

The Case for Continuing RHIC Operations

The Relativistic Heavy Ion Collider (RHIC) — the nation's only remaining particle collider, located at Brookhaven National Laboratory — has made a series of landmark discoveries and continuing breakthroughs in science and technology. One major accomplishment has been RHIC's ability to recreate and study in detail a type of matter that last existed at the beginning of the universe to better understand the strongest force in nature — the force that holds together the fundamental particles that make up 99 percent of visible matter in the universe today, everything from stars to planets to people. In addition to giving us a new way to explore and understand the nature of the early universe and the force that holds together ordinary matter, research at RHIC has revealed stunning connections to other seemingly unrelated areas, including string theory, condensed matter physics, and high-temperature superconductivity.

This widespread impact has attracted worldwide acclaim and substantial financial and intellectual investments, not just within the U.S., but from international collaborators as well. It has also inspired students whose training at RHIC benefits the entire nation as they go on to apply their expertise in a range of fields in and beyond physics — for example, in teaching, computing, national security, and medicine. As the only operating

collider in the U.S., RHIC therefore serves as a vital national resource for cutting-edge discovery, accelerator science and engineering R&D, future workforce development, and continued U.S. leadership — not just in physics but in science and technology in general. If we lose that leadership, we risk losing a key driver of the economic and technological advancement that has made this great nation the envy of the world.

Significant discoveries

At RHIC, scientists have recreated the extreme temperatures of the early universe — 250,000 times hotter than the center of the sun. Surprisingly, this early universe matter behaves like a nearly friction-free liquid. In this hot soup, ordinary matter “melts,” temporarily liberating normally inseparable particles called quarks and gluons so that they are relatively free to roam and interact as they did before the universe cooled to form the stuff that surrounds us today. Yet even with incredibly low viscosity, this quark-gluon plasma (QGP) can stop energetic subatomic particles in their tracks. These unusual properties suggest that the particle interactions in QGP may be similar to and offer insight into surprising behavior observed in more conventional condensed matter systems, such as superconductors and quantum spin liquids. There are also hints that RHIC’s quark soup may offer clues about why the early universe had more matter than antimatter — an imbalance essential to the very existence of the universe today.

Compelling questions

RHIC’s discoveries raise a number of deeper questions: What does the transition from hot quark soup to ordinary matter look like? How do the properties of the plasma evolve with temperature? How does the matter reach such a high temperature so rapidly with quarks and gluons behaving collectively? Are the hints that offer clues to the matter/antimatter imbalance in the early universe real? Do they persist in the hot, dense environment? Key measurements and comparisons will help answer these questions and connect what we’re learning at RHIC to our understanding of the early universe and its evolution to its present form. The search for answers may also expand our understanding of other kinds of matter we hope to make

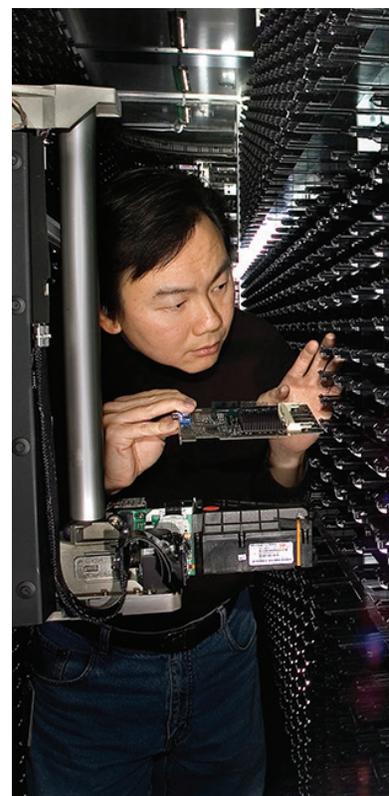
use of in today’s world, such as high-temperature superconductors.

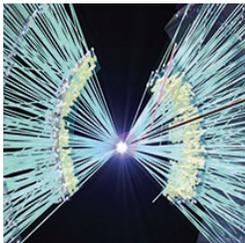
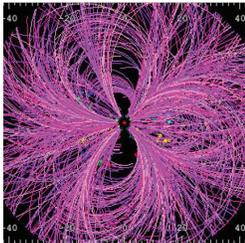
Technological breakthroughs

Recently completed upgrades place RHIC in an ideal position to answer these questions. Accelerator upgrades have dramatically increased the rate of particle collisions to 20 times the machine’s original design. This achievement was completed at one-seventh the cost and five years sooner than originally projected. Upgrades to the detectors that track and analyze collision results have further improved performance. A new beam injector broadens the range of ion types that can be accelerated at RHIC — and also enables collisions between different types — at the wide range of energies needed to explore the transition between ordinary matter and the quark-gluon plasma of the early universe.

Complementarity with LHC

The exploration of early universe matter at RHIC is complementary with a much more limited heavy-ion program at the Large Hadron Collider (LHC) in Europe. Though the LHC operates at higher energy, it cannot reach the lower energies where some of the most interesting phenomena appear, including the crucial transition between quark-gluon plasma and ordinary matter. Physicists from both facilities agree that the combined energy range of RHIC and the LHC is needed to fully explore and understand how critical properties emerge and change with temperature. Indeed, RHIC is in the energy “sweet spot” for exploring the QGP transition, and has unique capabilities for addressing some of the most compelling questions. LHC’s heavy ion program is secondary to its focus on High Energy Particle Physics, occupying a relatively small percentage of running time. RHIC is dedicated to exploring quark-gluon matter.





Spin mystery

RHIC is the only collider in the world that can accelerate and collide beams of protons with their “spins” (analogous to an axis of rotation) aligned in a chosen direction. This unique capability is essential for exploring how gluons contribute to a proton’s overall spin. This intrinsic property is put to use in magnetic resonance imaging (MRI) every day, but it still remains one of the biggest mysteries in physics because the individual quarks that make up a proton account for only a small fraction of its total spin. RHIC’s polarized proton collisions are starting to reveal that gluons play a significant role. Further explorations at a future Electron-Ion Collider (EIC) would play a crucial role in resolving this mystery.

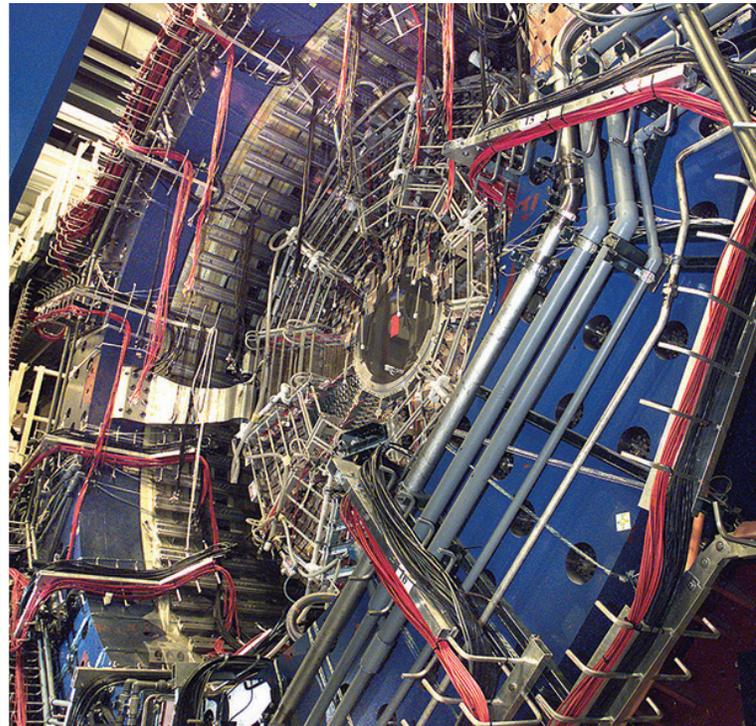
Path forward

RHIC provides the U.S. Nuclear Physics community with a cost-realizable path to building a future Electron-Ion Collider (EIC) — judged by many to be

the next important priority for the U.S. Nuclear Physics community. Adding an electron ring inside the existing RHIC tunnel would provide a staged path forward by making use of much of the existing RHIC accelerator and detector infrastructure. An EIC would allow both the intense study of how gluons contribute to proton spin, and also a deeper exploration of how gluon fields contribute to the properties of the quark-gluon plasma.

Tangential benefits

The RHIC facility and accelerator physics program also bring important ancillary benefits to society: Beams from the RHIC pre-injectors are used to produce medical radioisotopes for the diagnosis and treatment of disease; through a program funded by NASA, these beams are also used to study radiation hazards of deep space travel; RHIC accelerator physicists are working with industry to develop next-generation cancer therapy facilities;



high-temperature superconducting magnet technology developed in part for accelerating beams at RHIC is being adapted for use in energy storage systems; a high-current electron accelerator needed for EIC has potential defense applications; the computing capacity, techniques, and expertise developed to manage large volumes of data generated by RHIC experiments could be applied to a wide range of fields that require data-intensive computing—from astrophysics, to climate modeling, protein studies for drug development, and even finance.

What's at stake

Past investments at RHIC have produced a strong record of payoffs in terms of science and tangential benefits. It would be unwise for the U.S. to consider unilaterally ceding leadership in this emerging subfield of physics. Shutting down RHIC would lead to a devastating loss of U.S. scientific leadership and an important resource for workforce development. It would be unlikely for the funding “saved” to be made available

for construction of new projects at other laboratories. A more sensible approach would be to find creative ways to fully exploit the resources that have been built up by past investments, as long as they are still operating at full efficiency. This strategy forms the basis of the leading conclusion in a recent National Research Council report on the current status and future of Nuclear Physics. The RHIC science program remains vibrant and highly productive, with a well-defined vision and promise of discoveries for both the short- and long-term future. RHIC and the Brookhaven National Laboratory staff who operate it are too important a resource for the U.S. Nuclear Physics community, the DOE Office of Science, and our nation to lose.



Research at RHIC is funded primarily by the U.S. Department of Energy's Office of Science, and also by the agencies and organizations listed here:
<http://www.bnl.gov/rhic/funding.asp>.

For more information, see:
www.bnl.gov/rhic

Or contact:
Berndt Mueller
Brookhaven National Laboratory
Associate Laboratory Director
for Nuclear and Particle Physics
631-344-5397
bmuller@bnl.gov