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REACTIONS

FROM THE AMERICAN NUCLEAR SOCIETY TO TEACHERS INTERESTED IN THE NUCLEAR SCIENCES

What Was the Universe Like Immediately After the Big Bang?

How RHIC Will Help Expand Physicists' Knowledge

Wanting to know more — about ourselves, our universe, and our place in it — is a human characteristic. Humankind's ongoing search for knowledge about our origins and the origins of our universe has stimulated a great deal of scientific research over the centuries.

Now, scientists using Brookhaven National Laboratory's Relativistic Heavy Ion Collider (RHIC) hope to gather information that will provide clues to what the universe was like at the beginning of time. The results of their experiments are expected to help physicists better explain fundamental properties of matter, from the tiniest subatomic particles to the largest stars.

The RHIC was designed to create under laboratory conditions the state of the universe just a tiny fraction of a second after the Big Bang. Using the RHIC, about 1,000 physicists from around the world are expected to participate in this research.

RHIC - An Overview

The RHIC consists of two crisscrossing rings of superconducting magnets in a tunnel which is 2.4 miles in circumference. The RHIC utilizes several BNL accelerator devices that are linked together to produce and accelerate beams of heavy ions (gold ions) or polarized protons to 99.995 percent the speed of light. The two crisscrossing beams of high-speed particles circle the RHIC in opposite directions, their paths intersecting at six places. Over 1,700 superconducting magnets steer the beams of particles and cause them to collide. Specially constructed detectors gather data about the collisions.

RHIC – A Sequence of Events

Particles to be collided in the RHIC begin their journey in one of two places. The Tandem Van de Graaff accelerator strips electrons from atoms of gold, creating positively charged heavy ions. Or, a linear accelerator produces polarized protons.

The ions or protons travel to a small circular Booster where they are accelerated to higher speed and energy. Next, the particles travel to the Alternating Gradient Synchrotron (AGS) which speeds up the particles even further and injects the particle beams into the RHIC rings. In the RHIC, the particles get a final speed boost from highly focused radio waves. The particle beams travel around the RHIC ring, some clockwise and some counter clockwise, at nearly the speed of light, "surfing" on the magnetic field

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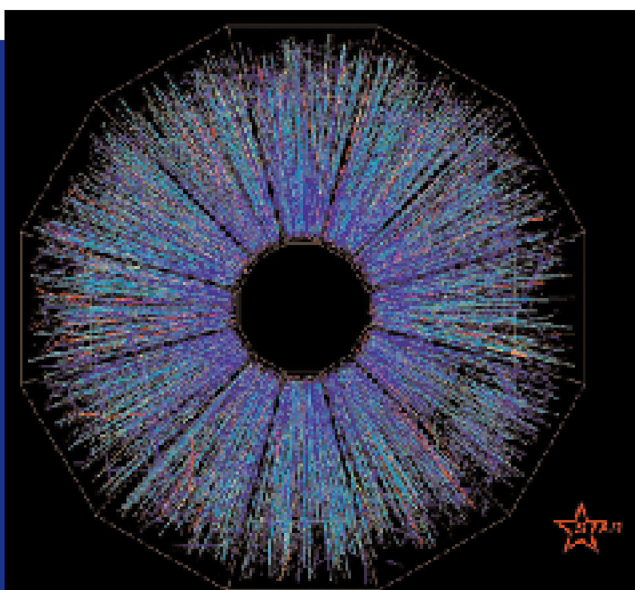

Photo: Brookhaven National Laboratory

End view of a collision of two 30-billion-electron-volt gold beams in the STAR detector at the Relativistic Heavy Ion Collider at Brookhaven National Laboratory. The beams travel in opposite directions at nearly the speed of light before colliding.

How did RHIC get its name?

Relativistic - relates to anything which occurs at or *near* the speed of light.

Heavy **I**on - a charged particle created from a heavy atom (one with many protons and neutrons)

Collider - device which causes particles to collide

Get general information about RHIC at http://www.rhic.bnl.gov/

Take a virtual tour of RHIC at http://www.rhic.bnl.gov/html2/tour.html

See an animation representing the collision of heavy ions in RHIC at http://www.rhic.bnl.gov/html2/intro.html (scroll to bottom of page)

Learn some fascinating facts about RHIC at http://www.rhic.bnl.gov/html2/facts.html

Learn about the Physics of RHIC at http://www.rhic.bnl.gov/html2/rhicphysics.html

What is a quark? a gluon? quark-gluon plasma? What was the Big Bang? What's a hadron? For the answers, check out the Physics primer at http://www.rhic.bnl.gov/html2/primer.html

Read a Press Release about experimental results from RHIC as of January 15, 2001, at http://www.pubaf.bnl.gov/pr/bnlpr011501.html

After the Big Bang...

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for about 10 hours, while making nearly 100,000 trips around the collider every second.

The two RHIC rings intersect at six points. The superconducting magnets allow scientists to steer the beams of particles and make them collide at one or more places. Thousands of collisions will occur each second and each collision will produce thousands of particles, providing physicists with a wealth of data.

The RHIC Experiments

Physicists have constructed primary experiments at several collision points. PHENIX and STAR are referred to as the "large" experiments. Each of these detectors is as big as a small house and weighs several thousand tons. Although BRAHMS and PHOBOS are referred to as "small" experiments, both weigh hundreds of tons. Another experimental set-up is referred to as pp2pp. Additional experiments/detectors may be added later.

The PHENIX detector will look for many different particles that emerge from particle collisions. Large steel magnets surround the collision area and will be employed to detect photons, electrons, muons and hadrons, which contain quark particles. This detector weighs 3,000 tons. The PHENIX will concentrate on photons and leptons in an effort to look "inside" the collision and gain insight into its internal structure.

The STAR experiment will track the thousands of charged particles produced by particle collisions in RHIC. This gigantic detector will search for signs of quark-gluon plasma, measuring many parameters simultaneously. It seeks to detect and track thousands of particles, compared to the hundreds targeted by PHENIX.

BRAHMS is one of the smaller detectors to be used at RHIC. It will study charged hadron particles as they pass through spectrometers. It will measure momentum, energy and other characteristics of the particles.

PHOBOS, another of the smaller experiments, is designed to examine a very large number of collisions and to develop a broad view of the results. In addition, it will seek to develop detailed information about a small number of fragments ejected from the plasma.

The pp2pp experiment (polarized proton on polarized proton) will study proton-proton elastic scattering.

Photo: Brookhaven National Laboratory

A view of the superconducting magnets at Brookhaven's Relativistic Heavy Ion Collider. As gold particles zip along the collider's 2.4 mile long tunnel at nearly the speed of light, 1,740 of these magnets guide and focus the particle beams.

Initial Collisions in June 2000

The first dramatic collisions of gold ions in RHIC were recorded on June 12, 2000. STAR first produced spectacular images of particles streaming from a head-on collision point. A few hours later, data from PHOBOS indicated collisions. The PHENIX detector documented evidence of collisions on June 15. The BRAHMS plots showing collision data followed the same day.

Previously, lower-energy collisions at the CERN laboratory in Switzerland hinted at the existence of quark-gluon plasma. But the higher-energy collisions possible using RHIC are expected to produce far more definitive results.

Breaking News in January 2001

Nearly 700 physicists gathered at the Quark Matter 2001 Conference at Stony Brook University on January 15, 2001, to hear the latest news about the search for quark-gluon plasma. Researchers from RHIC reported early findings. Collisions between gold ions in RHIC have created nuclear matter resulting from the highest energy density ever achieved in a scientific experiment — at least 70 percent higher than in similar experiments at CERN, the

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Two New Brochures From ANS

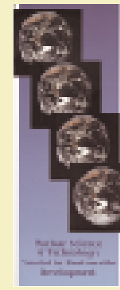
Available on Web; Suitable for Teachers and Students

Two new brochures have been introduced by ANS. They are **Nuclear Power: A Sustainable Source of Energy** and **Reducing Carbon Dioxide Emissions: Moving Toward the Targets? (1999 Performance)**.

Sustainable development is seen as development that meets the needs of the present generation without compromising the ability of future generations to meet their needs. Growing worldwide demand for energy, particularly electricity, has raised questions about the sustainability of various energy sources. The **Nuclear Power** brochure addresses those concerns. The brochure will be of interest to teachers and students as they discuss nuclear power. It can serve as a resource for students who are evaluating positions for classroom debates.

The brochure was originally prepared for distribution at the recent Congress of the Parties (COP 6) held in the Hague, Netherlands. COP 6 was a meeting of those involved in the United Framework Convention on Climate Change (UNFCCC). Representatives assembled to discuss the procedures by which they would reduce carbon dioxide emissions, as outlined in the Kyoto Accords.

The **Reducing Carbon Dioxide Emissions** brochure provides a graphic report on how various countries are doing in their efforts to reduce carbon dioxide emissions. The brochure is similar to one prepared a year ago, but this one contains new data compiled at the end of 1999 (the latest available). It compares the progress of nations in achieving their targets as outlined in Kyoto.



A third brochure, **Nuclear Science & Technology: Crucial to Sustainable Development**, is also available. Prepared about a year ago, it briefly highlights the multitude of ways in which sustainable development is supported or made possible by applications of nuclear science and technology. These include contributions toward improved health (diagnostic and treatment applications), food preservation, industrial materials and processes, electrical power, efficient development of natural resources, basic scientific research, studies of environment and the ecosystem, and reductions in carbon dioxide emissions.

All three brochures are excellent resources for teachers and suitable for many high school students. They are posted on the ANS web site as "pdf" files (http://www.ans.org/pi/brochures/) which are easily printed, using Adobe Acrobat. In addition, printed copies are available for purchase.

Medical Applications

Tin Isotope Used in Treatment for Bone-Cancer Pain

Researchers Refine Formulation

Prostate, breast or lung cancer may spread to the patient's bones, causing severe pain in the later stages of illness. Researchers in the Medical Department at Brookhaven National Laboratory (BNL) have completed another in a series of developments of a tin formulation (Sn-117m DTPA) that helps manage the pain associated with metastasized bone cancer.

An improved formulation of the tin compound, developed by BNL researchers Suresh Srivastava and George Meinken, targets the bone, spares marrow and soft tissue, and delivers a high dose of electrons (beta radiation) to the bone tumors, easing the pain without sedation. Both the improved formulation and the processes for making it are covered by a new U.S. patent, issued in December 1999, the third related to the research.

The first patent related to this formulation was issued to Srivastava, Meinken and Powell Richards in 1985. Additional work on the material continued in the 1990s, when BNL scientists concentrated on developing tin-117m DTPA as an addition to the collection of radiopharmaceuticals used for bone-cancer pain relief. Using BNL's High Flux Beam Reactor, they turned regular tin (Sn-117) into the isotope Sn-117m. Then, they attached diethylenetriaminepentaacetic acid (DTPA).

DTPA helps the tin reach the bone by preventing interactions with the blood or uptake into soft tissue. Srivastava, Meinken, Harold Atkins, and Leonard Mausner hold a 1998 patent that describes usage of this tin formulation for pain palliation.

New developments covered in the third patent are significant because they reduce the amount of unchelated DTPA to which patients are exposed. Unchelated DTPA is soluble and free to attach to other molecules in the body. This was a cause for concern because excess amounts of DTPA can be toxic. The new, improved formulation was designed so that, during preparation, each molecule of DTPA binds to the tin. With the DTPA chelated in this way, physicians can use higher doses of the radiopharmaceutical for cancer treatment without causing a toxic reaction.

BNL has a collaborative research and development agreement (CRADA) with Diatide Research Laboratories, Division of Berlex Laboratories, Inc. All three patents are licensed by Diatide. The current CRADA extends the research effort to evaluate use of the special tin formulation in the treatment of primary bone cancer.

Photo: Brookhaven National Laboratory

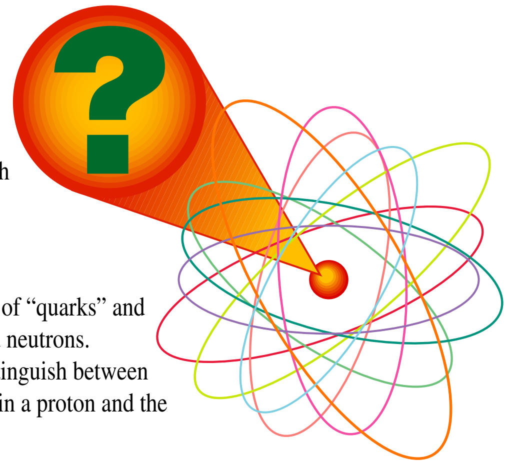
Left to right, BNL Medical Department researchers Suresh Srivastava, George Meinken and Zizhong Li.

Nuclear Sciences

Project 64 – Activity

Building a Model of an Atomic Nucleus

Refer your students to the Physics Primer of the RHIC website (http://www.rhic.bnl.gov/html2/primer.html) or other suitable resources for background information that describes the concept of quarks and gluons as constituents of nucleons. Then, challenge them to build a model of an atomic nucleus, starting with objects/materials which represent the quarks and gluons.



They should create combinations of "quarks" and "gluons" to represent protons and neutrons. There should be some way to distinguish between the combination of quarks found in a proton and the

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Beyond Discovery™ Web Site Is Rich Resource

Whether you and your students are focused on biology, chemistry, earth sciences, or ecology, the Beyond Discovery web site (http://www.beyonddiscovery.org/) will interest you. **Beyond Discovery: The Path from Research to Human Benefit**, is a collection of articles providing insight into the origins of technological and medical advances. The site brings together the strengths of the National Academy of Sciences, National Academy of Engineering, Institute of Medicine, and the National Research Council.

The 16 articles currently posted cover a wide range of topics, including ozone depletion, human gene testing, the laser and fiber-optic revolution, childhood leukemia, cochlear implants, lasers and eye surgery, plate tectonics, polymers, protease inhibitors, hepatitis B, and nitric oxide in biology and medicine.

Each article provides an in-depth exploration of the topic, along with interesting illustrations and links to additional background information.

Visitors to the Beyond Discovery web site can also link to the National Academies web site (http://www.nationalacademies.org/), where they will find a search mechanism for locating articles on other topics of interest.

Nuclear Sciences

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combination found in a neutron. One should be able to identify, with ease, how many protons and neutrons are present in the model nucleus.

For simplicity, students may want to confine their efforts to atoms with small atomic numbers and masses.

Some students may want to add “electrons” to their model. Ask them if this is really a practical idea. Discuss with them the problems they might encounter due to size limitations (see the section on size in the Physics Primer). This exploration will provide an opportunity to point out the vast amount of “empty” space within the atom and how small the particles in an atom actually must be.

The questions that arise as they attempt to create these models will provide an opportunity to teach many concepts rather than just have them memorize a diagram.

Also, you may want to discuss whether the models they create are representations of “fact” or “current theory” about the structure of matter. This can give way to discussion about how research, such as that conducted at RHIC or CERN, improves our understanding of matter.

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European laboratory for particle physics. More subatomic particles were created by collisions between protons and neutrons from gold ions than in similar collisions of protons at the same energy. Data from the experiments suggests that the conditions in RHIC are closer to those believed to have existed at the beginning of the universe than the conditions produced during similar experiments at CERN.

It is not yet clear how these results will contribute to scientists’ understanding of the possible transition to quark-gluon plasma. Some results were consistent with expectations based on previous experiments, while others are quite different from previous experiments.

During the experimental work on which the researchers reported, RHIC was operated at up to two-thirds of its design energy. When operations resume in the spring, RHIC will operate at higher energy. This is expected to take scientists further in their quest for quark-gluon plasma.

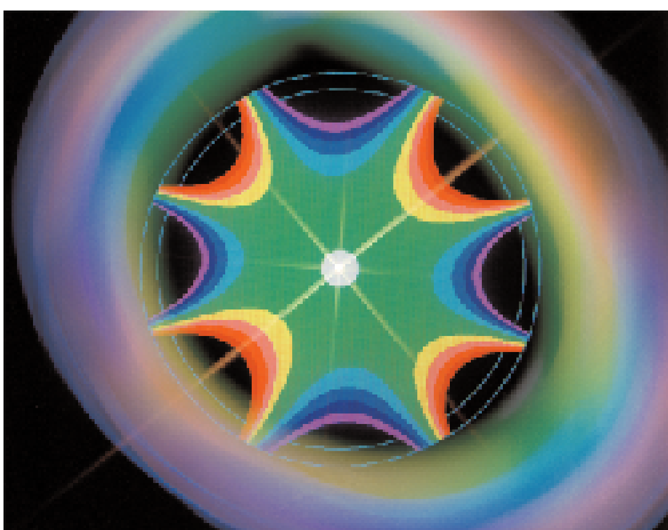
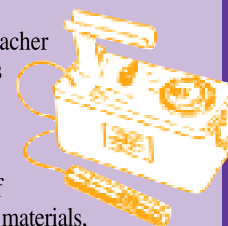


Photo: Brookhaven National Laboratory

A representation of the magnetic field created by one of the 1,740 superconducting magnets in the Relativistic Heavy Ion Collider. RHIC collides speeding heavy ions and polarized protons in an effort to re-create a state of matter not seen since moments after the Big Bang.

Attend a Workshop: Get Information and a Geiger Counter



ANS sponsored teacher workshops focus on the theme, “Detecting Radiation in Our Radioactive World.” They provide a variety of information, educational materials, and insights for teaching about radioactivity and nuclear science and technology.

These are just some of the concepts covered in a typical ANS teacher workshop.

Humankind has always lived in a radioactive world. Cosmic radiation and uranium and other naturally occurring materials in the earth’s crust provide varying amounts of background radiation. The amount of radiation exposure we receive annually varies, depending upon where we live and some details of our daily life. It is possible to estimate our annual personal radiation dose.

Radiation can’t be detected by our senses. Geiger-Muller tubes, used in the familiar Geiger counter, are one way of detecting radiation. Photographic film can also be used.

Nuclear science and technology are used in medicine (diagnostic and therapeutic applications), industrial processes and gauging, basic science research, environmental research, forensics, and, of course, generation of electricity.

The extent to which each topic is addressed depends upon whether you attend a 90-minute introductory session or a full-day, 6-hour workshop, or something in between.

In ANS workshops, teachers learn how to use Geiger counters to detect radiation from background and man-made sources. Teachers who complete a workshop receive a FREE CD-V700 analog Geiger Counter along with an ANS Teacher Handbook on Detecting Radiation. Workshops provide ideas for classroom use of the Geiger counter, instructions, and information about radioactive sources that can be used safely in the classroom.

Workshop content is designed for grades 7-12; it is applicable to grades 5-12.

Click for a current **list** of ANS teacher workshops.