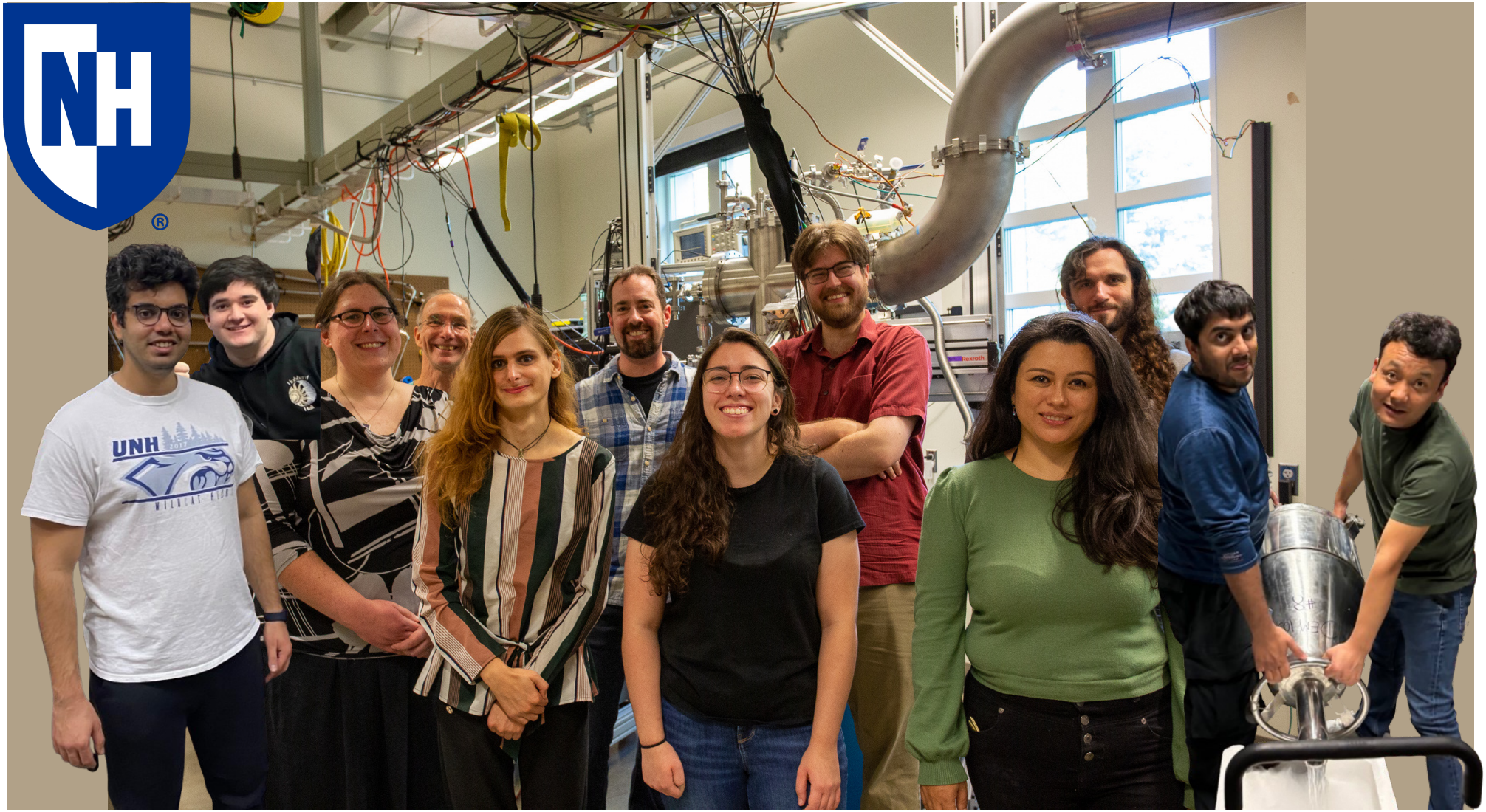
UNH Target Group Status and Goals

b_1/A_{zz} Tensor Collaboration

Jefferson Lab
2025-10-13

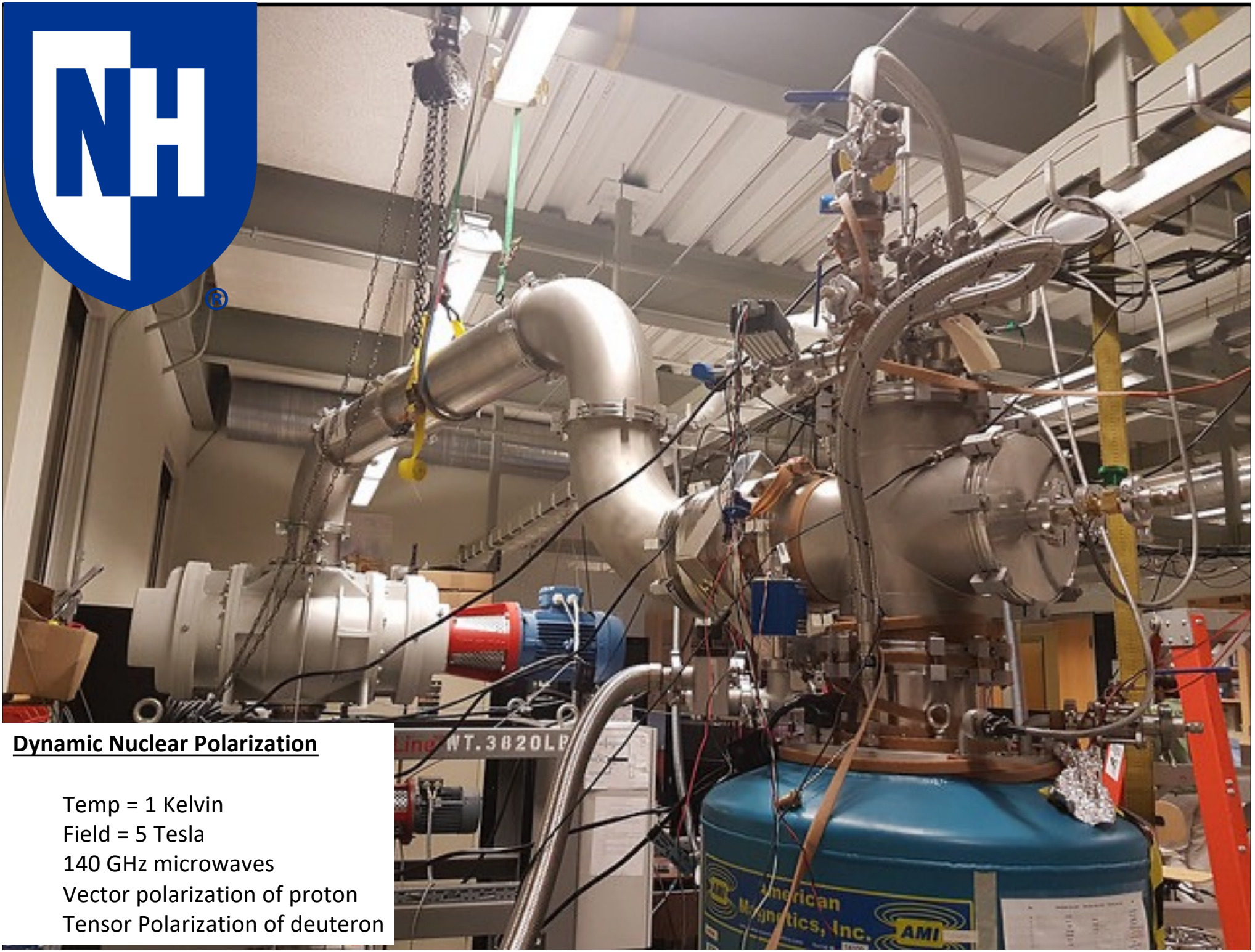
Karl J Slifer
University of New Hampshire

Polarized Target Group



Slightly out of date photo

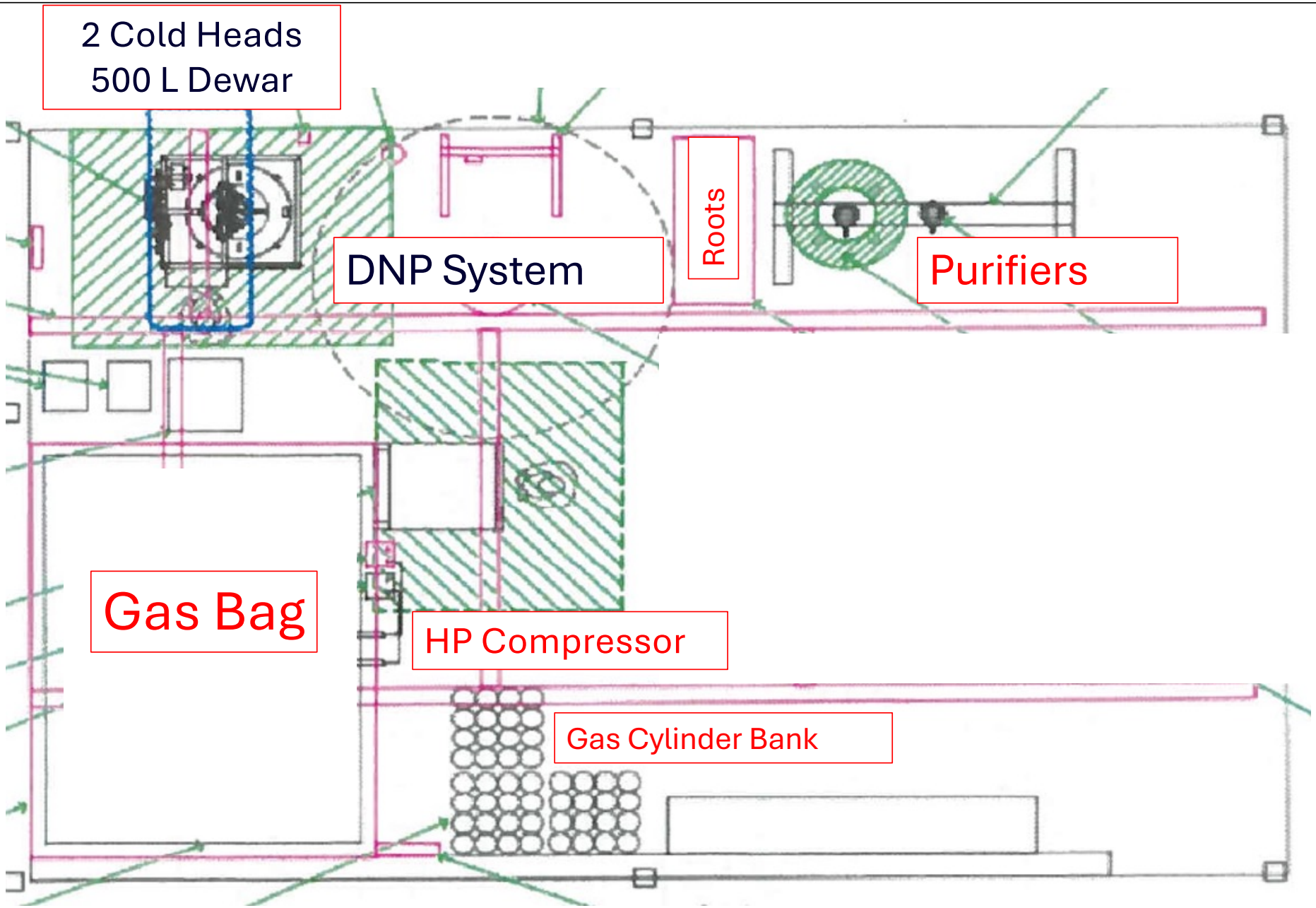
David Ruth → NMSU
Allison Zec → Hall A
Aden Whitney has joined the group



Dynamic Nuclear Polarization

Temp = 1 Kelvin
Field = 5 Tesla
140 GHz microwaves
Vector polarization of proton
Tensor Polarization of deuteron

Helium Recovery System



Helium Recovery System

HP Gas cylinders

Gas Bag

Helium Purifier (dual)

Cold Heads
500 L Mother Dewar

Helium Recovery System Status

Rate: 40 L/day (average), 30-50L/day (variable)

Recapture efficiency : >90%

Helium Recovery System Status

Rate: 40 L/day (average), 30-50L/day (variable)

Recapture efficiency : >90%

Liquid Capacity: 500-800 Liquid Liters Storage

Gas Capacity: 580 Liquid Liters Equivalent in 48 HP cylinders

Helium Recovery System Status

Rate: 40 L/day (average), 30-50L/day (variable)

Recapture efficiency : >90%

Liquid Capacity: 500-800 Liquid Liters Storage

Gas Capacity: 580 Liquid Liters Equivalent in 48 HP cylinders

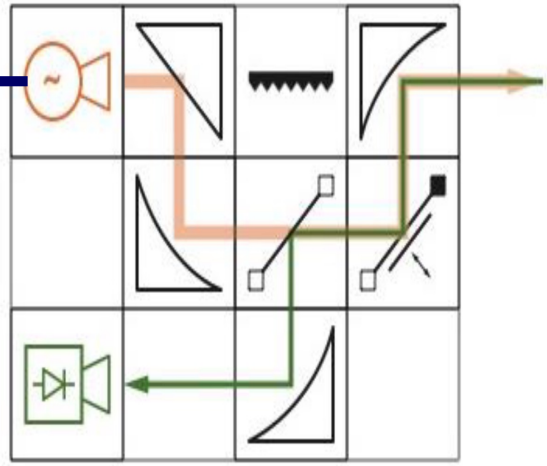
Duty cycle: 5 days of physics followed by 3 weeks of recovery

6 cooldowns in the last 12 months

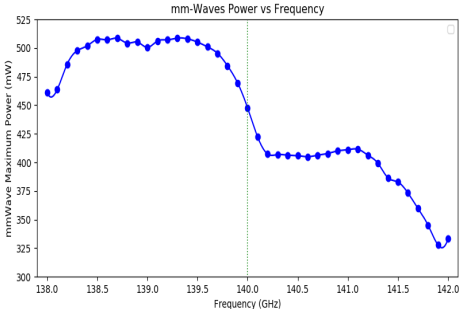
Solid State mm-Wave System

12x Frequency Multiplier & Amplifier Chain

12 GHz Signal Generator



400 mW @139 GHz



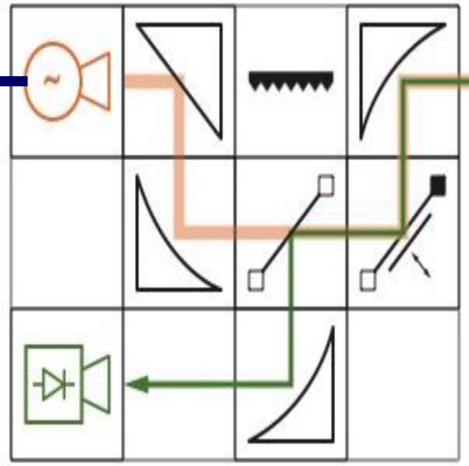
Cheaper than EIO
No cooling
Sits directly above target
Passes thru air gap

400 mW of microwave power delivered by a robotic solid state system suspended on a large gantry that straddles the cryostat

Solid State mm-Wave System

12x Frequency Multiplier & Amplifier Chain

12 GHz Signal Generator

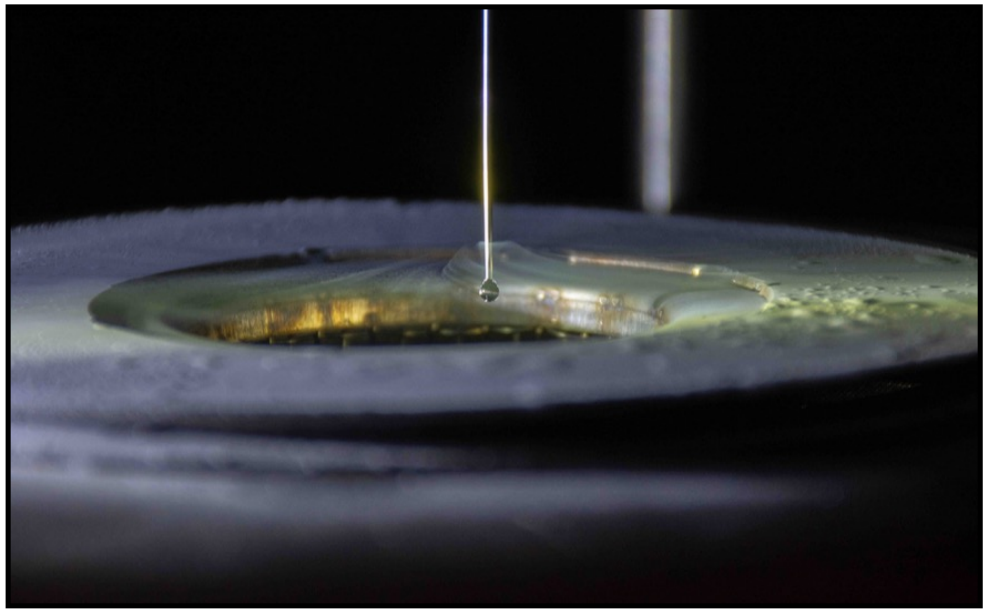


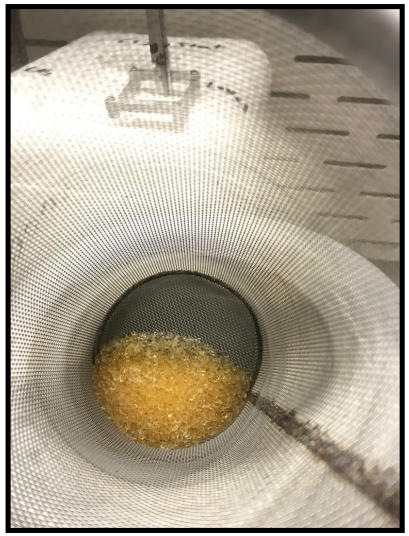
400 mW
@139 GHz

Has been down for about 2 months with a damaged amplifier.

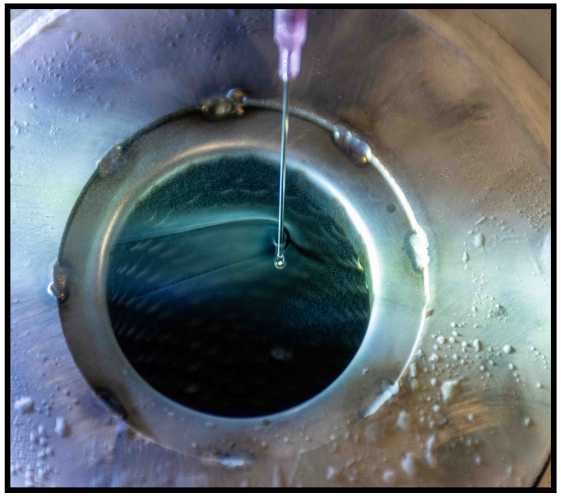
Scheduled back by end of October

Target Material Production



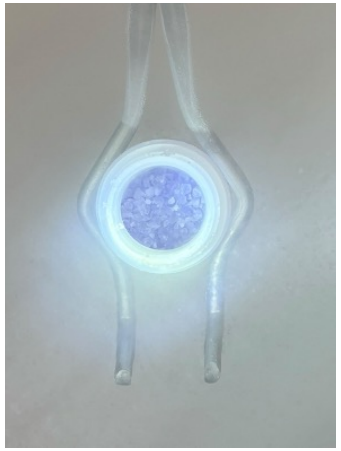


Target Material Production

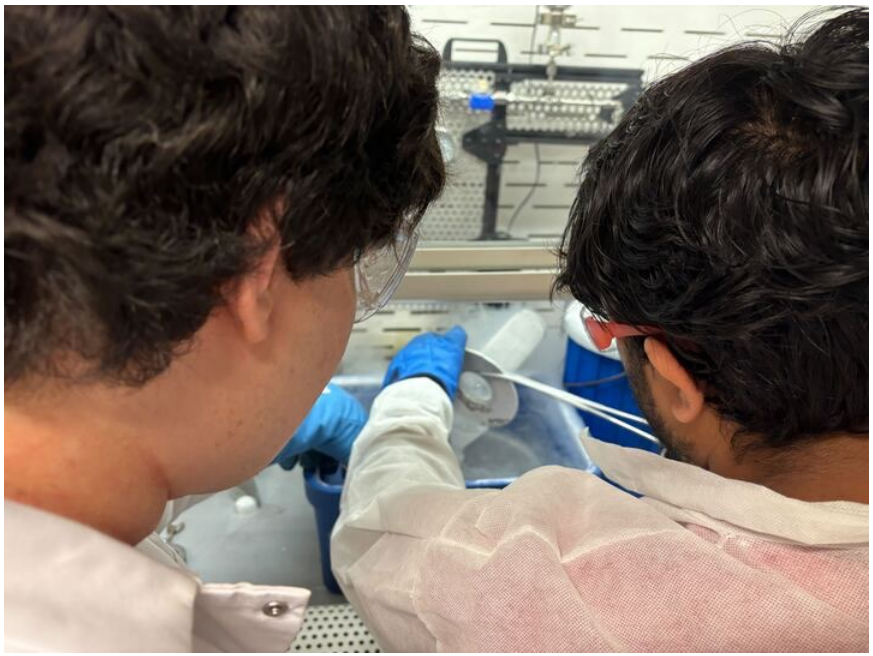


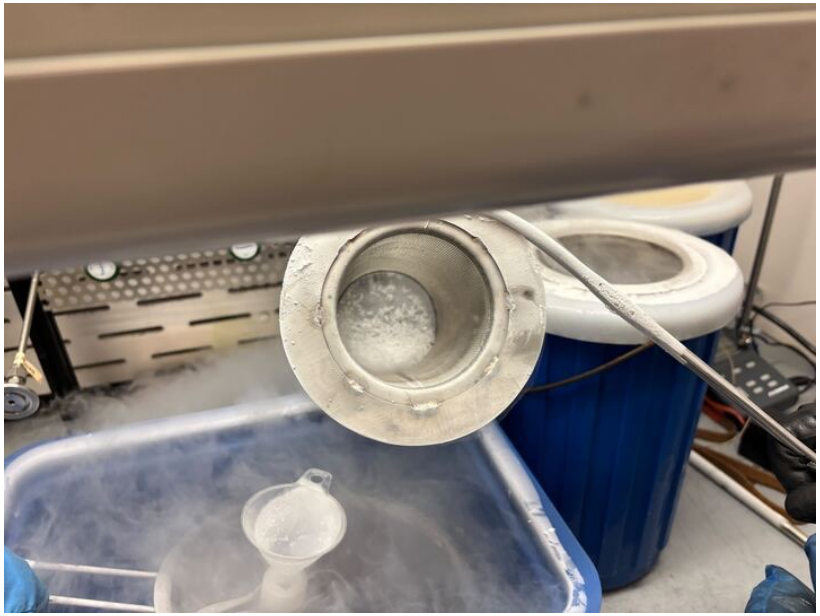
Butanol and other alcohols solidification

grade 5.5 NH_3 & ND_3



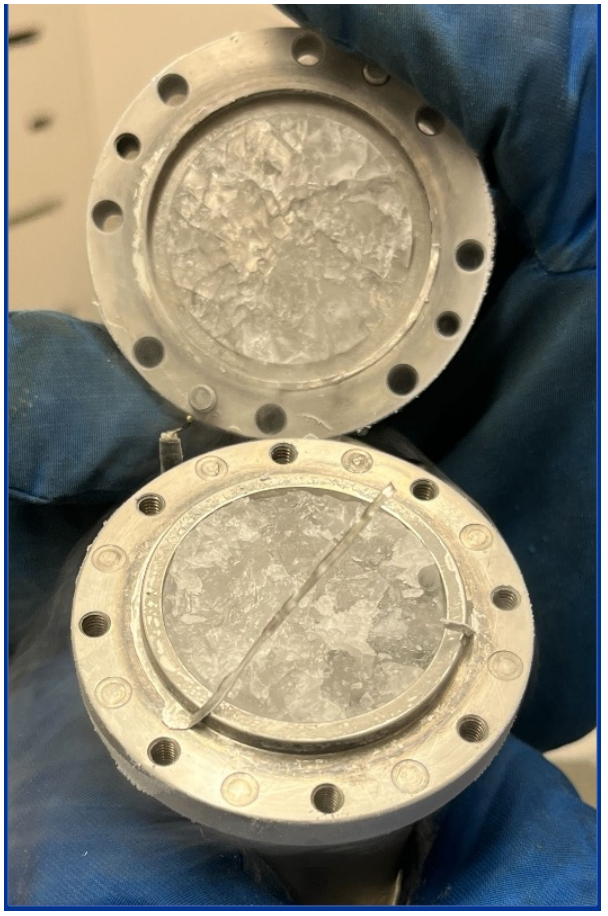
Chemical Doping





Target Material Production

Solidifying ND3



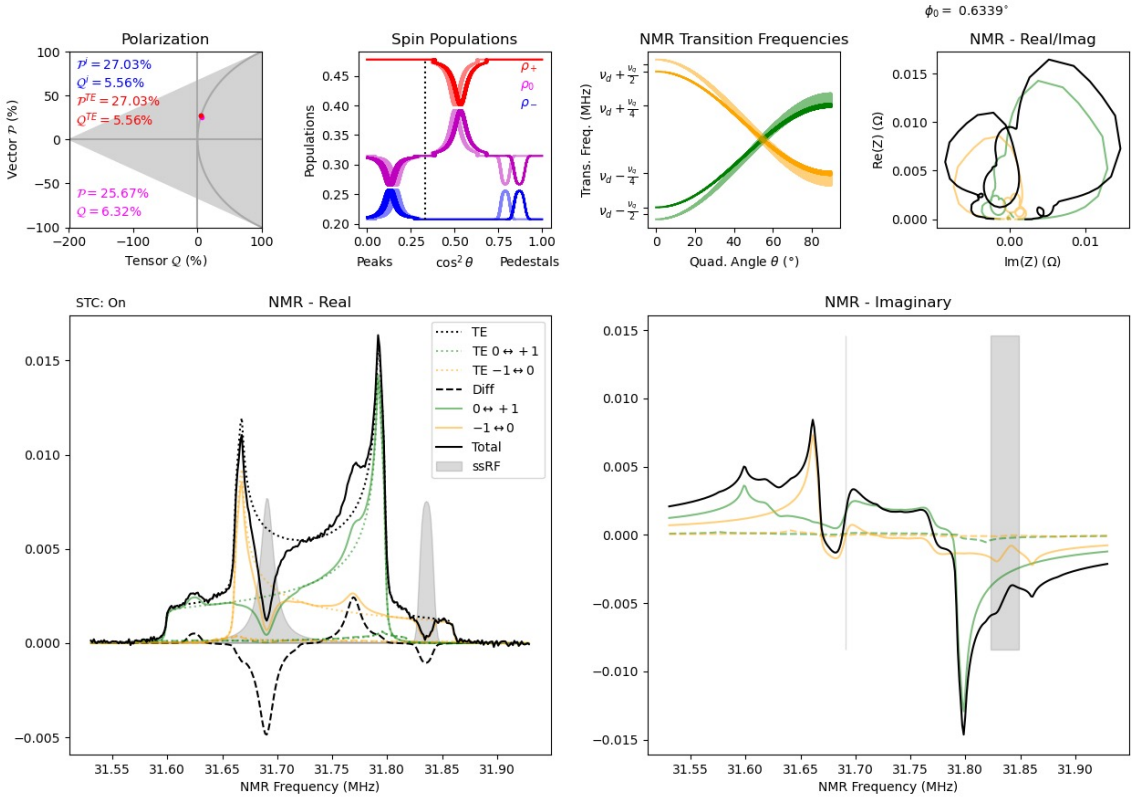
Summer 2025

Quantitative study of Flash Freezing vs Slow Cooling

(See Eli's talk tomorrow)

NMR Simulation

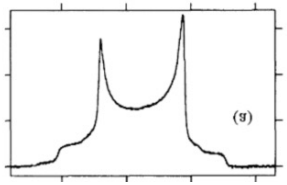
- NMR simulation based on spin-flip counting developed by E. Long
- **Current Status:**
  - Simulates arbitrary P & Q
  - Simulates fully complex signal, and outputs ‘Real’ and ‘Imaginary’ signals based on phase angle
    - ‘Real’ = Phase Measurements on Q-meter
  - Simulates ssRF
    - Can handle multiple ssRF with arbitrary power, width, and shape (shown in gray)
  - Simulates AFP
  - Simulated noise + Q-curve
- **Ongoing Work:**
  - Rewriting code to run on GPUs
  - Dynamic simulation with full DNP rates + time-dependent spin diffusion + time-dependent ssRF
  - Expected Completion: December ‘25



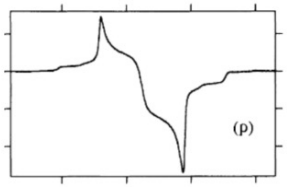
Hautle et al, PRB **46**, 6596 (1992)

AFP Data on d-Butanol:

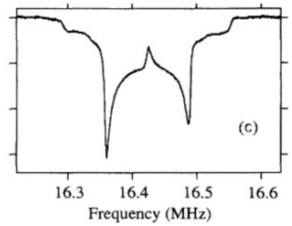
Before Sweep

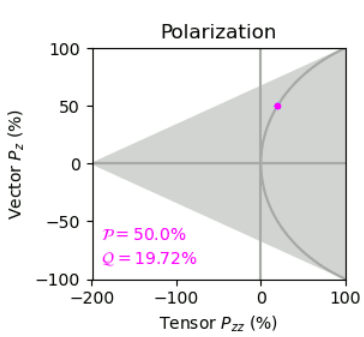


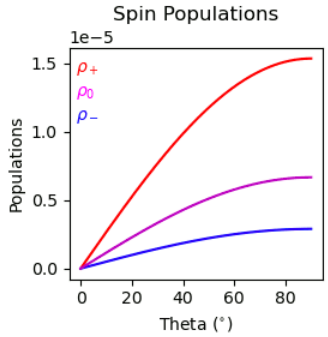
After 1st Full Sweep

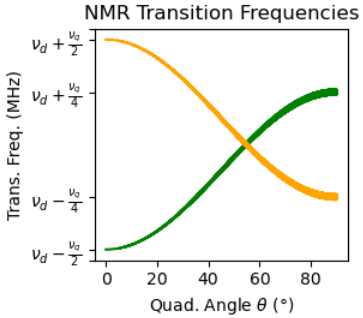


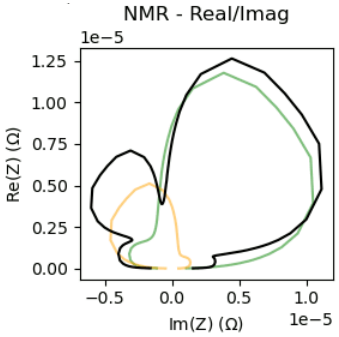
After 2nd 1/2 Sweep

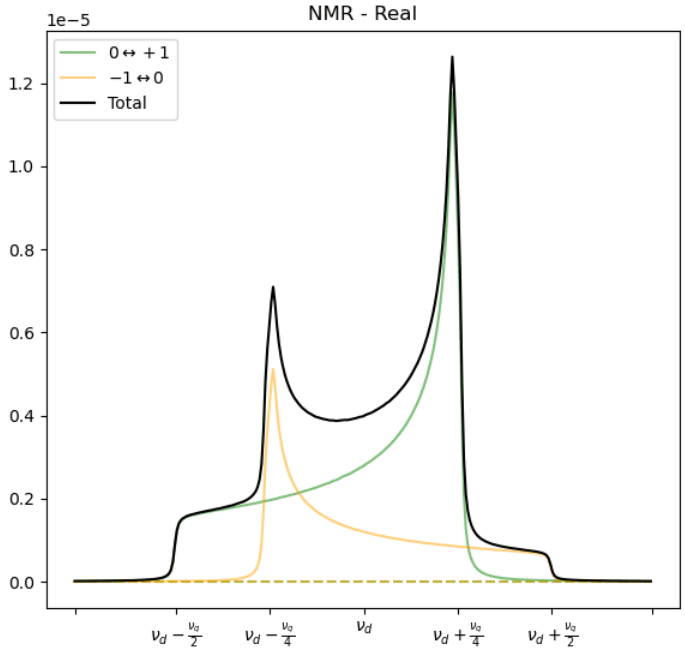


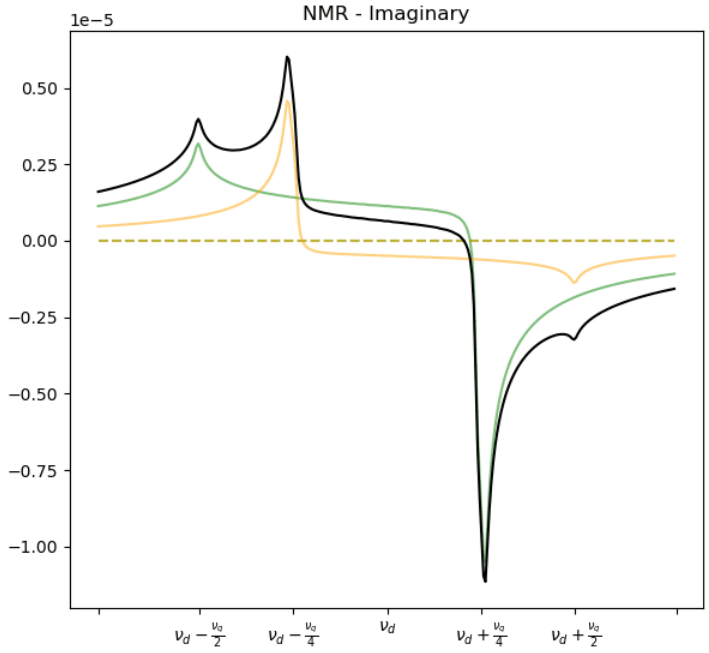


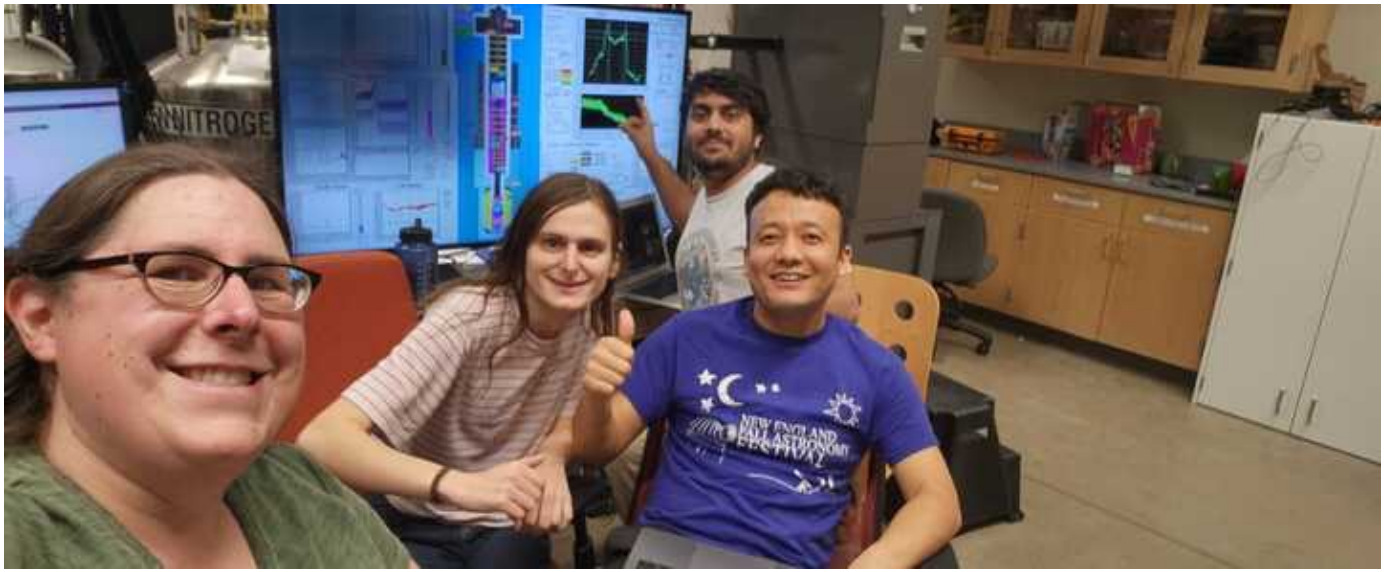


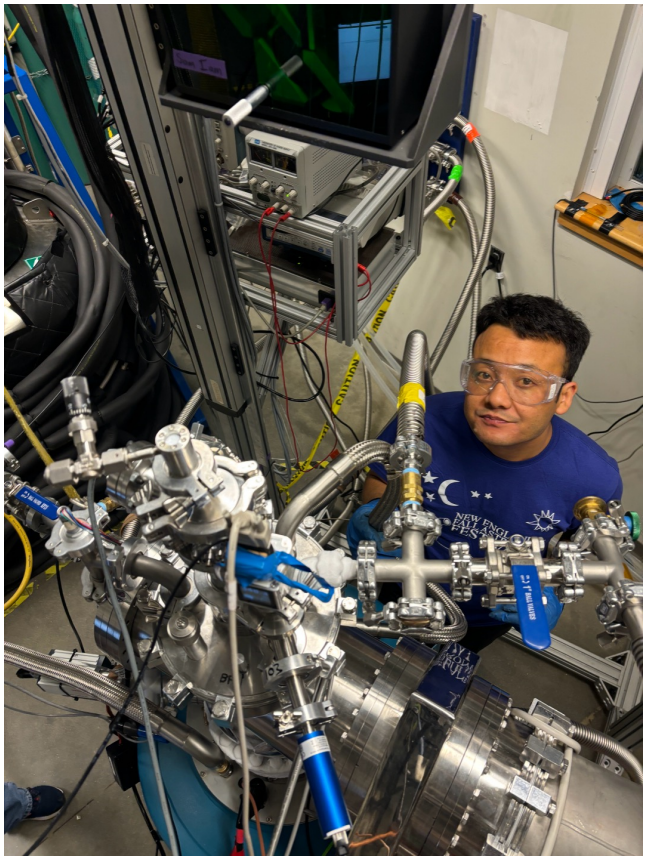




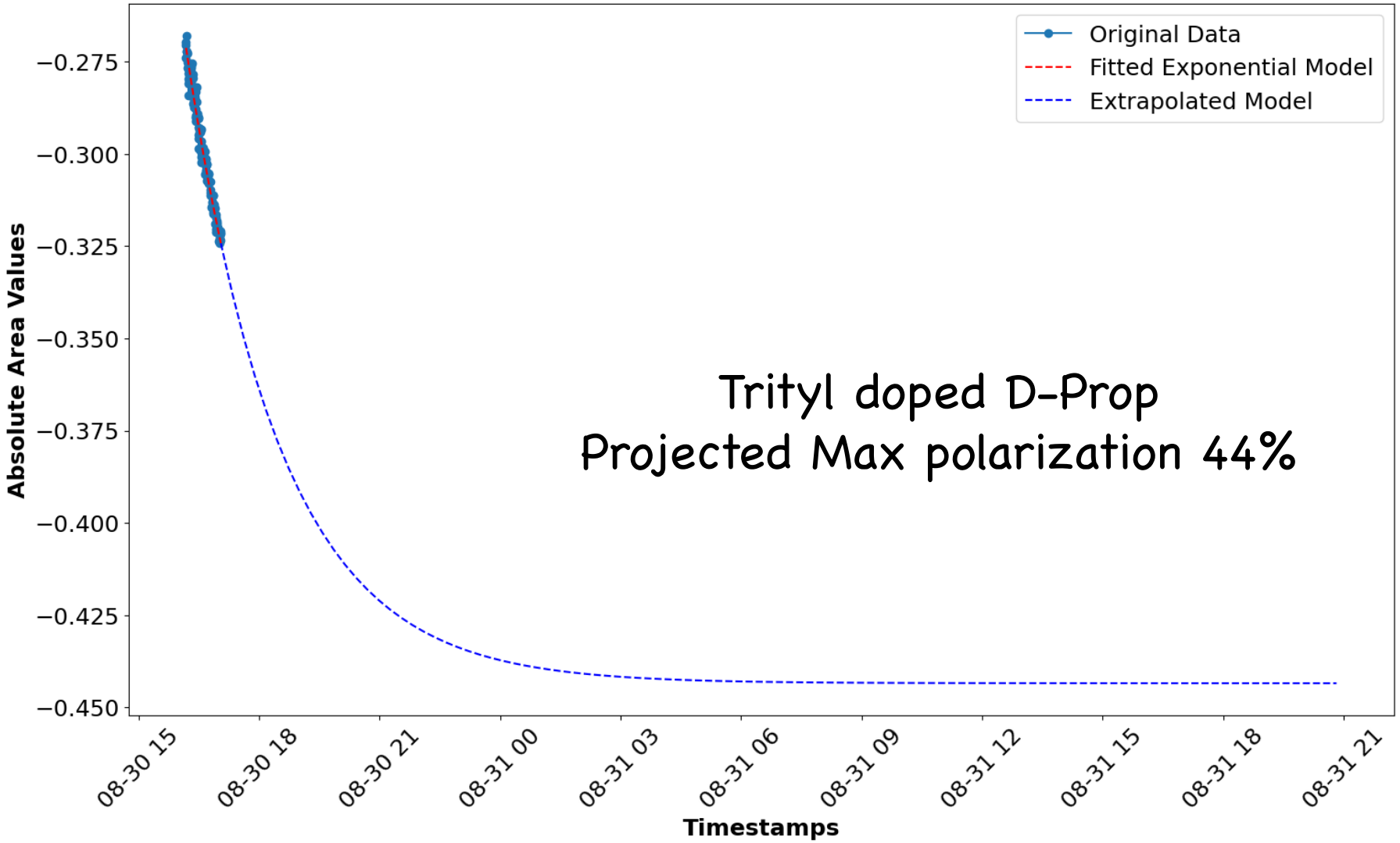




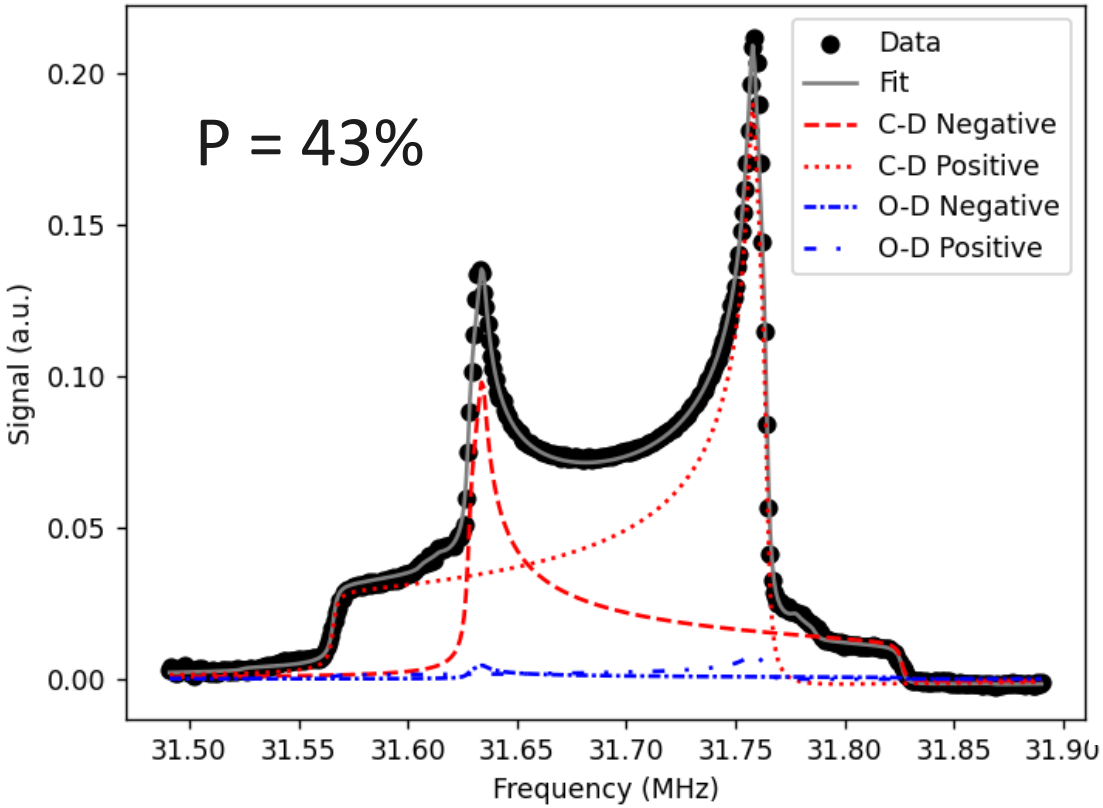


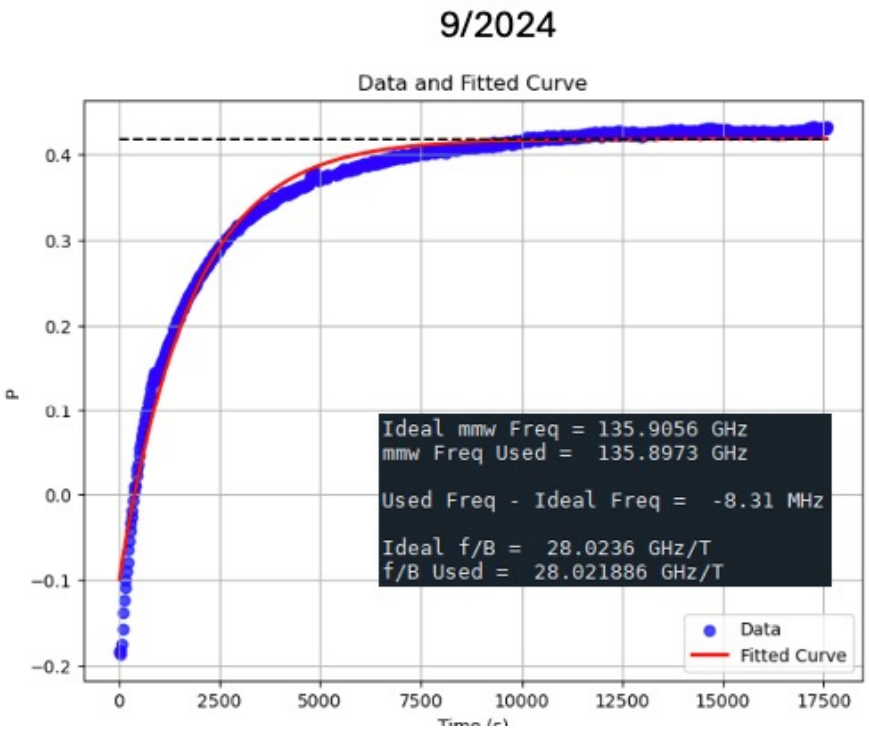


D-Propanediol

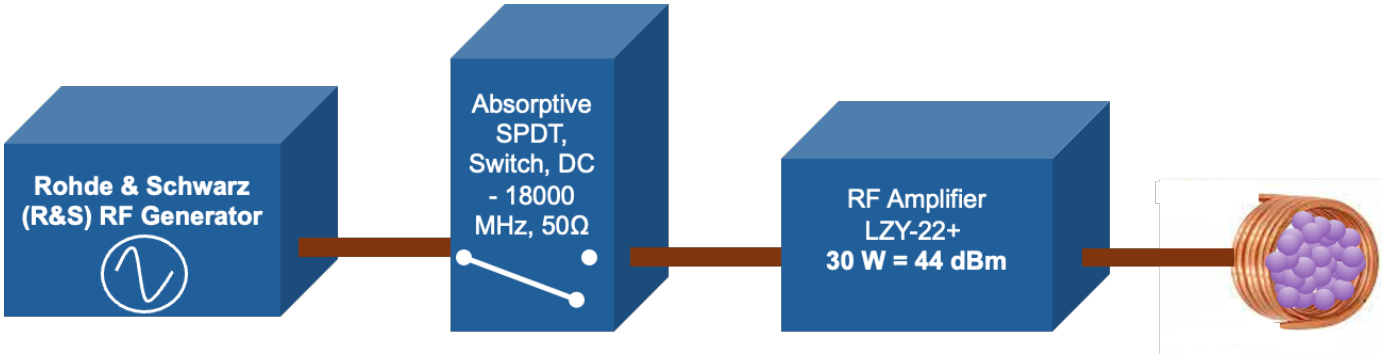


Irradiated D-Butanol





New SSRF Circuit



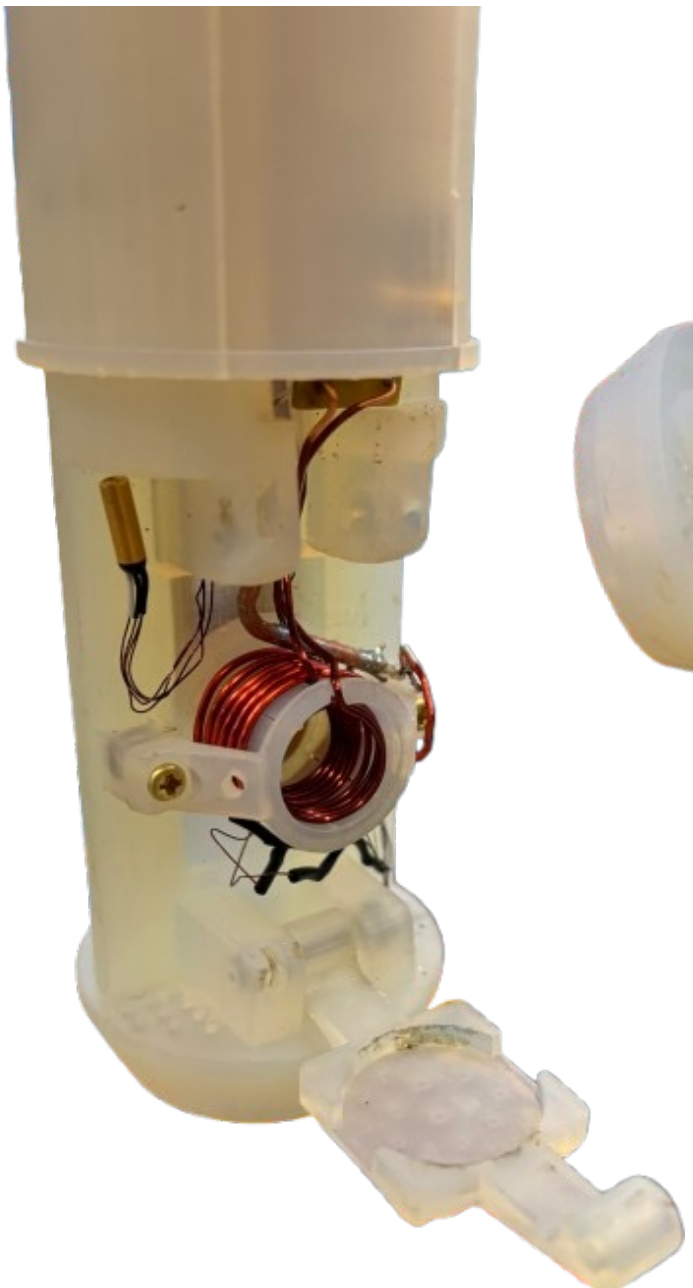
RF techniques for enhancing tensor polarization in solid targets

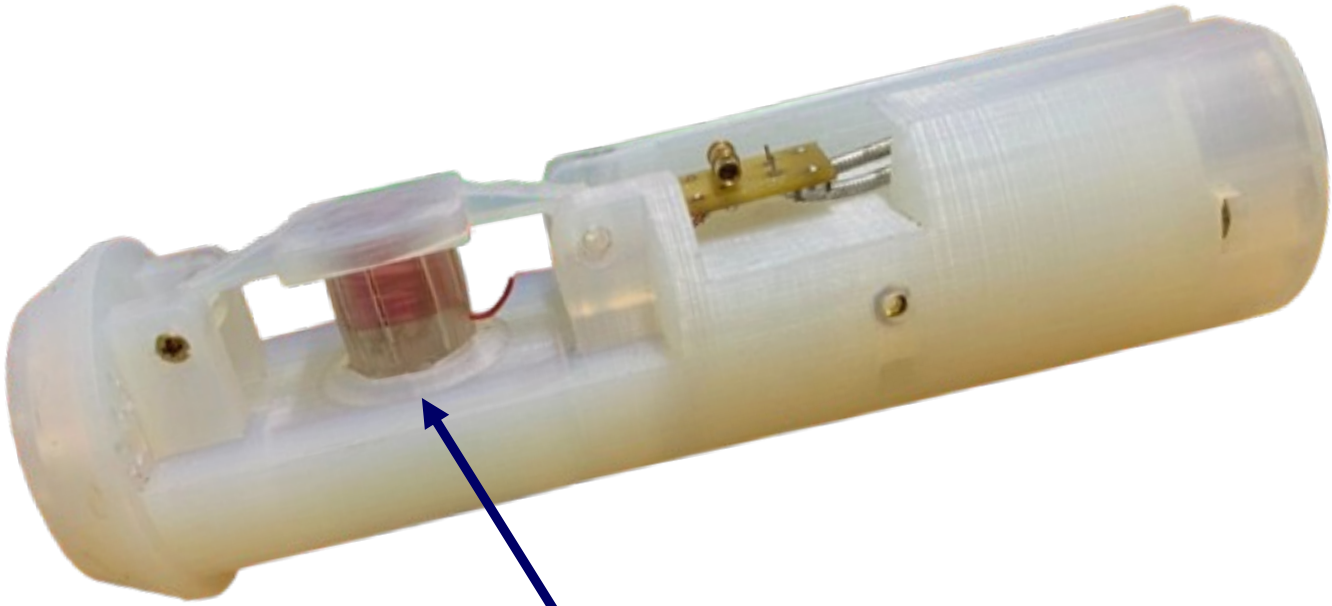
David Ruth[a,*] **and Nathaly Santiesteban**[a]

[a] *University of New Hampshire,*
Durham, NH, USA 03824

E-mail: david.ruth@unh.edu, nathaly.santiesteban@unh.edu

New Target ladder and coils for December cooldown

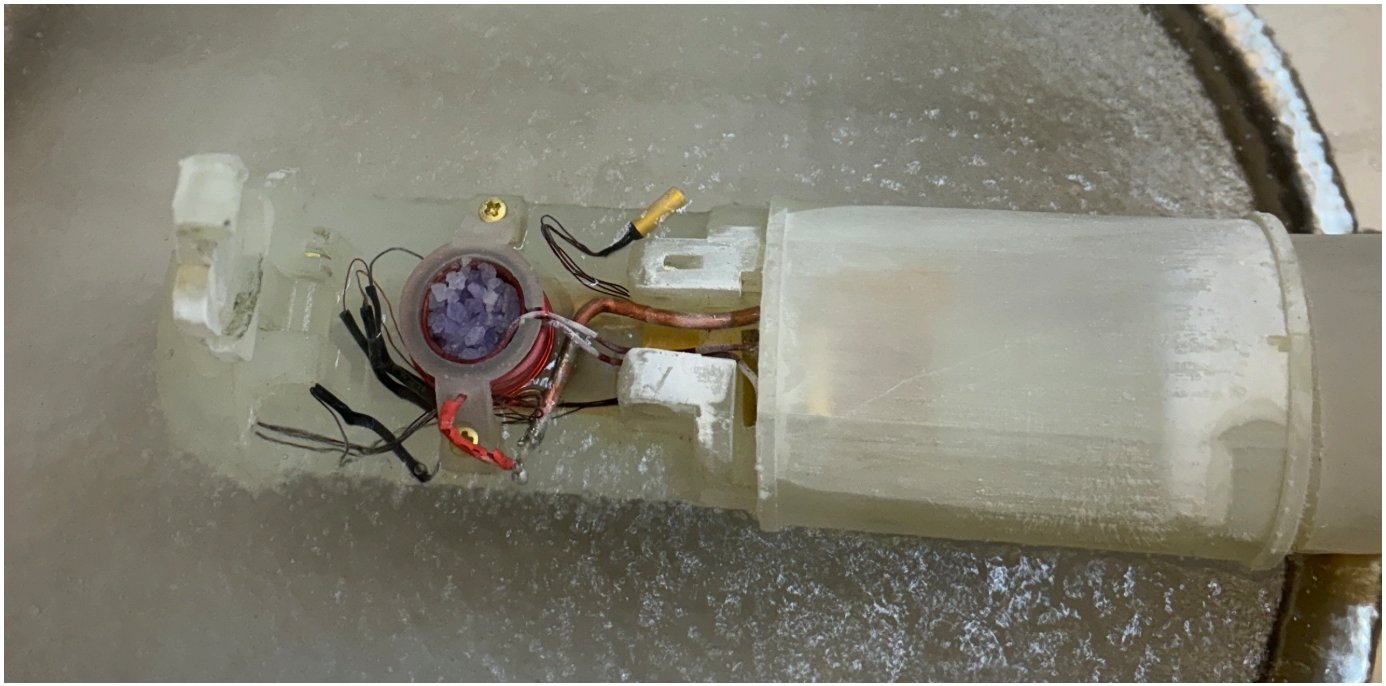




solenoidal Hole burning coil

(Allison Zec)

December: Warm Irradiated ND_3



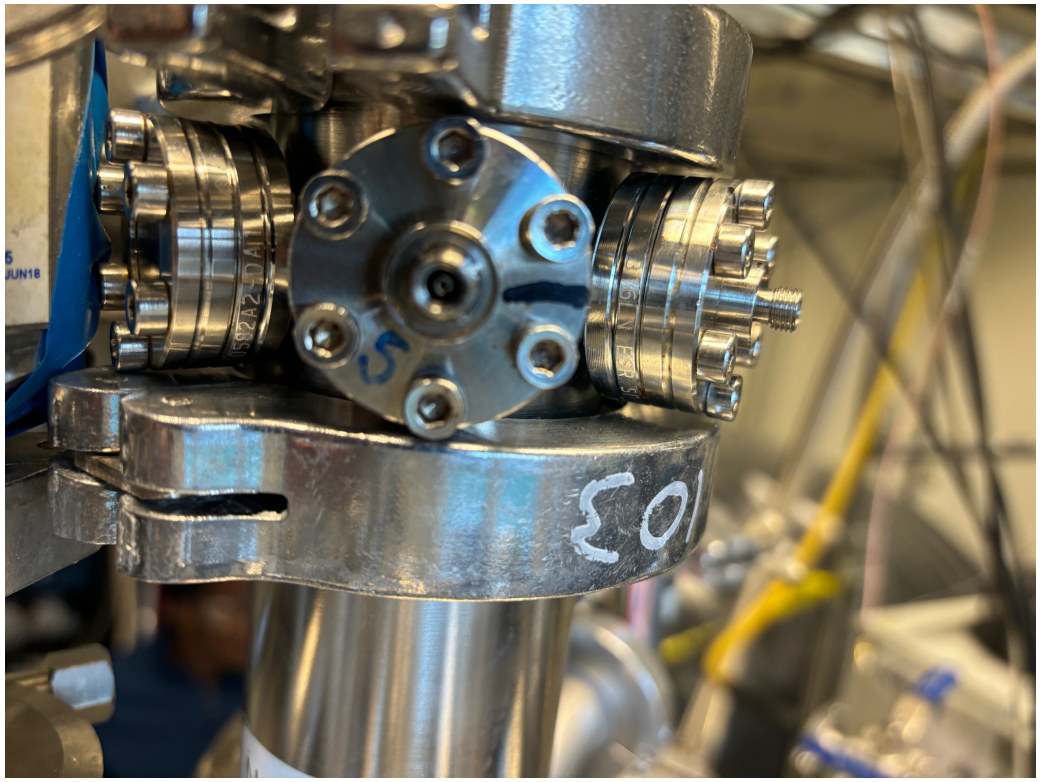
Notes

Polarization was low (<10%)

Microwave power delivered to target was low (~60 mW)
compared to 188 mW in September
NMR was noisy due to broken SMA connector

Beads are relatively lightly colored

December: Warm Irradiated ND_3

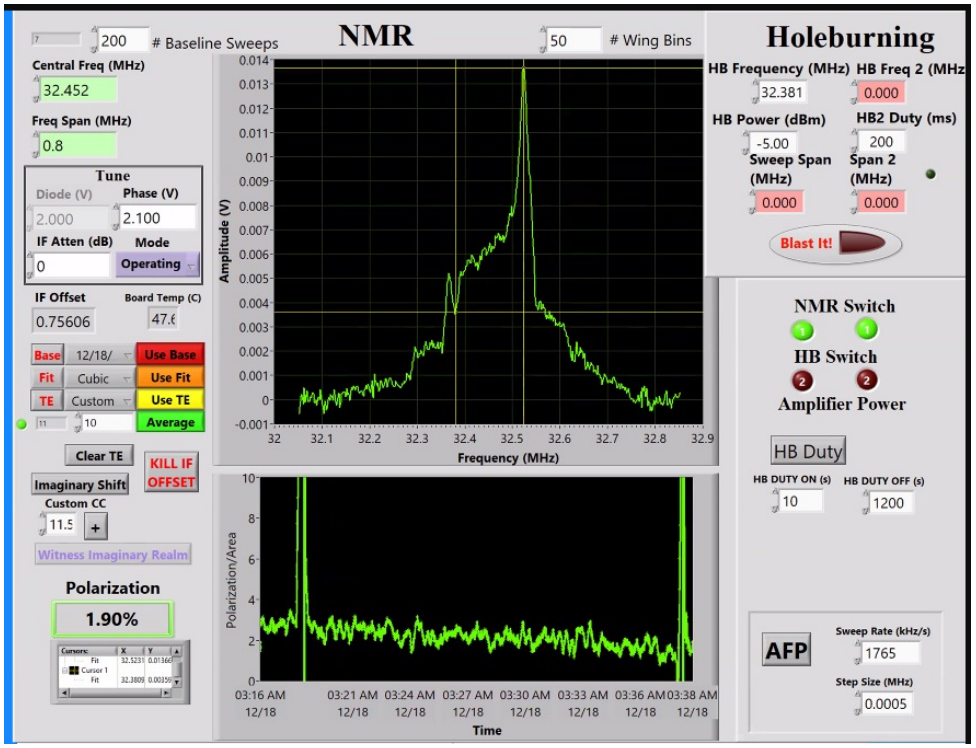


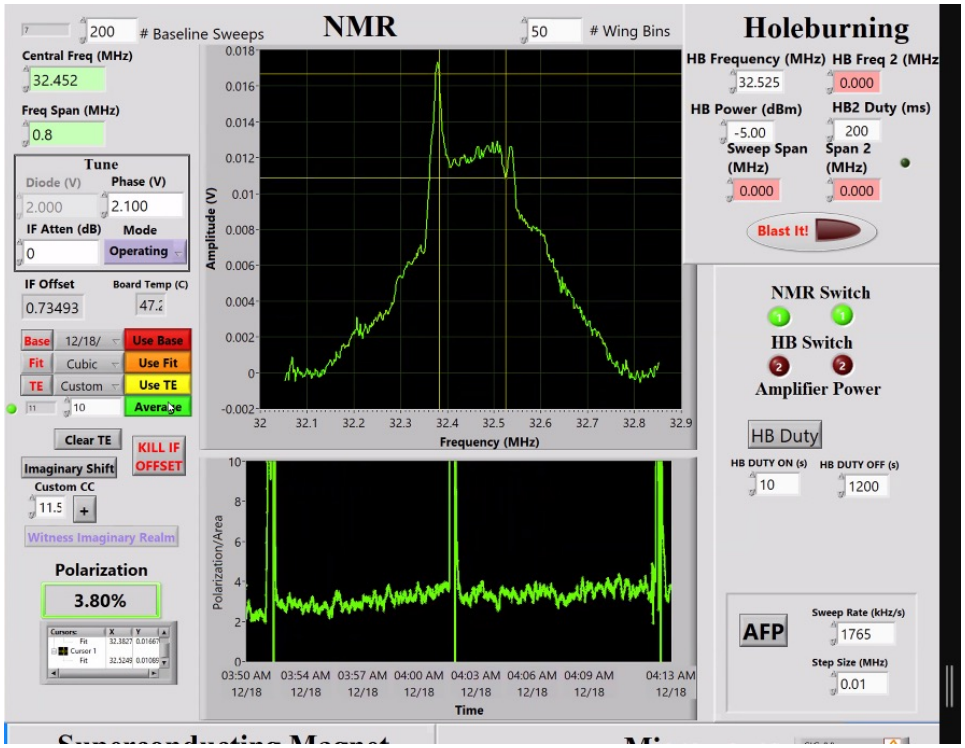
NMR was noisy due to broken SMA connector

RF power applied varied from a few mW to 140 mW

RF applied as delta function to left, right peak or right shoulder

RF applied from 1 – 12 seconds and then observed the recovery time

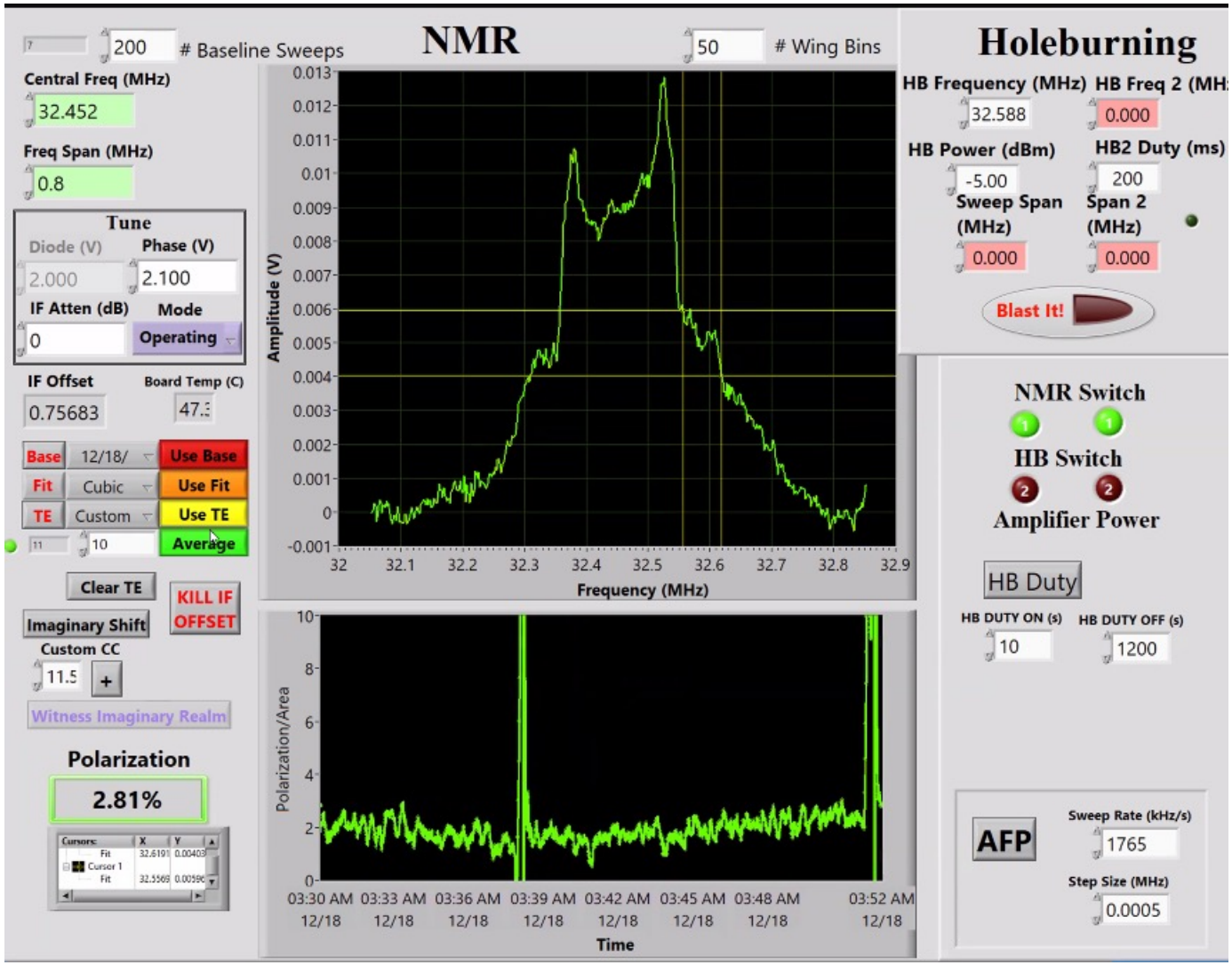




Left Peak Burn: 32.381 MHz

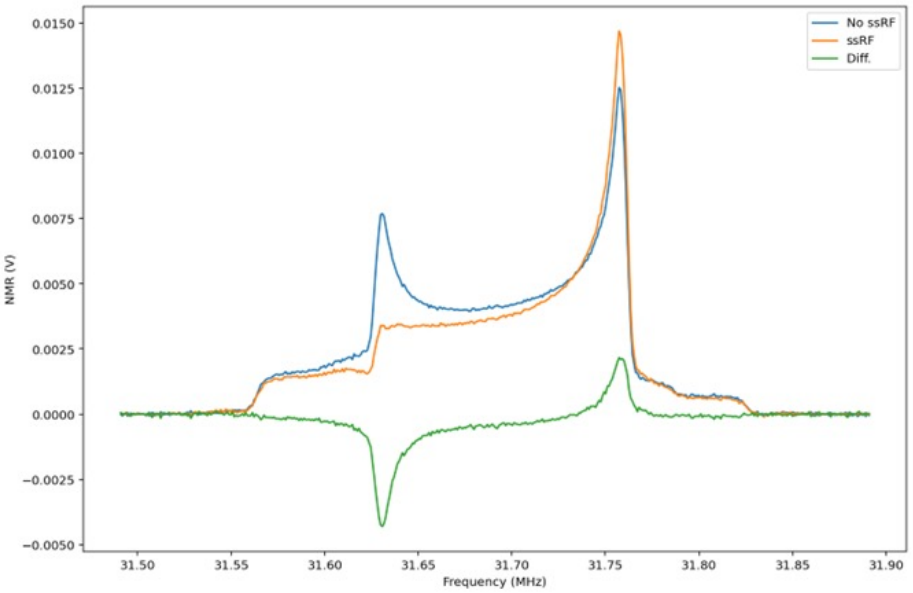
Right Peak Burn : 32.525 MHz

Right Shoulder Burn : 32.588 MHz

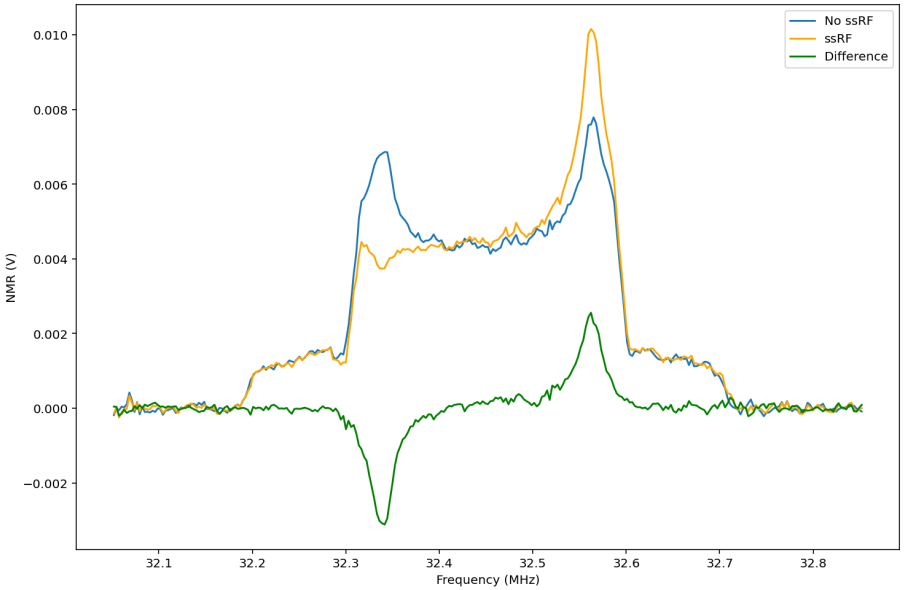


ss-RF Tests

Irradiated D-butanol

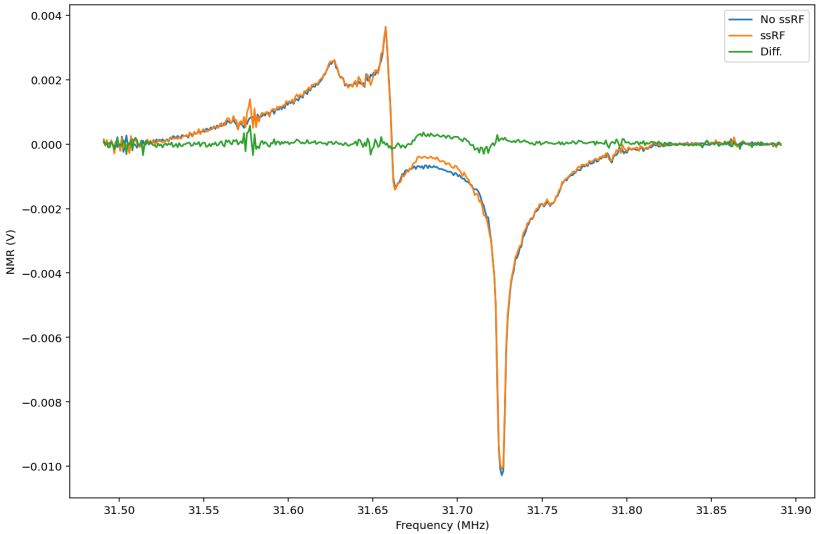


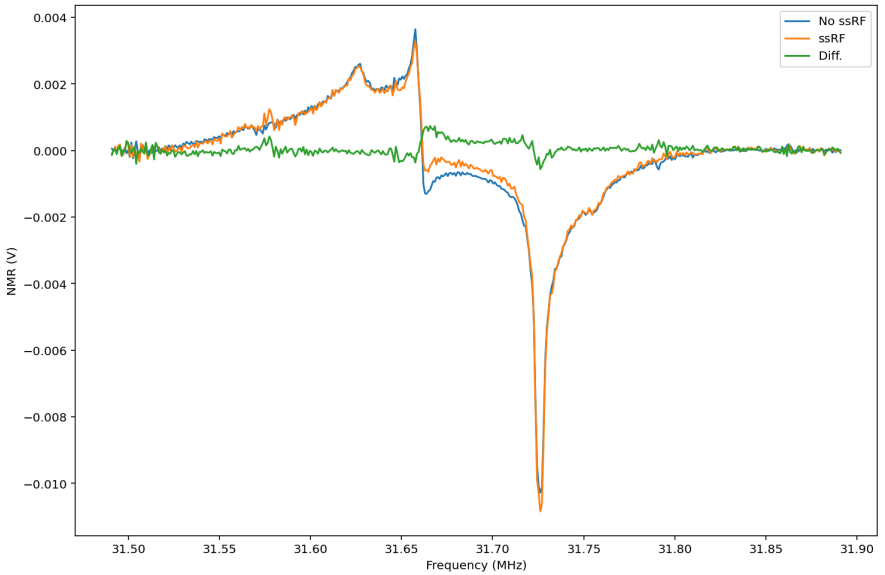
Warm Irradiated ND3



Tests of $A_{dip} = 2\,A_{bump}$

ss-RF (Imaginary channel)





Plots courtesy M. McClellan

Hole Burning Repopulation Times in ND3

Time	Power (dbm)	SLM diff	Power (mW)	Duration (s)	Frequency (MHz)	Recovery time (s)
02:38	-25			10	Left peak	480
02:51	-25			11	Left peak	530
03:02	-20	0.1	6	12	Left peak	750
03:17	-15	0.26	16	10	Left peak	772
03:38	-5	2.25	140	10	Left peak	803
03:50	-5	2.25	140	10	shoulder	490
04:02	-5	1.5	94	3	Right peak	485
04:13	-5	1.5	94	1	Right peak	500

Preliminary

Conditions

Microwaves : ON

Temp : 1.65 K (vapor pressure) 1.7K (cernox)

RF applied with delta function

Left Peak: 32.381 MHz

Right Peak : 32.525 MHz

Right Shoulder : 32.588

Notes

NMR was very noisy

Polarization was <10%

Extremely Preliminary Conclusions

RF applied to ND3 on time scale of 1 second results in recovery times on the order of 10 mins

We did not max out RF power applied. Goal is around 200 mW

Our NMR was very noisy, and we had relatively low Polarization so the recovery time measurements have large uncertainties,

but they are approximately an order of magnitude longer than the typical recovery times we measured in irradiated butanol

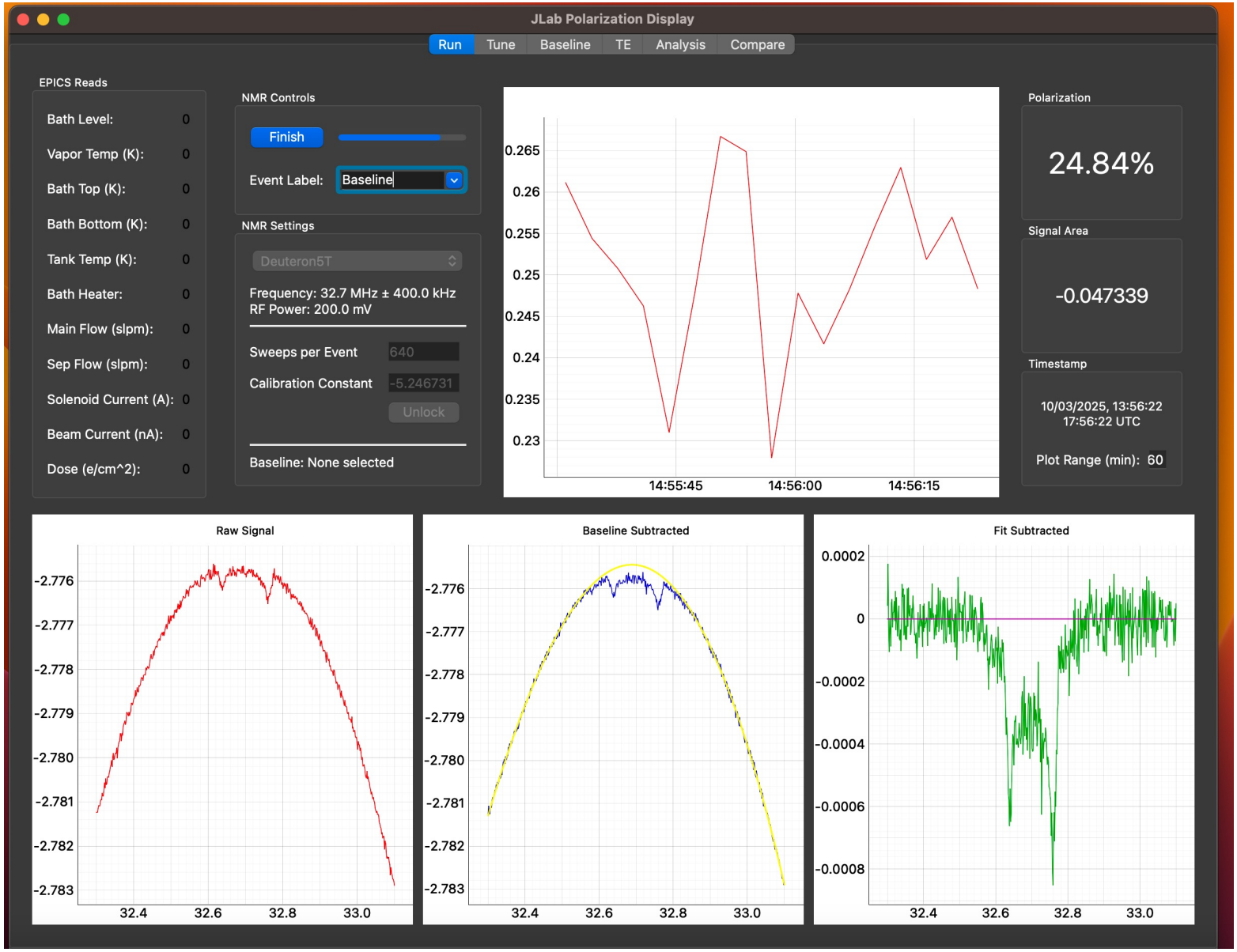
Optimization needed to find best duty cycle, but this seems very usable under experimental conditions for b1/Azz

See Chhetra's talk for details

Next 3 planned cooldowns

Late October 2025	VDI returns repaired amplifier
Early November	Dbutanol. Reproduce max polarization
December	ND_3 (preferably cold irradiated)
January	AFP focused cooldown.

Jlab (James Maxwell) Python Based NMR



Summary

Helium Recapture System

Fully operational after a painful commissioning period
Rate: 40 L/day (average), 30-50L/day (variable)
Recapture efficiency : >90%
Capacity: 500-800 Liters
Duty cycle: 5 days of physics followed by 2 weeks of recovery

DNP and ssRF Results

Approaching max expected polarization in d-Butanol, d-prop
Cooldown with warm irradiated ND_3
- Low polarization
- measured ssRF recovery times

Solid state source amplifier being repaired

Eager to repeat tests with cold-irradiated ND_3