Hall D Cryotarget for Short Range Correlation Studies

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This presentation addresses Charge Item Two

CHARGE ITEM 2

What is the operational status/performance requirements of the target system needed by the experiment?

E12-19-003 will utilize three targets inside the standard Hall D target system.

- Liquid deuterium
- Liquid helium
- Carbon foils

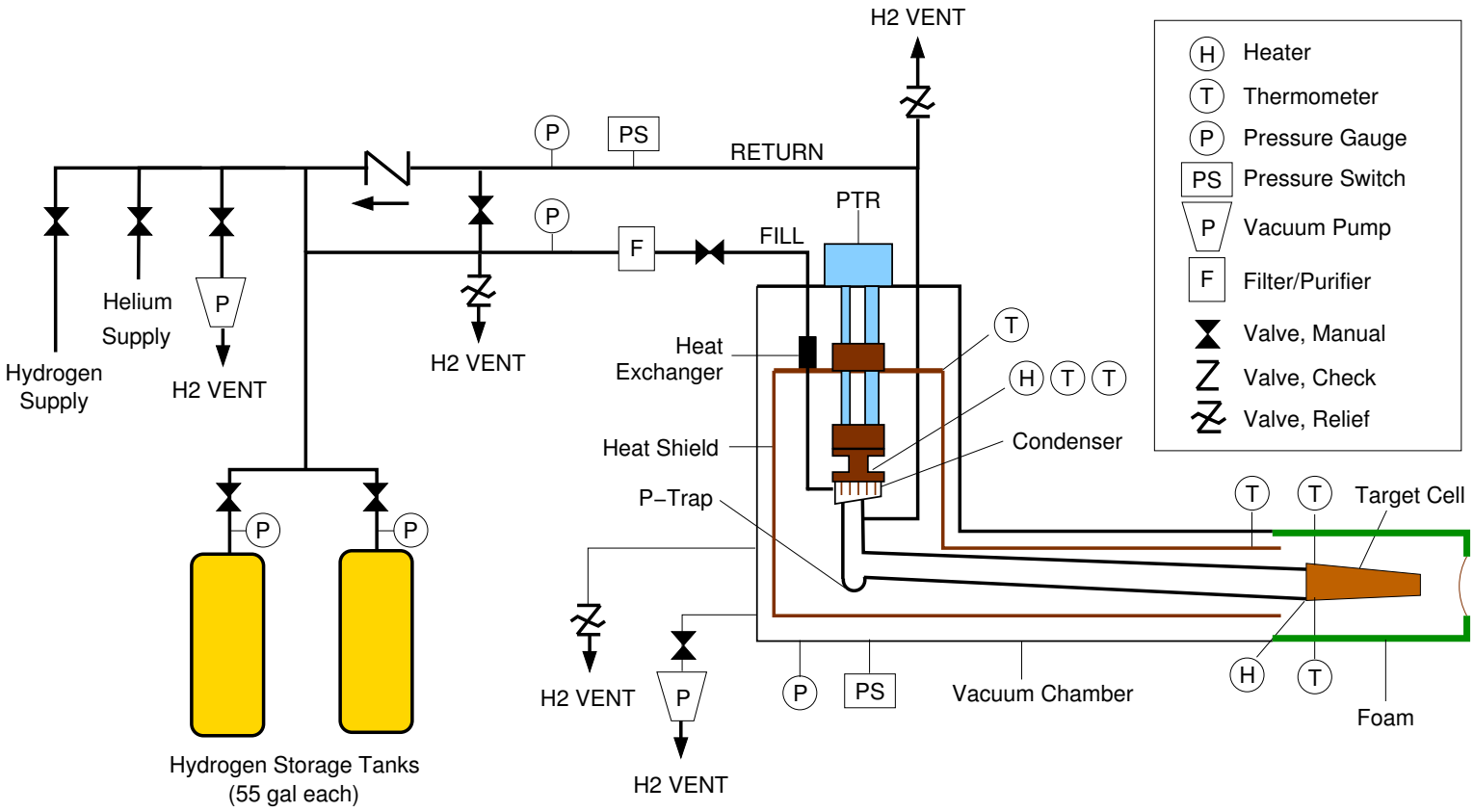
Target Group will be responsible for all target prep and sample changes.

If not completed, what are the completion/commissioning schedules, tasks and user commitment?

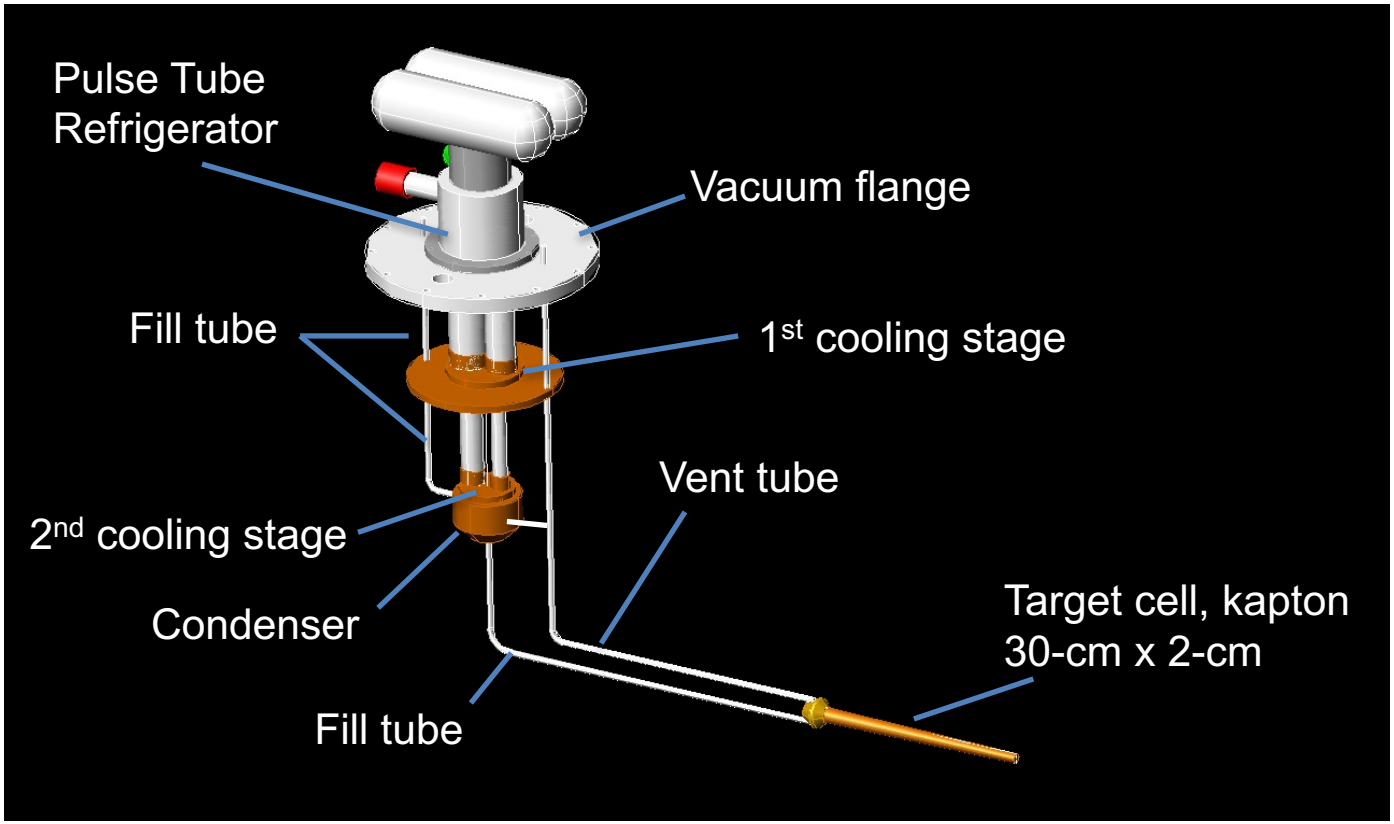
➢ See talk by Holly Szumila-Vance

Hall D Cryotarget: LH_2 & LD_2

GlueX Liquid Hydrogen Cryotarget



Hall D Cryotarget: LH_2 & LD_2



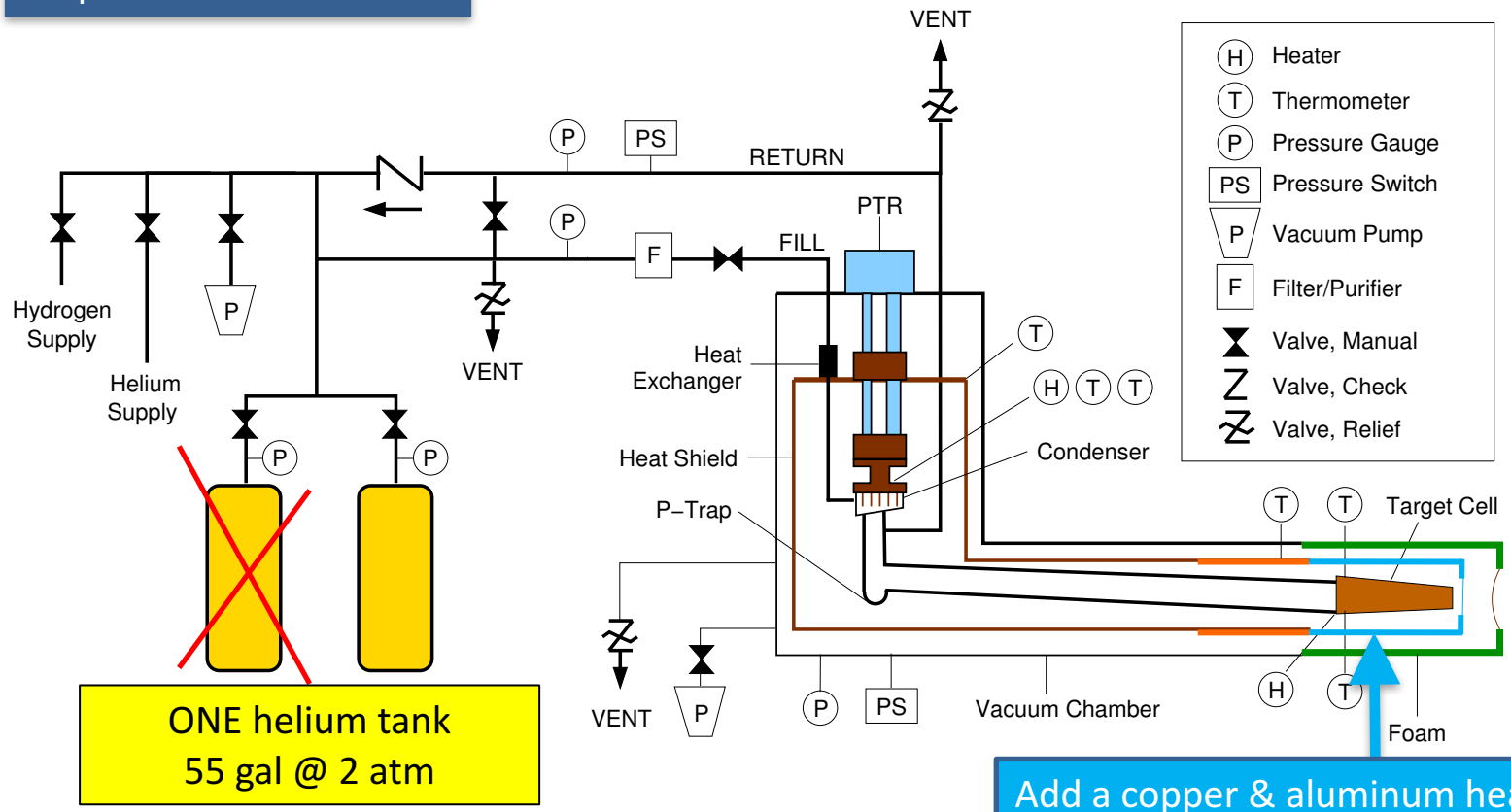
Liquid hydrogen (or deuterium) is condensed in the target cell, condenser, and fill & vent tubes.
The liquid is subcooled 1-2 K below the SVP curve to suppress boiling.

$\rho_{H2} = 71.2 \pm 0.3$ mg/cc

A similar accuracy is expected for D2

Hall D Cryotarget: LHe

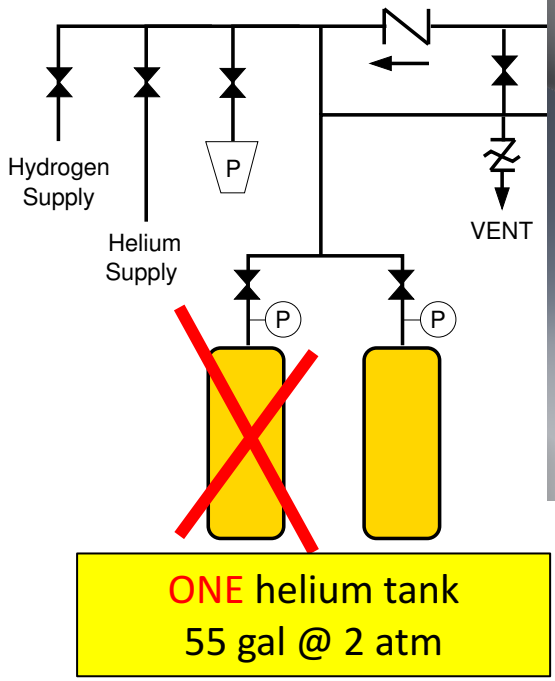
Modifications for Liquid Helium



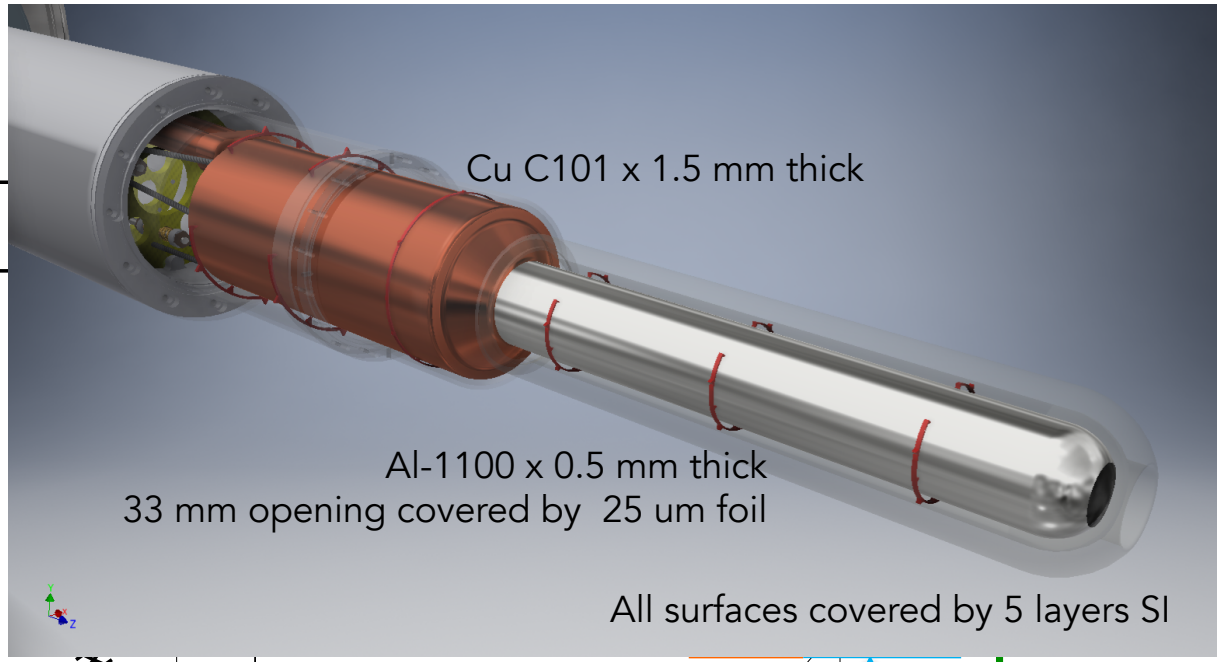
Add a copper & aluminum heat shield around the target cell.
To reduce overhead, the heat shield will also be in place during LD2 runs.

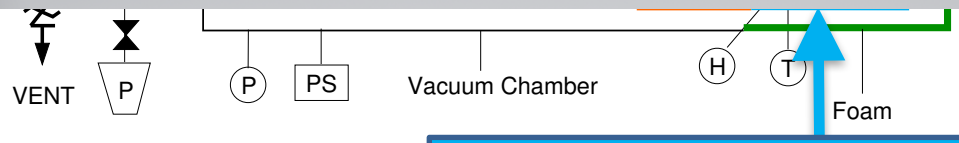
Hall D Cryotarget: LHe

Modifications for Liquid Helium



ONE helium tank
55 gal @ 2 atm





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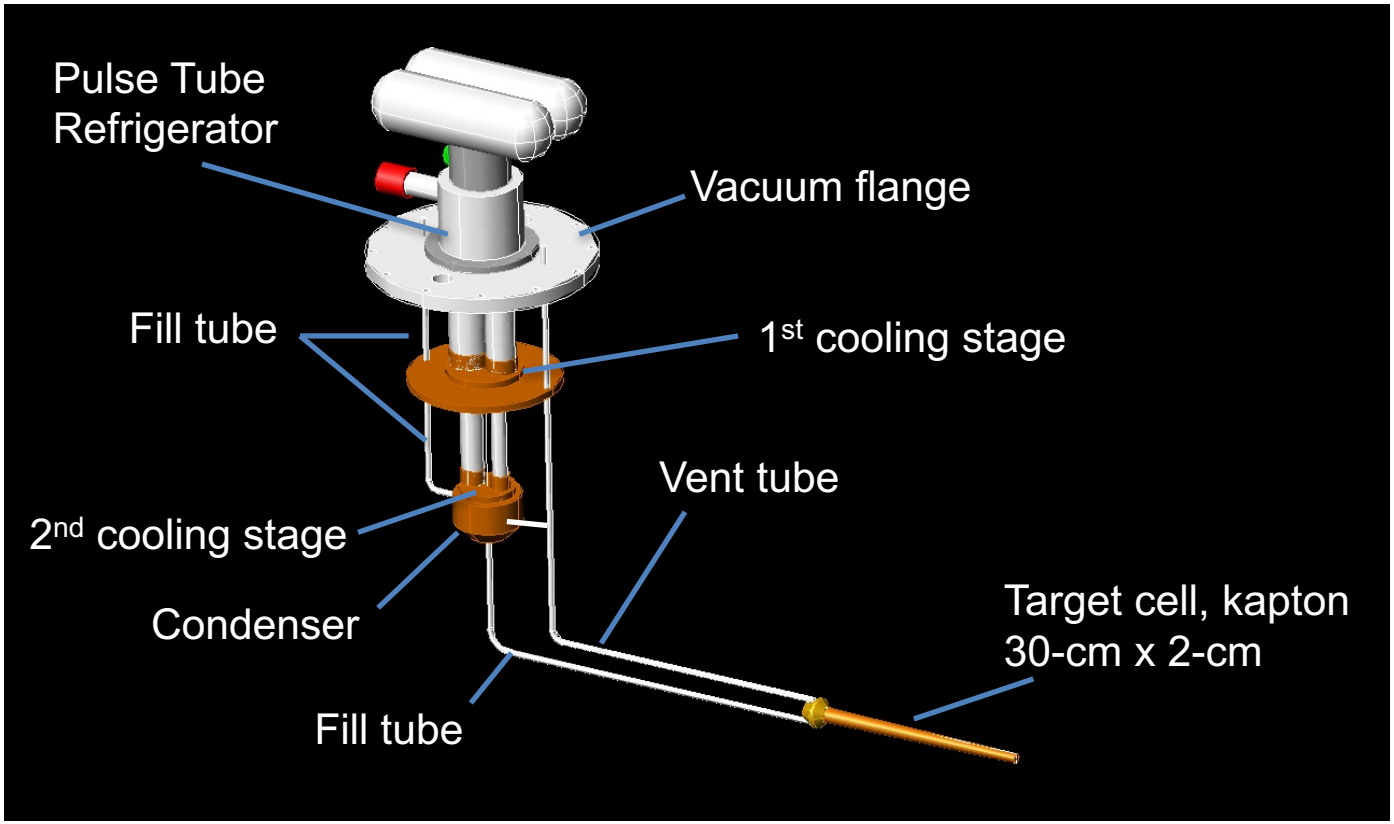
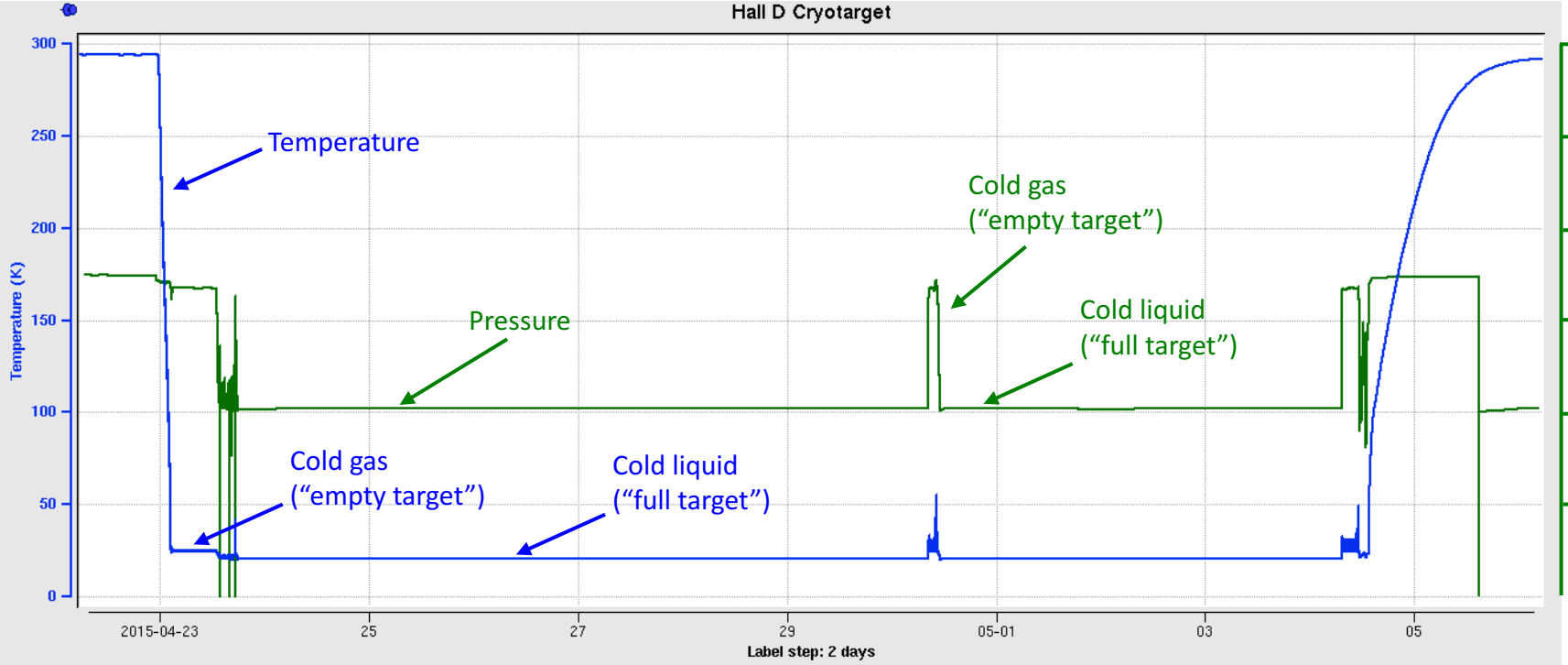
Hall D Cryotarget: LHe



In the case of LHe, only the target cell is filled with liquid.
Subcooling is not possible, and the liquid is on the SVP curve.
Some boiling is present.

$$\rho_{He} = 117 \pm 2 \text{ ? mg/cc}$$

Hall D Cryotarget: performance

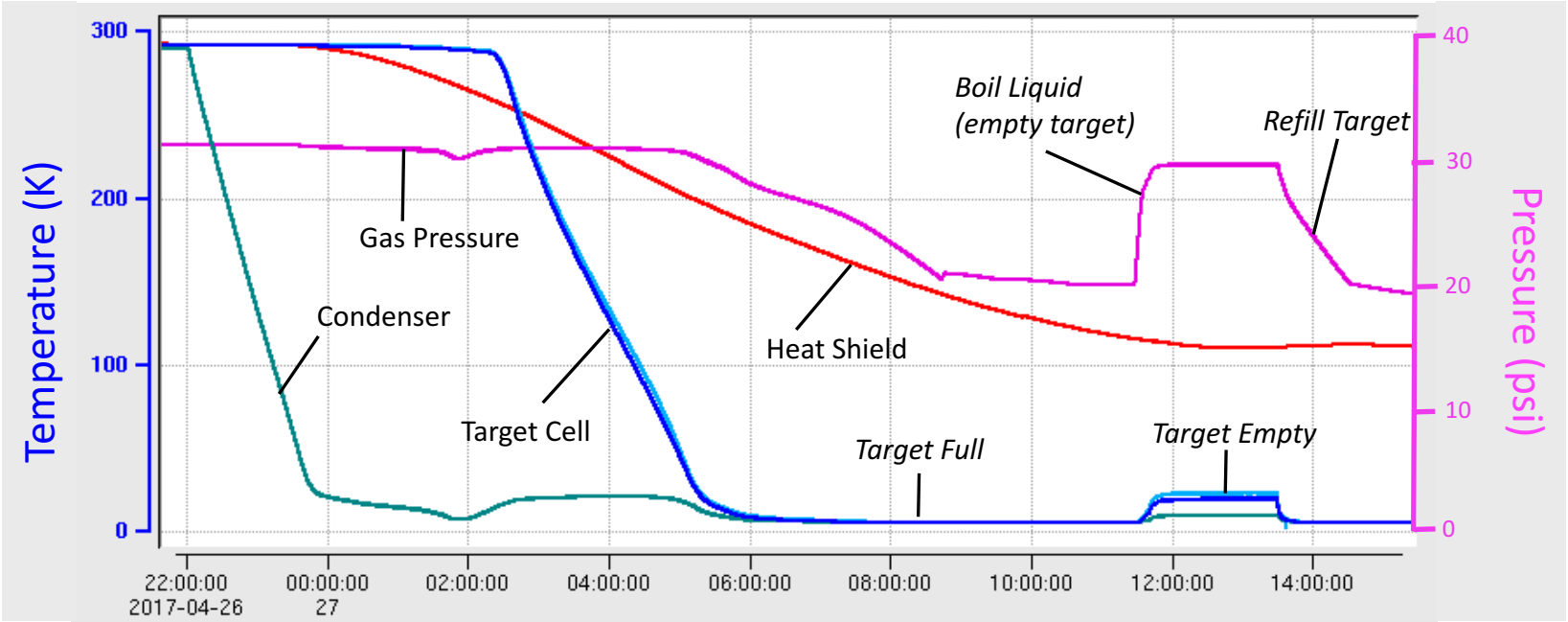


Liquid hydrogen

Cooling & filling target requires about 8 hours;
Emptying target takes ~15 minutes;
Re-filling target takes ~30 minutes;

Similar performance is expected for D2

Hall D Cryotarget: performance

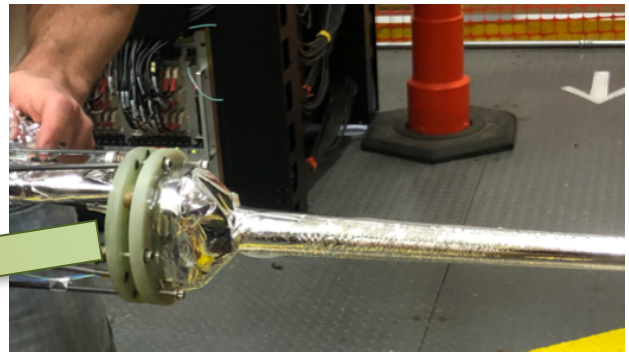


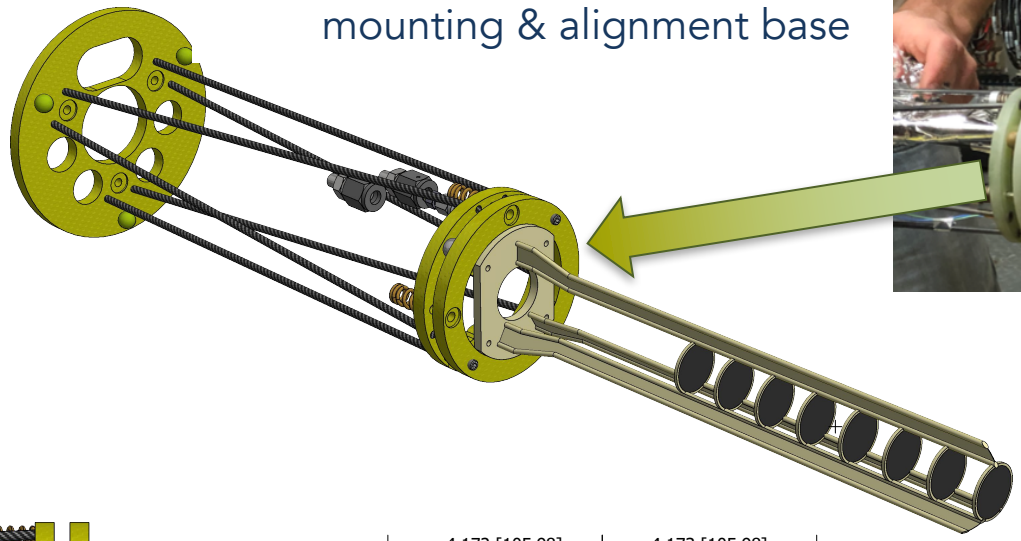
Liquid helium

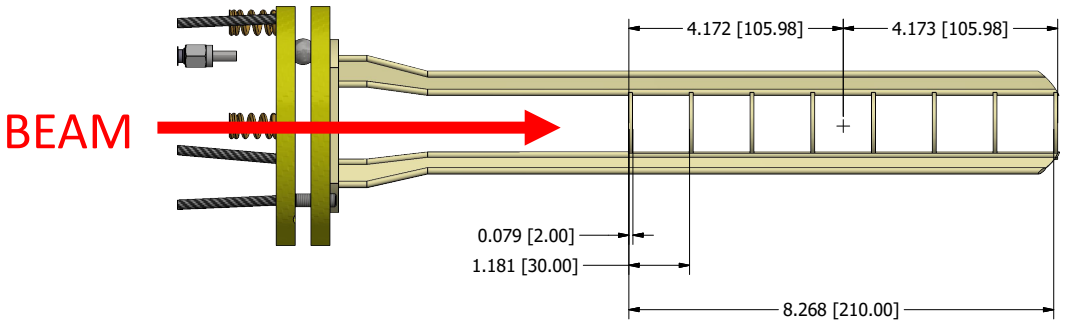
Cooling & filling target requires about 12 hours;
Emptying target takes ~15 minutes;
Re-filling target takes ~45 minutes;

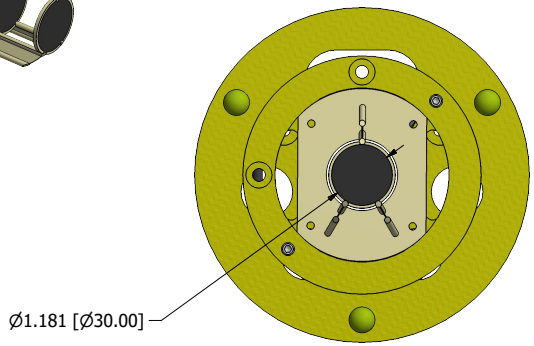
Hall D Cryotarget: carbon foil target

Use existing cryotarget
mounting & alignment base









Design courtesy of J. Brock

Eight ⌀3 cm carbon foils, each 1.7 mm thick
(total RL ≈ 7%)

Hall D Cryotarget: safety considerations

The Hall D cryotarget has been approved for operation with hydrogen (GlueX) & helium (PrimeX)

Designed & constructed in accordance with
- ASME B31.12 2011
- ASME BPVC VIII D1 2010
- ASME BPVC VIII D2-2013

Deuterium has same flammability properties as hydrogen

D_2 will require a slightly higher pressure in the storage tanks
➢ 37 vs 32 psia (relief valves are set at 40 psia)

During Loss-of-Vacuum, deuterium has a lower pressure rise than H_2
(Relief calculation is on my inaccessible desktop PC)

Hall D Cryotarget: safety considerations

Hand-waving argument

During Loss-of-Vacuum, a heat flux $\dot{Q}$ boils liquid at a rate $\dot{m}$

$$\dot{m} = \frac{\dot{Q}}{\mathcal{L}}$$

Q = heat flux (W)
$\mathcal{L}$ = latent heat (J/g)

Or, in terms of liquid *volume*:

$$\dot{V}_L = \frac{1}{\rho_L}\frac{\dot{Q}}{\mathcal{L}}$$

ρ_L = density of liquid (g/cc)

This generates a volume of *gas* at a rate:

$$\dot{V}_g = \frac{R}{\rho_L}\frac{\dot{Q}}{\mathcal{L}}$$

R = expansion ratio at SVP

Deuterium
0.61 cc/s per W

<

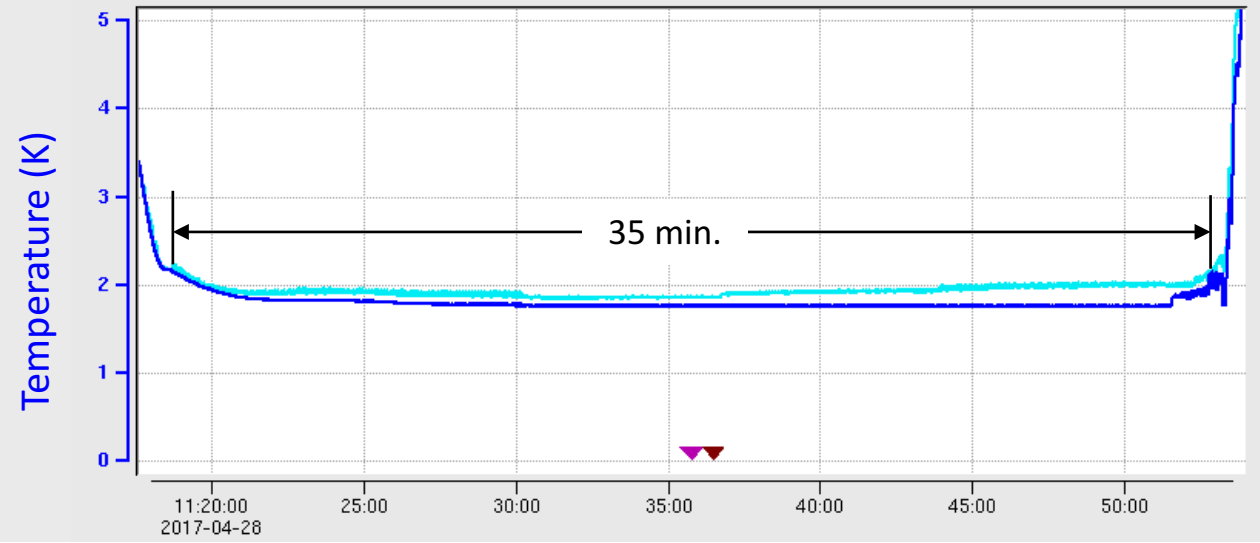
Hydrogen
0.68 cc/s per W

Hall D Cryotarget for SRC

Summary

- The Hall D cryotarget has been approved and demonstrated to work with both LH_2 and LHe
- It will also work with liquid deuterium (new alarm and heater settings)
- A simple array of carbon foils can be installed in the scattering chamber using the same mounting fixture as the cryotarget cell
- Remaining tasks:
  - Procurement of D2 gas (4 weeks)
  - Design, procurement, & assembly of carbon foil target (8 weeks)
  - Install & align carbon foil target (1 - 2 days)

A Helium Cryotarget for Hall D

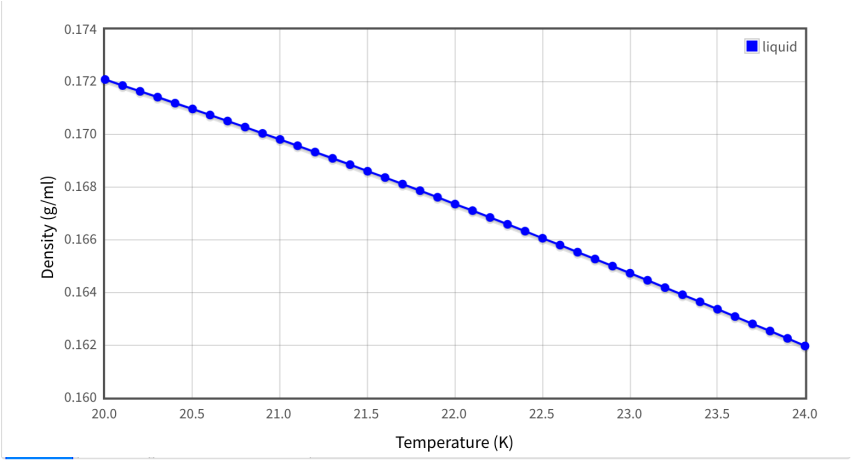


Rough estimate of the density reduction from boiling

- 35 min. to pump 16 g of LHe from the cell ➡ boiling rate = 8 mg/s
- Latent heat $\mathcal{L}$(1.75 K) ≈ 23 J/g ➡ 0.18 W of heat
- Latent heat $\mathcal{L}$(4.55 K) ≈ 19 J/g ➡ 9 mg/s boiling rate @ 4.55 K
- The vapor density at 4.55 K is 23 mg/cm^3
- The vapor production rate is then 0.4 cm^3/s
- This is equivalent to one bubble with radius R = 0.5 cm
- Avg. chord length is 4R/π ➡ 2% reduction of target thickness

Density of Deuterium (NIST)

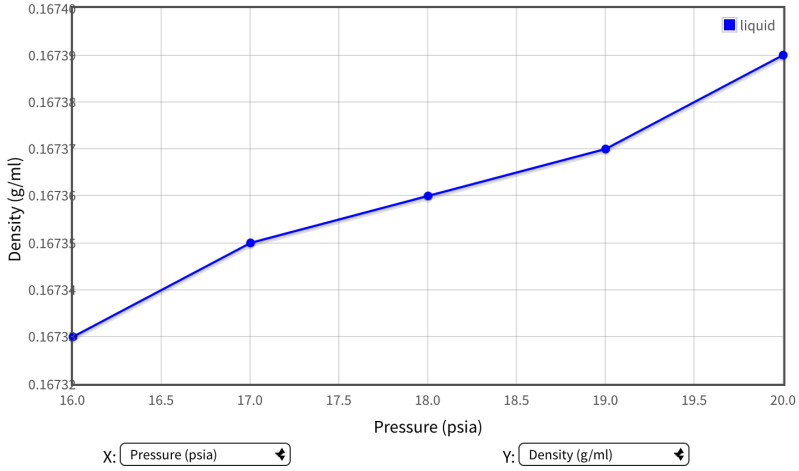
Operate LD2 at 18 psia → 24.0 K on SVP curve
subcool 2 K → 22.0 K



Temperature dependence

ρ = 167 mg/cc ± 1.5% per K

ΔT = 0.2 K → $\Delta\rho/\rho$ = 0.3%



Pressure dependence

ρ = 167 mg/cc ± 0.03% per psi

ΔP = 0.1 psi → $\Delta\rho/\rho$ = 0.00%