React and wind type MgB_2 based MRI segment Coil: Development, Instrumentation, and Initial Cool down

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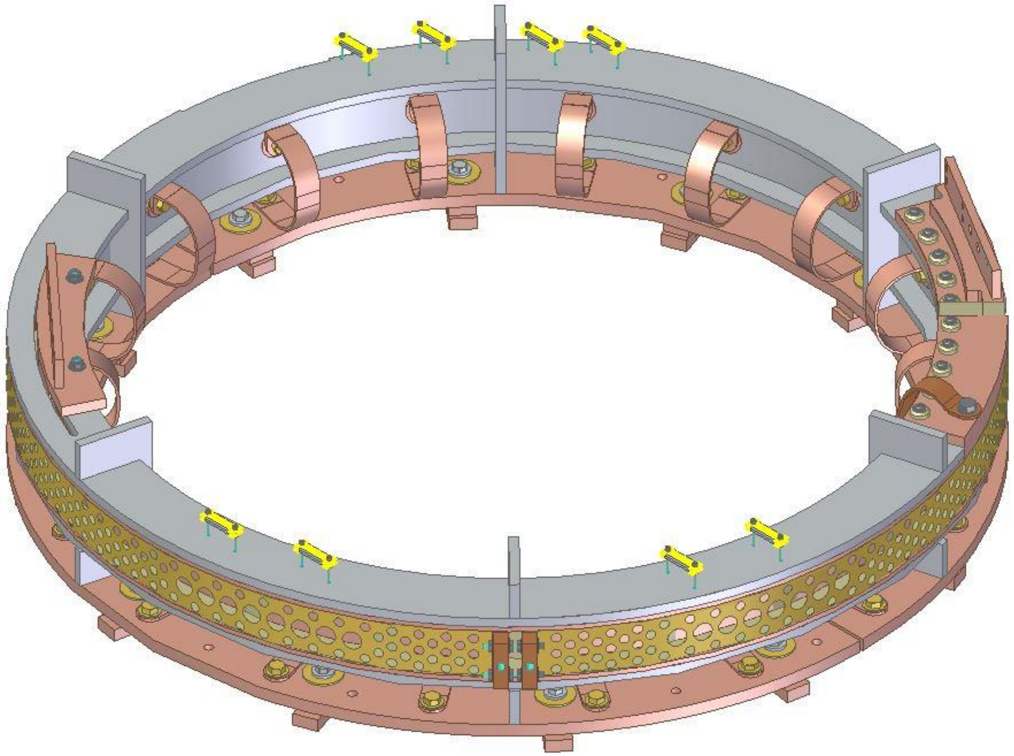
Motivation

- MgB_2-based MRI systems are of significance because they can be used to develop liquid-cryogen(He)-free MRI systems to lower cost.
- This is made possible by MgB_2's High T_c (~ 39K), giving the possibility of conduction cooling. High T_c also increases the MQE while not suppressing NZP too much
- HTR and OSU have pushed the conductor to the level needed for MRI application, and conductor designs appropriate for MRIs are now being made at HTR
- This present effort part of an NIH phase III to develop an MRI for an Image guided treatment system
- Hyper Tech Research and Case Western have developed the designs for a full magnet system
- This coil is one segment coil for that system– the manufacture and testing of one of the segments in a conduction cooled mode will be accompanied by measurement of temperature uniformity, NZP formation, and a quench protection scheme

Key Items Tested in this work

1. **The testing of a large (0.9 m OD) MRI segment coil for performance under conduction cooling**
2. **The winding of a large coil using a react and wind approach for MgB_2, and the use of MgB_2 MRI specific wire**
3. The test of the stability of the coil against heat perturbation, the growth of the normal zone, and the testing of a specific coil protection scheme
4. **Exploration of an active quench protection scheme**

IN THIS talk, only coil development, instrumentation, and cool down are described – our coil tests will be in ***September 2017***



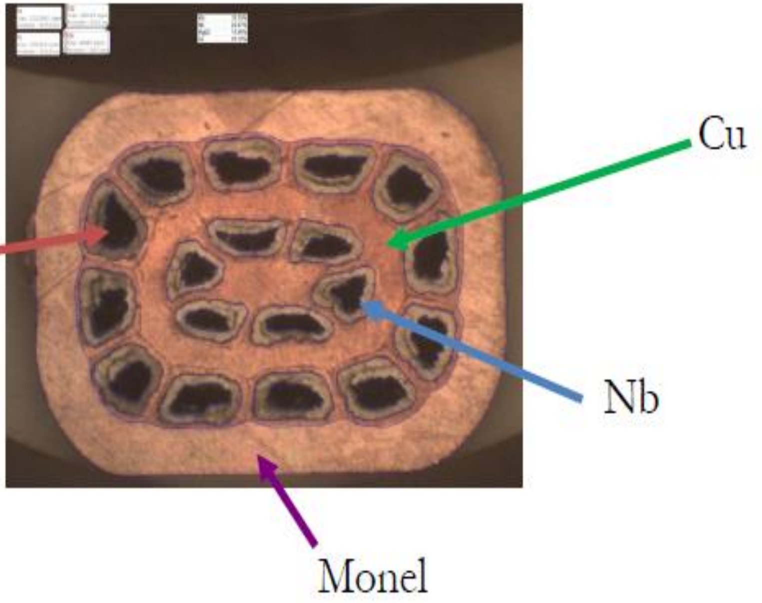
Outline

- ❑ Conductor/Coil specification
- ❑ Instrumentation details
- ❑ Devices and instruments info
- ❑ Cool down measurement
- ❑ Discussions and conclusions
- ❑ Future work

Conductor

Wire Architecture

Monel – 39%
Nb – 24%
MgB_2 – 10%
Cu – 27%



Strand #	Suff	# Mono	Barrier	Mono sheath	Multi sheath	Central fil(s)	area (mm^2)	% powder
3700	3S	18	Nb	Cu	Monel	Cu	1.467 mm^2 ‡	12.5

‡ area is provided instead of dimensions; area = 1.53 mm x 1.02 mm – corners

Coil Design

Coil material

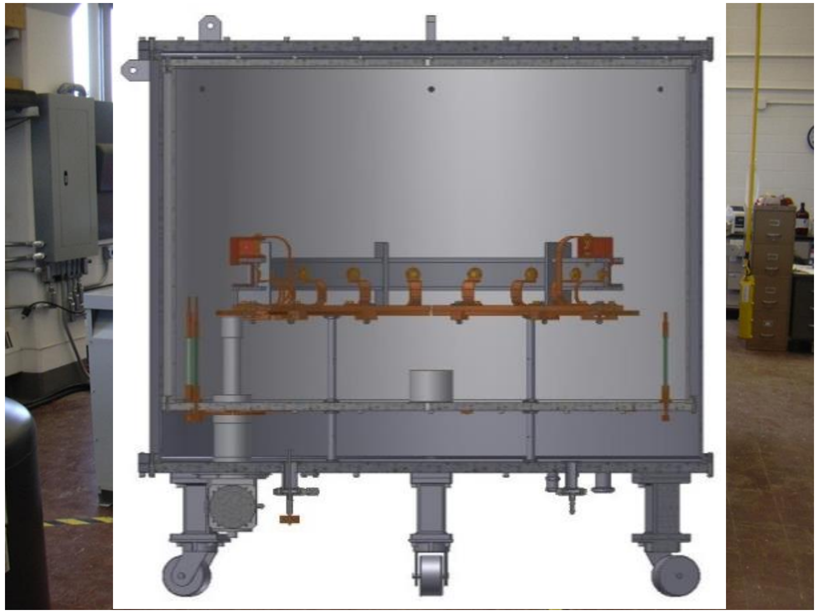
Former	Stainless Steel

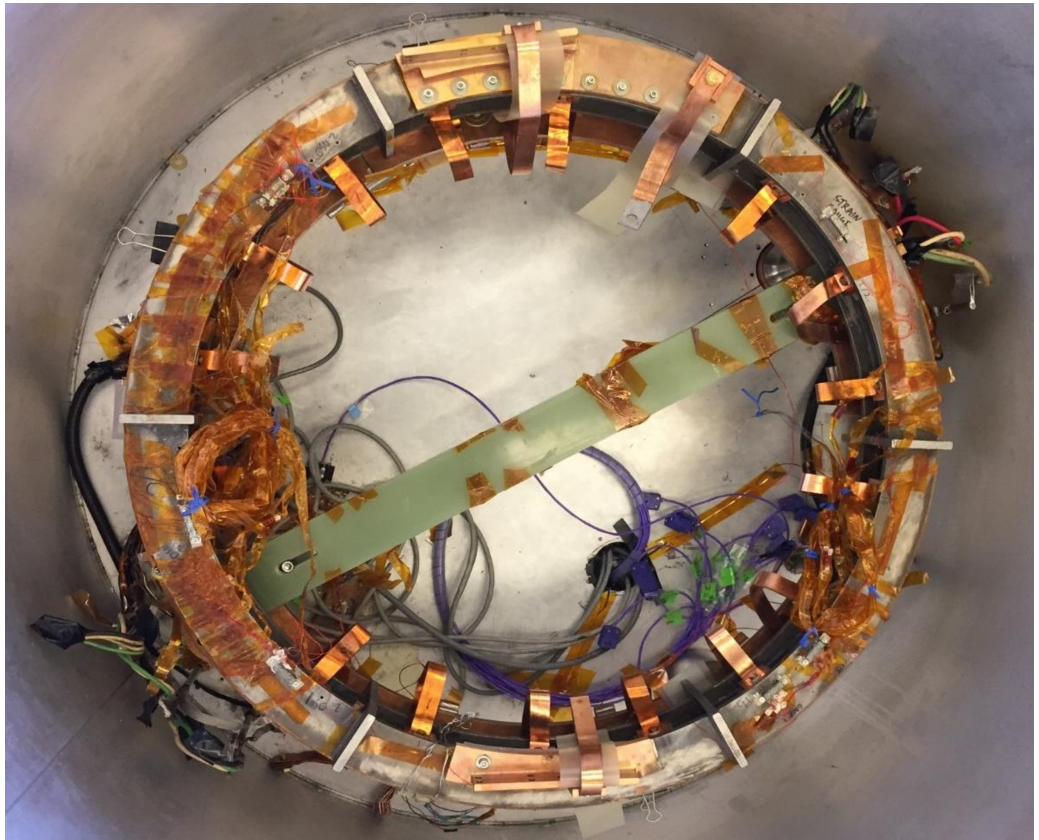
Coil Parameters

Winding pack OD	: 35.484" approx. (901.29 mm) (based on heat band circumference)
Winding Pack ID	: 33.750" (857.25 mm) (based on drawings)
Winding Pack Height	: 1.993" (50.62 mm) (avg of 12 measurements)
No. Turns	: 636.5
Total Conductor L	: 5723.23 ft (approx. 1744.44 meters)
Turns/layer	: 29 (approx.)
No. Layers	: 22

Devices and instruments info

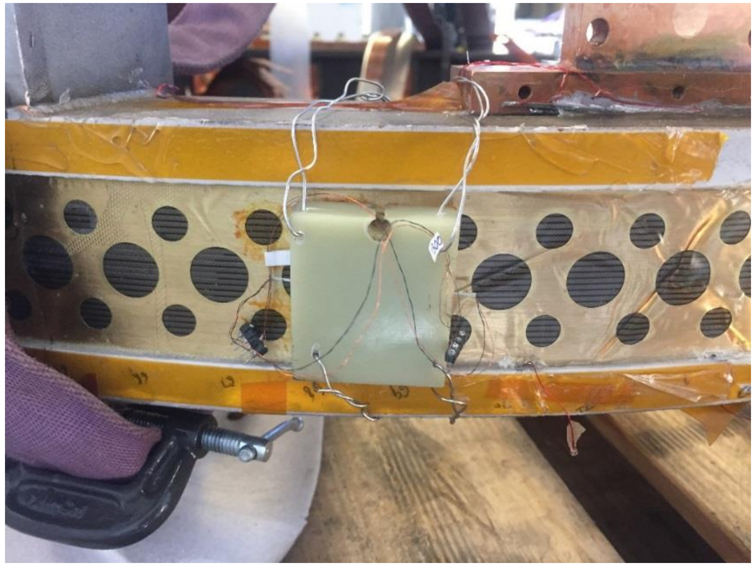
- (2) two stage GM cryocoolers
- (2) cold heads attached to the copper ring
- Cu ring and coil are thermally connected with OFHC copper strips
- (4) BSCCO leads for each current tap



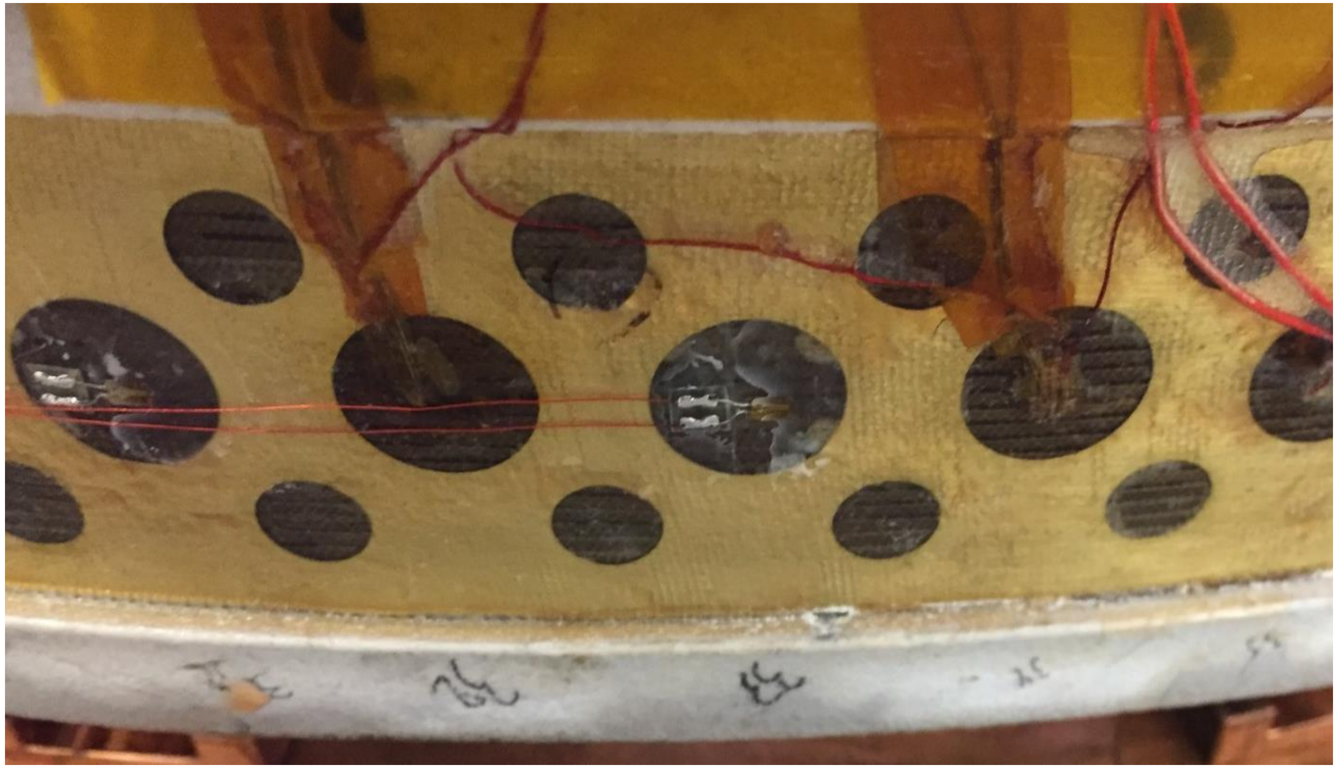


- Heater attached in the copper ring to control the temperature of coil
- Data acquisition system: Nanovoltmeters (Keithley), Thermometers (Lakeshore), Data acquisition (Labview)

Instrumentation Details

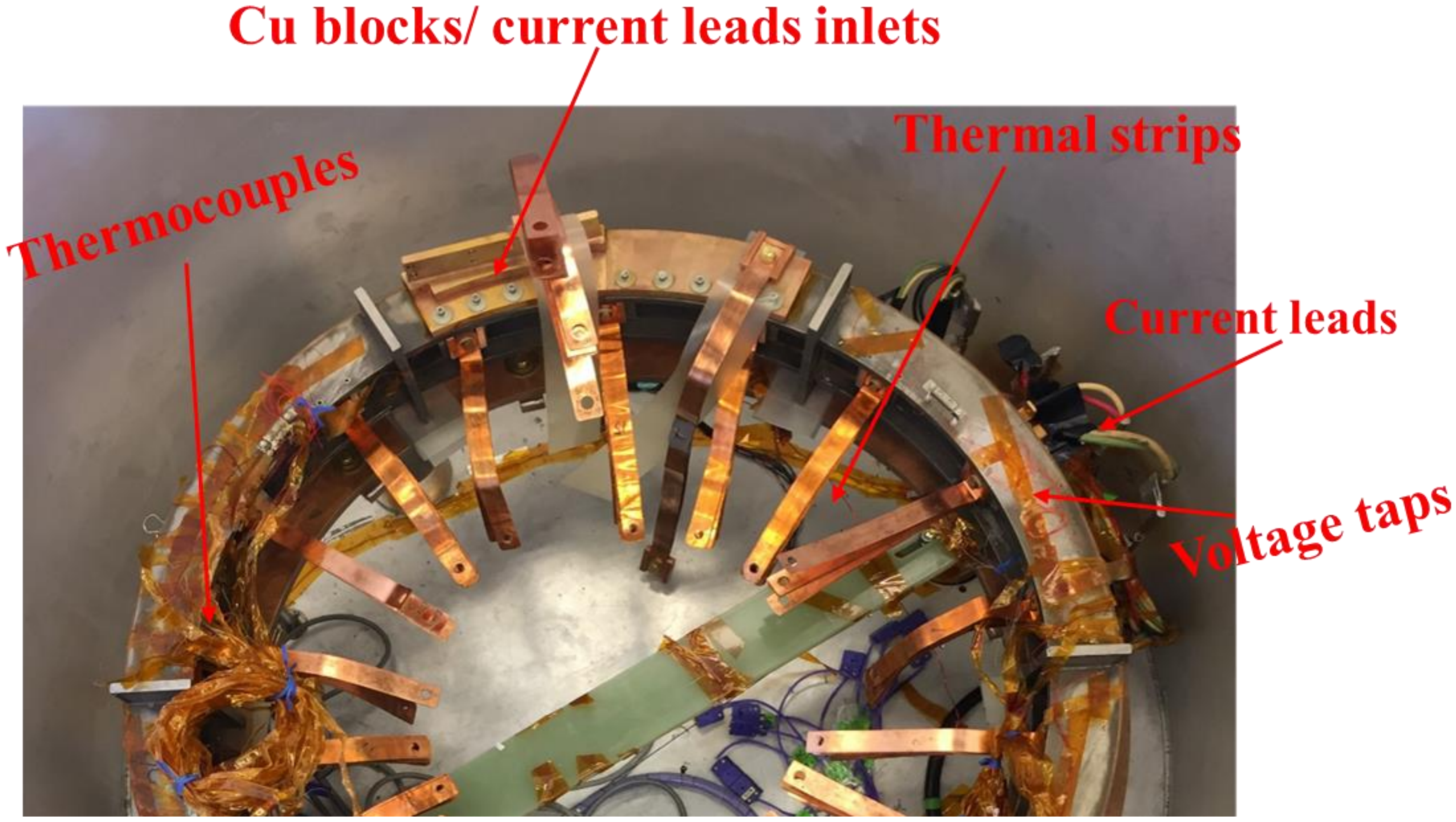


Hall sensors

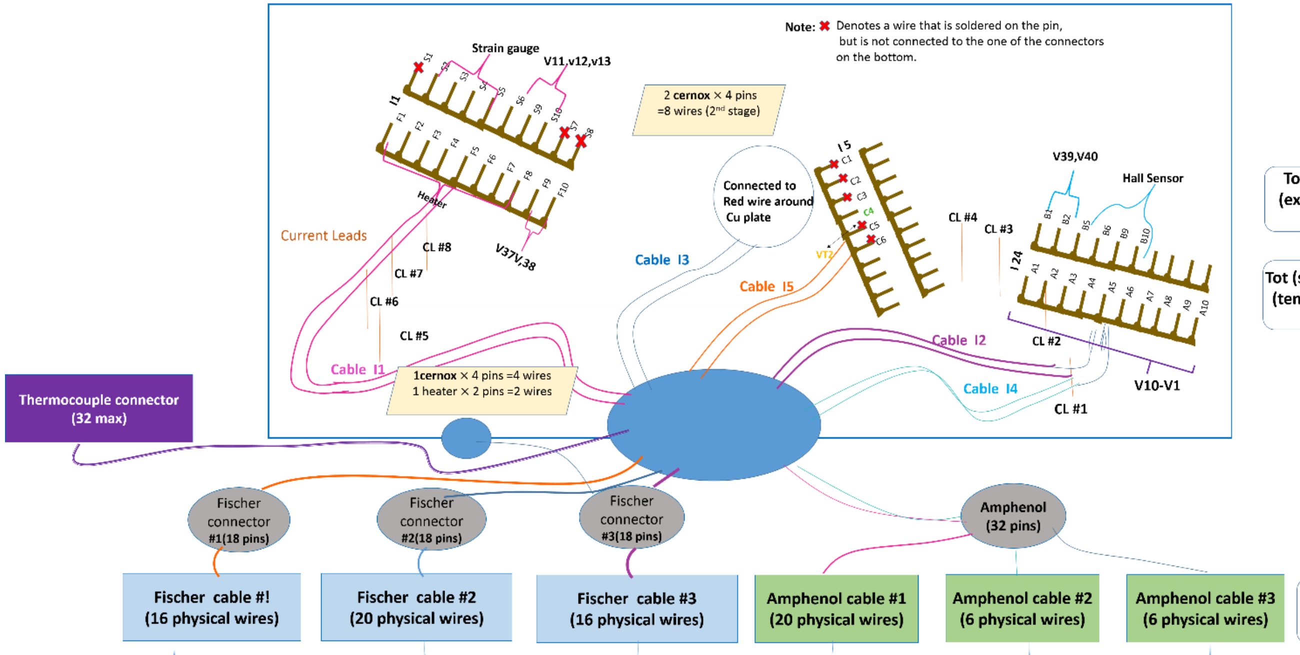


Strain gauges

Instrumentation Details



Wiring diagrams made for future measurements



a) Systematic voltage taps for HTS current leads :
2 pins/ lead × 8 leads =16 pins
b) 6 current leads voltage taps inside the cryostat (on the top) are connected:
Top 2- CL2; Top 3- CL3;Top 5- CL5; Top 6- CL6; Top 7- CL7, Top 8- CL8.
c) 5 current leads \voltage taps on the bottom are connected:
Bot #3- CL 3; Bot #4- CL 4; Bot #5- CL 5;Bot #6- CL 6;Bot #7- CL 7; Bot #8- CL 8.

Temperature (cernox) sensors:
4 pins/ sensor × 4 sensors=16 pins
a) 2 built-in sensors with 8 pins on 1st stage
b) 2 sensors (one on the coil top, the other on the Cu ring) with 8 pins on 2nd stage

a) A1 – A10 (10 voltage taps)
b) 1 Heater (2 pins)
c) 1 Cernox sensor(4 pins)
[The cernox sensor is on side of the coil]

17 Pins
a) Quench zone voltage taps V11-13(3)
b) Must-haves: V37,38
c) heater (8),
d) strain gauge (4)

6 Pins
a) Must-have Voltage taps: V39,V40 (2)
b) Hall sensor (4)

0

NOTE

Tot (in): 56 physical wires (excluding thermocouples) for instrumentation

Tot (system): 24 physical wires (temp sensor wires + HTS VT wires)

Tot(out): 84 physical wires(excluding thermocouples)

Pins that are connected all the way to the wires inside the dewar

For example, level 1 (voltage tap to measure) goes to one end of the intermediate connector (one end of level 2), then the other end of level 2 goes to the cable for DAQ device (level 3).

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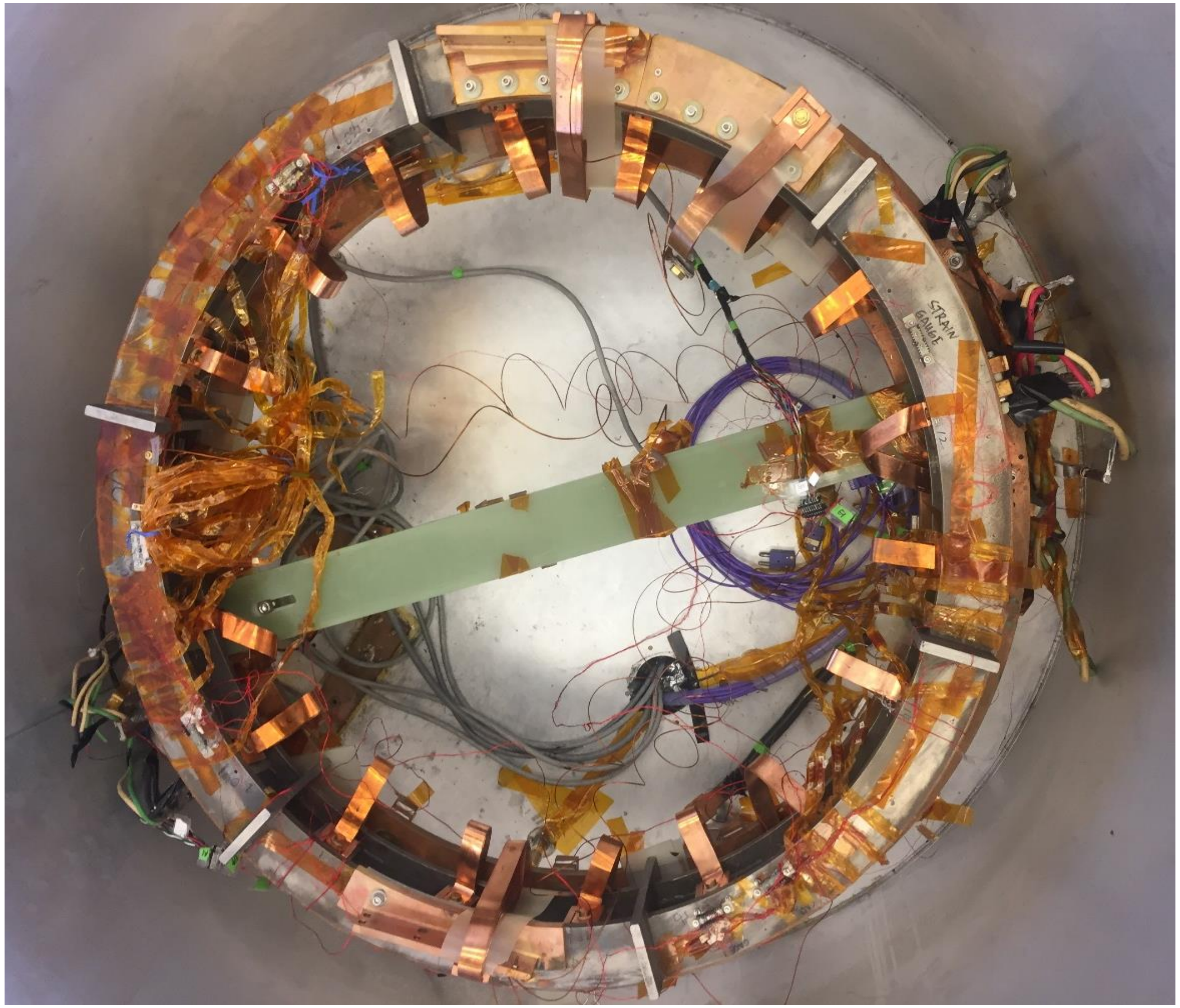
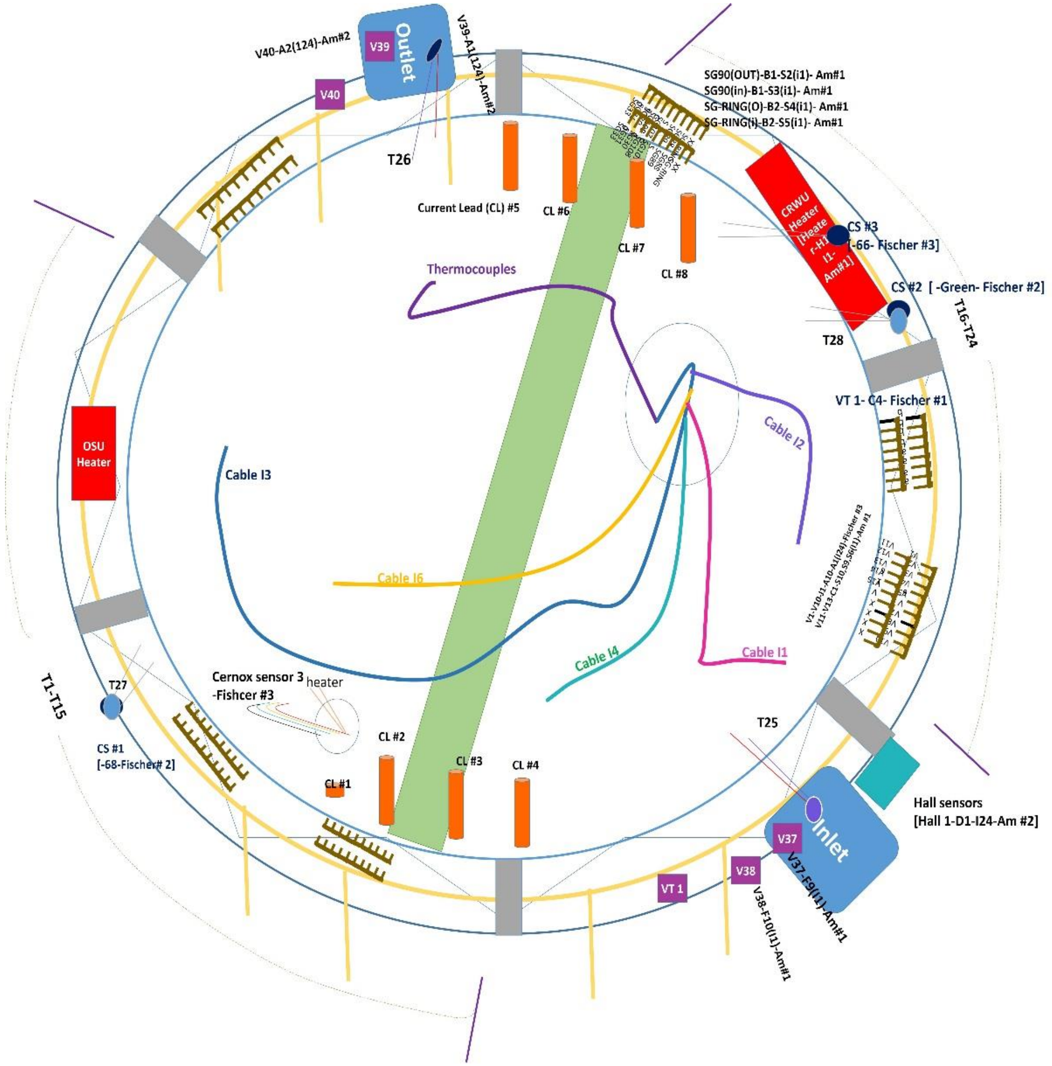
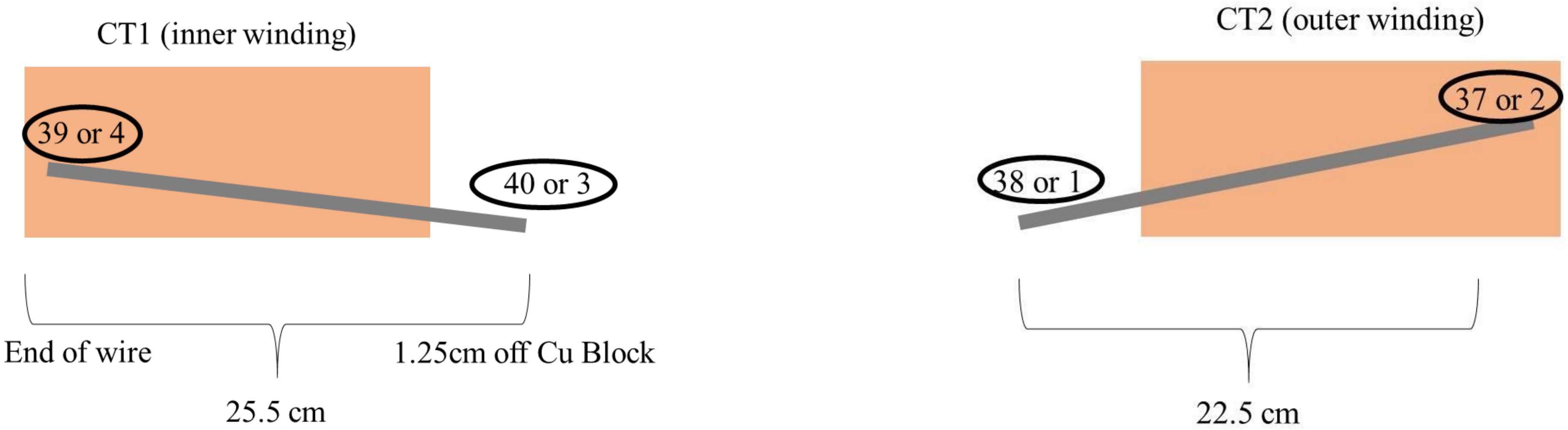


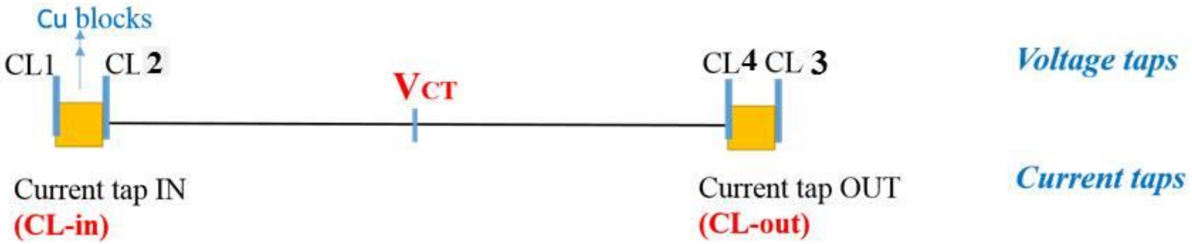


Overview of the wiring diagram for the coil measurement

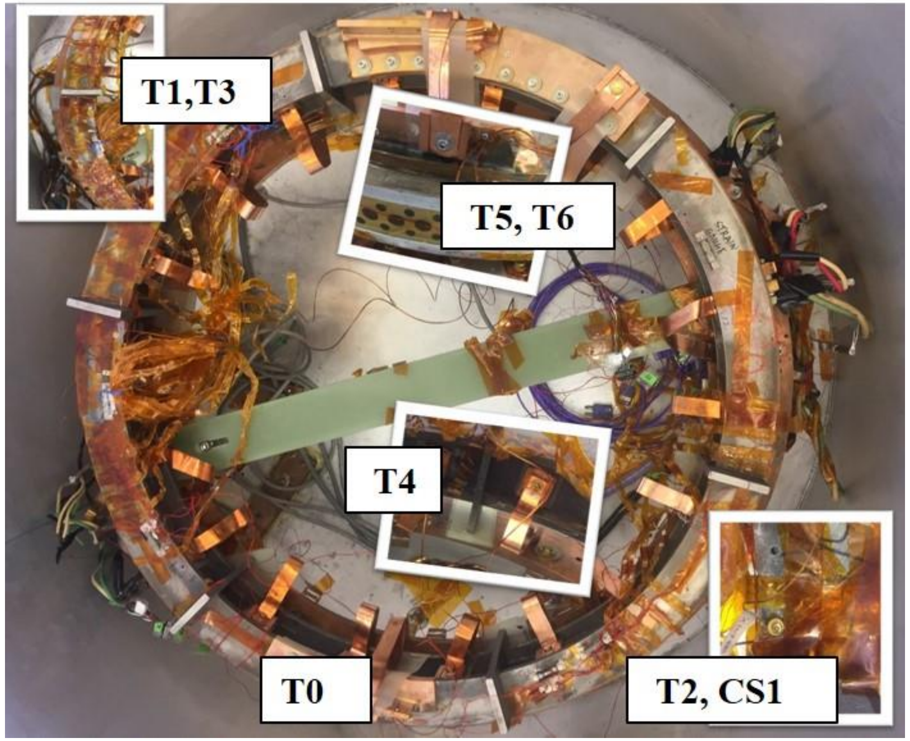
Voltage taps

Whole coil resistance: 56 Ω,
Total conductor length: 1744.44 m



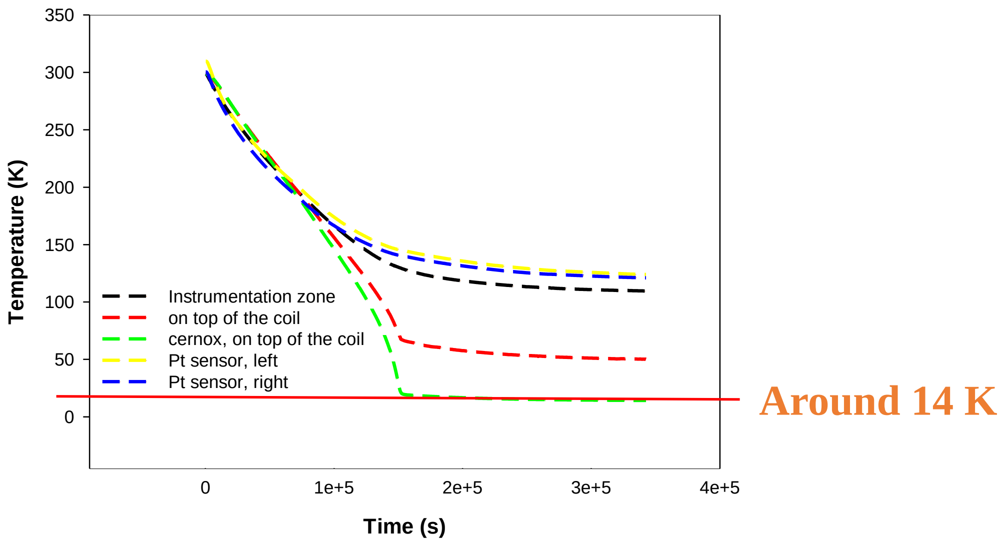


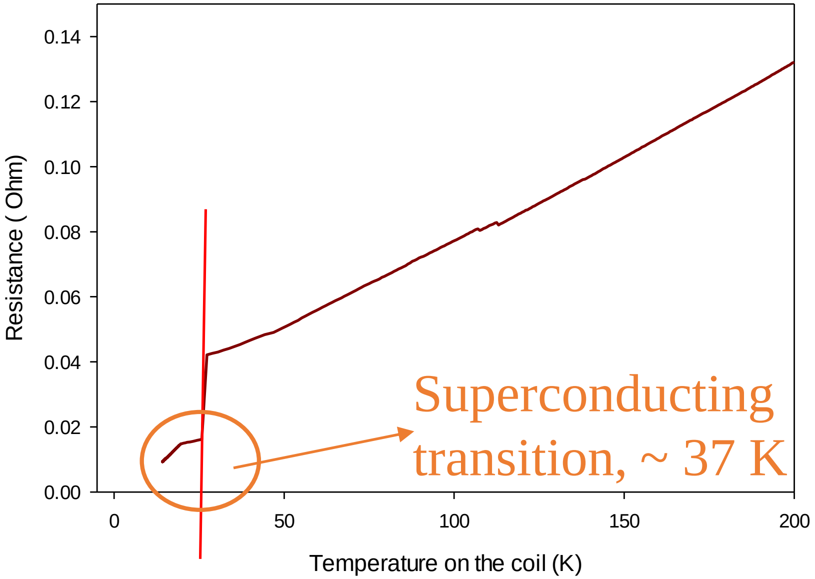
Temperature Sensors

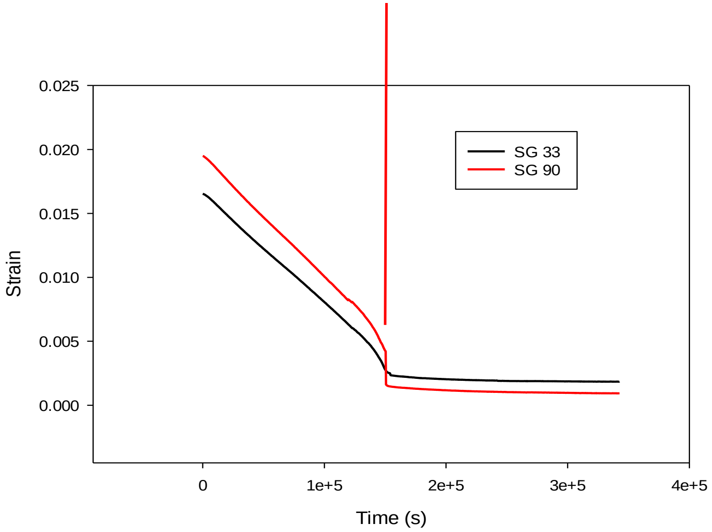


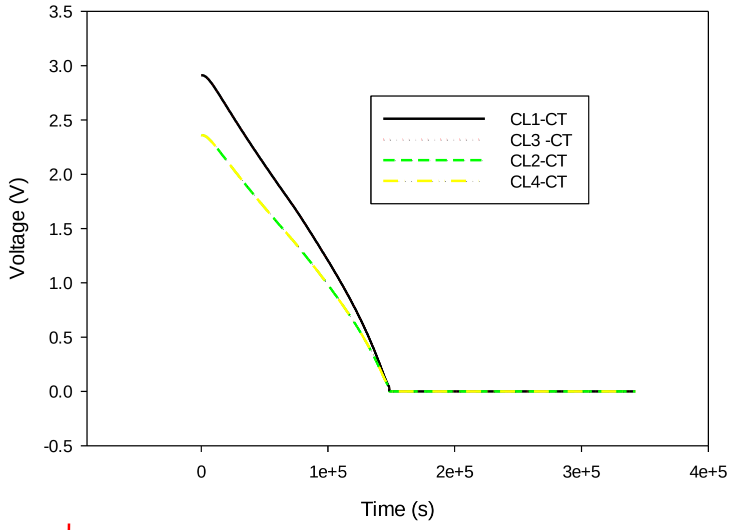
Name	Location	Details
T0	On the Cu current outlet	Type E, detect temp on the Cu block
T1	Instrumentation zone, CASE side	Type E thermocouples
T2	On the top of the coil	Type E, to compare to the cernox sensor values
T3	Instrumentation zone, CASE side	Type E thermocouples
T4	Inside the wall of the coil	Type E thermocouples
T5	On the Cu current inlet	Type E thermocouples, get temp on the current inlet
T6	On the Cu current inlet	Type E thermocouples, get temp on the current inlet
CS 1	On top of the coil	cernox sensor, to calibrate T2
Pt1	On the 1st stage of the system,left	Pt, to get the 1st temperature
Pt2	On the 1st stage of the system, right	Pt, to get the 1st temperature and compare results

Cool down measurement









Summary

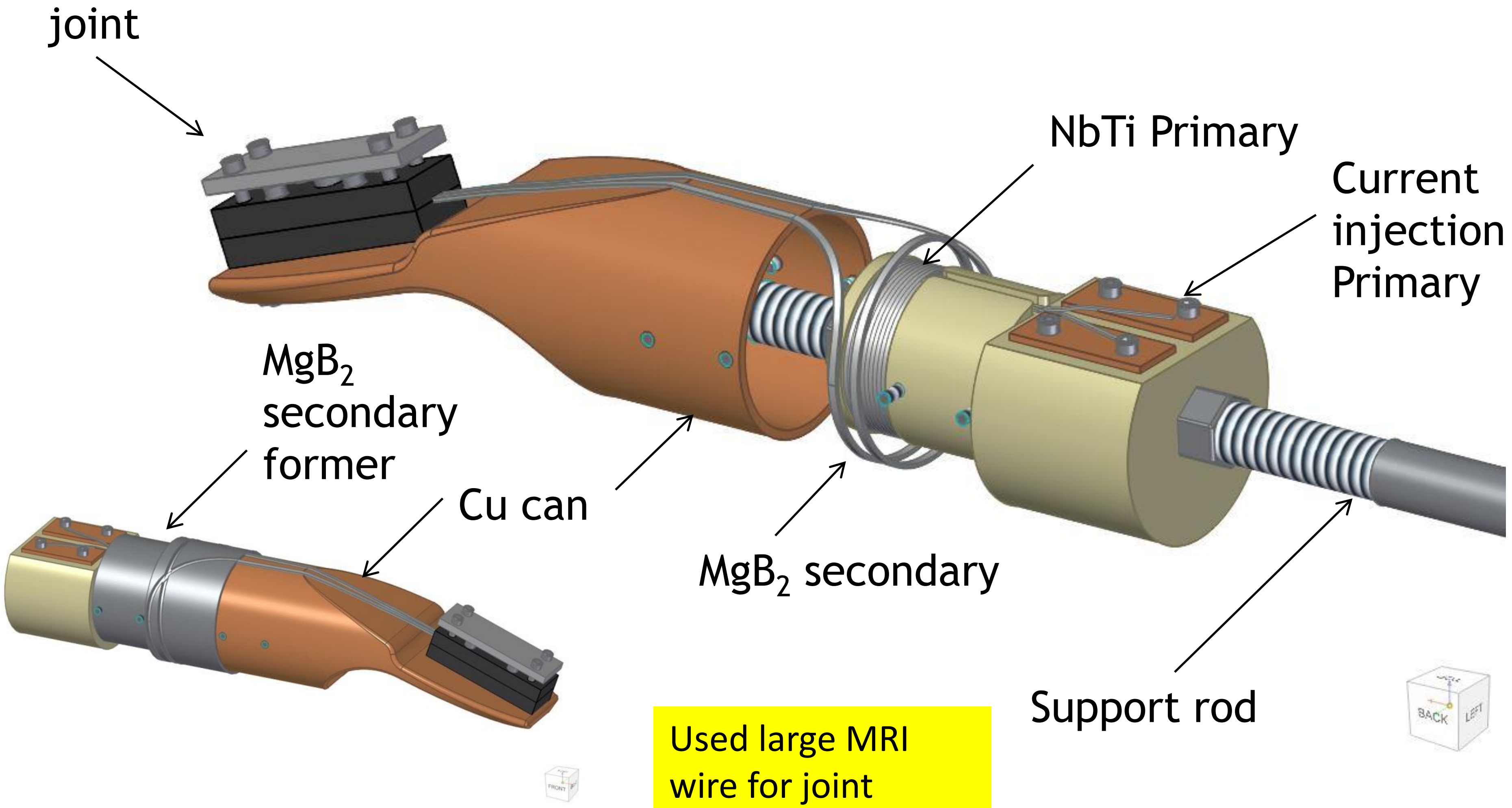
- An MgB_2-based react and wind coil (MRI coil) was made and is in the process of being tested as part of a technology development effort for MgB_2-based, cryogen-free, MRI.
- A square-shaped MgB_2 conductor was used to wind a large MRI-segment coil. The coil has an ID of 857.25 mm and used a total length of conductor of 1744.44 m.
- The coil was instrumented,epoxy impregnated, further instrumented, and is now being tested. In Initial cool down, the coil reached the target temperature 14K, next run target 10 K

Future Work

- To demonstrate target operational current and measure the load line
- To measure temperature distribution during a quench
- To initiate a quench, and investigate the voltage propagation property
- To investigate coil protection using an active quench protection scheme
- To incorporate SC joints and switches

Appendix

Larger Strand, vertical Persistent Joint Test Assembly



Used large MRI wire for joint

W&R style Joint -- Persistent Current vs B

Protocol

- Ramp to 4 T
- Ramp to zero field
- Observe decay