

JLab Target Group R&D Progress

J. Maxwell



Tensor Collaboration Meeting
Newport News, VA
October 14th, 2025



Outline

- 1 Development Lab DNP Stand
- 2 NMR Development
- 3 Artificial Intelligence/Machine Learning
- 4 Python-based EPICS



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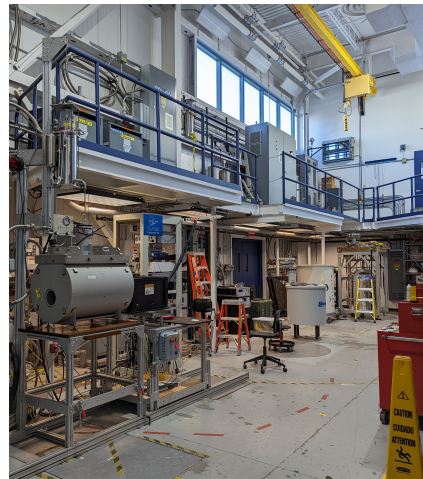
Dynamic Nuclear Polarization Tests at JLab

- Although we have one of the most experienced groups in the world, we have never had a dedicated DNP apparatus for tests!
- Our R&D performed in preparation for experiments in the halls:
 - For RGC: Horizontal fridge with trolley, removable cells, LAr anneals, new NMR system, tunable cold board NMR
- With irradiations coming to JLab, a facility to test materials and methods is crucial to our mission
- New lab space dedicated to Target R&D
- Work by J. Brock, C. Keith



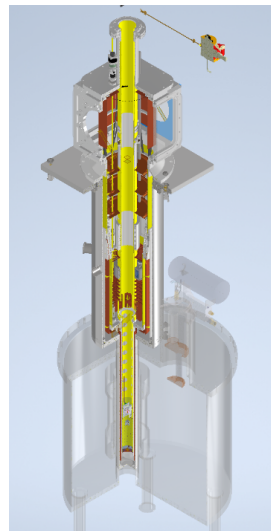
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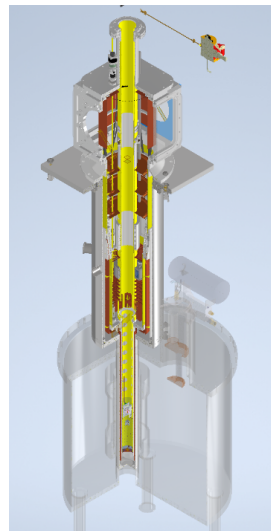
Development Lab DNP Stand Goals

- Polarize the same day of irradiation!
- A flexible, modular system to allow experimentation with many methods
 - RF manipulation, NMR, EPR, Microwaves, Inserts, Cells, Near-infrared Spectroscopy
- Key Challenge: Obtaining LHe at reasonable cost and in a timely manner
 - Cryogen-free magnets from now on!
 - Can't avoid the need for LHe in the fridge
- Early refrigerator designs were closed-loop with limited volume
- Open-recirculating system possible with supply and return from CTF!



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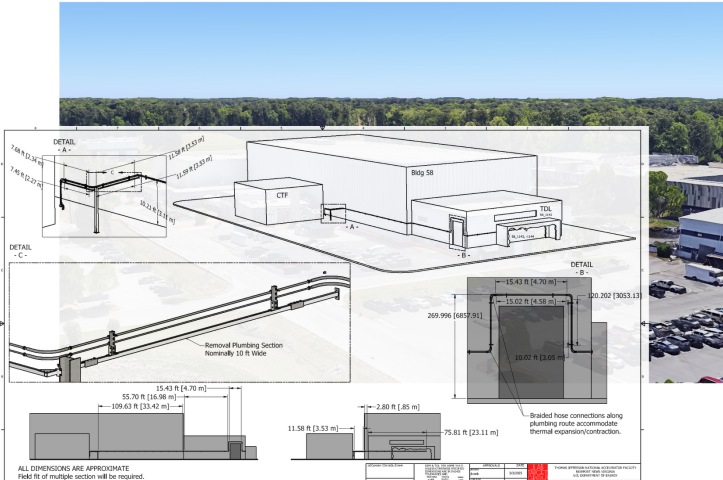
Delivering He to the Target Dev Lab



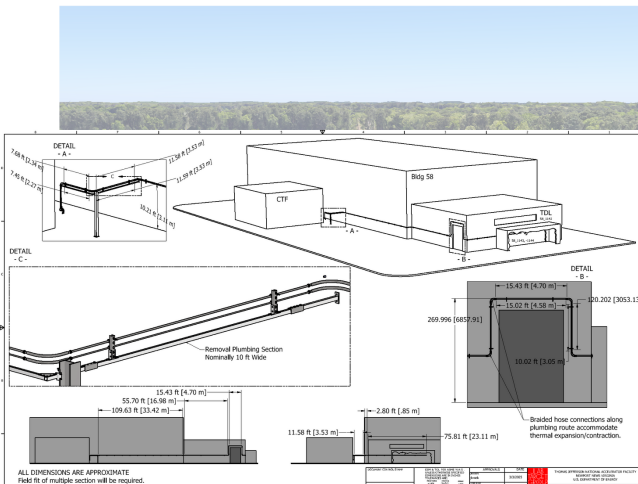
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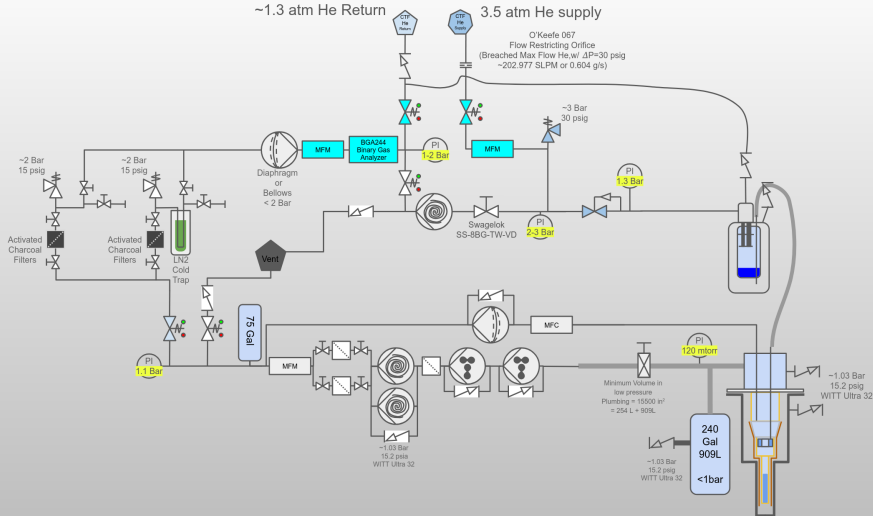


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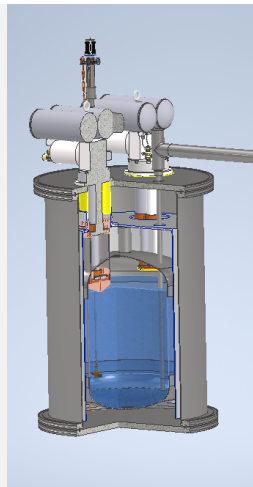
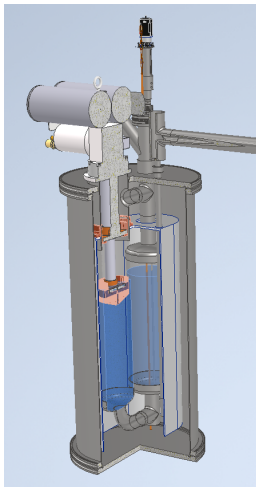
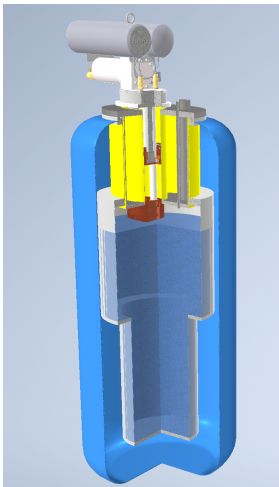


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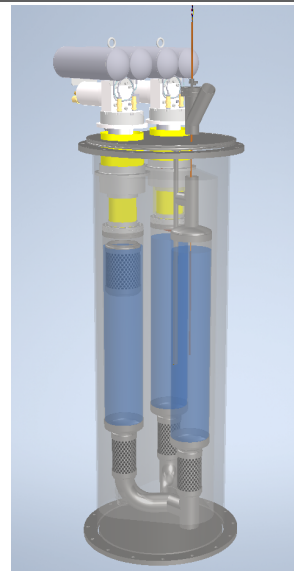


Liquifier Options



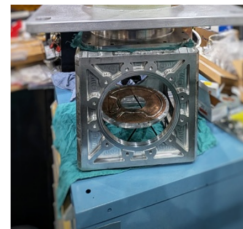
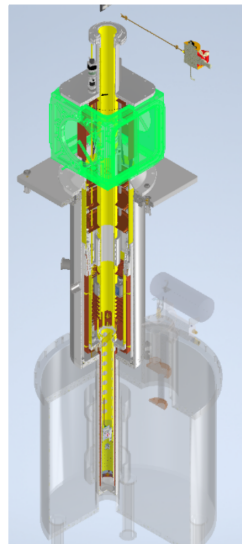
JLab ASME-Compliant Liquifier Dewar

- Reviewed several commercial and purpose-built liquifiers
- Under safety and engineering constraints, arrived at a JLab-built design
- Based around 2 PT425 Cryomech Pulse-tubes to provide >56 L/day
 - Volume from pipe for safety compliance
 - Volume of 42 LLHe
 - Boiloff ~ 1 L/day



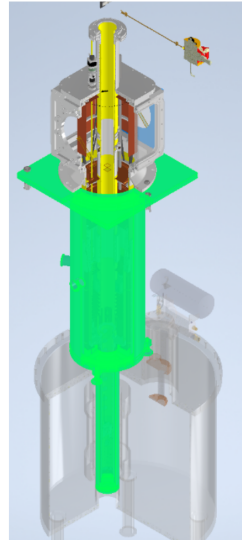
Refrigerator Progress

- Fridge is under construction!
- Modular pumping cross
- Outer vacuum
- Inner vacuum



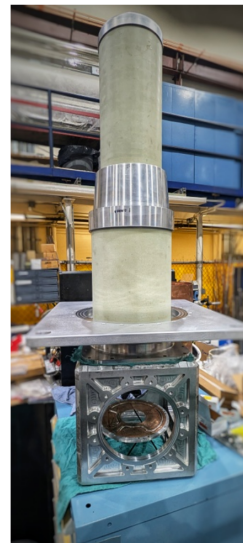
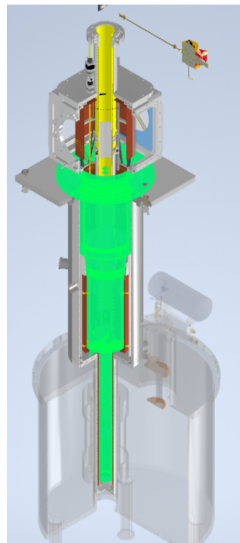
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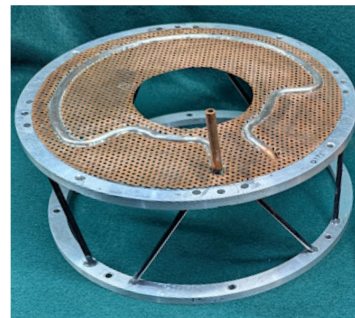
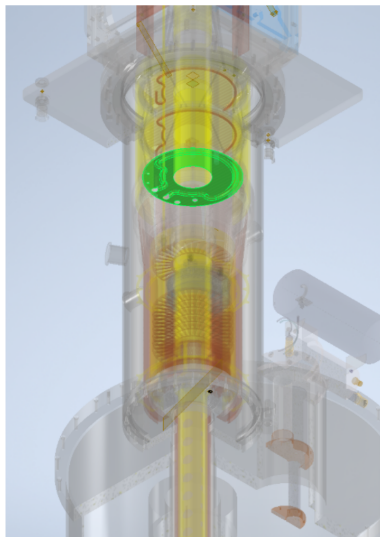
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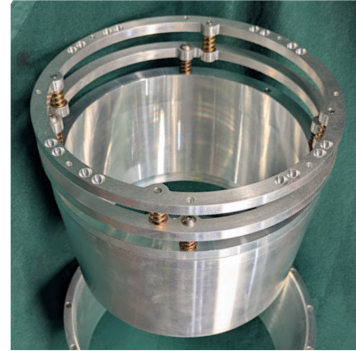
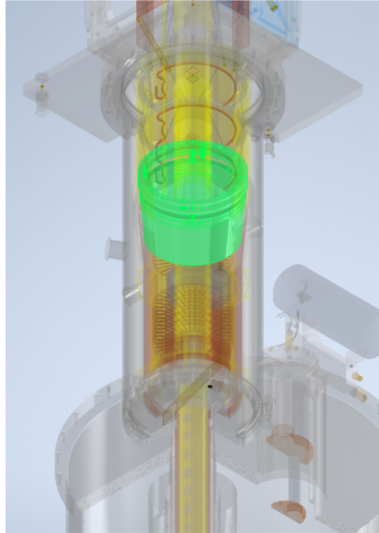
Refrigerator Progress

- Fridge is under construction!
- Upper baffles
- Conical heat exchanger
- Separator
- Lower baffles
- Valves
- Valve connection



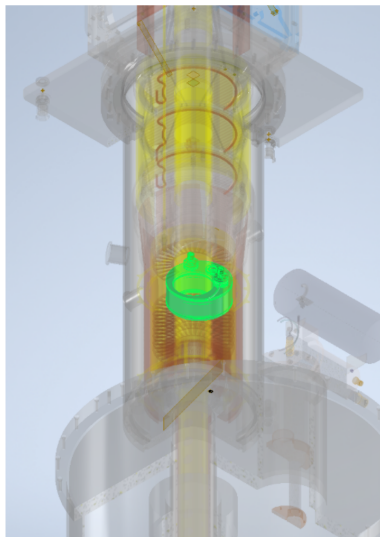
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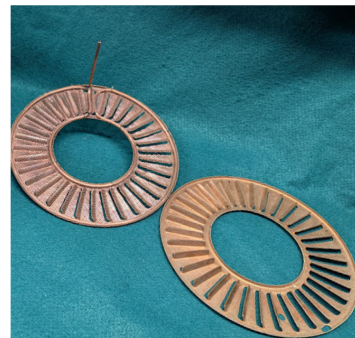
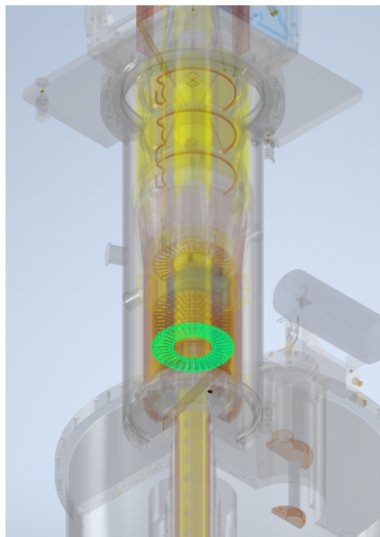
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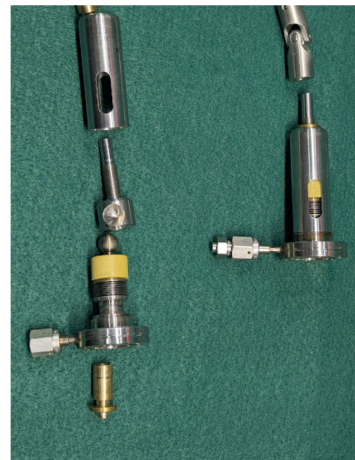
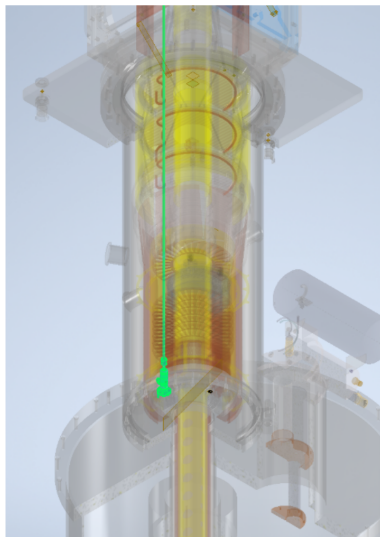
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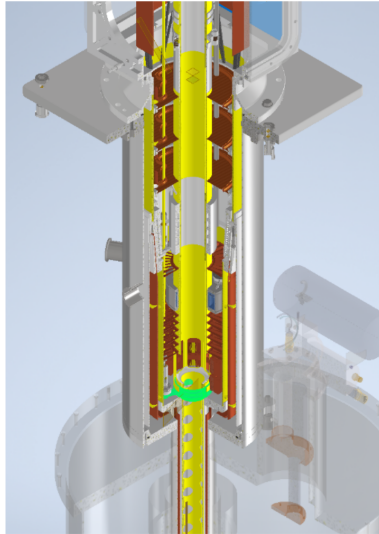
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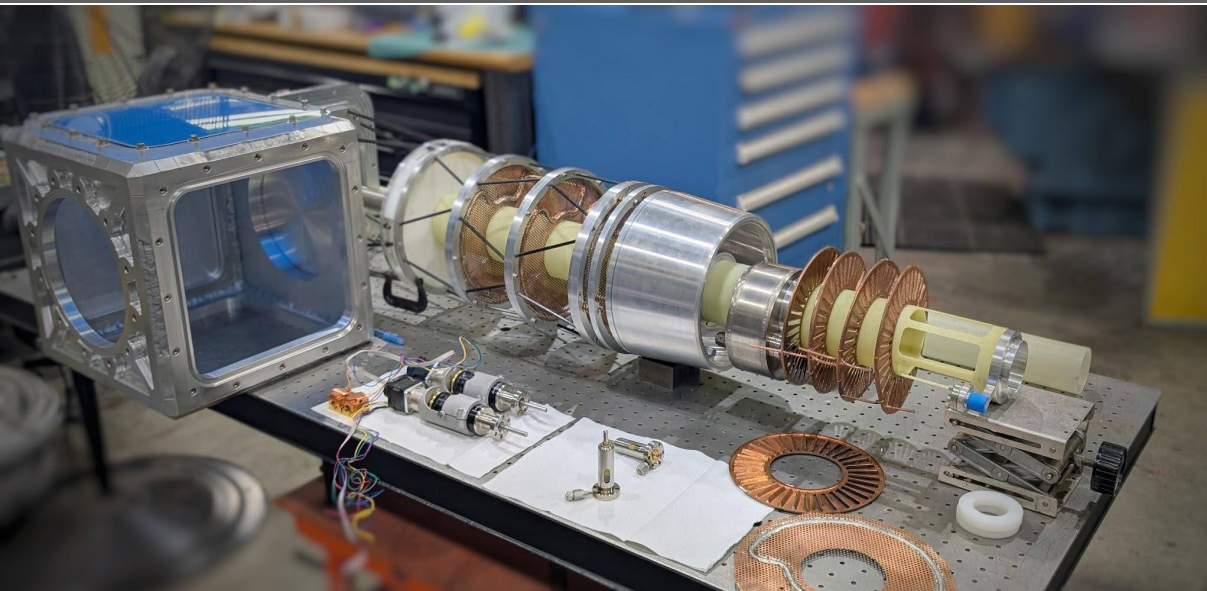
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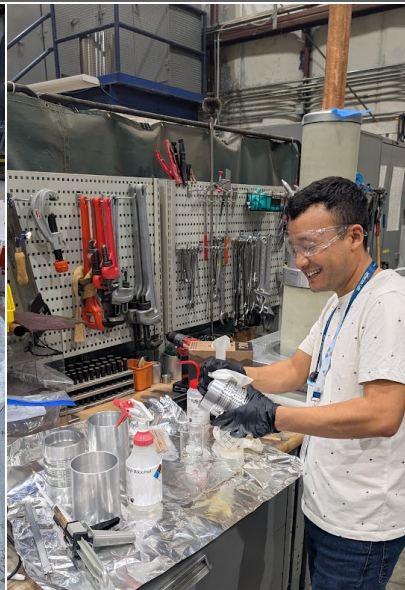
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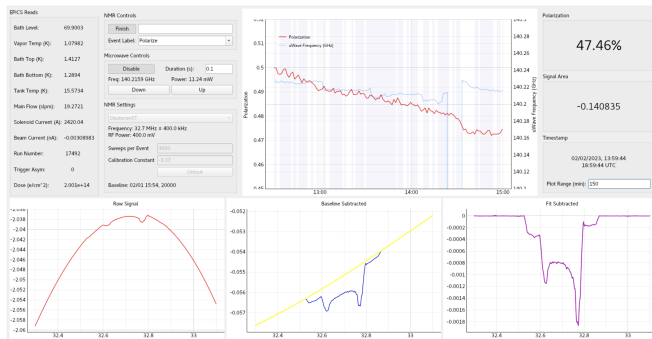
JLab NMR System Implemented for RGC, 2022

- Q-Meter Improvements:
 - New modular design
 - Improved gain blocks
 - Voltage phase, diode tuning
- DAQ Improvements:
 - FPGA control of tuning voltages
 - Direct synthesizer access for fast switching ($30\ \mu\text{s}$)
 - arxiv.org/abs/2506.14637
- Software Improvements:
 - Python-based system, with modular online analysis
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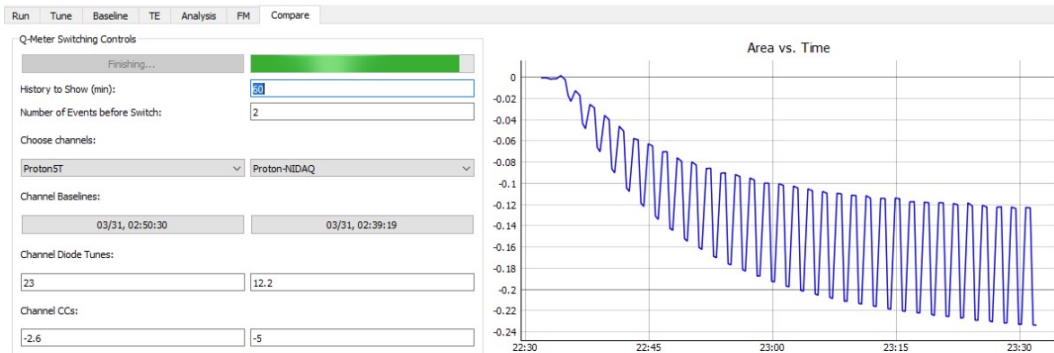


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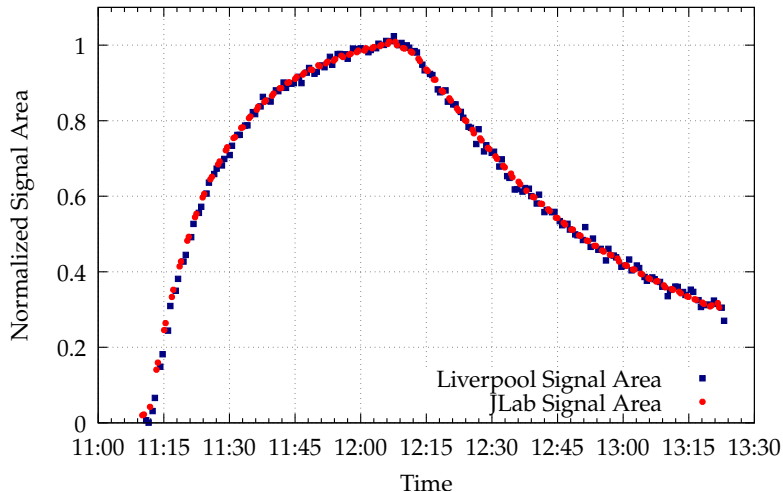
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Comparison with Liverpool



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Looking forward with JLab NMR

- 3 channels were made: 2 for RGC and 1 for ORNL
 - 4th channel under construction (H. Chinchay, C. Lama)
- Collaboration with ORNL to produce many more channels, improve industrial design (J. Pierce, M. Yurov)
- Important change: trigger based frequency switching to make system signal generator agnostic
 - VHDL change to output trigger already implemented (H. Dong)
- Overhaul of Python GUI software underway
- Next steps: Quadrature measurements, internal generator, all-digital implementation

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AIOP: AI Optimized Polarization

- Improve polarization for fixed target experiments at JLab through the use of automated AI/ML controls.
 - Two subprojects: Polarized Photon Source in Hall D, Polarized Targets
- Collaboration between EPSCI, Data Science, Target Group
 - T. Britton, T. Jeske, D. Lawrence, A. Kasparian, M. Rahman, M. Schram

Polarized Target Effort has focused on a couple narrow goals:

- Primary: ML control of microwave frequency with dose accumulation
- ML methods to improve NMR measurements
- BONUS: Relational database for long-term storage of NMR data

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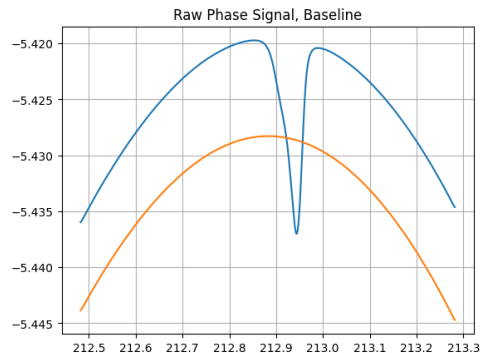
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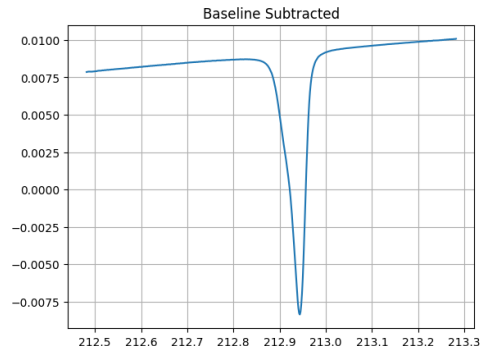
Integrating ML to NMR Analysis

- Proton NMR analysis method is well-understood:
 - Use baselines, taken without a polarization signal, to subtract away contribution of electronics
- Subtraction leaves residual, which could be important for very small signals: TEs!
- Where could ML contribute? Artificial baselines?
- Feeding baselines from data, lab
- [NMR Analysis Walkthrough, Python Deuteron Fit](#)



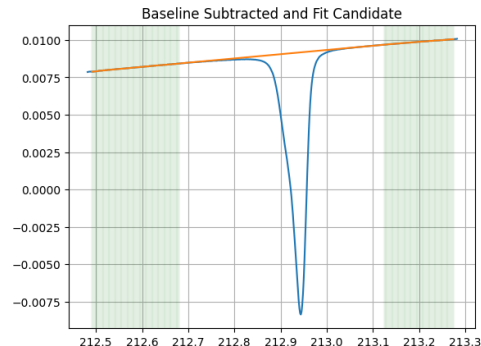
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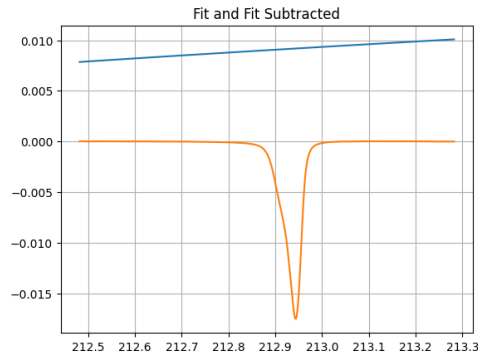
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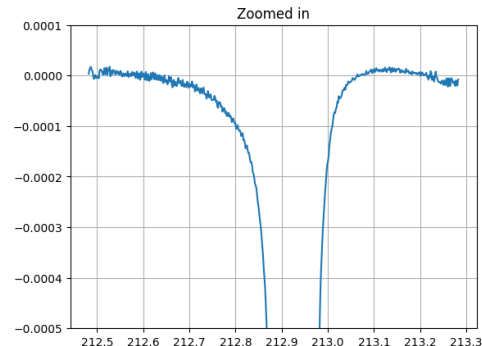
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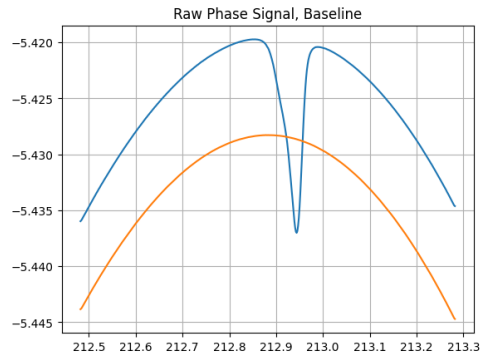
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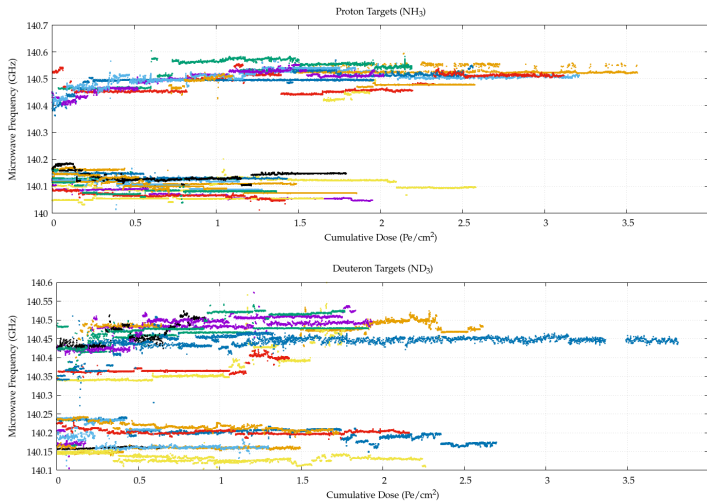


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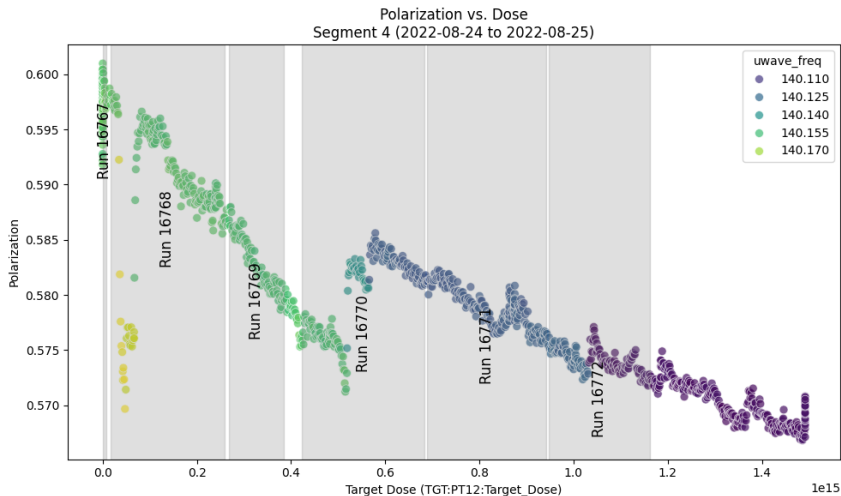
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Microwave Frequency Adjustment by Humans

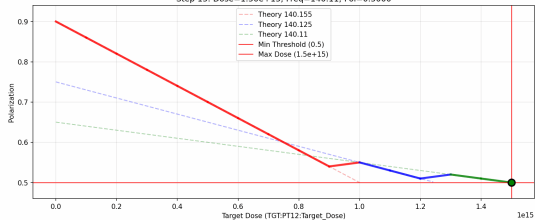


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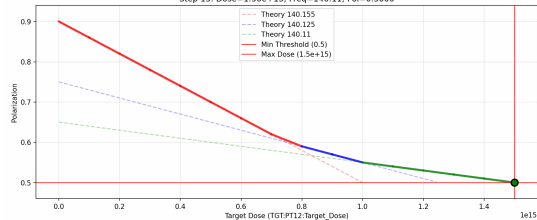
Polarization Environment - Dynamics

Step 15: Dose=1.50e+15, Freq=140.11, Pol=0.5000

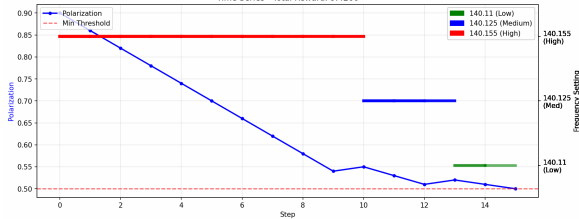


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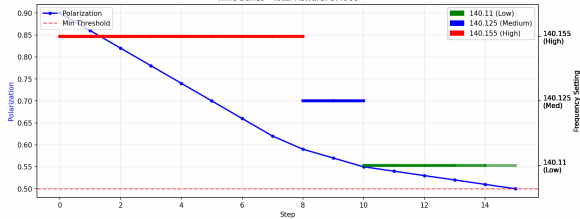
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Time Series - Total Reward: 9.4200



Time Series - Total Reward: 9.4900

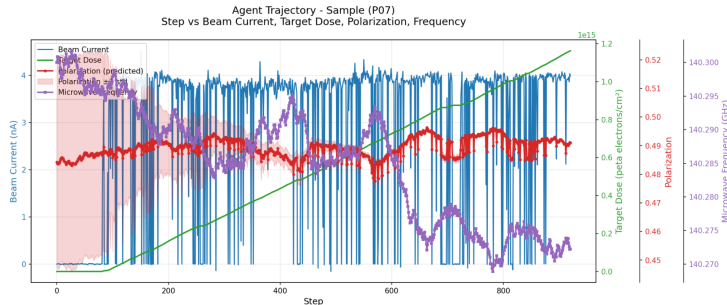


Uncertainty Aware Surrogate Models

- We use surrogate models, like Multilayer Perceptrons (MLP) and Gaussian Processes (GP), to mimic complex or time-consuming calculations so we can get results faster.
 - These models also provide uncertainty estimates, which are important because they indicate how confident the model is in its predictions.
- The surrogate model was trained on a small subset of data taken during RGC (specifically, P07). Input features were beam current, target dose, and microwave frequency. The surrogate model uses these input features to predict the polarization.
 - By building a surrogate model that can predict the polarization, it can respond to an agent randomly adjusting the frequency and see how polarization responds.

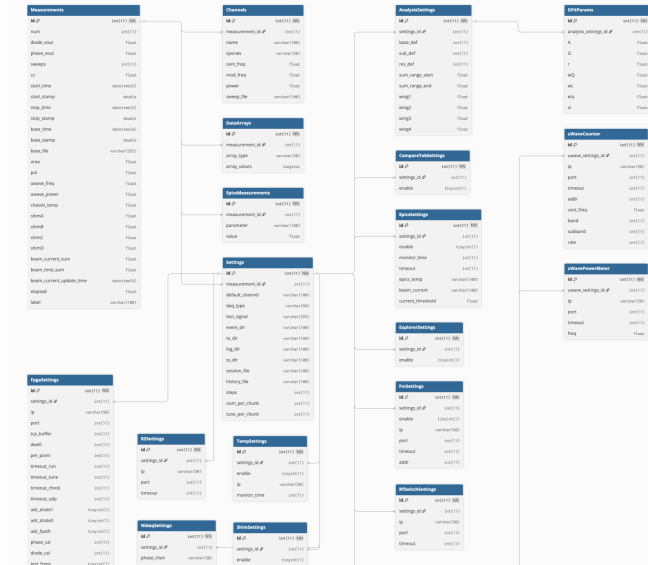
Baby Frequency Agent's First Steps

- First implementation of Reinforcement Learning agent guessing frequencies
- MLP surrogate model trained on RGC data provides predicted polarization



- The larger error bars on the polarization correspond to points where the microwave frequency is out-of-domain (outside of training data). We expect the uncertainty on the polarization predictions to increase in these instances.
- This was basically a sanity check for the surrogate model.

- Data from past experiments saved in various places as text files
- Easier access for AIOp and other projects: building a relational database (T. Jeske)
- Currently includes: RGC, g2p/GEN, SANE
- Can push new data directly to DB
- Web interface under construction
- Enable meta-analyses!



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EPICS for Small-Scale Laboratories with Python Soft IOCs

J. D. Maxwell

Thomas Jefferson National Accelerator Facility, Newport News, VA

E-mail: jmaxwell@jlab.org

- Framework for fully instrumenting a lab in EPICS using only Python. Initially designed and implemented for Hall B Cryotarget.
- EPICS is tricky. Focus on ease to use, deploy and extend.
- <https://github.com/jdmax/softioc-toolkit>
- <https://arxiv.org/abs/2508.20800>

JLab Target Group:

- D. Akers, J. Brock, C. Carlin, C. Flanagan, D. Griffith, M. Hoegurl, P. Hood, T. Kageya, **C. Keith**, S. Madlock J. Maxwell, D. Meekins, J. Thornton, D. Williams

JLab Fast Electronics:

- H. Dong

EPSCI:

- T. Britton, T. Jeske, D. Lawrence

JLab Data Science:

- A. Kasparian, M. Rahman, M. Schram

Thank you for your attention!

