Jefferson Lab
Target Group

Testing a new polarized target for CLAS12 at JLab

Chris Keith
JLab Target Group

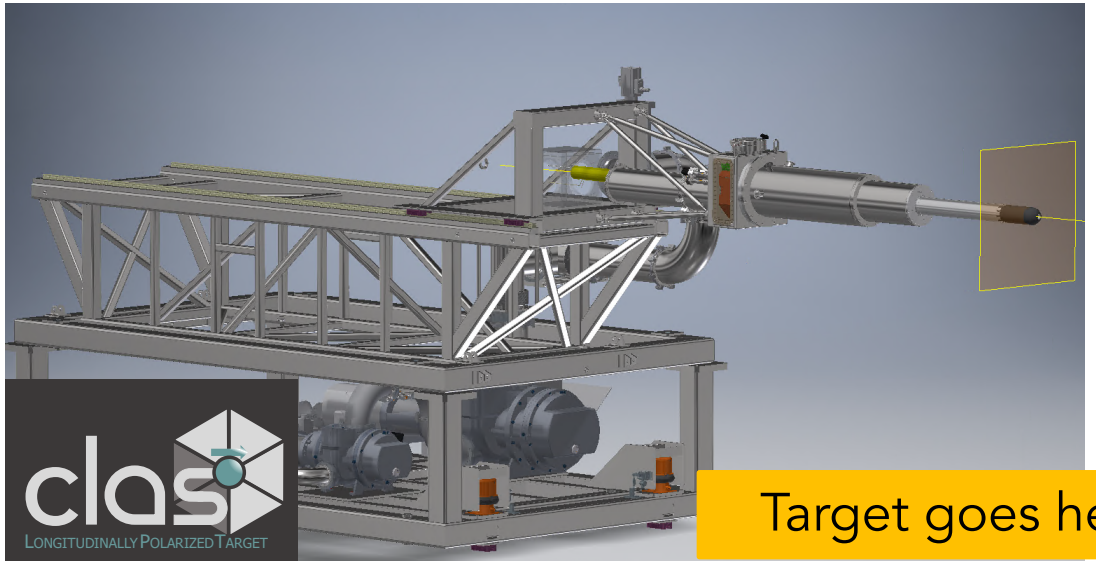
U.S. DEPARTMENT OF ENERGY

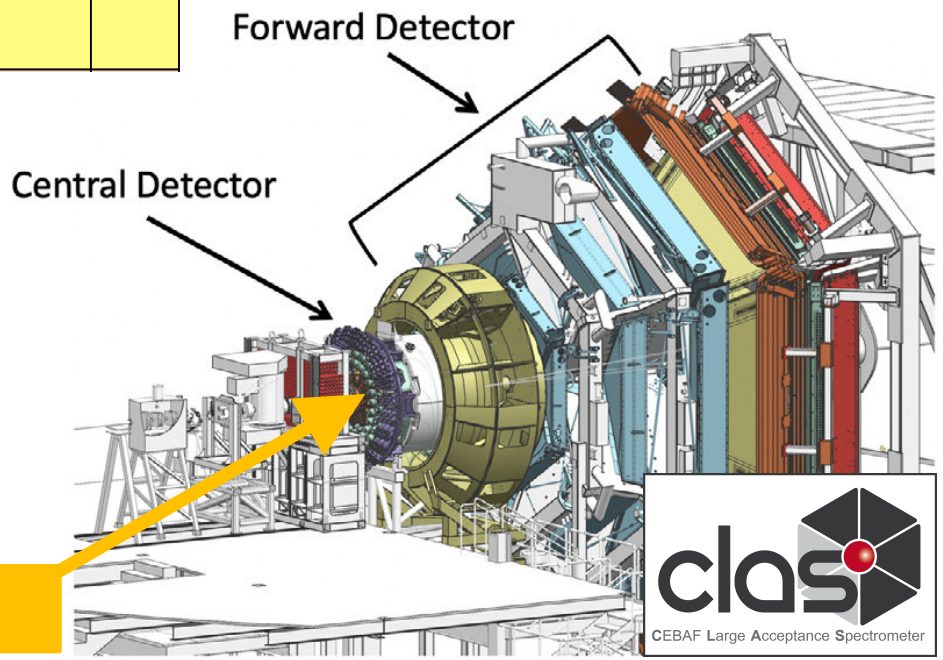
Jefferson Lab
Thomas Jefferson National Accelerator Facility

Run Group C

An experimental program to measure the spin structure of protons and neutrons utilizing polarized electrons and a longitudinally polarized target inside CLAS12 in Hall B.
It will be the first polarized solid target experiment at JLab in the 12 GeV era.
It is scheduled to run June 1, 2022 – February 28, 2023.

E12-06-109	Longitudinal Spin Structure of the Nucleon	Kuhn	A	80	185	Polarized target RICH (1 sector) Forward tagger	11	C S. Kuhn	NH_3 ND_3
E12-06-109A	DVCS on the neutron with polarized deuterium target	Niccolai		(60)					
E12-06- 119(b)	DVCS on longitudinally polarized proton target	Sabatie	A	120					
E12-07-107	Spin-Orbit Correl. with Longitudinally polarized target	Avakian	A-	103					
E12-09-007(b)	Study of partonic distributions using SIDIS K production	Hafidi	A-	80					
E12-09-009	Spin-Orbit correlations in K production w/ pol. targets	Avakian	B+	103					

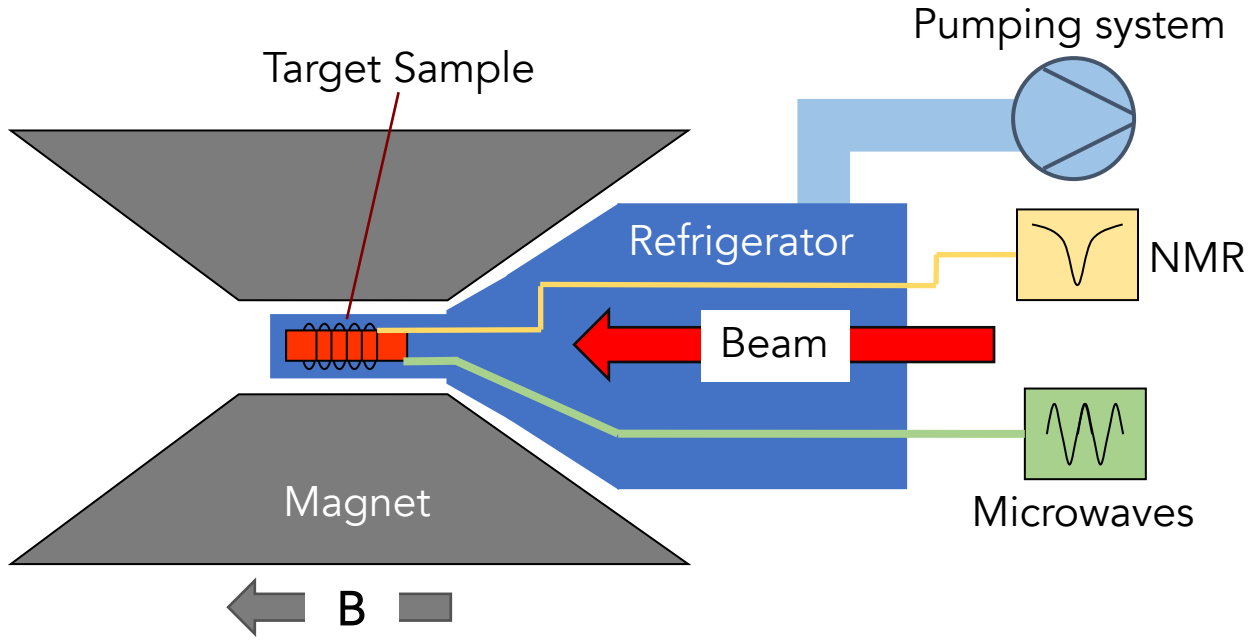




Dynamic Nuclear Polarization

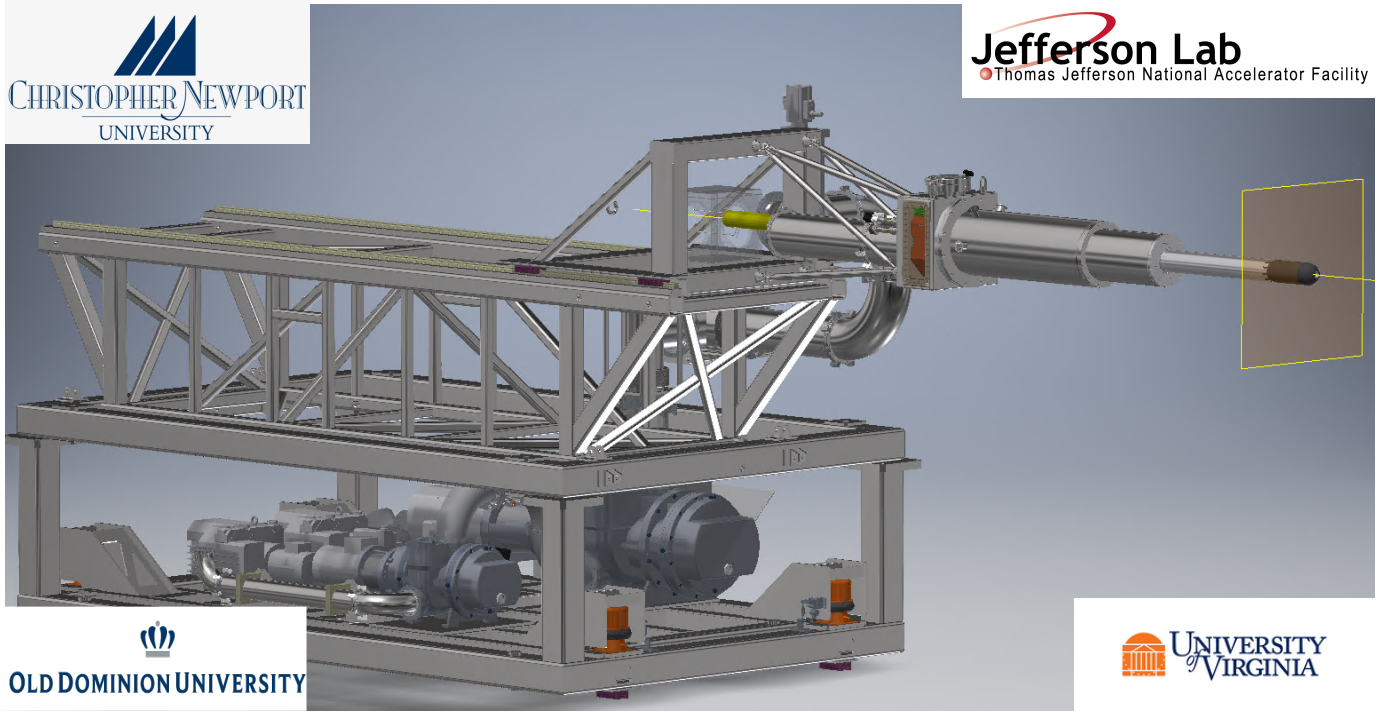
Ingredients for Dynamic Nuclear Polarization

- Target sample with paramagnetic radicals
- High magnetic field
- Low temperature
- Microwaves
- NMR



Target Specifications

Sample material: Irradiated NH_3 and ND_3
Sample size: ⌀1.5 x 5 cm^3
Temperature: 1 K
Magnetic Field: 5 T
Microwave Freq: 140 GHz
Beam current: 10 nA
Luminosity: 10^{35} $s^{-1}cm^{-2}$



Jefferson Lab
James Brock
Chris Carlin
Hai Dong
Dave Griffith
Paul Hood
Mark Hoegerl
Tsuneo, Kageya
James Maxwell

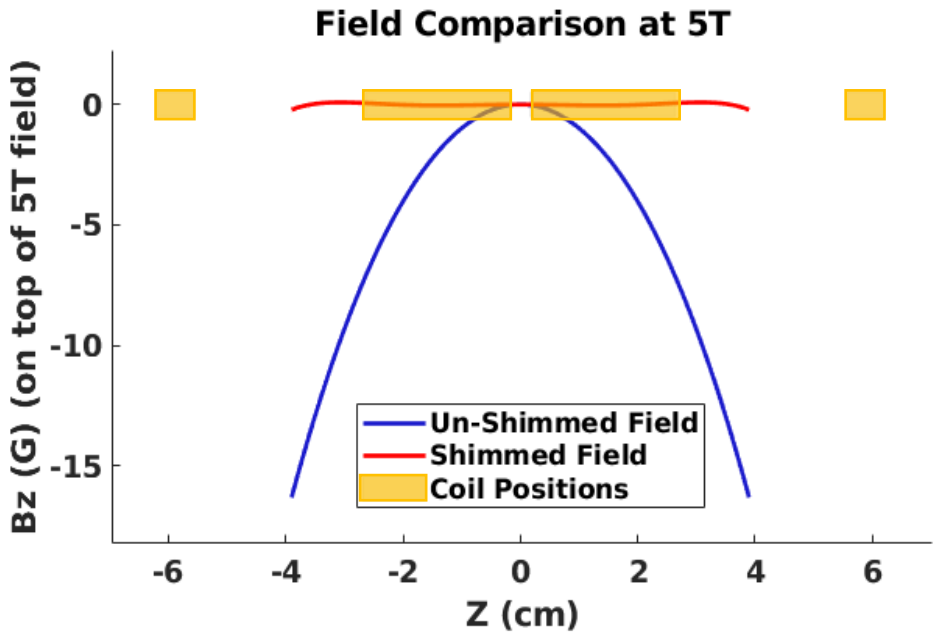
Old Dominion University
Sebastian Kuhn
Victoria Lagerquist
Pushpa Pandy

Magnets

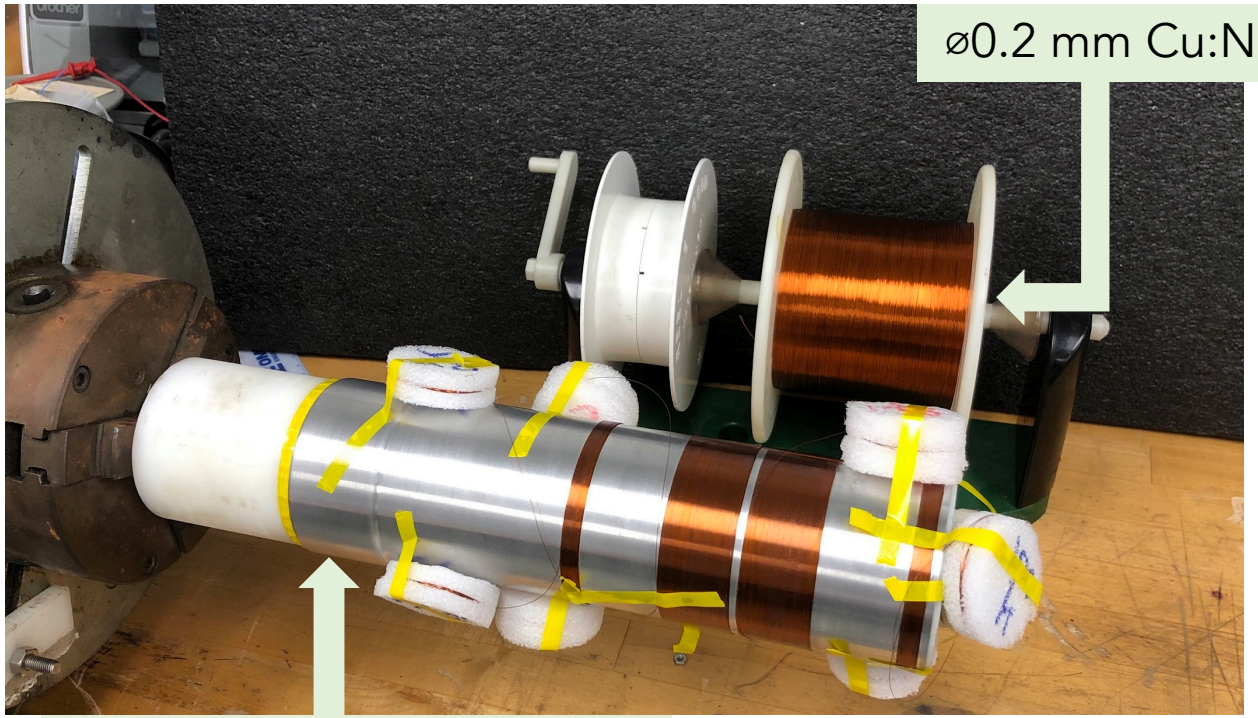
CLAS12 Solenoid

The CLAS12 solenoid will provide the 5 T field for polarizing the target.

Uniformity will be improved from ~300 ppm to < 10 ppm using thin superconducting coils installed inside the refrigerator.



Four-coil superconducting shim magnet

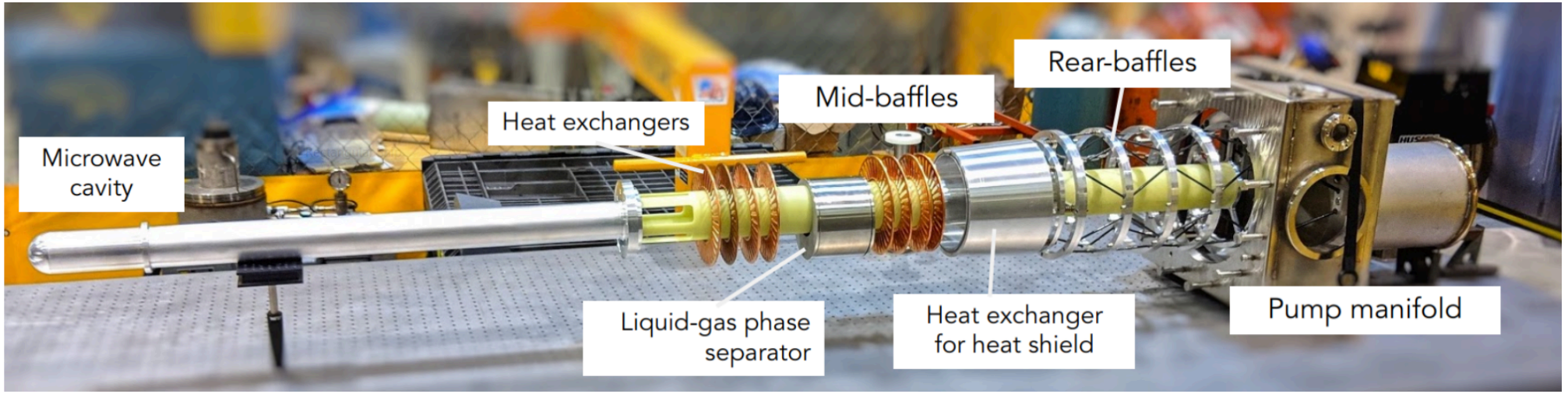


Victoria Lagerquist

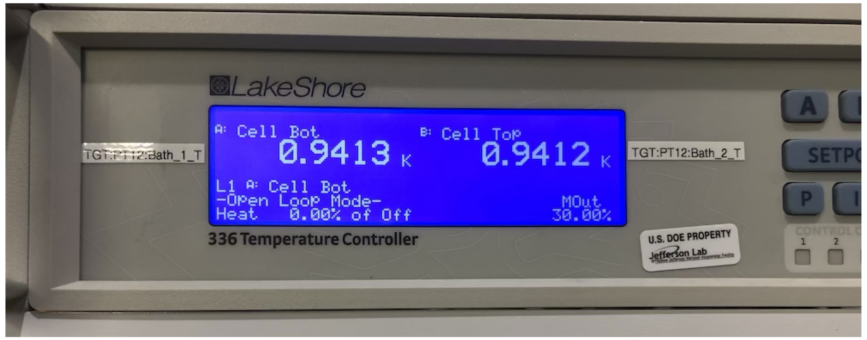
Potential Uses

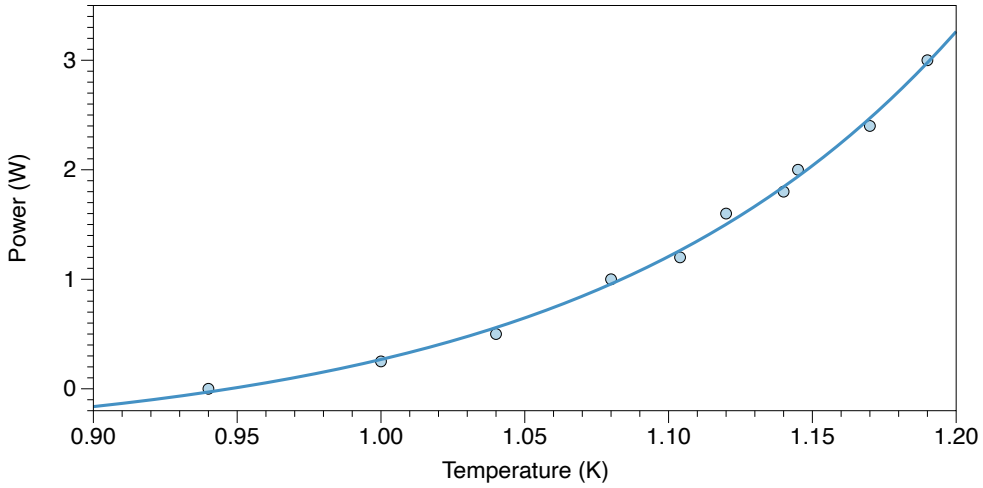
- Improve uniformity of polarizing field
- Shift field for NMR calibrations
- Shift field for polarization reversals

1 K refrigerator



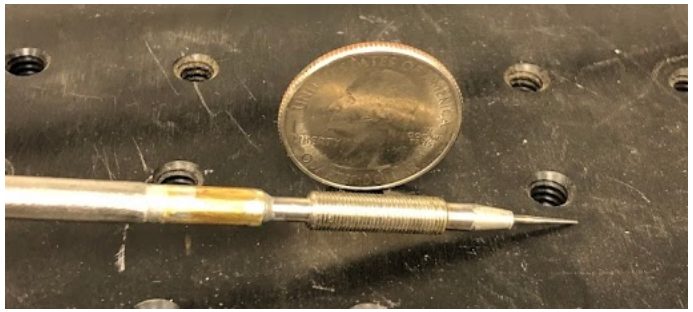
James Brock



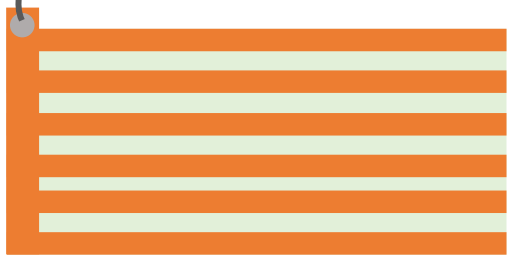


1 K refrigerator

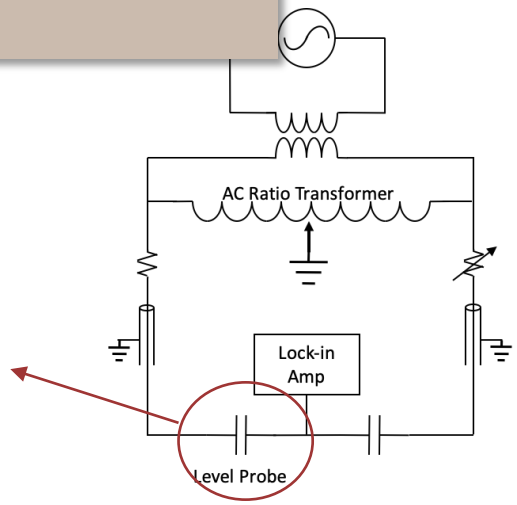
Flow of liquid helium through the refrigerator and to the target bath is controlled by miniature Joule-Thomson valves, actuated by stepper motors.

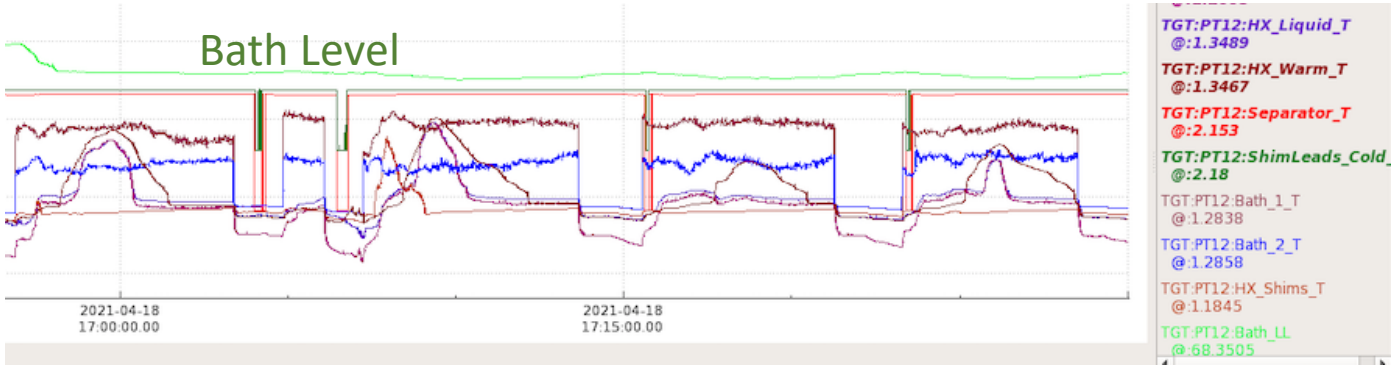


The level of superfluid in the bath is measured by a capacitance level probe with sub-mm precision and maintained by a PID algorithm with the JT valves.



Copper-clad G10 capacitor plate (1 of 2)

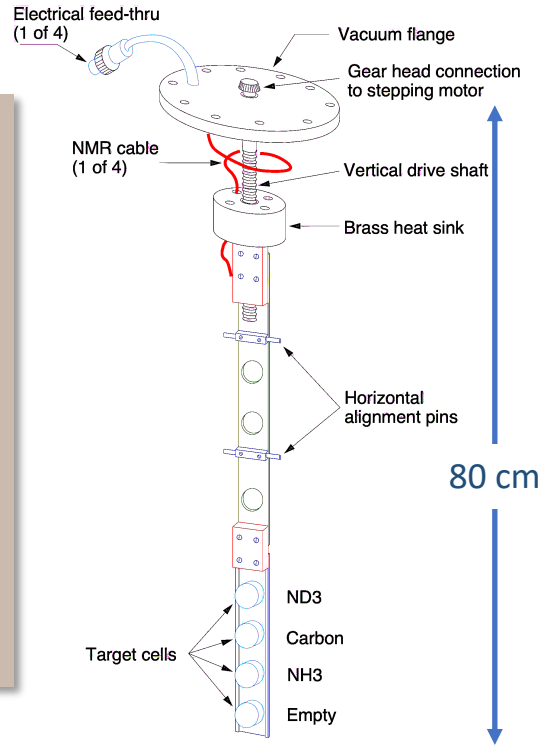




Sample loading

The horizontal geometry of the target system precludes the use of a sample insert with multiple target samples. The extreme length of the cryostat (>3m), along with the need to swap samples frequently (2-3x per week), was the greatest challenge to the system's design and execution.

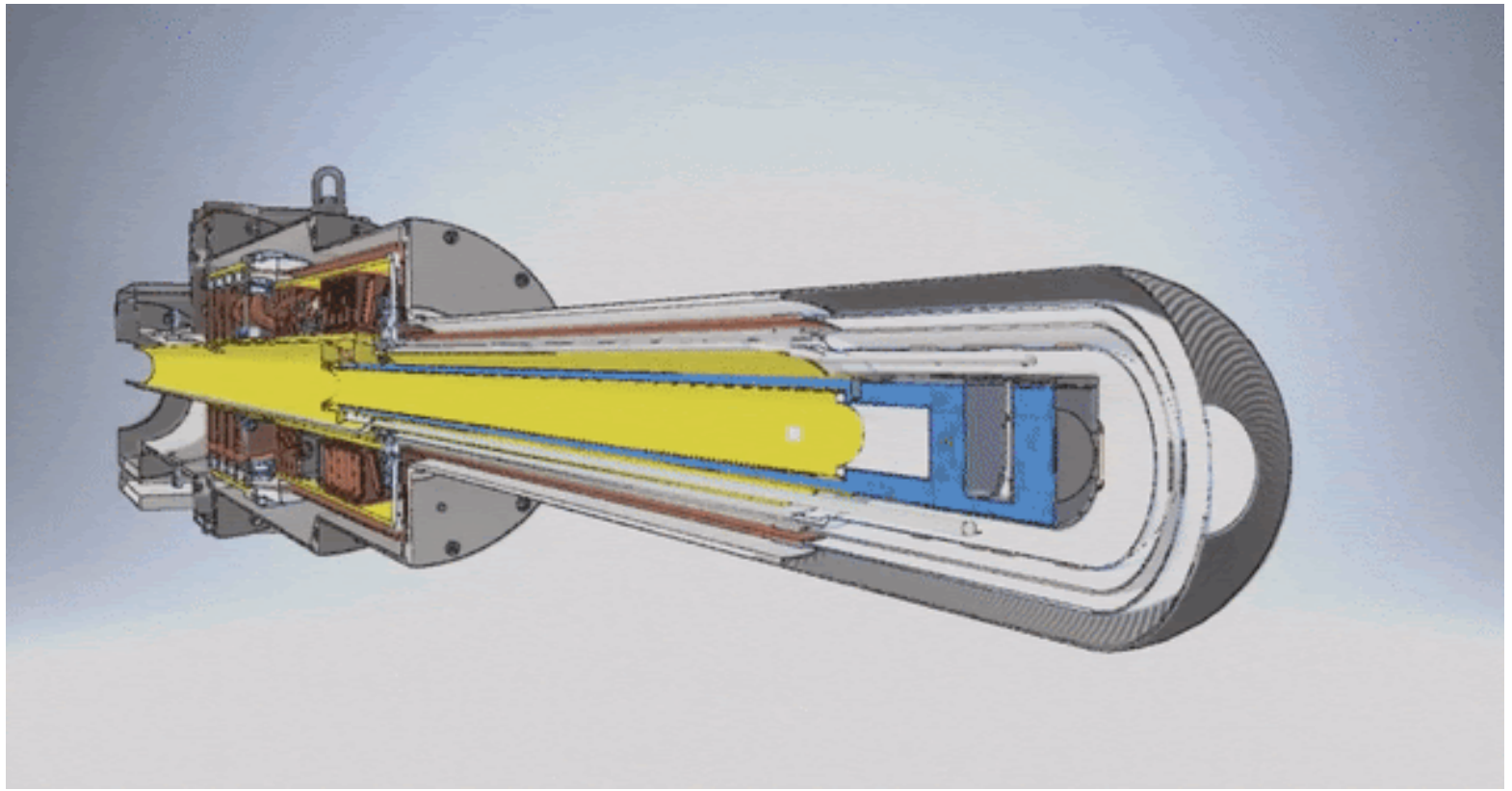
Our solution:
bring the superfluid bath to the sample!



6 GeV polarized target insert for CLAS, vertical

Mock-up of similar insert needed for RGC polarized target, horizontal

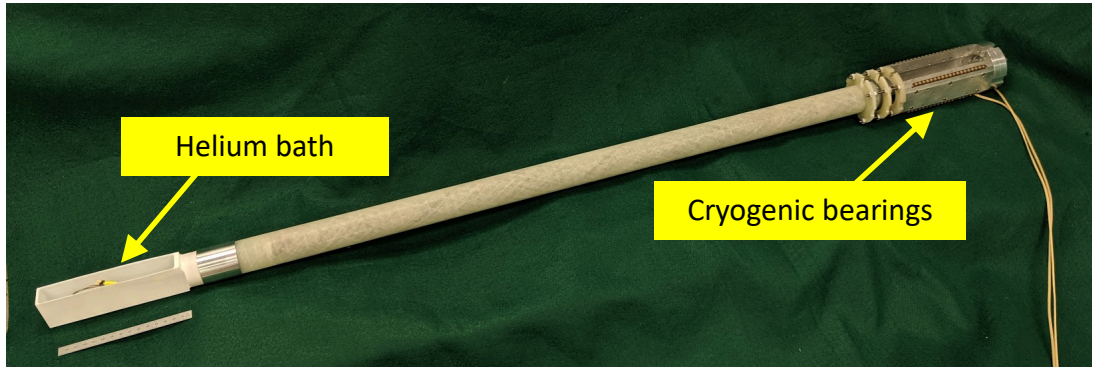
Sample loading



The target bath is retracted to an upstream load-lock position, where an old target sample is removed and replaced with a fresh sample.

The bath is moved back to the in-beam position and filled with superfluid helium.

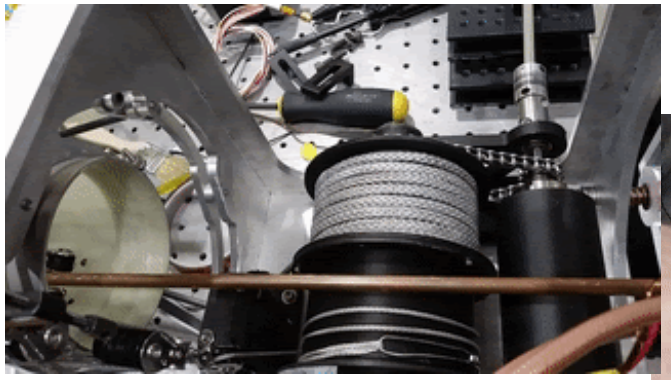
Sample loading



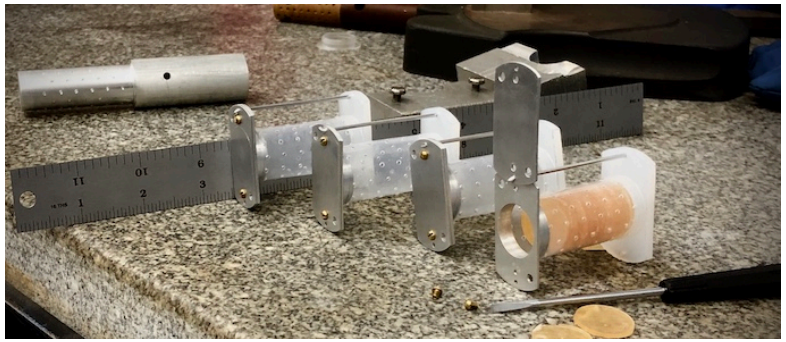
Prototype bath and trolley

James Brock

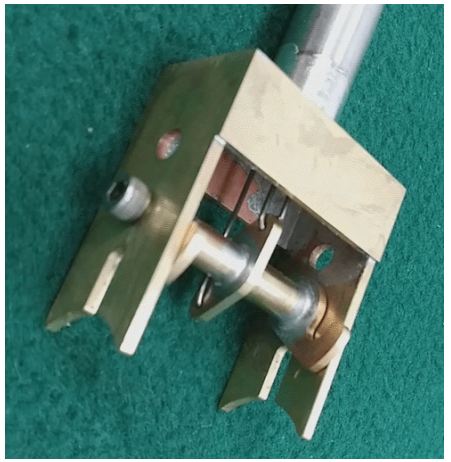
Bath retraction spool



Sample loading



Prototype sample cells

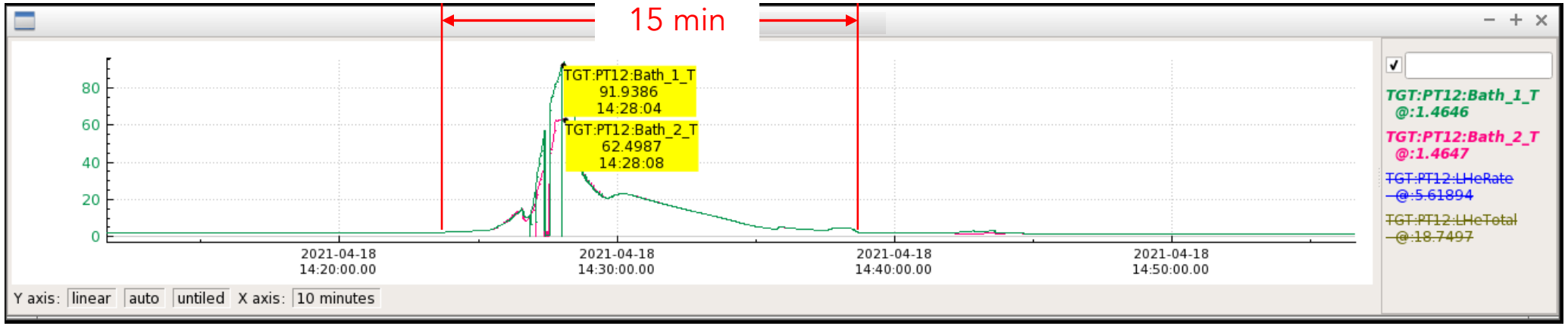


Sample extraction tool

Sample loading

Loading & unloading of target samples

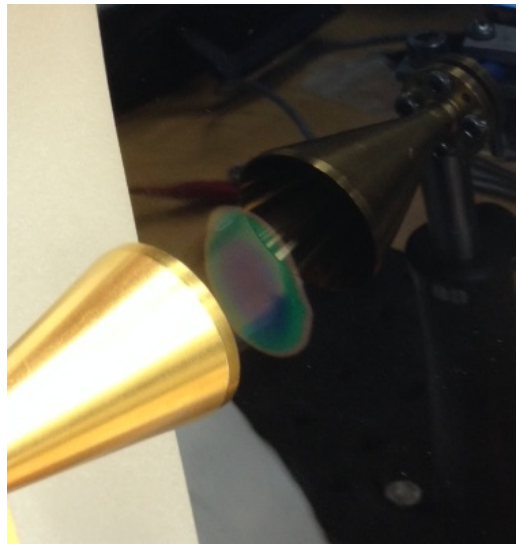
- Total time from cold sample ➔ cold, fresh sample is less than 30 minutes
- Sample temperature kept below 100 K



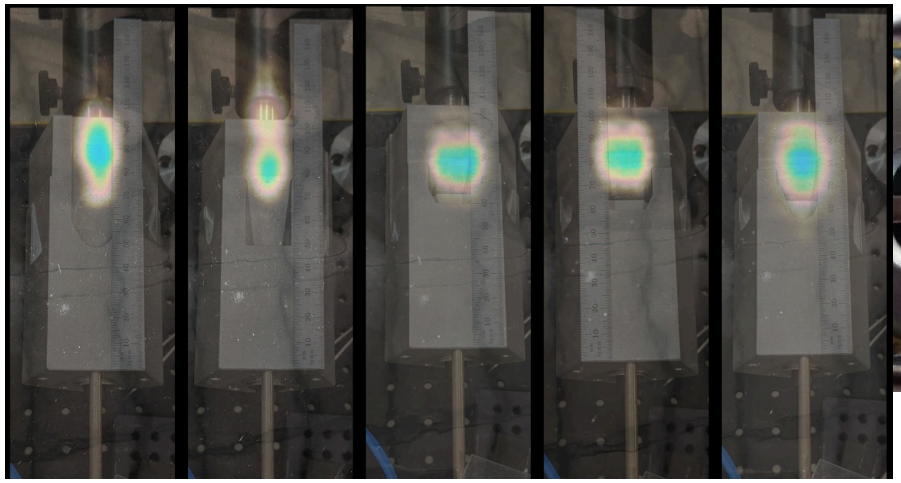
A few lessons we learned

- We dropped one sample inside the refrigerator
- We need a stronger helium purge
- Wait longer for liquid nitrogen to drain from target cell

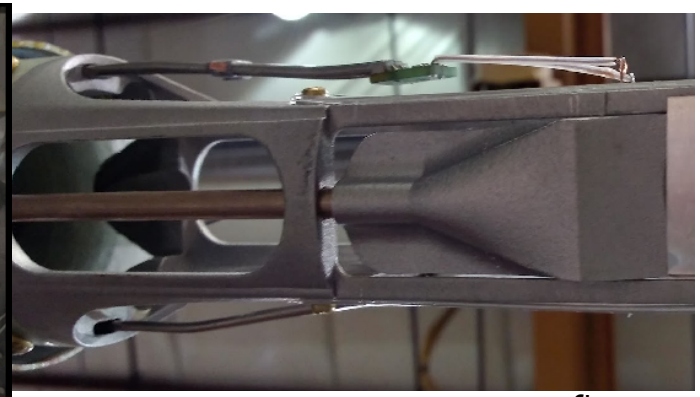
Microwaves



Microwave tests with liquid crystal film



Optimize shape of microwave reflector



Microwave reflector

Extended Interaction Oscillator (EIO), 140 GHz

Current system can deliver >3 W of microwave power to the target sample.
TOO MUCH!!
Reduce to ~1 W for best results.

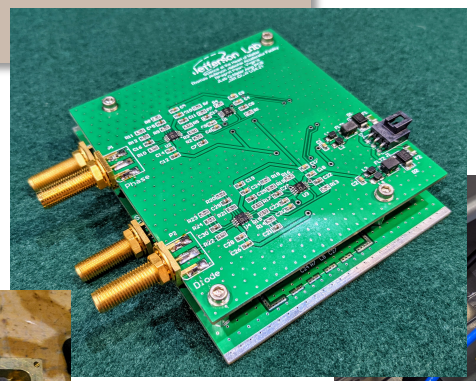
Tsuneo Kageya is resurrecting microwave frequency modulation to optimize deuteron polarization.

NMR Q-meter

New CW-NMR system developed by JLab Target and Fast Electronic Groups

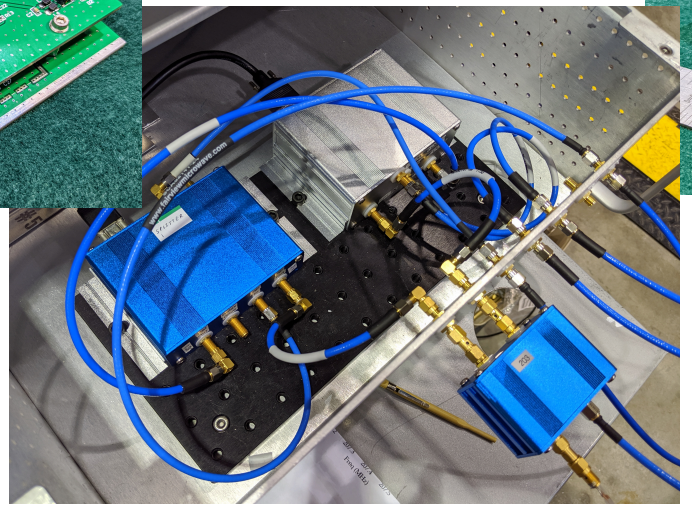
- Replaces the aging Liverpool Q-meter
- Similar design and operation
- Modular architecture, upgraded components
- Ergonomic improvements
- Improved signal-to-noise
- FPGA-based DAQ

NMR coils

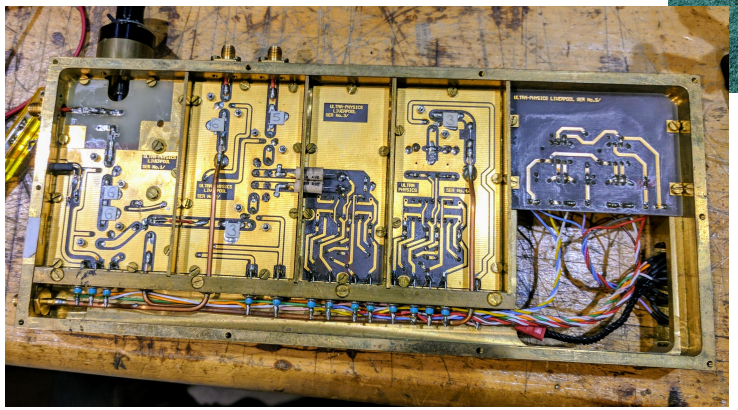


EMI-shielded enclosure

James Maxwell & Hai Dong



Modular design philosophy

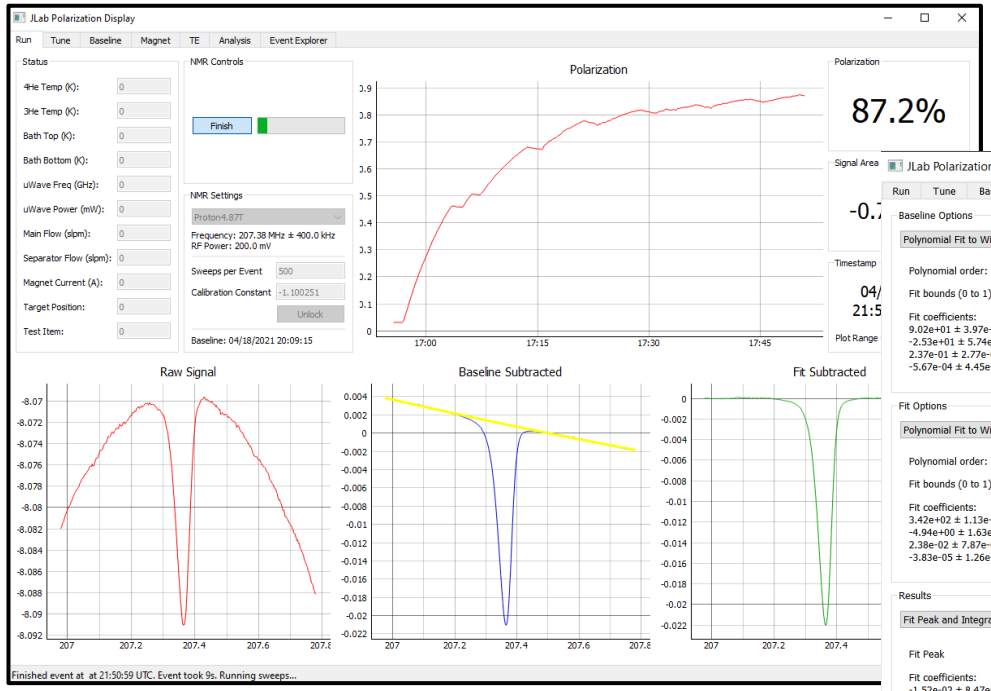


Liverpool Q-meter, ca. 1985

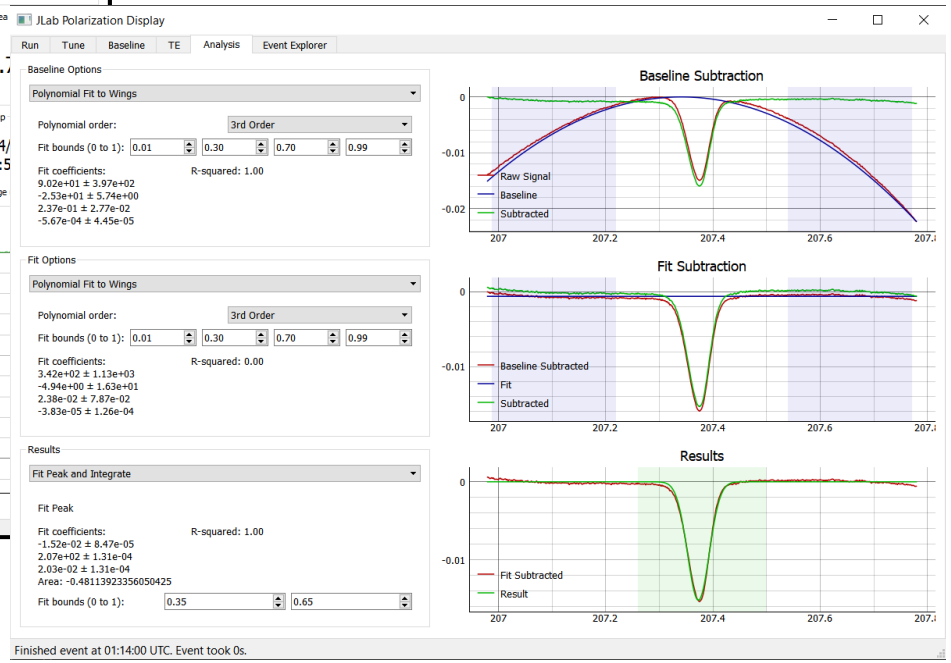
New NMR software

A ground-up re-write of the NMR software based in PYTHON

- Specific tabs for tuning, calibrations, data-taking, and analysis
- EPICS read/write
- Backwards compatible with old NI-DAQ hardware



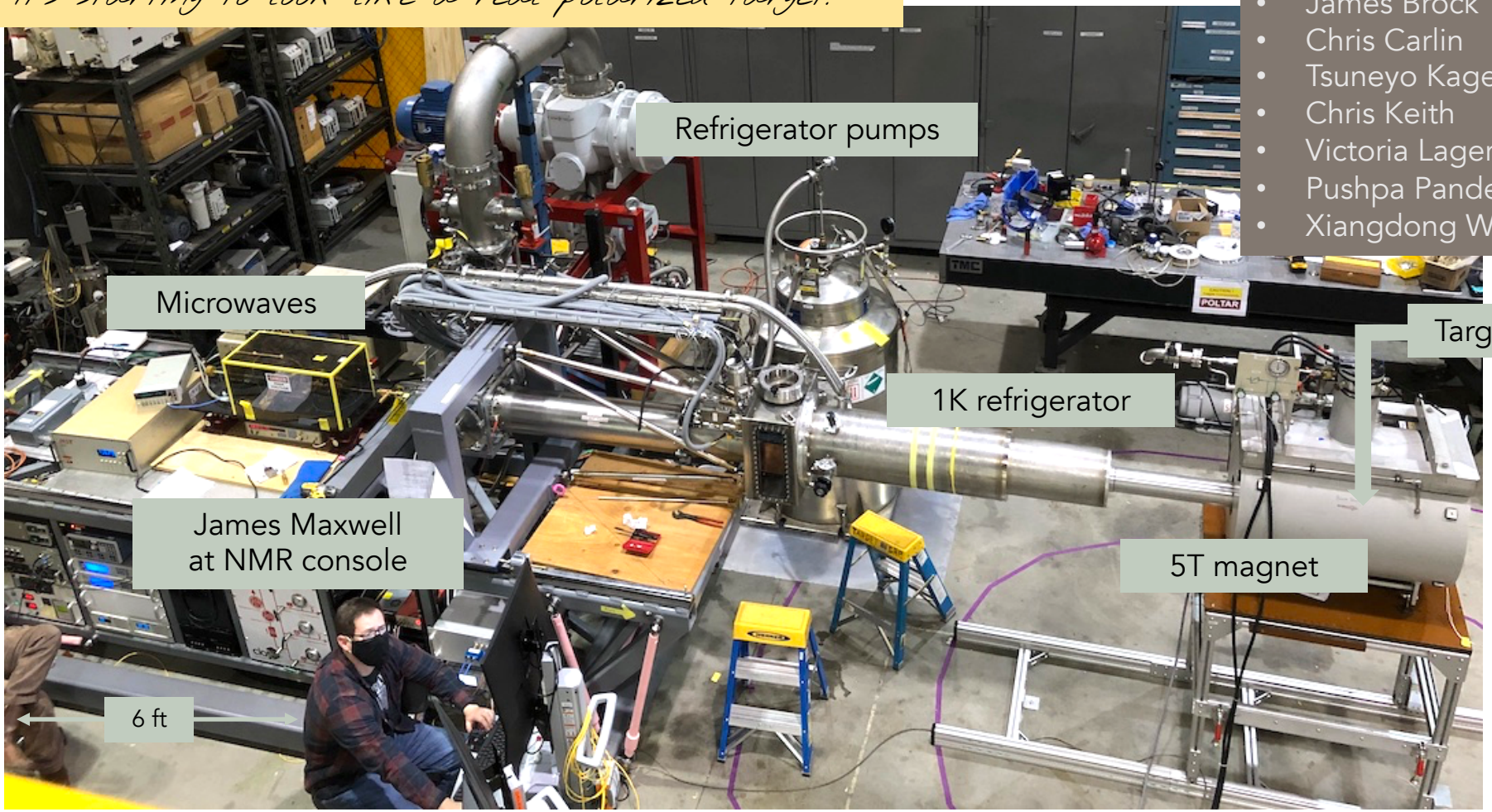
James Maxwell



Polarization test results

Target Lab, April 2021

It's starting to look like a real polarized target!



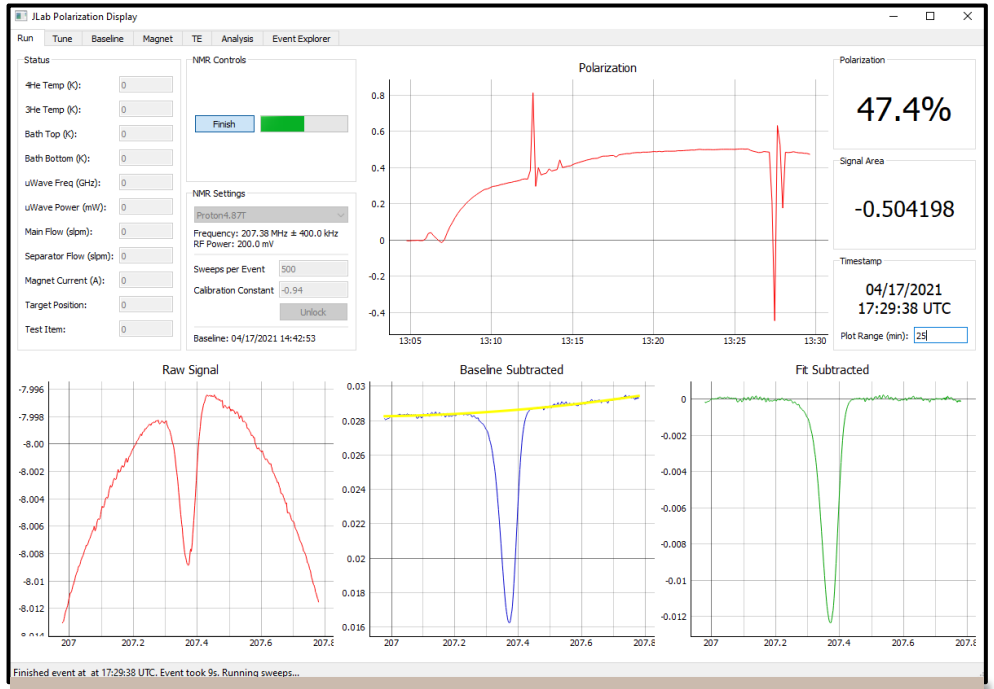
NOT SHOWN

- James Brock
- Chris Carlin
- Tsuneyo Kageya
- Chris Keith
- Victoria Lagerquist
- Pushpa Pandey
- Xiangdong Wei

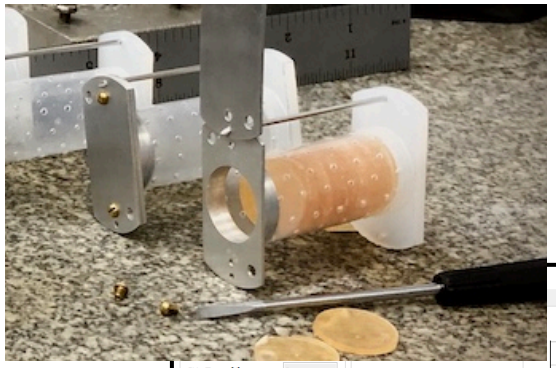
Polarization test results

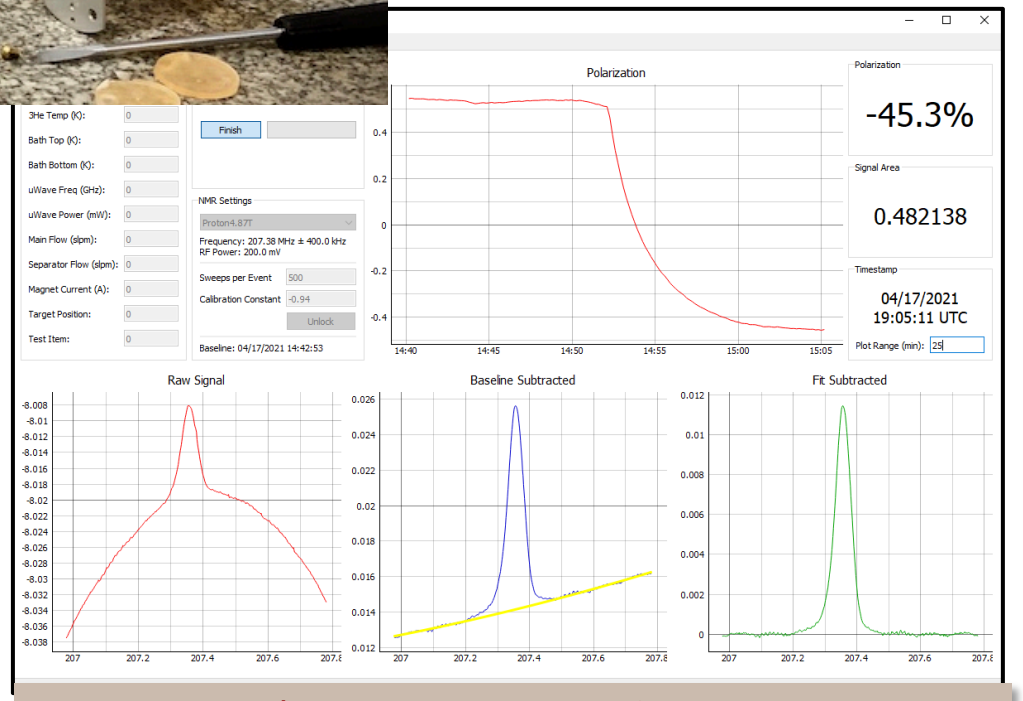
Two-part epoxy + TEMPO

Y. Noda, T. Kumada, D. Yamaguchi, S. Shamoto, NIM A 776 (2015) 8.



+45% polarization in about 15 minutes
Eventually reached +56%

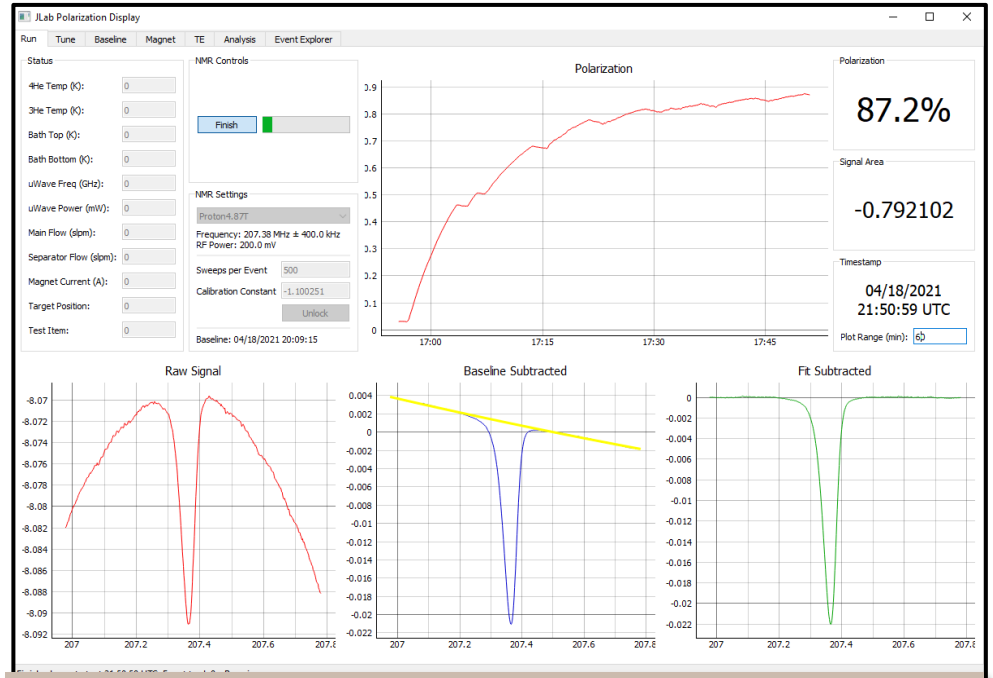




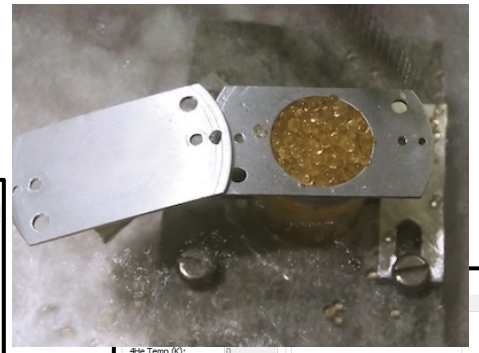
Reverse polarization to -45% in <20 minutes

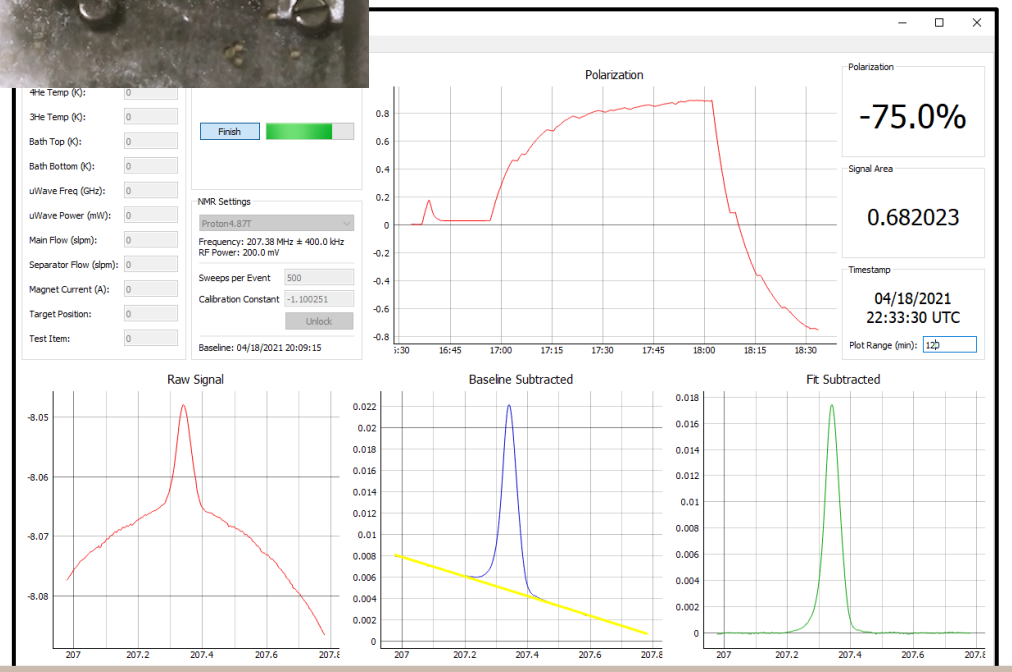
Polarization test results

Butanol + TEMPO



Butanol reached +87% in about 50 minutes

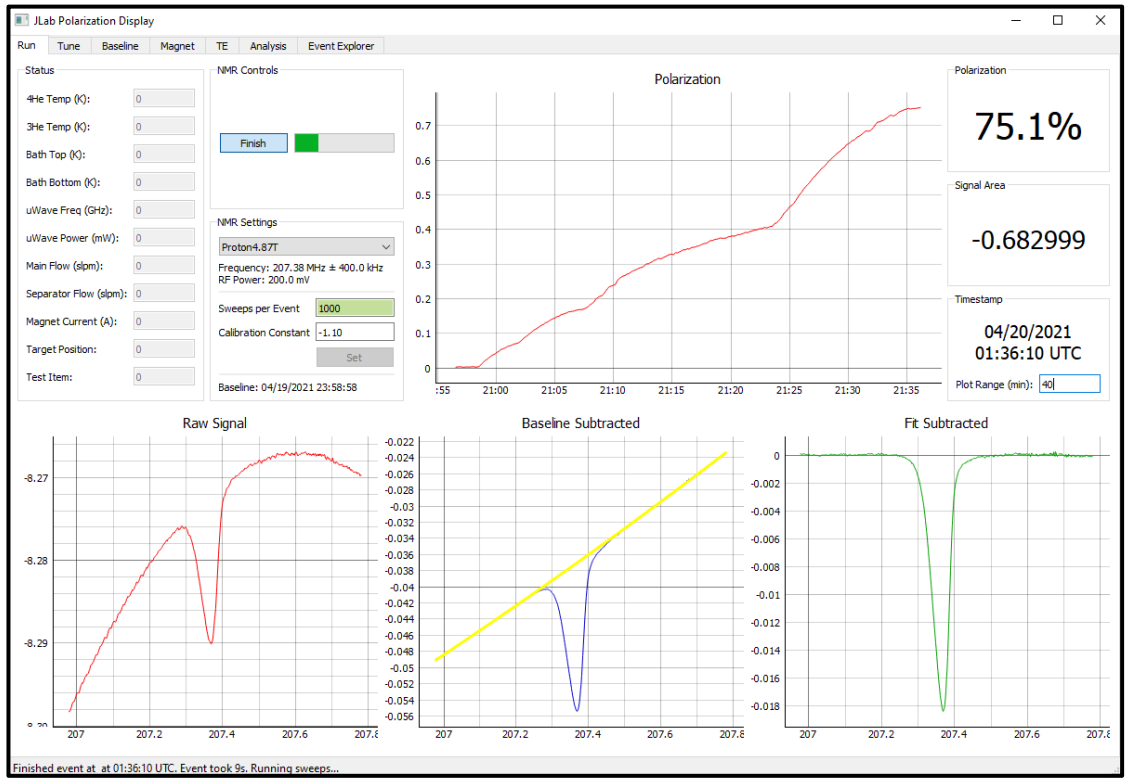




Reverse polarization to -75% in about 30 minutes

Polarization test results

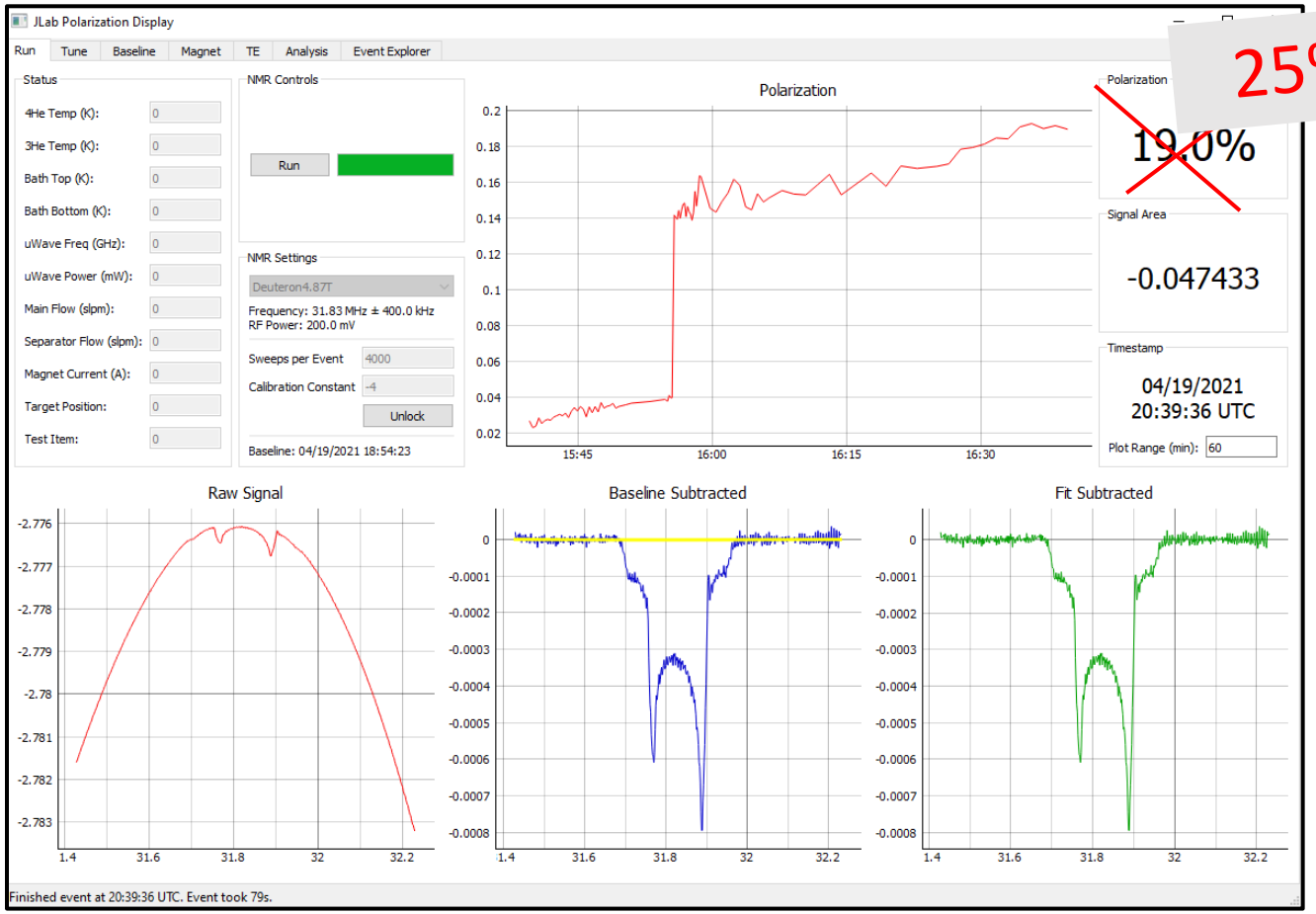
Irradiated NH_3 (courtesy of UVa)



Slowest polarization, longest T_1

Polarization test results

Deuterated-butanol + TEMPO

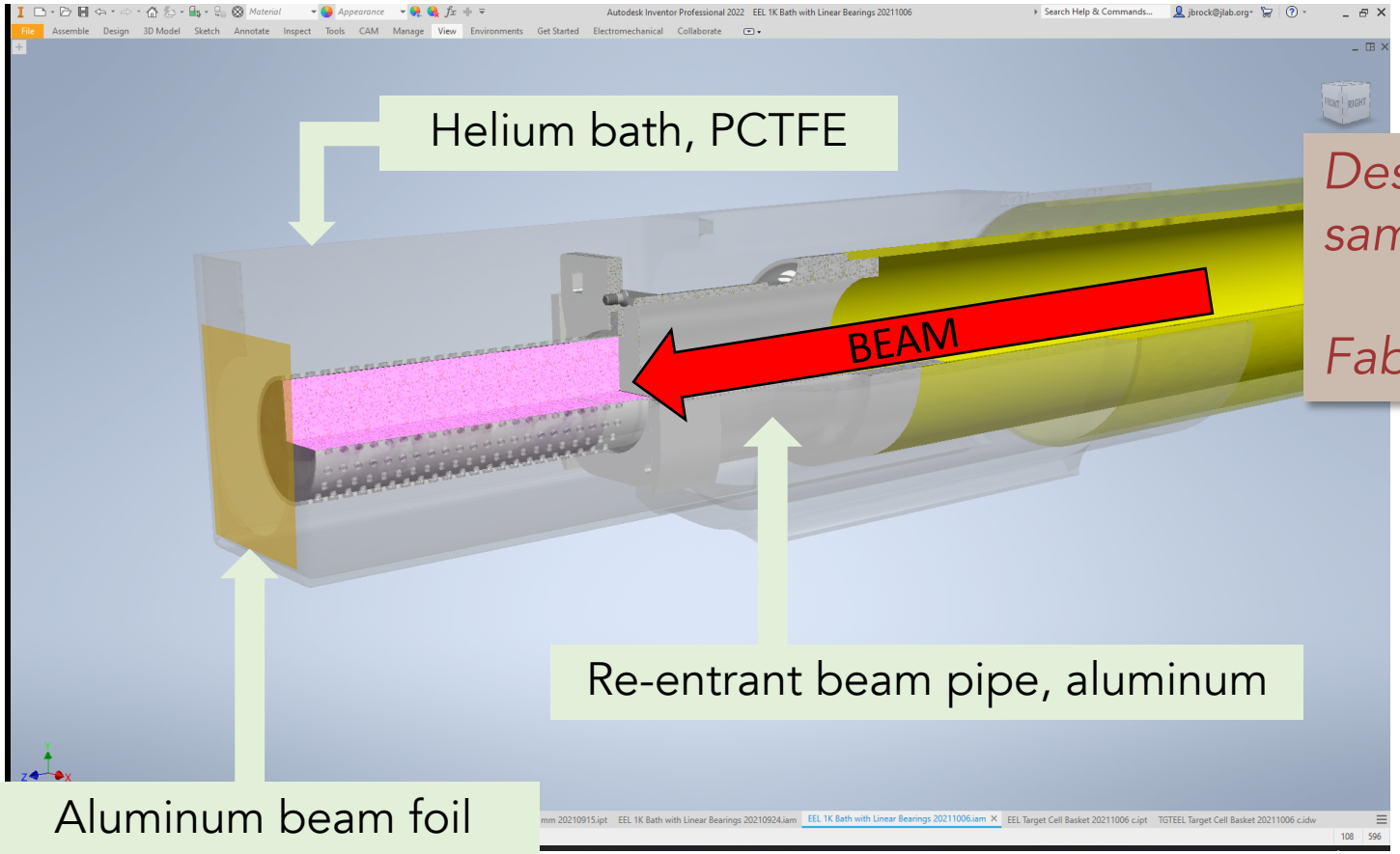


25%

Deuteron polarization is estimated by relative peak heights

Deuterated ammonia (ND_3) will be tested during the next cool-down.

Remaining work

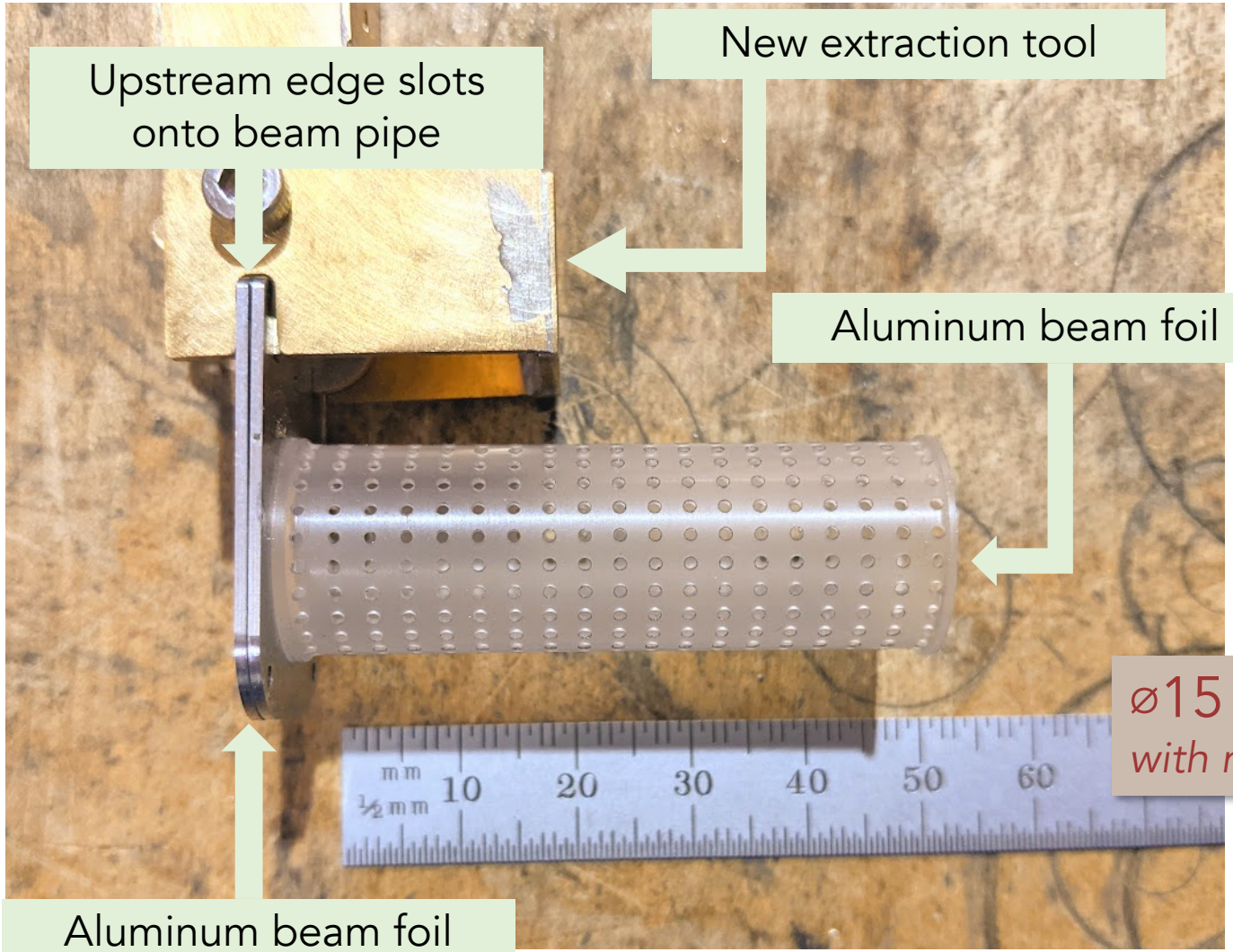


Design of beam-ready bath and sample containers is complete.

Fabrication has begun.

James Brock

Remaining work

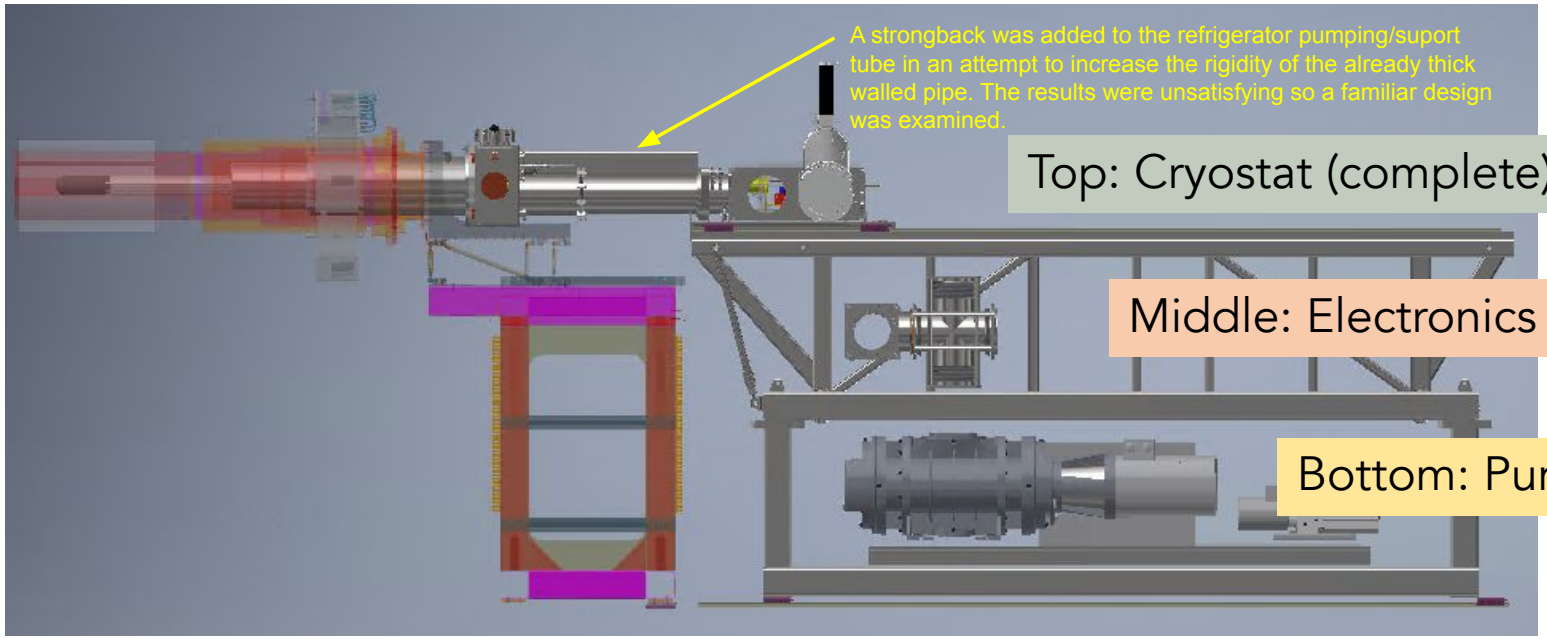


ø15 x 50 mm sample cups
with new insertion/removal tool

James Brock

Remaining work

The target system will be mounted in Hall B using a *three-tiered insertion cart.*

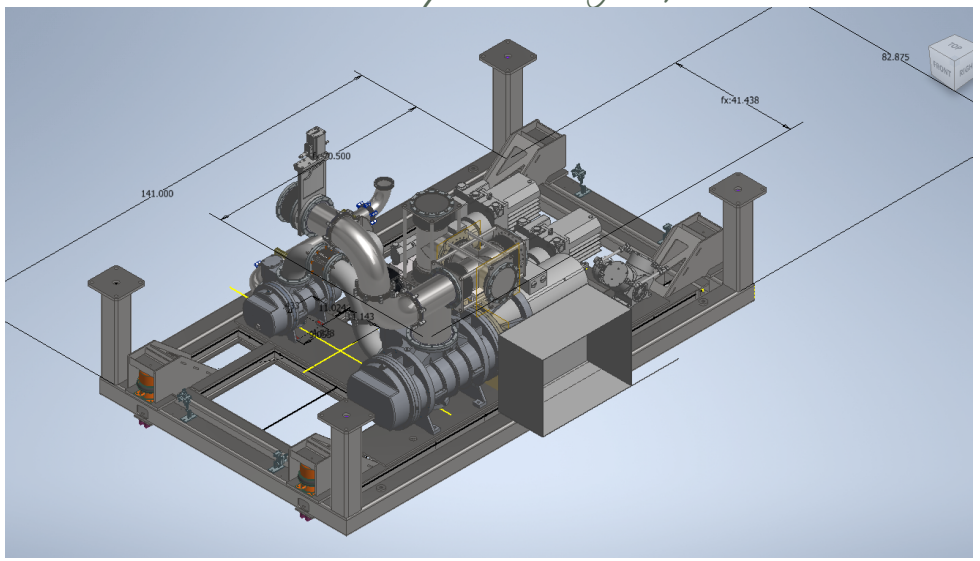


Casey Flanagan, James Brock

Remaining work

Bottom portion of target insertion cart

Casey Flanagan, James Brock



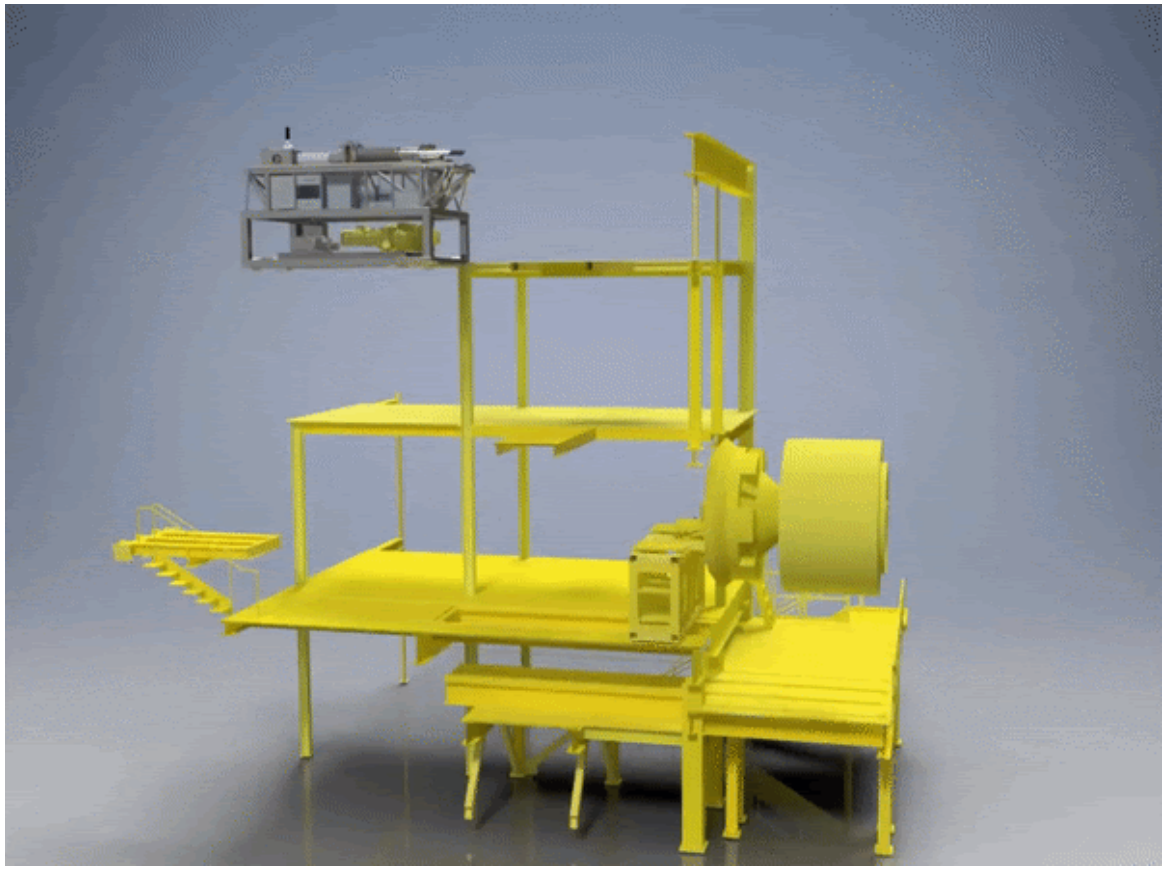
Target Group technicians will mount pumps to this plate later this month.

Remaining work

The target system will be mounted in Hall B using a *three-tiered insertion cart.*

Installation is expected to begin April 2022 and require eight weeks.

The experiment will run June 1, 2022 – February 28, 2023



Summary

- A dynamically polarized target of NH_3 and ND_3 is nearing completion at Jefferson Lab
- Tests of the target have been very positive and will continue through 2021
- The target will be installed in spring 2022 and utilized for the Run Group C experiments with the CLAS12 spectrometer in Hall B at JLab
- RGC will be the first polarized solid target experiment at JLab during the 12 GeV era.
- Others will follow: Hall A, Hall B, Hall C, and Hall D

Thank you for your attention!

Remaining work