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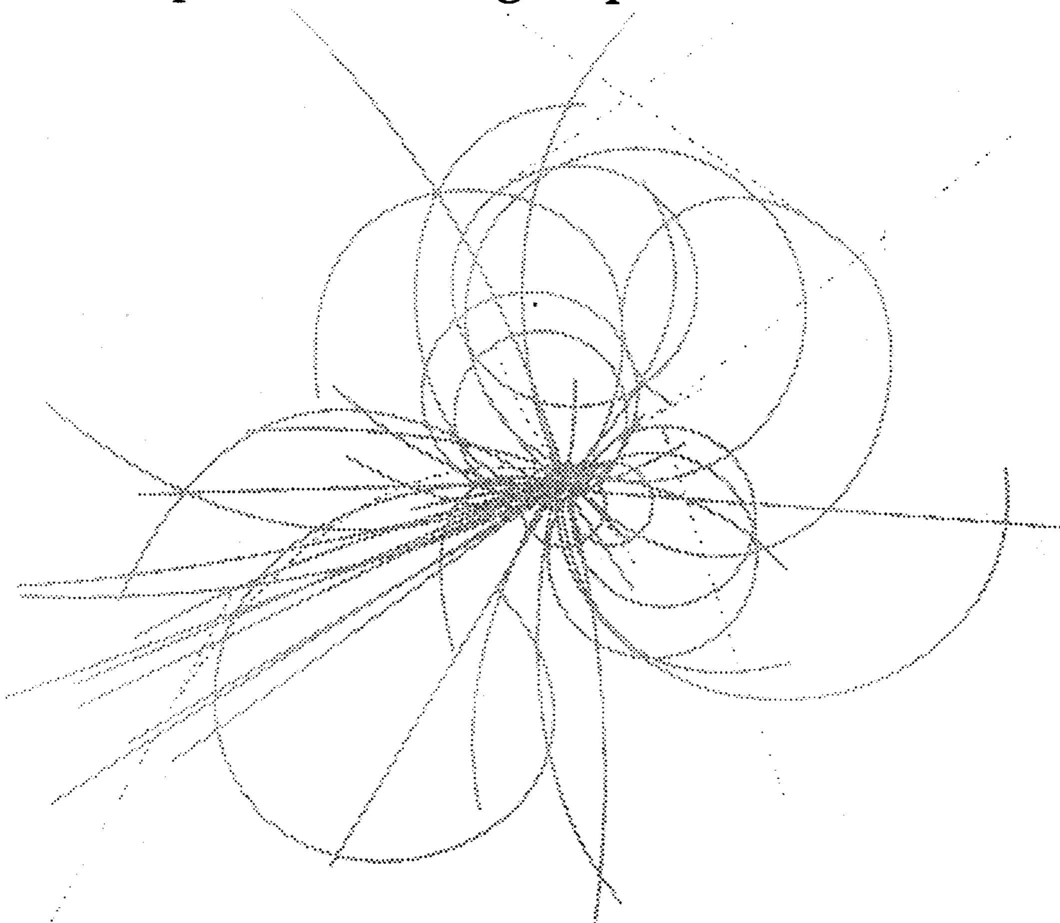

Solenoidal Detector Collaboration Resource Requirements Report

December 1990

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SOLENOIDAL DETECTOR COLLABORATION RESOURCE REQUIREMENTS REPORT

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CONTENTS

Tables iii
Figures v
1.0 INTRODUCTION AND DETECTOR DESCRIPTIONS 1
1.1 Introduction 1
1.2 Detector Description 1
1.3 Detector LOI Option 1 (Pb/Scintillator Calorimeter) 9
1.4 Detector LOI Option 2 (Liquid Argon Calorimeter) 9
2.0 DETECTOR SUBSYSTEMS 18
2.1 Silicon/Pixel Tracking 18
2.2 Central Tracking 18
2.2.1 Wire Tracking Option 41
2.2.2 Fiber Tracking Option 41
2.3 Solenoid Coil 41
2.4 Calorimeter 41
2.4.1 Pb/Scintillator Tile Option 41
2.4.2 Liquid Argon Calorimeter Option 41
2.5 Muon System 42
2.6 Data Acquisition 42
2.7 Weights and Measures 42
3.0 HALLS 97
3.1 Hall Sizes 97
3.2 Hall Cranes 97
3.3 Shafts 97
4.0 SURFACE FACILITIES 105
4.1 Buildings 105
4.2 Cranes 105
5.0 SDC ASSEMBLY / CONSTRUCTION 108
5.1 EOI Type-S Description 108
5.2 EOI Type-S Weights and Measures 108
5.3 EOI Type-S Assembly Story Board 108
6.0 REPAIR TIME ESTIMATES 134
7.0 OPERATIONAL REQUIREMENTS 137
7.1 LOI Option 1 Detector 137
7.2 LOI Option 2 Detector 137
8.0 SAFETY 158
8.1 Fire Safety 158
8.2 Solenoid Coil Safety 159
8.3 Liquid Argon Safety 160
8.4 Tracking Systems Safety 161
9.0 TEST BEAMS 162
10.0 COSTS 163
11.0 SCHEDULES 165

12.0 ALTERNATE SYSTEMS 166
12.1 Pre-Radiator 166
13.0 REFERENCES 171

TABLES

Table 1.2-1 Detector Design Goals ... 3
Table 1.2-2 Central Tracking ... 3
Table 1.2-3 Intermediate Angle Tracking ... 4
Table 1.2-4 Parameters for the Calorimeter Options ... 4
Table 1.2-5 Layout and Channel Count for the Muon System ... 5
Table 2.1-1 Pixel, Central, Transition, and Forward Dimensions ... 19
Table 2.1-2 Coverage of Different Sections ... 20
Table 2.1-3 Silicon Detector Cooling ... 20
Table 2.1-4 Weight Estimates (in Kilograms) ... 20
Table 2.1-5 Pixel Details ... 21
Table 2.1-6 Central Detector Details ... 21
Table 2.1-7 Transition and Forward Region Details ... 21
Table 2.1-8 Channel Count for Planes ... 22
Table 2.2.1-1 Barrel Wire Tracking ... 43
Table 2.2.2-1 Location of Center of Sublayers Within Central Tracker ... 53
Table 2.2.2-2 Location of Center of Sublayers Within Intermediate Tracker ... 53
Table 2.2.2-3 Intermediate Fiber Tracker ... 53
Table 2.3-1 Superconducting Solenoid Parameters ... 58
Table 2.4.1-1 Scintillator Plate Calorimeter Barrel Physical Parameters ... 70
Table 2.4.1-2 Scintillator Plate Calorimeter End Cap Physical Parameters ... 71
Table 2.4.2-1 Liquid Argon Calorimeter, Current Weight Summary ... 74
Table 2.4.2-2 Number of DA-Readout Channels for LAr Calorimeter ... 77
Table 2.5-1 Toroid Mass ... 84
Table 2.5-2 Muon Cerenkov Counter ... 85
Table 2.6-1 Front End, Trigger and DAQ Crate Estimates ... 90
Table 2.7-1 SDC Specifications Option 1 Detector ... 91
Table 2.7-2 SDC Specifications Option 2 Detector ... 94
Table 3.2-1 Collision Hall Cranes ... 101
Table 3.3-1 Collision Hall Shafts ... 101
Table 4.1-1 Space Allocation for Operations Building ... 107
Table 4.2-1 Cranes in Surface Facilities ... 107
Table 5.2-1 SDC Specifications Detector Type-S ... 112
Table 6.0-1 Repair Time Estimates ... 134
Table 7.1-1 SDC Utilities Option 1 - Power Consumption ... 138
Table 7.1-2 SDC Utilities Option 1 - Primary Cooling Needs ... 141
Table 7.1-3 SDC Utilities Option 1 - Liquid and Gas Consumption ... 144
Table 7.1-4 SDC Utilities Option 1 - Secondary Cooling Needs ... 147
Table 7.2-1 SDC Utilities Option 2 - Power Consumption ... 148
Table 7.2-2 SDC Utilities Option 2 - Primary Cooling Needs ... 151
Table 7.2-3 SDC Utilities Option 2 - Liquid and Gas Consumption ... 154

Table 7.2-4	SDC Utilities Option 2 - Secondary Cooling Needs	157
Table 9.1-1	SDC Test Beam Requirements	162
Table 10-0-1	Costs	164
Table 12.1-1	Pre-Radiator	166

FIGURES

Figure 1.2-1 Tracking System for the SDC Detector 6
Figure 1.2-2 Momentum Resolution 7
Figure 1.2-3 Trigger Efficiency 7
Figure 1.2-4 Muon Momentum Resolution (1) 8
Figure 1.2-5 Muon Momentum Resolution (2) 8
Figure 1.3-1 Isometric View of the Solenoid Detector 10
Figure 1.3-2 Subsystem Boundaries (Option 1) 11
Figure 1.3-3 Subsystem Supports (Option 1) 12
Figure 1.3-4 Utilities Locations (Option 1) 13
Figure 1.4-1 Liquid Argon Detector 14
Figure 1.4-2 Subsystem Boundaries (Option 2) 15
Figure 1.4-3 Subsystem Supports (Option 2) 16
Figure 1.4-4 Utilities Locations (Option 2) 17
Figure 2.1-1 Layout of Silicon Detector Cylindes and Planes 25
Figure 2.1-2 Overall View of Tracker with Enlargement of Central and Transition Regions 26
Figure 2.1-3 Overall View Showing Some of the Structural Members and the Beam Tube 27
Figure 2.1-4 Schematic of the Butane Cooling System 28
Figure 2.1-5 Cross Cestion of Central Region with Dimensions 29
Figure 2.1-6 View of Segment of Plane Defining Terms Used by Table 2.1-8 30
Figure 2.1-7 Detail of Detector on Plane 1 31
Figure 2.1-8 Detail of Detectors on Planes 2 and 6 32
Figure 2.1-9 Detail of Detectors on Planes 3 and 7 33
Figure 2.1-10 Detail of Detectors on Planes 4 and 8 34
Figure 2.1-11 Detail of Detectors on Planes 1 and 5 35
Figure 2.1-12 Detail of Detectors on Planes 9 - 14 36
Figure 2.1-13 Detail of Detectors on Planes 15 and 16 37
Figure 2.1-14 Detail of Detectors on Planes 17 and 18 38
Figure 2.1-15 Detail of Detectors on Planes 19 and 20 39
Figure 2.1-16 Detail of Detectors on Planes 21 and 22 40
Figure 2.2.1-1 Wire Tracker (end view) 44
Figure 2.2.1-2 Wire Tracker (cut away) 45
Figure 2.2.1-3 Section Through End of Module 46
Figure 2.2.1-4 View "A" 47
Figure 2.2.1-5 View "X" 48
Figure 2.2.2-1 Scintillating Fiber Central Tracking 49
Figure 2.2.2-2 Fiber Bundle Edge Clamp 50
Figure 2.2.2-3 Fiber Tracker (profile) 51
Figure 2.2.2-4 Cross-section of a Superlayer 52
Figure 2.2.2-5 Intermediate Tracking Superlayer 54
Figure 2.2.2-6 Super Sublayer of the Intermediate Tracker 55
Figure 2.2.2-7 Intermediate Tracker 56

Figure 2.2.2-8 Trigger Momentum Resolution 57
Figure 2.3-1 Coil-iron-calorimeter geometries for Type-U solenoid....................59
Figure 2.3-2 Field Map (iron end cap calorimeter) 60
Figure 2.3-3 Field Integrals for End Cap Options 61
Figure 2.3-4 Field Map (non-iron end cap calorimeter) 61
Figure 2.3-5 Axial and Radial Supports 62
Figure 2.3-6 Axial Support 63
Figure 2.3-7 Radial Support 64
Figure 2.3-8 Radiation Length vs. Pseudorapidity (Sec. A-C) 65
Figure 2.3-9 Radiation Length vs. Pseudorapidity (Sec. A-C, Zooming) 65
Figure 2.3-10 Radiation Length vs. Pseudorapidity (Sec. D-G) 66
Figure 2.3-11 Radiation Length vs. Pseudorapidity (Sec. D-G, Zooming) 66
Figure 2.3-12 Radiation Length vs. Pseudorapidity (Sec. H) 67
Figure 2.3-13 Radiation Length vs. Pseudorapidity (Sec. I) 68
Figure 2.3-14 Helium Cryogenic Schematic for SDC Solenoid 69
Figure 2.4.1-1 Tower Structure (Pb/scintillatc 72
Figure 2.4.1-2 Tower Structure (Pb/scintillator option) 73
Figure 2.4.2-1 LAC Module Numbering 75
Figure 2.4.2-2 Liquid Argon Calorimeter 75
Figure 2.4.2-3 Radial Dimensions and Cell Structures of the Barrel 76
Figure 2.4.2-4 Liquid Argon Calorimeter 78
Figure 2.4.2-5 SDC LAr Endcap Segmentation/LOI 78
Figure 2.4.2-6 Dimensions of the Vessels 79
Figure 2.4.2-7 Assembly of Barrel and End Cap 80
Figure 2.4.2-8 Detector Module Cooling and Argon Pipes 81
Figure 2.4.2-9 LAr in Operating Position 82
Figure 2.4.2-10 LAr Detector Being Repaired 83
Figure 2.5-1 Vessel Dimensions 86
Figure 2.5-2 Muon Cerekov Counter 87
Figure 2.5-3 Photoelectrons Per Meter 88
Figure 2.5-4 Cerenkov Angle 89
Figure 3.1-1 Hall Sizes (1) 98
Figure 3.1-2 Hall Sizes (2) 99
Figure 3.1-3 Hall Sizes (3) 100
Figure 3.3-1 Cross-sections of Personnel and Equipment Shafts 102
Figure 3.3-2 Cable Shaft Plan 103
Figure 3.3-3 Utility Shaft 104
Figure 4.1-1 Surface Facilities 106
Figure 5.1-1 Cross Section View of EOI Type-S Detector 110
Figure 5.1-2 View of EOI Type-S Detector 111
Figure 5.3-1 Hall at 0 Months 115
Figure 5.3-2 Hall at 3 Months 116

Figure 5.3-3 Hall at 5.1 Months 117
Figure 5.3-4 Hall at 5.2 Months 118
Figure 5.3-5 Hall at 5.3 Months 119
Figure 5.3-6 Hall at 5.6 Months 120
Figure 5.3-7 Hall at 5.9 Months 121
Figure 5.3-8 Hall at 6 Months 122
Figure 5.3-9 Hall at 15 Months 123
Figure 5.3-10 Hall at 15.1 Months 124
Figure 5.3-11 Hall at 18 Months 125
Figure 5.3-12 Hall at 21 Months 126
Figure 5.3-13 Hall at 24 Months 127
Figure 5.3-14 Hall at 27 Months 128
Figure 5.3-15 Hall at 30 Months 129
Figure 5.3-16 Hall at 33 Months 130
Figure 5.3-17 Hall at 36 Months 131
Figure 5.3-18 Hall at 39 Months 132
Figure 5.3-19 Hall at 42 Months 133
Figure 12.1-1 Pre-Radiator (pre-shower ends) 167
Figure 12.1-2 Pre-radiator 168
Figure 12.1-3 Pre-radiator 169
Figure 12.1-4 Pre-Shower Ends 170

1.0 INTRODUCTION AND DETECTOR DESCRIPTIONS

1.1 Introduction

This document contains design criteria and requirements for the Solenoid Detector Collaboration's (SDC) proposed detector for the Superconducting Super Collider.

The proposed detector is optimized for high-p_t physics; it also has diverse capabilities that make it a premier exploratory tool for a broad range of physics topics. The intent is to construct a detector whose subsystems are fully functional at the design luminosity of $10^{33}cm^{-2}s^{-1}$, and which, with somewhat reduced functionality, can pursue the more specialized physics issues which require substantially higher luminosity.

The document includes a description of the detector and its associated subsystems, experimental halls, surface facilities, assembly and construction, repair time estimates, operational requirements, safety considerations, test beam data, costs, schedules, alternate systems, and appropriate references. Figures and tables support the textual information.

1.2 Detector Description

The SDC detector is a large, general purpose detector with a hermetic calorimeter surrounding a tracking volume immersed in a 2.0 tesla solenoidal magnetic field. Fine-grained electromagnetic and hadron calorimeters cover the pseudo rapidity range between 3 and -3 in the central region. The far forward (backward) region between pseudo rapidities of 3 and 5 (-3 to -5) is covered by a separate calorimeter. Its purpose is to record the energy flow close to the beam direction so that the balance of transverse energy in each event can be determined. External to the central calorimeter is the muon system consisting of iron toroids, tracking chambers and an extensive trigger system employing scintillators and Cerenkov counters. See Table 1.2-1 for detector design goals.

The tracking volume is a right cylinder in length with a radius of 1.7 m centered on the interaction point. The tracking detectors consist of a precision silicon tracking chamber surrounded by a larger central tracking chamber. Table 1.2-2 provides a description of the central tracking system. The momentum resolution of the combined system is designed to measure the charges of tracks with transverse momenta well in excess of 1 TeV. The technology for the central tracking chamber has not been chosen, but will be either a wire straw system, a fiber tracking system, or a combination of the two.

For the central calorimeter two possible options are presented: A scintillator-based calorimeter with photomultiplier tube readout (Option 1), or a calorimeter based on liquid argon (Option 2). The scintillator calorimeter option permits the use of magnetized material for the calorimeter absorber. We have therefore identified two choices for the scintillator calorimeter: Model A, with a ferro-magnetic endcap, and Model B, with a non-magnetic calorimeter. For definiteness, Model B is used in the LOI Option 1. In the same spirit, we have arbitrarily assigned the wire tracking system to Option 1, and the fiber system to Option 2. In fact, either calorimeter can accommodate any choice for the tracking system.

The weight of the detector is dominated by the magnetized iron of the muon toroid system which surrounds the central calorimeter. At 90° the iron is 1.5 m thick. At intermediate angles the thickness of the toroid steel is increased to 4 m, and these end toroids provide most of the momentum information for very high momentum tracks.

Between the toroid steel and the calorimeter is a system of chambers that measure the direction of tracking emerging from the back of the calorimeter. An equivalent set of chambers on the outside of the toroids allows the bend angle (and hence the momentum) of tracks penetrating the steel to be determined. Scintillation counters are used to indicate the presence of a high-momentum track at trigger level 1. At intermediate angles these counters are supplemented by nitrogen gas Cerenkov counters. The logical arrangement of the muon system is the same for both detector options, but the dimensions have been adjusted to accommodate the two different calorimeter sizes as well as differing access and safety requirements.

Tables 1.2-3 to 1.2-5 and Figures 1.2-1 to 1.2-5 provide additional information about the structure, operation and goals of the SDC detector. Tracking systems using wire chambers and scintillating fibers for the outer tracking technologies are shown in Figure 1.2-1 (a) and (b). All tracking elements are organized into superlayers, with each superlayer measuring the space coordinate and the local slope of track segments. As superlayers have significant local pattern-finding capabilities, this results in substantial immunity to detector backgrounds and allows a powerful first-level trigger. The track segments found in each superlayer are readily linked into complete tracks, for example by finding clusters in curvature-azimuth space. Simulations of *Higgs* $\rightarrow ZZ \rightarrow e^+e^-\mu^+\mu^-$ with tracking elements as in Figure 1.2-1 (b) result in high lepton tracking efficiencies even for luminosities substantially greater than 10^{33} $cm^{-2}s^{-1}$

Table 1.2-4 summarizes some of the parameters of the two options. In the scintillator option, lead absorber is used in the electromagnetic section, but two choices of absorber are being explored for the hadronic section. The first is a fine-sampling lead section of about seven interactions lengths (including the electromagnetic section) followed by about three interaction lengths of iron with coarser sampling, that also acts to return the magnet flux from the solenoid. The other choice is a full iron hardonic section, possibly with small amounts of lead to attempt to adjust the ratio of electron to hadron response to be near unity. This second choice has the advantage of somewhat lower cost and a uniform magnetic field for tracking. A combination of the two techniques, iron hadronic calorimetry in the end cap region and lead/iron hadronic calorimetry in the barrel, is also being explored. This would also provide a uniform field.

Table 1.2-5 gives the basic layout and channel count. This arrangement tends to place muon detectors preferentially away from massive iron absorbers. This is beneficial because high-energy muons are often accompanied by soft electromagnetic debris at substantial angles to the muon trajectory. The additional lever arm allows the debris to separate transversely from the muon track so that it will be less often confused with the muon signals at either the trigger or pattern-recognition stage.

Table 1.2-1. Detector Design Goals

	Central $\|\eta\| \lesssim 1.5$	Intermediate $1.5 \lesssim \|\eta\| \lesssim 3.0$	Forward $\|\eta\| \lesssim 3.0$
Tracking:			
Magnetic field	2.0 T	2.0 T	No
Radius	1.70 m	1.70 m	
$\delta p_t/p_t^2$ at 1 TeV/c	< 0.25 (TeV/c)$^{-1}$	1.3 (TeV/c)$^{-1}$ [a]	
Calorimeter:			
Inner boundary[b]	2.05 m	4.2 m	17 m
Depth	$\gtrsim 9\lambda$	$\gtrsim 12\lambda$	$\gtrsim 14\lambda$
Segmentation (Had)	0.05-0.10[c]	0.05-0.10[c]	10 cm × 10 cm
Resolution (Had) $\delta E / E$	$< 0.7/\sqrt{E} \oplus 0.04$[d,e]	$< 0.7/\sqrt{E} \oplus 0.04$	$< 1.0/\sqrt{E} \oplus 0.05$
Resolution (EM) $\delta E / E$	$< 0.25/\sqrt{E} \oplus 0.02$	$< 0.25/\sqrt{E} \oplus 0.02$	
Electron ID	Yes	Yes	None
Muon system:			
Total absorber	$\gtrsim 14\lambda$	$\gtrsim 14\lambda$	
$\delta p_t/p_t^2$ at 1 TeV/c (central tracker plus toroids)	$\lesssim$ 0.13(TeV/c)$^{-1}$	$\lesssim$ 0.45(TeV/c)$^{-1}$ [a]	

[a] At $|\eta| = 2.5$; full tracking capabilities extend to $\eta = 2.5$.
[b] Radius for central calorimeter and z-position for intermediate and forward calorimenters.
[c] $\Delta\eta = \Delta\phi$.
[d] E is in GeV unless otherwise specified.
[e] Here and elsewhere, $\oplus$ indicates addition in quadrature.

Table 1.2-2. Central Tracking

Detector type	Pixels	Silicon Strips	Outer Wires	Outer Scifi
Total number of elements	3.0×10^7	3.6×10^6	1.9×10^5	1×10^6
Number of superlayers	1	4	8	4
Measuring layers/superlayer	2	4	6 (8)	8 (16)
Approx. occupancy per element (in 2 T field at $\mathcal{L} = 10^{33}$ cm^{-2}s^{-1})	10^{-4}	10^{-3}	10^{-1}	10^{-2}
Total radiation lengths at normal incidence	1.5%	5%	4.5%	6.7%
Resolution/measurement	10 μm x 100 μm	15 μm	150 μm	(text)
Two-track resolution	100 μm x 500 μm	150 μm	2 mm	1 mm

Table 1.2-3. Intermediate Angle Tracking

Detector type	Pixels	Silicon Strips	Outer Wires	Outer Scifi
Total number of elements	9×10^6	4.9×10^6	5×10^4	2×10^5
Number of superlayers	1	5[a]	5	3
Measuring layers/superlayer	2	4	8	12
Approx. occupancy per element (in 2 T field at $\mathcal{L} = 10^{33}$ cm^{-2}s^{-1})	10^{-4}	10^{-3}	10^{-1}	10^{-2}
Total radiation lengths at normal incidence	1.5%	6%	6%	8%
Resolution/measurement	10 μm × 100 μm	15 μm	150 μm	250 μm
Two-track resolution	100 μm × 500 μm	150 μm	2 mm	1 mm

[a]Number of superlayers intersected by a track.

Table 1.2-4. Parameters for the Calorimeter Options

	Scintillator Tile Fiber Pb/Fe Absorber	Liquid Argon Lead Absorber
Channel count--towers	41000	93696
Channel count--strips	25000	0[a]
EM depth (X^o) at 90°	25	25
Full depth (λ) at 90°	~ 10	~ 9
Depth segmentation	2 EM, 2 HAD	MG,[b] 2 EM, 2 HAD
$\Delta\phi \times \Delta\eta$	~ 0.05 × 0.05	0.025-0.05 × 0.025-0.05
Peaking time, EM /HAD	15-30/15-30 ns	100/200 ns
EM resolution	$15\%/\sqrt{E} \oplus < 1\%$	$15\% \sqrt{E} \oplus 0.5\%$
Hadronic resolution	$\sim 40\%/\sqrt{E} \oplus \sim 2\%$	$\sim 60\% \sqrt{E} \oplus <4\%$
EM position resolution	2-3 mm[c]	2-5 mm[c]
Electronic plus pileup noise, $\Delta R = 0.15$ cone at 10^{33} cm^{-2}s^{-1}	0.2 GeV	1.2 GeV

[a]EM position resolution is provided by fine tower segmentation. If strips are used, channel count will remain about the same.

[b]MG = Massless gap.

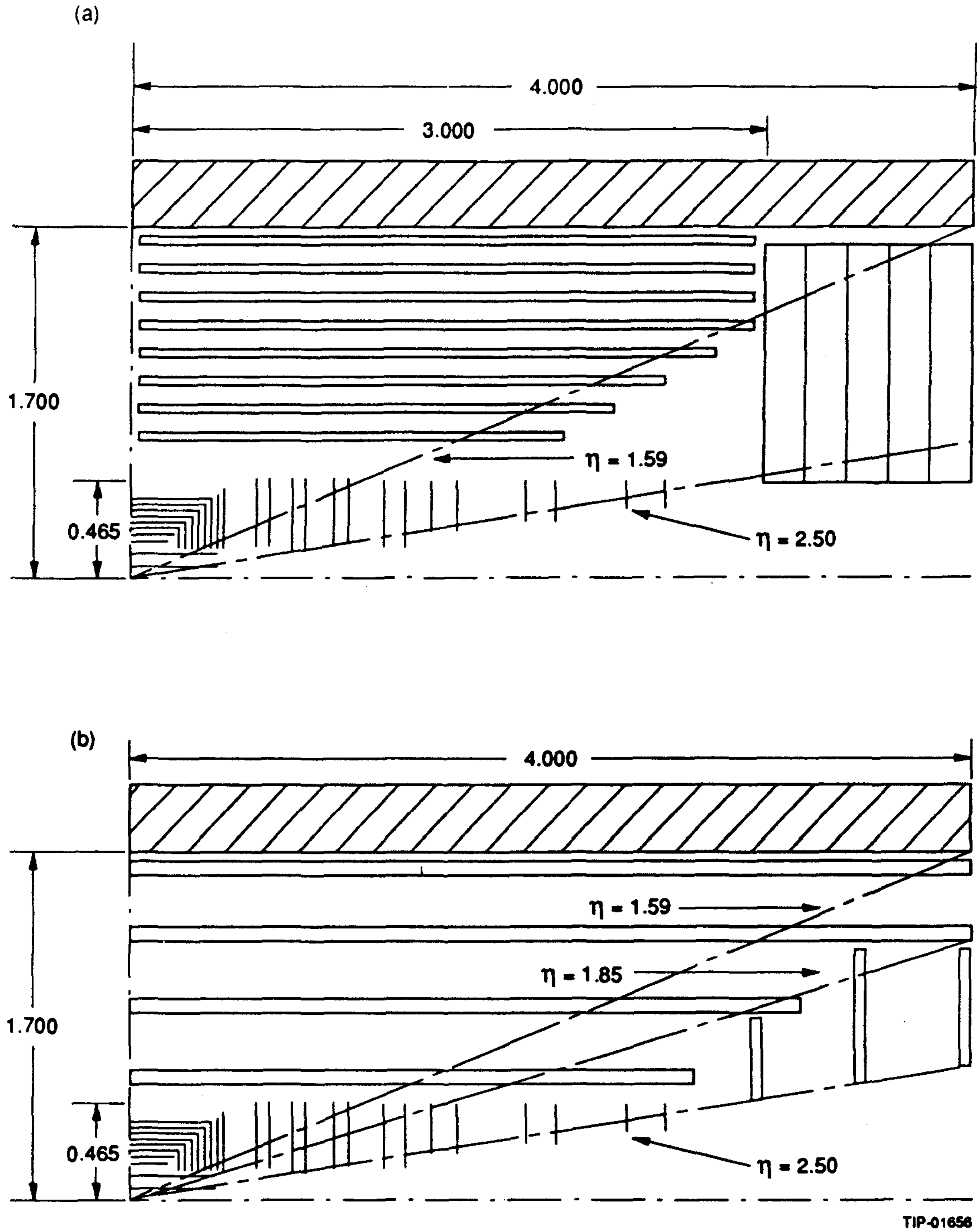
[c]EM position resolutions for one transverse direction for scintillator, and both transverse directions for liquid argon.

Table 1.2-5. Layout and Channel Count for the Muon System

In the first column, WC stands for "wire chamber," SC stands for "scintillation counter," and CC stands for "Cerenkov counter." The coordinates are polar angle θ, azimuthal angle ϕ, and stereo projections s, s_1, s_2 (there are two stereo projections, as explained in the text, at intermediate angles). Furthermore, in the intermediate angle region, the third and fourth chamber layers and the first scintillator layer are split in z since only the region $|\eta| > 1.5$ is behind the 4 m thick iron toroid. Radial and z coordinates are given to the nearest 0.5 m.

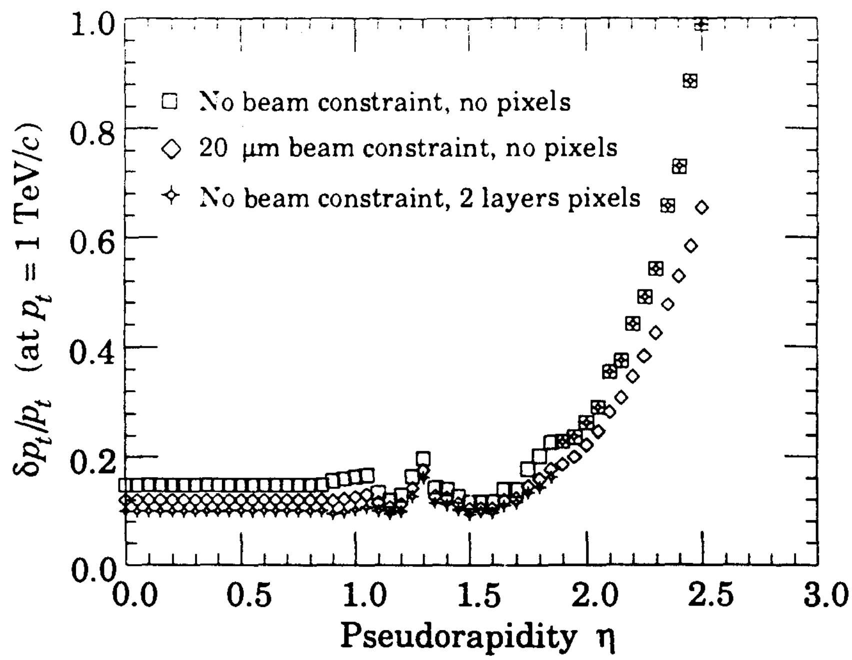
Central Region				
Layer #	Radius (m)	Coor-dinate	Layers	Channels (k)
WC1	6.5	θ	6	12.1
		ϕ	4	4.0
		s	2	4.1
WC2	9.0	θ	4	11.2
SC1	9.5	θ	1	2.5
WC3	11.0	θ	6	18.6
		ϕ	4	10.0
		s	2	6.2
SC2	11.5	θ	1	2.5
Totals			28 WC 2 SC	66.2 WC 5.0 SC
Grand Total				

Intermediate Angle Region				
Layer #	z (m)	Coor-dinate	Layers	Channels (k)
WC1	8.0	θ	4	4.0
WC2	10.0	θ	4	5.2
		s_1, s_2	4	5.2
SC1	13.0/16.0	θ	1	1.4
WC3	12.5/15.5	θ	4	7.2
CC1	17.0		1	0.5
SC2	16.0/18.0	θ	1	1.4
WC4	15.5/17.5	θ	6	12.4
		s_1, s_2	4	8.2
Totals			26 WC 2 SC 1 CC	42.2 WC 2.8 SC 0.5 CC
Grand Total				108.4 WC 7.8 SC 0.5 CC



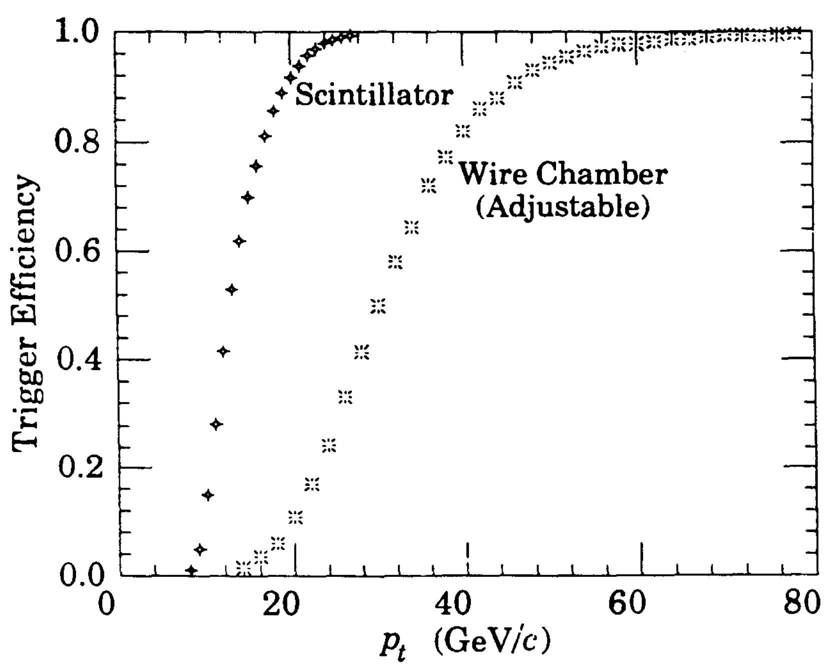
At small radius are silicon pixel and strip detectors. Surrounding these are (a) barrel superlayers of straw tubes with radial wire chambers covering the intermediate-angle region; (b) an alternative implementation employing scintillating fiber modules for both the barrel and end regions. Dimensions are in meters.

Figure 1.2-1. Tracking System for the SDC Detector



Momentum resolution vs. η for either the pixel/silicon strip/wire chamber outer tracking system or the pixel/silicon strip/scintillating fiber outer tracking system, based on 100% measurement efficiency and the resolution given in Tables 1.2-2 and 1.2-3. Systematic errors are not included.

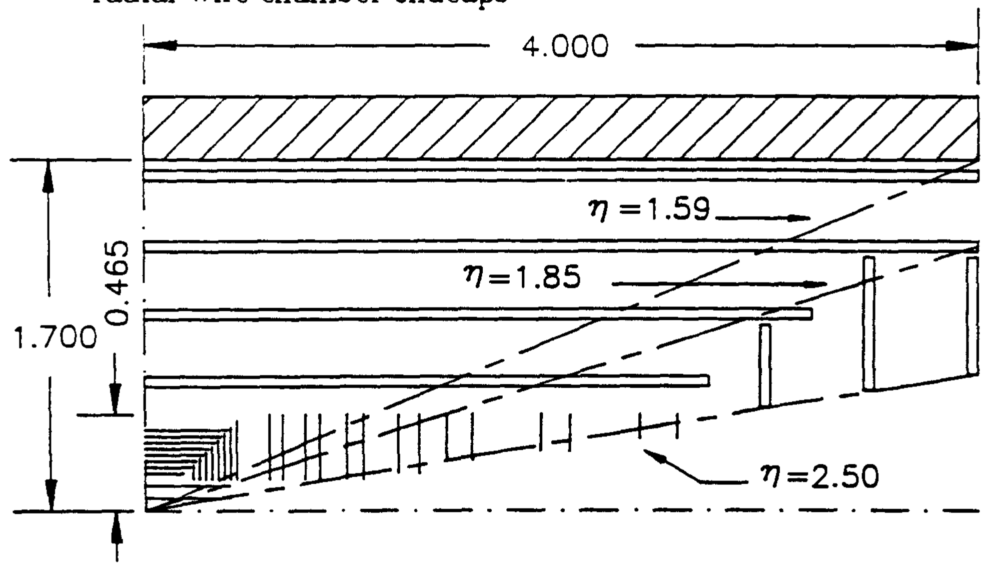
Figure 1.2-2. Momentum Resolution



First-level trigger efficiency of the muon system scintillator and wire chamber triggers. The wire chamber trigger threshold is adjustable. A typical setting is shown.

Figure 1.2-3. Trigger Efficiency

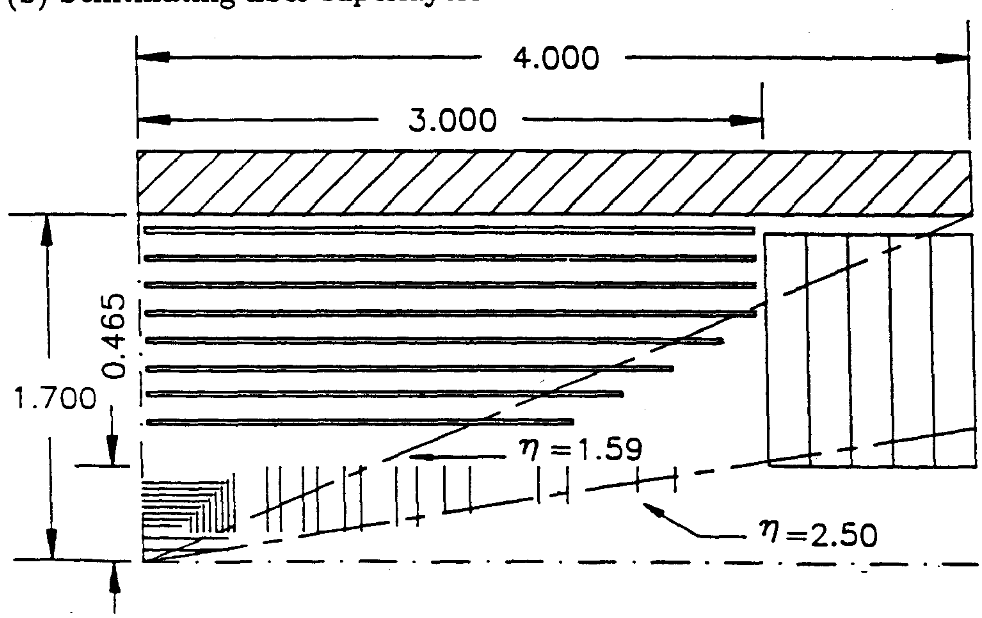
(a) Barrel superlayers of straw tubes,
radial wire chamber endcaps



Muon momentum resolution as a function of pseudorapidity for various values of transverse momentum.

Figure 1.2-4. Muon Momentum Resolution (1)

(b) Scintillating fiber superlayers



Muon momentum resolution as a function of pseudorapidity for higher-than-design luminosity. It is assumed that the only operational tracking elements are the outer superlayer of the central tracker and the muon system.

Figure 1.2-5. Muon Momentum Resolution (2)

1.3 Detector LOI Option 1 (Pb/Scintillator Calorimeter)

Figure 1.3-1 shows an isometric view of the SDC detector. Figure 1.3-2 shows the detector with calorimetry based on lead and iron absorbers and scintillator-tiles with wave-shifting fiber readout. Inside the short coil, the central tracker consists of a small-radius silicon strip and pixel system, plus a wire or scintillating fiber tracking system at the larger radii. The return flux is carried partly by the structural element shown at the back of the calorimeter and partly by steel used as the absorbing medium in the last few interaction lengths of the calorimeter. The muon system consists of two scintillator layers for triggering and a set of wire tracking modules. Momentum measurements independent of central tracking information are provided by the iron toroids in both the central and forward directions. It should be noted that the combination of measurements in the ϕ direction in the central tracker and in the muon system provides a precision for high energy muons that is significantly better than with either system alone. Figures 1.3-3 and 1.3-4 depict subsystems supports and locations of utilities, respectively.

1.4 Detector LOI Option 2 (Liquid Argon Calorimeter)

Figure 1.4-1 shows a view of the Option 2 detector with liquid argon calorimetry in operating position. Figure 1.4-2 is a quadrant view of the detector. Note the absence of radial access space, which is motivated by the larger radial dimension of the liquid argon calorimeter and by the likelihood that safety considerations would preclude use of access space with a liquid argon calorimeter. The flux return is completely external. The central tracking and muon systems are unchanged. Figures 1.4-3 and 1.4-4 depict subsystems supports and locations of utilities, respectively.

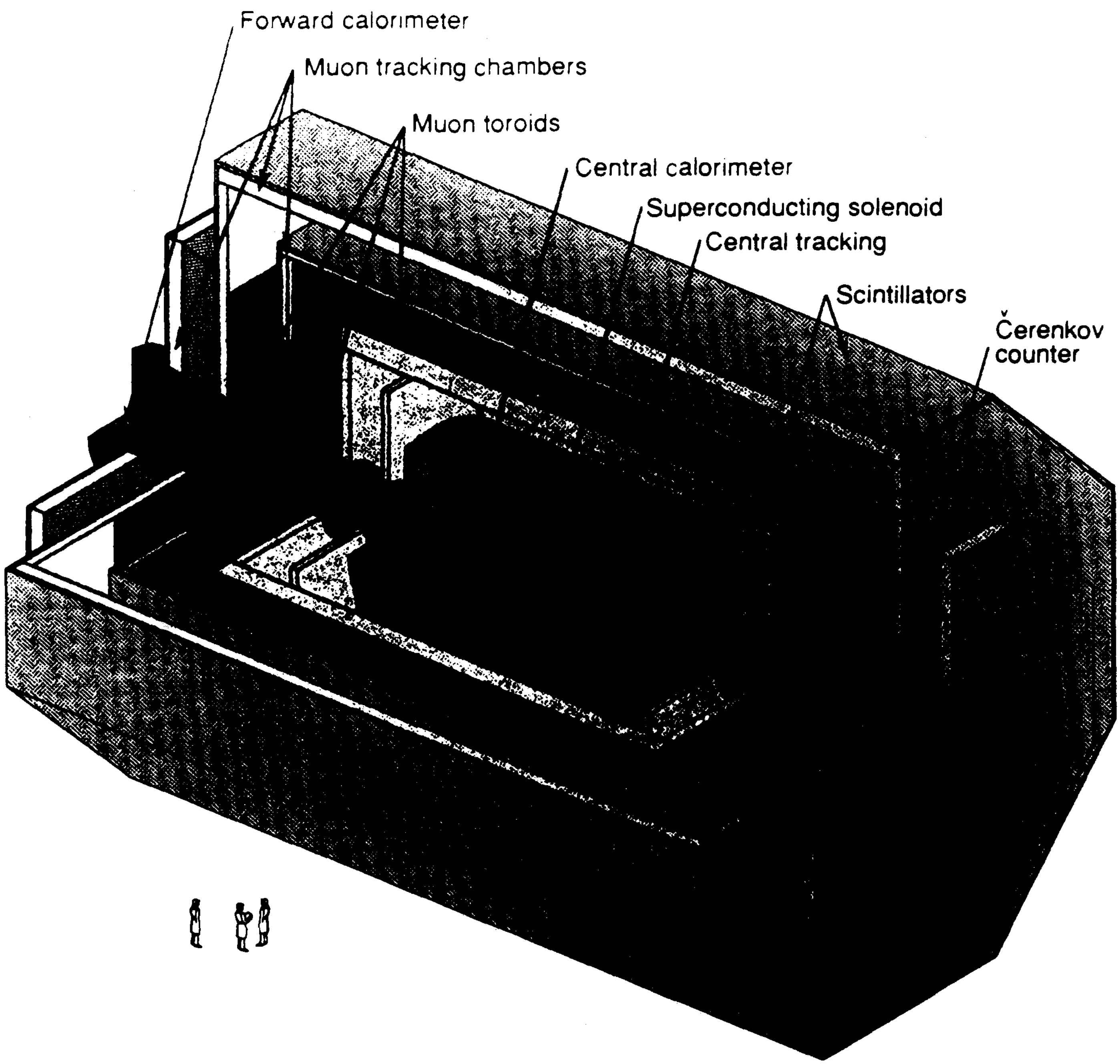


Figure 1.3-1. Isometric View of the Solenoid Detector

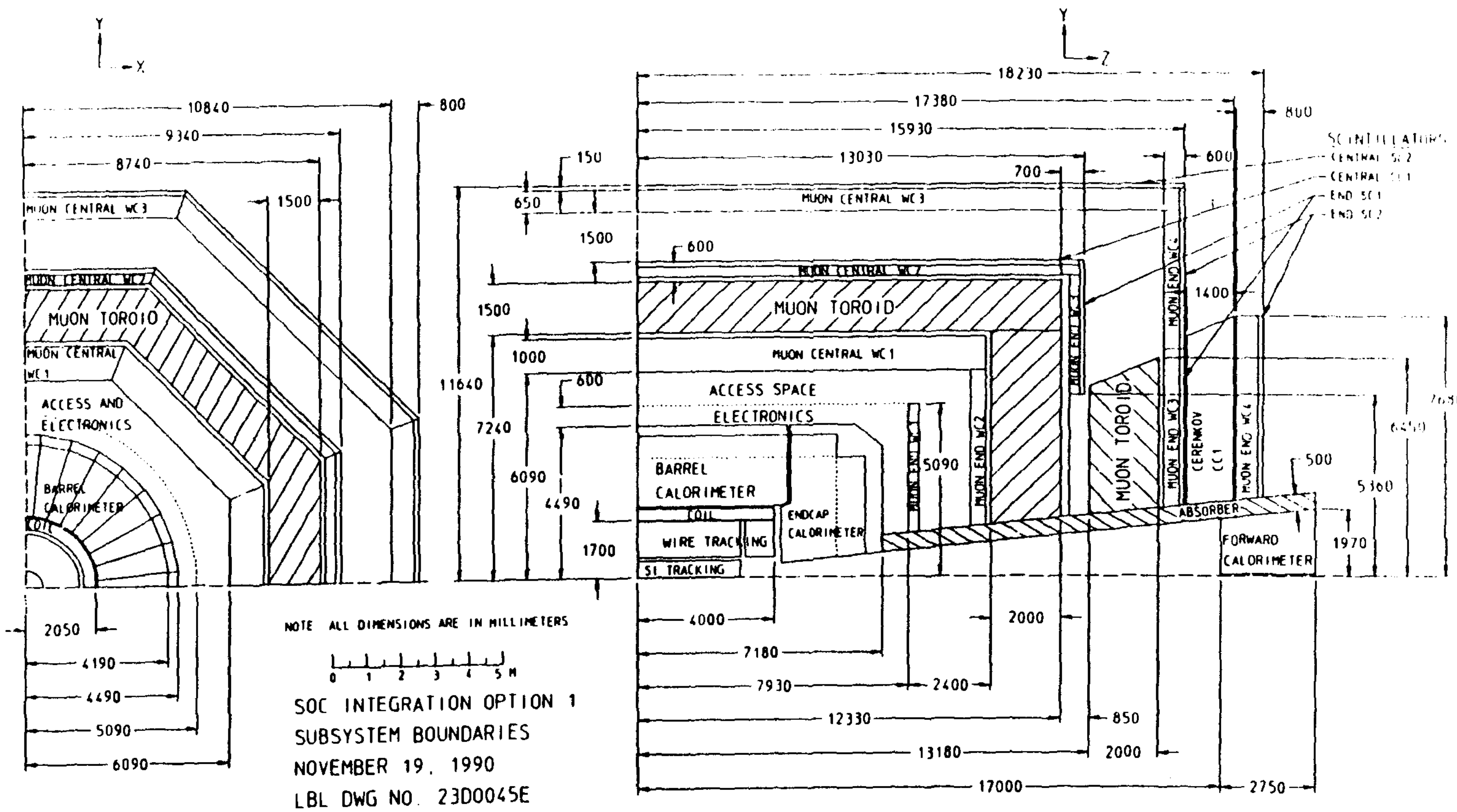


Figure 1.3-2. Subsystem Boundaries (Option 1)

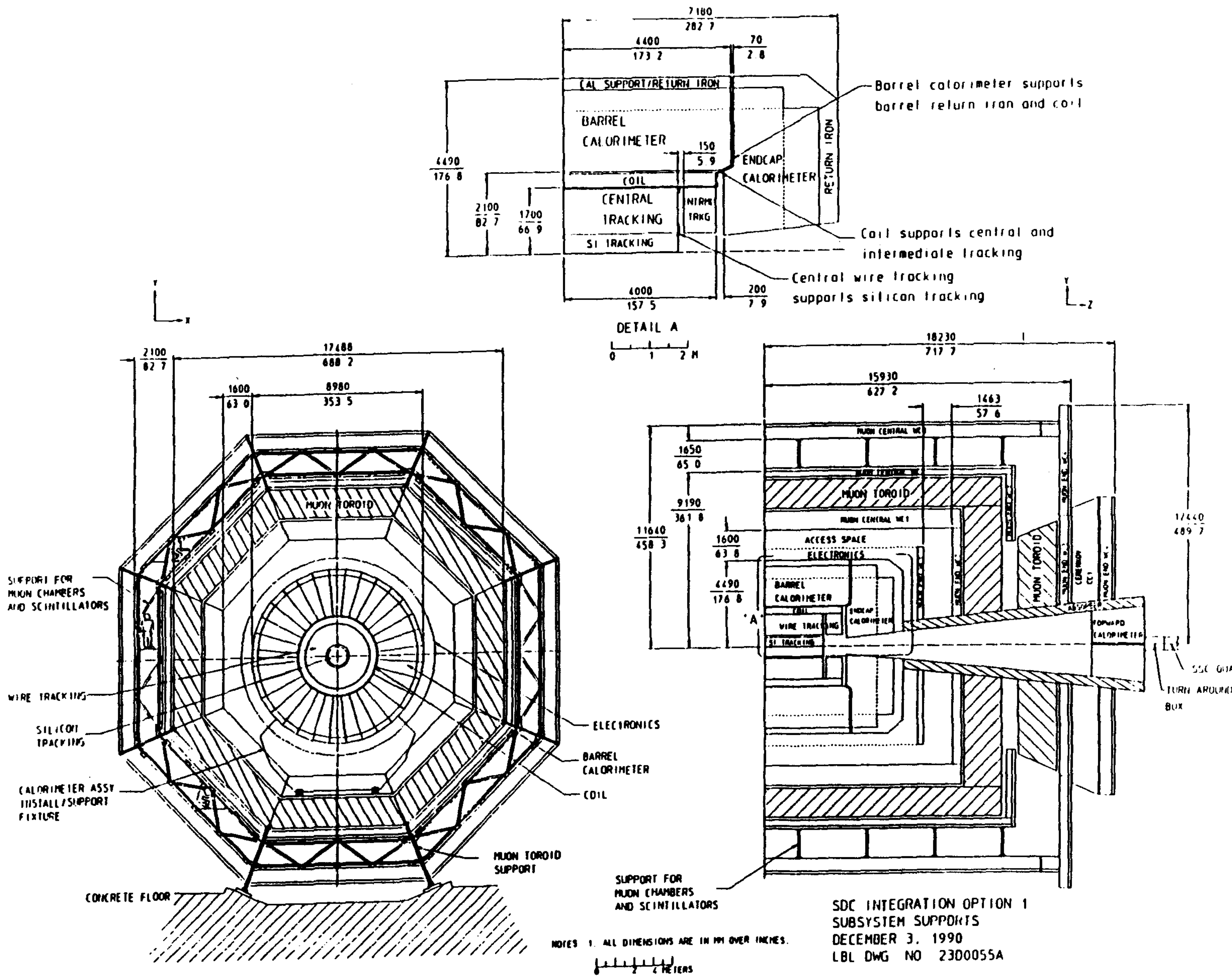


Figure 1.3-3. Subsystem Supports (Option 1)

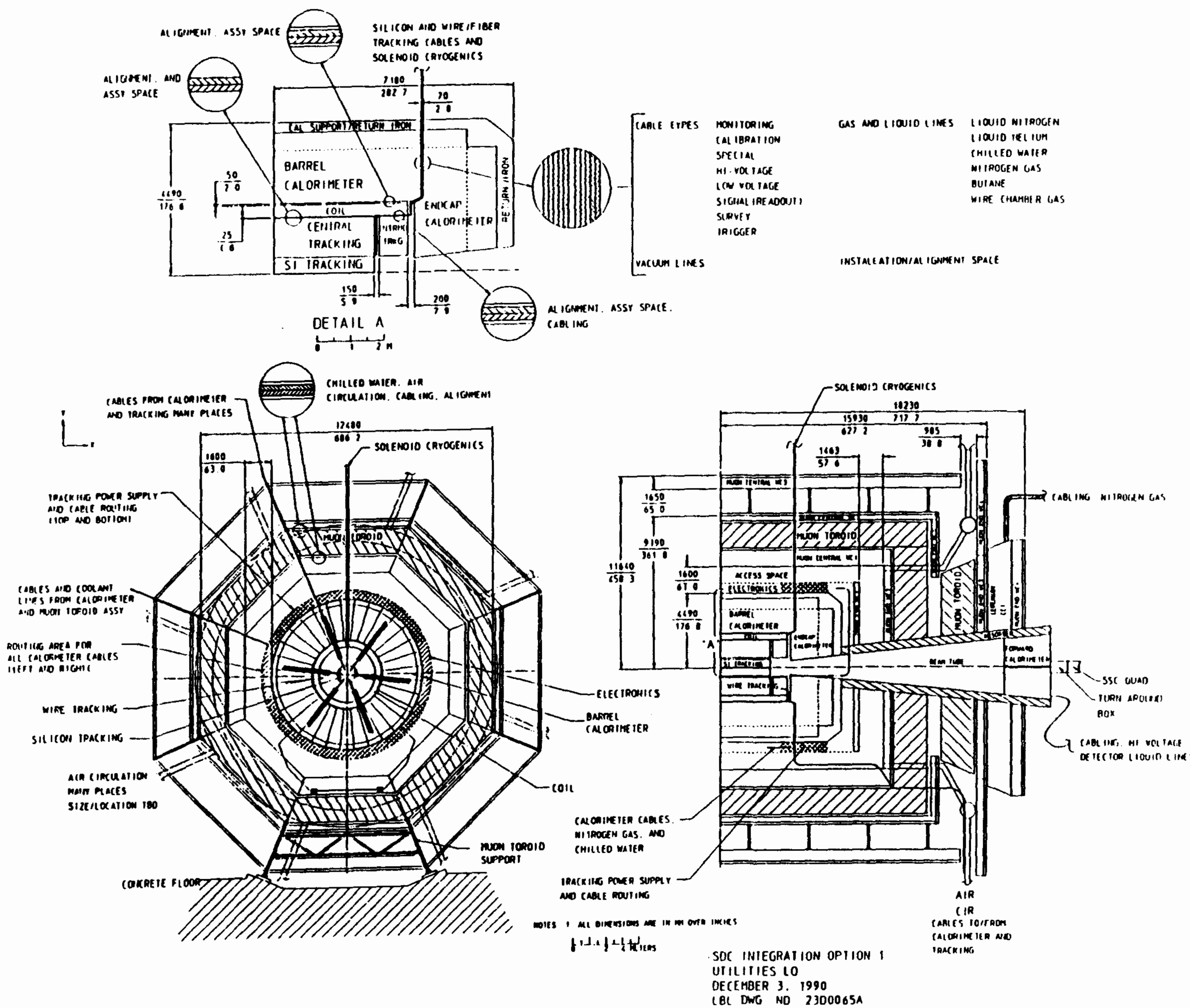


Figure 1.3-4. Utilities Locations (Option 1)

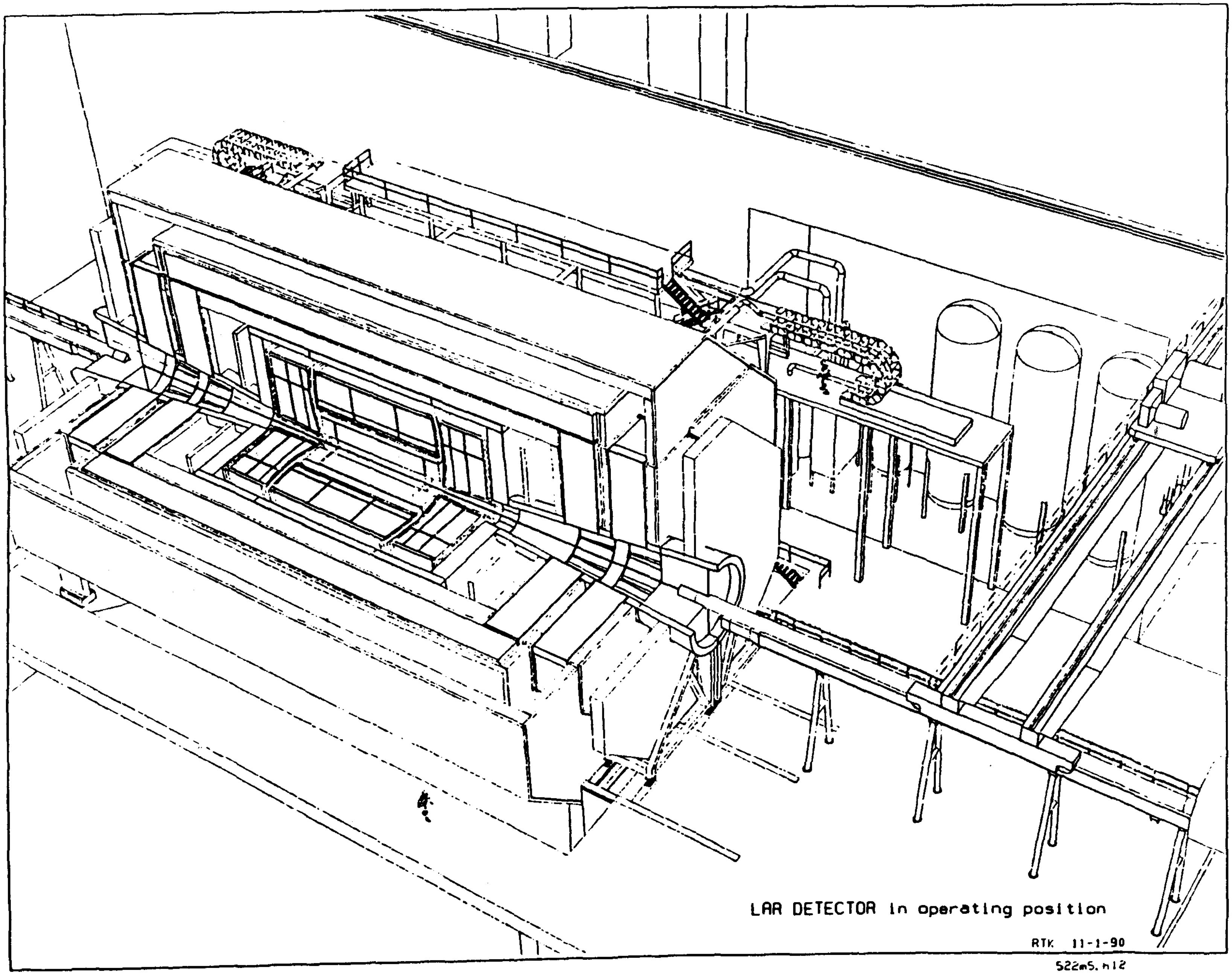


Figure 1.4-1. Liquid Argon Detector

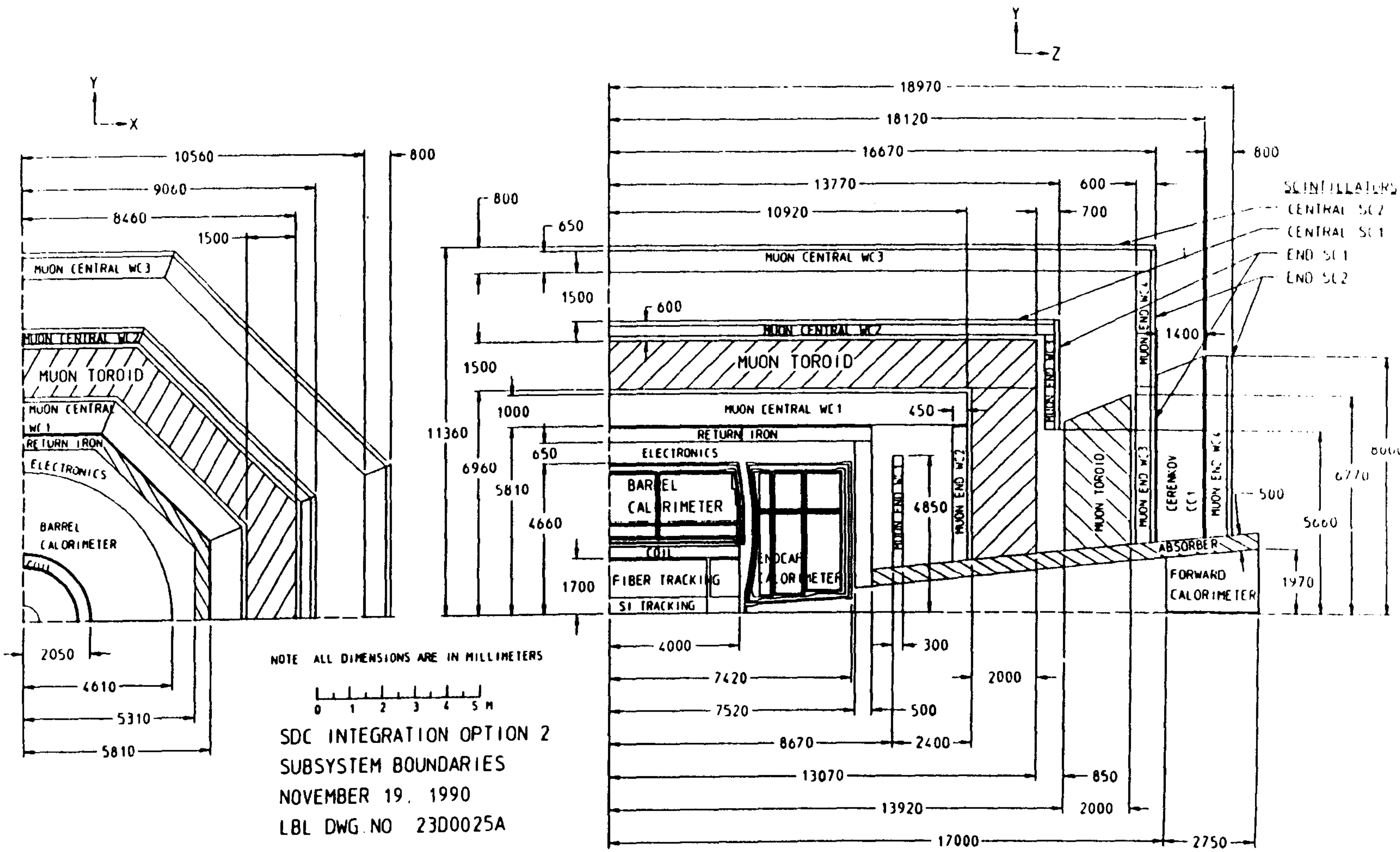


Figure 1.4-2. Subsystem Boundaries (Option 2)

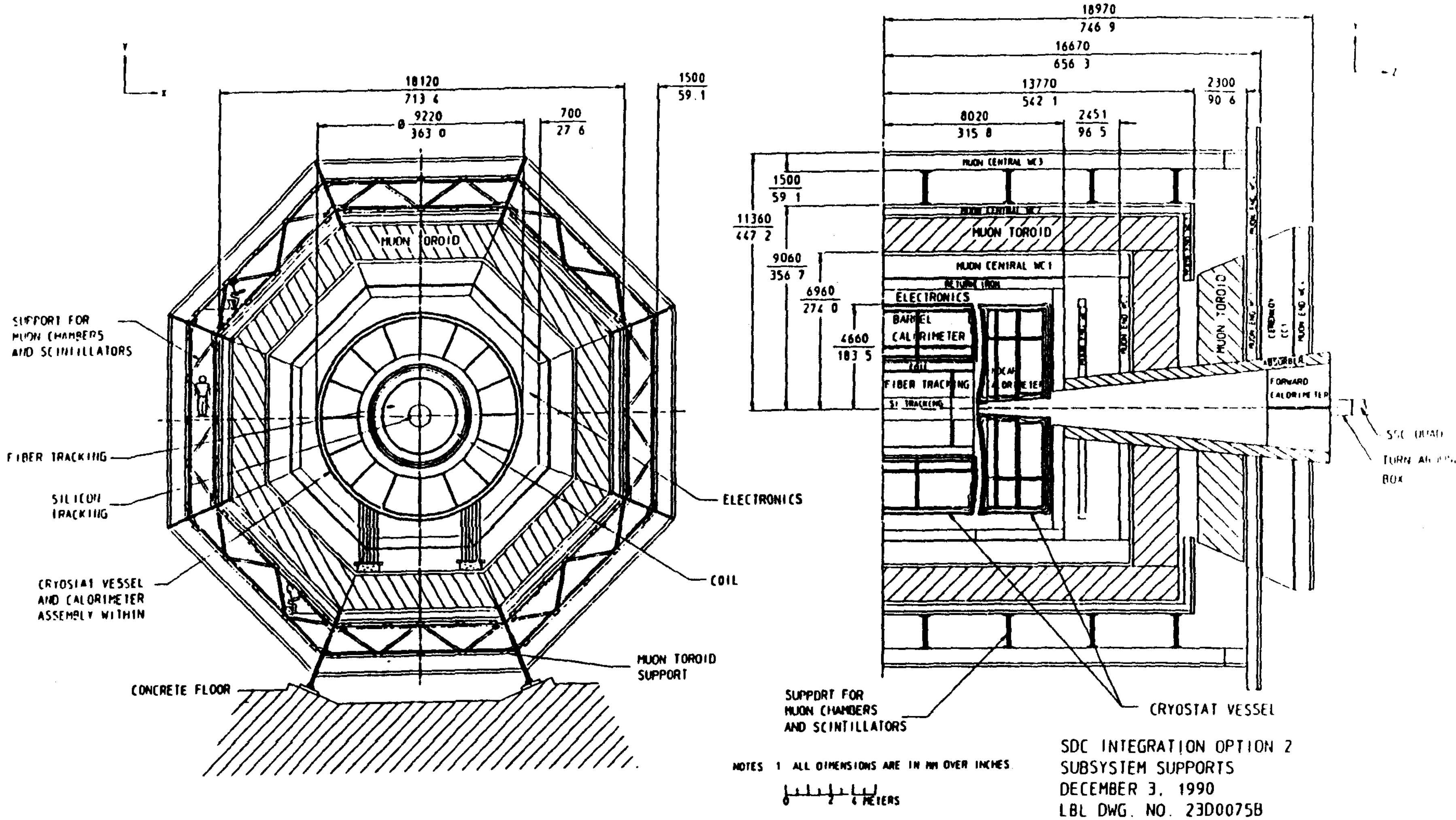


Figure 1.4-3. Subsystem Supports (Option 2)

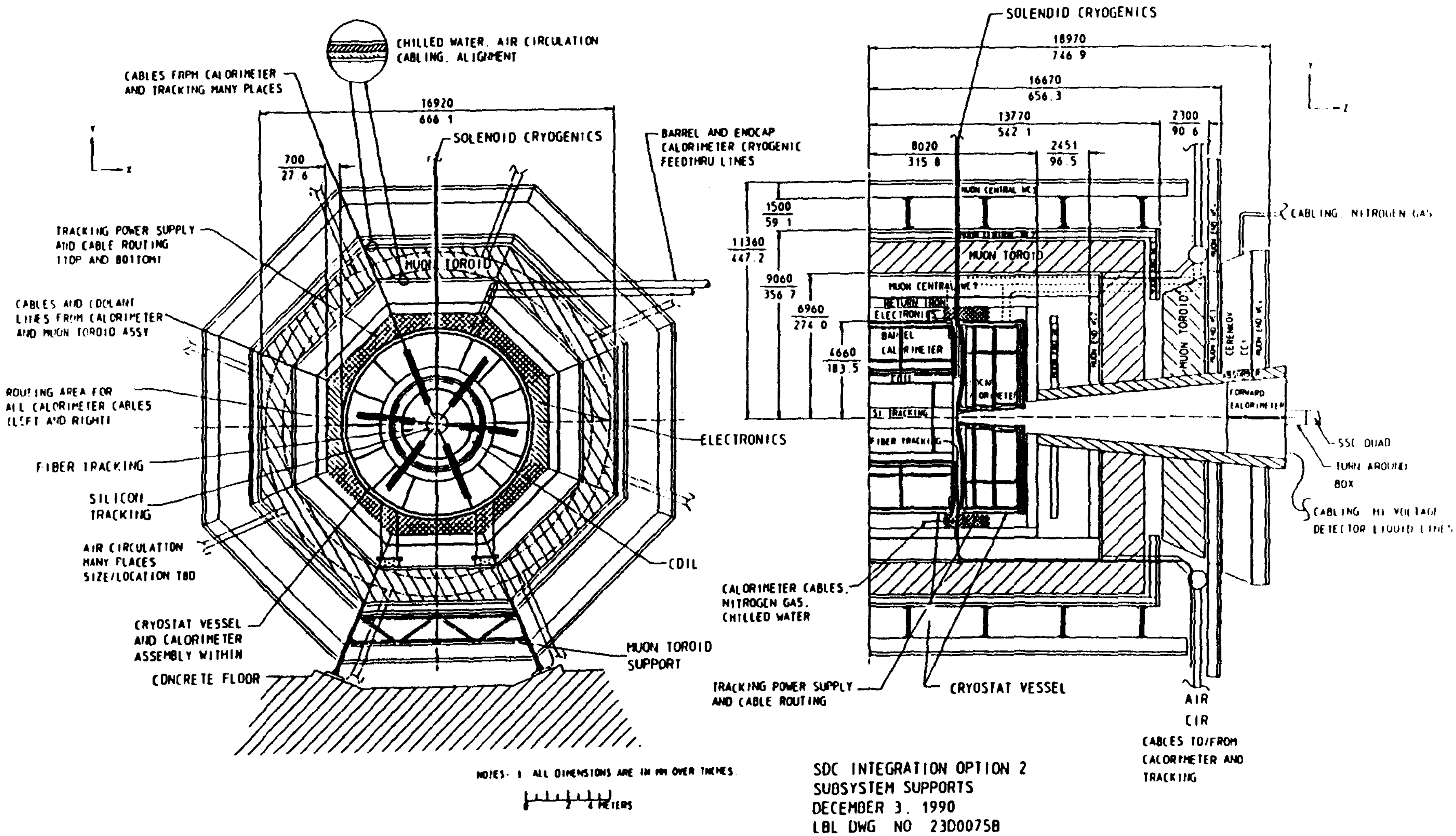


Figure 1.4-4. Utilities Locations (Option 2)

2.0 DETECTOR SUBSYSTEMS

The physics goals of the SDC include studies of electroweak symmetry-breaking and of properties of the top quark; searches for heavier gauge bosons, for evidence of compositeness, and for new particles implied by supersymmetry; and above all, the quest to uncover totally new and unexpected phenomena.

To meet the challenges implicit in these goals, a general purpose detector is proposed, with central tracking in a solenoid field, hermetic calorimetry, identification and energy measurement of electrons and muons, and high resolution vertex detection. This section considers the design and operation of the detector subsystems critical to the realization of these goals.

2.1 Silicon/Pixel Tracking
2.2 Central Tracking
  2.2.1 Wire Tracking Option
  2.2.2 Fiber Tracking Option
2.3 Solenoid Coil
2.4 Calorimeter
  2.4.1 Pb/Scintillator Tile option
  2.4.2 Liquid Argon Calorimeter Option
2.5 Muon System
2.6 Data Acquisition
2.7 Weights and Measures

2.1 Silicon/Pixel Tracking

The silicon system (Figures 2.1-1 to 2.1-16 and Tables 2.1-1 to 2.1-8) consists of an array of two-dimensional pixel detectors plus a large array of silicon strip detectors. The pixel detector consists of two concentric cylindrical layers and two disk arrays, and covers a pseudorapidity interval $|\eta| < 1.9$. The pixel detector is contained within a radius of 10 cm and ±22 cm along the beam direction. Pixel sizes are expected to be 30 μm × 300 μm in the ϕ and z directions respectively, and the position resolutions are expected to be better than 10 μm in ϕ and 100 μm in z. The pixel superlayer aids pattern recognition, provides superb capability to detect separated vertices from heavy quark decays, and contributes to momentum resolution.

The silicon strip detectors are arranged in 8 cylindrical layers and 44 planar layers. The silicon layers will be instrumented with either double-sided strip detectors or with single-sided short-strip detectors. The double-sided strip detectors have axial (or ϕ) strips on one side and small-angle stereo strips on the other side of each detector, while the single-sided short-strip detectors have each strip subdivided into many short strips to provide pixel-like information. Two layers of such detectors form a superlayer.

2.2 Central Tracking

The central tracking system consists of the following elements, listed in order of increasing radius:

1. Two-dimensional pixel silicon detectors to aid pattern recognition and detect separated vertices from heavy quark decay;

2. An array of silicon strip detectors to provide pattern recognition and momentum measurement in the pseudorapidity range $|\eta| < 2.5$;

3. A wire-chamber and/or scintillating fiber system to provide the curvature determination needed for high precision momentum and vertex measurements and trigger information for high-p_t particles over the same pseudorapidity range.

Table 2.1-1. Pixel, Central, Transition, and Forward Dimensions (Refer to Figure 2.1-1)

Pixel

Cylinder	R		Z, ±	Area	
1	0.050		0.100	0.126	Superlayer
2	0.100		0.200	0.251	
			Area subtotal	0.377	

Plane	R 1	R 2	Z, ±	Area
1	0.032	0.060	0.120	0.016
2	0.059	0.110	0.220	0.054
			Area subtotal	0.070

Total pixel area 0.447 m^2

Central

Cylinder	R	Z, ±	Area
1	0.180	0.180	0.407
2	0.210	0.210	0.554
3	0.240	0.240	0.724
4	0.270	0.270	0.916
5	0.300	0.300	1.131
6	0.330	0.330	1.368
7	0.360	0.360	1.629
8	0.390	0.390	1.911
		Total area =	8.641

Transition

Plane	R 1	R 2	Z, ±	Area
1	0.150	0.225	0.225	0.177
2	0.150	0.255	0.255	0.267
3	0.150	0.285	0.285	0.369
4	0.150	0.315	0.315	0.482
5	0.150	0.345	0.345	0.606
6	0.150	0.375	0.375	0.742
7	0.150	0.405	0.405	0.889
8	0.150	0.435	0.435	1.048
			Total area =	4.580

Forward

Plane	R 1	R 2	Z, ±	Area
9	0.150	0.465	0.595	1.217
10	0.150	0.465	0.645	1.217
11	0.150	0.465	0.770	1.217
12	0.150	0.465	0.840	1.217
13	0.150	0.465	0.970	1.217
14	0.150	0.465	1.050	1.217
15	0.180	0.465	1.220	1.155
16	0.180	0.465	1.320	1.155
17	0.240	0.465	1.450	0.997
18	0.240	0.465	1.570	0.997
19	0.285	0.465	1.900	0.848
20	0.285	0.465	2.040	0.848
21	0.345	0.465	2.370	0.611
22	0.345	0.465	2.550	0.611
			Total area =	14.525
			Total planner area =	19.105

Total silicon area = 28.19 m^2

Table 2.1-2. Coverage of Different Sections

Section	Pseudorapidity Coverage	Number Channels	Number Chips	Area Covered, m ^2
Pixel	0-2.03	29,209,600	4,564	0.45
Central	0-0.88	2,138,880	33,420	8.64
Transition	0.88-1.79	1,402,624	21,916	4.58
Forward	1.07-2.70	4,652,544	72,696	14.52
TOTALS =	0-2.70	37,403,648	132,596	28.19

Table 2.1-3. Silicon Detector Cooling

Estimated heat load	10 kW
Design heat load	40 kW
Method of cooling	Evaporative
Coolant	Hydrocarbon
Operating pressure	0.101 MPa
Operating temperature	0 Deg. C
Liquid flow rate	0.095 kg/s
Vapor flow rate	0.0376 m ^3/s

Above rates based upon butane coolant.

Table 2.1-4. Weight Estimates (in Kilograms)

Component	Silicon	Material Graphite/ Epoxy	Metal Matrix Composite	Misc.
Detectors				
Central	6.1			
Trans/forward	13.4			
Support box/cooling rings				
Central		3.3*		
Trans/forward			19.7**	
Support Shells				
Central		4.2		
Internal Support Frame			21.7***	
External Enclosure		25.0		
Cabling				74.0****
Misc.				5.0
Subtotals =	19.5	32.5	41.4	79.0
		Grand Total =	172.4 kg	

* Based on 26 rings
** Based on 82 rings
*** Frame tube 35-mm OD; 25-mm ID
**** Based upon 40 kW with 1 kW loss in conductor

Table 2.1-5. Pixel Details

Size	30 × 300 μm
Detector width	10 - 20 mm
Detector length	10 - 20 mm
Detector thickness	150 - 200 μm
Readout width	12 - 22 mm
Readout length	10 - 22 mm
Readout thickness	150 - 250 μm
Readout power	250 mW/cm ^2
Channels/detector	10000 - 40000
Input voltage, data functions	5 V
Input voltage, depletion	60 - 100 V

Table 2.1-6. Central Detector Details

Detector	Single and Double-sided strips
Maximum detector width	36.2 mm
Minimum detector width	33.0 mm
Detector length	6.0 mm
Detector thickness	300 μm
Angle from tangent	7.4 Degrees
Strip pitch	50 μm
Strips/chip	64
Cylinders 4 & 5	Single sided
Power/channel	1 mW
Electronic heat flux	100 μW/m ^2

Table 2.1-7. Transition and Forward Region Details

Detector size	See Figures 2.1-7 to 2.1-16
Channels/plane	See Table 2.1-8
Strip orientation	All point to centerline
Channels/readout	64
Planes 12 & 16	Single sided

Table 2.1-8. Channel Count for Planes

plane	Z cm	R1 cm	R2 cm	Area m^2	Ra cm	Rb cm	Rc cm	Rd cm	sides	Wafer ab	Wafer cd
1	22.5	15	22.5	0.177	15	22.5			2	23	0
2	25.5	15	25.5	0.267	15	25.5			2	26	0
3	28.5	15	28.5	0.369	15	28.5			2	30	0
4	31.5	15	31.5	0.482	15	31.5			1	31	0
5	34.5	15	34.5	0.606	15	22.5	22.5	34.5	1	23	36
6	37.5	15	37.5	0.742	15	25.5	25.5	37.5	2	26	38
7	40.5	15	40.5	0.889	15	28.5	28.5	40.5	2	30	42
8	43.5	15	43.5	1.048	15	31.5	31.5	43.5	2	31	44
9	59.5	15	46.5	1.217	15	28.5	28.5	46.5	2	30	48
10	64.5	15	46.5	1.217	15	28.5	28.5	46.5	2	30	48
11	77	15	46.5	1.217	15	28.5	28.5	46.5	2	30	48
12	84	15	46.5	1.217	15	28.5	28.5	46.5	2	30	48
13	97	15	46.5	1.217	15	28.5	28.5	46.5	2	30	48
14	105	15	46.5	1.217	15	28.5	28.5	46.5	1	30	48
15	122	18	46.5	1.155	18	28.5	28.5	46.5	2	36	48
16	132	18	46.5	1.155	18	28.5	28.5	46.5	2	36	48
17	145	24	46.5	0.997	24	34.5	34.5	46.5	2	36	48
18	157	24	46.5	0.997	24	34.5	34.5	46.5	1	36	48
19	190	28.5	46.5	0.848	28.5	34.5	34.5	46.5	2	36	48
20	204	28.5	46.5	0.848	28.5	34.5	34.5	46.5	2	36	48
21	237	34.5	46.5	0.611			34.5	46.5	2	0	48
22	255	34.5	46.5	0.611			34.5	46.5	2	0	48
SUM				19.105						616	832

Table 2.1-8. Channel Count for Planes (cont)

	Widths in cm							Pitch in µm			
plane	Width a	Width b	Width c	Width d	Chip Chans	ab IN-OUT	cd IN-OUT	chips ab	chips cd	pitch ab El	pitch ab -
1	4.098	6.147	0.000	0.000	64	1	0	19		50.548	33.698
2	3.625	6.162	0.000	0.000	64	1	0	19		50.677	29.810
3	3.142	5.969	0.000	0.000	64	1	0	18		51.814	27.271
4	3.040	6.385	0.000	0.000	64	1	0	19		52.504	25.002
5	4.098	6.147	3.927	6.021	64	1	0	19	12	50.548	33.698
6	3.625	6.162	4.216	6.201	64	1	0	19	13	50.677	29.810
7	3.142	5.969	4.264	6.059	64	1	0	18	13	51.814	27.271
8	3.040	6.385	4.498	6.212	64	1	0	19	14	52.504	25.002
9	3.142	5.969	3.731	6.087	64	1	1	18	19	51.814	27.271
10	3.142	5.969	3.731	6.087	64	1	1	18	19	51.814	27.271
11	3.142	5.969	3.731	6.087	64	1	1	18	19	51.814	27.271
12	3.142	5.969	3.731	6.087	64	1	1	18	19	51.814	27.271
13	3.142	5.969	3.731	6.087	64	1	1	18	19	51.814	27.271
14	3.142	5.969	3.731	6.087	64	1	1	18	19	51.814	27.271
15	3.142	4.974	3.731	6.087	64	1	1	15	19	51.814	32.725
16	3.142	4.974	3.731	6.087	64	1	1	15	19	51.814	32.725
17	4.189	6.021	4.516	6.087	64	1	1	18	19	52.269	36.361
18	4.189	6.021	4.516	6.087	64	1	1	18	19	52.269	36.361
19	4.974	6.021	4.516	6.087	64	1	1	18	19	52.269	43.179
20	4.974	6.021	4.516	6.087	64	1	1	18	19	52.269	43.179
21	0.000	0.000	4.516	6.087	64	1	1		19		
22	0.000	0.000	4.516	6.087	64	1	1		19		

Table 2.1-8. Channel Count for Planes (cont)

plane	pitch cd El	pitch cd -	.5 SUM chips ab	.5 SUM chips cd	Chips sum	channels	
1			874	0	1,748	111,872	
2			988	0	1,976	126,464	
3			1080	0	2,160	138,240	
4			589	0	1,178	75,392	
5	51.133	78.403	437	432	1,738	111,232	
6	50.677	74.525	988	988	3,952	252,928	
7	51.245	72.822	1080	1092	4,344	278,016	
8	50.203	69.328	1178	1232	4,820	308,480	Trans sum
9	50.056	30.680	1080	1824	5,808	371,712	1,402,624
10	50.056	30.680	1080	1824	5,808	371,712	
11	50.056	30.680	1080	1824	5,808	371,712	
12	50.056	30.680	1080	1824	5,808	371,712	
13	50.056	30.680	1080	1824	5,808	371,712	
14	50.056	30.680	540	912	2,904	185,856	
15	50.056	30.680	1080	1824	5,808	371,712	
16	50.056	30.680	1080	1824	5,808	371,712	
17	50.056	37.138	1296	1824	6,240	399,360	
18	50.056	37.138	648	912	3,120	199,680	
19	50.056	37.138	1296	1824	6,240	399,360	
20	50.056	37.138	1296	1824	6,240	399,360	
21	50.056	37.138	0	1824	3,648	233,472	
22	50.056	37.138	0	1824	3,648	233,472	Forwd sum
			19850	27456	94,612	6,055,168	4,652,544

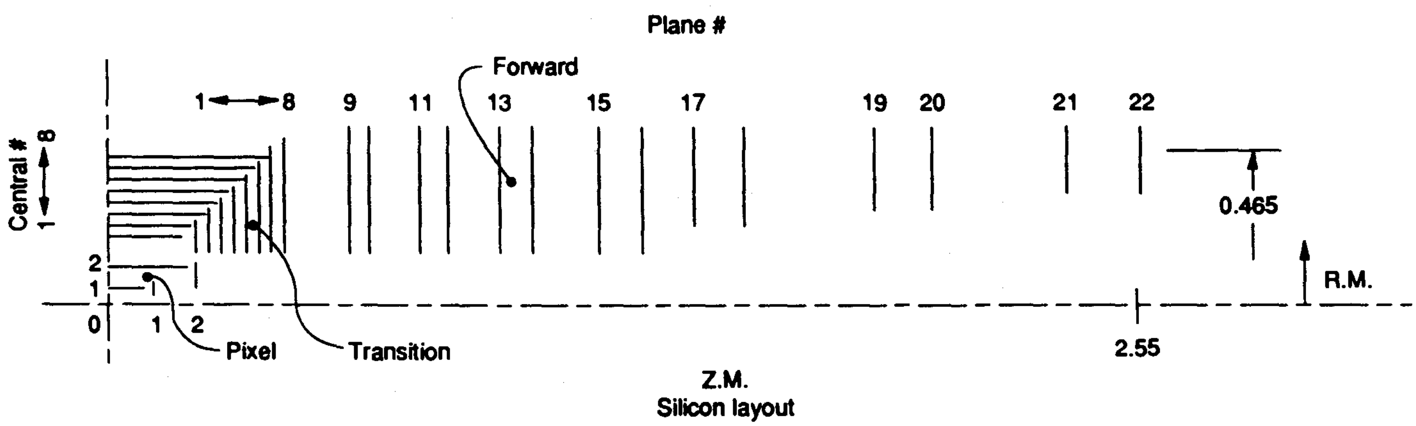


Figure 2.1-1. Layout of Silicon Detector Cylinders and Planes.

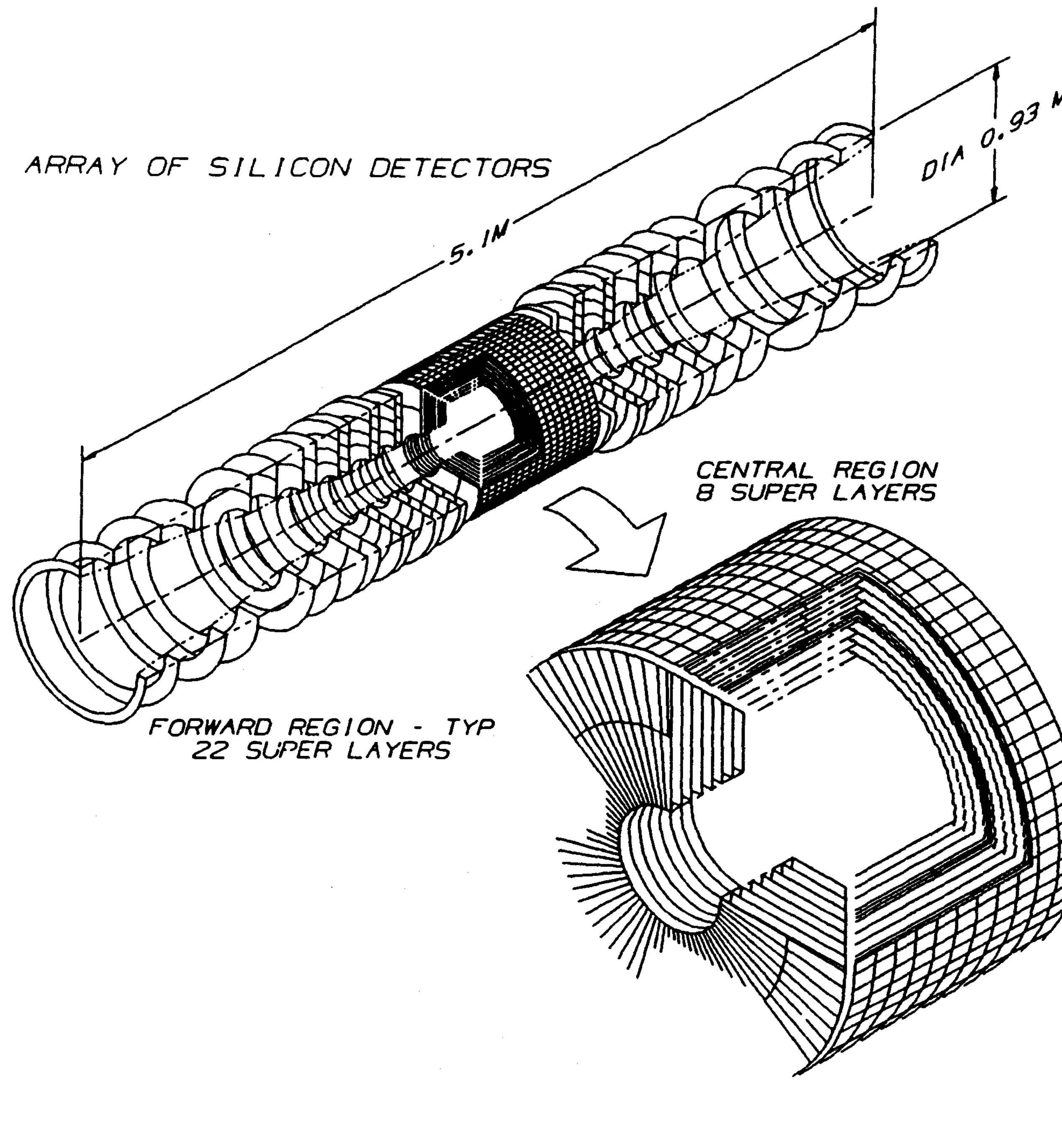


Figure 2.1-2. Overall View of Tracker with Enlargement of Central and Transition Regions

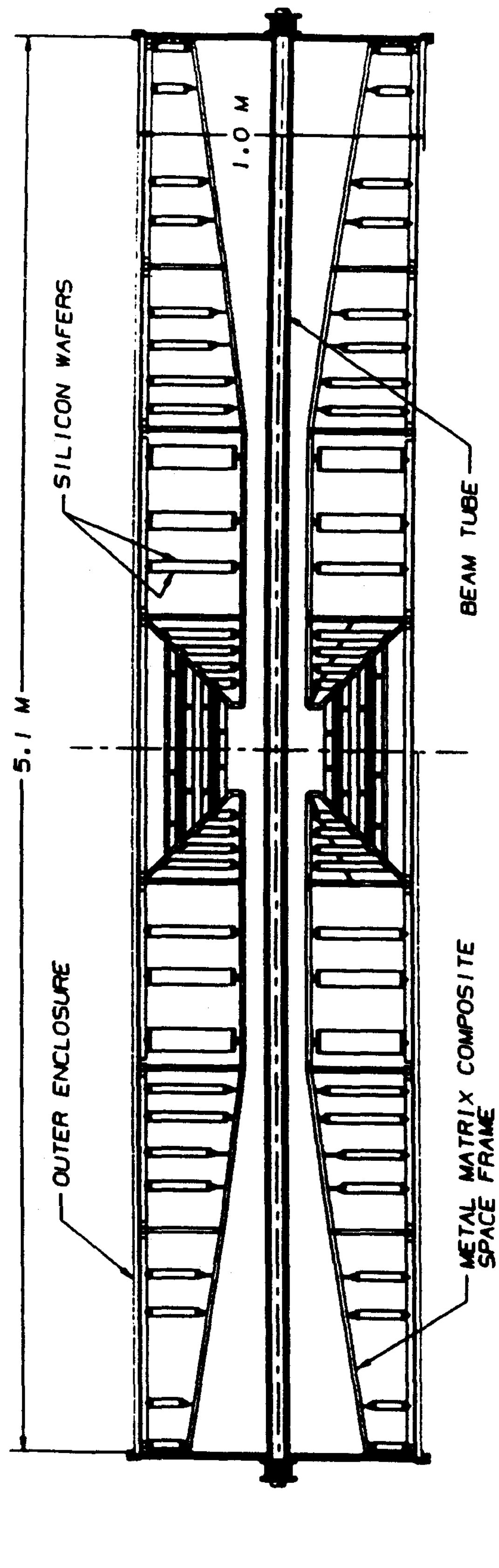


Figure 2.1-3. Overall View Showing Some of the Structural Members and the Beam Tube

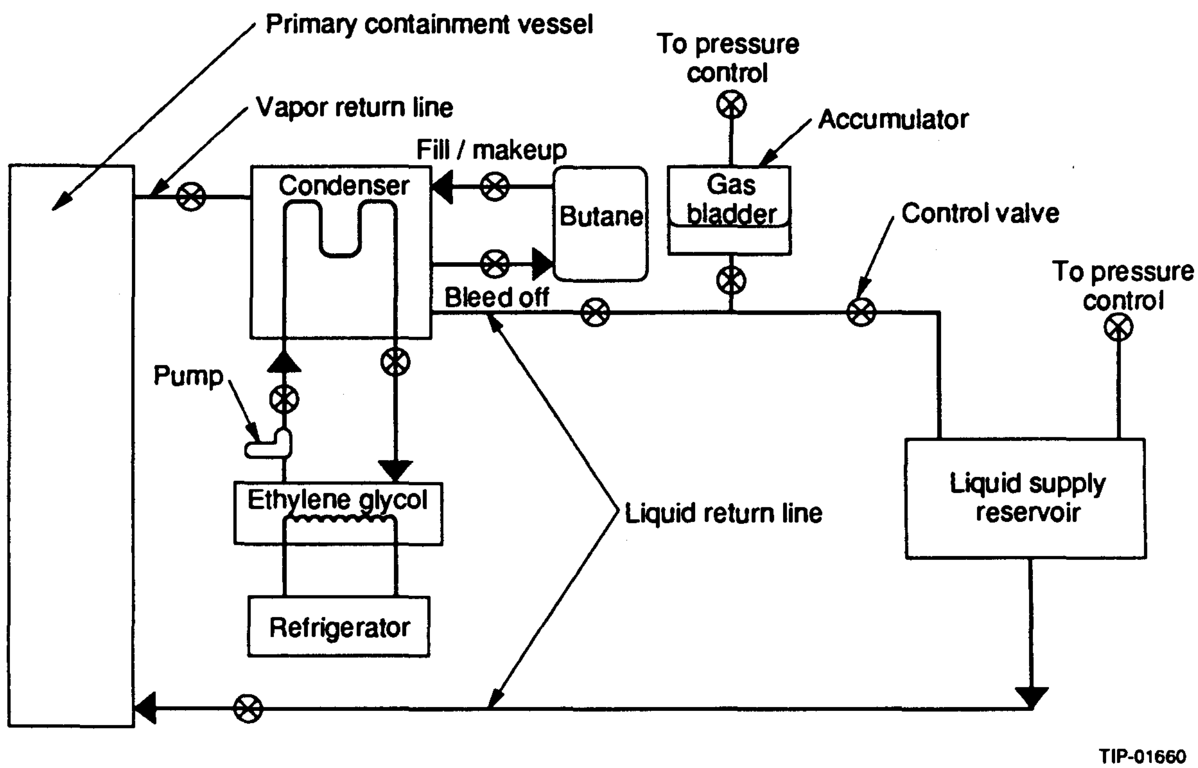


Figure 2.1-4. Schematic of the Butane Cooling System

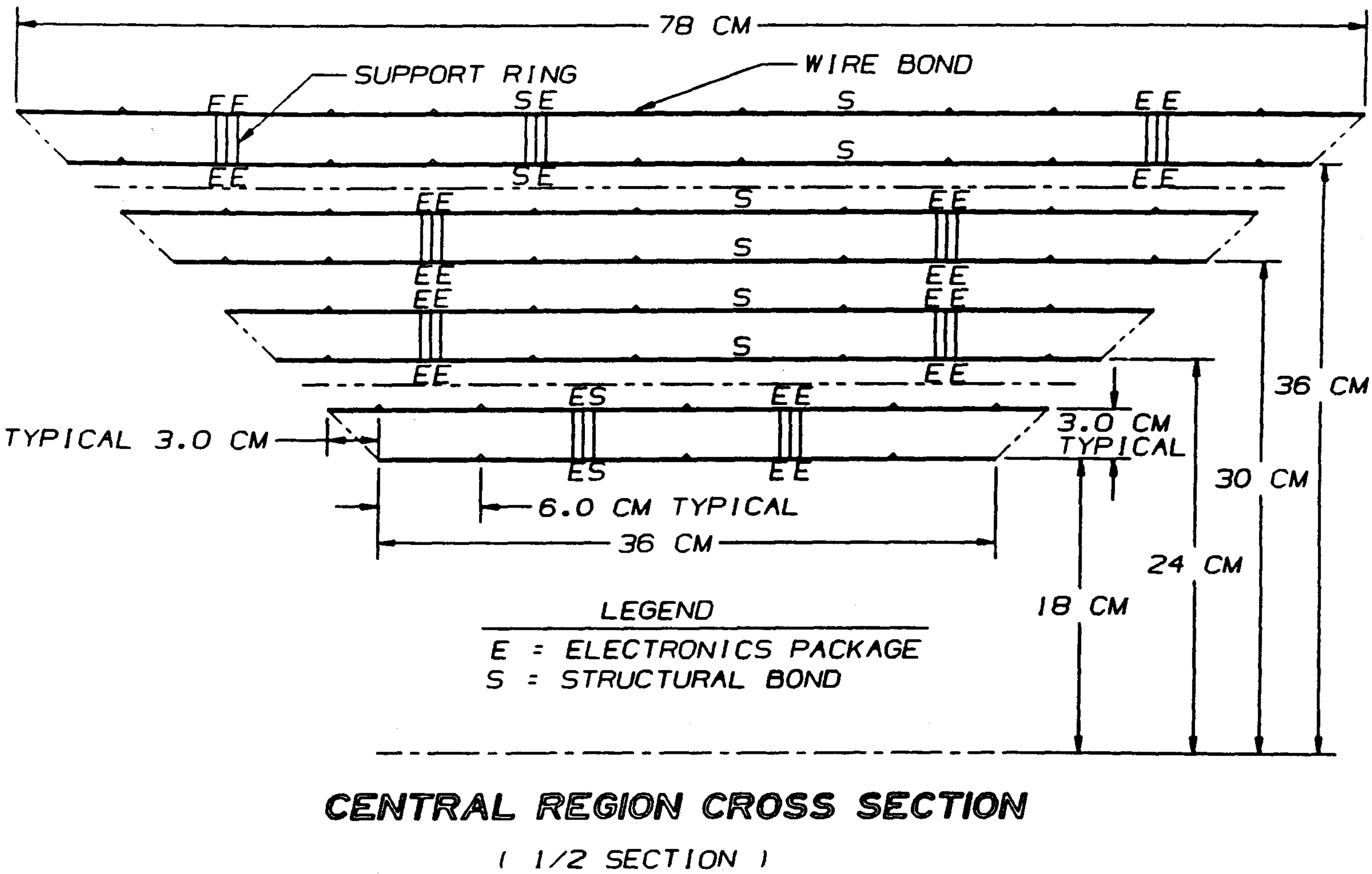


Figure 2.1-5. Cross Section of Central Region with Dimensions

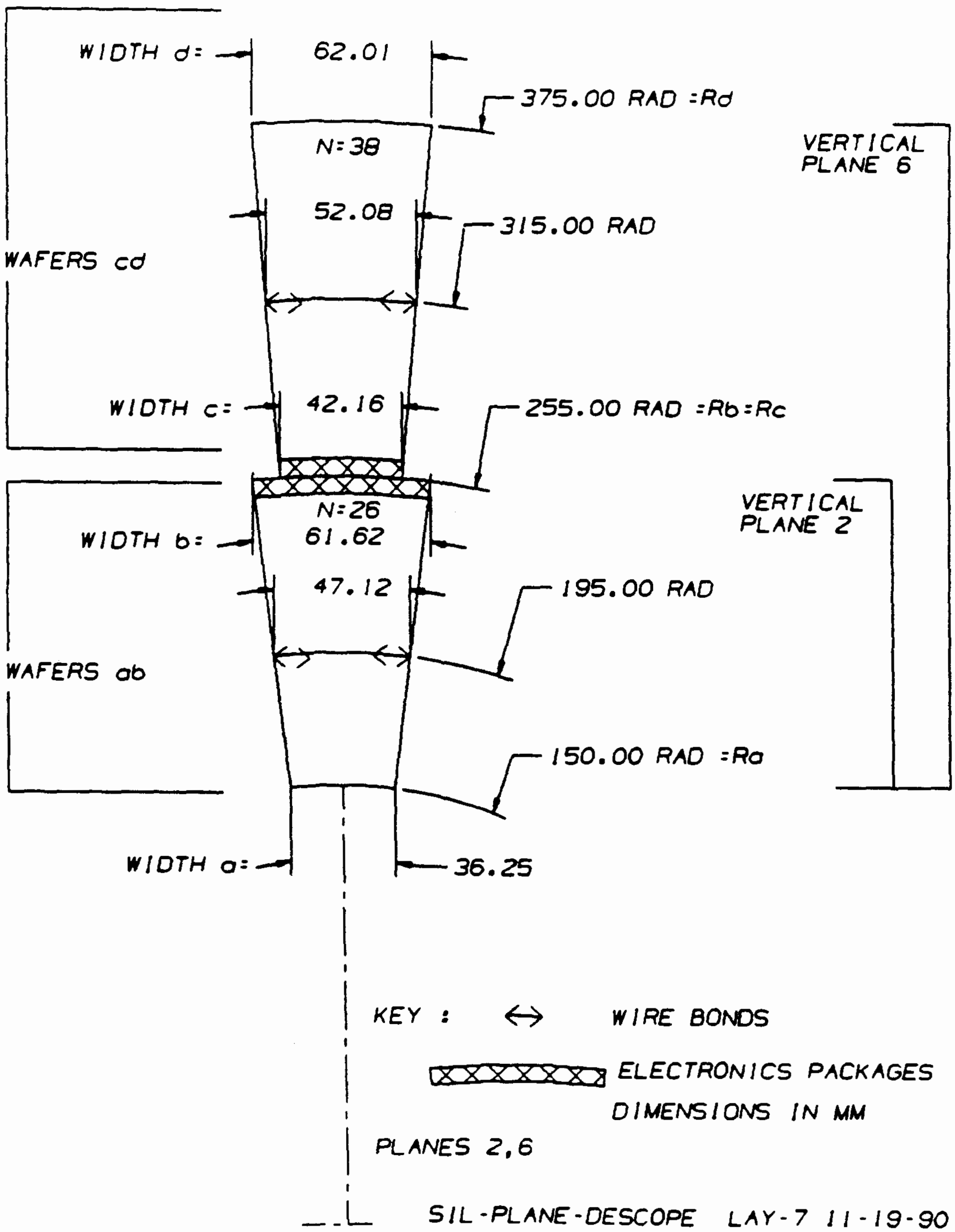


Figure 2.1-6. View of Segment of Plane Defining Terms Used by Table 2.1-8

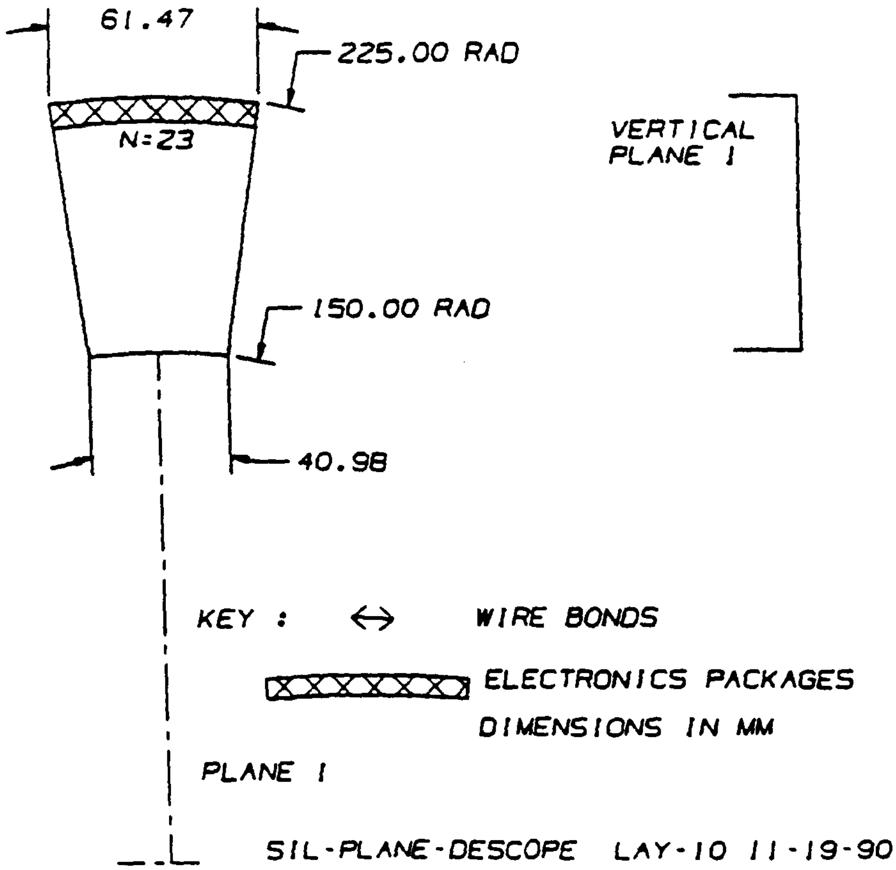


Figure 2.1-7. Detail of Detector on Plane 1

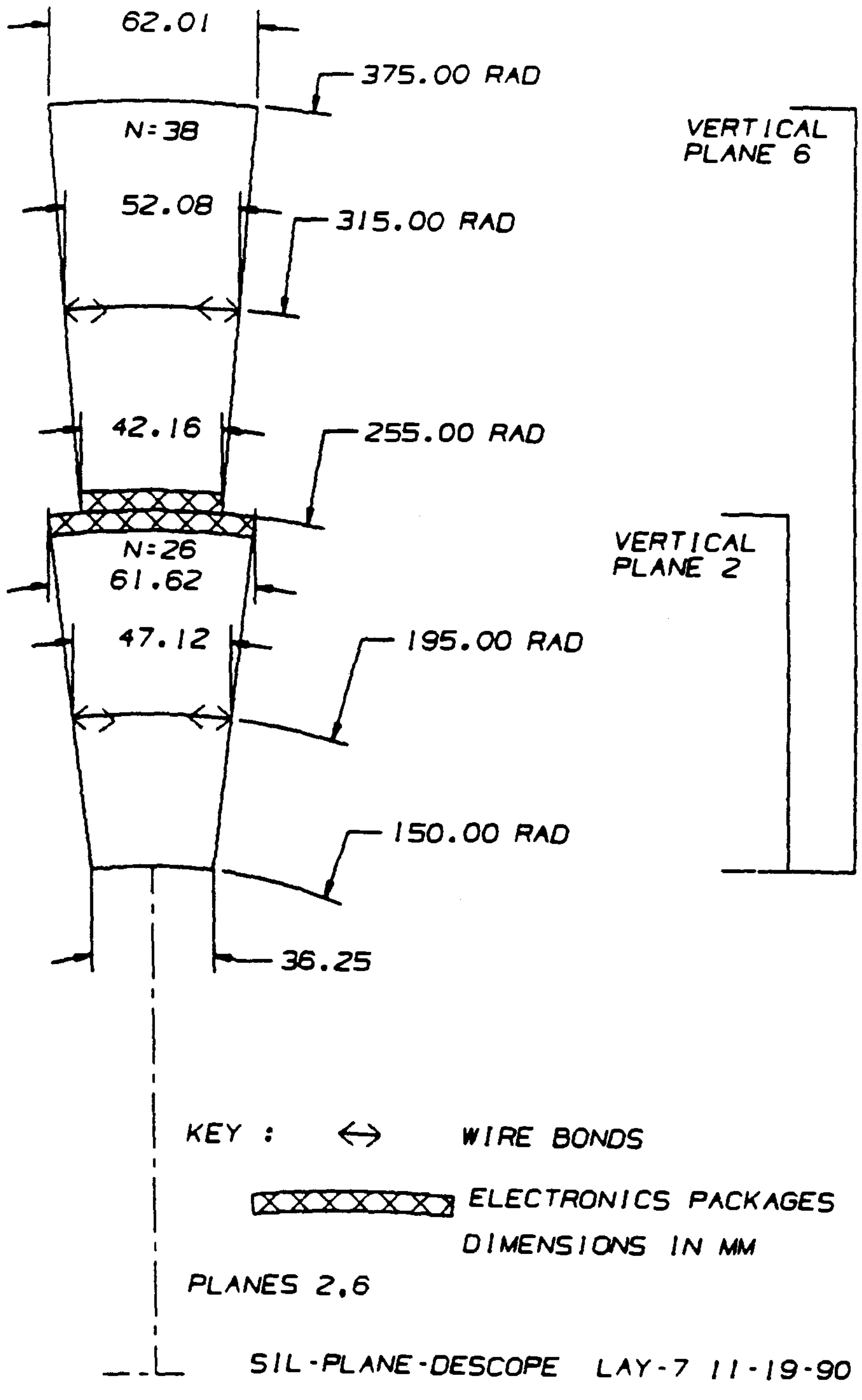


Figure 2.1-8. Detail of Detectors on Planes 2 and 6

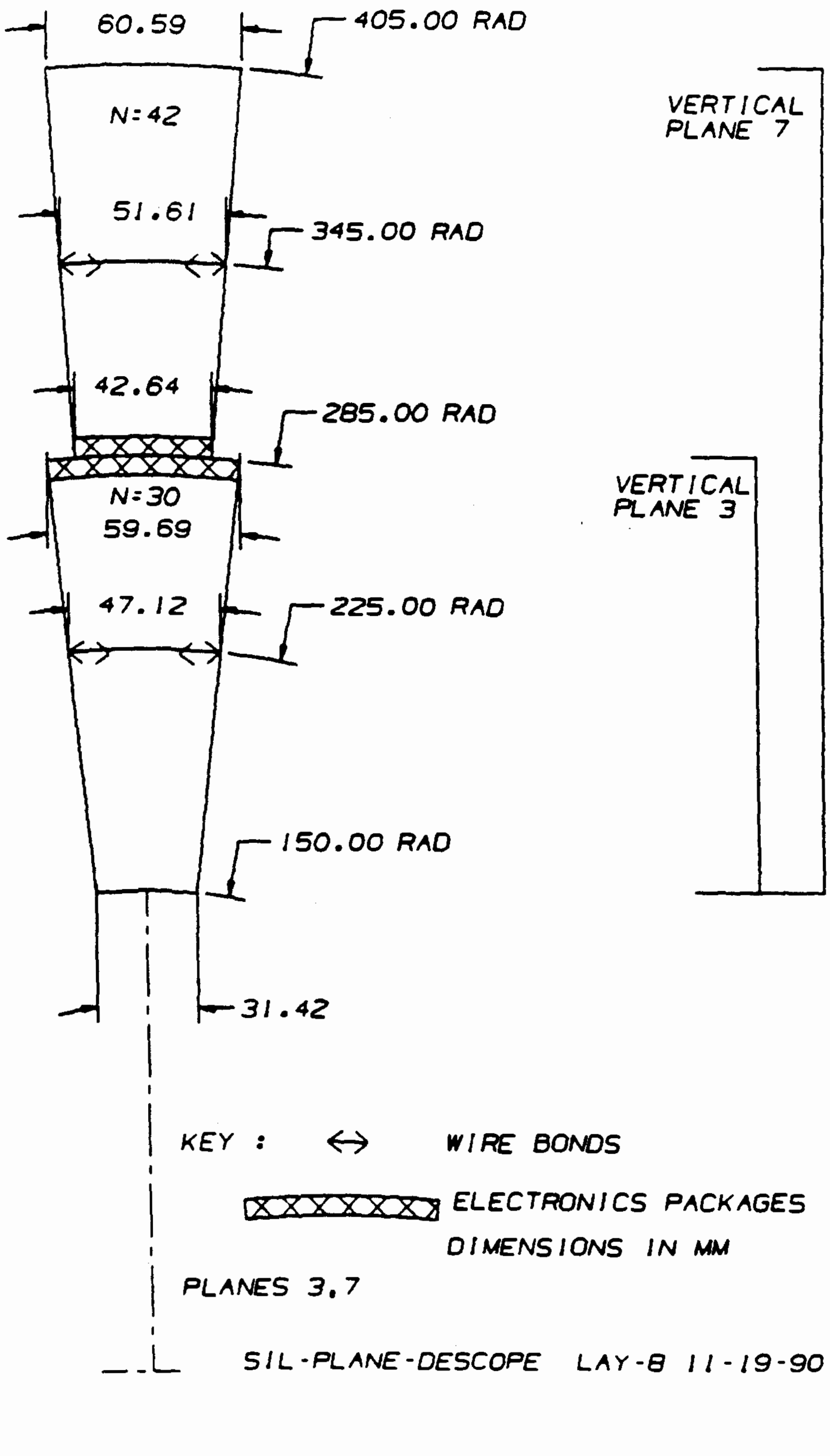


Figure 2.1-9. Detail of Detectors on Planes 3 and 7

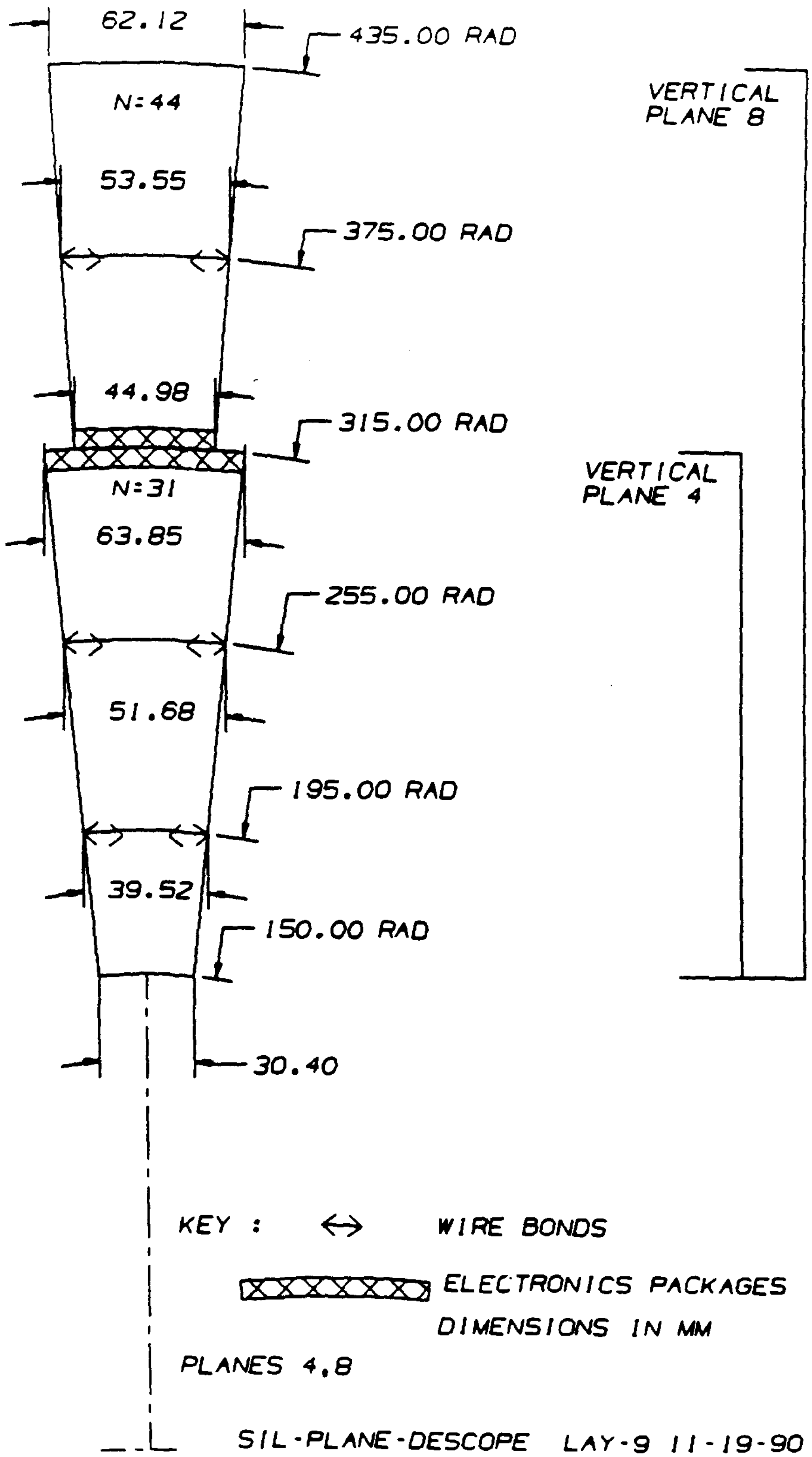


Figure 2.1-10. Detail of Detectors on Planes 4 and 8

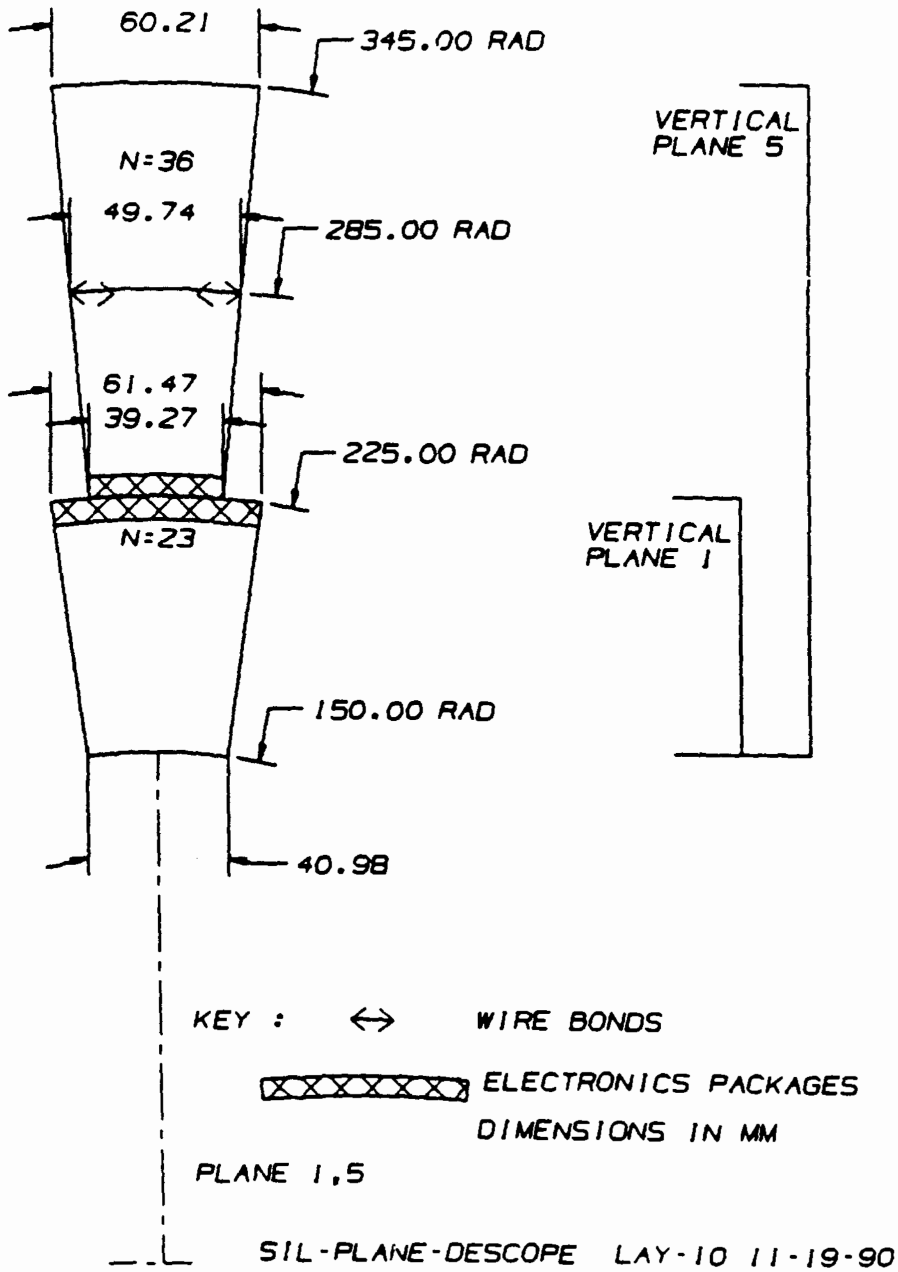


Figure 2.1-11. Detail of Detectors on Planes 1 and 5

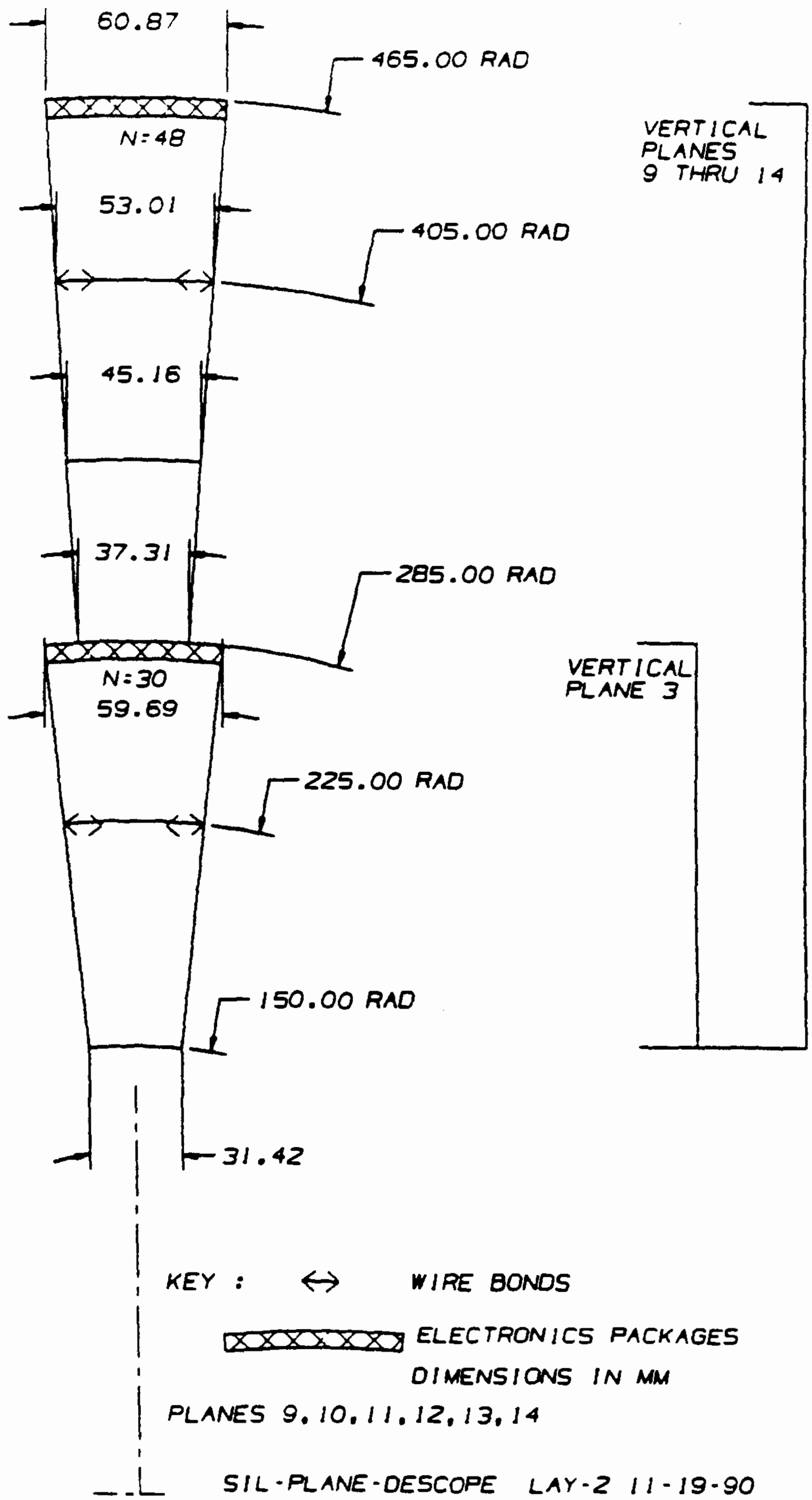


Figure 2.1-12. Detail of Detectors on Planes 9 - 14

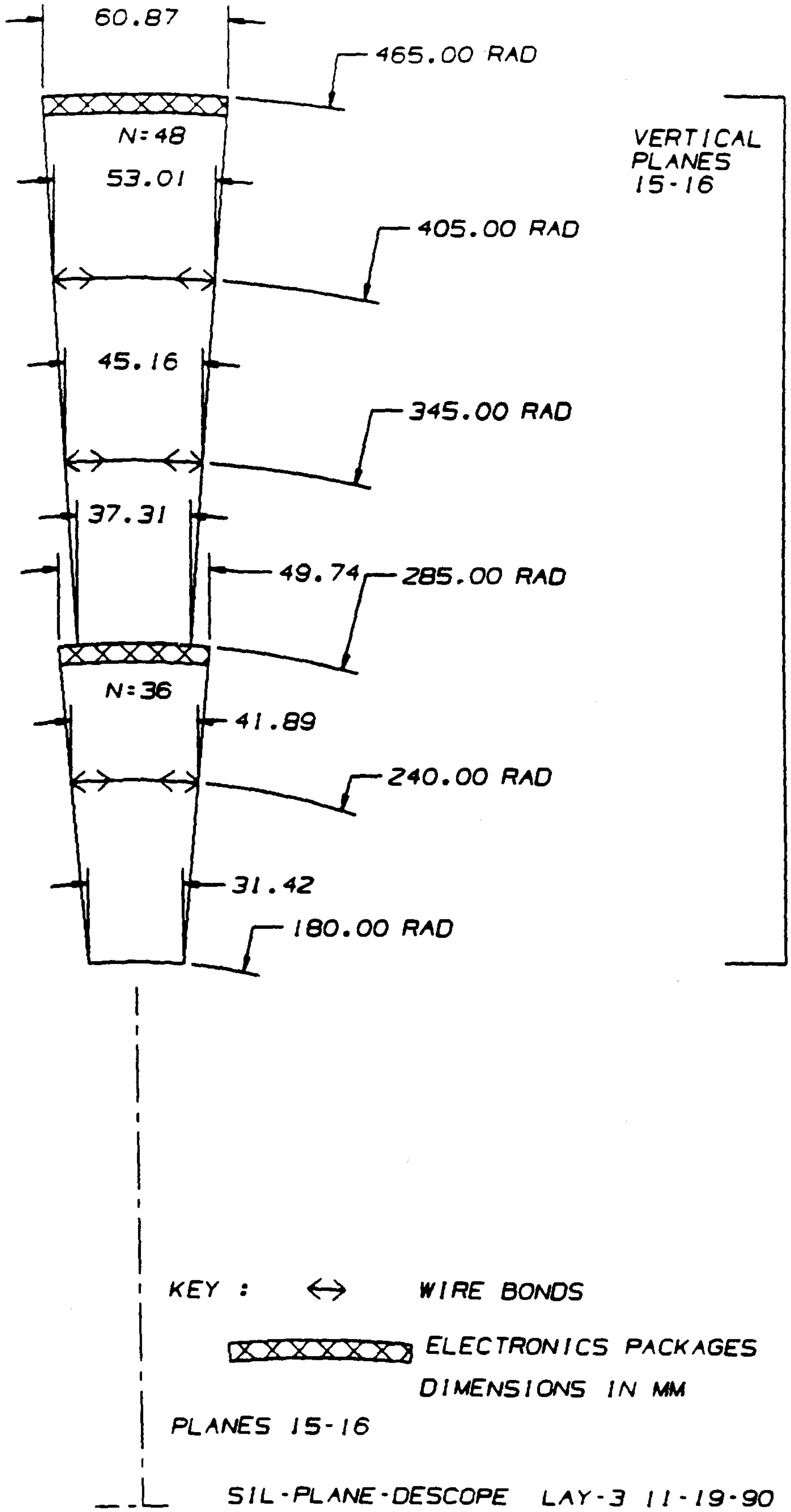


Figure 2.1-13. Detail of Detectors on Planes 15 and 16

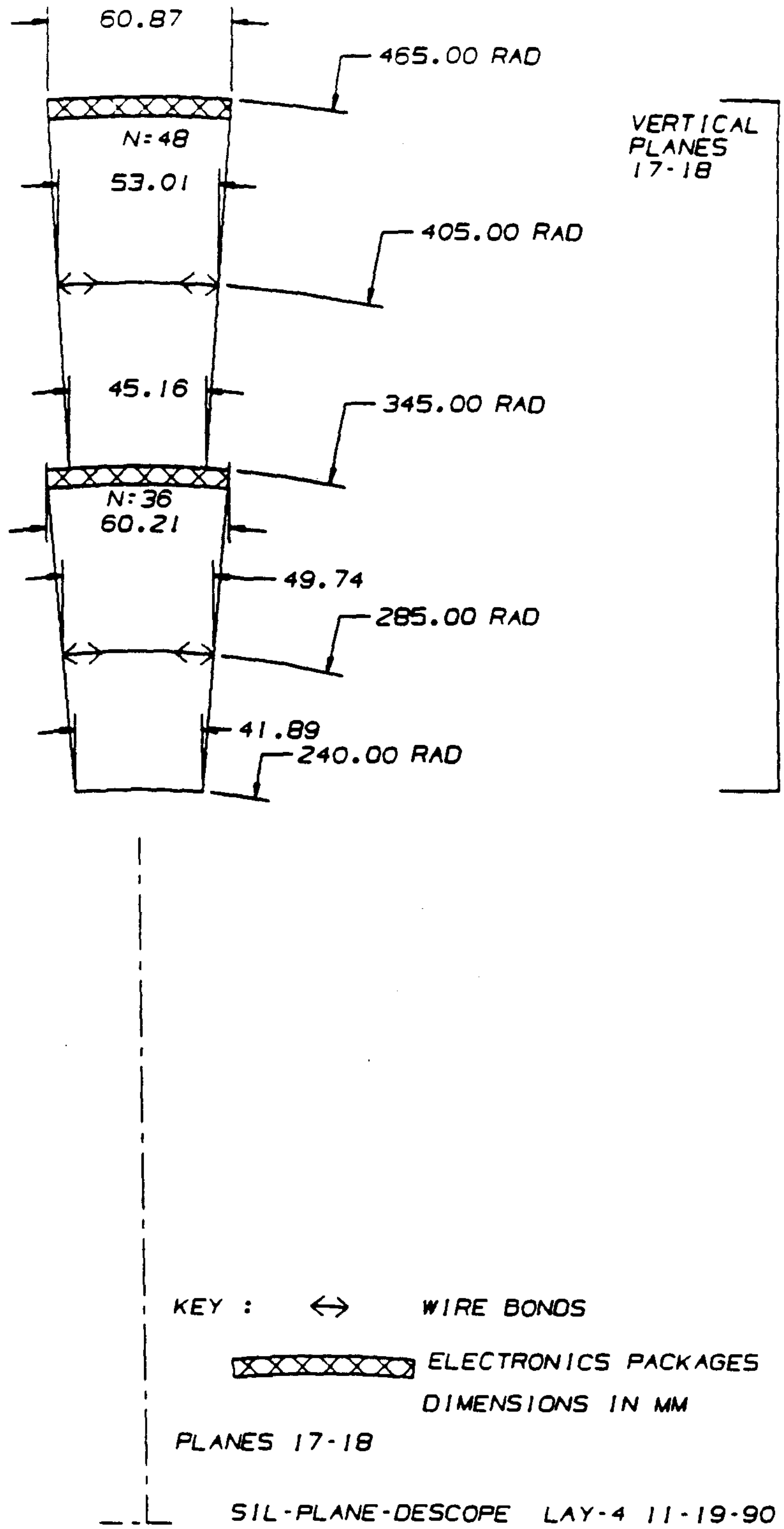


Figure 2.1-14. Detail of Detectors on Planes 17 and 18

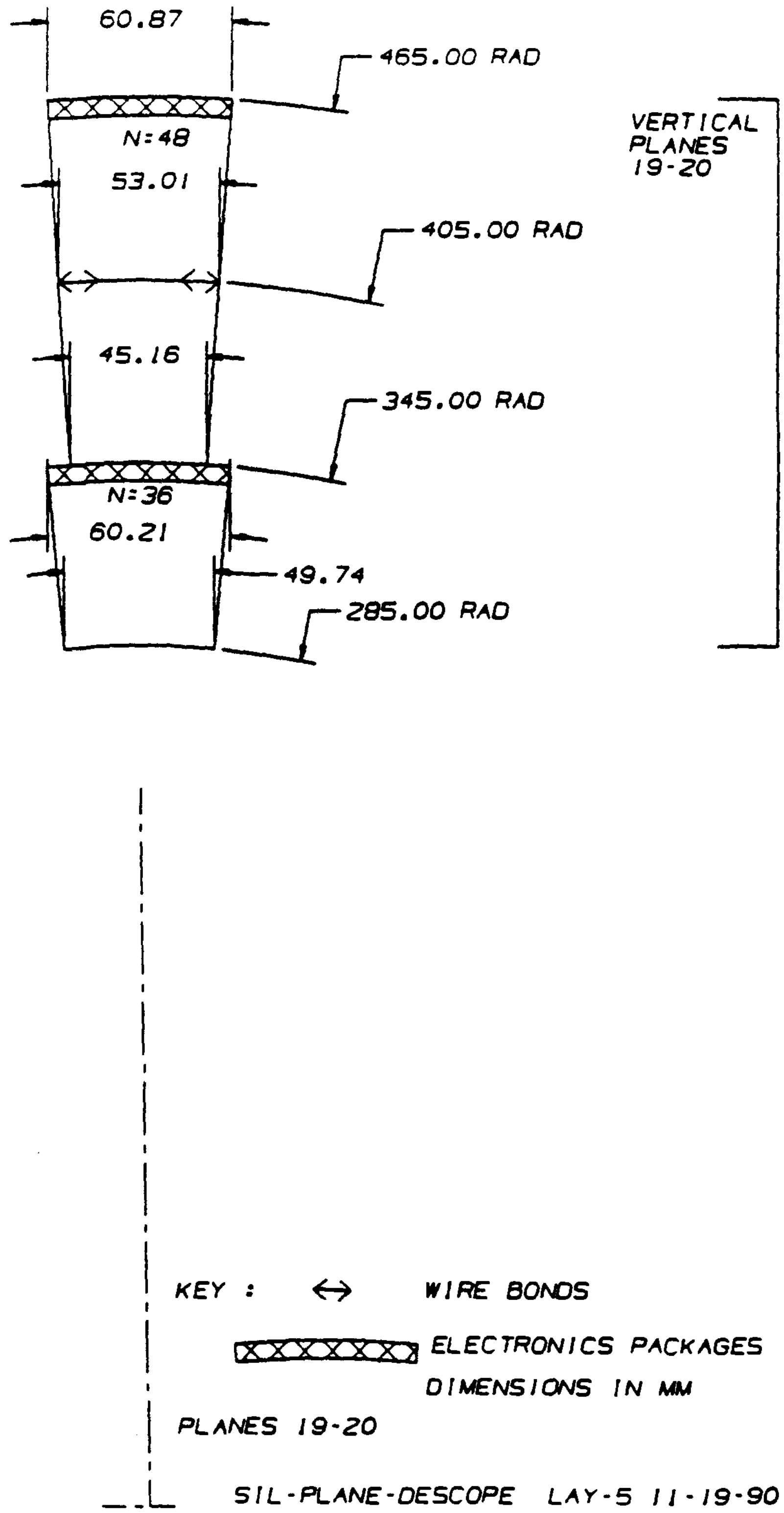


Figure 2.1-15. Detail of Detectors on Planes 19 and 20

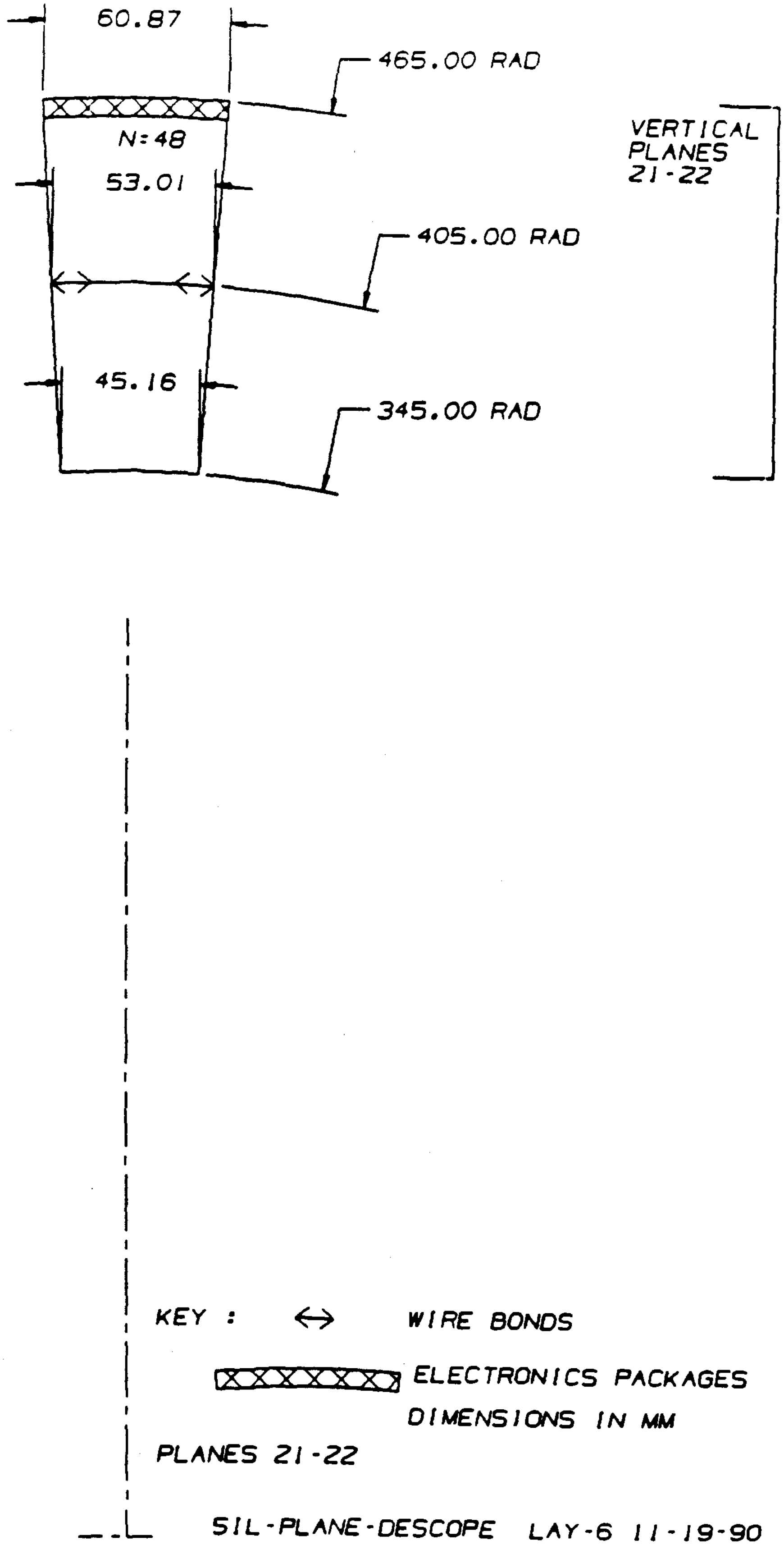


Figure 2.1-16. Detail of Detectors on Planes 21 and 22

2.2.1 *Wire Tracking Option*

The wire tracking option is described in Table 2.2.1-1 and Figures 2.2.1-1 to 2.2.1-5.

2.2.2 *Fiber Tracking Option*

The fiber tracking option is described in Tables 2.2.2-1 to 2.2.2-3 and Figures 2.2.2-1 to 2.2.2-8.

2.3 Solenoid Coil

Three possible solenoid coil configurations were originally considered. One (type-L) was dropped, and the remaining two (type-S and type-I) were combined into a single unified design (type-U), which will be the focus of engineering design and R&D activities. This design is to be usable with either a ferro-magnetic endcap calorimeter (Model A) or non-magnetic endcap (Model B).

Parameters, descriptions, and performance requirements of the solenoid are detailed in Table 2.3-1 and in Figures 2.3-1 to 2.3-14.

Present design calls for 4.5 K liquid helium supply to the valve box. The return flow is 4.5 K helium gas from the cold mass and 300 k helium gas from current leads. The system shows a helium circulation pump to overcome the pressure drop in the system. Also shown is a helium cold compressor which allows the subcooler pressure to drop below atmospheric pressure for possible operation at 4.0 K or below.

The 80 K magnet shield is cooled by liquid nigtrogen supply.

According to analysis done at FNAL, the estimated steady state heat load of the magnet, the valve box and the pump box is 66 W and 23 liter/hr at 4.5 K. The 80 K heat load is 700 watts.

If all other heat loads are considered, the steady state heat load could be 200 to 300 watts. That is a small refrigerator. However, if we must have available capacity for cooldown and quench recoveries, we may need a 1500-watt refrigerator (that will cost about $1.5M). It would be more cost-effective to define some kind of safe coupling between the detector cryogenic needs during cooldown and the collider helium storage system at the IR locations.

2.4 Calorimeter

The SDC calorimeter systems consists of a central, high-precision calorimeter ($|\eta|<3$) and forward calorimetry covering the region $3 < |\eta| < 5$. Two technologies with complementary risk elements have been chosen for engineering development; these two options will be pursued with comparable priority to guarantee at least one technology that can meet our cost, physics performance, and other requirements.

The options are: (1) scintillating tiles with wave-shifting fiber readout and lead/iron absorber; and (2) liquid argon with lead absorber. The choice will be based on a comparison of the physics performance, technical risks, costs, schedule, and the impact of the integration of the calorimeter with the other detector elements.

2.4.1 *Pb/Scintillator Tile Option*

There is a wealth of experience with scintillator plate calorimeters at hadron collider experiments (CDF, UA1, and UA2). More recently, a high quality scintillator plate calorimeter has been constructed for operation in the ZEUS detector. Members of the SDC have participated in the construction and operation of the CDF calorimeters and in the construction of the ZEUS calorimeter. This experience gives us confidence that a scintillating tile calorimeter can be constructed to meet our physics goals through adequate longitudinal and lateral segmentation, excellent hermeticity, and intrinsically fast and low-noise signal readout and accurate calibration by radioactive sources and high-rate processes.

Tables 2.4.1-1 and 2.4.1-2, and Figures 2.4.1-1 and 2.4.1-2 present physical parameters and descriptions for the Pb/scintillator tile option.

2.4.2 *Liquid Argon Calorimeter Option*

Large liquid argon calorimeters have been reliably operated in many experiments, and substantial experience has been accumulated by members of the SDC in the MARK-II, D0), and VENUS experiments. This experience gives us confidence that a liquid argon system can be constructed to meet our goals. Liquid argon calorimetry is intrinsically radiation resistant; in addition, it is known to provide excellent uniformity, stability, and ease of calibration. The critical issues for LAr are *e/h*, electronic and pileup noise, hermeticity, engineering design and reliability, integration into the total detector, safety, and cost.

Tables 2.4.2-1 and 2.4.2-2, and Figures 2.4.2-1 through 2.4.2-10 present physical parameters and descriptions for the liquid argon option.

2.5 Muon System

The elements of the muon system are drift tubes, scintillation counters, and possibly gas Cerenkov counters in the intermediate region. The drift tubes are approximately 8 cm wide (4 cm maximum drift), except in the inner layers of the intermediate region, where they are 4 cm wide to allow for higher occupancy. Their maximum length is 8.3 m.

The muon detection system has five distinct goals, each of which puts different requirements on the design of the system. These five goals are the following:

1. To provide a Level 1 trigger;
2. To provide information for the Level 2 and Level 3 triggers;
3. To identify muons;
4. To improve the momentum resolution at very high muon transverse momenta;
5. To provide the capability of operation at luminosities above the design level.

Parameters and requirements of the muon system are detailed in Tables 2.5-1 and 2.5-2, and Figures 2.5-1 through 2.5-4.

2.6 Data Acquisition

Estimates for the front end, trigger, and DAQ crate are presented in Table 2.6-1.

2.7 Weights and Measures

Table 2.7-1 provides specificatons for the SDC Option 1 detector. Table 2.7-2 provides specifications for the Option 2 detector.

Table 2.2.1-1. Barrel Wire Tracking

Barrel Trk (wires 2 ends)	191136							
Nr of superlayers	8							
Number of modules	512							
Area tubes (mm^2 one end)	15926							
Area cables (mm^2 one end)	45861							
Total area conn. (one end)	61787							
	layer 0	layer 1	layer 2	layer 3	layer 4	layer 5	layer 6	layer 7
mod/spr layer	36	44	52	60	68	76	84	92
wires per module	165	165	165	165	165	165	228	228
Connections/Layer/End								
Tubes								
gas supply dia (mm)	25							
number per layer	1	1	1	1	1	1	1	1
gas return dia (mm)	25							
number per layer	1	1	1	1	1	1	1	1
cooling gas dia (mm)	25							
number per layer	1	1	1	1	1	1	1	1
cooling gas rtn dia (mm)	25							
number per layer	1	1	1	1	1	1	1	1
Leak detection dia (mm)	6							
number per layer	1	1	1	1	1	1	1	1
area of tubes (mm ^2)	1990.8	1991	1990.8	1991	1991	1991	1991	1990.8
Cables	layer 0	layer 1	layer 2	layer 3	layer 4	layer 5	layer 6	layer 7
temperature monitor								
diameter (mm)	3							
number per layer	3	3	3	3	3	3	3	3
Survey Monitor								
diameter (mm)	3							
number per layer	1	1	1	1	1	1	1	1
area per layer (mm ^2)	28.26	28.26	28.26	28.26	28.26	28.26	28.26	28.26
Connections per Module								
Cables								
1 readout + LV								
size (mm ^2)	50	1.5						
number per module	1							
HV								
Diameter (mm)	3							
number per module	1							
Calibration								
diameter (mm)	3							
number per module	1							
Area per module (mm^2)	89.13							

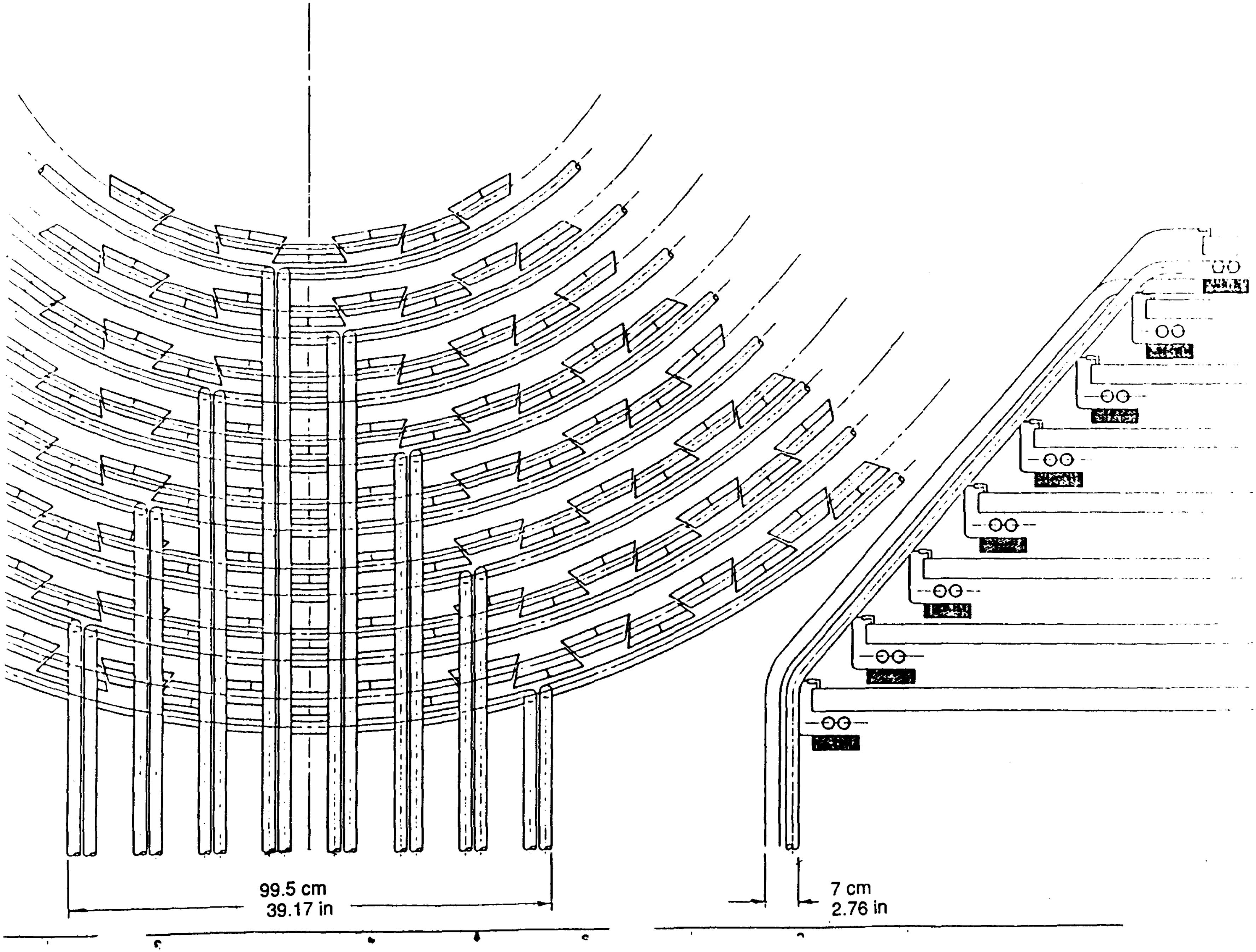


Figure 2.2.1-1. Wire Tracker (end view)

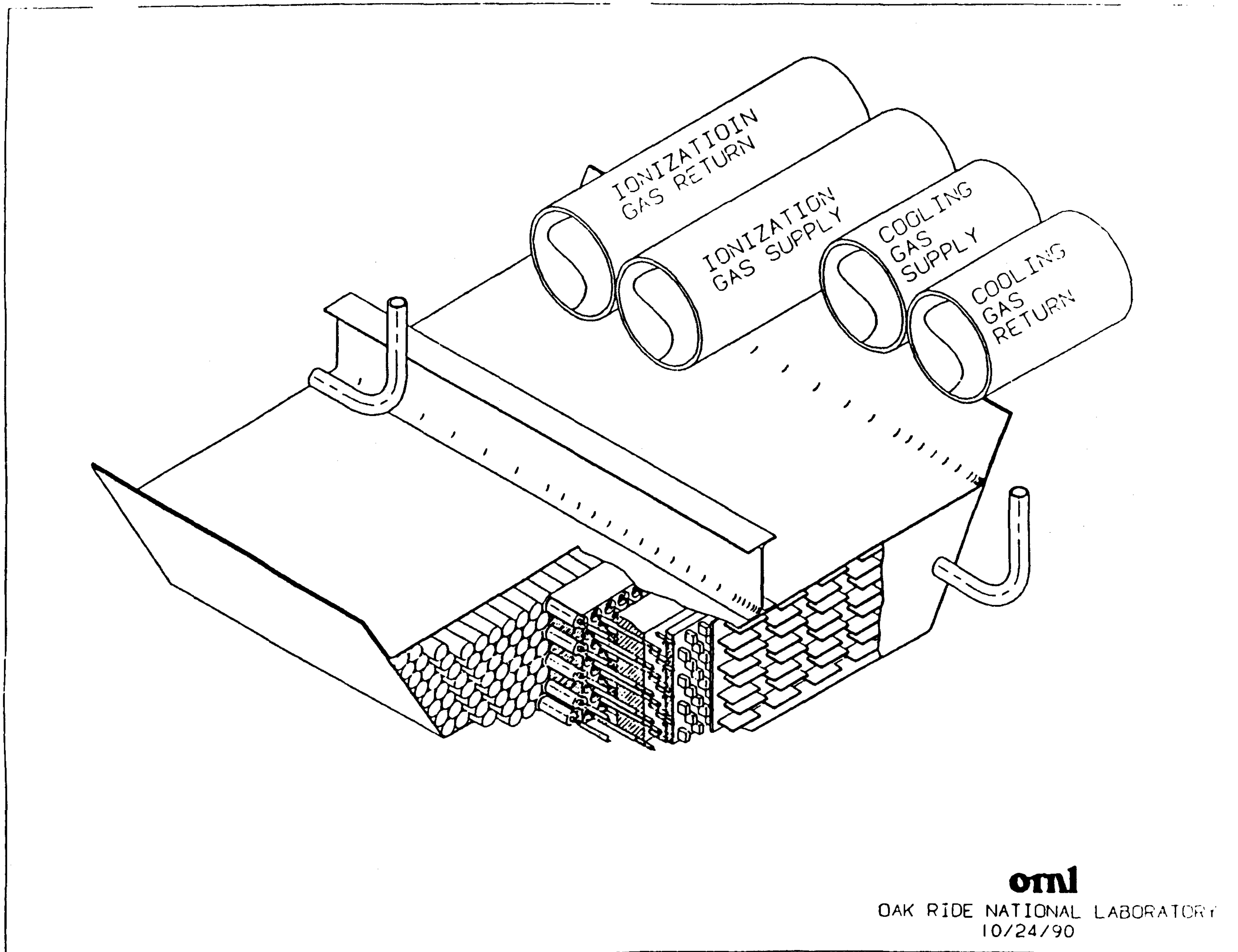


Figure 2.2.1-2. Wire Tracker (cut away)

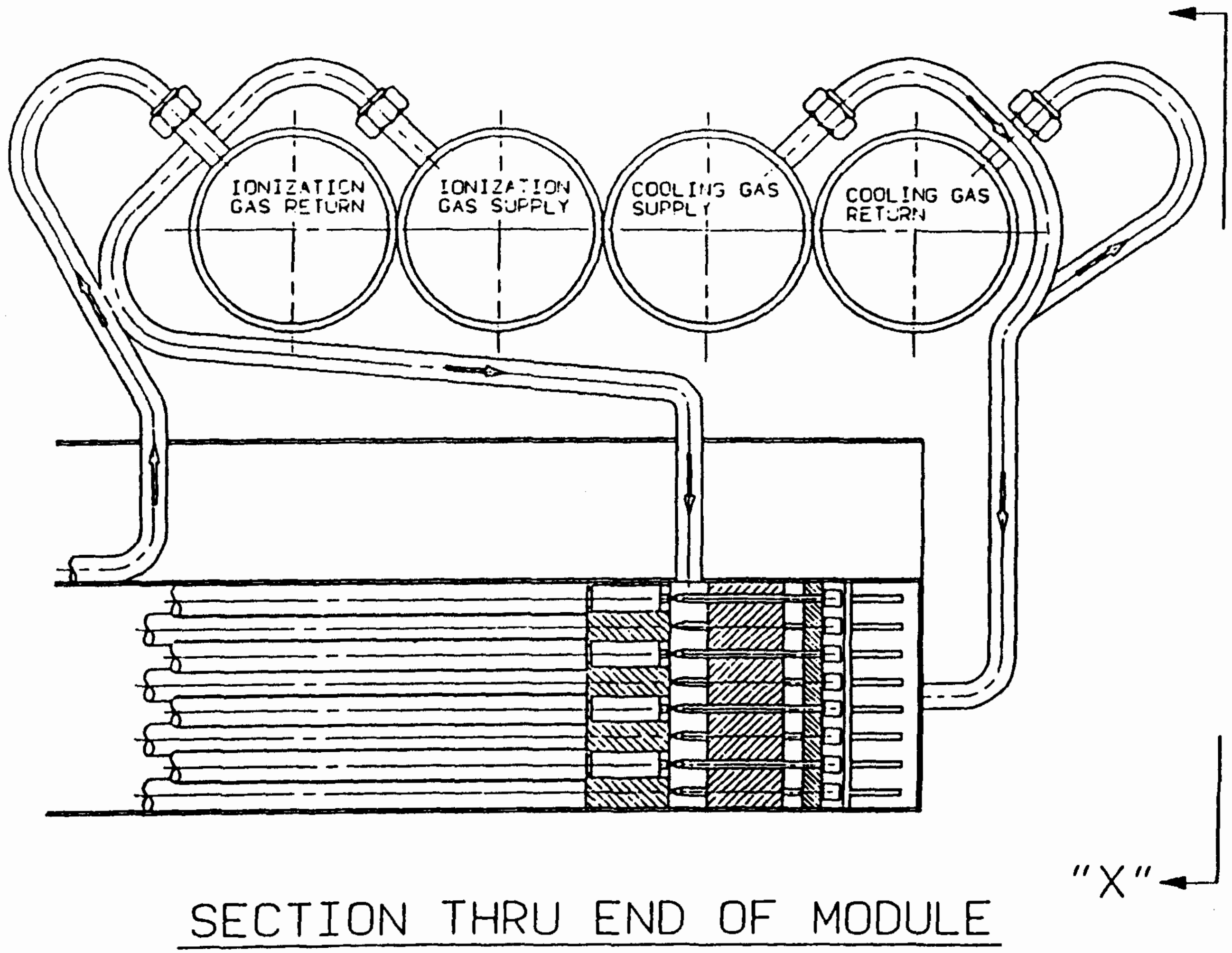
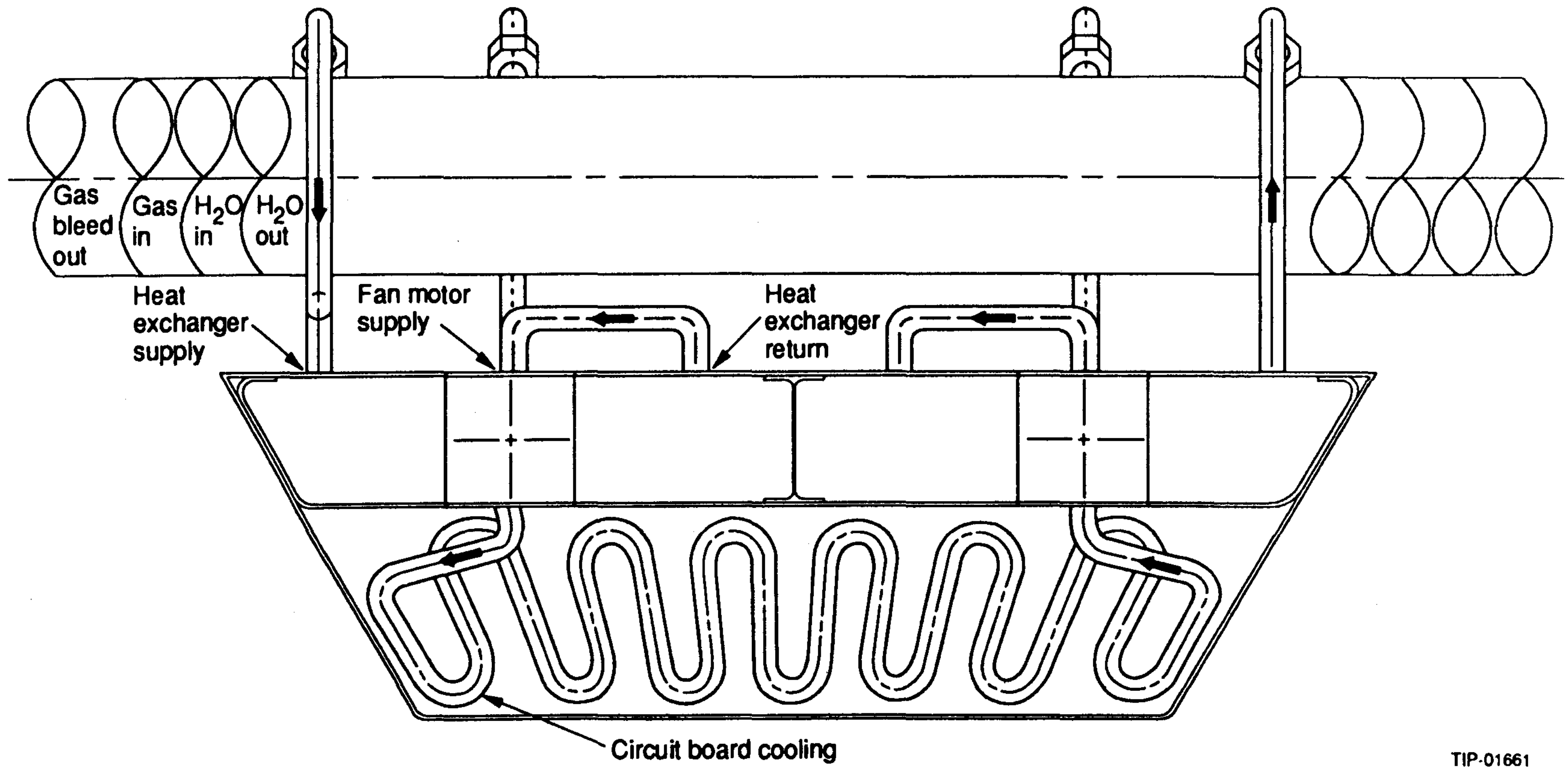


Figure 2.2.1-3. Section Through End of Module



View "A"

Figure 2.2.1-4. View "A"

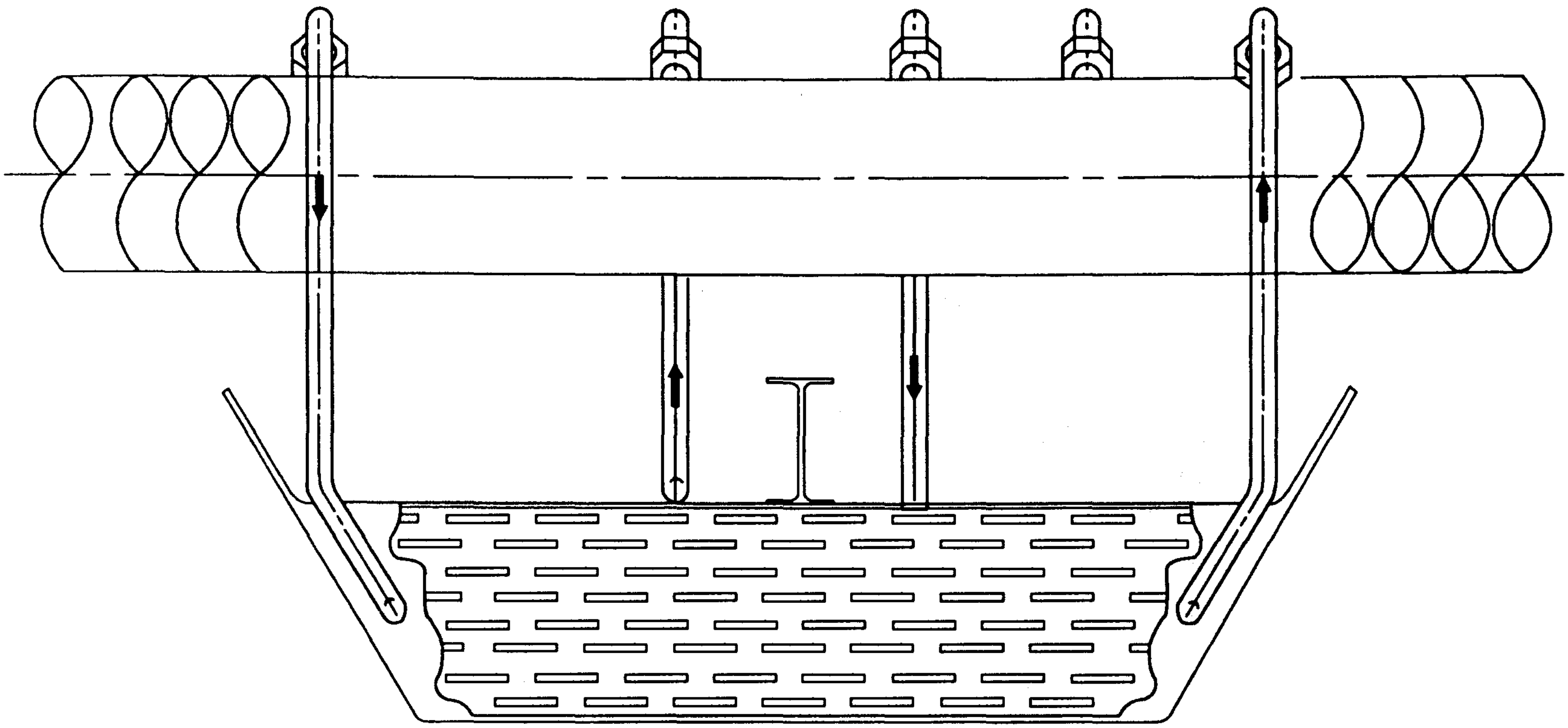


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Figure 2.2.1-5. View "X"

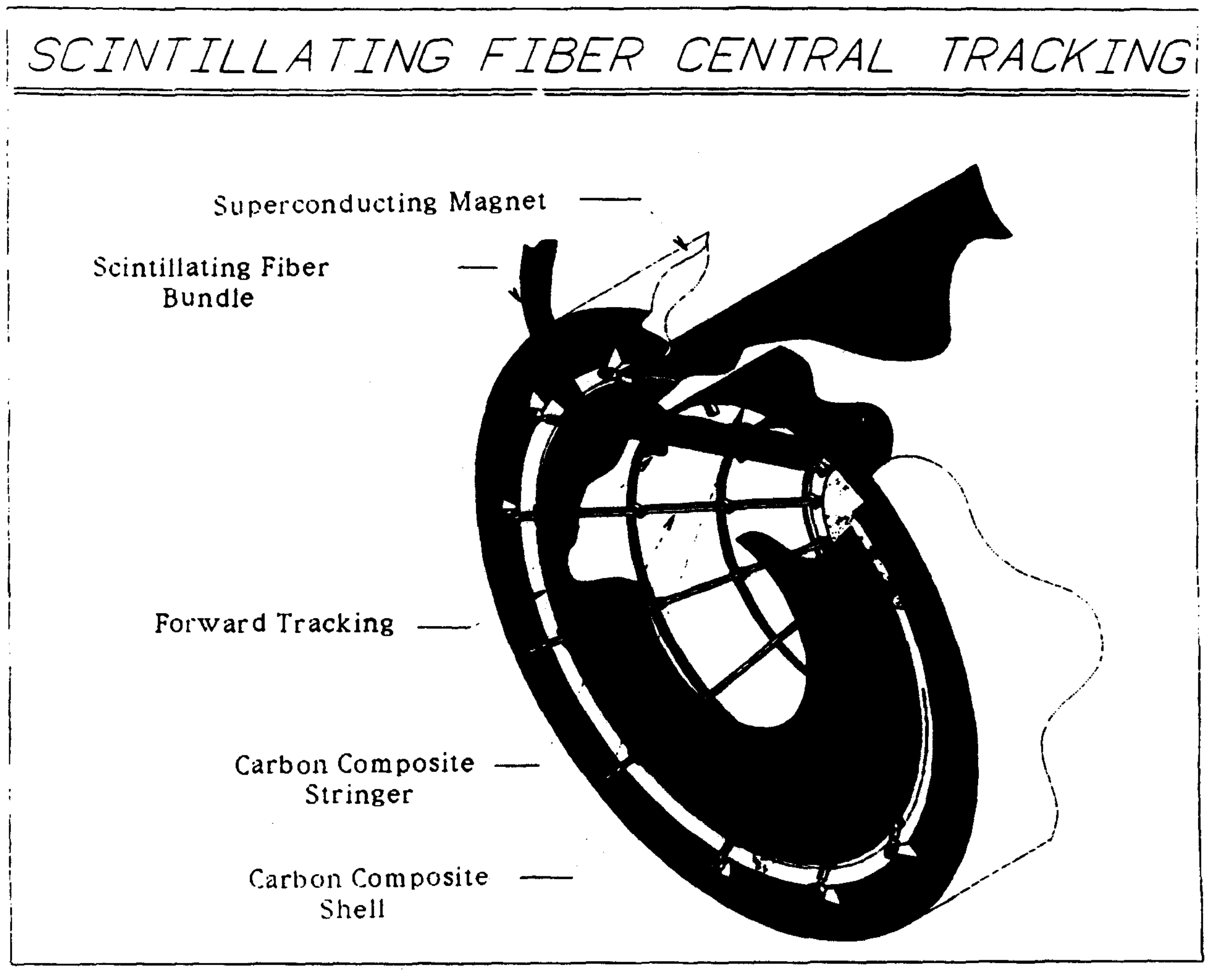


Figure 2.2.2-1. Scintillating Fiber Central Tracking

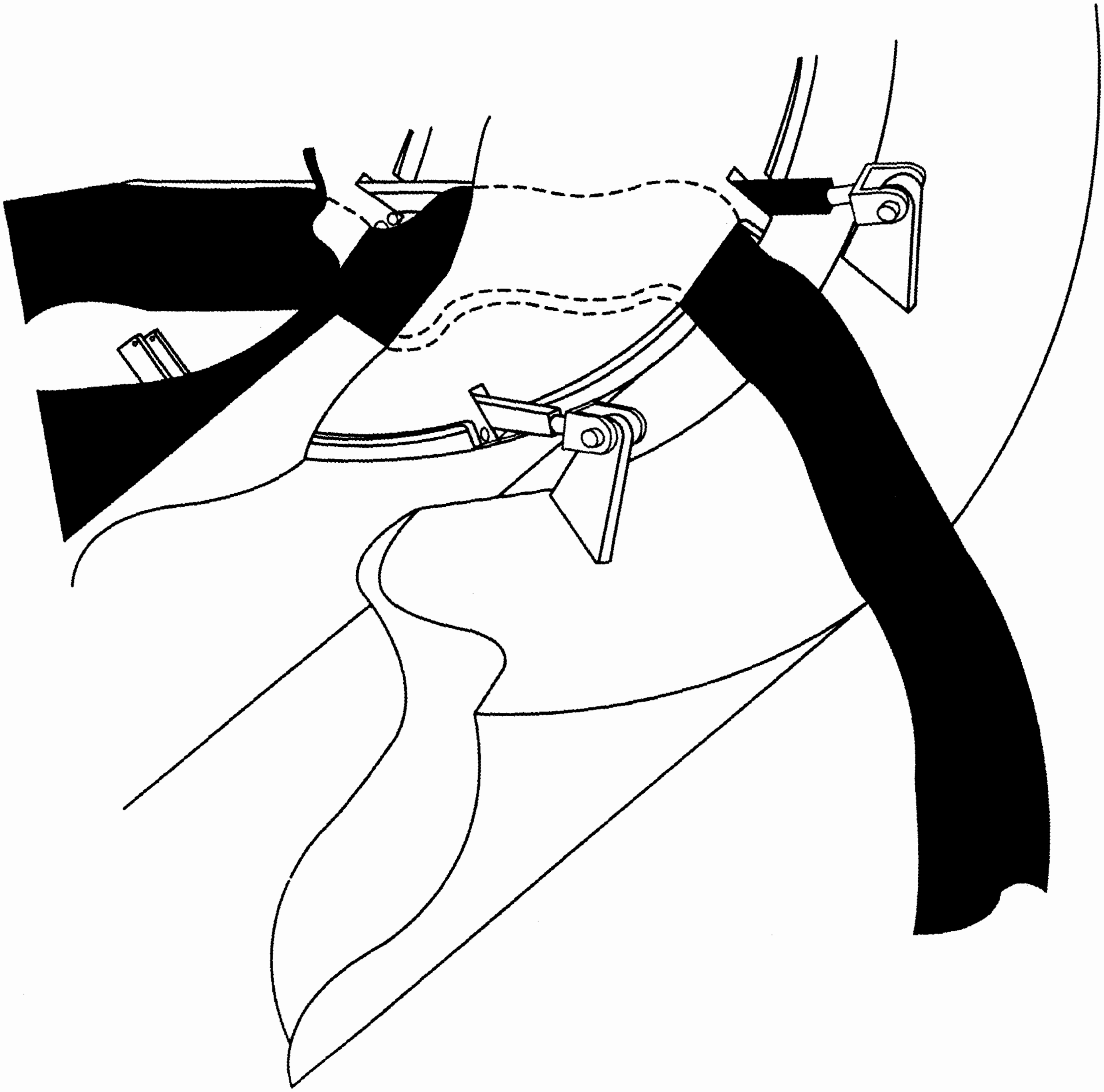


Figure 2.2.2-2. Fiber Bundle Edge Clamp

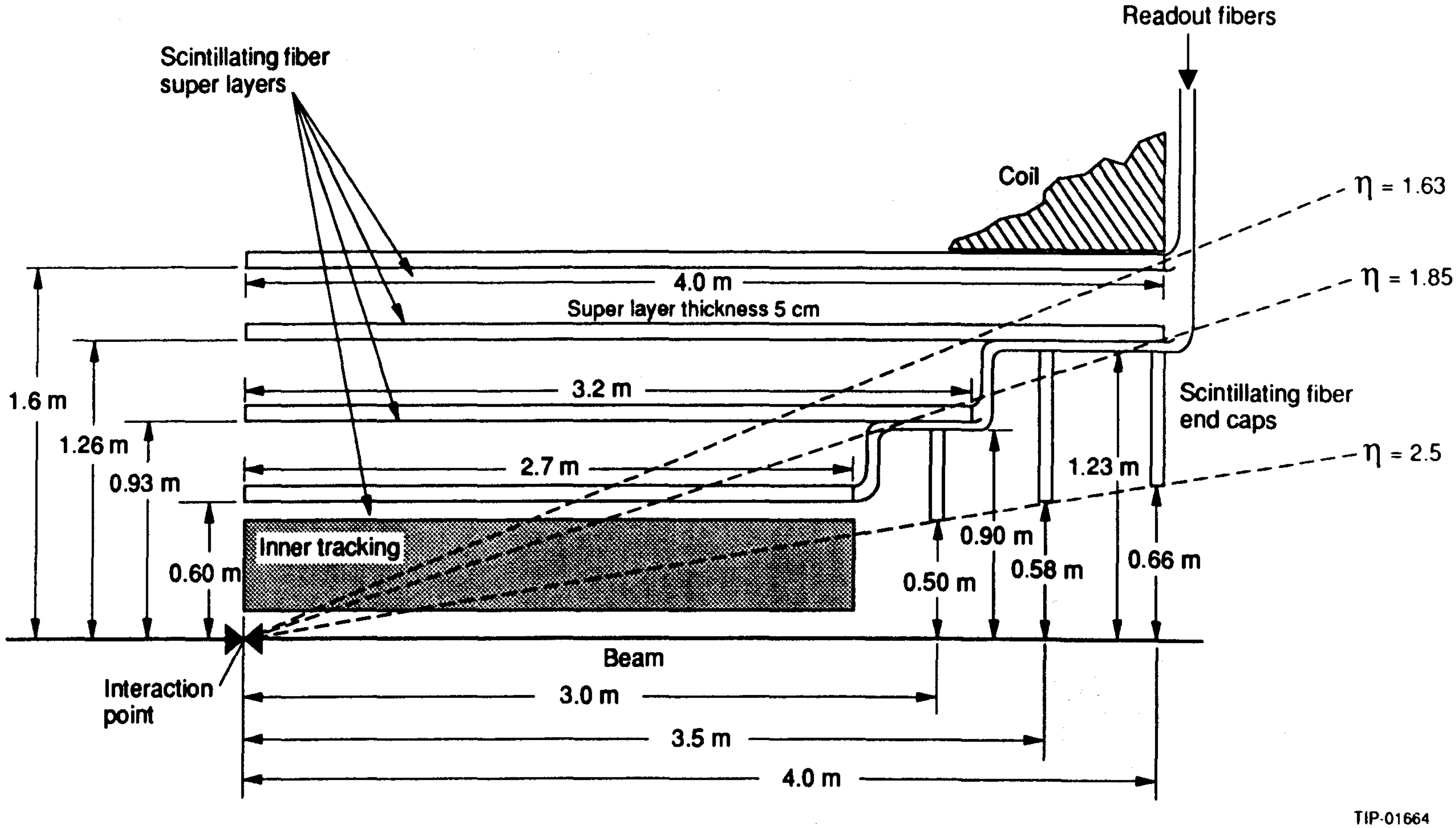
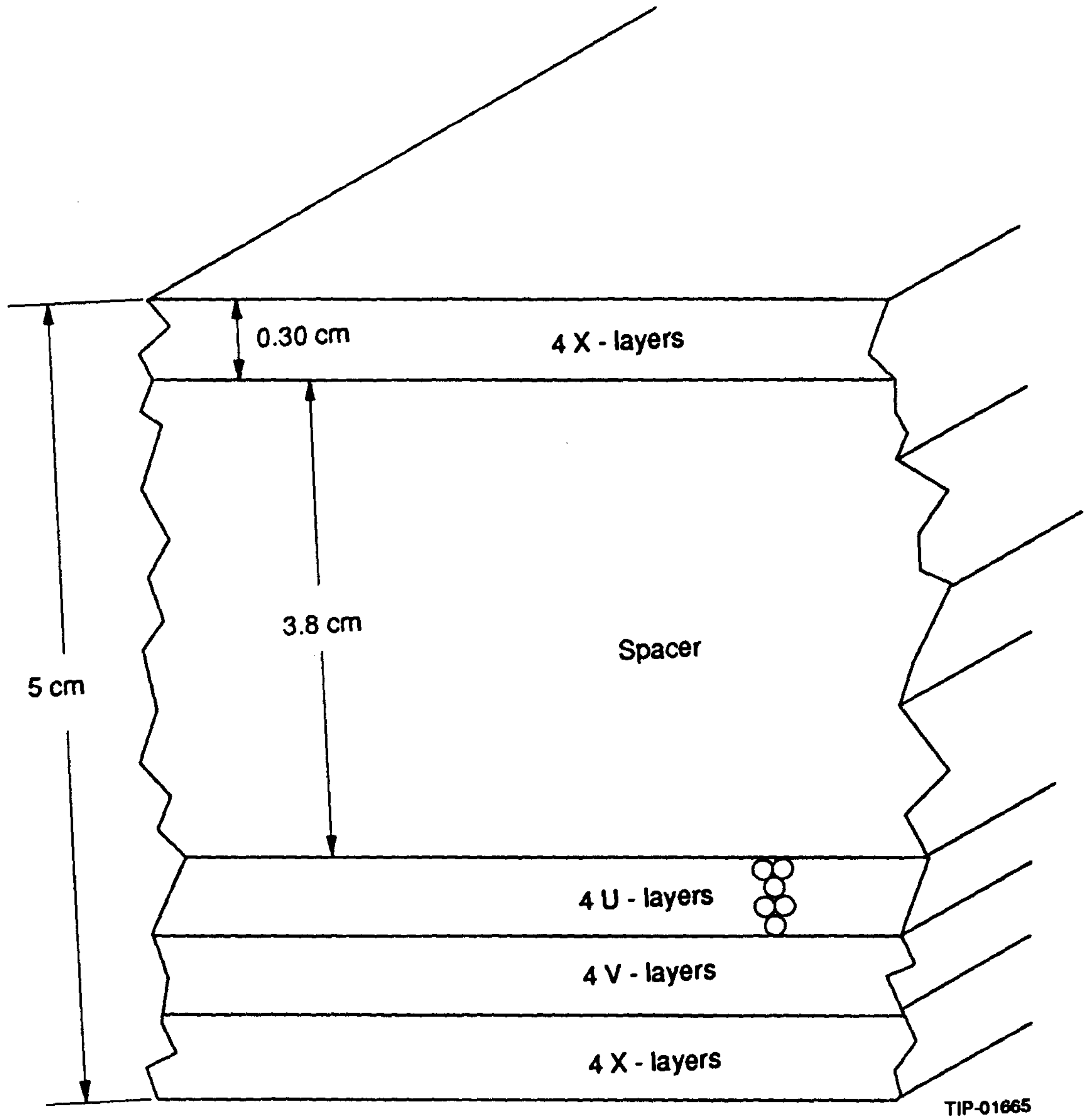


Figure 2.2.2-3. Fiber Tracker (profile)



$$\frac{\text{\# fibers}}{\text{super layer}} = \text{\# layers} \times 2\ R_{average} \ \frac{1}{d_{fiber}} \quad (d_{fiber} = 0.075 \text{ cm})$$

Superlayer	ave. Radius (cm)	# of Layers	# of fibers
1	62.5	8	41,890
2	96	8	64,340
3	129	16	172,920
4	162.5	16	217,790
			496,940

Total no. of fibers = 2 halves x 496,940 = 993,880

Figure 2.2.2-4. Cross-section of a Superlayer

Table 2.2.2-1. Location of Center of Sublayers Within Central Tracker

		650μm Fiber	750μm Fiber
Superlayer #1	z-layer	60.13 cm	60.15 cm
	z-layer	64.87 cm	64.85 cm
Superlayer #2	z-layer	93.13 cm	93.15 cm
	z-layer	97.87 cm	97.85 cm
Superlayer #3	z-layer	126.13 cm	126.15 cm
	u-layer	126.39 cm	126.45 cm
	v-layer	126.65 cm	126.75 cm
	z-layer	130.87 cm	130.85 cm
Superlayer #4	z-layer	160.13 cm	160.15 cm
	u-layer	160.39 cm	160.45 cm
	v-layer	160.65 cm	160.75 cm
	z-layer	164.87 cm	164.85 cm

Table 2.2.2-2. Location of Center of Sublayers Within Intermediate Tracker

		500μm Fiber
Superlayer #1	Sublayer 1	299.85 cm
	Sublayer 2	295.15 cm
Superlayer #2	Sublayer 1	349.85 cm
	Sublayer 2	345.15 cm
Superlayer #3	Sublayer 1	399.85 cm
	Sublayer 2	395.15 cm

Table 2.2.2-3. Intermediate Fiber Tracker

Superlayer	Z(m)	R_1(m)	R_2(m)	Φ Layer Count 1mm	R Layer Count 500μm	Total Superlayer
1	3.0	0.50	0.90	3150	1600	28,300
2	3.5	0.58	1.23	3650	2600	34,400
3	4.0	0.66	1.23	4150	2280	37,700
Total						100,400

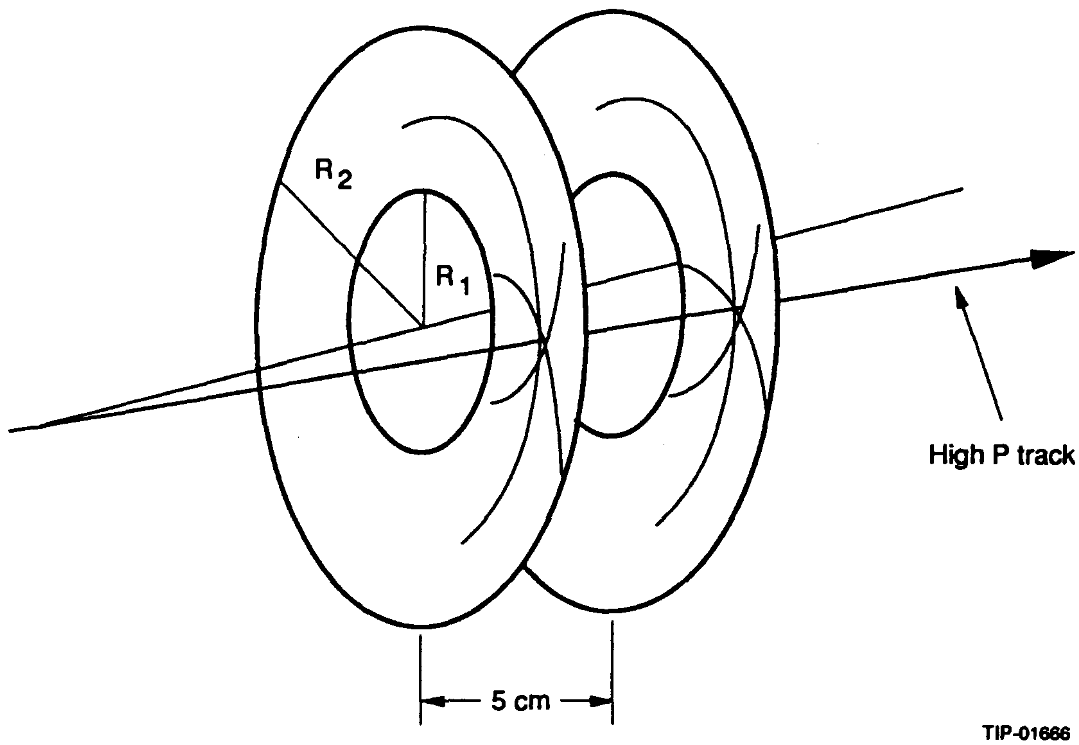
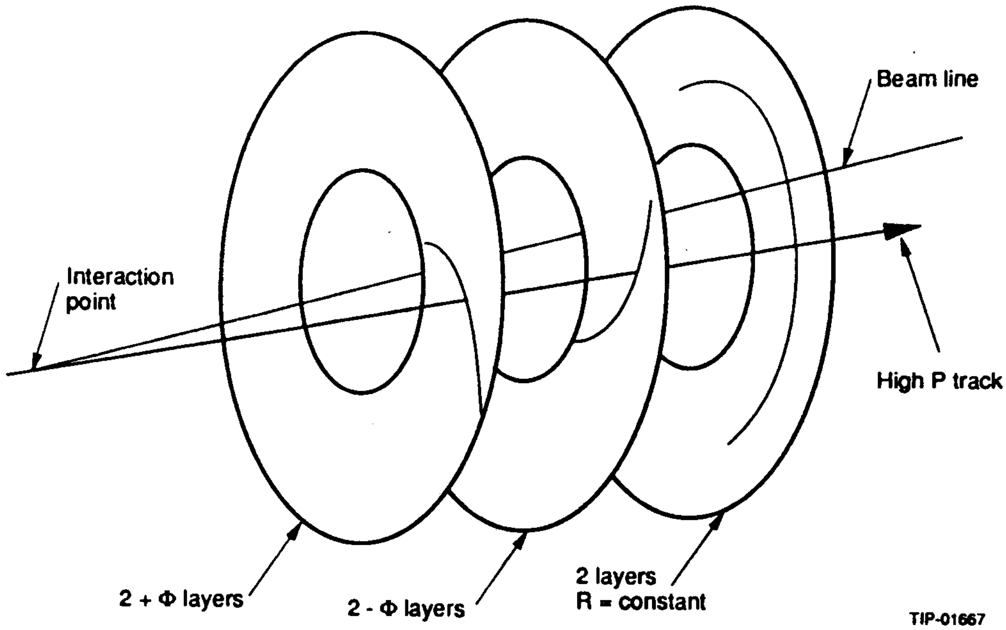


Figure 2.2.2-5. Intermediate Tracking Superlayer

Intermediate fiber tracker

Superlayer	Z(m)	R_1 (m)	R_2 (m)	Φ Layer count 1 mm	R Layer count 500 μm	Total Superlayer
1 2 3	3.0 3.5 4.0	0.50 0.58 0.66	0.50 0.58 0.66	3,150 3,650 4,150	1,600 2,600 2,280	28,300 34,400 37,700
Total						100,400



Fiber Equations for Super Sublayers:

$$\phi - \phi_0 = \pm\left[\sqrt{\left(\frac{r}{r_0}\right)^2 - 1} \ \ \mathrm{Cos}^{-1}\left(\frac{r_0}{r}\right) \right]$$

R = Constant

All "ϕ" Fibers = 1mm

All R = Constant Fibers = 500 μm

Figure 2.2.2-6. Super Sublayer of the Intermediate Tracker

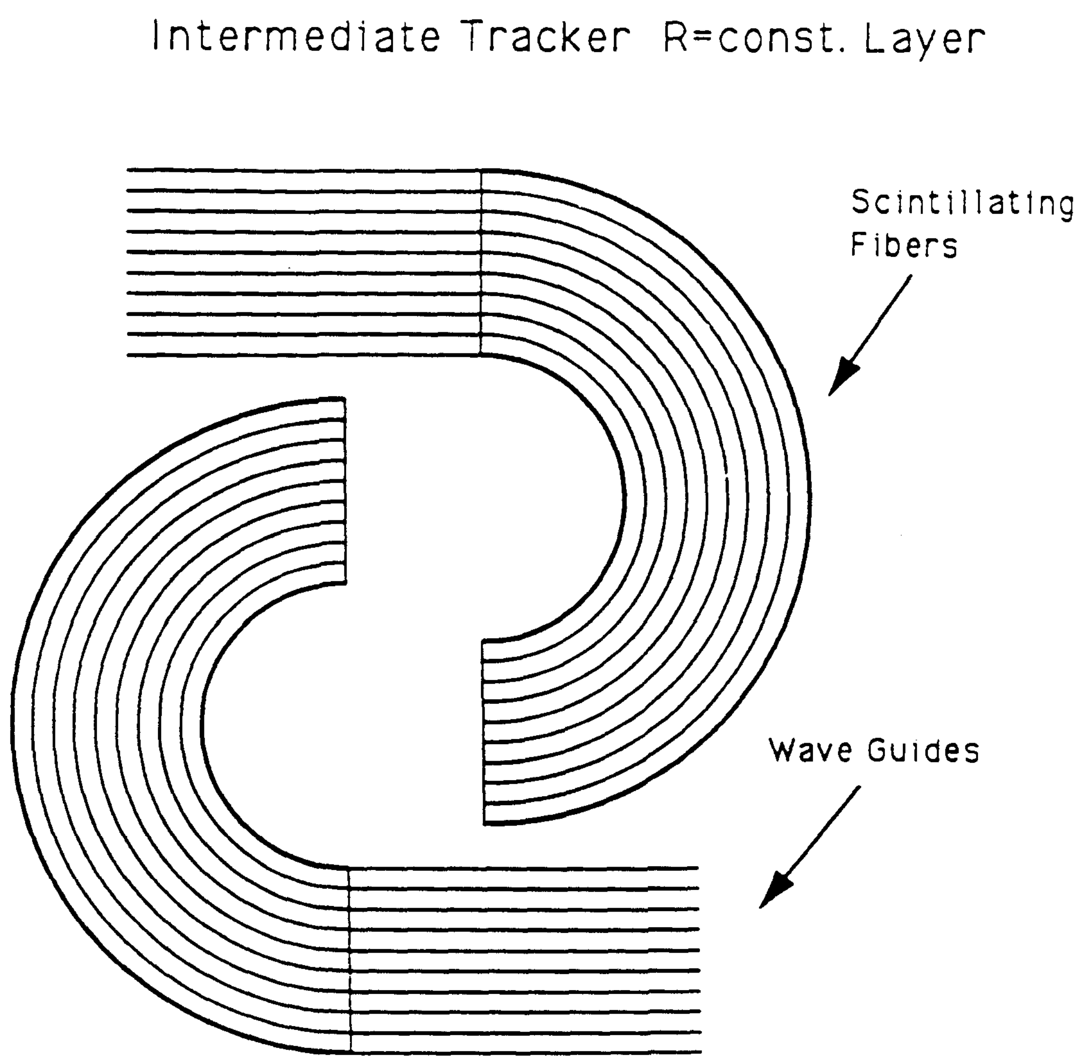
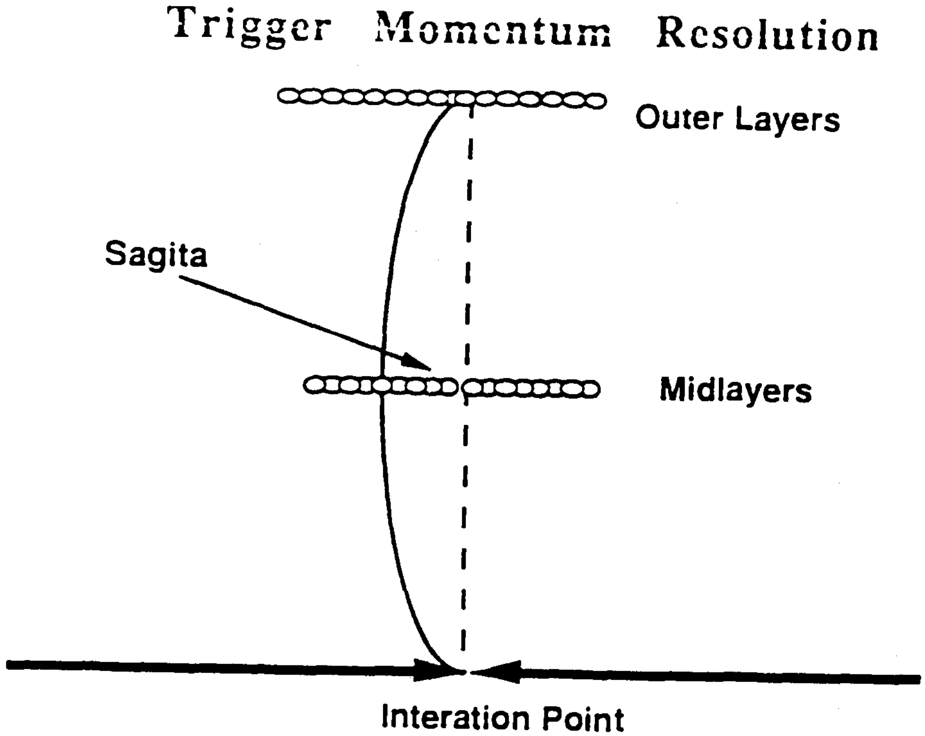


Figure 2.2.2-7. Intermediate Tracker



The Trigger will make only a simple momentum measurement with no attempt to correlate all the hits into coordinates. It will find the sagita by counting fiber separation between a straight line drawn between the outer layers and the beam and the hits in intermediate layers. The Momentum resolution in this case is:

$$\frac{\delta P}{P} = \frac{-8P\delta S}{0.3BL^2}$$

Where: $\delta S = 750\mu m$

$B = 2\text{Tesla}$

$$\frac{\delta P}{P} = 0.004P(\text{GeV/c})$$

$L = 1.65$ m

Figure 2.2.2-8. Trigger Momentum Resolution

Table 2.3-1. Superconducting Solenoid Parameters

Name	Value	Units
Inner radius of cryostat	1700	mm
Outer radius of cryostat	2050	mm
*Total length of cryostat	8000	mm
Mean conductor radius	1810	mm
*Total length of conductor	7600	mm
Central magnetic field	2.0	Tesla
Nominal operating current	8000	amp
RRR of Al stabilizer	750	--
I_{op}/I_c	50	%
Max hoop stress	4.5	Kgf/mm^2
Max stress intensity	6.0	Kgf/mm^2
Max shear stress at epoxy	0.5	Kgf/mm^2
Max temp after quench	< 100	^oK
Max voltage after quench	< 500	V
Conductor type:	Cu/Nb-Ti	
Approx. size of Al + superconductor cable	50×5	mm^2
*Stored energy	122	MJ
*Axial support force constant	0.5	T/mm
*Axial compressive force	1614	T
Thickness at $\theta = 90^o$	1.2	radiation lengths
Approx. chimney diameter	305	mm

*Assumes non-magnetic calorimeter

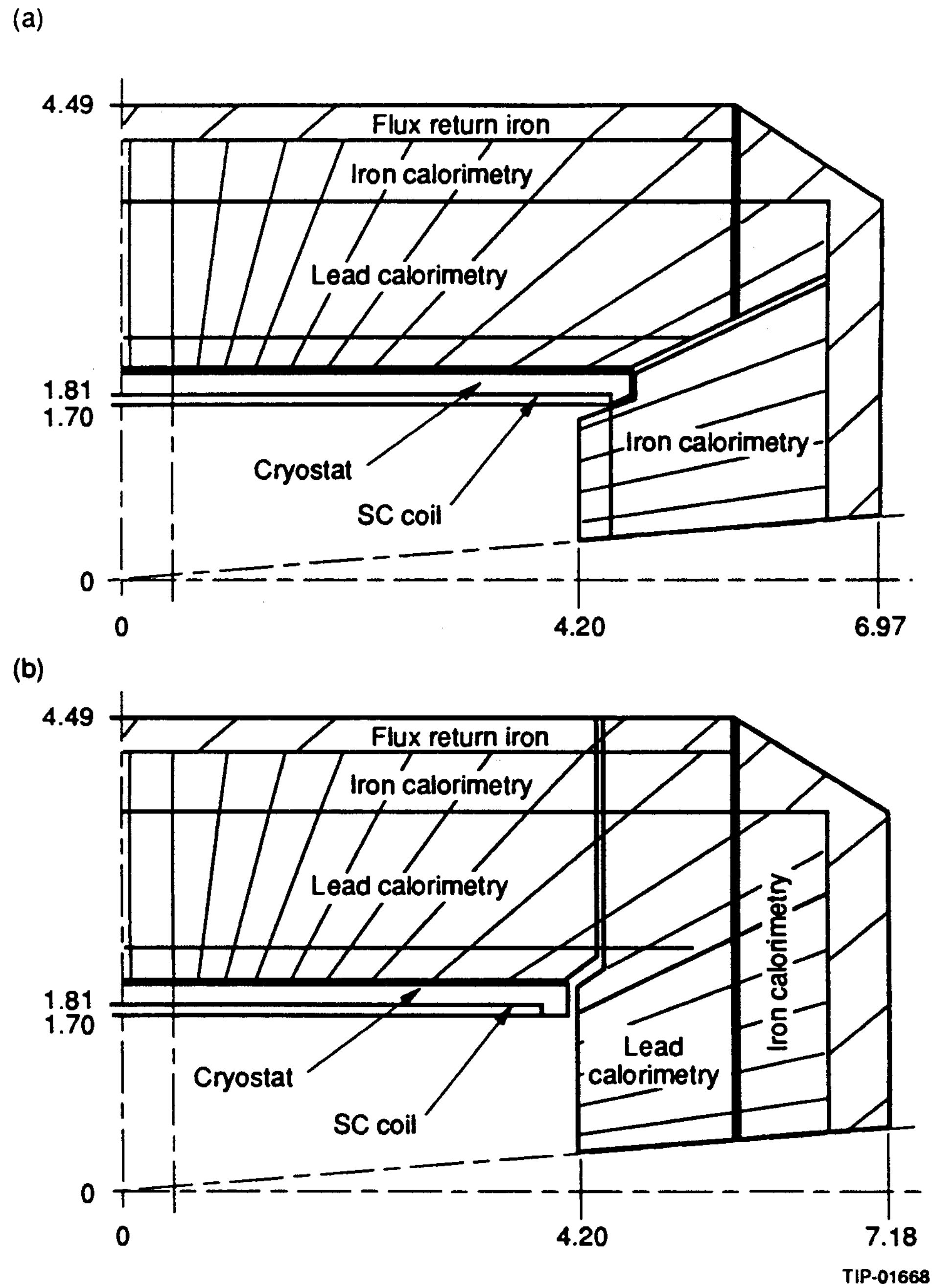


Figure 2.3-1. Coil-iron-calorimeter geometries for Type-U solenoid. With magnetic endcap calorimetry (a) and with nonmagnetic endcap calorimetry (b). The axial field at the origin is 2 T in either case. The stored energy with iron calorimetery is 147 MJ; with nonmagnetic calorimetery it is 122 MJ.

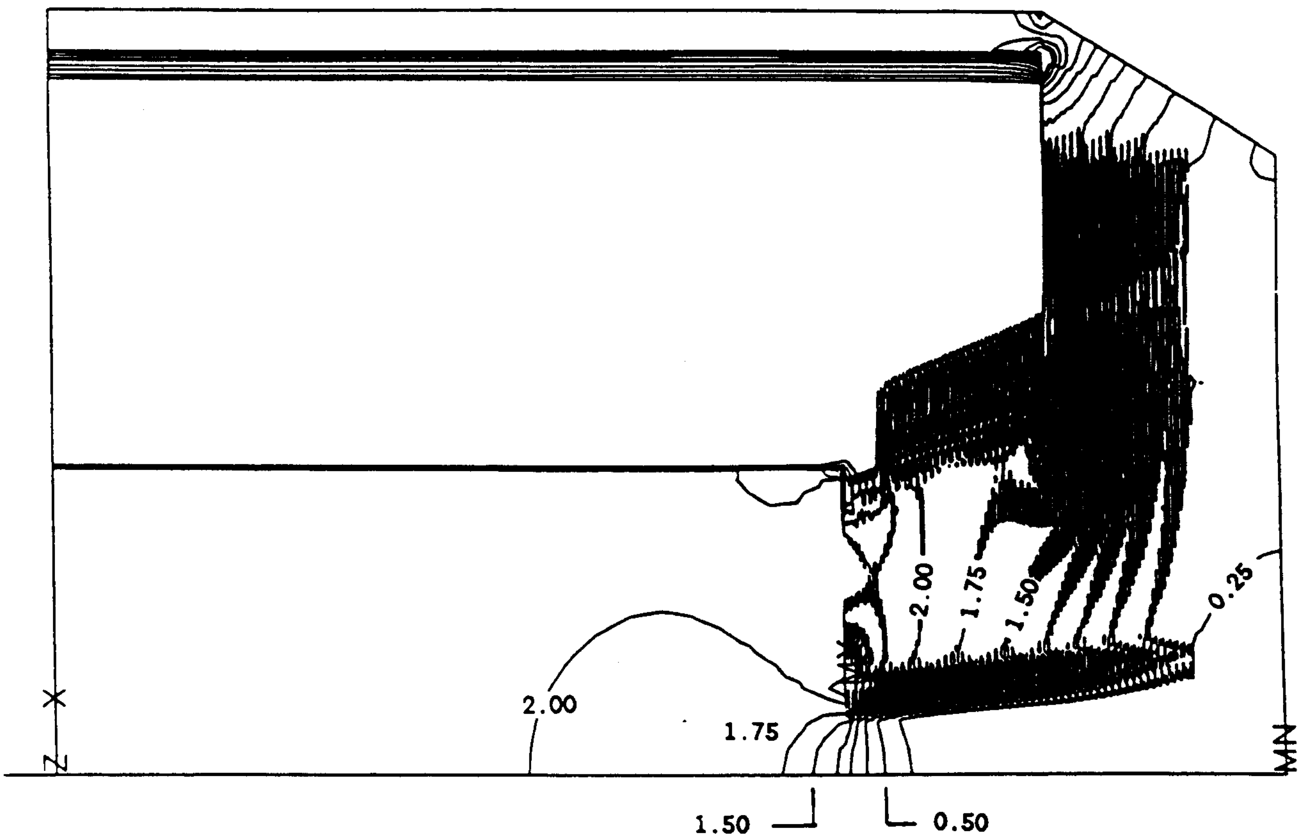


Figure 2.3-2. Field Map (iron end cap calorimeter)

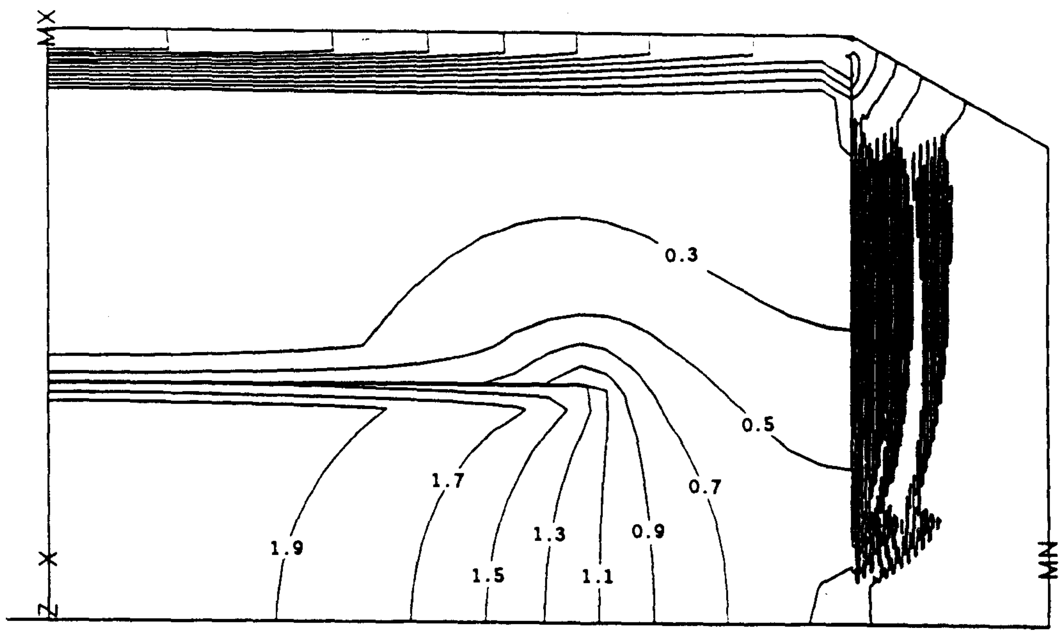


Figure 2.3-3. Field Map (non-iron end cap calorimeter)

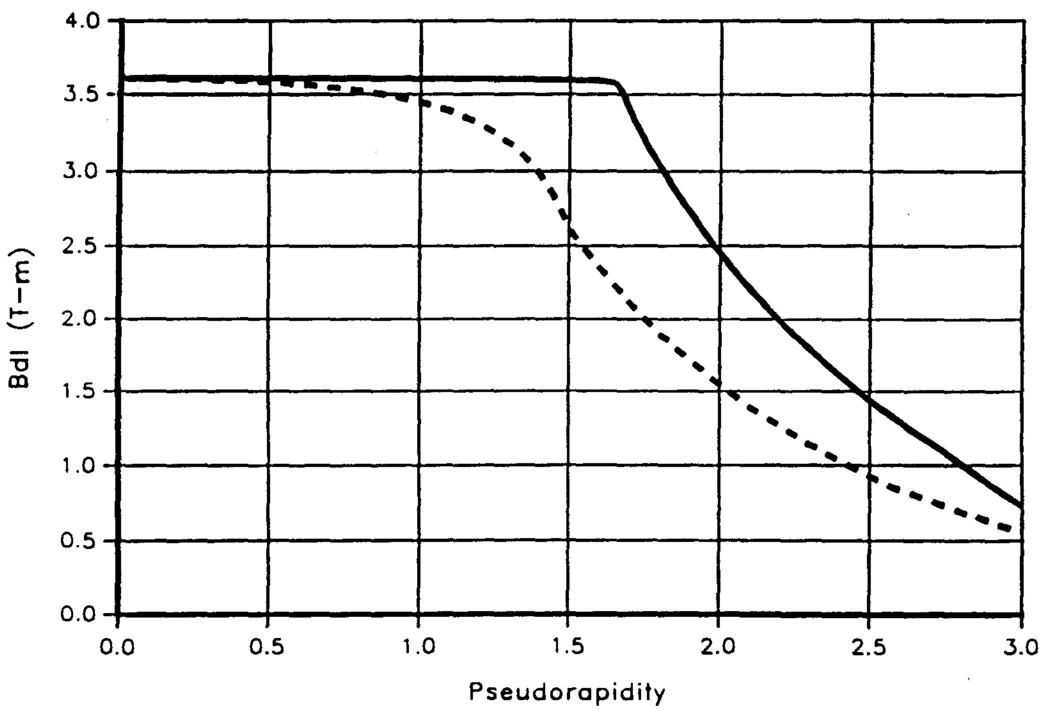


Figure 2.3-4. Field Integrals for End Cap Options

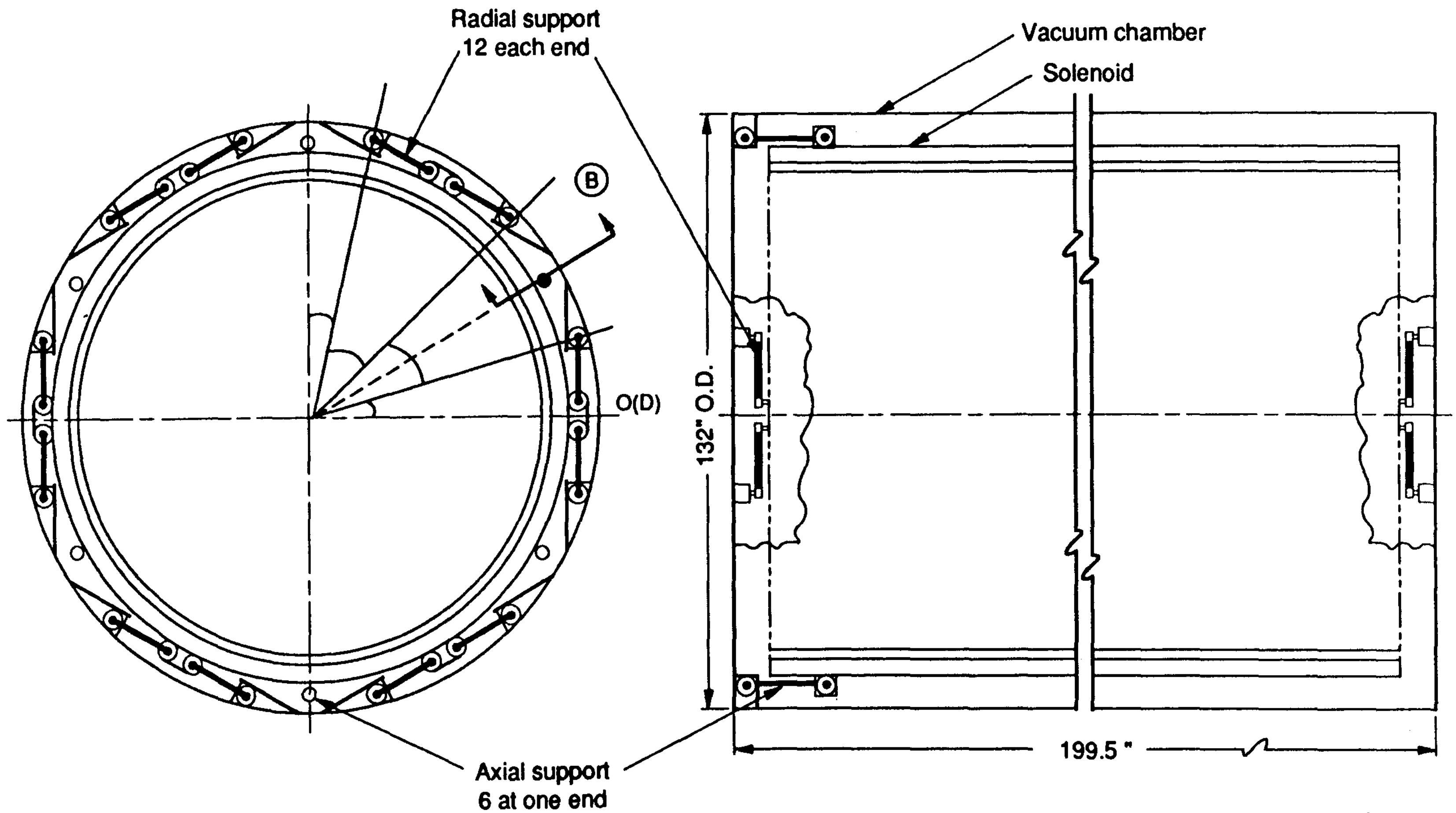


Figure 2.3-5. Axial and Radial Supports

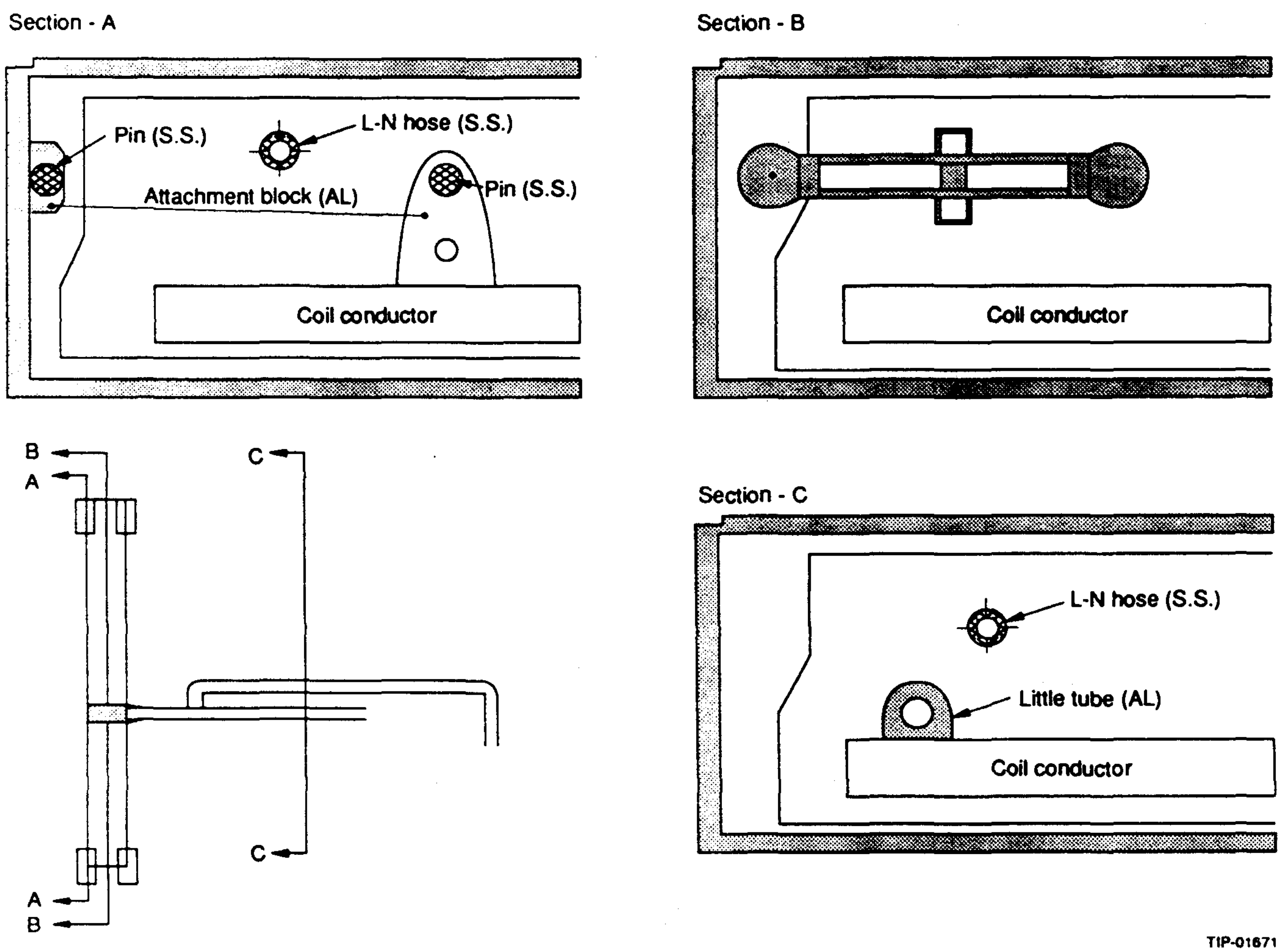


Figure 2.3-6. Axial Support

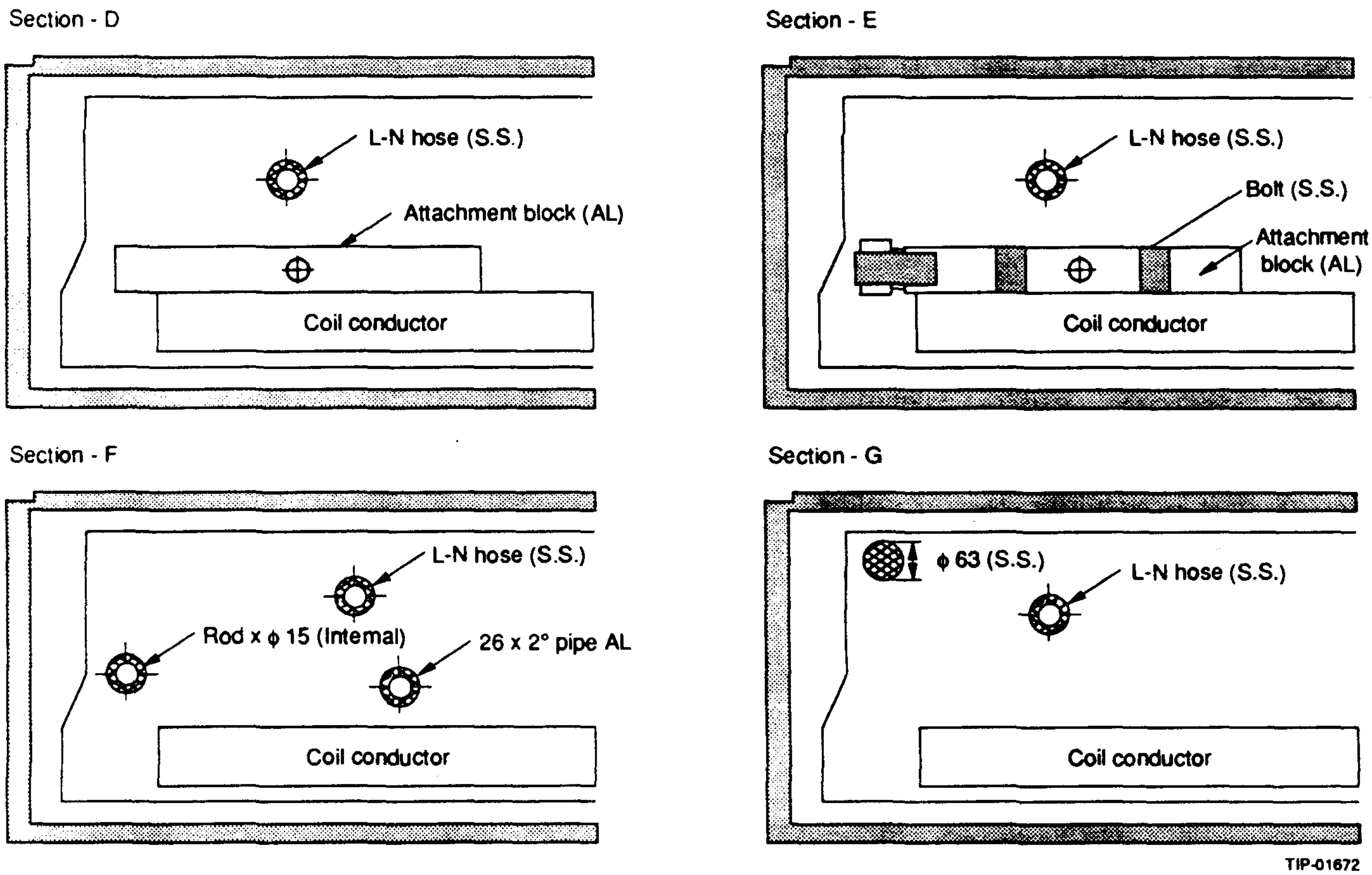


Figure 2.3-7. Radial Support

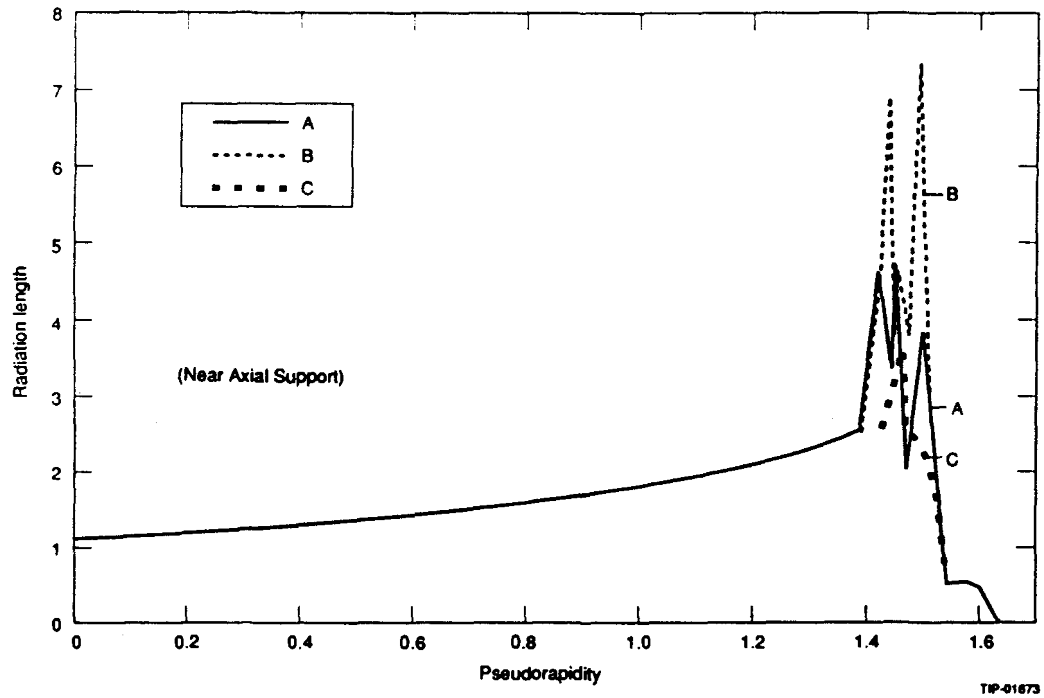


Figure 2.3-8. Radiation Length vs. Pseudorapidity (Sec. A-C)

Figure to be Supplied

Figure 2.3-9. Radiation Length vs. Pseudorapidity (Sec. A-C, Zooming)

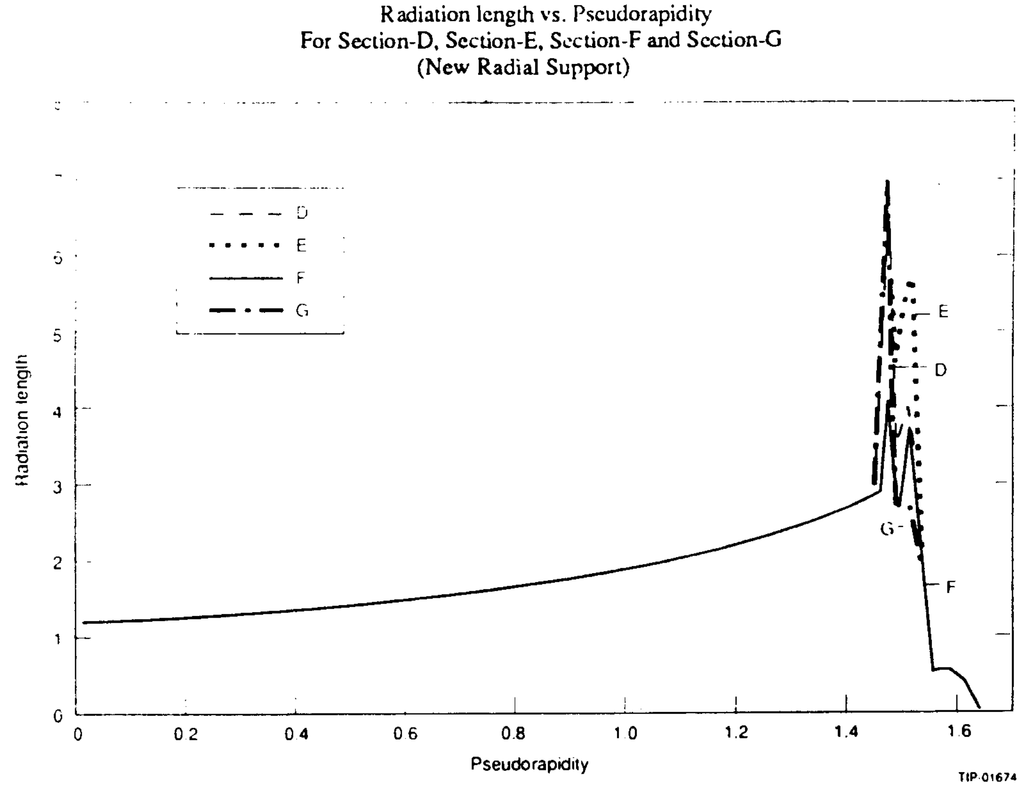


Figure 2.3-10. Radiation Length vs. Pseudorapidity (Sec. D-G)

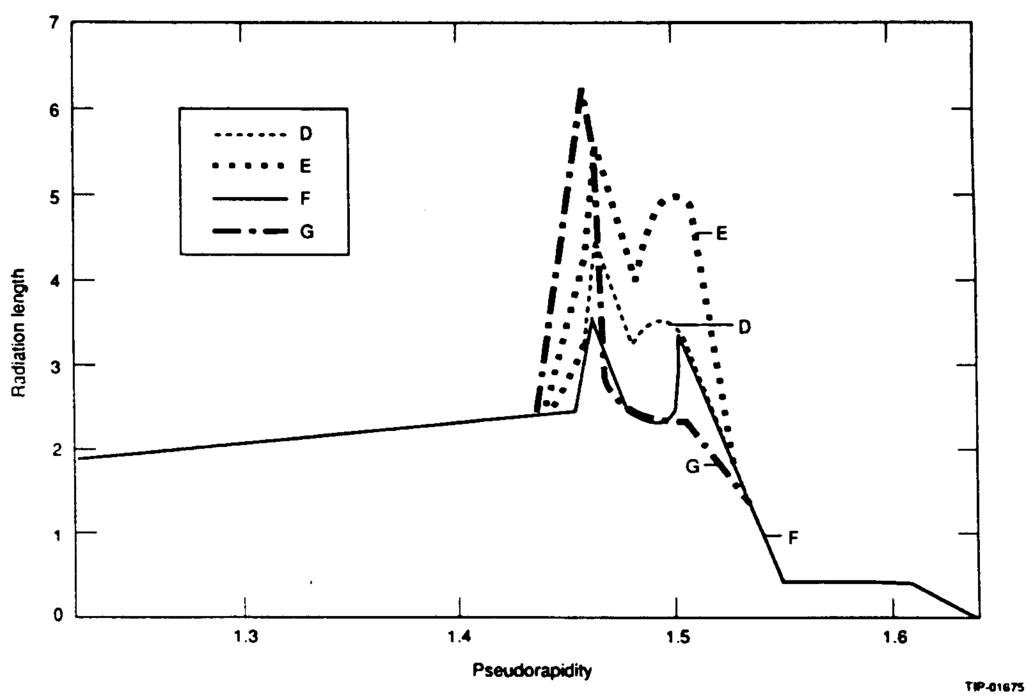


Figure 2.3-11. Radiation Length vs. Pseudorapidity (Sec. D-G, Zooming)

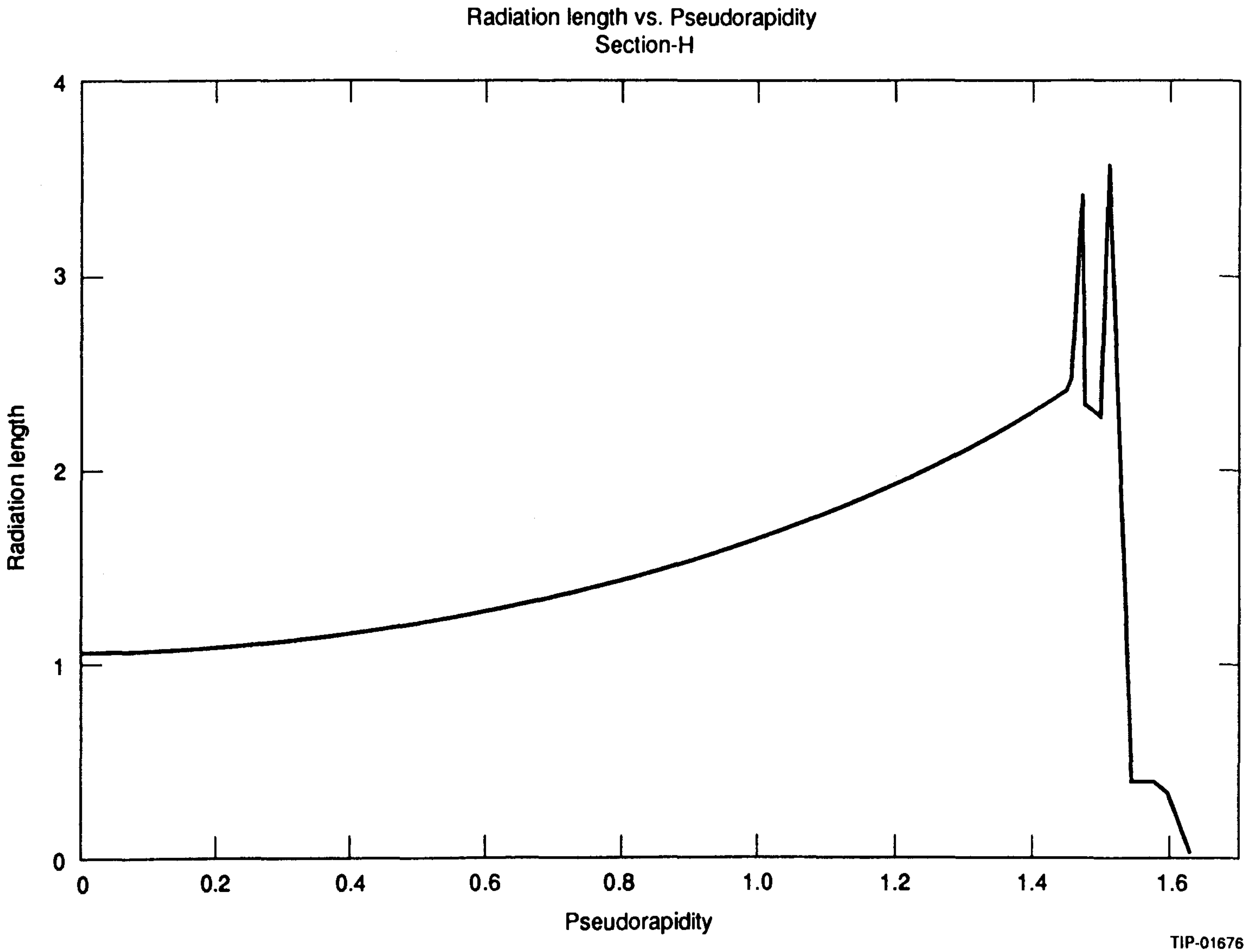


Figure 2.3-12. Radiation Length vs. Pseudorapidity (Sec. H)

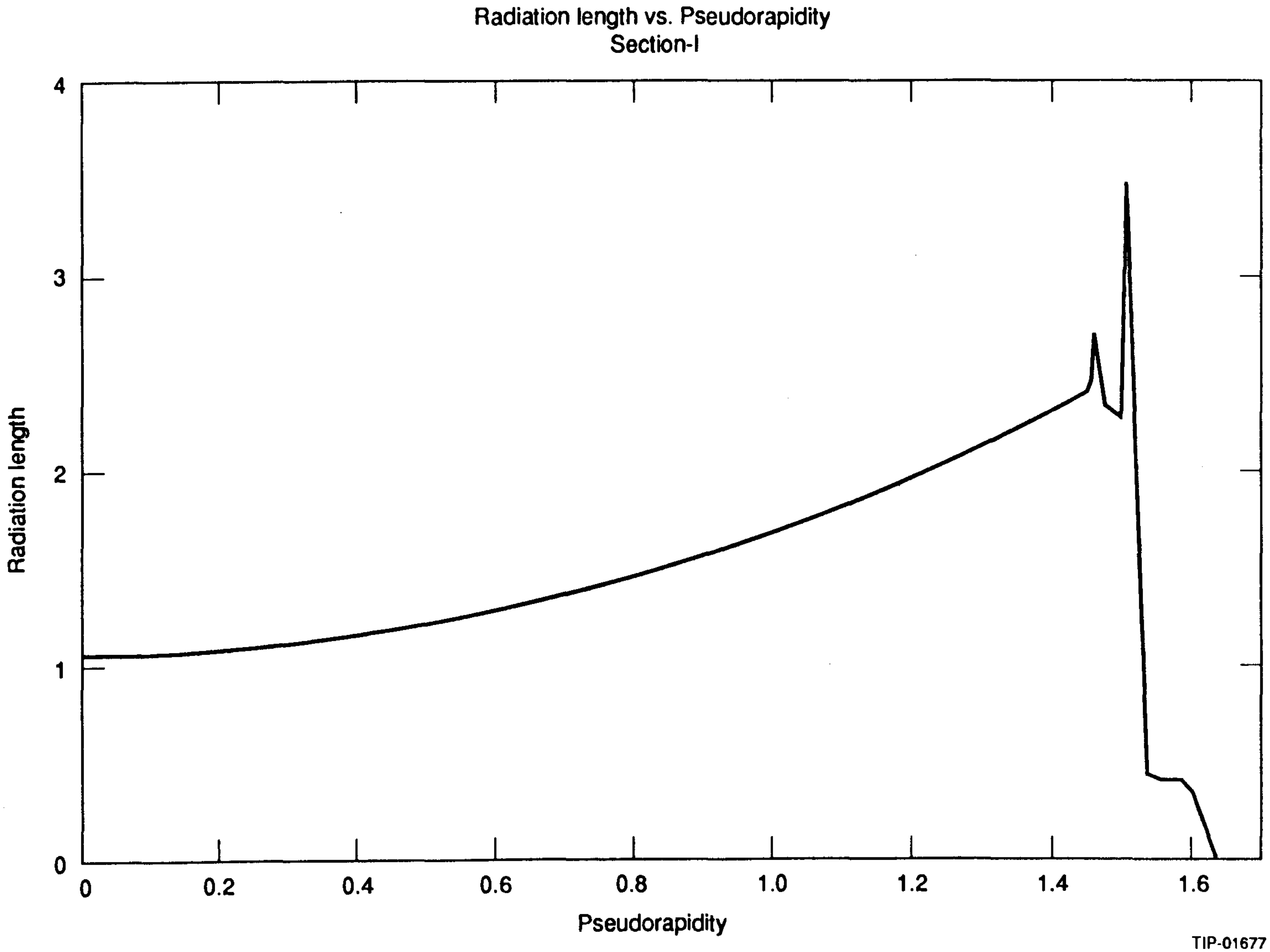


Figure 2.3-13. Radiation Length vs. Pseudorapidity (Sec. I)

CRYOGENIC REFRIGERATION REQUIREMENT FOR THE SOLENOIDAL MAGNET

Present design calls for 4.5 K liquid helium supply to the valve box. The return flow is 4.5 K helium gas from the cold mass and 300 K helium gas from current leads. The system shows a helium circulation pump to overcome the pressure drop in the system. Also shown is a helium cold compressor which allows the subcooler pressure to drop below atmospheric pressure for possible operation at 4.0 K or below.

The 80 K magnet shield is cooled by liquid nitrogen supply.

According to analysis done at FNAL, the estimated steady state head load of the magnet, the valve box and the pump box is 66 W and 23 liter/hr at 4.5 K. The 80 K heat load is 700 watts.

If all other heat loads are considered, the steady state head load could be 200 to 300 watts. That is a small refrigerator. However, if we have to have available capacity for cooldown and quench recoveries, we may need a 1500 watts refrigerator (that will cost about $1.5M). It would be more cost effective to define some kind of safe coupling between the detector cryogenic needs during cooldown and the collider helium storage system at the IR radiations.

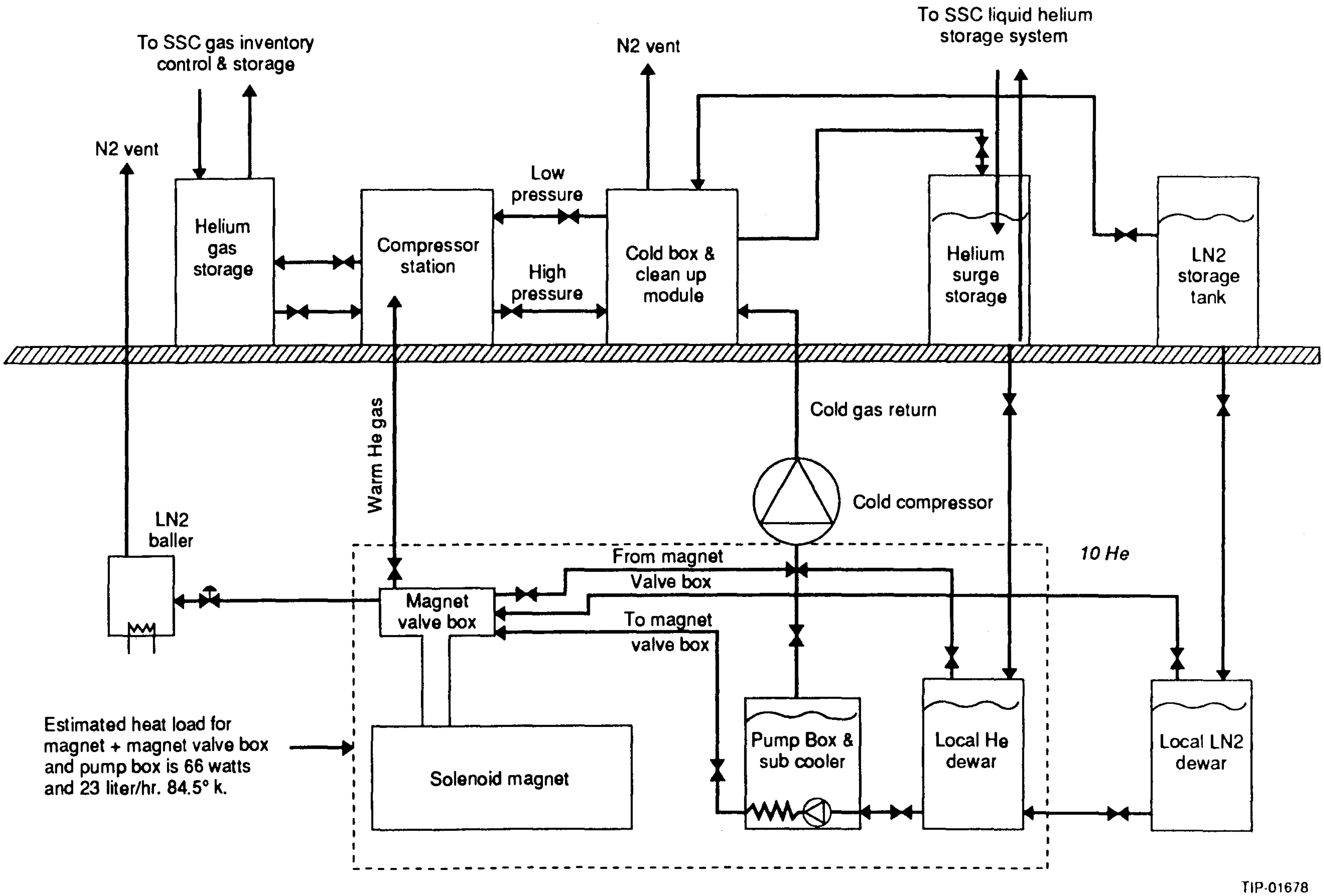


Figure 2.3-14. Helium Cryogenic Schematic for SDC Solenoid

Table 2.4.1-1. Scintillator Plate Calorimeter Barrel Physical Parameters

Parameter	Model "A"	Model "B" LOI
Inner Radius (M)	2.10	2.10
Half Length (M)	4.80	4.14
End Matching Slope - Dr/Dz	0.43	0.54
Azimuthal Tower Segments (No.)	128	128
Azimuthal Tower Size (Radians)	0.05	0.05
Total Axial Tower Segments (No.)	63	59
Axial Tower Size (Rapidity)	0.05	0.05
Total Barrel Towers (No.)	8064	7552
Long. Segmentation (No.)	4	4
EM Depth (X0)	25.11	25.11
EM Depth (Lambda)	0.91	0.91
Absorber Xo (Cm)	0.56	0.56
Absorber Lambda (Cm)	17.09	17.09
No. Long. EM Cells	28	28
Scin. Plate Thickness (Cm)	0.25	0.25
Abs. Plate Thickness (Cm)	0.50	0.50
Total Long. Cell Size (Cm)	0.85	0.85
Shower Max. Profile Detector		
No. Scin. Elements per Tower	5	5
Scin. Element Thickness (Cm)	0.50	0.50
HAC1 Depth (Lambda)	6.10	6.10
Absorber Lambda (Cm)	17.09	17.09
No. Long. Had Cells	80	80
Scin. Plate Thickness (Cm)	0.25	0.25
Abs. Plate Thickness (Cm)	1.25	1.25
Total Long. Cell Size (Cm)	1.60	1.60
HAC2 Depth (Lambda)	2.99	2.99
Absorber Lambda (Cm)	16.77	16.77
No. Long. Had Cells	13	13
Scin. Plate Thickness (Cm)	0.25	0.25
Abs. Plate Thickness (Cm)	3.81	3.81
Total Long. Cell Size (Cm)	4.16	4.16
EM Abs. Density (Gm/Cm**3)	11.35	11.35
Aver. EM Density (T/M**3)	6.97	6.97
HAC1 Abs. Density (Gm/Cm**3)	11.35	11.35
Aver. HAC1 Density (T/M**3)	9.02	9.02
HAC2 Abs. Density (Gm/Cm**3)	7.87	7.87
Aver. HAC2 Density (T/M**3)	7.27	7.27

Table 2.4.1-2. Scintillator Plate Calorimeter Endcap Physical Parameters

Parameter	Model "A"	Model "B" LOI
Inner Face Half Length (M)	4.20	4.20
Inner Min. Radius (M)	0.43	0.43
Outer Min. Radius (M)	1.64	2.05
Inner Radius Slope - Dr/Dz	0.10	0.10
Outer Radius Slope - Dr/Dz	0.43	0.54
Av. Azl. Tower Width (Cm)	9.52	10.06
Av. Radial Tower Width (Cm)	9.52	10.06
Barrel Ext. Endcap Towers (No.)	640	1152
Full Length Endcap Towers (No)	2480	2494
Total Endcap Towers (No.)	3120	3646
Long. Segmentation (No.)	4	4
EM Depth (X0)	25.11	25.11
EM Depth (Lambda)	0.90	0.90
Absorber Xo (CM)	0.56	0.56
Absorber Lambda (Cm)	17.09	17.09
No. Long. EM Cells	28	28
Scin. Plate Thickness (Cm)	0.25	0.25
Abs. Plate Thickness (Cm)	0.50	0.50
Total Long. Cell Size (Cm)	0.85	0.85
Shower Max. Profile Detector:		
No. Scin. Elements per Tower	5	5
Scin. Element Thickness (Cm)	0.50	0.50
HAC1 Depth (Lambda)	6.45	6.09
Absorber Lambda (Cm)	16.77	16.77
No. Long Had Cells	28	80
Scin. Plate Thickness (Cm)	0.25	0.25
Abs. Plate Thickness (Cm)	3.81	1.25
Total Long. Cell Size (Cm)	4.16	1.60
HAC2 Depth (Lambda)	4.60	4.97
Absorber Lambda (Cm)	16.77	16.77
No. Long Had Cells	20	21
Scin. Plate Thickness (Cm)	0.25	0.25
Abs. Plate Thickness (Cm)	3.81	3.92
Total Long. Cell Size (Cm)	4.16	4.27
EM Abs. Density (Gm/Cm**3)	11.35	11.35
Aver. EM Density (T/M**3)	6.97	6.97
HAC1 Abs. Density (Gm/Cm**3)	7.87	11.35
Aver. HAC1 Density (T/M**3)	7.27	9.02
HAC2 Abs. Density (Gm/Cm**3)	7.87	7.87
Aver. HAC2 Density (T/M**3)	7.27	7.28

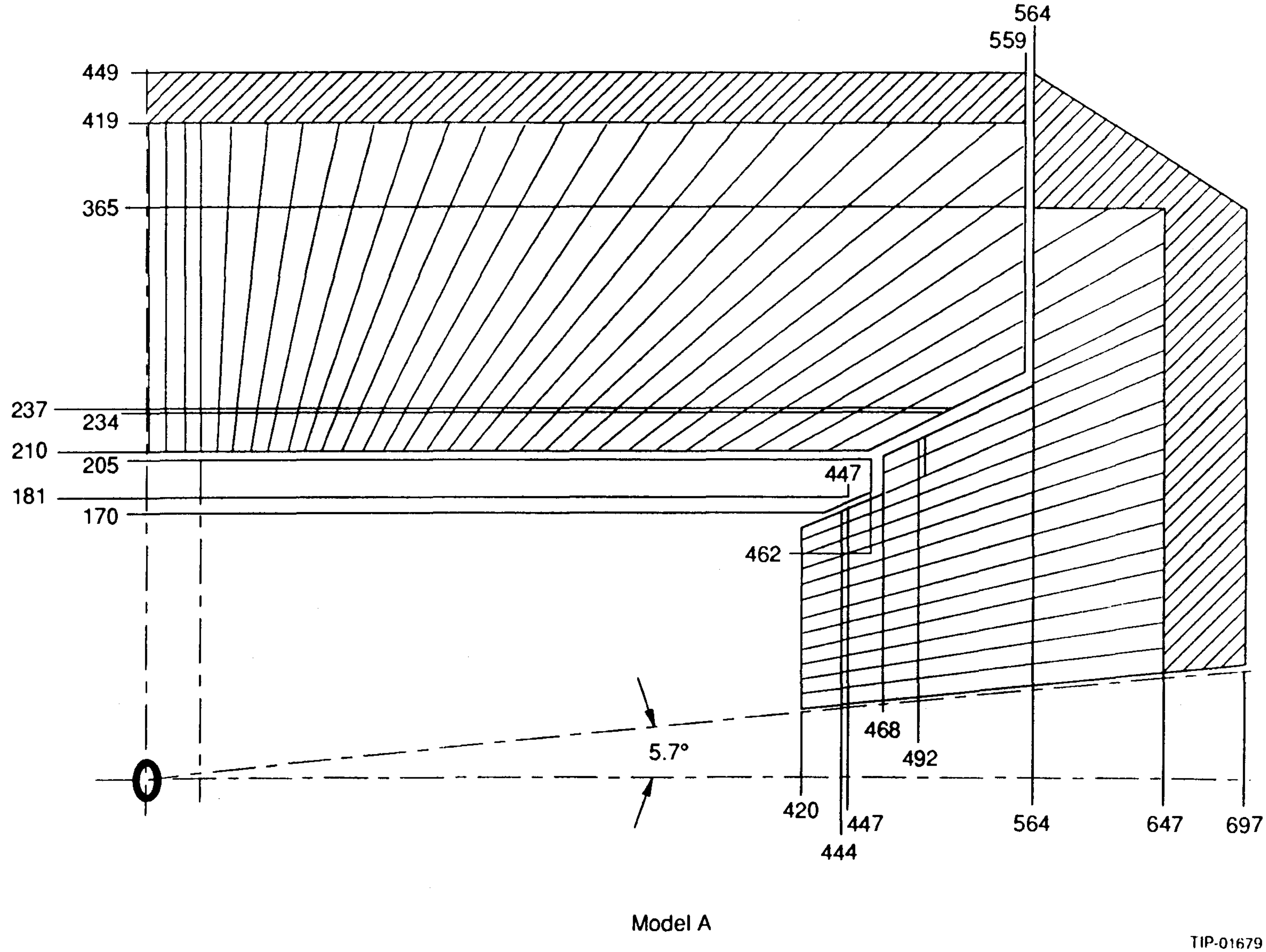
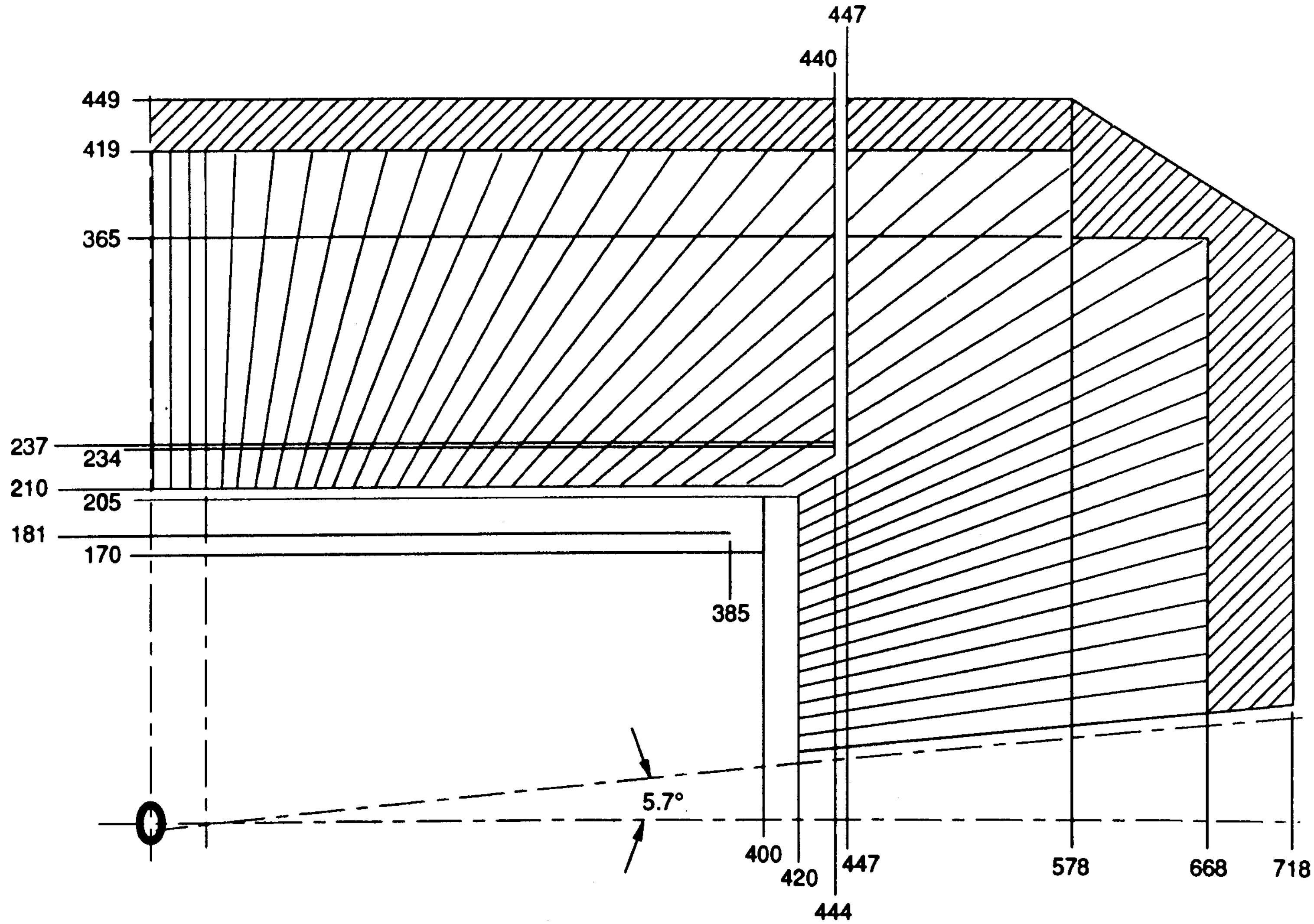


Figure 2.4.1-1. Tower Structure (Pb/scintillator option)



Model B

TIP-01680

Figure 2.4.1-2. Tower Structure (Pb/scintillator option)

Table 2.4.2-1. Liquid Argon Calorimeter, Current Weight Summary
Module Details (See Figure 2.4.2-1 for Module I.D. Number)

Module I.D. No.	Outer Radius (mm)	Inner Radius (mm)	Avg. Z Length (mm)	No. of Modules per ring	No. of Absorber plates*	Module Phi Gap (mm)	Module weight each (tons)
1	2688.0	2331.5	2650.0	64	33	3.00	
2	2688.0	2331.5	2580.3	64	33	3.00	1.33
3	4284.8	2818.0	2630.0	32	87	5.00	25.50
4	4284.8	2818.0	1740.0	32	87	5.00	16.87
5	4284.8	2818.0	732.9	32	87	5.00	7.11
6	3065.0	461.0	356.5	16	33	3.00	3.63
7	3065.0	508.0	728.0	32	42	5.00	5.87
8	3065.0	593.0	1078.0	32	63	5.00	8.67
9	4350.0	3155.0	363.0	32	21	5.00	2.86
10	4350.0	3155.0	728.0	32	42	5.00	5.87
11	4350.0	3155.0	1078.0	32	63	5.00	8.76

*Absorber plates in EM Modules (1, 2 and 6) are 4.0 mm thick. The rest are 14 mm thick.

Total Number of Electromagnetic Modules	224
Total Number of Hadronic Modules	480
Total Number of Modules	704
Module Weight	
Barrel Modules	2608 (tonn)
Endcap Modules	2166 (tonn)
Total Modules	4774 (tonn)
Calorimeter Weight (not including LAr)	
Barrel Calorimeter	2814 (tonn)
Endcap Calorimeter	2412 (tonn)
Total Calorimeter	5226 (tonn)
Cryostat Weight	
Barrel Cryostat	206 (tonn)
Endcap Cryostat (2)	123 (tonn)
Total Cryostat	452 (tonn)

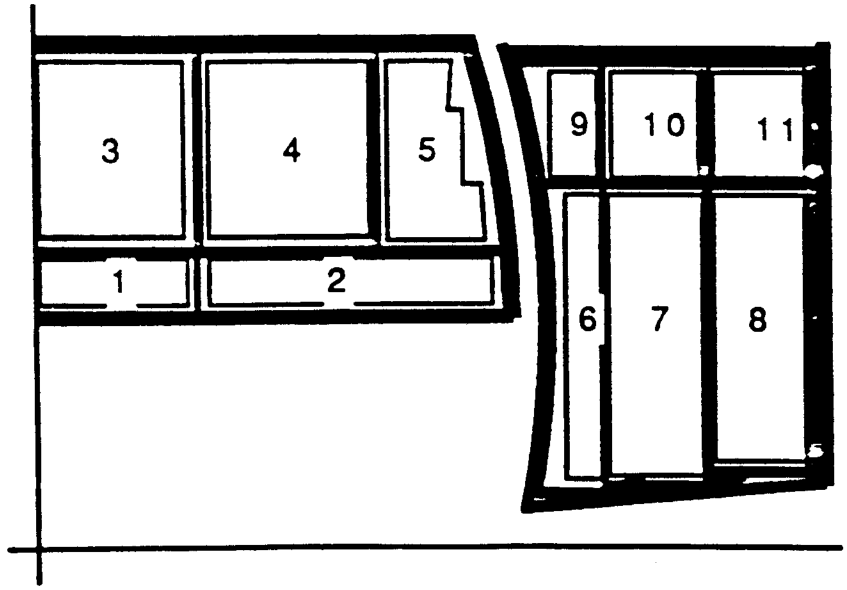
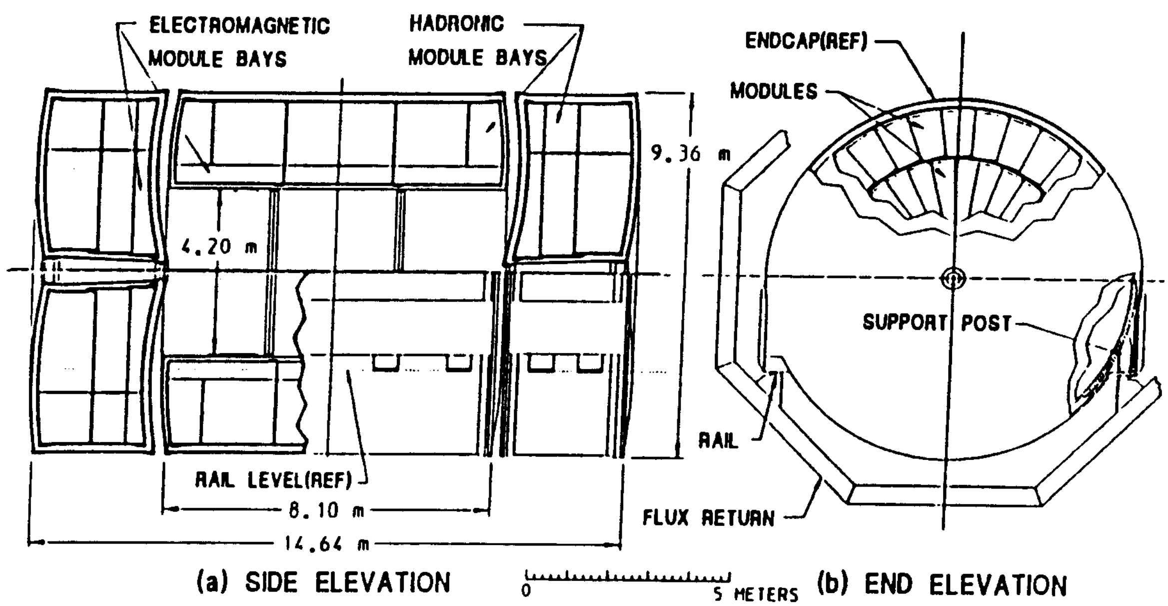


Figure 2.4.2-1. LAC Module Numbering



Side elevation (a) shows vessel structural features and EM and Hadronic Module bays. The Barrel LAr vessel has 8 conduction intercepted, cold mass support "posts"; each Endcap has 4. End elevation (b) shows the LAC's external rail supports to the Flux Return and the Endcap's Hadronic Module outlines. All Calorimeter Modules are tilted 3 degrees in Ø and overlap radially to eliminate projective cracks.

Figure 2.4.2-2. Liquid Argon Calorimeter

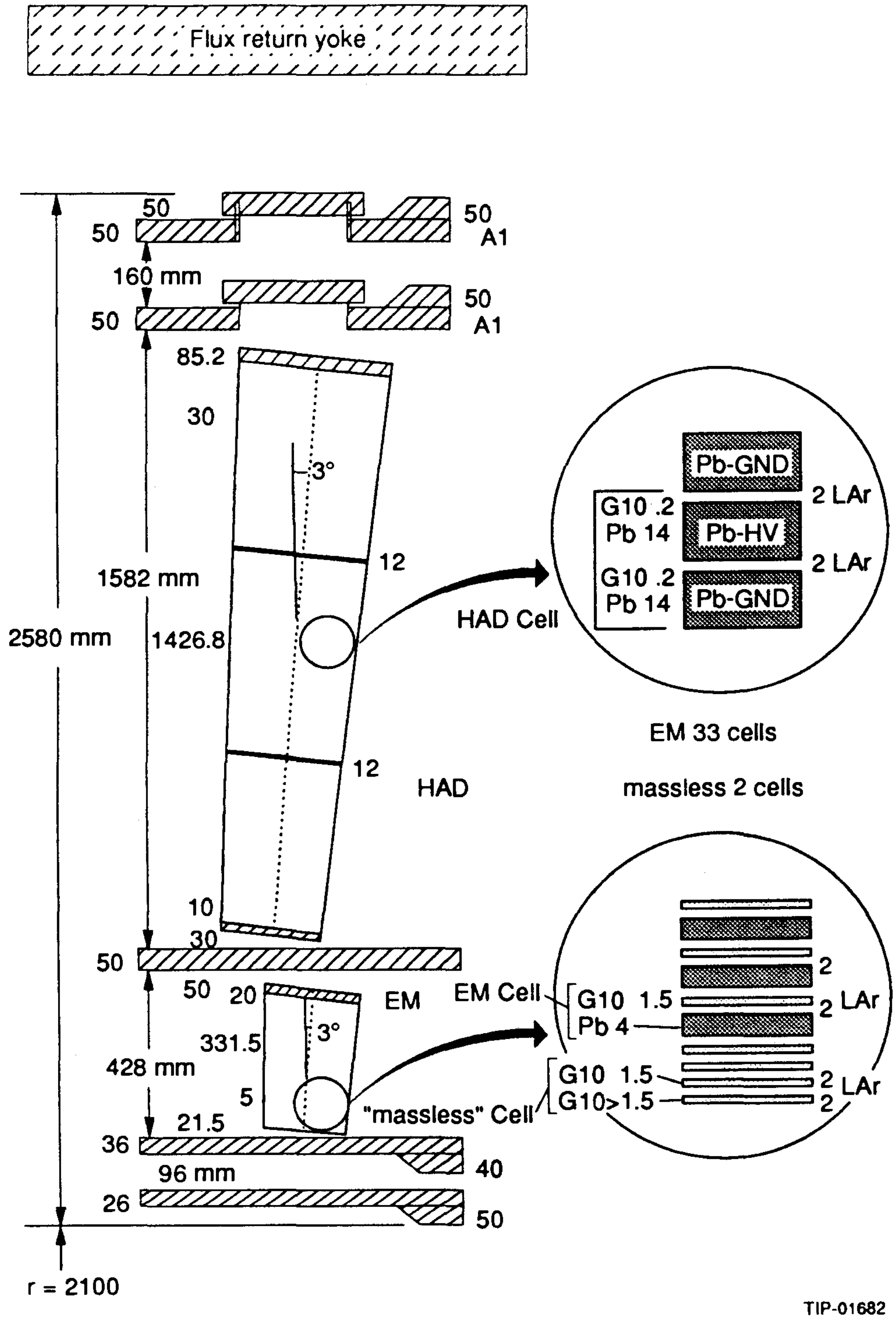


Figure 2.4.2-3. Radial Dimensions and Cell Structures of the Barrel

Table 2.4.2-2. Number of DA-Readout Channels for LAr Calorimeter
Basic Tower Size $\Delta\eta \times \Delta\phi = 0.5 \times 0.5$ except near $\eta = 3$.

Barrel	**(± z) × tower (φ) × towers (η)**		**nr channels**
Massless Gap	$2 \times 128 \times 25$		6400
EM #1	$2 \times 128 \times 25 \times 4$		25600
EM#2	$2 \times 128 \times 25$		6400
HAD#1	$2 \times 128 \times 23$		5888
HAD#2	$2 \times 128 \times 19$		4864
Extra channels due to washers			
Massless Gap		0	
EM#1	$2(\pm 8) \times 128(\phi) \times 2(\text{subdiv}) \times 1$	512	
EM#2	$2 \times 128 \times 1$	256	
Extra EM (washers)			768
HAD#1	$2 \times 128 \times 1 \times 2(\text{towers})$	512	
HAD#2	$2 \times 128 \times 1 \times 2(\text{towers})$	512	
Extra HAD (washers)			1024
	EM Barrel		39168
	HAD Barrel		11776

End Cap per side	**towers (φ) × towers(η)**		**nr channels**
Massless	32 x 1 + 48 x 2 + 64 x 3 + 80 x 2 + 96 x 3 + 112 x 2 + 128 x 11		2400
EM#1	(32 x 1 + 48 x 2 + 64 x 3 + 80 x 2 + 96 x 3 + 112 x 2 + 128 x 11) x 4		9600
EM#2	32 x 1 + 48 x 2 + 64 x 3 + 80 x 2 + 96 x 3 + 112 x 2 + 128 x 11		2400
HAD#1	32 x 1 + 48 x 2 + 64 x 3 + 80 x 2 + 96 x 3 + 112 x 2 + 128 x 15		2912
HAD#2	32 x 1 + 48 x 2 + 64 x 3 + 80 x 2 + 96 x 3 + 112 x 2 + 128 x 12		2528
HAD#0	128 x 5		640
Extra channels			
Massless		0	
EM#1	$128(\phi) \times 2(\text{subdiv}) \times 1$	256	
EM#2	$128(\phi)$	128	
Extra EM			384
HAD#1	$128(\phi) \times 2(\text{towers})$	256	
HAD#2	$128(\phi) \times 2(\text{towers})$	256	
Extra HAD			512
	EM each End Cap		14784
	HAD each End Cap		6592
	Barrel + 2 End Caps — EM		68736
	HAD		24960
	Total		93696

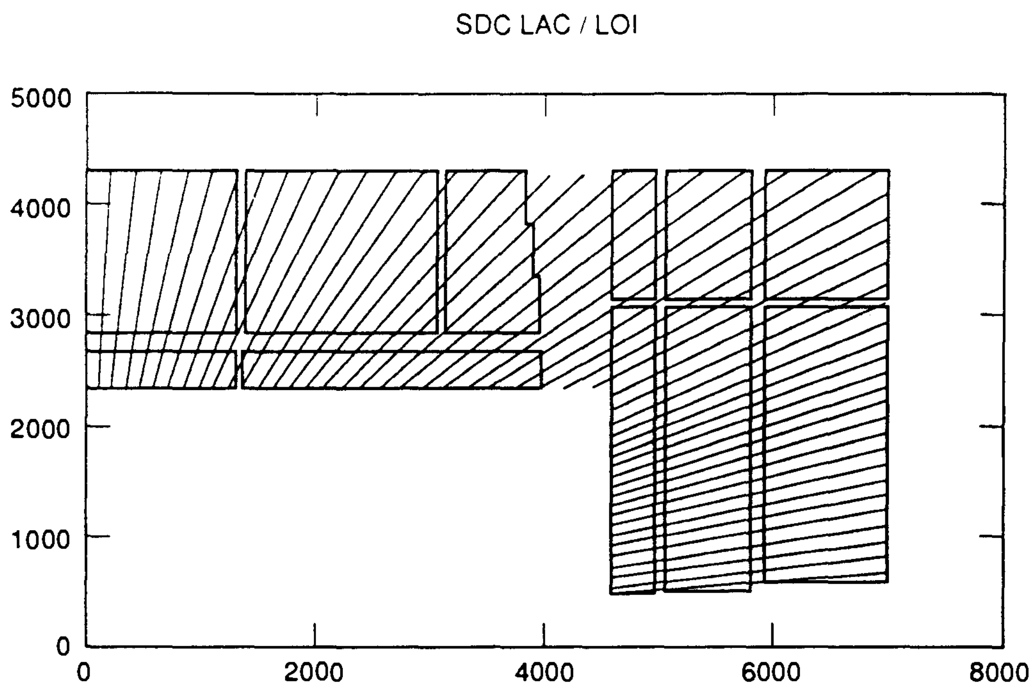


Figure 2.4.2-4. Liquid Argon Calorimeter

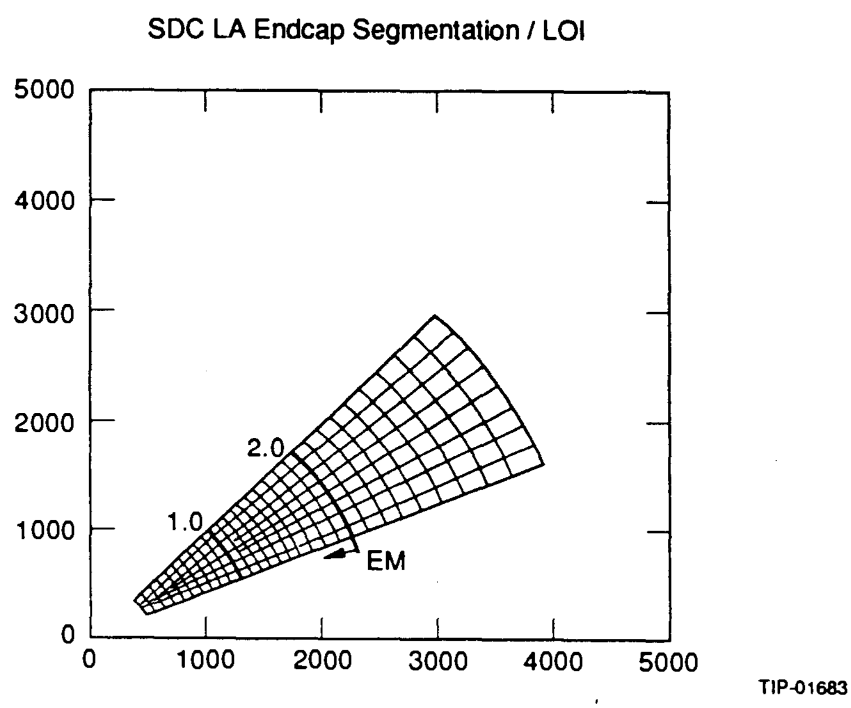


Figure 2.4.2-5. SDC LAr Endcap Segmentation/LOI

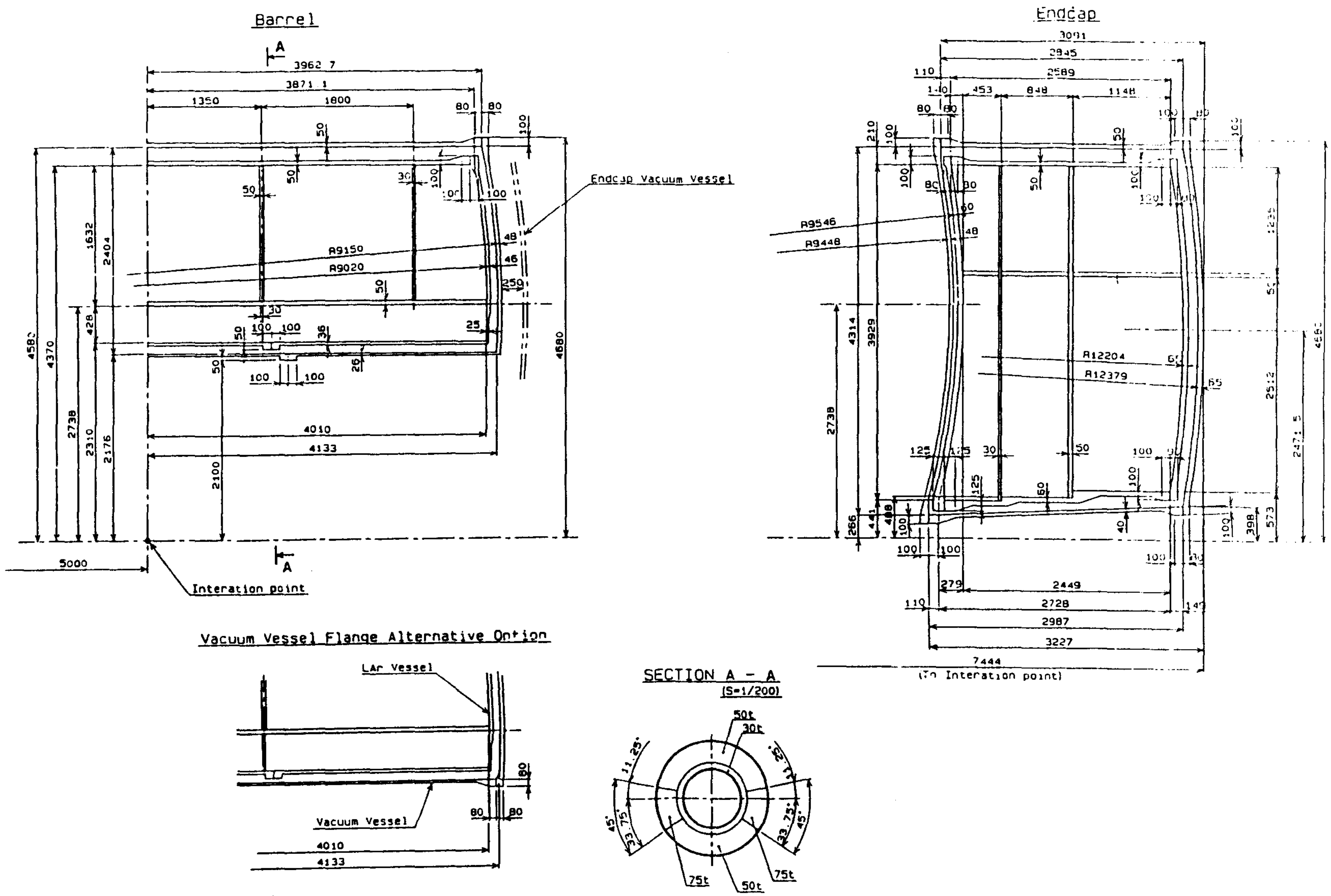


Figure 2.4.2-6. Dimensions of the Vessels

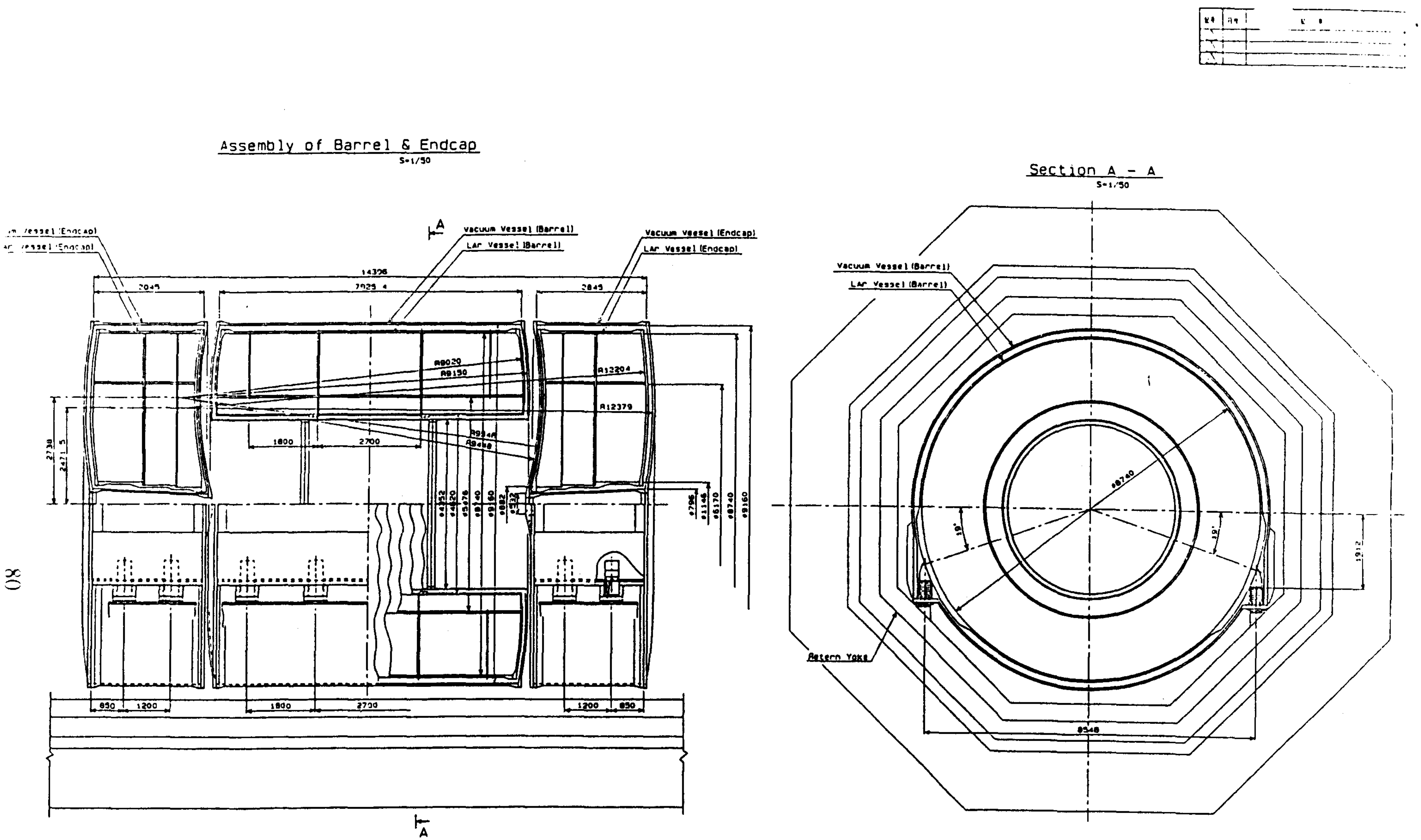


Figure 2.4.2-7. Assembly of Barrel and Endcap

SCALE 1/50
DESIGNING DEPT.
JOB NO. 5187672
OWNER
PROJECT NAME SDC Liquid Argon Calorimeter
DESIGNED
DRAWN
Assembly Drawing of Barrel & Endcap
DATE 1990.10.4
DWG NO. 6723A003

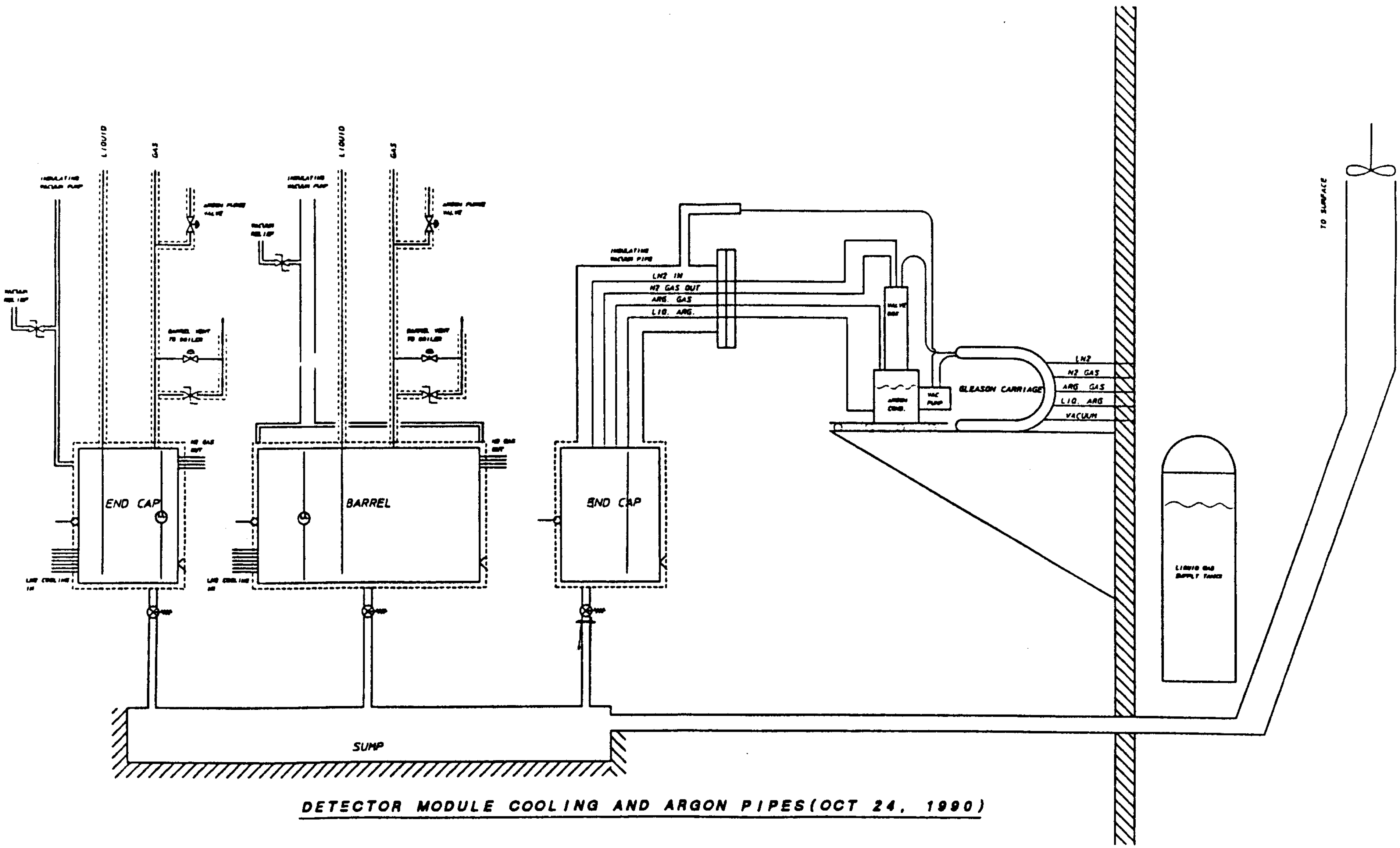


Figure 2.4.2-8. Detector Module Cooling and Argon Pipes

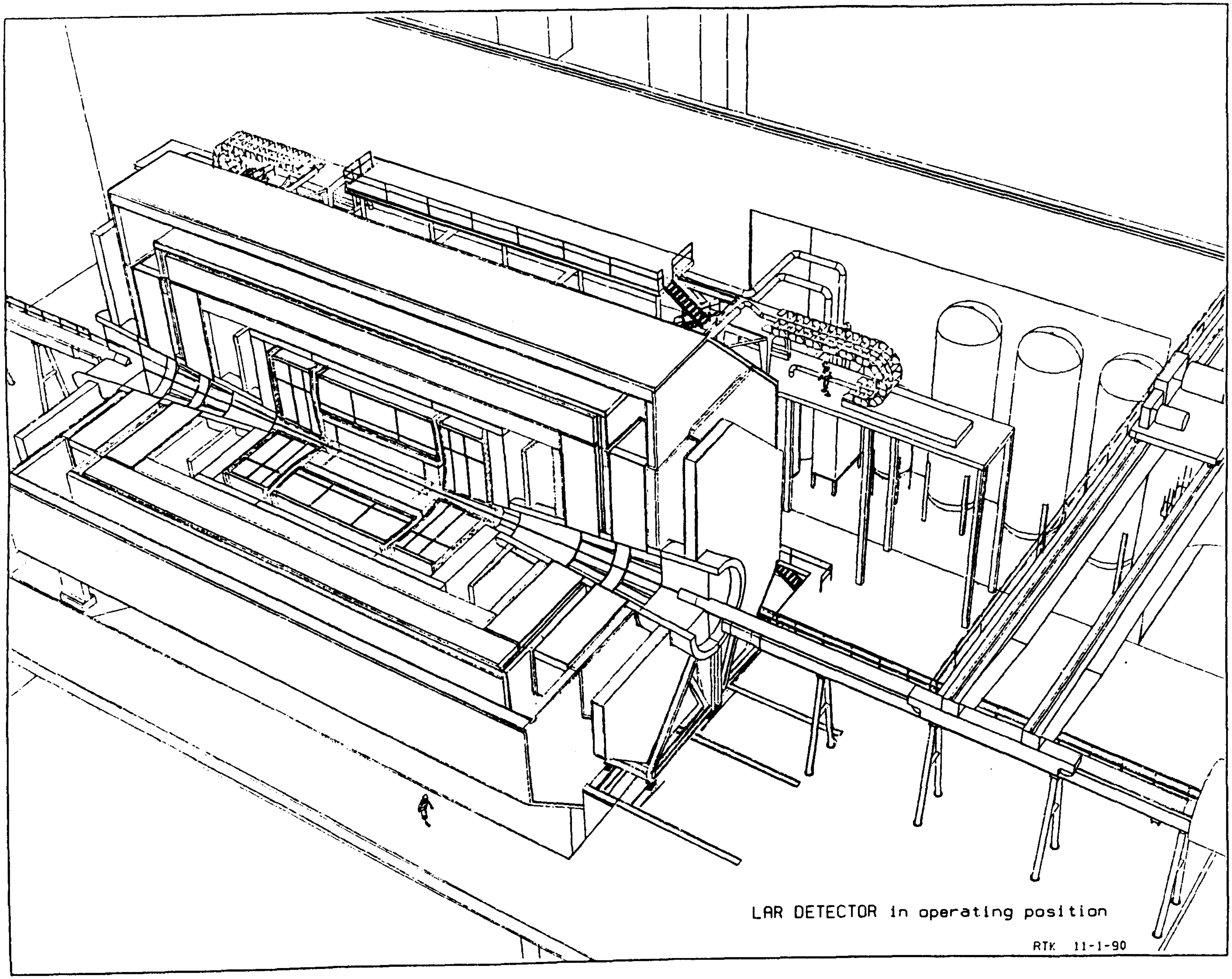


Figure 2.4.2-9. LAr in Operating Position

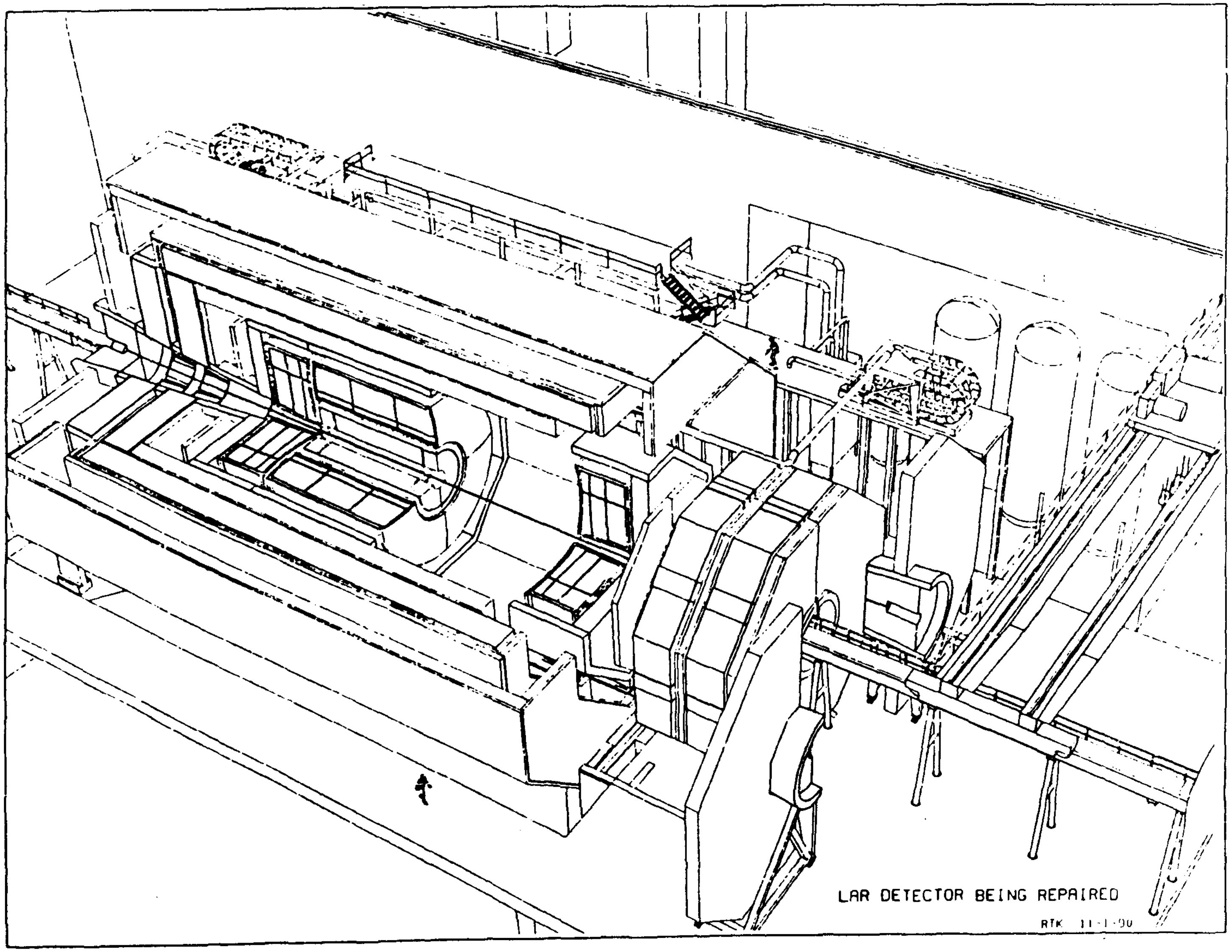


Figure 2.4.2-10. LAr Detector Being Repaired

Table 2.5-1. Toroid Mass

	A	B	C	D	E	F
1.	Toroid Parameters					
2.		Option 1-E	Option 2-A	Option 1-E	Option 2-A	
3.		Scint Tile Cal	LAC			
4.						
5.	Forward Toroid (each) (fig. of revolution)			Volume	Volume	
6.	r1 (m)	1.821	1.89	202.83	225.81	m^3
7.	r2 (m)	2.022	2.092	Mass	Mass	
8.	R1 (m)	5.597	5.915	1,596,284	1,777,134	Kg
9.	R2 (m)	6.45	6.77	1,759.90	1959.29	short tons
10.	Z (m)	2	2			
11.	Coil Packs	8	8			
12.	Turns/pack	5	5			
13.	Copper			6,369	6,622	Kg
14.	Current			4,743	5,032	Amps
15.	Voltage			29.70	32.76	Volts
16.	Power			140,882	164,837	Watts
17.	LCW	10 degrees C		52.05	60.90	gpm
18.						
19.	Intermediate toroid (each)			Volume	Volume	
20.	s (m)	7.24	6.96	330.67	302.73	m^3
21.	r1 (m)	1.531	1.606	Mass	Mass	
22.	r2 (m)	1.73	1.806	2,602,361	2,382,524	Kg
23.	Z (m)	2	2	2869.10	2626.73	short tons
24.	Coil Packs	8	8			
25.	Turns/Pack	6	6			
26.	Copper			9,455	9,172	Kg
27.	Current			4,656	4,361	Amps
28.	Voltage			57.44	51.22	Volts
29.	Power			267,423	223,354	Watts
30.	LCW	10 degrees F		98.80	82.52	gpm
31.						
32.	Forward/Intermediate Toroid Total (both ends)					
33.			Mass	8,397,290	8,319,316	Kg
34.			Weight	9,258.01	9,172.05	short tons
35.						
36.						
37.						
38.	Barrel			Volume	Volume	
39.	s1 (m)	7.24	6.96	1,958.73	2,003.53	m^3
40.	s2 (m)	8.74	8.46	Mass	Mass	
41.	Thickness (m)	1.5	1.5	15,415,235	15,767,769	Kg
42.	Length (m)	24.66	26.14	16,995.30	17,383.97	short tons
43.	Coil Packs	16	16			
44.	Turns Pack	8	8			
45.	Copper			87,584	92,376	Kg
46.	Current			4,494	4,321	Amps
47.	Voltage			387.01	392.39	Volts
48.	Power			1,739,369	1,695,335	Watts
49.	LCW	10 degrees C		642.60	626.33	gpm
50.						
51.						
52						
53.						
54.		Totals	Steel Mass	23,812,525	24,087,085	Kg
55.			Steel Weight	26,253.31	26,556.01	short tons
56.			Copper Mass	119,232	123,963	Kg
57.			Power	2,555,978	2,471,717	Watts
58.			LCW	944	913	gpm

Table 2.5-2. Muon Cerenkov Counter

Cerenkov Gas	N_2
Pressure	1 atm
Length of Cerenkov Medium	1.4 m
Number of Photoelectrons	7 to 9
Number of Mirrors per Cell	4
Number of Cells per Endcap	232
Total Channels	464

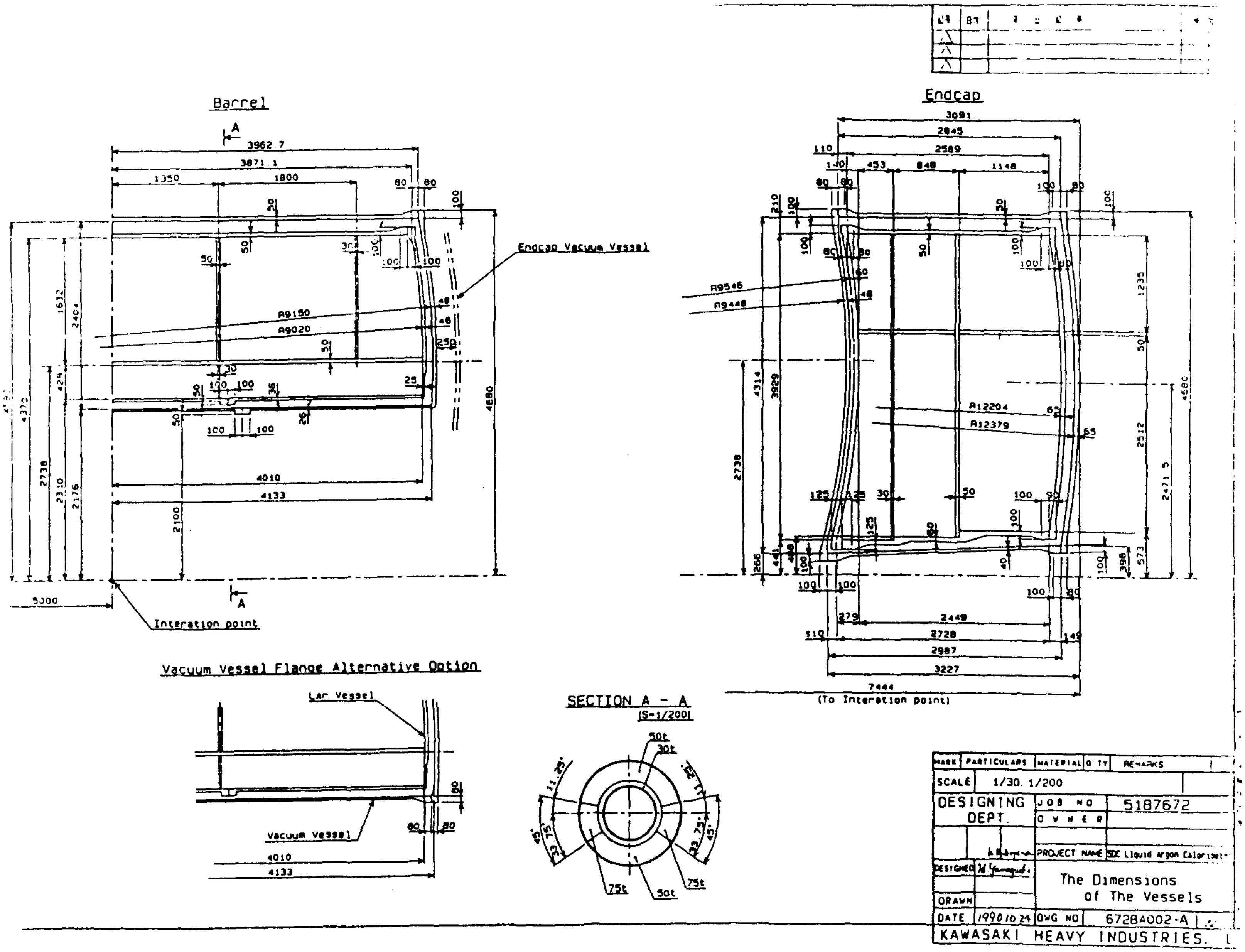
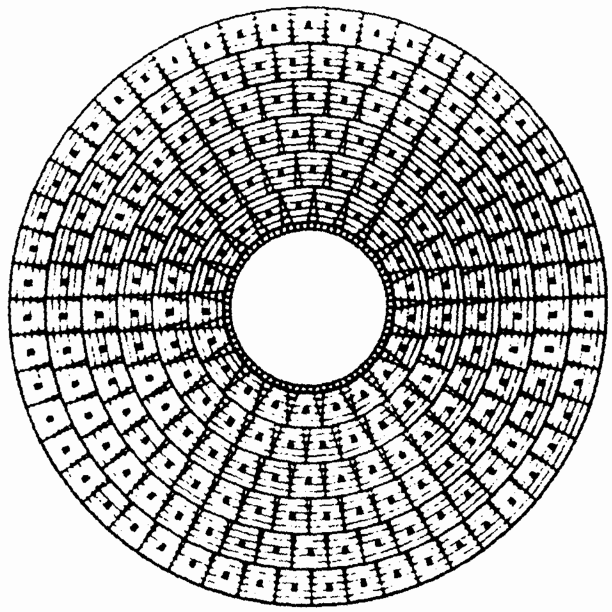


Figure 2.5-1. Vessel Dimensions

End View Looking Into Mirrors



3-D View of Mirrors

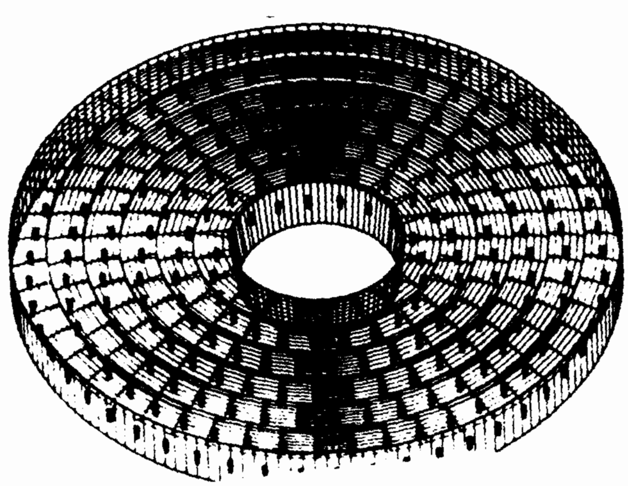


Figure 2.5-2. Muon Cerekov Counter

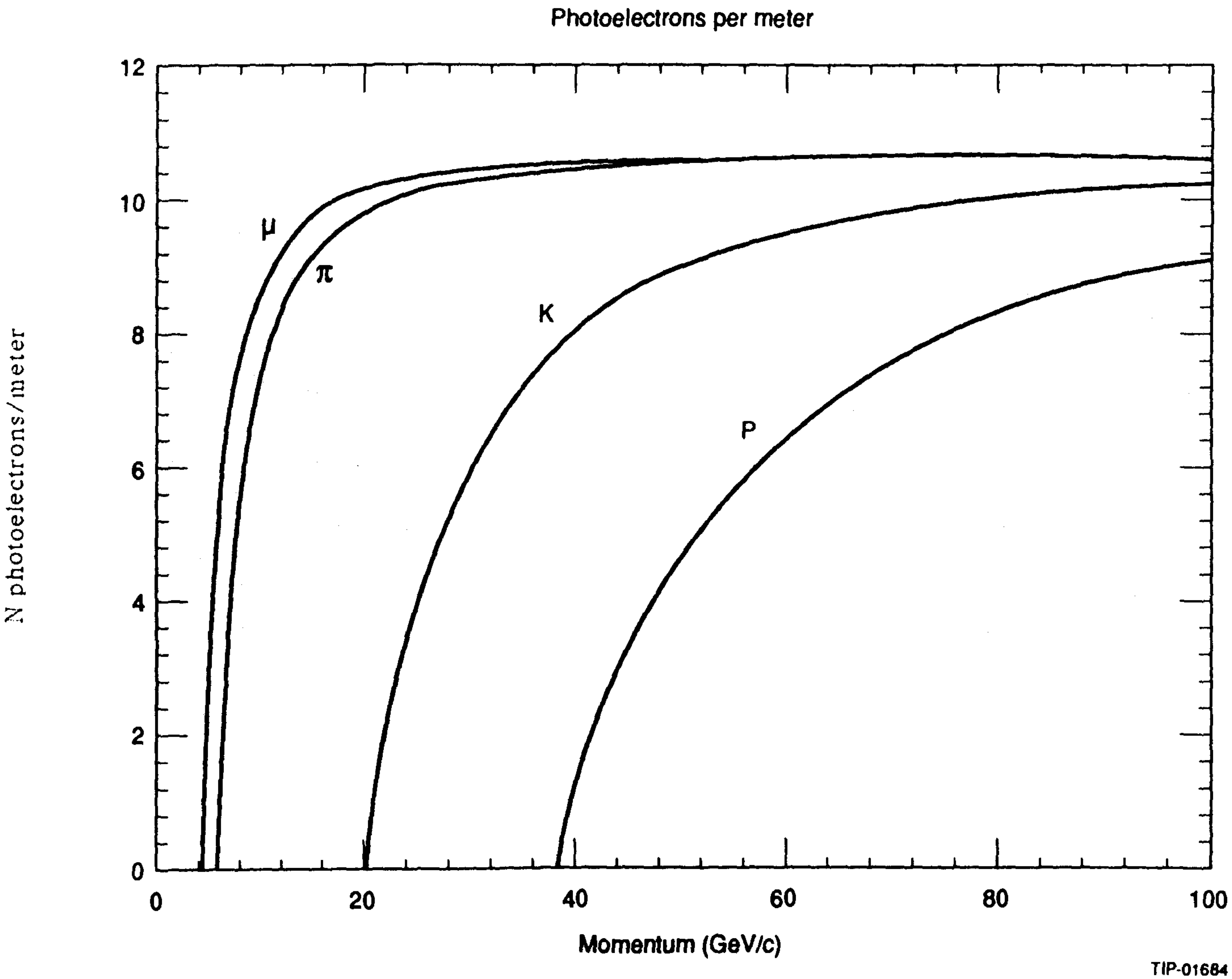


Figure 2.5-3. Photoelectrons Per Meter

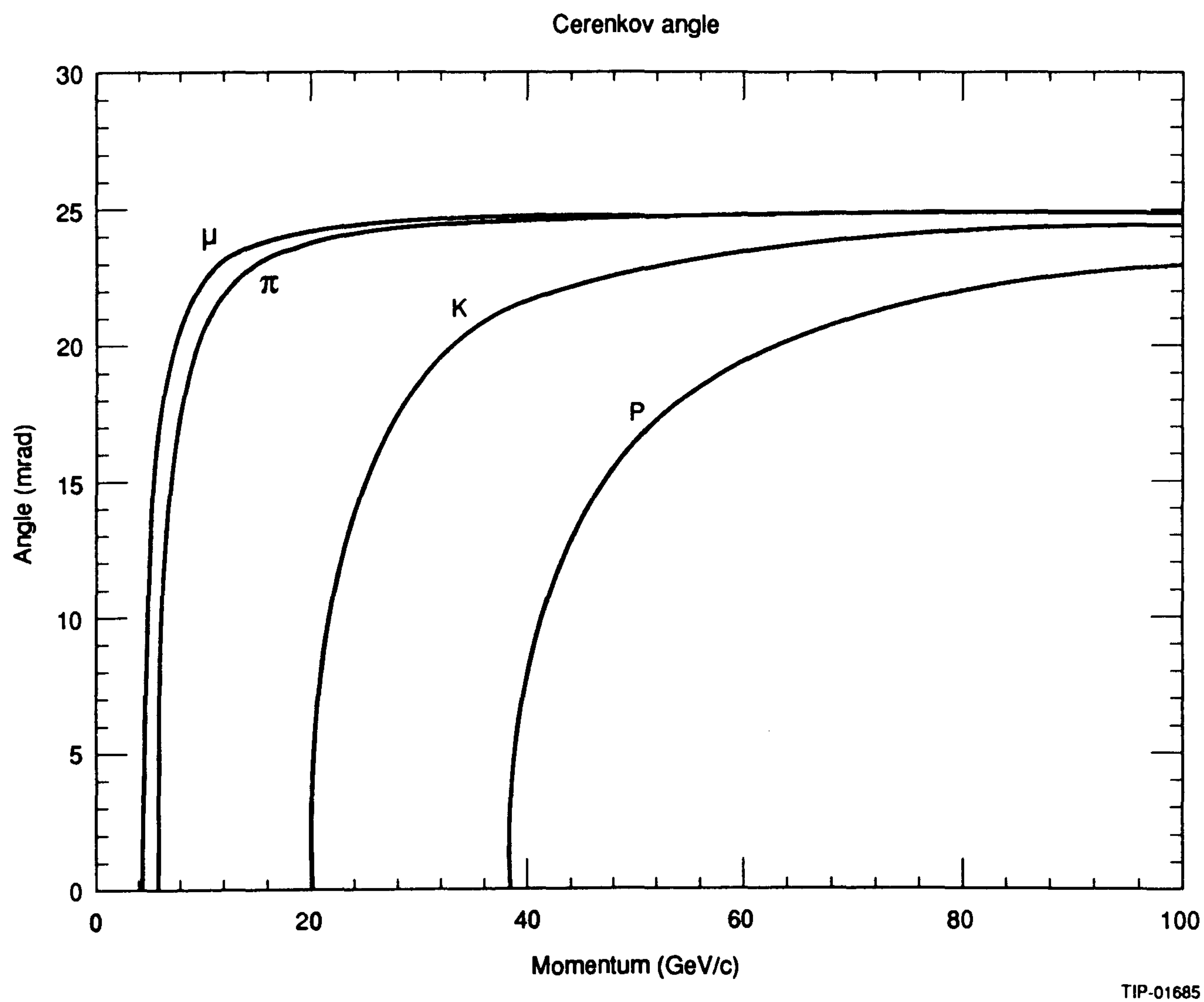


Figure 2.5-4. Cerenkov Angle

Table 2.6-1. Front End, Trigger and DAQ Crate Estimates

Calorimeter	Front End (incl. Trigger)	78
	Regional Trigger Processor	6
	Global Level 1 Trigger Processor	1
	Regional Level 2 Processor	4
	Global Level 2 Processor	1
Tracking	Front End (incl. Trigger)	128
	Global Level 1 Trigger Processor	1
	Regional Level 2 Processor	4
	Global Level 2 Processor	1
Silicon Tracking	Level 2 Processing System	8
Muons	Front End (incl. Trigger)	128
	Regional Trigger Processor	6
	Global Level 1 Trigger Processor	1
	Regional Level 2 Processor	4
	Global Level 2 Processor	1
Overall System	Clock system	16
	Control system	16
	Regional Level 1 Trigger Processor	8
	Global Level 1 Trigger Processor	1
	Regional Level 2 Processor	4
	Global Level 2 Processor	1
DAQ	Gallery	9
	Operations Center	11
	Level 3	40
	Online storage	9

Table 2.7-1. SDC Specifications Option 1 Detector

Detector Elements	Inner Radius meters	Outer Radius meters	Length meters	Z min meters	Z max meters	Number of Layers	Number of Channels Kilochannels	Weight Tons
Tracking								
Silicon Vertex	0.015	0.5	6	-3	3	10		0.2
C. Tracker	0.6	1.675	8	-4	4	50	240	2
Solenoid	1.7	2.05	8	-4	4			30
Calorimeter								
Barrel	2.1	4.19	8.8	-4.4	4.4	4		3600
Endcap North	0.42	4.19	2.48	4.2	6.68	4		850
Endcap South	0.42	4.19	2.48	-4.2	-6.68	4		850
Total Central							66	
Forward North	0.05	2.7	2.75	17	19.75	2	3.5	450
Forward South	0.05	2.7	2.75	-17	-19.75	2	3.5	450
Return Steel								
Barrel	4.19	4.49	8.8	-4.4	4.4			Included above
Endcap North	0.7	4.49	2.71	4.47	7.18			
Endcap South	0.7	4.49	2.71	-4.47	-7.18			
Electronics Volume								
Barrel	4.49	6.09	14.36	-7.18	7.18			
Endcap North	1.2	6.09	0.75	7.18	7.93			
Endcap South	1.2	6.09	0.75	-7.18	-7.93			
Muon System								
Chamber WC1								
Central	6.09	7.09	20.36	-10.18	10.18	12	20	
End North	1.3	5.09	0.3	-7.93	-8.23	4	2	
End South	1.3	5.09	0.3			4	2	
Chamber WC2								
Central	8.89	9.19	25.76	-12.88	12.88	4	11.2	
End North	1.48	6.09	0.45	9.73	10.18	8	5.2	
End South	1.48	6.09	0.45	-9.73	-10.18	8	5.2	

Table 2.7-1. SDC Specifications Option 1 Detector (cont)

Detector Elements	Inner Radius meters	Outer Radius meters	Length meters	Z min meters	Z max meters	Number of Layers	Number of Channels Kilochannels	Weight Tons
Chamber WC3								
Central	10.84	11.49	31.56	-15.78	15.78	12	34.8	
North(z=13 m)	5.37	8.89	0.3	12.58	12.88	4		
North(z=16 m)	2.03	6.707	0.45	15.33	15.78	4		
Total North							3.6	
South(z=-13 m)	5.37	8.89	0.3	-12.58	-12.88	4		
South(z=-16 m)	2.03	6.707	0.45	-15.33	-15.78	4		
Total South							3.6	
Chamber WC4								
North(z=16 m)	6.71	10.84	0.45	15.33	15.78	10		
North(z=18 m)	2.25	7.684	0.65	17.43	18.08	10		
Total North							10.3	
South(z=-16 m)	6.71	10.84	0.45	-15.33	-15.78	10		
South(z=-18 m)	2.25	7.684	0.65	-17.43	-18.08	10		
Total South							10.3	
Sum of All Chambers								915
Scintillator SC1								
Central	9.19	9.34	25.76	-12.88	12.88	1	5	
North(z=16 m)	2.09	6.707	0.15	15.78	15.93	1		
North(z=13 m)	5.36	9.34	0.15	12.88	13.03	1		
Total North							1.4	
South(z=-16 m)	2.09	6.707	0.15	-15.78	-15,93	1		
South(z=-13 m)	5.36	9.34	0.15	-12.88	-13.03	1		
Total South							1.4	

Table 2.7-1. SDC Specifications Option 1 Detector (cont)

Detector Elements	Inner Radius meters	Outer Radius meters	Length meters	Z min meters	Z max meters	Number of Layers	Number of Channels Kilochannels	Weight Tons
Scintillator SC2								
Central	11.49	11.64	31.86	-15.93	15.93	1	5	
North(z=18 m)	2.32	7.684	0.15	18.08	18.23	1		
North(z=16 m)	6.71	11.49	0.15	15.78	15.93	1		
Total North							1.4	
South(z=-18 m)	2.32	7.684	0.15	-18.08	-18.23	1		
South(z=-16 m)	6.71	11.48	0.15	-15.78	-15.93	1		
Total South							1.4	
Sum of all Scintillators								12
Muon Toroid								
Central	7.24	8.74	24.66	-12.33	12.33			15400
End North	1.55	7.24	2	10.33	12.33			2600
End South	1.55	7.24	2	-10.33	-12.33			2600
End Muon Toroid								
End North	1.85	6.452	2	13.18	15.18			1600
End South	1.85	6.452	2	-13.18	-15.18			1600
Absorber								
North								612
South								612
Cerenkov CC1 North	2.09	7.864	1.4	15.98	17.38	1	0.25	50
Cerenkov CC1 South			1.4	-15.98	-17.38	1	0.25	50
Beam Pipe	0	bp						
Totals							437.3	32283.2

Table 2.7-2. SDC Specifications Option 2 Detector

Detector Elements	Inner Radius meters	Outer Radius meters	Length meters	Z min meters	Z max meters	Number of Layers	Number of Channels Kilochannels	Weight Tons
Tracking								
Silicon Vertex	0.015	0.5	6	-3	3	10		0.2
C. Tracker (Fiber)	0.6	1.675	8	-4	4	48	240	2
Solenoid	1.7	2.05	8	-4	4			30
Calorimeters								
Barrel	2.1	4.66	8.3	-4.15	4.15	5		2814
Endcap North	0.21	4.66	3.2	4.22	7.42	5		1206
Endcap South	0.21	4.66	3.2	-4.22	-7.42	5		1206
Total Central							93	
Forward North	0.05	2.11	2.75	17	19.75	2	3.5	450
Forward South	0.05	2.11	2.75	-17	-19.75	2	3.5	450
Electronics Volume								
Barrel	6.66	5.31	15.04	-7.52	7.52			
Return Steel								
Barrel	5.31	5.76	16.04	-8.02	8.02			2085
Endcap North	0.75	5.31	0.5	7.52	8.02			360
Endcap South	0.75	5.31	0.5	-7.52	-8.02			360
Muon System								
Chamber WC1								
Central	5.81	6.81	21.84	-10.92	10.92	12	20	
End North	1.4	4.85	0.3	8.67	8.97	4	2	
End South	1.4	4.85	0.3	-8.67	-8.97	4	2	
Chamber WC2								
Central	8.61	8.91	27.24	-13.62	13.62	4	11.2	
End North	1.5	5.76	0.45	10.47	10.92	8	5.2	
End South	1.5	5.76	0.45	-10.47	-10.92	8	5.2	

Table 2.7-2. SDC Specifications Option 2 Detector (cont)

Detector Elements	Inner Radius meters	Outer Radius meters	Length meters	Z min meters	Z max meters	Number of Layers	Number of Channels Kilochannels	Weight Tons
Chamber WC3								
Central	10.56	11.21	33.04	-16.52	16.52	12	34.8	
North(z=13 m)	5.66	8.61	0.3	13.32	13.62	4		
North(z=16 m)	2.2	7.02	0.45	16.07	16.52	4		
Total North							3.6	
South(z=-13 m)	5.66	8.61	0.3	-13.32	-13.62	4		
South(z=-16 m)	2.2	7.02	0.45	-16.07	-16.52	4		
Total South							3.6	
Chamber WC4								
North(z=16 m)	7.02	1.56	0.45	16.07	16.52	10		
North(z=18 m)	2.3	8	0.65	18.17	18.82	10		
Total North							10.3	
South(z=-16 m)	7.02	1.56	0.45	-16.07	-16.52	10		
South(z=-18 m)	2.3	8	0.65	-18.17	-18.82	10		
Total South							10.3	
Sum of All Chambers								915
Scintillator SC1								
Central	8.91	9.06	27.24	-13.62	13.62	1	5	
North(z=14 m)	5.66	9.06	0.15	13.62	13.77	1		
North(z=17 m)	2.1	7.02	0.15	16.52	16.67	1		
Total North							1.4	
South(z=-14 m)	5.66	9.06	0.15	-13.62	-13.77	1		
South(z=-17 m)	2.1	7.02	0.15	-16.52	-16.67	1		
Total South							1.4	

Table 2.7-2. SDC Specifications Option 2 Detector (cont)

Detector Elements	Inner Radius meters	Outer Radius meters	Length meters	Z min meters	Z max meters	Number of Layers	Number of Channels Kilochannels	Weight Tons
Scintillator SC2								
Central	11.21	11.36	33.34	-16.67	16.67	1	5	
North(z=17 m)	7.02	11.21	0.15	16.52	16.67	1		
North(z=19 m)	2.4	8	0.15	18.82	18.97	1		
Total North							1.4	
South(z=-17 m)	7.02	11.21	0.15	-16.52	-16.67	1		
South(z=-19 m)	2.4	8	0.15	-18.82	-18.97	1		
Total South							1.4	
Sum of all Scintillators								12
Muon Toroid								
Central	6.96	8.46	26.14	-13.07	13.07			15770
End North	1.65	6.96	2	11.07	13.07			2380
End South	1.65	6.96	2	-11.07	-13.07			2380
Forward Muon Toroid								
End North	1.9	6.76	2	13.92	15.92			1780
End South	1.9	6.76	2	-13.92	-15.92			1780
Absorber								
North								612
South								612
Cerenkov CC1 North	2.2	7.98	1.4	16.72	18.12	1	0.25	50
Cerenkov CC1 South	2.2	7.98	1.4	-16.72	-18.12	1	0.25	50
Beam Pipe	0	bp						
Totals							464.3	35304.2

3.0 HALLS

The hall design shown here was developed for the EOI Type-S detector. While the dimensions of the tracking volume have been significantly reduced, the overall dimensions of the EOI Type-S detector are approximately the same size as the two LOI detector options. The major difference from the perspective of the hall specification and utilities is that the air core toroids of the EOI detectors have been replaced by magnetized iron toroids.

For the EOI Type-S detector assembly shown in Section 5.0, we have assumed the iron muon toroids and central calorimeters are constructed in the below-ground hall. The solenoid, tracking systems and air core toroids are brought into the hall as completed units and installed into the detector. Additional design considerations are that the personnel and equipment shafts are designated as emergency evacuation routes. These shafts carry no toxic gases, cables or other material that would prove hazardous in an emergency. Pressurized evacuation tunnels connect these two shafts to the underground assembly hall to allow a safe escape route in the event of fire or ODH condition in the assembly hall.

During the construction of the detector, the hall is partitioned into two volumes, each with its own crane and independent air conditioning system. The muon toroids and other heavy construction and welding are limited to one area, and the calorimeter is assembled at the other end of the hall in a relatively clean environment. These areas are shown in the accompanying construction story board for this detector (see Section 5).

We have only begun the assembly process for the LOI-Option 2 detector (liquid argon calorimeter), and all of the details are not yet complete.

A 3-D CAD picture of the entire detector was presented in the RRR in Section 1.4 on the liquid argon calorimeter. The major differences are the addition of insulated drain lines and a sump at the bottom of the hall for collection of liquid argon in the case of a failure of the vacuum vessel, and the addition of an alcove for holding the liquid argon and nitrogen storage vessels.

3.1 Hall Sizes

Figures 3.1-1 to 3.1-3 provide views of the proposed detector hall.

3.2 Hall Cranes

Capacities of collision hall cranes are shown in Table 3.2-1.

3.3 Shafts

Descriptions of collision hall shafts are provided in Table 3.3-1 and Figures 3.3-1 to 3.3-3.

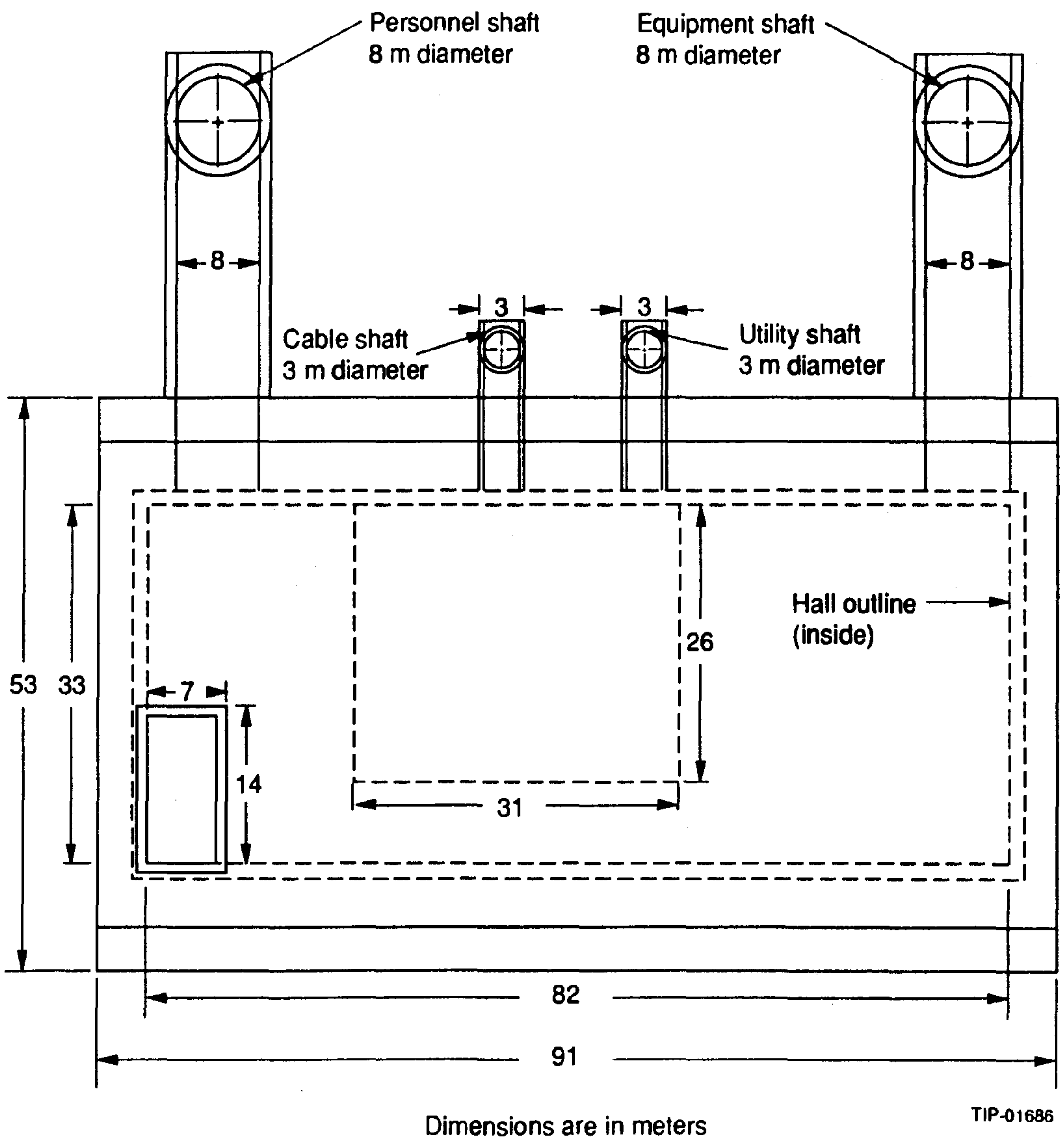


Figure 3.1-1. Hall Sizes (1)

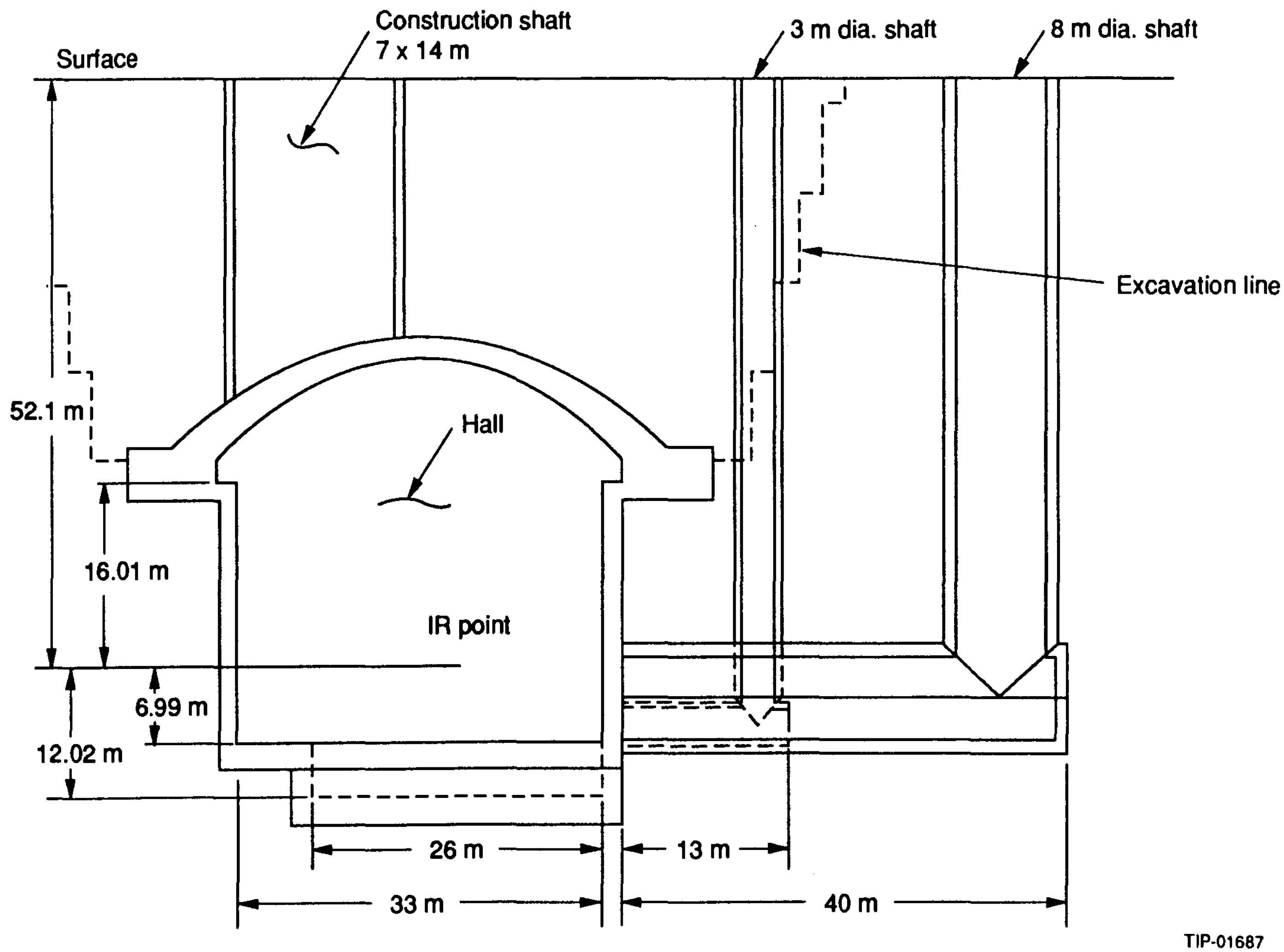


Figure 3.1-2. Hall Sizes (2)

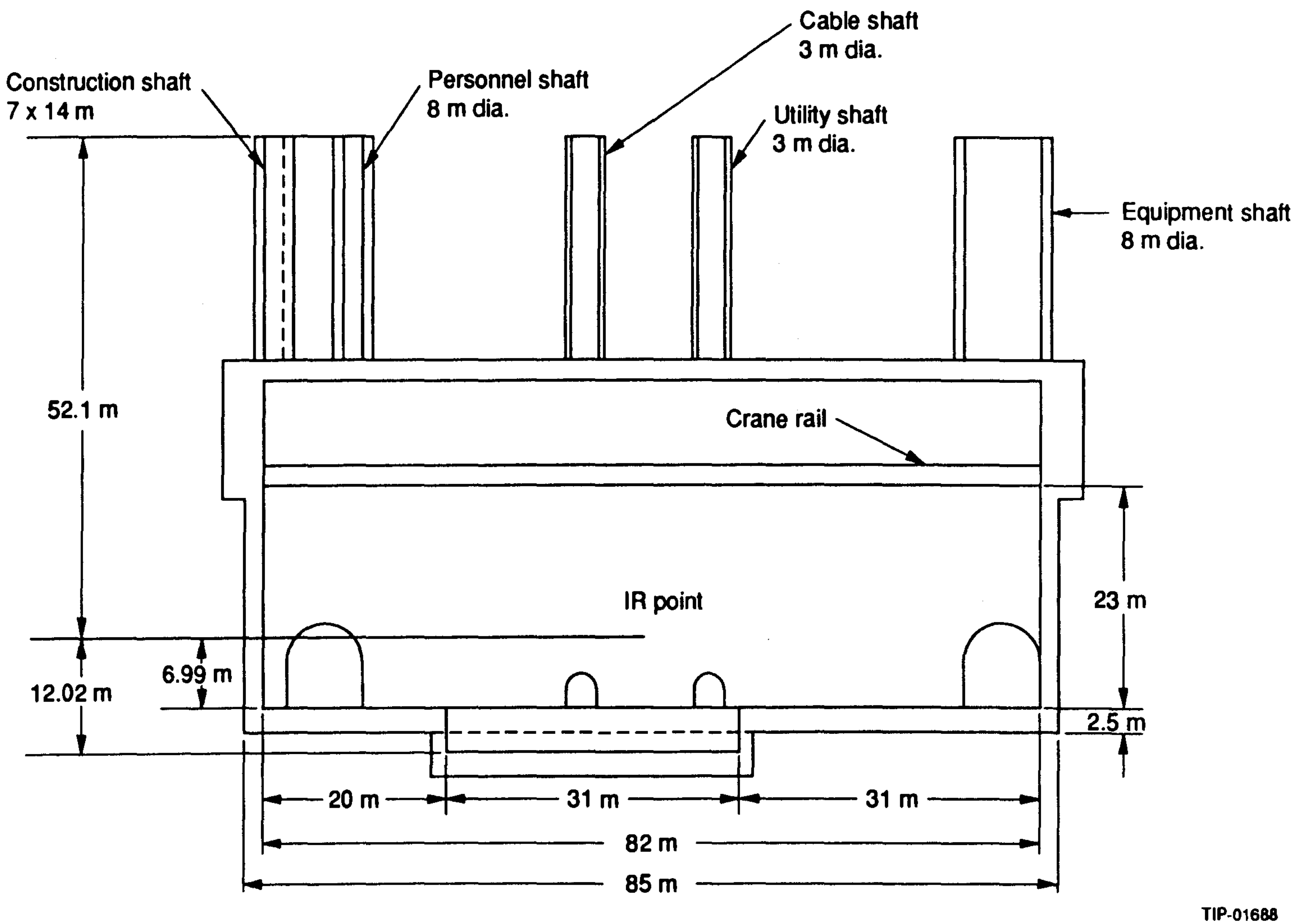


Figure 3.1-3. Hall Sizes (3)

Table 3.2-1. Collision Hall Cranes

		Trollies	
Crane 1	(Muon Assembly)	75T	25 T
Crane 2	(Calorimeter Assembly)	50 T/10T	

Table 3.3-1. Collision Hall Shafts

	Diameter (m)	Figure
Personnel Shaft	8	3.3-1
Equipment Shaft	8	3.3-1
Cable Shaft	3	3.3-2
Utility Shaft	3	3.3-3
Construction Shaft	14×7	N/A

(Assumes Option 1 Detector)

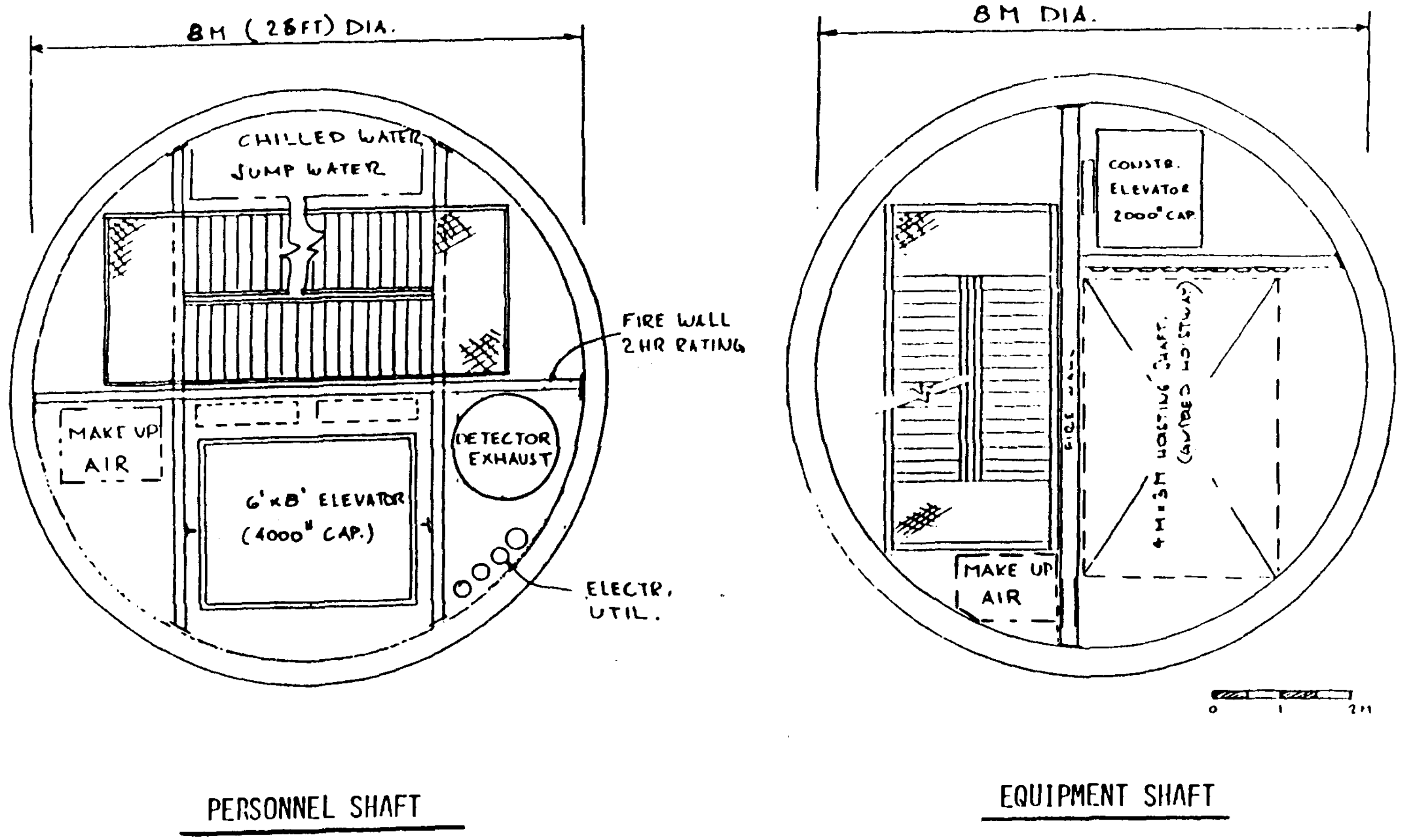


Figure 3.3-1. Cross-sections of Personnel and Equipment Shafts

1/20/90

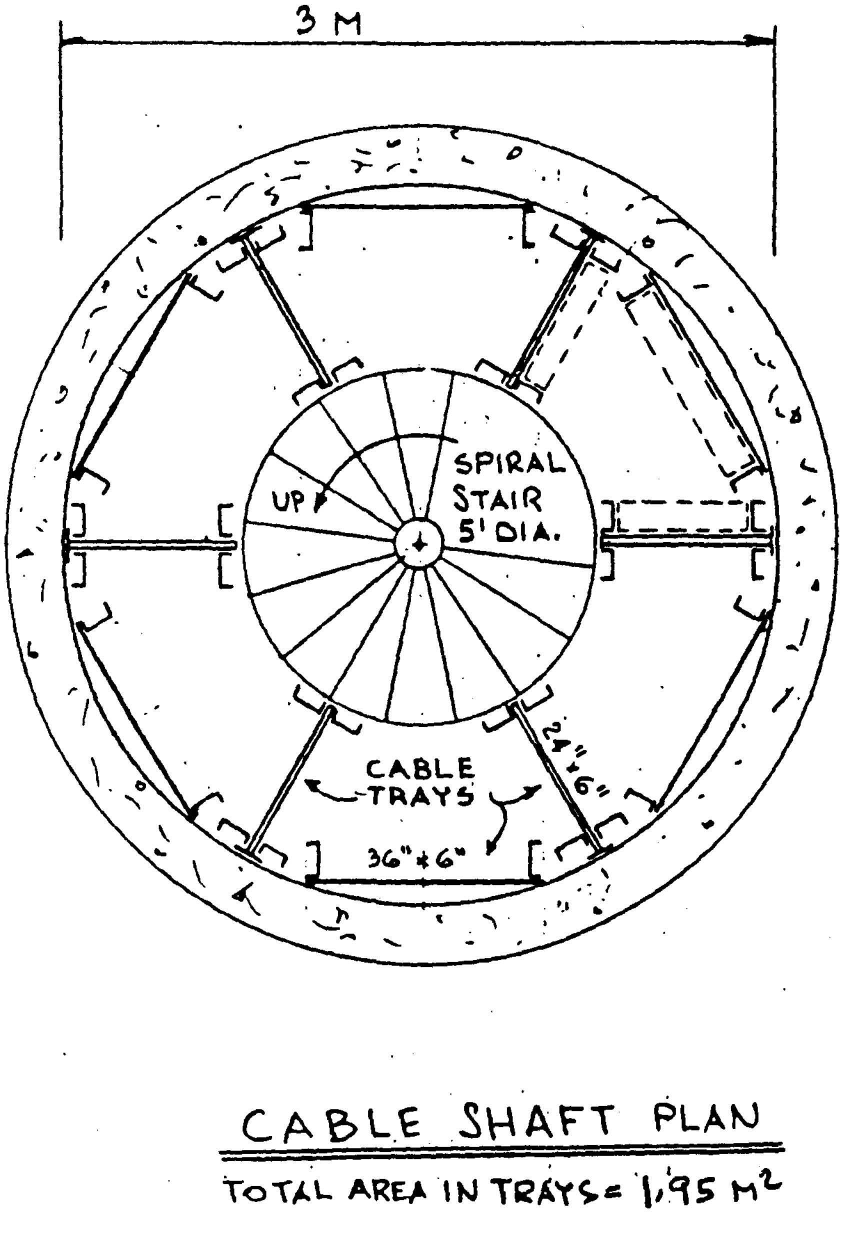
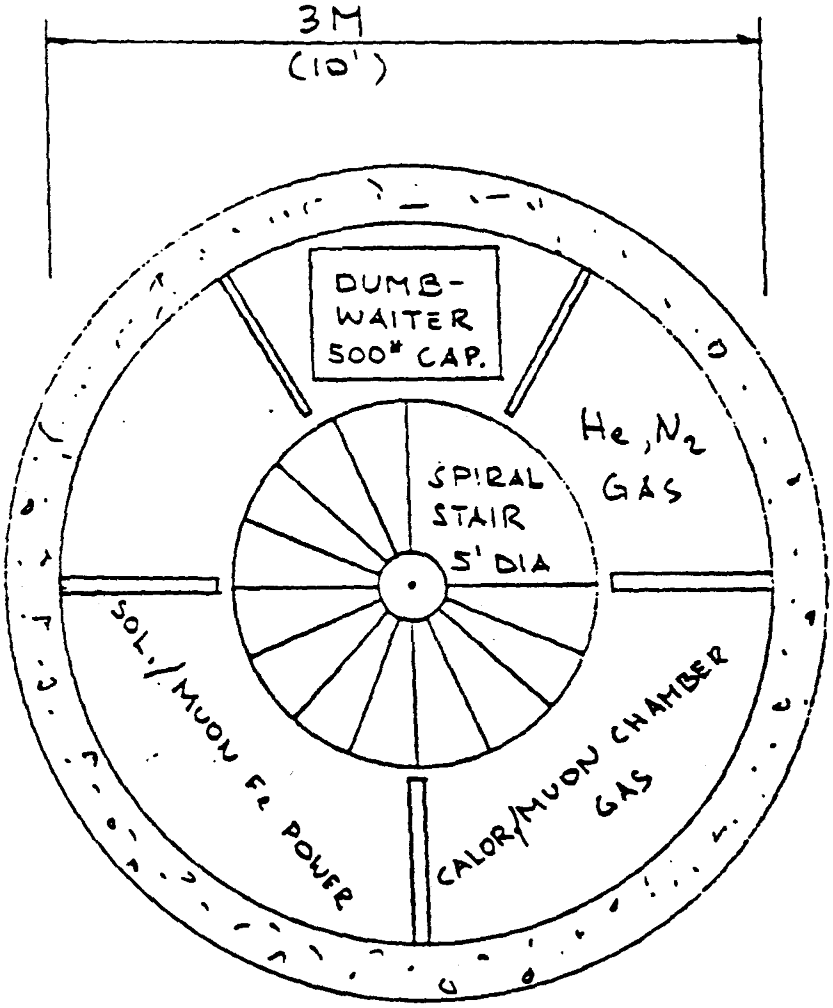


Figure 3.3-2. Cable Shaft Plan



UTILITY SHAFT

TOTAL NET UTILITY AREA = 35 FT^2

Figure 3.3-3. Utility Shaft

4.0 SURFACE FACILITIES

The surface facilities developed here were estimated from the EOI Type-S detector, and assume that the calorimeter is assembled below ground. In addition to the facilities drawn, an additional light assembly building for the muon and tracking system is required. This building is approximately 80 m × 27 m and has a 25-ton crane.

4.1 Buildings

Surface facilities and space allocation for the Operations Building are described in Figure 4.1-1 and Table 4.1-1.

4.2 Cranes

Capacities of surface facility cranes are shown in Table 4.2-1.

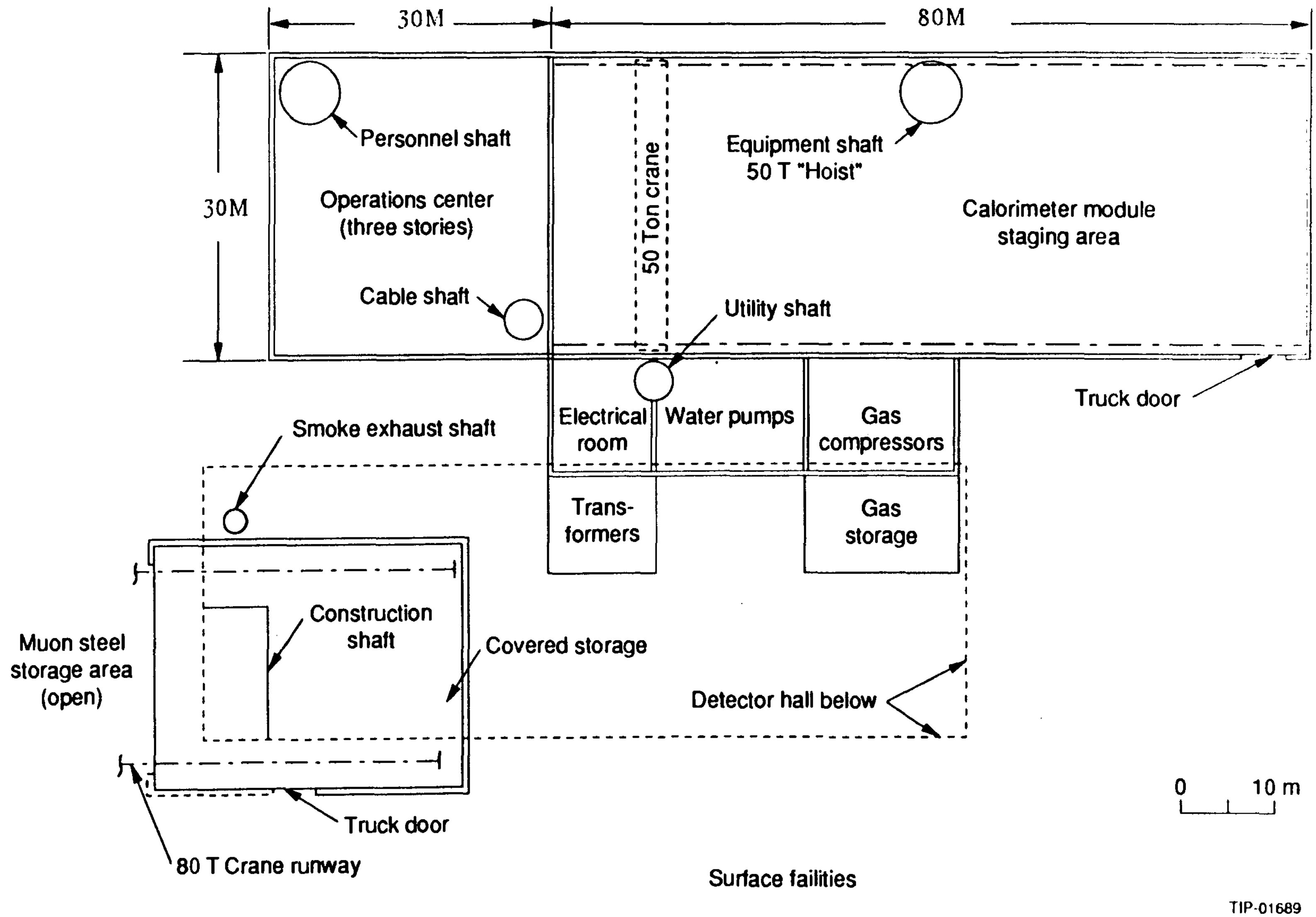


Figure 4.1-1. Surface Facilities

Table 4.1-1. Space Allocation for Operations Building

	Use	Space (Square Meters)
1st Floor	Lunch Room	50
	Stock Room	100
	Storage Area	100
	Light Shop	150
	Mech. Tech. Room	200
	Data Acquisition	250
	Total	850
2nd Floor	Large Conference Room	70
	Small Conference Room	30
	Control/Trigger Room	250
	Electrical Tech. Room	100
	Sec. Office	200
	Admin. Office	150
	Terminal Room	50
	Total	850
3rd Floor	Conference Room	50
	Terminal Room	50
	Computer Ranch	250
	Data Storage	100
	Stock Room	200
	Computer Operations	200
	Total	850

Table 4.2-1. Cranes in Surface Facilities

	Trollies	
Calorimeter Staging Building		
Crane	50 T / 10 T	
Hoist	50 T / 10 T	
Construction Shaft Head House		
Gantry Crane	80 T	25 T
Muon Chamber Assembly Building		
Crane	25T	

5.0 SDC ASSEMBLY / CONSTRUCTION

The asssembly sequence and story board presented here is for the EOI Type-S detector. This assembly sequence is approximately the same as for the LOI detectors. For completeness, we have added the figures of the EOI Type-S detector as well as the weights and measures tables for this detector.

5.1 EOI Type-S Description

Views of the EOI Type-S Detector are presented in Figures 5.1-1 and 5.1-2.

5.2 EOI Type-S Weights and Measures

Weights and measurements for the SDC Type-S Detector are provide in Table 5.2-1.

5.3 EOI Type-S Assembly Story Board

This section provides a construction sequence for the detector hall at various stages from 0 months through 42 months (completion).

Figure 5.1-1	**Hall at 0 Months** Hall at Beneficial Occupancy
Figure 5.1-2	**Hall at 3 Months** Muon Steel Supports Completed
Figure 5.1-3	**Hall at 5.1 Months** Lower Layer of Steel Laid on Floor Support
Figure 5.1-4	**Hall at 5.2 Months** 45° Inclined Sides Installed with Temporary Support
Figure 5.1-5	**Hall at 5.3 Months** Assembly Fixture Installed for Temporary Support of Sides and Roof Steel
Figure 5.1-6	**Hall at 5.6 Months** Vertical Sides of Toroid Installed
Figure 5.1-7	**Hall at 5.9 Months** Roof Members Installed and Second Set of Floor Members Laid on Floor Support
Figure 5.1-8	**Hall at 6 Months** Clean Room Constructed Center Calorimeter Started Muon Steel Barrel Started
Figure 5.1-9	**Hall at 15 Months** Muon Steel Barrel Completed Begin Testing 2nd End Calorimeter Start Erection of Endcap Calorimeter Start Construction of Muon Steel Toroid Start Installation of Barrel Steel Coils
Figure 5.1-10	**Hall at 15.1 Months** Muon Steel Toroid Assembly

Figure 5.1-11 **Hall at 18 Months**
Finished Installation of Barrel Coils
Finished Construction of Muon Steel Toroids
Installed Coils on One Muon Steel Toroid
Finished Construction of One Endcap Calorimeter

Figure 5.1-12 **Hall at 21 Months**
Start Testing Endcap Calorimeter
Start Construction of Last Endcap Calorimeter
Added Coils to Second Muon Steel Toroid
Constructed First Absorber Cone
Started Construction of 2nd Absorber Cone

Figure 5.1-13 **Hall at 24 Months**
Started Installation of Inner Muon Chambers
Finished Absorber Construction
Started Testing Last Endcap Calorimeter
Constructed Paltforms on Far Wall
Moved Calorimeter to Opposite End of Hall

Figure 5.1-14 **Hall at 27 Months**
Begin Installation of Outer Muon Chambers

Figure 5.1-15 **Hall at 30 Months**
Outer Muon Chamber Installation Complete
Central Calorimeters Installed
Begin Coil Installation

Figure 5.1-16 **Hall at 33 Months**
First Absorber/Act/Toroid Assembly Complete
Coil Field Mapping in Progress

Figure 5.1-17 **Hall at 36 Months**
Second Absorber/Act/Toroid Assembly Complete
Muon Chamber Installation on First Toroid Assembly Complete
Begin Muon Chamber Installation on Second Toroid Assembly
Begin Central Tracking Installation

Figure 5.1-18 **Hall at 39 Months**
Final Installation of Endcap Calorimeters Install Act
Begin Assembly of Forward Calorimeters
Begin Magnet Installation

Figure 5.1-19 **Hall at 42 Months**
Hall at Completion

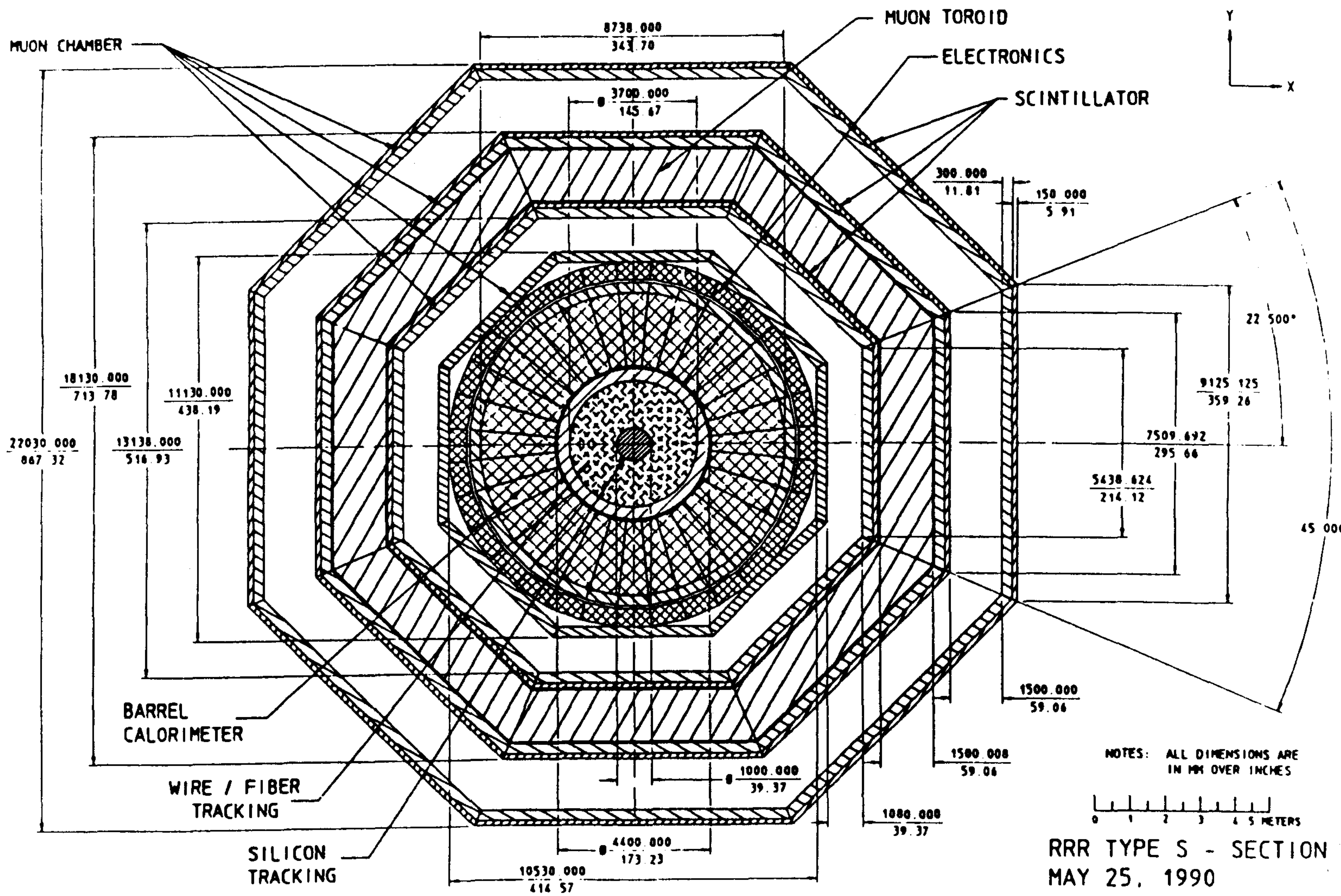


Figure 5.1-1. Cross Section View of EOI Type-S Detector

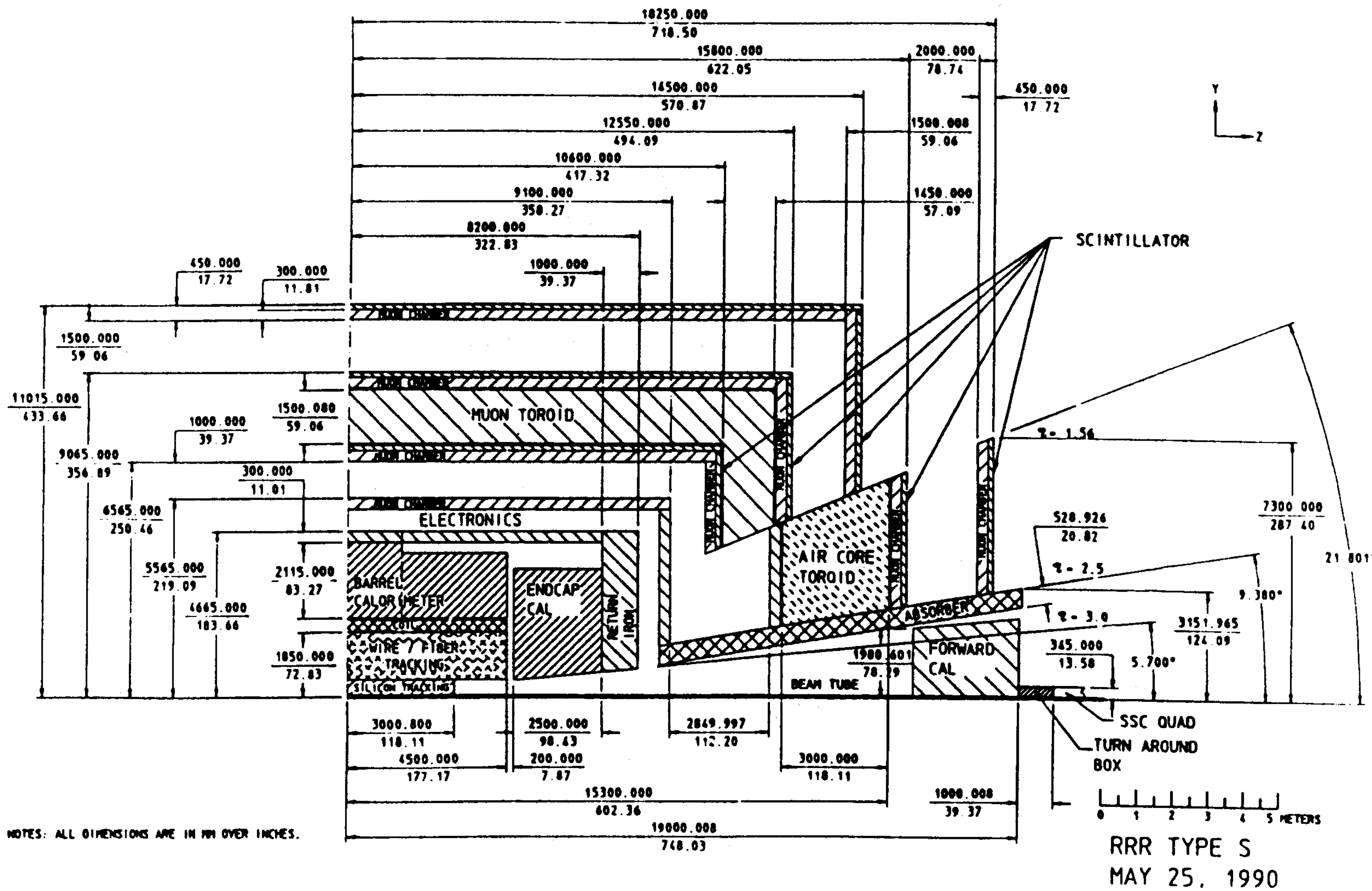


Figure 5.1-2. View of EOI Type-S Detector

Table 5.2-1. SDC Specifications Detector Type-S

Detector Elements	Inner Radius meters	Outer Radius meters	Length meters	Z min meters	Z max meters	Number of Layers	Number of Channels Kilochannels	Weight Tons
Tracking								
Silicon Vertex	0.05	0.5	6	-3	3			0.3
Central Tracker	0.05	1.85	9	-4.5	4.5		200	10
Solenoid	1.85	2.2	9	-4.5	4.5		-	25
Calorimeter								
Barrel	2.25	4.365	9	-4.5	4.5		120	3414
Endcap North	0.4	3.628	2.5	4.7	7.2		(see above)	918
Endcap South	0.4	3.628	2.5	-4.7	-7.2		(see above)	918
Forward North	0.05	1.9	3	16	19		7	300
Forward South	0.05	1.9	3	-16	-19		(see above)	300
Return Steel								
Barrel	4.365	4.665	14.4	-7.2	7.2			2150
Endcap North	0.7	4.665	1	7.2	8.2			
Endcap South	0.7	4.665	1	-7.2	-8.2			
Calorimeter Electronics								
Barrel	4.665	5.265	17.6	-8.8	8.8			
Endcap North	1.5	4.665	0.6	8.2	8.8			
Endcap South	1.5	4.665	0.6	-8.2	-8.8			
Muon System								
Inner Chambers 1								
Barrel	5.265	5.565	18.2	-9.1	9.1			200
Forward North	3.52	5.565	0.3	8.8	9.1			(all chambers)
Foward South	3.52	5.565	0.3	-8.8	-9.1			
Inner Chambers 2								
Barrel	6.565	6.865	20.8	-10.4	10.4			
Forward North	4.04	6.565	0.3	10.1	10.4			
Foward South	4.04	6.565	0.3	-10.1	-10.4			

Table 5.2-1. SDC Specifications Detector Type-S (cont)

Detector Elements	Inner Radius meters	Outer Radius meters	Length meters	Z min meters	Z max meters	Number of Layers	Number of Channels Kilochannels	Weight Tons
Inner Trig. Scint. 2								
Barrel	6.865	7.015	21.1	-10.55	10.55			
Forward North	4.18	6.865	0.15	10.4	10.55			
Forward South	4.18	6.865	0.15	-10.4	-10.55			
Muon Toroid								
Barrel	7.065	8.565	24.1	-12.05	12.05			15580
Forward North	4.18	7.065	1.45	10.6	12.05			1195
Forward South	4.18	7.065	1.45	-10.6	-12.05			1195
Outer Chamber 1								
Barrel	8.615	8.915	24.2	-12.1	12.1			
Forward North	4.7	8.915	0.3	12.1	12.4			
Forward South	4.7	8.915	0.15	-12.1	-12.25			
Outer Trig. Scint. 1								
Barrel	8.915	9.065	24.8	-12.4	12.4			
Forward North	4.8	8.915	0.15	12.4	12.55			
Forward South	4.8	8.915	0.15	-12.4	-12.55			
Outer Chamber 2								
Barrel	10.565	10.865	28.1	-14.05	14.05			
Forward North	5.62	10.865	0.3	14.05	14.35			
Forward South	5.62	10.865	0.3	-14.05	-14.35			
Outer Trig. Scint. 2								
Barrel	10.865	11.015	29	-14.5	14.5			
Forward North	5.56	10.865	0.15	14.35	14.5			
Forward South	5.56	10.865	0.15	-14.35	-14.5			
Air Cord Toroid	2	6.12	3	12.3	15.3			80
ACT Chambers 1								
North	1.7	4.04	0.3	10.1	10.4			
South	1.7	4.04	0.3	-10.1	-10.4			

Table 5.2-1. SDC Specifications Detector Type-S (cont)

Detector Elements	Inner Radius meters	Outer Radius meters	Length meters	Z min meters	Z max meters	Number of Layers	Number of Channels Kilochannels	Weight Tons
ACT Chambers 2								
North	1.9	4.9	0.3	11.95	12.25			
South	1.9	4.9	0.3	-11.95	-12.25			
ACT Chambers 3								
North	2.3	6.32	0.3	15.35	15.65			
South	2.3	6.32	0.3	-15.35	-15.65			
ACT Scintillator 3								
North	2.5	6.3	0.15	15.65	15.8			
South	2.5	6.3	0.15	-15.65	-15.8			
ACT Chambers 4								
North	2.9	7.2	0.3	17.8	18.1			
South	2.9	7.2	0.3	-17.8	-18.1			
ACT Scintillator 4								
North	3	7.3	0.15	18.1	18.25			
South	3	7.3	0.15	-18.1	-18.25			
Beam Pipe	0	bp						
Totals							327	26285.3

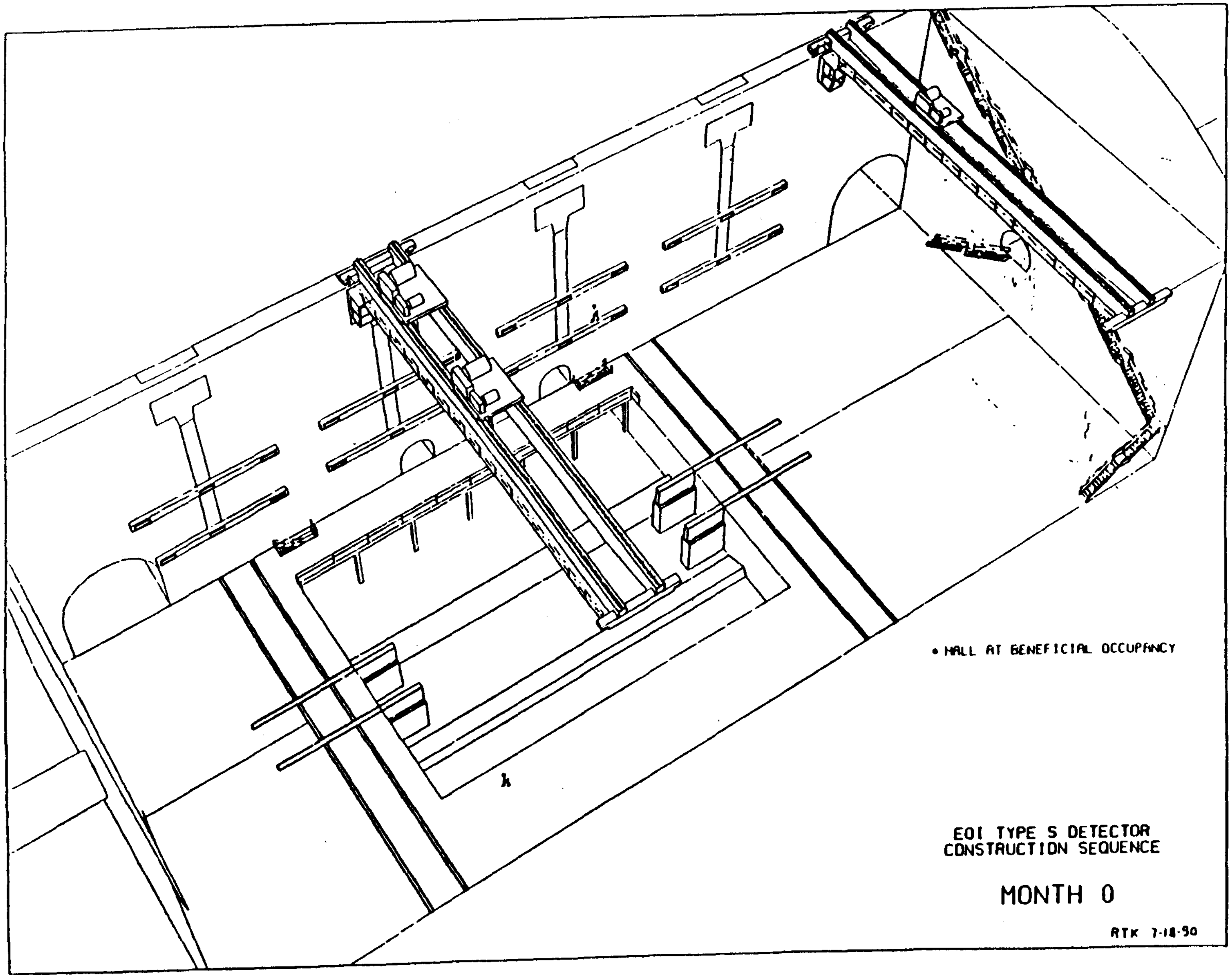


Figure 5.3-1. Hall at 0 Months

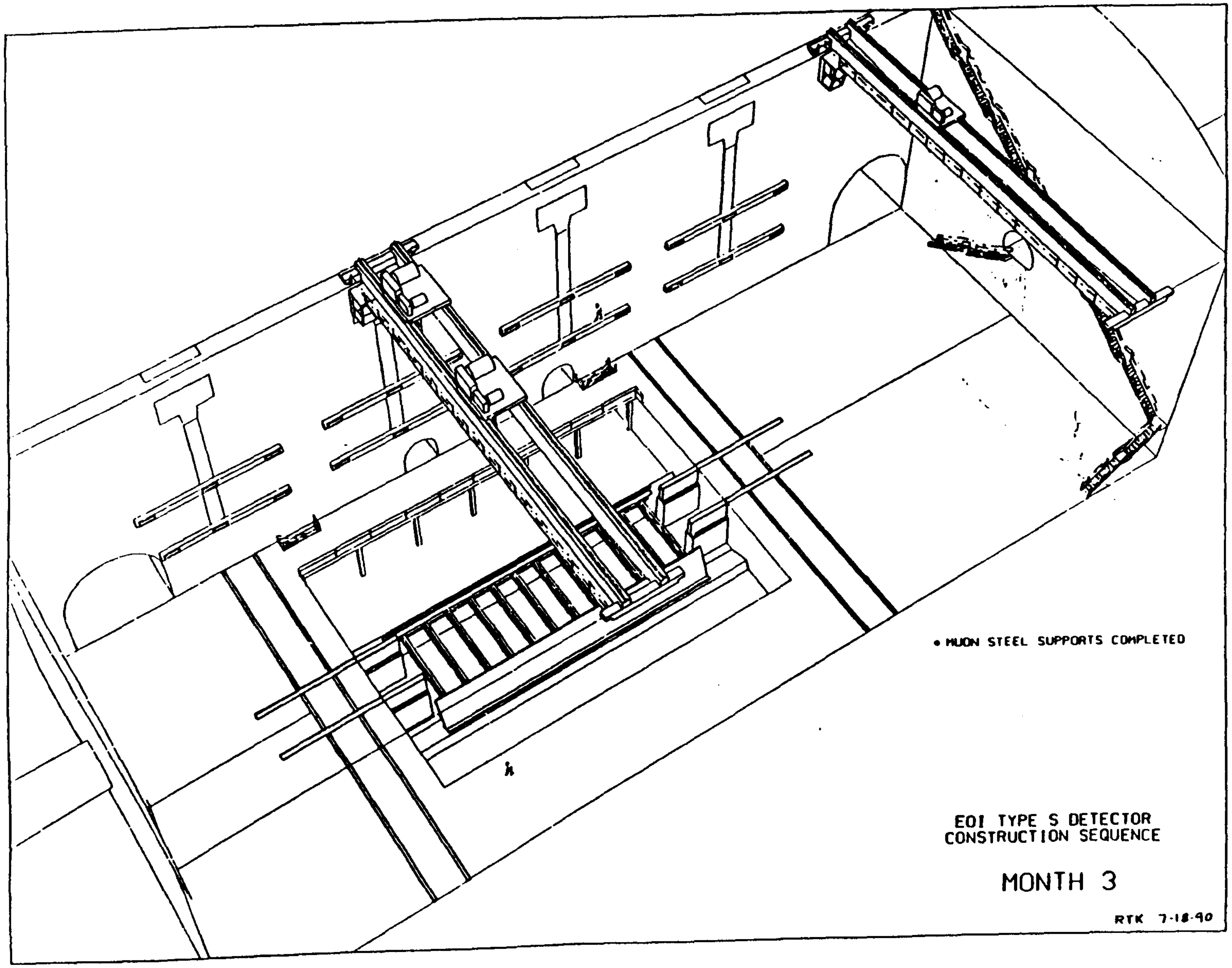


Figure 5.3-2. Hall at 3 Months

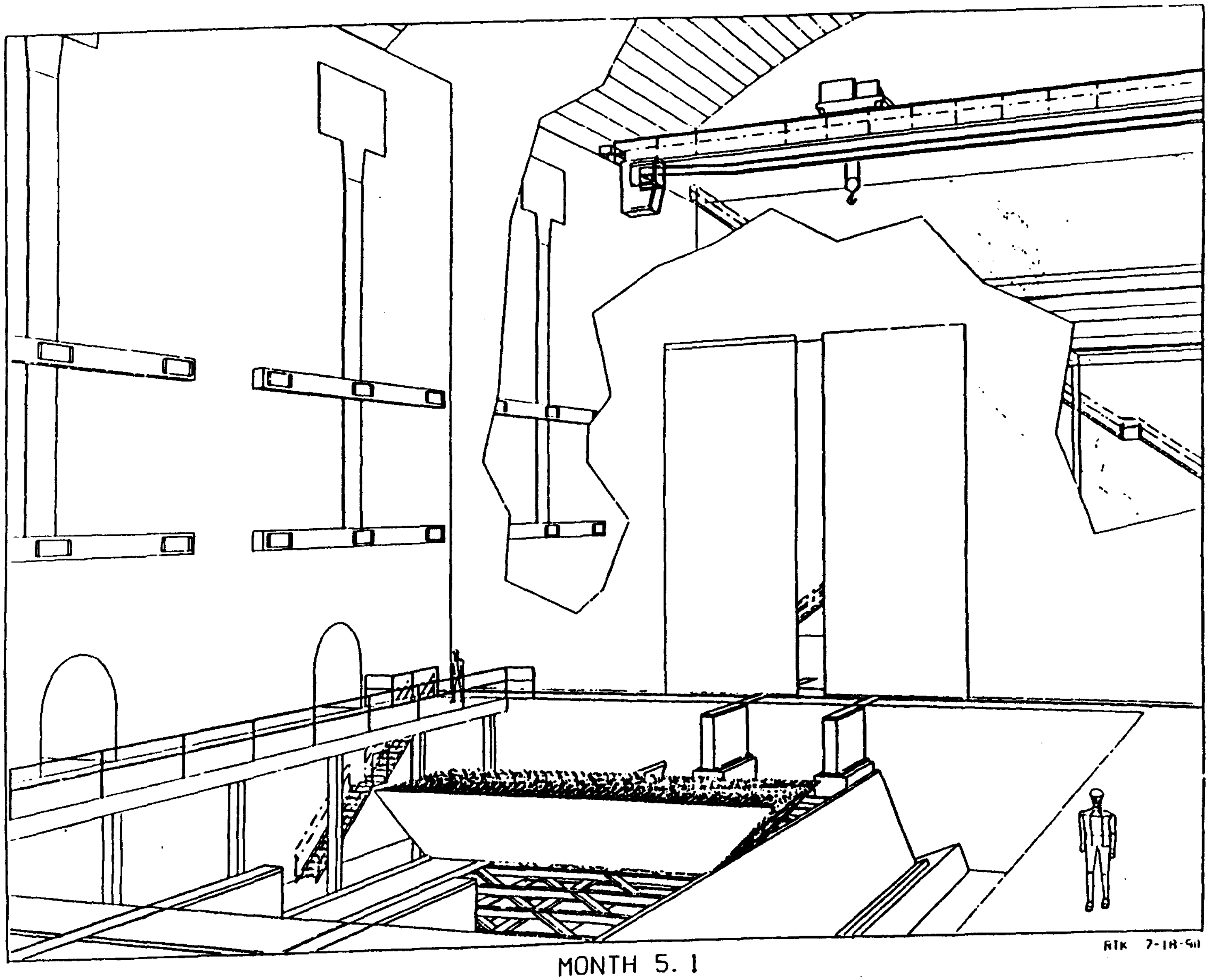


Figure 5.3-3. Hall at 5.1 Months

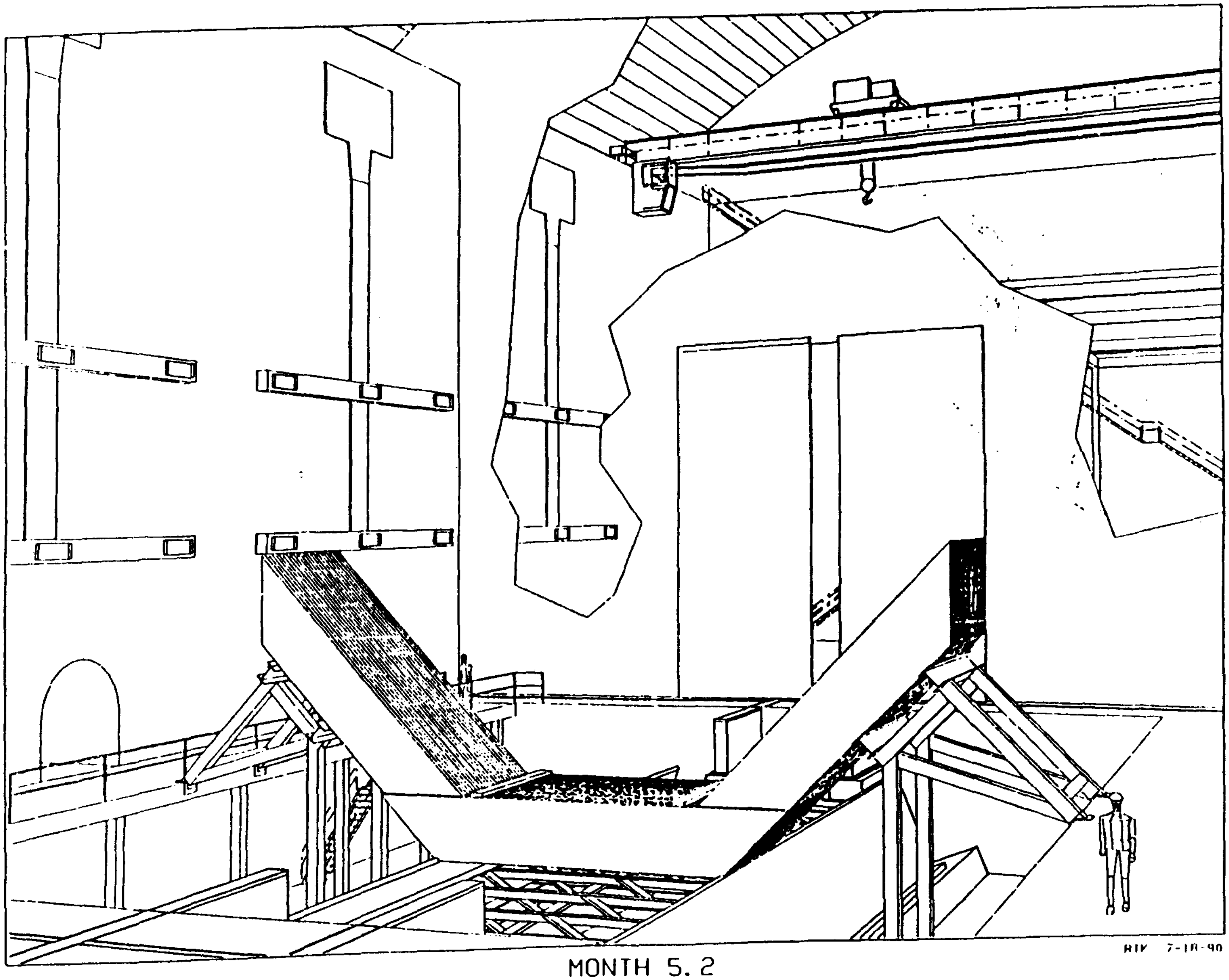


Figure 5.3-4. Hall at 5.2 Months

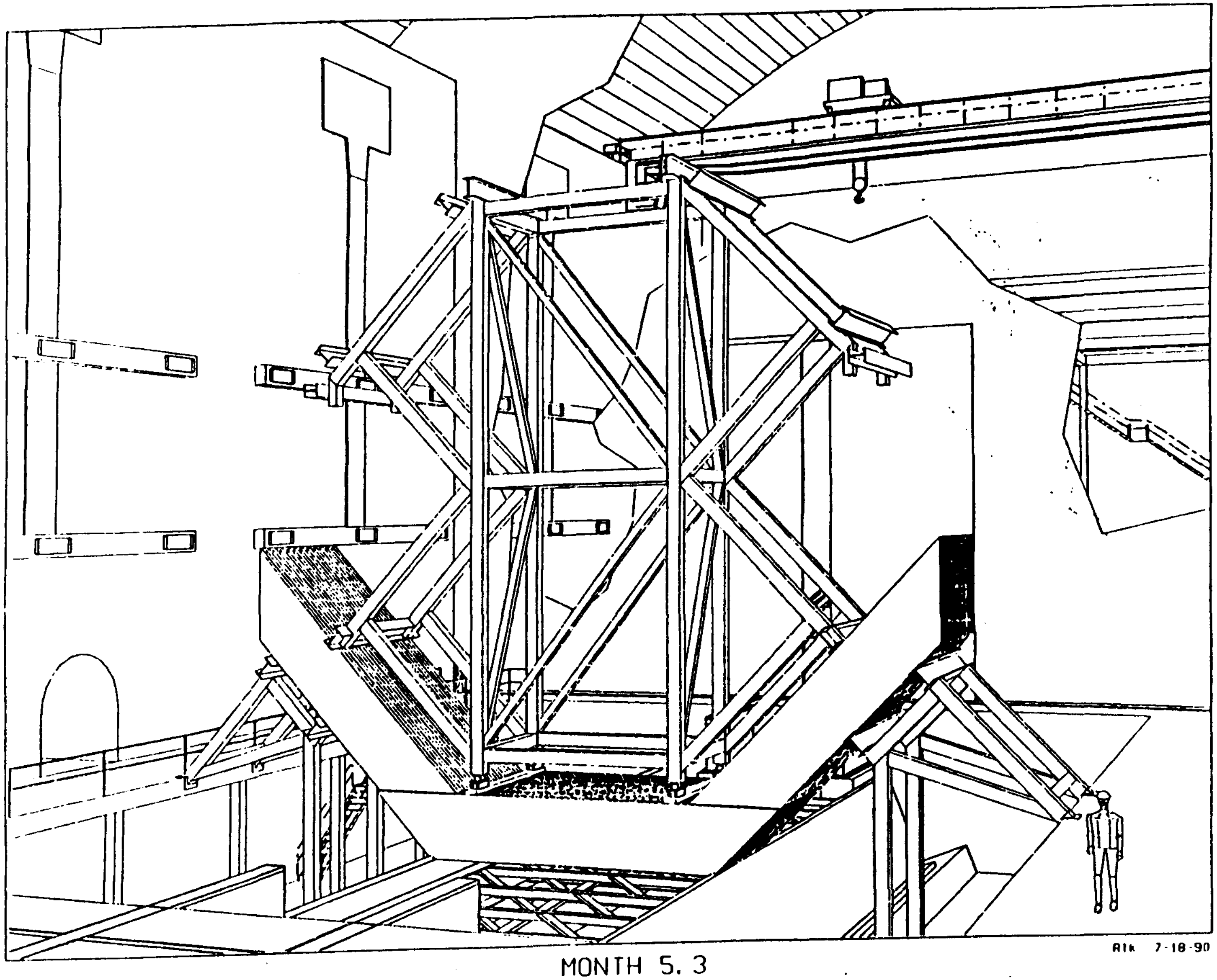


Figure 5.3-5. Hall at 5.3 Months

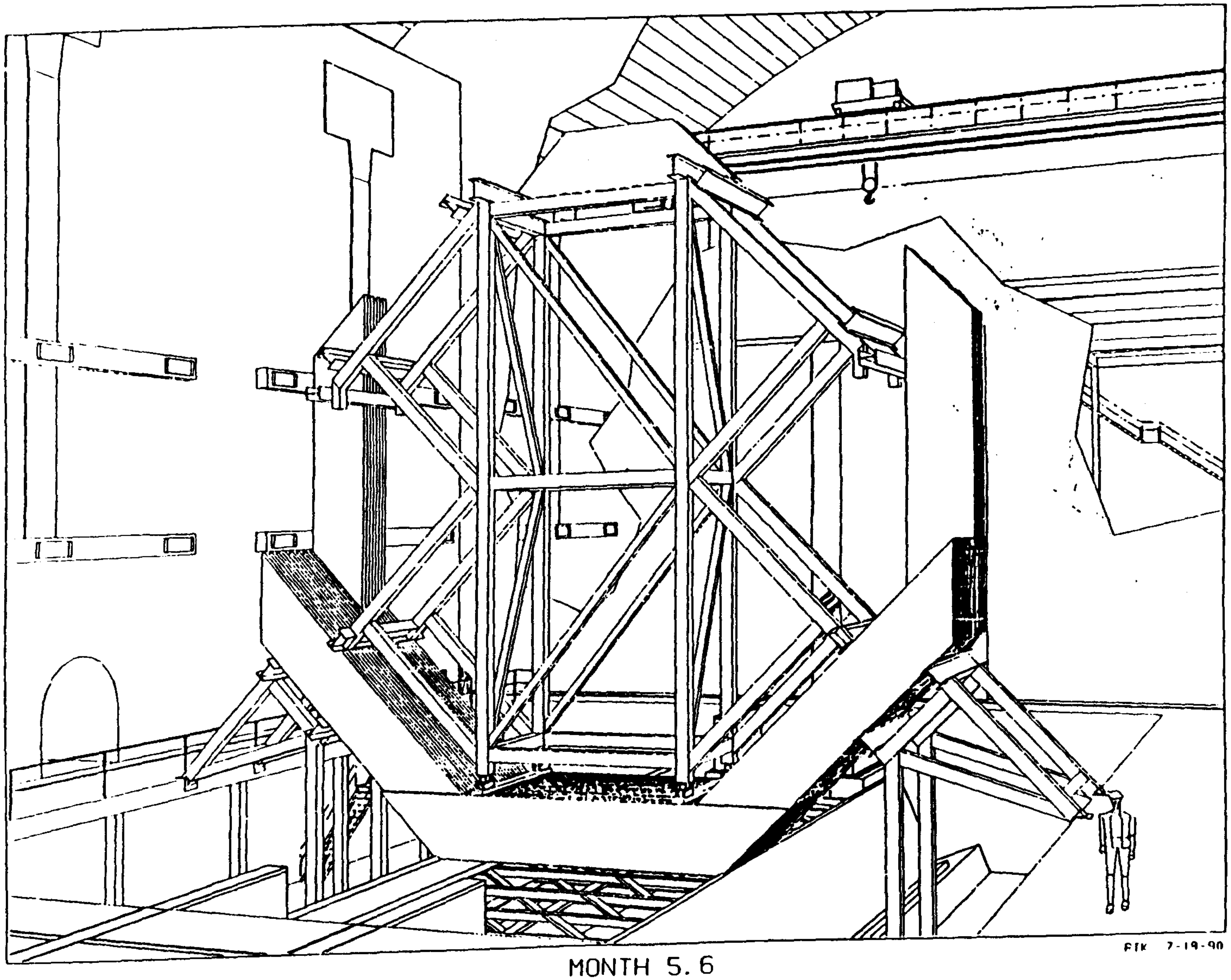


Figure 5.3-6. Hall at 5.6 Months

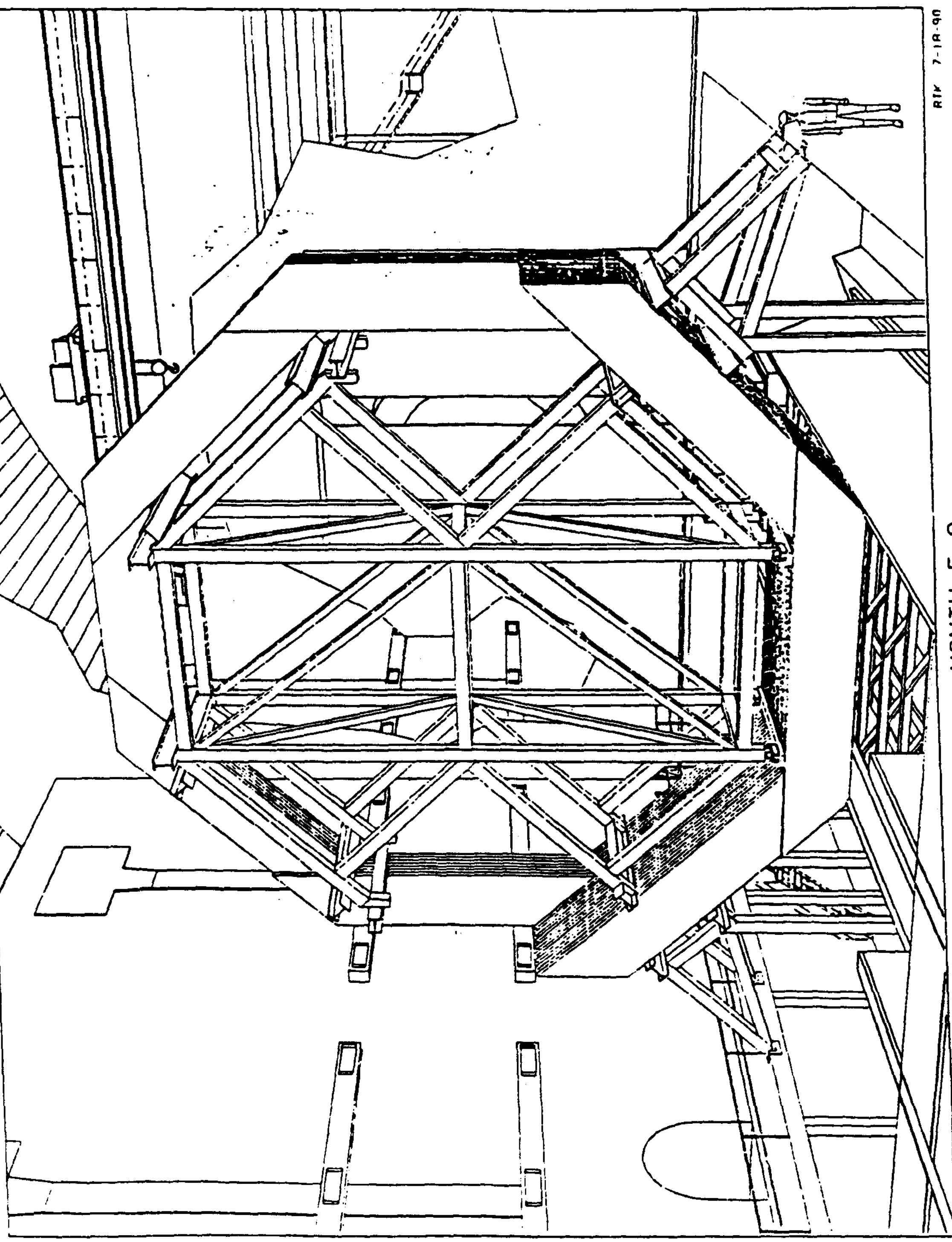


Figure 5.3-7. Hall at 5.9 Months

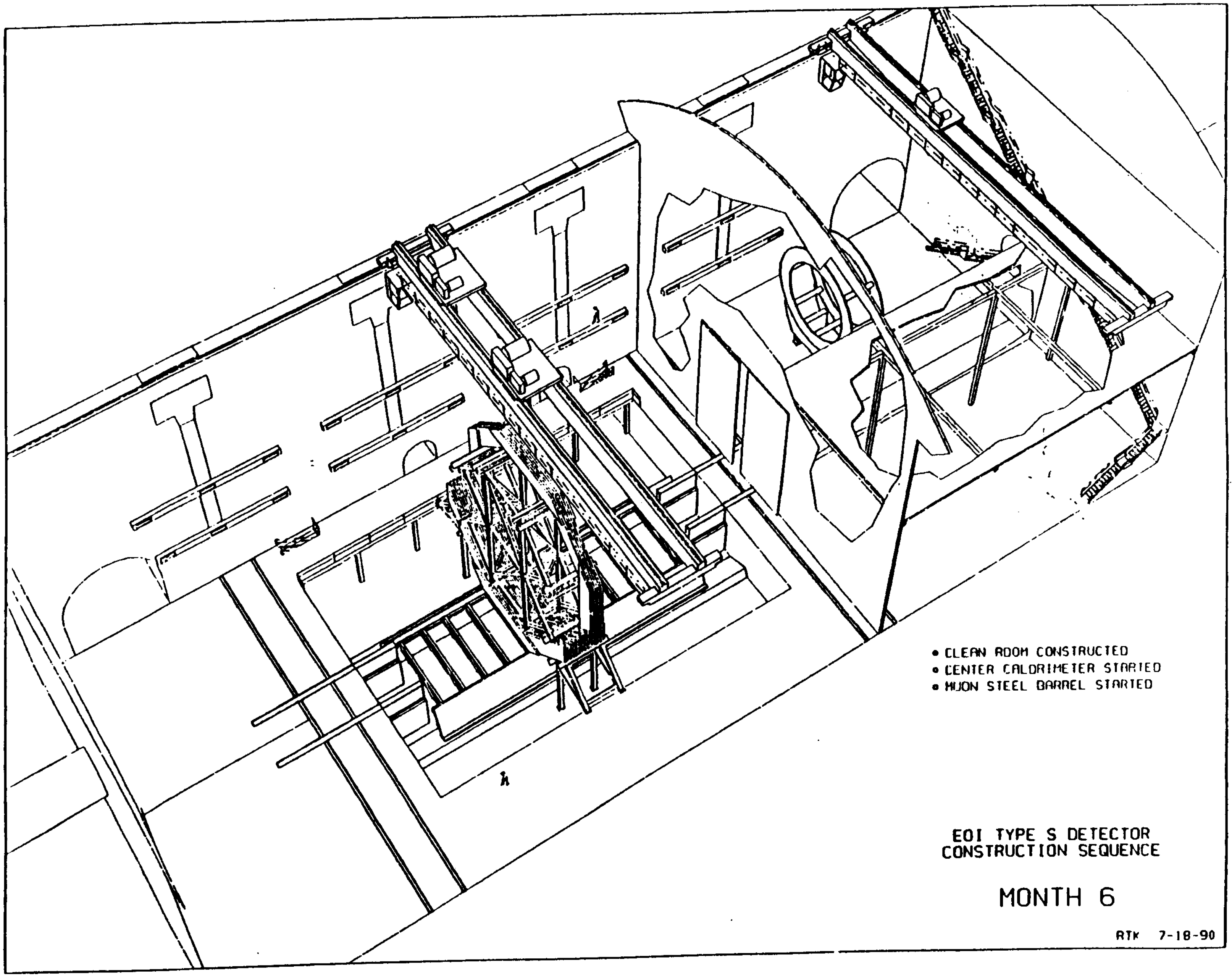


Figure 5.3-8. Hall at 6 Months

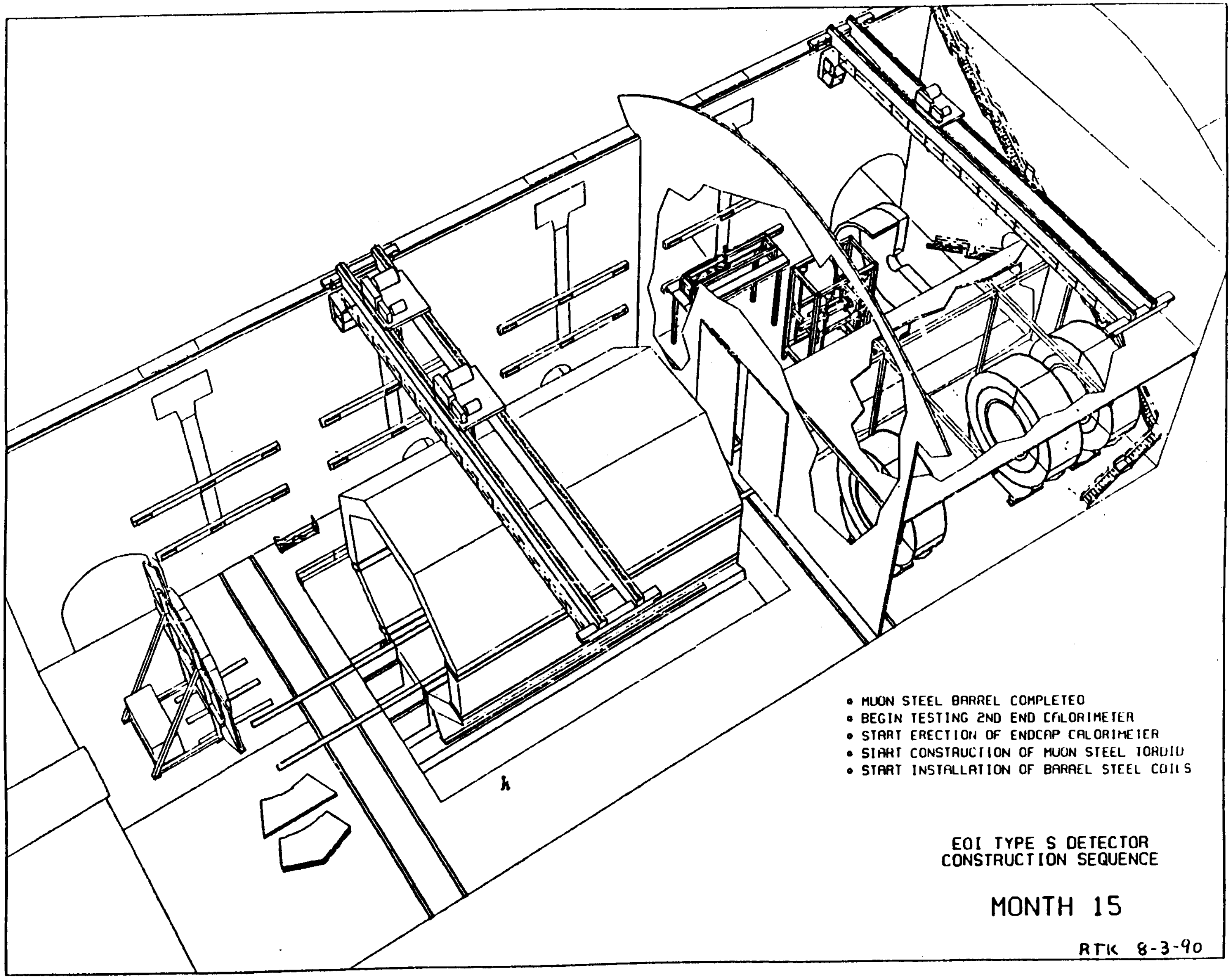


Figure 5.3-9. Hall at 15 Months

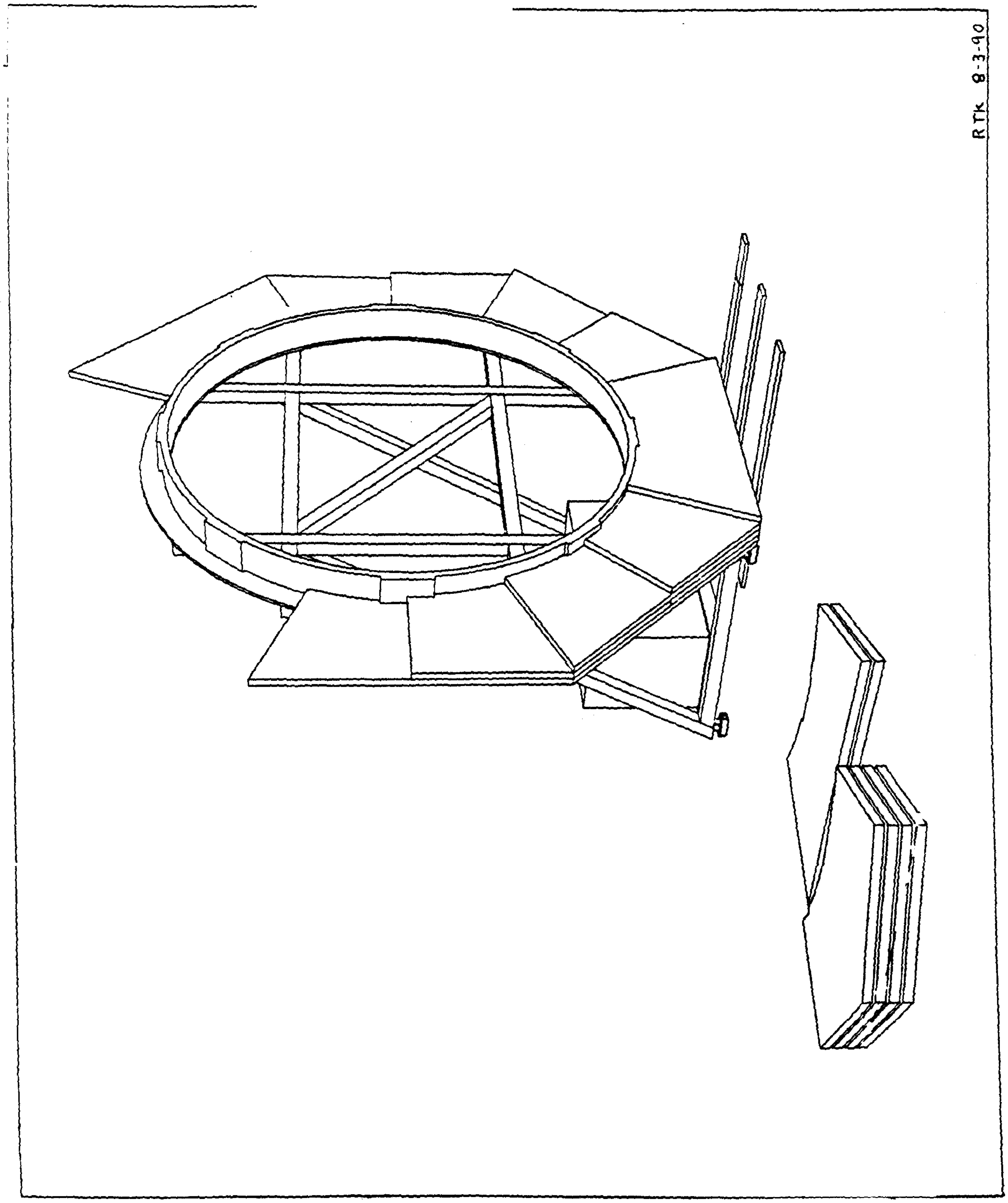


Figure 5.3-10. Muon Steel Toroid Assembly at 15.1 Months

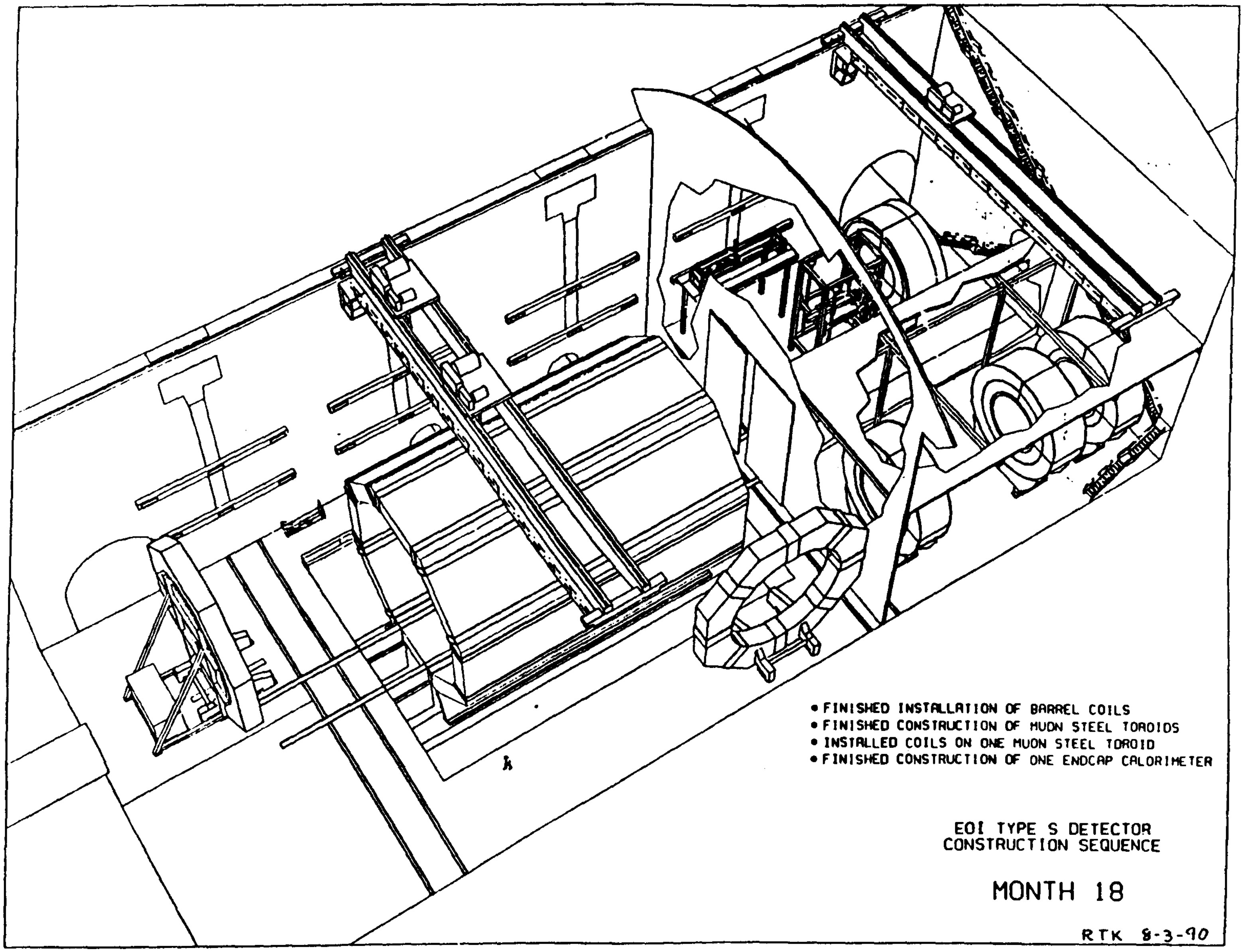


Figure 5.3-11. Hall at 18 Months

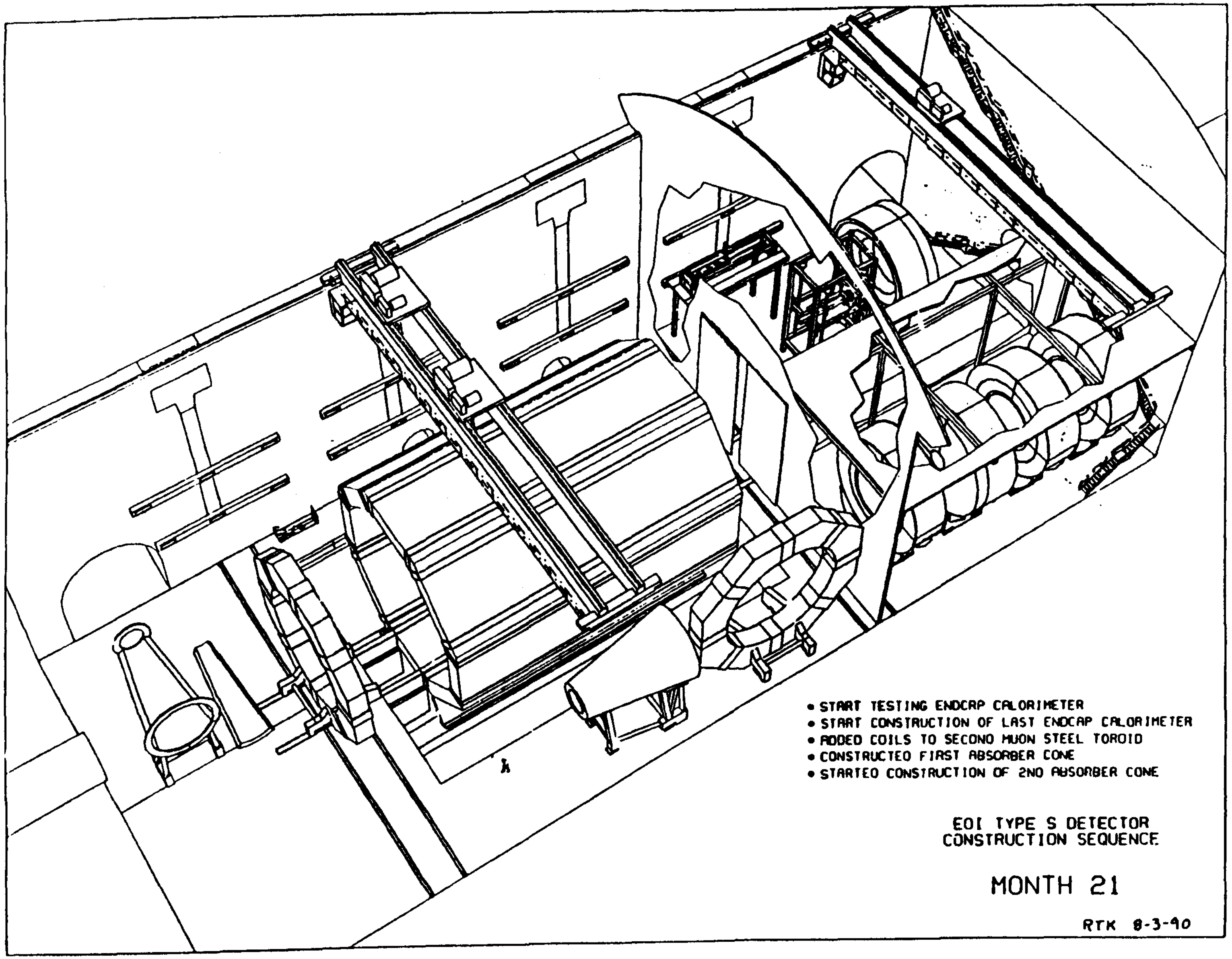


Figure 5.3-12. Hall at 21 Months

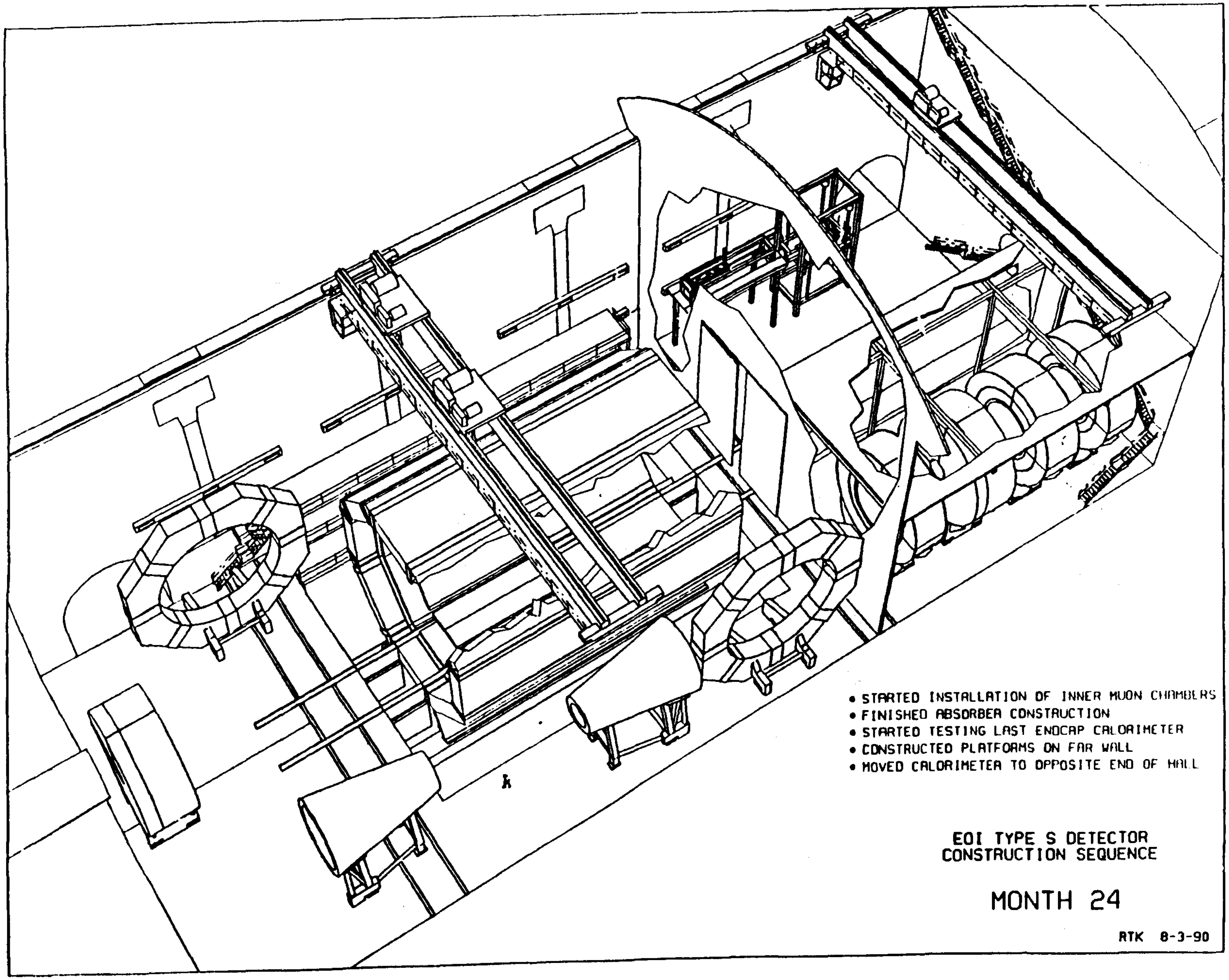


Figure 5.3-13. Hall at 24 Months

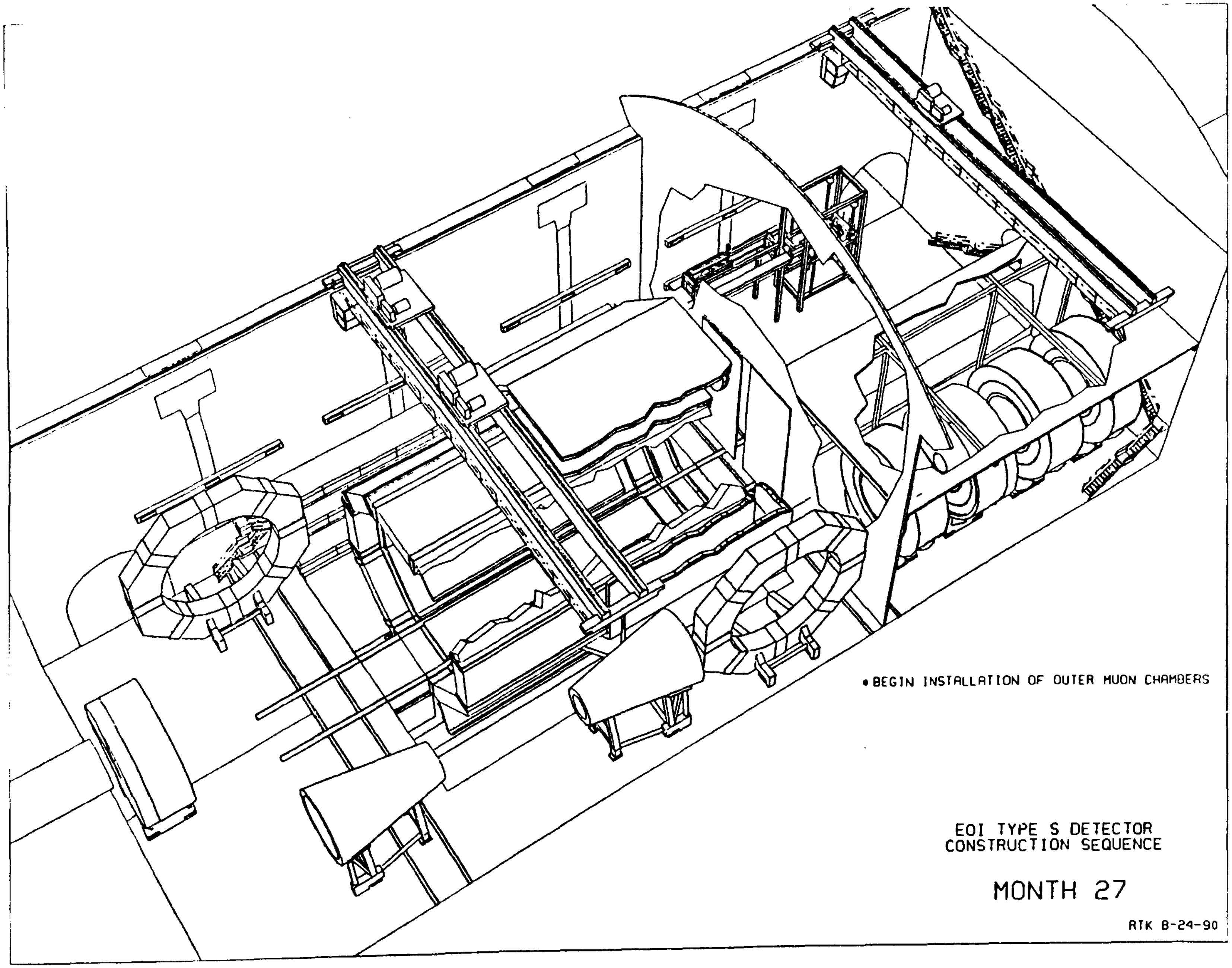


Figure 5.3-14. Hall at 27 Months

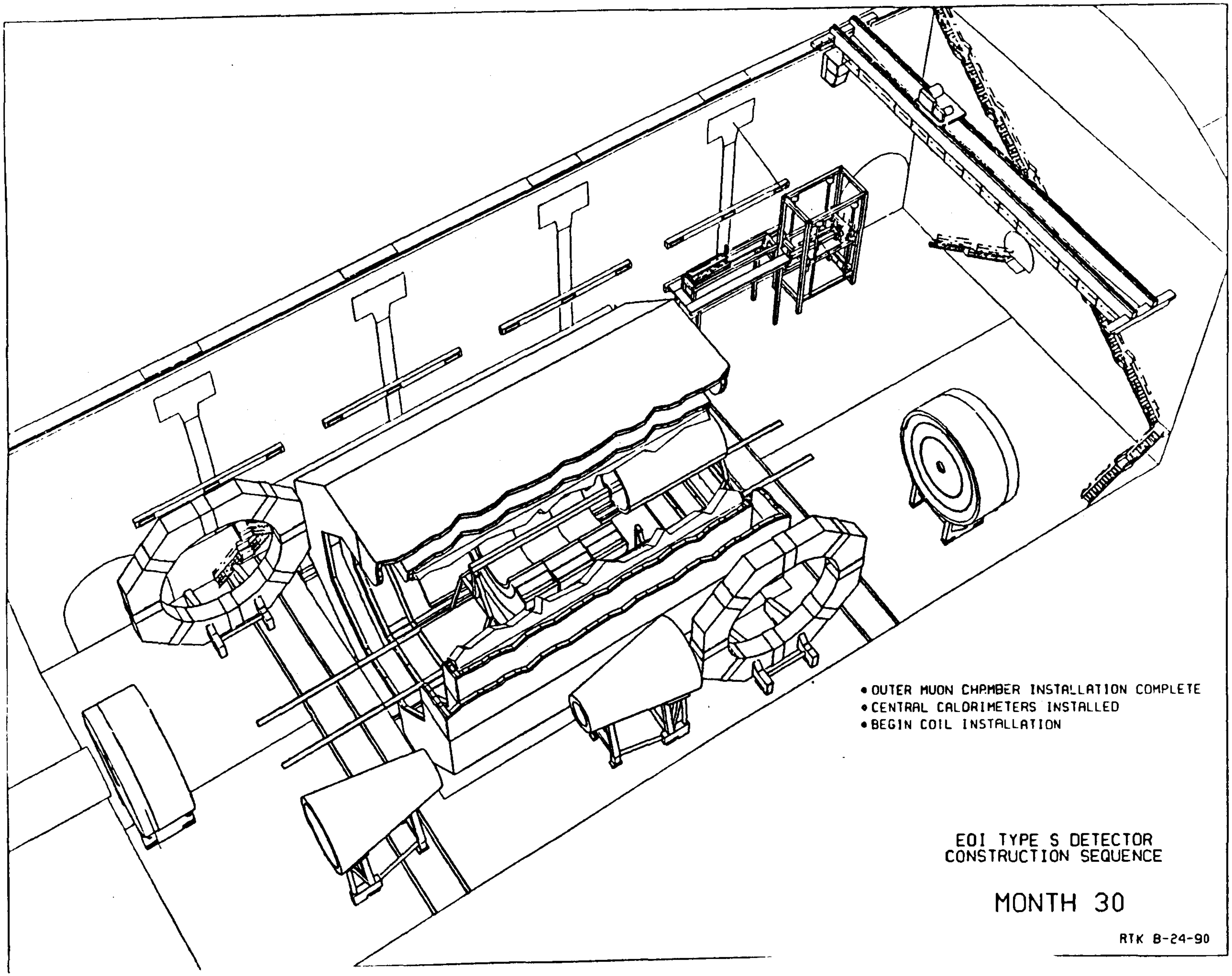


Figure 5.3-15. Hall at 30 Months

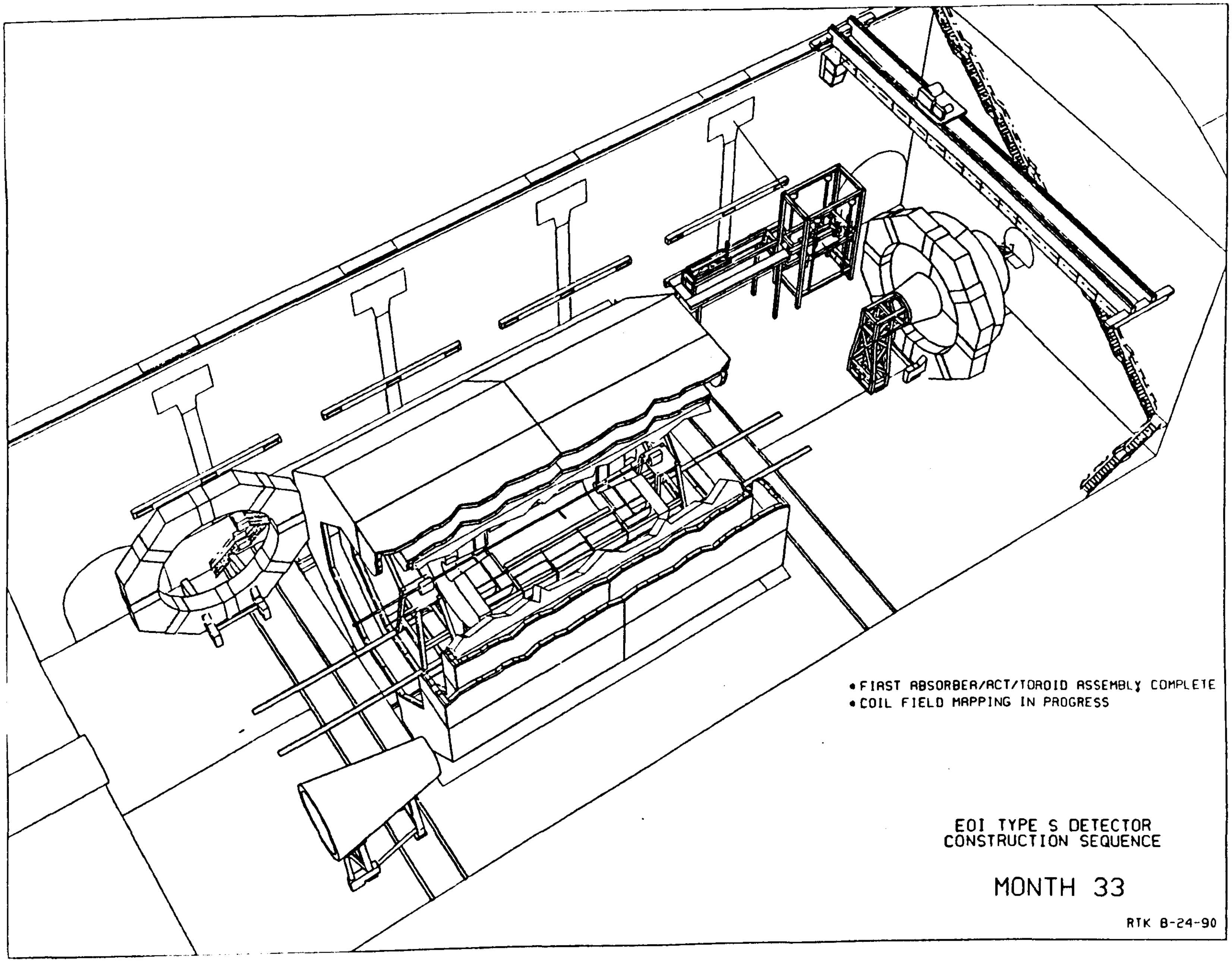


Figure 5.3-16. Hall at 33 Months

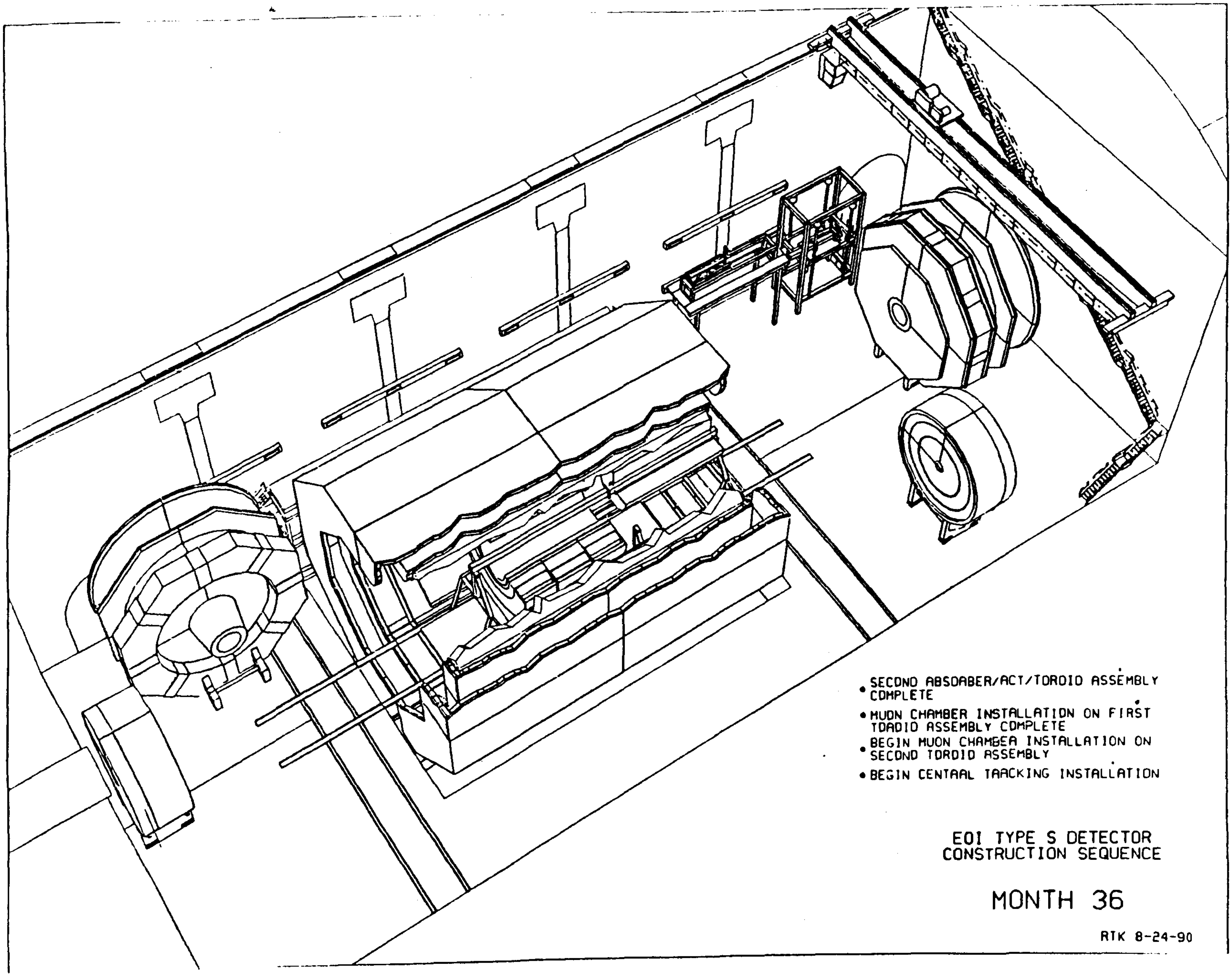


Figure 5.3-17. Hall at 36 Months

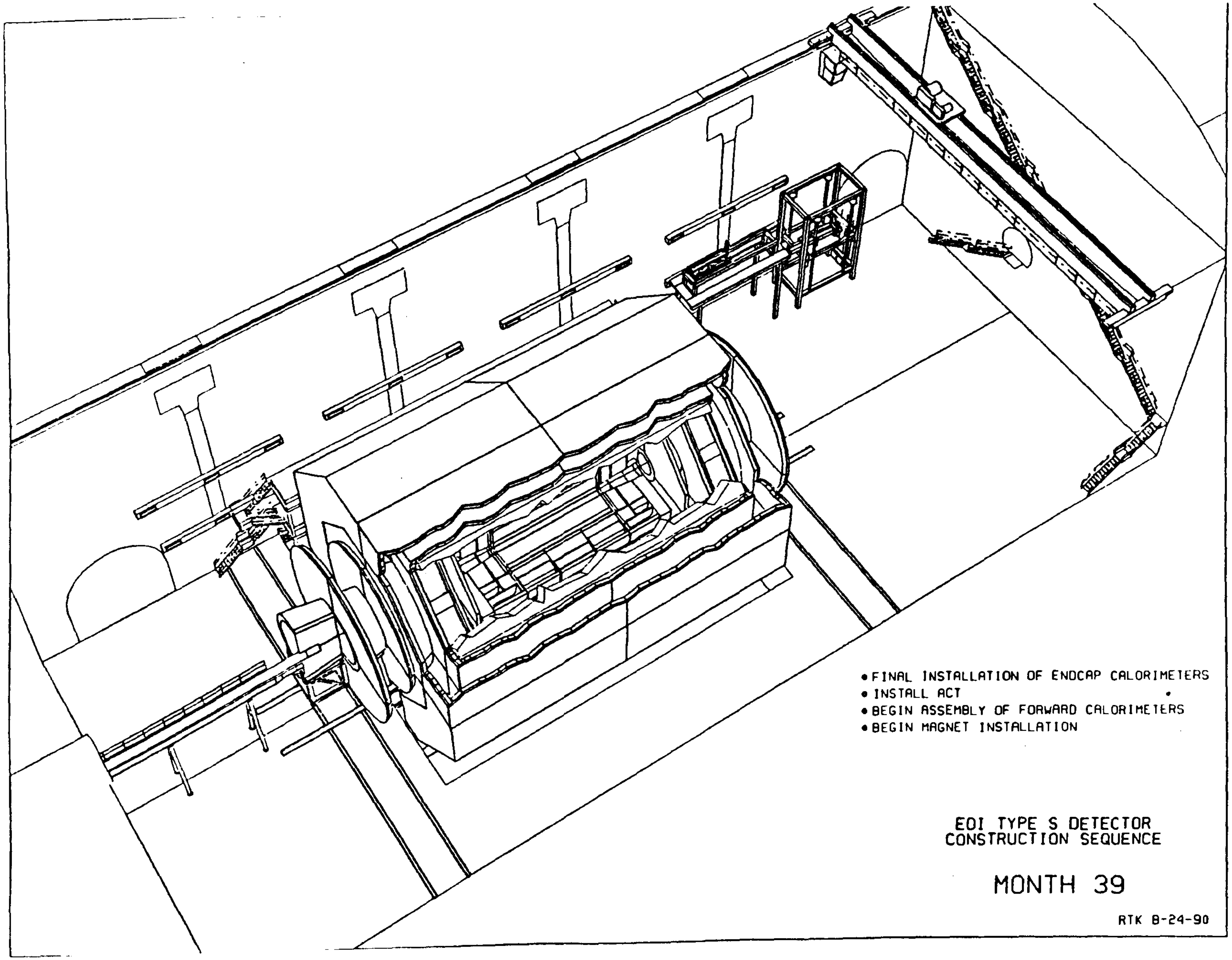


Figure 5.3-18. Hall at 39 Months

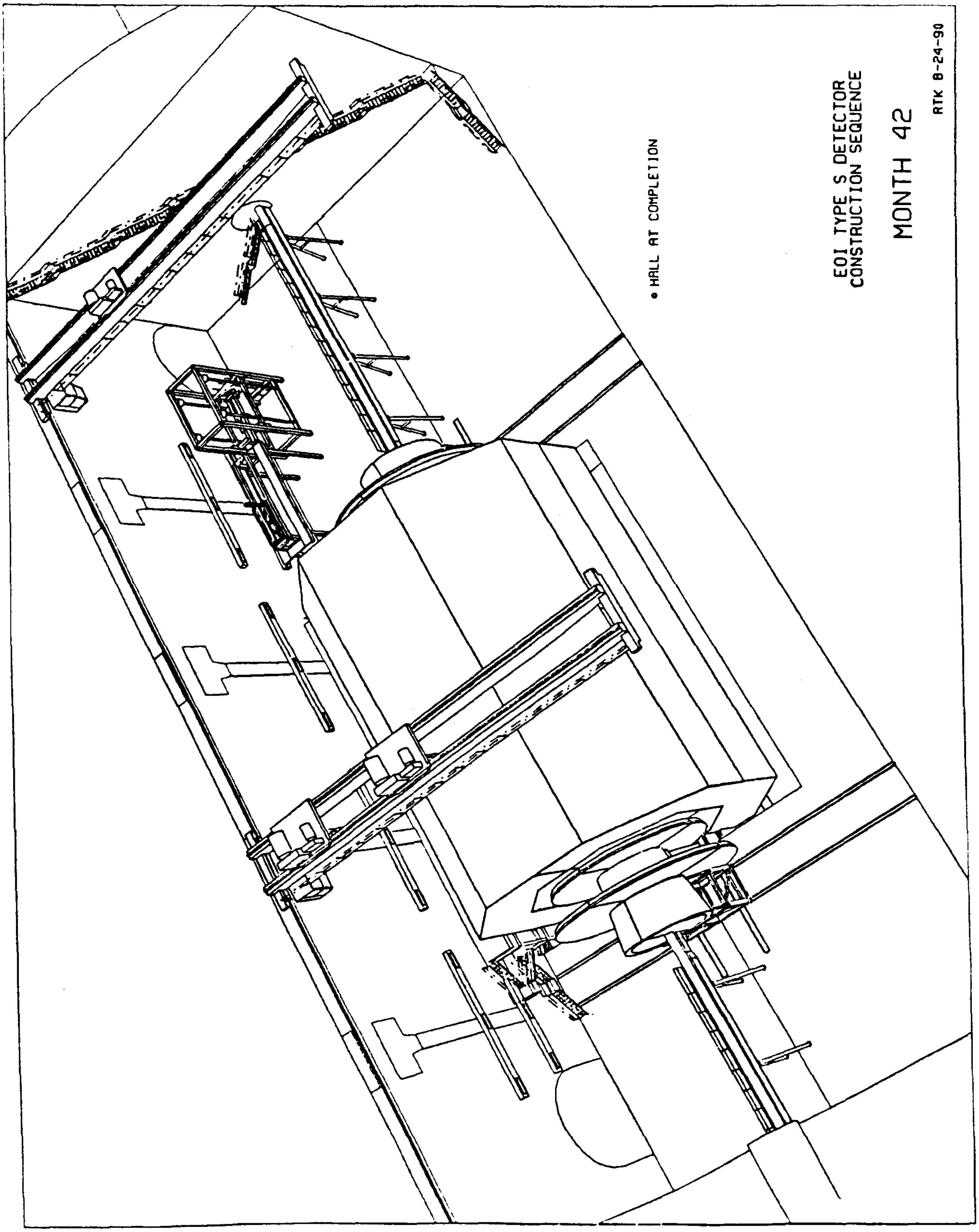


Figure 5.3-19. Hall at 42 Months

6.0 REPAIR TIME ESTIMATES

This section provides estimated times for repair of the components of the SDC detector.

Table 6.0-1. Repair Time Estimates

- Tracking:
  - Intermediate Tracking:
    - Repair electronics:
      - Example: amplifier card replacement
      - Time estimate: 3.5 days
        - Retract endcap calorimeter 1.5 days
        - Repair and checkout .5 days
        - Reposition endcap calorimeter 1.5 days
    - In situ repair:
      - Example: disconnect high voltage from wire
      - Time estimate: 3.5 days
        - Retract endcap calorimeter 1 m 1.5 days
        - Repair and checkout .5 days
        - Reposition endcap calorimeter 1.5 days
    - Major repair: Beam pipe remains in place
      - Example: replace one layer
      - Time estimate: 14 days
        - Move forward calorimeter .5 days
        - Retract forward toroids 1 day
        - Retract endcap calorimeter 2 days
        - Repair and checkout 7 days
        - Reposition endcap calorimeter 2 days
        - Reposition forward toroids 1 day
        - Reposition forward calorimeter .5 days
  - Barrel or Silicon:
    - Repair electronics:
      - Example: amplifier card replacement
      - Time estimate: 11.5 days
        - Move forward calorimeter .5 days
        - Retract forward toroids 1 day
        - Retract endcap calorimeter 2 days
        - Retract intermediate tracking 2 days
        - Repair and checkout . 5 days
        - Reposition intermediate tracking 2 days
        - Reposition endcap calorimeter 2 days
        - Reposition forward toroids 1 day
        - Reposition forward calorimeter . 5 days
    - In situ repair: Beam pipe remains in place
      - Example: disconnect high voltage from wire
      - Time estimate: 11.5 days
        - Move forward calorimeter .5 days
        - Retract forward toroids 1 day
        - Retract endcap calorimeter 2 days
        - Retract intermediate tracking 2 days
        - Repair and checkout .5 days
        - Reposition intermediate tracking 2 days
        - Reposition endcap calorimeter 2 days
        - Reposition forward toroids 1 day
        - Reposition forward calorimeter .5 days

- Major repair: beam pipe removed
    - Example: complete removal of silicon tracker
    - Time estimate: 14 days
        - Move both forward calorimeter . 5 days
        - Retract both forward toroids 1 day
        - Retract both endcap calorimeter 2 days
        - Extract silicon tracking system 7 days
        - Reposition both endcap calorimeters 2 days
        - Reposition both forward toroids 1 day
        - Reposition both forward calorimeters .5 days

Solenoid:

- Repair electronics:
    - Example: replace component in control dewar
    - Time estimate: direct access 1 day
- In situ repair:
    - Example: fix component in control dewar
    - Time estimate: direct access 1 day
- Major repair:
    - Example: coil failure
    - Time estimate: no estimate (long)

Calorimetry:

- Forward:
    - Repair electronics:
        - Example: replace readout card
        - Time estimate: all accessible .5 days
    - In situ repair:
        - Example: remove high voltage from cal. section
        - Time estimate: all accessible .5 days
    - Major repair:
        - Example: replace calorimeter module
        - Time estimate: 7 days
- Endcap:
    - Repair electronics:
        - Example: replace readout card
        - Time estimate: all accessible .5 days
    - In situ repair:
        - Example: remove high voltage from cal. section
        - Time estimate: all accessible .5 days
    - Major repair: no disengagement of beam pipe
        - Example: replace calorimeter module
        - Time estimate: 82 days
            - Move forward calorimeter . 5 days
            - Retract forward toroids 1 day
            - Retract endcap calorimeter 2 days
            - Empty calorimeter 3 days
            - Unstack/restack endcap 64 days
            - Refill calorimeter 3 days
            - Recable/checkout 5 days
            - Reposition endcap calorimeter 2 days
            - Reposition forward toroids 1 day
            - Reposition forward calorimeter .5 days
- Barrel: (central bay)
    - Repair electronics:
        - Example: replace readout card
        - Time estimate: all accessible .5 days

Table 6.0-1. Repair Time Estimates (cont)

- In situ repair:
  - Example: remove high voltage from cal. section
  - Time estimate: all accessible .5 days
- Major repair: beam pipe disengaged
  - Example: replace calorimeter module
  - Time estimate: Complete disassembly of detector required. No estimate (long).

Muon system:

- Inner chambers or scintillator:
  - Repair electronics:
    - Example: replace readout card
    - Time estimate: all accessible 1 day
  - In situ repair:
    - Example: remove high voltage from chamber layer
    - Time estimate: all accessible 1 day
  - Major repair:
    - Example: replace chamber (assume near center)
    - Time estimate: 10 days
      - Move forward calorimeter .5 days
      - Retract forward toroids 1 day
      - Remove and replace chambers 7 days
      - Reposition forward toroids 1 day
      - Reposition forward calorimeter .5 days
- Outer chambers or scintillator:
  - Repair electronics:
    - Example: replace readout card
    - Time estimate: all accessible 1 day
  - In situ repair:
    - Example: remove high voltage from chamber layer
    - Time estimate: all accessible 1 day
  - Major repair:
    - Example: replace chamber (assume near center)
    - Time estimate: 7 days
      - Remove and replace chambers 7 days

7.0 OPERATIONAL REQUIREMENTS

7.1 LOI Option 1 Detector

In Tables 7.1-1 to 7.1-4, power consumption, primary cooling needs, liquid and gas consumption, and secondary cooling needs are presented for the Option 1 Detector.

7.2 LOI Option 2 Detector

In Tables 7.2-1 to 7.2-4, power consumption, primary cooling needs, liquid and gas consumption, and secondary cooling needs are presented for the Option 2 Detector.

Table 7.1-1. SDC Utilities Option 1 - Power Consumption

Power Consumption Location	Numb Chan Kchan	Watts Chan	400 Hz Power Use KWatt	400 Hz Power 1/Eff	400 Hz Power Load KWatt	400 Hz Power Spare	400 Hz Power Total KWatt	60 Hz Detector Use KWatt	60 Hz Detector 1/Eff	60 Hz Detector Load KWatt	60 Hz Detector Spare	60 Hz Detector Total KWatt	60 Hz Other Load KWatt	60 Hz Other Spare	60 Hz Other Total KWatt	DC Power Load KWatt	DC Power Spare	DC Power Total KWatt	Line Power Use KWatt	Line Power Spare KWatt	Line Power Div.	Line Power 1/Eff	Line Power Load Kwatt	Line Power 1/PF	Line Power Supply KVA
Inside Coil																									
Silicon Vertex			10		10	2	20																		
HV Dissipation								0.66		0.66															
Straw Tracking	240	0.02	4.8		4.8	2	9.6																		
HV Dissipation								0.36		0.36															
Fiber Tracking																									
HV Dissipation																									
Inside Coil Total			14.8		14.8		29.6	1.02		1.02															
Solenoid Magnet																									
Cryostat																									
Power Leads																									
Ht Leak/Coldwn																									
Solenoid Cryostat																									
Inside Muon Steel																									
Calorimeter	66	1.5	99	2	198	2	396																		
HV Dissipation								0.99		0.99															
Muon Chamber	35	0.02	0.7	2	1.4	2	2.8																		
HV Dissipation								0.053		0.053															
Muon Trigger	0	1.5	0	2	0	2	0																		
HV Dissipation								0		0															
Inside Tracking PS				2	14.8	2	29.6																		
Total Inside Muon Steel			99.7		214.2		428.4																		
Muon Toroids																									
Barrel																1739	1.25	2174							
Near End Cap																535	1.25	668.8							
Far End Cap																282	1.25	352.5							
Total Muon Toroid																2556		3195							
Outside Muon Steel																									
Muon Chambers	73	0.02	1.46	2	2.92	2	5.84																		
HV Dissipation								0.11		0.11															
Muon Trigger	16	1.5	24	2	48	2	96																		
HV Dissipation								24		24															
Forward Calorimeter	7	0.4	2.8	2	5.6	2	11.2																		
HV Dissipation								0		0															

*= Not included in totals. PF = Power Factor. Div = Diversity Factor. Eff = 1/(Power Supply Efficiency). Frac = Fraction of Cooling.

Table 7.1-1. SDC Utilities Option 1 - Power Consumption (cont)

Power Consumption Location	Numb Chan Kchan	Watts Chan	400 Hz Power Use KWatt	400 Hz Power 1/Eff	400 Hz Power Load KWatt	400 Hz Power Spare	400 Hz Power Total KWatt	60 Hz Detector Use KWatt	60 Hz Detector 1/Eff	60 Hz Detector Load KWatt	60 Hz Detector Spare	60 Hz Detector Total KWatt	60 Hz Other Load KWatt	60 Hz Other Spare	60 Hz Other Total KWatt	DC Power Load KWatt	DC Power Spare	DC Power Total KWatt	Line Power Use KWatt	Line Power Spare KWatt	Line Power Div.	Line Power 1/Eff	Line Power Load KWatt	Line Power 1/PF	Line Power Supply KVA
Level 1 Trigger			36	2	72	2	144																		
DAQ			14.67	1.5	22.01	2	44.01																		
High Voltage																									
Tracking									2	1.02	2	4.08													
Calorimeter									2	0.99	2	3.96													
Muon Chambers									2	0.162	2	0.324													
Muon Trigger									2	24	2	48													
Monitoring								50		50	2	100													
Liquid Handling													100		100										
Lights													115	1.5	172.5										
Outlet Power													25	1.5	37.5										
*Welding													120	2	240										
*Crane													250	1.5	375										
Air Handling													37	1.5	55.5										
Sump Pumps													25	2	50										
Safety													50	2	100										
Total Outside Muon Steel			78.93		150.5		301.1	74.11		100.3		156.4	352		515.5	0		0							
Utility Shaft																									
Toroid Power bus																100	2	200							
Solenoid Power Bus																20	2	40							
Total Utility Shaft																120		240							
Surface																									
DAQ			300	2	600	2	1200																		
Trigger Level 2			56	2	112	2	224																		
Trigger Level 3								90	1.5	135	2	270													
Control Room								100	2	200	2	400													
Monitoring								100		100	2	200													
Computer System								100		100	2	200													

*= Not included in totals. PF = Power Factor. Div = Diversity Factor. Eff = 1/(Power Supply Efficiency). Frac = Fraction of Cooling.

Table 7.1-1. SDC Utilities Option 1 - Power Consumption (cont)

Power Consumption Location	Numb Chan Kchan	Watts Chan	400 Hz Power Use KWatt	1/Eff	Load KWatt	Spare	Total KWatt	60 Hz Detector Use KWatt	1/Eff	Load KWatt	Spare	Total KWatt	60 Hz Other Load KWatt	Spare	Total KWatt	DC Power Load KWatt	Spare	Total KWatt	Line Power Use KWatt	Spare KWatt	Div.	1/Eff	Load KWatt	1/PF	Supply KVA
Cryogenic System																									
Helium Comp.																			800	200	1	1.3	1300	1.2	1,560
Solenoid Coil PS																			500	125	1	1.3	813	1.2	975
Control/Cold Box													60	2	120										
Compressed Air													20	2	40										
Auxiliary													50		50										
Muon Toroid PS																			2656	739	1	1.3	1019	1.2	5,296
400 HZ MG Set																			1092	1092	0.3	1.3	426	1.2	2,214
Solenoid Pwr Bus																			20	20	1	1.3	52	1.2	62
Crane																									
HVAC System																									
CHW Prod/Circ													984.9	1.5	1477										
Air Circ Fan													40	1.5	60										
Util Water Pumps													125	1.5	187.5										
Power Transformer																									
60 HZ Detector																									
60 Hz Other																			686.3	640.1	0.3	1.3	263	1.2	1370
Vent Fan																			1667	841	0.3	1.3	576	1.2	2994
Safety													25	1.5	38										
Noninterruptable Pwr								50		50	2	100	10	2	20										
Total Surface			356		712		1,424	440		585		1,170	1,315		1,992	0		0	7,421	3,657			4,448		14,471
Total			549		1,092		2,183	515		686		1,326	1,667		2,508	2,676		3,435	7,421	3,657			4,448		14,471

*= Not included in totals. PF = Power Factor. Div = Diversity Factor. Eff = 1/(Power Supply Efficiency). Frac = Fraction of Cooling.

Table 7.1-2. SDC Utilities Option 1 - Primary Cooling Needs

Location	ICW					LCW					CHW					Butane Cooling					A/C				
	Frac	Load KWatt	T in °F	T out °F	Flow gpm	Frac	Load KWatt	T in °F	T out °F	Flow gpm	Frac	Load KWatt	T in °F	T out °F	Flow gpm	Frac	Load KWatt	T in °C	T out °C	Flow cc/min	Frac	Load KWatt	T in °F	T out °F	Flow CFM
Inside Coil																									
Silicon Vertex HV Dissipation																1	20	10	10	5000					
Straw Tracking HV Dissipation											1	4.8	45	60	2.128										
Fiber Tracking HV Dissipation																									
Inside Coil Total		0			0		0			0		4.8			2.128		20			5000		0			0
Solenoid Magnet																									
Cryostat Power Leads Ht Leak/Coldwn																									
Solenoid Cryostat		0			0		0			0		0			0		0			0		0			0
Inside Muon Steel																									
Calorimeter HV Dissipation											1	198	45	60	87.78										
Muon Chamber HV Dissipation																					1	1.4	75	80	903
Muon Trigger HV Dissipation																					1	0	75	80	0
Inside Tracking PS											1	14.8	45	60	6.561										
Total Inside Muon Steel		0			0		0			0		212.8			94.34		0			0		1.4			903
Muon Toroids																									
Barrel						0.98	1704	65	75	1,133											0.02	34.78	75	80	22,426
Near End Cap						0.98	524.3	65	75	349											0.02	10.7	75	80	6,899
Far End Cap						0.98	276.4	65	75	184											0.02	5.64	75	80	3,637
Total Muon Toroid		0			0		2505			1,666		0			0		0			0		51			32,962
Outside Muon Steel																									
Muon Chambers																					1	2.92	55	75	471
Muon Trigger																					1	48	55	75	7,738
Forward Calorimeter HV Dissipation											1	5.6	50	65	2.483										

*= Not included in totals. PF = Power Factor. Div = Diversity Factor. Eff = 1/(Power Supply Efficiency). Frac = Fraction of Cooling.

Table 7.1-2. SDC Utilities Option 1 - Primary Cooling Needs (cont)

Location	ICW Frac	ICW Load KWatt	ICW T in °F	ICW T out °F	ICW Flow gpm	LCW Frac	LCW Load KWatt	LCW T in °F	LCW T out °F	LCW Flow gpm	CHW Frac	CHW Load KWatt	CHW T in °F	CHW T out °F	CHW Flow gpm	Butane Cooling Frac	Butane Cooling Load KWatt	Butane Cooling T in °C	Butane Cooling T out °C	Butane Cooling Flow cc/min	A/C Frac	A/C Load KWatt	A/C T in °F	A/C T out °F	A/C Flow CFM
Level 1 Trigger											1	72	50	65	31.92										
High Voltage																									
Tracking																									
Calorimeter																									
Muon Chambers																									
Muon Trigger																									
Monitoring																					1	50	55	75	8,060
Liquid Handling																					0.2	20	55	75	3,224
Lights																					1	115	55	75	18,538
Outlet Power																					1	25	55	75	4,030
*Welding																									
*Crane																									
Air Handling																					0.3	11.1	55	75	1,789
Sump Pumps																					0.3	7.5	55	75	1,209
Safety																					0.3	15	55	75	2,418
Total Outside Muon Steel		0			0		0			0		77.6			34.4		0			0		294.5			47,476.6
Utility Shaft																									
Toroid Power Bus						1	100	100	130	22															
Solenoid Power Bus						1	20	100	130	4															
Total Utility Shaft		0			0		120			27		0			0		0			0		0			0
Surface																									
DAQ											1	600	45	60	266										
Trigger Level 2											1	112	45	60	49.65										
Trigger Level 3											1	135	45	60	59.85										
Control Room											1	200	45	60	88.67										
Monitoring											1	100	45	60	44.33										
Computer System																					1	100	55	75	16,120

*= Not included in totals. PF = Power Factor. Div = Diversity Factor. Eff = 1/(Power Supply Efficiency). Frac = Fraction of Cooling.

Table 7.1-2. SDC Utilities Option 1 - Primary Cooling Needs (cont)

Location	ICW Frac	ICW Load KWatt	ICW T in °F	ICW T out °F	ICW Flow gpm	LCW Frac	LCW Load KWatt	LCW T in °F	LCW T out °F	LCW Flow gpm	CHW Frac	CHW Load KWatt	CHW T in °F	CHW T out °F	CHW Flow gpm	Butane Cooling Frac	Butane Cooling Load KWatt	Butane Cooling T in °C	Butane Cooling T out °C	Butane Cooling Flow cc/min	A/C Frac	A/C Load KWatt	A/C T in °F	A/C T out °F	A/C Flow CFM
Cryogenic System																									
Helium Comp.	1	1300	100	125	346																				
Solenoid Coil PS						1	812.5	100	125	216.1															
Control/Cold Box	1	60	100	125	16																				
Compressed Air																					0.5	10	55	75	1,612
Auxiliary																					0.5	25	55	75	4,030
Muon Toroid PS						1	1019	100	125	270.9															
400 Hz MG Set						1	425.7	100	125	113.2															
Crane																									
HVAC System																									
CHW Prod/Circ																					0.3	53	55	75	8,463
Air Circ Fan																									
Util Water Pumps																									
Power Transformer																									
60 Hz Detector																									
60 Hz Other																									
Safety																									
																					1	50	55	75	8,060
Noninterruptable Pwr																									
Total Surface Cooling		1,360			362		2,257			600		1,147			509		0			0		238			38,285
Total Cooling		1,360			362		4,882			2,293		1,442			639		20			5,000		585			119,627

*= Not included in totals. PF = Power Factor. Div = Diversity Factor. Eff = 1/(Power Supply Efficiency). Frac = Fraction of Cooling.

Table 7.1-3. SDC Utilities Option 1 - Liquid and Gas Consumption

Liquid and Gas Consumption Location	Liquid Helium Watts	Liquid Helium l/hour	Liquid Nitrogen liters/hr	Liquid Argon lpm	Chamber Gas liters/hr
Inside Coil:					
Silicon Vertex					
HV Dissipation					
Straw Tracking					
HV Dissipation			240		1,500
Fiber Tracking					
HV Dissipation					
Inside Coil Total					
Solenoid Magnet:					
Cryostat					
Power Leads		33			
Ht Leak/Coldwn	750				
Solenoid Cryostat					
Inside Muon Steel:					
Calorimeter					
HV Dissipation					
Muon Chamber					14,600
Muon Trigger					
HV Dissipation					
Inside Tracking PS					
Total Inside Muon Steel					
Muon Toroids					
Barrel					
Near End Cap					
Far End Cap					
Total Muon Toroid					
Outside Muon Steel					
Muon Chambers					33,000
Muon Trigger					

*= Not included in totals. PF = Power Factor. Div. = Diversity Factor. Eff = 1/(Power Supply Efficiency). Frac = Fraction of Cooling.

Table 7.1-3. SDC Utilities Option 1 - Liquid and Gas Consumption (cont)

Liquid and Gas Consumption Location	Liquid Helium Watts	Liquid Helium l/hour	Liquid Nitrogen liters/hr	Liquid Argon lpm	Chamber Gas liters/hr
Forward Calorimeter					
HV Dissipation					
Level 1 Trigger					
High Voltage					
Tracking					
Calorimeter					
Muon Chambers					
Muon Trigger					
Monitoring					
Liquid Handling					
Lights					
Outlet Power					
*Welding					
*Crane					
Air Handling					
Sump Pumps					
Safety					
Total Outside Muon Steel					
Utility Shaft					
Toroid Power Bus					
Solenoid Power Bus					
Total Utility Shaft					
Surface					
DAQ					
Trigger Level 2					
Trigger Level 3					
Control Room					
Monitoring					

*= Not included in totals. PF = Power Factor. Div. = Diversity Factor. Eff = 1/(Power Supply Efficiency). Frac = Fraction of Cooling.

Table 7.1-3. SDC Utilities Option 1 - Liquid and Gas Consumption (cont)

Liquid and Gas Consumption Location	Liquid Helium Watts	Liquid Helium l/hour	Liquid Nitrogen liters/hr	Liquid Argon lpm	Chamber Gas liters/hr
Computer System					
Cryogenic System					
Helium Comp.					
Solenoid Coil PS					
Control/Cold Box					
Compressed Air					
Auxiliary					
Muon Toroid PS					
400 Hz MG Set					
Crane					
HVAC System					
CHW Prod/Circ					
Air Circ Fan					
Util Water Pumps					
Power Transformer					
60 Hz Detector					
60 Hz Other					
Safety					
Noninterruptable Pwr					
Total Surface					
Total					

*= Not included in totals. PF = Power Factor. Div. = Diversity Factor. Eff = 1/(Power Supply Efficiency). Frac = Fraction of Cooling.

Table 7.1 4. SDC Utilities Option 1 - Secondary Cooling Needs

Cooling Needs Secondary Cooling	Primary Cooling Load BTU/hr	Primary Cooling Flow Rate gpm,cfm	Pump or Blower Δp(psi, in H_2O)	Pump or Blower KWatt	Compressor KWatt	Auxiliary Pumps/Fans KWatt	Secondary Cooling Pond/Tower Btu/hr
ICW							
100 to 125° F	4,640,320	362	43	11			4,679,085
LCW							
65 to 75° F	8,546,651	1,667	250	304			
100 to 130° F	8,109,282	527	53	20			8,178,866
CHW (Primary)							
45 to 60° F	4,920,786	640	35	16	275		5,913,980
A/C							
55 to 75° F	1,092,113	51,602	4	37			
75 to 80° F Insd Stl	91,988	17,386	4	12			
Surface Blg	810,350	38,289	4	27			
CHW (Secondary)							
For A/C ΔT = 15° F	1,994,450	259	35	7	125		2,442,370
For LCW @ 65° F ΔT = 15° F	8,546,651	1,111	35	28	534		10,466,083

Power for CHW Production and Circulation = 985 KW
Hall HVAC Air Handling = 37 KW
Surface Bldg. & Hall Ventilation Fans = 40 KW
Line Power = 14,471 KVA   Total Ambient Heat Rejec   31,680,383

Table 7.2-1. SDC Utilities Option 2 - Power Consumption

Power Consumption Location	Numb Chan Kchan	Watts Chan	400 Hz Power Use KWatt	400 Hz Power 1/Eff	400 Hz Power Load KWatt	400 Hz Power Spare	400 Hz Power Total KWatt	60 Hz Detector Use KWatt	60 Hz Detector 1/Eff	60 Hz Detector Load KWatt	60 Hz Detector Spare	60 Hz Detector Total KWatt	60 Hz Other Load KWatt	60 Hz Other Spare	60 Hz Other Total KWatt	DC Power Load KWatt	DC Power Spare	DC Power Total KWatt	Line Power Use KWatt	Line Power Spare KWatt	Line Power Div.	Line Power 1/Eff	Line Power Load KWatt	Line Power 1/PF	Line Power Supply KVA
Inside Coil																									
Silicon Vertex			10		10	2	20																		
HV Dissipation								0.66		0.66															
Straw Tracking	0	0.02	0		0	2	0																		
HV Dissipation								0		0															
Fiber Tracking																									
HV Dissipation																									
Inside Coil Total			10		10		20	0.66		0.66															
Solenoid Magnet																									
Cryostat																									
Power Leads																									
Ht Leak/Coldwn																									
Solenoid Cryostat																									
Inside Muon Steel																									
Calorimeter	94	0.4	37.6	2	75.2	2	150.4																		
HV Dissipation								1.41		1.41															
Muon Chamber	35	0.02	0.7	2	1.4	2	2.8																		
HV Dissipation								0.053		0.053															
Muon Trigger	0	15	0	2	0	2	0																		
HV Dissipation								0		0															
Inside Tracking PS				2	10	2	20																		
Total Inside Muon Steel			38.3		86.6		173.2																		
Muon Toroids																									
Barrel																1700	1.25	2125							
Near End Cap																446	1.25	557.5							
Far End Cap																330	1.25	412.5							
Total Muon Toroid																2476		3095							
Outside Muon Steel																									
Muon Chambers	73	0.02	1.46	2	2.92	2	5.84																		
HV Dissipation								0.11		0.11															
Muon Trigger	16	1.5	24	2	48	2	96																		
HV Dissipation								24		24															
Forward Calorimeter	7	0.4	2.8	2	56	2	11.2																		
HV Dissipation								0		0															

*= Not included in totals. PF = Power Factor. Div = Diversity Factor. Eff = 1/(Power Supply Efficiency). Frac = Fraction of Cooling.

Table 7.2-1. SDC Utilities Option 2 - Power Consumption (cont)

Power Consumption Location	Numb Chan Kchan	Watts Chan	400 Hz Power Use KWatt	1/Eff	Load KWatt	Spare	Total KWatt	60 Hz Detector Use KWatt	1/Eff	Load KWatt	Spare	Total KWatt	60 Hz Other Load KWatt	Spare	Total KWatt	DC Power Load KWatt	Spare	Total KWatt	Line Power Use KWatt	Spare KWatt	Div.	1/Eff	Load KWatt	1/PF	Supply KVA
Level 1 Trigger			36	2	72	2	144																		
DAQ			14.67	1.5	22.01	2	44.01																		
High Voltage																									
Tracking									2	0.66	2	2.64													
Calorimeter									2	1.41	2	5.64													
Muon Chambers									2	0.162	2	0.324													
Muon Trigger									2	24	2	48													
Monitoring								50		50	2	100													
Liquid Handling													100		100										
Lights													115	1.5	172.5										
Outlet Power													25	1.5	37.5										
*Welding													120	2	240										
*Crane													250	1.5	375										
Air Handling													37	1.5	55.5										
Sump Pumps													25	2	50										
Safety													50	2	100										
Total Outside Muon Steel			78.93		150.5		301.1	74.11		100.3		156.6	352		515.0	0		0							
Utility Shaft																									
Toroid Power bus																100	2	200							
Solenoid Power Bus																20	2	40							
Total Utility Shaft																120		240							
Surface																									
DAQ			300	2	600	2	1200																		
Trigger Level 2			56	2	112	2	224																		
Trigger Level 3								90	1.5	135	2	270													
Control Room								100	2	200	2	400													
Monitoring								100		100	2	200													
Computer System								100		100	2	200													

*= Not included in totals. PF = Power Factor. Div = Diversity Factor. Eff = 1/(Power Supply Efficiency). Frac = Fraction of Cooling.

Table 7.2-1. SDC Utilities Option 2 - Power Consumption (cont)

Power Consumption Location	Numb Chan Kchan	Watts Chan	400 Hz Power Use KWatt	400 Hz Power 1/Eff	400 Hz Power Load KWatt	400 Hz Power Spare	400 Hz Power Total KWatt	60 Hz Detector Use KWatt	60 Hz Detector 1/Eff	60 Hz Detector Load KWatt	60 Hz Detector Spare	60 Hz Detector Total KWatt	60 Hz Other Load KWatt	60 Hz Other Spare	60 Hz Other Total KWatt	DC Power Load KWatt	DC Power Spare	DC Power Total KWatt	Line Power Use KWatt	Line Power Spare KWatt	Line Power Div.	Line Power 1/Eff	Line Power Load KWatt	Line Power 1/PF	Line Power Supply KVA
Cryogenic System																									
Helium Comp.																			800	200	1	1.3	1300	1.2	1,560
Solenoid Coil PS																			500	125	1	1.3	813	1.2	975
Control/Cold Box													60	2	120										
Compressed Air													20	2	40										
Auxiliary													50		50										
Muon Toroid PS																			2576	719	1	1.3	989	1.2	5140
400 Hz MG Set																			959.1	959.1	0.3	1.3	374	1.2	1945
Solenoid Pwr Bus																			20	20	1	1.3	52	1.2	62
Crane																									
HVAC System																									
CHW Prod/Circ													940.2	1.5	1410										
Air Circ Fan													40	1.5	60										
Util Water Pumps													125	1.5	187.5										
Power Transformer																									
60 Hz Detector																									
60 Hz Other																			686	640.6	0.3	1.3	263	1.2	1370
Vent Fan																			1622	818.6	0.3	1.3	560	1.2	2,914
													25	1.5	38										
Safety																									
								50		50	2	100													
Noninterruptable Pwr													10	2	20										
Total Surface			356		712		1,424	440		585		1,170	1,270		1,925	0		0	7,163	3,482			4,351		13,996
Total			483		959		1,918	515		686		1,327	1,622		2,441	2,596		3,335	7,163	3,482			4,351		13,996

*= Not included in totals. PF = Power Factor. Div = Diversity Factor. Eff = 1/(Power Supply Efficiency). Frac = Fraction of Cooling.

Table 7.2-2. SDC Utilities Option 2 - Primary Cooling Needs

Location	ICW Frac	ICW Load KWatt	ICW T in °F	ICW T out °F	ICW Flow gpm	LCW Frac	LCW Load KWatt	LCW T in °F	LCW T out °F	LCW Flow gpm	CHW Frac	CHW Load KWatt	CHW T in °F	CHW T out °F	CHW Flow gpm	Butane Cooling Frac	Butane Cooling Load KWatt	Butane Cooling T in °C	Butane Cooling T out °C	Butane Cooling Flow cc/min	A/C Frac	A/C Load KWatt	A/C T in °F	A/C T out °F	A/C Flow CFM
Inside Coil																									
Silicon Vertex HV Dissipation																1	20	10	10	5000					
Straw Tracking HV Dissipation											1	0	45	60	0										
Fiber Tracking HV Dissipation																									
Inside Coil Total		0			0		0			0		0			0		20			5000		0			0
Solenoid Magnet																									
Cryostat Power Leads Ht Leak/Coldwn																									
Solenoid Cryostat		0			0		0			0		0			0		0			0		0			0
Inside Muon Steel																									
Calorimeter HV Dissipation											1	75.2	45	60	33.34										
Muon Chamber HV Dissipation																					1	1.4	75	80	903
Muon Trigger HV Dissipation																					1	0	75	80	0
Inside Tracking PS											1	10	45	60	4.433										
Total Inside Muon Steel		0			0		0			0		85.2			37.77		0			0		1.4			903
Muon Toroids																									
Barrel						0.98	1666	65	75	1,108											0.02	34	75	80	21,923
Near End Cap						0.98	437.1	65	75	291											0.02	8.92	75	80	5,752
Far End Cap						0.98	323.4	65	75	215											0.02	6.6	75	80	4,256
Total Muon Toroid		0			0		2426			1,614		0			0		0			0		50			31,930
Outside Muon Steel																									
Muon Chambers																					1	2.92	55	75	471
Muon Trigger																					1	48	55	75	7,738
Forward Calorimeter HV Dissipation											1	5.6	50	65	2.483										

*= Not included in totals. PF = Power Factor. Div = Diversity Factor. Eff = 1/(Power Supply Efficiency). Frac = Fraction of Cooling.

Table 7.2-2. SDC Utilities Option 2 - Primary Cooling Needs (cont)

Location	ICW Frac	ICW Load KWatt	ICW T in °F	ICW T out °F	ICW Flow gpm	LCW Frac	LCW Load KWatt	LCW T in °F	LCW T out °F	LCW Flow gpm	CHW Frac	CHW Load KWatt	CHW T in °F	CHW T out °F	CHW Flow gpm	Butane Cooling Frac	Butane Cooling Load KWatt	Butane Cooling T in °C	Butane Cooling T out °C	Butane Cooling Flow cc/min	A/C Frac	A/C Load KWatt	A/C T in °F	A/C T out °F	A/C Flow CFM
Level 1 Trigger											1	72	50	65	31.92										
High Voltage																									
Tracking																									
Calorimeter																									
Muon Chambers																									
Muon Trigger																									
Monitoring																					1	50	55	75	8,060
Liquid Handling																					0.2	20	55	75	3,224
Lights																					1	115	55	75	18,538
Outlet Power																					1	25	55	75	4,030
*Welding																									
*Crane																									
Air Handling																					0.3	11.1	55	75	1,789
Sump Pumps																					0.3	7.5	55	75	1,209
Safety																					0.3	15	55	75	2,418
Total Outside Muon Steel		0			0		0			0		77.6			34.4		0			0		294.5			47,476.6
Utility Shaft																									
Toroid Power Bus						1	100	100	130	22															
Solenoid Power Bus						1	20	100	130	4															
Total Utility Shaft		0			0		120			27		0			0		0			0		0			0
Surface																									
DAQ											1	600	45	60	266										
Trigger Level 2											1	112	45	60	49.65										
Trigger Level 3											1	135	45	60	59.85										
Control Room											1	200	45	60	88.67										
Monitoring											1	100	45	60	44.33										
Computer System																					1	100	55	75	16,120

*= Not included in totals. PF = Power Factor. Div = Diversity Factor. Eff = 1/(Power Supply Efficiency). Frac = Fraction of Cooling.

Table 7.2-2. SDC Utilities Option 2 - Primary Cooling Needs (cont)

Location	ICW					LCW					CHW					Butane Cooling					A/C				
	Frac	Load KWatt	T in °F	T out °F	Flow gpm	Frac	Load KWatt	T in °F	T out °F	Flow gpm	Frac	Load KWatt	T in °F	T out °F	Flow gpm	Frac	Load KWatt	T in °C	T out °C	Flow cc/min	Frac	Load KWatt	T in °F	T out °F	Flow CFM
Cryogenic System																									
Helium Comp.	1	1300	100	125	346																				
Solenoid Coil PS						1	812.5	100	125	216.1															
Control/Cold Box	1	60	100	125	16																				
Compressed Air																					0.5	10	55	75	1,612
Auxiliary																					0.5	25	55	75	4,030
Muon Toroid PS						1	988.5	100	125	262.9															
400 Hz MG Set						1	374.1	100	125	99.5															
Crane																									
HVAC System																									
CHW Prod/Circ																					0.3	53	55	75	8,463
Air Circ Fan																									
Util Water Pumps																									
Power Transformer																									
60 Hz Detector																									
60 Hz Other																									
Safety																									
Noninterruptable Pwr																					1	50	55	75	8,060
Total Surface Cooling		1,360			362		2,175			579		1,147			509		0			0		238			38,285
Total Cooling		1,360			362		4,722			2,219		1,310			581		20			5,000		583			118,595

*= Not included in totals. PF = Power Factor. Div = Diversity Factor. Eff = 1/(Power Supply Efficiency). Frac = Fraction of Cooling.

Table 7.2-3. SDC Utilities Option 2 - Liquid and Gas Consumption

Liquid and Gas Consumption Location	Liquid Helium Watts	Liquid Helium l/hour	Liquid Nitrogen liter/hr	Liquid Argon lpm	Liquid Argon K liter	Chamber Gas liters/hr
Inside Coil:						
Silicon Vertex						
HV Dissipation						
Straw Tracking						
HV Dissipation			240			1500
Fiber Tracking						
HV Disssipation						
Inside Coil Total						
Solenoid Magnet:	z					
Cryostat						
Power Leads		33				
Ht Leak/Coldwn						
Solenoid Cryostat						
Inside Muon Steel:						
Calorimeter				22	200	
HV Dissipation						
Muon Chamber						14,600
Muon Trigger						
HV Dissipation						
Inside Tracking PS						
Total Inside Muon Steel						
Muon Toroids						
Barrel						
Near End Cap						
Far End Cap						
Total Muon Toroid						
Outside Muon Steel						
Muon Chambers						33,000
Muon Trigger						

*= Not included in totals. PF = Power Factor. Div. = Diversity Factor. Eff = 1/(Power Supply Efficiency). Frac = Fraction of Cooling.

Table 7.2-3. SDC Utilities Option 2 - Liquid and Gas Consumption (cont)

Liquid and Gas Consumption Location	Liquid Helium Watts	Liquid Helium l/hour	Liquid Nitrogen liter/hr	Liquid Argon lpm	Liquid Argon K liter	Chamber Gas liters/hr
Forward Calorimeter						
HV Dissipation						
Level 1 Trigger						
High Voltage						
Tracking						
Calorimeter						
Muon Chambers						
Muon Trigger						
Monitoring						
Liquid Handling						
Lights						
Outlet Power						
*Welding						
*Crane						
Air Handling						
Sump Pumps						
Safety						
Total Outside Muon Steel						
Utility Shaft						
Toroid Power Bus						
Solenoid Power Bus						
Total Utility Shaft						
Surface						
DAQ						
Trigger Level 2						
Trigger Level 3						
Control Room						
Monitoring						

*= Not included in totals. PF = Power Factor. Div. = Diversity Factor. Eff = 1/(Power Supply Efficiency). Frac = Fraction of Cooling.

Table 7.2-3. SDC Utilities Option 2 - Liquid and Gas Consumption (cont)

Liquid and Gas Consumption Location	Liquid Helium Watts	Liquid Helium l/hour	Liquid Nitrogen liter/hr	Liquid Argon lpm	Liquid Argon K liter	Chamber Gas liters/hr
Computer System						
Cryogenic System						
Helium Comp.						
Solenoid Coil PS						
Control/Cold Box						
Compressed Air						
Auxiliary						
Muon Toroid PS						
400 Hz MG Set						
Crane						
HVAC System						
CHW Prod/Circ						
Air Circ Fan						
Util Water Pumps						
Power Transformer						
60 Hz Detector						
60 Hz Other						
Safety						
Noninterruptable Pwr						
Total Surface						
Total						

*= Not included in totals. PF = Power Factor. Div. = Diversity Factor. Eff = 1/(Power Supply Efficiency). Frac = Fraction of Cooling.

Table 7.2-4. SDC Utilities Option 2 - Secondary Cooling Needs

Cooling Needs Secondary Cooling	Primary Cooling Load BTU/hr	Primary Cooling Flow Rate gpm,cfm	Pump or Blower Δp(psi, in H_2O)	Pump or Blower KWatt	Compressor KWatt	Auxiliary Pumps/Fans KWatt	Secondary Cooling Pond/Tower Btu/hr
ICW							
100 to 125° F	4,640,320	362	43	11			4,679,085
LCW							
65 to 75° F	8,279,150	1,614	250	295			
100 to 130° F	7,830,740	509	53	20			7,897,933
CHW (Primary)							
45 to 60° F	4,469,038	581	35	15	250		5,371,052
A/C							
55 to 75° F	1,089,383	51,473	4	37			
75 to 80° F Insd Stl	89,258	16,870	4	12			
Surface Blg	810,350	38,289	4	27			
CHW (Secondary)							
For A/C ΔT = 15° F	1,988,991	259	35	7	124		2,435,685
For LCW @ 65° F ΔT = 15° F	8,279,150	1,076	35	27	517		10,138,506

Power for CHW Production and Circulation = 940 KW
Hall HVAC Air Handling = 37 KW
Surface Bldg. & Hall Ventilation Fans = 39 KW
Line Power = 13,996 KVA

Total Ambient Heat Rejec 30,552,261

8.0 SAFETY

8.1 Fire Safety

The SDC detector environment will be similar to those at other colliding beam facilities in that it will be housed in an underground concrete enclosure and serviced of high capacity heat, ventilation, and air conditioning (HVAC) equipment. The principal combustibles are the cable plant and plastic scintillator. Other combustibles, flammable gas for chambers or liquids for evaporative cooling, may be present, but in significantly smaller quantities. Such an experimental facility is best classified as a special purpose industrial occupancy in terms of codes. In various fire protection orders and cited codes, DOE has placed emphasis on life safety, program continuity, minimization of loss, and more recently, on releases to the environment.

The following outlines a set of measures which, when taken as a whole, provide fire protection for the occupants, the structure, and the detector. Individual measures as mandated by DOE in First Priority Compliance Orders are not listed here (e.g., emergency lighting, fire-rated containment around accessory equipment, cable tray penetration seals); rather, the overall detection, suppression, smoke ejection, and loss mitigation techniques are described. The goal is to minimize the loss of experiment time through the use of commercially available systems.

A. Detection

It is well established that fires can be reliably detected in the incipient stage, well before the appearance of flames. For example, the CDF Parts-per-Million smoke detection system uses an evolved gas signature for unique gases liberated from overheated cables (and similar plastics) at temperatures 150^{o} to 250^{o} C below their ignition point. Sample draw aspiration systems such as VESDA have also demonstrated incipient detection capability. The principal difference between these two systems is one of coverage. The PPM system provides spot detection coverage for pinpointing the location of an alarm, while the VESDA system provides area of zone coverage only . Both have three-tiered alarm capability.

For SDC, both types of detection are planned. Aspiration units will be used to provide wide area coverage over the entire experimental hall, and to sample the various trapped volumes created by the detector layers. Spot detectors will be used near significant accumulations of potential fuels or ignition sources, principally cables, plastic scintillator, and electronics. Most probably, the signature gases will be CO and $(CH)_x$ as it is assumed that halogenated plastics will be banned due to the copious production of dense, corrosive smoke in a fire situation. Multi-tiered alarm systems are also planned to allow for mitigating actions in the case of minor off-normal incidents like an overheated electronics circuit or a fluorescent light ballast problem.

B. Suppression

It is extremely unfortunate that halon extinguishment has been phased out. This "magic bullet" is the ideal agent for the SDC detector type of hazard. No alternate, or combination of alternates, provides the same degree of life safety and loss minimization. On the other hand, it is the case that the very early warning detection system proposed above will provide a significant time window for manual intervention. Fire doubling times for configurations like the SDC detector are in the range of 4 to 5 minutes.

The experimental hall will be fitted with an Ordinary Hazard Group 3 hydraulically designed automatic sprinkler system with as reliable a dual-feed supply as the local area allows. Large droplet sprinkler heads will be utilized because of the high ceiling. Hand hose line standpipes will be installed according to the applicable code as will portable extinguishers. As the design of the detector becomes mature, we plan to review each major system from a fire protection point of view. The issues of material selection, trapped volumes, and possible local application suppression systems would make the most effective use of the early warning detection. The ability to control the amount of agent released and to select the locations served can mitigate the undesirable side effects of certain agents.

C. Smoke Ejection

Smoke removal is considered one of the most significant loss minimization measures. The SDC fire risk situation is comparable to that present in most high-tech facilities where a low probability fire event can result in very high non-thermal damage consequences. Passive smoke removal through roof hatches may not be adequate for the size and height of the experimental hall. For the SDC detector, the high capacity HVAC systems required for climate control and/or oxygen deficiency purge are capable of being designed to provide effective smoke ejection as well. The design requirement is to provide an operating mode in which outside air is injected into the deepest levels, and smoke is exhausted from the top level. The intake and the exhaust must be well separated at the surface. This same mode would also be used to pressurize the stairwells to maintain a smoke-free condition, and to create low smoke zones at the lowest levels to facilitate escape to the stairwells. Automatic backup power from local generator(s) will be applied to those parts of the HVAC system that affect life safety and loss control. Smoke ejection is a release to the environment, and the materials selection part of the fire reviews mentioned above must include this consideration.

D. Mitigating Actions

Since a sustained electrical fault or failure of electronic equipment constitute the most probable sources for ignition, it is planned to provide for both manual and automatic electrical shutdown of all power to the detector. This shutdown will be a manual intervention option (crash button) until alarm conditions reach a level of severity mandating automatic shutdown. Care will be taken to identify those systems that need to be exempt from the shutdown such as lighting, CCTV, ventilation, etc.

Should flammable gasses or liquids be used in detector subsystems, similar manual/automatic shutdowns will be used. In addition, the shutdowns will provide for isolation from supply tanks and reservoirs.

With detection and notification being provided at an early stage by the incipient fire detection system, manual intervention well before sprinkler release becomes a very probable circumstance. To ensure such intervention is as effective as possible, a CCTV surveillance system is planned with remote control of pan, tilt, and zoom. The pre-entry information provided a CCTV system can greatly improve the speed and accuracy of manual intervention fire-fighting or rescue efforts.

8.2 Solenoid Coil Safety

There are significant safety concerns associated with large superconducting magnets such as the solenoid used to provide the magnet field for the SDC tracking system. Possible hazards include:

1. High magnetic fields and large electromagnetic forces
2. Cryogenic fluids
3. Pressure vessels and high pressure piping
4. Large vacuum vessels
5. High voltage, high current electrical systems
6. Confined spaces
7. Oxygen deficiency hazards

In practice, personnel are protected from these hazards by a layered safety process. First and foremost, good engineering design practices combined with adherence to the spirit of the relevant pressure vessel and cryogenic fluid standards are important (e.g., ASME, CGA, etc.). To the extent possible, all designs are required to be passively "fail safe" such that for all possible operating conditions and failure modes, personnel safety is protected and possible equipment damage prevented or minimized with no action on the part of operation personnel or active protection devices. In many cases an active system of interlocks and alarms will be required (e.g., magnet quench protection, or ODH). The systems are also designed to be fail safe and often consist of redundant systems to ensure correct operation even in the event of "single point" failures. The next layer of safety protection is careful " in depth" safety reviews of the design and its execution in hardware by independent expert review committees, combined with a careful test program of all vessels and piping as per the above safety standards. Written operating and emergency procedures, combined with systematic operator training programs, provide the basis for operations personnel to recognize and correct hazardous conditions. Finally, the experimenters and all other people working around the detector are made familiar via training programs with the potential hazards and relevant safety systems, procedures and alarms so they respond correctly in an emergency.

8.3 Liquid Argon Safety

Work on the design of the liquid argon cryogenic system is underway. The general design philosophy addresses major safety concerns associated with a leak within the hall due to either the liquid argon cryostat or to one of the transfer lines. The major hazards resulting from these kind of accidents are asphyxiation, cryogenic burns, reduced visibility, and damage to structural members due to low temperature exposure.

The design places LAr dewars with holding capacity equal to 180,000 liters in a separate alcove in the hall. In addition, the hall includes a large insulated sump connected to the surface by a large vent line and blowers. These design features eliminate the possibilities of exposing the cryostats to large pressure head during cryostat filling and emergency dump.

In order to reduce the possibilities of large spills due to damage to transfer lines, pressure sensors are placed in the vacuum jacket of all the transfer lines and isolation valves are located at intervals of about 1000 liters of holding volumes. In case of vacuum loss, relief valves are opened to the vent line and the isolation valves are shut off. This limits the leak to a maximum of 1000 liters.

To address loss of the main vacuum on the argon calorimeter, we consider three possible accident scenarios with various degrees of importance:

1. A small leak which raises the vacuum to 100 microns:

   This type of leak could be a result of argon leaking from cracked bellows and may cause up to 20 kw of heat leak. Argon pressure can be kept at a safe level by increasing the LN_2 flow to cooling loops while LAr is slowly transferred from cryostat to the local holding dewars. This procedure presents no safety problems other than possible damage to the electronics due to water condensate.

2. Complete vacuum loss along with a small LAr leak into the vacuum space:

   The heat leak due to total vacuum loss could be as much as 500 kw. In order to avoid losing all the liquid argon to the surface through evaporation, the increase in pressure due to the temperature rise in the cryostat (from 90 K to 100 K) would be used to transfer liquid argon through the bottom fill line of the cryostat over the the storage dewars. When the pressure in the cryostat exceeds the relief valve setting, only a few thousand liters of argon would be vented to the surface and no liquid argon will be lost to the room . The only major safety concern with this type of leak is the harm that comes from freezing and soaking the electronics with condensed water.

3. Large liquid argon spill into the vacuum space:

   When the vacuum space if filled with LAr, the heat leak rate will go from several megawatts initially to about 500 kw after the vessel's wall temperature is cooled down. In order to avoid damage to the vacuum vessel, a 15-inch vent line will vent argon gas to the surface via suction fans. Pressure due to the liquid head within the vacuum space is reduced by minimizing accumulation of the liquid in the bottom of the annular space. This is done by installing a liquid dump system in the lower portion of the vacuum tank. The LAr in the annular spaces is transferred to the sump where it will initially boil vigorously, sending argon gas to the surface. After the sump is cooled down, the remaining LAr will boil very slowly.

8.4 Tracking Systems Safety

The primary hazards presented by the tracking systems are related to extremely high power per unit volume and flammable gases inside the confined volume defined by the solenoid coil cryostat.

The hazards to high power density can be mitigated by reducing the total power that can be supplied to any one detector element by segmentation and proper fusing of the power leads. The problem is most severe for the silicon tracker, where the total current into the detector is estimated to be 2,000 amps at about 5 volts. The high current hazards are substantially reduced if individual power leads are limited and fused at a significantly lower value, of order 20 amps per conductor. In the event that a current lead is shorted to the detector or its enclosures, the current should be sufficiently limited that it cannot cause a failure of the mechanical supports or the enclosing vessel through resistive heating. This may effect the materials choice for the enclosure or supports since highly resistive materials can reduce this hazard. The current leads can also be monitored to insure that they are carrying the correct current.

The second major problem with the tracking systems is flammable liquids and gases. We assume for the moment that the preferred cooling fluid for the silicon tracker is a hydrocarbon (e.g., butane) and the gas used in the wire tracking system is flammable.

After final installation, static pressure tests using inert gas and written operating procedures will be required prior to the introduction of the normal operating gas. Relief bubblers will prevent excess pressure to any detector system. We anticipate that the entire cylindrical tracking volume defined by the inner surface of the solenoid coil and the endcap calorimeters will be inerted with nitrogen gas during normal operations. This inerted volume will be monitored for oxygen as well as the flammable gases used in the active detectors. Gas sampling systems will monitor the oxygen or flammable gas levels and will sound alarms should the levels of these gases become too high within the inerted volume. Outside the inerting volume a second redundant set of gas sampling tubes will monitor leaks of the operating gases into the air. Low level sonic and visual alarms will alert operators that unusual condition exists. High level alarms will initiate automatic shutdowns of the low voltage power, high voltage power and flammable gas/liquid supplies to the entire detector.

Special procedures will be required to access the tracking for maintenance when it is filled with operating gas. These procedures will address shutdown, ODH hazards, flammable gas/liquid hazards, and startup after a failure.

9.0 TEST BEAMS

The plans for test beam work for the SDC can be summarized thusly:

1. R & D that has already begun, which will for the most part be finished by the end of 1933.
2. Prototype development that will mostly occur in the period 1991 to 1995.
3. System tests that will begin once prototypes are verified, and thus be done mostly during the period 1993 to 1997.
4. Calibration that will start as soon as production versions of the detector components are available and will continue beyond the initial runs of the SDC detector from 1995 to 2000.

The allocation of beam time in these categories is shown in Table 9.1-1. We have made a proposal to Fermilab for a test beam (SDC-90-00116) to meet these needs. We anticipate the need for a test beam facility devoted to SDC at the SSCL. The exact requirements would depend on the type of calorimeter chosen for the SDC and the time when such a test beam would become available at the SSCL.

Table 9.1-1. SDC Test Beam Requirements

	R & D	Prototyping	System	Calibration
Calorimetry	2000	2000	2000	2000
Tracking	200	500	500	0
Muon	Parasitic	500	500	0

10.0 COSTS

Projected costs for the SDC Detector are summarized in Table 10.0-1. The column labeled "base" refers to the cost of materials and labor to assemble components and subsystems. To this must be added the cost for engineering design, inspection and quality assurance (EDIA). The column labeled "cont" is our estimate of the contingency for each subsystem. Since we have been requested to essentially design to a fixed overall cost, the contingency factors reflect both our estimate of the uncertainty in actual cost and the uncertainty in scope we believe is allowable for each subsystem. Although we expect very substantial in-kind contributions from collaborators outside the United States, our estimate has not taken into account differences in accounting practices or labor rates in other countries.

Whenever possible we have used vendor quotes for major procurements (lead, silicon, electronics chips, etc.). If this was not possible, we have used costs from existing detectors (CDF, D0, etc.) to extrapolate to our design. Estimates of EDIA were generally made at the subassembly level, one to two levels below the summary shown in Table 10.0-1. All labor estimates were made in man-days and costs were computed using labor rates supplied by the SSC Laboratory. The estimated costs for Installation and Test (8.1) and Project Management (9) do not include contributions anticipated from the Experimental Facilities Support and Operations Groups at the SSC Laboratory.

In-kind contributions from collaborators outside the United States will represent a major fraction of the overall detector cost. The SDC is not now in a position to delineate precisely these contributions. Discussions are now underway within the collaboration, and we expect these to lead to agreements regarding in-kind contributions at the time of submitting a proposal or shortly thereafter. We expect in-kind contributions from non-US sources to be about forty percent of the equivalent total detector cost.

Off-line computing costs are not included in the total given in Table 10.0-1. By the time of the proposal we will have a detailed computing and networking plan, taking into account existing or potential resources within the collaboration. Substantial support will be needed from the SSCL. We request that about one-half of the computing resources available at the SSCL for physics research be devoted to the SDC.

We recognize that the cost estimate ($509M) presented here is preliminary. Much more work must be done over the next year or so to prepare a detailed proposal and a related cost estimate. Nevertheless we firmly believe that our preliminary estimate is the best that can be obtained today, and we are prepared to design a detector to meet this construction cost goal, assuming a completion date in late 1999.

Table 10-0-1. Costs
(in millions of dollars)

	Base	EDIA	% EDIA	Base + EDIA	Cont	% Cont	Subtotal
1. Tracking Systems							**94.8**
1.1 Silicon Tracking System	24.9	8.1	25%	33	6.6	20%	39.6
1.2 Central Tracker	26.3	9.3	26%	35.6	8.3	23%	43.9
1.3 Intermediate Tracker	6.7	2	23%	8.7	2.6	30%	11.3
2. Calorimetry							**138.6**
2.1 Central Calorimeter	55.3	9.1	14%	64.4	15.8	25%	80.2
2.2 Intermediate Calorimeter	25.5	4.8	16%	30.3	7.5	25%	37.8
2.3 Forward Calorimeter	14	2.5	15%	16.5	4.1	25%	20.6
3. Muon System							**103.2**
3.1 Iron Toroids	41.7	1.5	3%	43.2	6.5	15%	49.7
3.2 Muon Chambers	28.6	2.6	8%	31.2	7.8	25%	39
3.3 Muon Trigger Counters	11.8	0.8	6%	12.6	1.9	15%	14.5
4. Superconducting Magnets							**29.8**
4.1 SC Solenoid	22.7	2.1	8%	24.8	5	20%	29.8
5. Data Acquisition and Trigger							**69.3**
5.1 Data Acquisition Systems	12.5	4.2	25%	16.7	4.2	25%	20.9
5.2 Trigger Systems	18.9	19.8	51%	38.7	9.7	25%	48.4
6. Computing							**11.9**
6.1 On-Line Computing	4.4	5.5	56%	9.9	2	20%	11.9
7. Conventional Systems							**20.6**
7.1 Utilities	1.1	0.5	31%	1.6	0.3	19%	1.9
7.2 Controls	2.3	2.1	48%	4.4	1.3	30%	5.7
7.3 Safety Systems	1.9	2	51%	3.9	1.2	31%	5.1
7.4 Cryogenic Systems	3	0.8	21%	3.8	1	26%	4.8
7.5 Structural Support Systems	1.1	1.4	56%	2.5	0.6	24%	3.1
8. Installation and Test							**28.1**
8.1 Test Beam Program	6	1.5	20%	7.5	1.5	20%	9
8.2 Subsystem Install and Test	10	5.3	35%	15.3	3.8	25%	19.1
9. Project Management							**13.2**
9.1 Project Planning	0.4	0.9	69%	1.3	0.2	15%	1.5
9.2 Project Tracking	0.4	1	71%	1.4	0.2	14%	1.6
9.3 Document Dist. and Control	0.7	0.5	42%	1.2	0.2	17%	1.4
9.4 Subsystems Integration	1.8	5.8	76%	7.6	1.1	14%	8.7
Totals	**322.0**	**94.1**	**23%**	**416.1**	**93.4**	**22%**	**509.5**

11.0 SCHEDULES

This section, when complete, will contain projected schedules for both the Option 1 and Option 2 Detectors.

12.0 ALTERNATE SYSTEMS

12.1 Pre-Radiator

One system not yet included in the reference designs is a pre-radiator to aid in the detection of electrons. It would be located directly in front of the electromagnetic calorimeters. Table 12.1-1 and Figures 12.1-1 to 12.1-4 describe this detector. Because the detector has not been costed, it does not appear in the estimates of channel counts or detector costs.

Table 12.1-1. Pre-Radiator

Fiber Diameter	1.5	mm
Fiber Separations	2.25	mm
Number of Fibers		
Barrel	140000	
Endcaps (Both Ends)	40000	
Number of Channels		
Radial Thickness	approx. 100	mm
Weight of Lead (Barrel)	5.9	T
Weight of Detector (Barrel)	2.3	T
Weight of Endcaps (incl. Lead)	3.4	T

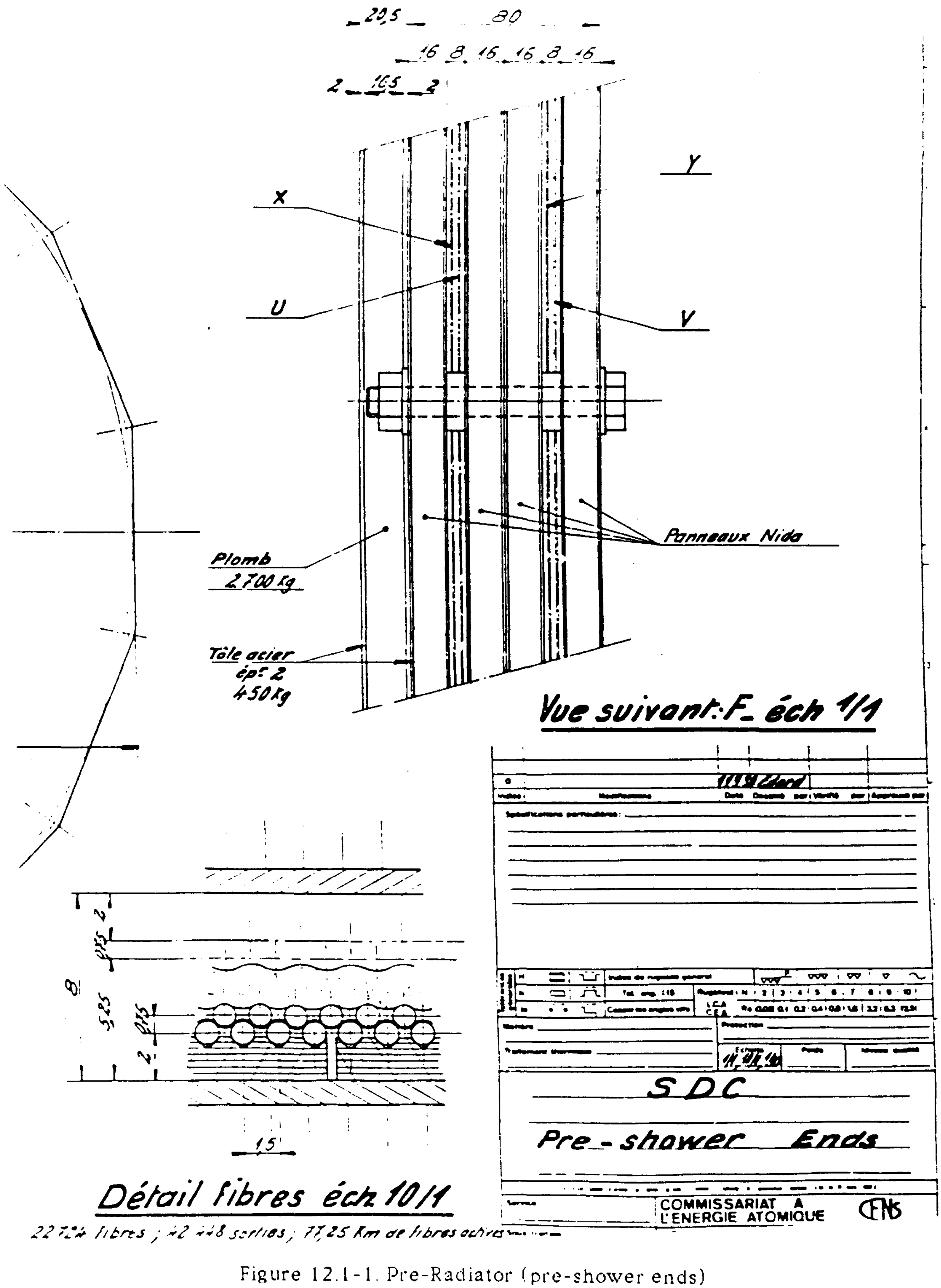


Figure 12.1-1. Pre-Radiator (pre-shower ends)

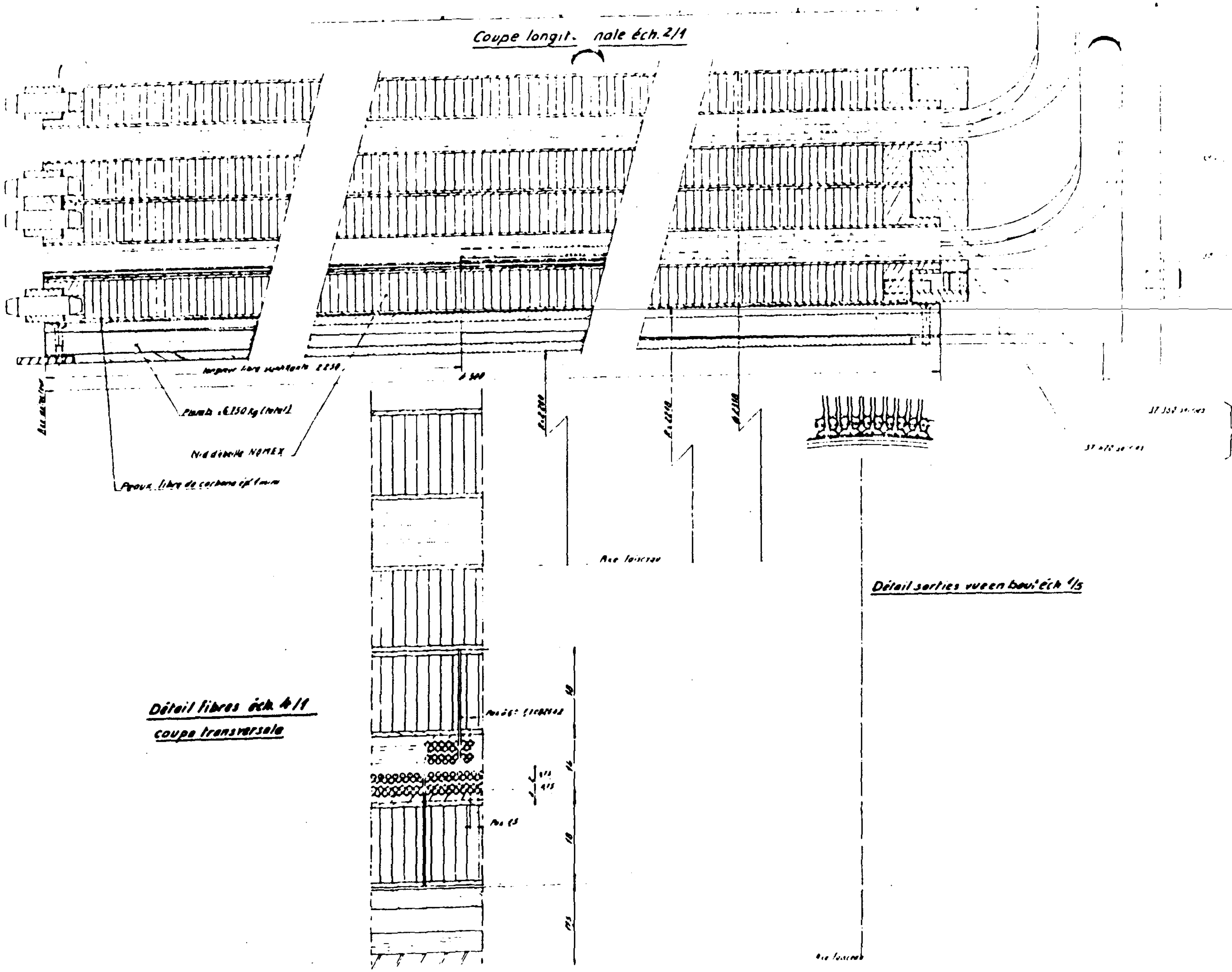


Figure 12.1-2 Pre-Radiator

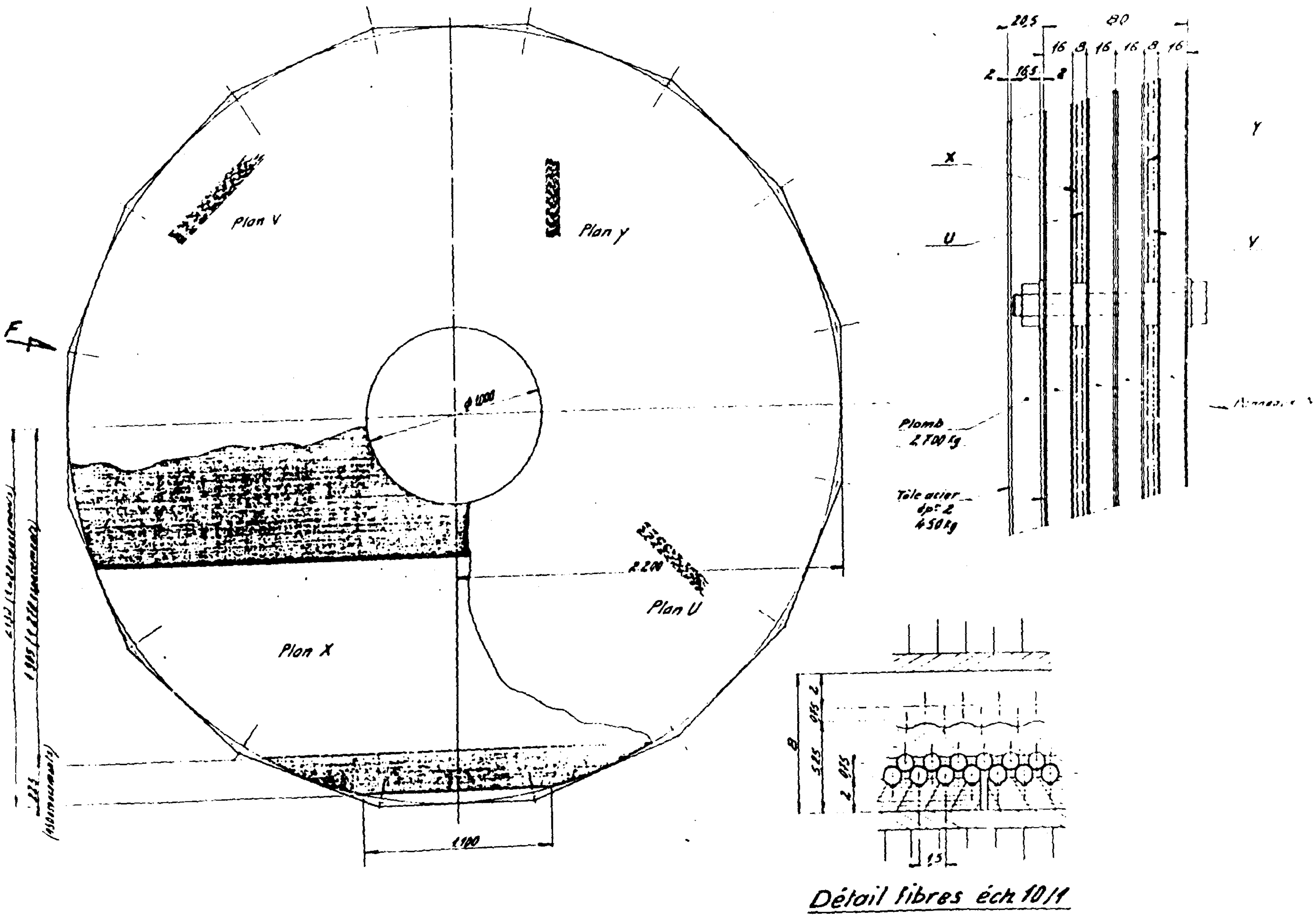


Figure 12.1-3 Pre-radiator

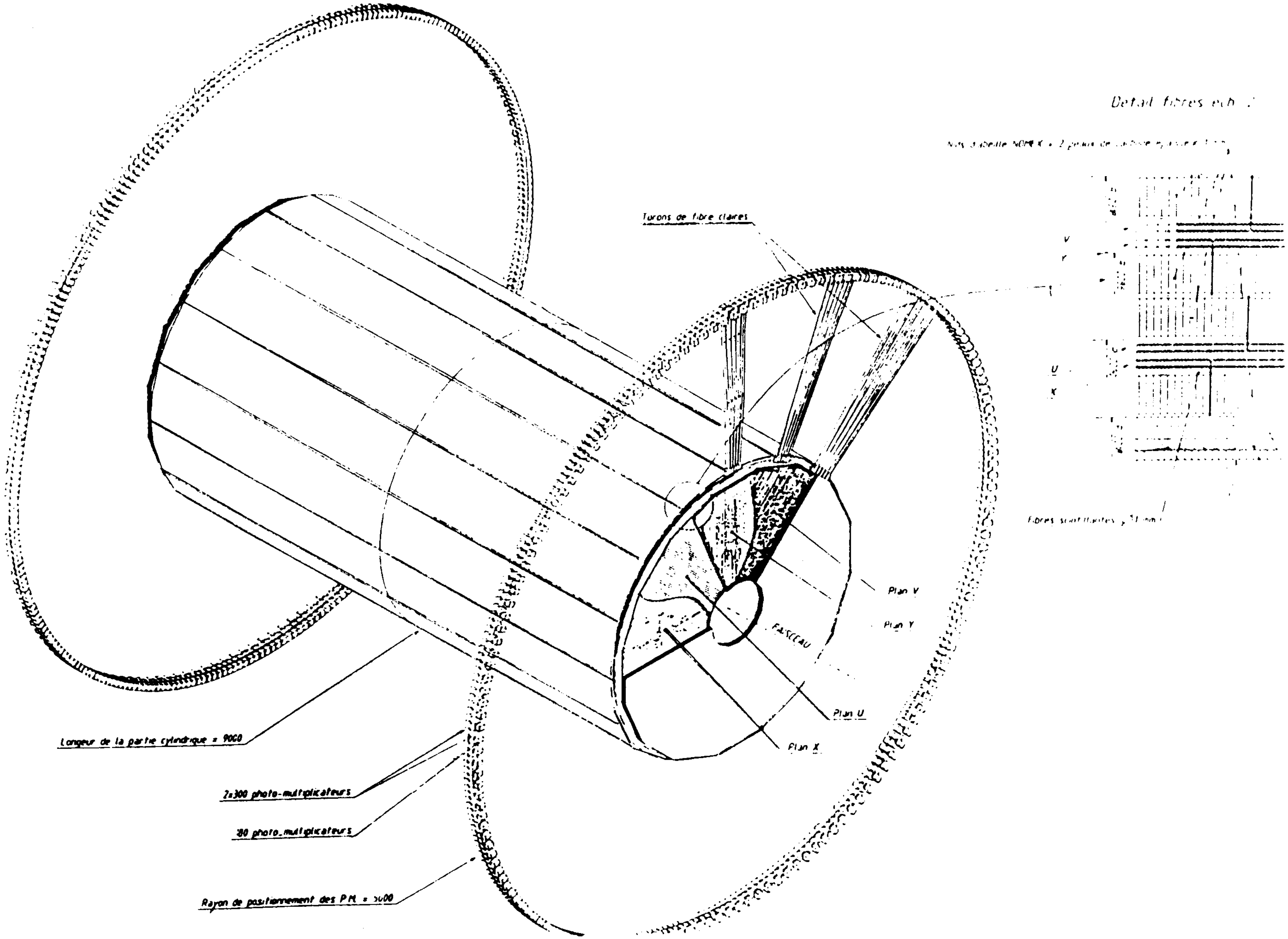


Figure 12.1-4. Pre-radiator

170

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SDC-90-00150	SDC Hadronic Mass Resolutions in Z and Z' Decays (in preparation) R.E. Blair, L.E. Price, H.J. Trost