New studies reveal further details of Higgs particle

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Studies by the two major collaborations of the Large Hadron Collider (LHC)—CMS and ATLAS—have shown that the Higgs boson also decays into a specific class of less massive particles, so-called down-type fermions. These compliment earlier studies of the Higgs which looked at up-type fermions. Both form a more complete picture of how the Higgs interacts with other particles.

Understanding the Higgs is the last major piece of the Standard Model of particle physics. Like the Periodic Table for chemistry, the Standard Model provides a theoretical framework to describe the nature and interactions of fundamental particles. Its major weakness is that the mass of every particle is an experimentally observed quantity, rather than being explainable by the theory. The current research into the Higgs is the first step in resolving this discrepancy.

The results are the latest in a lengthy program to experimentally verify many of the predicted properties of the Higgs boson. In 2012, when the European Organization for Nuclear Research (CERN) first announced it had discovered a new particle, it was only suspected that what had just been discovered was the Higgs because all that had been discovered was the mass. While that meant that researchers knew what range of energies to probe when using the data from the LHC, nothing else was concretely known.

The next several months were spent studying how the new particle decays, the primary way physicists discover the properties of new particles. A decay is a transformation of one particle to one or more others, in accordance with the physical laws that govern the process, such as the conservation of mass and energy. By looking at each type of a particle's decay and the frequency of its occurrence, physicists have an idea of how to integrate a new particle into the existing theoretical framework.

Another quantity that must be conserved when a particle decays is the esoteric quantum property called "spin," which has no direct counterpart in the behavior of matter in the macroscopic world. Particles can have either an integer quantity of spin (0, 1, 2, ...) and are called bosons, or a half-integer quantity of spin (1/2, 3/2, ...), and are called fermions, honoring the physicists Satyendra Bose and Enrico Fermi. The subatomic particles that are the building blocks of what we think of as "matter" are fermions. Those that mediate the interactions between all particles (including themselves) are the gauge bosons.

Subsequent research on the presumptive Higgs found that the particle decayed three separate ways: into a pair of photons (a type of boson), into a pair of W bosons and into a pair of Z bosons. The only particle predicted by particle physics that does this at the energies studied is the Higgs boson. This led CERN to confirm the discovery of the Higgs in 2013.

This was a triumph in many respects. In particular, it confirmed the deep connection between the Higgs boson and the electromagnetic and weak forces (governed by the photon and W/Z bosons respectively) that was predicted in 1964 by Robert Brout, Francois Englert and Peter Higgs. Yet, for the new particle to fully match predictions, it must also directly decay into fermions.

After a further year of studying the whole data set collected by the LHC, physicists found that the Higgs does in fact additionally decay directly into fermions. In this case, it was observed that the Higgs transforms into either a pair of tau leptons (more massive cousins of the electron) or b-quarks (more massive cousins of the down quark, one of the two subatomic particles that make up protons and neutrons).

Moreover, because of the connections between the more massive particles and their less massive counterparts, these results indicate that the Higgs *must also* directly decay into electrons and down quarks, though it is doubtful that such events will be detected in the current generation of particle accelerators. These results are in close agreement with the predictions of the Standard Model.

Like many predictions in physics, a great deal of time passed between the first proposal of the Higgs boson and when it was experimentally tested. While the technology existed in the late eighties and early nineties to discover the Higgs, shifts in the global political climate after the fall of the Soviet Union saw major scientific projects fall by the wayside. As a result, it took another two decades for the particle physics community to experimentally demonstrate that the Higgs does exist and may mediate the masses of all the particles.

Of course, the work is not done. The authors of the most recent papers openly admit that more data is needed to further nail down the properties of the Higgs as well as to rule out all but the most remote chances of a statistical fluke.