Radioactivity Measurement of ^{60}Co using $4\pi\beta(\mathrm{LS}) - \gamma$ Coincidence System

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May 18, 2023

KNS 2023 Spring

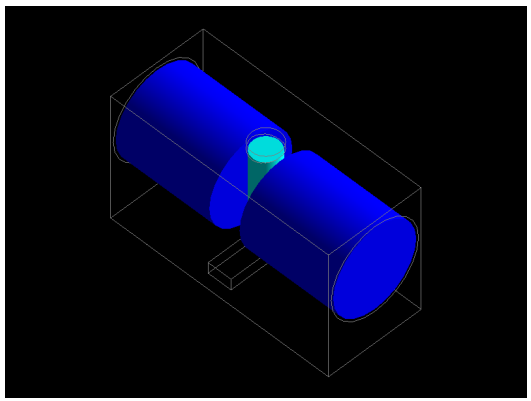
Introduction

- Production of radioisotopes (RI) in research reactor HANARO
- Reactor-produced ^{177}Lu → radioactivity measurement
- Measurement method: $4\pi\beta - \gamma$ coincidence counting

- HANARO

- Lutetium

- $4\pi\beta - \gamma$ coincidence counter



$4\pi\beta(\mathrm{LS}) - \gamma$ Coincidence Counting

- β & γ emissions from RI $\rightarrow$ coincidence counting
- Relation among observed counting rate & radioactivity

$$\frac{N_\beta N_\gamma}{N_c} = N_0[1 + k(\frac{1-\epsilon_\beta}{\epsilon_\beta})] = N_0[1 + k(\frac{N_\gamma}{N_c} - 1)]$$

$N_{\beta,\gamma,c}$: Observed counting rate of $\beta/\gamma/\beta$-γ coincidence events

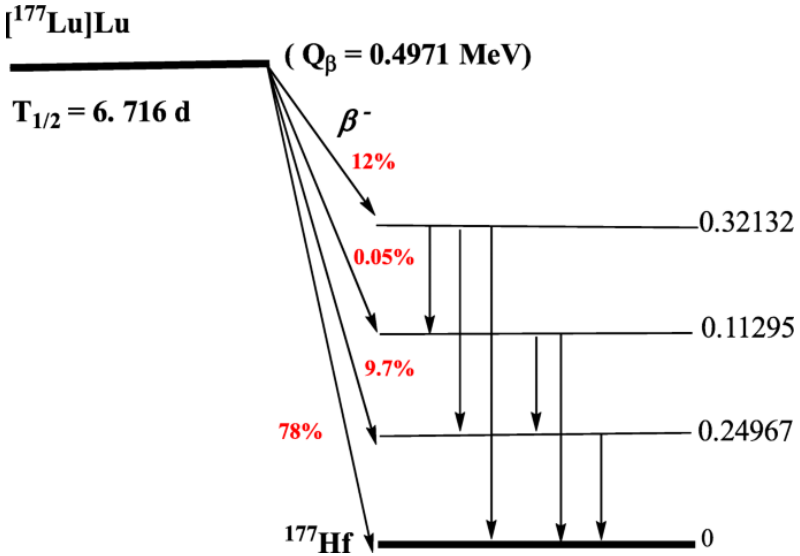
N_0: Radioactivity of RI

ϵ_β: β detection efficiency

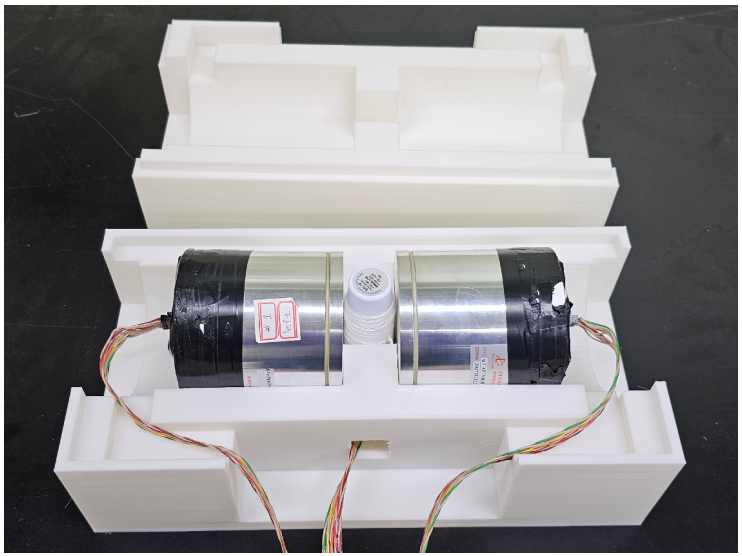
k: constant

- Efficiency-extrapolation ($\epsilon_\beta \rightarrow 1$): obtaining radioactivity of RI

- Decay scheme of radioisotope

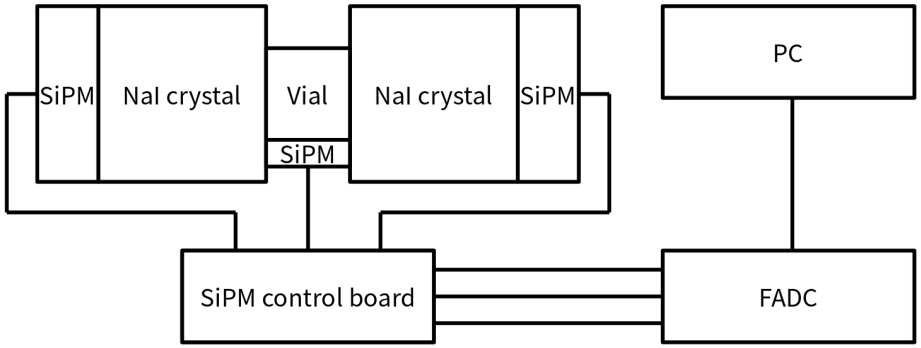


- $4\pi\beta - \gamma$ coincidence counter

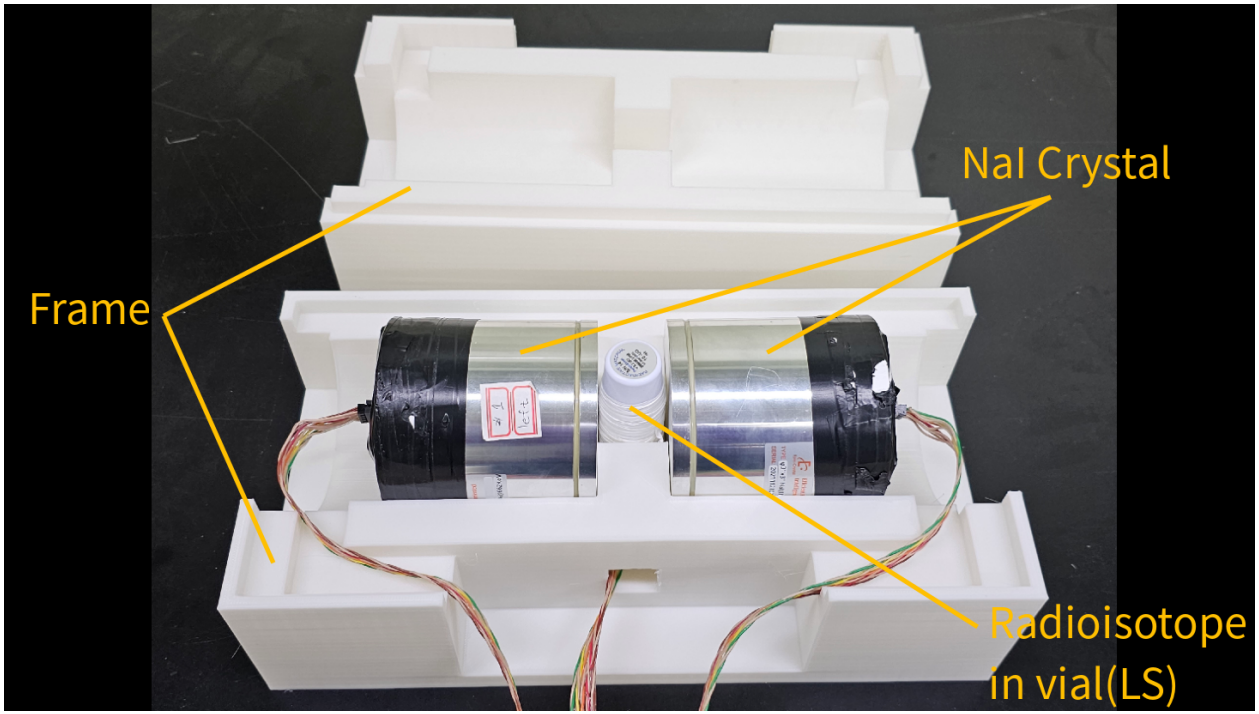


$4\pi\beta(\mathrm{LS}) - \gamma$ Coincidence System

- Diagram



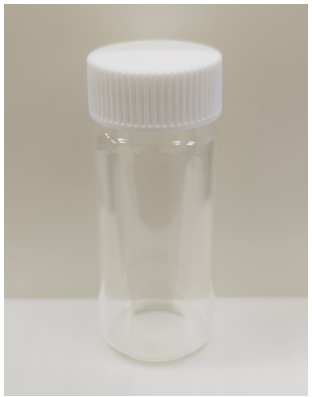
- $4\pi\beta - \gamma$ coincidence counter



Components of $4\pi\beta(\mathrm{LS}) - \gamma$ Coincidence Counter

- Vial: containg LS & radioisotope, β detection
- NaI crystal: 3-inch, γ detection
- SiPM: scintillation light detection
- SiPM control board: power supply, thermometer
- Frame: 3-D printing, plastic

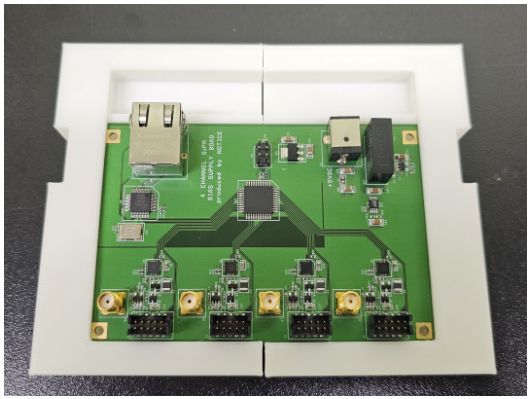
- Vial



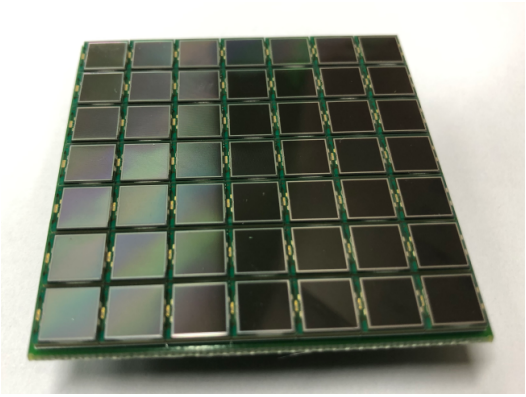
- LS

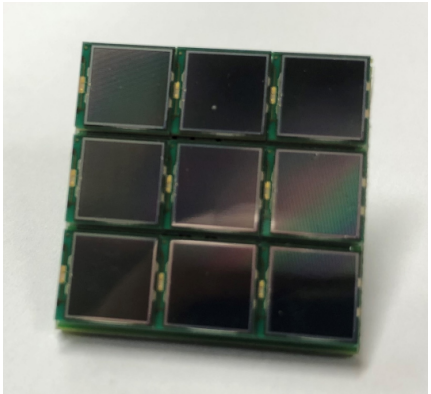
- NaI crystal

- SiPM control board

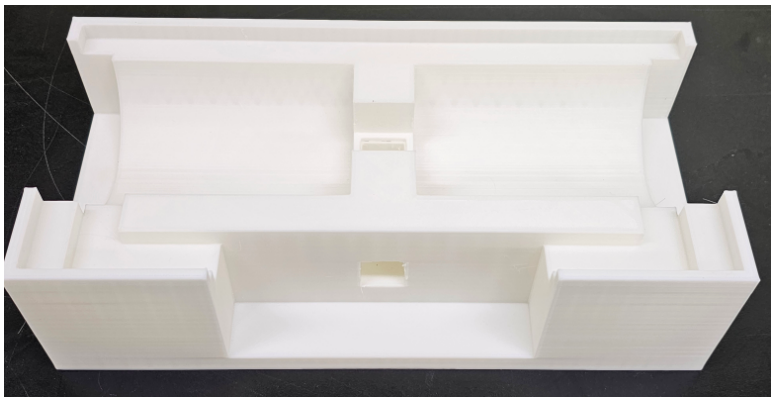


- SiPM





- Frame



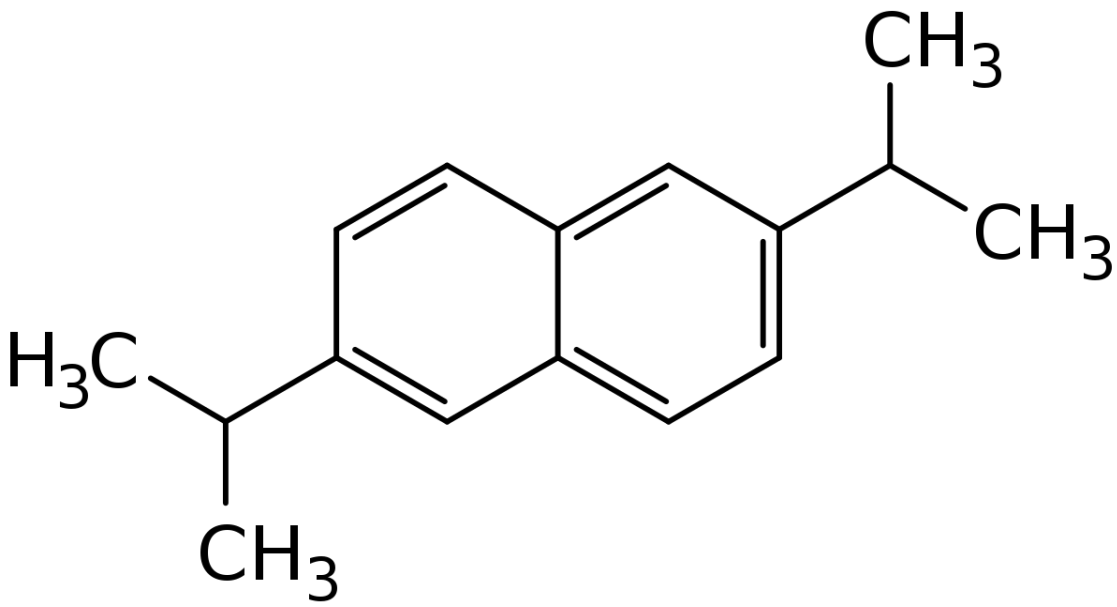
Detecting Materials: β

- Liquid scintillator
- Product name: Ultima Gold F
- Production: Perkin Elmer
- Main material: Diisopropylnaphthalene

- Light output: $\sim$10,000 photons/MeV
- Flash point: 140 $^{\circ}\mathrm{C}$
- Density: 0.96 $\mathrm{g/cm^3}$

- Ultima Gold F

- Diisopropylnaphthalene (DIN)

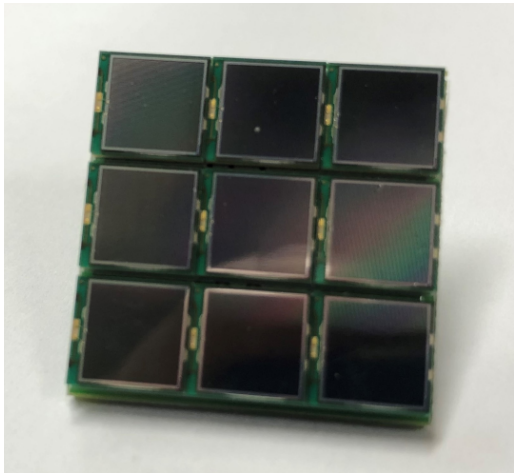


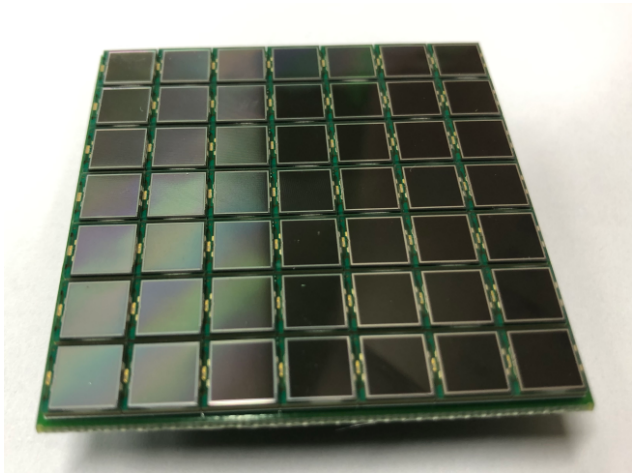
Detecting Materials: γ

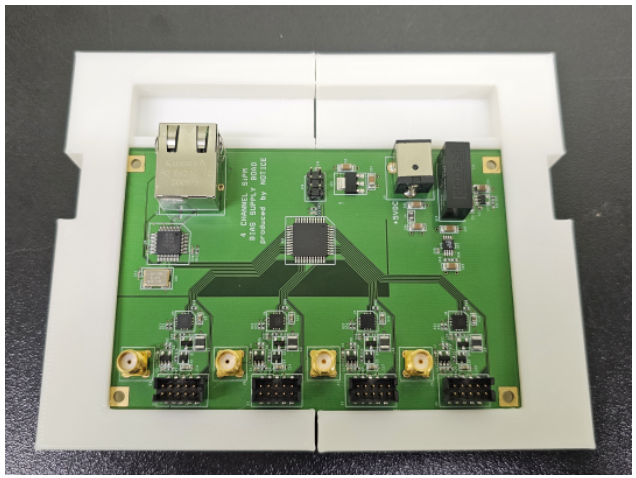
- NaI crystal
- Production: Epic-Crystal
- Growth technique: Bridgman
- Shape: cylindrical
- Light output: $\sim$40,000 photons/MeV
- Diameter: 3”
- Height: 8 cm
- Density: 3.67 $\mathrm{g/cm^3}$

SiPM & Control Board

- SiPM: Hamamatsu S13
  - Operating voltage: 52-60 V
  - Operating temperature: -20 to 60 °C
  - Gain: 1-5×10^6 @25 °C
  - Spectral response range: 320-900 nm
  - Photon detection efficiency: 40% @450 nm
- SiPM array & control board
  - Production: Notice Korea
  - 3×3 array: for vial(LS),
  - 7×7 array: for NaI,
  - Control board: 4 channels,
  - Connection: TCP/IP

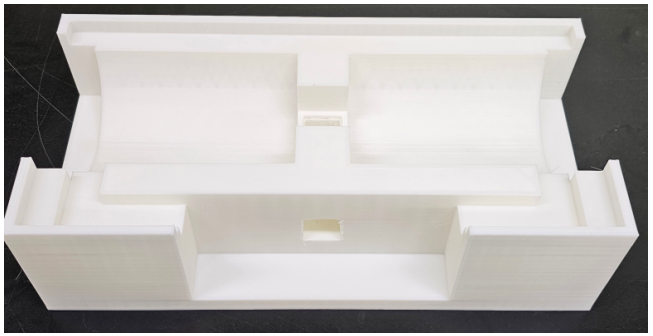


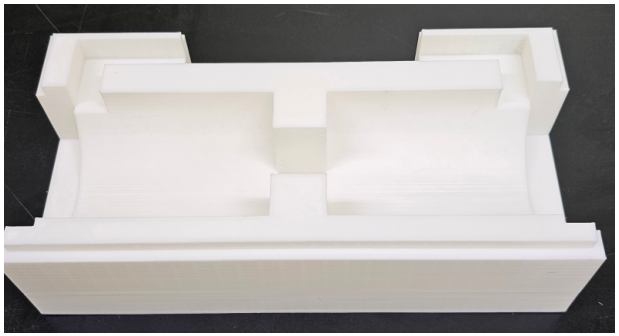


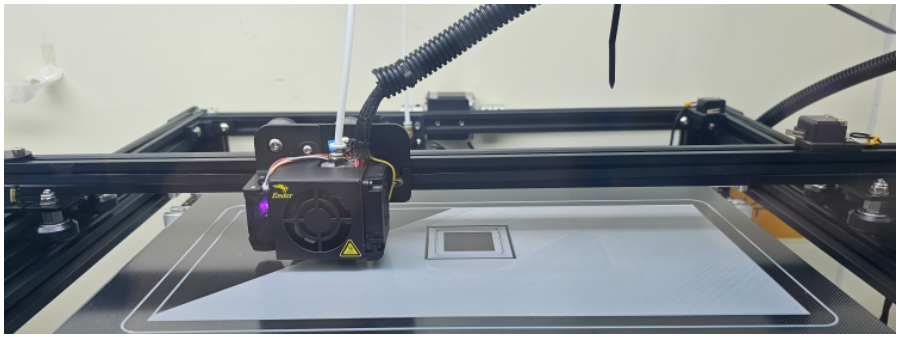


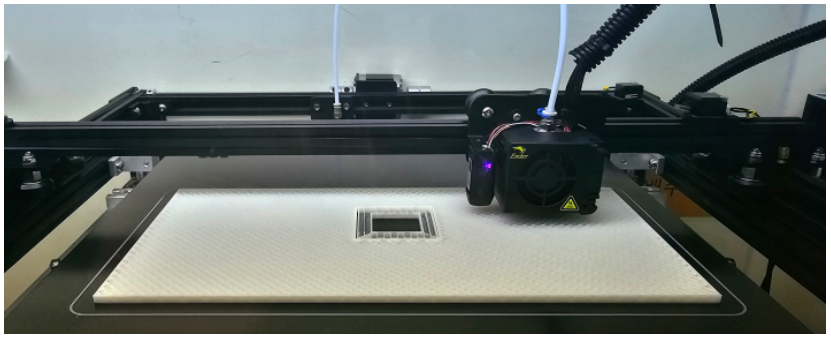
Frame Production

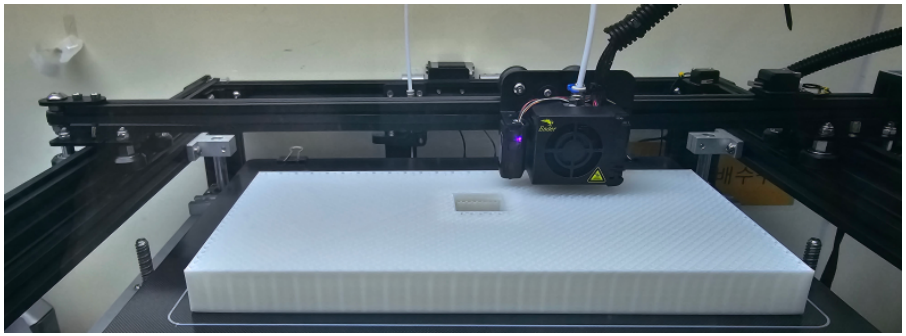
- 3-D printing
- Material: plastic
- Design: CAD
- Upper + lower
- Production time: 60 hr

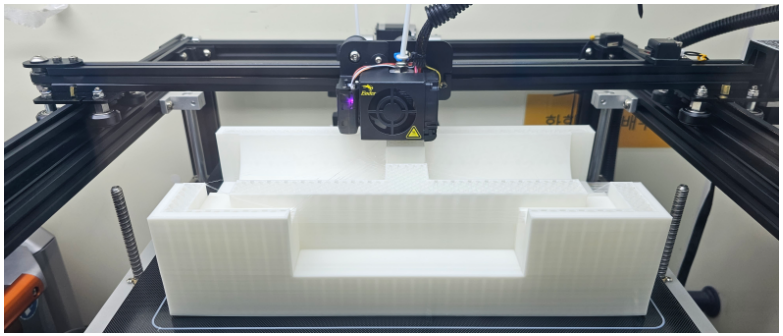




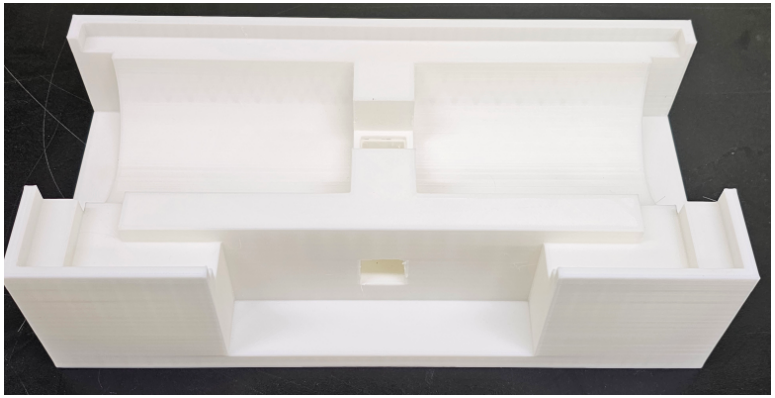


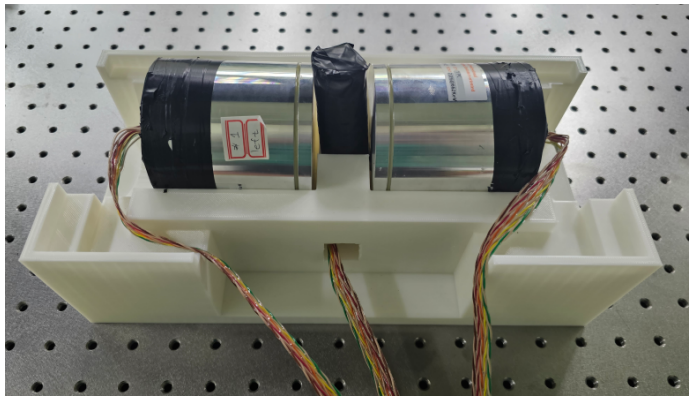






Counter Assembly

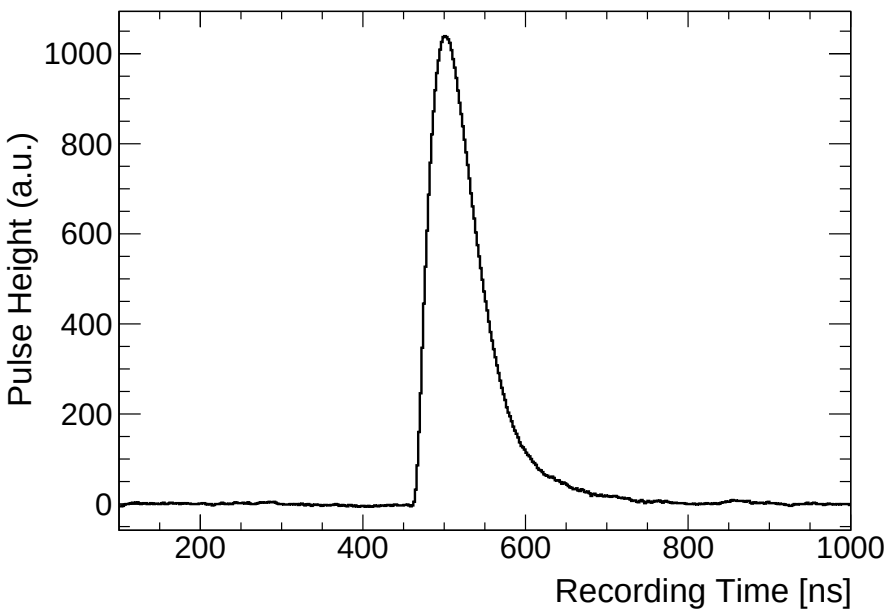




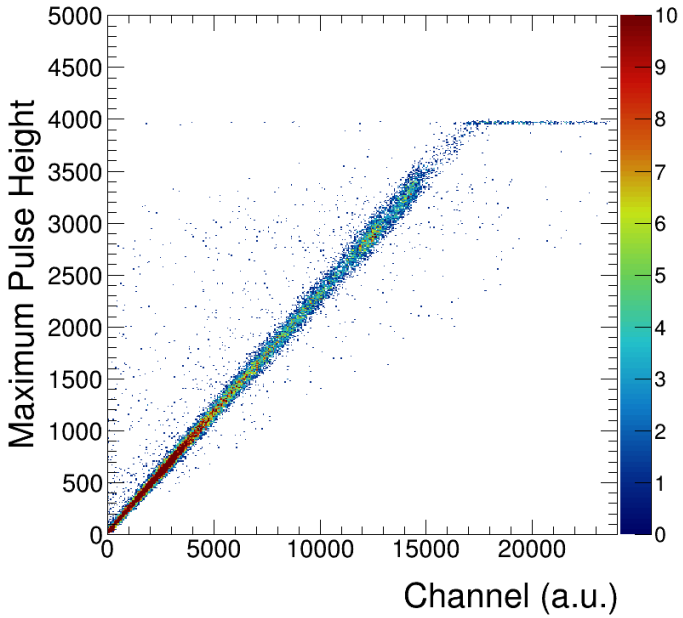
DAQ System

- FADC500 (Notice Korea)
- 4 channels
- 500 MHz sampling rate
- Dynamic range: 12 bit / 2.5 V
- Recording length: 0.1-32 μs
- Maximum trigger rate: $\sim$40 kHz

- Pulse



- Saturation



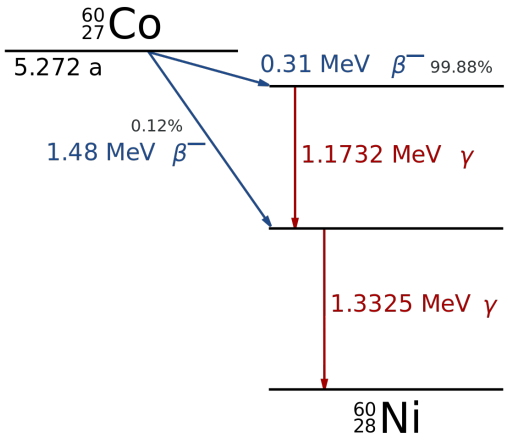
Test Run of the System

- Testing $4\pi\beta(\mathrm{LS}) - \gamma$ coincidence counter using ^{60}Co

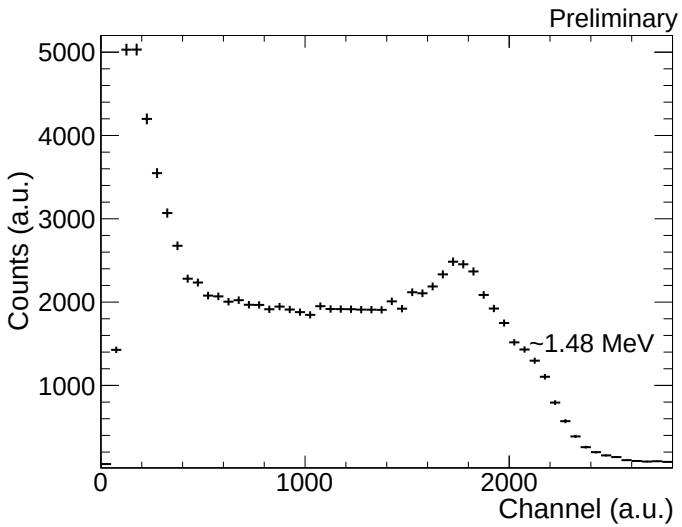
- ^{60}Co source

- Experimental setup

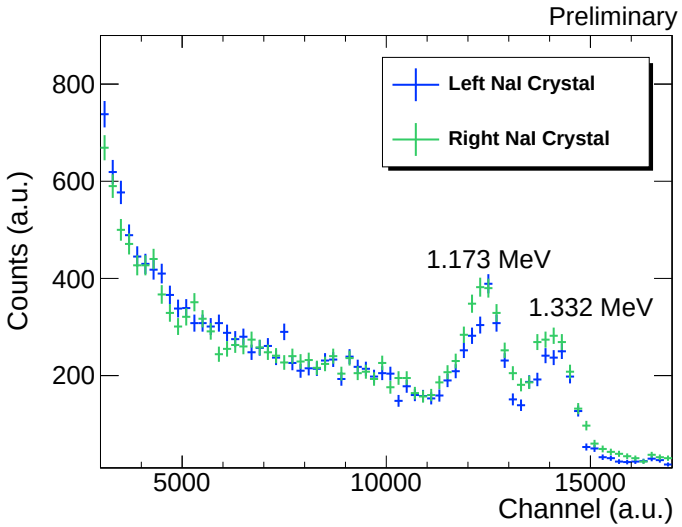
- Decay scheme for ^{60}Co



- β spectrum



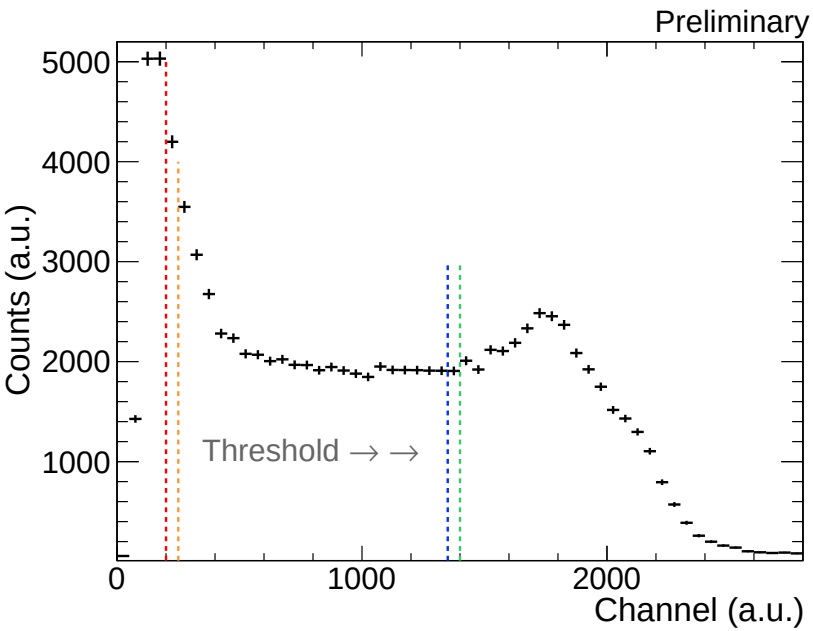
- γ spectra



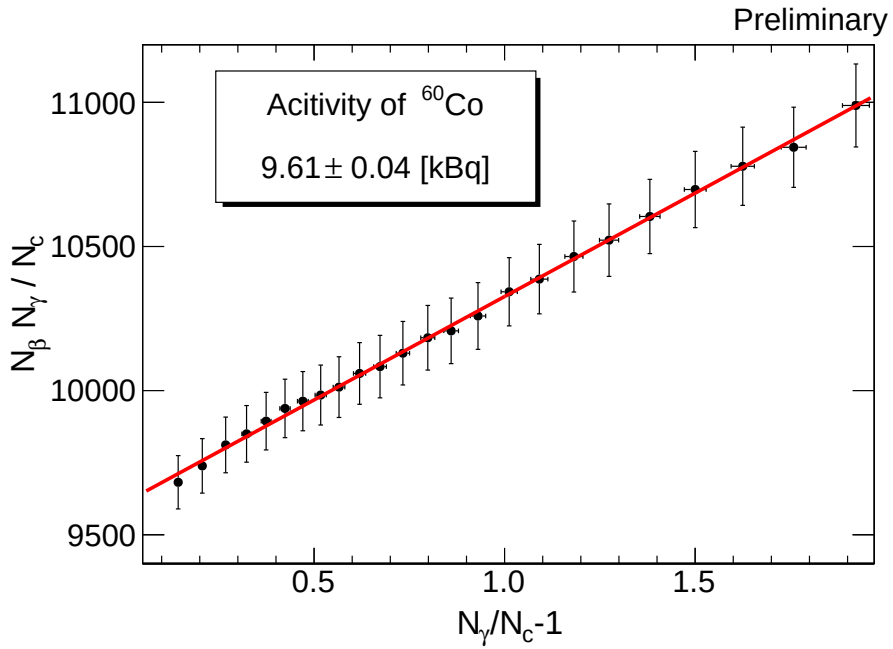
Radioactivity Measurement Test

- $N_\beta N_\gamma / N_c$ for various ϵ_β values → efficiency-extrapolation → radioactivity of RI
- Changing threshold for β → various ϵ_β values
- Fitting function: equation in page 3
- Error bar: statistical uncertainty only

- Thresholds for β



- Efficiency-extrapolation



Summary & Plan

- Development of $4\pi\beta(\mathrm{LS}) - \gamma$ coincidence system for radioactivity measurement
- Producing/selecting each part of the system → assembly
- Trying radioactivity measurement using ^{60}Co
- Detailed studies are ongoing
  - stability check
  - systematic uncertainties
- Production of ^{177}Lu → radioactivity measurement will be done.