Helical Solenoid 4-coil Model Test Results

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Introduction

Confirm cooling efficiency of Helical cooling channels based on the Helical Solenoids (HS)

Conceptual and engineering design of HS 4-coil model (NbTi), as well as a magnet simulation completed at TD/Magnet Systems Department

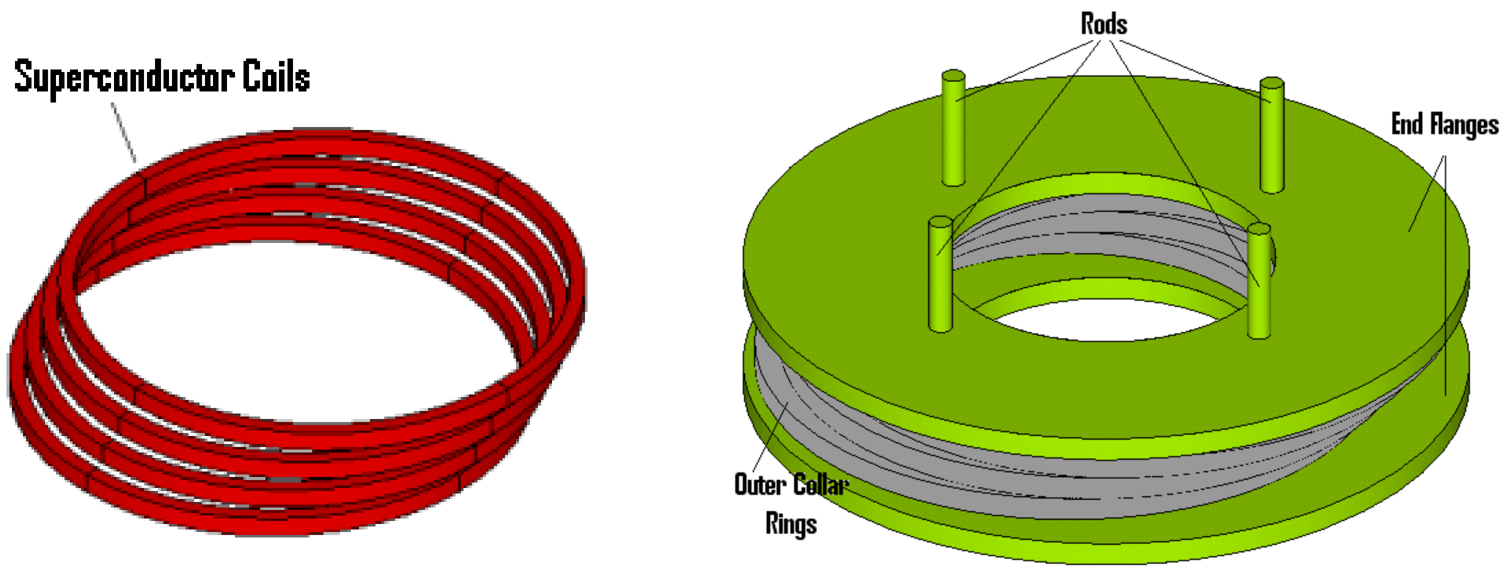
Cold magnet test performed from Dec.1 to Dec. 6 at the Vertical Magnet Test Facility (VMTF)

Magnetic measurements performed:
- warm measurements (300 K) at 10 A
- cold measurements (4.5 K) at 2000 A

Cold-Warm measurements compared

Test data analysis in progress

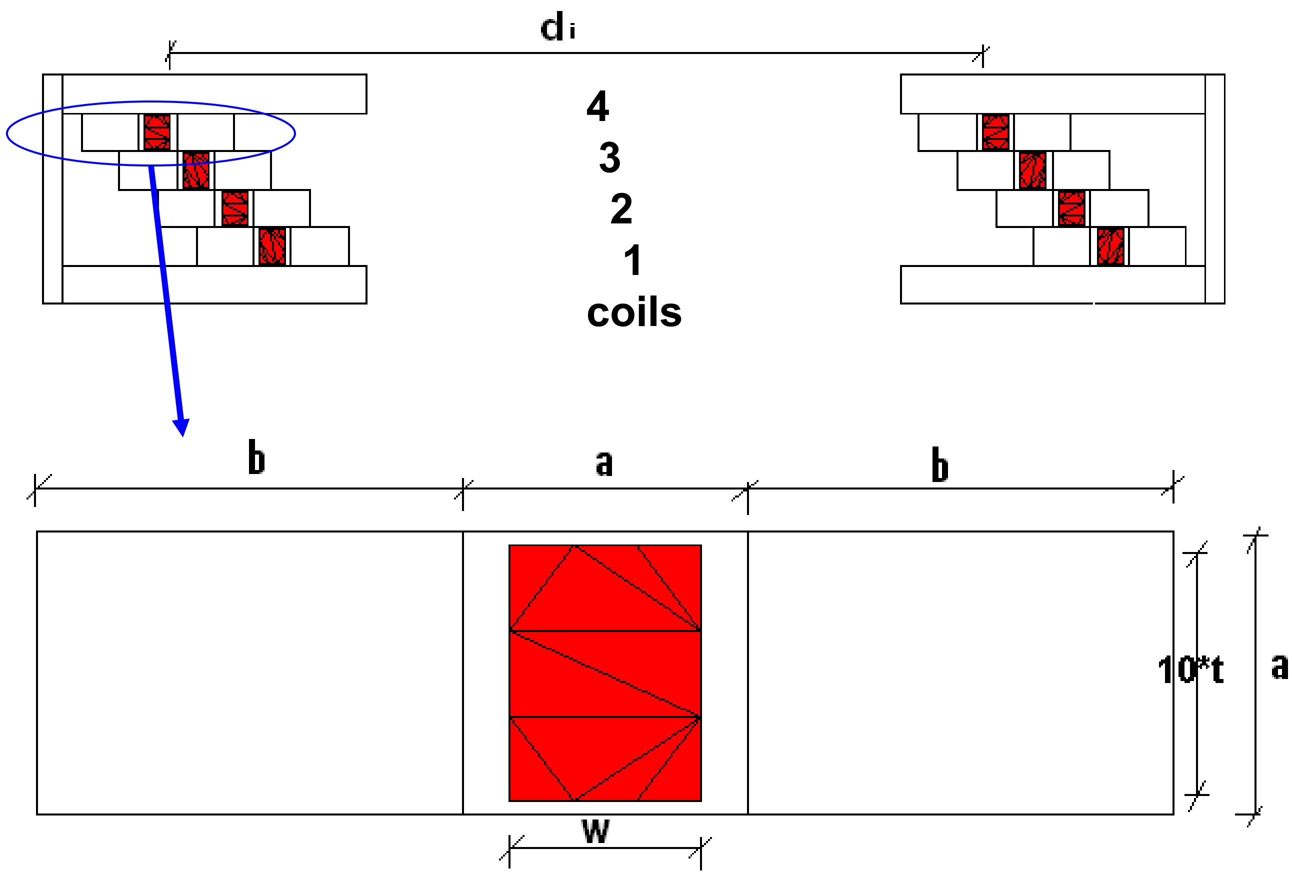
4-Coil HS Model



Circular short coils shifted in the transverse direction. All coil centers lay on a helical beam orbit and are equally distributed along z-axis

Solenoidal, helical dipole and helical quadrupole magnetic fields generated

Dimensions



d_i (mm)	426.5
w (mm)	13.5
t (mm)	1.8
a (mm)	20
b (mm)	30
# of turns (per coil)	10

Miao Yu

Test Program

Warm 3D Hall Probe Point Scan at Low Current

Cold 3D Hall Probe Scan (in Warm Bore) at High Current

Quench Training (4.5 K)

Temperature Dependence (3 K)

Ramp Rate Dependence (structure not laminated)

Test Heater Effectiveness

Residual Resistivity Ratio (RRR) Measurement

Magnetic Measurements

Warm 3D Hall Probe Point Scan

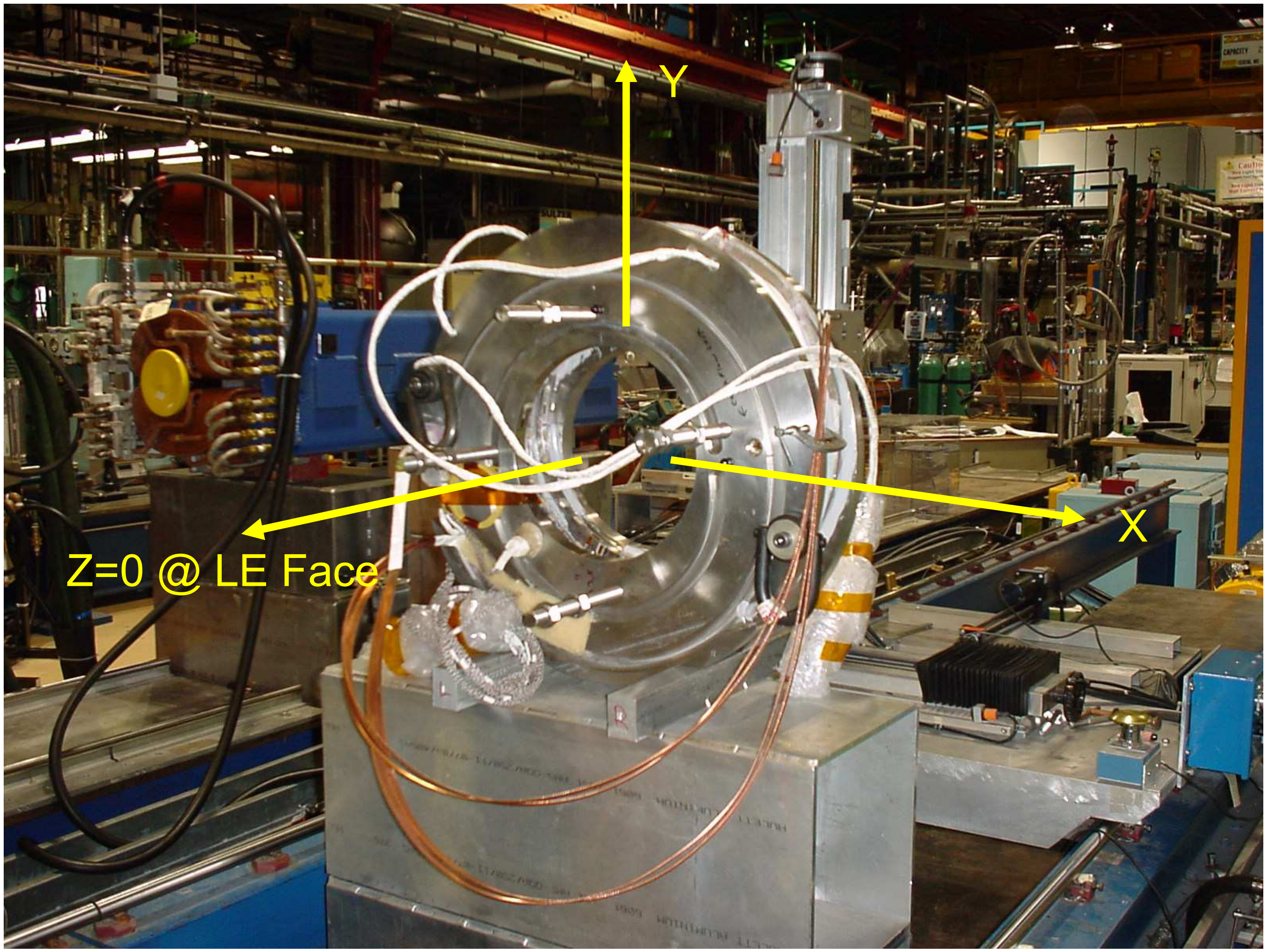
- At currents ± 10 A (eliminate background fields)
- "On axis" and at "large R", Various θ (45 degree increments)
  - There is no "center"; offset coil positions to be re-measured relative to surveyed X,Y,Z coordinates
  - Data look "reasonable", but need detailed comparison to model
  - Magnet orientation, Probe positioning required careful survey

Cold 3D Hall Probe Scan (in Warm Bore)

- At 2000 A (there's no flux return, no point in much higher currents)
- On a different, but not precisely known axis
  - close to above (~1mm); wherever the warm bore goes
- Probe orientation approximately aligned with solenoid X,Y axes

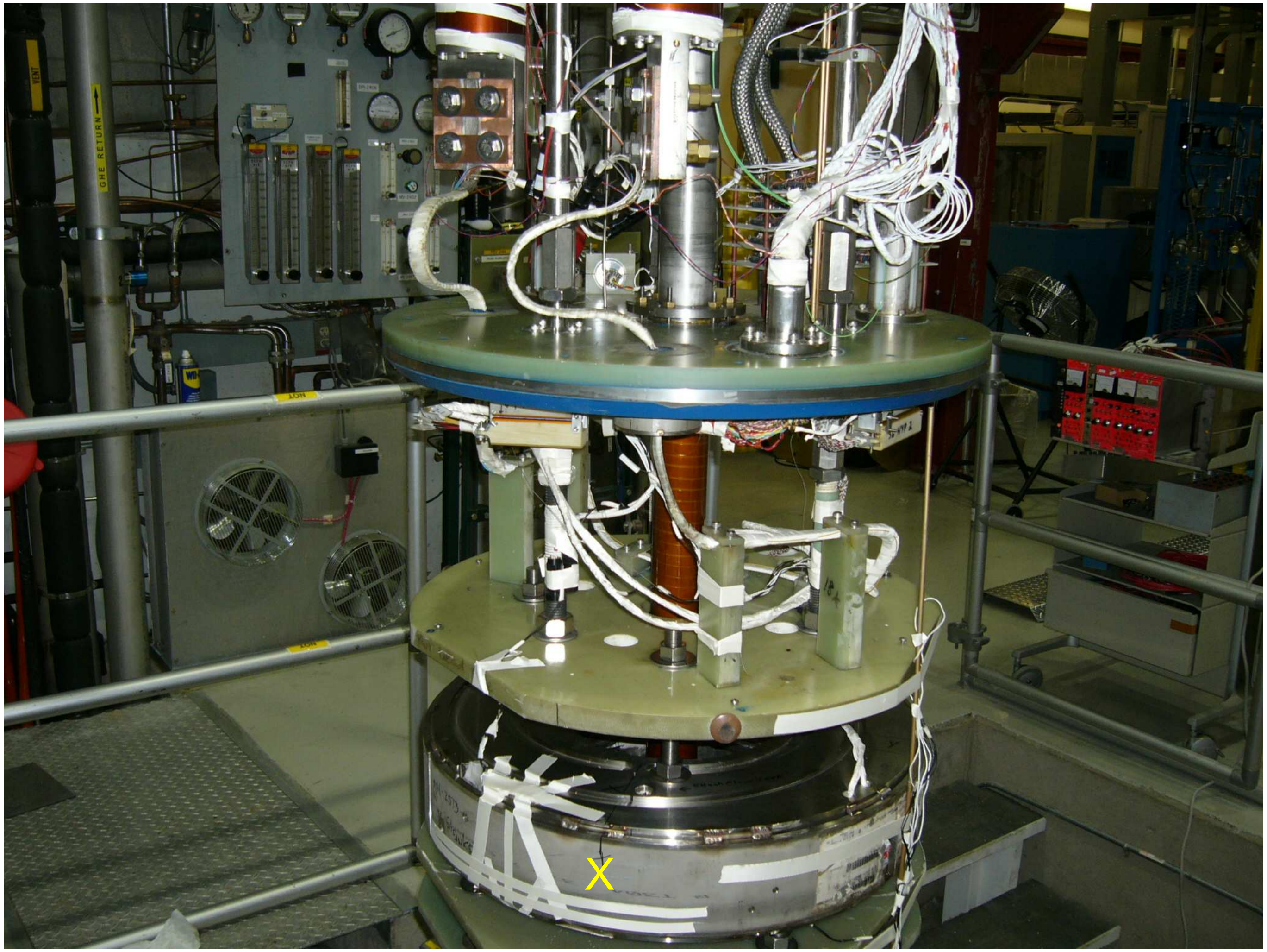
Warm Magnetic Measurements

Fermilab MTF/Stand B



Cold Magnetic Measurements

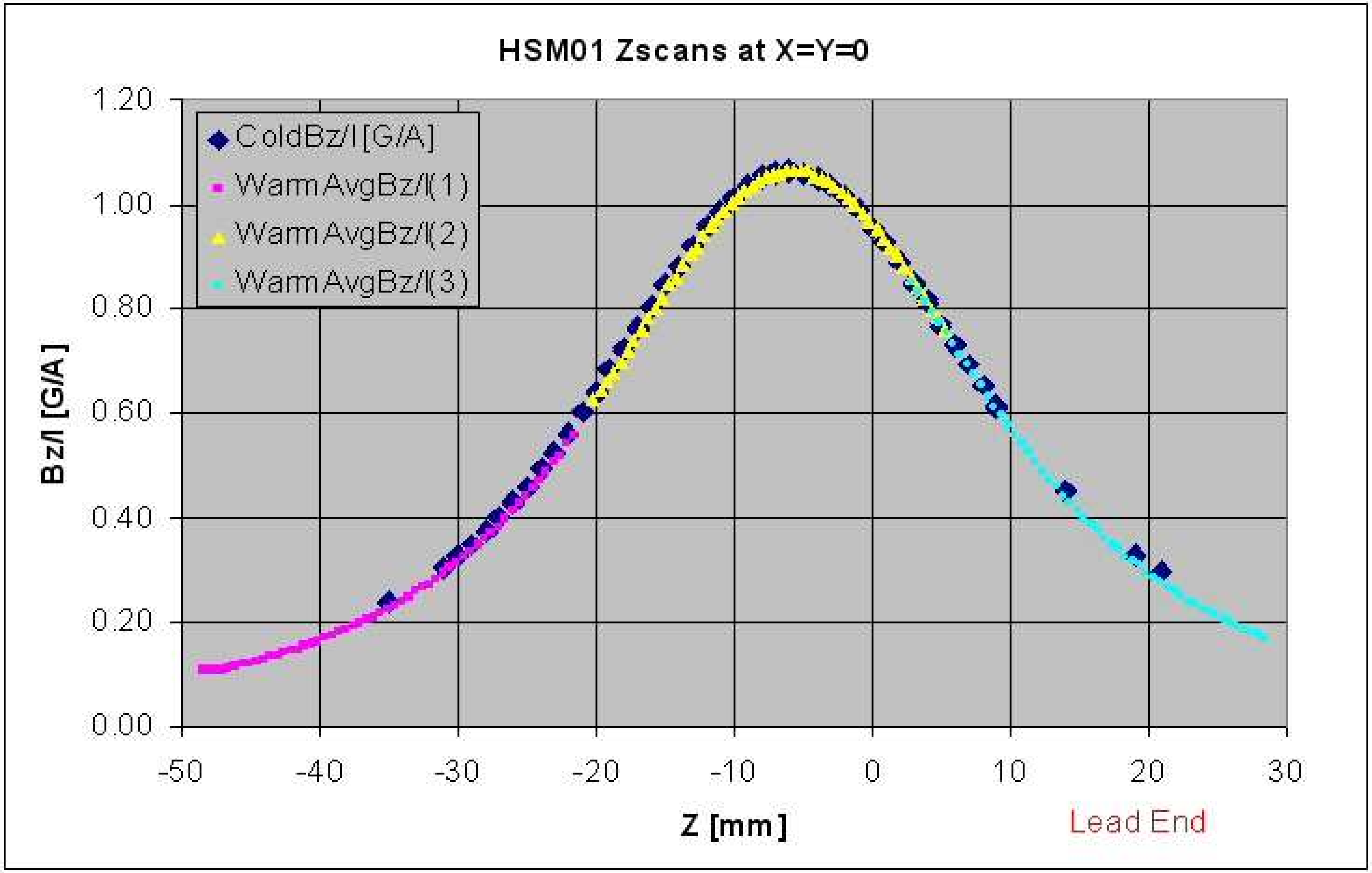
Vertical Magnet Test Assembly



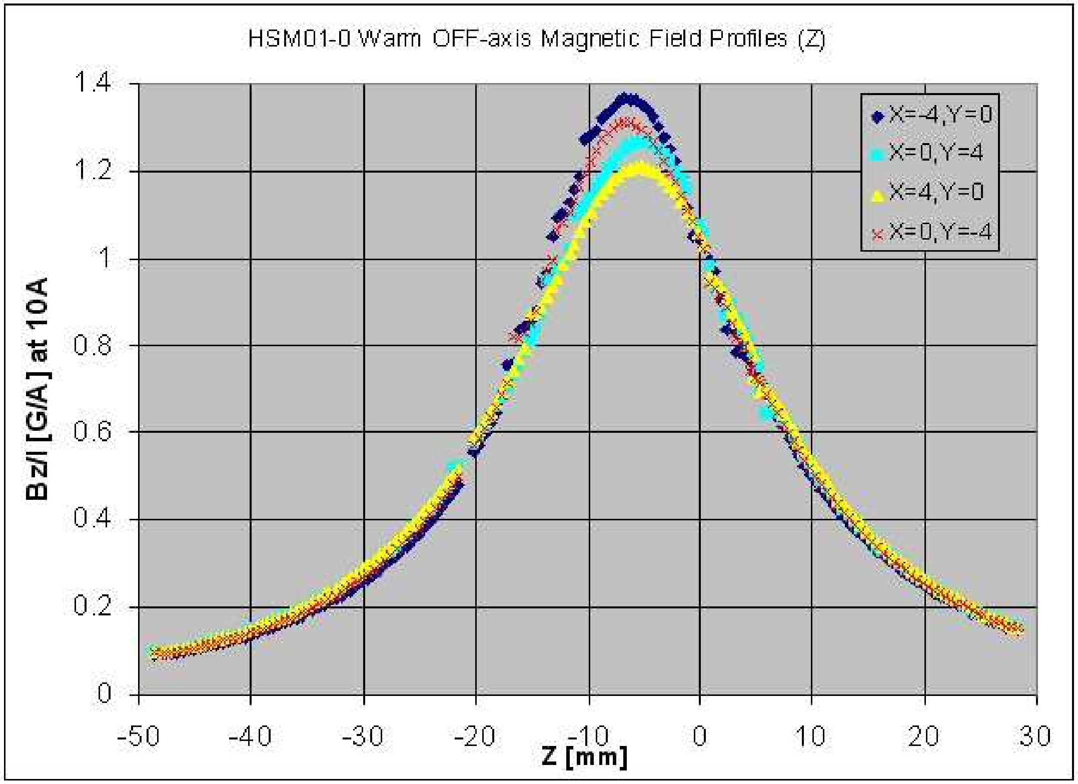
Magnetic Measurements

Transfer function Bz/I vs Z ("on axis")

- Cold data shifted to align peaks
- Warm data taken in three separate pieces (average +/-10A)

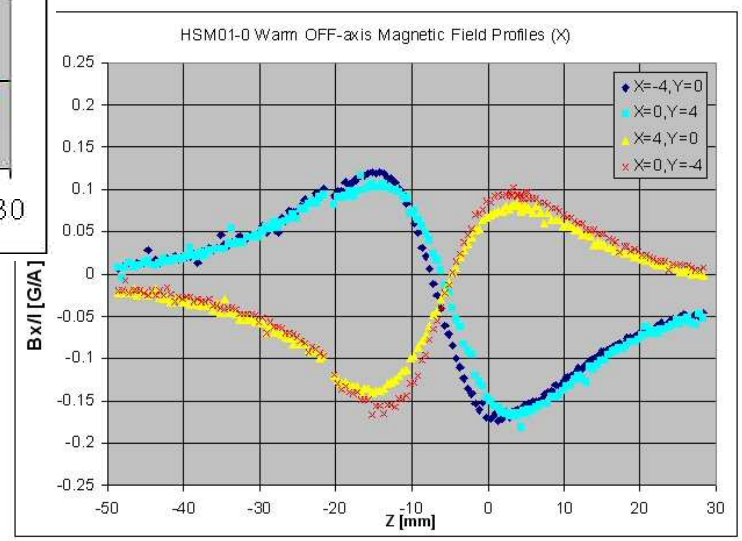


Magnetic Measurements



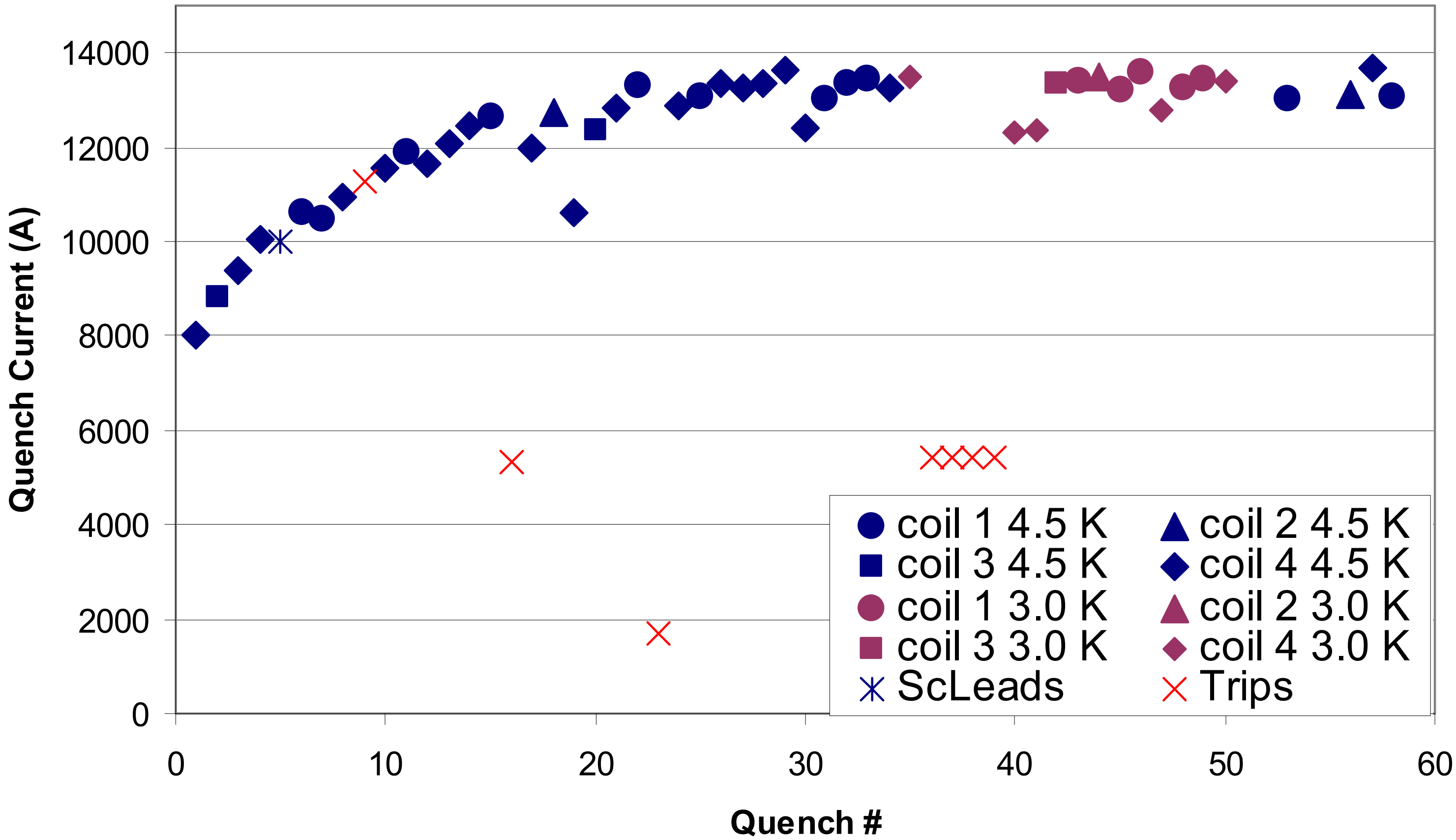
Bz/I, Bx/I and By/I
("off-axis")

4" radius, for warm measurements Only

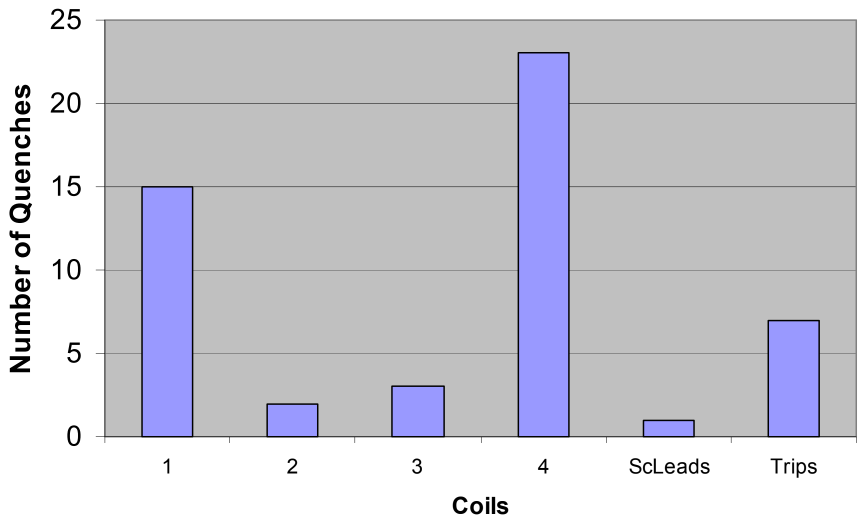


Quench Training

- The low inductance caused some PS regulation problems (low current trips)
- Short sample prediction 16.6 kA at 4.5 K (Vladimir Kashikhin)
- One SC Lead Quench: Large Forces at high current, inadequate support
- Looks limited by mechanics



Quench Locations, Ramp Rate (in)Dependence

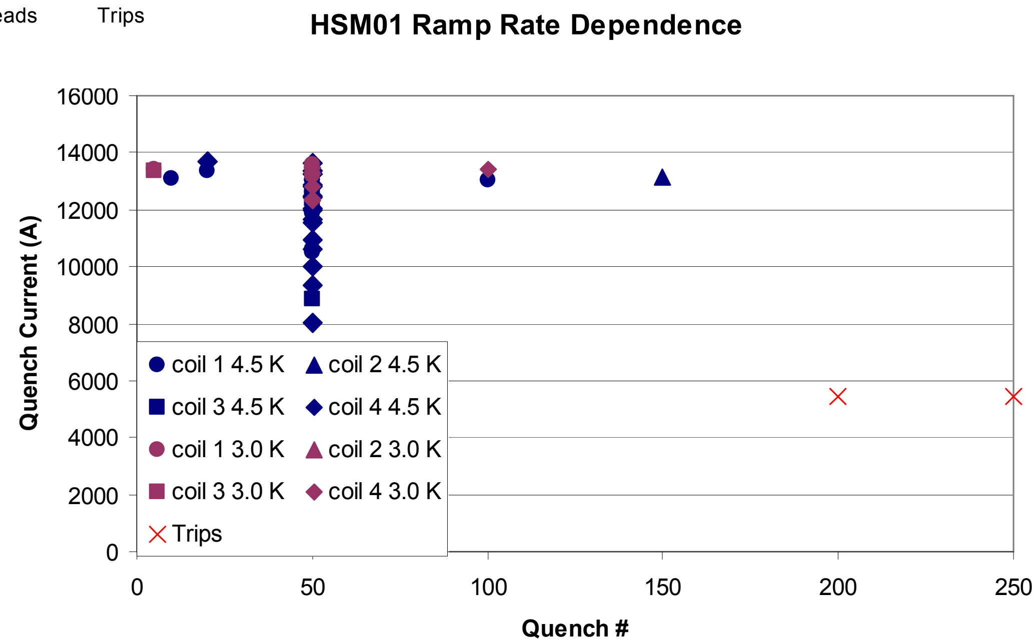


Coil 4 was at the negative lead end, where a lot of work took place to resolve SC Lead insulation problems

Coil 1 was at the non-lead end

No discernable ramp rate dependence as far as we were able to explore

Rather broad range of "plateau" currents (~2kA) (Training quenches are included in figure)



Guram Chlachidze

Protection Heater Test, RRR measurement

Heater Test done at 4 K, 12000 A

- Only one set of heaters tested
- Heaters on coils 1 and 2 connected in series
- Heater Capacitances: 4.8 mF, 9.6 mF
- 50 V was sufficient to quench in both cases
  - Tfn (for 4.8 mF) = 150.6 ms, coil 2 quench
  - Tfn (for 9.6 mF) = 119.2 ms, coil 2 quench

Cold (10 K) and warm (300 K) RRR data captured with ±10 A on coil
Whole coil RRR ~ 140

Summary

Helical solenoid 4-coil model built and successfully tested at Fermilab

Magnet reached ~ 82% of short sample limit

Consistent warm and cold magnetic measurements

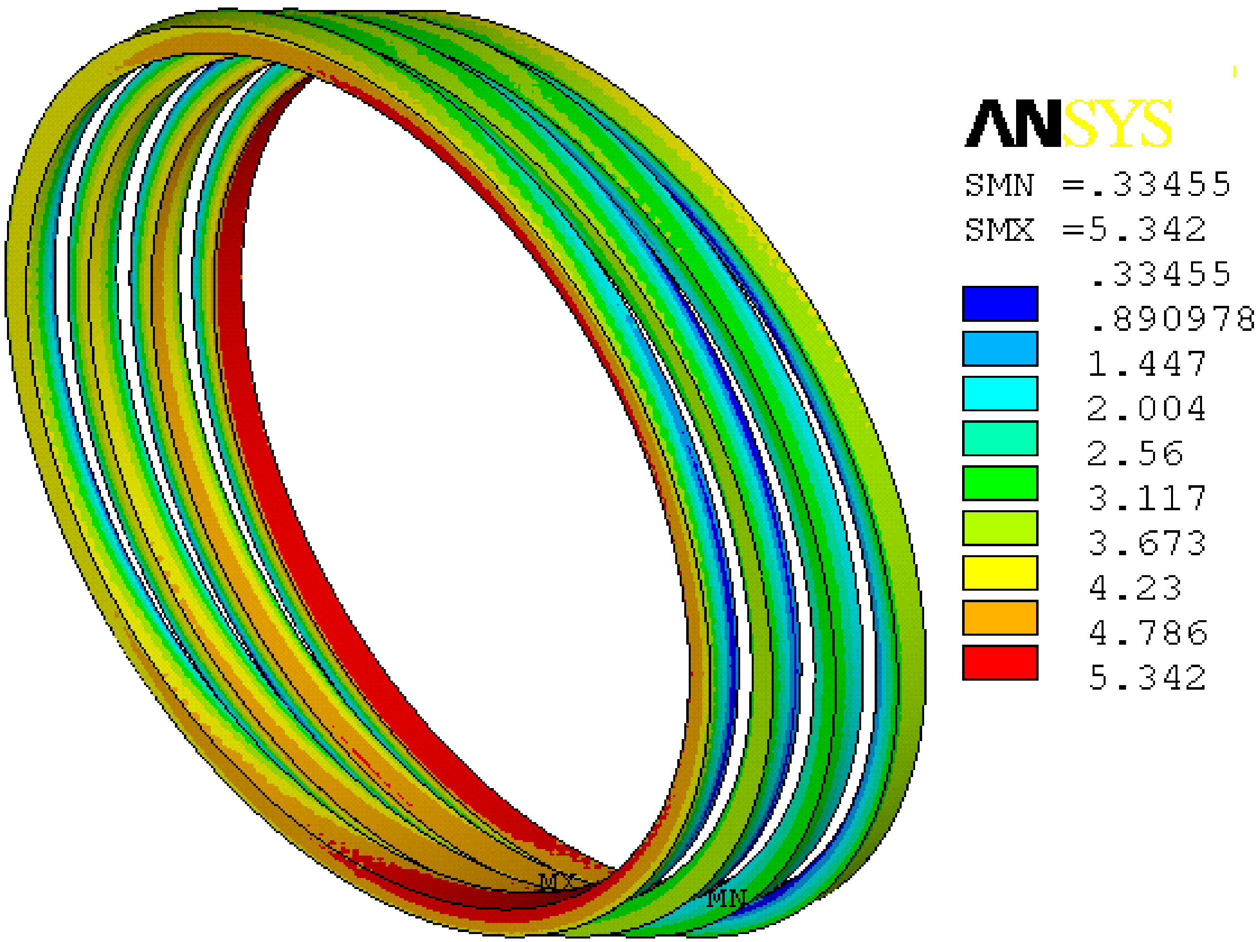
Currently working to finalize test data analysis and compare results to the model predictions

Planning future tests:

- Improvement of mechanical structure and cable insulation
- Development of technical solutions for the superconductor protection from large stresses and deformations due to large transverse forces
- Considering to build HS with Nb_3Sn cable and with different design

Backup Slides

Fields with14 KA Total Current



Central Field

Coil 1	1.53 T
Coil 2	1.57 T
Coil 3	1.57 T
Coil 4	1.53 T