Large Hadron Collider will continue experiments into 2012

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The European Organization for Nuclear Research (CERN) recently announced that the Large Hadron Collider will continue scientific operations in both 2011 and 2012 at the current limits of half its original design energy. This means postponing operation at full design energy until 2014.

Previously, the world’s most powerful particle accelerator was to be shut down for the entire year in 2012 to upgrade both the collider and detectors. However, in light of the research done in 2010, LHC scientists determined that the current energy terrain being explored is scientifically fruitful and should be understood fully before advancing further.

Nonetheless, LHC is expected to produce twice as many records of subatomic collisions over two years as the total collected at Fermilab, the now decommissioned accelerator that was previously the world’s most powerful.

The ultimate scientific goal of the LHC is to probe physical behavior at energies so high that they existed naturally only in the first moments of the universe, the so-called Big Bang. In doing so, physicists hope to answer certain basic questions that previous investigations have posed as a point of inquiry.

The foremost of these is the origin of mass in the universe. Mass is one of several fundamental characteristics of natural objects, and is observed in two ways: the first by gravitational attraction (“weight”) and the second by resistance to change in motion (“inertia”).

For all known forms of matter in the cosmos these independent definitions yield corresponding measurements, and yet physics has still not provided a satisfactory answer for this equivalence. Furthermore, why do subatomic particles exhibit such a range of masses? The proton and electron have equal but opposites charges, but the former is 2,000 times as massive as the latter.

This question of what underlying structure of nature might give rise to mass in a natural way was first tackled in 1964 by three separate groups of physicists, who all proposed a mechanism, an underlying property of the universe, by virtue of which particles have mass.[1][2][3]

In particular, Peter Higgs suggested a new property of space that existing particles would interact with. This coupling would produce a “drag” that generates the observed inertial mass of particles. In addition, this mechanism would manifest in self-bound states which would appear as the eponymous “Higgs” particle in some high energy collisions.

Gathering confirmation and refinement of this fundamental tenet of nature is one of the central goals for the LHC.

Numerous other theories have come about in an attempt to explain why particles have masses without the Higgs boson, in general called Higgsless models. It is expected that data from the Large Hadron Collider, when it is at full operational capacity, will determine which model is correct, or if some new theory beyond even what is currently being discussed is needed.

Astronomy has also looked to the LHC for illumination of one of its own central paradoxes. For some seventy years, since Fritz Zwicky’s work with the motions of galaxies in the great Coma Cluster, it has become apparent that far more mass exists in galaxies and clusters of galaxies that can be explained by ordinary matter. Vera Rubin, in the 1970s, quantified this deficit as the “missing mass” problem.

Originally, it was hypothesized that a more detailed inventory of the contents of galaxies would balance the books, but investigations to find the mass in comparatively “invisible” forms, such as inert “brown dwarfs” between stars, black holes, or similar hiding places, all failed to account for the discrepancy. Detailed astronomical measurements now suggest the substantial majority of gravitationally-active matter in the Universe is in the form of “dark matter,” which is for the most part both invisible and inert, reacting with other matter only gravitationally.

One proposed solution to the “missing mass” problem is offered by a physical hypothesis known as “supersymmetry.” In this model, there exist “supersymmetric” counterparts to the various known particles of physics. It is thought that the most common of these counterparts interact with normal matter only through gravity. Nevertheless, at high energies, supersymmetric particles, should they exist, would occasionally be created and destroyed in the extreme conditions of a particle collision, and their properties inferred and quantified by the analysis of the event. In a curious connection, the discrepancies of the largest structures in the Universe can find potential explanation through analysis of the behavior of some of the smallest physical interactions that we study.

If these questions of the origin of mass, and its additional appearance in hitherto unknown particles, find their expected experimental refinements, then we will approach more closely to understanding the relationship between the four fundamental forces which are known to operate in the Universe. For three of these—electromagnetism, the weak nuclear interaction, and the strong nuclear interaction—a central connection is now theoretically understood. Gravitational attraction remains a largely separate sphere, and other questions as to the discrepant behavior of these forces, in particular the hierarchy problem, remain unsolved.

The hierarchy problem is posed as follows: the universe is governed on a fundamental level by four fundamental forces, the strong force, electromagnetism, the weak force, and gravity. The question is why each force has such a large range of strengths. Despite what our everyday experience tells us, on a fundamental level, gravity is by far the *weakest* of the four forces, weaker than electromagnetism by more than 40 orders of magnitude. In a hydrogen atom, why do the proton and electron interact electromagnetically to a similar degree that the single atom interacts with Mount Everest gravitationally?

It should be noted that such a large scale physics experiment only occurred under the umbrella of an international organization. Despite the Euro-centricity of CERN, countries from across the globe have contributed both money and researchers, combining efforts to understand the basic building blocks of the cosmos. In total, ten thousand scientists and engineers from eighty nations are working in collaboration to uncover the underlying principles that govern the universe. Such advances can only be achieved with the collective force of humanity mobilized.

[1] Englert, François; Brout, Robert (1964). “Broken Symmetry and the Mass of Gauge Vector Mesons”. *Physical Review Letters* **13**: 321–23. doi:10.1103/PhysRevLett.13.321

[2] Higgs, Peter (1964). “Broken Symmetries and the Masses of Gauge Bosons”. Physical Review Letters13: 508–509. doi:10.1103/PhysRevLett.13.508

[3] Guralnik, Gerald; Hagen, C. R.; Kibble, T. W. B. (1964). “Global Conservation Laws and Massless Particles”. *Physical Review Letters* **13**: 585–587. doi:10.1103/PhysRevLett.13.585