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

PhD Students

Elena Long

Leiqaa K. Michael M. David R. Emad M.

undergrads

Taylor C. Lily S. Tristan A.

close collaboration with W. Brook’s group at USFSM

Nathaly S. (recent alum)
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 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

- 12x Frequency Multiplier & Amplifier Chain
- 12 GHz Signal Generator
- 500 mW @139 GHz

- 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

12 GHz Signal Generator

12x Frequency Multiplier & Amplifier Chain

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

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


We also use SDR-based Vector Network Analyzers (VNA)
- easy to tune at any frequency
- TE 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

Vapor Pressure

\[ T \approx 1.05K \]
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
- Chemical Doping
- grade 5.5 NH$_3$ & ND$_3$
- Rapid vs Slow Cooling 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.

(\textit{Red}=electrons, \textit{yellow}=photons, \textit{blue}=positrons)
Energy Deposition from E-Beam

NH₃ Target in liquid Argon
90% saturated at 5.5 cm

NH₃ Target in liquid Helium
90% saturated at 9 cm

NH₃ 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!
Proton Thermal Equilibrium Signals

5Tesla, 2.2 K

2.5Tesla, 2.1K

1Tesla, 2.5K

2019–12–20
Tempo Doped Butanol

1Tesla, 2.1K

2019–12–17
Tempo Doped Polymer

Analysis from Tristan Anderson
Proton Spin Up/Down

<table>
<thead>
<tr>
<th></th>
<th>12/19 tempo-araldite</th>
<th>12/21 Tempo-Butanol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buildup (s)</td>
<td>425</td>
<td>420</td>
</tr>
<tr>
<td>Relax</td>
<td>756</td>
<td>--</td>
</tr>
<tr>
<td>P max</td>
<td>6.3%</td>
<td>8.7%@2.1K</td>
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</tbody>
</table>

Analysis from Tristan Anderson
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

Figure 6.20: The deuteron thermal equilibrium and enhanced signals.

Deuteron Thermal Equilibrium

Deuteron Thermal Equilibrium (TE) signal ($P_z = 0.09\%$) and enhanced ($P_z = 37\%$)
Deuteron Enhancement Frequencies

Propanediol-d8 2020-12-07 (5:25-7:54 pm)

Pos: 28.031 GHz/T
Neg: 28.048 GHz/T
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 of 1,2-Propanediol-d8, chemically doped with OX063, with 5T/1K
Deuteron Tensor Enhancement

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

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

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

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

Dynamic Nuclear Polarization of $\text{NH}_3\text{ ND}_3$

5 T/140 GHz operation
Helmholtz superconducting magnet

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

Microwave Power
$>1$W at 140 GHz

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

fig. courtesy of C. Keith
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 10-60 MeV 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
    Lnl 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