two further vacuum leaks identified in July 2009; this pushed the start of operations to November of that year.[81]

Run 1: first operational run (2009–2013)


Seminar on the physics of LHC by John Iliopoulos (2009).[93]

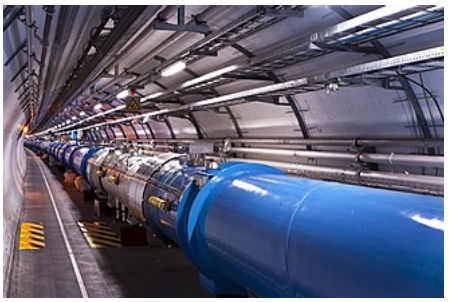
On 20 November 2009, low-energy beams circulated in the tunnel for the first time since the incident, and shortly after, on 30 November, the LHC achieved 1.18 TeV per beam to become the world's highest-energy particle accelerator, beating the Tevatron's previous record of 0.98 TeV per beam held for eight years.[94]

The early part of 2010 saw the continued ramp-up of beam in energies and early physics experiments towards 3.5 TeV per beam and on 30 March 2010, LHC set a new record for high-energy collisions by colliding proton beams at a combined energy level of 7 TeV. The attempt was the third that day, after two unsuccessful attempts in which the protons had to be "dumped" from the collider and new beams had to be injected.[95] This also marked the start of the main research programme.

The first proton run ended on 4 November 2010. A run with lead ions started on 8 November 2010, and ended on 6 December 2010,[96] allowing the ALICE experiment to study matter under extreme conditions similar to those shortly after the Big Bang.[97]

CERN originally planned that the LHC would run through to the end of 2012, with a short break at the end of 2011 to allow for an increase in beam energy from 3.5 to 4 TeV per beam.[5] At the end of 2012, the LHC was planned to get shut down until around 2015 to allow upgrade to a planned beam energy of 7 TeV per beam.[98] In late 2012, in light of the July 2012 discovery of the Higgs boson, the shutdown was postponed for some weeks into early 2013, to allow additional data to be obtained before shutdown.

Long Shutdown 1 (2013–2015)


A section of the LHC

The LHC was shut down on 13 February 2013 for its 2-year upgrade called Long Shutdown 1 (LS1), which was to touch on many aspects of the LHC: enabling collisions at 14 TeV, enhancing its detectors and pre-accelerators (the Proton Synchrotron and Super Proton Synchrotron), as well as replacing its ventilation system and 100 km (62 mi) of cabling impaired by high-energy collisions from its first run.[99] The upgraded collider began its long start-up and testing process in June 2014, with the Proton Synchrotron Booster starting on 2 June 2014, the final interconnection between magnets completing and the Proton Synchrotron circulating particles on 18 June 2014, and the first section of the main LHC supermagnet system reaching operating temperature of 1.9 K (−271.25 °C), a few days later.[100] Due to the slow progress with "training" the superconducting magnets, it was decided to start the second run with a lower energy of 6.5 TeV per beam, corresponding to a current of 11,000 amperes. The first of the main LHC magnets were reported to have been successfully trained by 9 December 2014, while training the other magnet sectors was finished in March 2015.[101]

Run 2: second operational run (2015–2018)

On 5 April 2015, the LHC restarted after a two-year break, during which the electrical connectors between