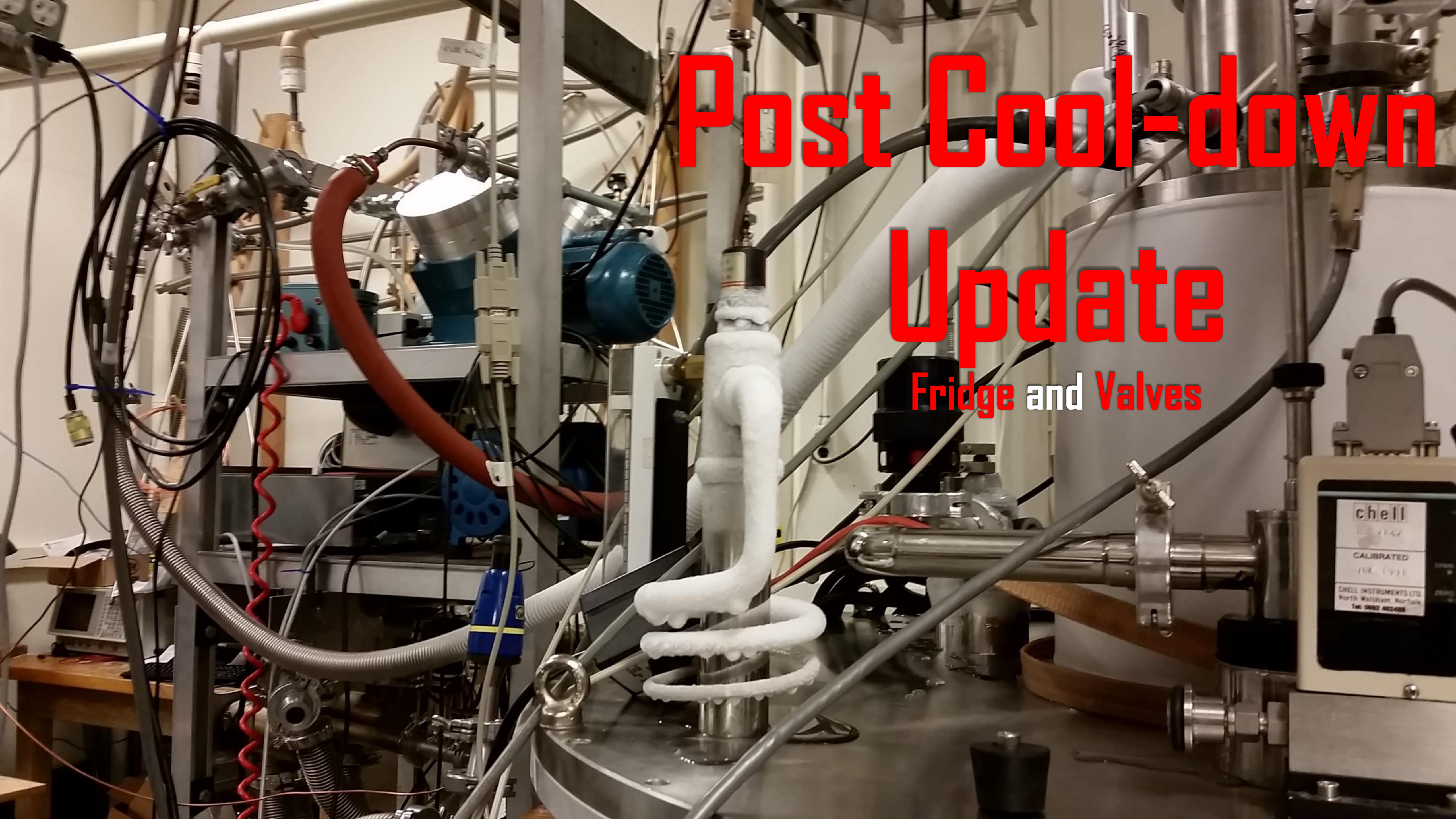
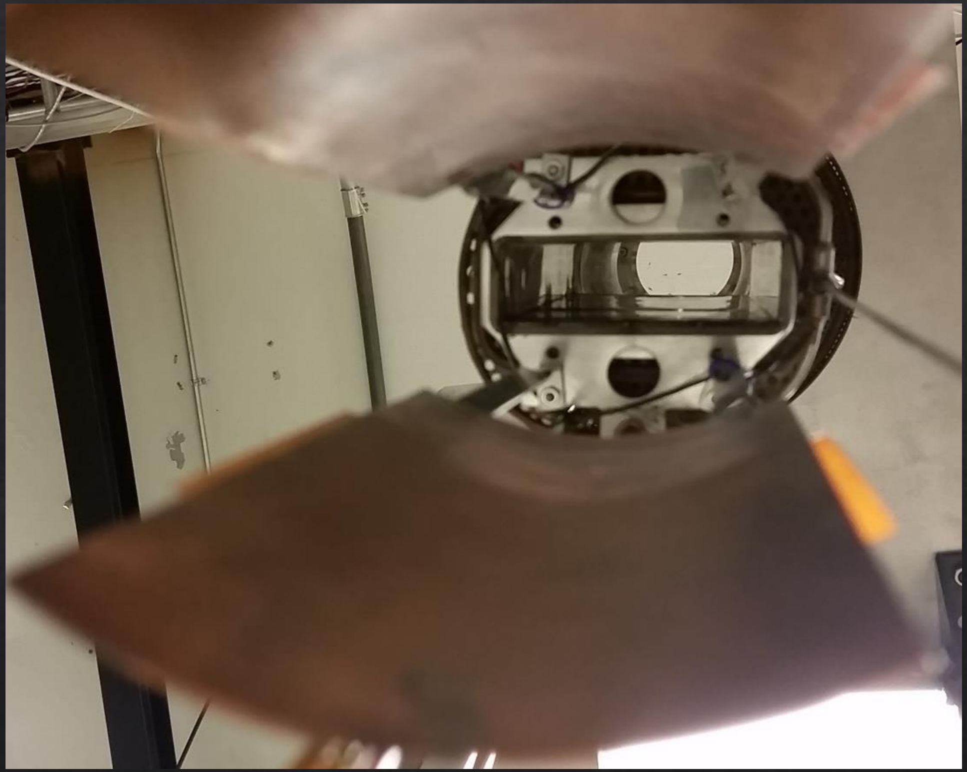
Post Cool-down Update

Fridge and Valves



Fridge Before Cool-down

- When we were doing final test fitting of the sticks, the "calibration stick" (the one with the cold NMR) got stuck in the fridge. One of the sharp corners of the insert ladder snagged the wall of the thin square tube in the lower heat exchanger and bent it such that the stick was trapped.
- We removed the fridge and Dave was able to fix it while we were at Fermilab.
- When we returned, we reinstalled the fridge.



Valves Before Cool-down

- We performed 'warm' tests to verify that the valves would open and close properly. These consisted of backfilling the fridge with first atmosphere, then ~1 atm. of warm Helium gas. The test procedure went as follows:
  - The separator was pumped down by the leak-checker until the leak rate was stable. Then the valve was opened 1 full turn, then closed. A timer was started when the valve was closed and stopped when the leak rate returned back to the starting leak rate or 10 minutes elapsed (whichever came first).
    - The valves were first operated by hand to generate a baseline.
    - Then the valves were operated by the stepper motors and the LabView VI.
    - Finally, the results were compared.
- Rationale: If the time it took for the leak rate to return to the starting value when the valves were operated by the stepper motors was considerably longer than the time when the valves were operated by hand, then the stepper motors aren't closing the valves sufficiently.
  - The fix would be to tighten the clutch.

Valves Before Cool-down: Results

Fridge backfilled with atmosphere

Run Valve	Baseline Leak Rate $\left(\frac{mbar \times L}{s}\right)$	Time back to baseline
Manual Operation	1.57×10^{-4}	1:14
Stepper Motor Operation	1.65×10^{-4}	1:10

Bypass Valve	Baseline Leak Rate $\left(\frac{mbar \times L}{s}\right)$	Time back to baseline
Manual Operation	1.45×10^{-4}	1:09
Stepper Motor Operation	1.40×10^{-4}	0:59

Valves Before Cool-down: Results

Fridge backfilled with ~1atm. of warm helium gas

Run Valve	Baseline Leak Rate $\left(\frac{mbar \times L}{s}\right)$	Time back to baseline	2 minutes elapsed	5 minutes elapsed	10 minutes elapsed
Manual Operation	2.75×10^{-4}	> 10:00	2.0×10^{-2}	3.0×10^{-3}	1.20×10^{-3}
Stepper Motor Operation	1.15×10^{-3}	~10:00	1.58×10^{-2}	3.2×10^{-3}	1.15×10^{-3}

Bypass Valve	Baseline Leak Rate $\left(\frac{mbar \times L}{s}\right)$	Time back to baseline	2 minutes elapsed	5 minutes elapsed	10 minutes elapsed
Manual Operation	$1.1. \times 10^{-3}$	~6:00	1.38×10^{-2}	1.64×10^{-3}	7.0×10^{-4}
Stepper Motor Operation	6.9×10^{-4}	~6:00	1.43×10^{-2}	1.59×10^{-3}	6.9×10^{-4}

Valves Before Cool-down: **Results**

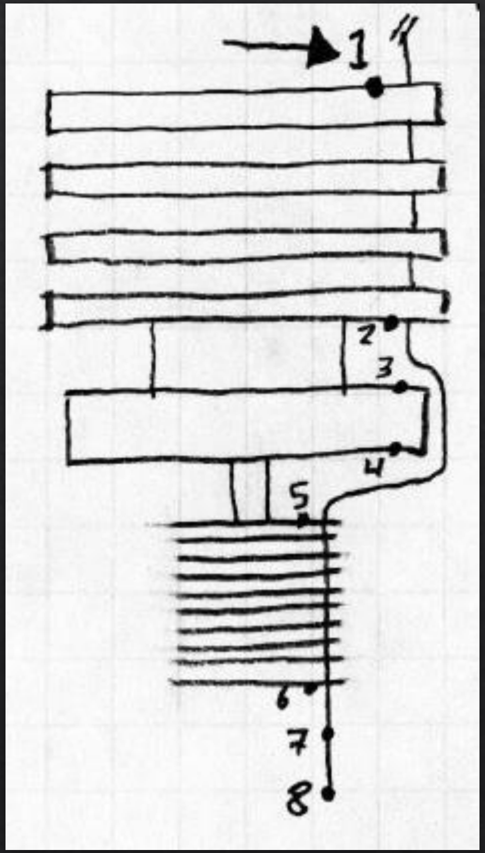
- Both valves performed consistently.
- It's interesting to note that the valves seemed to perform slightly better when operated by the stepper motors than by hand. That is, the time back to baseline was less with the stepper motor operation than the manual operation, especially with the fridge backfilled with atmosphere.
- Not too surprisingly, the time to return to baseline was tremendously longer when the fridge was backfilled with helium as opposed to atmosphere.
- <u>Note</u>: Helium saturation of the leak checker may have skewed the results for the helium tests, but the overall behavior still implied proper operations of the valves.
- Thus, we concluded that the valves are okay.

Fridge During Cool-down

- The fridge is outfitted with eight 1KΩ chip resistors that act as temperature sensors. Their operation is as follows:
  - At room temperature, the resistors are 1KΩ ±1% plus the series resistance of the cryo-wire which ranged from ~5Ω for sensor #1 (shortest wire) to about ~25Ω for sensor #8 (longest wire).
  - Thus at room temperature, the values ranged approximately as follows:

Sensor 1:	1005 Ω	Sensor 5:	1012 Ω
Sensor 2:	1007 Ω	Sensor 6:	1020 Ω
Sensor 3:	1009 Ω	Sensor 7:	1023 Ω
Sensor 4:	1011 Ω	Sensor 8:	1025 Ω

  - As the temperature of the resistor decreases, the resistance increases. The collected data hasn't been analyzed yet but rough values for 4K liquid helium is in the range of 1200 Ω and 1K around 1600 Ω.
- Issues:
  - Sensor 1 wasn't behaving as expected.
    - It was mounted on the perforated copper, not on the heat exchanger copper tube.
      - Not very responsive. eg. Sensor 2 would indicate liquid helium and sensor 1 just said it was kind of cold in there.
  - Sensor 8 gave erratic behavior when liquid helium was first introduced.
    - Likely broke free from its mount and has a loose lead.

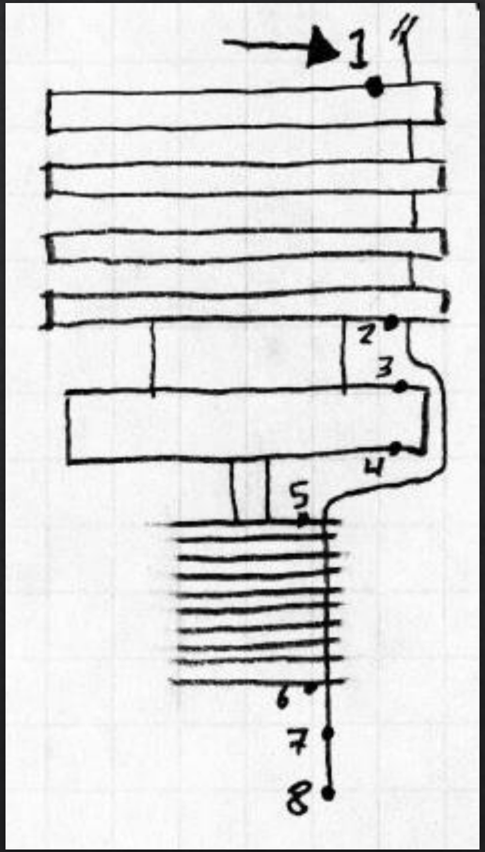


Fridge After Cool-down

- The Lake Shore showed the following readout this morning:

Sensor 1:	1004 Ω	Sensor 5:	1010 Ω
Sensor 2:	1007 Ω	Sensor 6:	1022 Ω
Sensor 3:	1007 Ω	Sensor 7:	1023 Ω
Sensor 4:	1009 Ω	Sensor 8:	1184 Ω

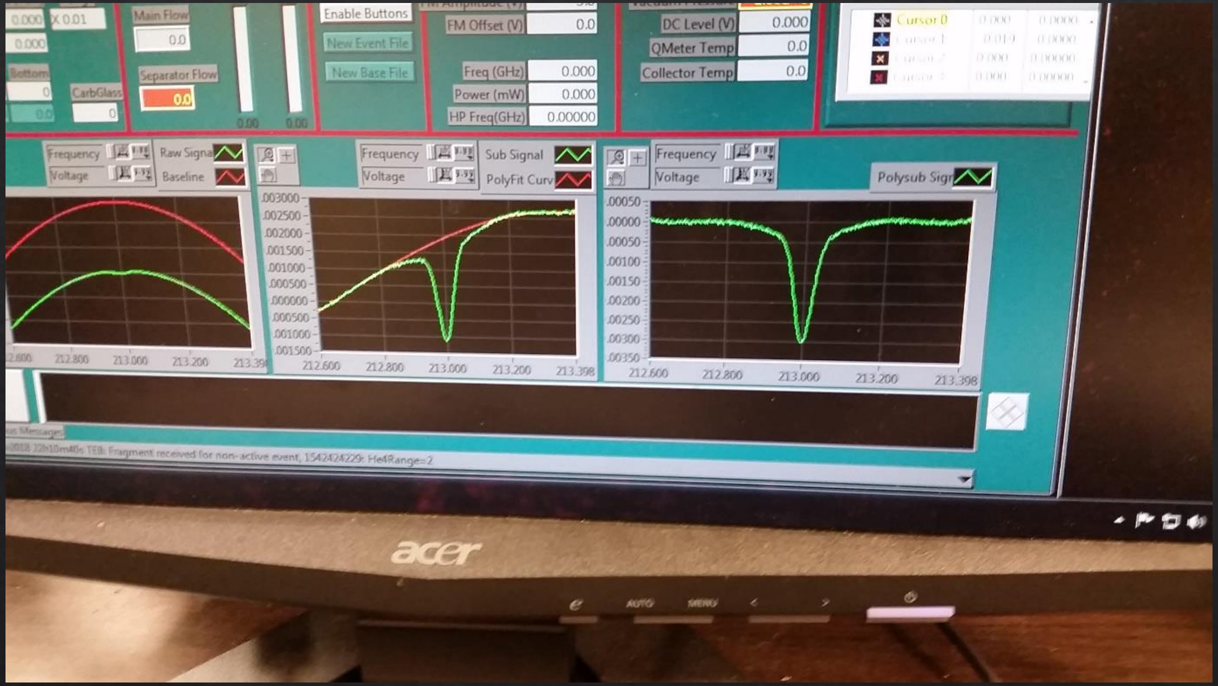
  - This implies there is a little liquid helium still in nose piece (unlikely) or sensor 8 is damaged/faulty.
- In either case, all sensors will be replaced mounted on the most effective locations the next time the fridge is removed.



Valves During Cool-down

- The software was able to control the valves in 'manual' mode without any issues. However, the 'automatic' mode was not operating correctly (at all). We learned this the hard way when we first started filling the fridge.
  - The VI was set to 'automatic' which should have maintained an 80% level in the nose.
  - However, the level probe instrument and the VI were not communicating properly so the true level was not being sent to the VI. Thus, the VI thought the level was 0% and never closed the run valve.
  - This led to the fridge filling to the top, freezing the O-ring on top of the magnet, breaking the vacuum and causing a quench.
- Fortunately, Emma was able to fix the VI and get the PID loop to work properly. We verified this during the latter half of the cool-down.
  - Unfortunately, this fix still has some limitations.
    - If the level stays in between 0% and 100% on the level probe during 'automatic' operation, then all is good. Ideally of course, this should always be the case.
    - However, since the world is not perfect, if the level is outside of that range, then the VI assumes the level is 0% and will operate the run valve accordingly. ie. Leave it open, leading to a flood and quench.
- What situation could cause one of these "out of bounds" situations?
  - The most probable is the run valve sticking. By sticking, I mean some atmosphere gets into the threads and freezes, preventing the valve from moving.
  - Potential solution: mechanical diode

Proton Signal



Deuteron Signal