Dynamic Nuclear Polarization Facility at UNH

PSTP 2024, JLab

2024-09-22

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University of New Hampshire

This Talk

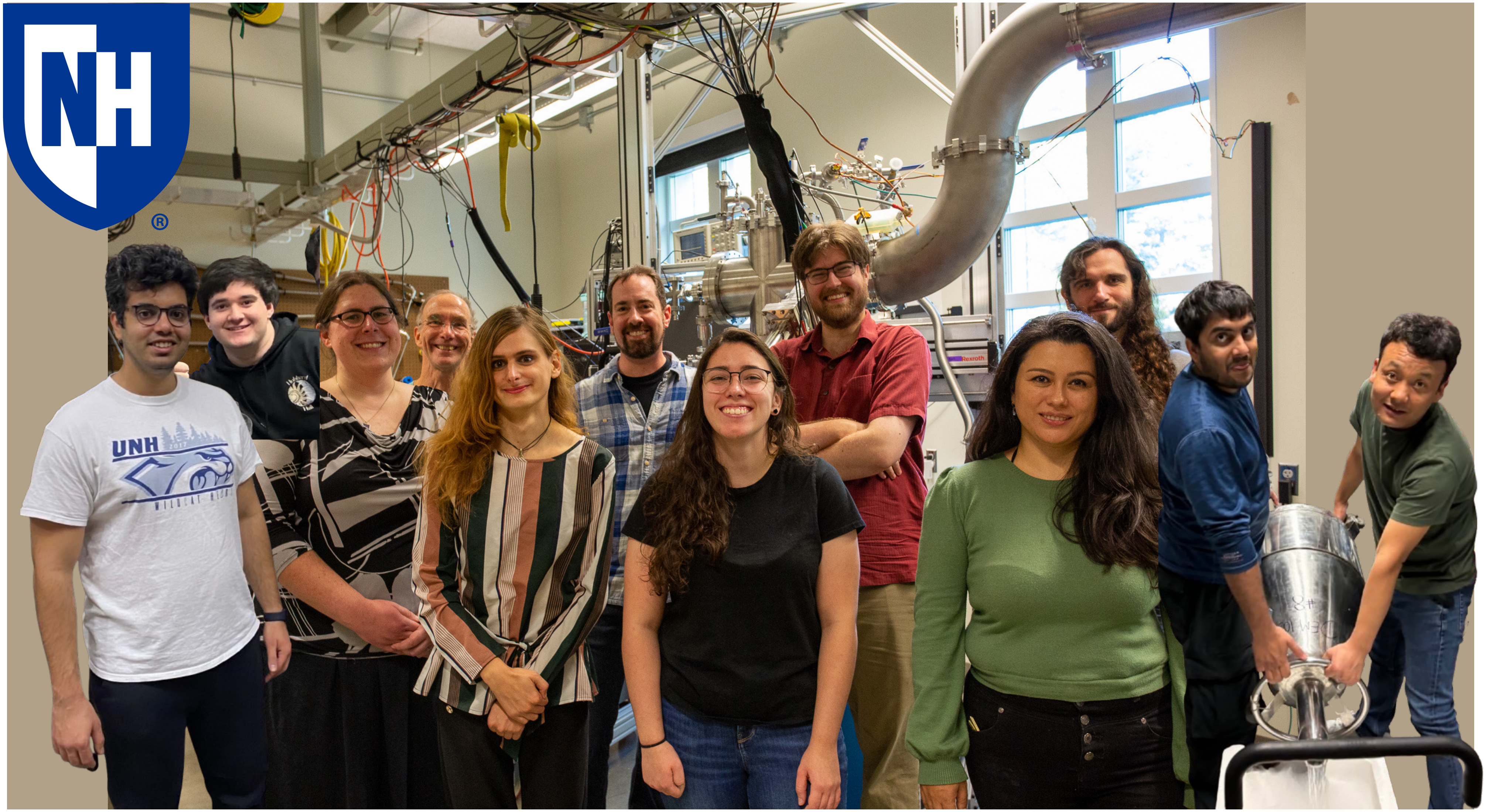
UNH DNP SYSTEM OVERVIEW

HELIUM RECAPTURE SYSTEM

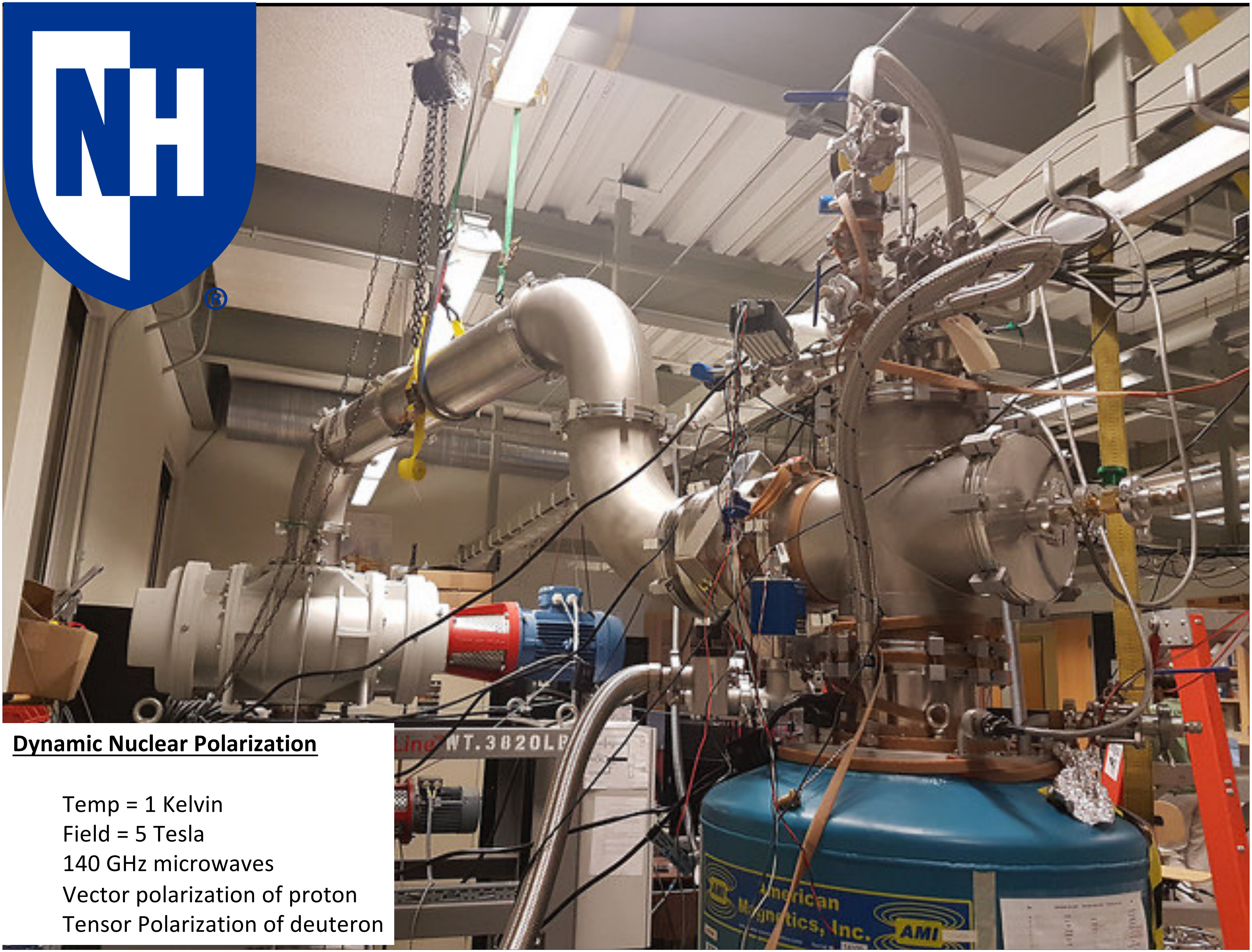
DNP/SSRF RESULTS

FUTURE PLANS

Polarized Target Group



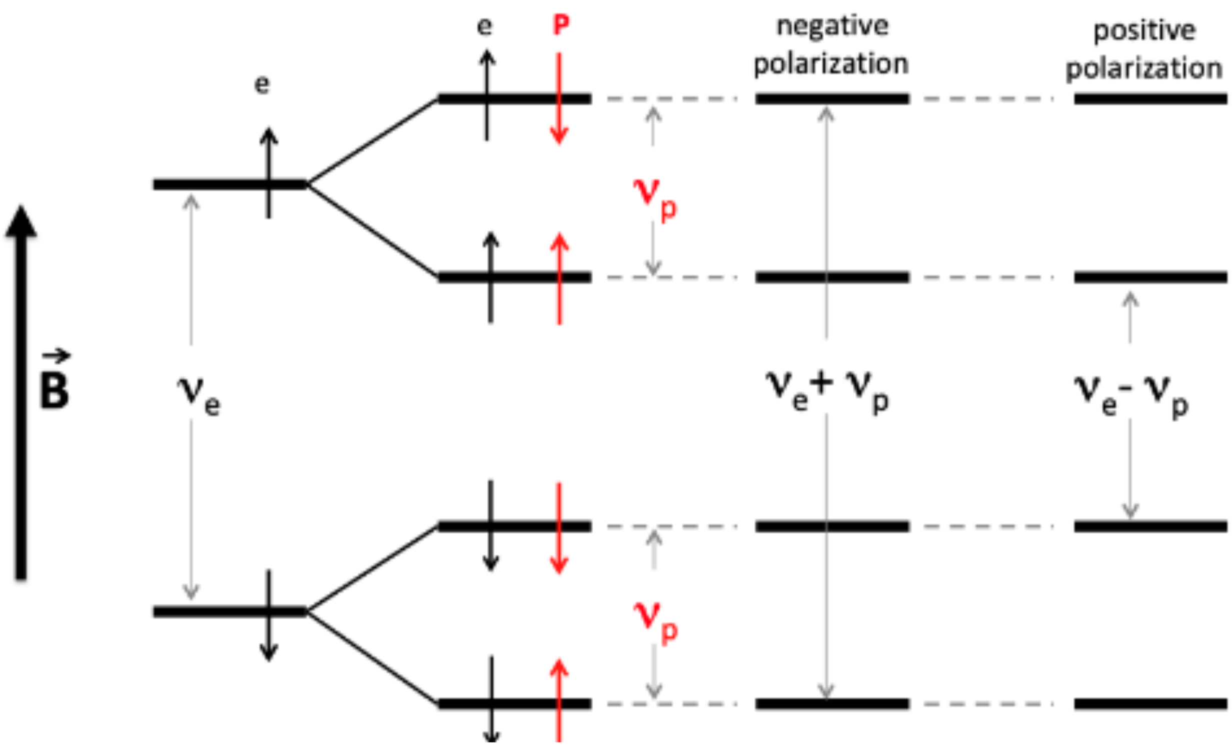
Tensor Polarization of Deuterons for Jefferson Lab Tensor Program
Polarized Target Material Production



Dynamic Nuclear Polarization

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

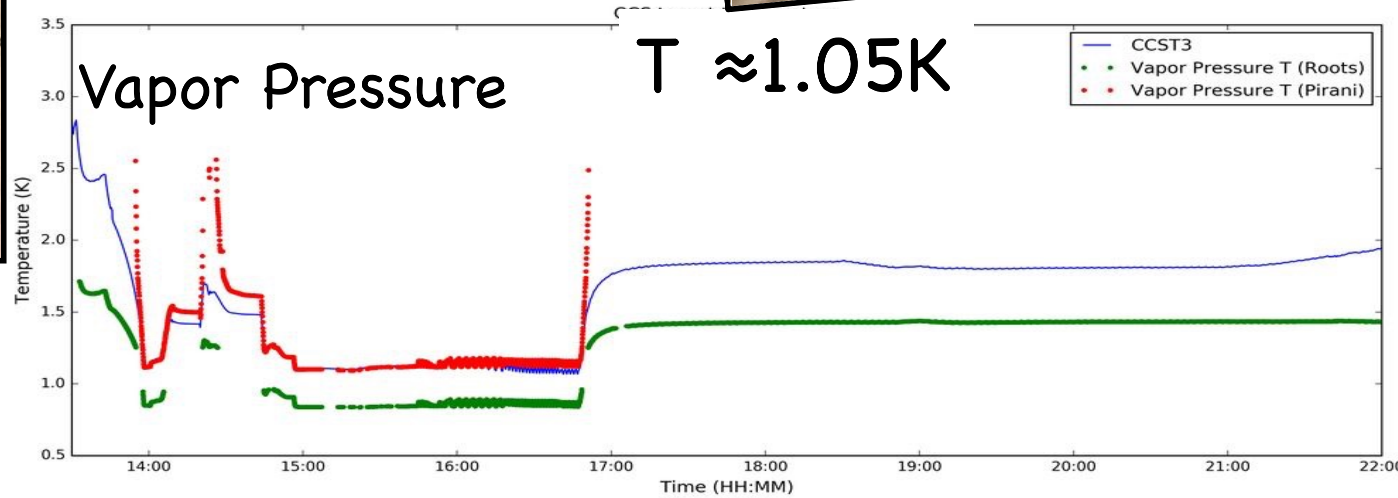
Dynamic Nuclear Polarization



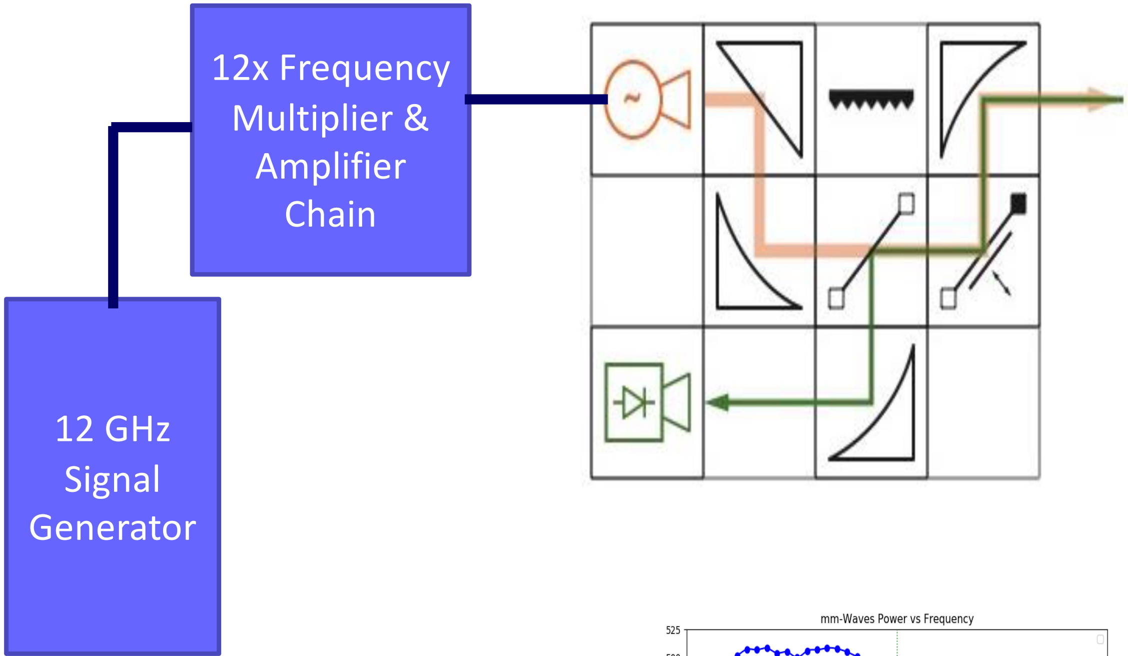
Flip the spins of unpaired e^- and transfer polarization to Nucleus

- Introduction of paramagnetic centers
- Large B Field : 5T
- Low Temp : 1K
- High Power microwaves

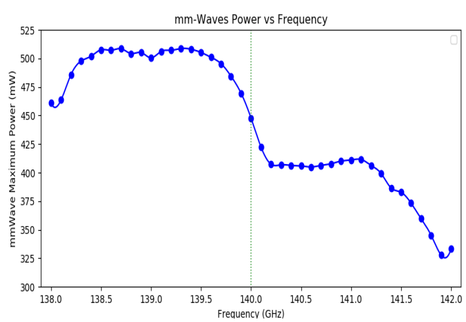
UNH He Evaporation Refrigerator



Solid State mm-Wave System



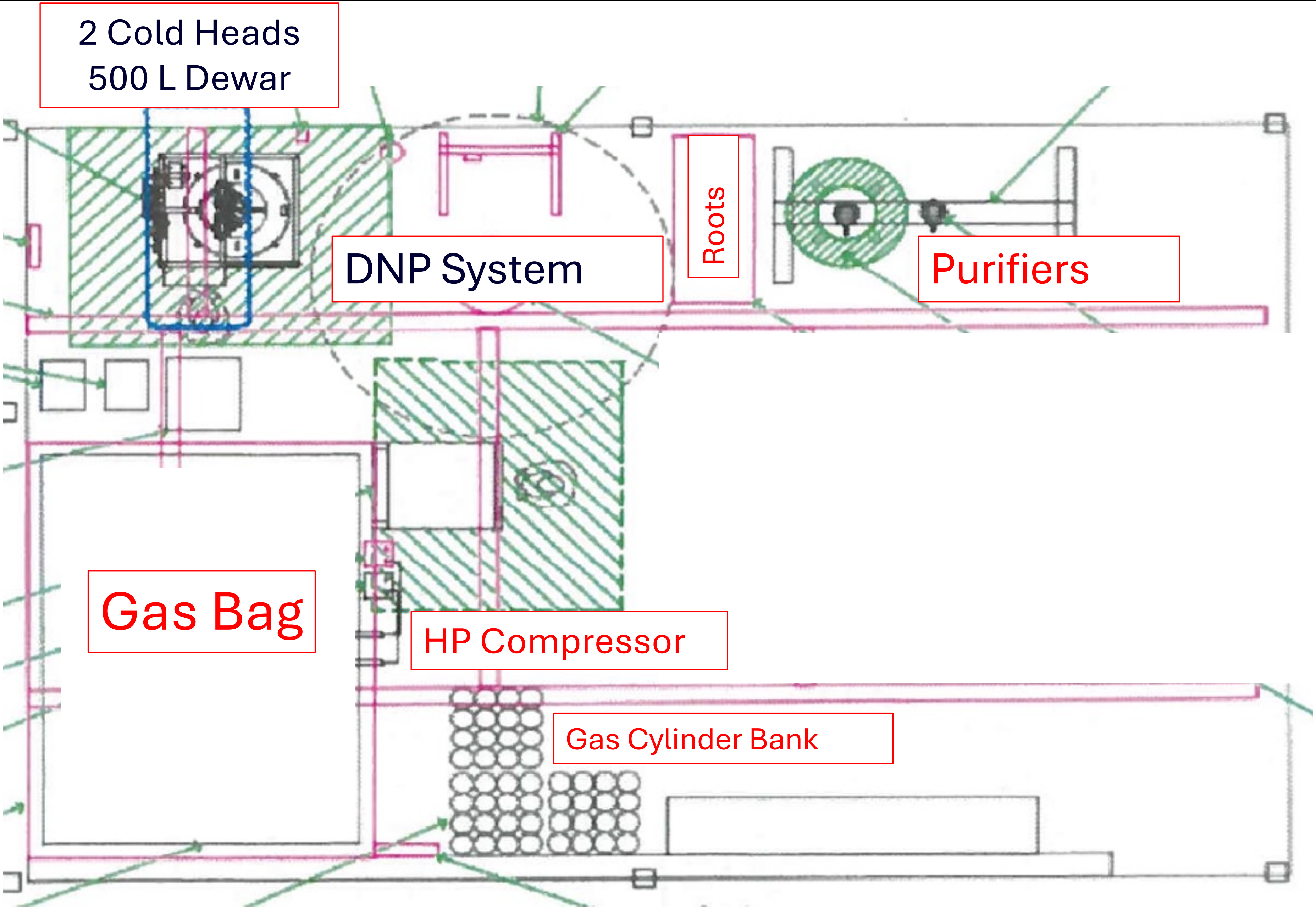
400 mW
@139 GHz



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

Helium Recovery System



Helium Recovery System

HP Gas cylinders

Gas Bag

Helium Recovery System

HP Gas cylinders

Gas Bag

Helium Purifier (dual)

Helium Recovery System

HP Gas cylinders

Gas Bag

Helium Purifier (dual)

Cold Heads
500 L Mother Dewar

Helium Recovery System Status

Fully operational after a painful commissioning period

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

Recapture efficiency : >90%

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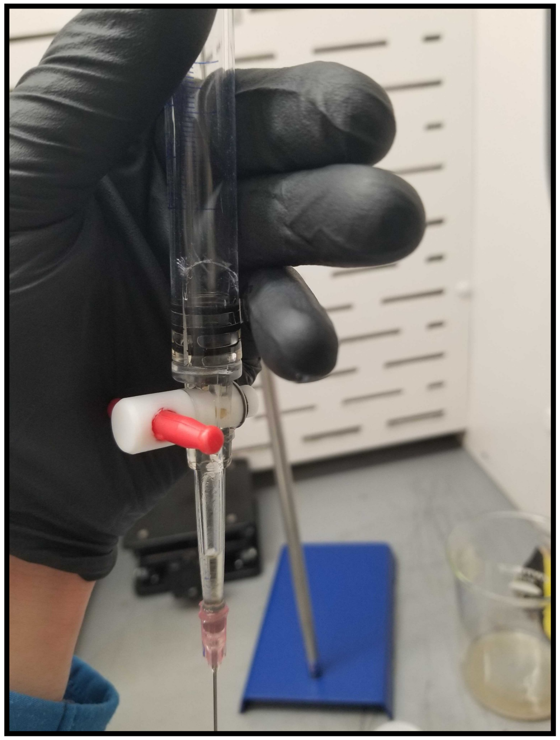
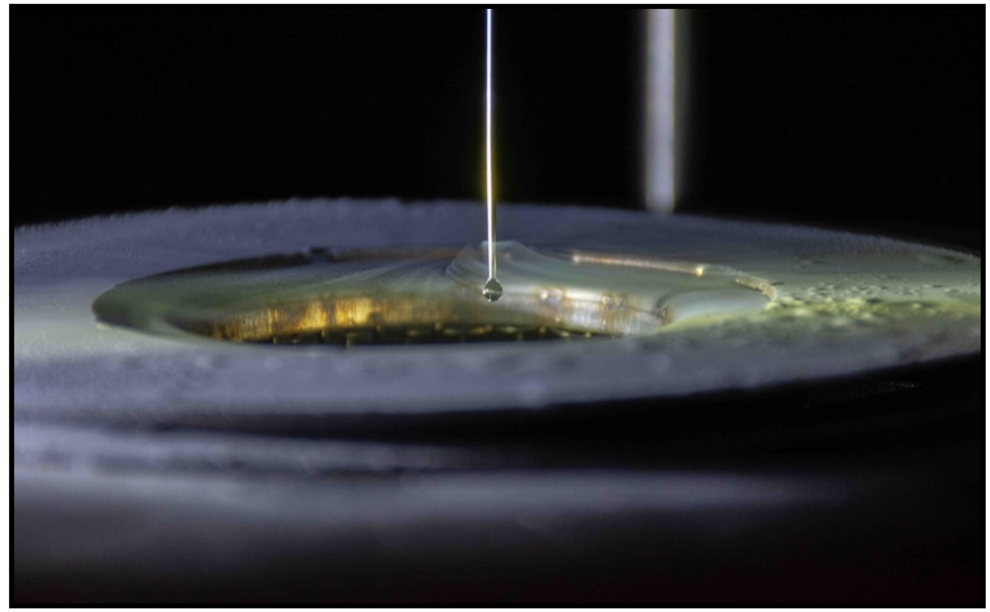
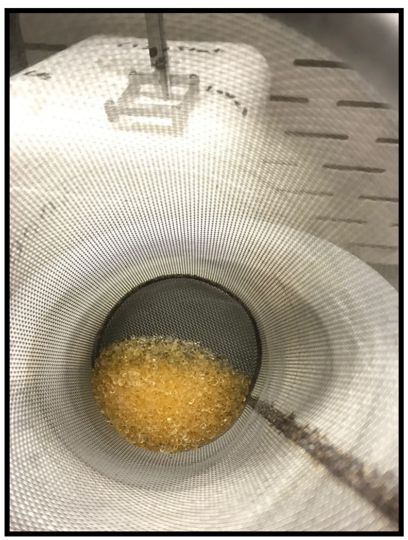
Duty cycle: 5 days of physics followed by 2 weeks of recovery

See Chhetra Lama's talk

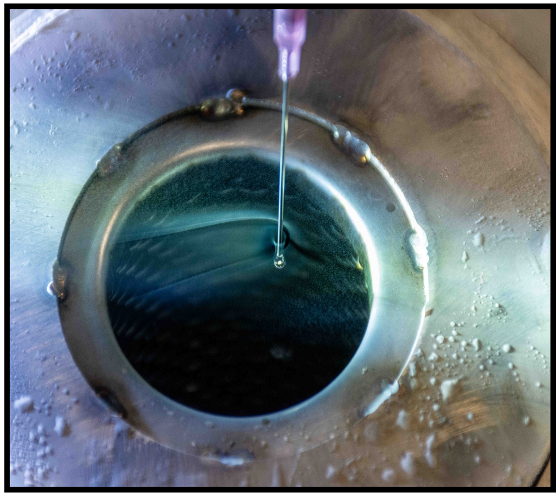
Target Material Production at UNH





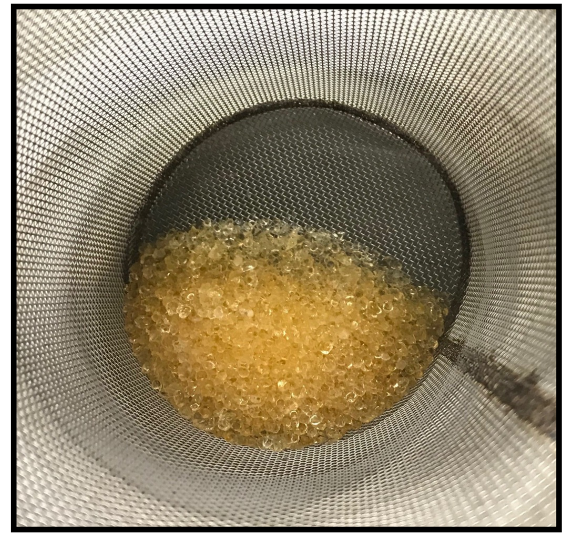


Target Material Production at UNH



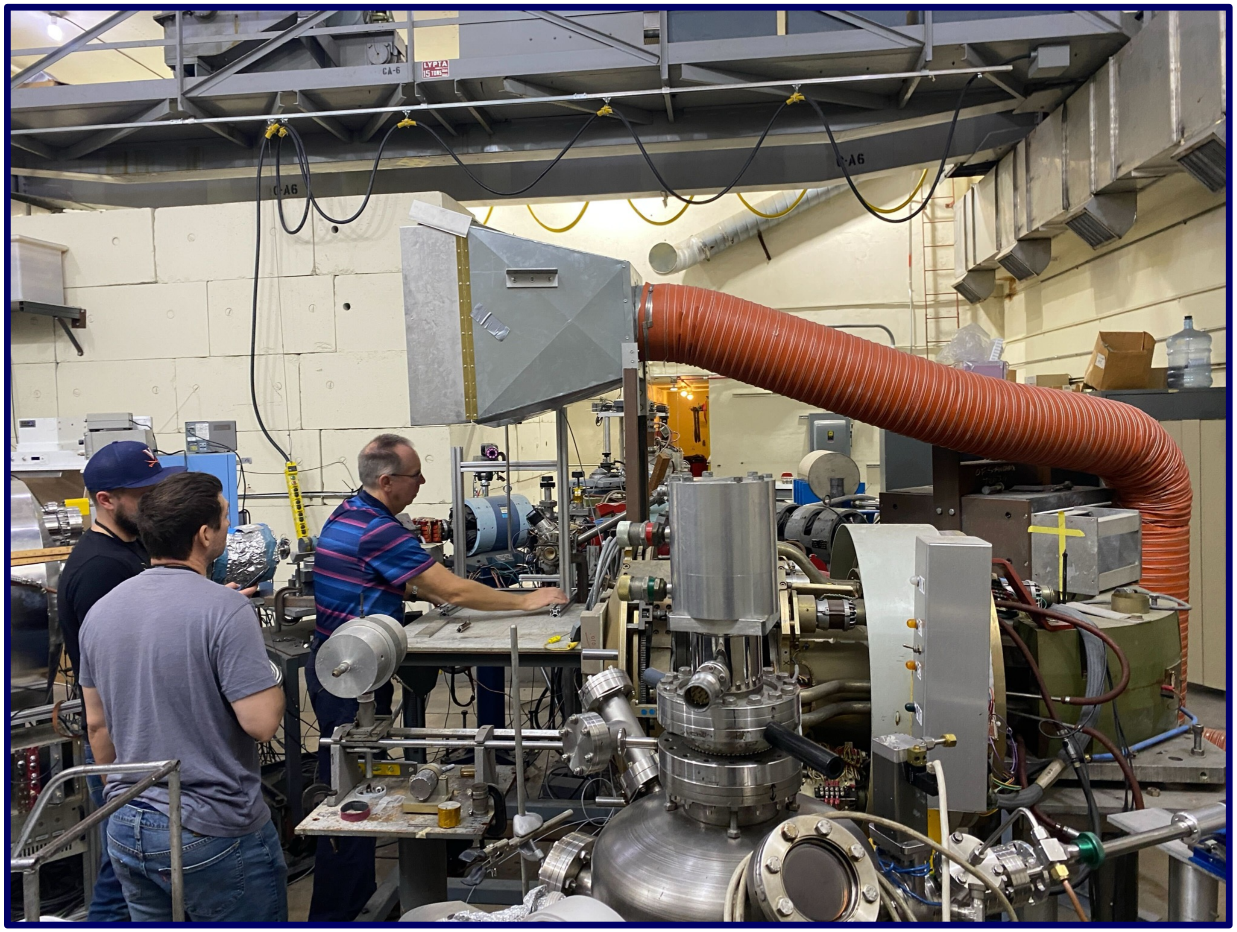
Butanol and other alcohols solidification

grade 5.5 NH_3 & ND_3

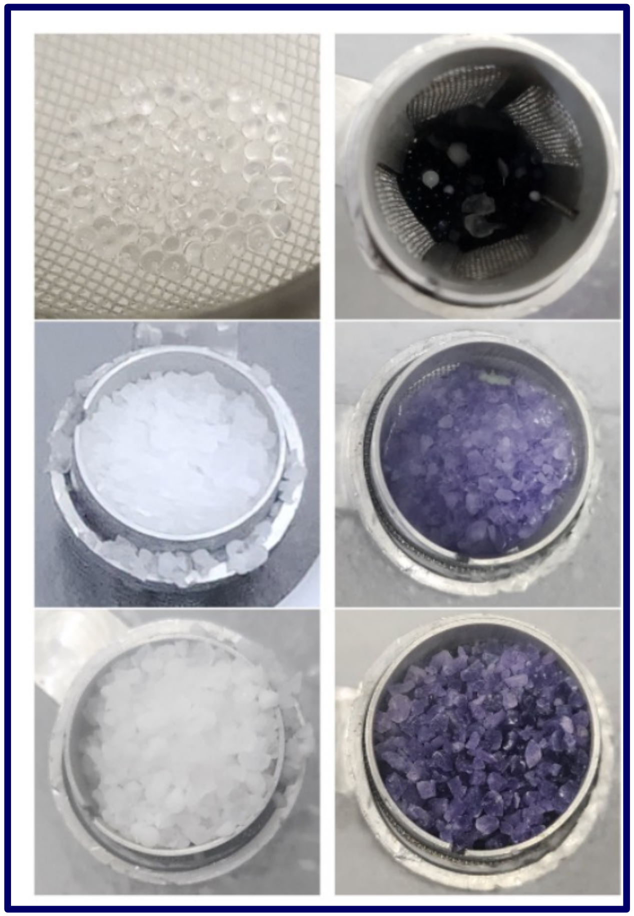


Chemical Doping

Material Irradiation at MIRF with UVA Group

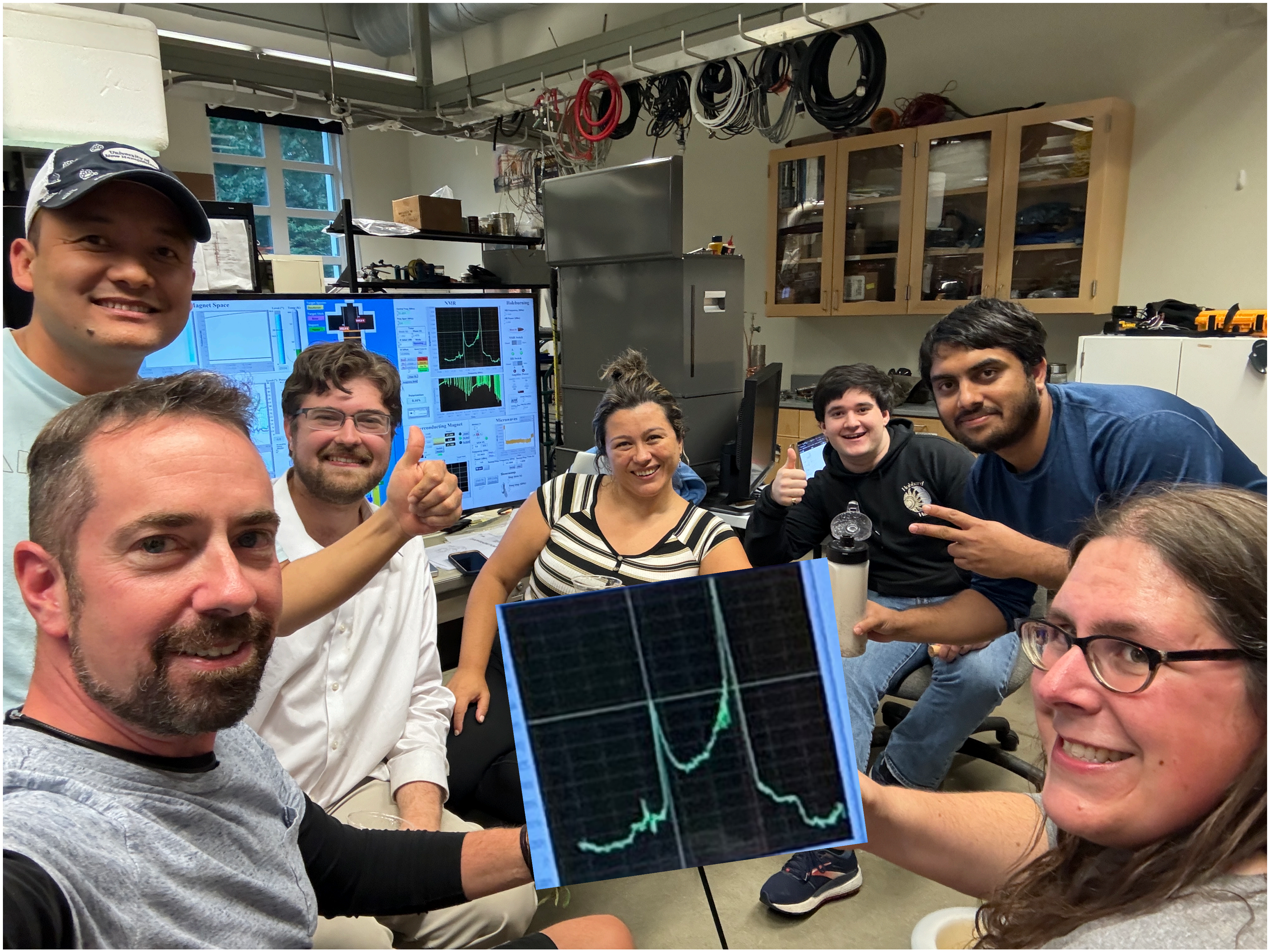


Target Material Irradiation at NIST with UVA Group

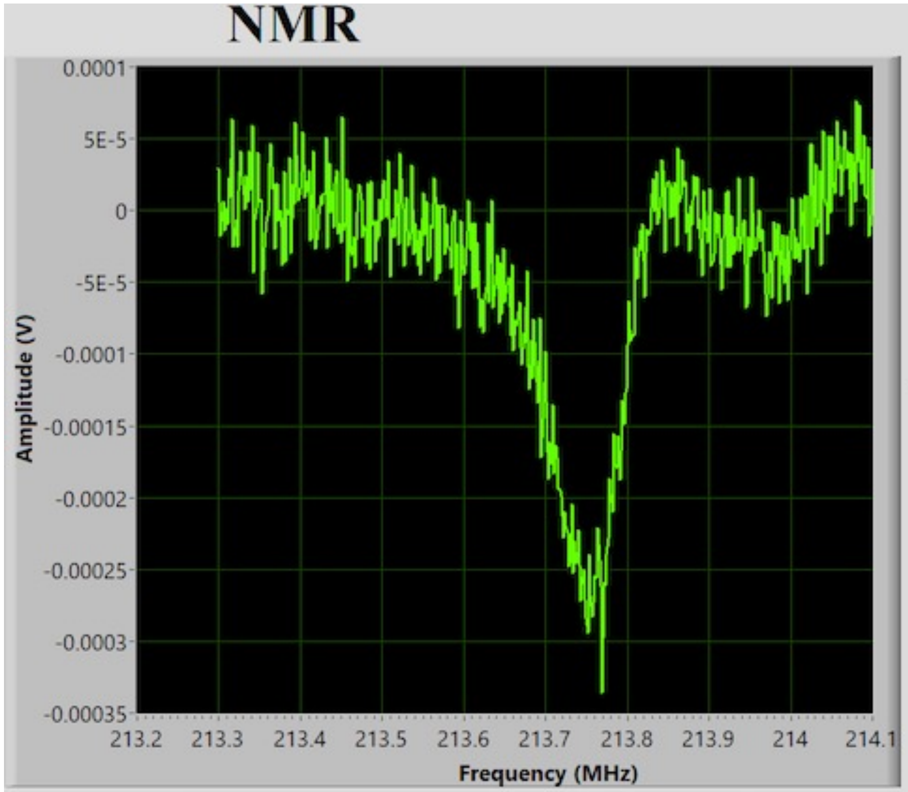


12.5 MeV electron beam material irradiation at 5 uA

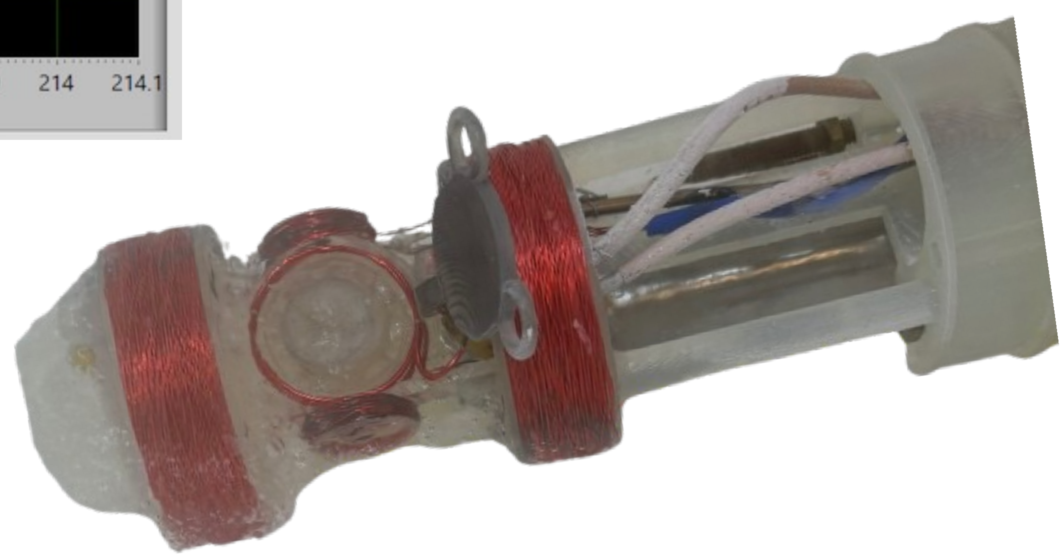
Results



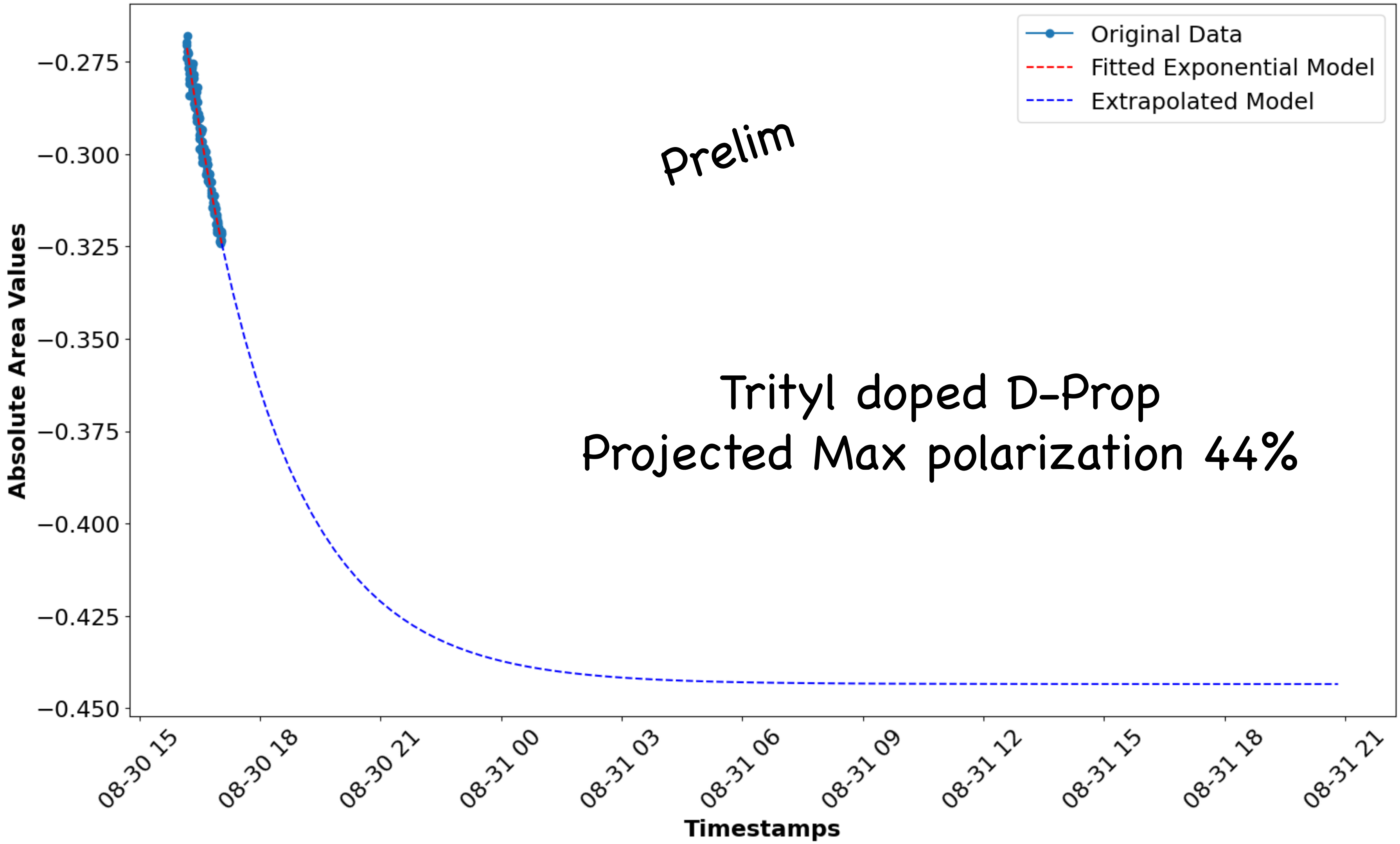
Proton TE



Proton T.E. Signal
Captured with cold NMR

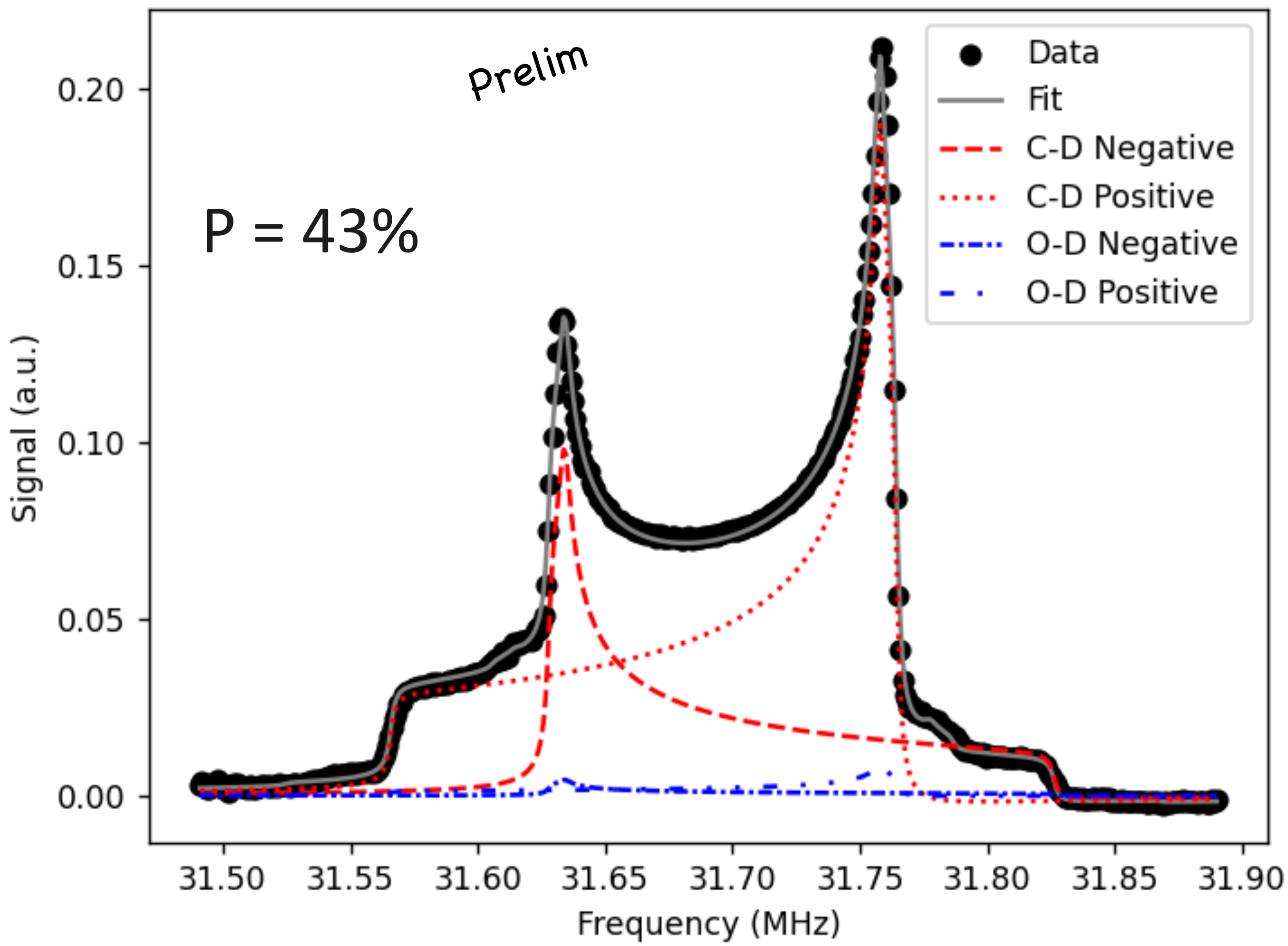


D-Propanediol



Courtesy M. Farooq

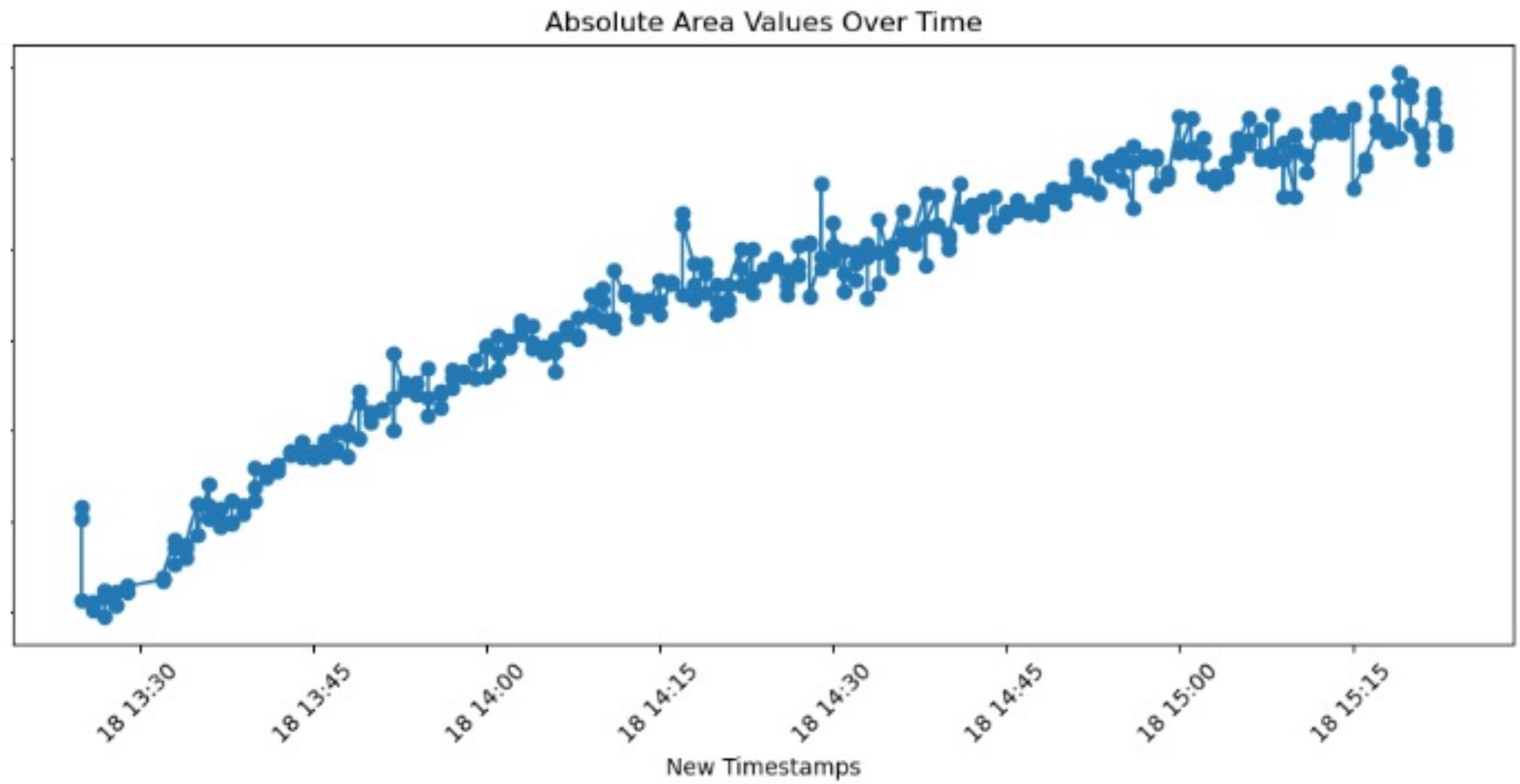
DNP



Irradiated D-Butanol

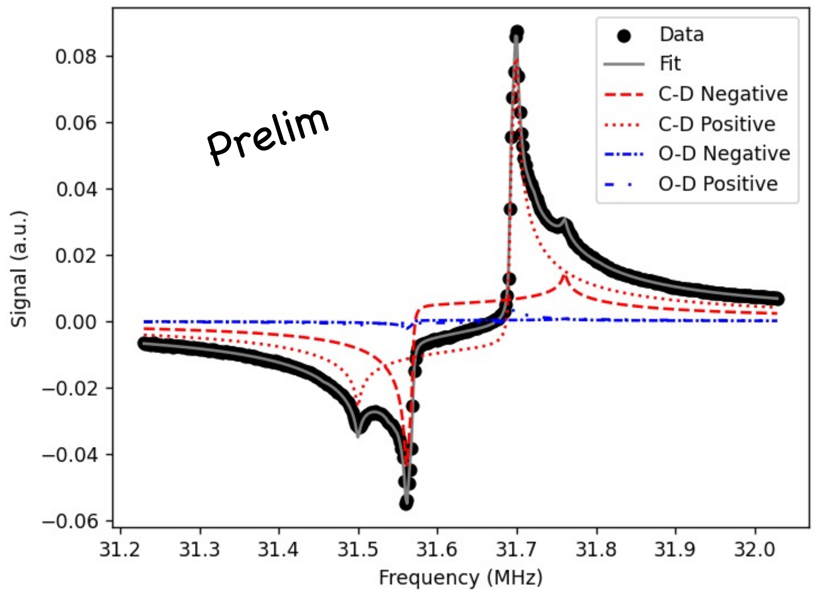
Plot courtesy M. McLellan

Irradiated D-Butanol Spin Up



Plot courtesy M. Farooq

Imaginary NMR Signal



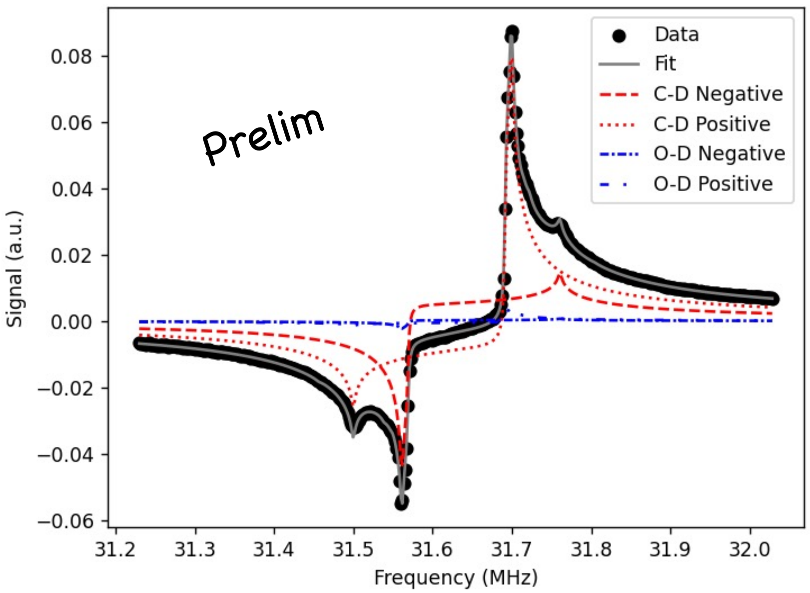
89.95 degrees out of phase

37.2% P, 10.7% Q

Irradiated D-Butanol

See M. McClellan's talk

Imaginary Signal

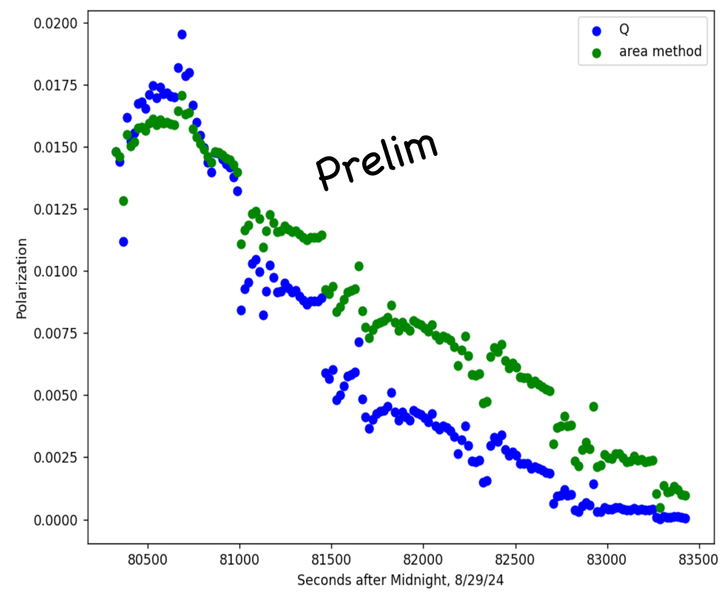


Irradiated D-Butanol

89.95 degrees out of phase

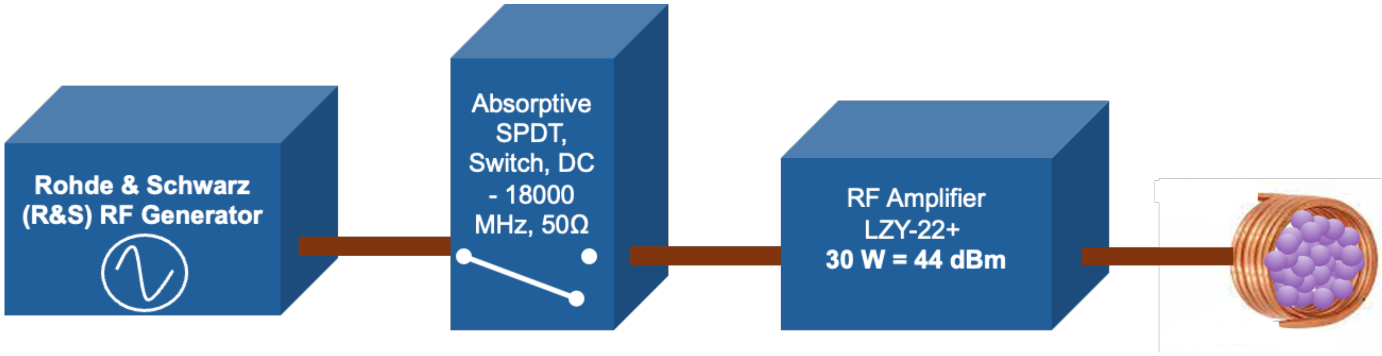
37.2% P, 10.7% Q

Modeling and data suggests that the area of
The imaginary signal is proportional to Q
May simplify getting Q from holeburnt data



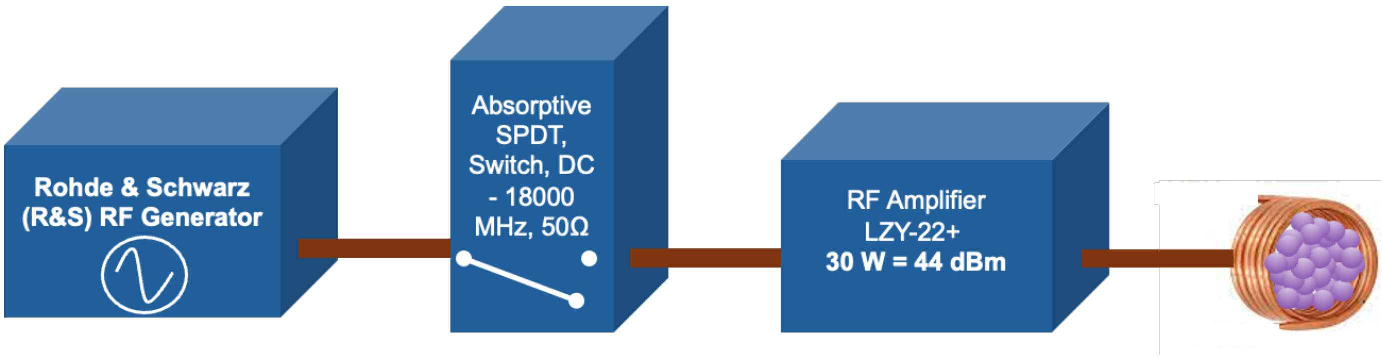
See M. McClellan’s talk

New SSRF Circuit



See Nathaly Santiesteban's talk

New SSRF Circuit



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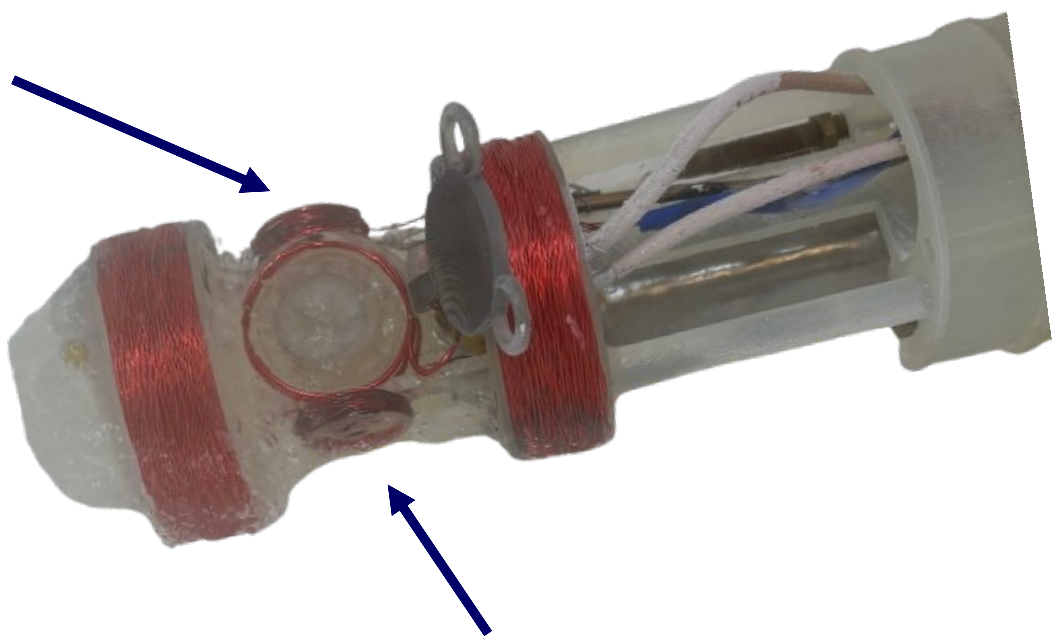
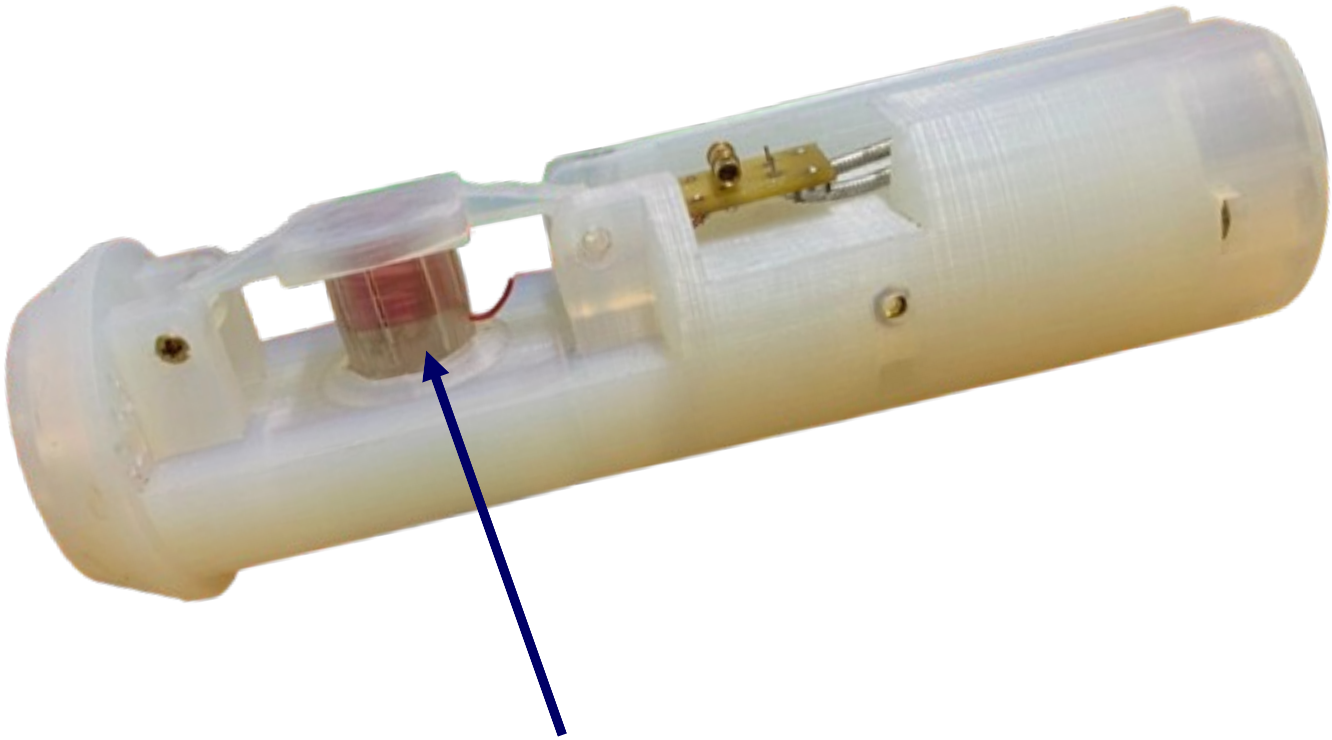


Proto-type Holeburning Coils
(very inhomogeneous)

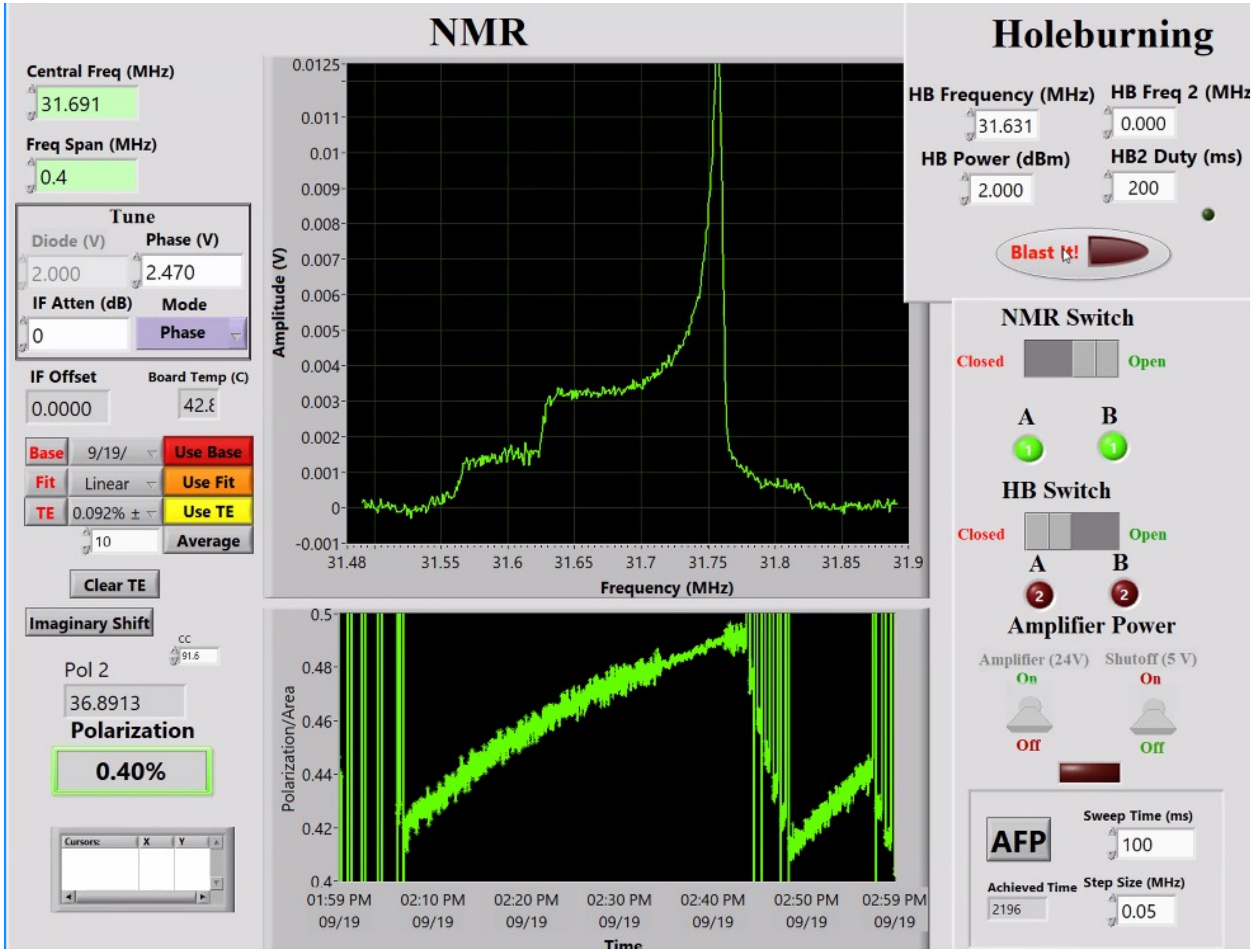
Next Steps



New solenoidal Holeburning coil

See Allison Zec's talk

SSRF Data

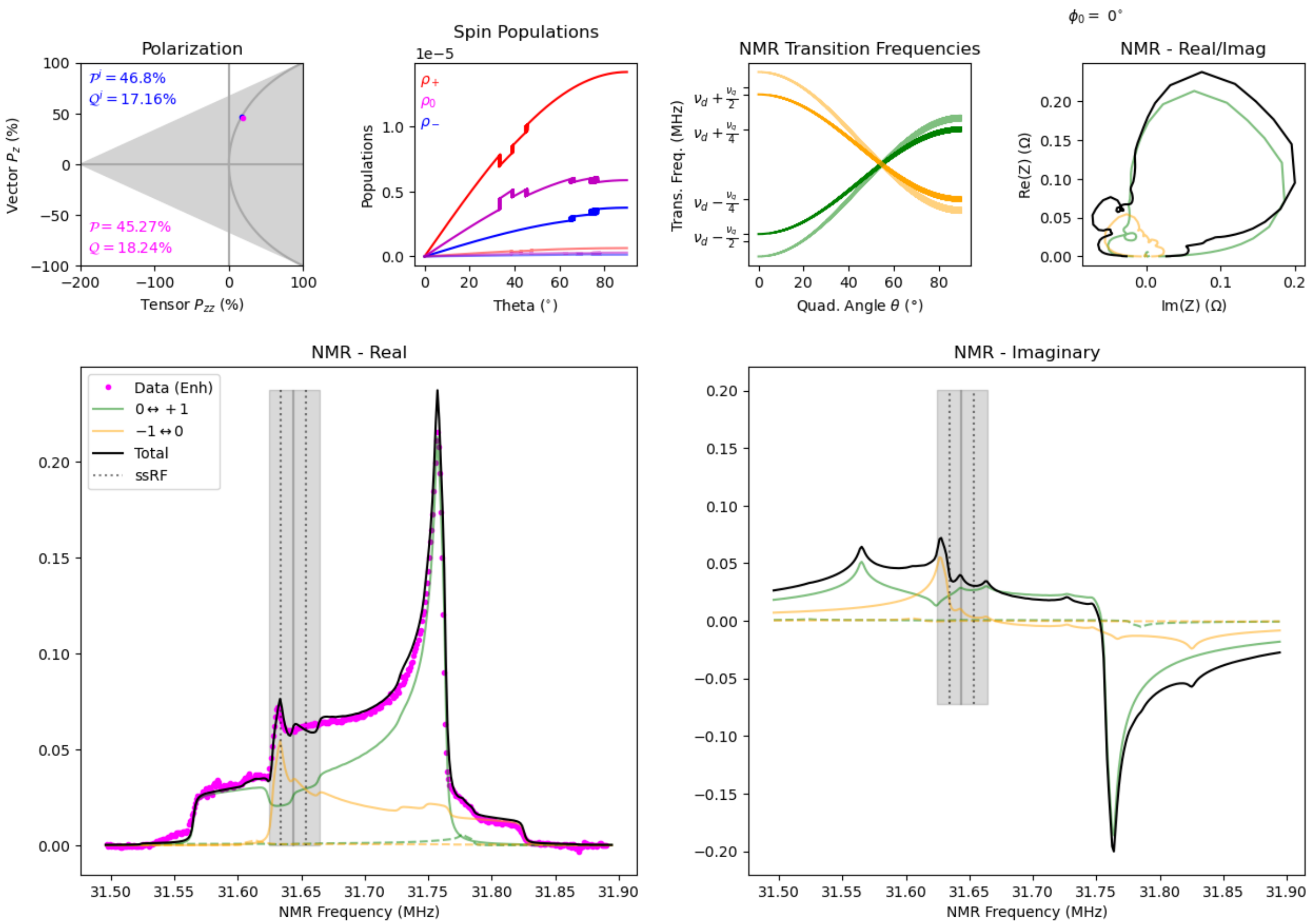


-1 --0

Irradiated D-Butanol

31.631
Q20

Simulation of SSRF Lineshape



See Elena Long's talk

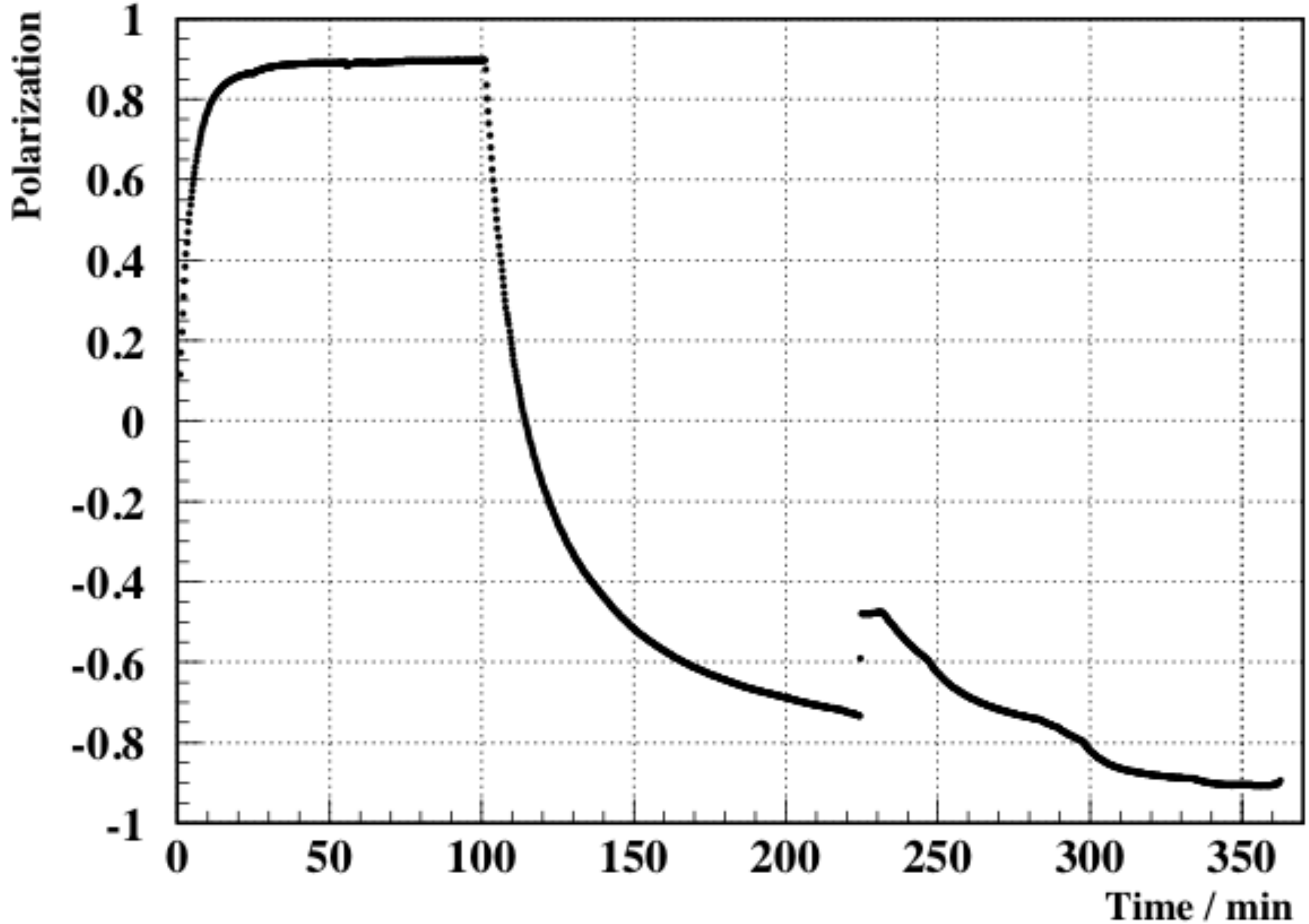
Observable: Tensor Asymmetry Azz

For an asymmetry measurement

$$\text{sensitivity to slow drifts} \propto \frac{1}{\sqrt{N_{flips}}}$$

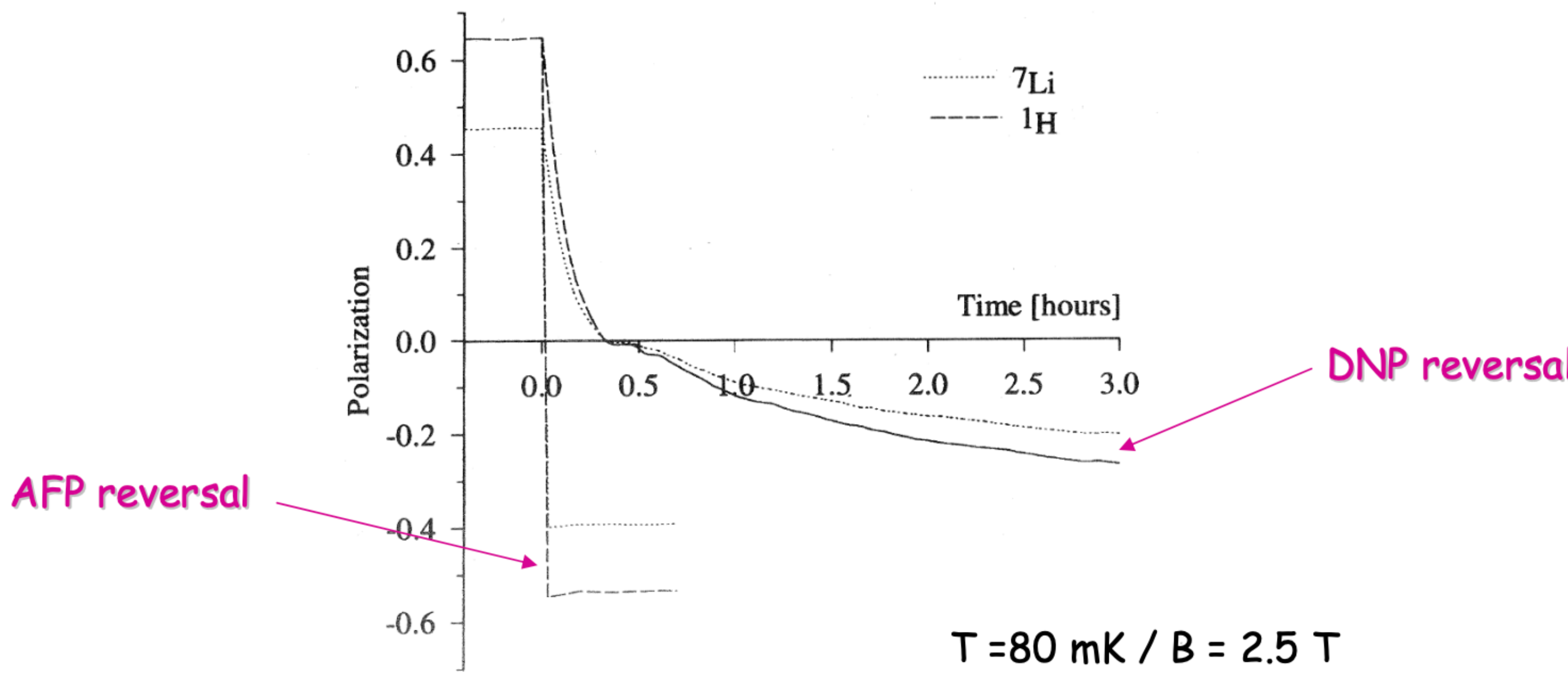
There's a clear advantage to rapidly switch Spin States

DNP Spin Flip takes too long…..



Adiabatic Fast Passage

In practice: polarization reversal AFP vs DNP



➡ *gain can be dramatic in certain cases (especially at low temperatures)*

AFP efficiency <-> DNP build up time

From: Hautle

Adiabatic Fast Passage

AFP : Method to quickly change the spin state of “all” spins in a sample

“all” : AFP efficiency < 100%

Adiabatic : Slow

Fast : Rapid

Which is it?.

Adiabatic Fast Passage

Adiabatic : Slow

Fast : Rapid

Which is it? Both.

AFP is a spin flip which is slow compared to the Larmor frequency
and
Fast compared to the dominant relaxation time(s) of the system

Adiabatic Fast Passage

$$\frac{1}{T_2} \ll \frac{1}{H_1}\frac{dH_0}{dt} \ll \gamma H_1$$

T_2: Relaxation time

H_0 : Holding Field

H_1 : "Tickling" RF field

Adiabatic Fast Passage

In Solids T_2 is much shorter than in gases which prevents strong satisfaction of the AFP condition, so AFP is not completely lossless

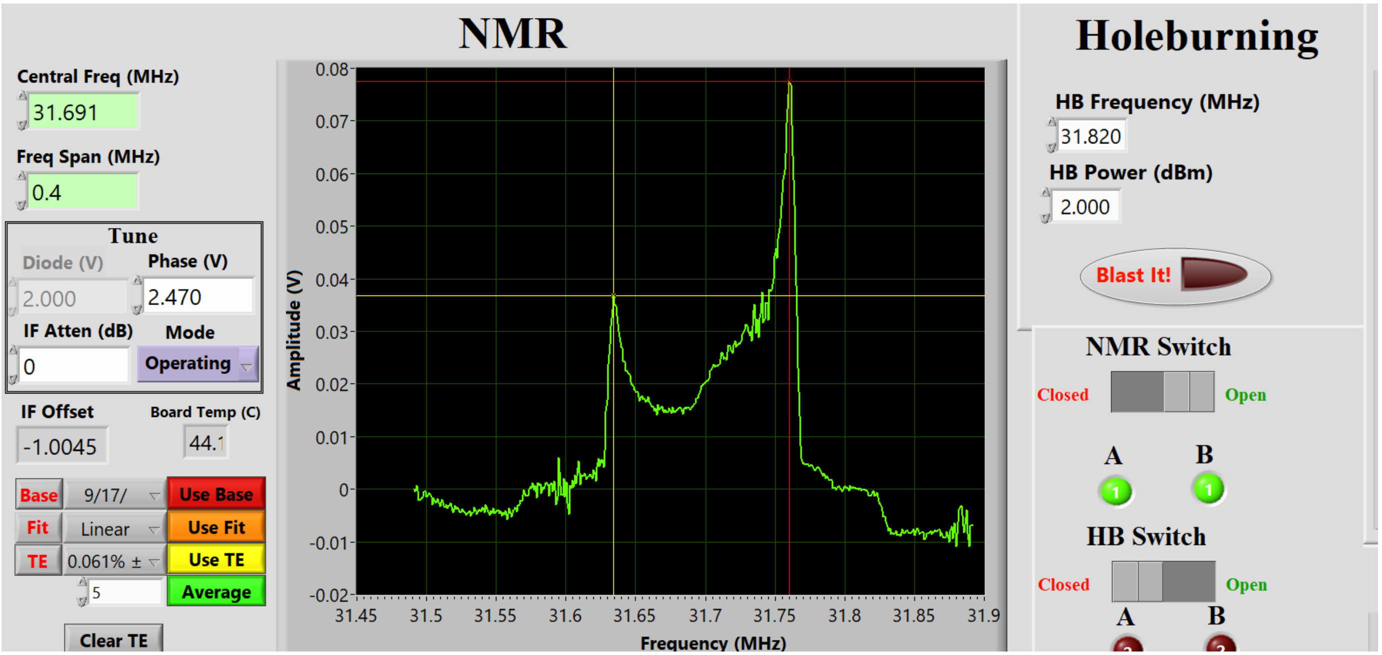
^7LiH : 90% AFP efficiency from data [Hautle]

NH_3 : models show should be low efficiency [Hautle]. Needs to be tested

ND_3 : models show should be good efficiency [Hautle] Needs to be tested

Adiabatic Fast Passage

Status: Work in progress



First attempt at AFP

poor homogeneity of RF coil and
not clear yet how much power we are delivering to the sample
AFP sweep is step-wize, not continuous. Will swap out RF generator

Stay tuned...

E12-13-011: The b_1 *experiment*

30 Days in Jlab Hall C
A⁻ Physics Rating

E12-15-005: A_{zz} *for x>1*

44 Days in Jlab Hall C
A⁻ Physics Rating

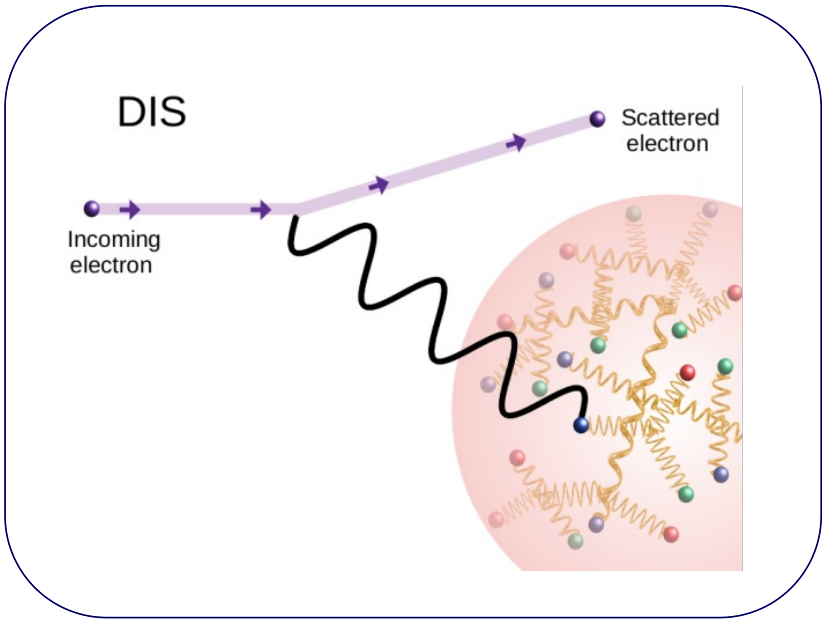
CAA Proposal: Spin 1 Transverse Momentum Dependent Tensor Structure Functions in CLAS12

LOI: **12-24-002**
Spin-1 TMDs and Structure Functions of the Deuteron

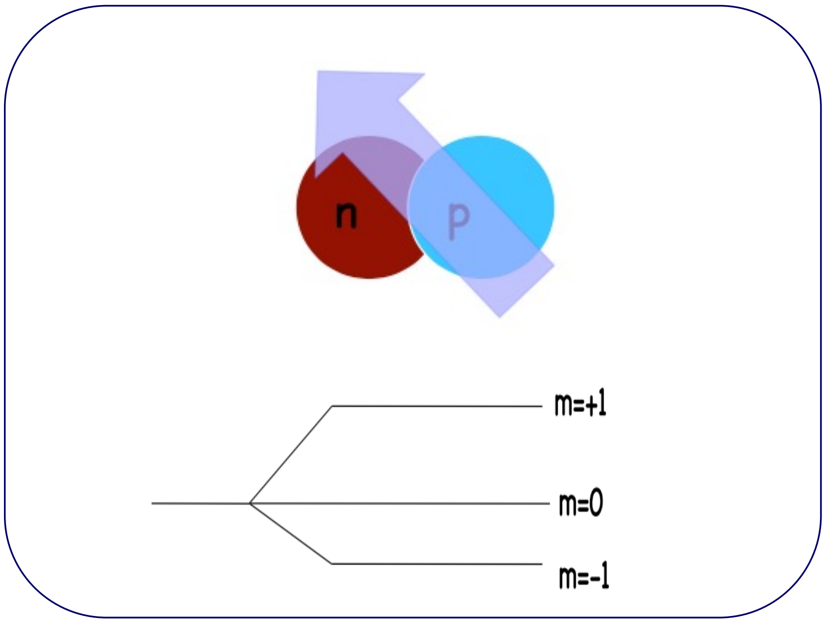
b_1 structure function

$$b_1(x) = \frac{q^0(x) - q^1(x)}{2}$$

DIS (probing quarks)

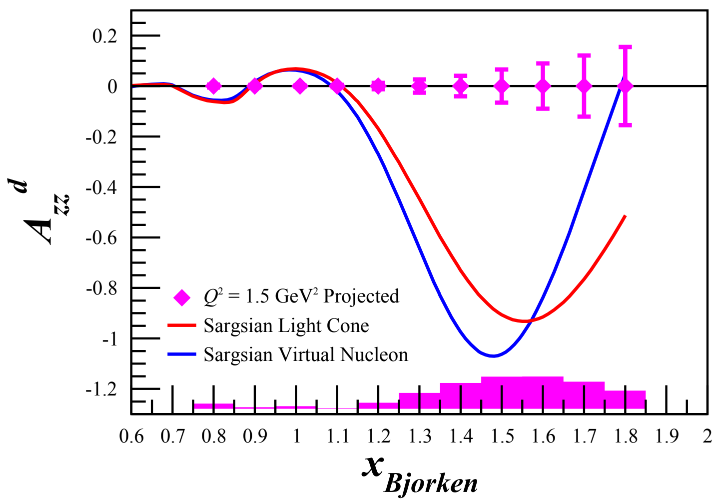


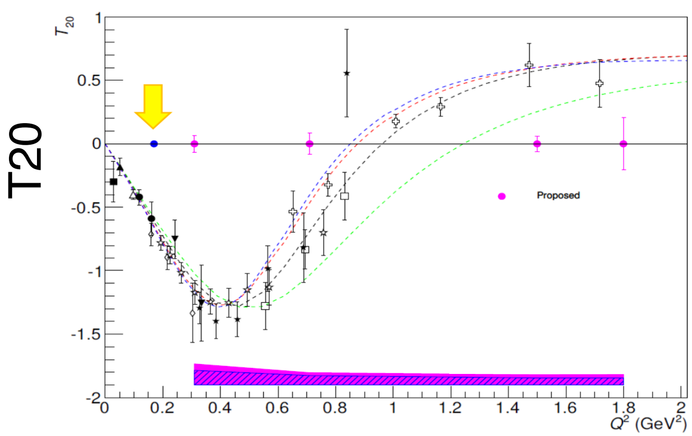
but depends on the Deuteron spin state



E12-15-005

A_{zz} in the x>1 Region





Very Large Tensor Asymmetries predicted

Sensitive to the S/D-wave ratio in the deuteron wave function

4σ discrim between hard/soft wave functions
6σ discrim between relativistic models

"further explores the nature of short-range pn correlations, the discovery of which was one of the most important results of the 6 GeV nuclear program."

PAC44 Theory Report

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 System

2 Cooldowns since August

Now we are ready for polarization by 9am each day

DNP/SSRF

Prelim results look very promising

FUTURE/Short Term Goals

New Target Stick: better wave guide/RF Coils/NMR Coils

Deuteron TE

AFP commissioning

SSRF Optimizing with ND_3

Dedicated program at Jlab to investigate Tensor Spin Observables

Material Production D-butanal, ND_3, …

Questions?