The Electron-Ion Collider (eRHIC)

Systematic Measurement of 'Color Glass Condensate' Properties

PURPOSE

To look for color glass condensate, the saturated or maximum density state that can be achieved at high energies by particles subject to the strong force, which is the short-range attraction holding atomic nuclei together

SPONSOR

Office of Nuclear Physics, Office of Science, U.S. Department of Energy

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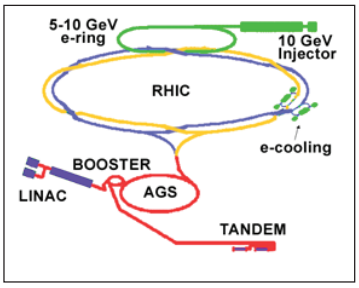
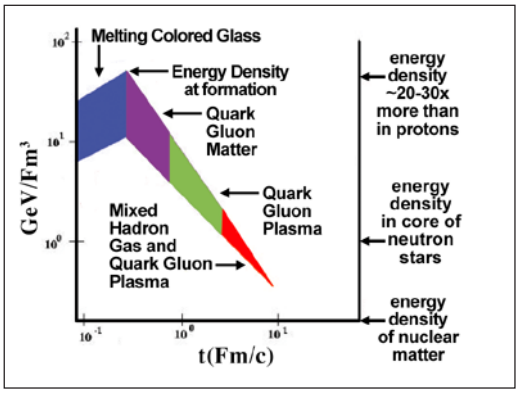


A schematic showing the addition of an electron synchrotron (top) to the Relativistic Heavy Ion Collider (center), to turn RHIC into the electron-heavy ion collider called eRHIC.

When the universe was less than 10 microseconds old, the constituents of protons and neutrons — called quarks and gluons — did exist, but in a super hot and dense state called a plasma. At 10 microseconds, the universe became too cold for quarks and gluons to remain in the plasma. Just as water turns to ice as the temperature gets colder, quarks and gluons combined to form familiar particles such as protons and neutrons, as well as other, more exotic particles. Since then, quarks and gluons have been inseparable, confined within protons and neutrons making up the nuclei of atoms.



In the search for color glass condensate, eRHIC will explore energy densities 10-100 times greater than those of neutron stars, as is shown by this graph of the relationship between energy density and time as heavy-ion collisions evolve.

Today, the discovery of quark-gluon plasma is being pursued using RHIC, the Relativistic Heavy Ion Collider at the U.S. Department of Energy's Brookhaven National Laboratory. Once confirmed, the existence of quark-gluon plasma will not only provide insight into the beginnings of our universe, but it will also open a window into the inner workings of atomic nuclei.

Following this discovery, RHIC physicists will be poised to conduct a further exploration — into the properties of an unusual state of matter called color glass condensate. It is thought to exist in heavy nuclei accelerated beyond RHIC's present energy. So Brookhaven is proposing to upgrade RHIC into eRHIC, to turn it into an electron-heavy ion collider to explore color glass condensate.

Why Collide Electrons?

Not made of other particles, the electron is point-like and weakly interacting, making it an ideal probe of nuclear structure. Experiments using electrons collided with unpolarized protons at HERA, Germany's electron synchrotron, have yielded much of the world's information about how quarks and gluons interact in forming particles subject to the strong force, the short-range attraction holding atomic nuclei together.

Evidence from HERA has, in fact, resulted in the prediction of color glass condensate, the saturated or maximum density state that can be achieved at high energies by particles subject to the strong force. It is hypothesized that, before colliding nuclei can make quark-gluon plasma, nuclei become densely compressed — a color glass condensate — in the direction they are being accelerated. Upon impact, color glass condensate is thought to "shatter," thus forming the plasma.

What Is Color Glass Condensate?

Color, in this sense, is a property of quarks and gluons that results from the strong force. The word "glass" is borrowed from the term for silica and other such materials that, in their solid state, are not crystallized, but remain amorphous structurally. Finally, the term condensate comes from condensation, whereby, at a certain energy, the density of gluons increases to a point of saturation, or maximum density.

By colliding heavy nuclei with electrons at high energy within eRHIC, physicists expect that the contents of the nucleus will be compressed to high enough densities to form color glass condensate, thus permitting its study.

National Scientific Importance

Because it is "absolutely central" to advancing U.S. science, eRHIC has received the highest science ranking from a future-facilities subcommittee of the Nuclear Science Advisory Committee reporting to DOE's Office of Science.

One of the Office of Science's ten national laboratories, Brookhaven National Laboratory is managed and operated for the U.S. Department of Energy, by Brookhaven Science Associates, a company founded by Stony Brook University and Battelle.

(01-06)