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Improving SNOLAB radon assay capability using activated charcoal

Nasim Fatemighomi

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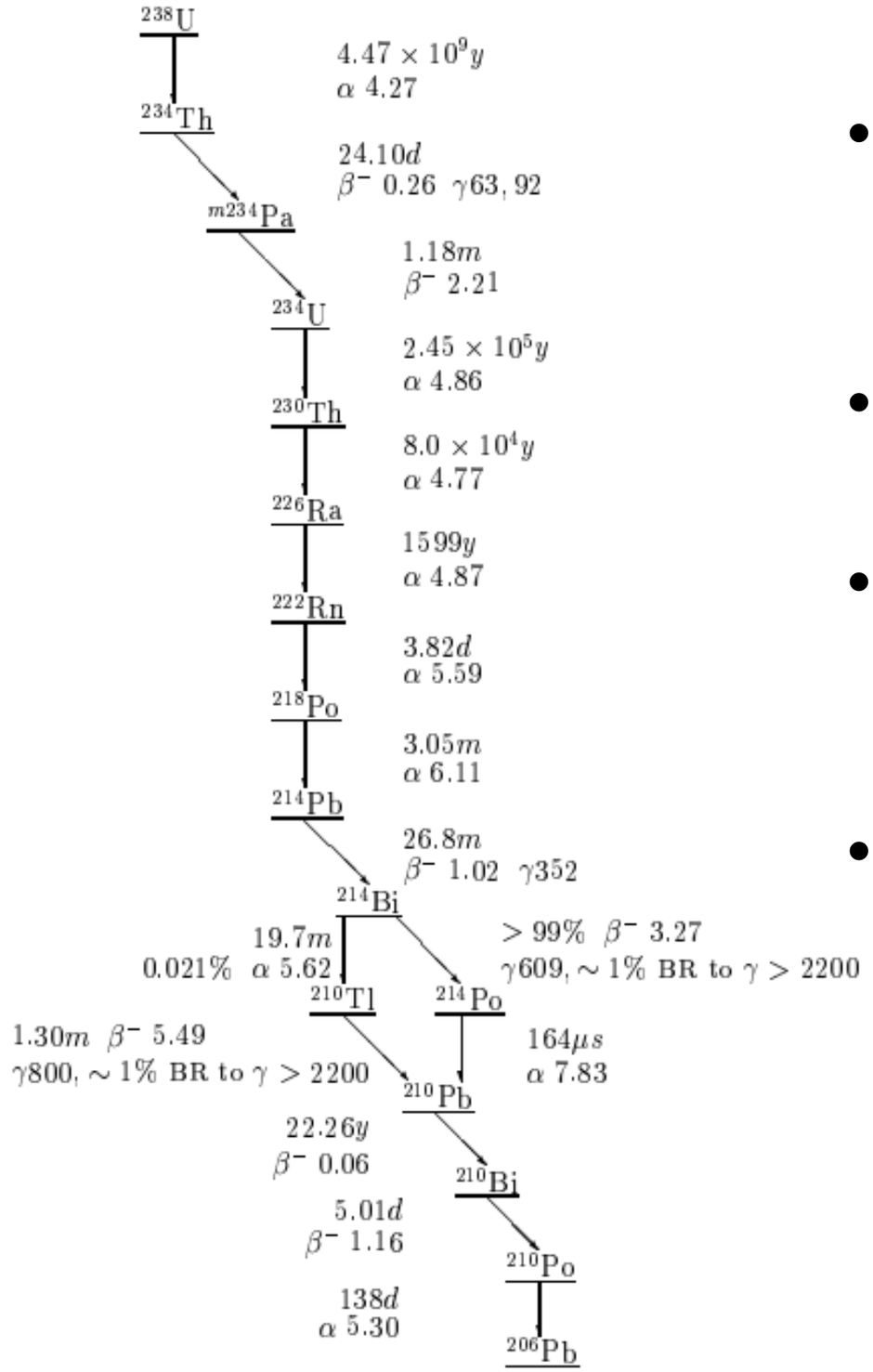
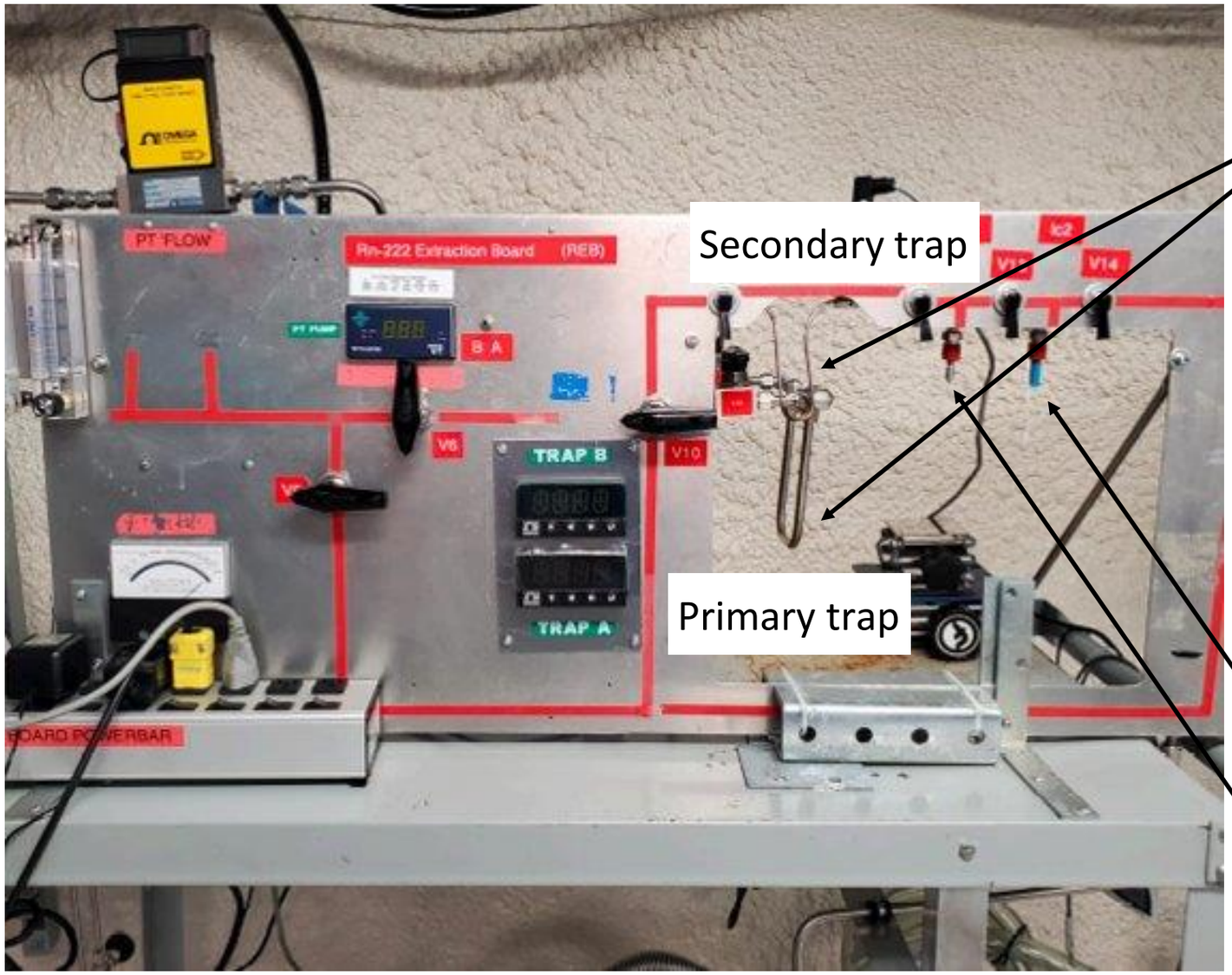
Introduction



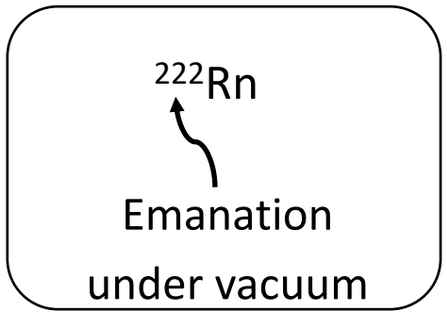
- ^{222}Rn progeny -> Background to low energy neutrino and rare event searches
- Present in SNOLAB ~ 120 mBq/m3 (~ 10 times higher than surface)
- To reduce ^{222}Rn: fill external experimental components with clean cover gas such as N_2
- ^{222}Rn concentration in gas can be measured using SNOLAB radon board

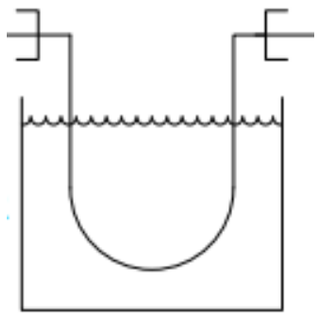
SNOLAB Radon board

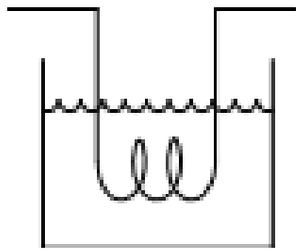


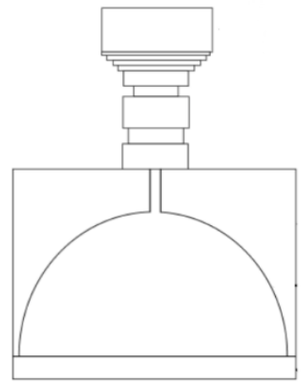
- Consists of couple of radon traps and couple of Lucas cell ports
- Used for ^{222}Rn material screening
- Refurbished for gas assays
- Been regularly used to monitor radon concentration in SNO+ cover gas system and SNOLAB boil-off N_2

SNO technique for radon assay under vacuum









Primary Trap

Secondary Trap

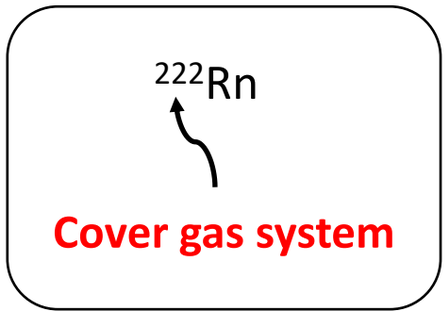
Lucas Cell

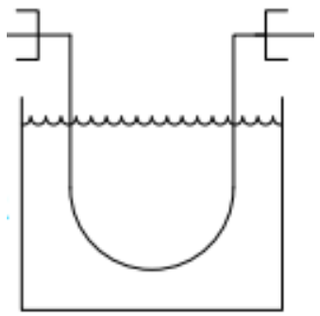
- Vacuum pull transfer
- Primary Trap cooled in Liquid N_2

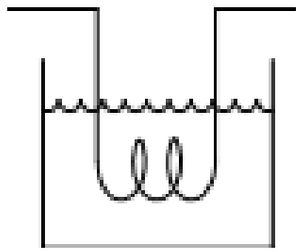
- Cryopump transfer
- Primary Trap (Bronze wool) heated to 100 C
- Secondary Trap cooled in Liquid N_2

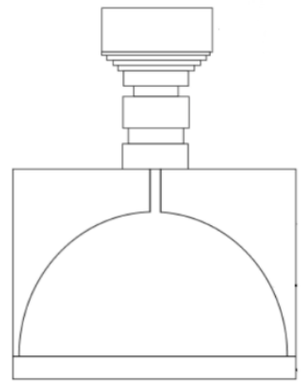
- Volume sharing
- Secondary Trap heated to room temperature

Gas assay technique









Primary Trap

Secondary Trap

Lucas Cell

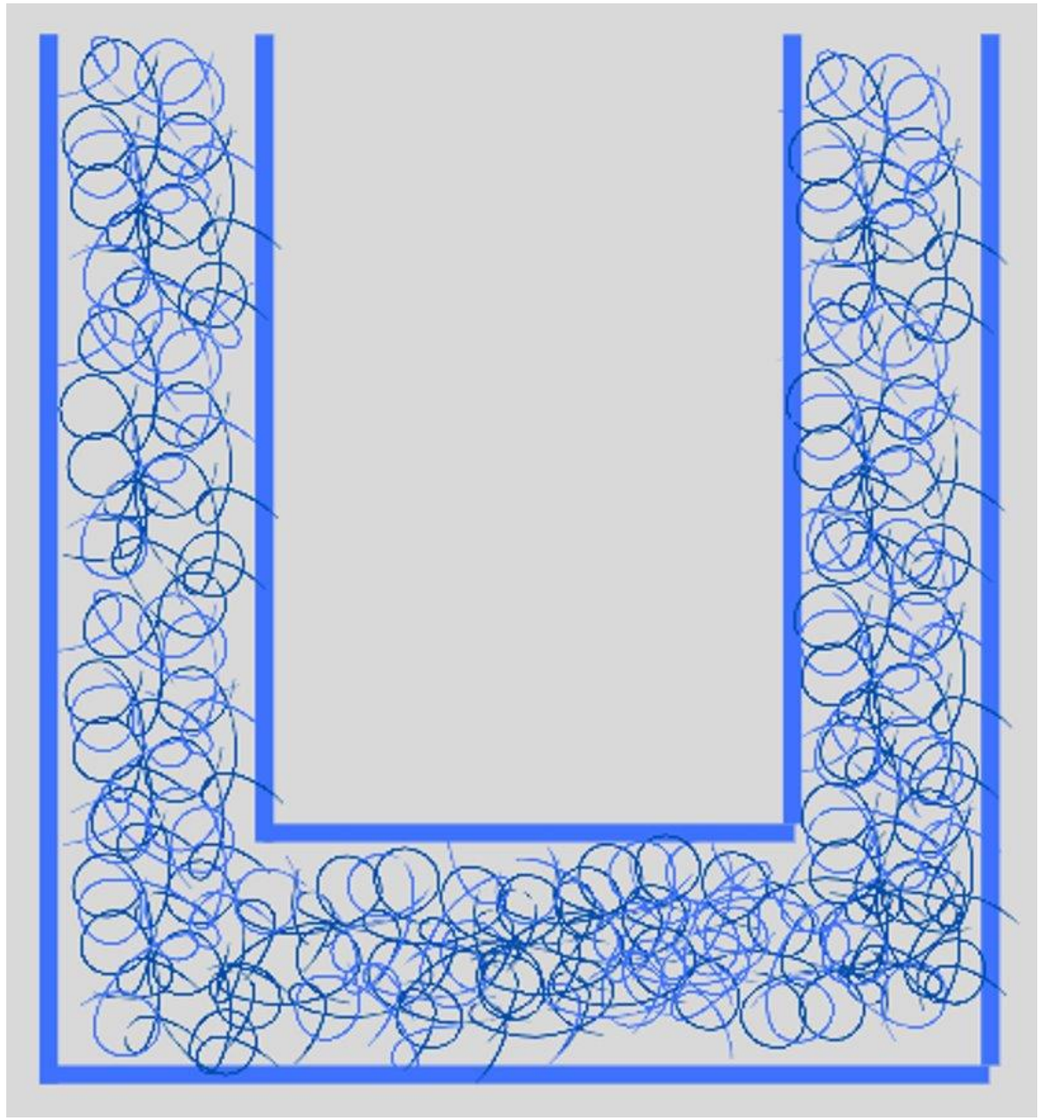
- **Transfer with carrier gas (1 SL/min)**
- Primary Trap cooled in Liquid N_2

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

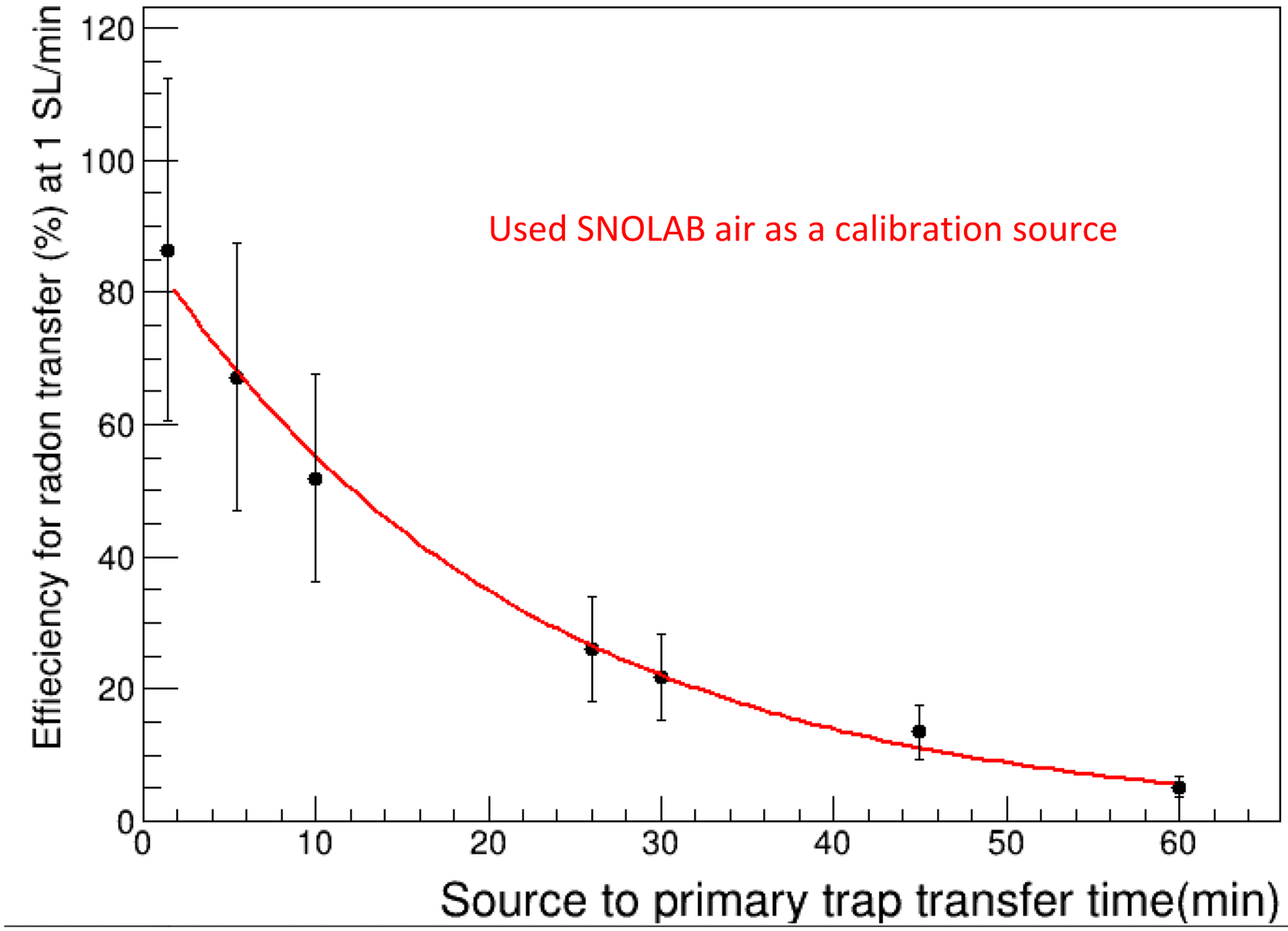
- Volume sharing
- Secondary Trap heated to room temperature

Primary trap limitation

- Primary trap is made of Bronze wool
- Assay time is limited as trap is warmed up by the carrier gas for longer assay times
- Operational requirement is to not to go higher than 1 SL/min flow rate because of known low thermal capacity of bronze wool



Primary trap limitation (Efficiency versus assay time)



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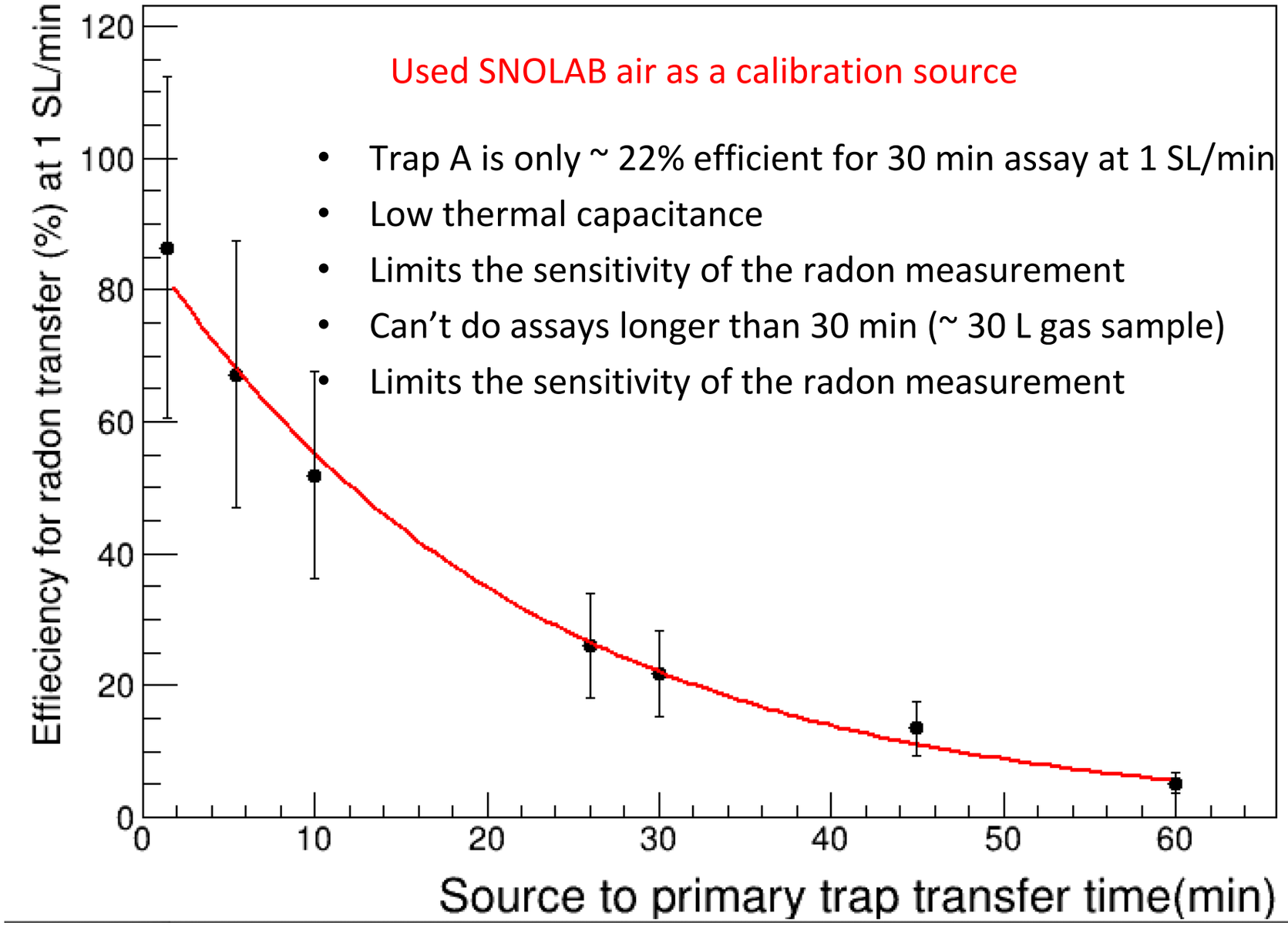


- Trap A is only ~ 22% efficient for 30 min assay at 1 SL/min
- Low thermal capacitance
- Limits the sensitivity of the radon measurement
- Can't do assays longer than 30 min (~ 30 L gas sample)
- Limits the sensitivity of the radon measurement

Target sensitivity

- Current ^{222}Rn sensitivity **~ 0.01 mBq/m^3** (roughly four order of magnitude smaller than SNOLAB ^{222}Rn concentration)
- The goal is to perform at least **10 times** better to make experimental goals
  - 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.

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

- Can we reduce the radon emanation in house?

Cleaning the sample

- Nitric acid washed the charcoal inhouse at SNOLAB
- It was counted by a SNOLAB's Germanium detector

Sample	^{238}U from ^{226}Ra (mBq/kg)	^{238}U from ^{234}Th (mBq/kg)	^{232}Th (mBq/kg)
Regular Activated Charcoal **(Calgon)**	465.50 +/- 47.48	<327.12	114.50 +/- 37.57
Nitric Acid Washed Activated Charcoal (30% diluted HNO3)	<33.25	<42.92	99.75 +/- 20.06

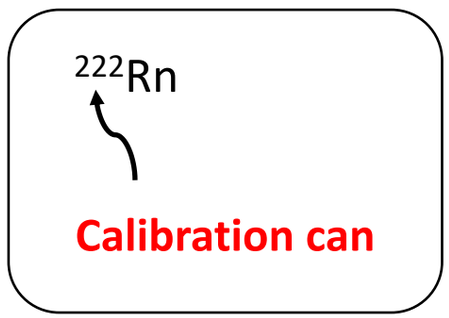
Radon emanation results using new SNOLAB's surface board = 3+/-1 mBq/kg

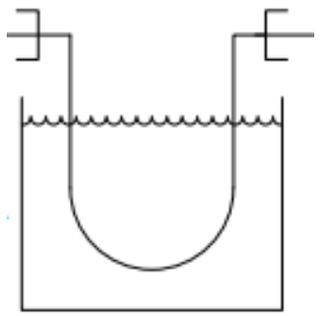
Charcoal test

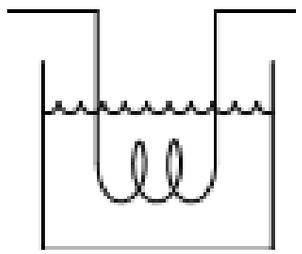
- ~ 22 gr of charcoal in a U-tube **~ Background: 0.3 ^{222}Rn decay /hour**

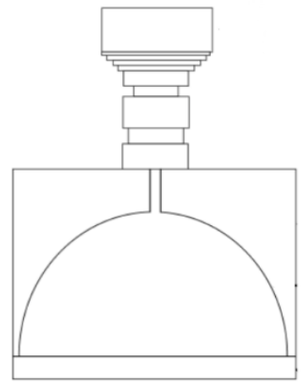
  Used a radon board on surface to do the measurement

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









Charcoal trap

Secondary Trap

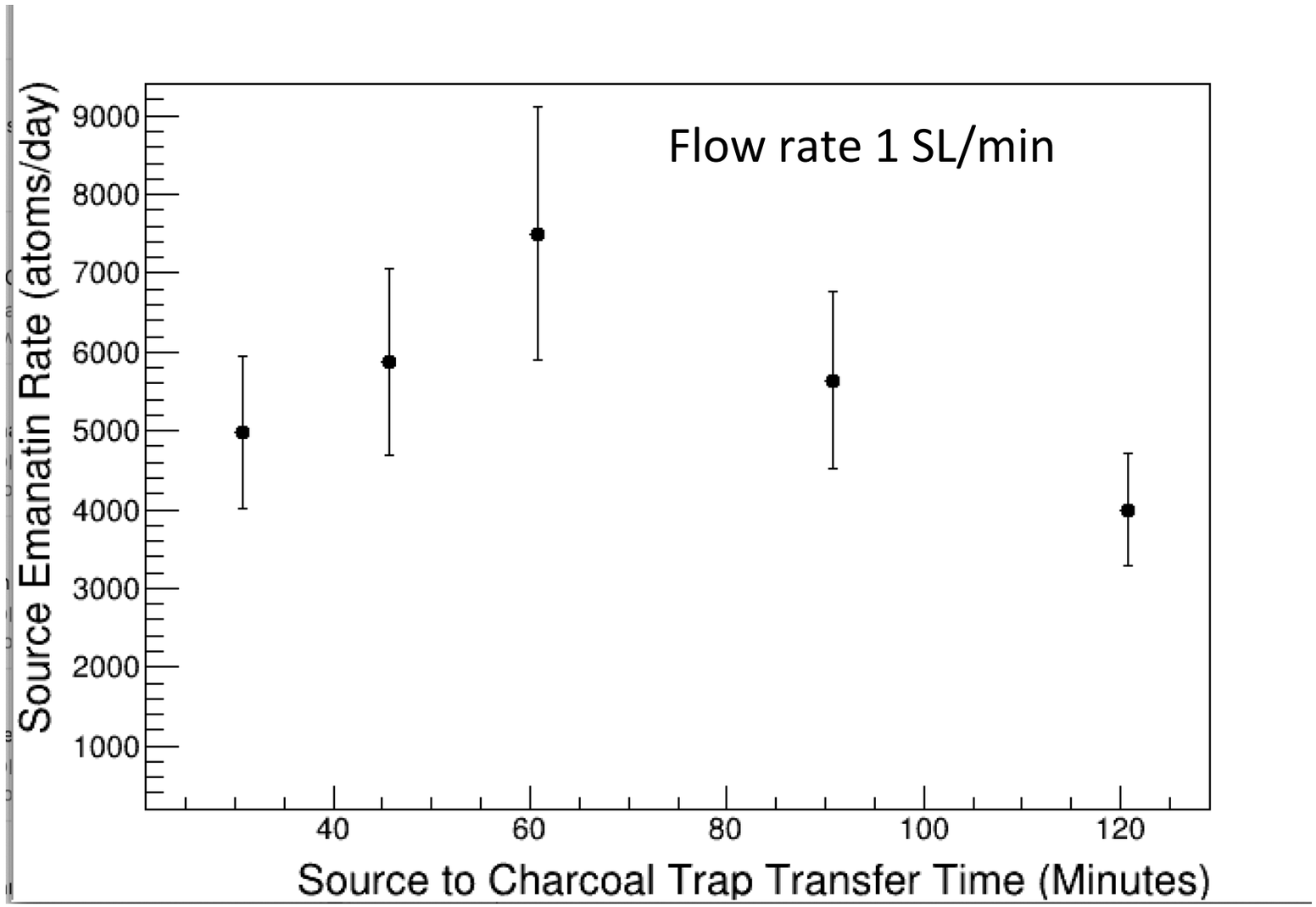
Lucas Cell

- **N_2 sweep gas transfer different flow**
- **Charcoal trap in -60°C alcohol slush**

- Cryopump transfer
- **Primary Trap heated to 150 C**
- Secondary Trap cooled in Liquid N_2

- Volume sharing
- Secondary Trap heated to room temperature

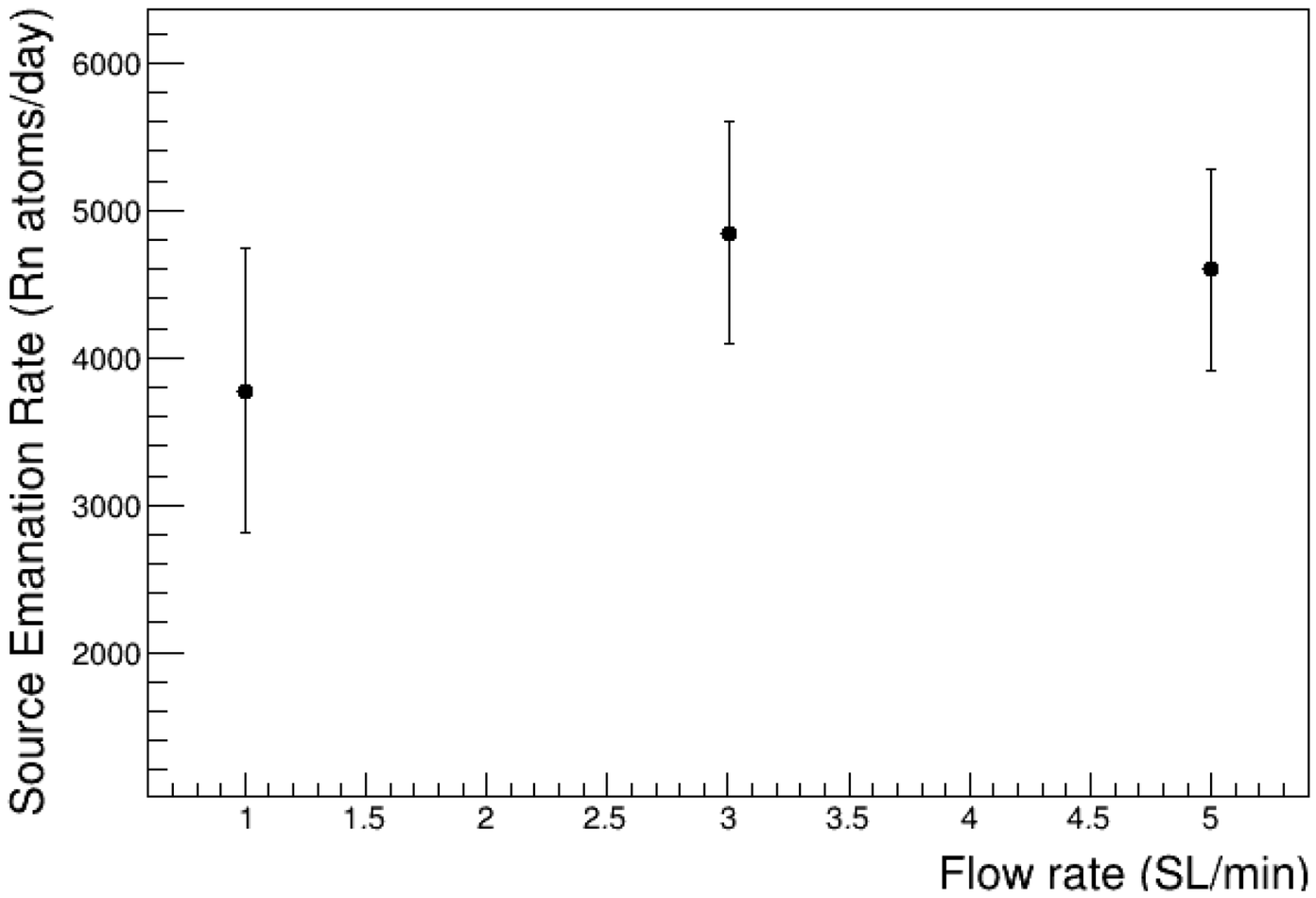
Calibration Can Results versus assay time



- Absolute emanation rate of the calibration source need to be finalized
- 25% uncertainty on the measurement was found by repeating 30 min measurement 5 times (errors are correlated)

Calibration Can Results versus flow rate

Uncertainty on the measurement was found by repeating each measurement at least three times



Conclusion and future work

- A radon board used for gas assays
- New charcoal trap will allow > 10 times higher volume extraction
    - Allow for higher sensitivity
- Radioactive background is negligible
- Will investigate the 25% systematic uncertainty
    - Trap cooling/baking temperature?
    - Source emanation rate uncertainty?
- This systematic is good enough to be able to use this for gas assays UG
- We also have different charcoal samples from other companies which we plan to test

Back up slides (calibration source)