Discovering the Higgs Boson in 6 Steps

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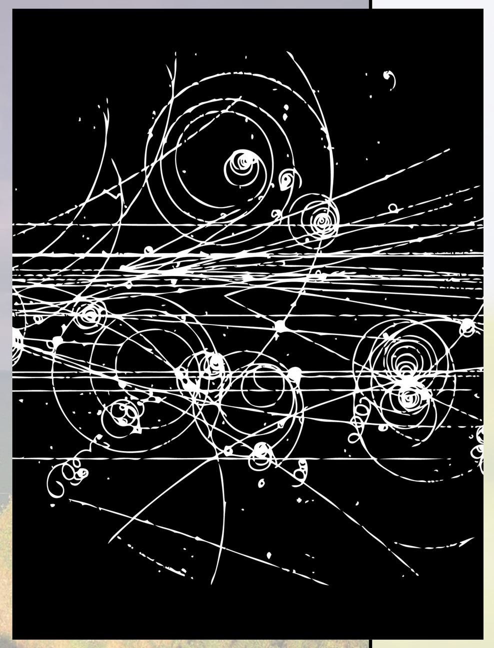
1. Model Construction

In Particle Physics, the tiniest building blocks of matter are studied. These building blocks we call **particles**, and all matter that we deal with in everyday life is composed of them: desks, pens, cars, food, air, the human body, …

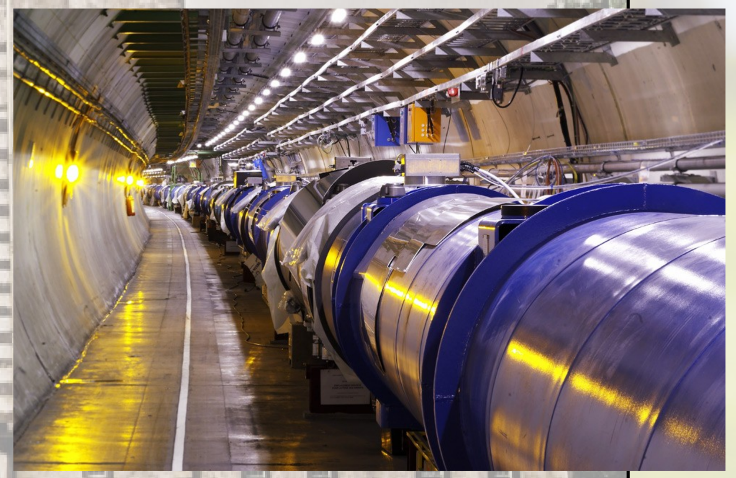


The aim of Particle Physics is to understand the laws of nature that those particles obey. This allows to make predictions for future experiments, and can eventually lead to technological advance.

From previous experiments, the Standard Model of Particle Physics has been developed. This theory predicts the outcome of those experiments in great detail. It also predicts the existence of a particle, called the **Higgs Boson**, which has not yet been observed in an experiment. However, without the existence of the Higgs Boson, the outcome of previous experiments cannot be explained coherently. The Higgs Boson is the key of the mechanism which generates the mass of all other particles.

2. The Large Hadron Collider

Experiments in Particle Physics are conducted by scattering (colliding) particles with each other. The first experiment of this type was performed by E. Rutherford in 1909 where particles were scattered on a thin gold foil. Since some particles were deflected by the foil at a large angle, it was concluded that the positive charge in an atom is concentrated only in a small core.

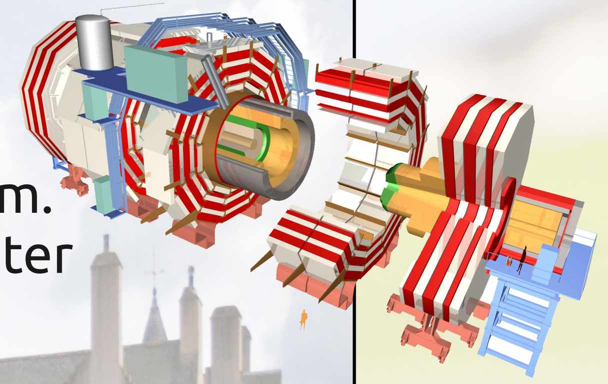


In modern days, two beams of highly energetic particles are collided with each other. The **Large Hadron Collider** (LHC) is a particle accelerator at CERN near Geneva, Switzerland. It is a ring collider 100 m underground with a circumference of 27km. It speeds up protons to unprecedented energies and collides them head-on.

The primary goal of the LHC is to produce Higgs Bosons in high energy particle collisions, if they exist.

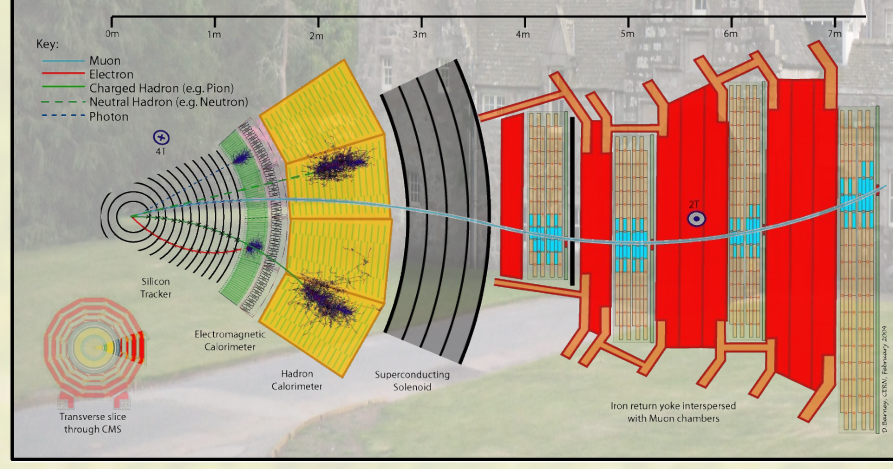
3. The Compact Muon Solenoid

The Higgs Boson is postulated to decay immediately after its creation into lighter, already known particles. These particles need to be recorded near the collision point so that properties of the Higgs Boson can be reconstructed.



Big particle detectors have been installed at the interaction points in the LHC tunnel. The **Compact Muon Solenoid** (CMS) is one of them. The apparatus is 21m in length, 16m in diameter and weighs 12.500 metric tons.

CMS consists of multiple sub-detectors each of which assists in identifying different types of particles. They are arranged concentrically around the collision point. A superconducting magnet bends the trajectories of charged particles, allowing to measure their charge and momentum.



4. Data Reduction

Particle Physics processes are of statistical nature, i.e. in order to discover the Higgs Boson, many collisions are required. This can be compared to rolling dice: when, out of 5 dice rolls, 2 times a six is obtained, this is not special. However, 200 sixes with 500 rolls are unexpected. One needs many experiments in order to be confident about a possible observation.

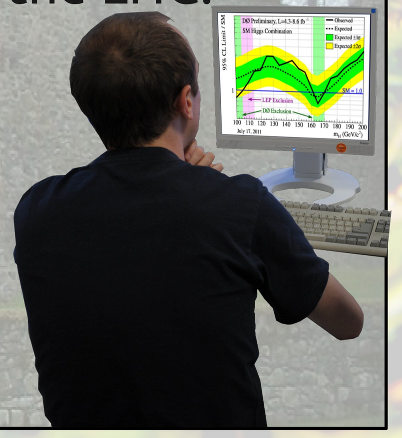
In the LHC, 1380 **bunches** of protons travel in the ring at the same time in both directions. About 15 million bunch crossings occur every second, with about 20 particle collisions in each crossing. This amounts to a data rate to be stored for future analysis of about 15 TB/s.

This amount is too large to be analyzed or even stored. Such collisions where it is clear from the beginning that no Higgs Boson was produced are discarded immediately. This procedure is called **Triggering** and reduces the number of stored collisions per second to about 300, which is a manageable number.

5. The LHC Computing Grid

Even after the data reduction step, about 10 PB of data need to be analyzed and archived per year. This also includes data from computer simulations which are compared to the data from the experiment, in order to spot any possible differences between theory and physics observation (reality).

The task of storing and processing the data is shared by a network of computing centers around the world, the **Worldwide LHC Computing Grid**. Only the combined resources of many institutions allow to cope with the enormous amounts of data produced by and for the LHC.



The worldwide distribution of the data also provides redundancy and quick access to the data for researchers all around the world, via their home institutions or the public internet.

6. Data Analysis and Results

By comparing measured data to simulated data with and without the presence of the Higgs Boson, physicists draw conclusions on whether the Higgs Boson exists in nature or not. When the data agrees, up to a certain degree of confidence, with the hypothesis of an existing Higgs Boson but not to the one without, a discovery can be claimed.

Indeed on July 4, 2012, the CMS and ATLAS experiments announced the **discovery of a new particle** not seen before which could be a Higgs-like Boson. Further studies are being conducted to measure the properties of the new particle so that it can be decided whether it is the Higgs Boson of the Standard Model or something new and unexpected.

The search for the Higgs Boson is not the only research topic at the LHC. Other studies include the search for **Supersymmetry** and **Dark Matter**, or the study of **Quark-Gluon Plasmas** which existed shortly after the Big Bang.