TransverseTarget for Run Group H - An Overview

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JLab Target Group
Nov. 13, 2026

Jefferson Lab

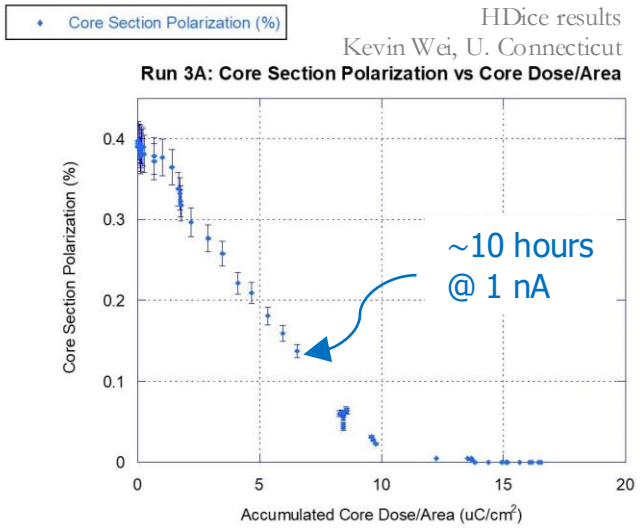
U.S. DEPARTMENT OF ENERGY

Jefferson Lab Target Group

How we got here

The original 2011 & 2012 proposals assumed a **frozen-spin** target of **brute-force** polarized solid **HD**

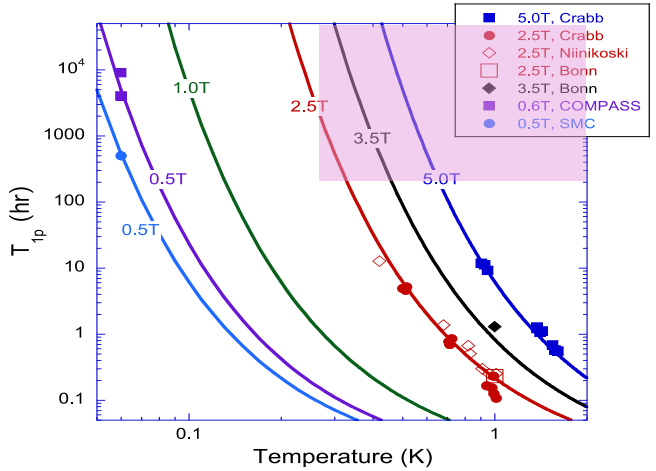
Subsequent tests at the UITF revealed **beam heating** and **radiation damage** would destroy the polarization after about ten hours



I examined the possibility of a **frozen-spin** target of **dynamically**-polarized solid **ammonia.**

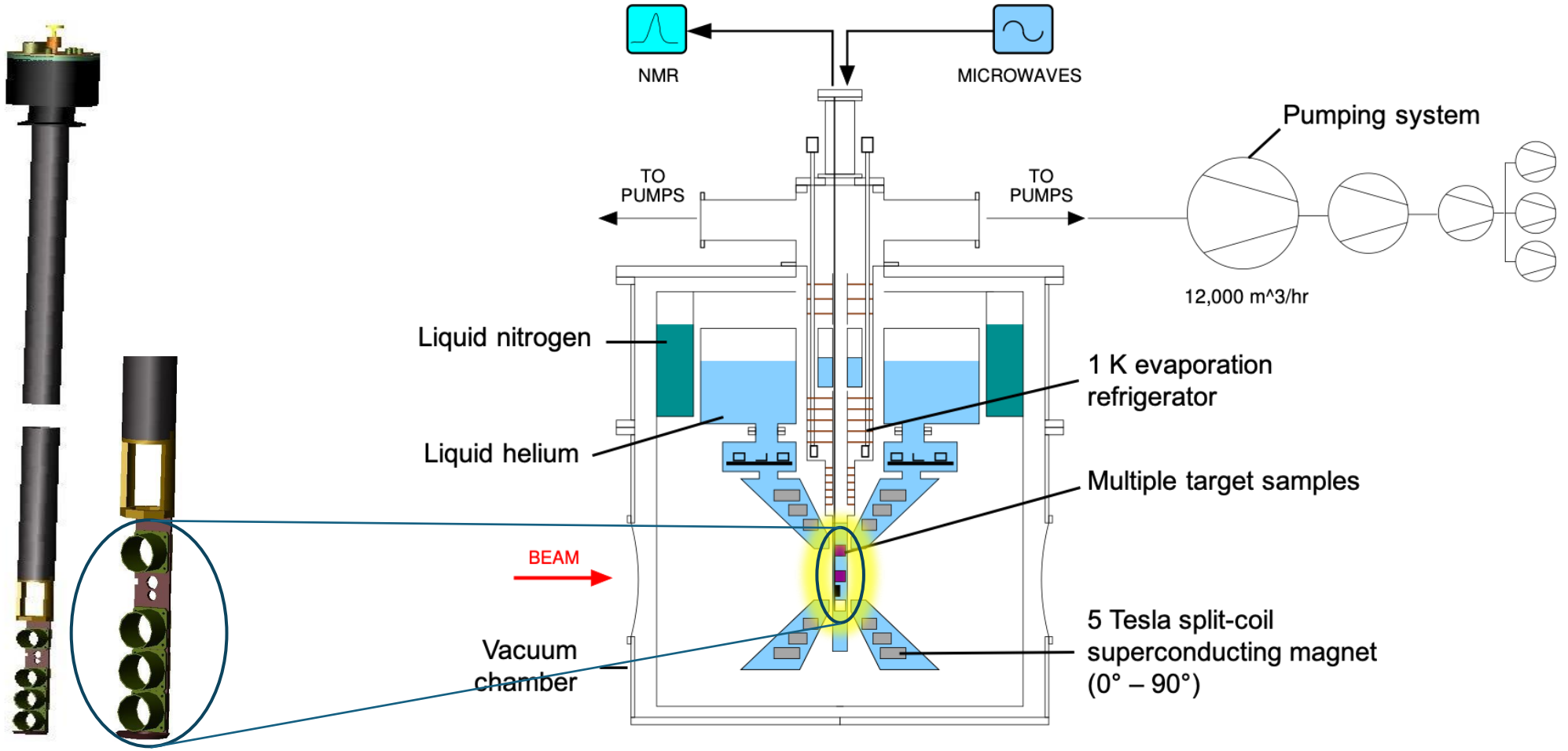
To obtain a reasonable lifetime of **200 hours** would require a holding field of at least **2.5 T**.

We decided to abandon the frozen-spin solution in favor of a standard, **5T/1K dynamically polarized target.**

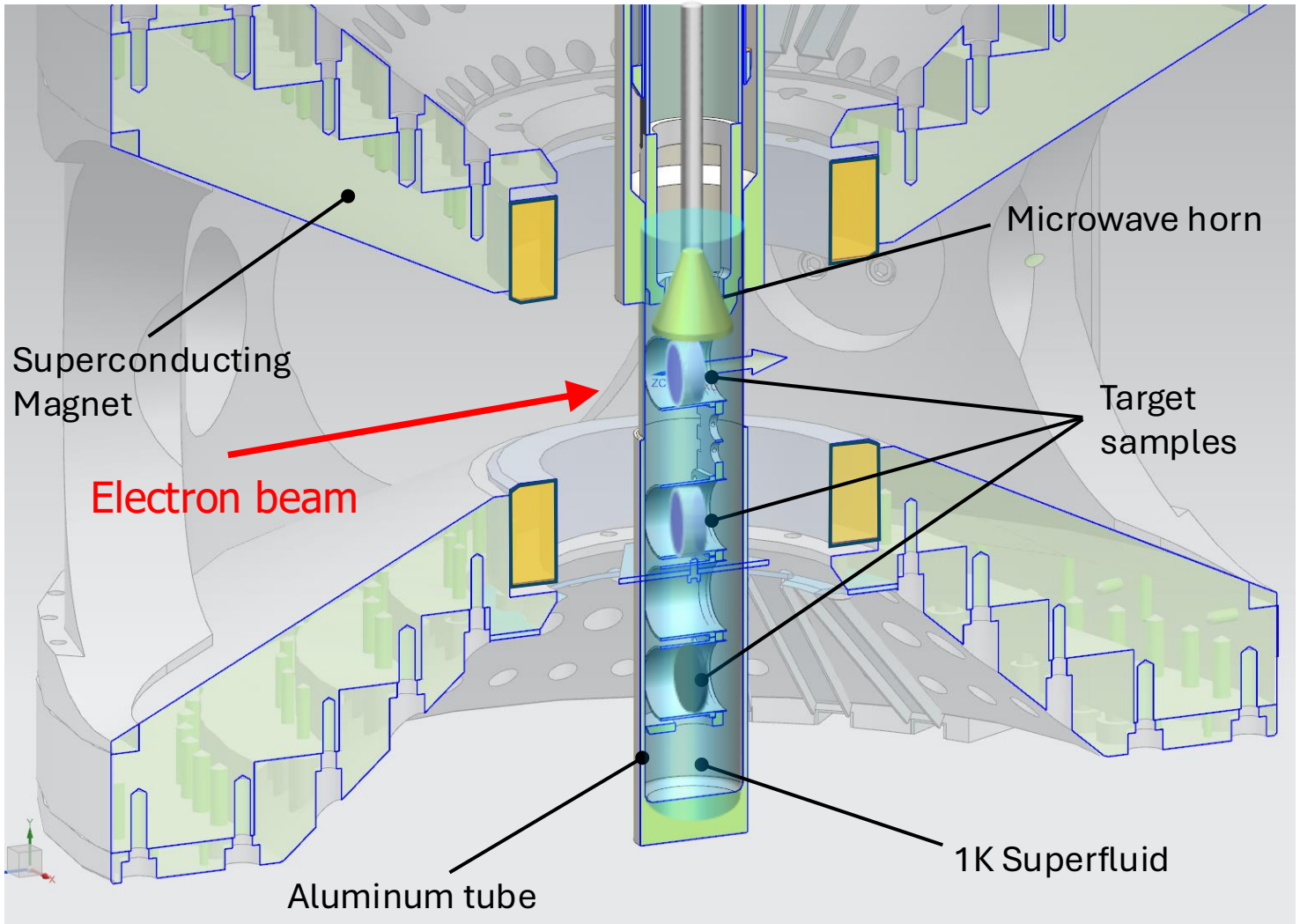


The current solution

The new solution looks like the standard 5T/1K dynamically polarized target used for decades in Halls A, B, & C.



List of targets

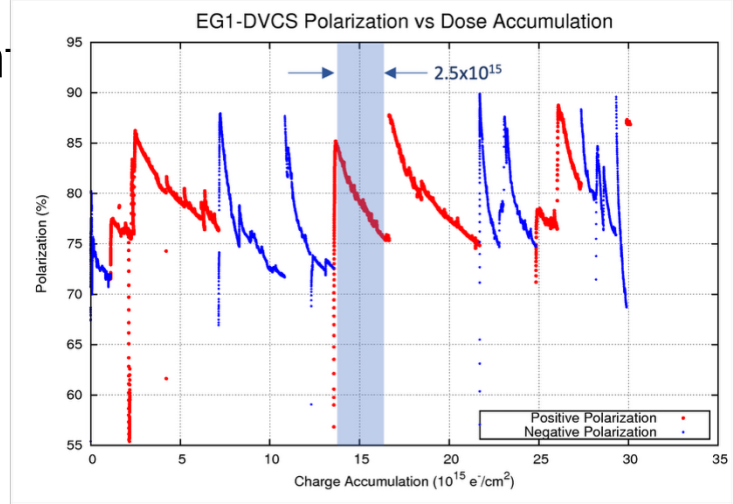


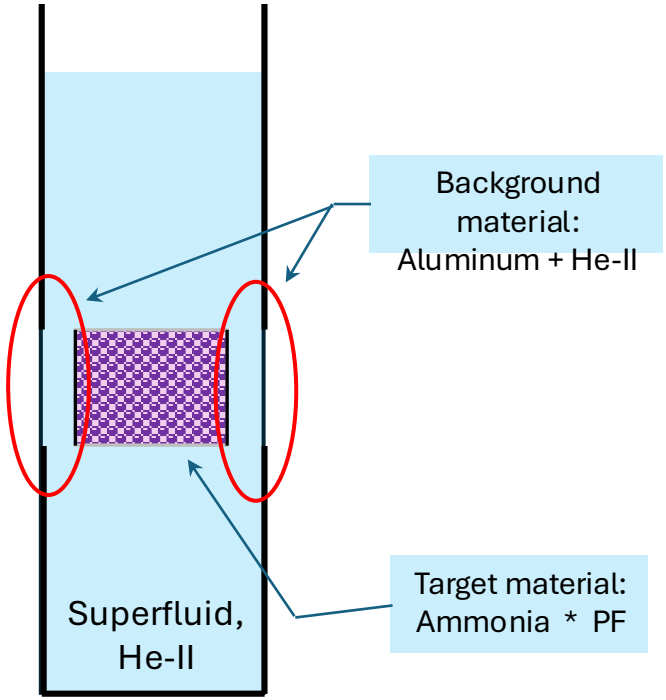
<u>Presumed list of targets</u>

1. Ammonia (NH3)
2. Ammonia (NH3)
3. Empty cup
4. Carbon
5. Polyethylene (CH2)
6. Alignment

Predicting the Target Performance

- Start with the design **luminosity**, 5 x 10^{33} cm^{-2} s^{-1}
- Determine beam current according to target length*density (include aluminum windows and He-II)
- Assume raster diameter (2 mm less than target) and calculate rate of radiation damage
- Assume N ammonia samples
- Anneal after N * 2.5 x 10^{15} $e^{-}cm$
- Replace after 4 - 5 anneals





Predicting the Target Performance

Example:

Two ammonia targets: (ø1.5 x 1) cm^3
Target thickness: 0.67 g/cm^2 (76% is NH_3)
Beam current: 1.9 nA
Raster diameter: 1.3 cm
Target lifetime: 2 x 3 days
Anneal frequency: once per week
Target replacement: 4 weeks (28 days)

An "ideal" week (21 shifts):

Ammonia 1: 8 shifts (+ pol.)
Carbon: 1 shift
Ammonia 2: 9 shifts (- pol.)
CH2: 1 shift
Empty: 1 shift
Annealing & NMR calibration: 1 shift

"Plans are useless, but planning is indispensable."
-Dwight D. Eisenhower

In this scenario, there is only about 5% overheard for target maintenance

We replace the target insert as few as three times (day 28, 56, & 84)

Measuring Target Polarization

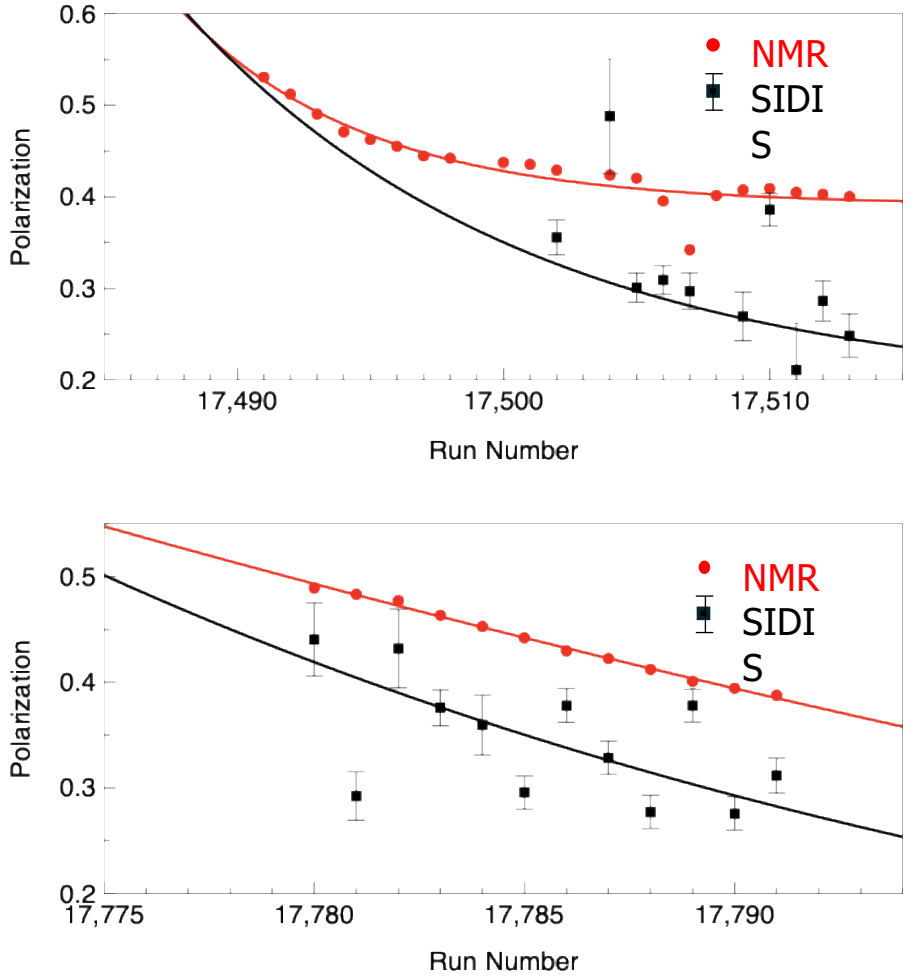
Target polarization is usually extracted as P_bP_t using elastic or quasi-elastic scattering.

The NMR coil is placed outside the target cell so it doesn't decrease the target's dilution factor.

NMR lacks sensitivity to the radiation damaged part of the target and over-estimates the real polarization.

The discrepancy increases as radiation damage accumulates.

Deuteron polarization during Run Group C



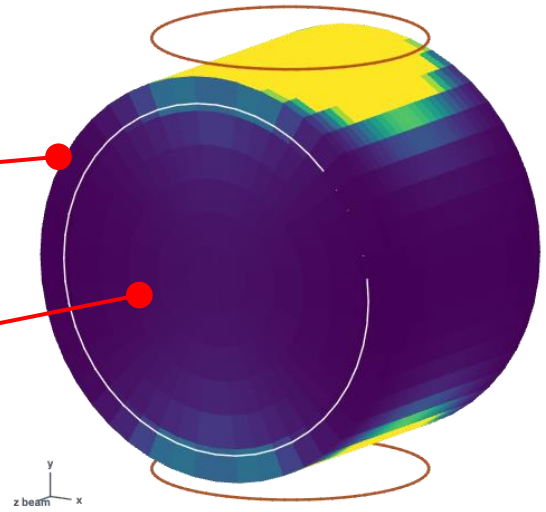
Measuring Target Polarization

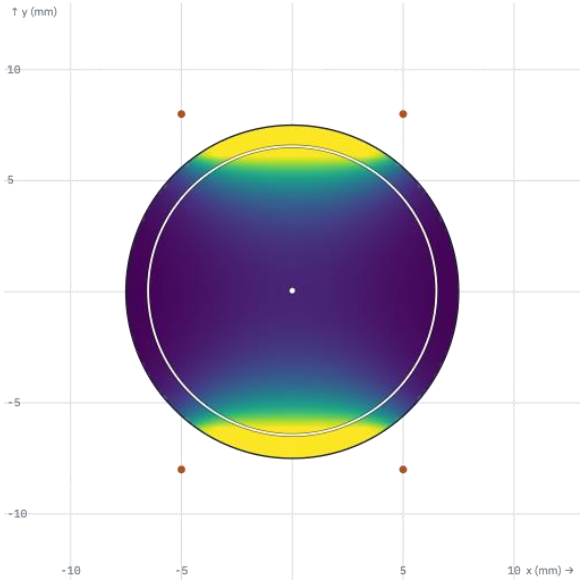
Example: ø15 mm x 10 mm sample
ø13 mm raster

External Helmholtz-*style* coils

90% outside raster

70% inside raster





50% of the NMR signal comes from unrastered target material

The NMR will report 80% polarization, not 70%

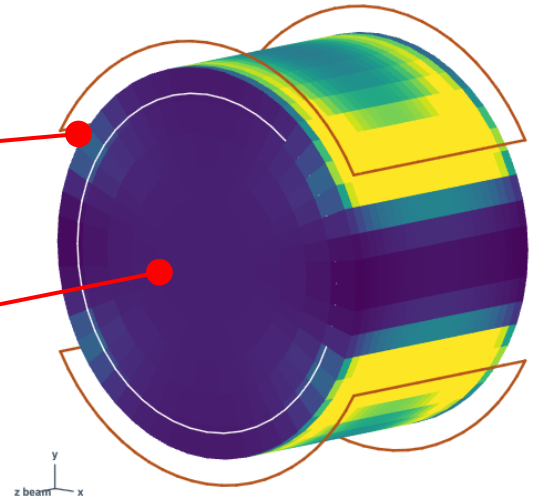
Measuring Target Polarization

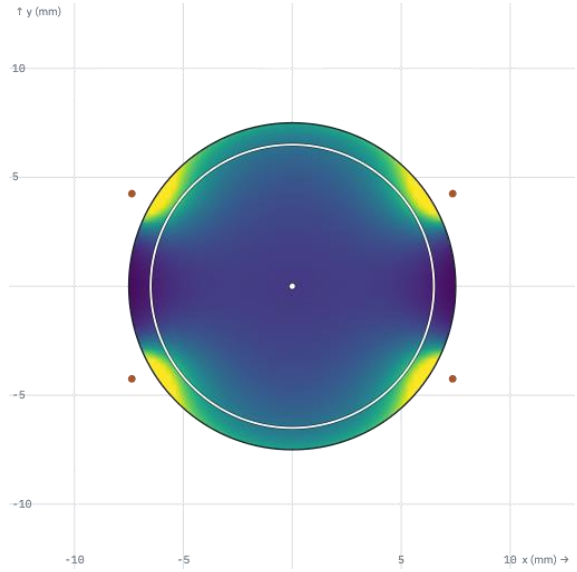
Example: ø15 mm x 10 mm sample
ø13 mm raster

External saddle coils

90% outside raster

70% inside raster





59% of the NMR signal comes from unrastered target material

The NMR will report 78% polarization, not 70%

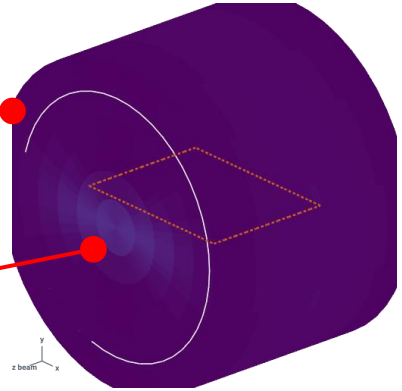
Measuring Target Polarization

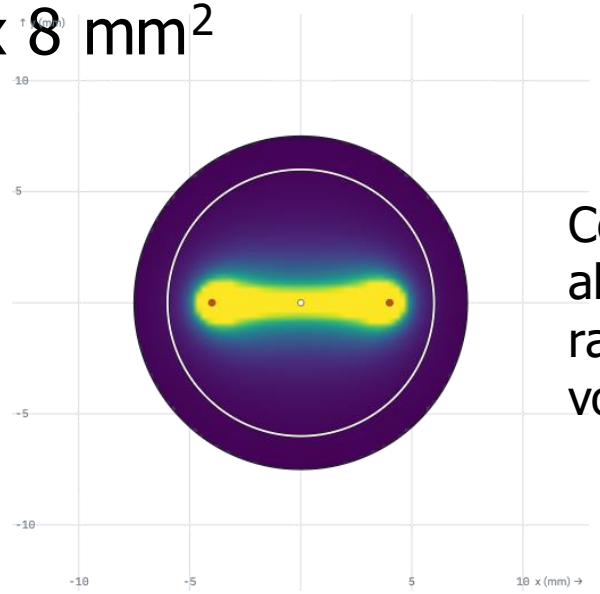
Example: ø15 mm x 10 mm sample
ø13 mm raster

Internal rectangular loop, 6 x 8 mm^2

90% outside raster

70% inside raster





Coil displaces about 4% of the rastered sample volume.

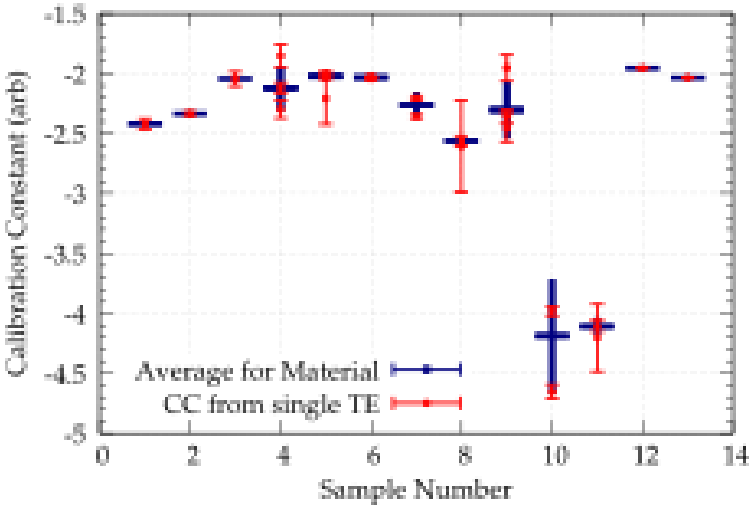
< 2% of the NMR signal comes from unrastered target material

The NMR will report 70%

Measuring Target Polarization

Measuring the NMR polarization accurately also requires frequent calibrations (**TE measurements**)

- Probably best to do these after each anneal
  - (about once per week)
- Requires about one shift
- Should also measure "false" proton NMR signal from the empty cup.



J.D. Maxwell et al. (SANE collab.) NIM A 885 (2018) 145.
- 26 Anneals
- 23 TE calibrations

Run Group H Target

We plan to save time and money by re-purposing as many components as possible from the Run Group C polarized target

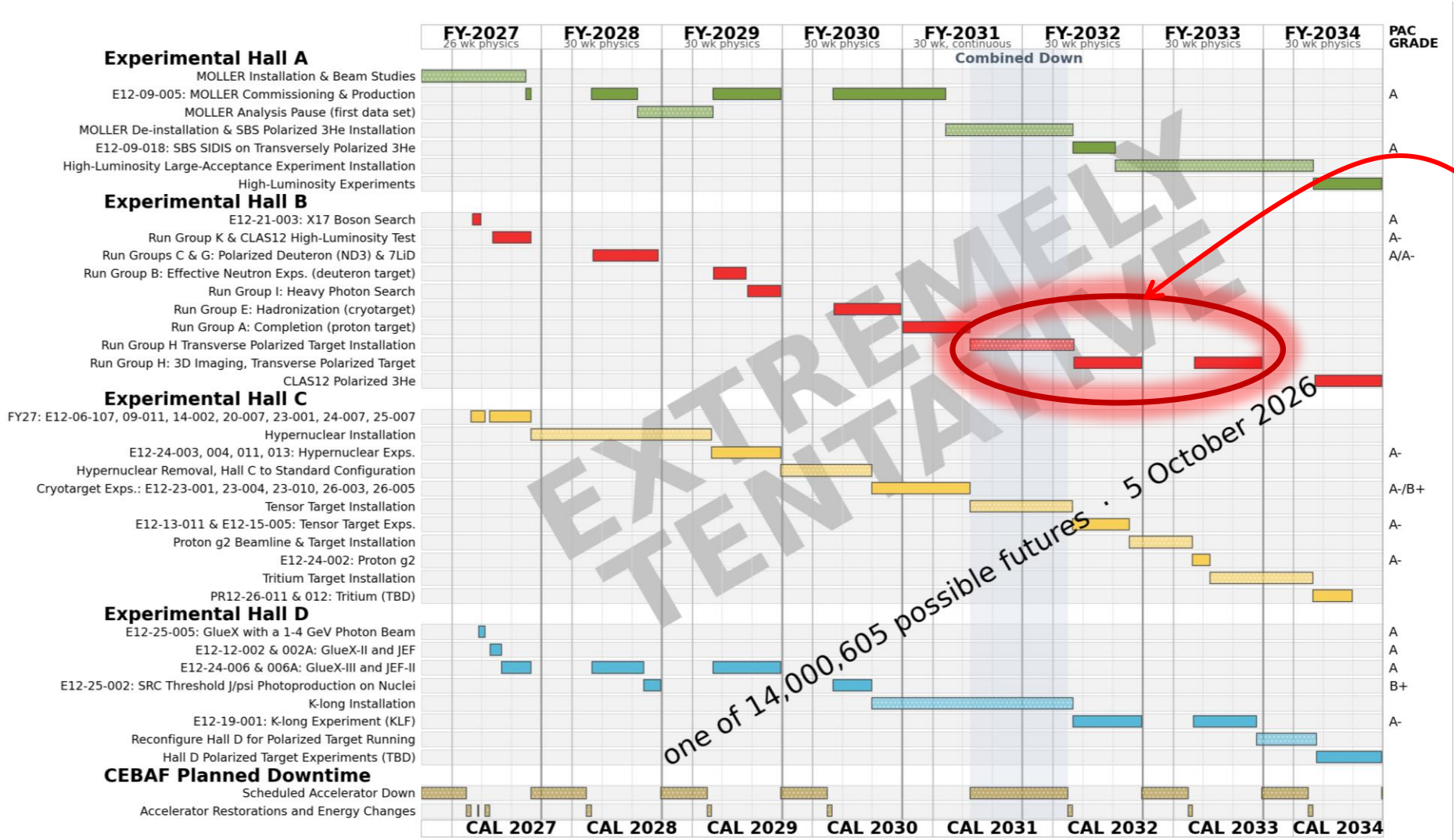
- Vacuum pumps
- Gas piping
- Electronics
- Microwaves

That means we "only" need new construction of a few items

- Superconducting magnet
- 1 K refrigerator
- Target ladder
- Vacuum chamber with exit window
- LHe transfer line
- Support/Alignment platform

I'm being ironic. This is a lot of work!

Run Group H Target

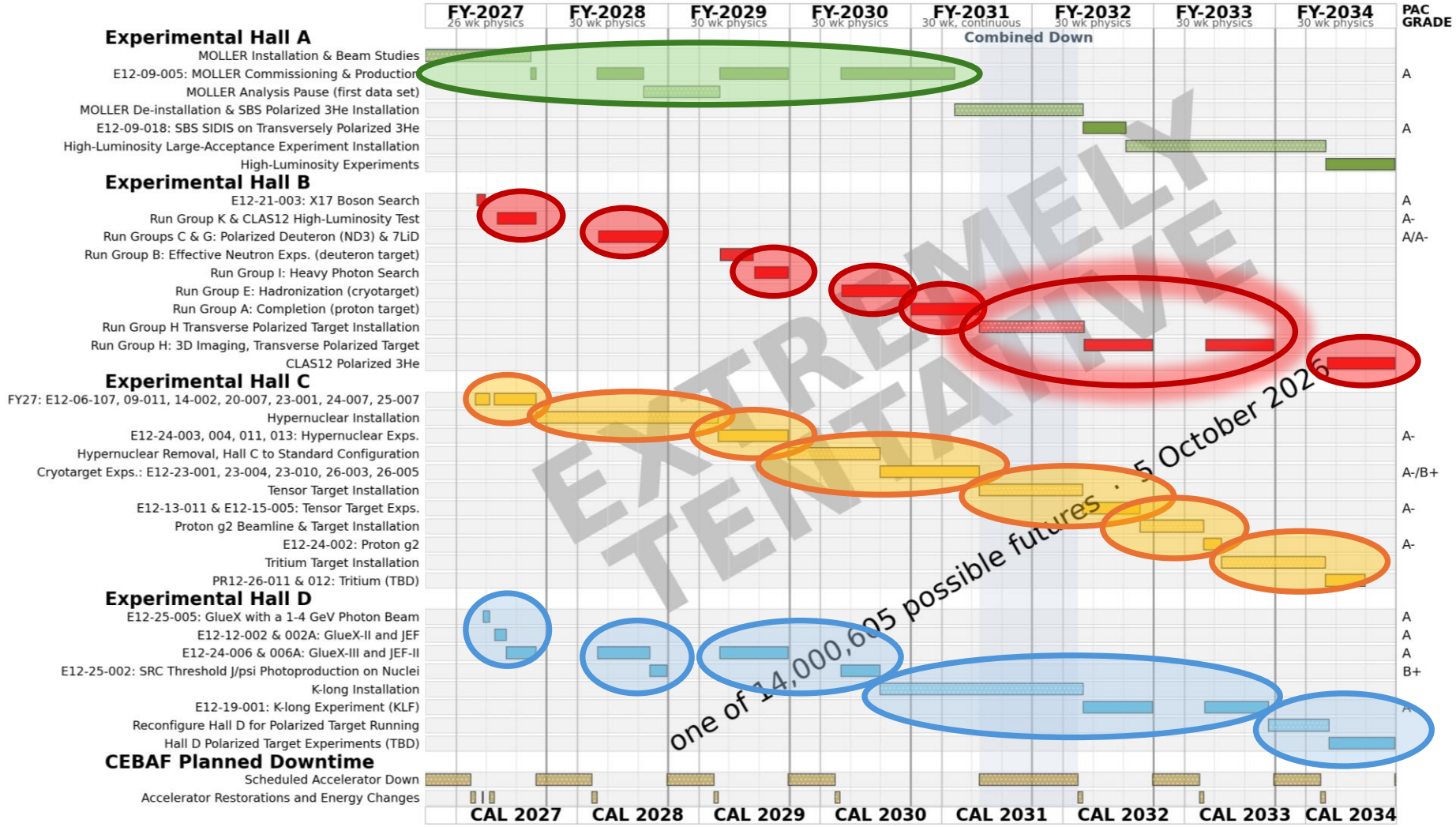


Run Group H is **tentatively** schedule for installation in 2031 and beam in 2032.

This will give the TG **four-and-a-half** years to design, fabricate, assemble and test the polarized target.

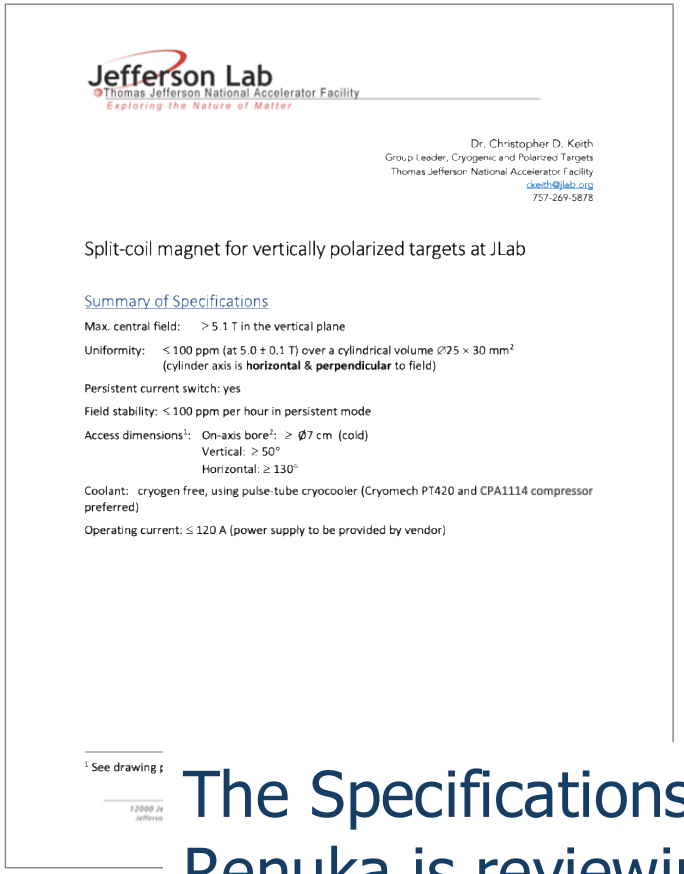
That seems reasonable.

Run Group H Target



But the Target Group will be working on other things as well.

Magnet Procurement Status



Jefferson Lab
Thomas Jefferson National Accelerator Facility
Exploring the Nature of Matter

Dr. Christopher D. Keith
Group Leader, Cryogenic and Polarized Targets
Thomas Jefferson National Accelerator Facility
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757-269-5878

Split-coil magnet for vertically polarized targets at JLab

Summary of Specifications

Max. central field: > 5.1 T in the vertical plane

Uniformity: < 100 ppm (at 5.0 ± 0.1 T) over a cylindrical volume Ø25 × 30 mm³ (cylinder axis is **horizontal** & **perpendicular** to field)

Persistent current switch: yes

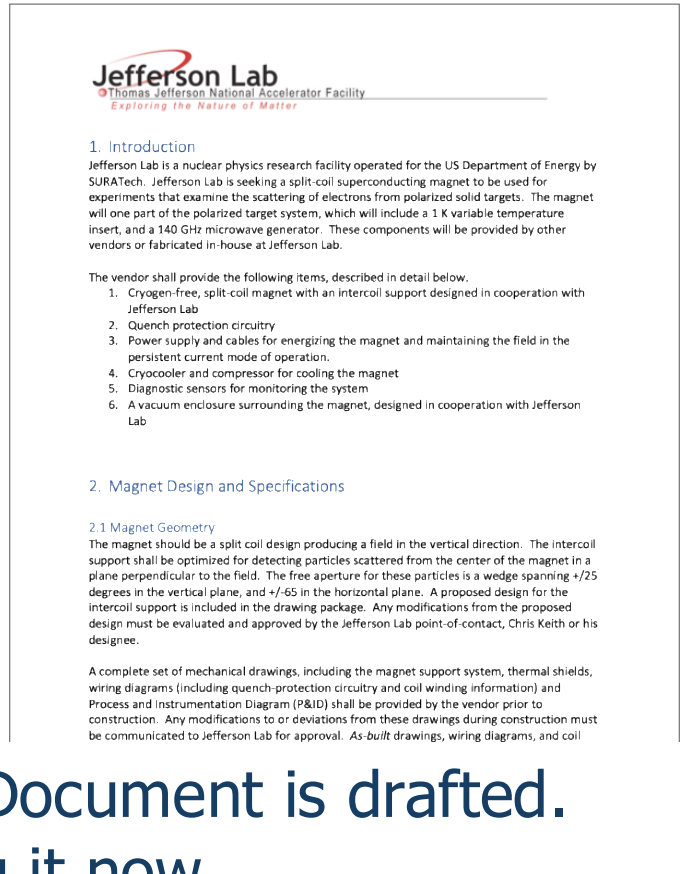
Field stability: < 100 ppm per hour in persistent mode

Access dimensions[1]: On-axis bore[2]: ≥ Ø7 cm (cold)
Vertical: ≥ 50°
Horizontal: ≥ 130°

Coolant: cryogen free, using pulse-tube cryocooler (Cryomech PT420 and CPA1114 compressor preferred)

Operating current: ≤ 120 A (power supply to be provided by vendor)

[1] See drawing p



Jefferson Lab
Thomas Jefferson National Accelerator Facility
Exploring the Nature of Matter

1. Introduction

Jefferson Lab is a nuclear physics research facility operated for the US Department of Energy by SURATech. Jefferson Lab is seeking a split-coil superconducting magnet to be used for experiments that examine the scattering of electrons from polarized solid targets. The magnet will one part of the polarized target system, which will include a 1 K variable temperature insert, and a 140 GHz microwave generator. These components will be provided by other vendors or fabricated in-house at Jefferson Lab.

The vendor shall provide the following items, described in detail below.

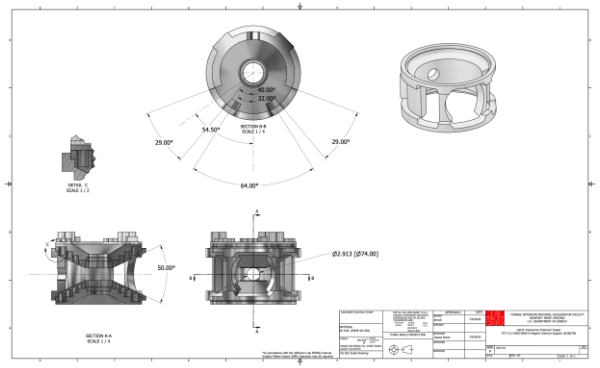
1. Cryogen-free, split-coil magnet with an intercoil support designed in cooperation with Jefferson Lab
2. Quench protection circuitry
3. Power supply and cables for energizing the magnet and maintaining the field in the persistent current mode of operation.
4. Cryocooler and compressor for cooling the magnet
5. Diagnostic sensors for monitoring the system
6. A vacuum enclosure surrounding the magnet, designed in cooperation with Jefferson Lab

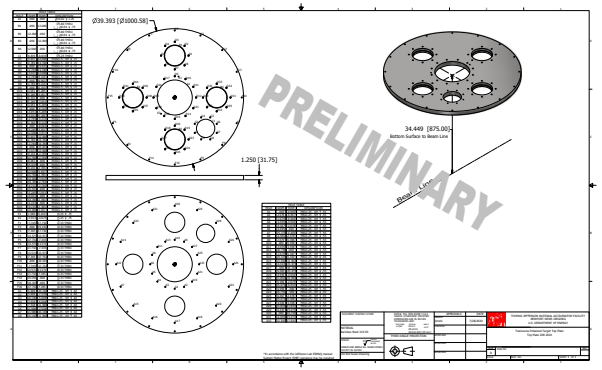
2. Magnet Design and Specifications

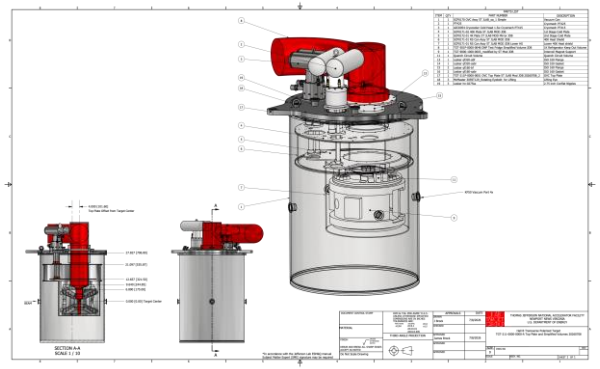
2.1 Magnet Geometry

The magnet should be a split coil design producing a field in the vertical direction. The intercoil support shall be optimized for detecting particles scattered from the center of the magnet in a plane perpendicular to the field. The free aperture for these particles is a wedge spanning +/25 degrees in the vertical plane, and +/-65 in the horizontal plane. A proposed design for the intercoil support is included in the drawing package. Any modifications from the proposed design must be evaluated and approved by the Jefferson Lab point-of-contact, Chris Keith or his designee.

A complete set of mechanical drawings, including the magnet support system, thermal shields, wiring diagrams (including quench-protection circuitry and coil winding information) and Process and Instrumentation Diagram (P&ID) shall be provided by the vendor prior to construction. Any modifications to or deviations from these drawings during construction must be communicated to Jefferson Lab for approval. *As-built* drawings, wiring diagrams, and coil







The Specifications Document is drafted.
Renuka is reviewing it now.
The RFQ should go out late-2026, early-2027.

Magnet Procurement Status

Timeline of its "sister magnet"

PR Created: 7/13/2020
Approvals: 7/16/2020
Ordered: 9/7/2020
Received: 11/16/2021

14 months





This gives an ETA for the magnet of Q1 2028.

Design of refrigerator etc. can (should) start earlier.

Summary

The Run Group H will utilize a **transversely** polarized target of solid ammonia (NH_3)

Samples will be dynamically polarized at 5 T and 1 K using a system that **closely mimics** previous targets utilized in Halls A and C

With **multiple samples** on the target ladder and low beam currents, the **overhead** for target operations (anneals, TEs, target changes…) can be kept very low, 5%

Multiple components from the existing RG-C polarized target can be re-purposed, but **new items** will require new procurement, design, and fabrication

Procurement of the 5 T polarizing magnet can proceed very soon

Meeting a possible 2032 start of the experiment will be **challenging but not impossible**

Summary

- QUESTIONS? -