LIGO Vacuum Equipment
Scientific Requirements Overview

M. E. Zucker
LIGO Project
Massachusetts Institute of Technology

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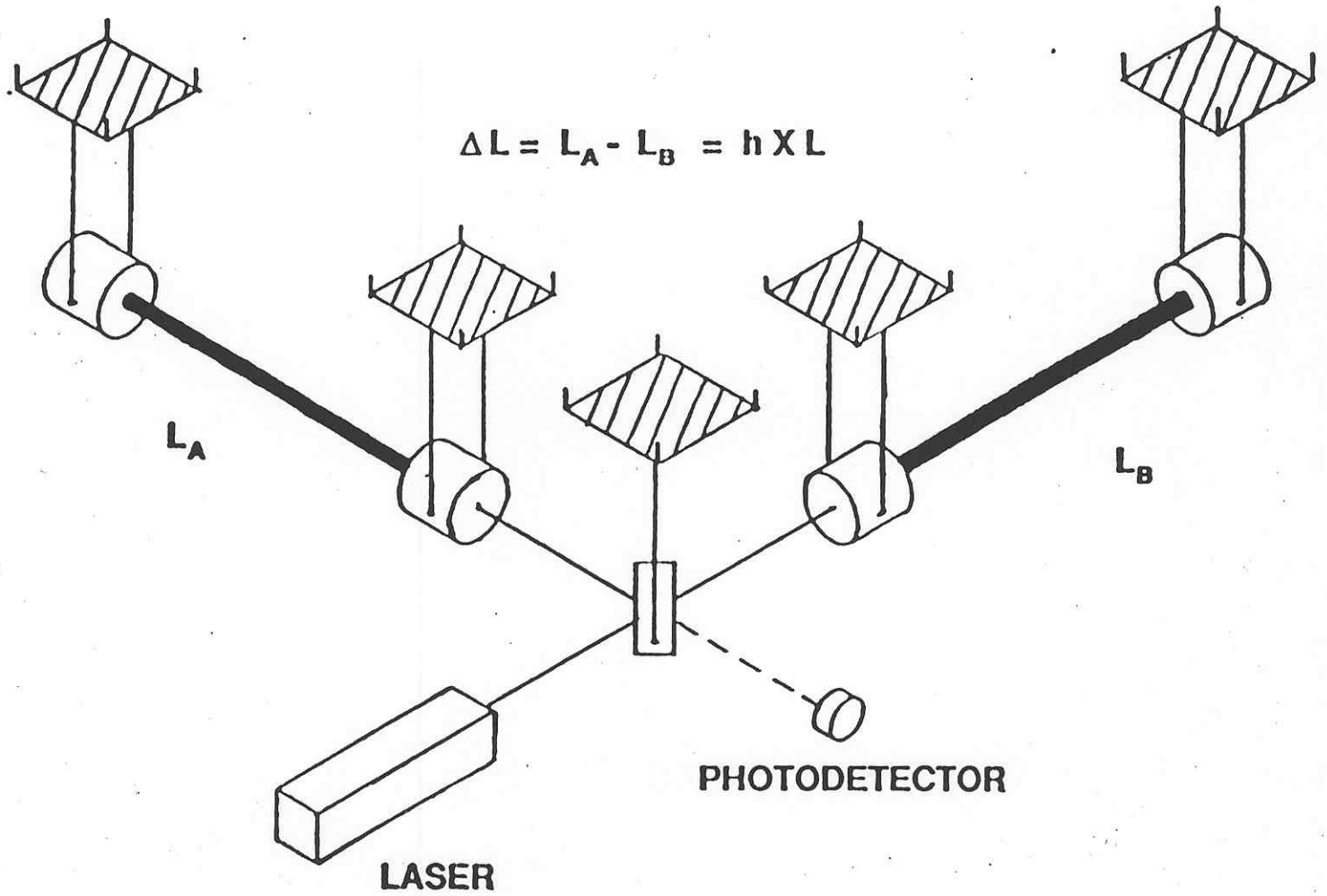
Envelope Volume, Dimensions & Interfaces

- Detector Subsystems in Vacuum
  - Core Optics
  - Input/Output Optics
  - Seismic Isolation Stacks
- Input/Output Optics: HAM Chambers
- Core Optics:
  - BSC Chambers
  - TMC Chambers
- Main and Auxiliary Laser Beams
  - Beam Size
  - Multiple Reflections, Internal Scattering & Beam Dumps
  - Auxiliary Beams for Alignment Controls
  - Beam I/O and Viewing Ports
- Access
- Independence of Interferometers Sharing Beam Tubes
- Modularity and Expansion Capability

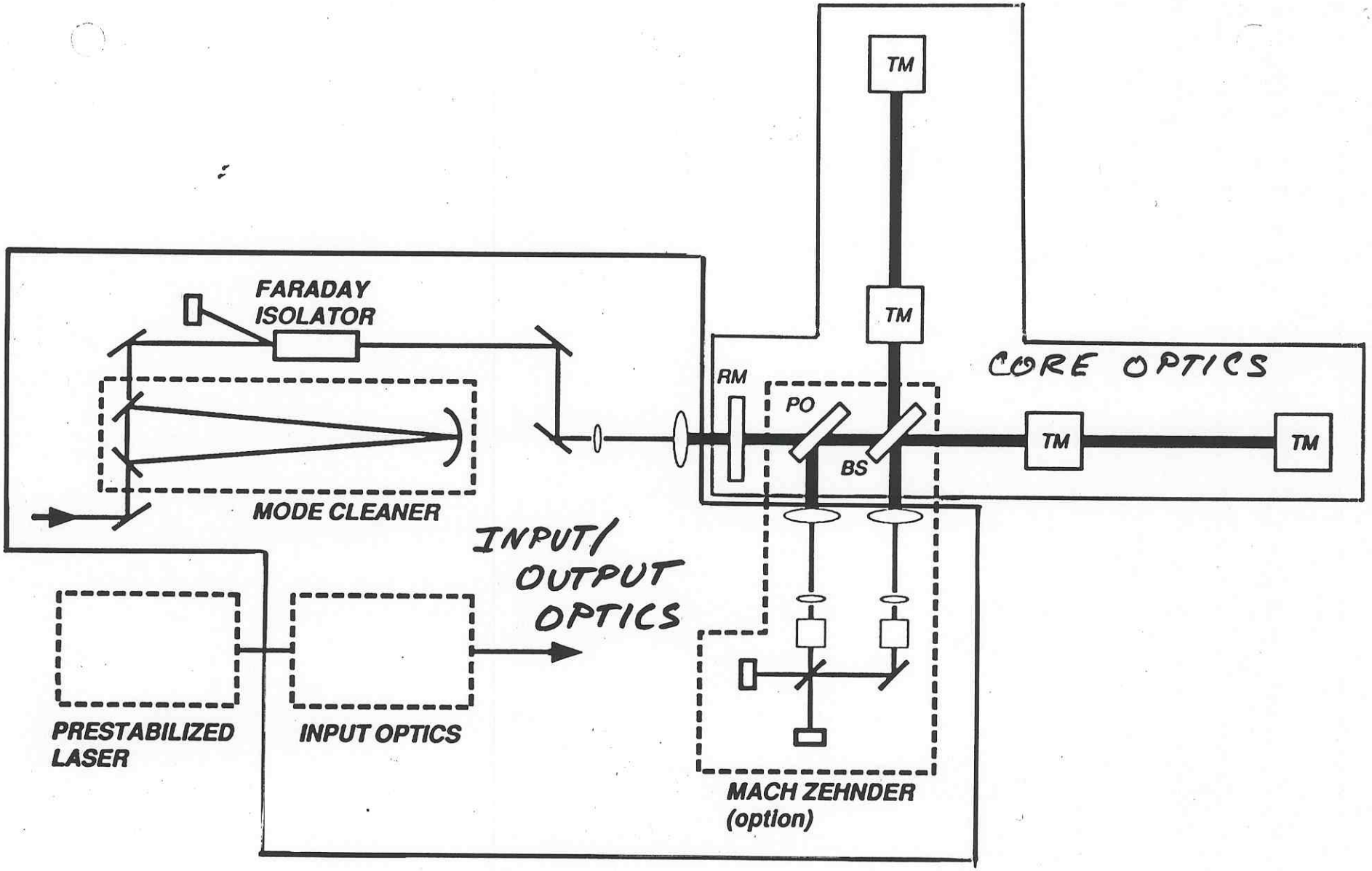
SCHEMATIC INTERFEROMETRIC DETECTOR



$h \leq 10^{-22}$

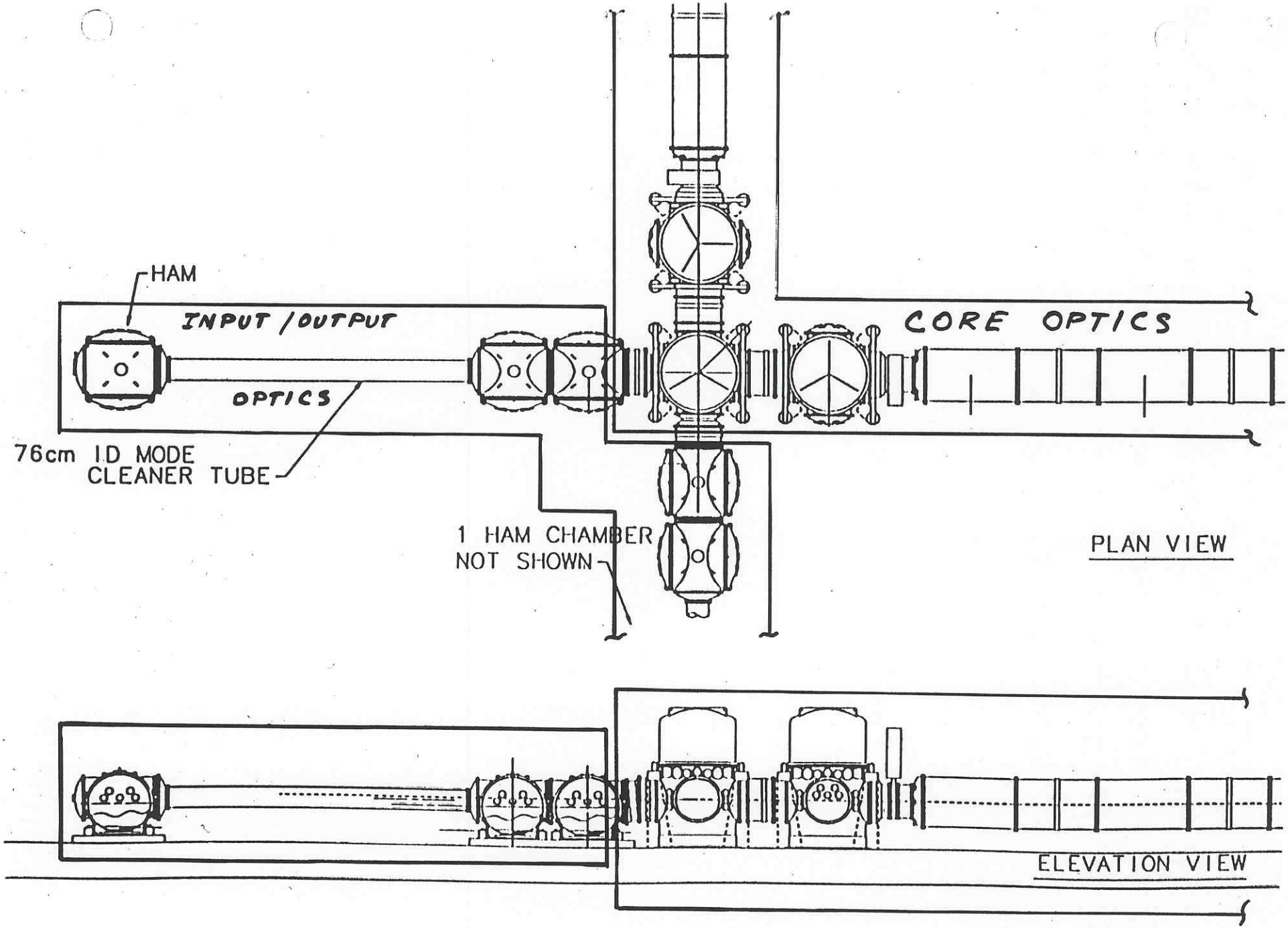
$\Downarrow$

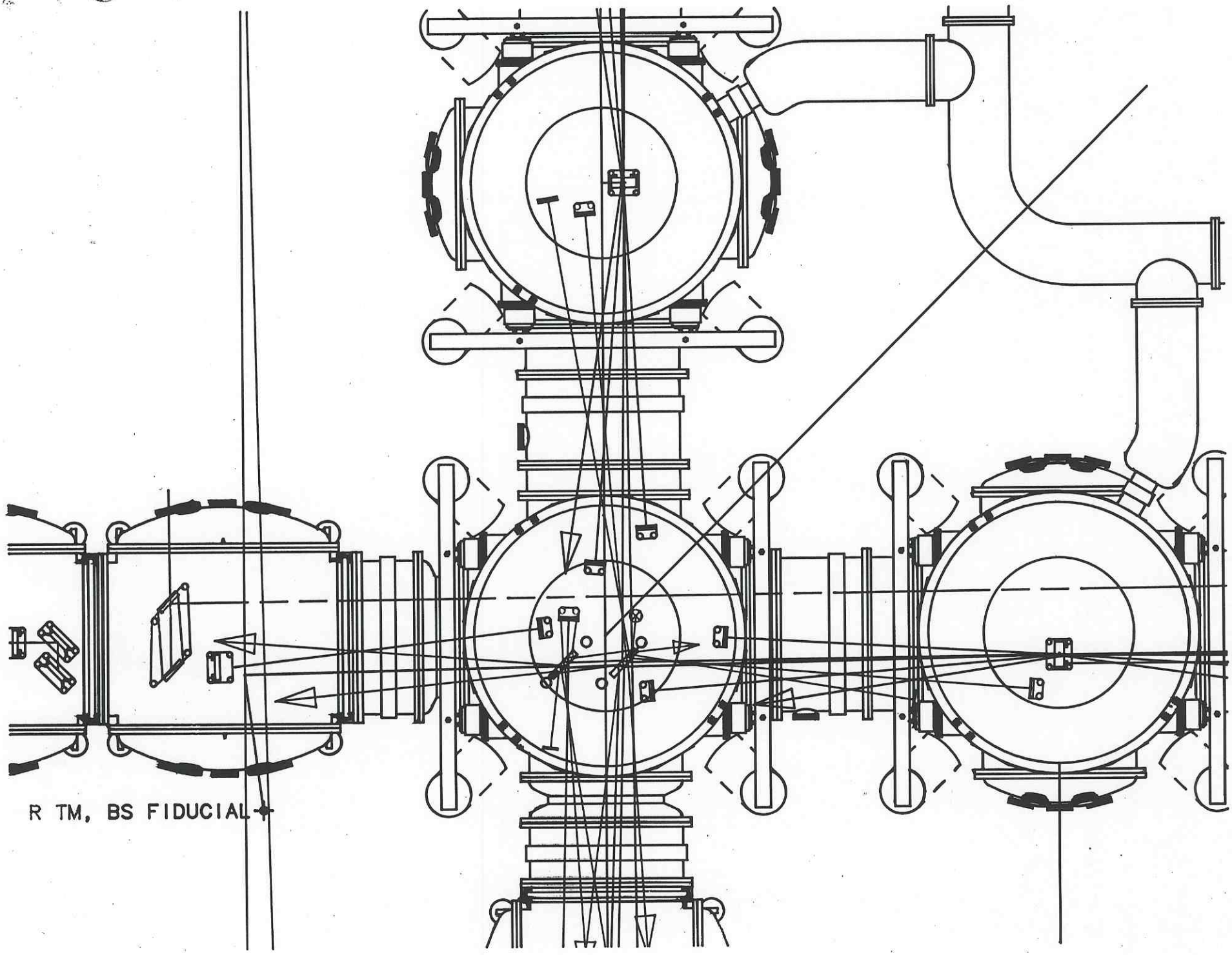
$\Delta L \leq 4 \cdot 10^{-19}\ m$



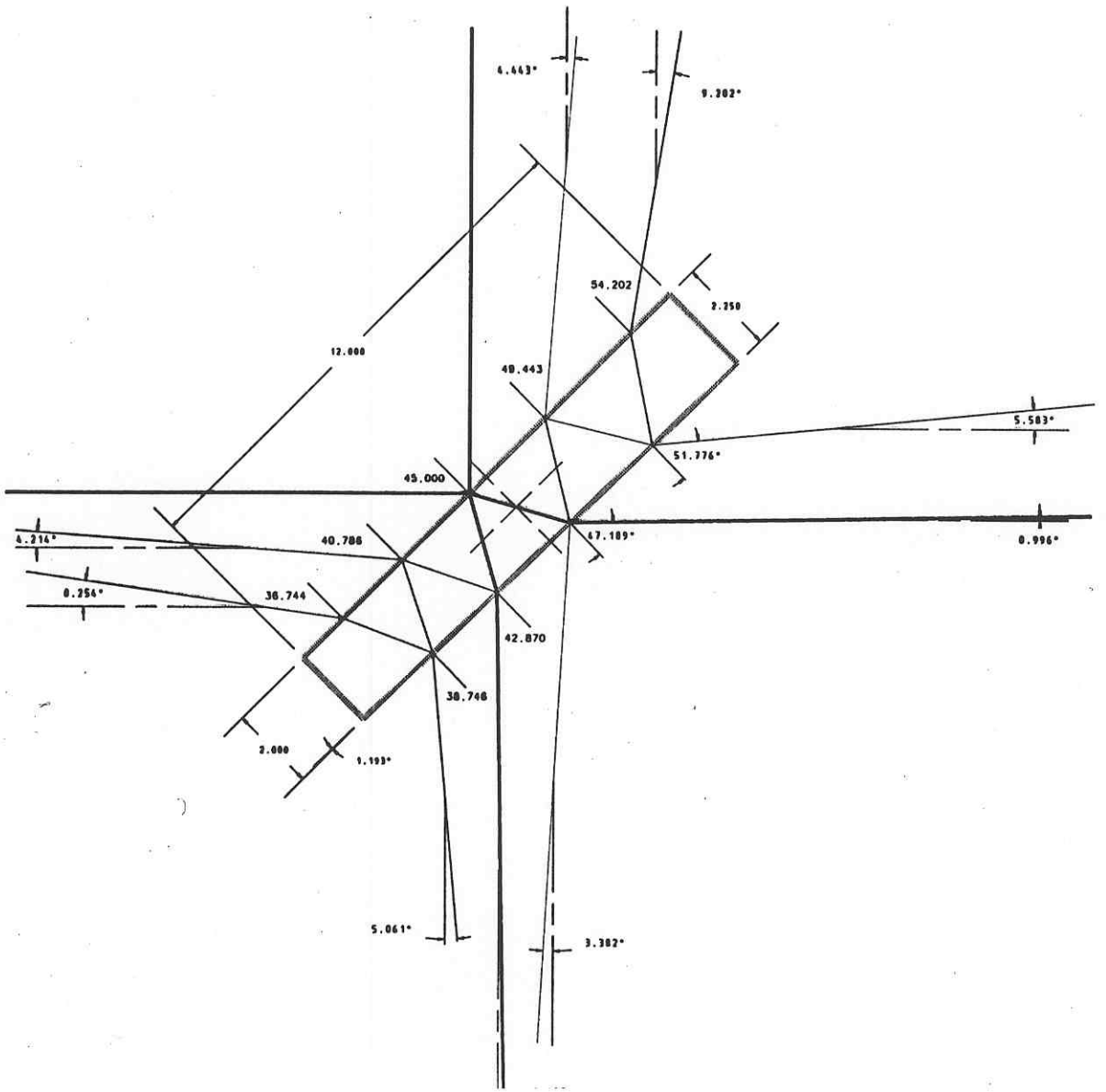
GENERIC INITIAL INTERFEROMETER

LIGO

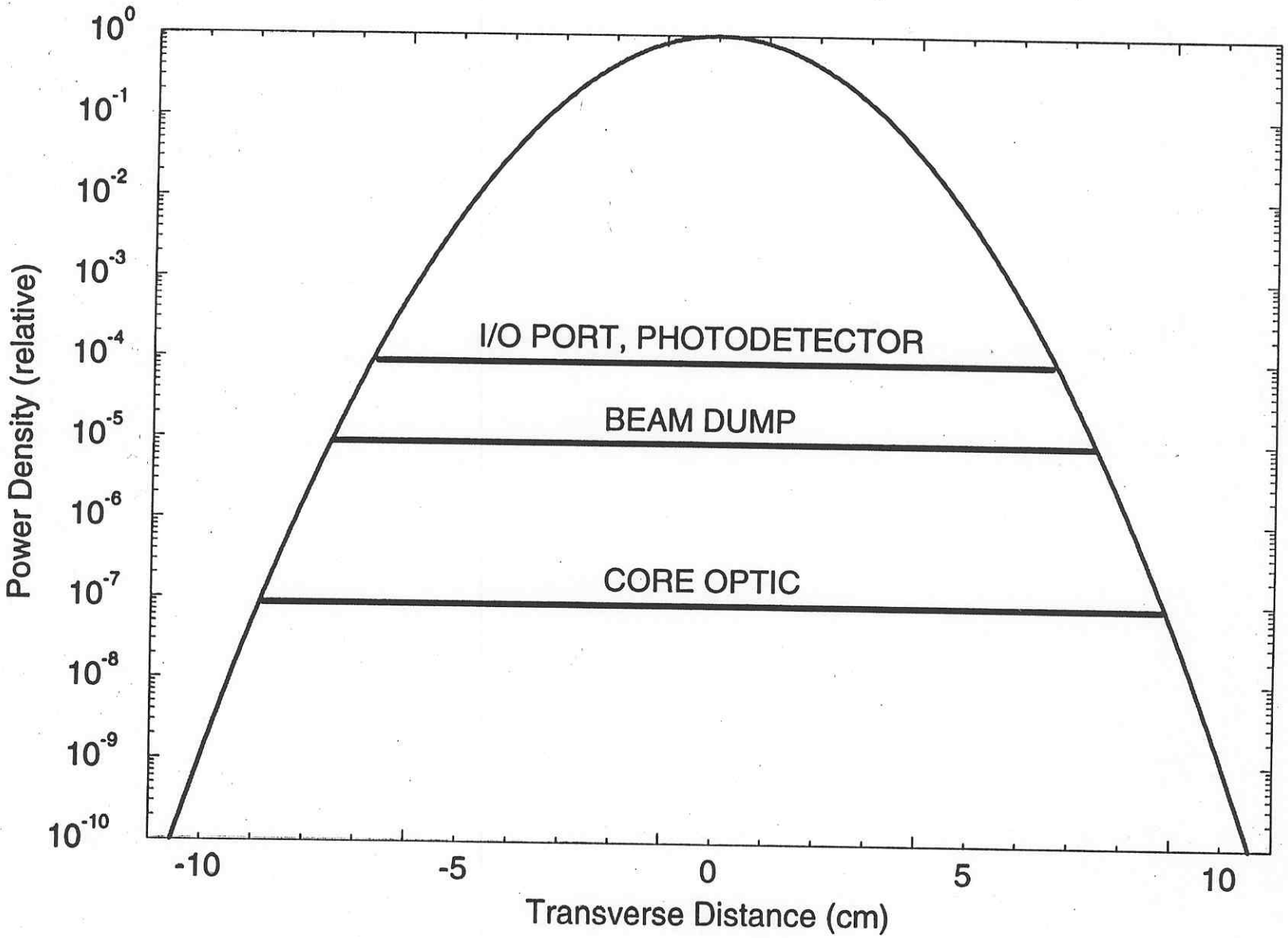

HAM
INPUT / OUTPUT
OPTICS
CORE OPTICS
76cm I.D MODE
CLEANER TUBE
1 HAM CHAMBER
NOT SHOWN
PLAN VIEW
ELEVATION VIEW


R TM, BS FIDUCIAL

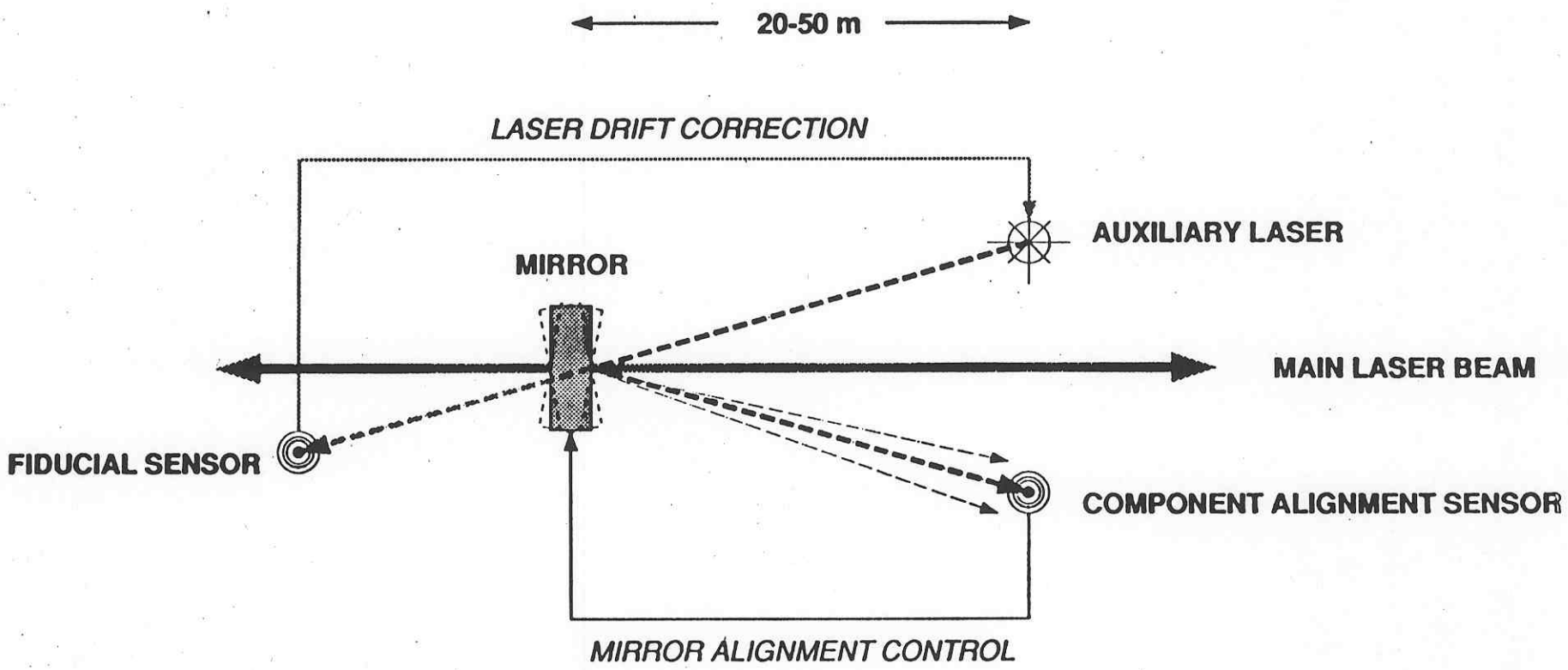
BEAMSPLITTER
PRIMARY AND SECONDARY BEAM RAY TRACE



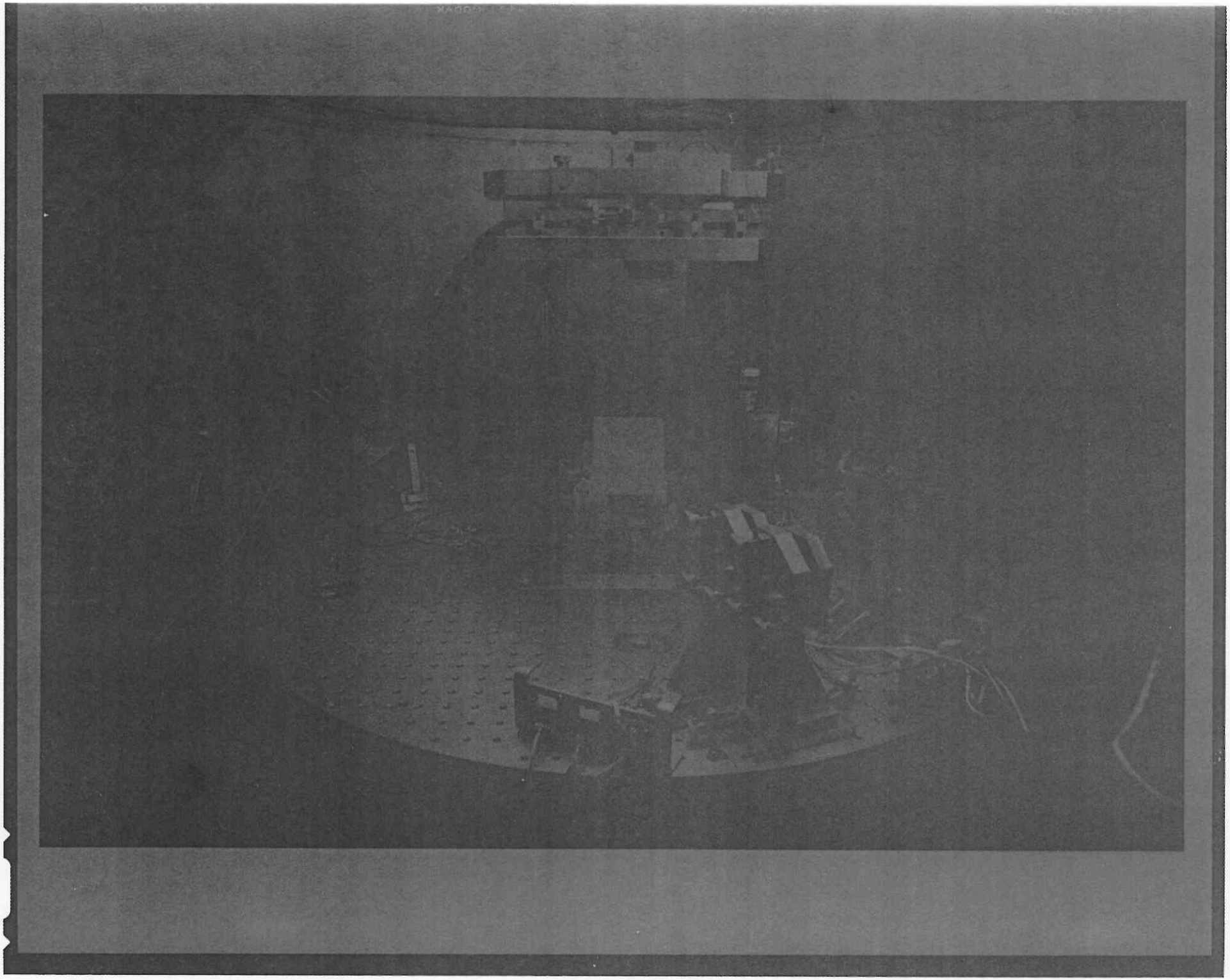
Beam and Component Diameters

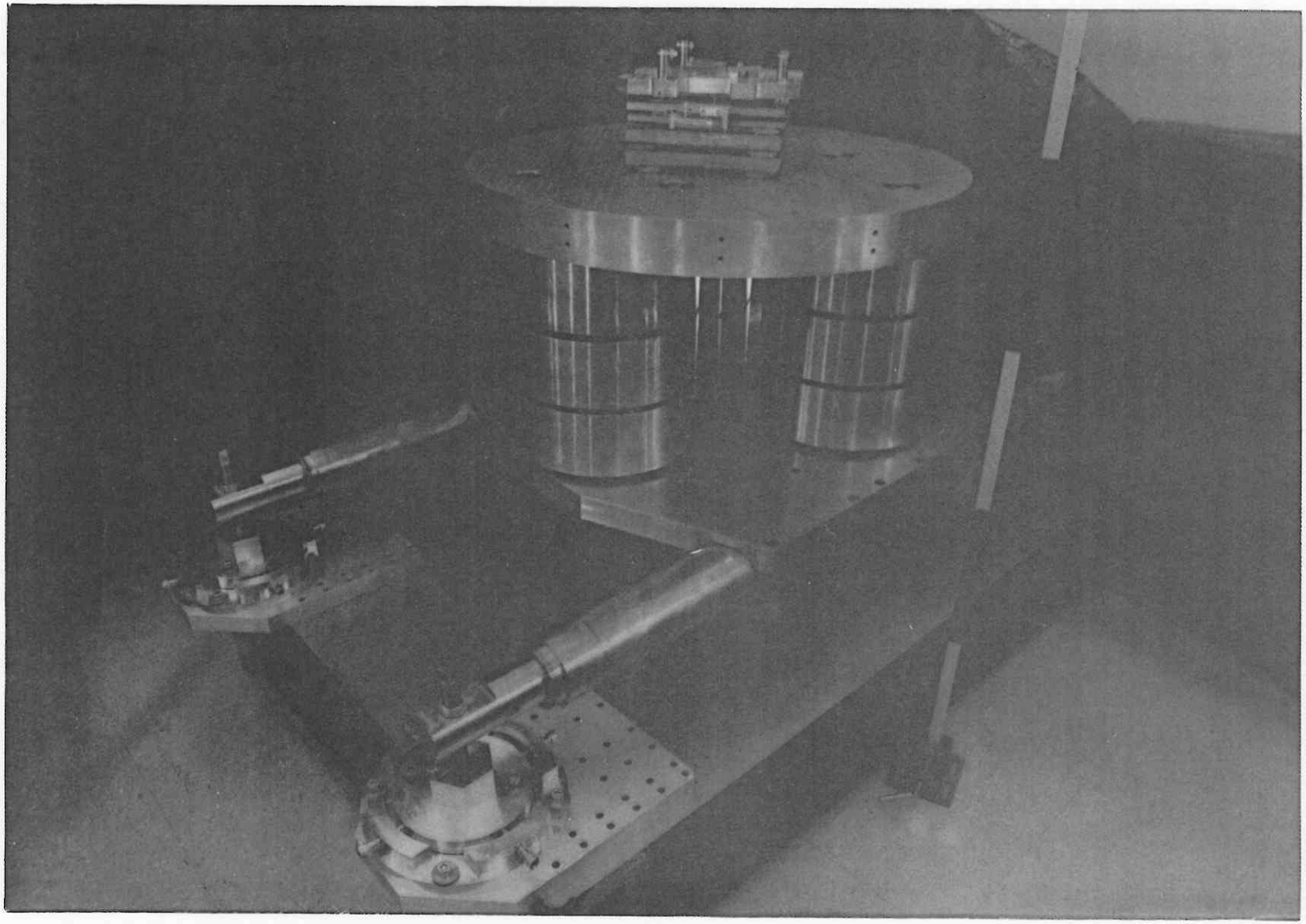


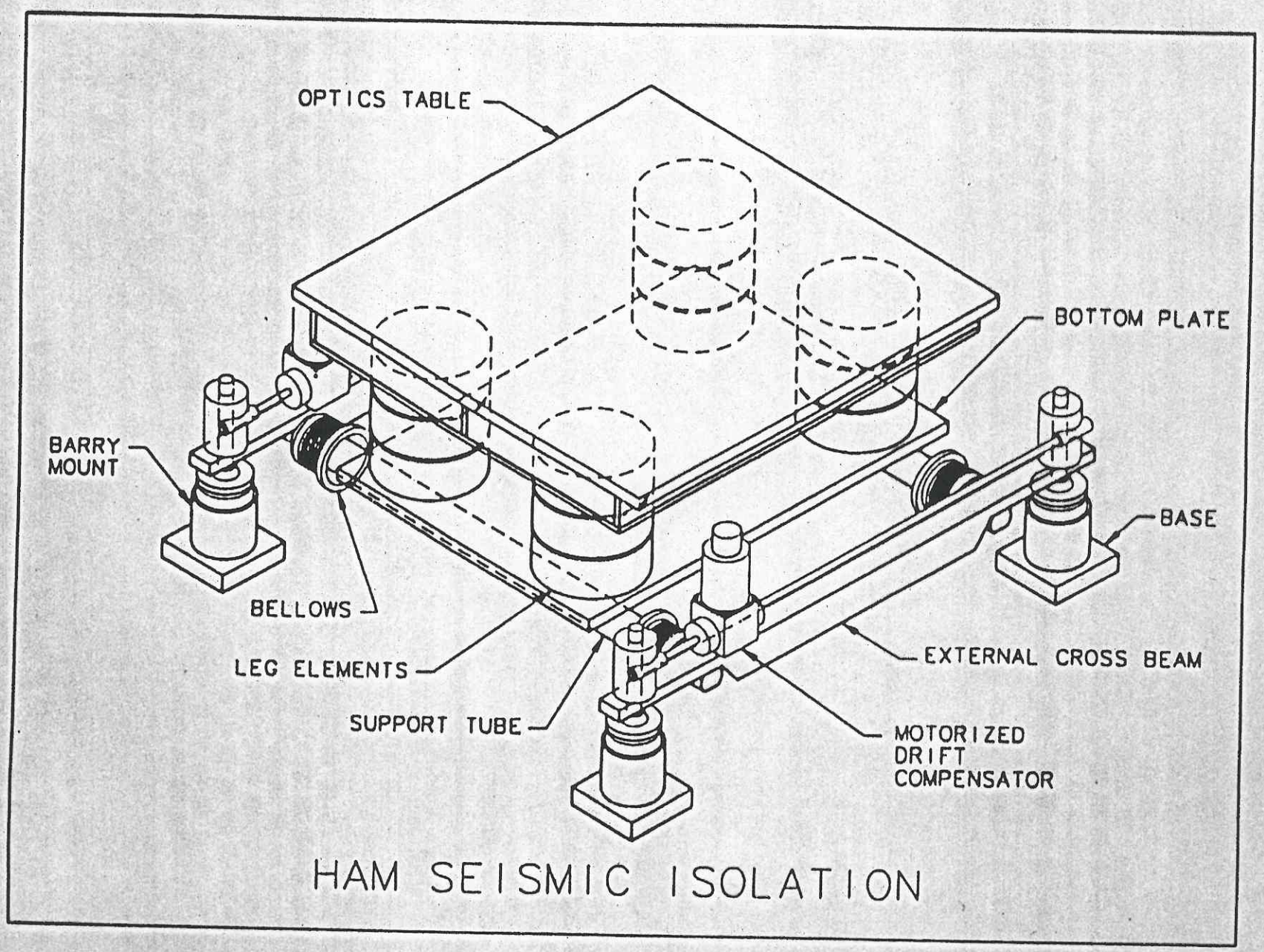
AUXILIARY LASER ALIGNMENT



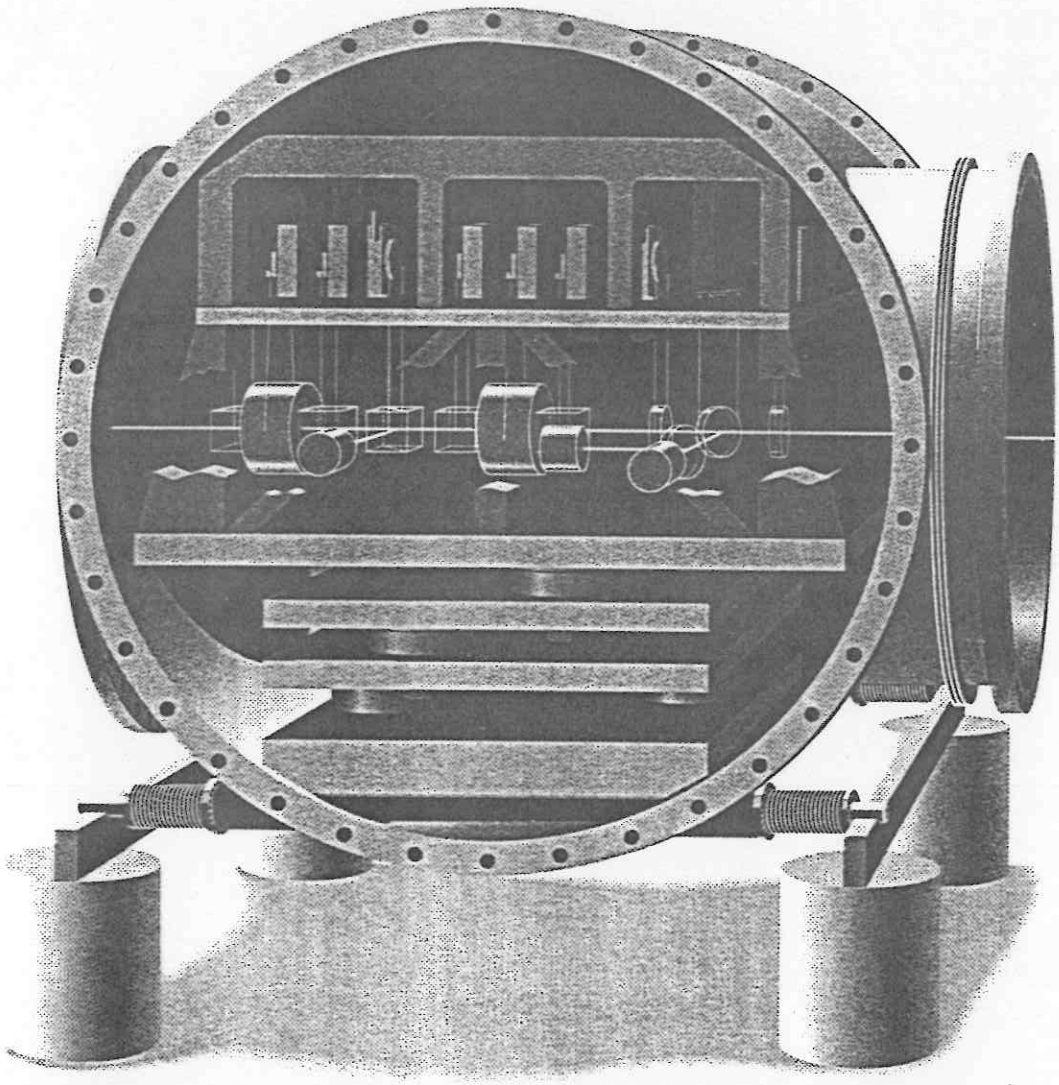
LIGO



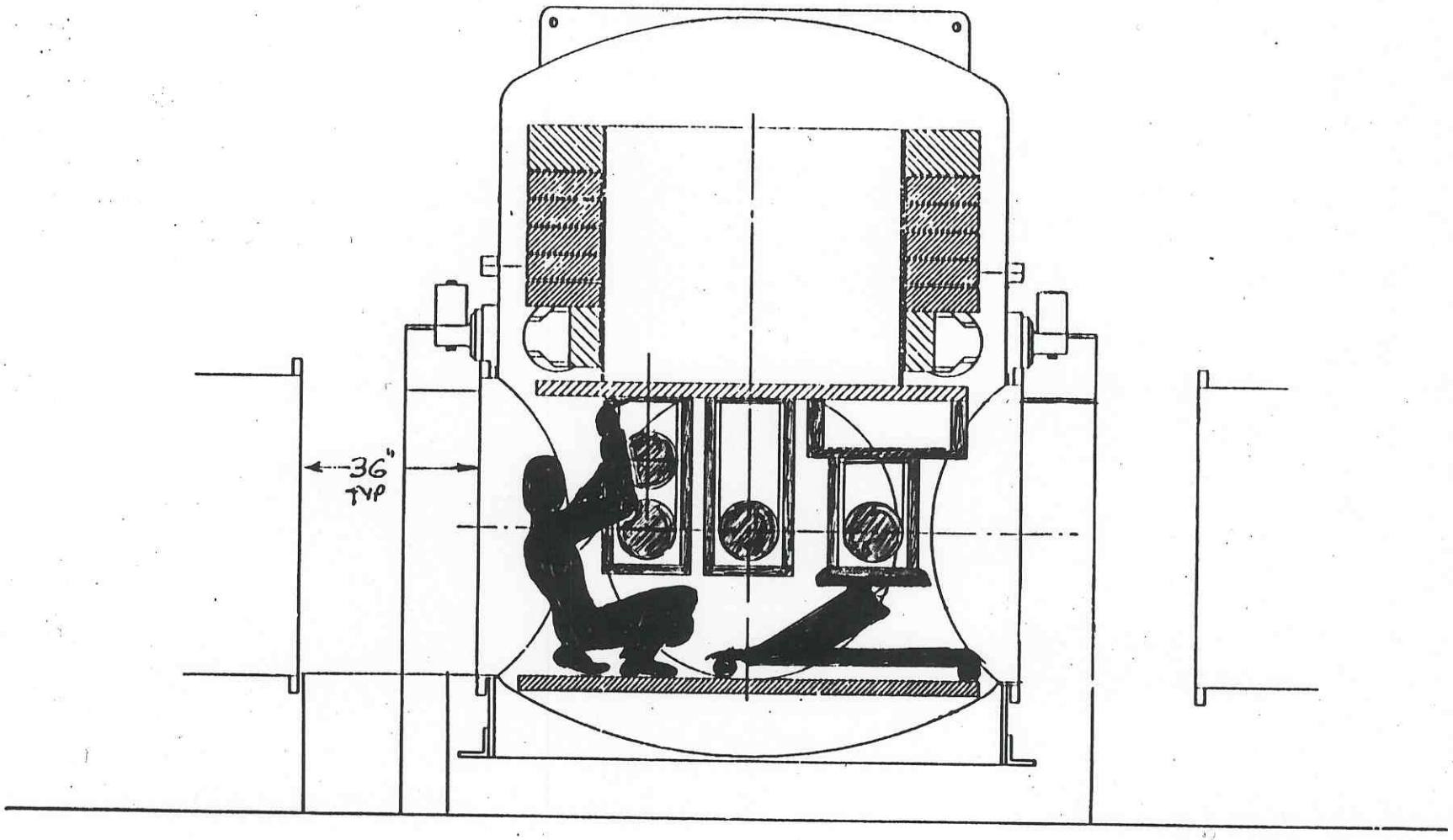




HAM SEISMIC ISOLATION



Rendering by J. Nils Lindstrom © 1989 Caltech



INTERNAL ACCESS

9-2-92

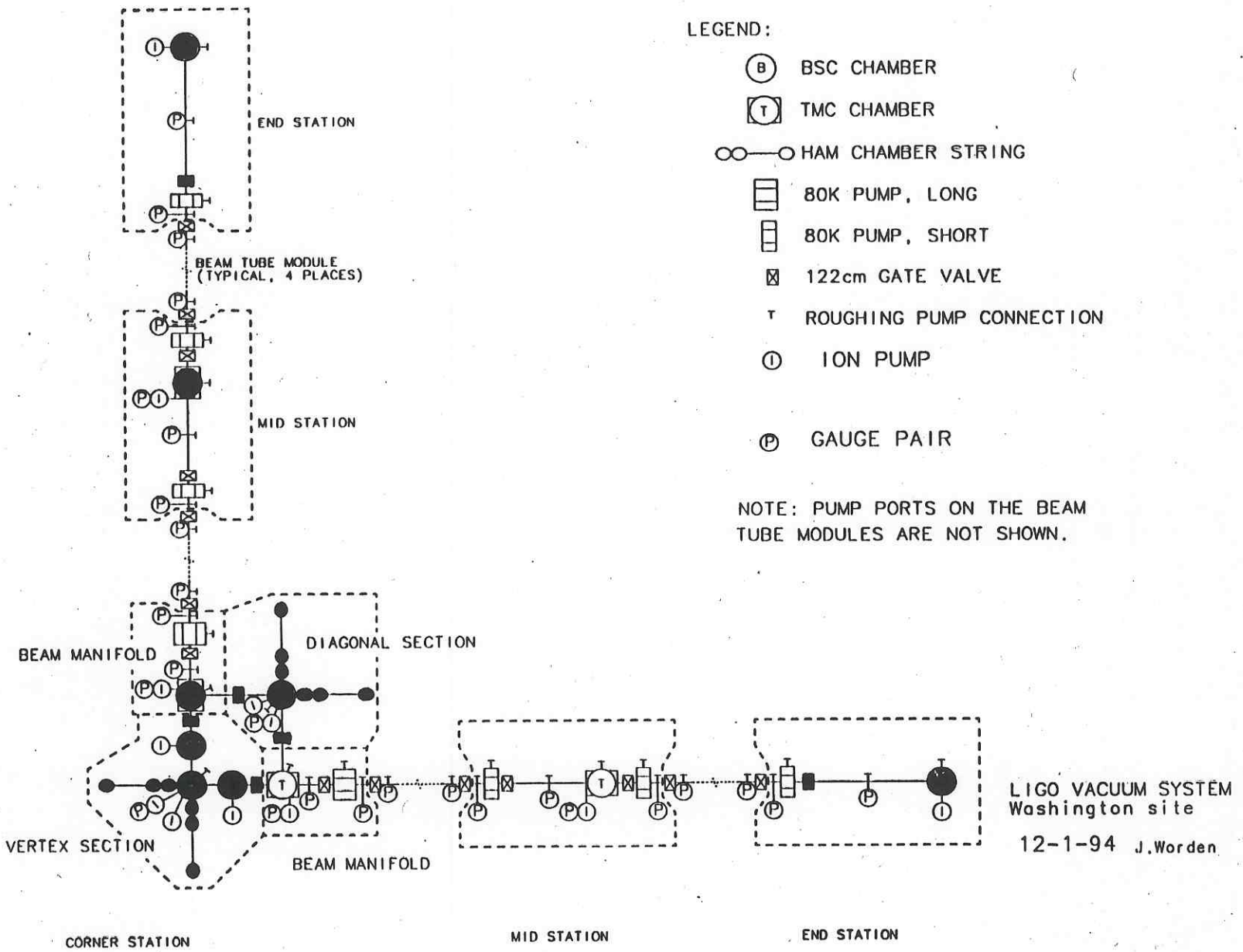
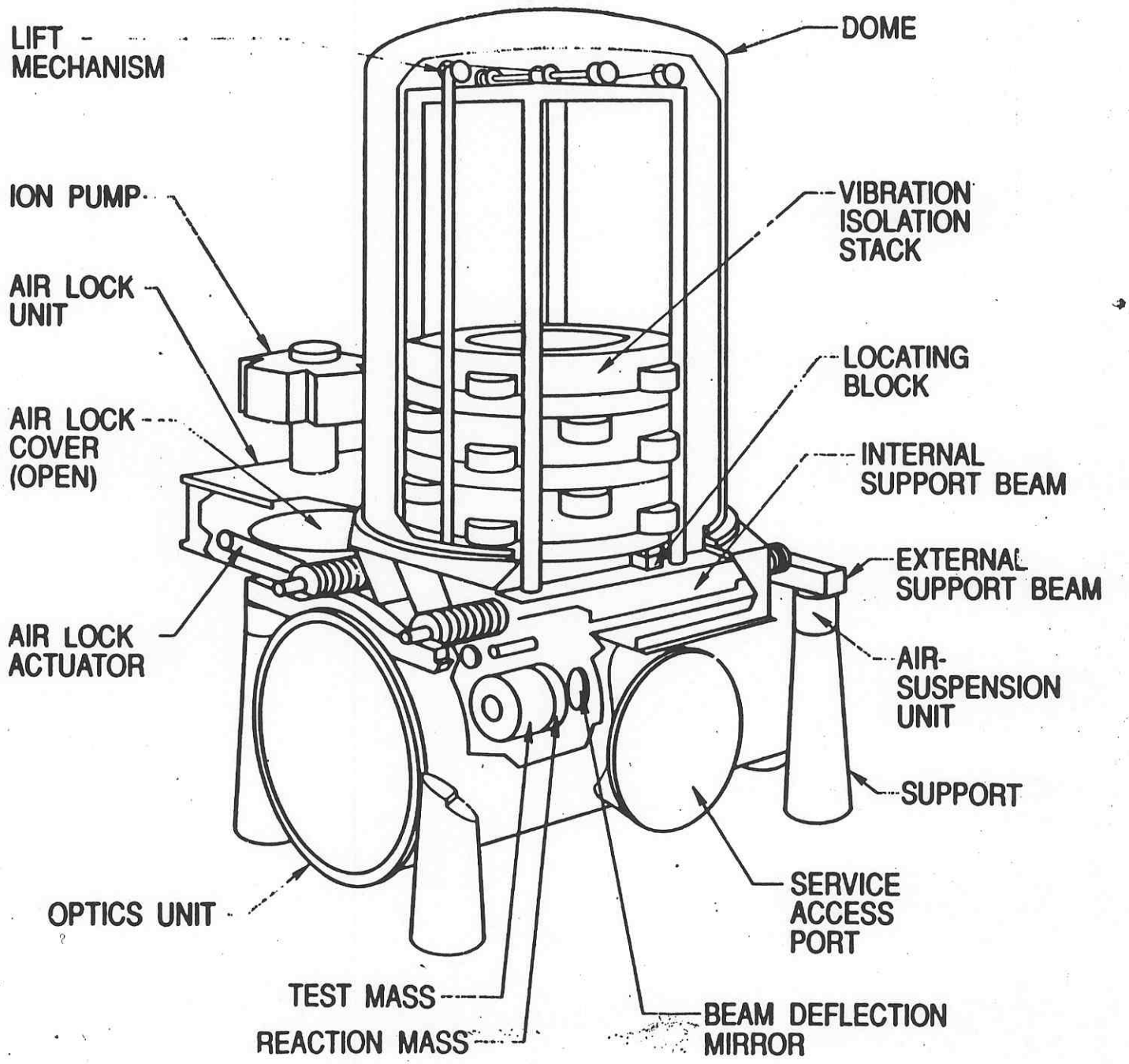
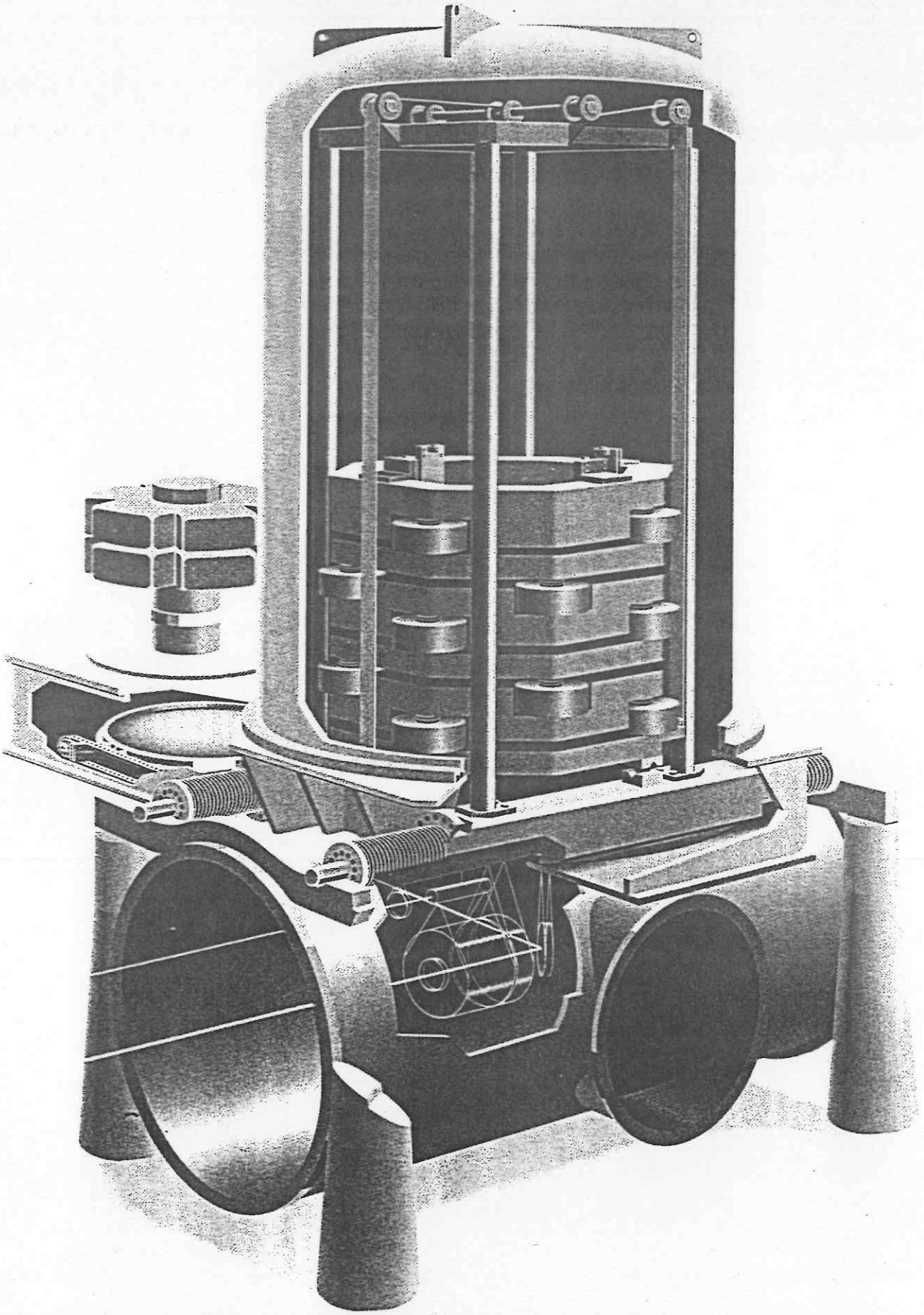
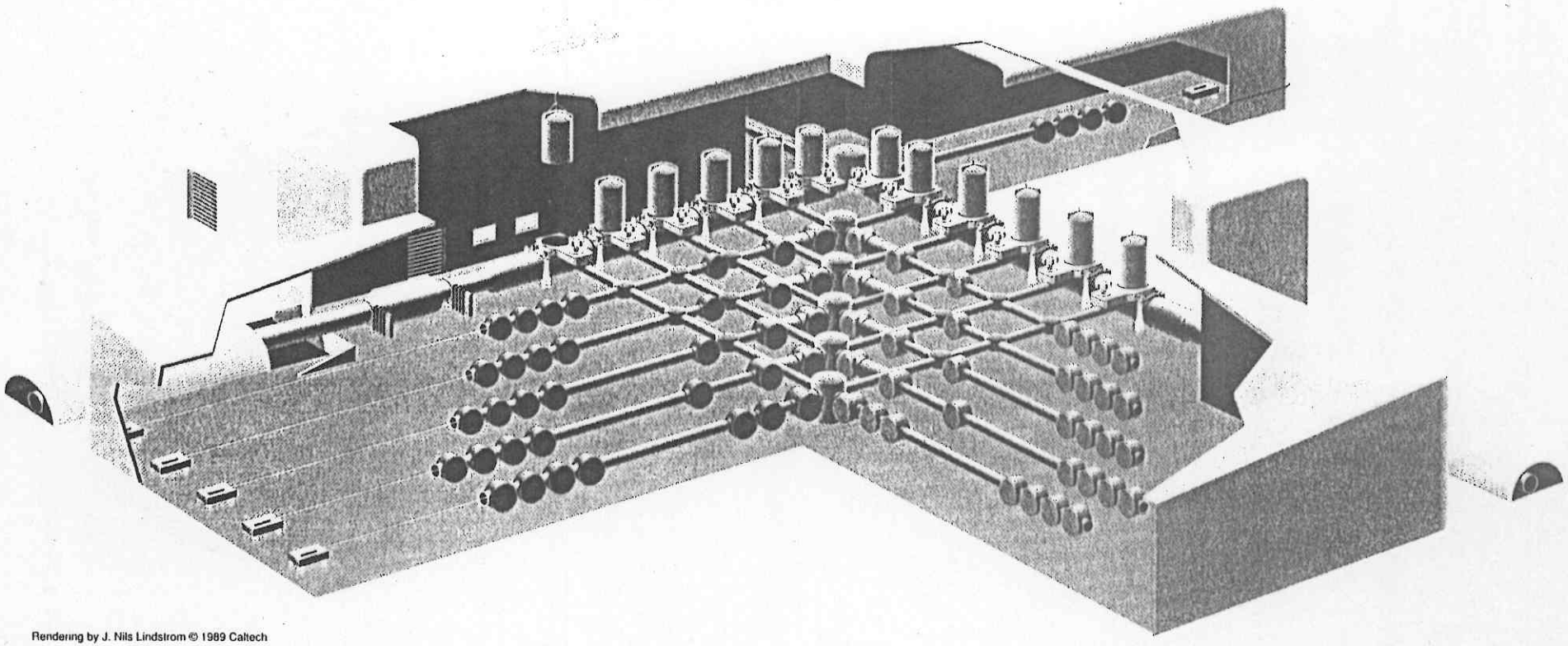

LEGEND:
BSC CHAMBER
TMC CHAMBER
HAM CHAMBER STRING
80K PUMP, LONG
80K PUMP, SHORT
122cm GATE VALVE
ROUGHING PUMP CONNECTION
ION PUMP
GAUGE PAIR
NOTE: PUMP PORTS ON THE BEAM TUBE MODULES ARE NOT SHOWN.
END STATION
BEAM TUBE MODULE (TYPICAL, 4 PLACES)
MID STATION
BEAM MANIFOLD
DIAGONAL SECTION
VERTEX SECTION
BEAM MANIFOLD
CORNER STATION
MID STATION
END STATION
LIGO VACUUM SYSTEM
Washington site
12-1-94 J.Worden

Figure 2.


LIFT - MECHANISM
DOME
ION PUMP
VIBRATION ISOLATION STACK
AIR LOCK UNIT
LOCATING BLOCK
AIR LOCK COVER (OPEN)
INTERNAL SUPPORT BEAM
EXTERNAL SUPPORT BEAM
AIR LOCK ACTUATOR
AIR-SUSPENSION UNIT
SUPPORT
OPTICS UNIT
SERVICE ACCESS PORT
TEST MASS
REACTION MASS
BEAM DEFLECTION MIRROR



Rendering by J. Nils Lindstrom

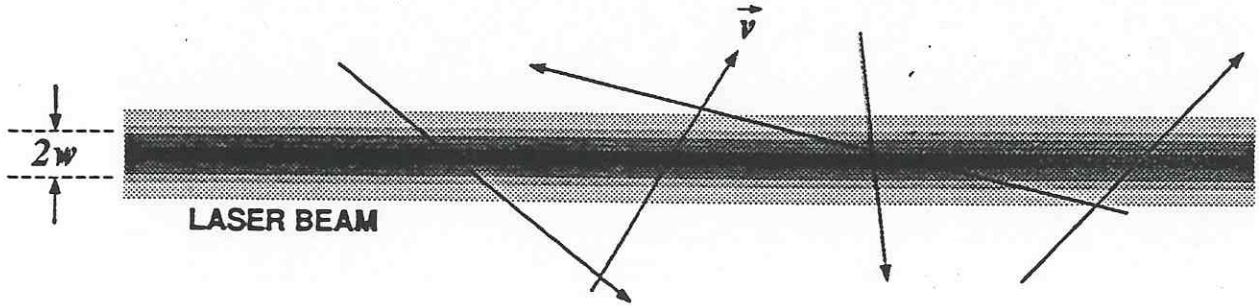


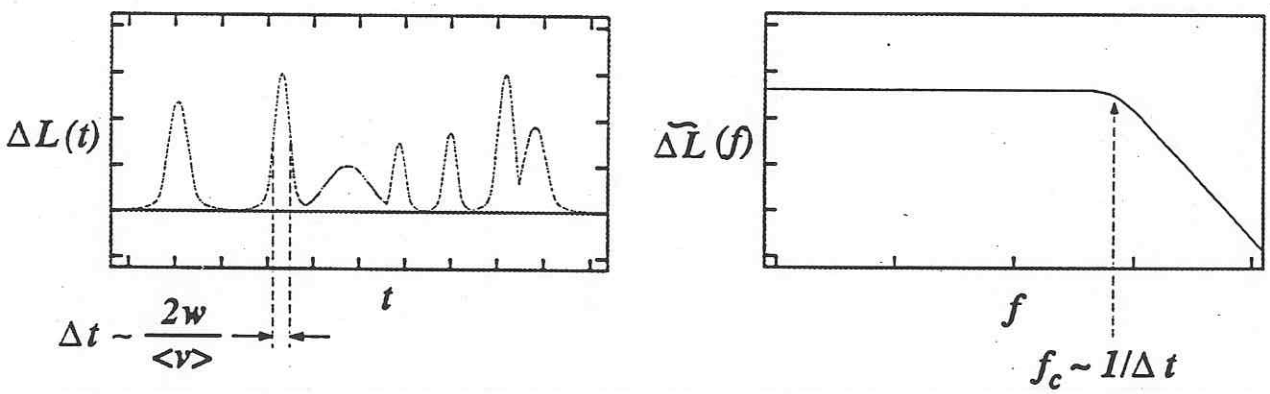
Rendering by J. Nils Lindstrom © 1989 Caltech

Residual Gas Pressure

- Refractive Index Fluctuation Noise
  - General Theory
  - Measured Example
  - Consequence: Allowable Partial Pressures
- Focus: H_2 and H_2O
  - Beam Tube Conductance and End Pumping
  - Condensible vs. Noncondensible
    - * Beam Tube H_2 Driven by Station Outgassing
    - * Beam Tube $H_2O \sim$ Independent of Station

EFFECT OF GAS MOLECULES ON OPTICAL PHASE





$$\widetilde{\Delta L}(f) \propto P^{1/2}\, m^{1/4}\, \alpha \left(\frac{L}{w}\right)^{1/2}$$

where P is the partial pressure of the gas,

α is its molecular polarizability, and

m is its molecular weight .

For diffraction-limited optical systems $w \propto L^{1/2}$ so strain noise

$$\tilde{h}(f) = \widetilde{\Delta L}(f)/L \propto L^{-3/4}.$$

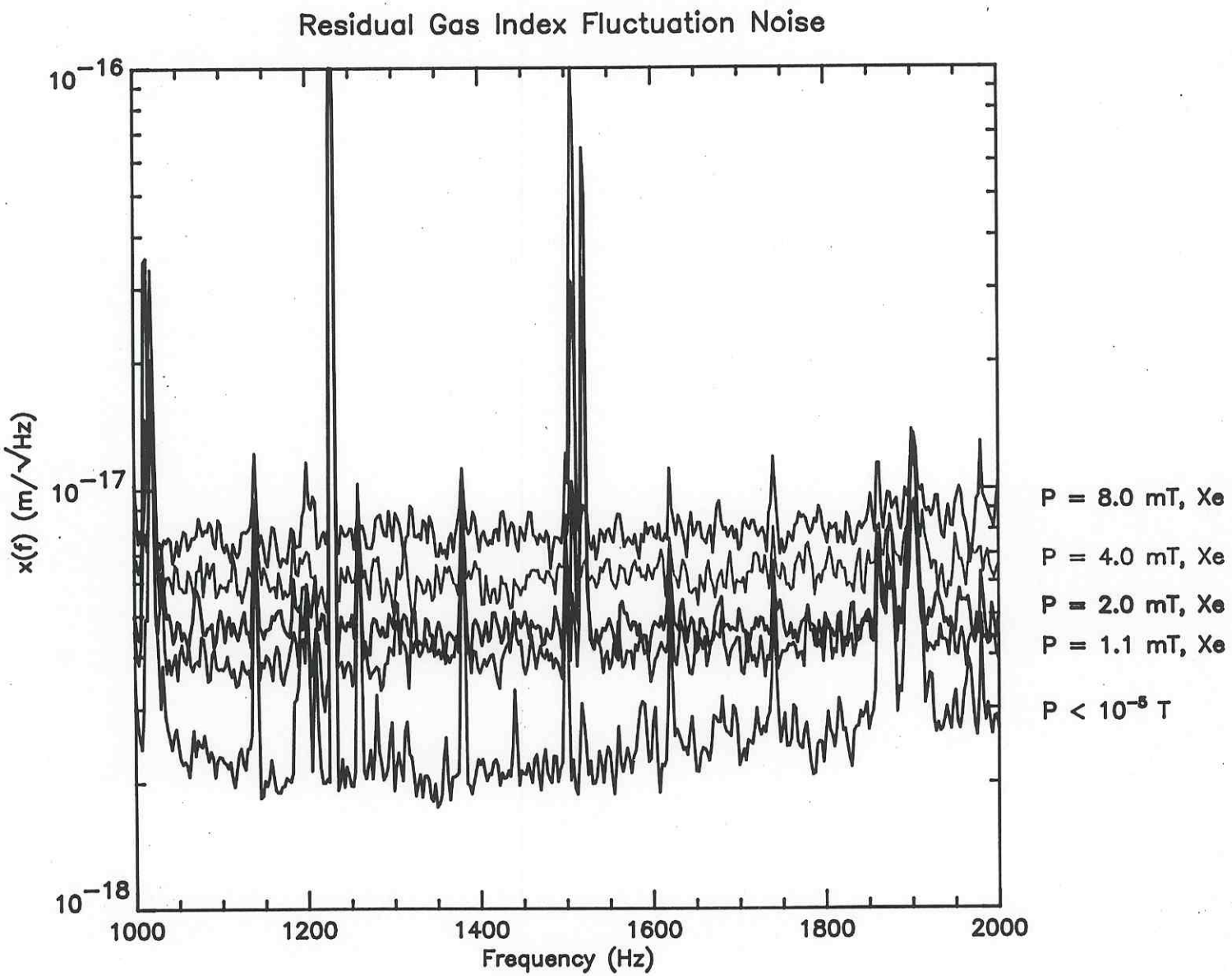
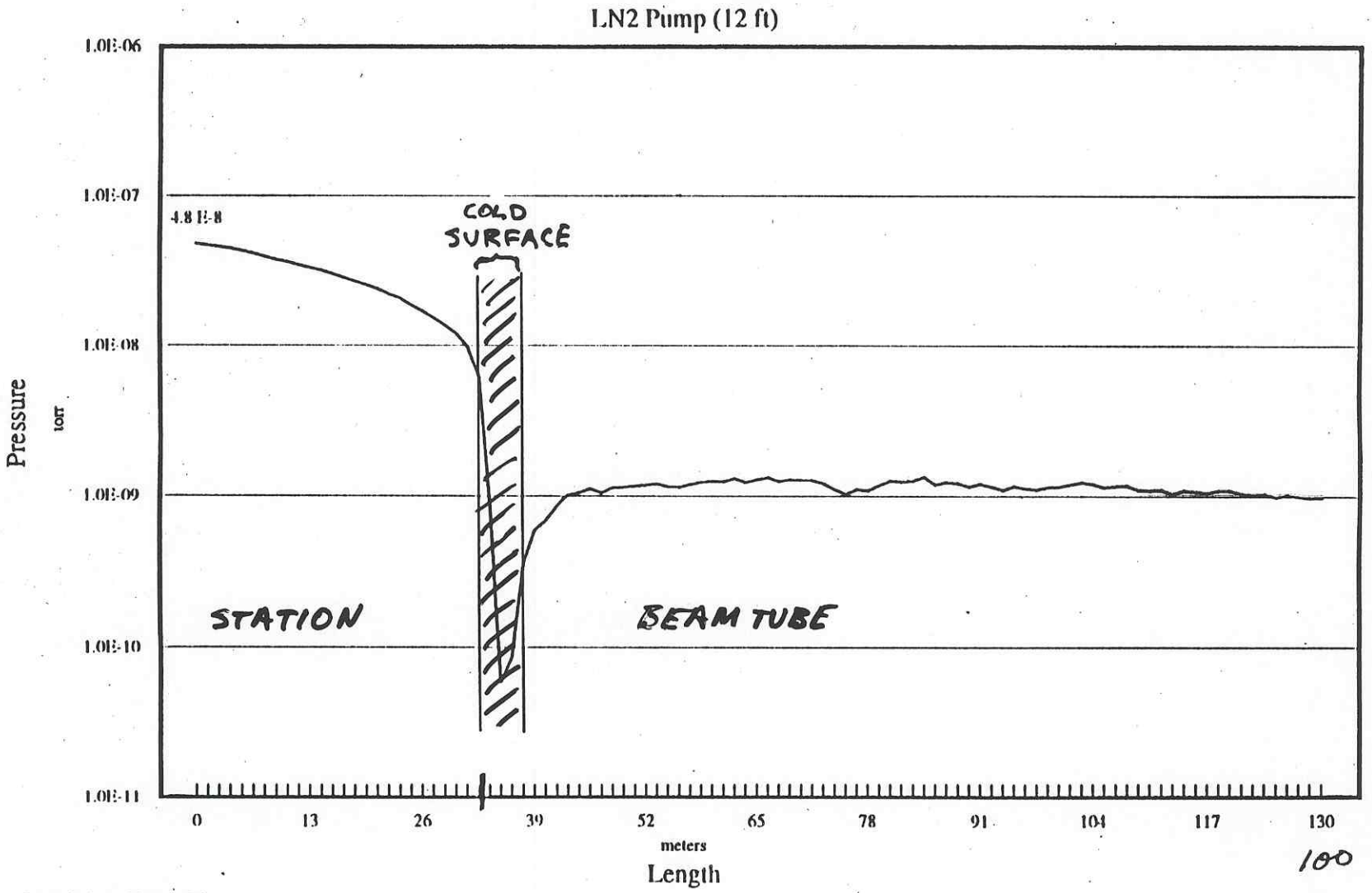

Residual Gas Index Fluctuation Noise
10^{-16}
10^{-17}
10^{-18}
x(f) (m/√Hz)
1000
1200
1400
1600
1800
2000
Frequency (Hz)
P = 8.0 mT, Xe
P = 4.0 mT, Xe
P = 2.0 mT, Xe
P = 1.1 mT, Xe
P < 10^{-5} T

Table 1 Maximum allowable residual gas partial pressures for each section, after conditioning procedures described in text. Measurements are to be taken with ion pumps operating, and with the section under test exposed to operating 80 K pump.

Gas Species	Partial Pressure - torr
H_2O	5×10^{-9}
H_2	5×10^{-9}
N_2	5×10^{-10}
CO	5×10^{-10}
CO_2	2×10^{-10}
CH_4	2×10^{-10}
All others	5×10^{-10}

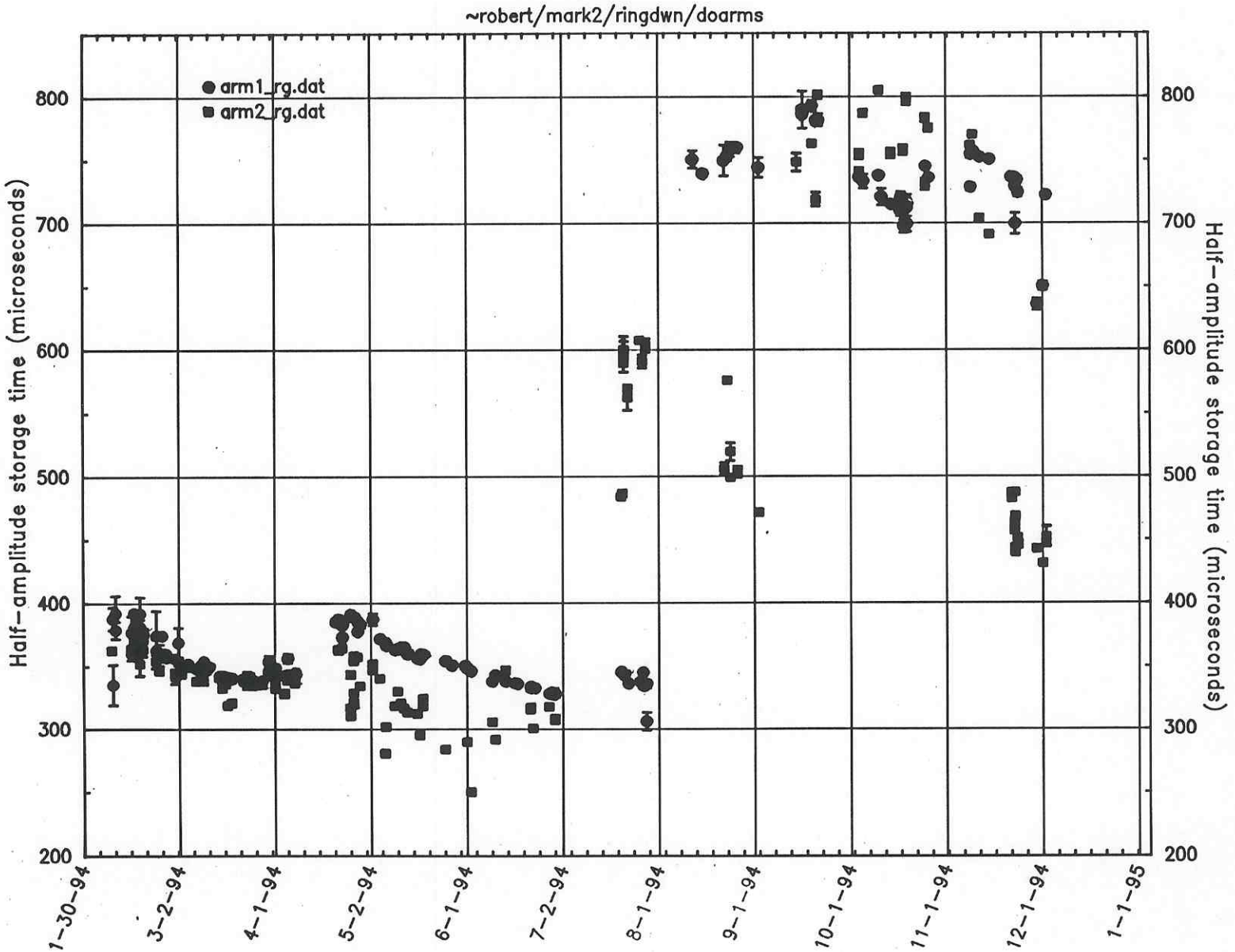
Pressure Distribution



Pump is from 33.6 to 37.2 m
Q(gas load) is .001 tl/s

40 m arm storage times

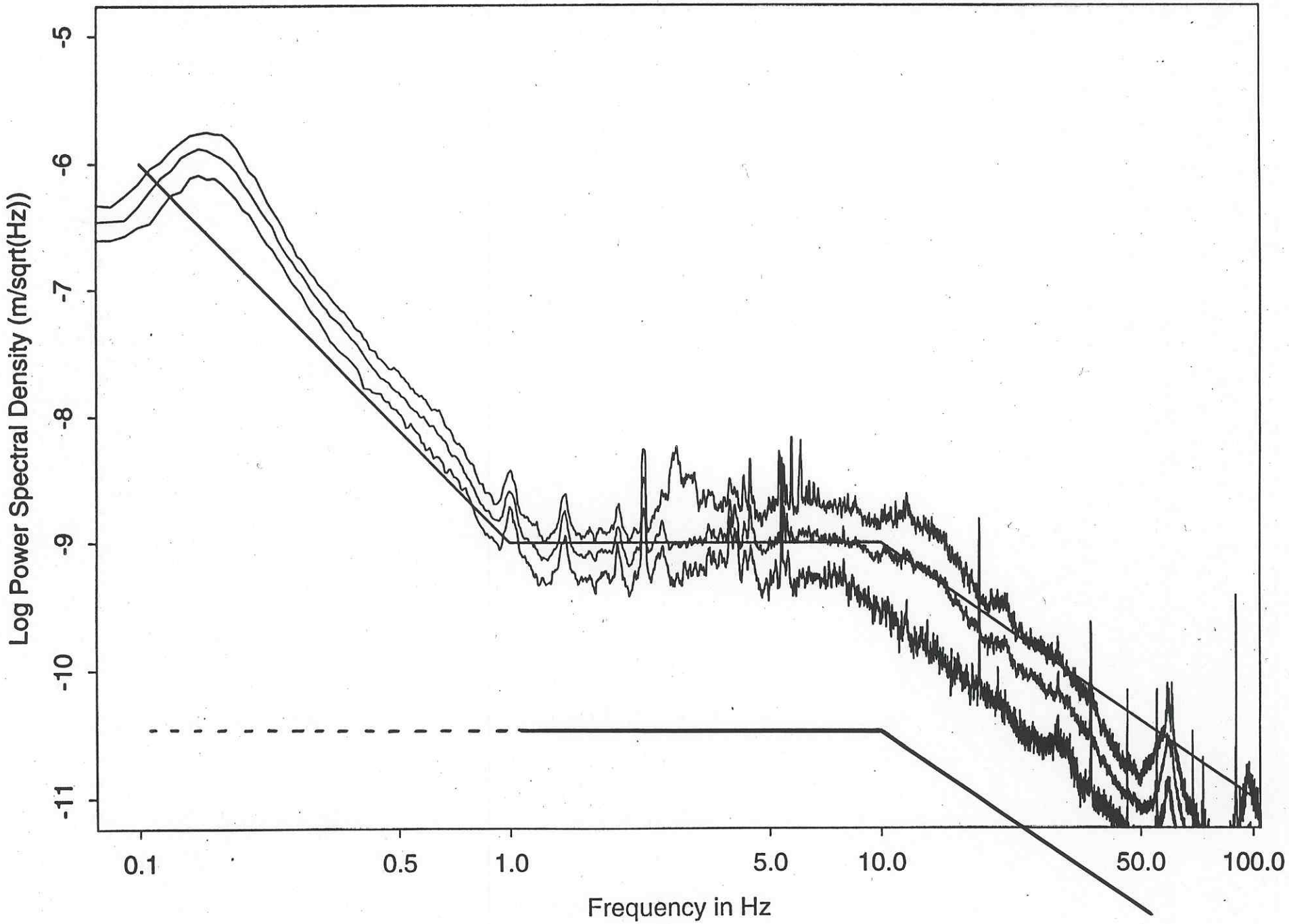
~robert/mark2/ringdwn/doarms



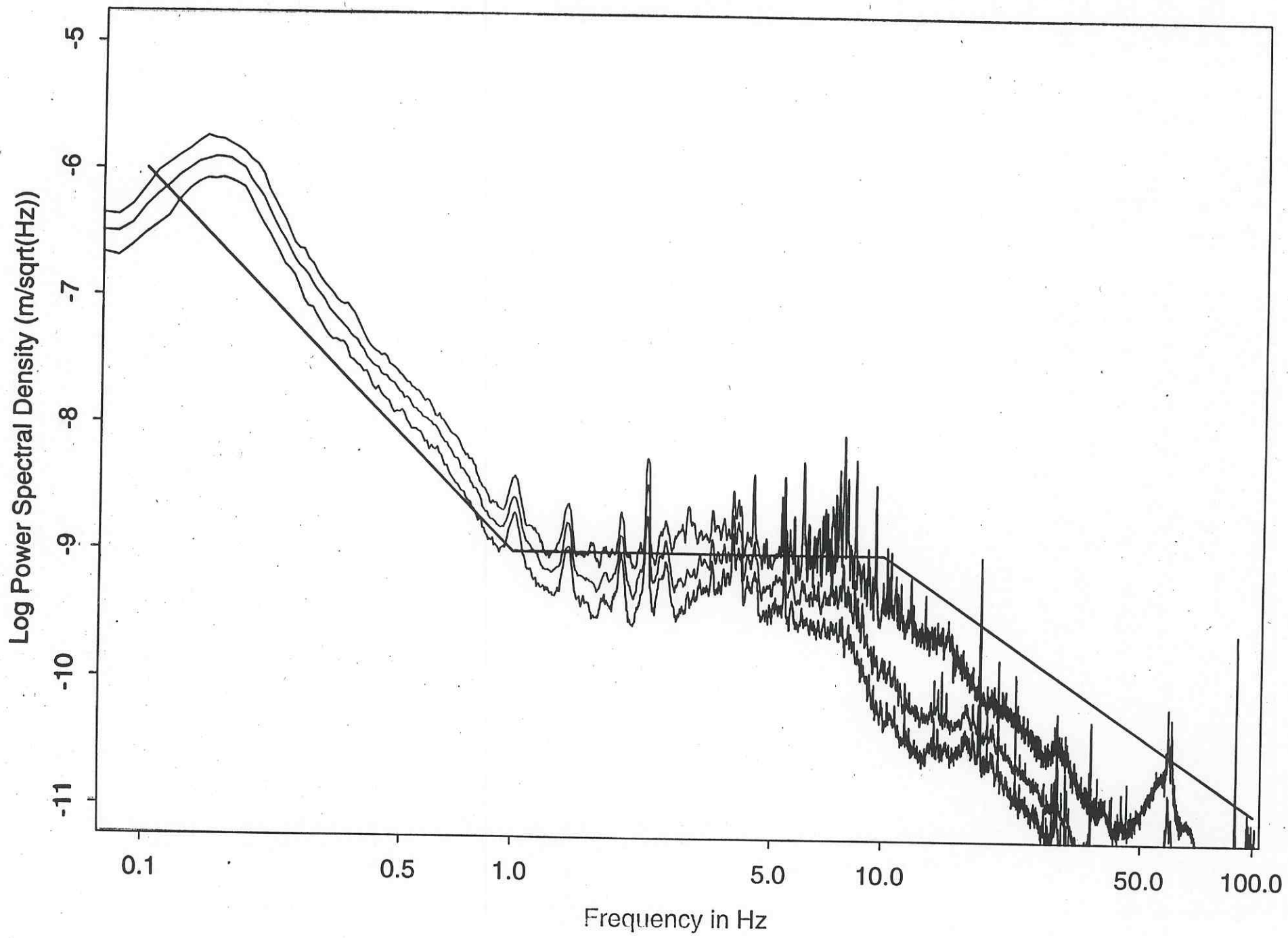
Special Environmental Constraints

- Particle generation
- EMI
- Shock, Vibration & Acoustics
  - Main Concern: Normal Operations (ion/getter, 80 K pumps)
  - Added Feature: Quiet Turbopumping
    Main Impact: Observing Operations and Availability
  - Shock Limit: Prevents "Irreversible" Misalignment

Corner Station North Axis, Morning Traffic December 13



Corner Station North Axis, Late Night December 12



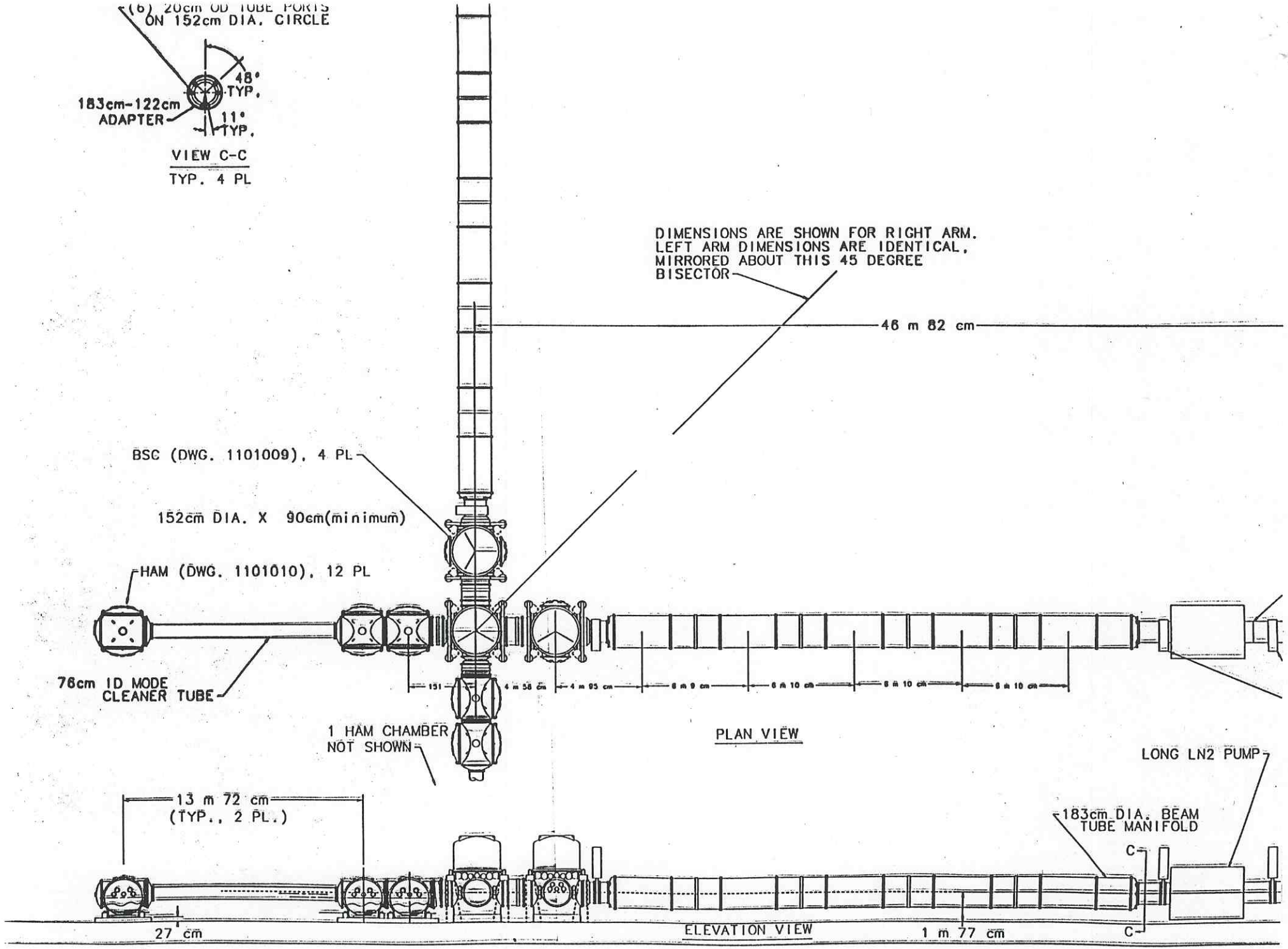
Operations

- Operating Phases
  - Installation & Commissioning
  - Observing Operations
  - Detector Service and Upgrades
- Cycling Scenarios

Operating Phase	Under Vacuum (typ.)	Vented (typ.)
Commissioning	1 month	2 weeks
Observing	$>$ 1 year	$<$ 1 week
Upgrade	3 months	3 weeks

Table 1: *Anticipated vent/pumpdown frequencies and durations during different phases of observatory operations. Preliminary, subject to revision.*

- Tolerable Interruptions & Downtime in Observing Phase:
  No more than 1/2 day per month (TBR) allotted for required maintenance, e.g. trap regeneration, which disables detector by blocking beam tube, causing elevated vibration levels, etc.


(6) 20cm OD TUBE PORTS ON 152cm DIA. CIRCLE
48° TYP.
183cm-122cm ADAPTER
11° TYP.
VIEW C-C
TYP. 4 PL
DIMENSIONS ARE SHOWN FOR RIGHT ARM. LEFT ARM DIMENSIONS ARE IDENTICAL, MIRRORED ABOUT THIS 45 DEGREE BISECTOR
46 m 82 cm
BSC (DWG. 1101009), 4 PL
152cm DIA. X 90cm(minimum)
HAM (DWG. 1101010), 12 PL
76cm ID MODE CLEANER TUBE
1 HAM CHAMBER NOT SHOWN
PLAN VIEW
13 m 72 cm (TYP., 2 PL.)
183cm DIA. BEAM TUBE MANIFOLD
LONG LN2 PUMP
C
C
27 cm
ELEVATION VIEW
1 m 77 cm