CERN

1954-2024
YEARS / ANS CERN

CERN’s Main Detectors

Dr. RADU Daniel

13.06.2024

July 1956

Setting up the CERN fire brigade

CERN is one of the few laboratories to have its own fire station. The CERN fire brigade was set up in July 1956 to provide a rapid response in the event of an accident and to tackle the risks specific to the Organisation's activities. Six members of the CERN fire brigade in 1959. From left to right: Messrs. Ubertin, Dalbignat, Verny, Vosdey, **Lissajoux**(!), Favre.

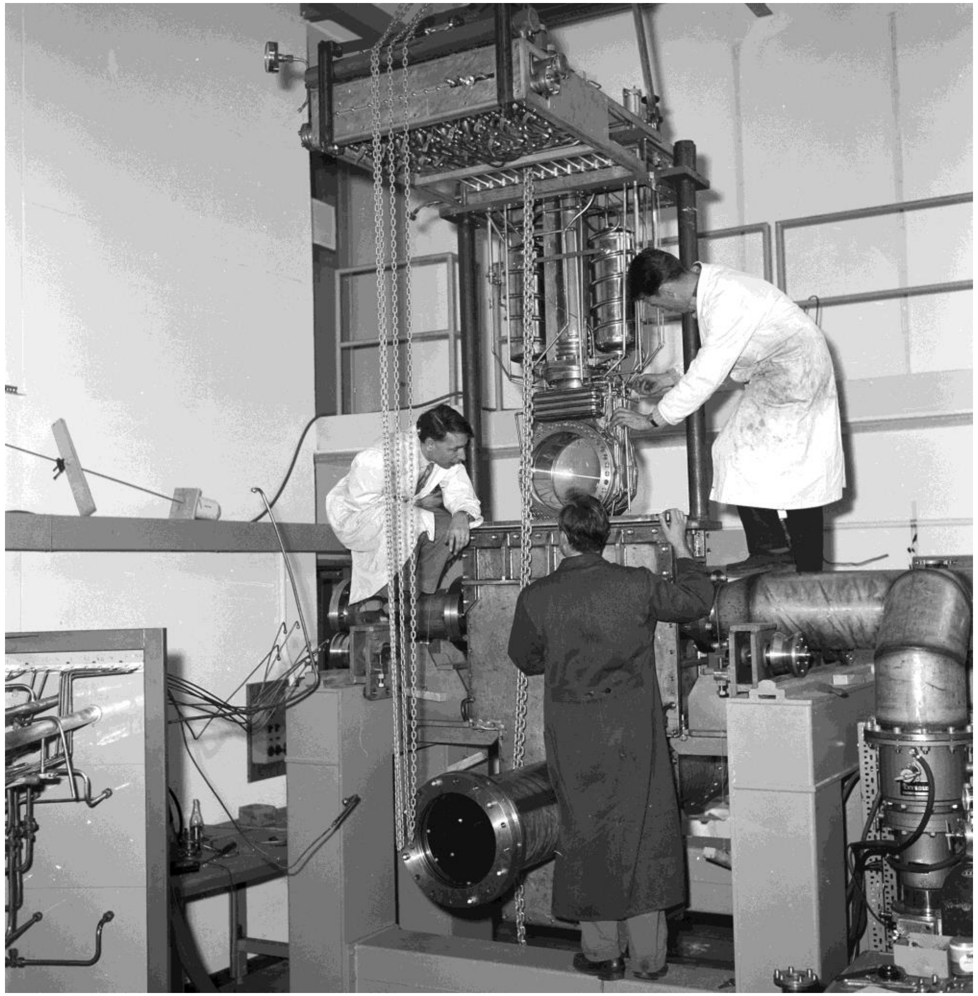
1958

First computer installed at CERN

CERN's first computer, a huge vacuum-tube Ferranti Mercury, was installed in building 2 in 1958. With its 60 microsecond clock cycle, it was a million times slower than today's big computers. The Mercury took 3 months to install and filled a huge room, even so, its computational ability didn't quite match that of a modern pocket calculator. "Mass" storage was provided by four magnetic drums each holding 32Kx20 bits – not enough to hold the data from a single proton-proton collision in the LHC. **It was replaced in 1960 by the IBM 709 computer, seen here being unloaded at Cointrin airport.** Although it was taken over so quickly by transistor equipped machines, a small part of the Ferranti Mercury remains. The computer's engineers installed a warning bell to signal computing errors – it can still be found mounted on the wall in a corridor of building 2.

1959

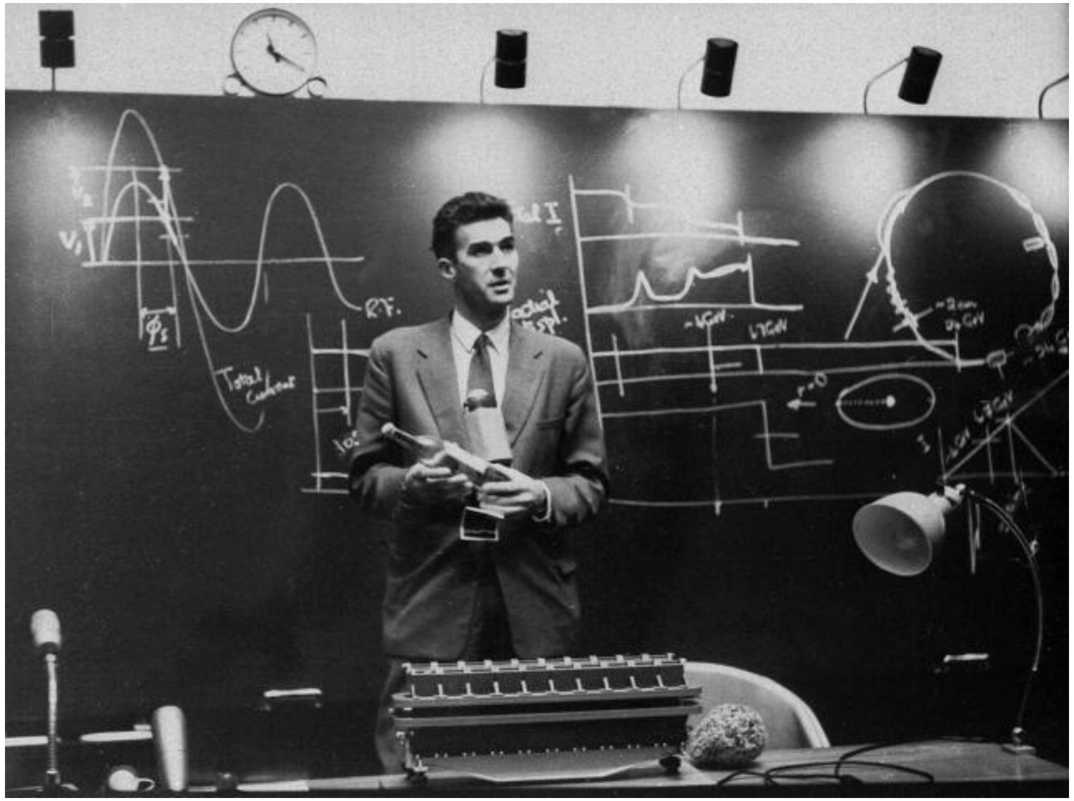
HBC30 – the first CERN's bubble chamber



In the 1950s and 1960s, bubble and spark chambers were the dominant experimental tools in high-energy physics. While spark chambers were usually built and fitted to specific experiments, bubble chambers were constructed as general purpose devices that could be used for a variety of experiments. At CERN, the bubble chamber programme started under Charles Peyrou in the late 1950s. **The first of CERN's bubble chambers, a 30 cm liquid hydrogen chamber, is seen here being inserted into its vacuum tank.** The **HBC30** (**H**ydrogen **B**ubble **C**hamber), as it was called, took its first beam from the SC in 1959. One of the first pictures taken, of a positive pion-proton interaction, began a long series of pretty images for which bubble chambers would become famous. When it stopped operating in spring 1962, the HBC30 had consumed 150 km of film in its 3 years of operation.

24 November 1959

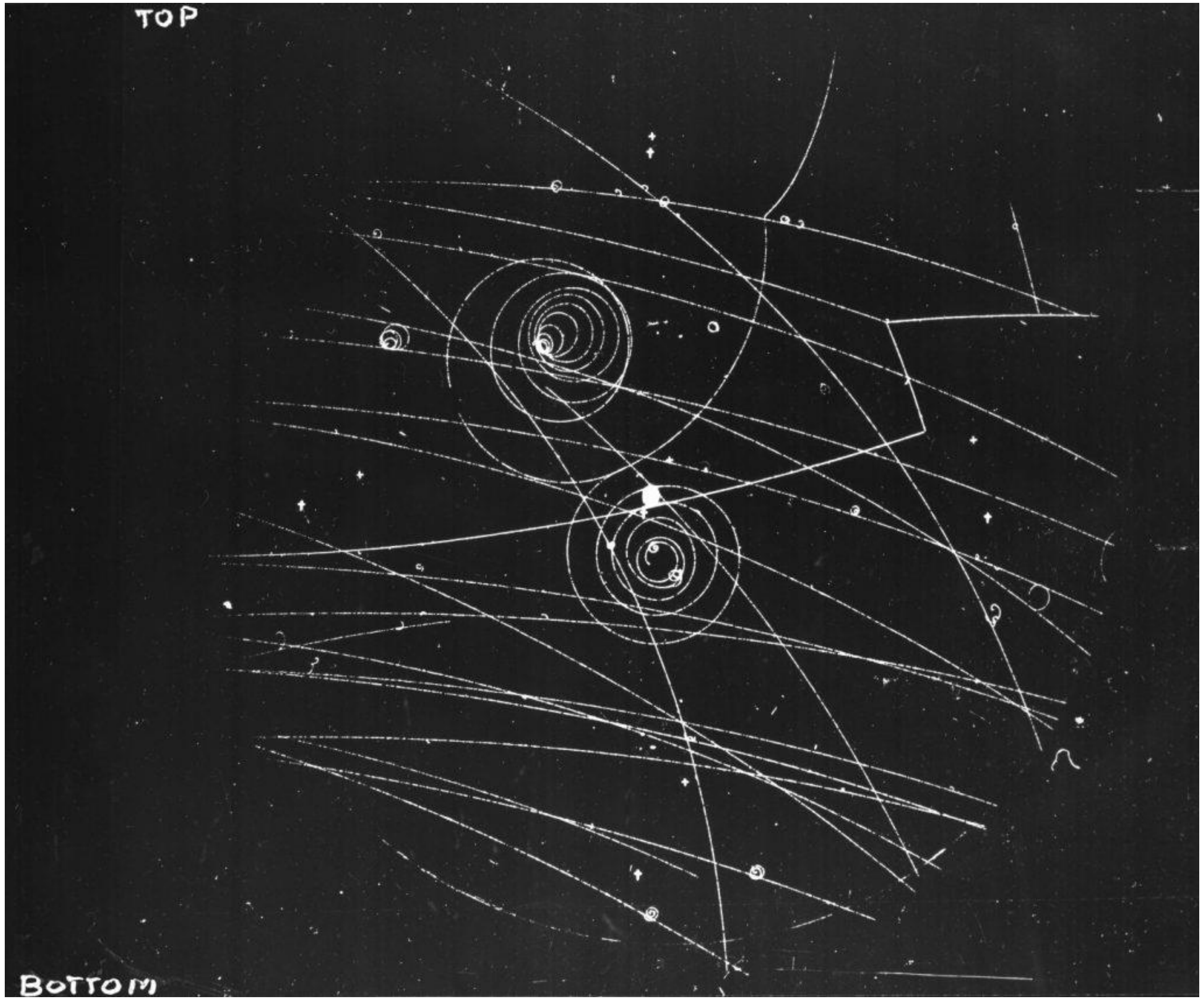
The Proton Synchrotron starts up



The **Proton Synchrotron** (PS) accelerated protons for the first time on 24 November 1959, becoming for a brief period the world’s highest energy particle accelerator. With a beam energy of **28 GeV**, the PS became host to CERN’s particle physics programme, and provides beams for experiments to this day.

During the night of 24 November 1959 the PS reached its full energy. The next morning John Adams (pictured) announced the achievement in the main auditorium. In his hand is an empty vodka bottle, which he had received from Dubna with the message that it was to be drunk when CERN passed the Russian Synchrophasotron’s world-record energy of 10 GeV. The bottle contains a polaroid photograph of the 24 GeV pulse ready to be sent back to Dubna.

Bubble chamber photo from 1961 showing particle tracks



17 January 1968

Georges Charpak revolutionizes detection

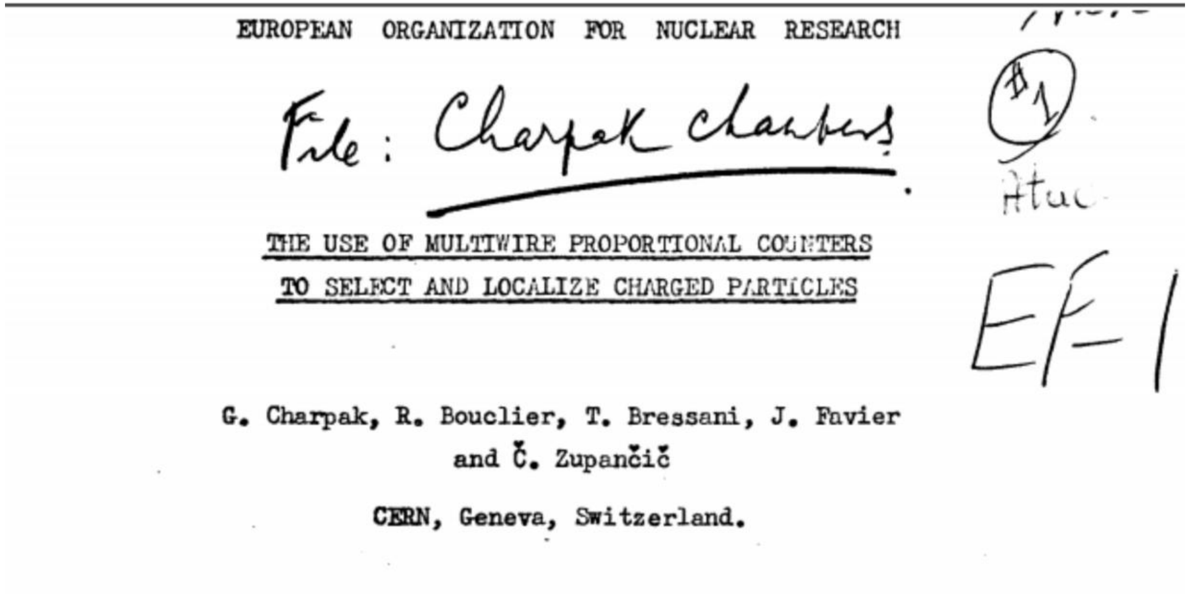
In the 1960s, detection in particle physics mainly involved examining millions of photographs from bubble chambers or spark chambers. This was slow, labour-intensive and unsuitable for studies into rare phenomena.

Then came a revolution in transistor amplifiers. While a camera can detect a spark, a detector wire connected to an amplifier can detect a much smaller effect. In 1968, **Georges Charpak** developed the “**multiwire proportional chamber**”, a gas-filled box with a large number of parallel detector wires, each connected to individual amplifiers. Linked to a computer, it could achieve a counting rate a thousand times better than existing detectors. The invention revolutionized particle detection, which passed from the manual to the electronic era.

Charpak, who joined CERN in 1959, was awarded the **1992 Nobel Prize in physics** "for his invention and development of particle detectors, in particular the multiwire proportional chamber".

Today practically every experiment in particle physics uses some track detector based on the principle of the multiwire proportional chamber. Charpak has also actively contributed to the use of this technology in other fields that use ionizing radiation such as biology, radiology and nuclear medicine.

Charpak’s article submitted to Nuclear Instruments and Methods



EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

File : Charpak chambers

#1

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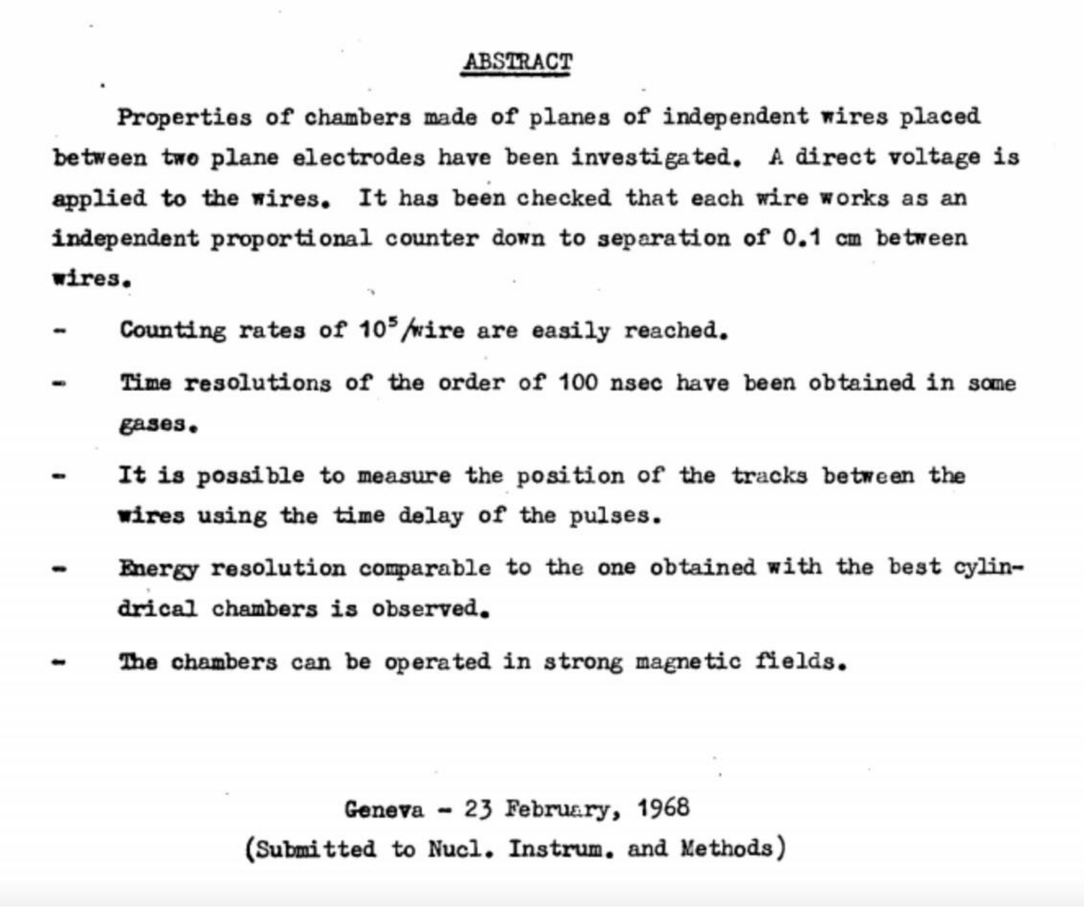
EF-1

THE USE OF MULTIWIRE PROPORTIONAL COUNTERS
TO SELECT AND LOCALIZE CHARGED PARTICLES

G. Charpak, R. Bouclier, T. Bressani, J. Favier
and Č. Zupančič

CERN, Geneva, Switzerland.



ABSTRACT

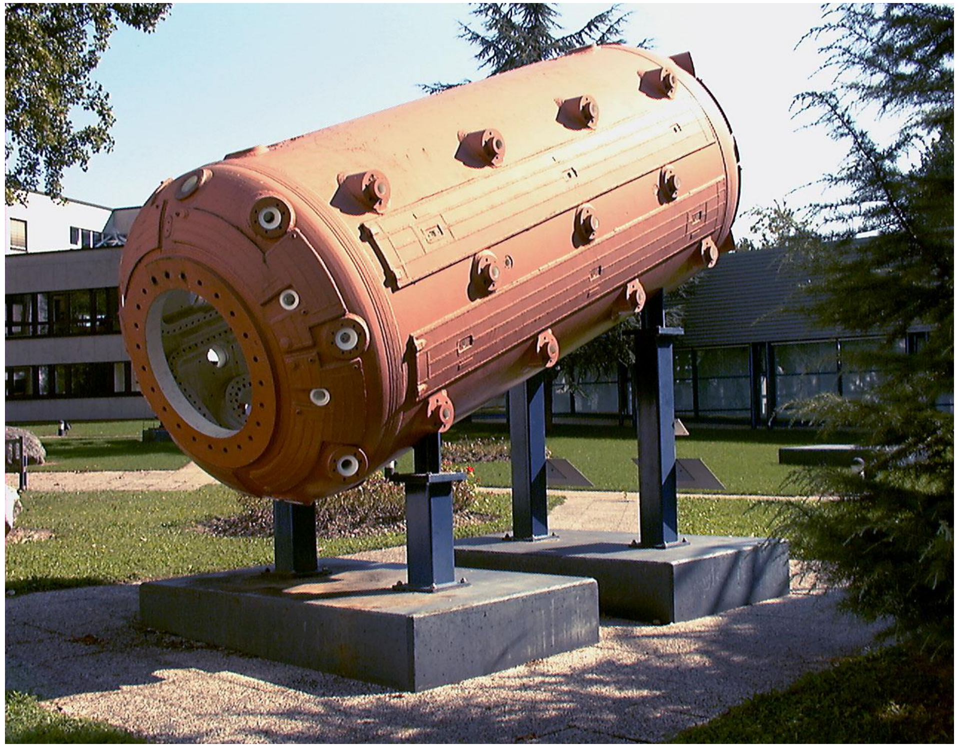
Properties of chambers made of planes of independent wires placed between two plane electrodes have been investigated. A direct voltage is applied to the wires. It has been checked that each wire works as an independent proportional counter down to separation of 0.1 cm between wires.

- Counting rates of 10^5/wire are easily reached.
- Time resolutions of the order of 100 nsec have been obtained in some gases.
- It is possible to measure the position of the tracks between the wires using the time delay of the pulses.
- Energy resolution comparable to the one obtained with the best cylindrical chambers is observed.
- The chambers can be operated in strong magnetic fields.

Geneva - 23 February, 1968
(Submitted to Nucl. Instrum. and Methods)

1970

Gargamelle – a bubble chamber at CERN designed to detect neutrinos



The name of the chamber derives from the giantess Gargamelle in the works of François Rabelais; she was Gargantua's mother. Gargamelle was a bubble chamber at CERN designed to detect neutrinos. **It operated from 1970 to 1976** with a muon-neutrino beam produced by the CERN PS, before moving to the SPS until 1979. Gargamelle was **4.8 metres long** and **2 metres in diameter**. It weighed **1000 tonnes** and held nearly **12 cubic metres of heavy-liquid freon** (CF_3Br). As neutrinos have no charge, they do not leave tracks in detectors. The freon in the Gargamelle detector revealed any charged particles set in motion by the neutrinos and so revealed the interactions indirectly. Using freon instead of the more typical liquid hydrogen increased the probability of seeing neutrino interactions. Early results from Gargamelle, in the period 1972-4, provided **crucial evidence for the existence of quarks**, the fundamental constituents of particles such as protons and neutrons. Combining the neutrino results with those from experiments using an electron beam at SLAC in the US showed that the quarks must have charges that are $^1/_3$ or $^2/_3$ the charge of the proton, just as predicted. In July 1973, in a seminar at CERN, the Gargamelle collaboration presented **the first direct evidence of the weak neutral current** – a process predicted in the mid-1960s independently by Sheldon Glashow, Abdus Salam and Steven Weinberg – that required the existence of a neutral particle to carry the weak fundamental force. This particle, called the Z boson, and the associated weak neutral currents, were predicted by electroweak theory, according to which the weak force and the electromagnetic force are different versions of the same force.

1970

Working on Charpak’s multiwire chamber

In 1968, Georges Charpak developed the 'multiwire proportional chamber', a gas-filled box with a large number of parallel detector wires, each connected to individual amplifiers. Linked to a computer, it could achieve a counting rate a thousand times better than existing techniques - without a camera in sight. From left to right, **Georges Charpak, Fabio Sauli** and **Jean-Claude Santiard** working on a multiwire chamber in 1970.

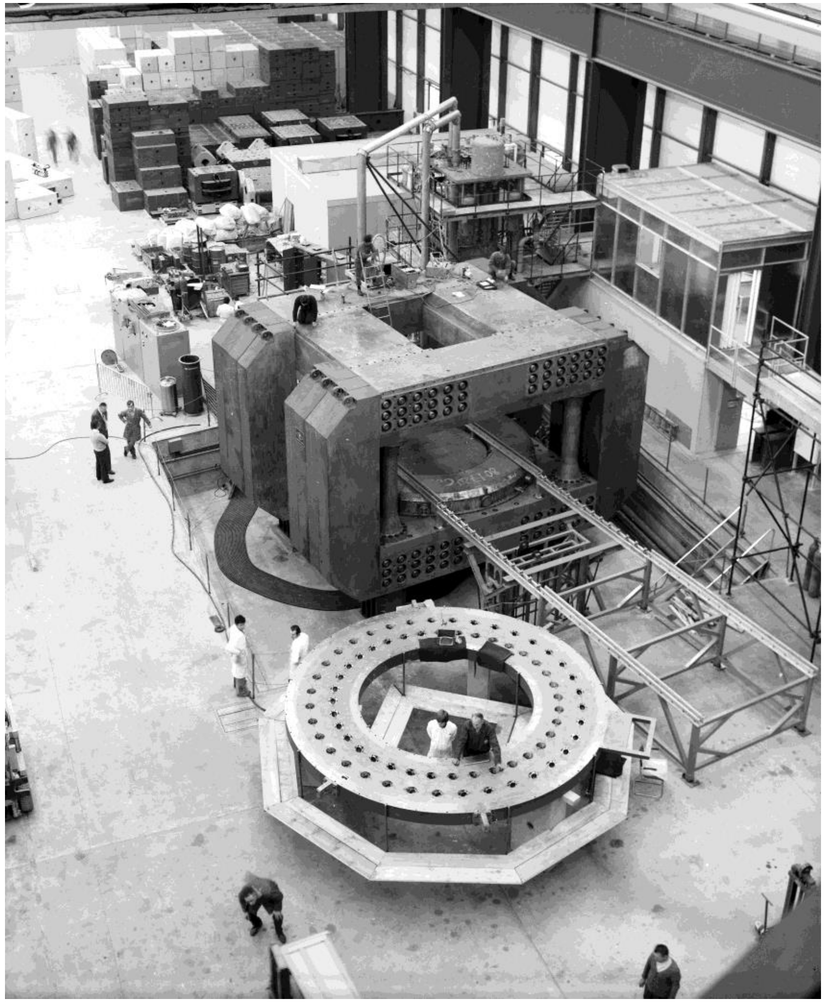
1970

BEBC – The Big European Bubble Chamber

The vessel of the **Big European Bubble Chamber, BEBC**, was installed at the beginning of the 1970s. The large stainless-steel vessel, measuring **3.7 metres in diameter** and **4 metres in height**, was filled with **35 cubic metres** of liquid (hydrogen, deuterium or a neon-hydrogen mixture), whose sensitivity was regulated by means of a huge piston weighing 2 tonnes. During each expansion, the trajectories of the charged particles were marked by a trail of bubbles, where liquid reached boiling point as they passed through it. The first images were recorded in 1973 when BEBC, equipped with the largest superconducting magnet in service at the time, first received beam from the PS. In 1977, the bubble chamber was exposed to neutrino and hadron beams at higher energies of up to 450 GeV after the SPS came into operation. By the end of its active life in 1984, BEBC had delivered a total of 6.3 million photographs to 22 experiments devoted to neutrino or hadron physics. Around 600 scientists from some fifty laboratories throughout the world had taken part in analysing the 3000 km of film it had produced.

September 1972

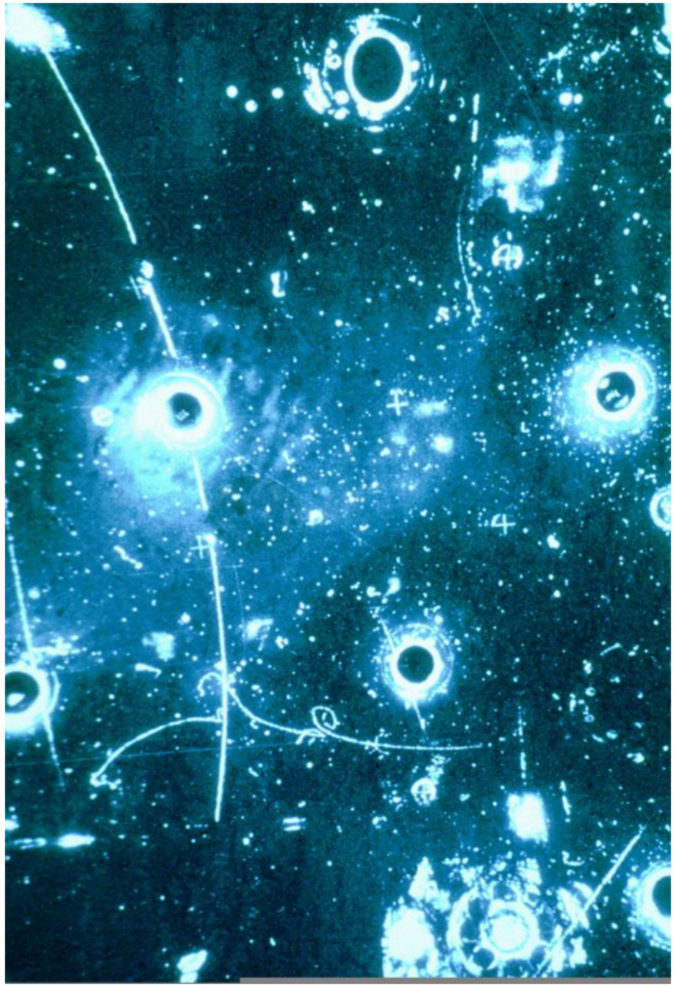
The OMEGA spectrometer was commissioned in the West Area of SPS



More than a million collisions were recorded that very first year (1972)! OMEGA was equipped with spark chambers – replaced at the end of the 1970s by electronic detectors – and a 15,000-tonne superconducting magnet. On this photo we can see the magnet's lower coil and, in the foreground, the support plate for the upper coil. No fewer than 48 experiments made use of this device, exploiting beams of various particles at various energies - from the PS at the beginning, and then from the highest energy beams of the SPS. OMEGA thus played a key role in many physics results and activities, notably the production of the J/psi particle, the study of particles carrying charm or beauty quarks, the study of «gluonia», and the CERN heavy ion programme. The OMEGA experiments ceased in 1996 when the facilities in the West Hall were shut down in preparation for the construction of the LHC.

July 1973

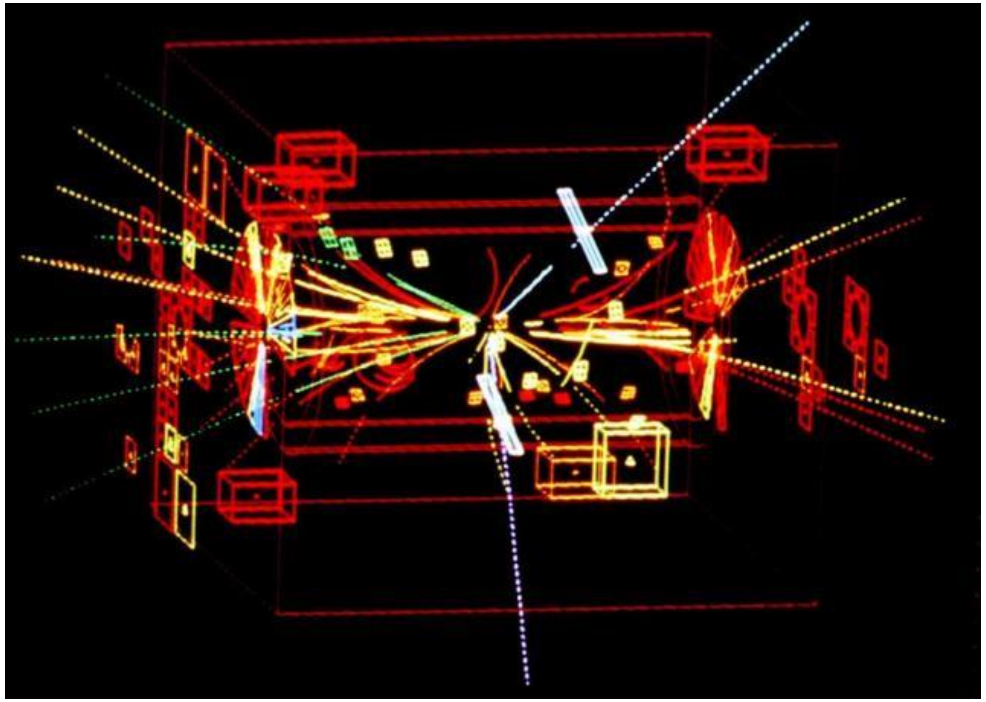
The discovery of the neutral current was announced



This event shows the **real tracks produced in the 1200 litre Gargamelle bubble chamber** that provided the first confirmation of a neutral current interaction. A neutrino interacts with an electron, the track of which is seen horizontally, and emerges as a neutrino without producing a muon. **The discovery of the neutral current was announced in the CERN main auditorium in July 1973**.

20 January 1983

W and Z particles discovered



In 1979, CERN decided to convert the Super Proton Synchrotron (SPS) into a proton–antiproton collider. A technique called stochastic cooling was vital to the project's success as it allowed enough antiprotons to be collected to make a beam. The first proton–antiproton collisions were achieved just two years after the project was approved, and two experiments, **UA1** (**U**nderground **A**rea 1) and **UA2**, started to search the collision debris for signs of W and Z particles, carriers of the weak interaction between particles. **In 1983, CERN announced the discovery of the W and Z particles**. The image above shows the the first detection of a Z^0 particle, as seen by the UA1 experiment on 30 April 1983. The Z^0 itself decays very quickly so cannot be seen, but an electron–positron pair produced in the decay appear in blue. UA1 observed proton-antiproton collisions on the SPS between 1981 and 1993 to look for the Z and W bosons. **Carlo Rubbia** and **Simon van der Meer**, key scientists behind the work, received the Nobel Prize in physics only a year after the discovery. Rubbia instigated conversion of the SPS accelerator into a proton-antiproton collider and was spokesperson of the UA1 experiment while Van der Meer invented the stochastic cooling technique vital to the collider’s operation.

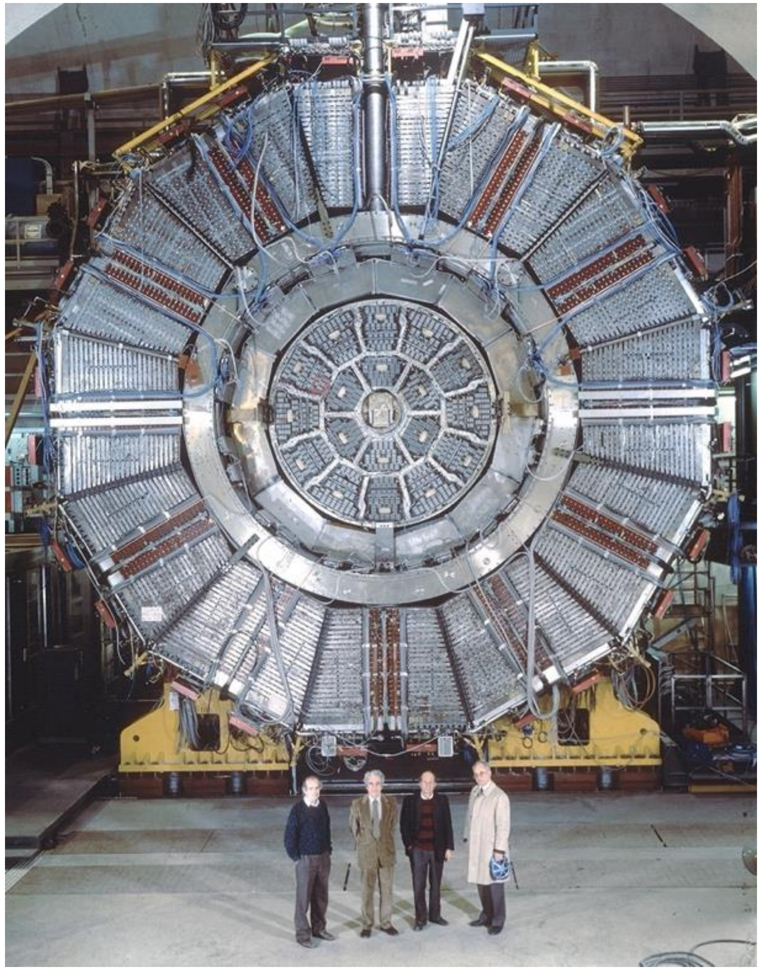
14 July 1989

Large Electron–Positron collider: First injection

With its **27-kilometre circumference**, the **L**arge **E**lectron–**P**ositron (**LEP**) collider was – and still is – **the largest electron–positron accelerator ever built**. LEP consisted of **5176 magnets** and **128 accelerating cavities**. CERN's accelerator complex provided the particles and four enormous detectors, **ALEPH** (**A**pparatus for **LE**P **PH**ysics), **DELPHI** (**DE**tector with **L**epton, **P**hoton and **H**adron **I**dentification), **L3** (**Third** **L**EP Experiment) and **OPAL** (**O**mni-**P**urpose **A**pparatus for **L**EP), observed the collisions. **LEP was commissioned in July 1989 and the first beam circulated in the collider on 14 July**. The picture above shows physicists grouped around a screen in the LEP control room at the moment of start-up. Carlo Rubbia, Director-General of CERN at the time, is in the centre and former Director-General Herwig Schopper is on his left. For seven years, the accelerator operated at **100 GeV**, producing **17 million Z particles**, uncharged carriers of the weak force. It was then upgraded for a second operation phase, with as many as **288 superconducting accelerating cavities** added to double the energy and produce W bosons, also carriers of the weak force. LEP collider energy eventually topped **209 GeV** in the year 2000. During **11 years of research**, LEP and its experiments provided a detailed study of the electroweak interaction based on solid experimental foundations. Measurements performed at LEP also proved that there are three – and only three – generations of particles of matter. **LEP was closed down on 2.11.2000 to make way for the construction of the LHC in the same tunnel**.

July 1989

The ALEPH detector on the Large Electron-Positron collider



The ALEPH detector had a time projection chamber at its core for detecting the direction and momenta of charged particles with extreme accuracy. In the foreground from the left, **Jacques Lefrancois, Jack Steinberger, Lorenzo Foa** and **Pierre Lazeyras**. ALEPH was an experiment on the LEP accelerator, which studied high-energy collisions between electrons and positrons (1989-2000).

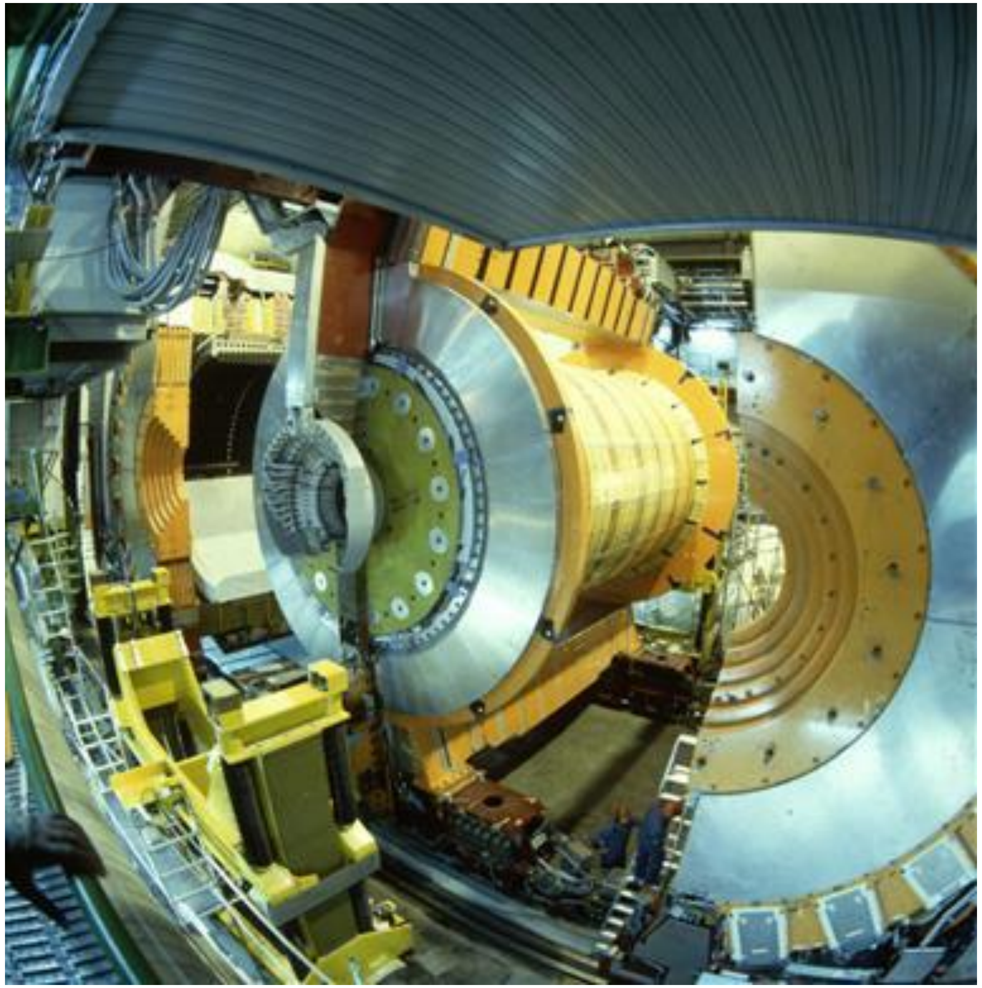
ALEPH (**A**pparatus for **LE**P **PH**ysics) was a particle detector on the Large Electron-Positron collider (LEP). It was designed to explore the physics predicted by the Standard Model (SM) and to search for physics beyond it.

ALEPH first measured events in LEP in July 1989. LEP operated at around 91 GeV – the predicted optimum energy for the formation of the Z particle. From 1995 the accelerator operated at energies up to 200 GeV, above the threshold for producing pairs of W particles.

The ALEPH detector was built in cylindrical layers around a beam pipe made of beryllium, with the electron-positron collision point in the middle. Working outwards from the beam pipe, ALEPH held a vertex detector composed of two layers of double-sided silicon microstrips; an inner drift-chamber that provided 8 tracking coordinates and a trigger signal for charged particles from the interaction point; a **time projection chamber** – **4.4 metres long** and **3.6 metres in diameter** – to detect charged particles; an electromagnetic calorimeter to identify electrons and photons; a hadron calorimeter to detect hadrons; and a **superconducting coil**, **6.3 metres long** and **5.3 metres in diameter**, to provide the **1.5 tesla magnetic field** necessary to work out a particle's charge and allow measurements of momentum. The whole system was housed inside a 12-sided cylinder and surrounded by a muon-detection system.

August 1989

OPAL – One of the four large detectors on the LEP

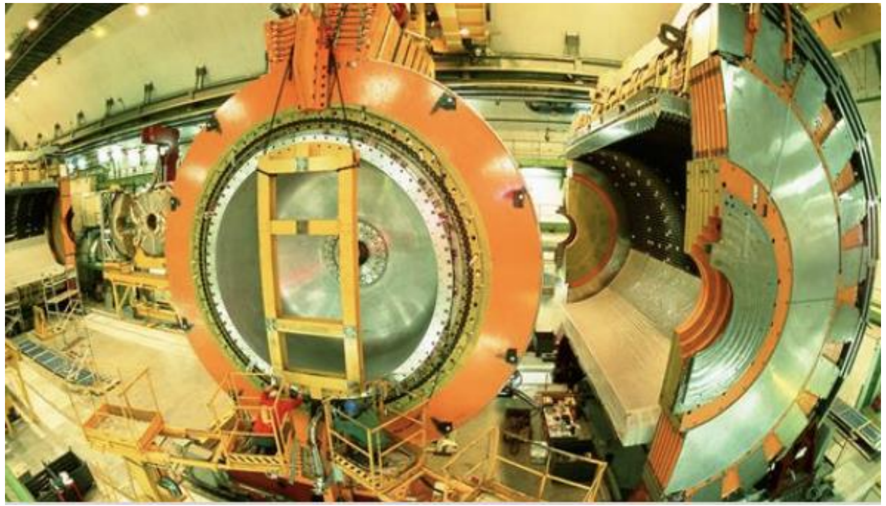


OPAL (**O**mni-**P**urpose **A**pparatus at **L**EP) was one of four large detectors on the Large Electron-Positron collider (LEP). **It started operation along with the collider in August 1989**. Data taking for OPAL ended on 2 November 2000 and the detector was dismantled the following year to make way for construction of the Large Hadron Collider (LHC).

The OPAL detector was about **12m long, 12m high and 12m wide**. Detector components were arranged around the beam pipe, in a layered structure like that of an onion. OPAL's central tracking system consisted of (from the beam pipe out) a silicon microvertex detector, a vertex detector, a jet chamber, and z-chambers. **OPAL detector delivered key measurements of Z and W bosons in its 11-year lifetime**.

1989

DELPHI – One of the four large detectors on the LEP



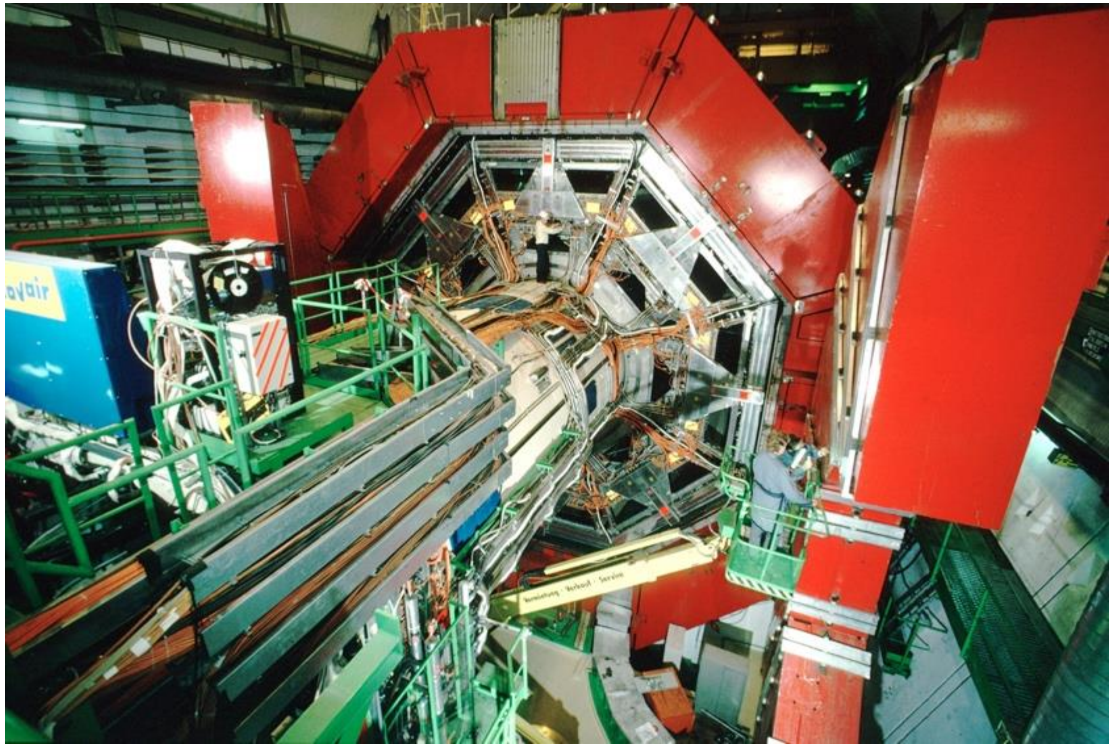
DELPHI (**DE**tector with **L**epton, **P**hoton and **H**adron **I**dentification) was one of four large detectors on the LEP. **It took 7 years to design and build, and it started up in 1989**. In December 2000, DELPHI stopped taking data and was dismantled to leave room for the construction of the LHC in the LEP tunnel.

DELPHI consisted of a central cylinder filled with subdetectors, with two end-caps. It was **10 metres in length and diameter and weighed 3500 tonnes**. The detector consisted of 20 subdetectors. A large superconducting magnet sat between an electromagnetic calorimeter (for tracking electrons) and a hadronic calorimeter (to detect hadrons). The magnet generated a field to deflect charged particles so their charge and momenta could be measured.

The DELPHI detector used the ring imaging Cherenkov technique to differentiate between secondary charged particles, and it had an advanced silicon detector to detect short-lived particles by extrapolating the tracks back towards the collision point.

1989

L3 – One of the four large detectors on the LEP



The muon spectrometer on the L3 detector at LEP can be seen with the magnet doors open

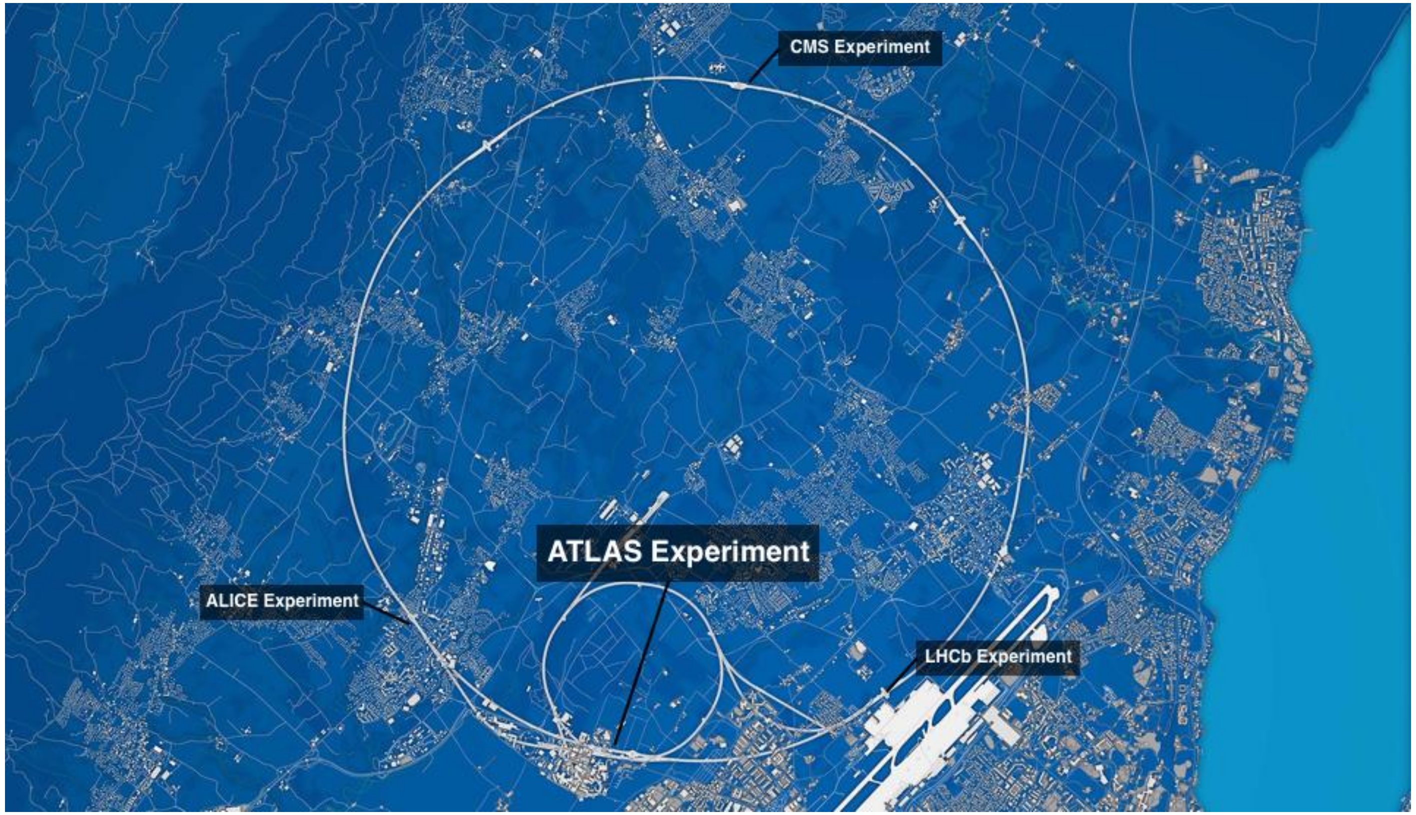
The **L3 experiment** (**which helped to measure important properties of the Z boson**) was one of four large detectors on the LEP. The detector was designed to look for the physics of the Standard Model and beyond. It started up in 1989 and stopped taking data in November 2000 to make room for construction of the LHC. The ALICE detector now sits in the cavern that L3 used to occupy, reusing L3's characteristic red octagonal magnet.

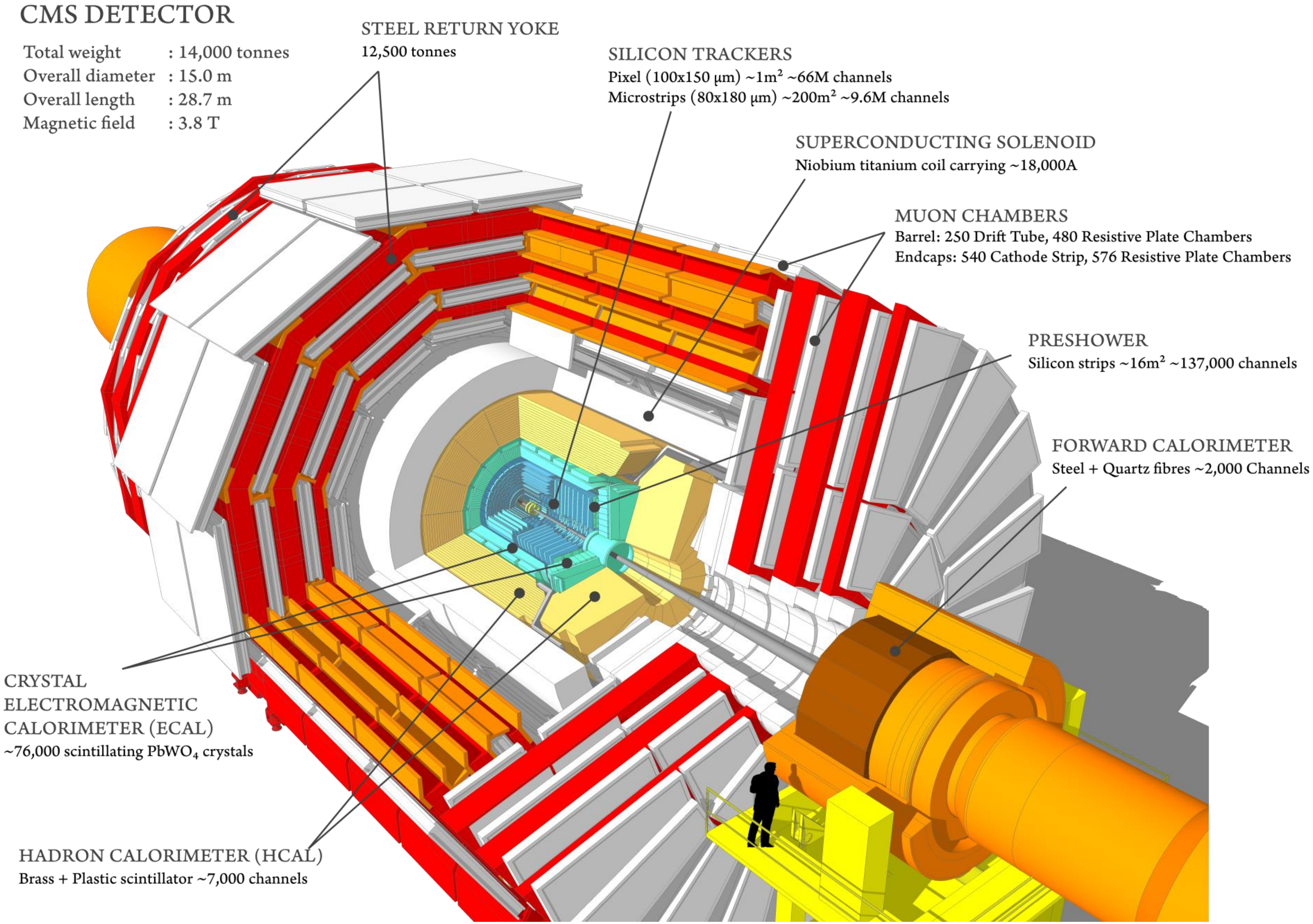
L3 was composed of numerous subdetectors around LEP's central beamline, where electrons and positrons were made to collide. The first subdetectors out from the beamline were a silicon strip microvertex detector and a time-expansion chamber, both of which traced the paths of charged particles from the collision.

31 January 1997

CMS and ATLAS experiments approved

Four years after the first technical proposals, the experiments **CMS (C**ompact **M**uon **S**olenoid**)** and **ATLAS (A T**oroidal **L**HC **A**pparatu**S)** are officially approved. Both are general-purpose experiments designed to explore the fundamental nature of matter and the basic forces that shape our Universe, including the Higgs boson.

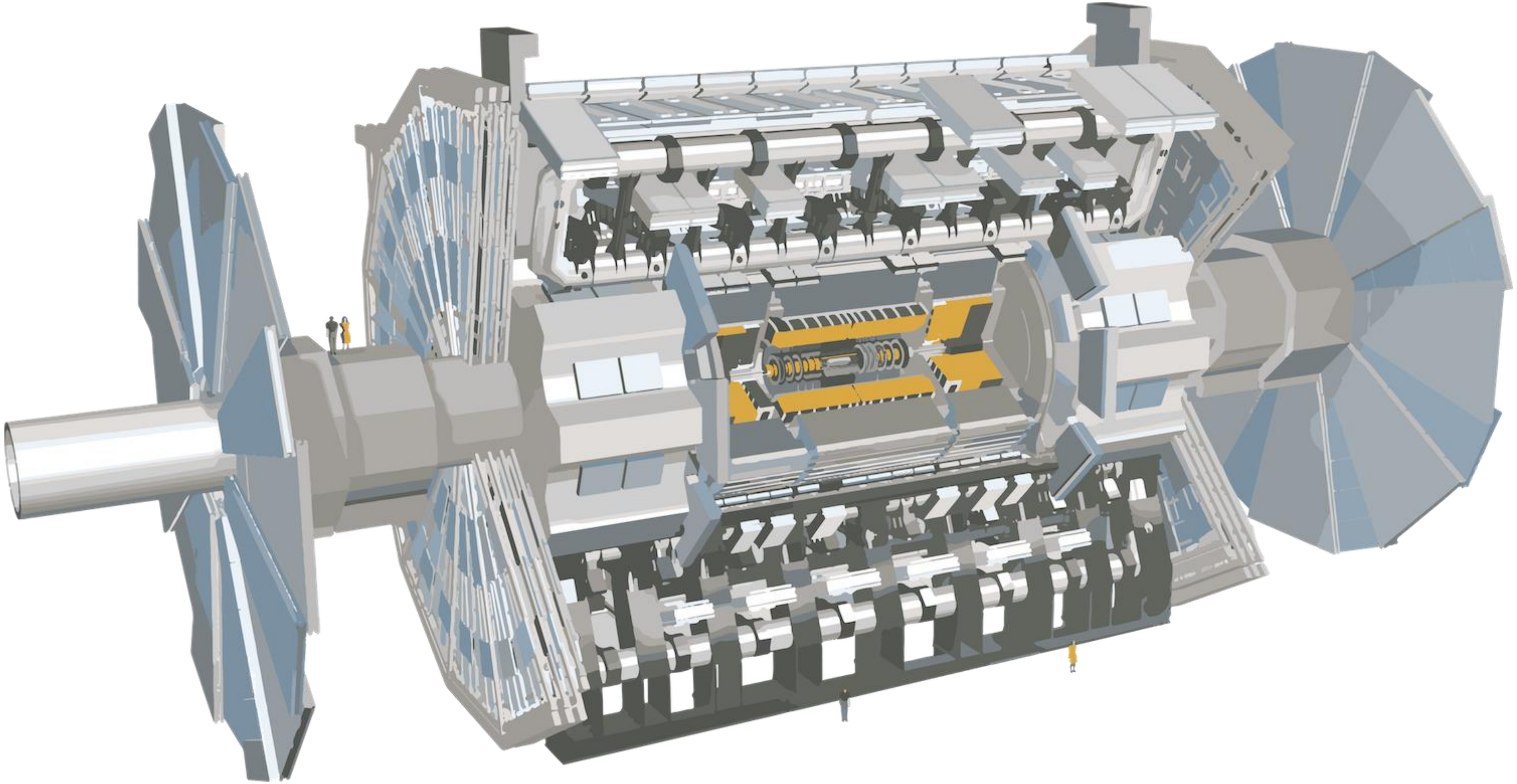




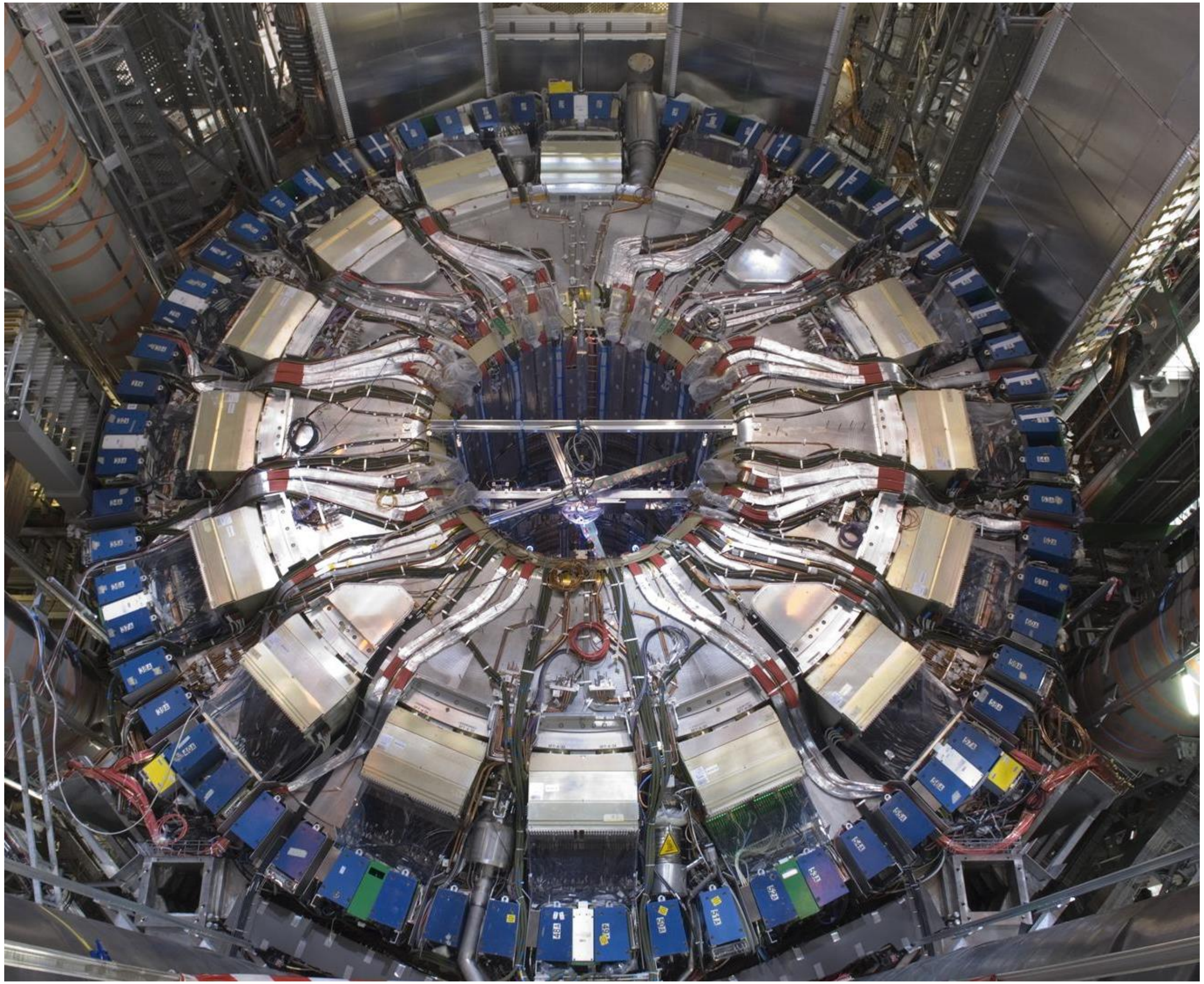
The **CMS detector** is shaped like a cylindrical onion, with several concentric layers of components. These components help prepare “photographs” of each collision event by determining the properties of the particles produced in that particular collision. This is done by:

1. **Bending Particles**
2. **Identifying Tracks**
3. **Measuring Energy**
4. **Detecting Muons**

An unusual feature of the CMS detector is that instead of being built in-situ like the other giant detectors of the LHC experiments, it was constructed in 15 sections at ground level before being lowered into an underground cavern near Cessy in France and then reassembled.



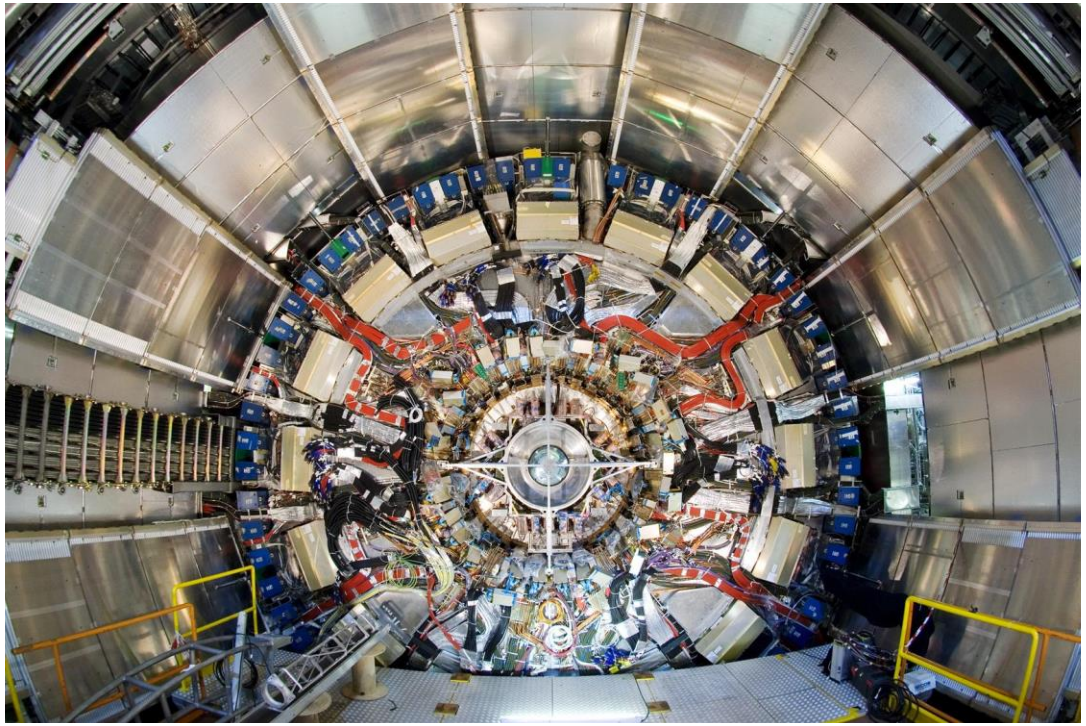
ATLAS is a general-purpose particle physics experiment at the **L**arge **H**adron **C**ollider **(LHC)** at **CERN**. It is designed to exploit the full discovery potential of the LHC, pushing the frontiers of scientific knowledge. ATLAS' exploration uses precision measurement to push the frontiers of knowledge by seeking answers to fundamental questions such as: What are the basic building blocks of matter? What are the fundamental forces of nature? What is dark matter made of?



The ATLAS Detector

The largest volume detector ever constructed for a particle collider. ATLAS has the dimensions of a cylinder, **46m long, 25m in diameter**, and sits in a cavern **100m below ground**. The ATLAS detector weighs **7,000 tonnes**, similar to the weight of the Eiffel Tower.

The ATLAS Detector

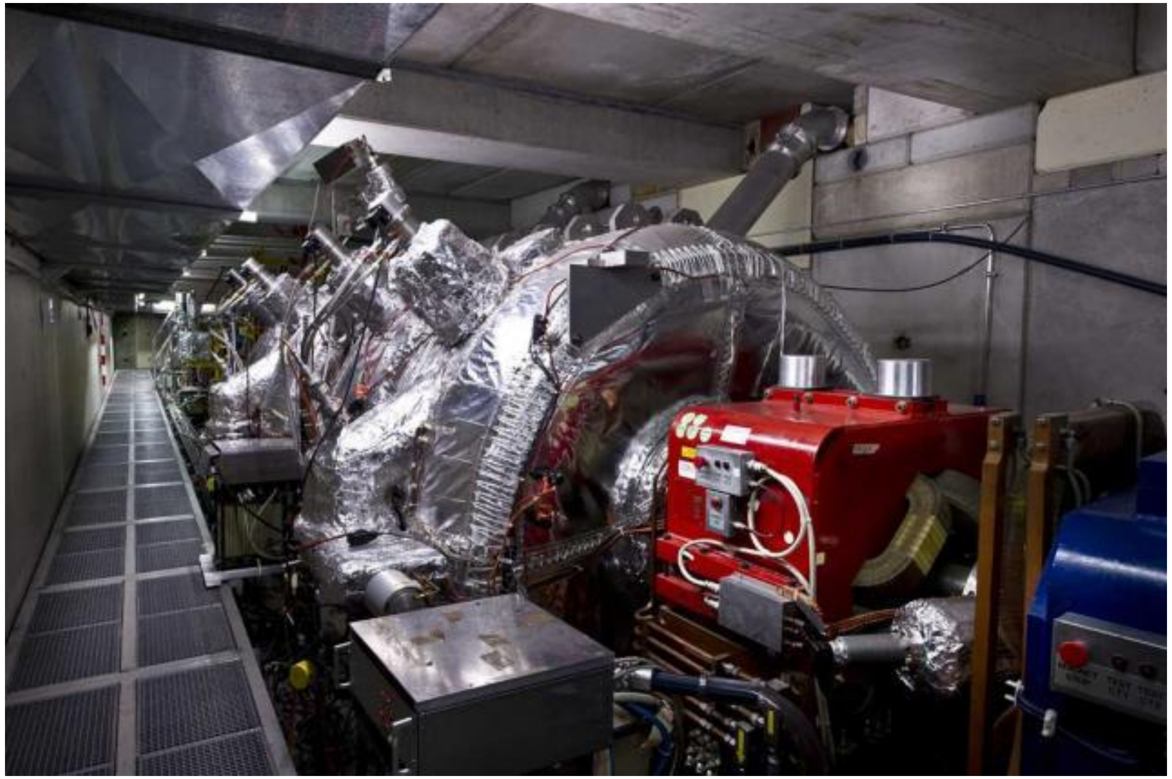


The detector itself is a many-layered instrument designed to detect some of the tiniest, yet most energetic particles ever created on earth. It consists of six different detecting subsystems wrapped concentrically in layers around the collision point to record the trajectory, momentum, and energy of particles, allowing them to be individually identified and measured. A huge magnet system bends the paths of the charged particles so that their momenta can be measured as precisely as possible.

Beams of particles travelling at energies up to seven trillion electron-volts, or **speeds up to 99.999999% that of light**, from the LHC collide at the centre of the ATLAS detector producing collision debris in the form of new particles which fly out in all directions. **Over a billion particle interactions take place in the ATLAS detector every second, a data rate equivalent to 20 simultaneous telephone conversations held by every person on the earth**. Only one in a million collisions are flagged as potentially interesting and recorded for further study. The detector tracks and identifies particles to investigate a wide range of physics, from the study of the Higgs boson and top quark to the search for extra dimensions and particles that could make up dark matter.

07 February 1997

Antiproton Decelerator approved



In 1996, CERN's antiproton machines – the **A**ntiproton **A**ccumulator (**AA**), the **A**ntiproton **C**ollector (**AC**) and the **L**ow **E**nergy **A**ntiproton **R**ing **(LEAR)** – were closed down to free resources for the Large Hadron Collider. But a community of antimatter scientists wanted to continue their LEAR experiments with slow antiprotons. Council asked the Proton Synchrotron division to investigate a low-cost way to provide the necessary low-energy beams.

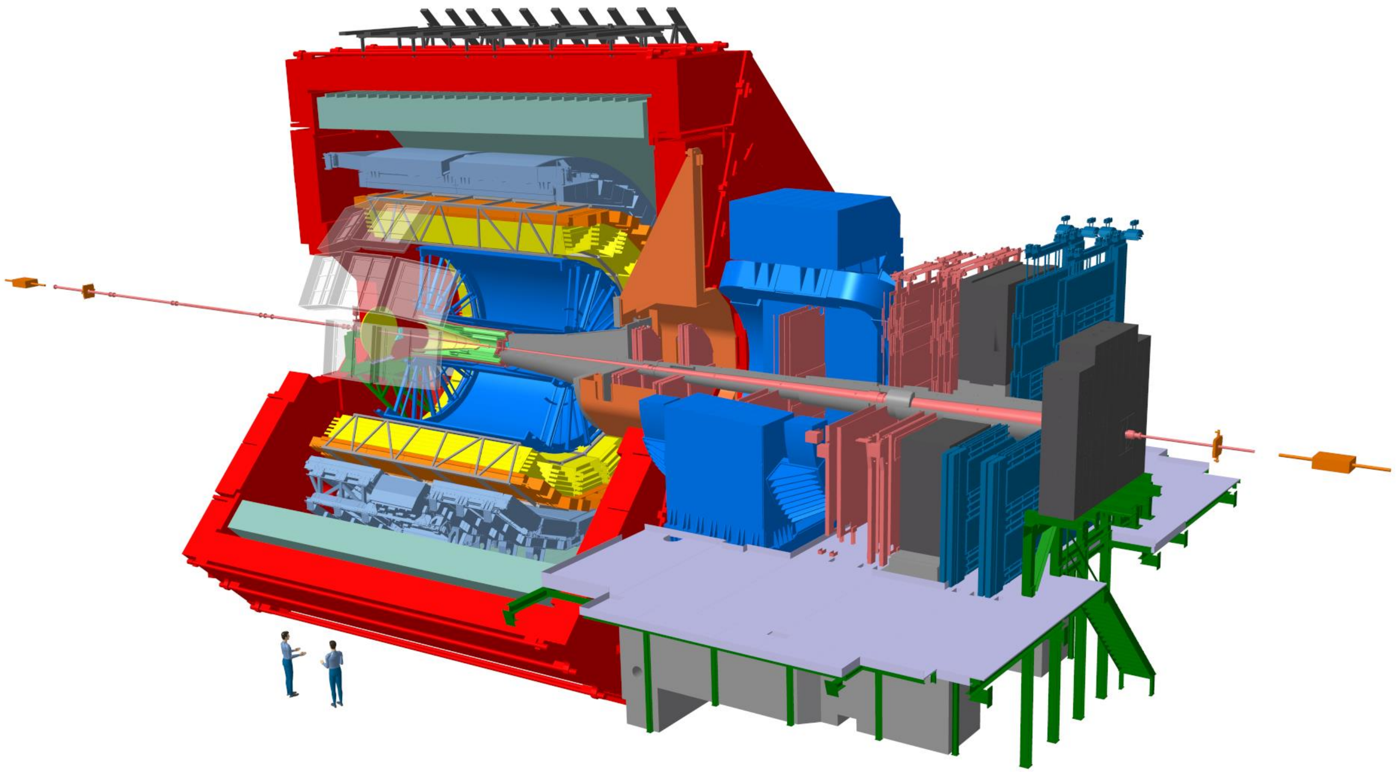
The resulting **design report for the Antiproton Decelerator** concluded:

“**The use of the Antiproton Collector as an antiproton decelerator holds the promise of delivering dense beams of 10^7 protons per minutes and low energy (100 MeV/c^2) with bunch lengths down to 200 nanoseconds**.”

The **Antiproton Decelerator** project was approved on **7 February 1997**.

14 February 1997

ALICE experiment approved



ALICE (**A** **L**arge **I**on **C**ollider **E**xperiment) is one of **9** detector experiments at the LHC at CERN. The other eight are: **ATLAS**, **CMS**, **TOTEM**, **LHCb**, **LHCf**, **MoEDAL**, **FASER** and **SND@LHC**.

ALICE is optimized to study heavy-ion (Pb-Pb nuclei) collisions at a centre of mass energy up to **5.36 TeV** per nucleon pair. The resulting temperature and energy density allow exploration of quark-gluon plasma, a fifth state of matter wherein quarks and gluons are freed. Similar conditions are believed to have existed a fraction of the second after the Big Bang before quarks and gluons bound together to form hadrons and heavier particles.

- **ALICE** – **A** **L**arge **I**on **C**ollider **E**xperiment;
- **ATLAS** – **A** **T**oroidal **L**HC **A**pparatu**S;**
- **CMS** – **C**ompact **M**uon **S**olenoid;
- **TOTEM** – **TOT**al cross section, **E**lastic scattering and diffraction dissociation **M**easurement at the LHC;
- **LHCb** – **L**arge **H**adron **C**ollider **b**eauty
- **LHCf** – **L**arge **H**adron **C**ollider **f**orward; LHCf experiment uses particles thrown forward by collisions in the LHC as a source to simulate cosmic rays in laboratory conditions. The first phase of data using the LHCf detectors was recorded in 2009-2013;
- **MoEDAL** – the **Mo**nopole and **E**xotics **D**etector **A**t the **L**HC was approved as the LHC's 7th experiment in 2010. It searches directly for the magnetic monopole.

In preparation for data taking during run 3 of the LHC, the MoEDAL detector has been upgraded to

- **MoEDAL-MAPP**. The addition detector, **MAPP** (**M**oEDAL **A**pparatus for **P**enetrating **P**articles), was approved in 2021 to extend MoEDAL's physics reach by providing sensitivity to milli-charged particles and long-lived exotic particles);
- **FASER** – **F**orw**A**rd **S**earch **E**xpe**R**iment, is designed to search for new, yet undiscovered, light and weakly-interacting particles and study the interactions of high-energy neutrinos – was approved by the CERN Research Board in March 2019;
- **SND@LHC** – **S**cattering and **N**eutrino **D**etector **at the LHC**, is designed to study neutrinos. SND@LHC was approved in 2021, constructed, installed and commissioned underground in about one year, and began taking data in Run 3 of the LHC, which started in July 2022.

17 September 1998

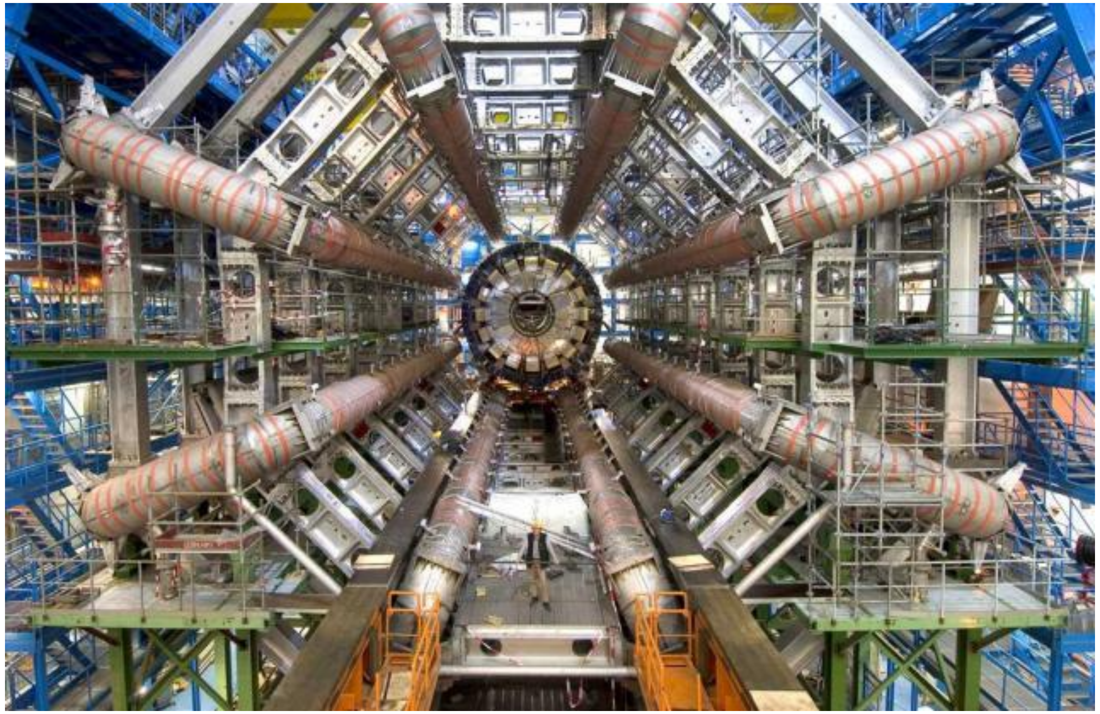
LHCb experiment approved

LHCb is the fourth experiment approved for the LHC. The experiment will study the phenomenon known as CP violation, which would help to explain why matter dominates antimatter in the universe.

LHCb is an experiment set up to explore what happened after the Big Bang that allowed matter to survive and build the Universe we inhabit today. Fourteen billion years ago, the Universe began with a bang. Crammed within an infinitely small space, energy coalesced to form equal quantities of matter and antimatter. But as the Universe cooled and expanded, its composition changed. Just one second after the Big Bang, antimatter had all but disappeared, leaving matter to form everything that we see around us – from the stars and galaxies, to the Earth and all life that it supports.

20 November 2006

World's largest superconducting magnet switched on



The ATLAS Barrel Toroid, then the largest superconducting magnet ever built, was switched on for the first time at CERN on 20 November 2006. The magnet is called the Barrel Toroid because of its barrel-like shape. It provides a powerful magnetic field for ATLAS, one of the major particle detectors taking data at the Large Hadron Collider (LHC). The magnet consists of eight superconducting coils, each in the shape of a round-cornered rectangle, **5 metres wide**, **25m long** and weighing **100 tonnes**, all aligned to millimetre precision. The ATLAS Barrel Toroid was cooled down over a six-week period from July to August 2006 to reach **–269°C**. It was then powered up step-by-step to higher and higher currents, reaching **21 thousand amps** for the first time during the night of 9 November. Afterwards, the current was switched off and the stored magnetic energy of 1.1 GigaJoules, the equivalent of about 10,000 cars travelling at 70 kilometres per hour, was safely dissipated, raising the cold mass of the magnet to –218°C.

Nobel Prizes at CERN

At CERN on 4 July, the ATLAS and CMS collaborations present evidence in the LHC data for a particle consistent with a Higgs boson, the particle linked to the mechanism proposed in the 1960s to give mass to the W, Z and other particles. (Image: CERN)

From left to right: **Jack Steinberger** **(1988)**, **Felix Bloch** **(1952)**, **Samuel Chao Chung Ting** **(1976)**, **Georges Charpak** **(1992)**, **Carlo Rubbia** **(1984)**, **Simon van der Meer** **(1984)**, **François Englert** **(2013)**, **Peter Higgs** **(2013)**