TAP 518-1: Some information about LEP at CERN

This information is provided for interest, perhaps to stimulate further research.

- First experiments: 1989
- Particle collisions: electrons and positrons
- Maximum beam energy: 100 GeV
- Luminosity: $2.4 \times 10^{3}\ s^{-1}$
- Time between collisions: 22 μs
- Filling time: 20 h
- Acceleration period: 550 s
- Injection energy: 550 MeV
- Bunch length: 1 cm
- Average beam current: 55 mA
- Circumference: 27.66 km
- Dipole (bending) magnets: 3280 plus 24 weaker dipoles
- RF resonant cavities: 128
- Peak magnetic field: 0.135 T
- Vacuum: 10^{-11} Torr

Between 1983 and 1989 the construction of LEP at CERN was the biggest civil engineering project in Europe. The accelerator tube is 26.67 km in circumference and is shaped to an accuracy of better than 1.0 cm. It runs underground in a specially excavated tunnel inclined at 14° to the horizontal between Geneva airport and the Jura mountains. There are four main experimental stations positioned around the ring. As it enters each of these the beam passes through a large solenoid whose magnetic field squeezes the beam to about 10 μm by 250 μm, increasing the luminosity (and hence the probability of interactions with the oncoming beam).

From 1989 to 1995 LEP was used as a Z_0 ‘factory’. This was done by setting the collision energy to about 91 GeV (rest energy of the Z_0). This allowed physicists to make accurate measurements of the Z_0 lifetime. From this they showed that there are only three generations of fundamental particles. If there were more then the lifetime of the Z_0 would be lower because it would have more alternative particles into which it could decay. This conclusion agreed with that of cosmologists based on the number of different types of neutrinos needed to explain relative abundances of different nuclei in the early Universe. It is a good example of the growing links between particle physics on the smallest scale and cosmology, the study of the Universe on the largest scale.

From 2005 LEP will be replaced by the LHC (large hadron collider, a new accelerator running in the existing LEP tunnel). This will accelerate protons and antiprotons to up to 14 TeV (1 TeV = 10^{12} eV) about 10 times greater than the Tevatron at Fermilab. Why? Whereas electron–positron collisions can be used to test precise aspects of the Standard Model, more massive particles are used in the hope of detecting rare but exotic events. LHC should reveal the supersymmetric partners of ordinary matter particles (as predicted by superstring theory) and may well reveal the Higgs particle – a force-carrier in the hypothetical Higgs field that endows all other particles with mass. The LHC is an amazing project, even by the standards of high-energy physics. The momentum of the high-energy protons and antiprotons is so high that extremely powerful superconducting dipole magnets must be used to keep them in the ring. Their peak field will be about 9 T! To maintain the superconducting properties these magnets must be cooled to 1.9 K. This requires eight cryogenic plants spaced equally around the 27 km ring pumping 70 000 litres of liquid helium through 40 000 leak-proof junctions to cool 31 000 tonnes of equipment!

Practical advice

This information should provide some insight into the engineering challenges to be overcome if the fundamental physics is to be explored.

Alternative approaches

Similar information can be gleaned from Web sites dedicated to most large accelerators.

Social and human context

The cost of such projects forces collaboration on national governments.

External reference

This activity is taken from Advancing Physics chapter 16, 40T