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Higgs boson

God particle

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INTRODUCTION

The higgs boson if nothing else the most expensive particle of all time it's a bit of an unfair comparison discovering the electron for instance required little more than a vacuum tube and some genuine genius while finding the higgs boson required the creation of experimental energies rarely seen before on planet earth

It's been called the god particle but thanks to the efforts of literally thousands of scientists We no longer have to take its existence on faith So why the scientist had to discover new particle ? what's it important for? how they proved its existence ? what's the ration between the higgs boson and the universe formation ?

In the standard model of particle physics the fundamental forces of nature arise from laws of nature called gauge symmetries and these forces are transmitted by particles known as gauge bosons and let us imagine that three is a double electron affecting on each other by electromagnetic force represent by a photon which it is exchanging photons the double electron in each other, simply imagine that the double electrons are tennis players exchanging the ball by the moving of the ball from player to another the second player will move to catch it and so on

According to the gauge theory the weak force's gauge symmetry should cause its gauge bosons to have zero mass but experiments show that the weak force's gauge bosons the w and z have mass , some particles which represent forces can pass a lot of distances with high speed close to the light speed which make the forces have an influence for long range While the others particles which have mass so it moves with limited speeds in certain places which means the influence of the forces are limited in short ranges

In tests But it has proved difficult to find any way to explain the unexpected mass

higgs field

this field was actually theorized before the higgs boson itself , according to the standard model afield of the necessary kind the higgs filed exists throughout space

shoring up existing theories by inventing new theoretical components to the universe is dangerous and in the past led physicists to hypothesize a universal aether _ but the more math they did the more they realized that the higgs field simply had to be real

the only problem ? by the very way they'd defined it the higgs field would be virtually impossible to observe higgs field breaks certain symmetry laws of the electroweak interaction the existence of this field triggers the high mechanism causing the gauge bosons responsible for the weak force to be massive and explaining their very short range

some years after the original theory was articulated scientists realized that the same field would also explain in a different way why other fundamental constituents of matter (including electrons and quarks)have mass

in the standard model of particle physics the higgs mechanism is essential to explain the generation mechanism of the property "mass" for gauge bosons without the higgs mechanism all bosons (a type of fundamental particle) would be massless, but measurements show that the w^+, w^- and z bosons actually have relatively large masses of around 80 GEV/c2.

The higgs field resolves this conundrum .

The simplest description of the mechanism adds a quantum field (the higgs field) that permeates all space , to the standard model below some extremely high temperature , the field causes spontaneous symmetry breaking [1](in a sense during interactions the universal medium which separates massless particles into different masses and it's often explained

[1] (kibble, 16 november 1964)

by way of analogy with light _ all wave light travel at the same speed in the medium of a vacuum ,but in the medium of a prism each wavelength can be separated from homogenous white light into bands of different wavelengths.

this is of course a flawed analogy , since the wavelengths of light all exist in white light whether or not we're capable of seeing that fact , but the example shows how the higgs field is thought to create mass through symmetry-breaking .

a prism breaks the velocity-symmetry of different wavelengths of light ,thus separating them , and the higgs field is thought to break the mass – symmetry of some particles which are otherwise symmetrically massless..) the breaking of symmetry triggers the higgs mechanism , causing the bosons it interacts with to have mass

in the standard model , the phrase" higgs mechanism " refers specifically to the generation of masses for the, W± And Z weak gauge bosons through electroweak symmetry breaking (in the standard model , at temperatures high enough that electroweak symmetry is unbroken , all elementary particles are massless at a critical temperature, the higgs field becomes tachyonic the symmetry is spontaneously broken by condensation and the w and z bosons acquire masses)[2].

Fermions , such as the leptons and quarks in the standard model , can also acquire mass as a result of their interaction with the higgs field ,but not in the same way as the gauge bosons .

[2] (wilczek, 28 jun 2012)

Higgs boson

It was not until later that physicists realized that if the Higgs field does exist, its action would require the existence of a corresponding carrier particle, and the properties of this hypothetical particle were such that we might actually be able to observe it.

This particle was believed to be in a class called the bosons; keeping things simple, they called the boson that went with the Higgs field the Higgs boson.

It is a so-called “force carrier” for the Higgs field, just as photons are a force carrier for the universe’s electromagnetic field; photons are, in a sense, local excitations of the EM field, and in that same sense the Higgs boson is a local excitation of the Higgs field. [3]

Proving the existence of the particle, with the properties physicists expected based on their understanding of the field, was effectively the same as proving the existence of the field directly

The existence of the Higgs field could be supported by searching for a matching particle associated with it — the "Higgs boson" Detecting Higgs bosons would prove that the Higgs field exists, and further support the validity of the Standard Model.

But for decades scientists had no way to discover whether Higgs bosons actually existed in nature either, because they would be very difficult to produce, and would break apart in about a ten-sextillionth (10^{-22}) of a second.[4]

[3] (wilczek, 28 jun 2012)
[4] (teresi, 1993)

Property of higgs boson

Since the Higgs field is scalar, the Higgs boson has no spin. The Higgs boson is also its own antiparticle and is CP-even, and has zero electric and colour charge.

The Minimal Standard Model does not predict the mass of the Higgs boson.[92] If that mass is between 115 and 180 GeV/c2, then the Standard Model can be valid at energy scales all the way up to the Planck scale (1019 GeV).[93] Many theorists expect new physics beyond the Standard Model to emerge at the TeV-scale, based on unsatisfactory properties of the Standard Model.[5]

The highest possible mass scale allowed for the Higgs boson (or some 6other electroweak symmetry breaking mechanism) is 1.4 TeV; beyond this point, the Standard Model becomes inconsistent without such a mechanism, because unitarily is violated in certain scattering processes.

It is also possible, although experimentally difficult, to estimate the mass of the Higgs boson indirectly.

In the Standard Model, the Higgs boson has a number of indirect effects; most notably, Higgs loops result in tiny corrections to masses of W and Z bosons.

Precision measurements of electroweak parameters, such as the Fermi constant and masses of W/Z bosons, can be used to calculate constraints on the mass of the Higgs.

As of July 2011, the precision electroweak measurements tell us that the mass of the Higgs boson is likely to be less than about 161 GeV/c2 at 95% confidence level (this upper limit would increase to 185 GeV/c2 if the lower bound of 114.4 GeV/c2from the LEP-2 direct search is allowed for[96]).[6]

[5] (Bernardi, Carena, & Junk, 2012)
[6] (Bernardi, Carena, & Junk, 2012)

These indirect constraints rely on the assumption that the Standard Model is correct.

It may still be possible to discover a Higgs boson above these masses if it is accompanied by other particles beyond those predicted by the Standard Model.[97]

Decay

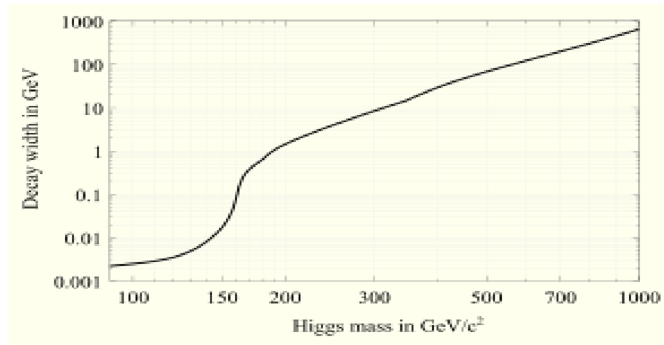

Figure 1

The standard model prediction for the decay width of the higgs particle depends on the value of its mass

mechanics predicts that if it is possible for a particle to decay into a set of lighter particles, then it will eventually do so.

This is also true for the Higgs boson.

The likelihood with which this happens depends on a variety of factors including: the difference in mass, the strength of the interactions, etc.

Most of these factors are fixed by the Standard Model, except for the mass of the Higgs boson itself.

For a Higgs boson with a mass of 126 GeV/c^2 the SM predicts a mean life time of about 1.6×10^{-22} s.[7]

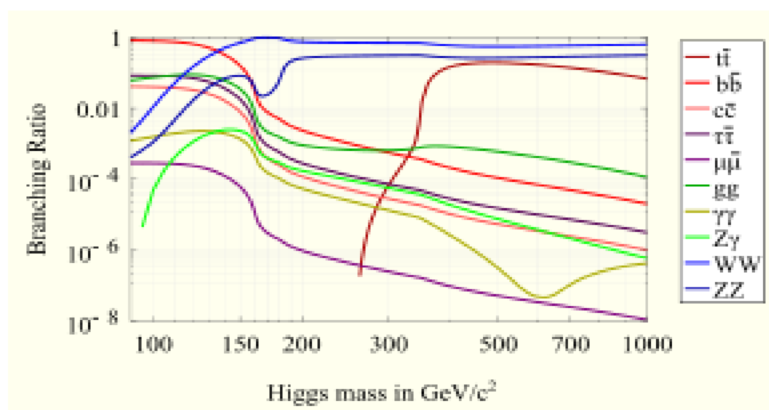

Figure 2

The standard model prediction for the branching ratios of the different decay modes of the higgs particle depends on the value of its mass

Since it interacts with all the massive elementary particles of the SM, the Higgs boson has many different processes through which it can decay.

[7] (Asquith, 2012)

Each of these possible processes has its own probability, expressed as the *branching ratio*; the fraction of the total number decays that follows that process.

The SM predicts these branching ratios as a function of the Higgs mass (see plot).

One way that the Higgs can decay is by splitting into a fermion–antifermion pair.

As general rule, the Higgs is more likely to decay into heavy fermions than light fermions, because the mass of a fermion is proportional to the strength of its interaction with the Higgs

By this logic the most common decay should be into a**top** –antitop quark pair. However, such a decay is only possible if the Higgs is heavier than ~346 GeV/c^2, twice the mass of the top quark.

For a Higgs mass of 126 GeV/$c^2$the SM predicts that the most common decay is into a **bottom** –anti bottom quark pair, which happens 56.1% of the time.[8]

The second most common fermion decay at that mass is a **tau** –anti tau pair, which happens only about 6% of the time.

Another possibility is for the Higgs to split into a pair of massive gauge bosons.

The most likely possibility is for the Higgs to decay into a pair of W bosons (the light blue line in the plot), which happens about 23.1% of the time for a Higgs boson with a mass of 126 GeV/c^2.

The W bosons can subsequently decay either into a quark and an antiquark or into a charged lepton and a neutrino.

However, the decays of W bosons into quarks are difficult to distinguish from the background, and the decays into leptons cannot be fully reconstructed (because neutrinos are impossible to detect in particle collision experiments).

A cleaner signal is given by decay into a pair of Z-bosons (which happens about 2.9% of the time for a Higgs with a mass of 126 GeV/c^2), if each of the bosons subsequently decays into a pair of easy-to-detect charged leptons (**electrons** or muons).

[8] (Asquith, 2012)

Decay into massless gauge bosons (i.e., **gluons** or **photons**) is also possible, but requires intermediate loop of virtual heavy quarks (top or bottom) or massive gauge bosons.

The most common such process is the decay into a pair of gluons through a loop of virtual heavy quarks.

This process, which is the reverse of the gluon fusion process mentioned above, happens approximately 8.5% of the time for a Higgs boson with a mass of 126 GeV/c^2.

Much rarer is the decay into a pair of photons mediated by a loop of W bosons or heavy quarks, which happens only twice for every thousand decays.[9]

However, this process is very relevant for experimental searches for the Higgs boson, because the energy and momentum of the photons can be measured very precisely, giving an accurate reconstruction of the mass of the decaying particle.

[9] (Group, et al., 15 Jan 2012)

lhc

Acceleration: The collider occupies a nearly 17-mile circular tunnel. Two proton beams travel around the ring in opposite directions, racing through tubes kept at an ultrahigh vacuum and guided by superconducting magnets chilled to a temperature colder than that of outer space. Moving at near light speed, the protons make 11,245 circuits per second.

2. Collision: The beams cross in four main detectors, where particles collide 800 million times per second. During the upcoming run, those collisions will produce an unprecedented 13 tera electron volts. That's 13 times the energy of a mosquito in motion, but squeezed into a space a trillion times smaller—a density similar to moments after the big bang.

3. Creation: As Einstein theorized in E=mc2, energy can be converted into mass (and vice versa). And so the energy of two protons colliding can combine and convert into massive new particles, including a top quark—the heaviest subatomic particle ever observed. Because they're unstable, these particles quickly decay into a number of new ones.

4. Detection: As these secondary particles fly away from the collision point, the detectors measure their properties—including positions in space, energy, momentum, mass, and charge. Physicists use this information to deduce the identity of the particles created at the moment of collision and scour the data for anomalies that may indicate something entirely new.

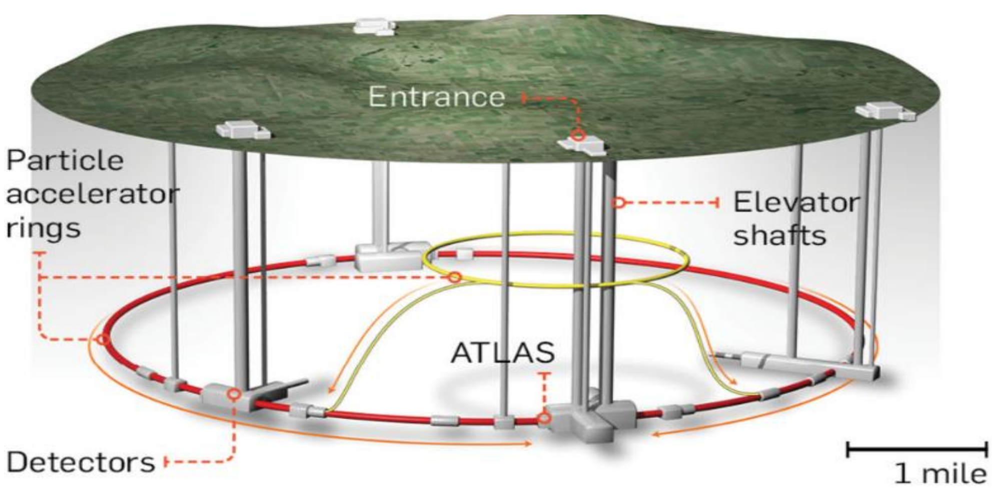

Figure 3

after many years of planning, the Large Hadron Collider (LHC), an experiment massive enough and the only place where the model can be tested. It's even nicer that two independent experiments are going to do it.

'The 17-mile loop of super-powered electromagnets can accelerate charged particles to significant fractions of the speed of light, causing collisions violent enough to break these particles into fundamental constituents, and deform space around the impact point.

With a high enough collision energy, it was calculated that scientists could basically super-charge the Higgs boson, pushing it up into an energy state where it would decay in ways that we can observe.

These energies were so great that some even panicked and said the LHC would destroy the world, while others went so far as to describe an observation of the Higgs as a peek into an alternate dimension[10]

Conclusion

In the end this theory importance isn't only describing the particles masses it also explains why some fundamental particles have mass when , based on the symmetries controlling their interaction they should be massless

also resolve several other long – standing puzzles ,such as the reason for the weak force's extremely short range.

[10] (Group, et al., 15 Jan 2012)

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