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SCAN-0006108

LEP-70/1
By the Study Group

About the LEP-70 Study

This note contains some ideas for the organization, aims and priorities of the study we are about to begin of a 70 GeV version (hopefully expansible) of the e^+e^- storage ring LEP. It is clear that some of this will change as we go along.

1. Organization

1.1 Members of the Study Group

The present composition of the study group is as follows:

B. Autin	J.R. Maidment
3265 B. Bianchi	2552 A. Mathewson
2991 F. Bonaudi	2336 E. Picasso
3947 P. Bramham	2979 L. Resegotti
3007 J. Gervaise	2964 W. Schnell
2989 O. Gröbner	3235 S. Turner
4009 H. Hoffmann	5976 A. Verdier
3034 A. Hofmann	3173 E.J.N. Wilson
5961 K. Hübner	P.B. Wilson
3264 A. Hutton	3764 C. Wyss
3380 E. Jones	2976 C.J. Zilverschoon
3426 E. Keil	3034 B. Zotter

It is expected that the composition of the study group will evolve during the study. The meetings of the Study Group will be convened by E. Keil, W. Schnell and C.J. Zilverschoon.

1.2 Schedule

We have been asked to have a report ready by the end of next year. To achieve this, we ought to follow the tentative schedule shown below.

End July 1977	considered as beginning of study
end October 1977	list of tentative parameters known
end May 1978	conceptual design of main components (e.g. magnet, vacuum, RF, tunnels, experimental halls) must be known

end June 1978	overall design as needed for the report essentially completed
end September 1978	individual contributions to report written
mid-November 1978	editing of report finished
mid-December 1978	report distributed

It seems very likely that the LEP study will continue beyond the end of next year. It is important, therefore, to distinguish between work required for a reasonably conclusive report, and the initiation of developments beyond the above schedule. Both types of work are important and the priorities will have to shift gradually from the first to the second.

1.3 Publications

We propose that a series of consecutively numbered LEP-70 Notes be created as a means of communication between the members of the study group and with our closest colleagues outside. Some of these LEP Notes may receive a wider distribution, e.g. to the physics community. A.M. Bugge will assign numbers and keep a complete file. Significant results on particular aspects of the LEP-70 design should be published as divisional reports, and the overall result probably as a Yellow Report.

2. Performance Parameters

The performance of LEP-70 as a high-energy physics tool is essentially determined by the following parameters:

- energy E
- luminosity L
- free space around crossings l_{int}
- number of crossings N_x

It is essential that our choices are supported and that the reasons for making them are understood by the experimental physicists. We must, obviously, keep close contact with potential users of this machine as the study progresses. At the moment we have every reason to believe that the following tentative choices are indeed supported by the physics community.

2.1 Energy E and Luminosity L

The highest energy E at which the maximum luminosity is reached is assumed to be 70 GeV for the initial installation. Since, even with this initial installation, there will be some luminosity for $E > 70$ GeV, the components should be specified in such a way that LEP-70 can be operated above 70 GeV.

The luminosity at 70 GeV is assumed to be $L = 10^{32} \text{cm}^{-2} \text{s}^{-1}$. The effect of small variations of this figure on the machine design should be studied, and discussed with the physicists. Studies should also be done on how the luminosity drops for energies $E > 70$ GeV with the initial RF system, and on the possibilities for converting LEP-70 to a higher energy by adding more RF cavities and/or more RF power and/or by replacing the conventional RF structure by a superconducting one. The requirements on the lattice parameters imposed by these considerations also need study.

For energies between the (as yet unknown) injection energy and 70 GeV there is some freedom in the choice of the luminosity variation. A luminosity proportional to E^2 is feasible at a constant machine aperture, using either variable tune or wiggler magnets for adjusting the beam size. Choices with a smaller luminosity variation require more aperture and are more likely to cause difficulties with collective phenomena, e.g., bunch lengthening and widening. We tentatively propose to base the LEP-70 design on a luminosity variation proportional to E^2 .

2.2 Free Space ℓ_{int}

The free space ℓ_{int} around the crossing points is used to install the detectors. The minimum length is determined by their size. Its maximum length is given by the increasing difficulties of chromaticity correction, which are proportional to $\ell_{\text{int}}/\beta^*$. If ℓ_{int} is fixed at ± 10 m, the value used in LEP-100 and assumed during the physics study, the chromaticity correction does not seem too difficult. It should be checked that the lattice of LEP-70 allows an increase of ℓ_{int} at the expense of a decrease in luminosity without a change in lattice geometry other than the position of the quadrupoles nearest to the crossing points. The inverse should also be checked in spite of the inconveniences of a reduced beam lifetime.

2.3 Number of Crossing Points N_x

The choice of the number of crossing points N_x is influenced by machine design considerations, e.g. superperiodicity and distribution of RF cavities, by the construction and operating cost of experimental halls and detectors, and by the number of experiments to be installed simultaneously. For LEP-100 $N_x = 8$ has been chosen. Another possible choice might be $N_x = 6$. The decision between these might be influenced by the, as yet unknown, site conditions. As the number of bunches is likely to be above 3 (because of RF problems) and as the number of unwanted crossings, necessitating electrostatic separation, should be kept to a minimum, we propose to adopt $N_x = 8$ for this study, being ready to change should the need arise.

3. Other Parameters

Many more parameters than those given in Section 2 must be defined before engineering studies on the RF, magnet, vacuum etc. systems can be launched. Therefore, a tentative set of parameters must be established very soon.

3.1 Vertical Amplitude Function β_y^*

The vertical amplitude function at the crossing points β_y^* should be small in order to minimize the RF power required for synchrotron radiation losses. How small it can be depends on two things, the beam-beam bremsstrahlung lifetime τ_{bb} and the chromaticity correction. τ_{bb} is proportional to β_y^* and is about 10 hours for $\beta_y^* = 0.2$ m at 70 GeV. It does not appear very attractive to design LEP-70 for a much smaller lifetime τ_{bb} . Hence it is proposed to adopt $\beta_y^* = 0.2$ m as the nominal design figure, and to work hard to arrive at a workable chromaticity correction scheme at this value of β_y^* .

3.2 Bending Radius and Length of RF Cavities

The bending radius ρ and the length of active RF cavities L_c can be obtained by a cost optimization. Using the unit prices arrived at in the LEP-100 study, and the value of β_y^* chosen above, one finds $\rho = 2.6$ km and $L_c = 1.5$ km. This choice also fixes the average radius of the arcs R and the circumference C of LEP-70 to a very large extent. Tentative values are $R = 2.8$ km and $C/2\pi = 3.5$ km.

3.3 Combined Function vs. Separated Function

For LEP-100 a combined-function magnet was considered impracticable from the outset, because of the steep gradient required. For LEP-70 it should be found out soon whether a combined-function is feasible and whether it is less sensitive to magnet excitation and alignment errors than a separated-function lattice, when both lattices have low- β insertions.

3.4 Number of Bunches k_b

The choice of the number of bunches k_b is influenced by the following considerations. Transient beam loading and higher-mode losses are small for a high value of k_b , and increase when k_b is reduced. The tune Q of the machine increases with k_b . A high tune increases the sensitivity of the machine to magnet excitation and alignment errors. If k_b is larger than $N_x/2$, the beams must be electrostatically separated in $2(k_b - N_x/2)$ places while collisions take place in the required intersections. The number of bunches must be chosen, balancing the conflicting requirements of transient beam loading, and of linear beam optics and beam separation.

4. Beam Dynamics Studies

The beam dynamics studies for LEP-70 will be based on the tentative parameters arrived at in Sections 2 and 3.

4.1 Linear LEP-70 Lattice

A completely matched linear lattice with the flexibility required for the variation of ℓ_{int} , β_x^* , β_y^* , and the variation of L with E will be developed. This will include the detailed choice of the horizontal and vertical tunes, and of the method for controlling the beam size variation with energy.

4.2 Chromaticity Correction

Sextupole arrangements for correcting the chromaticity of the lattice will be developed with the aim of finding one with the best beam behaviour at finite amplitudes of betatron and synchrotron oscillations.

4.3 Effects of Errors

The effects of errors in magnet excitation and alignment on the beam behaviour will be analysed, and a set of tolerances will be obtained. A closed-orbit correction scheme and a suitable scheme of gradual reductions in β_x^* , β_y^* and closed-orbit distortions to satisfy these tolerances will be developed.

4.4 Collective Phenomena

Collective phenomena, e.g. bunch lengthening and widening, higher-mode losses and coupled-bunch coherent instabilities will be analysed. Suitable cures for these phenomena will be considered.

5. Technical Components

The main "components" requiring a relatively detailed study urgently, appear to be the magnet system; the vacuum system; the RF system; the machine enclosure, most likely underground tunnels, including such aspects as shielding, access, transport, supplies, cooling, ventilation, survey, safety, etc.; the experimental areas, including the same aspects; the injector. Other, smaller, parts of the machine may have to be singled out for a study; two examples will be given below. To be consistent we should tentatively assume 30,000 hours of operation at 70 GeV, whenever this is needed for optimization.

5.1 The Magnet System

The most obvious problems with the magnet are the low bending field at injection, tolerance requirements and the need for low cost. For LEP-100 special air-cored bending magnets were proposed. LEP-70 will probably have a higher field at injection, and conventional magnets, relying mainly on steel for shaping the field, should be seriously reexamined. The choice and design of the vacuum system has a strong influence on the bending magnets as they have to provide room for distributed pumps (if such pumps are feasible at the low field) or access for numerous lumped pumps, or adequate aperture for pumping from the ends only, or, possibly, a combination of these features.

5.2 The Vacuum System

The most obvious problem with the vacuum system is the large gas load due

to desorption by synchrotron radiation and the necessity for low cost per running metre. The possibility of distributed pumping in spite of the low magnetic field should be reexamined as well as methods for in situ cleaning of the chamber walls. The chambers and their connections must be smooth to minimize (or otherwise designed to cope with) RF losses due to the tight and dense bunches. It seems desirable that the vacuum chamber absorbs, and its cooling copes with, the largest possible fraction of the synchrotron radiation, without having to resort to costly additional shielding. Synchrotron radiation penetrating and scattered into the tunnel atmosphere can generate toxic and corrosive chemical compounds.

5.3 The RF System

As in the LEP-100 study, the report will probably have to be based on the best-known proved solution, viz. five-cell coupled π -mode accelerating structures of copper (or possibly aluminium) at room temperature, fed from CW power sources. More advanced solutions must be studied in parallel. Experimental development of modulated cavities has started. The study of superconducting RF systems will probably be the subject of a cooperation between the Kernforschungszentrum at Karlsruhe, DESY and CERN. Transient beam loading is a fundamental problem and a reliable prediction of the maximum tolerable bunch charge is required in all cases.

5.4 The Buildings and Experimental Areas

Obviously, the problems related to the storage ring enclosure and the experimental areas depend very much on the site chosen. The cost and other consequences of a location near (or partly on) the present CERN site must be compared with those of an ideal flat site.

5.5 The Injector

The injector for LEP-70 is quite a large project in itself. A study was made for LEP-100 and led to the proposal of a 20 GeV fast-cycling synchrotron (in preference to a linac) for which a set of parameters was derived. To obtain

a reasonable positron filling time, two schemes were proposed, either a scheme of merging bunches or the use of a small positron accumulation ring. The second solution seems preferable. For LEP-70 new injector parameters have to be derived. Furthermore, some of the injector-synchrotron components, at least the magnet and the vacuum chambers, require detailed attention.

In addition to studying such a stand-alone injector, specially built and housed in a special tunnel, we shall study the possibility of using the SPS tunnel to house an injector. Such a study must obviously include the concomitant restrictions on siting.

5.6 Other Components

Measurement and correction of closed-orbit errors may require some detailed attention at an early stage because of the combination of tight tolerances and the large circumference over which these systems have to be distributed. Another specific problem to be examined is the electrostatic beam separation at unwanted crossings. The study of other systems may be postponed for a short time and for as long as no specific problems arise. However, cost estimates, at least, will also have to be made for such systems as overall controls, beam transfer and power supplies.