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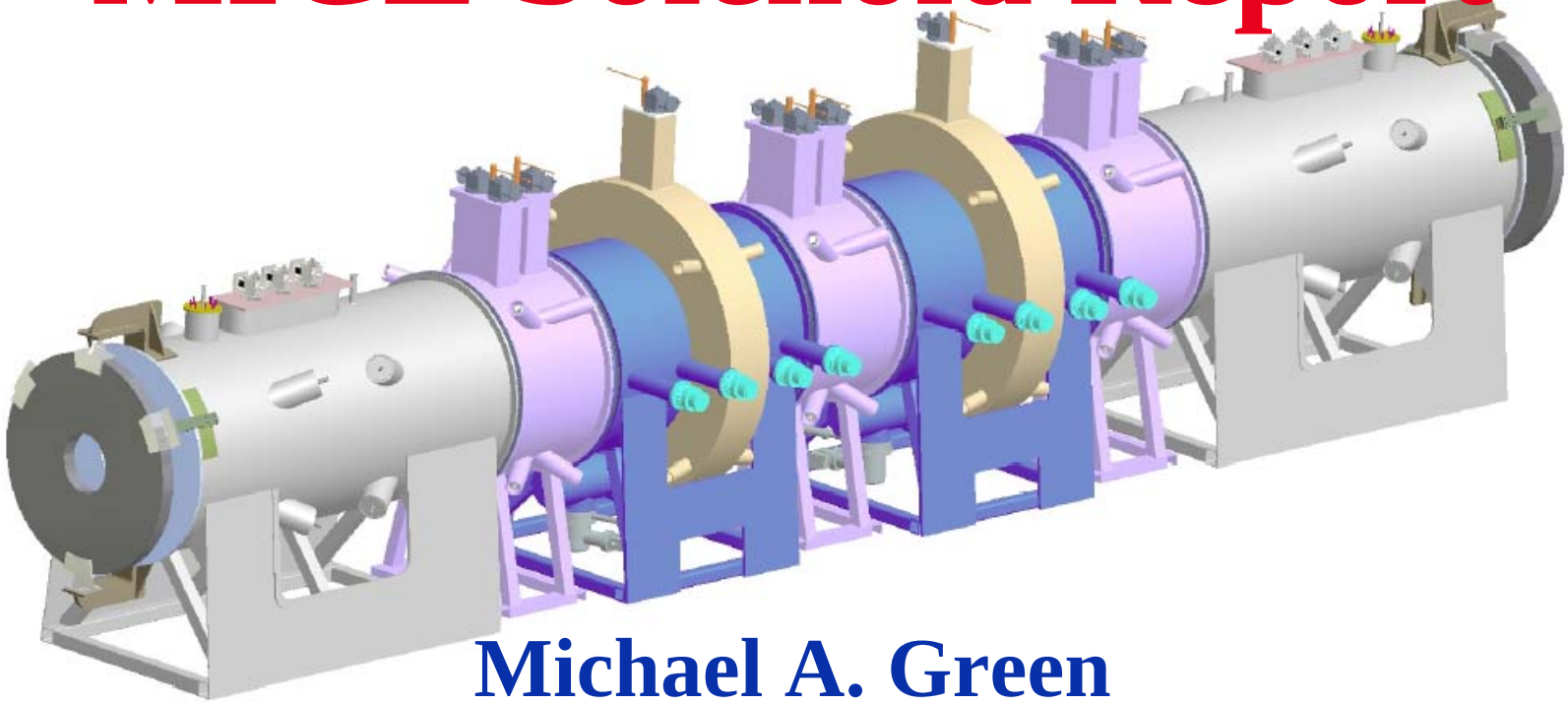
MICE Solenoid Report



Michael A. Green

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Eight Superconducting Solenoid Modules for MICE

The Pion Decay Solenoid in the Beam Line

- The pion decay solenoid is where the pions decay to muons

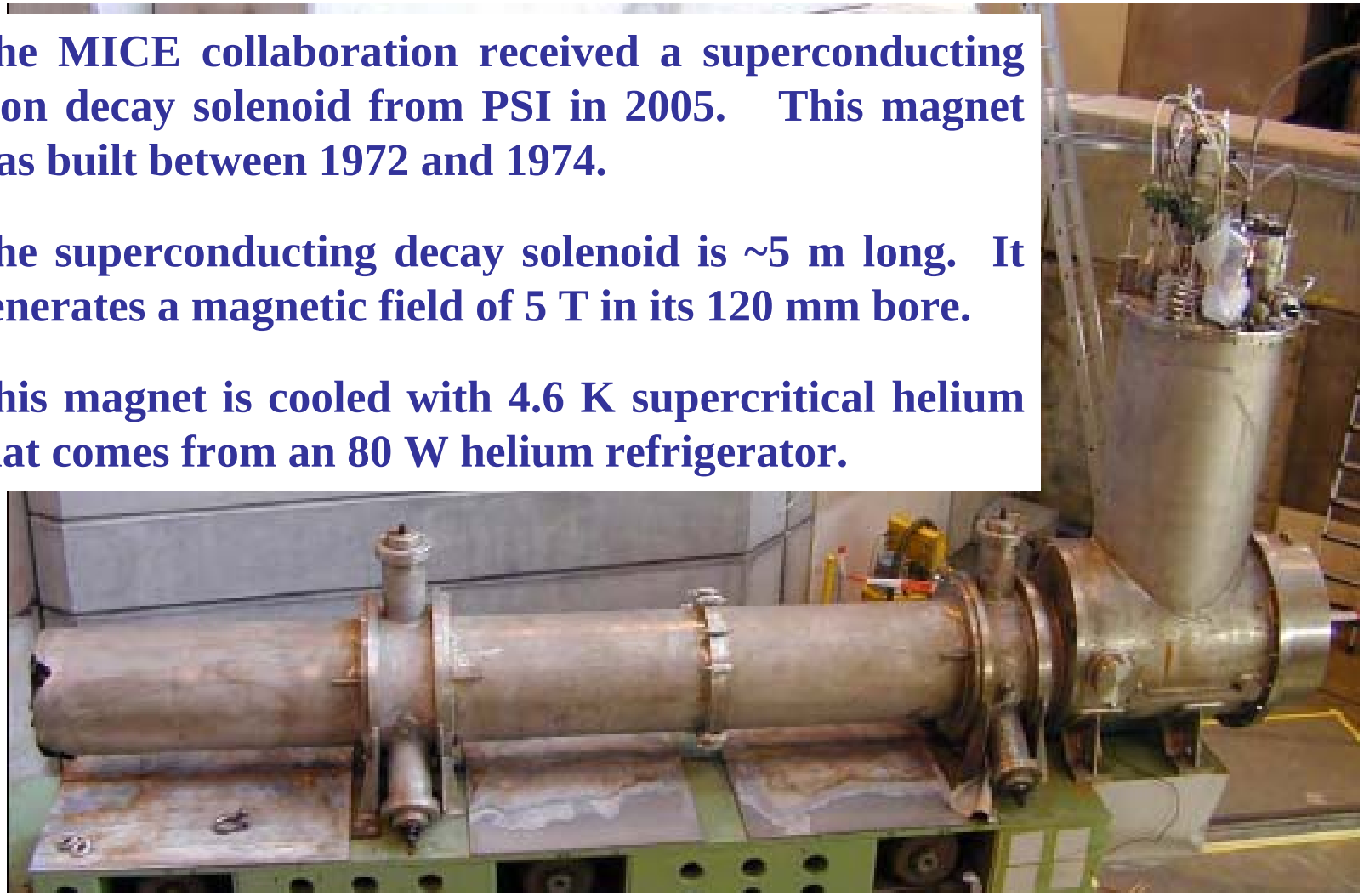
The MICE Cooling Channel

- Two Spectrometer Solenoids analyze and match the beam to/from the MICE cooling Channel
- Two Coupling Coil solenoids focus the beam between the three AFC modules, keeping the beam from hitting the RF cavity irises
- Three Focus Coil solenoids focus the beam at the solid or liquid absorber locations, where cooling takes place

The Pion Decay Solenoid

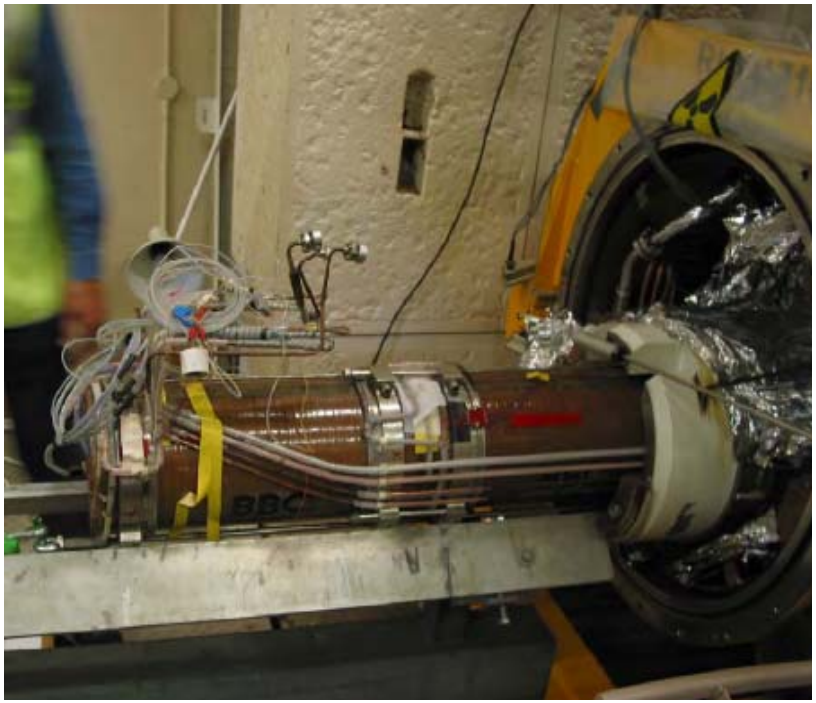
Pion Decay Solenoid for the Beam Line

- The MICE collaboration received a superconducting pion decay solenoid from PSI in 2005. This magnet was built between 1972 and 1974.
- The superconducting decay solenoid is ~5 m long. It generates a magnetic field of 5 T in its 120 mm bore.
- This magnet is cooled with 4.6 K supercritical helium that comes from an 80 W helium refrigerator.



The Pion Decay Solenoid at PSI

Decay Solenoid Progress

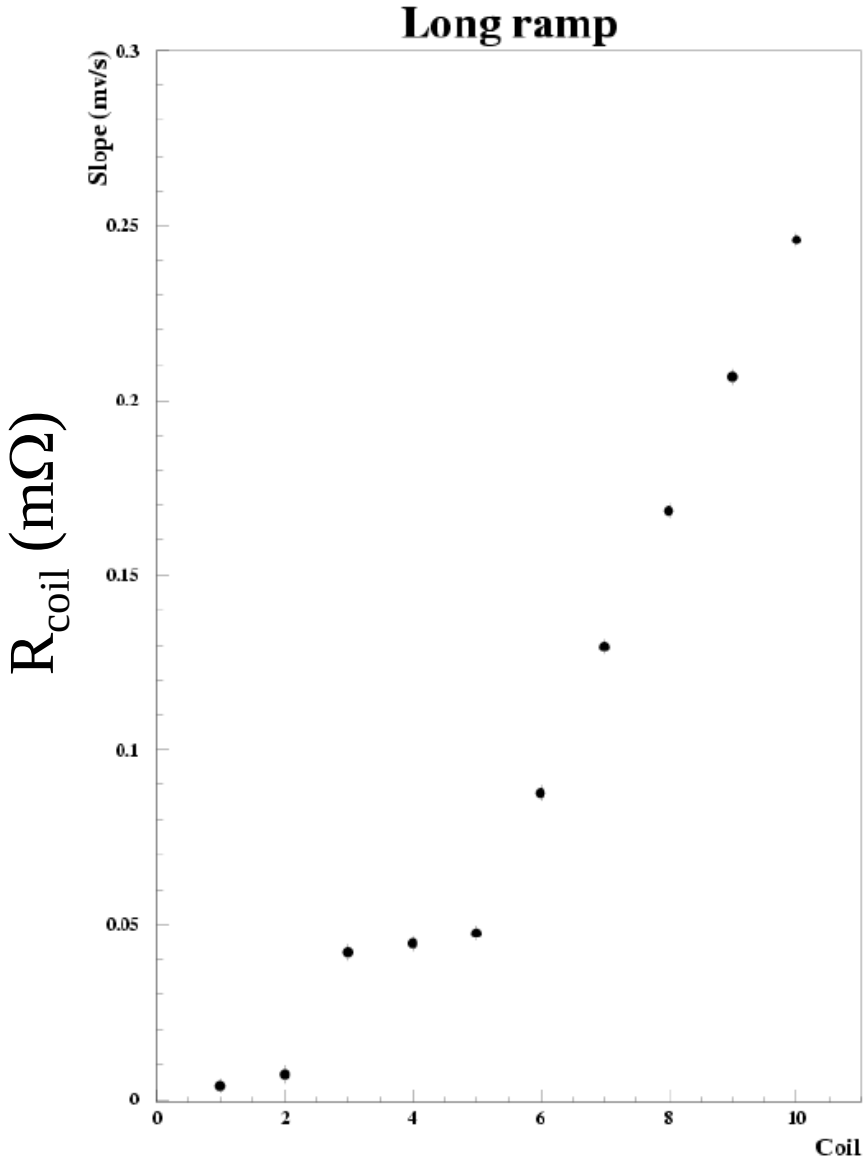


End Coil of the Decay Solenoid

- Making the Decay Solenoid operational is part of the UK contribution to MICE. This magnet will be the first operational superconducting magnet in MICE.
- Refrigerator was installed at RAL several years ago and is basically operational.
- Decay Solenoid has been installed for more than a year but is not yet operational. Much of the magnet is within the ISIS radiation shielding, which makes repairs difficult.
- The magnet has not yet reached its full design current. Excessive heat leaks into the magnet are believed to have prevented it from reaching full current (being fixed).

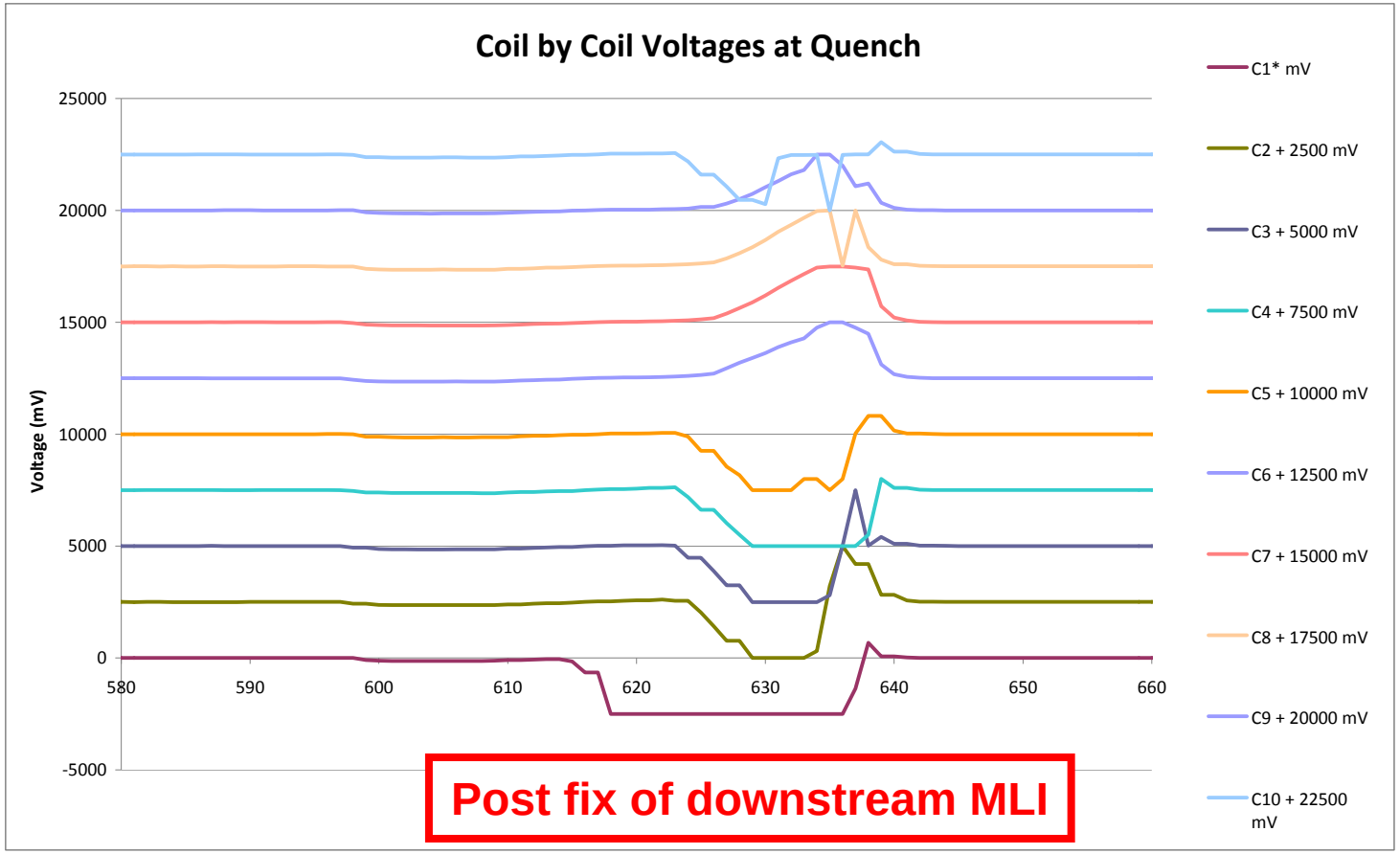
Decay Solenoid Diagnosis and Repair (1)

- Decay solenoid quenches:
  - Max stable current to date ~330 A
    - Nominal operating current is 720 A
    - 5 T current is 870 A
    - Maximum current is 1000 A
- Diagnostics indicated that coils increasingly ‘ohmic’ as you go from coil 6 to coil 10
  - consistent with heat leak at downstream end



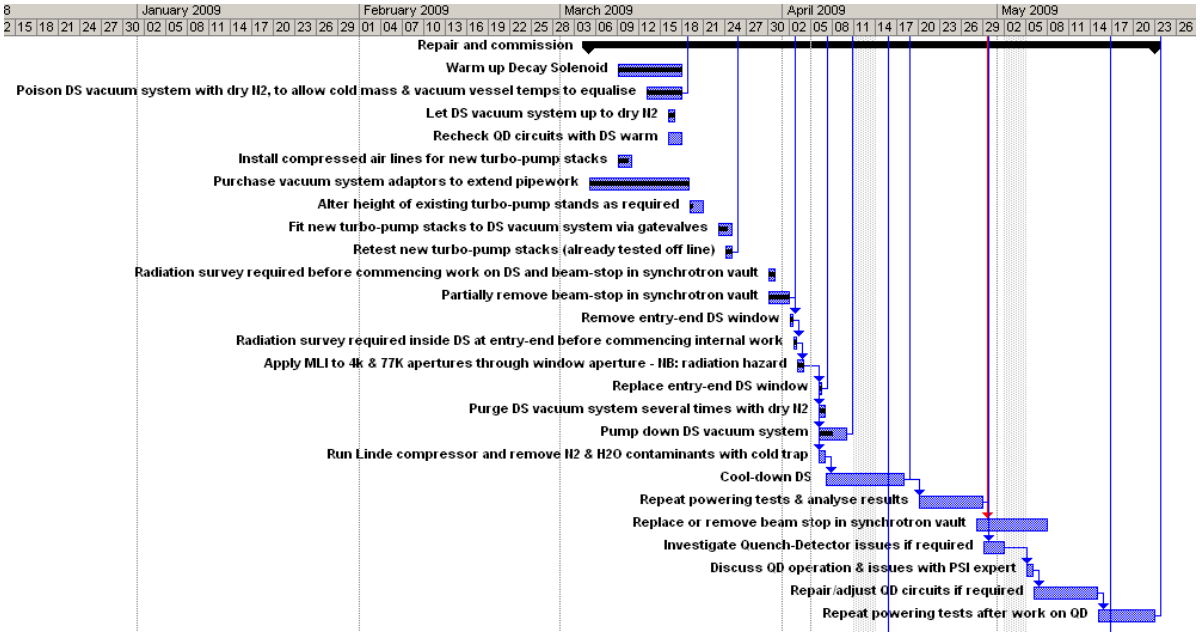
Decay Solenoid Diagnosis and Repair (2)

- Additional MLI fitted to downstream end:
  - Quench moved from coil 10 to coil 1 (as predicted by thermal model)

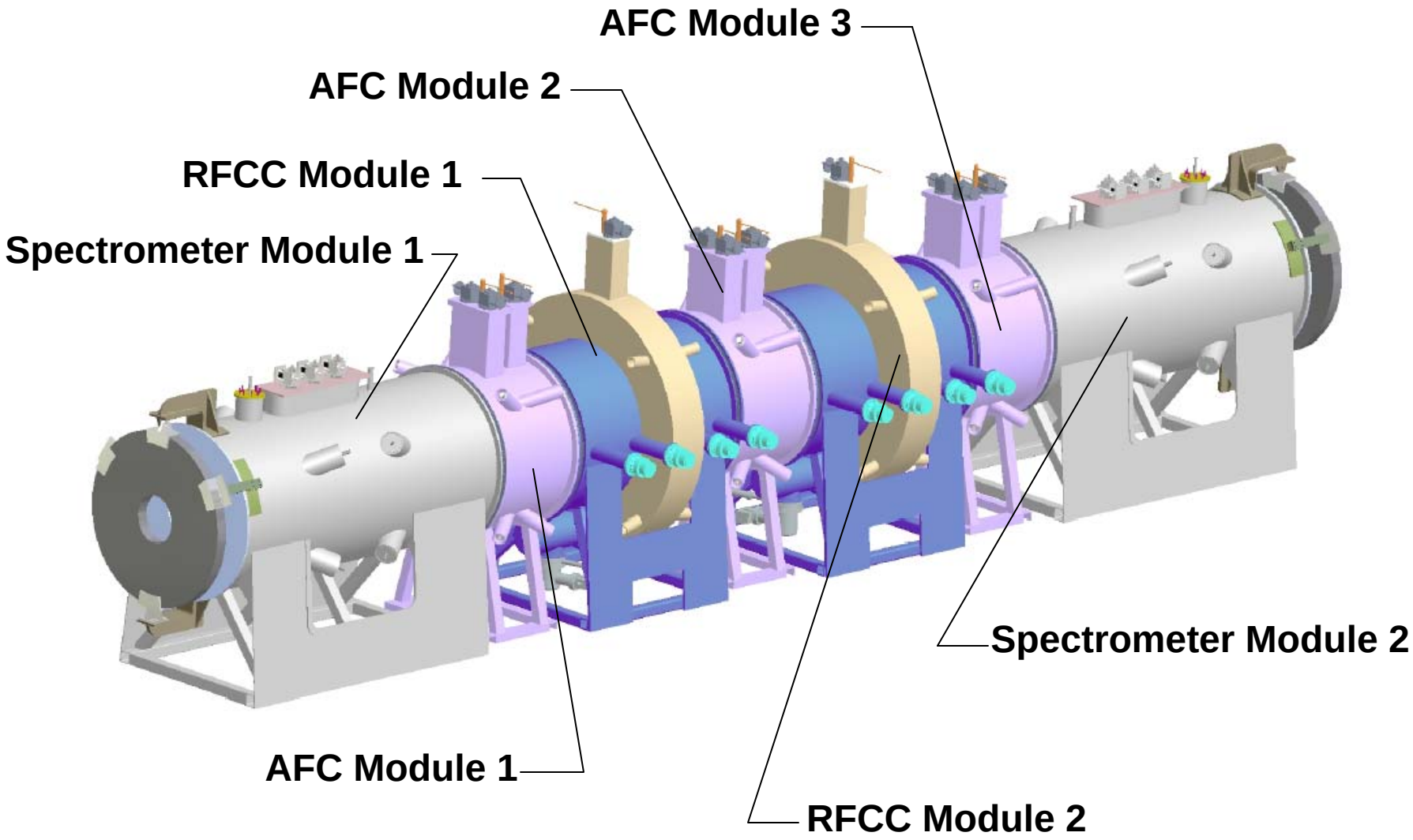


Decay Solenoid Diagnosis and Repair (3)

- Since ISIS shutdown last week, more repairs done
  - MLI added to upstream end of magnet (cold mass and thermal shield)
  - additional MLI added at downstream end
- Magnet pump-down started April 3
  - cool-down will start this week
- Magnet test plan is in place and being followed
  - optimistic that repairs will do the trick (test after Easter)
    - but cannot yet preclude possibility of additional thermal problems



MICE Channel with Spectrometer Magnets



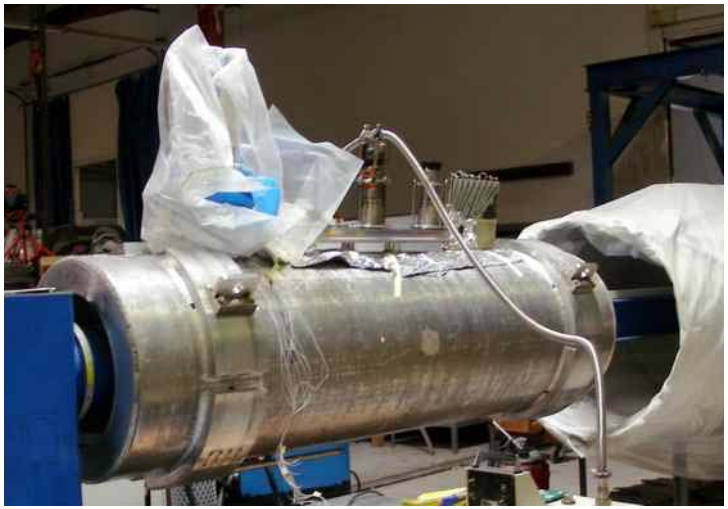
Drawing by S. Q. Yang

Spectrometer Solenoid Progress

Test of the 1st Spectrometer Magnet

- The first Spectrometer Solenoid was tested during the summer of 2008.
- The magnet cool-down took a long time. The shield could not be cooled until the magnet was cooled to 4 K.
- Once liquid helium was put into the magnet cryostat, the magnet was powered and reached two-thirds of its design current.
- We now believe that cooling wasn't delivered to the magnet from the coolers, because the LHe line was blocked with N_2 ice. Helium boil-off was ~7 L/hr. The shield temperature was also too high.

Assembly of 2nd Spectrometer Magnet



- 2nd Spectrometer Solenoid magnet modified to reflect the needed changes. Coolers now feed directly into LHe space, eliminating the possibility of being plugged with ice.
- The 80 K shield will be pre-cooled using a LN_2 reservoir. This will speed up the magnet cool-down.
- The thermal connection between the cooler 1st stage and the shield has been improved by a factor of ~20.
- Other changes have been made to reduce the heat leaks at 4 K.

Spectrometer Magnet April 2009

- The assembly of magnet two into its cryostat was within ±0.5 mm or 0.2 mrad. The cold mass position is mapped to fiducials on the outside of the vacuum vessel.
- Magnet stand was changed for both magnets to allow the magnet positions to be interchanged in MICE. The stand was improved to reduce the longitudinal deflection under loading and eliminate interference with magnetic shield.
- The 80 K thermal shield will be pre-cooled with liquid nitrogen in a tank attached directly to it. During normal operation, the liquid nitrogen freezes. The improved connection between the cooler first stage and the shield should reduce the shield and cold mass support intercept temperature by ~20 K.

Spectrometer Magnet April 2009 Cont.

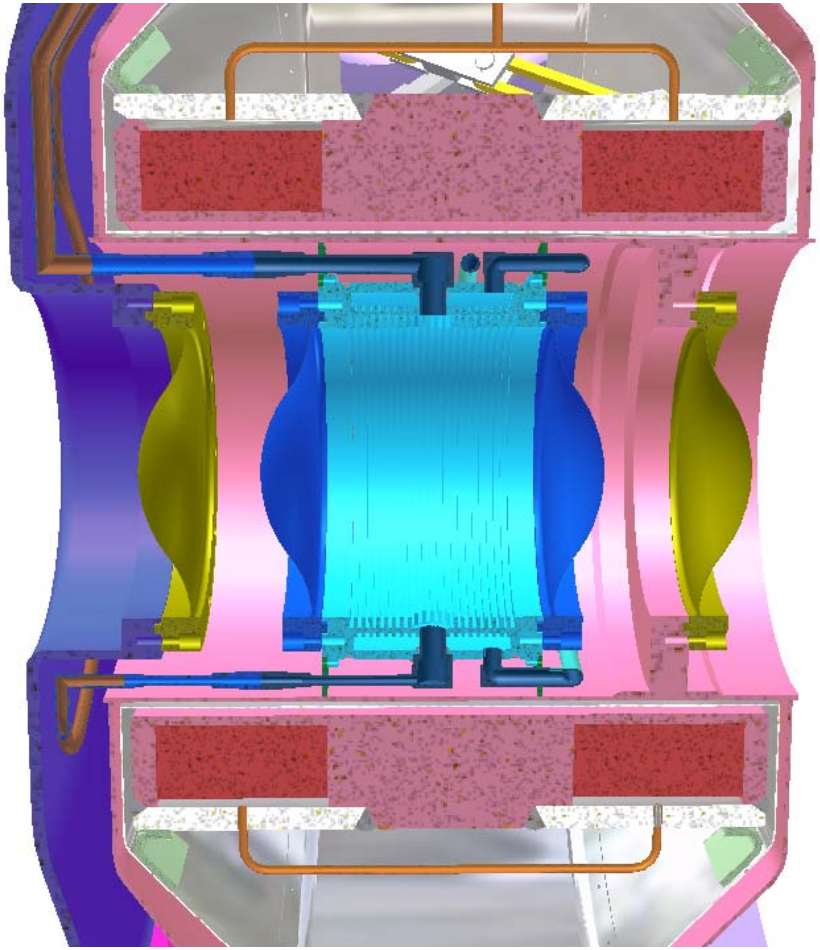
- **The changes that have been made to magnet 2 are expected to reduce the 4 K heat load to an acceptable level. The heat leak will be reduced by improved insulation and a lower temperature of the shield and cold mass intercepts.**
- **The condensate from the cooler condenser will drip into the magnet directly. Tests of a cooler in the cooler test facility showed that having the liquid helium drip into the helium tank is almost as effective as bringing the liquid into the bottom of the helium tank.**
- **Magnet 2 almost ready to test (this week or next).**
- **Magnet 1 is partially disassembled and is presently being modified in the same way as magnet 2.**

Focus Coil Solenoid Progress

Focusing Magnet Progress April 2009

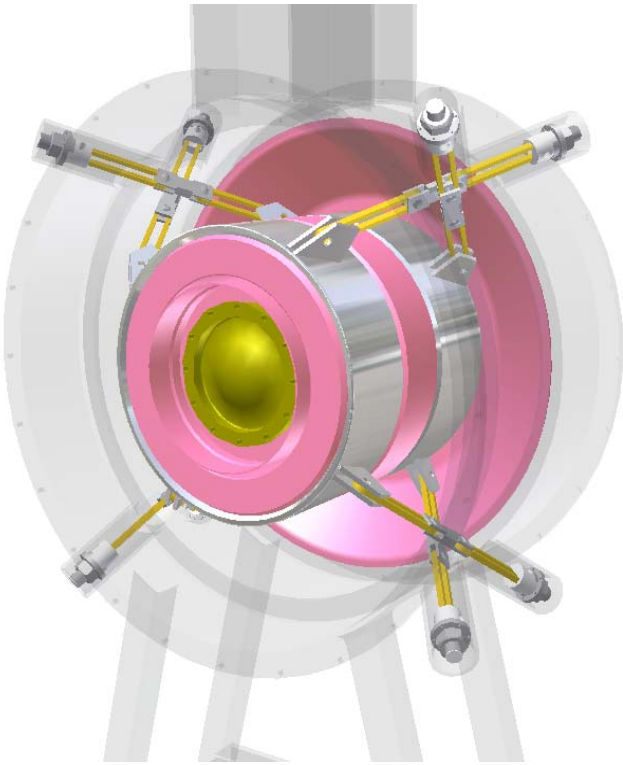
- **The contract to fabricate the AFC module was let to Tesla Ltd in the summer of 2008.**
- **MICE design review of AFC magnet was held in November 2008.**
  - **Design proposed by Tesla is close to the Oxford University/RAL design that evolved in 2004.**
    - **Changes included cooling the magnet using two-phase helium in tubes attached to the cold mass.**
  - **The quench protection system for the AFC magnet was finalized in March 2009.**

Focus Coil Magnet Cross Section

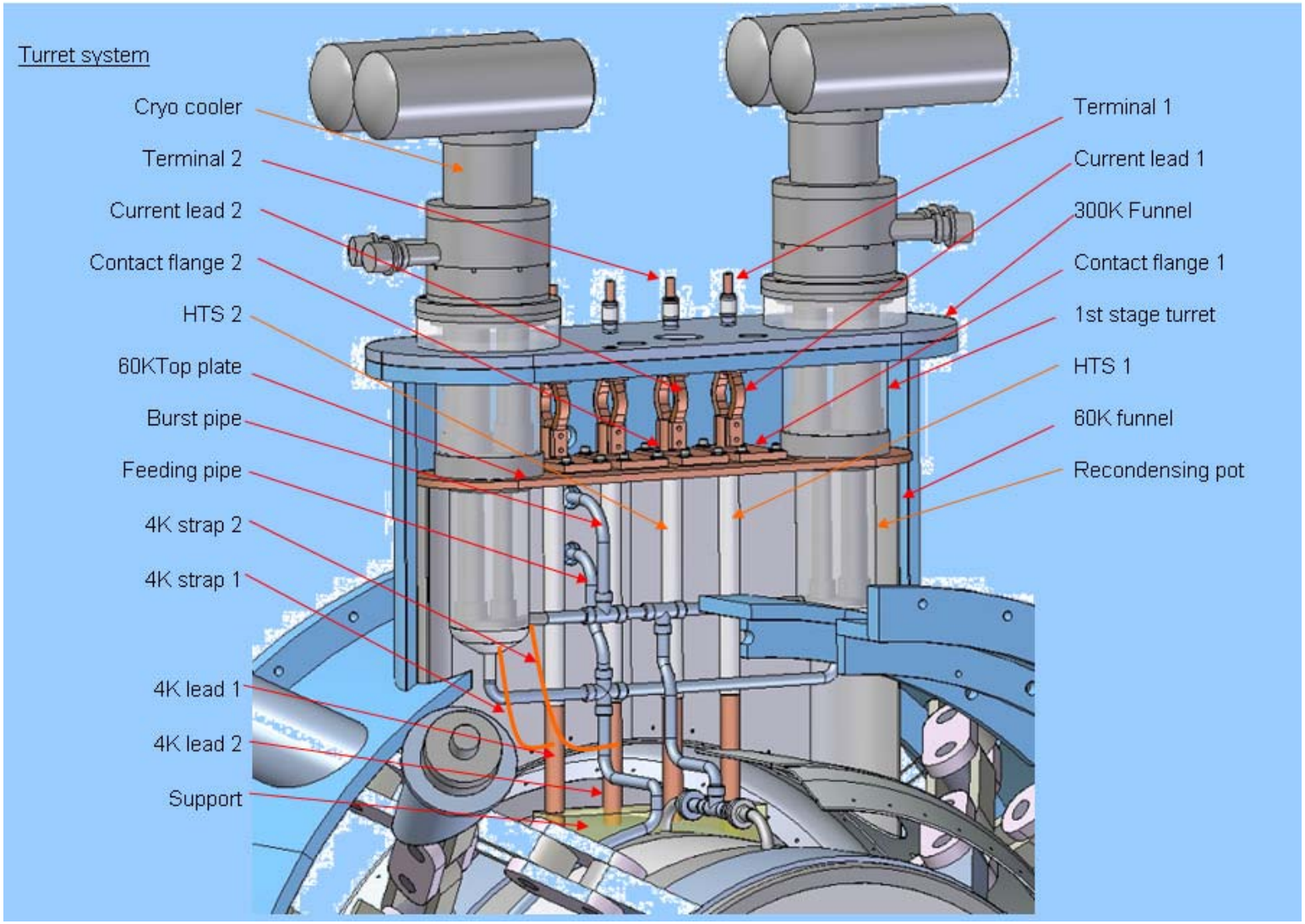


Magnet Coil and Absorber Cross-section

Drawings by S. Q. Yang



Focusing Magnet
Cold Mass Support



Turret System of the Focus Coil Magnet

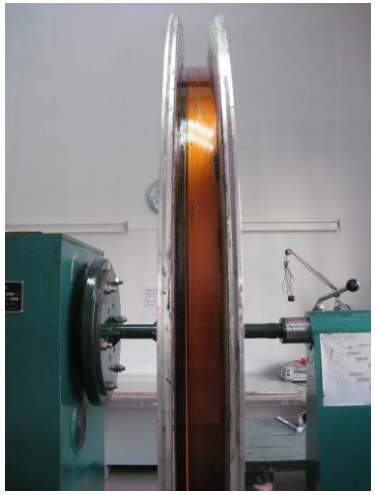
Coupling Solenoid Progress

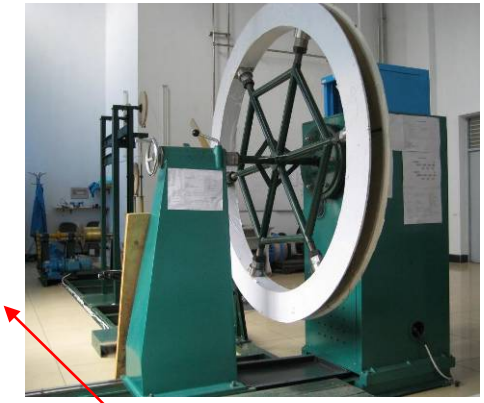
Coupling Magnet Progress April 2009

- **Two ICST test coils have been wound and welded. Both coils have been installed in their cryostat vessels. The large test coil test will occur in late April 2009. The small coil will then be tested, in particular to test the quench protection diodes in a magnetic field.**
- **The design of the coupling coils for MuCool and MICE was completed and reviewed in December 2008. Fabrication of the mandrels for the coupling coils has started.**
- **The coupling magnets will likely be fabricated by a Chinese company in Beijing. The split of work between the company and ICST is being negotiated. The winding of the first coupling coil will start as soon as the large test coil has been tested at its full current.**

The Coupling Magnet Large Test Coil

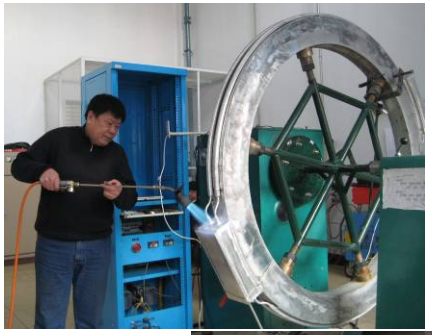
Winding of prototype coil

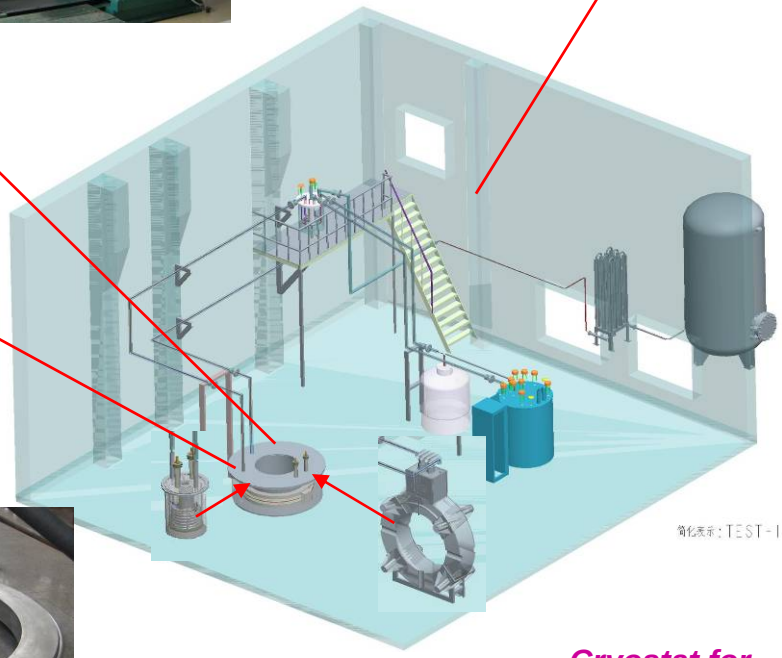




Cryo-test system

Welding





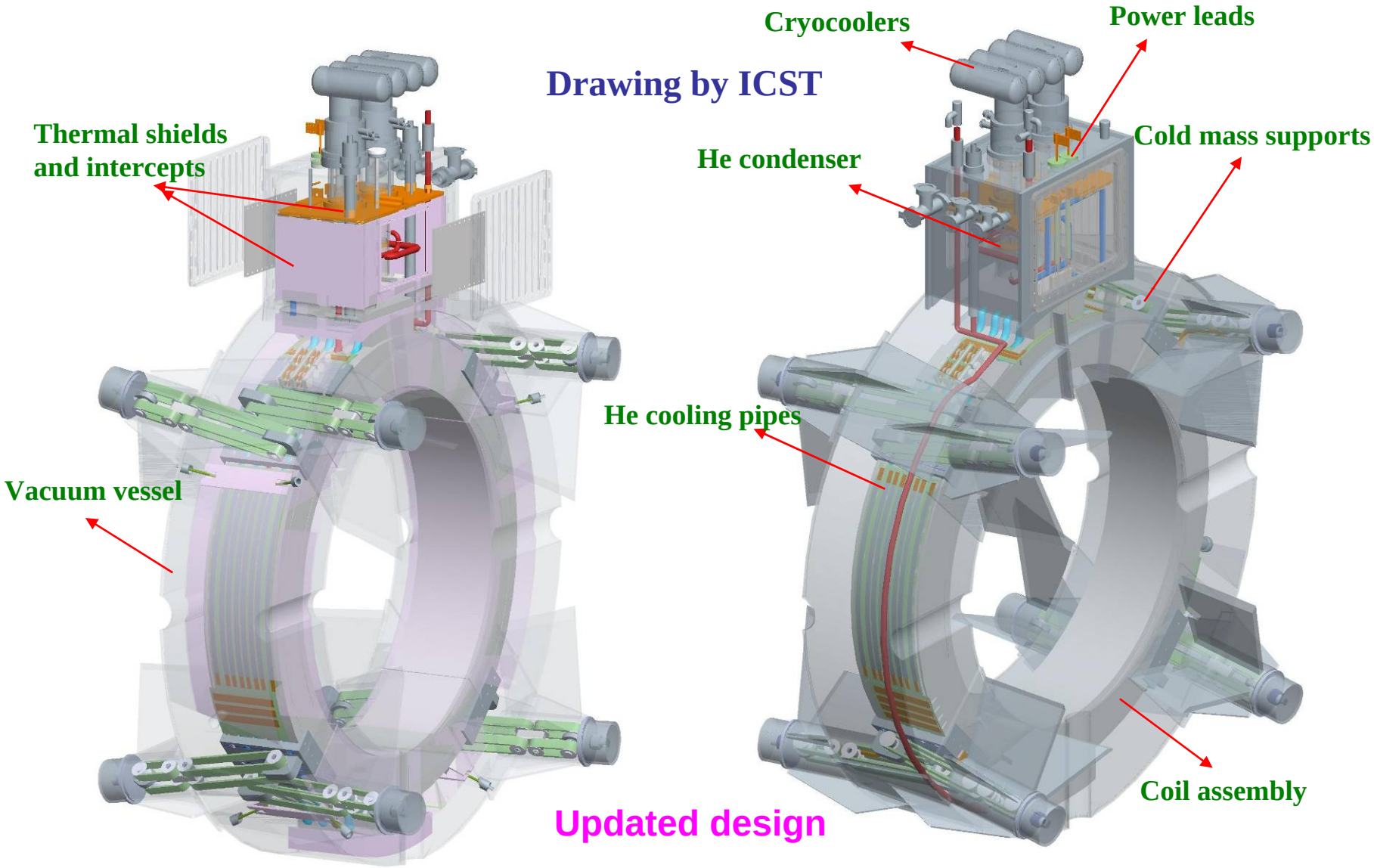
Large test coil

Cryostat for prototype coil

Coupling Magnet Design Changes

- **The magnet cover is thicker with two-phase He cooling tubes imbedded in it.**
  - **improves the magnet heat transfer and reduces the cool-down stress**
- **Thicker cover allows the cold mass support stresses to the cold mass itself to be handled more easily. More room for the quench protection diodes and resistors.**
- **Cold mass support changed from a single- to a double-band support. As a result, the stress within the cold mass support assembly is reduced.**
- **The vacuum vessel design has been changed to reduce stresses and deflections. Overall the magnet design is more robust.**

The Improved Coupling Magnet Design



Concluding Comments

- **Decay Solenoid is expected to be operational soon.**
- **Initial Spectrometer Solenoid will be tested this month. Thereafter, it will go to FNAL for mapping. Second solenoid will follow in about 3 months.**
- **Design of the Focus Coil solenoids has been finalized and fabrication of the first two (of 3) has begun.**
- **The Coupling Coil magnet design is completed and tooling is ready. Winding of the MuCool coil will start as soon as testing of the large test coil is completed and contract with industry is signed (expected this month).**
- **All magnets are now in production.**