2025/08/25

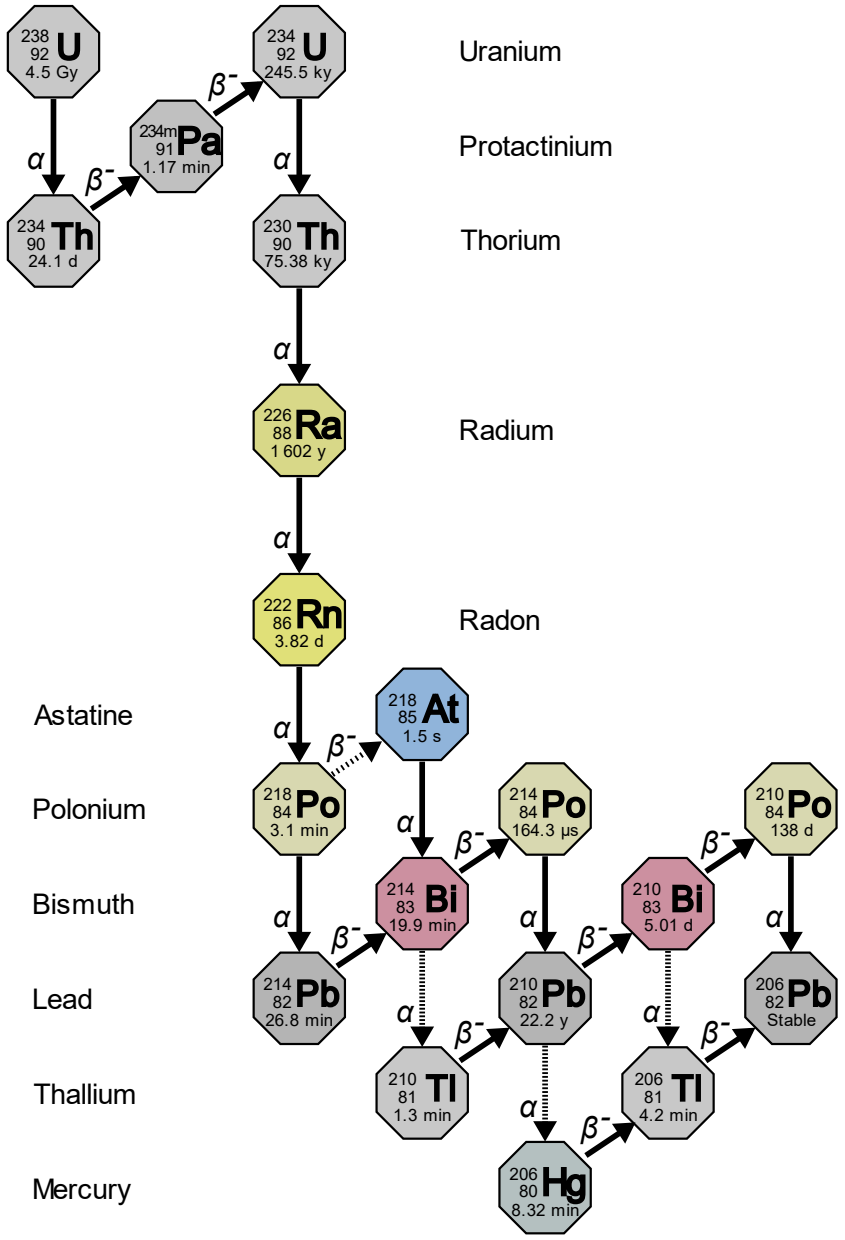
# Radon-222 Screening Capability and Research at SNOLAB

Dr Nasim Fatemighomi (she/her)

Staff Scientist

On behalf of SNOLAB Assay Group

TAUP 2025, Xichang, China




From Wikipedia

# Introduction

- $^{222}$Rn progeny are backgrounds to low energy neutrino and rare-event searches
- Emanates from material surfaces
- Present in SNOLAB air ~ 120 Bq/m$^3$
  - **$N_2$ is widely used as a cover gas to keep radon out of experiments**
- SNOLAB supports low level $^{222}$Rn screening at site using four different **radon extraction boards**
  - Measure $^{222}$Rn concentration in **ultra pure water (UPW)**, **$N_2$** and $^{222}$Rn **emanation from materials**

# Underground Radon Assay Systems

Water radon board (Refurbished in 2019)

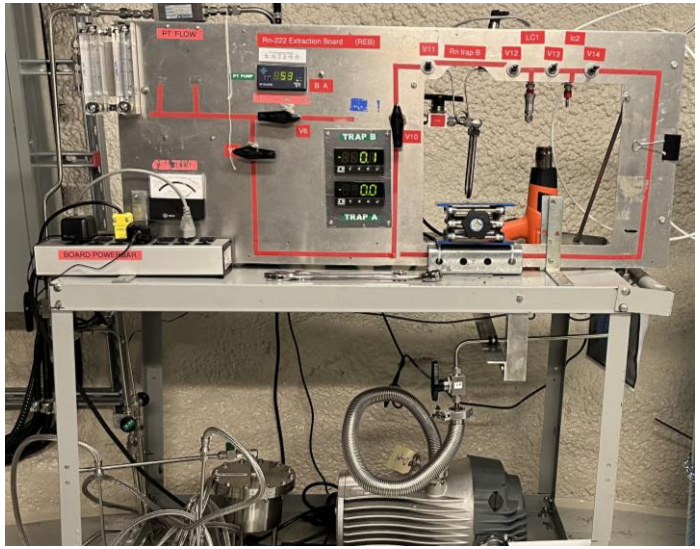
- **Sensitivity: $(1.5 \pm 0.5) \times 10^{-14}$ g$^{238}$U/g$H_2O$ equivalent** (slides 5-8)

(DOI: 10.1016/j.nima.2003.10.103)

SNO+ mobile board (Refurbished in 2021)

- Used primarily for $N_2$ gas assays
- **Board emanation rate: $44 \pm 7$ Rn atoms/day**
- **A new radon trap was developed to enhance gas assay sensitivity** (slides 9-16)

(DOI: 10.1016/j.nima.2025.170422)



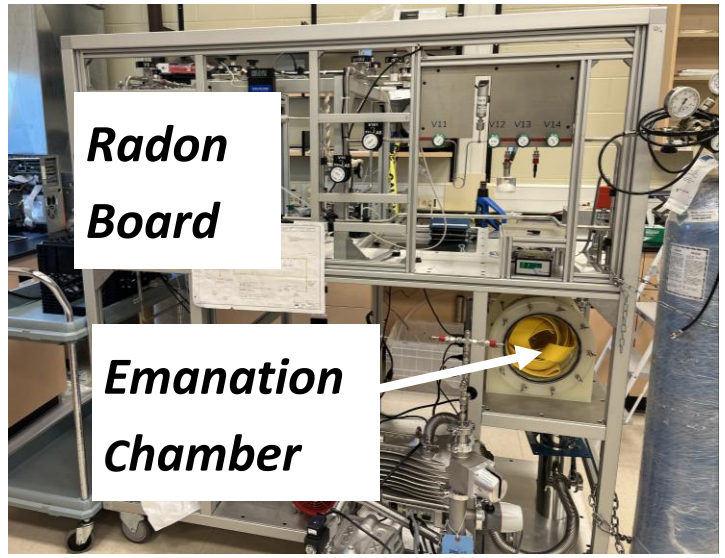
# Surface Radon Emanation Systems

SNOLAB radon emanation board (built 2021)

- High sensitive radon emanation measurement SNOLAB technical report:

  (SNOLAB-STR-2022-001) - available on request

- **Chamber emanation rate: $4 \pm 2$ Rn atoms/day**
- Radon research and development

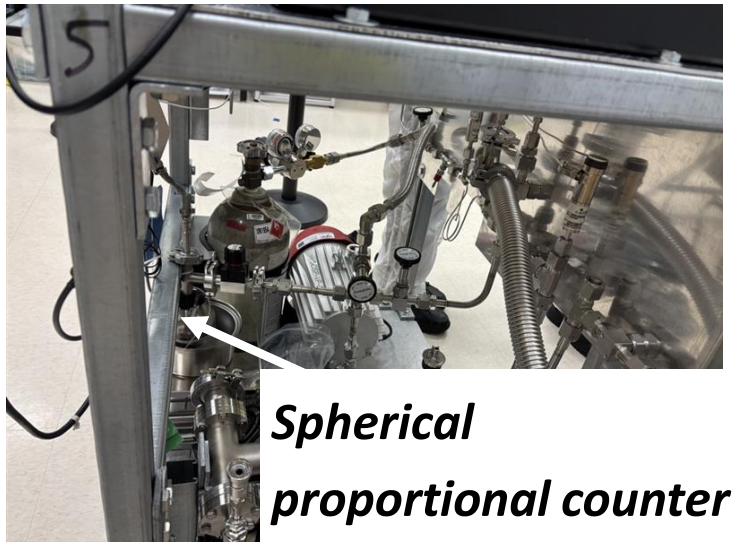



DEAP-3600 board (refurbished 2023)

- **The board emanation rate**

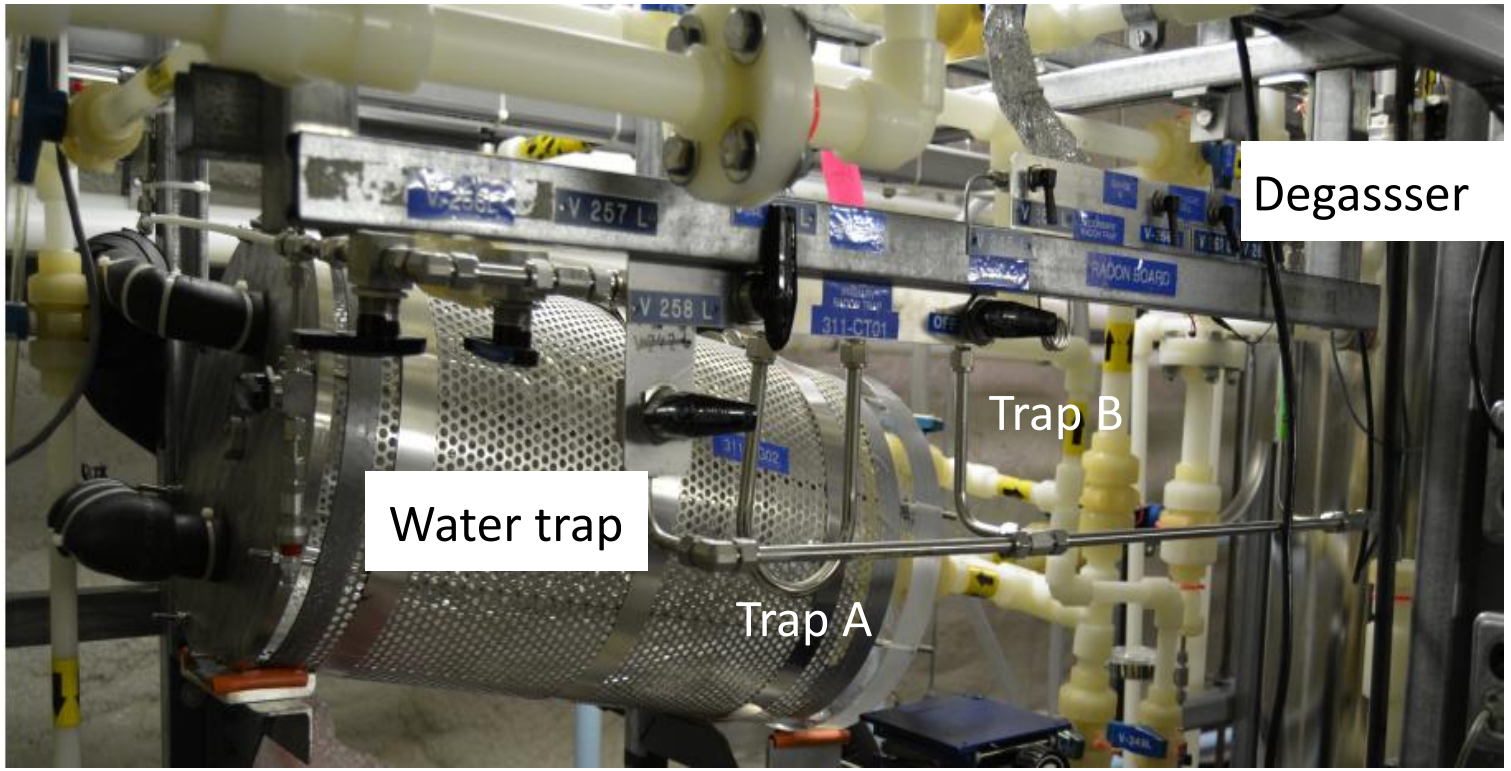
  **< 6 Rn atoms/day@90% CL**

- Testing **new radon detectors**



# Water Radon Assay System

- Designed and built by the SNO collaboration (DOI: 10.1016/j.nima.2003.10.103)
- Operated by SNOLAB and SNO+ to monitor $^{222}$Rn level of SNO+ cavity UPW and SNOLAB UPW plant

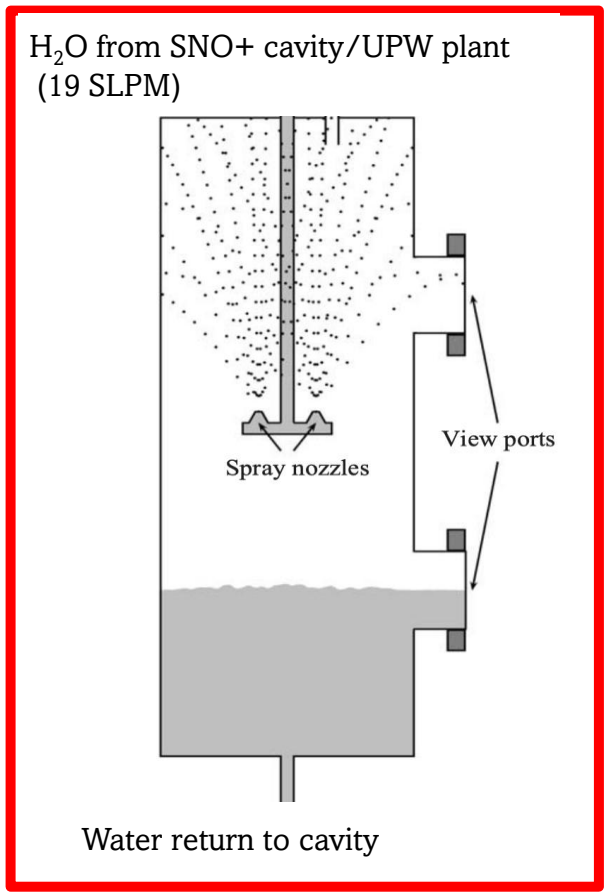


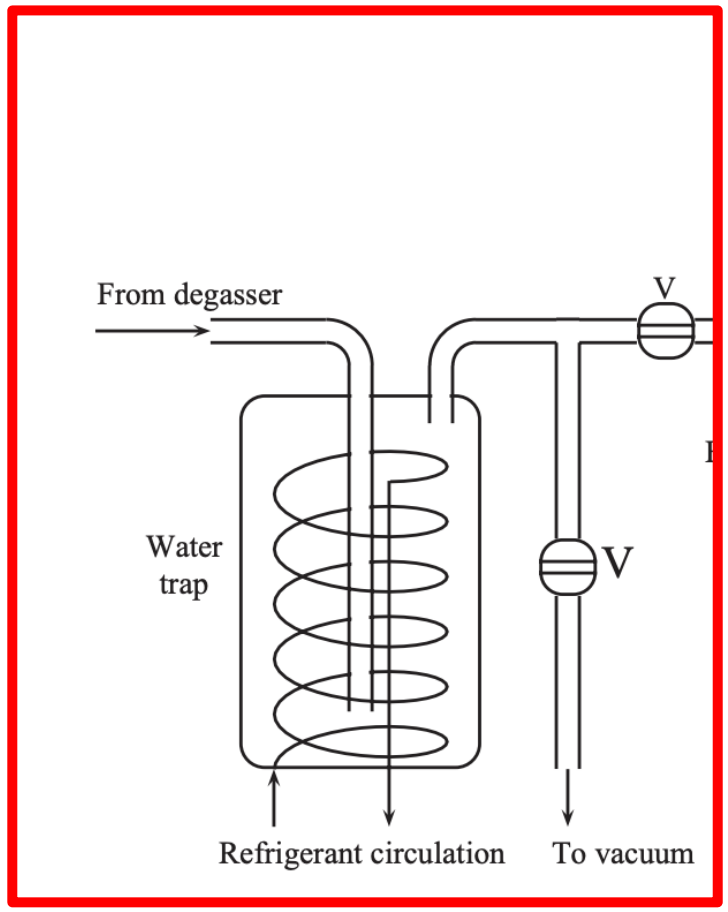


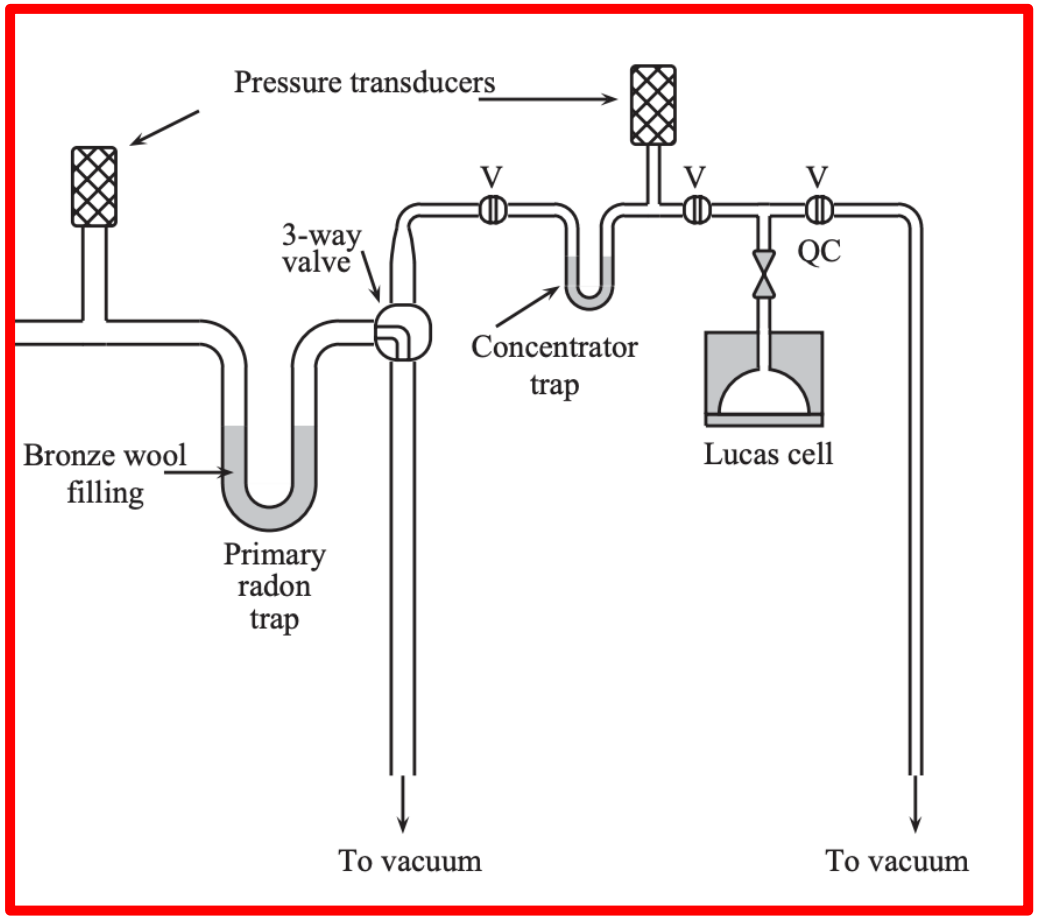
Water shielding
(7000 tonnes UPW)

# Water Radon Assay System

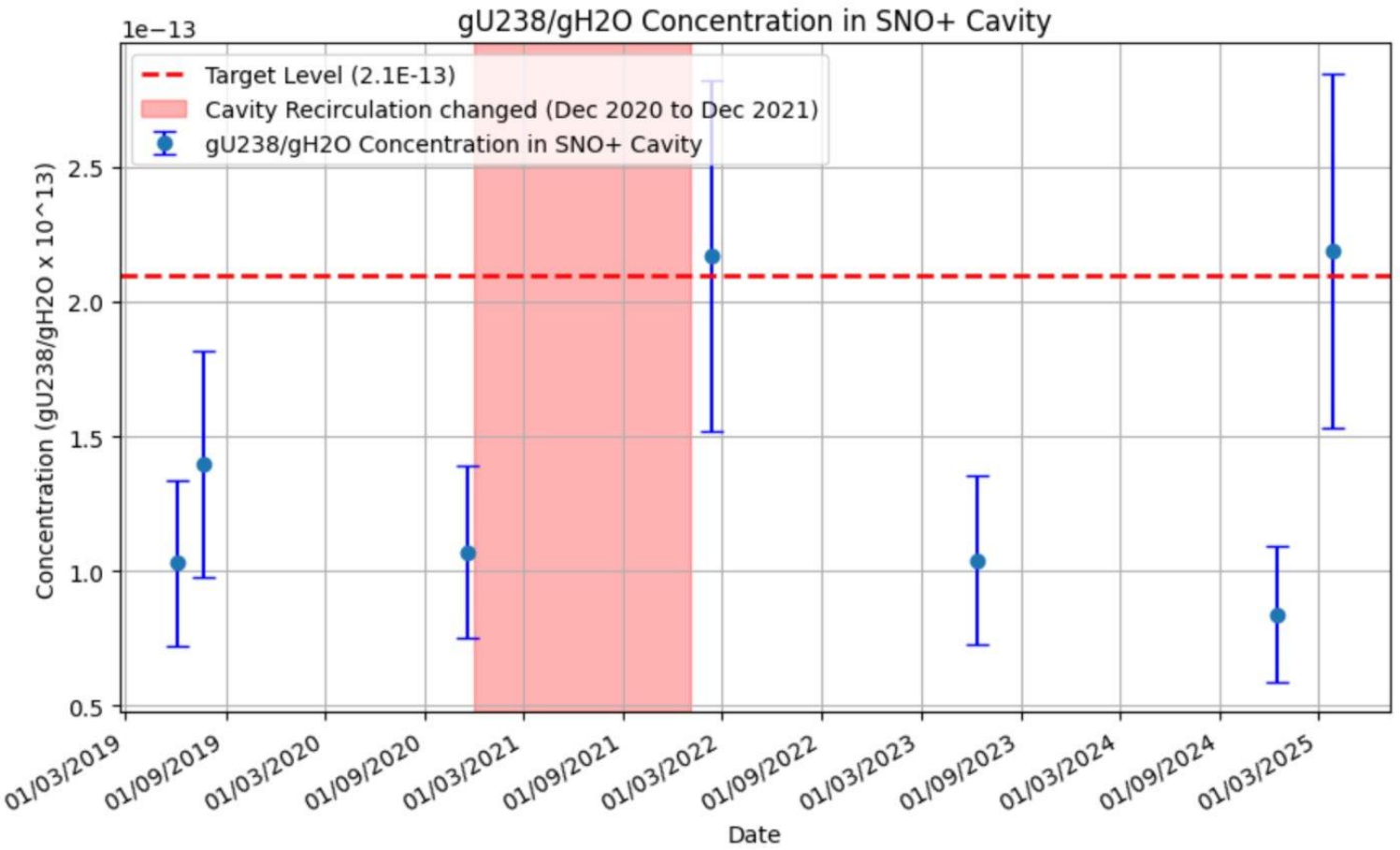
Degasser → Water trap (-60 C) → Radon extraction board

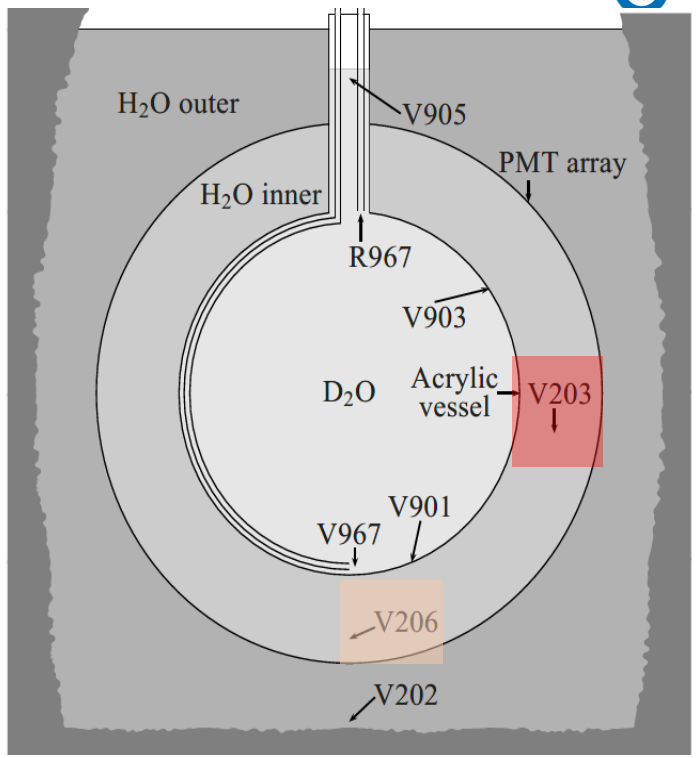


V203: Between Acrylic Vessel and PMTs

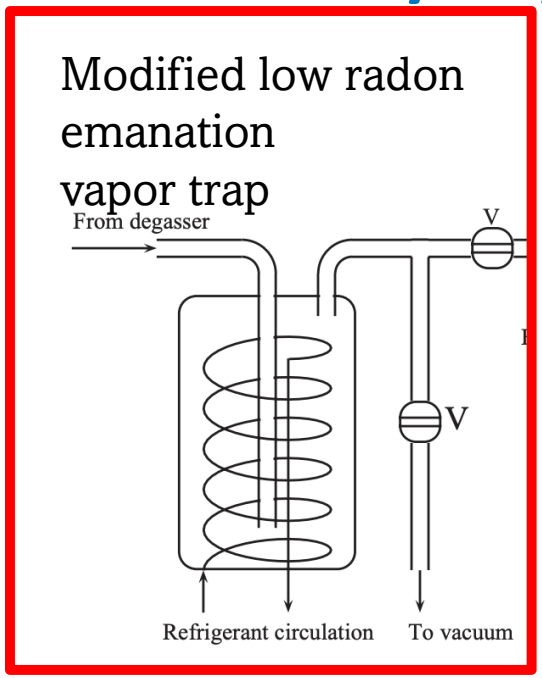


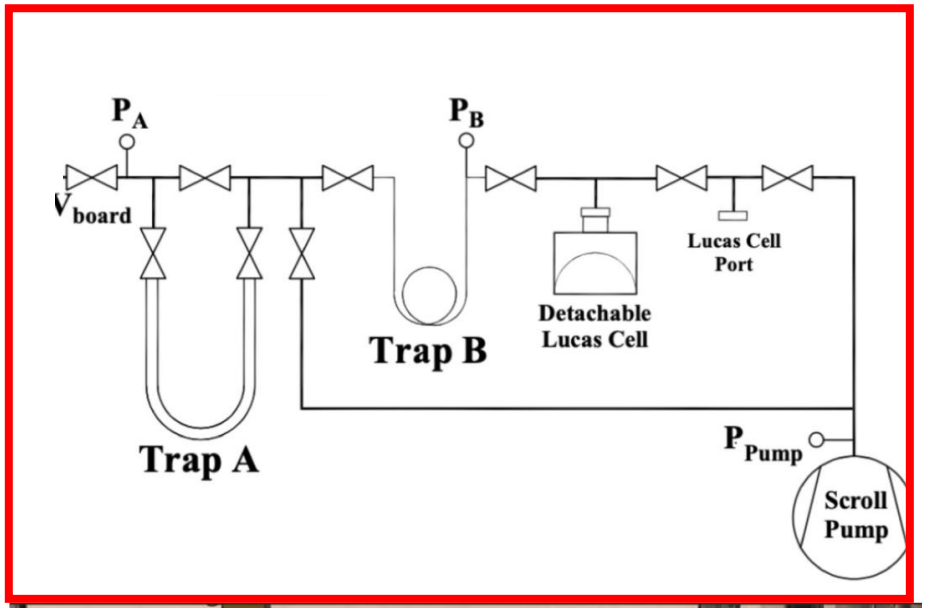



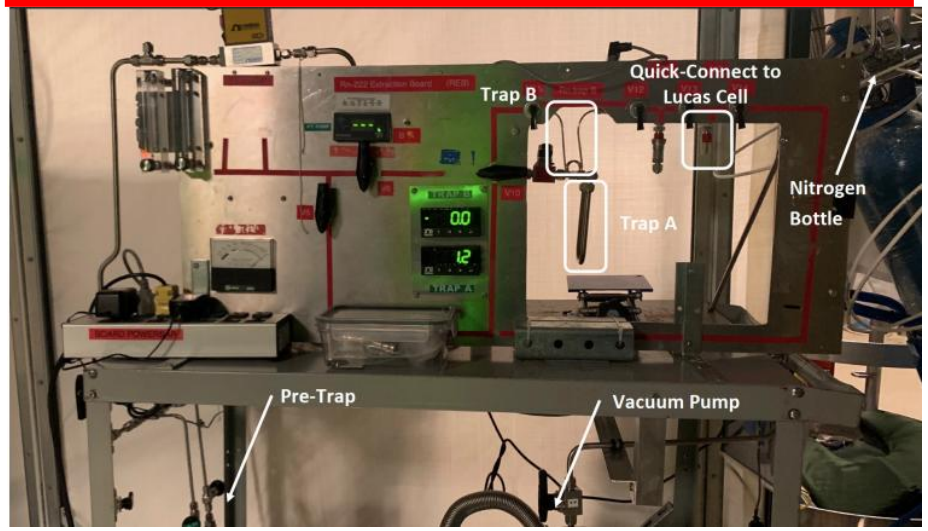

- Results are **consistent with SNO times**
- **SNOLAB UPW plant radon level** is $(2.4 \pm 0.7) \times 10^{-14}$ **g** $^{238}$**U/gH$_2$O equivalent**
  **= (0.14 ±0.04) Rn atoms/L**

# SNOLAB/SNO+ Gas Assay System

Gas system filled with $N_2$



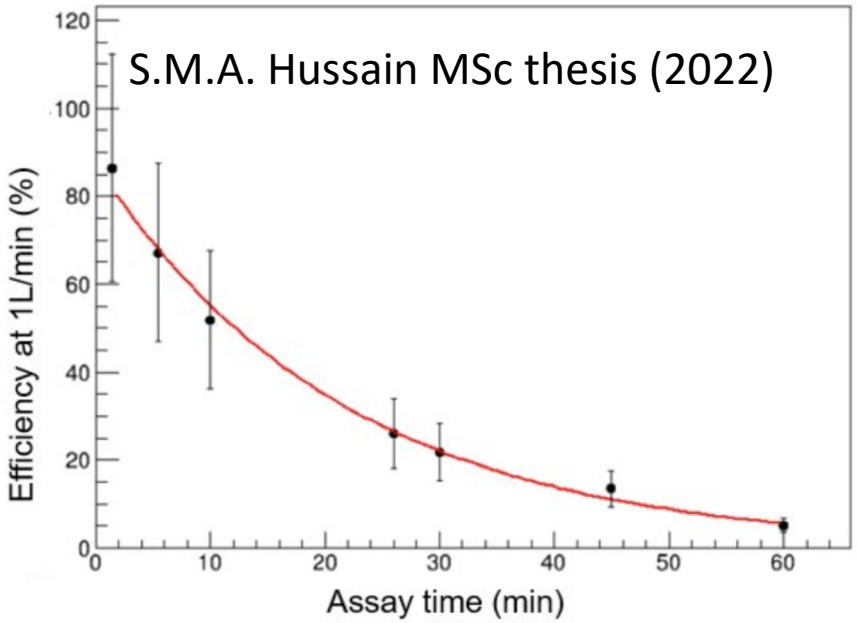




- Originally designed for vacuum radon emanation measurement
- Has been adopted to perform $N_2$ gas assays (SNO+/SNOLAB gas systems and PICO-500)

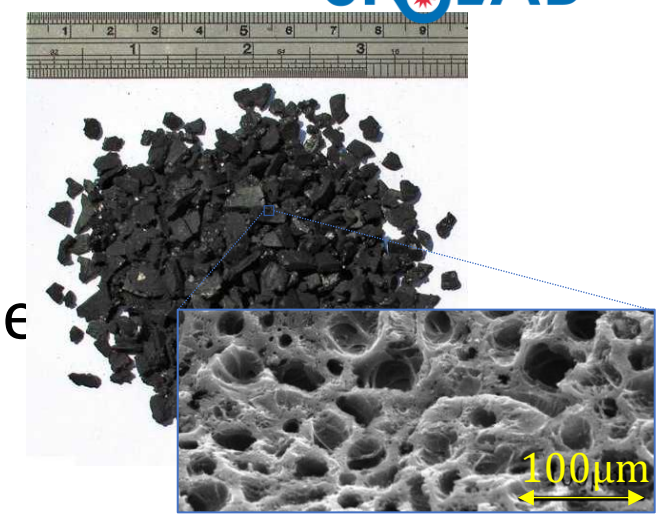
# Primary Trap Limitation for Gas Assays

- Radon traps use porous materials to enhance trapping
- Bronze wool highly efficient under high vacuum
- Gas assay efficiency decreases with longer duration or >1 SLPM flow
- Limited extracted gas volume constrains sensitivity
- **Need for traps with more porous material**



# Activated Charcoal Trap

- Activated charcoal traps used for gas purification
  - G. Heusser, *et al.* Appl. Radiat. Isot., 52 (2000)
- Gas assays require both trapping & efficient radon release
- Developed a portable activated charcoal trap to enhance radon trapping
  - Nasim Fatemighomi et al: Nucl.Instrum.Meth.A 1076 (2025)
- Used low background Calgon OVC 4 × 8 (coconut-based)
- In-house **nitric acid etching** to remove $^{238}$U background
- **Radon emanation: 18± 3 mBq/kg at room temperature**

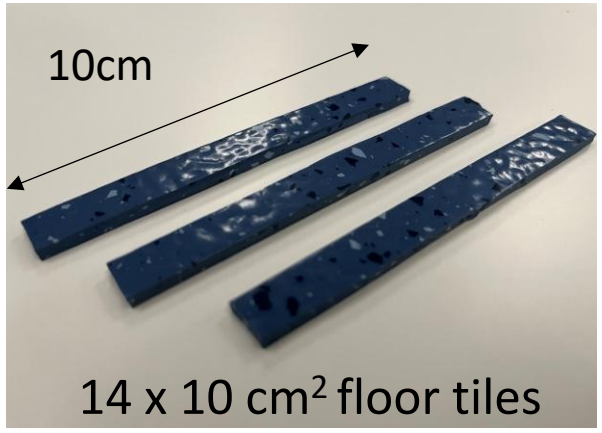




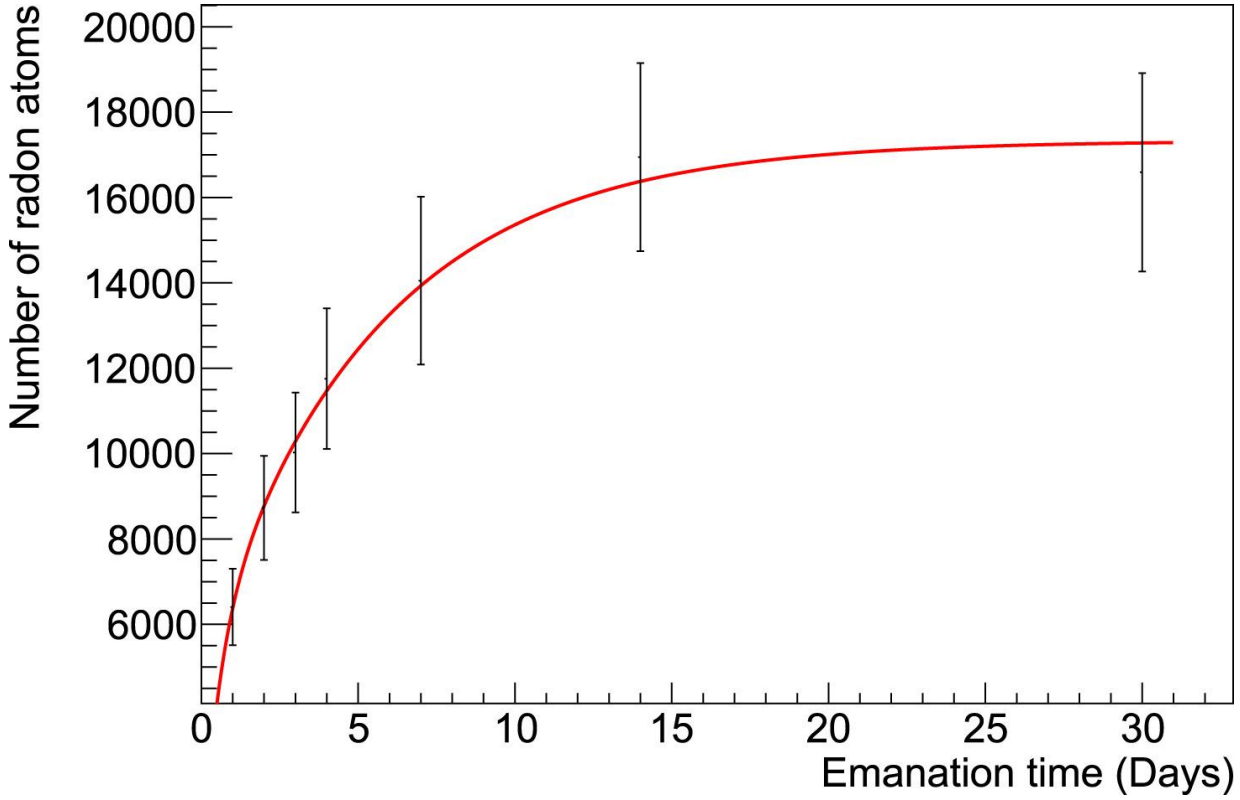
22 g trap

# Radon Calibration Source for Trap testing

- A calibrating source was made using Nora Xp 5319 rubber floor tile



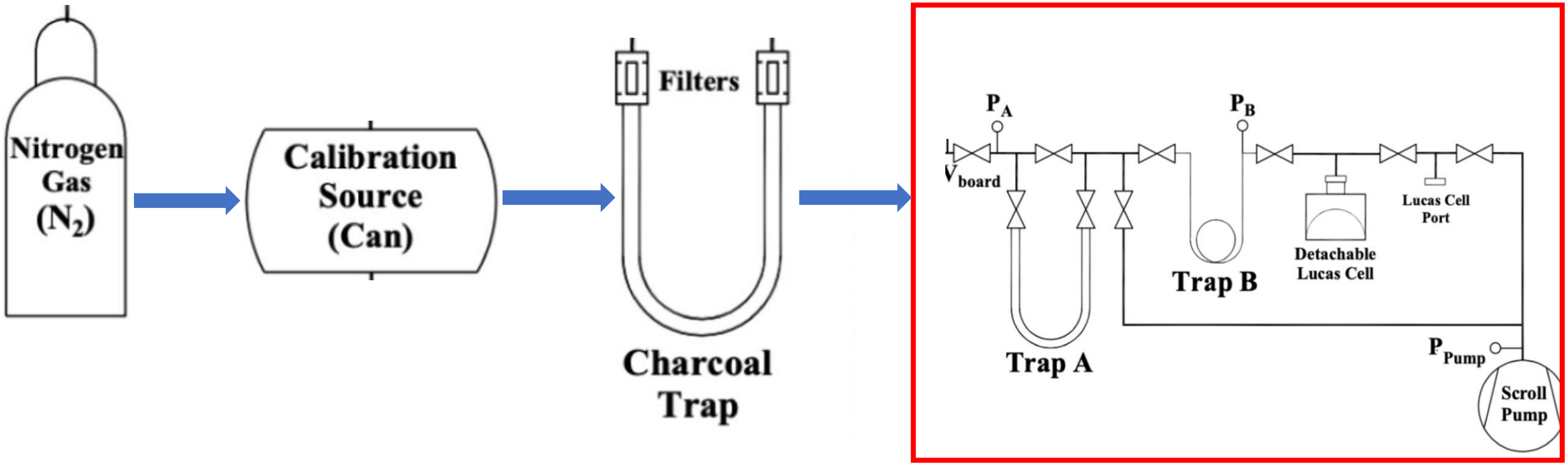





Fit is based on $^{226}$Ra-supported emanation and $^{222}$Rn outgassing from porous rubber tiles

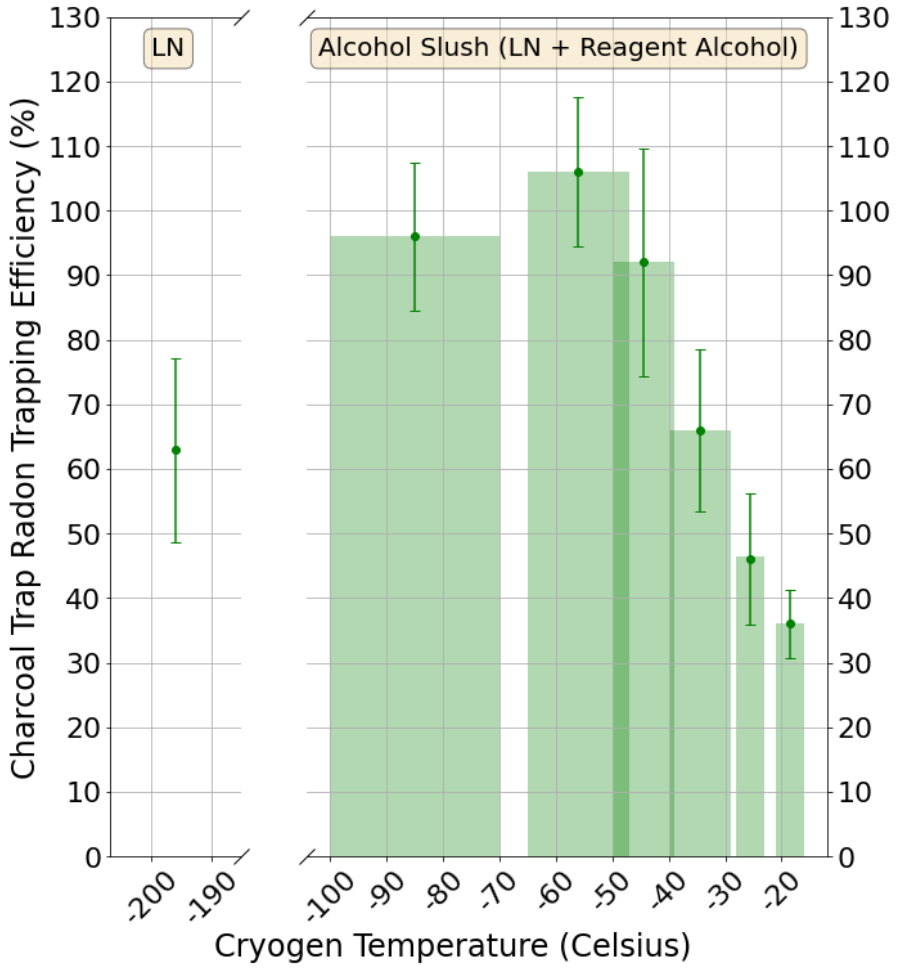
# Trap Efficiency Test Set-up

- $N_2$ flow through the source introduces radon atoms to trap
- Charcoal cooled with $LN_2$–alcohol mix to trap radon
- Radon released from charcoal trap by heating to 150 °C
- Released radon were extracted using the radon board



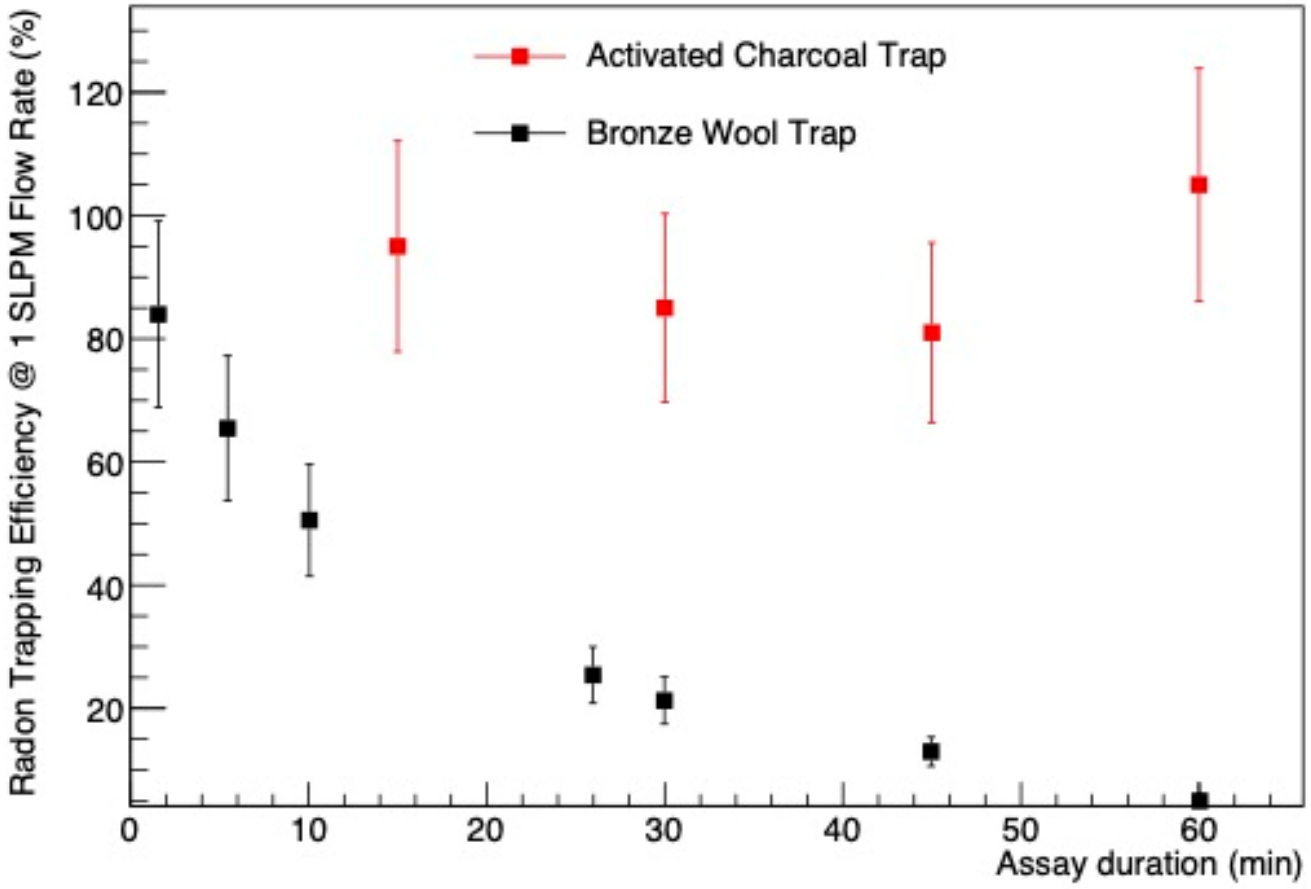
# Efficiency versus Cooling Temperature

- Trap temperature tuned by $LN_2$ ratio in $LN_2$-alcohol mix
- Efficiency: The ratio of radon extracted from radon trap to radon introduced to the trap
- The trap was tested up to 5 SLPM
- The efficiency of the trap is 100% for temperatures between -100° C to -50° C



# Charcoal versus Bronze Traps

- Unlike bronze wool trap, charcoal trap is 100% efficient after one hour of assay duration




Bronze wool data shown in slide 9…

# Charcoal Trap Sensitivity and Use

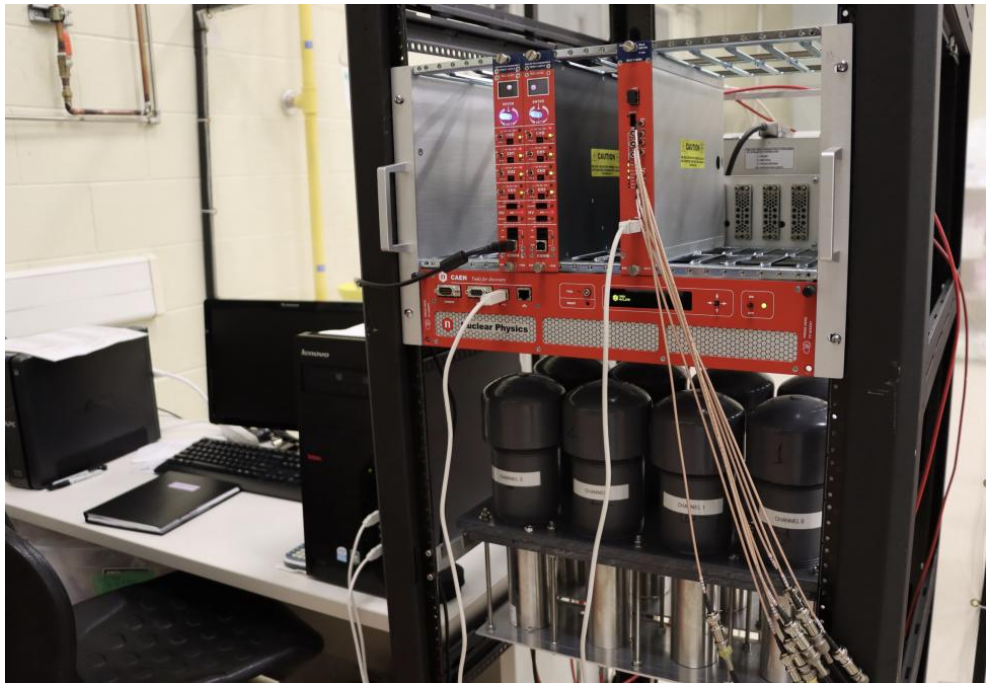
- $N_2$ assay sensitivity $>$ **90 $\mu$Bq/m$^3$**
  - Bronze wool sensitivity: 3.3 mBq/m$^3$
- Trap used to measure radon in $N_2$ systems, incl. SNOLAB $LN_2$ plant boil-off

SNOLAB $LN_2$ plant

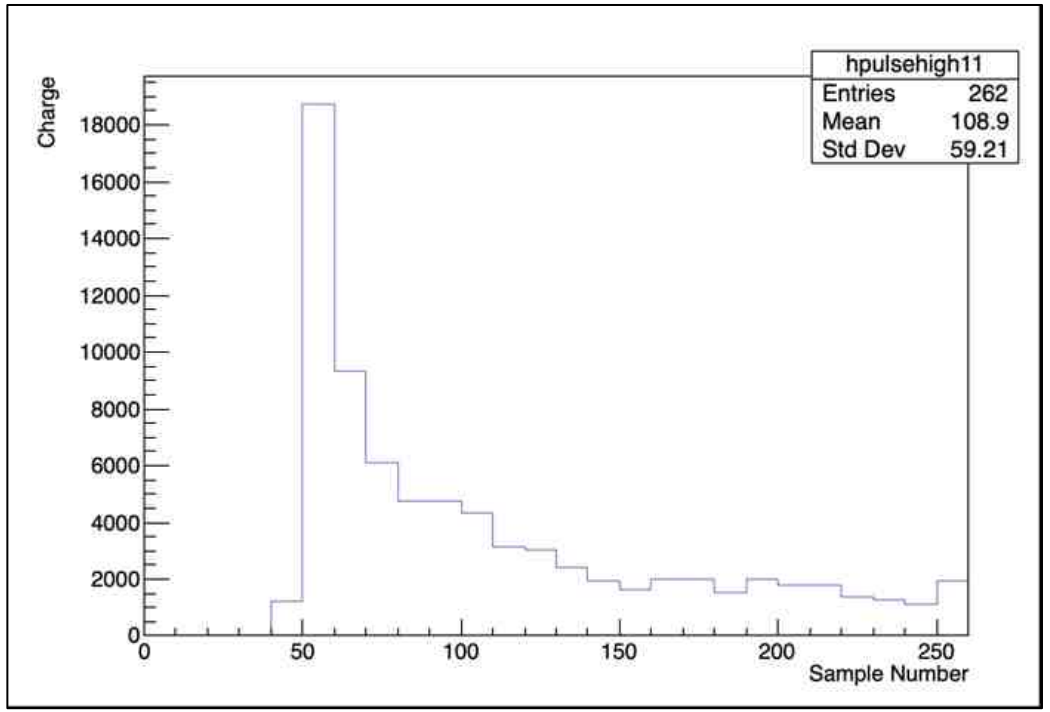
SNOLAB International Dewar

# Radon Counting

- Portable Lucas cells with ZnS(Ag) coating
- ZnS(Ag) scintillates with α particles → ideal for radon detection
- Eighteen Lucas cell channels available

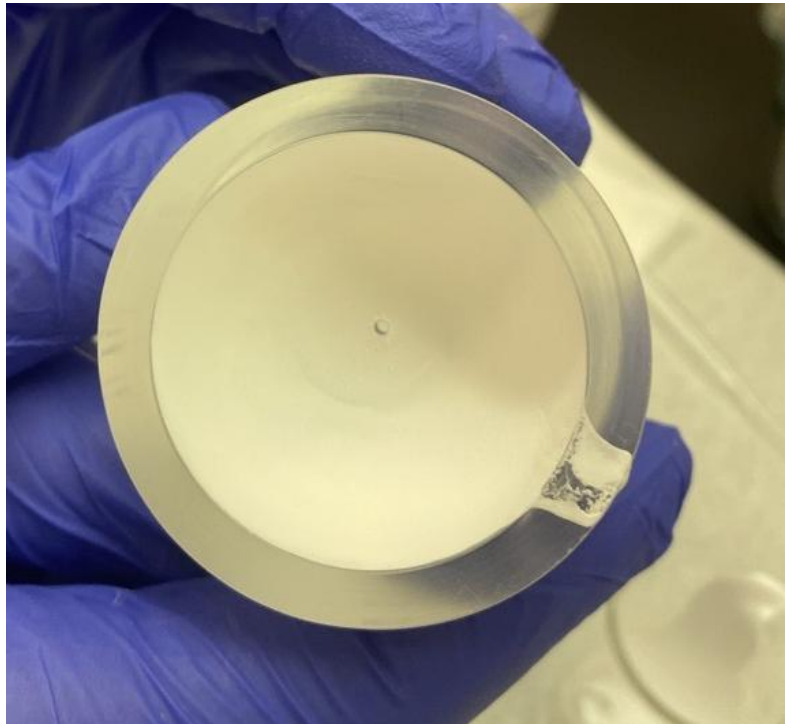
2” diameter PMTs and CAEN electronics



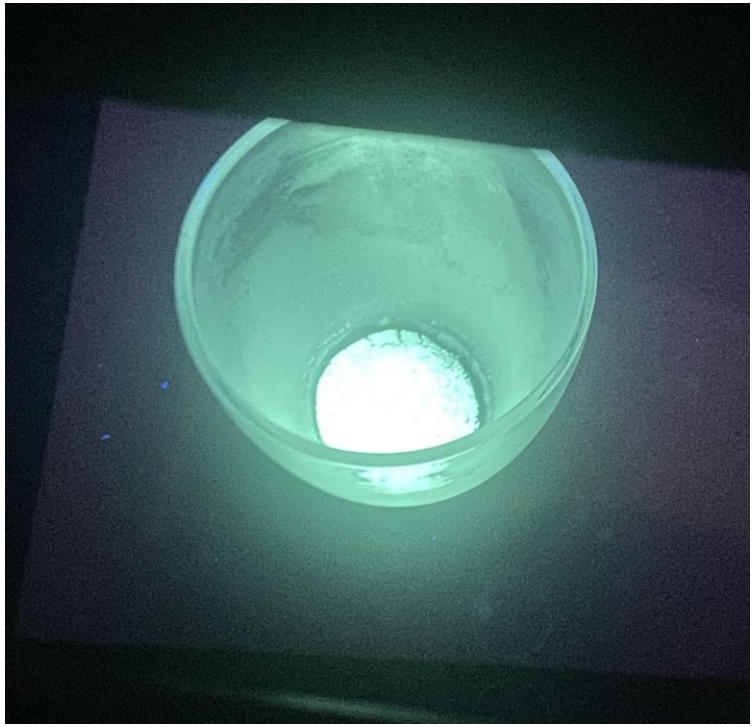

4 µs window

# Enhancing Radon Counting

- New low background Lucas cells were fabricated: 3 $\alpha$/day
- R&D toward lower background ZnS(Ag)
- Exploring small low background spherical proportional  counters (SPC) for β sensitivity (Dr. Pierre Gorel)



New Lucas cell



In-house ZnS(Ag)

SPC (a la NEWSG)

# Summary and Future Work

- At SNOLAB radon assay systems used to measure radon in UPW, solid samples, and $N_2$ gas
- Developed a low-background radon trap to improve $N_2$ gas assay sensitivity
- Continuing research on radon trapping methods
  - R &D for radon measurement in noble gases
- R &D toward making low background radon counting systems

# Acknowledgement

**Research Students (SNOLAB/SNO+):**
Yusuf Ahmed, Juliette Deloye, Peter Qin, Justin Suys, Keegan Paleshi, Adil Hussain, Jerry Lu and Ariana Pearson

**Scientific Support Team:**
Lina Anselmo, Steven Maguire, Sharayah Read and Deena Fabris