From two-trillion-degree heat, researchers create new matter -- and new questions

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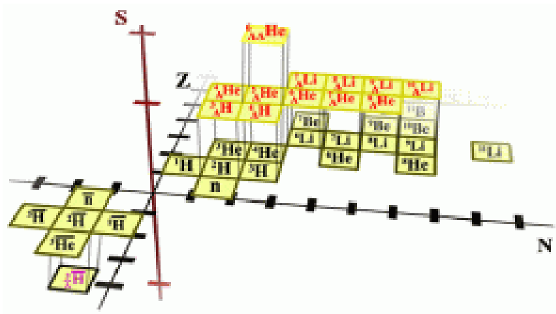


The diagram above is known as the 3-D chart of the nuclides. The familiar Periodic Table arranges the elements according to their atomic number, Z, which determines the chemical properties of each element. Physicists are also concerned with the N axis, which gives the number of neutrons in the nucleus. The third axis represents strangeness, S, which is zero for all naturally occurring matter, but could be non-zero in the core of collapsed stars. Antinuclei lie at negative Z and N in the above chart, and the newly discovered antinucleus (magenta) now extends the 3-D chart into the new region of strange antimatter.

(PhysOrg.com) -- A worldwide team of researchers have for the first time created a particle that is believed to have been in existence immediately after the creation of the universe - the so-called "Big Bang" - and it could lead to new questions and answers about some of the basic laws of physics because in essence, it creates a new form of matter.

An international team of scientists studying high-energy collisions of gold ions at the Relativistic Heavy Ion Collider (RHIC), a 2.4-mile-circumference particle accelerator located at the U.S. Department of Energy's Brookhaven National Laboratory, has published evidence of the most massive antinucleus discovered to date. The new antinucleus, discovered at RHIC's STAR detector, is a negatively charged state of antimatter containing an antiproton, an antineutron, and an anti-Lambda particle. It is also the first antinucleus containing an anti-strange quark. The results will be published online by *Science Express* on March 4, 2010.

“This experimental discovery may have unprecedented consequences for our view of the world,” commented theoretical physicist Horst Stoecker, Vice President of the Helmholtz Association of German National Laboratories. “This antimatter pushes open the door to new dimensions in the nuclear chart — an idea that just a few years ago, would have been viewed as impossible.”

The discovery may help elucidate models of neutron stars and opens up exploration of fundamental asymmetries in the early universe.

The Solenoidal Tracker at RHIC (STAR) is a detector which specializes in tracking the thousands of particles produced by each ion collision. The massive unit weighs 1,200 tons and is as large as a house. Credit: Photo courtesy of Brookhaven National Laboratory.

New nuclear terrain

All terrestrial nuclei are made of protons and neutrons (which in turn contain only up and down quarks). The standard Periodic Table of Elements is arranged according to the number of protons, which determine each element's chemical properties. Physicists use a more complex, three-dimensional chart to also convey information on the number of neutrons, which may change in different isotopes of the same element, and a quantum number known as "strangeness," which depends on the presence of strange quarks (see diagram). Nuclei containing one or more strange quarks are called hypernuclei.

For all ordinary matter, with no strange quarks, the strangeness value is zero and the chart is flat. Hypernuclei appear above the plane of the chart. The new discovery of strange antimatter with an antistrange quark (an antihypernucleus) marks the first entry below the plane.

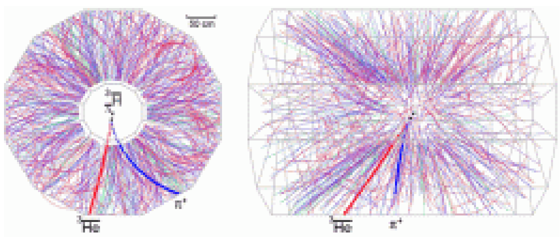
This study of the new antihypernucleus also yields a valuable sample of normal hypernuclei, and has implications for our understanding of the structure of collapsed stars.

"The strangeness value could be non-zero in the core of collapsed stars," said Jinhui Chen, one of the lead authors, a postdoctoral researcher at Kent State University and currently a staff scientist at the Shanghai Institute of Applied Physics, "so the present measurements at RHIC will help us distinguish between models that describe these exotic states of matter."

The findings also pave the way towards exploring violations of fundamental symmetries between matter and antimatter that occurred in the early universe, making possible the very existence of our world.

Collisions at RHIC fleetingly produce conditions that existed a few microseconds after the Big Bang, which scientists believe gave birth to the universe as we know it some 13.7 billion years ago. In both nucleus-nucleus collisions at RHIC and in the Big Bang, quarks and antiquarks emerge with equal abundance. At RHIC, among the collision fragments that survive to the final state, matter and antimatter are still close to equally abundant, even in the case of the relatively complex antinucleus and its normal-matter partner featured in the present study. In contrast, antimatter appears to be largely absent from the present-day universe.

"Understanding precisely how and why there's a predominance of matter over antimatter remains a major unsolved problem of physics," said Brookhaven physicist Zhangbu Xu, another one of the lead authors. "A solution will require measurements of subtle deviations from perfect symmetry between matter and antimatter, and there are good prospects for future antimatter measurements at RHIC to address this key issue."



In a single collision of gold nuclei at RHIC, many hundreds of particles are emitted most created from the quantum vacuum via the conversion of energy into mass in accordance with Einsteins famous equation E = mc2. The particles leave telltale tracks in the STAR detector (shown here from the end and side). Scientists analyzed about a hundred million collisions to spot the new antinuclei, identified via their characteristic decay into a light isotope of antihelium and a positive pi-meson. Altogether, 70 examples of the new antinucleus were found.

The STAR team has found that the rate at which their heaviest antinucleus is produced is consistent with expectations based on a statistical collection of antiquarks from the soup of quarks and antiquarks generated in RHIC collisions. Extrapolating from this result, the experimenters believe they should be able to discover even heavier antinuclei in upcoming collider running periods. Theoretical physicist Stoecker and his team have predicted that strange nuclei around double the mass of the newly discovered state should be particularly stable.

RHIC's STAR collaboration is now poised to resume antimatter studies with greatly enhanced capabilities. The scientists expect to increase their data by about a factor of 10 in the next few years.

Provided by Brookhaven National Laboratory