CERN

- LHC
- HIGGS BOSON AND EXPERIMENTS AT CERN

- GREAT DISCOVERIES

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INTRODUCTION

CERN or the European Organization for Nuclear Research is the largest research laboratory in Europe. It was founded in 1954, after the second world war and the main site is located in Switzerland. The main goal of CERN is to find out how the universe works. They attempt to do that with the Large Hadron Collider or the LHC. CERN's most essential function is to provide particle accelerators and other infrastructures for high-energy physics research. The main site has several computing facilities which are primarily used to store and analyse data from experiments. An interesting fact is that CERN is also the birthplace of the World Wide Web which is an important complex in the world of physics.

LHC

The Large Hadron Collider is the world's largest and most powerful particle accelerator and it is very important for CERN. It consists of a 27-kilometre ring of superconducting

magnets with a number of accelerating structures to boost the energy of the particles along the way.

Inside the accelerator, two high-energy particle beams travel at close to the speed of light before they are made to collide. The beams travel in opposite directions in separate beam pipes – two tubes kept at ultrahigh vacuum. They are guided around the accelerator ring by a strong magnetic field, maintained by superconducting electromagnets. The electromagnets are built from coils of special electric cable that operates in a superconducting state, efficiently conducting electricity without resistance or loss of energy. This requires chilling the magnets to -271.3°C – a temperature colder than outer space. For this reason, much of the accelerator is connected to a distribution system of liquid helium, which cools the magnets, as well as to other supply services.

Thousands of magnets of different varieties and sizes are used to direct the beams around the accelerator. These include 1232 dipole magnets, 15 metres in length which bend the beams, and 392 quadrupole magnets, each 5–7 metres long, which focus the beams. Just prior to collision, another type of magnet is used to "squeeze" the particles closer together to increase the chances of collisions. An important example can be to compare the collision of particles so small that they are compared to firing two needles 10 kilometres away and the accuracy is so high that the particles meet halfway.

All the controls for the accelerator, its services and technical infrastructure are housed under one roof at the CERN Control Centre. From here, the beams inside the LHC are made to collide at four locations around the accelerator ring, corresponding to the positions of four particle detectors – ATLAS, CMS, ALICE and LHCb.

Of course there’s more to CERN than only the Large Hadron Collider. This organisation consists of a large accelerator complex, including theAntiproton Decelerator, the Online Isotope Mass Separator (ISOLDE) facility, and the Compact Linear Collider test area, as well as the neutron time-of-flight facility (nTOF).

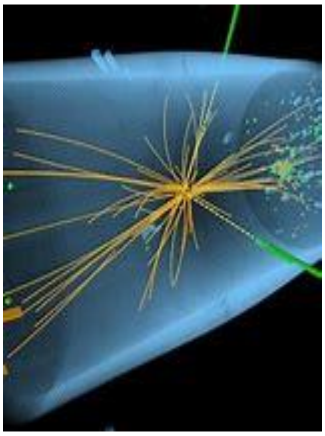
Previously it also fed the CERN Neutrinos to the Gran Sasso which photo is shown here at the top.

It wouldn’t be called a scientific organisation if they weren’t constantly looking for innovation and progress. This is why the FCC or Future Circular Colliderstudy has been

founded.
The FCC, of which CERN is the Host Organisation, is an open international collaboration and one of their main goals is to find ways to establish new accelerators and inaugurate the post-LHC era in high-energy physics. They are focussing on three scenarios: a hadron-hadron collider, a lepton-lepton collider and a hadron-lepton collider. Their biggest project is the study of the highest-luminosity high-energy lepton collider (FCC-ee) and an energy-frontier hadron collider (FCC-hh), which could, successively, be installed in the same 100 km tunnel.
Every year there is a large FCC Conference on which the leading minds of science come together and discuss the FCC study, but they also set near-term goals for the coming years.

HIGGS BOSON AND EXPERIMENTS AT CERN

The Large Hadron Collider plays a great role in discovering outer space. Its main purpose is to discover the substance and energy of the universe, in order to pave the way to the so called “New Physics”, a modern conception of physics which is centered on the field of High Energy. Since its set up in 2008, it has reached various achievements through multiple experiments. Among them, ATLAS and CMS are the most important, as they verified experimentally the speculations regarding the existence of a new boson, later named after the physicist Peter Higgs who was the first to theorize it in 1964.



Peter Higgs hypothesized the existence of a field in which all particles would move giving the particle mass. Higgs thought that this field had a particle associated with it. This particle was called the Higgs boson. It was also called "God particle". A few years later after the start of LHC, physicists had collected data from within the LHC that confirmed that the found particle was the Higgs. This is so far the first and only elementary scale particle which has been observed; that is, a very small elementary particle. It is also responsible for the mass of every existing particle in our universe and could play a key role in resolving the conceptual problems of modern physics such as the unification between Gravity and Quantic physics.

In 2012 at CERN, ATLAS and CMS have analyzed the particles created in the collision of protons at light speed inside the LHC. The experiment confirmed the existence of a new particle with the same characteristics as the one theorized back in the 1960s: the Higgs Boson was finally proven scientifically. The discovery of this Higgs boson completes the Standard Model of particle physics which is a theory that describes how three of the four fundamental forces interact at the subatomic level.

Among the experiments carried out at CERN, conducted in 2004 and 2009, MoEDAL and LHCf are relevant: they are central to the study of astroparticle physics as well as representing two of the detectors in the LHC accelerator at CERN. The photo in the right shows the interior of the LHC accelerator which consists of a 27 km ring of superconducting magnets with accelerating structures to boost the energy of the particles.

LHCf was designed to analyse the measurement of particles traveling towards the direction of colliding proton beams, in order to explain the origin of Ultra High Energy Cosmic Rays. MoEDAL's goal was to search for the magnetic monopole (that is, a hypothetical elementary particle made of an isolated magnet with only one magnetic pole) and pseudo-stable massive particles; so as to detect these particles, nuclear track detectors were used in the experiment.

Nowadays, CERN represents a truly important mean to the development of modern physics, thanks to its highly professional equipment and team of scientists.

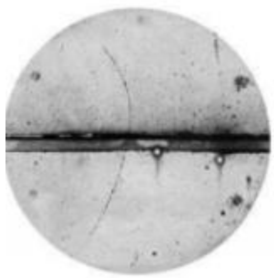
GREAT DISCOVERIES

Regarding the great discoveries obtained by CERN, we can point out the following aspects: The first great discovery was the discovery of weak neutral currents. These are currents that affect particles that interact with each other. This discovery occurred in 1973 in the Gargamellebubble chamber, which is the machine that allowed this discovery. The name Gargamelle refers to both the bubble chamber detector and the high-energy physics experiment. Weak neutral currents describe how subatomic particles can interact through weak force. This discovery helped unify two of nature's fundamental interactions, which are electromagnetic and weak force, that were seen as an electroweak force. The scientists who provided this theory have won the Nobel Prize for their work in 1979.

From CERN Neutrino Platform - CERN Document Server:

Light Neutrinos

Another important discovery was that of W and Z bosons in UA1 and UA2 experiments. In 1983, these bosons were discovered as elementary particles that mediate weak force. Physicists have discovered that there are two W bosons that have opposite charges and finally the Z boson that is without charge. This discovery contributed to the birth of the Standard Model. Through two very famous experiments called U1 and U2, two physicists whose names are Carlo Rubbia and Simon van der Meer -with the help of a very strong team- found an evidence to verify the existence of the W and Z bosons. The following year the two scientists received the Nobel Prize in Physics.



Antimatter

One discovery that greatly influenced the field of physics was the discovery of light neutrinos. These particles only sometimes interact with others and therefore are also called "ghost particles". Through the use of a machine called "ALEPH" detector, these new particles were discovered. The thing that was really amazing is that the results also agreed with the Standard Model. Therefore in 1989 the number of particle families containing light neutrinos was determined.

In 1995 there was the creation of antihydrogen atoms that were reached by the PS210 experiment. Anti-hydrogen is a form of antimatter, but is a negative-charged version of hydrogen. The antimatter, however, collided with matter and everything was destroyed before it could be studied. Antimatter is formed by particles that have the same mass as a particle of matter but with an opposite electric charge. When matter and antimatter come together, they destroy themselves and release enormous amounts of energy and thus produce high-energy particles such as gamma rays. Only in the following years, in 2010 CERN was able to isolate 38 antihydrogen atoms. And a year later, they were already able to maintain antimatter for more than 15 minutes.

And finally, another important discovery was the detection of a direct CP violation that occurred through the NA48 experiment. CERN physicists have been able to demonstrate that parity of charge is violated. Nuclear physicists James Cronin and Val Fitch found the first evidence to prove that the CP symmetry could be broken and were awarded with the Nobel Prize. The final evidence for the violation of this symmetry came only in 1999.

In conclusion, all these discoveries have led to important goals for the world of physics and have allowed scientists and later physicists to progress in the scientific field.

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