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Measurement of ^{nat}In(γ, xn) reaction cross sections with the 63 MeV bremsstrahlung

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Background & Motivation

Precise nuclear data information for indium (In) isotopes are important for the development of medical radioisotopes.

(Examples)

^{111}In :

- Cerebrospinal Fluid Imaging : ^{111}In-DTPA,
- Bone marrow scintigraphy : ^{111}In-Cl_3
- thrombo-scintigraphy : ^{111}In-Platelet

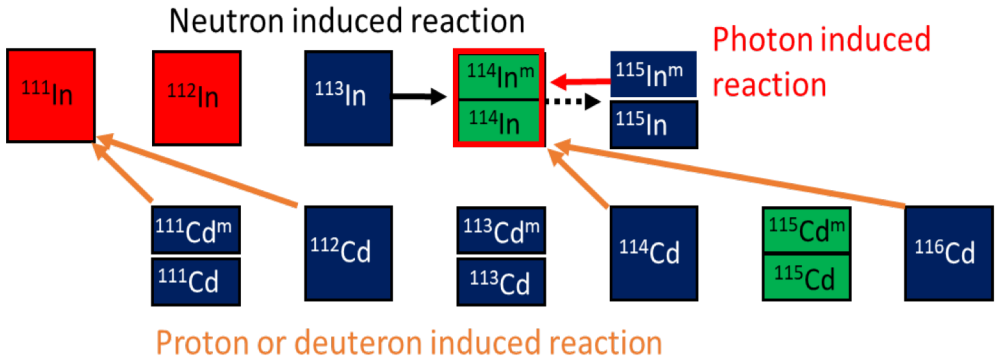
^{114}In^{m} :

- γ-ray190.34 keV($T_{1/2}$:49.51days)
- γ-ray imaging,
- ^{114}In β-ray Radioisotope therapy

IAEA publication deals with the production method of ^{114}In^{m} and assigned it as "emerging isotope"

Production method

Natural Indium
In-115(95.7%)
In-113(4.3%)



** Experiment was performed in 2013-2014.

Purpose:

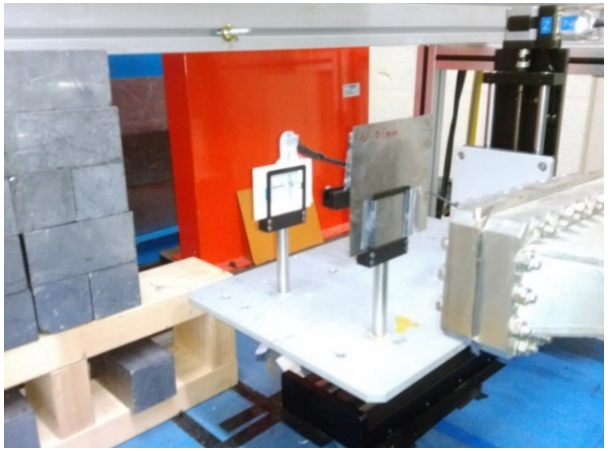
In this study, we measured the ^{nat}In(γ, xn) cross sections to evaluate the possibility of medical RI production method by using photons.

Experiment

Pohang Accelerator Laboratory (PAL)
100MeV electron linear accelerator

- Electron energy: 63 MeV
- Frequency : 15 Hz
- Beam current : 37 mA
- Target : Tungsten (W), 1.0mm thickness
- Irradiation time : 30 mins

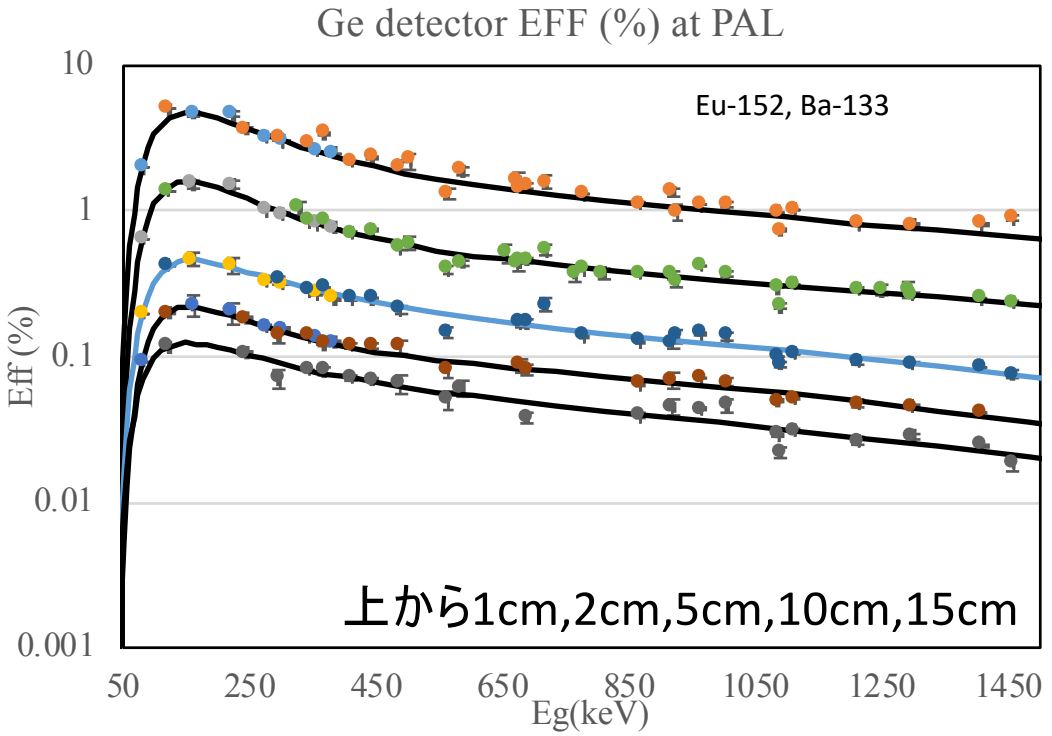
Irradiation room



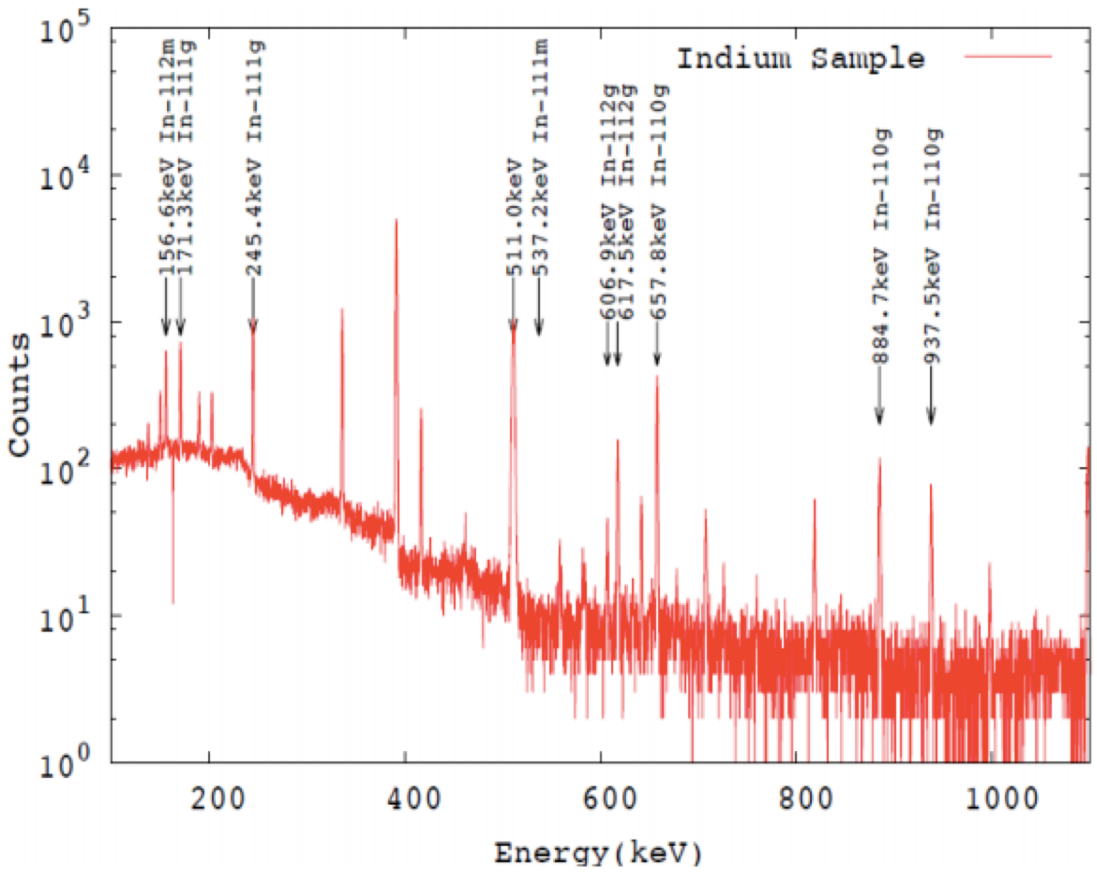
Sample

- ^{nat}In (0.0832g) 1cm x1cm x 0.1mm
- ^{197}Au (0.1905g) 1cm x 1cm x 0.1mm for the flux monitor

γ-ray counting
HPGe detector
（ORTEC)



Gamma-ray spectrum of products obtained from the $^{nat}In(\gamma, xn)$ reaction



Eγ(MeV)	放出確率	崩壊様式	半減期	生成物
156.56	13.2	IT	20.56 m	112mIn
171.28	90	e	2.8047 d	111In
190.29	15.56	IT	49.51 d	114mIn
242.75	41	e+b^+	58.0 m	108In
245.395	94	e	2.8047 d	111In
320.92	10.2	e+b^+	32.4 m	107In
336.24	45.83	IT	4.486 h	115mIn
391.69	64.2	IT	1.6582 h	113mIn
537.22	87	IT	7.7 m	111mIn
552.53	25.7	e+b^+	6.2 m	106In
632.97	100	e+b^+	58.0 m	108In
641.68	25.9	e+b^+	4.9 h	110In
649.9	93.7	IT	1.34 m	109mIn
657.7622	98.3	e+b^+	4.9 h	110In

Data analysis for activation cross sections

- Activation cross sections

$$N_{obs}\left(\frac{CL}{CT}\right) = \frac{n\sigma_R\phi I_\gamma\varepsilon\left(1-e^{-\lambda t}\right)e^{-\lambda T}\left(1-e^{-\lambda CL)}\right)}{\lambda}$$

n – Number of atoms (/cm^2)
ϕ – Number of incident photons
t & T – Irradiation time & Cooling time
CL & LT – Real time & Live time

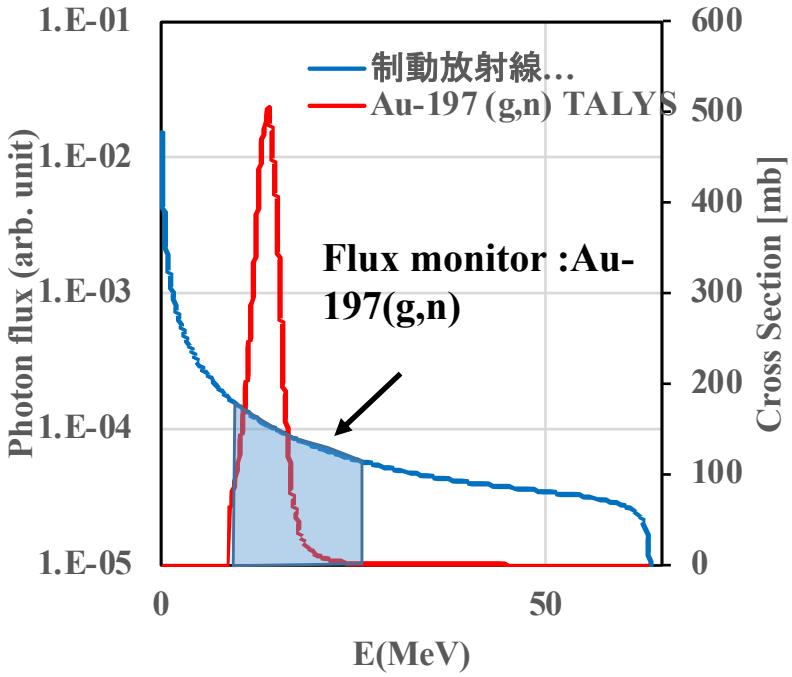
- ϕ was determined from the $^{197}Au(g,n)^{196}Au$ reaction

$$\phi = \frac{N_{obs}(CL/CT)\lambda}{n\sigma_R I_\gamma\varepsilon(1-e^{-\lambda t})e^{-\lambda T}(1-e^{-\lambda CL)})}$$

N_{obs} - Number of measured g-rays with 355 keV
σ_R - Calculation using TALYS1.6

- Correction factor of photon number

$$FACT = \frac{\int_{E_{th}}^{E_{max}}\phi(E)dE}{\int_{Esn(Au-197)}^{E_{max}}\phi(E)dE}$$



Activation cross sections of ^{nat}In (g, xn) reactions

- Experimental average cross sections

$$< \sigma exp >= \frac{N_{obs}(CL/CT)\lambda}{n\phi I_\gamma \varepsilon(1-e^{-\lambda t})e^{-\lambda T}(1-e^{-\lambda CL})}$$

- Theoretically determined average cross sections

$$< \sigma cal >= \frac{\int_{E_{th}}^{E_{max}} \sigma(E)\phi(E)dE}{\int_{E_{th}}^{E_{max}} \phi(E)dE}$$

$\sigma(E)$:Cross sections using

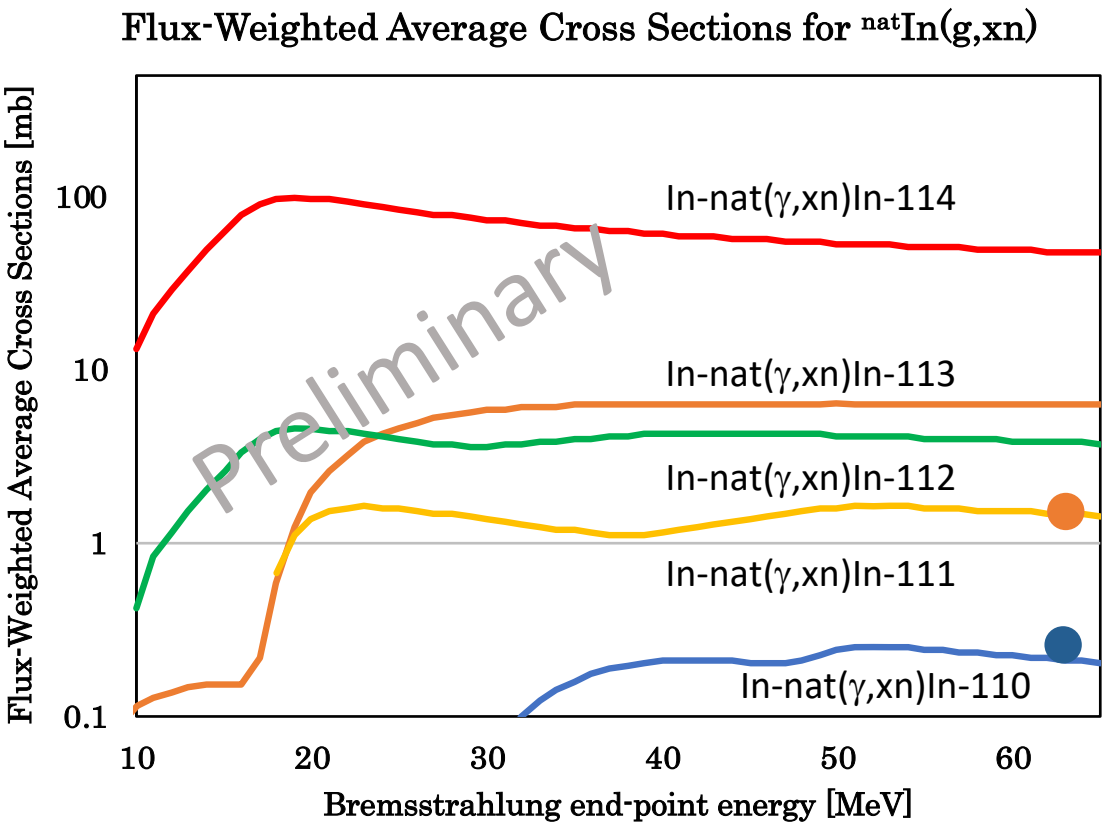
$\phi(E)$: Energy distribution of incident photons using Schiff formulae

- Total ERR (7 - 15 %)

-Statistical ERR 1-10%.

-Systematic ERR

  - Irradiation time ~0.5%
  - Detection efficiency ~4%
  - Photon flux 5-10%



Summary

- Photo activation experiment for the ^{nat}In(γ, xn) reactions was performed using 63 MeV bremsstrahlung at the Pohang Accelerator Laboratory in 2013 - 2014.

- Averaged production cross sections for ^{110,111}In were derived experimentally and theoretically (TALYS).

- In the future,
  - Analysis of the other cross sections in the ^{nat}In(γ, xn) reactions
  - Consideration of about medical applications

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