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Space Requirements in LEP Experimental Halls

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1. Summary

In this note I examine the space requirements in LEP experimental halls for set-up, running and repair of one or two experiments per hall. Information on the size of experiments comes from experience with SPEAR, PEP and PETRA. I conclude that the present hall design (40 × 16 m, with the long direction perpendicular to the beam line) is adequate to handle one experiment per hall but not two. The hall for two experiments would have to be about 60 m long and would require some provision for heavy equipment access at both ends.

2. Philosophy of operation of LEP

LEP will be an expensive machine to build and an extremely exciting place to work. There will be a great deal of pressure from the community of potential users for access to the machine, and it is desirable that the machine run for the maximum feasible amount of time. Shutdowns for installation and repair of apparatus should be minimized. It is reasonable to assume as a design goal ≥ 80% on-time (7000 hours/year), including fills, experimental time, machine development, and routine short accesses. The "off" time should then amount to about ten weeks/year, and this off-time must be compared to set-up time for an experiment.

At SPEAR, we have installed six different experiments in the East interaction region, two magnetic detectors in the West interaction region (Mark I and Mark II) and made two major modifications of the magnetic detectors (the lead-glass wall addition to Mark I and the side muon identifier to Mark II). The changeover of experiments in the East interaction region typically required 12 to 14 weeks to reach the point where the new experiment could begin system tests with cosmic rays. Mark I and Mark II installations each required about 20 weeks, while the major modifications to the large detectors required about eight weeks each.

At SPEAR, with only two interaction regions, we have been able to coordinate experiment changes so that work in both interaction regions was done in a long summer shutdown. This coordination is very much more difficult in a machine with many interaction regions, and both PEP and PETRA have adopted an operating philosophy requiring that experiments must be set up and tested off-beam-line and moved quickly into the beam line when ready to use the beam. At PEP, the designed moving time is to be three to four days. This same operating philosophy has been adopted for LEP.

PEP and PETRA each have one experimental hall sufficiently large to handle two experiments, and both labs feel that since their experimental halls are above ground they can be expanded to handle more than one experiment. In LEP, on the other hand, the experimental halls are to be deep underground, and the expansion of the hall after completion would not only be expensive but would seriously interfere with machine operation. Hence the LEP design philosophy is to have each hall large enough to handle one large and one medium-sized experiment, with the possibility of a quick interchange. With this arrangement, a new experiment can be set up while the previous one is running, a major repair of one can be made with the second quickly substituted, or experiments can "time share" the collision region on a systematic basis.

3. Space requirements for one experiment

Since no detector designs for LEP have been made yet, it is necessary to rely on PEP/PETRA experience with some appropriate modifications to handle the higher LEP energy. I shall use the PEP version of the Mark II detector as an example, for I know it best and it is reasonably representative of the sizes of experiments proposed for PEP/PETRA (HRS at PEP is considerably larger, TPC at PEP is somewhat smaller, CELLO at PETRA is the same size, and TASSO at PETRA is larger). The total size of the experiment is determined by the size of the detector itself, the necessary allowance for shielding between the detector and the external area, the size of the "trailer" attached to the detector that moves with it (containing counting electronics, cryogenics etc.), plus the necessary clearance to work on the apparatus. The Mark II central detector is 10 m wide × 8-m high. For work at higher energies, the iron muon identifier would surely be increased by about 1 m on each side for better muon identification and hadron calorimetry at higher energies. The central detector in our LEP example would then be 12-m wide × 10-m high.

The trailer attached to Mark II contains all fast electronics, drift chamber and liquid-argon electronics, power supplies for these components, and all pumps and controls for the liquid-argon cryogenic system. These components must be located close to the detector to minimize cable delays and attenuation and to allow a cryogenic system on the detector to be moved while it is cold. The Mark II trailer does not contain the on-line computer, main control console, chamber gas system, or the large storage dewars for cryogenic fluids. It is 6 m wide × 10 m along the beam line and has two levels.

In addition, a 1.5 m gap exists between the main detector and the trailer for installation of a shielding wall when the experiment is in the "m" position, and another 1.5 m is taken up with various access spaces.

The total size of this modified Mark II detector would be 21 m perpendicular to the beam line, by 10 m high and about 10 m along the beam line. With these dimensions, the minimum size perpendicular to the beam line for a LEP experimental hall capable of handling only one experiment is 39 m divided as follows:

Unload space at access shaft	4 m
Detection system in "out" position	21 m
Shield wall	1.5 m
Central detector in "in" position	12 m
Total for Mk-II at LEP	38.5 m

This arrangement is illustrated in Fig. 1.

In this example, 8 m are used for the electronics and cryogenics trailer, and as clearance for the shield wall. It might be possible to arrange some of this equipment along the side walls of the hall where crane coverage is poor and thus to reduce the size perpendicular to the beam. However I have made no provision for space for such things as assembly of forward spectrometer arms, sub-assembly of parts of the detector, on-line computers, control consoles etc. Further, Mark II is not the largest of the PEP/PETRA experiments, and therefore I conclude that a 40 m hall is adequate for one experiment but <u>not for more</u>.

4. Requirements for a second experiment

Before discussing space and access requirements for a second experiment, it is useful to re-emphasize the rationale for a hall large enough to handle two experiments. This is based upon the time required to install a large experiment and get it ready for tests with beam. On the basis of experience with PEP/PETRA/SPEAR, this time is about four to six months. If no other experiment can be using the beam during this period, then beam time in that experimental hall is lost and the effective running time of the machine is reduced. This reduction is negligible if experiments are changed very rarely, but experience at SPEAR and DORIS would indicate that major experiments require major modifications roughly every two years, and that medium-sized experiments change roughly once a year. The loss of effective machine time is serious if the machine is to be operated a large fraction of the year. Potential on-time is subject to both budgetary and technical limits, but with e^+e^- machines there seems to be no technical reason to prevent running $\geq$ 80% of the time. Thus to produce the maximum physics and to serve the largest number of users, some or all halls should be equipped to handle two experiments.

Space requirements for a second experiment are a matter of guesswork. They could range from 5 m for the smallest conceivable experiment, to the 25 m required for another major experiment like that described above. Since it is extremely difficult to modify halls deep underground, it is better to be over- than under-sized, and a rough round number for a hall long enough to accommodate two experiments would be about 60 m.

Access to the assembly area for the second experiment is complicated by radiation shielding requirements around the collision point. At PEP, extensive calculations and measurements have indicated that the collision point must be enclosed to protect people working outside the shield wall from radiation reflected from the roof of the experimental hall. The solution adopted at PEP is to place a half-metre thick curtain wall riding on the rails of the hall's crane above the main shield wall and extending to the roof. Calculations indicate that the LEP collision regions must also be enclosed, but a solution like that adopted at PEP would prevent the crane crossing the collision region while the beam is on and defeats the purpose of the extension of the hall for the second experiment. Two obvious solutions to this problem present themselves: (1) Install a second shaft to the surface at the opposite end of the hall from the main access shaft. This second access can be considerably smaller and hence less costly than the main shaft for it need be used only for equipment and need not include space for cables, personnel elevators, air vents etc. A shaft with a 60-ton hoist approximately 5 m in diameter should be sufficient. (2) Place a shielding roof $\sim$0.5 m thick over the top of the experiment and increase slightly the height of the experimental hall to allow enough crane clearance to carry heavy or bulky items over the collision region. A clearance of 4 m above the collision region should be enough, requiring an increase in the hall height of a few metres over the present design.

The specific method adopted is a matter to be decided on the basis of engineering studies and costs, but it is <u>necessary</u> to have beam-on crane coverage to the area of the second experiment.

5. Conclusion

The design goal for LEP experimental halls is to allow a second experiment to be in place or being set up while the first experiment is operating, and to allow quick interchange of the two experiments. Based on the size of PEP/PETRA/SPEAR experiments, I conclude that the 40-m halls in the present design are not adequate to meet this goal and that the long dimension of the halls must be about 60 m. Access for bulky or heavy items is required at both ends of the hall.

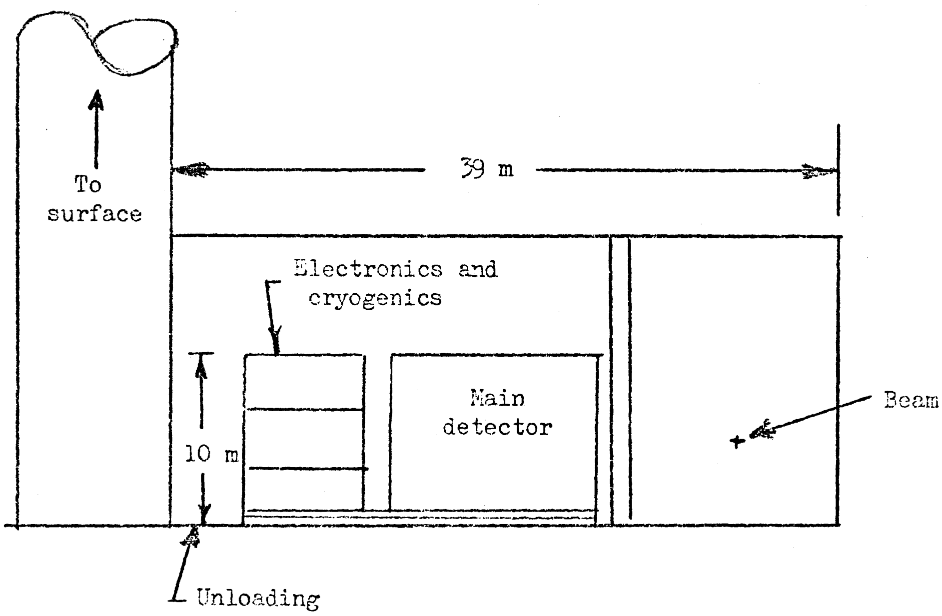

Figure 1 : Hall with one detector in "out" position.