CERN confirms Higgs discovery

Bryan Dyne
23 March 2013

Physicists from the European Organization for Nuclear Research (CERN) have announced that the new fundamental particle discovered last year is the long sought Higgs boson, the particle that governs how matter has mass. The results were presented jointly by the two major groups collaborating at the Large Hadron Collider (LHC), operating instruments known as CMS and ATLAS.

The results were released at this year's Moriond Conference, an annual particle physics conference, held March 9-16 in Italy. The total data set used is two and a half times what was collected up to last July and shows a Higgs that is approximately 125 gigaelectronvolts (GeV, a unit of mass/energy in particle physics), which agrees completely with the previous results. For comparison, a single hydrogen atom is just under one GeV.

This result both shows the strength of the modern model of the material universe, the Standard Model of particle physics, as well as open up possible new vistas for further understanding.

CMS and ATLAS are the two general purpose detectors operated by physicists at the Large Hadron Collider, whose primary job was the search for the Higgs. They are massive machines that use powerful magnets and highly sensitive electronics to record the collisions caused by the two counter-rotating beams of protons of the LHC. Within each detector, the beams of protons, whose speed is only a fraction below the speed of light, are focused to cause collisions at the rate of hundreds of millions per second. It is estimated that an event that produces a Higgs occurs once every trillion proton-proton interactions, thus the need for such a high collision rate.

A bank of specially designed computers then determine which events are particles glancing off each other versus colliding head on by the energy of each collision. The head-on interactions are the high-energy events that are used to search for new physical events, including searching for the Higgs.

The Higgs boson was the last unobserved particle of the Standard Model of particle physics, which describes the most advanced theory of the fundamental particles of nature and describes their interactions. The Standard Model in modern physics is akin to the Periodic Table for chemistry. Its latest formulation came about in the 1970s with the discovery of quarks, the constituent particles of protons and neutrons.

There are three categories of particles in the Standard Model: quarks, which are the building blocks of everyday matter; leptons, including electrons which orbit atomic nuclei and govern chemical reactions; and gauge bosons, which transmit the fundamental forces of nature between particles.

The bosons include gluons, photons and the W and Z bosons. Gluons are responsible for binding quarks together to form larger particles, photons govern electric and magnetic interactions and the W and Z bosons transmit the weak force, responsible for radioactive decay seen in heavy nuclei.

Uncovering the Higgs boson is bound up with the theory surrounding electromagnetism and the weak force. It was shown by physicists Abdus Salam, Sheldon Glashow and Steven Weinberg in the 1960s that at high enough energies, these two forces unify into a single "electroweak" force. Such energies do not occur in the present universe outside of collisions in accelerators like the Large Hadron Collider, but it was soon realized that the theory was applicable to the early moments of the universe, when such energies did exist, if briefly.

However, the theory also postulated that all the four particles that govern the electroweak force would be massless, due to a "symmetry" seen in the theory. Of these particles, the photon and the two types of W boson had already been discovered and the W boson was already observed to have a mass of 80 GeV. A fourth particle, the Z boson, was also predicted (and confirmed within a few years) to have a mass of about 90 GeV. A concept was then devised to explain this phenomenon, known as "symmetry breaking."

Symmetry breaking can be likened to looking into a mirror and raising one's right hand. Imagine that instead of seeing the mirror image of the right hand being raised, you see the mirror image of the left hand being raised. This represents the symmetry being broken, and is possible in the realm of particle physics. The concept has been successfully used to explain a variety of other strange processes that occur in particle physics.

The Higgs boson is the particle that governs this "symmetry breaking" mechanism. It was first postulated in 1964 by Peter Higgs, Robert Brout, Francois Englert, Gerald Guralnik, C. Richard Hagen and Tom Kibble. In the framework they developed, a "Higgs field" extends throughout the universe. At the energies required to unify electromagnetism and the weak force, the four particles look the same, i.e., they have symmetry between them. Below those energies, that symmetry is broken, causing the photon to be massless and the others to be very heavy.

Almost immediately, it looked as if the theory could be used to explain a more general question: Where does mass come from? All current particle masses are experimentally determined parameters inserted into the Standard Model. They do not come out of the theory itself. It is hypothesized that the mass of all particles is based on the interactions of the Higgs field and its mediator, the Higgs boson. This discovery will help clarify this problem.

A last and somewhat subtle question remains. The Standard Model, while powerful, is not a complete description of matter at the fundamental level. Outside of finding the Higgs, one of the main tasks of the Large Hadron Collider is to peer into possible realms beyond the Standard Model. In one of these models, known as supersymmetry, there are potentially five types of Higgs bosons. Only further measurements of how this Higgs decays will determine whether the particle that has been discovered is the Standard Model Higgs or one governed by the physics of supersymmetry. Either outcome will be a major advancement for our understanding of physics and both will open up new vistas of study.

The confirmed discovery of a Higgs boson is a great advance for physics and scientifically planned labor on a mass scale. Ten thousand of the most intelligent minds on the planet operate and maintain the Large Hadron Collider and the experiments surrounding it. The resources of 100 nations have contributed to its construction. The discovery of the Higgs is a milestone in the creative efforts of humanity spanning a century.

It is also a blow against all postmodern and anti-scientific trends. It shows that the material world not only can be understood and predicted but that humans are capable of doing so. Moreover, it demonstrates humanity's awesome capacity for understanding the material world, and in turn understanding humanity's place in that world, when the collective resources of Earth are not put towards profiteering or militarism but rather the basic human desire to understand nature.

The data about the Higgs poses both certain answers and a great deal of questions. As stated before, the precise characteristics of the Higgs must be determined. The particle must be properly placed within existing theory or act as the starting point for a fundamentally new understanding of the universe. No matter the outcome, the process of discovery will continue.