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CONSTRUCTION AND PERFORMANCE PLANS FOR THE LEP COLLIDER

by

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Abstract

Construction and Performance of the LEP Collider. W. Schnell (CERN, Geneva, Switzerland).

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LEP is a large electron positron collider in which energies of up to 130 GeV per beam can be reached in several stages of construction. The circumference of the storage ring, which will be built adjacent to the present CERN site, is 30 km and it will contain up to eight colliding beam areas. A storage ring of this size presents a number of unusual problems related to beam dynamics and to engineering, including civil engineering. The design study for this project has advanced to a stage of considerable detail. The main features and some components of LEP will be described as well as the progress of prototype work now being carried out.

1. Introduction

This project for a Large Electron Positron collider, called LEP, has been under study^{1,2,3)} at CERN since 1976. The present design has been described in several summary papers^{4,5)}, in a detailed Design Report⁶⁾ and it has been extensively reviewed by a large ECFA-LEP Working Group⁷⁾. In this paper the main emphasis will, therefore, be placed on recent evolution of the basic design and on progress with prototypes of main components.

2. Main Parameters and Construction in Stages

The design of LEP has been optimized for a nominal beam energy of about 90 GeV at $10^{32} \text{ cm}^{-2} \text{ s}^{-1}$ maximum luminosity, to be obtained with

This method has the additional advantage of permitting extension to the full energy with a minimum of perturbation to physics research. The intended programme of staged construction is shown in Table 2.

TABLE 2. Stages of LEP Construction

Fraction of RF installed	$1/6$	$1/3$	1	Superconducting RF
Design energy	49.4	62.3	86.1	130 GeV
Luminosity	0.39	0.62	1.1	$1.0 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$
Current	5.71	7.20	9.15	6.16 mA
RF power	16	32	96	96 MW
Length of RF	272	543	1629	1629 m
Number of five-cell room-temperature cavities	128	256	768	-

With $1/6$ of the nominal RF system installed a beam energy of 50 GeV can be obtained, which is expected to be very satisfactory for Z^0 physics. This stage of RF installation has, therefore, been given special attention and, combined with other measures of austerity, it will form "Phase One" of LEP operation. In Phase One only four experimental areas will be equipped and the RF system will be placed adjacent to two diametrically opposite beam crossings, although the civil engineering work for two more points of RF stations, the next stage of construction, will also be completed.

3. The General Layout

The layout of LEP, near the present CERN site, has been chosen so as to permit e-p collisions in an SPS bypass as well as injection of protons into the LEP tunnel at a later stage. In addition, it is now proposed to

shafts and accommodates two large experiments which can be pushed into the beam alternately as is foreseen in one area of PETRA. Three collision areas are situated under the Jura mountains and two of these will be equipped as experimental areas in Phase One. They will be similar to the one shown in Figure 3 but accessible via roughly horizontal access tunnels and laid out for only one large experiment each, which can, however, be withdrawn from the beam for maintenance or reconstruction.

4. Lattice, Collective Phenomena, Luminosity Variation

The main arcs of LEP are formed by a regular separate-function FODO lattice, as shown in Figure 4. The period length, 79 m, has been kept relatively long so as to reduce the number of quadrupoles, sextupoles and associated elements which are costly and do not contribute to the bending. Before the beam reaches an RF straight section and the subsequent collision point its dispersion is suppressed, i.e. particles of different energy within the beam are superimposed on the same orbit. The necessary optics are formed from essentially the same elements as the main arcs, albeit with individually adjustable quadrupoles. The lattice insertions forming the neighbourhood of the collision points are tunable, i.e. they permit injection at three times the nominal value of the amplitude functions, β^* , at the collision point (cf Table 1) followed by a gradual reduction with circulating beam, in order to cope with the high sensitivity to closed-orbit distortions.

Single beam collective phenomena determine the current which can be stored at the injection energy. The actual injection energy, 22 GeV, has been chosen as the minimum permissible value. The dominant two-beam phenomenon is the incoherent beam-beam limit. These effects are usually

cement and silica sand. Longitudinal tie rods, passing through punched holes near the outer edges of the laminations, precompress the mortar. As the price of the mortar is much lower than that of punched laminations the cost of these steel-concrete cores will be substantially reduced - by about a factor of two compared with a conventional core. Other advantages of the steel-concrete cores are their much-improved mechanical rigidity and their reduced weight (also by a factor of two).

So far, two full-size dipoles have been completed at CERN (Figure 6), and have undergone extensive mechanical and magnetic measurements. The rigidity in torsion and flexion is comparable to that of a concrete block of the same dimensions, and improved by roughly an order of magnitude compared with a typical laminated magnet of conventional construction. This is expected to facilitate transport and installation (about 10 cores per day will have to be manufactured and installed). Several additional prototype dipole cores have been ordered from specialized firms of the building industry, conductor bars and insulators for these prototypes are at hand.

The strengths of the lattice quadrupoles and sextupoles form one of the potential limitations of machine energy; they have been designed to allow operation up to 130 GeV. The cores of these magnets will be made in the conventional way of densely stacked punched laminations. However, the excitation coils will be fabricated from anodized aluminium strip of graded thickness, permitting the entire coil, of stepped cross-section, to be wound as a homogeneous unit. Prototype coils for quadrupoles and sextupoles have been designed and are on order from industry.

6. Vacuum System

The linear density of synchrotron radiation hitting the dipole chamber,

The 12 m dipole chambers will be terminated by welded-on aluminium flanges and jointed by clamped-on stainless-steel connection units (Figure 9). These contain hydroformed flexible bellows and sliding contacts⁹⁾ to ensure continuity for the beam-induced wall currents. Specially-developed copper-alloy gaskets permit direct joints between aluminium and stainless-steel flanges, by means of clamp-on rings as used in the SPS. Several pairs of these clamp-on connections have been thoroughly life-tested at 200⁰C during more than 400 bake-out cycles.

6. Injection

The preinjector, which is being developed by LAL Orsay¹⁰⁾, contains a linear accelerator up to 600 MeV, preceded by a 200 MeV high current linac and a conversion target for producing positrons. A 600 MeV accumulation ring (Figure 10) acts as a buffer between the linear accelerators of 100 Hz repetition rate and the slowly-cycling main injection system.

In the Design Report⁶⁾ the construction of a dedicated 22 GeV injector synchrotron was foreseen. Instead, it is now envisaged¹¹⁾ to reach the same injection energy by successive acceleration in the existing PS and SPS machines. The preinjector will be installed south of the PS and inject 600 MeV electrons and positrons in opposite directions. Modest additions to the existing PS RF systems will permit acceleration to about 3.5 MeV at which energy the beam will be transferred to the SPS via the existing complex of transfer systems. Again, electrons and positrons will be injected in opposite directions so that no polarity reversals are required in either the PS or the SPS. After acceleration in the SPS the beam will be transferred to LEP at 22 GeV, the LEP injection systems being located on either side of interaction region number 1 (Figure 1).

we propose to add a device that decreases the power dissipation in the cavities by a factor 1.5 by modulation. The method consists of coupling a low-loss, H-mode, storage resonator to the accelerating cavity and exciting the coupled system, with CW power sources, at both its resonant frequencies. This makes the stored energy oscillate between the two resonators, spending on average half the time in the low-loss environment. The coupling is adjusted to make peaks of the accelerating field coincide with the passage of a pair of e^+e^- bunches. One common storage resonator is sufficient for each five-cell accelerating cavity. The proposed design, employing a spherical storage resonator (H_{110} - mode in spherical coordinates) is shown in Figure 11. The method has been tested at low power. A 500 MHz high-power model is being fabricated (Figure 12) and tests will start soon.

The frequency of 350 MHz has been chosen in the region of an economic optimum. A higher frequency would lead to an increase of RF power as the shunt impedance per unit length, for a fixed beam aperture, remains approximately constant while the over-voltage and the parasitic losses increase. An appreciably lower frequency would lead to a steep increase of structure cost as the size of the structure would exceed standard machine tools. The strong longitudinal focussing resulting from the high frequency chosen leads to some beam-dynamical problems. To alleviate these, a third-harmonic RF system is foreseen.

In Phase One only 128 cavities, powered by 16 klystrons, will be installed adjacent to collision points 1 and 5 (Figure 1) and the third-harmonic system will probably be omitted.

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Figure 1 : General layout of LEP.

Figure 4 : Lattice layout in regular arc and dispersion suppressor.

Figure 5 : Concrete-filled dipole magnet.

Figure 8 : Stripline vacuum pump prototype, dismantled; the strips are superimposed, the five central ones forming the anode.

Figure 9 : Vacuum chamber clamp-on connection unit, prototype.

Figure 12 : 500 MHz model of storage cavity under construction.

Figure 13 : Model of superconducting cavity.