DIRECT MEASUREMENT OF **TOPOLOGICAL INFORMATION USING** HUNI-ZICOS FOR ZR-96 NEUTRINOLESS DOBLE BETA DECAY EXPERIMENT TAUP2021 17th International Conference on Topics in Astroparticle and Underground Physics August 31, 2021 Grant-in-Aid for Scientific Research on Innovatiy 19H05093 and 20H05241 Scientific Research (C) 18K036 Miyagi University of Education Y. Fukuda, T.Shimizu, Y.Kamei, Narengeril, A. Obata, D. Anzai Kamioka Observatory, ICRR, Univ. of Tokyo S. Moriyama, K. Hiraide University of Fukui I. Ogawa Tokyo University of Science T. Gunji, S. Tsukada, R. Hayami Institute for Materials Research, Tohoku University S. Kurosawa

Conceptual design of ZICOS detector

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⁹⁶Zr : 45 kg (nat.) → 865 kg(50 % enrich)→1/20 BG $T_{1/2}^{0\nu} > 4 × 10^{25}$ yrs → 2 × 10²⁶yrs → ~1 × 10²⁷yrs

Direct measurement of topological information using HUNI-ZICOS detector for Zr-96 neutrinoless double beta decay experiment.

2

Discrimination of signal and BG

Reconstructed vertex by scintillation light

 $0\nu\beta\beta$ event

 β decay

2.6 MeV γ

Reconstructed vertex by Cherenkov light Balloon or surface of detector

BG reduction using topological information



Topological information (averaged angle) of Cherenkov lights could be used for reduction of ²⁰⁸Tl backgrounds.

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August 21,2022

4

<u>Strategy to realize ²⁰⁸TI BG reduction using</u> <u>Cherenkov lights</u>

- 1. Selection of PMTs which receive Cherenkov lights among huge Scintillation lights.
 - Pulse shape discrimination
- 2. Confirm topology of Cherenkov lights
 - Directionality of Cherenkov lights
 - Direct measurement of topological information Averaged angle

3. Demonstrate BG reduction using beta-gamma sources with topological information (averaged angle) of Cherenkov light. (this autumn)

Pulse shape of Cherenkov and scintillation



 Pulse shape of ⁹⁰Sr using H2431-50 measured by V1751 with DES mode (2GS/s) Decay time of scintillation : 4.57 ns and 8.38 ns • Rise time of scintillation : 1.45 ns Rise time of Cherenkov 0.75 ns

Use the charge ratio Q_{time}/Q_{total} . Here, Q_{time} is FADC count in each time, and Q_{total} is sum count of FADC between 55 ns and 80 ns.

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Q_{total} distribution for γ sources





Co (1.17 MeV/1.33 MeV) Compton edge: 1.04 MeV ¹³⁷Cs (662 keV) Compton edge: 478 keV ¹³³Ba (356 keV) Compton edge: 207 keV ⁵⁷Co (122 keV which is under Cherenkov threshold "168 kev")

 \bullet

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0

Pulse shape with charge ratio in each FADC time.

Charge ratio in rise time using ZICOS LS



- There is difference in shape between t = 57 ns and 58 ns
- Charge ratio looks
 depend on the energy
 - For t > 58.5 ns, all shapes were almost same.

Cherenkov looks dominant between 57 ns and 58 ns.

Template waveform of scintillation between 57 ns and 58 ns for ⁵⁷Co.

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χ²distribution using ⁵⁷Co template



Most of backgrounds have lower χ^2 than 1.0 Most of backgrounds have lower energy than Cherenkov threshold, then only scintillation was seen.

It seems to events with Cherenkov lights should have large χ^2 value.

Measured by Compton edge event and BG sample



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1772/3606=49.1 \pm 1.4 % for BG sample The difference between Compton edge events and BG sample is 2.9 σ .

Iopology of Cherenkov lights for ~1 MeV e⁻ was strongly indicated.

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10

Direct measurement of topological information using HUNI-ZICOS



Direct measurement of topological information using HUNI-ZICOS detector for Zr-96 neutrinoless double beta decay experiment.

August 21,2022

Mounting PMTs on jig for hemisphere flask



Total 26 H3164-12 PMTs were used for HUNI-ZICOS In order to remove scintillation light (~300pm), SC-37 filter was covered around the hemisphere flask in this time. stector for Zr-96 August 21,2022 12

<u>Setting hemisphere flask to jig and locate</u> <u>on supporting stand</u>



 HUNI-ZICOS was putted on flask clip and the chimney was pinched by clamp.

 Assuming e⁻ generation position to be center of truncated icosahedron jig (not hemisphere flask).

Cable connection to FADC and HV



All channels are connected to FADC V1742 digitizer.

Electron with fixed direction and fixed energy using ⁸⁸Y gamma source



Compton scattering with fixed direction generates fixed energy electron. Compton angle 100 degree corresponds to 352 keV for scattered y and 1.484 MeV for electron Cherenkov angle 47 degree.

Measurement of averaged angle using 88Y







 Scattering gammas were detected by well calibrated La-GPS scintillator through the Pb collimation.

Event selection for scattered electron



Event selection criteria :

Number of PMT hit for BG are clustered below 5 hit. 1) Nhit ≥ 5 Qtotal for BG are also clustered below 1000. 2) Qtotal ≧1000 Observed energy of scattering gamma is clustered around 352keV. Due to SC-37 (UV cut) filter igodolwe observed almost only Cherenkov light in this time.

Measured averaged angle and sumulation



Averaged angle measured by HUNI-ZICOS has a peak at 40 degree. This is not consistent with the Cherenkov angle. This is due to PMT geometry of HUNI-ZICOS detector.

- Averaged angle obtained by EGS5 simulation of Cherenkov light has a peak at 40 degree. This is consistent with above measurement.
- Averaged angle obtained by EGS5 simulation of scintillation has a peak around 50 degree. This is quite different from Cherenkov light

Verified Cherenkov lights emitted from 1.484 MeV electron really maintain their topology

Direct measurement of topological information neutrinoless double beta decay experiment.

Demonstration of ²⁰⁸TI BG reduction



Demonstration of ²⁰⁸TI BG reduction



• Data taking will start in this autumn.

Observation of 2vββ signal using 2v-ZICOS



- 28 cm diameter flask using Ultra-pure quartz and 60 low BG 2" PMT Hamamatsu R3378-50 (R2083)18.5cm inner balloon 300g Zr(iPrac)₄ loaded \bullet liquid scintillator which contains 1.1 g ⁹⁶Zr 180 $2\nu\beta\beta$ events per • year is expected Location: Kamiøka mine igodol
- Start time: FY2024

Observation of 2vββ signal using 2v-ZICOS



Direct measurement of topological information using HUNI-ZICOS detector for Zr-96 neutrinoless double beta decay experiment.

August 21,2022

22

Summary

- Topological information (averaged angle) of Cherenkov light was directly measured by HUNI-ZICOS using actual low energy electron.
- Averaged angle distribution using fixed direction and fixed energy (1.484MeV) electron using ⁸⁸Y source has peak at ~40 degree. This is not Cherenkov angle due to hit PMT geometry. They also agree with the simulation.
- It is verified that Cherenkov light emitted from 1.484MeV electron really maintain their topology, in other words, ²⁰⁸TI BG reduction using averaged angle is possible even for scintillator experiment.
- Demonstration of βγ BG reduction using ⁶⁰Co source by UKI-ZICOS will be started in this autumn and the result will be reported at early next year.
- Next program to observe 2vββ decay will start in FY2024 after 2 years construction and checking. Stay tuned!