UNH Solid Polarized Target

Jefferson Lab
Hall A/C Collaboration Meeting

2021-07-07

Karl Slifer
University of New Hampshire

This Talk

Latest Developments with UNH Target

- System Overview
- Material Preparation
- NMR Analysis

Some possible future applications

UNH PolTarg Group

KS

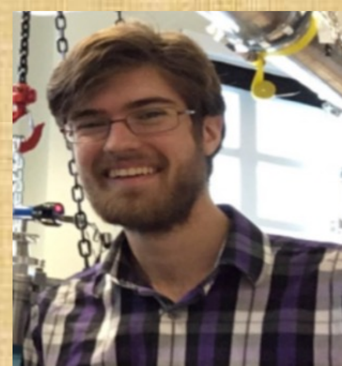
+1 Open
post-Doc slot

Elena Long

PhD
Students

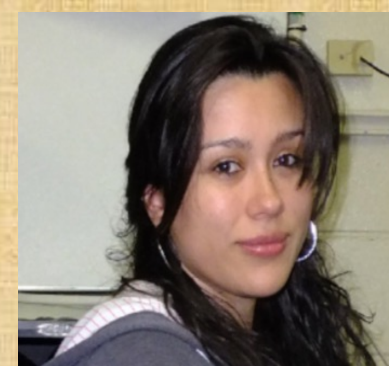
Leiqaa K.

Michael M.



David R.

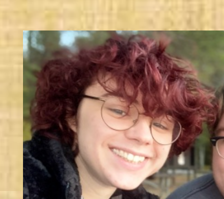
Emad M.



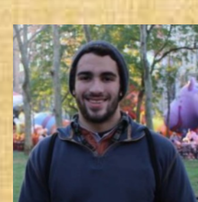
Nathaly S.
(recent alum)

undergrads

Taylor C.



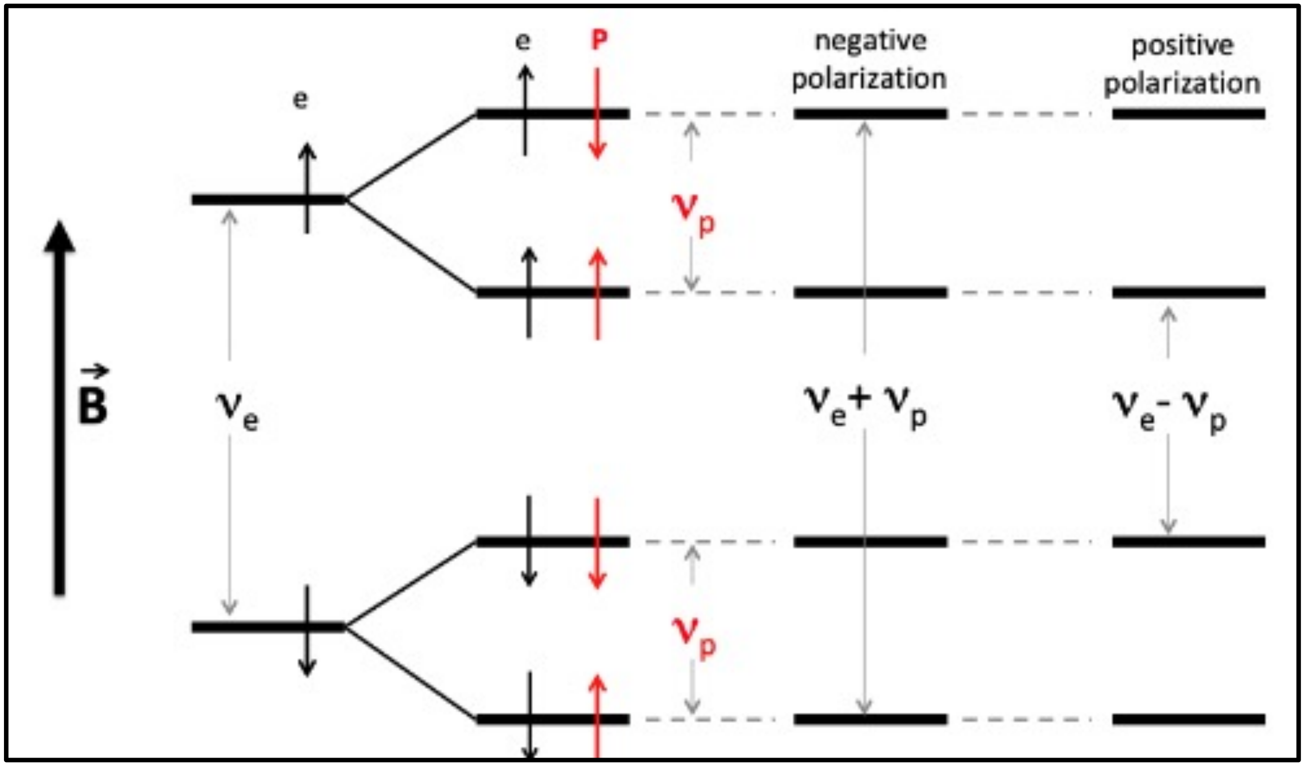
Lily S.



Tristan A.

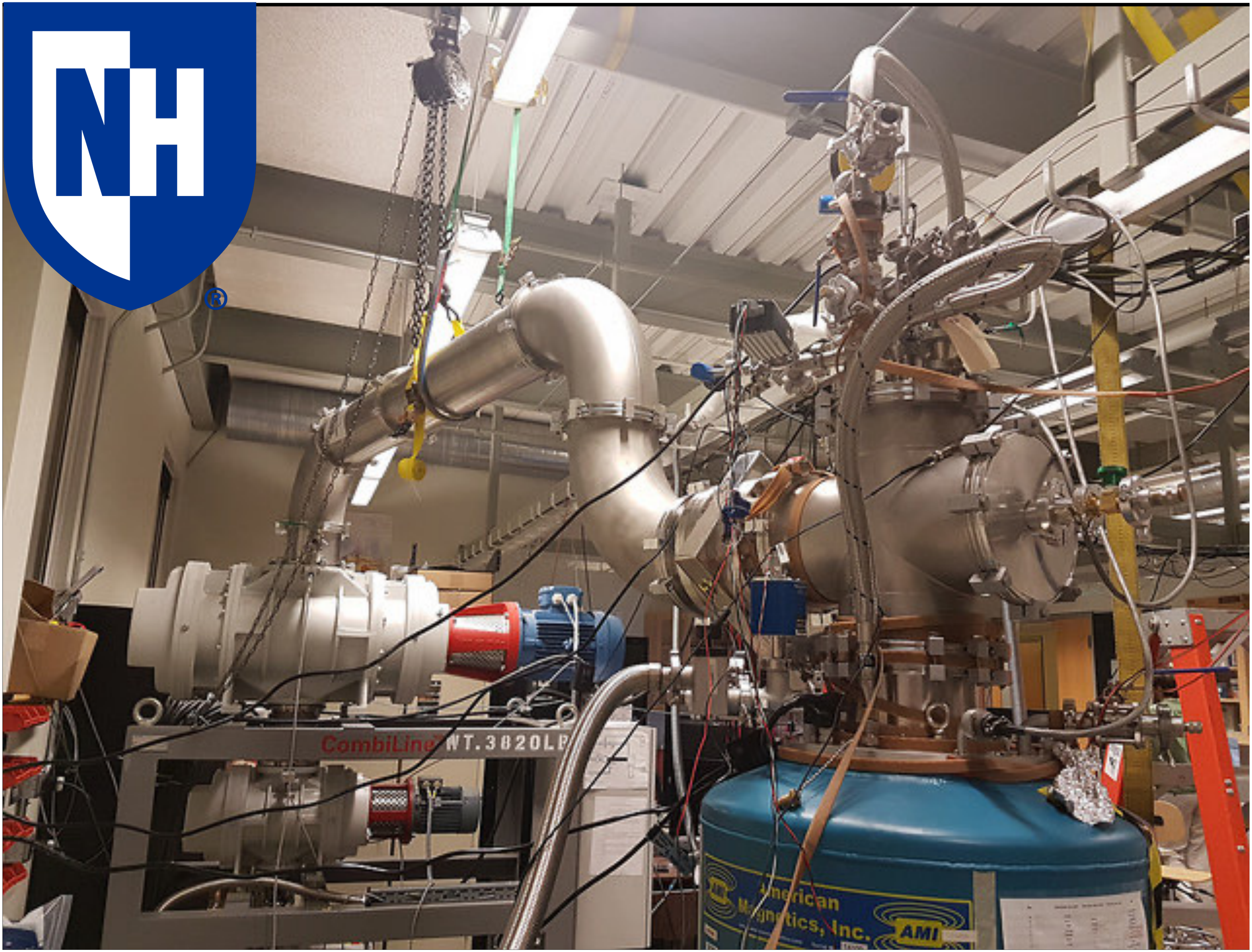
close collaboration with
W. Brook's group at USFSM

Dynamic Nuclear Polarization

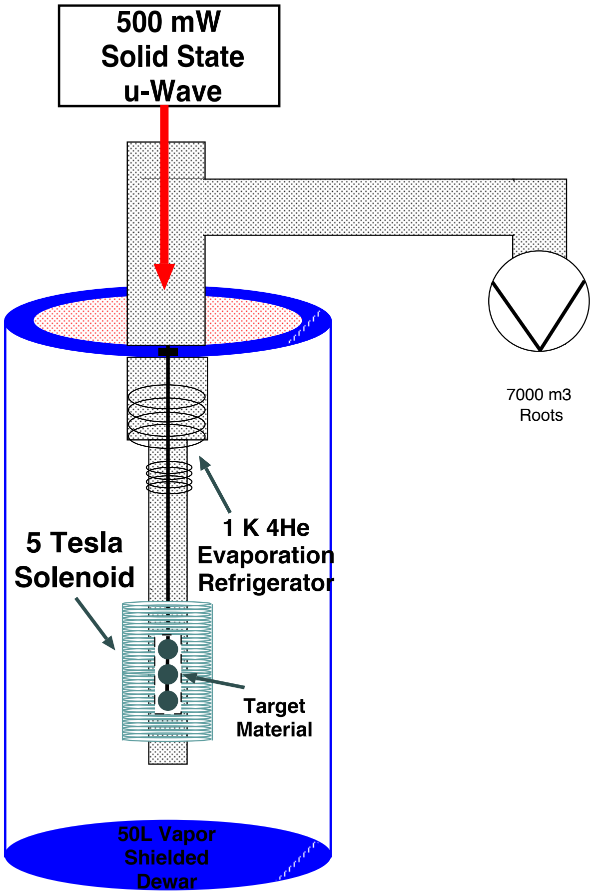


Flip the spins of unpaired e^- and transfer polarization to Nucleus

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


CombiLine WT.3820LP
AMI

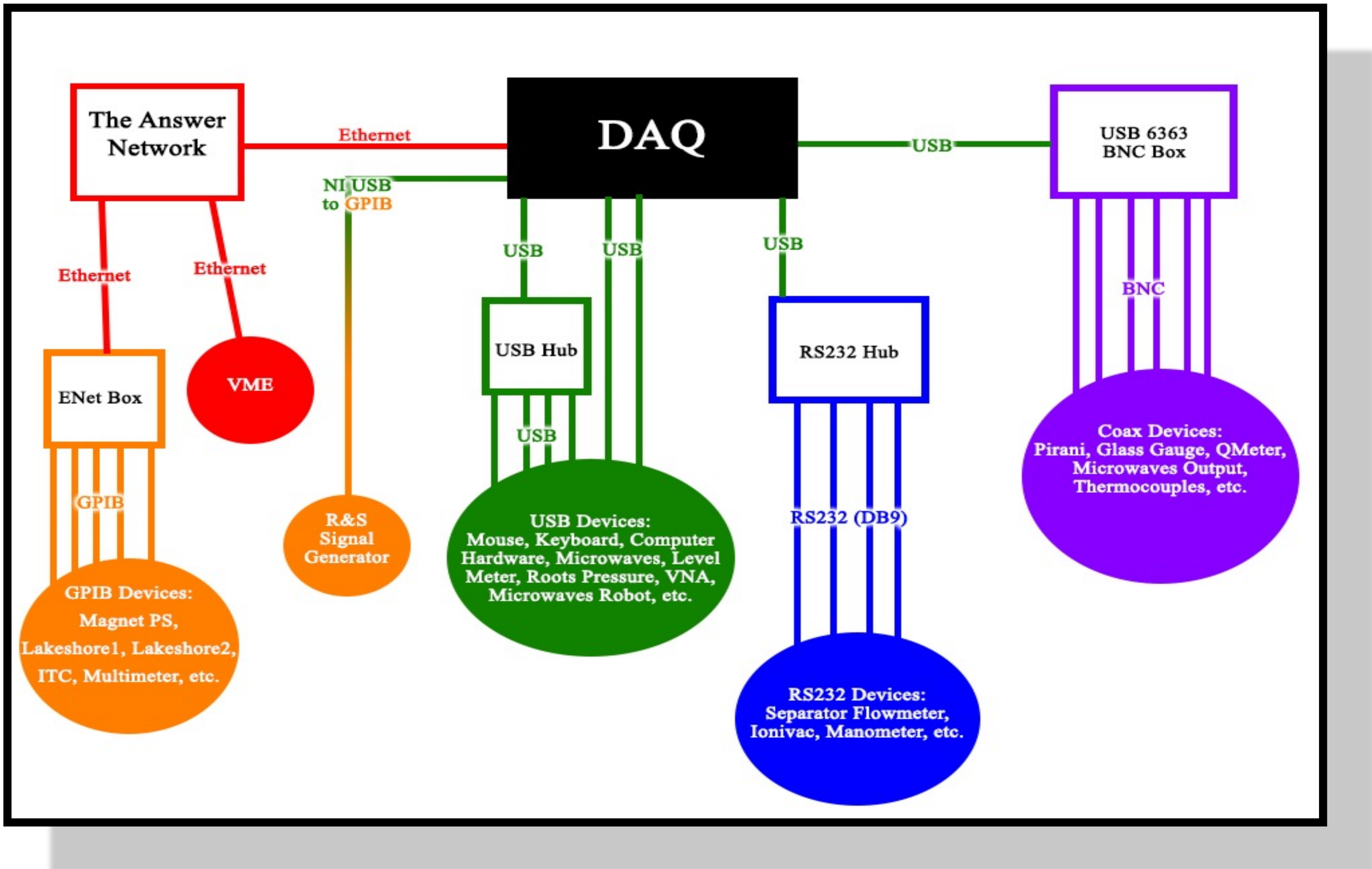
UNH Polarized Target Lab



Cryostat housing the 5T magnet and 1K Fridge
Microwave gantry straddles the cryostat

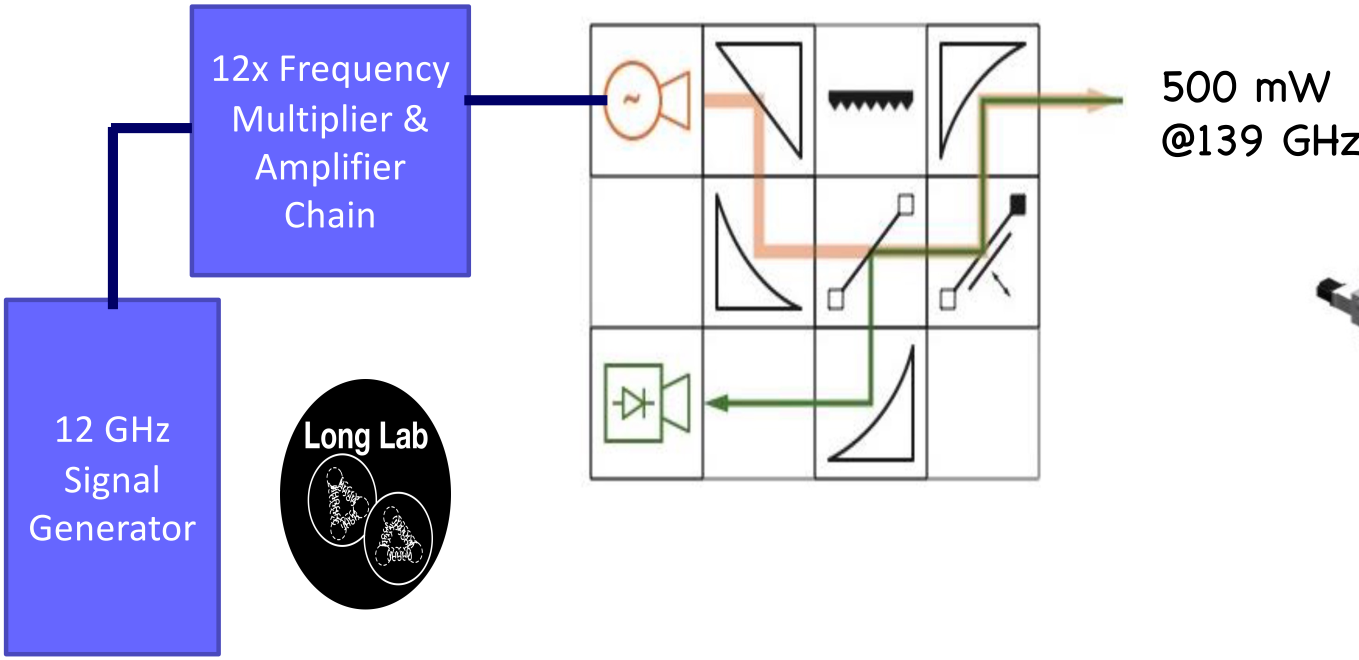
LabView Controls

(GPIB,RS232,USB,ethernet)
interfaced to Slack-based logbook



LabView controls written by D. Ruth

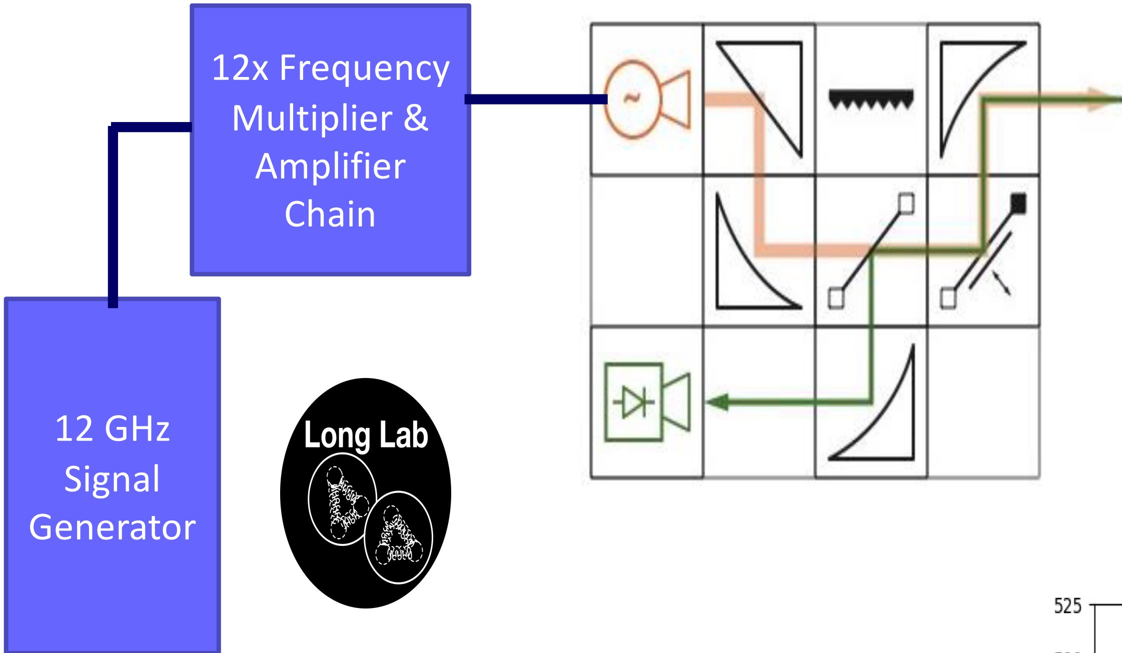
Solid State mm-Wave System



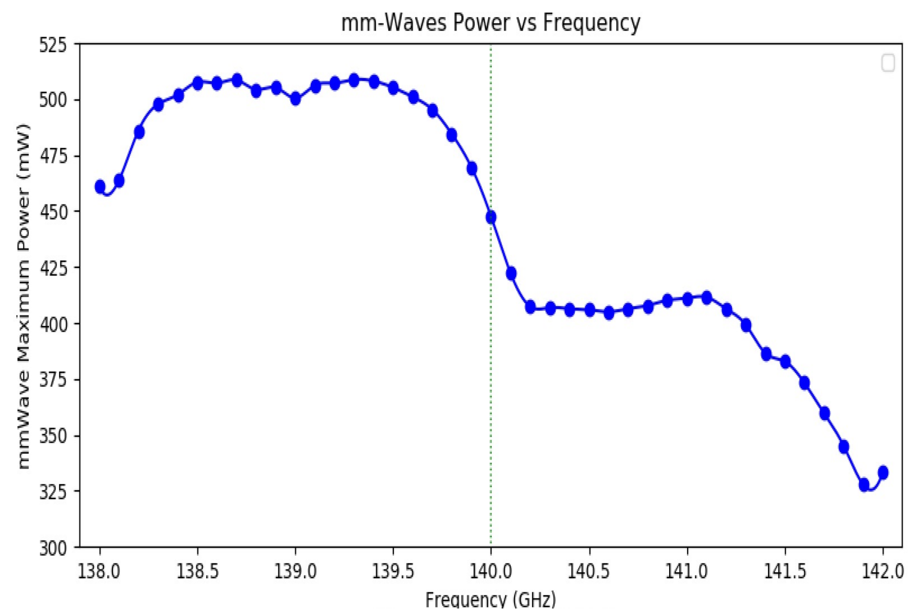
Cheaper than EIO
No cooling
Sits directly above target
Passes thru air gap

500 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



500 mW
@139 GHz



Cheaper than EIO
No cooling
Sits directly above target
Passes thru air gap
Low Loss Overmodal waveguide
Wide Frequency Range

NMR Systems used at UNH

ELSEVIER

Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment

Volume 995, 11 April 2021, 165045

A modern Q-meter system to measure the polarization of solid polarized targets ☆

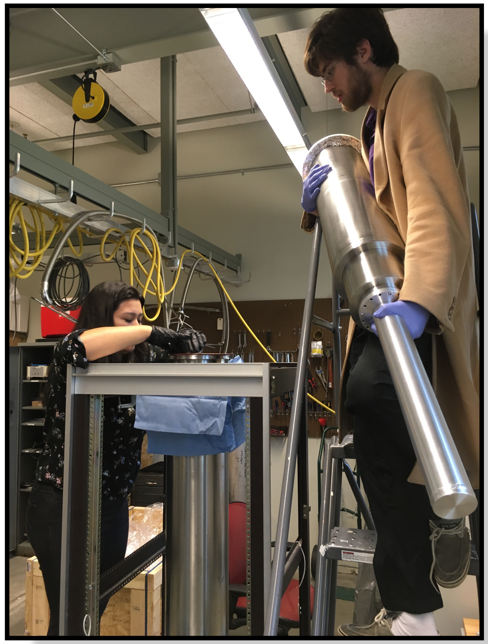
P. McGaughey, M. Yurov, A. Klein, D. Kleinjan, K. Liu, J. Mirabal-Martinez

New LANL VME based replacement for Q-Meter

We also use SDR-based Vector Network Analyzers VNA

- easy to tune at any frequency
- TEs at 1T, 2T, 5T
- Real and Imaginary Z
- We haven't yet tested linearity

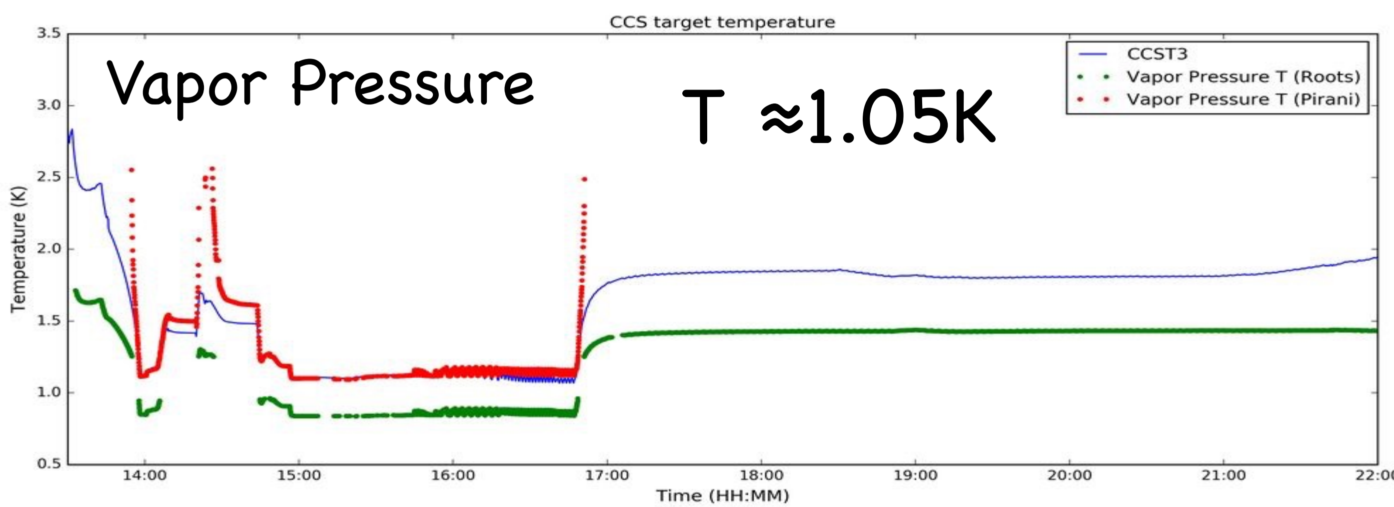
UNH He Evaporation Refrigerator



All Machining Completed at UNH

- ✓ Heat Exchanger
- ✓ Separator Pot
- ✓ Radiation Baffles
- ✓ Needle valves
- ✓ Vacuum Shells

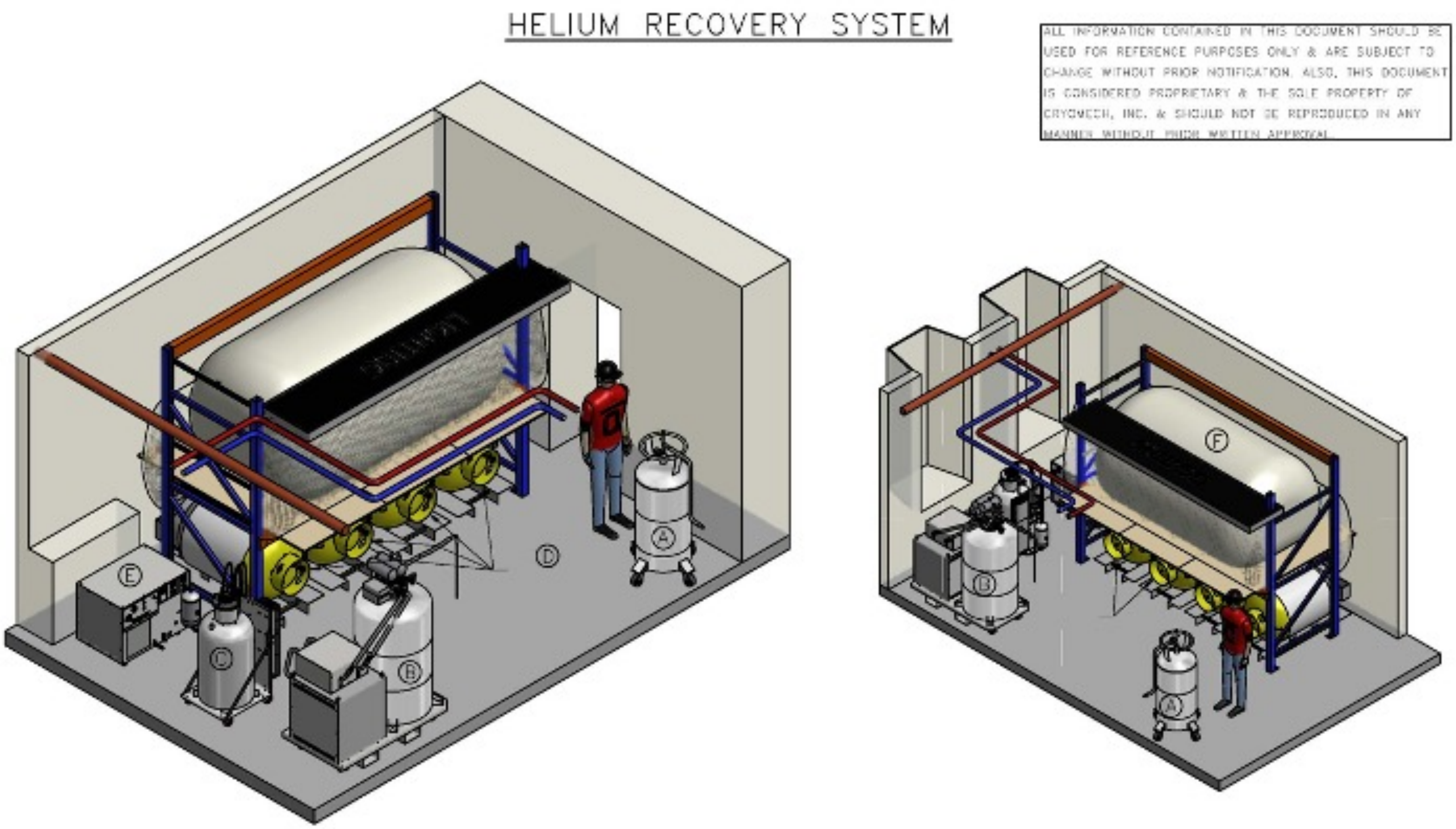
Final brazing/welding of needlevalves fittings @ Jlab



Target Stick

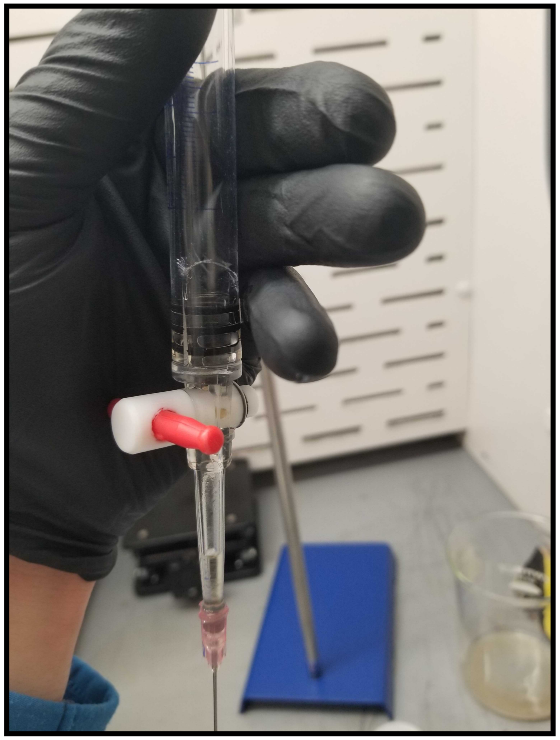
3D printed ladder
Gold plated waveguide
Calibrated thermistors
NMR, RF-hole burning
And EPR coils

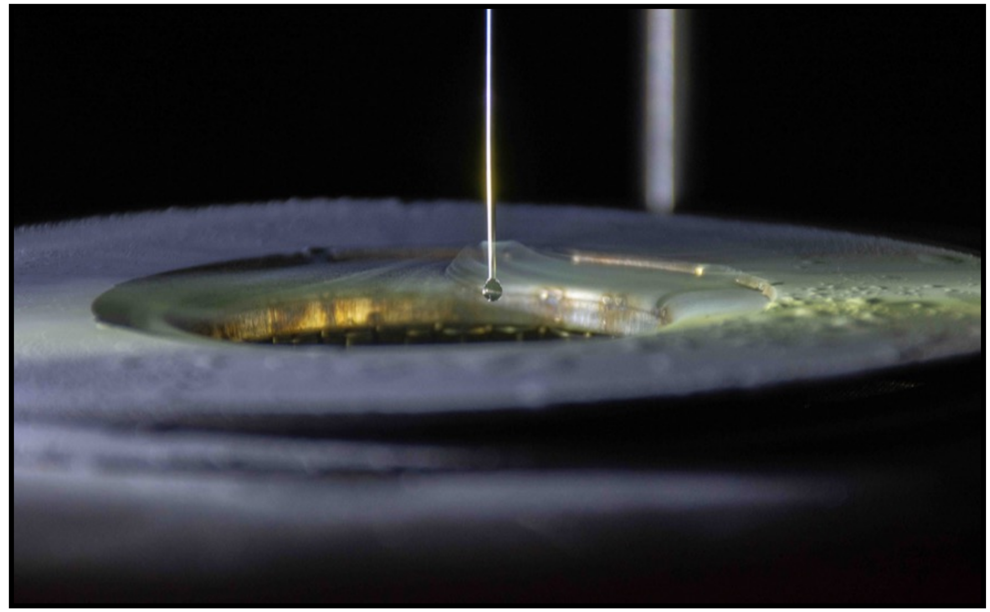
Helium Recovery System

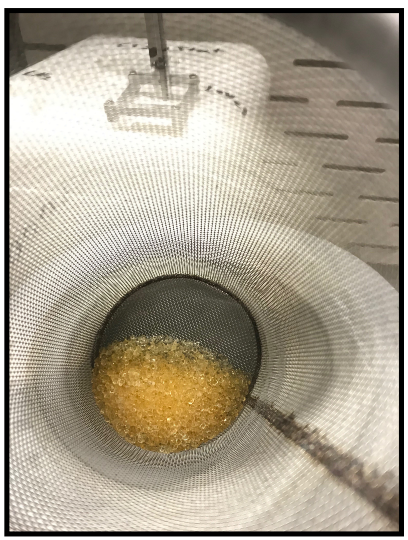


Working with Cryomech to
Design/Install new recapture system

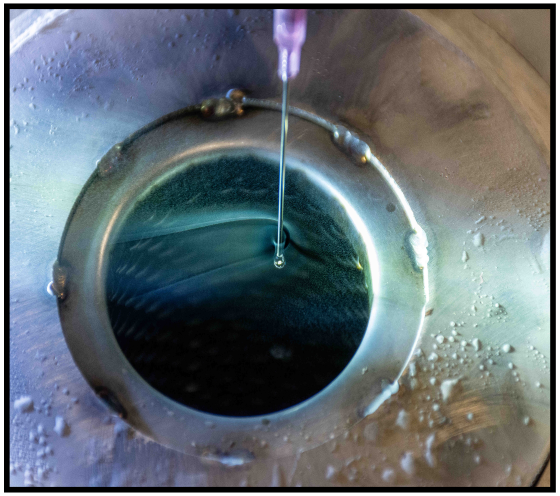
Target Material Production at UNH







Target Material Production at UNH

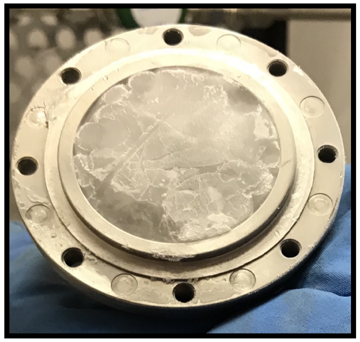


Butanol and other alcohols solidification

grade 5.5 NH_3 & ND_3

Chemical Doping

Rapid vs SlowCooling of NH_3



Target Material Production at UNH

-Dedicated **fume hood** for Handling Ammonia and other caustic/toxic materials

-**Vacuum GloveBox** allows for over/under-pressuring

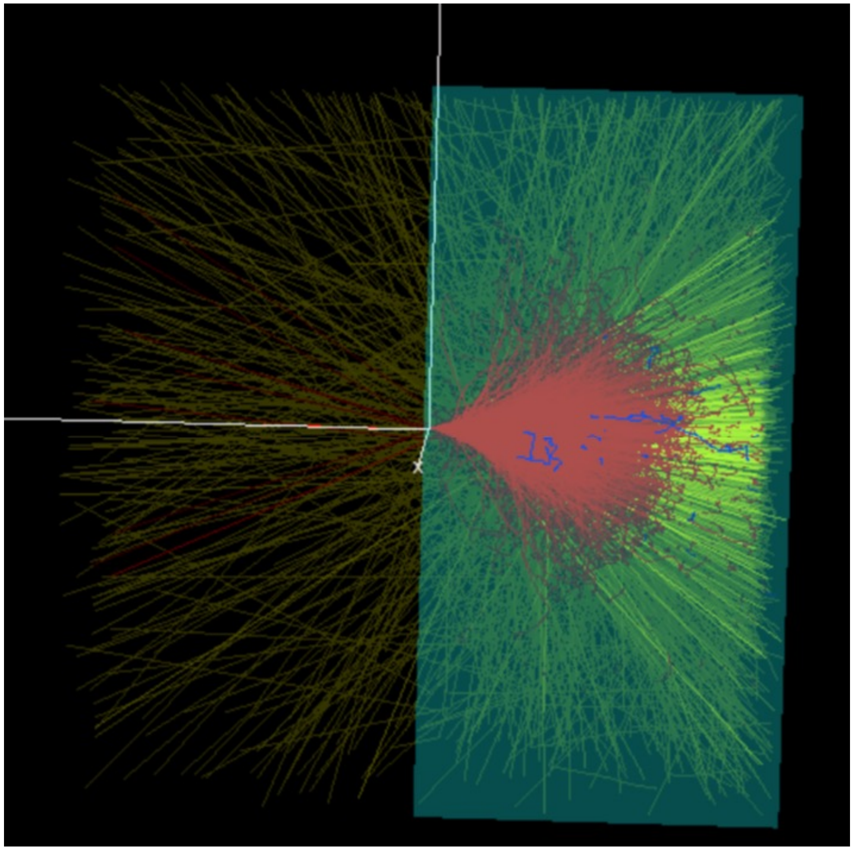
-Primarily chemical doping of ammonia and alcohols for now.
But potential to do much more.

We've produced about 200 grams of NH_3 plus a few grams of ND_3

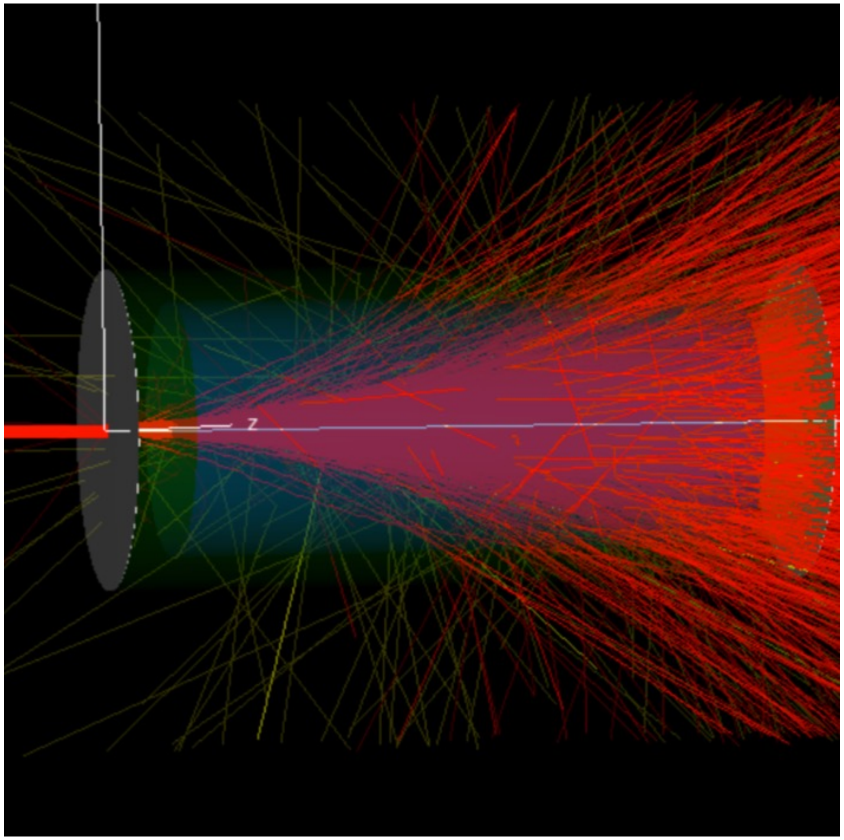
EGSNRC Simulation

egs work by Emad Mustafa

19 MeV electrons incident on target material



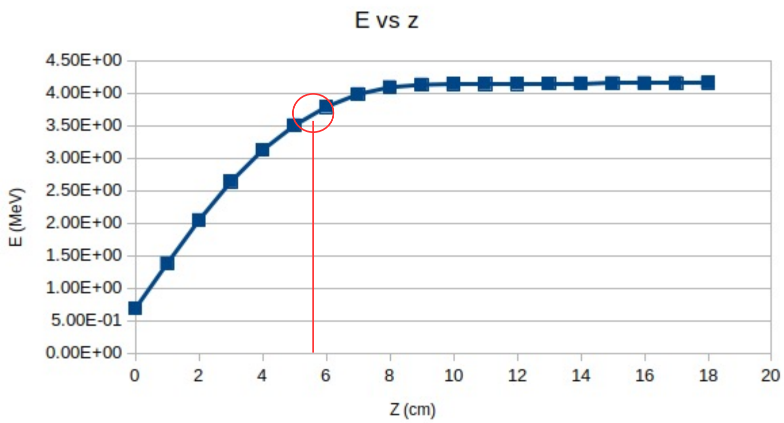
Butanol in liquid Argon.



Butanol in liquid Helium.

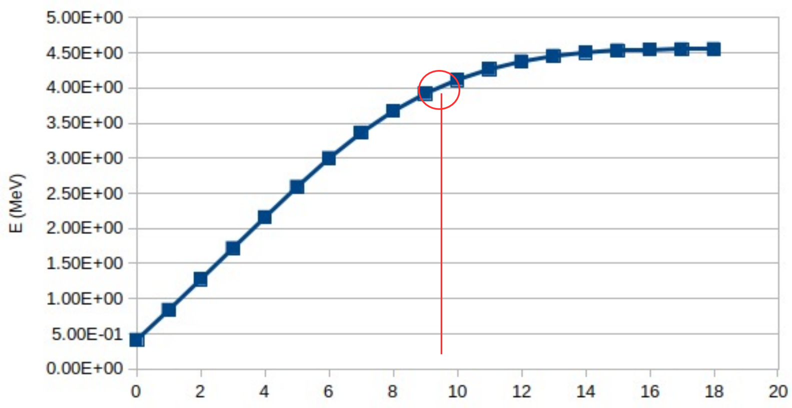
(Red=electrons, yellow=photons, blue=positrons)

Energy Deposition from E-Beam



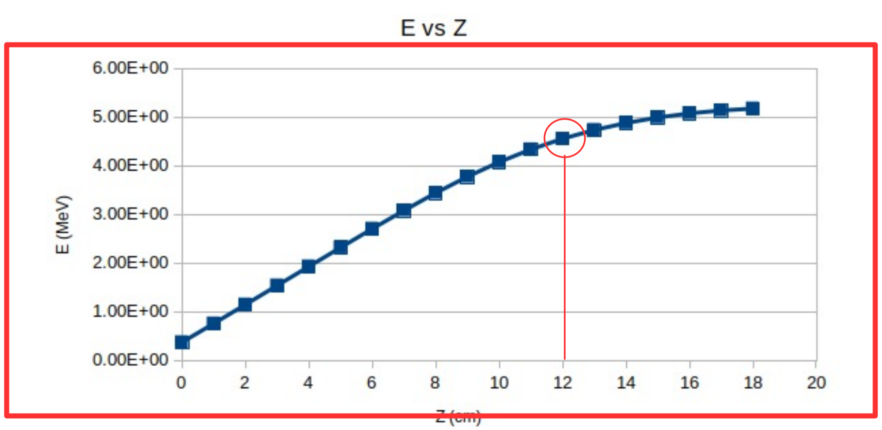
NH_3 Target in liquid Argon

90% saturated at 5.5 cm



NH_3 Target in liquid Helium

90% saturated at 9 cm

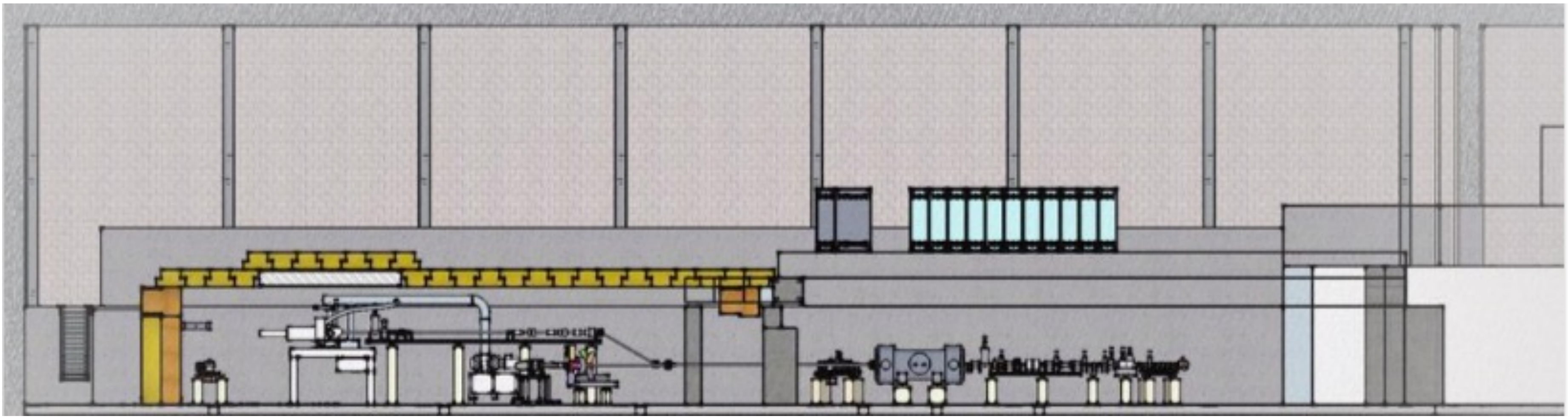


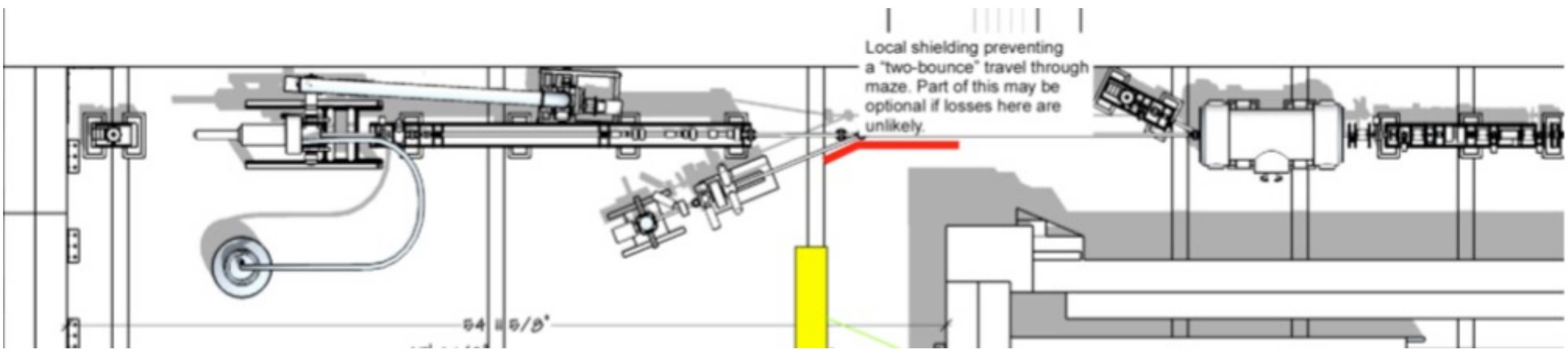
NH_3 Target in gaseous Helium (20K)

90% saturated at 12 cm

Upgrade Injector Test Facility

10 MeV, 10 uA rastered electron beam

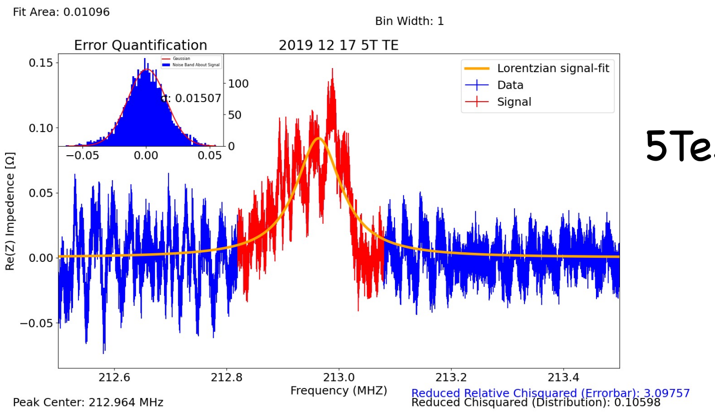




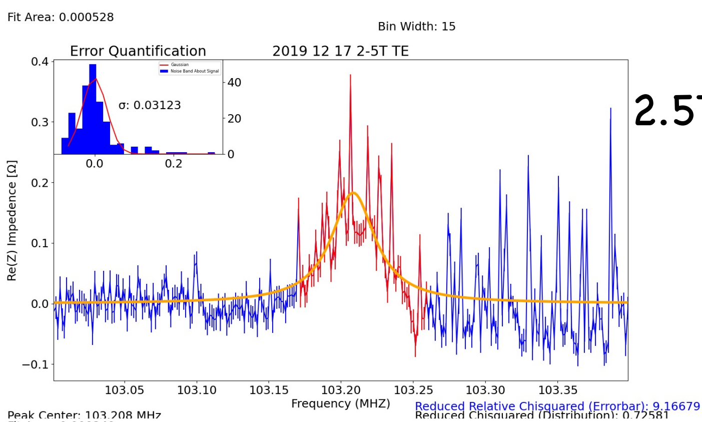
We're eager to bring target material to UITF for irradiations !

NMR Analysis

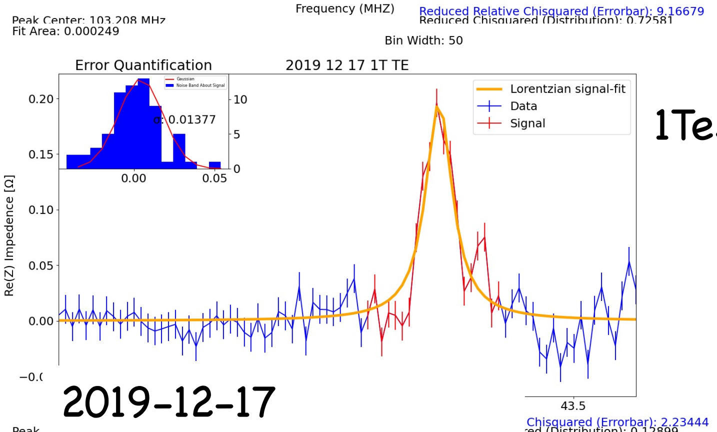
Proton Thermal Equilibrium Signals



5Tesla, 2.2 K

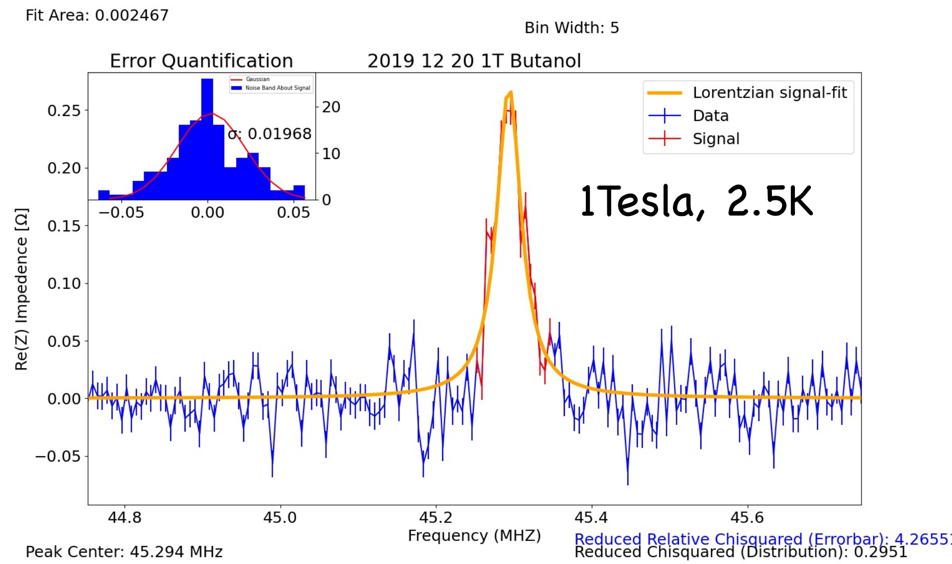


2.5Tesla, 2.1K



1Tesla, 2.1K

2019-12-17
Tempo Doped Polymer

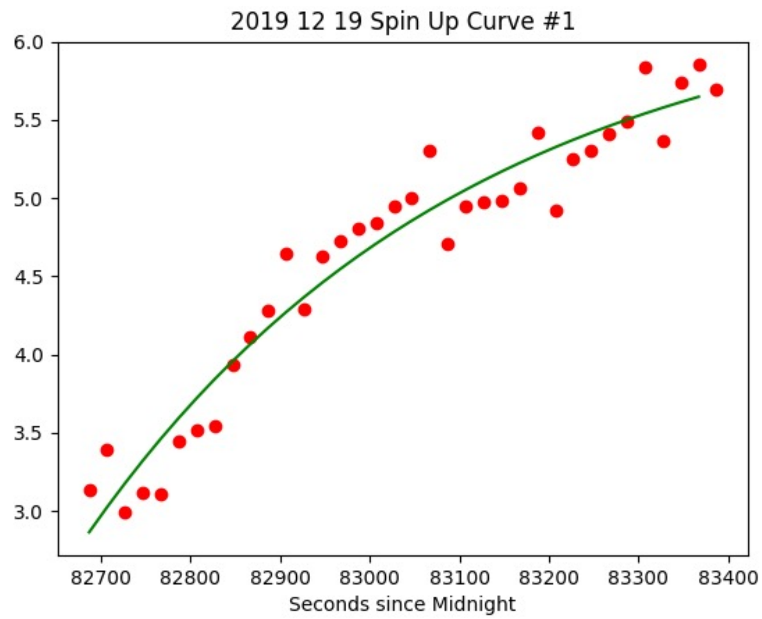


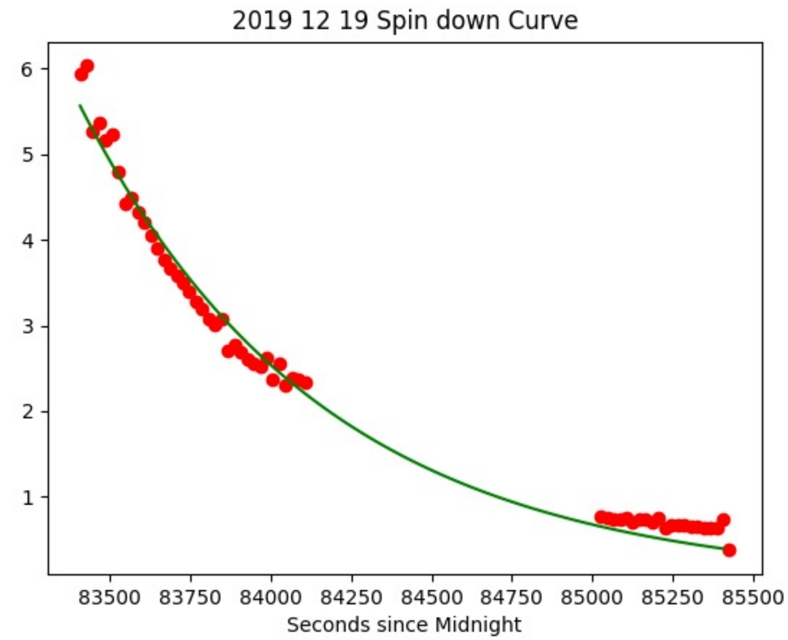
1Tesla, 2.5K

2019-12-20
Tempo Doped Butanol

Analysis from Tristan Anderson

Proton Spin Up/Down





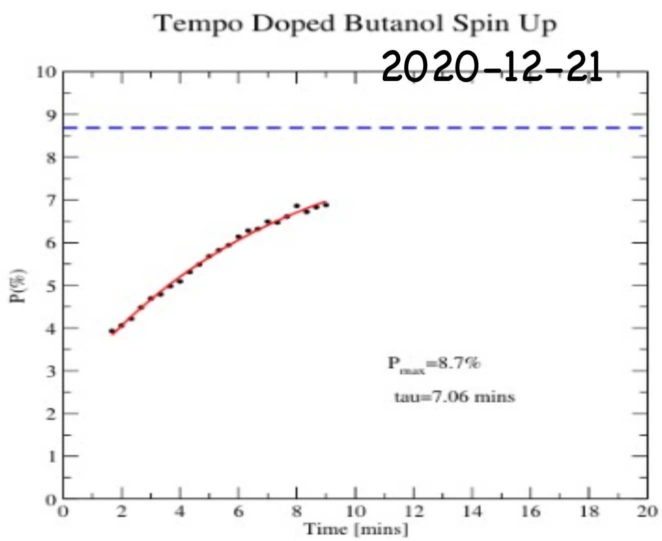
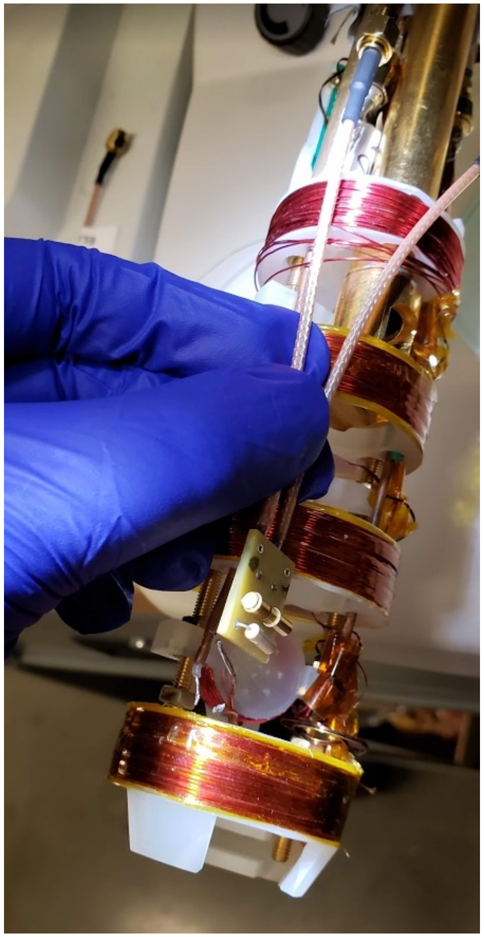


Figure 9: Butanol Spin Up

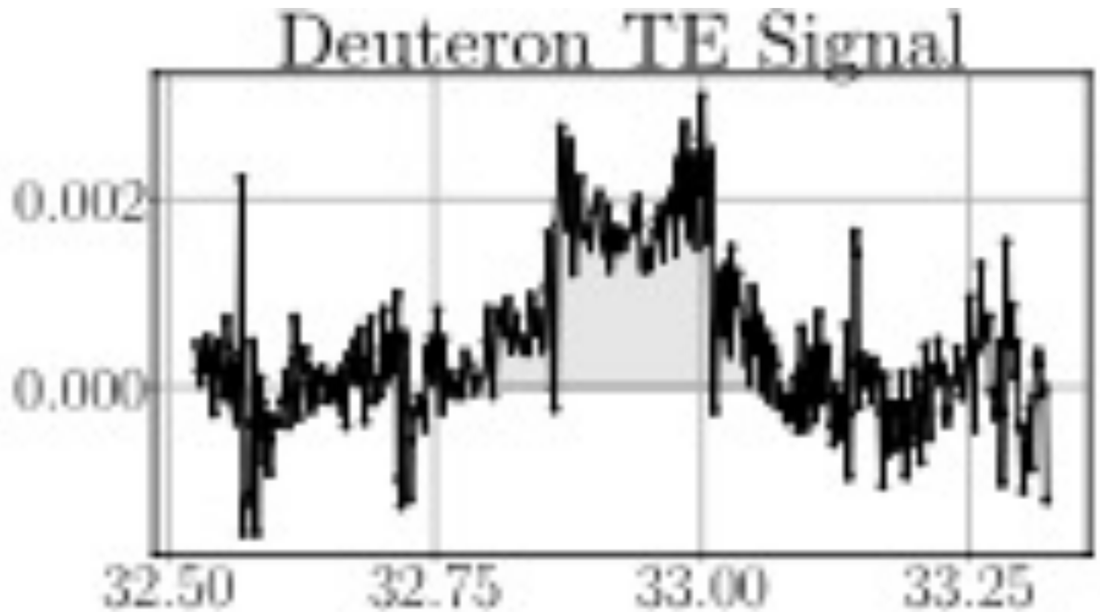
	12/19 tempo-araldite	12/21 Tempo-Butanol
Buildup (s)	425	420
Relax	756	--
P max	6.3%	8.7%@2.1K

Analysis from Tristan Anderson

Cold NMR Board



Cold NMR Board
+
LANL VME System



Excellent SNR
At 32 MHz!

Deuteron NMR

Note: Uva did Deuteron TE calibrations in 2000 for the GEN experiment

83

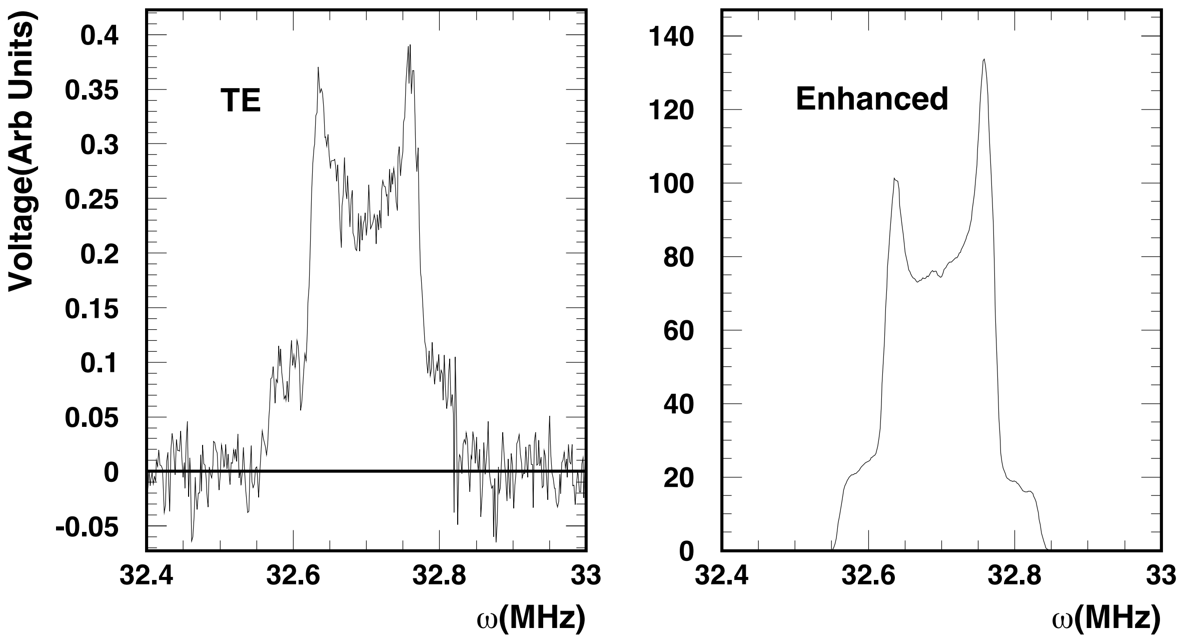
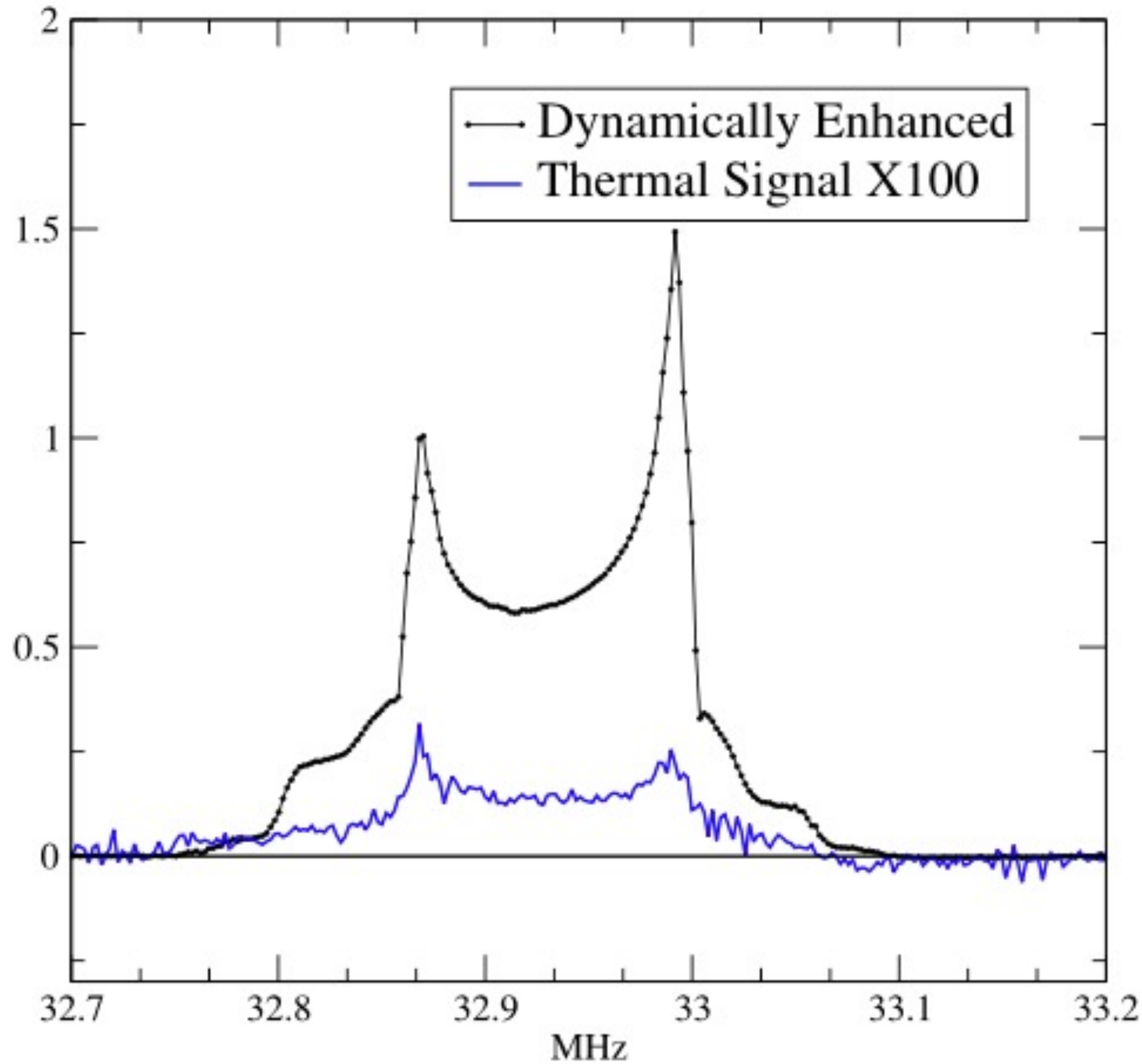


Figure 6.20: The deuteron thermal equilibrium and enhanced signals.

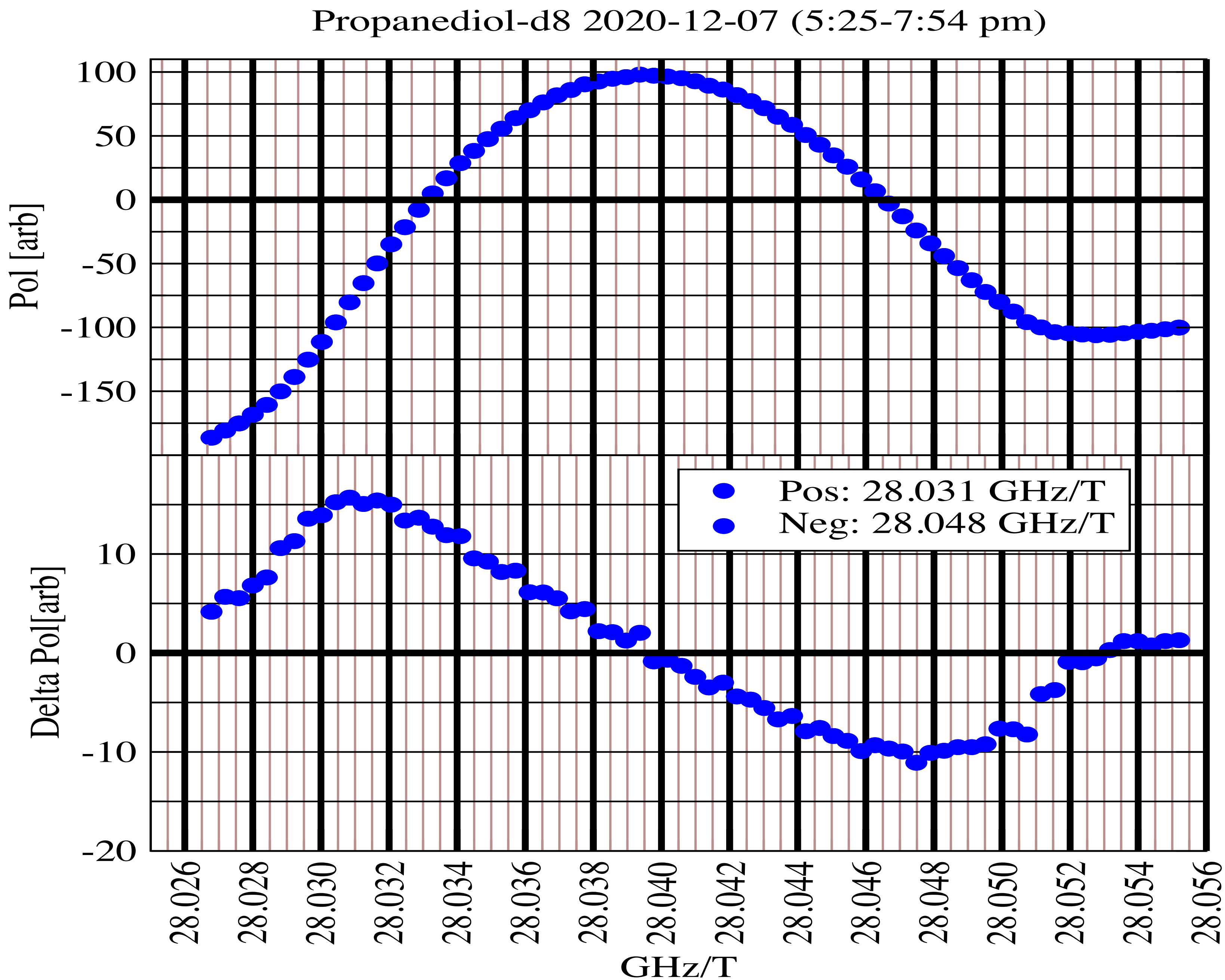
Hongghuo Zhu http://twist.phys.virginia.edu/Theses/zhu_thesis.ps

Deuteron Thermal Equilibrium

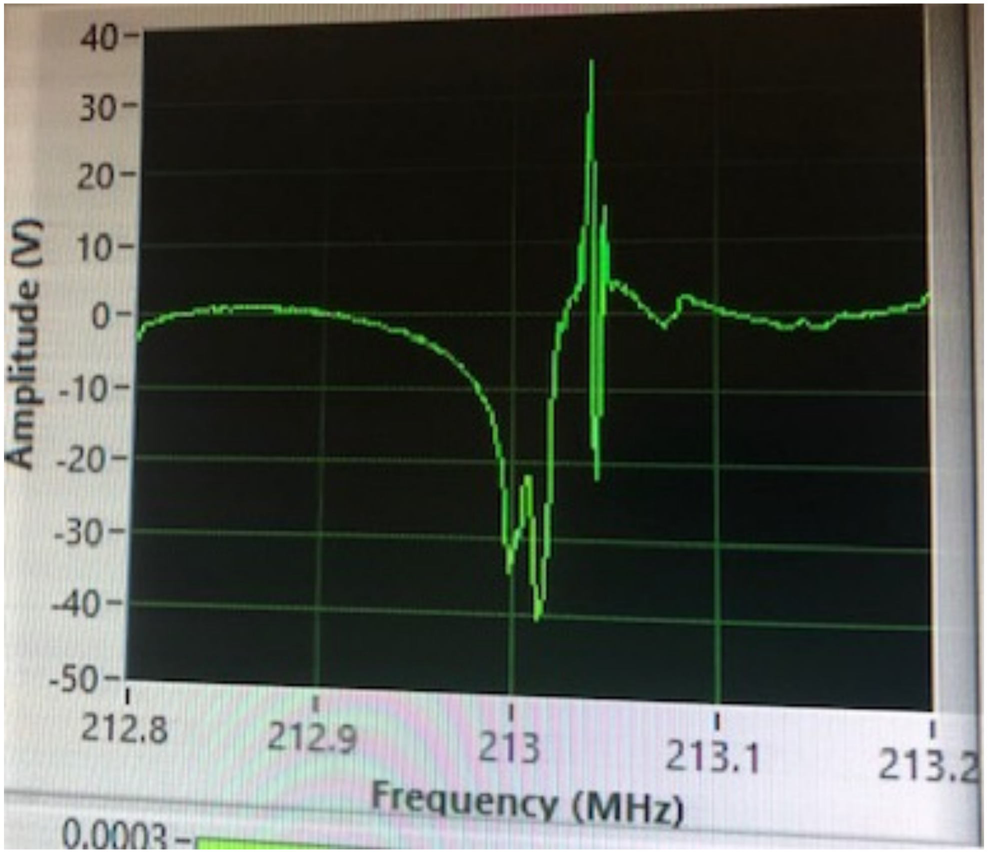


Deuteron Thermal Equilibrium (TE) signal (Pz= 0.09%) and enhanced (Pz=37%)

Deuteron Enhancement Frequencies



RF Hole Burning

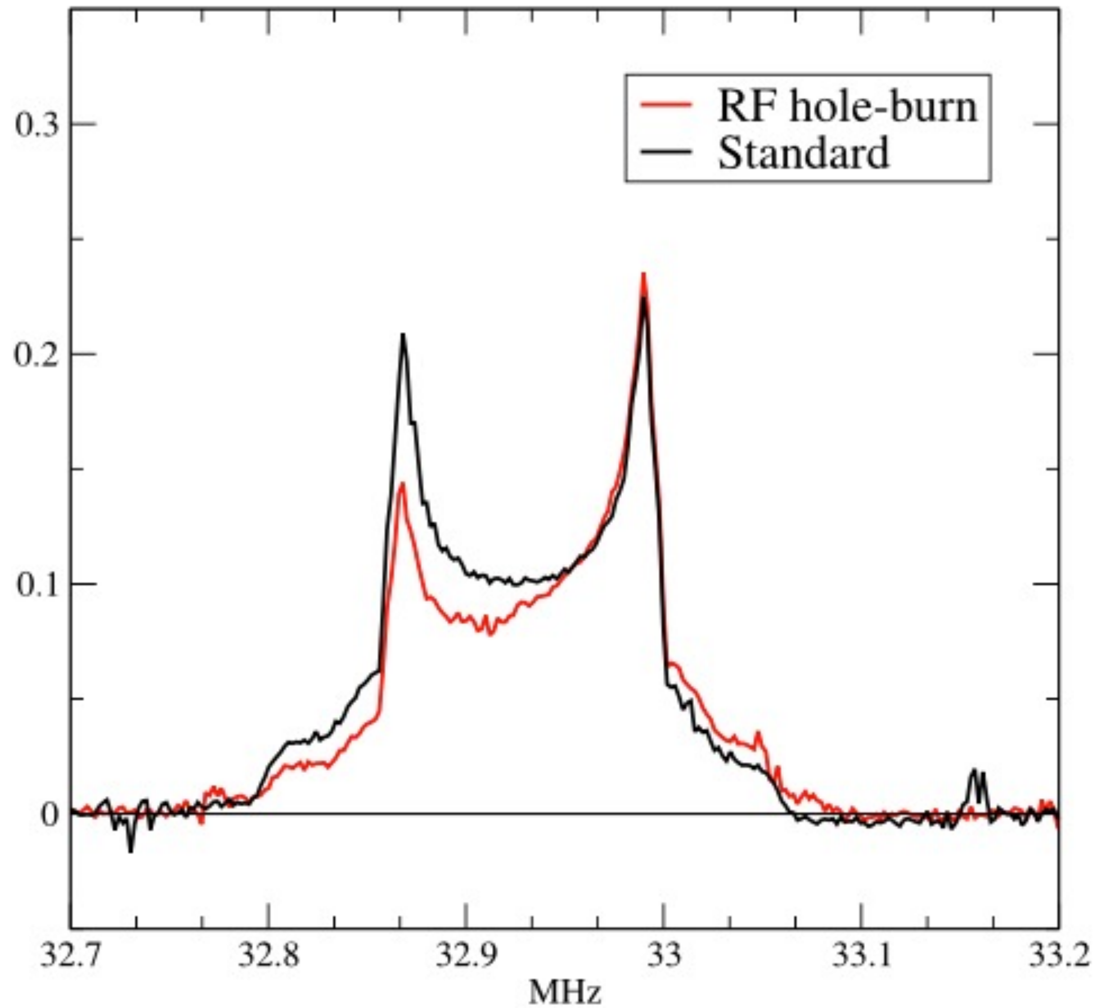


Proven method to enhance
Tensor polarization

We have a working RF system
And have performed hole burning
During last two cooldowns.

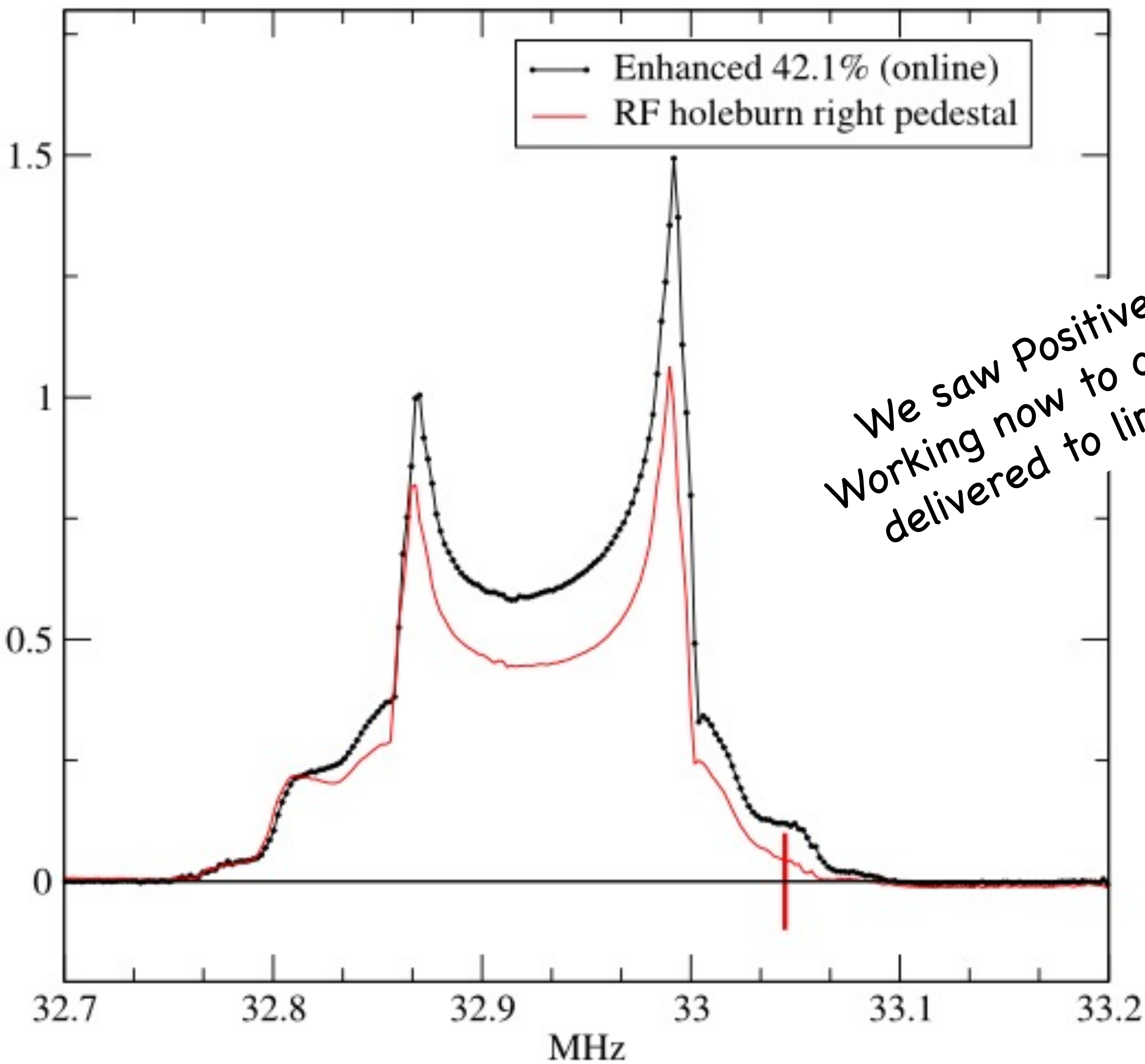
This technique (+ rotation)
has been used by D. Keller at Uva
to achieve P_{zz} =38% in DButanol

Deuteron Tensor Enhancement



Tensor Enhancement by factor of 5.7 after rf-hole burning the left peak
1,2-Propanediol-d8, chemically doped with OX063, with 5T/1K

Deuteron Tensor Enhancement



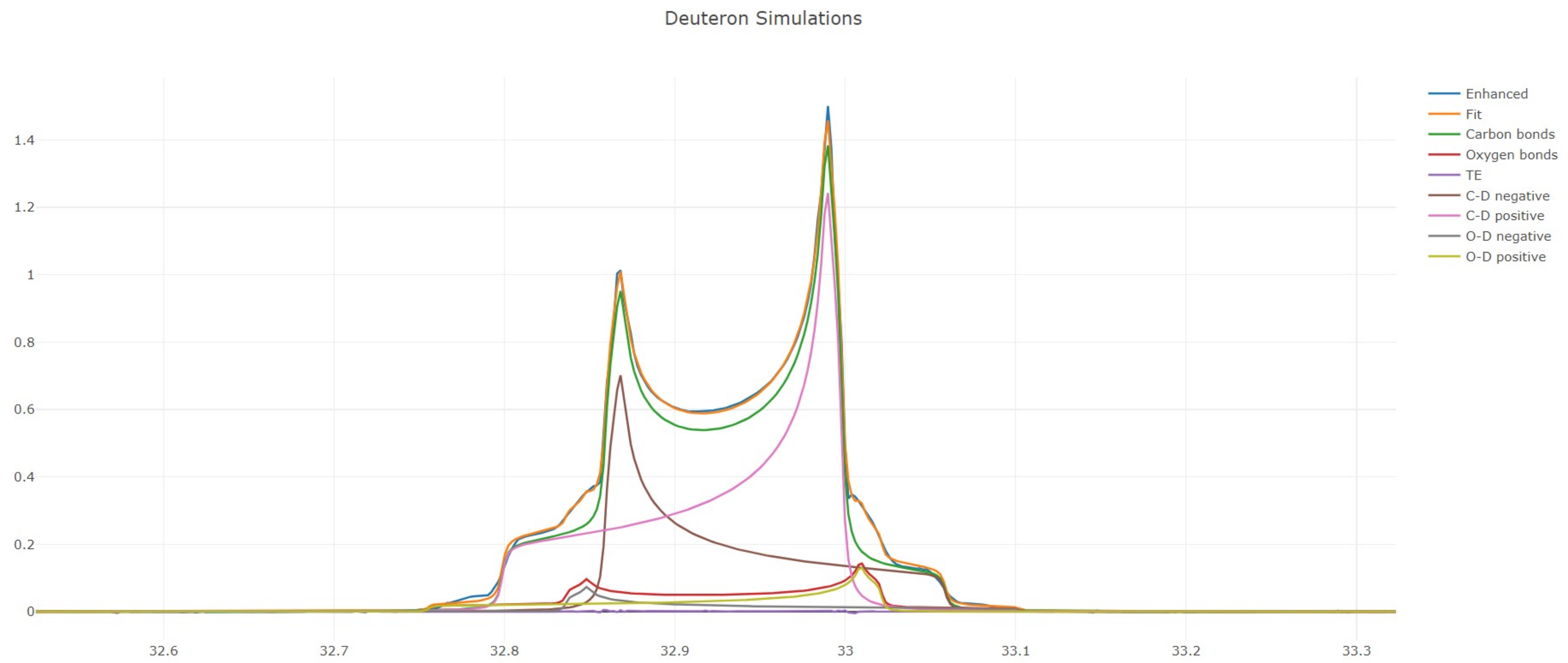
We saw Positive First Results!!
Working now to optimize rf power delivered to limit depolarization

Tensor Enhancement to $P_{zz} \cong 16(\pm 5)\%$

after rf-hole burning the left peak and right shoulder.

1,2-Propanediol-d8, chemically doped with OX063, with 5T/1K

Deuteron Line Shape Analysis

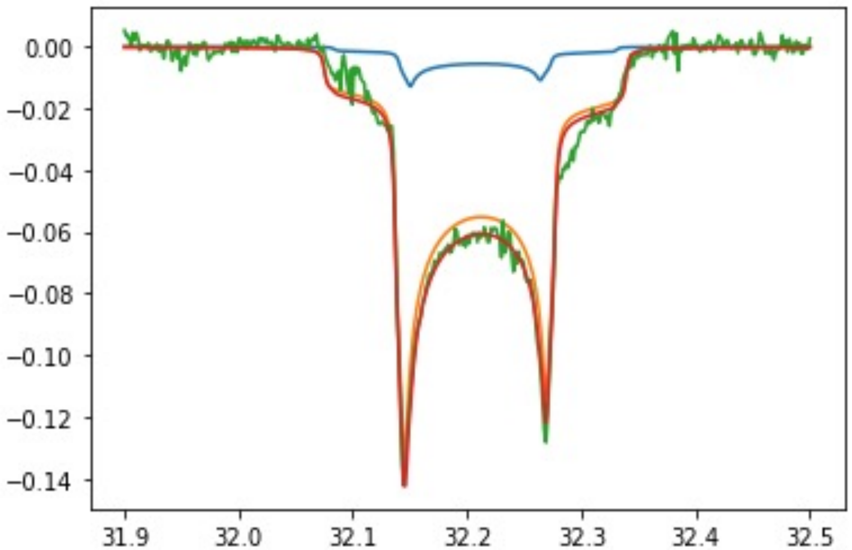


Following classic analysis of C.Dulya et al.,

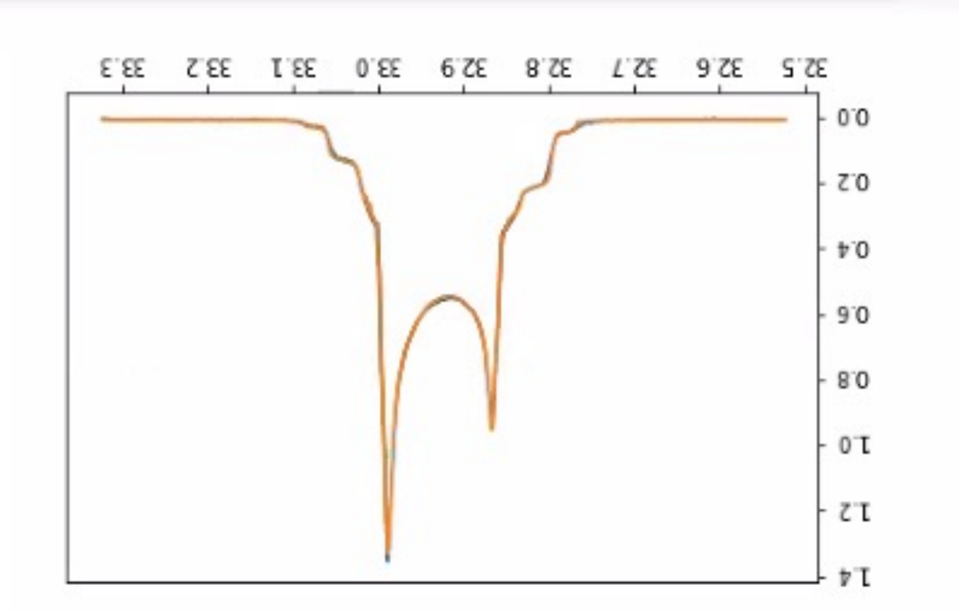
But complicated because d-Propanediol has both C-D and O-D bonds.

Fig. Courtesy M. McClellan

Deuteron Line Shape Analysis



Enhanced D-Propanediol Data
With initial fit

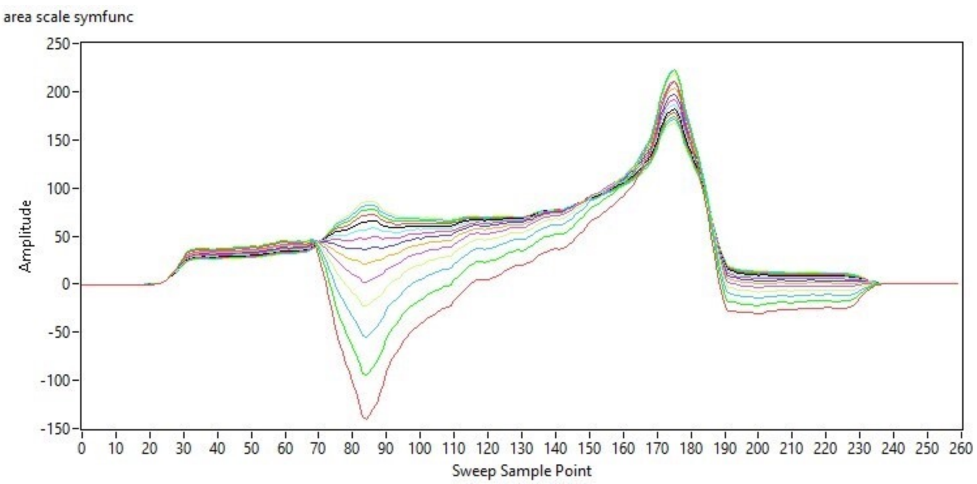


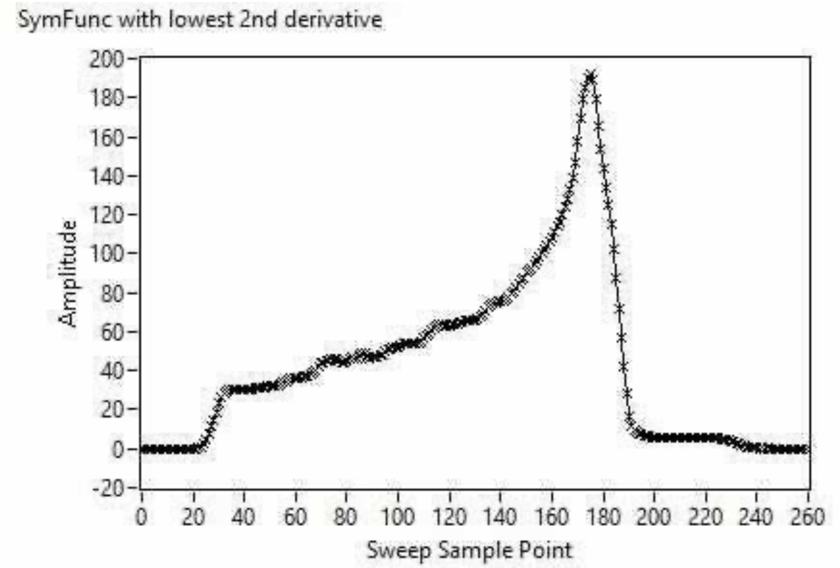
Improved Fit to Data
Including both OD and CD bonds

Figs. Courtesy E. Mustafa

Analysis also by M. McClellan

Deuteron Line Shape Analysis





Novel lineshape fitting approach by Lily Soucy

Generate large set of symmetric possible mathematical forms
Choose the one that is smoothest and best reproduces the data
Still testing how this approach compares to standard method.

Fig. Courtesy L. Soucy

Experiments

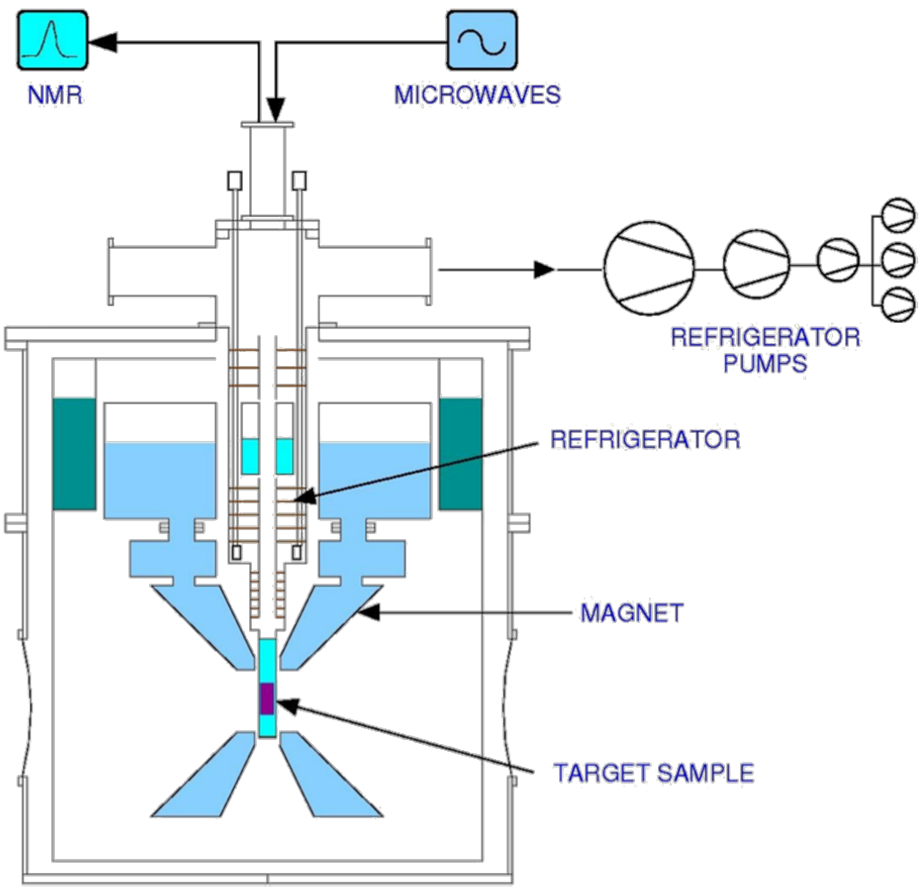


fig. courtesy of C. Keith

Dynamic Nuclear Polarization of NH_3 ND_3

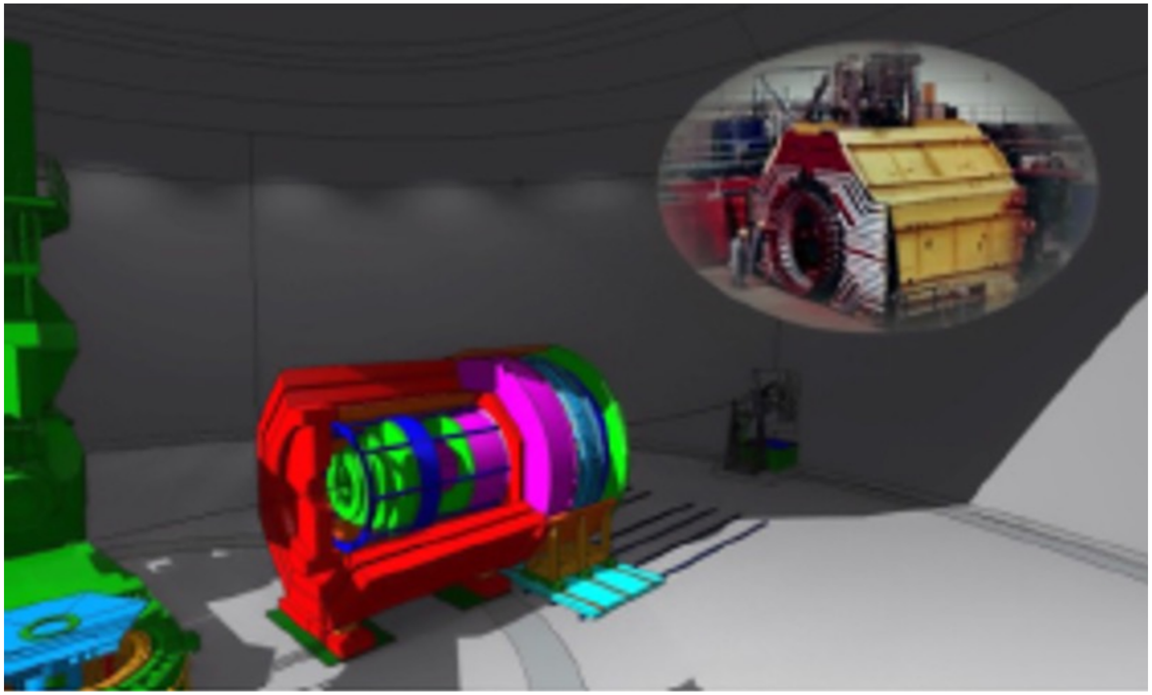
5 T/140 GHz operation
Helmholtz superconducting magnet

1K ^{4}He evaporation refrigerator
Cooling power: about 1 W

Microwave Power
>1W at 140 GHz

Insulated cryostat
85 L Liquid He resevoir
57 L Liquid N shield (300K BB shield)

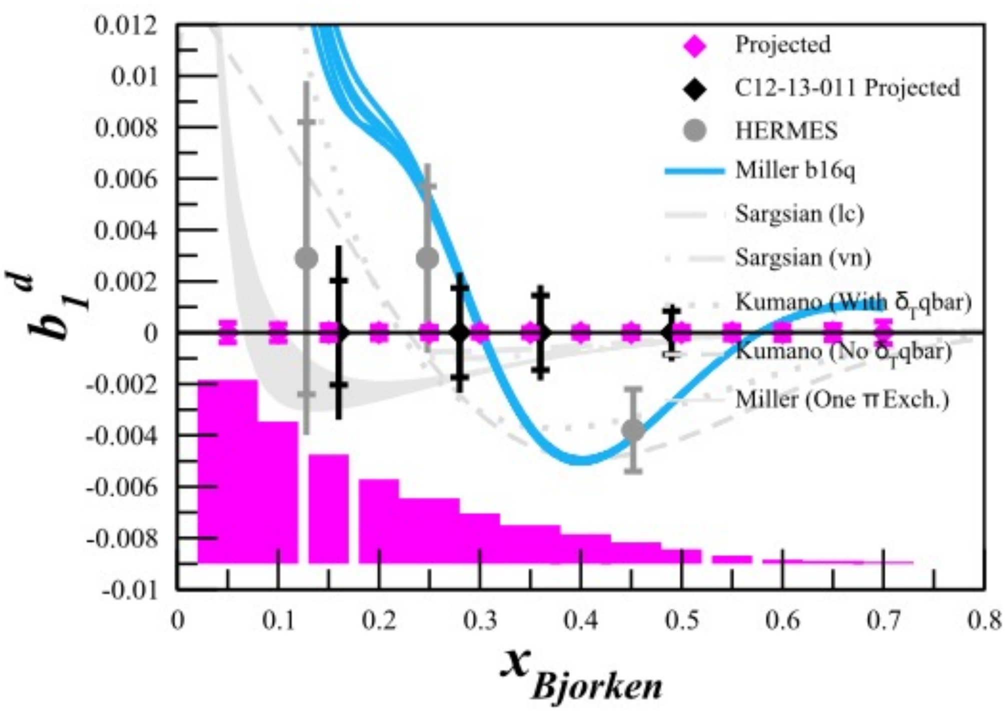
LOIs to measure tensor spin observables in SoLID



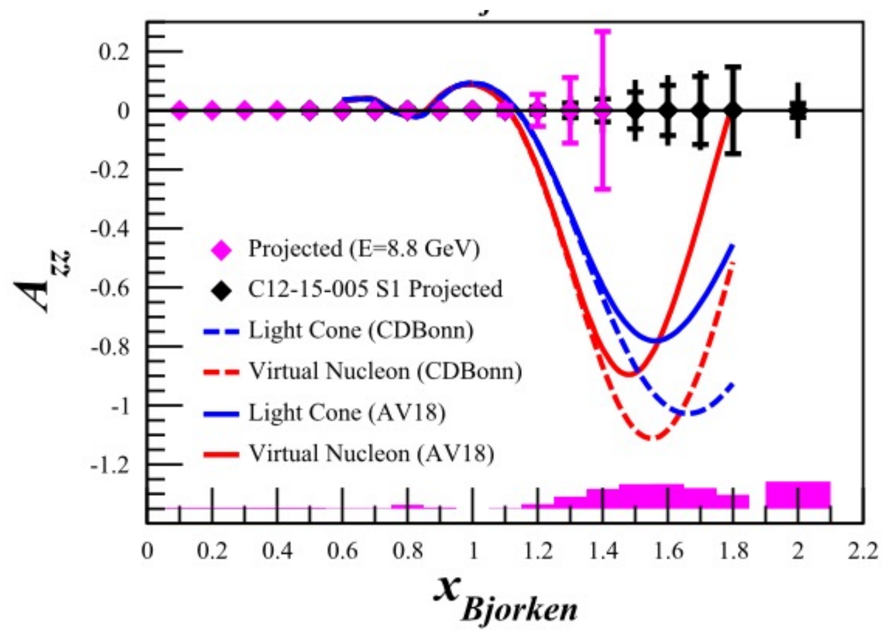
LOI12-21-004: "Tensor b_1 *Structure Function with SoLID*" Contact : K. Slifer

LOI12-21-002 "Measurement of Tensor A_{zz} *for x>1*" Contact : E. Long

Projections



7 Pac Days with SoLID



7 Pac Days with SoLID

Tensor Target opens new possibilities

Few Examples

Tensor Structure function b_2, $b_{3,}$ b_4

Azimuthal Asymmetries b_4

Elastic e-D scattering

T_{20}

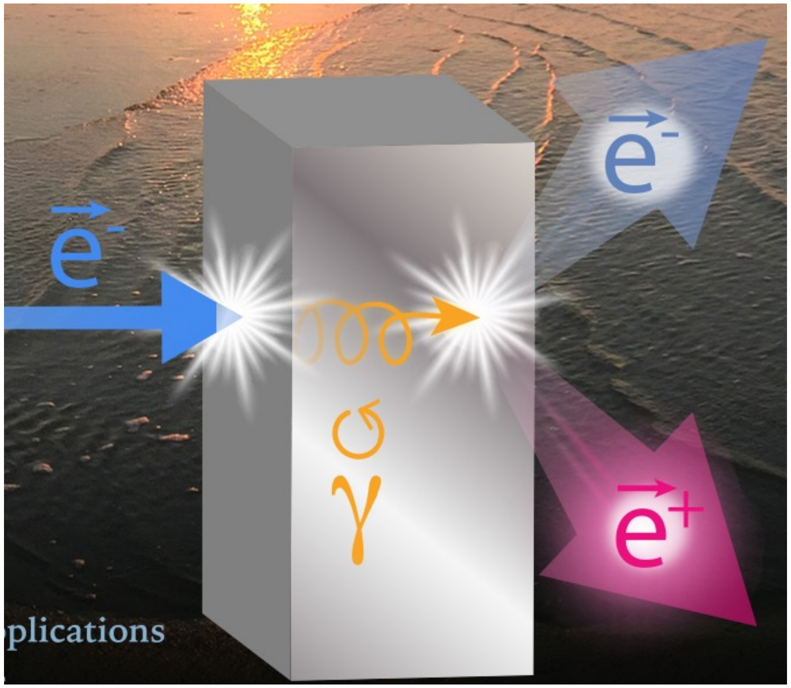
T_{11}

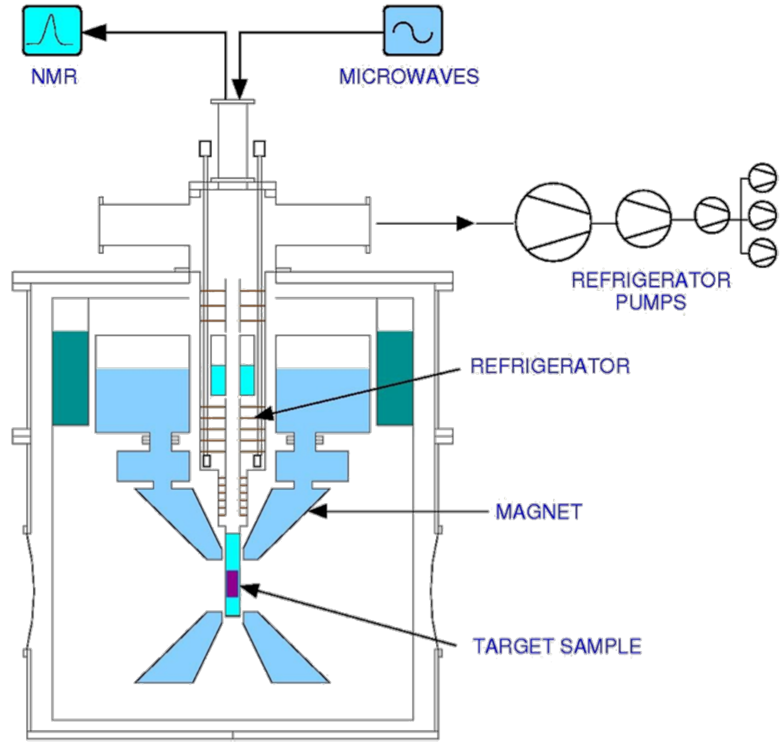
D(e,e'p) Cross Section on Tensor Polarized Deuterium.
H. Anklin, W. Boeglin et al., PR97-102, PAC13 rated A

X>1 Scattering, connection to SRCs : M. Sargian et al.

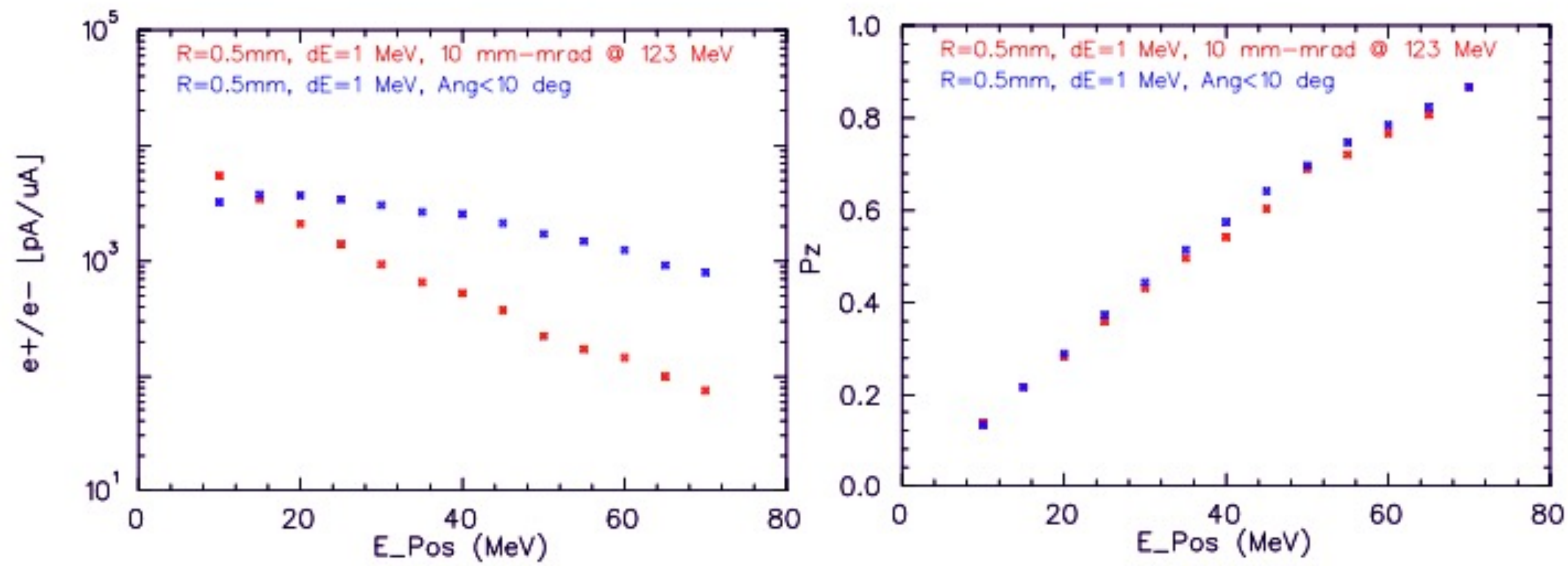
D-Wave Components of Deuteron Wave function : S. Luiti et al.

Positrons on Polarized Target?





Positrons on Polarized Target?



Cardman : *The PEPPo method for polarized positrons and PEPPo II (2018)*

Simulation : For a 1 mA 123 MeV 85% polarized initial electron beam

- Positron intensity decreases from 5 µA down to 100 nA in the 10-60 MeV energy range.
- Positron polarization increases from 10% up to 75% in the 10-60MeV energy range.

100 nA 60 MeV positron beam with 75% polarization

Help Wanted

We are looking for a Clever Ambitious Post-Doc

Last 5 UNH Post-Docs

Marie Boer : Tenure Track at Virginia Tech

Rafo Paramuzyan : JLab Staff Scientist

Elena Long : Tenure Track at UNH

James Maxwell : JLab Staff Scientist

Hovanes Egiyan : JLab Staff Scientist

Summary

5T/1K DNP system running well

Solid State mm-wave system

Lanl VME based NMR + cold NMR system

Material Production of NH3, ND3, Ammonias and diols, and doped polymers. Looking forward to irradiations

Deuteron

NMR Lineshape Analysis

traditional and novel methods

TE Calibrations of Deuteron!!

Tensor Polarization

Lots of possible experiments