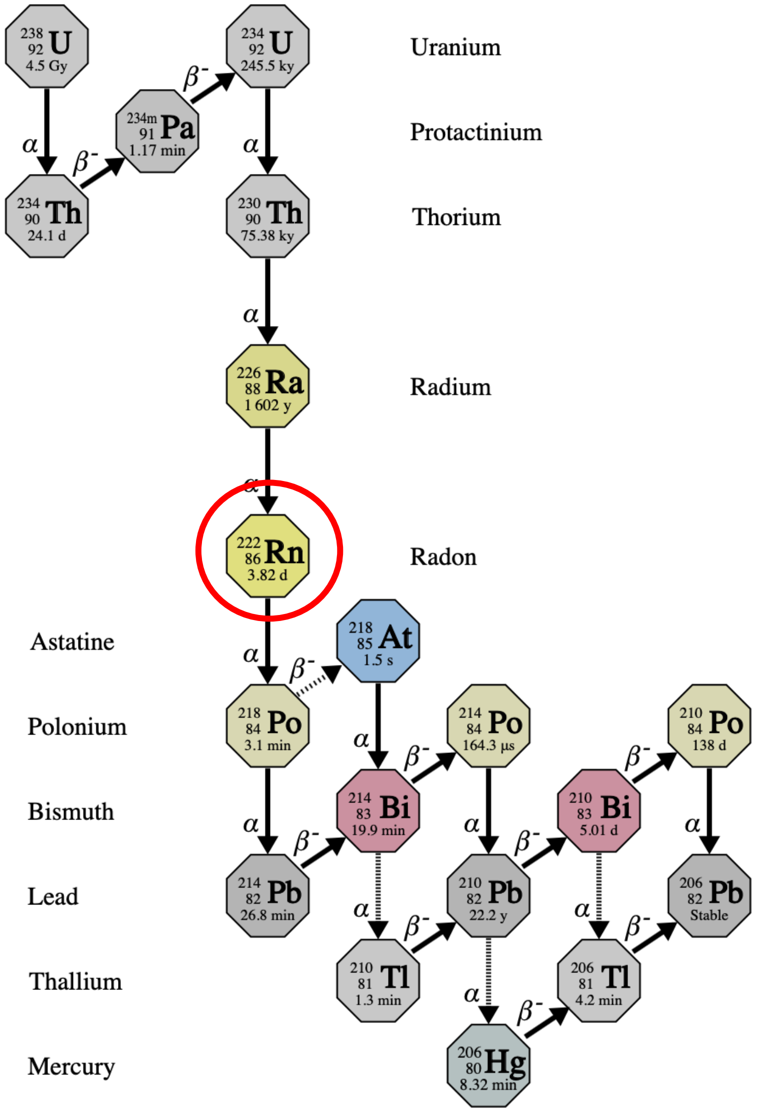
2026/07/22

Improving SNOLAB Radon counting sensitivity with low-background ZnS

Peter Qin (He/Him)

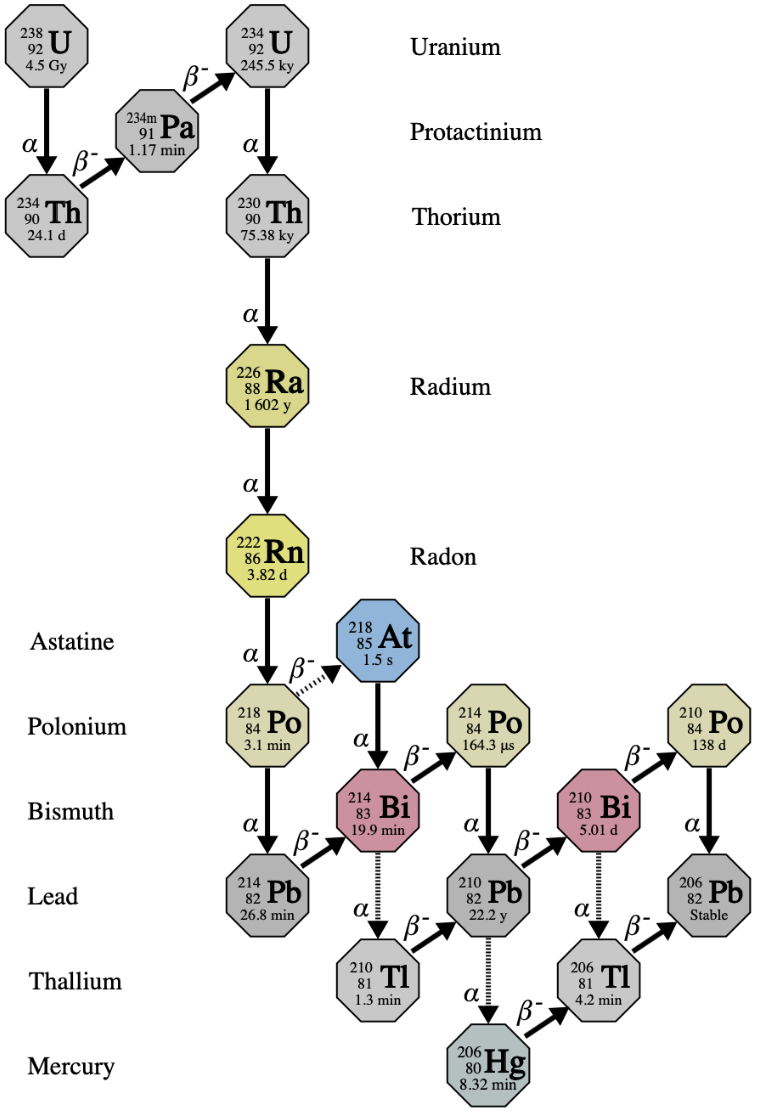
Research Assistant

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



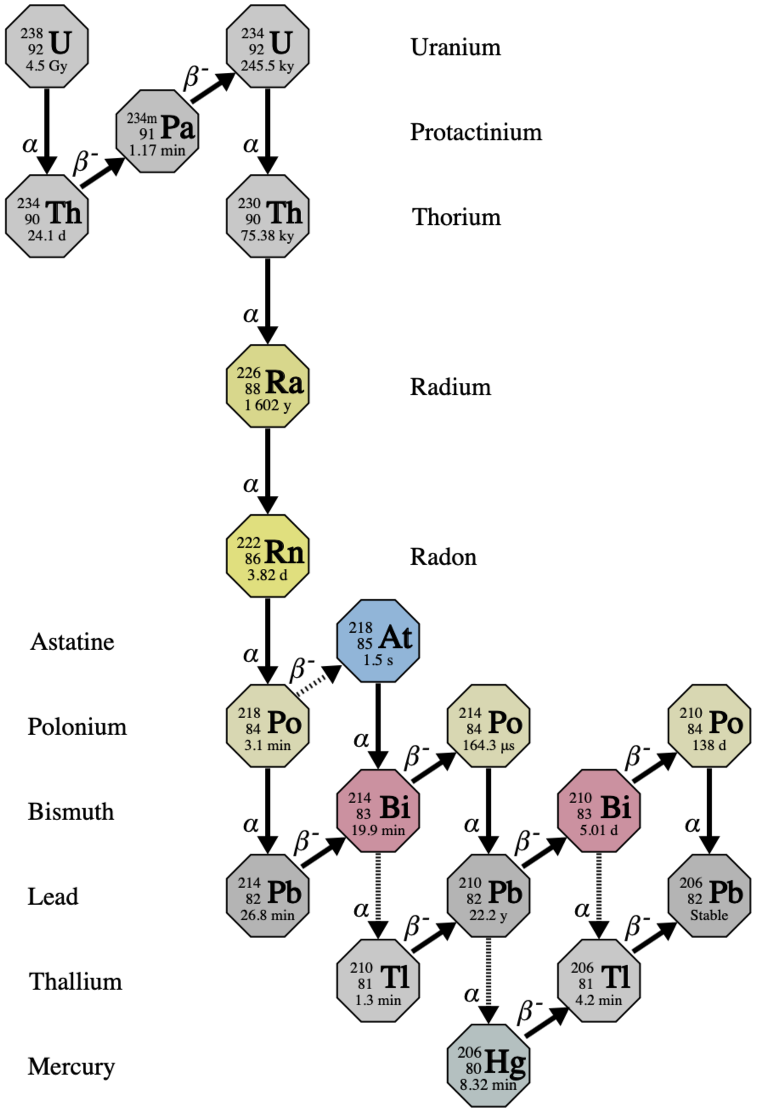
^{238}U chain and ^{222}Rn

- Abundant underground



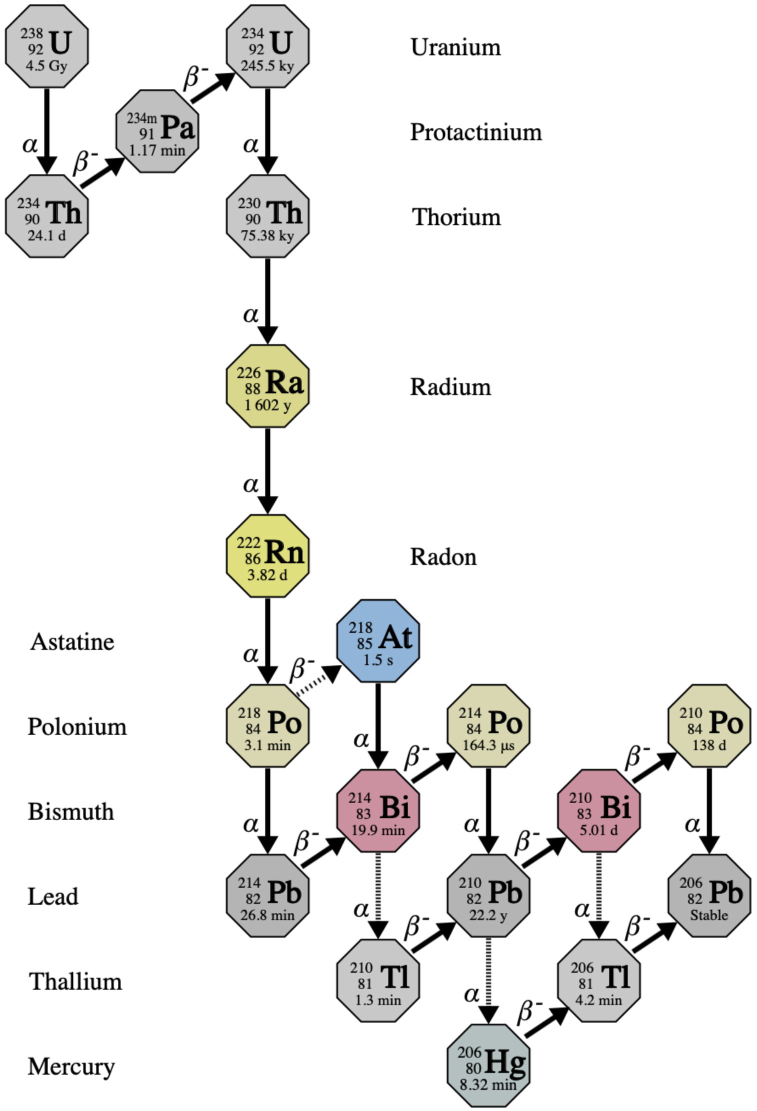
^{238}U chain and ^{222}Rn

- 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

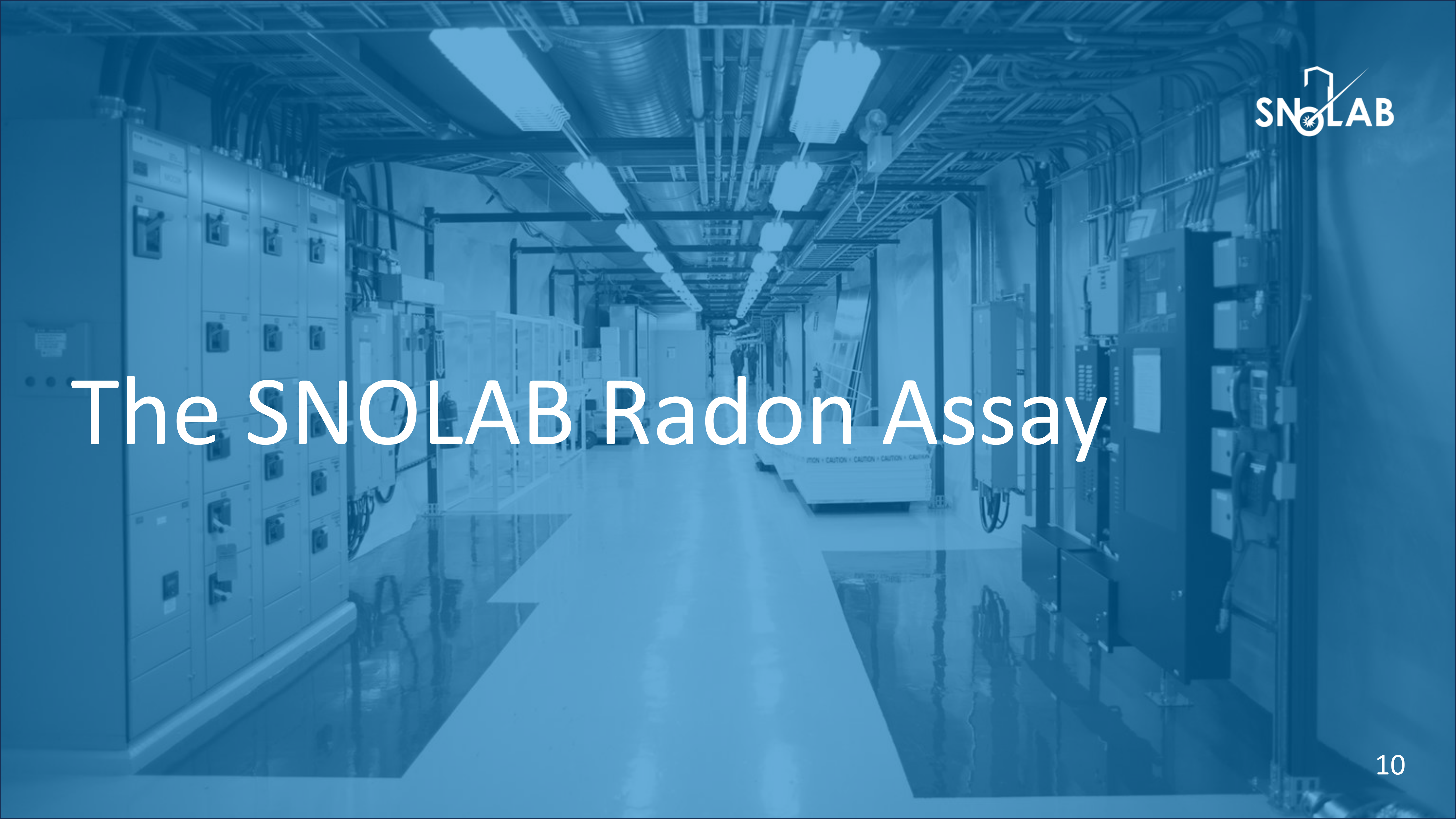
Radon control at SNOLAB

- Lab infrastructure
- Surface prep (etching/passivation)

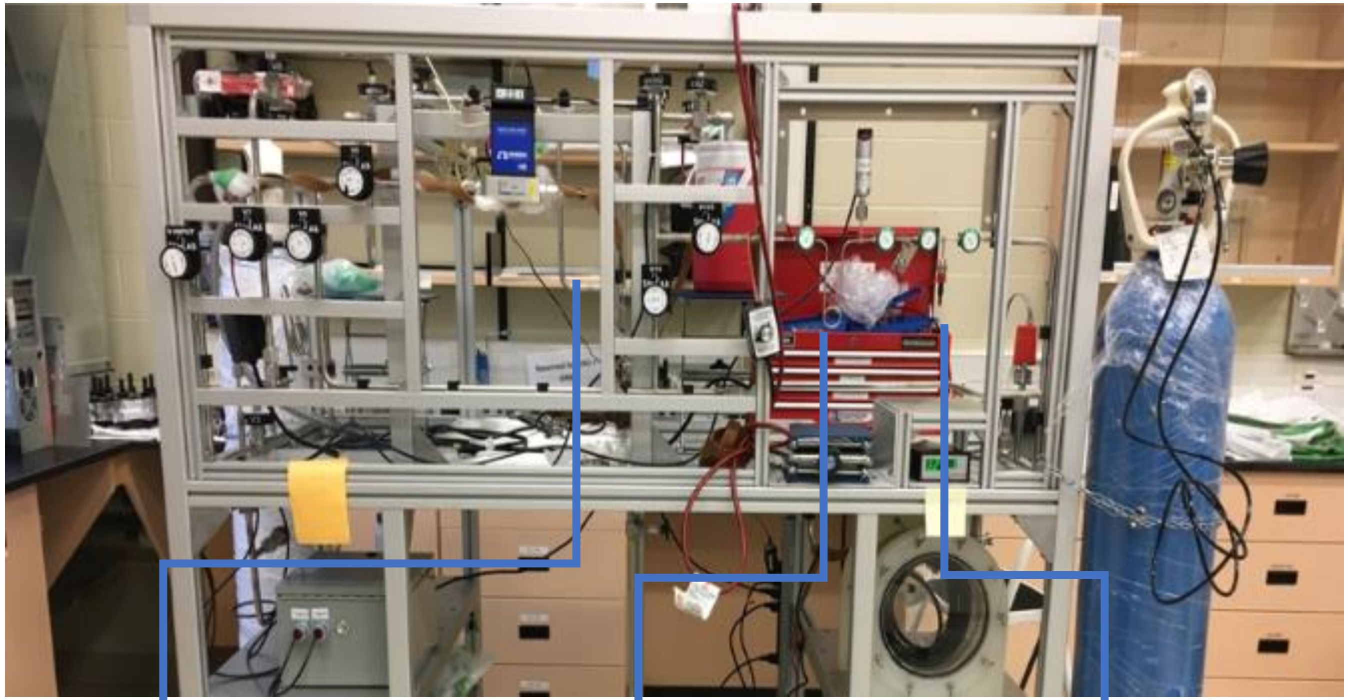
Radon control at SNOLAB

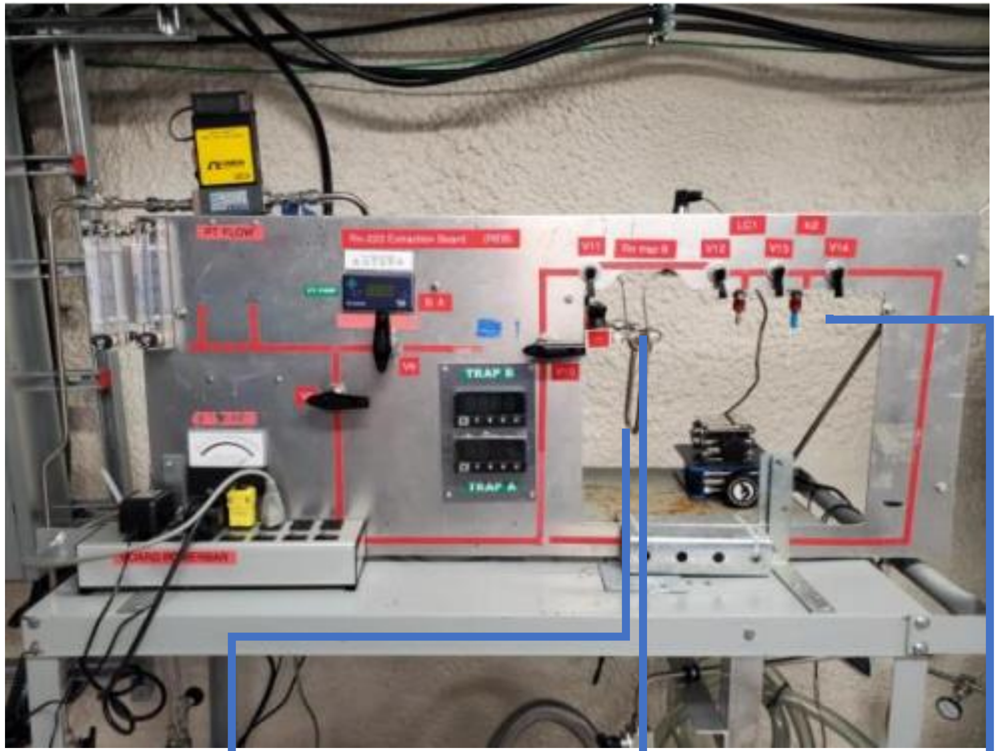
- Lab infrastructure
- Cleanroom fabrication, surface prep (etching/passivation)
- Materials screening program (ICP-MS, HPGe, XIA, etc.)

The SNOLAB Radon Assay



Radon assays





Primary trap

Concentrator trap

Port to scintillator cell

Primary trap

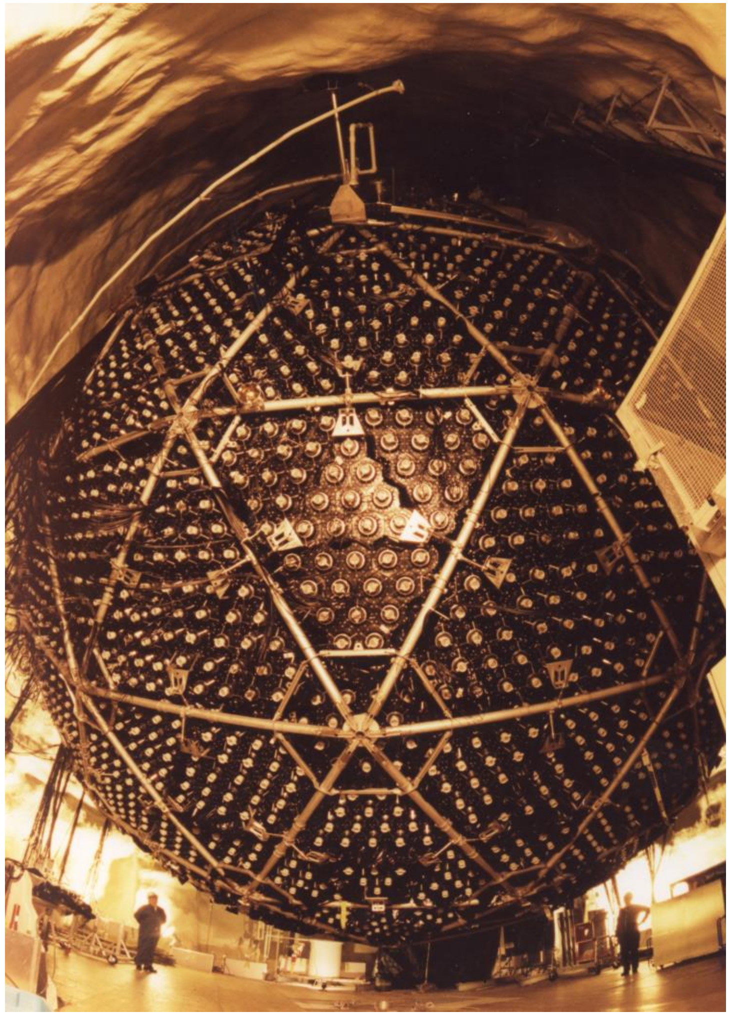
Concentrator trap

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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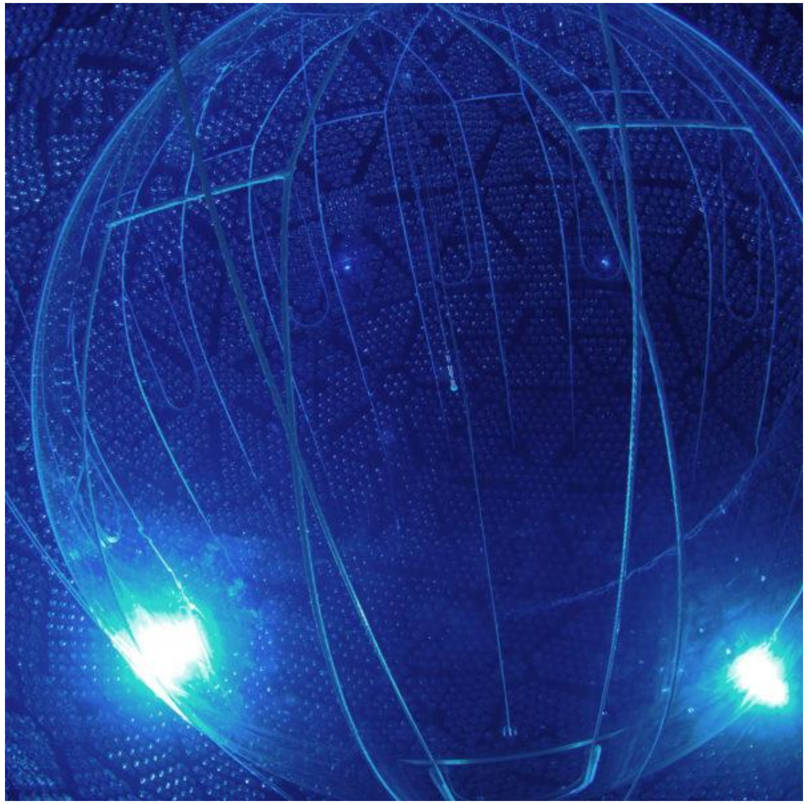

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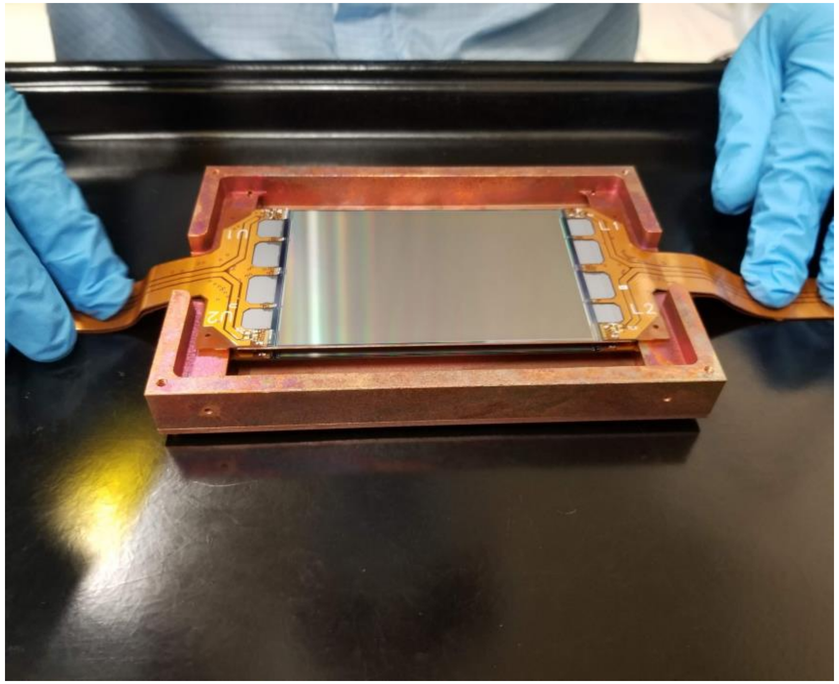

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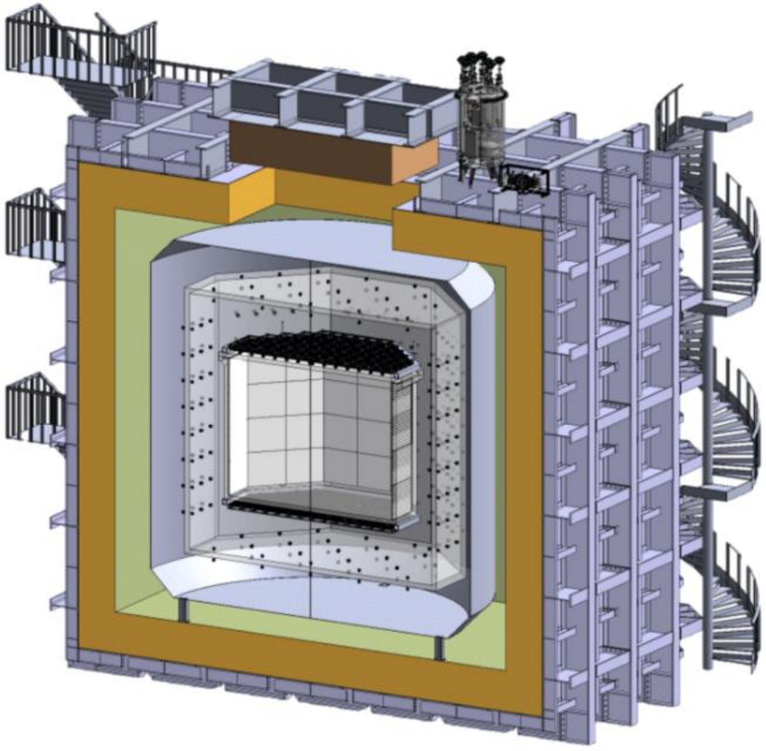

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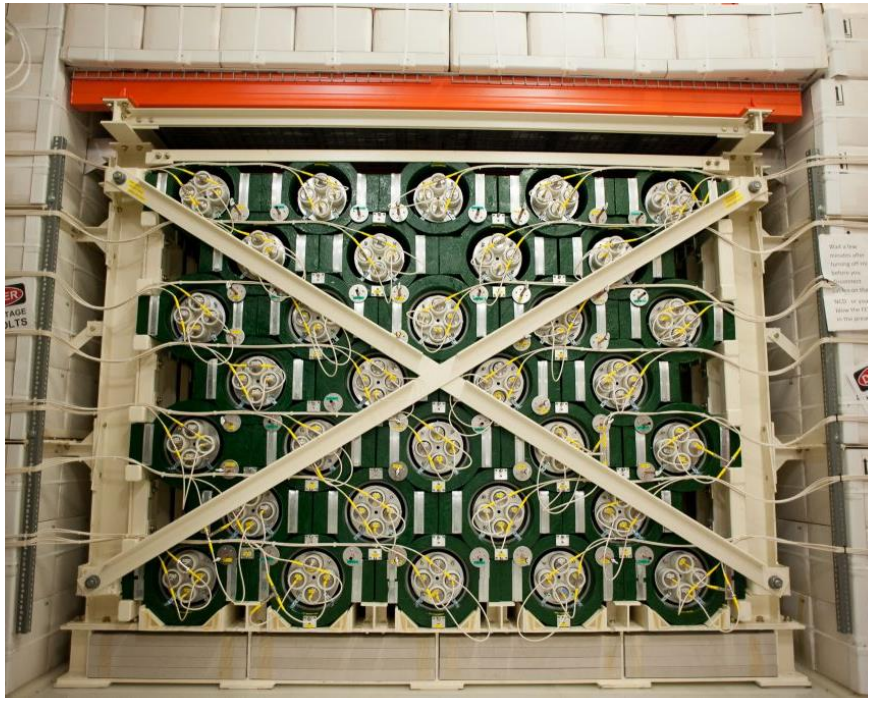
- PICO
- REPAIR
- SBC
- SENSEI
- SuperCDMS



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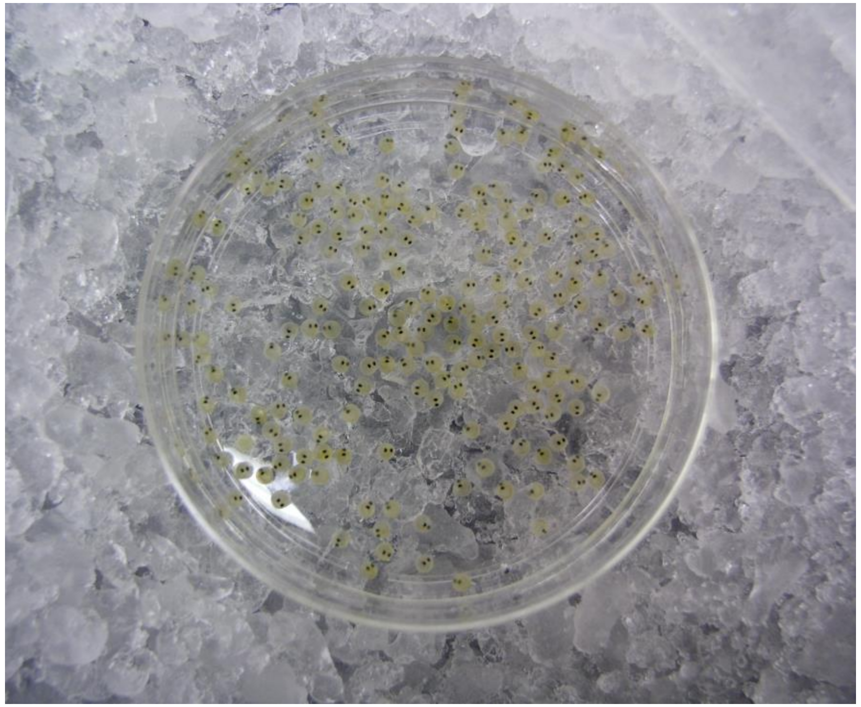

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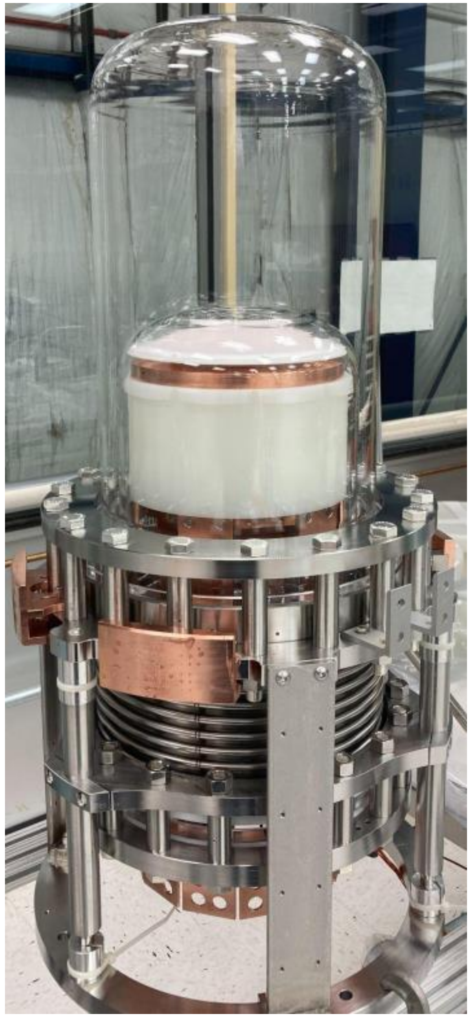

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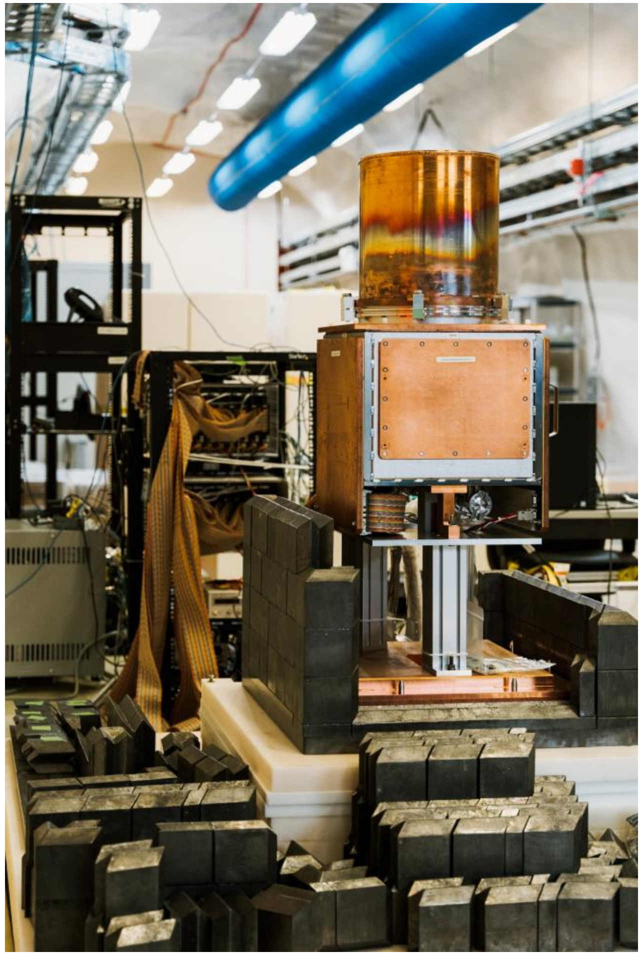

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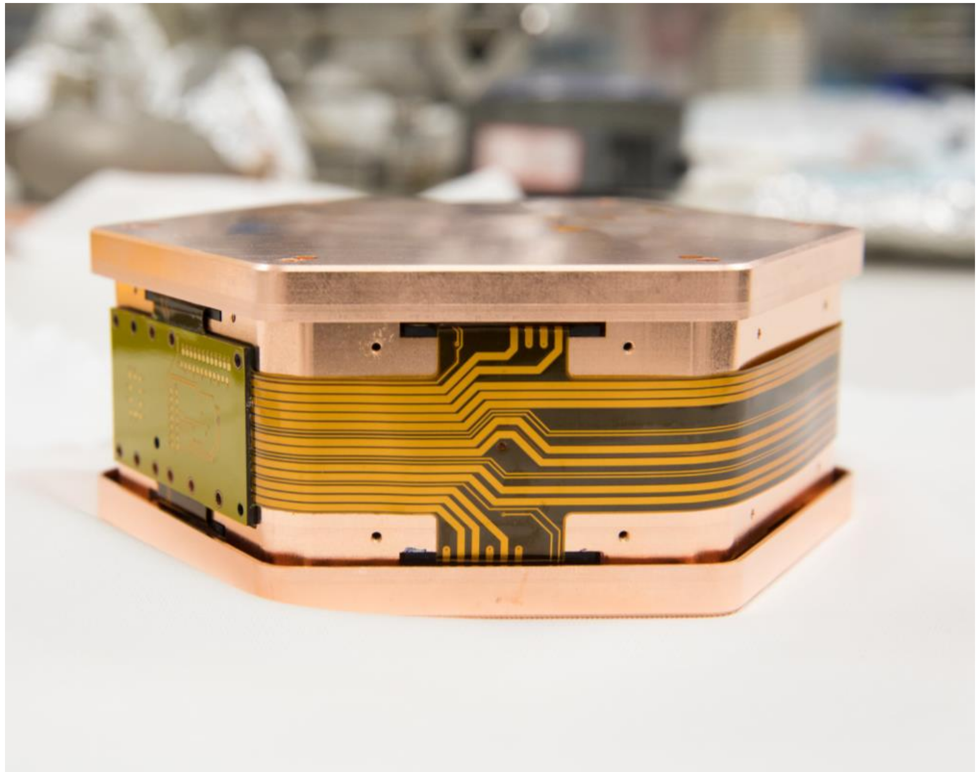

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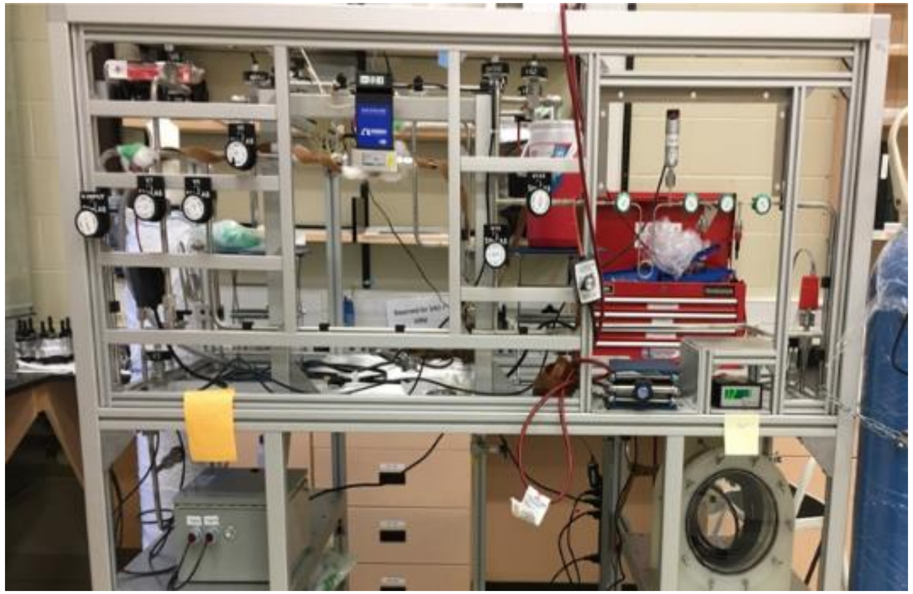
Improvements to SNOLAB Rn counting have far-reaching benefits for low-background science!

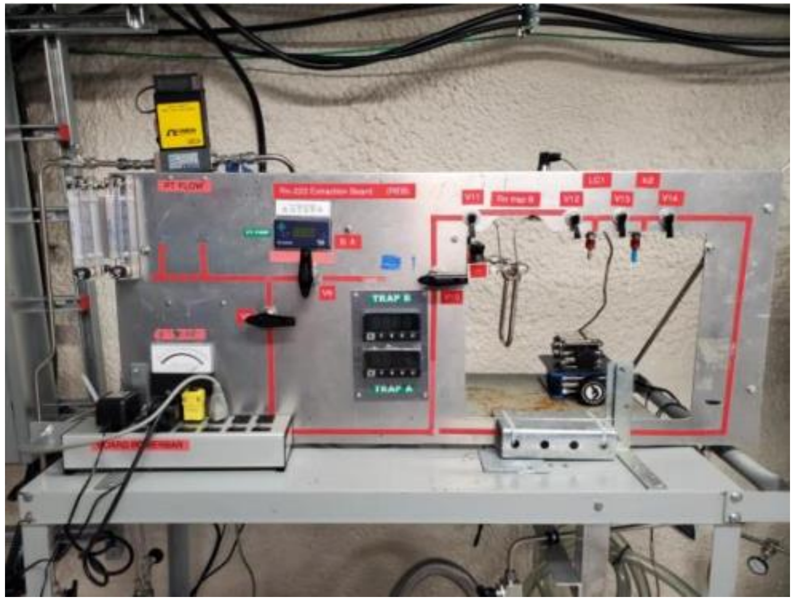
Maintaining and improving the Radon assay capability is a priority for SNOLAB

Improved sensitivity Rn assays

Four radon boards…

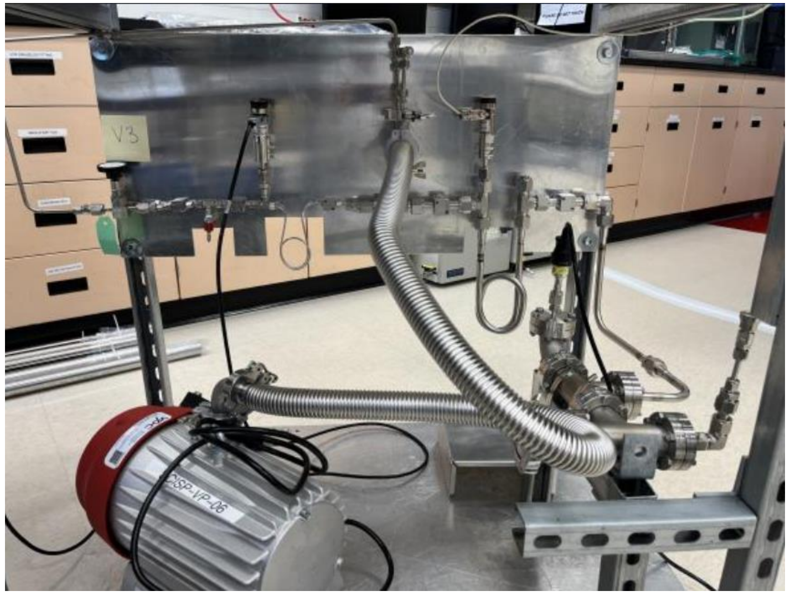
SNOLAB surface lab radon board





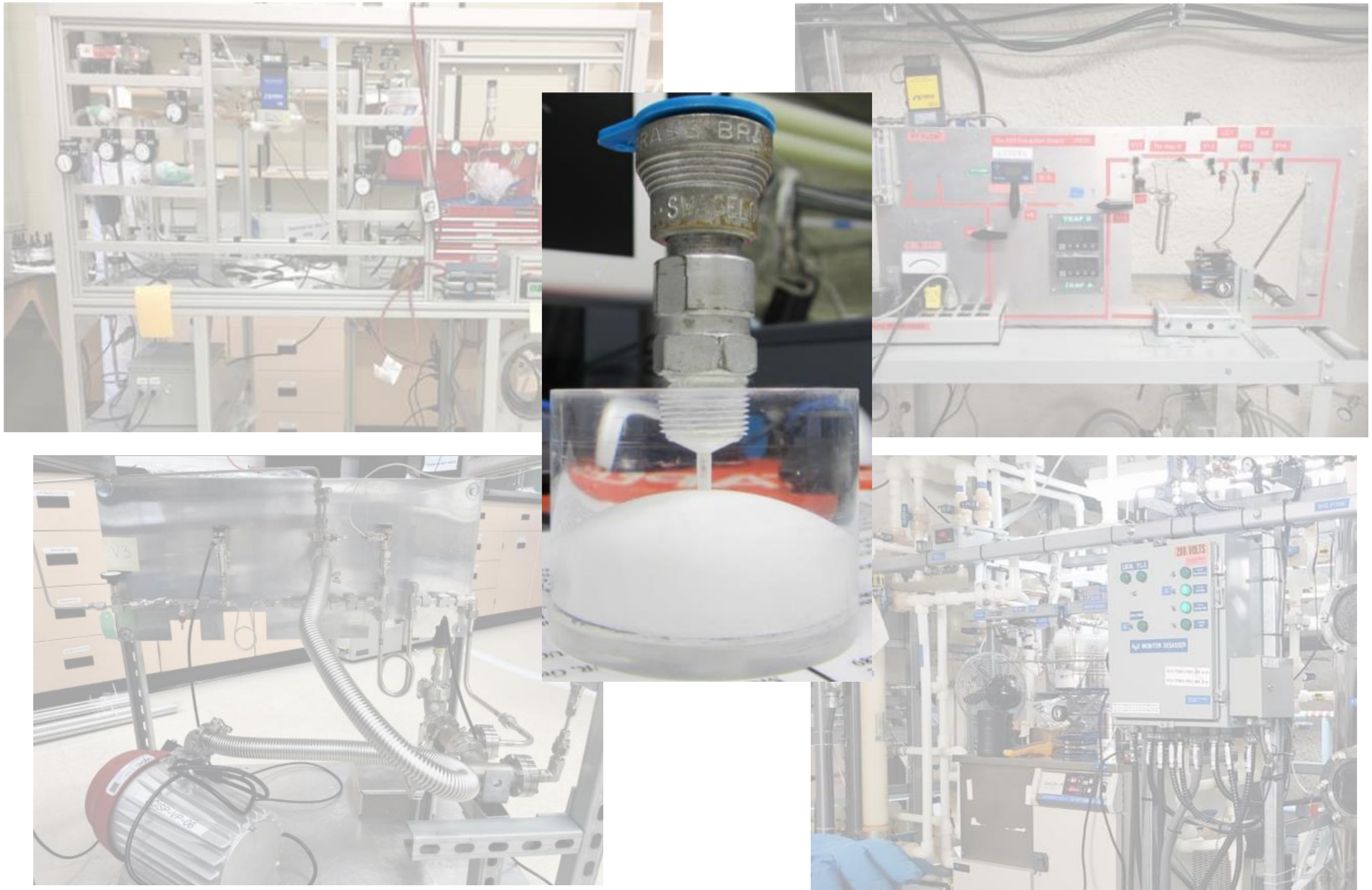
Underground mobile radon assay board

DEAP-3600 radon board



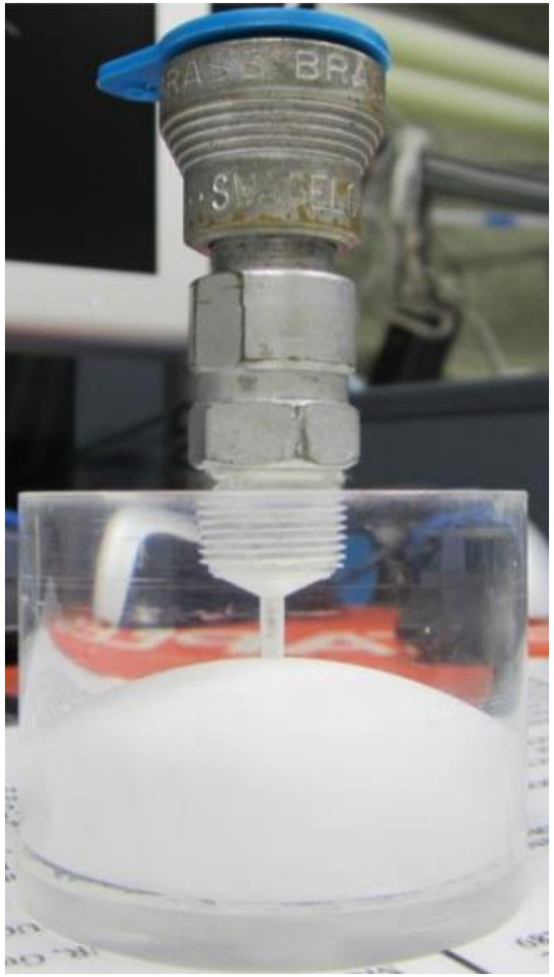
SNO+ UPW plant radon board

One Lucas cell!

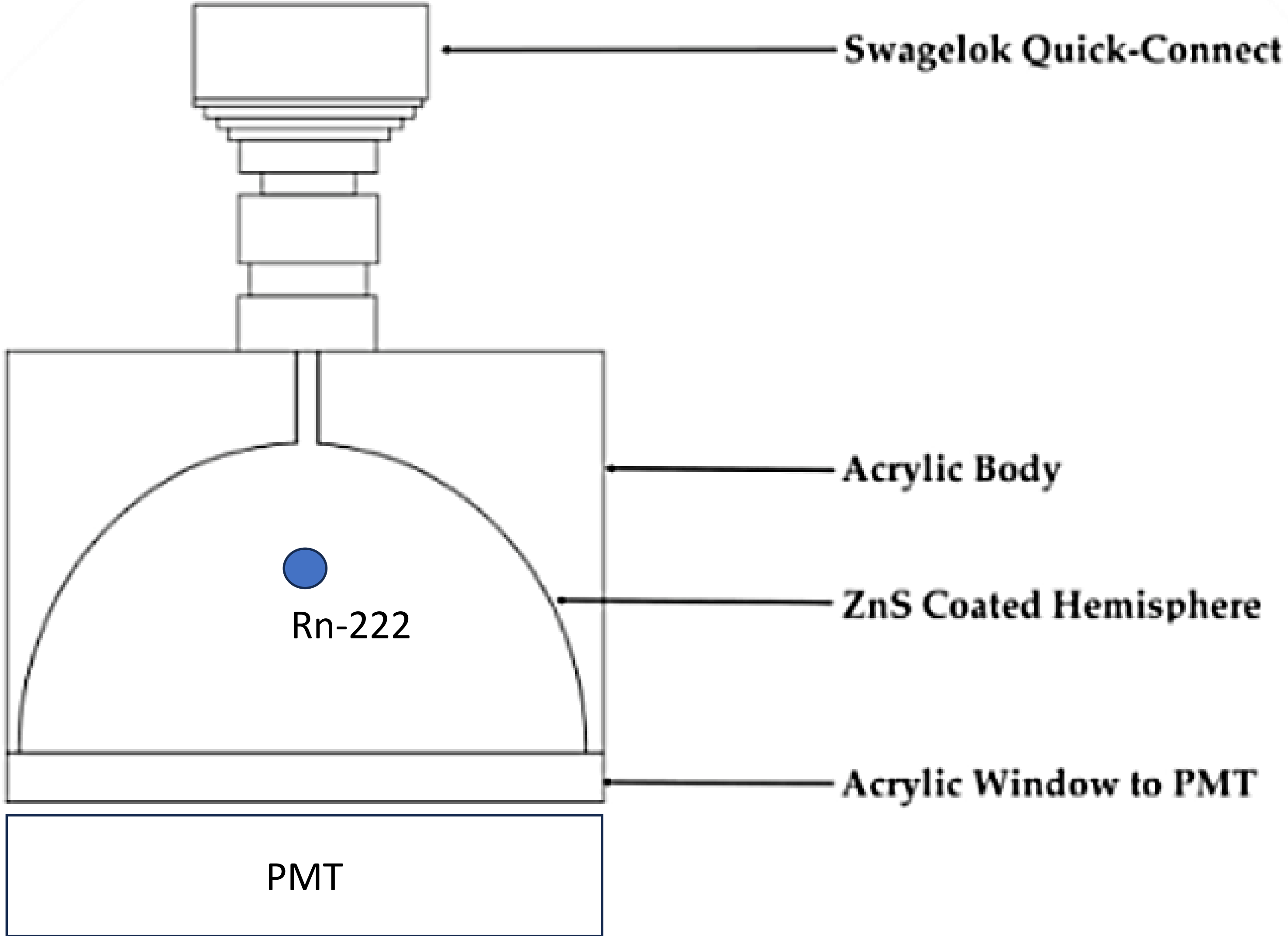


What are Lucas cells?

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



Principle of operation



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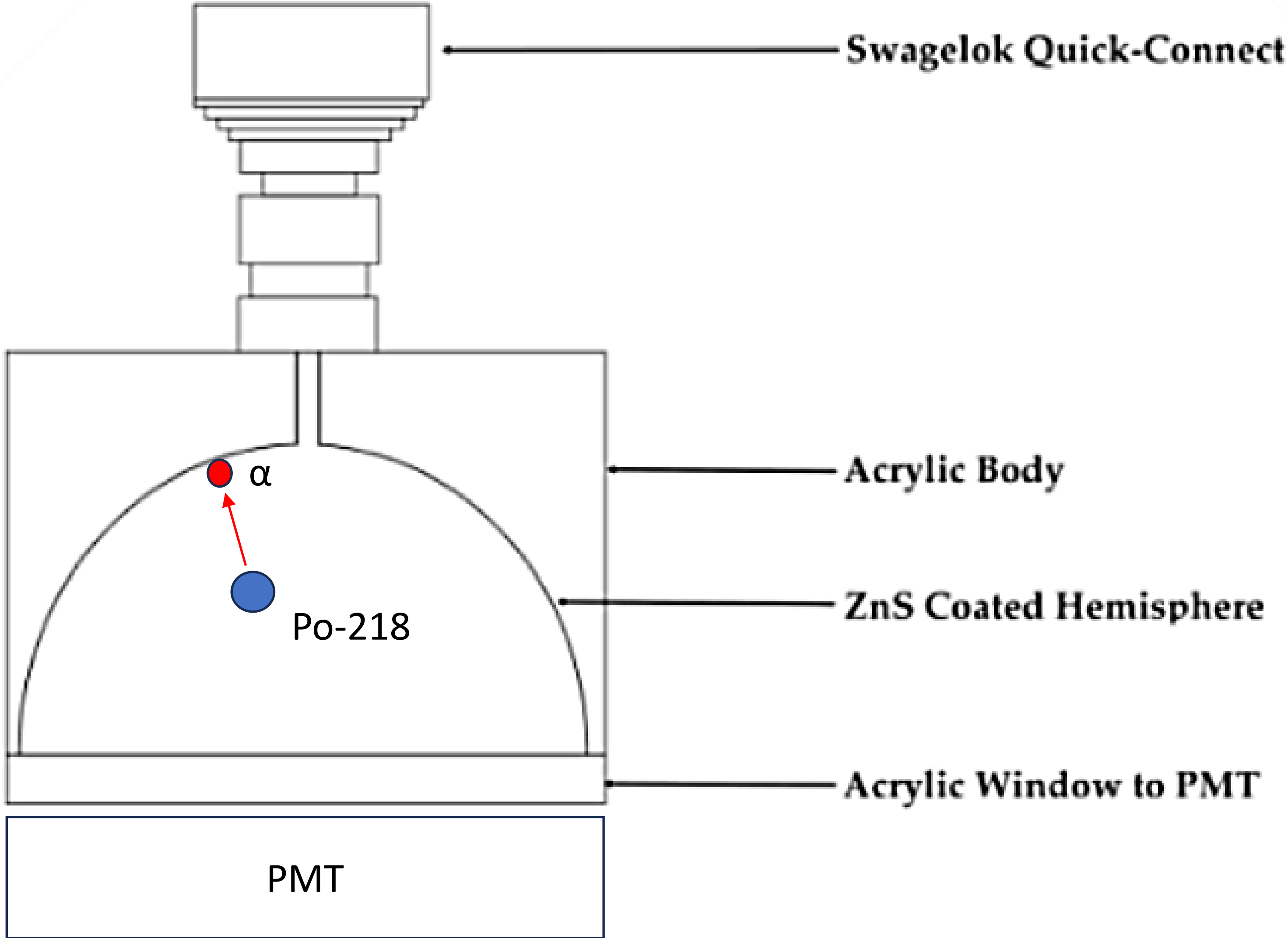

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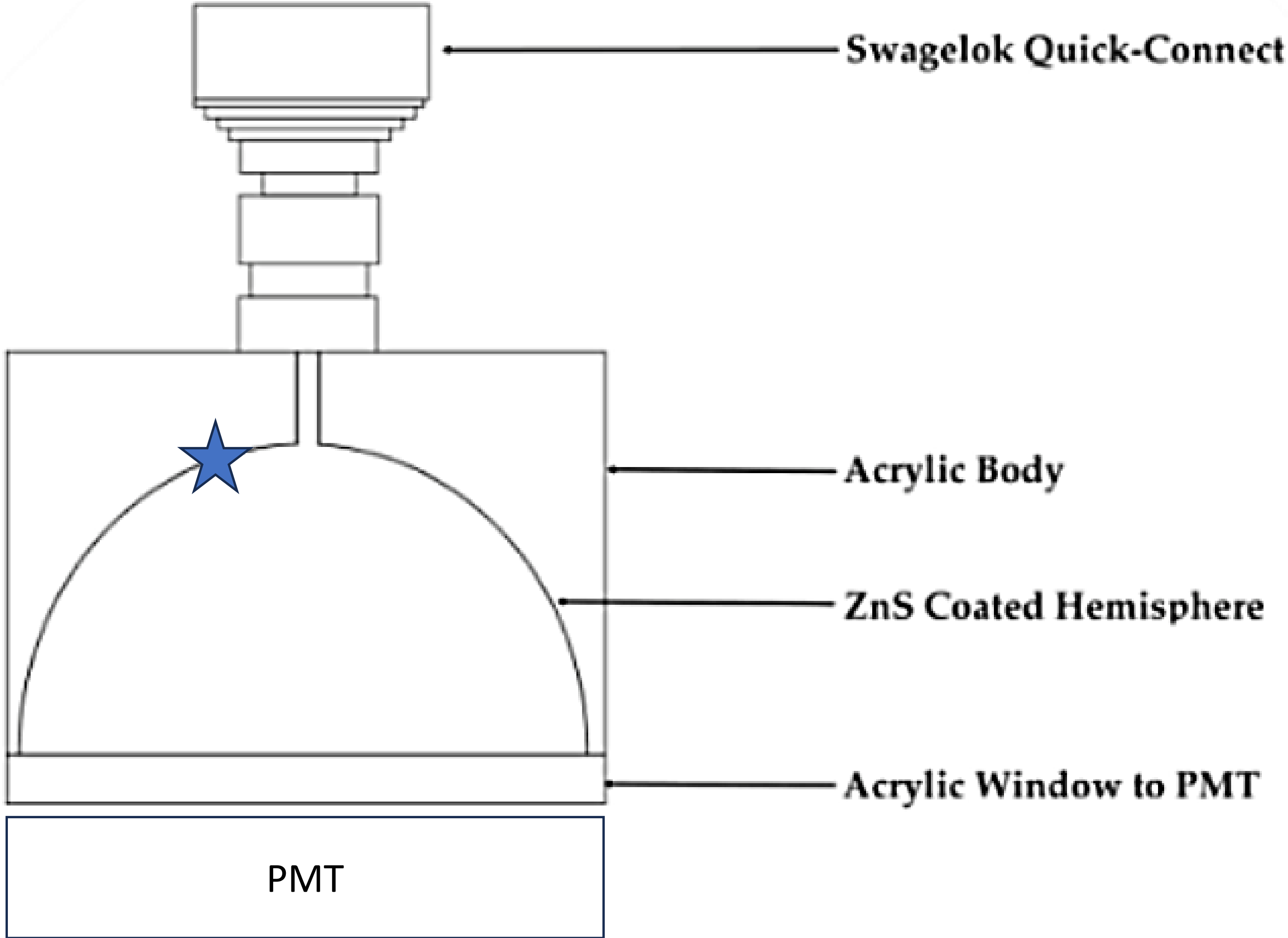

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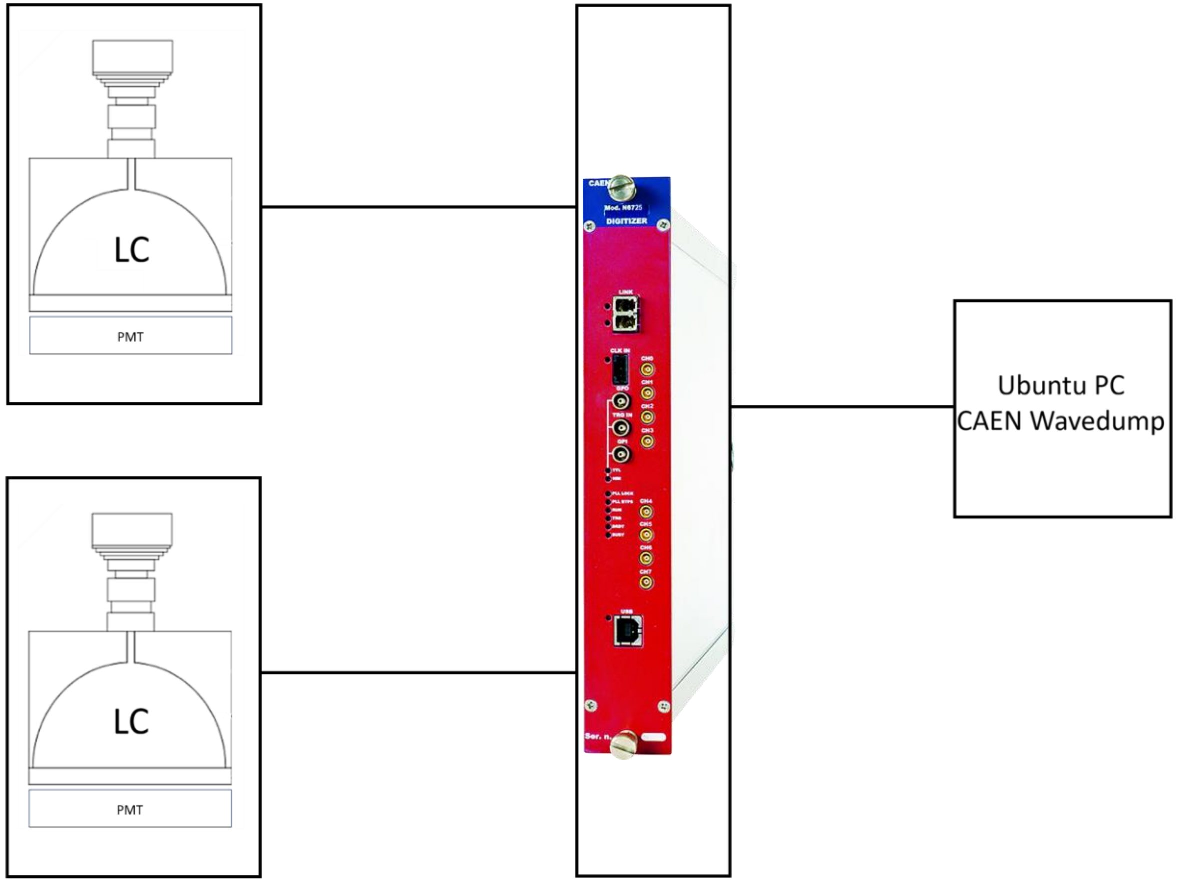
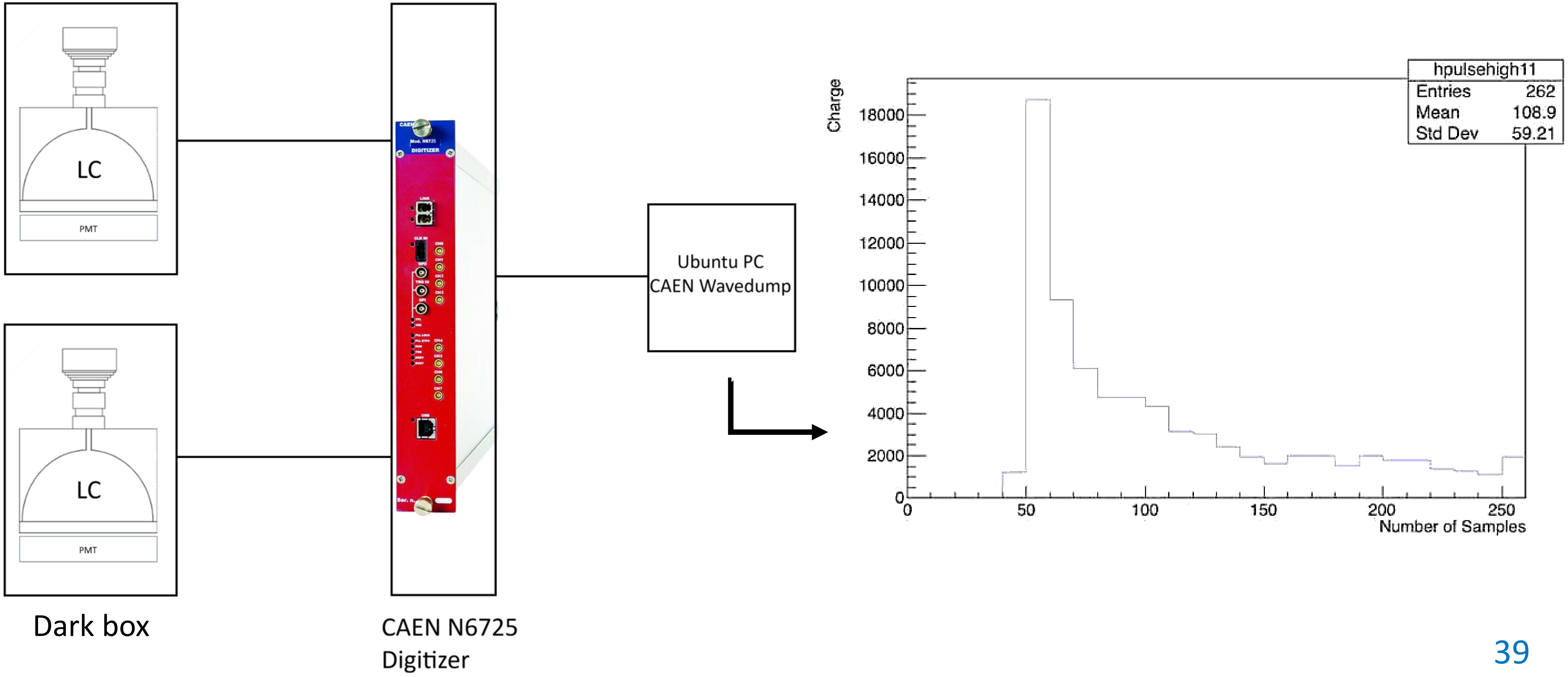


Dark box

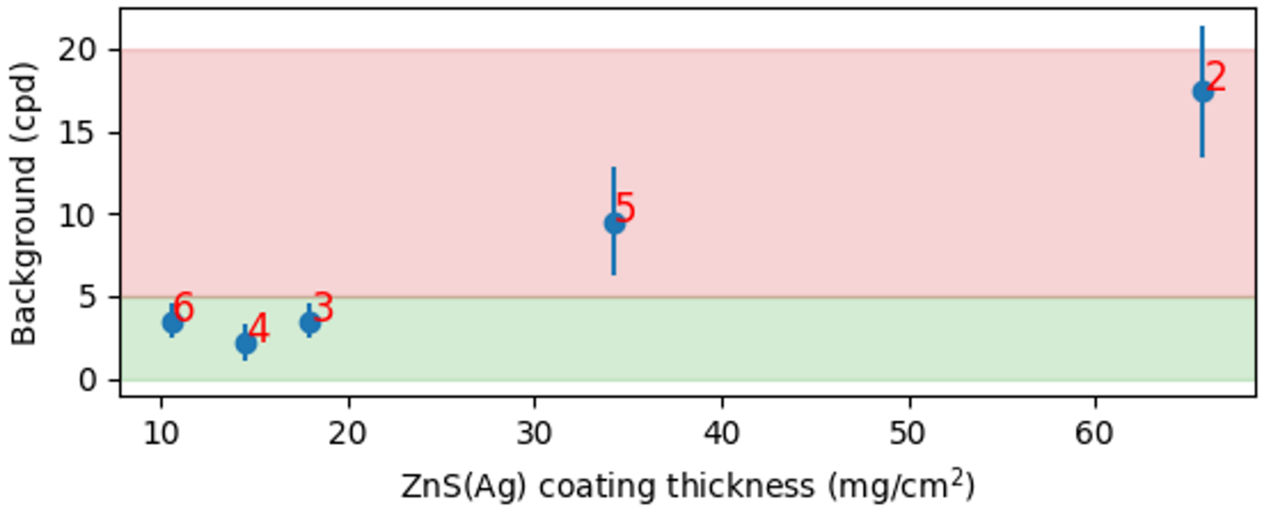
CAEN N6725
Digitizer

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



Can we produce our own low-background ZnS?

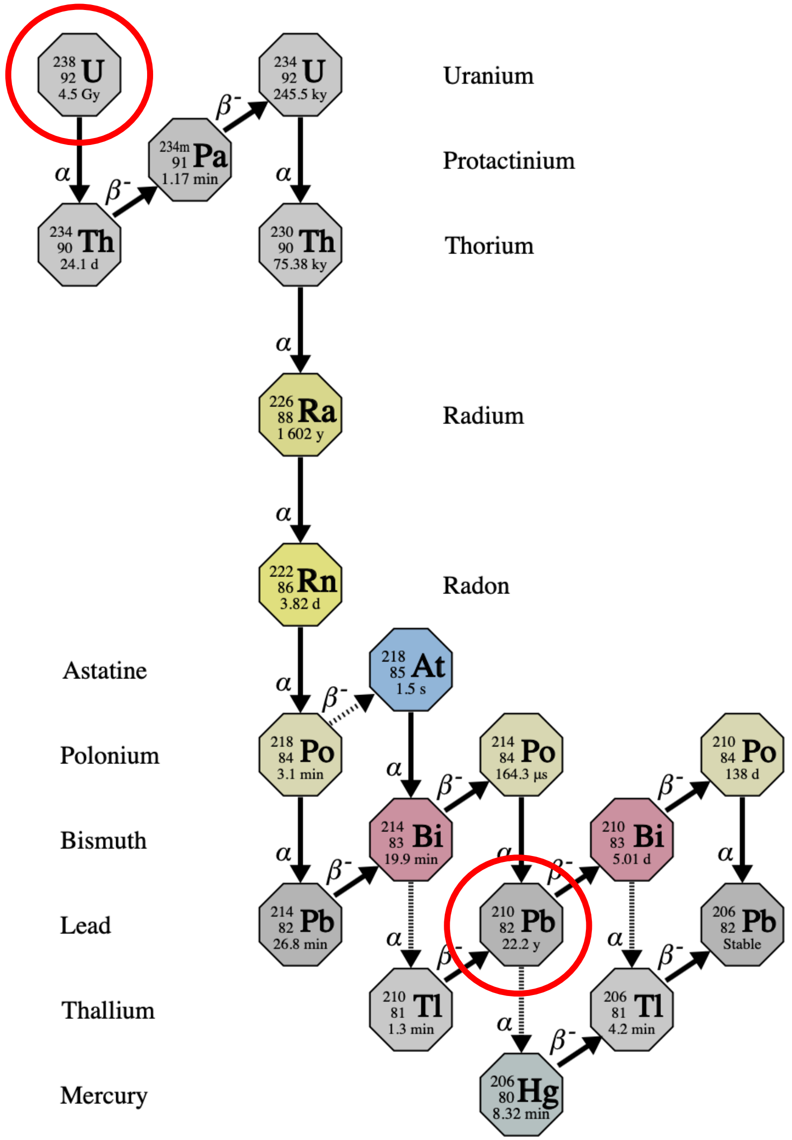
Selective precipitation of ^{238}U chain impurities

We can selectively precipitate Zinc Sulfide from solution while leaving behind ^{238}U chain impurities

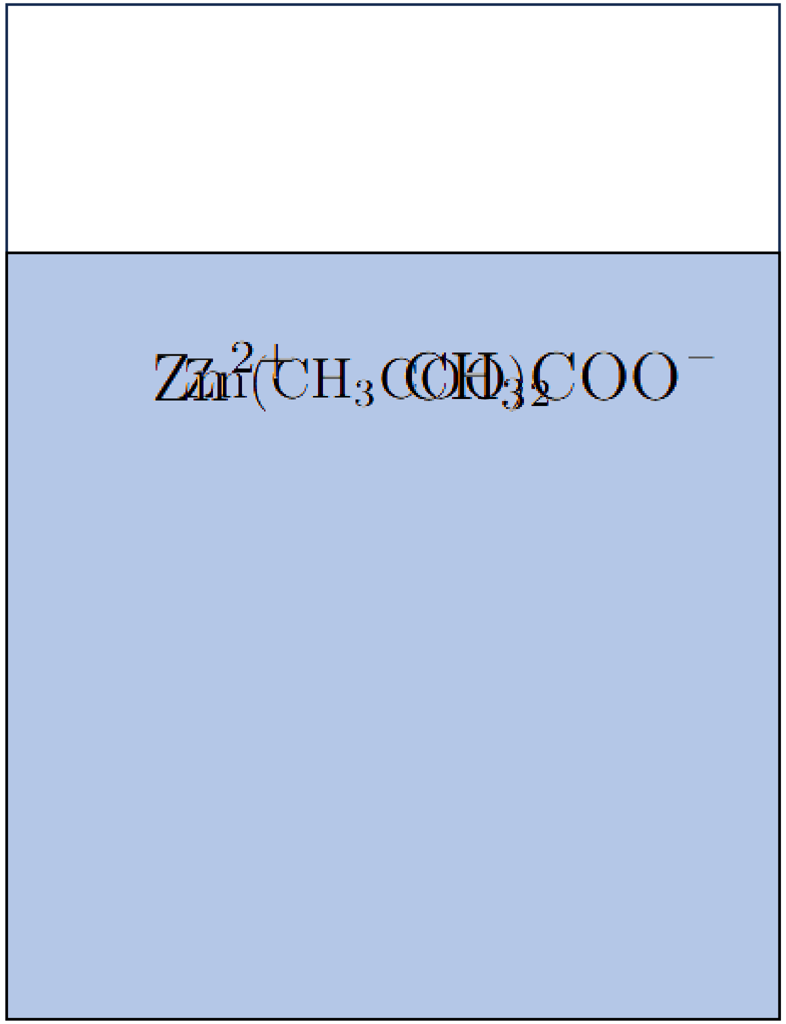
$\text{Log}(\text{ZnS } K_{sp}) \approx -22$

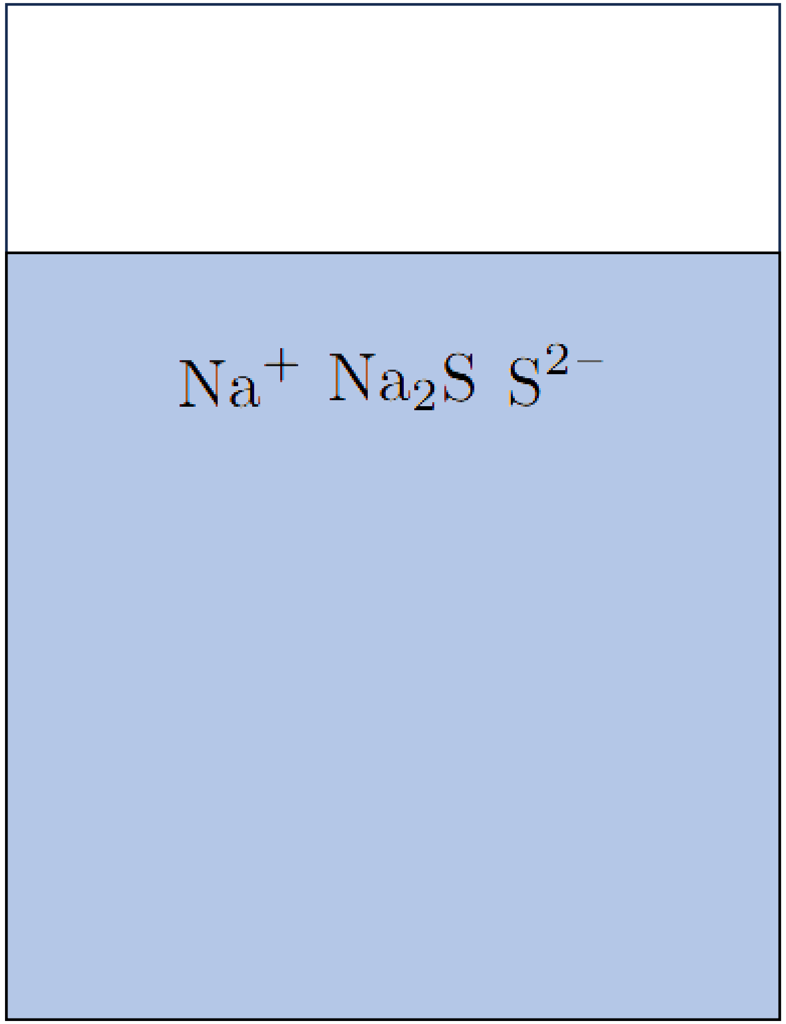
$\text{Log}(\text{PbS } K_{sp}) \approx -28$

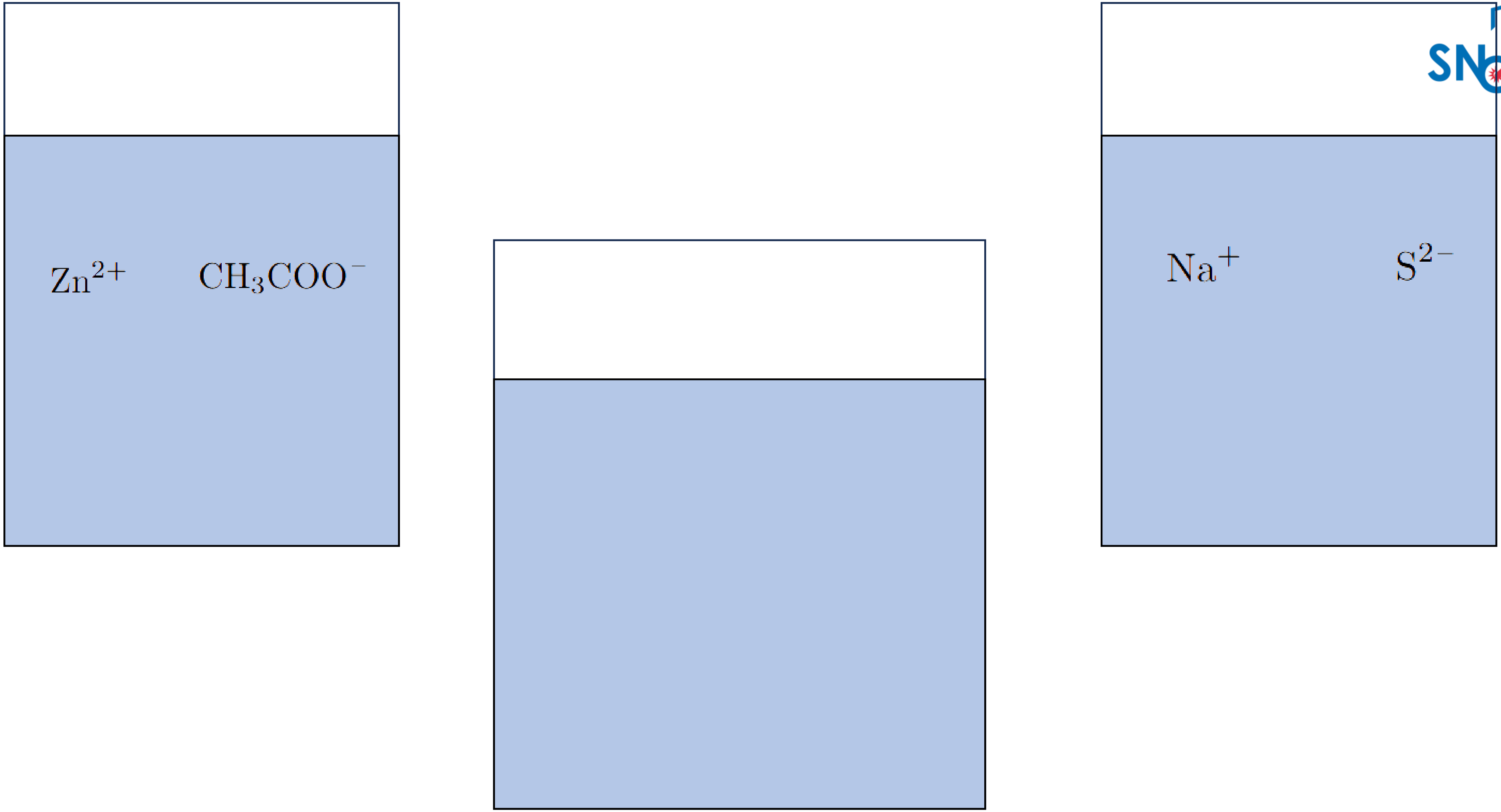
$\text{Log}(\text{U(IV)O}_2\ K_{sp}) \approx -53$

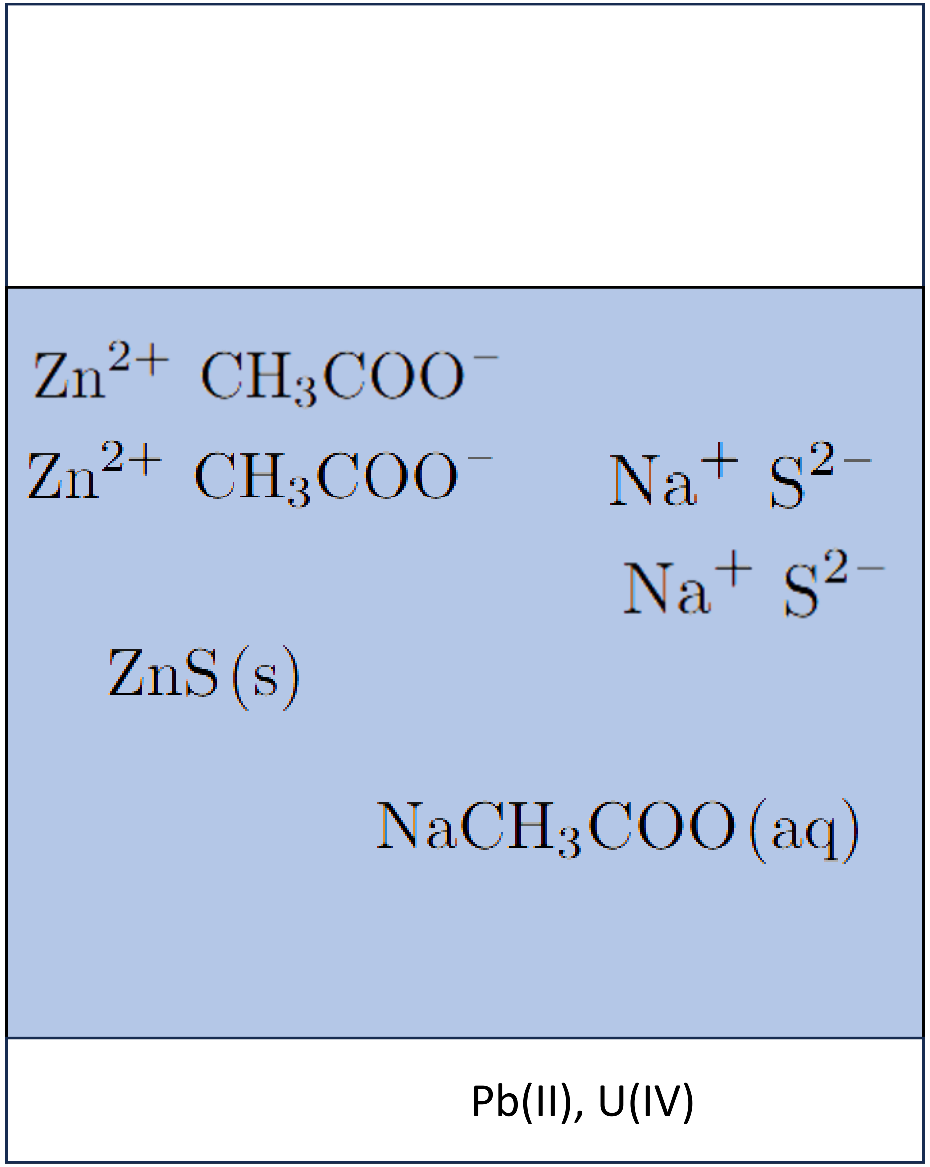


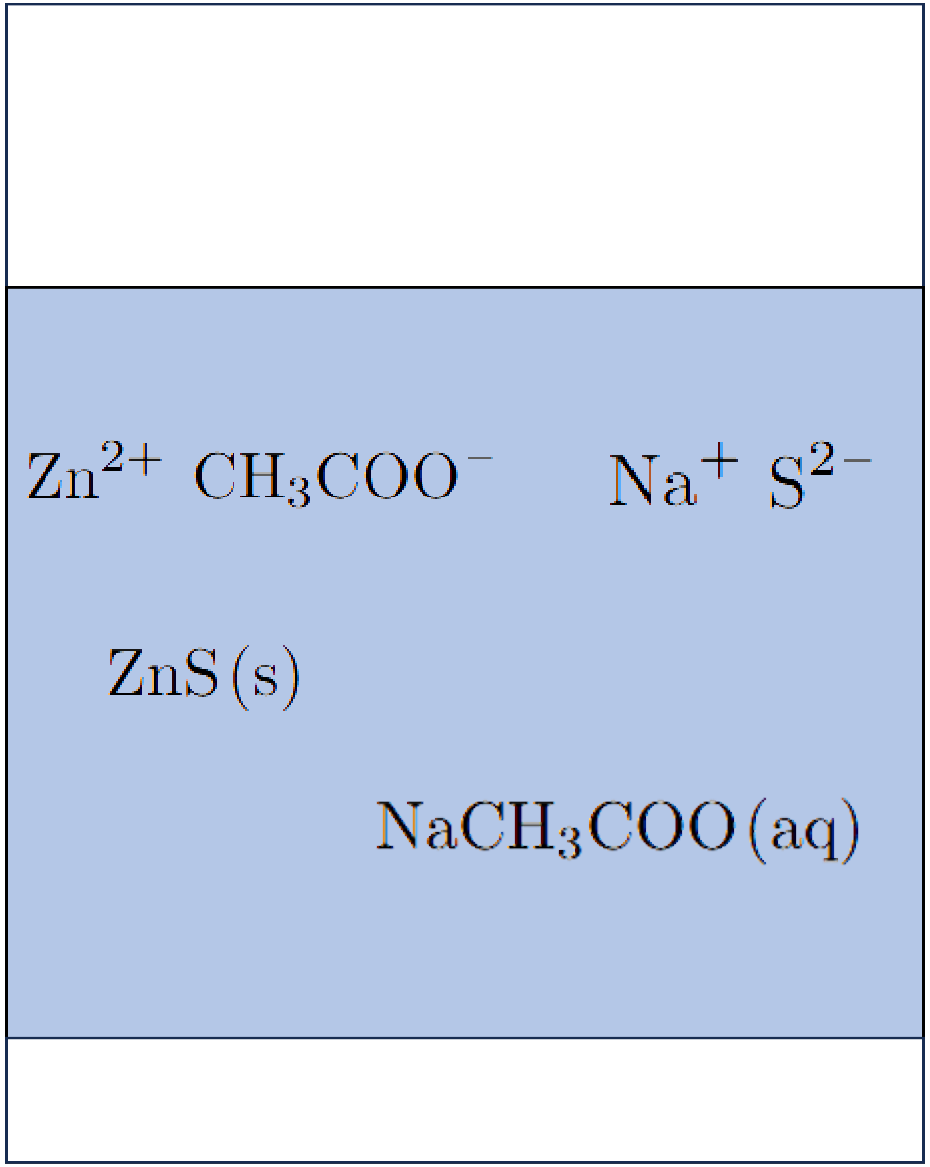
Preliminary ZnS synthesis





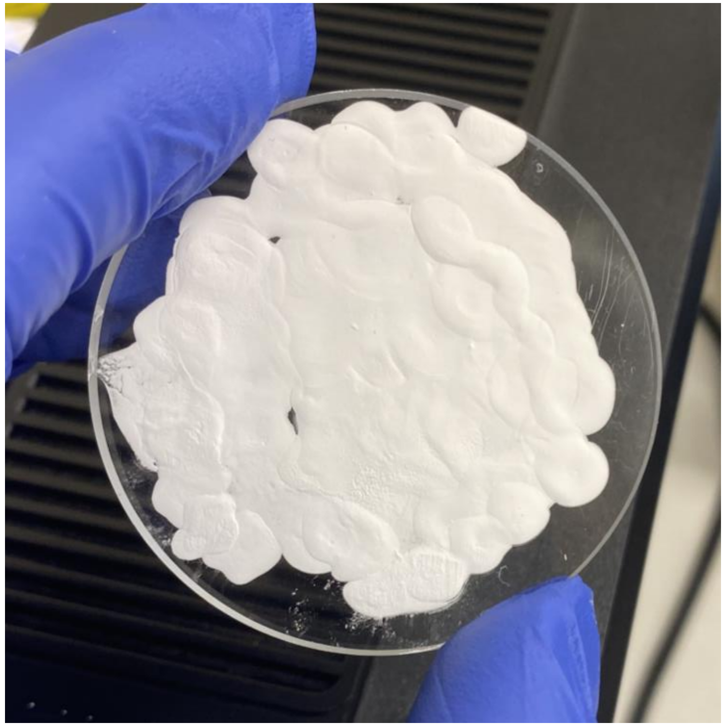

Zn^{2+}
CH_3COO^-
Na^+
S^{2-}


Zn^{2+} CH_3COO^-
Zn^{2+} CH_3COO^-
Na^+ S^{2-}
Na^+ S^{2-}
$ZnS\,(s)$
$NaCH_3COO\,(aq)$
Pb(II), U(IV)


Zn^{2+} CH_3COO^-
Na^+ S^{2-}
$ZnS\,(s)$
$NaCH_3COO\,(aq)$

Alpha scintillation test

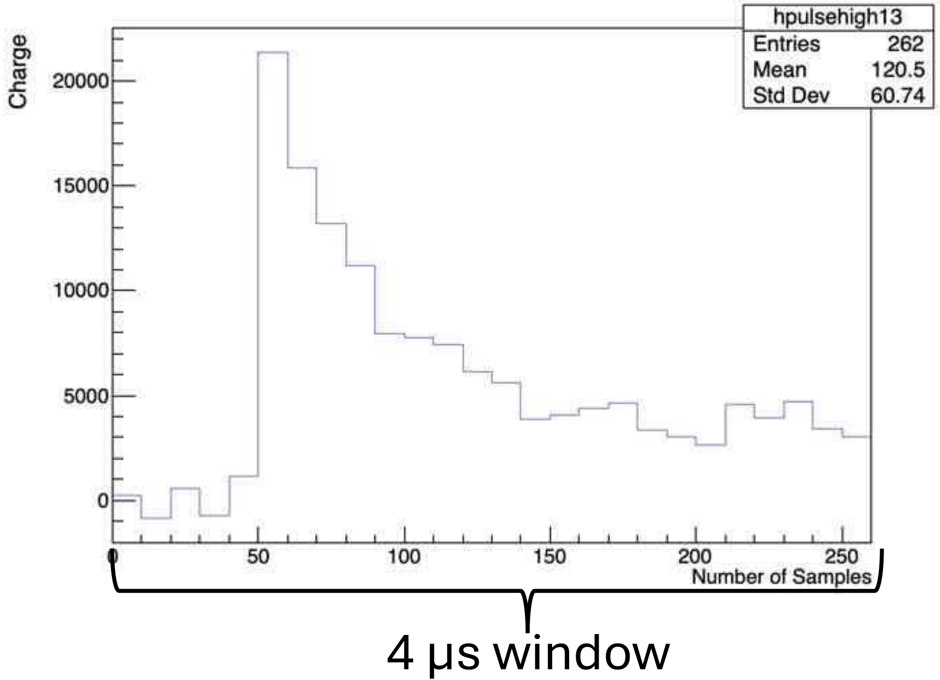
- ZnS painted on an acrylic disk may scintillate in response to alphas
- If PMTs detect alpha pulse:
    1. Our ZnS is sensitive to alphas, AND
    2. Our PMTs are sensitive to light emitted by our ZnS



A working Rn counter

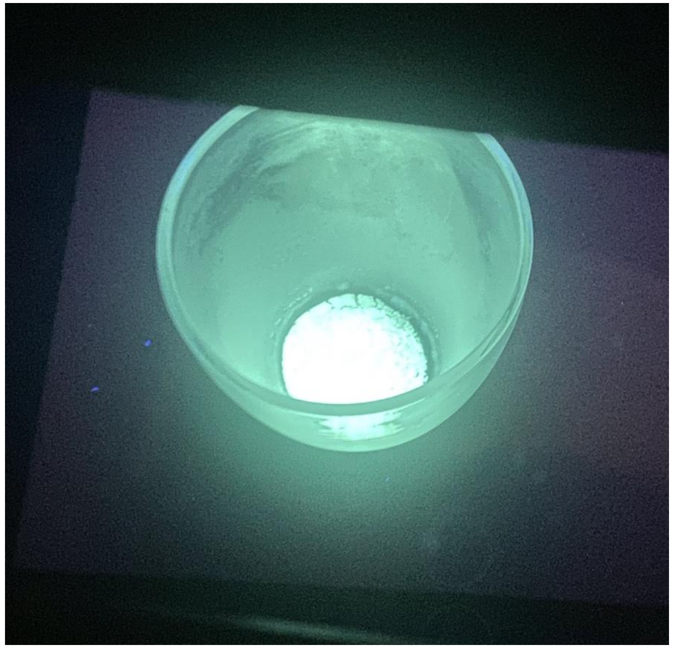
```
-bash-4.2$ ./AlphaCounting_v3.exe ../WaveDumpOutput/wave22025-08-08-170013.txt
Nday and Ndecays inday0 0 idayflag 0
0 0.00753361 0.115815 111111 chi2/ndf:: 184.626/16 par1par3ratio::0.249342
1 0.0207997 0.12161 44677.2 chi2/ndf:: 189.831/16 par1par3ratio::-0.669627
2 0.0219608 0.113885 87124.9 chi2/ndf:: 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!



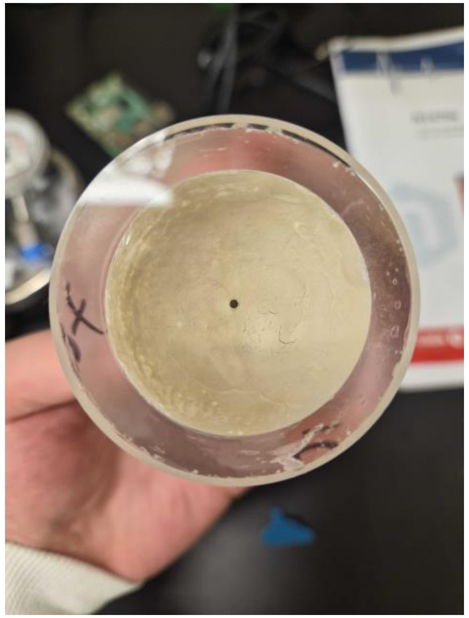
Sample alpha trace

First Lucas cells with SNOLAB ZnS



SNOLAB ZnS

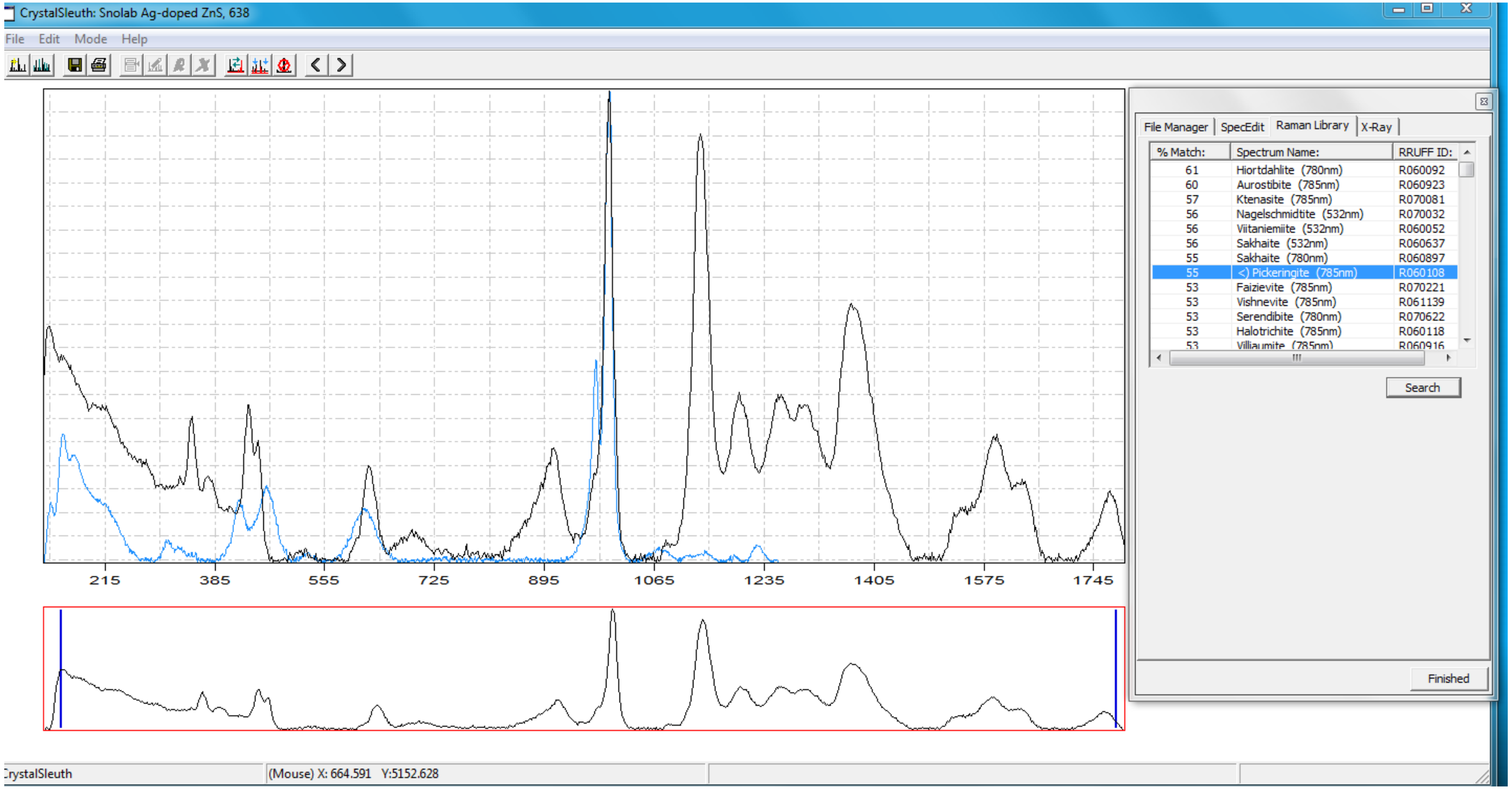
Commercial ZnS

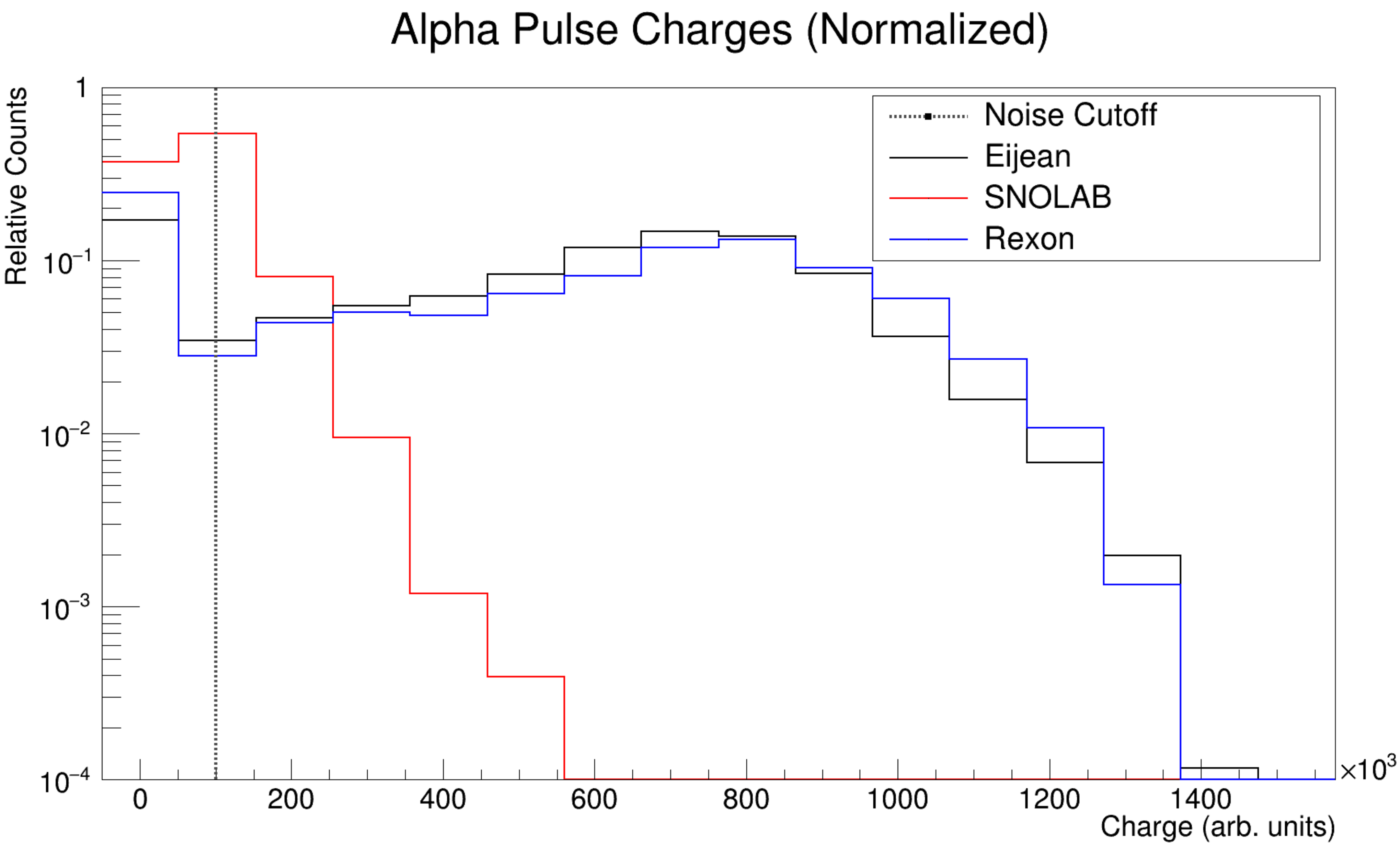


SNOLAB ZnS

Commercial ZnS

Insights from Raman spectroscopy





Credit: Connor Stubbs

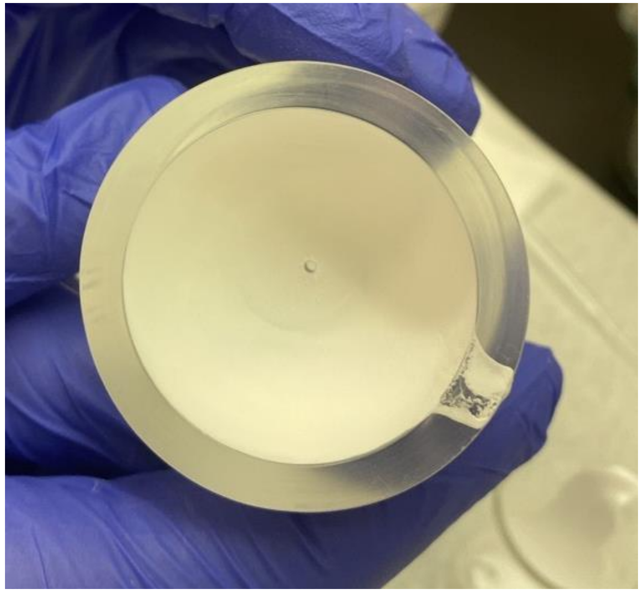
Summary

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

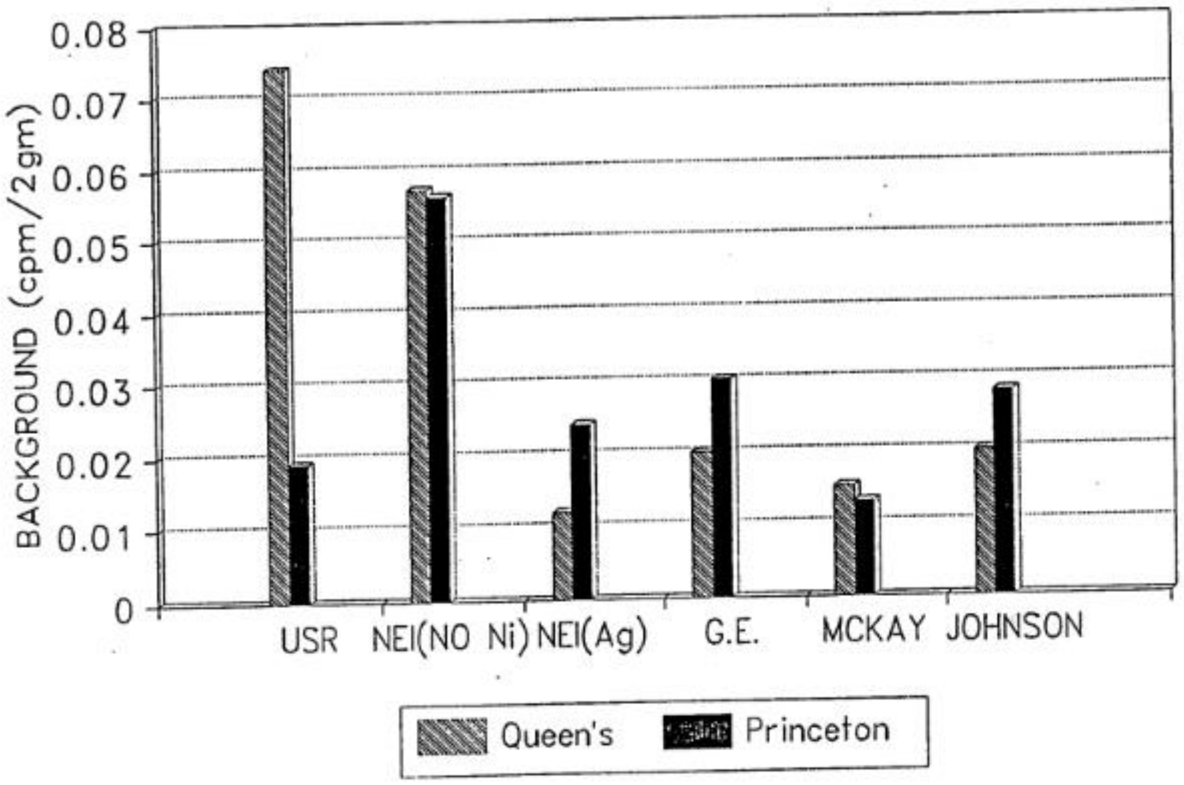


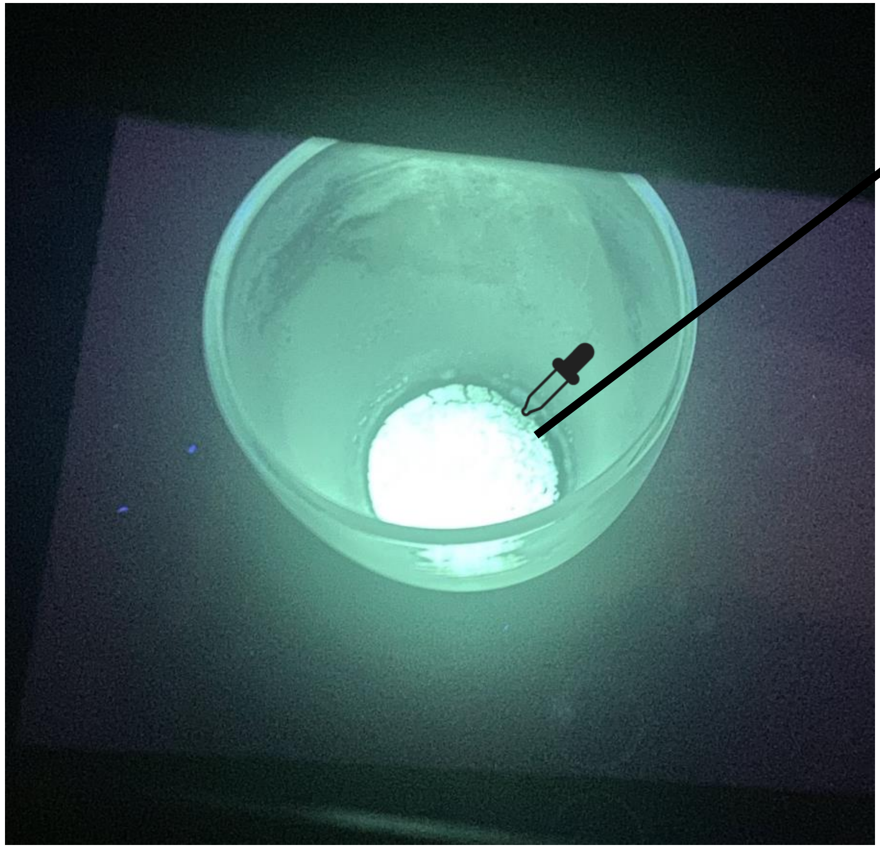
Figure 3.6: The alpha background of different ZnS samples.

M. Liu (1991)

The SNOLAB Radon assay

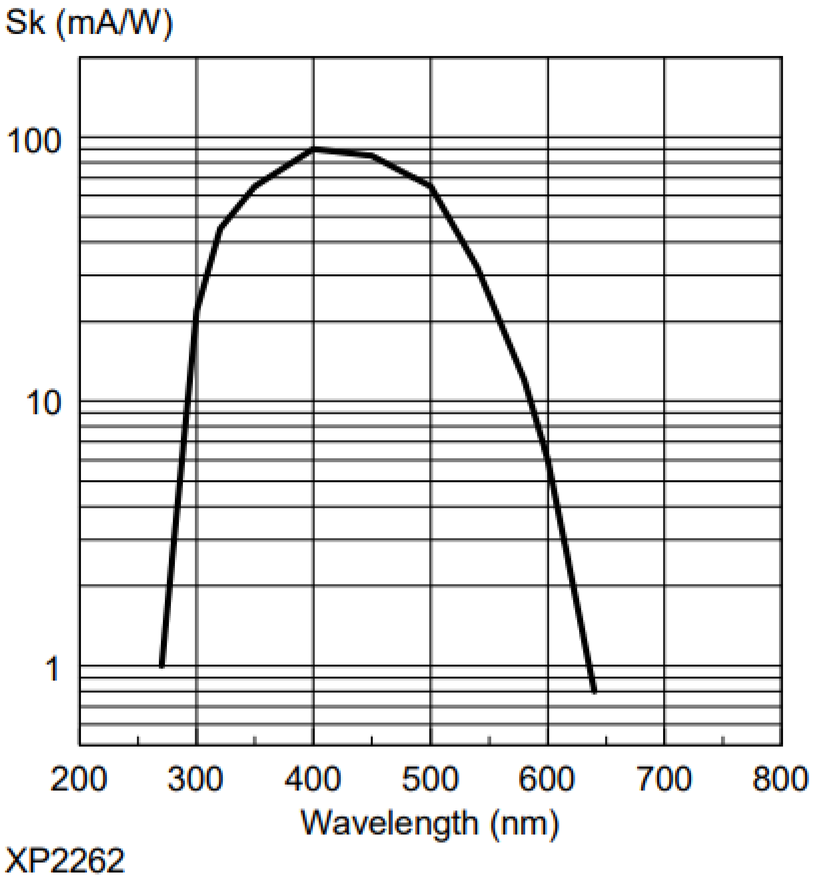
UPW plant Radon board, 2000 (Credit: SNO)

UPW plant Radon board, 2026

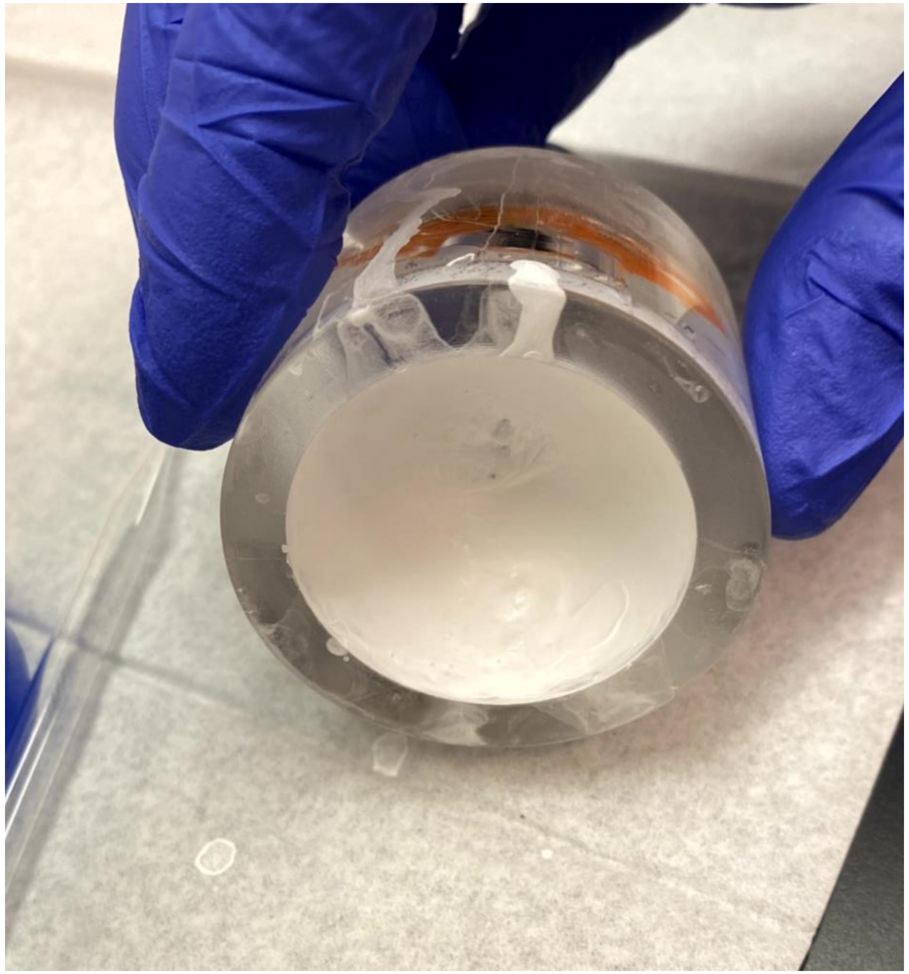


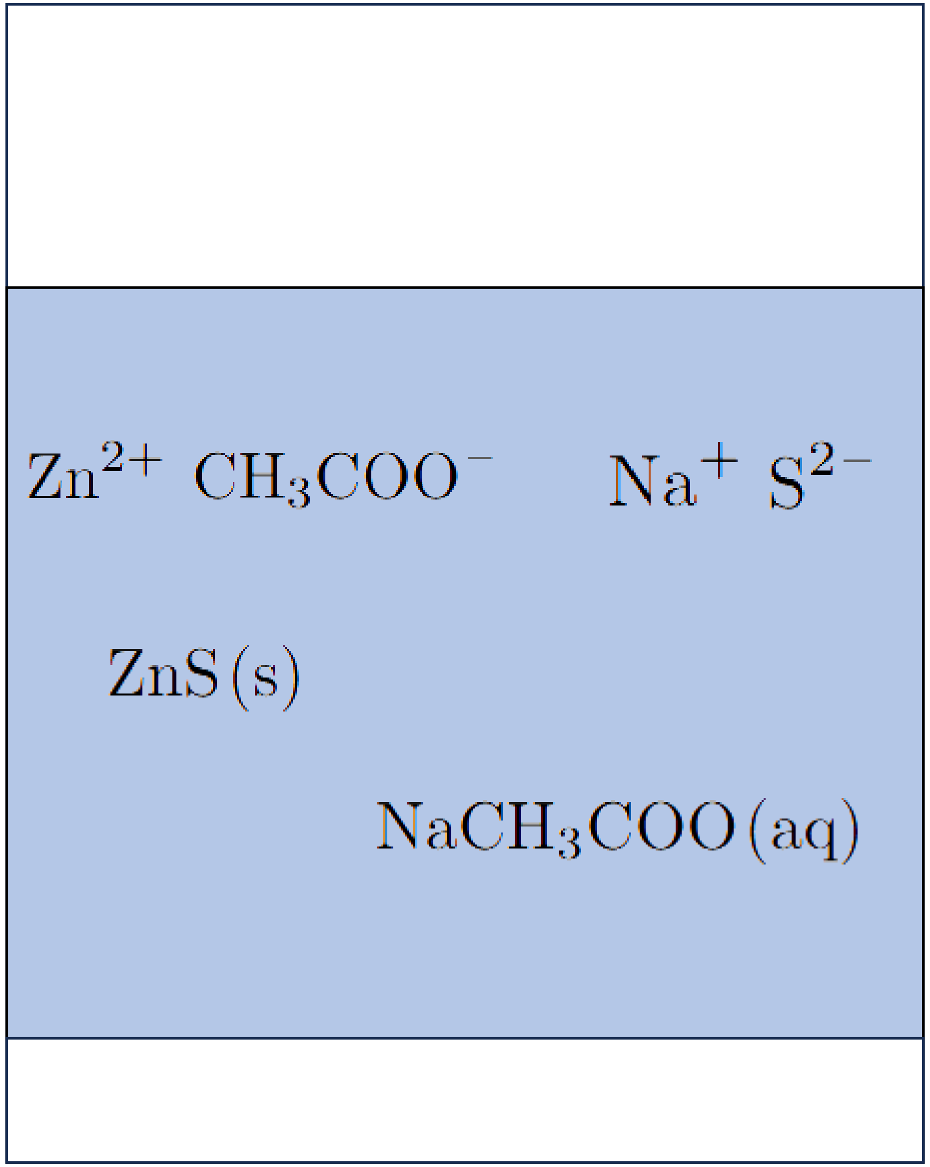
rgb(0, 255, 203)
Hex: #00ffcb
λ = 495 nm

Typical spectral characteristics



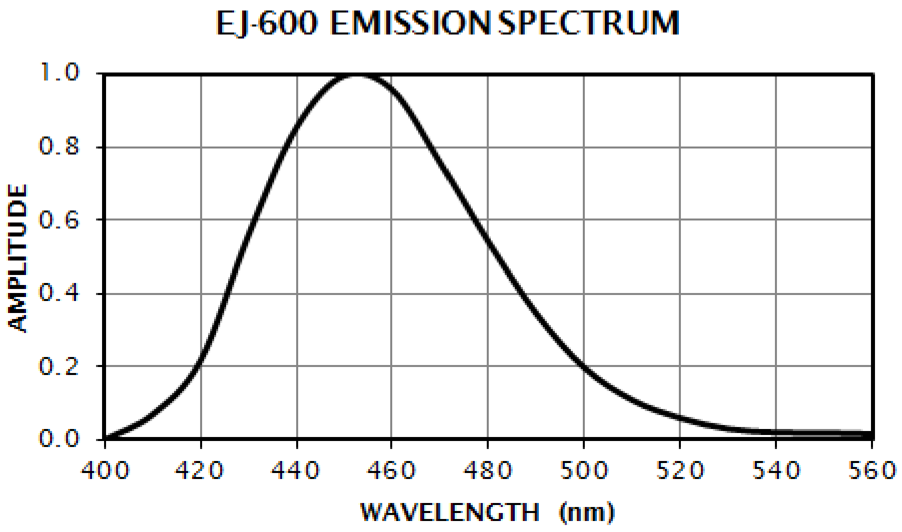
Lucas cell coating: process



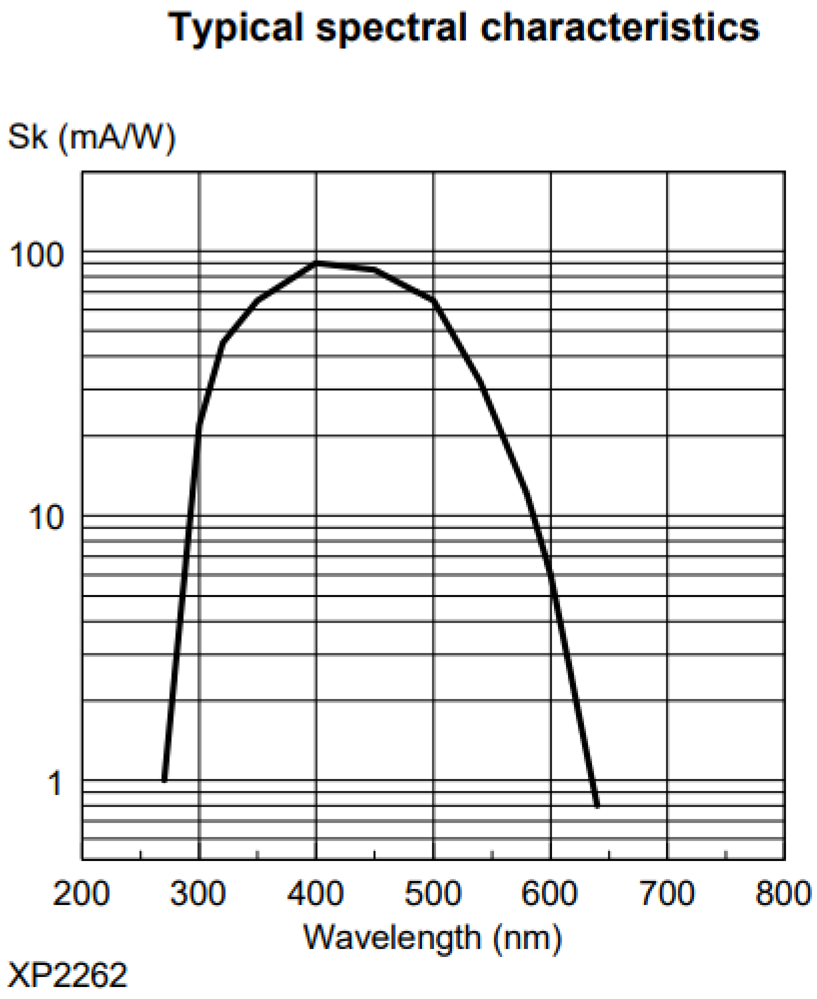

Zn^{2+} CH_3COO^-
Na^+ S^{2-}
$ZnS\,(s)$
$NaCH_3COO\,(aq)$

ZnS luminescence goals

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



Commercial ZnS(Ag) emission spectrum



Light sensitivity of Philips XP2262 PMTs

Improving the radon assay starts with improved Lucas cells