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Physics in the news

Hunting for Higgs

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On the 4 July 2012, physicists around the world were glued to their web browsers, Twitter feeds and Facebook accounts as the experimental teams from CERN confirmed the results of a 45-year scientific odyssey: the *Higgs boson* had been found.

Over 5500 physicists have been involved in the ATLAS and CMS experiments at the Large Hadron Collider (LHC) since 2003. The LHC is a particle accelerator running through a 27-km circumferential tunnel under the Swiss–French border. It boosts protons to 7 TeV energy before colliding them at the centre of huge detectors designed to measure and identify the streams of particles produced in the collisions. 1 Tev is 10^{12} eV, the energy acquired by a proton accelerated through 10^{12} V.

Occasionally, a Higgs particle is produced that then rapidly decays: too fast to be directly detected, but the decay products can be seen. The particles produced by the decay can also be formed from other processes going on. The trick is to separate those caused by the Higgs from the ‘background’. The best ‘signal’ has come from the decay into two photons, which has shown in one experiment an excess of 170 events out of 59 000 at a combined energy of 126 GeV. This gives the Higgs a mass of 126 GeV/c^2, which is 126 times greater than a proton.

What is the Higgs particle?

The Higgs particle has been shrouded in press hype since a popular science book dubbed it ‘the God particle’ in 1993. God it is not, but its discovery is a hugely important milestone in our understanding of the universe’s structure.

During the 1960s and 1970s, physicists assembled an elegant theory (the *standard model*) that brought together the fundamental matter particles (quarks and leptons) along with the exchange particles (photons, gluons, Ws and Zs) that mediate the fundamental forces. However, the equations only showed their underlying beauty (symmetry) if various particles that were known to possess mass were put into the models as being massless.

Einstein’s famous equation $E = mc^2$ tells us that mass is a property of energy. An elementary particle, such as an electron, separated from all fields and stationary with respect to an observer, has no kinetic or potential energy associated with it, yet it has mass. It has some intrinsic energy even in these circumstances.

In 1964, several physicists working independently suggested a way in which the beauty (symmetry) of the equations could be retained, yet mass inserted via a neat trick. The *Higgs mechanism* (after Peter Higgs, who worked on the theory while at the University of Edinburgh) relies on a *Higgs field* that permeates the entire universe. Elementary particles, with no intrinsic mass, interact with the field to varying extents, acquiring energy and therefore mass. The process, called *spontaneous symmetry breaking*, is hard to follow without the mathematics, but you can get some idea by visualising a ball-bearing being fired through a volume of sticky liquid, such as treacle.

With specially devised transparent and otherwise undetectable treacle, one could imagine that the friction with the ball makes the ball appear to be more massive than it actually is. The Higgs field gives particles that would otherwise have no mass the mass that they need.

Despite the enduring ingenuity of the trick and the huge progress that it allowed physicists to make, it was never entirely satisfactory to infer the presence of the Higgs field without direct proof of its existence: the Higgs boson had to be found.

Higgs field and Higgs particle

In quantum theory the distinction between a field and a particle is blurred. Imagine the Higgs field as being a deep lake with a totally smooth surface. With crystal clear water, the lake is hard to see. Throw a rock into the middle, however, and ripples spread out across the surface, revealing the water's presence. In quantum field theory, a 'ripple' is identified with a particle (a little bit like a 'ruck' in a carpet). A photon for example, is the 'ripple' of the electromagnetic field. What makes the Higgs field remarkable is how 'stiff' it is: a great deal of energy is required to make it ripple. That is why it has taken us so long to discover the Higgs field by generating ripples in it. The appropriate technology had to be developed to collide particles with sufficient energy to excite the field: 126 GeV to be exact.

Find out more

The Atlas experiment at the LHC:

http://en.wikipedia.org/wiki/ATLAS_experiment

The CMS experiment at the LHC:

http://en.wikipedia.org/wiki/Compact_Muon_Solenoid

The standard model of particle physics:

http://public.web.cern.ch/public/en/science/standardmodel-en.html

A CERN physicist blogs about the Higgs particle:

http://www.quantumdiaries.org/2012/03/02/all-on-the-higgs-for-nearly-everyone/

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