A Highly Sensitive Radon Emanation Measurement System at SNOLAB

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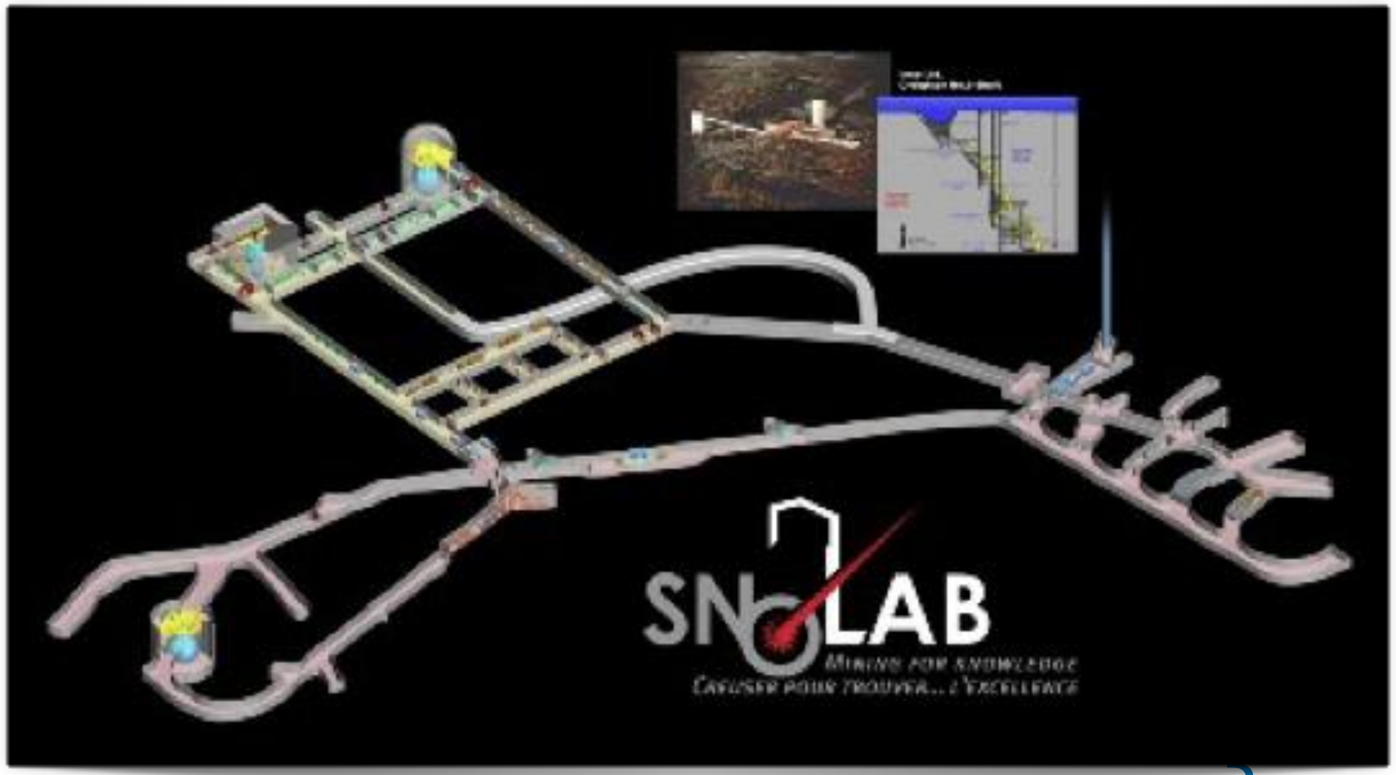
Overview

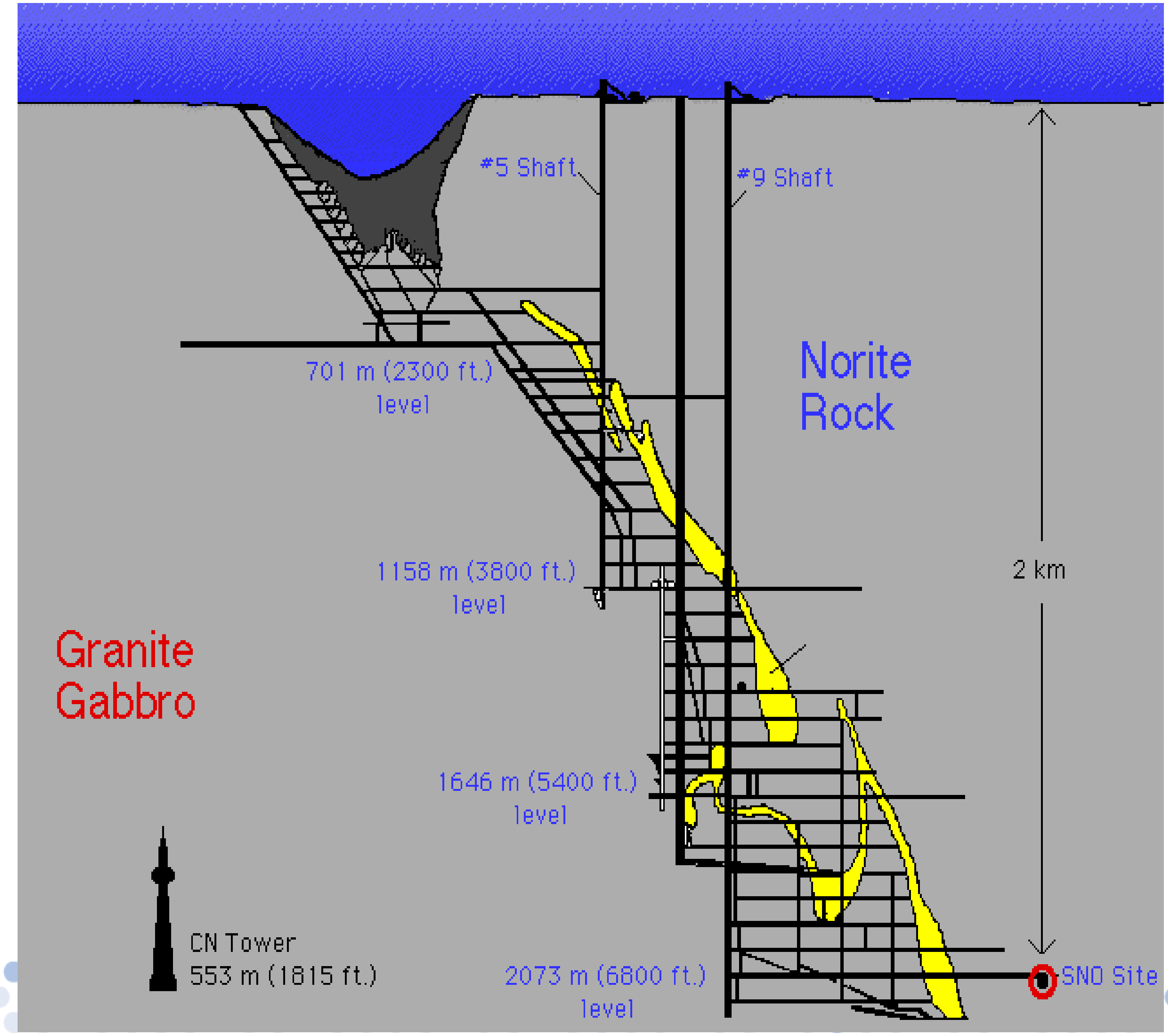
- Motivation
- Radon-222 Emanation Measurement System
- Efficiency and Sensitivity
- Services
- Summary

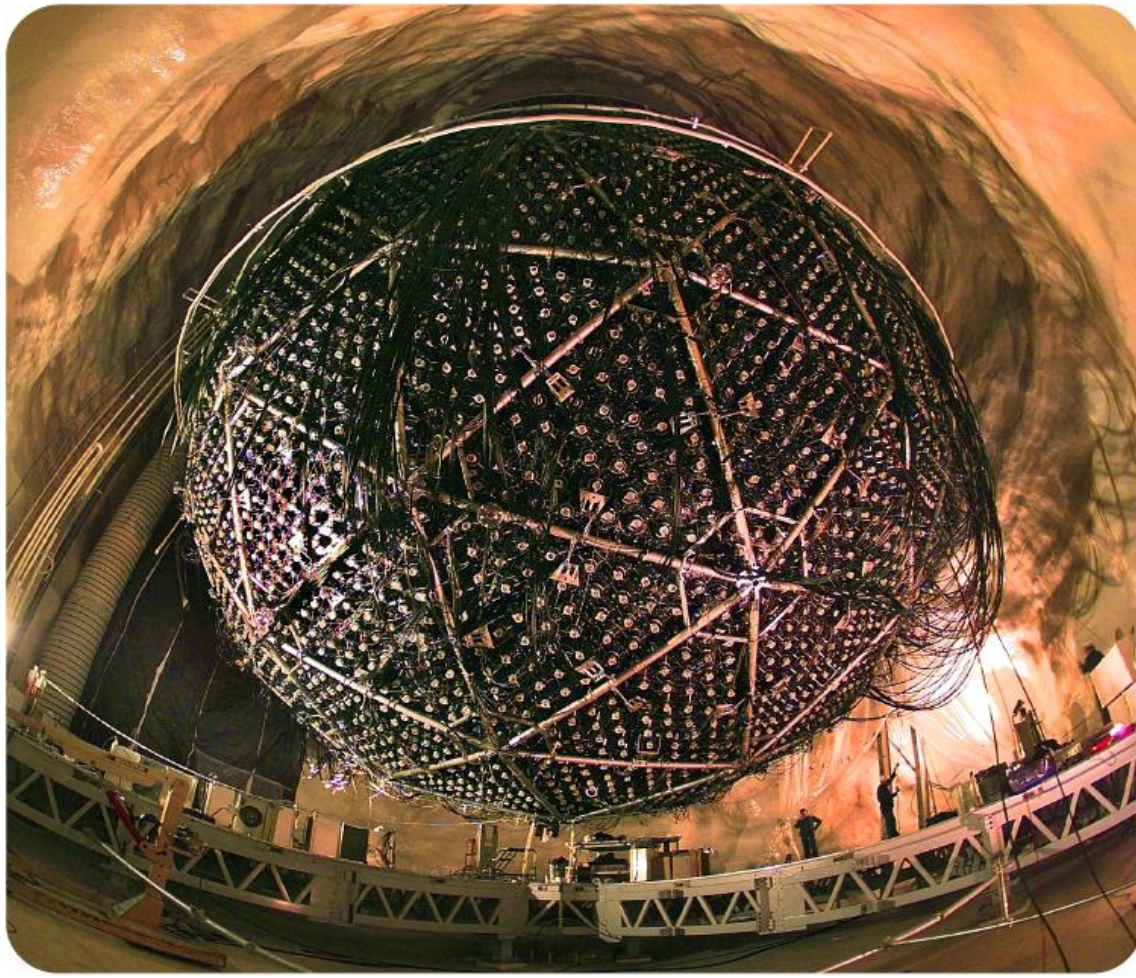
The SNOLAB Facility

- Hosted at the Vale Creighton Nickel Mine in Sudbury, Ontario, Canada
- Operated as a joint venture of 5 Canadian Universities (Carleton, Queen's, Montreal, Alberta, and Laurentian)
- Operations funded by the Canada Foundation for Innovation and the Province of Ontario



SNOLAB includes a campus 2km underground





Developed from original SNO detector as part of a competition to develop international facilities within Canada

Why go Deep Underground?

- High energy muons travel deep
- Deep UG facilities provide significant rock overburden-> reduction in cosmic ray flux.

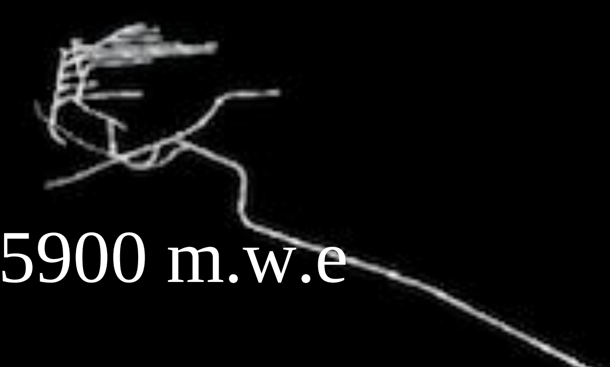
SNOLAB
Surface facility

- Offices
- Clean laboratory
- Warehouse
- Machine shop

166 muons/m^2/s

There is ~50 million times reduction in cosmic rays 2km underground at SNOLAB!

SNOLAB
Underground facility



0.27 muon/m^2/day 6800 ft/2072 m /5900 m.w.e

Cleanliness is critical to SNOLAB operations and science

Why do we care about cleanliness?

Radioactive backgrounds from the environment dominate underground

Why do we care about Radioactivity ?

- Many experiments require ultra low level of radioactive backgrounds to achieve required sensitivities for their searches.
- Main backgrounds: Naturally occurring radioactivity (238U and 232Th decay chains).
- These backgrounds (alphas, betas, gammas) may mimic the expected detector signal.

GOAL: To measure these backgrounds and apply techniques to reduce them as low as possible.

How to measure Radioactivity Related Backgrounds

- SNOLAB has several facilities which are used to directly measure these radioactive backgrounds
- Suppress radon in your experiment's environment (low radon rooms/lab)
- Build a big shield (water as radioactive shield)
- Performing regular assays of detector shield- Water Assay
- Choose radiopure materials for the detector. Different techniques exist (choose the one that works best for material in question)
  - Gamma counting using HPGe counters (identify radionuclides using their gamma energies)
  - **Rn emanation**

Motivation

- Rn-222 is chemically inert and has a half-life of 3.8 days.

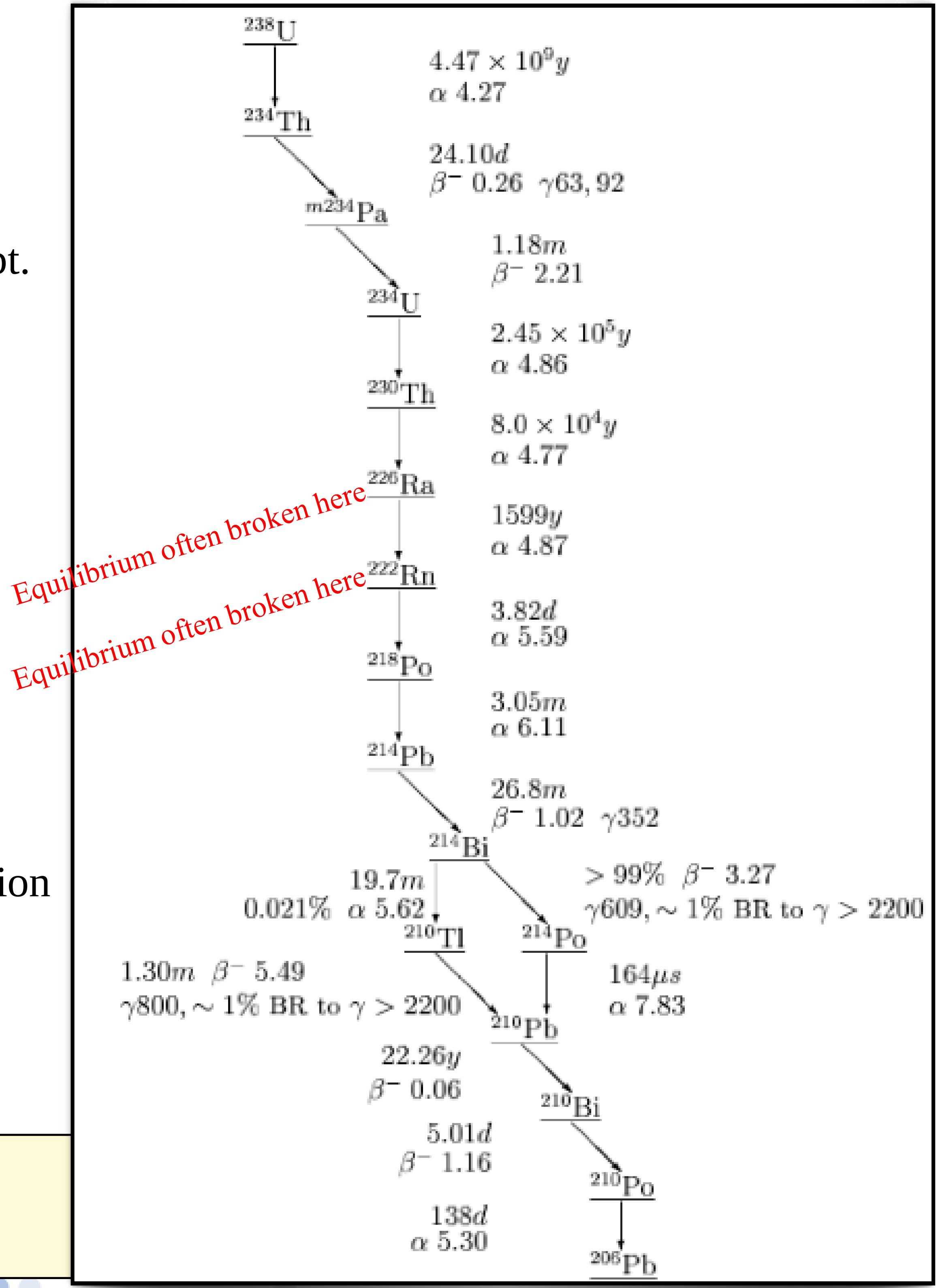
- Rn-222 can be emitted from the surface of materials (containing trace amount of U/Th) & can propagate throughout detector contaminating expt.

- Rn decays via alpha decay with MeV scale Q values & can result in decay products embedding themselves in the surface of materials.

  - ➢ Rn and its progeny are one of the dominant backgrounds to low background and rare event searches
  - ➢ Ultra low radioactive materials are needed in order to build experiments.

- Disequilibrium may occur between U-238 and Rn-222 (due to emanation of Rn from materials into the detector)

- Knowing U-238 concentration is not enough for material selection.

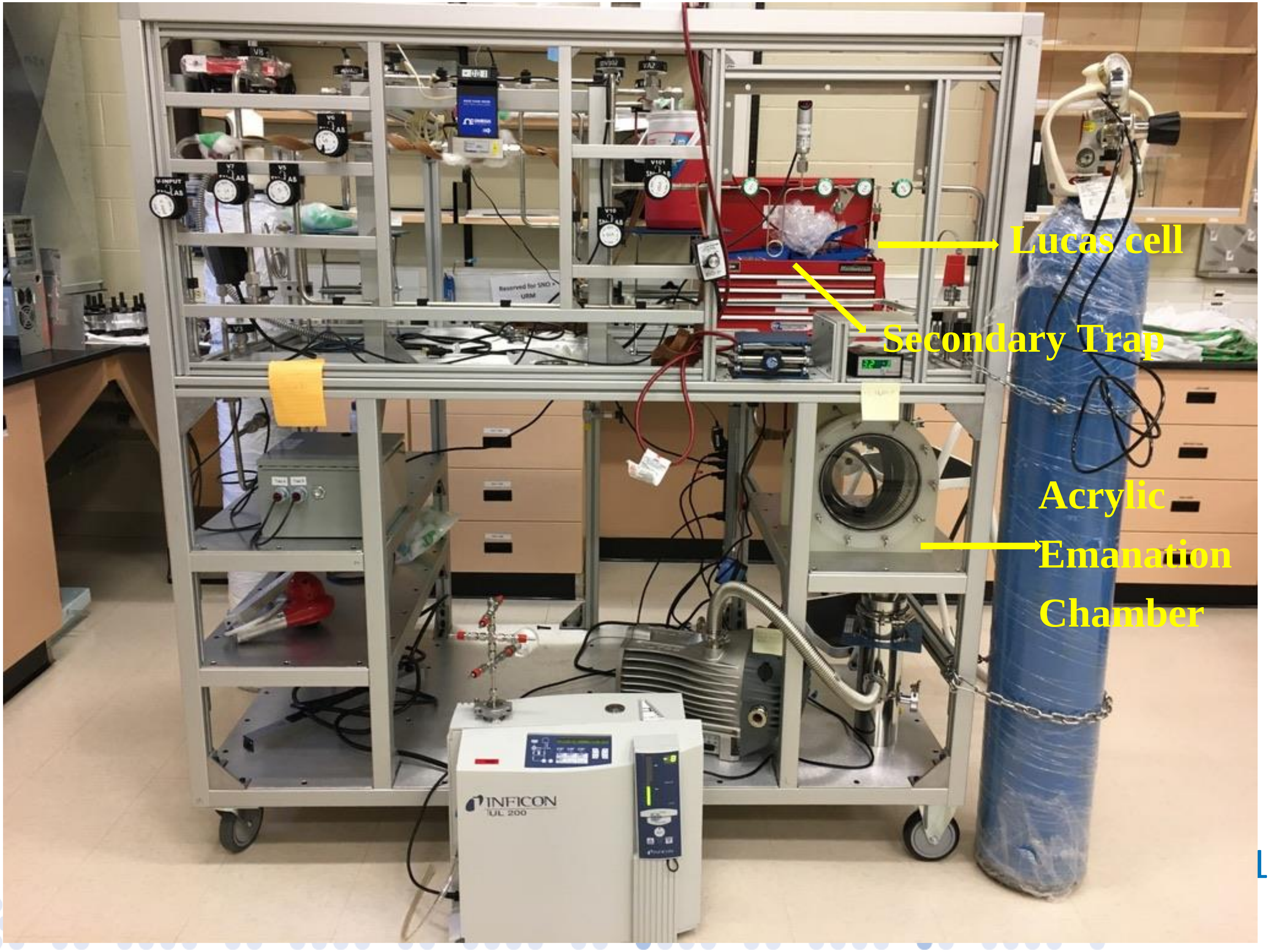


Measuring Rn-222 emanation rate has become important to enable construction of low background environments.

Radon Emanation Measurement System

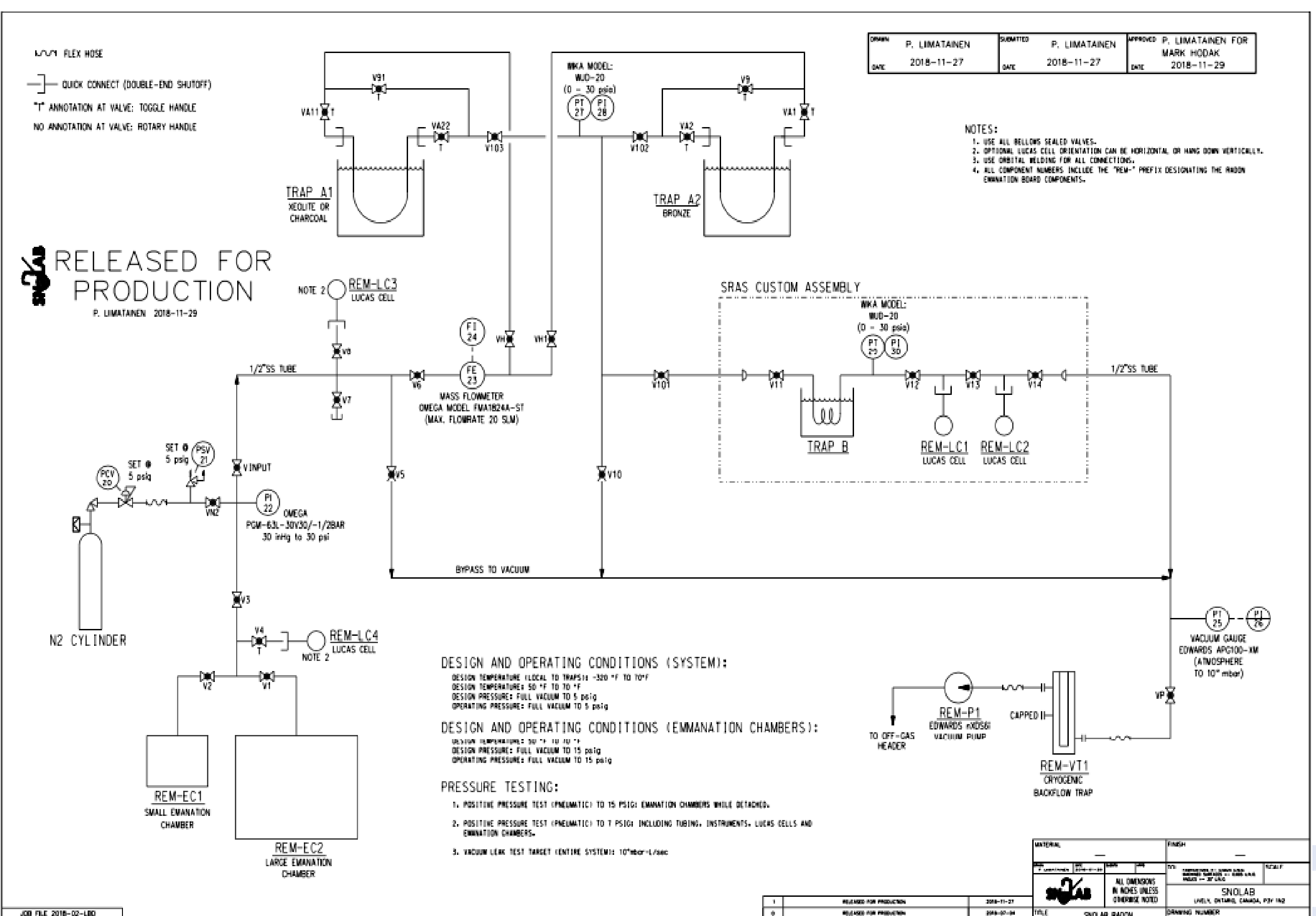
- We require low background, high efficiency radon detectors (near 100%) to determine background caused by Rn and its progeny.
- All detector components and construction materials are tested for their radon emanation levels.
- A technique was developed by SNO collaboration and later adapted by SNOLAB to fulfill these conditions.
- SNOLAB Radon emanation measurement system is made of low-radioactivity acrylic emanation chamber, a Rn transferring board and detection device.

New Portable Rn Emanation Measurement Panel



Portable Rn Emanation Measurement Panel

- Orbital welded to avoid ingress of outside air
- Acrylic chamber 20cm dia. x 20cm height. More chambers to be added
- Built on a moving cart



- Two primary traps (bronze wool/Chromosorb)
- Attachment port to connect sources or samples

Primary/Secondary Traps

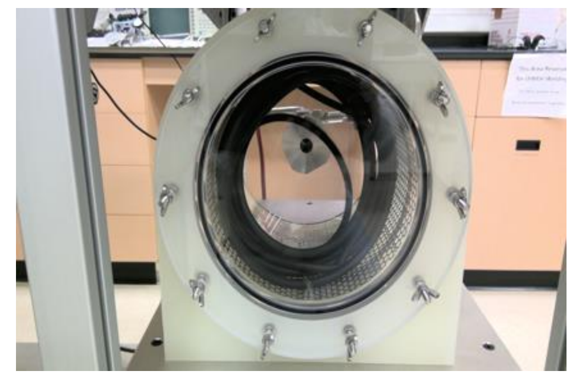
- Primary traps are U-shaped ½ inch SS tubing.
- Primary trap efficiency is increased by inserting bronze wool/chromosorb
  - ➢ Bronze wool generates an increased surface area in the trap
  - ➢ Chromosorb also has high effective surface area (300-400 m^2/g).

- Secondary trap custom designed by Swagelok.
- Coiled SS 1/8-inch diameter tube and has steel wire inserted to reduce volume.
- 1/8-inch selected to improve the Rn transfer efficiency by minimizing the dead volumes.

Radon Emanation/Extraction Process

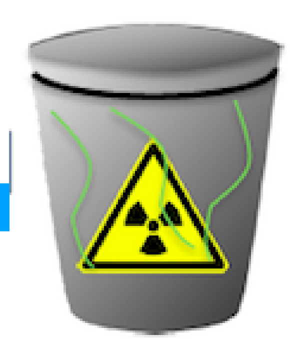
- Radon emanation is the process of removing all existing radon from a sample and letting new radon to be produced.
- Once sample has been refilled with radon intrinsic to the sample, it is harvested.

Clean chamber , sample



Put sample in the vacuum chamber

Pump down chamber, whole system



Wait ~2 weeks for Rn to be emanated from the sample. Rn exists as residual gas inside chamber

Perform Rn extraction using Rn gas board & allows most other residual gas to be exhausted from the system

Collected Rn is transferred into a counter (Lucas cell)

Radon Extraction Process

1. **Pump down Rn Board System**

- Primary trap (bronze wool/Chromosorb)
- Secondary trap
- The whole Board system (not the chamber).

Radon Extraction Process

2. Extraction of Rn from Chamber (Rn pumped out to primary trap using LN2)

- Radon freezes at ~61C, LN2 temperature is ~ -196 C
- Primary trap immersed in LN2. Chamber to trap valve opened.
- Rn freezes & sticks to bronze wool/chromosorb

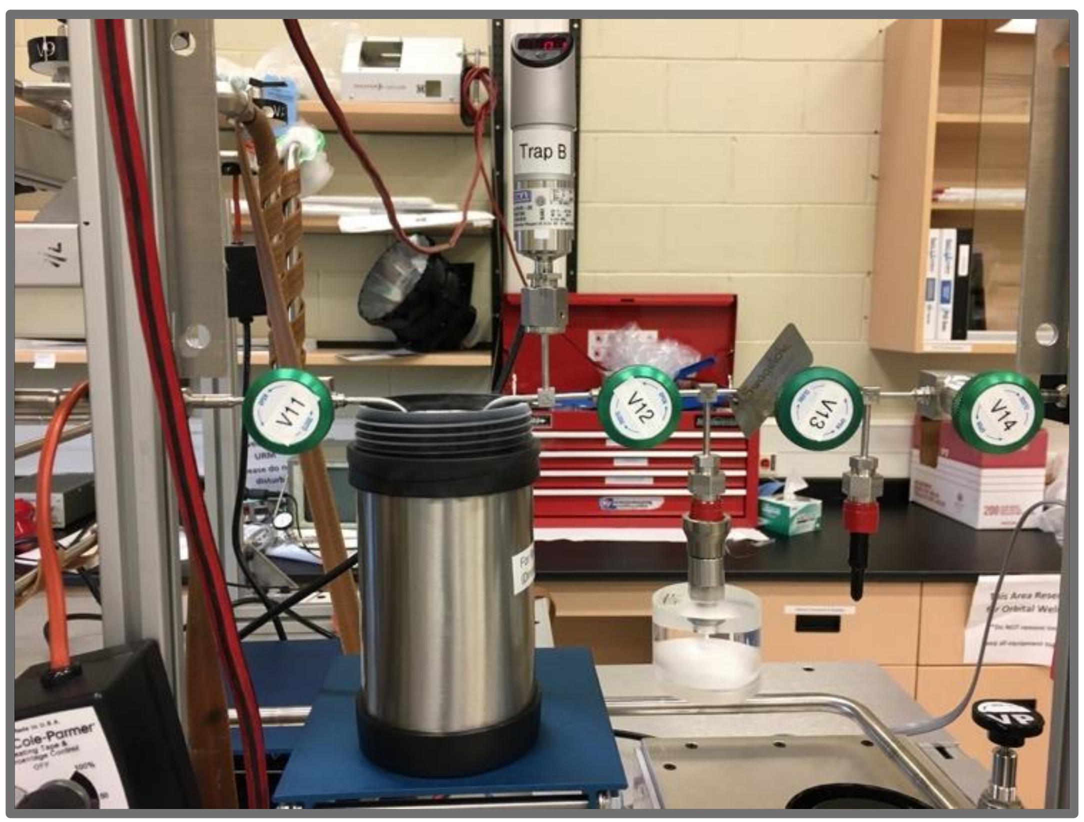
(other gases like CO_2, N_2 exhausted from the system)

- Extraction time: vacuum pull transfer for 1hour.

Radon Extraction Process

3. Transfer from Primary Trap to Secondary Trap

- Secondary trap immersed in LN2
- Primary trap warmed (~100C) restoring Rn to its gaseous state
- Inlet of Primary trap closed & valve between Primary and secondary trap opened
- Collected Rn transferred by cryo-pumping ~15 minutes.



Radon Extraction Process

4. Transfer from Secondary Trap to Lucas cell

- Attach LC to the system and evacuate
- Secondary trap isolated and valve between LC and secondary trap opened
- Secondary trap heated using heat gun ~3-4 minutes
- Collected Rn transferred by volume sharing (volume of LC > trap) ~15 minutes

5. Counting

- LC coupled to PMT to count the number of alphas
- Alpha particles produced in decay of 218Po, 214Po, 222Rn strike ZnS producing flash of light detected by the PMT.
- LC counted using CAEN DAQ system using 8 channels

❖ More channels will be incorporated to increase counting capabilities

Efficiency of the System

- Total efficiency= $eff_{pumping}$*$eff_{trapping}$*$eff_{transfer}$ * $eff_{detecting}$
- There are 3 alphas from Rn-222 daughters, this term causes the total efficiency to be more than 100%
- Total efficiency: Ratio of measured Rn atoms in LC to the calculated Rn atoms in the initial Rn sample

Pump Rn from chamber to Primary trap

Pumping Efficiency

Absorb Rn in LN2 cooled Traps

Trapping Efficiency

Transfer Rn from trap to LC

Transfer Efficiency

Measure the source activity

Detection Efficiency

Total Efficiency of the System

- Rn emanation is a multi-stage process.
- Performed set of independent measurements to obtain the total efficiency of the system.
- Systematic error expected to define uncertainty, since statistical error is small.
- Systematic studies in progress.

Test #	Efficiency (%)
Run 1	215 .65 +/- 11.36
Run 2	192.76 +/- 10.34
Run 3	245.87 +/- 16.07
Run 4	223.31 +/- 11.59
Run 5	222.89 +/- 11.70
X Run 6	157.93 +/- 8.30
Weighted average	**199.23 +/- 4.46**

Background Level of the System

- Board background is usually negligible if the board is not contaminated.
- Regular board background tests performed. Sensitivity of our system is 2 Rn/day
- Lucas cell background varies over time. Initially background is ~ 3 counts/day, but it builds up after few years if the Lucas cell continuously used for radon emanation studies
  - Pb-210 buildup (22 years half-life)
  - Need to build new Lucas cells regularly

Services to the community so far…

- Performed Rn emanation studies of DEAP filter – 3 tests, results sent to the collaboration.
- Rn emanation studies of PICO-40L vessel – performed 3 tests, detailed report sent to PICO collaboration.

Services to the community so far…

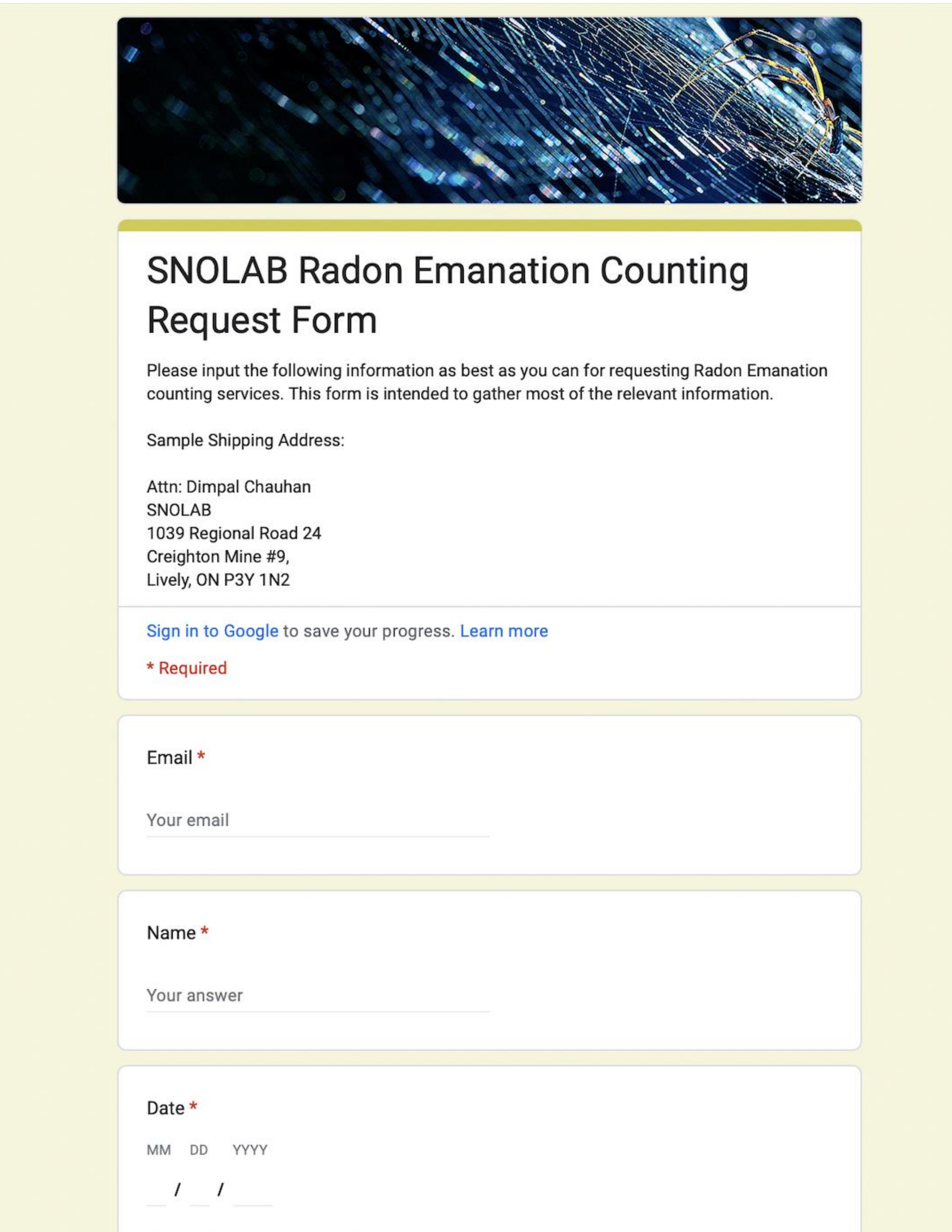
- Performed Rn emanation studies of SNO+ LAB assay components– Tests still ongoing.
- Rn emanation studies of material from Health Canada – Campaign expected to start February 2023.
- Other Rn emanation studies of samples performed.

Summary

- New surface Rn emanation measurement facility for material selection studies with a sensitivity of 2 Rn/day.
- We have a robust Rn-222 Emanation screening technique which can be used to study different detector construction materials.
- Good handle on Rn-222 emanation studies in vacuum mode. Systematic studies in progress.
- Carrier gas Rn-222 emanation studies in progress.
- Rn-222 emanation request form exist:

  https://www.snolab.ca/users/services/gamma-assay/assay_request_form.html

Please feel free to contact us if you want your samples to be counted :
dchauhan@snolab.ca



SNOLAB Radon Emanation Counting Request Form

Please input the following information as best as you can for requesting Radon Emanation counting services. This form is intended to gather most of the relevant information.

Sample Shipping Address:

Attn: Dimpal Chauhan
SNOLAB
1039 Regional Road 24
Creighton Mine #9,
Lively, ON P3Y 1N2

Sign in to Google to save your progress. Learn more

* Required

Email *

Your email

Name *

Your answer

Date *

MM DD YYYY

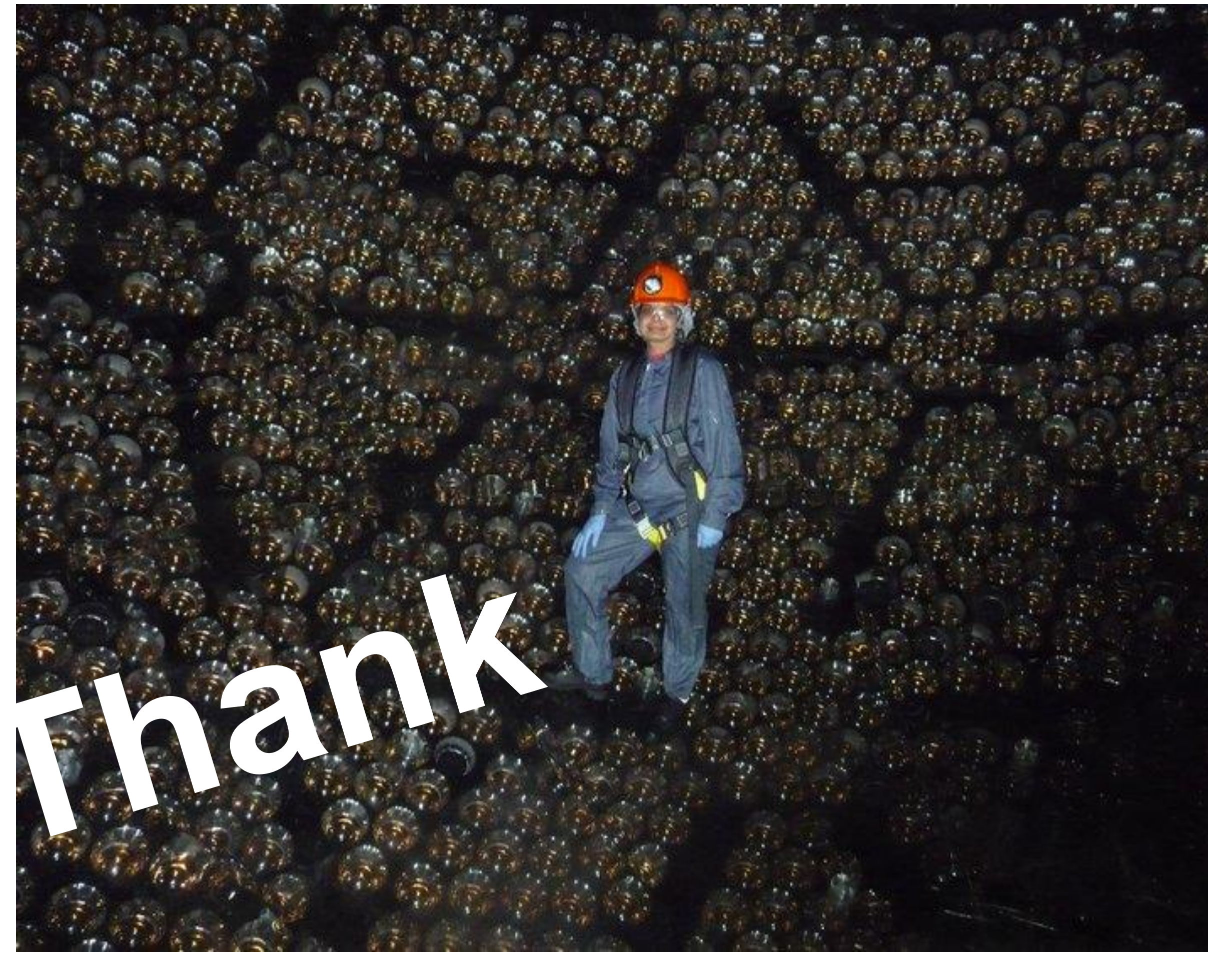
/ /

Summary

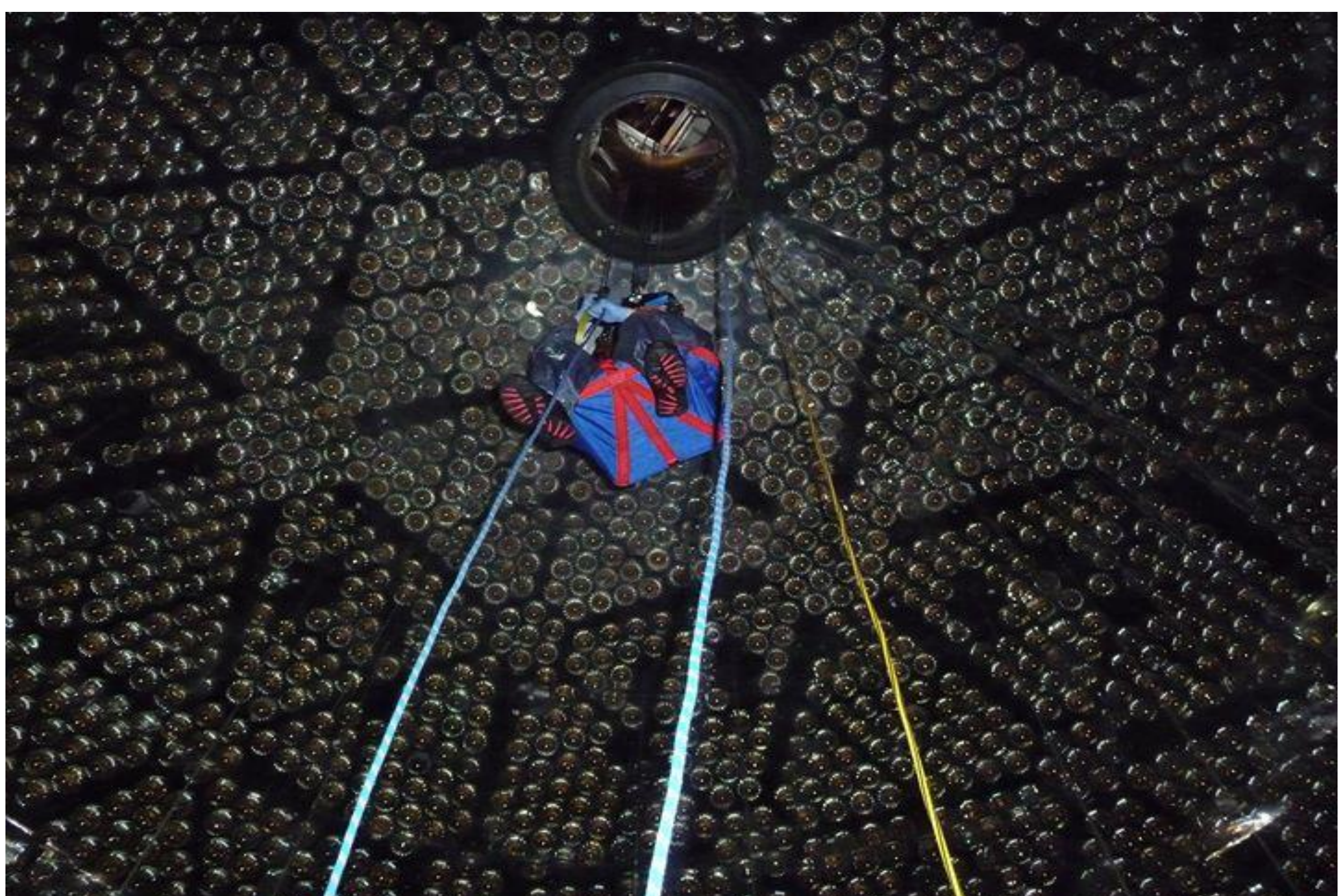
Please feel free to contact us if you want your samples to be counted : dchauhan@snolab.ca

3 minutes video of SNOLAB surface radon emanation measurement system

https://youtu.be/cjo2RsvApPE



Thank



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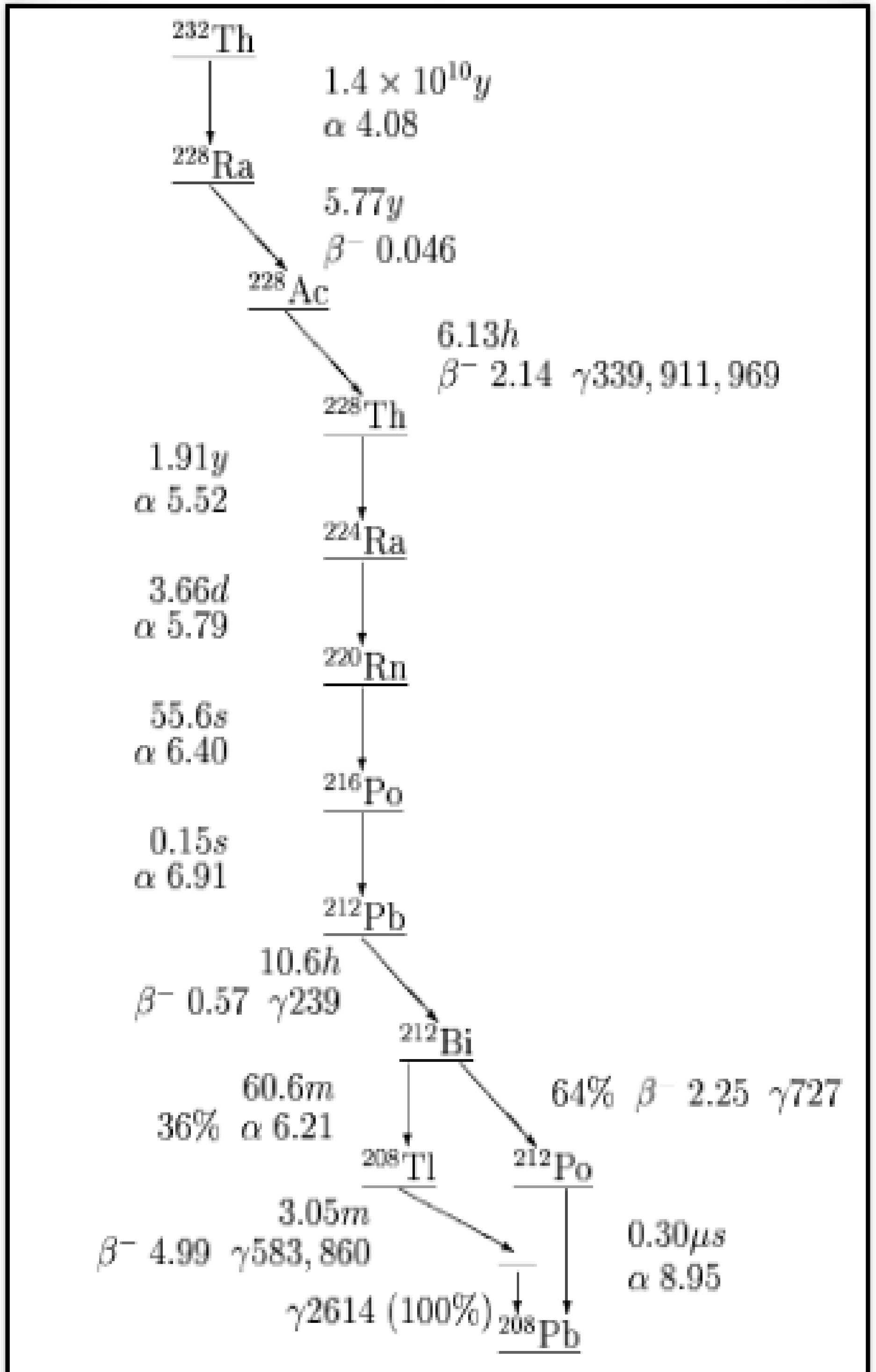
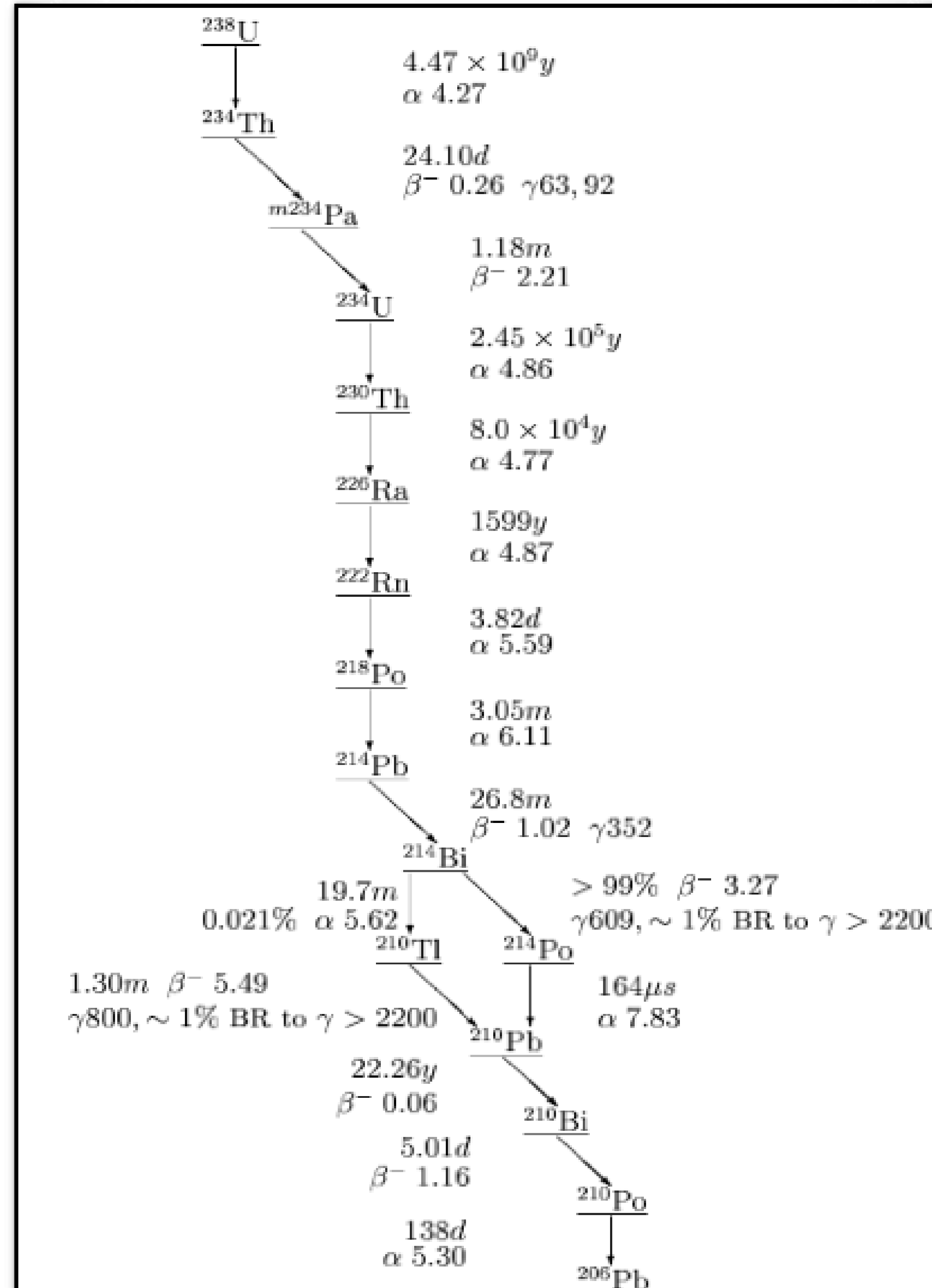
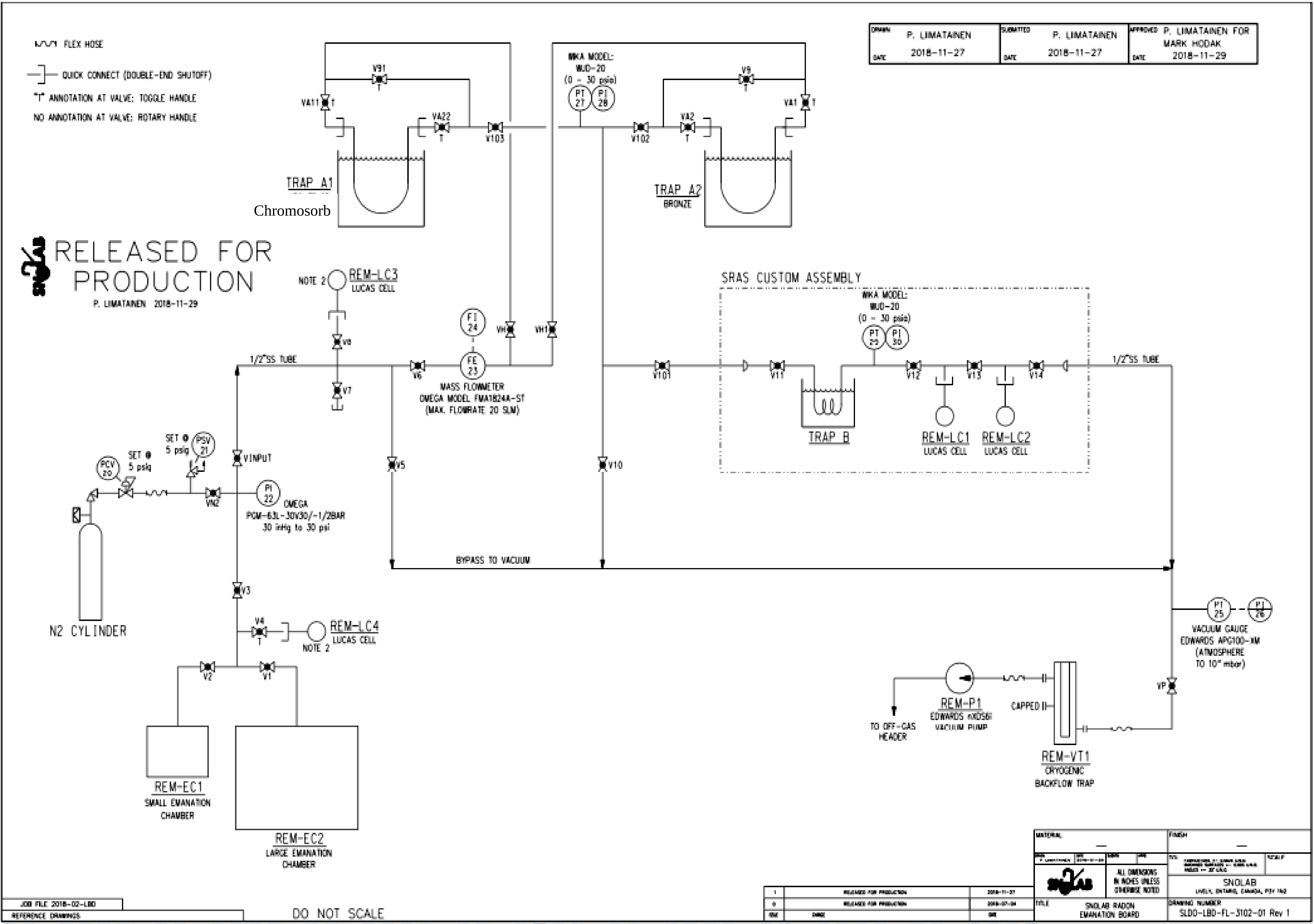
Backup Slides



^{232}Th
$1.4 \times 10^{10}y$
α 4.08
^{228}Ra
$5.77y$
β^- 0.046
^{228}Ac
$6.13h$
β^- 2.14 γ339, 911, 969
^{228}Th
$1.91y$
α 5.52
^{224}Ra
$3.66d$
α 5.79
^{220}Rn
$55.6s$
α 6.40
^{216}Po
$0.15s$
α 6.91
^{212}Pb
$10.6h$
β^- 0.57 γ239
^{212}Bi
$60.6m$
36% α 6.21
64% β^- 2.25 γ727
^{208}Tl
^{212}Po
$3.05m$
β^- 4.99 γ583, 860
$0.30\mu s$
α 8.95
γ2614 (100%)
^{208}Pb



^{238}U
$4.47 \times 10^{9}y$
α 4.27
^{234}Th
$24.10d$
β^- 0.26 γ63, 92
^{m234}Pa
$1.18m$
β^- 2.21
^{234}U
$2.45 \times 10^{5}y$
α 4.86
^{230}Th
$8.0 \times 10^{4}y$
α 4.77
^{226}Ra
$1599y$
α 4.87
^{222}Rn
$3.82d$
α 5.59
^{218}Po
$3.05m$
α 6.11
^{214}Pb
$26.8m$
β^- 1.02 γ352
^{214}Bi
$19.7m$
0.021% α 5.62
$> 99\%$ β^- 3.27
γ609, $\sim$ 1% BR to $\gamma > 2200$
^{210}Tl
^{214}Po
$1.30m$ β^- 5.49
γ800, $\sim$ 1% BR to $\gamma > 2200$
$164\mu s$
α 7.83
^{210}Pb
$22.26y$
β^- 0.06
^{210}Bi
$5.01d$
β^- 1.16
^{210}Po
$138d$
α 5.30
^{206}Pb



FLEX HOSE
QUICK CONNECT (DOUBLE-END SHUTOFF)
"T" ANNOTATION AT VALVE: TOGGLE HANDLE
NO ANNOTATION AT VALVE: ROTARY HANDLE
DRAWN P. LIMATAINEN DATE 2018-11-27
SUBMITTED P. LIMATAINEN DATE 2018-11-27
APPROVED P. LIMATAINEN FOR MARK HODAK DATE 2018-11-29
RELEASED FOR PRODUCTION
P. LIMATAINEN 2018-11-29
V91
VA11
VA22
V103
TRAP A1
Chromosorb
WIKA MODEL: WUD-20 (0 - 30 psia)
PT 27
PI 28
V9
VA1
VA2
V102
TRAP A2
BRONZE
NOTE 2
REM-LC3
LUCAS CELL
V8
V7
1/2"SS TUBE
V6
FI 24
FE 23
VH
VH1
MASS FLOWMETER
OMEGA MODEL FMA1824A-ST
(MAX. FLOWRATE 20 SLM)
SRAS CUSTOM ASSEMBLY
WIKA MODEL: WUD-20 (0 - 30 psia)
PT 29
PI 30
V101
V11
V12
V13
V14
TRAP B
REM-LC1
LUCAS CELL
REM-LC2
LUCAS CELL
1/2"SS TUBE
SET @ 5 psig
PSV 21
SET @ 5 psig
PCV 20
VINPUT
VN2
PI 22
OMEGA
PGM-63L-30V30/-1/2BAR
30 inHg to 30 psi
V5
V10
BYPASS TO VACUUM
N2 CYLINDER
V3
V4
REM-LC4
LUCAS CELL
NOTE 2
V2
V1
PI 25
PI 26
VACUUM GAUGE
EDWARDS APG100-XM
(ATMOSPHERE TO 10" mbar)
VP
REM-P1
EDWARDS nXDS6i
VACUUM PUMP
TO OFF-GAS HEADER
CAPPED
REM-VT1
CRYOGENIC
BACKFLOW TRAP
REM-EC1
SMALL EMANATION CHAMBER
REM-EC2
LARGE EMANATION CHAMBER
MATERIAL
FINISH
ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED
SNOLAB
LIVELY, ONTARIO, CANADA, P3Y 1N2
1 RELEASED FOR PRODUCTION 2018-11-27
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ISSUE CHANGE DATE
TITLE SNOLAB RADON EMANATION BOARD
DRAWING NUMBER SLDO-LBD-FL-3102-01 Rev 1
JOB FILE 2018-02-LBD
REFERENCE DRAWINGS
DO NOT SCALE