



Nagoya University

# Identification of High-Energy Levels in $^{147}\text{Ce}$ with a Total Absorption Clover Detector

Yosuke Shima<sup>1</sup>, Yasuaki Kojima<sup>2</sup>, Michihiro Shibata<sup>2</sup>, Hiroaki Hayashi<sup>3</sup>, Akihiro Taniguchi<sup>4</sup>



The University of Tokushima



Kyoto University  
Research Reactor Institute

## Introduction

For precise determination of  $\beta$ -branching ratios, high-energy levels should be identified. We propose an “Energy sum  $\gamma$ -ray spectrometry” method to measure high-energy levels using a total absorption clover detector. This method enhances sum peaks which correspond to the energy of excited levels in an add-back spectrum.

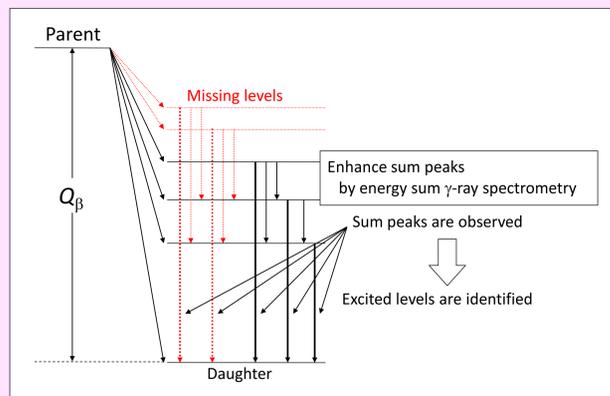
### Measurement of $\gamma$ -rays following the decay of $^{147}\text{La}$

( $^{147}\text{La} \rightarrow ^{147}\text{Ce}$ ;  $T_{1/2} = 4.06$  s)

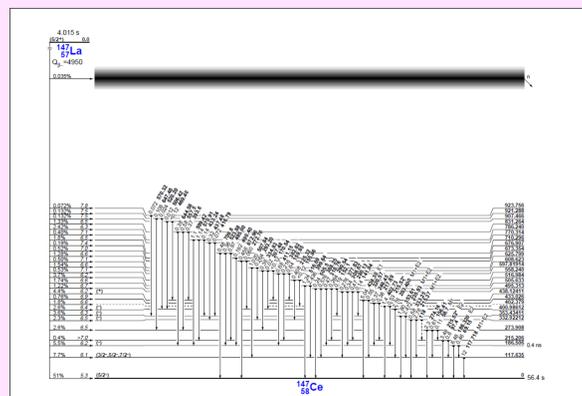
Previously reported levels in  $^{147}\text{Ce}$ :  $\leq 924.3$  keV [1]

Previously reported  $\beta$ -decay energy: 5366 keV [2]

➡ It is expected that  $^{147}\text{Ce}$  has much higher levels



Identification of missing levels by the energy sum  $\gamma$ -ray spectrometry.



A decay scheme of  $^{147}\text{La}$ .

## Purpose

- Development of a method to identify high-energy levels by energy sum  $\gamma$ -ray spectrometry.
- Determination of high-energy levels in  $^{147}\text{Ce}$ .
- Proposal of detailed decay scheme of  $^{147}\text{La}$ .

## Experiments

The total absorption clover detector was installed at the Kyoto University Research Reactor (KUR). The  $^{147}\text{La}$  isotope was produced with thermal neutron induced fission reaction of  $^{235}\text{U}$  and mass-separated by on-line isotope separator (ISOL).

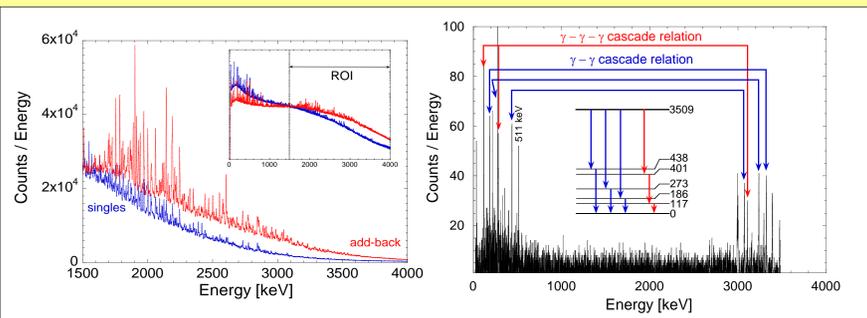
- Target: 50mg  $\text{UF}_4$  (93% enriched)
- Thermal neutron flux:  $6 \times 10^{11}$  n/cm<sup>2</sup>/s (1MW)
- Tape cycle: (8.0 s collection) – (8.0 s measurement)
- Measuring time: 24 hours



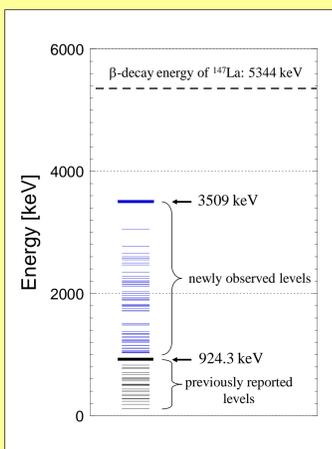
Photographs (left and center) and a schematic drawing (right) of experimental setup at KUR-ISOL.

## Analysis and Results

More than 50 levels in  $^{147}\text{Ce}$  were newly identified by the energy sum  $\gamma$ -ray spectrometry. In spectra which were decomposed sum peaks in add-back spectra,  $\gamma$ - $\gamma$ ,  $\gamma$ - $\gamma$ - $\gamma$  and  $\gamma$ - $\gamma$ - $\gamma$ - $\gamma$  cascade relations can be identified.



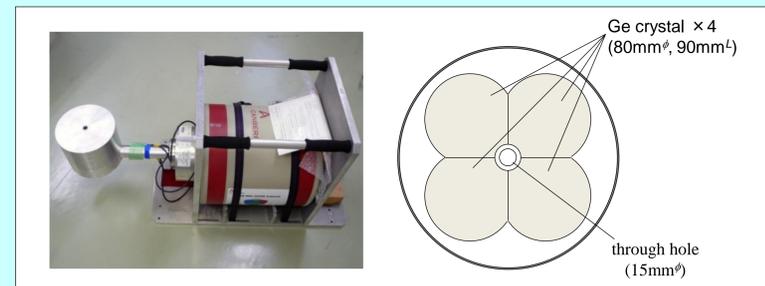
A singles and an add-back spectra of  $^{147}\text{La}$  (left) and a spectrum which was decomposed sum peak of 3509 keV (right).



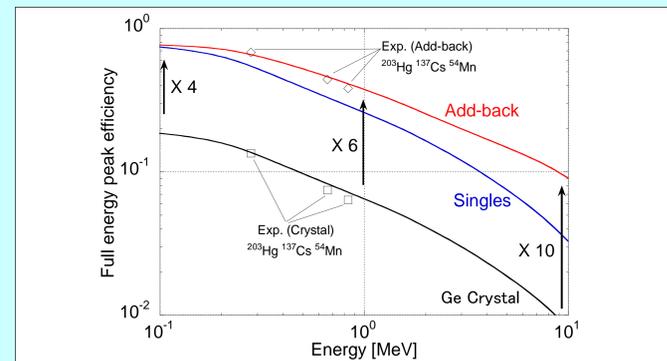
Beta-decay energy of  $^{147}\text{La}$  and excited levels in  $^{147}\text{Ce}$

## Total absorption clover detector

A total absorption clover detector is composed of four Ge crystals and a through hole. Energy signals and corresponding time information of four Ge crystals were recorded with data acquisition system in event-by-event mode. A singles (sum of Ge crystals) and an add-back (energy sum) spectra were obtained using an off-line sorting program.



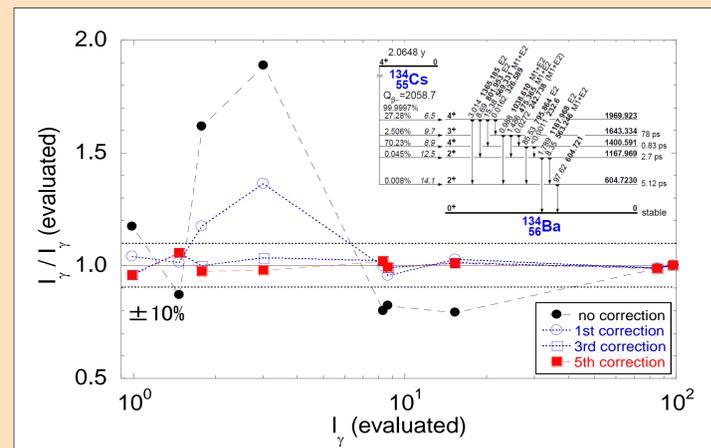
A photograph of the total absorption clover detector (left) and a schematic drawing of the detector (right).



Full energy peak efficiencies of a Ge crystal, a singles and an add-back spectrum.

## Correction of coincidence summing effects

For determination of newly observed  $\gamma$ -ray intensities using the total absorption clover detector, experimental intensities should be corrected. In the correction method, we considered internal conversion and summing X-rays and  $\gamma$ -rays. In order to check that experimental  $\gamma$ -ray intensities can be properly corrected, experimental intensities of  $^{134}\text{Cs}$ , whose decay scheme is well-known, were corrected. Corrected intensities were in good agreement with evaluated ones.



Ratios of experimental or corrected  $\gamma$ -ray intensities of  $^{134}\text{Cs}$  to evaluated ones.

## Conclusions

- In order to identify high-energy levels, the energy sum  $\gamma$ -ray spectrometry method was developed.
- More than 50 levels in  $^{147}\text{Ce}$  and about 300  $\gamma$ -rays following the decay of  $^{147}\text{La}$  were identified.
- Experimental  $\gamma$ -ray intensities were properly corrected by the correction method.
- Newly observed  $\gamma$ -ray intensities of  $^{147}\text{La}$  is now in progress.

## Acknowledgements

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## References

- [1] J. D. Robertson *et al.*, Phys. Rev. **40** (1989) 2804.
- [2] H. Hayashi *et al.*, Nucl. Instrum. Meth. A **606** (2009) 484.