Run Group C Update

Chris Keith
JLab Target Group

RGC overview

Hall B – Run Groups

HALL B

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					
E12-06-106	Color transparency in exclusive vector meson production	Hafidi	B+	60	60				
E12-06-117	Quark propagation and hadron formation	Brooks	A-	60	60				
E12-06-113	Free Neutron structure at large x	Bueltman	A	42	42	Radial TPC			

RGC is scheduled to run May 2 – Dec 20, 2021

- Originally approved for 185 PAC days
- PAC48 Jeopardy reduced to 120 (focus on DVCIS)

- 8 weeks for target installation and commissioning
- 30 PAC days FT-ON
- 90 PAC days FT-OFF

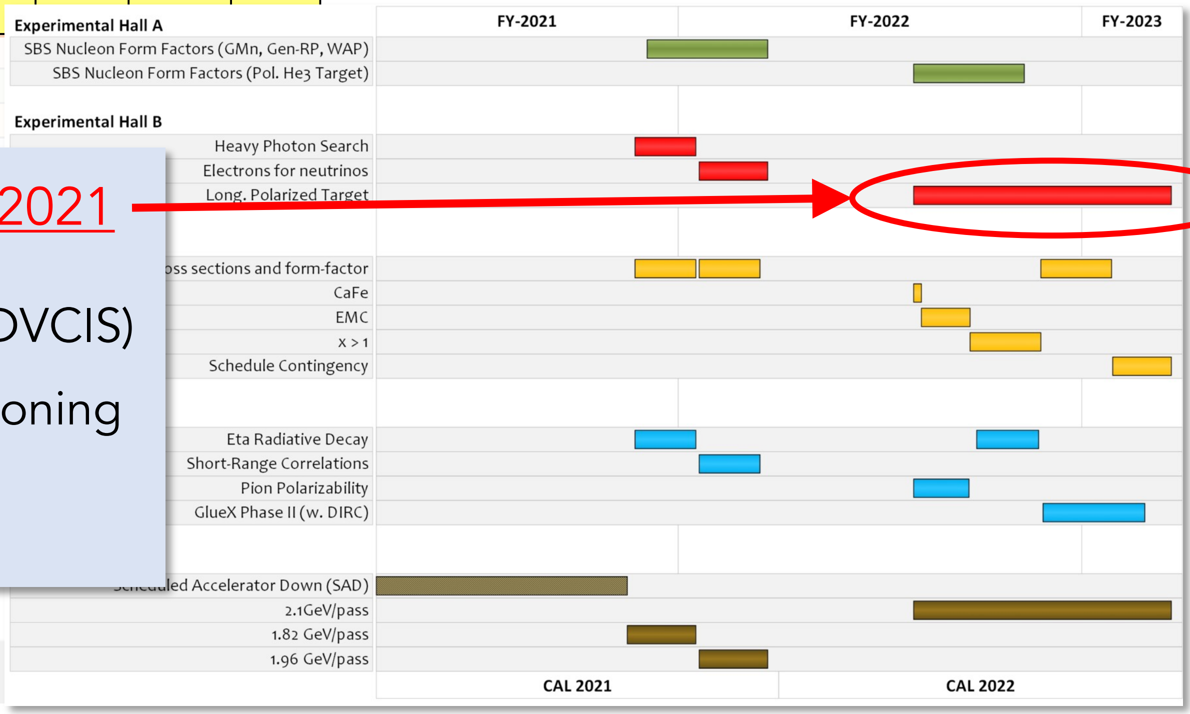


Figure 1 – Experiment schedule summary

RGC schedule

Goal: Support the hardware and software integration of RGC into CLAS12

Task Force	RG-C Polarized Target											
PI	V. Burkert											
Members	R. Miller (equipment integration), N. Baltzell (software & slow controls), R. De Vita (simulations), C. Keith (Target Group)											
Tasks/Subtasks	2020		2021									
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
1. In coordination with RGC team and Target Group develop an integration plan to install and operate a longitudinally polarized target in CLAS12												
1.1 Define Hall B Configuration			M1.1									
1.2 Buffer Dewar					M1.2							
1.3 Define power requirements					M1.3							
1.4 Space requirements				M1.4								
1.5 Polarized target installation				M1.5.1							M1.5.2	M1.5.3
2. In coordination with RGC team define beam line components and special requirements												
2.1 Raster magnets repair, test PS, install, operational, system tested					M2.1.1	M2.1.2	M2.1.3			M2.1.4		
2.2 New Moller shield				M2.2.1			M2.2.2				M2.2.3	M2.2.4
2.3 Forward Micromegas					M2.3.1	M2.3.2		M2.3.3		M2.3.4	M2.3.5	
2.4 Moller shield FT=IN/ON						M2.4.1	M2.4.2					~~M2.4.3~~
2.5 Fast Shut Down system (EP)			M2.5.1								M2.5.2	
3. In coordination with RGC team define and support the experiment related simulations, monitoring, and reconstruction framework												
3.1 Simulate Effect of Moller shield				M3.1.1		M3.1.2	M3.1.3		M3.1.4			
3.2 Simulate physics reaction w/ background (SN,CD)										M3.2.1		
4. In coordination with RGC team define the integration of RGC FE and DAQ into CLAS12 framework												
4.1 Read back of raster position into DAQ							M4.1.1		M4.1.2			
4.2 Other FE readout specific to RGC							M4.2.1					
5. In coordination with RGC team check the integration of slow controls into CLAS12 framework												
5.1 Define and implement Slow Controls needs for RGC beyond normal CLAS12 operation				M5.1.1					M5.1.2			
6. In coordination with RGC team define and support the integration of the RGC trigger into CLAS12 framework												
6.1 Define special trigger needs for RGC operation			M6.1.1								M6.1.2	

7. Assist the RGC team in preparation of the run												
7.1 Complete all Hall B run documentation that are specific to RGC operation												M7.1.1
7.2 Checkout operation of all CLAS12 detectors prior to beam operation and												M7.2.1
7.3 Provide "On Call" support by Hall B technical team for equipment operation before and during experiment												M7.3.1

Color code: Red/Blue/Green in order of decreasing priority (red is max)

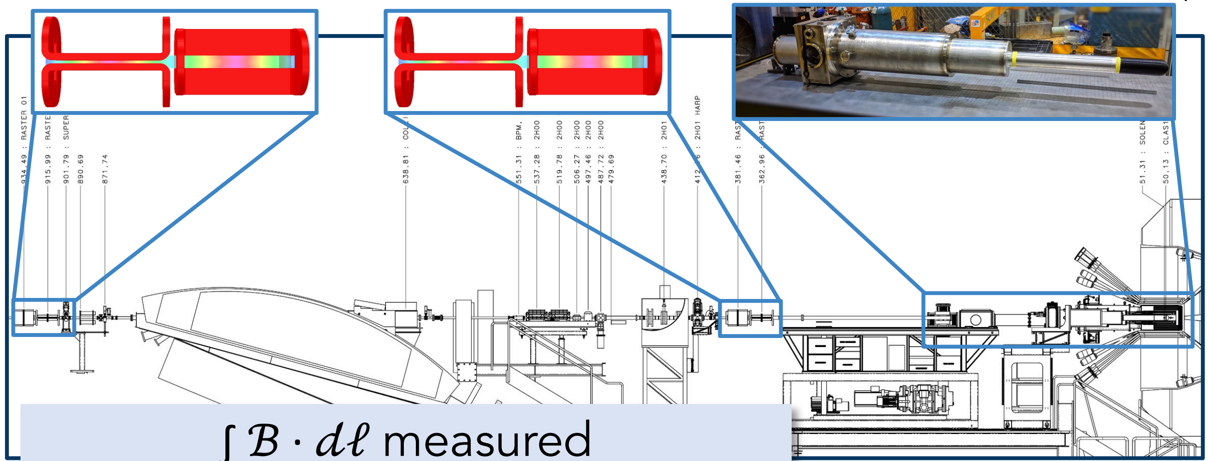
RGC Task Force (V. Burkert, PI)
Identified ~40 items in the punchlist

1. Target
2. Beamline
3. Simulations
4. FE & DAQ
5. Slow controls
6. Trigger
7. Documentation

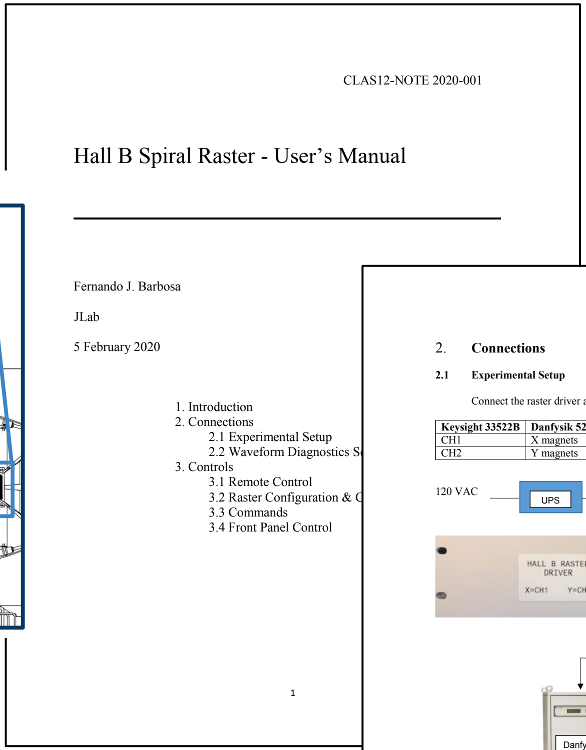
Roughly half of these have been completed (the ones not in BLACK)

RGC beamline

Raster magnets have been installed on Hall B beam line.
Tests with powers supplies scheduled for next week.



$\int \mathcal{B} \cdot d\ell$ measured
Sufficient for raster radius > 1 cm



CLAS12-NOTE 2020-001

Hall B Spiral Raster - User's Manual

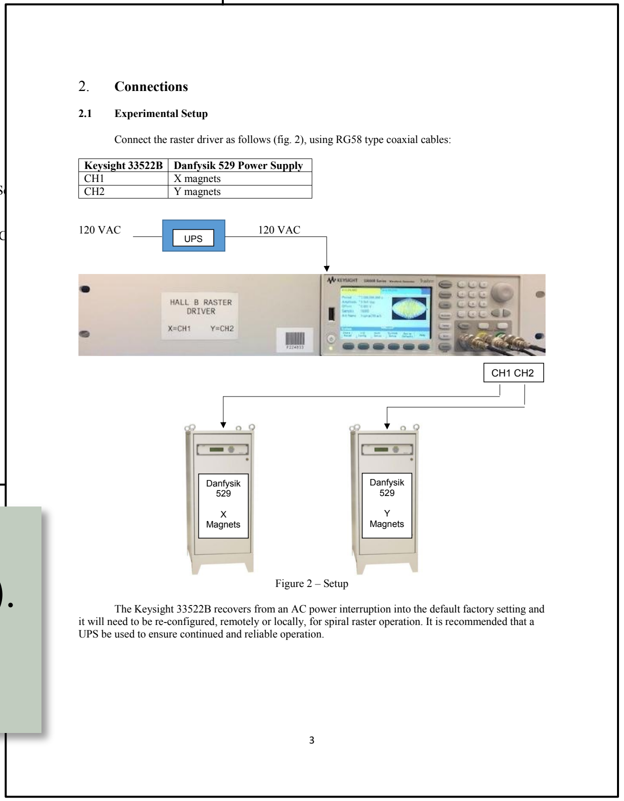
Fernando J. Barbosa

JLab

5 February 2020

1. Introduction
2. Connections
   2.1 Experimental Setup
   2.2 Waveform Diagnostics S
3. Controls
   3.1 Remote Control
   3.2 Raster Configuration & C
   3.3 Commands
   3.4 Front Panel Control

1



2. **Connections**

2.1 **Experimental Setup**

Connect the raster driver as follows (fig. 2), using RG58 type coaxial cables:

Keysight 33522B	Danfysik 529 Power Supply
CH1	X magnets
CH2	Y magnets

Figure 2 – Setup

The Keysight 33522B recovers from an AC power interruption into the default factory setting and it will need to be re-configured, remotely or locally, for spiral raster operation. It is recommended that a UPS be used to ensure continued and reliable operation.

3

New raster driver developed by Fast Electronics Group (F. Barbosa).
Requires EPICS interface & implementation of beam FSD

Credit: V. Lagerquist, E. Pasyuk, F. Barbosa

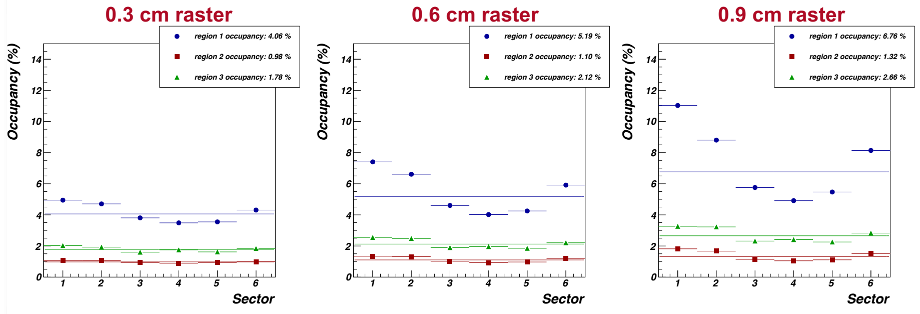
RGC beamline

FT-ON

Occupancies in R1 Drift Chamber
with rastered beam are high.
Operate with 6 mm raster radius and half luminosity.

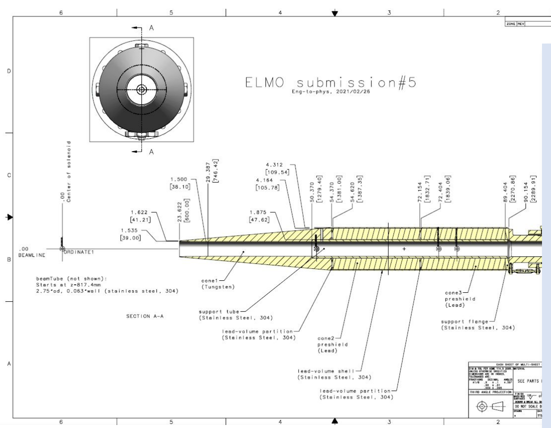
Dependence on raster size

- Strong dependence of DC occupancies on raster size
- Occupancies with 0.9 cm raster are 5x higher than RGA in R1, 2x in R2 and R3



2

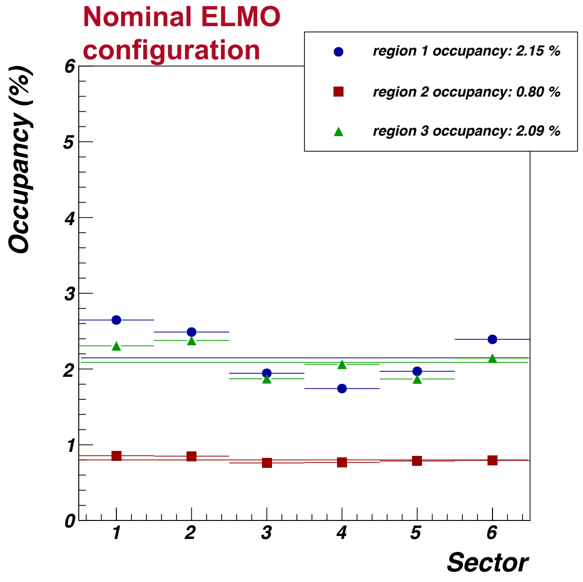
Credit: R. Devita, V. Lagerquist

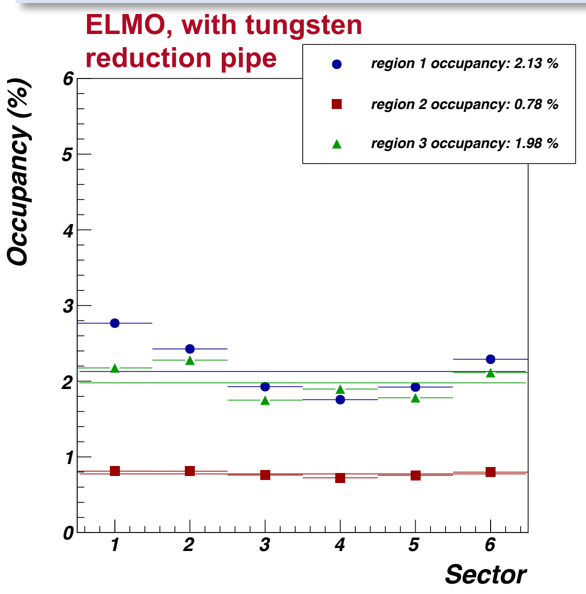


FT-OFF

Newly-designed Moller cone for RGC ("ELMO") reduces R1 occupancies by 2.5x

Design seems mostly optimized.
Tungsten cone out for procurement.
Procurement of other parts expected in August

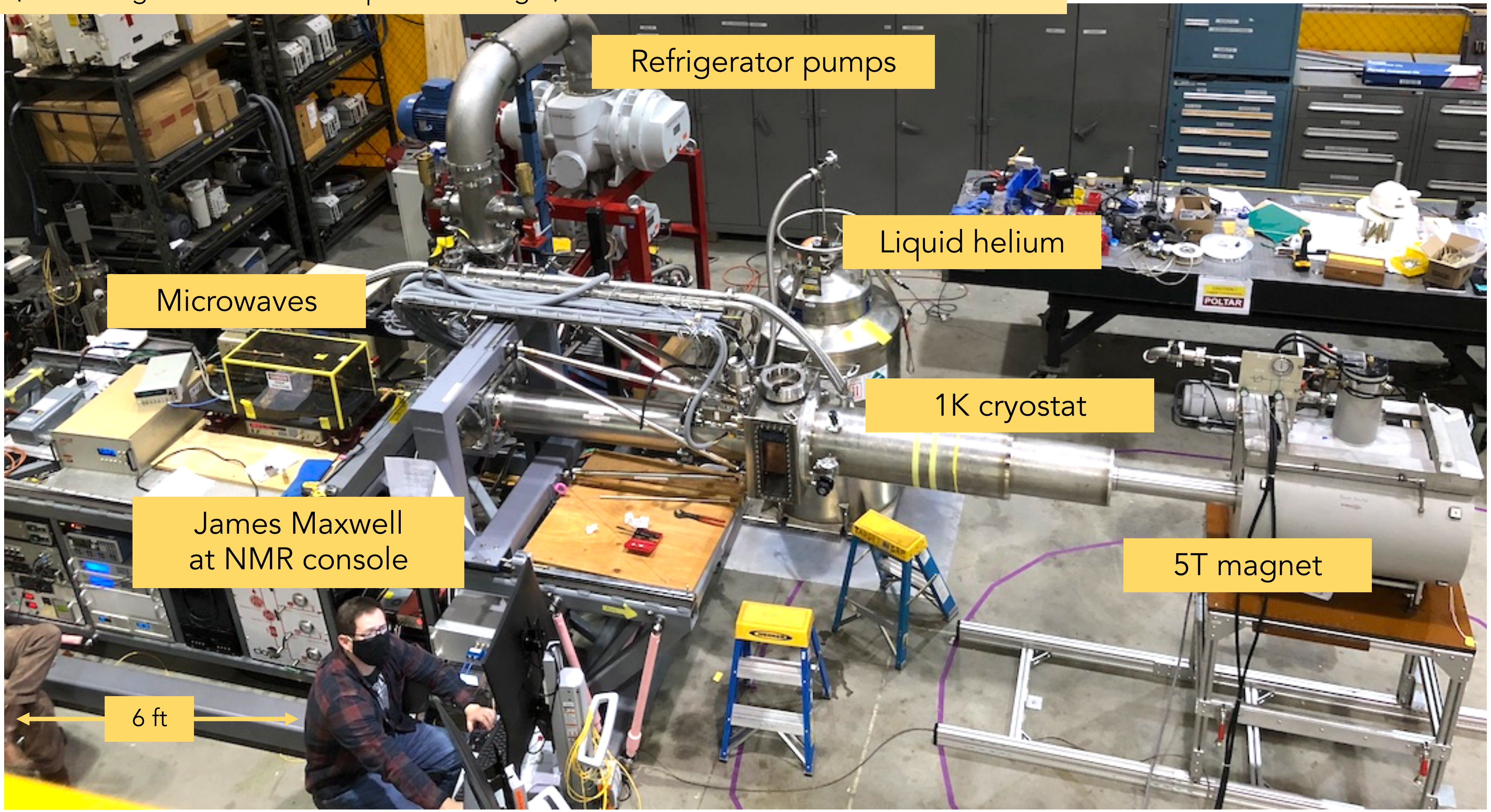




RGC polarized target

Latest tests in the 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

RGC polarized target

– Three Goals –

Loading and unloading of multiple target samples

High polarization of “standard” DNP target materials

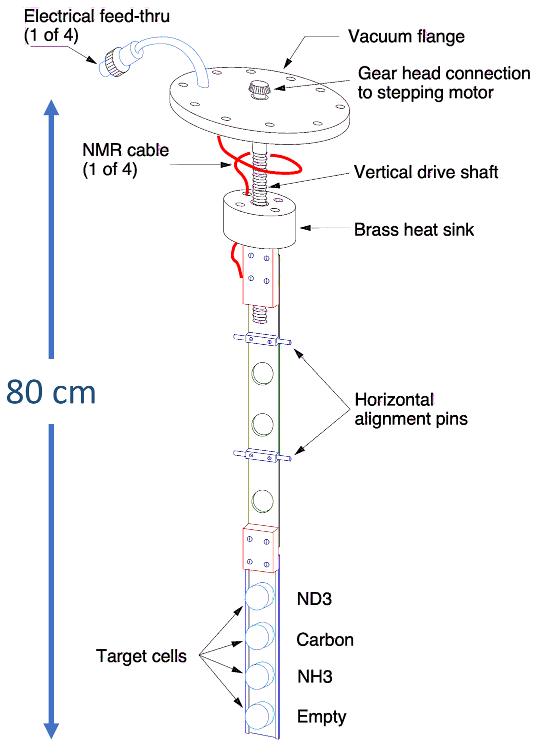
Accurate measurements of polarization w/ new JLab NMR System

RGC polarized target

The long, horizontal geometry of the RGC target makes loading and unloading of the ammonia samples very tricky.

In the original 6 GeV polarized target, the samples were attached to a ~0.8 m long stick that was inserted vertically into the bath of superfluid helium.

For the RGC target, this stick would need to be 4 m long and inserted horizontally.



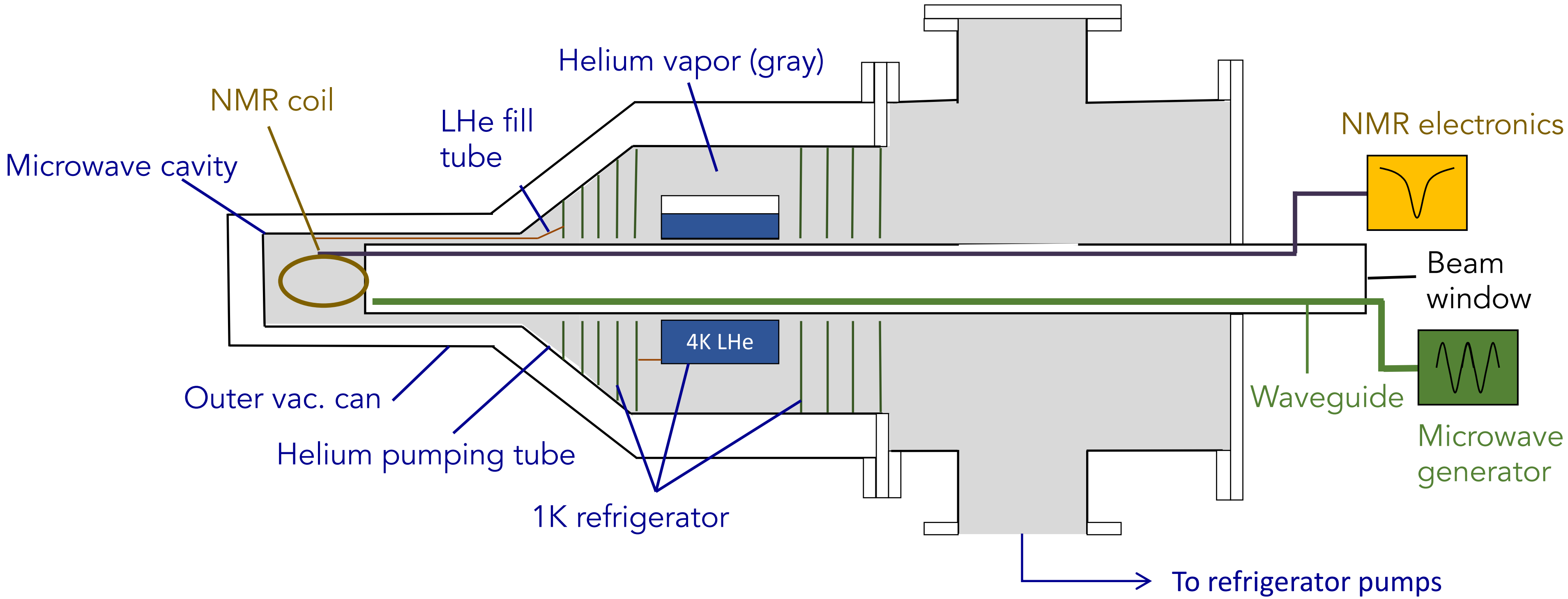
6 GeV polarized target insert for CLAS

Mock-up of similar insert needed for RGC polarized target

RGC polarized target

We intend to load and unload target samples in a rather novel manner…

The sample is placed into an *internal bath* for liquid helium that is then *moved to the in-beam position* and cooled to 1 K



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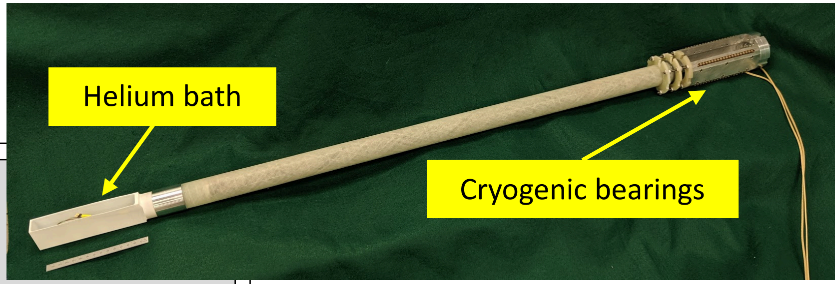
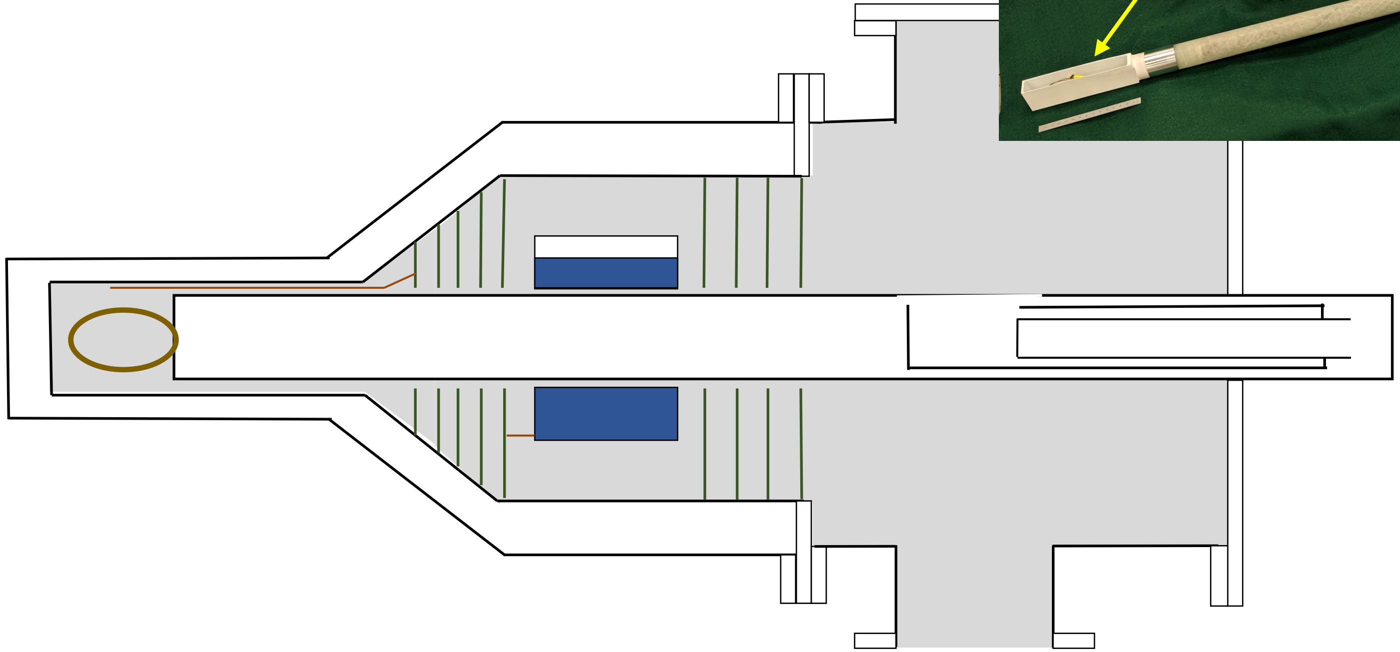
Credit: James Brock

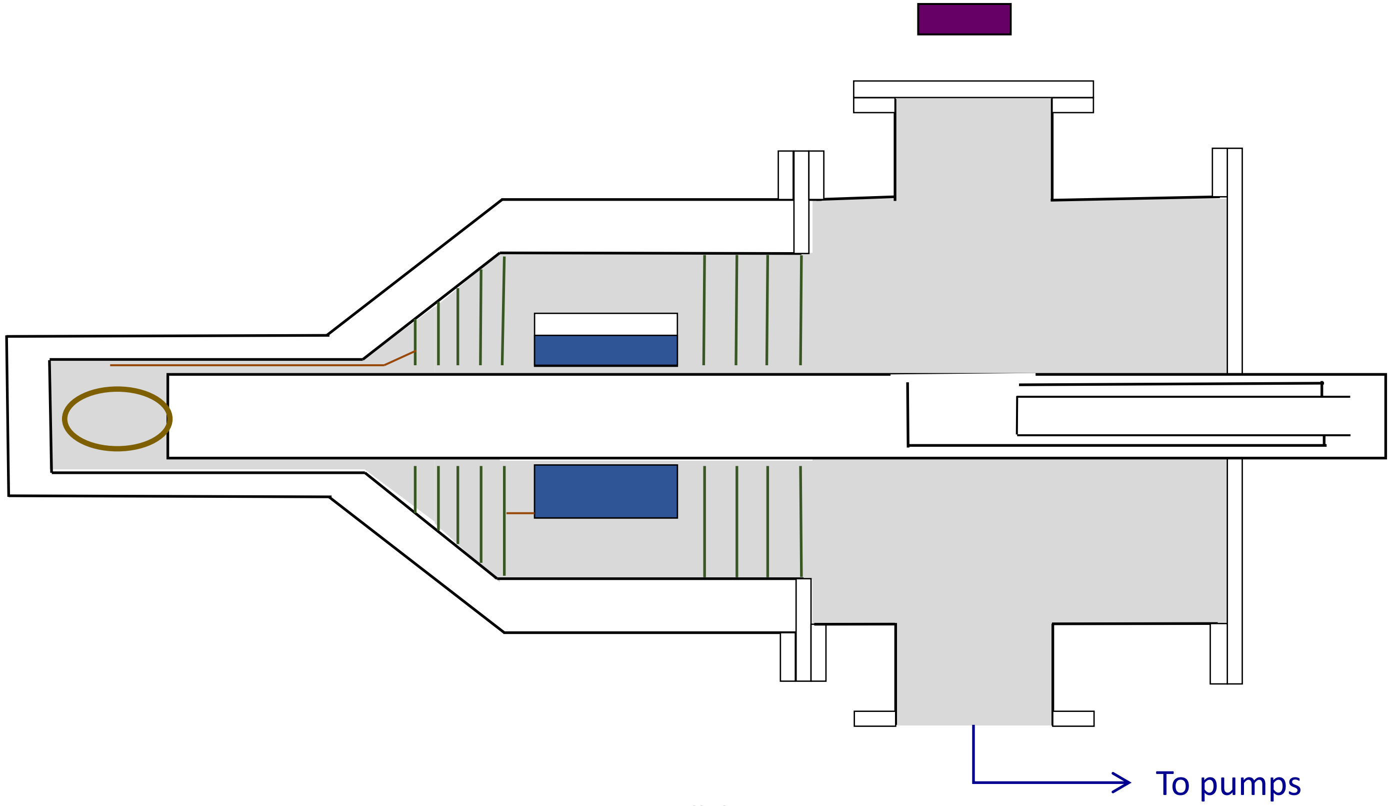




RGC polarized target

Preloaded ammonia "cartridges" are placed into the sample insert in the retracted position via a dedicated loading port.

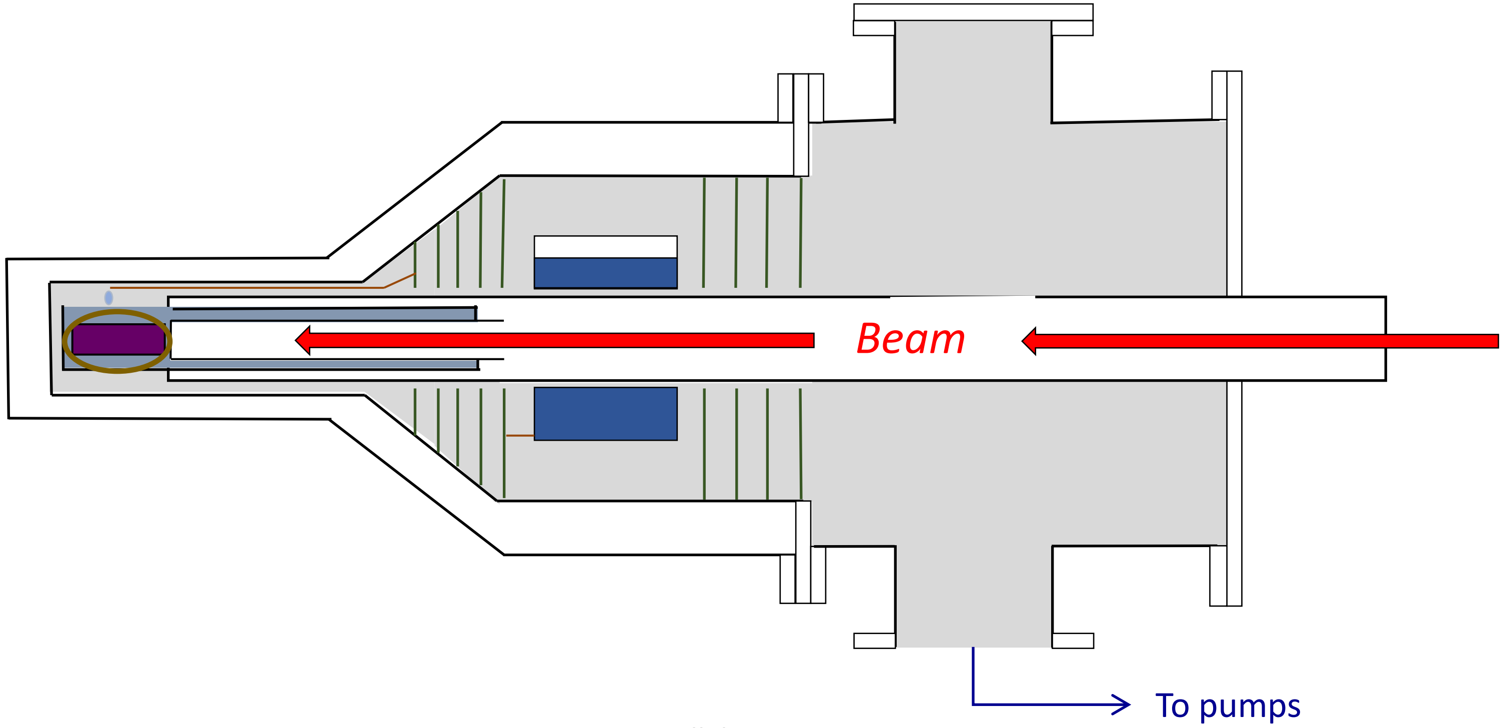
The sample is then moved into the center of the microwave cavity and NMR coil.



RGC polarized target

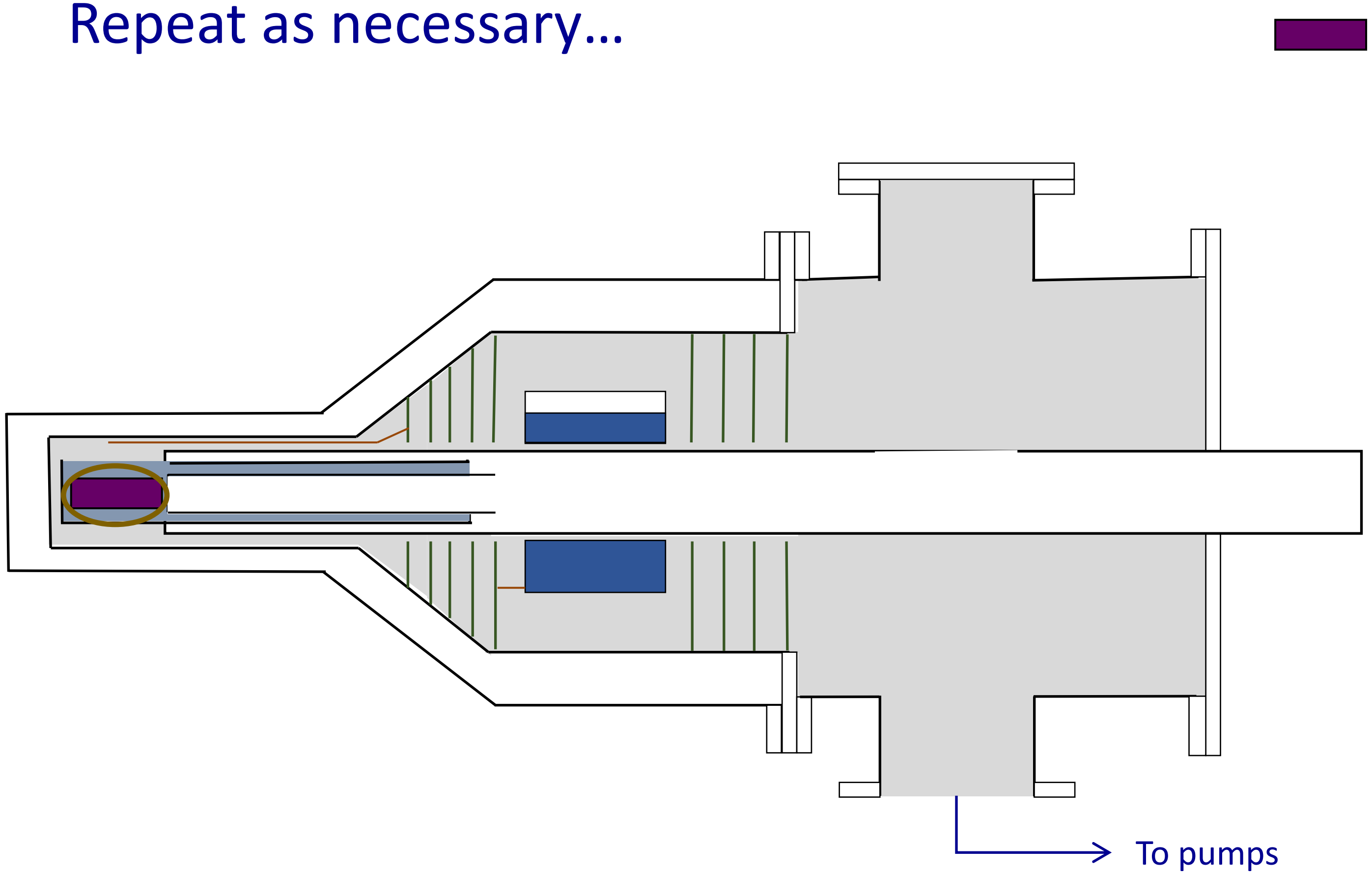
The sample insert is fill with 1K LHe from the refrigerator and the ammonia is dynamically polarized.

Ready for beam!



The sample is unloaded and replaced by a fresh sample in the same manner.

Repeat as necessary…



RGC polarized target

Loading & unloading of target samples

- Start w/ the cheap and easy stuff
- Progress to material that is expensive & melts (or sublimates) at non-cryogenic temperatures

At each step:

- Calibrate NMR with thermal equilibrium polarization (<1%)
- Measure maximum polarization and polarization rate

Two-part epoxy + TEMPO
Sample #1
Inexpensive, easy to prepare & handle
Moderate polarization

x 2

↓

Two-part epoxy + TEMPO
Sample #2
One-year old - (does it still work?)

↓

Frozen Butanol + TEMPO
Inexpensive, difficult to prepare & handle
High polarization

↓

Frozen d-Butanol + TEMPO
Expensive, difficult to prepare & handle
Low polarization

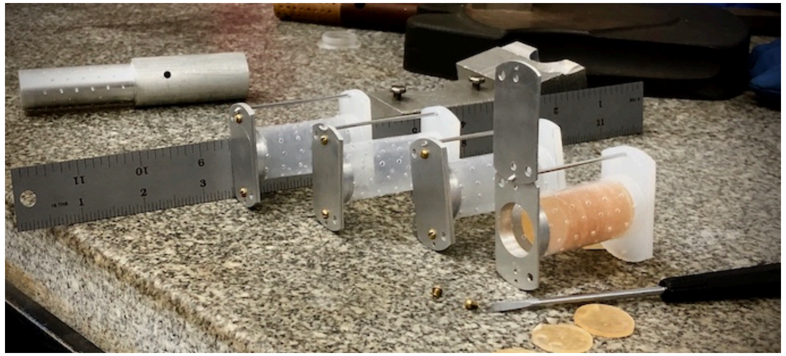
↓

Irradiated NH3 (UVa)
Expensive, very difficult to prepare & handle
High polarization

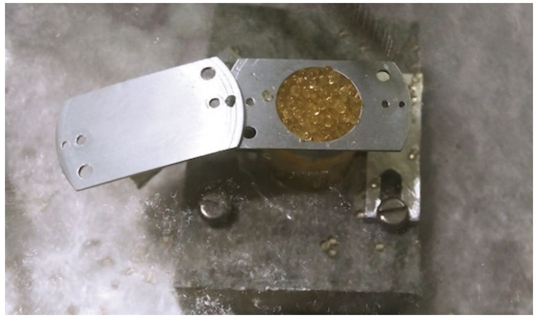
RGC polarized target

Target Loading and Unloading

- Retraction of 1K bath of superfluid
- Replacement of cold target samples
- Insertion and cooling of bath



Target sample cells (⌀2 x 5 cm^2)



Frozen butanol beads

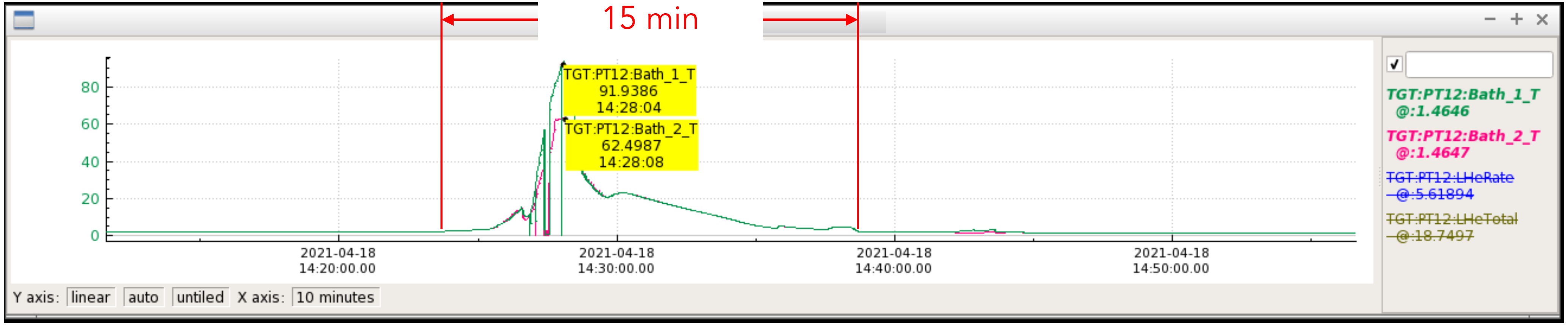
Sample grabber

Sample loading

Sample in bath

Loading & unloading of target samples went quite well

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



A few lessons we learned

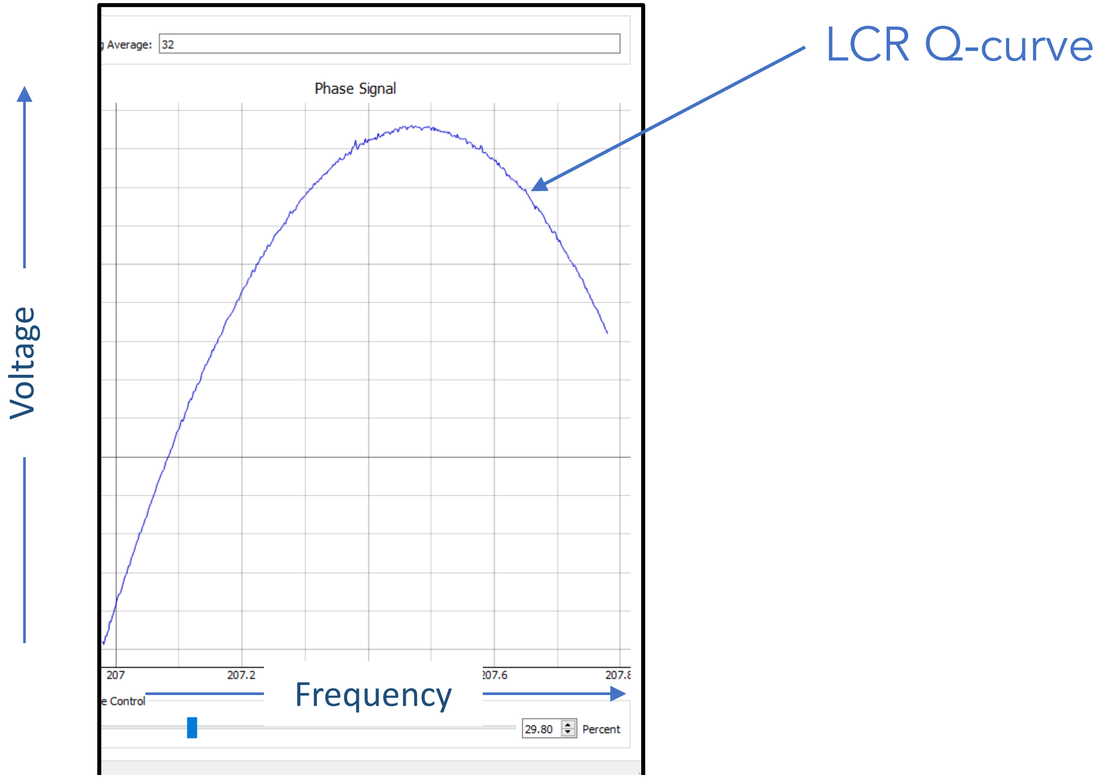
- We dropped one sample inside the refrigerator (epoxy, easy to retrieve)
- We need a stronger helium purge
- Wait longer for liquid nitrogen to drain from target cell

Stable and accurate NMR

- Measure & replicate the thermal equilibrium (TE) polarization signals used to calibrate the NMR systems

Our CW-NMR system is a simple LCR circuit tuned to the nuclear Larmor frequency.

Sweeping RF through the resonance frequency generates the LCR circuit response (“Q-curve”)…



What the signal should look like…

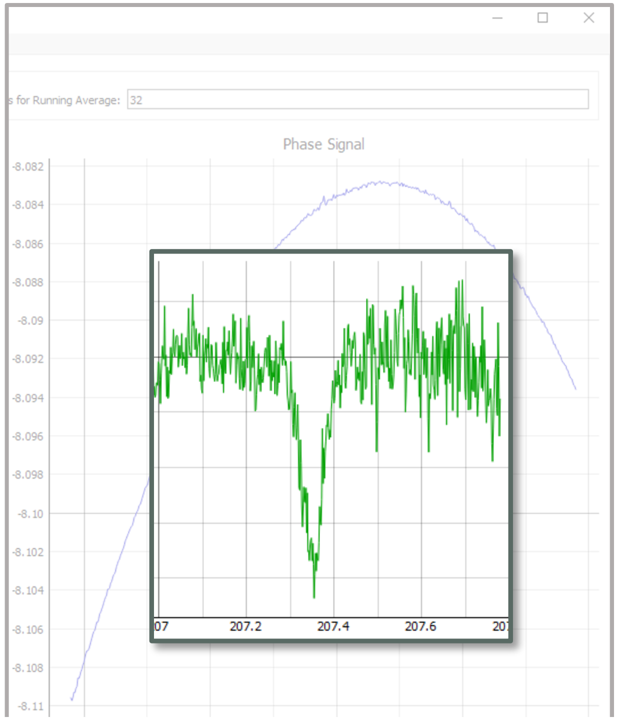
Stable and accurate NMR

- Measure & replicate the thermal equilibrium (TE) polarization signals used to calibrate the NMR systems

Our CW-NMR system is a simple LCR circuit tuned to the nuclear Larmor frequency.

Sweeping RF through the resonance frequency generates the LCR circuit response ("Q-curve")…

… with the NMR signal superimposed.



A tiny TE calibration signal buried inside the Q-curve.

Stable and accurate NMR

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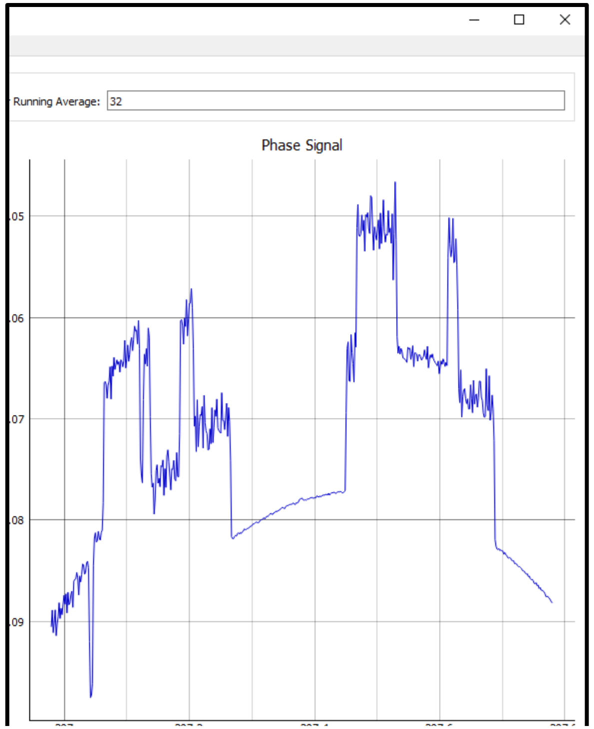
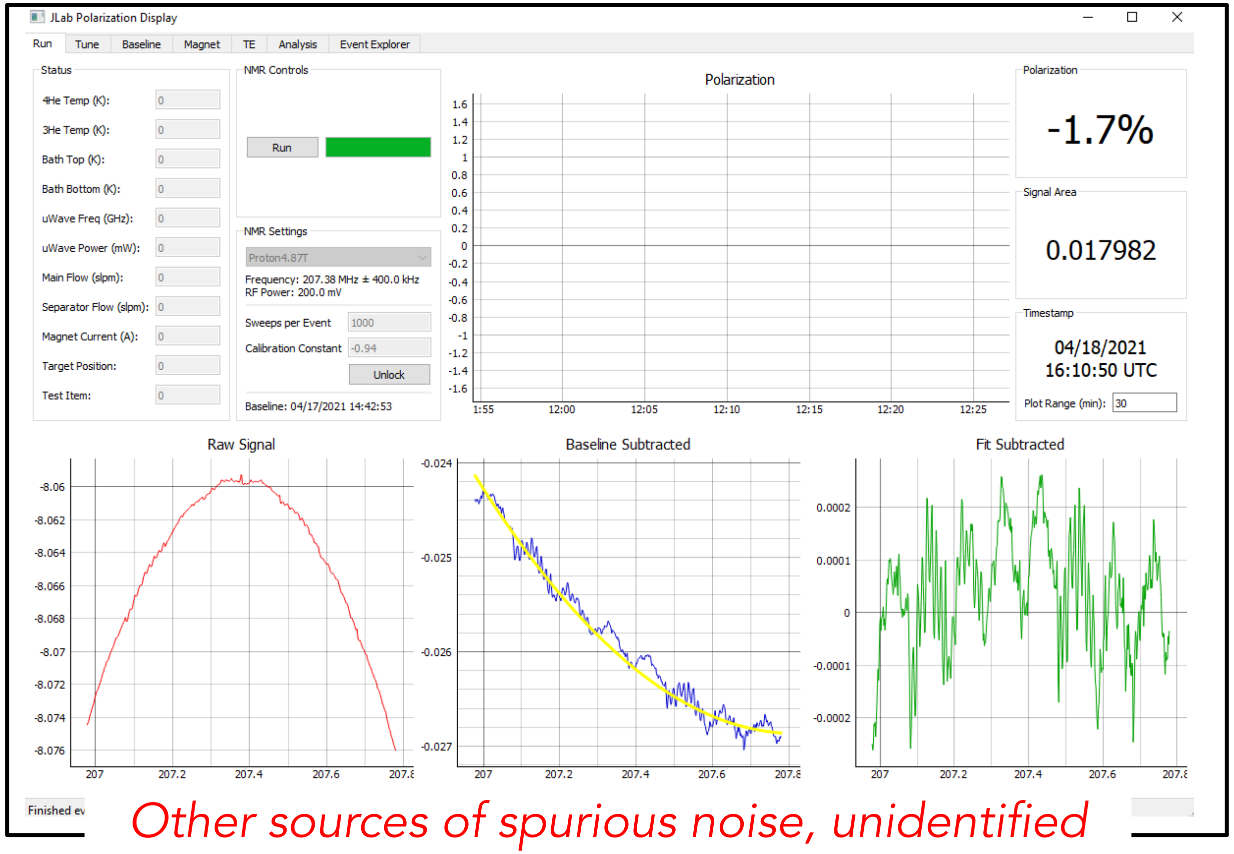


What it looked like when people used their cell phones

Stable and accurate NMR

- Measure & replicate the thermal equilibrium (TE) polarization signals used to calibrate the NMR systems

Unacceptable levels of noise limited the precision of NMR calibration measurements (aka “TE signals”)



Other sources of spurious noise, unidentified

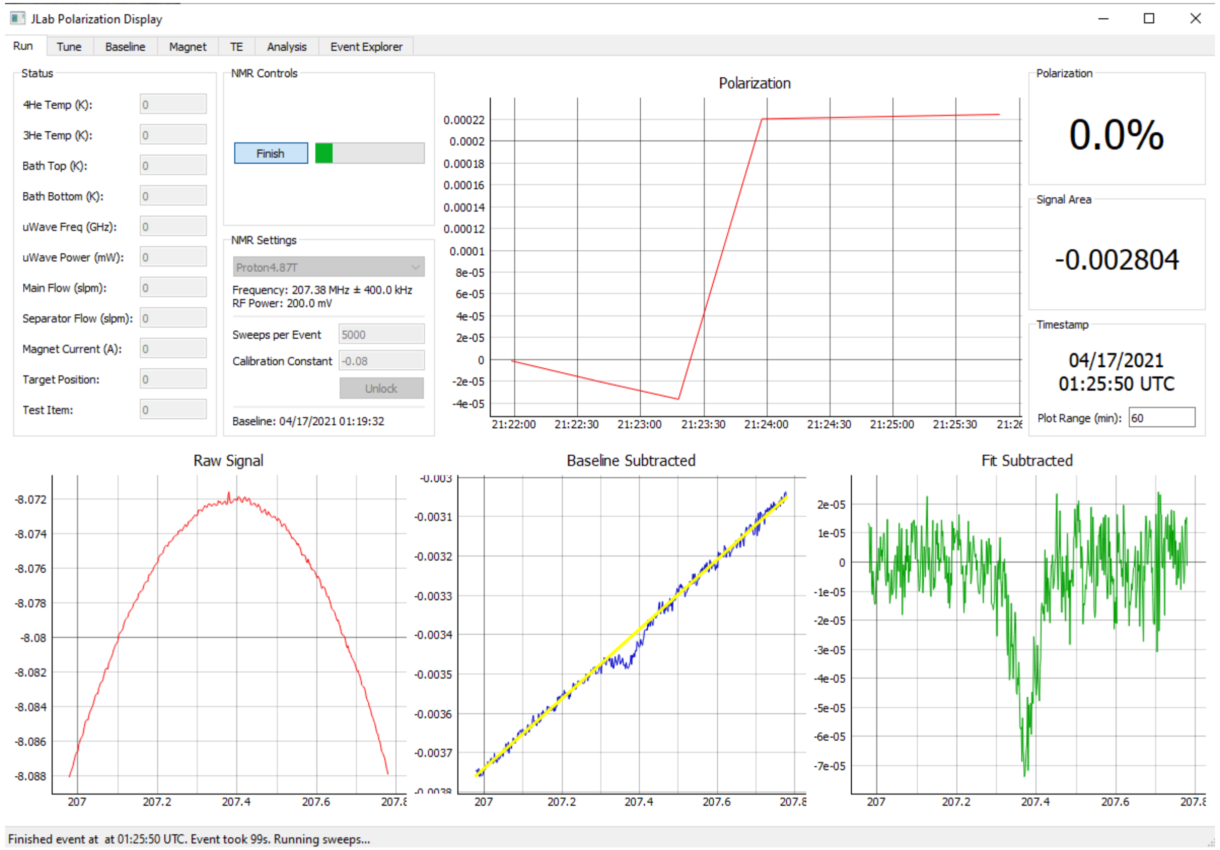
Stable and accurate NMR

- Measure & replicate the thermal equilibrium (TE) polarization signals used to calibrate the NMR systems

Despite the noise, we did manage to acquire TEs on epoxy and butanol samples, albeit with poor accuracy, ~10%

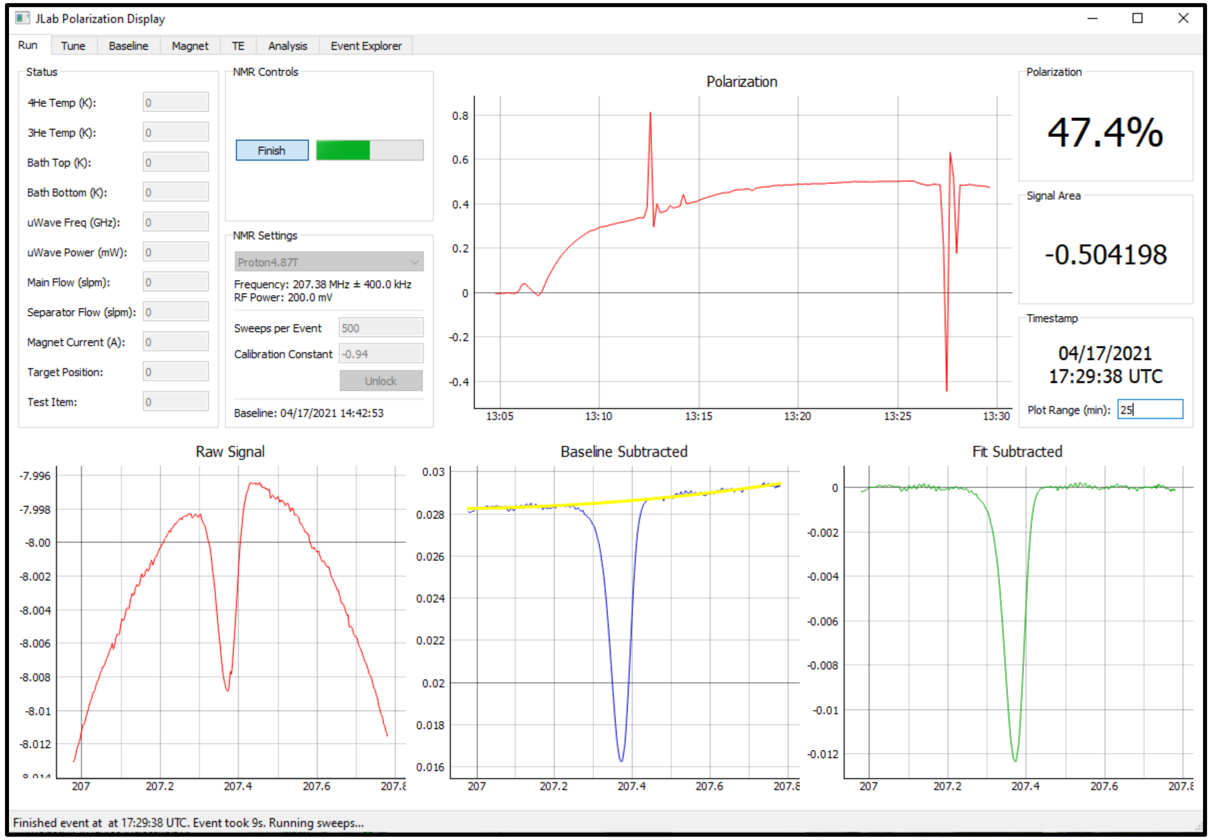
James Maxwell's new NMR software package (Python) worked great!

- Highly intuitive
- Significantly faster
- Nice analysis features



High Dynamic Polarization

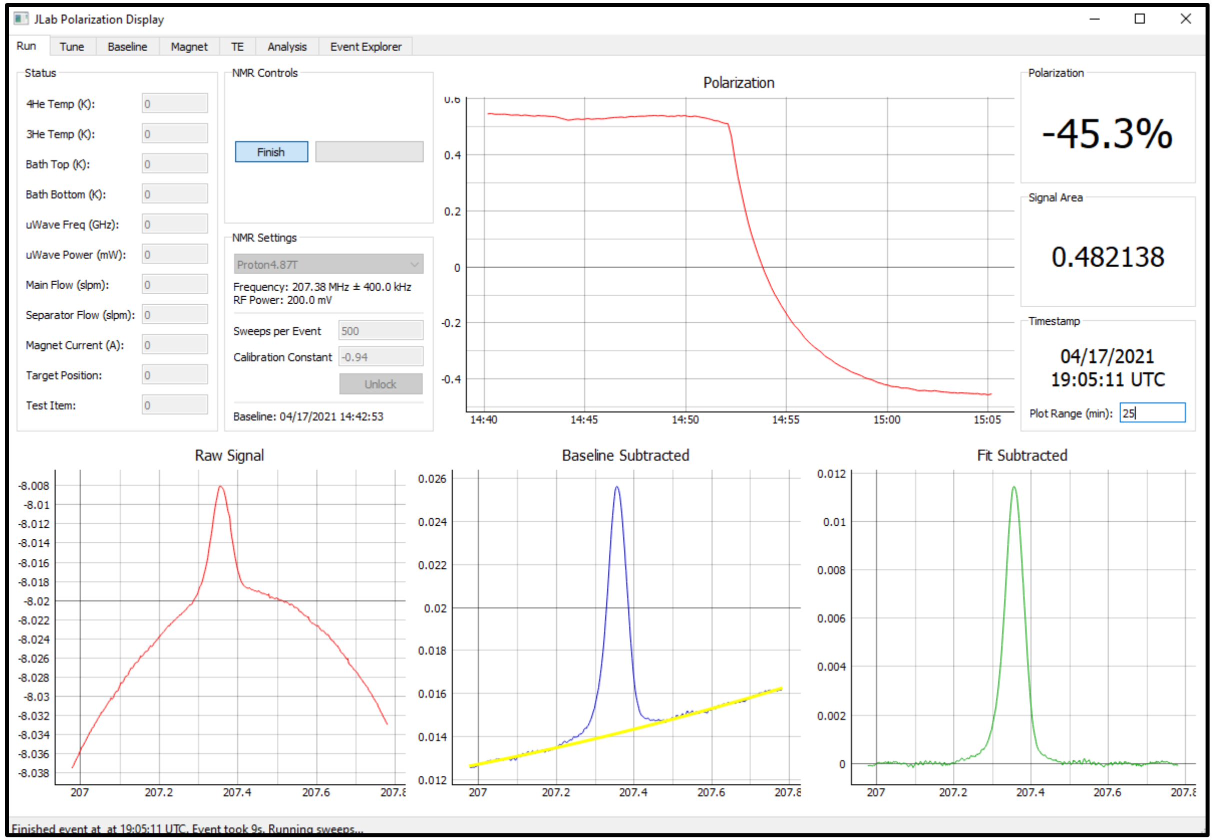
- Two-part epoxy + TEMPO



- Glitches in the polarization growth curve are due to cell-phone noise
- *We eventually reached +56%*

High Dynamic Polarization

- Two-part epoxy + TEMPO

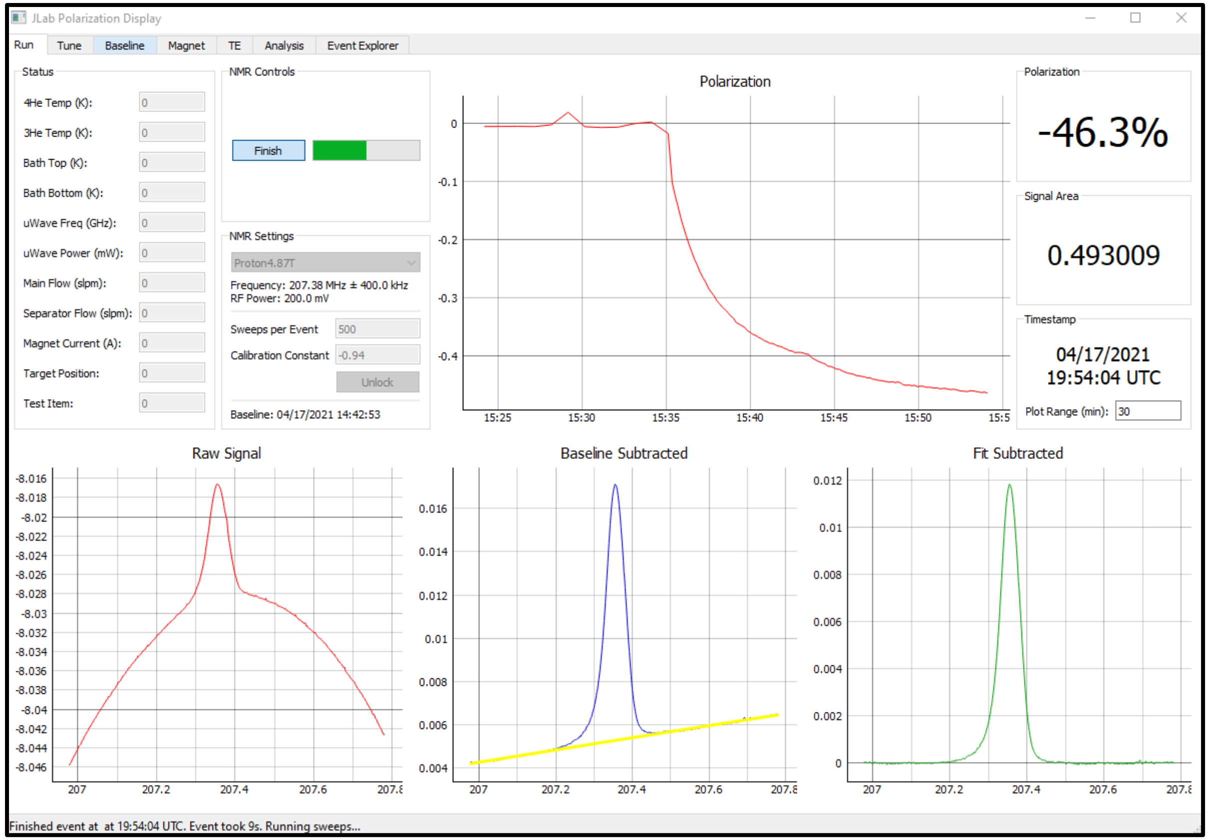


Reverse the polarization:

+56% ➔ -45% in 13 minutes

High Dynamic Polarization

- Two-part epoxy + TEMPO

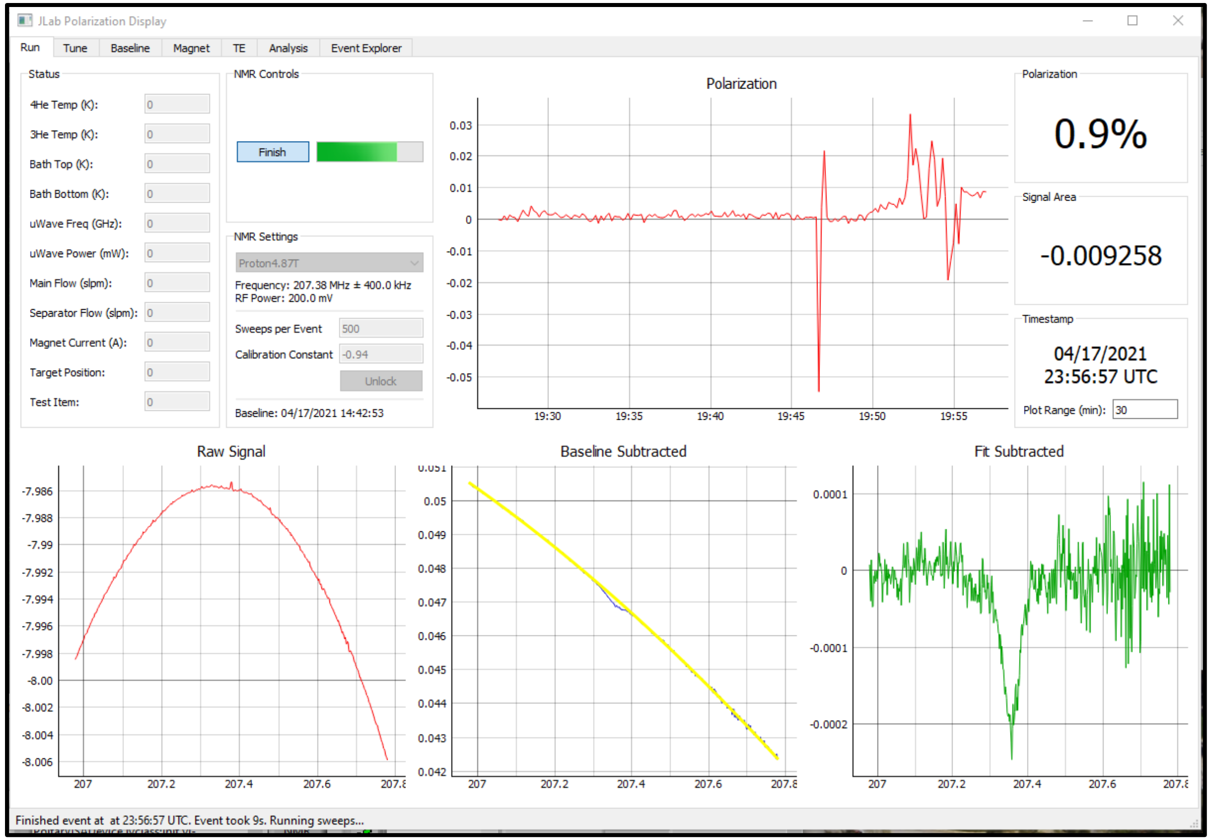


Remove sample from 'fridge then put it back:

➔ *Consistent polarization*

High Dynamic Polarization (one-year old)

- Two-part epoxy + TEMPO

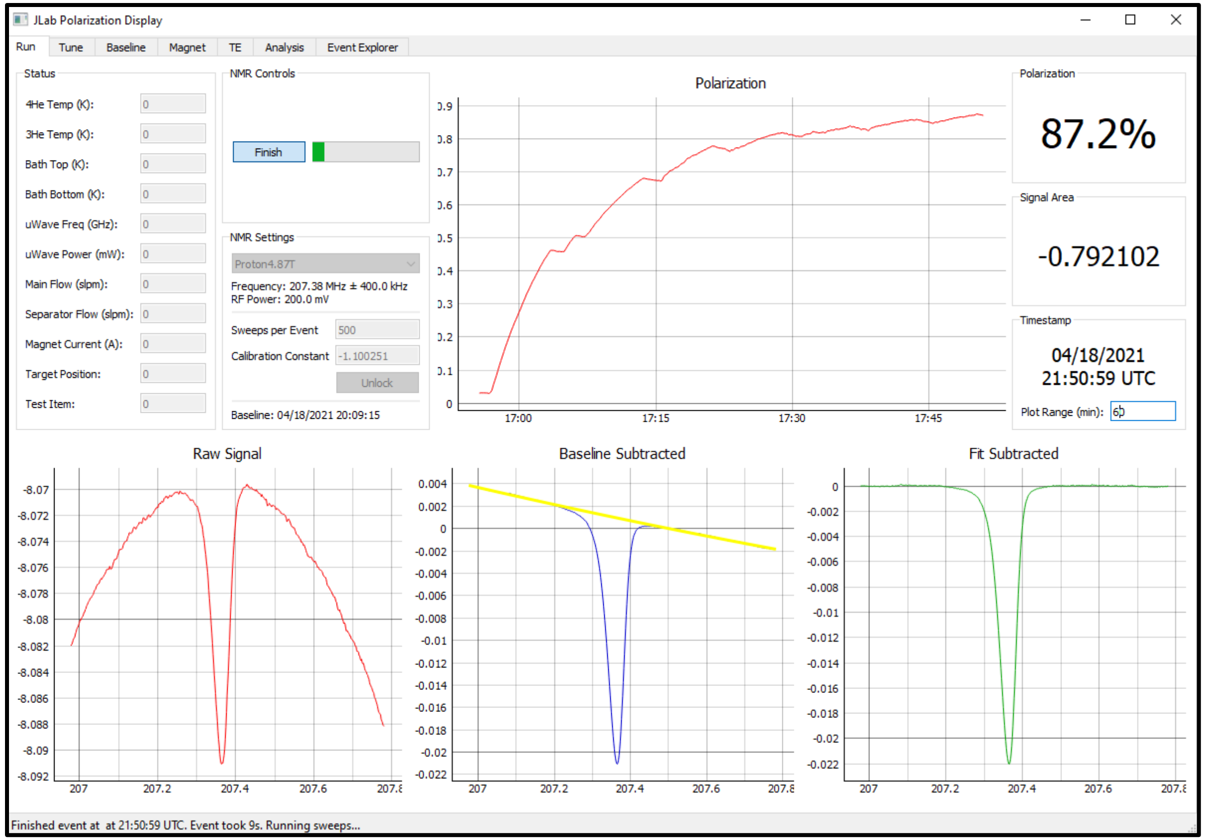


The one-year old epoxy sample did not polarize, probably due to degradation of TEMPO.

RGC polarized target

High Dynamic Polarization

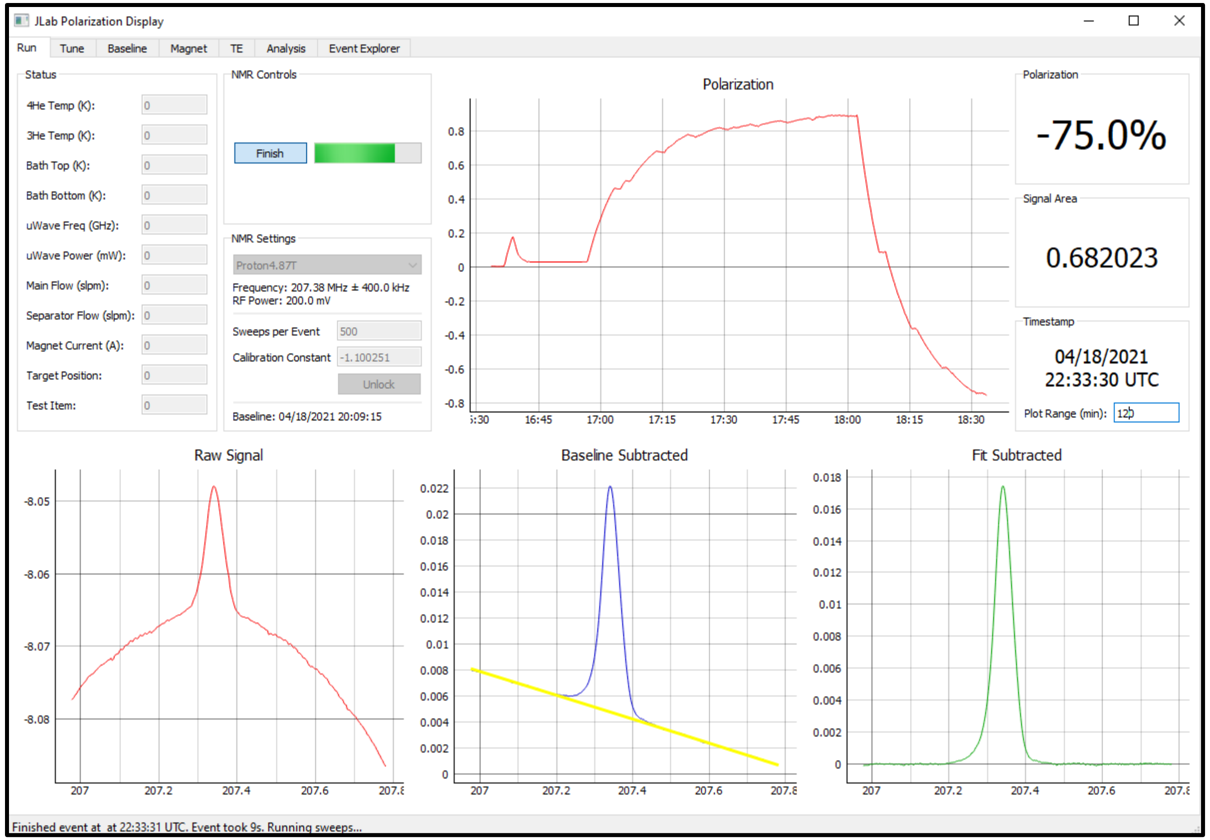
- Butanol + TEMPO



Butanol reached +87%
in about 50 minutes

High Dynamic Polarization

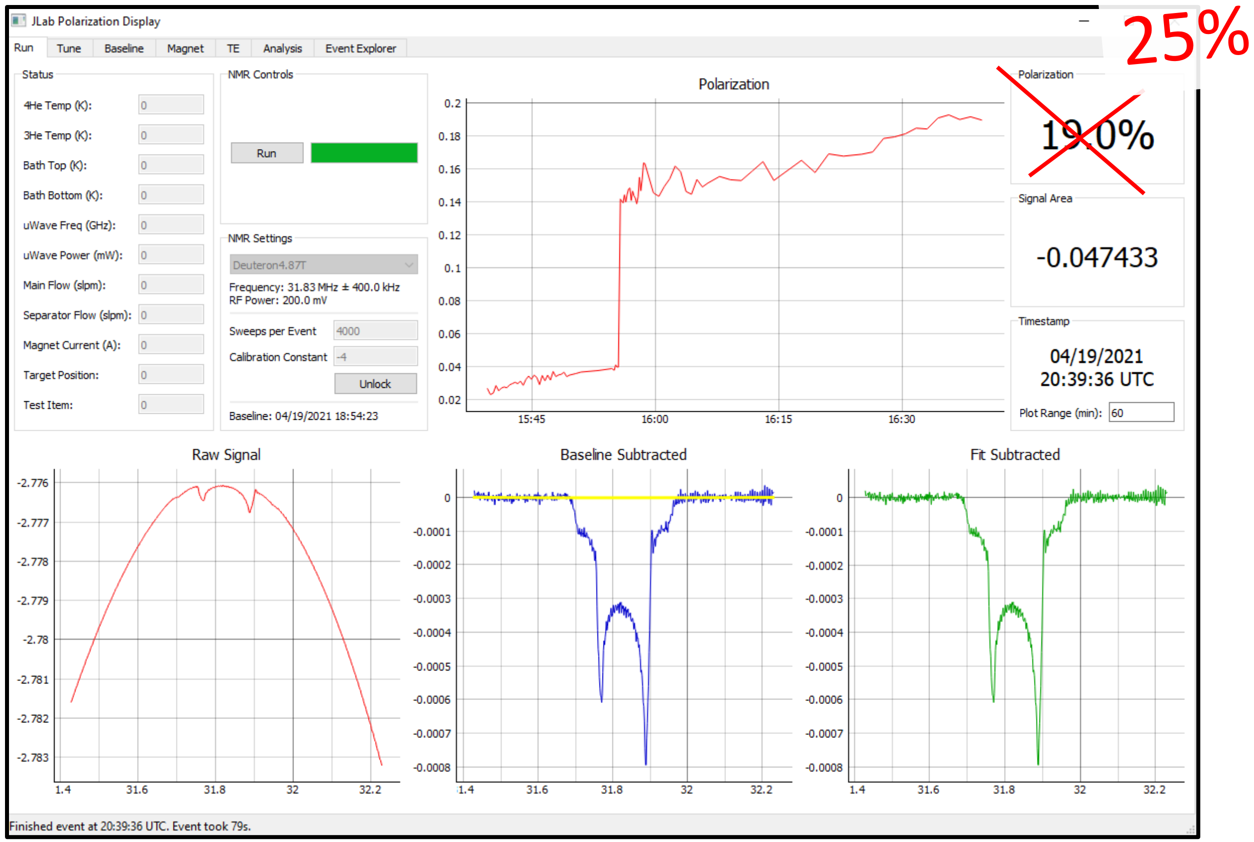
- Butanol + TEMPO



Reverse polarization to -75% in about 30 minutes

RGC polarized target

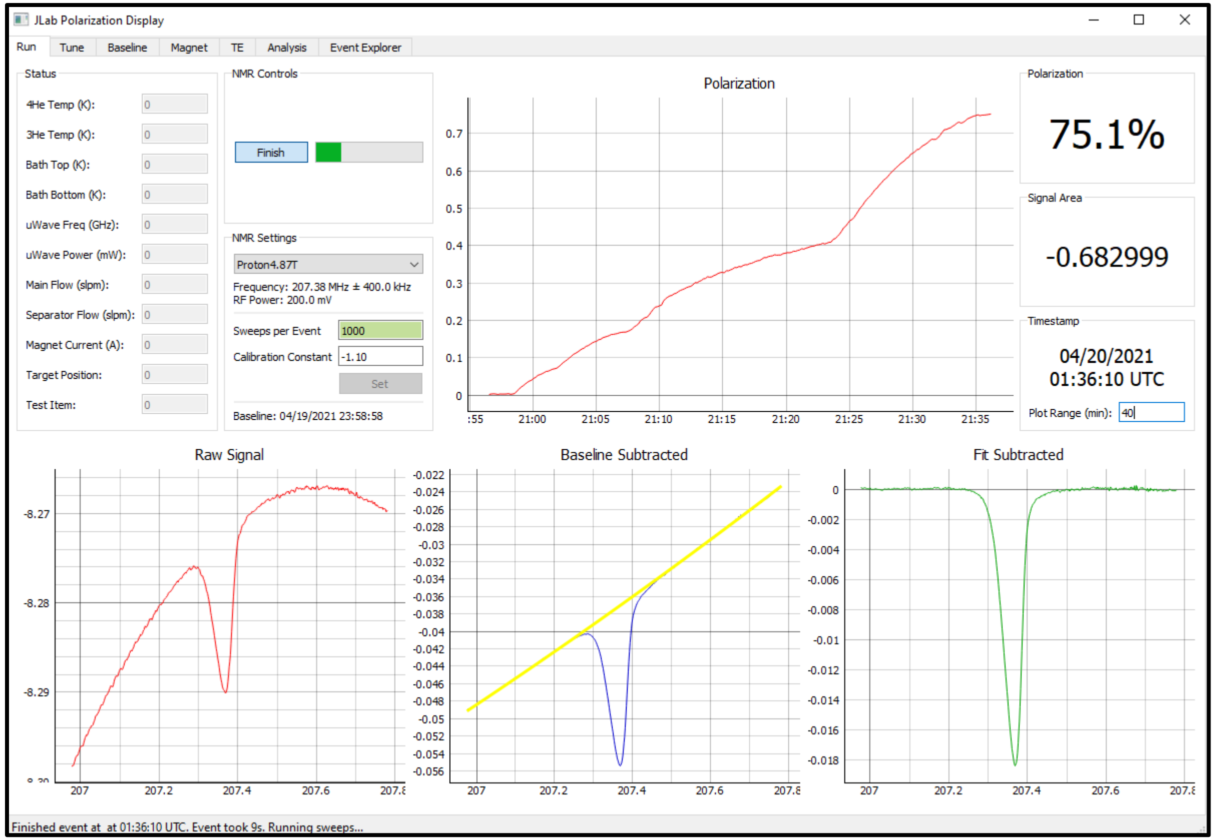
High Dynamic Polarization
- Deuterated-butanol + TEMPO



- Measuring the TE signal of d-butanol was hopeless (<0.1%)
- *Polarization can be estimated by the relative heights of the two peaks*

RGC polarized target

High Dynamic Polarization
- Irradiated NH3 (courtesy of UVa)



- No serious attempt to measure TE signal of ammonia sample. Polarization equilibrates too slowly.
- Use same NMR calibration constant for butanol (not a good idea…)

➢ *75% in ~40 minutes*

RGC polarized target

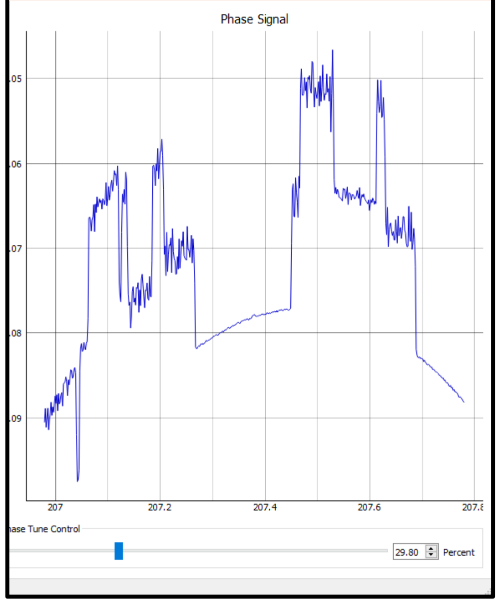
The latest test of the polarized target for CLAS12 went *mostly* ok

- 1K refrigerator continues to work well (high performance, low LHe consumption)
- Target loading and unloading went well
- We're getting reasonably good dynamic polarization
- NMR electronics and software show great promise
- NMR noise is a serious problem (James and Hai are on it!)

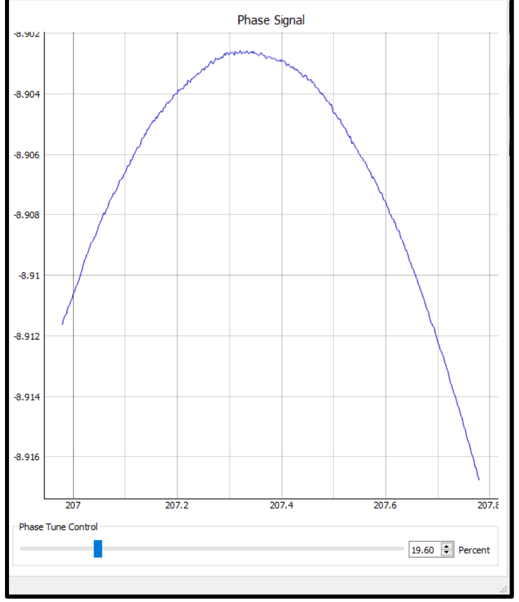
The latest test of the polarized target for CLAS12 went *mostly* ok

- 1K refrigerator continues to work well (high performance, low LHe consumption)
- Target loading and unloading went well
- We’re getting reasonably good dynamic polarization
- NMR electronics and software show great promise
- ~~NMR noise is a serious problem (James and Hai are on it!)~~ → Problem solved!

BEFORE



AFTER



Cell phone (and other) noise sources have been significantly reduced.

Currently equivalent to Liverpool Q-meters.

Further reduction expected.

RGC schedule

Remaining work for Polarized Target

- In-beam sample containers & bath
- Thin superconducting shim coils

Oct. 2021

- Thin-walled vacuum chamber
- Fabricate lower half of target cart

Dec. 2021

Installation in Hall B expected to commence March 7, 2022

- Eight weeks to install & commission the polarized target (1st time)

Work on the beamline and on other systems is well underway

Simulations with background are ongoing

We expect to be ready for beam on May 2, 2022!