2024/06/26

Improving Radon-222 assay at SNOLAB

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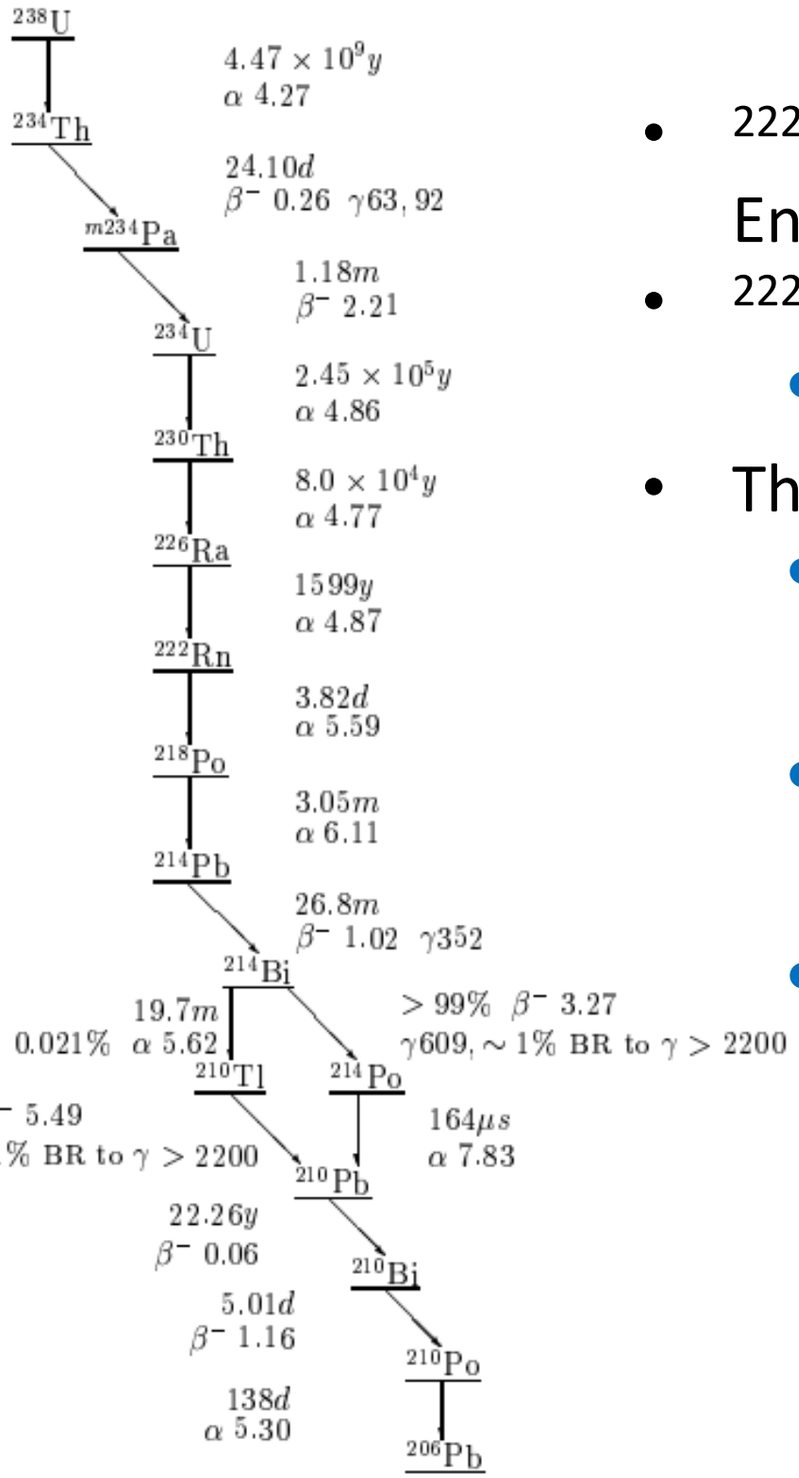
SNOLAB Users Meeting

Introduction



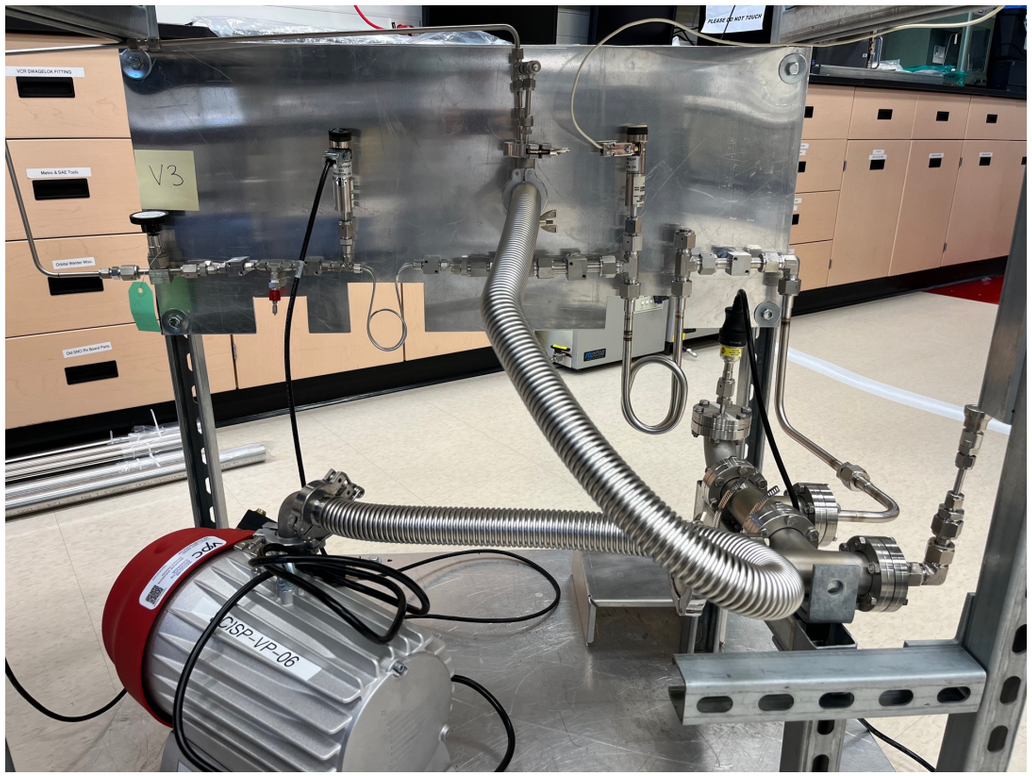
- ^{222}Rn progeny -> Limiting Background to Low Energy Neutrino and Dark Matter searches
- ^{222}Rn emanates from material surfaces
  - Strict Material selection is required
- The ^{222}Rn concentration in SNOLAB air ~ 120 Bq/m3
  - Need for N_2 cover gas systems and radon reduced air
- Make leak free process systems and detector volumes
- Monitor radon level in gas volumes are required

SNOLAB Radon assay system (surface)

SNOLAB surface board used for:

- High sensitive radon emanation measurement
  The emanation chamber background: 4.04 ± *2.34 Rn/day*

- Testing new radon traps/mechanisms



DEAP board used for:

- Radon emanation measurements
- Background is consistent with zero

- R&D of new radon detectors such as SPC

SNOLAB Radon assay system (Underground)

SNO+ mobile board:

- Used primarily for gas assays
- Current background level: 22 ± 13 Rn/day

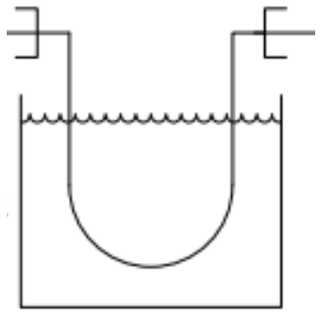
UPW radon board:

Sensitivity: $(2.46 \pm 0.74) \times 10^{-14}$ $g^{238}U/gH_2O$

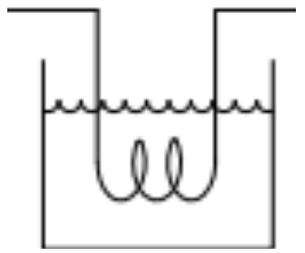
SNO technique for radon assay under vacuum

^{222}Rn

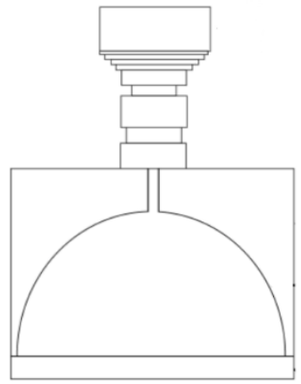
Emanation under vacuum



Primary Trap



Secondary Trap



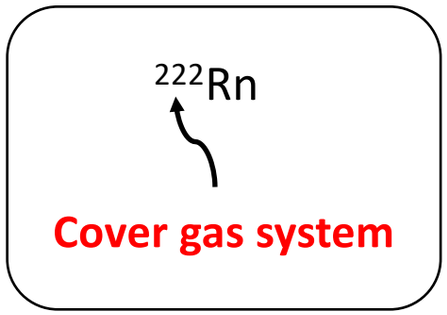
Lucas Cell

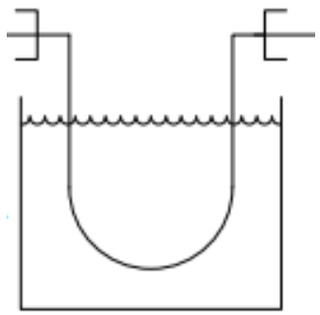
- Vacuum pull transfer
- Primary Trap cooled in Liquid N_2

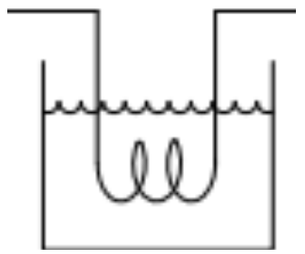
- Cryopump transfer
- Primary Trap (Bronze wool) heated to 100 C
- Secondary Trap cooled in Liquid N_2

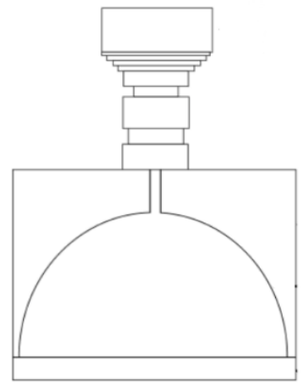
- Volume sharing
- Secondary Trap heated to room temperature

SNO+ gas assay technique









- **Transfer with carrier gas (1 SL/min)**
- Primary Trap cooled in Liquid N_2

- Cryopump transfer
- Primary Trap heated to 100 C
- Secondary Trap cooled in Liquid N_2

- Volume sharing
- Secondary Trap heated to room temperature

Improving sensitivity of gas assays

- Primary trap is made of Bronze wool
- Operational requirement is to not to go higher than 1 SL/min flow rate because of known low thermal capacity of bronze wool
- Maximum gas can be sampled is 30 L
- Current sensitivity 0.05 Bq/m^3
- Require to sample higher volume of gas to get better sensitivity
- Requires higher flow and longer assay time capability
- The bronze wool need to be replaced with something more porous
- The radioactive background from primary trap needs to be **negligible** during the assay period.

SNOLAB Liquid Nitrogen plant

New trap specification

- Constant efficiency versus different assay time and flow rate
- Radon emanation rate /gram need to be small
- Coconut charcoal is used for trapping radon in noble gases (NIM A.2011.09.051, NIM. A.2018.06.076)
- Need to be able to extract radon atoms that are trapped

Activated charcoal options

^{238}U concentration

Charcoal	Specific activity (mBq/kg)	Price (USD/kg)
Calgon OVC 4x8	53.6 ± 1.3	6
Shirasagi G2x4/6-1	101.0 ± 8.0	27
Saratech	1.71 ± 0.20	35
HNO_3 etched Saratech	0.51 ± 0.09	135
Carboact	0.23 ± 0.19	15,000
Carboact	0.33 ± 0.05	15,000

K. Pushkin et al., Study of radon reduction in gases for rare event search experiments, 2018

Managed to get 500 g free Calgon OVC 4 x 8 sample

Background measurement at site

HPGe	^{238}U from ^{226}Ra (mBq/kg)	^{232}Th (mBq/kg)
Regular Calgon	465+/- 47.48	114+/-37.57

Used 30% diluted HNO_3 Etched for 18 hours to reduce activity

(Sharayah Reed, Deena Fabris and Madeline Berube)

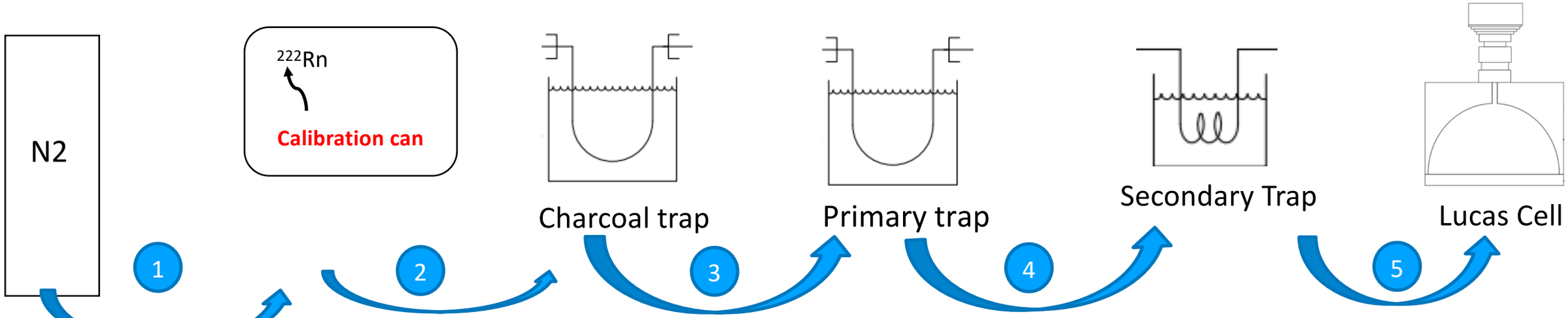
HPGe	^{238}U from ^{226}Ra (mBq/kg)	^{232}Th (mBq/kg)
HNO_3 etched Calgon	< 33.25	99.75+/20.06
Radon emanation	15+/-4	

Charcoal test

- ~ 22 gr of charcoal in a U-tube **~ Background: 1.5 +/- 0.3 ^{222}Rn decay /hour**

  Used surface radon board to do the measurement

Testing charcoal trap with a can filled with high radon emanating material



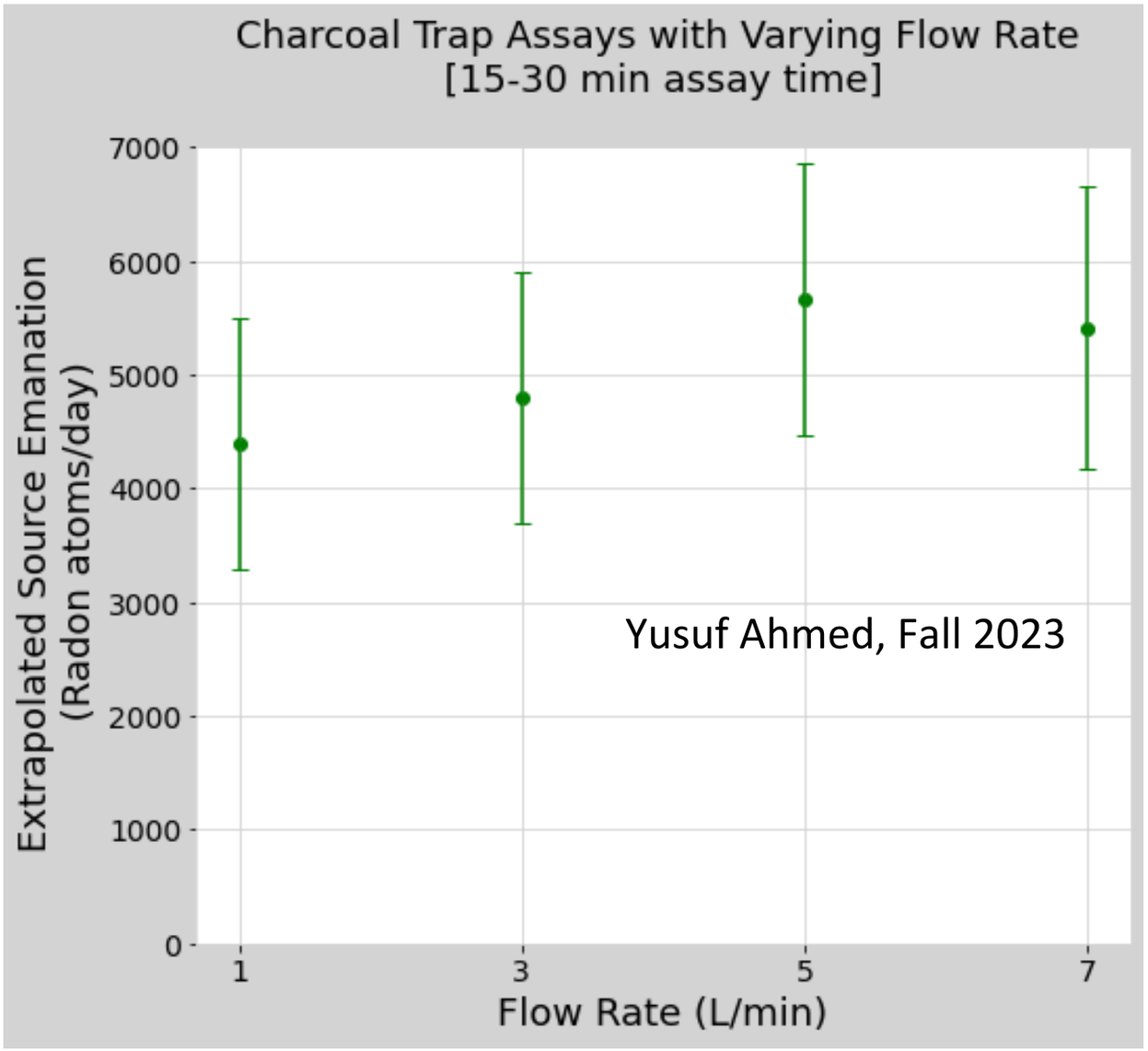
- **N_2 sweep gas transfer different flow**
- **Charcoal trap in LN alcohol slush (-100 C to - 20 C)**

- **Charcoal trap heated to 150 C**
- Primary trap cooled in Liquid N_2 and connected to vacuum

- Cryopump transfer
- Primary trap heated to 100C
- Secondary Trap cooled in Liquid N_2

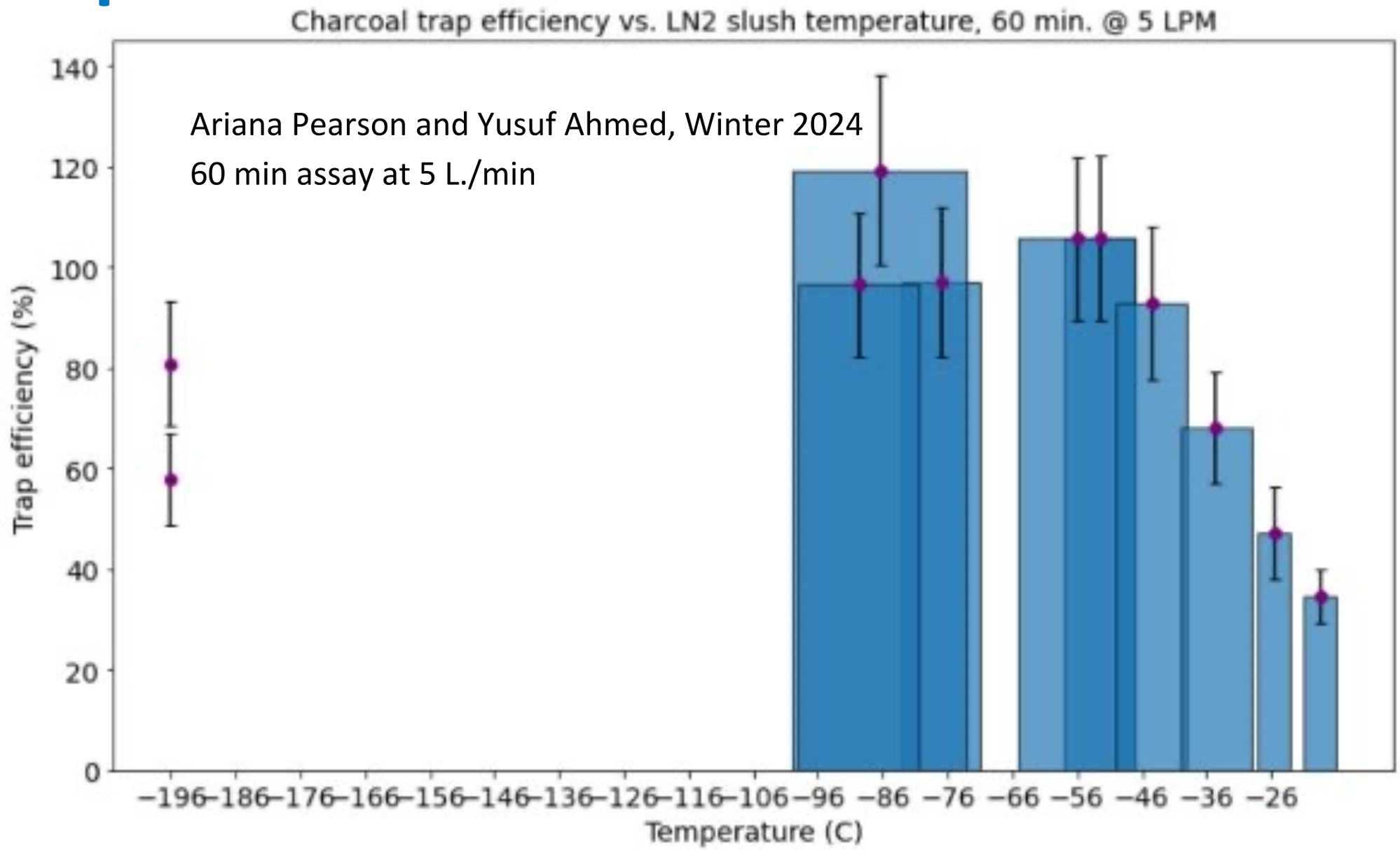
- Volume sharing
- Secondary trap heated to room temperature

Trap performance versus flow rate



Emanation rate of the source: 4996 +/- 503 Rn/day

Efficiency versus cryogenic temperature



Optimal operational temperature is between -100 C to -56 C

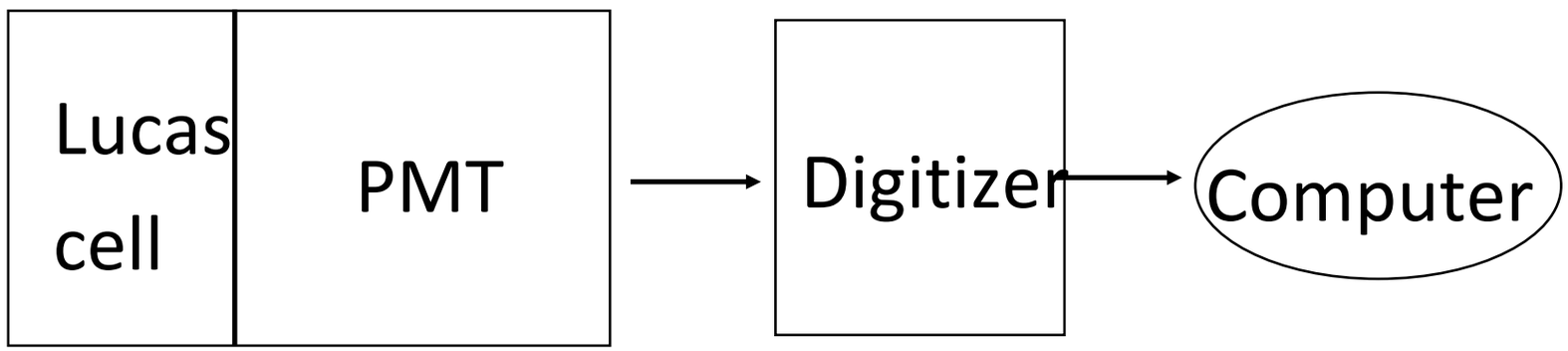
$$Q = \frac{N(Radon\ extracted\ from\ charcaol\ trap)}{N(Expected\ Radon\ atoms\ emanated\ from\ source)}$$

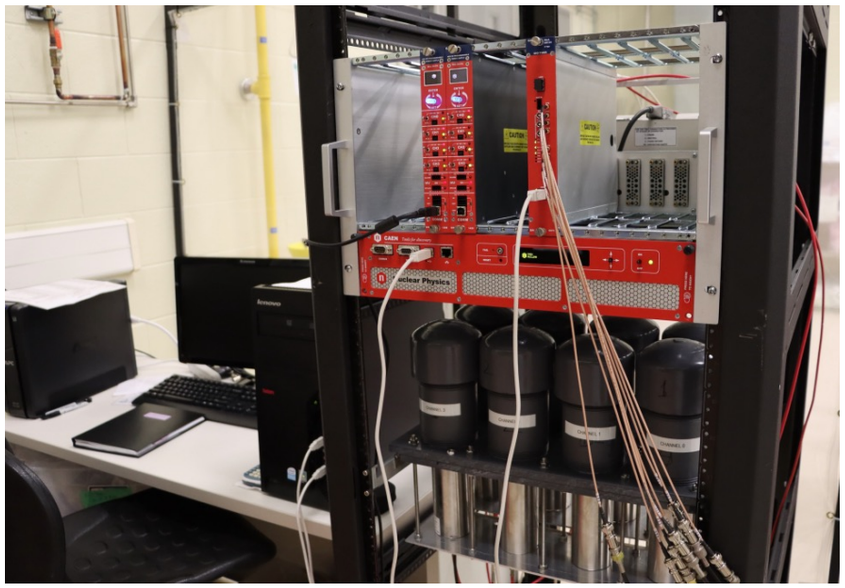
Final tests and future plans

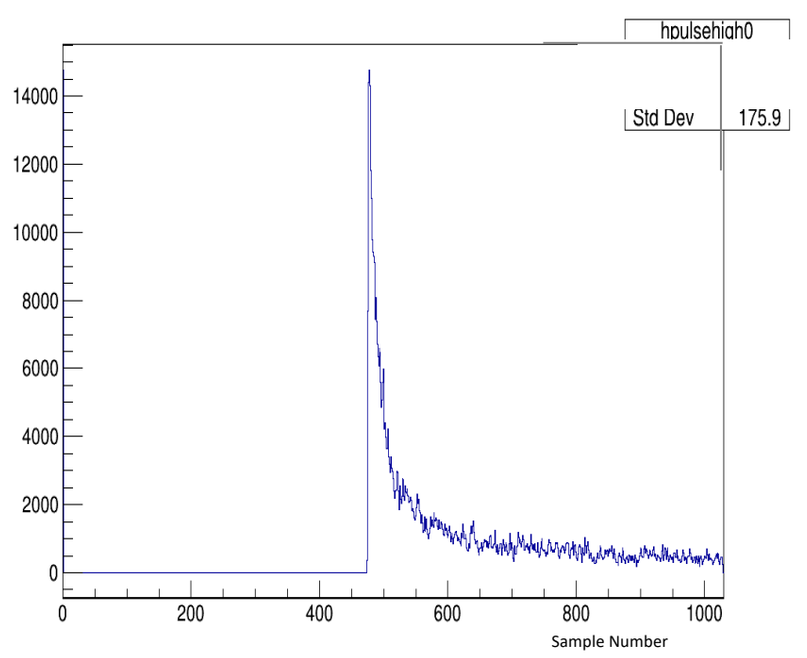
- Plan to make a trap with smaller charcoal mass to optimize background versus efficiency of the trap (current background is 1.5 +/-0.3 radon atoms per hour of operation)
- Used the current trap to measure radon level in Grade 5 N2 bottles : 0.69 +/- 0.12 radon atoms/L
- Plan to use it to measure radon level in boil-off of N2 plants UG and for SNO+ cover gas assays
- Publish results in a NIMA paper

Rådon counting (Lucas cells)

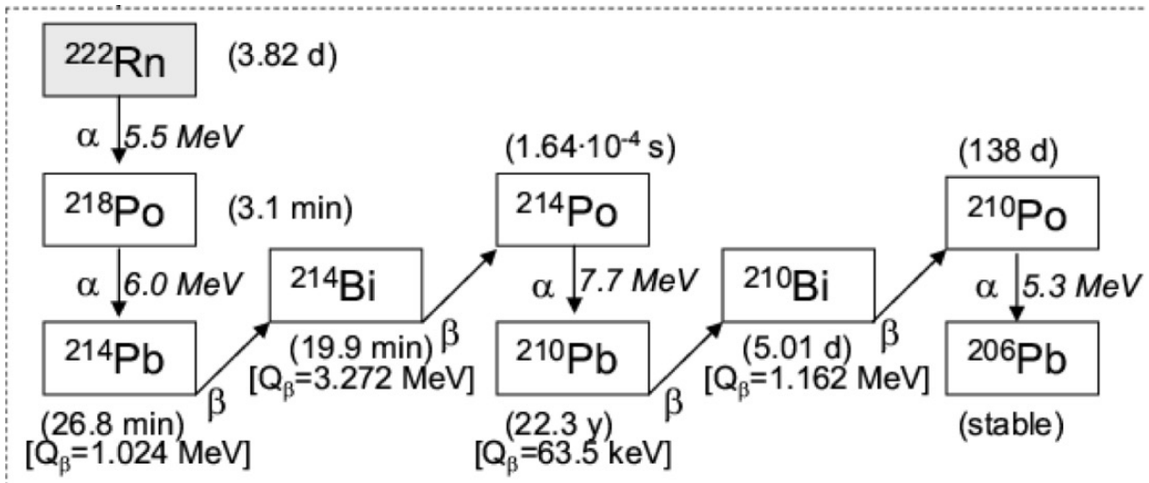
- Currently using Lucas cells to perform radon counting – sensitive to alpha's only
- 8 channels with CAEN electronics and 2" PMTs used for radon counting
- Funding approved to buy 8 new PMTs this year

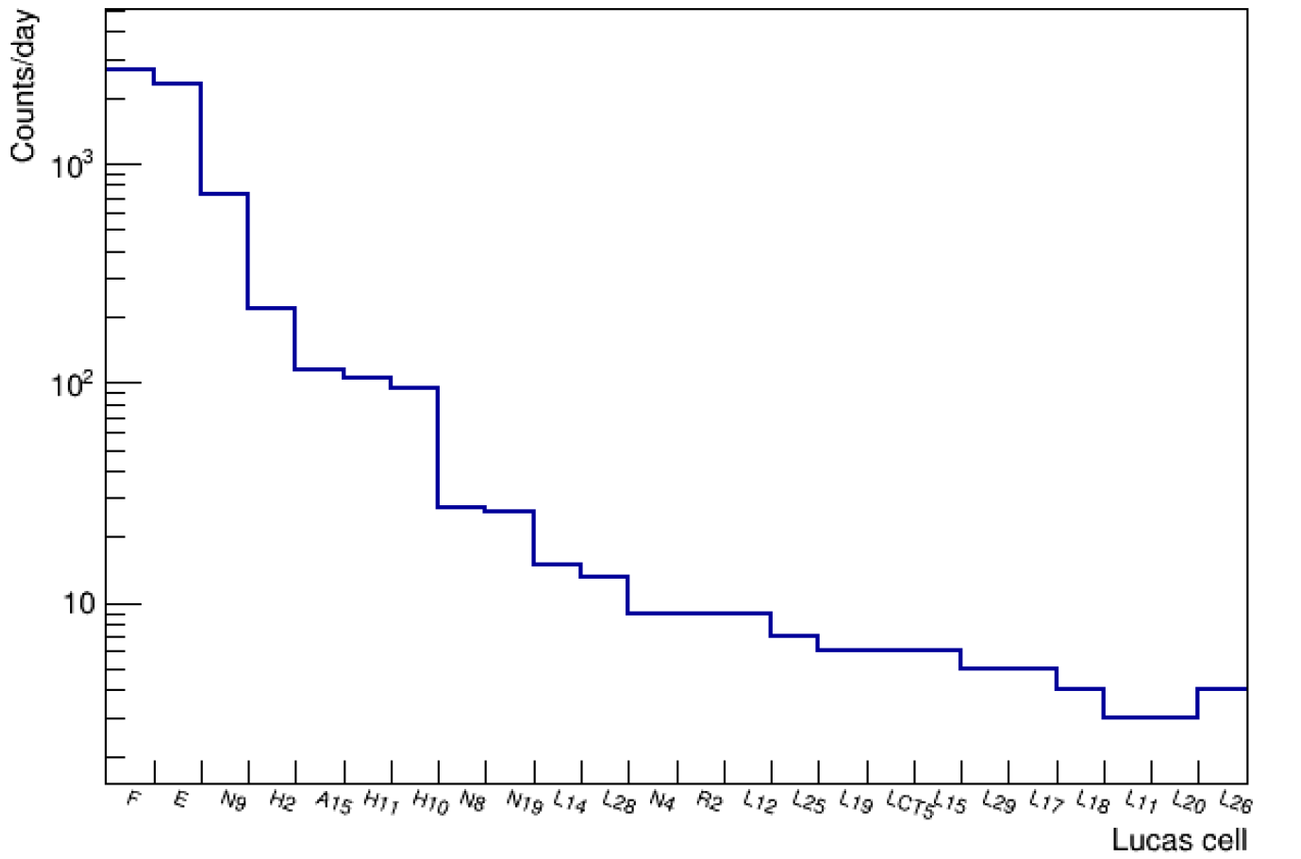






Lucas cell ^{210}Pb background increases with age





Increasing age

New cell has background of ~ 2- 3 counts/day

Plan to make new Lucas cells at SNOLAB with old design

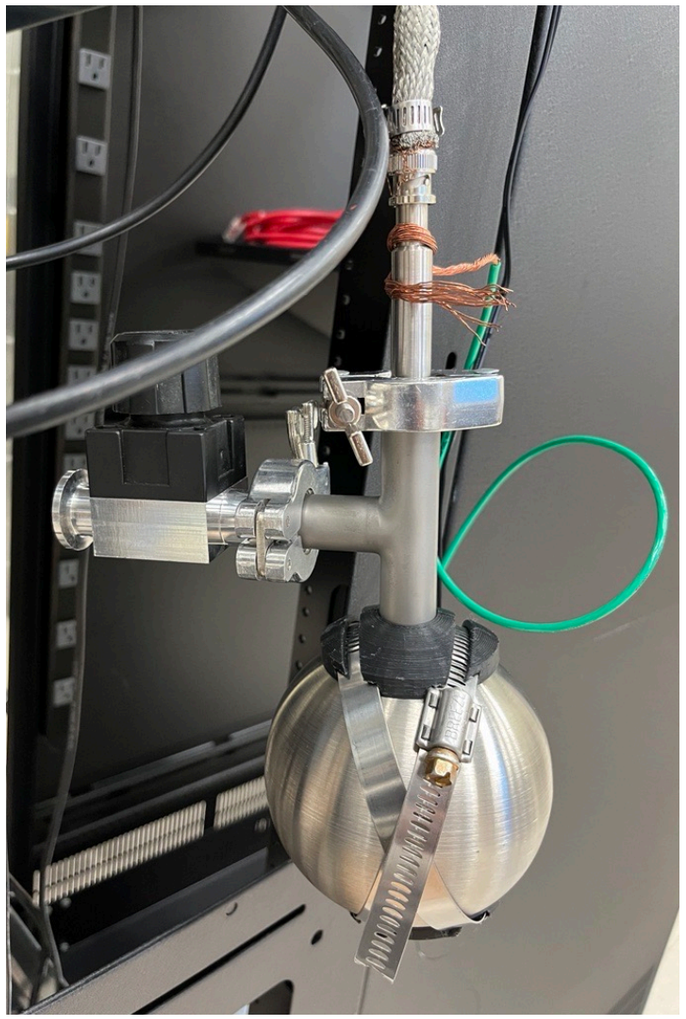
Design and production procedure needs to be revisited to reduce ^{210}Pb background

Radon counting (SPCs)

- High energy resolution – Can distinguish between different alphas
- ^{210}Pb background can be easily removed by etching

- The efficiency and the background level needs to be studied and compared with Lucas cells

Lead scientist: Pierre Gorel



Summary and outlook

- Plan to improve radon gas assay capability at SNOLAB by extracting higher volume of gas.
- SNO+ will benefit from the increased capability
- Technique developed will be used in future experiment (nEXO..)
- Plan to improve radon counting by SPCs and making new low background Lucas cells

Acknowledgment

Thanks Lina Anselma, Jeter Hall, Yusuf Ahmed, Jerry Lu, Ariana Pearson, Adil Hussain, Juliette Deloye, Deena Fabris, Sharayah Reed

Back up slides (calibration source)