nuclear Interacting Experiment.