Fermilab's MCTF Magnet Development Program

Michael Lamm

Goals of FNAL MCTF Magnet Effort

- **Support specific magnet projects for Local Cooling Demonstration**
  - Helical Muon Channels and Matching Sections*
- **Longer Term Magnet R&D**
  - 50 T Solenoid*
  - Next generation Helical Solenoid (future Muons Inc SBIR)
  - Collider and IR magnets? (not discussed here)
- **Provide Coordination for Muon Magnet Program for Fermilab Muon Experiments**
  - Interface with AP and Detector groups
  - Coordinate activities with other magnet laboratories (BNL, LBNL, NHMFL, Muons Inc.)

***Called out in MCTF charge and primary R&D focus**

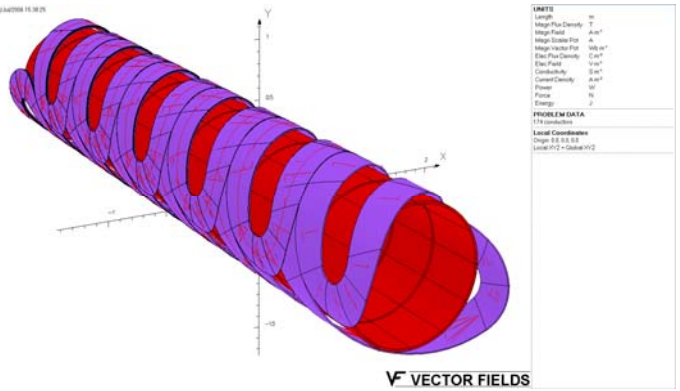
Helical Cooling Channel

- Cooling Channels proposed by Muons Inc for MANX experiment
- Solenoid, with superimposed helical quad/dipole filled with low Z material can reduce emittance in 6D
- Recent work by Vl. And Va. Kashikhin+ K. Yonehara present two practical designs for MANX muon cooling demonstration.
- SBIR have been submitted to carry this program to cooling channels suitable for full scale muon collider

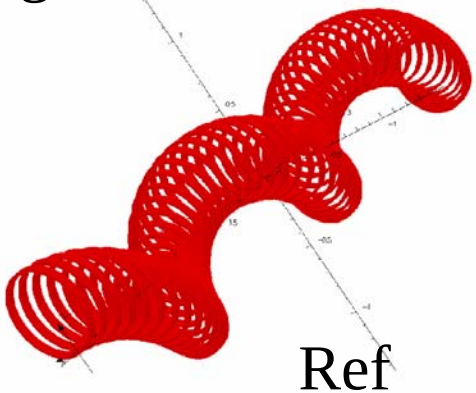
Competing Designs

Each Design requires the bore field to decrease along solenoid axis to compensate for decrease in momentum due to dE/dx loss

- **Large Bore**
  - Solenoid with helical dipole and quadrupole windings superimposed
- **Small**
  - 73- ½ diameter thin solenoids, offset transversely. Dipole and quad fields are a consequence of offset, coil diameter and helical periodicity



Large Bore



Small Bore

Ref

ASC paper

Criterion for selecting Cooling channel design.

- **Heavily dependent on (un)certainty about the design of the machine**
  - **Type "A" is harder to build, more expensive, but easier to adapt once built**
- **Conceptual design work on matching sections**
- **Resource loaded schedule for magnet system including cryostat design, quench protection, etc. to estimate labor/M&S for each design**

Engineering Design Tasks in FY07

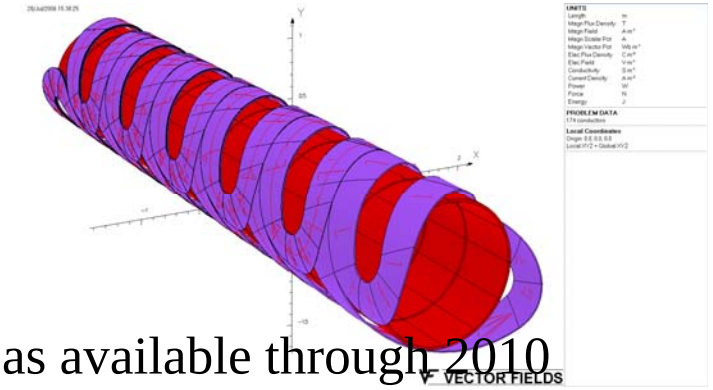
- Mechanical Designs for coils structure (helical option)
  - **5cm multiturn stack of hardway bend NbTi cable, potted?**
  - **Shrink cylinder for radial forces**
- Electrical design- linear longitudinal decrease in field accomplished by:
  - **Separate PS**
  - **Nested PS**
  - **Coil density**
- Quench Protection
  - **Dependent on coil powering**

How this is accomplished in FY07

- Yonehara/Kashikhin/Kashikhin continue to validate two designs + matching section
- Practical details of how this magnet would be designed. (ie. Cable vs strands, mechanical support, alignment, cryostat)
  - **Additional 0.5 FTE of existing staff**
  - **Hire engineer as soon as possible to assist staff**
  - **Contract designer**
- Work with T&I Dept. to develop testing plans
  - **Single coil or coils in-line can be tested in Magnet dewar**
  - **Future multi coil test with offset requires separate cryostat**
    - **Not possible for FY07**
- Purchase materials for engineering model towards end of fiscal year
- Estimated cost in FY07: $160K M&S, $250k SWF

Outline for Production Helical Solenoid

- **FY06**
  - Tracking studies
  - Two designs under consideration
- **FY07**
  - Complete Conceptual Design/Design Comparison/Design Decision
  - Build “engineering model”
  - Design and Prototype plan presented in Sept 2007 report
- **FY08**
  - Complete Engineering Design
  - Bids placed, prototype built in Industry
  - Test in IB1 (in sections)
  - Preproduction Review
- **FY09**
  - Production Magnets order placed
  - Installation in Muon Cooling Experiment as available through 2010



50 T Solenoid

- **Proposed for end of cooling channel for final emittances**
- **~50 T DC, 30 cm aperture, 4 m lengths**
- **Superconducting for manageable power reqs**
  - HTS or HTS/Nb3Sn/NbTi hybrid
- **Beyond present capabilities (has never been attempted)**
  - Proposals to built 25-30 T HTS solenoids
  - Conceptual design studies performed with Muons Inc. in collaboration with BNL.

Interest in HTS materials for high field applications

- NHMFL developing HTS inserts, plans for 15-20T solenoids
- Design work Muons Inc. with Palmer/Gupta at BNL on going
- Muons Inc has pending SBIR's on HTS application to magnet design
- Fermilab, BNL and LBNL experience on conductor and small coils
- Input from others on various aspects of design

Fermilab 2007 Effort on 50 T R&D

- **Evaluation of HTS Materials**
  - Bi 2212 wires/cable
  - We have requested samples of Bi and YBCO tapes from conductor vendors
- **Mechanical/electrical probe design and construction**
  - Tensile strain
  - Field orientations
- **HTS coil insert designs**
  - 1-5 T insert(s) suitable for SC R&D lab 16 T or 17 T Teslatron
- **Investigate possible collaborations/cooperations with NHMFL, BNL, Muons Inc….to develop long term strategy**

FNAL Superconductor R&D

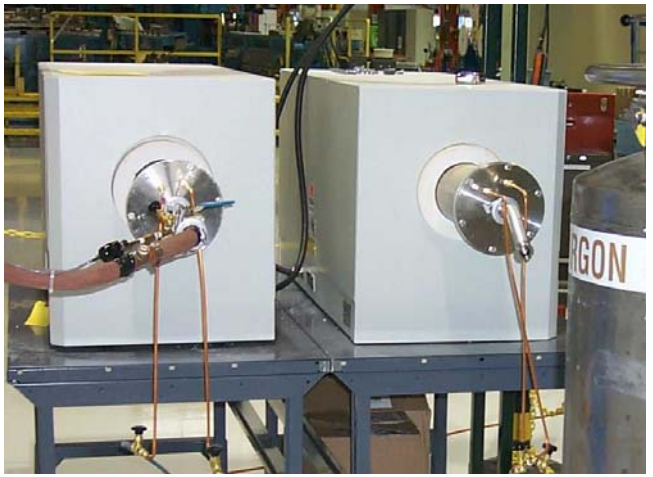
15/17T Teslatron

64 mm bore

14/16T Teslatron

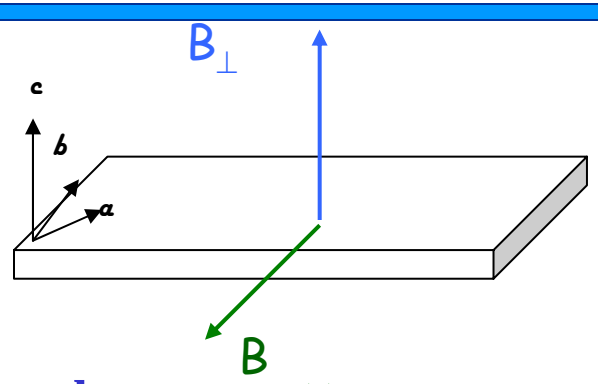
77 mm bore

Two 1100°C tube furnaces plus a third under repair

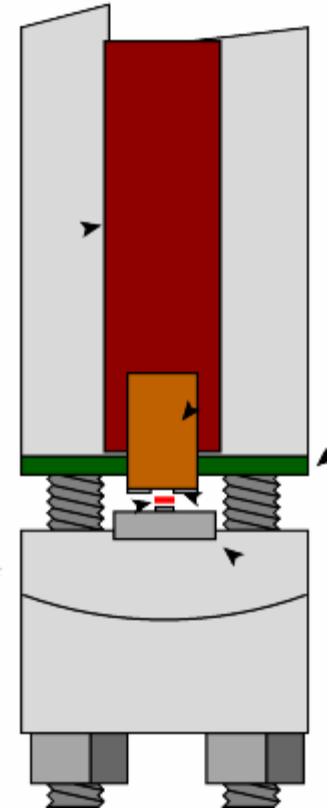


SEM and Optical microscopes

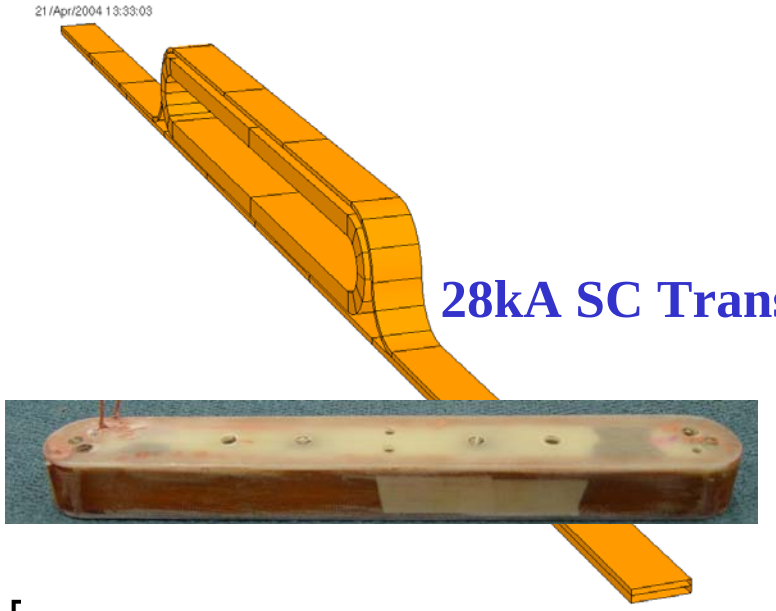
Probes for HTS Strand and Cable Tests



1kA probe //



Transverse pressure

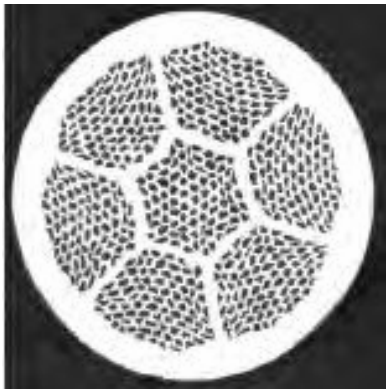


28kA SC Transformer

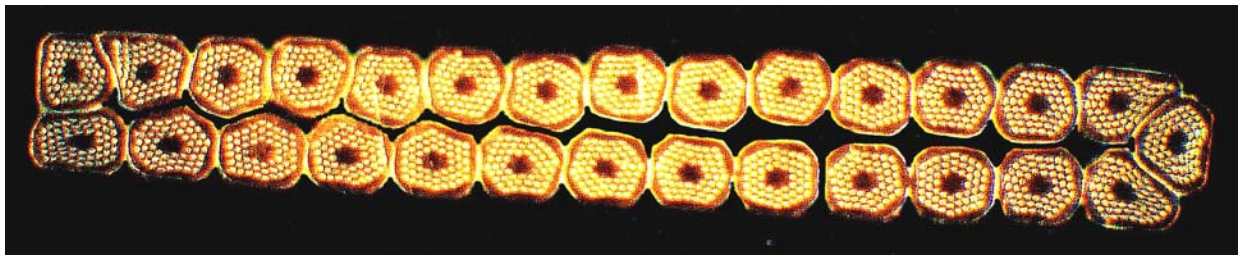
Cable Machine (IB3)

- Strand number: up to 42
- Strand diameter: 0.3-1.5 mm
- Cable transposition angle: 8-16 degree

Collaboration with OST on Conductor Technology



BSCCO-2212 Wire



Rutherford Cable (can be cabled with SS core)

For a replication of the complete process that leads a flawless round strand to become part of a cable first, and of a coil next. The characterization of each step of such process, including heat treatment, transport tests of strands and cables, and analysis of cable damage, provide feedback to the manufacturer for improvement of the strand design.

E. Barzi

Expenditures for FY07

- **Hire entry level engineer/post doc to assist in probe and coils design**
- **Part time effort for Supercond. R&D Staff**
- **Contract technician**
- **Cost of test materials**
  - Helium for sample tests
  - Parts/machining of probe materials
- **Proposed costs**
  - M&S $200K, SWF $115K

Outline for Fermilab 50 T Solenoid

- **Up to and Including FY06**
  - Significant work done by Muons Inc. on Magnet Concept
  - Muons Inc supported work on HTS materials at Fermilab
  - Prepare plan for Sept 2006 report
- **FY07**
  - Focus on Material Studies, available materials, relation to magnet design
  - 1-5 T insert(s) suitable for SC R&D lab 16 T or 17 T Teslatron
  - Present Status of Feasibility Study and Conceptual Design as part of Sept 2007 report
- **FY08**
  - Material Choice(s)
  - Develop Measurement equipment for Feasibility Study
  - Lower field prototype to study Design Feasibility
  - Engineering Design
- **FY09**
  - ?

MCTF Effort at other DOE Labs

- **MCTF Proposal calls for modest magnet effort at BNL and LBNL in support of Fermilab muon Collider:**
  - BNL
    - Material Studies for 50 T Solenoids, particularly Bi2232 and YBCO tapes
    - Make solenoid insert
  - LBNL
    - Design studies for muon collider dipole
    - Open midplane dipole made from existing Nb3Sn coils

Magnet Conclude

- **Fermilab continues to work with Muons Inc to make Helical solenoid with ~2009 delivery date**
  - In FY07 need to develop detailed plan which leads to delivery of helical solenoid.
- **50 T Solenoid with FNAL, BNL and Muons Inc. Work focused on materials for first year. Goal to make 1-5 T insert suitable for ~15 T Teslatron with 77 mm bore.**
  - FY07 will be a year of studying HTS materials, building a collaboration to coordinate long term effort

Magnet Conclude (2)

- **Muon collider magnet program is only possible through laboratory magnet base program**
  - Fractional use of several experienced, base supported scientists, engineers and technicians.. Note:
    - Up to this points, we have been paying for much of this effort out of the magnet base program (although Muons Inc support has been critical)
    - Requested support for effort will just cover the effort in FY07 required for progress, particularly if 2010 goal for Helical solenoid is real
  - Cabling machine, tooling, strand testing facilities supported entirely through base program
  - For 50 T work, we will likely start with conductor acquired through base program
  - For Helical cooling channel, we will likely start with left over cable for mechanical model.