MICE Magnets

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Muon Accelerator Program Review-Fermilab
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  - Current status
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- Coupling Coils
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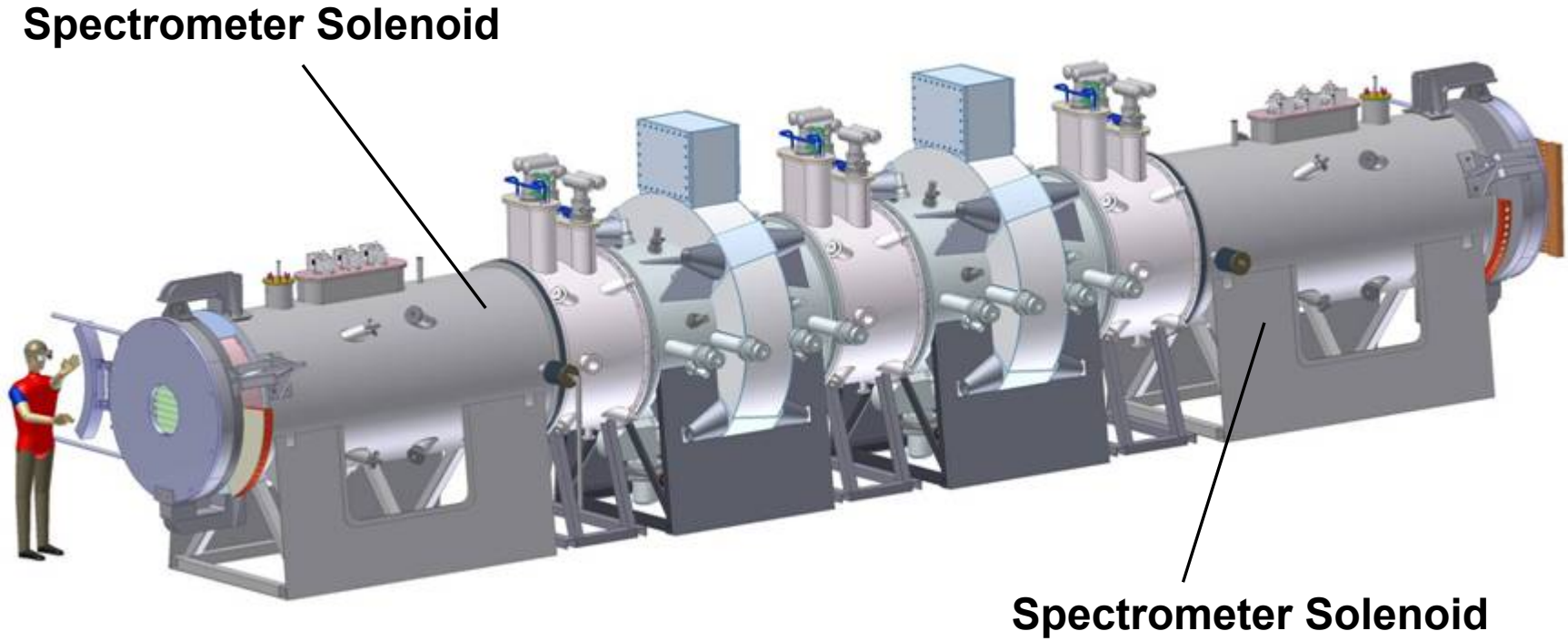
Introduction

- The full MICE cooling channel will incorporate 7 superconducting magnet modules comprised of a total of 18 solenoid coils
- LBNL is responsible for the two 5-coil Spectrometer Solenoids and the two single-coil Coupling Coils
- The Spectrometer Solenoids were designed and are being built by a vendor local to LBNL (Wang NMR)
- The Coupling Coils were designed by the Institute for Cryogenics and Superconductivity Technology in Harbin, China (a MICE collaborator) and are being built by a company in Beijing (the QiHuan Company)

Spectrometer Solenoids in MICE



Spectrometer Solenoid Overview

- Each magnet has five coils wound on a common Al mandrel
- The radiation shield and cold mass are cooled by a series of two-stage cryocoolers
- A recondensation circuit maintains LHe in the cold mass

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- Magnet history:
  - Both magnets were previously fully assembled and tested
  - The training goal is to reach 275 amps in all five coils
  - Magnet #1 trained to 196 amps before disassembly to modify the recondensing circuit, which was prone to blockage
  - Magnet #2 was assembled with a modified condensing circuit and several other design enhancements
  - The second magnet trained to 238 amps when an HTS lead burned out due to inadequate cooling of the upper lead ends

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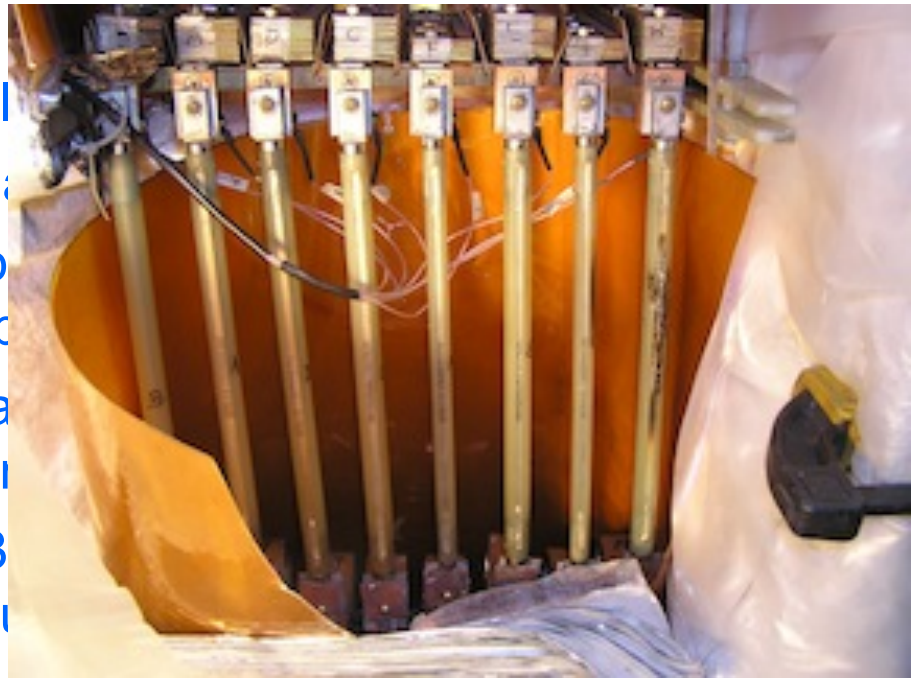
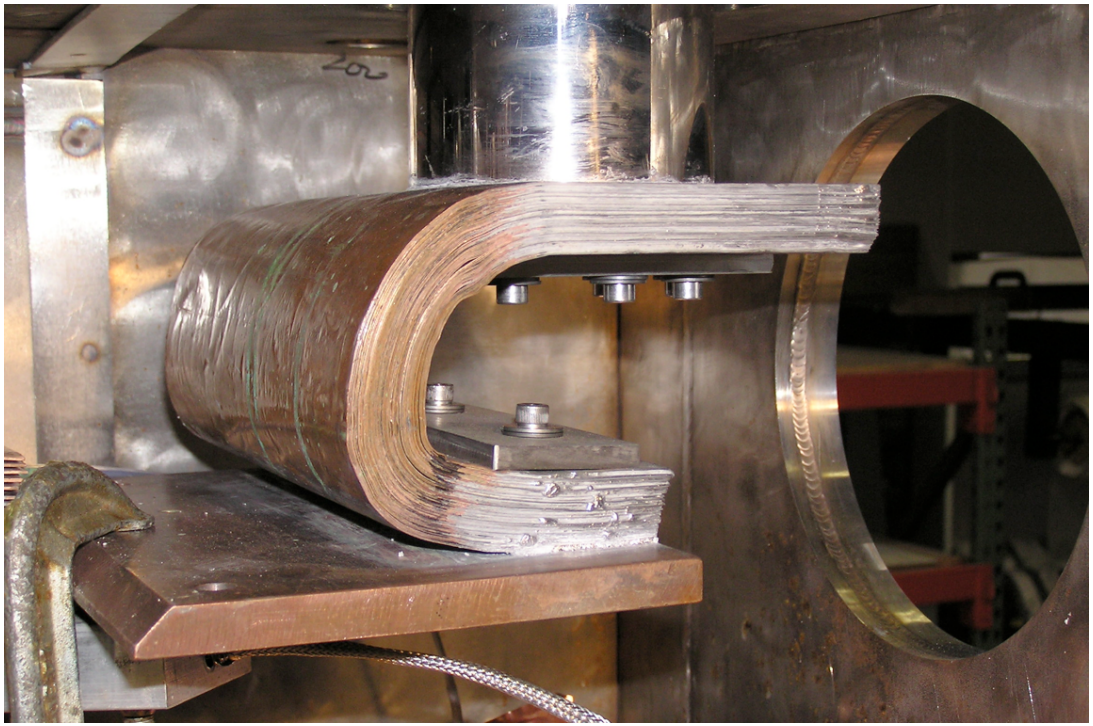


Added Single Stage Cryocooler



Current Spectrometer Solenoid Status

- Magnet history (cont'd):
  - Two review committees have been assembled to assess the design and assembly of the Spectrometer Solenoid magnets
  - An 11/09 MICE project committee developed recommendations before Magnet #2 was prepared for a 2nd round of testing
  - Per the committee's recommendation, a single-stage cooler was added to increase the shield and HTS lead cooling
  - With the HTS lead issue solved, Magnet #2 trained to 258 amps when a coil lead was found to contain an open circuit
  - Also, the three 2-stage coolers + the 1-stage cooler could not maintain a closed LHe system (per boil-off measurements)
  - Magnet #2 has been disassembled and the cold mass opened
  - The failed lead was just inside the cold mass feedthrough

Preliminary Repair of Leads

Preliminary Assessment & Plan

- A 2nd committee of 3 FNAL magnet experts was assembled to review and assess the lead failure and the helium boil-off issue
- LBNL is developing a plan to respond to the committee's recommendations before incorporating any design changes
- The initial steps in the process are shown below:
  - A complete set of the latest as-built drawings (including future changes) is being compiled to facilitate engineering calculations
  - All heat loads are being reassessed to ensure that the LHe in the cold mass can be maintained with the selected number of cryocoolers
  - All EM calculations will be redone for both test and operational conditions
  - The instrumentation plan will be reviewed and changes implemented to allow confirmation of the thermal and EM calculations during testing
  - Further analysis will demonstrate that the mechanical support of the magnet, leads, piping and other internal components are adequate

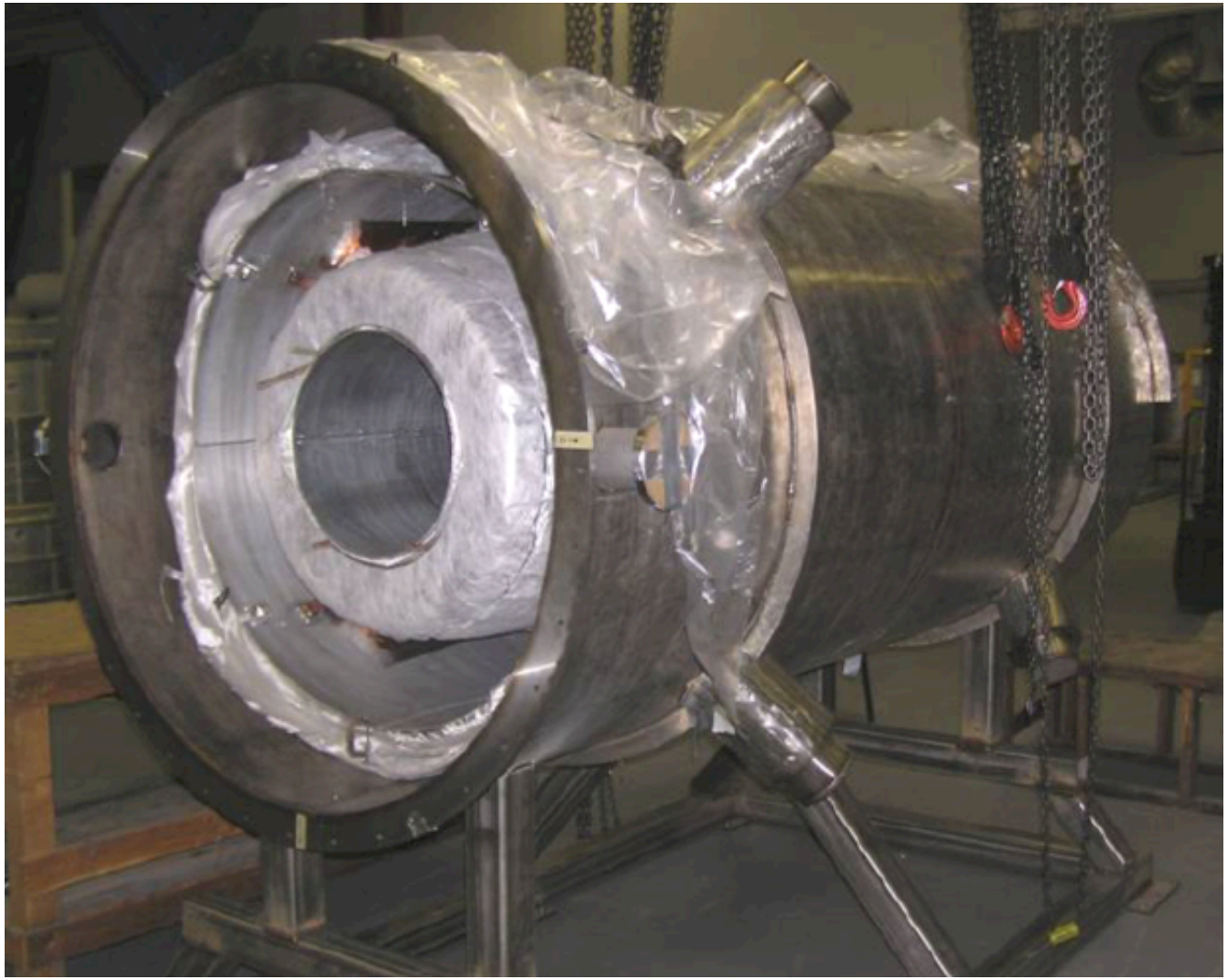
Design Modification Plan

- In parallel to the analysis effort, a modification and assembly plan is being developed and will likely include the following:
  - reduction of heat leaks to the cold mass
  - the addition of more cryo cooling power
  - modification of the cold leads near the feedthroughs to prevent burn-out
- The preliminary plan (pending results of analyses) is shown below and on the next slide:
  - LBNL/MICE personnel will be present to document/oversee all aspects of magnet reassembly
  - Improved vacuum pumping and instrumentation will be implemented to ensure there is adequate insulation of the cold mass
  - All 4K components will be covered with actively cooled shield where possible – the effects of partially covered areas will be analyzed

Design Modification Plan (cont'd)

- The total cooling power will be increased by using five 2-stage pulsed tube coolers and one single-stage cooler (preliminary)
- The thermal/mechanical stabilities of the cold leads will be improved by adding extra copper and superconductor near the cold mass feedthrus
- The heat loads from the following will be decreased as possible: shield pass through holes for the cold mass supports, intermediate cold mass support heat intercepts, and shielding of the warm end of the supports
- Detailed inspection of MLI during assembly will be part of the QA plan
- The individual leads will be wrapped with super insulation
- Possible thermal acoustic oscillations in vent lines will be addressed
- The vent line heat loads will be evaluated and reduced where possible
- Sensor wires to be optimized to reduce the heat loads as needed
- A fast DAQ system will continuously monitor the voltage tap signals

Assembly of Spectrometer Solenoid



Schedule

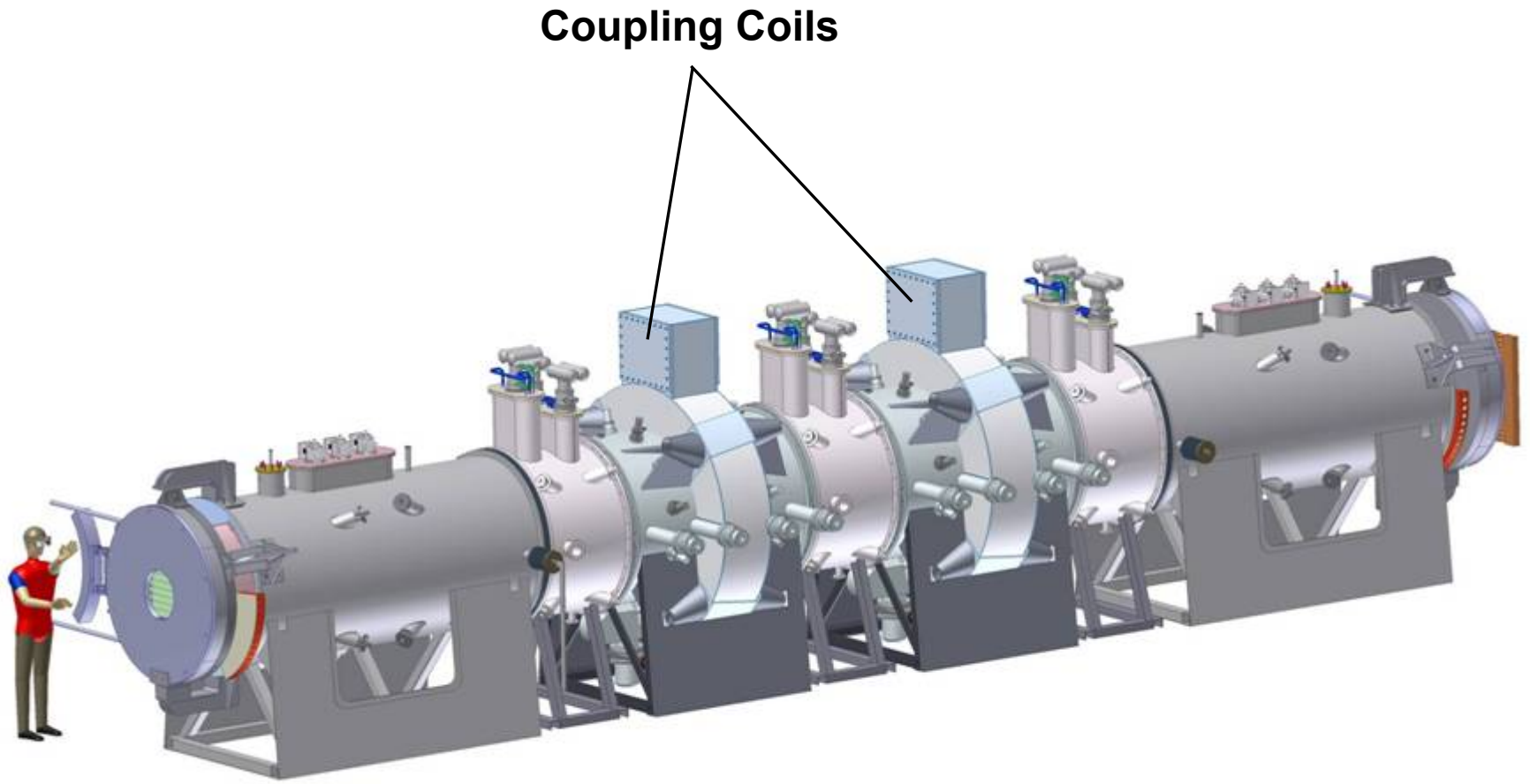
Task Description	Date
Complete EM, thermal and mechanical analyses	mid-Sept.
Complete the design modification plan	early-Oct.
Presentation to review committee(s)	end-Oct.

- The nominal reassembly time for the magnets is expected to be approximately four months
- Actual assembly time will depend on the degree of modification required
- The second magnet will follow the first by 2 to 3 months

Manpower

- Thermal calculations
  - Soren Prestemon (LBNL Engineering Division – Cryogenic Engineer)
- EM analysis
  - GianLuca Sabbi et al (LBNL Supercon Group)
- Mechanical analysis
  - Steve Virostek (LBNL Engineering Division – Mechanical Engineer)
- Drawings
  - Steve Virostek, Allan DeMello (LBNL Mechanical Engineers), Wang NMR
- Instrumentation plan
  - Soren Prestemon, Mike Green (LBNL Cryogenic Engineers), Wang NMR
- Fabrication oversight
  - Nanyang Li (LBNL Engineering Division – Production Engineer)
- Management & manpower
  - Steve Gourlay (LBNL AFRD Division Director)
  - Ross Schlueter (LBNL Mechanical Engineering Department Head)

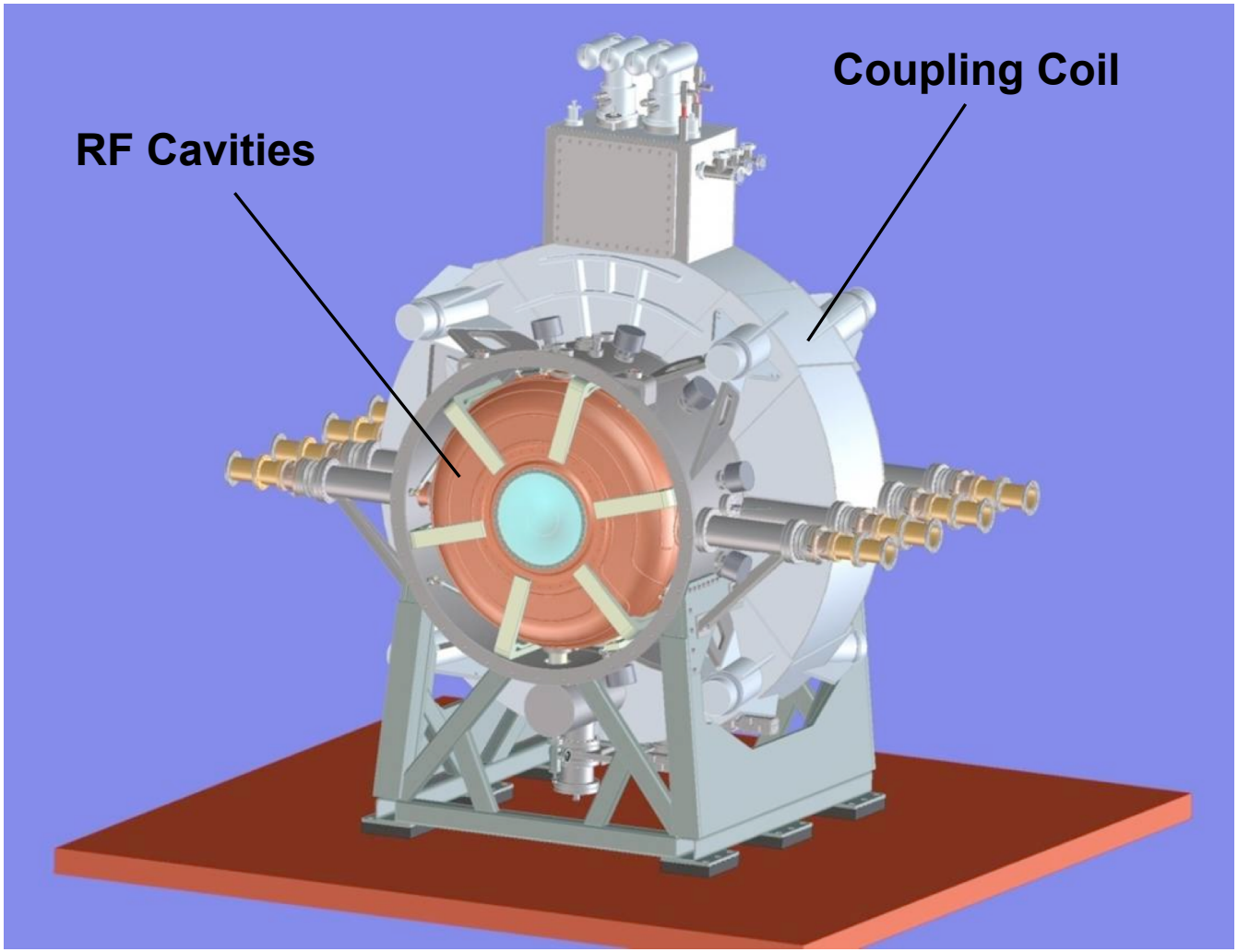
Coupling Coils in MICE



Coupling Coil Overview

- The Coupling Coils are single coils wound on a forged aluminum mandrel
- Cooling of the radiation shield and cold mass is provided by a series of two-stage cryocoolers
- Liquid helium is maintained in aluminum tubes welded to the cold mass by means of a recondensation circuit
- The coils are designed so as to allow integration with the vacuum vessel for the RF/Coupling Coil (RFCC) Module
- The full MICE cooling channel will contain two of these modules
- A third coil (MuCool) is being built for the MTA Facility at FNAL
- The RFCC vacuum vessel will contain a set of four 201 MHz, normal conducting copper cavities (5 complete, 5 under way)

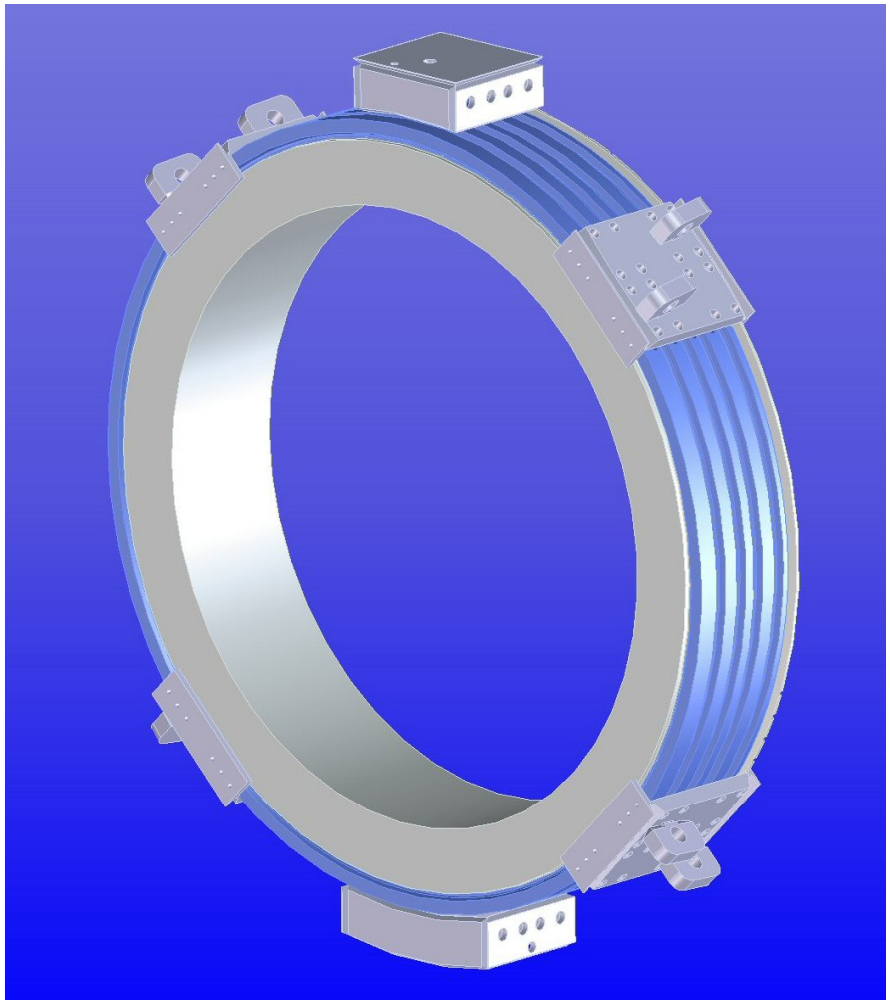
RFCC Module CAD Model

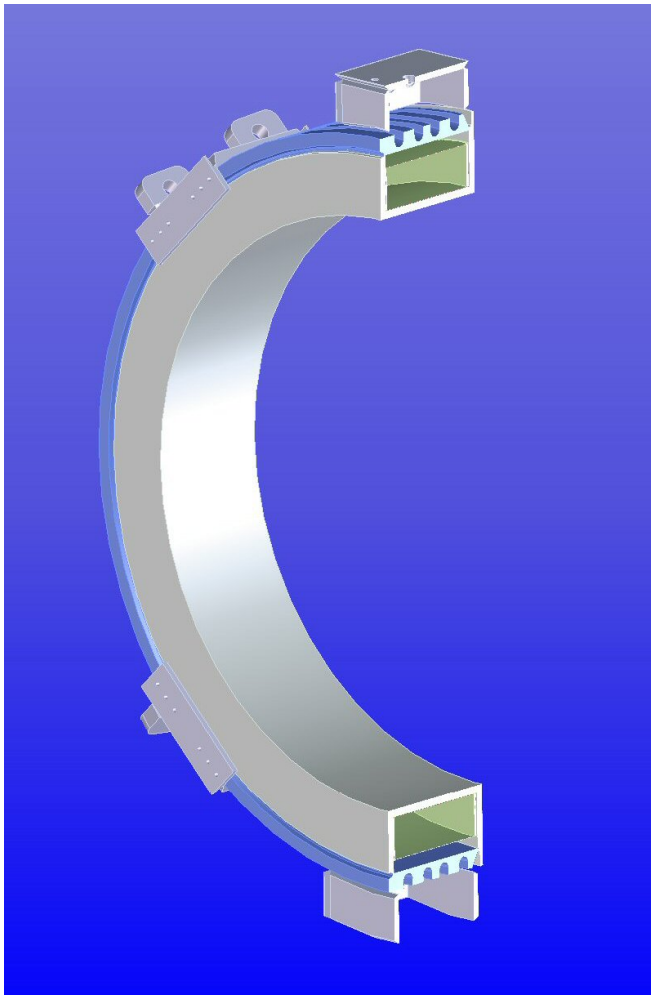


Coupling Coil Status

- The coupling coils are being designed and built through a collaboration with the Institute of Cryogenics and Superconductivity Technology (ICST) in Harbin, China
- The cold-mass design is complete; a fabrication contract was awarded to the QiHuan Company in Beijing in March 2010
- The cryostat design will be complete in September 2010
- A collaboration between LBNL and the Shanghai Institute of Applied Physics will allow the cryostat design to be completed
- The first magnet coil winding is approximately 40% complete
- To test cold-mass before magnet assembly, the cryogenic test system at ICST must be ready by late November 2010
- The first cold-mass test will be conducted at ICST in Dec. '10

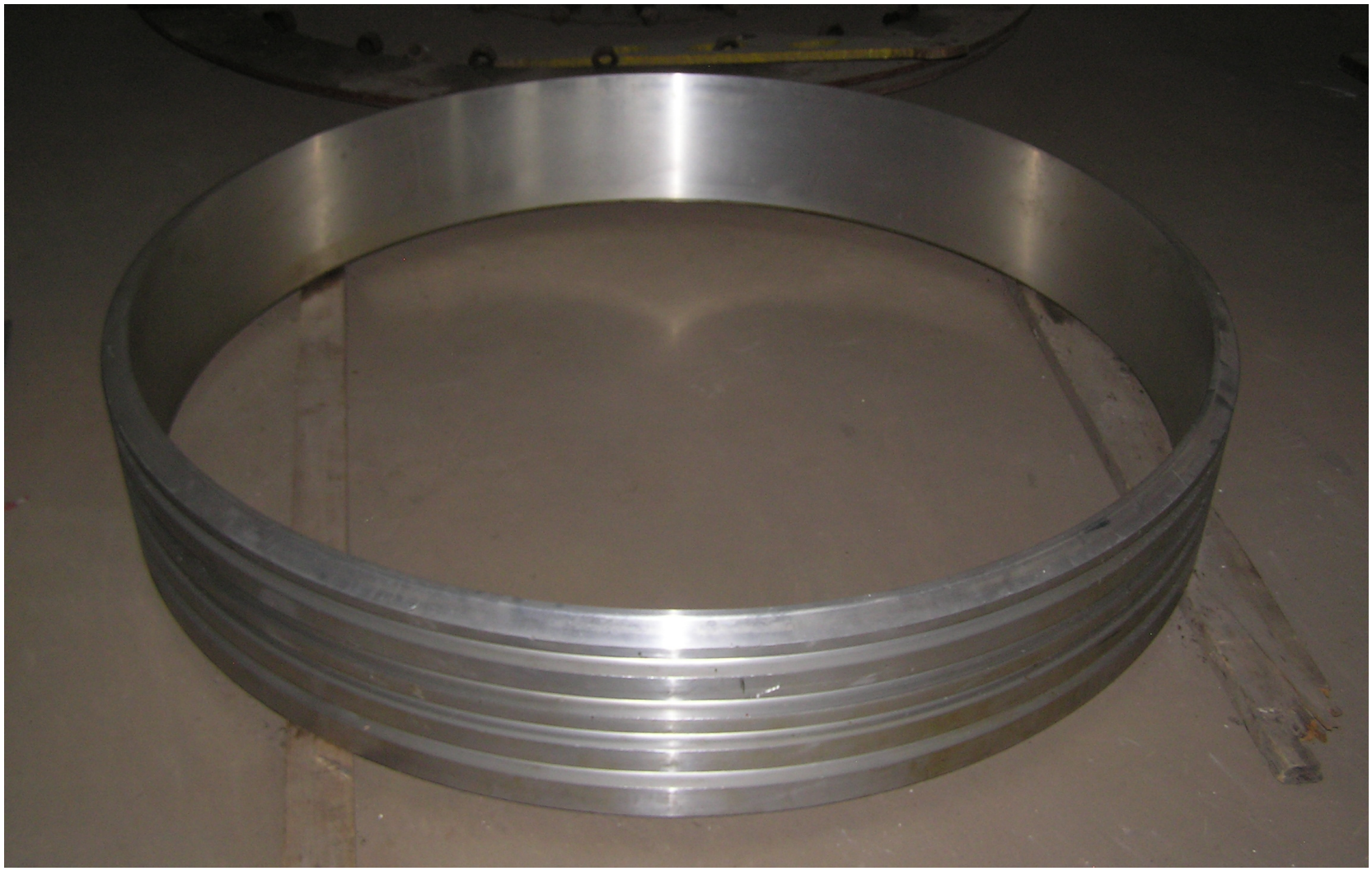
Cold Mass CAD Model





First Magnet Coil Winding

Completed Cold Mass Cover



Schedule to Complete

Task Description	CY 2010	CY 2011	CY 2012
MuCool Coupling Coil			
Cold mass fabrication and assembly			
Cryostat fabrication and final assembly			
Magnet testing and factory acceptance			
MICE Coupling Coil #1			
Cold mass fabrication and assembly			
Cryostat fabrication and final assembly			
Magnet testing and factory acceptance			
MICE Coupling Coil #2			
Cold mass fabrication and assembly			
Cryostat fabrication and final assembly			
Magnet testing and factory acceptance			

Project Manpower

- Project management at ICST
  - Fengyu Xu (ICST Project Engineer/Electrical Engineer)
- Engineering design at SINAP
  - Wang Li (SINAP Cryogenic Engineer, formerly ICST Deputy Director)
  - Prof. Lixin Yin and Yun Cao (SINAP Mechanical Engineers)
  - Design review scheduled at SINAP for September 13th
- Drawing verification at LBNL
  - Allan DeMello (LBNL Engineering Division – Mechanical Engineer)
  - Sisi Shan (LBNL Engineering Student Intern)
- Fabrication oversight
  - Fengyu Xu of ICST will spend a large portion of his time at the fabricator
  - The following MICE collaborators will participate in rotating visits to the QiHuan Company during fabrication (~once per month):
    - Steve Virostek, Derun Li, Allan DeMello, Nanyang Li (LBNL)
    - Wang Li (SINAP)
    - Consultants: M. Green (LBNL), K. Hosoyama (KEK), H. Chen, C. Yi (IHEP)
    - Periodic visits by other MICE collaborators

MICE Magnet Summary

- Spectrometer Solenoids
  - Recent testing/training of the magnets has uncovered some deficiencies in the design
  - Work is under way to develop plans to modify the design and reassemble the magnets
  - The 1st reassembled magnet is to be tested early 2011
- Coupling Coils
  - The design of the magnet cold mass is complete and fabrication is under way in China
  - Final cryostat design will be reviewed next month
  - The 1st magnet is expected to be ready in late 2011