

# LANL/UVA Solid Polarized Target

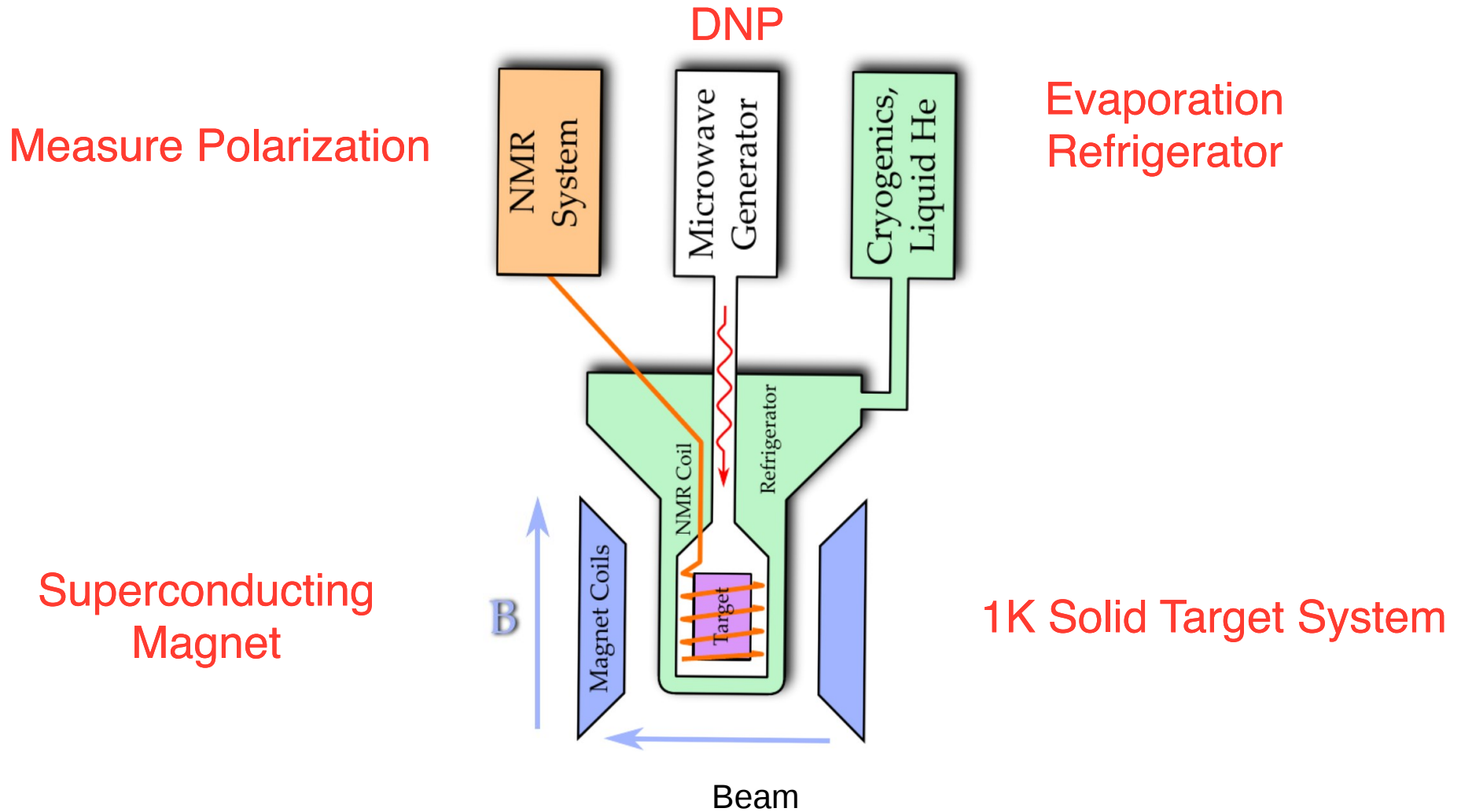
Dustin Keller  
University of Virginia

*Progress and developments with E1039 polarized target system*

# Outline

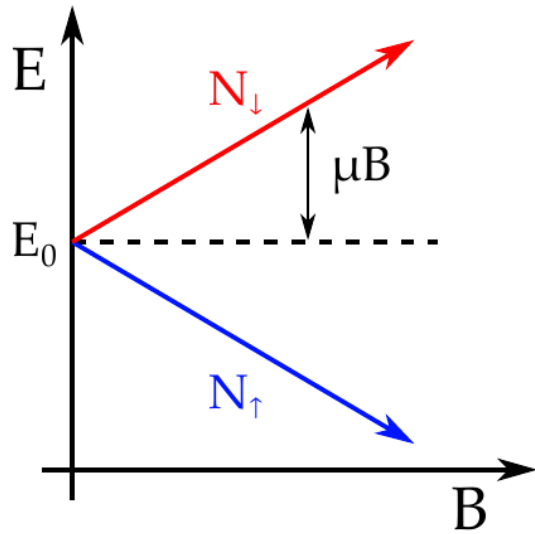
- Polarized Target Setup
- System Status
- Expectations and Uncertainties
- Personnel Requirements
- Still to Come

# Polarized Target System

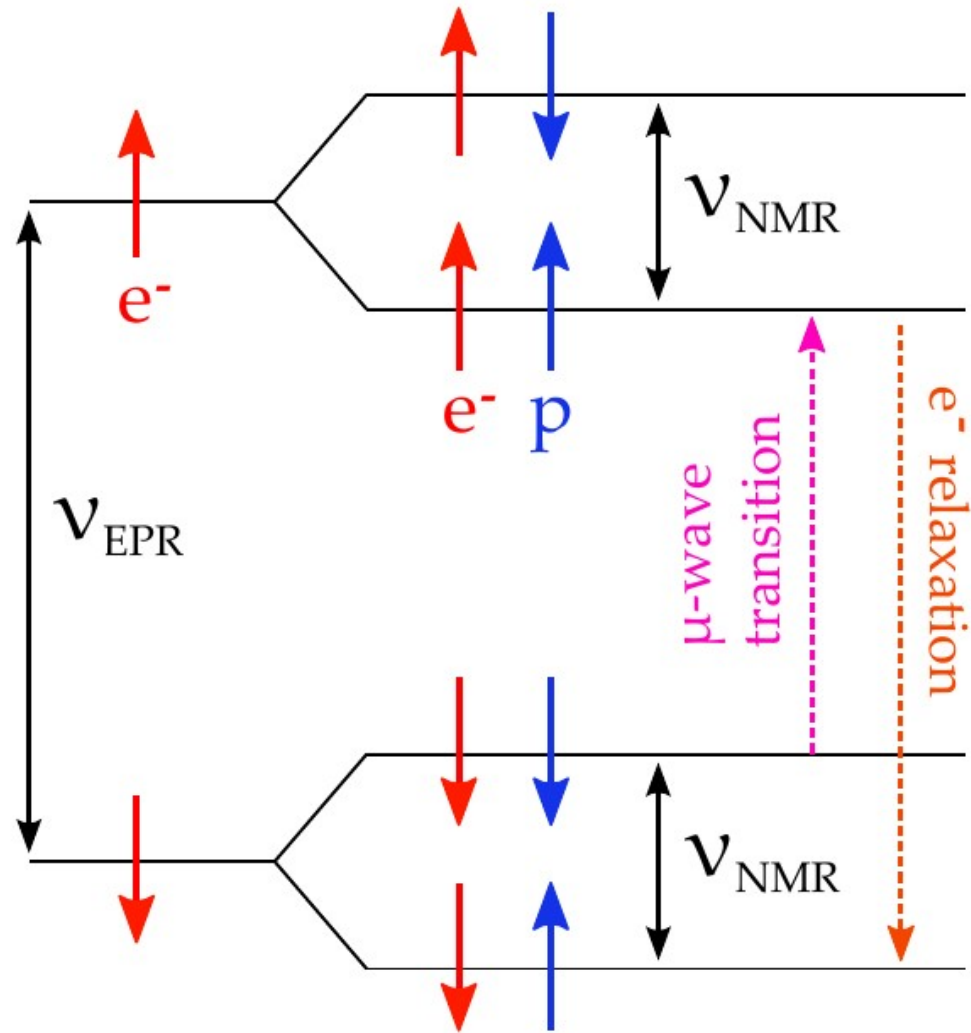


Vertically Pointing 5T Split Pair

# DNP Proton Polarization



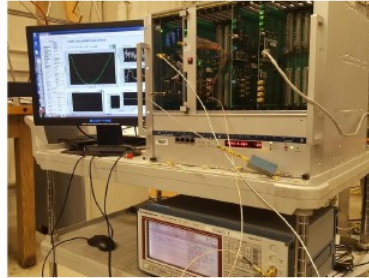
$$P_{TE} = \frac{e^{\frac{\mu B}{kT}} - e^{-\frac{\mu B}{kT}}}{e^{\frac{\mu B}{kT}} + e^{-\frac{\mu B}{kT}}} = \tanh\left(\frac{\mu B}{kT}\right)$$



# E1039 Polarized Target

Hardware Ready  
Controls Near Ready

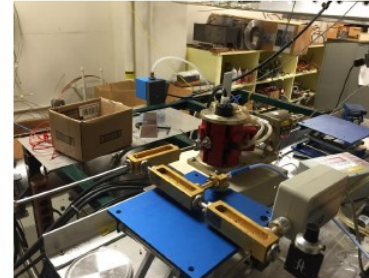
Getting Ready



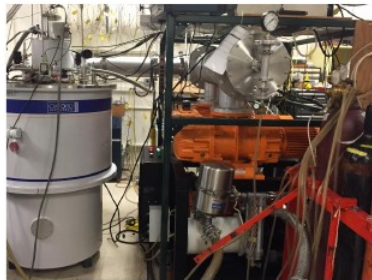
○ NMR

3 Getting Ready  
Ready

○ Insert

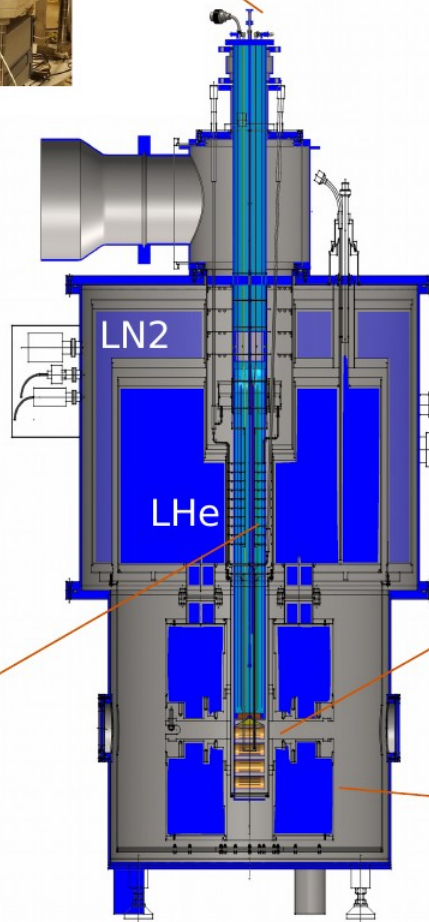


○ Microwave



○ Pumps

Ready To Install



○ Target material

50% Ready

○ Fridge

Hardware Near Ready  
Controls (not ready)

○ Magnet

Ready to Install  
Controls (near ready)

# So Far Accomplished

- Rotation/Modification of Magnet
- Fridge Repairs/Modifications
- Design Build Target Insert (3-built, one metal)
- Redesign/Build NMR for VME (low noise cold system)
- Machine 2 nose pieces with beam window
- Production of some material (50% for proton 5% of deuteron)
- Automated Microwave Control system
- Integrated Cryocontrols (test version showing up on website)
- Target Annealing system test
- Three Fully integrated System Tests

Last 3 Cooldowns :

1.) New NMR, Magnet, Fridge, Pol

2.) NMR, Max Pol

3.) Microwave opt, Autocontrols

# POLARIZED TARGET SUBSYSTEMS

Magnet

Fridge

Insert

NMR

Microwave

Pumps

Target material

Original design by S.Penttila, Oxford Instr.  
kept at LANL storage since ~2000

Feasibility study

shipped to UVA in 2013

1st cooldown 06/2013

Rotation of the coils

shipped to Oxford Instruments

new configuration, 2nd cooldown

$dB/B < 10^{-4}$  on 3d grid, 5T over 8cm

Back to UVA

3rd cooldown, rotated coils test

magnet is in a very good shape

Previous cooldown saw some drift



# POLARIZED TARGET SUBSYSTEMS

Magnet

Fridge

Insert

NMR

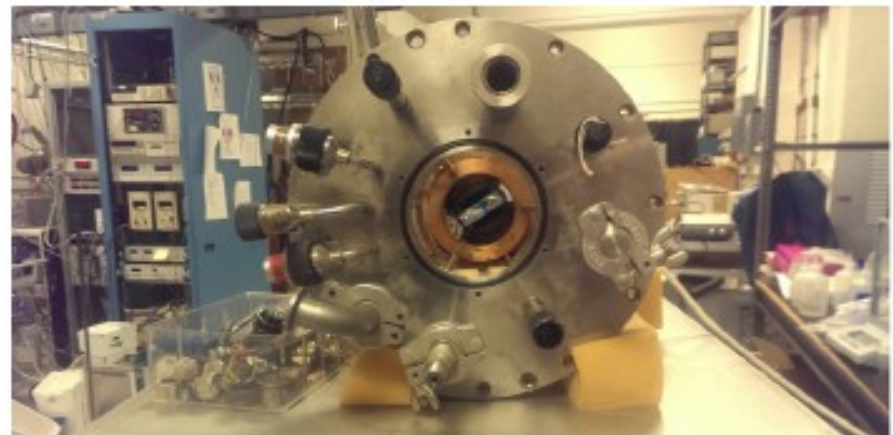
Microwave

Pumps

Target material

## Fridge modifications

- replaced separator can
- cleaned heat exchangers oxide/corrosion
- leak checked
- refitted run and bypass valves
- installed new LHe channel
- installed 8 temperature sensors
- manufactured new nose, 10mil window

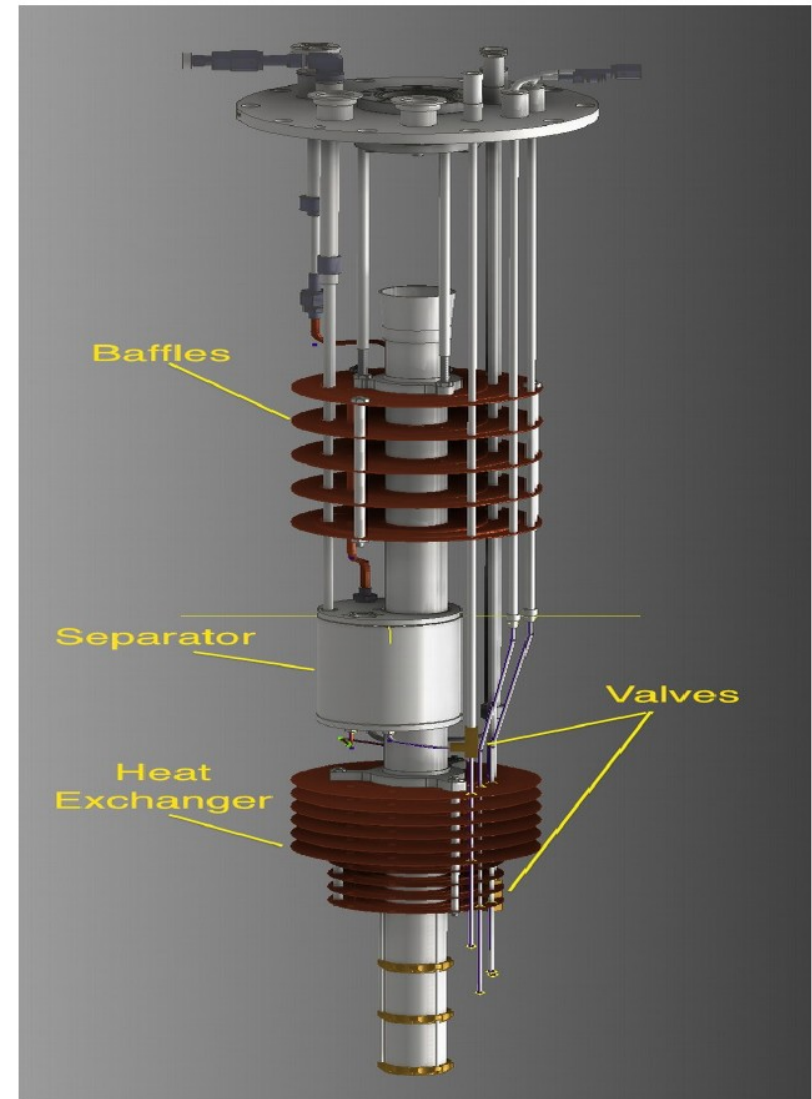




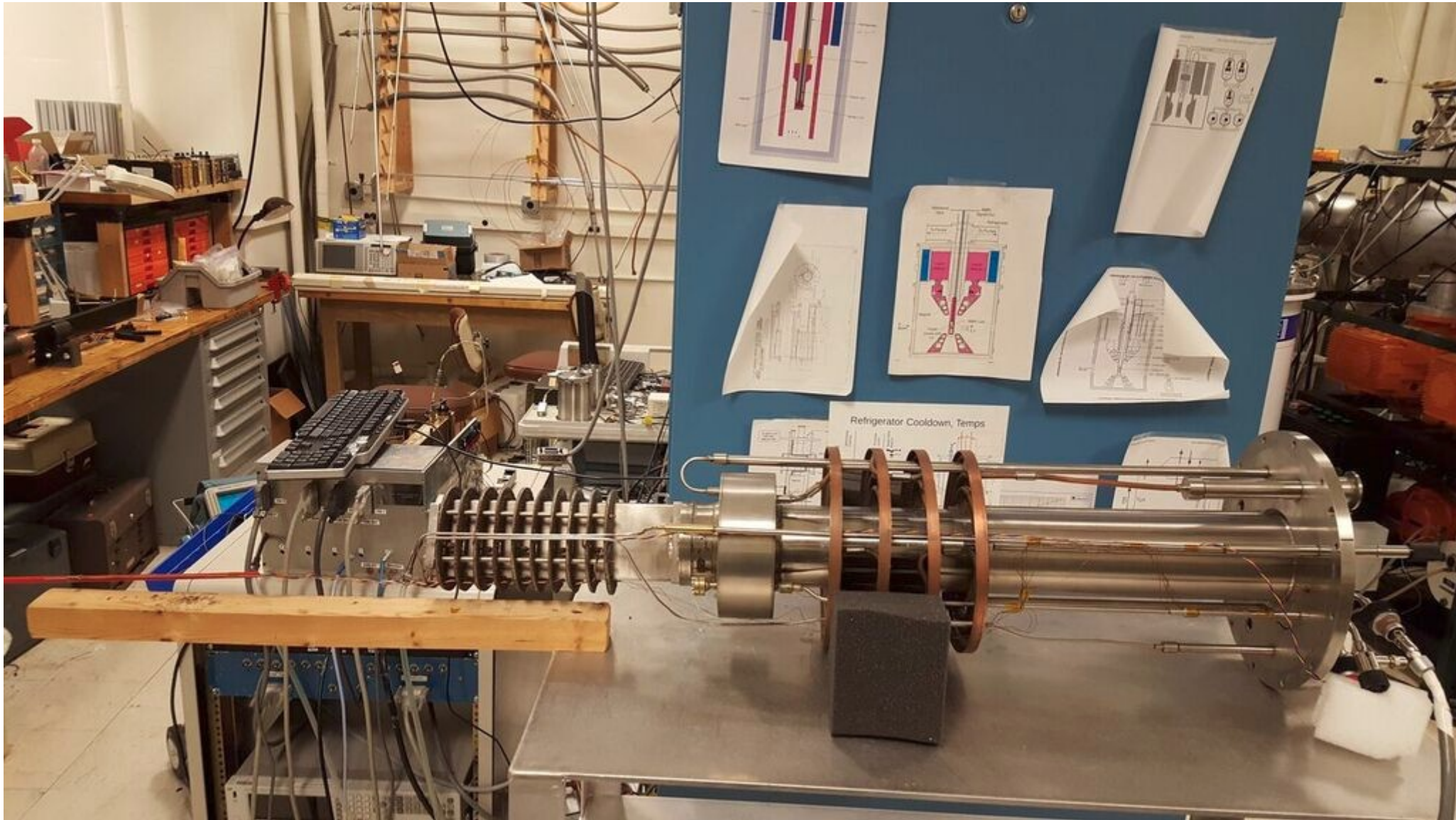
# Fridge Modifications

- Separator Can (New)
- Heat exchangers (Clean)
- Leak check
- Valves (re-fit)
- New Helium channel (nose)
- 8-sensors

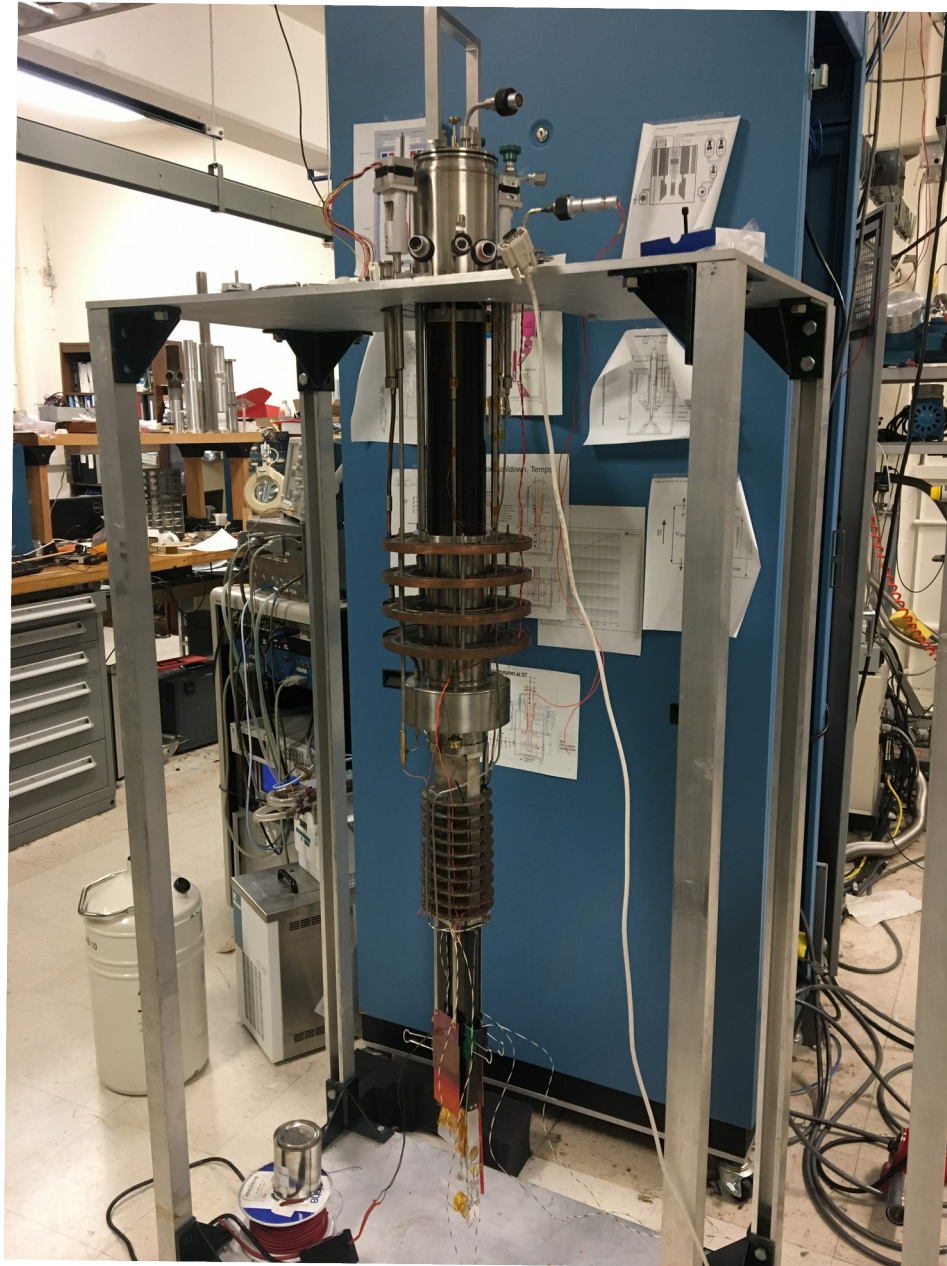
This cooldown:  
Seem to have a leaky valve



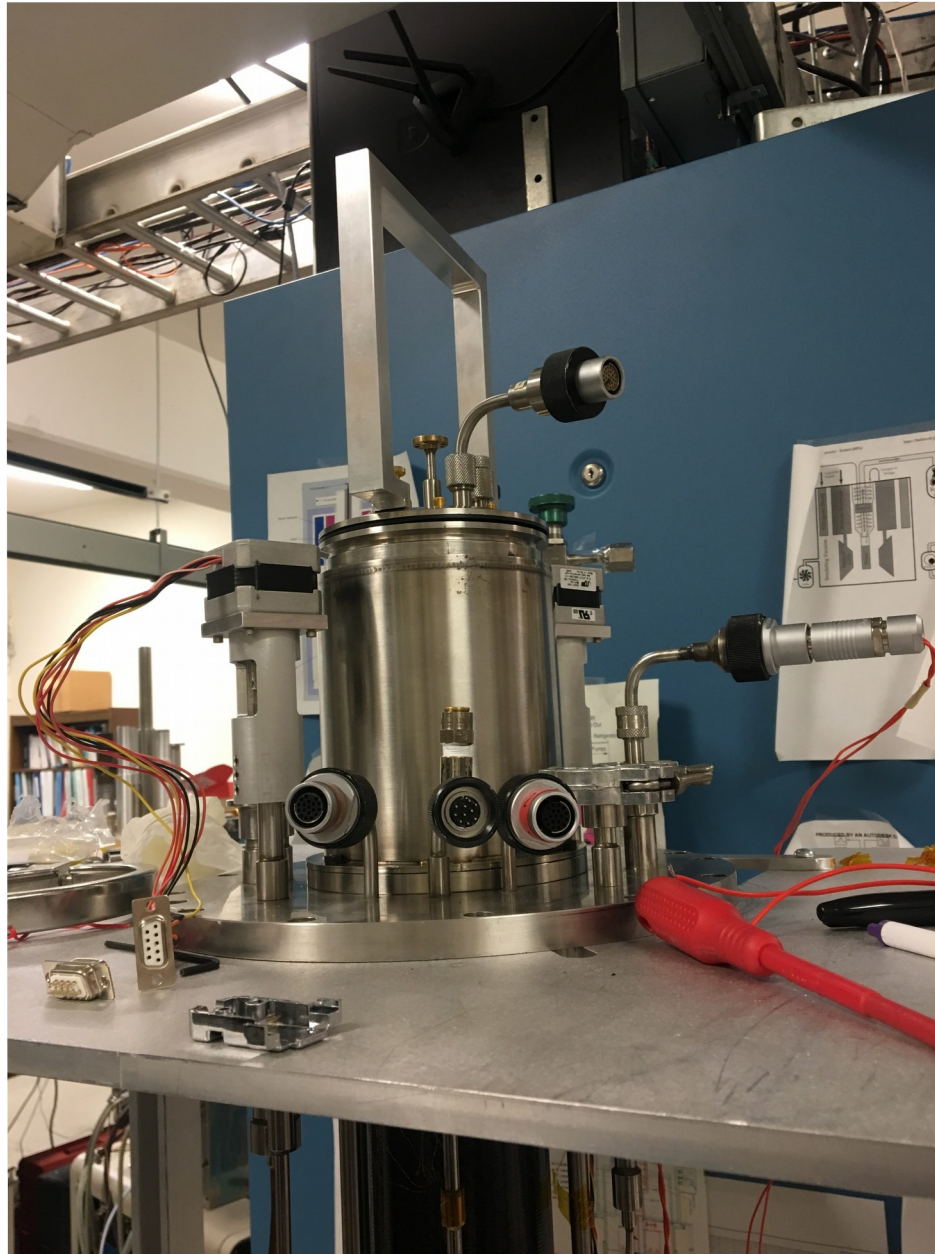
# Recent Modifications



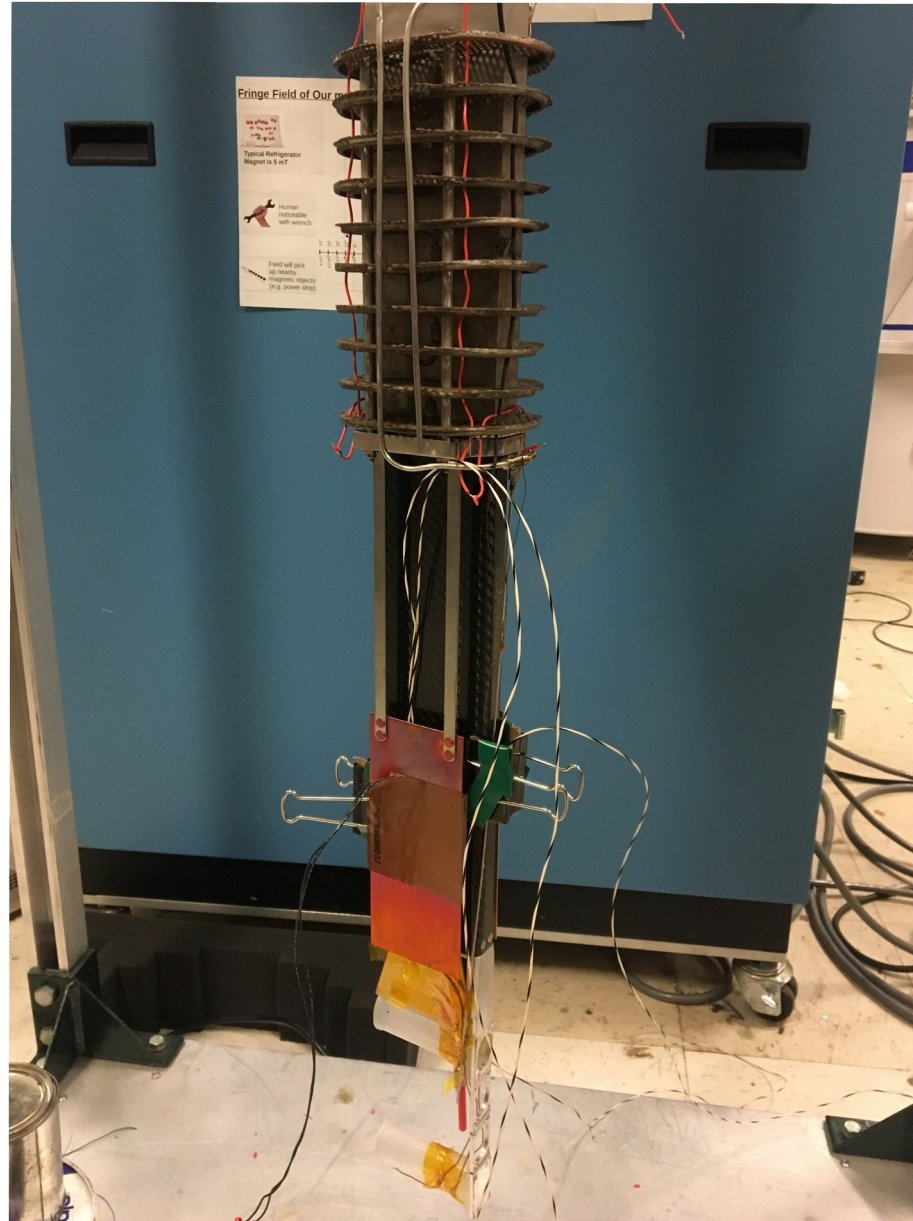
# Upright Full View



# Upright top



# Upright Heater



# POLARIZED TARGET SUBSYSTEMS

Magnet

Fridge

Insert

NMR

Microwave

Pumps

Target material

## New insert

- four 2.7x2x80mm long target cups
- NH<sub>3</sub>, C disk, empty
- six NMR channels (3 per cup)
- microwave horn for full cup volume
- temperature sensors
- He3 bulb line
- copper thermal barrier
- carbon fiber enclosure



# POLARIZED TARGET SUBSYSTEMS

Magnet

Fridge

Insert

NMR

Microwave

Pumps

Target material

New NMR system developed by LANL

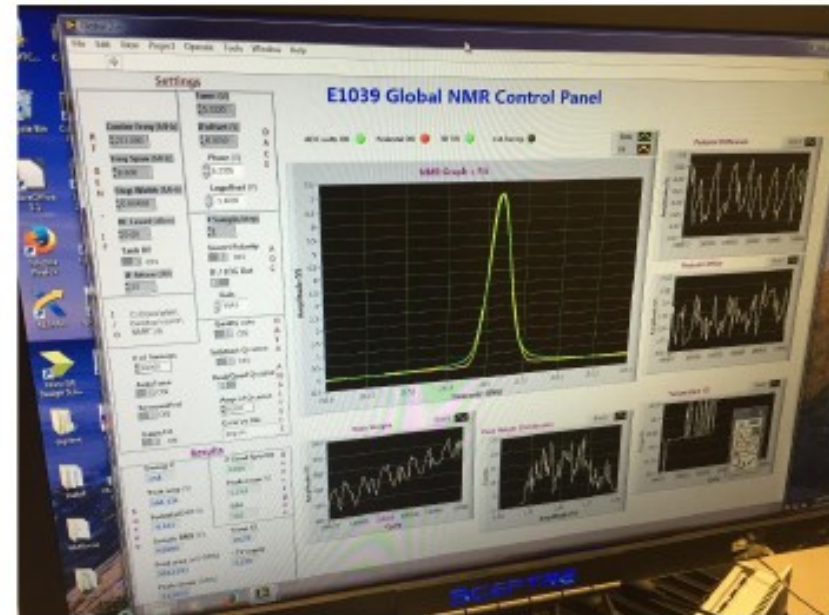
followed general Liverpool design

Q-meter as double wide VME module

1 analog / 1 digital boards, crate controller

16 bit ADCs/DACs, modern RF electronics

USB/Ethernet interface, LabView based DAQ



LANL NMR system tests at UVA

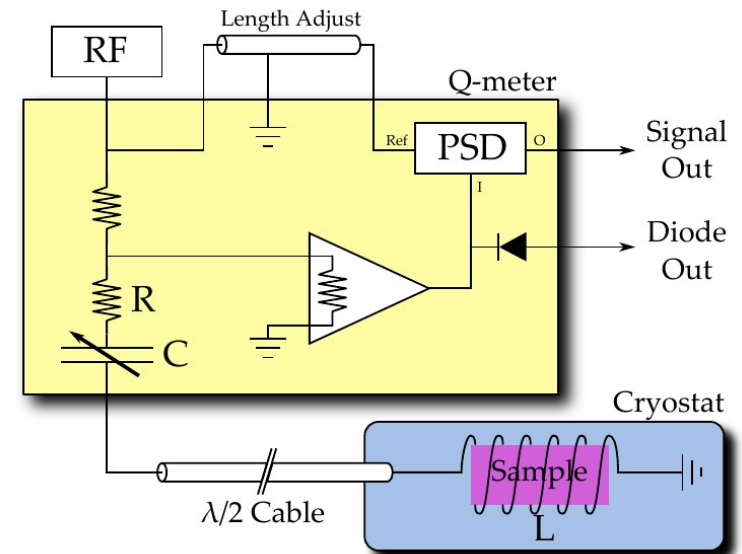
1st NMR cooldown 2014 (total 3 cold tests)

04/2016 full comparison to Liverpool Q-meter  
signal/noise ratio - waiting for results

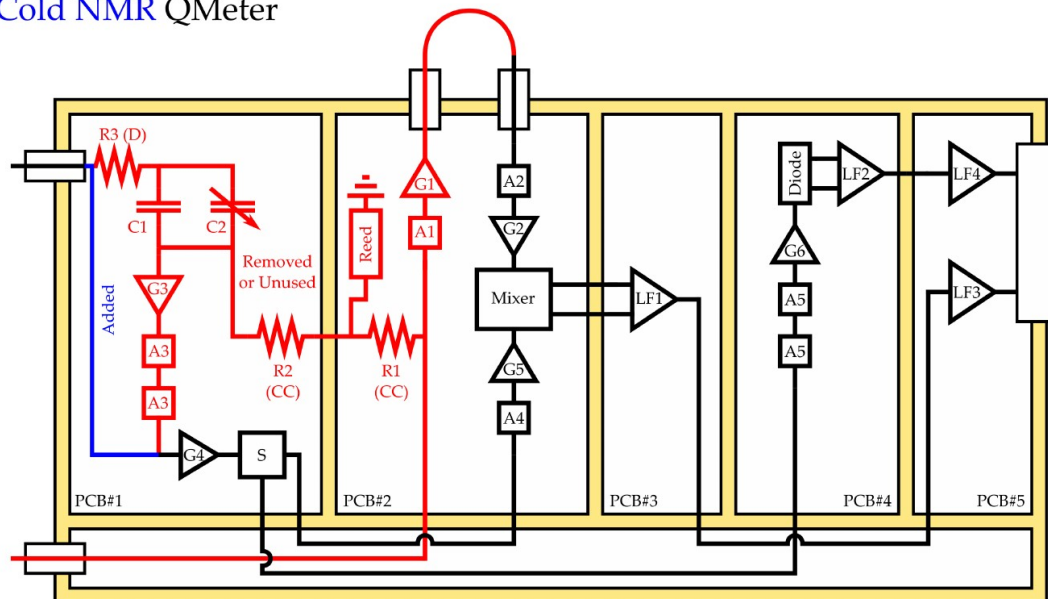


# NMR System

- New LANL-NMR checked
- Compares to UVA-Liverpool
- Cold LANL-NMR
- Compares to Cold UVA-Liverpool?



Cold NMR QMeter

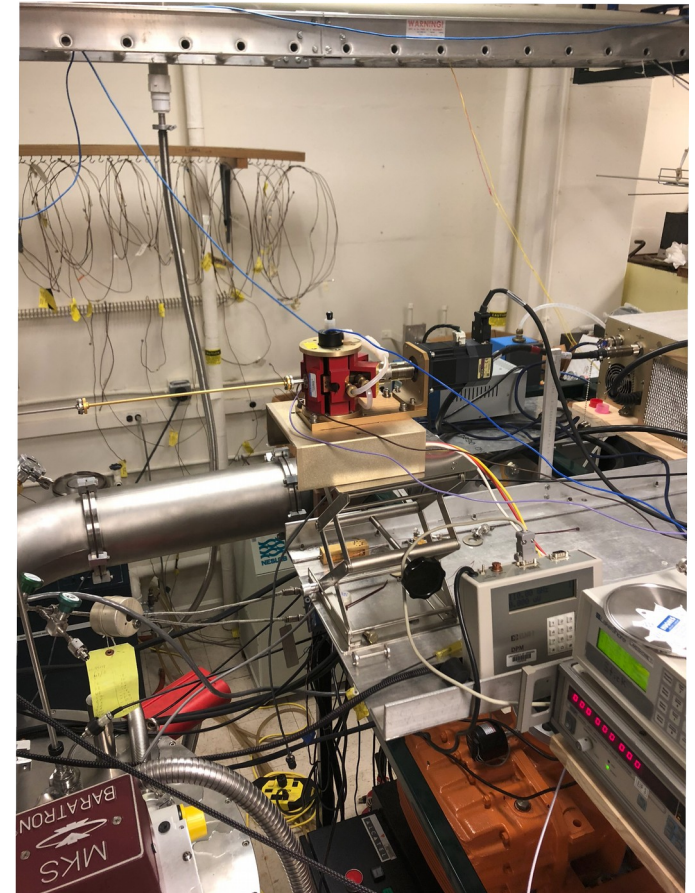
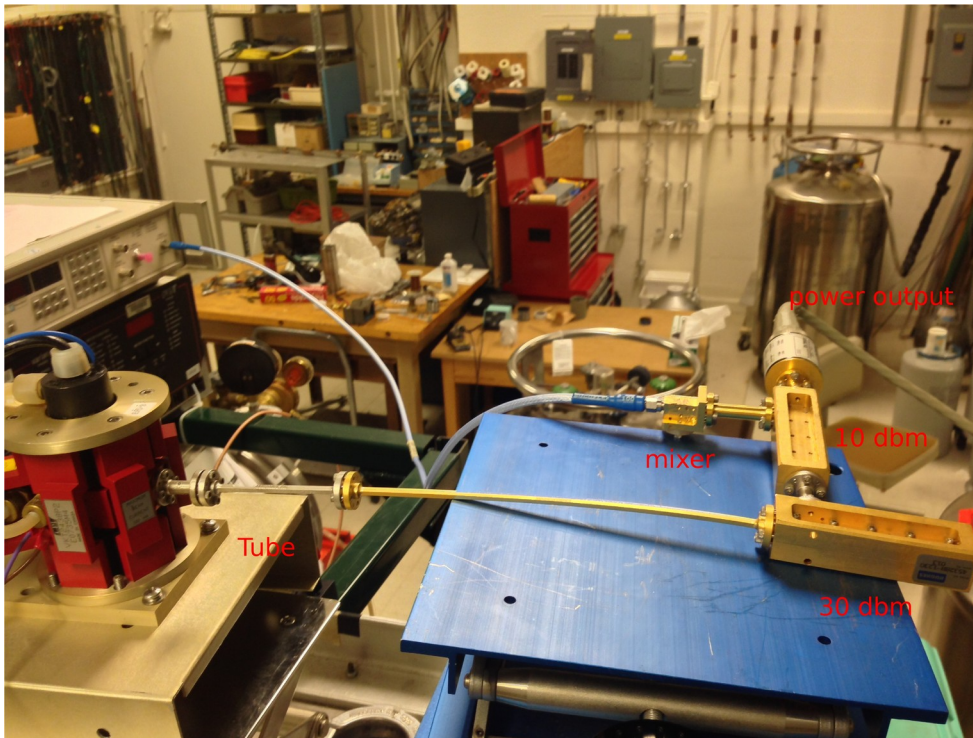




# NMR Comparison tests

- Signal to Noise (Liverpool to New)
- Temperature variation (temp control + record)
- Linearity (Liverpool to New: Ratio  $\sim 1\%$ )
- Full scale polarization comparison (pol  $\sim 3\%$ )

# Microwave Generator Setup

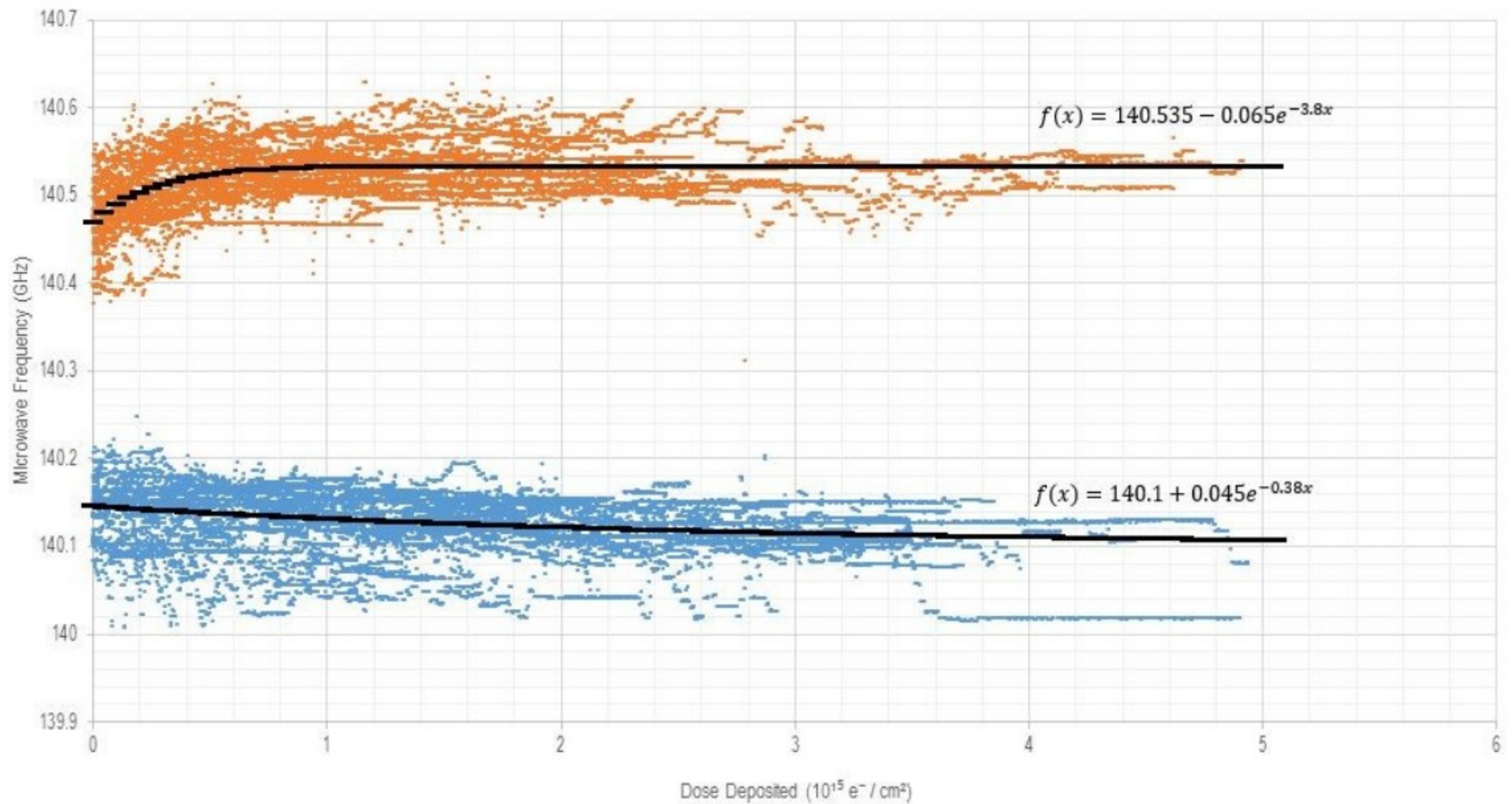


- 20W EIO attenuate down to mW scale:  
Mixer and Power meter
- Mixer has 10 mW damage threshold
- F→D (140 GHz), right angle bend
- Cavity size adjustment allows an additional 1.5%
- Variation of beam voltage allows to an additional 0.5% frequency adjustment
- Measure power at EIO and measure at helium evaporation (10 l/s per Watt)

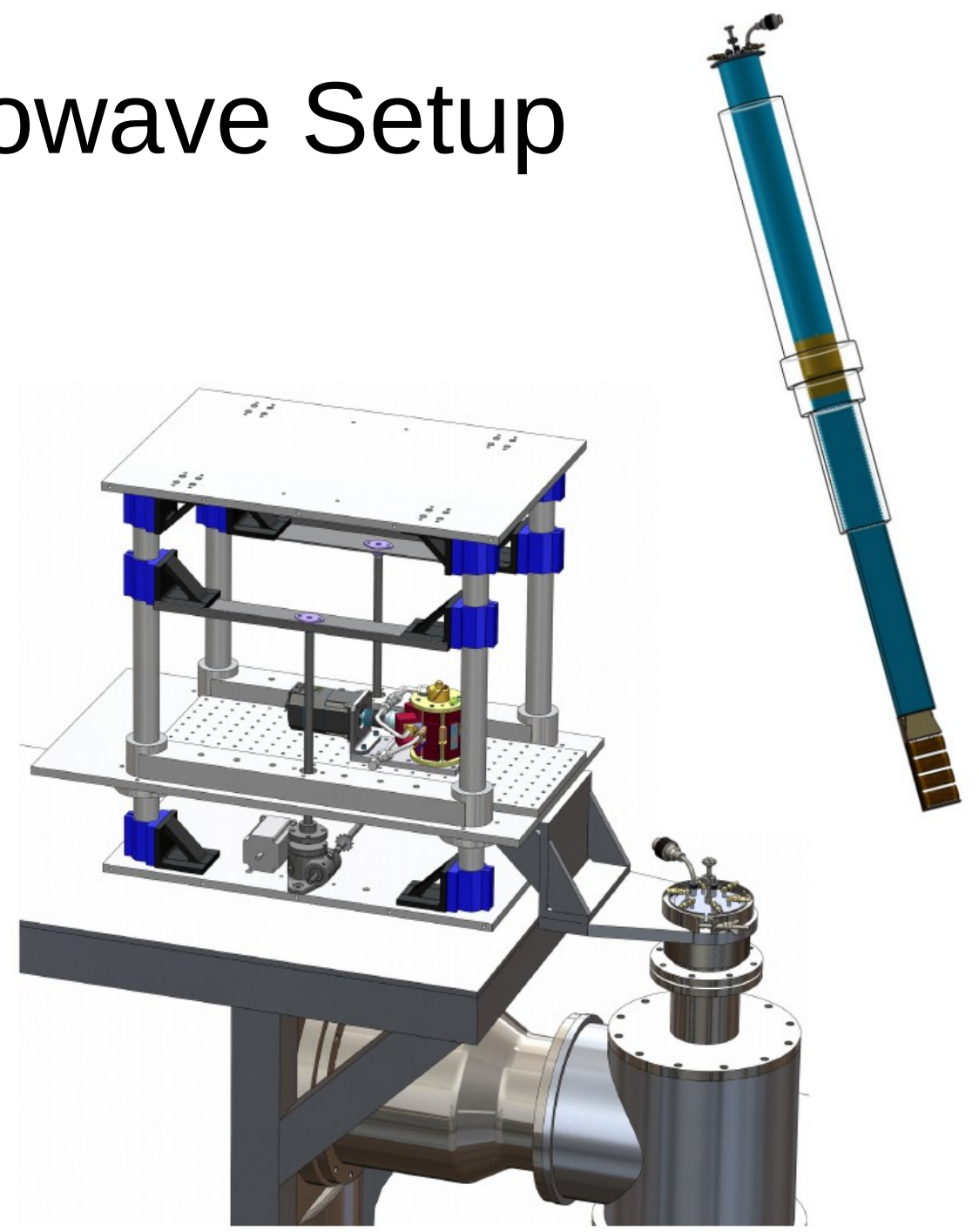
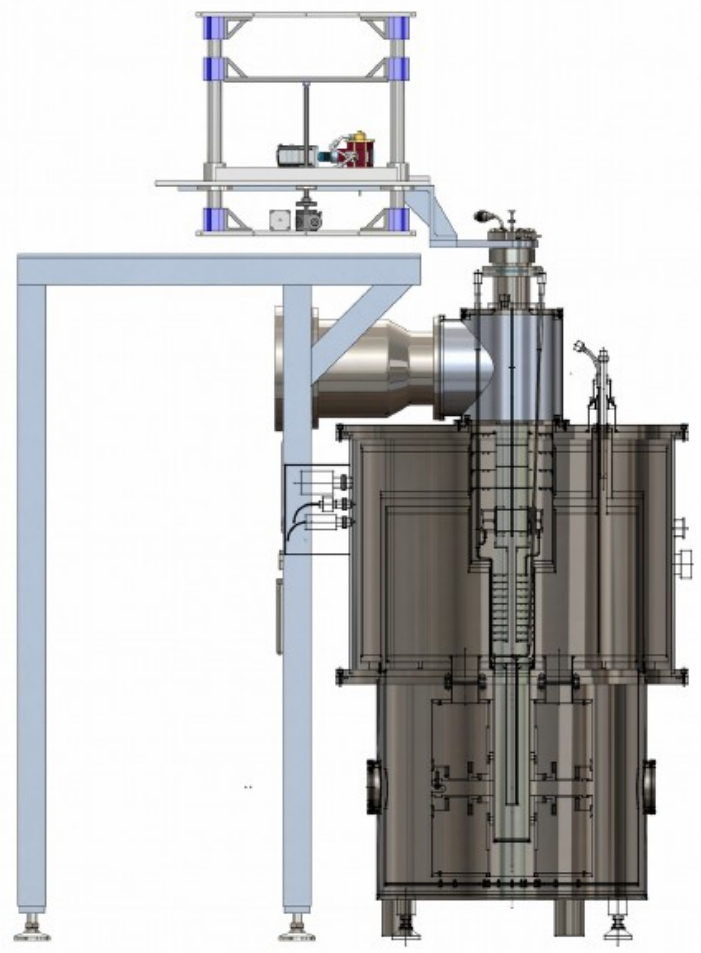


# Polarization Frequency

SANE  $\mu$ Wave Frequency vs Dose since last Anneal



# Microwave Setup



# Microwave Test

- Testing Slow Controls for Microwave
- Testing for homogeneous irradiation
- Testing for optimal cell configuration

Microwave each cell equally

Microwave each coil equally

Need for reflectors

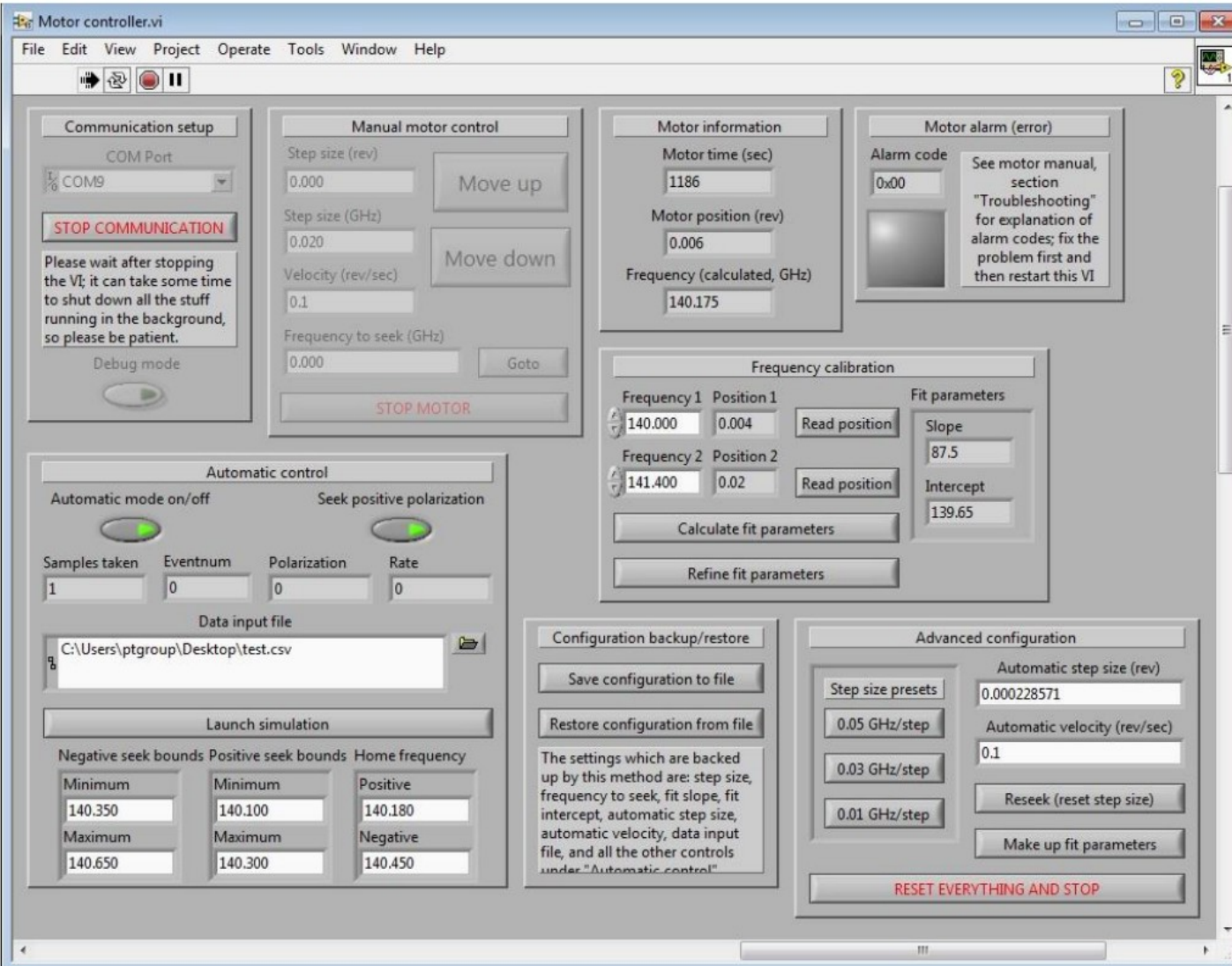
# Motor Control

This is the main microwave controller VI.

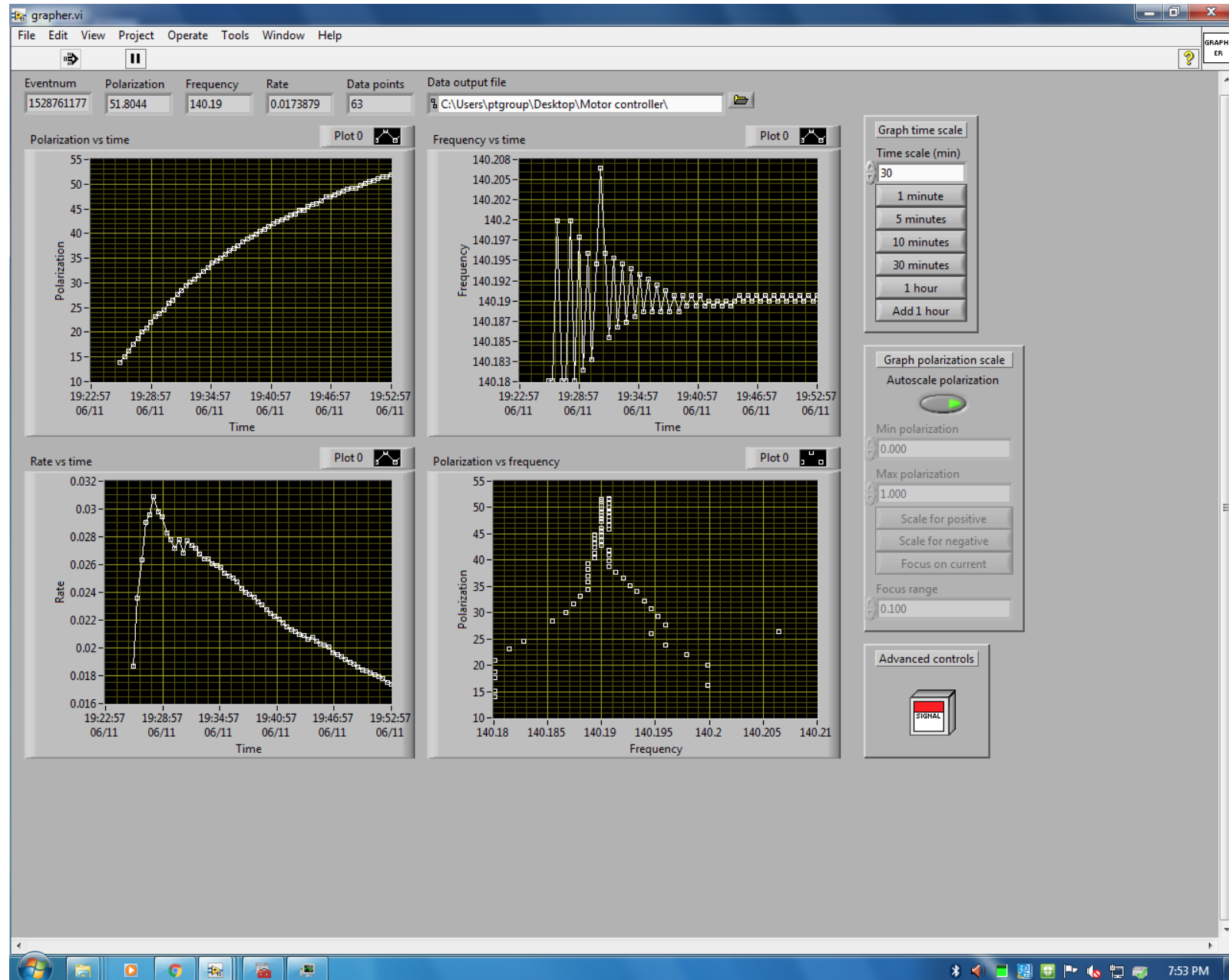
Can be run in automatic mode or manual mode.

First we should do the frequency calibration by moving the motor manually.

Can be run in real time experiment or in simulation mode.



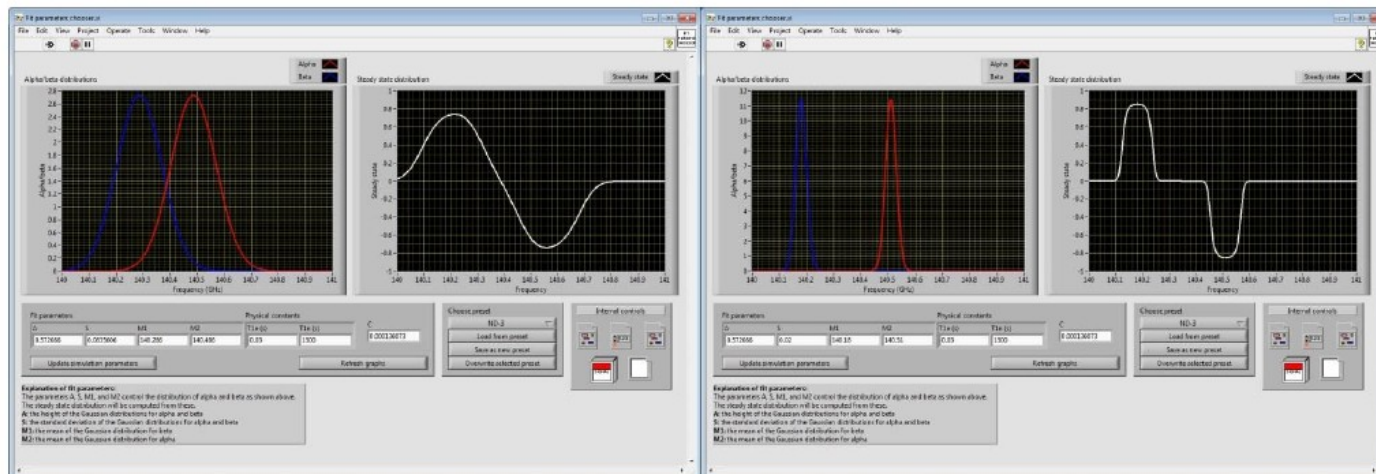
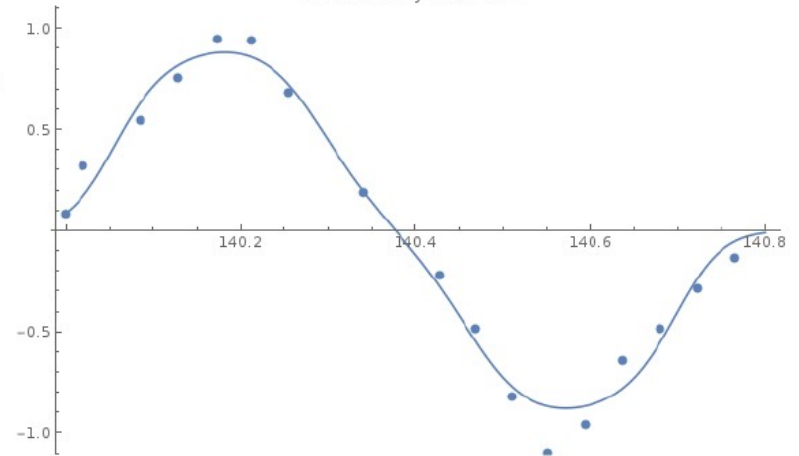
# Automated Frequency Control



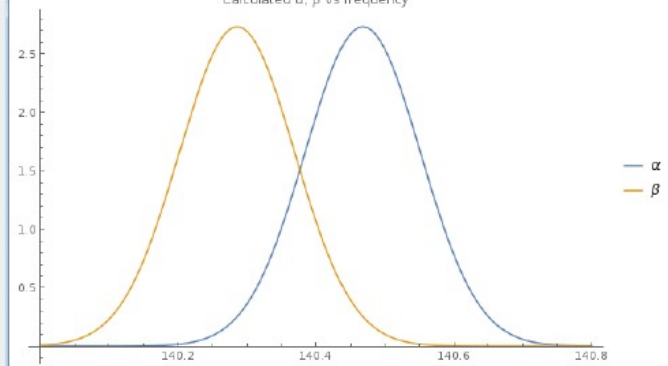
# Simulation

- Written in LabVIEW to work with stepper motor
  - Can also be run by itself to produce data
- Implements model
  - Parameters  $\alpha$  and  $\beta$  calculated from frequency

Actual steady state vs fit



Calculated  $\alpha$ ,  $\beta$  vs frequency





# Simulation

Advanced parameters (physical constants and debugging)

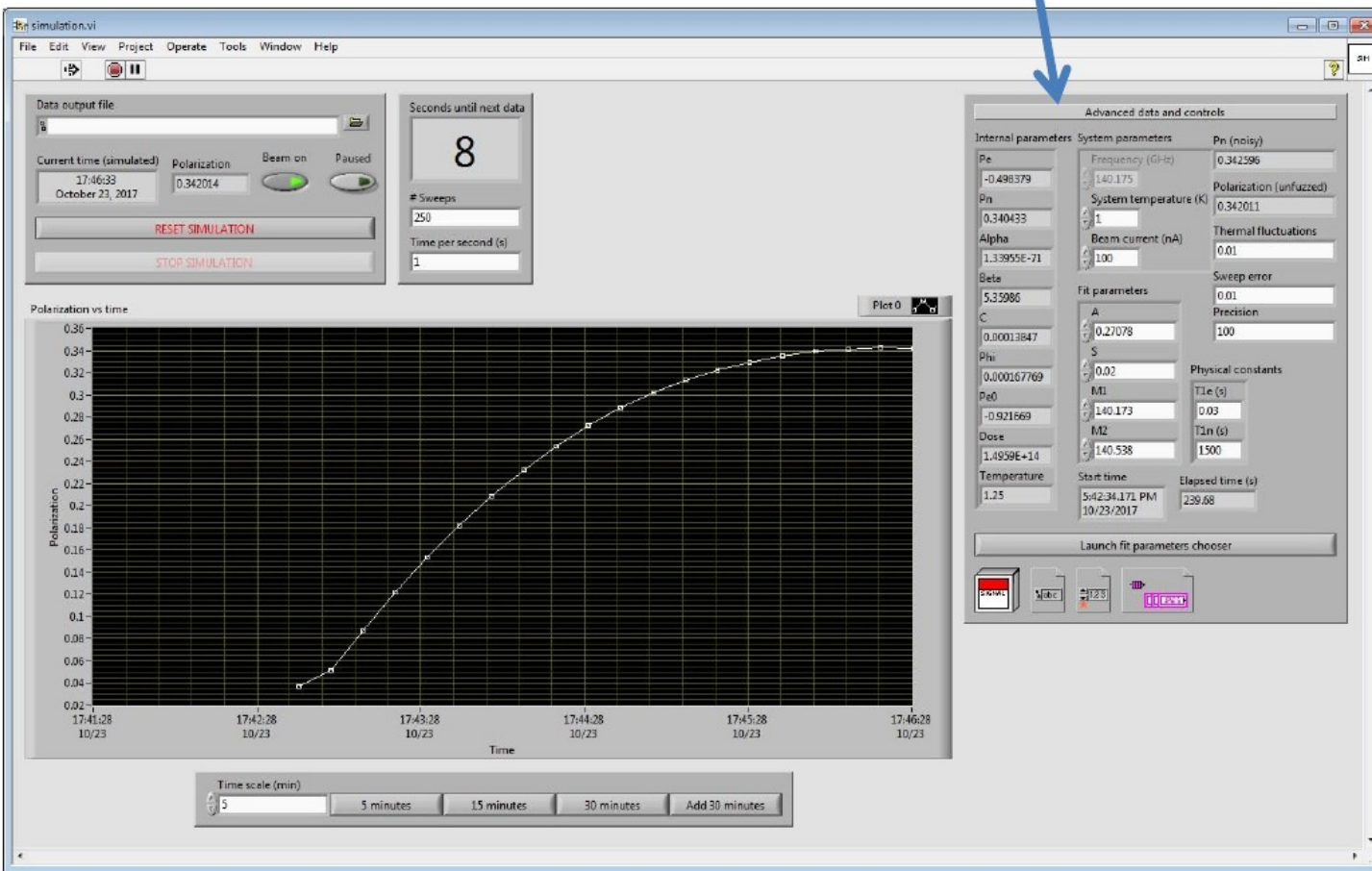
This is the main microwave simulation controller VI.

Can be started through main controller VI.

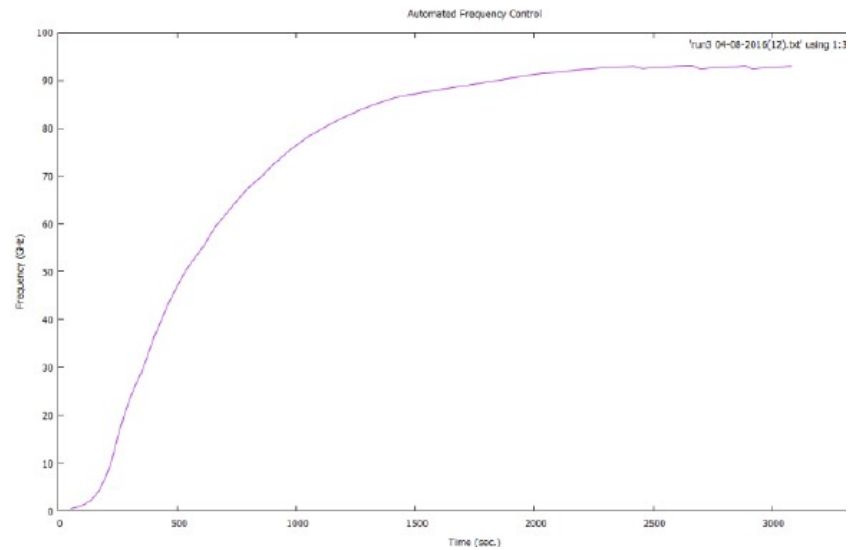
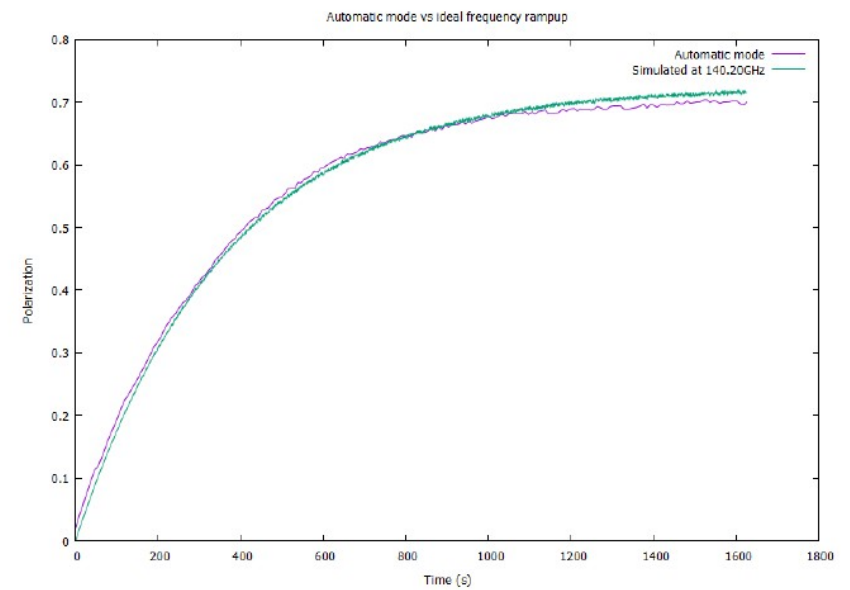
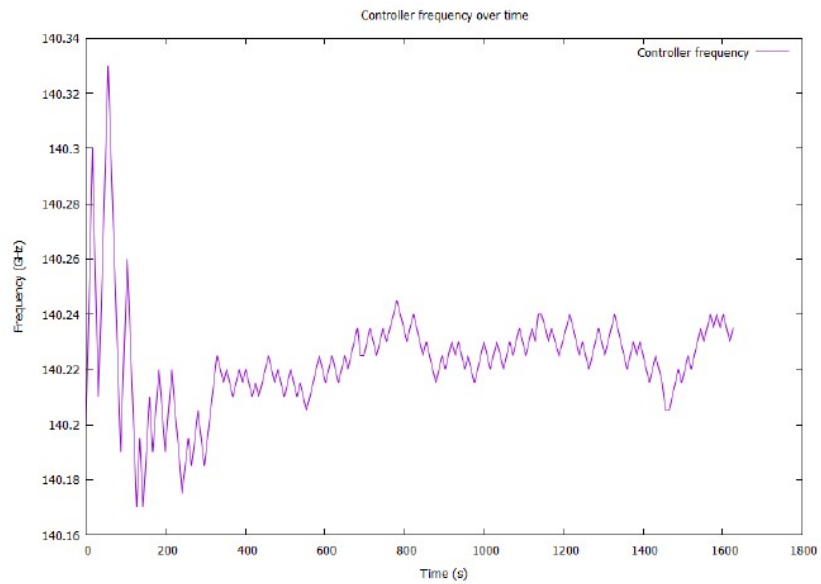
Can change many parameters and run for different material.

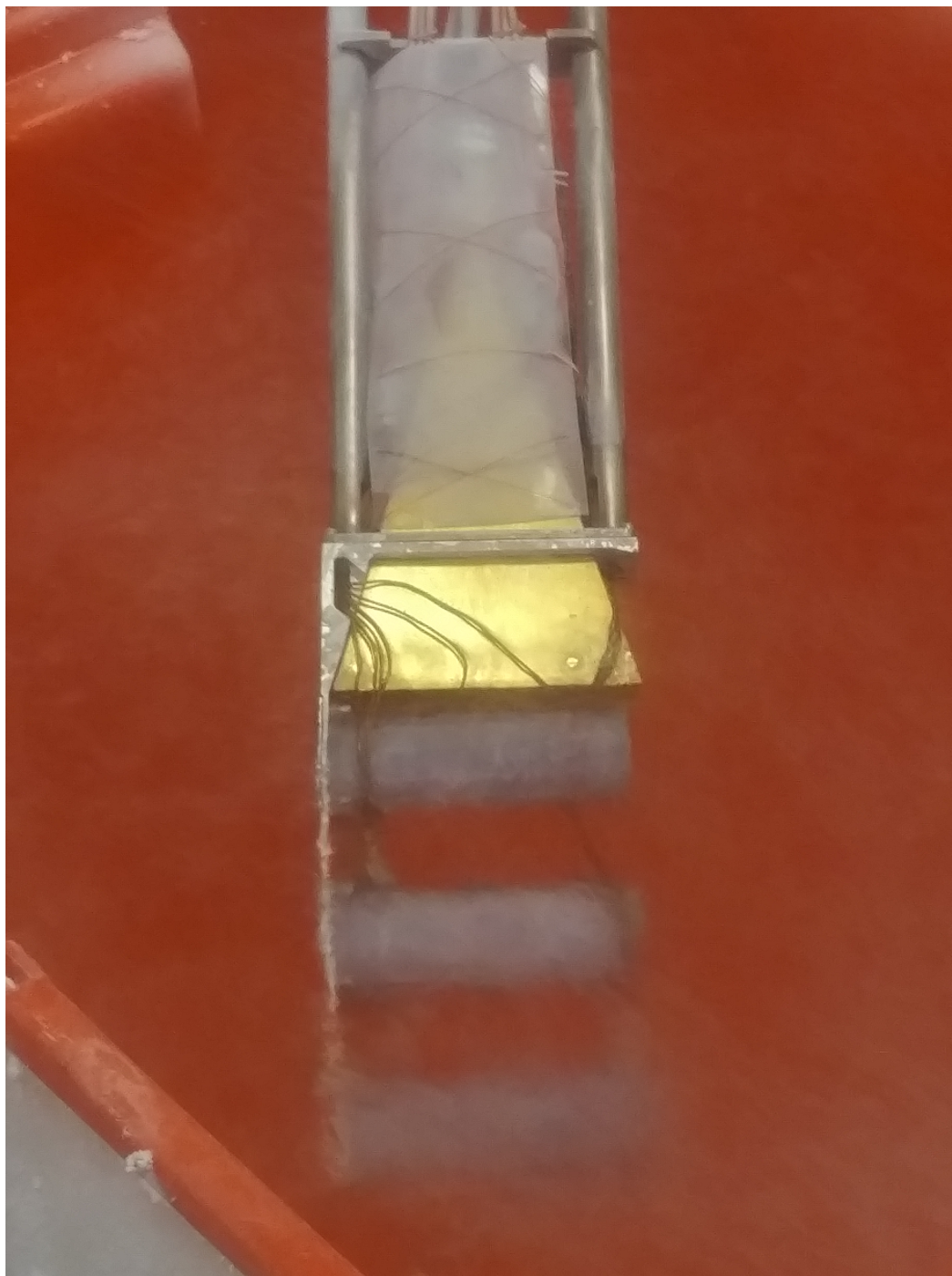
Mimic the real experimental NMR setup.

Can be used for training purposes and testing purposes

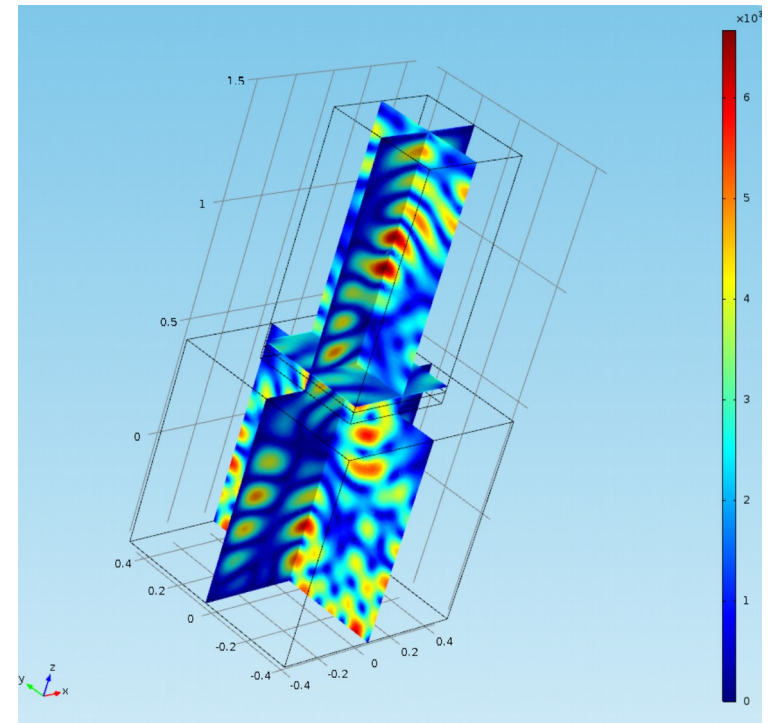
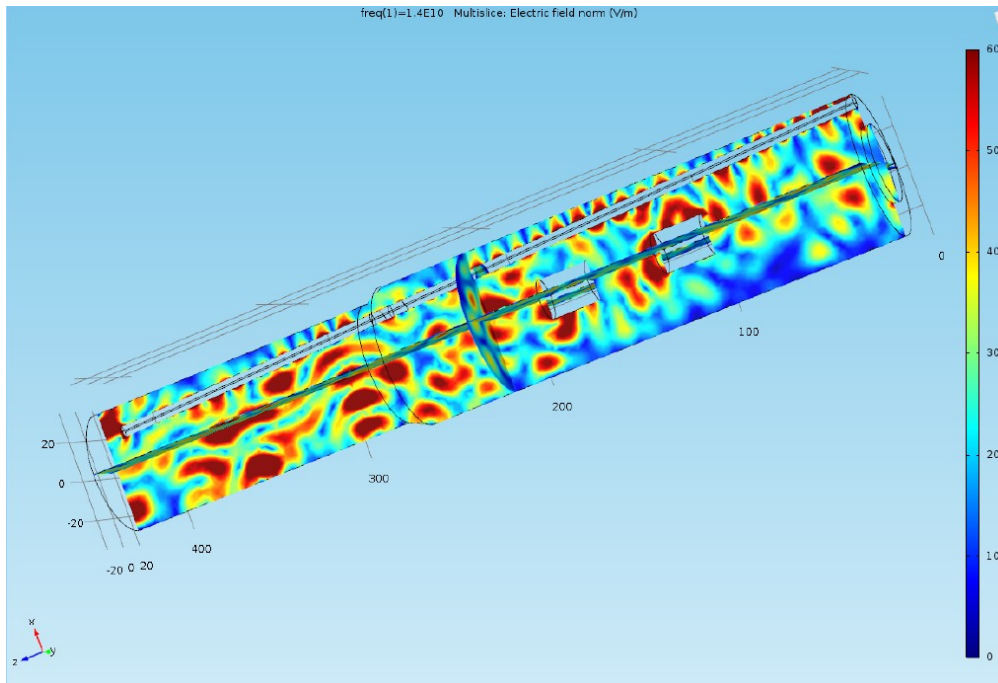
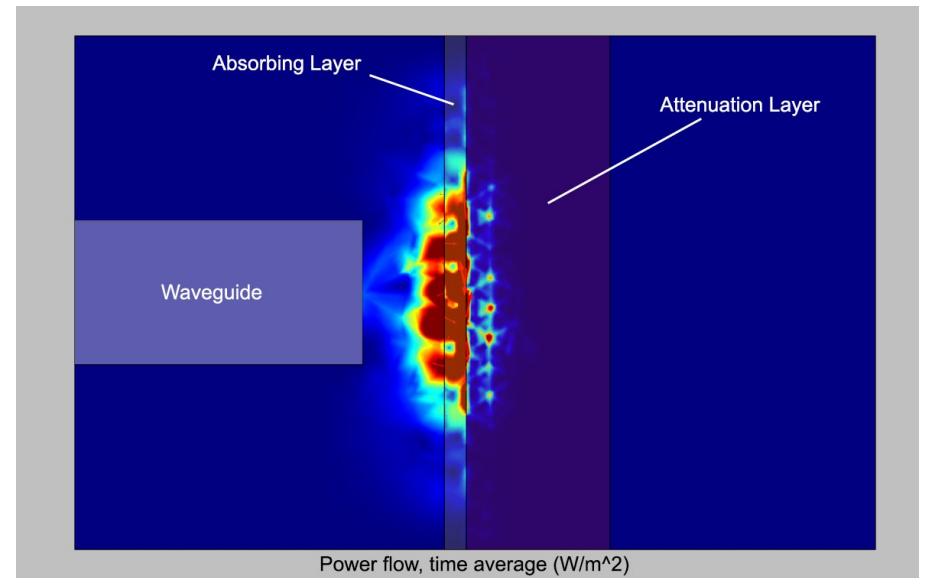
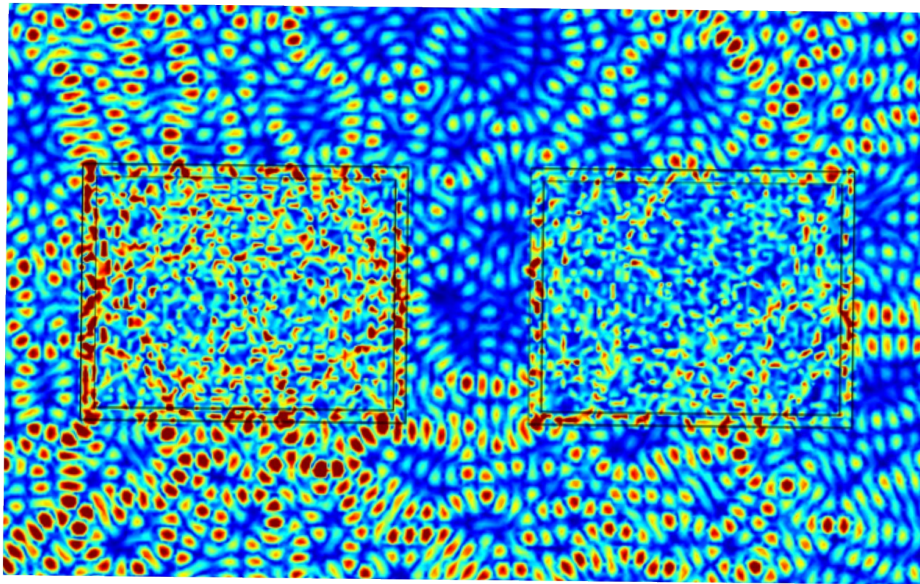


# Testing Performance

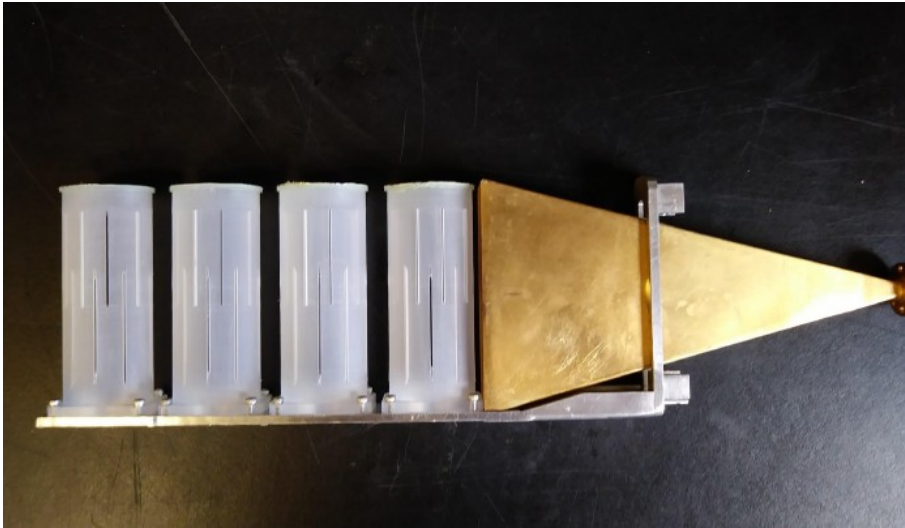




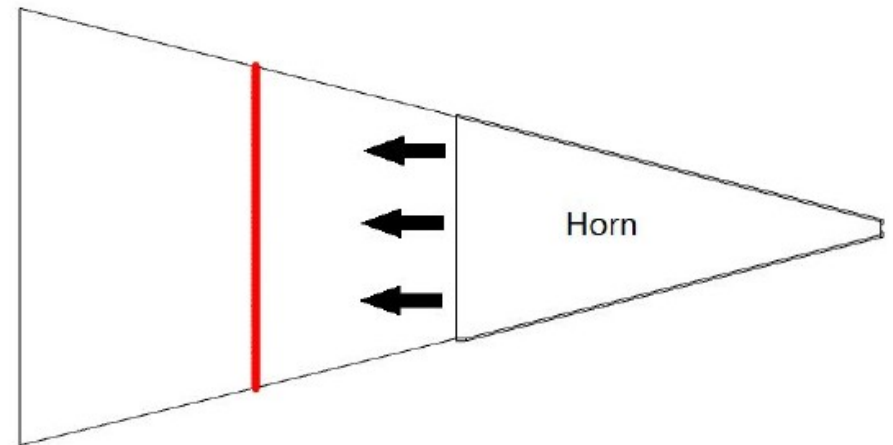
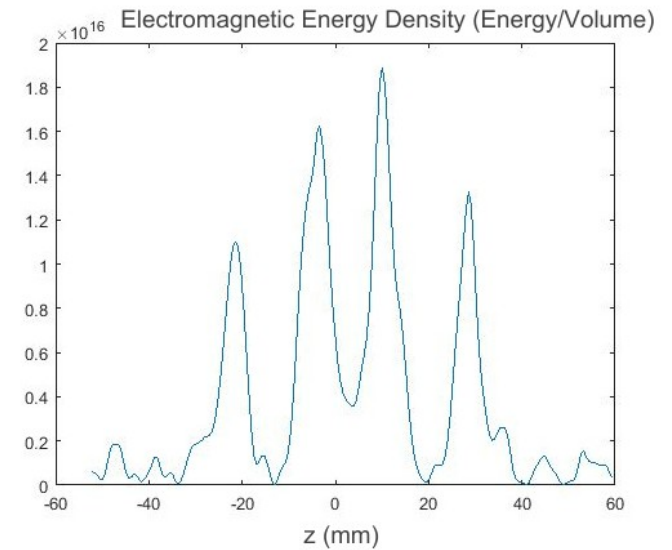
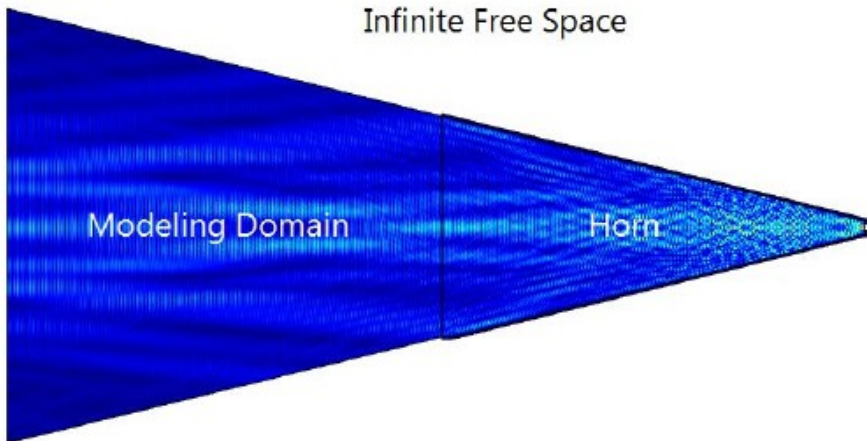
# COMSOL Microwave Simulation



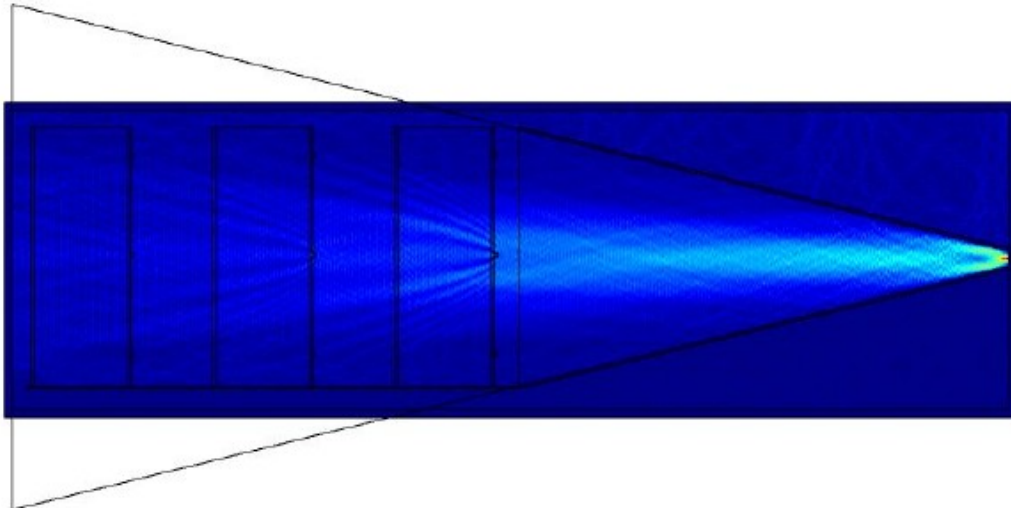
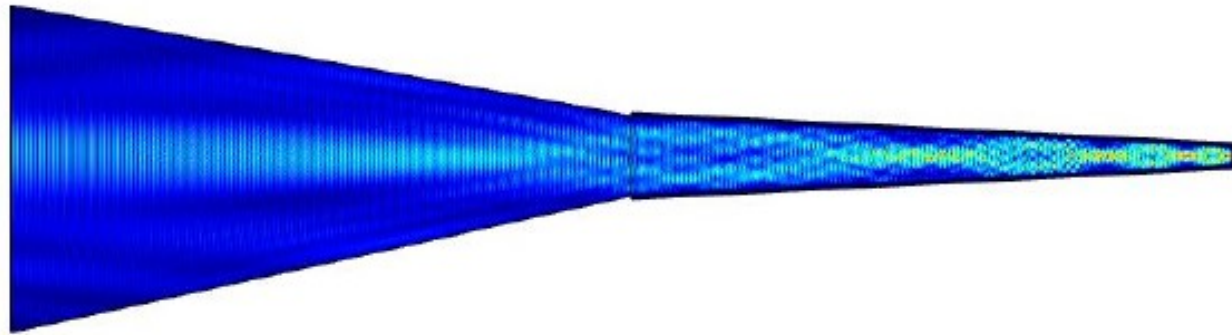
# Microwave Profile



Infinite Free Space



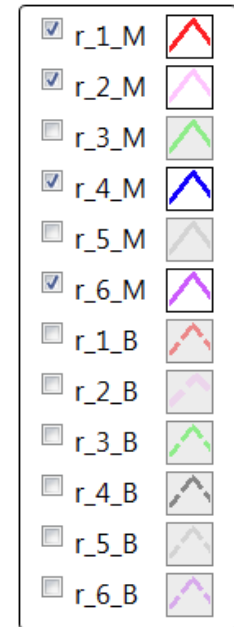
# Microwave Profile



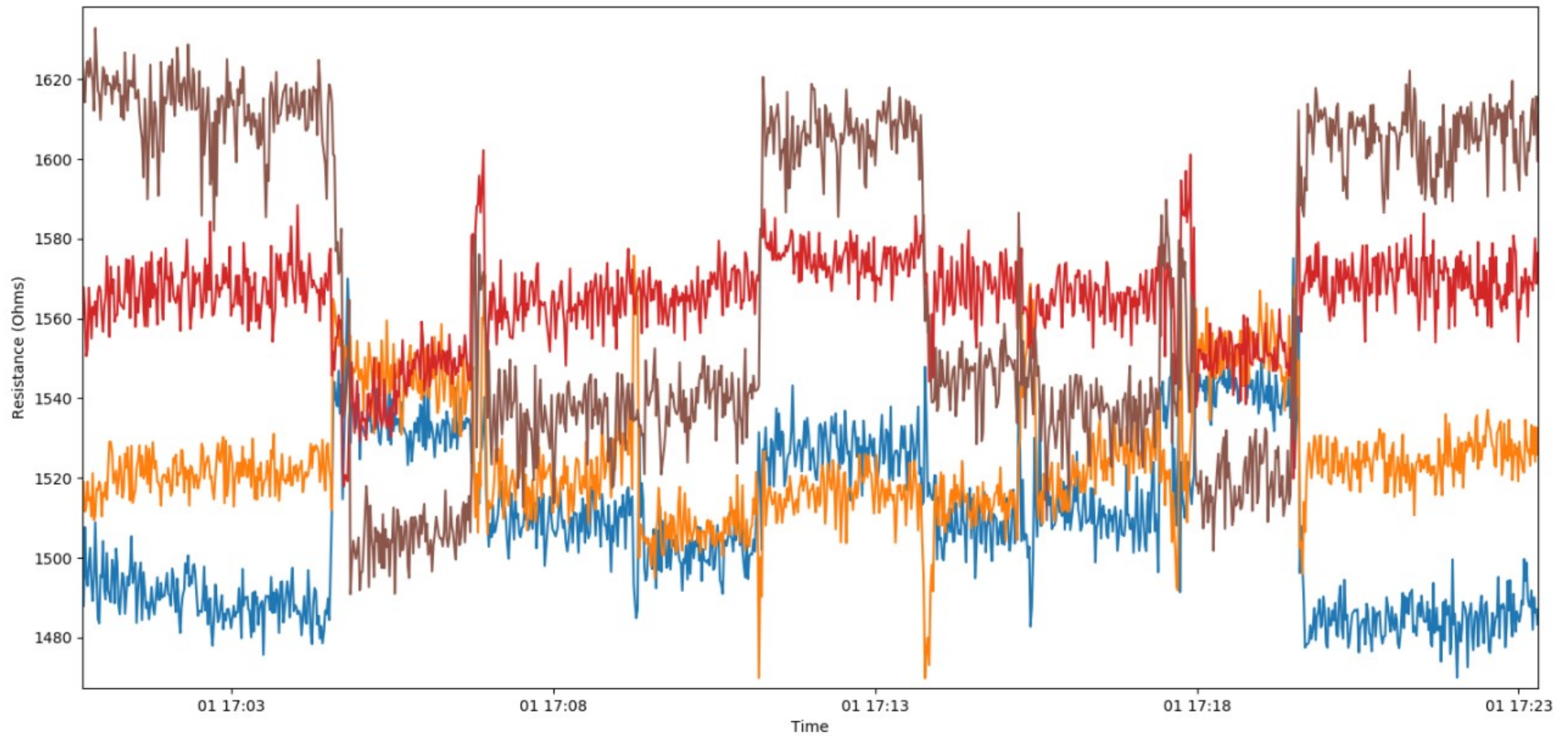
$-7.243e-7$ W	$-1.012e-6$ W	$-8.026e-7$ W
$-8.043e-6$ W	$-2.200e-5$ W	$-4.518e-5$ W
$-5.172e-7$ W	$-1.887e-6$ W	$-1.056e-6$ W

# Absorption at Resonance

Sensor data



# Microwave Studies





# POLARIZED TARGET SUBSYSTEMS

Magnet

Fridge

Insert

NMR

Microwave

Pumps

Target material

## Pumping system

designed and built by Oerlikon

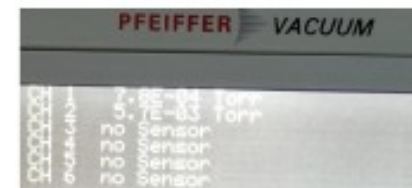
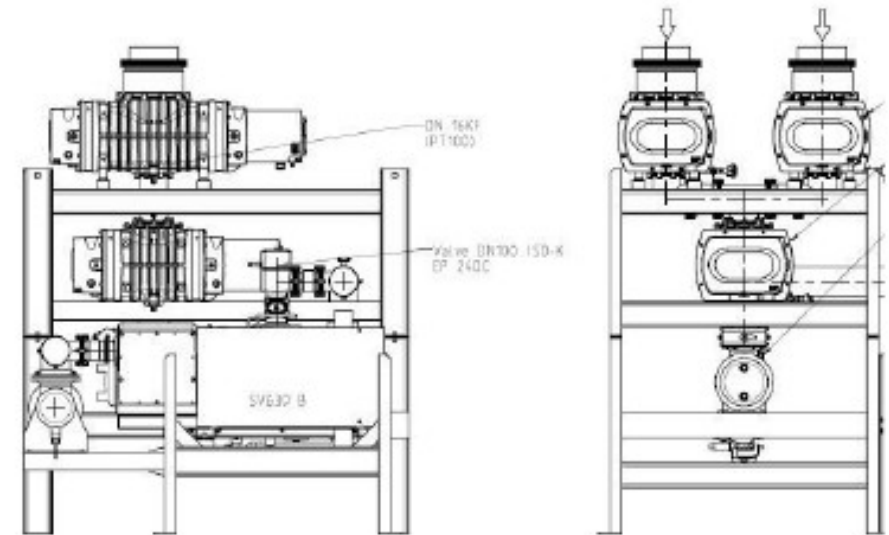
target heat load  $\sim 1.4\text{W}$

$\mu$ -wave:  $\sim 1\text{W}$ , beam:  $\sim 0.37\text{W}$

3 roots (7000), 1 rotary vane (840)

requires 100L LHe per day

14000 m<sup>3</sup>/hr pumping capacity



## Construction and tests

first assembly at LANL spring 2015

tested and shipped to FNAL

assembled and tested 10/2015



# POLARIZED TARGET SUBSYSTEMS

Magnet

Fridge

Insert

NMR

Microwave

Pumps

Target material

## Production

dedicated setup to produce NH<sub>3</sub> beads

NH<sub>3</sub> gas slowly frozen above LN<sub>2</sub> bath

~1000 g is needed for 2 yr run

~450 g currently produced

purchased three LN<sub>2</sub> dewars for storage

## Pre-Irradiation

creates paramagnetic centers for DNP

14 MeV electron beam under LAr bath

routinely done at NIST (Gaithersburg)

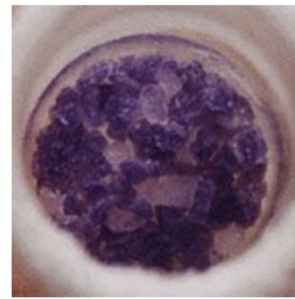
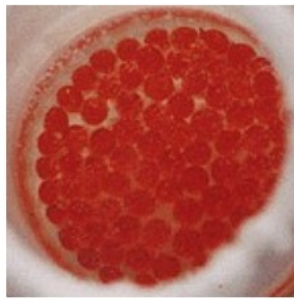
time consuming, trained manpower

~100 g irradiated and ready for experiment



# Target Material

- ◆ Successful material for DNP characterized by three measures:
  1. Maximum polarization
  2. Dilution factor
  3. Resistance to ionizing radiation



Material	Butanol	Ammonia, $\text{NH}_3$	Lithium Hydride, ${}^7\text{LiH}$
Dopant	Chemical	Irradiation	Irradiation
Dil. Factor (%)	13.5	17.6	25.0
Polarization (%)	90-95	90-95	90

Material	D-Butanol	D-Ammonia, $\text{ND}_3$	Lithium Deuteride, ${}^6\text{LiH}$
Dil. Factor (%)	23.8	30.0	50.0
Polarization (%)	40	50	55

Rad. Resistance

moderate

high

very high

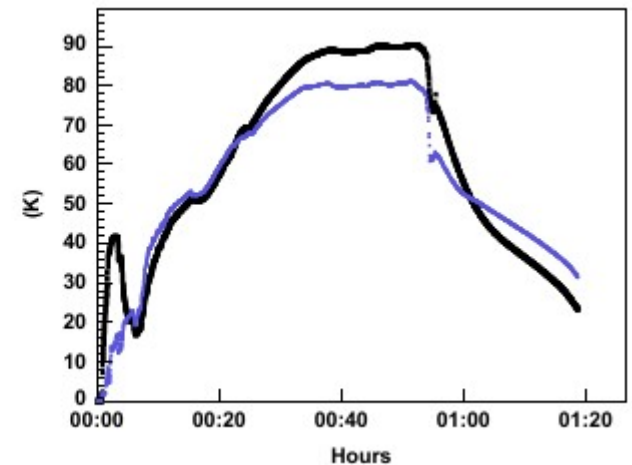
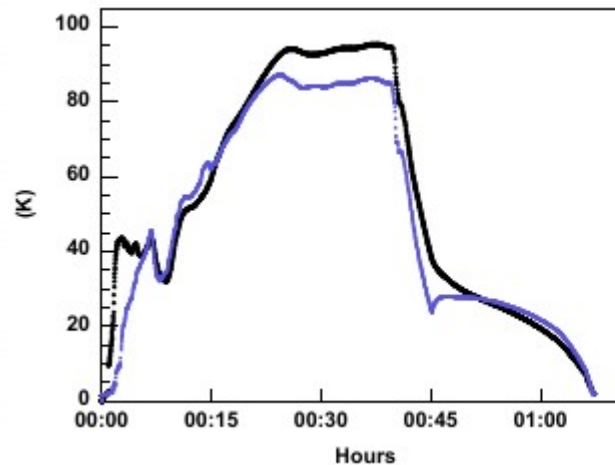
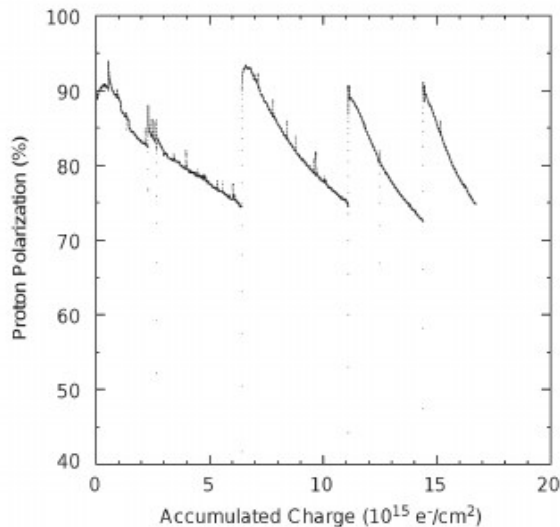
*Comments*

*Easy to produce and handle*

*Works well at 5T/1K*

*Slow polarization, but long  $T_1$*

# Radiation Damage and Recovery



- Maximum Polarization decays as a function of dose
- Heat material (Anneal) to allow radicals to recombine
- Done by heat wire around target cell raising to 80-100K for 20-60 minutes
- Needed at 4Pprotons/cm<sup>2</sup> (about every shift)
- Once exhausted (40 Pprotons/cm<sup>2</sup>) need target material replacement

# A Word on Systematics

Target Temperature Change over beam spill

Microwave Profile

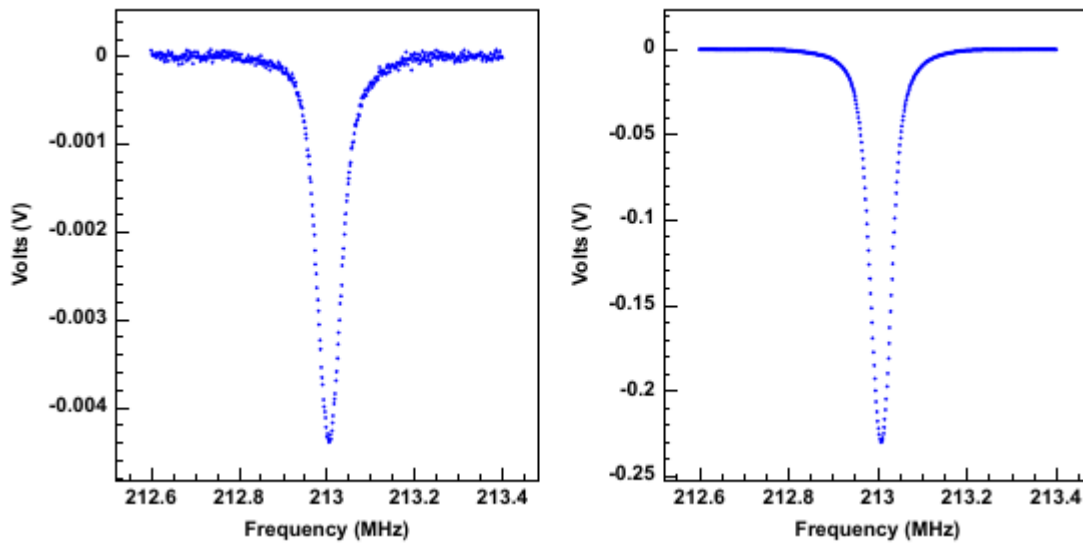
Dose Accumulation

TE Calibrations Take Time

Dilution Factor and Packing Fraction

# Polarization Calibration and Measurement

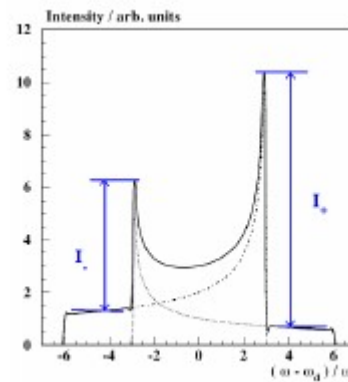
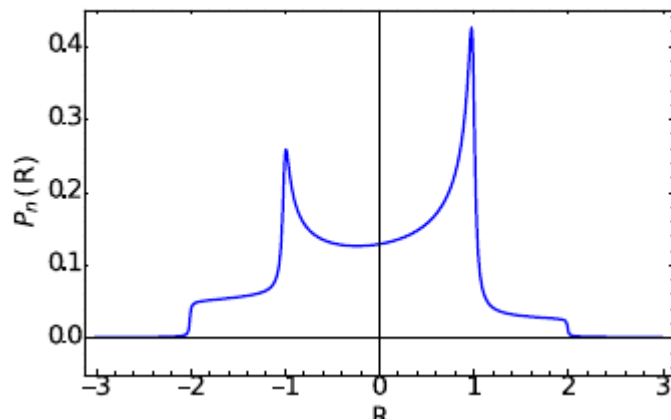
~0.3%



Proton

$$P_{TE} = \tanh\left(\frac{\mu B}{kT}\right)$$

~0.05%



Deuteron

$$P_{TE} = \frac{4 + \tanh \frac{\mu B}{2kT}}{3 + \tanh^2 \frac{\mu B}{2kT}}$$

$$P_z = \frac{R^2 - 1}{R^2 + R + 1}$$

Neutron

$$P_n = (1 - 1.5\alpha_D)P_d \approx 0.91P_d$$

# Uncertainty in Polarization

$$P_{TE} = \tanh\left(\frac{\mu B}{kT}\right)$$

$$P_E = G \frac{\int S_E(\omega) d\omega}{\int S_{TE}(\omega) d\omega} P_{TE} = GC_{TE}A_E$$

$$C_{TE} = \frac{P_{TE}}{A_{TE}}$$

Procedural errors  
can be to be pretty small:  
Assuming the right procedure  
(Target is thermalized to TE)

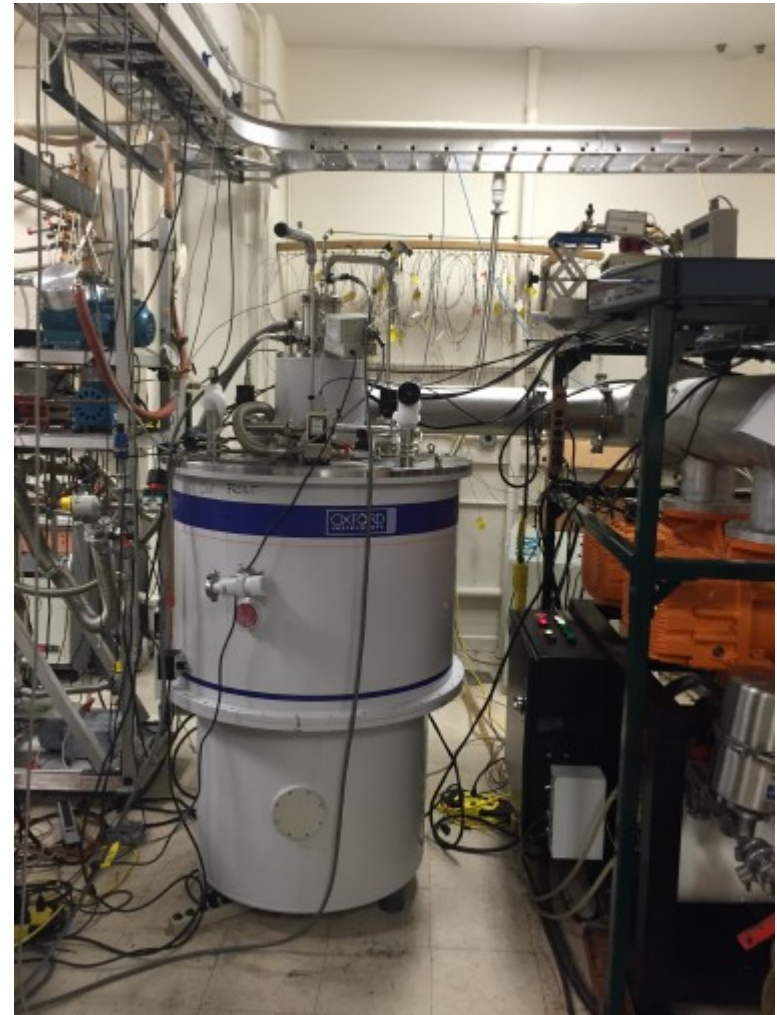
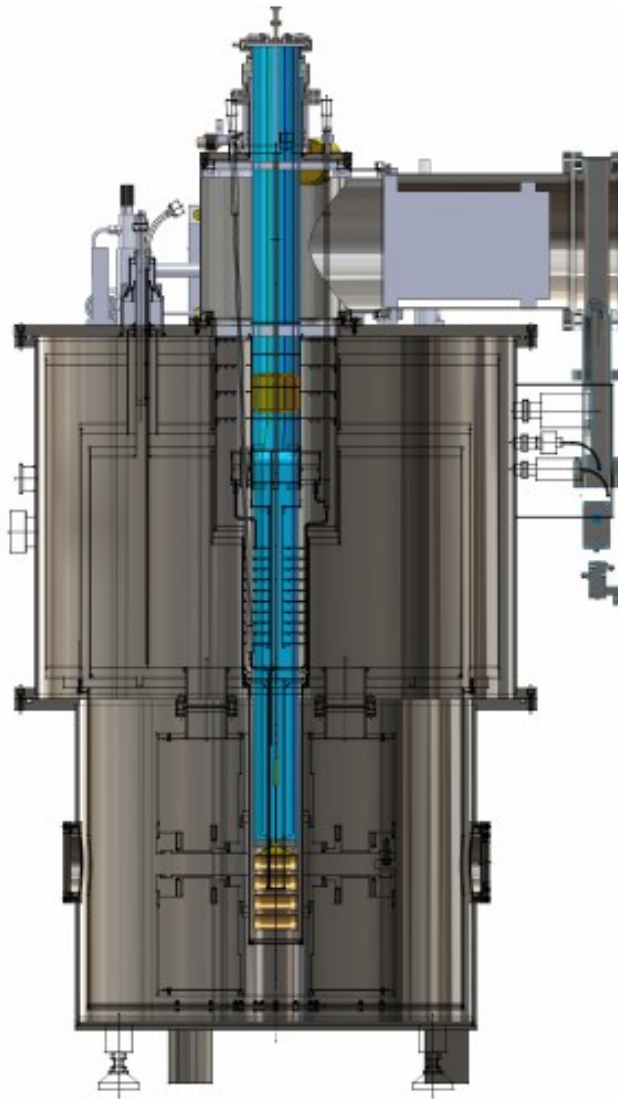
(#)	Type	Source	Error (%)
(1)	$S_{TE}$	$\Delta T$	1.45
(2)	$A_{TE}$	$\Delta A_{TE}$	1.61
(3)	$A_{TE}$	$\Delta A_{fit}$	0.75
(4)	$S_E$	$R_B$	0.50
(5)	$S_E$	$\Delta V_Q$	0.75
(6)	$S_E$	NMR-tune	0.47
(7)	$S_E$	$\Delta B_{drift}$	0.25
(8)	G	$\Delta V_{Yale}$	0.10
(9)	-	$\Delta P_{run}$	0.50
		$\Delta P/P$	2.60

(Temp/pressure measurements)  
(area measurements)  
(background subtraction)  
(setability)  
(NMR temp sensitivity)  
(NMR tune and tune drifts)  
(Charge averaging)

$$\frac{\delta P_E}{P_E} = \left[ \left(\frac{\delta G}{G}\right)^2 + \left(\frac{\delta P_{TE}}{P_{TE}}\right)^2 + \left(\frac{\delta A_{TE}}{A_{TE}}\right)^2 + \left(\frac{\delta A_E}{A_E}\right)^2 + \left(\frac{\delta S_{TE}}{S_{TE}}\right)^2 + \left(\frac{\delta S_E}{S_E}\right)^2 \right]^{1/2}$$

# Full System

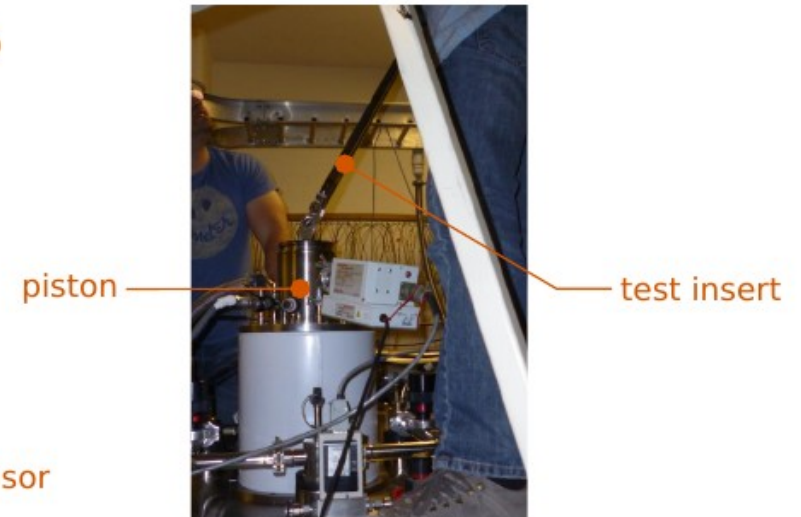
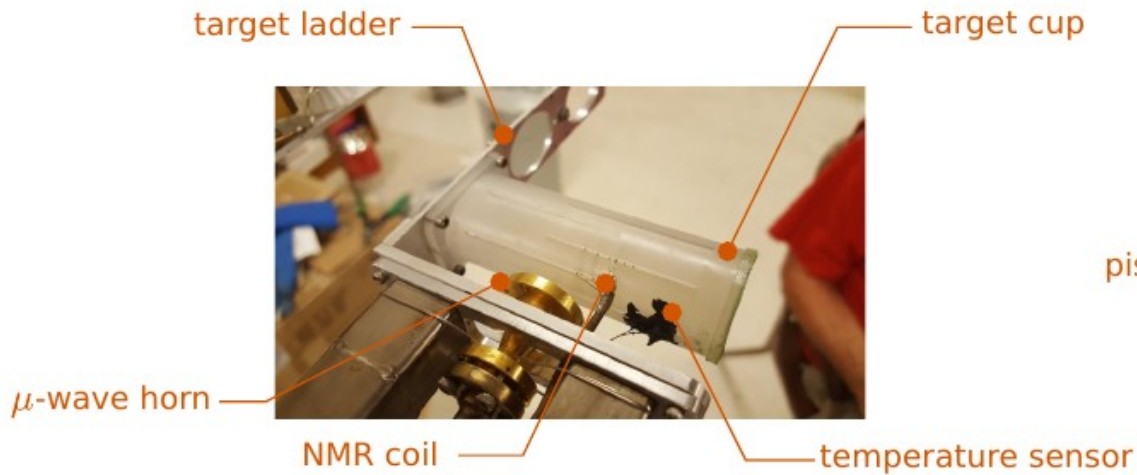
## UVA Cooldowns



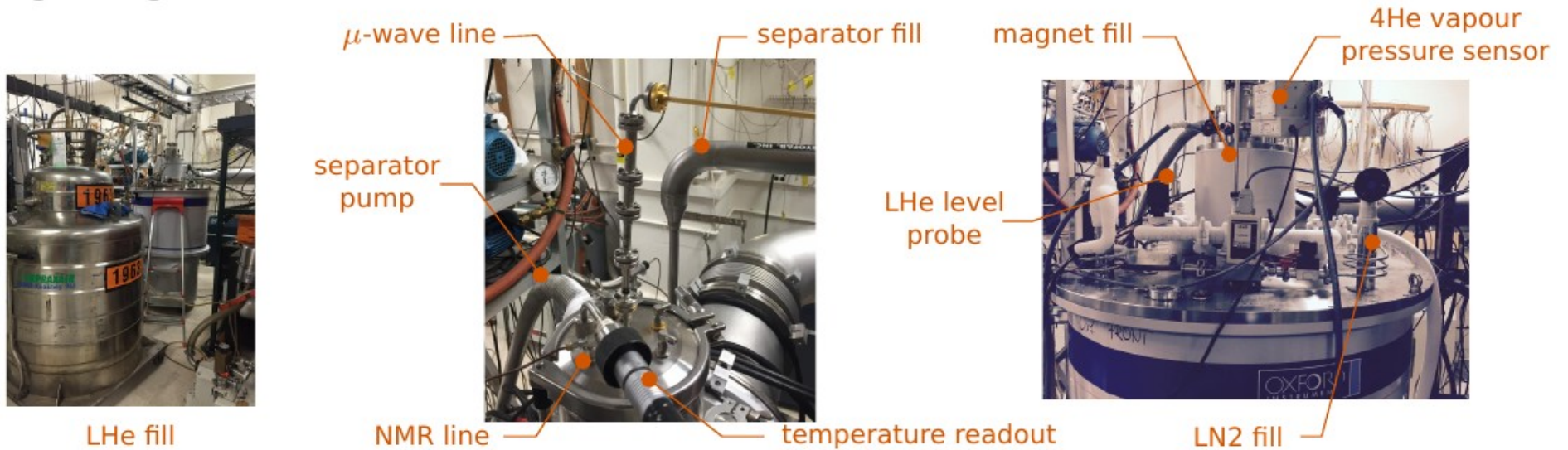


# 3 Test Full System

Final preparations and run  
made test target insert, practiced installation



getting cold



# Last Cooldown Highlights

Got Insulating Vacuum down to  $3.7 \times 10^{-6}$ ,  
average boil off 17 SLM

First Polarization of ND3: 20%

Coil Position Tests:

Position 1: coil 1=80%, coil 2=85%, coil 3=80%

Position 2: NM

Position 3: Coil 1=78%, Coil 2=85%, Coil 2=NM

Position 4: Coil 1=NM, 80%, coil 3=85%

Magnetic Field Drifts: 0.02A/4days

Generate Field Map

# Cryogenic Performance

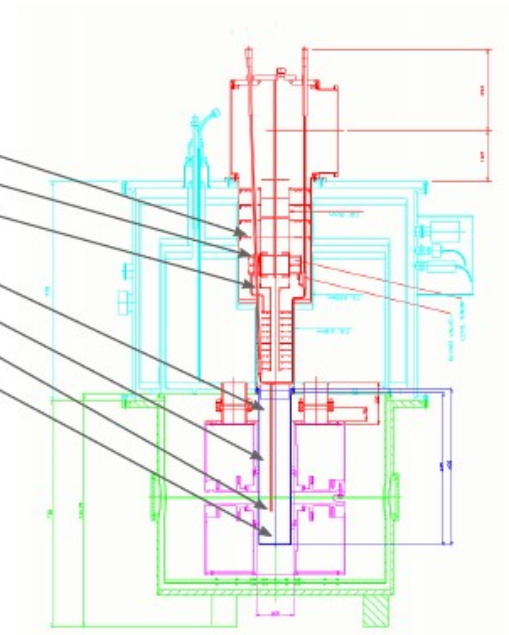
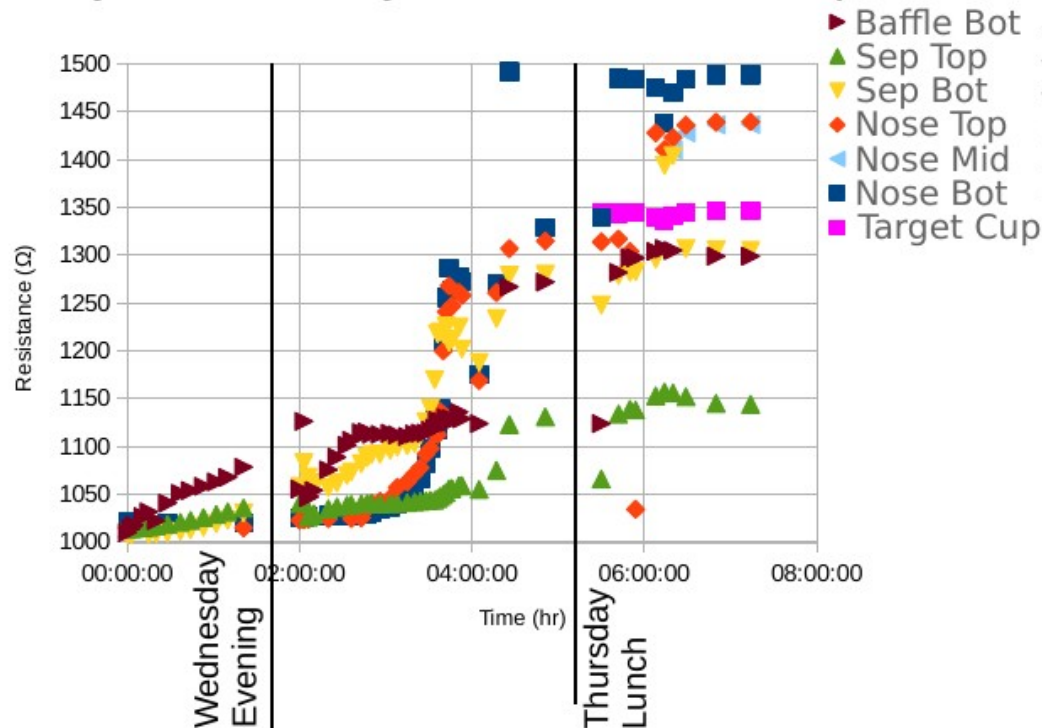
## Test results

### Fridge performance

separator and nose fill

~1hr to fill the nose after a night on standby

very stable, very little attention required

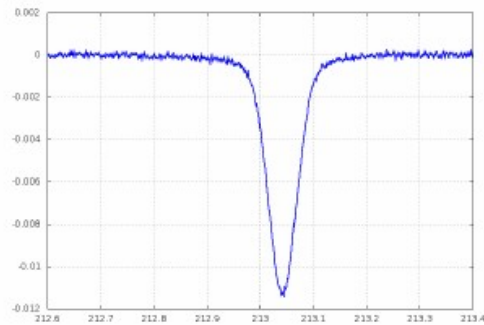


# Results of All the Work

## Test results

### Polarization

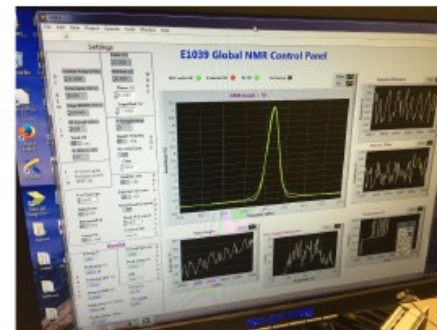
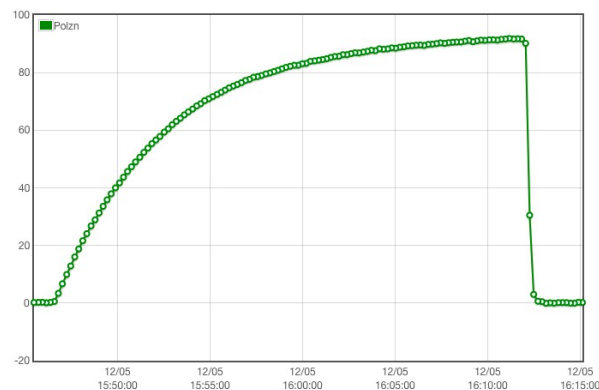
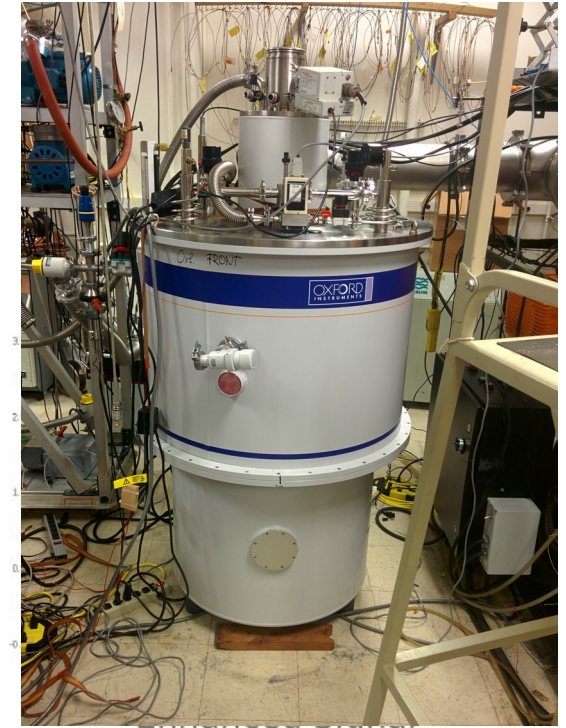
polarized fresh NH<sub>3</sub> both positively and negatively  
took extensive TE measurements  
alternated UVA and new LANL NMR systems



Frequency, MHz  
TE signal



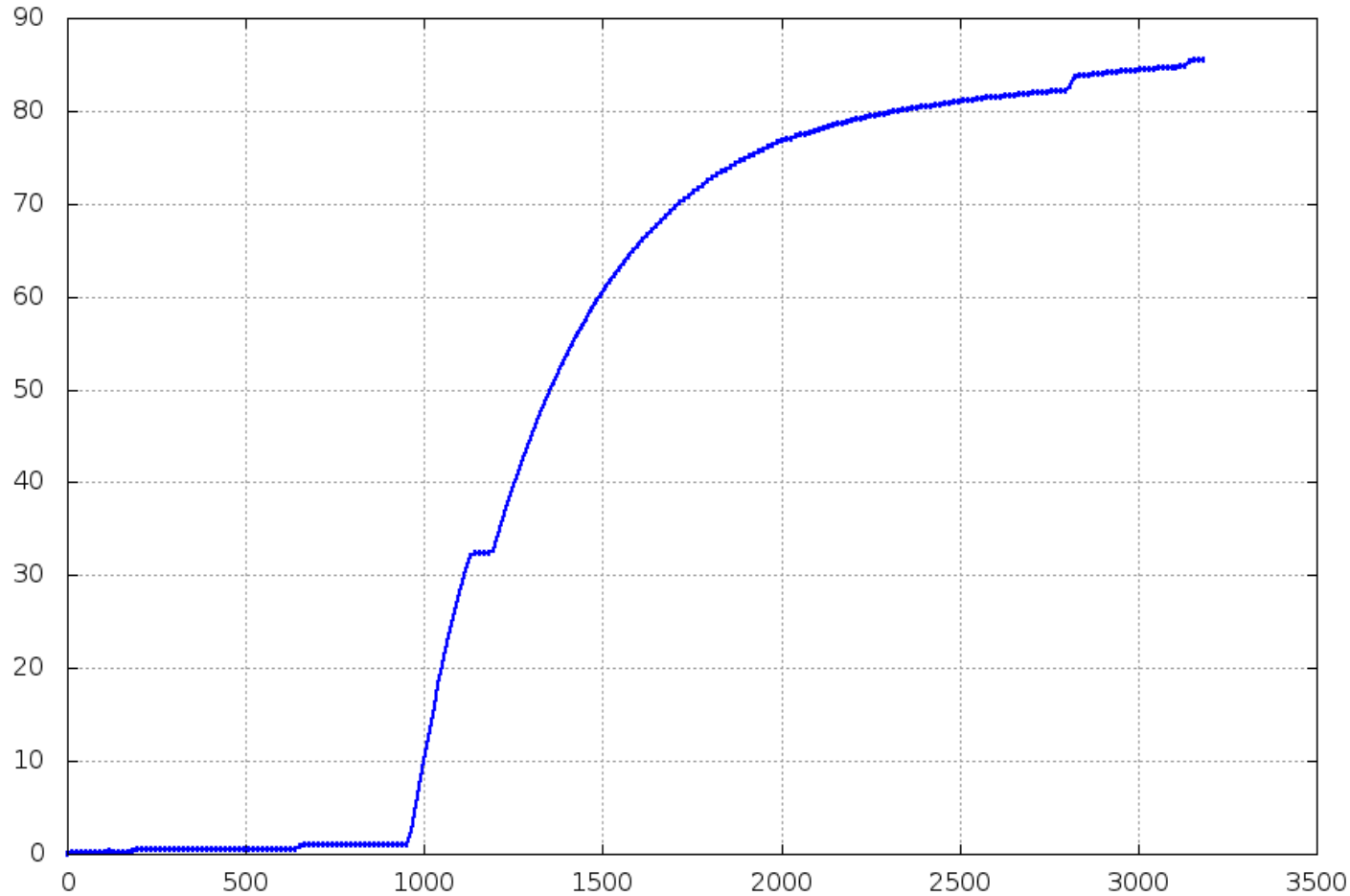
UVA NMR Signal



LANL NMR Signal



# Initial Run: Central Top Coil

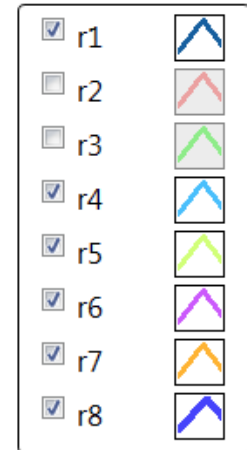
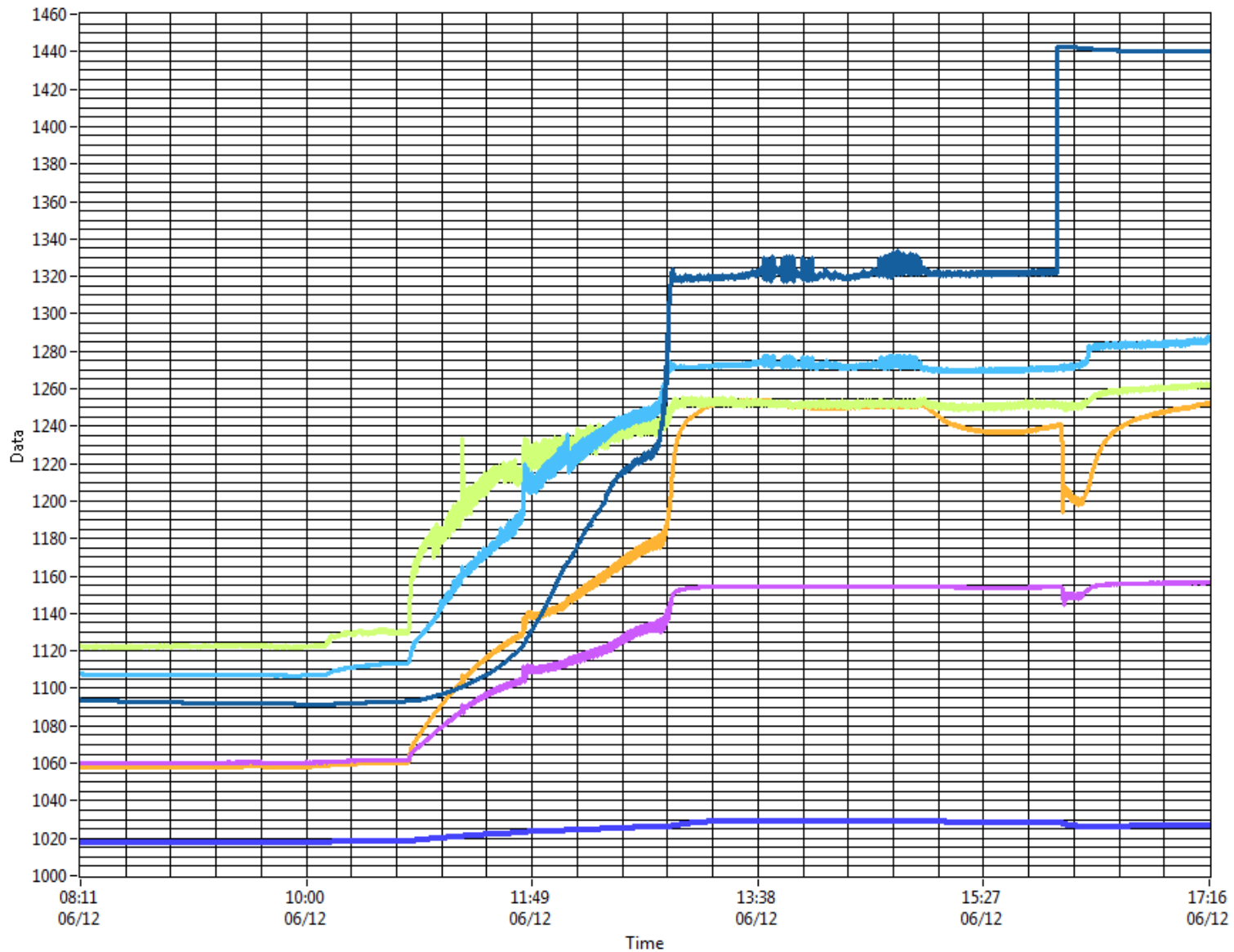


- 85.5%(2.7%)(5.5%)
- 5-10:1

# Results of This Cooldown

# Fridge Sensors

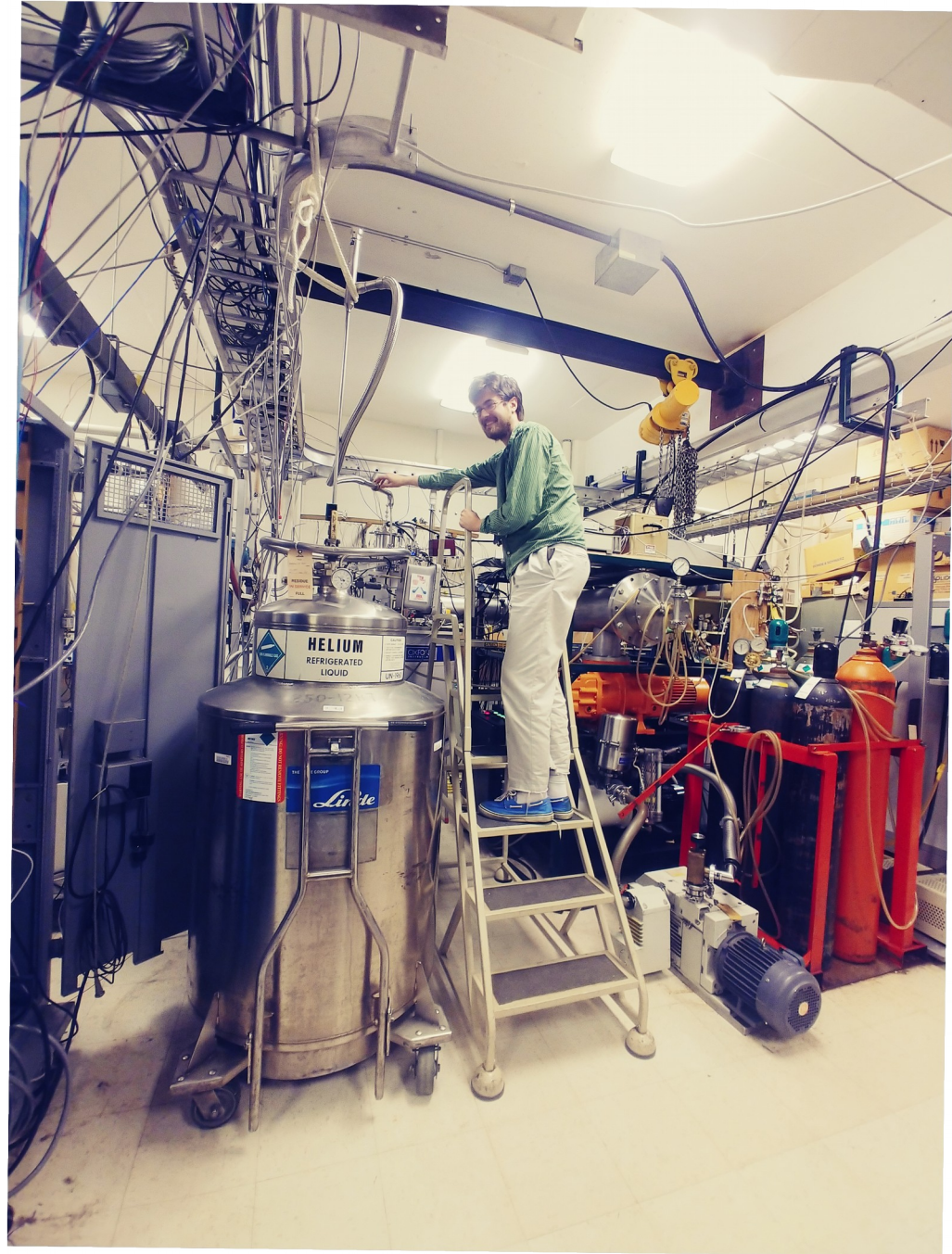
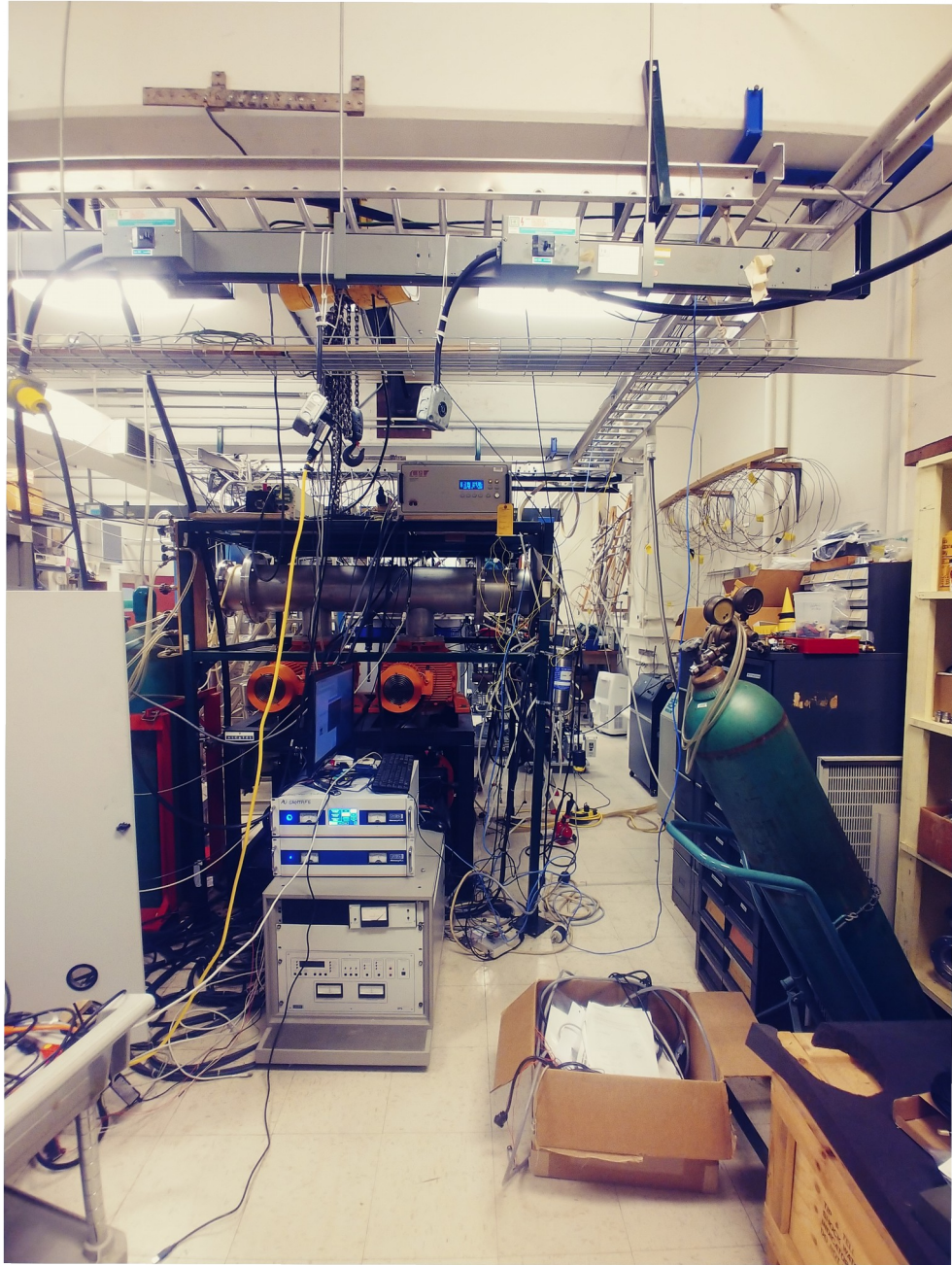
Sensor data

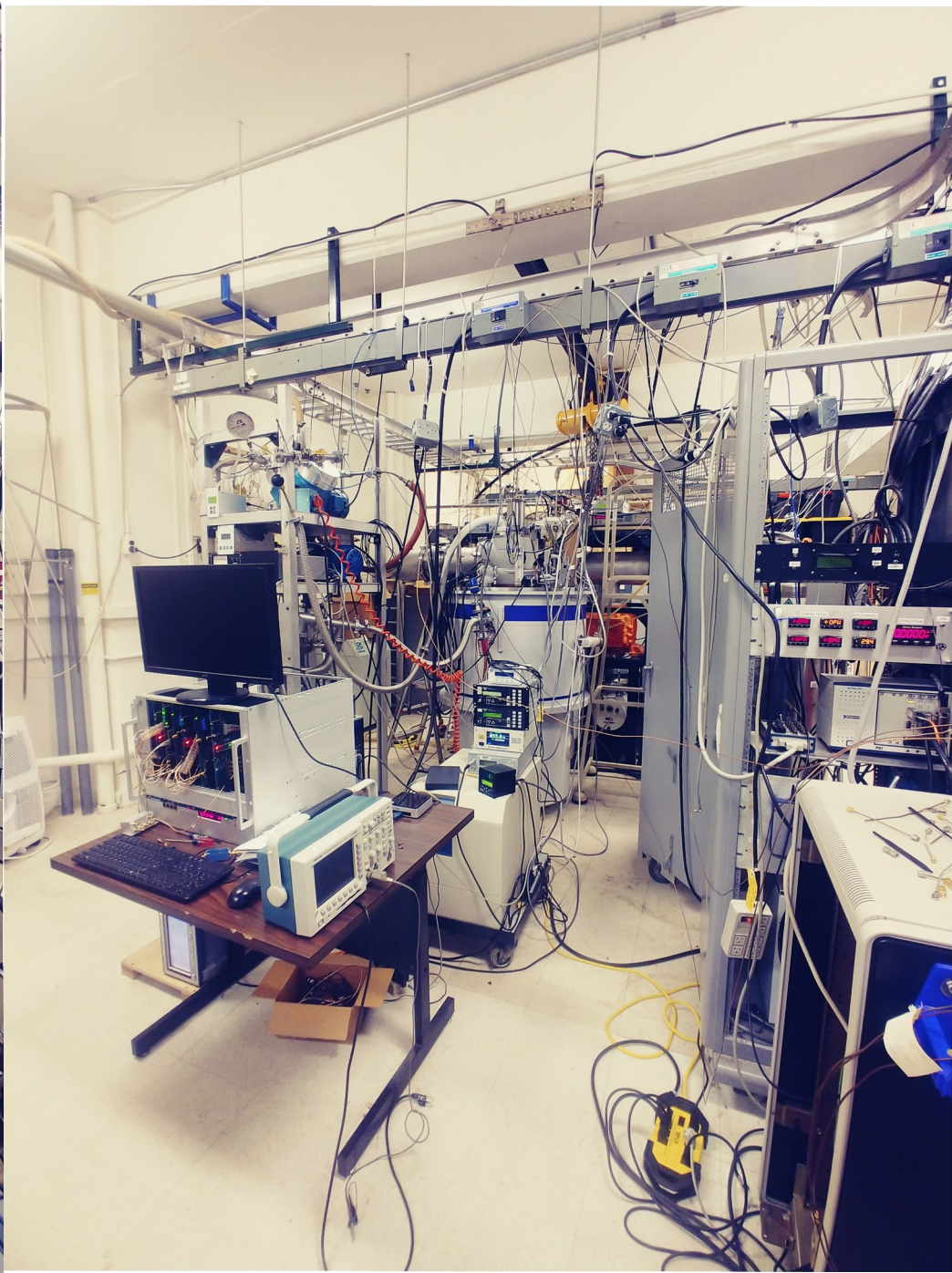
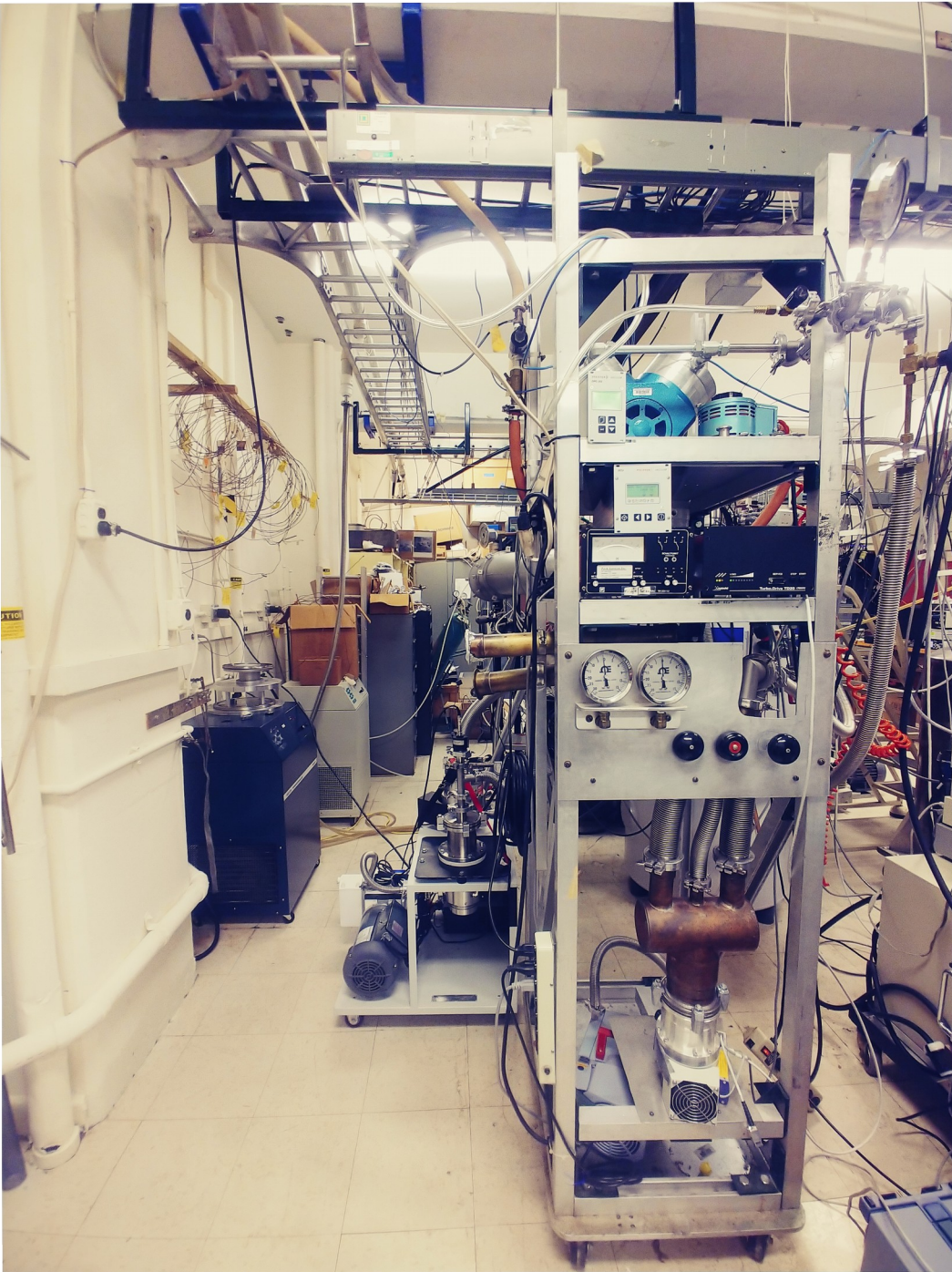


- 8: Upper Top HX
- 7: Upper Bot HX
- 6: Top Separator
- 5: Mid Separator
- 4: Top Lower HX
- 1: Bot Lower HX











250-1485

**HELIUM**  
REFRIGERATED  
LIQUID

**CAUTION**  
• KEEP AWAY FROM HOT SURFACES  
• TEST FOR CONTAMINATION BEFORE EACH FILLING  
• DO NOT OPEN WITHOUT PROTECTIVE EQUIPMENT  
• HANDLE CAREFULLY WITH GLOVES  
UN-1963

NON-MAGNETIC

ALL INFORMATION IS PROVIDED AS IS WITHOUT WARRANTY OF ANY KIND. THE USER ASSUMES ALL LIABILITY FOR ANY DAMAGE TO PERSONS OR PROPERTY.

OXFORD  
INSTRUMENTS

DANGER  
HIGH VOLTAGE

Pressure gauge

CAUTION

STOKES

# Focus on Slow Controls and Automation and Hardware

MKS - Main Flow

MKS - Separator Flow Control

Run Valve Repair

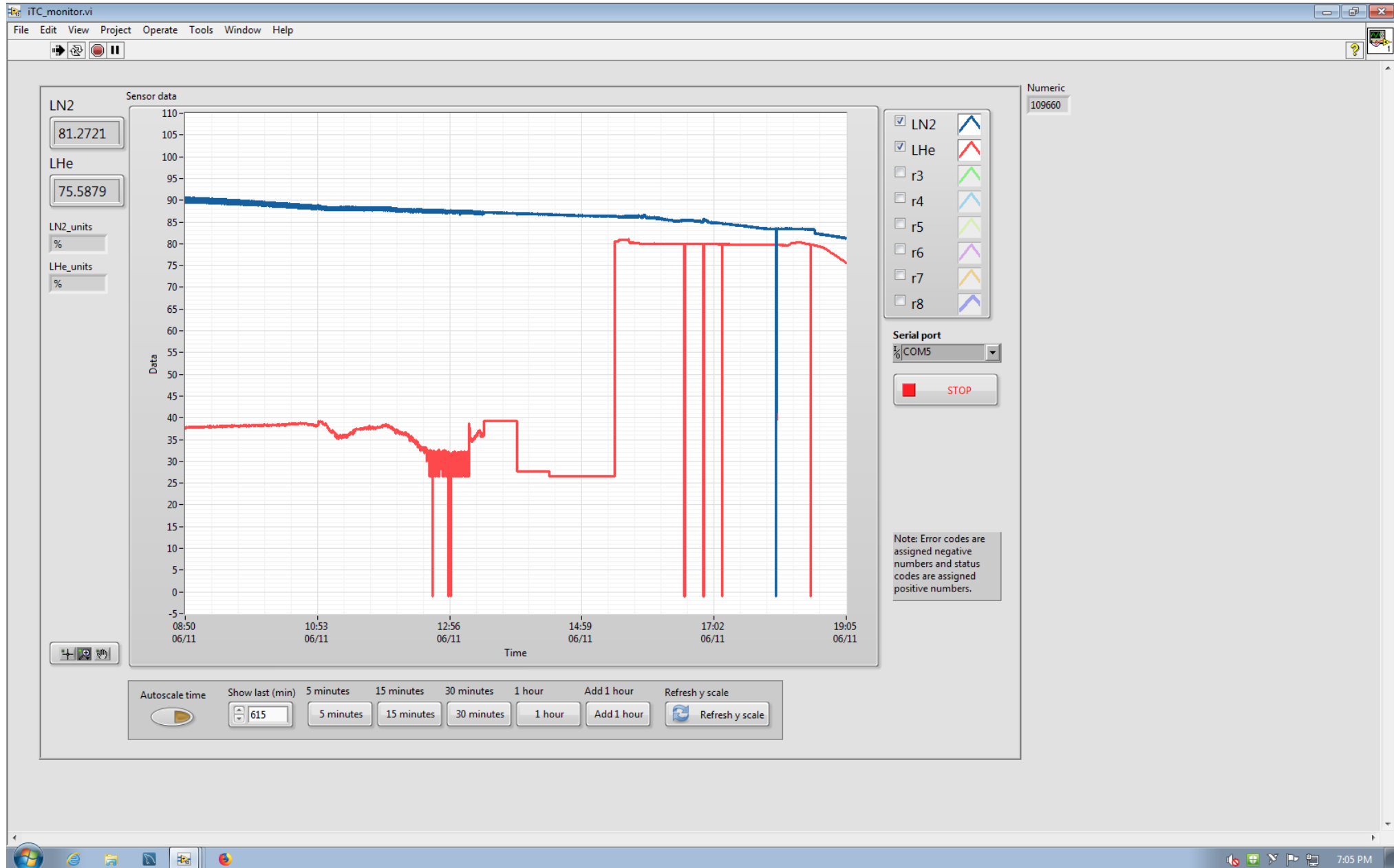
He3-pressure

Software - first time all at once

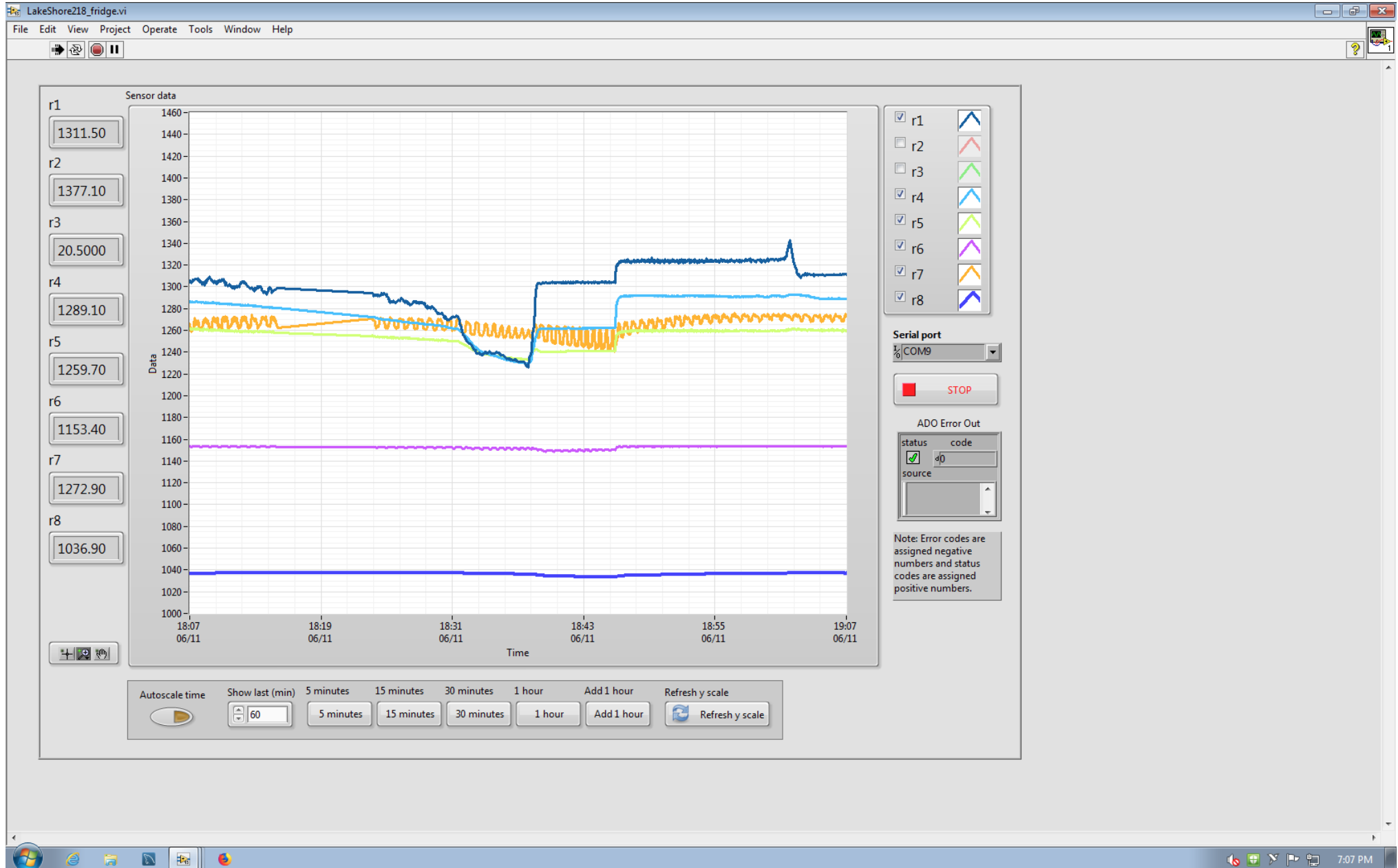
# Target Insert Sensors



# Liquid Helium and Nitrogen Level



# Fridge Sensors



# Microwave Control VI

The screenshot displays the 'Motor controller.vi' software interface, which is organized into several functional panels:

- Communication setup:** Includes a COM Port dropdown set to 'COM7', a 'STOP COMMUNICATION' button, a warning message: 'Please wait after stopping the VI; it can take some time to shut down all the stuff running in the background, so please be patient.', and a 'Debug mode' toggle.
- Manual motor control:** Features input fields for 'Step size (rev)' (0.001), 'Step size (GHz)' (0.020), 'Velocity (rev/sec)' (0.1), and 'Frequency to seek (GHz)' (140.190). It includes 'Move up', 'Move down', and 'Goto' buttons, along with a 'STOP MOTOR' button.
- Motor information:** Displays 'Motor time (sec)' (2305), 'Motor position (rev)' (0.000), and 'Frequency (calculated, GHz)' (140.190).
- Motor alarm (error):** Shows an 'Alarm code' of '0x00' and a text box with instructions: 'See motor manual, section "Troubleshooting" for explanation of alarm codes; fix the problem first and then restart this VI'.
- Frequency calibration:** Contains two frequency/position pairs (140.000/0 and 140.400/0) with 'Read position' buttons. It also includes 'Fit parameters' (Slope: -0.657895, Intercept: 140.19) and buttons for 'Calculate fit parameters' and 'Refine fit parameters'.
- Power data:** Shows 'Microwave power (mW)' (1.000) and 'New power (mW) Width (GHz)' (1.000, 0.050) with an 'Add power reading' button.
- Automatic control:** Includes 'Automatic mode on/off' and 'Seek positive polarization' toggles. A table displays real-time data:

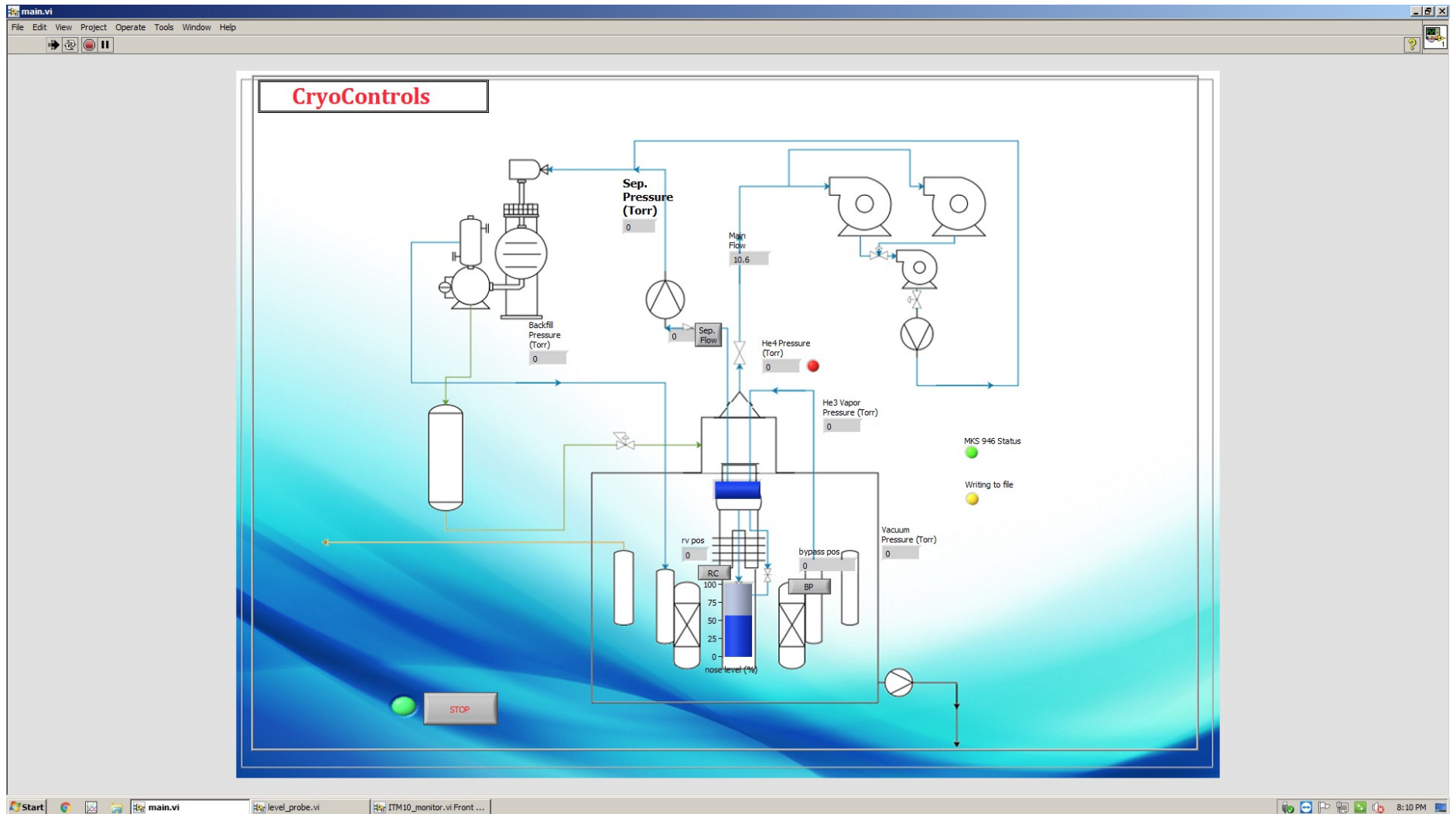
Samples taken	Eventnum	Polarization	Rate
2	1528761229	52.7069	0.0172687

It also has a 'Data input file' field containing 'Z:\b28\events\events.csv' and a 'Launch simulation' button.
- Configuration backup/restore:** Provides 'Save configuration to file' and 'Restore configuration from file' buttons, with a note: 'The settings which are backed up by this method are: step size, frequency to seek, fit slope, fit intercept, automatic step size, automatic velocity, data input file, and all the other controls under "Automatic control".'
- Advanced configuration:** Offers 'Step size presets' (0.05, 0.03, 0.01 GHz/step), 'Automatic step size (rev)' (0.0304), and 'Automatic velocity (rev/sec)' (0.1). It includes 'Reseek (reset step size)' and 'Make up fit parameters' buttons, and a prominent 'RESET EVERYTHING AND STOP' button.

The interface is presented in a standard Windows-style window with a menu bar (File, Edit, View, Project, Operate, Tools, Window, Help) and a taskbar at the bottom showing the system clock at 7:54 PM.

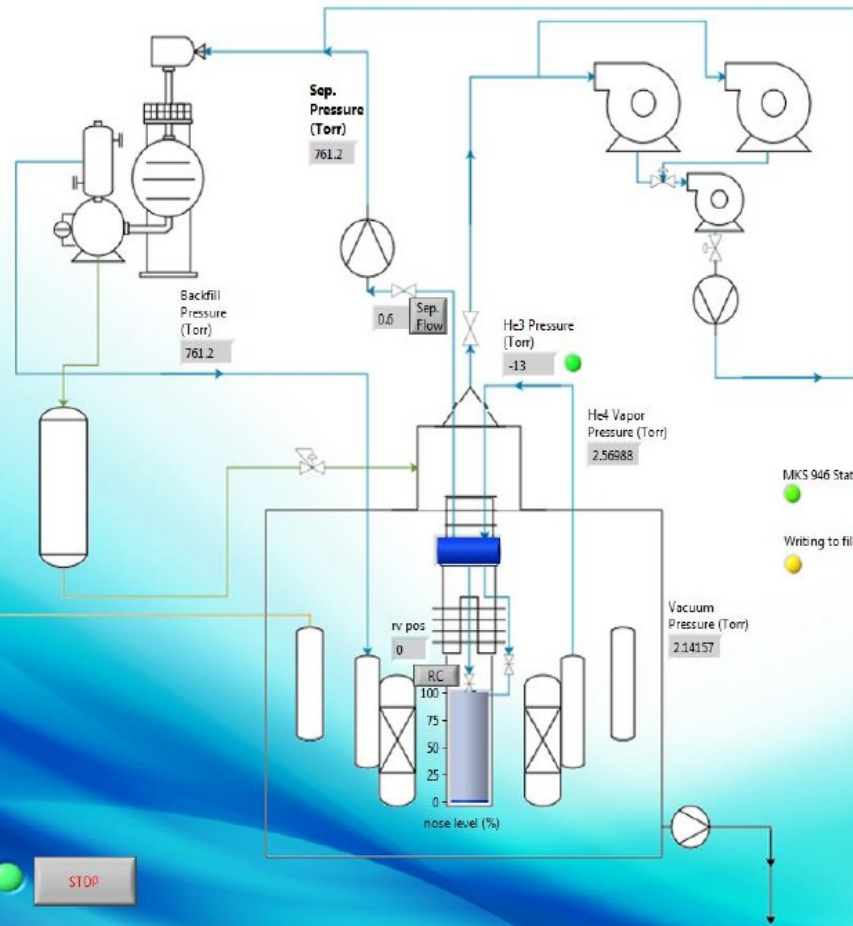


# Cryocontrols



# The main cryocontrol VI

CryoControls



This contain all monitoring for the target including the pressures, flows, valve position and He level probe reading.

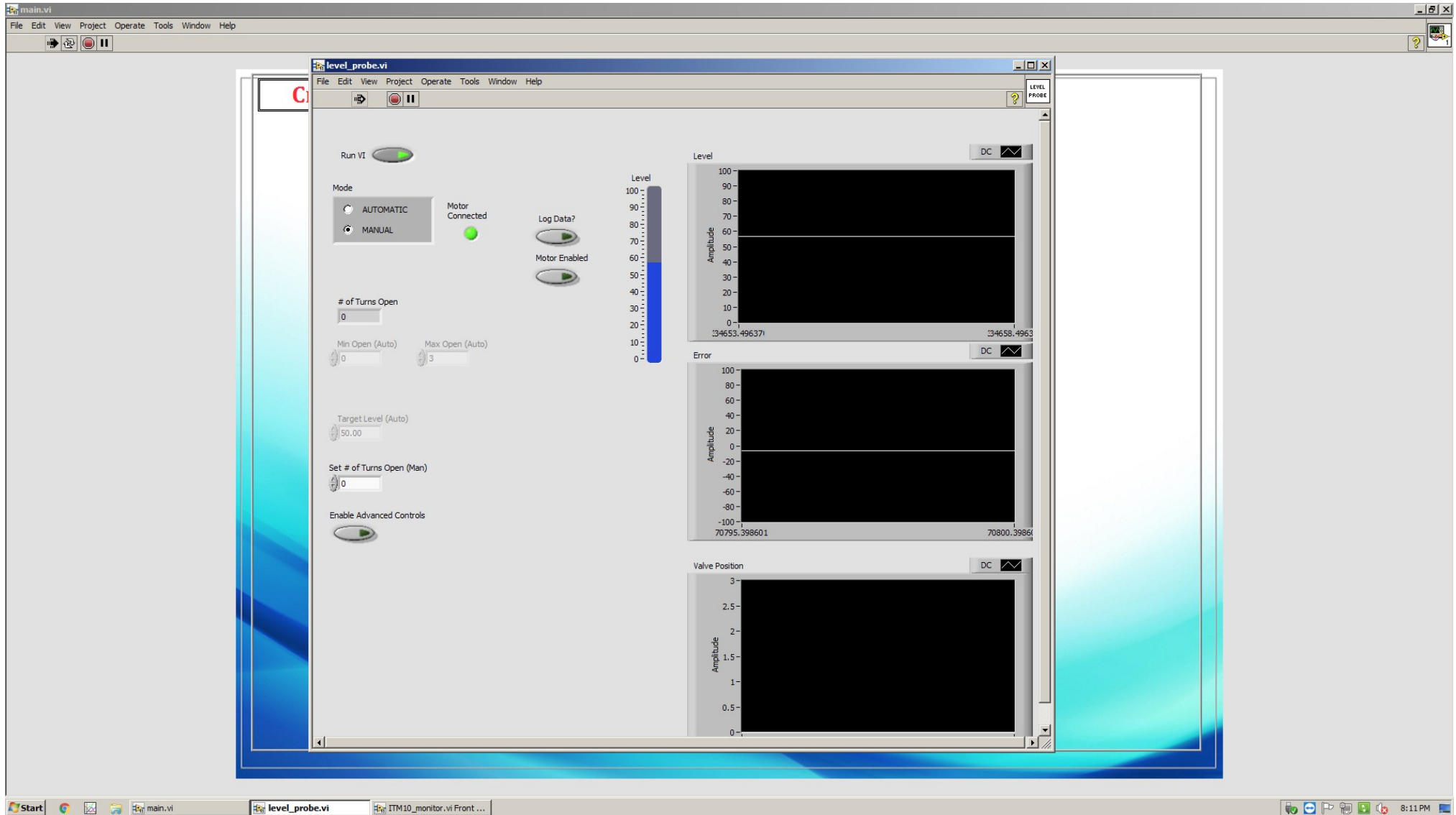
This also include buttons to access the flow, pressure and valve position controls next to their reading.

This main VI check whether the devices are connected to correct ports and function continuously.

Graphics shows where these readings are from.

Logs all the readings to a text file ~each second.

# Pop-up Controls





# SOLID POLARIZED TARGET GROUP *at the* UNIVERSITY OF VIRGINIA

## SOLID POLARIZED TARGET GROUP *at the* UNIVERSITY OF VIRGINIA

- RESEARCH
- EXPERIMENTS
- PEOPLE
- GROUP THESES AND TECHNICAL NOTES
- TOOLS
- GROUP HOSTED WORKSHOPS
- POLARIZED TARGET GROUPS
- WORK LINKS
- UNDERGRADUATE JOB OPPORTUNITIES
- VIDEOS
- STORAGE DEWARs



Our research program is at the forefront of the studies of the fundamental properties of the nucleons, i.e. the proton and neutron, which are the two building blocks of the atomic nucleus. The interactions of quarks and gluons, the underlying constituents of strongly interacting matter, are well described by the basic theory, Quantum Chromodynamics (QCD). However, the way in which quarks and gluons are confined within the nucleons and the mesons (responsible for nuclear forces), is poorly understood in QCD.

We concentrate on experiments that use spin degrees of freedom (i.e. using polarized targets and beams) in electron-nucleon/nucleus interactions to extract new information about the properties of these fundamental building blocks of nature and lend new insights into these basic and longstanding problems. We are unique among university based research groups as we have the capabilities of developing, building and maintaining the cryogenic polarized targets critical for this research which is carried out at the Jefferson Lab whose unique capabilities make this research possible.

### Drell-Yan Polarized Target System

The polarized target system to be used in E1039 is a high cooling power fridge connected to a large pump stack (14,000 m<sup>3</sup>/hour) and a microwave generator used to dynamically polarize the nucleons in the target. The magnet has a 5 T field with a homogeneous region of 6 cm and will be used to polarize protons and neutrons in the sample.



Here the target system is shown our polarized target lab where the system is setup of testing and optimization. Solid polarized target experiments are demanding and require of team of well trained polarized target expert in order for the experiment to run smoothly.

### Main Pages and Important Links

- [E1039 Polarized Target Wiki](#)
- [UVA Collab Utilities](#)
- [Fermilab E996/E1039 docdb](#)
- [Fermilab E996/E1039 software](#)
- [Fermilab MCR logbook](#)
- [Fermilab Machine logbooks](#)
- [Fermilab External Beams logbook](#)

### Drell-Yan Work Dir

### Drell-Yan Meetings

At this time have the following working group meetings for E1039 (All US Eastern Time):

- o Polarized Target meeting (biweekly on Tuesday at 3PM)
- o Engineering meeting (weekly on Tuesday 4PM)
- o Labview meeting (biweekly on Tuesday 5PM)
- o General biweekly meeting (Tuesday 6PM)
- o Software/Simulations meeting (biweekly Thursday 7PM)

Join from PC, Mac, Linux, IOS or Android

Target Meetings  
Meeting ID: 438621341

LabView Meetings  
Meeting ID: 705516494

## E1098 Target Wiki

# Target Tools

NMR Calculator | TE Calculator with Polcalc

## NMR Calculator

NMR Calculator | TE Calculator with Polcalc  
TE Calculator with Polcalc

TE Importer:

Start Date and Time:

Number of Events:

(Imports Area and He4Pressure. Date in mm/dd/yyyy hh:mm format. Format must be "Webpage" to import.)

TE Calculator:

Species	Magnetic Field	Column 2	Cell	Output Format
Proton	5.0033	Temperature	Top	Web Page
Deuteron		He3 Pressure	Bottom	Printer
6Li		He4 Pressure		
7Li				
13C				
14N				
15N				
129Xe				
131Xe				
Electron				

Area & Temp/Pressure Data

## TE Wizard

Input #1	Input #2
Magnet Current (A)	Magnet Current (A)
Current/Field Ratio (A/T)	Current/Field Ratio (A/T)
Field (T)	Field (T)
Proton Frequency (MHz)	Proton Frequency (MHz)
Deuteron Frequency (MHz)	Deuteron Frequency (MHz)
6Li Frequency (MHz)	6Li Frequency (MHz)
7Li Frequency (MHz)	7Li Frequency (MHz)
13C Frequency (MHz)	13C Frequency (MHz)
14N Frequency (MHz)	14N Frequency (MHz)
15N Frequency (MHz)	15N Frequency (MHz)
129Xe Frequency (MHz)	129Xe Frequency (MHz)
131Xe Frequency (MHz)	131Xe Frequency (MHz)
Electron Frequency (MHz)	Electron Frequency (MHz)

Value:  Value:

## Results

Magnet Field  T

Species	Frequency	Lambda/2	External Cable Length				
			n=1	n=2	n=3	n=7	n=8
Proton	212.697 MHz	55.0 cm				214.0 cm	269.0 cm
Deuteron	32.650 MHz	358.3 cm	187.3 cm	545.6 cm	904.0 cm	2337.4 cm	2695.7 cm
6Li	31.303 MHz	373.8 cm	202.7 cm	576.5 cm	950.3 cm	2445.3 cm	2819.1 cm
7Li	82.667 MHz	141.5 cm		112.0 cm	253.6 cm	819.7 cm	961.2 cm
13C	53.483 MHz	218.8 cm	47.7 cm	266.5 cm	485.2 cm	1360.3 cm	1579.0 cm
14N	15.375 MHz	761.0 cm	590.0 cm	1351.0 cm	2111.9 cm	5155.9 cm	5918.9 cm
15N	21.567 MHz	542.5 cm	371.5 cm	913.9 cm	1456.4 cm	3626.4 cm	4168.9 cm
129Xe	58.829 MHz	198.9 cm	27.8 cm	226.7 cm	425.6 cm	1221.1 cm	1420.0 cm
131Xe	17.564 MHz	666.1 cm	495.1 cm	1161.3 cm	1827.4 cm	4492.0 cm	5158.1 cm
Electron	140000.000 MHz	0.1 cm					

The Solid Polarized Target Group-UVA

<http://twist.phys.virginia.edu/>

# Minimum Target Personnel

- Team Leader + Senior Advisers
- Min. 3 Target Experts (on call near exp)
- Min. 1 Slow Controls Software Expert
- Min. 1 Target Technicians
- Dedicated grad and undergrads students
- Target Operators: all collaboration members, training materials will be provided by UVA

# Still to Come

- Secondary pressure/temp sensor calibration ( $^3\text{He}$  bulb-Just test) +MKS Units
- Infrastructure for target changes Moving to FNAL
- Cold NMR system optimal signal to noise for Deuteron/Neutron Still UVA
- Configure one stick with 3 active cells 2 cold-NMR one warm 3 inserts now
- Remote Control for Microwave (further testing) add modulation
- Cryosystem auto-control (further testing)
- Annealing system (testing needed with temp sensors on insert) testing still needed
- Material purchase and irradiation ( $\text{ND}_3$  ~\$40K)
- Making material and doing the irradiations (only 500g done out of 2.6kg)
- Lots of work on radiation protection for equipment (motors, etc...)
- Lots of work on setting up full cryocontrols and target variables data flow to run and test all at once
- Need more cooldowns coming up soon but where?  
Fridge cooldown:  
UVA  
Magnet cooldown:  
FNAL