

## Detector Calibration and Initial Measurement of Double Beta Decay of $^{96}\text{Zr}$ in the ZICOS Experiment

S. Kato (e-mail: [m26c1106@ems.u-toyama.ac.jp](mailto:m26c1106@ems.u-toyama.ac.jp)),Y. Nakano (e-mail: [ynakano@sci.u-toyama.ac.jp](mailto:ynakano@sci.u-toyama.ac.jp)),Y. Fukuda<sup>A</sup>, S. Moriyama<sup>B</sup>, K. Hiraide<sup>B</sup>, I. Ogawa<sup>C</sup>, T. Gunji<sup>D</sup>, S. Kurosawa<sup>E</sup>University of Toyama, Miyagi University of Education<sup>A</sup>, Institute for Cosmic Ray Research, The University of Tokyo<sup>B</sup>, University of Fukui<sup>C</sup>, Tokyo University of Science<sup>D</sup>, Nagoya Institute of Technology<sup>E</sup>

UGRP2026

Okayama Campus, Institute of Science Tokyo | September 28-29, 2026

### 1. Introduction

#### ZICOS Experiment

~Search for  $0\nu\beta\beta$  in  $^{96}\text{Zr}$ ~

#### ► Toward probing the Majorana nature through $0\nu\beta\beta$ in $^{96}\text{Zr}$

- High  $Q_{\beta\beta}$ -value of 3.35 MeV: **3rd highest**  
→ Less obscured  $0\nu\beta\beta$  spectrum by environmental BG
- Only one dataset available: NEMO-3<sup>[1]</sup>  
→ Target: World-leading sensitivity of  $T_{1/2}^{0\nu} > 10^{27}$  yr!

#### 2ν-ZICOS Experiment

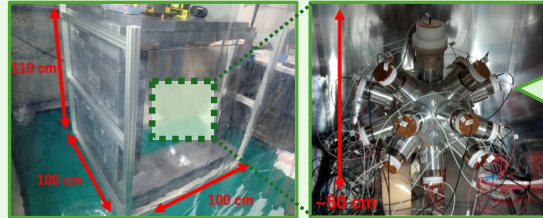
~Measurement of  $2\nu\beta\beta$  in  $^{96}\text{Zr}$ ~

#### ► Discrimination between $2\nu\beta\beta$ and $0\nu\beta\beta$

- Separation based on the spectrum and electron emission direction
- Identification and mitigation of major BG in the measurement

### 2. 2ν-ZICOS detector

#### Detector Performance & BG Evaluation for $^{96}\text{Zr}$ - $2\nu\beta\beta$ : Targeting 3.5% @3.35 MeV Energy Resolution!



Zr-LS : 723.5 ml

 $^{96}\text{Zr}$  : 0.27 g  
 (Number of nuclei:  
 $\sim 1.7 \times 10^{21}$ )

- Constructed a **15 cm-thick lead shield** for environmental BG suppression
- Constructed a detector using **20 PMTs<sup>[2]</sup>** and a flask filled with **Zr-LS**
- In November 2025, Evaluated the detector performance and performed the first measurement of  $2\nu\beta\beta$  in  $^{96}\text{Zr}$  at the Kamioka Underground Laboratory

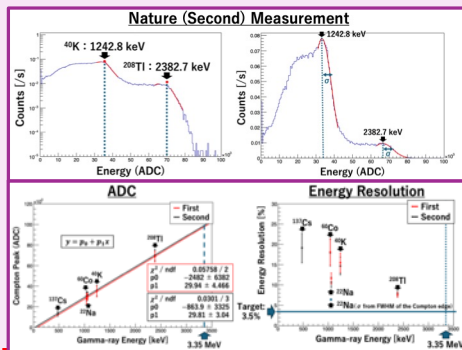
### 3. Detector Calibration

- Used 5 gamma-ray sources:

| Sources            | $^{137}\text{Cs}$    | $^{60}\text{Co}$      | $^{22}\text{Na}$      | $^{40}\text{K}$ (Nature) | $^{208}\text{Tl}$ (Nature) |
|--------------------|----------------------|-----------------------|-----------------------|--------------------------|----------------------------|
| Compton Edge [keV] | 477.3 <sup>[3]</sup> | 1040.4 <sup>[3]</sup> | 1061.0 <sup>[3]</sup> | 1242.8 <sup>[3]</sup>    | 2382.7 <sup>[3]</sup>      |

- Performed 2 measurements: "First" and "Second," 54 h apart

- Determined the peak position and width of the Compton edges



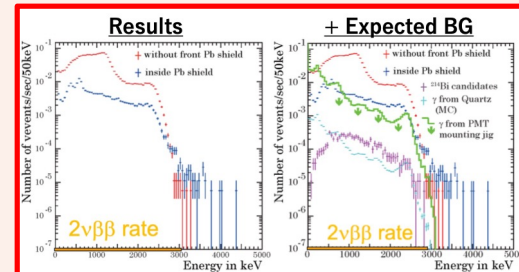
#### [Results]

- Determined **97,757.1-98,940.0 ADC @3.35 MeV**
- Observed an ADC value **increase of ~1200 @3.35 MeV** after 54 h of detector operation
- The corresponding shift in the  $0\nu\beta\beta$  peak width is **only 0.0025 MeV @3.35 MeV, which is negligible.**

#### [Next]

- Add the Compton edge of  $^{88}\text{Y}$  (699.1, 1611.8.1 keV)<sup>[3]</sup> and determine the resolution from FWHM of the Compton edge and Gaussian fit to the backscattering peak

### 4. First Measurement



|                | Measurement Time |
|----------------|------------------|
| Without Shield | 100800 sec       |
| Inside Shield  | 180000 sec       |

- With the lead shielding, BG is reduced by 1 order of magnitude.
- The observed event rate was **4 orders of magnitude higher** than expected for  $2\nu\beta\beta$  in  $^{96}\text{Zr}$  ( $\sim 10^7$  event/s/50 keV).

| [Cause]                                                           | vs. expected $2\nu\beta\beta$ rate |
|-------------------------------------------------------------------|------------------------------------|
| $\gamma$ from PMT jig                                             | $\sim 10,000$ times                |
| $\gamma$ from quartz flask                                        | $\sim 1,000$ times                 |
| $^{214}\text{Bi}$ from $^{226}\text{Ra}/^{222}\text{Rn}$ in Zr-LS | $\sim 1,000$ times                 |

#### [Solution]

1. Replace the PMT mounting jig with oxygen-free copper
2. Use a flask made of synthetic quartz glass
3. Use a higher-precision digitizer to remove not only  $^{214}\text{Bi}$ - $^{214}\text{Po}$ , but also  $^{212}\text{Bi}$ - $^{212}\text{Po}$  ( $T_{1/2} = 0.3 \mu\text{s}$ )

### 5. Summary & Future

- The **ZICOS experiment** aims to observe  $0\nu\beta\beta$  in  $^{96}\text{Zr}$ . The current goal is to observe  $2\nu\beta\beta$  in  $^{96}\text{Zr}$ .
- In this study, we evaluated the detector performance and performed the first measurement of  $2\nu\beta\beta$  in  $^{96}\text{Zr}$ .
- Based on the calibration results, the  $Q_{\beta\beta}$ -value of  $^{96}\text{Zr}$  corresponds to an ADC range of 97,757.1~98,940.0.
- Based on the first measurement results, the observed event rate was **4 orders of magnitude higher** than expected for  $2\nu\beta\beta$  in  $^{96}\text{Zr}$ . The BG sources were radioactive isotopes present in the PMT mounting fixtures and the flask.
- From late February 2027, we will perform measurements of  $2\nu\beta\beta$  in  $^{96}\text{Zr}$  using a new detector with oxygen-free copper PMT mounting fixtures and a lower-impurity flask.

Ref: [1]Phys.Atom.Nucl. 74, 312-317 (2011), [2]Nucl. Instrum. Methods Phys. Res. A, 171-176 (2019), [3]U. Schötzgig and H. Schrader, PTB-Bericht Ra-16/5, 98 (1998).