BROOKHAVEN
NATIONAL
LABORATORY

Relativistic Heavy Ion Collider (RHIC)

Purpose

To study the fundamental properties of matter from elementary atomic particles to the evolution of the universe

Sponsor

U.S. Department of Energy's Office of Nuclear Physics

Replacement Cost

More than $2 billion

Operating Costs

$190 million per year (FY 2019)

Features

- Two intersecting rings in a tunnel
- 2.4 miles in circumference
- 1,740 superconducting magnets
- Detectors: STAR, sPHENIX (under construction)

Users

More than 1,000 per year from national and international laboratories, universities, and other research institutions

- More than 670 on STAR
- 150 continue PHENIX data analysis
- 300 working on sPHENIX upgrade

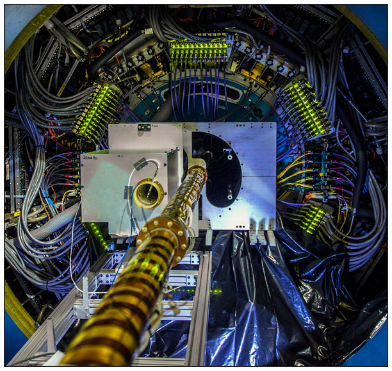
www.bnl.gov/rhic

BROOKHAVEN NATIONAL LABORATORY

Relativistic Heavy Ion Collider

The Relativistic Heavy Ion Collider (RHIC) is the world's premiere research facility for exploring the building blocks of visible matter as they existed at the dawn of time, and for unlocking the secrets of proton spin.

The Science



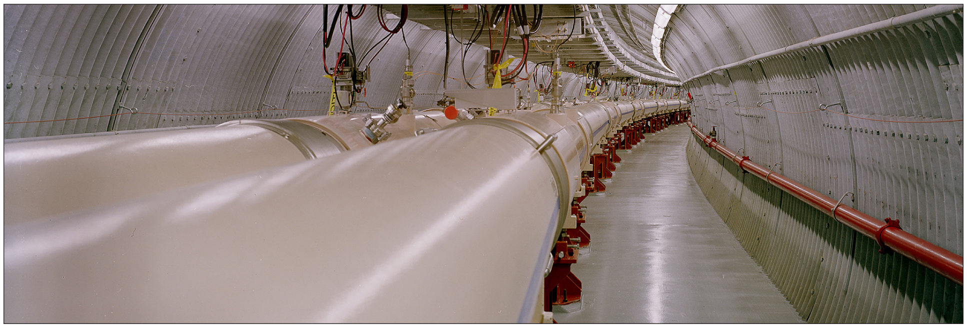
RHIC, a U.S. Department of Energy Office of Science user facility for nuclear physics research, accelerates heavy ions (atoms of heavy elements, such as gold, stripped of their electrons) to very high energies, and smashes them into one another to mimic the hot, dense conditions of the very early universe. These collisions "melt" the atoms' protons and neutrons to release their inner building blocks—quarks and gluons.

RHIC experiments reveal that the resulting "quark-gluon plasma" is 250,000 times hotter than the center of the sun, and behaves as a nearly perfect liquid—not a gas, as scientists had predicted. Physicists use RHIC to study this extraordinary plasma over a wide range of conditions to understand its remarkable properties, as well as how it transforms into the familiar particles that make up the visible matter of today's world.

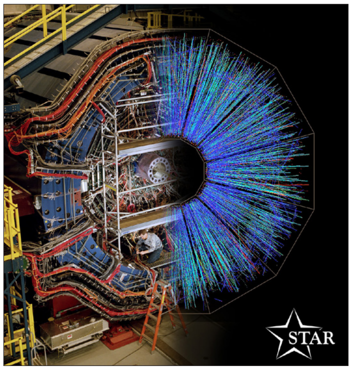
RHIC physicists also accelerate and collide polarized protons—protons with their intrinsic "spins" aligned—to learn how quarks and gluons contribute to this essential property. Proton spin makes magnetic resonance imaging possible, but how it arises from the proton's inner building blocks is an unsolved puzzle.

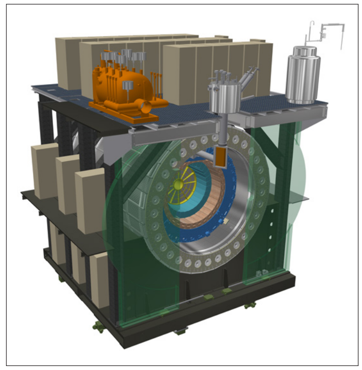
The Machine

RHIC is two accelerators in one—made of crisscrossing rings of superconducting magnets, enclosed in a tunnel 2.4 miles in circumference. In each ring, beams of heavy ions or protons are accelerated to nearly the speed of light in opposite directions, guided by powerful magnetic fields. The particles can collide at six points around the circles where RHIC's two rings intersect. Thousands of collisions take place every second, each producing a spray of thousands of subatomic particles.



Currently, one house-sized detector, STAR (near right), collects the collision products, providing physicists worldwide with data about the microscopic structure of the ion interactions and conditions at different energies. A second large detector, PHENIX, is undergoing a transformation to sPHENIX (far right), which will track jets of particles interacting with the plasma to help reveal its structure.

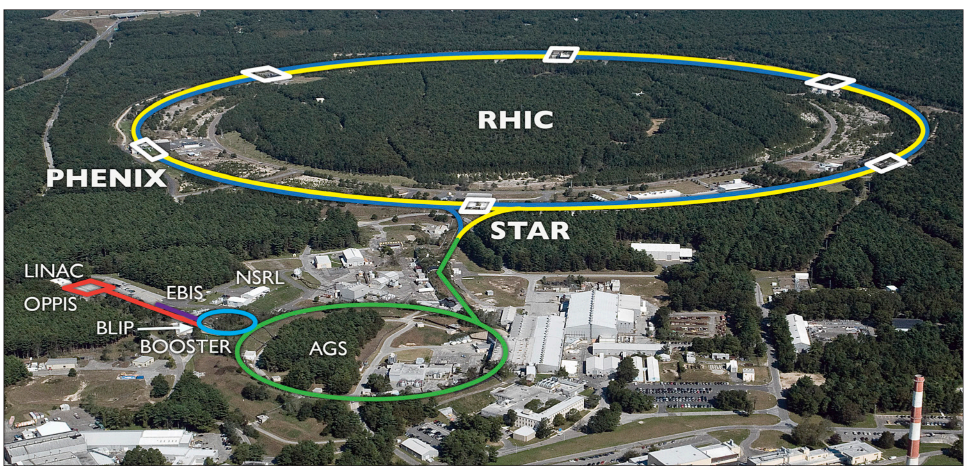




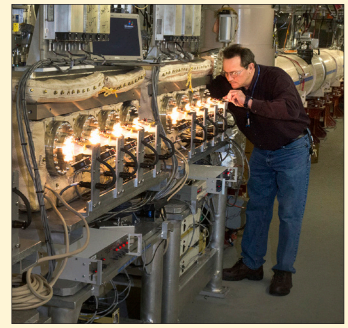
Accelerator Chain

RHIC is fed by a "chain" of accelerators at Brookhaven Lab. Beams of particles begin their journeys in the Electron Beam Ion Source (EBIS) or Optically Pumped Polarized Ion Source (OPPIS). They then travel into the small, circular Booster, then on to the Alternating Gradient Synchrotron (AGS), which injects them into the two rings of RHIC. At each stage, the beams get a "kick up" in energy from powerful radio waves. Once accelerated to full energy, the beams can circulate in RHIC's rings for many hours.

This same accelerator chain also feeds beams to the NASA Space Radiation Laboratory (NSRL), where scientists conduct research that will help protect future astronauts, and the Brookhaven Linac Isotope Producer (BLIP), where researchers make crucial medical isotopes that are used to diagnose and treat diseases such as cancer.



The Future



Accelerator and detector upgrades and innovative beam-cooling technologies have continuously improved RHIC's performance, increasing collision rates and data production far beyond the original design. Scientists are using these advanced capabilities to explore compelling questions raised by RHIC's early discoveries.

Work continues on the state-of-the-art sPHENIX detector, expected to begin operating in 2023. A longer-term proposal would add a high-energy electron ring to transform RHIC to an Electron-Ion Collider (eRHIC). This one-of-a-kind facility would open a new frontier in the exploration of the substructure of the world around us.

U.S. DEPARTMENT OF ENERGY | Office of Science