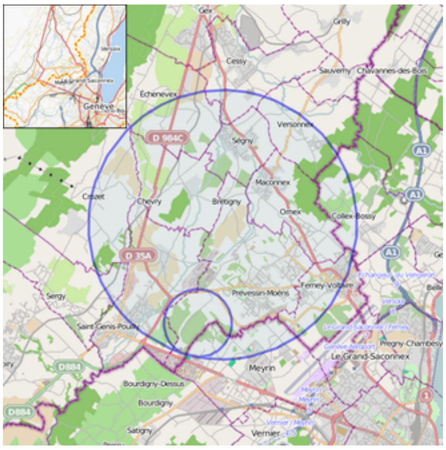
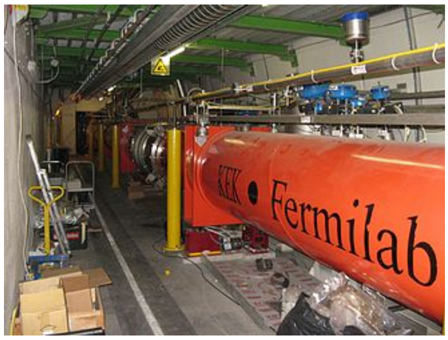


Map of the Large Hadron Collider at CERN

The 3.8-metre (12 ft) wide concrete-lined tunnel, constructed between 1983 and 1988, was formerly used to house the Large Electron–Positron Collider.[30] The tunnel crosses the border between Switzerland and France at four points, with most of it in France. Surface buildings hold ancillary equipment such as compressors, ventilation equipment, control electronics and refrigeration plants.



Superconducting quadrupole electromagnets are used to direct the beams to four intersection points, where interactions between accelerated protons will take place.

The collider tunnel contains two adjacent parallel beamlines (or *beam pipes*) each containing a beam, which travel in opposite directions around the ring. The beams intersect at four points around the ring, which is where the particle collisions take place. Some 1,232 dipole magnets keep the beams on their circular path (see image[31]), while an additional 392 quadrupole magnets are used to keep the beams focused, with stronger quadrupole magnets close to the intersection points in order to maximize the chances of interaction where the two beams cross. Magnets of higher multipole orders are used to correct smaller imperfections in the field geometry. In total, about 10,000 superconducting magnets are installed, with the dipole magnets having a mass of over 27 tonnes.[32] Approximately 96 tonnes of superfluid helium-4 is needed to keep the magnets, made of copper-clad niobium-titanium, at their operating temperature of 1.9 K (−271.25 °C), making the LHC the largest cryogenic facility in the world at liquid helium temperature. LHC uses 470 tonnes of Nb–Ti superconductor.[33]

During LHC operations, the CERN site draws roughly 200 MW of electrical power from the French electrical grid, which, for comparison, is about one-third the energy consumption of the city of Geneva; the LHC accelerator and detectors draw about 120 MW thereof.[34] Each day of its operation generates 140 terabytes of data.[35]

When running at the current energy record of 6.5 TeV per proton,[36] once or twice a day, as the protons are accelerated from 450 GeV to 6.5 TeV, the field of the superconducting dipole magnets is increased from 0.54 to 7.7 teslas (T). The protons each have an energy of 6.5 TeV, giving a total collision energy of 13 TeV. At this energy, the protons have a Lorentz factor of about 6,930 and move at about 0.999 999 990 *c*, or about 3.1 m/s (11 km/h) slower than the speed of light (*c*). It takes less than 90 microseconds (μs) for a proton to travel 26.7 km around the main ring. This results in 11,245 revolutions per second for protons whether the particles are at low or high energy in the main ring, since the speed difference between these energies is beyond the fifth decimal.[37]

Rather than having continuous beams, the protons are bunched together, into up to 2,808 bunches, with 115 billion protons in each bunch so that interactions between the two beams take place at discrete intervals, mainly 25 nanoseconds (ns) apart, providing a bunch collision rate of 40 MHz. It was operated with fewer bunches in the first years. The design luminosity of the LHC is 10^{34} $cm^{-2}s^{-1}$,[38] which was first reached in June 2016.[39] By 2017, twice this value was achieved.[40]

Before being injected into the main accelerator, the particles are prepared by a series of systems that successively increase their energy. The first system is the linear particle accelerator LINAC 4 generating 160-MeV negative hydrogen ions (H^- ions), which feeds the Proton Synchrotron Booster (PSB). There, both