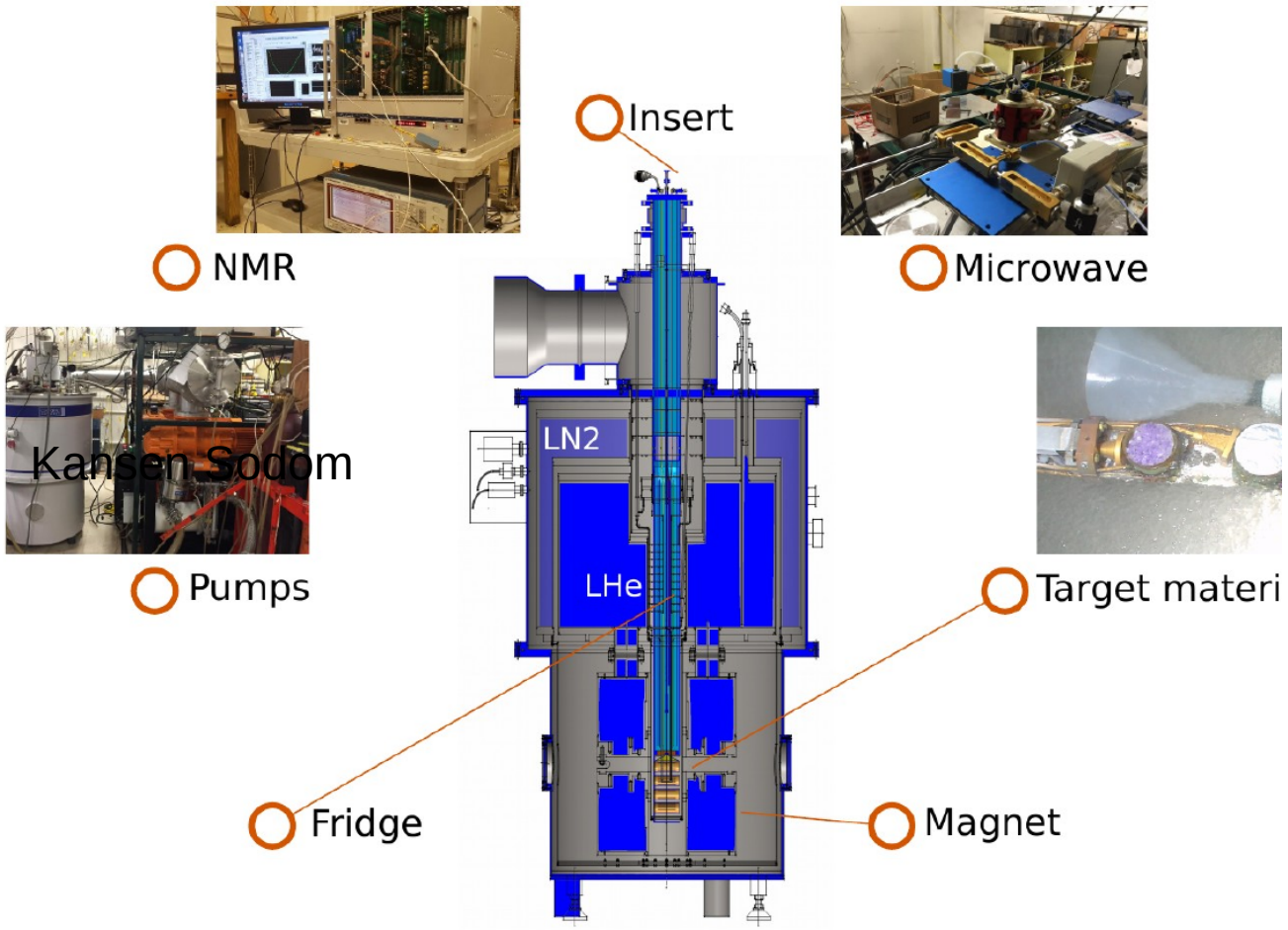
Polarized Target Update E1039

Polarized Target Group

University of Virginia

- NMR System
- Microwave Generator
- Magnet/Pumps
- Evaporation Fridge



* Thanks to Misha

Dynamic Nuclear Polarization (DNP)

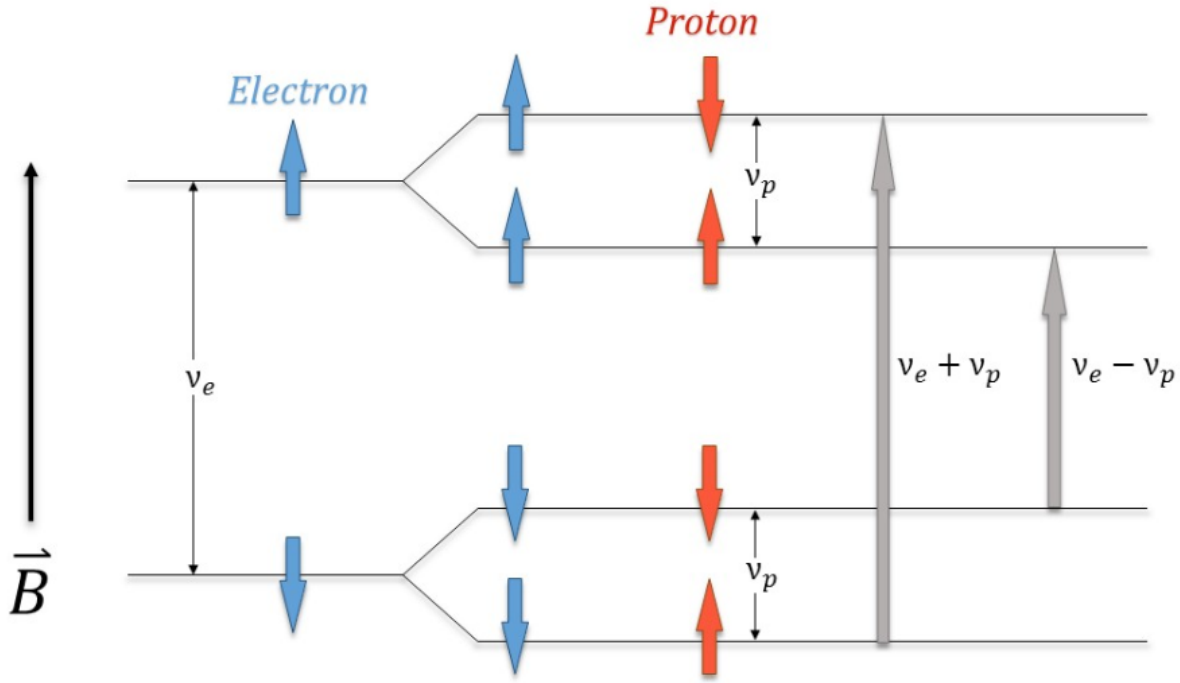
For a system with of unpaired electrons in the target material, hyper-fine splitting gives four discrete energy levels.

$$H = \mu_e B + \mu_p B + H_{ss}$$

Applying an RF signal at the proper frequency we can driven into a preferential state; the relatively short relaxation time of the electron versus the proton is crucial in pumping the polarization to a higher value.

The electrons spins are flipped using an RF-signal at the electron paramagnetic resonance frequency (epr).

The proton spins are flipped using a RF-signal at the nuclear paramagenetic resonance frequency (nmr).



In this way, positive or negative proton polarization can be achieved using the proper RF-signal size.

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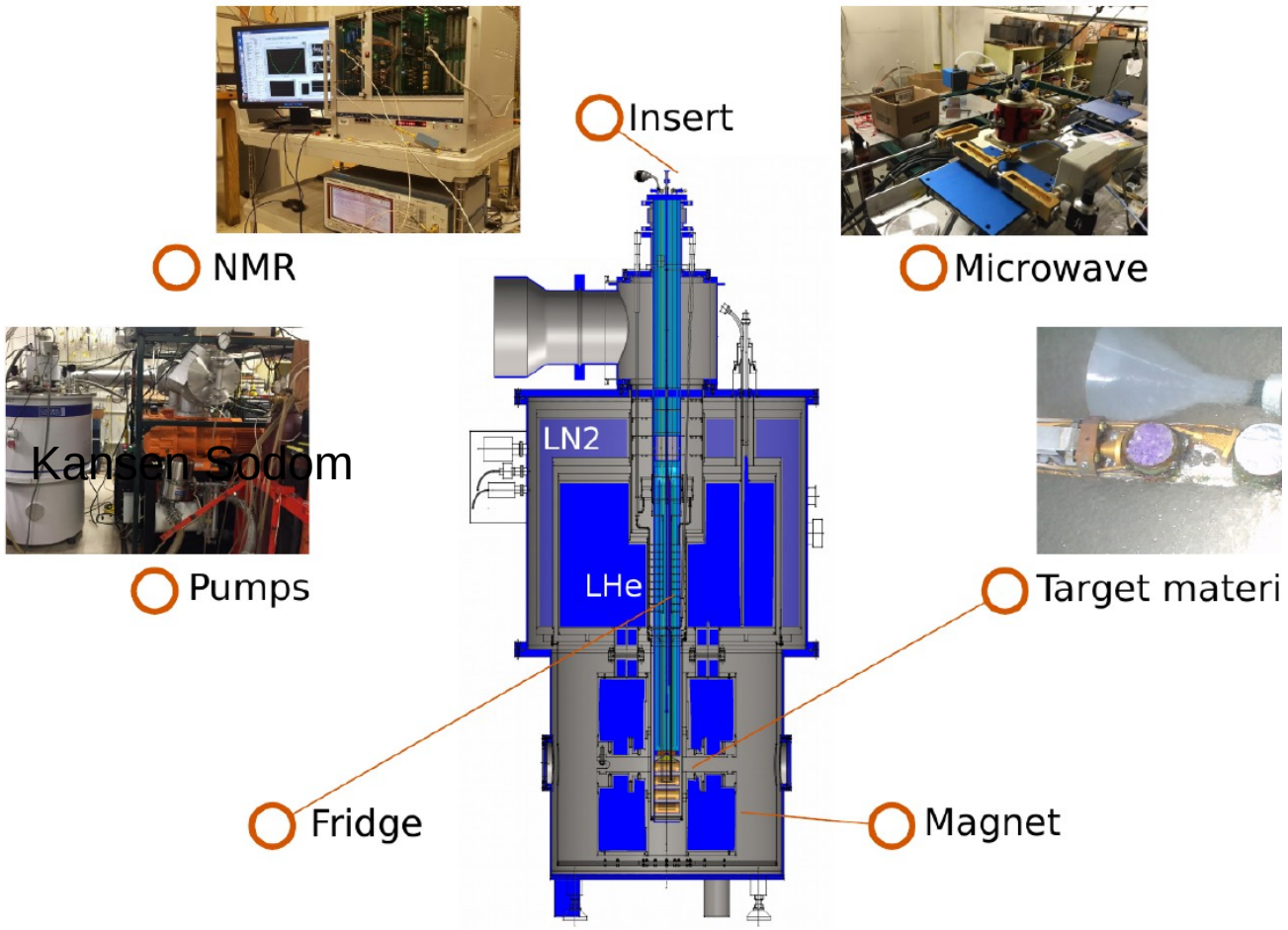


NMR Systems

LANL NMR and cold NMR delivered and setup thanks to Kun.

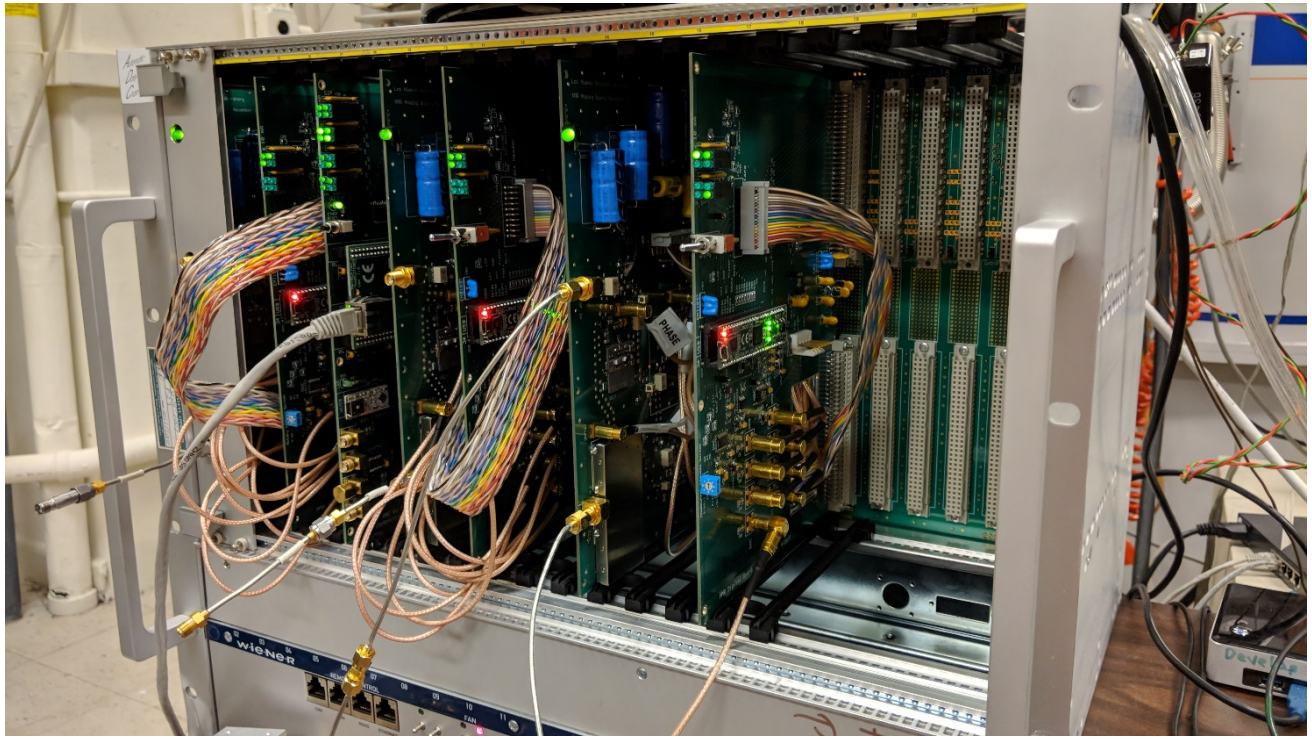
Bench tests to determine behavior of each system are needed.

- Linearity (Started)
- Temperature sensitivity
- Phase sensitivity

Testing of systems has been slow until recently due to documentation issues and differing data formats between PDP and the LANL NMR .

Libraries that exist to analyze PDP data modified slightly to work with LANL data format – needed an intermediary.

Long term it would be beneficial to make some small changed to LANL data format that would make integration much easier.

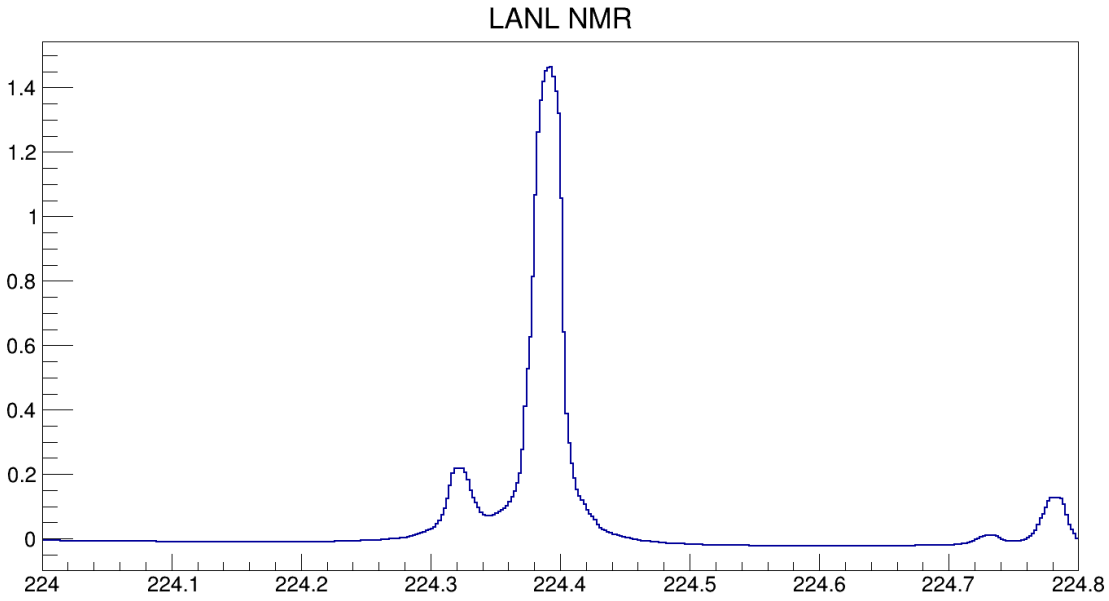


After cooldown we would like to test both systems more rigorously, including the cold NMR.

NMR Systems

Linearity test: comparison of systems done using resonance crystal. Compare how each system scales with increased signal size. Ratio of signal areas for each system at each signal setting should be the same.

Initial test suggest that the systems change with the same proportion when the signal is changed but more testing is needed to quantify who closely they align and to what degree they are linear.



Going forward:

1. Need online calibration tool to measure pressure and temperature simultaneously as well as calculate TE in real time. Could be done in Labview.

2. Fast phase adjustment to measure dispersion(absorption) at the same time. Hardware exists just need software option in Labview

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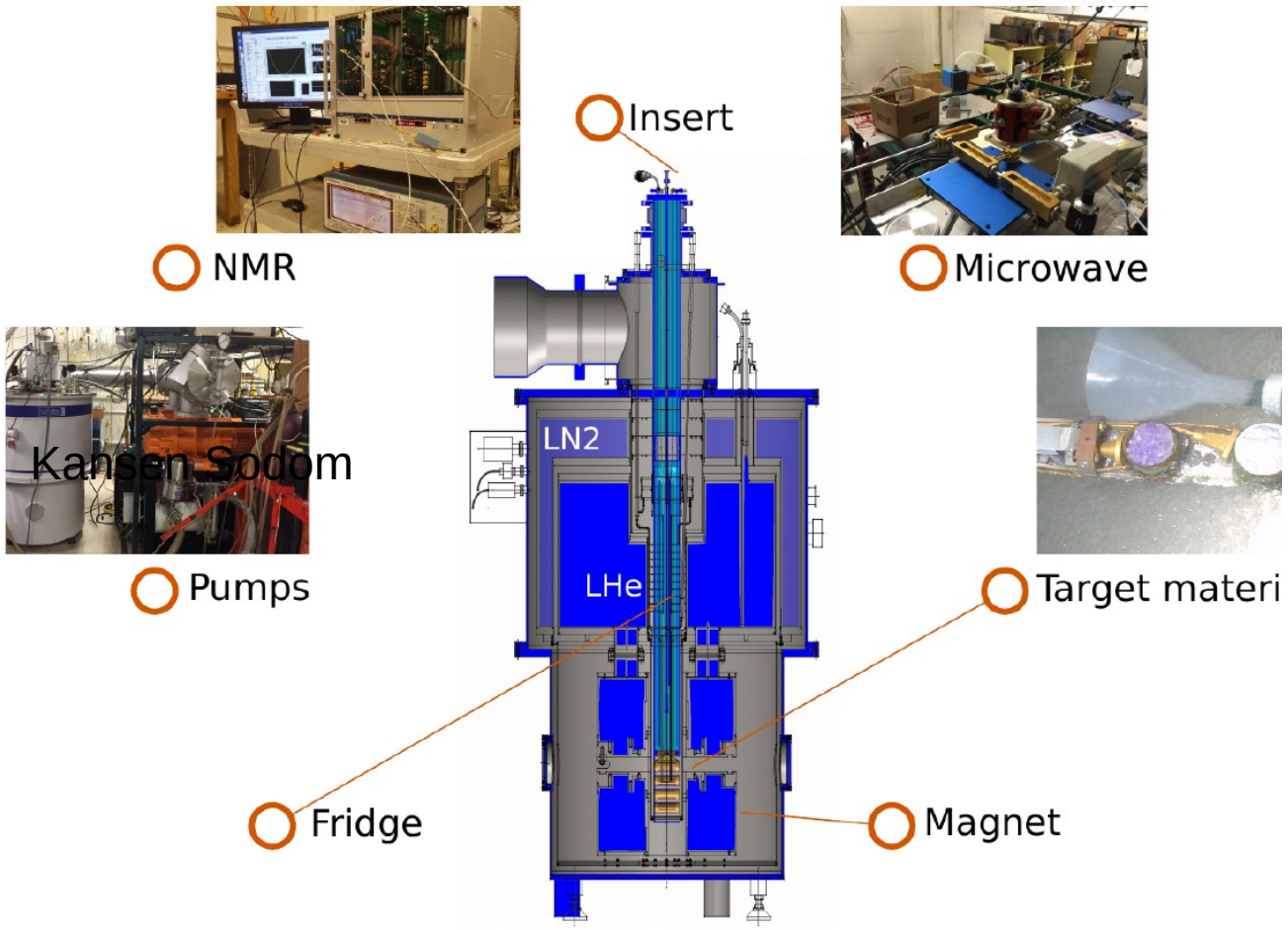
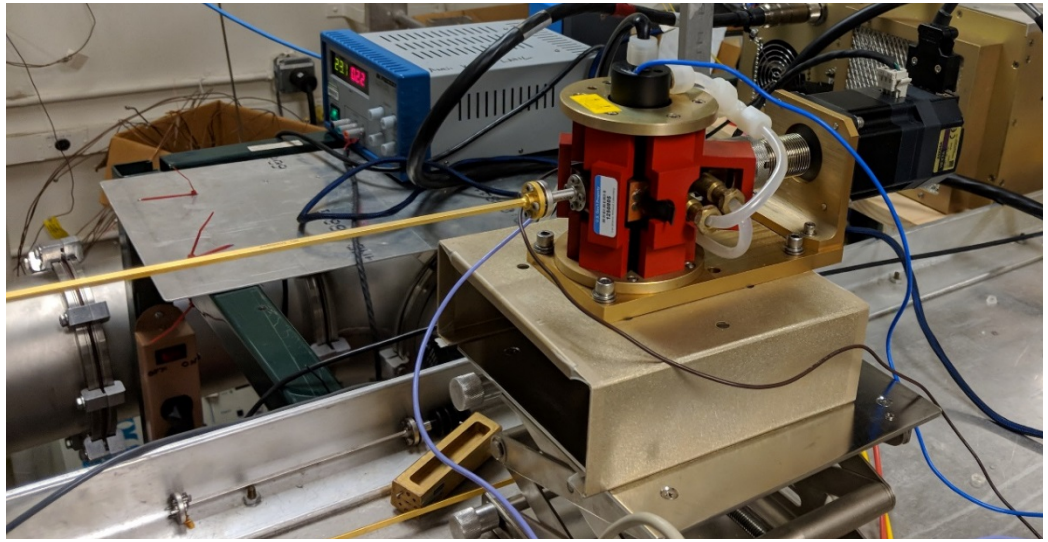




Microwave Generator (EIO)

Safety interlock has been added which includes:

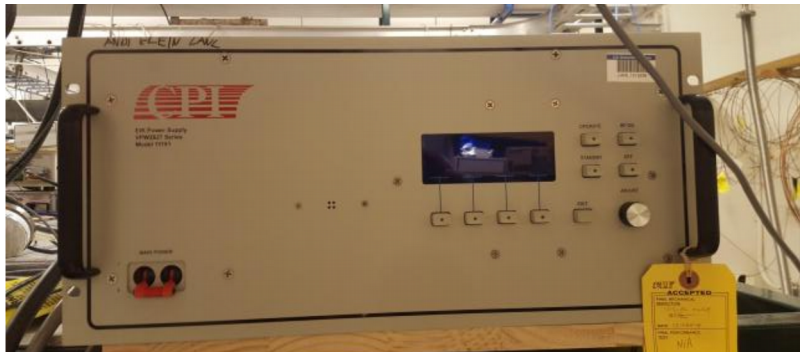
- Chiller flow rate monitor
- Outlet water temperature monitoring
- Collector temperature monitoring

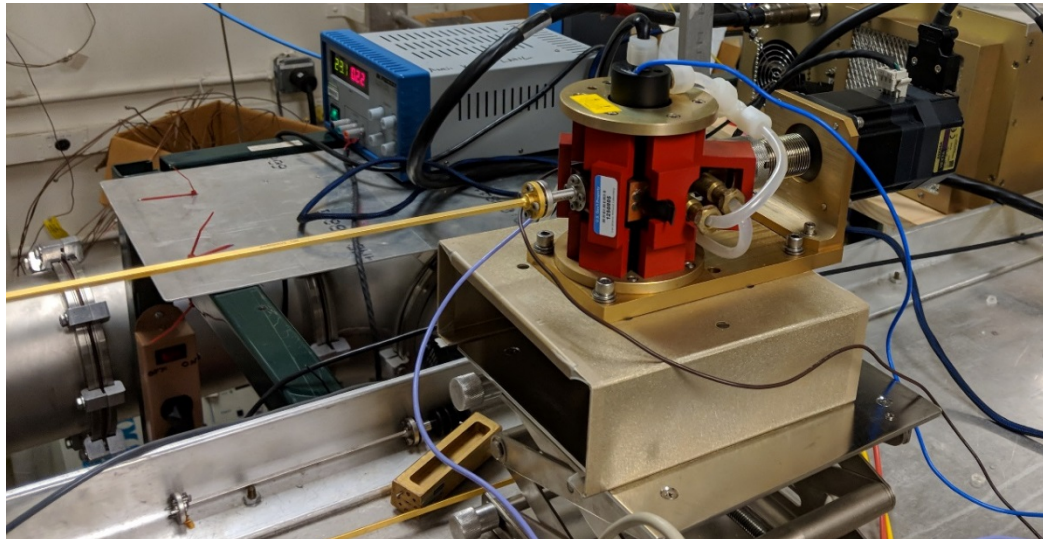
Cooling requirements ~1kW.

EIP Frequency Counter Model (588C)

We are capable of remotely monitoring the EIO frequency with this module → currently not yet configured.

The controls VI for the microwave system has a software calculation for what the frequency should be for a linear relationship between stepper motor position and output frequency.





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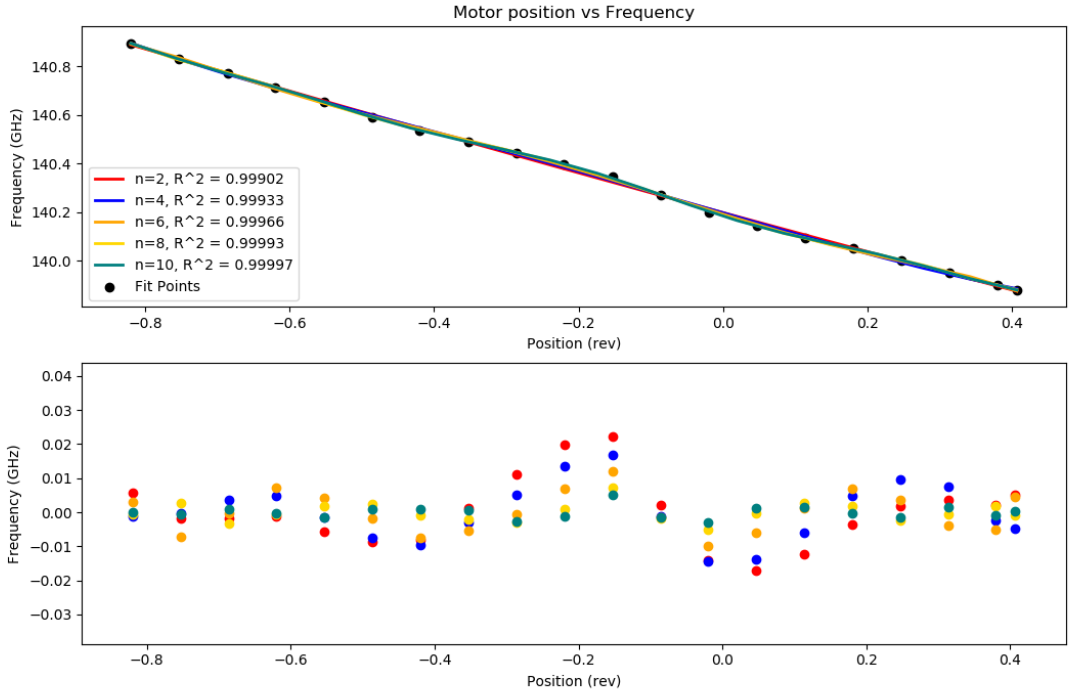
The relation is *mostly* linear but not to the degree we would like.

To increase the accuracy of the calculated frequency different methods were tried:

- Polynomial regression trained using sample data
- Map file calculation – position to frequency if very linear locally.

Simplest solution was chosen. The calculation is now done using a lookup table the extrapolates between the nearest neighbor values in the map file.

This seems to work well after some early testing.



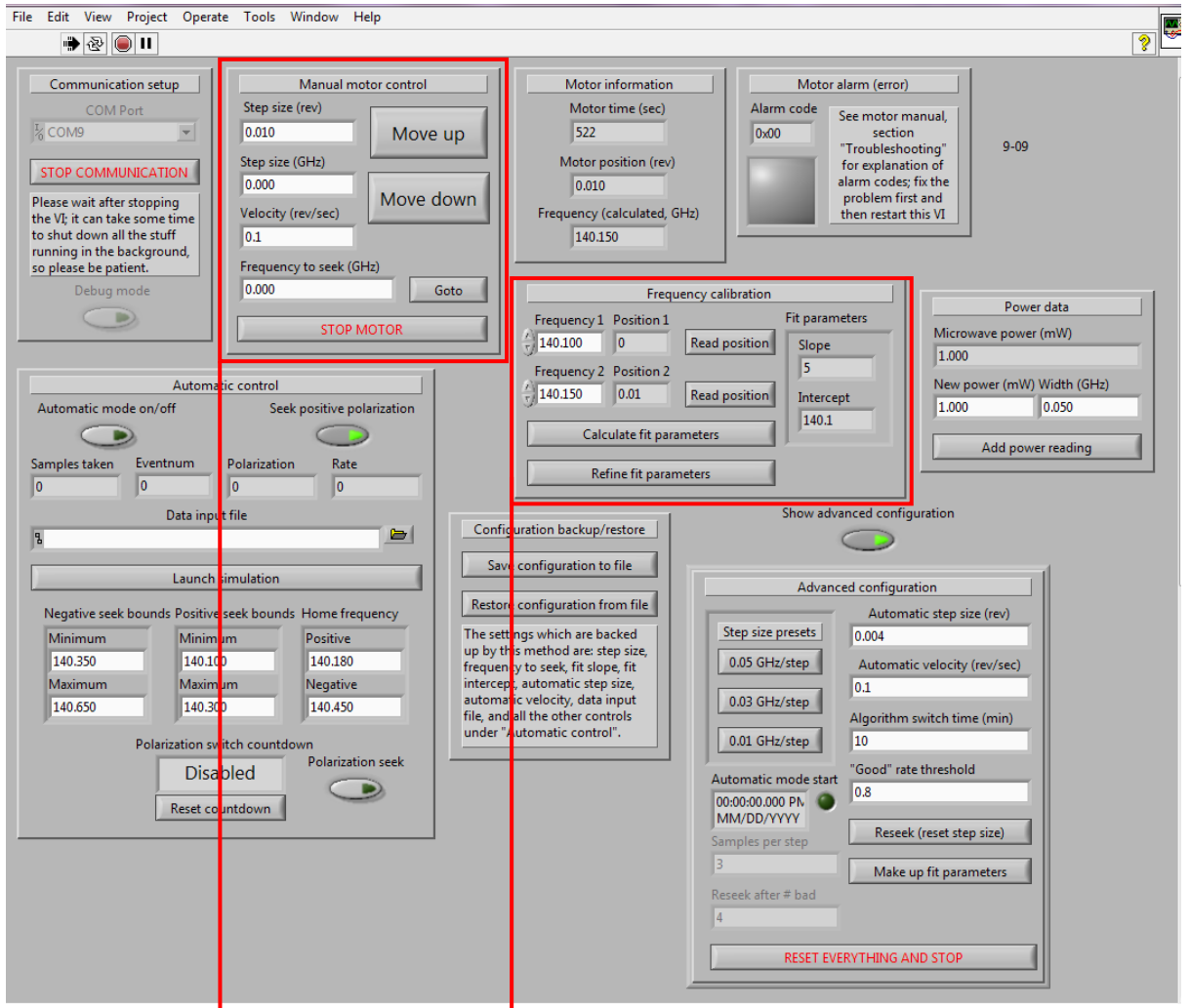
Software Controls

- Microwave generator frequency can be controlled externally from Labview GUI.
- The Labview GUI allows for full configuration and read-back of the stepper motor.
- Stepper motor position, which controls frequency, can be set manually or automatically.
- Frequency calibration used to map stepper motor position to frequency.

Stepper Motor Controls

Due to high radiation in target area, the motor controller, which is a solid-state device, is not safe → needs to be placed external to the target area.

Accomplished by relocating the controller and making an extension cable to connect to the controller externally.



Manual motor controls

Frequency calibration maps motor position to frequency output.

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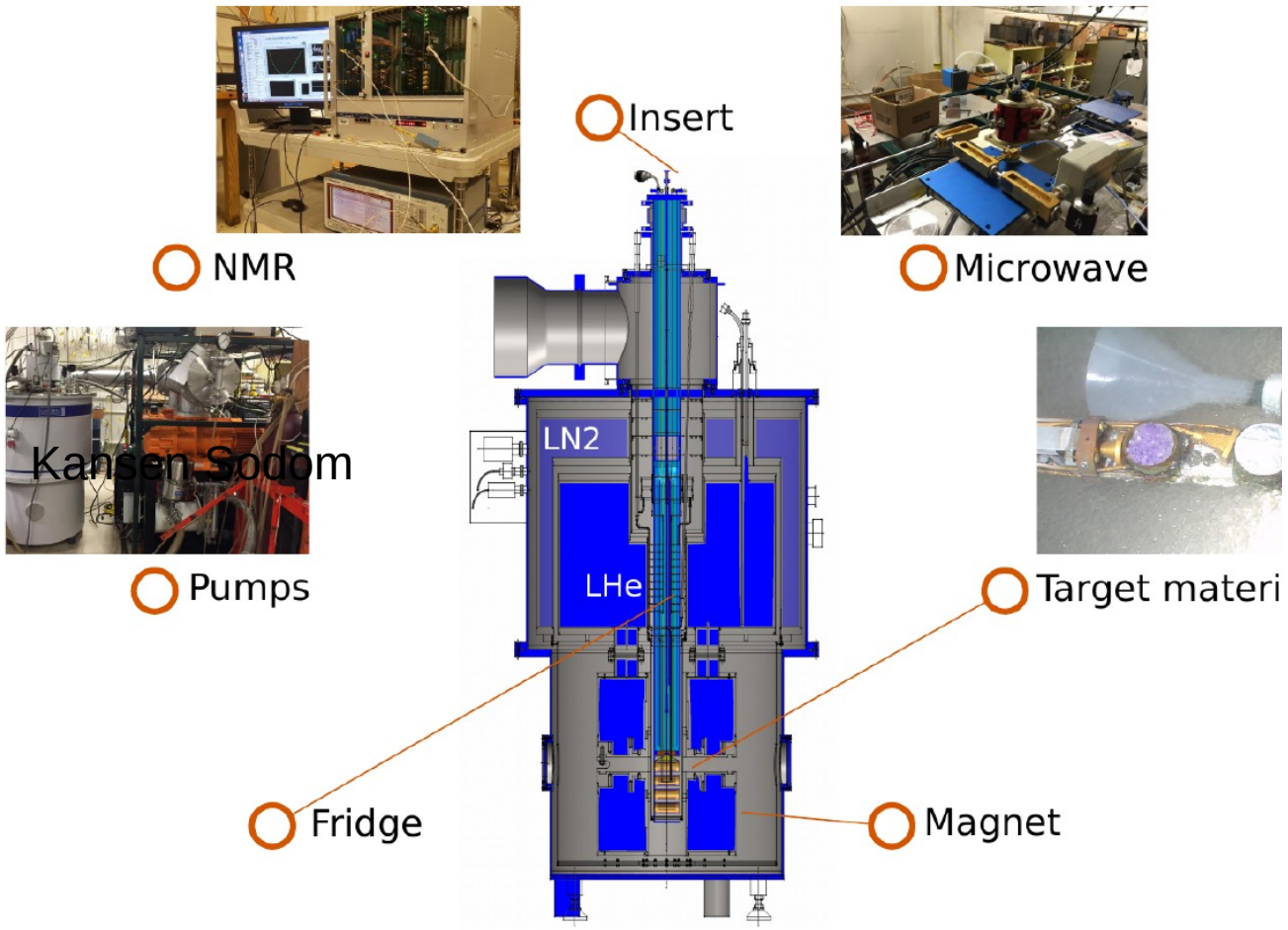

Magnet

Magnet subsystems: Magnet, vacuum, power supply.

The magnet power supply + USB shim relay controller arrived from UNH

The power supply and the VI are already tested and setup (with very low current).

Full test with full current and shim coil are part of the cool down test when we already have the LHe

Turbo Molecular Pump

Early test of turbo pump indicated vacuum below $x10^{-5}$ was not possible due to leaking. Also we could not reach maximum pump frequency (660Hz).

Leaks are now fixed and the pump is running well at maximum frequency.

During practice cooldown we reached $1.7x10^{-6}$ Torr with liquid Nitrogen on the fridge and we expect to reach low $x10^{-7}$ Torr during actual cooldown with liquid Helium.

Backup pump 10 m^3/hr

Turbo ramps to maximum frequency (660 Hz)

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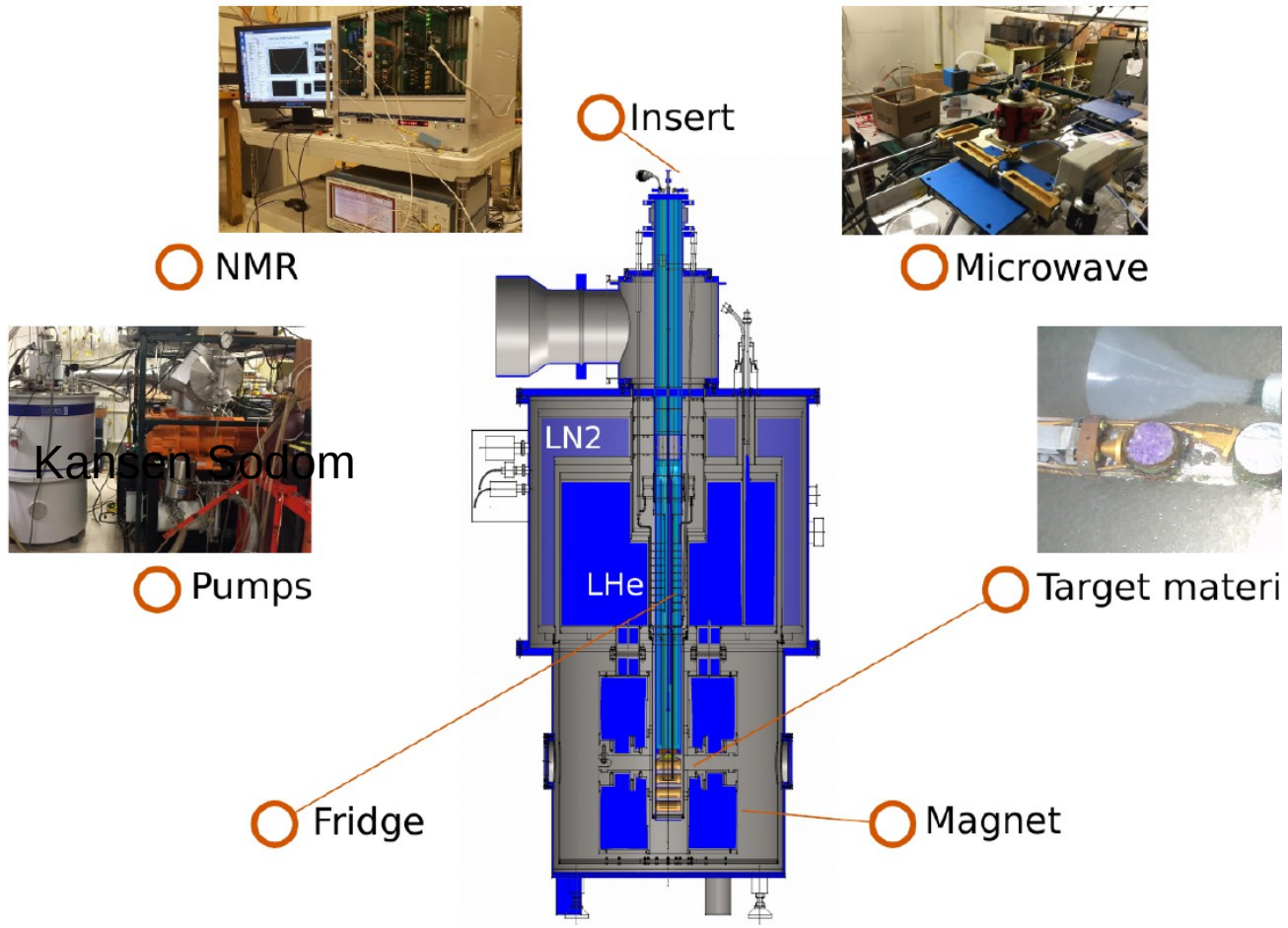
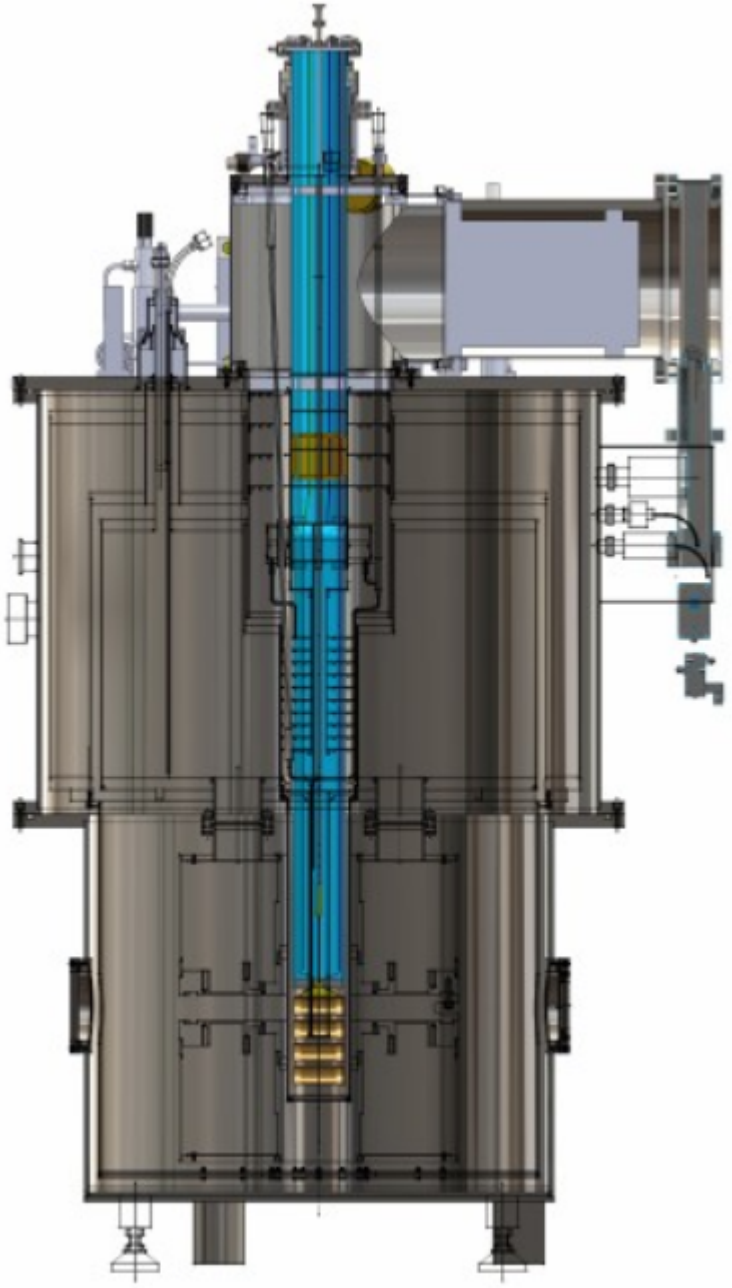


Evaporation Fridge

The target's temperature directly affects the efficiency of polarization. The cryogenic evaporation fridge is designed to provide high cooling power of (1 W) at 1 K.

- Separator replaced and added guide ring to help with installation.
- Modified the insert channel and installed copper annealing plates.
- Installed level probe to monitor helium level.
- Positioned the helium delivery line to be out of beamline.
- Added eight new temperature sensors index from bottom to top.
- Helium test nose pieces. Already leak tested.



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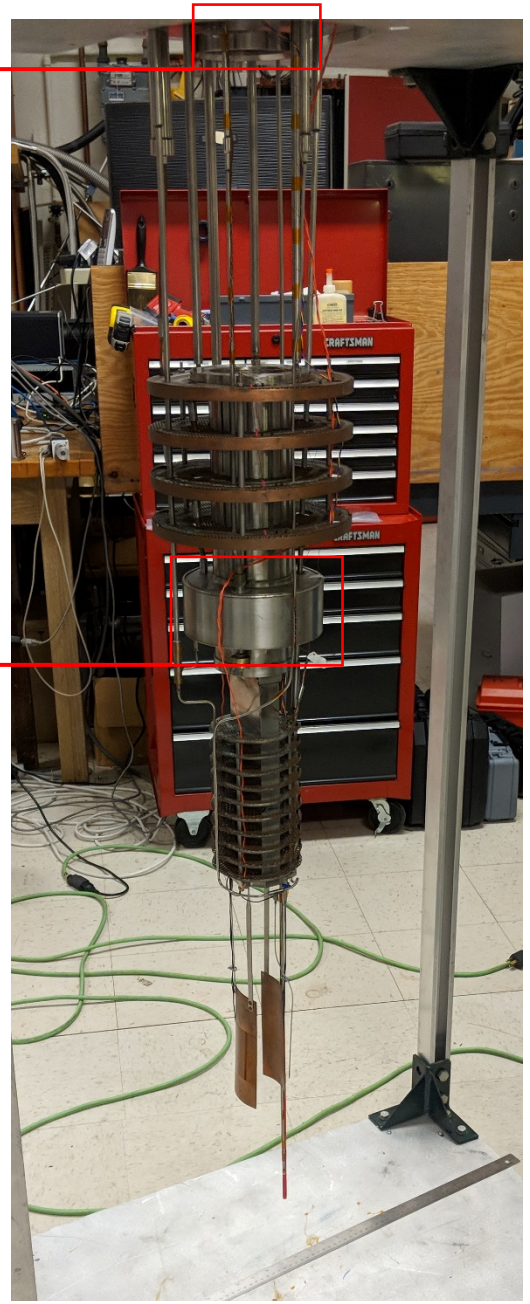
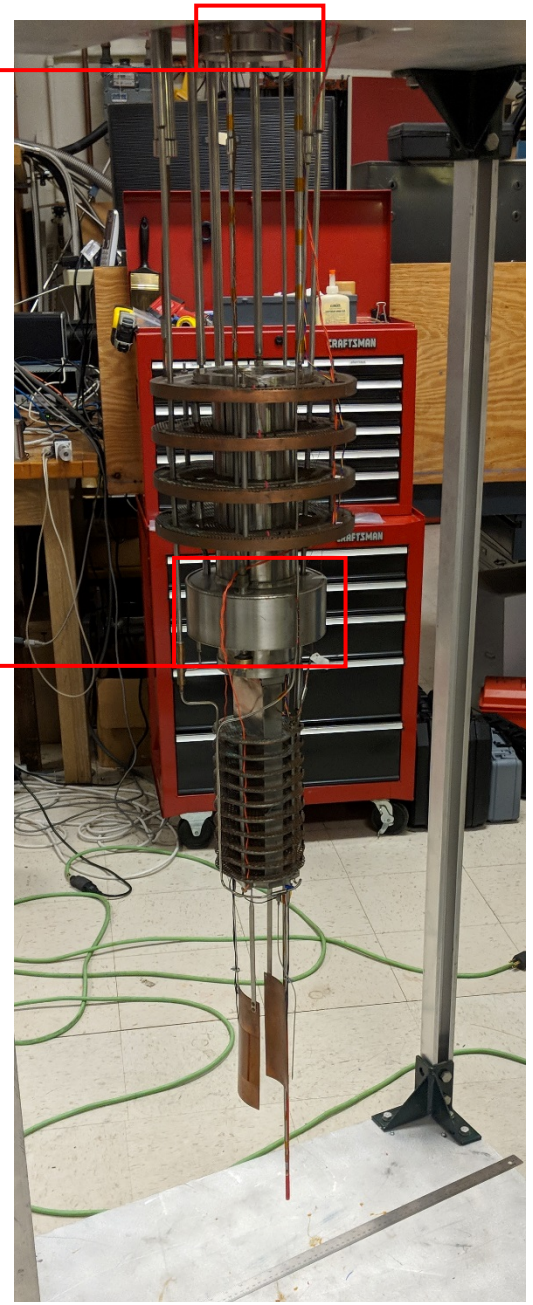


Evaporation Fridge

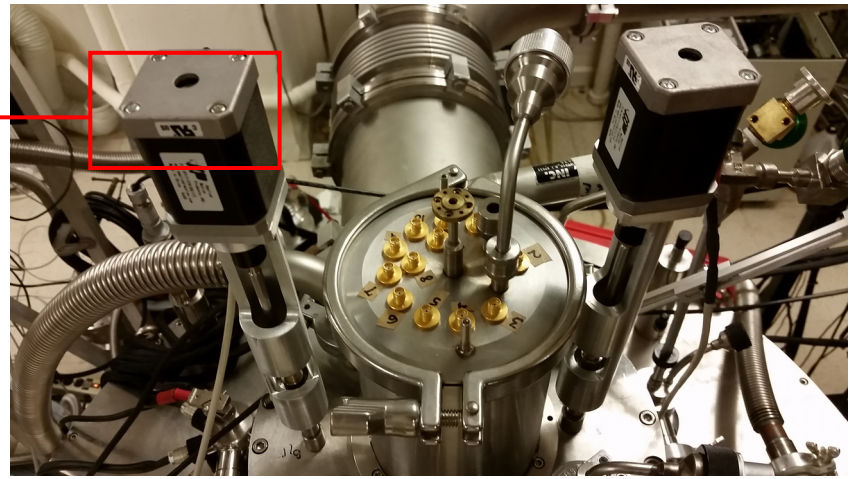
- Installed new run and bypass valves.
- Stepper motor controls for each valve with software controls for each. Run valve has PID control, bypass manual/remote.
- Controller will need to be placed to prevent radiation damage.
- Temperature monitor system working in Labview – tested.
- Installed new liquid helium pressure probe (old probe was leaking).

Guide ring

Separator



Run/Bypass valve controls



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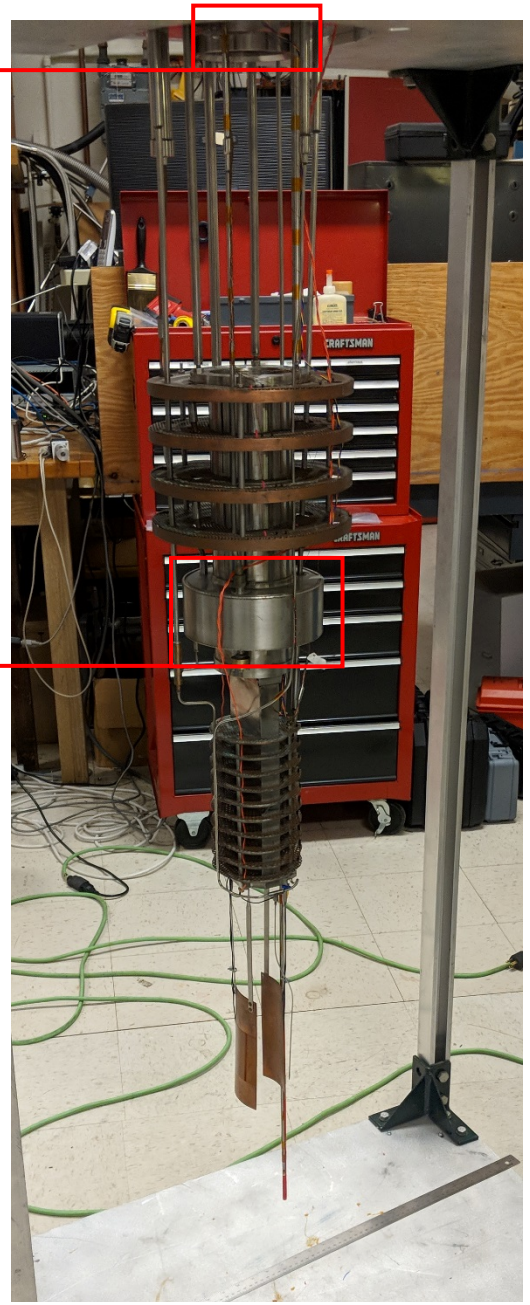
- Stepper motor controls for each valve with software controls for each. Run valve has PID control, bypass manual/remote.
- Controller will need to be placed to prevent radiation damage.
- Temperature monitor system working in Labview.
- Installed new liquid helium pressure probe (old probe was leaking).

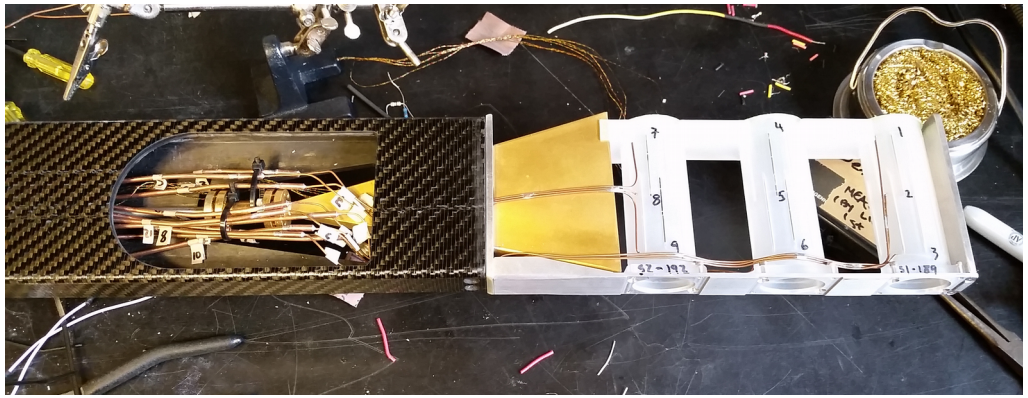
Still to do:

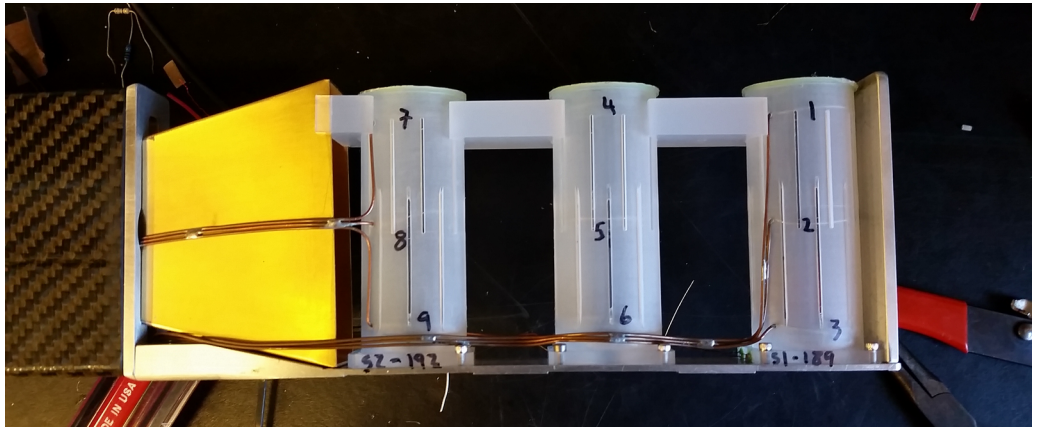
- Need to do cold test for both new valves.
- Test liquid helium probe.



Target Inserts

- Two proton inserts: One with four target cups (large), one with three target cups (small).
- One neutron insert: This will be the old full steel test insert fitted with at least three cold NMR coils.
- Proton inserts surrounded by carbon fiber shell for minimal thermal conductivity and guidance.
- Each insert will has three cernox temperature sensors to determine liquid level for annealing.
- NMR coils installed and tested on each target cup.





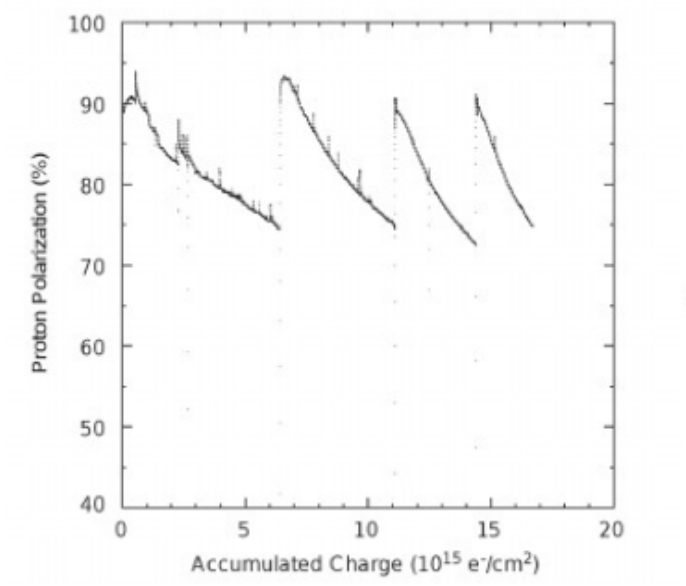
Target Polarization and Annealing

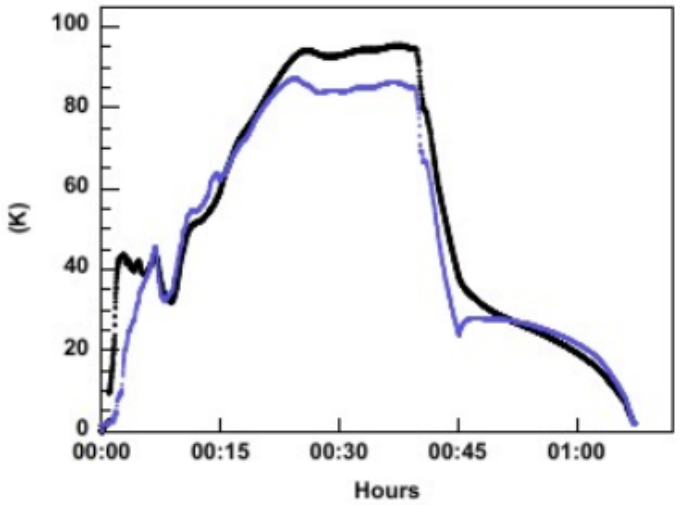
As radiation dose from the beam continues, the DNP process becomes less efficient and the polarization will fall.

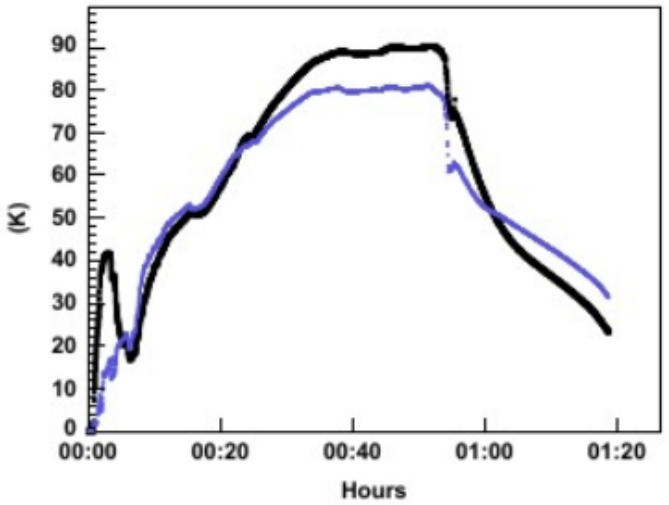
By heating the target material, we can temporarily increase the DNP process again. This heating is called annealing.

There is a limit to the lifetime however. As successive anneals are performed on a material sample, the decay rate of the polarization will increase, requiring more anneals per day.

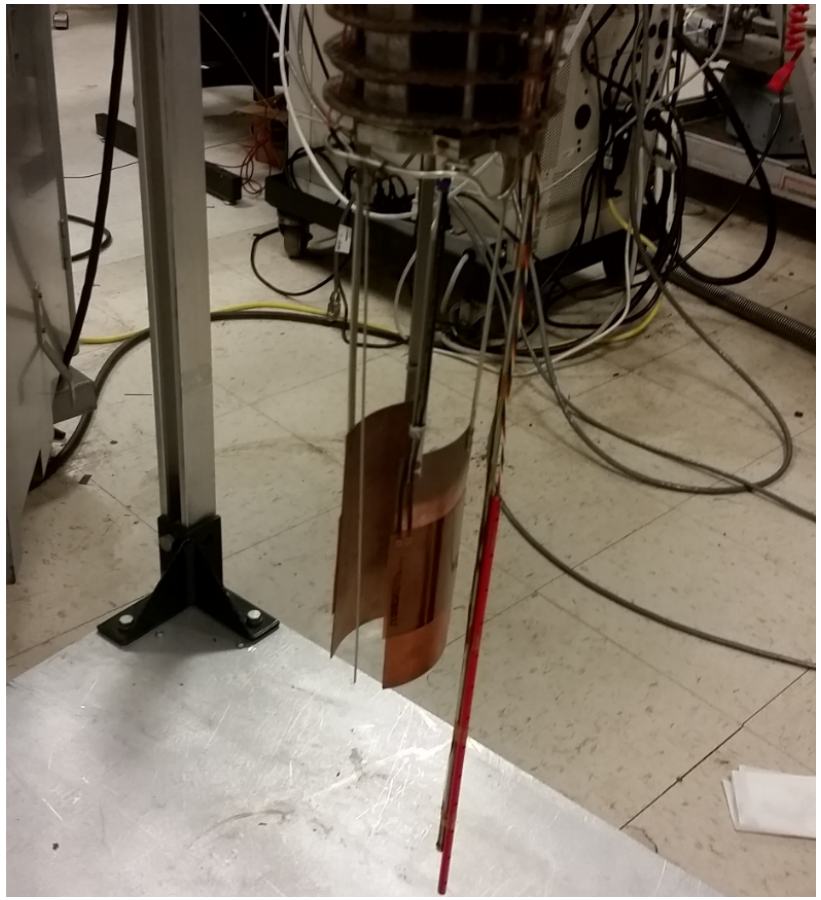
Eventually, the polarization decay rate will be so fast that it is no longer practical to use the material, so a new sample will be used.



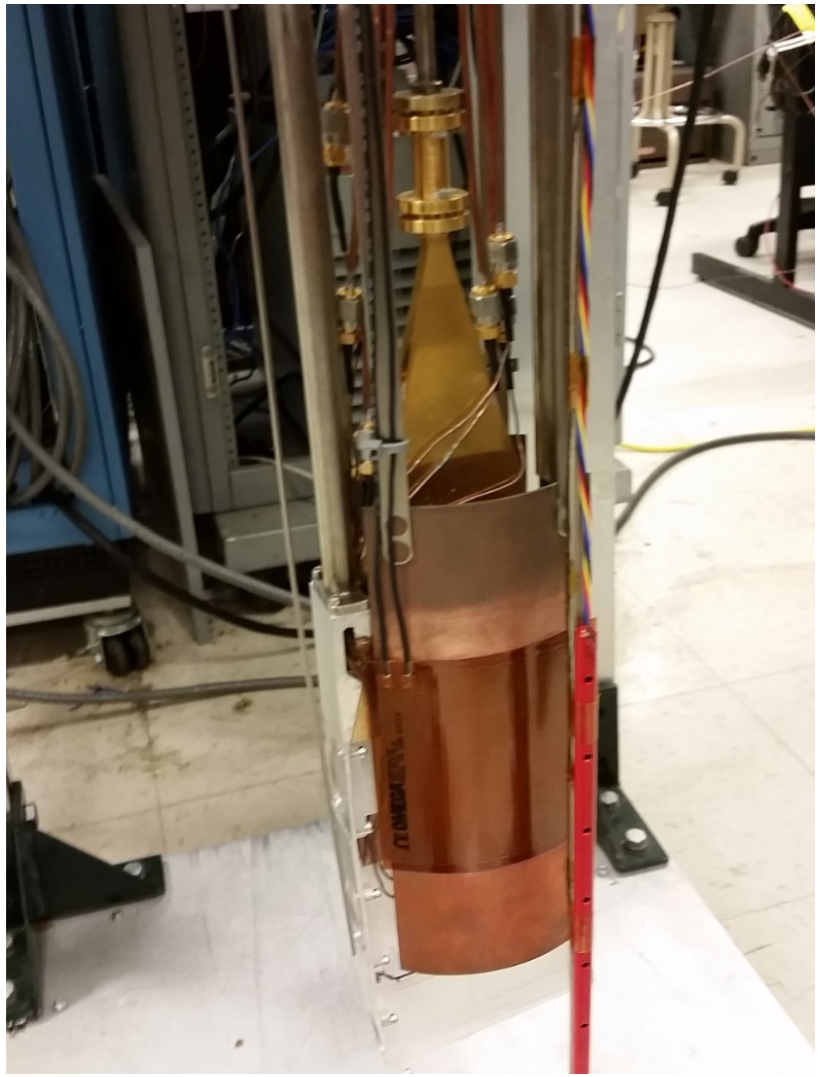




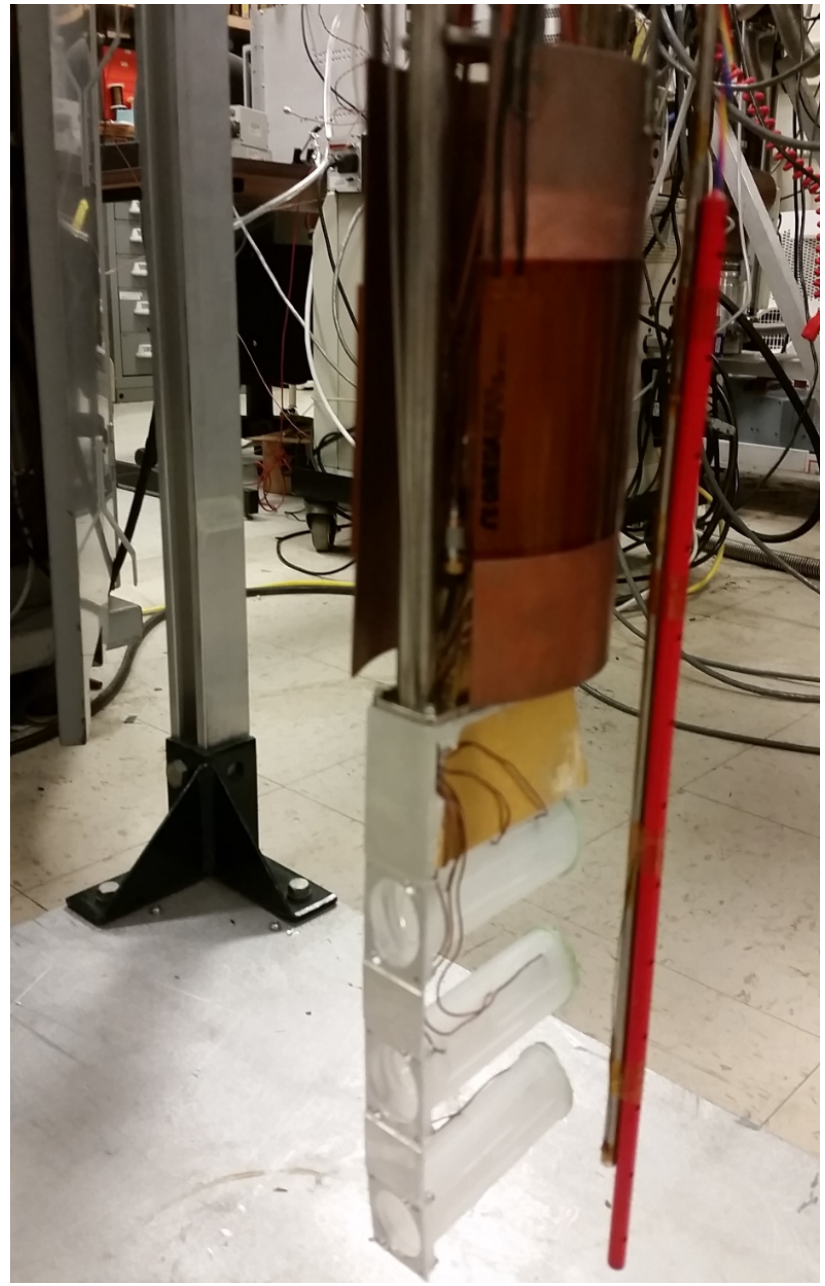
Annealing Plates



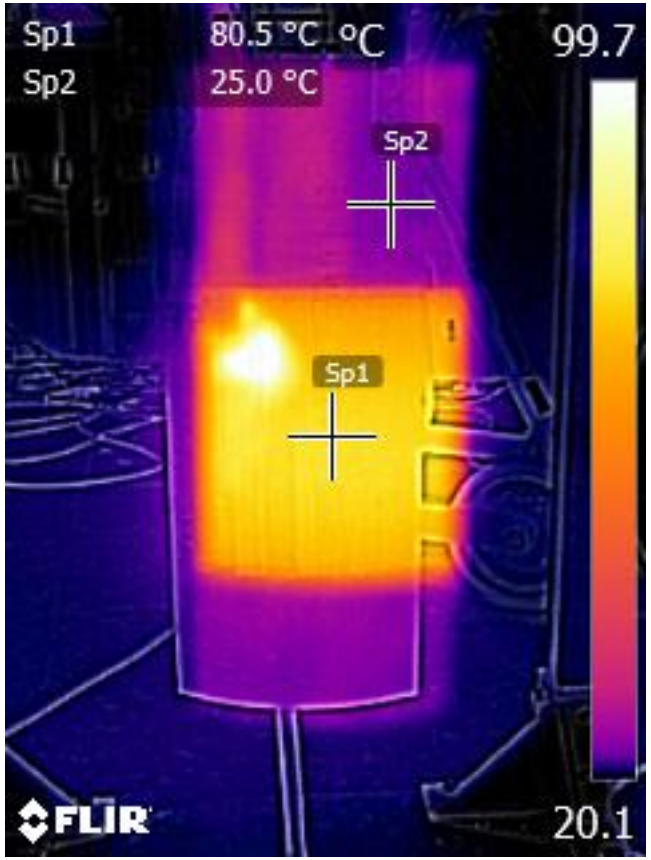
Placement during anneal

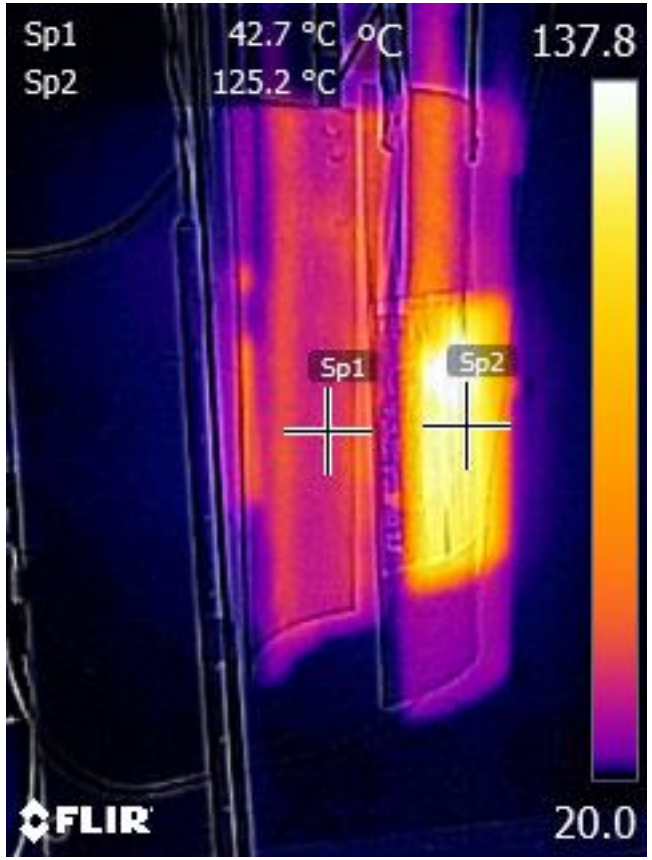


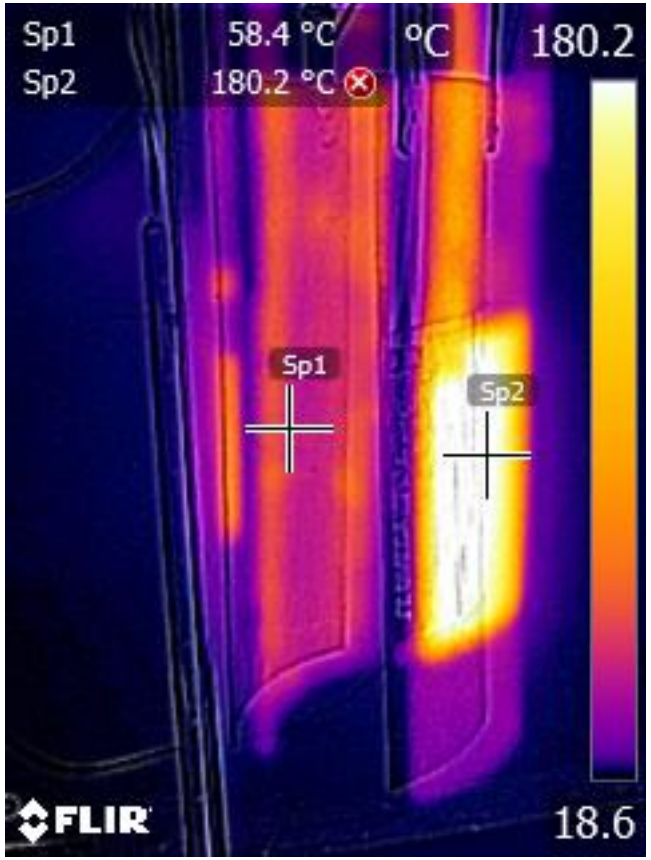
Placement during beam



Annealing Plates with Heaters Running







Note that this is the annealing plates running at room temperature in the lab. The heat on the plates will be different In a helium bath.

Cooldown planned for the week of 11/12/2018

- Fridge and valve tests (Biggest Priority)
- Automation tests with working valves and controls
- Microwave calibration and automation test
- Separator flow control with LANL New hardware
- Magnet PS test/Shim tests of controller VIs
- Turbo/Vacuum test and corresponding mag boil off
- Temperature sensors calibration
- NMR studies
  a.) Test signal burning potential (LANL-NMR)
  b.) Area ratio test (compare systems)
  c.) cold NMR test with ND3
- Try to improve resolution on magnet fringe field map (need hardware)
- Training specifically with material handling and insert loading

Future work when not working on cooldown

- Determine the relationship between the power delivered during annealing and the change in temperature of the target insert.
- Finish second proton target insert and work on neutron insert.
- Work on optimizing target loading procedure.
- Setup turbo pump VI.
- Rigorous study of LANL NMR and cold NMR
- Improved interlock controls and read-back.
- EIO motor tracking and controls bug testing.

Thank You.