SCIENCE MEDIA CENTRE OF CANADA
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- Backgrounder -
HIGGS BOSON

February 16, 2012

At the AAAS Annual Meeting in Vancouver, a symposium including two Canadian participants will discuss the new developments in particle physics:

Things that go bump

Embargoed until 11:00 a.m. PST / 2:00 p.m. ET Feb 17, 2012

Canadian Speakers: Timothy Meyer, TRIUMF; Lia Merminga, TRIUMF. Also including Rob M. Roser, Fermilab and Sergio Bertolucci, CERN

News briefing: Feb 17th, 11:00 AM

Event: Friday, February 17, 2012: 1:00 PM-2:30 PM — Things that Go Bump: The Latest Discoveries in Particle Physics

In December, researchers at CERN announced they had found a signal that could be the Higgs boson, the final particle in physics' Standard Model still to be confirmed. Around the same time, researchers in Italy announced they had detected neutrinos going faster than the speed of light. What do these new developments from some of the world's most powerful atom-smashers mean for physics?

As always, if you'd like some help locating a Canadian expert to interview on this or any other science stories, we are on the ground at the AAAS. Please call us at **613-249-8209**.

Additional stories you want to cover at the AAAS meeting in Vancouver? Let us know! We're here to help.

Register with SMCC (click on the "For Media" tab at www.sciencemedia.ca) to access references, additional resources, and a list of Canadian experts available for media interviews about the Higgs boson. Or call us at **613-249-8209.**

The Higgs Boson

What is it?

The Higgs boson is a hypothesized elementary particle that, if confirmed, would provide the mechanism by which the other elementary particles in the universe have mass.

Elementary particles are the smallest fundamental units of matter. Atoms were once considered the smallest units, but then the atomic nucleus was discovered, consisting of two types of subatomic particles: protons and neutrons. We now know that the protons and neutrons are made of even smaller elementary particles called quarks. All of the matter around us is made up of quarks and electrons. Electrons are in another class of elementary particles called leptons.

Elementary particles are divided into two classes, fermions and bosons, which are defined by a quantum mechanical property know as “spin”. Fermions have half-integral spin (like 1/2, 3/2, etc.) while bosons have integral spin (like 0, 1, 2, etc.)

Quarks and leptons are fermions. It’s hypothesized that at a quantum level the forces that cause quarks and leptons to attract or repel each other are carried by bosons.

The Standard Model (SM) of elementary particle physics is a theory of how quarks and leptons interact in terms of three forces: The electromagnetic force, strong nuclear force, and weak nuclear force. The bosons that carry the electromagnetic force are photons. Gluons are the bosons that carry the strong nuclear force, and W and Z bosons carry the weak nuclear force.

Gravity, the fourth known force, isn’t part of the SM but is hypothetically carried by a boson called a graviton.

The Higgs boson is notable in that its interactions with the other particles give these particles their mass, a fundamental constituent of our universe. The Higgs boson is also notorious as the only particle in the SM that has not been directly observed.

Okay, but what does it do?

The Higgs boson gives each type of particle its own mass. Its existence is needed to explain many features of the SM, such as why some particles have very large masses while others are quite light.

Physicist Peter Higgs proposed what we now call the Higgs field, and hypothesized that it spreads through the universe. All particles would acquire mass by interacting with this field. As is the case with the other interactions, at a quantum level this Higgs interaction predicts that we should be able to produce and detect the boson associated with it, or the Higgs boson.

Particle mass would be the result of interaction with the Higgs field. This interaction produces a Higgs boson.

Because the boson is predicted by the field, finding the Higgs boson would be evidence that the Higgs field exists.

One example of an inconsistency in the Standard Model that the Higgs boson remedies is the lack of symmetry between the particles that carry electromagnetic force (photons, which are massless) and particles that carry the weak nuclear force (W and Z bosons, which are actually more massive than an atom of hydrogen).

This lack of symmetry was an obstacle to unifying these two forces under a theory called the electroweak theory. This theory is part of the Standard Model. However, if the Higgs field exists, then photons and W or Z bosons would be essentially manifestations of the same type of boson, with their differences coming from how they interact with the Higgs field.

This model of the electroweak force was tested for over twenty years through many experiments performed at high-energy particle accelerators around the world. The model has successfully predicted many of these results, and it can be considered one of the best-tested theories of elementary particle physics today.

Yet, one of its key elements, the Higgs boson, as not been observed.

Why is the Higgs boson important?

If the Higgs boson is found, then the Standard Model will be further validated.

If the Higgs boson is not found, then original problems with the Standard Model would need other explanations. There are other theories, besides the Higgs boson, that would help explain these inconsistencies. However, it may also indicate the model has fundamental flaws.

How do you find it? (CERN detectors)

Most elementary particles are found by colliding pairs of elementary particles at high energy. The collision creates other particles. To do this, particles must be accelerated towards each other at high speeds in a particle accelerator, and the results of the collisions must be observed by large detectors surrounding the collision point. Data from the detectors must then be analyzed.

The Large Hadron Collider (LHC) at the CERN laboratory in Geneva, Switzerland was built over the last two decades to create these collisions. The LHC collides protons together at the highest energy achieved in a laboratory, 7 tera-electron Volts (TeV).

Very occasionally, a Higgs boson would be produced in these collisions. However, there are many other collisions that are very similar to those that produce Higgs bosons. They are considered “background” events, and they have to be quantified. Only a significant excess of “Higgs-like” events above the expected background would be evidence for the existence of a Higgs boson.

How will it be measured?

Thanks to Einstein’s famous equation, $E = mc^2$, where c is the speed of light in vacuum, we know that mass and energy are proportional. Therefore, elementary particle masses aren’t measured with familiar units like grams, but rather a unit of energy called the electron Volt divided by the speed of light squared - abbreviated eV/c^2. For convenience, people often use the same unit — eV — in referring to mass and energy. One billion electron Volts —a thousand-million electron Volts- is a giga electron volt, or GeV.

There are some clues to what the mass of the Higgs boson might be. Combined data from the ATLAS and CMS experiments at CERN suggests its mass is above 114 and below 141 gigaelectron Volts (GeV), with a statistical confidence of 95 per cent (this means that the chances of it being outside this range are less than 1 in 20). Measurements from a proton-antiproton collider at the Fermilab laboratory outside of Chicago, IL known as the Tevatron have also excluded Higgs boson masses from 156 GeV to 177 GeV.

In particle physics, the “confidence level” –the likelihood that the results are right– is stated in units of “standard deviations”, or sigmas. An observation, for example, with a confidence level of at least five sigmas in particle physics is considered very strong evidence and often declared a discovery. This translates into a probability of being wrong of about 0.00003%, or 3 in 10 million.

Who’s looking?

Only a few accelerators operate at high enough energies to produce the collisions required to observe the Higgs boson. The only one currently operating is CERN’s Large Hadron Collider, a 27-km-circumference tunnel, 100 m underground, producing 7 TeV proton-proton collisions. Two large collaborations have built detectors designed, in part, to search for the Higgs boson.

1. The CMS, or Compact Muon Solenoid, is one detector in the LHC that is specifically looking for the Higgs Boson.

2. The ATLAS (A Toroidal LHC ApparatuS) project, also at the LHC, is trying to find the Higgs boson. There are over 100 Canadian researchers that are part of the ATLAS experiment, listed here.

Experiments at the Fermilab Tevatron accelerator in Illinois also searched for the Higgs boson until being shut down last year. The most recent results of those experiments have ruled out a Higgs boson with a range of masses between 156 and 177 GeV and 100 to 108 GeV.

Searches for the Higgs boson also were done by experiments studying electron-antielectron collisions at the Large Electron Project at CERN in the 1990s. They ruled out a Higgs boson with a mass less than 114 GeV.

What’s next?

If the results from the two separate experiments at CERN suggest that the Higgs boson exists, and they are in agreement about the approximate mass, then the search for the Higgs boson will intensify with the experiments analyzing additional data and possibly combining their results. Regardless, the LHC will run next year, and both experiments expect to collect several times more data. The next batch of results should be released next year.

Its possible that the Higgs boson predicted by the Standard Model doesn’t exist, and the data collected next year may be able to confirm this. If this is the case, then elementary particle physics will be tossed upside down as the experiments will intensify their efforts to seek signs of what actually is the reason for the mass in our universe.