Stitching Up the LHC

The story of the Large Hadron Collider (LHC) began in the 1970s, when the European particle physics community began discussing the construction of a Large Electron-Positron collider. This required the construction of a 27km tunnel running underneath Geneva, Switzerland, and now the tunnel currently houses the LHC. The LHC produces high-energy particle collisions in order to study the fundamental constituents of the universe, including the famous discovery of the Higgs Boson, discovered in 2012.

The Compact Muon Solenoid (CMS) experiment of the LHC was originally designed to search for evidence of the Higgs Boson. Almost 4000 people from 43 countries built and operate the detector, which has been active since the end of its construction in September 2008.

WHY THE HIGGS?

We have been able to describe our universe through four fundamental forces: electromagnetism, gravity, the weak force and the strong force. During the 1970s, the weak and electromagnetic forces were seen to be facets of one electroweak force, after scientists realised the similarities between the two fundamental forces.

The combined theories of the electroweak and strong forces form the backbone of the standard model of particle physics, which describes all elementary particles and their interactions with one another. However, there is evidence that the standard model is incomplete.

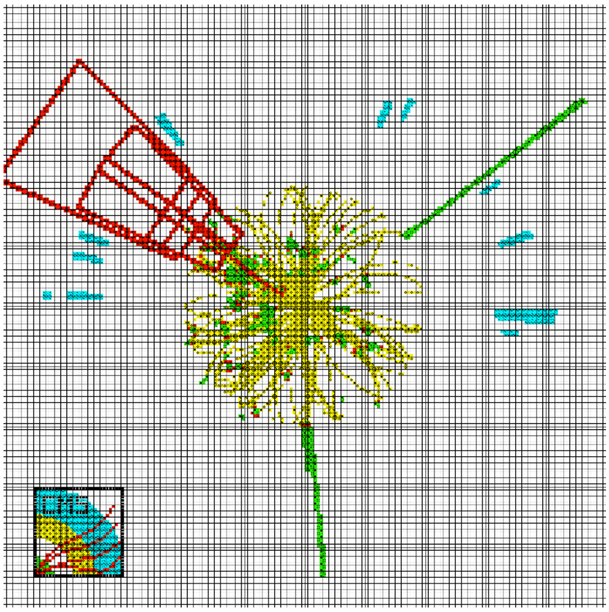
In order to adapt theory to match our observations in nature, several physicists proposed a new mechanism that would explain this; once integrated with existing equations it successfully allows these particles to have mass. Peter Higgs and Francois Englert explained a proposed mechanism to explain why particles have mass, which would only work if an unseen particle existed. This has since been known as the Higgs boson. Evidence for the existence of the Higgs boson was found in 2012, after which Higgs and Englert received Nobel prizes in Physics.

THE FUTURE OF PARTICLE PHYSICS

In 2021, the LHC and CMS experiment will be coming out of maintenance. When this shutdown period ends, the CMS experiment will be used to investigate even higher energy particle interactions to test new theories of particle physics.

CROSS-STITCH

What can you expect to see in your cross-stitch chart?



In red, we have signals from muons (heavier versions of electrons). Four layers of detectors track the movement of the muon through space. Muons can penetrate through a lot of materials, so the detectors are at the edge of the detector.

In green are signals in the ECAL detector. ECAL stands for *electromagnetic calorimeter*. This determines the energies of electrons and photons.

In blue, we have signals in the HCAL detector. HCAL stands for *hadronic calorimeter*, and its main purpose is to measure the energies of hadrons (particles made up of smaller particles called quarks).

In yellow, we can see the tracks from electrically charged particles. This region is highly sensitive and has many layers of detectors, in order to get precise measurements of the trajectories of particles produced in the collision.

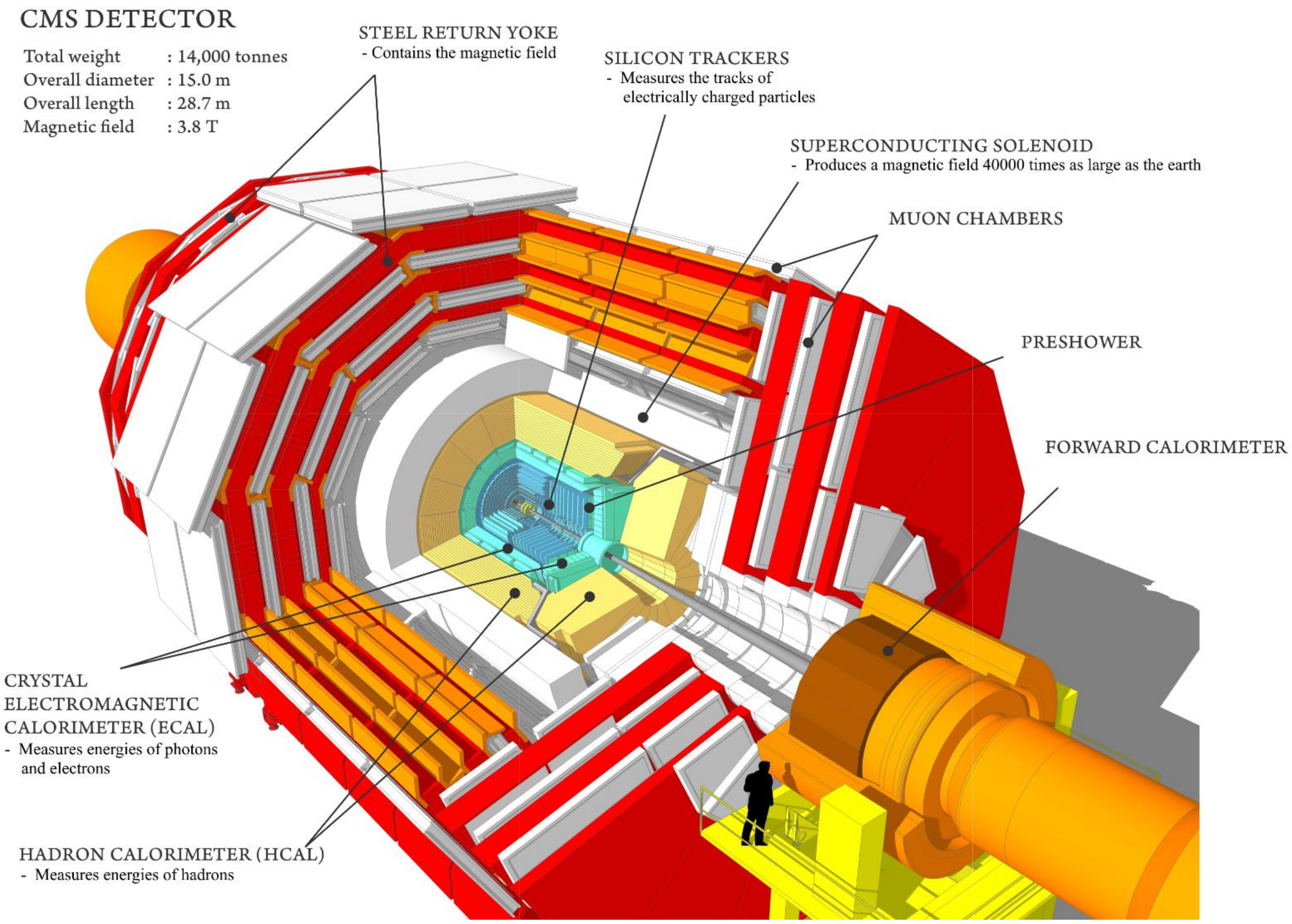


Image credit: CERN

WHAT CAN YOU SEE IN YOUR CHART?

The Higgs Boson decays very quickly into several smaller particles. We can detect the Higgs Boson by finding these decay products. On the right, the probabilities of decay modes depending on the energy of the Higgs are shown. Some of the decay modes are:

<u>4-Lepton</u>

One decay mode of the Higgs Boson is into four leptons (electrons or muons). In this case, the Higgs Boson will decay into two bosons, where each boson will decay into two leptons.

<u>Di-photon</u>

Another decay mode is into two photons. Although unlikely, this is easy to observe as these photons are indicated by two large energy spikes in the ECAL.

FACTS ABOUT THE LHC

- The LHC is the collective results of over 10000 scientists and engineers from over 60 countries and a decade of work
- At full power, the LHC can produce almost 600 million collisions per second
- In a typical 12 hour run, there are around 30 million collision events, totalling in 2000 petabytes of data per run.
- So much data is produced, that only 0.004% of data generated through collisions are stored.

FURTHER READING

cms.cern/collaboration

cms.cern/tags/outreach

home.cern/science/physics

home.cern/tags/outreach

home.cern/resources/faqs/facts-and-figures-about-lhc