Liquid D2, ^{3}He, and ^{4}He Cryotarget for Hall D

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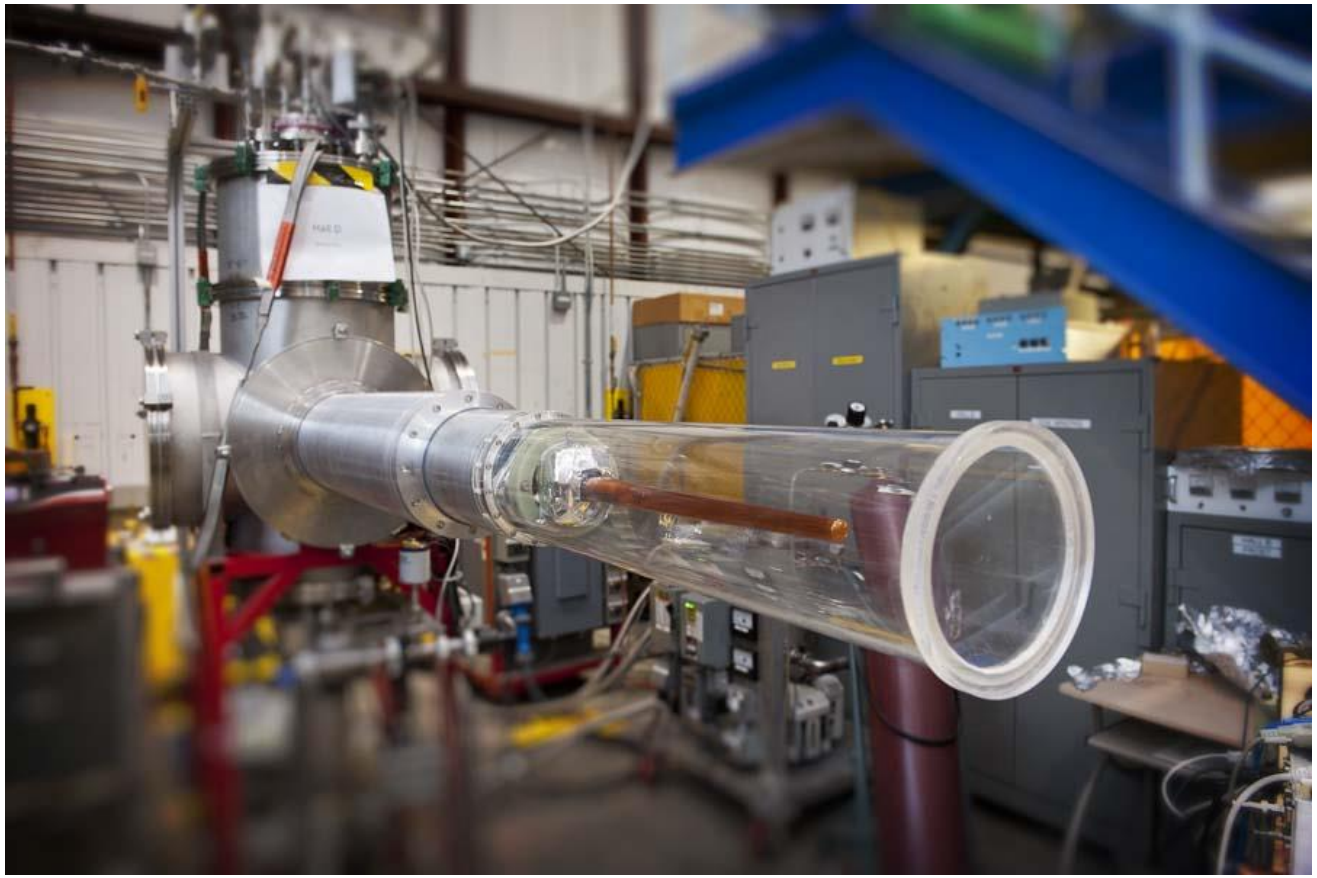
The Hall D Cryotarget

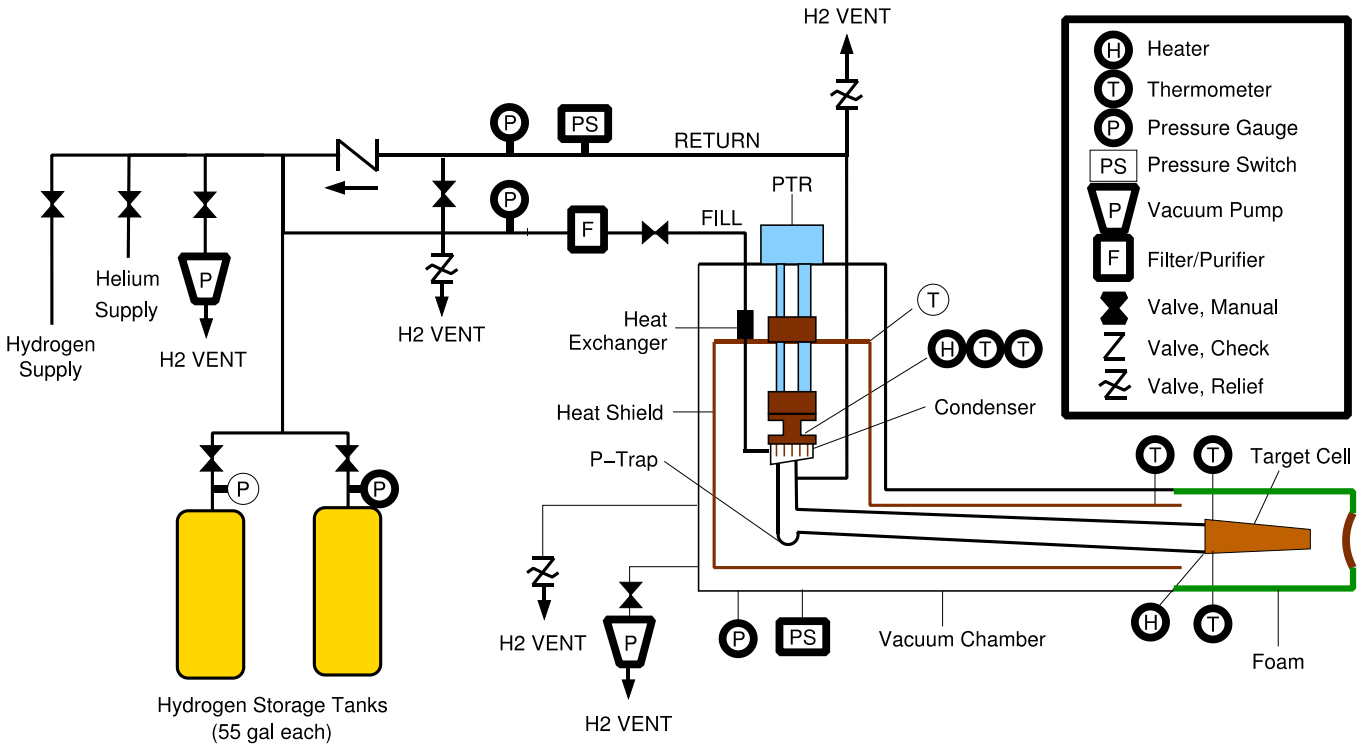
- Originally designed and constructed for the GlueX experiment in Hall D
- Operational since 2014

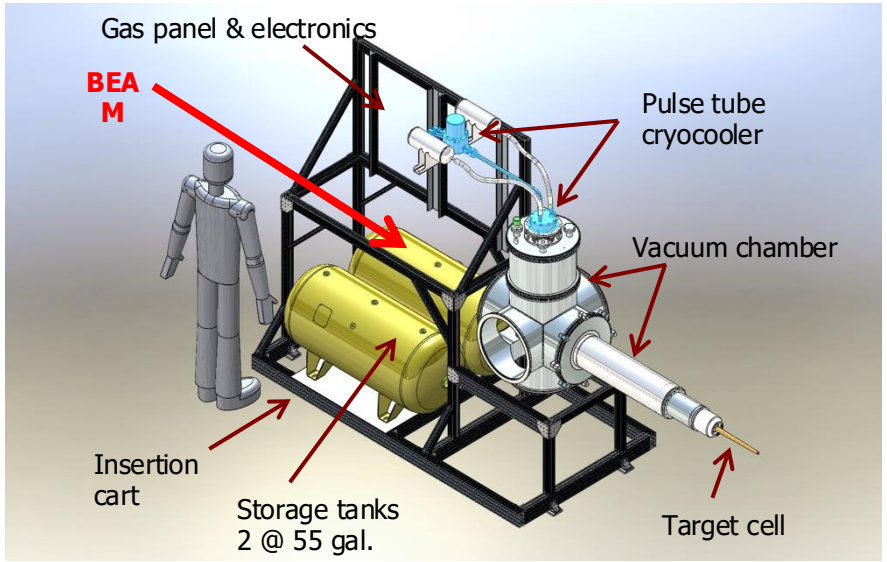


The Hall D Cryotarget

- Liquid Hydrogen
- Liquid Deuterium
- Liquid ^{4}He
- Liquid ^{3}He?

How it works





A small cryocooler cools a copper/stainless condenser to the liquefaction temperature of the target gas.

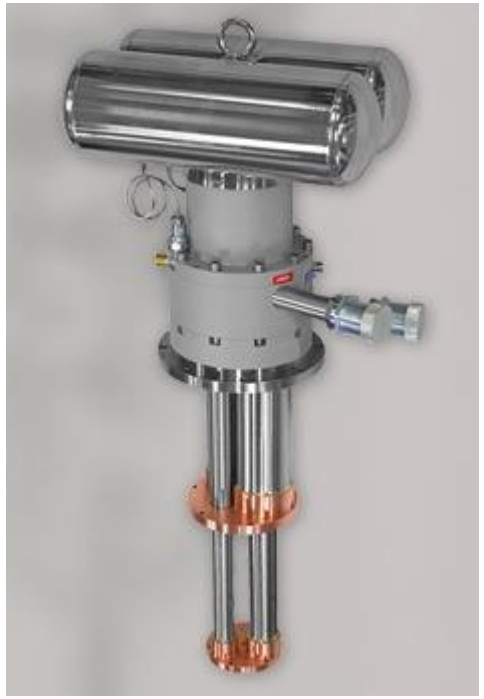
Liquid is collected in the condenser and drains into the target cell.

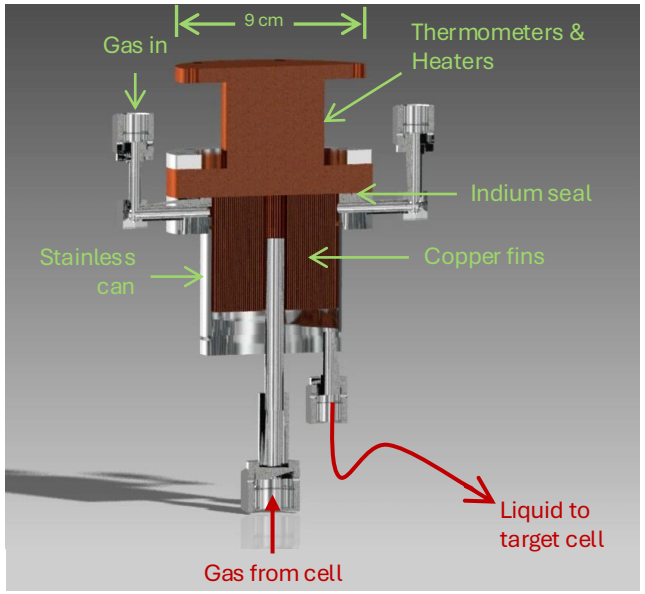
A heater regulates the temperature.

Cell is warmed to 40 K for “empty” (gaseous) runs.

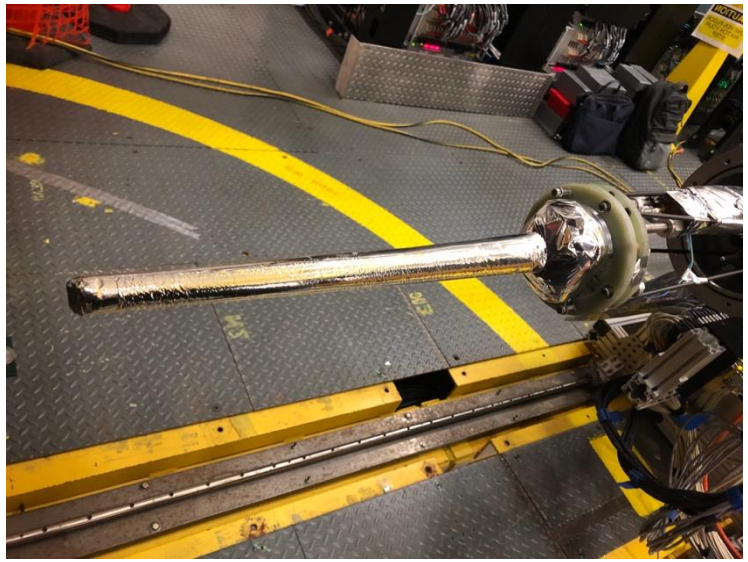
How it works

Pulse Tube Cryocooler

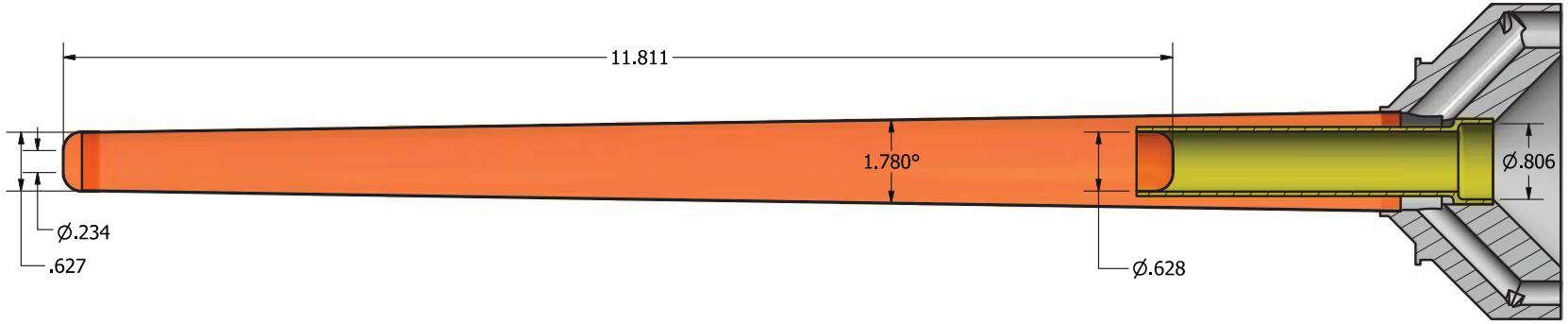




Condenser



Target Cell



Hydrogen vs Helium

Hydrogen (deuterium)

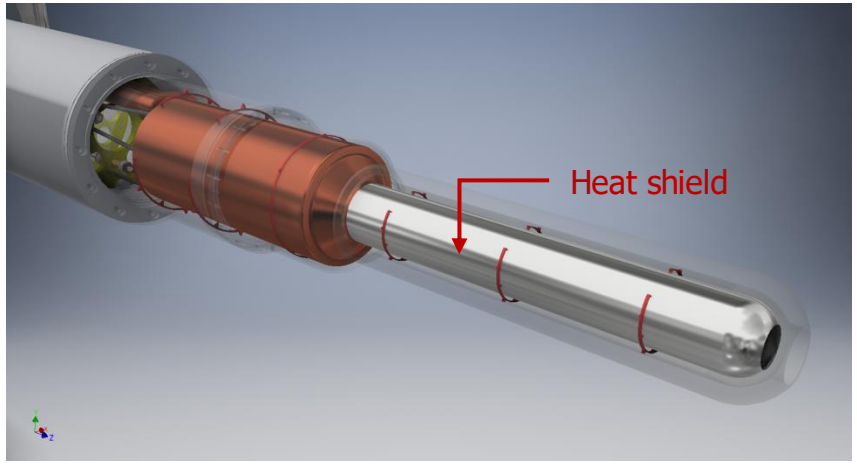
Density: 0.07 g/cc (0.16 g/cc)
Boiling point: 20.4 K (23.3 K)
Latent Heat: 223 J/g (322 J/g)
Expansion ratio: 850:1 (900:1)

For **hydrogen or deuterium**, it is sufficient to wrap the target cell in several layers of super-insulation.
→ Estimate 5 W radiative heat load.

The hydrogen/deuterium liquid is **subcooled by 2K** to suppress boiling.

Helium-4 (helium-3)

Density: 0.125 g/cc (0.08 g/cc)
Boiling point: 4.2 K (3.1 K)
Latent Heat: 20 J/g (9 J/g)
Expansion ratio: 750:1 (600:1)

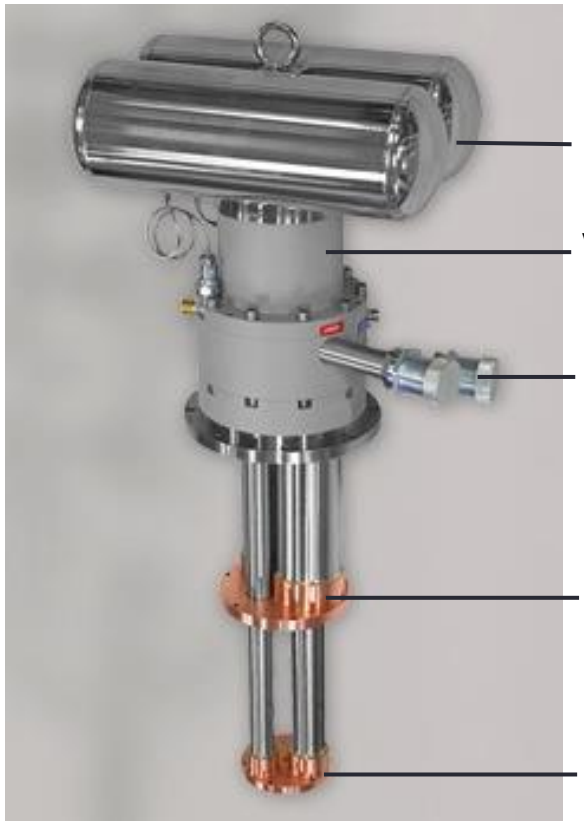


For **helium-4**, it is necessary to surround the the target cell by a thin, 100 K **aluminum heat shield.**
→ Reduces radiative heat load to about 0.2 W

The liquid helium is not subcooled; it boils on the **saturated vapor pressure curve**.

Helium-3 won't work!

CRYOMECH
WORLD LEADERS IN CRYOREFRIGERATION FOR MORE THAN 50 YEARS



Cryomech PT415

- 2.8 K base temperature
- 17 W at 20 K
- 1.5 W at 4.2 K
- **0.2 W at 3 K**

Insufficient cooling at ^{3}He liquefaction temperature

Helium-3 will work!

CRYOMECH
WORLD LEADERS IN CRYOREFRIGERATION FOR MORE THAN 50 YEARS

Cryomech **PT310**

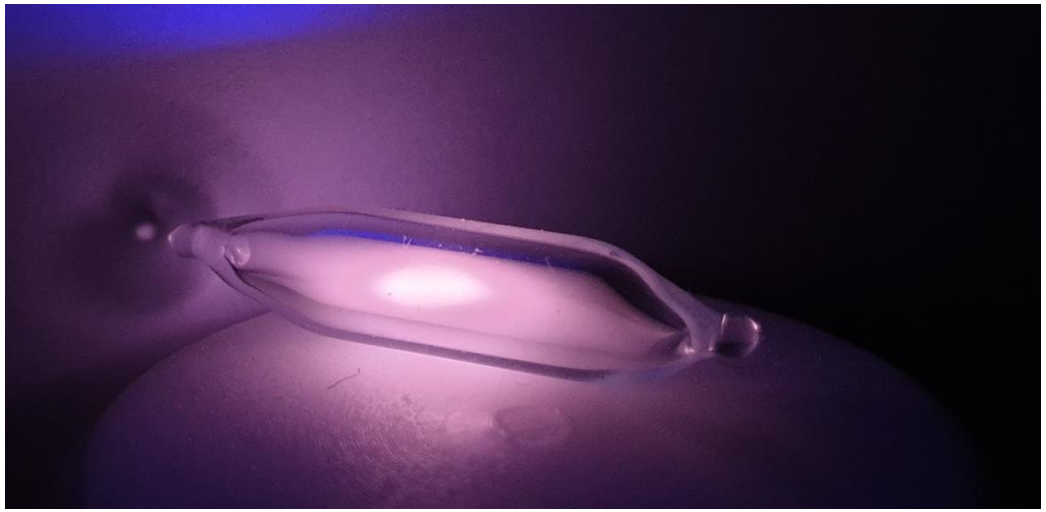
- 2.3 K base temperature
- ~20 W at 20 K
- 2 W at 4.2 K
- **1 W at 3 K**

5x the cooling at 3 K.
Probably enough!

Slightly larger than the existing cryocooler, more powerful helium compressor

Cost: $100k

Don’t forget the Helium-3



With the DOE discount, ^{3}He costs about $1000/liter ($7.5k/gram)

We need 9 g (70 liters) to fill the cell → $70k

We need 210 liters to maintain tank at 1 atm → $210k
(Or use a compressor, but this complicates operation…)

Summary

The existing Hall D cryotarget can provide 30 cm long liquid targets of **hydrogen, deuterium, and ^{4}He**

Switching from one fluid to another takes about one day.

A target of **liquid 3He** will require a new, more powerful cryocooler ($100k) and approximately 300 STP liters of 3He gas ($300k).

The Hall A & C cryotargets have an inventory of about 3200 liters.
Can we transfer 10% to Hall D?