Radon-222 Screening Capability and Research at SNOLAB

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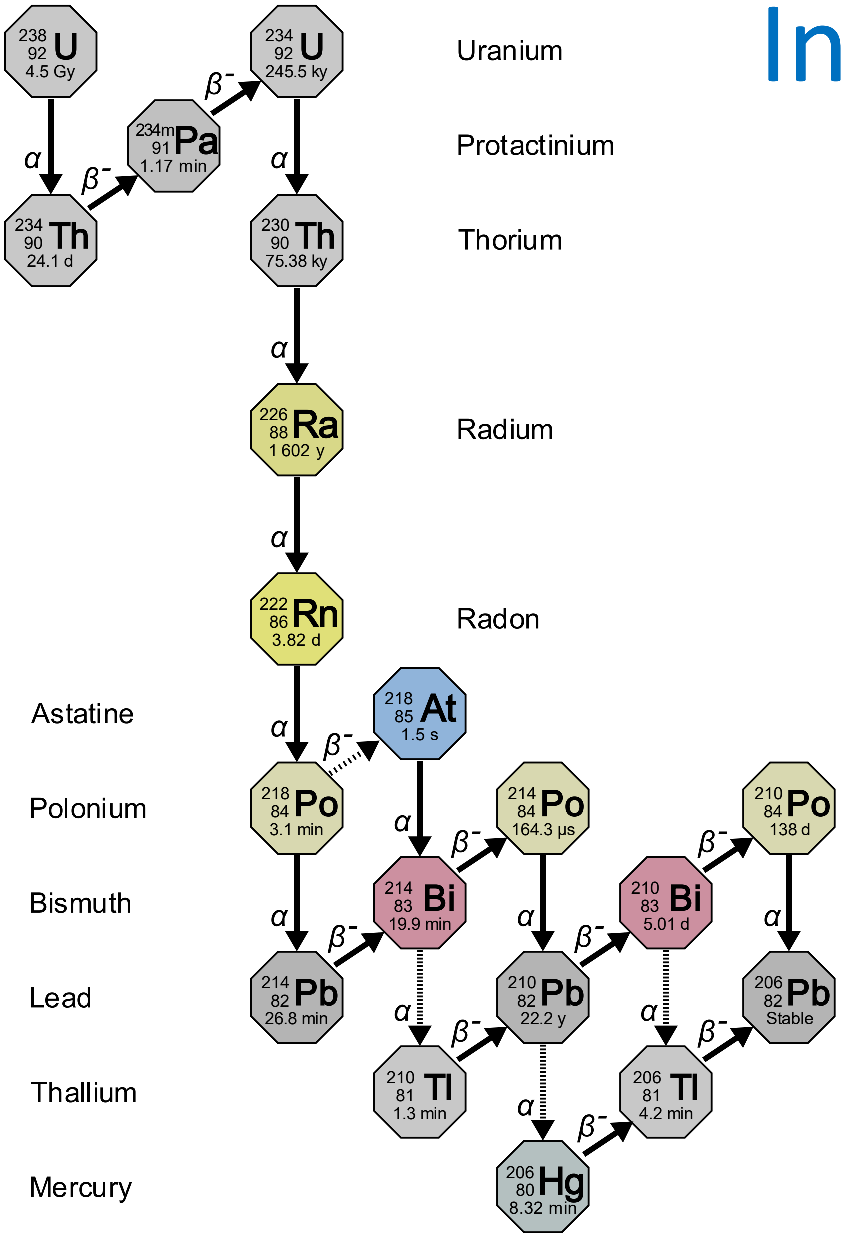
Introduction

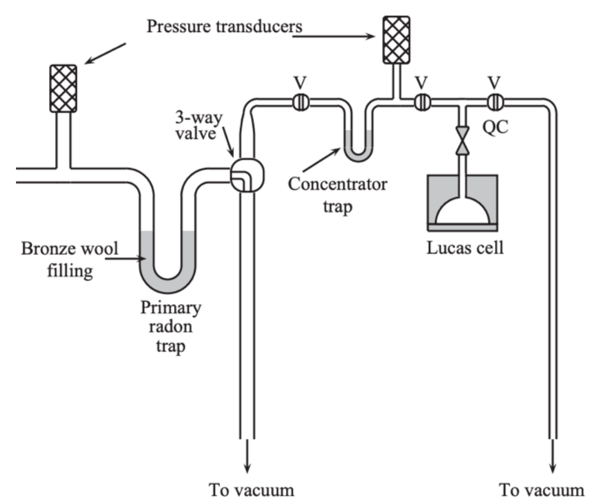


- ^{222}Rn progeny → backgrounds in low energy neutrino and rare-event searches
- Emanates from material surfaces
- Strict material selection is essential
- SNOLAB supports low level ^{222}Rn screening through:
  - **Radon assays**
  - **R&D to reduce assay backgrounds and improve efficiency**

Trapping - Concentration Technique

- Based on a design developed by Queen's University (M. Liu, *et al.* NIM A, 517 (1993), pp. 291-293)
- Radon atoms collected by cooling down radon traps using liquid nitrogen (LN)
- Radon released by warming up the traps (100°C)
- Radon transferred to a Lucas cell (LC) through volume sharing
- LC is detached and put on top of a PMT for counting

Emanation Chamber (Under vacuum)



SNOLAB Radon Emanation System

Background:
4 ± 2 Rn atoms/day

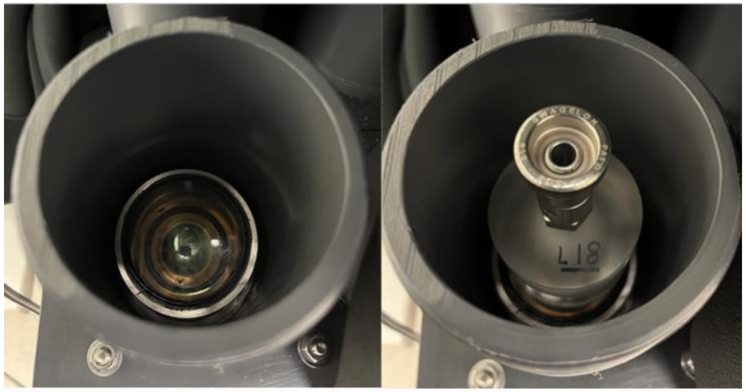
Emanation Chamber

Vacuum Pump

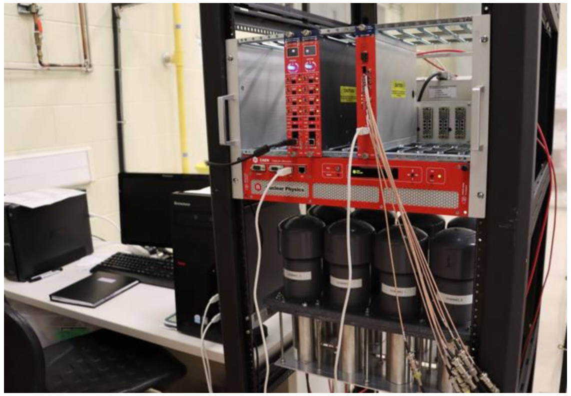
Commissioning a new lower-background, all-metal emanation chamber this year

LC Radon Counting

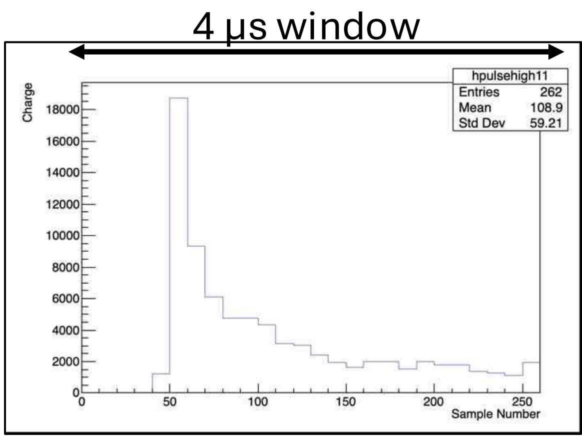
- Portable Lucas cells (LCs) with ZnS(Ag) coating
- ZnS(Ag) scintillates with α particles → ideal for radon detection
- Sixteen LC channels available



2” PMTs

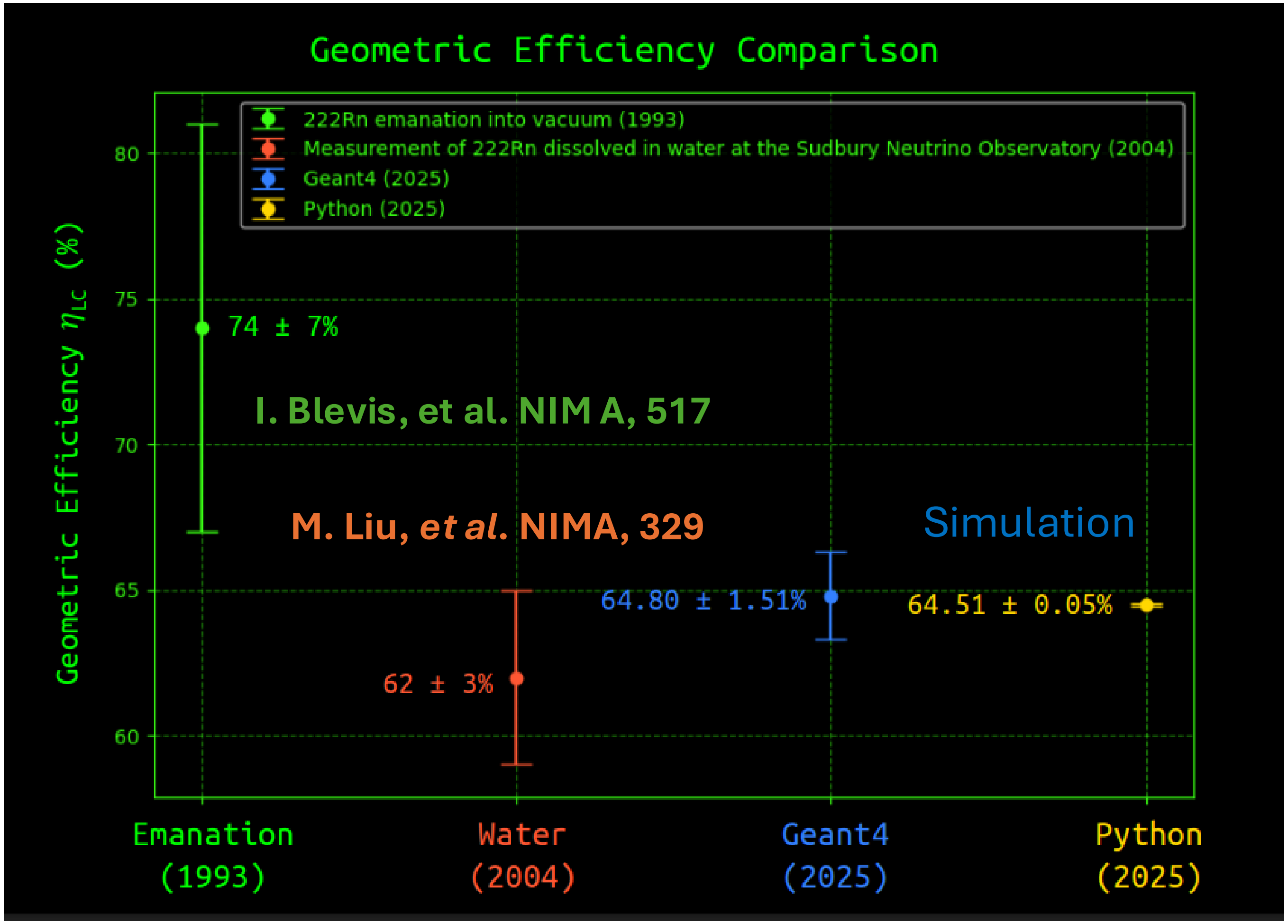


CAEN digitizer



Typical alpha pulse

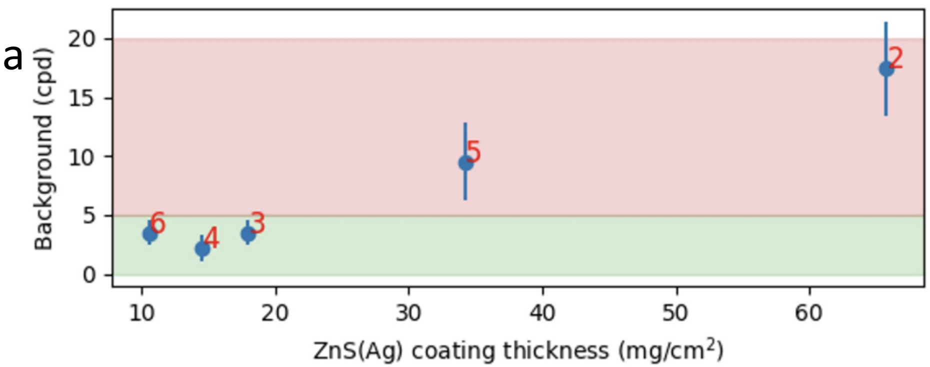
LC efficiency



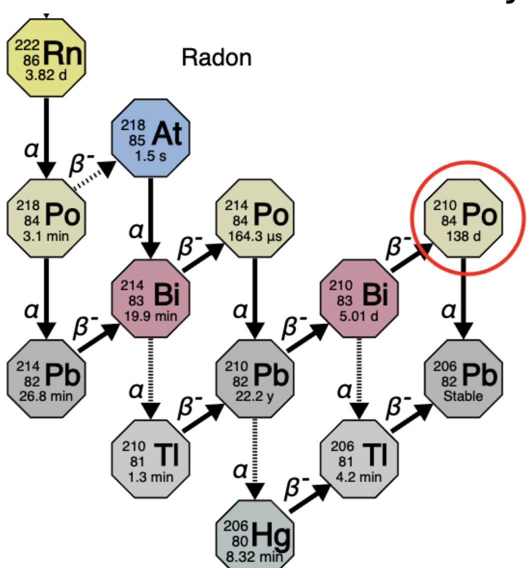
- Recently purchased a 30.0 ± 1.5 Bq RNC Pylon source to measure efficiency at SNOLAB

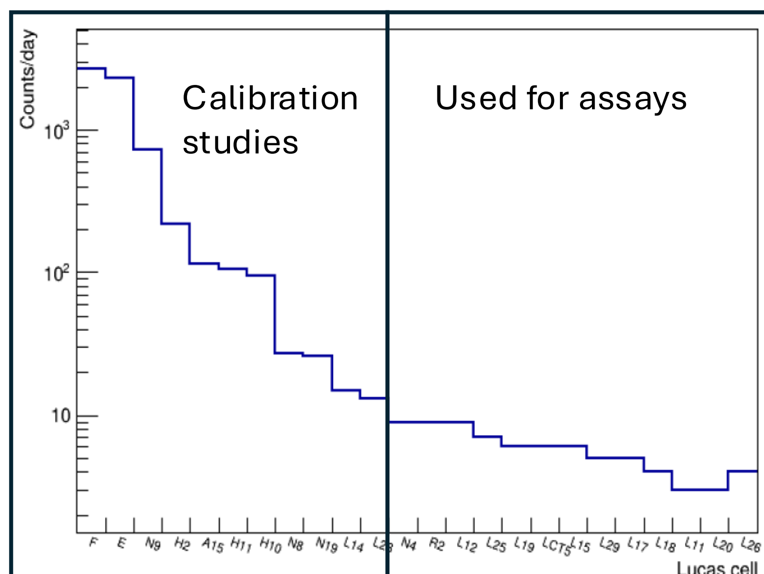
LC Background

- New LCs have background of 3 to 5 alpha counts day
- **Background is due to intrinsic radioactivity in ZnS(Ag)**
  - **Supported by HPGe and LC counting system measurments**

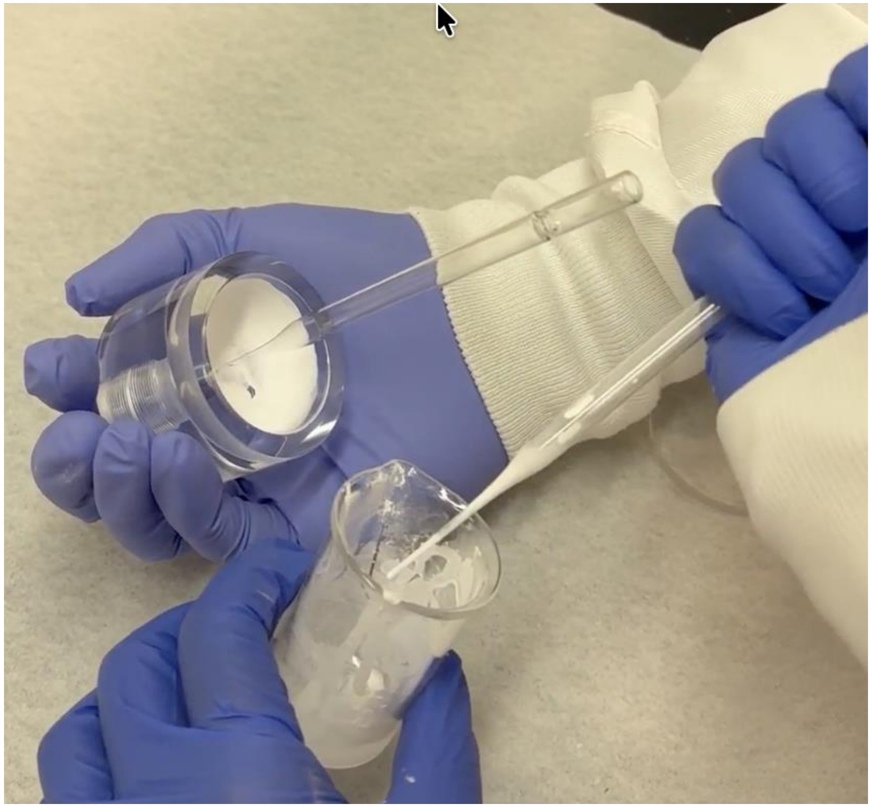


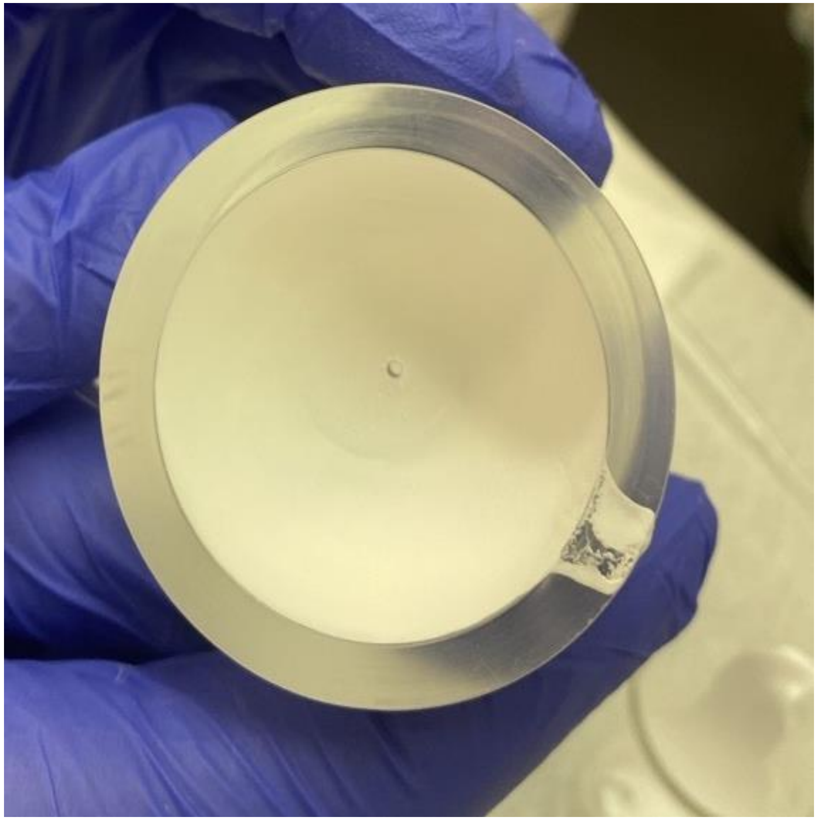
- ^{210}Po background increases overtime
- Need to make new LCs every few years





Making new LCs

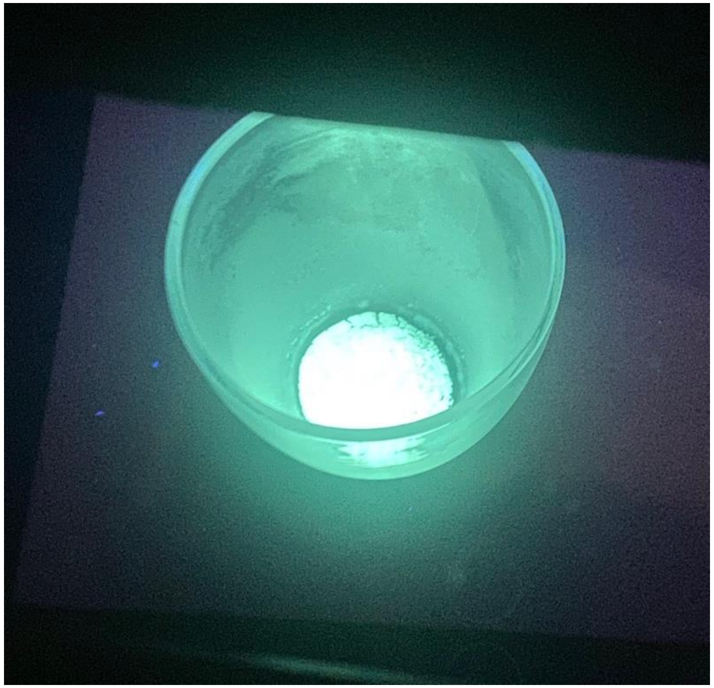




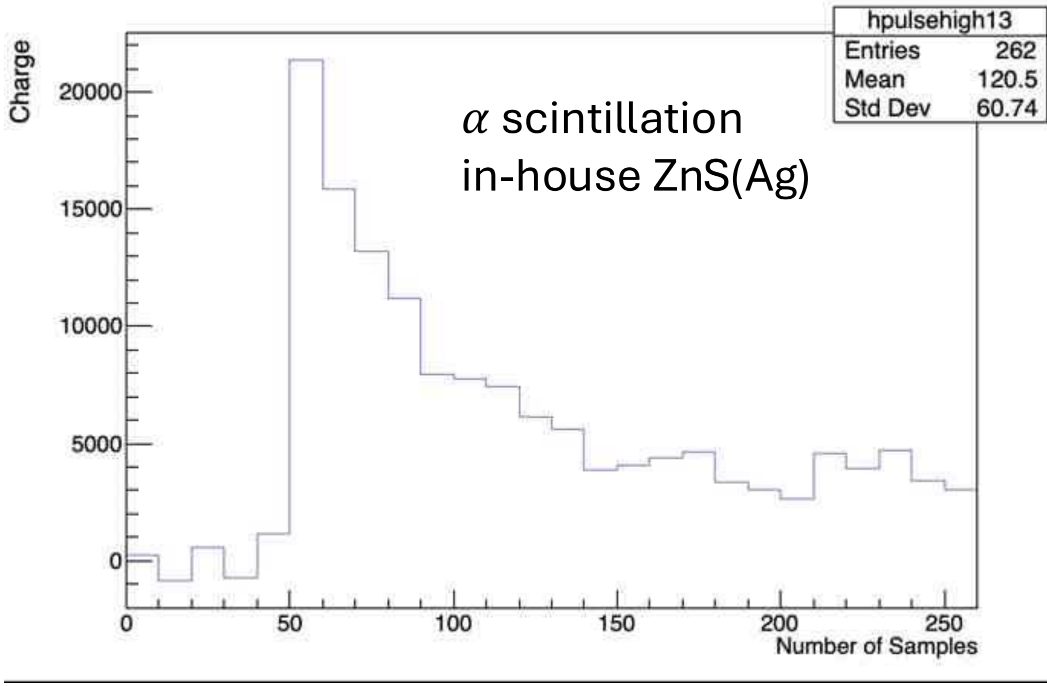
- **Methylene Chloride** used as solvent-bonding agent to bound ZnS(Ag) with acrylic
- We developed the procedure to make new LCs at SNOLAB

Reducing LC Background

- R&D toward fabricating lower background ZnS(Ag)



In-house ZnS(Ag)



The initial results is promising
Working on optimizing background reduction and ZnS(Ag) light yield

Measurement of ^{222}Rn level in N_2

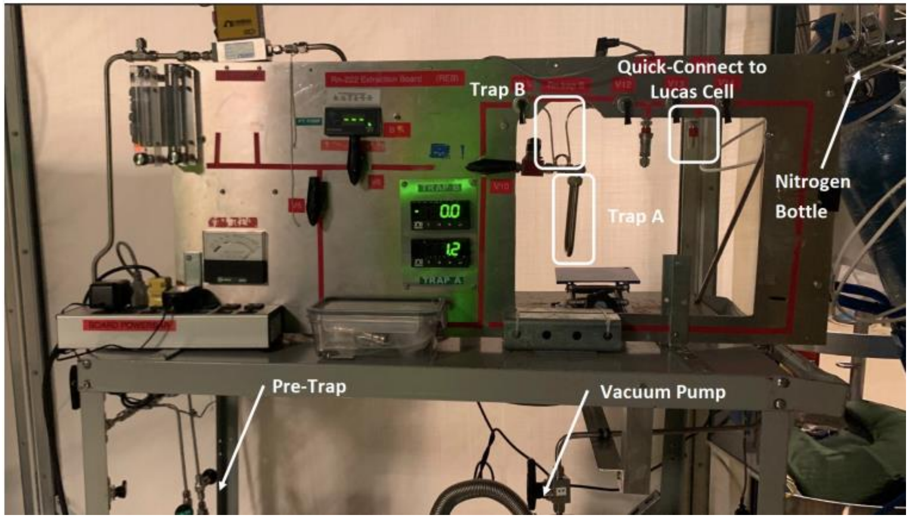
- N_2 is widely used as a cover gas to prevent Rn ingress in the detector
- For large-volume systems, N_2 is used as a carrier gas to sweep out emanated Rn

SNO+ Cover Gas System

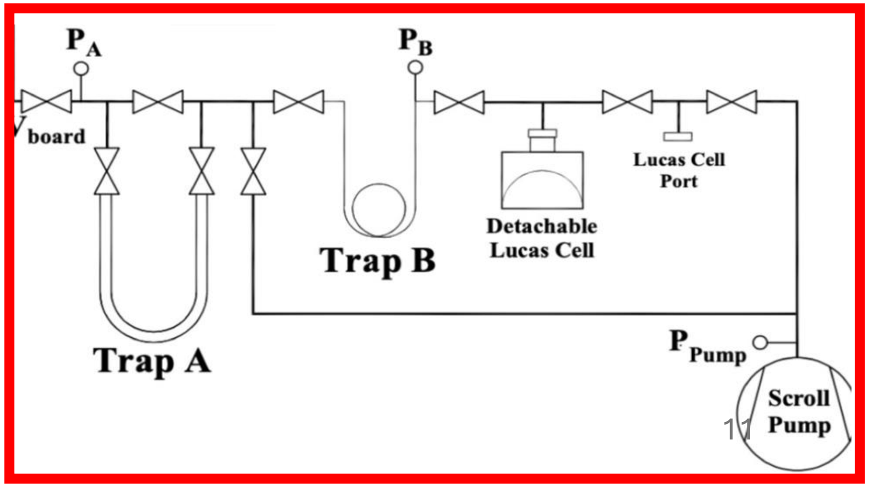
PICO-500 Steel Shell

UG Mobile System

- Designed for vacuum radon emanation measurement
- Was adopted to perform N_2 gas assays

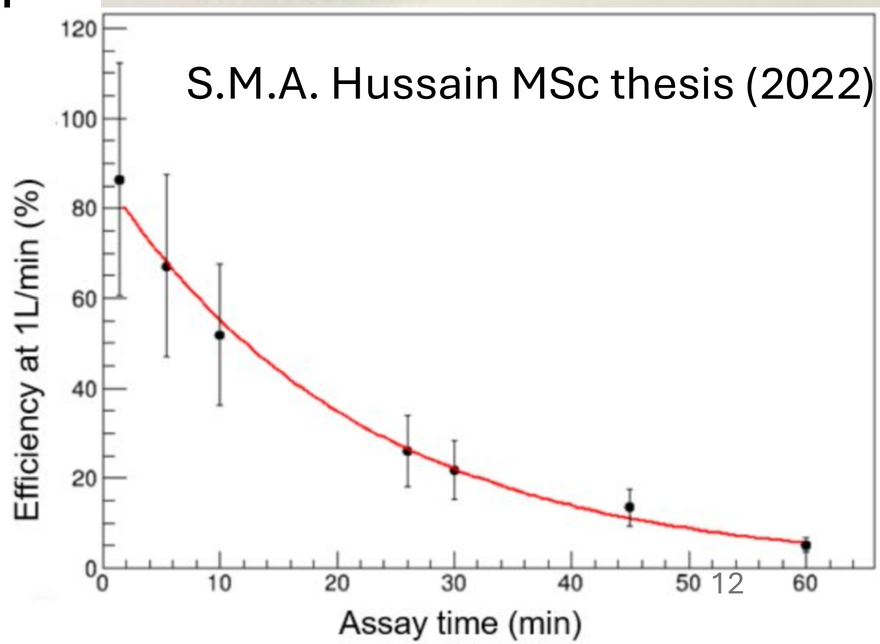


Cover Gas system filled with N_2 → vapor trap →



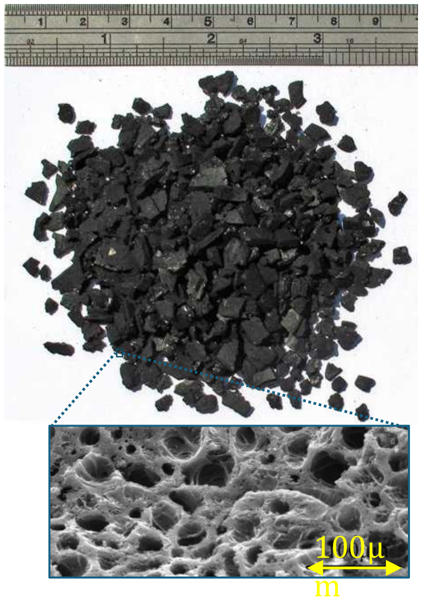
Primary Trap Limitation for Gas Assay

- 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 (> 3.3 mBq/m^3)
- **Need for traps with more porous material**



Activated Charcoal Trap

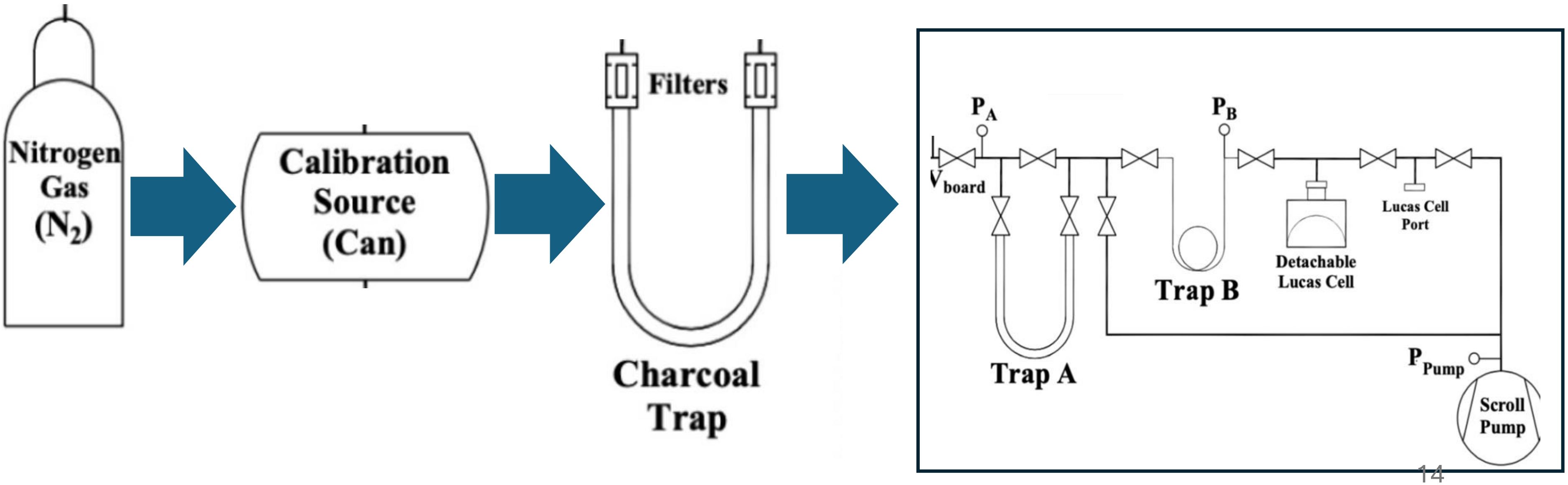
- Activated charcoal traps used for gas purification
  - G. Heusser, *et al.* Appl. Radiat. Isot., 52 (2000)
- Gas assays require both trapping & efficient radon release
- Developed a portable activated charcoal trap to enhance radon trapping
  - Nasim Fatemighomi et al: Nucl.Instrum.Meth.A 1076 (2025)
- 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

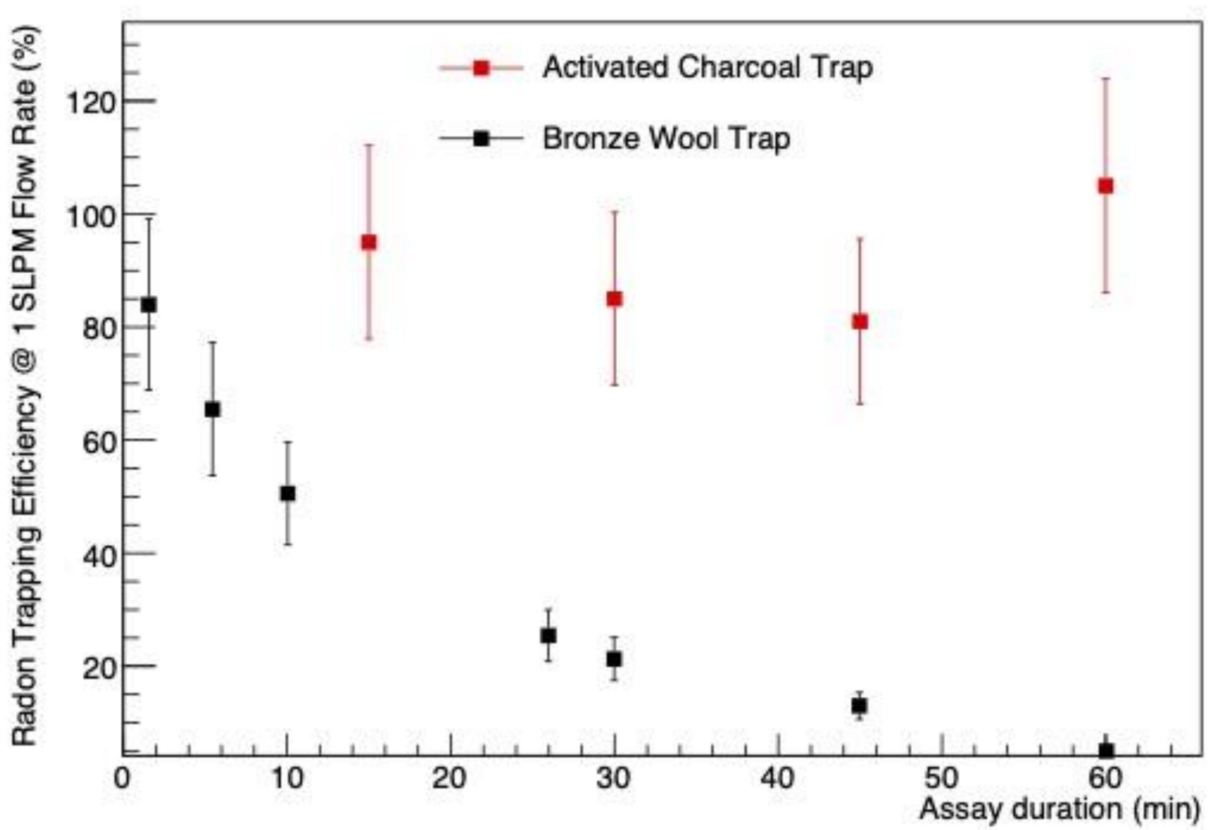
Trap Efficiency Measurement

- 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
- Released radon were extracted using the radon board



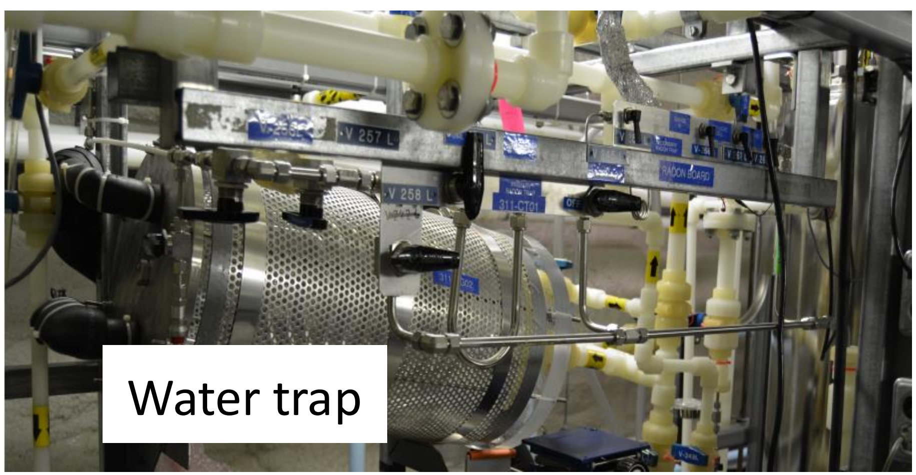
Charcoal versus Bronze Traps

- Unlike bronze wool trap, charcoal trap is 100% efficient after one hour of assay duration
- The trap is also 100% efficient for flow rate of up to 5 SLPM
- N_2 assay sensitivity $>$ **90 μBq/m^3**

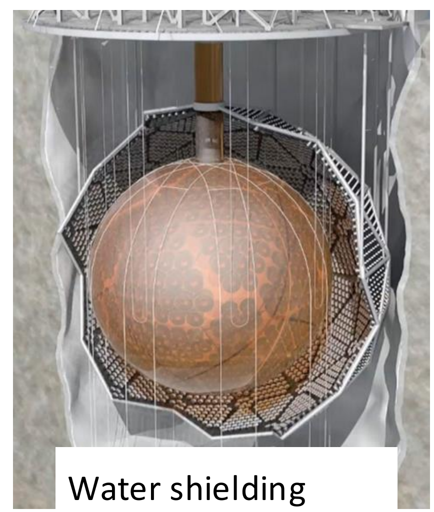


Water Radon Assay

- 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
- For double beta decay physics knowing level of external ^{214}Bi is important

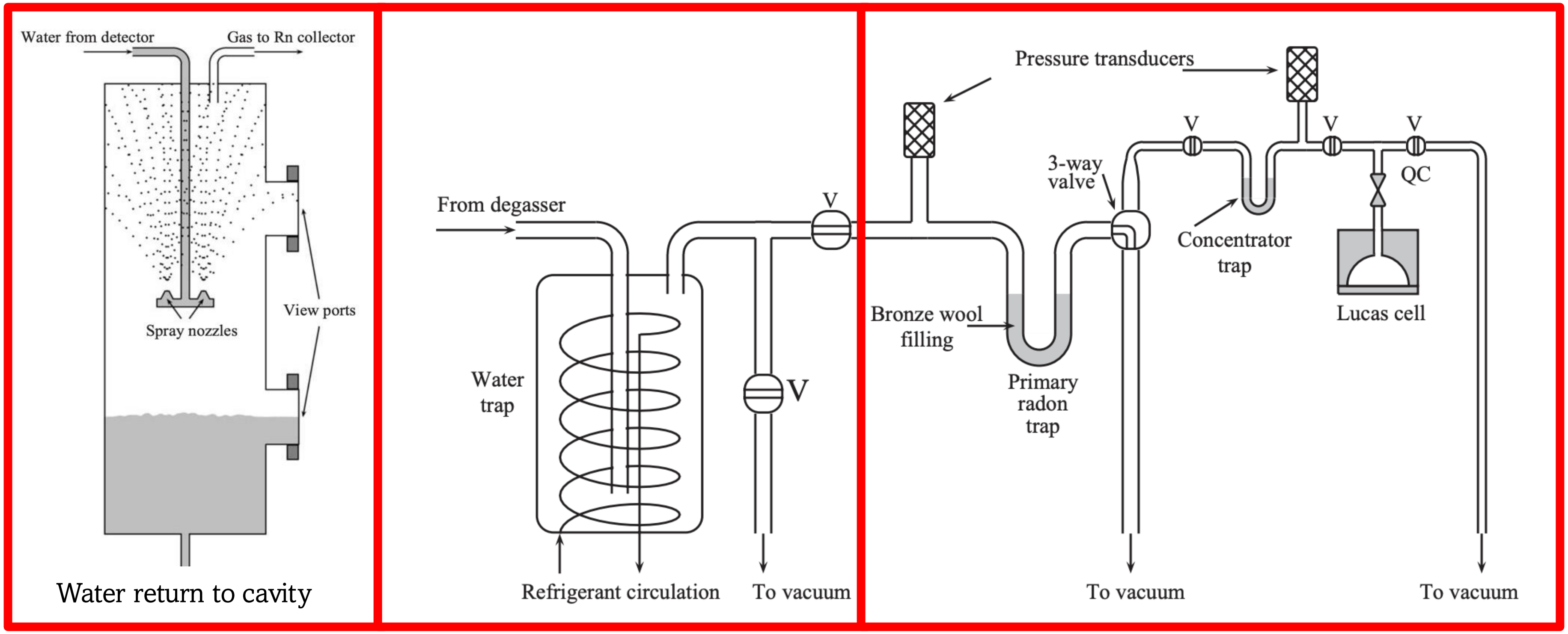


The SNO+ experiment



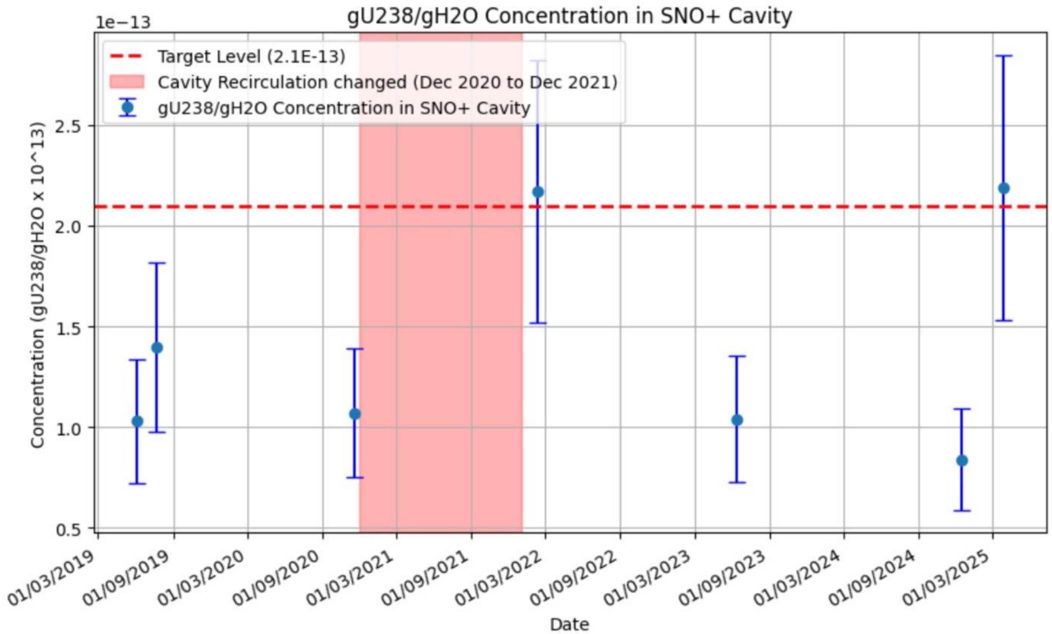
Water shielding
(7000 tonnes UPW)

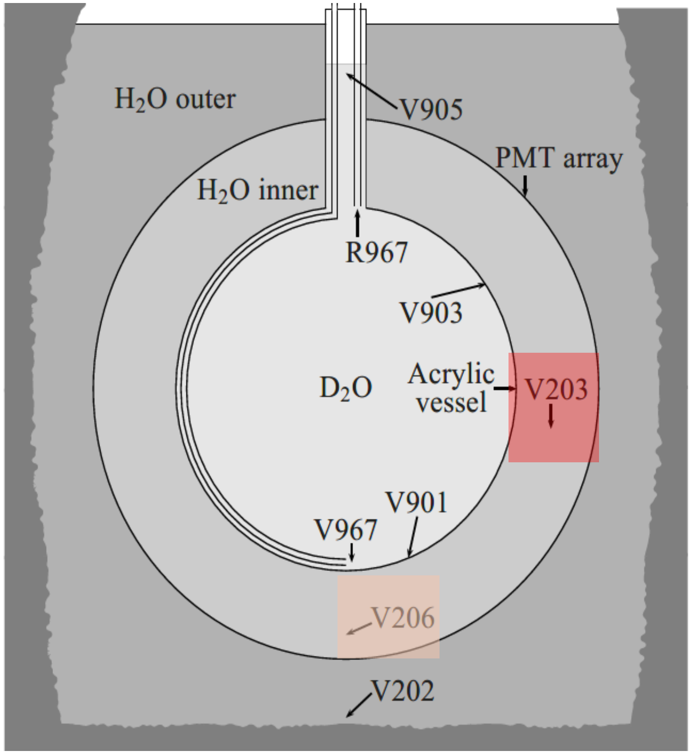
Degasser → Water trap → Radon extraction board



UPW Assay Results

V203: Between Acrylic Vessel and PMTs

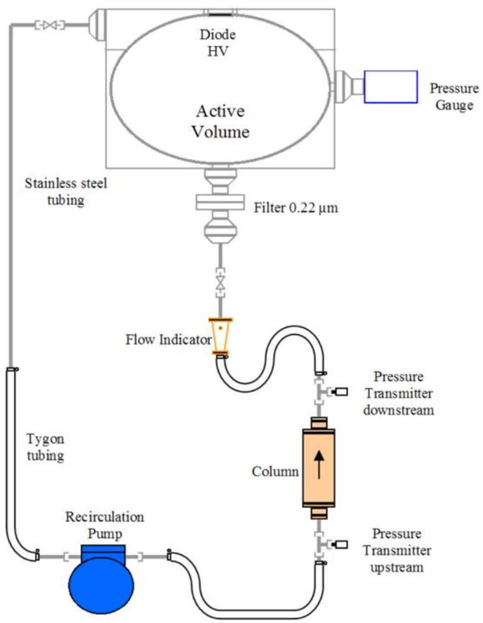


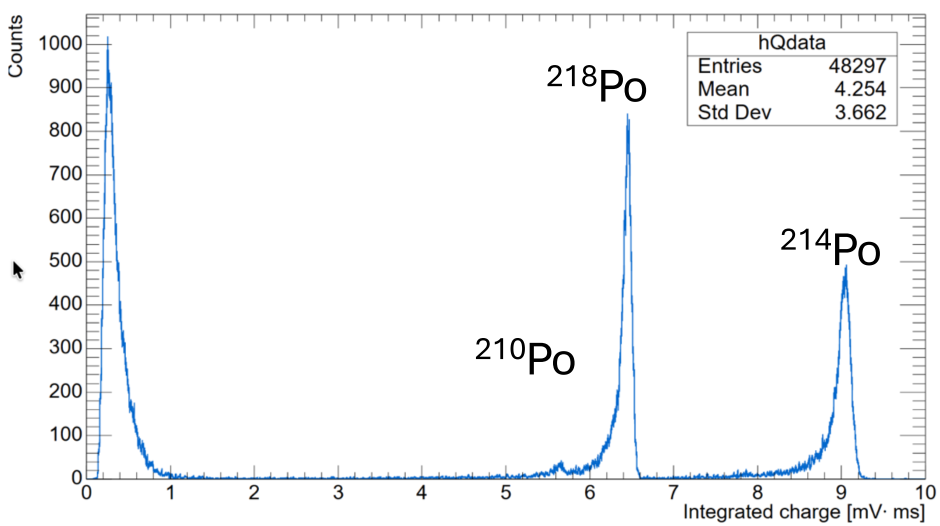


- Results are **consistent with SNO times**
- **SNOLAB UPW plant radon level** is $\mathbf{(2.4 \pm 0.7) \times 10^{-14} g^{238}U/gH_2O}$ **equivalent,** $\mathbf{(0.14 \pm 0.04)}$ **Rn atoms/L**

Recirculation Technique

- Electrostatic chambers (ESCs) Developed for ^{224}Ra and ^{226}Ra measurement in SNO (J. Wang, NIMA 421)
- Used for ^{222}Rn assay measurement for EXO-200 and nEXO.
- Detect positively charged radon progeny drifting to a negatively biased detector
- A recirculation pump forces a carrier gas gas through the sample and into the ESC for analysis
- Continuous radon transport and detection
- Two units being refurbished with a new DAQ system (expected sensitivity: 200 μBq)





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
- Bringing ESCs back to operation