DURRIDGE

Radon Capture & Analytics

DURRIDGE Radon Measurement Technology – Present & Future

Dr. S. W. Sadler

NORM-IX, Denver, 24 September 2019

Contents

1. Comparison of current DURRIDGE technology (RAD7) with Pulse Ionization Chambers.

2. Future DURRIDGE technology – Preliminary sensitivity measurements of our next-generation prototype.

Part 1

1. Comparison of current DURRIDGE technology (RAD7) with Pulse Ionization Chambers.
2. Future DURRIDGE technology – Preliminary sensitivity measurements of our next-generation prototype.

Radon Overview

- Radioactive gas found in the environment.
- Collects in dwellings and workplaces under certain conditions.
- Inert, colorless, odorless – undetectable by the human body.
- Radon and its decay products emit ionizing radiation when they decay.
- **21,000 deaths per annum in the USA** caused by radon-related lung cancers.

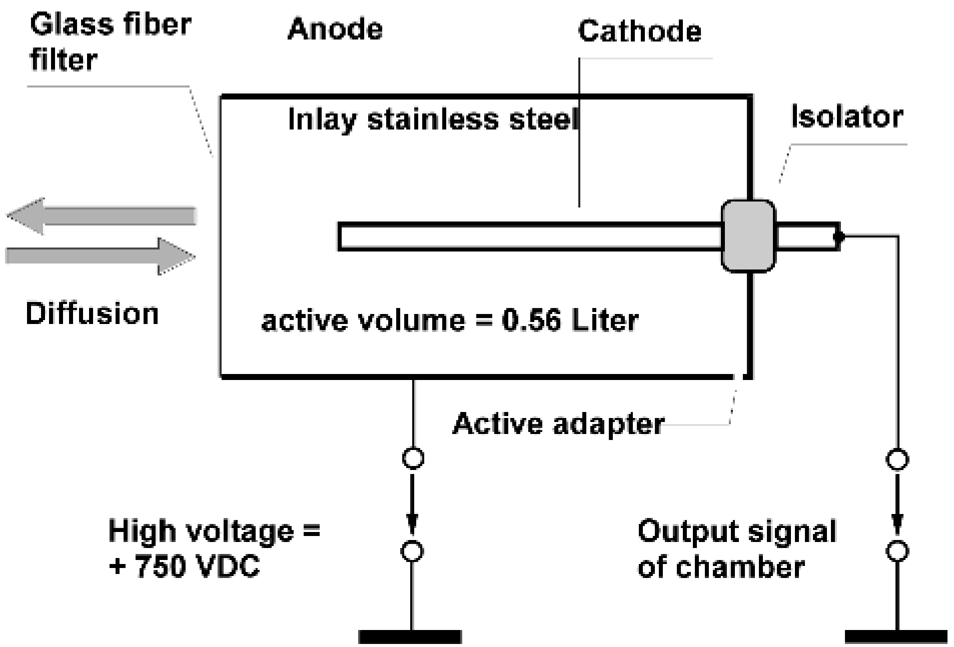
Overview of Continuous Radon Measurement Technologies

4 types:

1. Ionization Chambers
2. Scintillation Counters (Lucas Cells)
3. **Pulse Ionization Chambers**
4. **Electrostatic Precipitation Instruments**

Pulse Ionization Chambers - Overview

- Ionization electrons created as decay alphas are stopped in the air inside the chamber. These form negative ions with O_2 molecules, which then drift to the anode.
- Signal is the primary alpha decay of radon + subsequent ^{218}Po decay.
- Energy resolution of ~ 0.25 MeV achievable for ~ 5 MeV alpha decays.
- Large volumes and high collection efficiencies are possible, leading to sensitivities as high as 50 cpm/kBq/m^3.



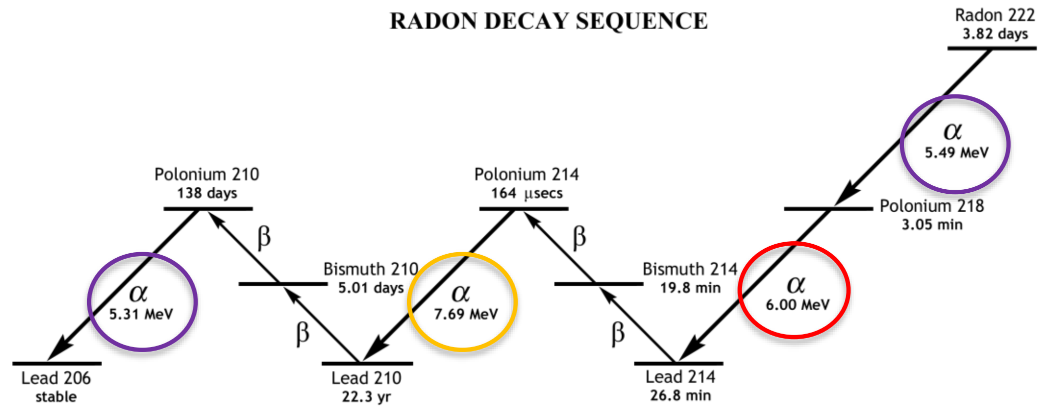
From https://www.bertin-instruments.com/wp-content/uploads/secured-file/ALGU_Manual_2012-08_E.pdf

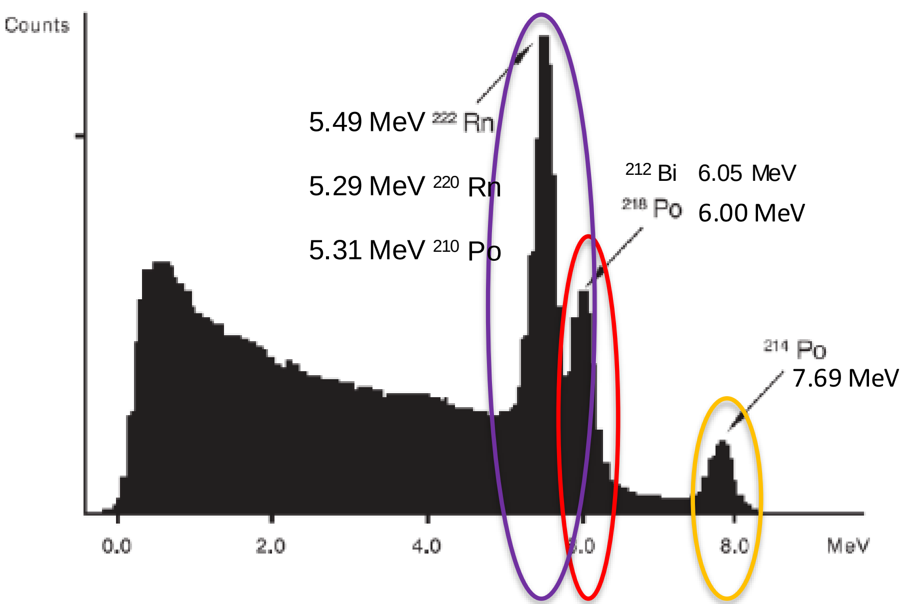
2 major drawbacks:

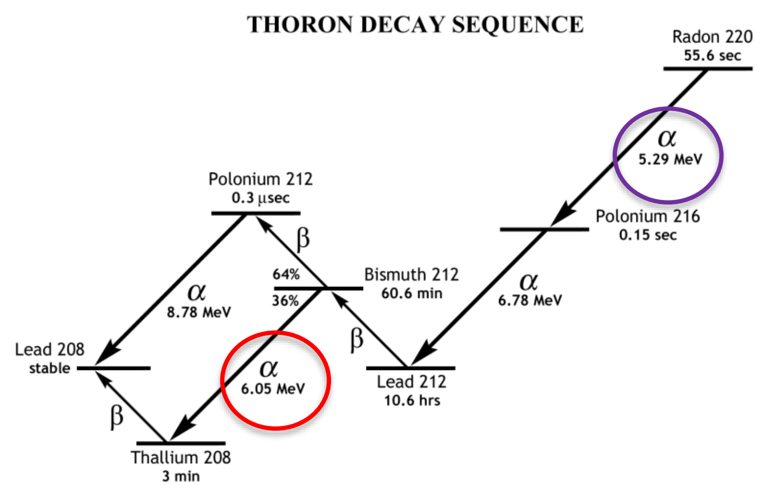
- **1) Background from ^{210}Po increases over the lifetime of the instrument.**
- **2) No thoron / radon discrimination.**

Example Pulse Ionization Chamber Energy Spectrum

- Changes in radon concentration are seen near-instantly in the purple peak.
- Energy peaks from radon, thoron and ^{210}Po background overlap in this peak. **No clear energy separation.**
- Only partial separation of ^{218}Po and ^{222}Rn peaks.







Modified from http://www.gammadata.se/assets/Uploads/ATMOS-12-DPX-EN-ver1.51.pdf

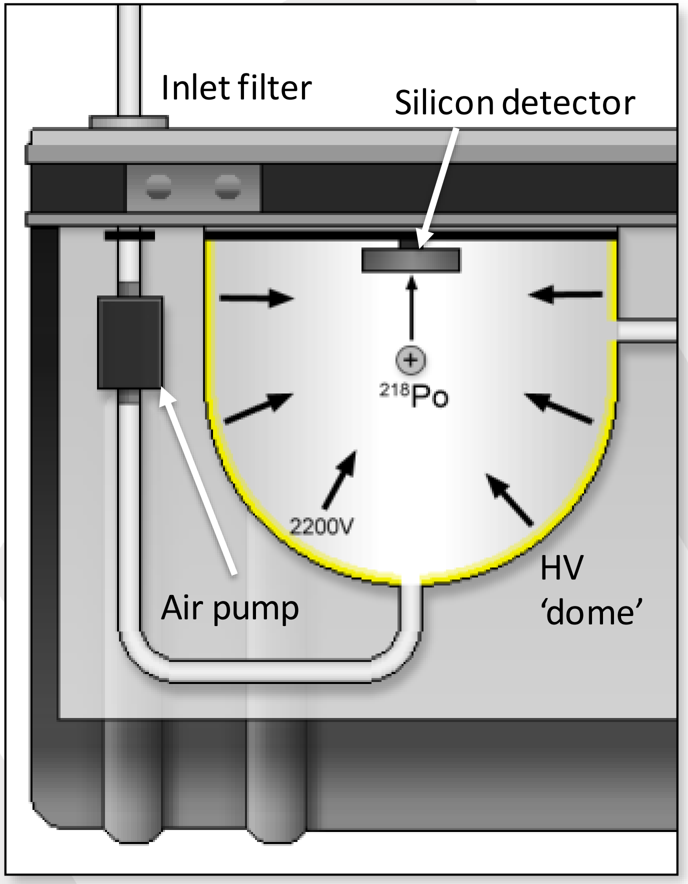
Electrostatic Precipitation Instrument – RAD7

- High-resolution alpha spectrometry of radon decay products to determine radon and thoron concentration and reject backgrounds.
- Electrostatic collection of radon daughters on a silicon detector, followed by high-resolution alpha spectrometry.
- Simultaneous, independent measurement of radon and thoron.
- Normal (Sniff) Mode Sensitivity:
  13 (6.7) cpm/kBq/m^3
- Intrinsic Background:
  0.2 Bq/m^3 for lifetime of the instrument.

RAD7 Measurement Technology

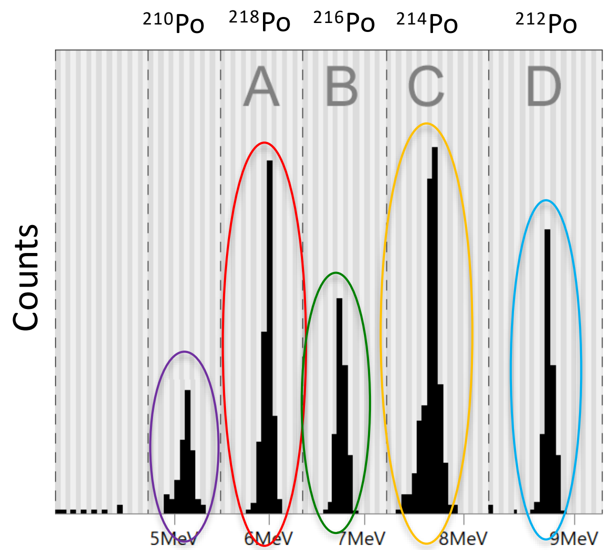
Electrostatic precipitation with Alpha Spectrometry

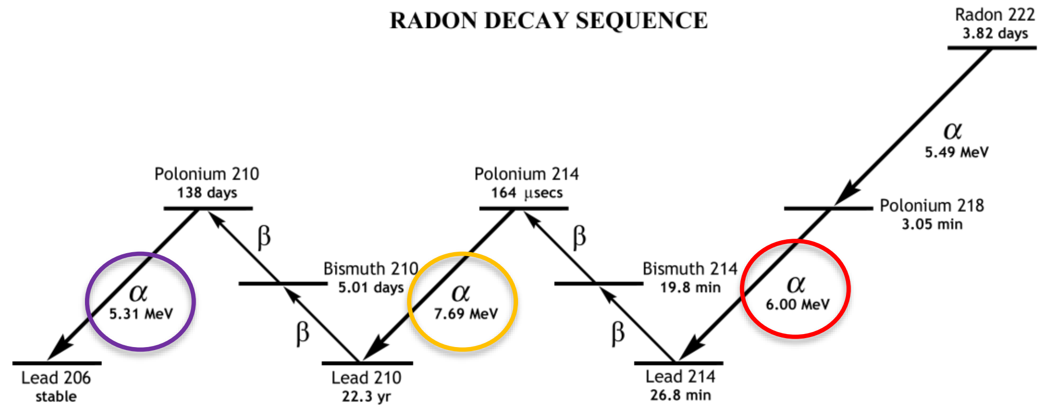
- Radon and thoron admitted, progeny blocked.
- Radon decays to charged ^{218}Po.
- ^{218}Po precipitated onto a silicon detector by electric field.
- ^{218}Po decays to ^{214}Po, 50% chance to be measured (due to geometry). Full energy seen by silicon detector.
- ^{214}Po decays, 50% chance to be measured. Again, full energy seen.
- Radon concentration calculated by:
  <u>Sniff Mode</u>: Rate of decay of ^{218}Po in the A Window.
  <u>Normal Mode</u>: Rate of decay of ^{218}Po + ^{214}Po in the A and C Windows

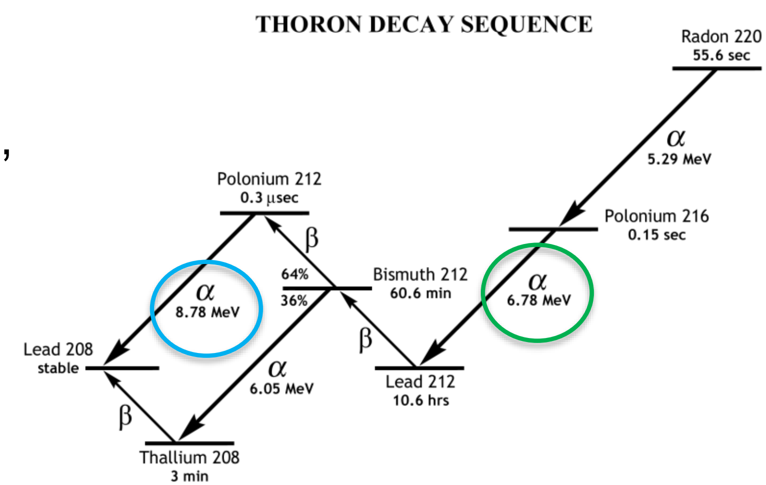


RAD7 Measurement Chamber

RAD7 Alpha Energy Spectrum



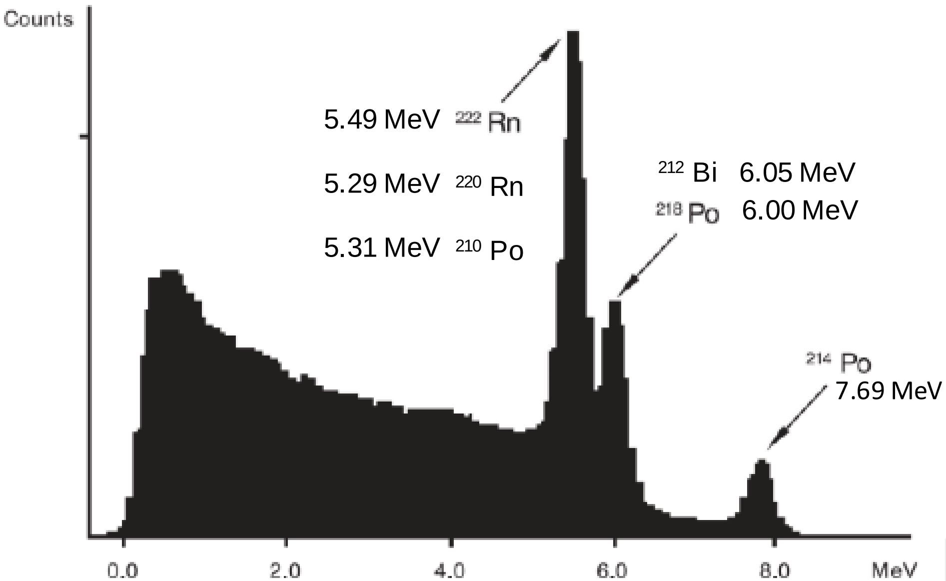




- Near-perfect background rejection, including long-lived ^{210}Po contamination (purple peak).
- Near-perfect Radon/Thoron Discrimination (green/blue vs red/orange peaks).

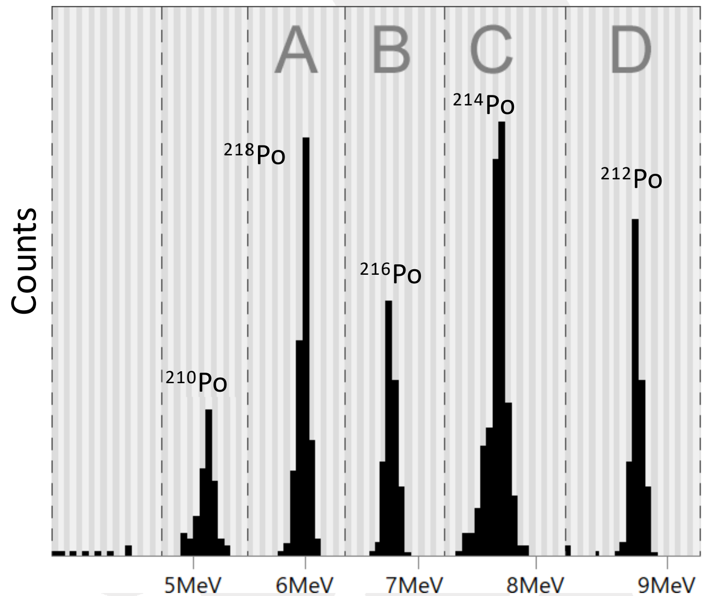
Side-By-Side Spectrum Comparison

Pulse Ionisation Chamber



Example spectrum from a pulse ionisation type radon detector. Radon and thoron peaks overlap with each other, and with the ^{210}Po background peak. Low-energy shoulder from partially contained (mis-measured) events. Energy resolution of this model: 0.25 MeV.

Electrostatic Precipitation



Example RAD7 spectrum showing radon daughter and granddaughter peaks (^{218}Po and ^{214}Po), thoron daughter and granddaughter peaks (^{216}Po and ^{212}Po), plus rejected ^{210}Po peak. All peaks show near-perfect energy separation, allowing near-perfect background rejection and simultaneous, independent measurement of radon and thoron.

Pulse ionization chamber spectrum image modified from http://www.gammadata.se/assets/Uploads/ATMOS-12-DPX-EN-ver1.51.pdf

Part 2

1. Comparison of current DURRIDGE technology (RAD7) with Pulse Ionization Chambers.

2. Future DURRIDGE technology – Preliminary sensitivity measurements of our next-generation prototype.

Next-Generation Prototype Spec.

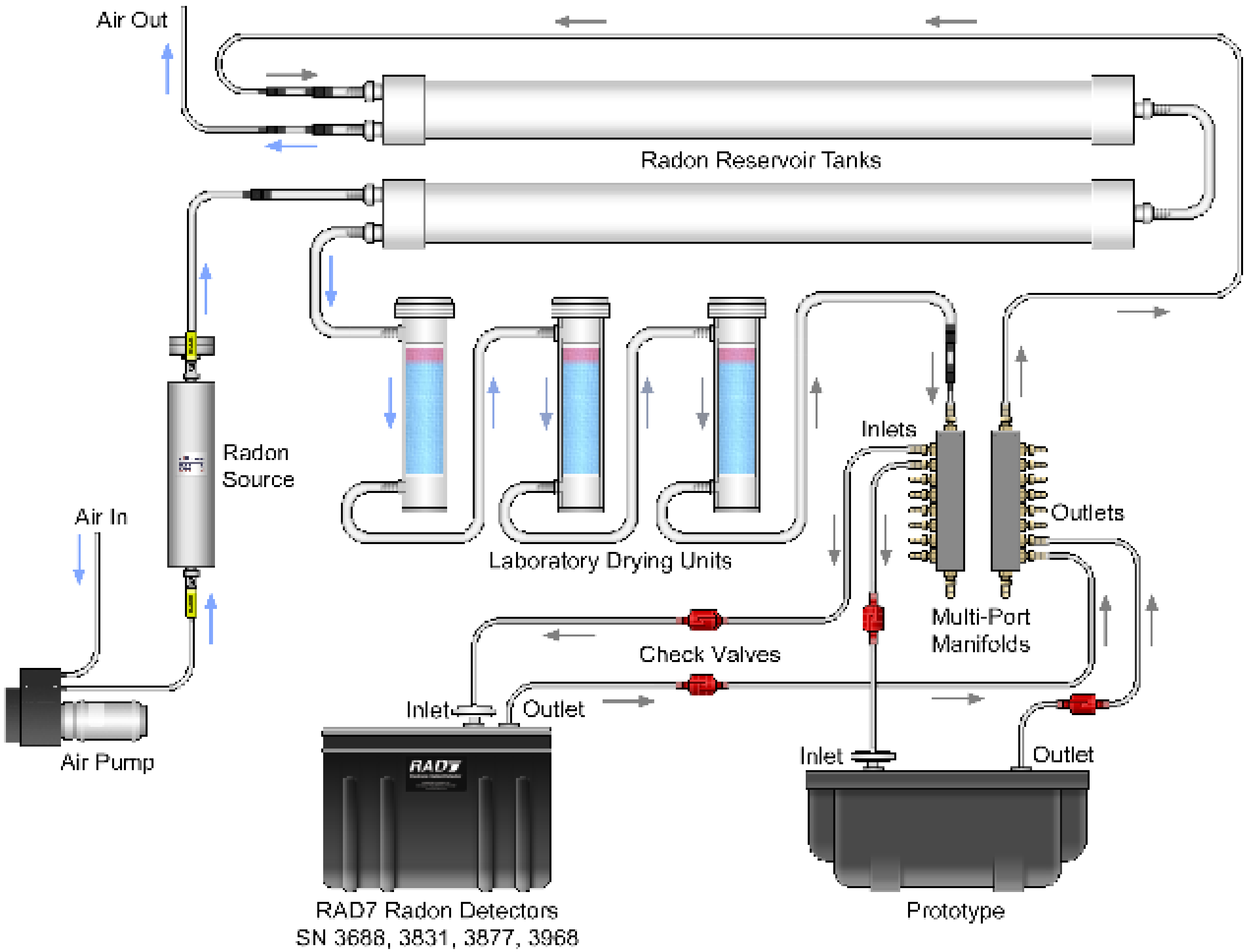
- Same operating principle as the RAD7.

- Several improvements…

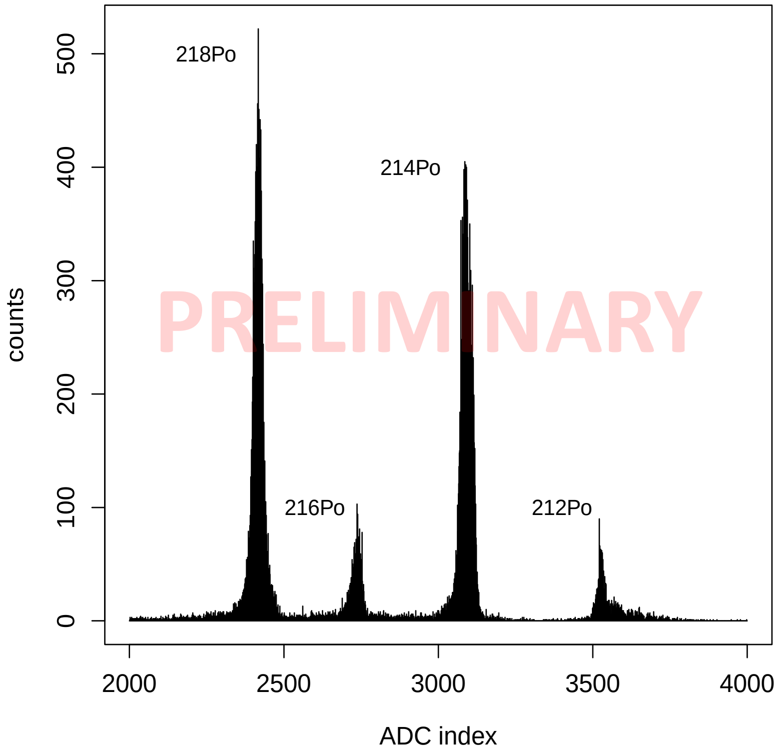
1. Waterproof and dustproof.
2. Large color touchscreen.
3. WiFi connectivity.
4. Faster electronics.
5. Higher-resolution digitizer.
6. **Sensitivity the same as, or better than, the RAD7.**

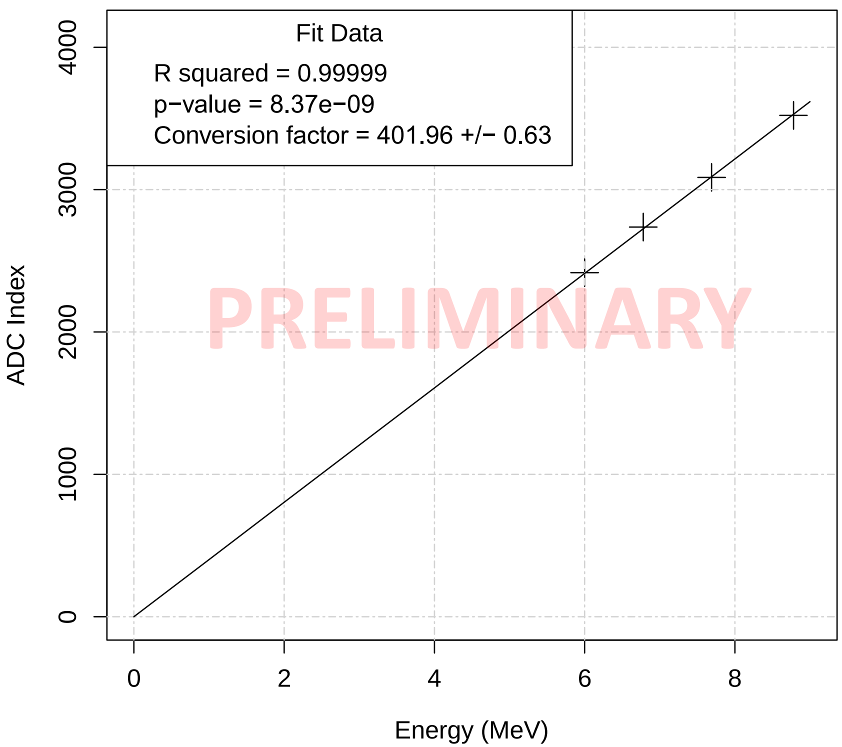
Prototype – Sensitivity Measurement

- Sensitivity measured at DURRIDGE's European calibration facility in Sheffield, UK.
- Constant radon concentration maintained in the radon reservoir tanks.
- 4 x RAD7 reference standards give the 'true' radon concentration.
- Simultaneous measurement with Prototype.
- Expose to radon for 24 x 2hrs. Discard first two data points to allow equilibration.
- Output: raw 12-bit spectrum of counts (4096 x 2.5 keV energy bins).
- **Need to set the energy scale in order to calculate sensitivity…**



Setting the Energy Scale





- Find maxima of four alpha decay energy peaks.
- Plot the Analogue-to-Digital Converter (ADC) index against the known alpha decay energy.
- Straight line fit forced through the origin yields an extremely good fit, demonstrating a linear energy response.
- Resulting conversion factor: **402.0 +/- 0.6 ADC points per MeV**.

Energy Windows

- Combine energy scale with RAD7 A, B, C, D window definitions (which we saw on slides 10 & 11) to yield energy windows for the prototype in ADC units:

Energy Window	Species	Lower Bound ADC index	Upper bound ADC index
A	^{218}Po	2248	2569
B	^{216}Po	2570	2890
C	^{214}Po	2891	3291
D	^{212}Po	3292	3733

- Sum counts in A window (Sniff mode) and A+C windows (Normal mode), and divide by run time and radon concentration to yield sensitivity...

Prototype – Preliminary Results

- Sniff (fast) mode sensitivity = **7.64 +/- 0.06 cpm/kBq/m^3**
- Normal (slow) mode sensitivity = **15.39 +/- 0.04 cpm/kBq/m^3**
- 15% higher than RAD7, which is the most sensitive electrostatic precipitation instrument on the market.
- Improvement achieved with a measurement chamber half the physical size of the RAD7's.
- Lower than the leading pulse ionization chamber instrument, but with the benefit of radon/thoron discrimination and ^{210}Po background rejection.
- Work is ongoing to improve on this sensitivity with further optimization of the dome geometry.

Summary

- **Pulse ionization chamber** radon detectors have a fast initial response and high sensitivity.
- However, it is important to also consider two important drawbacks:

1. ^{210}Po background build-up. Every radon decay you measure with such an instrument adds to the background, eventually making low-level measurements impossible.
2. No real-time radon/thoron discrimination.

- Both of these problems are solved by **electrostatic precipitation** instruments like the DURRIDGE RAD7, thanks to near-perfect separation of the various alpha decay energy peaks associated with the progeny of radon and thoron, and ^{210}Pb.
- DURRIDGE's prototype instrument has superior sensitivity to the RAD7 (currently the most sensitive electrostatic precipitation device on the market), as well as a host of other improvements.

DURRIDGE
Radon Capture & Analytics

Thanks for listening!