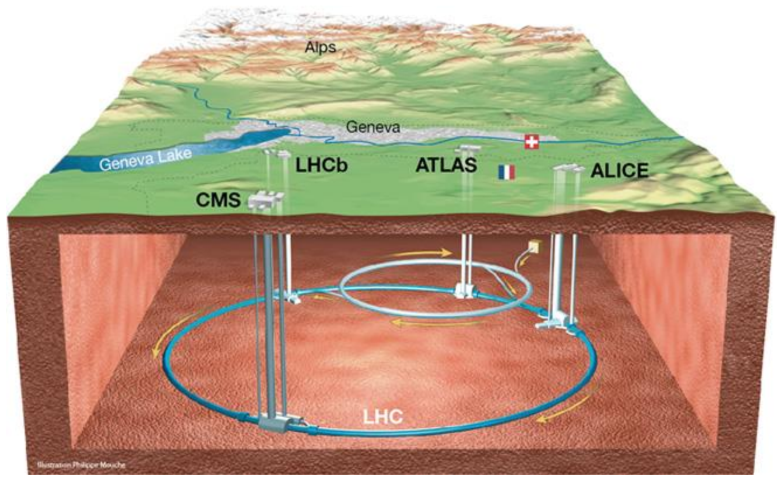
The LHC

After two decades of preparation, the LHC started operating in spring 2010. The accelerator's performance increased dramatically in 2011 and 2012, enabling experiments to obtain significant results before an energy ramp-up in 2015. Every year, technical upgrades are made to increase the intensity of the beam.



Credit: CERN/P. Mouche

The LHC under France and Switzerland

Conceptual image of the LHC underground accelerator (scales not represented). The protons produced and arranged in bunches upstream are stored in a 7-km ring, the SPS. They are then injected at a 450 GeV energy into the LHC, where the final acceleration takes place. The energy of proton-proton collisions has increased over time: 7 TeV in 2010, then 8 TeV in 2011-2012, 13 TeV after the first long-term shutdown (2013-2014) and 13.6 TeV since 2022.

The Large Hadron Collider is an underground accelerator straddling the French-Swiss border near Geneva. The LHC is the flagship project of the European laboratory CERN. Thanks to its collisions, which are the most energetic in the world, the thousands of scientists participating in the project are hoping to improve their understanding of the elementary constituents of matter.

The heart of the LHC is a 27-km ring on which seven experiments are based. The main four are ALICE, ATLAS, CMS and LHCb, and the other three are LHCf, MoEDAL and TOTEM. Beams of particles of the same type – most often, protons, sometimes lead nuclei, for specific data collection – travel in opposite directions in two vacuum tubes at a speed very close to that of light. At certain points in the ring, the beams cross at the centre of detectors, which observe the resulting collisions.

Protons and lead ions are produced upstream the LHC and pass through a series of accelerators in which they are accelerated and arranged into dense, homogeneous bunches. This circuit follows CERN's history, using older accelerators: the 'Super Proton Synchrotron', the LHC's predecessor, had its moment of glory in the early 1980s, with the discovery of the W and Z bosons.

The LHC has dizzying features. Around 9,300 superconducting magnets cooled to –271.3°C – a temperature colder than interplanetary space – are arranged one after the other in the ring. The vacuum tubes are cleared of any molecules that might hinder the progress of the beam: the residual pressure in the tubes is ten times lower than that on the Moon.

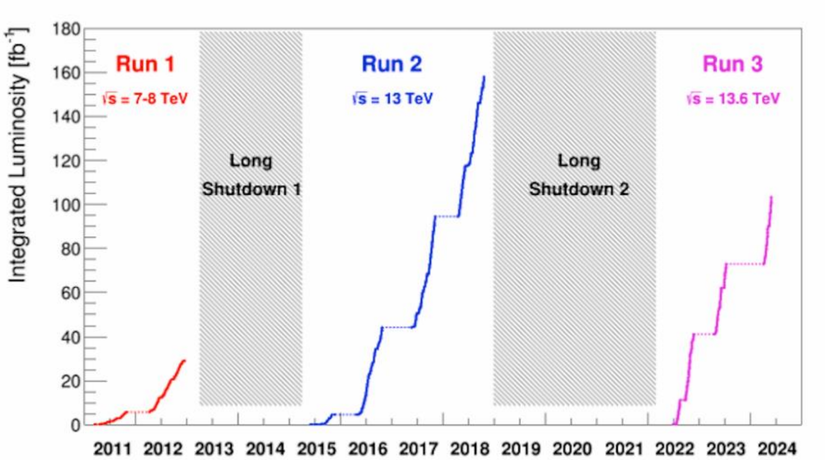
Credit: CERN

The LHC tunnel

This view of the LHC tunnel shows the vacuum tubes in which high-energy proton bunches circulate.

In the tubes, protons, grouped in small loads called bunches, travel at 99.9999998 per cent of the speed of light. They are 10^{11} per bunch, generating more than 1.7 billion collisions per second. Over its last years of operation, temperatures 100,000 times higher than those prevailing at the centre of the Sun will be reached in a tiny volume. Experiments use extremely fast algorithms to filter the collisions, recording a few thousands per second, which are then sent and processed on the Worldwide Computing Grid.

Thanks to the combined efforts of the teams in charge of the accelerator and the detectors, the LHC's performance has steadily improved, in terms of both luminosity – or collision rate – and collision energy. Each data-collection period, known as a run, lasts three consecutive years and is followed by a two-year shutdown, used to upgrade the accelerator and the experiments. A final upgrade cycle, 'High Luminosity LHC', will enable the scientific community to collect data until 2042.



Credit: CERN

Amount of data accumulated each year by the LHC

Luminosity is an essential indicator of an accelerator's performance. Instantaneous luminosity measures the number of potential collisions per surface unit over a given period of time. Integrated luminosity corresponds to the collected data size, measured in femtobars. Here, the graph shows the increasing integrated luminosity for ATLAS and CMS detectors since the start of the LHC, along with the increase in collision energy, from 7-8 TeV (Run 1) to 13.6 TeV (Run 3, current run).

Translated from 'Le LHC'*, Passeport pour les deux infinis*, IN2P3/Dunod, https://pass2i.ijclab.in2p3.fr/ (French); updated with ICHEP2024 conference (https://ichep2024.org) for IPPOG