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Silver-Exchanged Zeolite Trap for Radon Mitigation

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What Will Be Covered



01

Refresher on SNO+

Why ultra-low backgrounds are essential?

02

Zeolite Project

What makes this material promising for radon capture?

03

Building Zeolite Trap

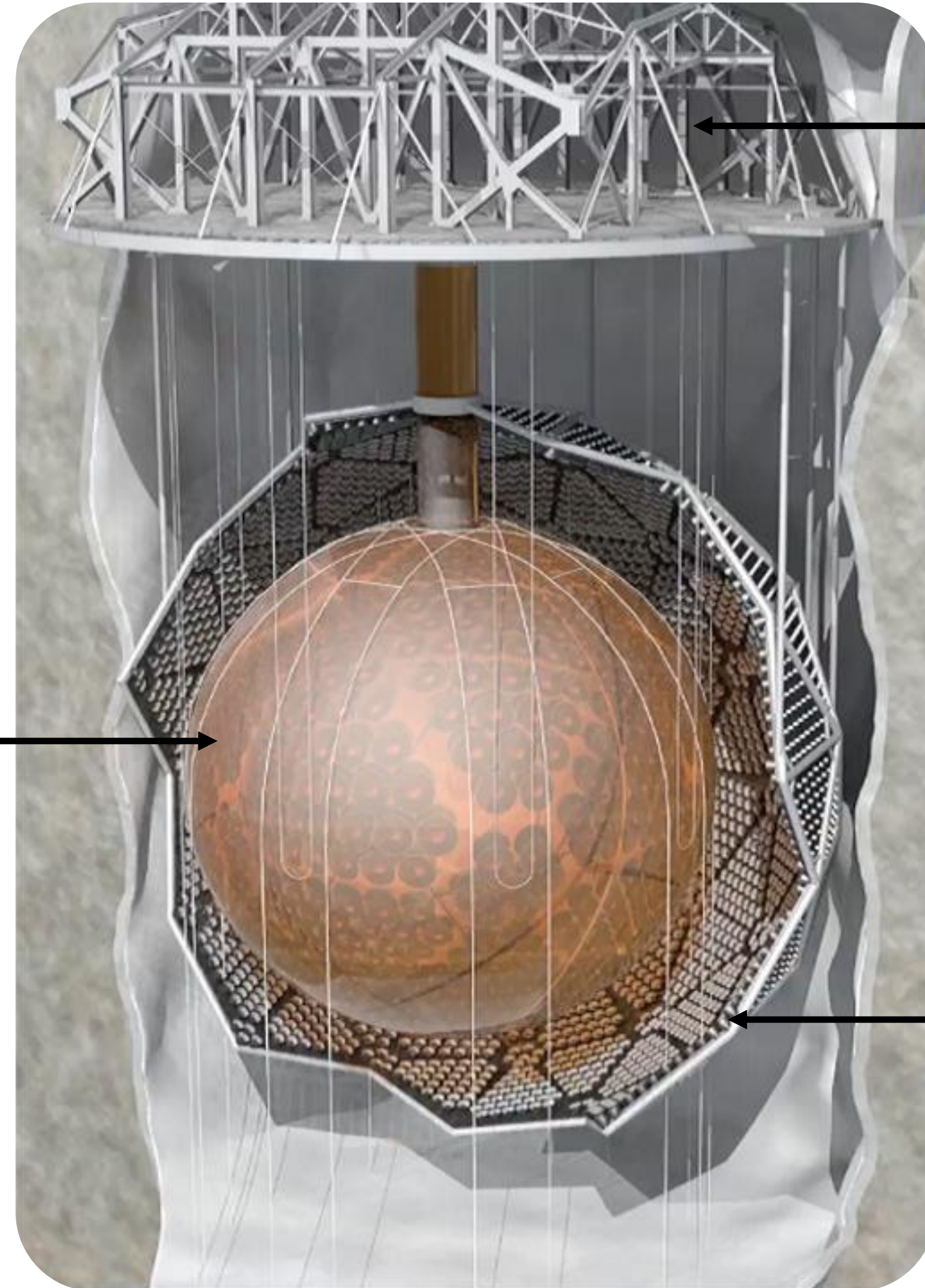
How did we build, fill and bake the new trap?

04

Zeolite Assay

How we use assay to test the trap efficiency?

Reminder of SNO+

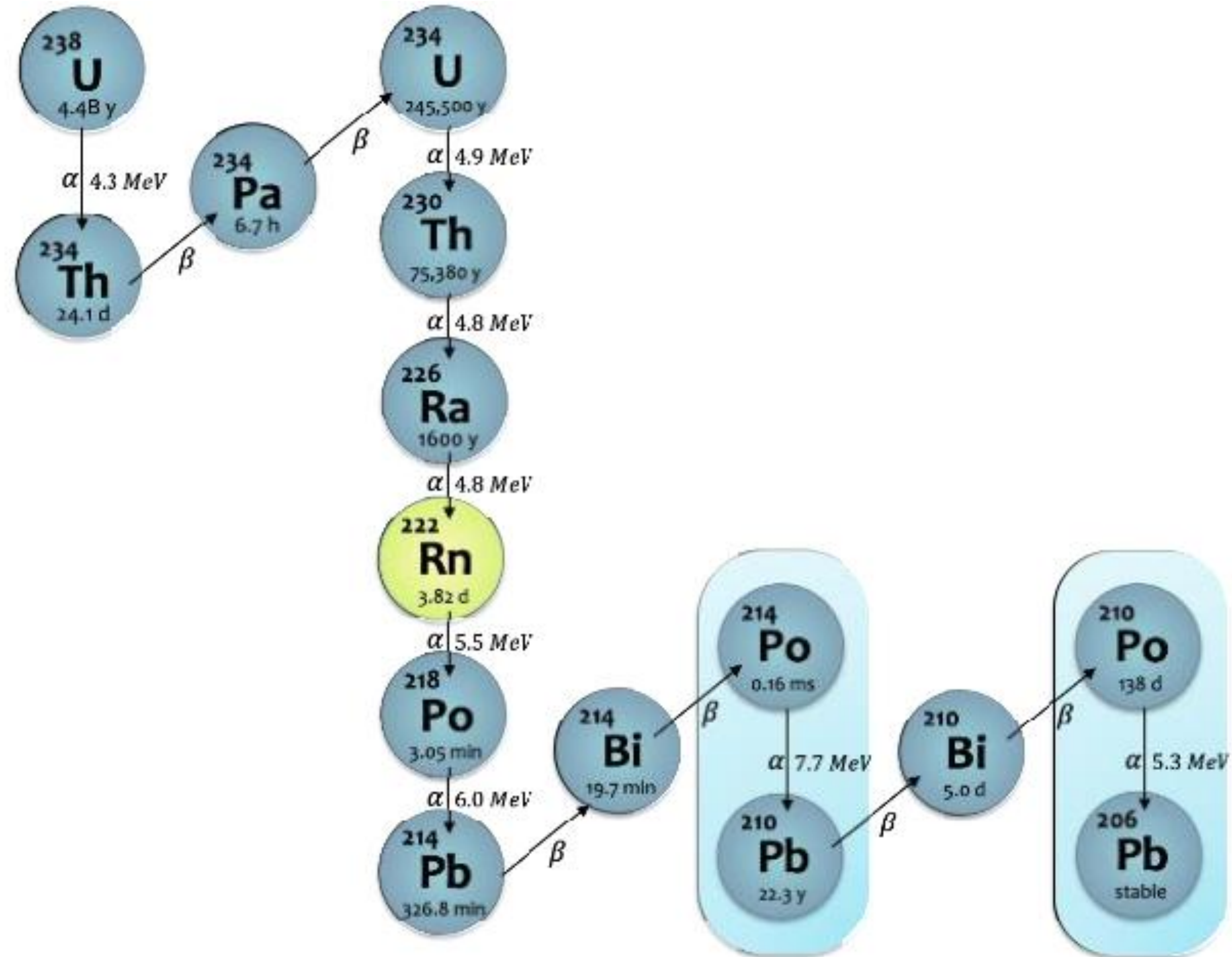


Cover Gas and Universal Interface
in the DCR (Deck Clean Room)

Liquid Scintillator

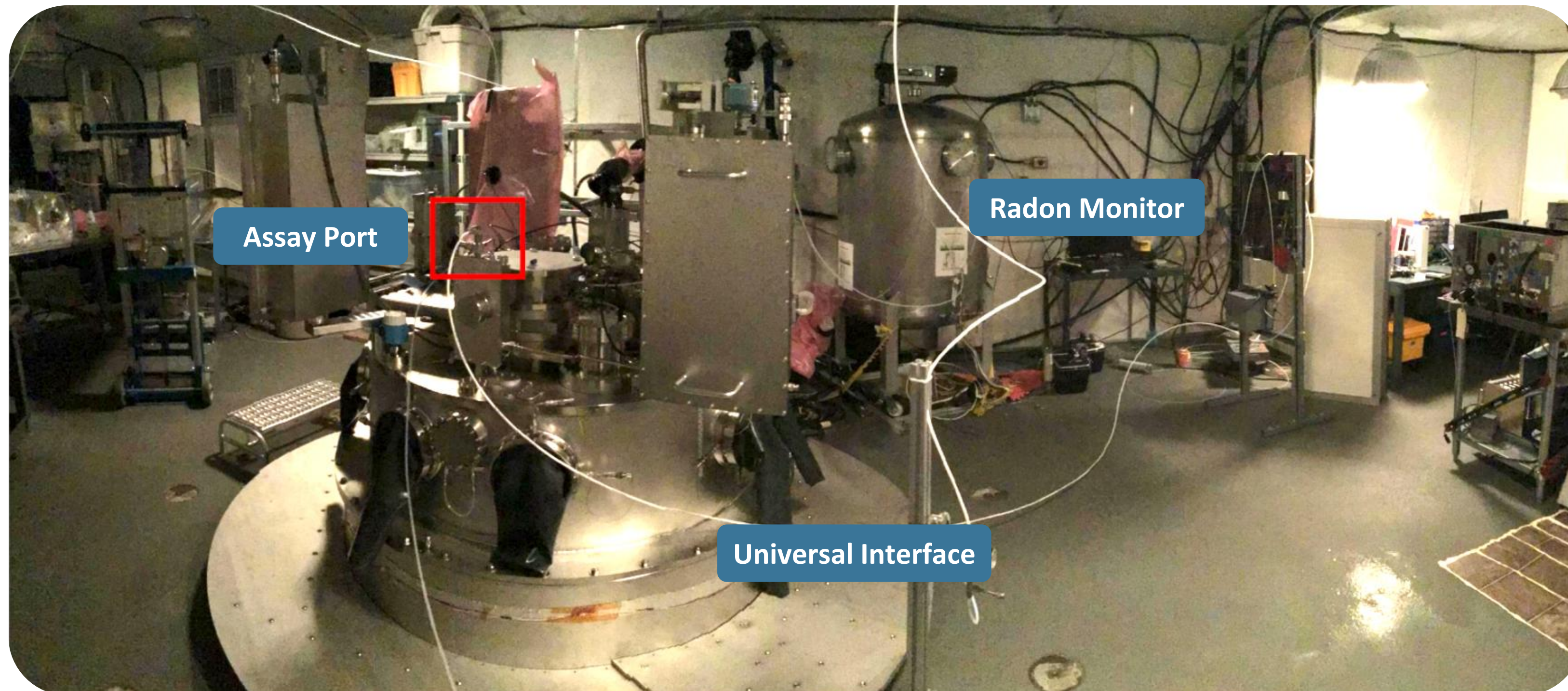
Detector Cavity

Uranium-238 Chain

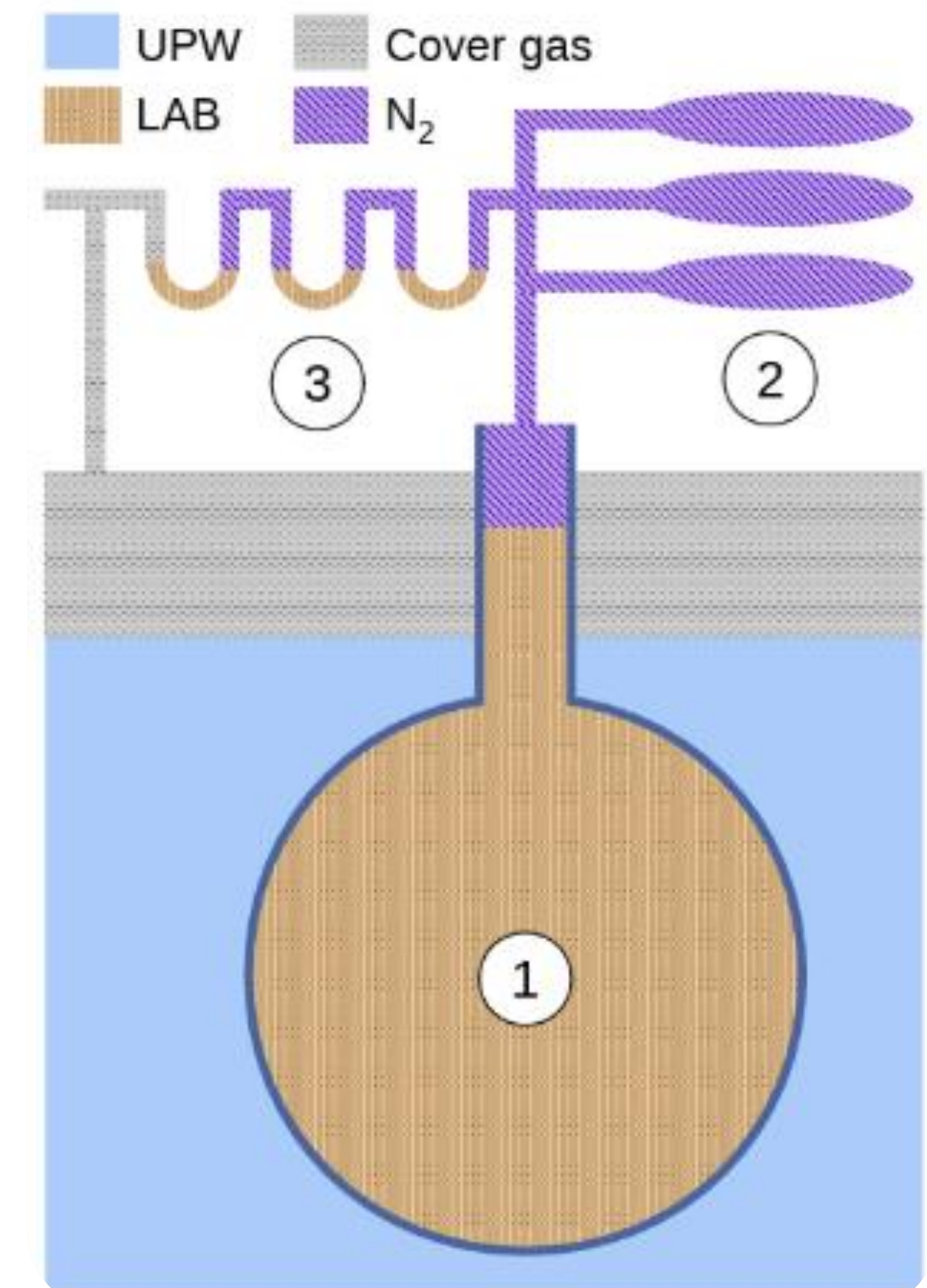


Uranium-238 decay chain

The SNO+ Cover Gas System: A Barrier Against Radon Ingress

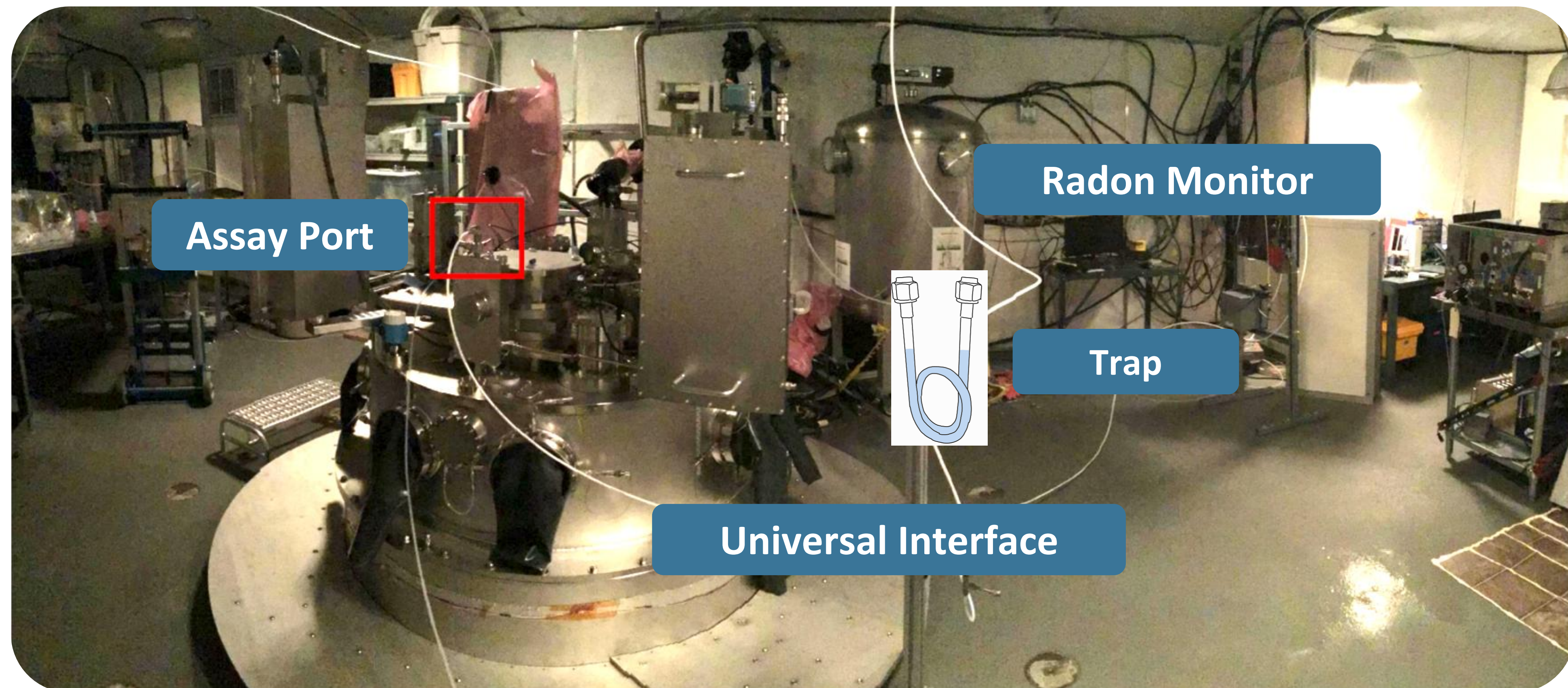


DCR



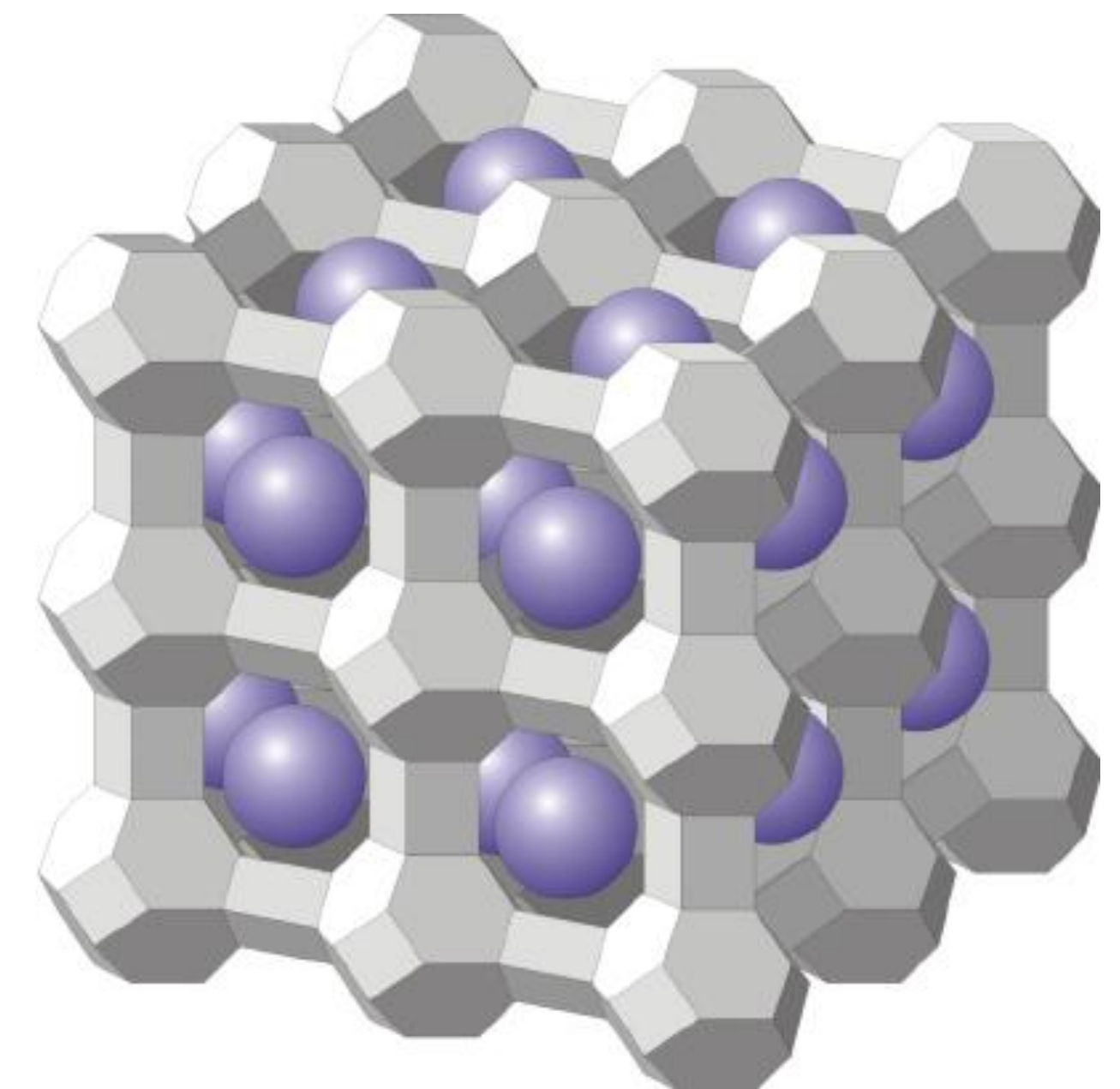
Schematic of SNO+

The SNO+ Cover Gas System: A Barrier Against Radon Ingress



What is Silver-Exchanged Zeolite?

- Zeolite: Microporous material with structured pores that act as molecular sieves
- Advantage: Works at room temperature, no cryogenic cooling needed

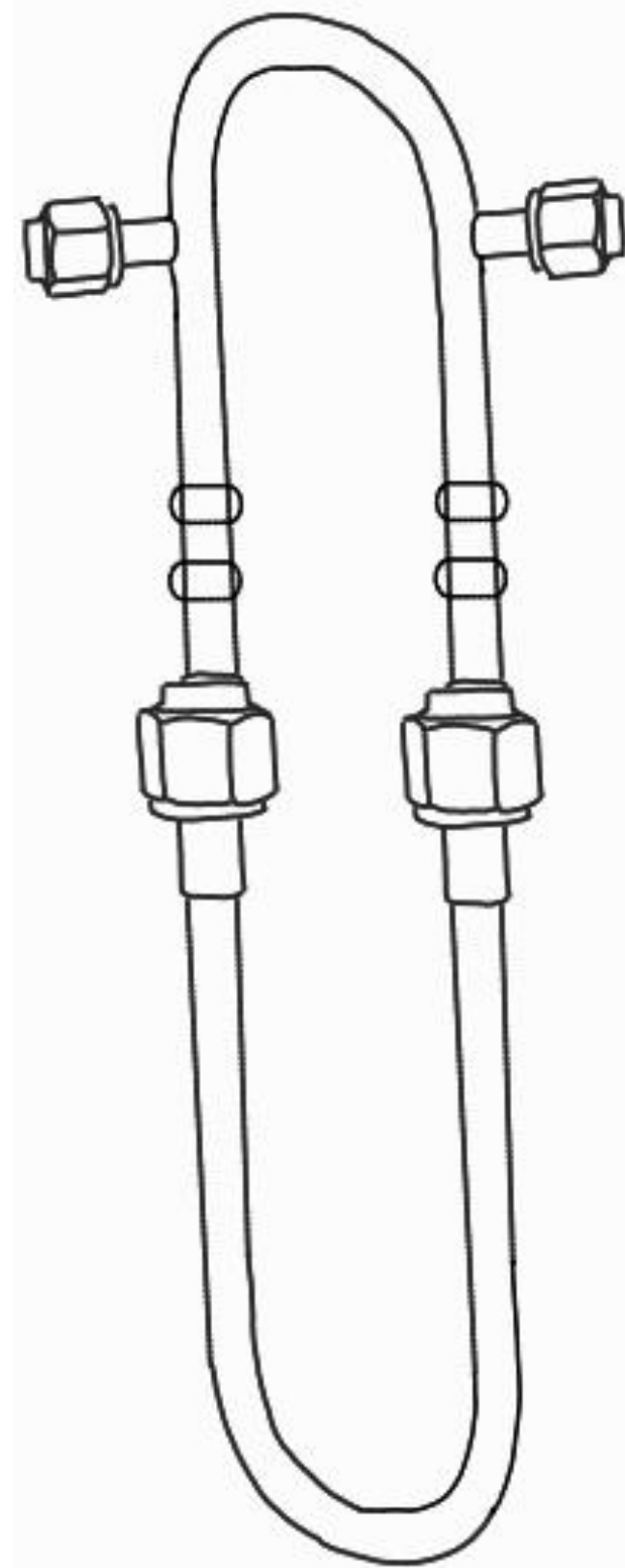


Zeolite crystal structure

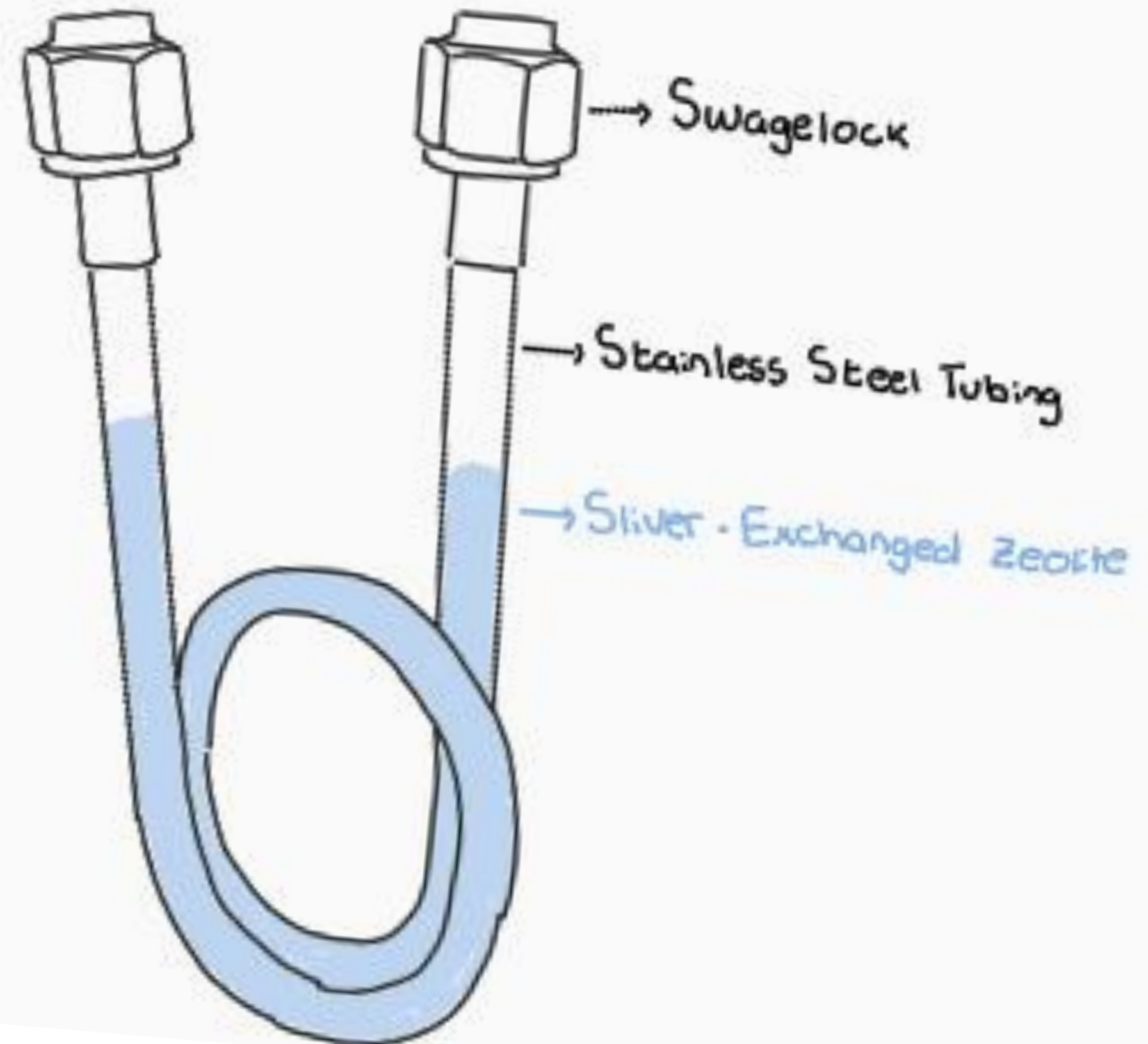
Comparing Zeolite Trap at Room Temperature and Cooled Temperature

Atoms in Calibration Can at time of Assay $\sim 16000 \pm 2080$	Zeolite Trap at Room temperature	Zeolite Trap at cooled temperature (-20C)
Counting Time (Days)	14	14
Decayed Radon Atoms in Primary Trap	500.7 ± 64.1	375.9 ± 48.9
Breakthrough Percentage	$3.1\% \pm 0.4\%$	$2.3\% \pm 0.3\%$

Scaling Up: Designing a Larger Zeolite Trap



Current Zeolite Trap filled with ~41g of Zeolite



New Zeolite Trap filled with ~85g of Zeolite

Construction of new Zeolite Trap

- Construction: Bend non electropolished stainless steel tubing
- Fill with ~85g silver-exchanged zeolite
- Check for leaks and structural integrity
- Bake at ~200°C for 20 hours



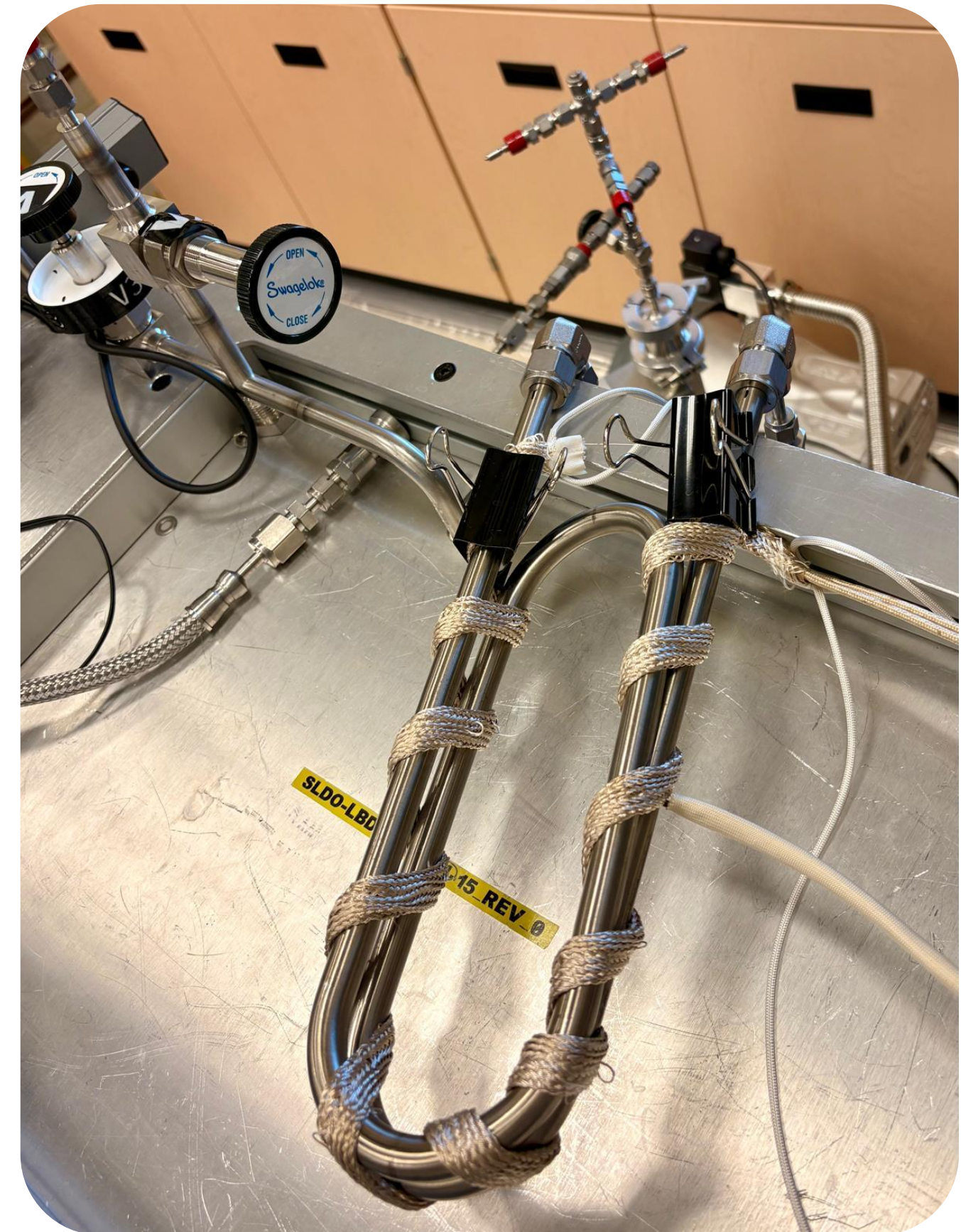
New Zeolite Trap



Filled trap with ~85g of Zeolite

Baking of the Zeolite Trap

- Regeneration: Heating the trap drives out trapped contaminants from zeolite pores
- Thermal energy weakens the weak bonds holding contaminants to pore surfaces, releasing them
- Clearing occupied pores frees up radon capture sites
- More clean pores = more available adsorption sites



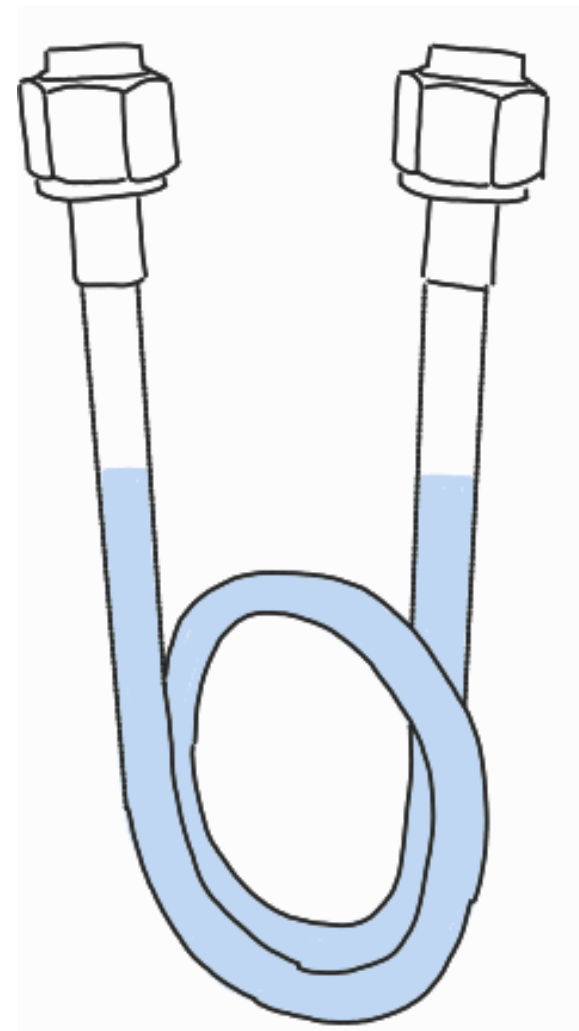
Baking the Zeolite Trap

Using Assays to Test Trap Efficiency

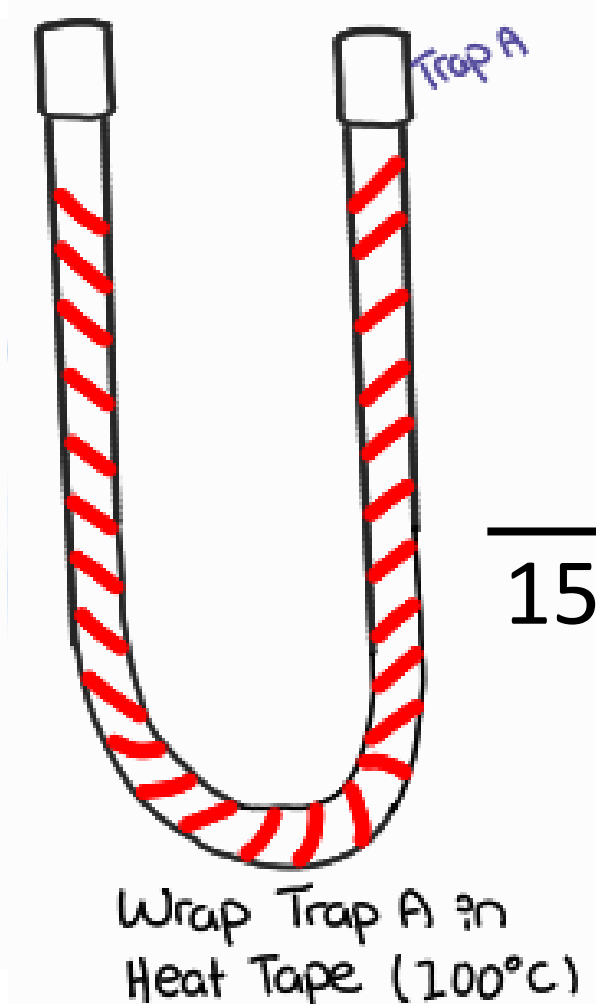
- Measurement technique to quantify radon emission from materials
- Essential for managing radon background in SNO+
- Uses custom-built Lucas cells for alpha detection.



Surface Assay Board

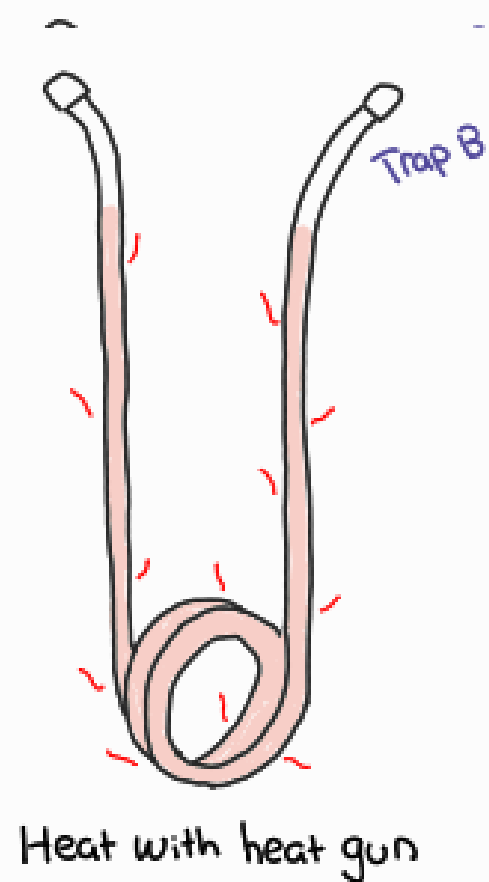


20 mins
Transfer

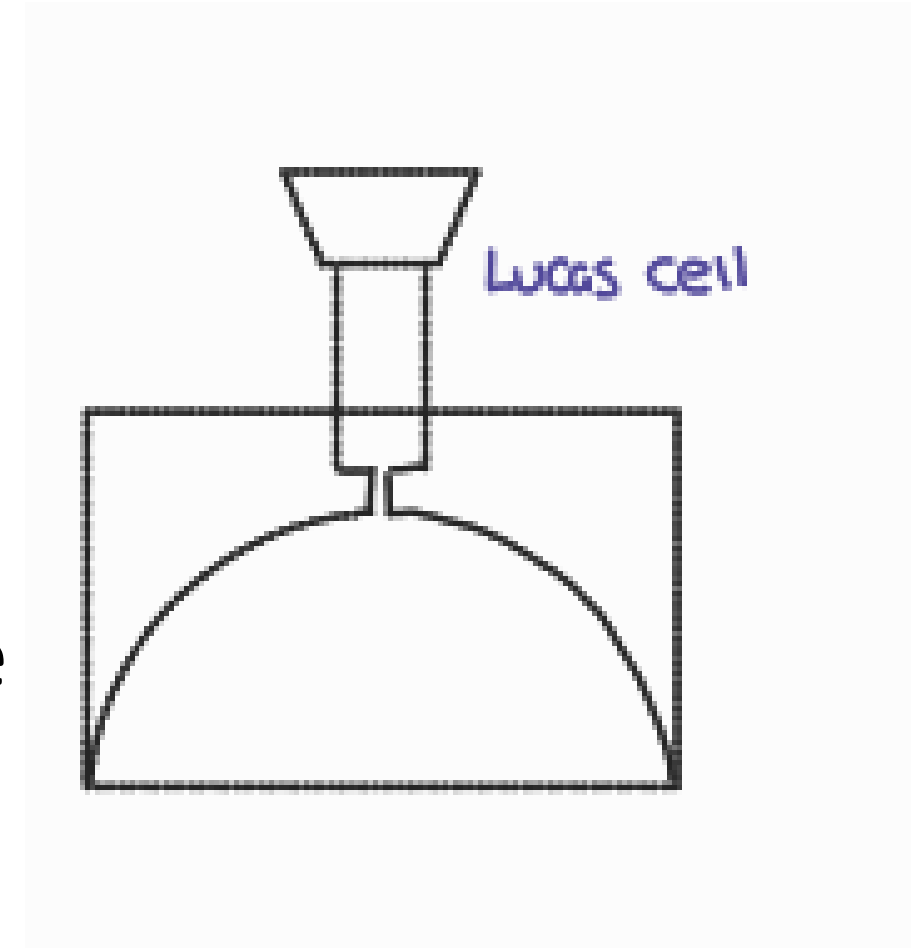


immerse Trap A in LN

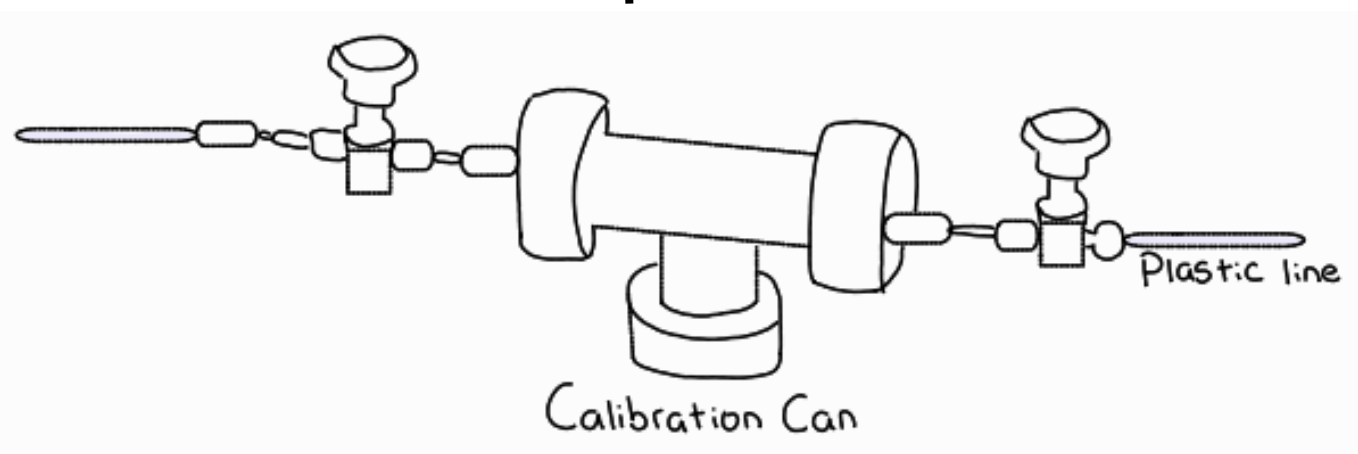
15 mins Cryo-
pumping



10 mins Volume
Sharing



Lucas cell



Calibration Can

Plastic line

Comparing Zeolite Trap Background assay

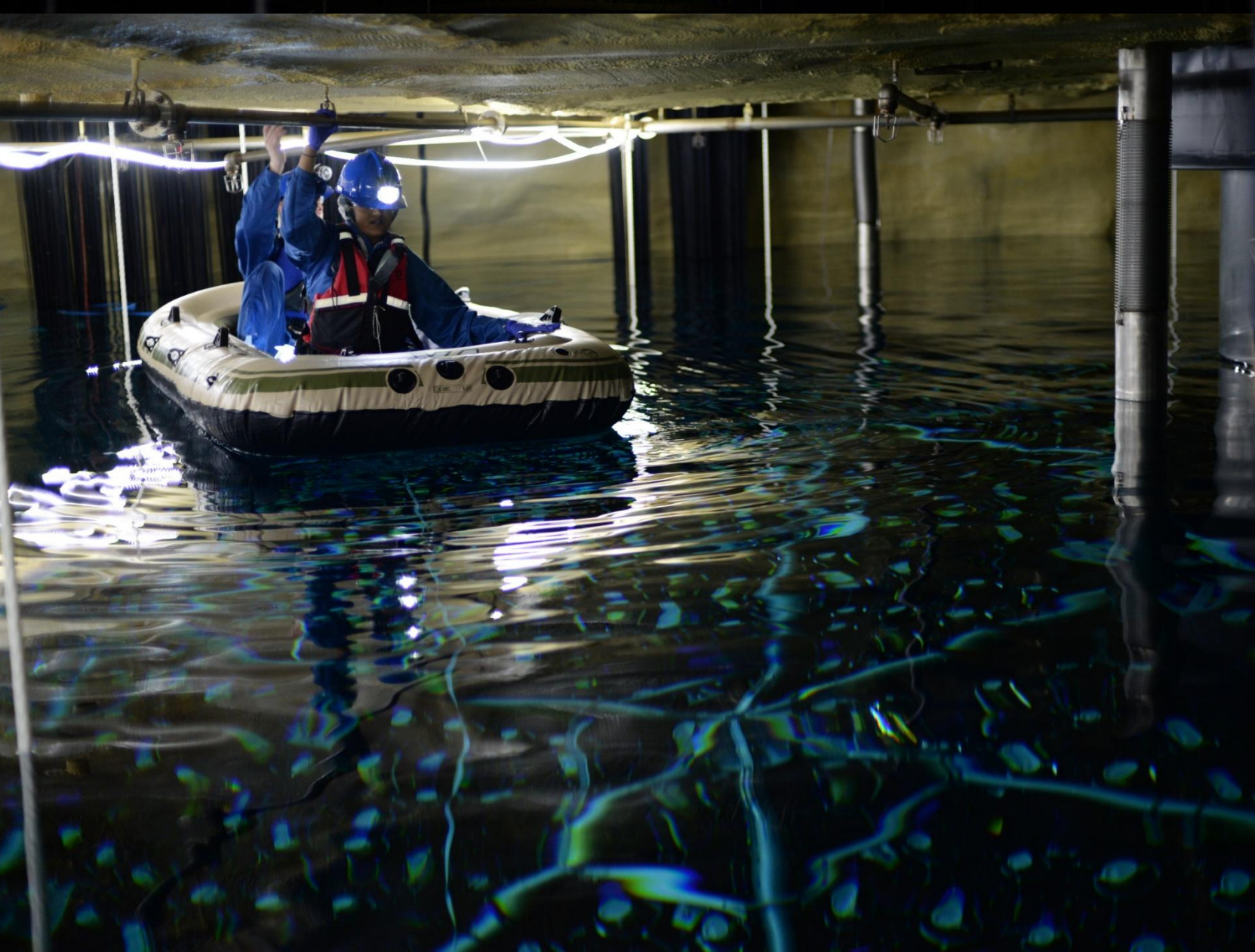
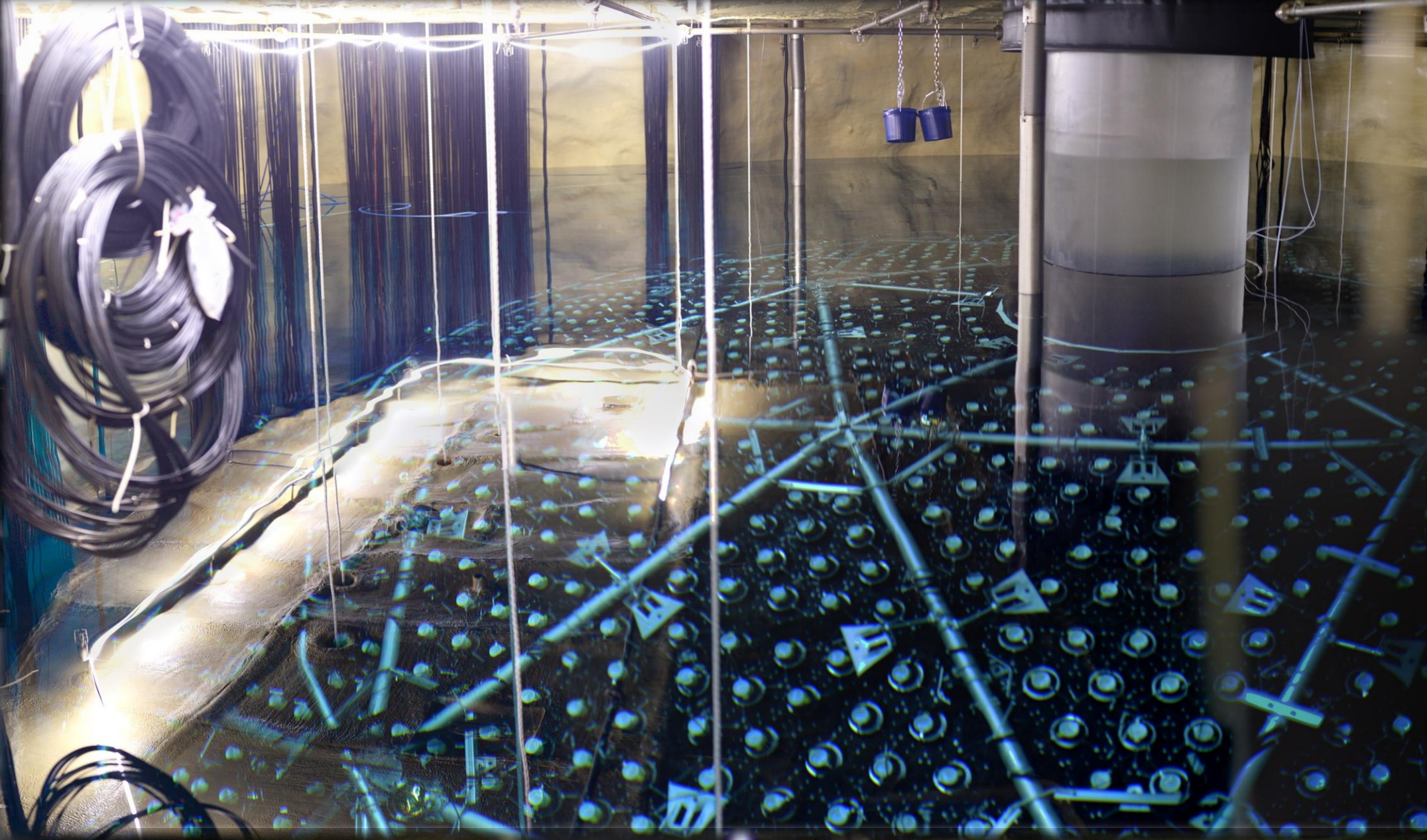
Atoms in Calibration Can at time of Assay $\sim 16000 \pm 2080$	Old Zeolite Trap Background	New Zeolite Trap Background
Counting Time (Days)	2	6
Decayed Radon Atoms in Primary Trap	34.1 ± 9.17	41.12 ± 5.38

Summary

- Radon is SNO+'s primary external background challenge
- Previous results with smaller trap were promising and motivated to build a larger trap
- Preliminary assays show improved breakthrough at room temperature

Next Steps

- Collect measurements from calibration can assay
- Perform assay at room temperature
- Perform assay at modest cooling temperature (-20C)
- Experiment with different kinds of Zeolite



Thank you

Dr. Christine Kraus

Dr. Nasim Fatemighomi

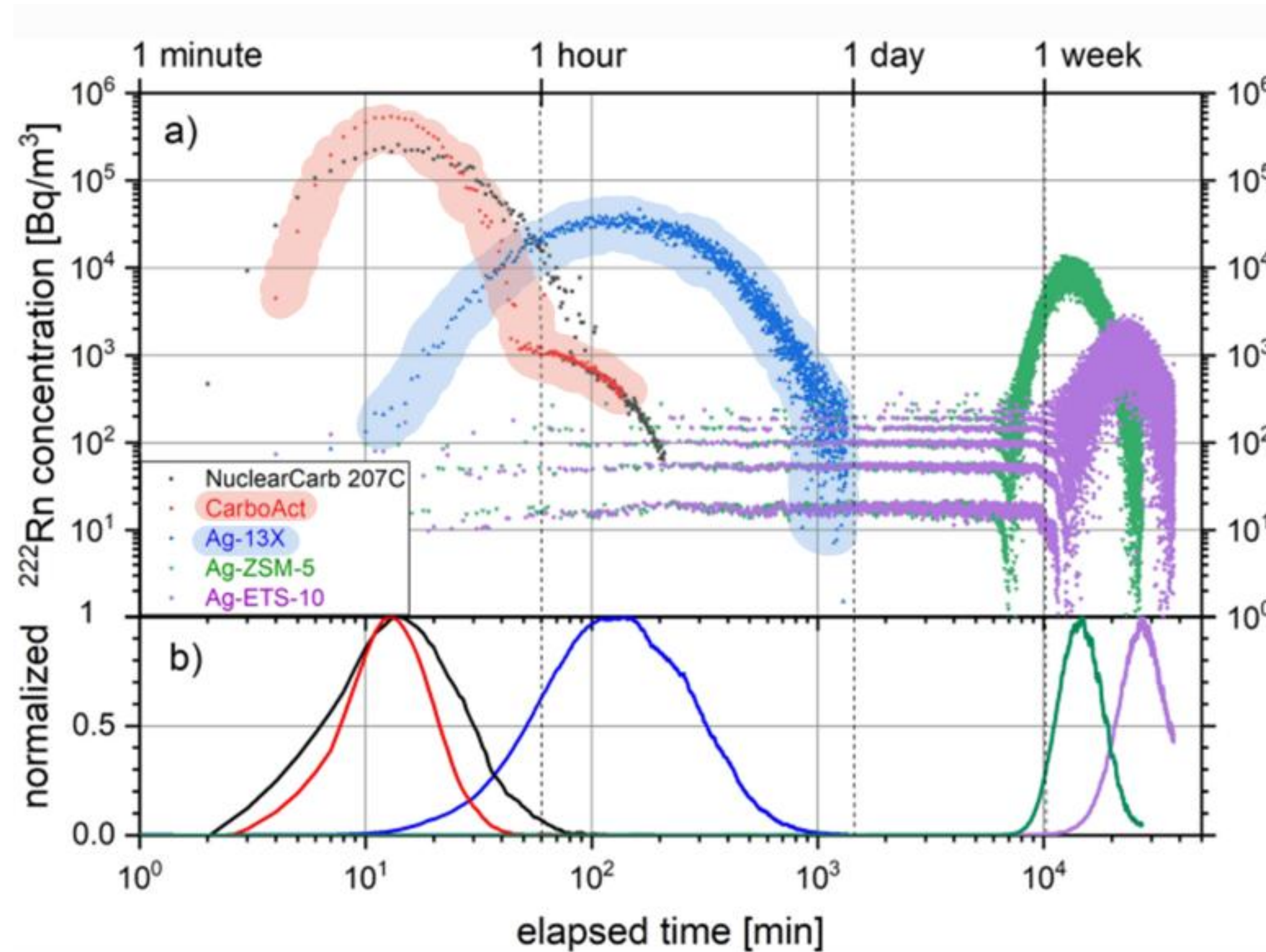
Juliette Deloye

SNO+ Team

Extra Slides

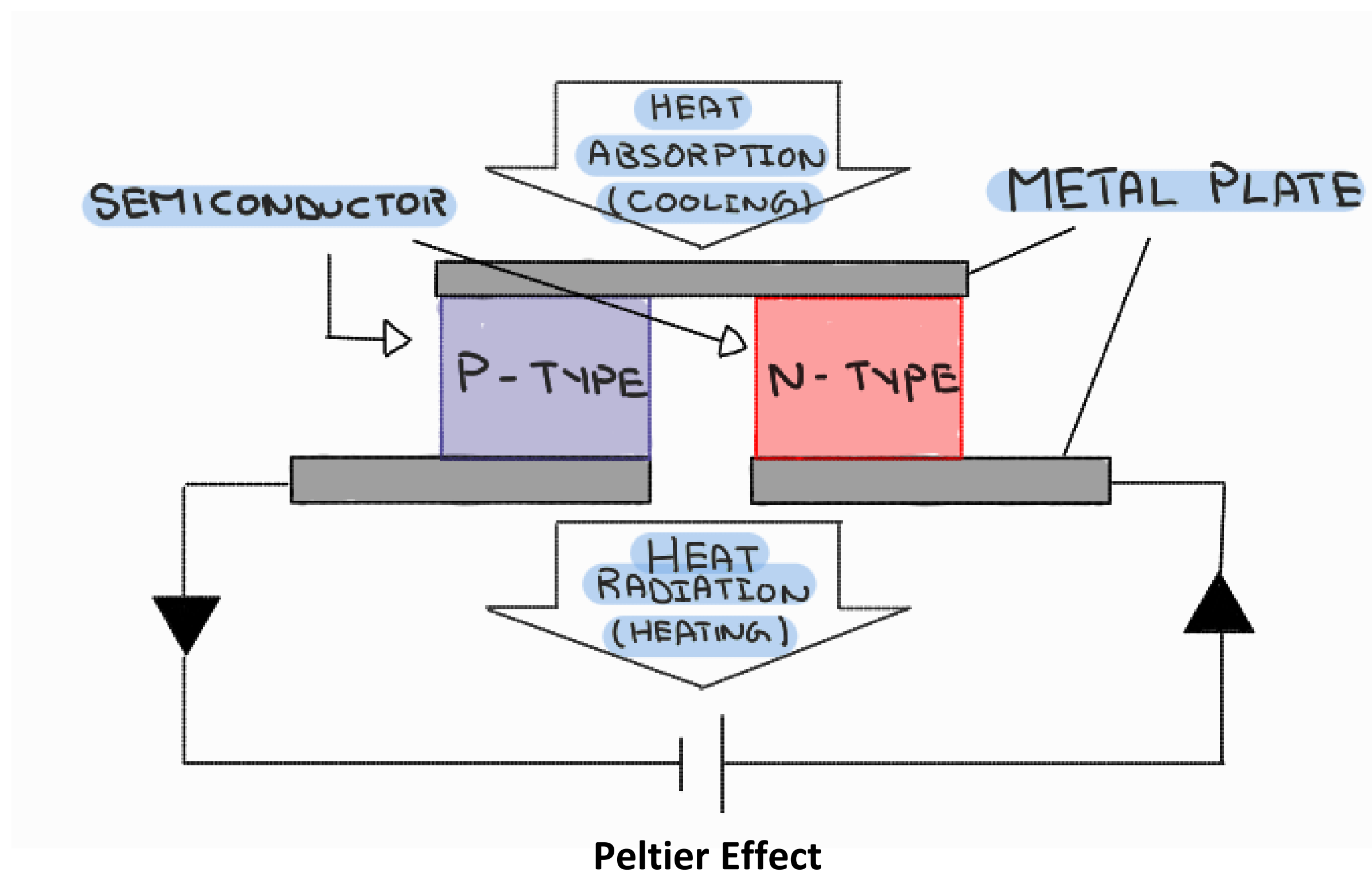
Comparison of elapsed time between Carbon and Silver Exchanged Zeolite (Ag-13X) at room Temperature

16.3g of material



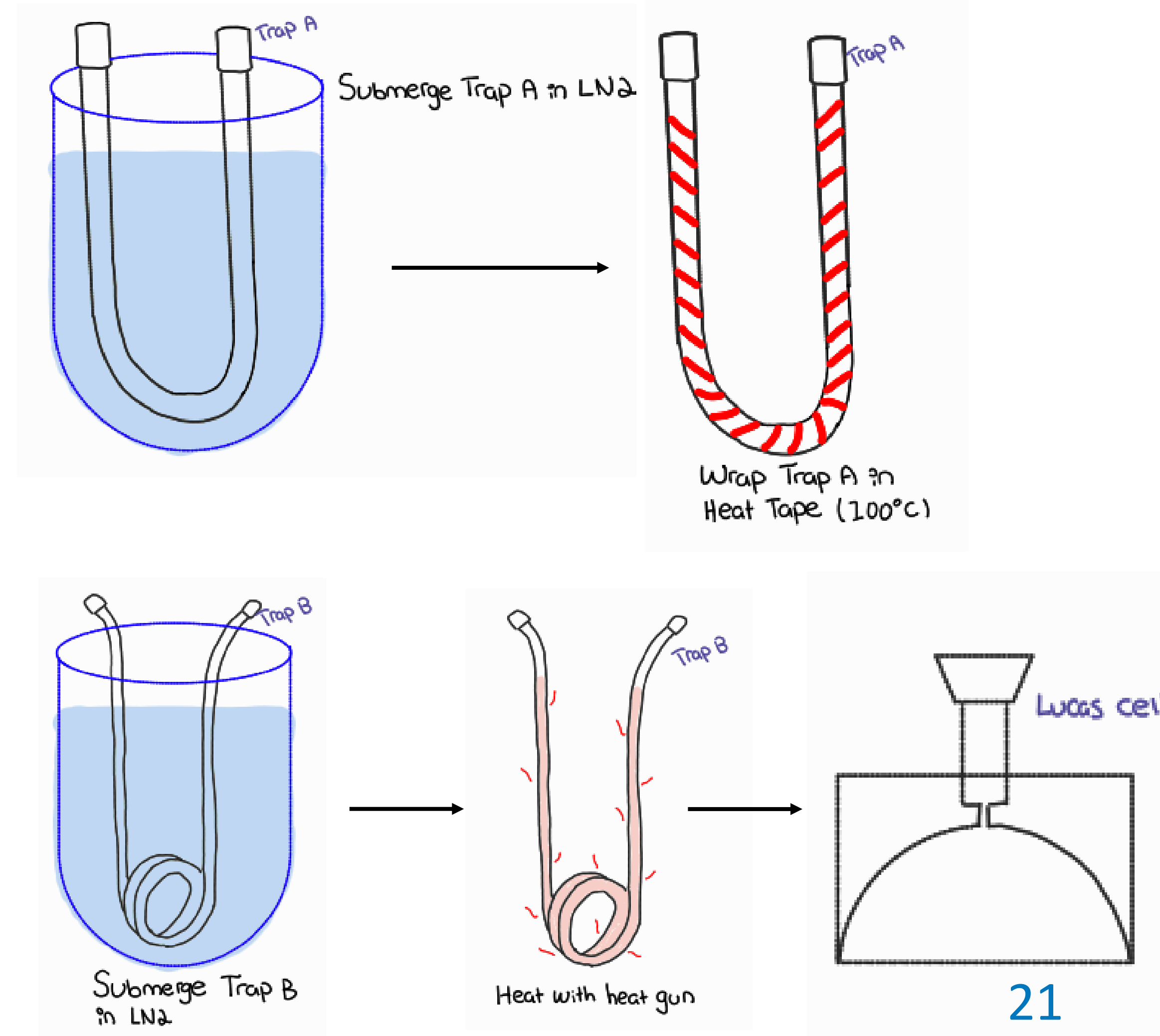
Peltier Cell

- Peltier cell: Solid-state thermoelectric heat pump using electric current to create temperature gradients
- Advantages over LN₂: Compact, precise temperature control, no hazardous gas handling
- -20°C is an achievable operating temperature
- Zeolite + Peltier: Combines room-temp adsorption advantage with modest cooling for enhanced performance



In depth about the assay workflow

- **Cooling Trap A:** Radon atoms in the incoming gas lose energy and adsorb efficiently onto the cold bronze wool
- **Heating Trap A:** Releases the captured radon
- **Cooling Trap B:** Radon released from Trap A preferentially condenses/adsorbs into Trap B's much smaller volume
- **Heating Trap B:** Drives the concentrated radon into the cell for counting with high transfer efficiency.



Why cool the Zeolite trap?

- Zeolite trap is to improve radon capture efficiency
- Cooling strengthens adsorption without damaging the zeolite structure
- Radon atoms adhere to the pore walls via weak van der Waals forces
- Lower temperatures slow down radon movement, making it harder for atoms to escape

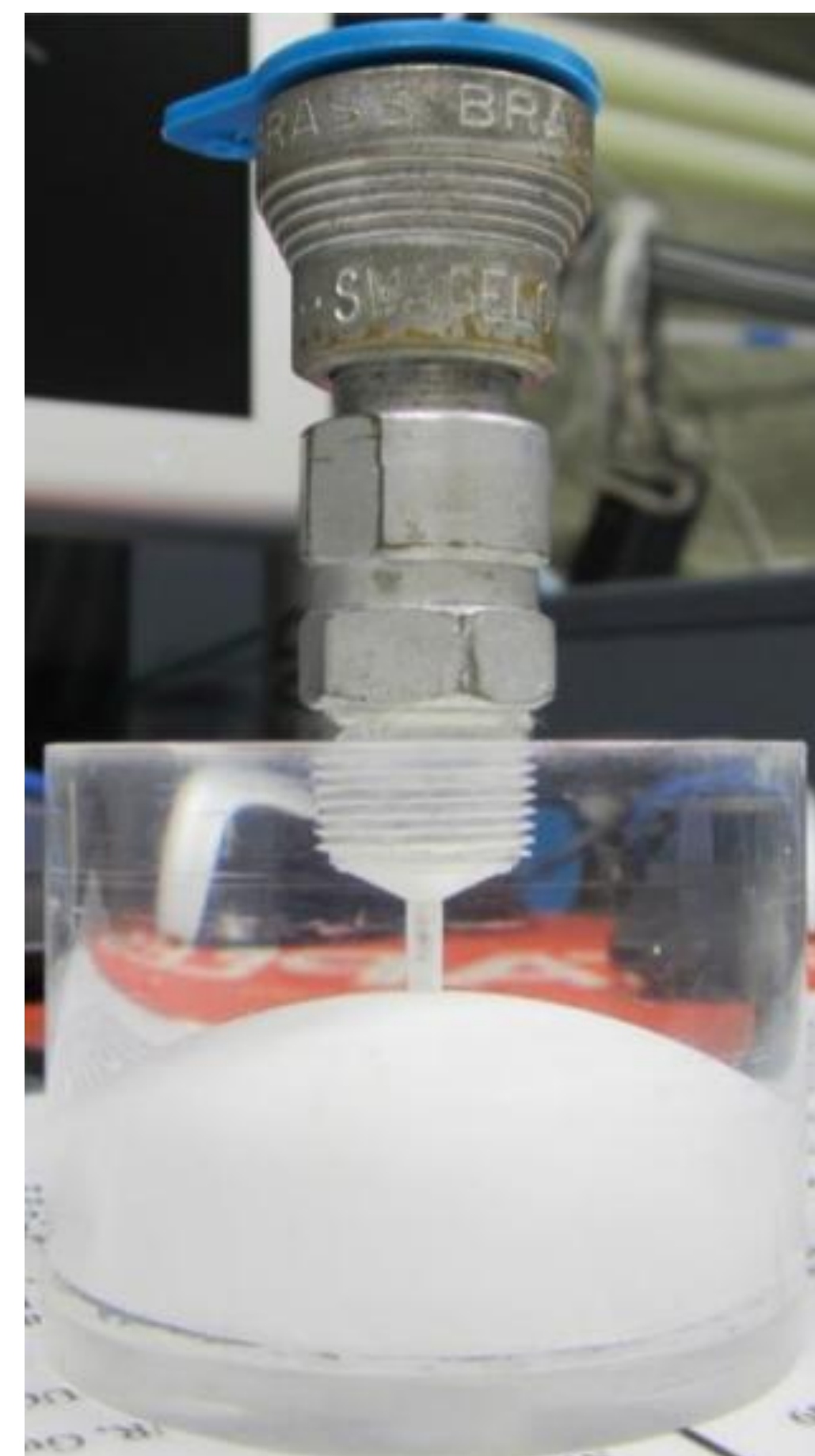
Zeolite

- Molecular sieve: Pores act as selective filters — only molecules of the right size can enter and be trapped
- Silver exchange advantage: Silver ions dramatically increase heat of adsorption, enhancing radon capture
- Ag-ETS-10 is more expensive Zeolite compared to Ag-13X

	Ag-13x	Ag-ETS-10	Ag-ZSN-5
Composition	High alumina content	Contains titanium (Ti) in the framework	Highly siliceous
Key Differences	High capacity for CO ₂ adsorption but slower regeneration.	different adsorption entropy behavior for gases like CO ₂	Stronger interaction with specific adsorbates due to confinement effects from its pore size

What is a Lucas Cell?

- Scintillator Alpha counter for Radon detection
- Acrylic body holds gas sample with trapped radon
- Inner volume is coated with ZnS: Ag (Zinc Sulfide + Silver)
- Used to count decays of radon atoms from assays



How Lucas Cells Work?

- Radon enters Lucas Cell and is coupled to PMT
- Radon undergoes alpha decay
- Alpha particles hit ZnS coating then deposit energy
- The ZnS emits scintillation light which is detected by the PMT

