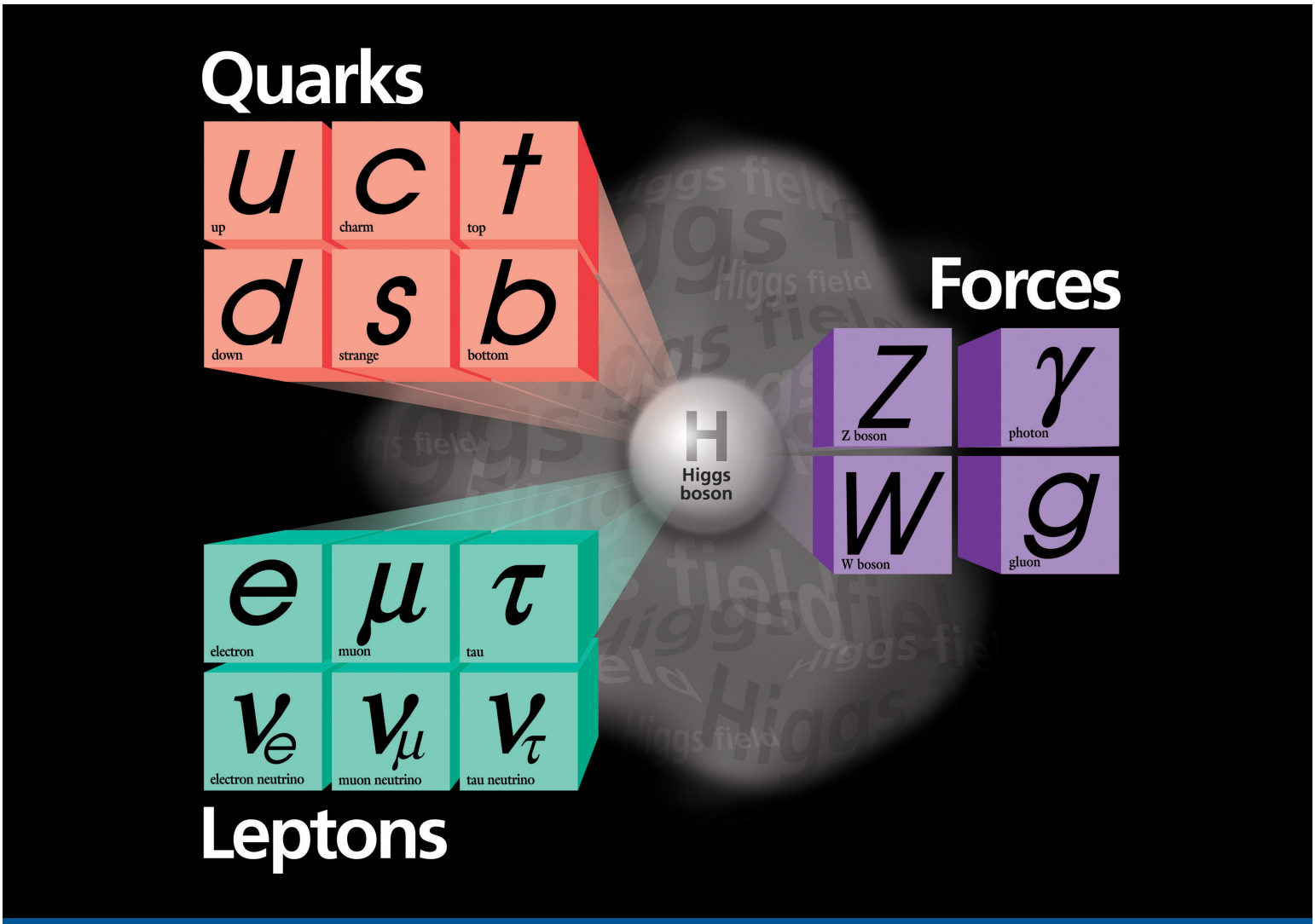
What is a Higgs boson?

In 2012 at the Large Hadron Collider, scientists discovered the long-sought Higgs boson. Now the question is: Are there more types of Higgs bosons?



The Higgs field provides mass to quarks and other elementary particles that are the building blocks of matter. The photon and the gluon do not interact with the Higgs field, and hence they have no mass. Whether the Higgs field is the origin of the mass of dark matter or the tiny mass of the three known types of neutrinos is not yet known.

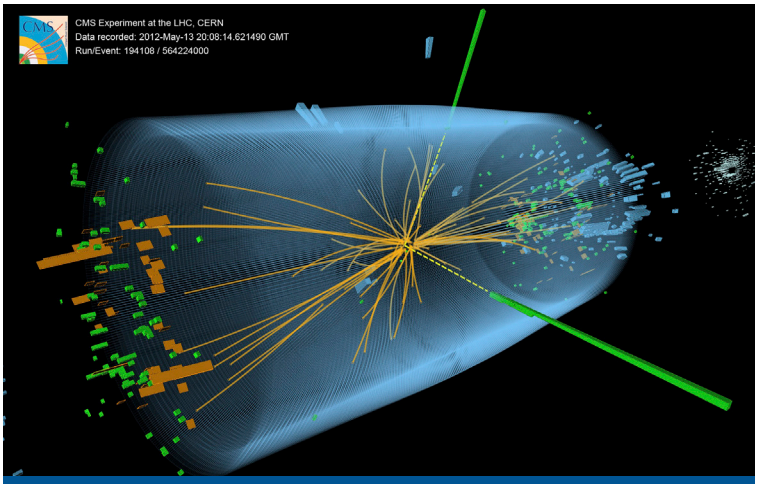
What is a Higgs field? What is a Higgs boson?

The Higgs field is a force field that acts like a giant vat of molasses spread throughout the universe. Most of the known types of particles that travel through it stick to the molasses, which slows them down and makes them heavier. The Higgs boson is a particle that helps transmit the mass-giving Higgs field, similar to the way a particle of light, the photon, transmits the electromagnetic field.

When did scientists discover the Higgs boson?

Scientists searched for the Higgs boson for more than two decades, starting with the LEP experiments at CERN in the 1990s and the Tevatron experiments at Fermilab in the 2000s. Years' worth of LEP and Tevatron data narrowed the search for the Higgs particle. Then, in 2012 at CERN's Large Hadron Collider (LHC), two experiments, ATLAS and CMS, reported the observation of a Higgs-like particle. With further analysis the new particle was confirmed as the Higgs boson in 2013. About 7,000 scientists from more than 40 countries, including the United States, contributed to this discovery. It resulted in a Nobel Prize in physics to Peter Higgs and François Englert, who first had proposed the existence of the Higgs boson in 1964.

About 1,700 U.S. scientists participate in research at the Large Hadron Collider.



The pattern of particles emerging from this proton-proton collision, recorded by the CMS experiment at the Large Hadron Collider, is consistent with the production of the Higgs particle. Scientists needed to identify many particle collision events like this one to determine that the Higgs particle exists and what properties it has.

What would the world look like without the Higgs boson or a similar particle?

You wouldn't recognize the world. Without the Higgs boson or something like it giving mass to the basic building blocks of matter, electrons would zip about at the speed of light. They would not form unions with protons or other would-be nuclei to make atoms. Without atoms, there would be no chemical reactions, no molecules, no ordinary matter as we know it and no template for life. We would not exist.

How do scientists create a Higgs boson?

A high-energy particle accelerator like the LHC can recreate the extreme energies of the very early universe, shortly after the Big Bang. Scientists collide particles at these energies to produce other particles, including Higgs bosons, turning energy into matter following Einstein's famous equation $E=mc^2$. When the Higgs boson was discovered at the LHC, it was being produced about once per four billion proton-proton collisions.

How did scientists know they had found a Higgs boson?

The Higgs boson, like other heavy particles, decays into lighter particles, which then decay into even lighter particles. This process can follow a certain number of paths, and it's more likely to decay through some paths than others. The decay paths also depend on the particle's mass.

To determine the mass of the Higgs boson, scientists compared the decay paths they observed after a particle collision to the decay paths they simulated with computers and mapped out for a possible range of Higgs masses. When they observed a decay path that looked similar to the one they predicted—in other words, when they saw a match—they knew they had seen a Higgs boson.

By adding up the energy of all the lighter particles appearing in a particular decay path, scientists calculated the Higgs boson's mass to be about 125 billion electron volts (GeV), or about 125 times heavier than a hydrogen atom.

What else can scientists learn about the Higgs boson?

Scientists still have much to learn about the Higgs boson: how it relates to other particles, whether it gives mass to neutrinos and dark matter, and whether there is more than one type of Higgs boson. While scientists have observed some of the predicted Higgs decays into other particles, they have not yet observed all of them. In 2015, the LHC began its second run at a 60 percent higher energy, which will enable ATLAS and CMS to produce more Higgs bosons for study and opens up the possibility for producing additional types of Higgs bosons. One particular model of particle interactions, known as Supersymmetry, predicts the existence of at least five types of Higgs bosons.

How is the Higgs boson related to the Big Bang?

About 13.8 billion years ago, the Big Bang sent massless particles and radiation energy zooming through the universe. Scientists theorize that fractions of a second later, part of the radiation energy congealed into the Higgs field. When the universe began to cool, particles acquired mass from the Higgs field, slowed down and began to bunch up to form composite particles and, eventually, atoms.

How did the Higgs boson get the nickname "the God particle"?

Nobel laureate Leon Lederman, who was Fermilab's second director, wrote a book in the early 1990s about particle physics and the search for the Higgs boson. His publisher coined the name as a marketable title for the book. Many scientists dislike the nickname.

How many U.S. institutions are involved in CERN's ATLAS and CMS experiments at the LHC?

Seven U.S. national laboratories and 94 U.S. universities have scientists working on the LHC and its experiments. A significant fraction of the technological innovation, computing and data analysis for LHC research occurs in the United States, and U.S. scientists based at CERN help implement U.S.-designed technology in the experiments and collaborate with our international partners to search for new physics and phenomenon.

How is Fermilab involved in the LHC?

Fermilab supports the CMS experiment by providing about 1,000 U.S. CMS scientists and engineers with access to computing facilities, office and meeting space, as well as the LHC Remote Operations Center that directly links Fermilab to the CMS experiment at CERN. Fermilab helped design and build the CMS detector as well as equipment for the LHC accelerator. The laboratory also leads the U.S. effort to help upgrade the LHC and its CMS experiment. Data centers and computers at Fermilab store and analyze particle collisions recorded at the LHC.