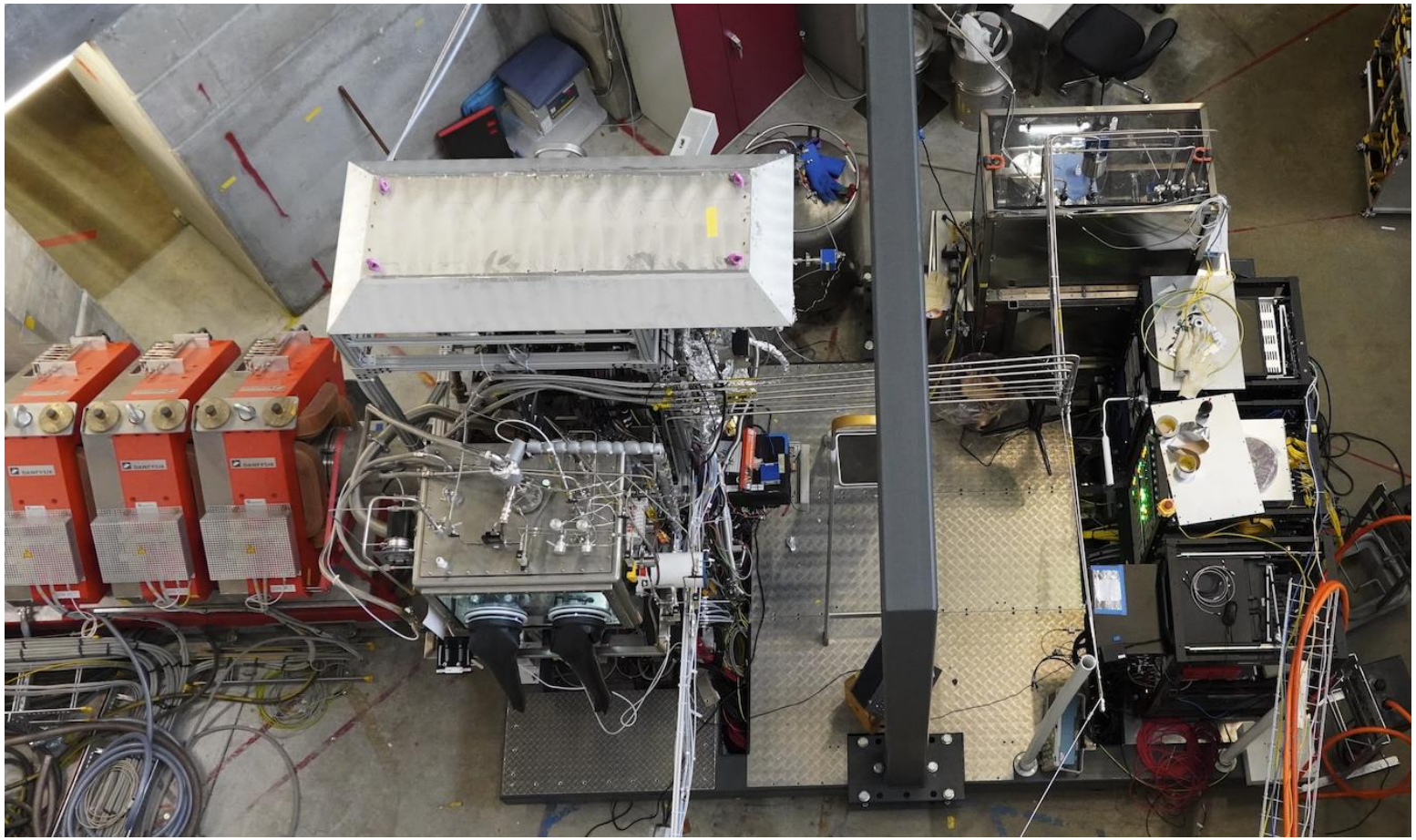
Recent Tritium Activities in µCF



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Rochester, New York, USA

International Workshop on µCF and Future Applications
University of Liverpool, Liverpool, United Kingdom
July 2 – 3, 2026

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Outline

- Describe the tritium handling system
- Highlight the emission mitigation infrastructure
- Discuss tritium safety considerations

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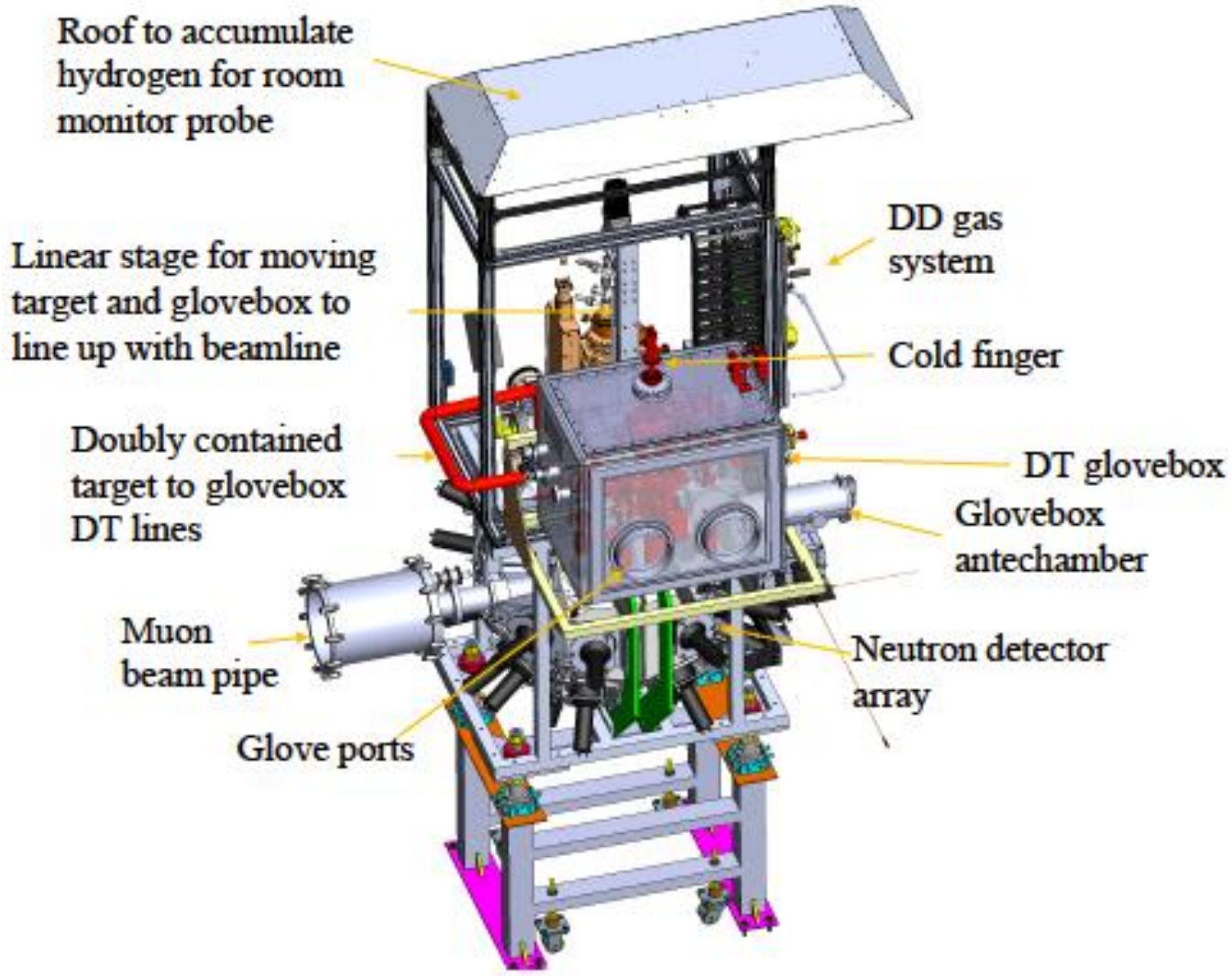
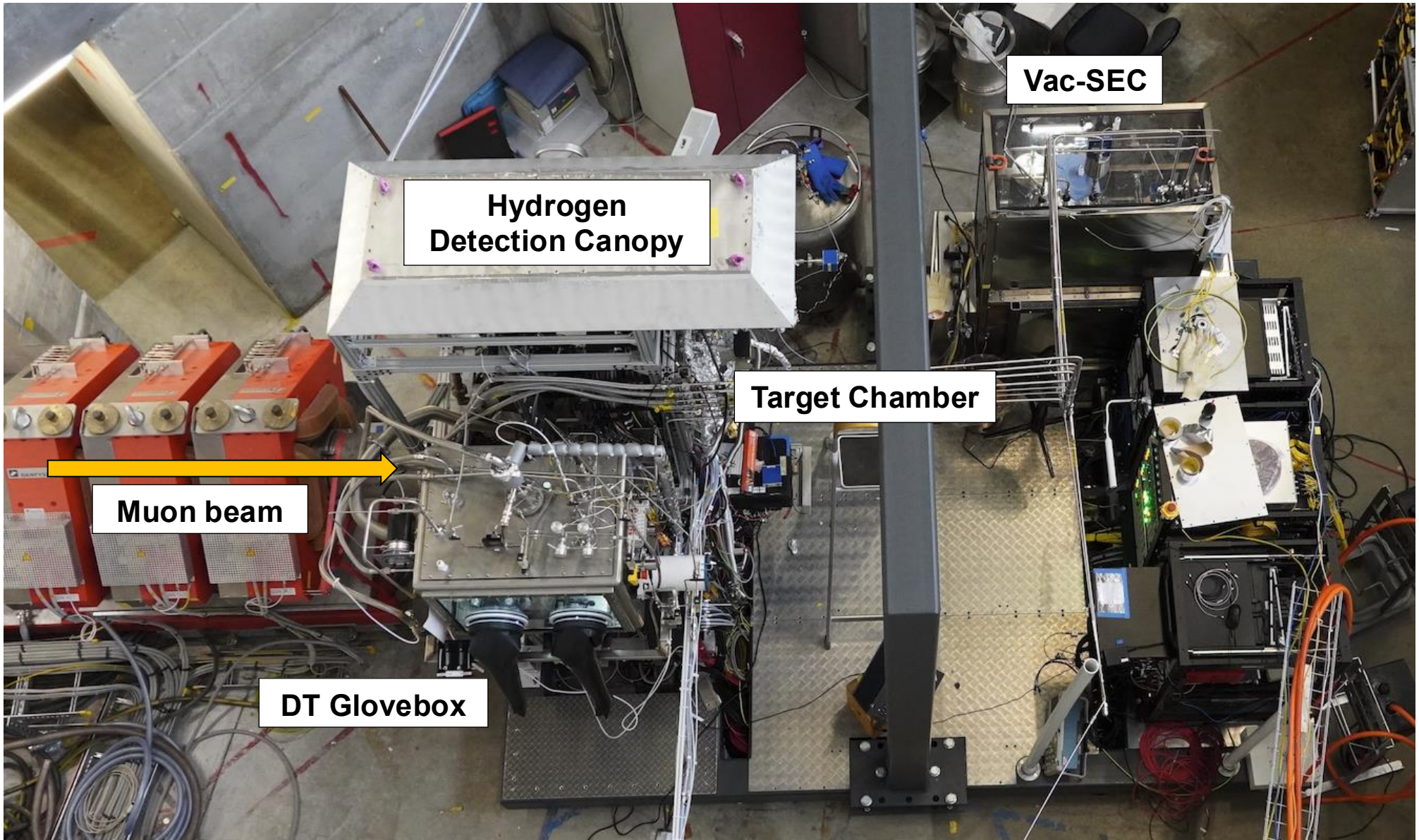
Solid works model of the muon catalyzed fusion test rig portrays the key features of the experimental setup deployed at PSI



Acceleron handled 0.6 grams of tritium pressurized to 10^5 atmospheres to measure the muon sticking fraction



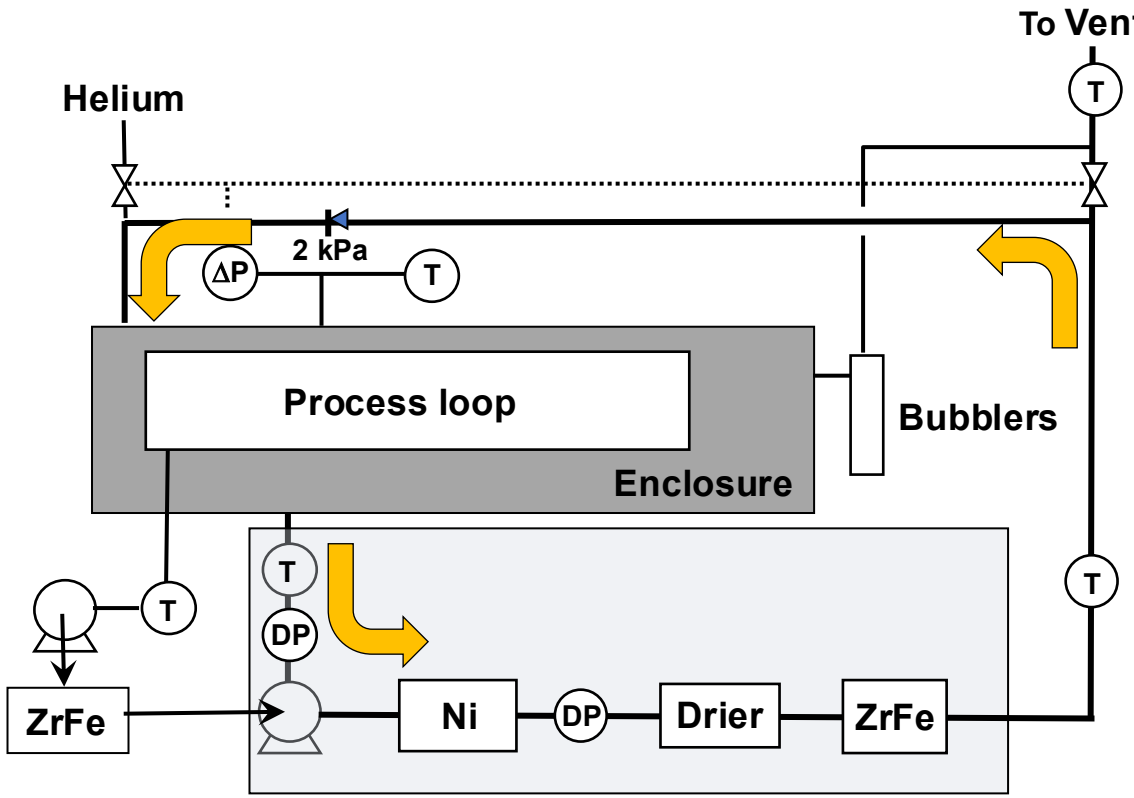
Getter-based cleanup-system for the enclosure using a helium cover gas mitigated accidental releases without conversion to tritiated water

Functions:

- Recovery of elemental tritium
- Maintain negative pressure relative to the ambient

Operational parameters:

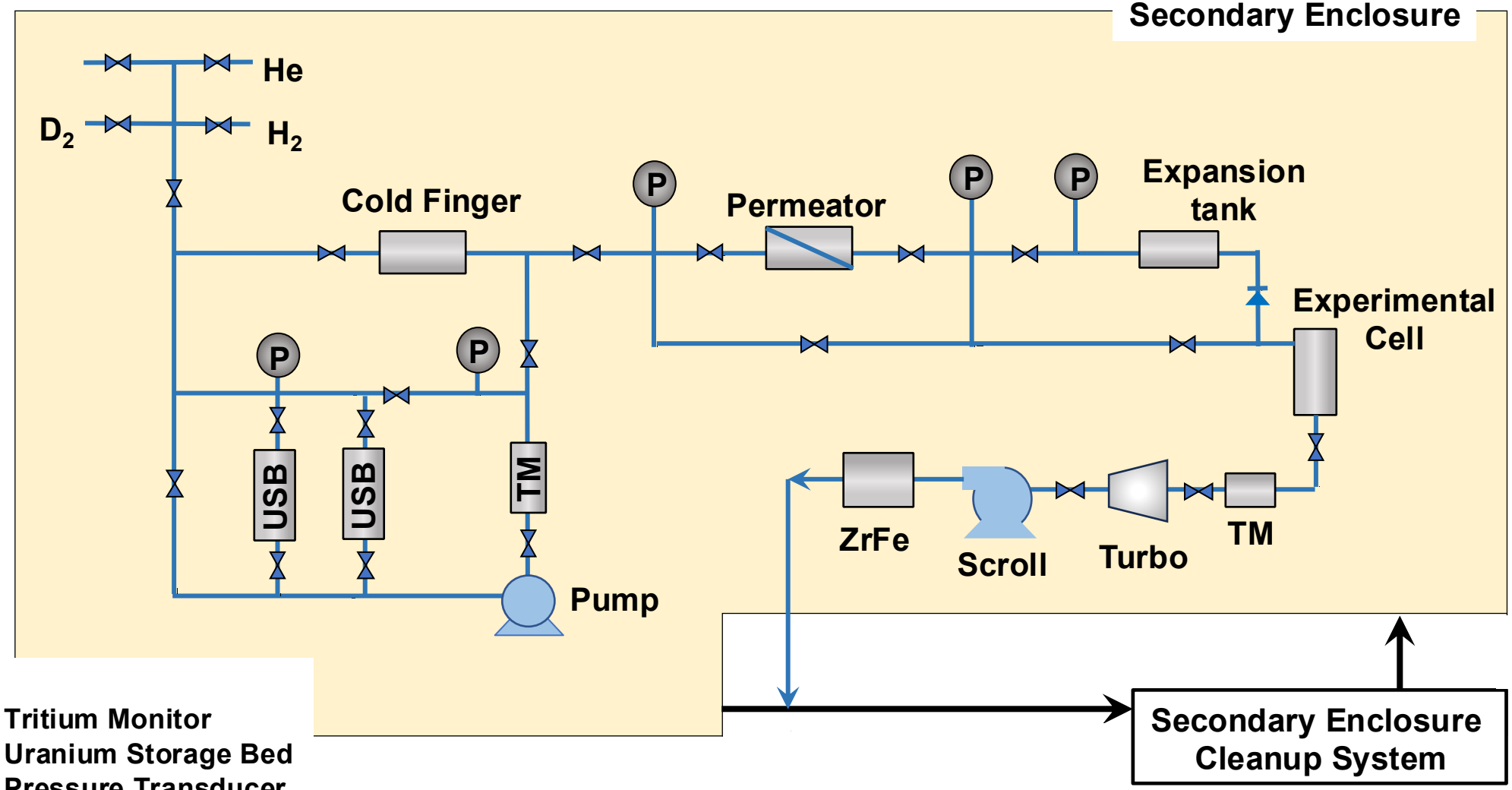
- Dew Point: - 60°C
- O_2 concentration: ~ ppm
- Glovebox activity: ~ 1 mCi/m^3



Legend:
DP = Dew Point sensor
T = Tritium monitor
P = Pressure sensor
Ni = Nickel bed
ZrFe = Tritium scavenger bed

W.T. Shmayda et al., *Fusion Science & Tech.*, 21, 1992, 616–621

The tritium delivery and high-pressure systems were housed in a glovebox under a helium cover gas



Legend:
- TM: Tritium Monitor
- USB: Uranium Storage Bed
- P: Pressure Transducer

Flow-through, doubly-contained uranium storage beds offer safe, reliable, and robust tritium storage capabilities

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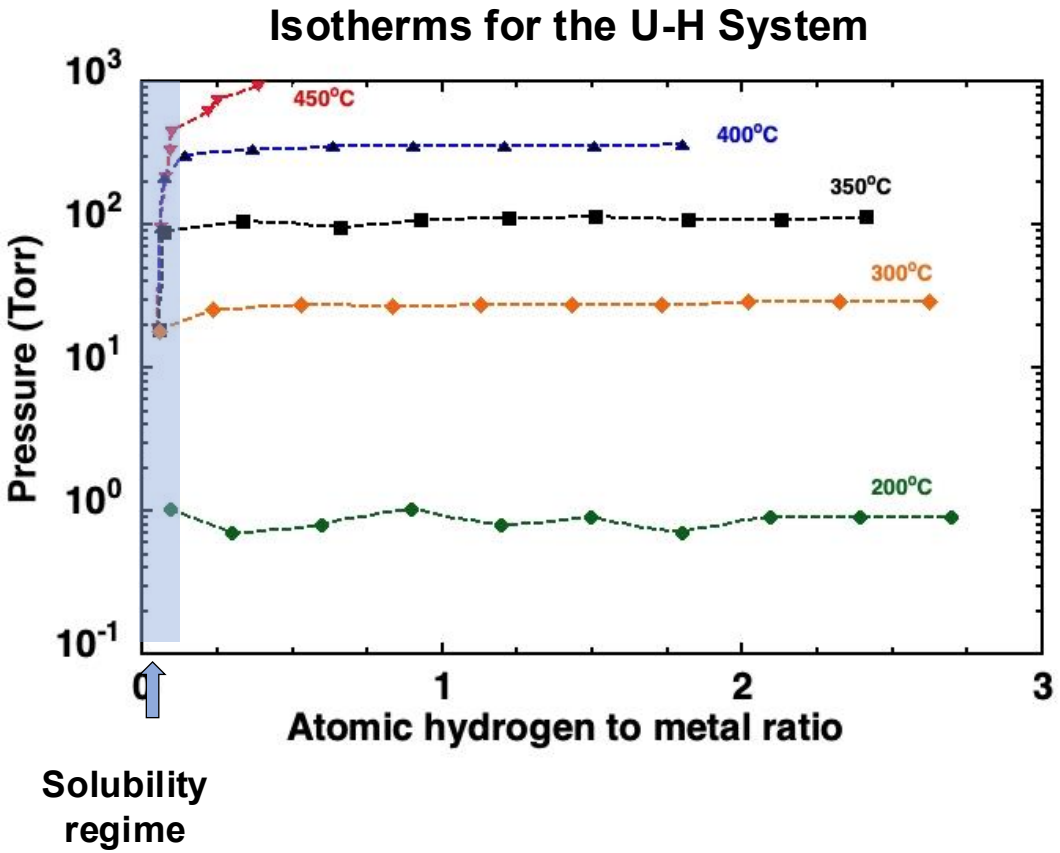
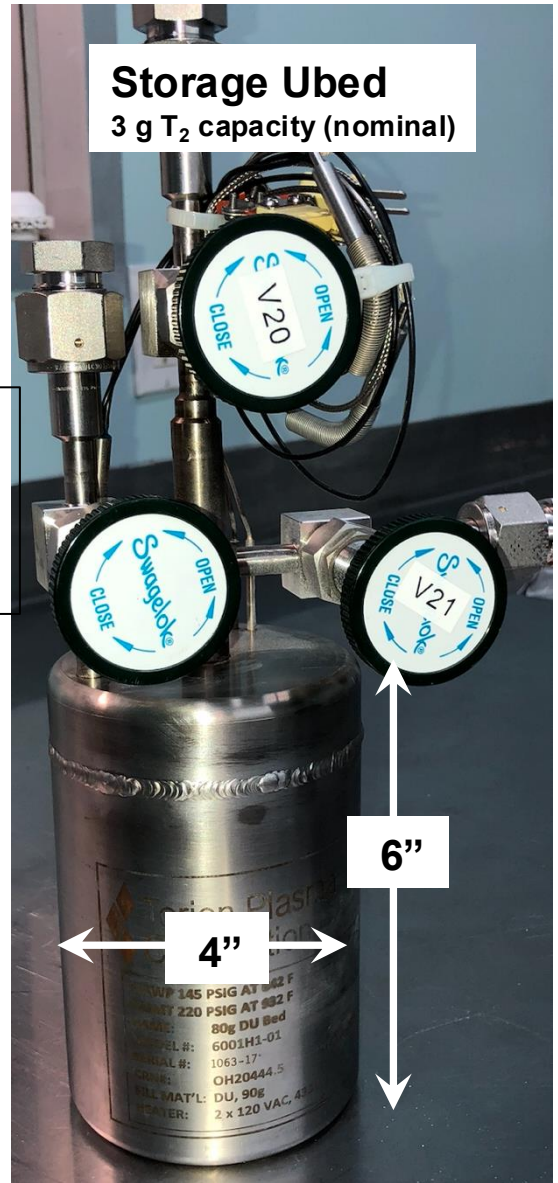


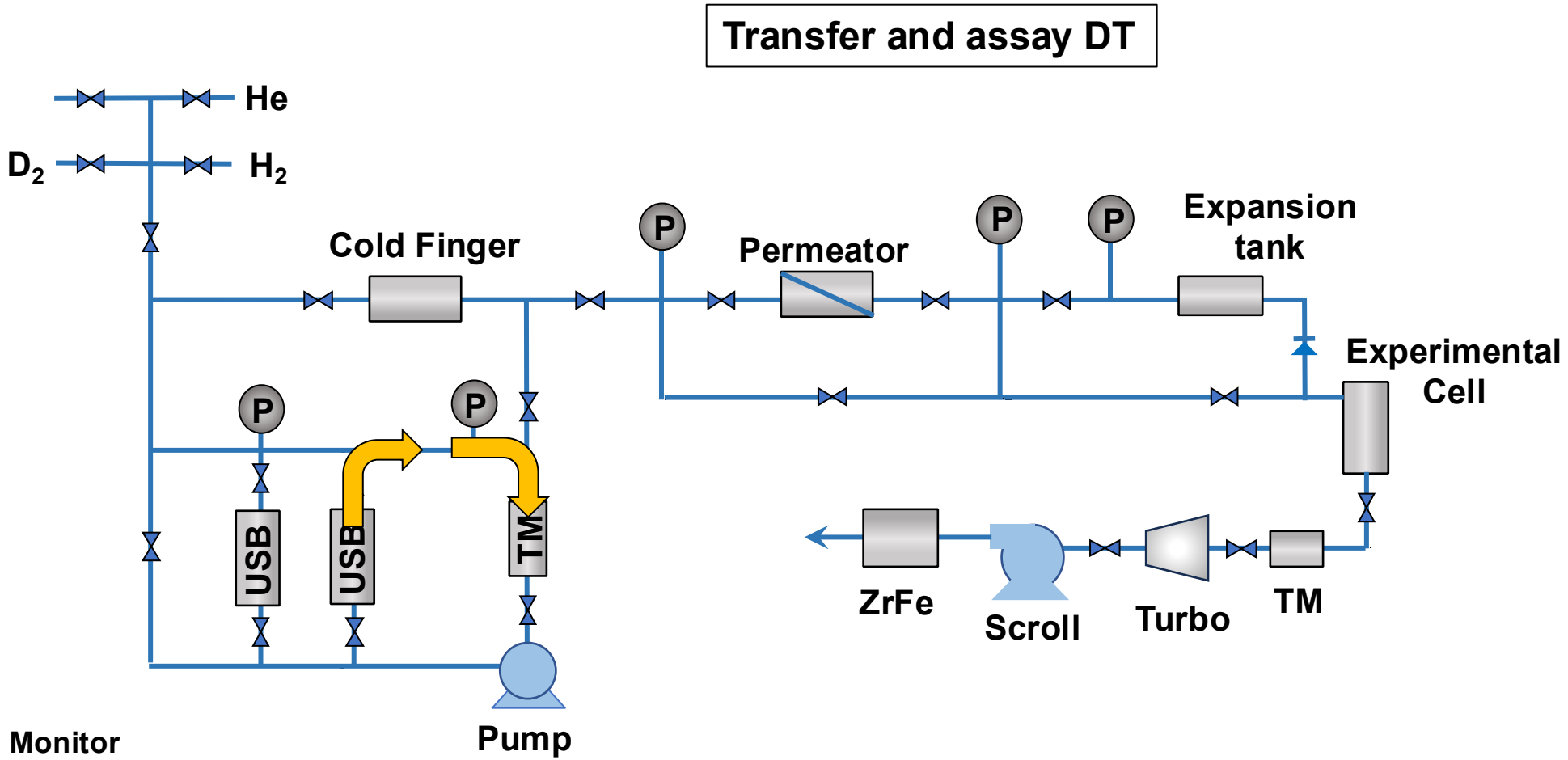
Tritium Storage & Delivery System provides four functions:

- Remove helium-3
- Assay tritium inventory
- Provide safe storage medium
- Accept gas from various sources



A. G. Heics and W. T. Shmayda, *Fusion Technol.*, 1157 (1992)

DT is transferred to the tritium process monitor (TM) to be assayed



Legend:

- **TM:** Tritium Monitor
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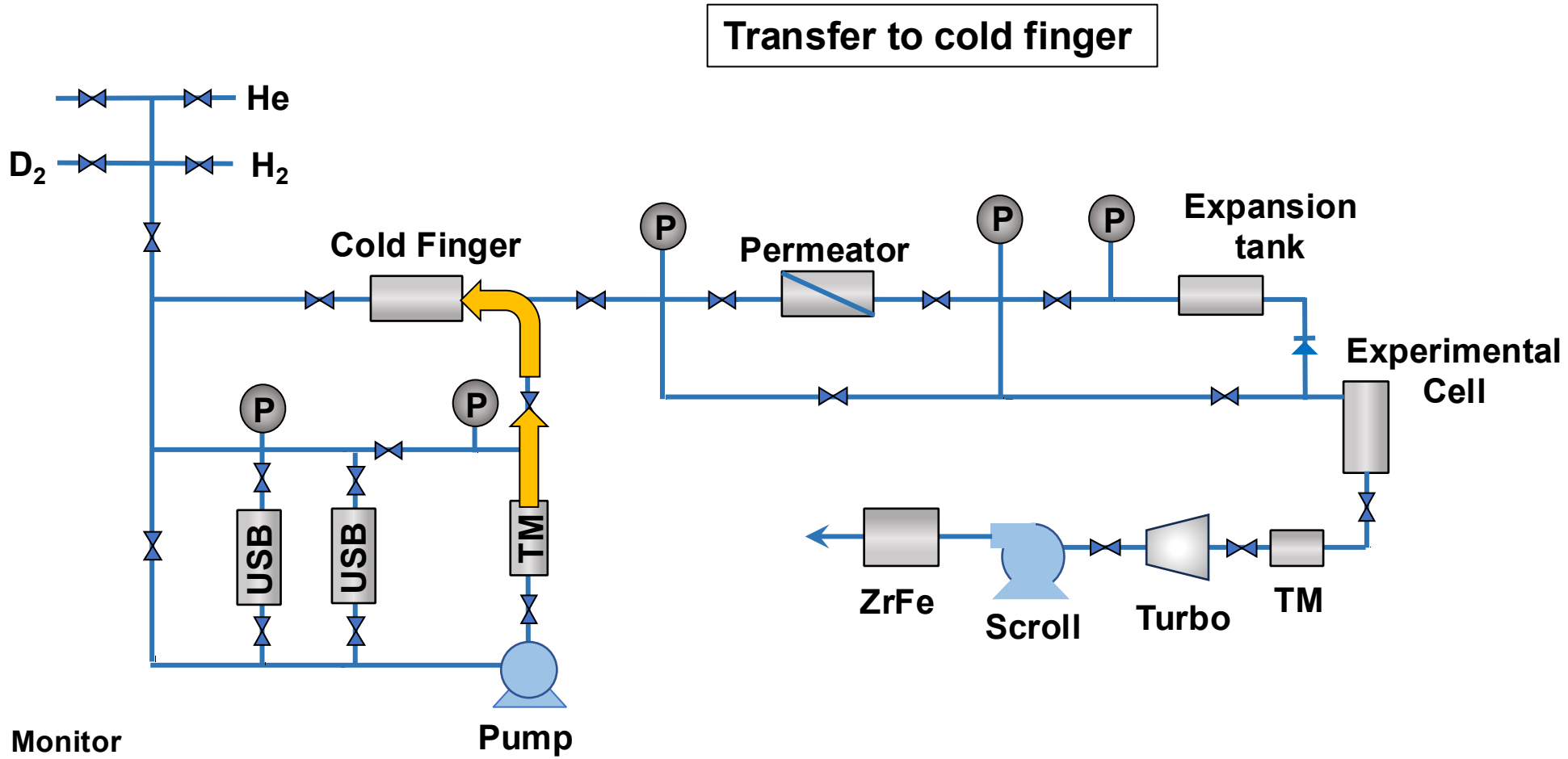
DT moved cryogenically into the cold finger



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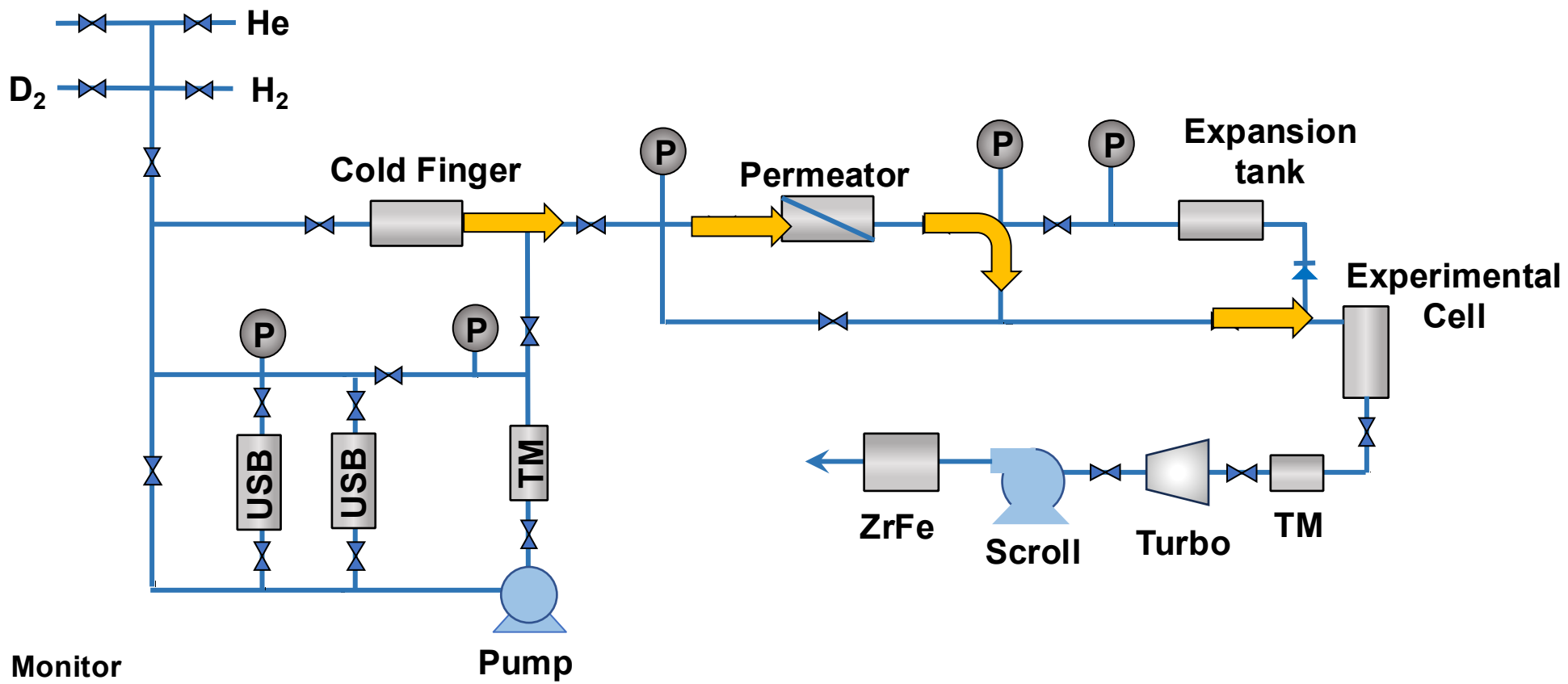
^{3}He is removed from the DT gas with a Palladium/silver permeator

Remove ^{3}He from DT and deliver to cell



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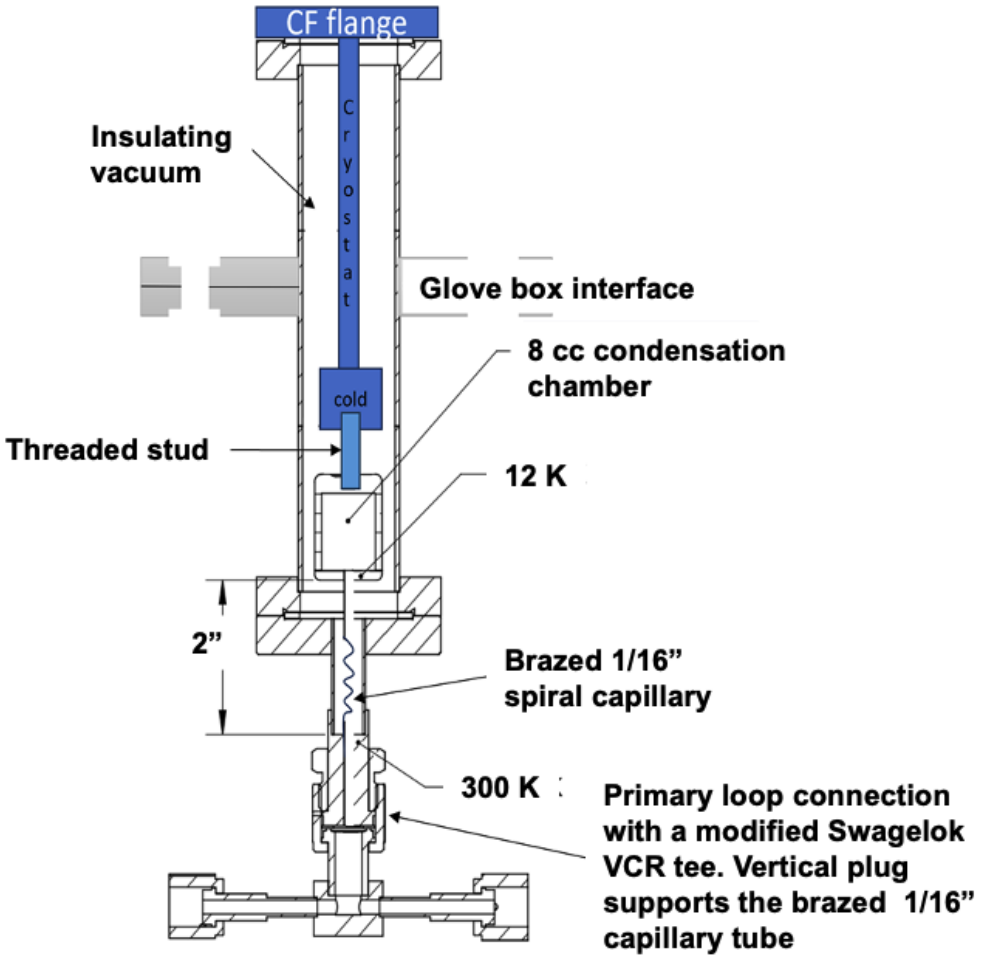
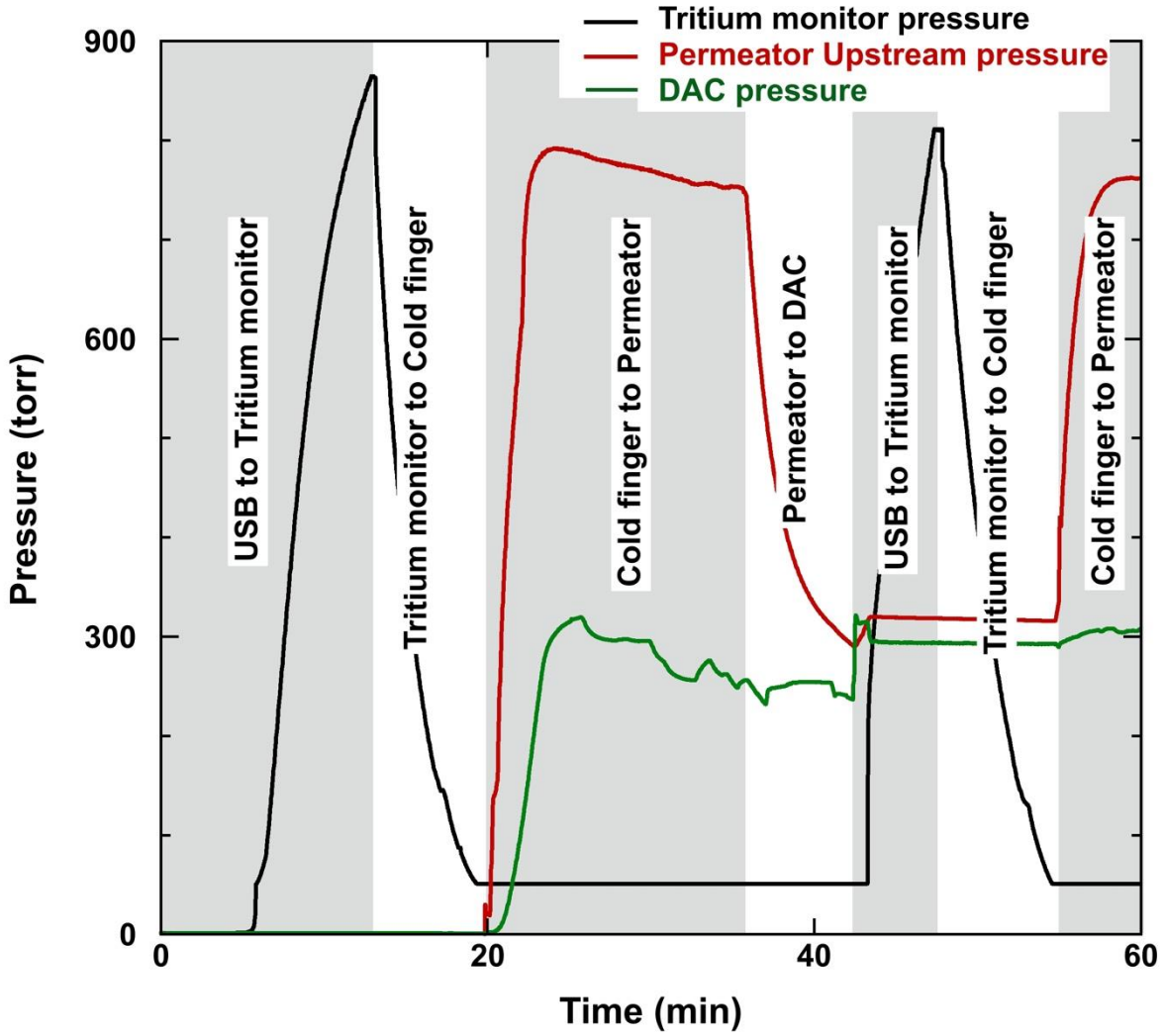
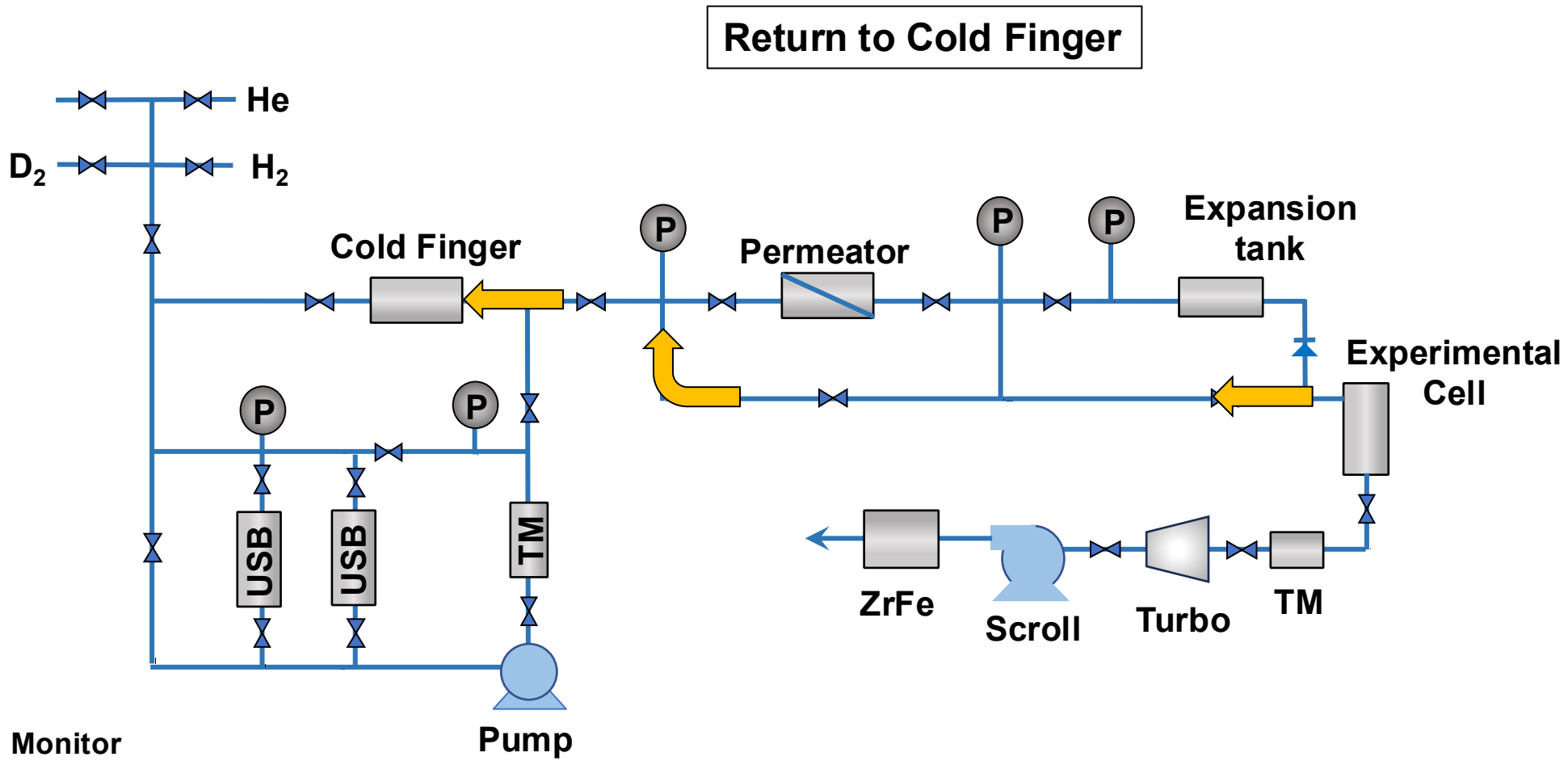
The cold finger provides an elegant method to pressurize tritium into the permeator without using mechanical pumps





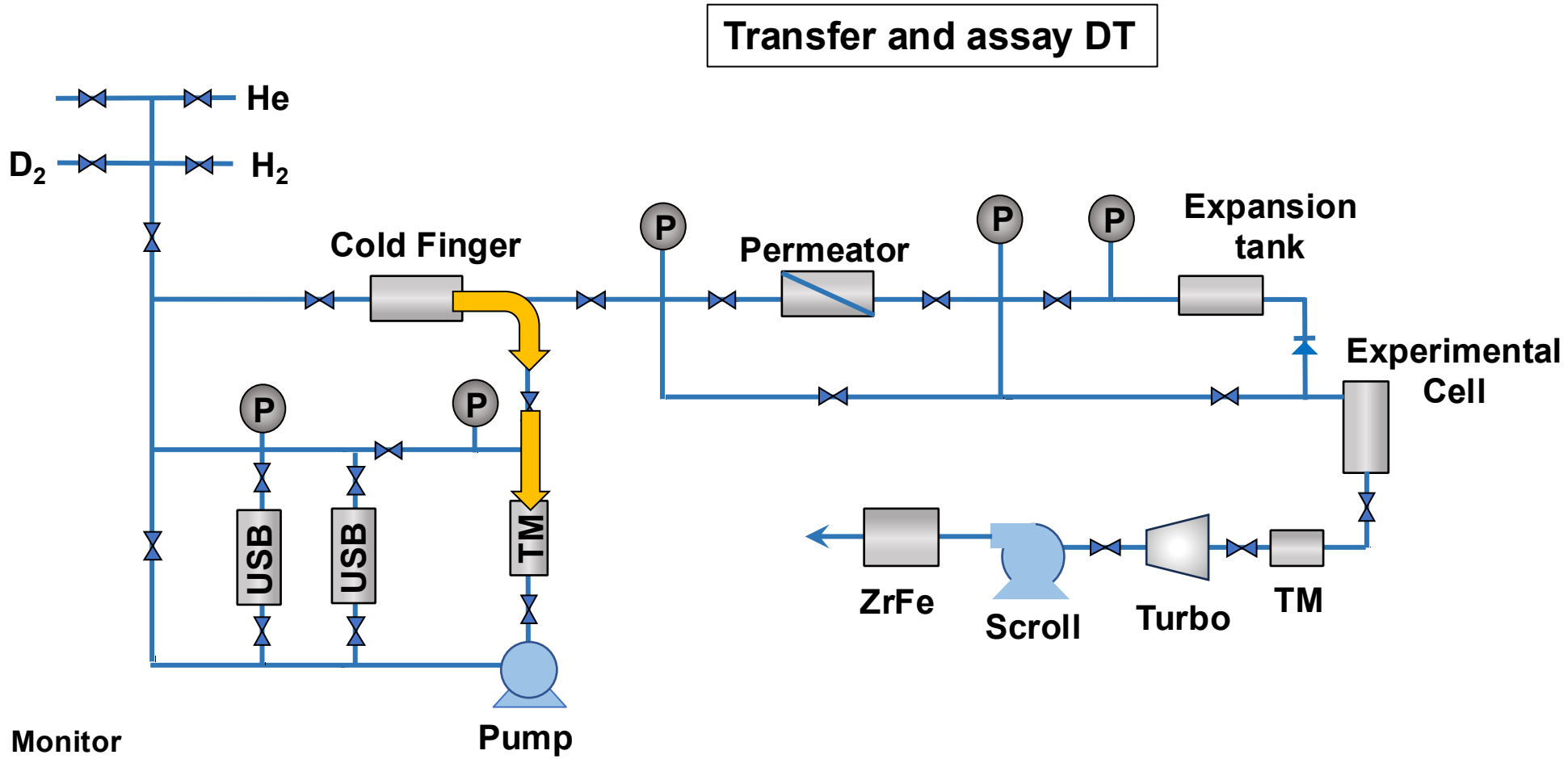
DT gas is returned to the the storage system using the cold finger



Legend:

- **TM:** Tritium Monitor
- **USB:** Uranium Storage Bed
- **P:** Pressure Transducer

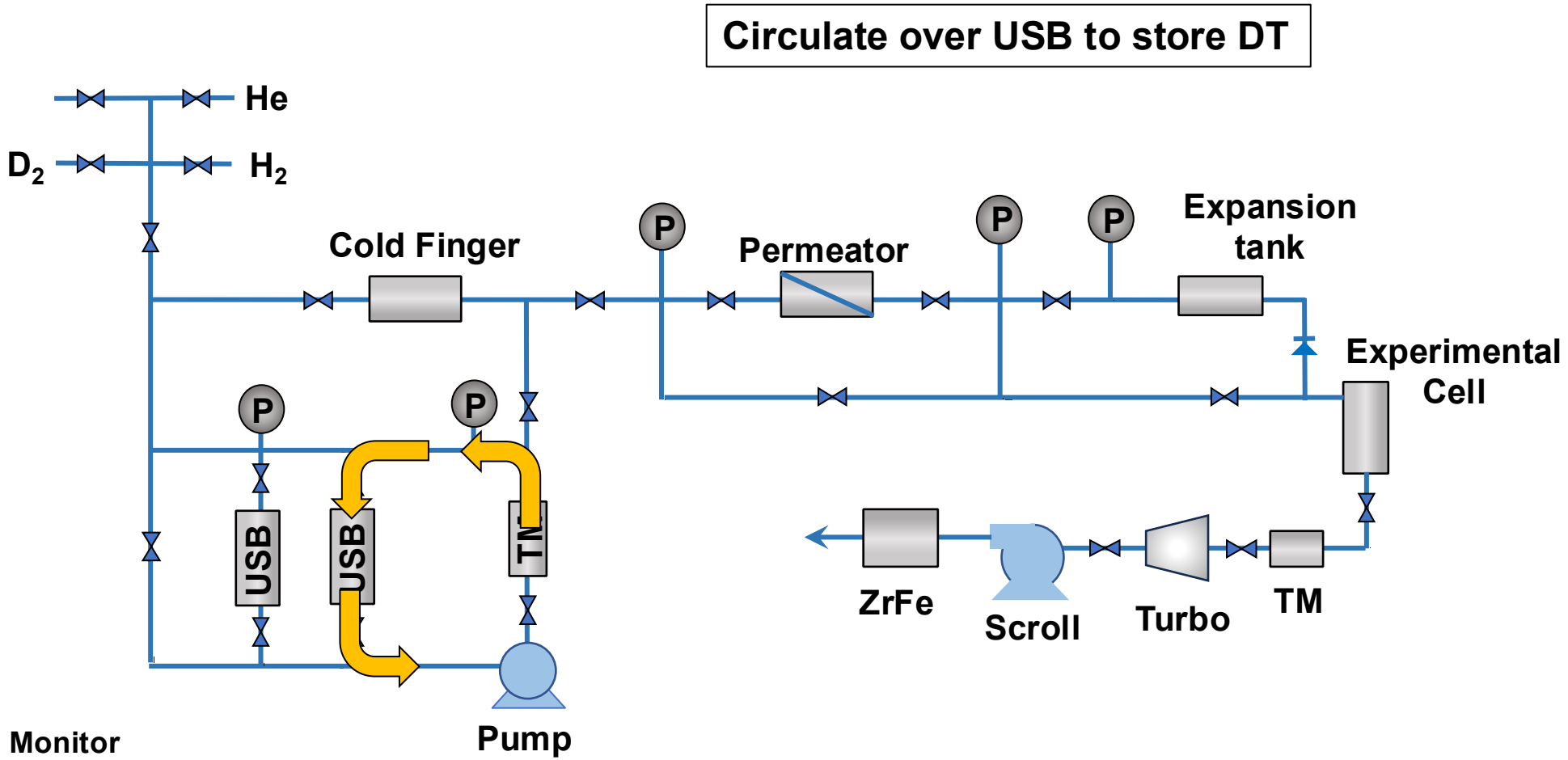
DT is assayed before returning to the USB



Legend:

- **TM:** Tritium Monitor
- **USB:** Uranium Storage Bed
- **P:** Pressure Transducer

DT is circulated over the USB to prevent the blanketing effect



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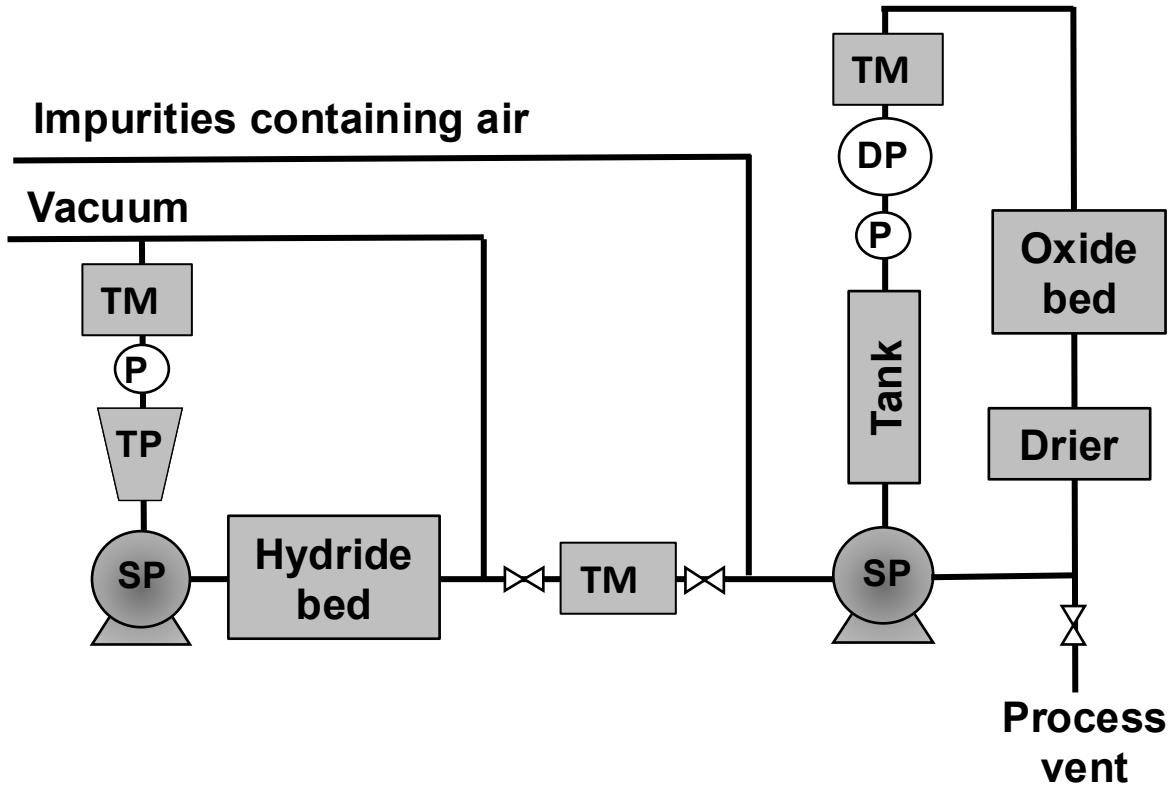
- **P:** Pressure Transducer

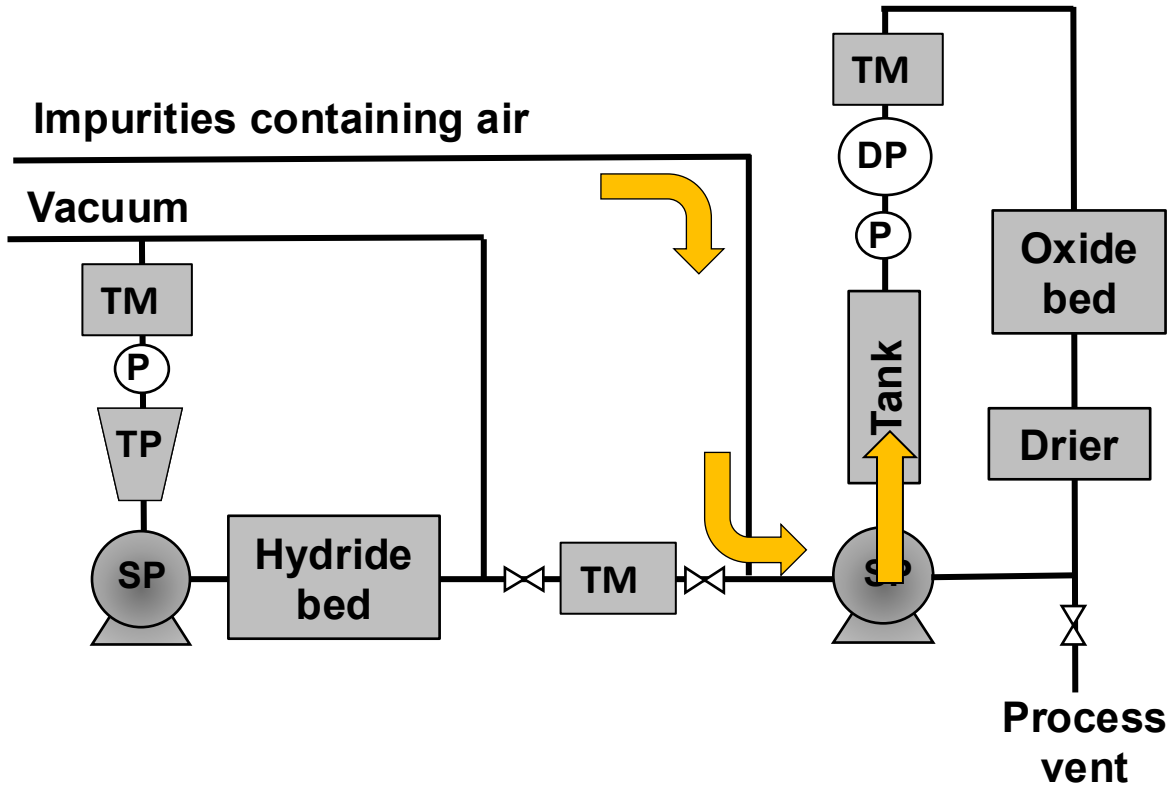
Emission reduction systems need to capture both inert gas and air bearing tritiated effluent streams



Legend:

- TM = tritium monitor
- P = pressure transducer
- TP = turbomolecular pump
- SP = scroll pump
- DP = dewpoint sensor

Air containing tritiated effluents need to convert HT to water vapor (HTO) over an oxide bed



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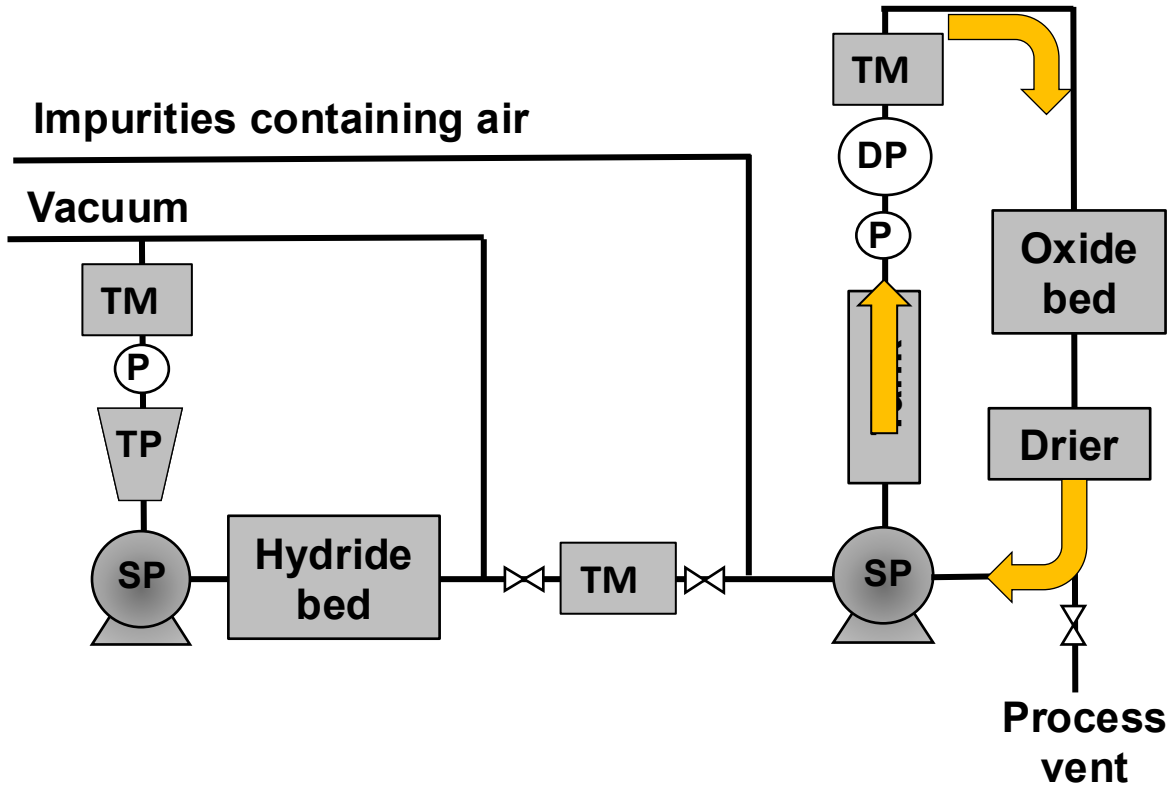
Air containing tritiated water vapor (HTO) is circulated and captured on a drier before release to the environment



Legend:

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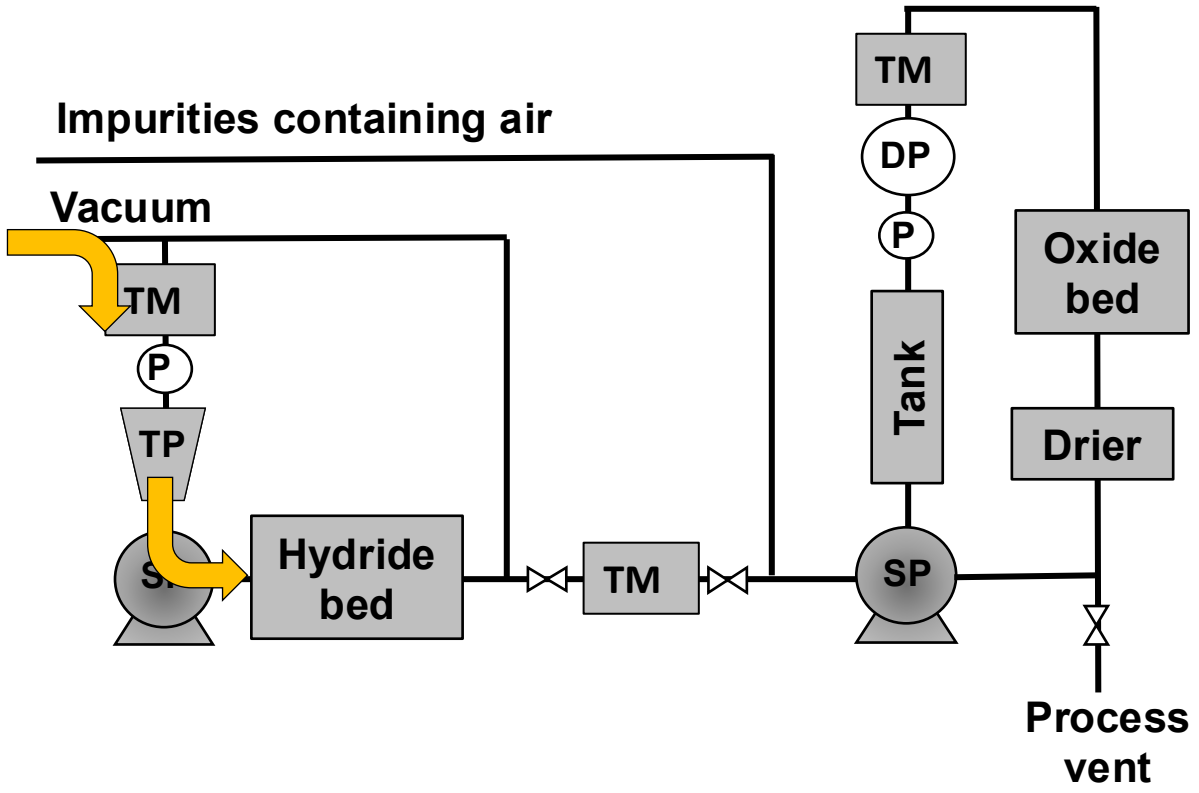
Inert gases containing tritiated effluents can be captured on a getter



Legend:

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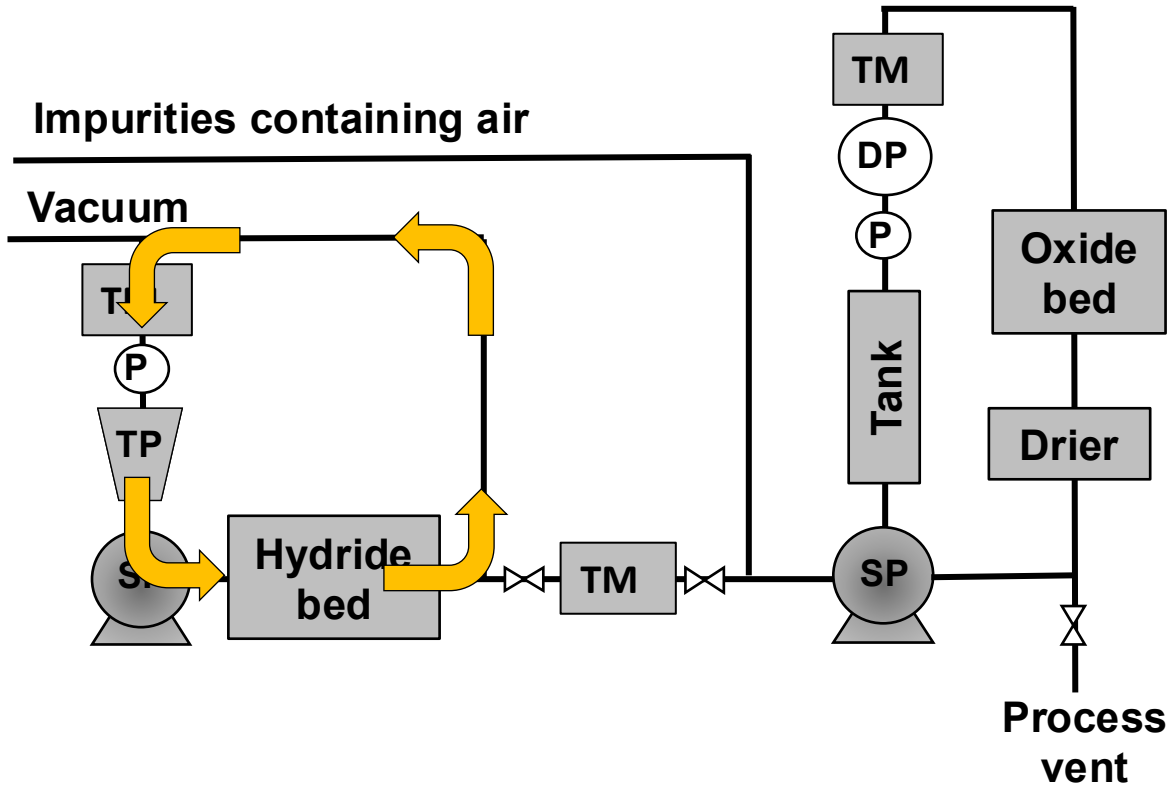
Circulation over the getter reduces blanketing effects



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Process loop is a high integrity system

- Constructed from 316 stainless steel tubing
- Minimize the number of demountable joints with orbital welding
- VCR coupling of components to the loop using copper gaskets
- Leak-tightness of each joint/weldment < $1*10^{-9}$ scc/s helium
  - Process loop will be leak checked any time the system is relocated or modified
- Permeator designed in accordance with ASME Section VIII, Div. 1
- Loop constructed in accordance with ASME B31.3 Section X, High Purity

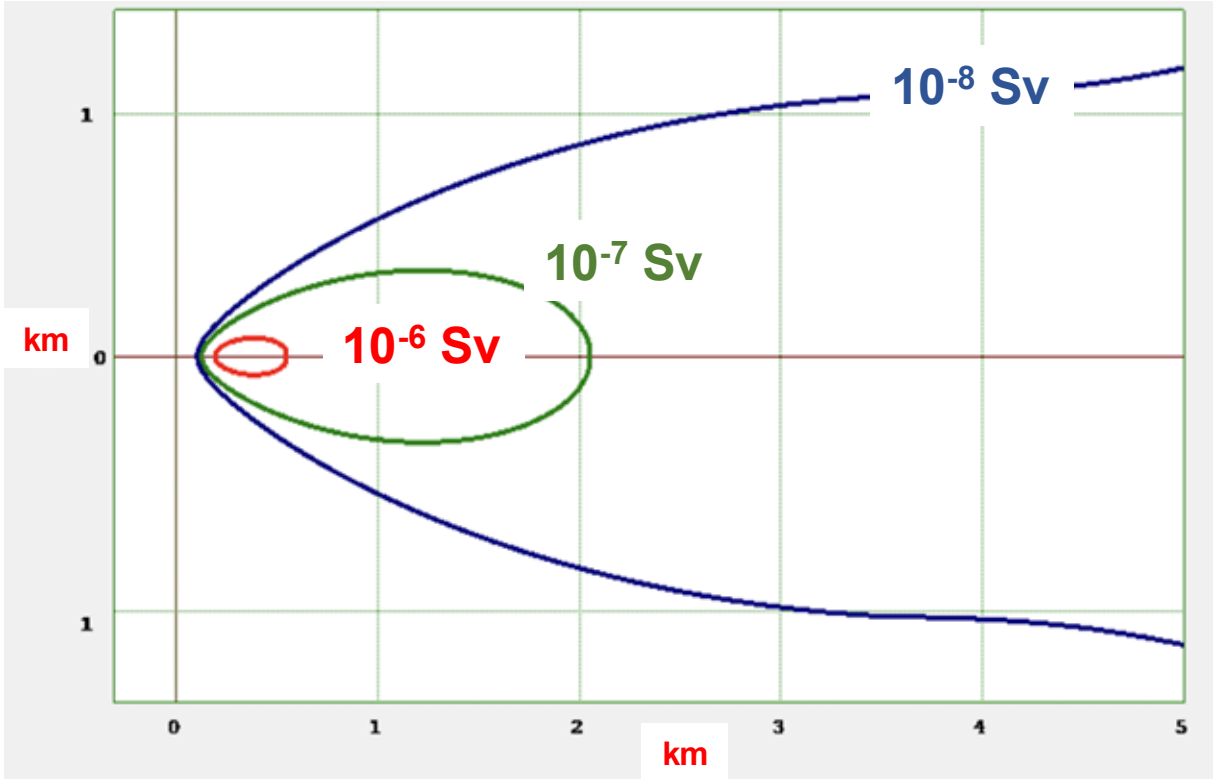
Commissioning with tritium was a staged process

- Process verification using D_2
- Preliminary commissioning with 0.01% tritium in deuterium
  - Search for low level leaks
  - Verify performance of tritium monitors
- Intermediate commissioning with 0.1% tritium in deuterium
  - Gain operational experience with no risk of exceeding the PSI emission limits
- Final commissioning run with 1 and 10% tritium in deuterium
  - Finalize procedures
- No tritium operations if the enclosure cleanup system is not functioning

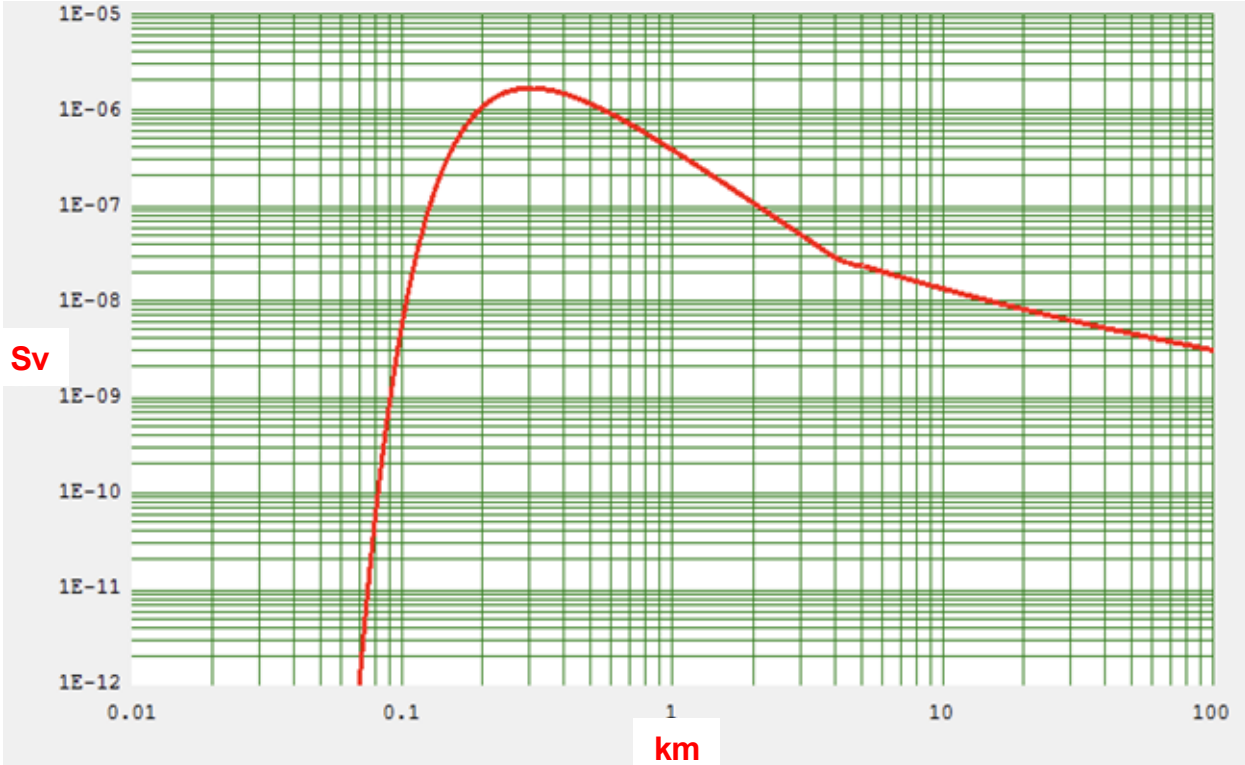
Supervision of the system anytime tritium is off the Ubed

Doses to the public resulting from an accidental maximum tritium release were projected to be negligible under very unstable, Class A, conditions

Plume contours



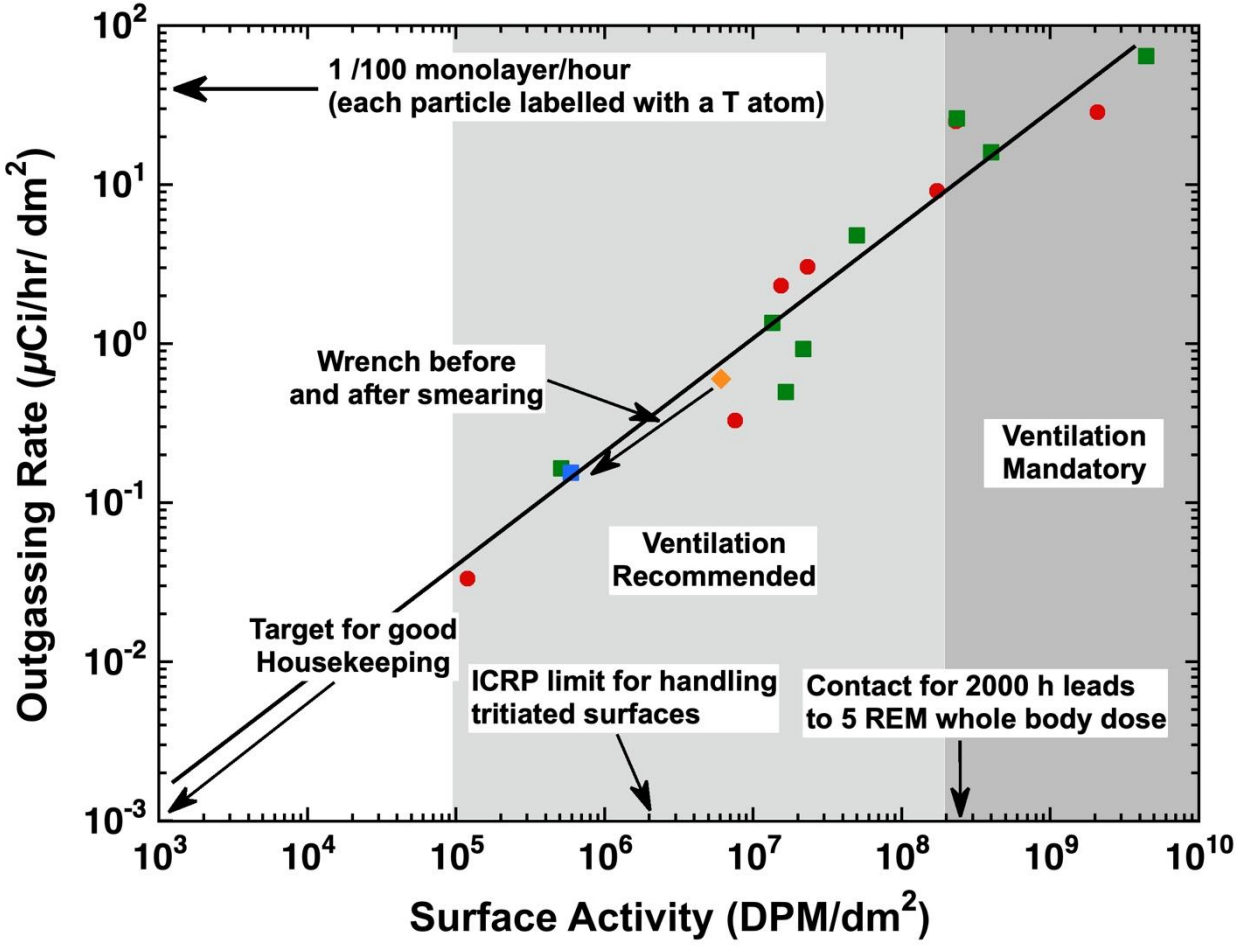
Plume centerline



Assumptions:

Stack: 44.6 m high, 1.54 m dia, 9.4 m/s
Release: 148 TBq, 5% DTO
Stability class: A (very unstable)
Inversion layer: 1 km

Chronic outgassing from tritiated surfaces at room temperature leads to the spread of contamination



- Tritium contaminated surfaces present three concerns:
  - respiratory dose
  - contact dose
  - cross-contamination

Outgassing species are 'sticky'

ICRP: International Commission for Radiation Protection

A. B. Antoniazzi, W. T. Shmayda, T. Palma, *IEEE CH* 3348-0 (1993), *915*.

Response to tritium contamination of surfaces must account for regrowth

DPM/100 cm^2	Action
< 1000	• None
> 10^3	• Establish a Controlled Surface Contamination Area (CSCA) • Decontaminate the component/area • Two surveys taken 8 hours apart to verify that the component is not contaminated
> 10^5	• Decontaminate using air purges or pump/vent cycles • Monitor breathable air with portable tritium detector • Double gloves, exchange every 30 minutes • Objective is to reduce/control outgassing and not decontamination

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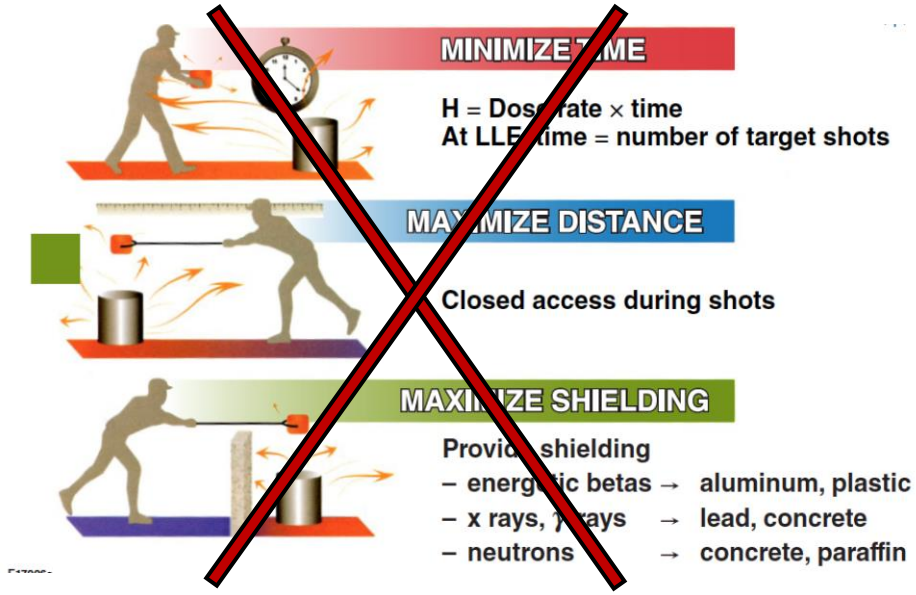
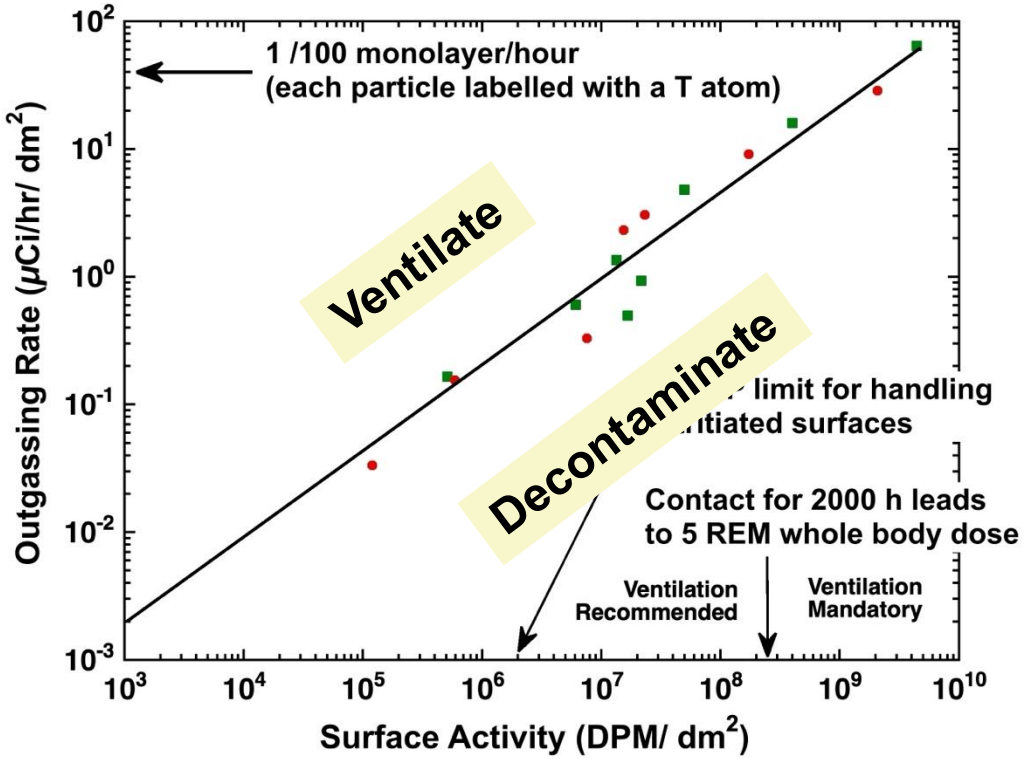
Tritium is a diffuse radiation source. Use *ventilation* and *decontamination* to practice the ALARA principle: As Low As Reasonably Achievable.

Fixed/Activated Sources

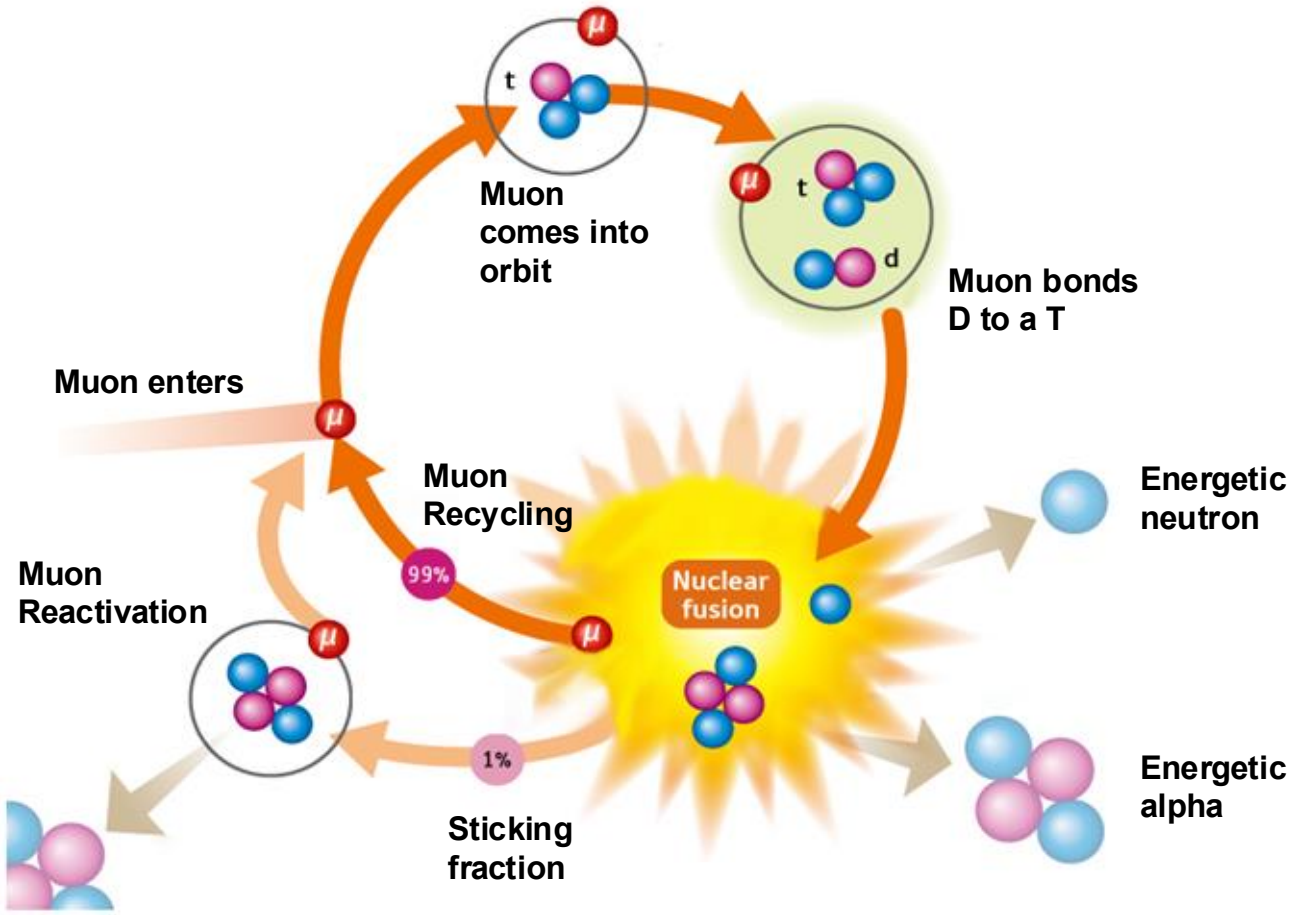


Diffuse Sources

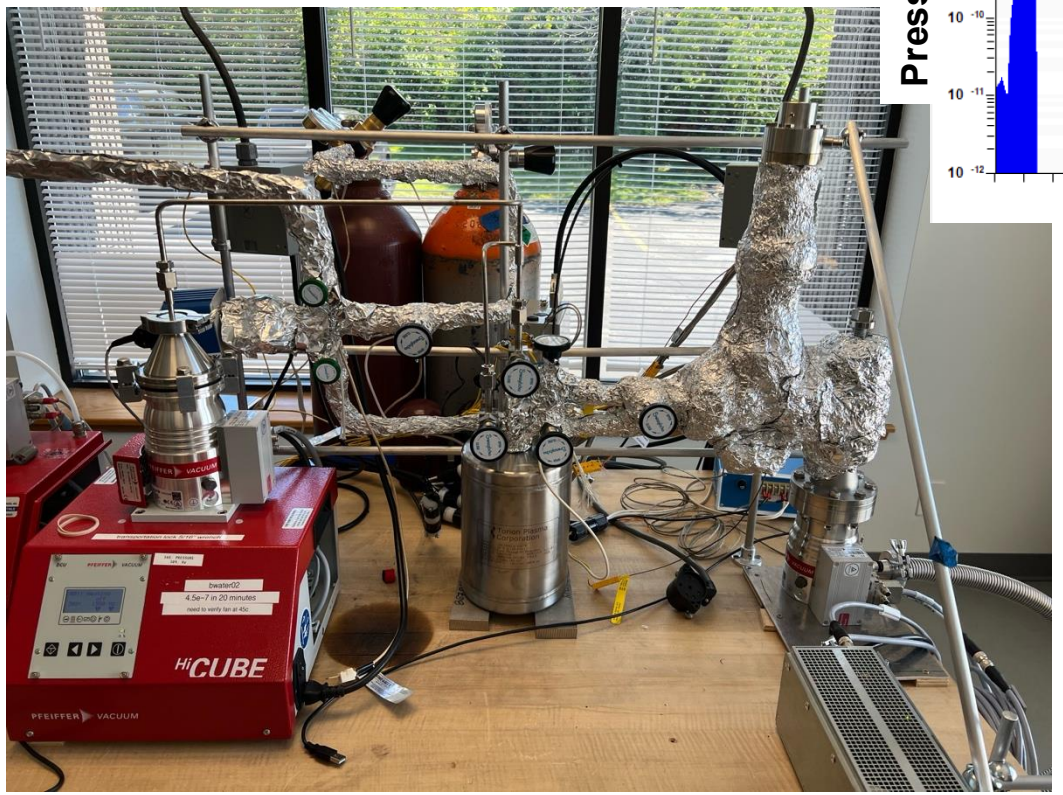


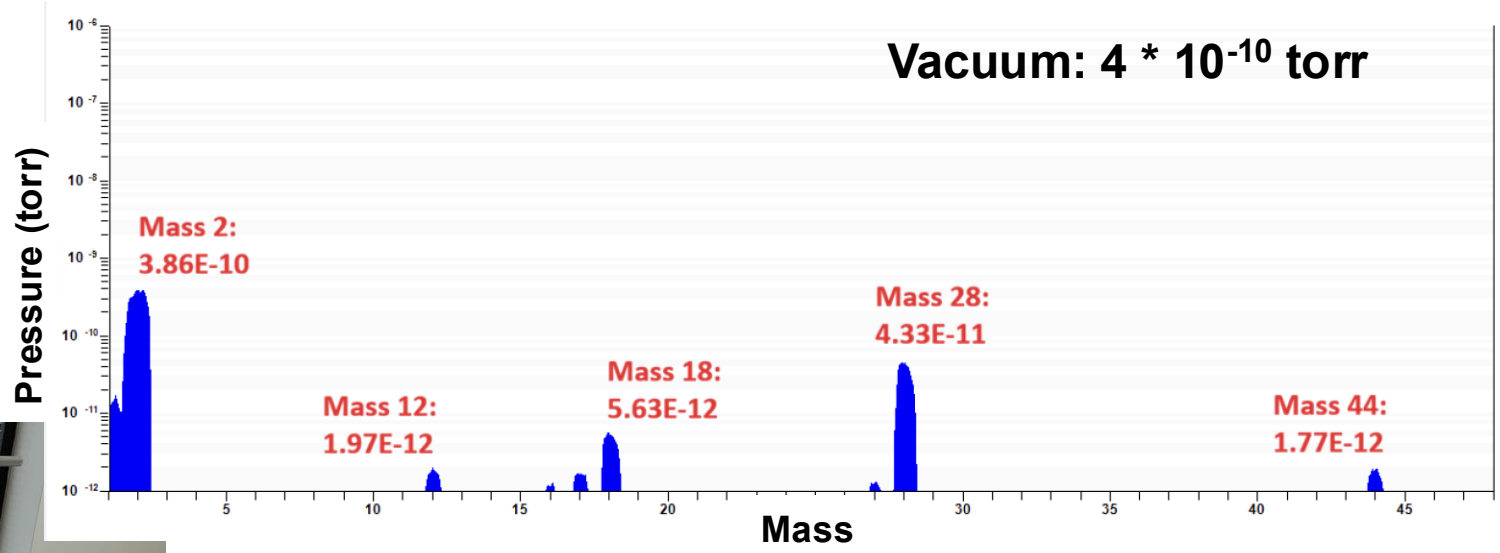
The principle of ALARA used for Activated sources does not apply to Diffuse sources

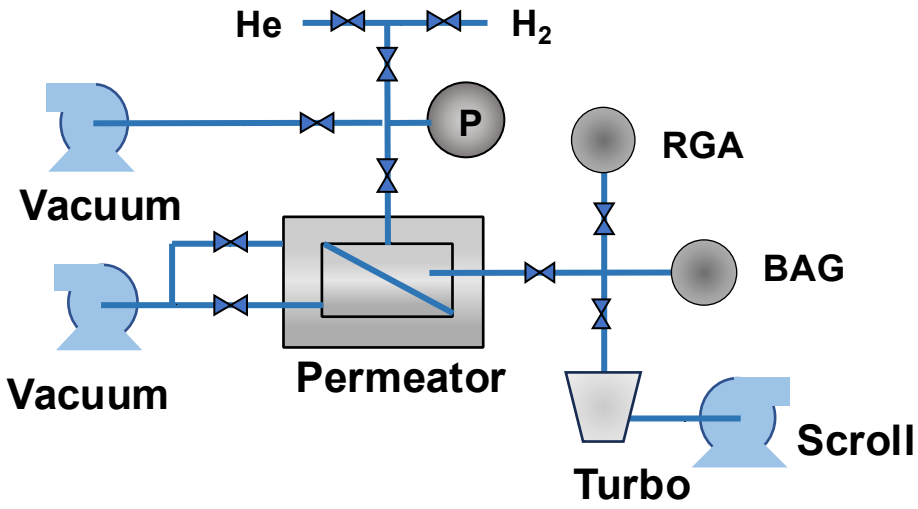
Do we loose muons to impurities?



Does H_2 (or DT) interact with stainless steel surfaces to evolve impurities?







Summary

- Successful two-week campaigns were executed in 2024 and 2025
  - No emissions
  - No dose to personnel
  - No contamination of the work-space
- 4000 Ci were deployed in 2024; a total of 10,000 Ci were deployed in 2025
- Improvements to reduce gaseous impurity levels into the ppb range are planned

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Acknowledgements

- Torion Plasma Corporation
- Torion USA
- Acceleron Fusion
- Paul Scherrer Institute


Thank you for your attention
Questions ????