The breakout session has a lot of material to cover so it is impractical to produce 4 separate magnet talks for the session to cover all possible topics. Instead we'd like Achim to collect the information on the plans for cryo, power, quench protection/controls, mapping, magnet mechanics including the valve box and the two cold tests, into one set of slides. Since the scope of the material is so broad our collection of magnet experts will need to assist him. We need to keep in mind that the November review will not be a design review, but a technical cost and schedule review so the technology informs the discussion but the main emphasis should be on the resources, cost and schedule for performing all of the work we plan for the magnet

# Roles and Responsibilities – Low Field Test

| | | | |
|---|---|---|---|
| sPHENIX Superconducting Magnet Project Management | | | |
| | Project Manager | | Kin Yip |
| | Subsystem Lead Engineer | | Dave Phillips |
| | | | |
| | | | |
| | Subsystem for Magnet | | Technical Manager |
| Low Field Coil Test | | | |
| | | | |
| | Cryogenics | | |
| | | Cryo System | Roberto Than |
| | | Cryo Controls | Tom Tallerico |
| | | Cryo Safety | Roberto Than |
| | Internal Mechanical Equipment | | |
| | | Radial and Axial Supports | Paul Kovach |
| | | Strain Gage and Potentiometers | Paul Kovach |
| | | Mechanical connections to coil (electromechanical and mechanical) | Paul Kovach |
| | Power Supply | | |
| | | Power Supply | Piyush Joshi |
| | | Controls | Piyush Joshi |
| | | Support Instrumentation (strain gage/potentiometer output) | Piyush Joshi |
| | | Safety System (current limiting device) | Piyush Joshi |
| | | Installation of AC Power | Dave Phillips |
| | | DC Distribution Cabling and Installation | Dave Phillips |
| | Infrastructure Support | | |
| | | Hall Safety | Dave Phillips |
| | | Overall Coordination of Magnet testing | Dave Phillips |
| | | Convention Systems Support (AC Power, work platform, access ladder) | Dave Phillips |
| | Field Measurement | | |
| | | Measure Field | Achim Franz |

# Roles and Responsibilities – High Field Test

| | | | |
|---|---|---|---|
| High Field Coil Test with Temporary Flux Return and Pole Tips | | | |
| | | | |
| | Cryogenics | | |
| | | Cryo System | Roberto Than |
| | | Cryo Controls | Tom Tallerico |
| | | Cryo Safety | Roberto Than |
| | Internal Mechanical Equipment | | |
| | | Radial and Axial Supports | Paul Kovach |
| | | Strain Gage and Potentiometers | Paul Kovach |
| | | Mechanical connections to coil | Paul Kovach |
| | Power Supply | | |
| | | Power Supply | Pablo Rosas (Bob Lambiase, Ioannis Marneris) |
| | | Controls/Communication/Signal | Charlie Theisen |
| | | Safety System (current limiting device) | Bob Lambiase |
| | | Quench Detection | Piyush Joshi |
| | | Dump Resistor | Pablo Rosas (Bob Lambiase, Ioannis Marneris) |
| | | Installation of AC Power | Dave Phillips/PK Feng |
| | | DC Distribution Cabling and Installation | Dave Phillips |
| | Infrastructure Support | | |
| | | Hall Safety | Dave Phillips |
| | | Overall Coordination of Magnet testing | Dave Phillips |
| | | Convention Systems Support (AC Power, work platform, access ladder) | Dave Phillips |
| | Magnet Flux Return Steel | | |
| | | Backleg Steel | Jon Hock |
| | | Cryostat Alignment and Support | Jon Hock |
| | | Pole Tips | Jon Hock |
| | Field Measurement | | |
| | | Measure Field | Achim Franz |

# Roles and Responsibilities – Installation B1008

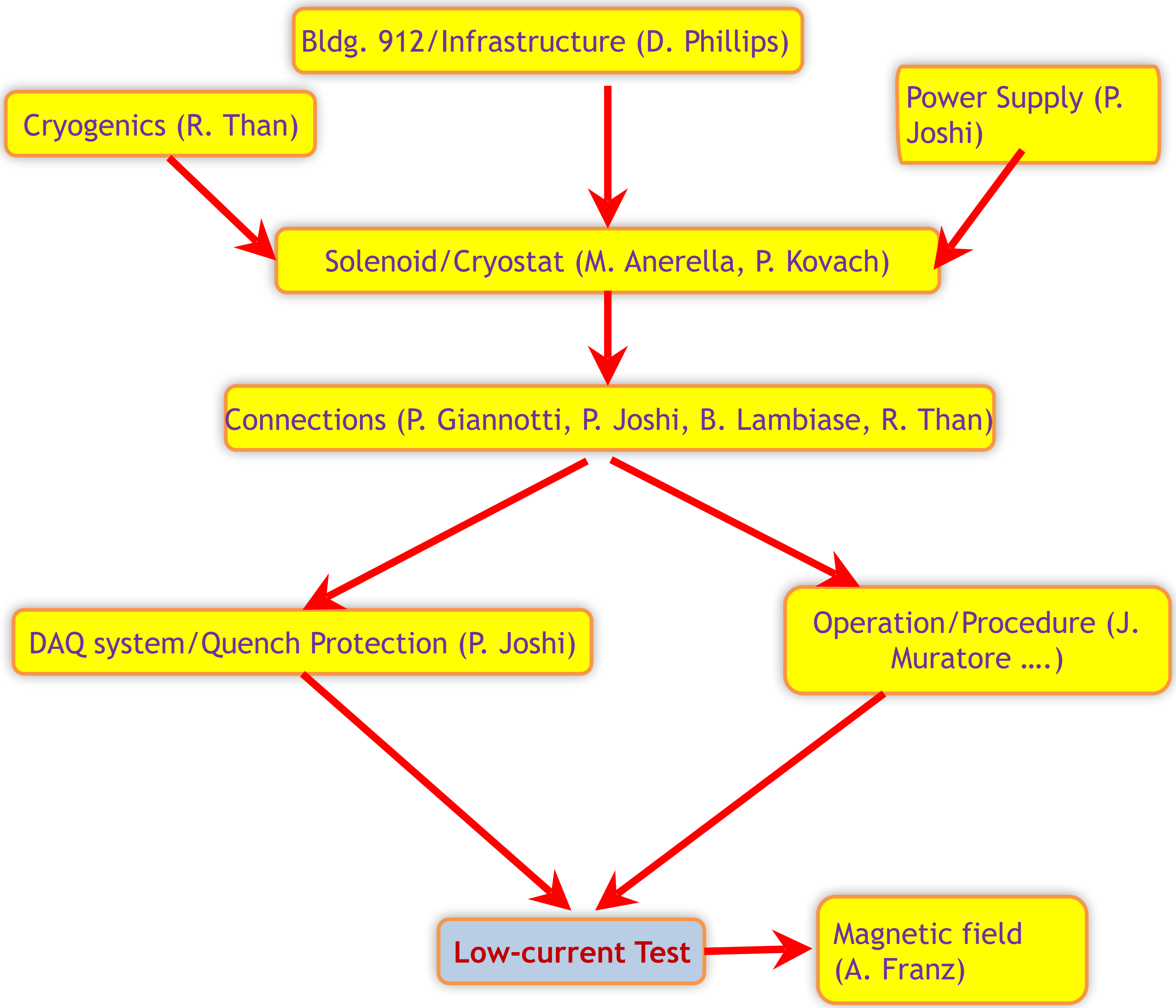
| | | | |
|---|---|---|---|
| sPHENIX Installation Major Facility Hall | | | |
| | | | |
| | Cryogenics | | |
| | | Cryo System | Roberto Than |
| | | Cryo Controls | Tom Tallerico |
| | | Cryo Safety | Roberto Than |
| | Internal Mechanical Equipment | | |
| | | Radial and Axial Supports | Paul Kovach |
| | | Strain Gage and Potentiometers | Paul Kovach |
| | | Mechanical connections to coil | Paul Kovach |
| | Power Supply | | |
| | | Power Supply | Pablo Rosas (Bob Lambiase, Ioannis Marneris) |
| | | Controls | Charlie Theisen |
| | | Safety System (current limiting device) | Bob Lambiase |
| | | Quench Detection | Piyush Joshi |
| | | Dump Resistor | Pablo Rosas (Bob Lambiase, Ioannis Marneris) |
| | | AC/DC Distribution Cabling and Installation | Dave Phillips |
| | Infrastructure Support | | |
| | | Hall Safety | Paul Giannotti |
| | | Overall Coordination of Magnet Construction | Kin Yip |
| | | Convention Systems Support (AC Power, work platform, access ladder) | Dave Phillips/PK Feng |
| | | Magnet Testing Coordination | Kin Yip |
| | | Field Testing and Mapping | Achim Franz |
| | Magnet Flux Return Steel | | |
| | | Backleg Steel | Anatoli Gordeev (Outer Hcal Steel) |
| | | Cryostat Alignment and Support | Jon Hock |
| | | Pole Tips | Jim Mills |
| | | Magnet/Detector Support Structure | Jim Mills |
| | Field Measurement | | |
| | | Field Mapper | Achim Franz |
| | | Field Measurements | Achim Franz |
| | | | |
| | Detector Integration/ Installation Design | | |
| | | Integration and Installation Overall Detector | D. Lynch, R. Ruggiero |

# SC-Magnet Management Team

**Management through the low power test:**
**Mike Anerella – Manager of the LP test**
**Dave Phillips – Facilities, installation, engineering support**
**Roberto Than – Cryogenics**
**Bob Lambiase –PS and Controls**

**Proposal for Management through the completion of sPHENIX:**
**Dave Phillips + CAD Physicist – Level 2 Manager**
**Roberto Than – Cryogenics**
**Bob Lambiase – PS and Controls**
**Achim Franz – Magnet Mapping**
**Level 3 managers**
**Dave Phillips – Facilities, installation and engineering support**
**Additional support will be needed from C-AD cryo and PS groups, ES&F esp. Wuzheng Meng and consultation w/ SMD**

# Roles and Responsibilities – Low Field Test



# SPHENIX: MAGNET: Cryogenics

| Support Cylinder MASS | |
|---|---|
| Outer Diameter, m | 3.205 |
| Inner diameter, m | 3.1 |
| Length, m | 3.59 |
| Mass, kg | 3,750 |

| COIL MASS | |
|---|---|
| Outer Diameter, m | 3.1 |
| Inner diameter, m | 3.02 |
| Length, m | 3.59 |
| Mass, kg | 3,940 |

| THERMAL ENERGY [MJ] | |
|---|---|
| Mass KG | 7,700 |
| Specific Heat Integral, J/kg | 172,800 |
| Thermal energy 293K to 90K, MJ | 1,328 |
| Cooldown time, 2kW, DT=20K | 7.5 day |
| Thermal energy 90K to 4.5K, MJ | 102 |
| Cooldown time, 400W | 3 days |

# SPHENIX: MAGNET: Cryogenics

| SOLENOID & VALVEBOX LOADS<br>ITEM | Original Design / Nominal Load<br>Operation / Test | Forced 2 phase flow operation<br>And Design Load |
|---|---|---|
| Magnet load and valvebox | 35W @ 4.5K [siphon mode] | 7.5 g/s, 145W [with Valvebox separator loading heaters] |
| Shield | 0.35 g/s, From 4.5K to 50K, 110W | 0.5 g/s, From 4.5K to 50K |
| Vapor cooled leads | 0.51 g/s, 4.5K to 300K, | 0.6 g/s, 4.5K to 300K, |
| | | |
| | | |
| TOTAL, 4.5K Ref equivalent | 129 W | 255 W |

| EXTERNAL EQUIPMENT / TRANSFER LINES LOADS: OPTION A, RHIC INTERFACE<br>ITEM | Nominal Load |
|---|---|
| 500 L Reservoir Dewar. Transfill valve + bayonet | 9W @ 4.5K |
| Transfer line jumper: Vapor return from 500 L Reservoir | 7 W @4.5K |
| Transfer line: Liquid supply from RHIC 120ft, 3 cryogenics valves, 2 bayonets | 10+10 = 20 W @4.5K |
| Transfer line: Vapor return to RHIC 120ft<br>3 cryogenics valves, 4 bayonets | 15+15 = 30 W @4.5K |
| Transfer line: Shield return to RHIC 120ft<br>2 cryogenics valves, 2 bayonets | 150 + 8 = 158 W<br>0.5 g/s Liq load |
| RHIC CRYO PLANT LOAD REFRIGERATION @ 4.5K | 321 W [118 kW] |
| RHIC CRYO PLANT LOAD LIQUEFACTION | 1.6 g/s [55 kW] |

# SPHENIX: MAGNET: Cryogenics

| SOLENOID & VALVEBOX LOADS<br>ITEM | Original Design / Nominal Load<br>Operation / Test | Forced 2 phase flow operation<br>And Design Load |
|---|---|---|
| Magnet load and valvebox | 35W @ 4.5K [siphon mode] | 7.5 g/s, 145W [with Valvebox separator loading heaters] |
| Shield | 0.35 g/s, From 4.5K to 50K, 110W | 0.5 g/s, From 4.5K to 50K |
| Vapor cooled leads | 0.51 g/s, 4.5K to 300K, | 0.6 g/s, 4.5K to 300K, |
| | | |
| TOTAL, 4.5K Ref equivalent | 129 W | 255 W |

| EXTERNAL EQUIPMENT / TRANSFER LINES LOADS:<br>OPTION B, INDEPENDENT CRYO PLANT | Nominal Load | Design Load |
|---|---|---|
| 500 L Reservoir Dewar | 5W @ 4.5K | 10 W |
| Transfer line jumper:<br>Vapor return from 500 L Reservoir | 7 W @4.5K | 10 W |
| Transfer line jumper: Liquid helium from 500L to valvebox 1 cryogenics valve, 2 bayonets | 13 W @4.5K | [20 W] included in above table |
| Transfer line jumper: Vapor return to 500L / Solenoid Valvebox to cryo plant. 1 cryogenics valves, 4 bayonets | 17 W @4.5K | 20 W |
| Transfer line: Shield | Budget with solenoid/valvebox load<br>Accounted as 0.35 g/s liquefaction load | Budget with solenoid/valvebox load<br>Accounted as 0.5 g/s liquefaction load |
| | | 285 W<br><br>320 W plant |

# mechanical changes, valve box

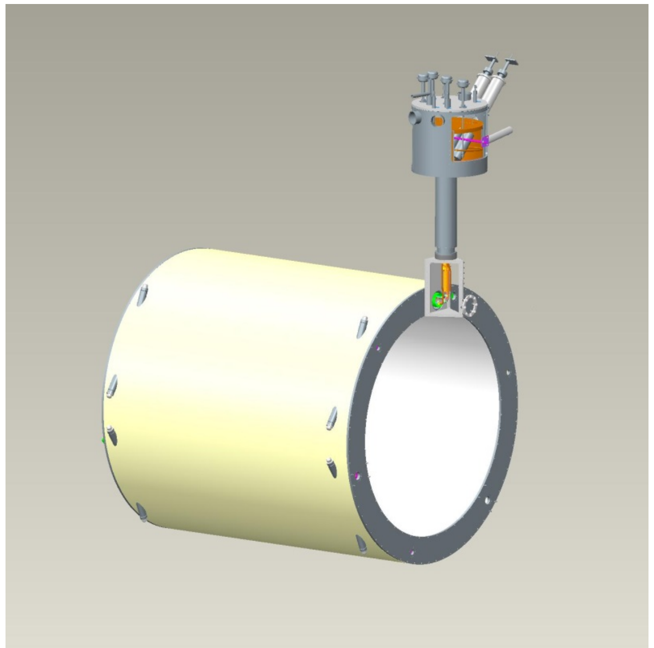
sPHENIX SC Magnet - Valve Box Extension, Mechanical Design Review

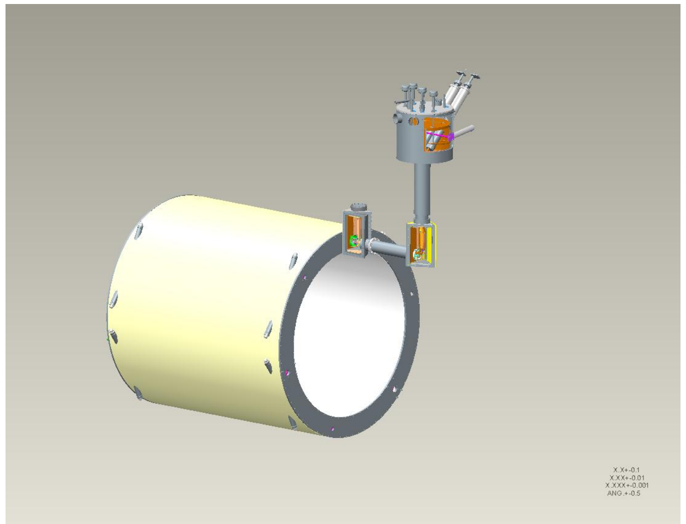
Thursday, May 14, 2015 from 13:15 to 15:20 (US/Eastern)

at Universe ( Building 510 Room 2-160 )

# Chimney modification

- In order to keep the acceptance of the hadronic calorimeter as uniform as possible, we would like to avoid a penetration for the chimney leading to the valve box
- Working from drawings, Paul Kovach has designed a rather non-invasive way to do this that he will describe





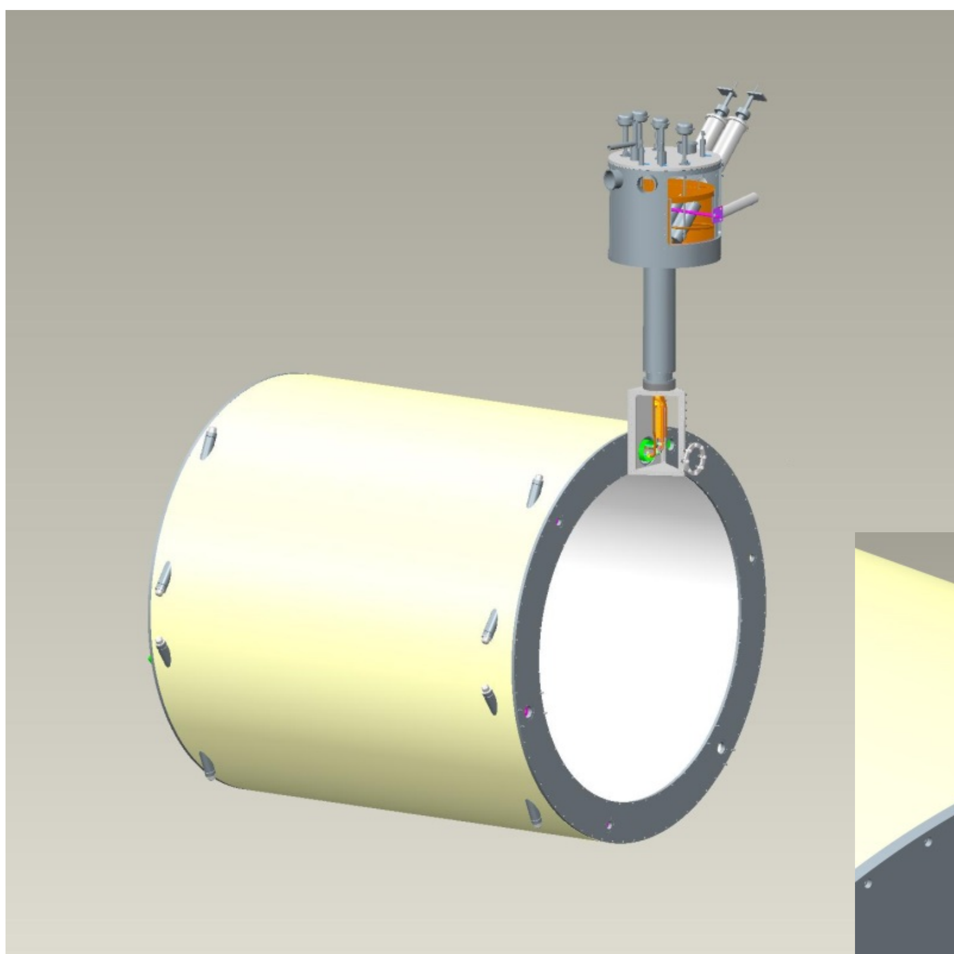
Before and after

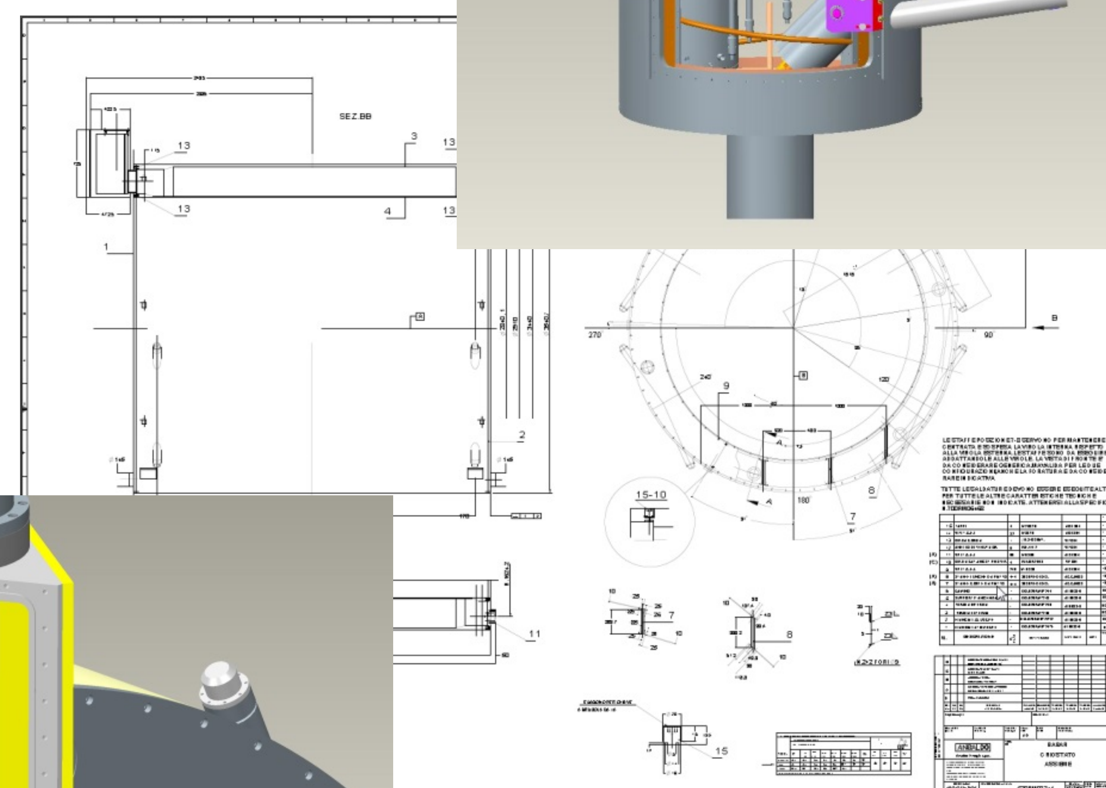
BROOKHAVEN
NATIONAL LABORATORY

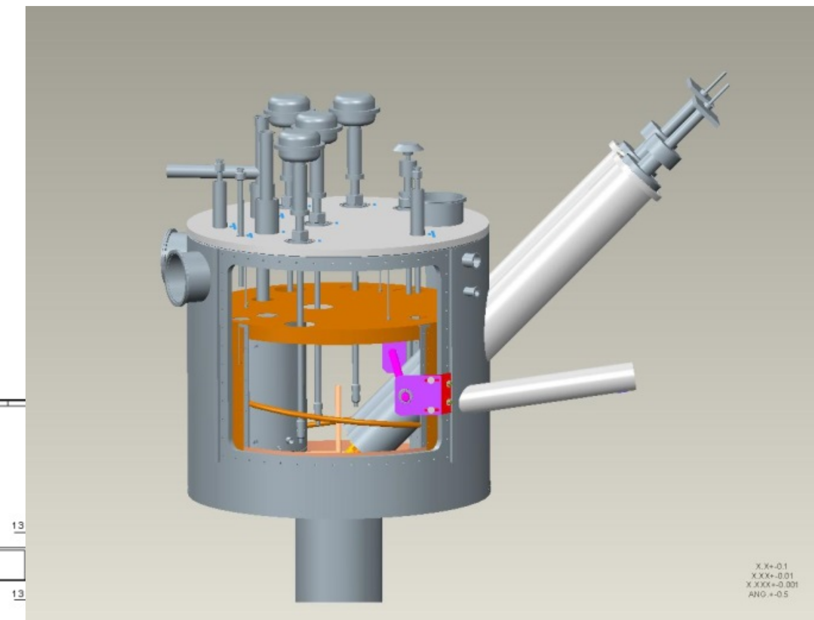
Superconducting
Magnet Division

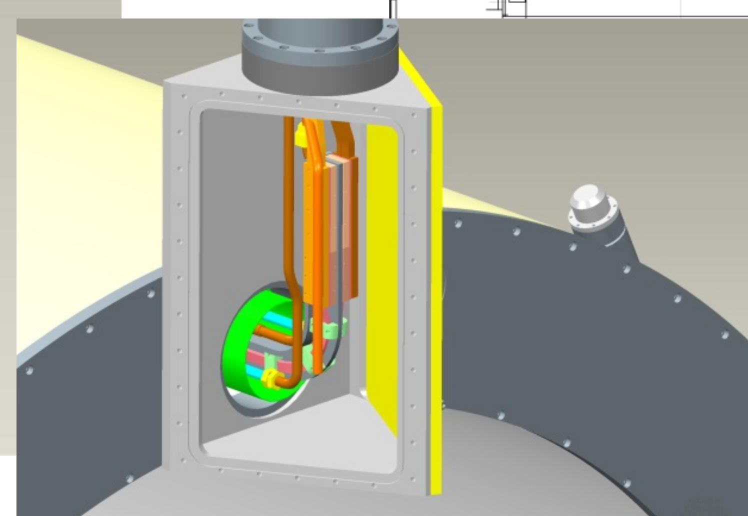
# BaBar Magnet Shipping Restraints And Valve Box Relocation

Construct 3-D Model From Original 2-D Drawings (in Italian) To The Extent Necessary To Design Shipping Restraints And Valve Box Extension







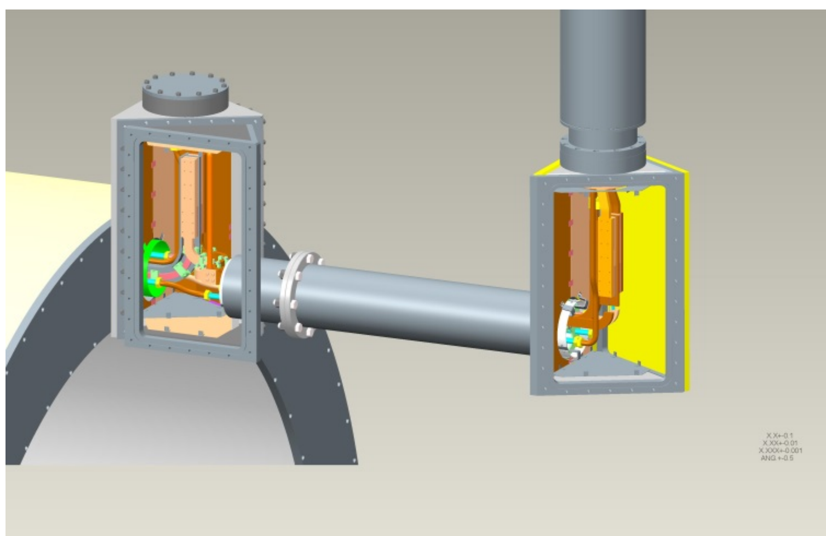


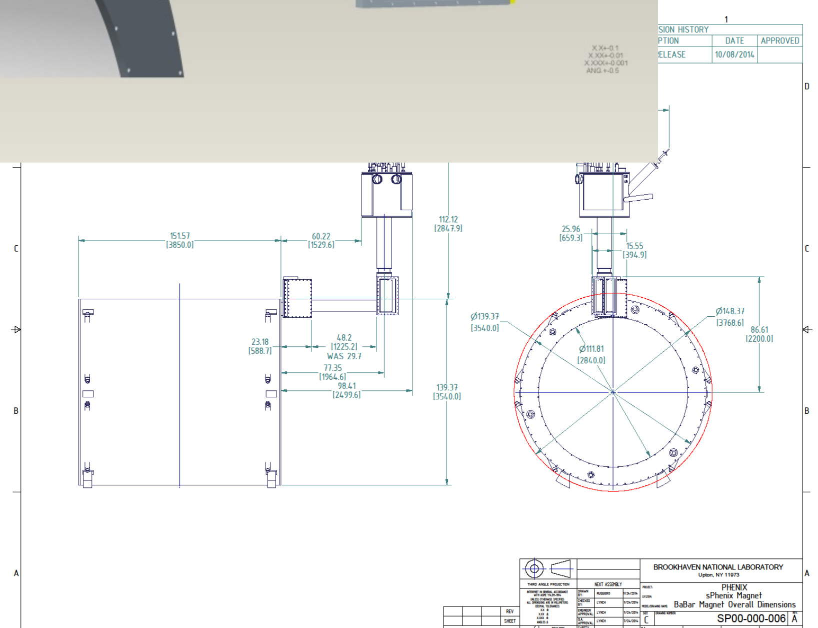
Superconducting

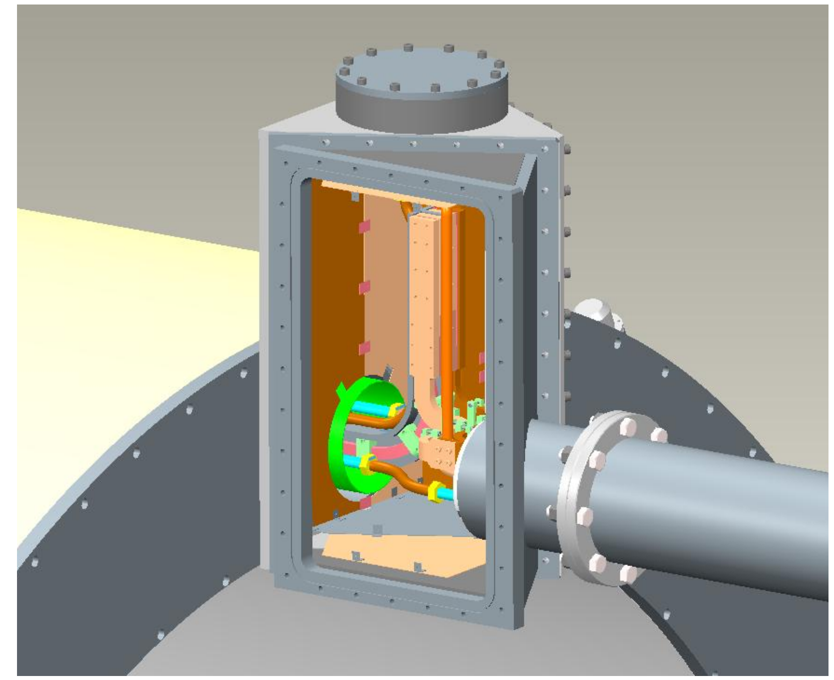
Magnet Division

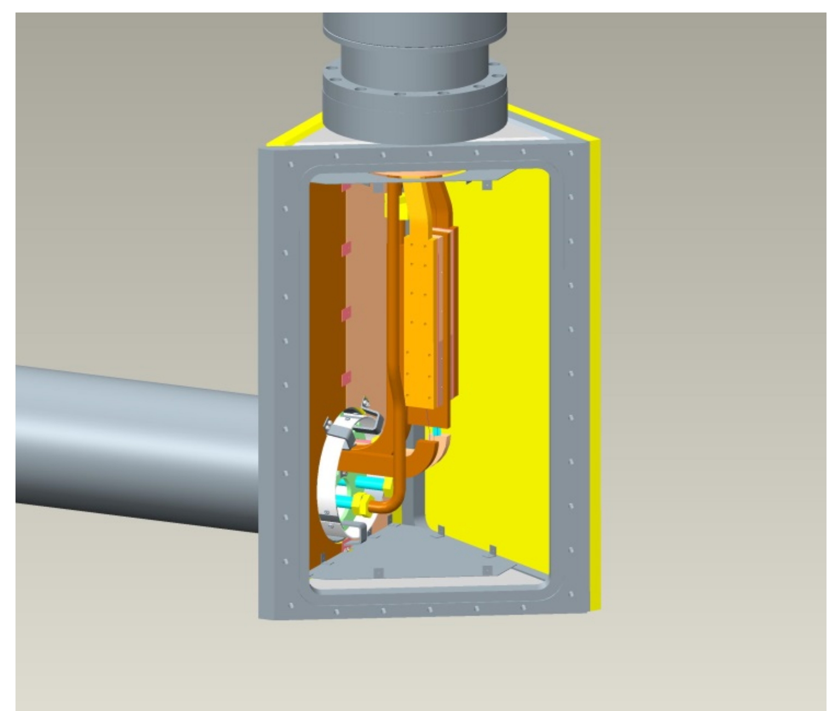
# Valve Box Extension Interfaces

Design Extension And Interface Details To Mate With Existing Valve Box





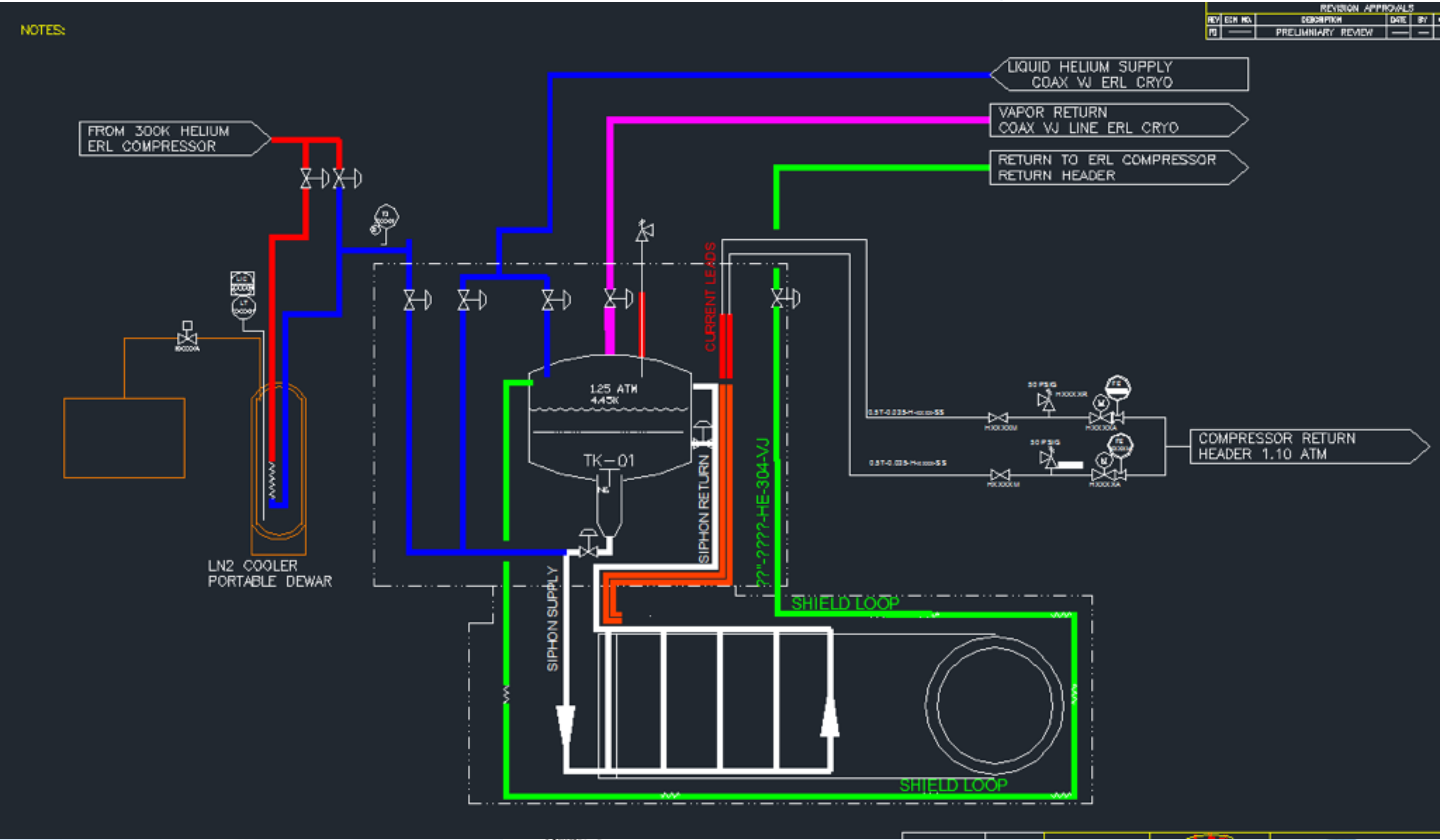




# 4.5K Low Power Test in Bldg 912

- Use ERL Cryogenic Plant
- Operate in thermo-siphon mode
- Add Tie-in on VTF side of ERL distribution lines
  - Isolation valves and Bayonets
- Re-use Co-axial cryogenic transfer line from SLAC
  - Modifications to shorten and get matching bayonets on ERL interface end of this cryogenic transfer line.
- Independent (from ERL) pre-cool using Small LN2 precooling system for controlled cool down of solenoid using some helium flow from ERL compressor
  - 240 Liter LN2 Dewar with subcooler coil exchanger
  - Control valves for mixing 300K and 85K helium gas

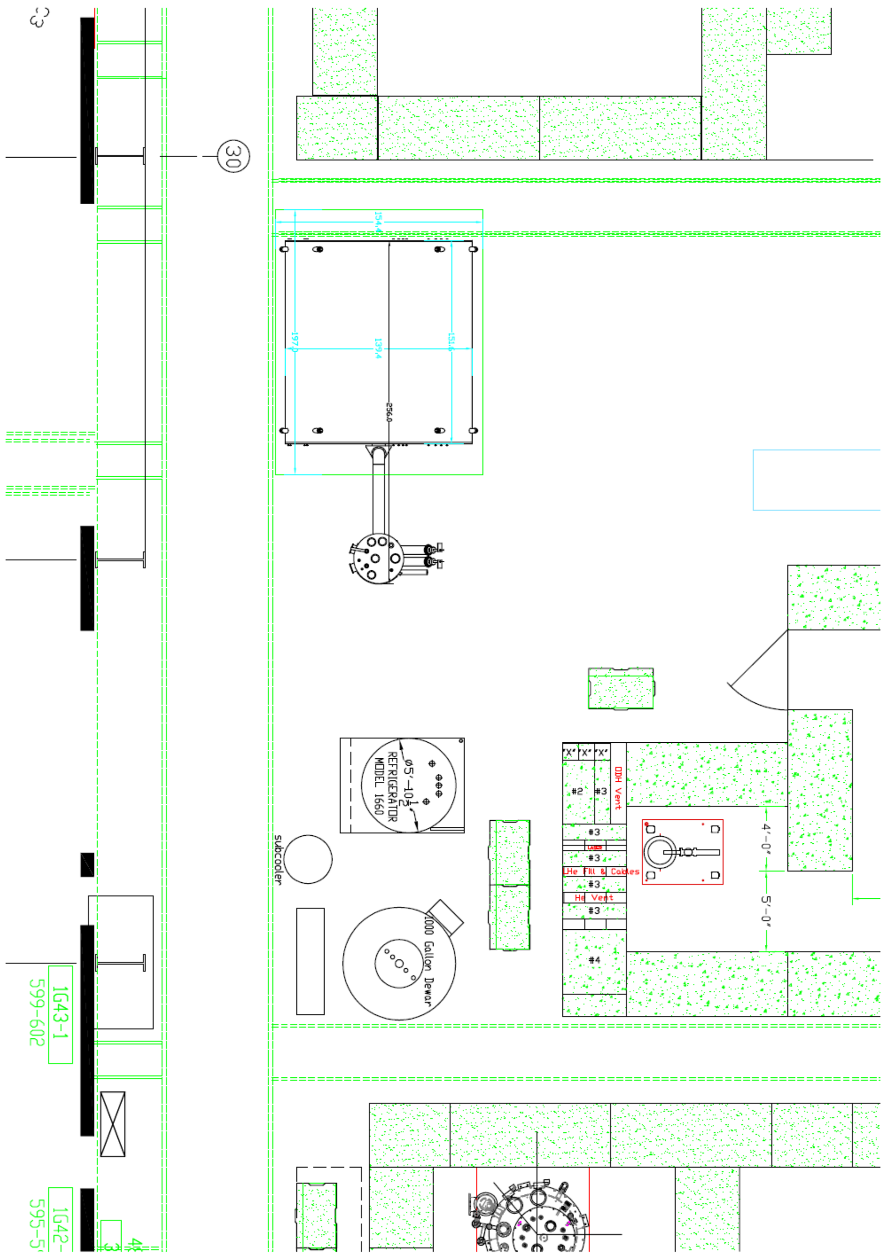
# 4.5K Low Power Test in Bldg 912



Superconducting
Magnet Division

# FY15 Low Power Cold Test

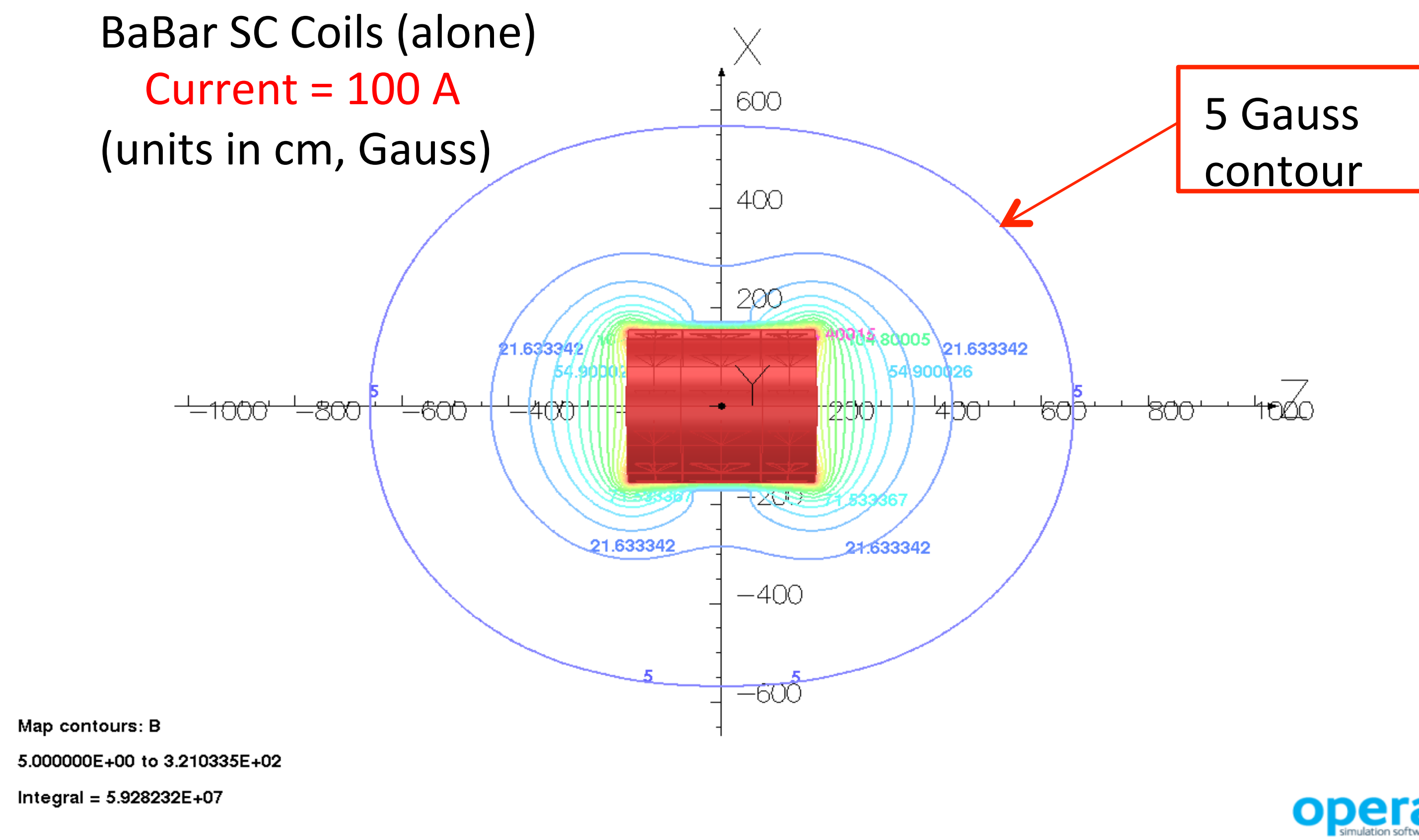
From Dave Phillips
**Bldg. 912 test location**



- Power supply (from Ioannis Marneris) = 500A, 30V; 0.1 Ω resistor in series.
- C-AD also to provide free wheel diode.
- Data Acquisition System from SMD

From Wuzheng Meng

BaBar SC Coils (alone)
Current = 100 A
(units in cm, Gauss)



# SPHENIX: MAGNET: Cryogenics

**Tie-in RHIC Option: A**

Interface to RHIC cryogenic distribution system

- 80K summer shutdown LN2 keep cool system
  - 5 g/s Helium compressor
- RHIC interface valve-box
  - S header: 4.8K, 3.5 bar
  - H header: 45-80K, 12 bar
  - U header: 4.5K, 1.25 bar
  - WR header: 293K, 1.25 bar
  - Isolation valves to RHIC
  - cooldown gradient control Heat exchanger
  - LN2/He exchanger
- 500L Interface and Hold up reservoir dewar
  - Transfer bayonet for portable 500L
- Cryogenic Transfer VJ jumpers between supply bundle and valvebox/dewar

**Stand Alone Plant Option: B**

300W Helium Plant

- 4.5K Coldbox
  - located on detector superstructure platform
- Compressor
  - Service building or Heated shack
- 500L Hold up reservoir dewar
- Gas storage tanks
- Cryogenic lines
- Warm-piping
- LN2 supply Line to coldbox
- UTILITIES
  - Compressor
    - 150 kW, 480VAC
    - Tower water: 50 GPM
    - Air cooling to compressor cabinet: 1400 CFM
    - Instrument Air: 5 CFM
    - Space: 300 $ft^2$
  - Coldbox
    - 3 kW, 120VAC
    - Air 10 CFM
    - Small chiller for turbines: 3 kW
    - Space: 400 $ft^2$.
  - Return heater shield flow: 5 kW/480VAC

# SPHENIX: MAGNET: Cryogenics

## Tie-in RHIC Option: A

- Superstructure/Platform piping connection:
  - Relief vent header
  - Liquid helium supply VJP
  - Helium Vapor return VJP
  - Shield return
  - Lead cooling return
- 1008B service building
  - LN2 supply
  - GN2 vent
- Summer shutdown:
  - LN2 Keep cold system @100K
  - 4.5K Test
    - 10 x 500L for cooldown from 90K to 5K
    - 4.5K Test: 500L every 3-4hrs

## Stand Alone Plant Option: B

Superstructure/Platform piping connection:

Warm helium supply

Warm helium return

Relief vent header

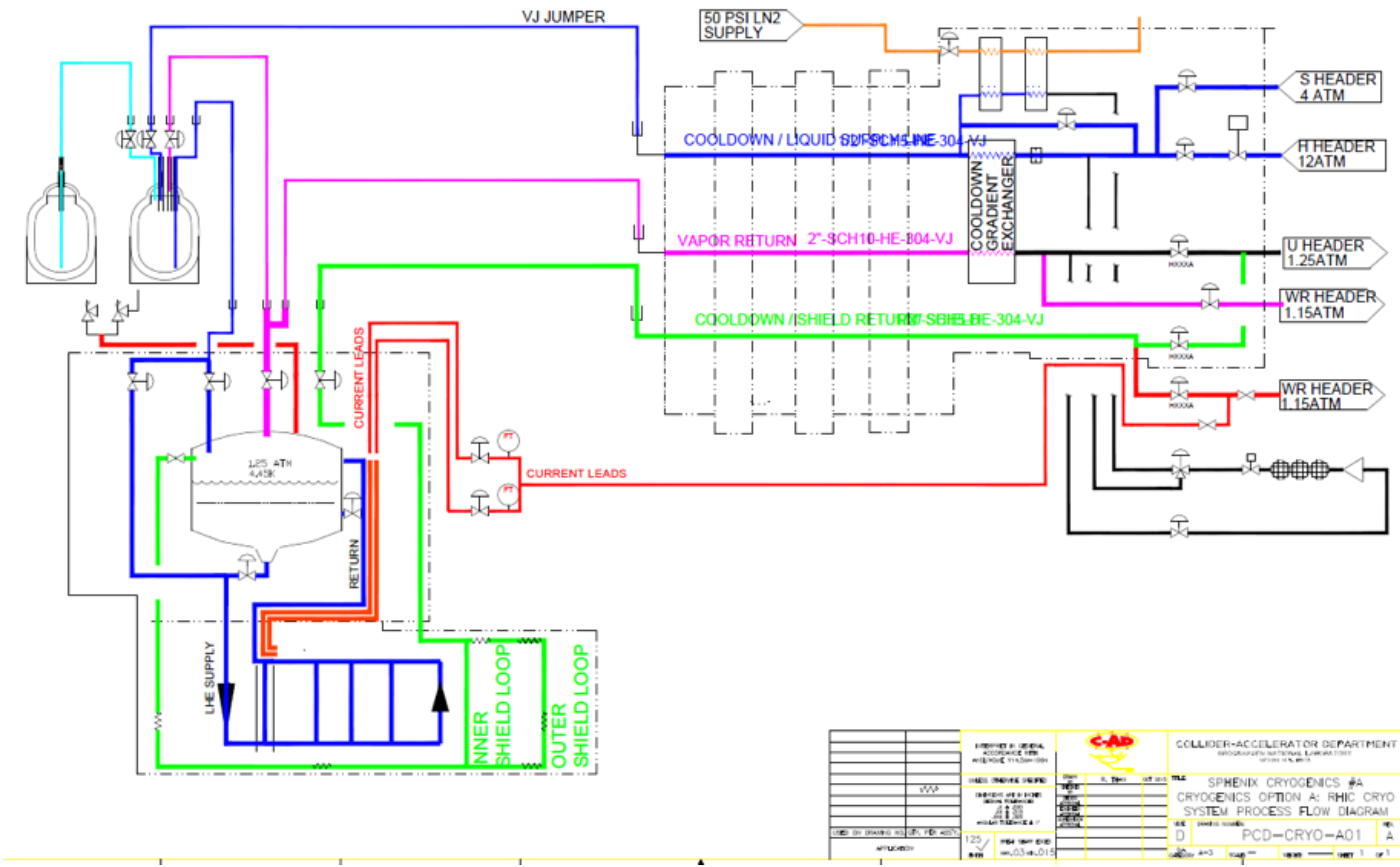
GN2 vent

LN2 supply to IP8 to plant coldbox

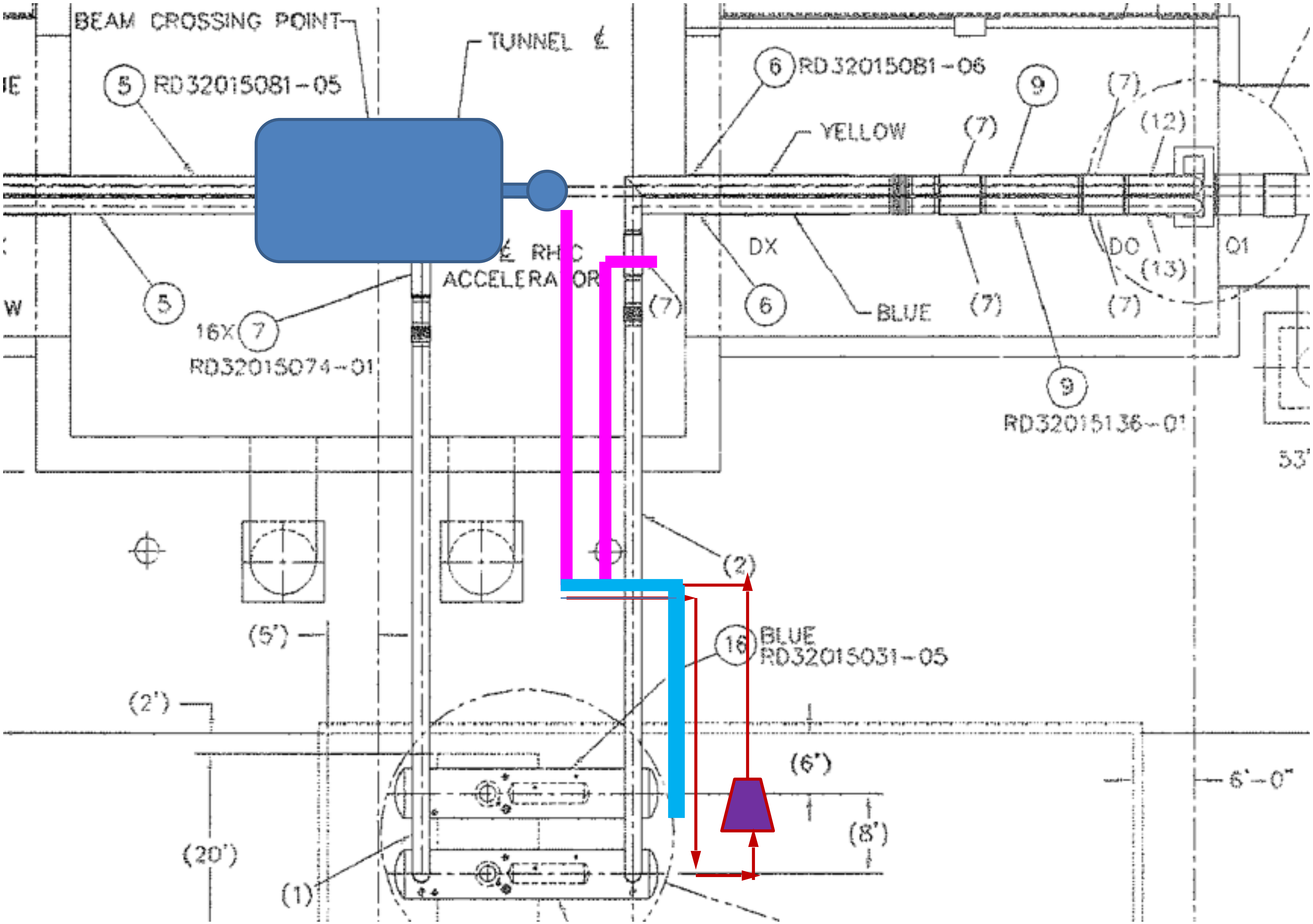
LN2 supply tee to assembly hall

- Summer shutdown:
  - 4.5K Test on plant
  - Plant maintenance
    - Drift to 90K ~ 150 hrs

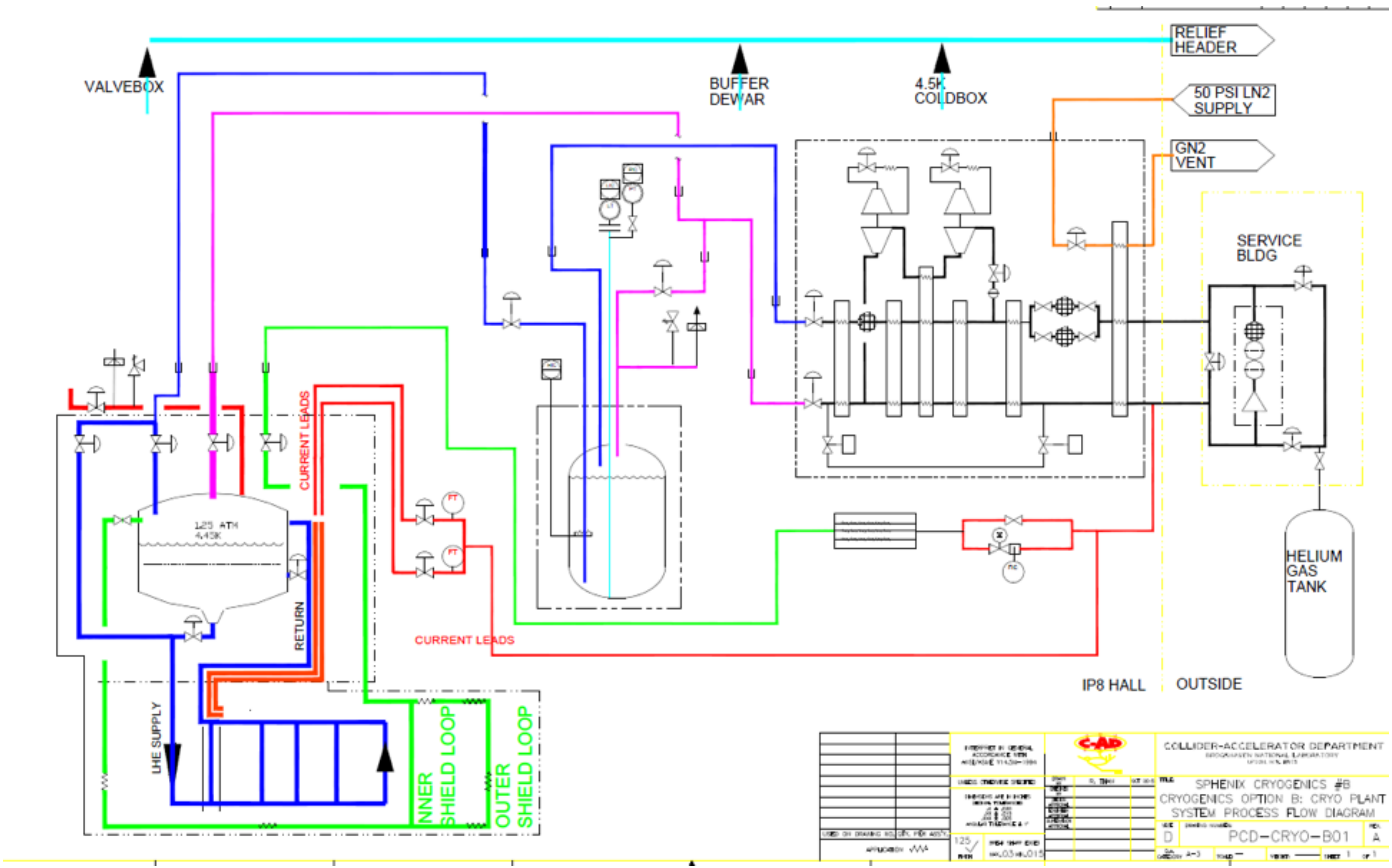
# SPHENIX: MAGNET: Cryogenics System diagram: RHIC Interface Option A



# SPHENIX: MAGNET: Cryogenics



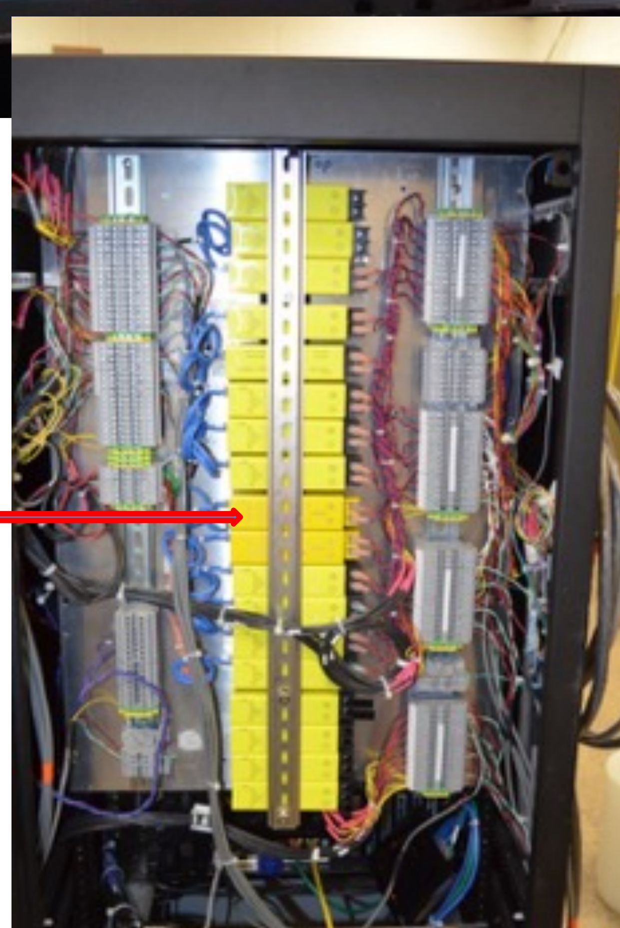
# SPHENIX: MAGNET: Cryogenics INDEPENDENT PLANT OPTION B



# Power supplies, 912 and 1008

# Test Setup Components

100A, 16V PS



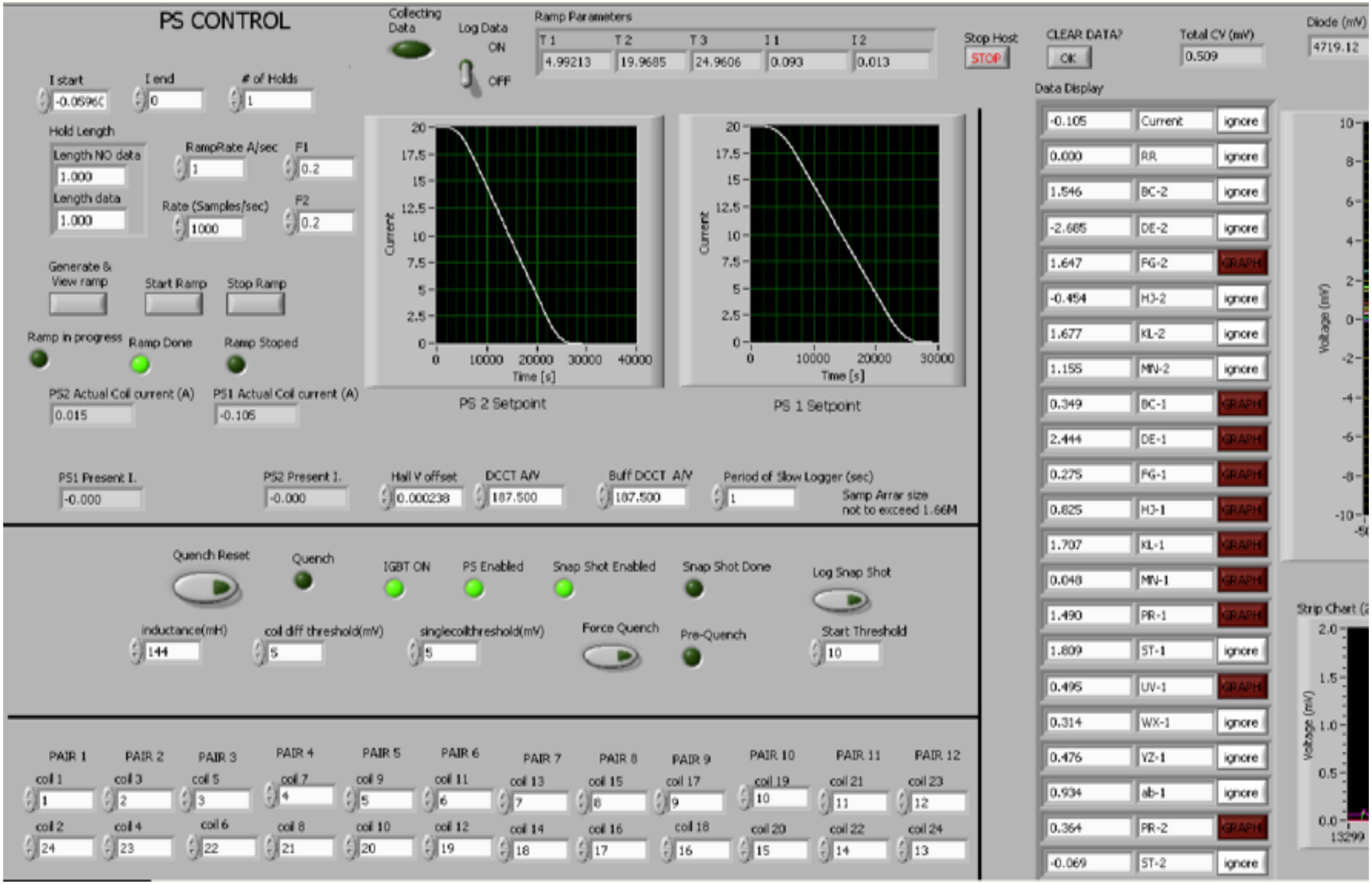
Isolators

Quench Detector

Slow Data Logger

Fast Data Logger

LabView based program to control power supply and capture data

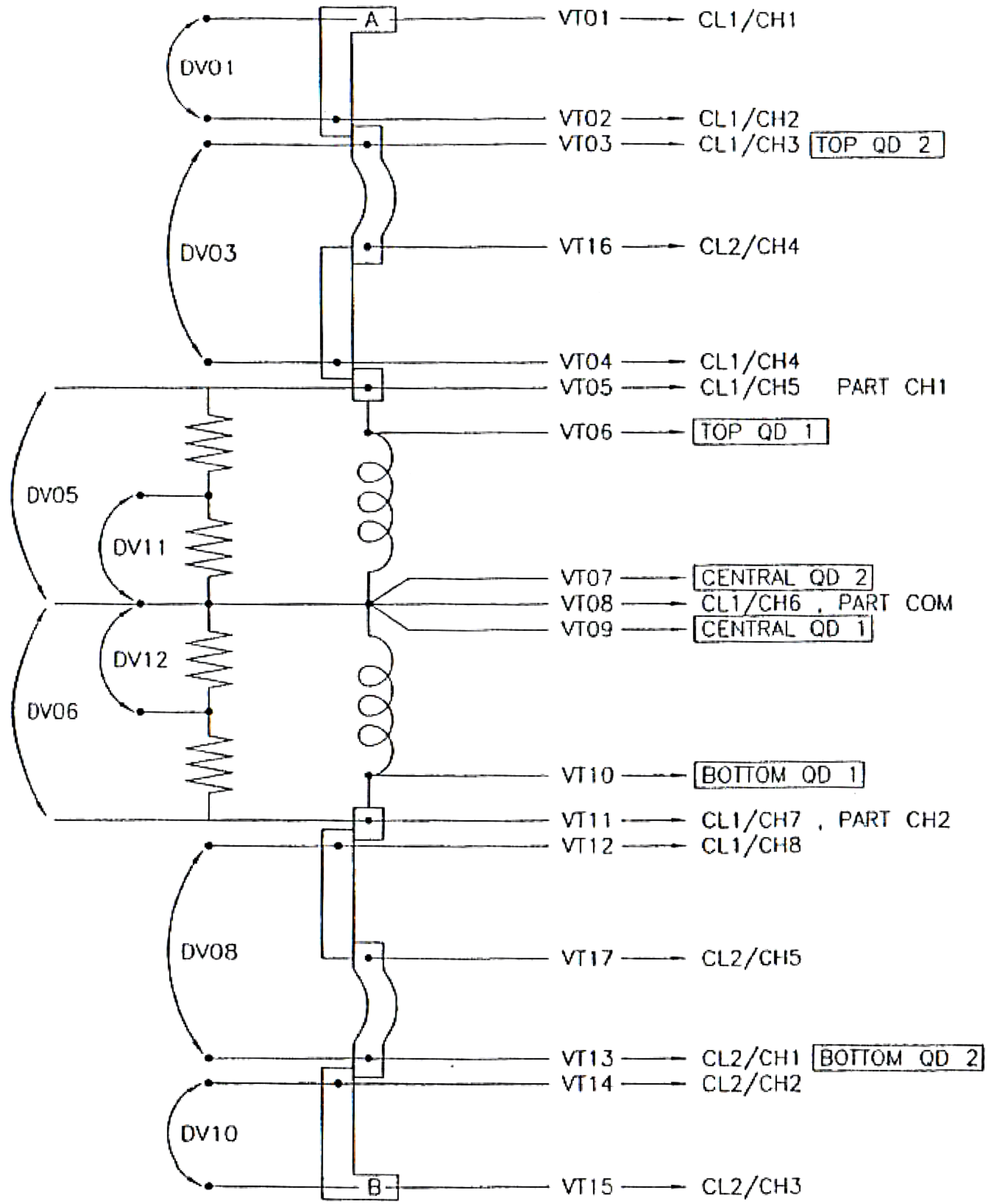


# quench protection and controls, 912 and 1008

The quench detector should be sensitive to a voltage rise of about 100 mV. This is simple when the current in the solenoid is constant. But, when the current is ramping up or down, the induced voltage, $V = L\, di/dt$, is much greater than 100 mV. With a ramp rate of 2.5 Amps/sec, $V = 6.25$ V.

There is a voltage tap at the connection between the inner and outer solenoid windings. During ramping, if the inductance of these windings were identical, the voltage across the top coil (VT05 with respect to VT07) would be exactly negative of the voltage across the bottom coil with respect to the same point (VT10 with respect to VT09).

The sum of these two voltages would add to zero. An imbalance caused by a 100 mV quench voltage can then be detected in the sum.




Fifteen years have passed since the original quench detection system in the BaBar experi- ment has been designed and implemented. In the future implementation which will be done by the cooperation of Superconducting Magnet Division and the Collider-Accelerator Department, new hardware and software will make more accurate and reliable quench detection possible for this Magnet.

# Field Simulations

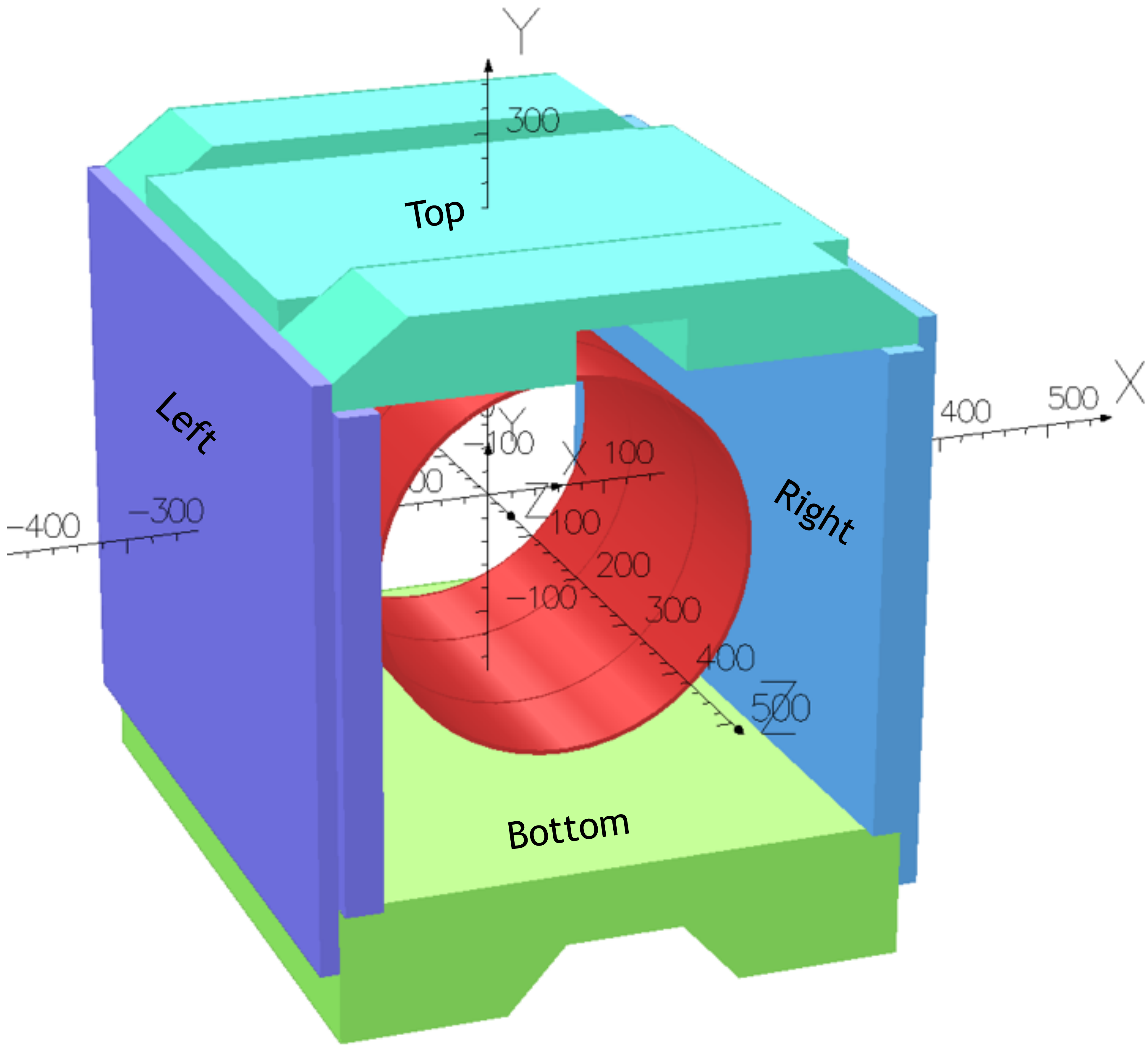
Wuzeng Meng, BNL
Walt Sondheim, LANL
Achim Franz, BNL

initial Opera2D simulations for Geant4 detector simulations

3D simulations by W.M. to calculate forces on coil

3D simulations by W.S. for the high current test and final setup

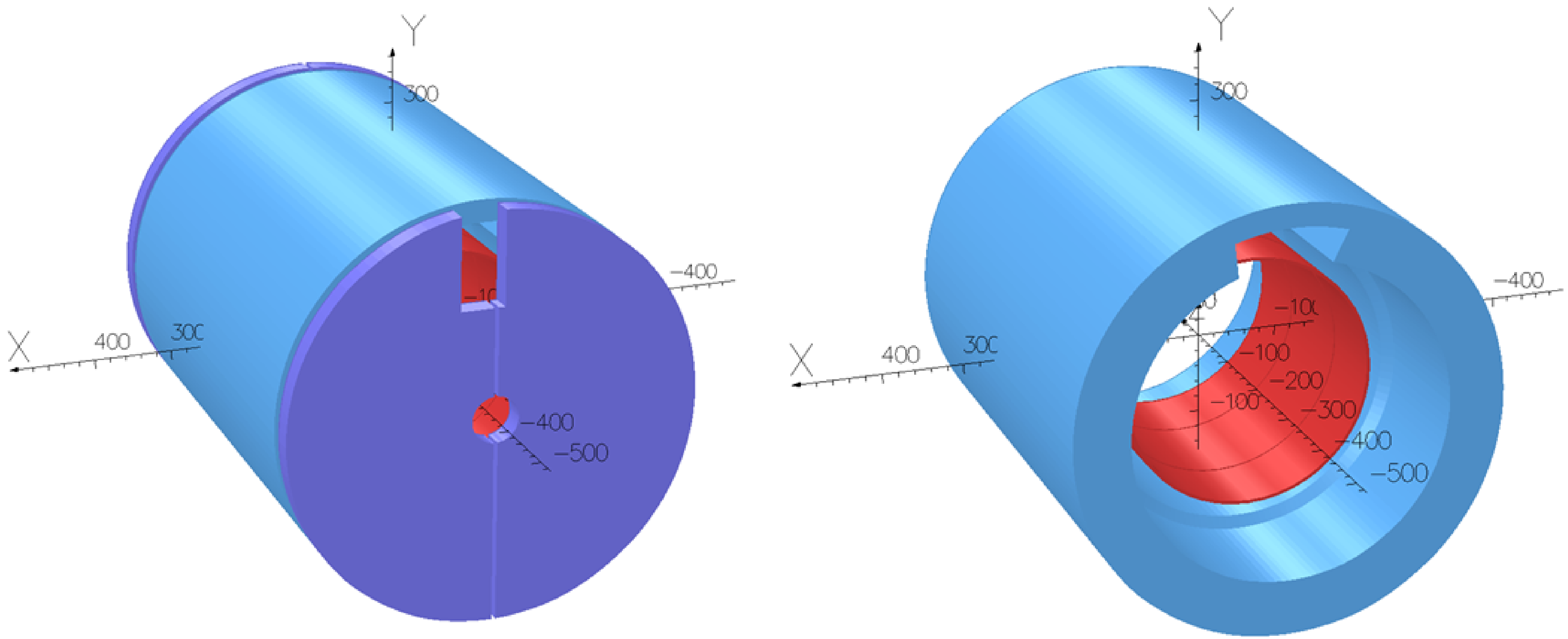
ANSYS mechanical force calculations during cool down



Top
Left
Right
Bottom

# Magnetic Forces on each Wall (at full current/ field)

| | Fx (Lbf) | Fy (Lbf) | Fz (Lbf) | Est. Weight (Lbm) |
|---|---|---|---|---|
| Bottom | 4 | 148,551 (up) | 23 (towards cut direction) | 450,560 |
| Top | -67 | -142,436 (down) | 3709 (towards cut direction) | 237,600 |
| Left | 135,171 (pointing coil) | -342 (down) | 42 (towards cut direction) | 204,424 |
| Right | -135,071 (pointing coil) | -341 (down) | 42 (towards cut direction) | 204,424 |



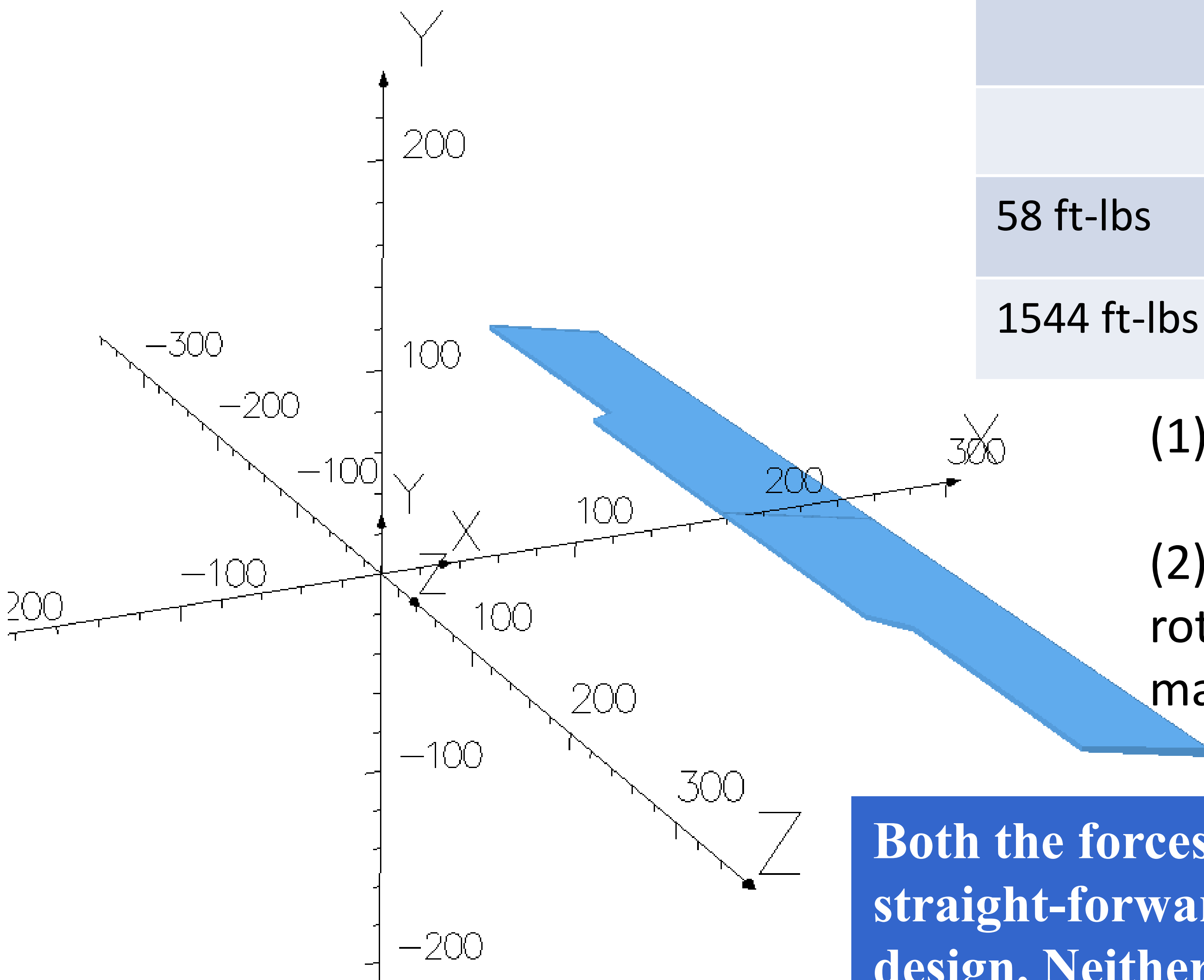

From the simulations of this model, the magnetic forces and torques at the yoke center due to the coils being misaligned are shown in Table 3.1.

| | Fx | Fy | Fz | Tx | Ty | Tz |
|---|---|---|---|---|---|---|
| No misalignments | -1043 N | -14072 N | 15640 N | 335007 N-cm | 160904 N-cm | 0 N-cm |
| Coils shift, dx=2 mm | 9412 N | -14077N | 15647N | 335345 N-cm | 157079 N-cm | -2815 N-cm |
| Coils shift, dz=3 mm | -1033 N | -13903 N | 21207N | 354464 N-cm | 159326 N-cm | 0 N-cm |

**Table 3.1:** Magnetic forces (Fx, Fy, Fz) and torques Tx,Ty,Tz in the non-symmetric model.

## Forces and Torques on Each Steel Plate are Calculated by Integrating Maxwell Stress around its Surfaces (4596 A):

| Without End-caps | | Without End-caps | With End-caps |
|---|---|---|---|
| 1607 lbs | Fx (N) | -7157.5 | -6342.0 |
| 232 lbs | Fy (N) | -1032.2 | -824.2 |
| | Fz (N) | -2.6 | -2.1 |
| | Tx (N-cm) | -169.0 | -139.8 |
| 58 ft-lbs | Ty (N-cm) | 7886.0 | 6445.1 |
| 1544 ft-lbs | Tz (N-cm) | -209287.2 | -166852.6 |




(1) The plate essentially sees a radial inward force;
(2) Tz indicates it has the tendency to rotate (with respect to the center of magnet).

**Both the forces and torques on the HCal plates are straight-forward to deal with in the mechanical design. Neither are particularly challenging**

# Mapping

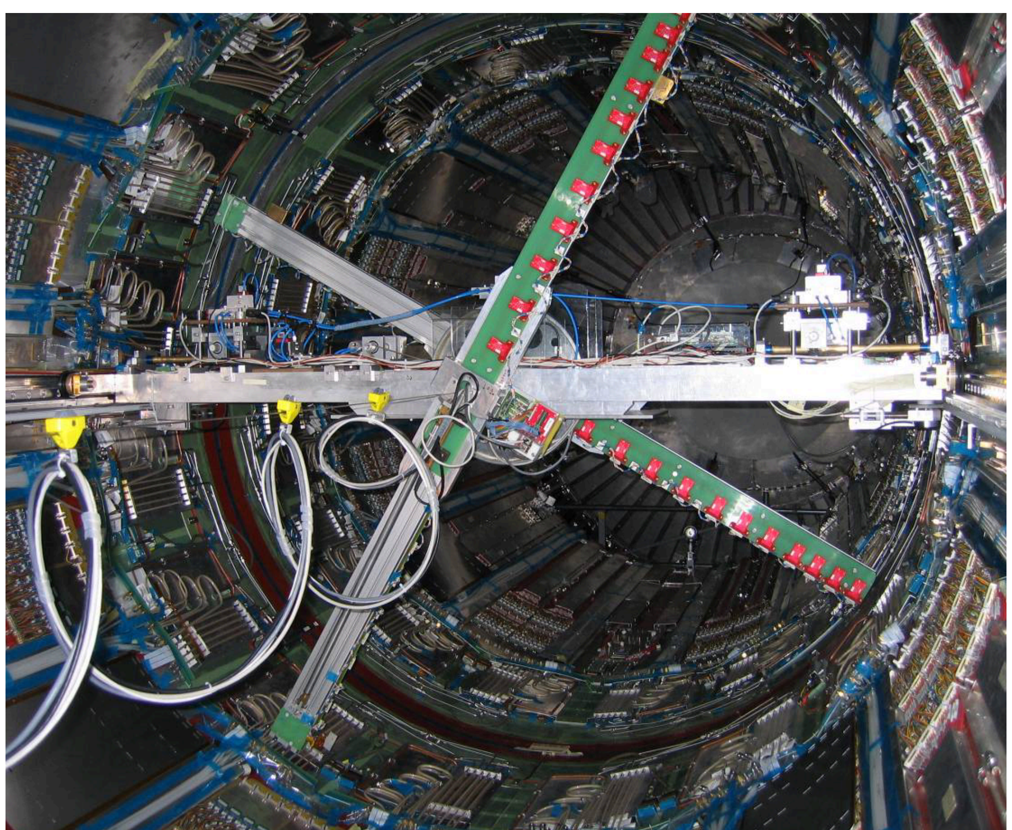
Final field map

The total amount +/- 20% without transport, travel and lodging will be

| | |
|---|---|
| Bench | 37530 |
| Monitor system | 9680 |
| Installation, dismount | 10300 |
| Total | 57510 CHF |

# Field Mapping

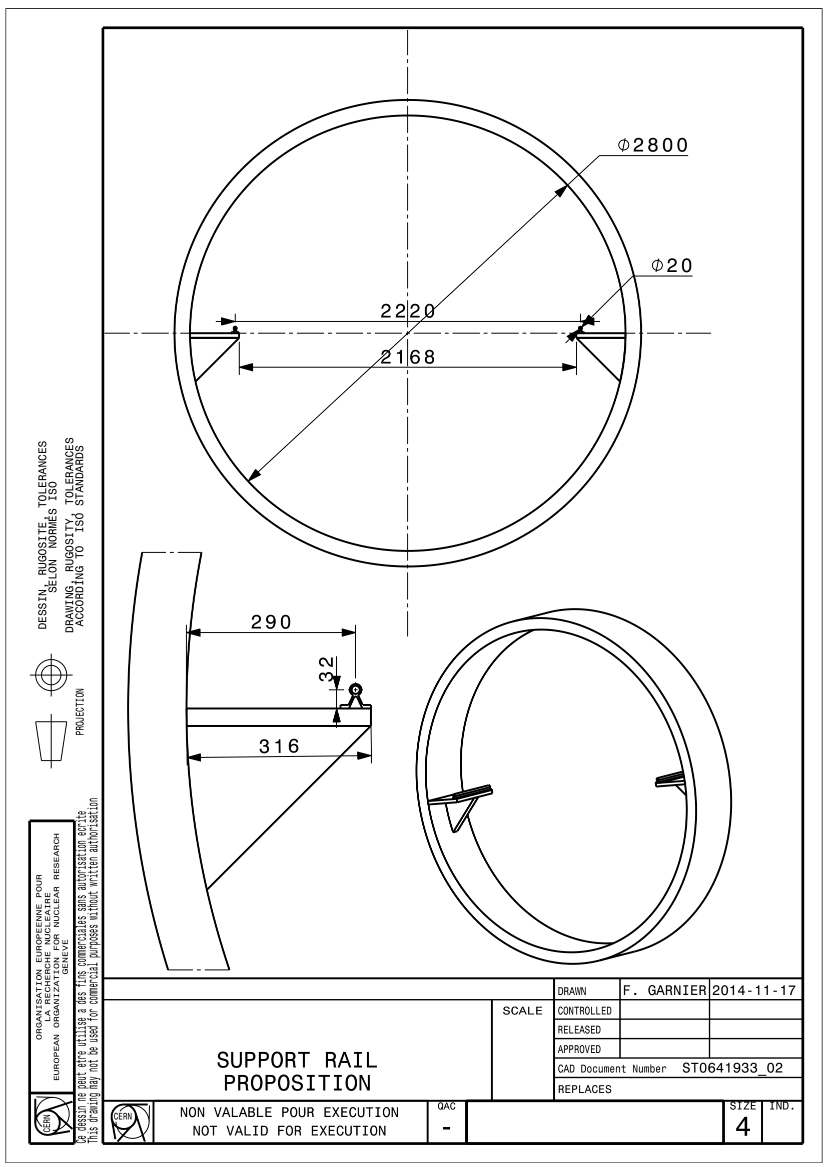
use existing probes for the low and high field tests, 2015/16
read out separately or together with voltage tabs, …



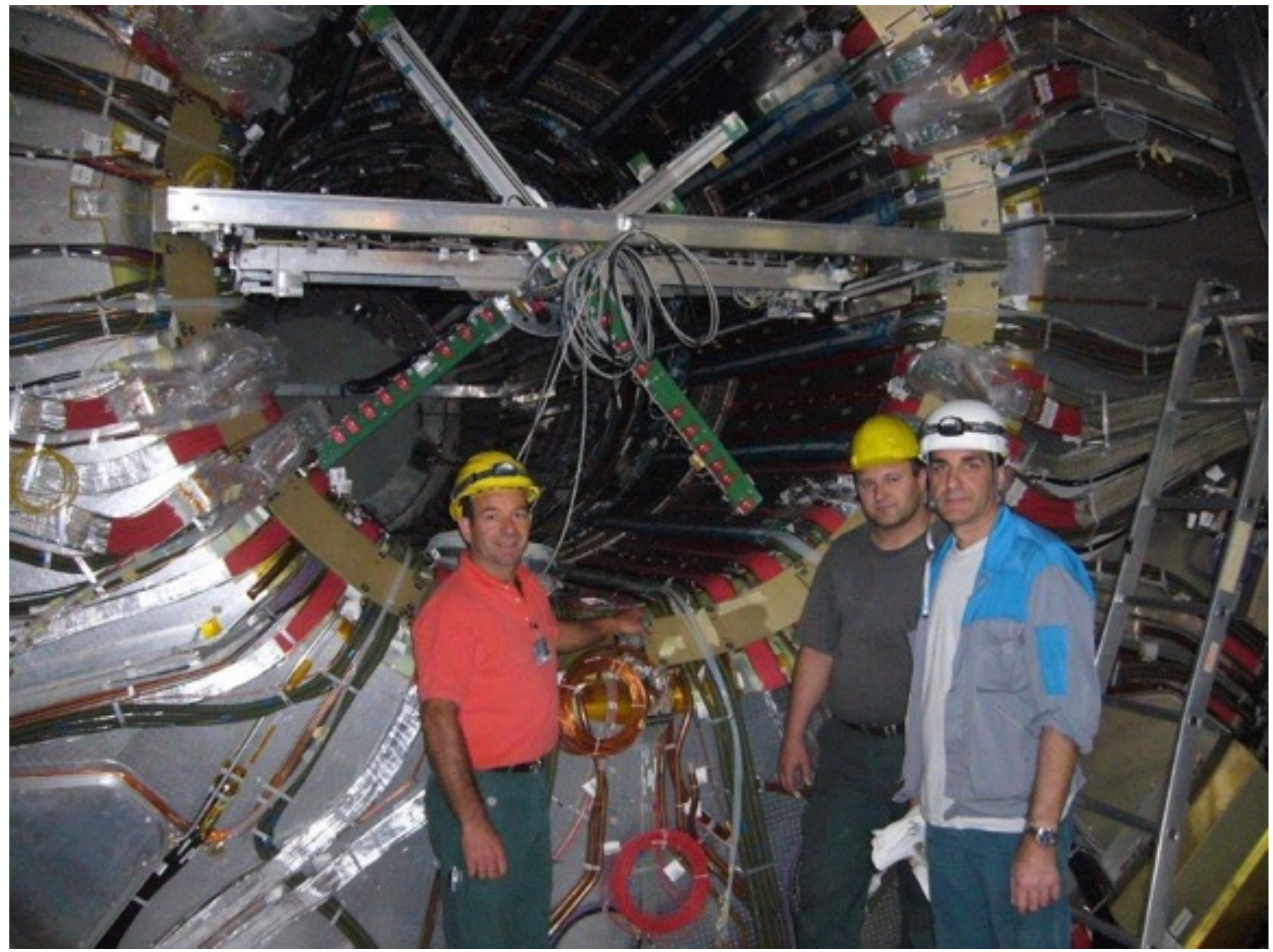
final mapping done by CERN mapping group, F.Bergsma

# Magnet mapping using the existing CERN mapper that was used for STAR and recently ATLAS

Contacts at CERN:
Pierre-Ange Giudici
Felix Bergsma




suggested supports



We can build a solenoid mapper to map the BaBar magnet for sPHENIX at BNL based on the pneumatic ATLAS-mapper and mechanics of the OPAL-bench. We would install the following improvements, developed since:

- New pneumatic engines with encoder on the primary axis and stm32f429 control
- Improved B-sensors: smaller distance between Hall centers, One-Wire addressing, more stable 3D-calibration in PT7 magnet at 2.5 Tesla (±0.2 mT in all components).
- Improved DAQ: BatCAN + software
- Carbon fiber arms.

This bench will have equal or superior performance as the one used to map the ATLAS solenoid ( http://iopscience.iop.org/1742-6596/110/9/092018/pdf/1742-6596_110_9_092018.pdf ).

We don't make profit and we only charge one-third of the real costs because the bench will be used by future experiments except for the monitor system. This is a rough estimate, values can change by +/- 20%. Transport, travel and lodging are left open to be determined by the user. CHF is used as currency.

The total amount +/- 20% without transport, travel and lodging will be

| | |
|---|---|
| Bench | 37530 |
| Monitor system | 9680 |
| Installation, dismount | 10300 |
| Total | 57510 CHF |