computer network infrastructure initially connecting 140 computing centres in 35 countries (over 170 in 36 countries as of 2012). It was designed by CERN to handle the significant volume of data produced by LHC experiments,[49][50] incorporating both private fibre optic cable links and existing high-speed portions of the public Internet to enable data transfer from CERN to academic institutions around the world.[51] The Open Science Grid is used as the primary infrastructure in the United States, and also as part of an interoperable federation with the LHC Computing Grid.

The distributed computing project LHC@home was started to support the construction and calibration of the LHC. The project uses the BOINC platform, enabling anybody with an Internet connection and a computer running Mac OS X, Windows or Linux to use their computer's idle time to simulate how particles will travel in the beam pipes. With this information, the scientists are able to determine how the magnets should be calibrated to gain the most stable "orbit" of the beams in the ring.[52] In August 2011, a second application (Test4Theory) went live which performs simulations against which to compare actual test data, to determine confidence levels of the results.

By 2012, data from over 6 quadrillion (6 x 10^{15}) LHC proton-proton collisions had been analysed,[53] LHC collision data was being produced at approximately 25 petabytes per year, and the LHC Computing Grid had become the world's largest computing grid in 2012, comprising over 170 computing facilities in a worldwide network across 36 countries.[54][55][56]

Operational history

The LHC first went live on 10 September 2008,[57] but initial testing was delayed for 14 months from 19 September 2008 to 20 November 2009, following a magnet quench incident that caused extensive damage to over 50 superconducting magnets, their mountings, and the vacuum pipe.[58][59][60][61][62]

During its first run (2010–2013), the LHC collided two opposing particle beams of either protons at up to 4 teraelectronvolts (4 TeV or 0.64 microjoules), or lead nuclei (574 TeV per nucleus, or 2.76 TeV per nucleon).[63][64] Its first run discoveries included the long-sought Higgs boson, several composite particles (hadrons) like the χ_b (3P) bottomonium state, the first creation of a quark–gluon plasma, and the first observations of the very rare decay of the B_s meson into two muons ($B_s^0 \to \mu^+\mu^-$), which challenged the validity of existing models of supersymmetry.[65]

Construction

Operational challenges

The size of the LHC constitutes an exceptional engineering challenge with unique operational issues on account of the amount of energy stored in the magnets and the beams.[41][66] While operating, the total energy stored in the magnets is 10 GJ (2,400 kilograms of TNT) and the total energy carried by the two beams reaches 724 MJ (173 kilograms of TNT).[67]

Loss of only one ten-millionth part (10^{-7}) of the beam is sufficient to quench a superconducting magnet, while each of the two beam dumps must absorb 362 MJ (87 kilograms of TNT). These energies are carried by very little matter: under nominal operating conditions (2,808 bunches per beam, 1.15×10^{11} protons per bunch), the beam pipes contain 1.0×10^{-9} gram of hydrogen, which, in standard conditions for temperature and pressure, would fill the volume of one grain of fine sand.

Cost