Irradiating Ammonia at JLab for Polarized Solid Targets

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U.S. DEPARTMENT OF ENERGY | Office of Science

Jefferson Lab

Outline

Irradiating ammonia & the results
Where to irradiate at JLab
Our plans
Current status

Irradiation and the results

Warm irradiation

- Bonn/Bochum & Virginia
- Performed in liquid argon (87.3 K)
- Electron energy 10 – 20 MeV
- Nominal fluence is about 10^{17} e^- cm^{-2}
- Produces about 4 x 10^{19} spins/g
- Store samples in LN2
- Test DNP results days or weeks later

Results at 5 T & 1 K

- NH3 reaches > 90%
- ND3 reaches about 25%

Cold irradiation

- Mike Seely (SLAC)
- Performed in superfluid helium (1 K)
- Electron energy 20 GeV
- Fluence up to few 10^{15} e^- cm^{-2} with anneals 10 – 40 K
- Radical concentration unknown
- Test DNP during irradiation

Results at 5 T & 1 K

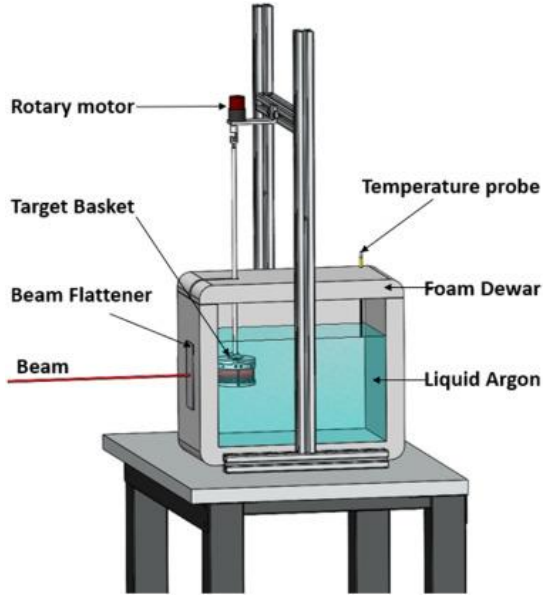
- NH3 reaches > 75% (after anneal)
- ND3 reaches about 25% (after anneal)

Irradiation cryostats

If the sample is submerged in liquid argon, the cryostat can be a simple styrofoam bucket or a more sophisticated metal dewar.

Periodically or continually rotate the sample for a more uniform dose.

A. Berlin, PhD thesis, Bochum (2015)



A. Conover et al, NIM, 1068 (2024) 169717

ADVANTAGES

- Cheap and simple
- Not much can go wrong
- Fixed temperature

DISADVANTAGES

- Fixed temperature

Irradiation cryostats

Variable temperature cryostats using forced convection of helium gas thru LN2 have been used in Germany and SLAC

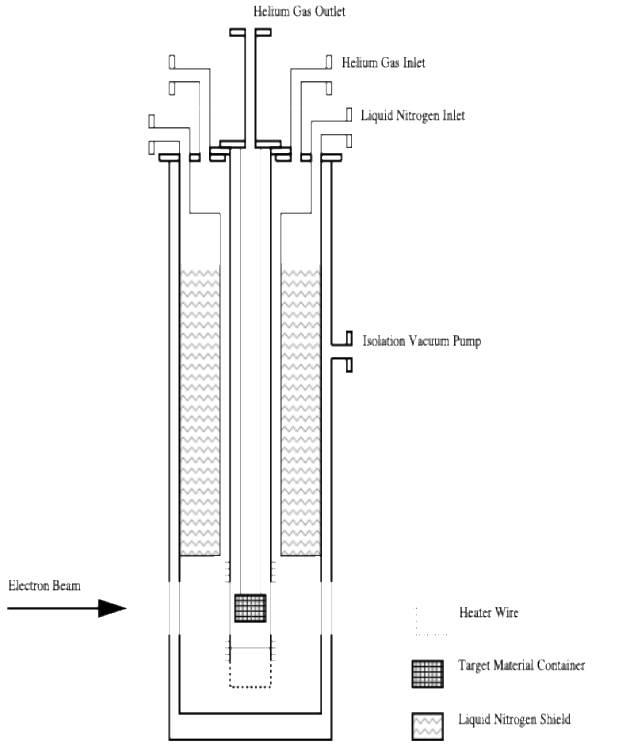


Figure 1: The irradiation dewar for the lithium deuteride target material. The material is cooled by circulating He gas at 183 K. The gas is cooled by a liquid nitrogen shield and temperature controlled by a heater.

S. Bultmann et al, SLAC-PUB-97904 (1998)

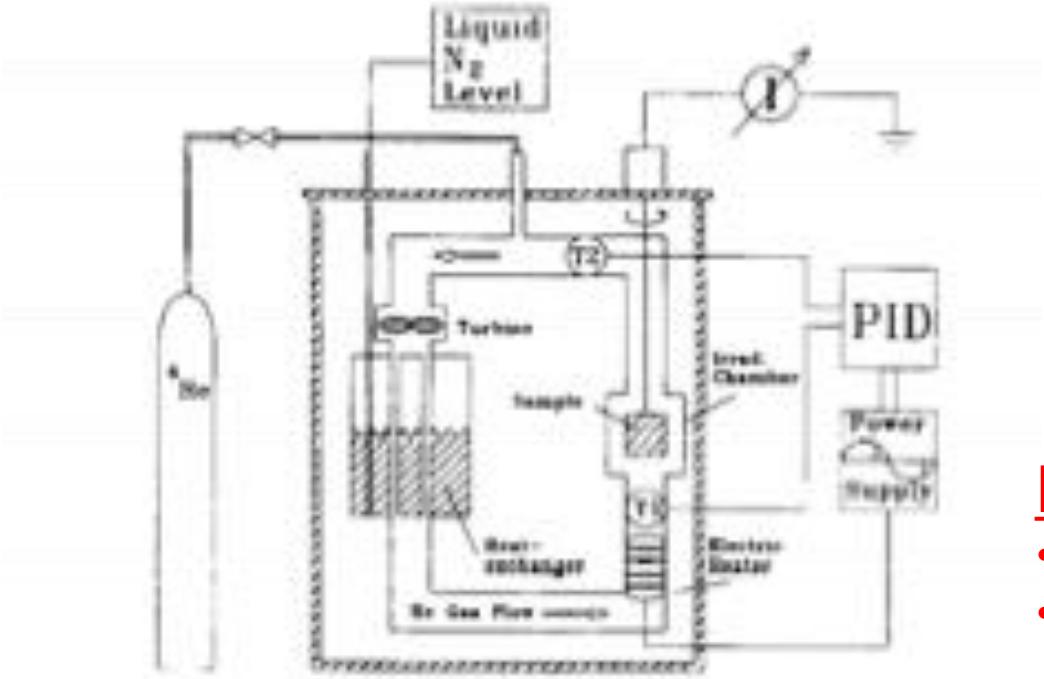


Fig. 1. Block diagram of the irradiation cryostat.

St. Goertz, NIM A 356 (1995) 20.

ADVANTAGES

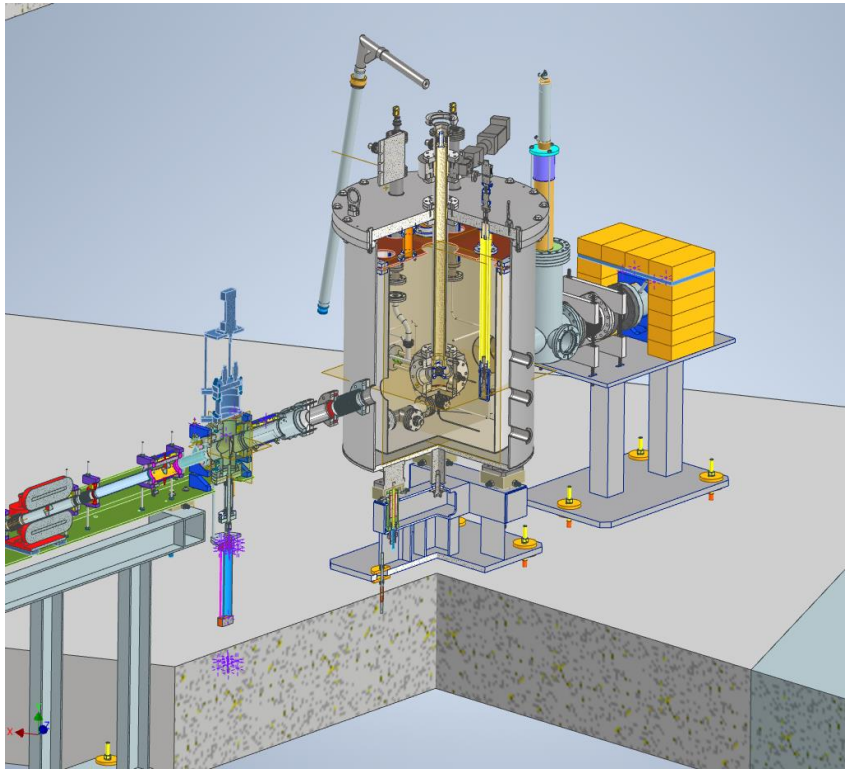
- Temperature > 87 K

DISADVANTAGES

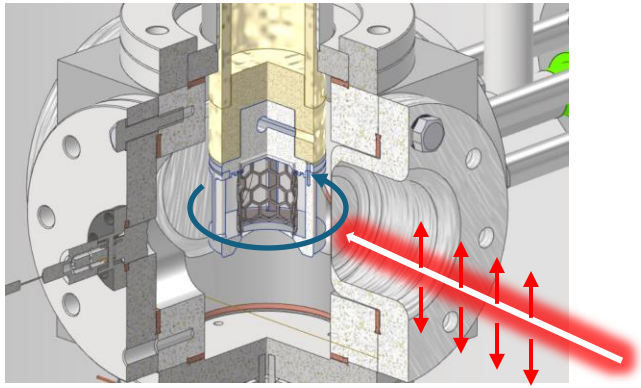
- More complicate
- Temperature > 87 K

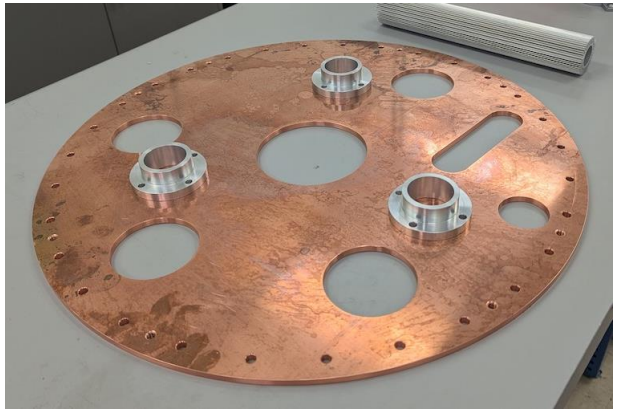
JLab Irradiation cryostat

We're building a variable temperature using helium from one of JLab's cryogenic plants.



Casey Flanagan, Daniel Akers





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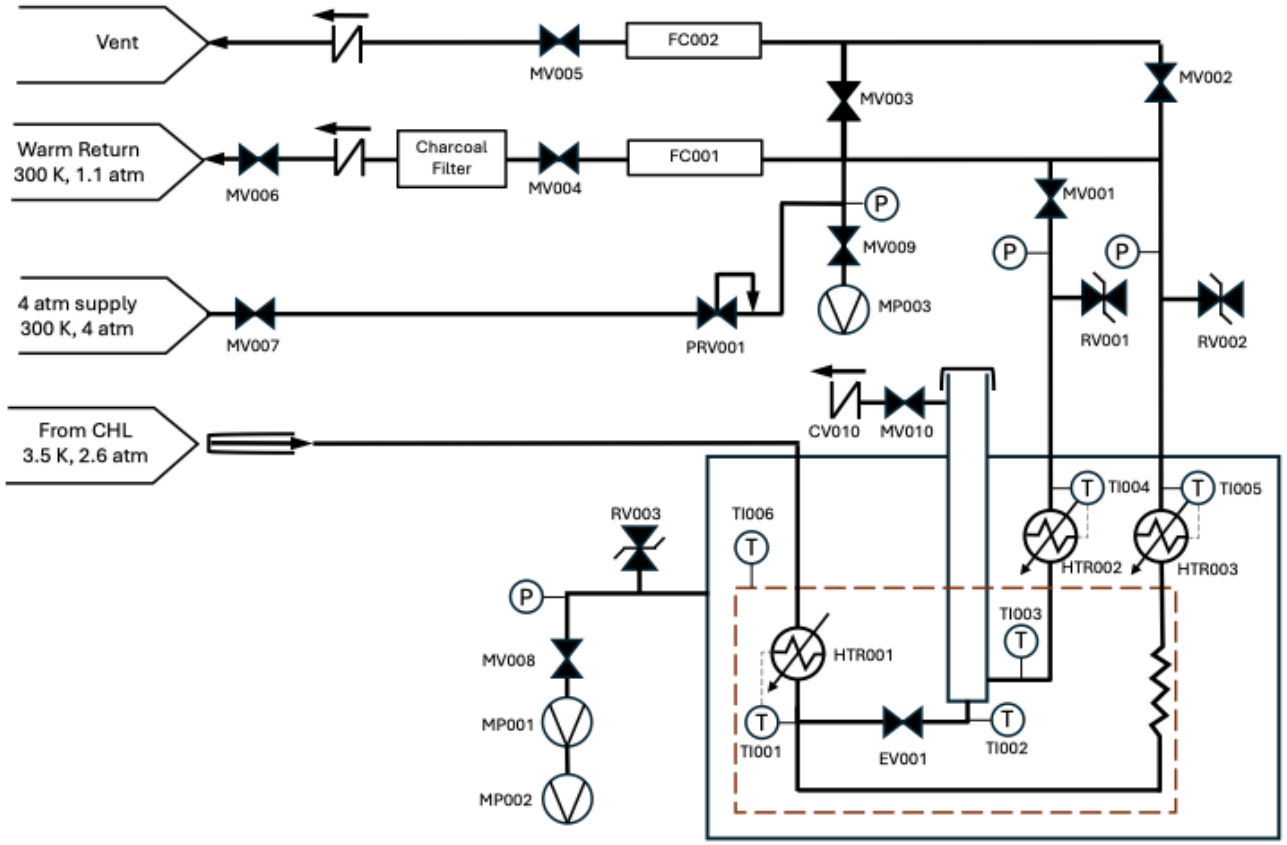

ADVANTAGES

- Temperatures 2 – 300 K

DISADVANTAGES

- More complicated

JLab Irradiation cryostat

We're building a variable temperature using helium from one of JLab's cryogenic plants.

GOAL PARAMETERS
Temperature: ≥ 2K
Beam energy: up to 8 MeV
Beam current: up to 10 μA
Sample size: up to 40 cm^3

EXAMPLE: Warm Irradiation
Temperature: 85 ± 5 K
Fluence: 10^{17} e^- cm^{-2}
Beam current: 10 μA
Irradiation time: 3-6 h
Heat load: 44 W
Helium flow: 0.85 g/s

EXAMPLE: Cold Irradiation
Temperature: 2 K
Fluence: 5 X 10^{15} e^- cm^{-2}
Beam current: 1 μA
Irradiation time: 1-2 h
Heat load: 4.4 W
Helium flow: 0.2 g/s

Where to irradiate

Three accelerator facilities are on site, and they have ALL been recommended to me!

1. UITF (Upgraded Injector Test Facility)
2. LERF (Low Energy Recirculator Facility)
3. CEBAF Injector

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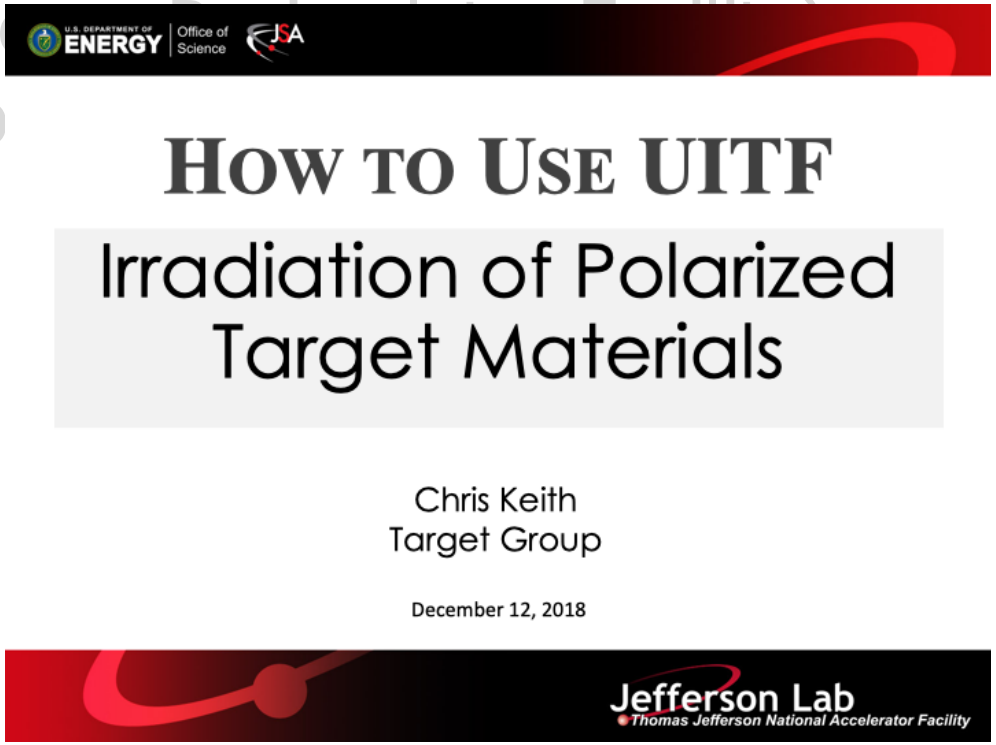
The current plan!



Status

- Cryostat design is 90% complete
- Fabrication is about 50% complete (spending paused since August)
- Dedicated beam line for target irradiation is under design
- UITF functioning and stable at 8 MeV and 20 μA
- **Operational limit** is 100 nA (additional shielding is necessary for 10 μA – waiting for quote)

- UITF in operation (Brimrose Technolgy) until March/April 2026
- BeamNetUS proposals now open

→ https://www.beamnetus.org/

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The competition

HALL A

MOLLER cryotarget*
SoLID cryotarget*
SoLID polarized target*

HALL B

Cryotargets
Longitudinal polarized target*
Transverse polarized target*
Polarized ^{3}He target*
Tritium target*

HALL C

Cryotargets
Hypernuclear target*
Tensor polarized target*
Transverse polarized target*

HALL D

Cryotargets
K-Long cryotarget*
Frozen spin target*

*Substantial construction and/or R&D