RHIC: Dazzling Discoveries, Bright Future

Research at RHIC is a compelling, ongoing exploration of the fundamental properties of matter and the infant universe. By looking back to a time before protons and neutrons existed, we can study nature’s strongest force — which holds everything from those fundamental particles to stars, planets, and people together — and delve into mysteries such as why the stuff around us even exists and how the universe evolved. This endeavor:

- **Captivates worldwide attention** and ignites public imagination
- **Draws researchers** from around the globe
- **Showcases U.S. leadership** in science
- **Inspires and trains** next-generation scientists and innovators
- **Provides cutting-edge technological advances** and expertise for fields from medicine to national security

**Compelling discoveries**
- First facility to clearly see the transition to quark-gluon matter
- “Perfect” liquid nature of the early universe, markedly different from the anticipated ideal gas
- Heaviest antimatter nucleus ever detected, likely to stand for foreseeable future
- “Bubbles” in which matter appears to violate fundamental symmetries
- Temperatures reaching ~ 4 trillion degrees Celsius, substantially above the predicted melting temperature of neutrons and protons
- First indication of gluon saturation
- First measurements of significant gluon contribution to “missing” proton spin
- First evidence of how properties change above and below transition from early universe quark-gluon plasma to ordinary nuclear matter
- Important contributions to “jet physics”

**Vibrant future**
Rate of discovery increasing due to cost-effective, ongoing upgrades
- 10-fold increase in collision rates achieved by exploiting accelerator technology breakthroughs made at RHIC, for a total cost of ~$10M (saving ~$100M vis-à-vis originally anticipated technology)
- Ion source upgrade (EBIS) expands range of ions available and enhances cost-effectiveness of operations
- Ongoing incremental detector upgrades greatly improve precision and sensitivity to rare processes

**Future research directions enabled by upgrades and versatility**
- Quantitative characterization of the early-universe matter
- Confirmation/refutation of symmetry-violating bubble prediction
- Search for a unique critical point (“continental divide”) at which quark matter coalesces, or freezes out, to form protons, neutrons, and all other ordinary matter

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How does the force between quarks change inside dense quark-gluon matter

Scientifically compelling path to long-range future (eRHIC) is fueled by additional accelerator science breakthroughs being pursued at RHIC

Strong productivity
> 350 refereed papers with > 35,000 citations
> 350 Ph.D.s in first 12 years, hundreds more in the pipeline

Internationally competitive
- Hits the “sweet spot” for detailed study of matter at the threshold of the universe due to extensive energy and ion species flexibility
- Dedicated primarily to heavy ion collisions (unlike LHC, where focus is high-energy physics)
- World’s only spin-polarized proton collider
- The only operating collider facility in the U.S.
- Major foreign investments, especially from Japan
- More than 1000 international collaborators

Benefits beyond physics
- Production of medical radioisotopes for heart scans and cancer diagnosis/treatment
- Beams used to study effects of space radiation, with strong NASA support
- Major accelerator technology breakthroughs that advance physics and other areas of science as well as cancer treatment systems
- R&D to advance energy-storage systems using superconducting magnets (ARPA-E and Army funding)
- R&D on accelerator technology with possible defense applications (ONR funding) in addition to relevance for discovery science at a future proposed electron-ion collider at RHIC (eRHIC)
- Accelerator technologies that could drive future, safer nuclear reactors
- Advances in computing and “big data” management and analysis applicable to many fields
- Supports ~850 BNL staff (including indirects) and > 1000 international scientific users

For more information about RHIC, go to www.bnl.gov/rhic.