LHC experiments bring new insight into matter of the primordial universe

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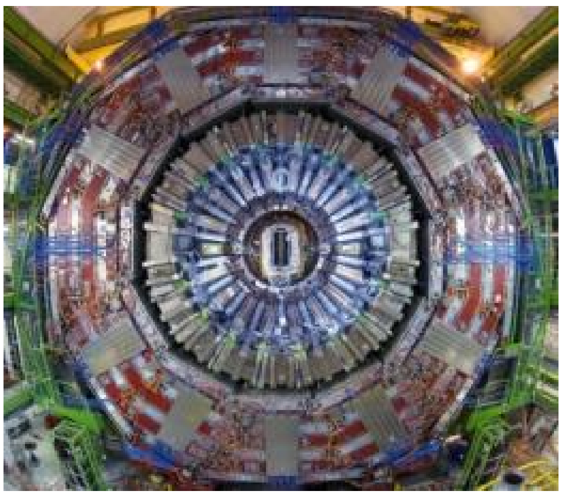

A view of the detector in the 12,500-ton Compact Muon Solenoid experiment (CMS). Image courtesy of CERN

(Phys.org) -- Experiments using heavy ions at CERN's Large Hadron Collider (LHC) are advancing understanding of the primordial universe. The ALICE, ATLAS and CMS collaborations have made new measurements of the kind of matter that probably existed in the first instants of the universe. They will present their latest results at the Quark Matter 2012 conference, which starts today in Washington DC. The new findings are based mainly on the four-week LHC run with lead ions in 2011, during which the experiments collected 20 times more data than in 2010.

Just after the big bang, quarks and gluons – basic building blocks of matter – were not confined inside composite particles such as protons and neutrons, as they are today. Instead, they moved freely in a state of matter known as "quark–gluon plasma". Collisions of lead ions in the LHC, the world's most powerful particle accelerator, recreate for a fleeting moment conditions similar to those of the early universe. By examining a billion or so of these collisions, the experiments have been able to make more precise measurements of the properties of matter under these extreme conditions.

"The field of heavy-ion physics is crucial for probing the properties of matter in the primordial universe, one of the key questions of fundamental physics that the LHC and its experiments are designed to address. It illustrates how in addition to the investigation of the recently discovered Higgs-like boson, physicists at the LHC are studying many other important phenomena in both proton–proton and lead–lead collisions," said CERN Director-General Rolf Heuer.

At the conference, the ALICE, ATLAS and CMS collaborations will present more refined characterizations of the densest and hottest matter ever studied in the laboratory – 100,000 times hotter than the interior of the Sun and denser than a neutron star.

ALICE will present a wealth of new results on all aspects of the evolution of high-density, strongly interacting matter in both space and time. Important studies deal with "charmed particles", which contain a charm or anticharm quark. Charm quarks, 100 times heavier than the up and down quarks that form normal matter, are significantly decelerated by their passage through quark–gluon plasma, offering scientists a unique tool to probe its properties. ALICE physicists will report indications that the flow in the plasma is so strong that the heavy charmed particles are dragged along by it. The experiment has also observed indications of a thermalization phenomenon, which involves the recombination of charm and anticharm quarks to form "charmonium".

"This is only one leading example of the scientific opportunities in reach of the ALICE experiment," said Paolo Giubellino, spokesperson of the ALICE collaboration. "With more data still being analysed and further data-taking scheduled for next February, we are closer than ever to unravelling the properties of the primordial state of the universe: the quark–gluon plasma."

In the 1980s, the initial dissociation of charmonium was proposed as a direct signature for the formation of quark–gluon plasma, and first experimental indications of this dissociation were reported from fixed-target experiments at CERN's Super Proton Synchrotron in 2000. The much higher energy of the LHC makes it possible for the first time to study similar tightly-bound states of the heavier beauty quarks. The hypothesis was that, depending on their binding energy, some of these states would "melt" in the plasma produced, while others would survive the extreme temperature. The CMS experiment now observes clear signs of the expected sequential suppression of the "quarkonium" (quark–antiquark) states.

"CMS will present important new heavy-ion results not only on quarkonium suppression, but also on bulk properties of the medium and on a variety of studies of jet quenching," said CMS spokesperson Joseph Incandela. "We are entering an exciting new era of high-precision research on strongly interacting matter at the highest energies produced in the laboratory."

The quenching of jets is the phenomenon in which highly energetic sprays of particles break up in the dense quark–gluon plasma, giving scientists detailed information about the density and properties of the produced matter. ATLAS will report new findings on jet quenching, including a high-precision study of how the jets fragment in matter, and on the correlations between jets and electroweak bosons. The results are complementary to other exciting ones, including groundbreaking findings on the flow of the plasma.

"We have entered a new phase in which we not only observe the phenomenon of quark–gluon plasma, but where we can also make high-precision measurements using a variety of probes," said ATLAS spokesperson Fabiola Gianotti. "The studies will contribute significantly to our understanding of the early universe."

Provided by CERN