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DESIGN CONSIDERATION FOR THE COLLIDING BEAM AREA

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I. Introduction

Preliminary designs for the Colliding Beam experimental areas have been studied for many years under the supervision of many different people. The design has gone through many changes and may go through more. But soon it has to come to realization. With funding in Fiscal Year 1981, the design will be engineered and finalized so that major construction can begin in the spring of 1981.

The following report will attempt to summarize the work done on the project in the last several months. At all times it must be remembered that the work done to date has all been conceptual. Also we collected the relevant information for the construction of the colliding beam areas.

II. Location of the Colliding Beam Areas

The general colliding beam area will be located at the B0 long straight section of the main ring and will be used only for colliding beam experiments.[1)] There will be another colliding beam area possibly at the D0 long straight section. The straight section at D0 will first be used for the installation of the extraction system for the 1000 GeV external beam[2)] for the Tevatron Phase II operation. When colliding beam experiments are installed at D0, the extraction system will have to be removed so that the area can accommodate the colliding beam detector.

There are also future plans for the straight section at D0 to be used for e-p colliding experiments. An electron accelerator (10-20 GeV) may be built to osculate with the main ring at D0.[3] Therefore, any experimental hall constructed at D0 would have to accomodate components for the 1000 GeV beam extraction system, an electron accelerator ring, and the colliding beam detectors.

III.1 General Description of Colliding Beam Area (CBA)

The B0 colliding beam area will consist of a collision hall, assembly hall with connected loading garage, and possibly with future support building. The D0 colliding beam area will be a much more complex structure due to the extra complications created by the extraction systems, the electron accelerator ring, and the colliding beam detectors.

A complete description to date of the B0 area will follow in Section VI.1-VI.2. Work on the D0 area is still in a very primitive form and will not be presented in this report in details.

III.2 Brief Construction Schedule

During the summer of 1981 the B0 collision hall is expected to be built. The structure will be only the minimum needed to put the main accelerator back in working order at the end of the shutdown. During the next one to three years while the detectors are being assembled, the collision hall will be brought up to the standards necessary for experiments to take place.

With the new budget in Fiscal Year 1982, construction of the assembly hall is expected to begin. It is hoped that the B0 colliding beam area will be ready for occupation by summer 1982.

III.3 Interior Components of CBA

There will be a central detector and a set of forward detectors. The central detector (described later in detail IV.2) will be directly connected to the equipment housing. It will actually be a two to three story structure and contains counting rooms with the roof space possibly used for the cryogenic equipment. The housing will be connected to the central detector through a shared carriage. Also on the carriage will be the intermediate removable concrete shielding blocks between the detector and the housing.

All the electronic signal cables from the detector will be permanently connected through the carriage to the counting room, and the whole thing moves as a unit. This will save valuable experimental time that might otherwise have to be used for recalibration of the system. The whole structure including the carriage, the central detector, the equipment housing, and the intermediate concrete blocks is expected to weigh approximately 2500 tons, and the carriage will move on rollers and rails. Due to this great load and its variable location, caissons are being investigated to support the slab below the carriage system.

In the collision hall, there will be several low beta quadrupole magnets and a pair of compensating solenoid coils. They need liquid helium transfer lines, and their power supply must be placed in the support area. These magnets may be substituted by other scheme. A satellite liquid helium refrigerator will be installed in the support area to take care of various superconducting magnets in this area.

IV.1 Design of Detectors

To date design studies have been done for detectors to be housed in the B0 collision hall. There will be one central colliding detector and a set of forward detectors. Only very preliminary design work has been done for the detectors that would be located at D0; therefore, information concerning these detectors will not be included in this report.

IV.2 CDF Central Detector

The central detector for B0 has changed drastically since it was first reported a year ago in Colliding Beam Detector report, Ref. 4. The most notable change is in the structure of the magnet yoke. The present overall shape and dimensions of the central detector should be noted in Fig. 1.

The outside radius of the hadron calorimeter is 11 ft.-6 in., with a 2 ft. space for mounting electronics boxes and phototubes and another 2 ft. space for the muon counters. The length of the steel structure is 23 ft. with 1 ft.-6 in. spaces for phototubes on both sides. The overall shape of the detector is a cylinder, 31 ft.-0 in. in diameter and 26 ft.-0 in. long. In Table I, the parameters of the central detector are listed. The center of the detector will be on the Energy Doubler beam line, 18 ft-0 in. above the floor.

A detailed design for the supporting superstructure has not yet been completed. A smaller detector, Mark II at SLAC, is said to have a cross section of approximately 30 ft. in width and 28 ft. in height; therefore, the overall dimensions of the B0 detector are very likely to increase.

IV.3 The Forward Detectors

The collision hall at B0 is being designed to accommodate two sets of forward detectors. The detectors will be placed on both sides of the central detector and on the beam line. In early stages of the experiment, there will most likely be only one set of the forward detectors; the compliment detector may be added in later stages of the experiment.

The preliminary design of the forward detectors is shown in Fig. 2, which is taken from, "Conceptual Design of a Forward Detector for the Antiproton-Proton Collider." The major design parameters are shown in Table II.

The total weight of a set of the forward detectors will be approximately 2200 tons. It is expected that the toroidal magnets will be built in place and would remain permanently in the collision hall. It is expected that the toroids and its related detectors will not require too much maintenance once they are put in place. The front toroid (closest to the central detector) will be built so that it can be split 15 ft. apart along a vertical centerline and provide space for the removal of the endcaps of the central detector.

The particle identifier and calorimeter will be assembled and checked in the assembly hall and brought into the collision hall on some type of carriage. The carriage will be designed so that the center of the forward detectors will be on the beam line. It is generally felt that a uniform floor level in the collision hall will allow easy maintenance for all detectors and greater freedom for future changes in the design of the forward detectors. Since the floor level of the collision hall has been set by the size of the central detector, the forward detector will need to be raised off the floor approximately 5 ft. If it is necessary to cut down the total cost for the area construction, it is conceivable to raise the floor level for the forward detector both in the collision hall and in the assembly hall.

The combined weight of all the detectors in the collision hall is approximately 6000 tons. The floor slab to support loads this great must be carefully computed and evaluated by structural engineers. At this time, it is not decided whether the floor slab should be supported on caissons or remain a floating slab (independent of the walls).

V.1 Radiation Shielding

The detectors will be assembled and tested in the assembly hall over a year. During this time, the accelerator will run at 400 or 1000 GeV. In case of an accidental beam loss in the collision hall the level of radiation in the assembly hall must be kept below 50 millirems per accident.

V.3 Radiation Loss Calculation for B0

To design the proper radiation shield, the following assumptions were made for an accident: a 1000 GeV proton beam of 1×10^{13} ppp being dumped in the collision hall: maximum acceptable dose in the assembly hall being 50 millirems.

Through calculation, it was shown that 10 ft. of normal concrete (with a density of 2.4 g/cm^3) would be needed to maintain a level of 50 millirems in the assembly hall at the occurrence of an accidental beam loss in the collision hall.

Therefore, the shielding between the collision hall and assembly hall will be 10 ft. of concrete. Likewise the shielding material for the ceiling of the collision hall will be equivalent to 10 ft. of concrete. At the roof of the collision hall, the concrete can be reduced to 3 ft. if an earth berm is built up above at 9 ft. deep.

The inside of the assembly hall will be a restricted area where only authorized personnel can gain access. The area will be fenced and gated, and the thickness of the shielding wall will be made thick enough to limit the accidental radiation dose below 50 millirems. The level of radiation will be monitored at all times by radiation detectors that will trip the main ring beam should the level exceed 50 millirems. In principle, five accidents per hour would be allowed of this magnitude. The top area of the berm will be fenced.

During colliding beam experiments, the detectors themselves will act as radiation shield material for the radiation coming from collision events. The mass of the detectors will also assist in reducing the radiation level due to an accidental loss. The shielding properties of the detector may allow the thickness of the shield wall between the collision hall and counting room to be reduced somewhat from 10 ft.

V.3 Radiation Loss Calculations for D0

At D0, there are not only the same problems as in B0, but also a problem due to the extraction system. During the 1000 GeV external beam operation, a portion of the beam will be lost in the extraction system.

If a loss of 1 percent of 1×10^{13} ppp at the operation mode of 1 pulse per minute is assumed, then 6×10^{12} protons will be lost per hour. This will amount to 30 millirems per hour in the assembly hall, if the same shielding were to be used at D0 as at B0. This is far above the level of tolerance, and special shielding material around the hot spots is needed. To reduce the radiation level by an order of magnitude, as a rule of thumb, we need 2 ft. of regular concrete.

VI.1 Dimensions of the B0 Collision Hall

The B0 collision hall that will house the colliding beam detector will be on the main ring tunnel line, with a floor level approximately 42 ft. below the existing grade elevation. The floor level of D0 will be about 38 ft. below. As mentioned earlier, the Saver beam level will be 18 ft. above the floor or at 723 ft.-4.5 in. above datum. The B0 collision hall will be provided with a 20 ton crane.

The height of the ceiling will be based on the required clearance (6 ft.) between the top of the central detector and the hook of the crane at its highest point, and installation space of a 20 ton crane (6 ft.-10 in.) as well as any space needed for structure to support the ceiling. The height of the ceiling appears to be approximately 48 ft.-4 in. Major dimensional parameters for B0 collision hall are listed in Table III. The section of the collision hall is shown in Fig. 3.

The width of the hall, perpendicular to the beam line, will be about 45 ft.-0 in. and will include a bypass for main ring traffic. The bypass will be at least 3 ft. wide to accommodate golf carts for main ring maintenance. Whether the bypass will be structurally designed to support a magnet vehicle is still undecided. In this case, it is 6 ft. wide. The width of the vehicle is 51 in. The beam line is set at 24 ft. from the inside wall.

The length of the hall along the beam line should be approximately 120 ft.-0 in. long, if possible. Since the exact length may cause the removal of only a portion of a pre-cast tunnel section, which is difficult, the hall would be made longer so that a complete section could be removed. The main ring tunnel is made up of pre-cast concrete sections approximately 10 ft.-5 in. long. By removing five and six sections in the downstream and upstream sides respectively (relative to proton beams), the total length will be about 130 ft.

The collision hall will be joined to the assembly hall by shielding walls. The collision hall will be constructed out of concrete. Preliminary design drawings of the collision hall and the assembly hall are shown in Fig. 4 and 5. In Fig. 5, two cases with a high and low ceiling for the assembly hall are shown.

VI.2 Dimensions of the Assembly Hall

The B0 assembly hall will be located to the outside of the main ring or toward Road "D". The floor level of the assembly hall will be the same as the collision hall, approximately 42 ft. below grade. The walls below grade will be constructed in concrete by the same method as the walls of the collision hall. The upper walls above the grade will be constructed with metal panels similar to existing industrial buildings on site at Fermilab. The building will be provided with a 20 ton crane. The major parameters of the B0 assembly hall are listed in Table IV.

The assembly hall will be attached to a loading garage where components of the detectors will enter, at grade, by a flatbed truck and be lowered into the assembly hall by a 20 ton crane. The loading garage will be constructed with metal panels. Two sectional views of the assembly halls, corresponding to two cases in Fig. 5, are shown in Fig. 6. The maximum height of the crane hook is at 14 ft. in the loading garage. In Case A, we need two 20 ton cranes while in Case B, only one 20 ton crane is used.

Another grade building may also be attached to the assembly hall at a later date. This service building would be at grade and used as work space by the technicians and as office space by the experimenters. It could also house support equipment. The structure will most likely use metal panels.

VI.3 Dimensions of the D0 Collision Hall

A preliminary design of D0 collision hall is shown in Fig. 7, where the size of the hall is 45 ft. wide and 160 ft. long. In this case, eight pre-cast concrete tunnel sections are taken out from both sides, because the extraction system extends to full length of the straight section. It is necessary to install and use a 20 ton crane to move out the component magnets with a minimum time, which will be highly radioactive.

VII.1 Alternative Construction Methods

At present there are two alternate methods of construction being proposed for the concrete walls of the collision and assembly halls:

1. Conventional reinforced cast-in-place concrete walls.
2. Non-conventional reinforced concrete slurry walls.

Designing each type of wall will be done by structural engineers to compute and evaluate. The final decision concerning which method will be used to construct the walls of the area will be based on their technical and economical evaluations and estimated schedules.

VIII. Slurry Wall Technique

The slurry wall technique is being investigated as a possible method of construction for the collision and assembly halls at B0. A general description and its advantages over conventional construction methods, when applied to this structure, are described in a previous report.[7] Its major advantages are time saving, less excavation area, eliminating some water problems, and construction costs may be comparable to conventional construction methods.

The assumed time for construction of the collision halls was 3-1/2 to 4-1/2 months during our study. The building could be completed on time with the slurry method because the walls could be made before the shutdown starts. If the conventional method was used, it could hardly be done on time with such a short period. If there would be a much longer shutdown time, 6-1/2 or 7-1/2 months, construction could meet the time schedule with meticulous organization and motivated overtime work.

With a conventional construction schedule, the excavation of large areas of earth is necessary before construction of the walls can begin. With the slurry wall method, the walls are constructed before the excavation is begun. The amount of time necessary to construct a building using the slurry wall method may be as long as that of conventional methods. The major advantage of this technique for Fermilab would be that the walls and also the roof, if needed, could be constructed before the accelerator shutdown.

Another advantage associated with the slurry wall method is the elimination of granular fill outside the walls. When a conventional wall is constructed, the area around it must be backfilled. In the case where granular backfill is used, water is able to seep down beside the walls and under the floor slab creating hydrostatic pressure on the walls and floor slab, thus necessitating outside deep wells and a sump pump system. When a slurry wall is put into the ground, the area around it is not backfilled because only the interior of the structure is excavated, not needing an outside deep well and sump pump system. The hydrostatic pressure is reduced on the floor slab. The horizontal hydrostatic pressure is taken care of by the design of the reinforcing in the walls.

Another advantage, in our case, with the slurry wall is that it extends into the impermeable clay as shown in Fig. 8, preventing substantial amounts of water from flowing under the floor. The soil diagrams at B0 and D0 are taken from soil test reports.[8)] This will eliminate the uplift force due to the hydraulic pressure under the floor, which may happen with a conventional structure if the sump pumps fail. The possible uplift force is about 8000 tons on both the collision hall and the assembly hall.

An example of a slurry wall for our project (approximately 42 ft. high from the floor level to the grade level and extra several feet above it) may be of 3 ft. thick reinforced concrete, interspersed with 3 ft. wide H beams at approximately every 8 ft. The slurry wall is extended 10 to 15 ft. below the floor level. The H beams run from the top of the wall down to bedrocks, and will be about 75 ft. in total length. The tie back system for the slurry wall will be expensive and may or may not be eliminated in this case. Feasibility study should be done on the design.

IX. Roof Structure for the Collision Hall

The construction of the roof structure for the collision hall is independent of the construction method used to form the walls. The roof structure must be designed to support the concrete roof itself and an earth berm, equivalent to 10 ft. of concrete for shielding purposes. The roof structure will also have to help resolve some of the great forces exerted on the walls of the collision hall.

The forces on the collision hall walls are complex because a structural wall, for all practical purposes, does not exist between the collision and assembly halls. Forces that the fourth wall would normally help resolve must, therefore, be resolved by the remaining three walls and the roof structure.

Some methods that could be used to construct the roof structure are as follows:

1. Cast-in-place concrete.
2. A metal structural system with a thin concrete slab or other membrane.
3. Precast concrete beams with a thin concrete slab. The prefabricated beams would take any number of shapes such as rectangular, tee-shaped, or channels.

To avoid counterbalancing the horizontal force from the wall, both ends of the prefabricated roof material could be tied down after wall is finished (i.e., either after filling with granular with conventional method, or after excavating inside volume with slurry method). Or we should form and make the reinforced concrete ceiling after walls are done.

If we use the reinforced concrete beams, the size of the concrete beams can be calculated according to the following equation as a rule of thumb.[9)]

$$d = 0.071 \times \sqrt{\frac{W}{b}} \times \ell$$

where d is thickness of the beam given in inches, b the width in inches, ℓ is the length in feet, and W the load in lb./ft.^{2}.

If we use W = 1,500 lb./ft.^{2} for 10 ft. equivalent of concrete blocks, ℓ = 45 ft., b = 12 in., and d will be 36 in. = 3 ft. The weight of a concrete beam, 50 ft. long, 3 ft. high, and 1 ft. wide will be about 11.3 tons. If we use a 2 ft. wide beam, the beam will be 2 ft. wide, 2 ft. high, and 50 ft. long and weighs about 16.3 tons. This weight is manageable with a temporary crane.

Concrete beams 2 to 3 ft. deep may be strong enough to carry the weight of the berm, but may not for any construction equipment that may run over the beams or the berm.

The total weight of the berm including the concrete roof structure is about 5000 tons for a collision hall of 45 ft. x 130 ft. The wall bearing is about 20 tons/ft.

X. Removable Shielding Wall

The thickness of the shielding wall should be 10 ft. of regular concrete. A shielding wall, which is largely removable, could consist of four columns 40 ft. apart, which would carry a beam to support the ceiling structure. The dimensions of the beam would be on the order of 130 ft. long, 3 ft. wide, and 5 ft. deep. This would weigh about 45 tons.

The columns could be made of caissons, which extend to bedrock. The beam carried by the columns could be cast in place, using slurry wall method or making use of forms.

Concrete shielding blocks would then be piled in front of the columns. Each shield block would be 5 ft. x 5 ft. x 10 ft. and weigh 19 tons. We need about 190 such blocks. These blocks could be handled by a 20 ton crane. These blocks could be slid under the beam if we could design inexpensive carriage mechanism.

XI. Possible Disasters and Precaution

There are several possible disasters that could occur during construction and later during use of the colliding beam area. The following is a list of the more important consideration.

1. Wall cave-in. The walls of the collision and assembly halls, which are 45 to 50 ft. high, must be designed so that intermediate interior bracing will not be needed. Any interior bracing for the walls must be at a height that will not interfere with the clear space needed for the experimental equipment.
2. Pumps. Any outside and inside deep sump pumps used to remove water from the soil around the underground portion of the structure, thus reducing hydrostatic pressure that could cause the walls to cave-in, must be hooked up to an emergency generating system that will kick on when there is failure in the regular power system. If the building is built using conventional methods and the space below the floor were saturated with water, the collision hall and assembly hall would have 6000 to 7000 tons of uplift force due to the water. This necessitates outside sump pumps. This problem could be avoided with slurry methods as mentioned before.
3. Flood. There have been several accidents, including one at Fermilab, where underground experimental areas have flooded from a rain storm, thus damaging experimental equipment. Reasonably large sump pumps inside the experimental areas, which should be connected also to an emergency power generator, are necessary to prevent flooding. The colliding beam area will be the lowest point around the main ring. For precaution, we prefer to have the loading area on the grade and not accessed by a ramp, which is harder to maintain during winter.
4. Nitrogen gas and flammable gas. A lot of liquid nitrogen is used in conjunction with the Energy Doubler magnets and superconducting solenoids at CBA for thermal radiation shield. Cold nitrogen is heavier

than air, and proper air circulation must be maintained to prevent the nitrogen from settling in the collision and assembly halls before it can be exhausted. Other gases used in conjunction with the proportional chamber are heavier than air and also flammable. In this case, proper ventilation as well as no smoking must be maintained. Helium gas, also used in this area, is lighter than air and again must be properly exhausted. When the colliding beam area is finally constructed, it will have the lowest floor level on the main ring. Any heavy gases in the main ring would tend to accumulate and settle in the colliding beam area. Therefore, it will be important to eliminate any gas leaks in the main ring tunnel and CBA and to prevent failure of the ventilation system. The ventilation and exhaust system should be hooked up to an emergency generating system to avoid any of the above problems when there is a power outage. Gas monitors for each gas should be installed.

XI. Construction Schedule

The construction schedule will be based on the amount of time available during the accelerator shutdown during the summer of 1981. At this time, it is still unclear how long the shutdown will last. The shutdown may range from 4-1/2 to 7-1/2 months.

Regardless of the length of the shutdown and construction method used, the following jobs must be completed before any major construction starts:

1. Any existing utilities that will interfere with construction must be relocated.

2. The existing pedestrian and minor vehicle accessways must be removed and relocated if still regarded vital to the operation.
3. Caissons should be put in from grade level before the shutdown. Otherwise the caissons would disrupt the construction schedule.
4. Before the end of shutdown, the main ring elements necessary for the operation of the accelerator must be reinstated so that the ring will be ready for use. This may take a month.

Assuming a 4-1/2 month shutdown and the use of the slurry wall method for constructing the walls, it would be possible to construct a major portion of the collision hall in 4-1/2 months.

XII. Cost Estimation

The cost for the bare minimum concrete structure of a colliding hall may be in the range of $1.5 to $1.7 M regardless of the construction technique. The concrete shielding blocks for the wall will occupy a volume of 120 ft. long, 40 ft. high, and 10 ft. thick and will cost about another $450 K at the unit cost of $250/cubic yard.

If we make the bare minimum concrete structure of a colliding hall and an assembly hall without the metal panel building for the assembly hall but with concrete shielding blocks, the cost will be about $3 M.

The additional cost, including the metal panel building, utilities, and two 20 ton cranes may run $1 M to $1.5 M. Therefore, the total cost of B0 building as shown in Fig. 9 may cost $4 M to $4.5 M.

The unit cost of concrete work is listed in Table V together with other related parameters. In recent years, the inflation rate for concrete work was stated at 30 percent/year.

XIII. Special Items to be Considered and Designed

1. The superstructure for the central detector. We have to know how to hold and how to maintain the elements of the detector, including muon counters, calorimeter modules, endcaps, and so on. The over-all dimensions may grow and increase the required width of the collision hall.
2. The carriage system and the floor for the central detector. The carriage itself needs mechanical design, and its rail and moving mechanism should be designed. The use of caissons and concrete beam under the floor should be designed as well as the floor thickness.
3. The carriage system and the floor for the forward detector. This carriage may be of simpler design but still needs some mechanical design and considerations. The possible use of caissons for torodial magnets and the floor thickness should be decided. Slab technique might be used without caissons.
4. Moving mechanism for concrete shielding blocks under the concrete beam.
5. Equipment housing. Its functions and the required space for each function should be specified.
6. Emergency power generator. It will be used for sump pumps, exhaust fans, air intake fans, gas monitors, and some control circuits for maintaining superconducting magnets.
7. Gas monitors. Several different type of gas monitors will be needed for personal safety in the collision and assembly halls.

8. Connection to equipment housing. The following items should be connected to it from the outside: AC power lines, signal cables, liquid helium and nitrogen transfer lines, helium gas lines, cooling water lines, and some exhaust gas lines.
9. Connection to forward detectors. The following items should be connected to it: AC power lines, DC power lines, signal cables, detector gas lines, and exhaust lines.
10. Connection to low beta quadrupole magnets and compensating solenoid magnets. The following items should be connected to them: DC power lines, control signal cables, liquid helium and nitrogen transfer lines, and helium and nitrogen gas lines.
11. A satellite liquid helium refrigerator. It will be installed in the support building for the superconducting magnets in B0 area.
12. Radiation monitors.

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Table I

Dimensions and Parameters of Central Detector

Radially		
Radius of Calorimeter	11 ft.-6 in.	
Phototubes and Crate	2 ft.	
Muon Detector	2 ft.	
	15 ft.-6 in.	Diameter 31 ft.
Lengthwise		
Steel Core	23 ft.	
Phototubes	1 ft.-6 in., x 2	
	26 ft.	

Weight of detector itself about 1600 tons. Total weight of carriage, detector, shield, and equipment housing about 2500 tons.

Table II

Parameters of Forward Detectors

A Set of Forward Detector:	Weight	Diameter	Area
Front set of toroids	800 tons	25 ft.	25 ft. x 8 ft.
Particle identifier	10 tons		
EM and hadron calorimeters	550 tons	19 ft.	19 ft. x 7 ft.
Back set of toroids	800 tons	25 ft.	25 ft. x 8 ft.

Total weight of a set of forward detector: 2200 tons

Total space occupied by a set of detector: 25 ft. x 32 ft.

Total electrical power for a set of detector: 2 MW

Opening angle $\pm 15^{\circ}$

Table III

Major Parameters of B0 Collision Hall

Main Parameters of Collision Hall

Width	45 ft., including 6 ft. bypath	
Length	≥ 120 ft.	
E/D beam level	723 ft.-4.5 in.	
Floor level	705 ft.-4.5 in.	41 ft.-7.5 in. below grade
Floor concrete thickness	2 ft. ∿ 3 ft. (?)	2000 ton/30 ft. x 25 ft. = 2.7 ton/ft.^{2}
Beam height	18 ft.	23 ft.-7.5 in. below grade
Main ring tunnel level	722 ft.-6 in.	
Grade level	747 ft.	
Ceiling height	18 ft. + 15 ft.-6 in. + 6 ft. (clearance) + 6 ft.-10 in. (crane) + 6 in. (clearance) + 1 ft.-6 in. (brace) = 48 ft.-4 in.	
Berm thickness	10 ft. concrete equivalent thickness (3 ft. concrete + 9 in. dirt)	
Berm height	19 ft. above grade	
Crane	20 ton	6 ft.-10 in. for crane height
	(50 ton provision (10 ft.-8 in.))	
Passage	34 ft. wide	4 ft. clearance on both sides
	35 ft.-6 in. high	2 ft. clearance at top

Table IV

Major Parameters of BO Assembly Hall

Main Parameters of Assembly Hall		
Width	50 ft.	
Length	120 ft.	
Floor level	705 ft.-4.5 in.	41 ft.-7.5 in. below grade
Floor concrete thickness	2 ft. ∿ 3 ft.	
Grade level	747 ft.	
Ceiling height	22 ft.-10 in. or 7 ft.-10 in.	
Crane	20 ton	
Thickness of shielding wall	10 ft. concrete	
Main Parameter of Space for Equipment Housing		
Area	25 ft. x 45 ft.	
Main Parameter of Loading Garage		
Width	60 ft.	
Length	30 ft.	
Floor level	747 ft.-6 in.	6 in. above grade
Ceiling height	4 ft. (flatbed truck) + 6 ft. (calorimeter) + 4 ft. (clearance) + 6 ft.-10 in. (crane) + 6 in. (clearance) + 1 ft.-6 in. (brace) = 22 ft.-10 in.	
Crane	20 ton	

Table V

Related Parameters

Density	g/cm^3	lb./ct	ton/cy
Dirt	2.0 (∿ 2.3)	125	1.7
Normal concrete	2.4	150	2.0
Heavy concrete	3.8	237	3.2

Price of Concrete

Concrete itself	$ 50/cy
Reinforced concrete blocks	250/cy
Reinforced concrete beam (∿ 50 ft. long)	300/cy
Formed concrete	400/cy
Floor	290/cy

Caisson 100 ton/ft.^{2}	3 ft.-6 in. diam.	5 ft. diam.	6 ft. diam.
Maximum loading	∿ 1000 tons	∿ 2000 tons	∿ 2800 tons

Floor Loading

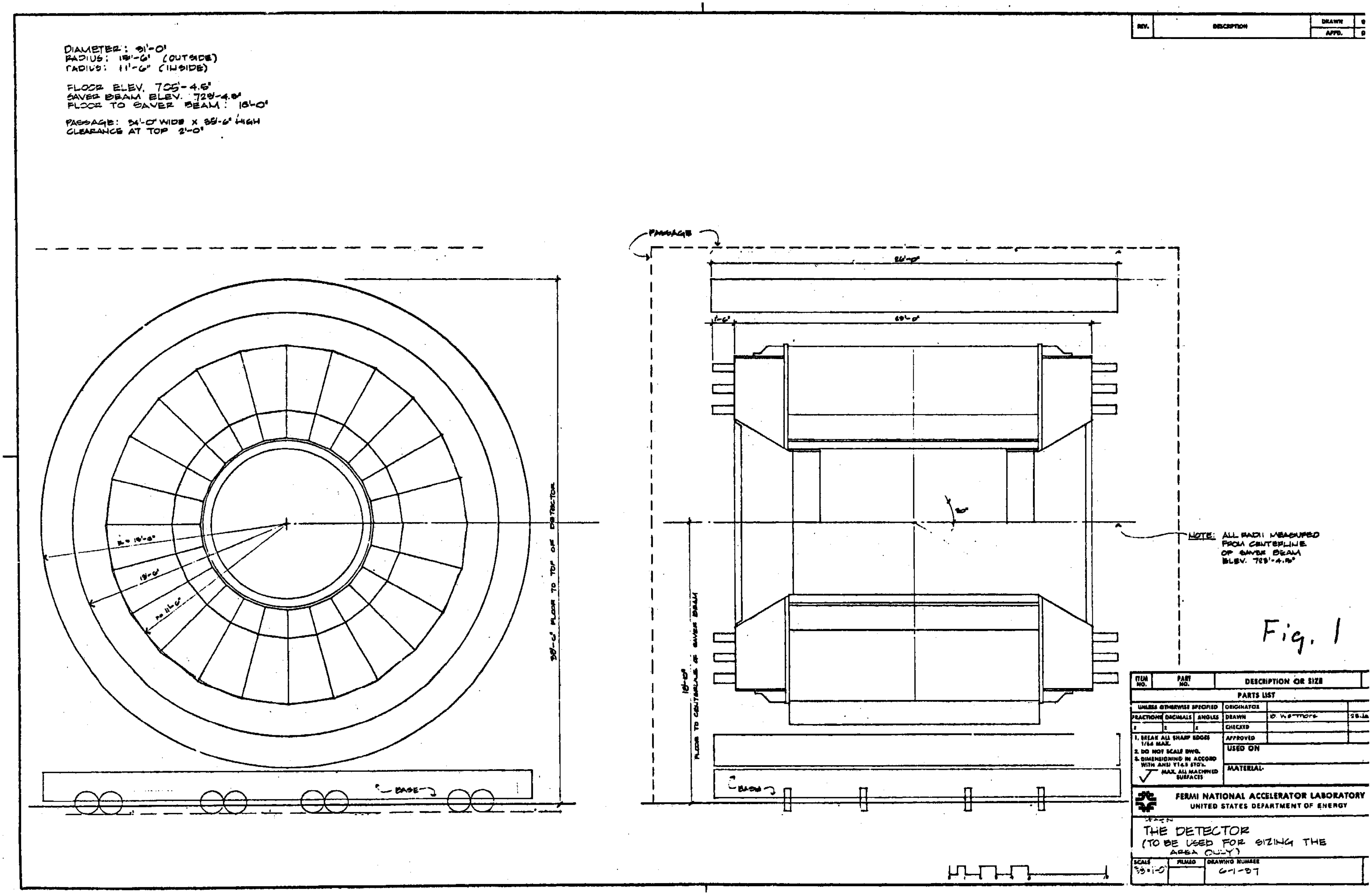
Not clear cut, depending on soil, depth, area, and criteria

Existing Examples	Floor Thickness	
Proton Lab, High Intensity Beam Area	3 ft.-6 in. thick	200 tons/5 ft. x 10 ft. = 4 tons/ft.^{2}
Neutrino Lab C, 24 ft. toroids	1 ft.-6 in. thick	
Neutrino Lab E, 12 ft. toroids	1 ft.-8 in. thick	
Meson, Exp. 605	2 ft. and 3 ft. thick	1500 tons/16 ft. x 57 ft. = 1.7 ∿ 3 tons/ft.^{2}

Radiation Shielding Berm

Proton-Neutrino Lab	14 ft. of dirt

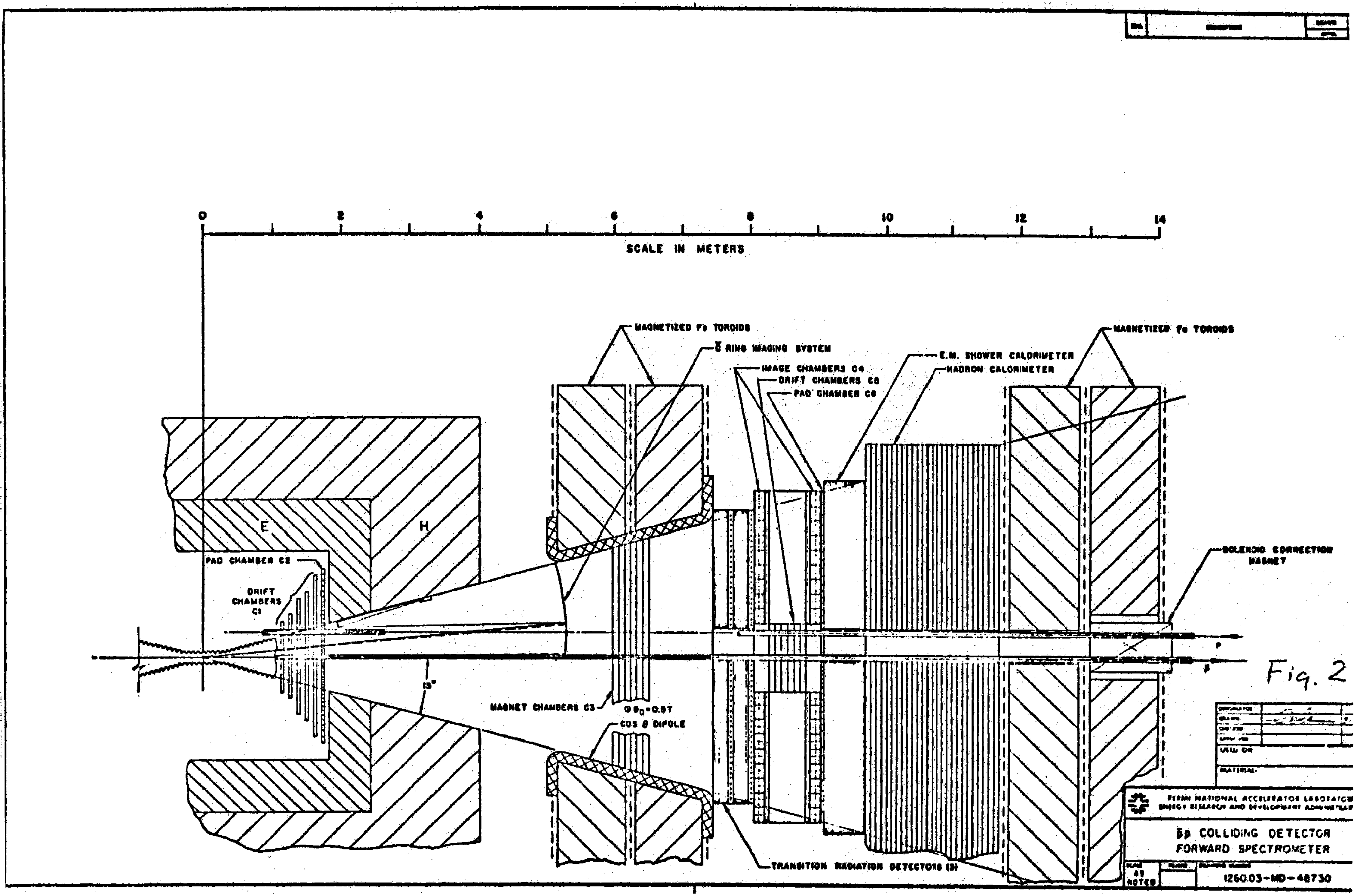
Drawings



DIAMETER: 31'-0"
RADIUS: 15'-6" (OUTSIDE)
RADIUS: 11'-6" (INSIDE)
FLOOR ELEV. 705'-4.5"
SAVER BEAM ELEV. 723'-4.5"
FLOOR TO SAVER BEAM: 18'-0"
PASSAGE: 34'-0" WIDE x 35'-6" HIGH
CLEARANCE AT TOP 2'-0"
PASSAGE
NOTE: ALL RADII MEASURED FROM CENTERLINE OF SAVER BEAM ELEV. 723'-4.5"
BASE
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY
THE DETECTOR
(TO BE USED FOR SIZING THE AREA ONLY)

Fig. 1

TM-995



SCALE IN METERS
0 2 4 6 8 10 12 14
MAGNETIZED Fe TOROIDS
Č RING IMAGING SYSTEM
IMAGE CHAMBERS C4
DRIFT CHAMBERS C5
PAD CHAMBER C6
E.M. SHOWER CALORIMETER
HADRON CALORIMETER
MAGNETIZED Fe TOROIDS
E
H
PAD CHAMBER C2
DRIFT CHAMBERS C1
SOLENOID CORRECTION MAGNET
15°
MAGNET CHAMBERS C3
GB0=0.8T
COS θ DIPOLE
TRANSITION RADIATION DETECTORS (3)
p
p̄
VIEW ON
MATERIAL
FERMI NATIONAL ACCELERATOR LABORATORY
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
p̄p COLLIDING DETECTOR
FORWARD SPECTROMETER
AS NOTED
1260.03-MD-48730

Fig. 2

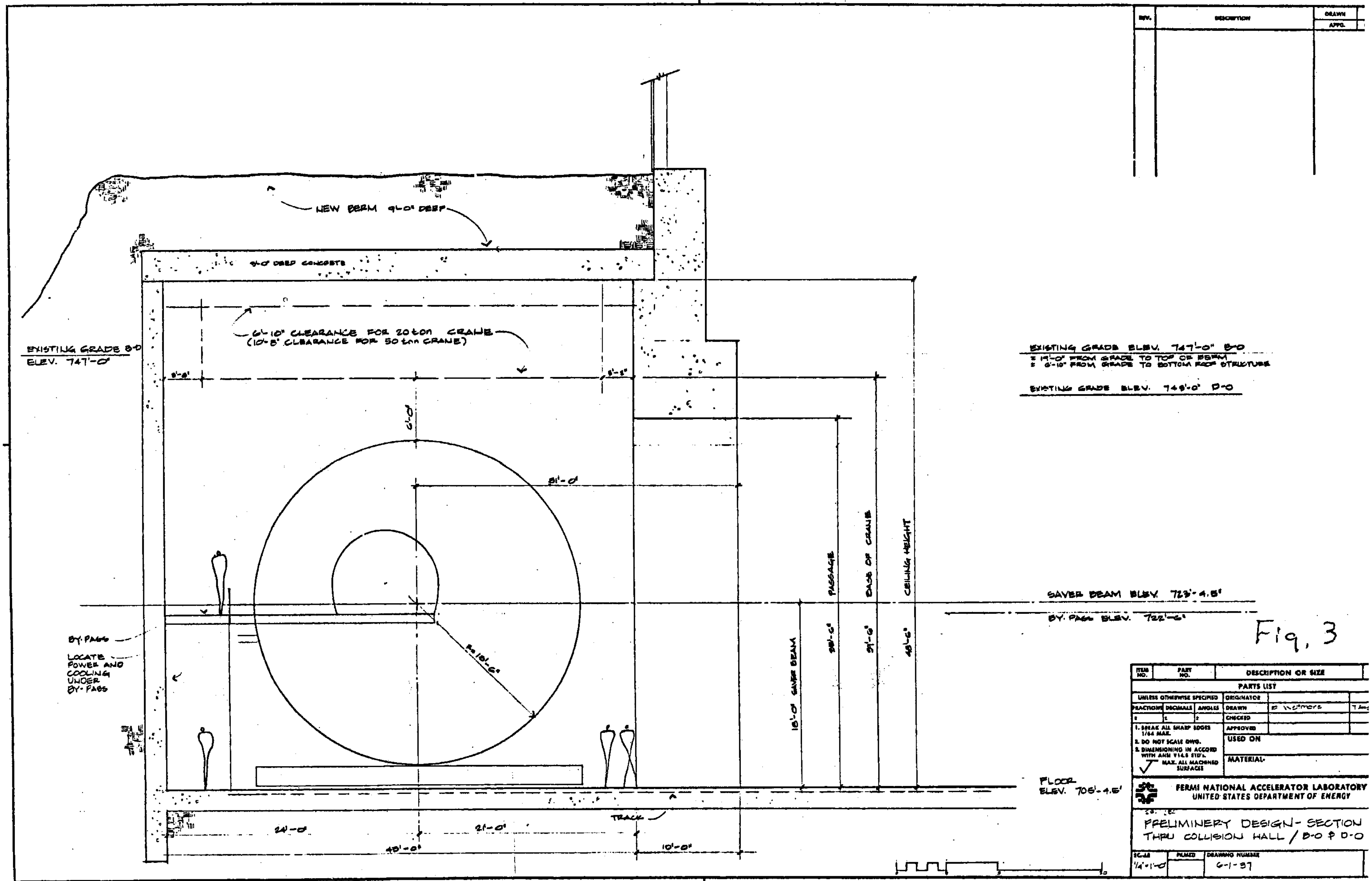

NEW BERM 9'-0" DEEP
9'-0" DEEP CONCRETE
6'-10" CLEARANCE FOR 20 ton CRANE
(10'-8" CLEARANCE FOR 50 ton CRANE)
EXISTING GRADE B-0
ELEV. 747'-0"
EXISTING GRADE ELEV. 747'-0" B-0
± 11'-0" FROM GRADE TO TOP OF BERM
± 6'-10" FROM GRADE TO BOTTOM ROOF STRUCTURE
EXISTING GRADE ELEV. 743'-0" D-0
6'-0"
81'-0"
R=10'-6"
PASSAGE
BASE OF CRANE
CEILING HEIGHT
18'-0" SAVER BEAM
38'-6"
41'-6"
48'-6"
SAVER BEAM ELEV. 723'-4.5"
BY-PASS ELEV. 722'-6"
BY-PASS
LOCATE POWER AND COOLING UNDER BY-PASS
FLOOR ELEV. 705'-4.5"
TRACK
24'-0"
21'-0"
45'-0"
10'-0"
REV.
DESCRIPTION
DRAWN
APPD.
ITEM NO.
PART NO.
DESCRIPTION OR SIZE
PARTS LIST
UNLESS OTHERWISE SPECIFIED
FRACTIONS
DECIMALS
ANGLES
ORIGINATOR
DRAWN
CHECKED
APPROVED
USED ON
MATERIAL
1. BREAK ALL SHARP EDGES 1/64 MAX.
2. DO NOT SCALE DWG.
3. DIMENSIONING IN ACCORD WITH ANSI Y14.5 STD'S.
MAX. ALL MACHINED SURFACES
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY
PRELIMINERY DESIGN - SECTION THRU COLLISION HALL / B-0 & D-0
SCALE
1/4"=1'-0"
FILMED
DRAWING NUMBER
6-1-87

Fig. 3

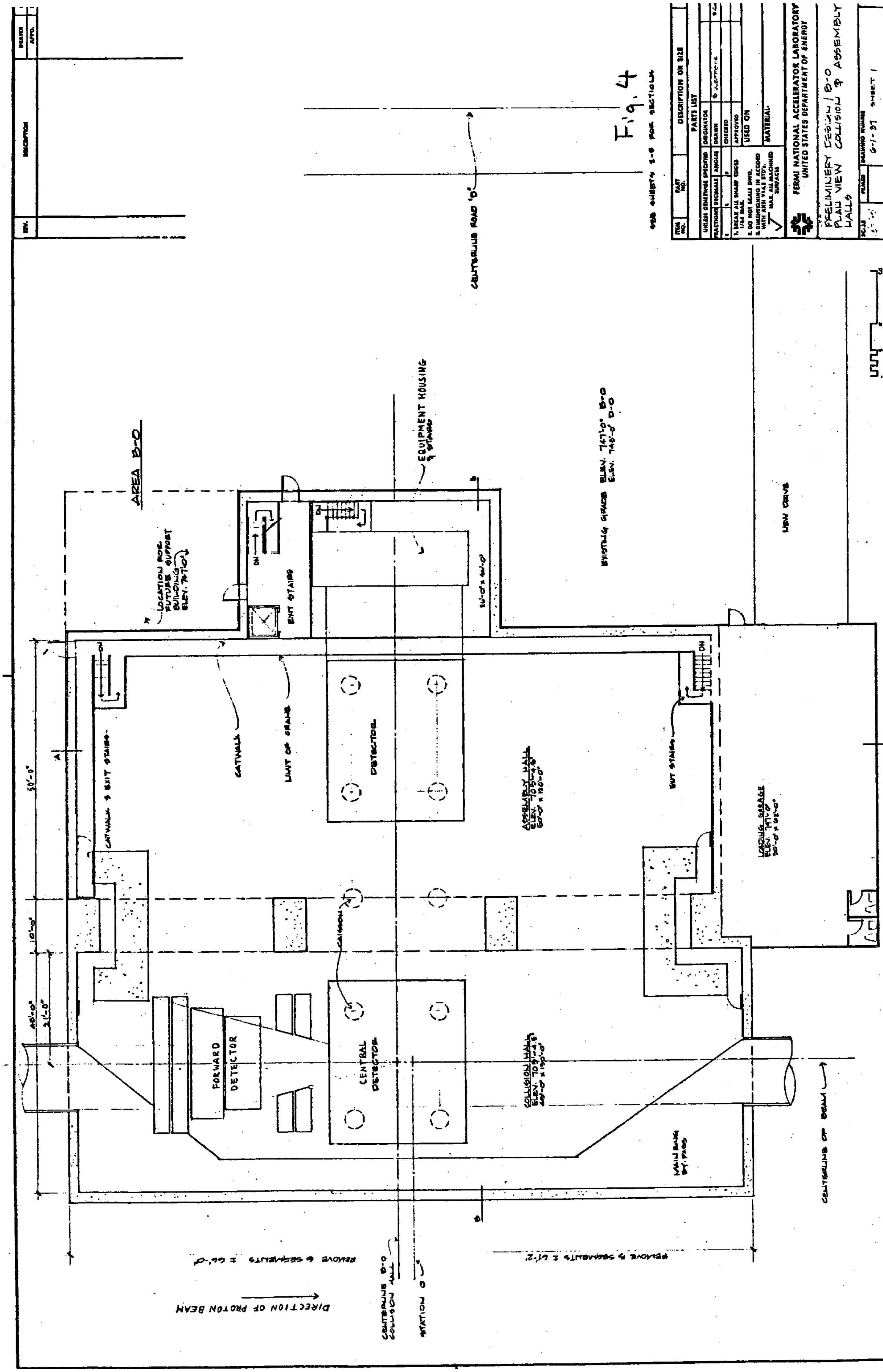

AREA B-0
EQUIPMENT HOUSING
EXIT STAIRS
CATWALK
LIMIT OF CRANE
DETECTOR
ASSEMBLY HALL
LOADING GARAGE
CAISSON
FORWARD DETECTOR
CENTRAL DETECTOR
COLLISION HALL
DIRECTION OF PROTON BEAM
CENTERLINE OF BEAM
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

Fig. 4

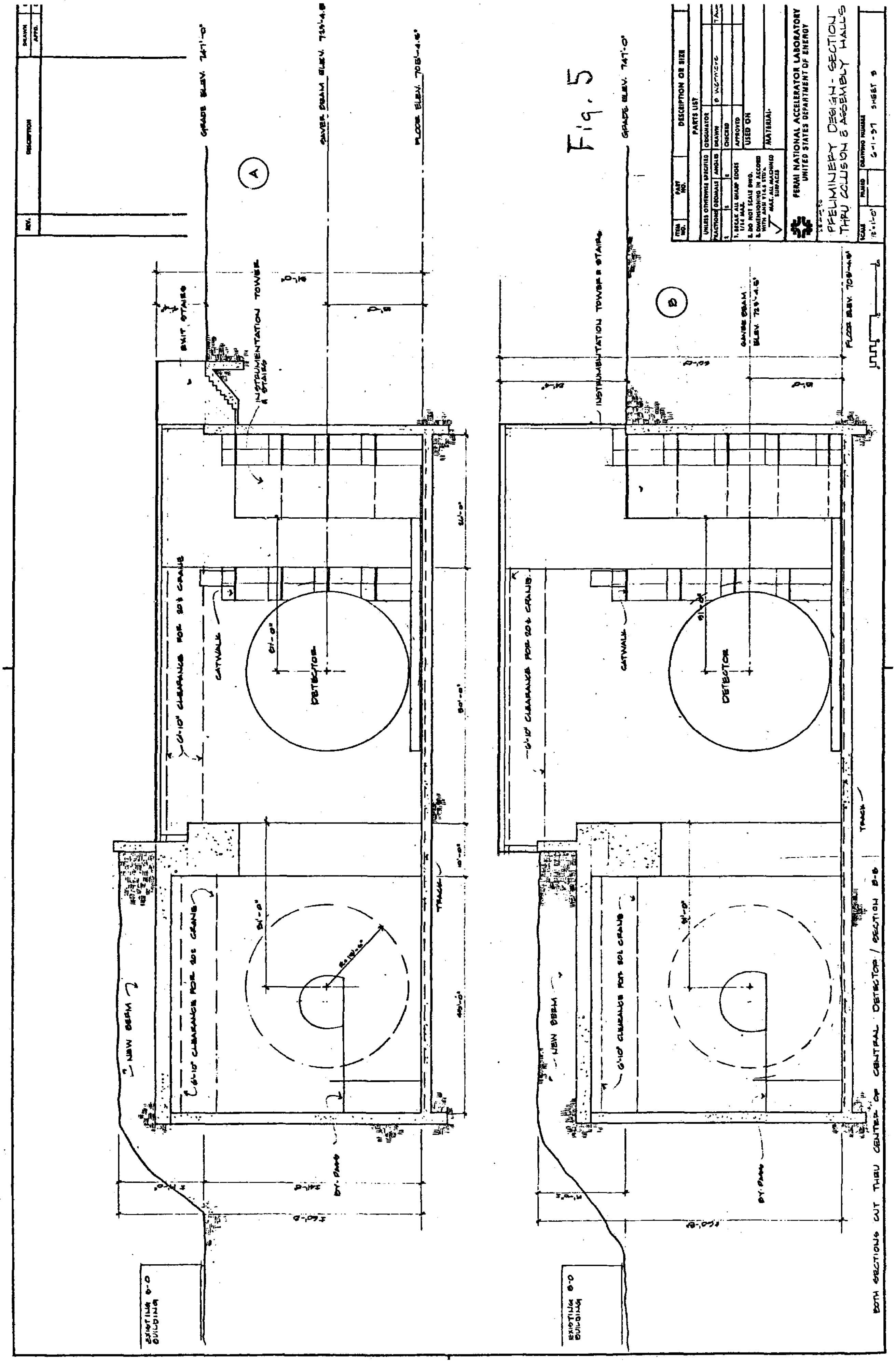


Fig. 5
GRADE ELEV. 741'-0"
FLOOR ELEV. 708'-4.5"
EXIT STAIRS
INSTRUMENTATION TOWER
INSTRUMENTATION TOWER & STAIRS
CATWALK
DETECTOR
6'-10" CLEARANCE FOR 20t CRANE
NEW BERM
TRACK
EXISTING B-0 BUILDING
BOTH SECTIONS CUT THRU CENTER OF CENTRAL DETECTOR / SECTION B-B
PARTS LIST
DESCRIPTION OR SIZE
DRAWN
CHECKED
APPROVED
USED ON
MATERIAL
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY
PRELIMINARY DESIGN - SECTION THRU COLLISION & ASSEMBLY HALLS

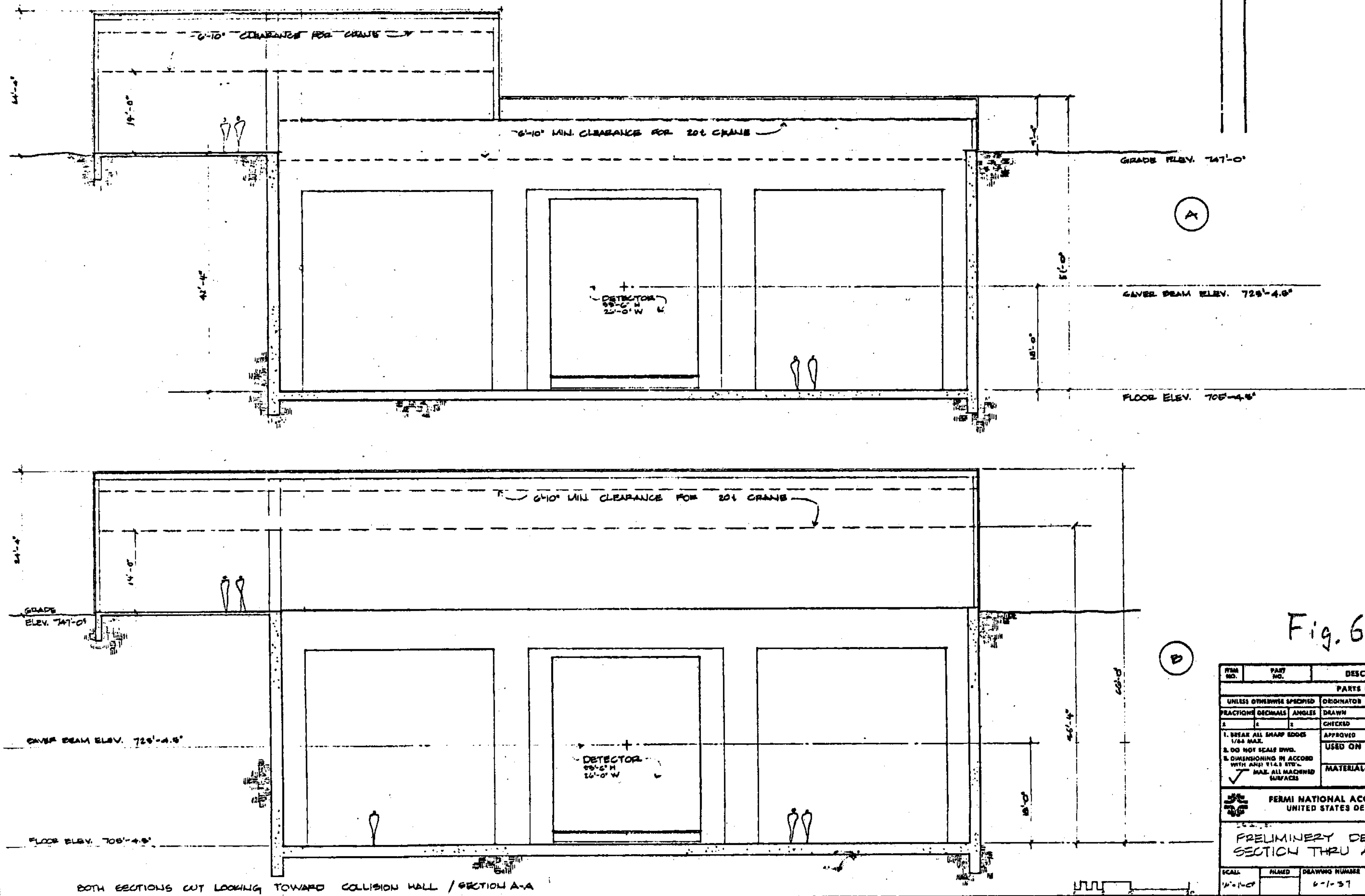


Fig. 6

ITEM NO.	PART NO.	DESCRIPTION OR SIZE	QTY. REQ.

PARTS LIST

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

PRELIMINARY DESIGN
SECTION THRU ASSEMBLY HALL

SCALE | FILMED | DRAWING NUMBER | REV. A

TM-995

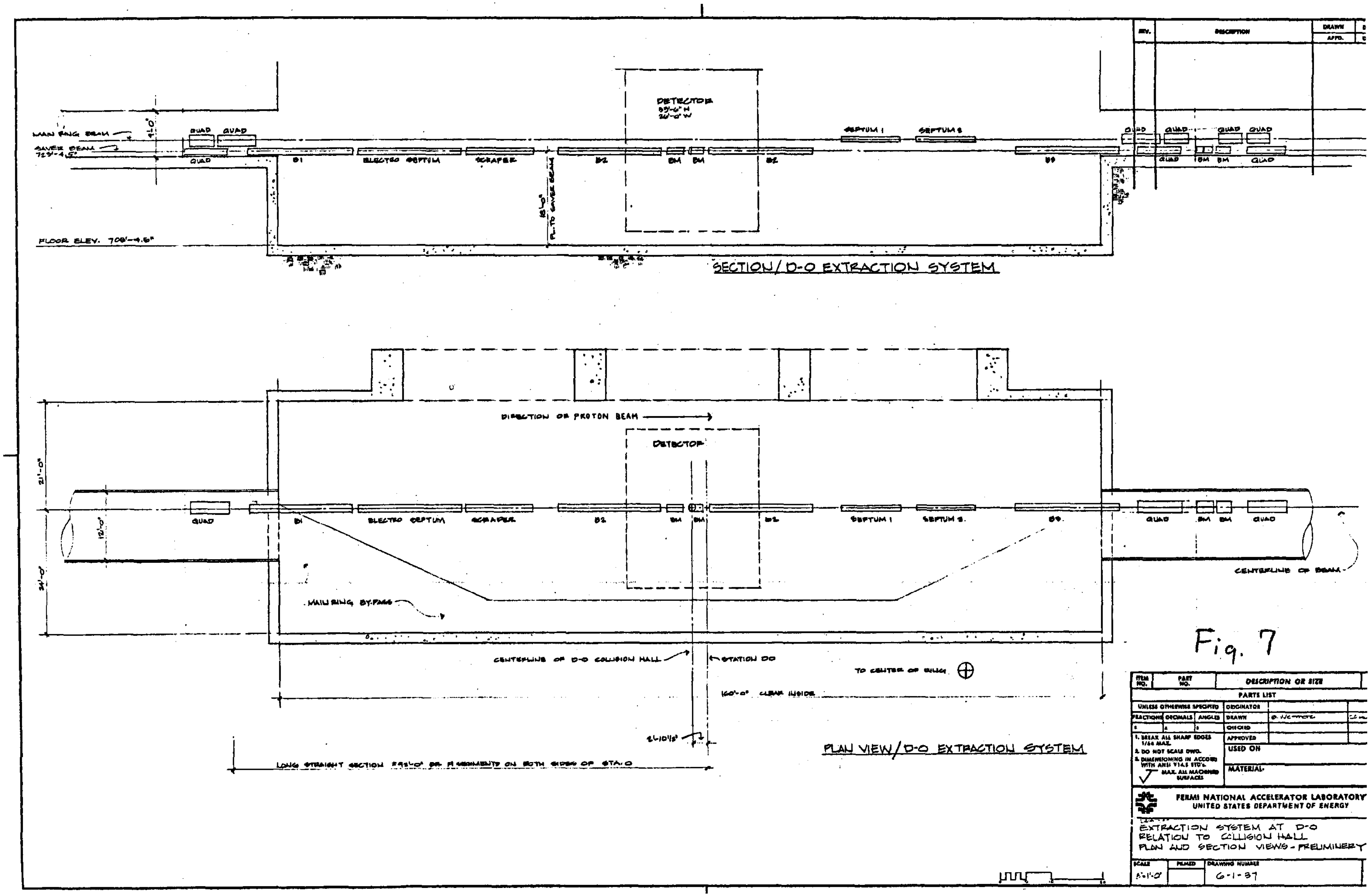
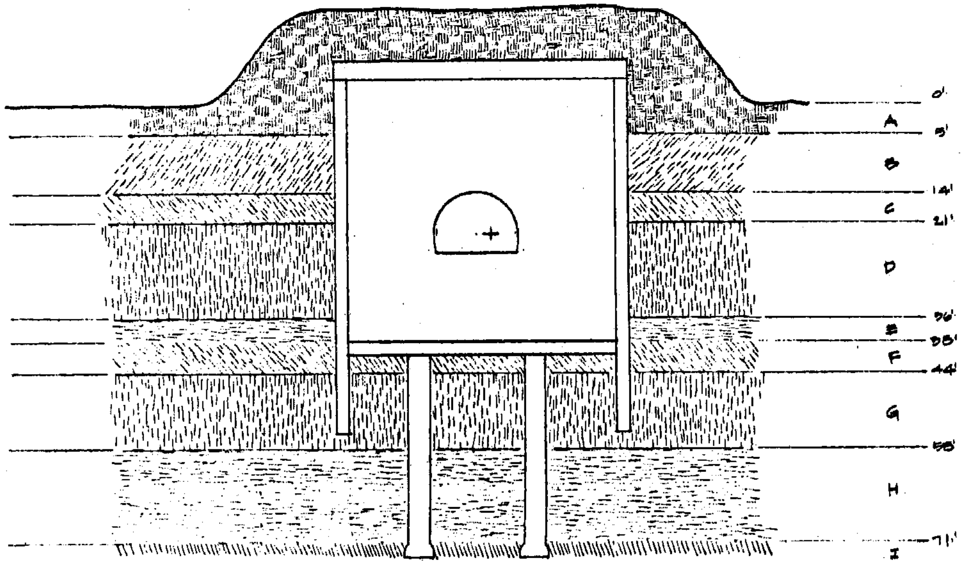

DETECTOR
MAIN RING BEAM
SAVER BEAM
QUAD
B1
ELECTRO SEPTUM
SCRAPER
B2
BM
SEPTUM 1
SEPTUM 2
B3
FLOOR ELEV. 708'-4.5"
SECTION/D-O EXTRACTION SYSTEM
DIRECTION OF PROTON BEAM
MAIN RING BY-PASS
CENTERLINE OF BEAM
CENTERLINE OF D-O COLLISION HALL
STATION D0
TO CENTER OF RING
160'-0" CLEAR INSIDE
PLAN VIEW/D-O EXTRACTION SYSTEM
PARTS LIST
DESCRIPTION OR SIZE
USED ON
MATERIAL
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY
EXTRACTION SYSTEM AT D-O
RELATION TO COLLISION HALL
PLAN AND SECTION VIEWS-PRELIMINARY
6-1-87

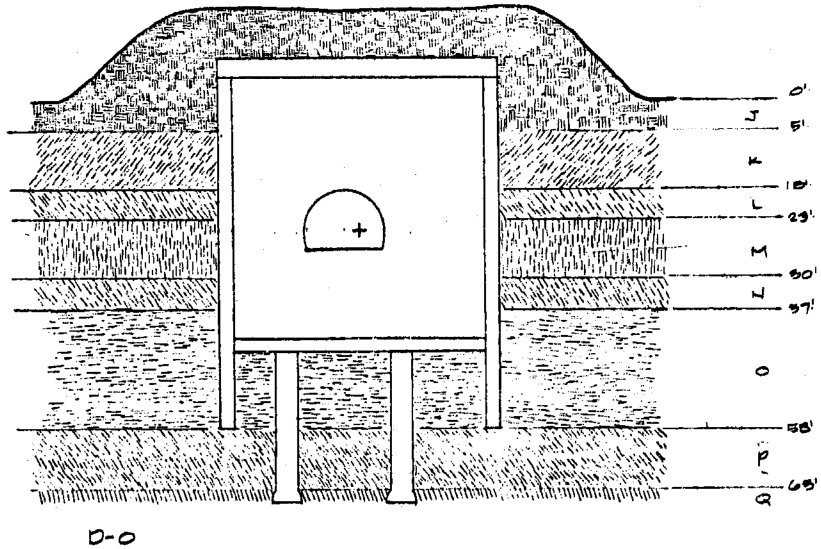
Fig. 7

TM-995

REV.	DESCRIPTION	DRAWN	DATE
		APPD.	DATE



B-0



D-0

B-0
A - BACKFILL
B - SILT
C - SANDY SILT & FINE SAND
D - SILTY CLAY
E - SILT
F - SANDY CLAY
G - SILTY CLAY
H - SAND
I - LIMESTONE BEDROCK

D-0
J - BACKFILL
K - SILTY CLAY
L - SILTY SAND
M - SILTY CLAY
N - SILTY SAND
O - SILTY CLAY
P - LIMESTONE GRAVEL
Q - LIMESTONE BEDROCK

- 0'-0" = EXIST. GRADE ELEV.

Fig. 8

ITEM NO.	PART NO.	DESCRIPTION OR SIZE	QTY. REQ.

PARTS LIST

UNLESS OTHERWISE SPECIFIED			ORIGINATOR		
FRACTIONS	DECIMALS	ANGLES	DRAWN	B. Wetmore	28 Aug 80
±	±	±	CHECKED		
			APPROVED		

1. BREAK ALL SHARP EDGES 1/64 MAX.
2. DO NOT SCALE DWG.
3. DIMENSIONING IN ACCORD WITH ANSI Y14.5 STD's.

√ MAX, ALL MACHINED SURFACES

USED ON

MATERIAL-

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

28 Aug 80
DIAGRAM OF SOILS BELOW COLLISION HALLS B-0 / D-0

SCALE	FILMED	DRAWING NUMBER	REV.
NONE		6-1-37	A

NOTE: THIS DRAWING IS ONLY A DIAGRAM AND SHOULD NOT BE USED FOR DESIGN WORK.

TM-995

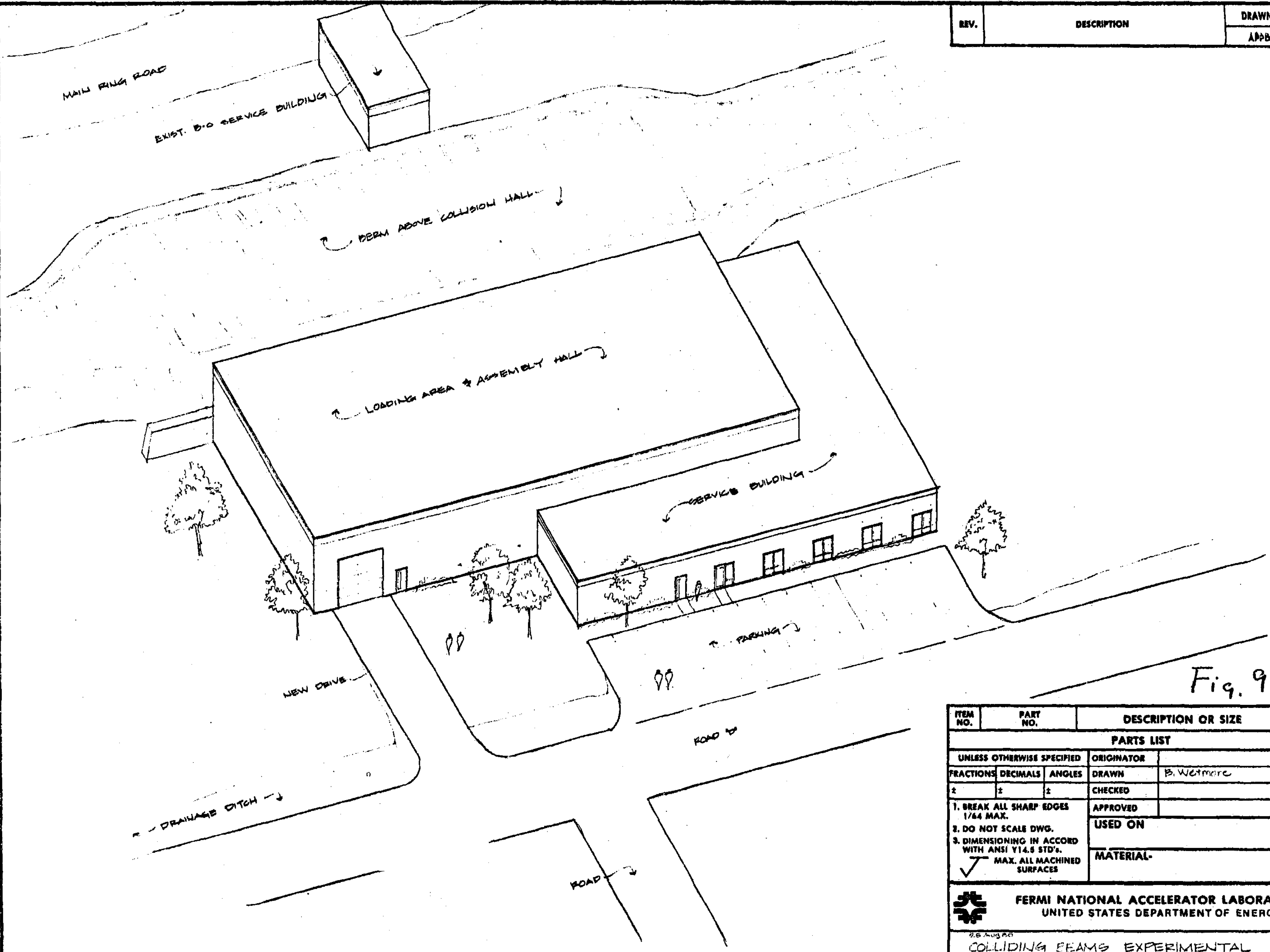


Fig. 9

REV.	DESCRIPTION	DRAWN	DATE
		APPD.	DATE

ITEM NO.	PART NO.	DESCRIPTION OR SIZE	QTY. REQ.

PARTS LIST

UNLESS OTHERWISE SPECIFIED			ORIGINATOR		
FRACTIONS	DECIMALS	ANGLES	DRAWN	B. Wetmore	19 Aug 80
±	±	±	CHECKED		
			APPROVED		

1. BREAK ALL SHARP EDGES 1/64 MAX.
2. DO NOT SCALE DWG.
3. DIMENSIONING IN ACCORD WITH ANSI Y14.5 STD's.

√ MAX. ALL MACHINED SURFACES

USED ON

MATERIAL-

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

26 Aug 80

COLLIDING BEAMS EXPERIMENTAL AREA AT SITE B-0

SCALE	FILMED	DRAWING NUMBER	REV.
NONE		6-1-37	

TM-995