

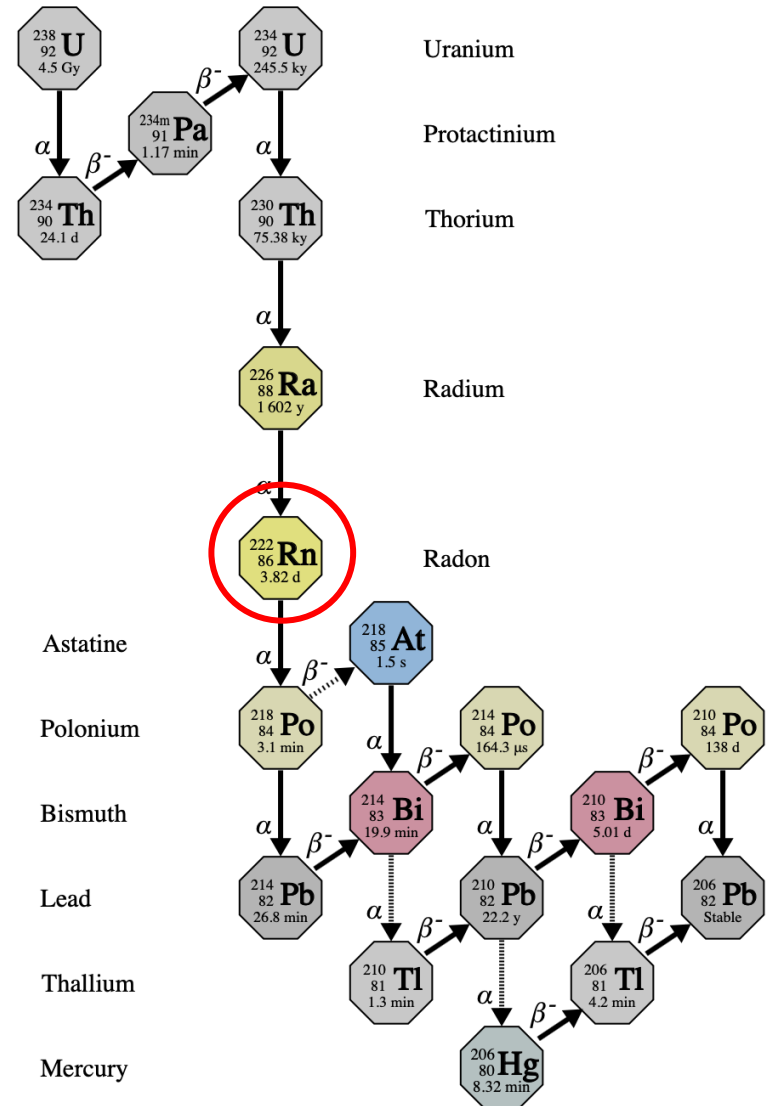
2026/07/23

Improving SNOLAB Radon counting sensitivity with low- background ZnS

Peter Qin (He/Him)

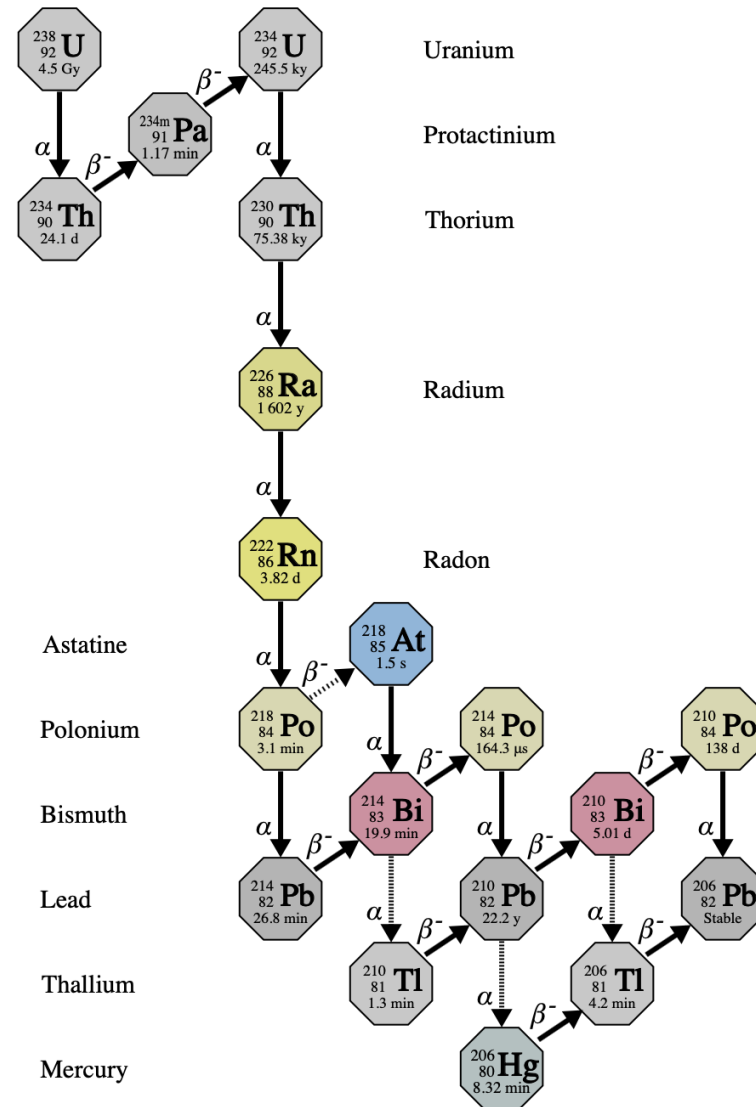
Research Assistant

^{238}U chain and ^{222}Rn



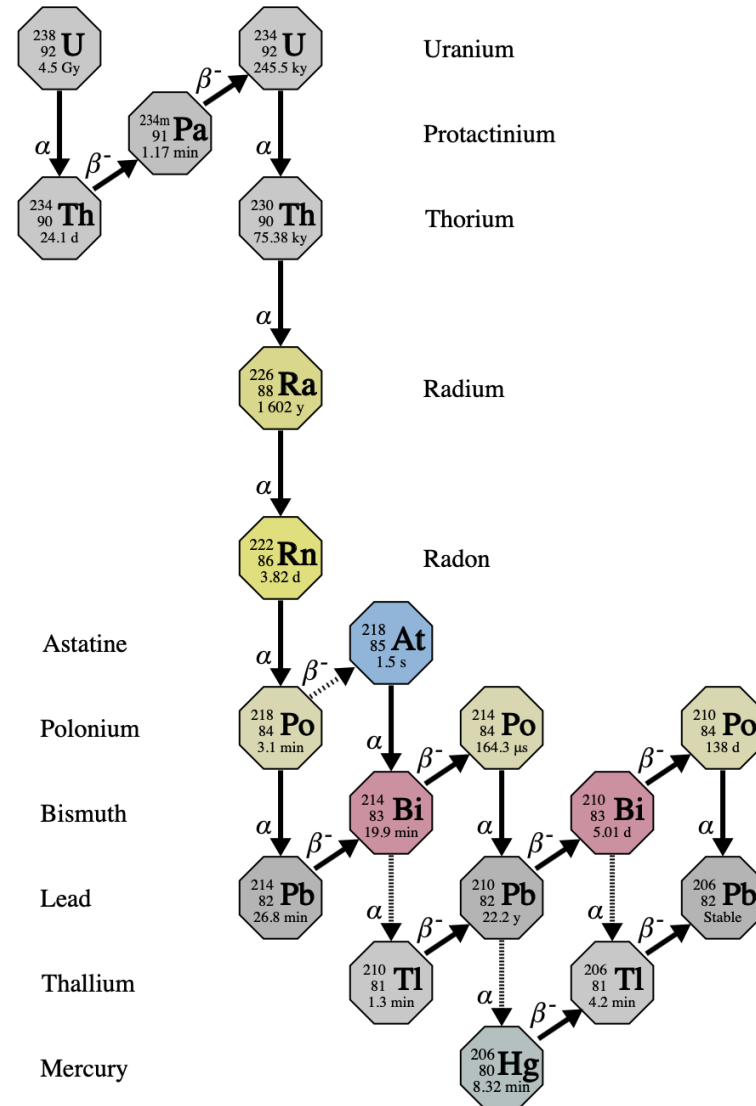
^{238}U chain and ^{222}Rn

- Abundant underground



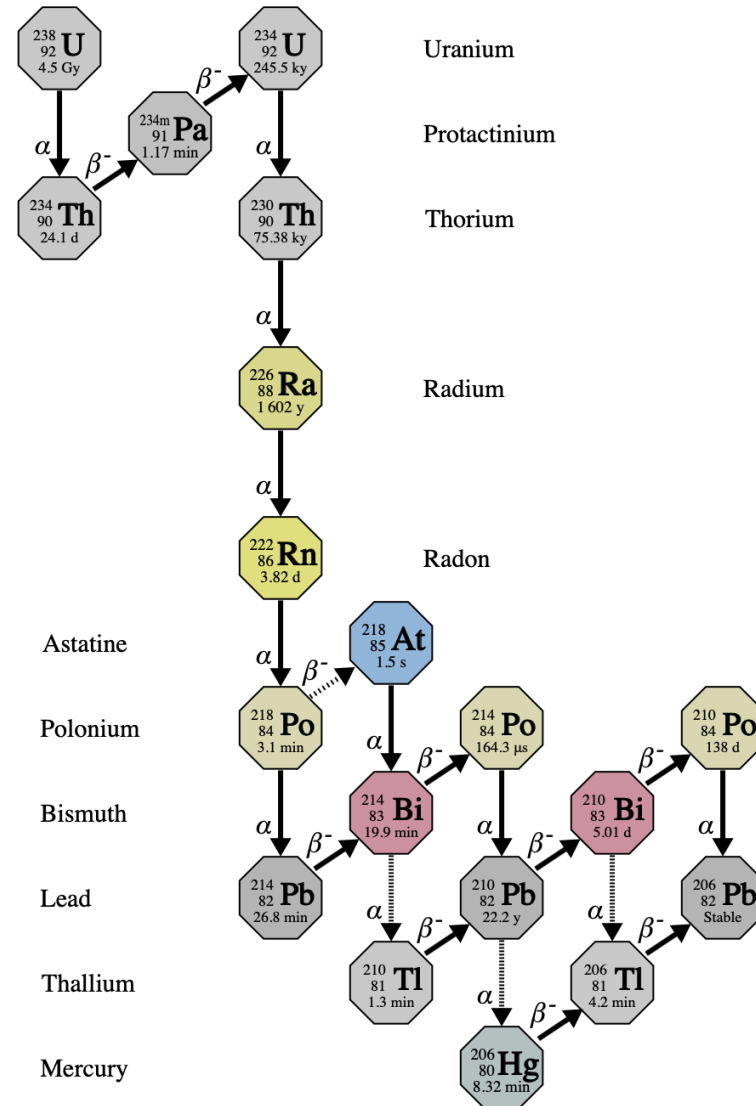
^{238}U chain and ^{222}Rn

- Abundant underground
- Background to rare-event searches



^{238}U chain and ^{222}Rn

- Abundant underground
- Background to rare-event searches
- Gaseous



Radon control is a priority for low-background science

Radon control at SNOLAB

- Lab infrastructure



Radon control at SNOLAB

- Lab infrastructure
- Surface prep (etching/passivation)



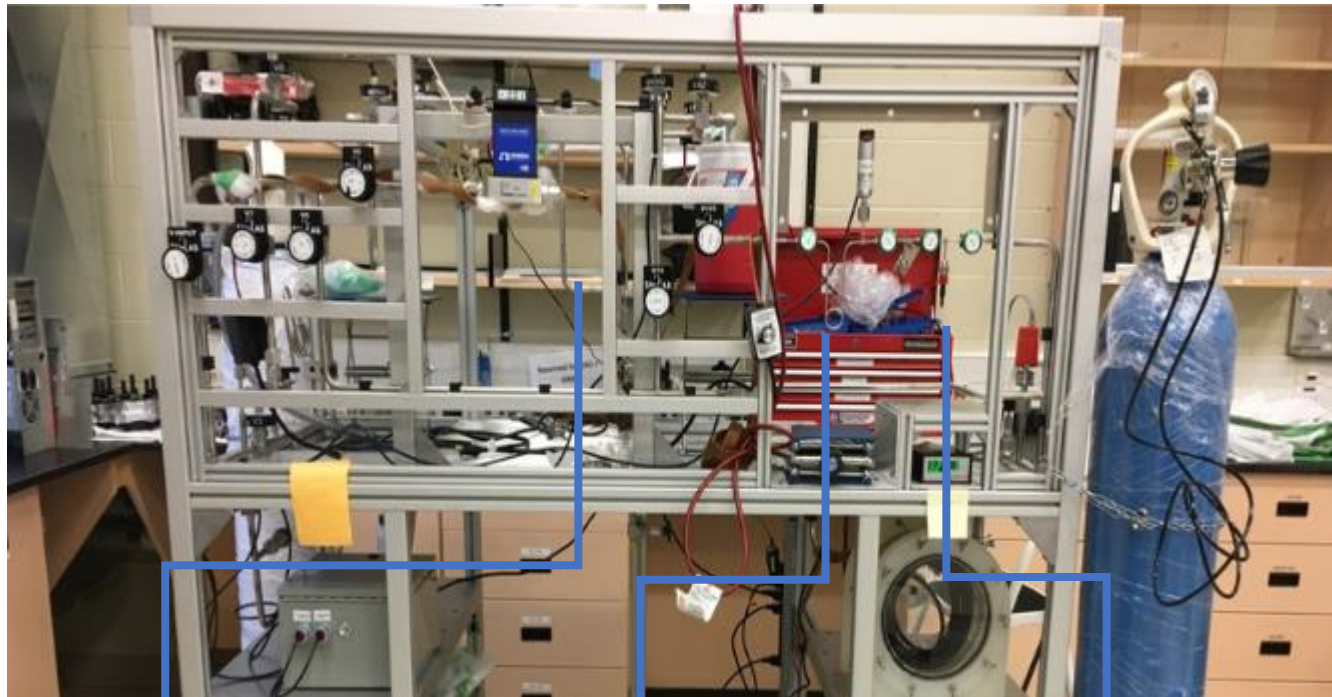
Radon control at SNOLAB

- Lab infrastructure
- Cleanroom fabrication, surface prep (etching/passivation)
- Materials screening program (ICP-MS, HPGe, XIA, etc.)



The SNOLAB Radon Assay

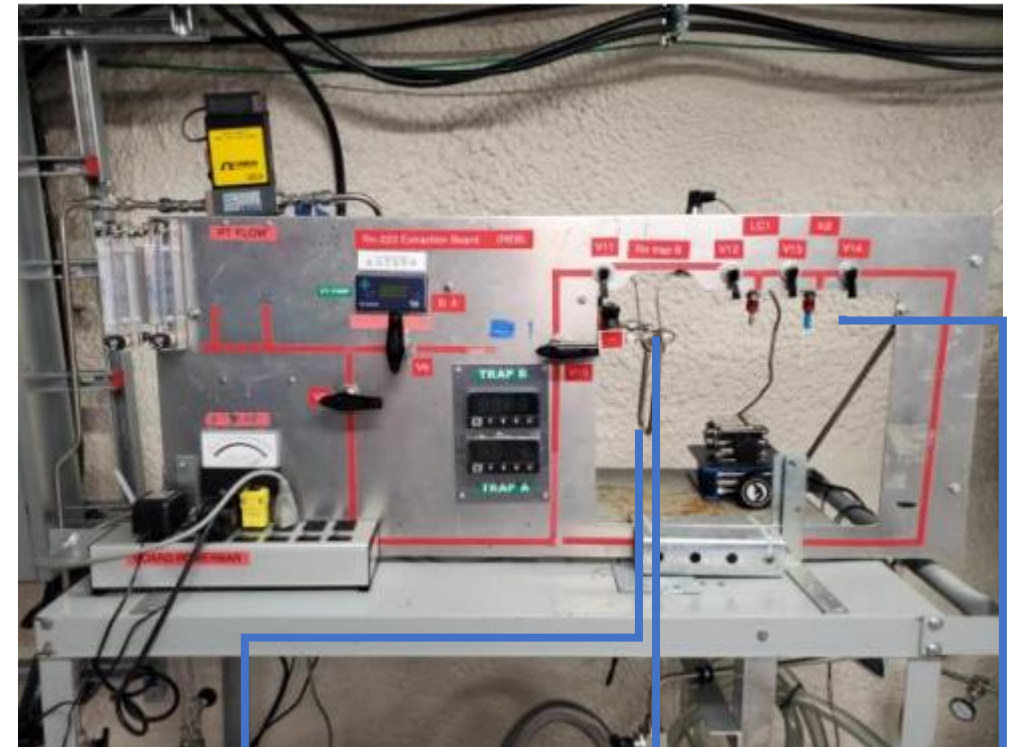
Radon assays



Primary trap

Concentrator trap

Port to scintillator cell



Primary trap

Concentrator trap

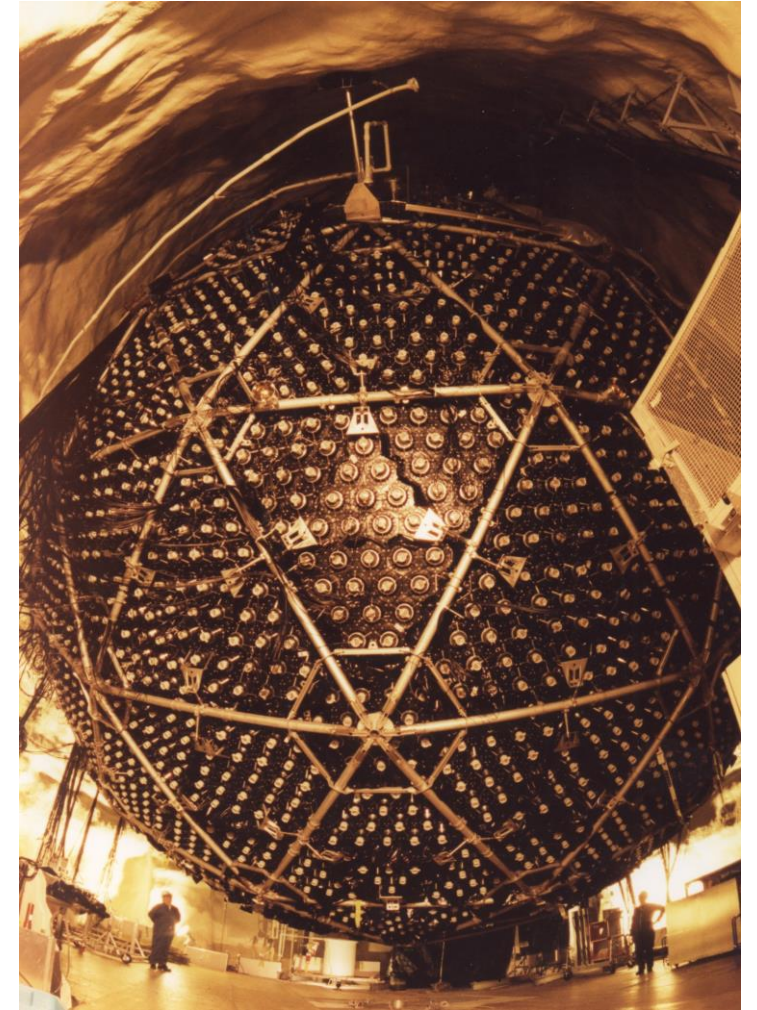
Port to scintillator cell

Origin of the SNOLAB Rn assay

- Technique developed ~1991
- Used during SNO for radon emanation of solids and radon measurement in UPW



Credit: SNO



Credit: SNO

Current state of the Radon assay

- Mobile board was recommissioned in 2019
- Used by SNO+ for assays of cover gas, UPW
- Measurements of SNOLAB LN2 plant
- Radon emanation as part of SNOLAB low-background counting facility

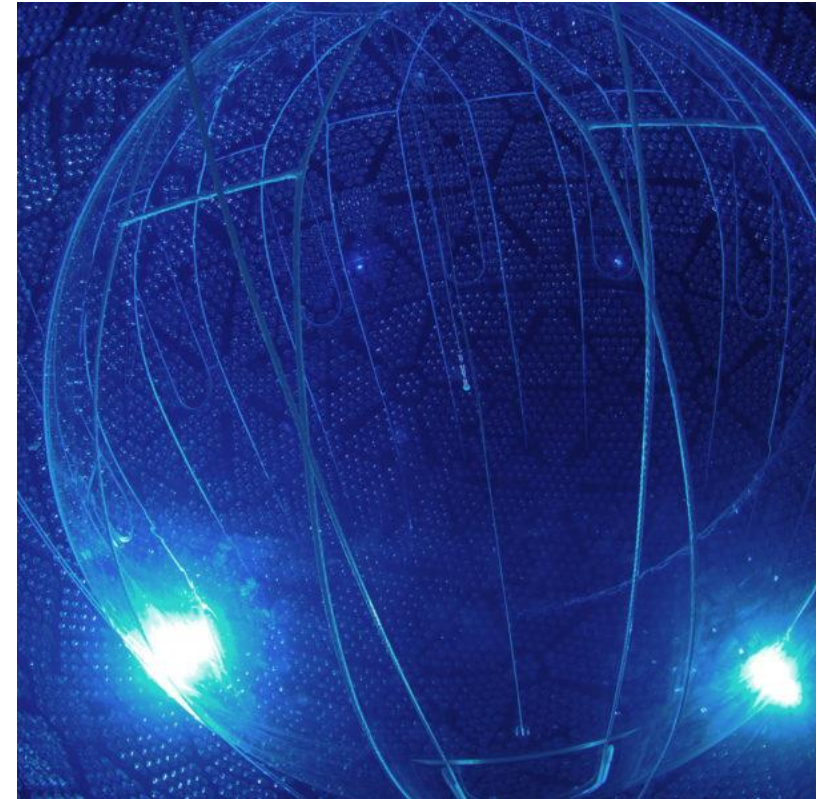


Experiments using Rn emanation results

- SNO+
- CUTE
- DAMIC
- DarkSide
- DEAP-3600
- DM-Ice
- XLZD

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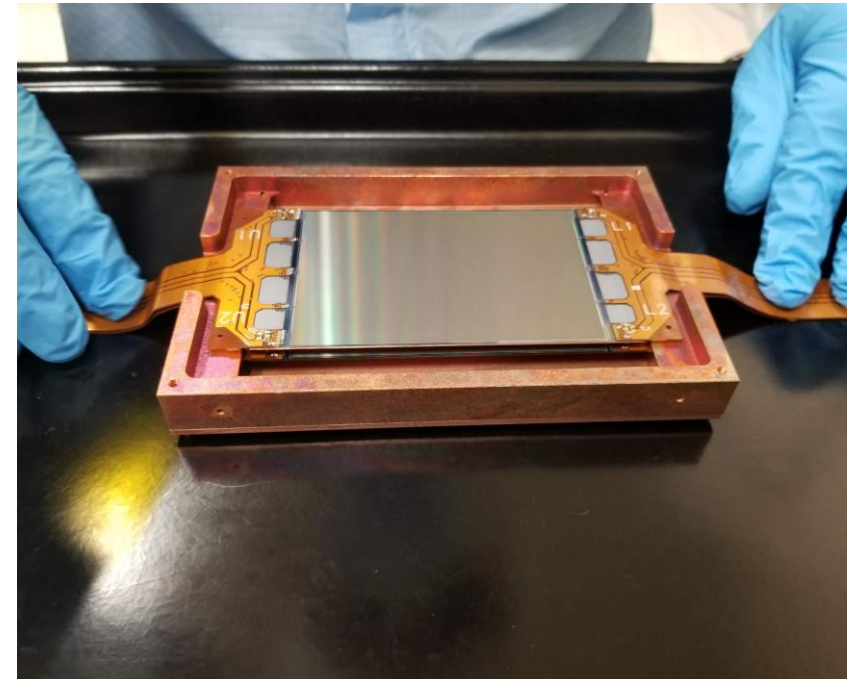
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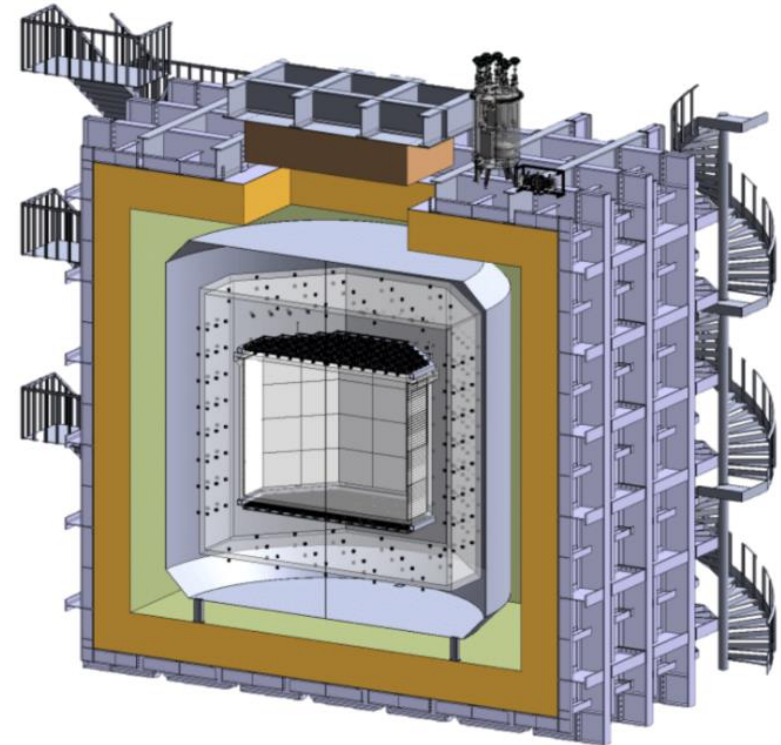
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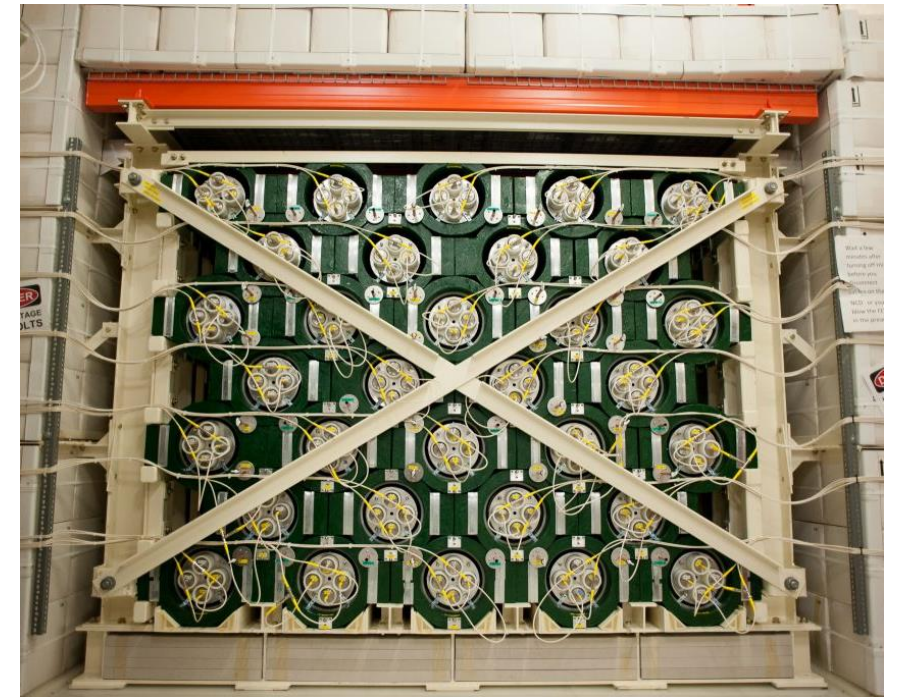
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- NEWS-G
- PICO
- REPAIR
- SBC
- SENSEI
- SuperCDMS



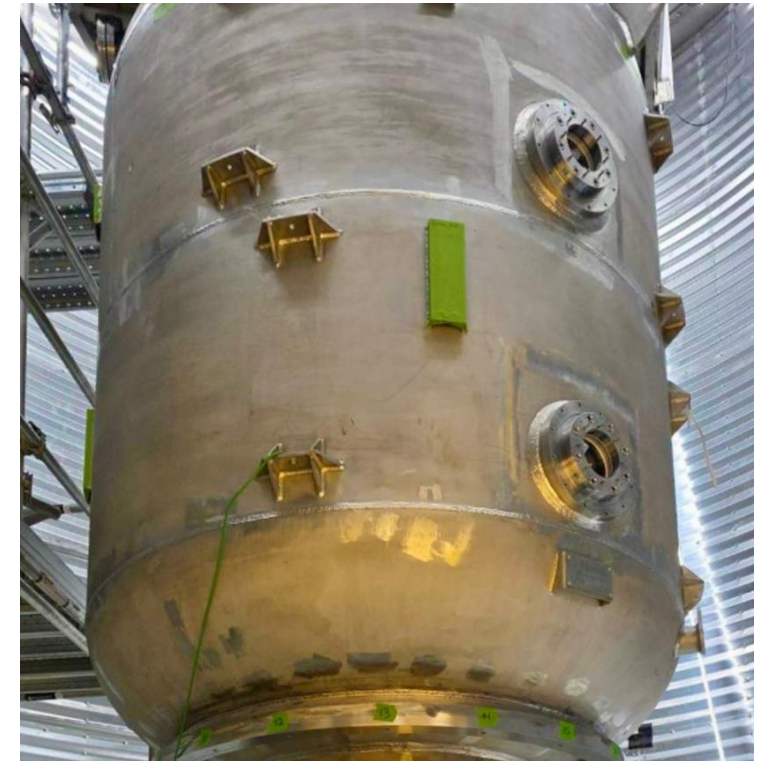
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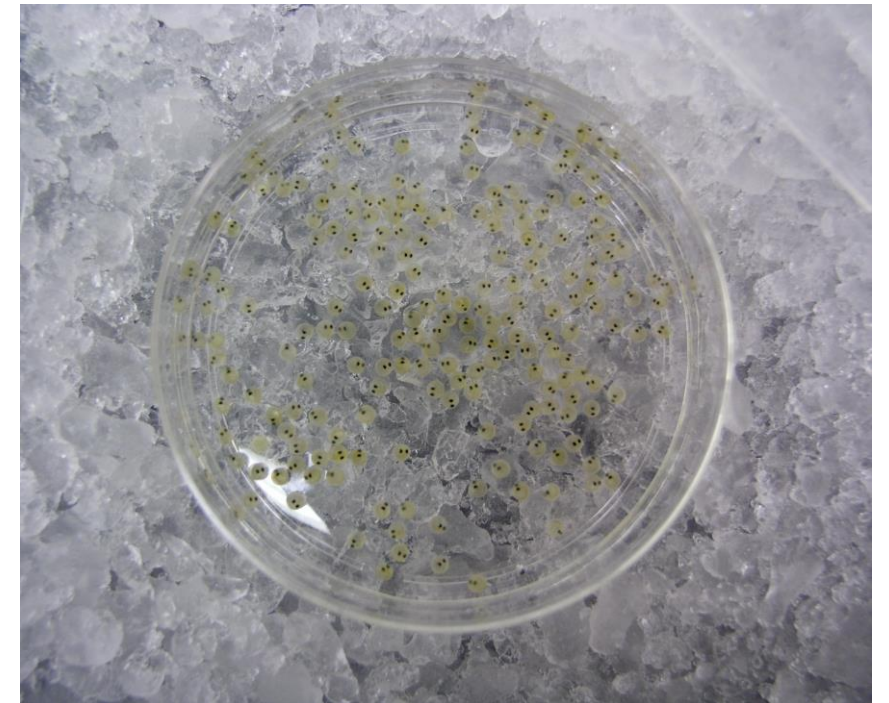
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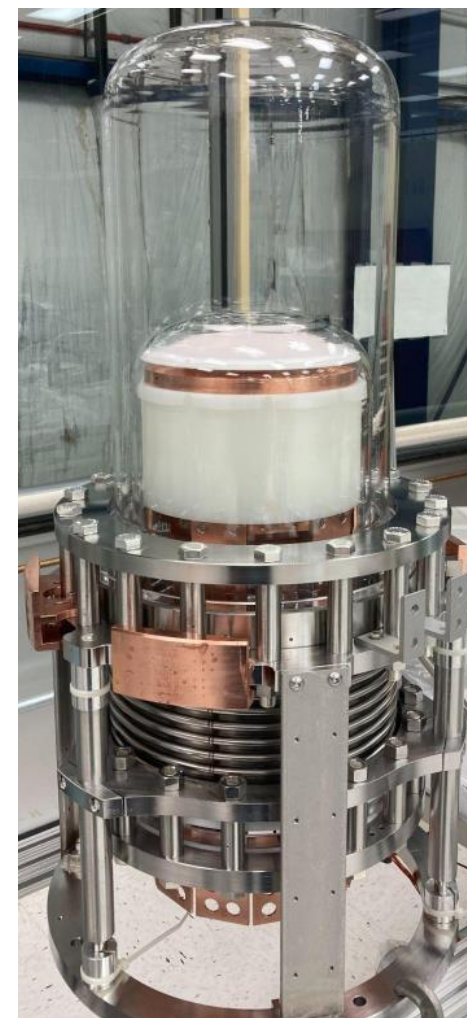
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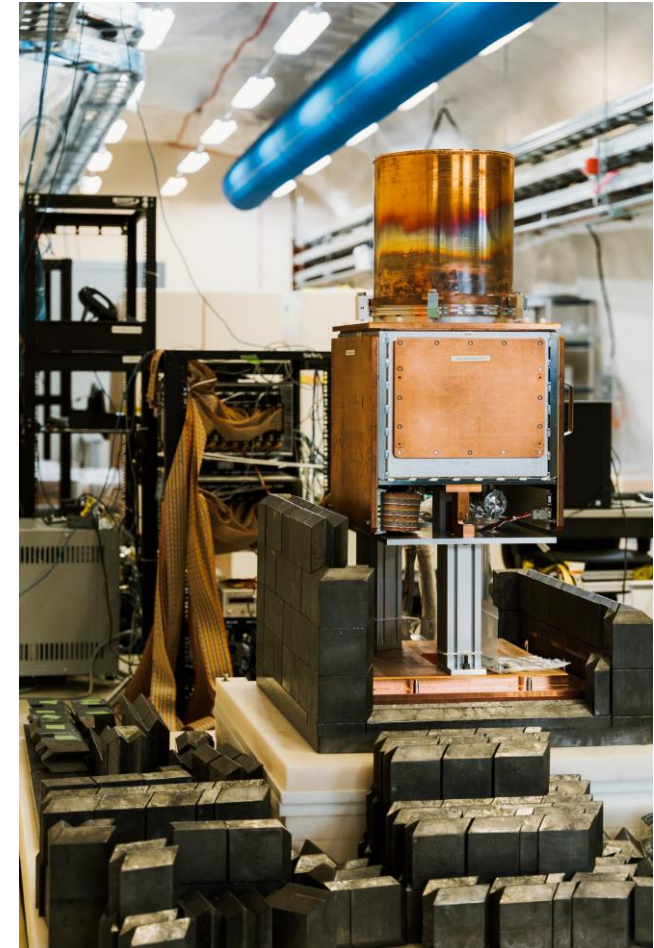
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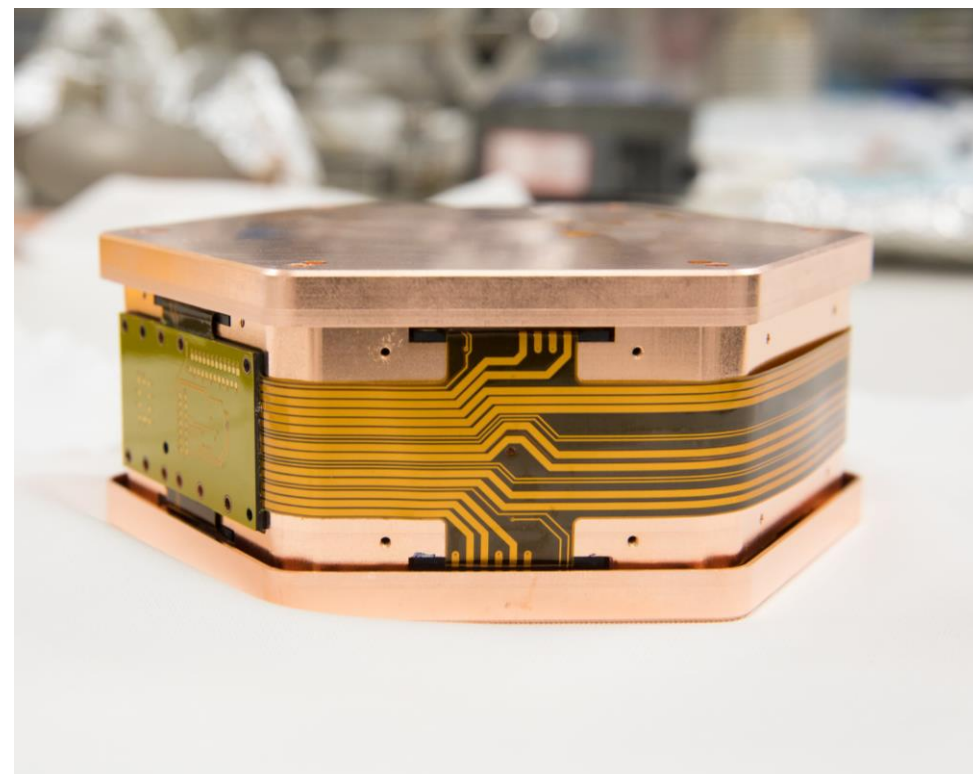
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Experiments using Rn emanation results

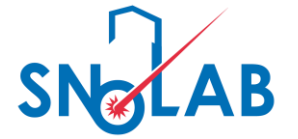
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- REPAIR
- SBC
- SENSEI
- SuperCDMS

Improvements to
SNOLAB Rn counting
have far-reaching
benefits for low-
background science!

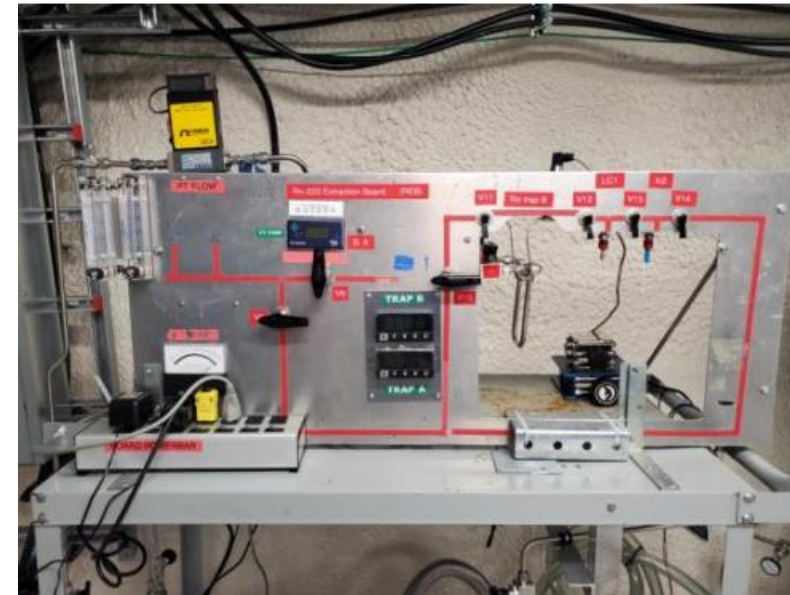
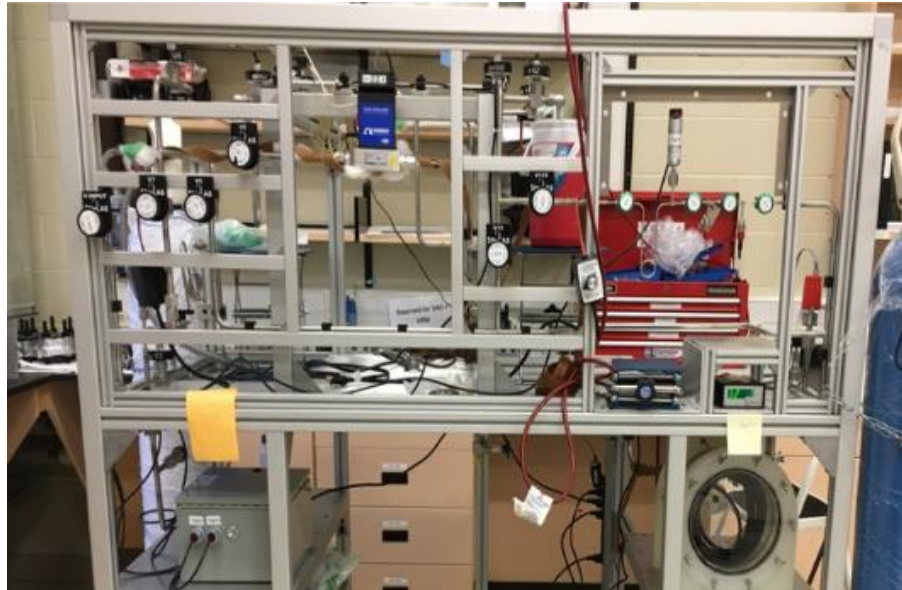
Maintaining and improving the Radon assay capability is a priority for SNOLAB

Improved sensitivity Rn assays

Four radon boards...

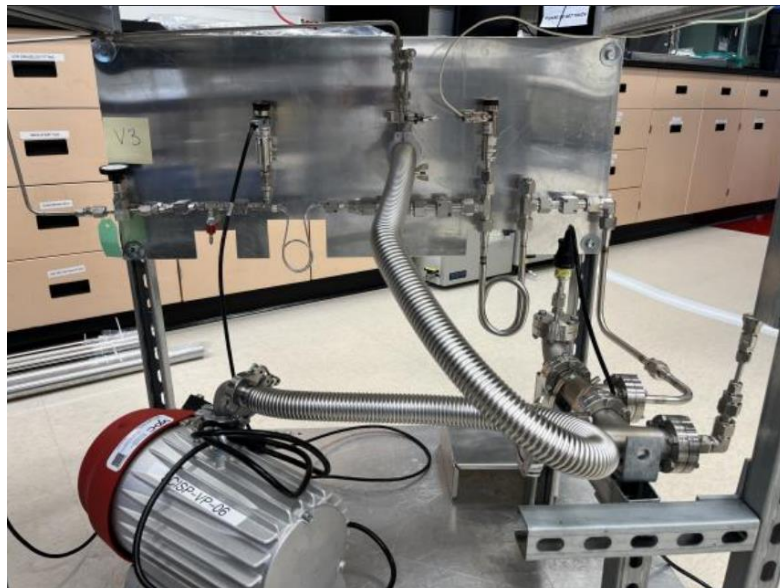


SNOLAB
surface
lab radon
board



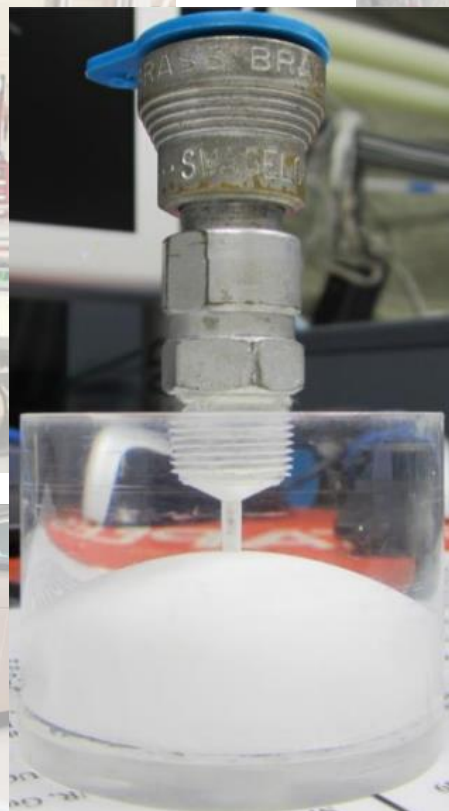
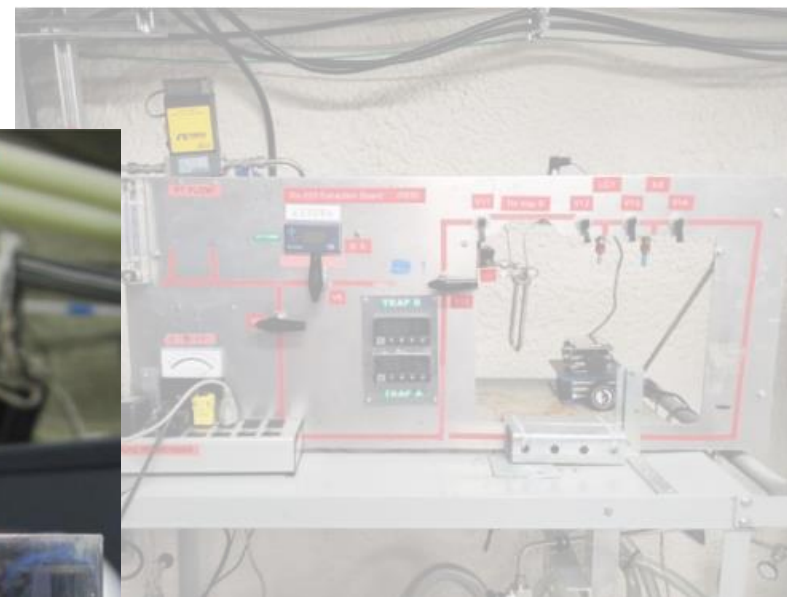
Underground
mobile radon
assay board

DEAP-3600
radon board



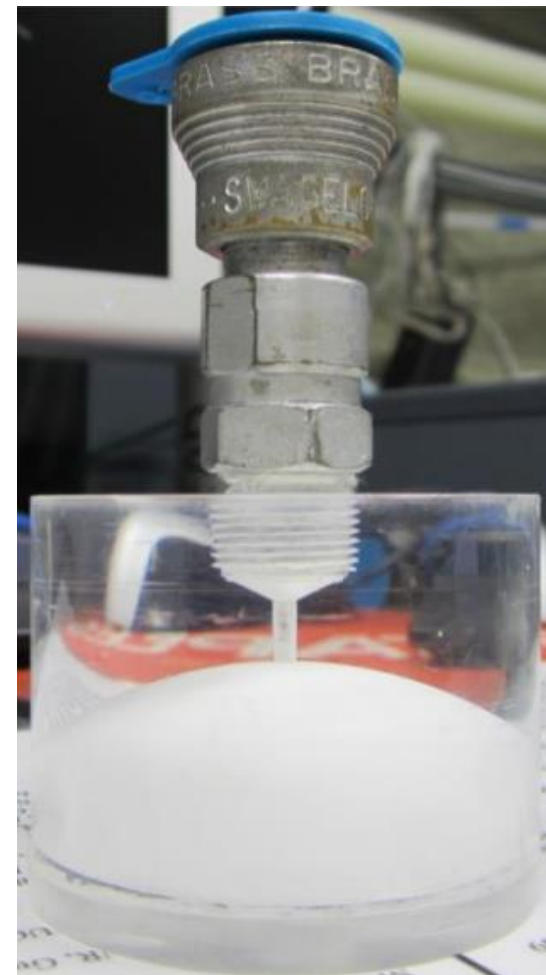
SNO+ UPW plant
radon board

One Lucas cell!

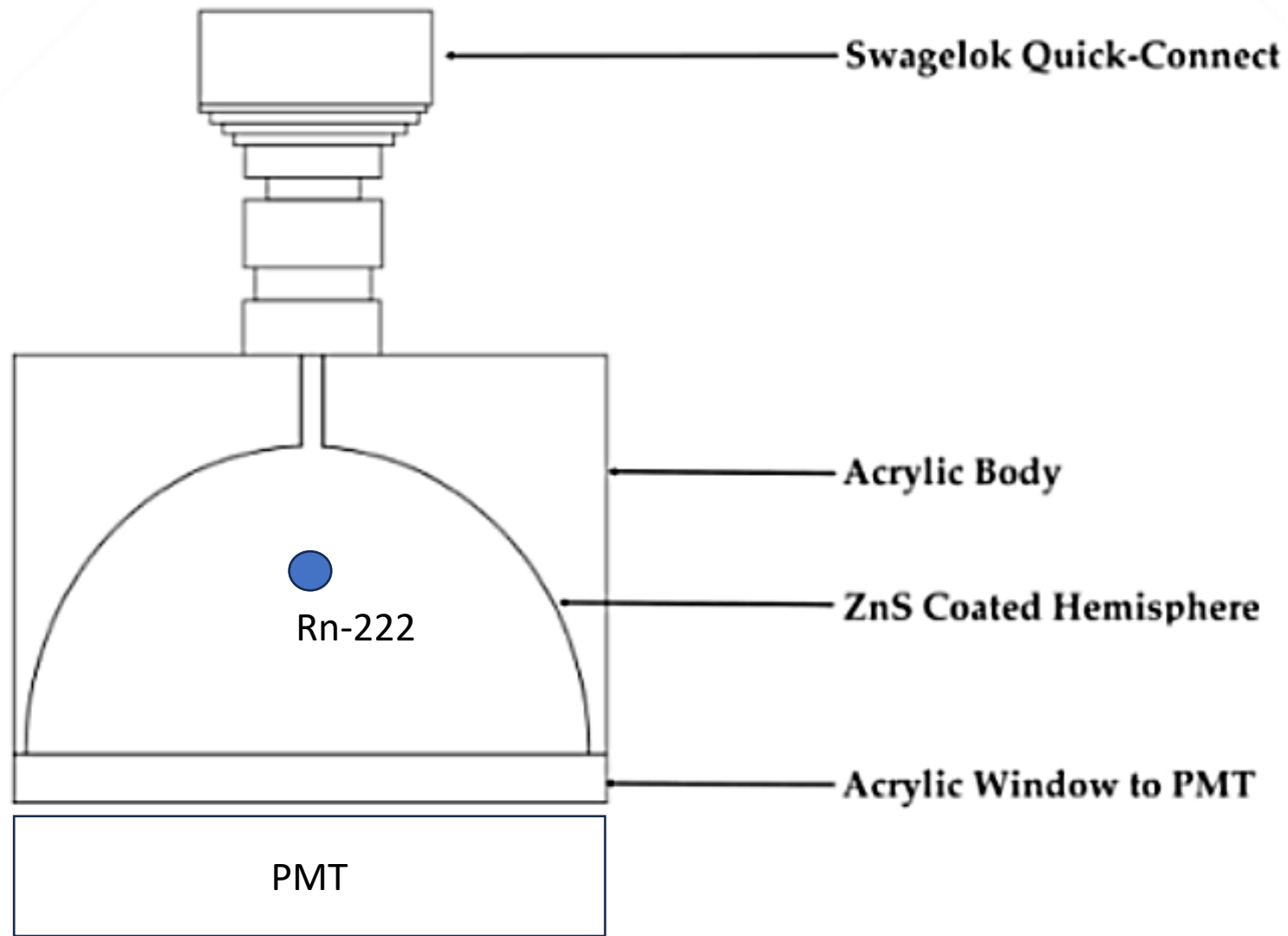


What are Lucas cells?

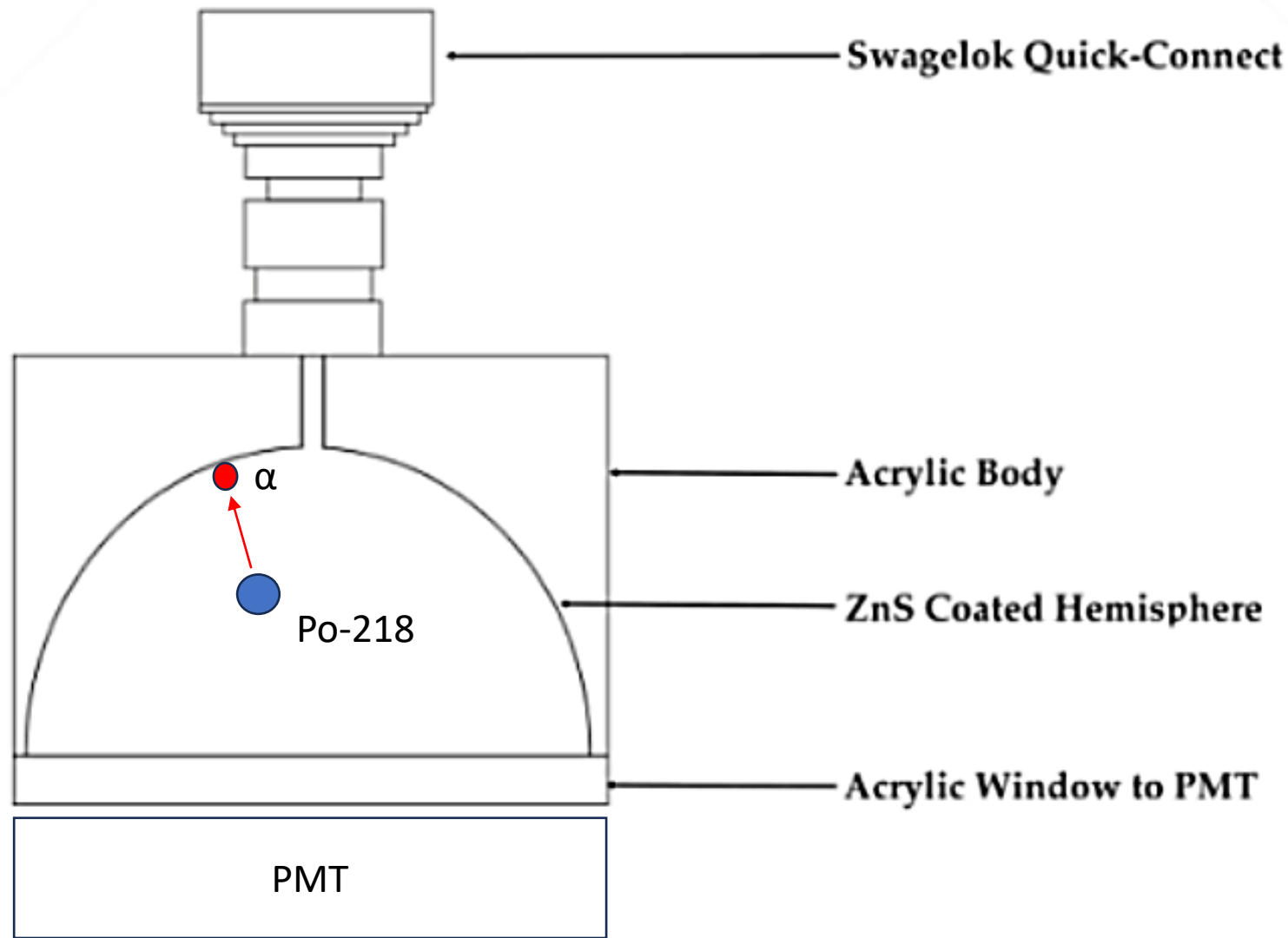
- Scintillator alpha counter
- ZnS(Ag)-coated inner volume stores Rn
- Used to count decays of Rn atoms trapped using assays



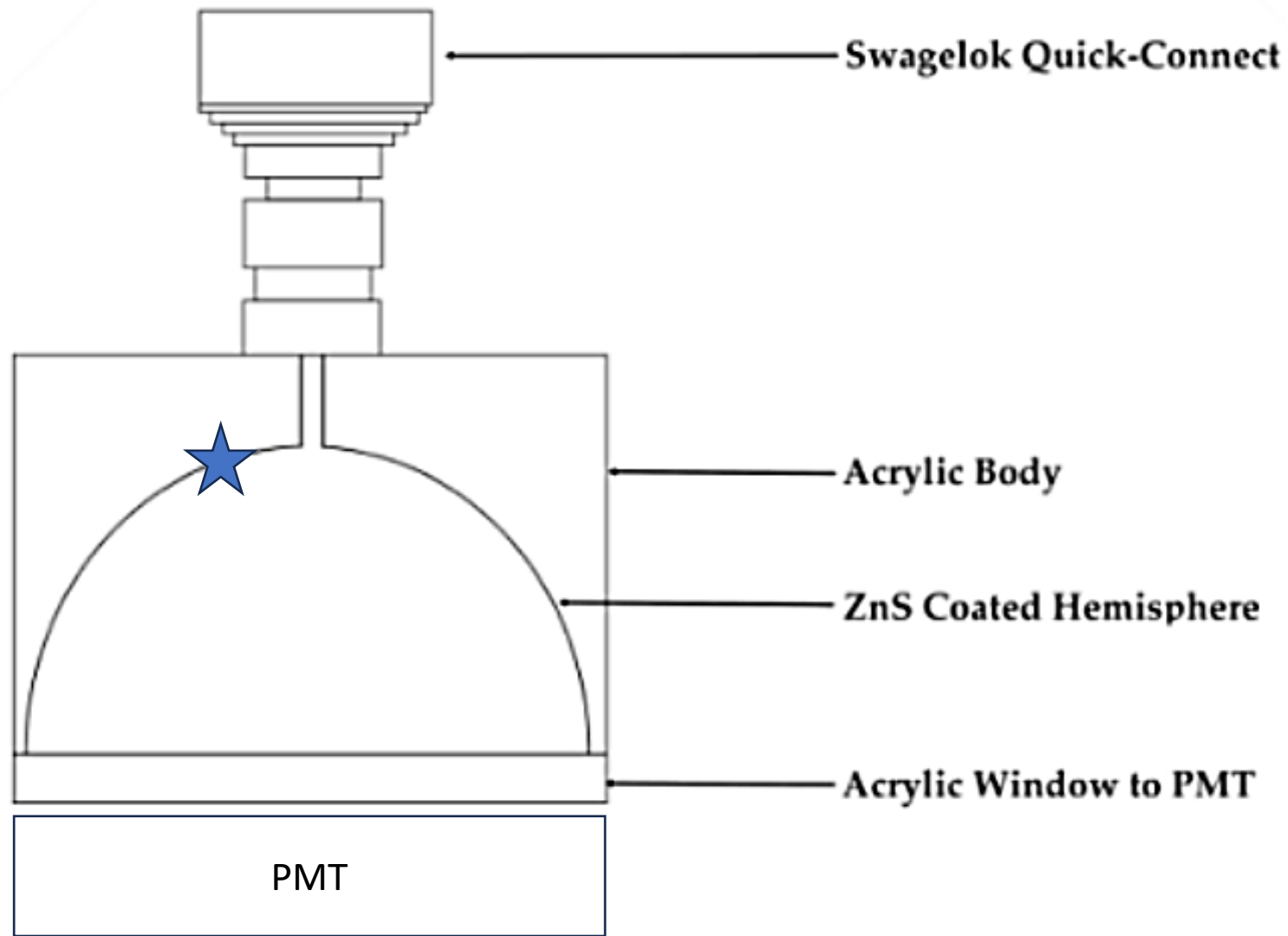
Principle of operation



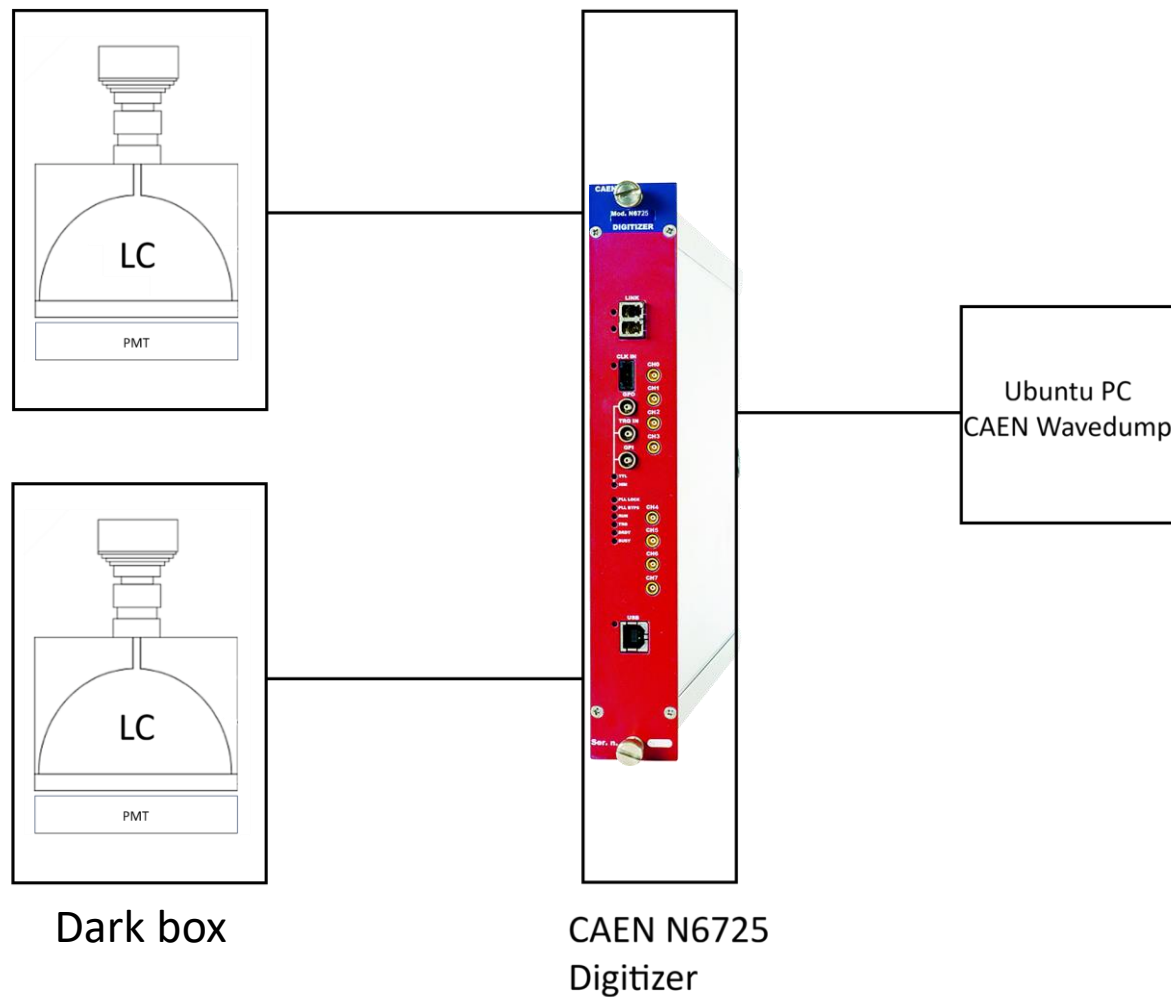
Principle of operation



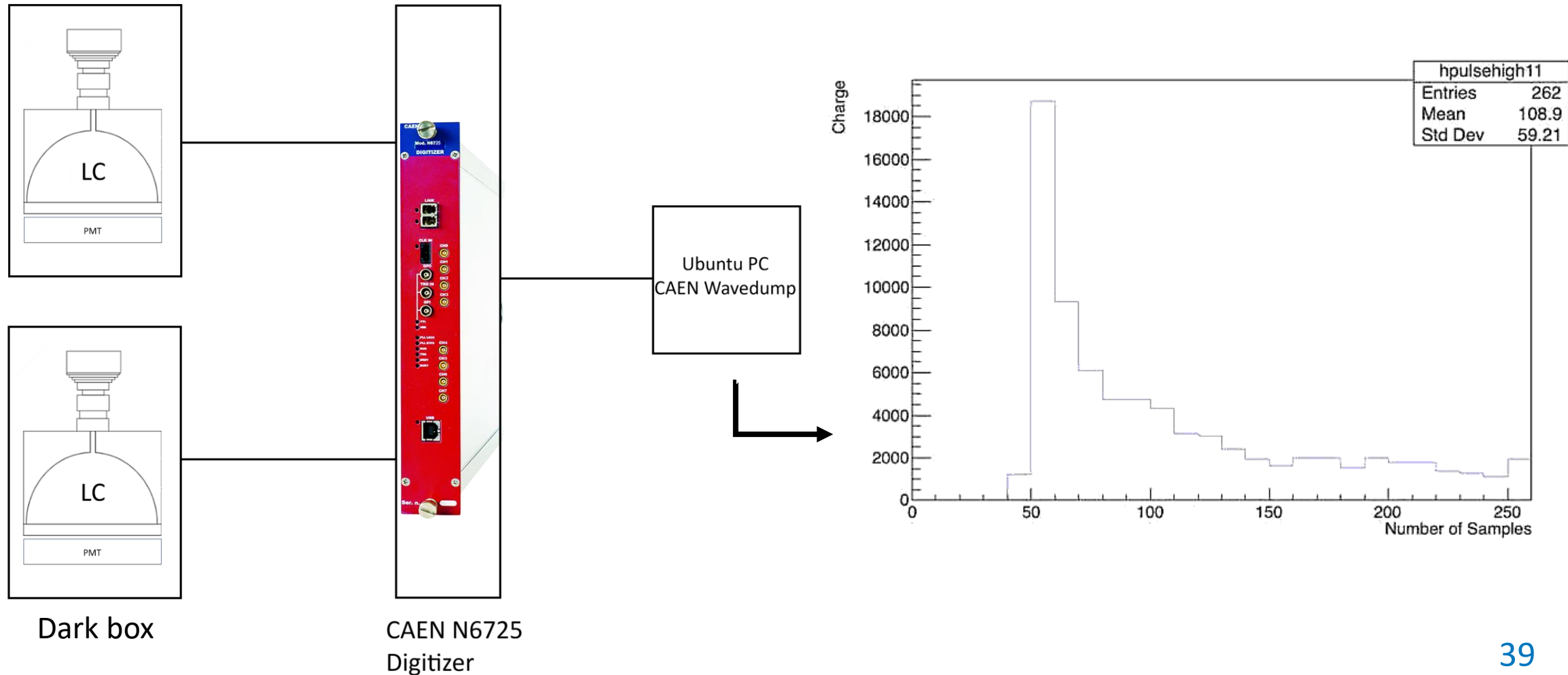
Principle of operation



Principle of operation

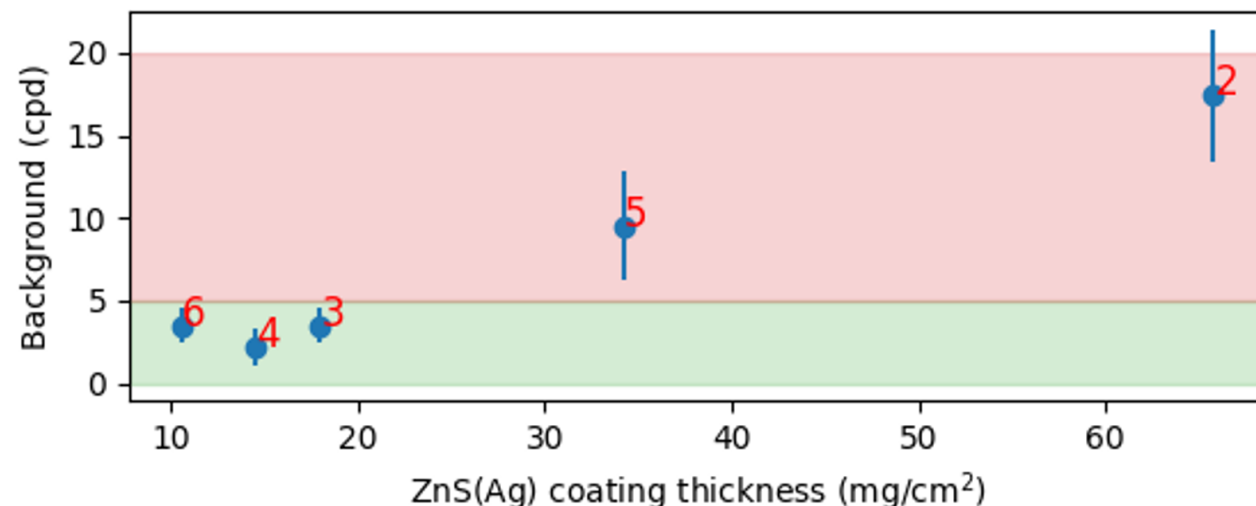


Principle of operation



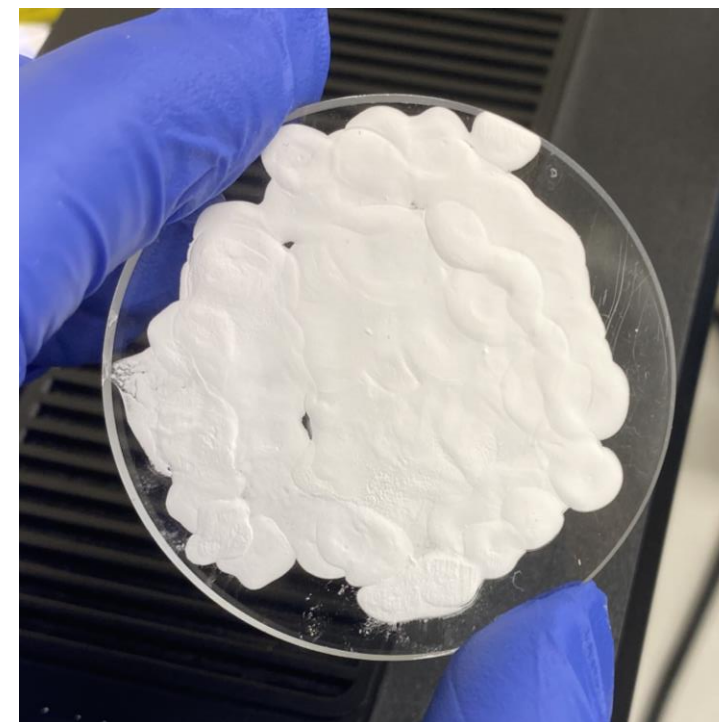
Lucas cell backgrounds

- Radon assays are background limited by Lucas cells!
- Intrinsic background due to Lucas cell materials
- ZnS scintillator is greatest background contributor in Lucas cells
- Current Lucas cells use most radiopure ZnS commercially available



Alpha scintillation test

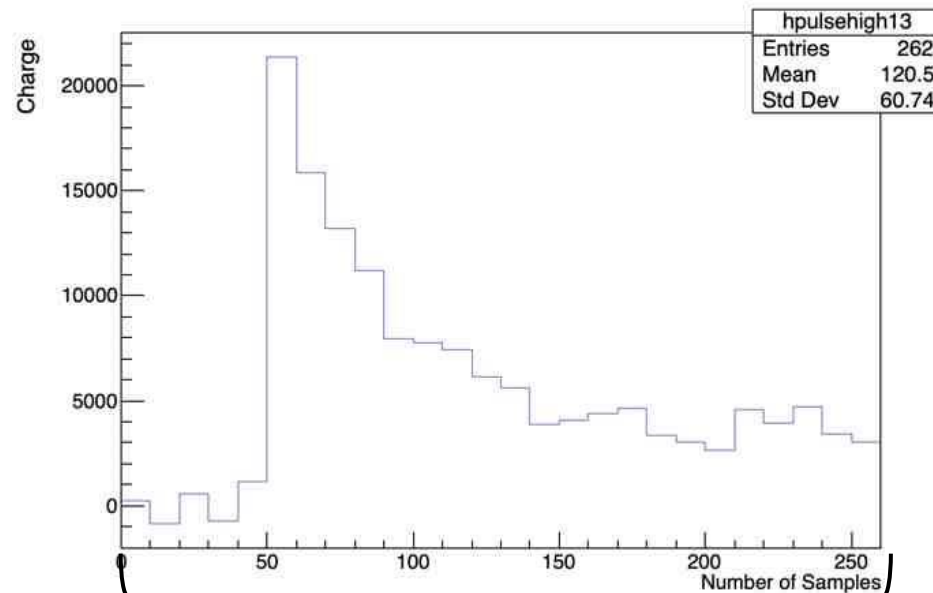
- ZnS painted on an acrylic disk may scintillate in response to alphas
- If PMTs detect alpha pulse:
 1. Our ZnS is sensitive to alphas, AND
 2. Our PMTs are sensitive to light emitted by our ZnS



A working Rn counter

```
-bash-4.2$ ./AlphaCounting_v3.exe ../WaveDumpOutput/wave22025-08-08-170013.txt
Nday and Ndecays inday0 0 idayflag 0
0 0.00753361 0.115815 111111 chi2/ndf:: 184.626/16 par1par3ratio::0.249342
1 0.0207997 0.12161 44677.2 chi2/ndf:: 189.831/16 par1par3ratio:: -0.669627
2 0.0219608 0.113885 87124.9 chi2/ndf:: 164.365/16 par1par3ratio::0.298249
3 0.0252756 0.133403 41076.6 chi2/ndf:: 167.899/16 par1par3ratio:: -1.47887
4 0.0254053 0.165871 89852.7 chi2/ndf:: 198.421/16 par1par3ratio::0.0555701
```

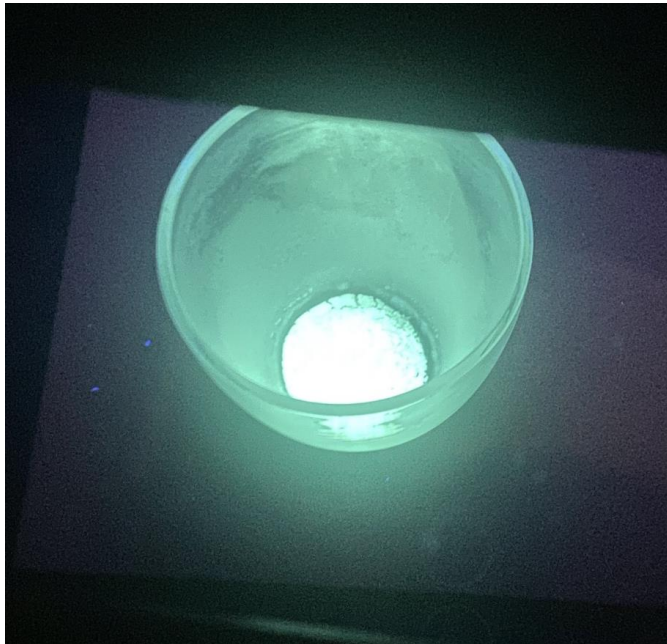
These are
alphas!



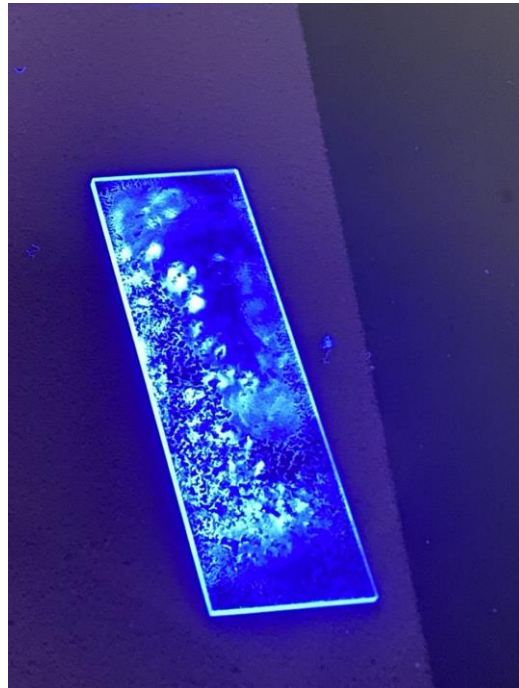
Sample
alpha trace

4 μ s window

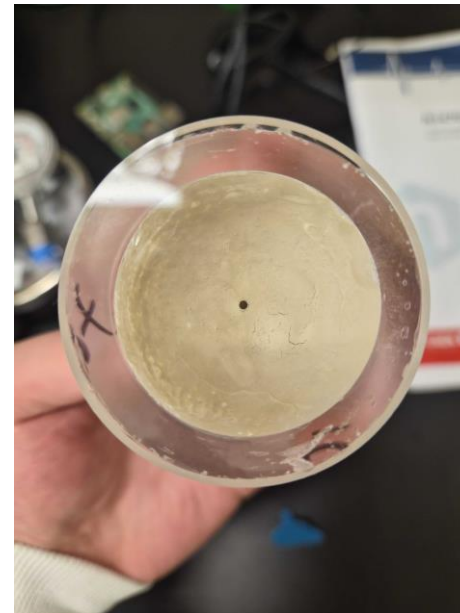
First Lucas cells with SNOLAB ZnS



SNOLAB ZnS



Commercial ZnS

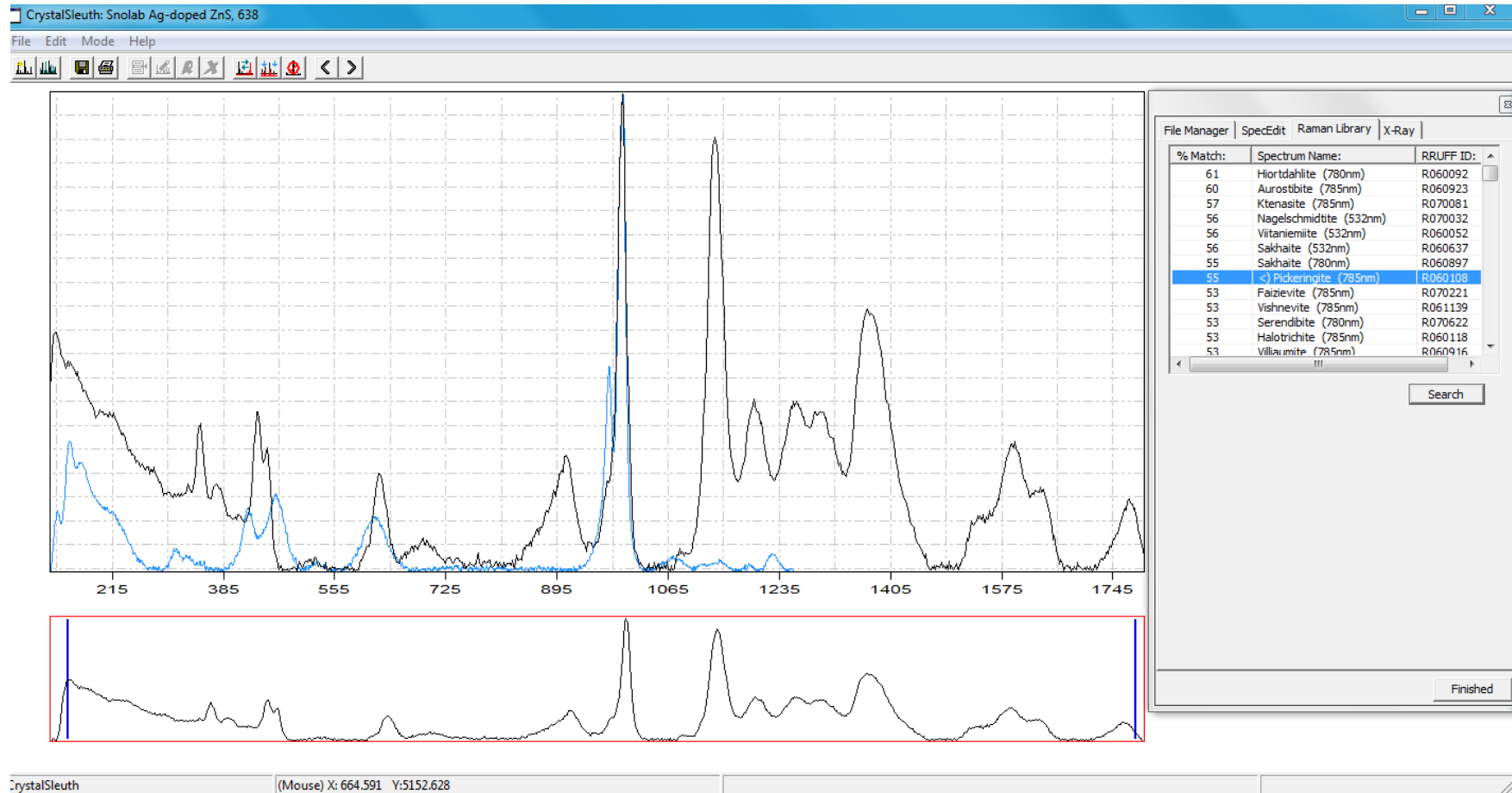


SNOLAB ZnS

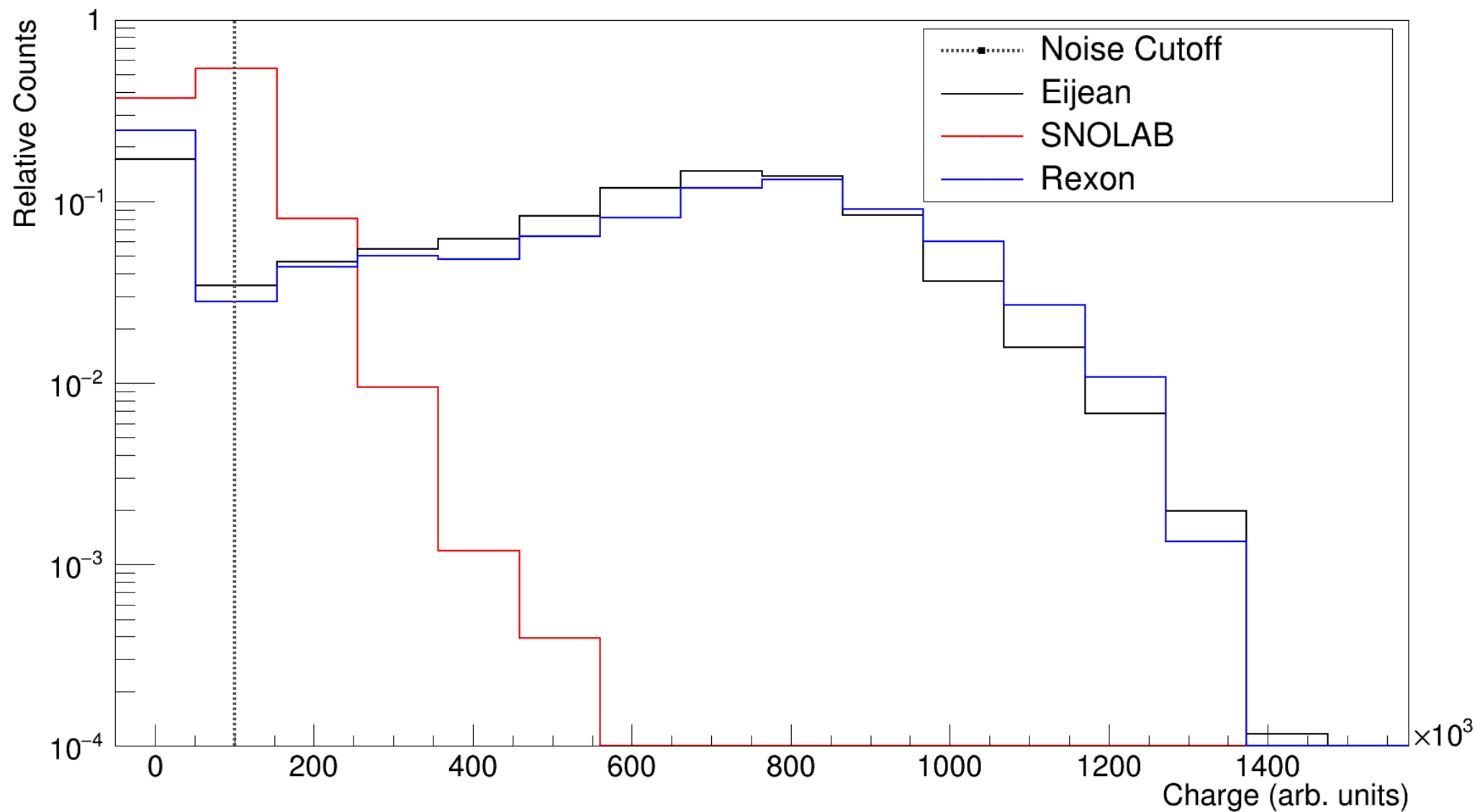


Commercial ZnS

Insights from Raman spectroscopy



Alpha Pulse Charges (Normalized)



Credit: Connor Stubbs

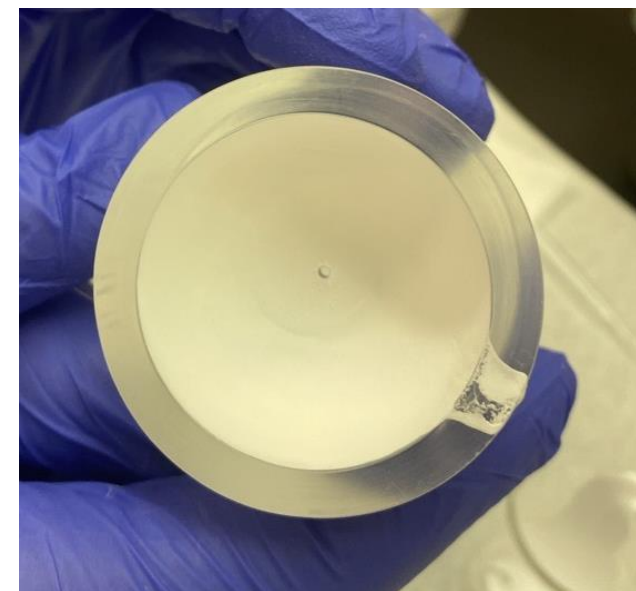
Summary

Determined the source of Lucas cell backgrounds

Developed method to fabricate Lucas cells/low-background ZnS

Developed a procedure to rapidly produce and test scintillator for Lucas cells

Identified ZnO presence as obstacle in usability of SNOLAB ZnS



Outlook and next steps

- SNOLAB has acquired a vacuum furnace for production of ZnS in low-oxygen environment
- A calibrated radon source is also being procured for precision measurement of counting efficiency of Lucas cells

Acknowledgements

- Nasim Fatemighomi
- Lina Anselmo
- Steve Maguire
- Scientific Support
- Keegan Paleshi
- Connor Stubbs
- Varshini Rajakumaran



Thanks for listening!

Questions?

Backup slides

ZnS alpha background

- ZnS alpha background varies by manufacturer
- Current standard for Lucas cells is 3-4 cpd
- Motivates us to investigate synthesizing our own

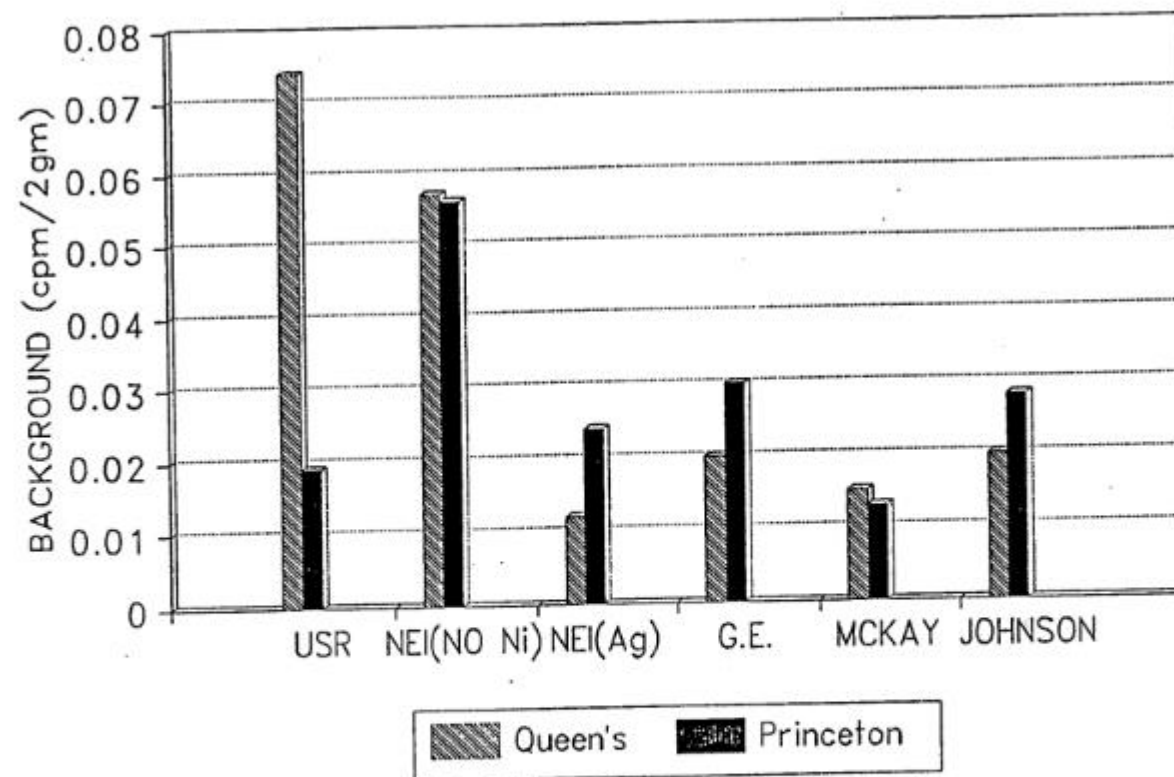


Figure 3.6: The alpha background of different ZnS samples.

The SNOLAB Radon assay

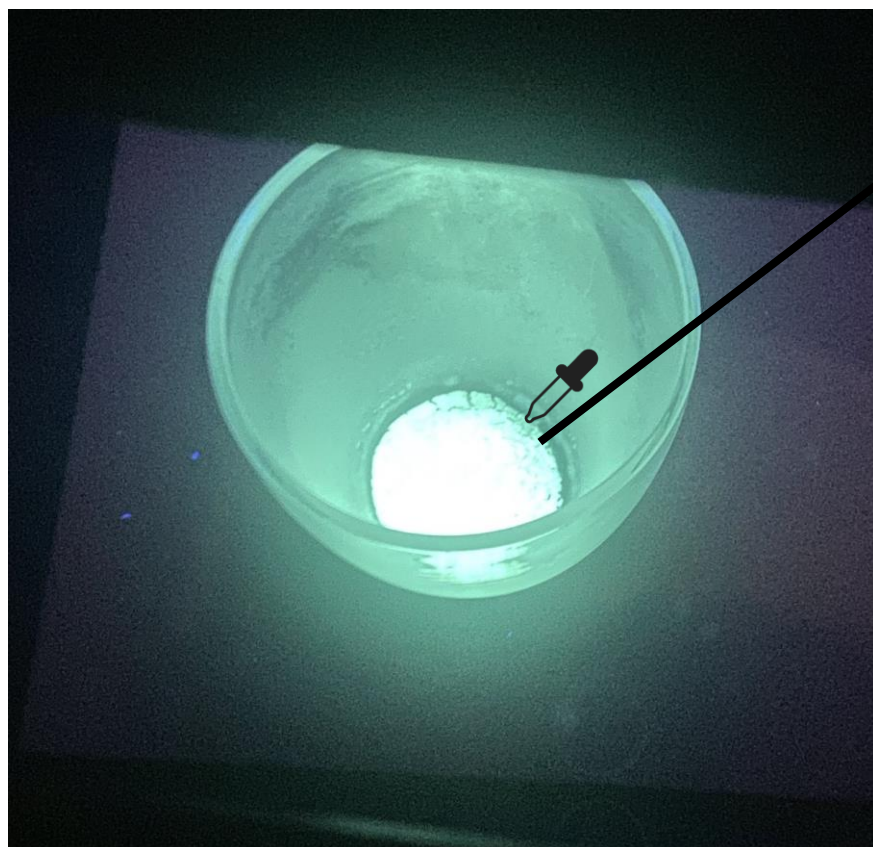


UPW plant Radon board, 2000 (Credit: SNO)

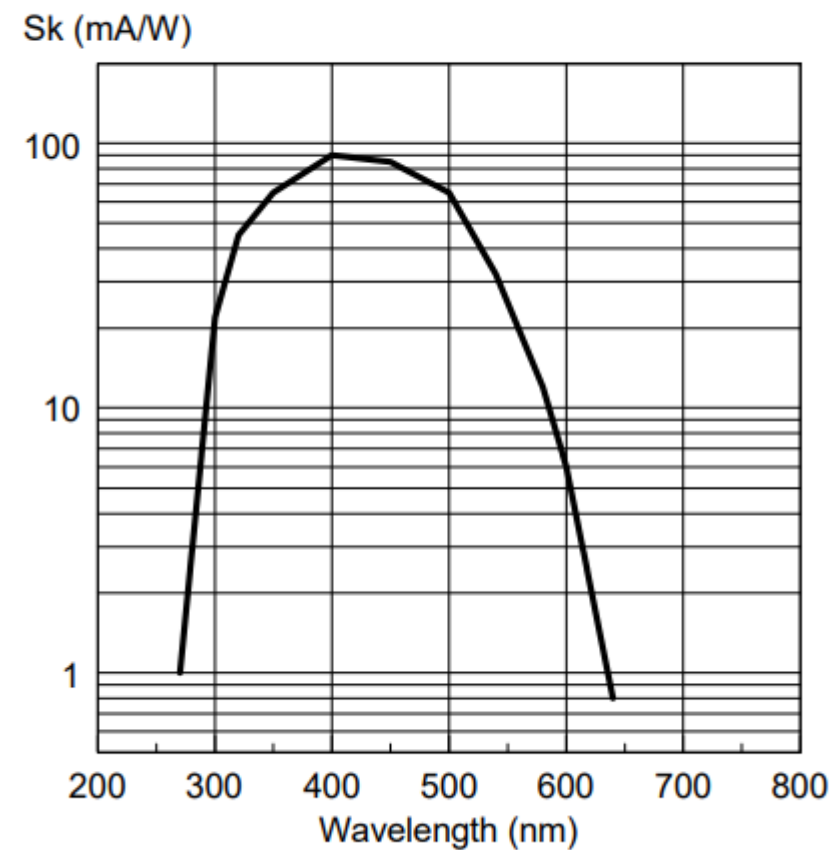


UPW plant Radon board, 2026

Typical spectral characteristics

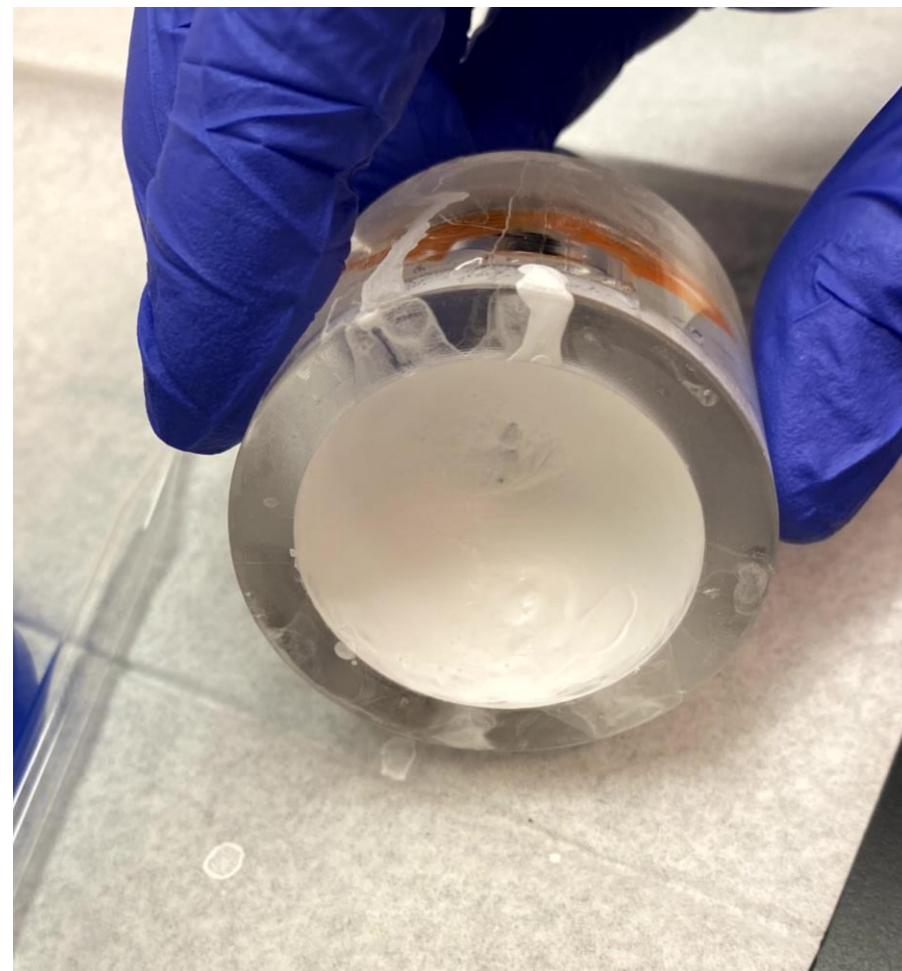


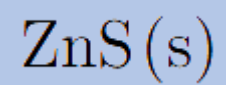
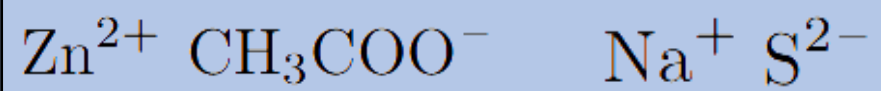
rgb(0, 255, 203)
Hex: #00ffcb
 $\lambda = 495 \text{ nm}$



XP2262

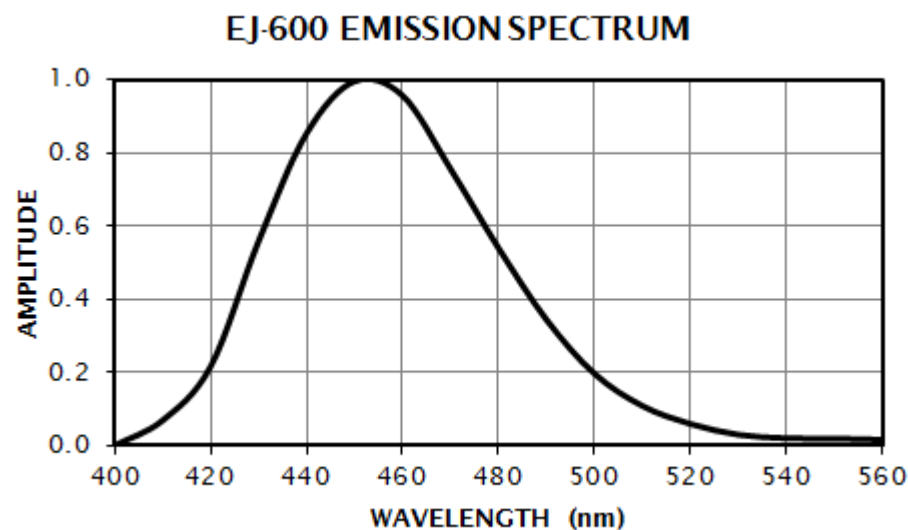
Lucas cell coating: process





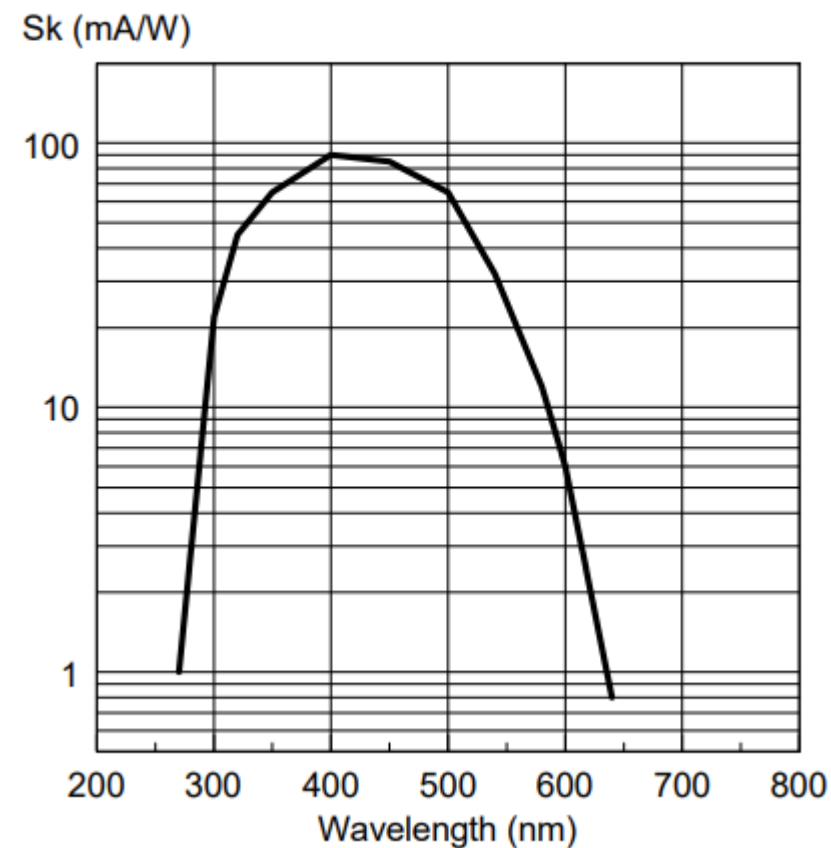
ZnS luminescence goals

- Commercial ZnS emits around 450nm, while our PMTs are most sensitive around 420 nm



Commercial ZnS(Ag) emission spectrum

Typical spectral characteristics



XP2262

Light sensitivity of Philips XP2262 PMTs

Improving the radon assay starts with improved Lucas cells