Spectrometer Solenoid Update

MICE Collaboration Meeting #30
Oxford University

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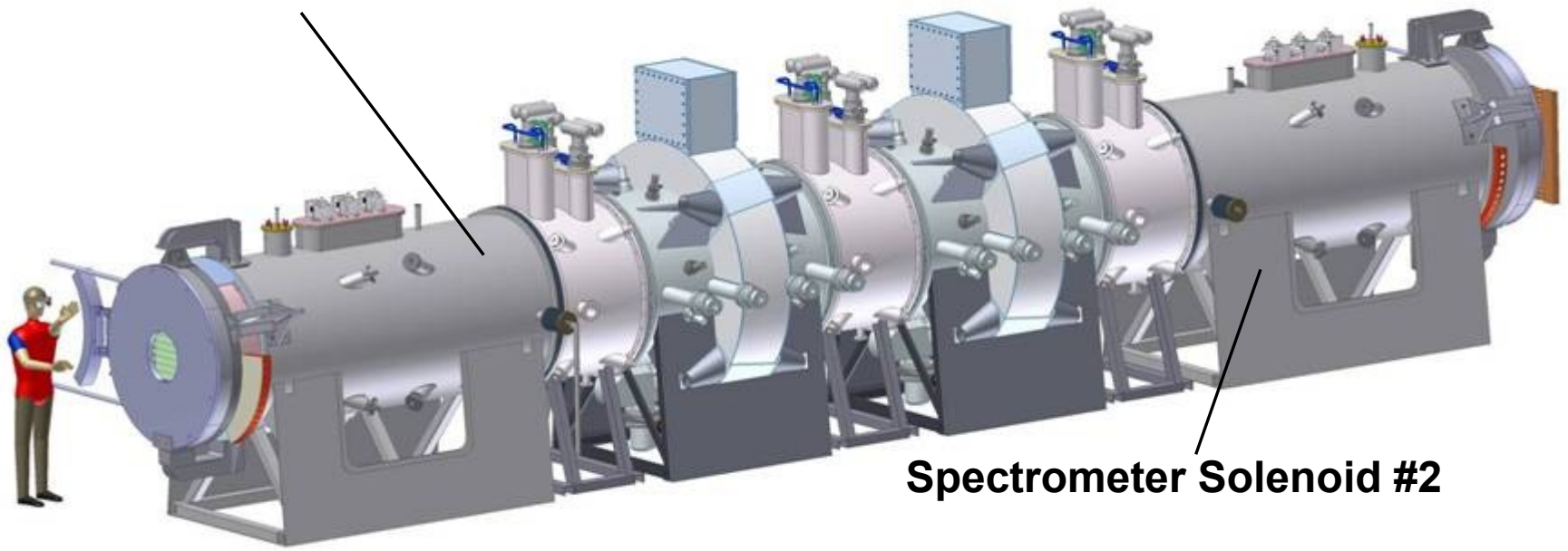
Topics

- Spectrometer Solenoid workshop at LBNL
- Design modifications
- Magnet quench analyses
- Quench resistor overheating
- Schedule, budget and manpower
- Current progress

MICE Cooling Channel Layout



Spectrometer Solenoid Workshop at LBNL

- A workshop was held at LBNL in early May to assess the current design of the magnet, to review the recent analyses and to evaluate the proposed design modifications
- The following personnel participated in person at the workshop:
  - RAL: Andy Nichols, Mike Courthold, Roy Preece
  - INFN: Pasquale Fabbricatore
  - FNAL: Alan Bross, Vladimir Kashikhin
  - MIT: Brad Smith, Joe Minervini, Alexey Radovinsky
  - SINAP: Wang Li
  - LBNL: Steve Gourlay, Mike Zisman, Steve Virostek, Derun Li, Heng Pan, Soren Prestemon, Allan DeMello, Tapio Niinikoski, John Joseph

Analysis and Design Assessment

- LBNL has completed a series of tasks prior to incorporating design changes
- The steps carried out are shown below:
  - All heat loads have been reassessed to ensure that the LHe in the cold mass can be maintained with the final number of cryocoolers
  - EM calculations have been redone for testing and operation
  - The instrumentation plan has been modified to allow confirmation of the thermal and EM calculations during testing
  - The mechanical supports of the magnet, leads, piping and other internal components have been reassessed
  - A complete set of the latest as-built drawings (w/current changes) has been compiled

Design Modification Plan

- A design modification plan has been developed by LBNL and includes the following:
  - reduction of heat leaks to the cold mass
  - the addition of more cryo cooling power
  - assessment of the suitability of the passive quench protection system
  - adding a scheme to address the quench resistor overheating
  - modification of the LTS leads to prevent burn-out
- The finalization of the plan is still pending the confirmation of the quench analysis results
- Mechanical modifications are moving forward

4.2K Heat Load Reduction

- Improved vacuum pumping and instrumentation will be implemented to ensure adequate cold mass insulation
- All 4K areas will be covered with actively cooled shield where possible – partially covered areas will be analyzed
- Baffles will be added to the vent lines to prevent direct radiation shine to 4.2K
- Possible thermal acoustic oscillations in vent lines will be addressed by monitoring with fast pressure gauges
- Application of MLI on cold mass bore will be improved
- Sensor wires will be optimized & w/proper heat sinking

Radiation Shield Improvements

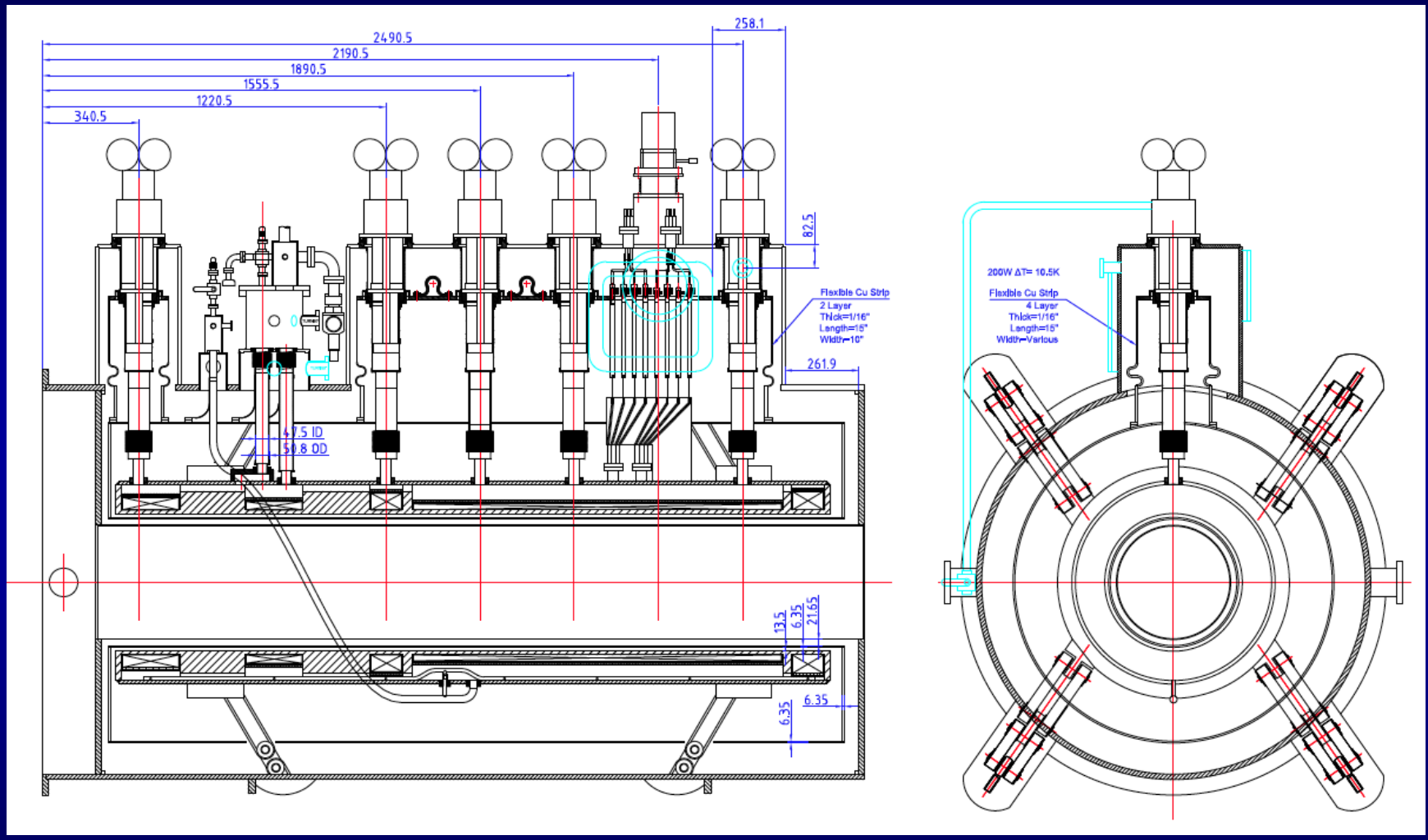
- The radiation shields will be remade using 6.35 mm thick 1100 series aluminum to replace the existing 6061 aluminum shields
- The thermal connection between the cooler first stage and the radiation shield will be improved by using sheets of copper rather than tubes of aluminum
- Reduced compression on shield bore tube MLI
- The following heat loads will be decreased as possible: cold mass supports shield pass-through holes, intermediate cold mass support heat intercepts, shielding of support warm ends
- Currently analyzing increased eddy current forces due to lower resistivity material

New Rolled Shields at Wang NMR

Other Design Modifications

- Other key improvements:
  - The total cooling power will be increased by using five 2-stage pulsed tube coolers and one single-stage cooler
  - The thermal/mechanical stabilities of the cold leads will be improved by adding extra copper/superconductor near the cold mass feedthroughs
- Other improvements/additions:
  - LBNL/MICE personnel will be present to document and oversee all aspects of magnet reassembly
  - Detailed MLI inspection will be carried out during ass'y
  - A fast DAQ system will continuously monitor voltage taps
  - Additional temperature sensors will be added to the logging system

5 + 1 Cryocooler Layout



Magnet 2B Cold Lead Repair

Instrumentation Plan

- The current configuration of the instrumentation on the spectrometer solenoid magnets has been revised
- The instrumentation under consideration includes temperature sensors, voltage taps, helium level gages, and pressure gages
- In most cases, the proposed changes to the instrumentation scheme came about due to shortcomings that were identified during the previous rounds of magnet training and testing
- Another prime consideration is the ability to record data relevant to the confirmation of our heat load analyses
- Feedthroughs have been reconfigured to separate the various types of instrumentation

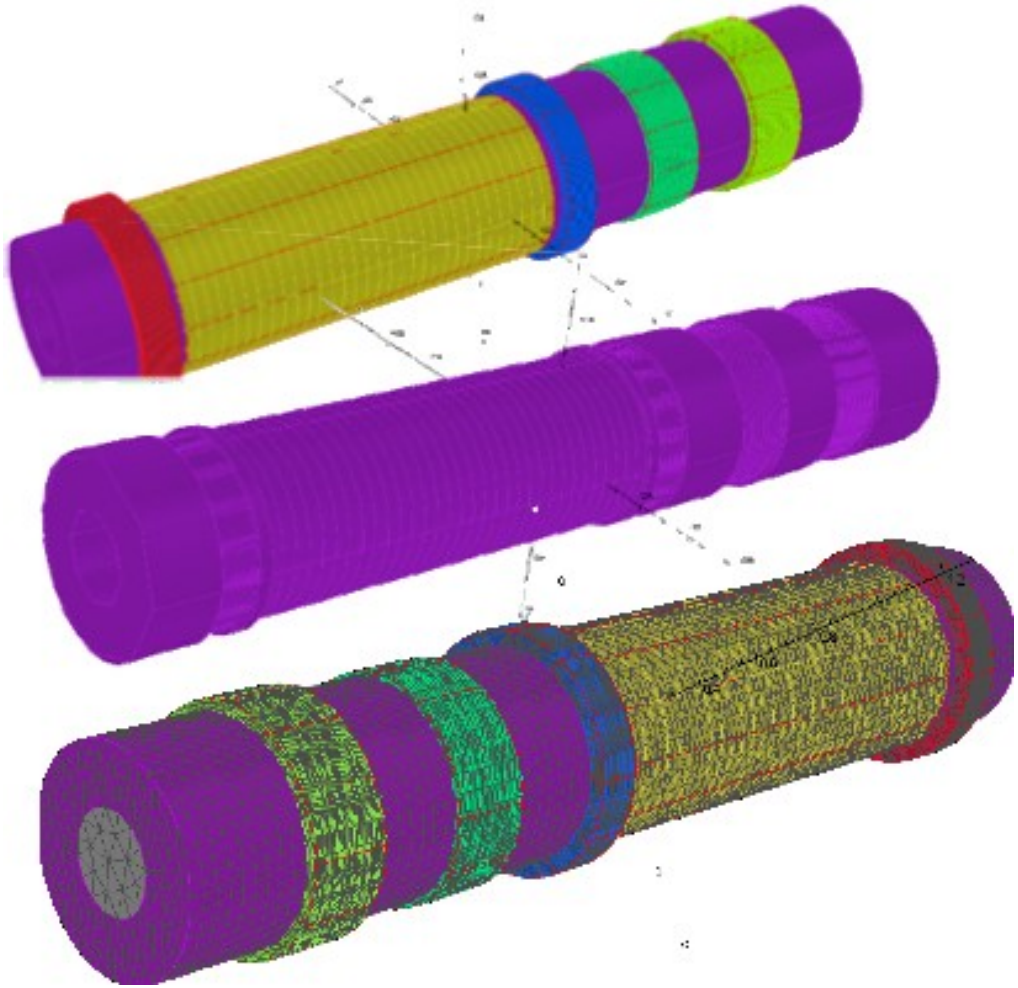
Fabrication Drawings

- Nearly 200 detail fabrication drawings representing the latest assembly of the Spectrometer Solenoid (Magnet 2B) collected from Wang NMR
- Drawings have been organized in the form of a drawing tree list
- The drawings are a fairly complete representation of the previously as-built magnet
- Wang NMR has completed the update of the fabrication drawings to reflect the latest design changes
- In parallel with the effort to organize the drawings, LBNL has developed a preliminary 3D CAD model of the magnets
- The CAD model will be updated to reflect the as-built magnets

Electromagnetic Assessment

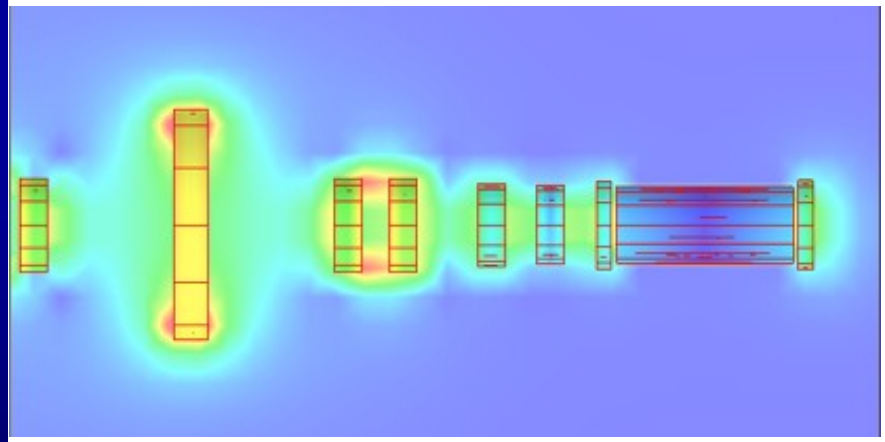
- The design of the passive magnet protection system has been reviewed and analyzed under the various operational regimes
- The areas covered include
  - calculation of the magnet self and mutual inductance parameters
  - determination of the coil current decay versus time during a quench
  - calculation of the hot spot temperature in the magnet for different scenarios
  - analysis of coil voltage versus time during a quench
- Overheating of the quench resistors has been analyzed and a cooling scheme has been devised and tested

Spectrometer Solenoid 3D EM Model



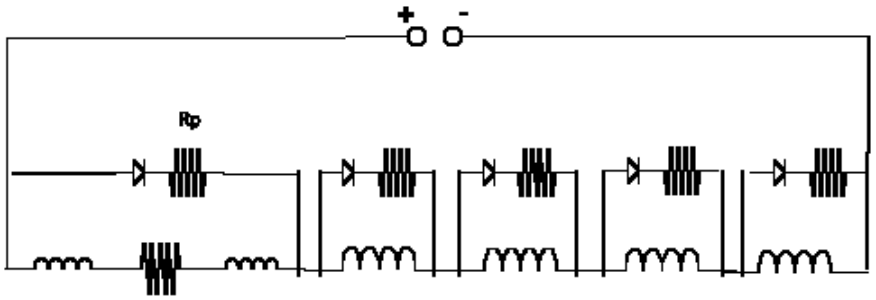
Quench Modeling

- VF quench code:
  - Allows simulation of…
    - Quenchback (e.g. from Al. mandrel)
    - Various circuit configurations
  - Provides access to…
    - Temperature and voltage evolution in time and space
    - Current distribution and decay

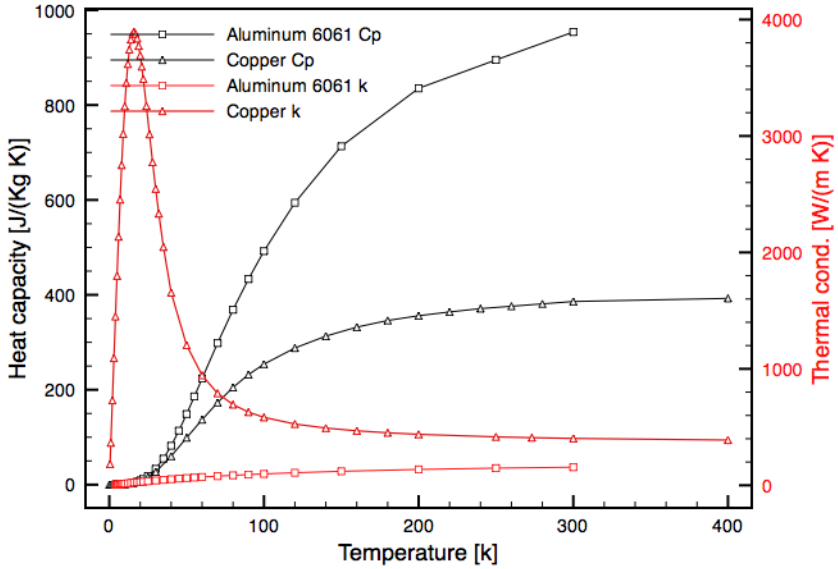


Distribution of field

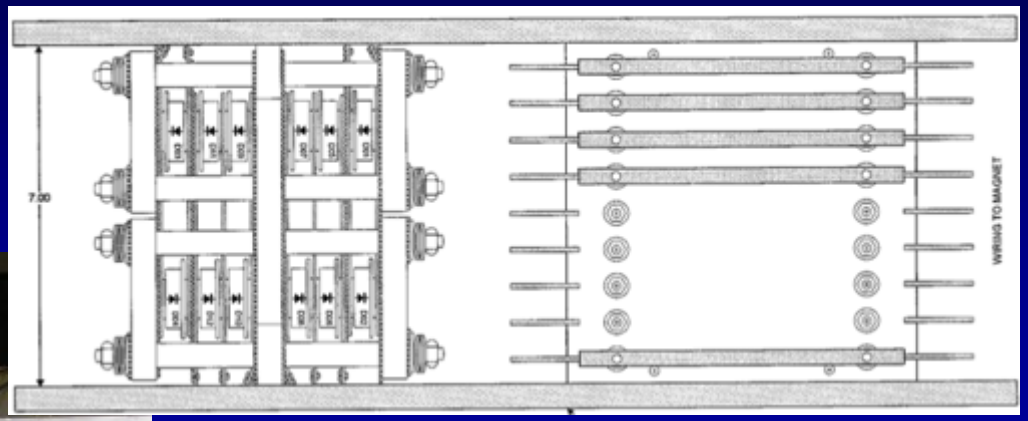
Example circuit of spectrometer test sim.

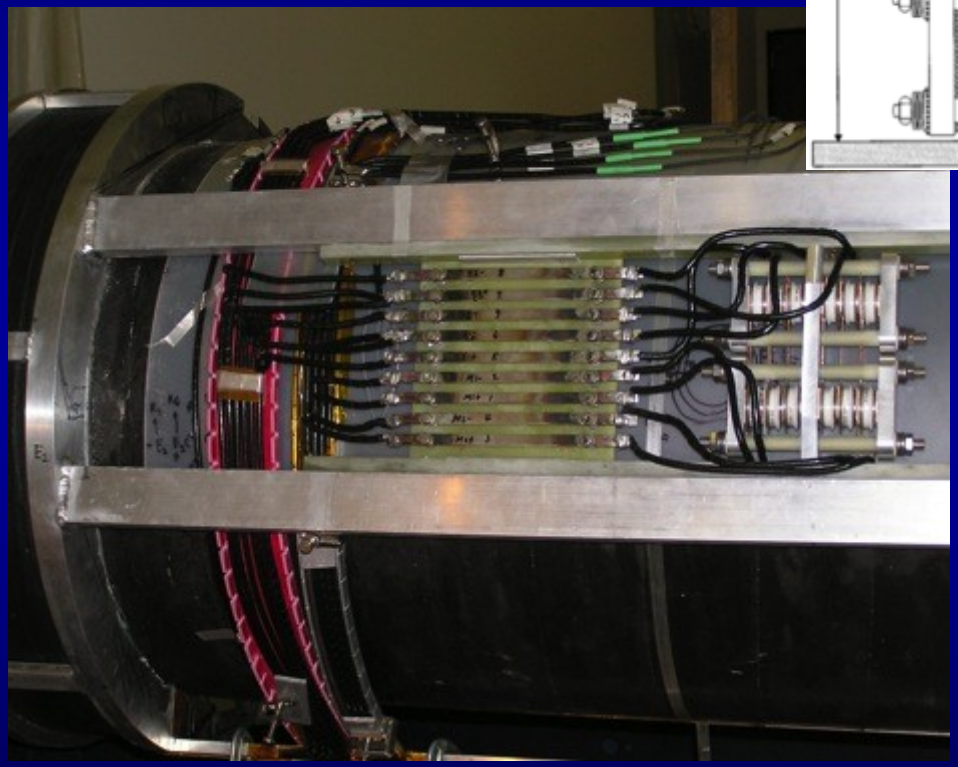


Quenching coil Superconducting coils



Internal Quench Protection Circuitry



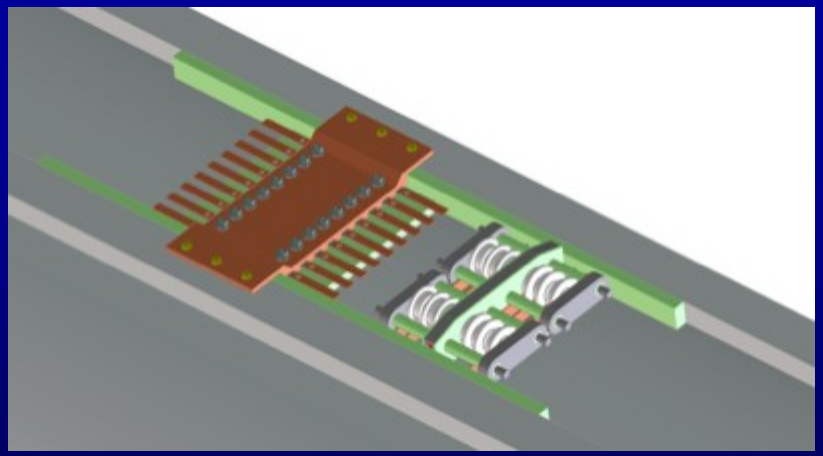


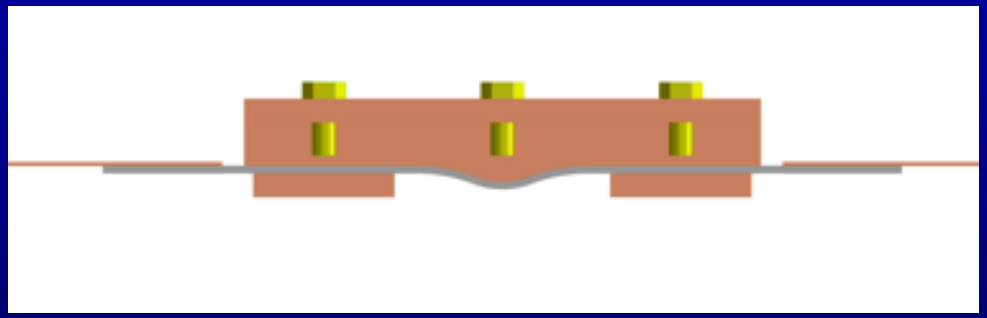
- Need to protect resistors from
  - Open circuit
  - Low-current quench

  => need to sink resistors
    - Preferably to mandrel nearby:
      - large heat capacity,
      - access all helium,
      - induce coil quenches

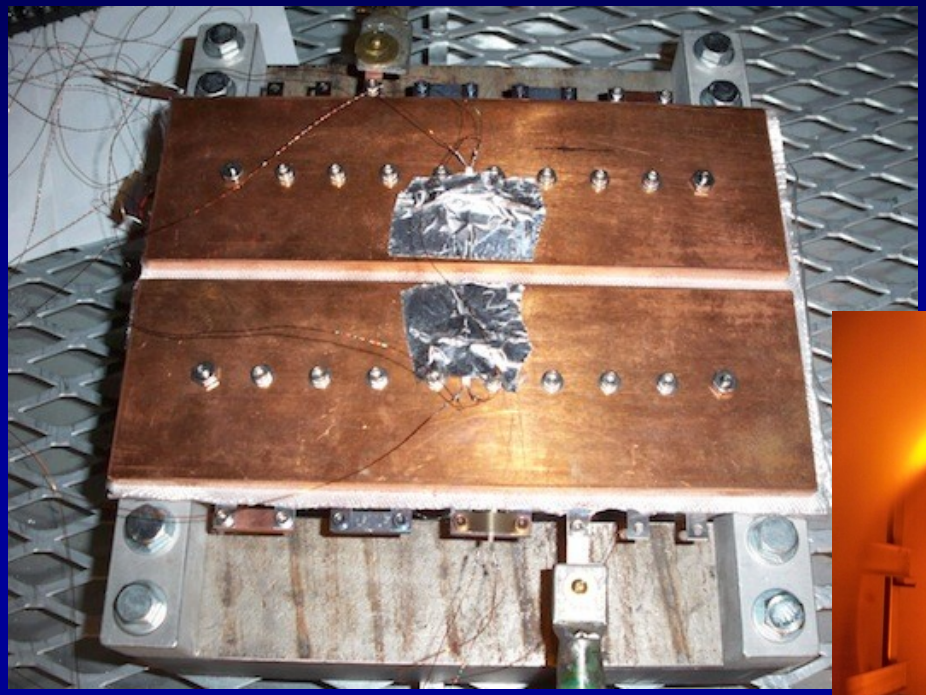
Resistor Cooling Scheme

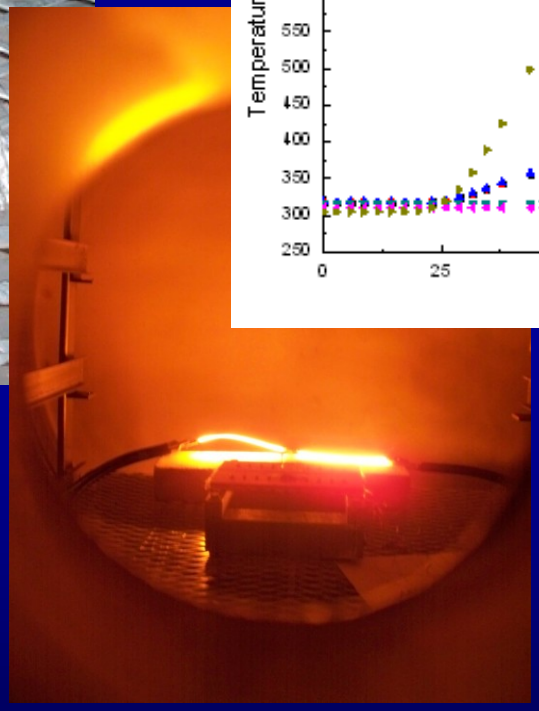
- The design provides a path for thermal transport from the resistors to the cold mass:
  - Simple design that minimizes risk to resistors
    - Avoids shorts and significant deformations while allowing resistors to flex
  - Capable of transferring ~2kW DC with dT=300K

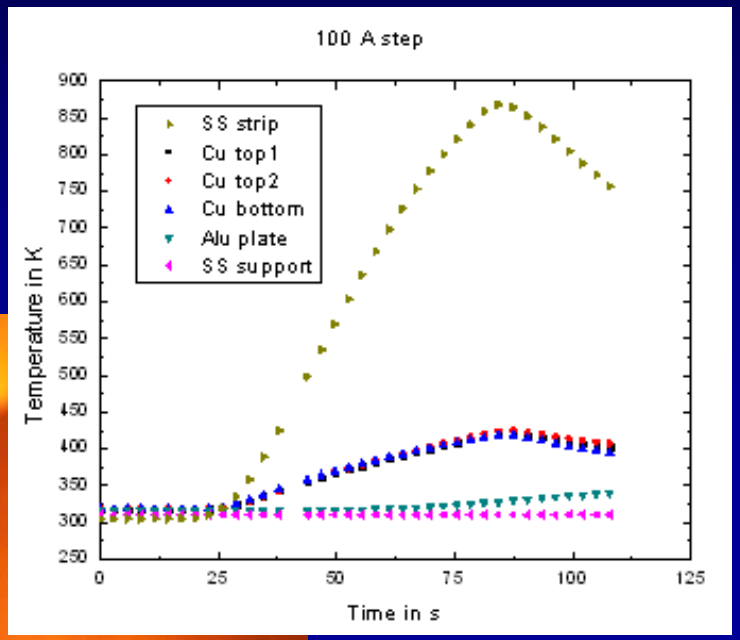




Resistor Cooling Test at LBNL







Overall Quench System Plan

- Finish test of bypass resistor cooling scheme (now complete)
  - Demonstrated reduction in peak temperature
  - Demonstrated no electrical shorts under cycling
- Implement resistor cooling scheme on spectrometer solenoids
- Finalize all 3D simulations with detailed engineering note
  - Find sources of the few remaining discrepancies between the different quench models
- Implement strict controls:
  - Temperature limits on HTS leads
  - Automate PS shut-off based on quench voltage signals
- Give serious consideration to adding active protection
  - Weigh pros and cons – evaluate risks

Schedule, Budget and Manpower

- A detailed straw man schedule has been assembled based on LBNL experience that provides a compilation of the tasks with an estimate of the required durations
- A resource loaded schedule is being developed in conjunction with Wang NMR – 1st magnet to be tested by the end of 2011
- An estimate of the remaining costs to MAP to complete the Spectrometer Solenoids has been compiled, including both manpower and hardware
- Contingency was estimated to account for uncertainties, including the possible need for active quench protection
- Required manpower has been identified and is available

Manpower

The following individuals are part of the Spectrometer Solenoid team:

Steve Gourlay – LBNL AFRD Division Director
- LBNL technical contact for Spectrometer Solenoid and Coupling Coil magnets
- oversight of the LBNL Spectrometer Solenoid team
- contact for the DOE Office of High Energy Physics

Steve Virostek - Sr. Mechanical Engineer
- overall project management
- some oversight of magnet assembly and training
- documentation

Tapio Niinikoski - Sr. Cryogenic Engineer
- CERN retiree, hired 1/2 time by LBNL
- magnet design analysis and modification
- some oversight of magnet assembly and training
- magnet training oversight

Dennis Calais - Cryogenic Technician
- on site at Wang NMR during assembly
- Mainly working on instrumentation and cryocoolers

Roy Preece - Mechanical Engineer (RAL)
- oversight of magnet assembly
- magnet training oversight
- integration and documentation

Nanyang Li - Mechanical Engineer
- oversight of magnet assembly
- magnet training oversight
- documentation

Soren Prestemon - Cryogenic Engineer
- magnet design analysis
- design modification recommendations
- occasional oversight of magnet assy

Heng Pan - Cryogenic Postdoc
- quench analysis
- radiation shield eddy current and force analysis

Latest Magnet Progress

- A PO change order was issued to Wang NMR to complete the layout and detailed design of the modified magnet mechanical design – this work has been completed and a small review held at Wang NMR
- The 5+1 cooler layout has been completed
- Both radiation shields will be remade from scratch using 6.35 mm thick 1100 series aluminum (material rec'd and rolling is complete)
- The cold mass vent lines are being enlarged and radiation light baffles are being added
- The magnet instrumentation plan and feedthrough layout have been updated and sensors and feedthroughs have been ordered
- A second change to the PO for actual modifications to be placed soon
- The final modification plans still have to be presented to MAP and the MICE Tech Board