SINGLE PASS COLLIDER MEMO **CN-** 183

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TITLE: The SLC IR Conceptual Design

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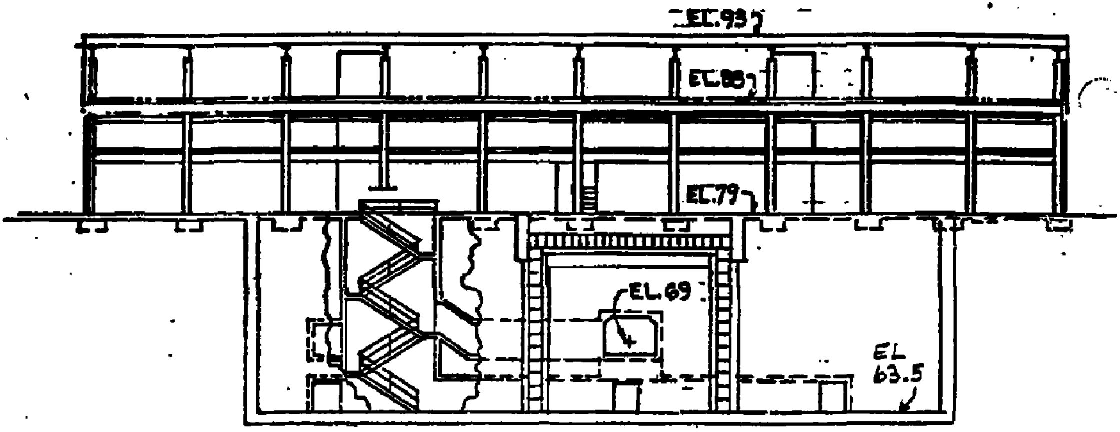
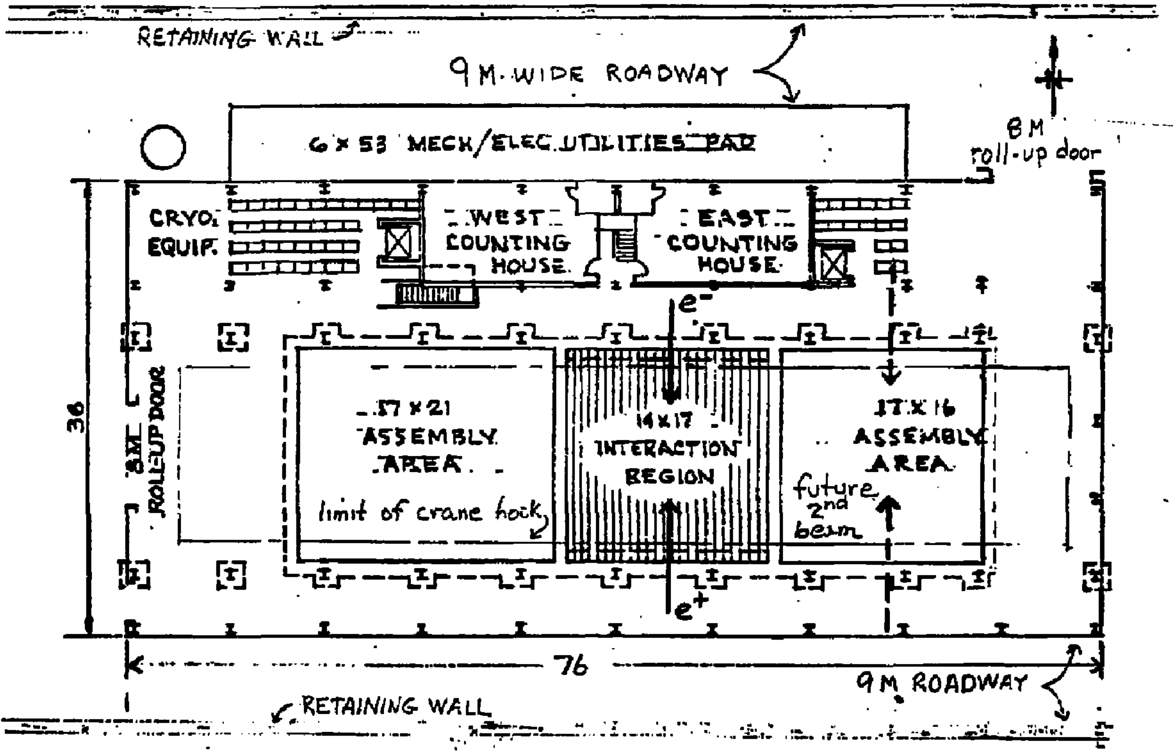
I. Introduction

Following the report of the SLC Study Group[1] in December 1981, a group of us[2] began working on a one IR, push-pull conceptual design. A series of meetings were held with representatives[3] from PEP experiments who were considering proposals for the SLC. The idea was to involve the interested groups in the conceptual design of the IR hall and especially to try to develop a design which didn't exclude existing experiments, and satisfied the ground rules defined in the Guidelines and Procedures for Approval of SLC Experiments, Revision I, February 24, 1982. A key point is that the first detectors have a "well established track record". The move to SLC must therefore not result in changes which would cause lengthy checkout at SLC beyond understanding and dealing with new backgrounds. In addition, the practicalities of the IR hall construction schedule may not leave much time between beneficial occupancy of the hall and beam delivery. Therefore, the design of the hall should allow the first detector to be ready for collisions less than six months after occupancy of the building, and should keep sight of the requirements of a "grounds up" detector. Approval of the first two SLC experiments is presently scheduled to occur before detailed design of the IR (Title I) has begun. This means that the exact dimensions of the hall do not have to be fixed before it is known which experiments will be there first.

The concept which has received the most attention is the below ground hall shown in Figure 1. It is a 15 m deep rectangular pit covered by a surface building which houses counting rooms, power supplies, cryogenics and other auxillary equipment. In Section IX we present alternative designs and cost comparisons, although many of the parameters discussed in this report are independent of the alternative chosen.



(a) ELEVATION



(b) PLAN

ALL DIMENSIONS IN METERS

FIGURE 1.

II. Floor Dimensions

A. Length (z) Along the Beam

This dimension is determined not so much by physics requirements as by the space needed for installation and access to the central detectors. Because the SLC hall will be a push-pull arrangement with moveable shielding walls on both sides of the beam line, most power panels, link boxes, water lines, cabletrays, etc., will have to be located on the north and south walls (perpendicular to z) similar to IR-6 at PEP. With this in mind it appears that existing PEP experiments can function in a hall with z = ±8.5 m, although HRS would have to offset the magnet from z = 0 to install or remove the inner drift chamber or barrel shower counters. The MAC experiment at PEP is operating in a hall with z = ±8 m. All other PEP halls have z = ±10 m, with the front face of the last insertion quadrupoles at ±6.3 m.

B. Width (x) Transverse to the Beam

To setup PEP experiments in their present configuration requires an assembly area width of at least 20-22 meters depending on the experiment. The PEP experiments all have a fast electronics trailer just outside the shielding wall with a minimum length cable plant running thru ports in the bottom row of wall blocks. Extensive cryogenic and utility platforms are located above the electronics trailer. In general the PEP experiment representatives felt that either capturing electronics in the radiation area or relocating electronics and cryogenics upstairs were major changes which violated the ground rules for a first detector at SLC. On-the-other hand a grounds up detector will probably want to forego a separate electronics trailer which moves with the experiment and mount electronics on the detector and/or upstairs near the computer. This scenario requires a minimum assembly area width of about 15 meters, which we are pre- presently showing on the east end of the hall.

It was suggested that to save assembly area space, fast electronics can be located over the experiment but shielded from the beam. For most PEP detectors, this requires a permanent roof over the experiment and beam line, a new cableplant, and new longer cryogenics transfer lines. This option is fraught with problems involving crane access to the ends and top of the detector and portability of electronics; so that at this time we are not recommending it.

C. Beam Height (y)

The maximum elevation of the final focus tunnel is set by a combination of geometrical conditions involving radiation shielding in Stanford Hills Park, arc tunnel grade, and length of the final focus optics. For PEP experiments it would be much more convenient and less expensive to keep the floor of the hall 4.0 m below the beam. However, there seemed to be general agreement in our group that 5.5 m was a reasonable compromise with the needs of a grounds up detector. LEP halls are being designed with a 6.3 m beam height (see Appendix D). For a given beam elevation at the IP, it was estimated that each meter of IR hall floor depth costs about $70K. Any PEP detector and possibly its electronics trailer/ cryogenics platform will have to be placed on a 1½ m undercarriage. The undercarriage may take the form of 1½ m wide steel or concrete beams, fastened to the floor, along which the experiment can roll.

III. Upper Level

Figure 1(b) is a plan view of the upper level building showing also the outdoor utility pads and access roads. There are large rollup doors on the west and northeast sides of the building which service the two assembly areas. The building contains two 2-story counting/computer rooms which have about 80 m^2/floor. The crane rails are near the edge of the pit and extend over the apron on either end. Space is provided for final focus, polarimeter, and detector magnet power supplies. Since this is the only above-ground building in the SLC, the instrumentation and control racks for the arcs and final focus beam lines will also be located here. Outside the building on the north side are the mechanical and electrical pads containing transformers, heat exchangers, chillers, nitrogen dewars, and detector gas systems.

IV. Shielding Tunnel

A. Thickness

PEP experiments have been designed around a one meter thick wall between the detector and the electronics/cryogenics platform, so it would be desirable not to increase the wall thickness beyond one meter. For a so-called "worst case accident", defined here as two 70 kW beams dumping at a point in the IR, the calculated dose rate behind a one meter thick concrete wall whose outside surface is 7 m from the beam line is 25 R/hr from neutrons and 50 R/hr from photons. The present SLAC rule for this type of situation allows ≤ 25 R/hr assuming the beam will be turned off very quickly. Adding 10 cm of steel around the beam pipe would reduce the photon rate an order of magnitude and the neutron rate by a factor of 1.5. Constructing iron-loaded concrete with a density of 180 lb/ft^3 instead of the standard 150 lb/ft^3 would also provide sufficient containment of the photons. If the outside surface of the wall was moved inward to 3 m from the beam line, for example during the first months of SLC checkout, about 20 cm of steel or lead is required around the beam line to stay under the 25 R/hr limit if the wall is one meter of standard concrete. It was suggested that some experiments could be self-shielding and require concrete only at either end of the detector as is being contemplated for some LEP proposals. At SLC this appears not to be possible unless hadron calorimetry is done with concrete, or there are new ways to guarantee that the beams will be turned off a few pulse periods after a dump in the IR.

B. Wall Location

Unless the first SLC experiment is assembled on the beam line, it would be very desirable to have extra space in the assembly area; and over the time span of several experiments it might be convenient to have a variable wall position. We are therefore recommending that the roof block supports and earthquake restraints be designed such that the transverse position of the wall be a variable, as in PEP. The wall should be able to be located as close as a few meters from the beam line.

C. Roof Blocks

The roof of the tunnel will consist of 17 m long concrete "logs" which span the hall parallel to the beam as in IR-6 at PEP. Their support will be a ledge built into the end walls of the hall as shown in Figure 1.

V. Crane

The favored crane design (and also the most expensive) is to have two 50 ton bridges on a single set of rails sized for 100 ton loads. This allows the two assembly areas to be independent of one another and still have 100 ton capacity available, and provides backup in case of breakdown of one unit.

VI. Access Routes

Figure 1 (b) shows the location of two elevator shafts on either side of the counting rooms and a stairway adjacent to the west elevator. The elevators have stops at the upper and lower levels and a stop in-between for access to the north collider arc. Figure 2 is a plan of the access routes at the level of the arc tunnels. As in PEP there will also be stairs and platforms extending from the end of the arc tunnels into the hall on each side. At the lower level, access between the assembly area and the detector will be thru a tunnel which exits underneath the beam line. Each of these tunnels will have to have a radiation gate and keybank.

VII. Utility and Cable Routing

As discussed in Section II, cables and cryogenic lines between the detector and assembly area or detector and counting room can be passed thru special blocks in the shielding wall either near the floor level or near the shielding tunnel roof. Cables and other utilities between the upper and lower levels will be routed in raceways or cabletrays up the north wall of the pit, under the upper level floor and into the counting room or to cryogenics equipment as required. There will also be a need for an extensive cable and utility plant between the north and south arcs and between the arcs and the upper level of the IR building.

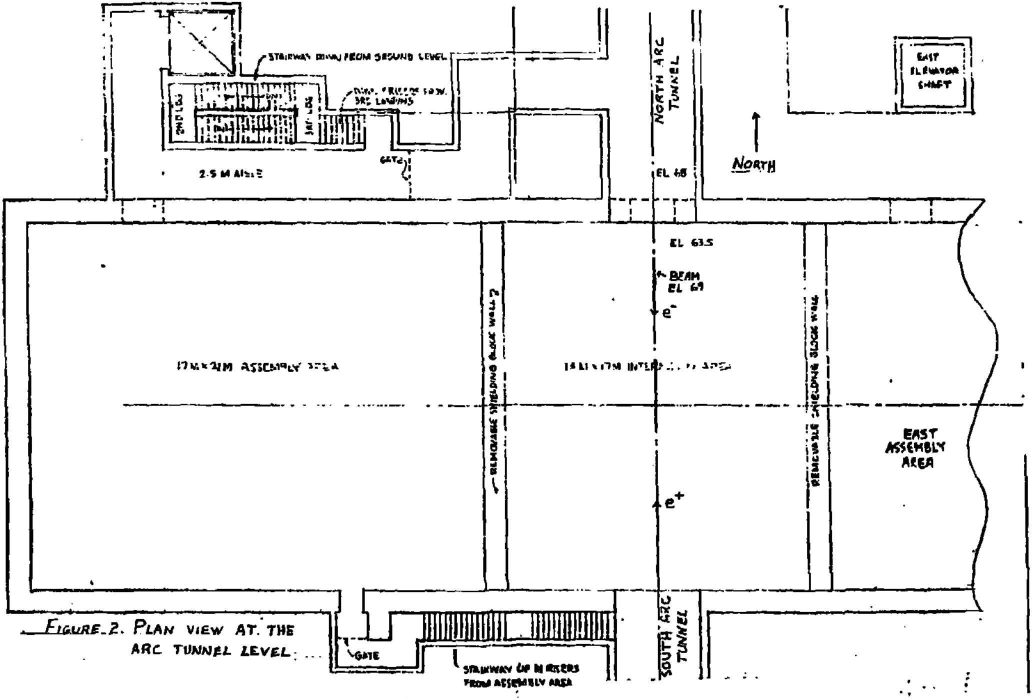


FIGURE 2. PLAN VIEW AT THE ARC TUNNEL LEVEL.

We are currently looking into including a utility shaft as part of the stairway/elevator shaft on the north side.

There are several schemes for bringing cables and utilities from the south arc to the north arc: 1) cable "trees" or trays around the east end of the building 2) a catwalk which spans the pit near the top of the shielding tunnel wall, 3) cabletrays around the walls of the pit. Schemes 2) and 3) offer the most direct route but both interfere with experiment space. Ductbanks crossing the pit under the floor are also a possibility, but our experience with these in PEP is not good.

VIII. Gas and Earthquake Safety

As in the past each collaboration is responsible for both earthquake and hazardous gas safety of their equipment. Regarding gas safety, there will be 0.5 m diameter vertical penetrations equipped with vent fans behind the wall of the pit which then run under the upper level floor to the outside. There will also be roof fans above the experiment floor. Earthquake proofing of experiments at SLC should in general be able to use the same techniques as used at PEP as long as restraints are revised to be consistent with the 5½ m beam height.

IX. Cost Comparison with other Concepts

One of the most difficult issues our study group has faced is that of comparing the so-called "below ground" design (described in this report) with the "cut and fill" design (floor-level access). There are many intangibles, mainly having to do with the safety of equipment and personnel, which make a true quantitative cost comparison impossible. Considering construction costs alone, four concepts, two below ground and two cut and fill, have been analyzed. Figure 3 shows schematics of the four options. The estimated[4] construction cost of these is:

a)	Below ground rectangular	$ 6.3M
b)	Below ground circular	7.2
c)	Cut and fill rectangular	9.5
d)	Cut and fill tee	11.5

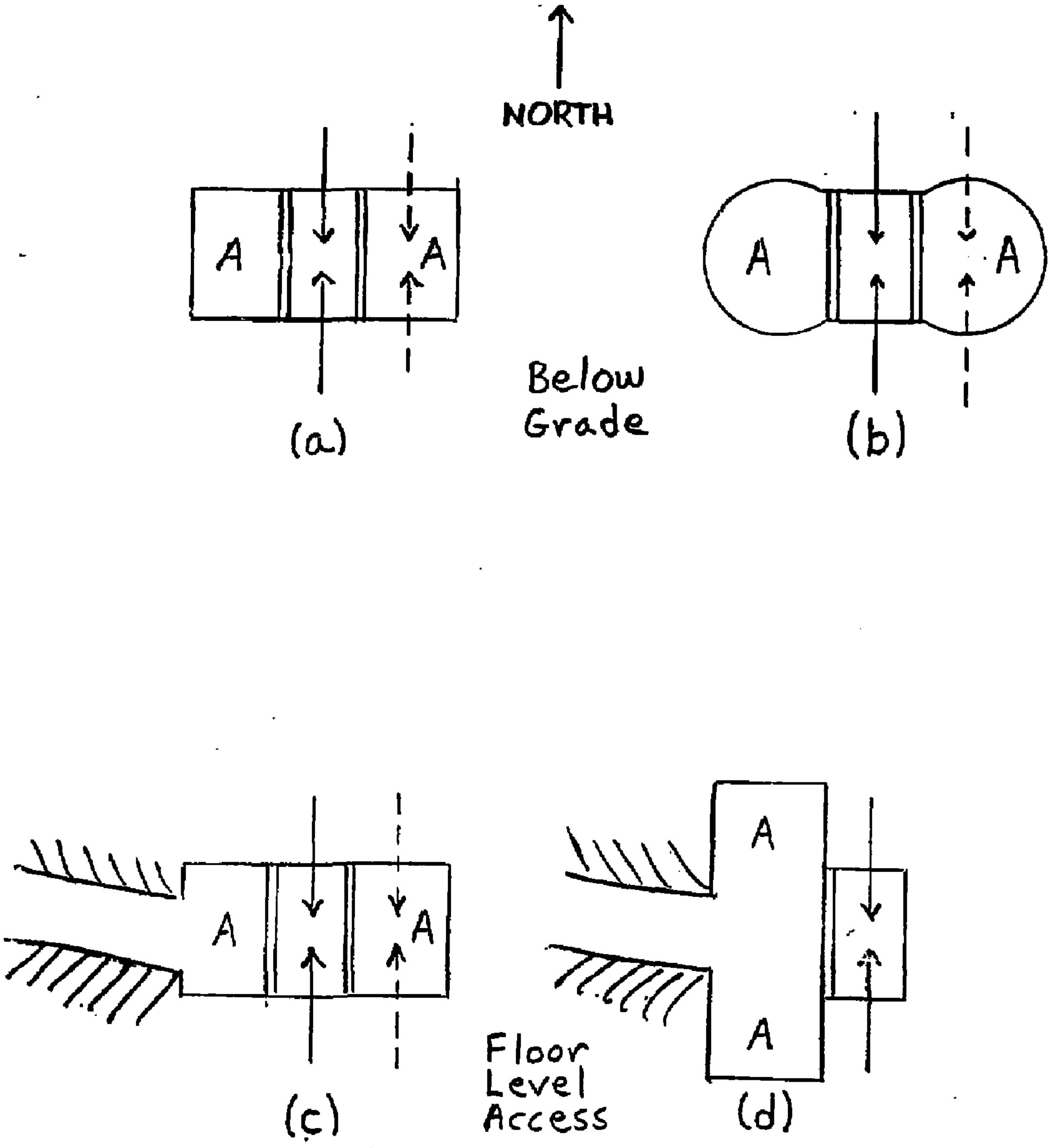


FIGURE 3. Schmatics of Four IR Alternatives.

All layouts in this report show option (a), but essentially all of the parameters and concepts discussed are applicable to options (b) and (c) as well. Option (d) is a completely different design concept[5] and is the only one which cannot accept a second beam line.

In Appendix A we estimate that the order-of-magnitude cost to lower an existing detector into a 15 m deep pit is \$0.5M. The cost of removal is probably about the same. If this turnaround happens only once or twice in the life of the project, then the cost is low relative to the difference in cost of options (a) and (c), i.e., \$3.2M. What cannot be estimated is the risk of the lowering operation, not just a catastrophic accident, but relatively minor damage which can take time to repair and may delay quick turnon of an experiment. On-the-other-hand experience at the CERN SPS has shown that large experiments can in fact be constructed and operated in a deep undergraound cavern (see Appendix D).

References

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2. R. Bell, F. Halbo, F. Hall, G. Hughes, K. Johnson, J. Kadyk, L. Keller, D. Leith, T. Pulliam, W. Savage, H. Weidner

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7. K. Brown, F. Bulos, J. Mathews, SLC Workshop Note 65.

8. G. Fischer, Comments on Ground Motion, AATF/80/18, March 1980.

9. H. Weideman, Alignment Tolerances for the Linear Colliding Beam System, AATF/79/7, September 1979.

10. R. Steining, CN-14, February 1980

11. G. Fischer, S. Gray, private communication.

Appendix A. Moving Assembled Detectors to SLC

While there is still some apprehension about lowering assembled PEP detectors into a deep pit, it is pretty well agreed that even the most massive PEP detectors can be moved to SLC.[6] The problems of moving are the same, whether or not floor-level access is available. There are several alternative methods of moving: Pieces up to about 400 tons can be moved on rubber tires. Heavier detectors can be moved on crawlers with caterpiller threads, or with a creepy-crawlie like that used by the 82" bubble chamber, or on multi-ton rollers.

SLAC has had experience in successfully moving heavy loads on multi-ton rollers in flat and level areas only. Such moves involved the Streamer Chamber, 82" HBC, MAC, HRS and TPC. There are no known reasons why it should not be possible to move a large detector from a PEP IR to SLC on multi-tons; there are many problems that have to be worked out, however. For example, some people have expressed fears about the consequences of a runaway on a steep hill (the steepest grade encountered would be about 10%), but there are a number of possible ways to stop a runaway within a fraction of an inch. When MAC and Mark II were moved to PEP, the movers kept the trailer brakes locked while moving up and down hills. When using multi-ton rollers the equivalent precaution would be to remove the multi-tons and drag the detector on steel plates.

It might take as long as 50 8-hour shifts to move HRS to SLC at a bare bones estimated cost of $150K for hardware and labor.

Appendix B. Lowering Large Loads into a Pit

Two schemes for lowering an assembled detector into a pit have been proposed:

a) Segmented support columns and jacks a'la' Mark II and Mark III at SPEAR.

b) A gantry with chains or cables.

Of these, the Mark III scheme has received the most attention because it does not require as much special rigging equipment and can probably be done with in-house labor. Briefly, it involves rolling the detector over the pit on large beams which are supported on columns extending to the floor of the pit. Separate, segmented columns are then erected from the floor of the pit to each corner of the detector to pick up the load, so that the beams can be removed. Using jacks whose stroke is longer than a column segment, the columns can be taken down piece by piece. A major difficulty is that the detector can be laterally stayed by the pit walls only on three sides, as it traverses the length of the vertical shaft. For a 2000 ton load the order-of-magnitude estimates of cost and time for this procedure are $0.5M and two months.

At this time, the gantry scheme has only been proposed by an off-site contractor. It involves specialized equipment which would be impractical for the laboratory to purchase for its own use and whose use may affect the design of the upper level building and walls of the pit. Nevertheless, once setup, it has the advantage of much shorter exposure time to an earthquake. In addition, with the detector suspended on flexible supports from an overhead structure, the pendulum period of the hanging weight would not couple with expected earthquake motions.

We are planning to investigate further the in-house capability of the gantry scheme, especially since the IR design parameters do not have to be frozen for some time yet.

Appendix C. Support and Alignment of Final Focus Quadrupoles.

The support, installation, and alignment of the inner three pairs of final focus quadrupoles present very special problems to an SLC detector. Table C-1 lists parameters of the quads nearest the IP for the "mini-quad" solution[7]. In this solution the first two quadrupoles, Q1 and Q2, are made of permanent magnet material, samarium cobalt ($SmCo^5$); so that they can be placed inside the detector solenoid without disrupting the axial field. These quads have to be tuned by physically rotating sections of the $SmCo^5$. Iron free superconducting quads are also a possibility; their physical size and weight are disadvantages compared to $SmCo^5$ while turnability is an advantage. Q1 and Q2 will almost certainly have to be supported from the detector, although no details of the supports and tuning mechanism have been worked out at this time. The support/alignment system for Q1, Q2, and possibly Q3 must allow an exchange of experiments in approximately one week.

The mechanical vibration of the final focus elements generated by the steady noise of vacuum and water pumps, ventilation fans, transformer hum, and compressors must be isolated[8]. Motion of elements in one arm of the collider arc with respect to the other with amplitudes of a few tenths of a micron are enough to cause the beams to begin to miss each other[9]. Feedback systems to correct this steering are limited to below about 30 hz[10].

A seismic noise check of a "noisy" PEP experiment (HRS magnet) was performed in March 1982[11]. The largest vibration occurred at 8.5 hz with a peak to peak amplitude of 0.25 microns. In this particular case, the motion was traced to a Stokes pump which could be easily isolated from the magnet if necessary.

TABLE C-1. Miniquad Final Focus System

		Distance from IP					
Quad	Length	inboard end	center	outboard end	Bore	Radius of outer surface	Weight
Q1	1.67 m	0.25 m	1.085 m	1.92 m	2 cm	5 cm	~0.5 tons
Q2	1.65	2.17	2.995	3.82	2	5	~0.5
Q3	1.80	4.32	5.22	6.12	4	15	~1
Q4	1.50	17.72	18.47	19.22	10	30	~ 3
⋮	⋮		⋮		⋮		
Q17	0.5		111.0		4		

Appendix D. IR Designs at Other Laboratories

1) LEP Interaction Regions

Figure D-1 is a schematic of one of the eight LEP interaction regions. They will have a circular cross-section with a diameter of about 20 m. The width at the floor is 14.5 m. The LEP beam runs through one end of the hall 6.3 m above the floor. There are two access shafts which go to the surface 70 m above. The shaft at the far end will contain an elevator, stairs, cabletrays, and ventilation. The vertical shaft near the center of the hall will be the main accessway for all equipment going into the hall. A crane traverses the full length of the hall. The blocks which make up the shielding wall must be handled twice; once by the hall crane to get them under the accessway, the second time by the crane in the service building at the surface. Studies are underway to eliminate the shielding wall by taking advantage of the detector magnet iron for shielding.

2) LSS5 at the SPS

Experiment UA-1 is in LSS5 at the CERN SPS. The experimental area is 28 m below the surface. The beam height is 6.3 m. The hall consists of two circular pits 20 m in diameter, 27 m center to center, connected by a rectangular tunnel which has a slot going to the surface for shielding blocks. The SPS beam passes through one pit one meter off center. This pit has a domed roof 23 m high. The other pit is open to the surface.

The whole experimental area is covered by a metal building at the surface housing a 70 ton crane. All materials used in the experimental area, with the exception of small items which may be carried in the elevator are handled by this crane. The sheilding blocks are also handled by the crane. They just about fill the service building when the wall is dismantled. There is a bridge crane with circular rails over the beam line.

The UA-1 experiment has a local electronics house which moves with the

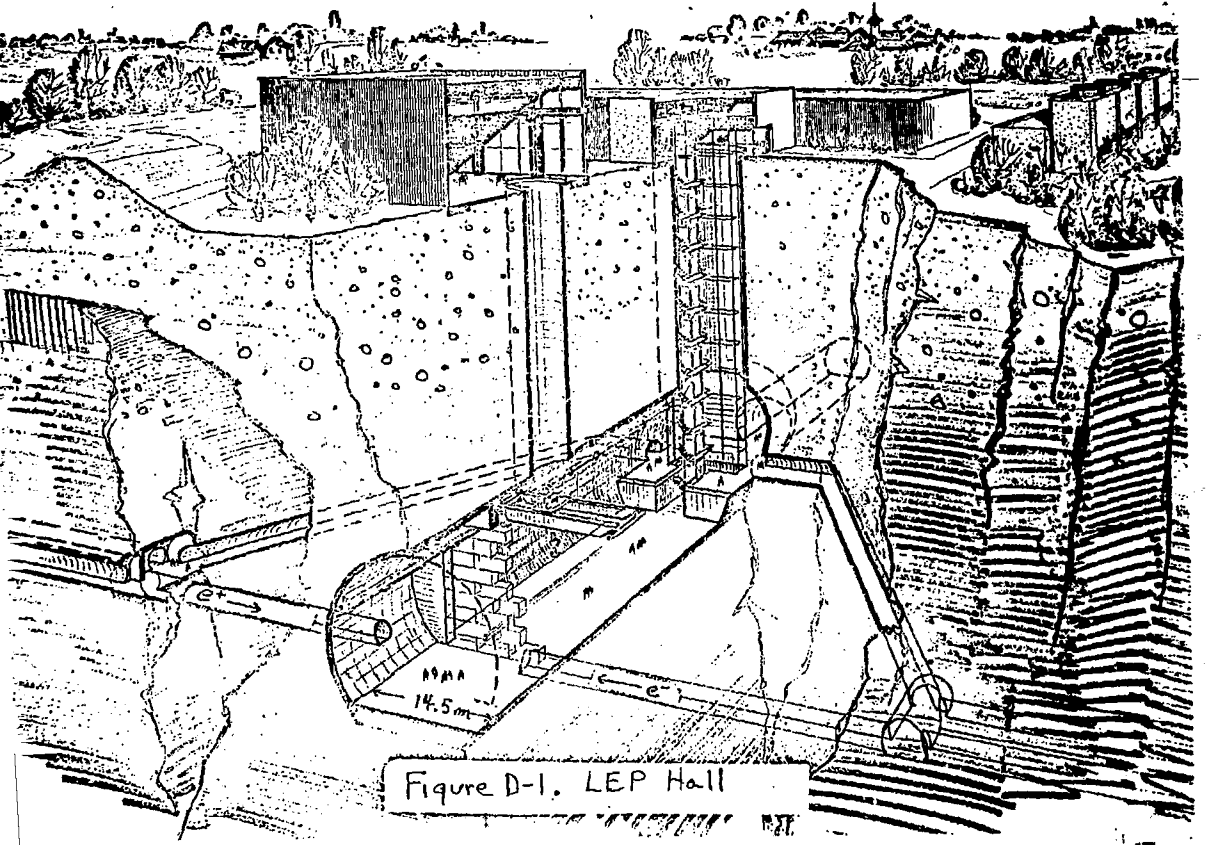

Figure D-1. LEP Hall

detector. The counting house and magnet power supplies are located at the surface.

3) LSS4 at the SPS

Experiment UA-2 is in LSS4 at the CERN SPS. LSS4 is an underground hall 43 m long and with a circular cross-section 21 m in diameter. The width at the floor is 15.5 m. The SPS beam line runs 6 m from the back wall, 5.5 m above the floor. The interaction region has a 10 ton crane running parallel to the beam direction. It is separated from the assembly hall by a shielding wall during machine operation. There is a 40 ton crane in the assembly hall which runs transverse to the beam. Two shafts lead to the surface, which is about 50 m above the pit floor. The shaft at the far end of the assembly hall away from the beam line contains the elevator and a stairway. The other is centered over the assembly hall and is the main access for materials to be used in the hall. There is a metal building over the entire area. It has a 40 ton crane which is used to install and remove equipment, including shielding blocks, from the hall. The shielding blocks must be handled twice since the above-ground crane cannot reach the wall location.

The electronics for UA-2 is located at the back of the hall and does not move with the experiment.

4) CDF Hall at FNAL

Figure D-2 is a schematic of the CDF hall at FNAL. The central volume of the collision hall which houses the central detector on beam is 16 m long x 16 m wide x 13 m high. This section has no crane coverage. The detector pole pieces are designed to be removable on a permanent rail/jacking system. Jib booms may be added later for small lifts.

The assembly area is separated from the collision hall by an 11 m long tunnel whose transverse size is the minimum needed for passage of the central detector. The tunnel is plugged by a retractable 4 m thick concrete wall.

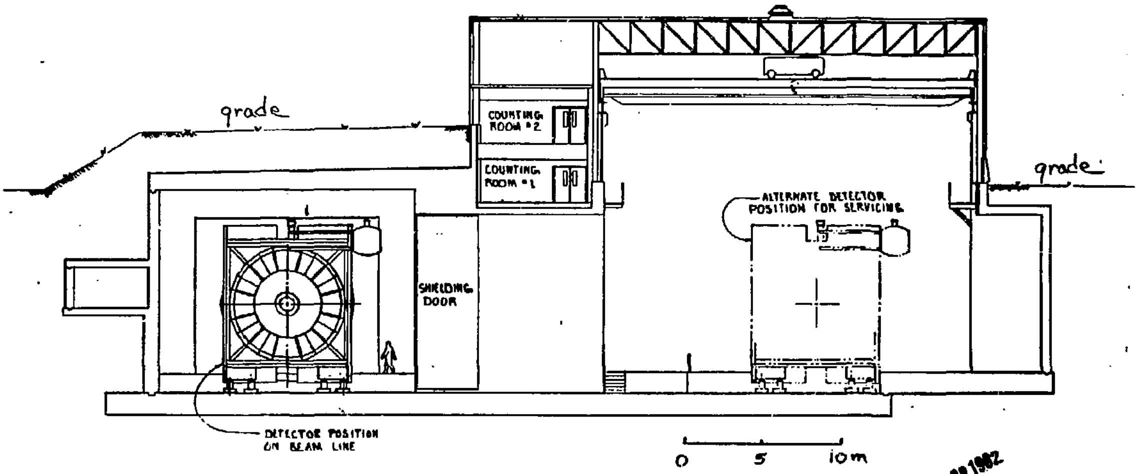

Figure D-2. CDF Hall at FNAL

The assembly area consists of a below grade 12 m deep pit at the same level as the collision hall, an on-grade construction area, and two floors of electronics, computer, and control rooms on the side closest to the collision hall. The detector rolls directly under the counting rooms. The assembly area is served by a 50 ton crane that runs the entire length of the building.