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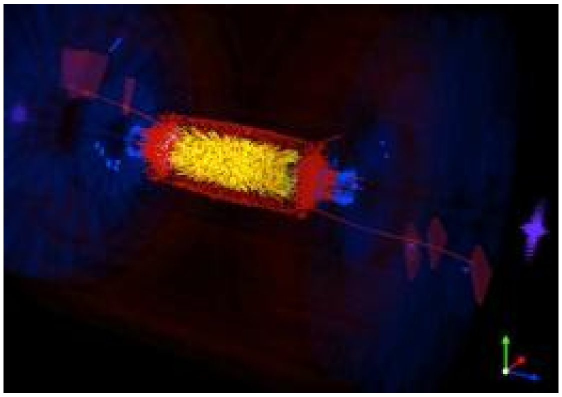
Scientists crash lead nuclei together to create the hottest and densest nuclear material ever

December 6 2010, By Phillip F. Schewe



A computer display taken from the first lead collisions. Credit: CERN | iSpy and Fireworks, CMS

The thousand-degree temperatures reached in the hottest of industrial furnaces is nothing compared to the equivalent temperatures achieved when particles traveling near the speed of light slam into each other.

On December 2 several scientists at the CERN laboratory in Geneva, Switzerland reported the first results of an experiment in which the nuclei of lead atoms were shot around the 17 mile racetrack called the Large Hadron Collider and then smashed into each other to create, for an instant, a speck of matter at a temperature of trillions of degrees.

Although the miniature fireballs that occur at the lead-lead collision points only last a fleeting moment -- about a trillionth of a trillionth of a second -- the immense detectors poised nearby are designed to act rapidly and sort through the myriad debris particles streaming outwards.

"This is the hottest nuclear matter ever created in a lab," said Bolek Wyslouch of the Ecole Polytechnique near Paris who spoke at the CERN gathering. He is a representative of the Compact Muon Solenoid collaboration, which uses one of the giant detectors at LHC to observe the lead-lead collisions.

"I like to call this the Little Bang," said Juergen Schukraft, also speaking at the CERN colloquium, suggesting that the violent collisions of heavy ions at the LHC were smaller cousins of the Big Bang explosion that ushered in the visible universe some 14 billion years ago. Indeed, the conditions of the mini-fireballs at LHC resemble the early universe as it was only microseconds after the Big Bang in terms of energy density and temperature. Schukraft represented a second CERN detector group called Alice.

Never before has so much energy -- in this case hundreds of trillions of electron volts abbreviated as TeV -- been deliberately deposited in a volume of space only a few times the size of a proton. A proton is one of the constituents of the nucleus inside each atom, and is some 10,000 times smaller than the atom itself. Scientists who work at accelerators often use the electron volt as their unit of energy since it is precisely the energy gained by an electron accelerated by an electric force difference of one volt.

What happens when two lead nuclei containing hundreds of protons and neutrons, each of which have an energy of 1.4 TeV, smash into each other in an almost head-on collision? As they meet and interact the protons and neutrons melt into even more basic constituents, called quarks and gluons. What you get is a seething liquid of hundreds of strongly interacting particles, called by physicists a quark-gluon plasma.

Earlier this year scientists at the Relativistic Heavy Ion Collider at Brookhaven National Laboratory in New York reported on RHIC's collision measurements from a quark-gluon plasma made by colliding gold nuclei. They reported the temperature of the plasma to be 4 trillion degrees, the hottest temperature ever carefully measured in an experiment.

The LHC scientists haven't yet directly measured the temperature of their quark plasma. Schukraft said that since the energy density of the collisions is some three times larger at LHC than at RHIC, the temperatures will be higher also.

In following weeks, a series of specific results from the LHC heavy ions will appear in scientific journals. Scientists from the Atlas collaboration -- which operates a third large detector at LHC -- report on their observations of huge jets emerging sideways from the collisions. A jet is a powerful cone of energy, in the form of flying particles that emerges from the fireball shortly after the collision. Scientists expect that if a powerful jet shoots out of the collision on one side, there should be a complementary jet on the other side that balances momentum.

In many collision events, however, only one jet is observed. In an article about to appear in the journal *Physical Review Letters*, the Atlas scientists report the first such examples of the imbalance between jets in the lead-lead collisions. But what happened to the missing jet?

Brian Cole, speaking at CERN on behalf of the Atlas team, said that the quark-gluon plasma itself is probably absorbing part or all of the jets on their way outwards. This process doesn't have to be symmetric.

"The more central the collision," Cole said, referring to how head-on the collision, "the more asymmetric the jets are."

Another Atlas scientist, Peter Steinberg, said that scientists expected that some of the jet energy would be absorbed, but were surprised that in some events the jet seemed to be completely absorbed.

The asymmetric appearance of jets, the scientists hope, can be used to understand the unprecedented nature of this densest matter ever observed in a lab.

Provided by Inside Science News Service

Citation: Scientists crash lead nuclei together to create the hottest and densest nuclear material ever (2010, December 6) retrieved 23 April 2024 from https://phys.org/news/2010-12-scientists-nuclei-hottest-densest-nuclear.html