Testing position dependence for activity measurement using 4πβ(LS)-γ coincidence counting

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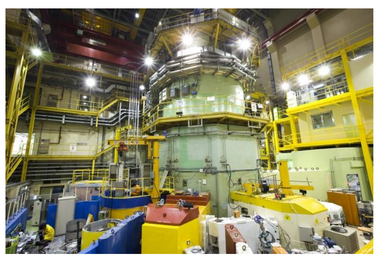
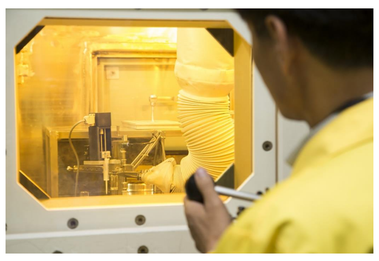
Introduction

- Radioisotope (RI) production in HANARO (^{177}Lu, ^{166}Ho, ^{60}Co, etc.)
- β/γ spectra & radioactivity measurement for reactor-produced RI, in a narrow space (hot cell)

→ mini size activity measurement system



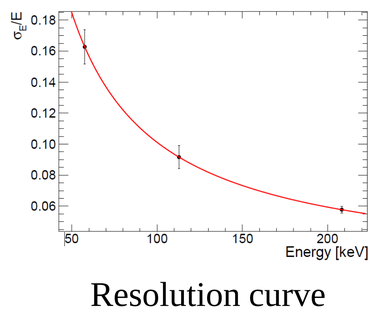
Research reactor HANARO



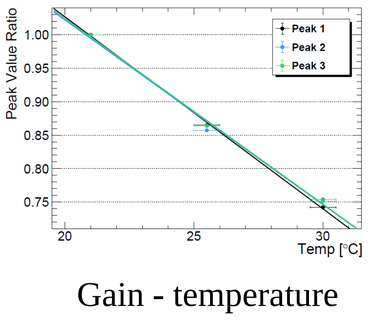
Hot cell at KAERI

Characteristic of the System

- Resolution of γ detectors: ~5% @ 662 keV
- Temperature dependence
  - 3% gain change for ±1 ℃ change
  - activity fluctuation: < 0.4% for ±1 ℃ change



Resolution curve

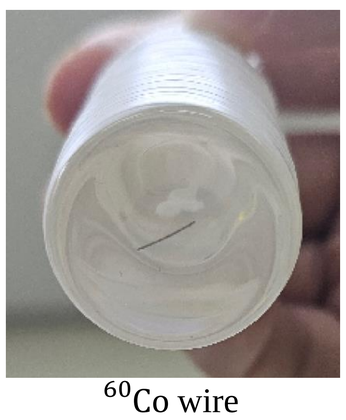


Gain - temperature

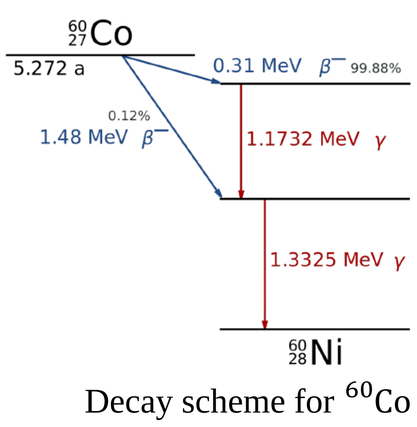
Testing Position Dependence

- Configuration for 4πβ-γ coincidence counting
  - radionuclide sample in aqueous solution
  - uniform distribution of radionuclide sample
- Solid-state radionuclide sample
  - cannot uniformly distributed

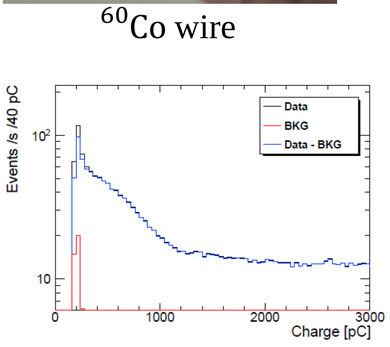
  → testing position dependence
- Testing position dependence using ^{60}C*o* wire
  - neutron irradiation to ^{59}C*o* wire in HANARO

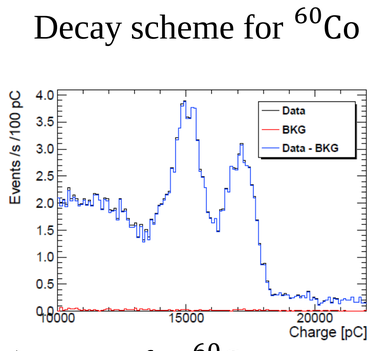


^{60}Co wire



Decay scheme for ^{60}Co





β (left) and γ (right) spectra for ^{60}Co

- Wire source holders
  - produced using 3-D printer (mat.: PLA+)
  - 6 (left) and 11 (right) positions

4πβ-γ coincidence system

- Measurement of correlated β and γ from the radioactive decays of produced radioisotope
- Estimating absolute radioactivity of the radioisotope (Efficiency-extrapolation method)
- $\frac{N_\beta N_\gamma}{N_c} = N\left[1 + C\left(\frac{1-\varepsilon_{\beta m}}{\varepsilon_{\beta m}}\right)\right] = N\left[1 + C\left(\frac{1-N_c/N_\gamma}{N_c/N_\gamma}\right)\right]$

Activity Measurement System

- Developed in 2023 / activity measurements were validated using the reference materials
- Composition: detection part (β/γ detectors) + DAQ system
- Detecting material: Liquid scintillator (β, Ultima Gold AB), NaI crystal (γ, Saint-Gobain)
- SiPM array: scintillation light sensor
  (SiPM: Hamamatsu SP13360-1350PE, array production: Notice Korea)
- DAQ system: FADC (flash analog-to-digital converter) + server

The activity measurement system

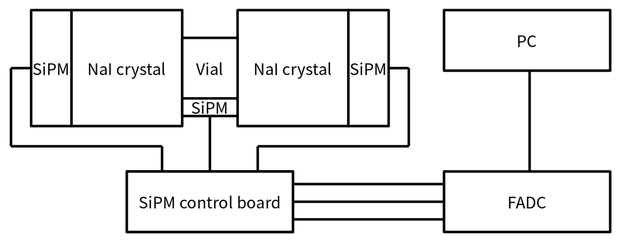
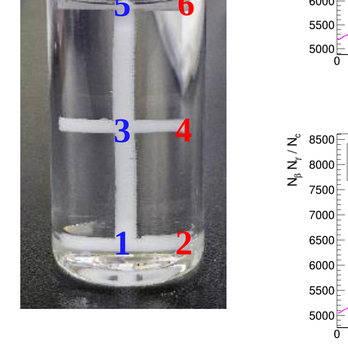
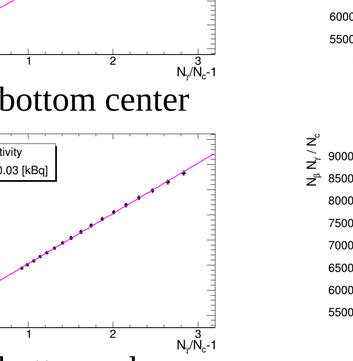


Diagram for the activity measurement system

Measurements using the system

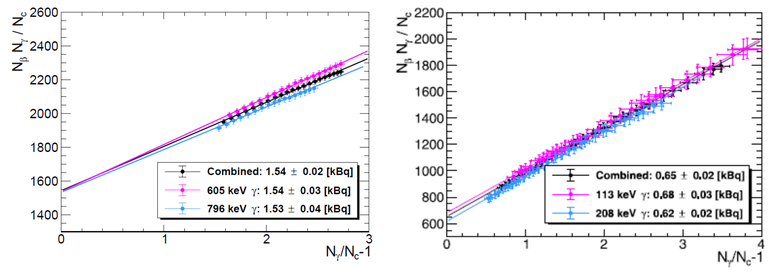
- β/γ spectra & activity measurements for the reference materials ^{177}Lu & ^{134}Cs





β/γ spectra for ^{134}Cs

β/γ spectra for ^{177}Lu



Nulcide	Activity	Reference	Differences
^{134}Cs	1.54 ± 0.03 [kBq]	1.58 ± 0.05 [kBq]	2.2%
^{177}Lu	0.654 ± 0.023 [kBq]	0.637 ± 0.008 [kBq]	2.6%

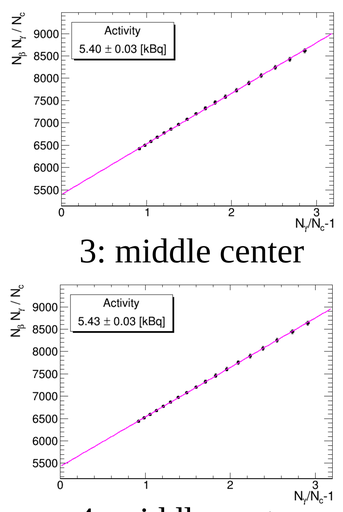
Activity measurements for ^{134}Cs (left) & ^{177}Lu (right)

Results of Position Dependence Test

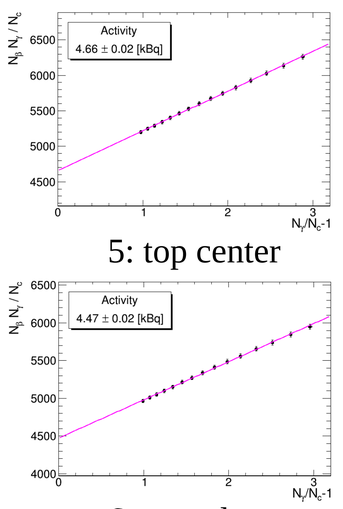
- Testing and comparing 6 positions (center/edge)

  → measured activity values: center ≥ edge, middle > bottom > top

1: bottom center



3: middle center



5: top center

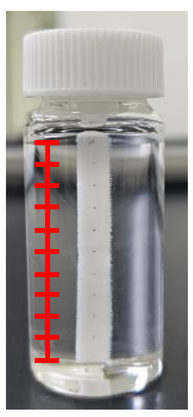
2: bottom edge

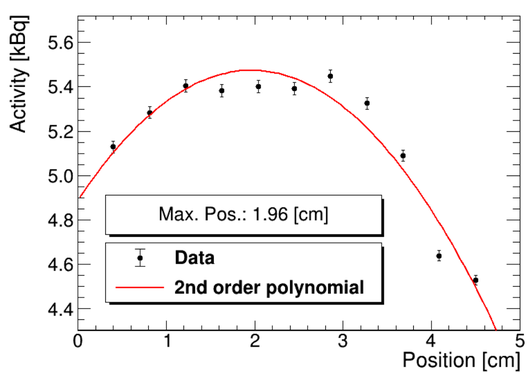
4: middle center

6: top edge

- Testing and comparing 11 positions (center, bottom-top (0.4-4.8 cm), 0.4cm interval)

  → measured activity values: middle > bottom > top, the maximum activity at middle





- Study plans
  - the origin of differences between bottom and top
  - size dependence of the solid-state radioactive sample
  - γ detection in β detector

  → preparing Monte Carlo simulation