MuCool Overview

Muon Cooling R&D
Alan Bross

Outline

- MuCool Overview AB
  - Collaboration
  - MuCool Test Area
  - Program Synopsis

- MTA RF Program Derun Li
  - 805 MHz program
    - Pillbox cavity
    - Button cell
    - High Pressure Gas filled Test Cell (Muons Inc.)
  - 201 MHz program

MuCool

- **Mission**
  - Design, prototype and test all cooling channel components
    - 201 MHz RF Cavities, LH_2 absorbers, SC solenoids
  - Support MICE (cooling demonstration experiment)
  - Perform high beam-power engineering test of cooling section components

- Consists of 10 institutions from the US, UK and Japan

RF Development
ANL
Cockcroft Institute
Fermilab
IIT
JLAB
LBNL
Mississippi

Solenoids
LBNL
Mississippi

Absorber R&D
Fermilab
IIT
KEK
NIU
Mississippi
Osaka

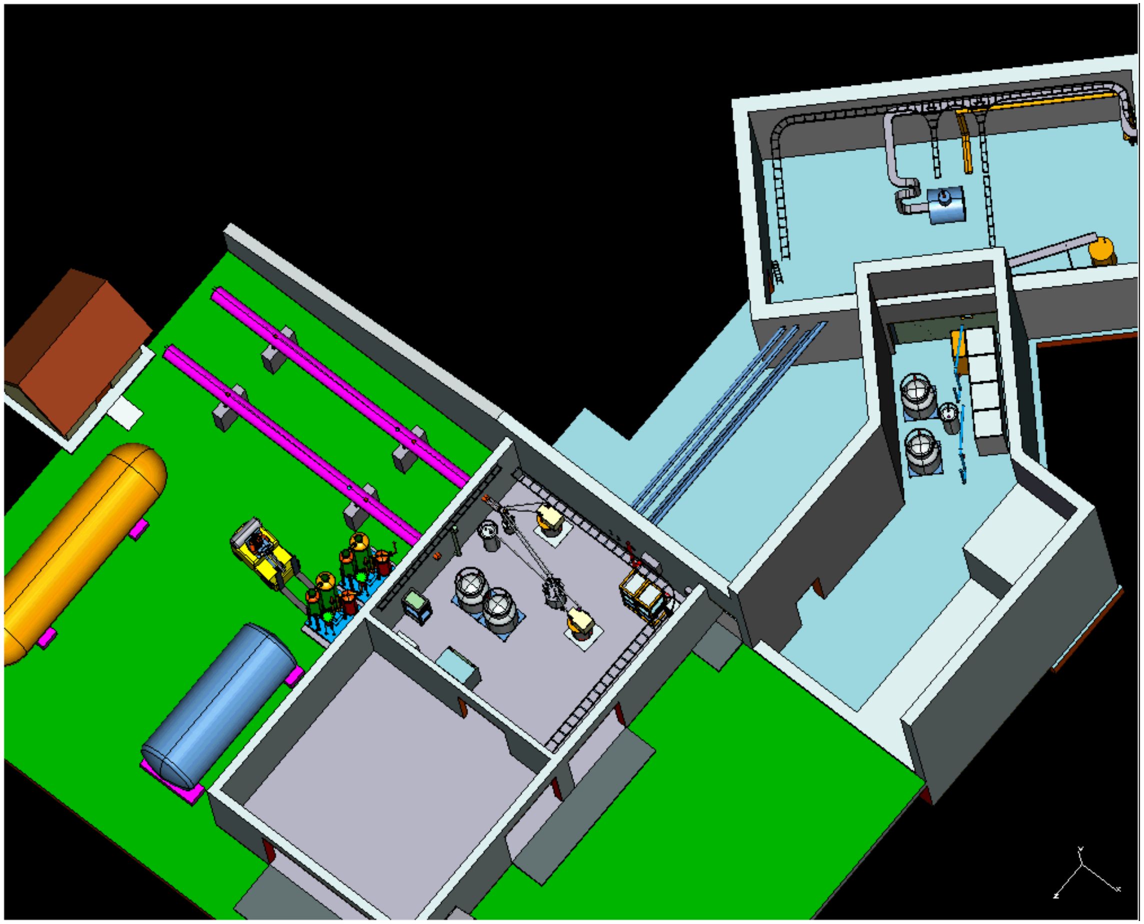
MuCool Test Area

- Fa test of
  ion

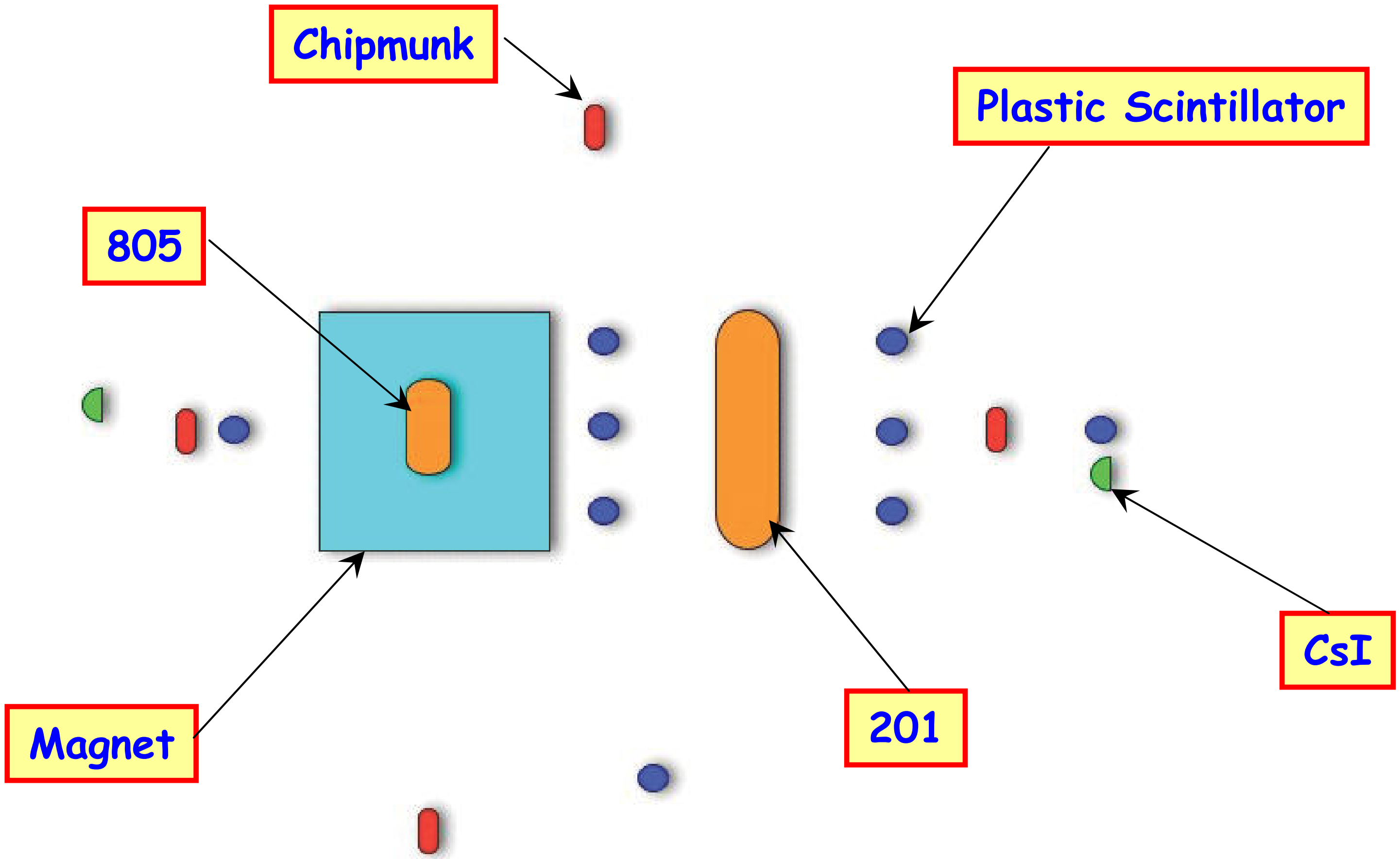
MTA Hall

MTA

- The MTA is the focus of our Activities
  - RF testing (805 and 201 MHz)
  - High pressure H_2 gas-filled RF
  - LH_2 Absorber tests
  - High Intensity Proton Beam
    - Will start with low intensity



MTA Hall Instrumentation



RF Cavity R and D

ANL/FNAL/IIT/LBNL/UMiss

RF R&D Program

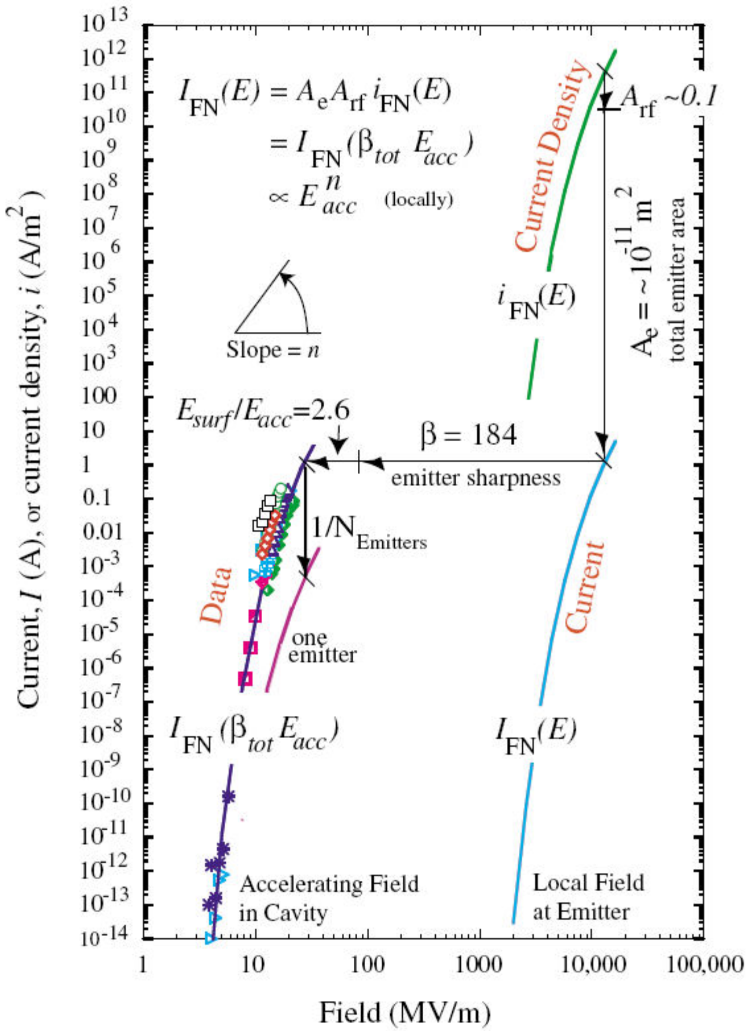
- Basic Questions:
  - Can we do anything to make MICE work better?
  - How does magnetic field affect rf cavities”
  - What materials and material properties are desirable?
  - What surface modification is possible?
  - NF and Muon Colliders also require SCRF, Can we optimize this?
- Accomplishments
  - Better understanding of conditioning with magnetic field in 805 cavity.
  - Full gradient operation of 201 MHz cavity in solenoid fringe field
  - Installation of Be windows and button test assembly.
  - Better modeling of breakdown limits.
  - Involvement with SCRF and material science community

RF R&D Program II

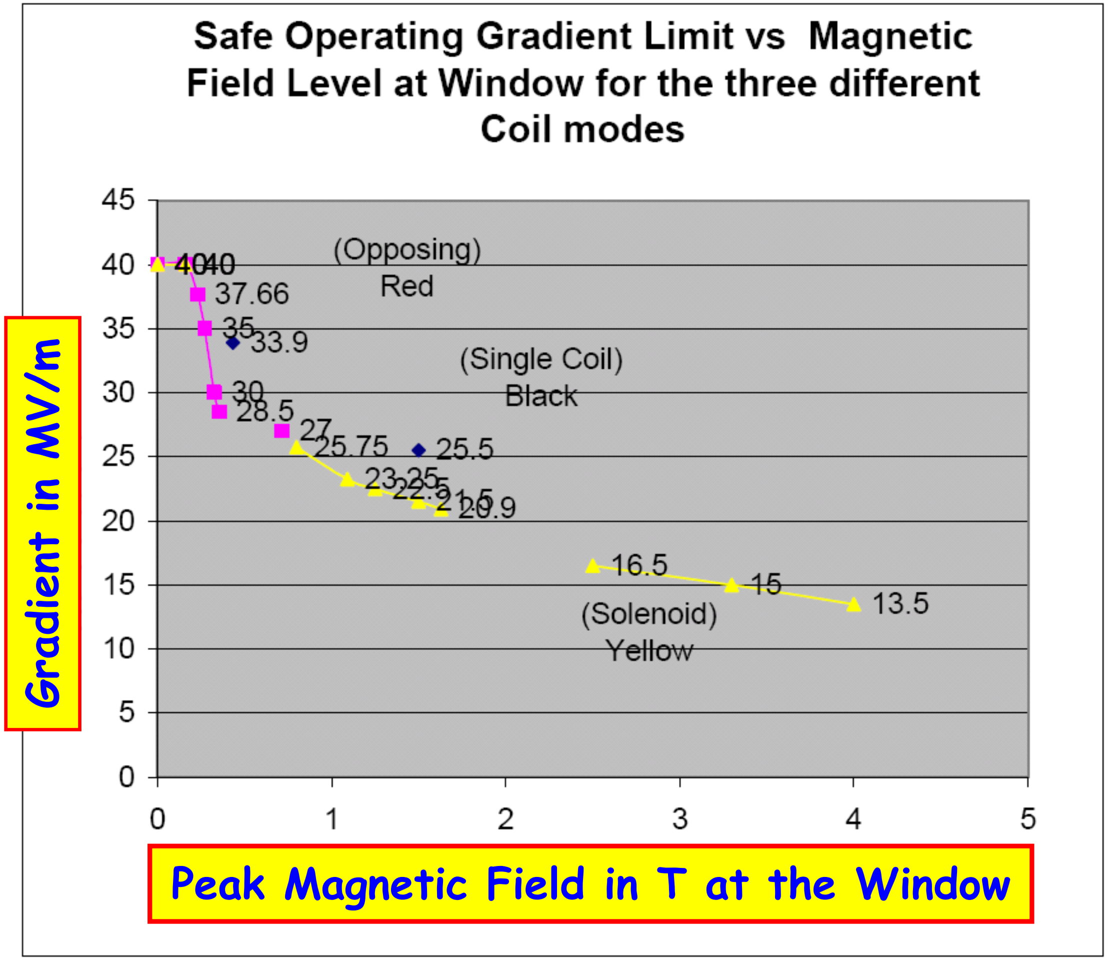
- **Major papers:**
  - X ray Spectra, Nucl. Instrum. Meth. Phys. Rev. A. 472, 600 (2001)
    - http://www-mucool.fnal.gov/mcnotes/public/pdf/muc0139/muc0139.pdf
    - Measurements of x-rays from a single cell cavity
  - Open Cell Cavity, Phys. Rev. STAB 6, 072001 (2003)
    - http://link.aps.org/doi/10.1103/PhysRevSTAB.6.072001
    - Measurements of 6 cell cavity, dark current measurements, w/wo B fields, comp. with other cavities, tensile stress
  - Cluster emission, Phys. Rev. STAB 7, 122001 (2004)
    - http://link.aps.org/doi/10.1103/PhysRevSTAB.7.122001
    - Emission of clusters, thermal and field dependence,
  - Breakdown mechanics, Nucl. Instrum. and Meth A 537, 510, (2005)
    - http://www-mucool.fnal.gov/mcnotes/public/pdf/muc0286/muc0286.pdf
    - General theory of tensile stress triggered breakdown
  - Magnetic fields, Phys. Rev. STAB 8, 072001 (2005)
    - http://link.aps.org/doi/10.1103/PhysRevSTAB.8.072001
    - Measurements with 805 MHz pillbox, measurement of *s*2(*b*)
  - Surface damage, Phys. Rev. STAB 9, 062001 (2006)
    - http://link.aps.org/doi/10.1103/PhysRevSTAB.9.062001
    - Relationship between surface damage and maximum operating fields.

Fundamental Focus Of RF R&D

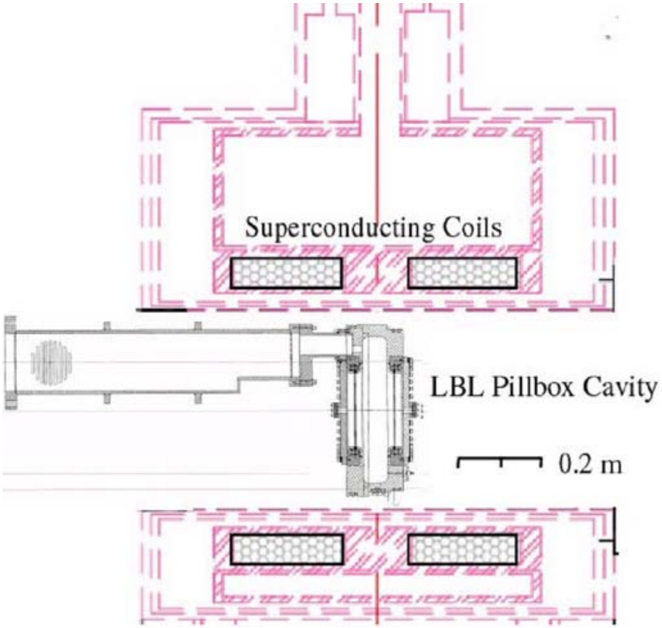
- Study the limits on Accelerating Gradient in NCRF cavities in magnetic field
- We believe that the behavior of RF systems in general can be accurately described (predicted) by universal curves
- This applies to all accelerating structures



805 MHz

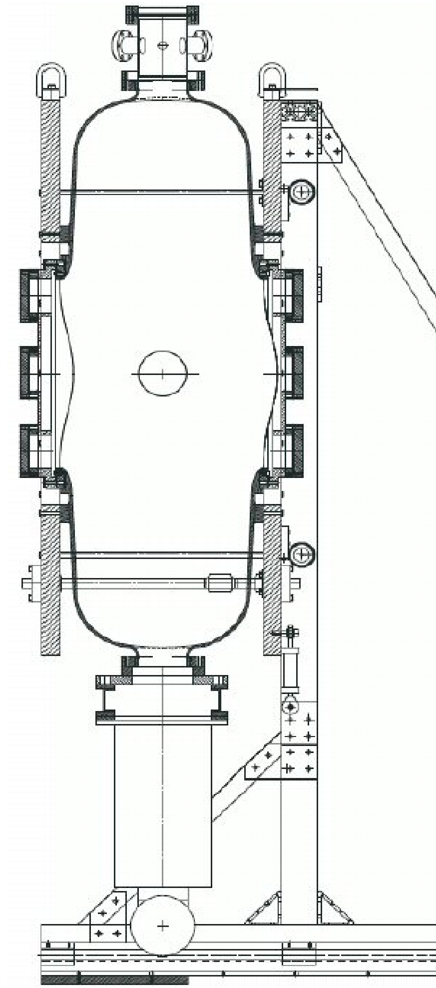


- Data seem to follow universal curve
  - Max stable gradient degrades quickly with B field
- Remeasured
  - Same results
  - Does not condition



RF R&D – 201 MHz Cavity Design

- The 201 MHz Cavity – *16 MV/m Gradient Achieved*
  - New data on x-ray backgrounds will be presented



Absorber R and D

IIT/KEK/NIU/Osaka/UMiss

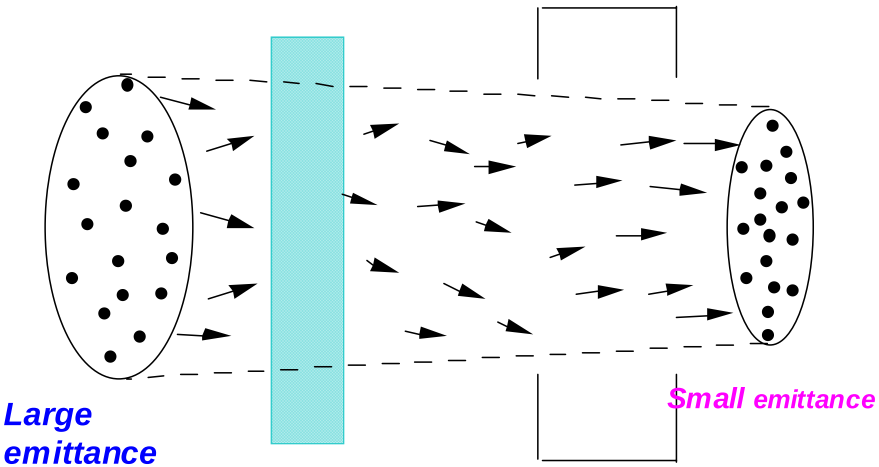
Absorber Design Issues

- **2D Transverse Cooling**

$$\frac{d\epsilon_N}{ds} = -\frac{1}{\beta^2}\frac{dE_\mu}{ds}\frac{\epsilon_N}{E_\mu} + \frac{\beta_\perp (0.014\ \mathrm{GeV})^2}{2\beta^3 E_\mu m_\mu L_R}$$

and

$$\epsilon_{N,\min} = \frac{\beta_\perp (14\ \mathrm{MeV})^2}{2\beta m_\mu \frac{dE_\mu}{ds} L_R}$$



- **Figure of merit: $M=L_R dE_\mu/ds$**

M^2 (4D cooling) for different absorbers

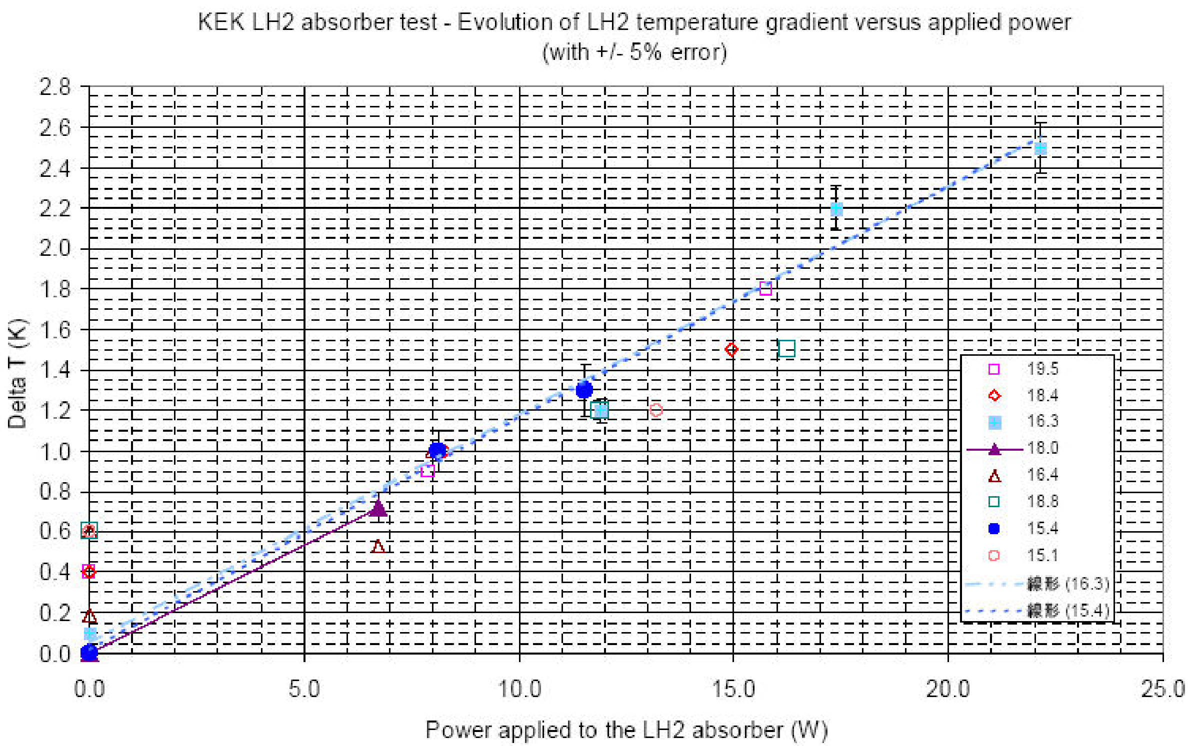
Material	$\langle dE/ds\rangle_{min}$ (MeV g^{-1}cm^2)	L_R (g cm^{-2})	Merit
GH_2	4.103	61.28	1.03
LH_2	4.034	61.28	1
He	1.937	94.32	0.55
LiH	1.94	86.9	0.47
Li	1.639	82.76	0.30
CH_4	2.417	46.22	0.20
Be	1.594	65.19	0.18

H_2 is clearly Best -
Neglecting Engineering Issues
Windows, Safety

Convective Absorber Activities

- First Round of studies of the KEK absorber performed in the MTA
  - GHe used to input power

Convective Absorber Activities II

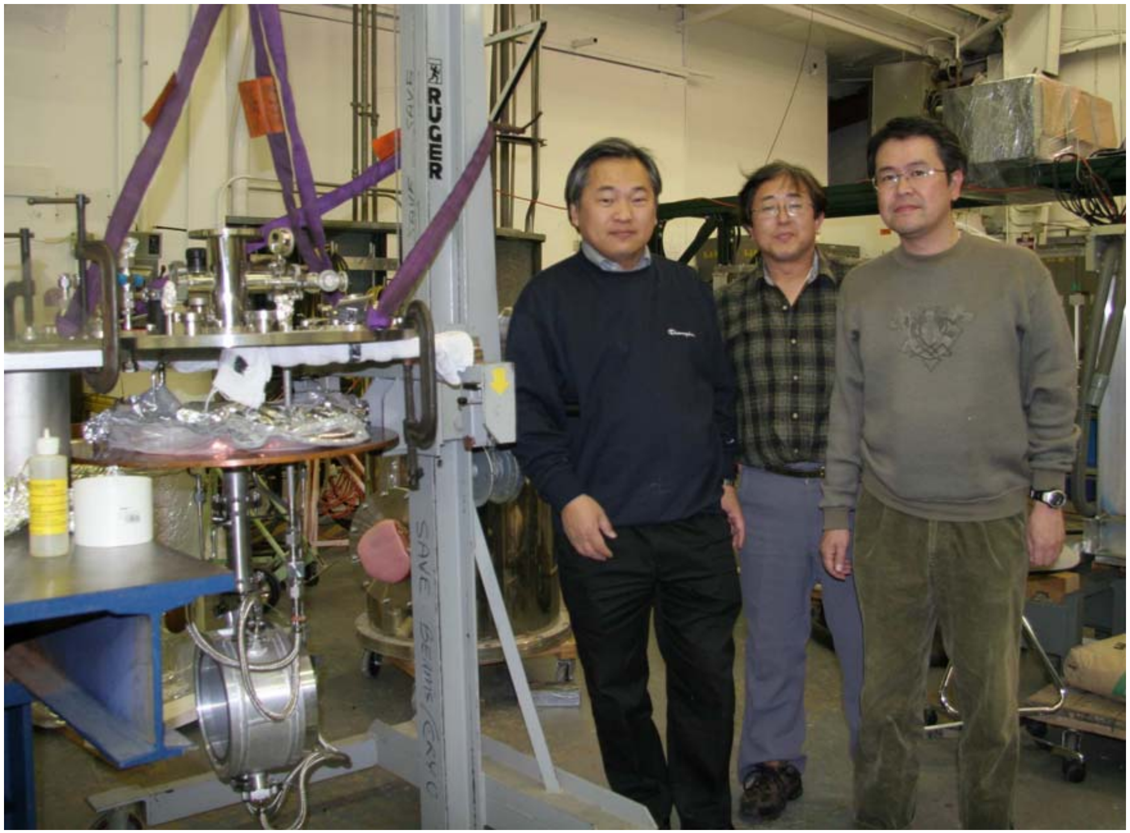


Temperature gradient (TC-106-H - TC-110-H) versus applied heat for several LH2 absorber bath temperatures.

dT=2.4K at 20W → dT=9K at 75W ?

(T_{max}=23K, T_{min}=14K)

Convective Absorber Activities



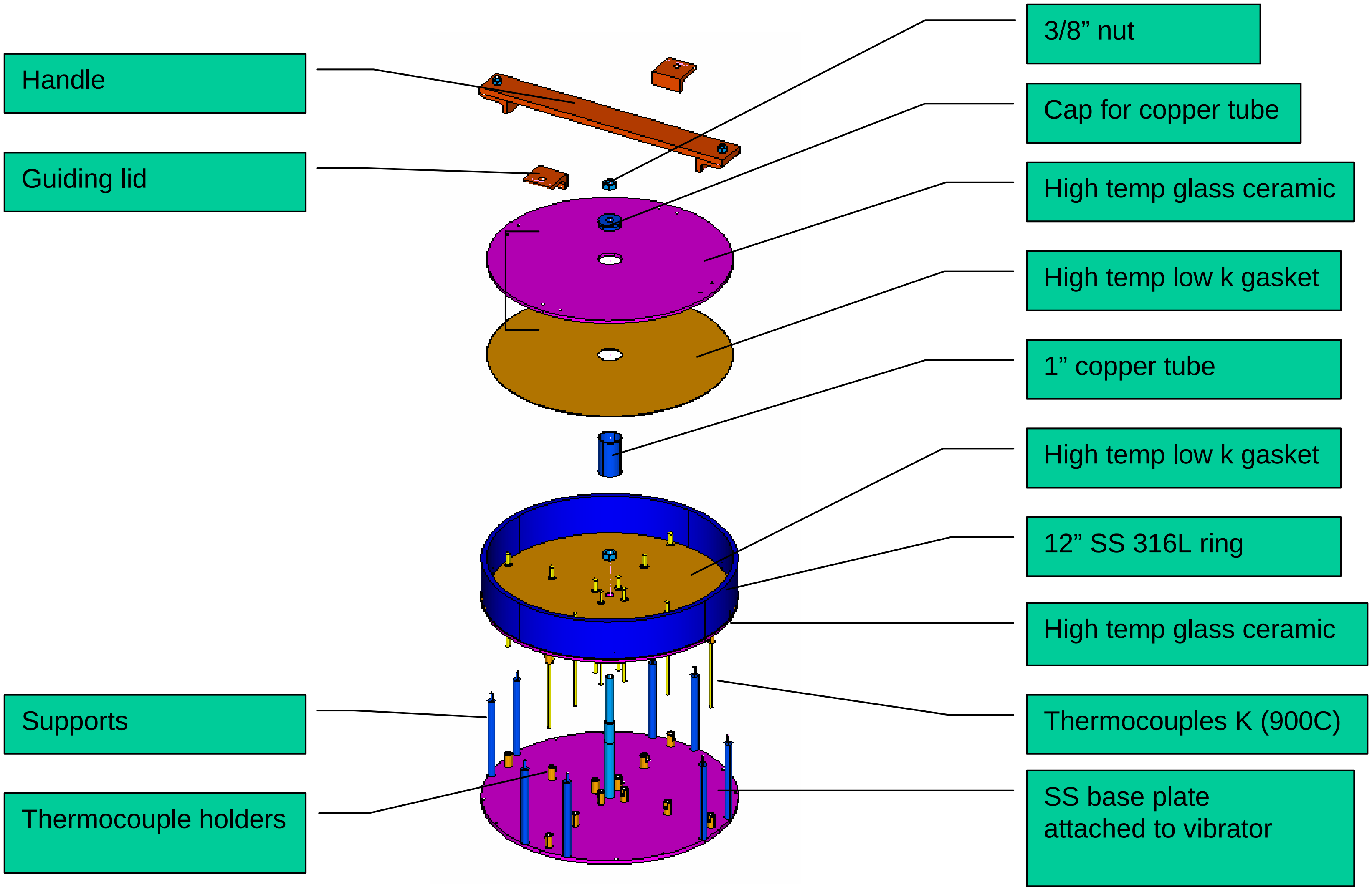
Absorber Body being modified in Lab 6 at Fermilab

- KEK Convector Absorber upgrades
  - Electrical Heater
  - New Temperature sensors
  - LH liquid level sensor
- Have now been installed and system has been tested
  - Ready for LH_2 run
    - After safety approval

LiH Test Program

- Produce encapsulating cast (not pressed) samples
  - Small disks (5-10 cm)
    - Test casting procedures
    - Examine mechanical properties
    - Destructive tests for voids
  - Large disk (30 cm) for detailed thermal conductivity studies
    - External Cooling + Internal Heating
    - Potential absorber for MICE Phase I
      - Non-instrumented, no cooling

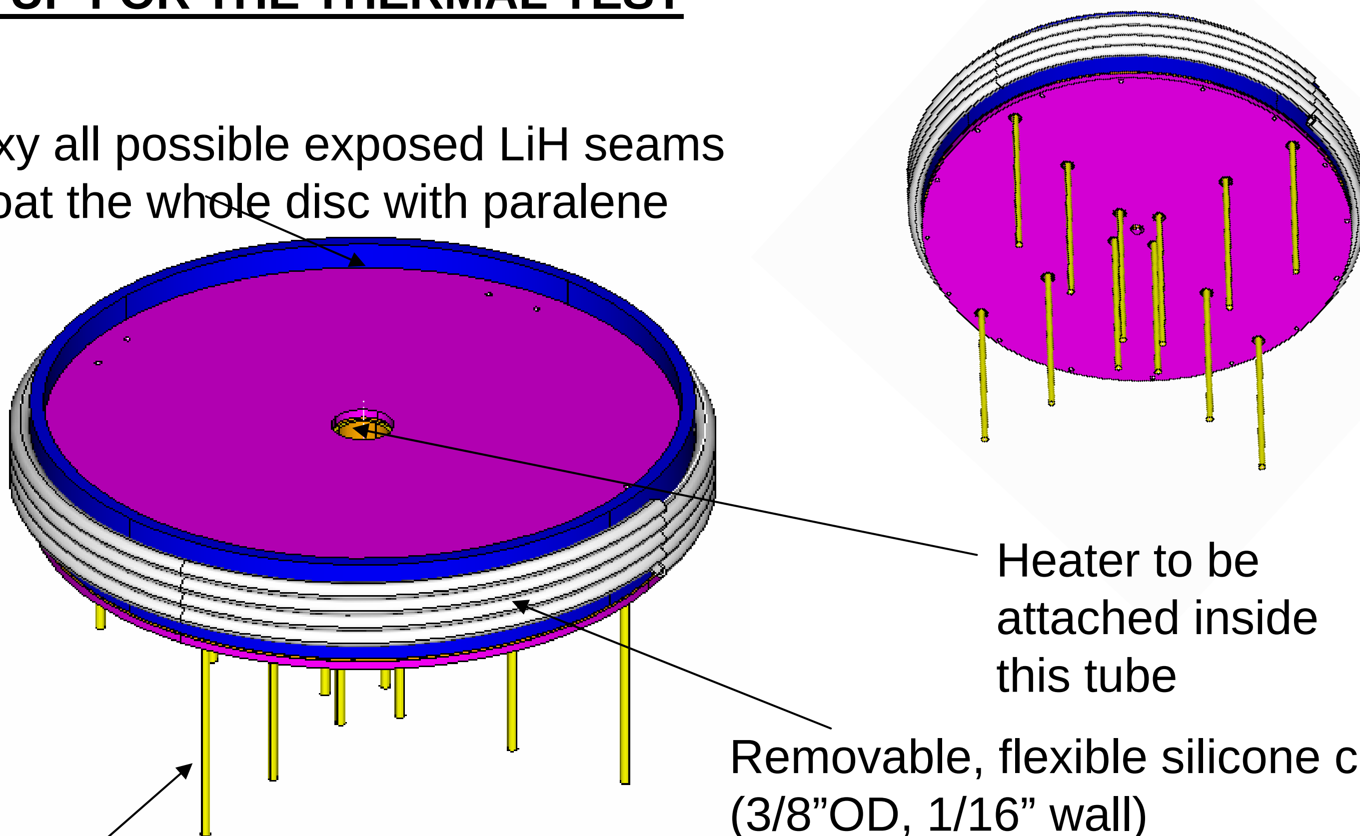
Engineering Design for Large Disks



Thermal Properties Test

SET UP FOR THE THERMAL TEST

Epoxy all possible exposed LiH seams or coat the whole disc with paralene



Heater to be attached inside this tube

Removable, flexible silicone cooling tube (3/8"OD, 1/16" wall)

Thermocouples

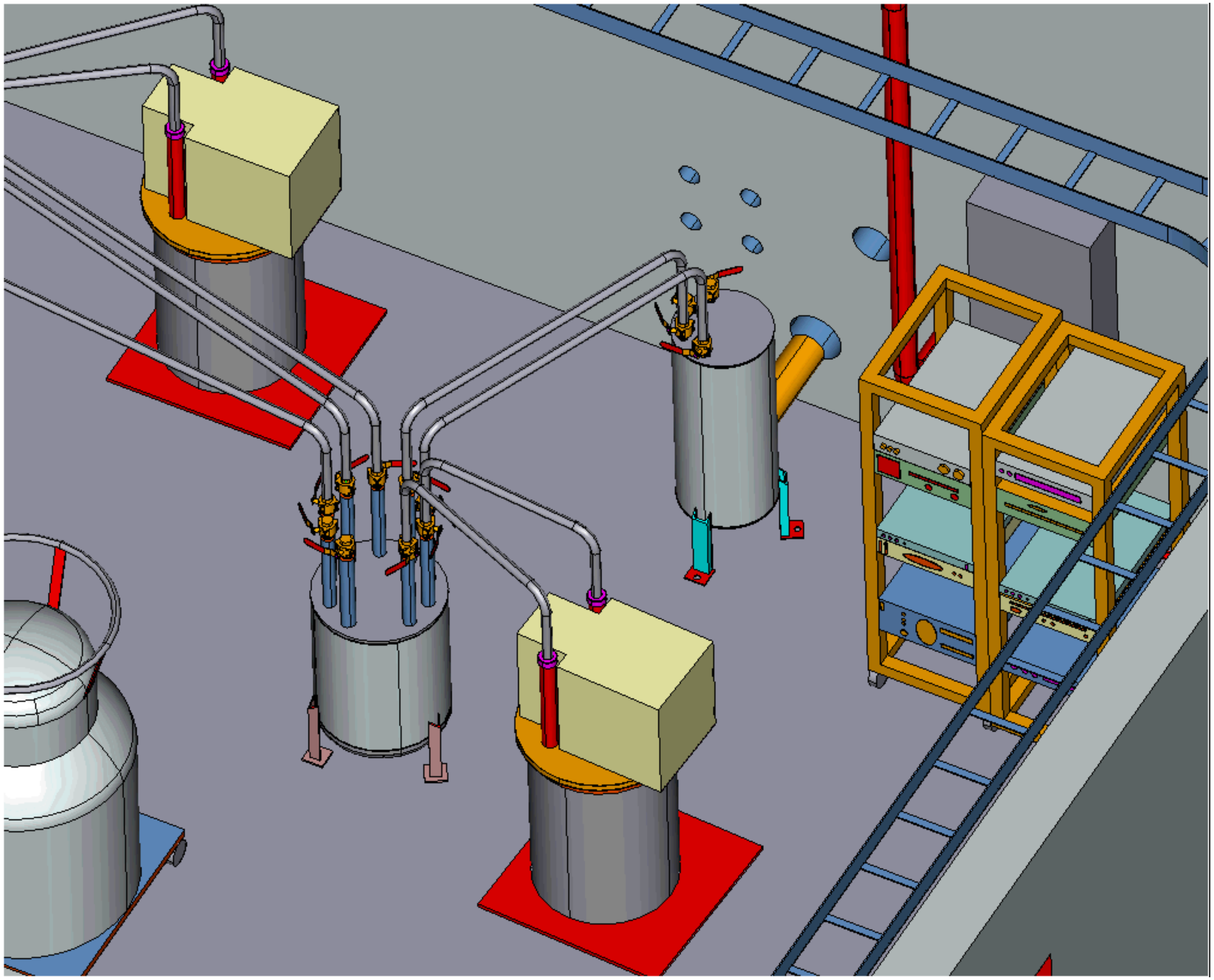
MTA Cryo-Infrastructure

- We are making good progress with completion of the cryo-plant and transfer-line system.
  - Transfer line system parts complete
- Our goal is to install/commission the system this FY (*well our goal was to install last FY*)
  - Before the shutdown (August) in we can start by June
    - We define the beginning of the window to be when the cryo-plant is up and running (producing LHe)
  - After the shutdown otherwise
- Our current operating costs (LHe) for the MTA magnet are **$3-5k/week**
  - Fermilab is providing $100k of support for MTA operations
    - Will allow us to run the magnet off LHe dewars for the remainder of FY07 if required

Existing Dewar-Fed Cryogen System

- All of this is removed
- New (simpler) shield wall
  - Will allow for easier pit access to hall
  - More shielding needed for beam operations in MTA Hall

MTA - Refrigerator Room Artist's Conception



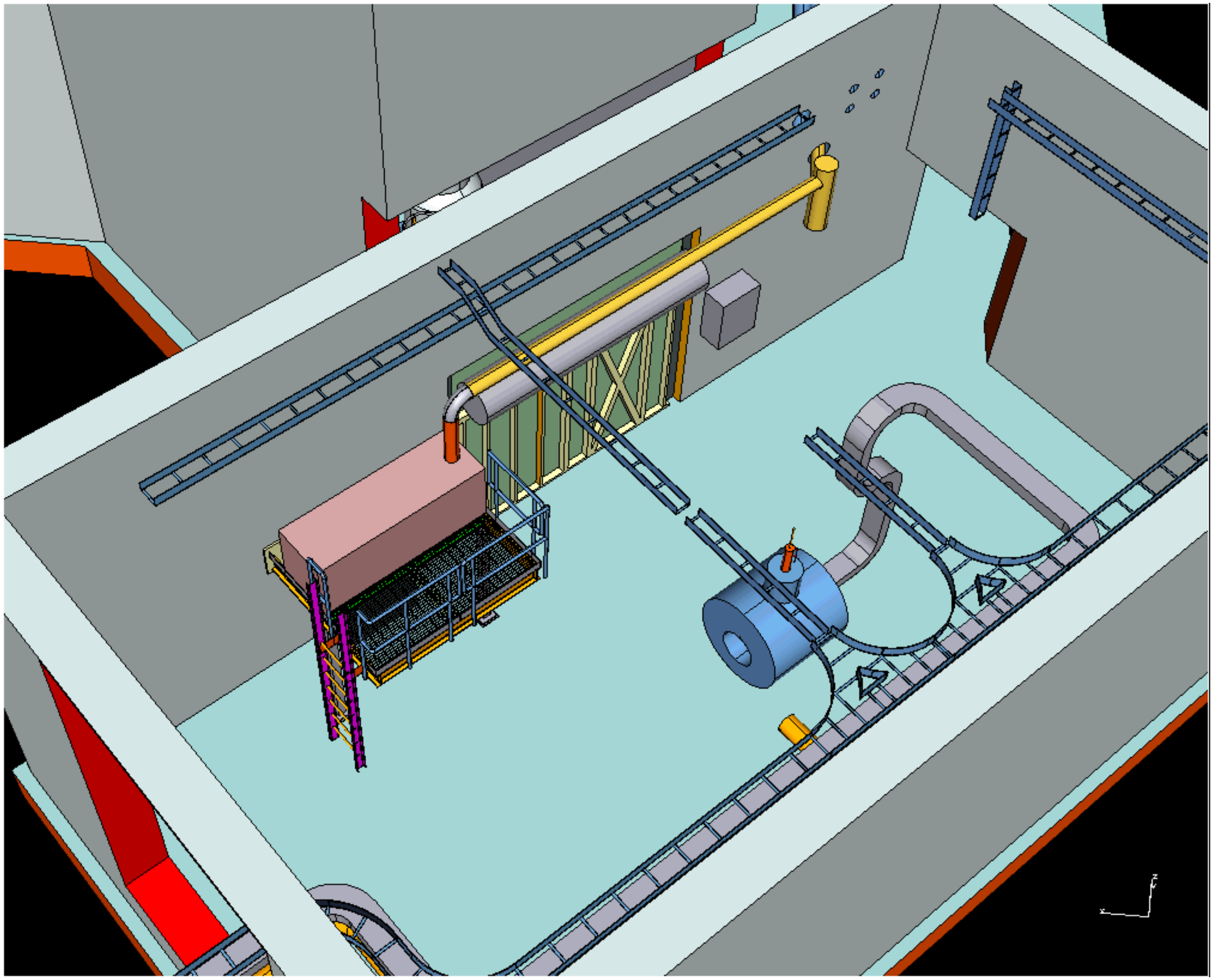
Storage Area

GHe, LN_2
Storage
Heat Exch.

Compressor Room

Refrigerator Room

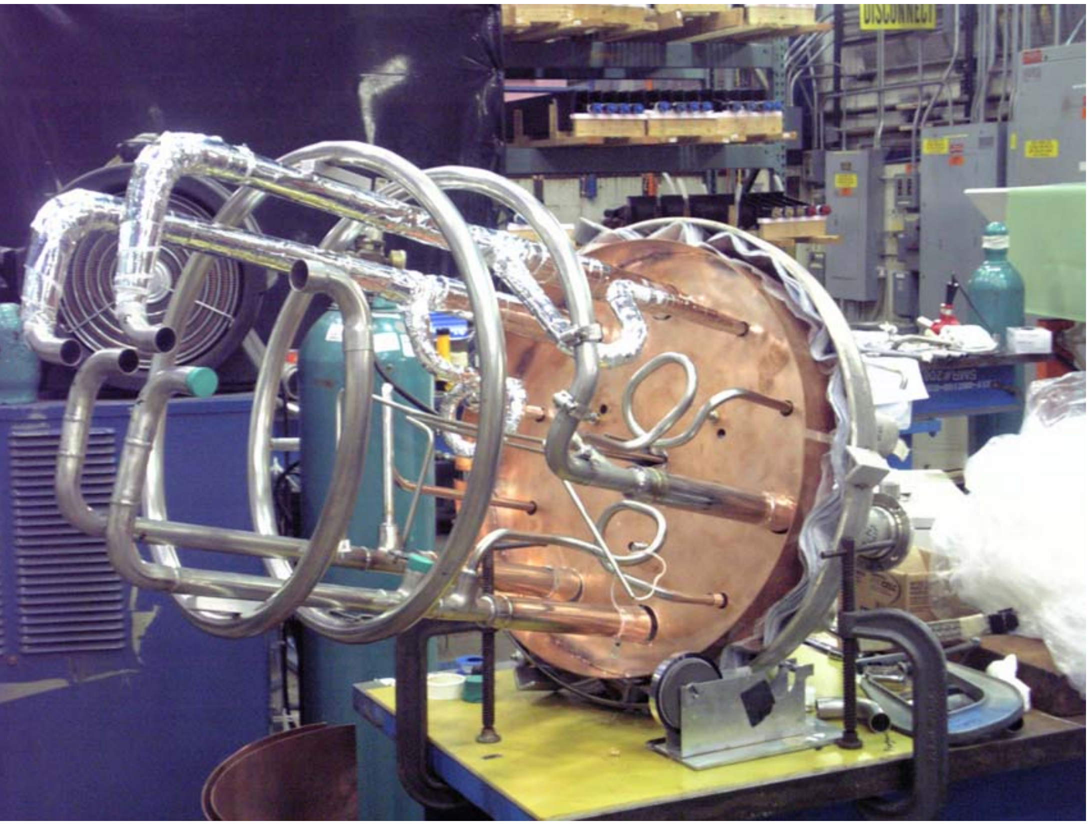
Transfer Line System



Transfer Line System

Valve Box Piping

Completed Valve Box



Refrig Room Valve Can

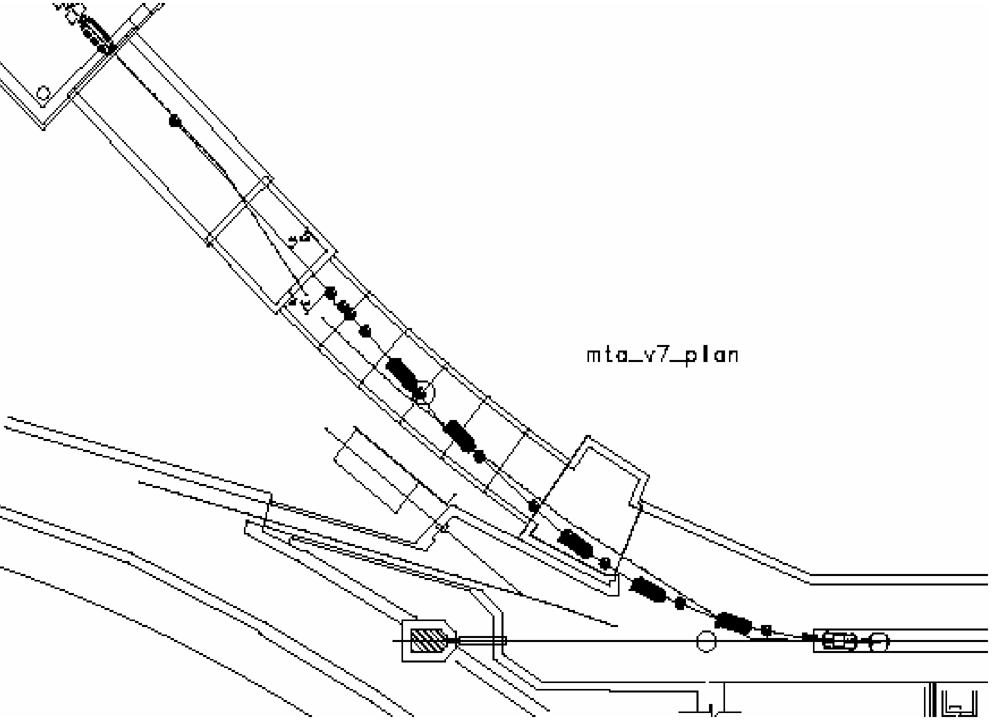
Xfer Line

MuCool Phase II

Cryo-Infrastructure Installation
Beam Line Installation

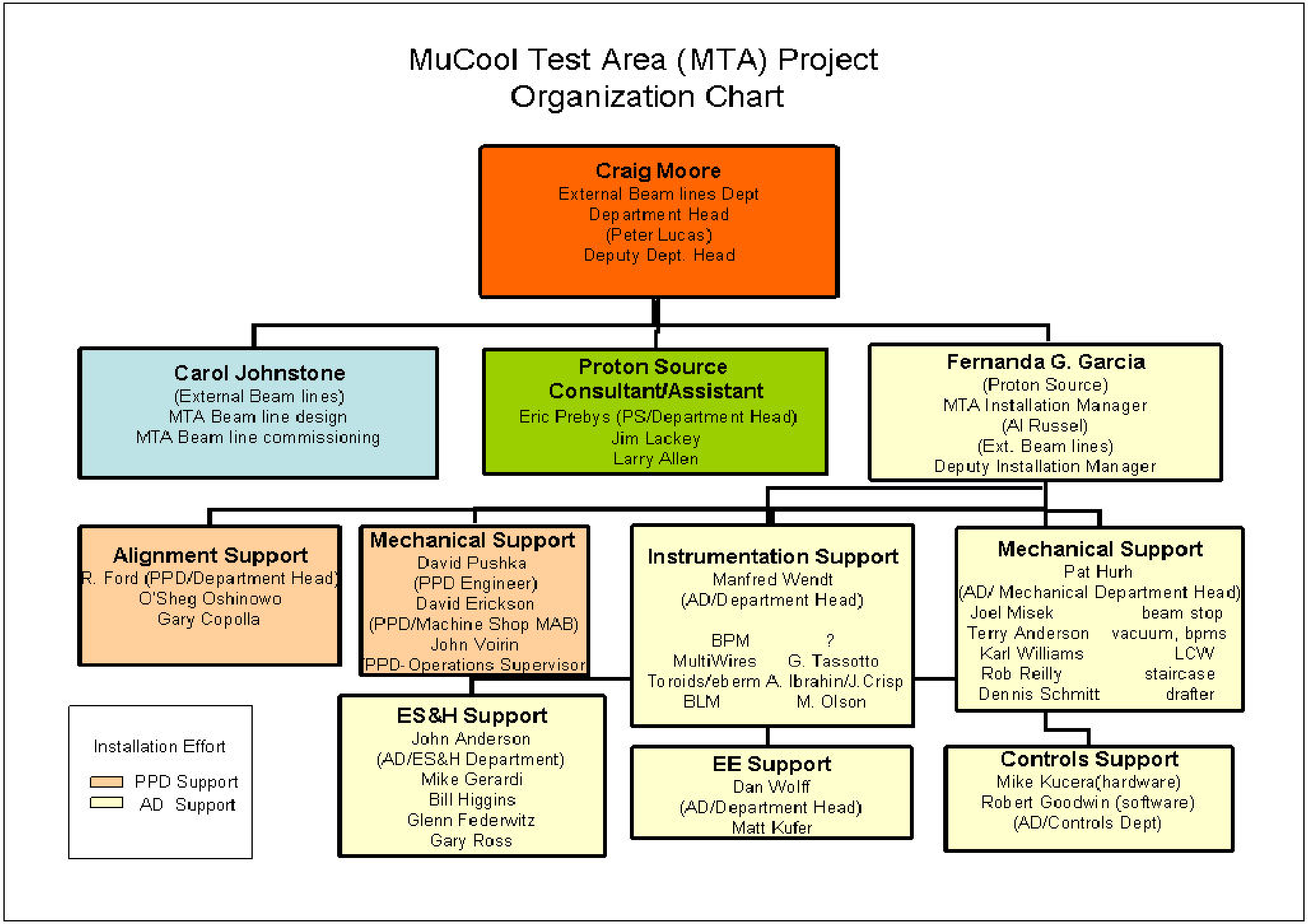
MTA Beam Line

MTA



- 400 MeV beamline for the MTA has been designed
  - Under Craig Moore/Carol Johnstone
    - External Beams Department
  - Engineering Design mature
    - Cost
  - Safety Analysis
    - Linac Area and Beamline
    - Shielding Assessment for MTA
  - First Phase will be low-intensity
    - Funded by Fermilab + NFMCC
    - Installation group now formed
      - F. Garcia (Proton source group)

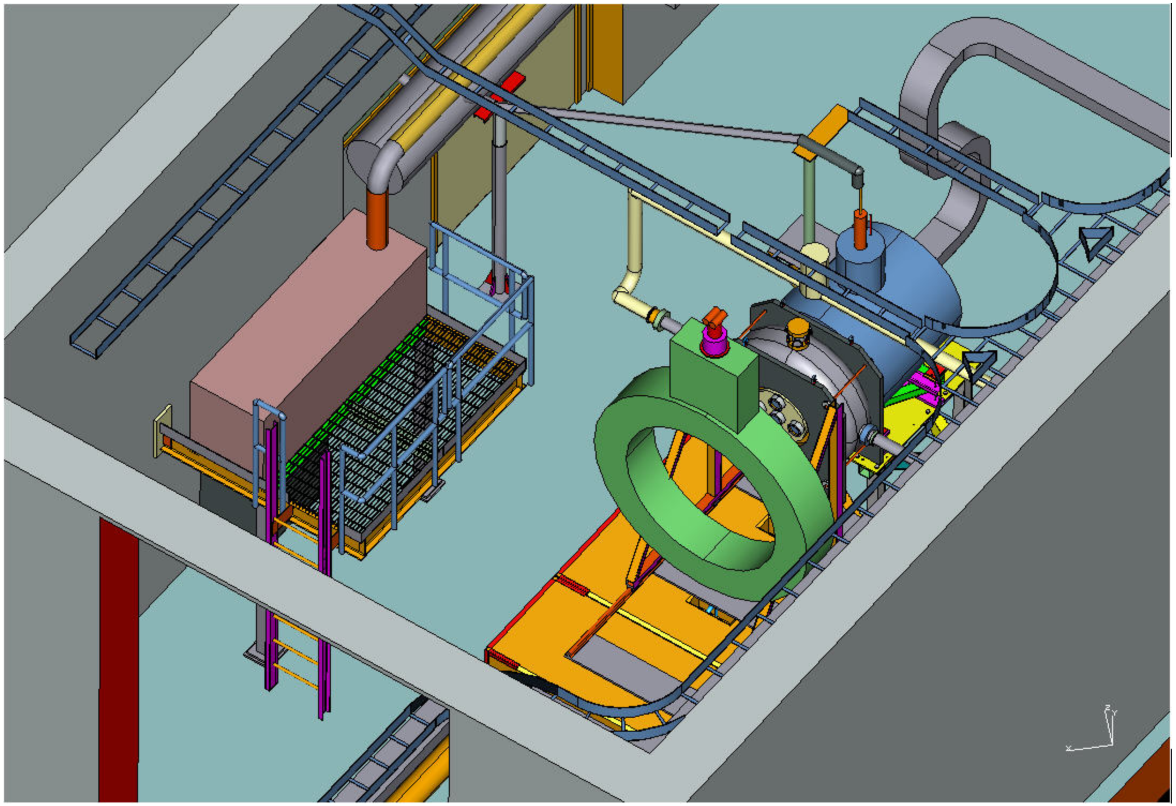
MTA Beam Line Group



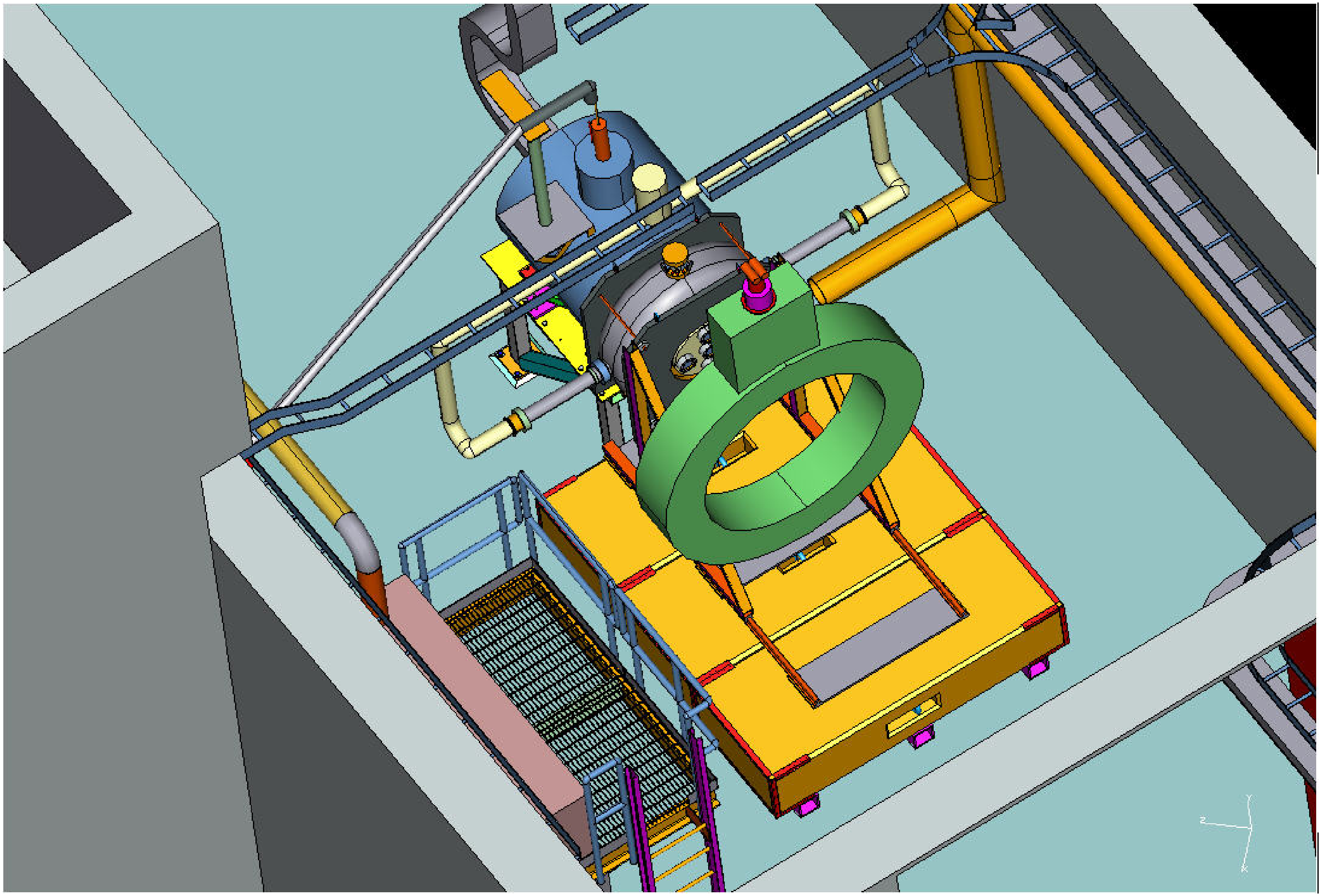
First Beam Experiments

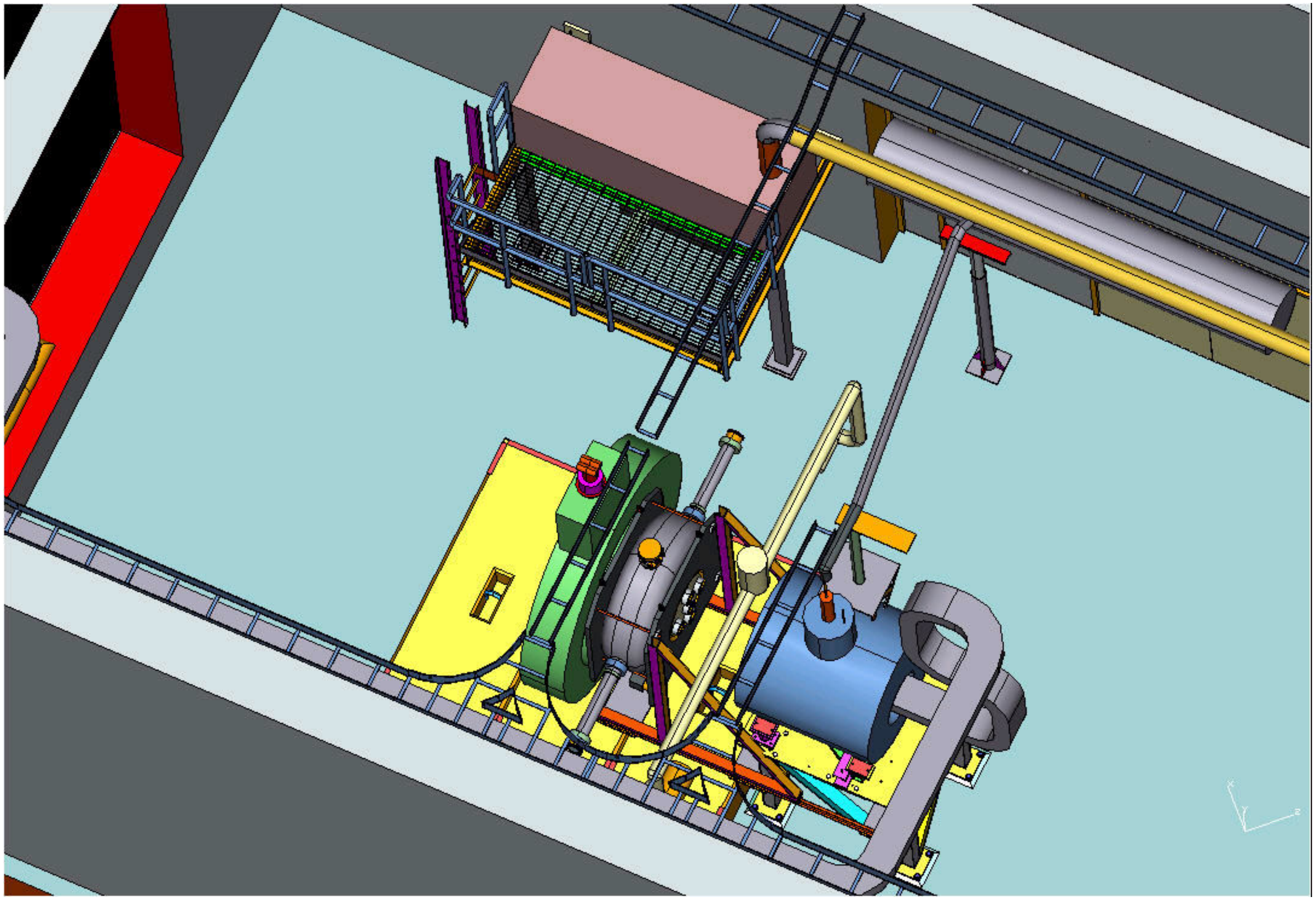
- Currently 5T magnet and 201 cavity on floor (below beam ht.)
- First experiments will pitch beam down to center of magnet
  - Allows for early tests of gas filled cavity operation in intense beam
  - Very-low integrated intensity
    - Few full-intensity linac pulses

Phase II



- Raise equipment to beam height
- Install cryo-infrastructure
  - Valve box
  - Transfer lines
  - Weld system
  - Connect to cryo-plant
- Expect 2-3 month duration with appropriate technical resources





- Addition of Coupling Coil (B field studies of 201 operation) requires the 201 MHz cavity to be rotated 180 degree

MuCool Plans for the Coming Year

- 805 MHz RF studies – Buttons (with and without B field)
    - Materials tests
    - Surface treatment
    - Use information from ultra-high resolution surface studies
        - Local Electrode Atom Probe
- 201 MHz RF
    - Conditioning in B field
    - Install Curved Be Windows and repeat
- Second round of tests with KEK convective absorber
    - Window of opportunity is until cryo installation starts
- Begin thermal and mechanical tests on cast LiH absorber prototypes
- Complete MTA cryo infrastructure installation and commission system
- Begin Installation of beam line components during summer shutdown