Performance of a silicon PIN photodiode based radon detector for low radioactivity environment

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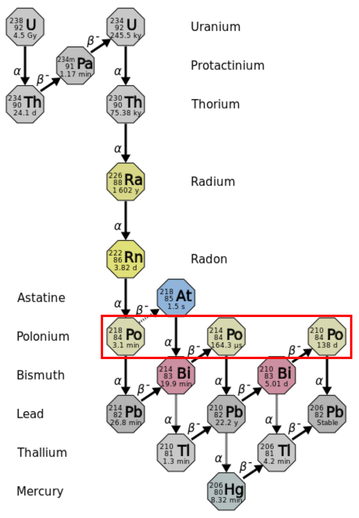
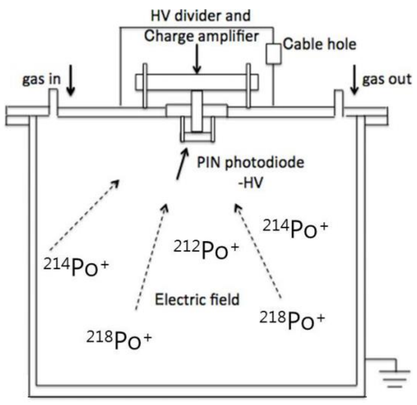
It is very important to monitor the amount of radon (Rn-222) in the underground experiments such as rare decay and dark matter experiments with ultra low background requirements. The radioactivity from the radon can be a significant background source to the experiments and need to be measured precisely. We have upgraded a radon detector with a volume of ~70 L which was used in the KIMS (Korean Invisible Matter Search) experiment by replacing with a Hamamatsu silicon PIN photodiode and a Hamamatsu pre-amplifier. The positively charged radon's daughter particles (Po-214 and Po-218 mostly) produced in the air of the detector chamber are collected by the photodiode in a negative high voltage. The energy resolutions of alpha particles emitted from the decays of the daughter particles are measured to be better than 0.6% with very clean signals to be identified. We also have had about 3 months of data with the air sealed after closing the chamber. The half-lifetimes of Rn-222 from two daughter particles measured together with the background level of the chamber are going to be presented.

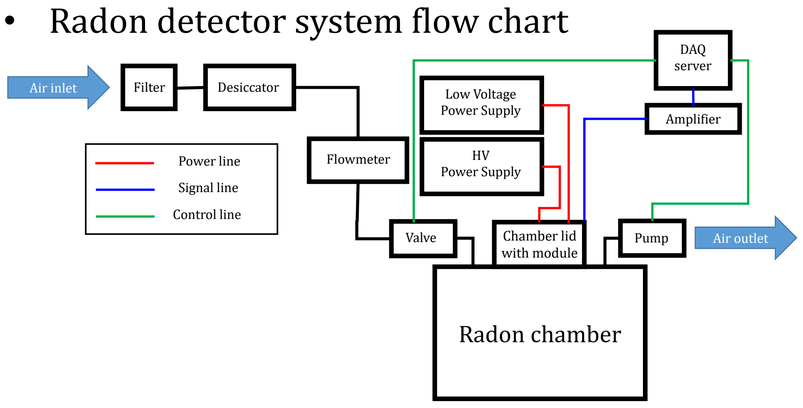
1. Introduction

- Radon detection process





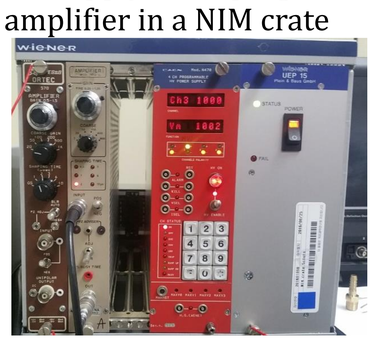
- Radon detector system flow chart



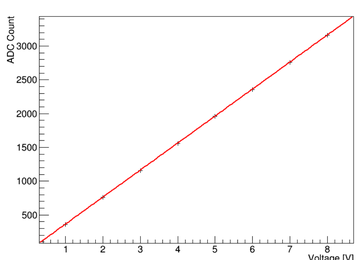
- Equipment

Low voltage power supply

HV supply & Shaping amplifier in a NIM crate

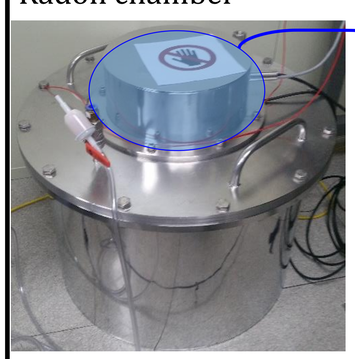


Flash ADC 25



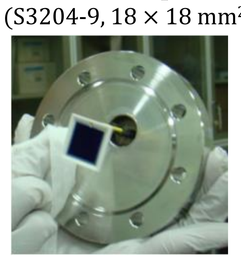
- Standalone 1 channel FADC
- 25 MS/s sampling rate, 12 bit resolution
- 0~10 V input range (modified from 4 V)
- Data buffer for 130 k samples

Radon chamber



HV divider circuit & preamp (H4083, Hamamatsu)

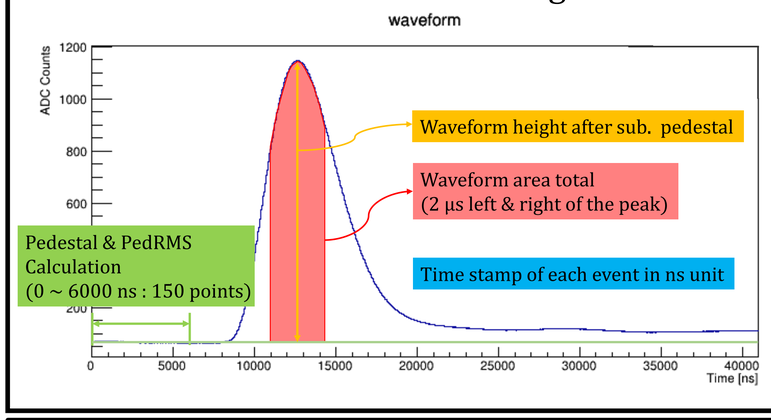
Silicon PIN photodiode (S3204-9, 18 × 18 mm², Hamamatsu)



- Internal Volume: 70 L
- High Voltage: -1,000 V
- Bias: 30 V
- Stainless steel with electro polished inside surface

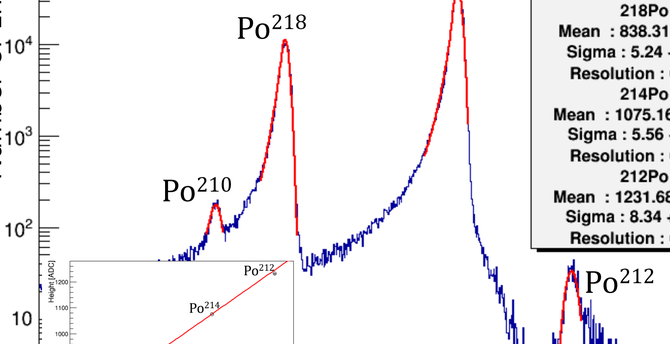
2. Waveform

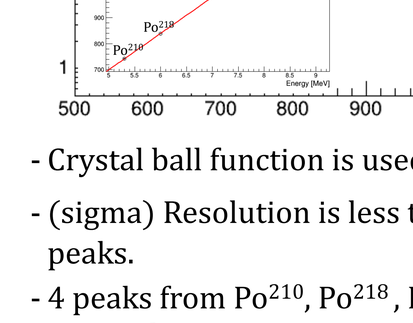
- FADC25 waveform from an α signal



3. Noise rejection

- Area total & Waveform height distribution (3 months of data)





While taking data, narrower waveforms than normal ones appeared.
⇒ it was possible to distinguish them by using the ratio of area and height .

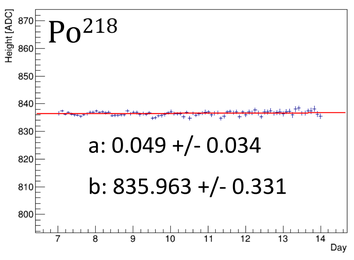
4. Pulse height distribution

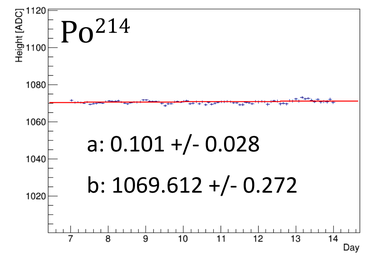
- Height distribution using data of 3 months

- Crystal ball function is used for fitting of all peaks.
- (sigma) Resolution is less than or equal to **1 %** for each peaks.
- 4 peaks from Po^{210}, Po^{218}, Po^{214} and Po^{212} show a good energy linearity.

5. Stability check

- Profiles of Po^{214} & Po^{218} with time
  - Selected within 2 sigma region
  - Linear function fit (ax + b)

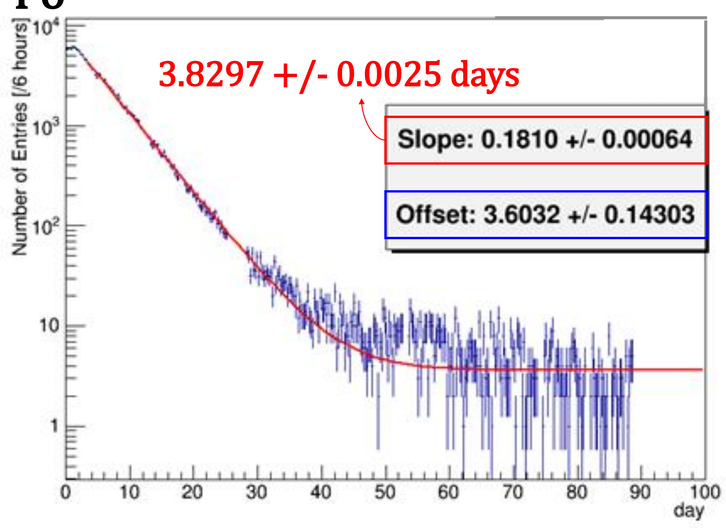




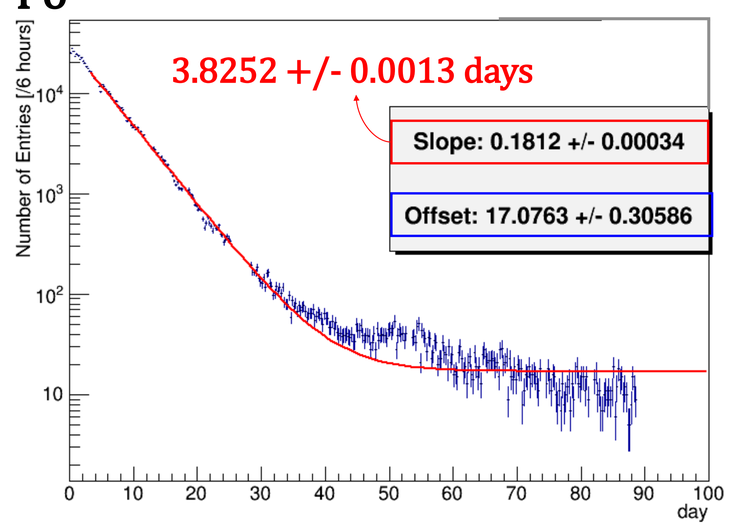
6. Half lifetime measurements

- Measured the half lifetime of Rn^{222} using Po^{214} & Po^{218} events (within 2 sigma)
  - $T_{1/2}$ (NNDC): 3.8235(3)days NNDC: National Nuclear Data Center
  - Fitting function: $ae^{-bt} + c$

Po^{218}



Po^{214}



- The background level obtained from the offset is $\sim \frac{1}{2000} \times \max$
- Radon concentration of the initial air: 150 Bq/m³ (RAD7)

⇒ **0.075 Bq/m³ BKG level**

7. Summary

- The upgraded radon chamber has stably collected data for 90 days after sealing an office air.
- Noise events were removed effectively using a waveform area and height ratio parameter.
- From the 90 days data, 4 radon daughters (Po^{210}, Po^{218}, Po^{214}, and Po^{212}) were observed and a good energy linearity among them was confirmed.
- The half lifetime of Rn^{222} using Po^{214} and Po^{218} was measure to be 3.8252 days and 3.8297 days, respectively. They are within 2.5 sigma of the Rn^{222} half lifetime from NNDC.
- The background level of this radon chamber is estimated as ~75 mBq/m³.