Spectrometer Solenoid Design and Test Results

Spectrometer Solenoid Review

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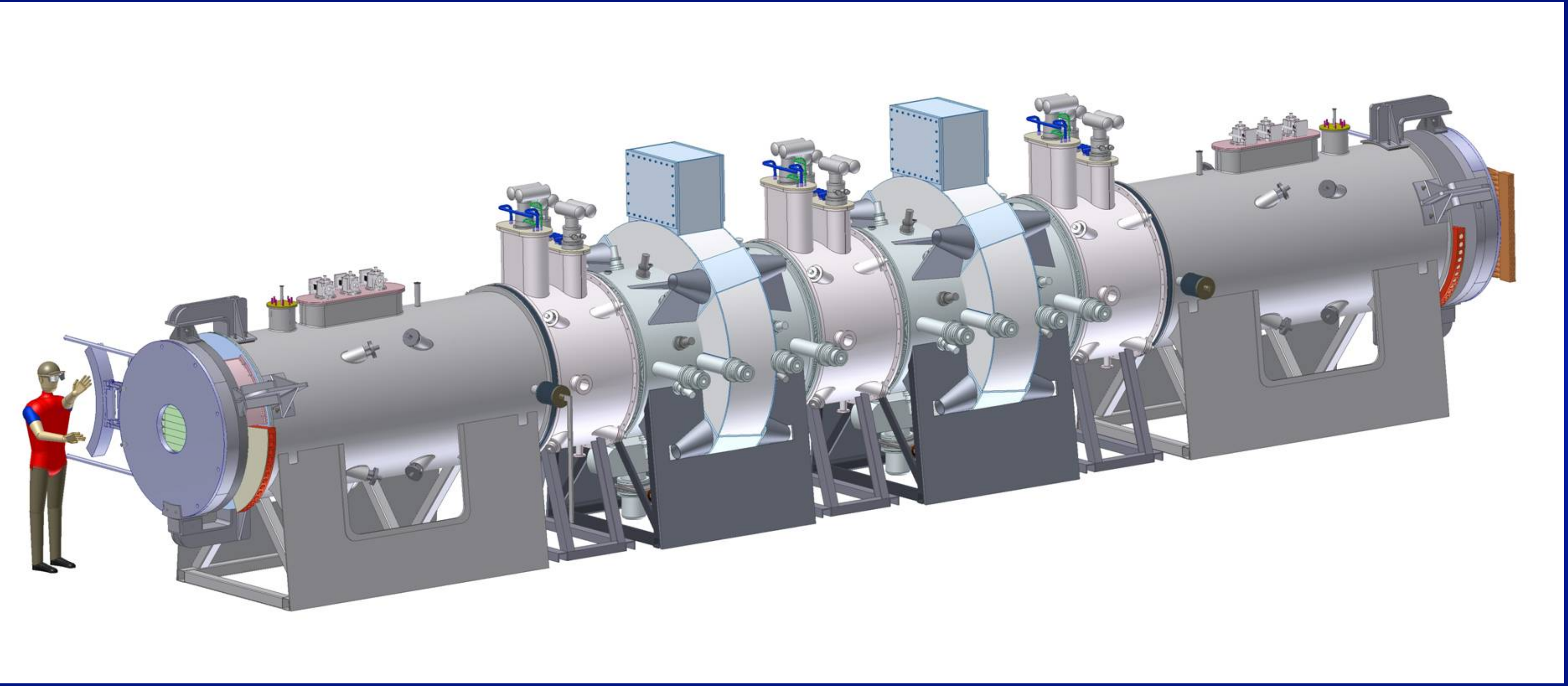
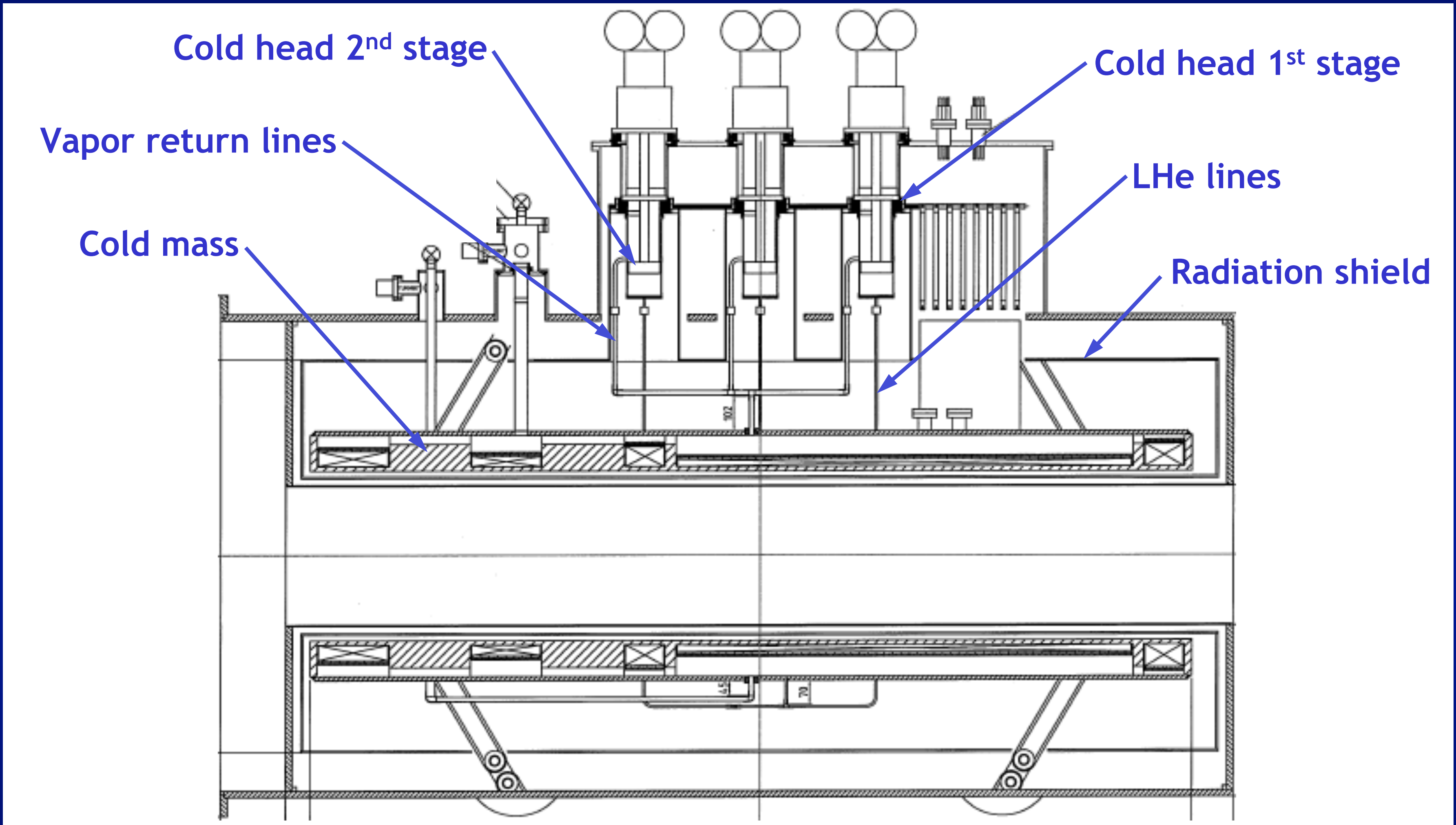
MICE Cooling Channel Layout



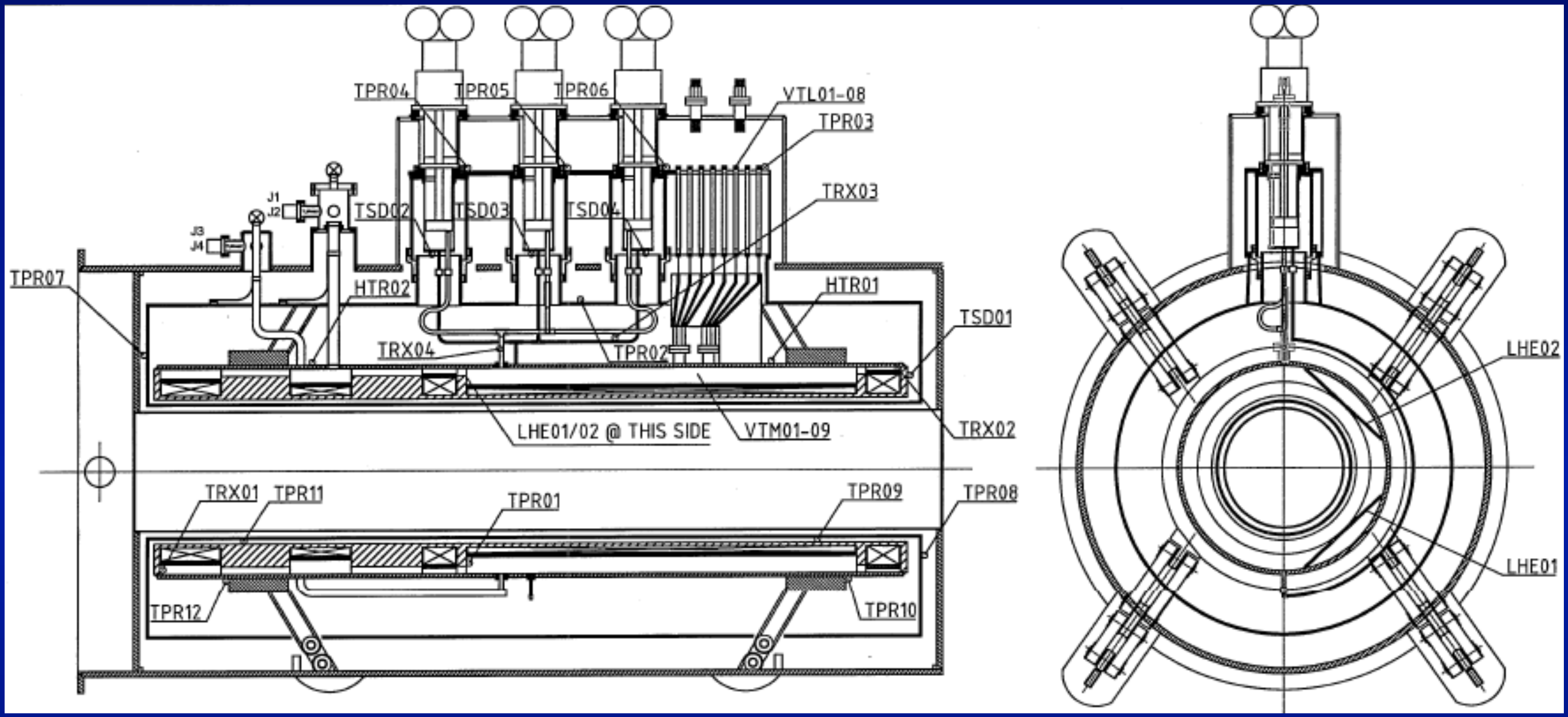
Topics

- Magnet 1 design features
- Magnet 1 testing results
- Modifications for Magnet 2
- Magnet 2 test results
- Photos for discussion

Magnet 1 Original Design



Temperature Sensor Locations



TPR: platinum resistor
TRX: Cernox
HTR: heater
TSD: silicon diode
VTM: voltage tap

Magnet 1 Testing Results

- Magnet cold mass was successfully cooled down to <5K using a combination of LN and LHe
- Cool down of the shield was very slow as there was no direct connection to the LN (i.e. shield cooling by radiation and conduction thru cold mass suppts only)
- LHe was boiling off from cold mass at a high rate
- Helium was not being condensed at all by the coolers
- Since the magnet was cold, an attempt was made to train the coils

Magnet 1 Testing Results (cont'd)

- The training reached 196 A in all coils (270 A needed to reach 4 T in the central coil)
- Magnet training was discontinued when the available cryogens ran out and so modifications could begin
- Based on measurements and observations, the coolers were not maintaining the LHe level, and the shield temperature was ~120 K rather than the specified 80 K
- These two issues were due to the thermal siphon line being plugged by frozen N_2 and an inadequate thermal connection between the cooler 1^{st} stages and the shield

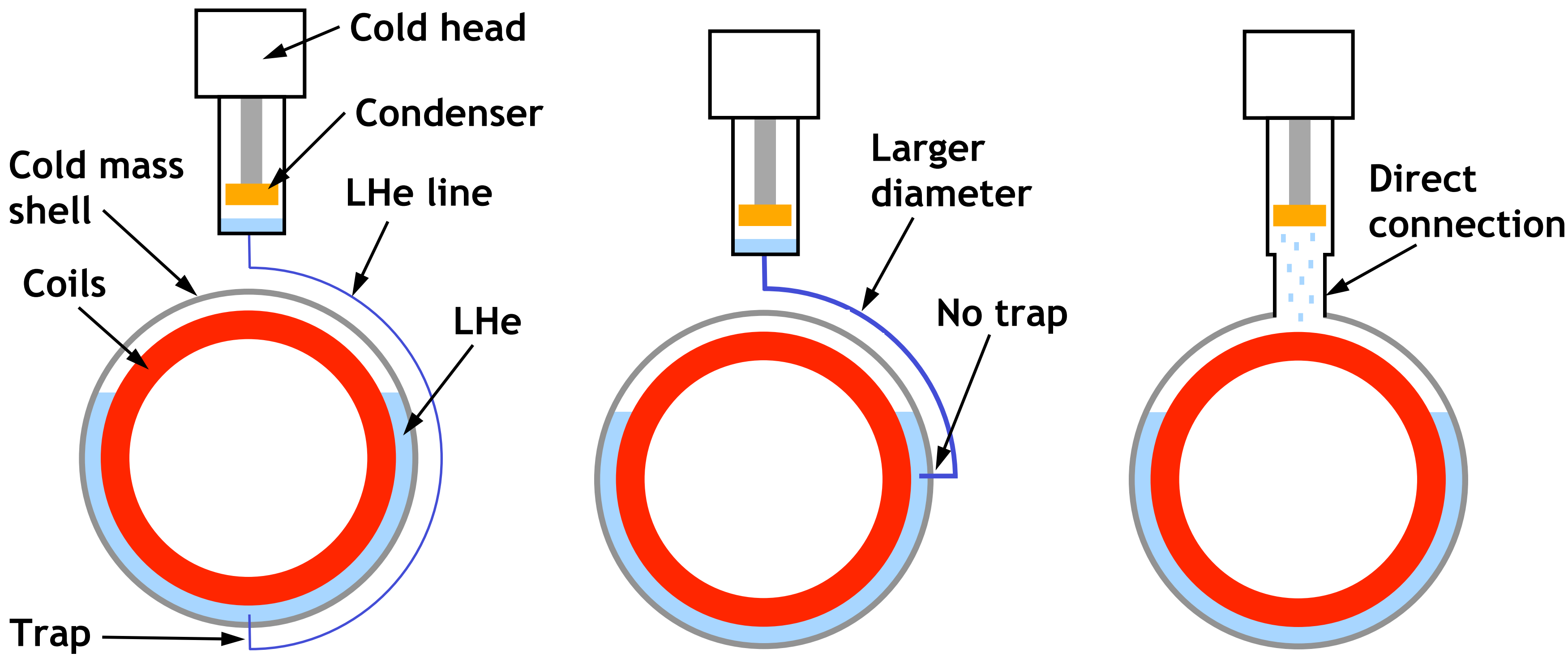
Magnet 1 Testing Results (cont'd)

- The blocked helium lines was mainly a procedural and partially a design issue
- Also, the pressure rise observed within the cold mass during quench was too high
- It was determined that the venting of the cold mass during quench was not sufficient due to crowding of the single vent line with instrumentation wires
- Several mechanical issues also arose: magnet alignment in vacuum vessel, support stand height, iron shield support pads, support stand offset

Magnet Design Modifications

- Based on the results of the Magnet 1 testing, several design modifications were proposed
- Work proceeded to complete the Magnet 2 assembly with design changes while starting Magnet 1 disassembly
- A new cold mass cooling scheme was devised as well as an improved cooldown procedure
- The 1st stage radiation shield connection was modified an an attempt to increase the thermal conduction
- An additional vent line was added to the cold mass
- An LN reservoir was added for direct cooldown of shield

Magnet Cooling Configurations



Original Design

(Magnet 1)

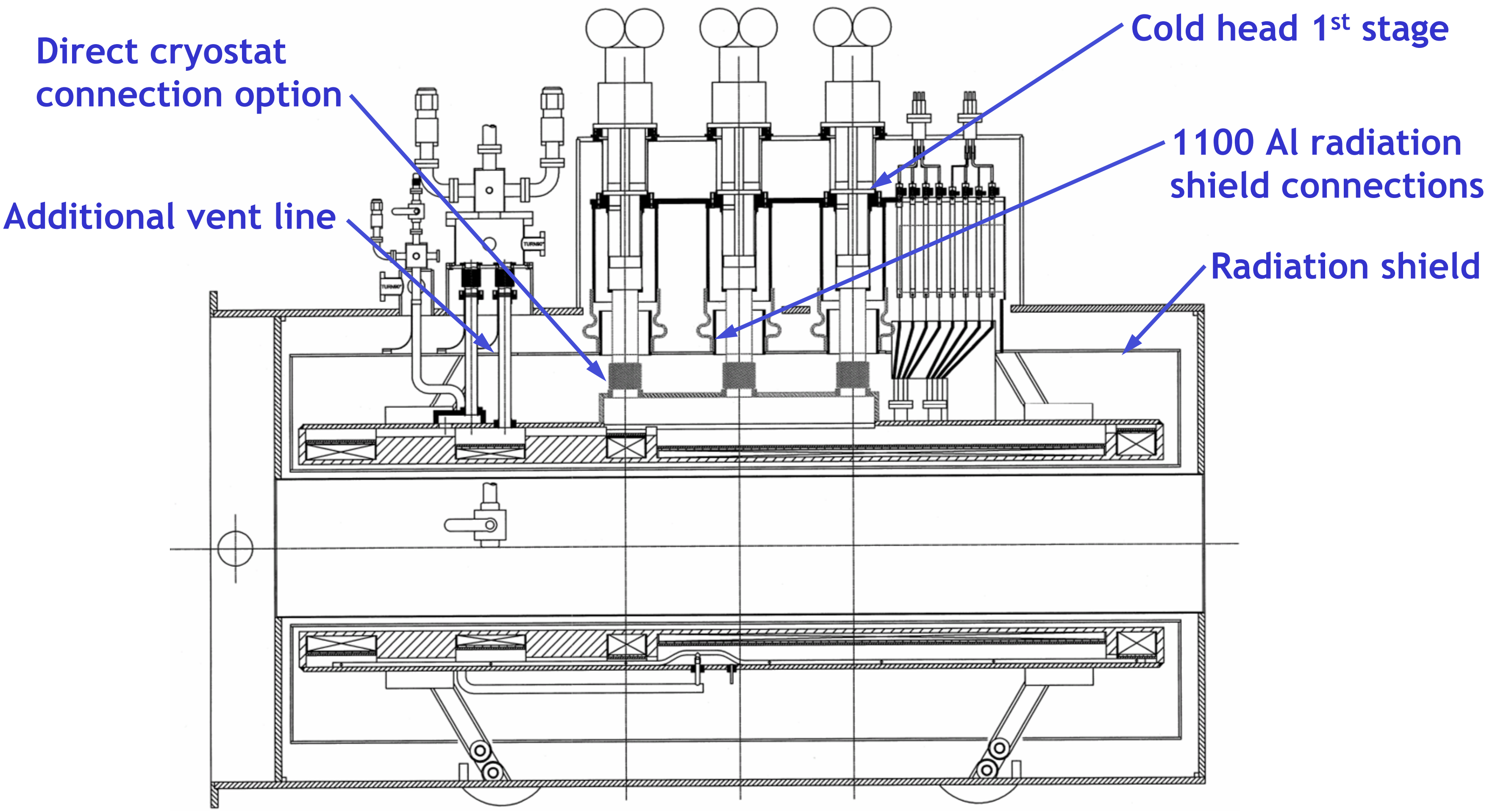
Design Option A

(not adopted)

Design Option B

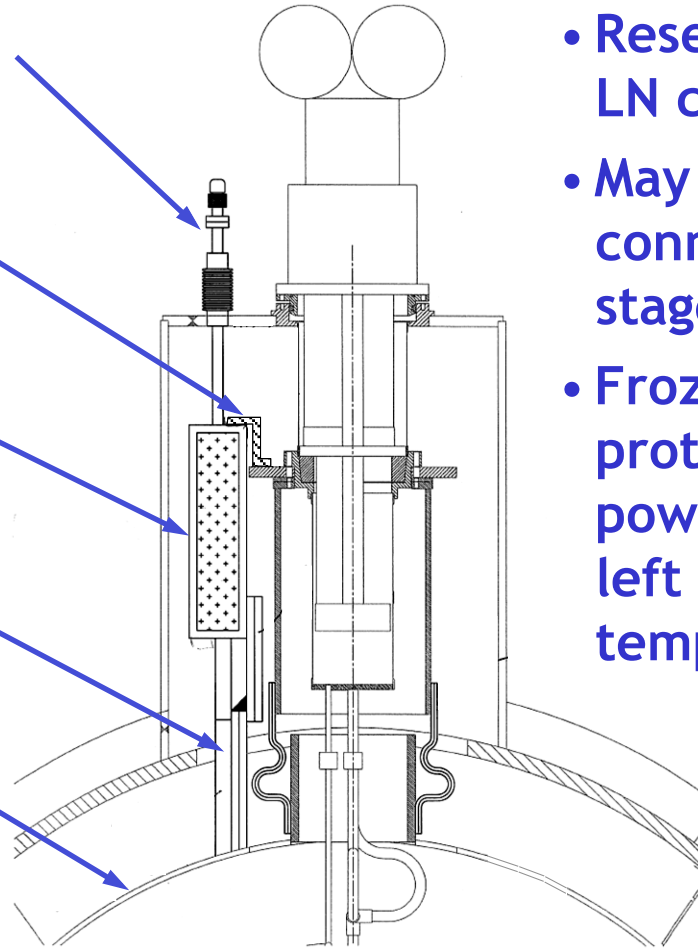
(Magnet 2)

Cryostat and Cooling System Mods



Liquid/vapor He
accumulator and
cryocooler sleeves

Liquid Nitrogen Reservoir



- Reservoir provides direct LN cooldown of shield
- May improve thermal connection between 1st stage of cryos and shield
- Frozen mass of nitrogen protects leads in event of power failure (if LN is left in reservoir and temp. is low enough)

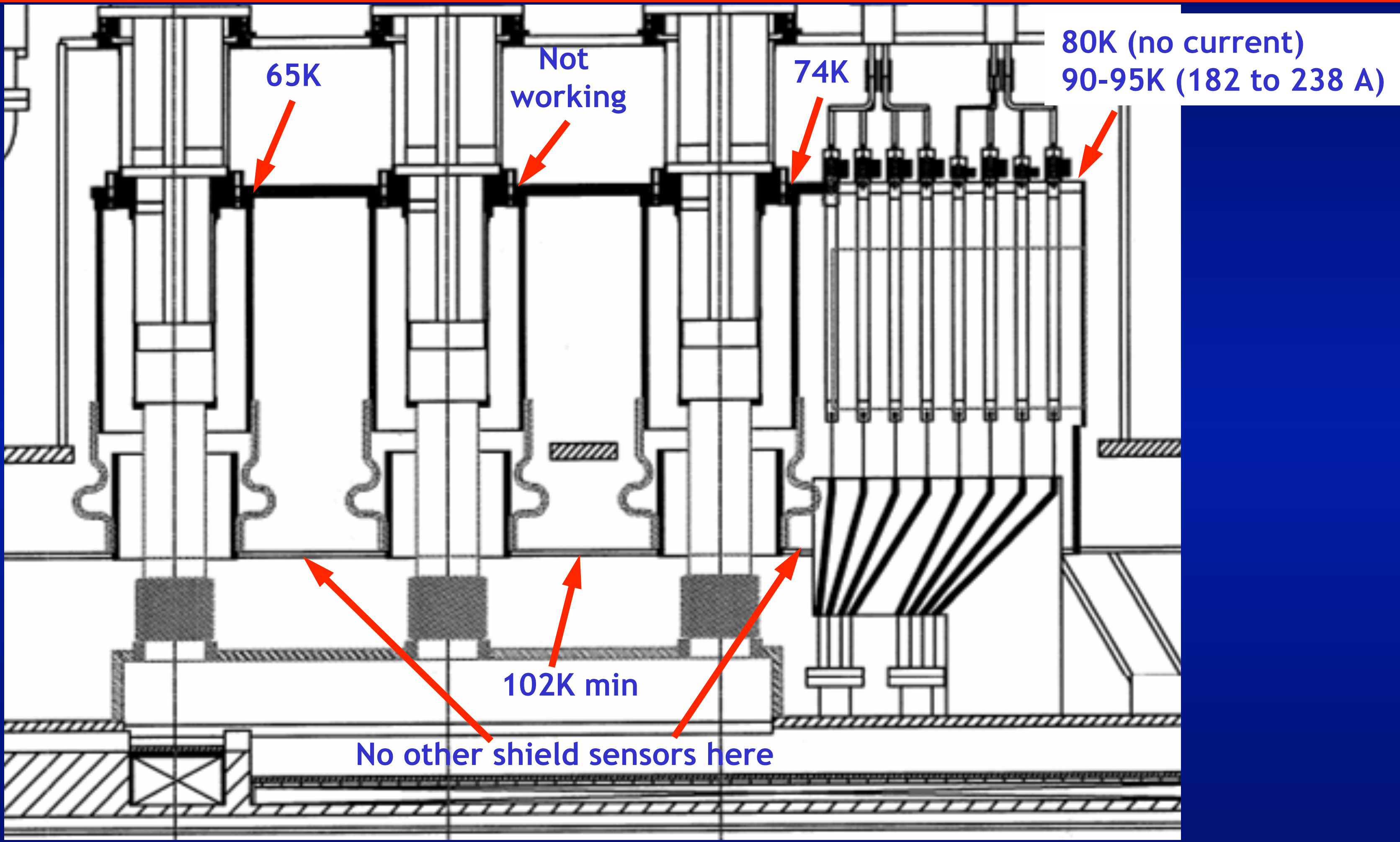
Magnet 2 Testing Results

- After completing the described modifications earlier this year, an attempt was made to cool Magnet 2 with cryogens
- An ice blockage developed within the cold mass fill line
- The fill line geometry (90° bends) prevented clearing of the blockage, and the vendor moved the stinger to a vent line
- Continuing the fill process led to a leak in a Conflat flange in the 2nd vent line (the one not being used for filling), venting the vacuum space to helium and aborting the cooldown
- The Magnet 1 fill line routing has been changed to avoid sharp bends and thus improve the ability to clear a blockage

Magnet 2 Testing Results (cont'd)

- After warming up the magnet, the Conflat flanges were replaced with welded joints
- Since the fill line blockage was likely a procedural issue, a safer and more robust technique for cooldown was devised (Bross/FNAL) and has worked well
- The subsequent cooldown was successfully completed in only ~3 days w/o incident
- However, the shield temperature fell slowly to only about ~115 K at the ends of the cylinder, resulting in added heat flow into the cold mass via the cold mass supports

Magnet 2 Measured Temperatures



Magnet 2 Testing Results (cont'd)

- The improved(?) shield thermal connections and the LN reservoir did not solve the previous shield problems
- The coolers are expected to maintain the LHe level after filling; ~1% of the LHe was being lost overnight (unpowered)
- At this point, training began and appeared to be going well
- The magnet underwent five training quenches at currents ranging from 182 to 238 A
- At 238 A (w/all coils in series), one of the HTS leads burned out due to a higher than allowable temp. at the upper end

Magnet 2 Testing Results (cont'd)

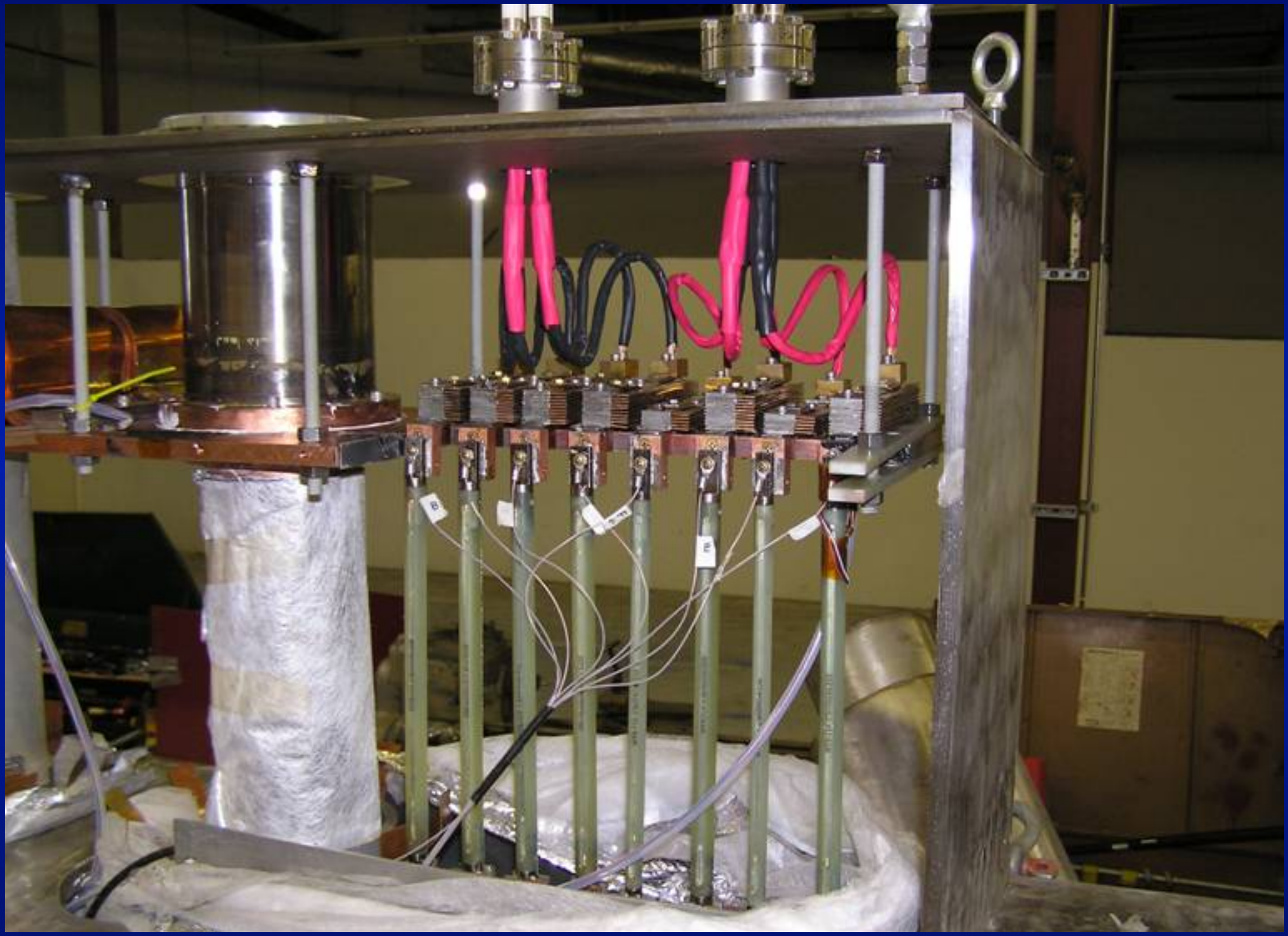
- The upper lead temperature without current was ~80 K, increasing to >90 K with current, eventually resulting in failure of the lead farthest from the coolers
- The lead problem was a surprise, as it was not noticed in the earlier Magnet 1 tests; the feedthroughs and all the leads are the same ones used before in Magnet 1
- We are currently thermally testing the feedthroughs and leads in an off line test to see what can be learned

Testing Results Discussion

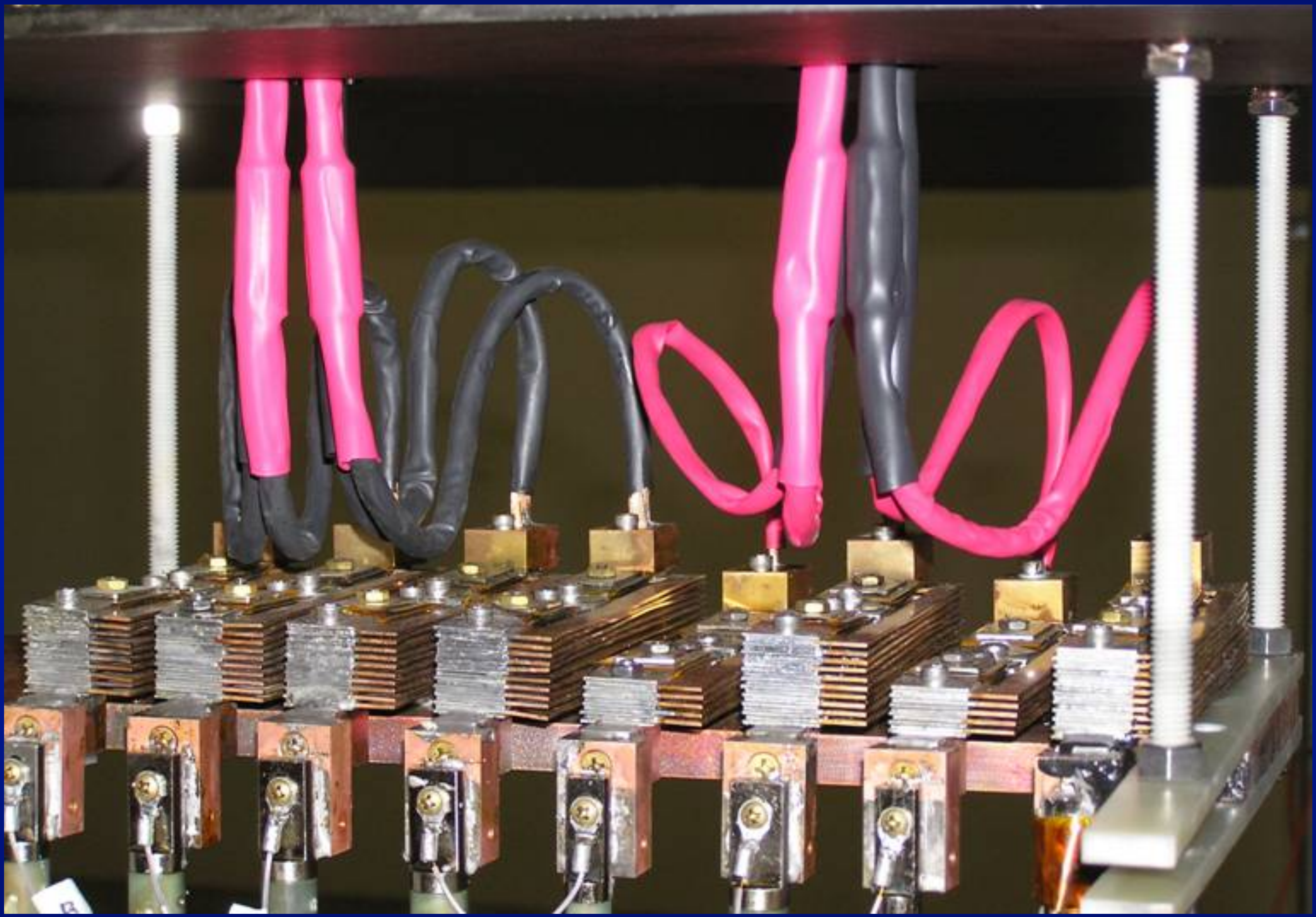
- Changing flexible connection does not appear to have had a major impact on shield temperatures
- New Al straps are thicker than the original Cu, but the Cu conductivity was better and the original straps were shorter
- Our vendor, Bert Wang, has stated that he believes the connection to the shield is inadequate
- There have been no indications of vacuum problems other than the seal failure that occurred in the vent line
- No local icing has been observed on the vacuum vessel
- Temperature measurements using a thermal laser probe have not revealed any irregularities

Photos for Discussion

Upper Leads and HTS Leads



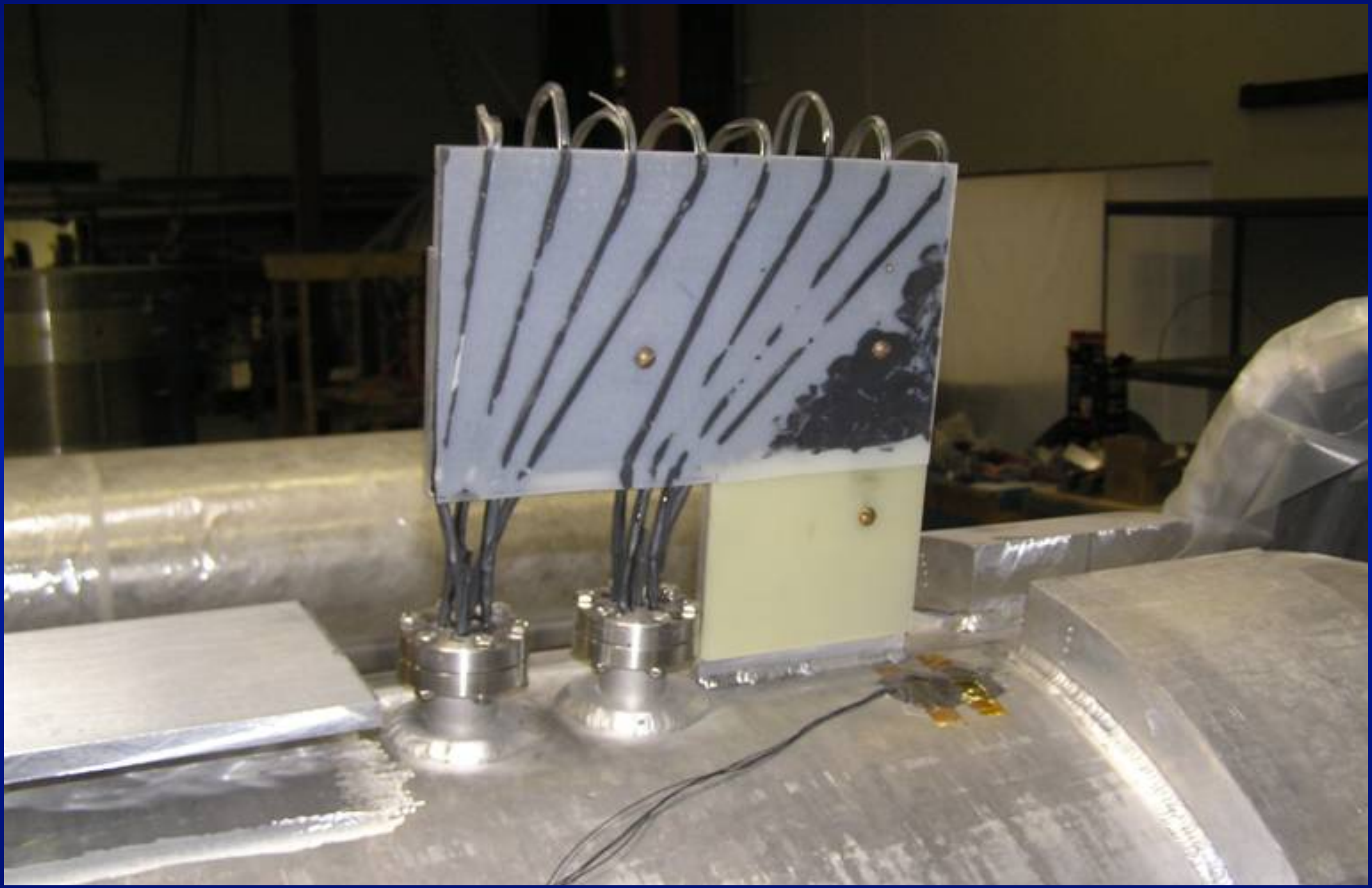
Upper Leads and Thermal Intercepts



Upper Leads and 300K Feedthrough

Upper HTS Leads Thermal Intercept

SC leads at cold mass feedthrus

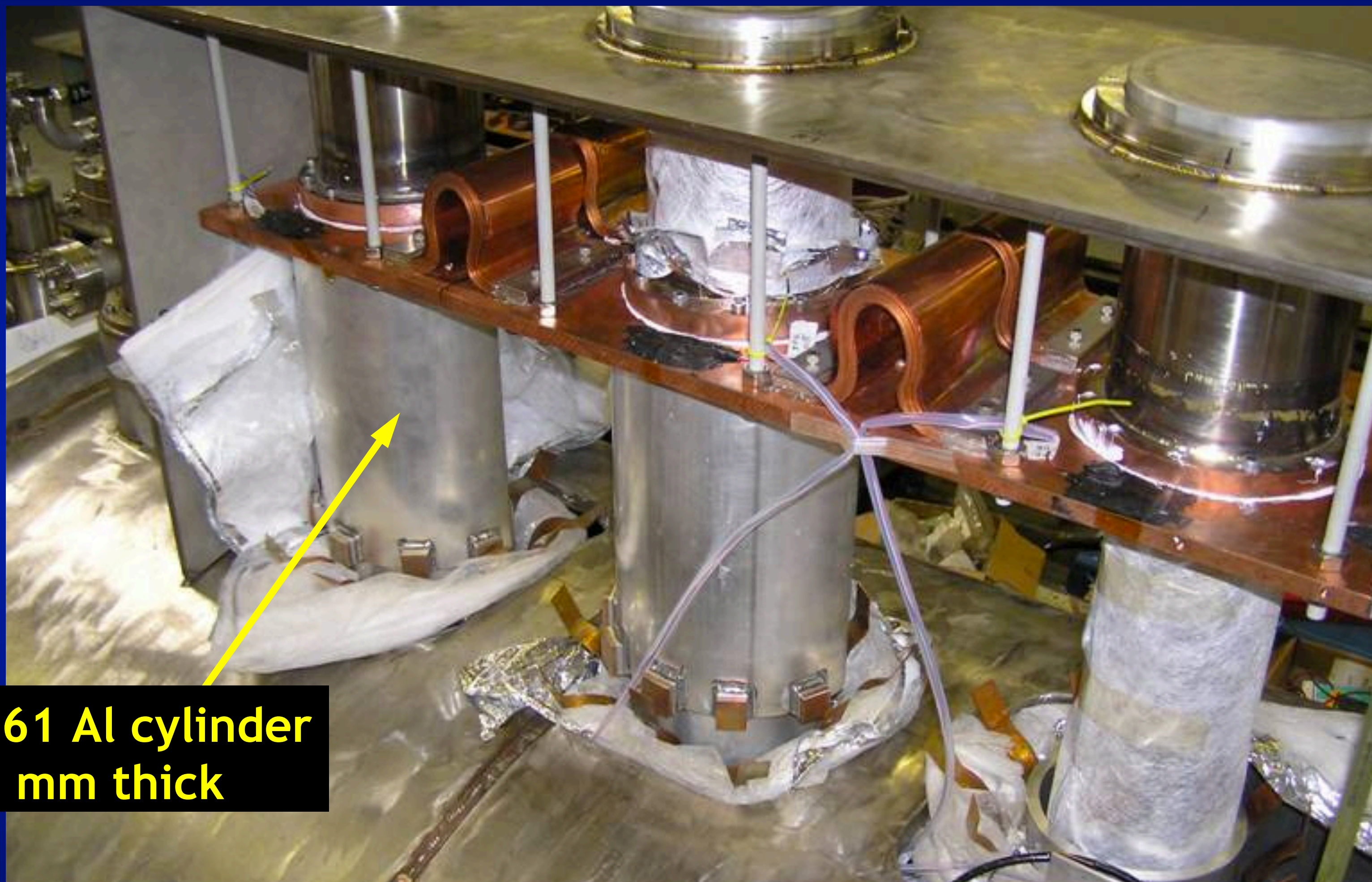


Coil Taps & Intercepts for Lower HTS Leads

Coil Taps & Intercepts for Lower HTS Leads

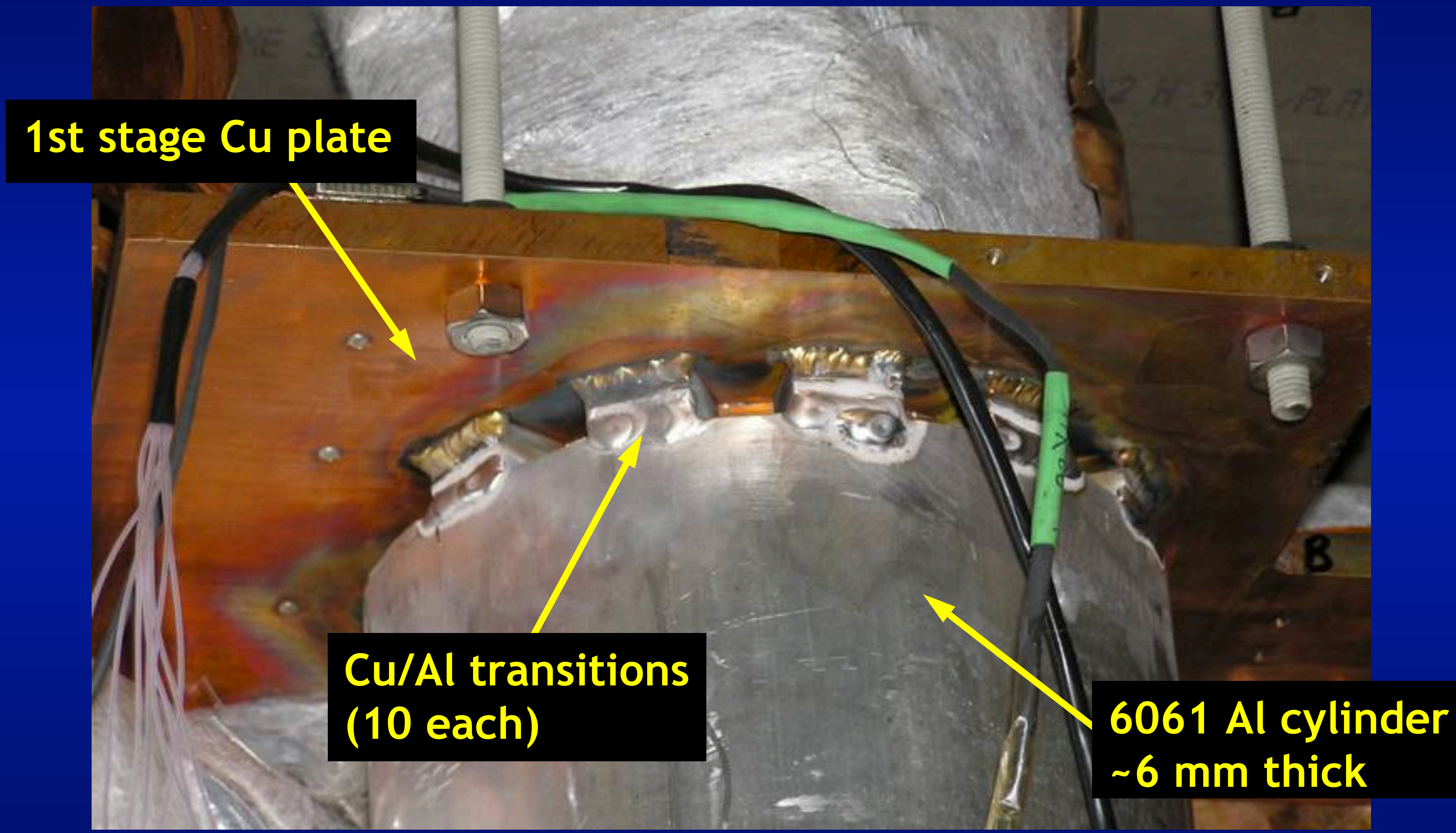
Magnet 2 HTS Leads (right lead burned out)

Radiation Shield Thermal Connection

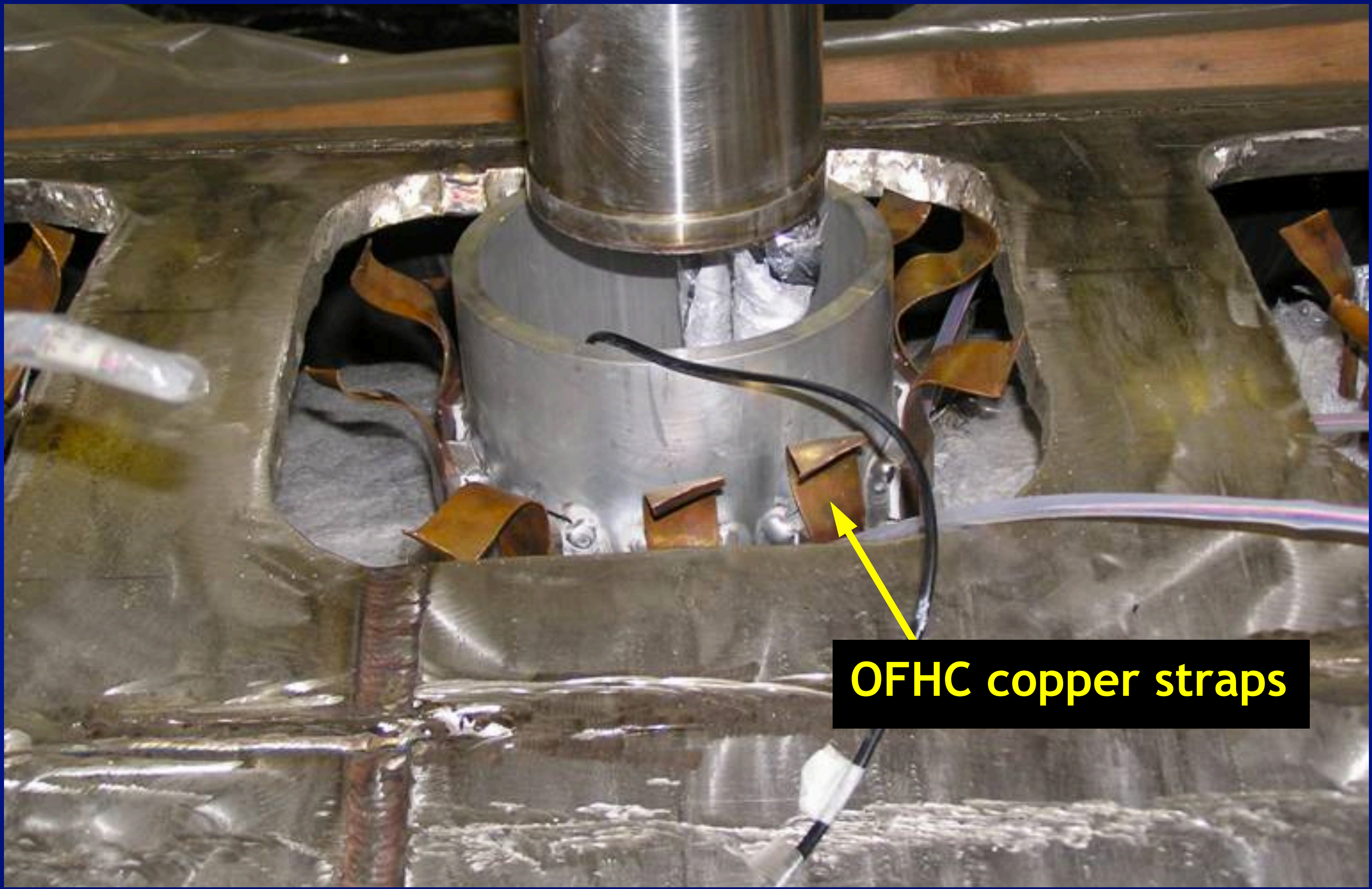


6061 Al cylinder
~6 mm thick

Upper Thermal Shield Connection

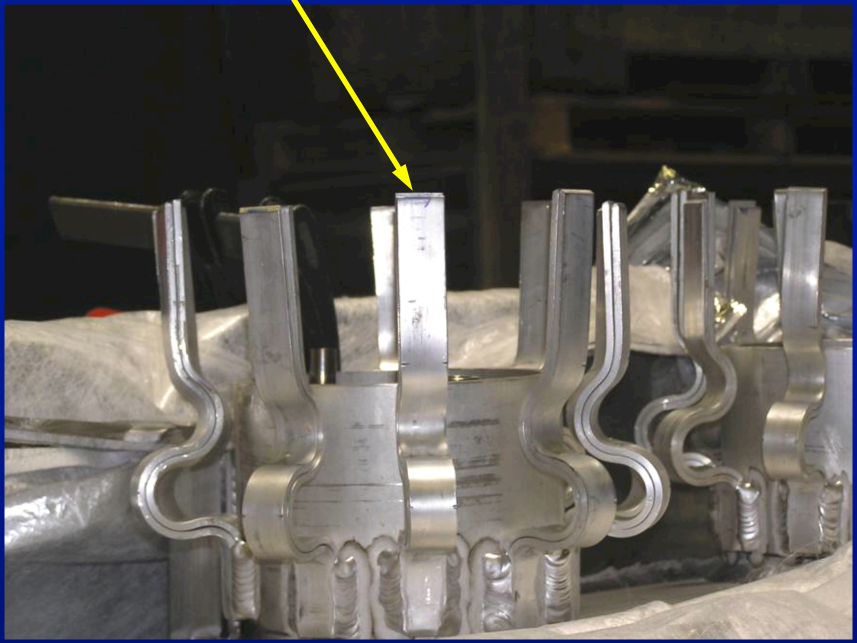


Magnet 1 Shield Flexible Connection



Magnet 2 Shield Thermal Connection

1100 series aluminum connection to thermal shield (previously thin copper)

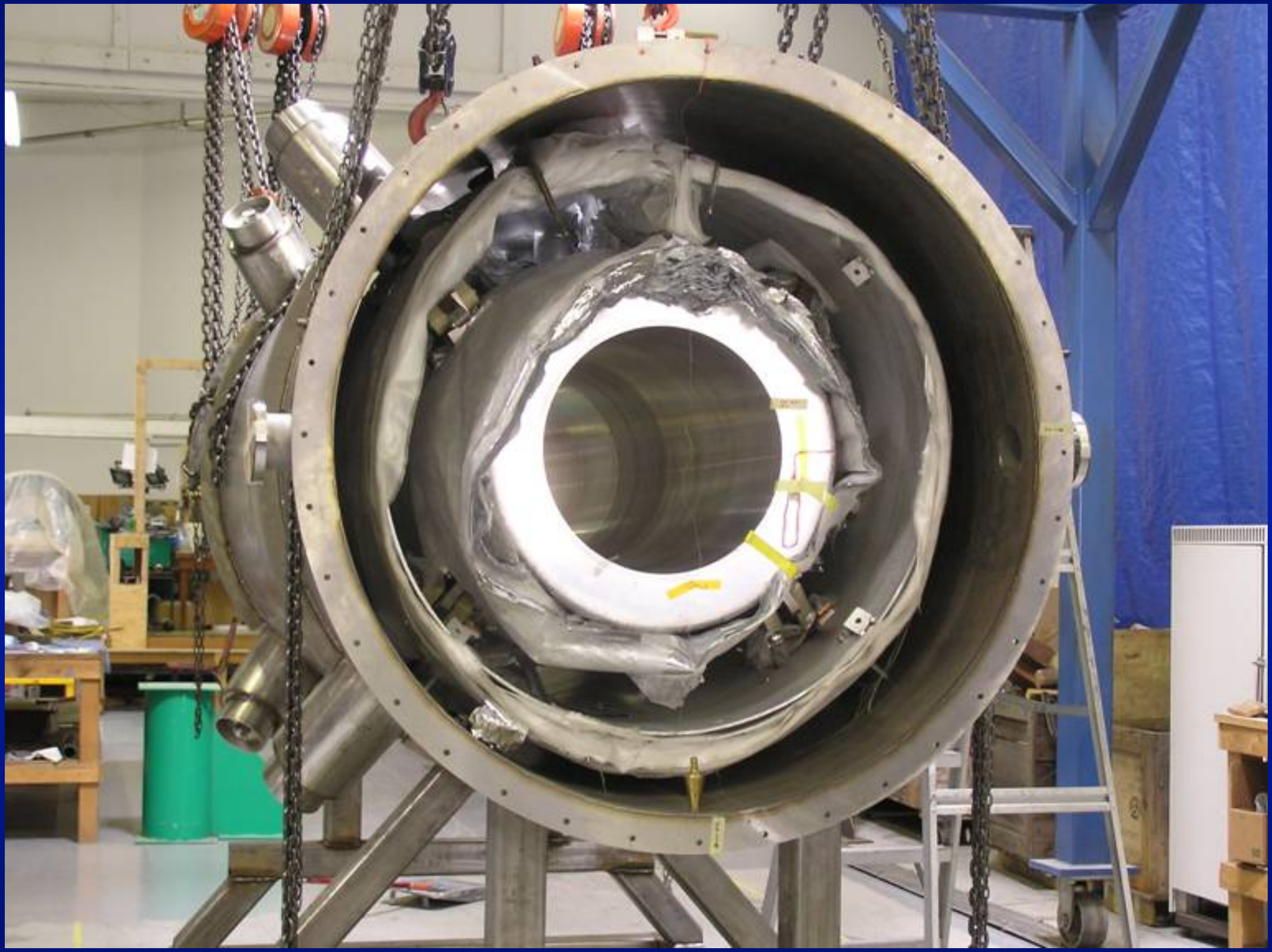


Magnet 2 Shield with Flexible Connections

Plates Welded to Shield for LN Reservoir

MLI Wrapped Cold Mass and Shield

Partially Assembled Magnet



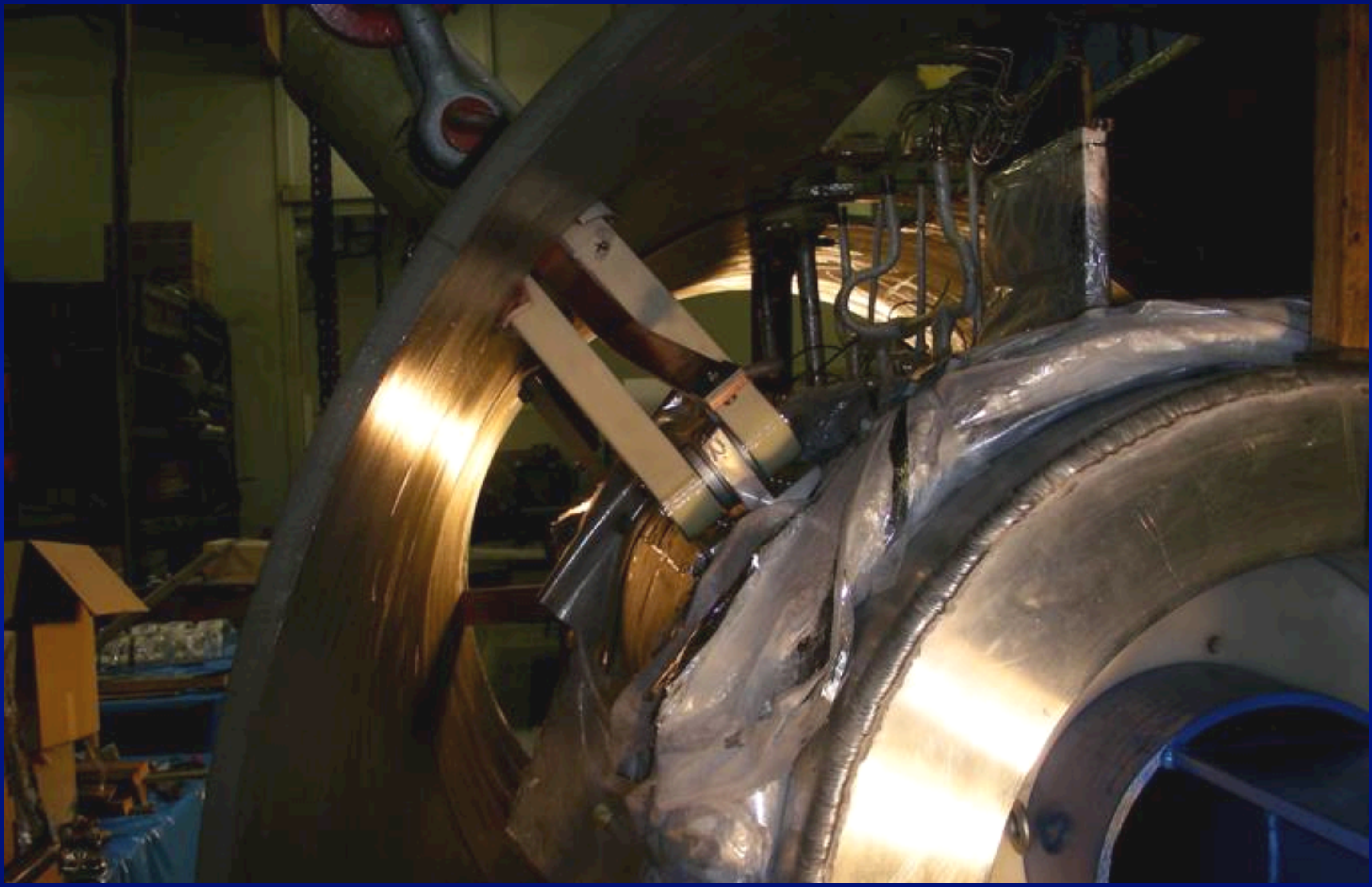
Close Up of Cold Mass End

MLI on Shield & Vacuum Vessel Inner Bores

MLI Wrapped Cooler Sleeves and Leads

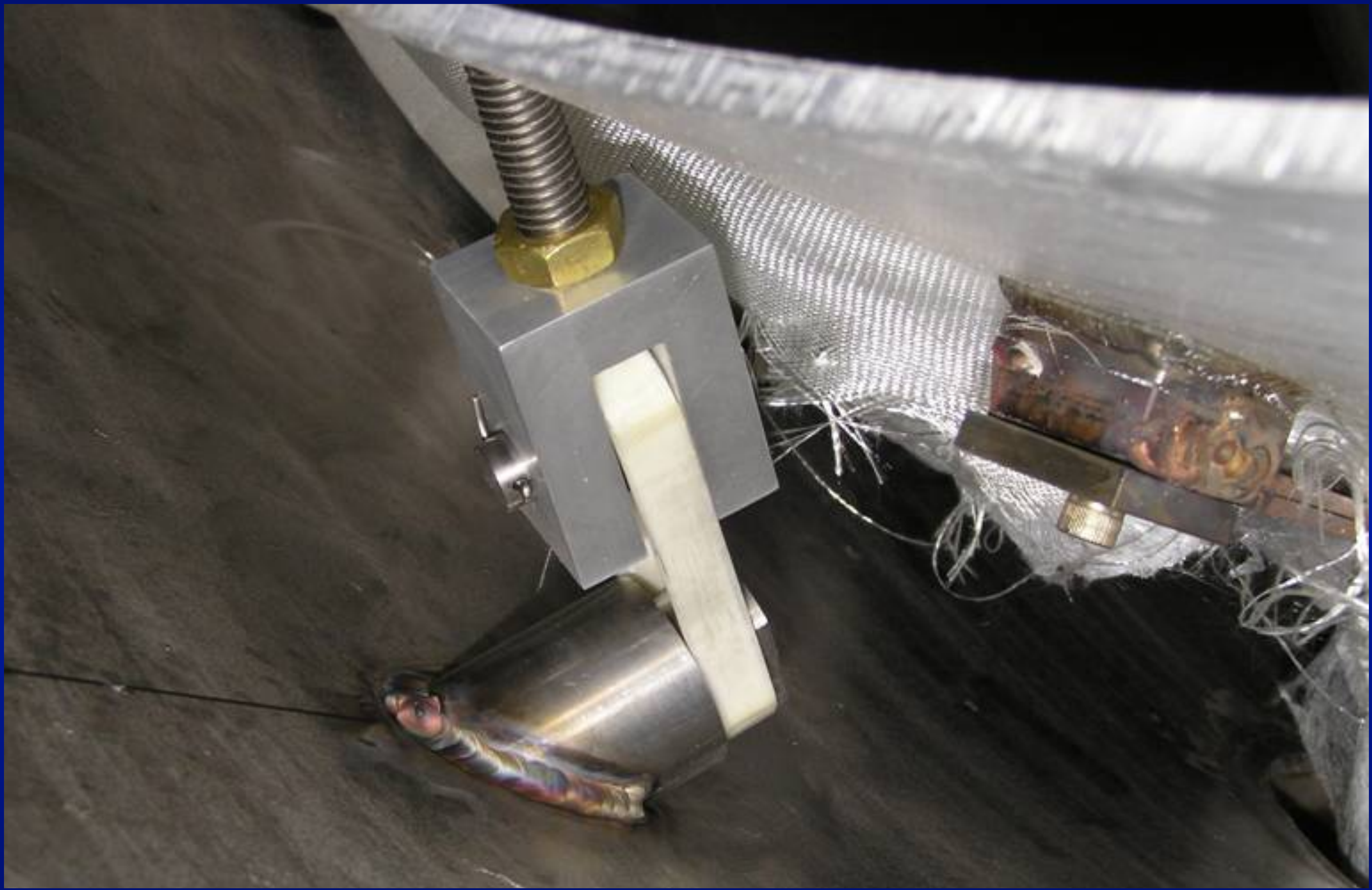
Cold Mass Connections (Magnet 1)

Cold Mass Support during Fit Up

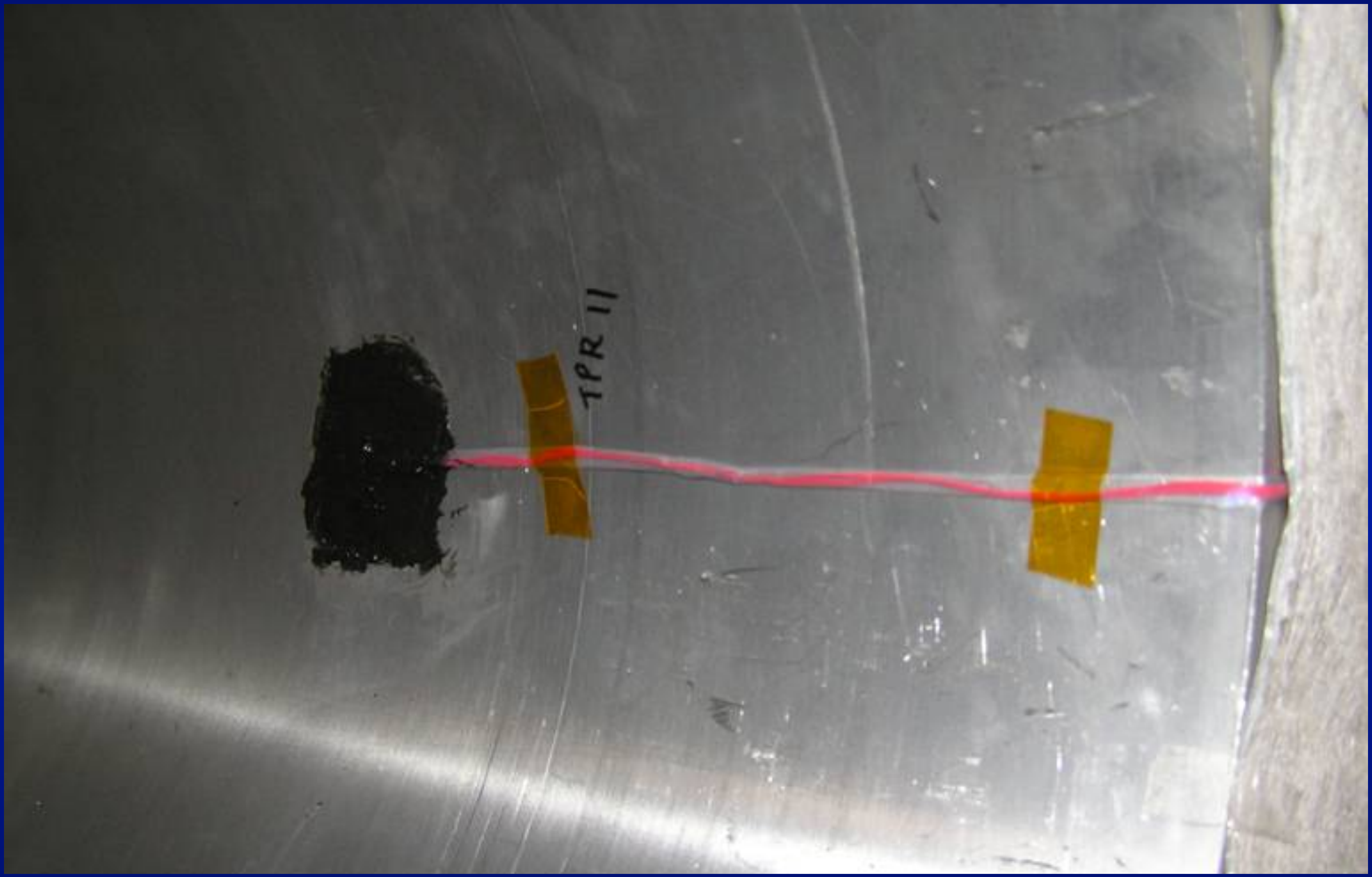


Cold Mass Support Connection to Shield

Thermal Shield Support



Temperature Sensor on Cold Mass Bore



LHe Cooldown of Magnet