DURRIDGE
Radon Capture & Analytics

# DURRIDGE Radon Measurement Technology – Present & Future

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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.

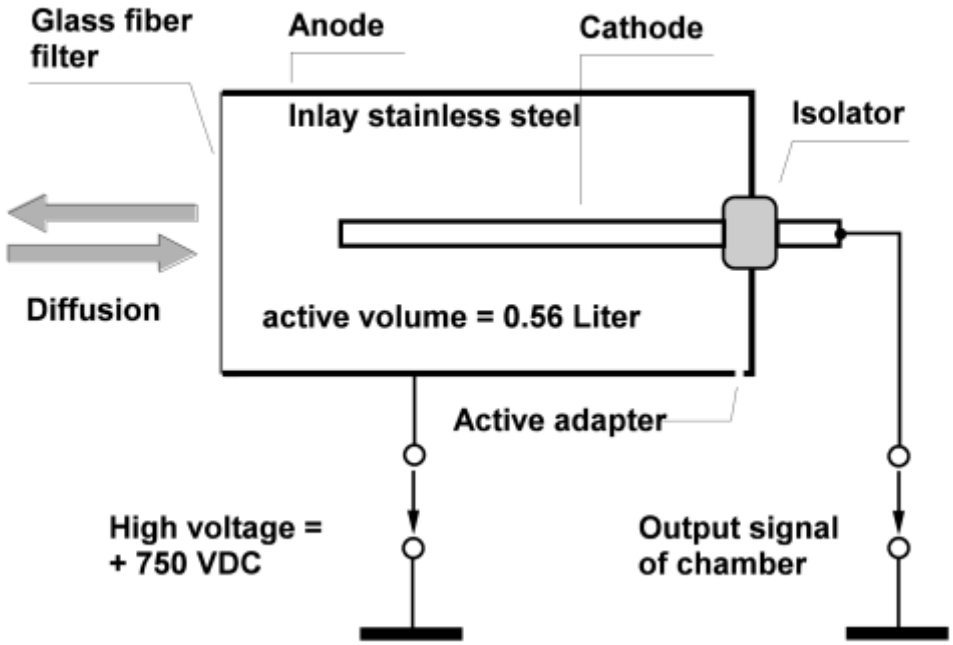
# Overview of Continuous Radon Measurement Technologies

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$^3$.

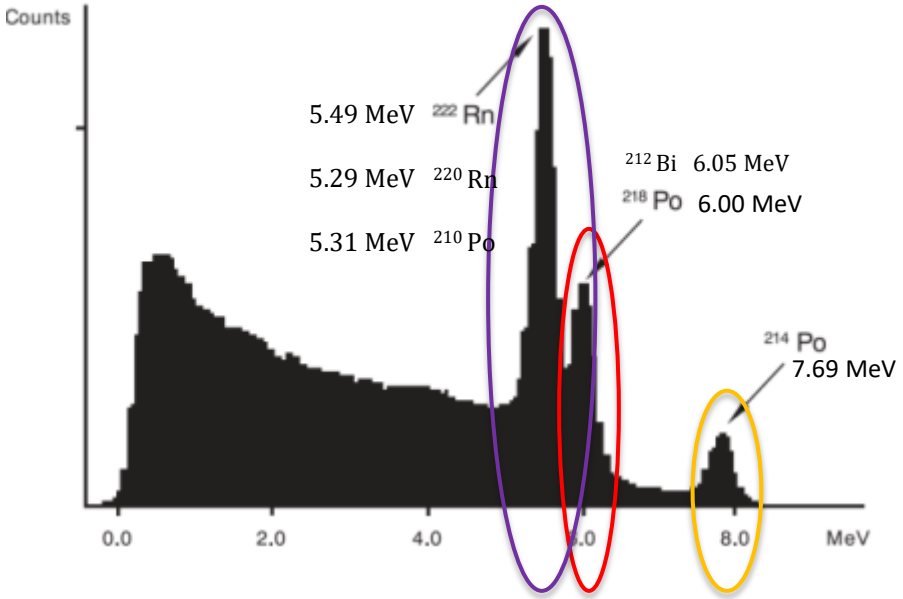


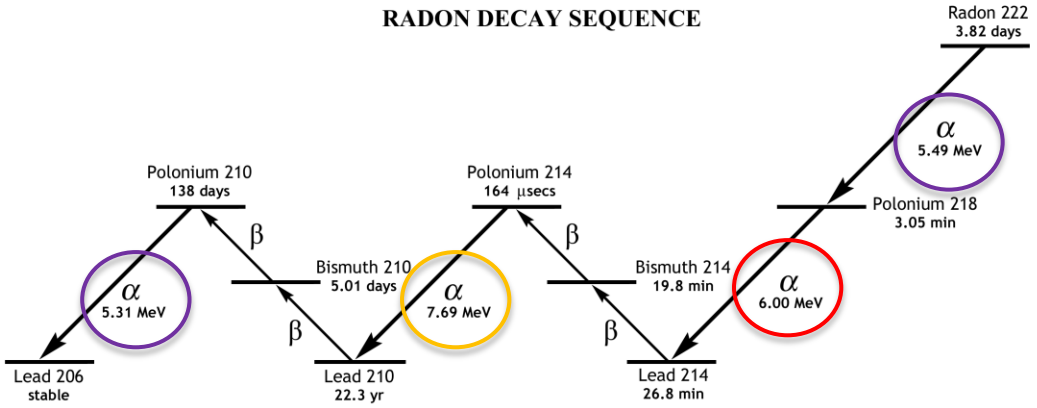

2 major drawbacks:

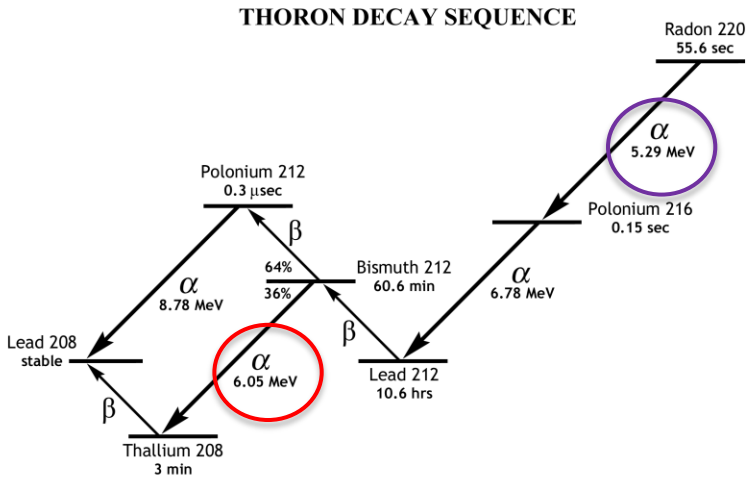
- **1) Background from $^{210}Po$ increases over the lifetime of the instrument.**
- **2) No thoron / radon discrimination.**

# 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.



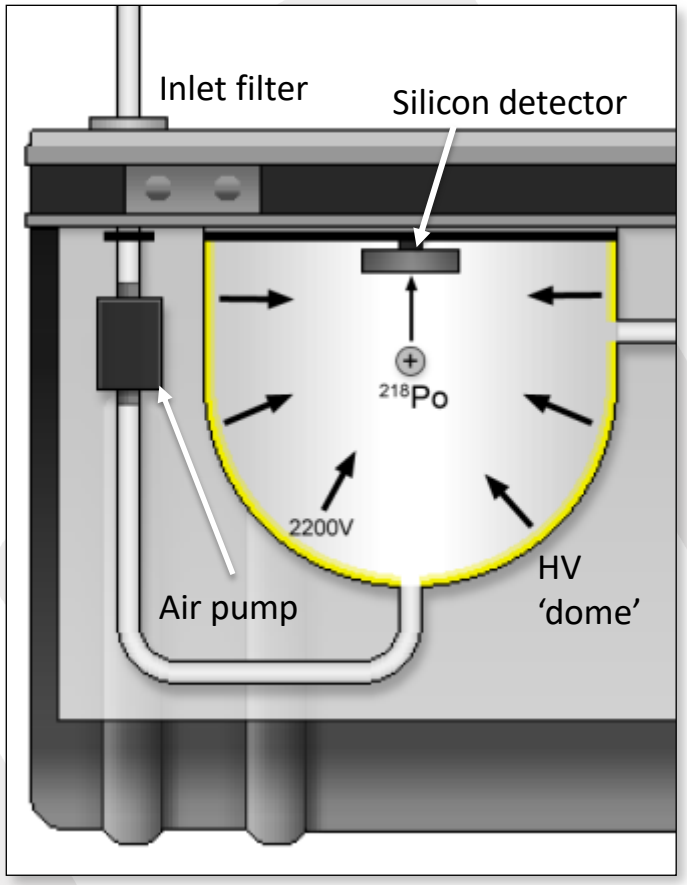
# Electrostatic Precipitation Instrument – RAD7

- 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

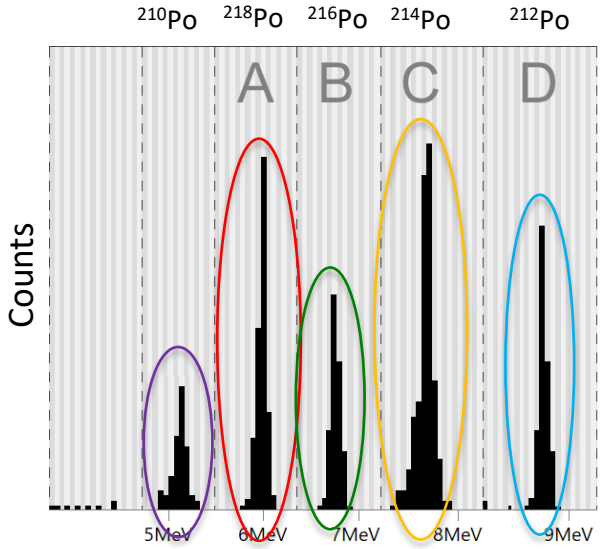
## Electrostatic precipitation with Alpha Spectrometry

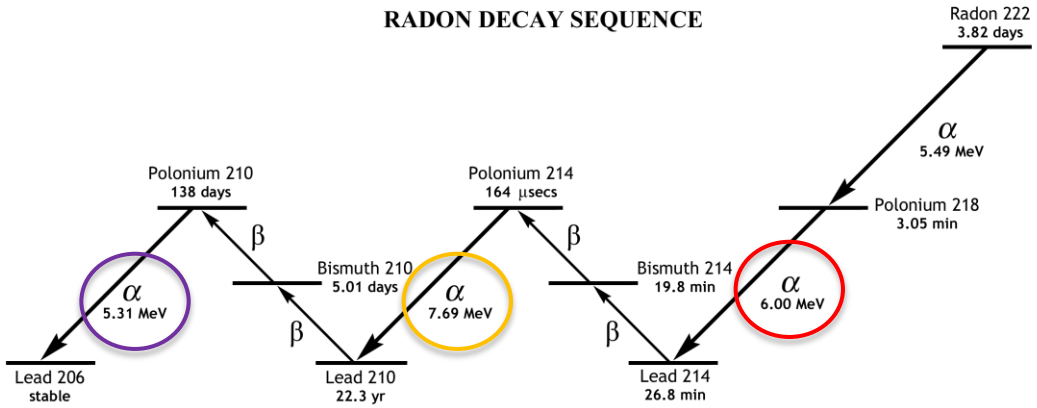
- Radon and thoron admitted, progeny blocked.
- Radon decays to charged $^{218}Po$.
- $^{218}Po$ precipitated onto a silicon detector by electric field.
- $^{218}Po$ decays to $^{214}Po$, 50% chance to be measured (due to geometry). Full energy seen by silicon detector.
- $^{214}Po$ decays, 50% chance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

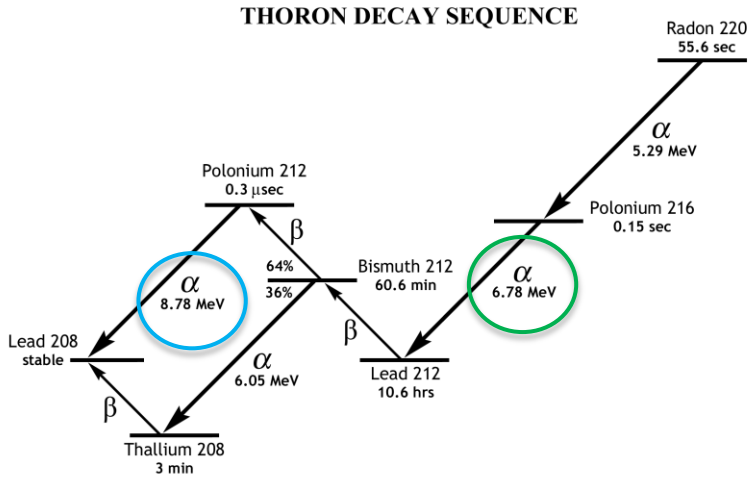



RAD7 Measurement Chamber

# RAD7 Alpha Energy Spectrum



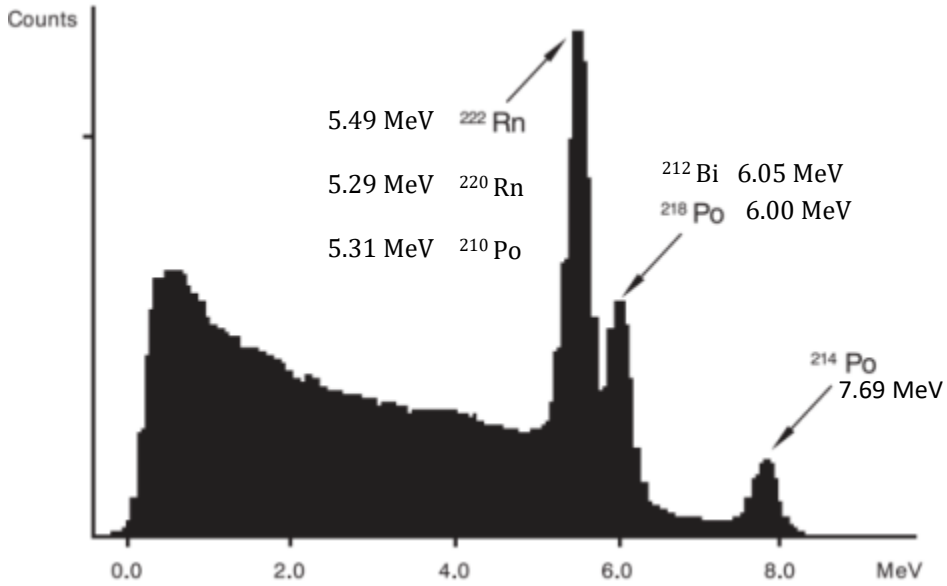




- Near-perfect background rejection, including long-lived $^{210}$Po contamination (purple peak).
- Near-perfect Radon/Thoron Discrimination (green/blue vs red/orange peaks).

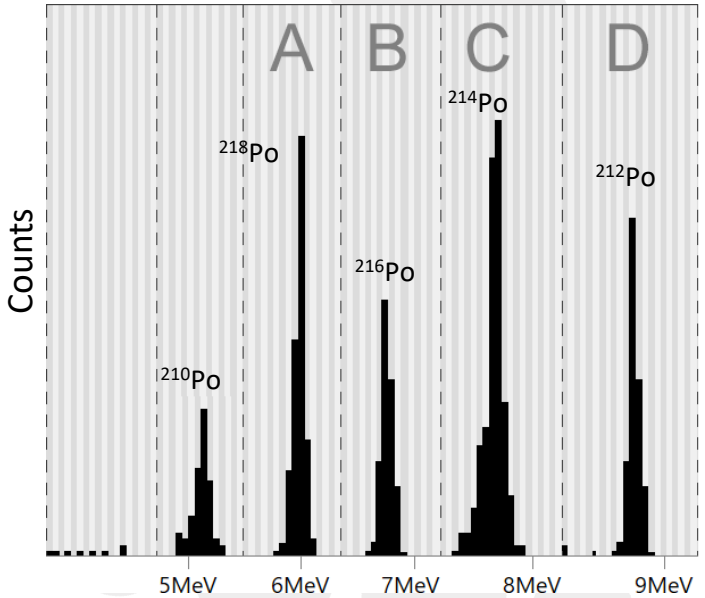
# Side-By-Side Spectrum Comparison

## Pulse Ionization 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.

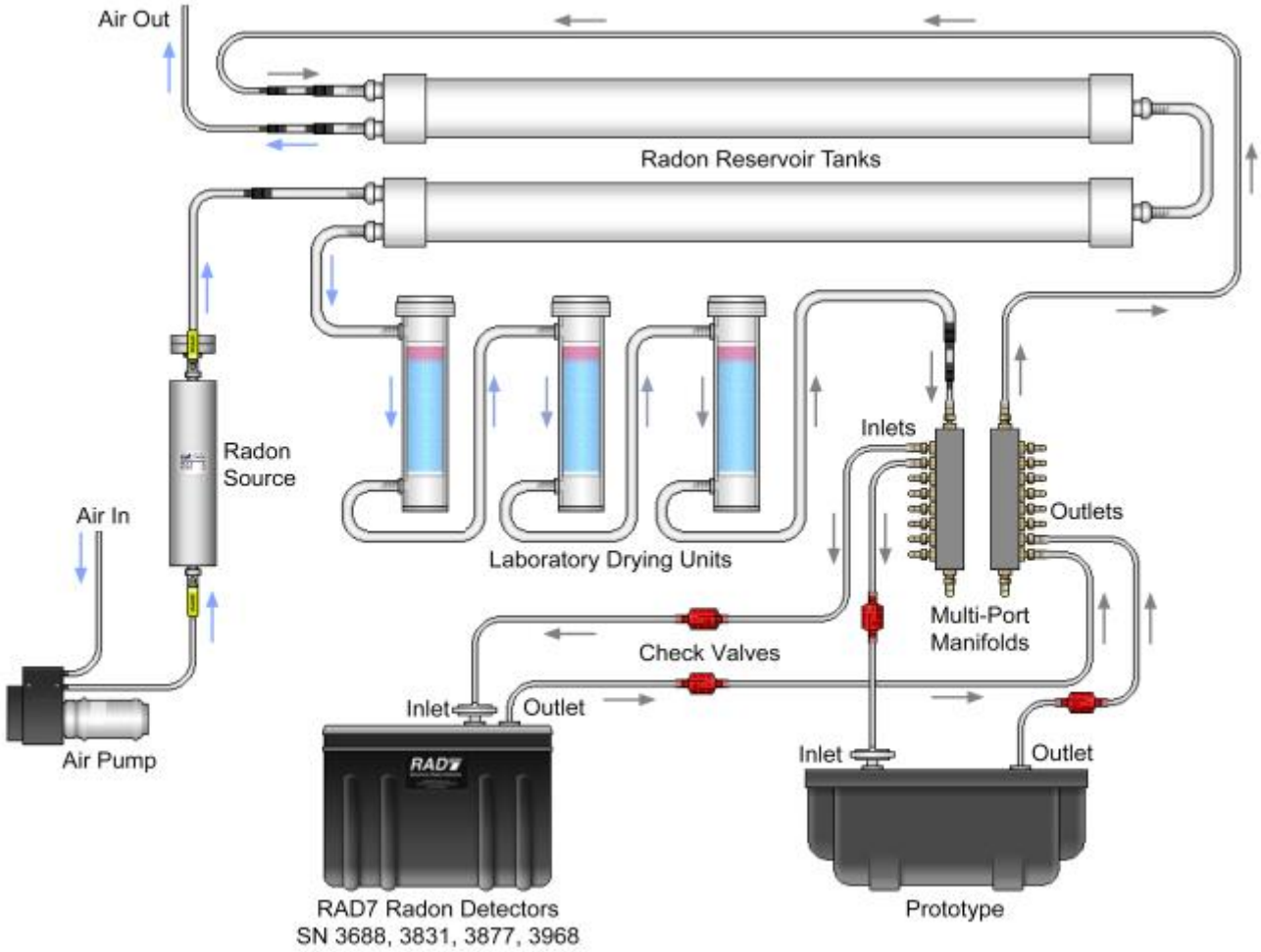
# Part 2

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

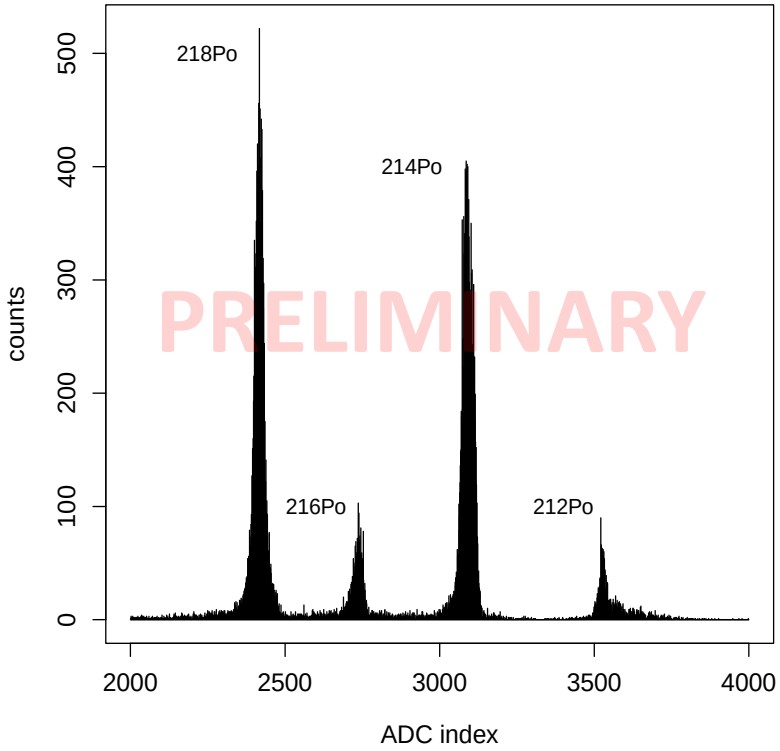
2. Future DURRIDGE technology – Preliminary sensitivity measurements of our next-generation prototype.

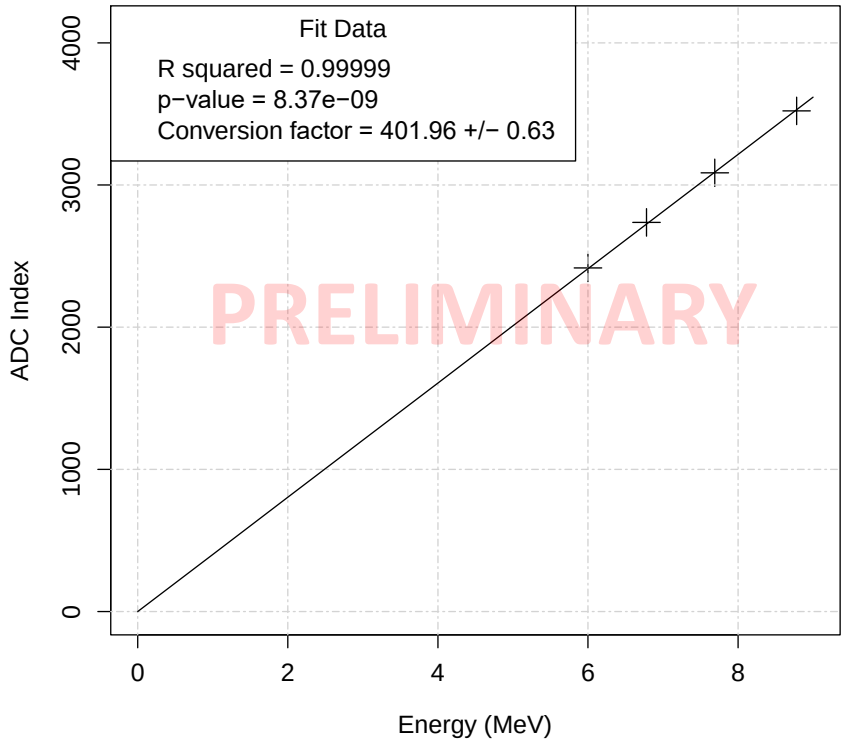
# Prototype – Sensitivity Measurement

- 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.

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Thanks for listening!