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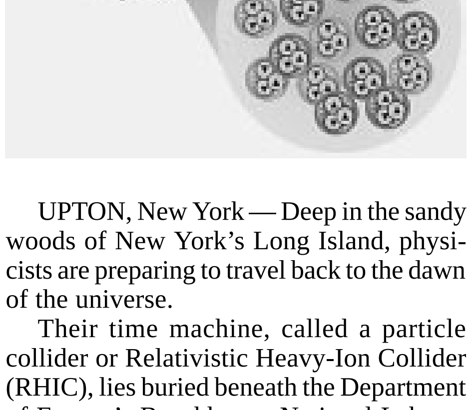
Atom Bashing To Glimpse Big Bang



UPTON, New York — Deep in the sandy woods of New York's Long Island, physicists are preparing to travel back to the dawn of the universe.

Their time machine, called a particle collider or Relativistic Heavy-Ion Collider (RHIC), lies buried beneath the Department of Energy's Brookhaven National Laboratory, will begin stripping gold atoms of their electrons and accelerating them to 99.995 percent of the speed of light. Then it will smash pairs of the atoms together with such violence that the collisions will generate temperatures 10,000 times hotter than the sun.

Because the objects involved are submicroscopic, the total energy in each collision will be comparable to that of a mosquito landing on a screen door. But that energy will be released into a space one-millionth of a millimeter across, concentrated enough to tear apart an atomic nucleus.

First Moments

Current theory indicates that the first atoms first appeared about a second after the universe itself — so tearing them apart means recreating what came before. Physicists picture that realm, which would have formed just microseconds after the Big Bang, as a trillion-degree cauldron known as the quark-gluon plasma. Atoms did not exist. Neither did protons and neutrons.

There were just quarks and gluons, swimming in a superhot brew. Then, before the universe was a second old, the quark-gluon plasma congealed into the protons and neutrons that make up atomic nuclei today. How small are atoms and subatomic particles like their nuclei? In terms of inches or centimeters with a ruler, there'd be a lot of zeros to deal with. For example, a typical atom is 0.000000001 meters across — that's one billionth of a meter!

"What we hope to do is to make the quark-gluon plasma and then to actually probe and understand its properties," said John Harris, a Yale University physicist involved in the project.

The quark-gluon plasma's brief moment of glory is lost in the past, obscured from us by 13 billion years of cosmic evolution.

But if the new particle collider succeeds in recreating the primordial substance, physicists might learn how it formed, how long it lasted and how it reconstituted itself into protons and neutrons.

They would have glimpsed the first millisecond of creation.

Why Build RHIC?

To answer our questions about the universe, to advance the frontiers of science, and to make and explore a rare state of matter — that's the answer. RHIC will allow physicists to do the kind of science known as basic research.

Basic research, sometimes known as a fundamental research, seeks knowledge for its own sake and explores the unknown. Scientists can't predict the exact outcome of basic research, though they can develop theories of what might happen based on what they've already learned.

Basic research is very different from applied research, which uses the information we already know to solve the problems we face now.

But basic research isn't useless! Far from it — in fact, most of the technology and medicines we have today were made possible because someone, somewhere, did basic research.

Here's one example: Physicists at the beginning of this century did basic research on a particle called the proton, examining and cataloging its properties. Because of their discoveries about a property called spin, scientists and doctors were able to develop magnetic resonance imaging (MRI) technology to see inside the human body. Today, doctors use MRIs to diagnose disease better and faster than ever before.

Microscope For The Universe

Why are the RHIC collisions scientifically interesting? The information found at RHIC can be applied in nuclear physics (the study of the atom), particle physics (the study of the atom's parts), astrophysics (the study of stars and planets), condensed matter physics (the science of solid matter) and cosmology (the study of the universe), even archeology (see related story below) and medicine. At the Center for Imaging and Neurosciences, a joint effort of BNL's Chemistry and Medical Departments, three imaging facilities provide a window into the workings of the brain. Two positron emission tomography cameras, a 4-Tesla magnetic resonance imaging machine and a single-photon-emission computed tomography camera are all used to explore addiction, aging, mental disorders and normal brain function.

The Particle Racetrack Is Where The Action Is

The components of the RHIC complex are:

• Tandem Van de Graaff (Tandem) Completed in 1970 and upgraded in 1999, the tandem is the generator and the "launch pad" for RHIC and AGS heavy ions. Also simulates cosmic rays for tests of satellite parts.

• Heavy Ion Transfer Line (HITL) Built in 1986 especially to bring heavy ions from the Tandems to the AGS and RHIC.

• Booster Added in 1991 to increase beam energies for the AGS and RHIC.

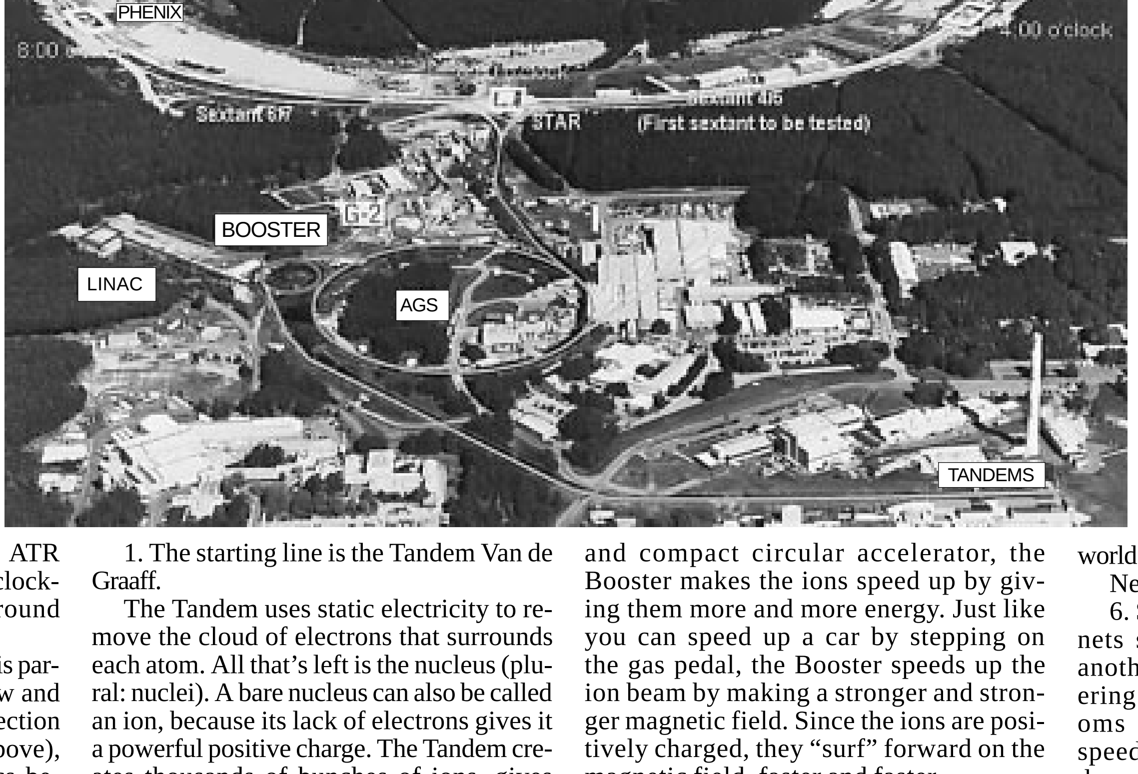
• Linear Accelerator (Linac) Makes beams of polarized protons for RHIC and the AGS.

• Alternating Gradient Synchrotron (AGS) Since 1960, one of the world's premier particle accelerators. Injects beam into RHIC while maintaining its own experimental program. Three Nobel Prizes have been awarded for AGS experiments.

• AGS-to-RHIC Transfer Line (ATR) The final link between BNL's existing accelerators and RHIC. The ATR splits the beam in two, sending half clockwise and half counterclockwise around RHIC.

• RHIC ring At 2.4 miles around, this particle "racetrack" has two lanes, yellow and blue, for the split beam. At six intersection points (orange boxes in the image above), the beams collide — and the physics begins. At four of the intersections, physicists have built giant experiments to capture the products of RHIC collisions for study.

RHIC may be visualized as a racetrack, but for particles, not cars! And hold on tight — this race goes at the speed of light and lasts only a few fractions of a second!



1. The starting line is the Tandem Van de Graaff.

The Tandem uses static electricity to remove the cloud of electrons that surrounds each atom. All that's left is the nucleus (plural: nuclei). A bare nucleus can also be called an ion, because its lack of electrons gives it a powerful positive charge. The Tandem creates thousands of bunches of ions, gives them a boost of energy, then sends them on their way — a few millionths of a second apart. And they're off!

2. From the Tandem, the bunches of ions are carried on a magnetic field to the Booster. At this point, they're traveling at about 4.6% the speed of light. A powerful and compact circular accelerator, the Booster makes the ions speed up by giving them more and more energy. Just like you can speed up a car by stepping on the gas pedal, the Booster speeds up the ion beam by making a stronger and stronger magnetic field. Since the ions are positively charged, they "surf" forward on the magnetic field, faster and faster.

3. The Booster then feeds the ion beam into the larger ring of the Alternating Gradient Synchrotron, or AGS. By this time, the ions are traveling about 37% the speed of light. As they whirl around and around the AGS, the ions get even more energy — until they're going 99.7% the speed of light! Light travels at 186,000 miles per second, the fastest that anything in the universe can go.

4. When the ion beam is going nearly as fast as it can, the AGS sends it careering down a long straight pipe called the AGS-to-RHIC Transfer Line. At the end of this line, there's a fork in the road, where sorting magnets separate the ion bunches. If one goes left, the next goes right, and so on. Next stop, RHIC!

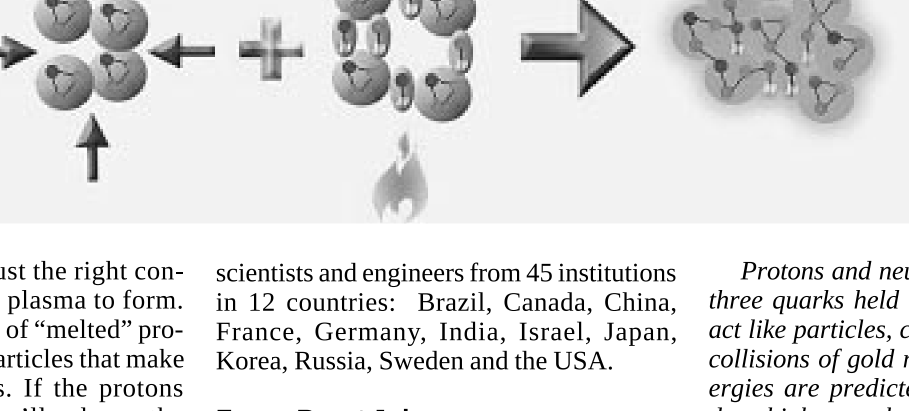
5. Inside the RHIC's tunnel 12 feet under the ground, the ion bunches are racing around RHIC's 2.4-mile ring in opposite directions. The tube-shaped rings are actually made of hundreds of magnets, strung together like beads on a necklace. RHIC uses superconducting niobium titanium wire to carry the energy that powers the magnets. When this special wire (left) is cooled to -451.6 degrees Fahrenheit, it carries electricity very efficiently. Because of superconducting technology, RHIC can accelerate heavy ions faster than any other machine in the world.

Next stop, the Demolition Derby

6. Smash-'em-up excitement. The magnets steer the beams to crash into one another, a pretty impressive feat considering that RHIC beams are only a few atoms wide and traveling at near light speed! In a RHIC collision, just like in a demolition derby, the colliding objects won't be completely destroyed.

The ion bunches will actually pass through one another, creating a hot, dense area that will last only a tiny fraction of a second. As this area cools, some of the ions' energy will convert to matter — just like Einstein's equation $E=mc^2$ predicts!

From Matter To Quark-Gluon-Plasma



RHIC sets out to create really high temperatures and pressures by colliding atomic nuclei together at high speeds. In the illustration, physicists believe that the combined effects of sufficient pressure and heat will result in the release of Q-G-P.

When they hit, the nuclei may create just the right conditions for quark-gluon plasma to form. This plasma will consist of "melted" protons and neutrons, the particles that make up the center of atoms. If the protons and neutrons melt, they'll release the quarks and gluons inside themselves. The quarks and gluons will be able to flow freely for just an instant — almost like flowing water.

This phase transition from normal, everyday matter to quark-gluon plasma is just the opposite of what scientists think happened just after the Big Bang. Just like with ice that melts and then freezes again, this phase transition can go both ways!

Nuclear physicist Brant Johnson, the Phenix Web Master, list manager, and Secretary of the Phenix Institutional Board and Executive Council, and Manager of the Phenix Office, e-mailed the Post a "layman's" explanation of the process. Brant coordinates the collabortion of 450 scientists and engineers from 45 institutions in 12 countries: Brazil, Canada, China, France, Germany, India, Israel, Japan, Korea, Russia, Sweden and the USA.

From: Brant Johnson <brant@bnl.gov>
Subject: Re: Quark Query

The best analogy I have heard to explain the Quark-Gluon Plasma (QGP) is to ask you to picture in your mind an extremely cold world in which water exists only in its solid phase: ice.

Now, imagine that some brash scientists convince their government to fund — at great taxpayer expense — an enormous machine to accelerate "ice cubes" and cause them to collide with each other at great speeds. Suppose some theorists predict that the energy produced in these collisions will melt the ice and form an — as yet undetected — new liquid phase: water. The theorists also predict that the liquid water will very quickly freeze back into solid ice, but the scientists may be able to study the resulting ice crystals and determine that they were not born as ordinary ice chips, but rather were produced from a "re-freezing" of the liquid water.

That is what we are trying to do at RHIC.

Protons and neutrons are composed of three quarks held together by forces that act like particles, called qluons. Head-on collisions of gold nucleii at very high energies are predicted by theorists to produce high enough temperatures to "melt" the normally "frozen" protons and neutrons into a plasma of free quarks and glons.

This QGP is indeed an — as yet undetected — new phase of matter, which will quickly expand and cool, resulting in a "re-freezing" into composite particles of two, three, or more quarks bound together by gluons.

By detecting, identifying, and measuring the momentum of each of the thousands of particles (the "ice crystals") that come flying out from these collisions, we hope to characterize and to better understand the QGP state of matter that last existed only a few microseconds after the Big Bang at the beginning of the universe. **Brant**

A Kababayan At Brookhaven

Meet Rudy Alforque, a research engineer at Brookhaven National Laboratory for over 15 years now. Rudy is a member of the team building the Relativistic Heavy-Ion Collider.

Born and raised in a small barrio called Cantao-an in the municipality of Naga, Cebu province of Cebu, Rudy joined the Collider Ring Division (CRD) of RHIC as the Design Safety Engineer. "In this capacity, I provide, on request, the necessary technical assistance to the engineers, and designers in our division to ensure that their projects are safe and sound from the standpoint of structural and thermal integrity," he explains. Rudy designed, procured, and initiated the installation of more than 1700 magnet stands in the Rhic tunnel, among others.

Rudy Alforque caught by NAIA's candid camera arriving for a vacation.

Although he has a Master of Engineering in Nuclear Engineeering, Rudy says he loves tennis, ballroom, Latin and swing dancing, and cooking. Dancing, he says, "is my solution (that I recommend to everyone) in the Stress-Management department; It certainly beats the Finite Element Approach!"

Six Flutes From China Date Back To 7000 BC

Researchers in China have uncovered what might be the oldest playable musical instrument.

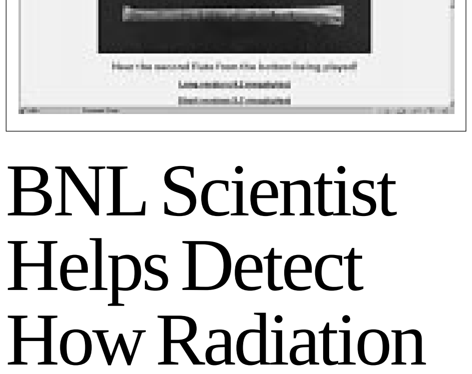
Excavations at the early Neolithic site of Jiahu, located in Henan province, China, have yielded six complete bone flutes between 7,000 and 9,000 years old. Fragments of approximately 30 other flutes were also discovered. The flutes may be the earliest complete, playable, tightly-dated, multinote musical instruments.

Garman Harbottle, a chemist at the US Department of Energy's Brookhaven National Laboratory and member of the Jiahu research team, helped analyze data from carbon-14 dating done in China on materials taken from the site. "Jiahu has the potential to be one of the most significant and exciting early Neolithic sites ever investigated," said Harbottle. "The carbon dating was of crucial importance to my Chinese colleagues in establishing the age of the site and the relics found within it."

The exquisitely-crafted flutes are all made from the ulnae, or wing bones, of the red-crowned crane (Grus japonensis Millen) and have five, six, seven or eight holes. The best-preserved flute has been played and tonally analyzed in tests at the Music School of the Art Institute of China.

Want to hear the second flute from the bottom being played?

If you have a multimedia equipped Internet-enabled computer, surf over to http://www.bnl.gov/bnlweb/flutes.html (see accompanying screenshot of the webpage) and click on either of the two hyperlinks to audio recordings (one short, one long) of a section of the Chinese folk song Xiao Bai Cai (The Little Cabbage; in Tagalog: Ang Munting Petsay) Please note: the audio data are 1.7MB and 4.2MB in size, respectively.



BNL Scientist Helps Detect How Radiation Causes Damage

While attempting to "photograph" the chemical reactions of an important enzyme of the nervous system, an international team of scientists found that the high-intensity x-ray beam was systematically destroying their target. The resulting molecular images were the first-ever direct observation of how proteins break apart when exposed to high-energy x-rays.

Weizmann Institute researchers in Rehovot, Israel, have captured the first-ever time-resolved "movie" demonstrating how molecules break apart when exposed to high doses of radiation. Their findings, published in the Jan. 18 issue of the Proceedings of the National Academy of Science (PNAS) may pave the way to improved techniques for studying biological molecules, as well as to pharmacological measures for preventing high-dose radiation damage, a common cause of cancer and birth defects.

"The observation was stunning," said collaborator Joel Sussman, a member of the Weizmann Institute Structural Biology Department who has a joint appointment at the Brookhaven National Laboratory in New York, where some of this research took place. The Brookhaven work and studies with other enzymes elsewhere confirmed that the chemical bonds of specific materials are susceptible to x-rays. Organisms are constantly exposed to radiation, mainly from natural sources, such as sunlight and cosmic rays, as well as man-made sources such as diagnostic x-rays.

Radiation damage and its prevention is a central issue which 'spills over' beyond laboratory walls. "The ability to visualize the specific damage caused by radiation at a 'test-tube' level offers an important diagnostic tool for developing pharmacological means to protect against radiation damage," says Israel Silman, also a guest scientist at BNL's Biology Department. Scientists say this can lead to the examination of the anti-radiation potential of other substances that might be used as protective gear or shields.