Kolkata Superconducting Cyclotron

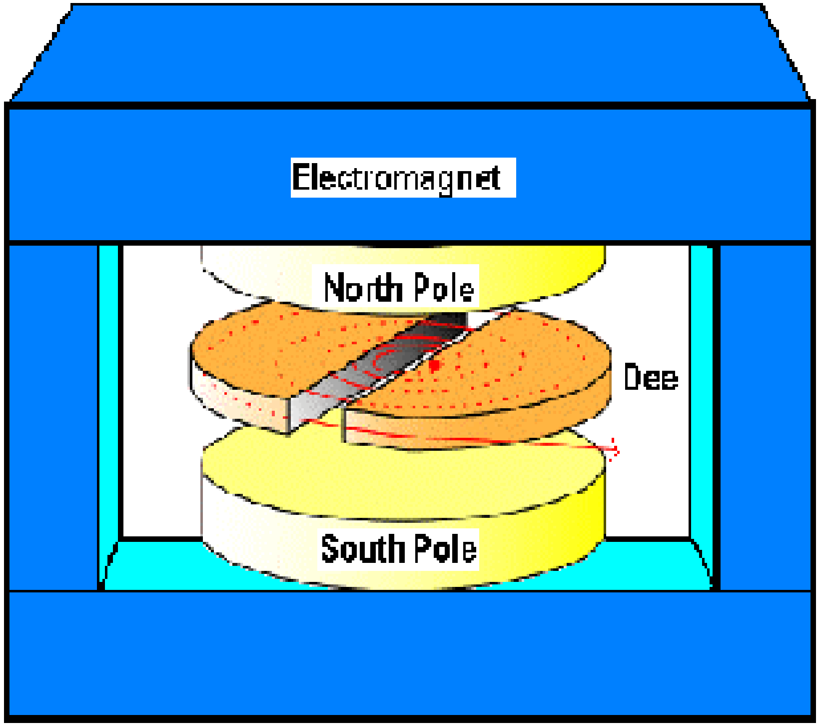
R.K. Bhandari

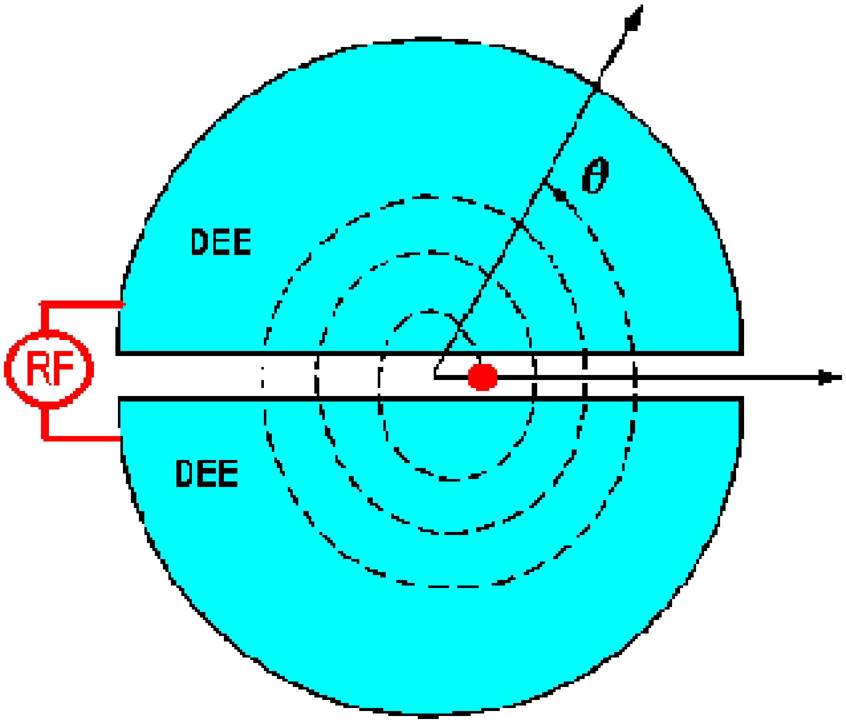
Variable Energy Cyclotron Centre
Kolkata, INDIA

Joint Accelerator School(JAS'08), RRCAT, Indore, January 14, 2008

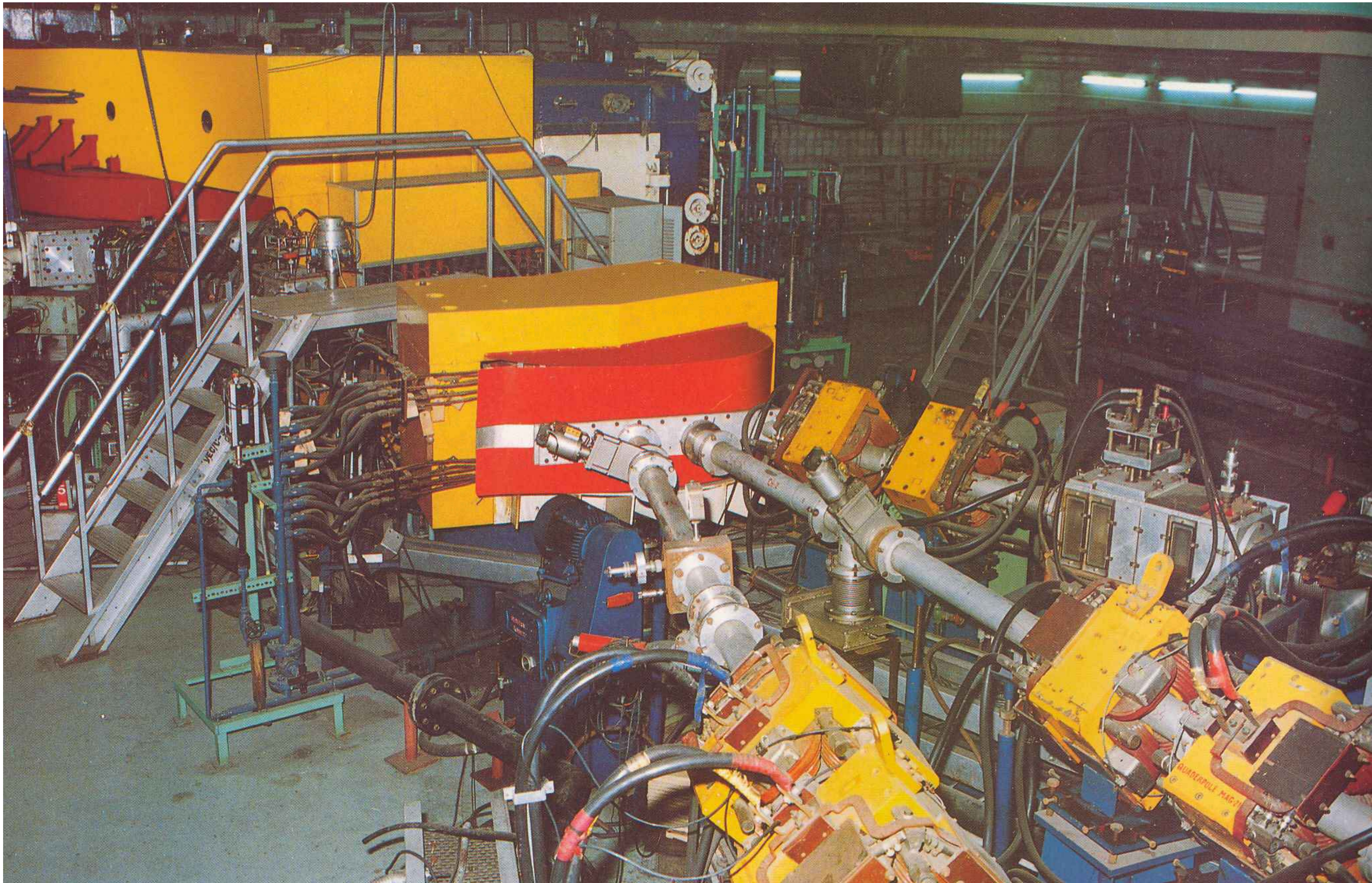
Cyclotron

$$(E/A = q^2B^2R^2/2m^2)$$



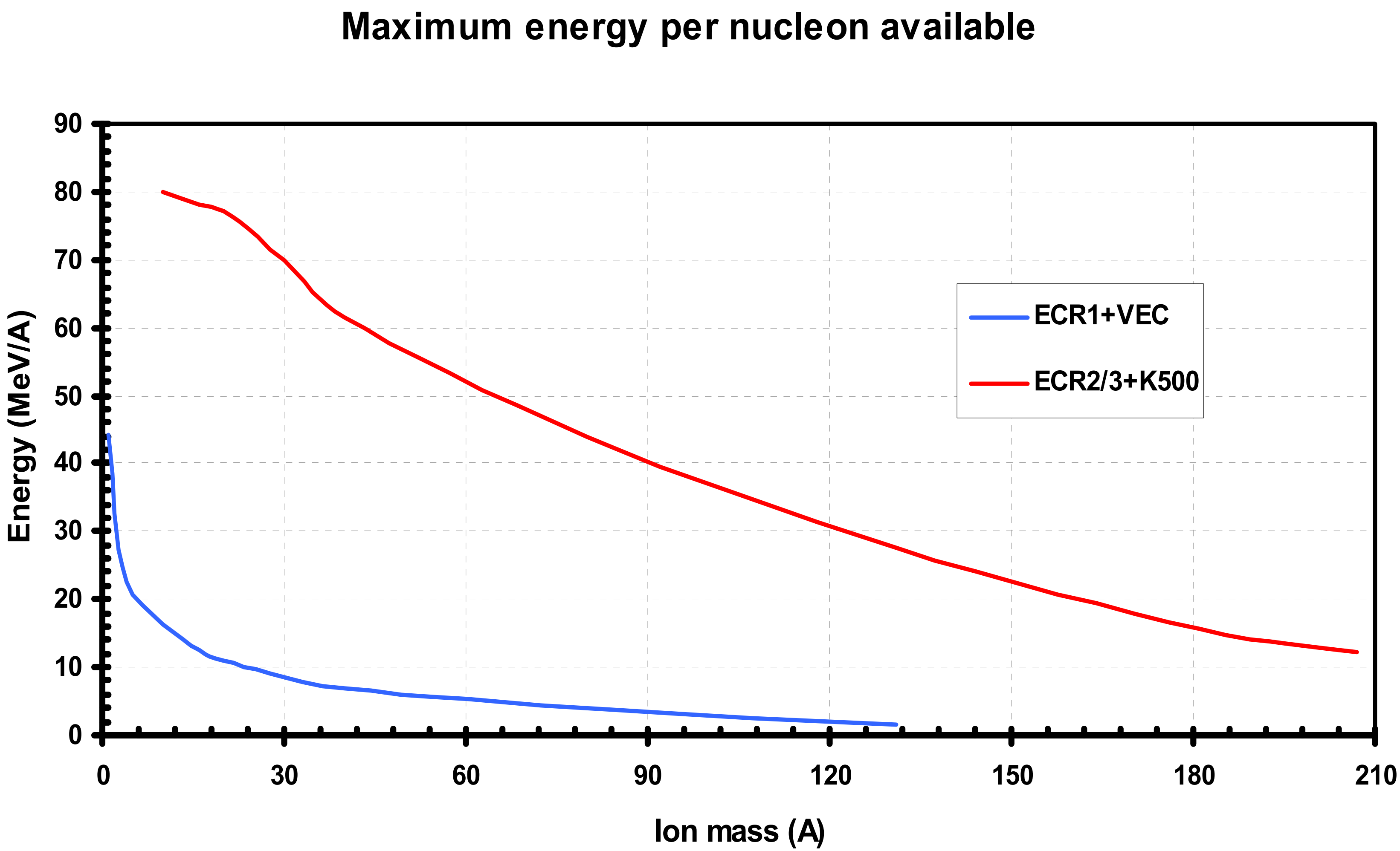


224cm Variable Energy Cyclotron

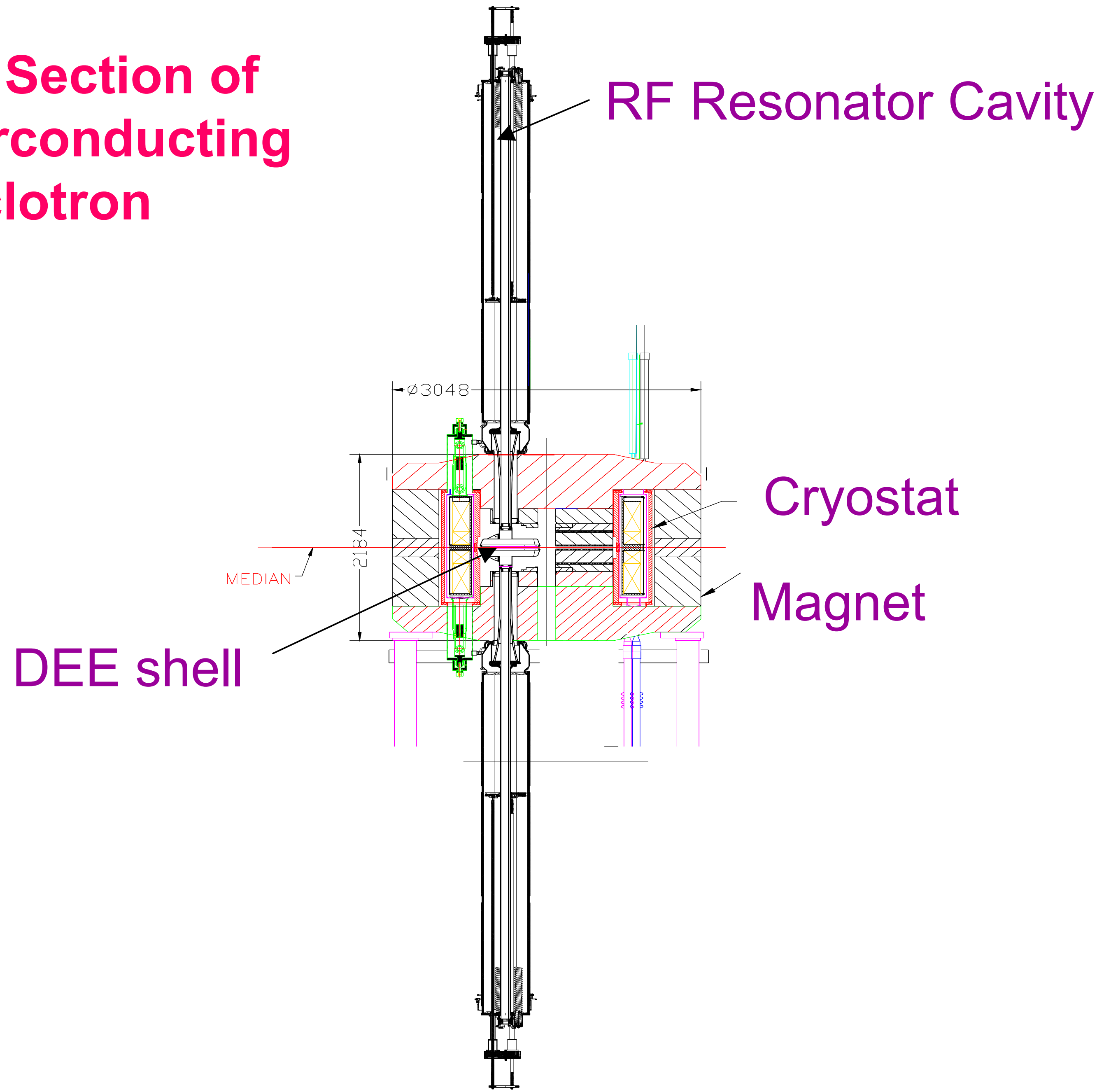


Expected Ion Beams from K 500 SC

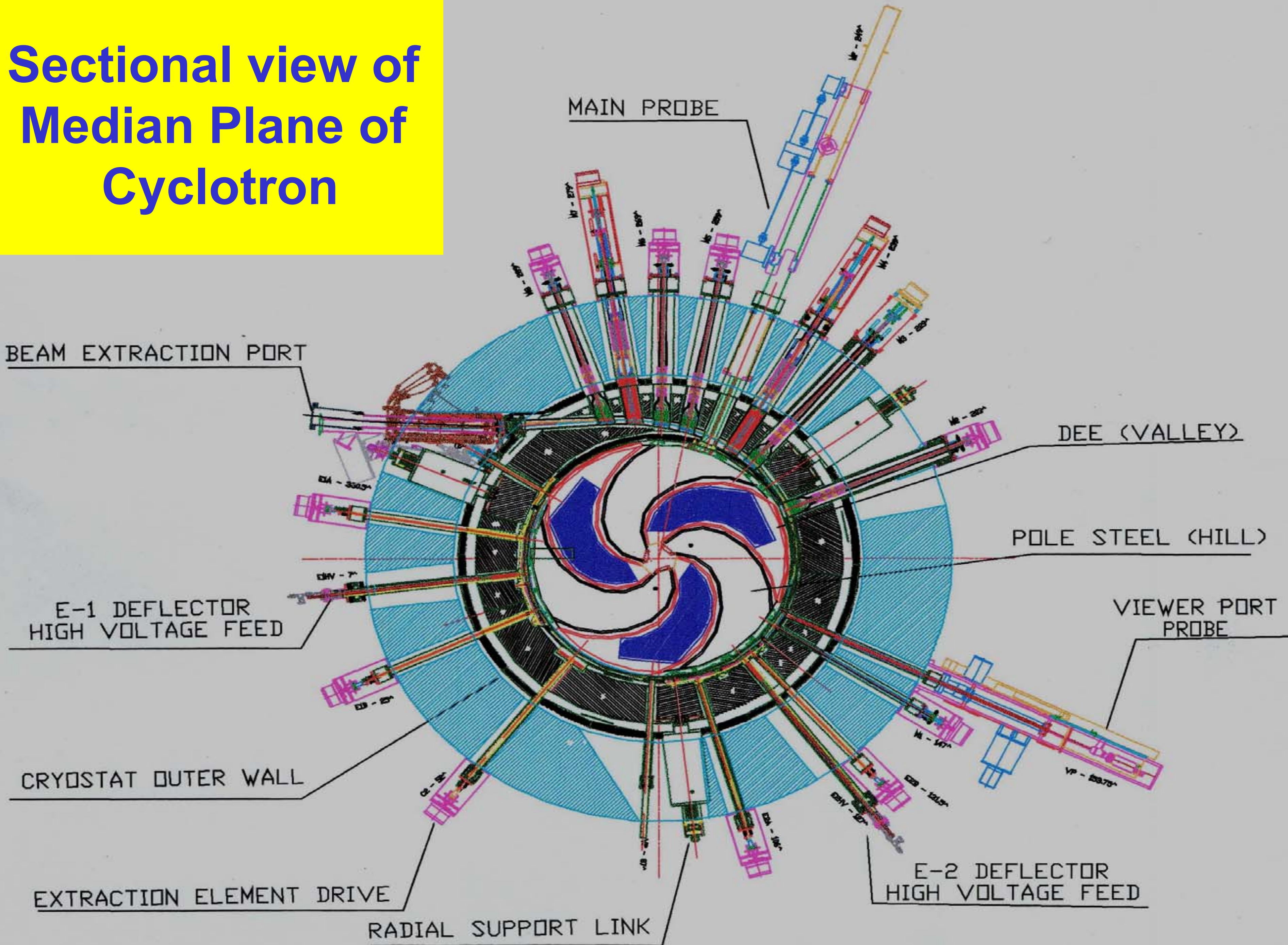
(based on 10 μA extracted from ion source)



Vertical Section of the Superconducting Cyclotron

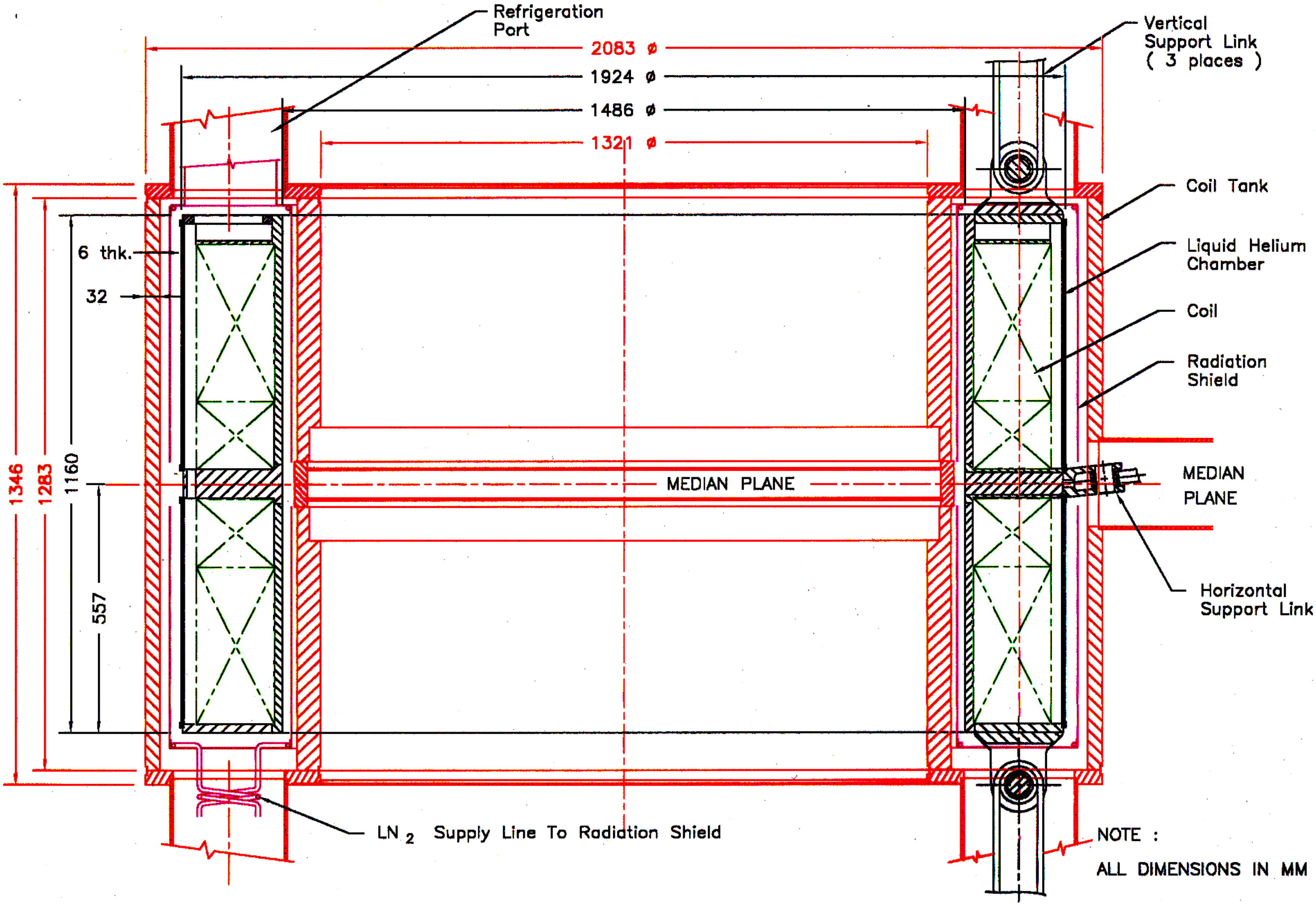


Sectional view of Median Plane of Cyclotron

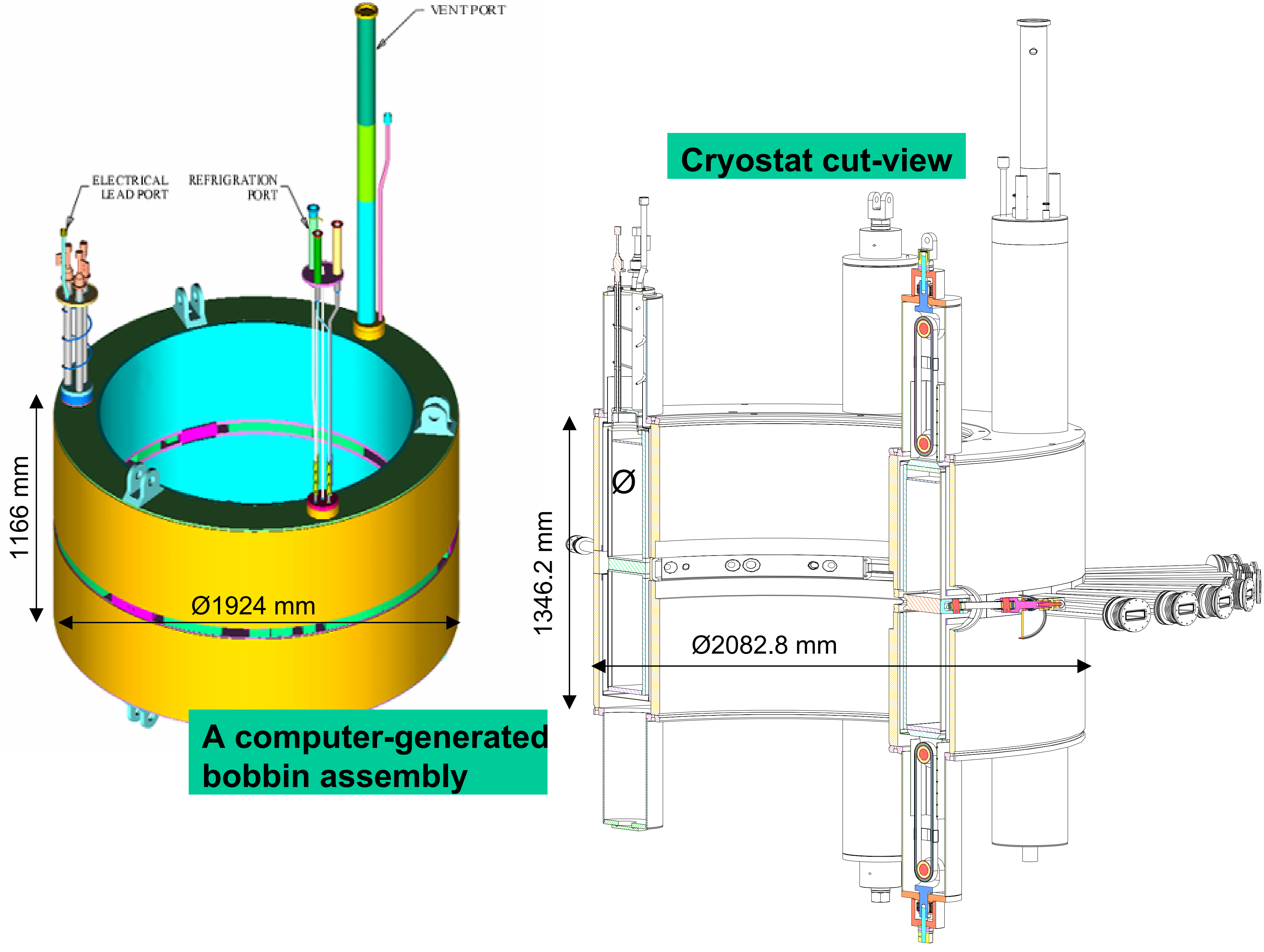


Lower part of the magnet frame

SUPERCONDUCTING COIL AND CRYOSTAT



CRYOSTAT ASSEMBLY

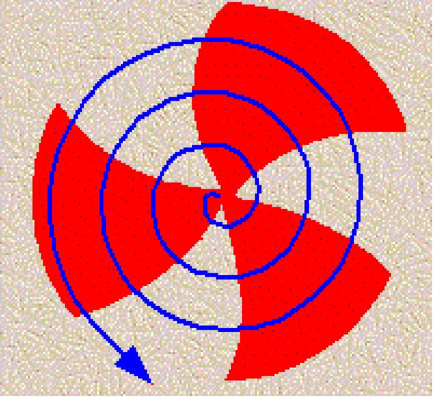

VENT PORT
ELECTRICAL LEAD PORT
REFRIGRATION PORT
1166 mm
Ø1924 mm
A computer-generated bobbin assembly
Cryostat cut-view
Ø
1346.2 mm
Ø2082.8 mm

Cryogenic Test Laboratory

Superconducting coil winding facility

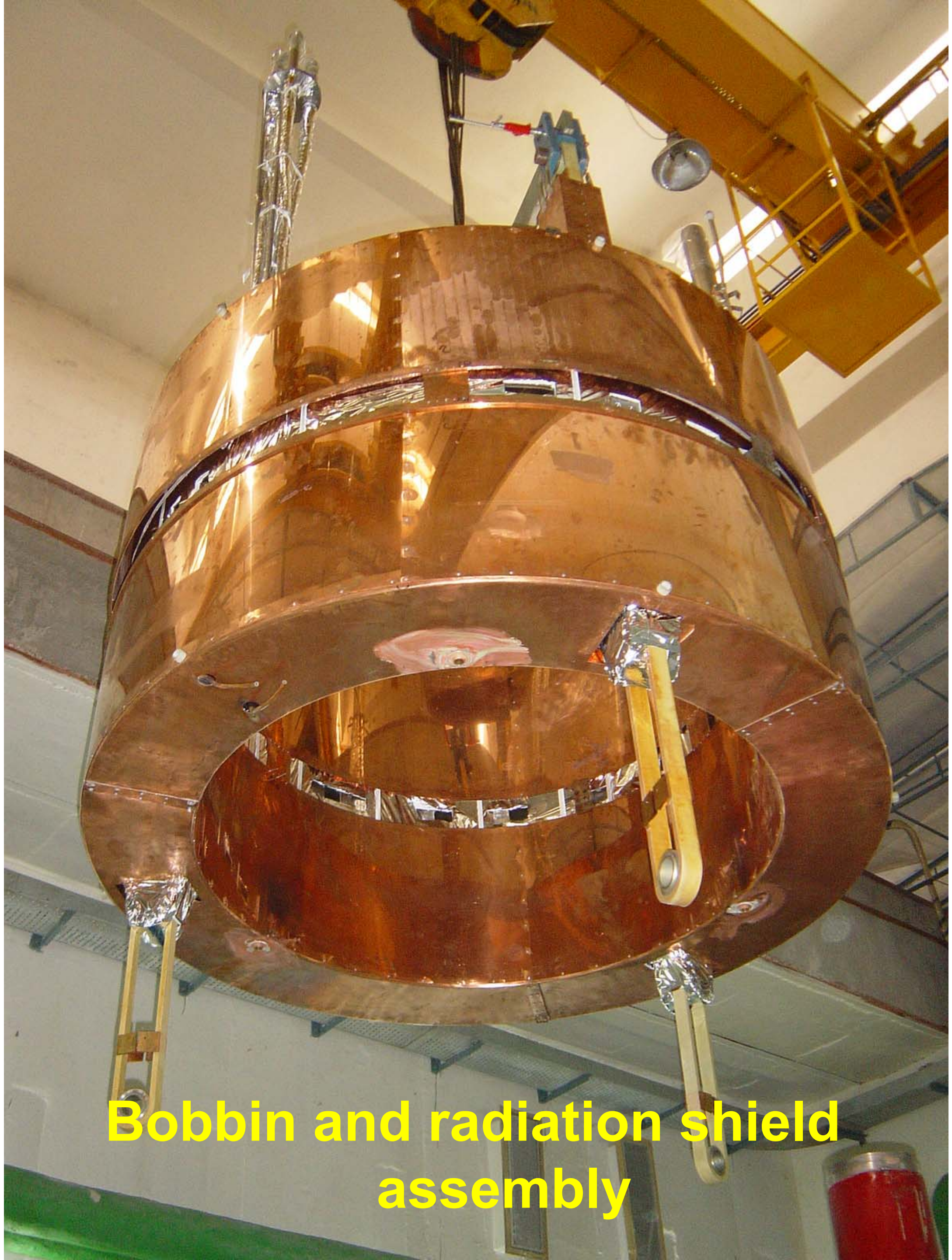
Pressure arm assembly of the winding machine

Bobbin with helium lines

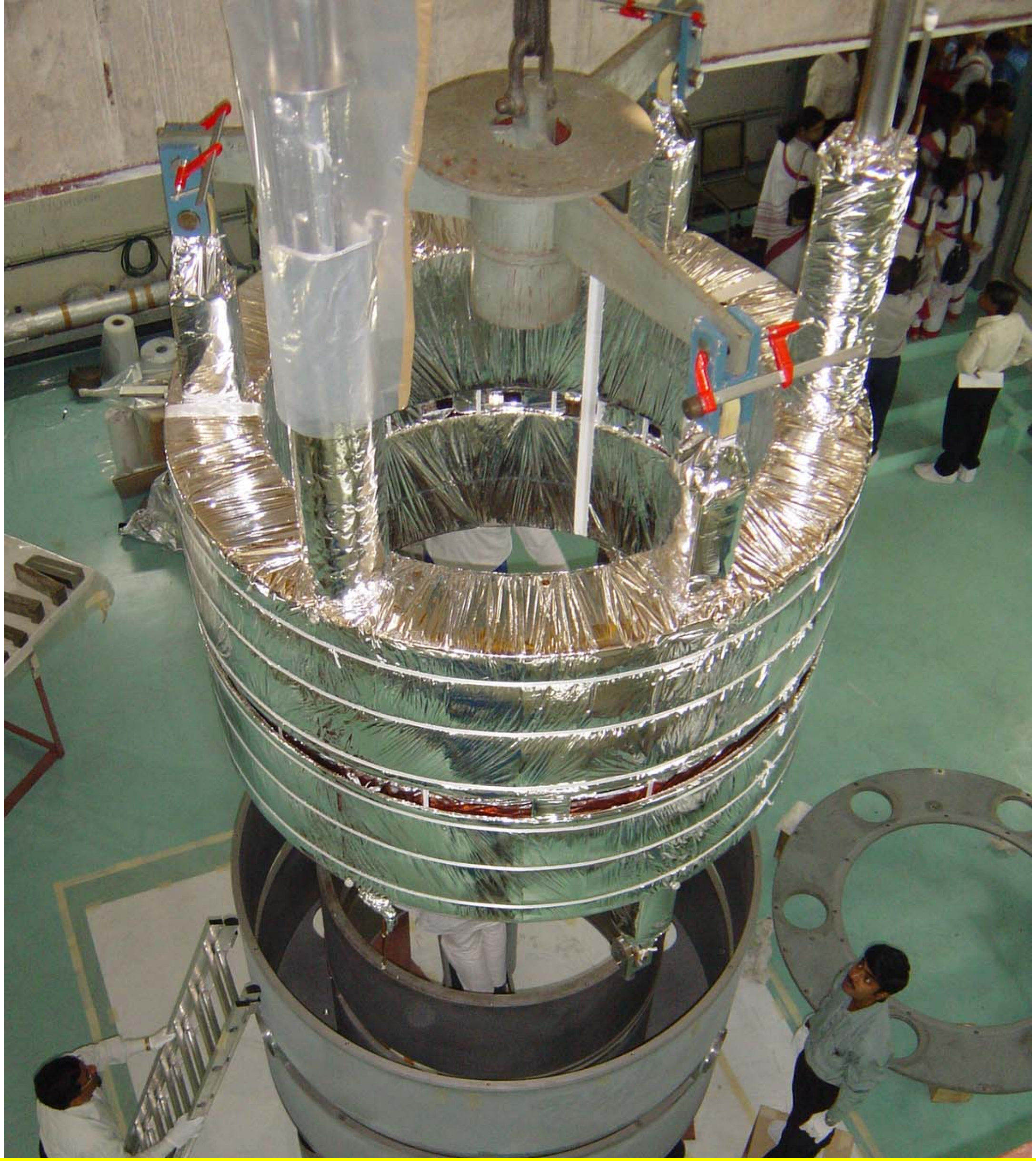


Cryostat bobbin with vapour-cooled current leads and refrigeration port.

Insulated Bobbin assembly



Bobbin and radiation shield assembly

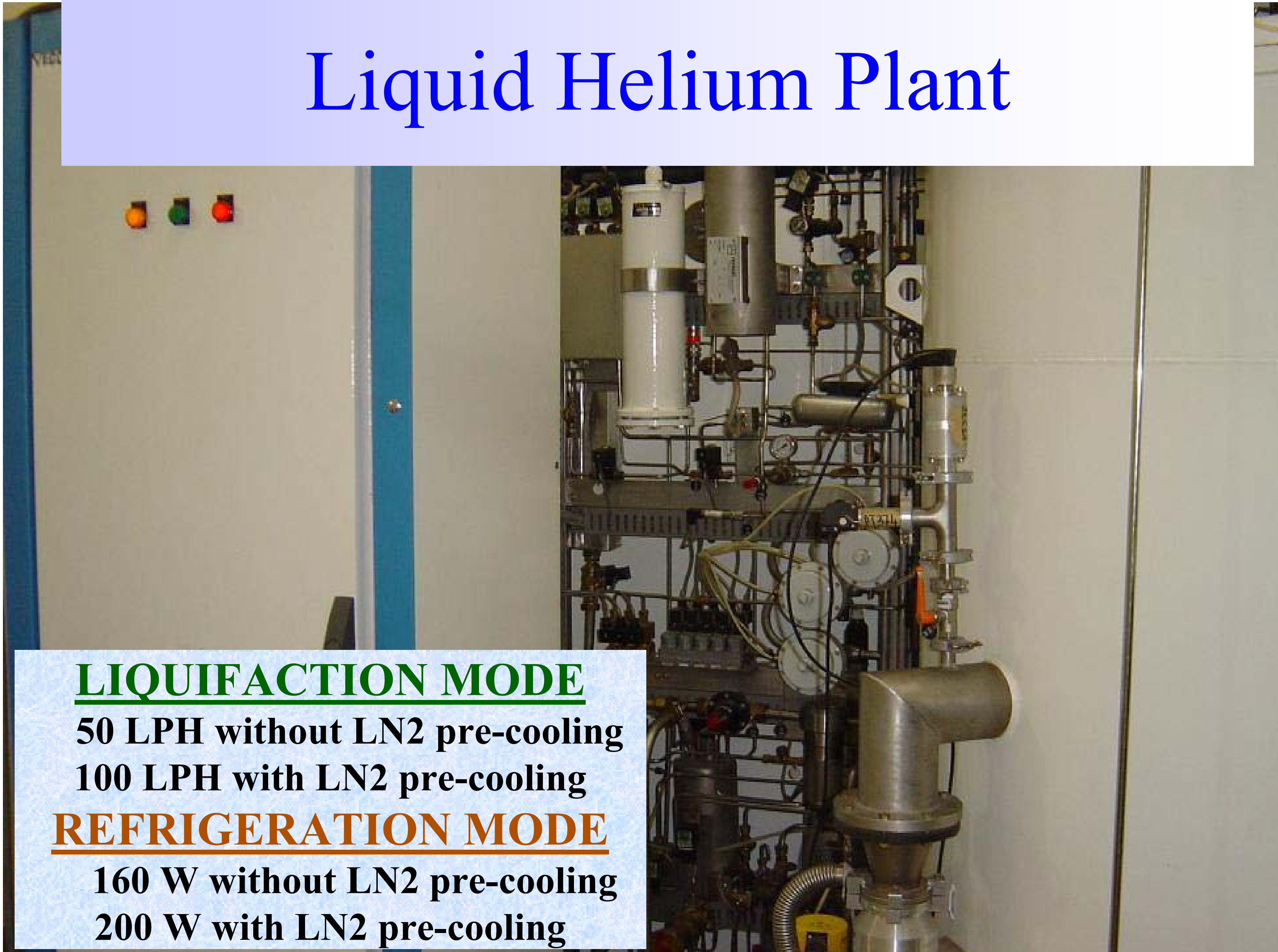


Insulated bobbin & radiation shield being inserted into vacuum chamber

Cryostat assembly

CRYOGENIC PLANT
&
CRYOGEN DELIVERY SYSTEM

Liquid Helium Plant



LIQUIFACTION MODE

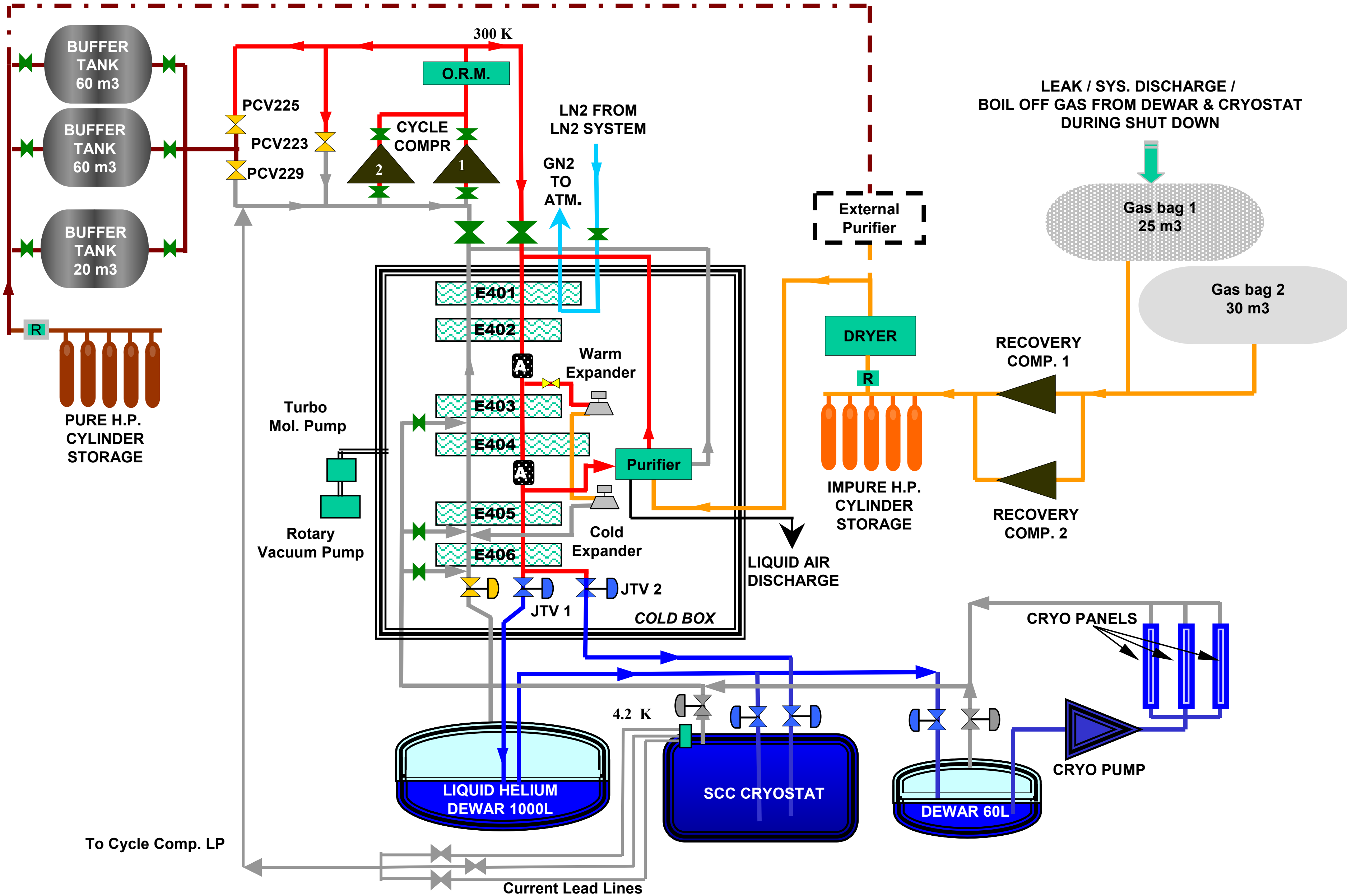
50 LPH without LN2 pre-cooling

100 LPH with LN2 pre-cooling

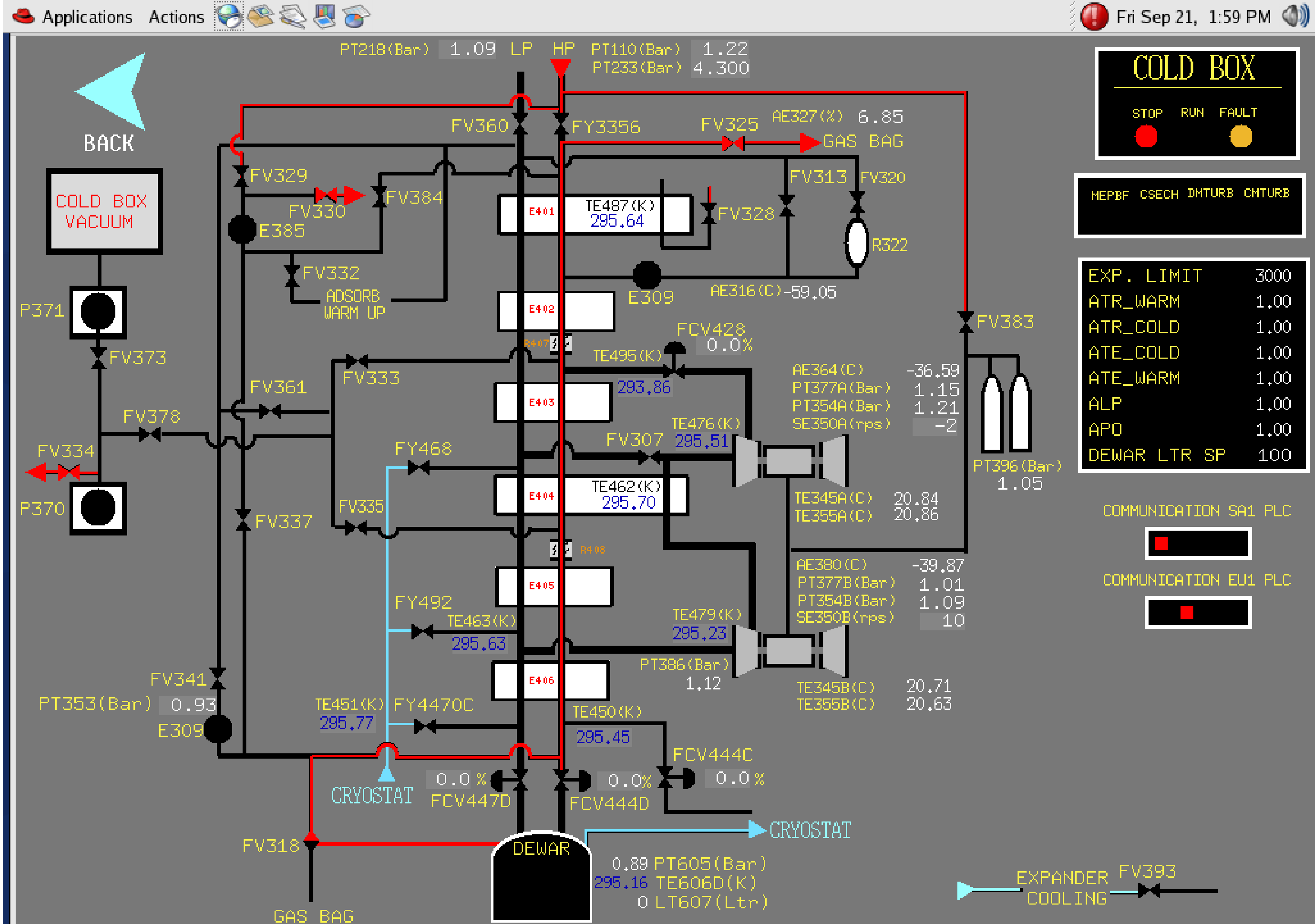
REFRIGERATION MODE

160 W without LN2 pre-cooling

200 W with LN2 pre-cooling



Schematic PID of cryogenic system for helium

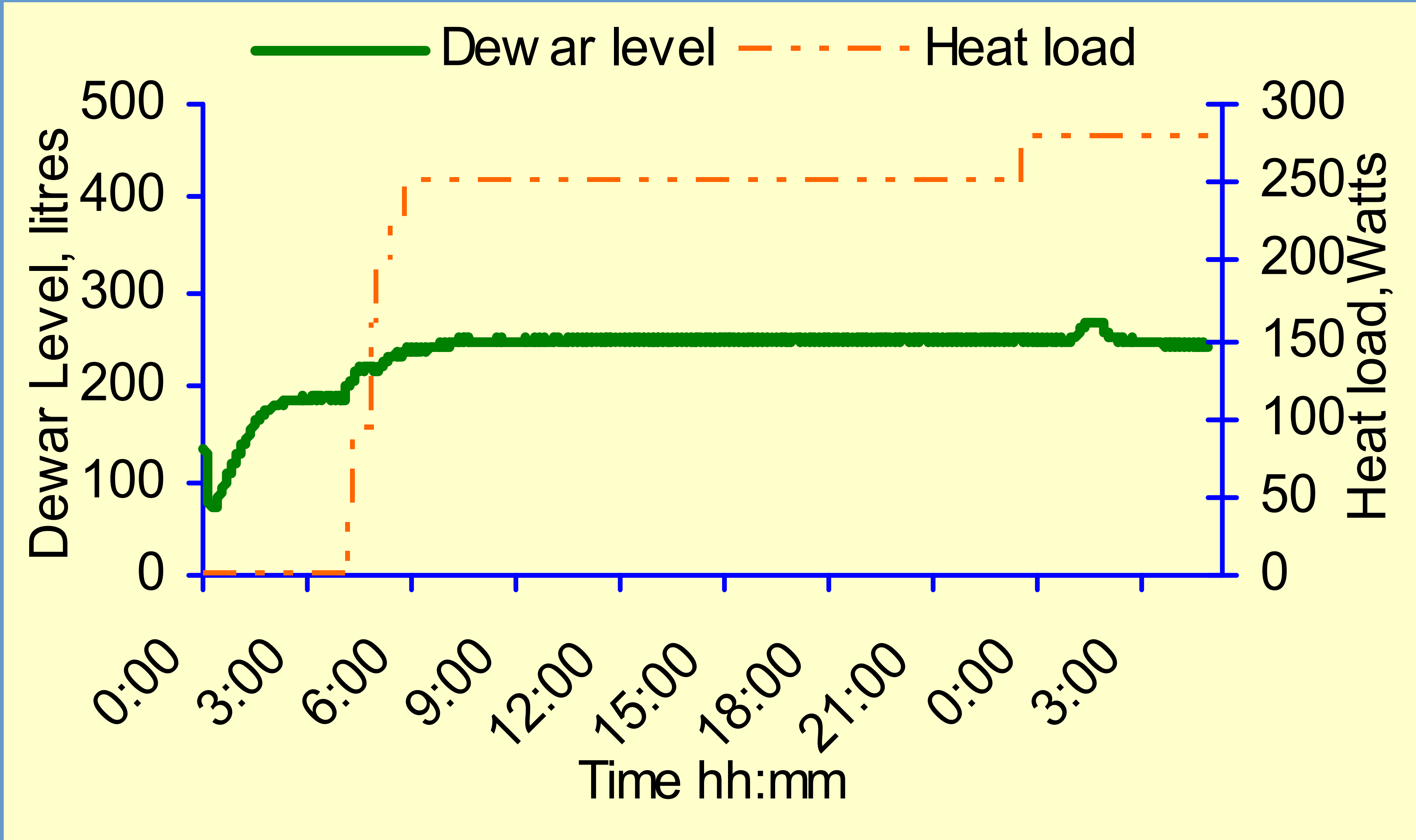


HMI window for the helium plant

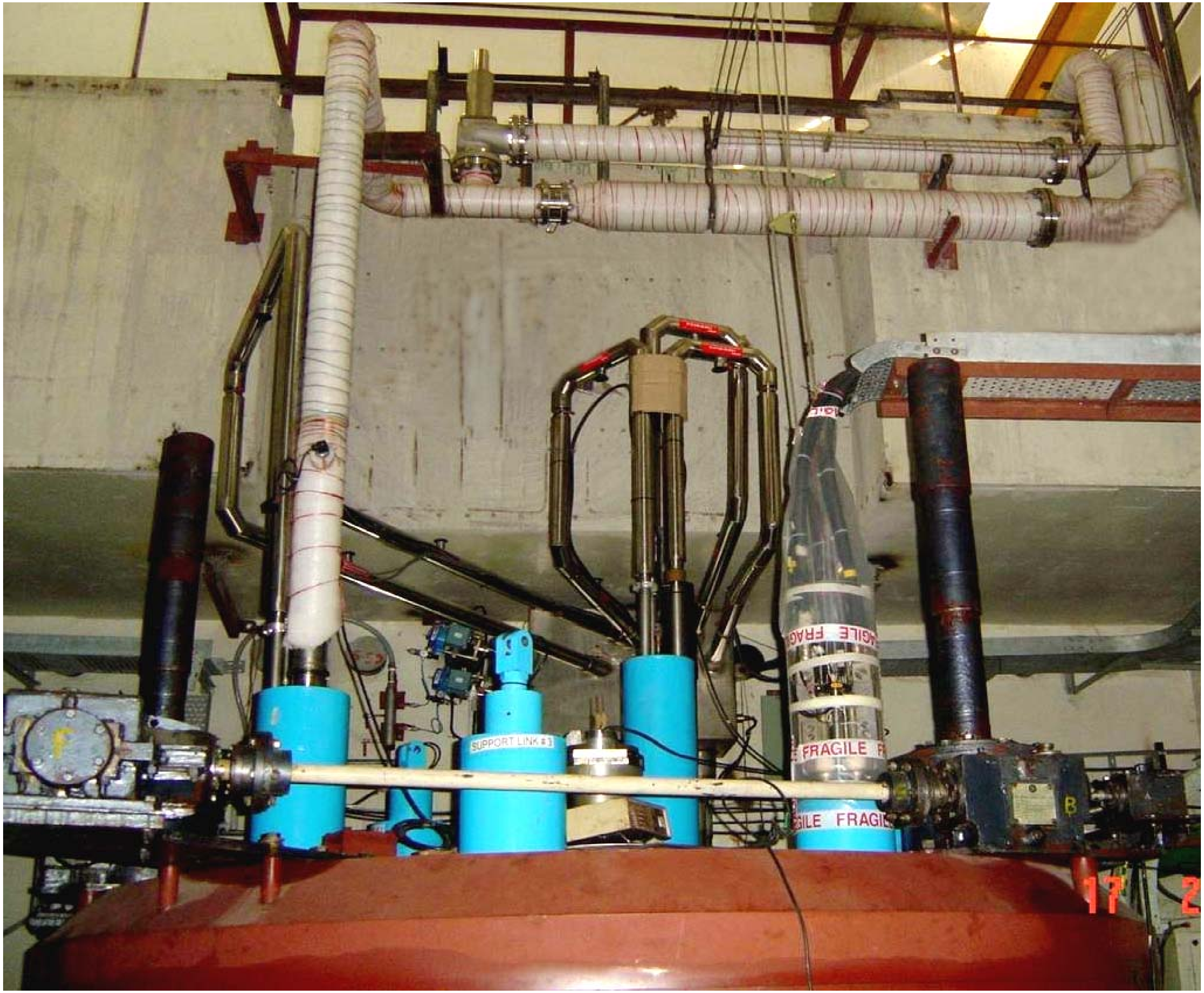
Inside the Liquid Helium Plant

Cold Box With Exterior MLI

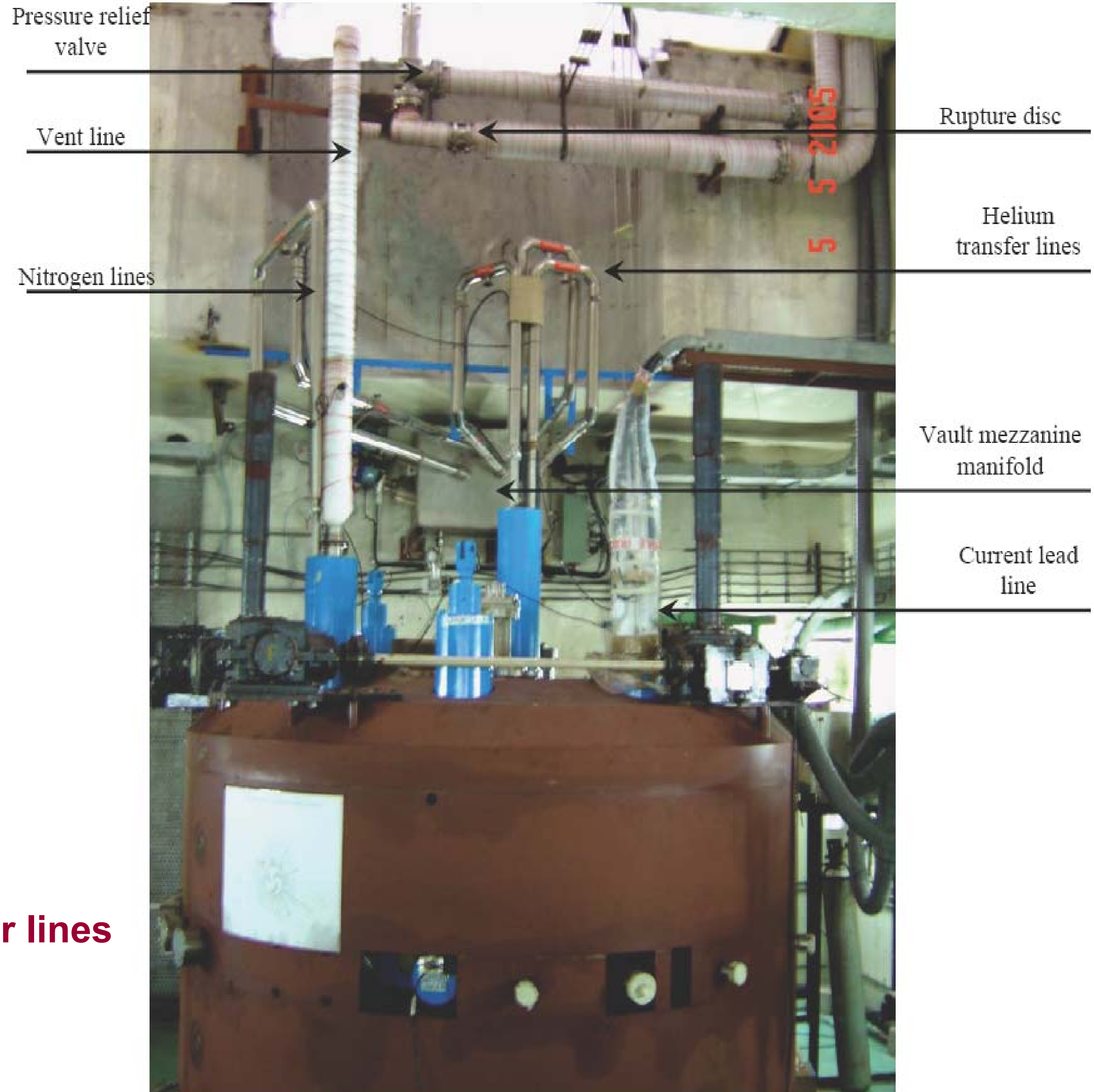
Cold Box Without MLI



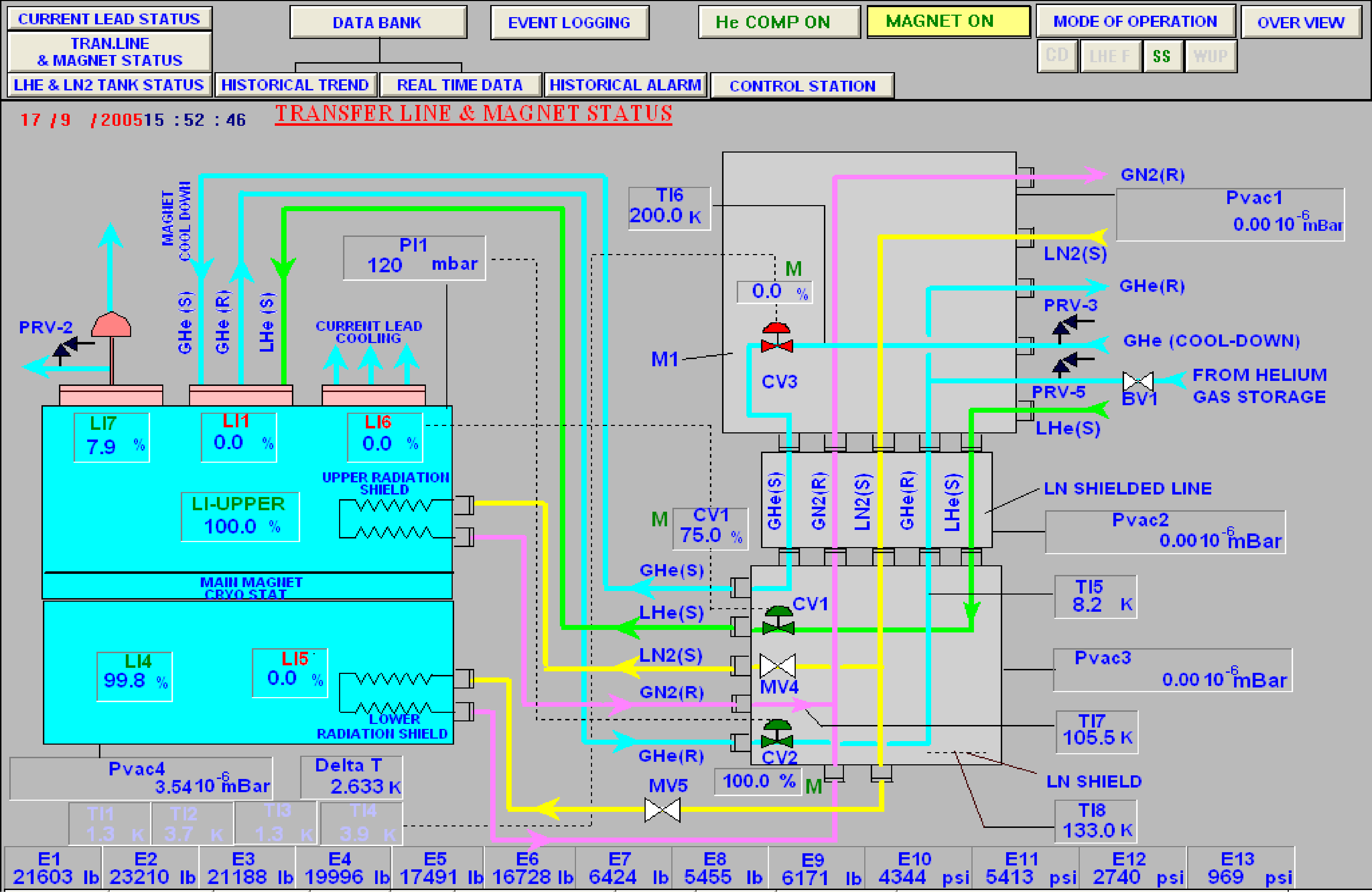
Measured refrigeration load of helium liquifier at 4.5K without LN2 pre-cooling



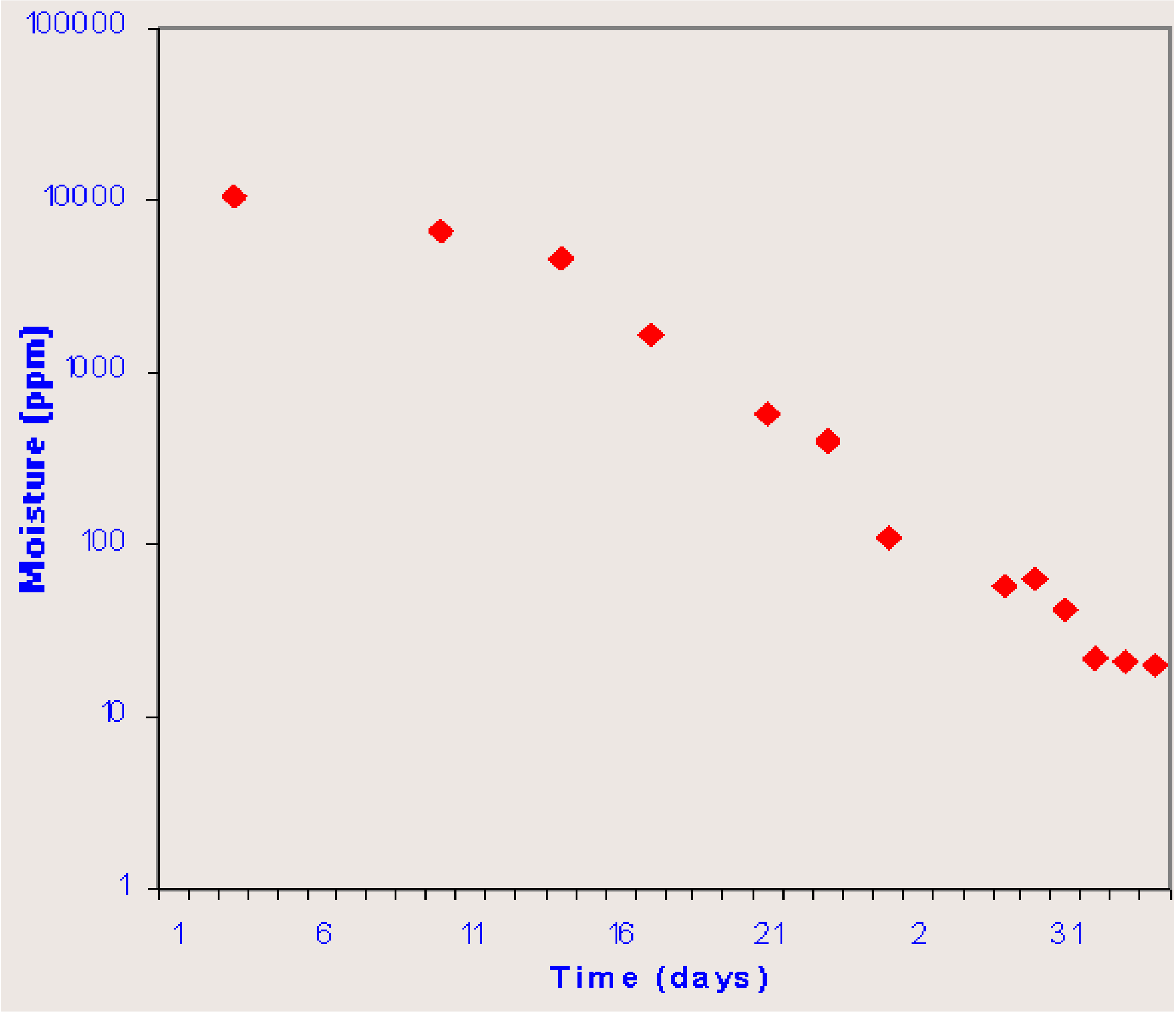
Transfer lines connected to the SC magnet



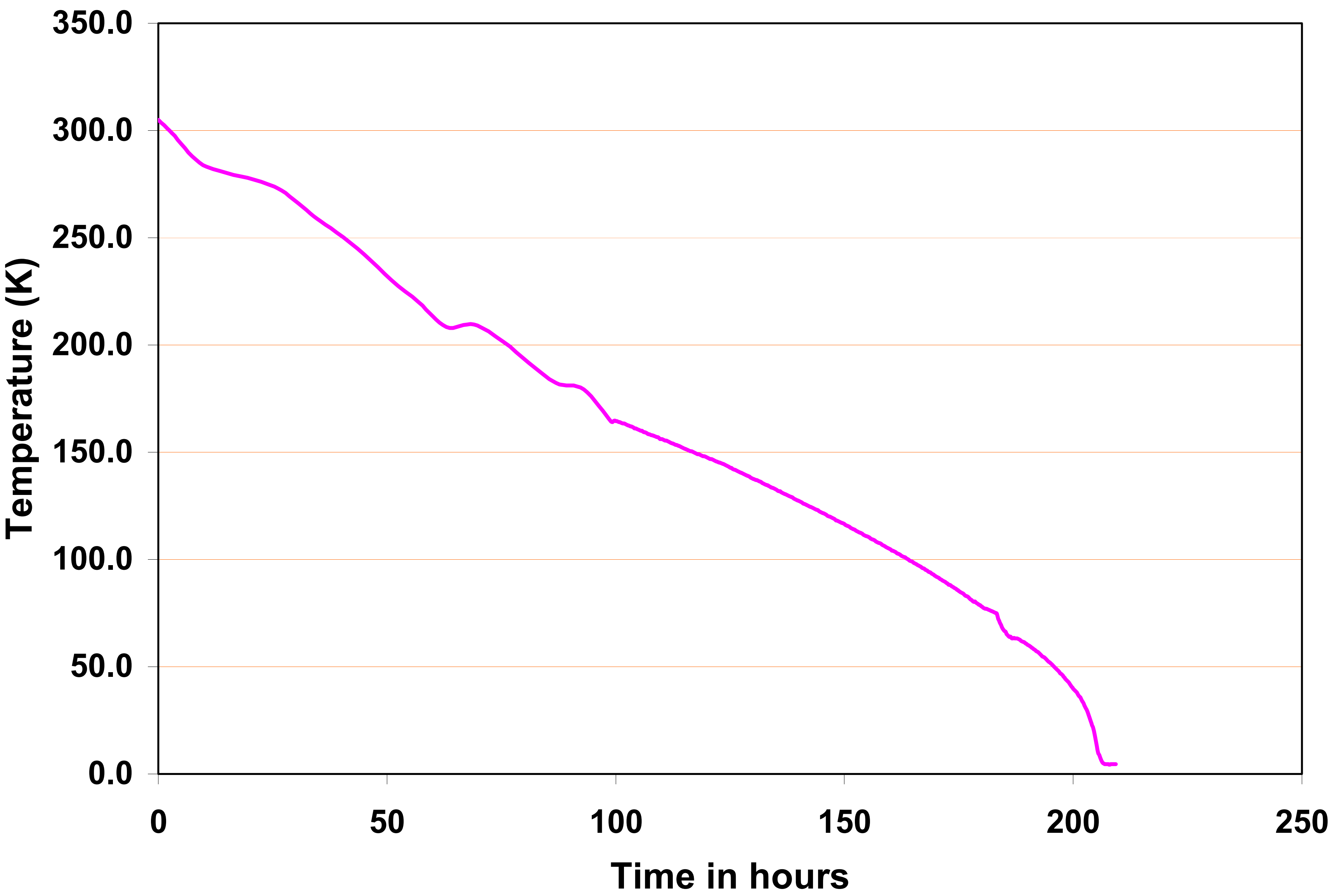
Cryogenic transfer lines connected to superconducting cyclotron magnet



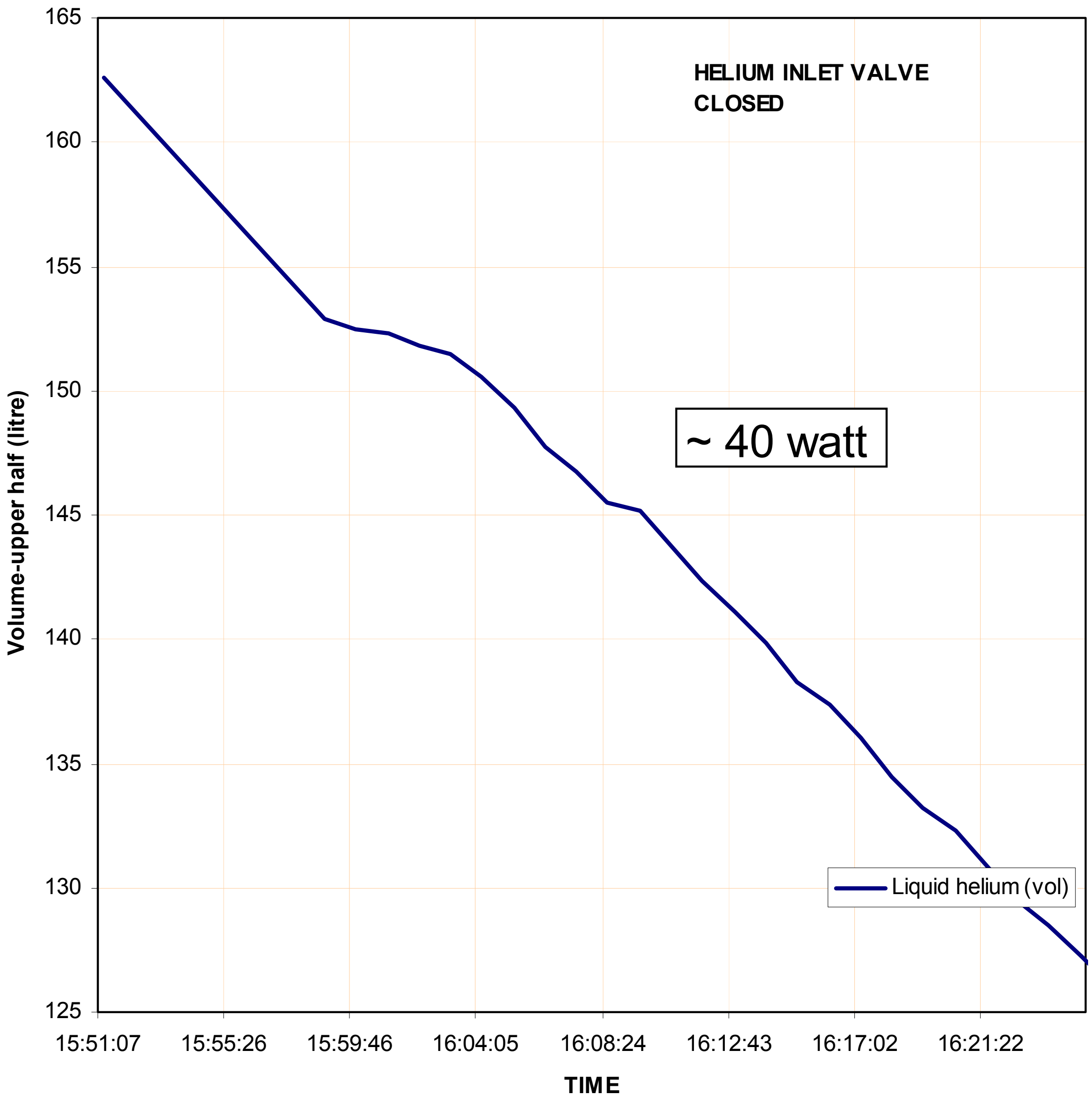
MMI showing flow diagram for the SC magnet



Reduction of moisture level in the cryostat

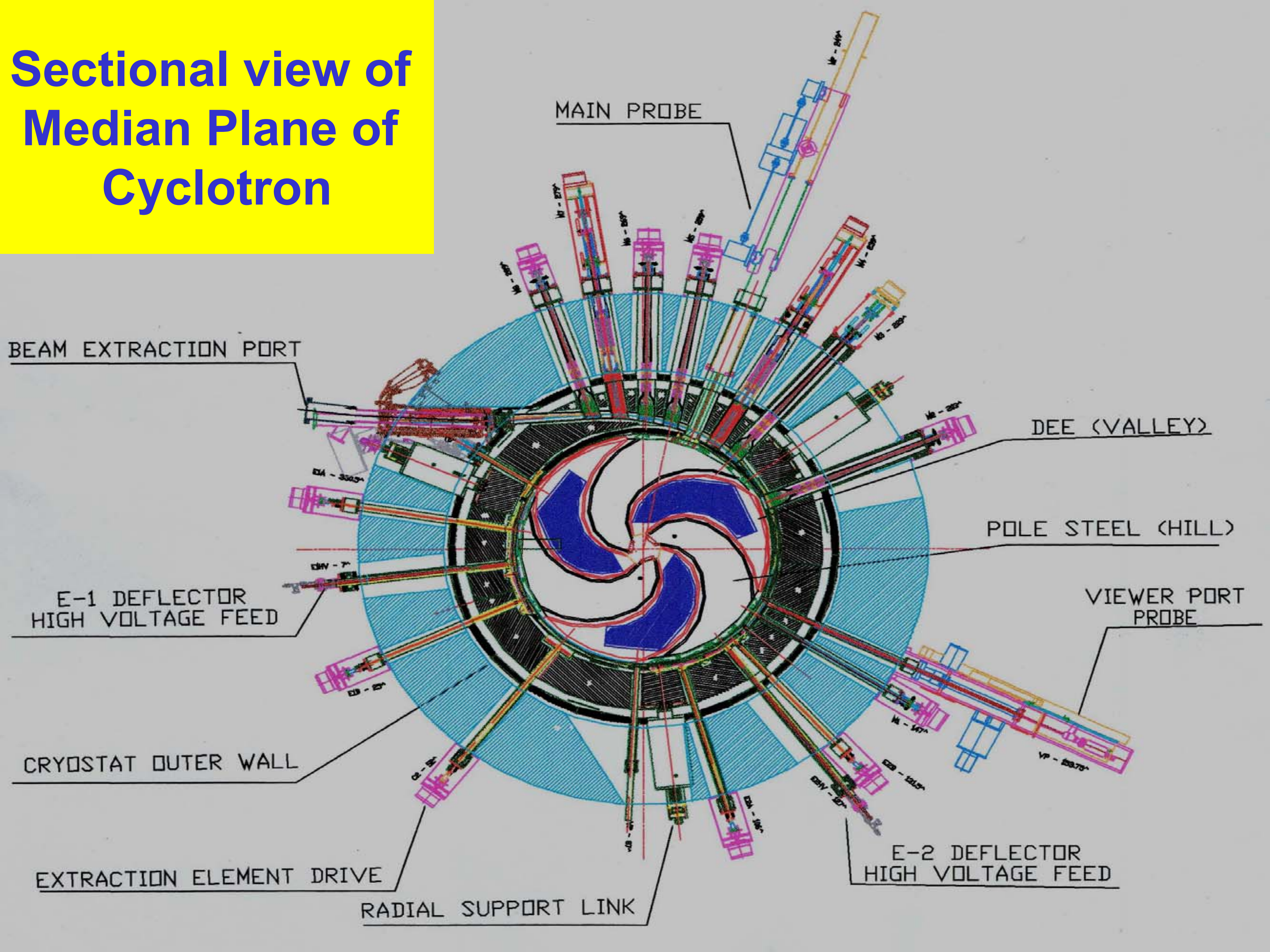


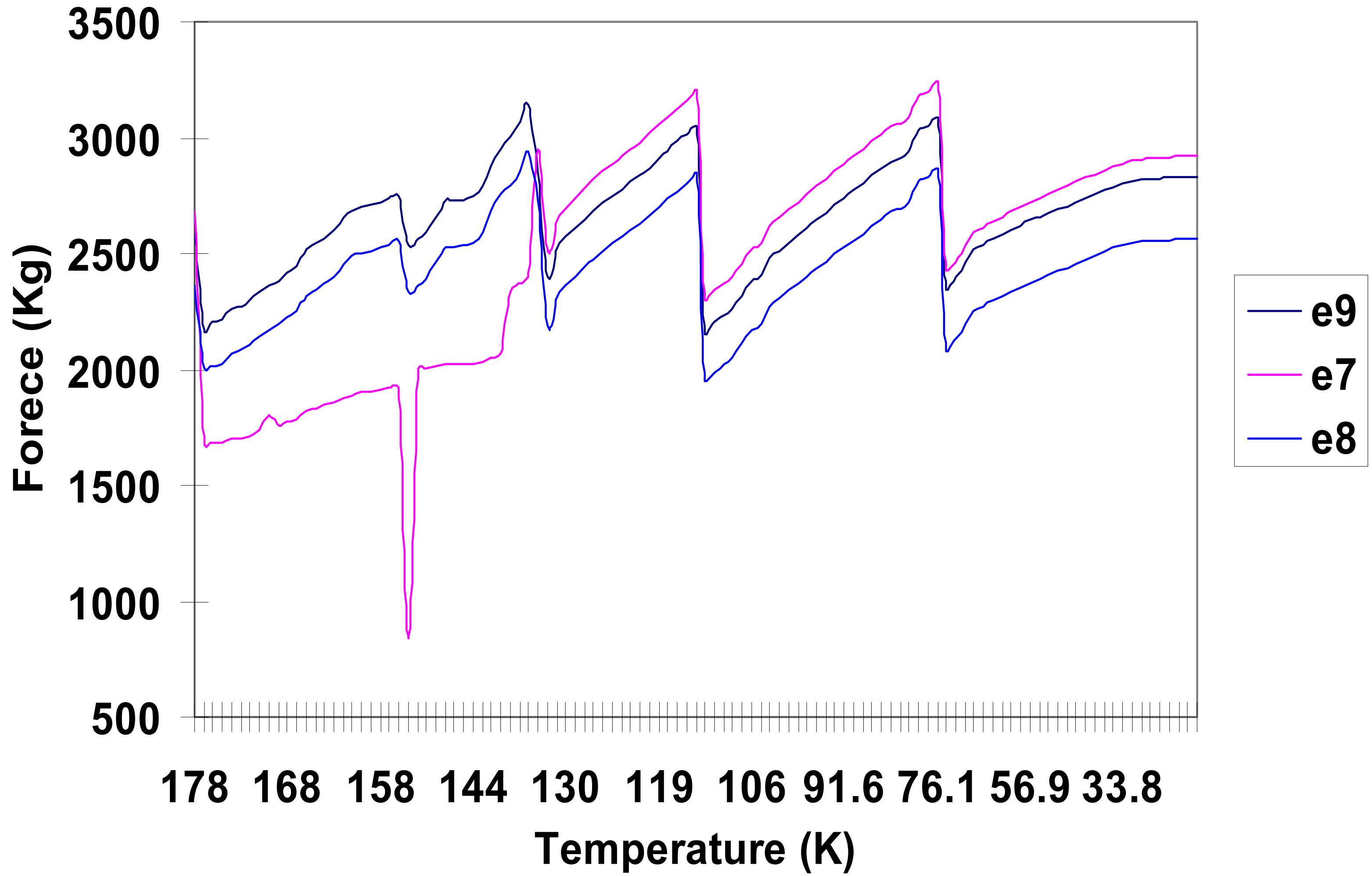
Cool-down of superconducting cyclotron magnet



Heat load of cryostat

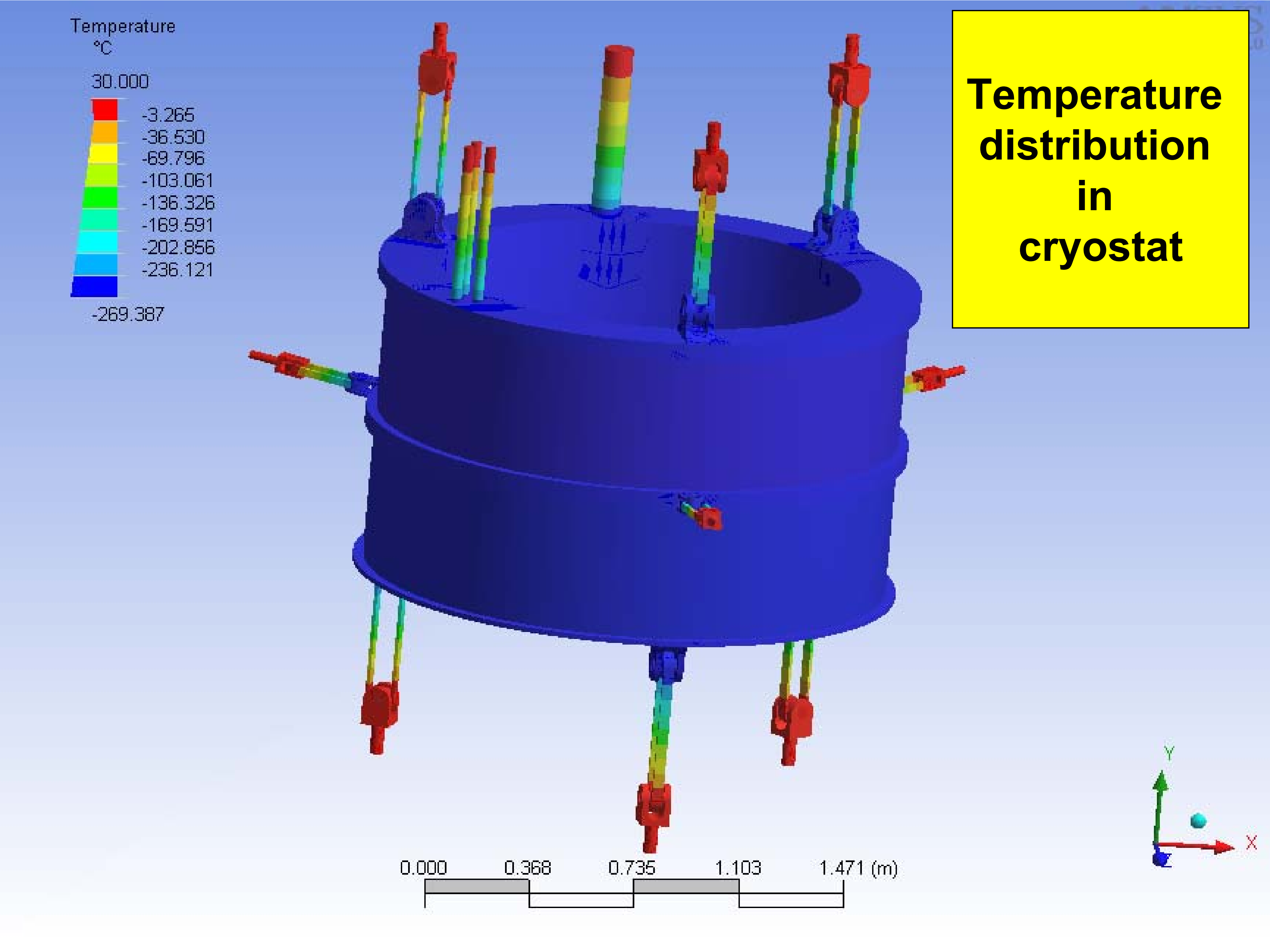
Sectional view of Median Plane of Cyclotron





Horizontal link force during cool down

Temperature distribution in cryostat

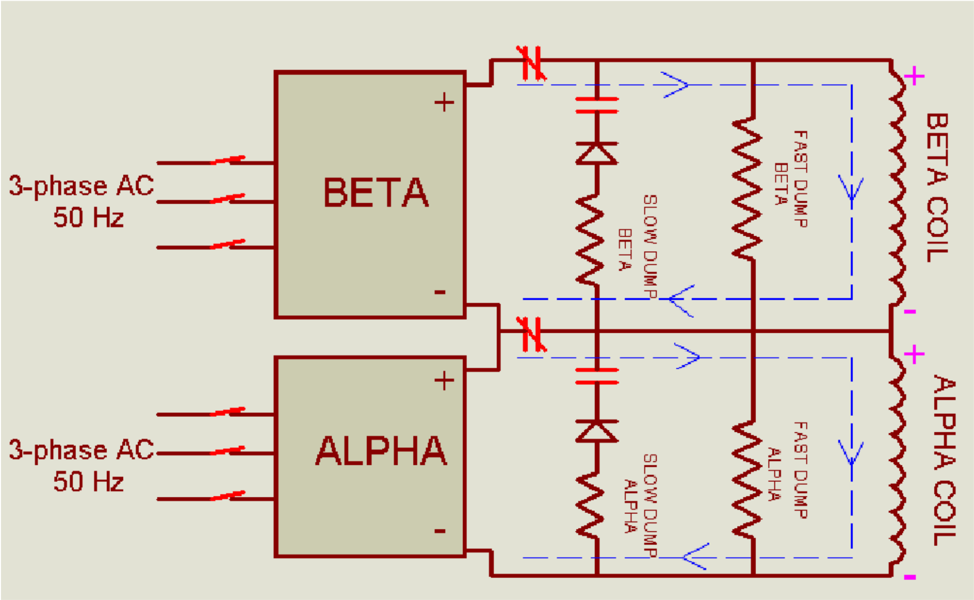


ENERGISATION OF THE SUPERCONDUCTING MAGNET

Main Magnet Power Supplies

GENERAL FEATURES

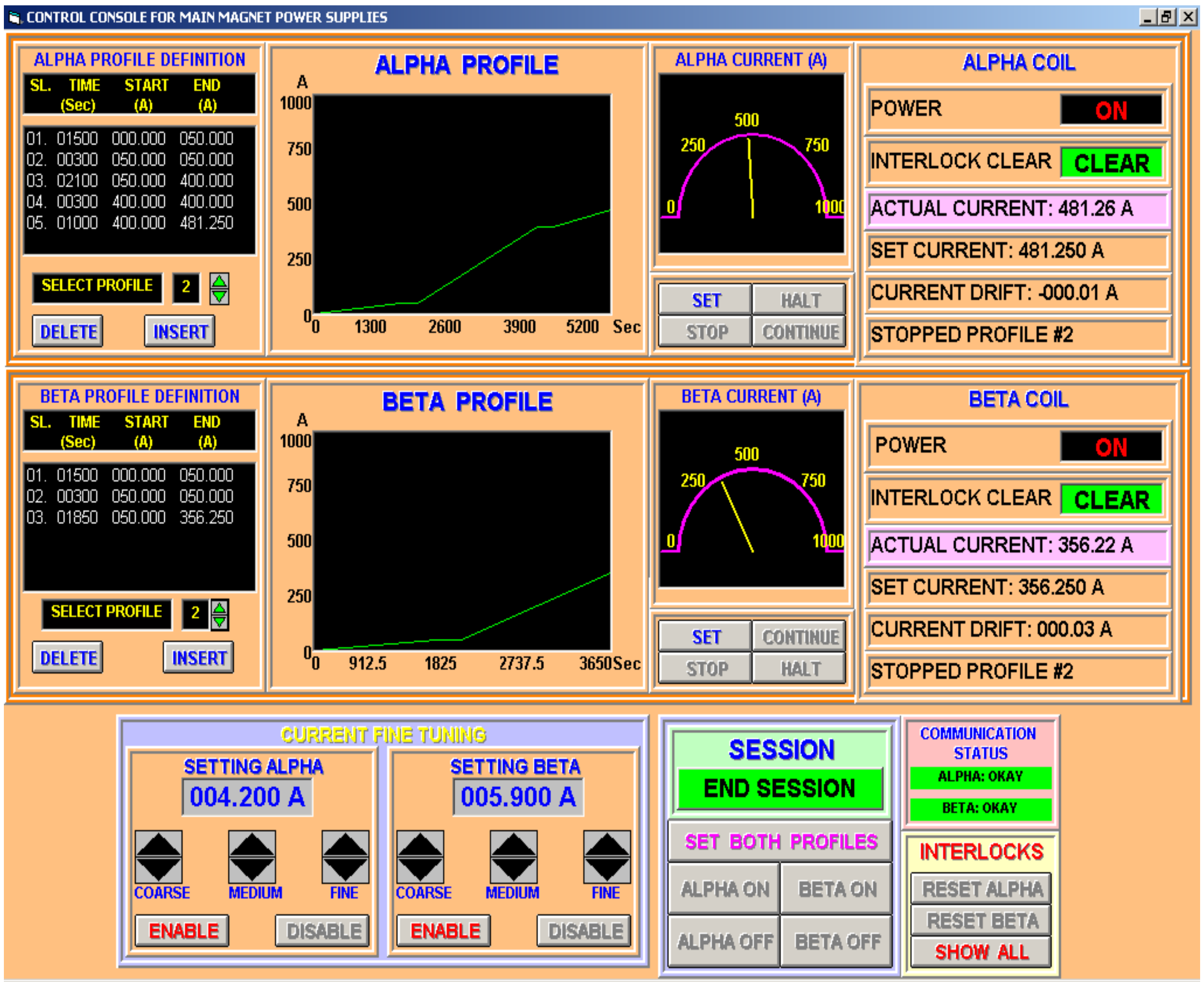
- 1000 A / 20 V, 10 ppm (current regulated)
- Series pass element - transistor bank
- 12-pulse thyristor-based controlled rectifier
- SCR pre-regulator
- RF shielding and filters
- Safety interlocks
- 18-bit D/A Converter
- 16-bit A/D Converter
- Computer interface (RS-232 / 422)



SPECIAL FEATURES

- ***Slow dump resistors*** **and** ***fast dump resistors*** **are provided for dissipating the energy stored in the coils outside the cryostat**

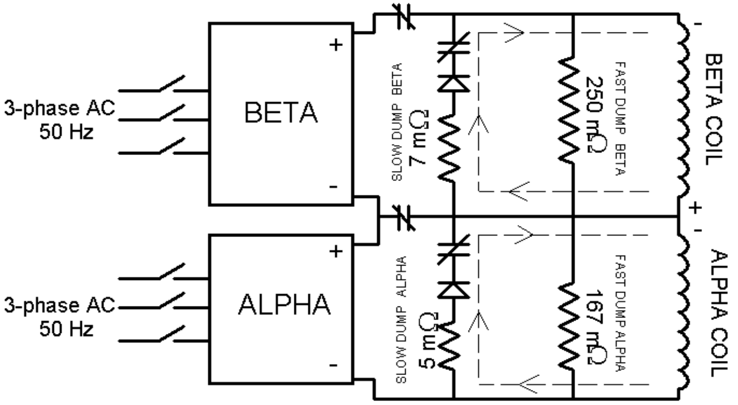
Operator's Console for Main Magnet Power Supplies



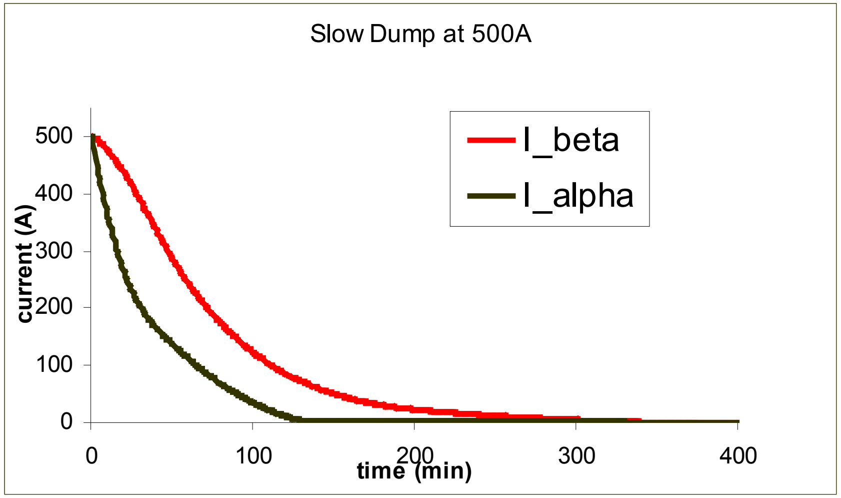
FACILITIES

- Remote operation (ON/OFF, HALT, STOP)
- Current setting
- Status and parameter monitoring
- Online data logging with time stamp

Slow Dump

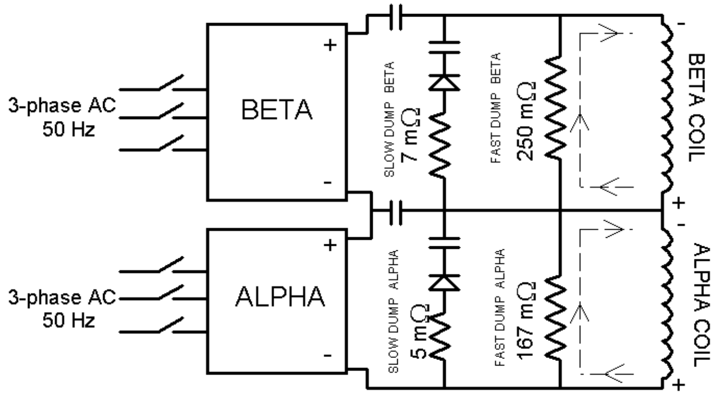


The states of the four contacts when slow dump is in progress

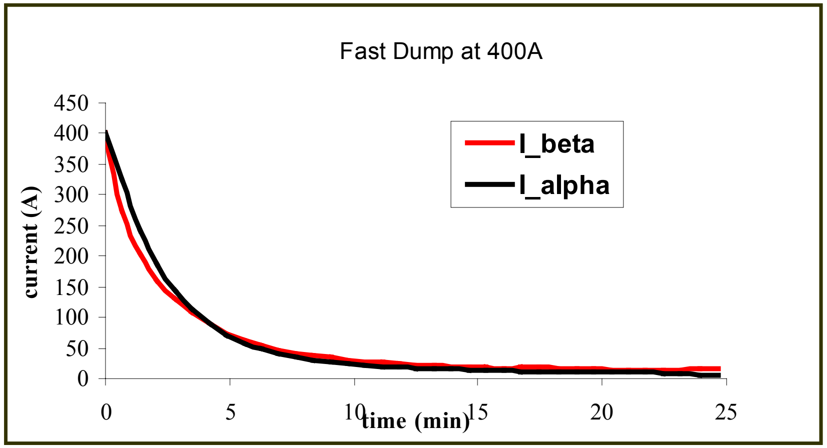


Profile of current decay for slow dump initiated at 500 A

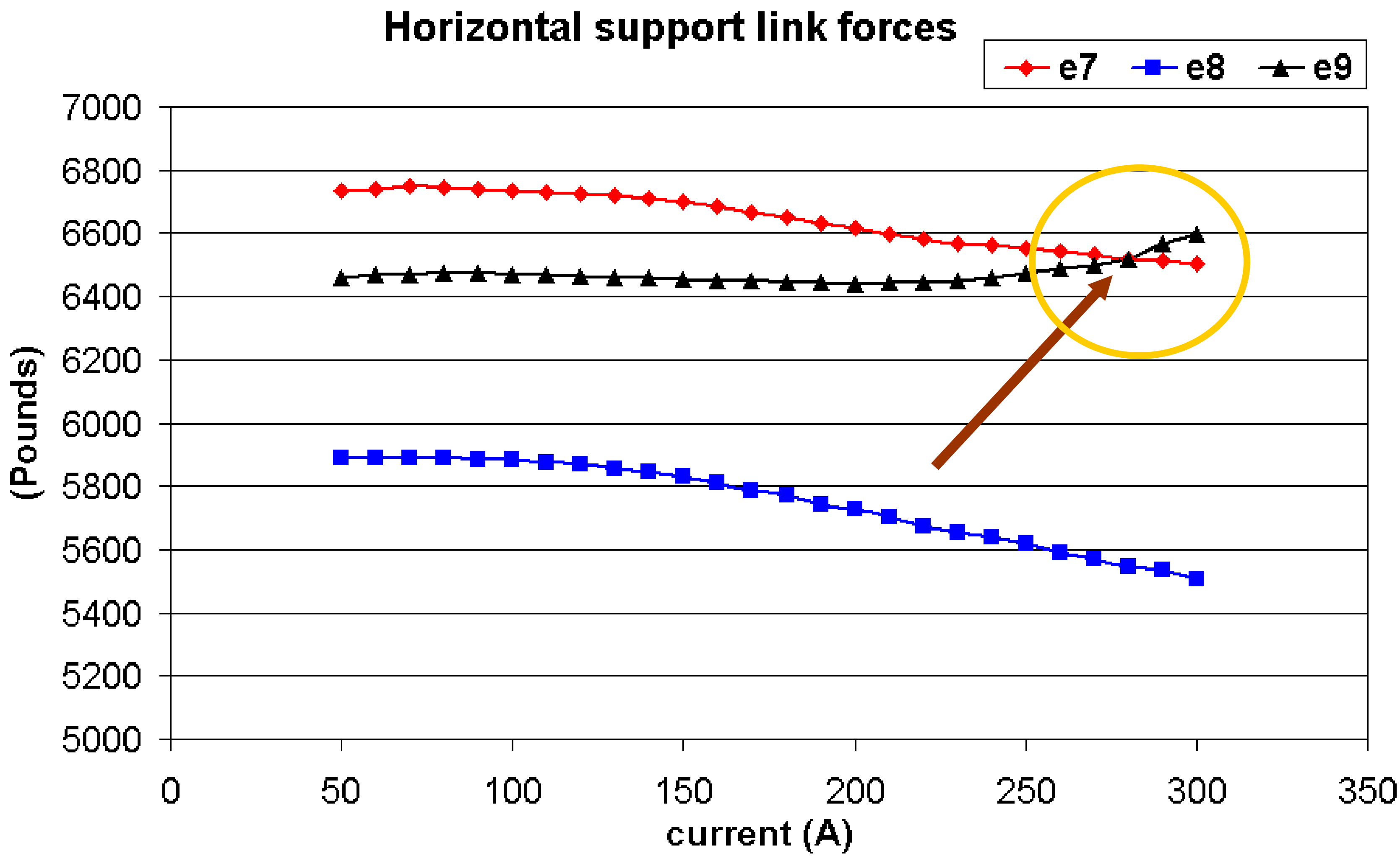
Fast Dump



The states of the two contacts when fast dump is in progress

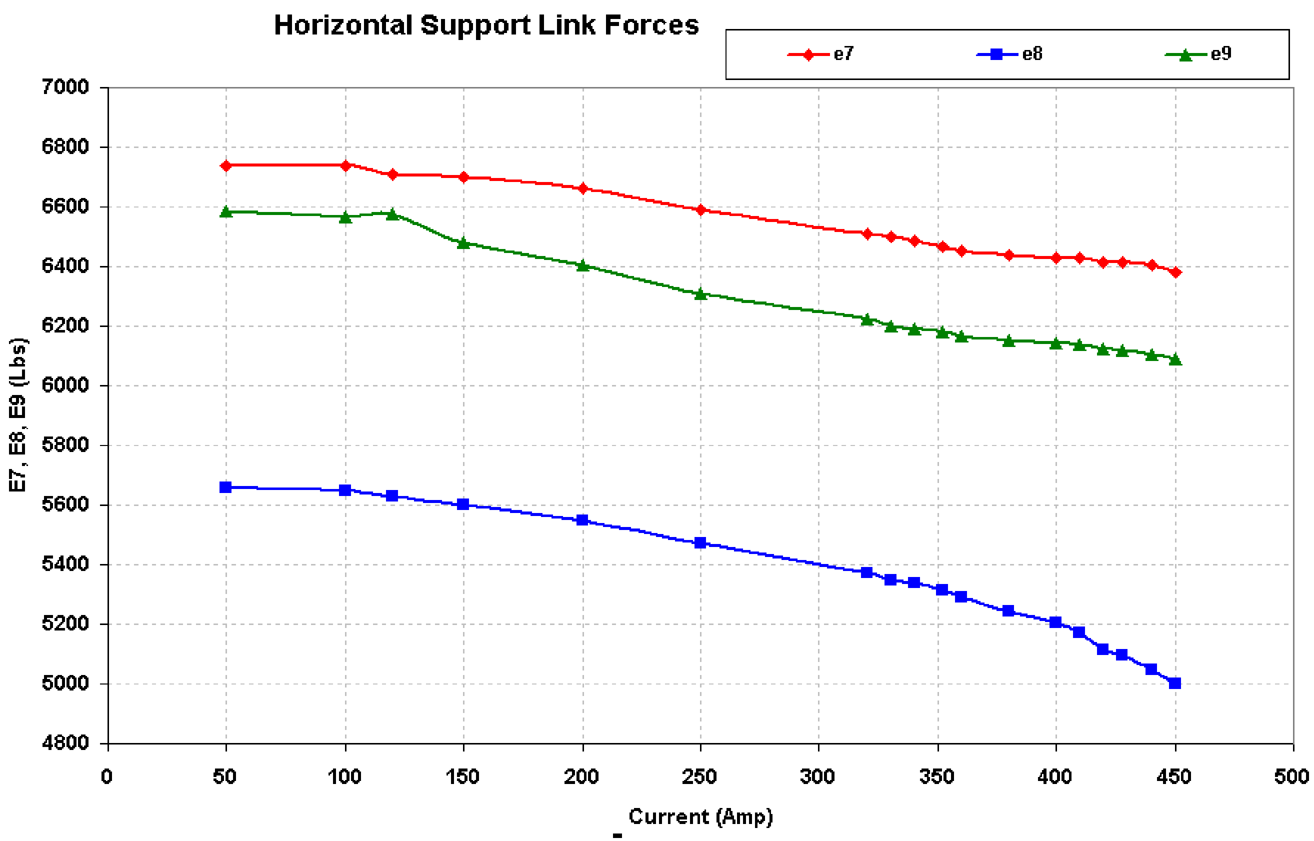


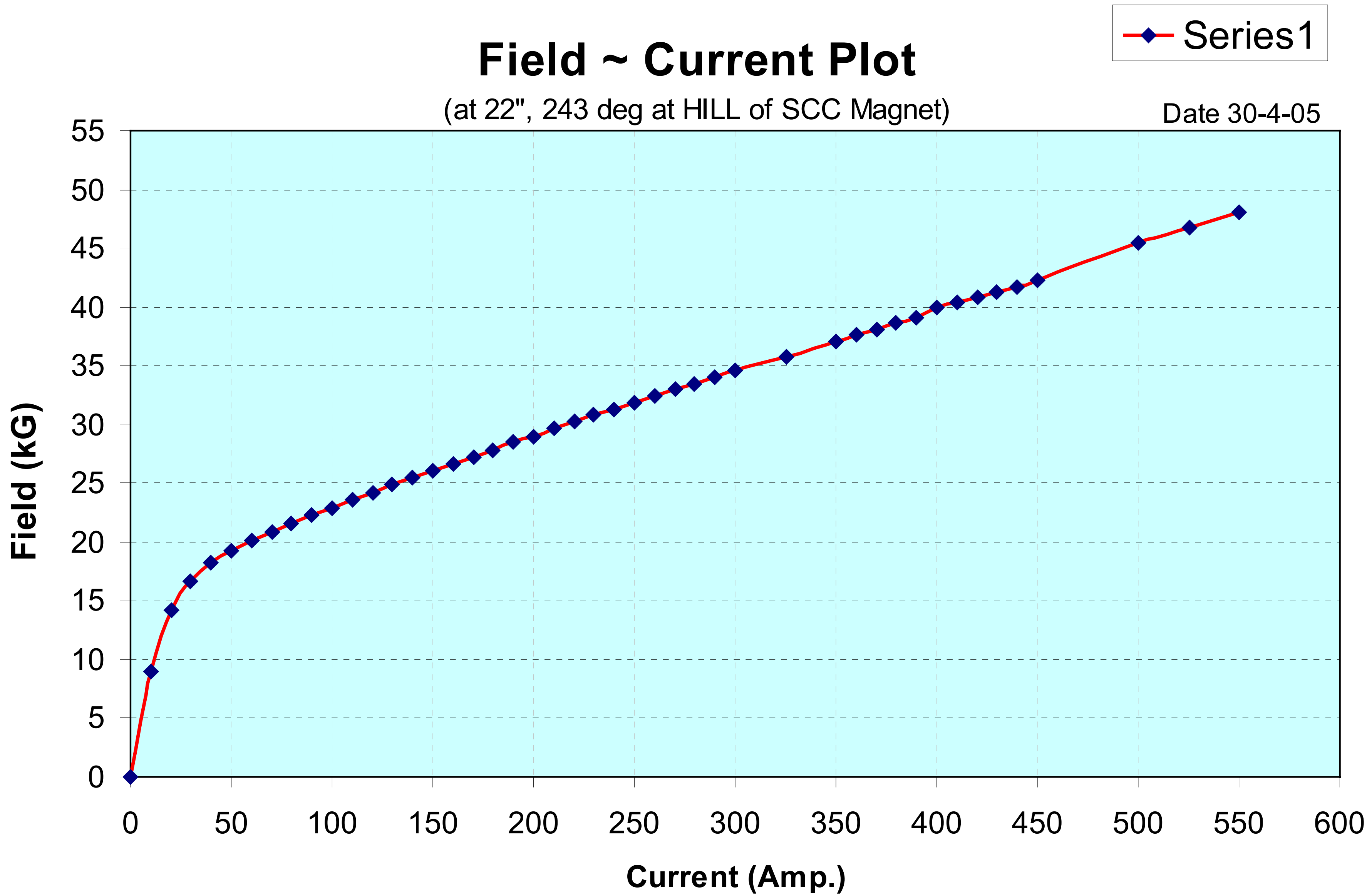
Profile of current decay for fast dump initiated at 400 A



Horizontal support link forces
e7
e8
e9
7000
6800
6600
6400
6200
6000
5800
5600
5400
5200
5000
(Pounds)
0
50
100
150
200
250
300
350
current (A)

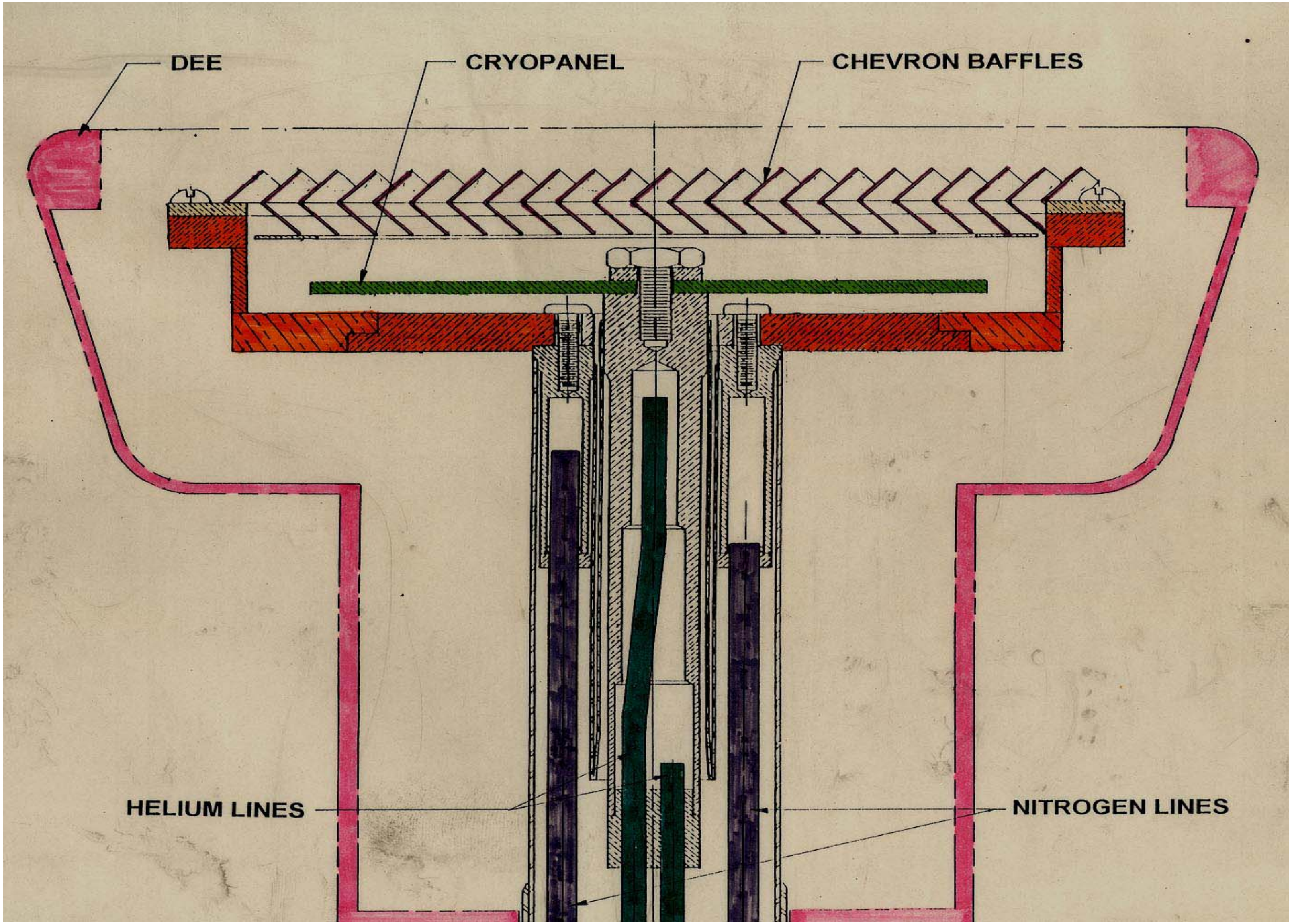
E9 Support Link was tightened to +145 degrees



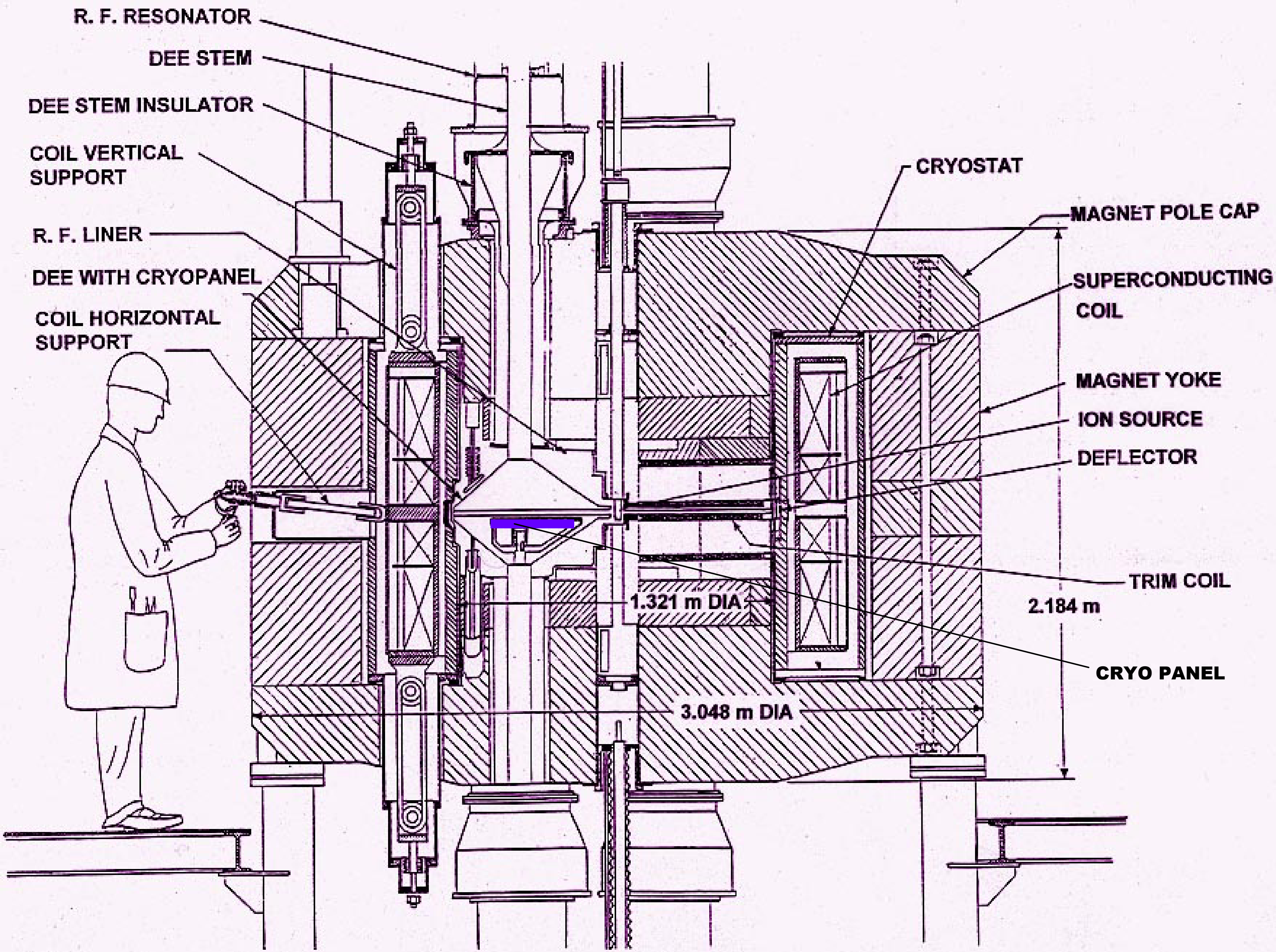


Max. Current: 750 A

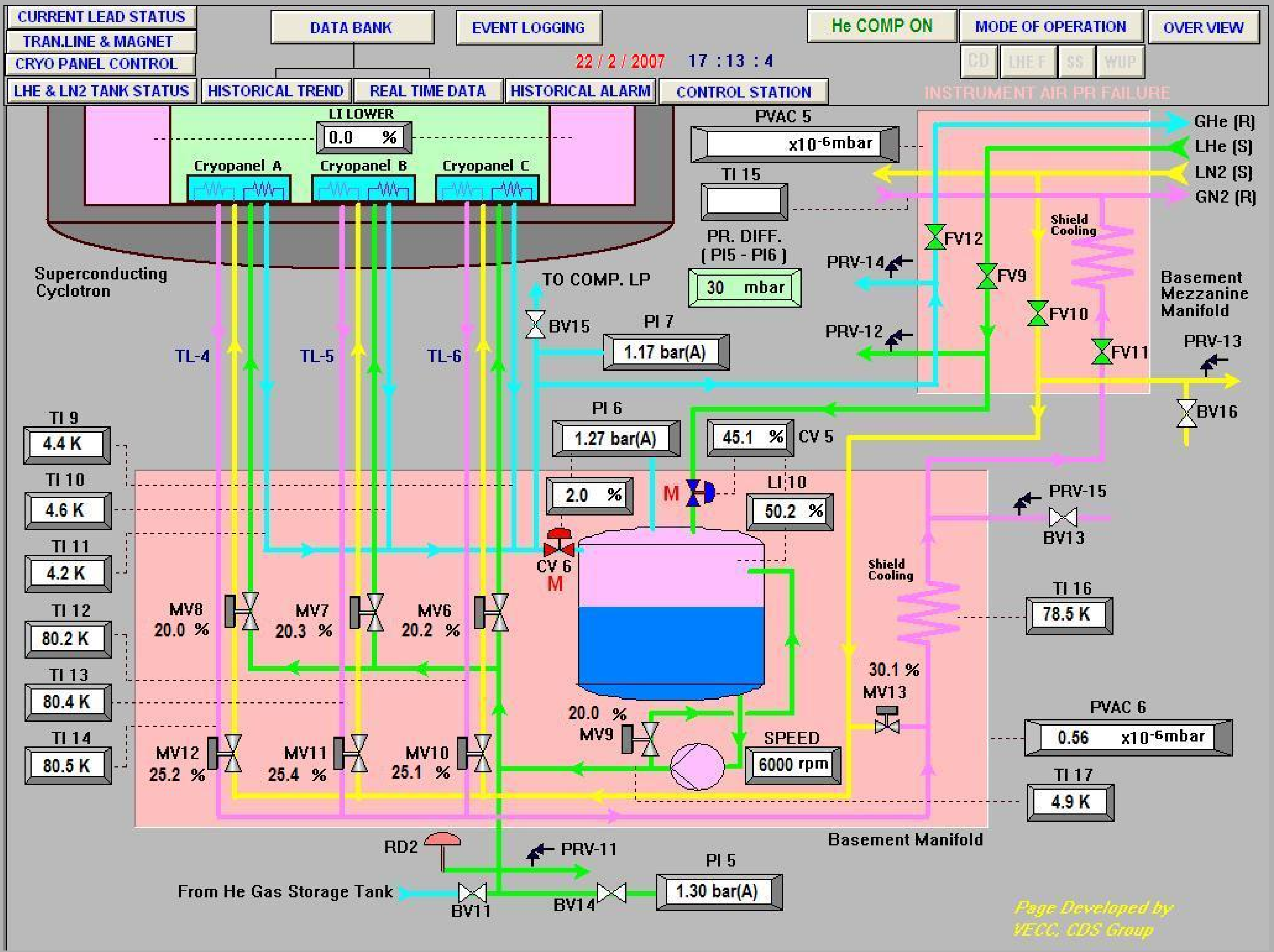
CRYOPANELS
&
THEIR CRYOGEN DELIVERY SYSTEM



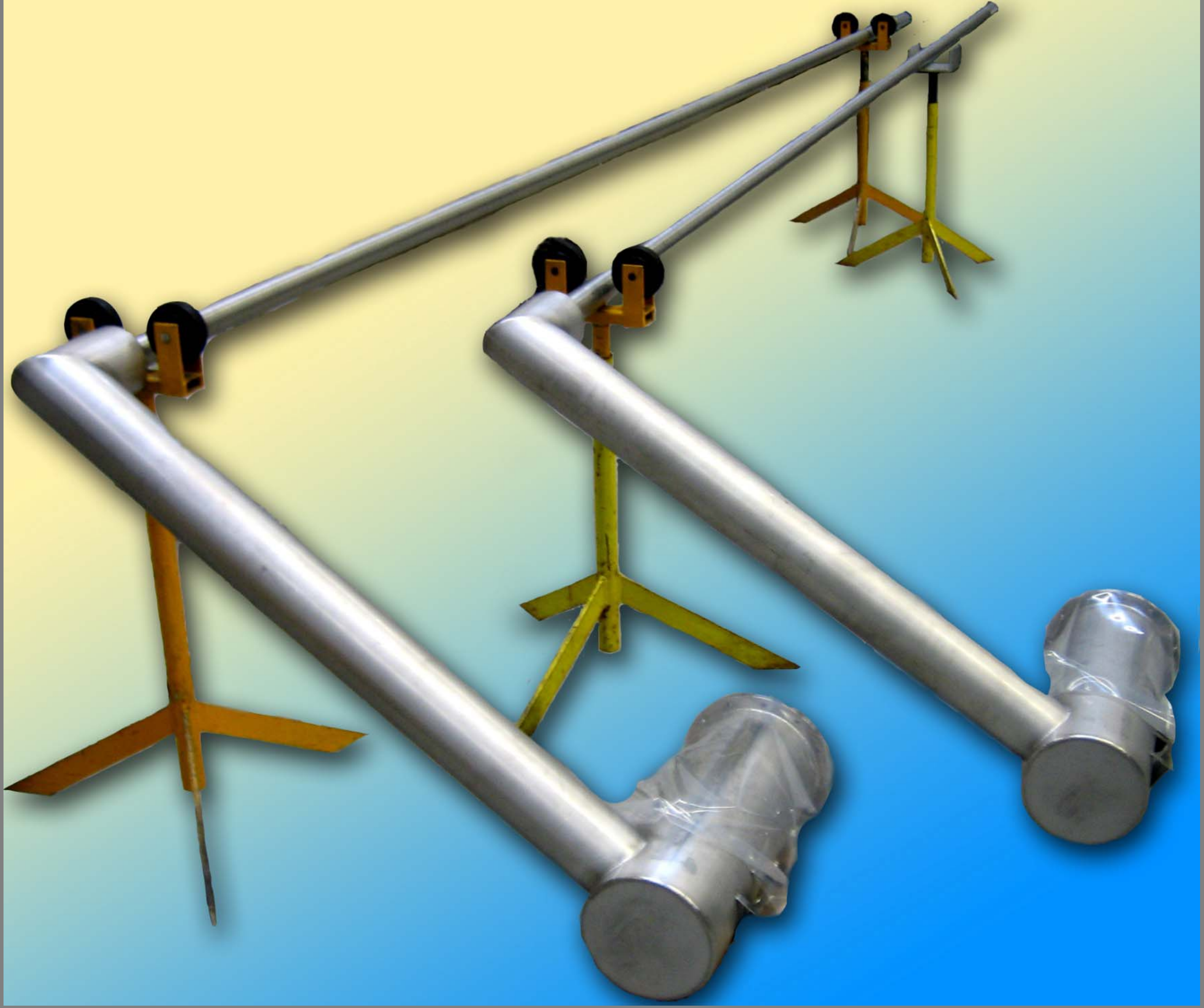
Cryopanel for the superconducting cyclotron



K500 SUPERCONDUCTING CYCLOTRON AT VECC



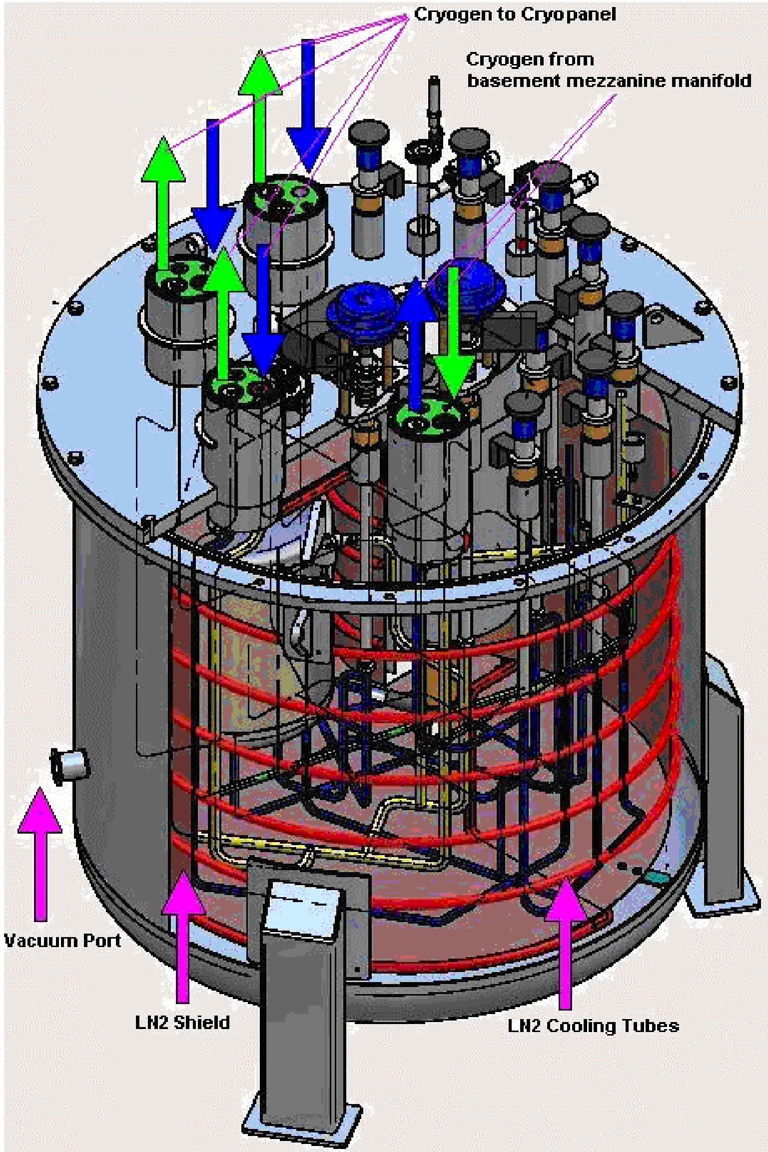
MMI showing flow diagram for cryogen delivery to the cryopanels

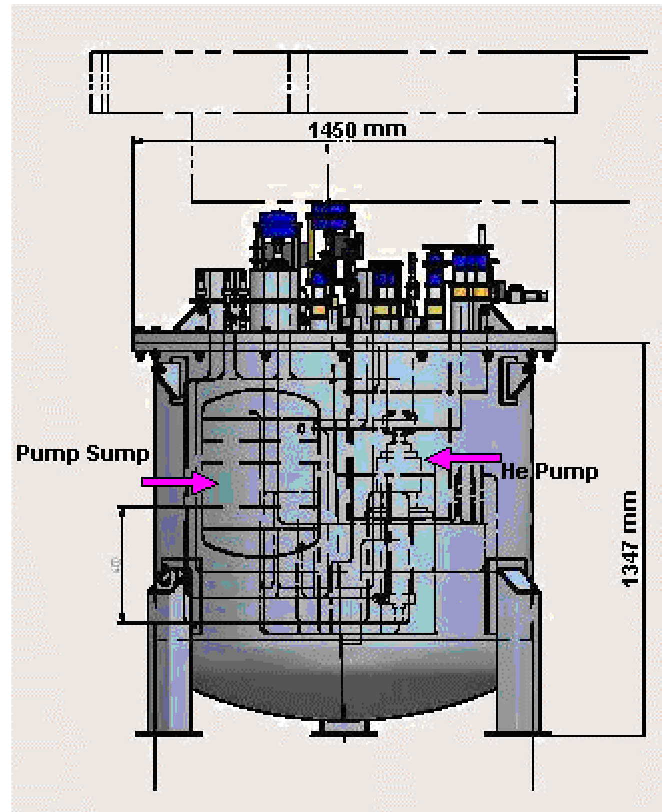


Transfer lines and bayonet for cryopanels

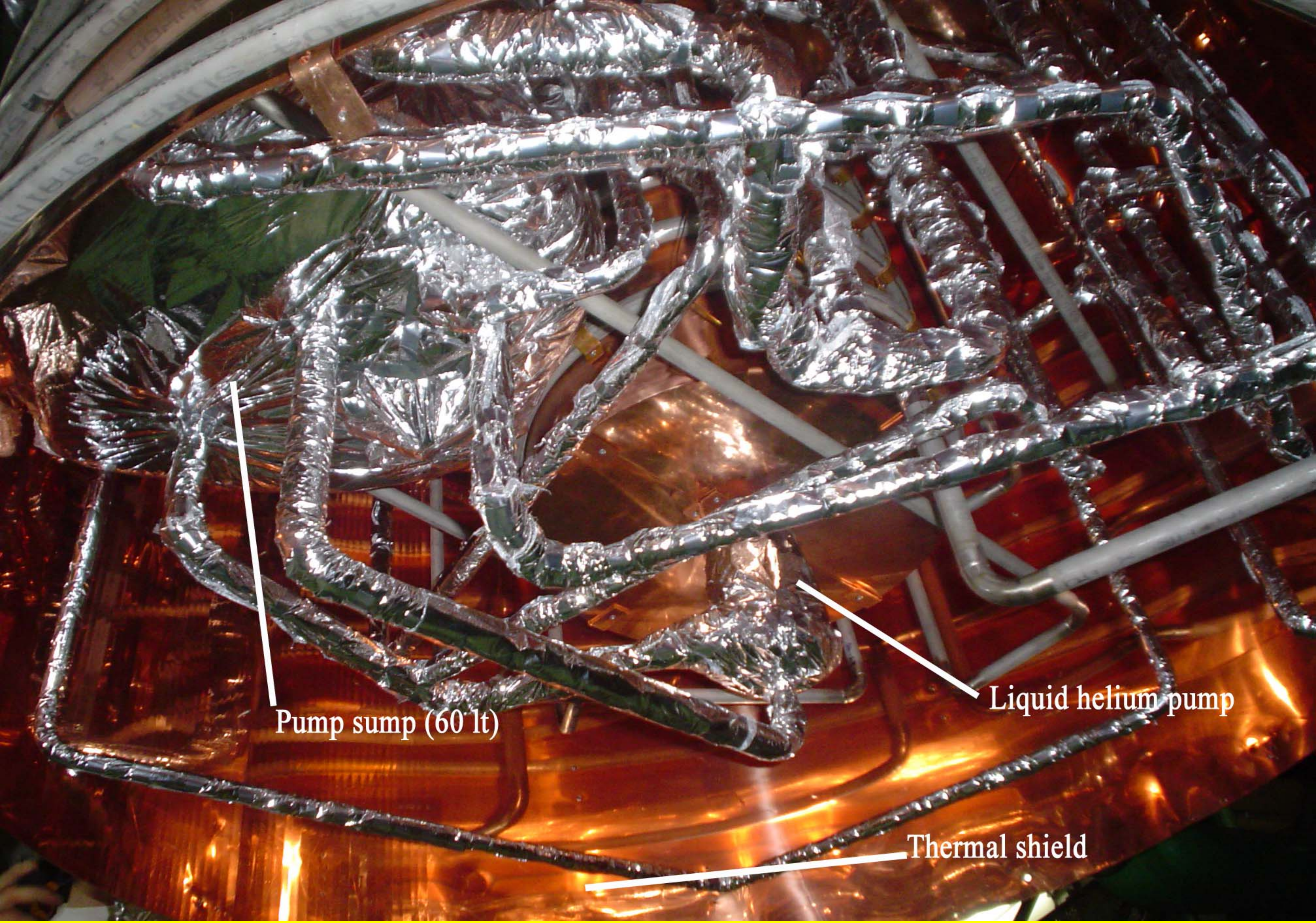
Cold head for the cryopanel

Basement mezzanine manifold for supplying liquid nitrogen to the magnet cryostat





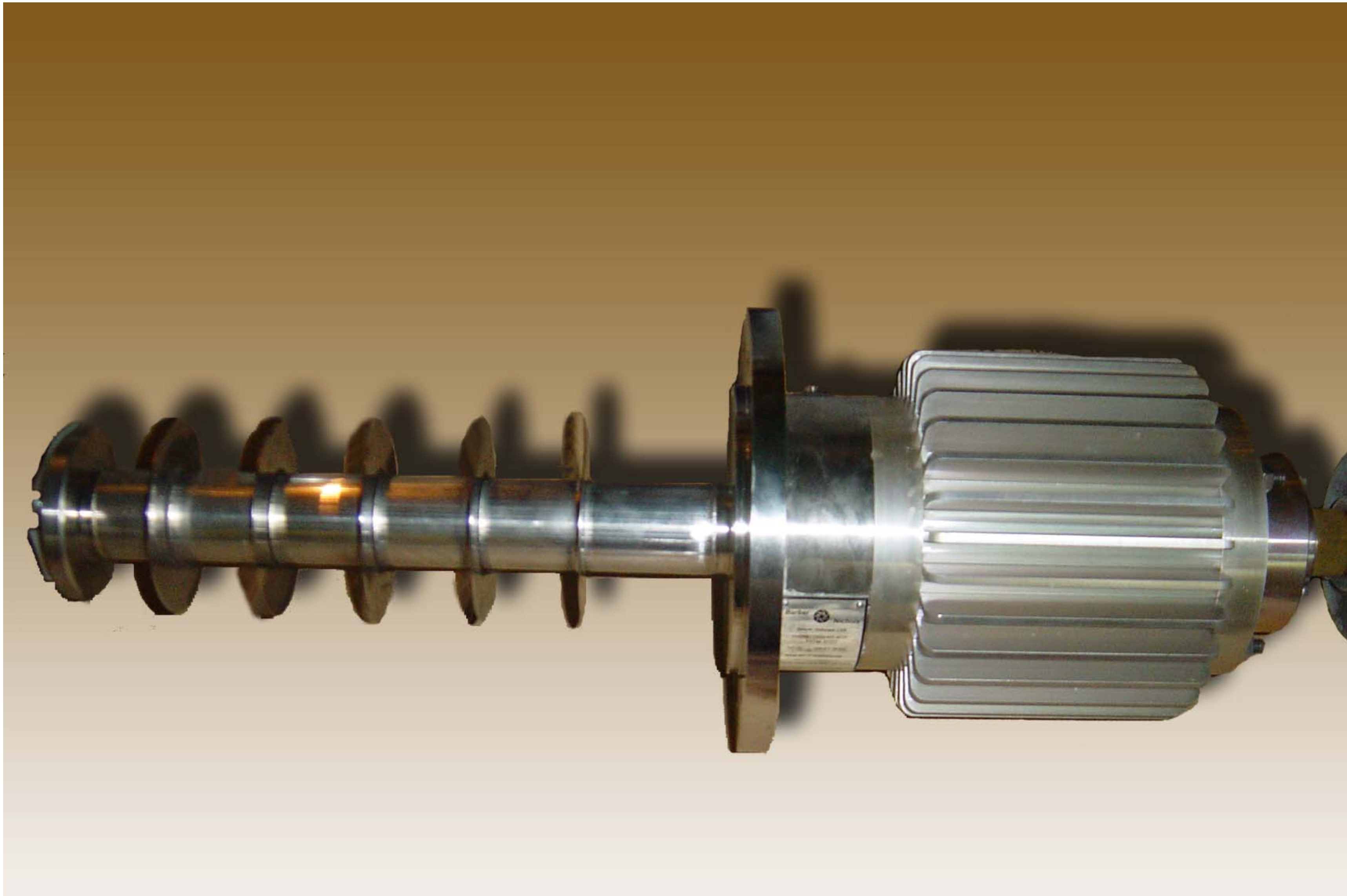
Basement manifold with liquid helium pump (computer model)



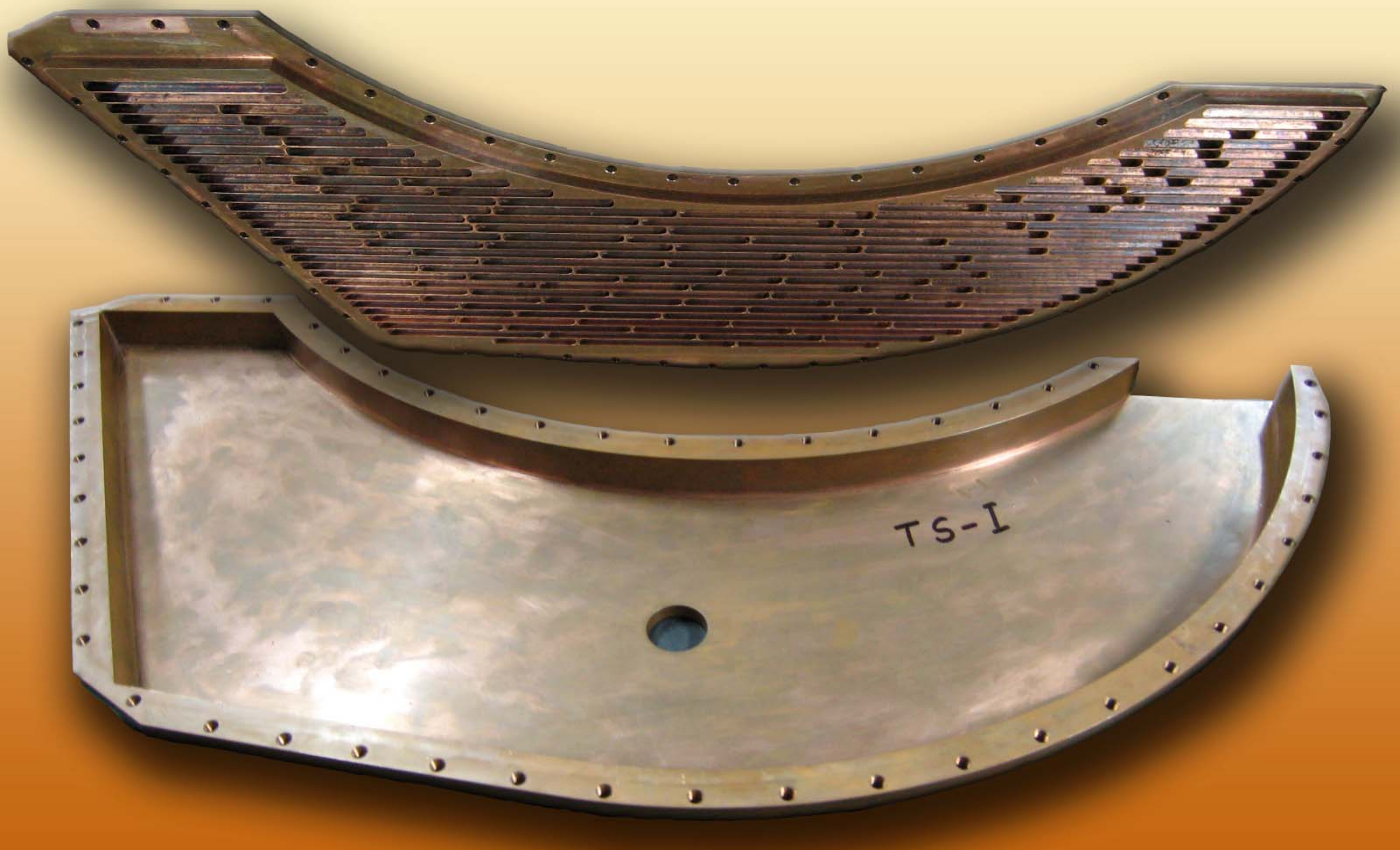
Inside the basement manifold

Basement manifold ready for the final assembly

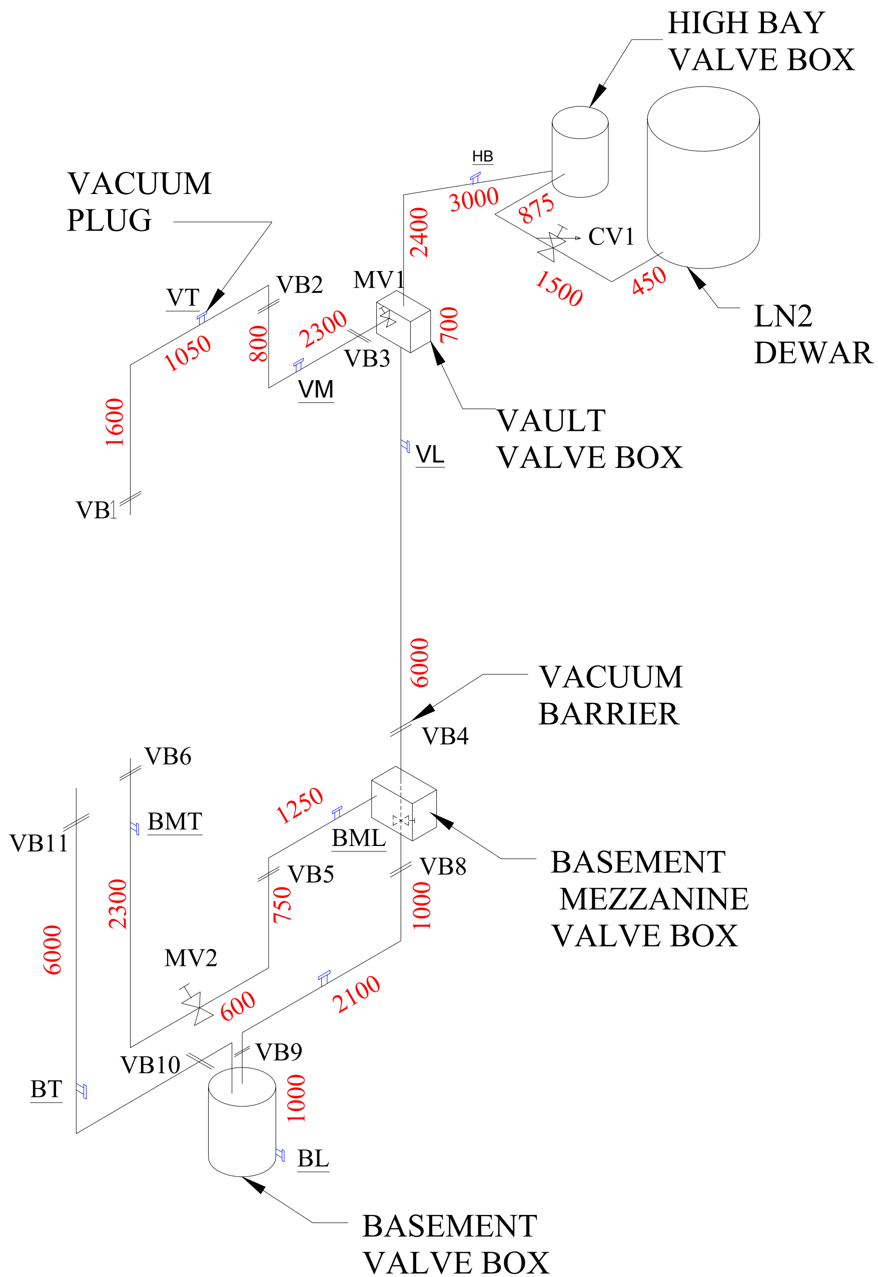
Basement manifold
for circulation of LHe and LN2
to cryopanels



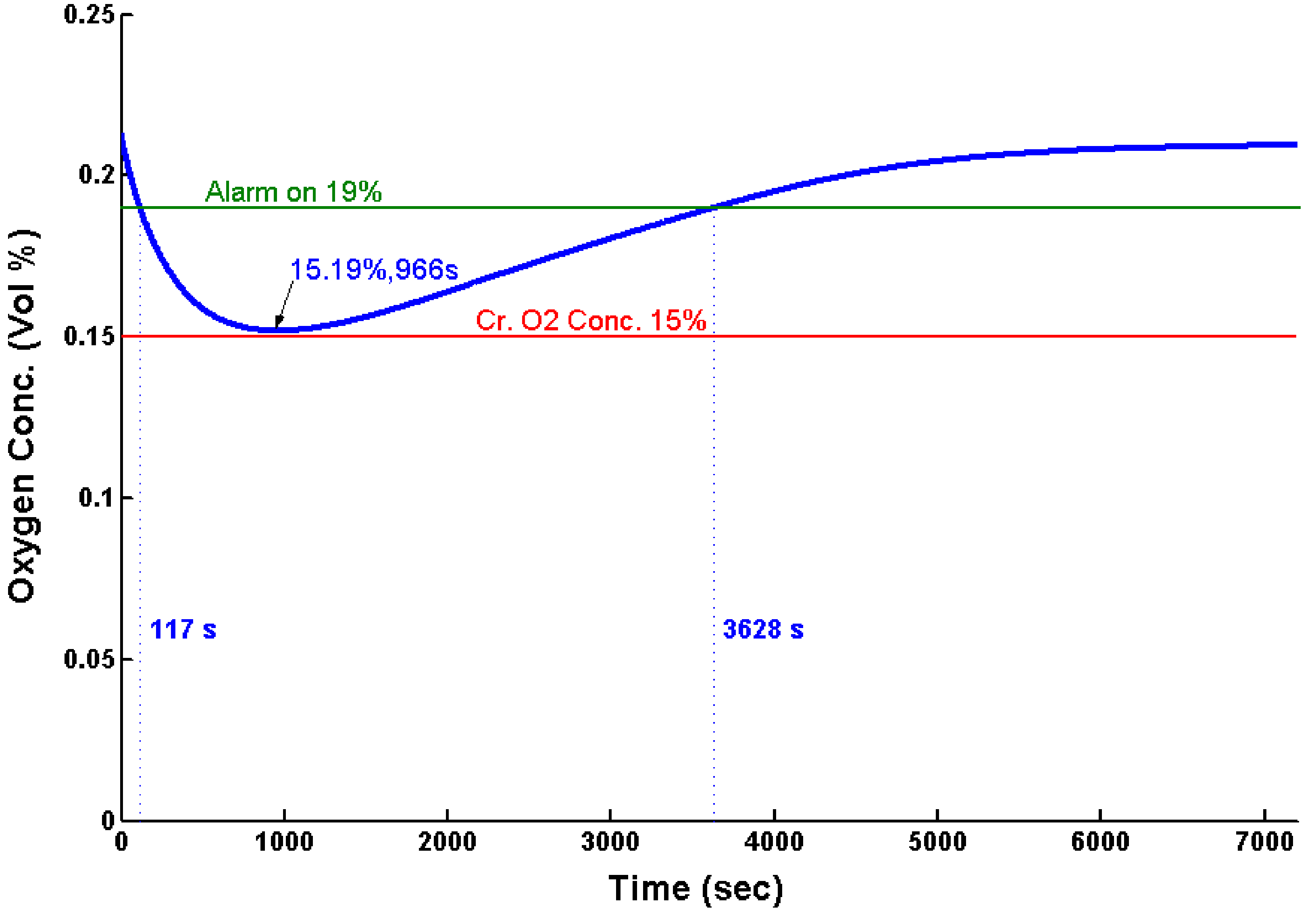
LHe pump



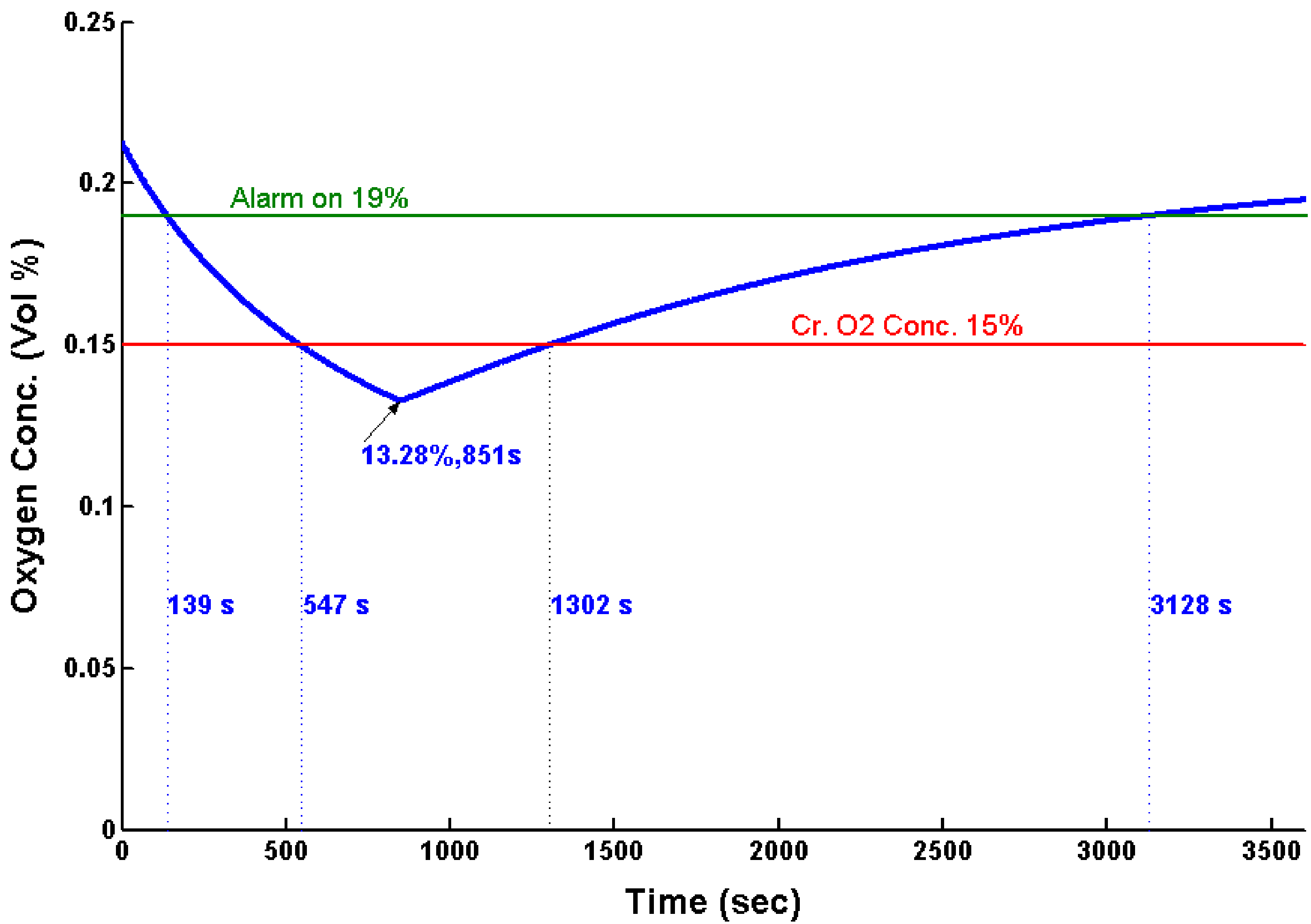
Chevron baffle and thermal shield for cryopanel



Simulation of cryogenic system for safety studies



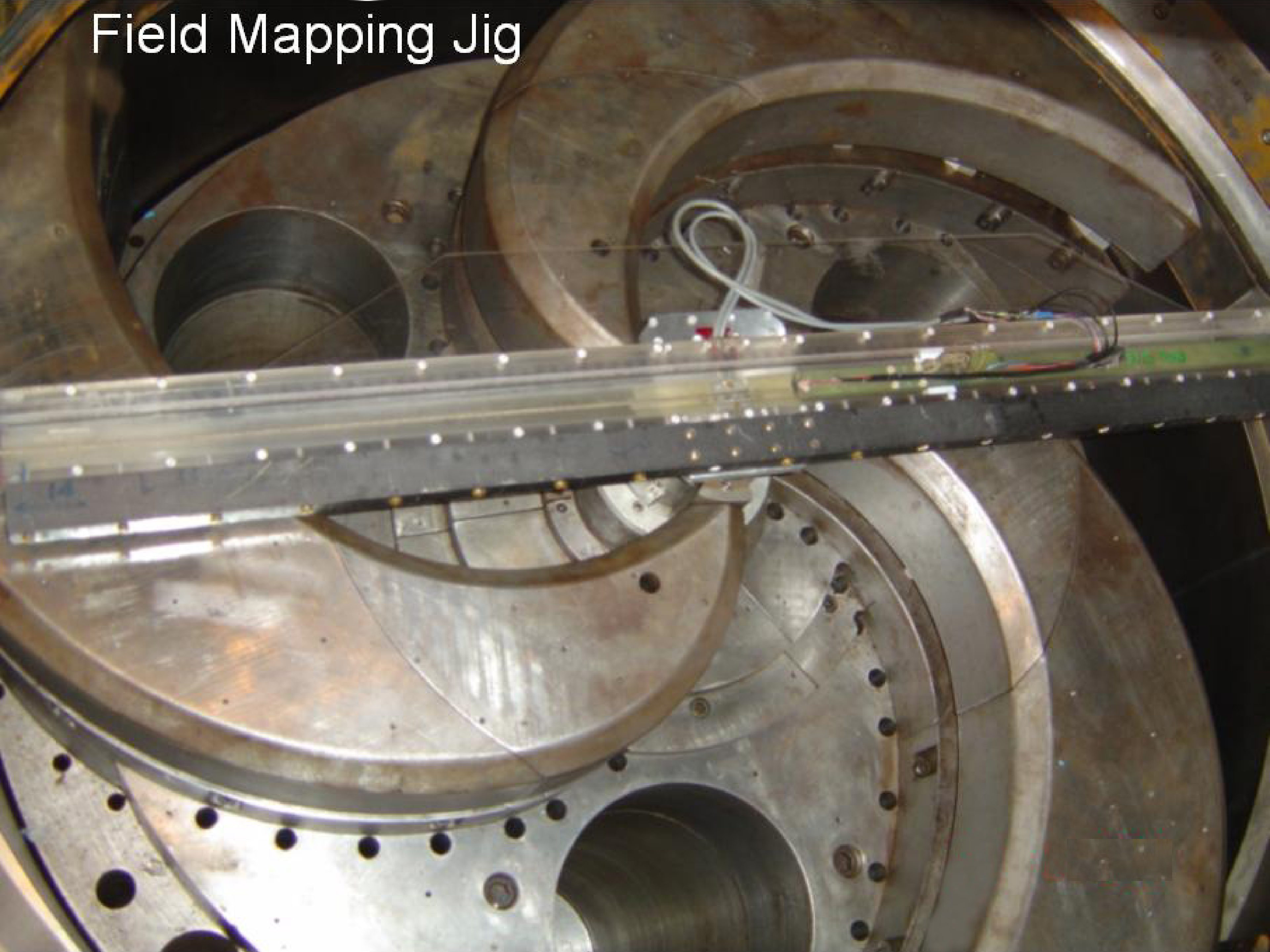
Effect of spillage of liquid nitrogen in SC building



Effect of spillage of liquid helium in SC building

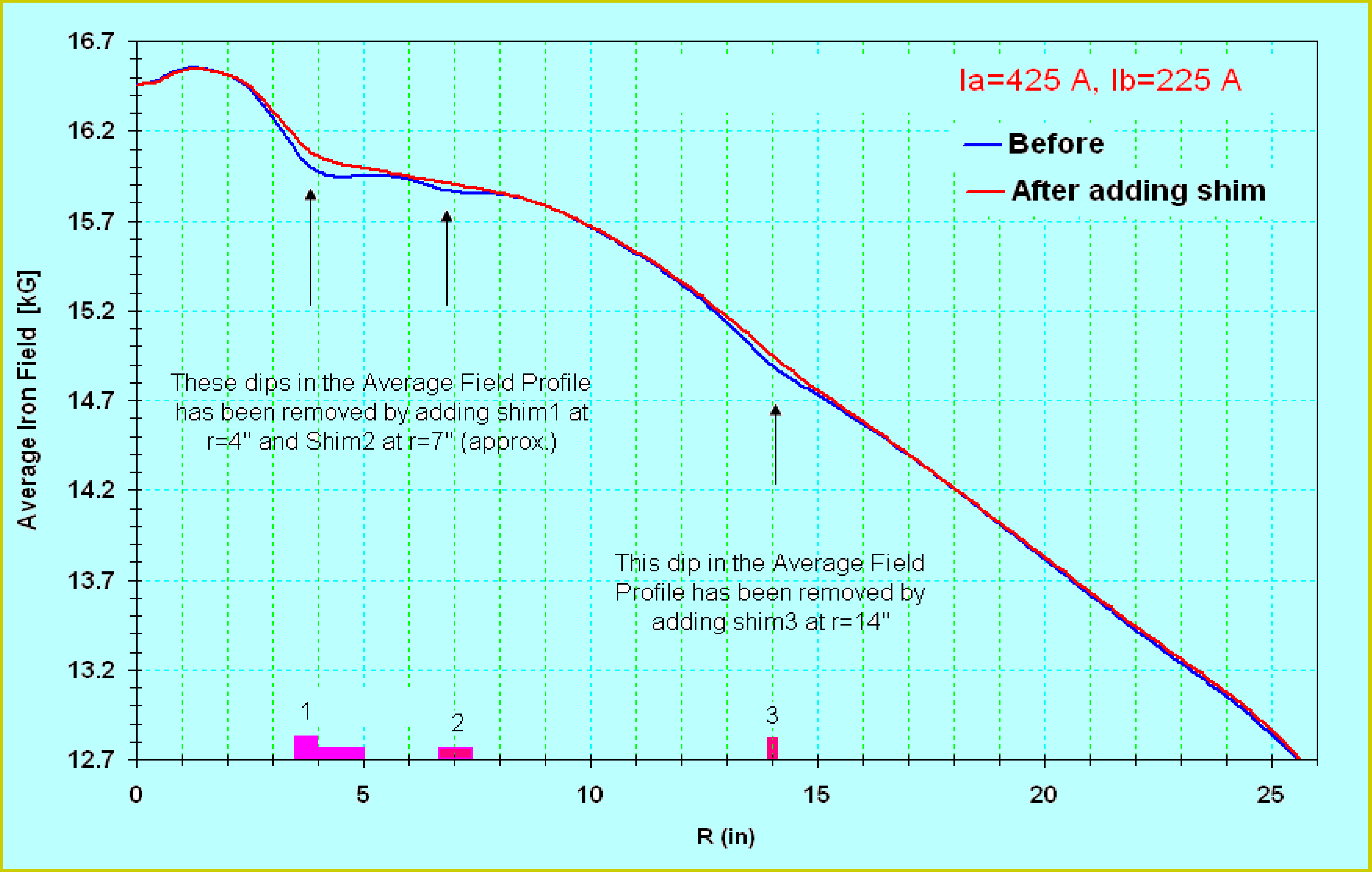
MAGNETIC FIELD MEASUREMENTS AND ANALYSIS

Field Mapping Jig



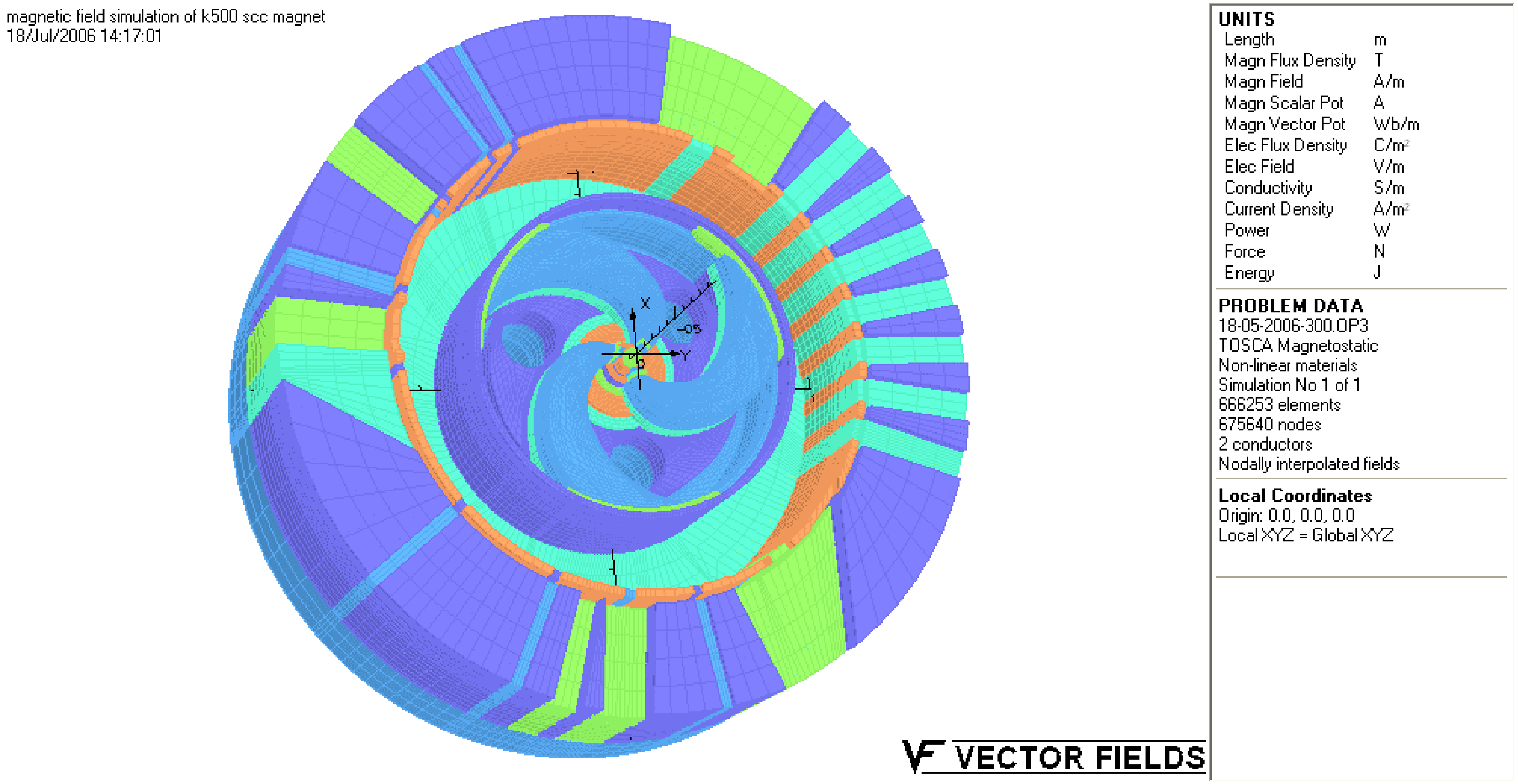
1st Harmonic minimization

First Harmonic Minimization By Adding Iron Shims



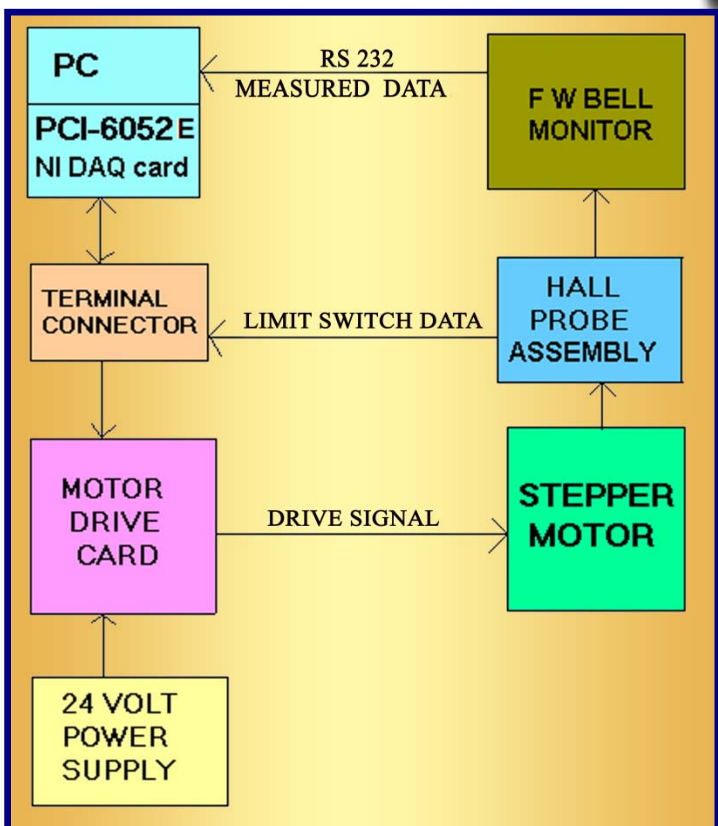
Shiming To Correct Average Field Profile

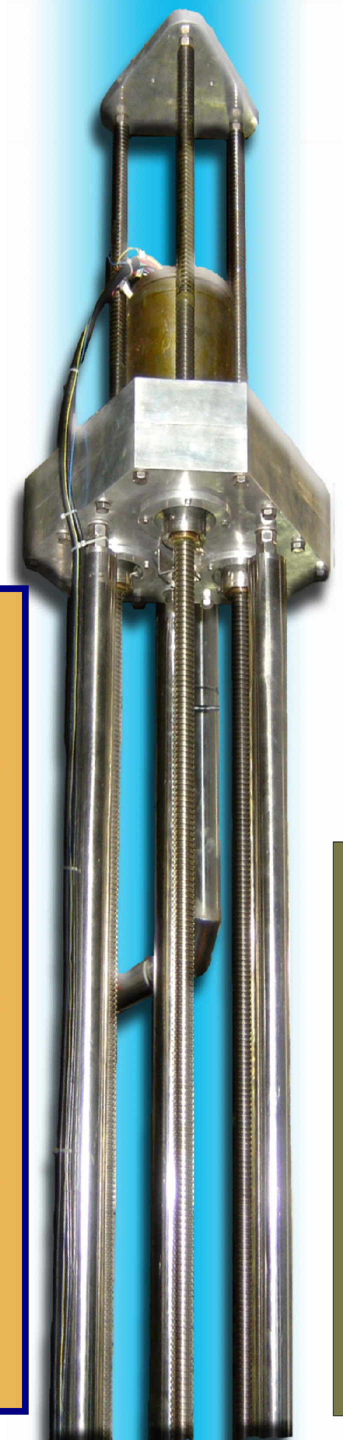
Simulation of 3D Field Distribution with TOSCA

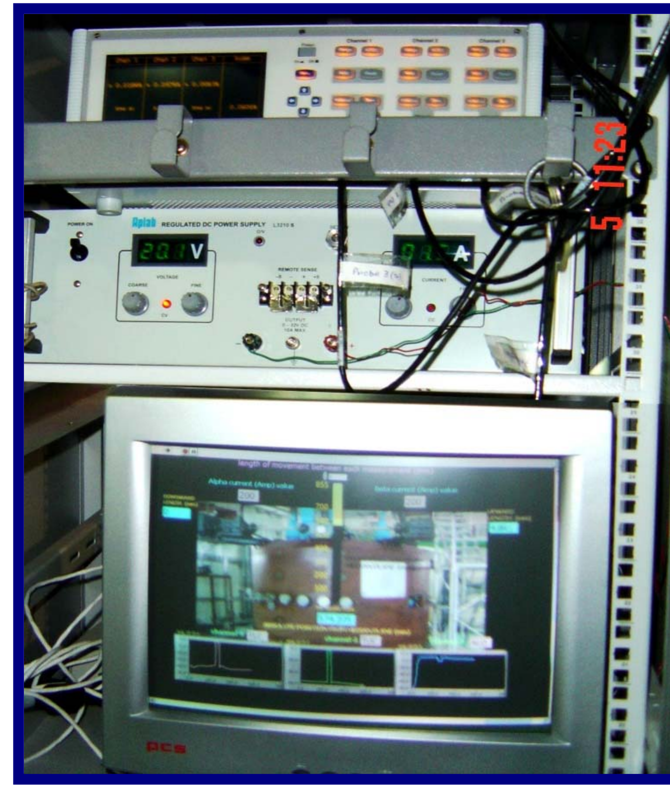


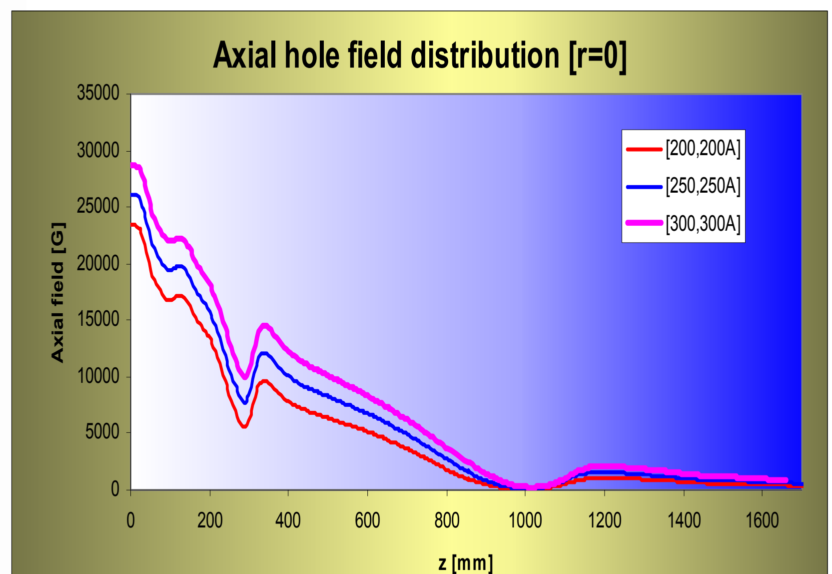
Field measurement was not possible at all excitations and at all places due to inaccessibility. TOSCA simulation has been done to make up the data.

Axial hole field mapping









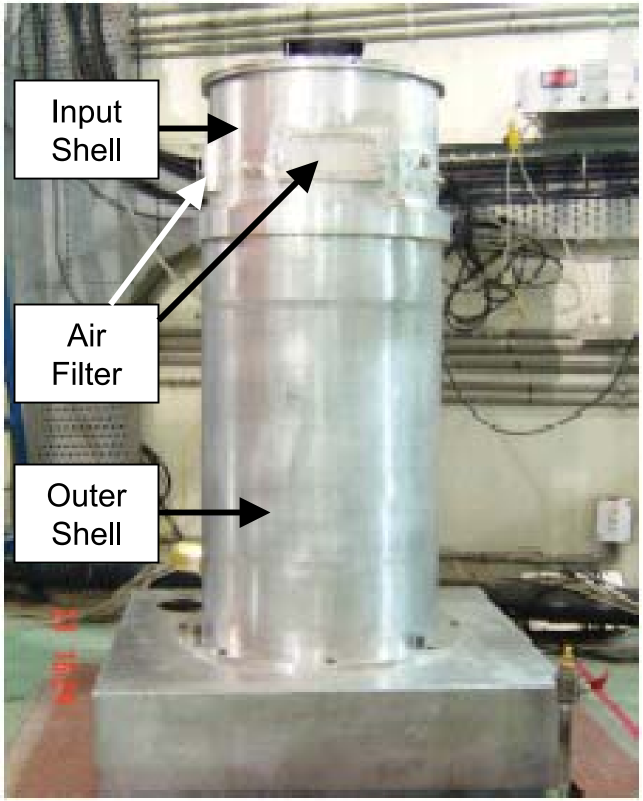
RF SYSTEM

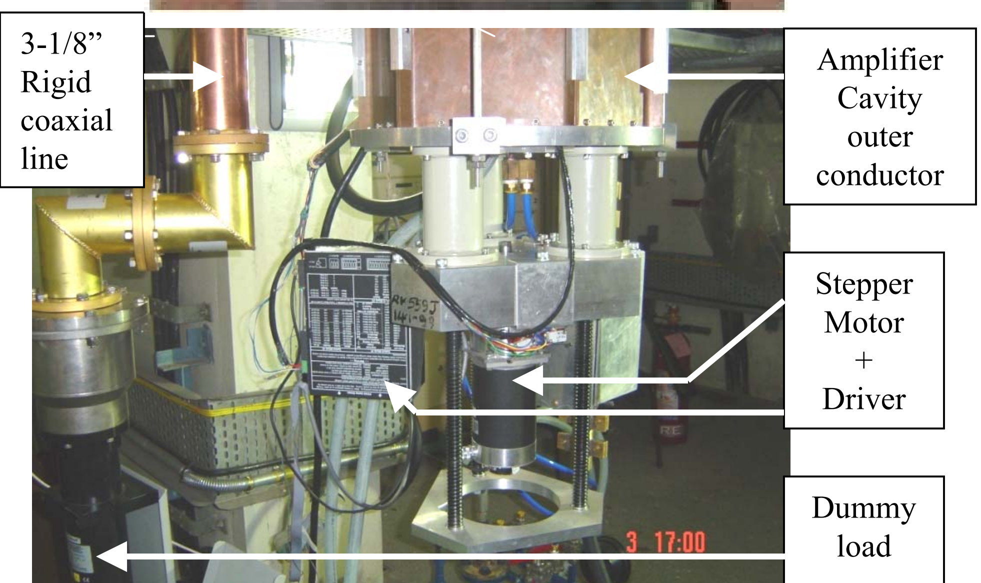
&

RF POWER SUPPLIES

RF SYSTEM SPECIFICATION

• Frequency range:	9 to 27 MHz
• Harmonic Modes:	1,2,3,4,5,7
• Peak Dee Voltage:	100 kV
• Frequency Stability:	1×10^{-7}
• Amplitude Stability:	1×10^{-4}
• Phase Stability:	$\pm 0.5^{o}$

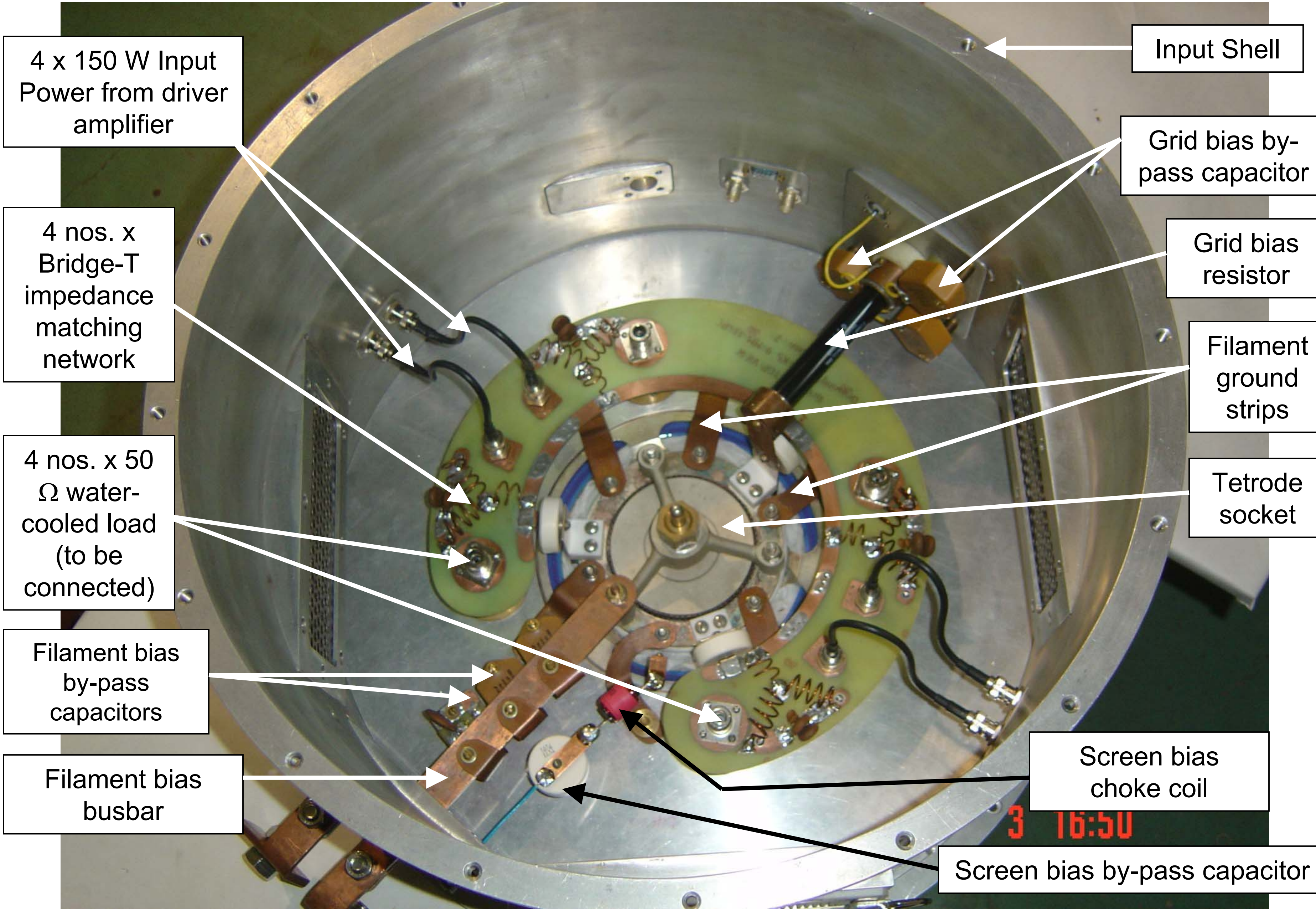




FINAL RF AMPLIFIER

- Eimac 4CW 150000E Tetrode based power amplifier
- Output Power: 100 kW max. at 50 Ohm
- Power gain ~ 22 dB
- Input Power: 600 W at 50 Ohm
- Mode of operation: Class AB
- $\lambda/4$ Resonant cavity similar to main Dee-cavity
- Tunable from 9 MHz to 27 MHz by movable Sliding short
- Sliding short travel ~ 2184 mm. max.
- Precise movement of sliding short by PC-based stepper motor controlled system

INPUT CIRCUIT FOR RF AMPLIFIER



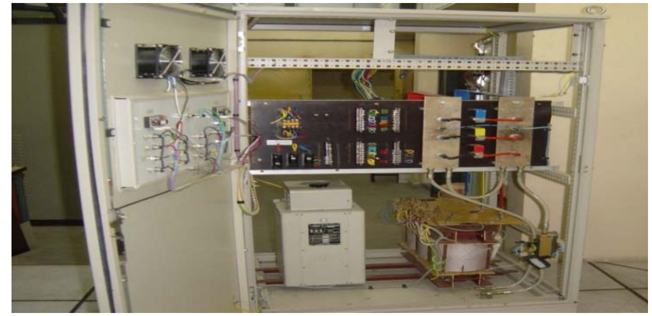
RF Power Supplies Fabricated at VECC

250 KVA Transformer

Rectifier Bank Assembly

Anode Power Supply

(0 to 20KV DC, 22.5A, 7% load regulation, fast crowbar protection)



Filament Power Supply

(0 to 15.5 V ± 0.75 V DC, 215A at 15.5 V)

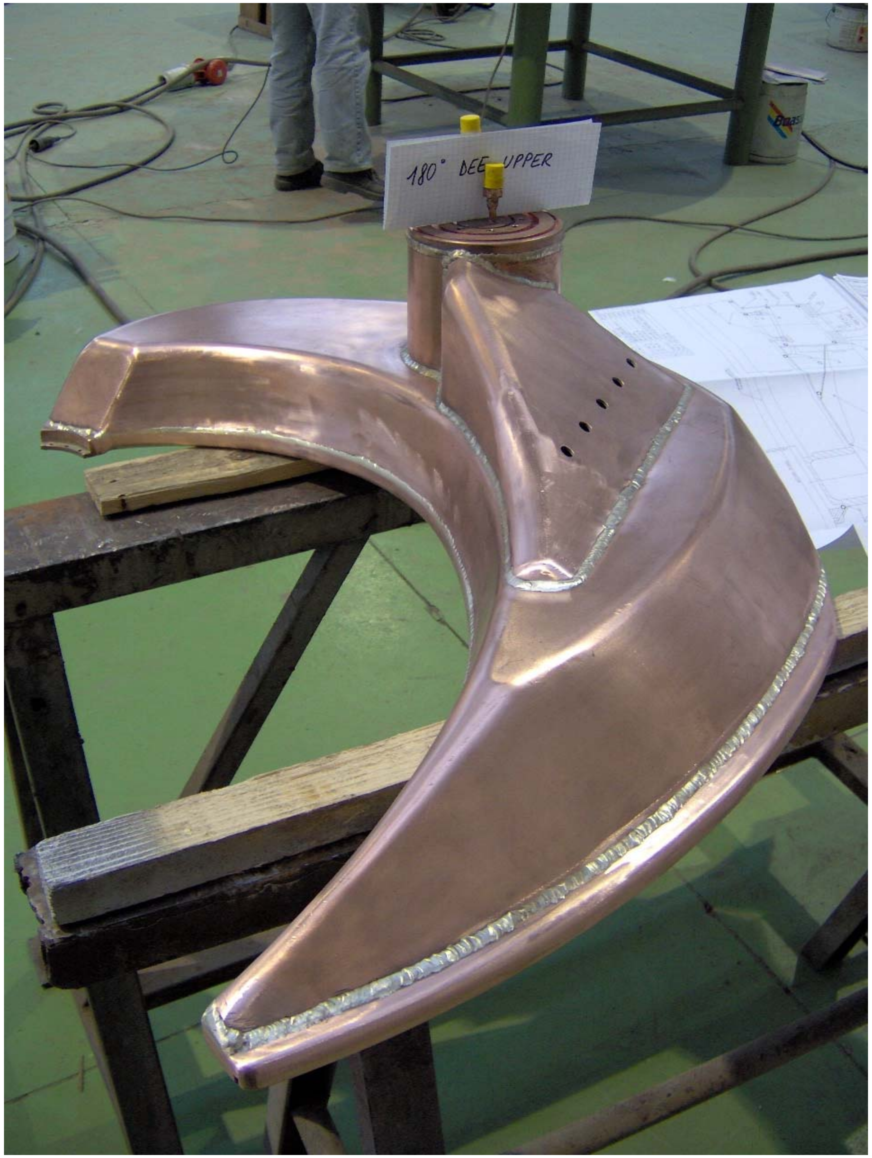
Control Grid Power Supply

(-400 to -500 V DC, 100 mA, 0.01% load regulation)

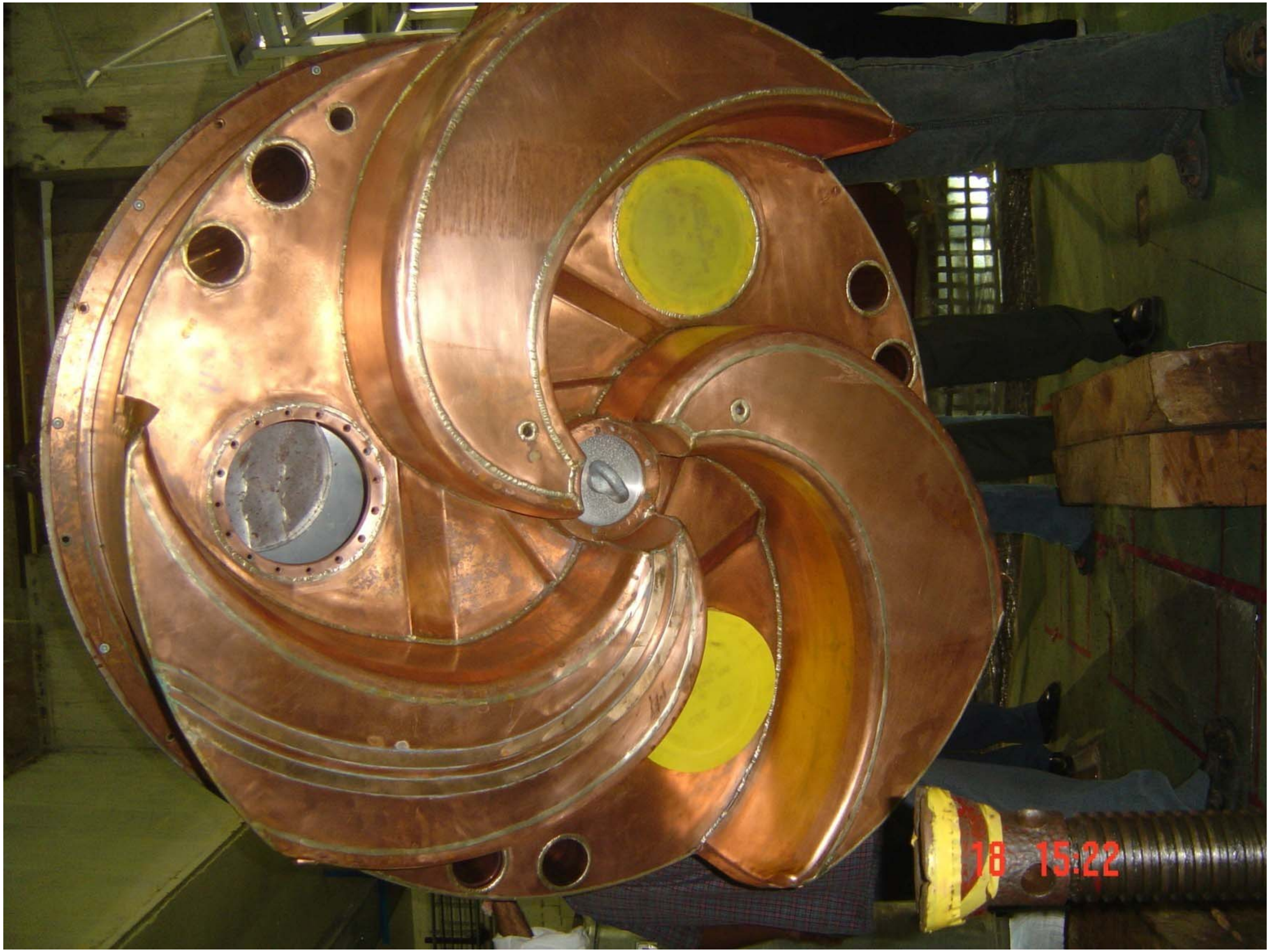
Screen Grid Power Supply

(500 to 1600 V DC, 0.5A, 0.006% load regulation)

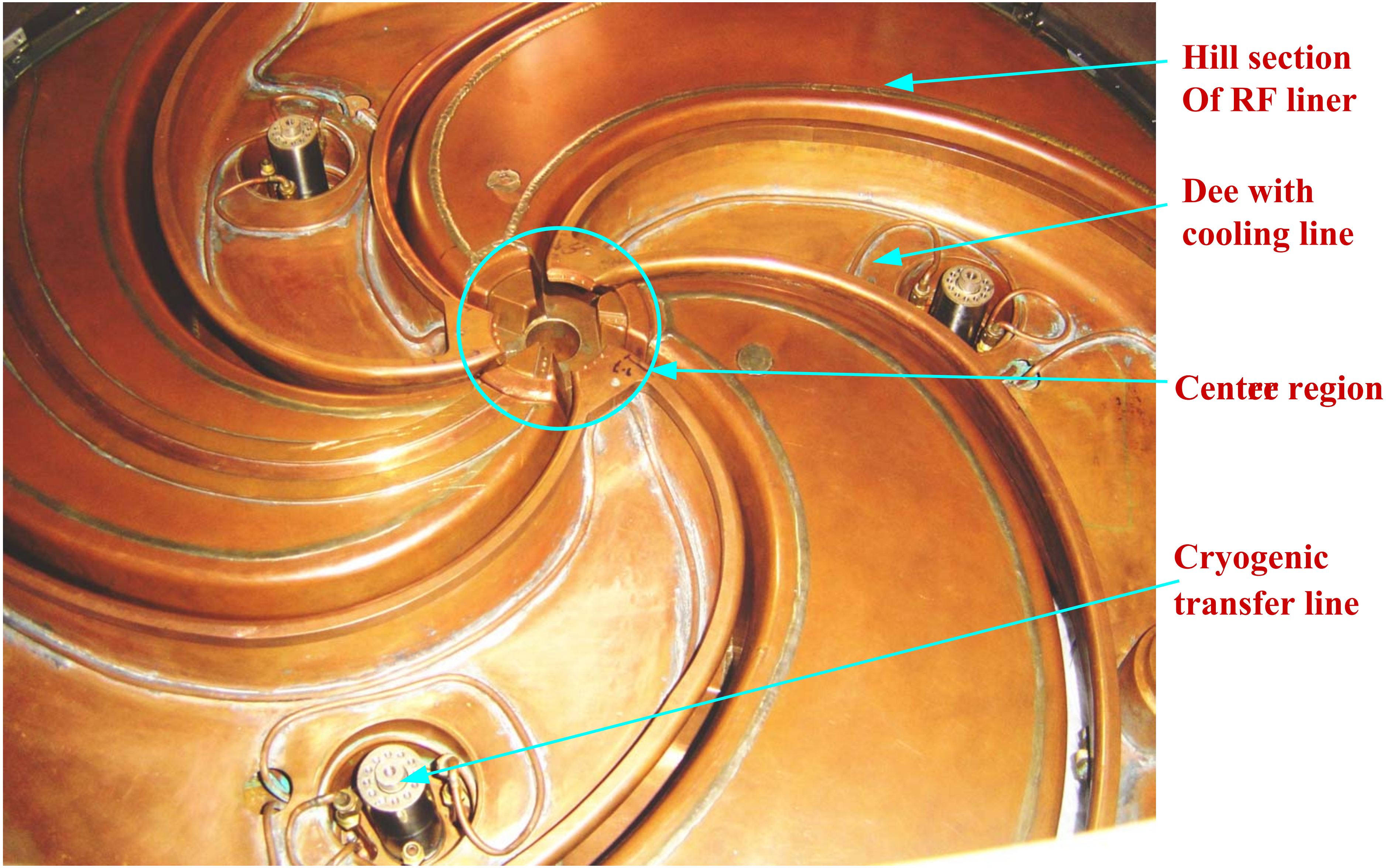
RF SYSTEM
(Mechanical)



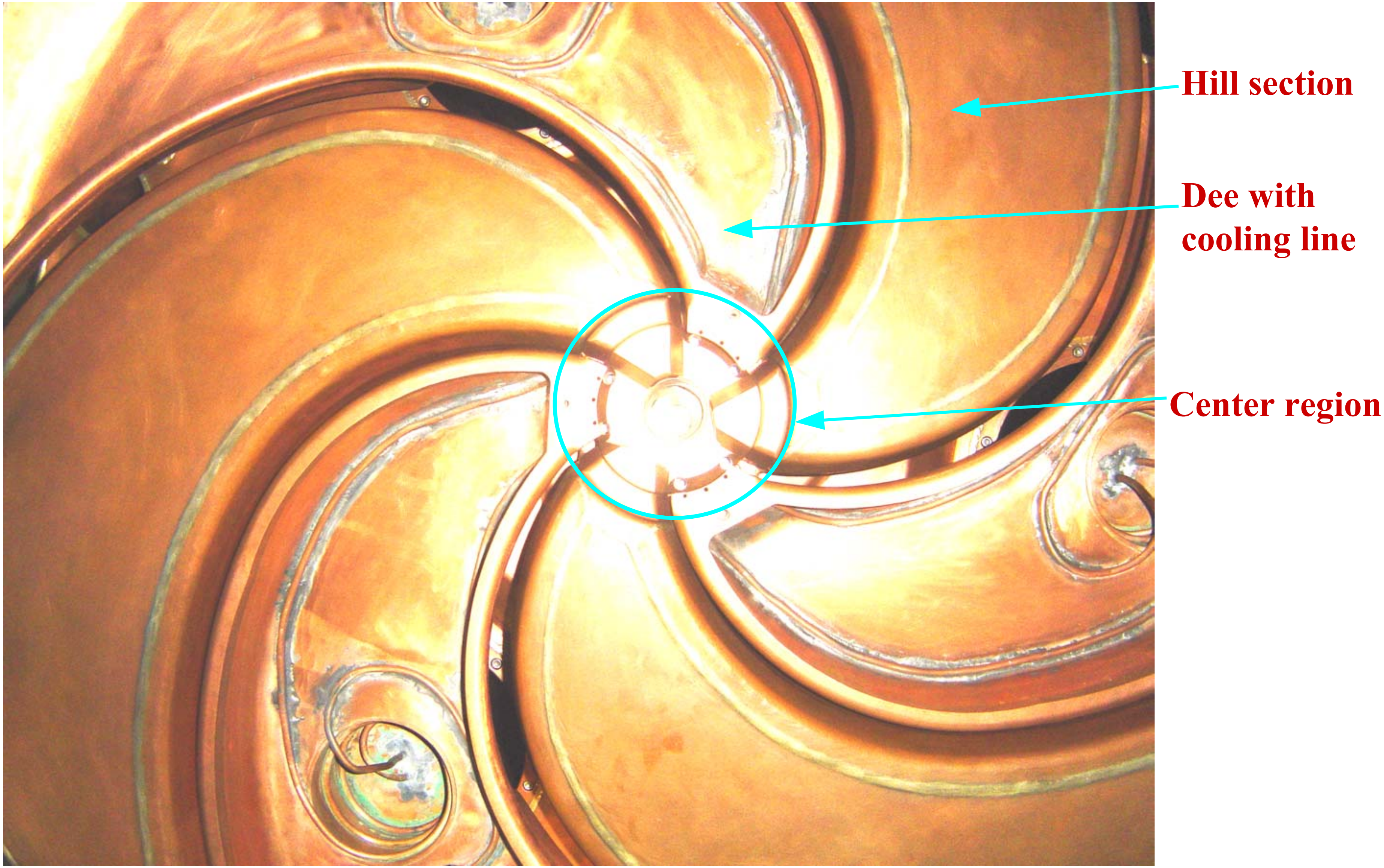
DEE



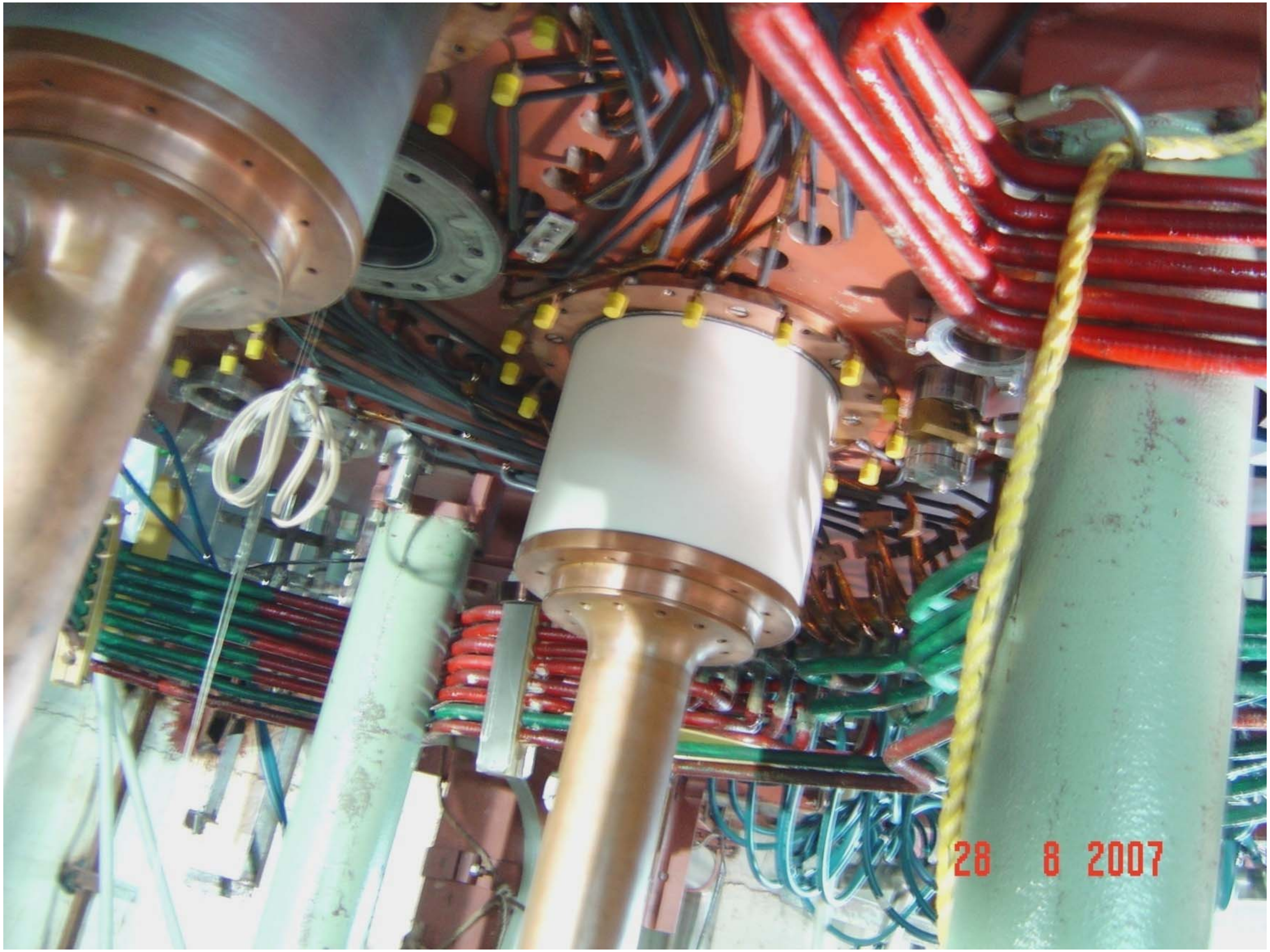
Lower RF Liner



Lower RF Liner with Dees and Centre region Components

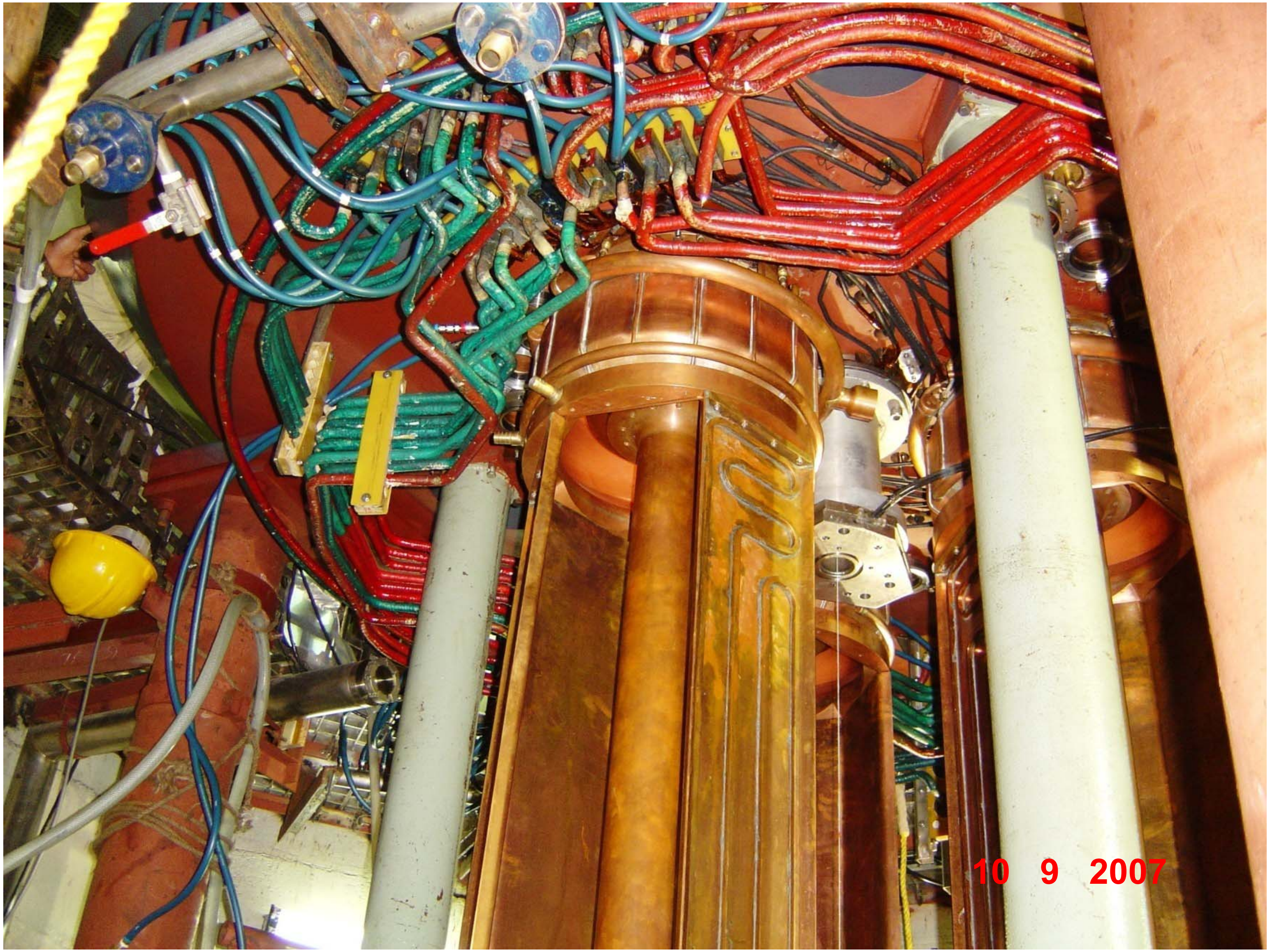


Upper RF Liner with Dees and Centre region components

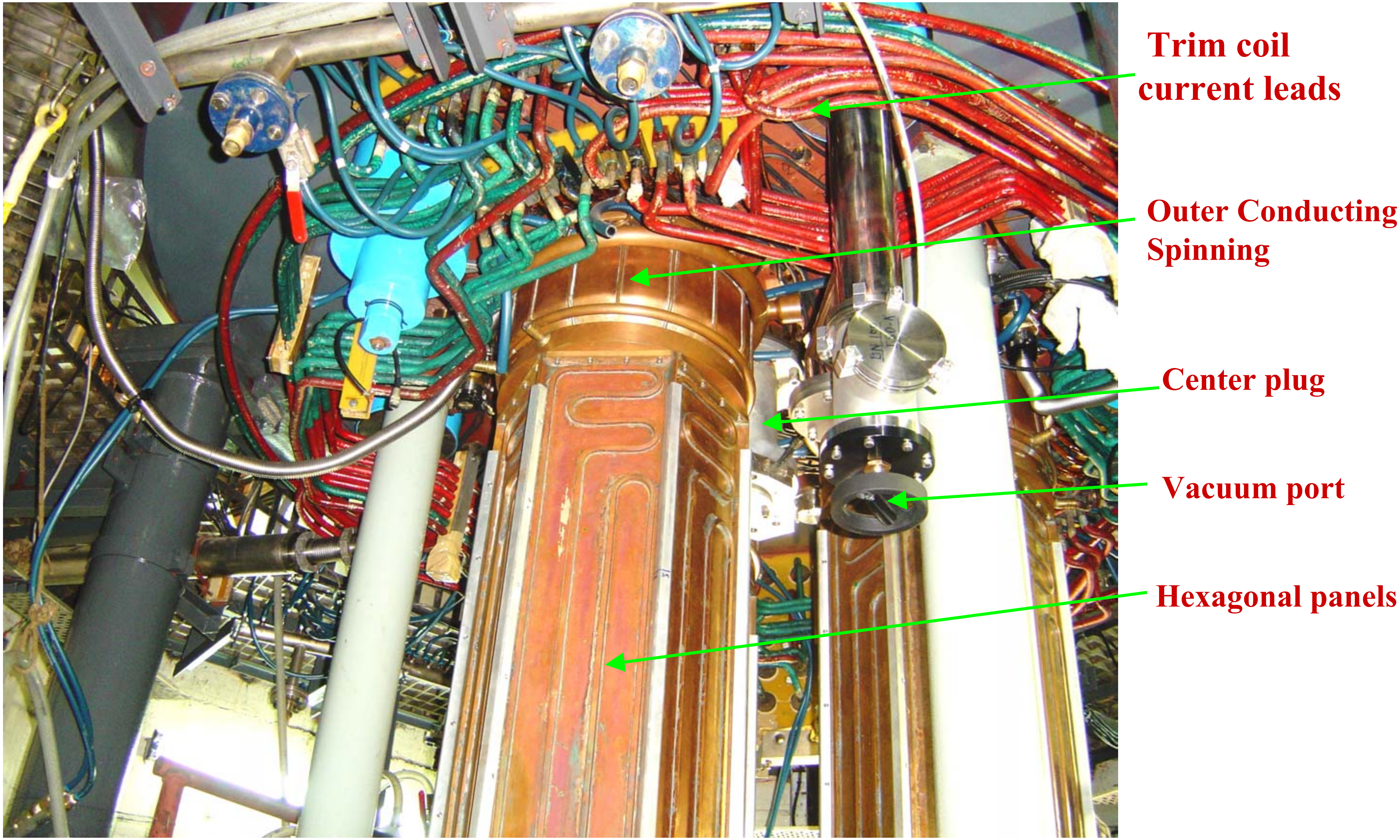


Installation of inner conductors below the magnet

OUTER CONDUCTOR SPINNING

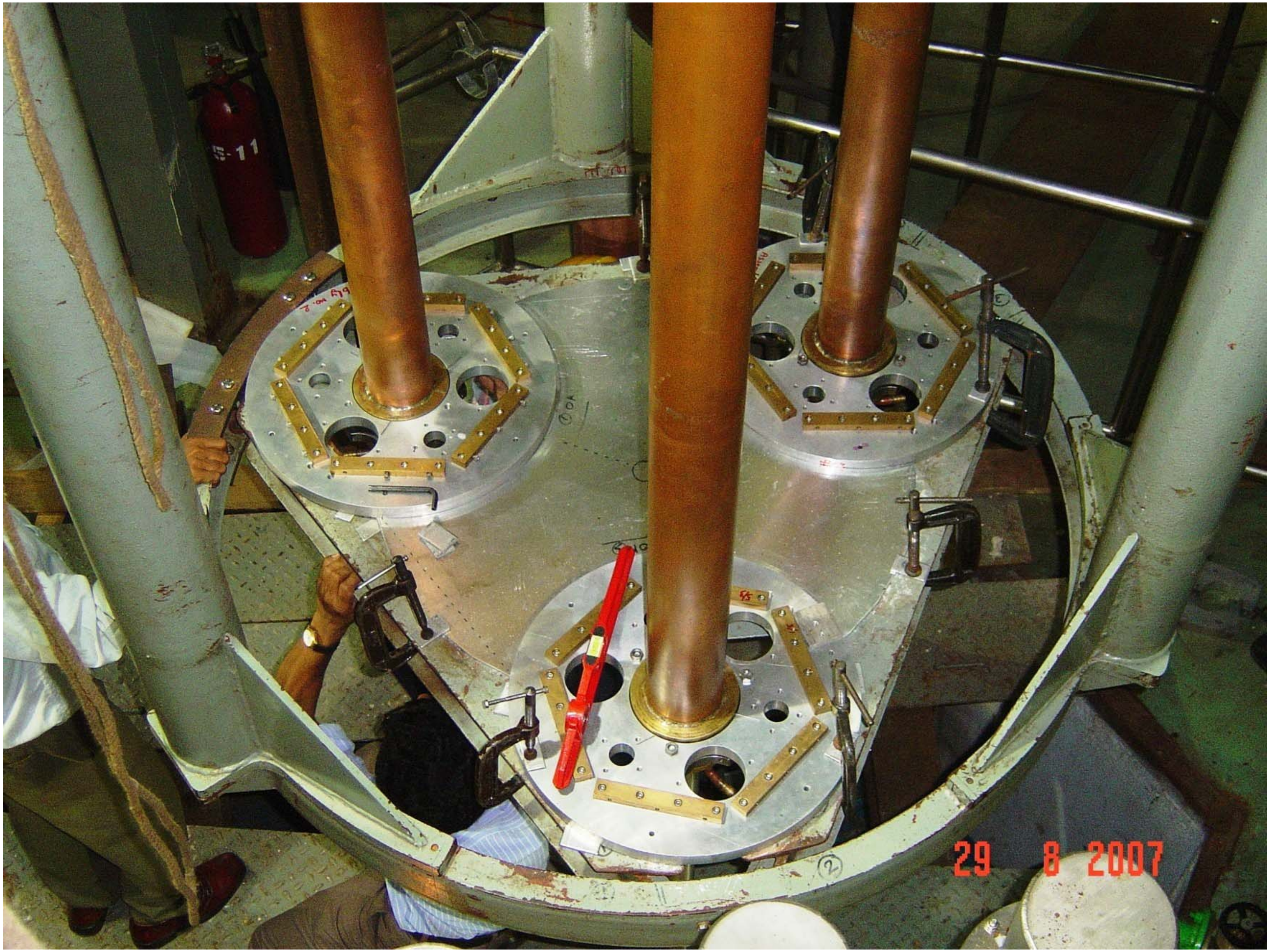


Lower outer conductor spinning assemblies

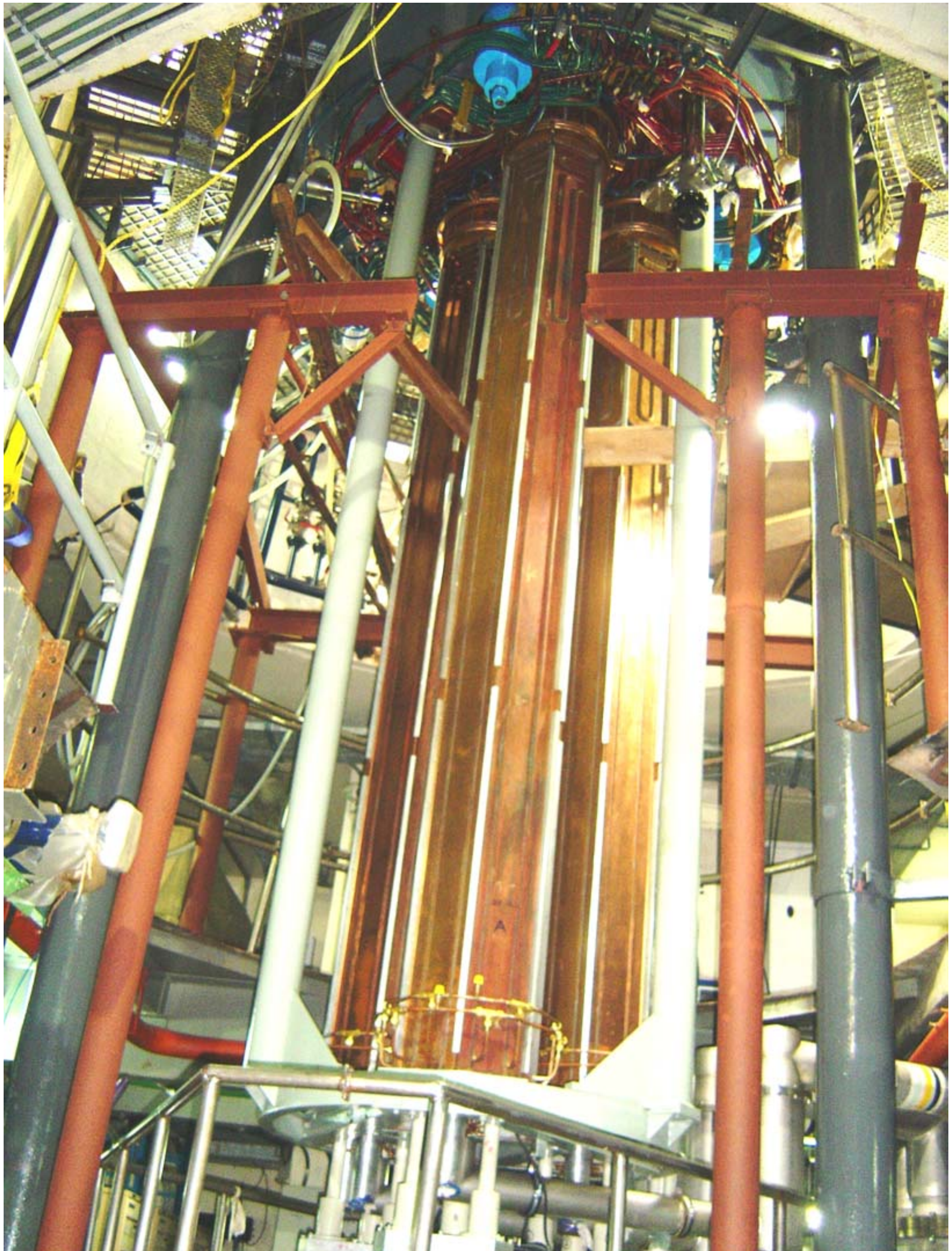


View from bottom of Magnet showing Trim Coil leads.

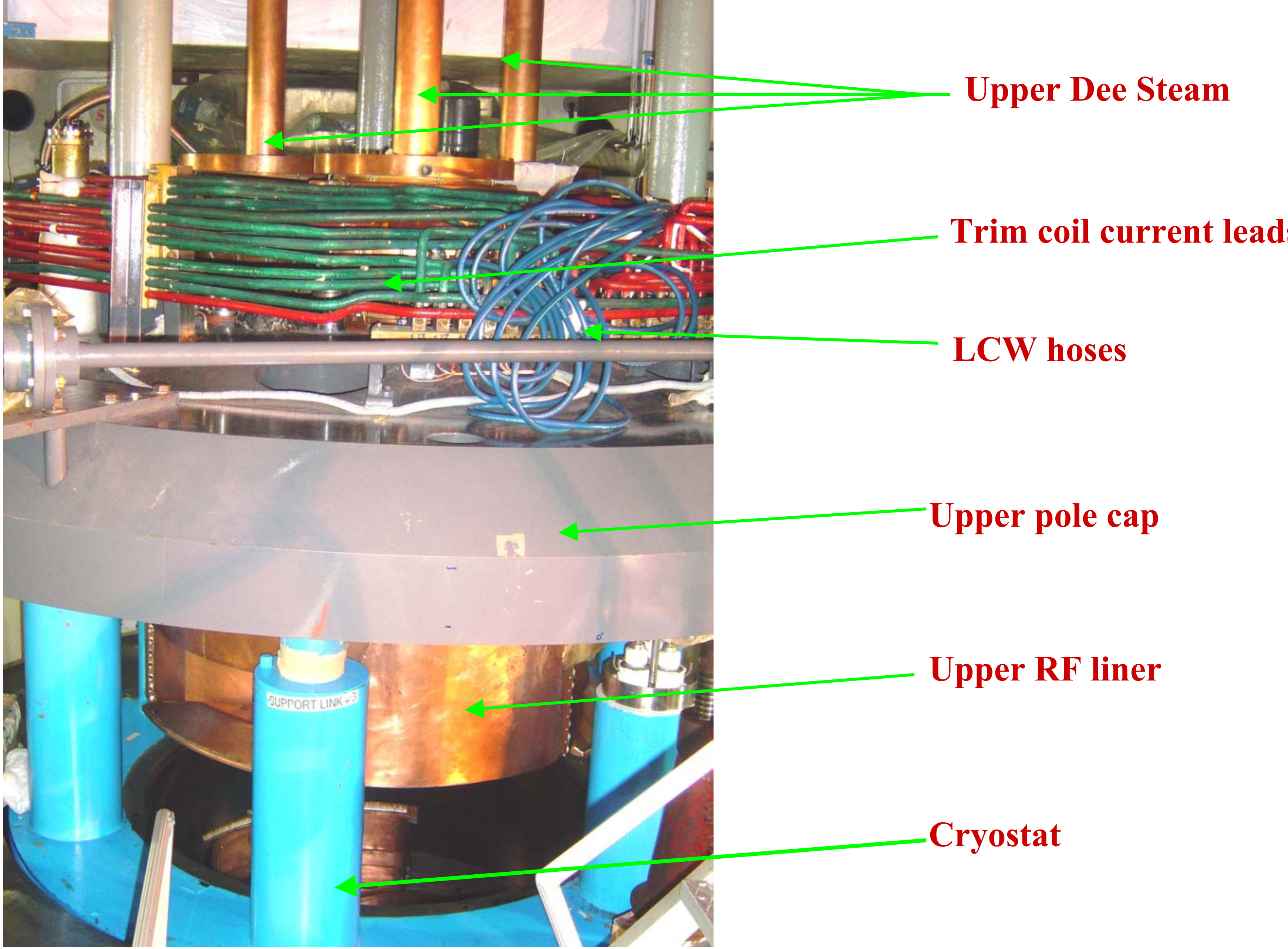
View from bottom of Lower RF Cavity



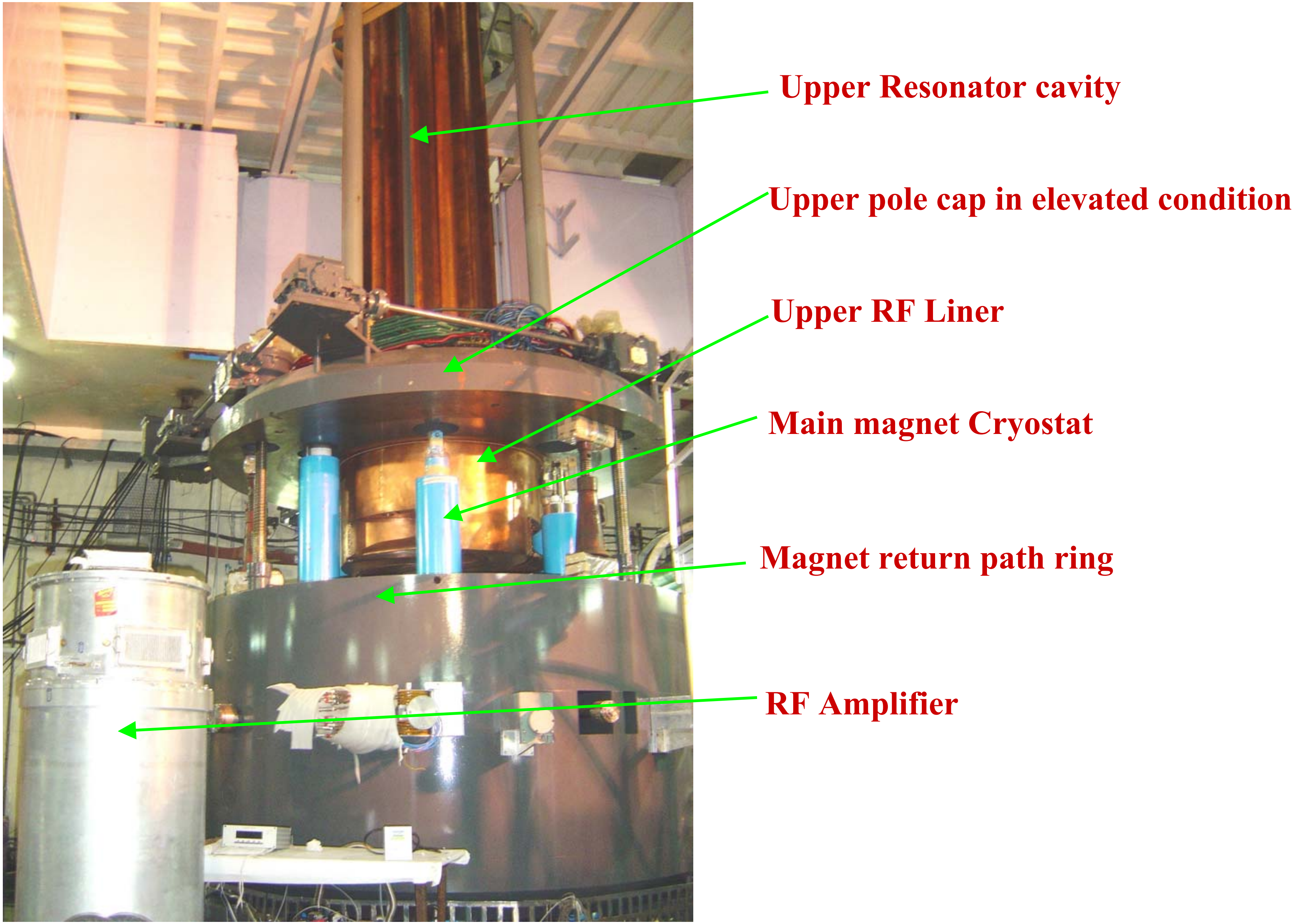
Three inner conductor assemblies on lower support structure



Lower RF Cavity in position

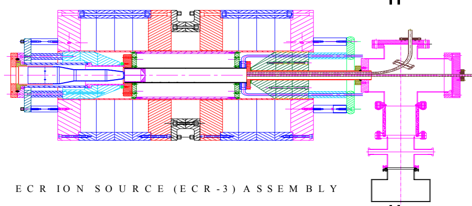


Upper pole cap in elevated condition
Showing Cryostat & Upper RF cavity

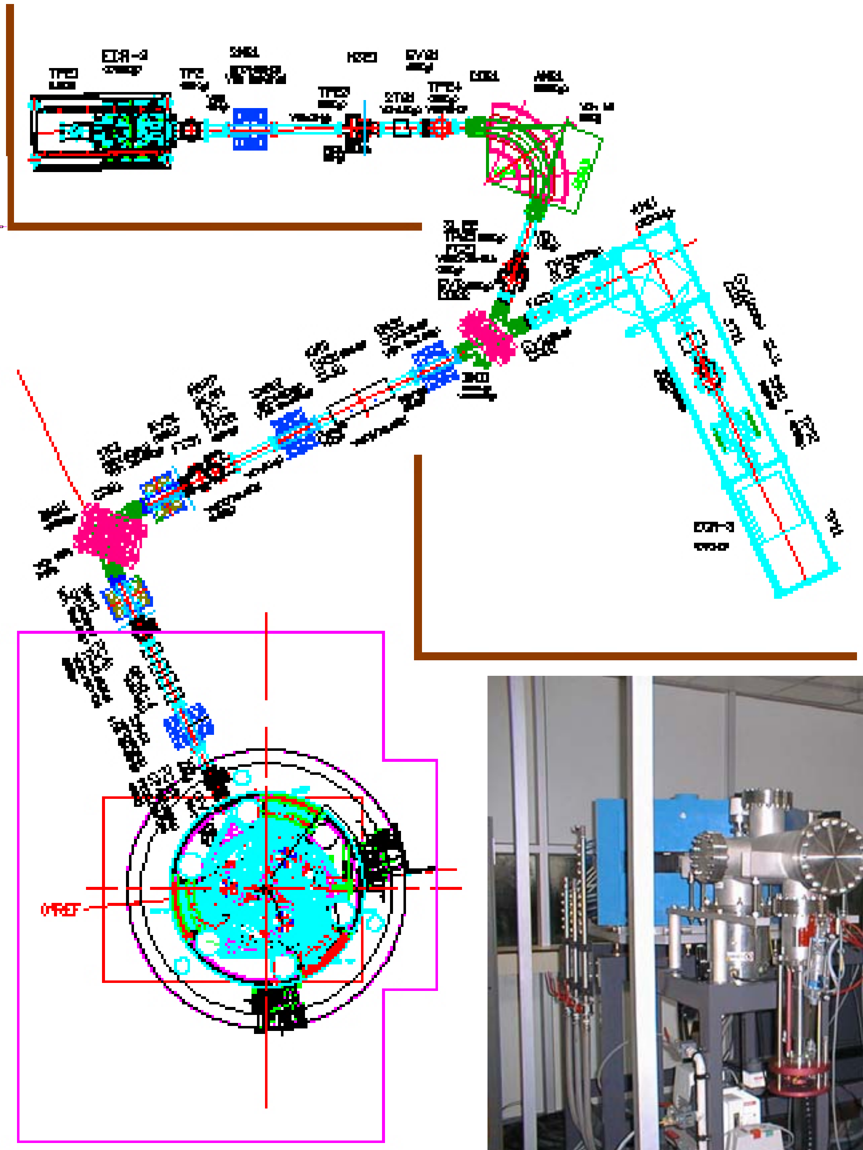


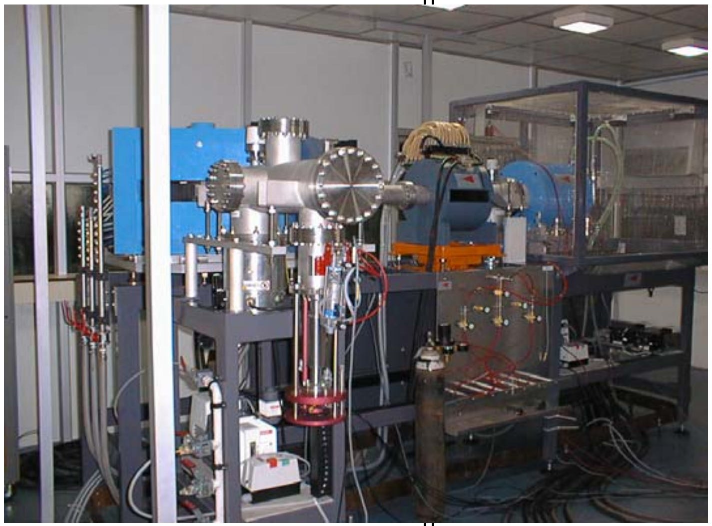
K-500 Cyclotron Magnet and RF System

INJECTION, EXTRACTION & BEAM DIAGNOSTICS

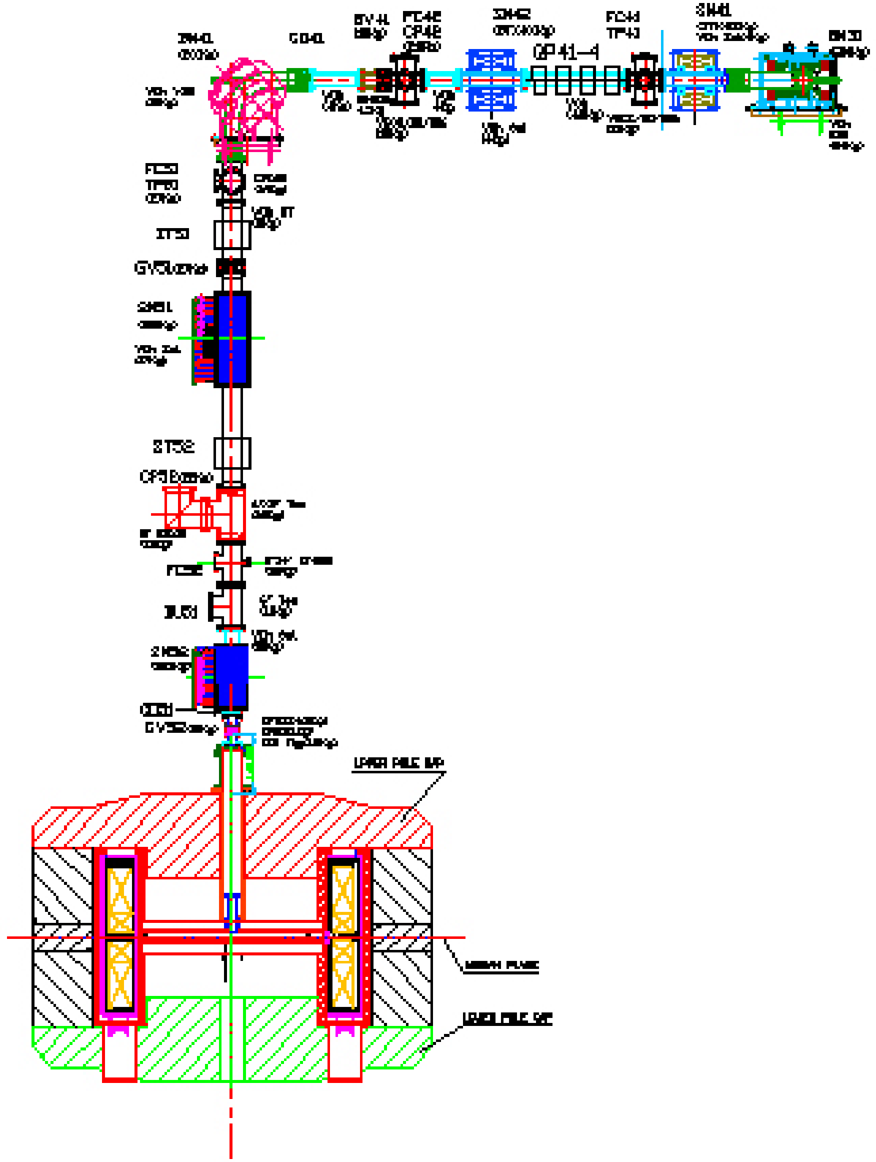


E C R ION S O U R C E (E C R - 3) A S S E M B L Y

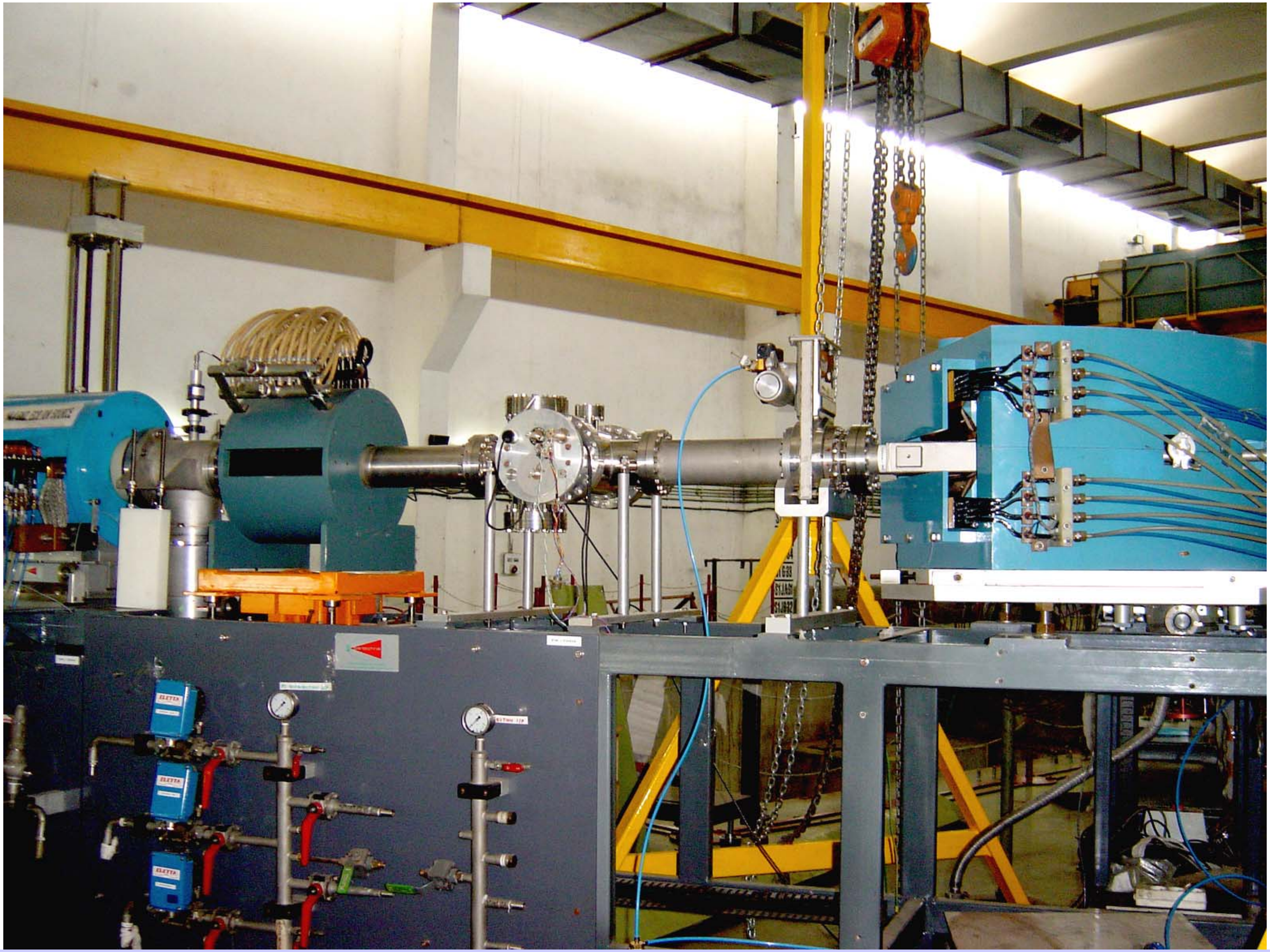




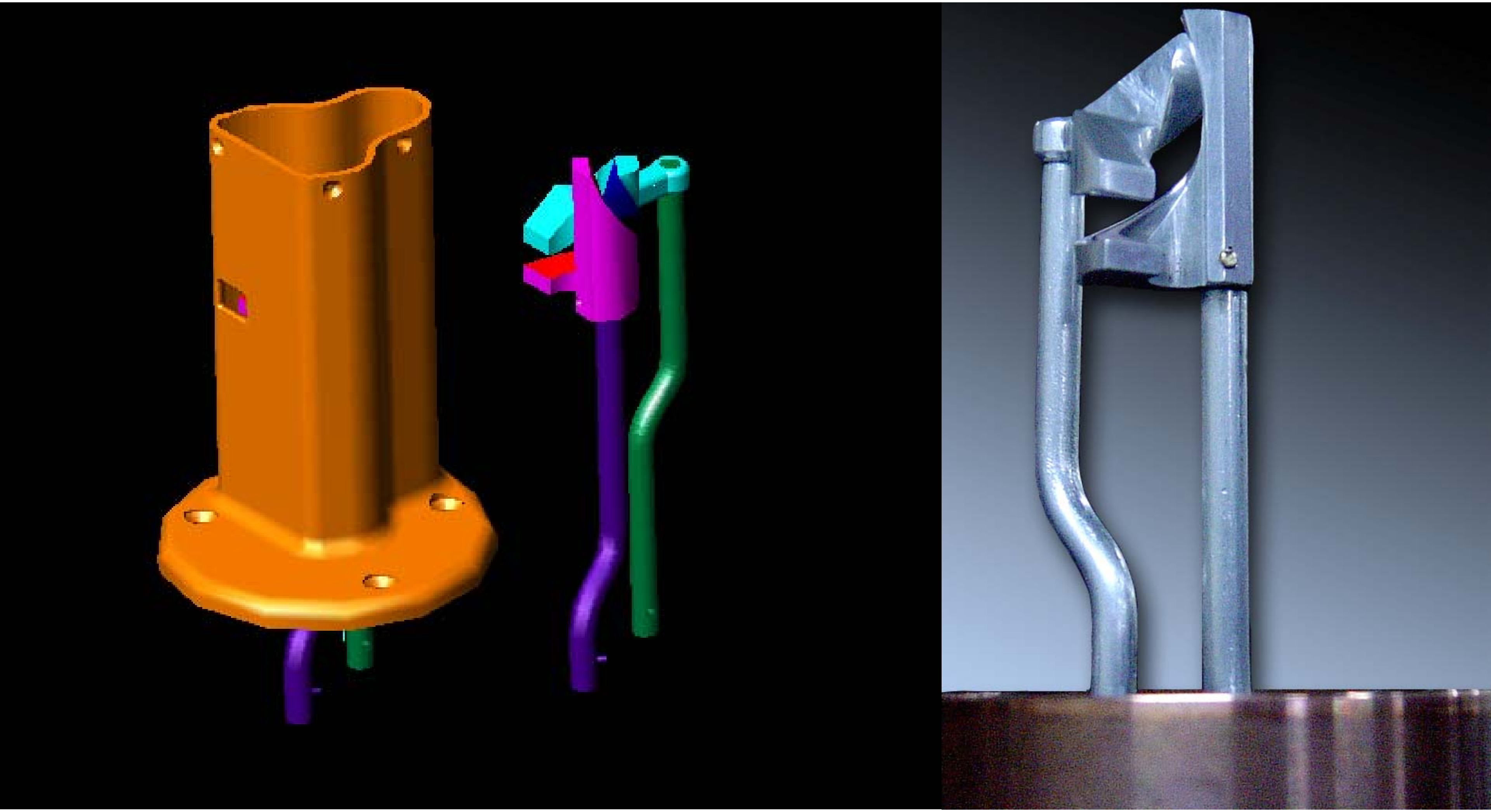
LAYOUT OF HORIZONTAL SECTION OF INJECTION LINE FOR VEC K-500 SUPERCONDUCTING CYCLOTRON



LAYOUT OF VERTICAL SECTION OF INJECTION LINE
FOR VEC K-500 SUPERCONDUCTING CYCCLOTRON

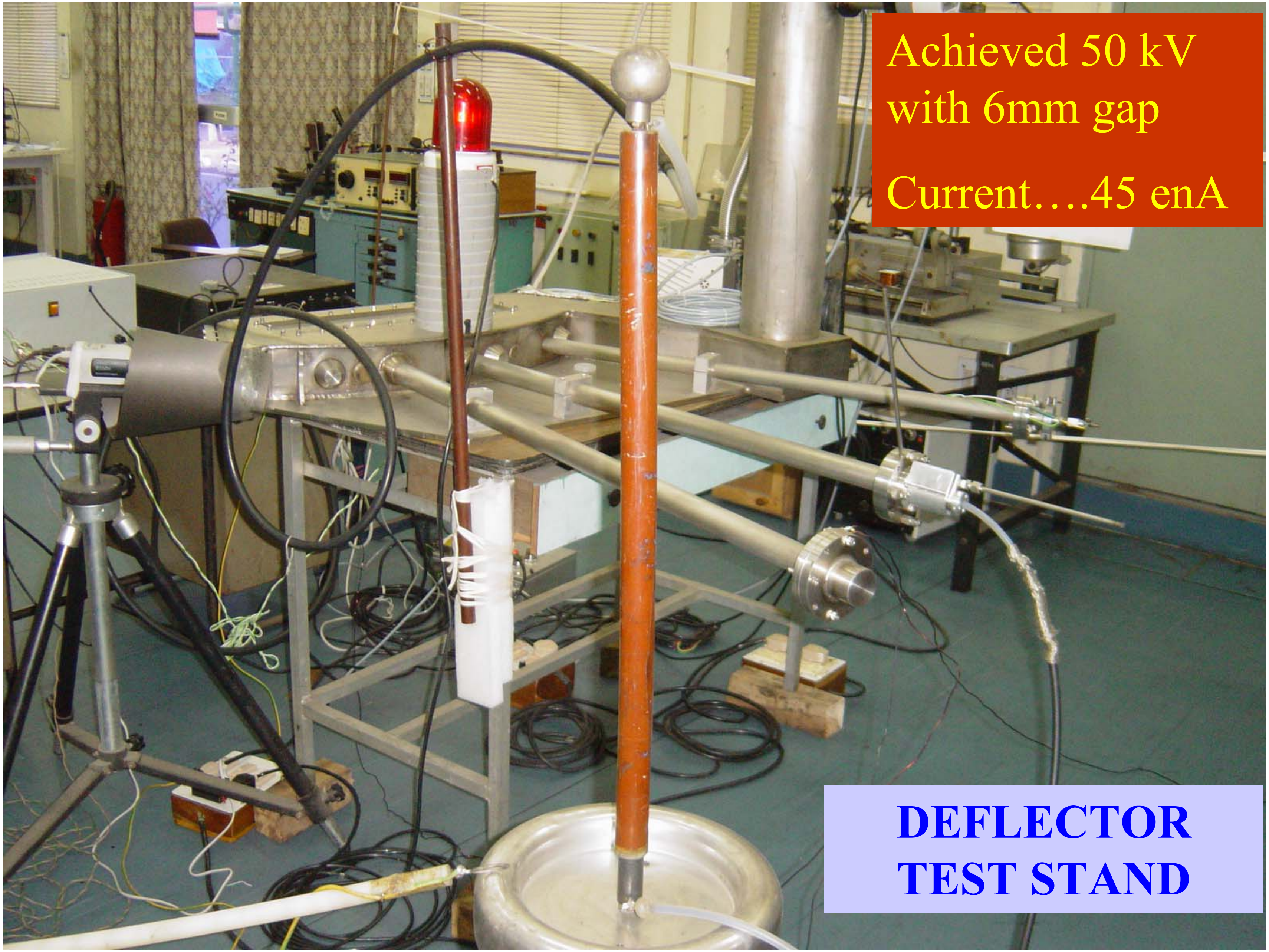


14 GHz ECR ION SOURCE



SPIRAL INFLECTOR

Fabrication work at CDM, BARC

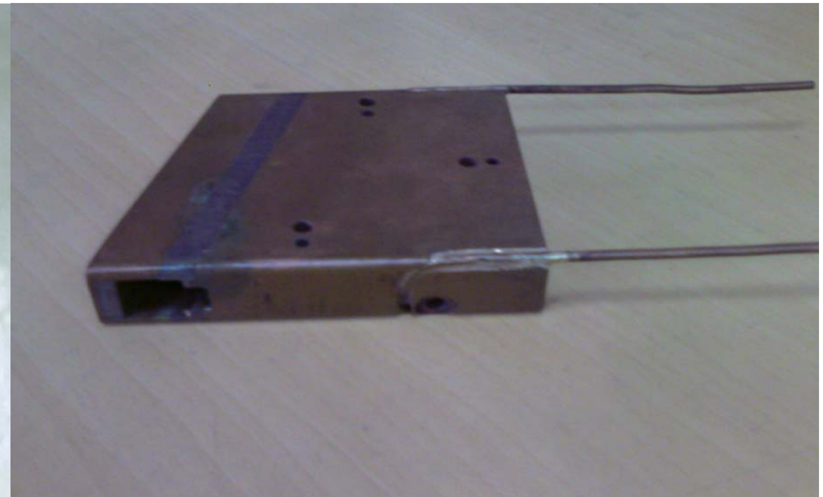


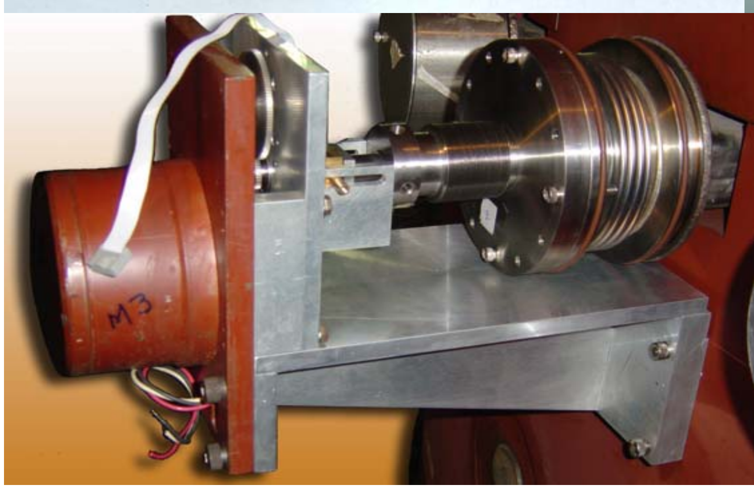
Achieved 50 kV with 6mm gap

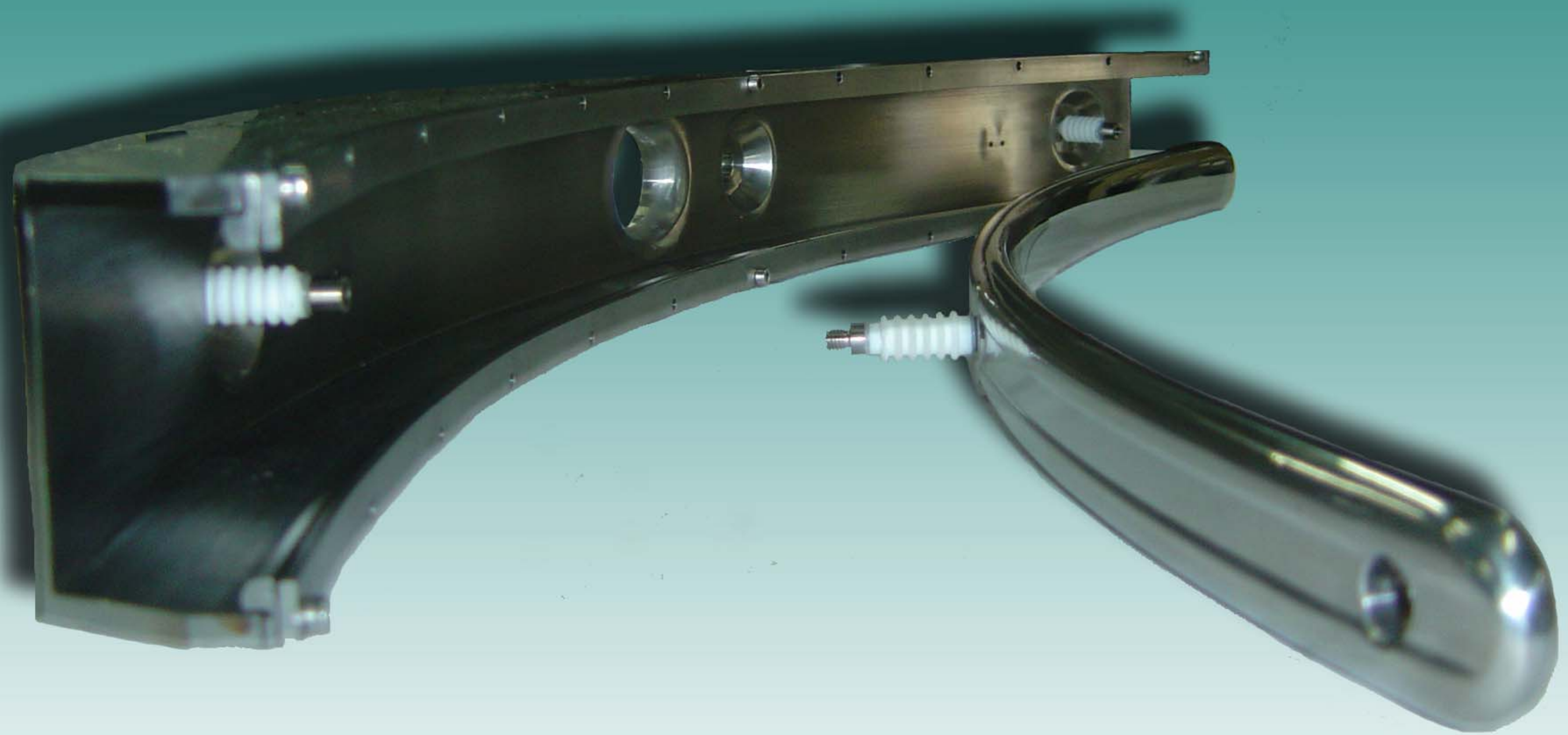
Current….45 enA

DEFLECTOR TEST STAND

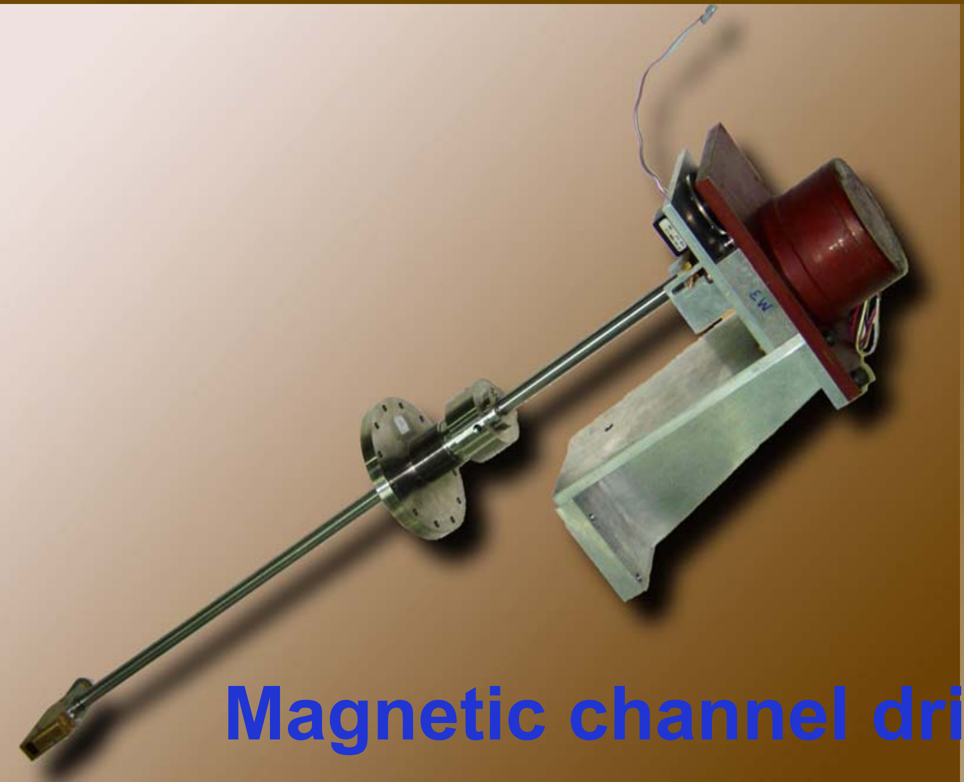
Passive magnetic channels

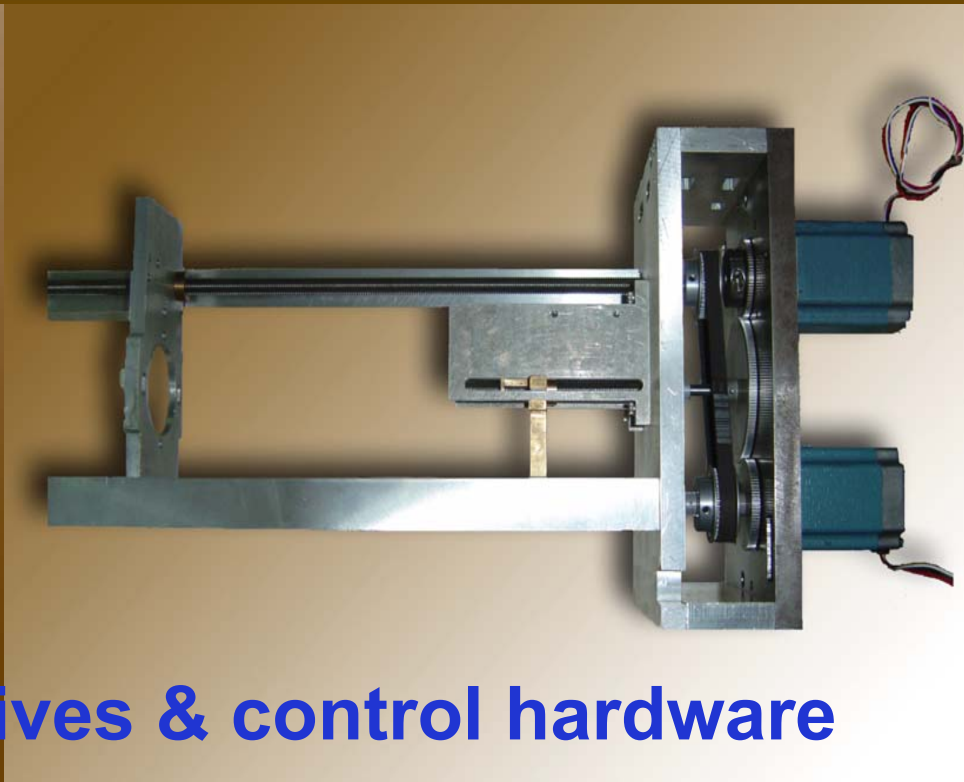




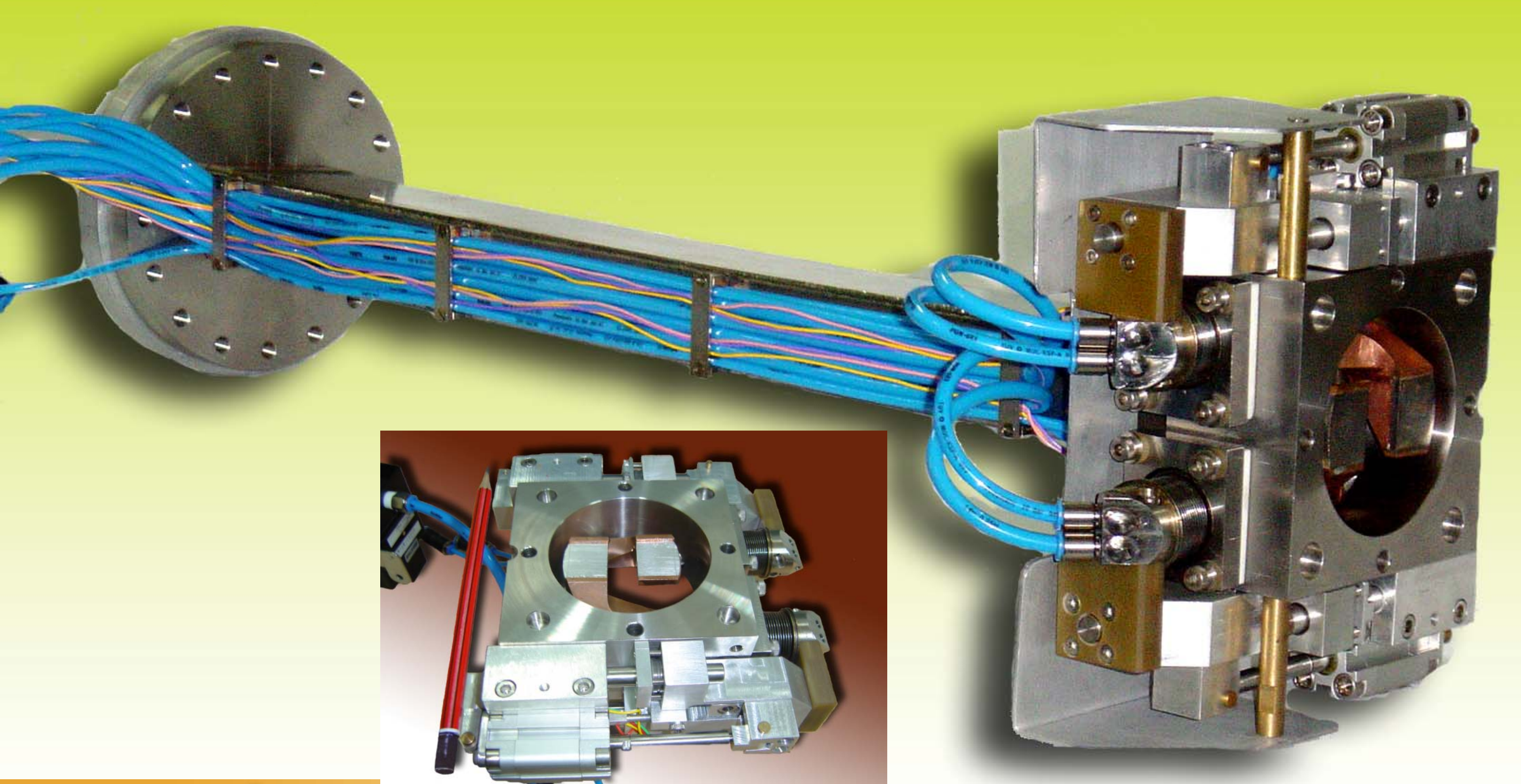


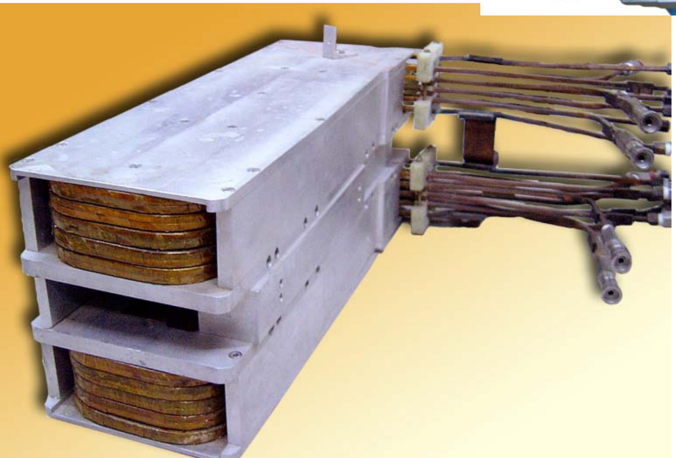
Electrostatic Deflector



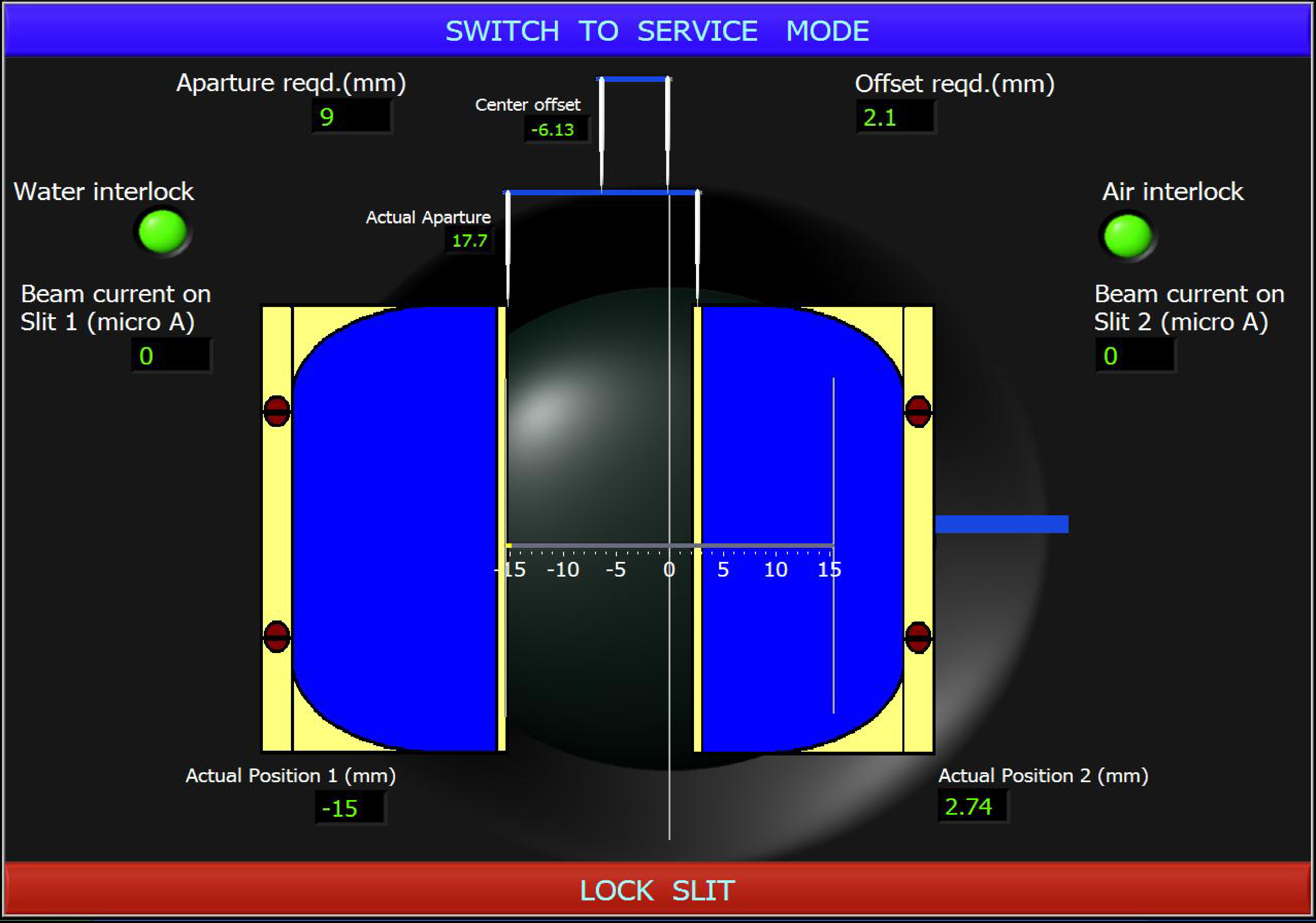


Magnetic channel drives & control hardware

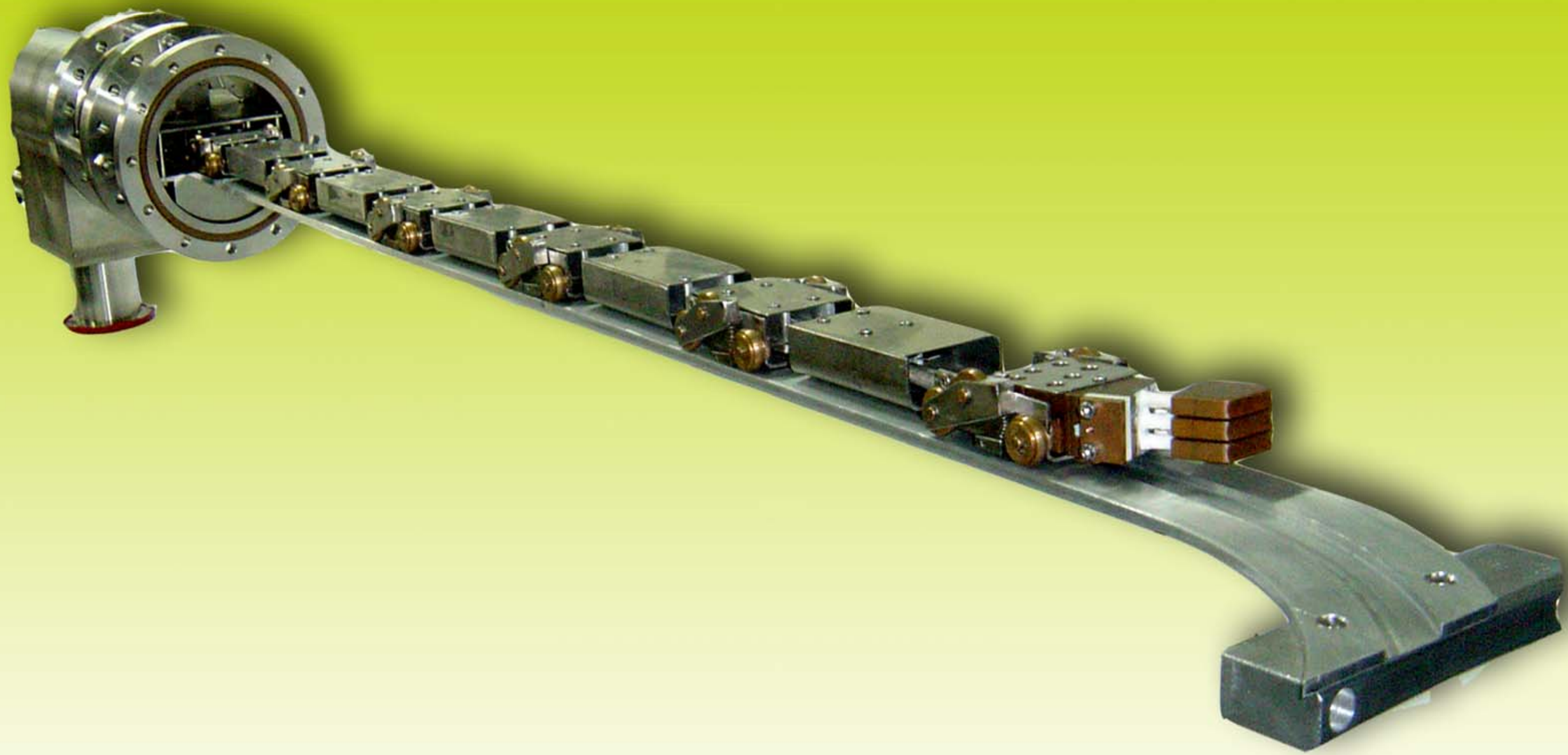




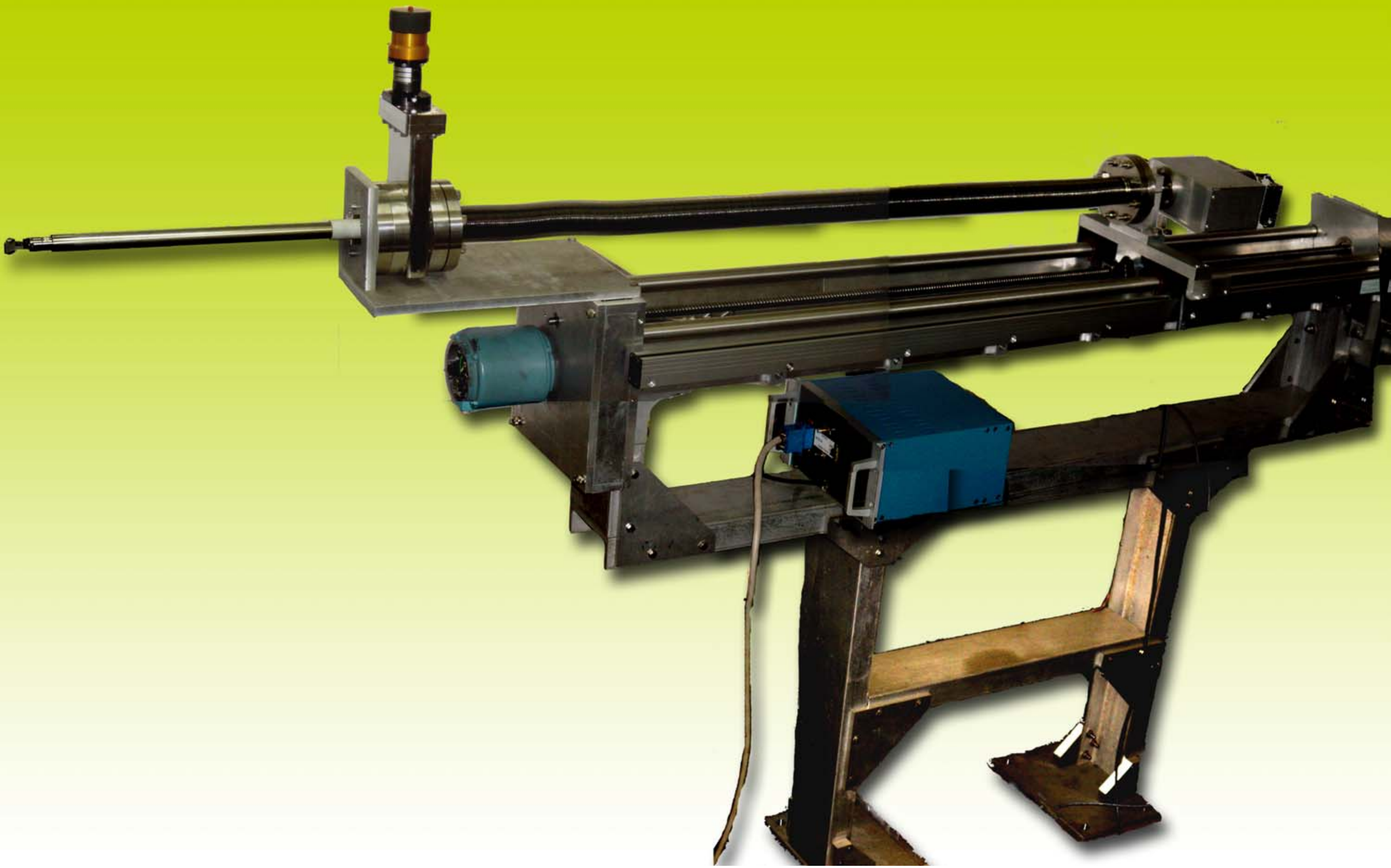
Magnetic channel (M9) Slit drive & coil



HMI for M9 Slit Control



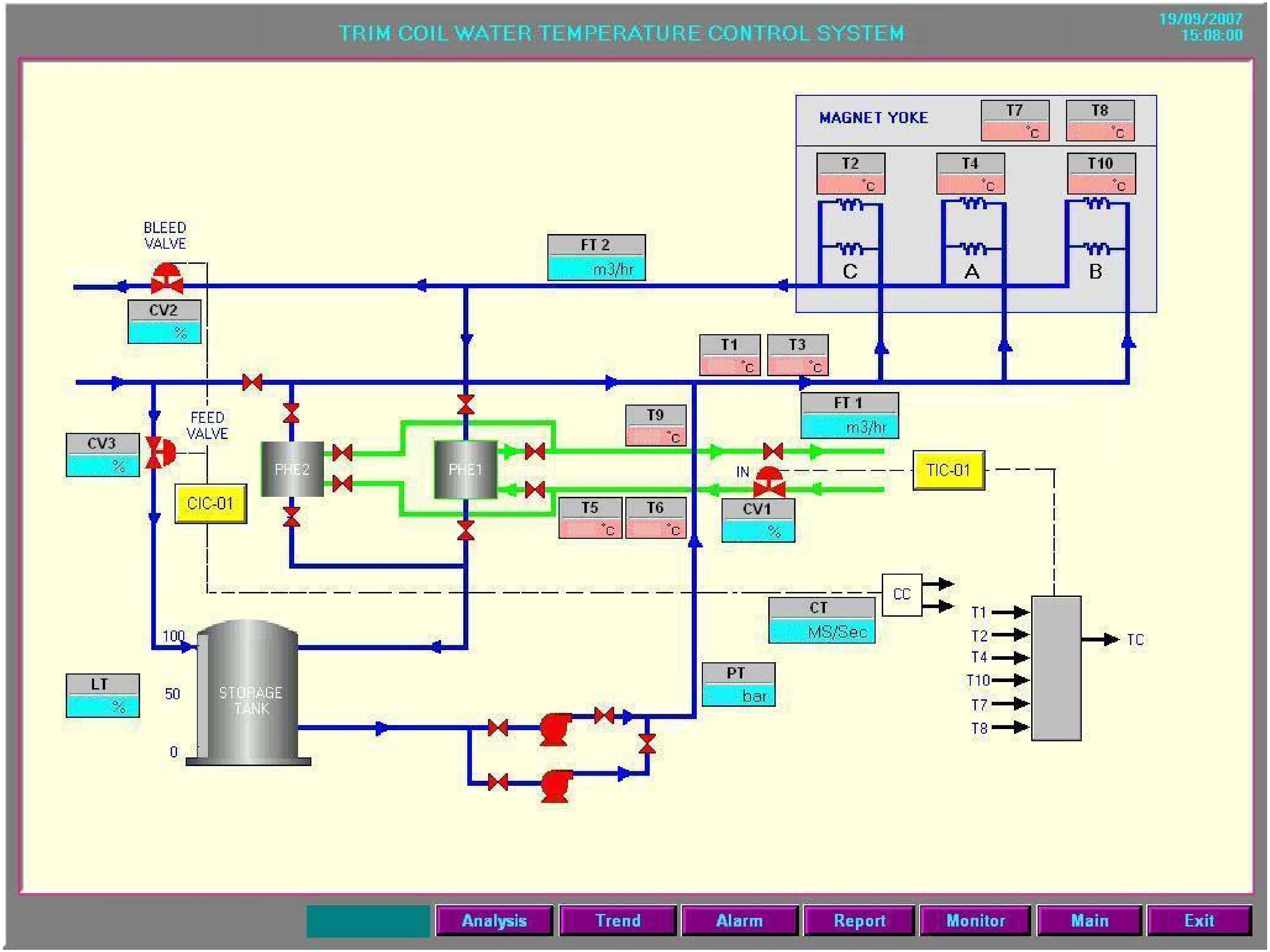
Beam Diagnostic Probe



Beam Viewer Probe

TRIM COIL WATER TEMPERATURE CONTROL SYSTEM

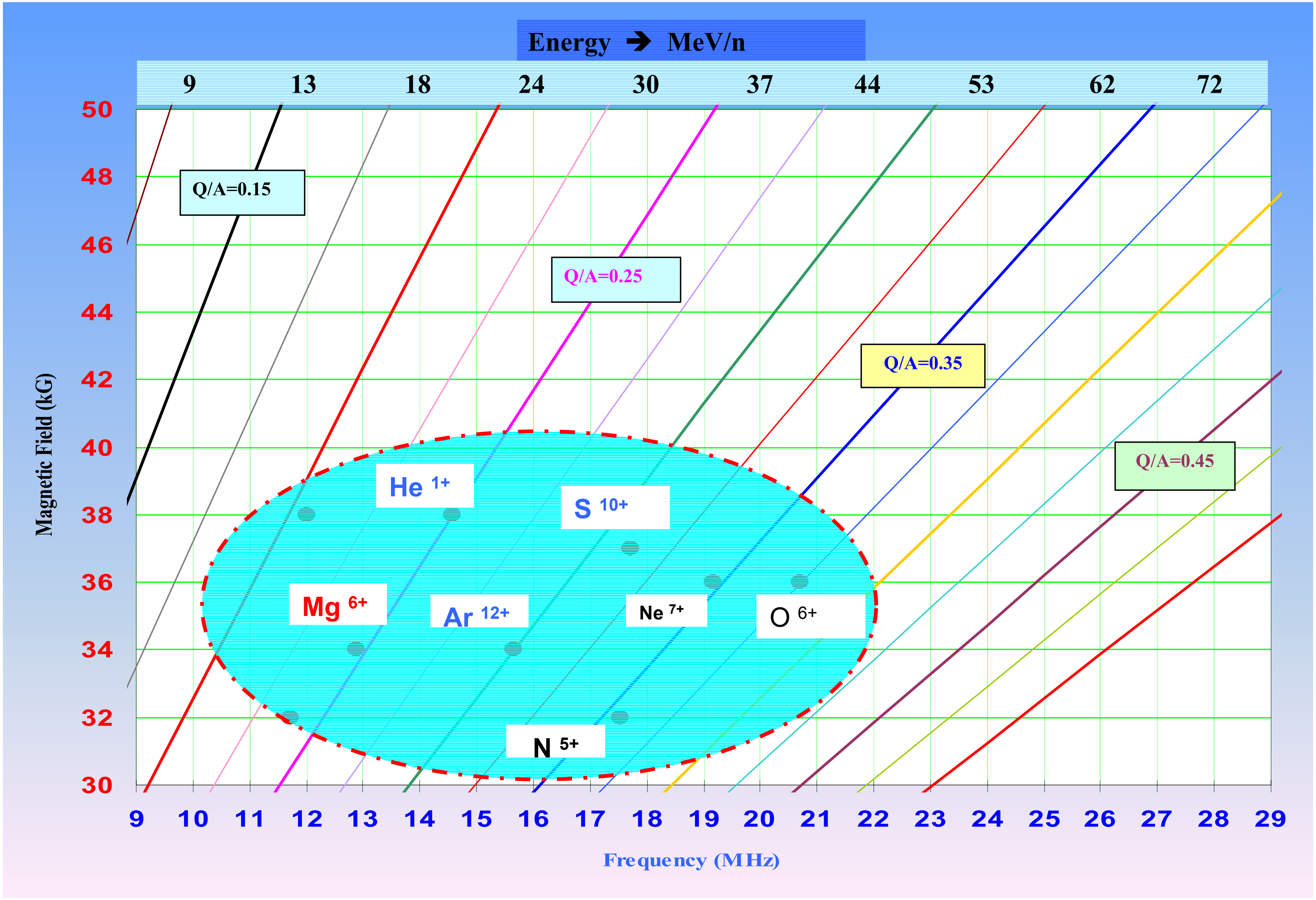
- **Redundant standalone controller architecture along with redundant temperature sensors**
- **Maintain temperature difference *within ±0.5°C* between pole tips and magnet yoke**
- **Minimise relative thermal expansion or contraction of pole tips with respect to magnet yoke of Superconducting Cyclotron**
- **Control conductivity by feed-bleed mechanism with main LCW system**


TRIM COIL WATER TEMPERATURE CONTROL SYSTEM
19/09/2007
15:08:00
MAGNET YOKE
T7
T8
T2
T4
T10
C
A
B
BLEED VALVE
FT 2
m3/hr
CV2
%
T1
T3
FT 1
m3/hr
CV3
%
FEED VALVE
T9
PHE2
PHE1
IN
TIC-01
CIC-01
T5
T6
CV1
%
CC
CT
MS/Sec
T1
T2
T4
T10
T7
T8
TC
100
50
0
STORAGE TANK
LT
%
PT
bar
Analysis
Trend
Alarm
Report
Monitor
Main
Exit

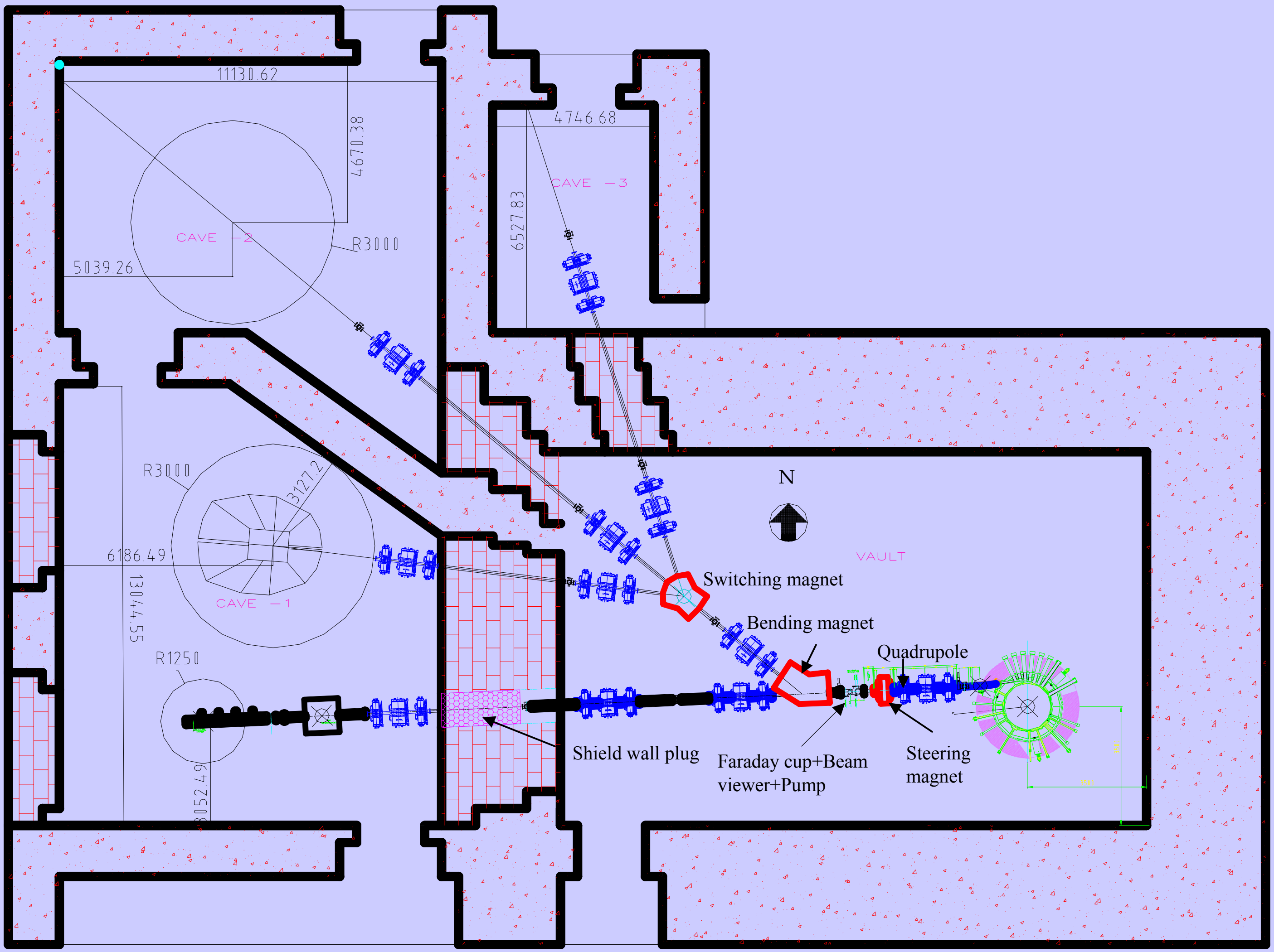
UTILIZATION OF THE SUPERCONDUCTING CYCLOTRON

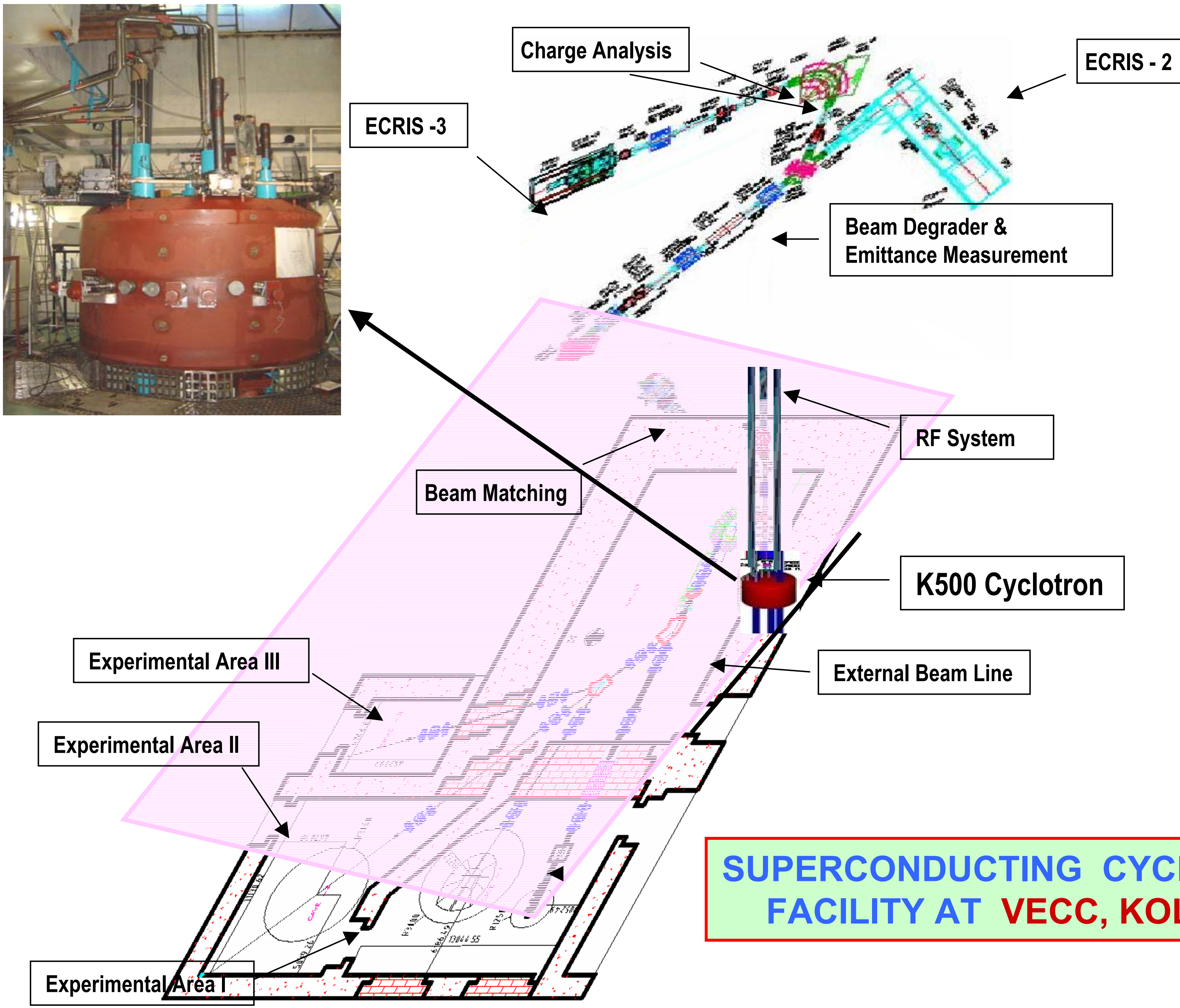
Operating Diagram & Initial Ions Expected

(November 2007)



K500 SUPERCONDUCTING CYCLOTRON EXTERNAL BEAMLINE LAYOUT





SUPERCONDUCTING CYCLOTRON FACILITY AT VECC, KOLKATA

Major Facilities

Nuclear Physics

- **Scattering Chamber**
- **Charged Particle**

Detector Array

- **Neutron Detector Array**
- **High Energy Gamma Ray**

Array

- **Ion Trap**

Condensed Matter

- X-ray Diffractometer
- Acoustic emission setup
- Vibrating sample magnetometer

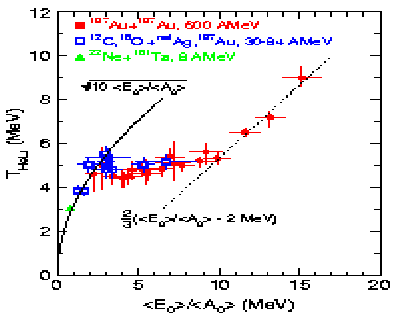
Nuclear Chemistry

- Activation analysis
- Pneumatic carrier facility
- Multitracer studies

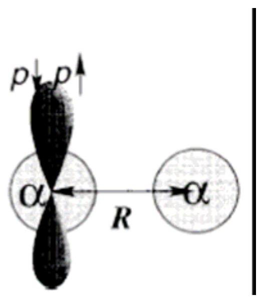
Nuclear Physics with superconducting cyclotron

Physics Goals :

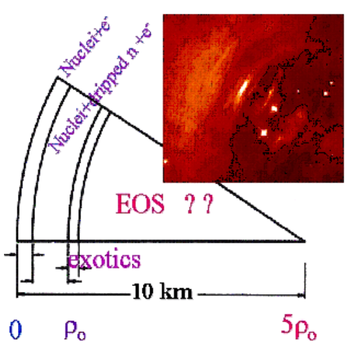
Liq. – gas Phase transition



Exotic Nuclear structures



Evolution of neutron star, supernovae



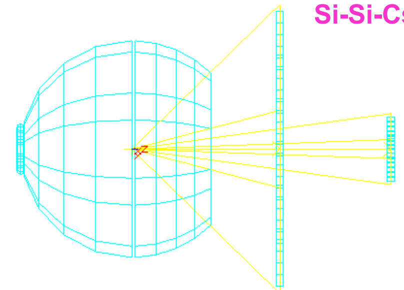
- Temperature
- Thermalisation
- Dynamics
- Deformation
- EOS
- Nuclear Compressibility
- Asymmetric Nuclear matter And Stellar Evolution
- Super Heavy Nuclei

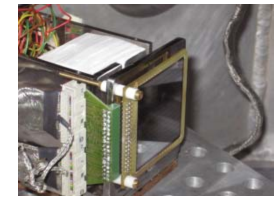
Facilities

Charged particle detector array

Back-ward Array
Si-CsI(Tl)

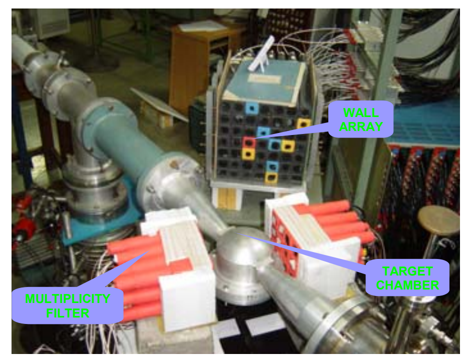
Forward Array
Si-Si-CsI(Tl)



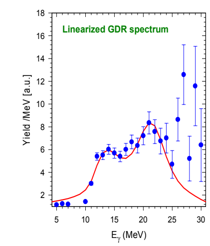


Prototype Si-Si-CsI(Tl) array

High energy gamma ray detector array

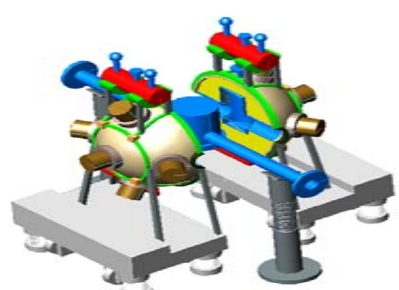


Gamma array at Exptl hall

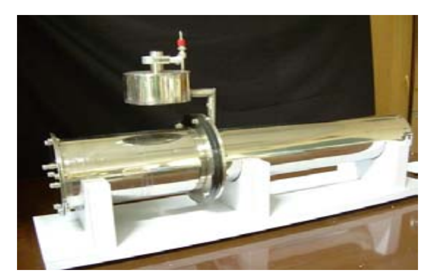


Deformed configuration of 32S*
Studied by GDR splitting

Neutron Multiplicity detector



4π neutron multiplicity detector



Prototype neutron detector

Thank you all !