Evaluating SNO+ External background through Radon Assays

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SNOLAB USER MEETING 2021

A little about myself!

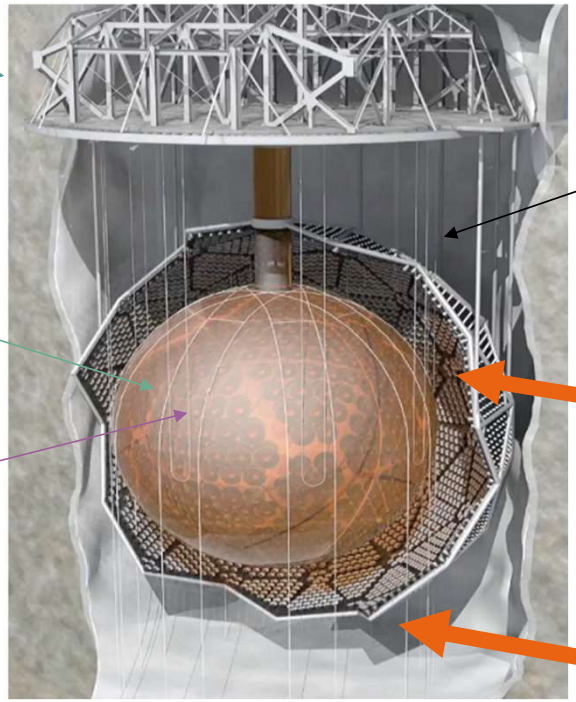
- Final year Masters student at Laurentian University
- International Student from Pakistan
- Completed my undergraduate degree from Lake Forest College (Illinois)
- Working under the supervision of Dr Christine Kraus
- Outside of work I like to follow sports like Cricket.
- I also like to cook

SNO+ Detector: Neutrino-less Double Beta Decay Experiment

2 km Underground

Acrylic Vessel (AV)-12 m diameter

Liquid Scintillator ~ 780 tonnes Te(Isotope in future)



PSUP(PMT Support structure)~ 9500 PMTS

Inner Cavity ~ 1700t UPW

Outer Cavity Water ~ 5300t UPW

Inherited from SNO

Backgrounds within SNO+

- There are two types of backgrounds: Internal and External.
- Internal Backgrounds are non signal events that occur within the AV volume.
- External backgrounds are events that occur outside the AV volume but can be reconstructed within the AV volume.
- Background Contributions are as follows:

- 2νbb
- Uranium-238 chain
- Thorium chain
- **External Backgrounds**
- Cosmogenic
- α,n
- B^8

External Backgrounds

Radioactivity:

- **U^{238} decay chain, Rn^{222} and its daughters(Bi^{214})**
- Th^{232} decay chain, Tl^{208} isotope

Sources:

- Surrounding rocks
- Acrylic Vessel
- Hold up and Hold down ropes
- PMTs

Target levels

- Bi^{214} : **2.1×10^{-13} gU^{238}/gH_2O**
- Tl^{208}: 5.2×10^{-16} gTh^{232}/gH_2O
- These target levels allow minimum backgrounds to leak into the Region of Interest(ROI).
- Fudicial volume cut is applied to remove external backgrounds from ROI.
- UPW plant consistently purifies cavity water from contaminants.

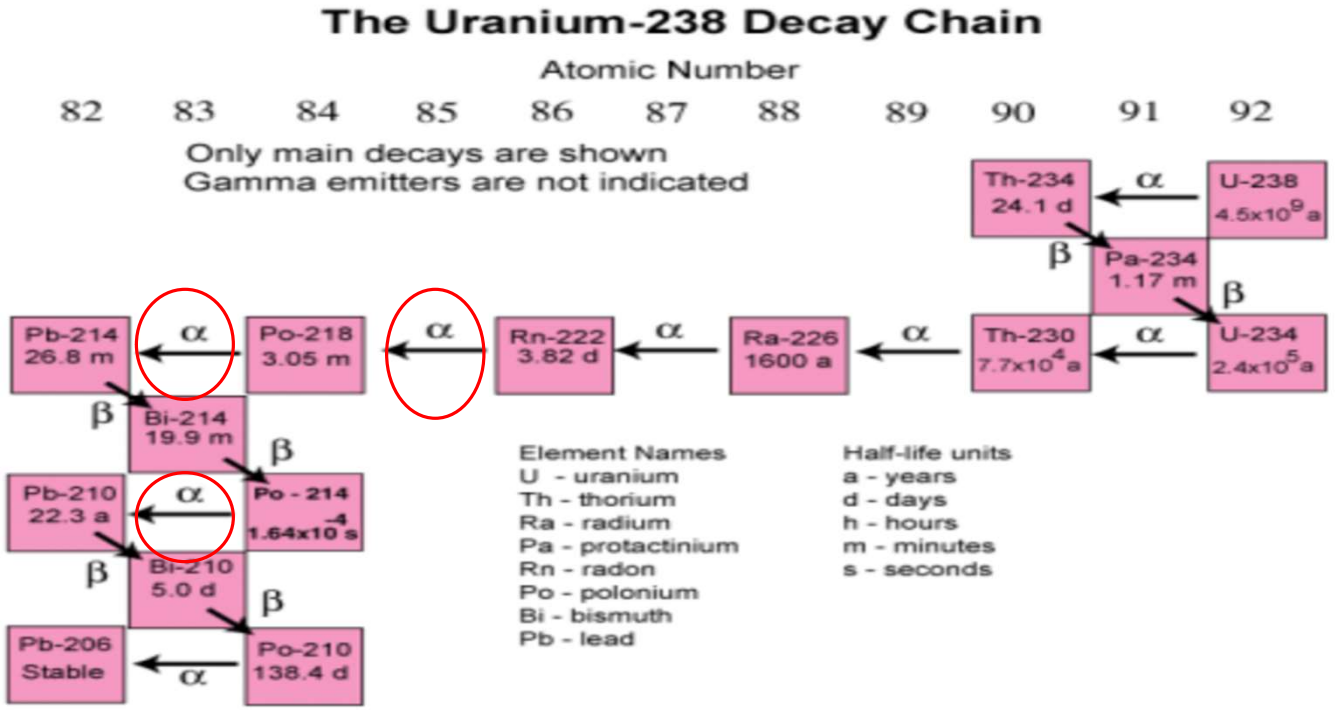
Expected backgrounds in ROI

Isotope	1 year	5 years
$2\nu\beta\beta$	6.3	31.6
B^8	7.3	36.3
Uranium chain	2.1	10.4
Thorium chain	1.7	8.7
External	**3.6**	**18.1**
α,n	0.1	0.8
Cosmogenic	0.7	0.8
Total	21.8	106.8

Expected $0\nu\beta\beta$ Signal: ~ 22 events/year

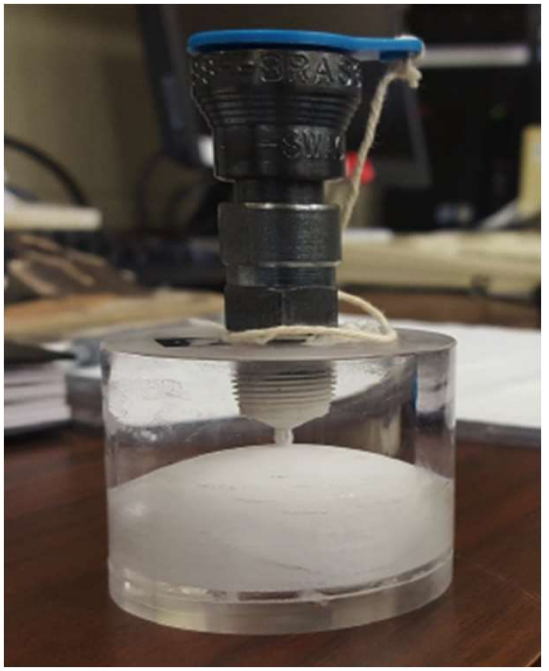
Backgrounds of SNO+

- Radon due to its long half life and mobility is readily prevalent in the mine air.
- Radon Assay was a technique developed during the SNO time to determine the radon concentration in the ultra pure cavity water.
- Radon decays into its daughter which results in 3 alpha decays for each radon atom.

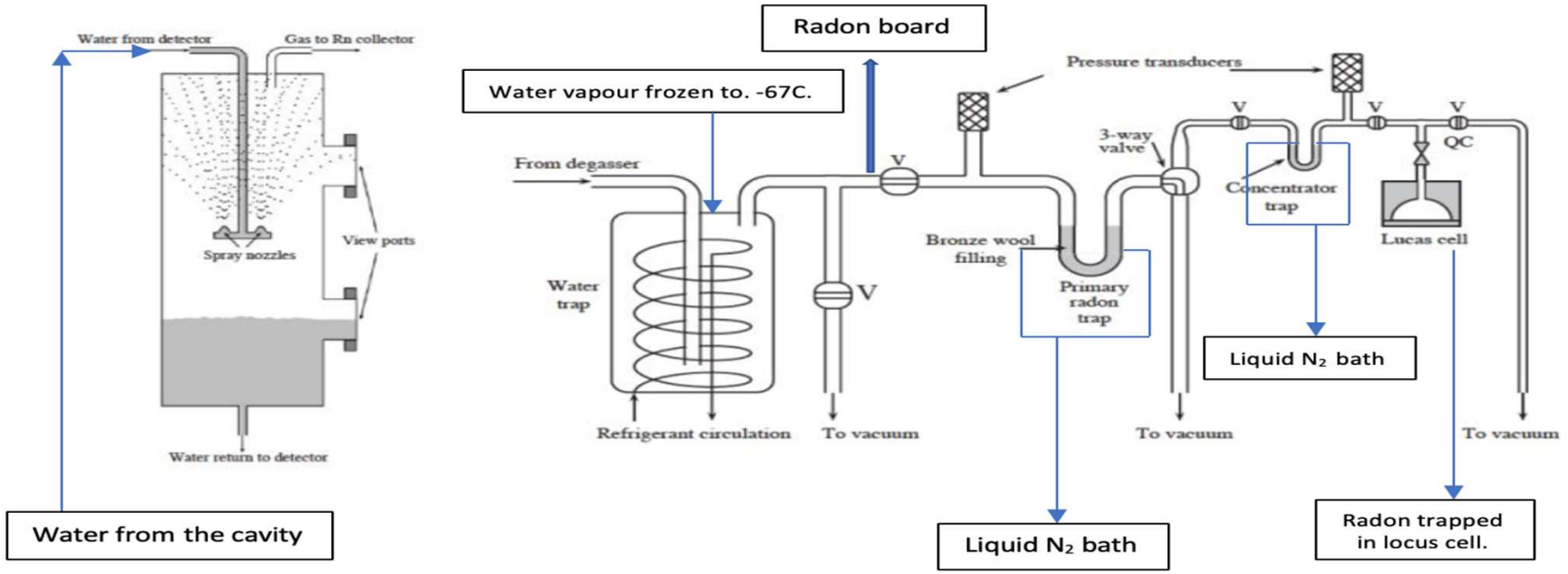


Radon Assays

- Radon assay allows for direct measurement for the external backgrounds of SNO+.
- To enable the alpha detection technique from radon decay, customized Lucas cells were produced.
- Lucas cells are ZnS scintillator coated which count alpha decays.
- Alphas emit scintillation light when they interact with ZnS
- It takes about a shift to perform a water assay.



ASSAY SYSTEM – located at SNOLAB



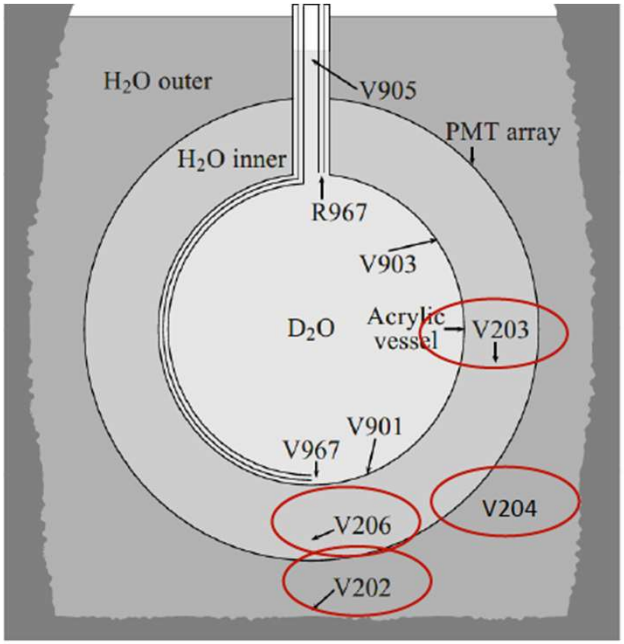
Radon Calculations

$$\boldsymbol{Rn}\ \frac{\boldsymbol{Atoms}}{\boldsymbol{Day}} = \frac{(N_{Alphas} - B_{Lucas} t_{counting})\lambda}{\varepsilon_{trapping}\ \varepsilon_{transfer}\ \varepsilon_{counting}(1 - e^{-i\lambda t_{count}})(\ e^{-i\lambda t_{delay}})(1 - e^{-i\lambda t_{assay}})} - R_{bg}$$

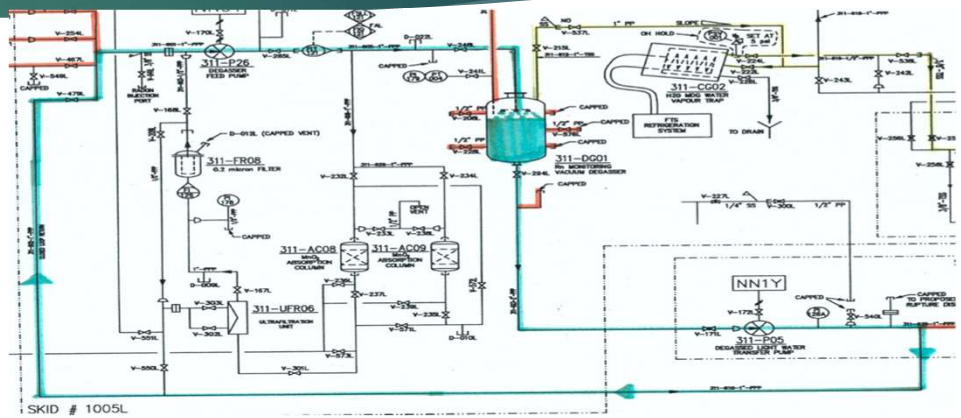
- N_{Alphas} = number of alphas
- B_{Lucas} = Background of Lucas cell
- $t_{counting}$ = counting time.
- T_{delay} = time between end of assay and start of counting.
- $\varepsilon_{trapping}$ = trapping efficiency = 0.640
- $\varepsilon_{counting} = counting\ efficiency = 0.740$
- $\varepsilon_{transfer}$ = transfer efficiency $= 1$

Assay results

- Assay is performed at several locations of the cavity.
- Assays are usually 30 to 60 minutes long.
- V202 is the **bottom** of the cavity.
- V203 is PSUP and **AV equator**.
- V204 is **bottom of the PSUP**.
- V206 is **between PSUP and AV bottom**.



Assay System Background



Date	Rn atoms/45 minute	Alphas	Counting time/days	Water/L	Assay Time/min
18/11/2020	94±28.2	101	6.958	810	45
20/04/2021	146.8±44	160	7.335	1140	60
26/07/2021	75.8 ± 22	78	6.125	540	30

Water Assay Results

SNO+ target = 2.1 x 10^{-13} gU^{238}/gH_2O

Date	Location	Rn atoms/sample	Water/L	Assay Time/min	Concentration gU^{238}/gH_20
09/05/2019	Bottom	1070 ± 321	640	40	2.82E-13
03/06/2019	AV Equator	467 ± 140	877	60	9.90E-14
20/06/2019	Between PSUP and AV Bottom	853 ± 255	1080	60	1.33E-13
04/07/2019	Bottom of PSUP	824± 247	1080	60	1.29E-13
19/11/2020	AV Equator	378± 113	600	30	1.06e-13
23/04/2021	**AV Equator**	**2291± 687**	**810**	**45**	**4.78e-13**
27/07/2021	**Bottom of PSUP**	**1100 ± 330**	**819**	**45**	**2.27e-13**

Summary

- Assay results and data analysis show an agreement.
- SNO+ is maintaining target level concentrations for external U-238.
- Assays are conducted very often to monitor any radon ingress.

A Huge thank you to Operations Group and Scientific Support Group for all their effort and Support!

Thank you!

QUESTIONS/COMMENTS?