



A method for detection for all three naturally occurring radon

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Introduction

- Radon is the most important source of ionizing radiation which poses human health risks especial lung cancer after smoking.
- We are developing a technique for determining radon based on Liquid Scintillation Counting (LSC) technique with photomultiplier tube (PMT) using delayed coincidence technique (DCT) and Pulsed Shape Discrimination (PSD) method implemented by Digital Charge Comparison (DCC).
- This technique can be used to detect all three isotopes of radon found in nature (^{222}Rn , ^{220}Rn and ^{219}Rn) which are the product of a natural decay series of Uranium (^{238}U), Thorium (^{232}Th) and Actinium (^{235}U), respectively. The target isotopes are shown in Table-1

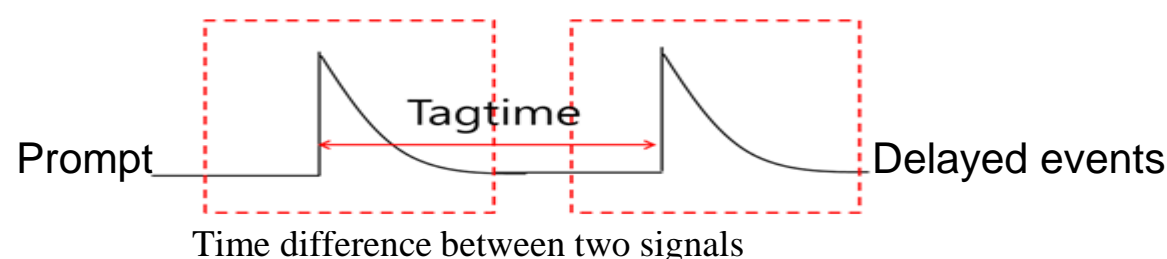
Table-1: Summary of target isotopes

	^{238}U family	^{235}U family	^{232}Th family
Mother isotope	^{214}Bi $Q_\beta = 3.27\text{ MeV}$ $T_{1/2} = 20\text{ min}$	^{219}Rn $Q_\alpha = 6.95\text{ MeV}$ $T_{1/2} = 3.97\text{ min}$	^{212}Bi $Q_\beta = 2.25\text{ MeV}$ $T_{1/2} = 60.55\text{ min}$
Daughter	^{214}Po $Q_\alpha = 7.83\text{ MeV}$ $T_{1/2} = 164\text{ }\mu\text{s}$	^{215}Po $Q_\alpha = 7.53\text{ MeV}$ $T_{1/2} = 1.78\text{ ms}$	^{212}Po $Q_\alpha = 8.95\text{ MeV}$ $T_{1/2} = 0.299\text{ }\mu\text{s}$
Granddaughter	^{210}Pb	^{211}Pb	^{208}Pb

Neutron Tagging Module (NGT400)

- NGT400 tags neutron signal from a liquid scintillation detector by utilizing digital pulse shape discrimination (PSD) implemented by digital charge comparison (DCC) method.
- NGT400 accepts an input pulse with width from 20 to 1270 ns.

Delayed Coincidence Technique (DCT)



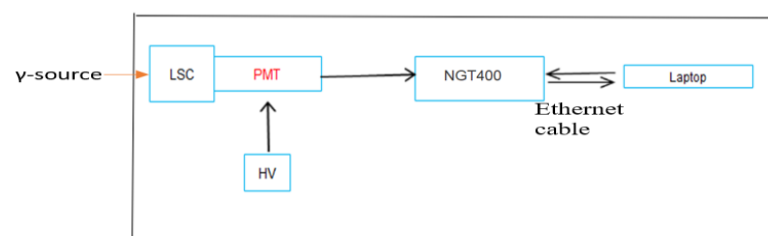
- Tagtime between prompt and delayed events is time difference between two signals.
- For example, to select out ^{214}Po in ^{238}U decay chain, we set the time difference from $2\text{ }\mu\text{s}$ to $656\text{ }\mu\text{s}$.
- The lower threshold of $2\text{ }\mu\text{s}$ in the time coincidence requirement adopted to reject the short ^{212}Bi - ^{212}Po coincidence in the ^{232}Th chain. This $2\text{ }\mu\text{s}$ is near about 7 half-lives of ^{212}Po .
- The upper limit was set as $656\text{ }\mu\text{s}$ which is four half-lives of ^{214}Po .
- The cutting conditions on the same region of interest (ROI) covers selection efficiency (S.E) 99.3% of its alpha events distribution, 82.6% of beta events distribution and 99.2% of its decay function.

Materials

- We use Ultima Gold AB liquid scintillation cocktail which are designed for alpha/beta discrimination in liquid scintillation counting. It is an excellent sample which can holding both aqueous and acidic sample types. Ultima Gold AB (UG-AB) \rightarrow 700 mL
- Radon source \rightarrow from air \rightarrow 48 hrs \rightarrow feed to the 700 mL of UG-AB
- Sample container \rightarrow one liter of Stainless Steel (SUS) container with teflon coating inside.

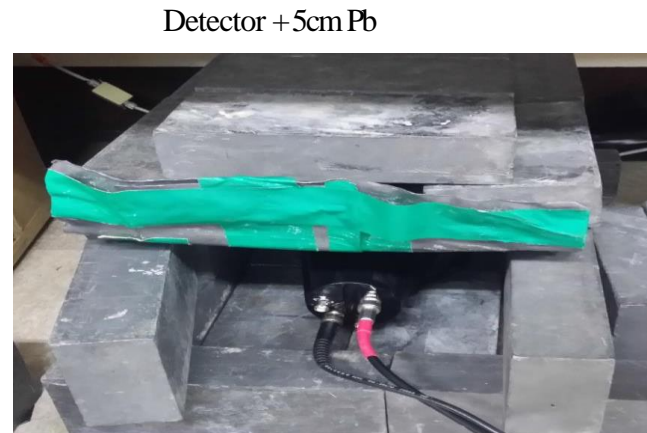
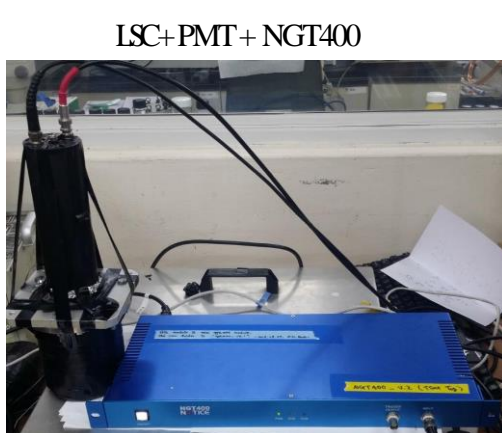
Schematic Diagram of Experimental Setup

- PMT \rightarrow Hamamatsu 7195
- High voltage \rightarrow -1800 V
- DAQ \rightarrow ngt400
- PC \rightarrow Linux operation system with root programming.

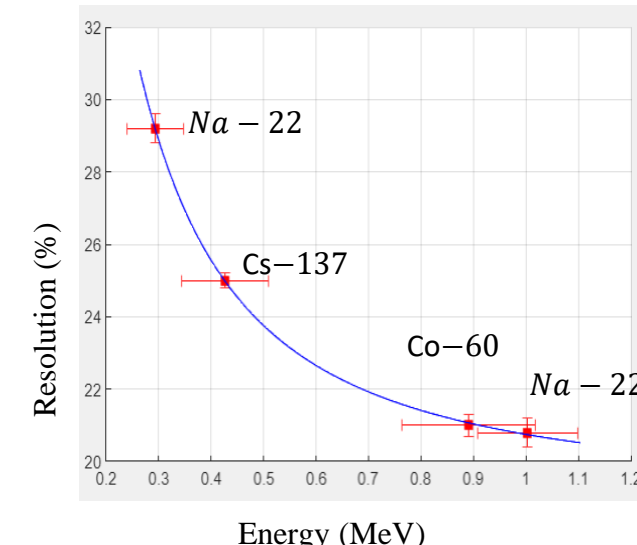
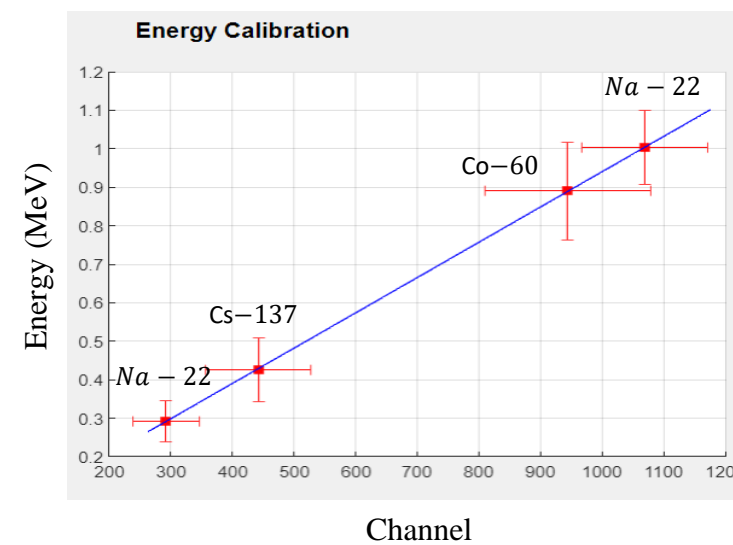


LSC detector with 5 cm Pb shielding

SUS container
V=1.0 L
d=2 mm Teflon+2 mm
SUS outside
5 mm glass window
Test with 700 mL
Ultima Gold AB



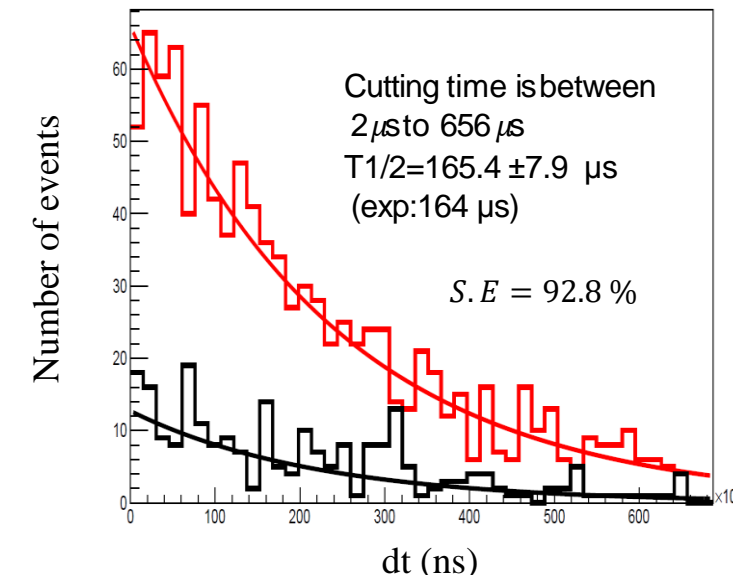
Energy Calibration and Energy Resolution



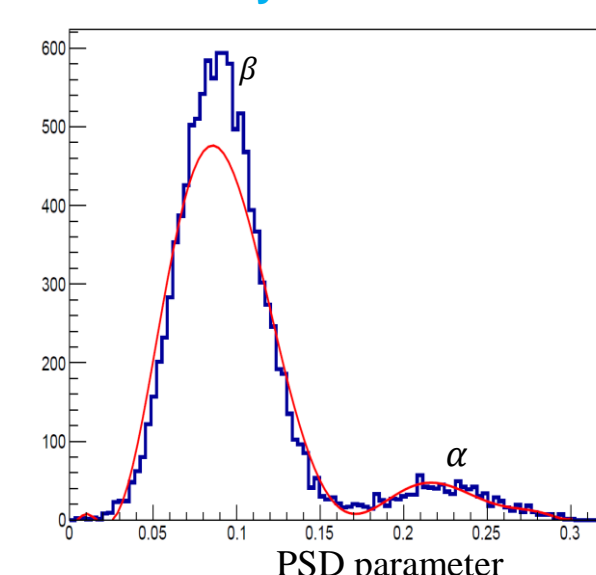
Results

Half life of $^{214}\text{Bi} \rightarrow ^{214}\text{Po} \rightarrow ^{210}\text{Pb}$ (^{238}U)

with Background spectrum within the same ROI

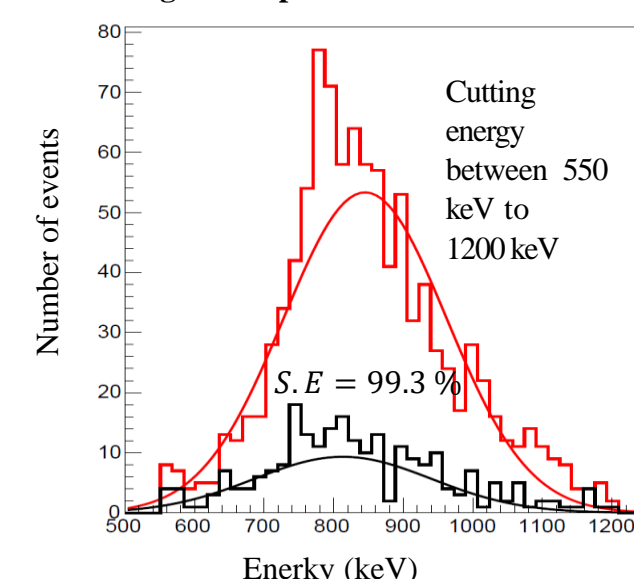


PSD by DCC method



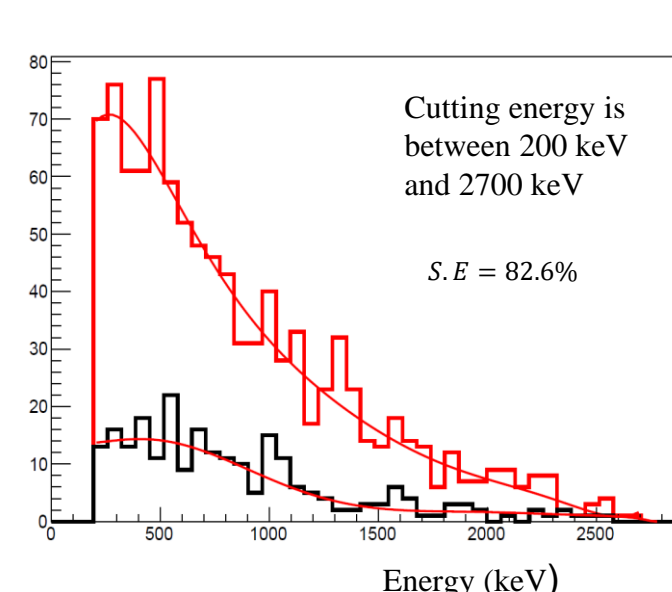
Energy spectrum for the ^{214}Po

with Background spectrum within the same ROI



Energy spectrum for the ^{214}Bi

with Background spectrum within the same ROI



Energy spectra of ^{214}Po (left) delayed and ^{214}Bi (right) prompt events selected by DCT method.

Detector Efficiency

	Cut	Efficiency (%)
Alpha Energy product from Po-214	$E_\alpha > 550 < 1200\text{ keV}$ & $dt > 2 < 656\text{ }\mu\text{s}$	99.3
Beta Energy product from Bi-214	$E_\beta > 0 < 2500\text{ keV}$	82.6
Half life of $^{214}\text{Bi} \rightarrow ^{214}\text{Po} \rightarrow ^{210}\text{Pb}$ (^{238}U)	$dt > 2 < 656\text{ }\mu\text{s}$	92.8
Total Efficiency		76.1

Minimum Detectable Activity (MDA)

- MDA of 3.2 mBq/L of ^{222}Rn (^{222}U decay chain) for 12.5 hours data taking was calculated by using Currie formula $MDA = \frac{2.71 + 4.65\sqrt{C_b T_b}}{\epsilon \times V_s \times T_s \times 60}$, where
- C_b is the background count rate (cpm)
- T_b is the background counting time (min)
- ϵ is the counting efficiency, V_s is the sample Volume,
- T_s is the sample counting time (min) and
- The factor of 60 is used to express the MDA in terms of Bq

Summary and Future plan

- Ultima Gold AB (UG-AB) was used for the detection of radon decay product in 700 mL UG-AB sample in the one liter of SUS container.
- We measured half life of ^{214}Po to be $165.4 \pm 7.9\text{ }\mu\text{s}$ which is consistent with expected half-life of $164\text{ }\mu\text{s}$.
- We found the total efficiency of the system of 76.1% for ^{222}Rn (^{238}U decay chain).
- We calculated the MDA of 3.2 mBq/L of ^{222}Rn (^{238}U decay chain).
- We will work on other target isotopes in order to calculate the efficiency and limit of the method for ^{220}Rn (^{232}Th decay chain) and ^{219}Rn (^{235}U decay chain).

Energy Calibration with gamma sources

