CERN discovers new fundamental particle

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After almost five decades of searching, the long hunt for the elusive Higgs boson—key to understanding the nature of mass—may be over. The latest results from the European Organization for Nuclear Research (CERN) indicate that a new fundamental particle has been discovered at the Large Hadron Collider (LHC) in Switzerland, which is most likely to be the Higgs boson. Furthermore, the chance that this tentative discovery is a statistical fluke is one part in three million.

The new findings were reported in a press conference in Geneva on Wednesday morning. They appear to provide stunning confirmation of one of the central components of the modern theory of the material world, the Standard Model of fundamental particles.

The results were released jointly by the CMS and ATLAS collaborations, the two general purpose experiments on the LHC, whose main purpose has been to search for the Higgs boson. Physicists working with both detectors report a new particle at between 124 and 126 Gigaelectronvolts (GeV, a unit of mass used by particle physicists)—about the same mass predicted for the Higgs Boson by the Standard Model. By comparison, a proton has a mass of about one GeV.

The Standard Model describes the fundamental particles of nature. These particles are organized into three broad categories: The quarks (which combine to form protons and the neutrons, the building blocks of atoms, among other particles); the leptons, including electrons, which orbit the nucleus and are all-important in chemical reactions; and the gauge bosons, the carriers of the fundamental forces of nature.

Among the bosons is the photon, responsible for transmitting electric and magnetic forces, and the gluons, which bind quarks together into larger composite particles, preventing them from existing in isolation. The W and Z bosons transmit the weak force, which is involved in the radioactive decay of Uranium, Radium and other heavy nuclei.

The Standard Model explains the interactions between the fundamental particles remarkably well (with the exception of gravitational interactions, which have as yet to be reconciled fully with the Standard Model). However, without the Higgs boson, there is no explanation for the origin of particle mass.

In the Standard Model of particle physics, the interaction of particles with the “Higgs field” is a hypothesized mechanism for generating the masses of fundamental particles. This field, long predicted by theory, corresponds to the existence of a particle, which can only be observed under extraordinary energies—such as those produced by the LHD particle accelerator. It is this theoretical prediction that was the subject of the experiments in question.

While the discovery is significant–this *is* a confirmed new fundamental particle–it is not strict confirmation of the Higgs boson. The particle itself has yet to be fully characterized, which will take additional months of research. All that is known is the mass of the new particle and three different ways the particle can decay. This is due to how particles are discovered in the LHC.

All particle colliders generate particles by focusing an extremely large amount of energy into a tiny volume of space by increasing the amount of particles in the beams that are collided as well as increasing the energy of each individual particle. The combined energy of all the accelerated particles of the Large Hadron Collider, at any moment, can be equivalent to 173 kilograms of TNT and collide in a space less than half a millimeter in diameter.

Each individual particle has a tiny fraction of that total energy, and it is these particles which actually collide with each other. Since particles need energy equivalent to their mass to be created, collisions to make the newly discovered particle, which is more massive than most others, need to be very high energy. Put a different way, the energy of the collisions acts as an energy surplus to the universe which then is converted to mass in the form of new particles. Thus higher energy collisions mean more massive particles, like the Higgs boson.

Most heavy particles, however, are highly unstable, and quickly decay into less massive particles. Although the Higgs boson decays too quickly to be observed, its decay products – the particles which it leaves behind – can be detected. The specific patterns of decay are the "signatures" of the particle. It is the combined fact that the newly discovered particle has a mass near what is predicted for the Higgs boson, along with three of the predicted Higgs signatures, that has the particle physics community extremely optimistic about the new particle being the Higgs. The reason the Higgs is so hard to detect is that its signatures are easily mimicked by other much more common processes.

If this new particle is indeed the Higgs, it will complete a search that began in 1964 by Peter Higgs, Robert Brout, Francois Englert, Gerald Guralnik, C. Richard Hagen and Tom Kibble. The origin of the proposed particle came from the need to resolve fundamental problems in the unification of the force which governs electricity and magnetism, and the so-called "weak" force, which is responsible for the decay of heavy nuclei, such as Uranium and Radium. If these forces were to be combined into one "electroweak" force, then the particles that govern each of the forces would have to be massless. However, it was already observed that two of the three known particles were already more than 80 GeV and a fourth predicted particle (which was soon confirmed) would be about 90 GeV. To explain this phenomenon, the above physicists all proposed what has come to be known as the Higgs mechanism, governed by the Higgs boson, which details the exact reason the masses of the known particles are so different.

In this framework, mass is a byproduct of the interactions of fundamental particles with the Higgs field. These interactions occur continuously, with Higgs bosons fleetingly popping into and out of existence as they are emitted and absorbed by the other fundamental particles.

This idea was soon expanded into another more general problem of particle physics: explaining the masses of each particle. Currently, the mass of each fundamental particle is not something which can be predicted theoretically, but must be determined experimentally. Understanding the origins of mass—and with it so much of the material world—is one of the great questions of modern physics, something which the discovery of the Higgs boson is expected to more fully clarify.

That these results are being published shows the great capacity for humans to understand the material world, no matter how counter-intuitive it may be to our everyday interactions. It shows that humans can in fact *know* something and use this knowledge to anticipate new discoveries of the universe. No doubt many strange things will be revealed in the coming months and years, in particle physics and other fields, but those in turn will be understood and used to anticipate even greater discoveries.

The in-depth study of the new particle will occur over the second half of the year, and will be a major area of research when the LHC reaches full design energy in 2014. A full confirmation that this is indeed the Higgs boson will simultaneously close a significant chapter in physics and open new ones. Scientists will have the ability to predict the masses of particles, but will theory match the already collected data? Moreover, there are plenty of other questions to be answered, like the composition of dark matter and dark energy, which make up most of the known universe.