

AFTER DINNER SPEECH

E. Picasso
CERN, Geneva, Switzerland

On the occasion of this conference on applied geodesy for particle accelerators, I have been asked to say a few words about the Large Electron-Positron collider (LEP) now in construction here at CERN.

I am very grateful to the organizers of the CERN Accelerator School for inviting me to give this after dinner speech.

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Why build a big new collider?

I have no better answer to offer than a few general remarks.

Mankind's curiosity about Nature has surely been the dominant force in the development of civilization. Man's history has been shaped by the irresistible urge to find out how the world works and how we can use this knowledge to improve our way of living.

Among the most basic questions we have always asked are: What is the ultimate structure of matter? What are the forces through which matter interacts? How did the Universe begin? Will it ever end? as well as many other questions in the same vein. These questions fall within the domain of elementary particle physics, upon which our knowledge of other sciences ultimately rests. As biology and medicine are founded in chemistry, and chemistry in physics, so all the physics is founded in the study of elementary particles and forces that govern their behaviour.

Until very recently it could scarcely have been foreseen that some of the age-old mysteries of astronomy might be solved by looking down to elementary particles, where powerful forces give all matter its form. Particle physicists, together with nuclear and atomic physicists, astrophysicists and cosmologists are beginning to understand not only what matter is, but where it comes from, when and how. Questions such as these are important since everything else about which we would like to know more is intimately linked to them.

LEP is one of the powerful and precise scientific instruments upon which further advances in our knowledge of Nature critically depend.

LEP will be the largest electron-positron storage ring in the world. In this giant accelerator, matter (e^-) and antimatter (e^+) will be brought into head-on collision and in the resultant mutual annihilation the total energy will become available for the production of other particles. The magic process through which energy can turn into matter has been stated by A. Einstein in his well-known

equation $E = mc^2$, where E is the energy of a particle, m its mass and c the speed of light. This formula essentially means that matter and energy are two different aspects of the same entity which can change from one to the other.

Only one storage ring is needed for electrons and positrons. Because of their opposite electric charges they are bent in opposite directions by the same magnetic fields. Thus they can circulate in opposite directions in the same ring, resulting in head-on collisions.

In the ring, a series of bending and focusing magnets will ensure that the particles follow the desired paths and stay concentrated in a narrow beam. A very good vacuum in the tube in which they circulate will greatly reduce the number of particles lost due to collisions with air molecules.

The amount by which the beams are bent depends upon the magnetic field and upon the energy of the particles. As particles are accelerated to higher energies, by passing them through electric fields generated by a radio frequency system, it is necessary to increase the magnetic fields to hold the beams on the same orbit.

The electron and positron beams will each be injected into LEP in four bunches equally spaced around the ring. Each of these bunches will be about 2 cm long, 200 m wide and 20 m high at the crossing points. As the beams circulate in opposite directions, these bunches will collide at four points around the ring and it is around these positions that detection systems will be installed to observe the results of the collisions. These experiments will involve complex detector systems, which generally require large collaborations of physicists for the conception, construction and operation of the detectors and for the analysis of the results. The realization of such complex systems requires new advanced technologies and collaboration with specialized industries is essential.

The LEP Project includes the construction of two Linacs and an Accumulator Ring (EPA), the necessary modifications to the existing PS and SPS machine complex to enable acceleration of electrons and positrons up to 22 GeV energy, and above all the construction of the main ring of LEP (see Fig. 1).

The construction of the LEP machine necessitates the use of well-advanced technologies such as magnets, radio-frequency cavities, vacuum systems, extremely stable power converters, etc. The machine control systems, including positioning of the beam and communications, constitute a fascinating aspect of the realization and the operation of the collider, and its realization demands the use of the more recent technological developments. LEP construction is not only an intellectual adventure but also a technological realization ahead of its time.

The main tunnel consists of eight arcs and eight straight sections, the latter containing the beam collision points. The underground system will consist of a tunnel approximately 27 km in length with an internal cross-section diameter of 3.76 m, after concreting. This will lie for approximately 10% of its length in the limestone strata, and for 90% in the molasse. Along this tunnel at a location corresponding to four of the eight beam collision points, will be constructed the experimental zones at P 2, P 4, P 6 and P 8 as seen on the map in Fig. 1. Additional galleries are built in parallel to the main tunnel at P 2 and P 6 to house the klystrons and the other radio-frequency

equipment. Let me point out that the underground excavations are about one million m³, and each experimental hall is about 25,000 m³, there are 19 pit shafts, the average depth of which is approximately 100 m, the diameter varying from 9 m to 24 m. The construction of LEP is an impressive task carried out by a team of scientists, technicians and skilled craftsmen. It is for me a great honour to be the conductor of such a wonderful orchestra.

So much for LEP. Let me say a few words about the work that the applied surveyors such as J. Gervaise and M. Mayoud and their group have done for LEP construction.

I am one of the scientists that has been able to measure quantities of quantum electrodynamics with extremely high precision. When I mention accuracy of one part per million or more, people undoubtedly express admiration for the accuracies that have been measured in such experiments. Let me express, in turn, my admiration for what you have done in your field. J. Gervaise and his collaborators have been able to establish a network of points of reference on the surface and deep underground so that it has been possible to drive the three huge full-face boring machines with great accuracy. It is for me incredible that man is able to guide these huge tunnelling machines, the heads of which weigh about 170 tons, with errors no greater than one or two centimeters! It is a fantastic achievement if one thinks that everything happens at about 100 m underground and the only communication with the surface reference points is via shafts around 3.5 km apart. The use of sophisticated devices such as the terrameter, satellite measurements, and the use of more conventional devices such as the gyroscope and similar ones have allowed us to do a wonderful job.

LEP is planned to operate at the end of 1988 at 50 GeV per beam and later, around 1993/1994 at an energy of about 100 GeV per beam.

It is clear that LEP is a joint adventure between CERN scientists, European industrial competence and collaboration with scientists of other disciplines, of which applied geodesy. If LEP operates according to our design a good share of the thanks goes to you all.

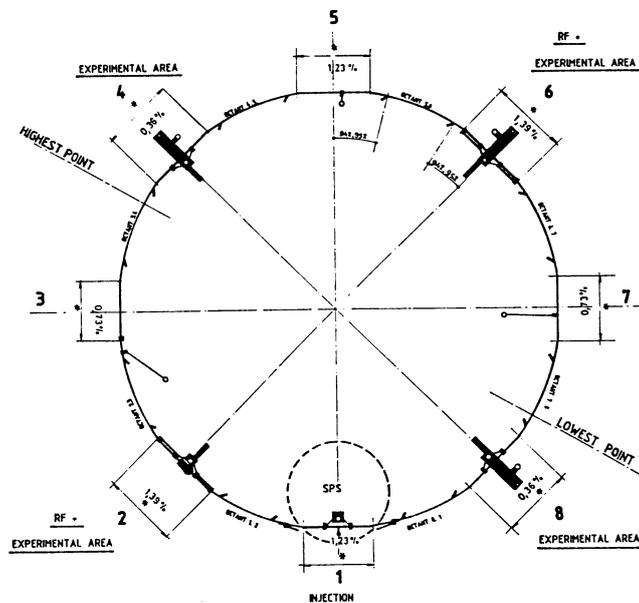


Fig. 1 General layout of the underground areas