CERN and LHC

Belgium, De Bron Tielt:

Céline Poignie

Hanne De Smet

Maarten Tack

Warre Van den Meerssche

Italy, Liceo Scientifico G. Ricci Curbastro :

Cecilia Roccati

Siria Valeck

Bianca Balbi

CERN

Introduction:

In the early 1945s, five pioneers decided to give life to a physics laboratory that associates different scientists from all over the world but also to share their extraordinary discoveries.

CERN was created at the end of World War II, and it's located in the northeast of Switzerland, in the suburbs of Geneva.

Its name is an acronym for the French word "Conseil Européen pour la Recherche Nucléaire", which means "European Organization for Nuclear Research". It is the most significant and largest laboratory in the world which deals with the physics of particles. Because of this, the laboratory operated by CERN is often referred to as the European Laboratory for Particle Physics.

Figure 1: CERN building

In June 1953, the CERN convention was signed by 12 Member States, which would contribute annually to CERN's budget. After 50 years, the Member states are 23, some of them non-European.

The CERN is made up of 7 main particle accelerators: two LINAC, Low Energy Ion Ring (LEIR), PS Booster, Proton Synchrotron (PS), Super Proton Synchrotron (SPS), and the Large Hadron Collider (LHC). They are all connected to form a sort of ring which creates a particle beam stronger than individually.

Today the main director of the CERN is Fabiola Gianotti, a renowned Italian scientist, and researcher in the field of particle physics. She has been the leader in many important experiments like the ATLAS, during which she was involved in the discovery of the Higgs Boson.

On 1st January 2016, she became the first female director in the history of CERN, and in 2019, she was renewed for a second term of office.

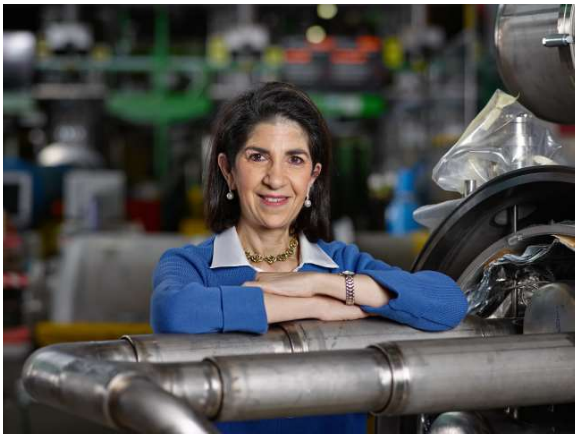


Figure 2: Fabiola Gianotti

The history of CERN

At the end of World War 2, scientists imagined creating a European nuclear and particle physics laboratory. Such a laboratory would not only unite European scientists but also allow them to share the increasing costs of nuclear physics facilities. After numerous of conferences, there came an agreement in 1951. The first 12 countries signed the agreement, which was the basis of the origin of the CERN. The construction of the laboratory started on the 17th of May 1954.

Their very first machine was a synchrocyclotron, built in 1957. With this machine, they started experimenting with particles and nuclear physics. A few years later, a proton synchrotron was built that could concentrate more on particle physics alone.

With its seven kilometres, the Super Proton Synchrotron (SPS) was the first of CERN's giant underground rings. it was switched on for the first time on 17 June 1976. It became the workhorse of CERN's particle physics programme. It permitted further research in matter and antimatter, the inner structure of protons.

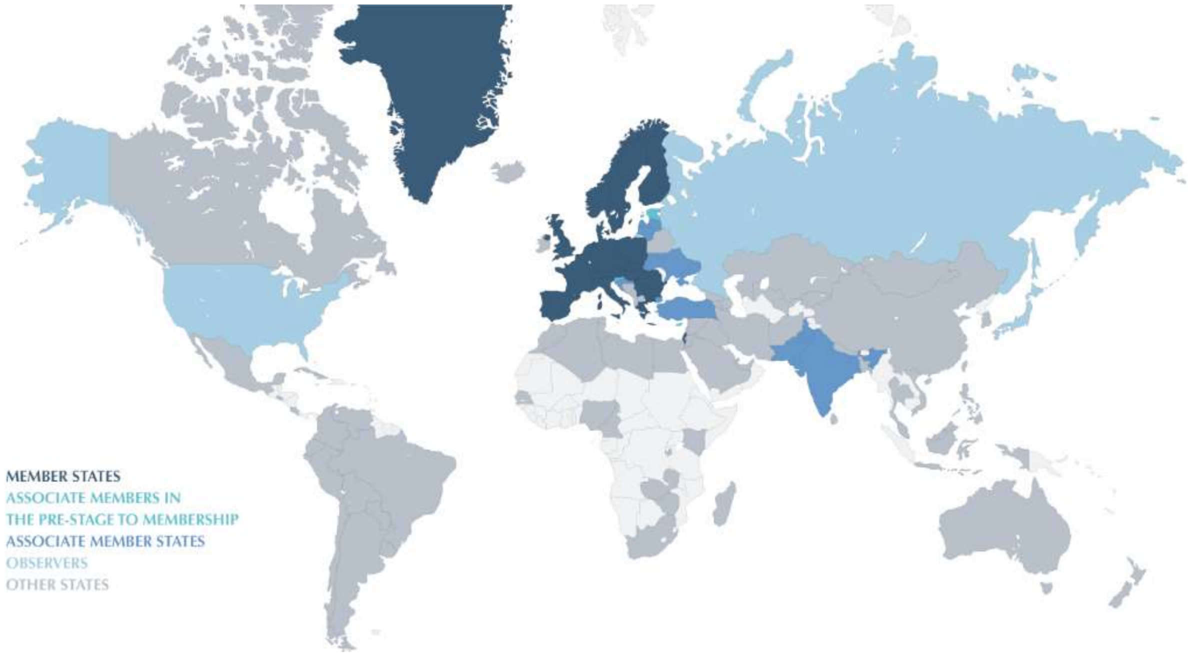
On 8 February 1988, the excavation of the tunnel for the Large Electron-Positron Collider was completed. With its 27 kilometres, it was a much bigger ring than the Super Proton Synchroton (SPS). It was the largest electron–positron accelerator ever built. LEP consisted of 5176 magnets. For seven years, the accelerator operated at 100 GeV, producing 17 million Z particles, an electrically neutral elementary particle. Later, it upgraded for a second operation phase, with 288 particle accelerators added to double the energy and production. The LEP was closed in the year 2000 to make the construction of the LHC in the same tunnel possible. The LHC (Large Hadron Collider) was constructed to answer certain questions: what gives matter its mass and what the invisible 96% of the universe is made of?

In November 2006, the ATLAS Barrel Toroid was switched on for the first time. The magnet provides a powerful magnetic field. in which beams of protons (produced by the LHC) collide. This was part of the ATLAS experiment. in which a variety of different particles with different energies were observed.

Members and budget:

Who are the member states?

CERN has 23 member states, these states have special privileges and duties. They contribute to the capital and operating costs of CERN's programmes and, are a member of the Council of the organization. They are responsible for all the important decisions the organization must make and the activities. The most recent new member state is Serbia, who joined in 2019. There are three countries who are Associate Member States in the pre-stage of getting a membership, seven other countries are just Associate Member States. The member states are all European countries, but many non-European states are involved as well, some of these countries, have an Observer Status, they can investigate the experiments. Three international organizations also have observer status, these are European Union, JINX and UNESCO. Almost 50 non-members have international co-operation contracts, approximately 20 other countries have scientific contacts with CERN. On the map, you can see all the different members and associates.



CERN. (2021, August). *CERN member states map* [Photo]. home.cern. https://cds.cern.ch/record/2777910

CERN's budget

There are over 600 institutes and universities all over the world that use CERN's materials and facilities. Both member states and non-members are the funding agencies responsible for the financing, construction, and operation of each experiment on which they collaborate. The largest part of the budget is used for the construction and experiments involving the LHC.

What is CERN trying to achieve?

CERN is mainly a particle physics laboratory and that the discoveries, in particle physics helps understand what the universe is made of and how it works.

Some of the discoveries are:

Neutral current:

Weak neutral current interactions are one of how subatomic particles can interact by means of the weak force. These interactions are mediated by the Z boson. The discovery of weak neutral currents was a significant step toward the unification of electromagnetism and the weak force into the electroweak force and led to the discovery of the W and Z bosons. This event shows the traces left in the 1200-liter tank of the Gargamelle bubble chamber, which led to the first confirmation of neutral currents.

Figure 3: Neutral current

W and Z bosons:

W and Z bosons are responsible for the weak force, one of four fundamental forces that govern the behavior of matter in our universe. The W boson, which is electrically charged, changes the very makeup of particles. It switches protons into neutrons, and vice versa, through the weak force, triggering nuclear fusion and letting stars burn. The Z boson carries the weak force. One curiosity is that the Italian physicist Carlo Rubbia was awarded the Nobel Prize for them.

The identification of neutrinos:

In 1989, CERN scientists determined the number of families of particles containing what are known as light neutrinos. Uncharged elementary particles with very little or no mass, neutrinos only rarely interact with other particles, and thus are sometimes called "ghost particles."

The Higgs boson:

A subatomic particle whose existence is predicted by the theory which unified the weak and electromagnetic interactions. That discovery was possible thanks to The Large Hadron Collider (LHC), One curiosity is that that the Belgian physicist Francois Englert has received the Nobel prize (together with Peter Higgs).

Figure 4: WWW at CERN

The World Wide Web:

In 1989 “www” was born as a tool to allow scientists around the world to share data. In very little time the first browser server went live at CERN and was announced on the internet. In 1993 the CERN put the www in the public domain and widespread all over the world.

How did CERN help computer technology?

How was the touchscreen born?

The touch screen was born out of a need. The CERN is composed of eight particle accelerators and one of these important scientific machines is the Super Proton Synchrotron (SPS), it is the second-largest machine in CERN’s accelerator complex.

Figure 5: The first touchsreen

This SPS needed a lot of buttons, knobs, and switches, and using it was very difficult. To simplify this system Frank Beck, responsible for the accelerator control room, asked Bent Stumpe to build the hardware for a system that had all the important commands. Stumpe chose a method that exploited electrical capacity and made an integrated circuit in a screen of glass so that when he touches the dielectric of the capacitor changes locally. This variation of dielectric causes another one in the electric capacity and finally software calculates the difference of capacity in the two areas: the one touched and the surrounding one, to find the exact spot on the screen you touched.

This innovative project was immediately approved and released, until it became one of the most important things in today's technology, like computers, tablets, and phones.

How can it be useful?

The touchscreen is not the only important social creation of the CERN, another thing that we cannot be without is the World Wide Web. The Web was originally developed to meet the demand for automated information-sharing between scientists in universities and institutes around the world.

The basic idea of the WWW was to join the technologies of computers, data networks, and hypertext into a powerful and easy-to-use global information system.

Tim Berners-Lee, a British scientist, invented the World Wide Web (WWW) in 1989, and then together with Belgian engineer Robert Cailliau in November 1990 created the first Web server and browser up and running at CERN.

Figure 6: World Wide Web logo

In the following years, it developed more and more, until it reached what it is today, where its main use is for commercial and private purposes.

Ongoing projects

The LHC isn't the only machine CERN is experimenting with. In fact, CERN-scientists work on different projects. Eight projects work around the LHC alone and search for the structure of matter and antimatter and try to 'catch' undiscovered particles created by a collision in the LHC.

Other than the LHC, CERN also experiments with smaller accelerators including the Super Proton Synchrotron, housing several experiments that investigate the outcome of directing a beam of accelerated particles on a fixed target in a solid, fluid or gas state.

The older and smaller Proton Synchrotron is still used for two experiments, one of them -CLOUD- searches for a link between cosmic rays and the other one -DIRAC- investigates the strong forces between quarks.

Furthermore, there is a decelerator, attached to the Proton Synchrotron, to create antiatoms. In the accelerator, a collision of beams forms antiprotons to fly around in any direction. The decelerator is used to align the antiprotons and bundle them into a beam that can create antiatoms

Next to the accelerators and decelerators, there are more experiments looking for axions and unfound particles. Satellites and telescopes are some of the equipment that is used for those.

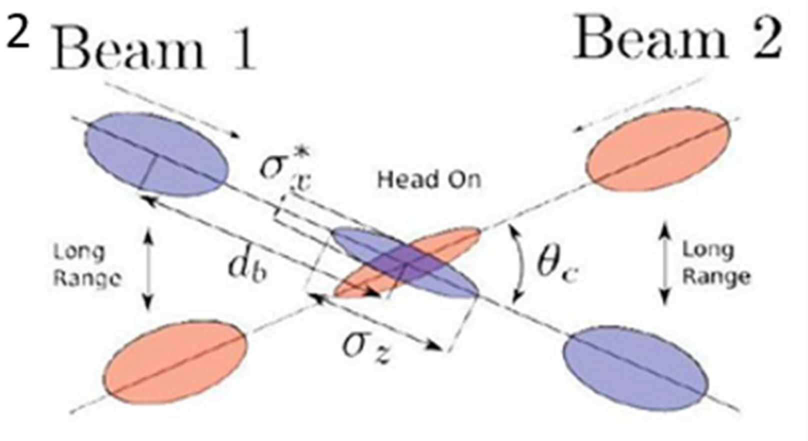
LHC

The working of the Large Hadron Collider

Pangchai, A. (n.d.). *Two particles ready to collide.Particles collision Astrophysics concept.* [Illustratie]. Shuttershock. https://www.shutterstock.com/nl/image-vector/two-particles-ready-collide-collision-astrophysics-1599765619

The LHC is a 27-kilometres ring, in a tunnel under the ground. It is the most powerful particle accelerator the world has ever seen. Using superconducting magnets with accelerating structures they boost the energy of particles over a period of 25 minutes. After that, the particles circulate for 10 hours while collisions occur in the experimental areas.

The particles used at CERN are protons or ions. Before they collide, two particles travel at the speed of light in opposite directions, in two vacuum pipes. The magnetic field, created by the superconducting magnets keeps them moving. These magnets are built out of coils of special electric cable. For the cables to be superconducting, they require a temperature of –273.1°C (which is colder than in outer space). To reach this temperature, liquid helium is used to cool down the magnets. This why there's no resistance or loss of energy."



CERN. (2010, 24 April). *LHC p collisions* [Illustration]. home.cern. https://www.lhc-closer.es/taking_a_closer_look_at_lhc/0.lhc_p_collisions

A beam is a line of radiation or particles flowing in one direction. To direct the beams around the accelerator, thousands of magnets of different varieties and sizes are used. Different magnets have different functions: 1232 dipole magnets 15 meters in length bend the beams, 392 quadrupole magnets, each 5–7 metres long focus the beams, and another type of magnet is used to "squeeze" the particles closer together to increase the chances of collisions just before the collision.

Precision is required for the particles to meet, since they are so tiny. The beams are made to collide in four different locations around the accelerator ring. In first the picture, you can see the collision of two particles. In the second picture it is explained more theoretically. You can see the two protons approach each other and in the middle they collide.

Particles are made to collide to extract information about matters smallest components. The secrets of particle physics become obsolete because of the information you get of the new created particles.

Bibliography:

- Fabiola Gianotti | CERN. (z.d.). Home Cern. Retrieved 29 January 2022, from https://home.cern/about/who-we-are/our-people/biographies/fabiola-gianotti
- CERN. (z.d.). treccani. Retrieved 29 January 2022, from https://www.treccani.it/enciclopedia/cern/
- F. (2013, 9 August). Higgs Boson: The Inside Scoop [Video]. YouTube. https://www.youtube.com/watch?v=CwMq_xqif8k&feature=youtu.be
- Bridge, R. (2015, 1 September). 10 mind-blowing facts about the CERN Large Collider you need to know. RT International. Retrieved 29 January 2022, from https://www.rt.com/op-ed/313922-cern-collider-hadron-higgs/
- 7 things you didn't know about CERN and the strange world of particle physics. (2020, 6 februari). World Economic Forum. Retrieved 29 January 2022, van https://www.weforum.org/agenda/2016/09/7-things-you-didn-t-know-about-cern-and-the-strange-world-of-particle-physics-c362a466-43a1-449d-9719-9e9d97e6a293
- short history of the Web. (2022, 12 January). CERN. Retrieved 29 January 2022, from https://home.cern/science/computing/birth-web/short-history-web
- Amaldi, U. (2018). le traiettorie della fisica 3 (2nd edition, Vol. 3). Zanichelli.
- Figure 1: Kenny, P. (2020, February 19). *CERN's particle collider set to get big brother* [Foto]. Aa.Com.Tr. https://www.aa.com.tr/en/science-technology/cerns-particle-collider-set-to-get-big-brother/1883280
- Figure 5: Johnson. (1967). *The first touchscreen* [Photo]. ARS technica. https://arstechnica.com/gadgets/2013/04/from-touch-displays-to-the-surface-a-brief-history-of-touchscreen-technology/
- Figure 2: CERN. (2015, December). *Fabiola Gianotti at CERN* [Photo]. home.cern. https://home.cern/about/who-we-are/our-people/biographies/fabiola-gianotti
- Figure 4: CERN. (2006, 20 January). *World Wide Web* [Photo]. home.cern. https://home.cern/resources/image/computing/world-wide-web-images-gallery
- Figure 6:Kumar, S. (2021, 1 August). *World Wide Web day* [Photo]. happydays365. https://happydays365.org/world-wide-web-day/world-wide-web-day-august-1/
- Figure 3: CERN. (2013, 19 July). *Forty years of neutral currents* [Photo]. home.cern. https://home.cern/news/news/physics/forty-years-neutral-currents
- Wikipedia-bijdragers. (2021, October 24). CERN. Wikipedia. Retrieved 29 January 2022, from https://nl.wikipedia.org/wiki/CERN
- CERN. (n.d.). Home.Cern. Retrieved 30 January 2022, from https://home.cern/