R. Kephart

SDC Solenoid Design Review
May 5, 1992

AGENDA

9:00 - 9:30	Introduction, Physics Goals, General Requirements (R. Kephart)
9:30 - 10:30	Solenoid Design (A. Yamamoto)
10:30 - 11:00	Break
11:00 - 11:30	Solenoid Design (A. Yamamoto)
11:30 - 12:00	Cryogenic system, Helium refrigerator, transfer lines, effect of VLPC (A Stefanik)
12:00 - 1:30	Lunch
1: 30 - 3:00	Prototype coil R&D
	Conductor, coil winding, cold mass support R&D (A Yamamoto)
	Outer Vacuum Shell R&D (R. Kephart)
3:00 - 4:00	Cost and Schedule (R. Stanek)
4:00 - ?	Questions / Comments / adjourn (Panel)

Introduction:

The work presented today is the result of the efforts of the SDC Super conducting Magnet Working Group. This a US - Japanese collaborative effort.

SDC Magnet Working Group

Co-leaders: A. Yamamoto (KEK) / R. Kephart (FNAL)

Contributors:

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Akira Yamamoto	KEK
Hiroshi Yamaoka	KEK

Charles Collins	SSCL
Jim Krebs	SSCL (FNAL)
Bob Richardson	SSCL

Industrial Participants:

Paul Slysh Assoc.	USA
Toshiba	Japan
Sumitomo Light metal	Japan
IHI	Japan
Furakawa Electric	Japan

Physics Goals:

The physics goals of the SDC collaboration require the study the properties of Proton-Proton collisions at the unprecedented center of mass energy of $\sqrt{s}$ = 40 TeV / c and at very high luminosity 10^{33} - 10^{34} cm^{-2} s^{-1}.

The SDC collaboration has proposed a general purpose detector designed to explore the Physics of this new energy and luminosity frontier. (Many difficult technical problems to be overcome !)

The detector proposed is optimized to measure quarks and gluons (jets), leptons, photons, and individual hadrons over the largest possible solid angle.

A major feature of this proposed detector is a large superconducting solenoid magnet that provides the magnetic field to momentum analyze charged particles emerging from the collisions.

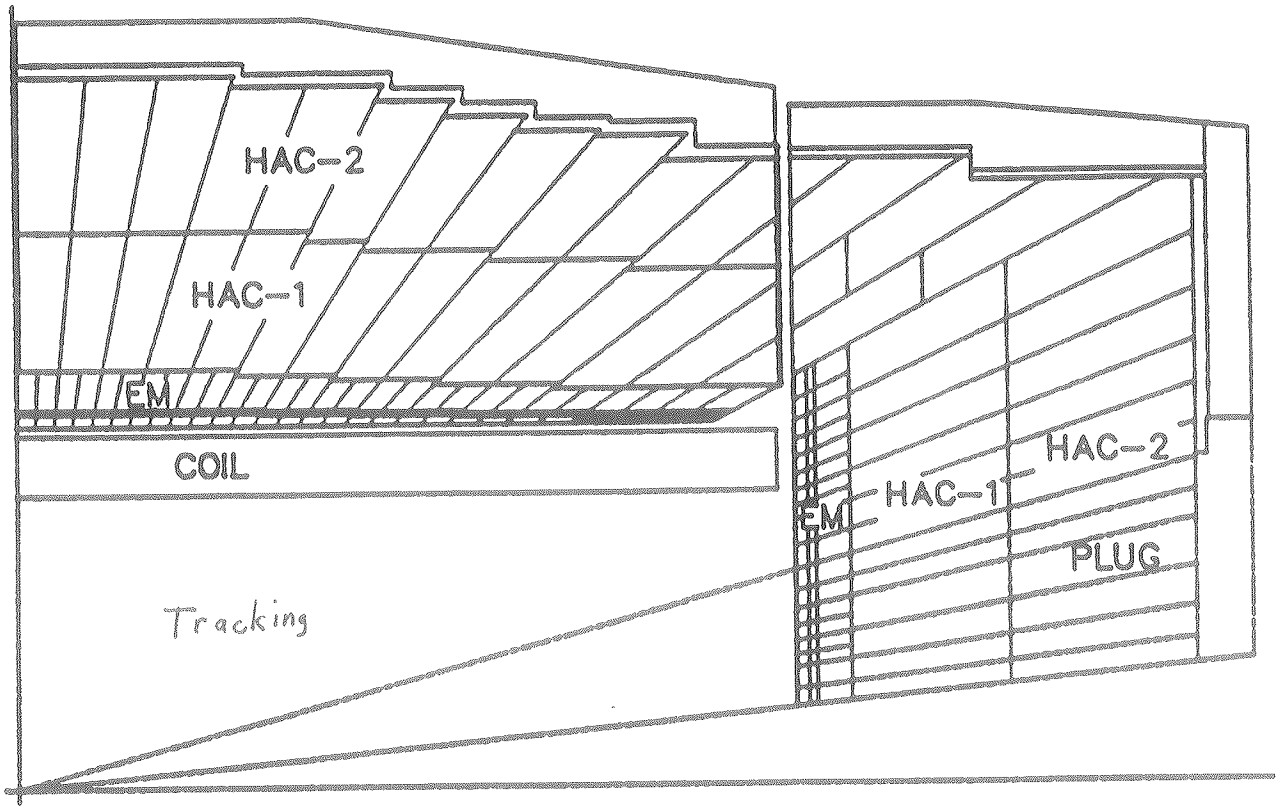
Design considerations:

- The overall geometry of SDC was chosen after extensive Monte Carlo evaluations of the Physics Performance of various detector configurations.

- The SDC central detector design consists of a large scintillating tile calorimeter enclosing the superconducting solenoid. A large central tracking system is immersed in the axial magnetic field provided by the solenoid

- The radiator plates of the hadronic calorimetry are made of iron and provide the solenoids's magnetic flux return.

- Large muon toroids surround the central detector and serve to identify muons and remeasure their momenta.



Longitudinal quarter section of the central calorimeter.

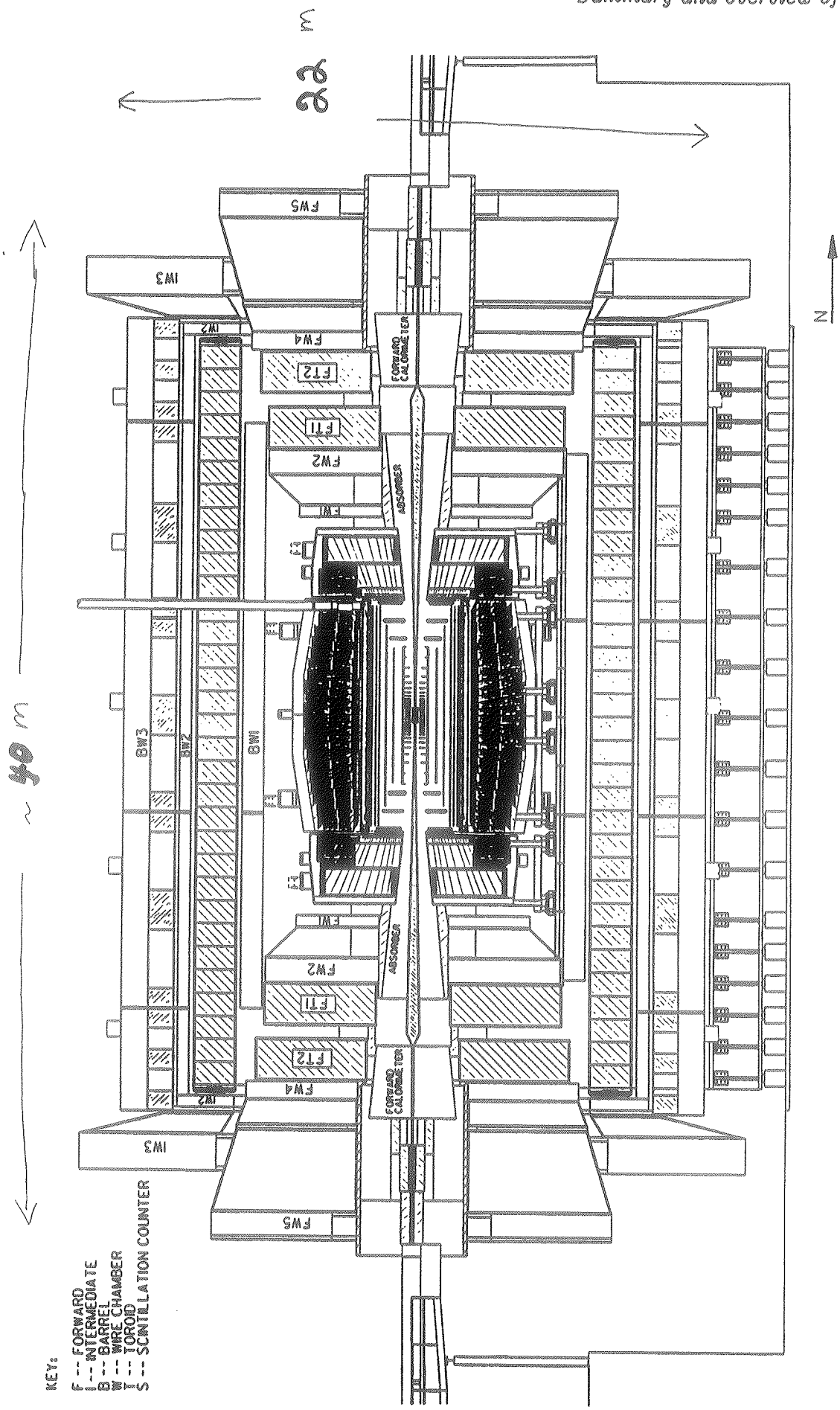


FIG. 2-2. Elevation view of the preliminary baseline detector configuration.

- The SDC coil diameter and central field were specified based upon the required momentum resolution of the SDC central tracking system.

$$\Delta P_T / P_T^2 = 0.15 \quad (\text{ where } P_T \text{ is in TeV / c})$$

- Radiation damage to the central calorimetry and channel occupancy of the central tracking system at high luminosity were also important considerations. Both argue for a large diameter high field coil.

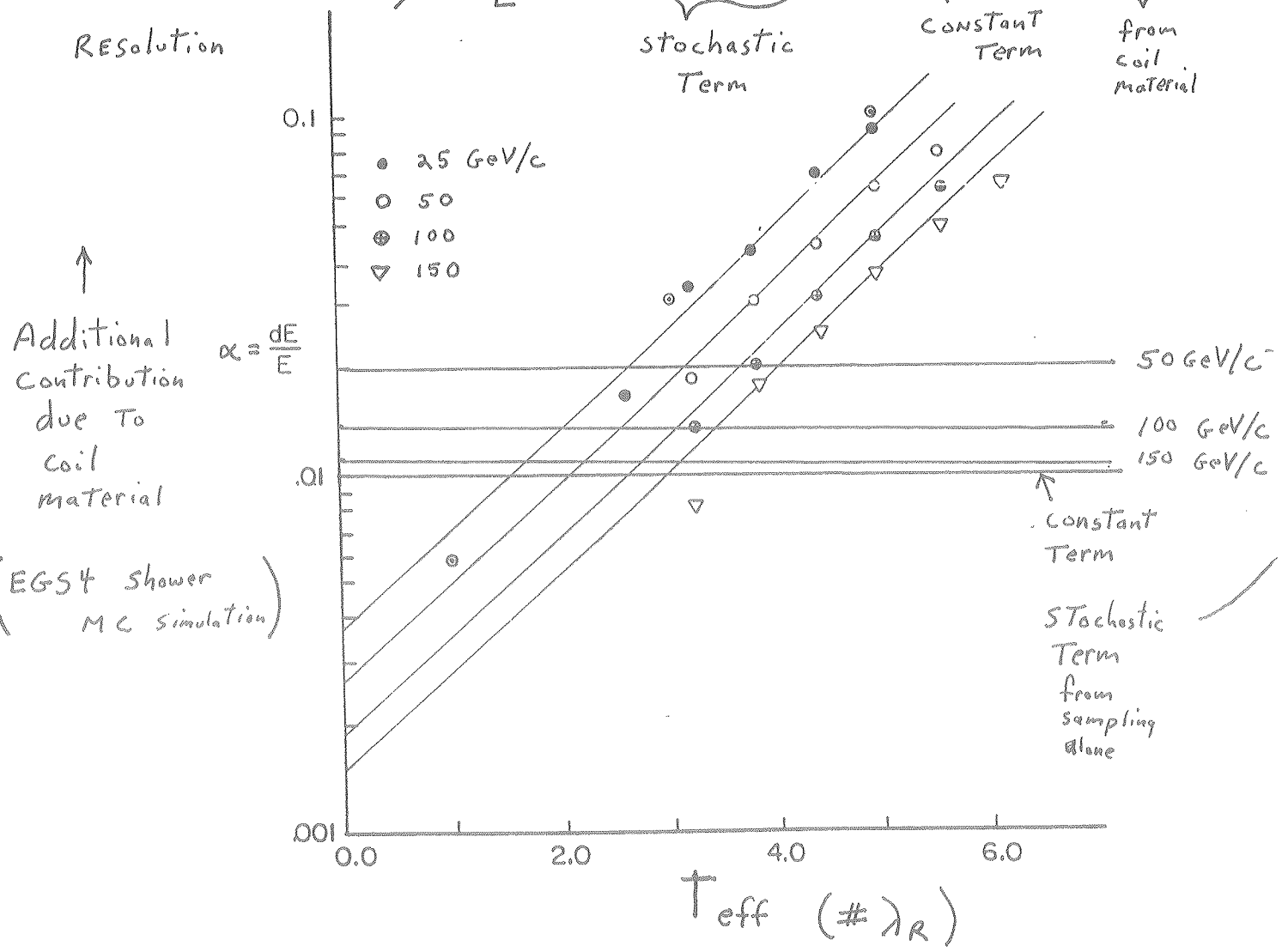
- Since all particles entering the central electromagnetic calorimetry must first pass through the solenoid, the magnet is required to be thin in terms of radiation lengths (λ_R) and interaction lengths (λ_I).

- The desired SDC Electromagnetic calorimeter performance $\sigma(E) / E < 0.14 / \sqrt{E_t} \oplus .01$ requires that the effective thickness of the coil be less than about 3 - 4 λ_R. (fig)

Effect of Coil Material on EM Calorimetry

RESOLUTION

SDC "Nominal" Resolution $\Rightarrow$ $\dfrac{\sigma(E)}{E} = \underbrace{0.14/\sqrt{E}}_{\text{stochastic Term}} \oplus \underbrace{.01}_{\text{Constant Term}} \oplus \underbrace{\alpha(E)}_{\text{from coil material}}$



Conclude: for $t_{eff} \gtrsim 3\lambda_R$ the addition term due to coil material dominates the EM calorimeter resolution.

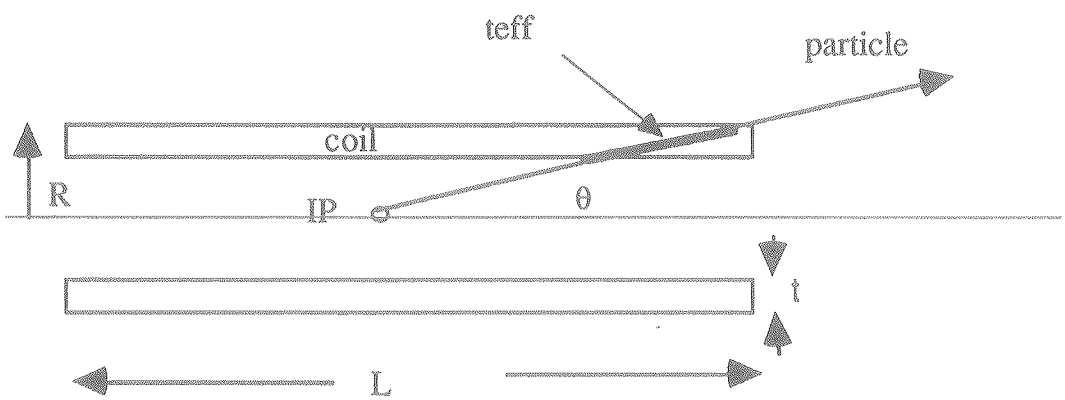
Design considerations (cont.) :

• For maximum pseudo-rapidity coverage (η)

$\eta = -\ln(\tan(\theta / 2)$ of the tracking system it is desirable to have the magnet be as long as possible. However, the effective thickness of the magnet near its ends grows rapidly as the magnet becomes longer.

$t_{eff} = t/\sin(\theta)$ where $\theta = \tan^{-1}(2R / L)$

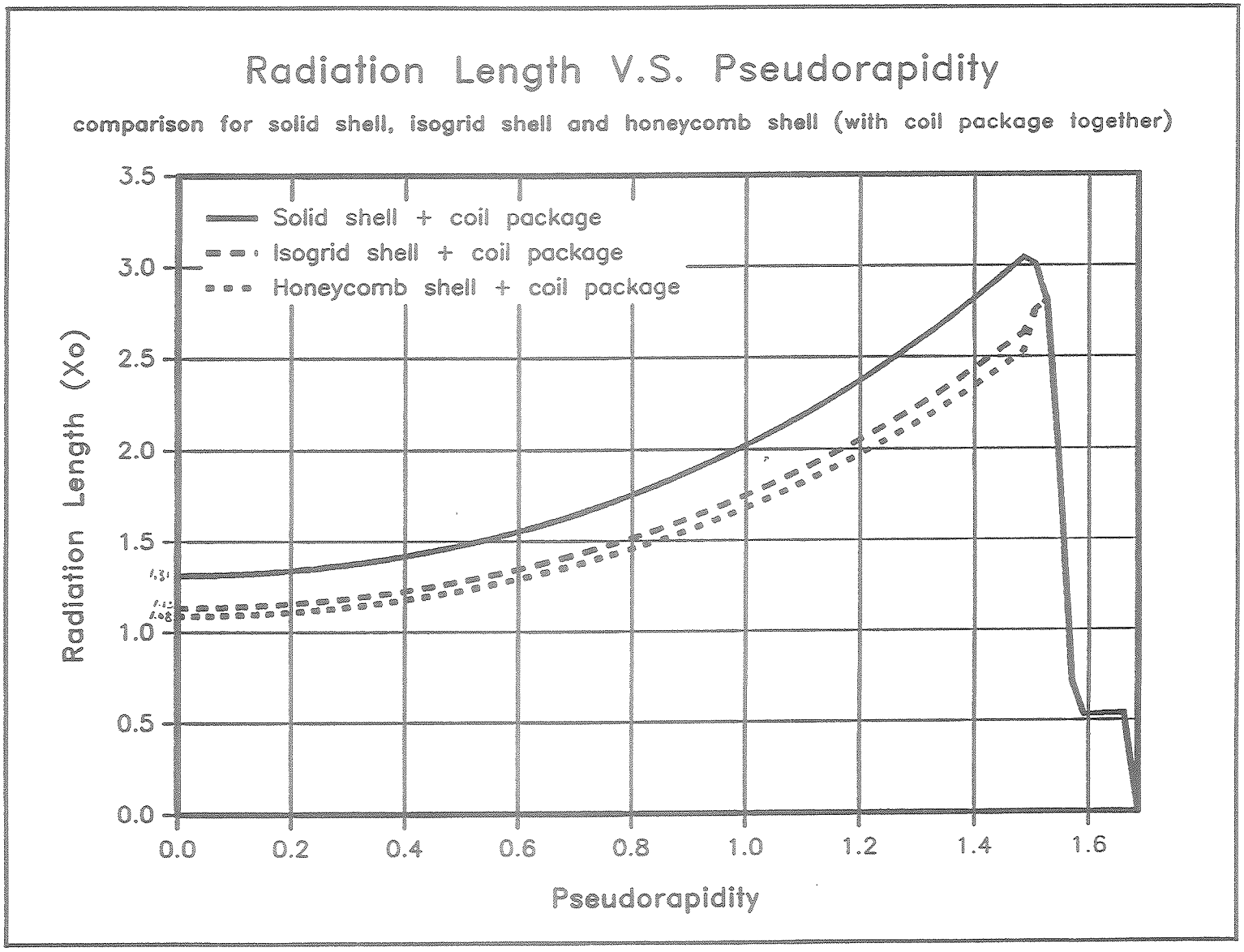
and R = coil radius
L = coil length
t = coil thickness at $\theta = 90°$



this effect limits the maximum practical length of the coil.

• Finally, overall detector COST issues argue for minimizing the coil Radius and Length.

The magnet design presented today was a result of an overall optimization that attempted to balance all these considerations to achieve the best overall Physics performance within the SDC overall budget constraints.


Radiation Length V.S. Pseudorapidity
comparison for solid shell, isogrid shell and honeycomb shell (with coil package together)
Solid shell + coil package
Isogrid shell + coil package
Honeycomb shell + coil package
Radiation Length (Xo)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
Pseudorapidity

SDC Superconducting Solenoid

General Requirements:

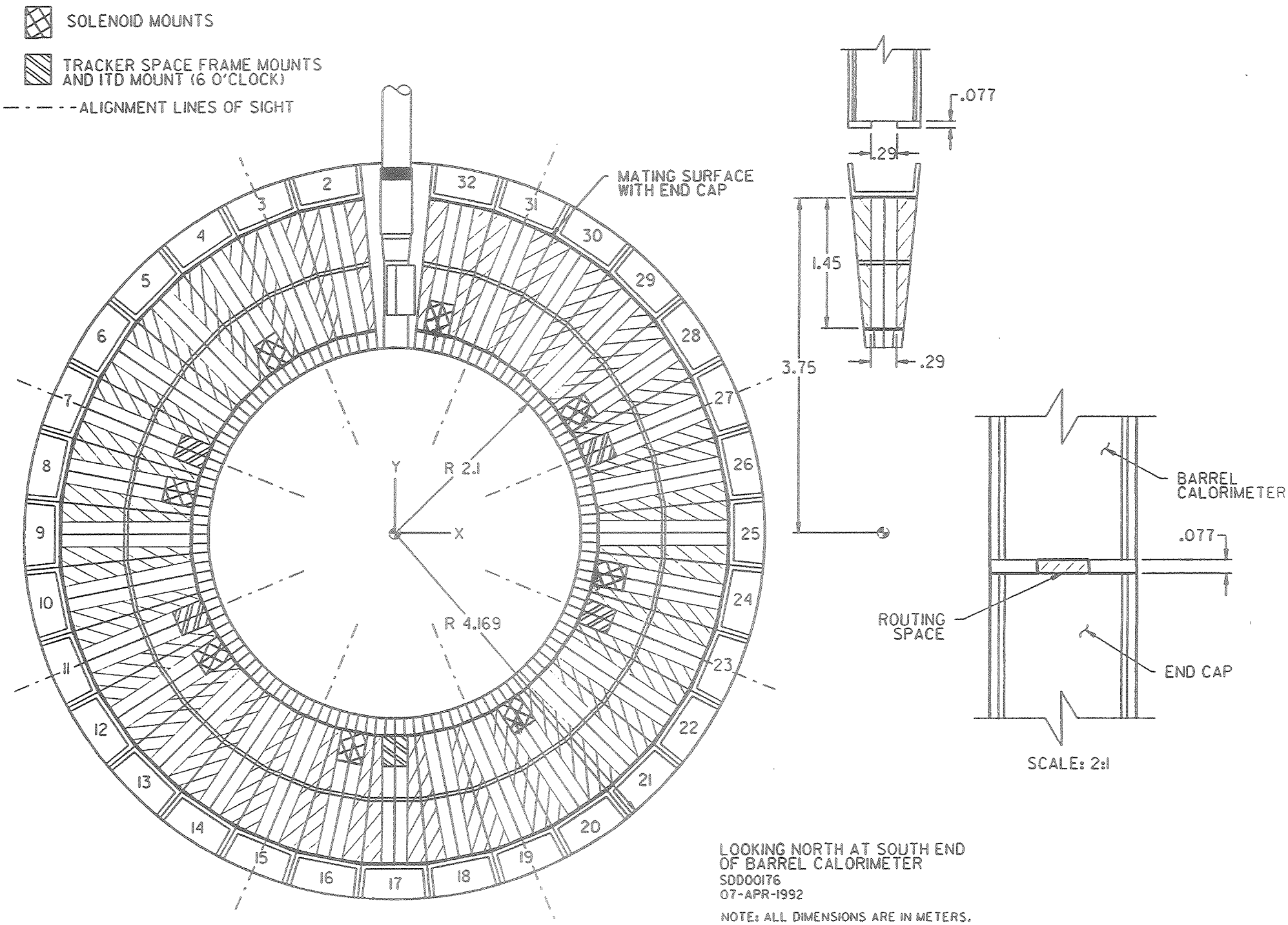
Diameter:	ID	3.4 Meters (useful bore)
	OD	4.1 Meters
Length:		8.8 Meters
Central Field:		2.0 Tesla
Type		Al Stabilized / indirectly cooled
Thickness		$\leq 1.2\ \lambda_R$ @ 90° incidence
		$\leq 0.25\ \lambda_I$

Operational Requirements:

Cooldown time:	≈ 14 days
Quench recovery time:	≈ 4 hours
Charge time to 2 T:	≈ 60 minutes
Slow discharge time const.:	≈ 500 sec.

Detector requirements:

Coil mounts:	Coil is attached to steel of SDC Barrel Hadronic Calorimeter
Cryogenic Services:	30 cm diameter vertical penetration for chimney at one end of coil. Chimney extends vertically to control dewar location above muon toroid iron.
Cryogenic plant:	The SDC cryo plant must also provide Helium for tracking VLPC's (visible light photon transducers)


SOLENOID MOUNTS
TRACKER SPACE FRAME MOUNTS AND ITD MOUNT (6 O'CLOCK)
ALIGNMENT LINES OF SIGHT
MATING SURFACE WITH END CAP
R 2.1
R 4.169
Y
X
.077
.29
1.45
3.75
.29
BARREL CALORIMETER
.077
ROUTING SPACE
END CAP
SCALE: 2:1
LOOKING NORTH AT SOUTH END OF BARREL CALORIMETER
SD00176
07-APR-1992
NOTE: ALL DIMENSIONS ARE IN METERS.

SDC LOCATION

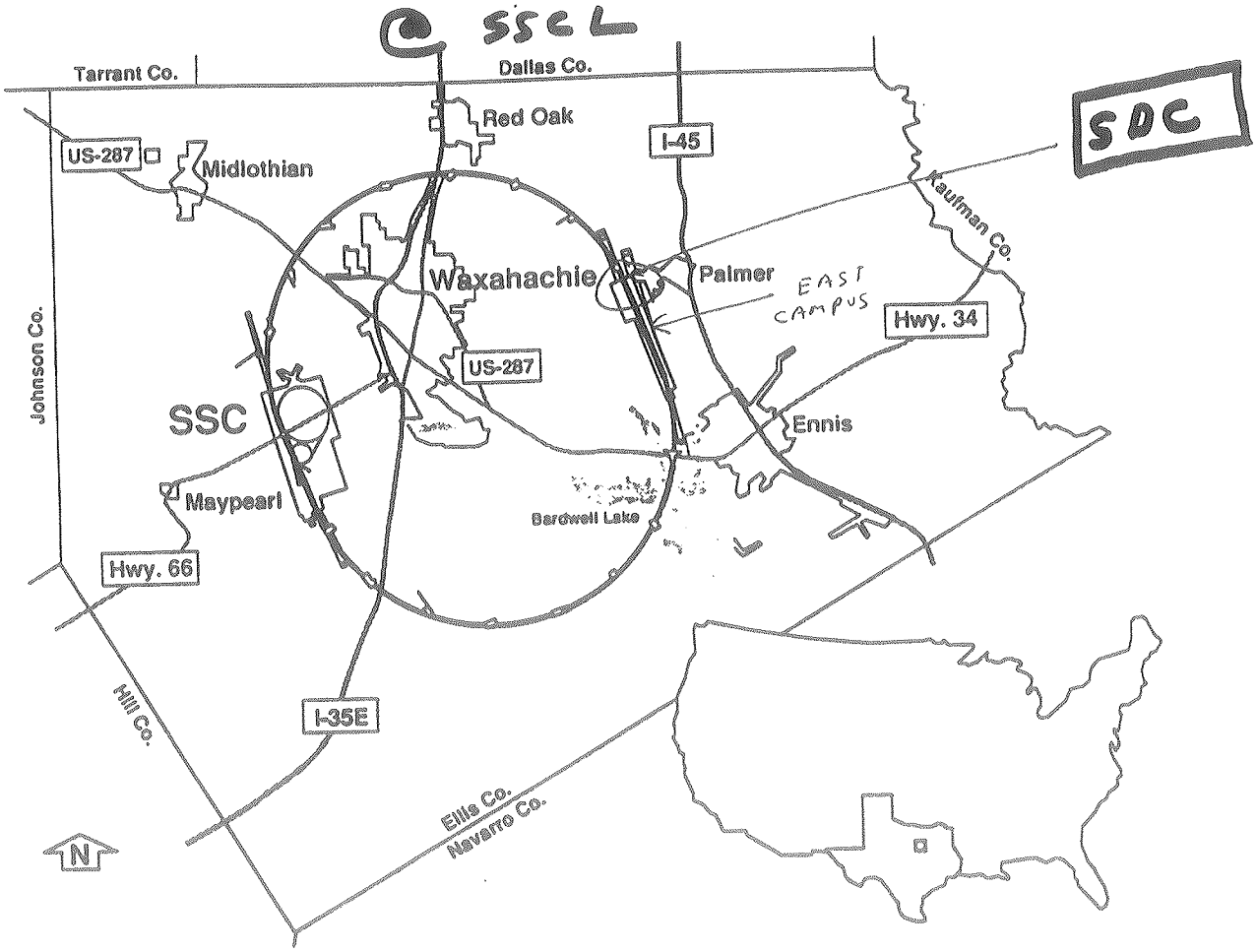


FIG. 12-1. The SSC site.

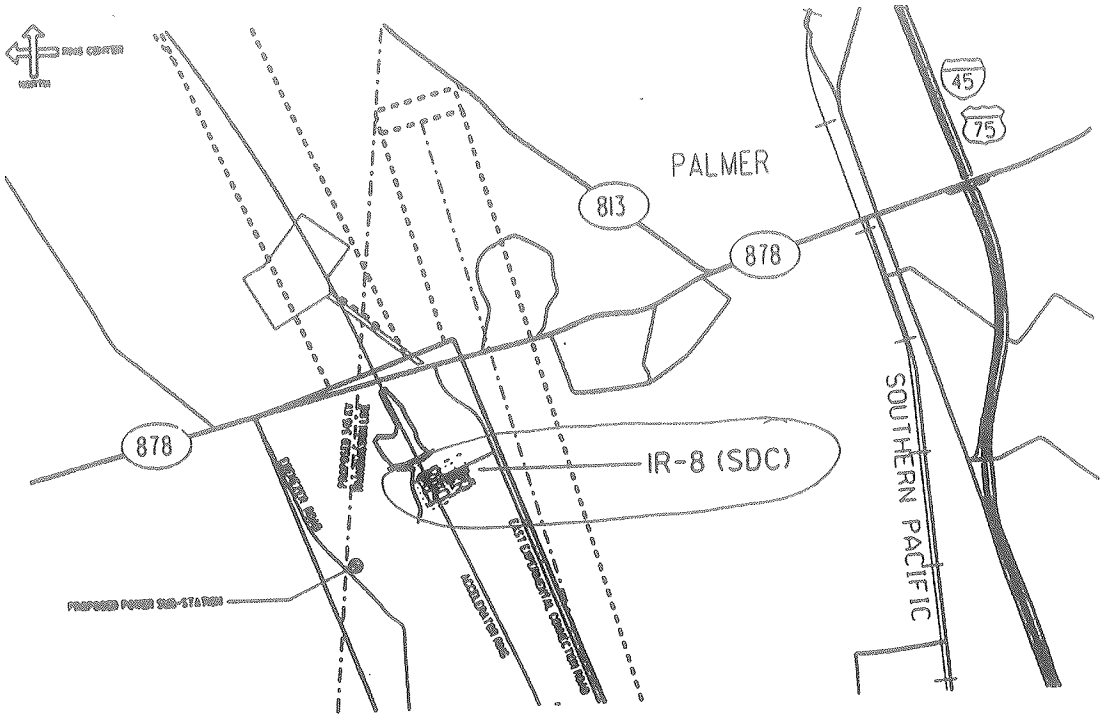


FIG. 12-2. The IR8 site.

Other requirements:

Solenoid location:	Axis of solenoid located 50 m below grade.
Utilities location:	Refrigerator and power supply located at surface level ==> 130 m long cryo lines and bus work.
Access:	SDC will be located in an interlocked radiation area. Access will be very restricted ==> high operational reliability
Radiation dose:	Solenoid must be designed to withstand > 10 years at 10^{34} cm^{-2} s^{-1} luminosity ==> >> 6 megarads without damage.
Construction:	All welded construction (e.g. no O-rings etc.,
Safety codes:	DOE/SSCL requires pressure vessels to be built to ASME / CGA code. Code approved allowable stress levels.

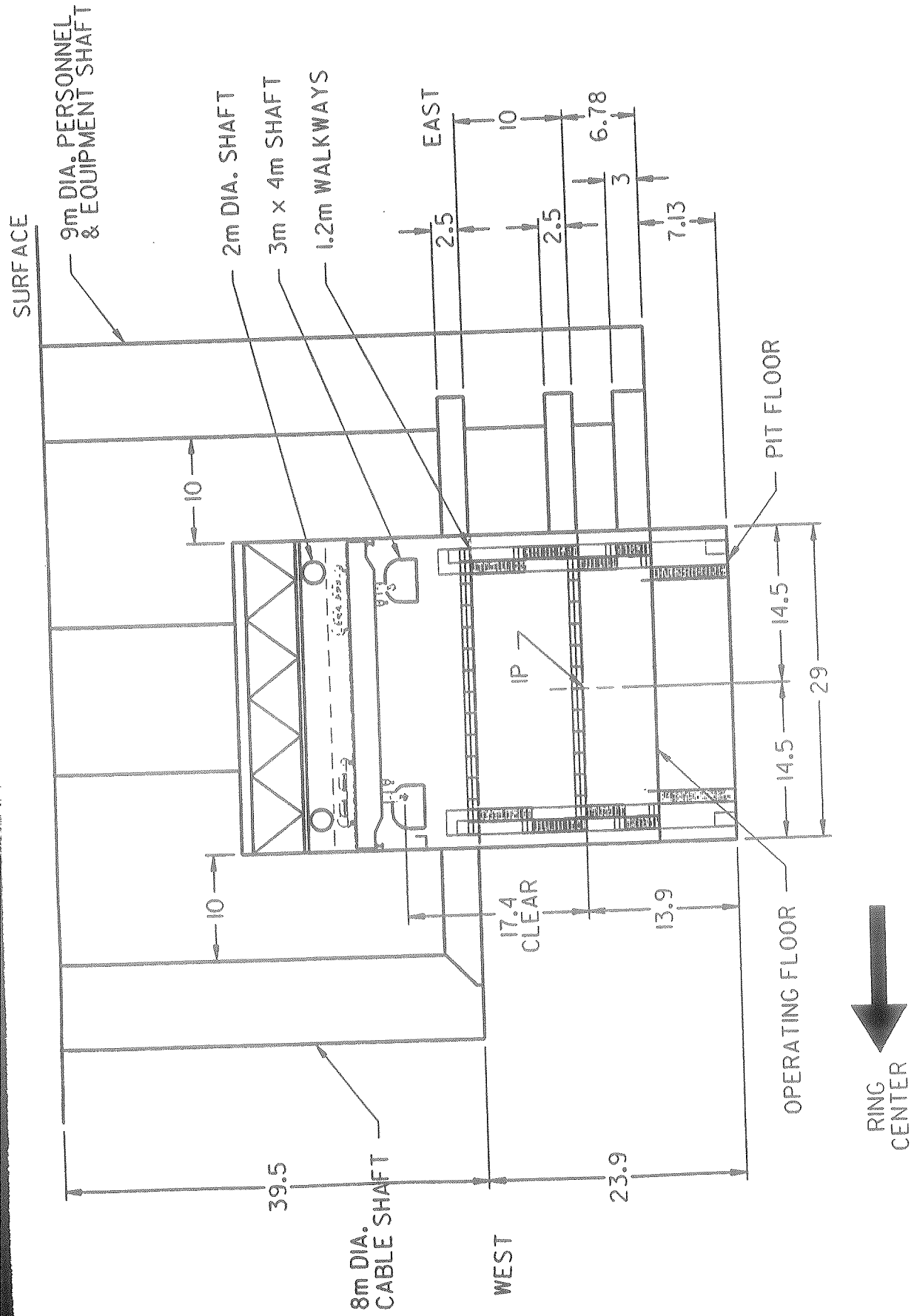


FIG. 12-10. End view of the SDC underground hall.

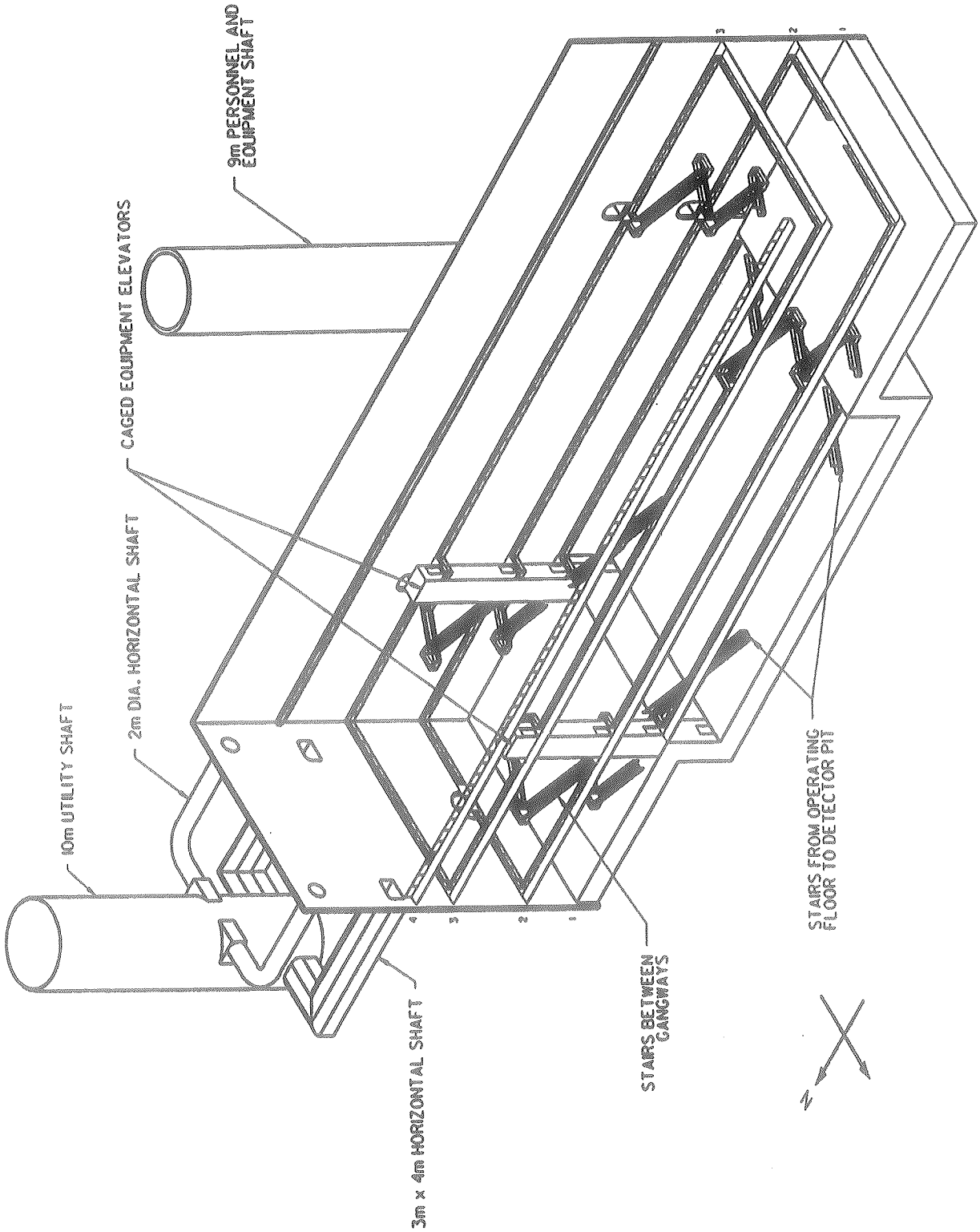


FIG. 12-9. Isometric view of the SDC underground hall showing gangways and access points.

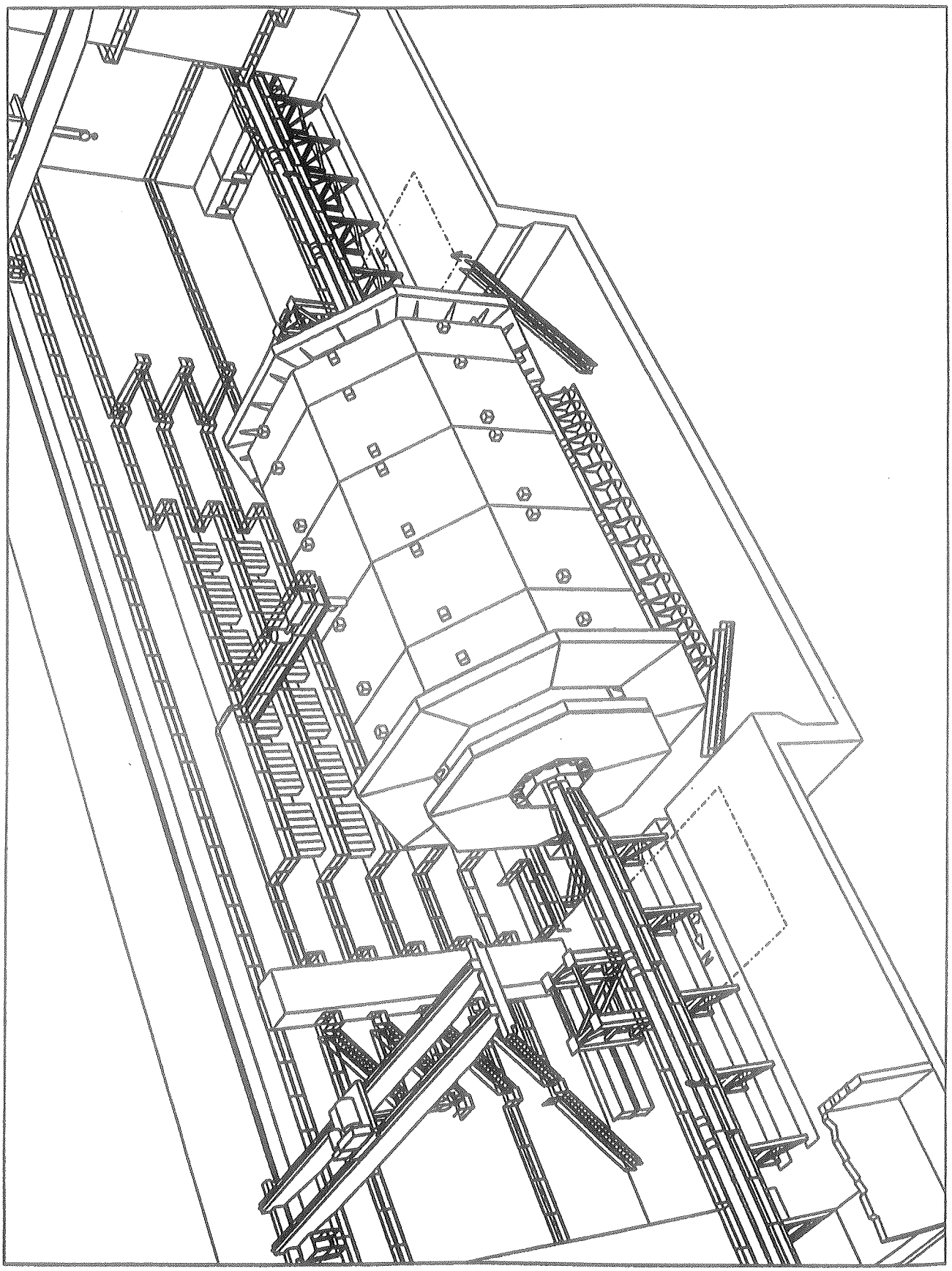


FIG. 13-14. View of the interaction hall showing the completed detector with accelerator components. Month 45 of the installation schedule.

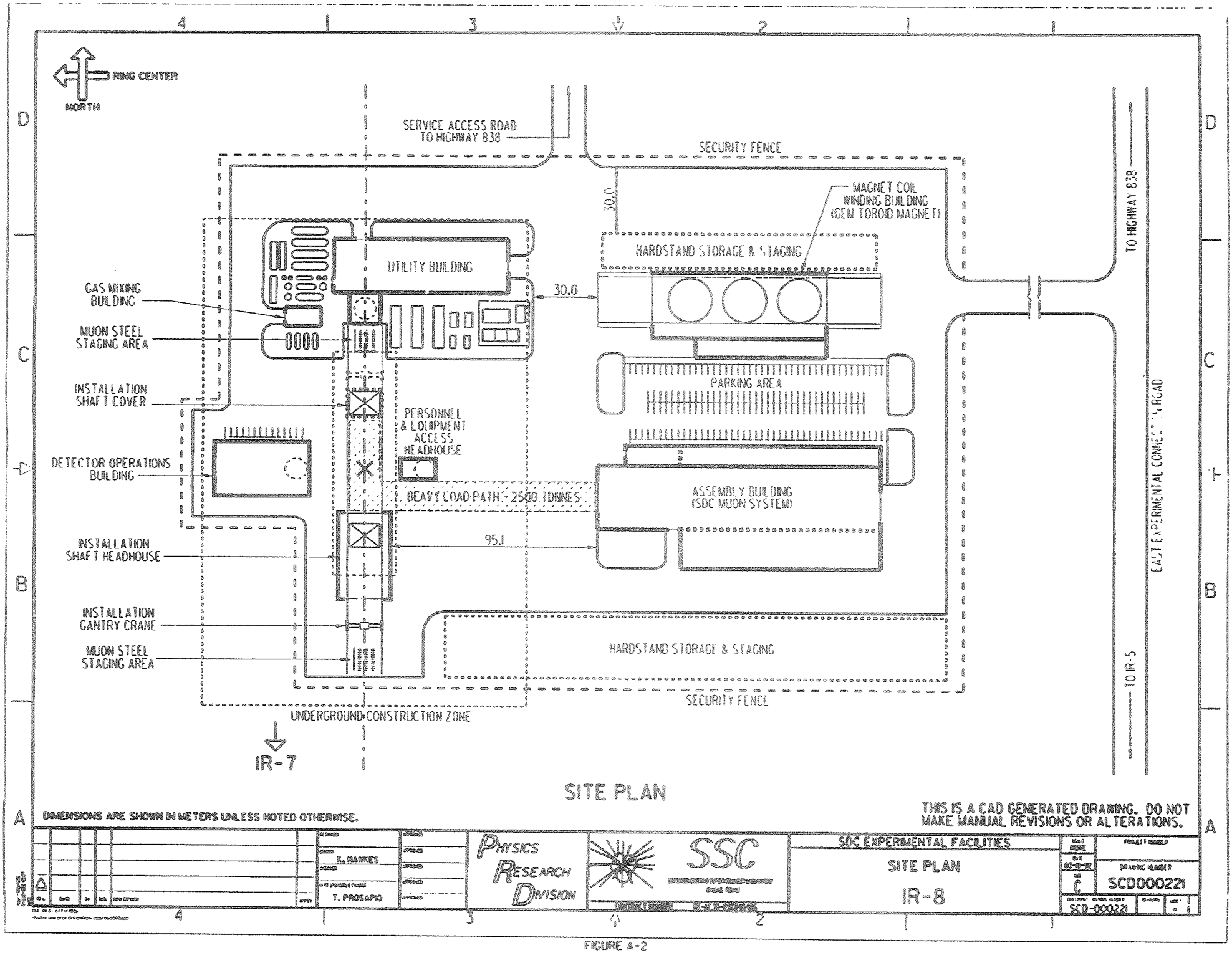
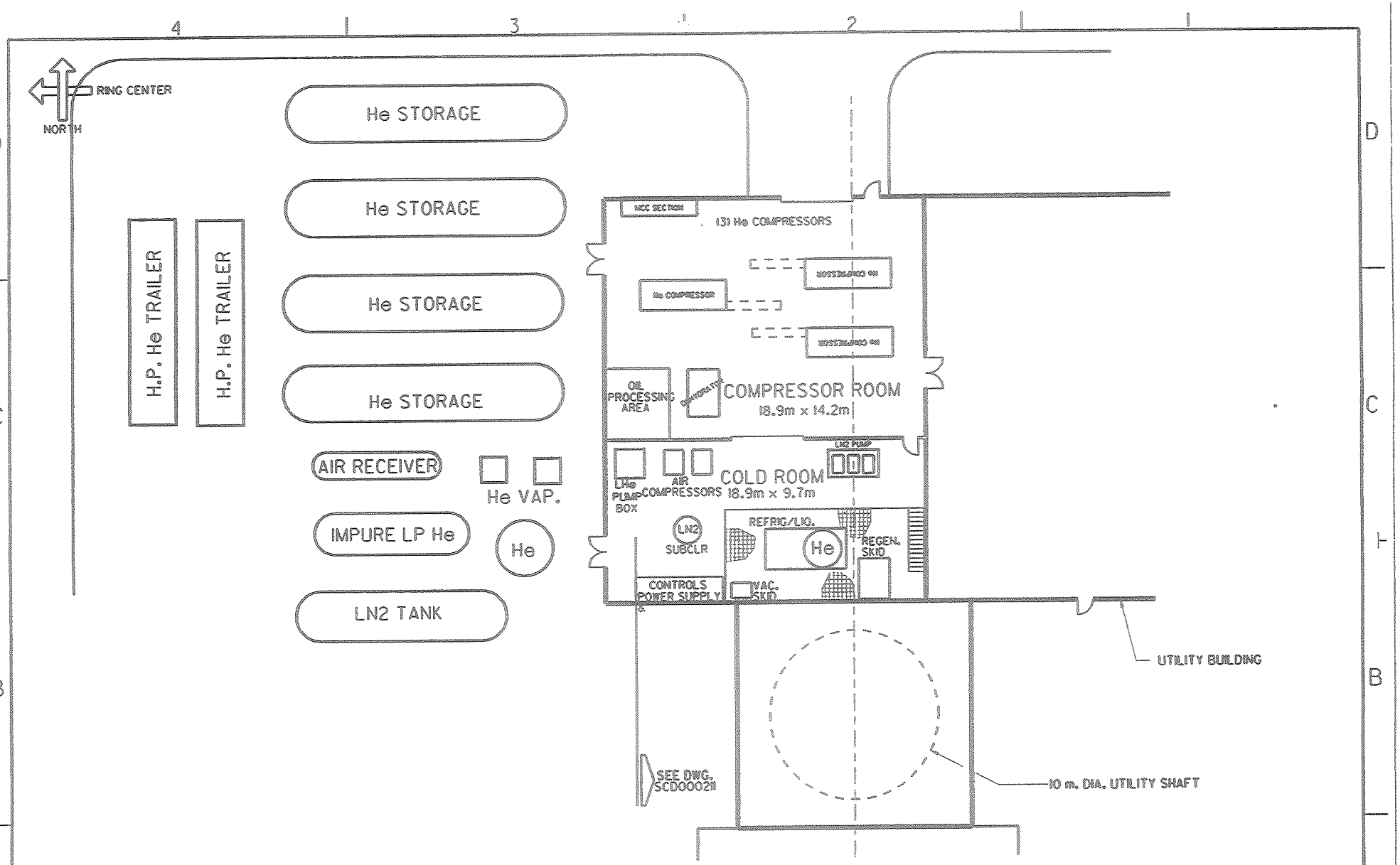

RING CENTER
NORTH
SERVICE ACCESS ROAD TO HIGHWAY 838
SECURITY FENCE
30.0
MAGNET COIL WINDING BUILDING (GEM TOROID MAGNET)
HARDSTAND STORAGE & STAGING
UTILITY BUILDING
30.0
GAS MIXING BUILDING
MUON STEEL STAGING AREA
INSTALLATION SHAFT COVER
PARKING AREA
PERSONNEL & EQUIPMENT ACCESS HEADHOUSE
DETECTOR OPERATIONS BUILDING
HEAVY LOAD PATH - 2500 TONNES
ASSEMBLY BUILDING (SDC MUON SYSTEM)
95.1
INSTALLATION SHAFT HEADHOUSE
INSTALLATION GANTRY CRANE
MUON STEEL STAGING AREA
HARDSTAND STORAGE & STAGING
SECURITY FENCE
UNDERGROUND CONSTRUCTION ZONE
IR-7
TO HIGHWAY 838
EAST EXPERIMENTAL CONNECTING ROAD
TO IR-5
SITE PLAN
DIMENSIONS ARE SHOWN IN METERS UNLESS NOTED OTHERWISE.
THIS IS A CAD GENERATED DRAWING. DO NOT MAKE MANUAL REVISIONS OR ALTERATIONS.
R. MARKES
T. PROSAPIO
PHYSICS RESEARCH DIVISION
SSC
SDC EXPERIMENTAL FACILITIES
SITE PLAN
IR-8
SCD000221
SCD-000221

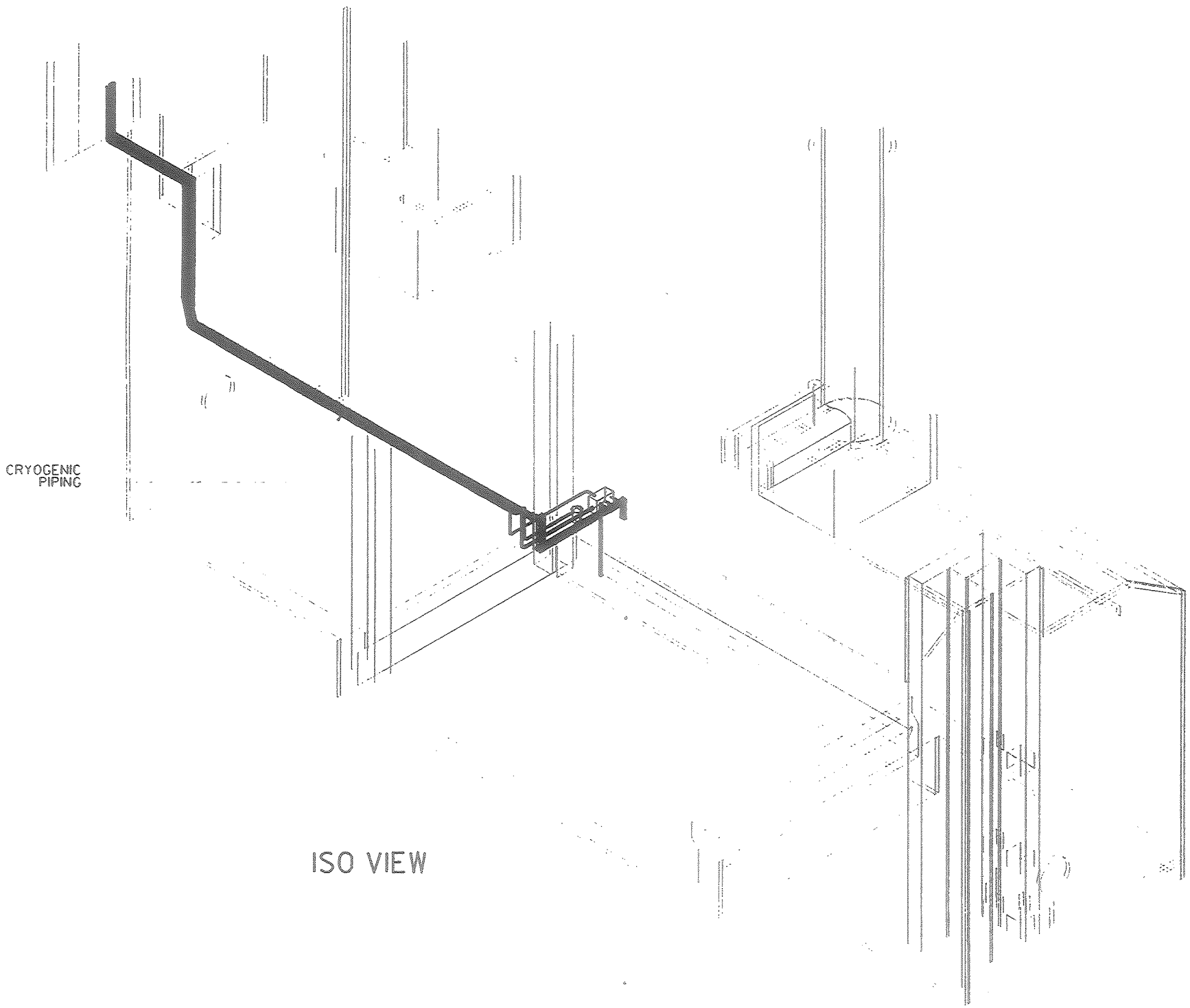
FIGURE A-2



UTILITY BUILDING - COLD ROOM AND COMPRESSOR ROOM FLOOR PLAN

THIS IS A CAD GENERATED DRAWING. DO NOT MAKE MANUAL REVISIONS OR ALTERATIONS.

DIMENSIONS ARE SHOWN IN METERS UNLESS NOTED OTHERWISE.


CRYOGENIC
PIPING
ISO VIEW

Other considerations:

The SDC solenoid will be at the heart of very complicated $580 M detector. Once assembled, access for repairs to the solenoid would require an extended major disassembly of the detector and would be catastrophic to SDC and to the SSCL physics program.

==>

A predictable design, combined with comprehensive R&D, prototype, quality control and testing programs are of paramount importance to insure success.

Conclusion:

The SDC magnet working group believes that it has developed a design that can meet the requirements of SDC and the details of that design are presented in the talks that follow.

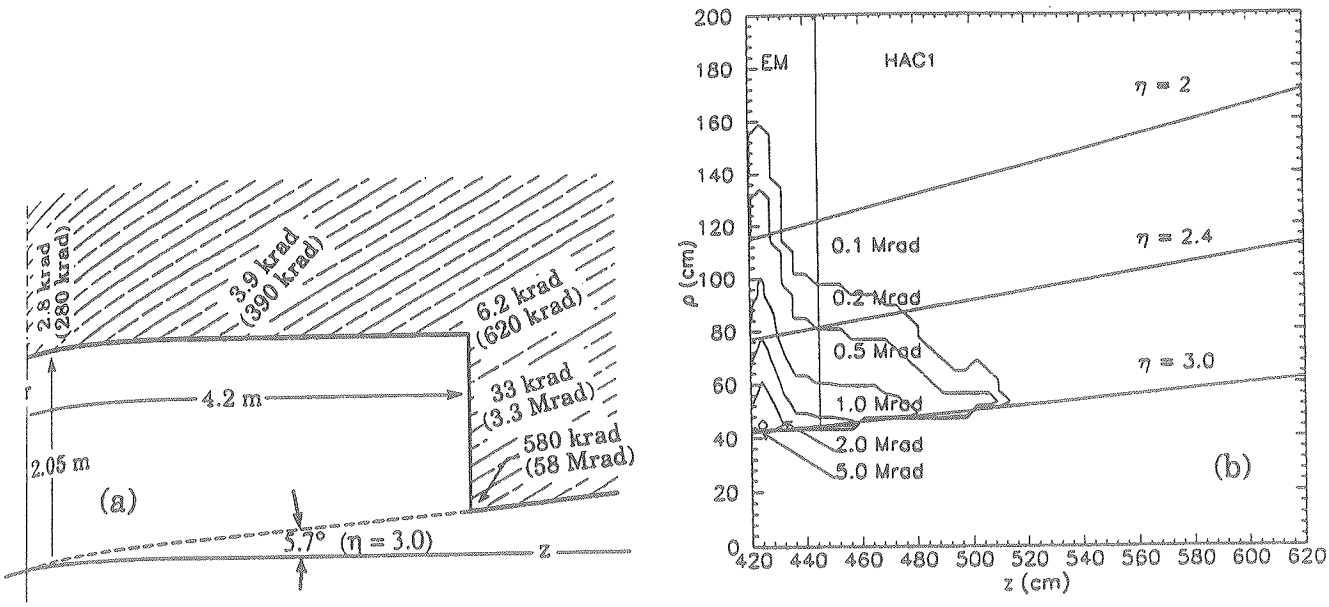


FIG. 6-7. (a) Maximum ionizing dose in the SDC calorimeter for one year of running at design luminosity and (in parentheses) for 10 years at 10 × design luminosity [1]. (b) Equal radiation dose contours for the SDC endcap calorimeter after ten years of running at design luminosity. We have indicated in (b) the separation between the EM and hadronic compartments and overlaid several η boundaries.

The SDC Magnet Working Group

The approximate division of design effort is as follows:

Conductor development, coil winding, support system , radiation shields, prototype coil (Japan)

Magnetostatic analysis, Cryogenics, He refrigerator, Power Supply/controls ,Utilities, detector integration. (USA)

Quench analysis, stress analysis, outer vacuum shell R&D (shared US-Japan)