

Status of C/N-1.0: Large gaseous detector for direction-sensitive dark matter search

Ryota Namai (Kobe University)

on behalf of NEWAGE group

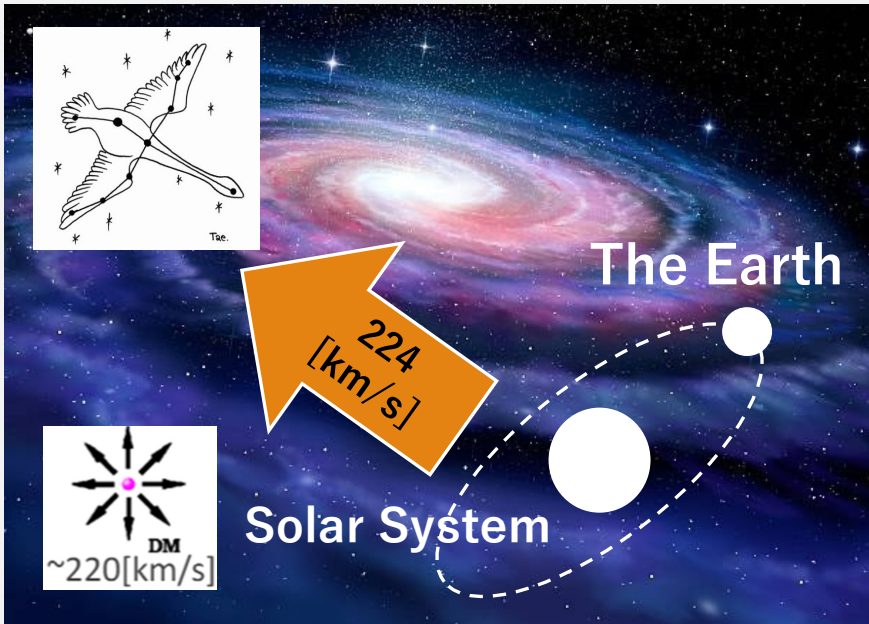
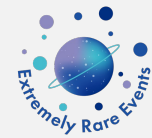
MPGD2026

Sep. 2nd, 2026

Prague, Czech Republic

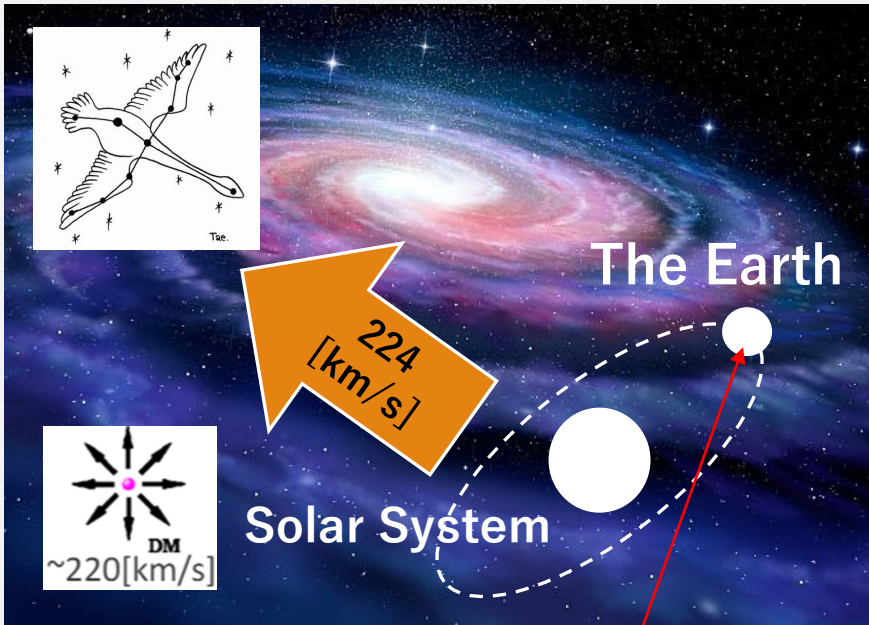
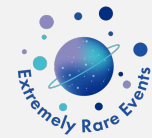
Introduction

Directional WIMP Direct Search

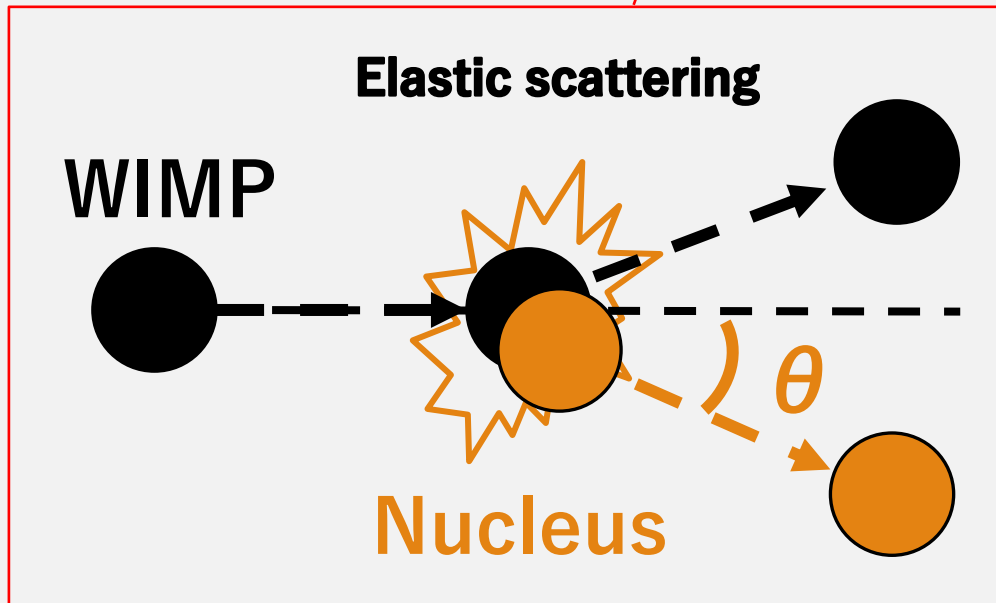


- DM is assumed to be a WIMP in this talk.
- Although numerous experiments around the world are searching for WIMPs, no experiment has reported an observation.
- If we assume that WIMPs are distributed following a Standard Halo Model (SHM), then many WIMPs would arrive from the direction of the solar system's motion.

Directional WIMP Direct Search



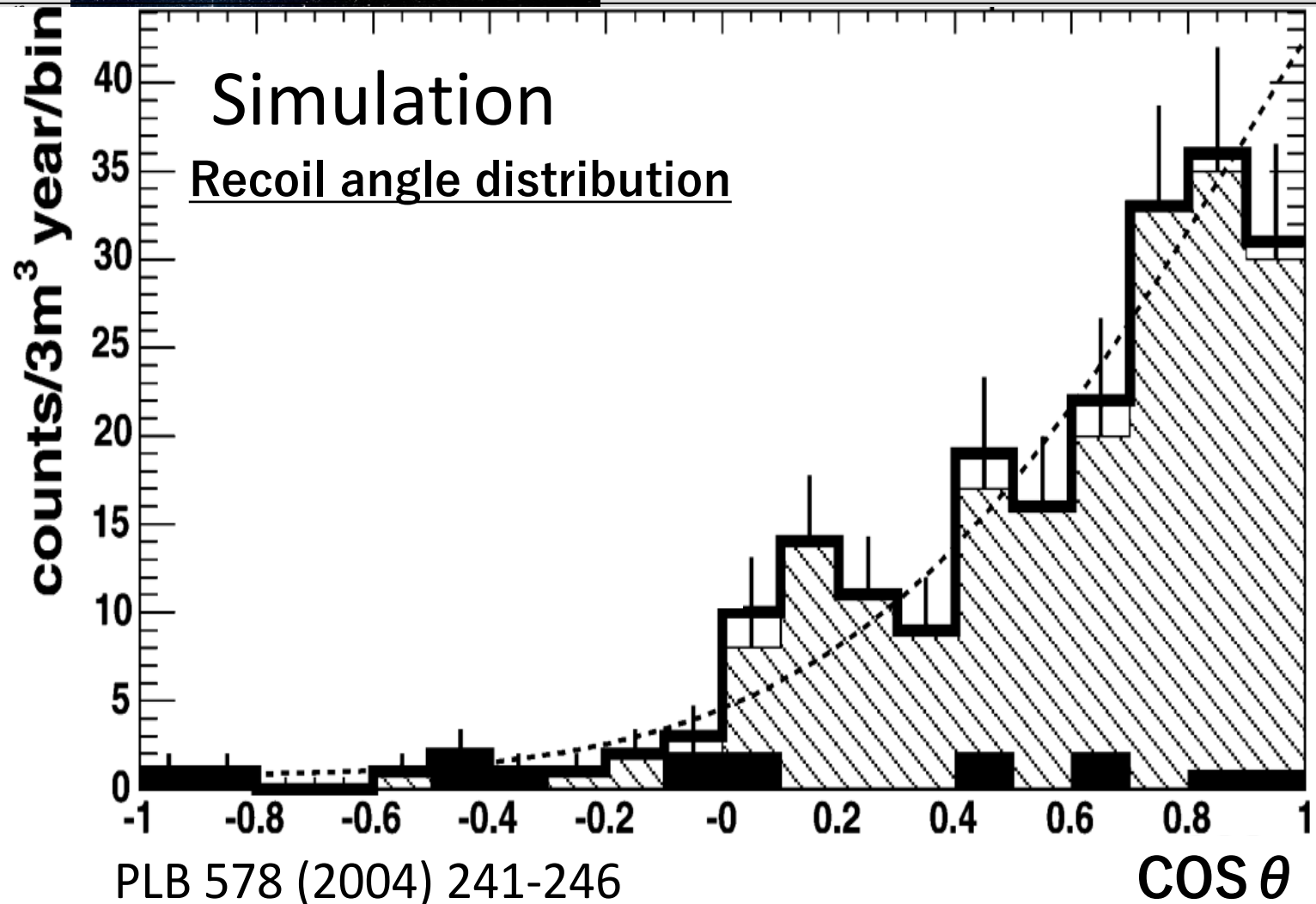
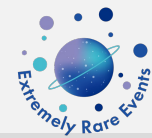
- DM is assumed to be a WIMP in this talk.
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- WIMPs rarely interact with SM particles.
- It is expected that measuring the distribution of scattering angles will provide information on the kinematics of WIMPs.

→ The aim of the directional WIMP search is to measure this anisotropy.

Directional WIMP Direct Search

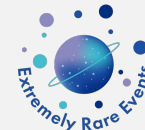


Expected Recoil Angle Distribution

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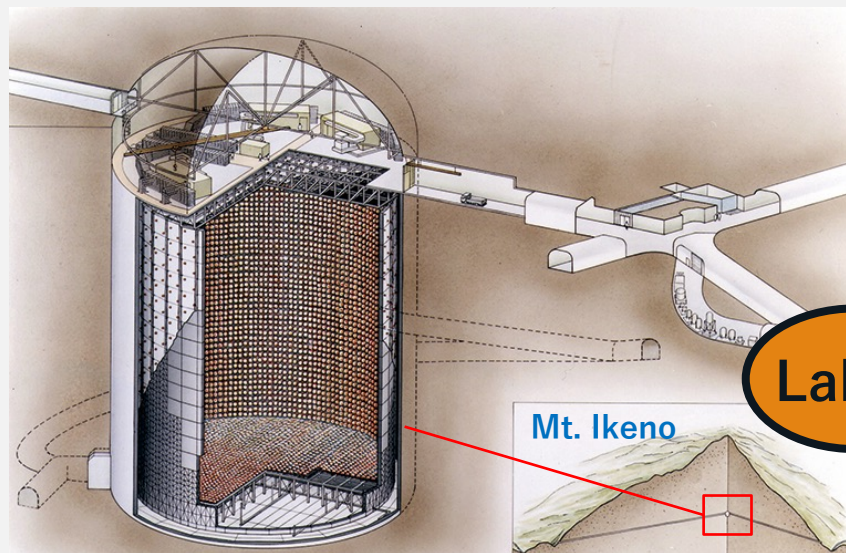
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The NEWAGE experiment

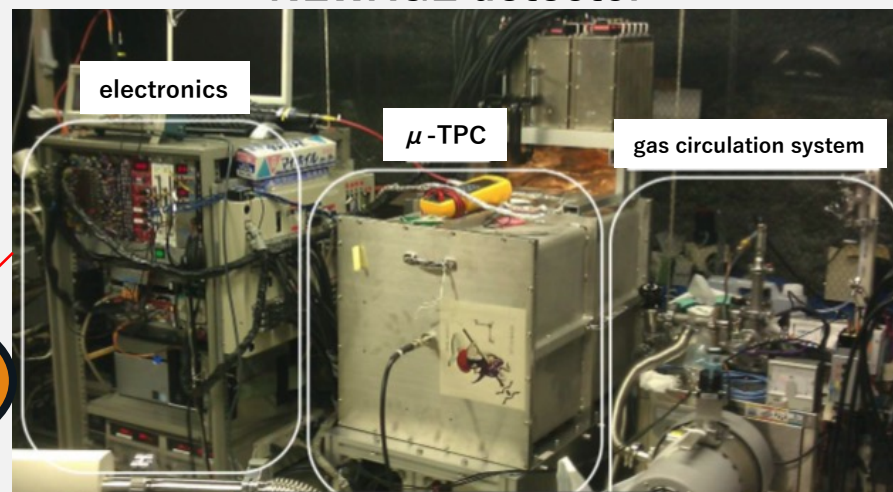


- Place: 1,000 m underground experiment in the Kamioka mine
- Detector setup:
 - ✓ Low pressure gaseous TPC
 - ✓ $30 \times 30 \times 41 \text{ cm}^3$ fiducial volume
 - ✓ filled with CF_4 gas (0.1 atm)

Kamioka mine

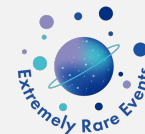


NEWAGE detector

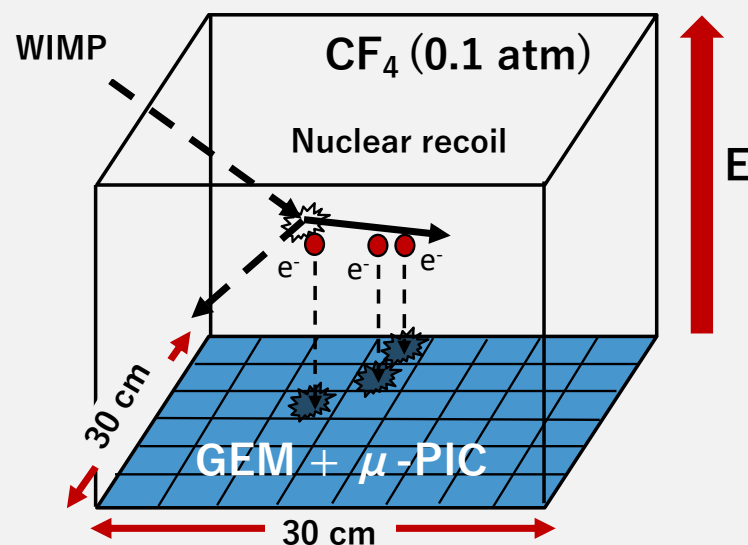


$30 \times 30 \times 41 \text{ cm}^3$

Detection principle



Gaseous Time Projection Chamber (TPC)

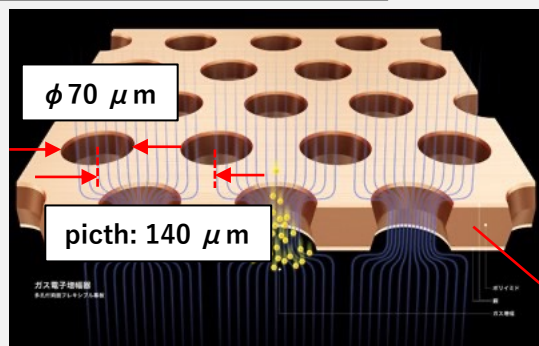


- A low-pressure gaseous TPC with MPGD allows to reconstruct 3D tracks.
- A GEM preamplifies electrons and a μ -PIC readouts the charge.

μ -PIC features

- Anode and cathode strips are aligned orthogonally with a $400 \mu\text{m}$ pitch.
- Two-dimensional position and timing information allow full 3D track reconstruction.
- Drift electrons are amplified by a high electric field formed around the pixels.

GEM (preamplifier)

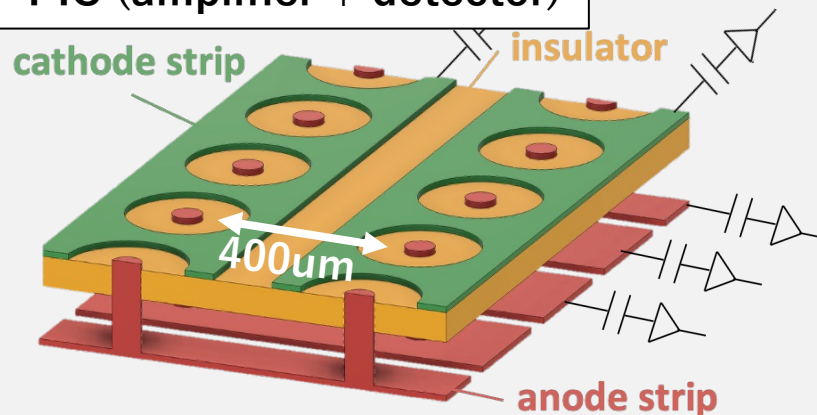


100 μm
thickness

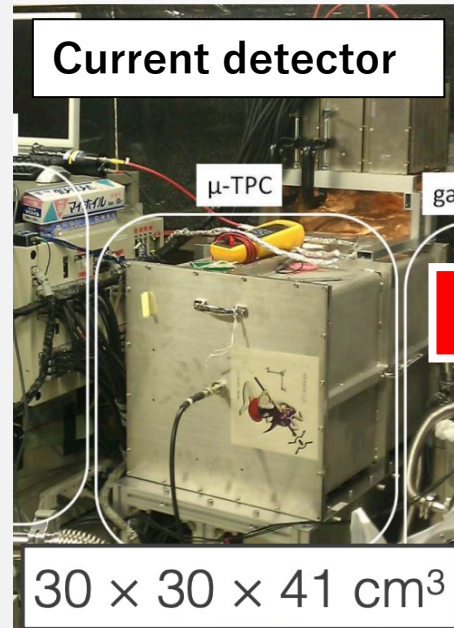
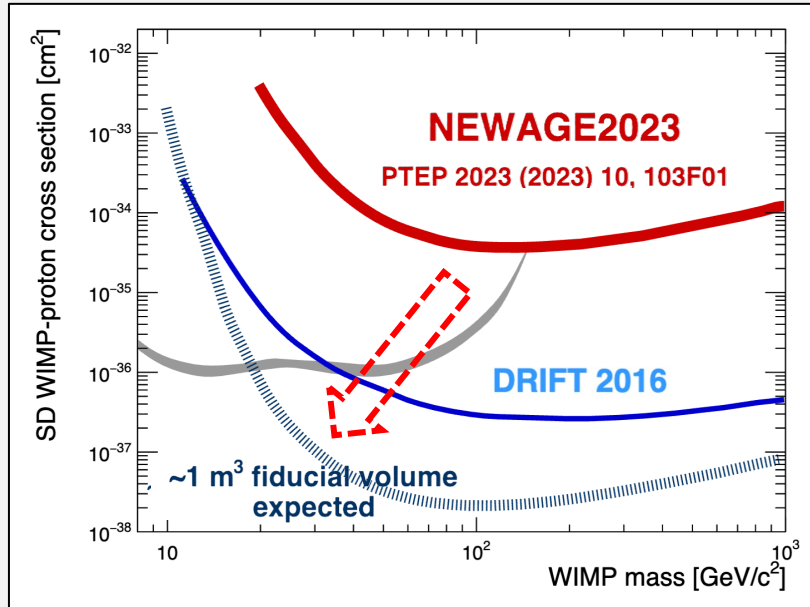
Insulator (LCP)



μ -PIC (amplifier + detector)



Future plans of NEWAGE

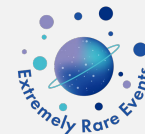


- NEWAGE has set a world-leading limit in direction-sensitive WIMP searches using 3D tracks.
- For future, Background reduction and **a large target volume** are necessary.



This presentation focuses on detector enlargement.

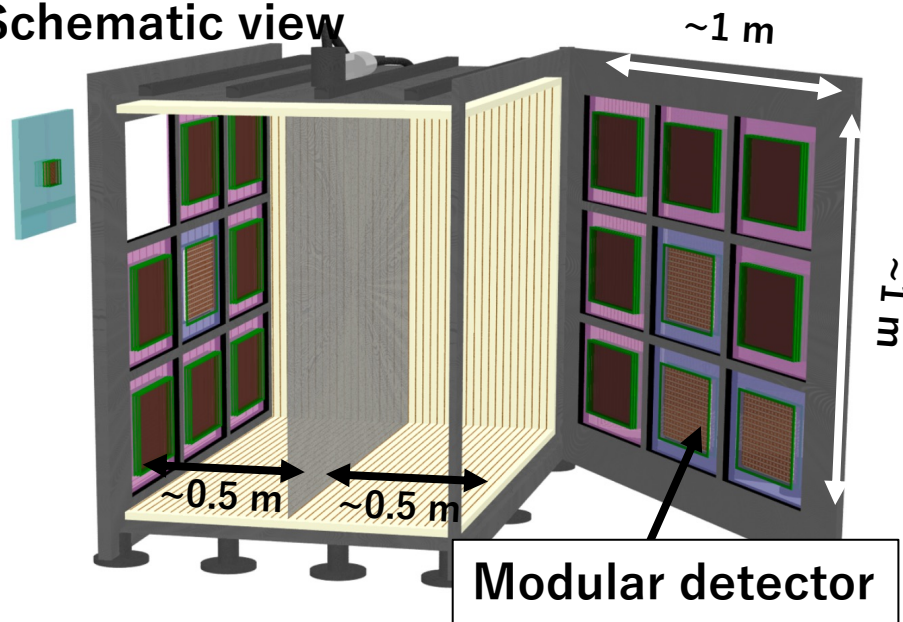
C/N-1.0



- The CYGNUS-KM / NEWAGE-1.0 (C/N-1.0) chamber is being developed at Kobe University.



Schematic view

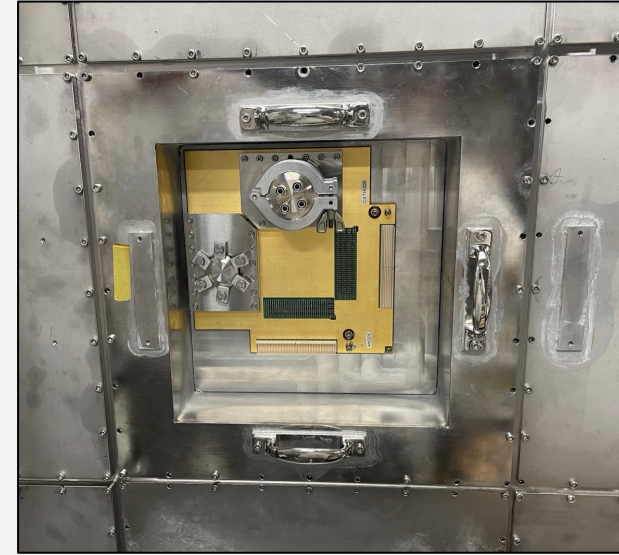
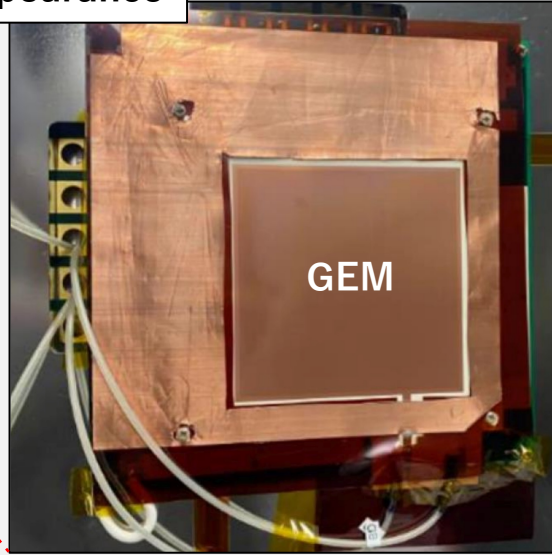
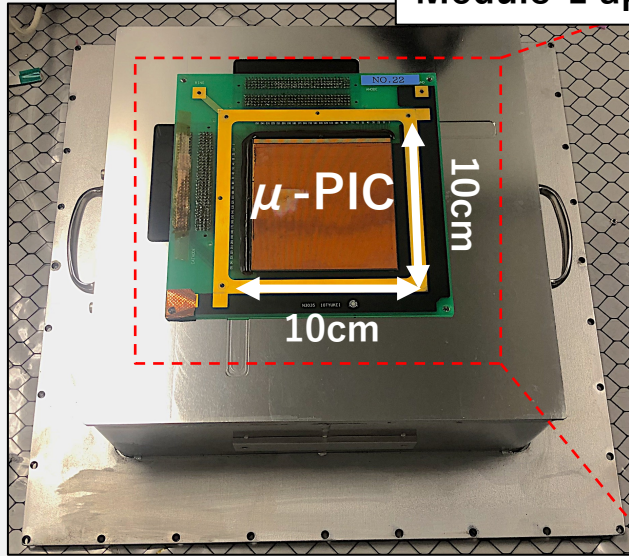


Features of C/N-1.0

- Approximately 30 times larger than the NEWAGE fiducial volume.
 - There are 18 module slots.
 - Module-1 detector ($10 \times 10 \text{ cm}^2$ detection area) is under development.
- Main topic in this talk

Module-1 features

Module-1 appearance

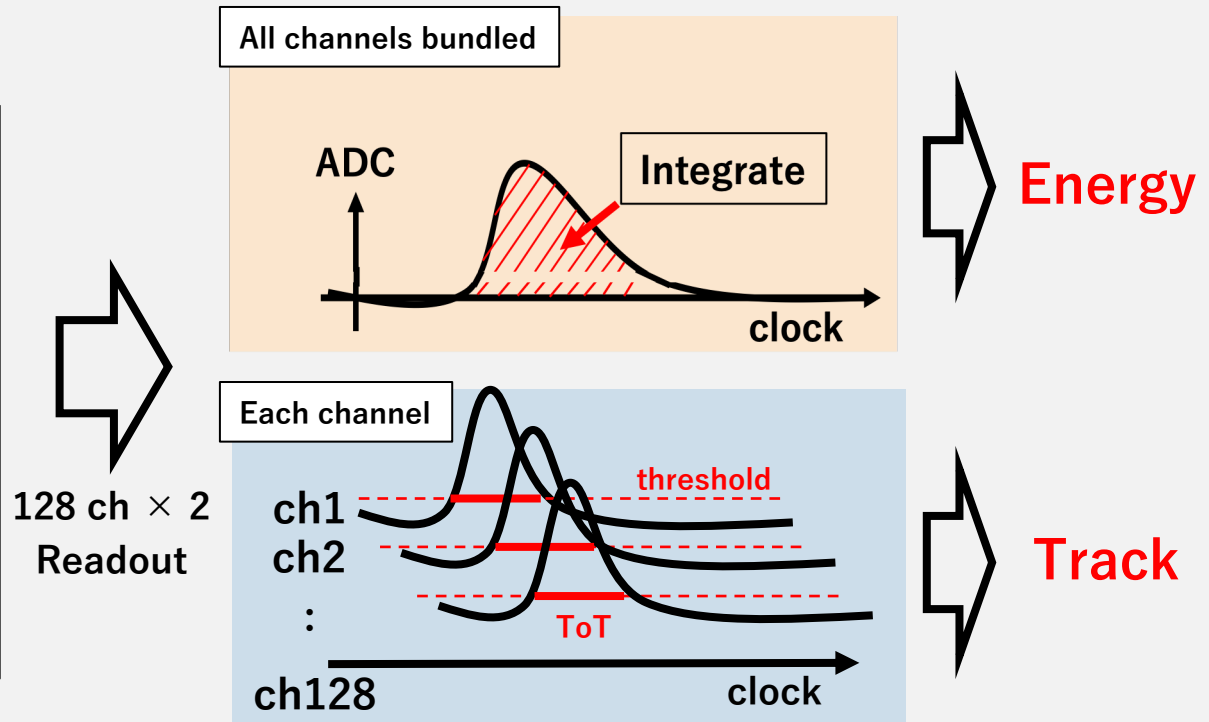
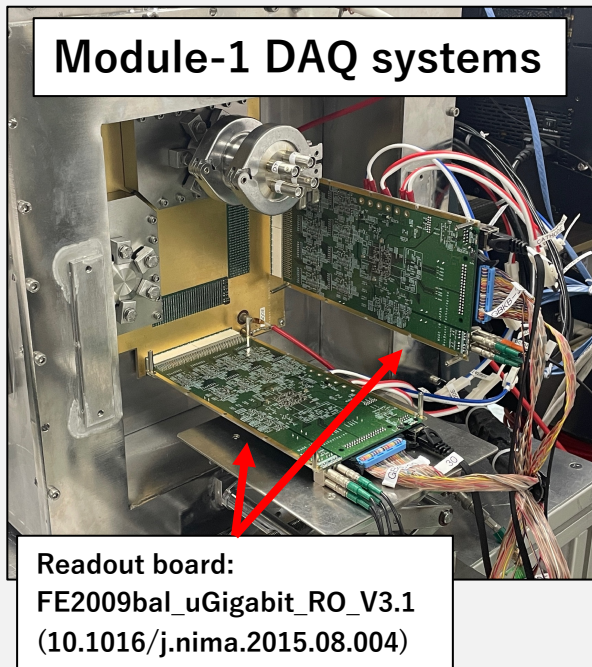


Features	Module-1	NEWAGE
detection area	10×10 cm ²	30×30 cm ²
readout pitch	800 μ m	400 μ m
energy threshold w/ directionality	100 keV _{ee}	50 keV _{ee}

- Since the number of channels of a prototype readout electronics are limited at this moment, we used a $10 \times 10 \text{ cm}^2$ detector with an 800 μm readout pitch.
- The detector enables analysis with directionality above 100 keV_{ee}.
→ The purpose is to demonstrate C/N-1.0.

Data acquisition

Data acquisition flow



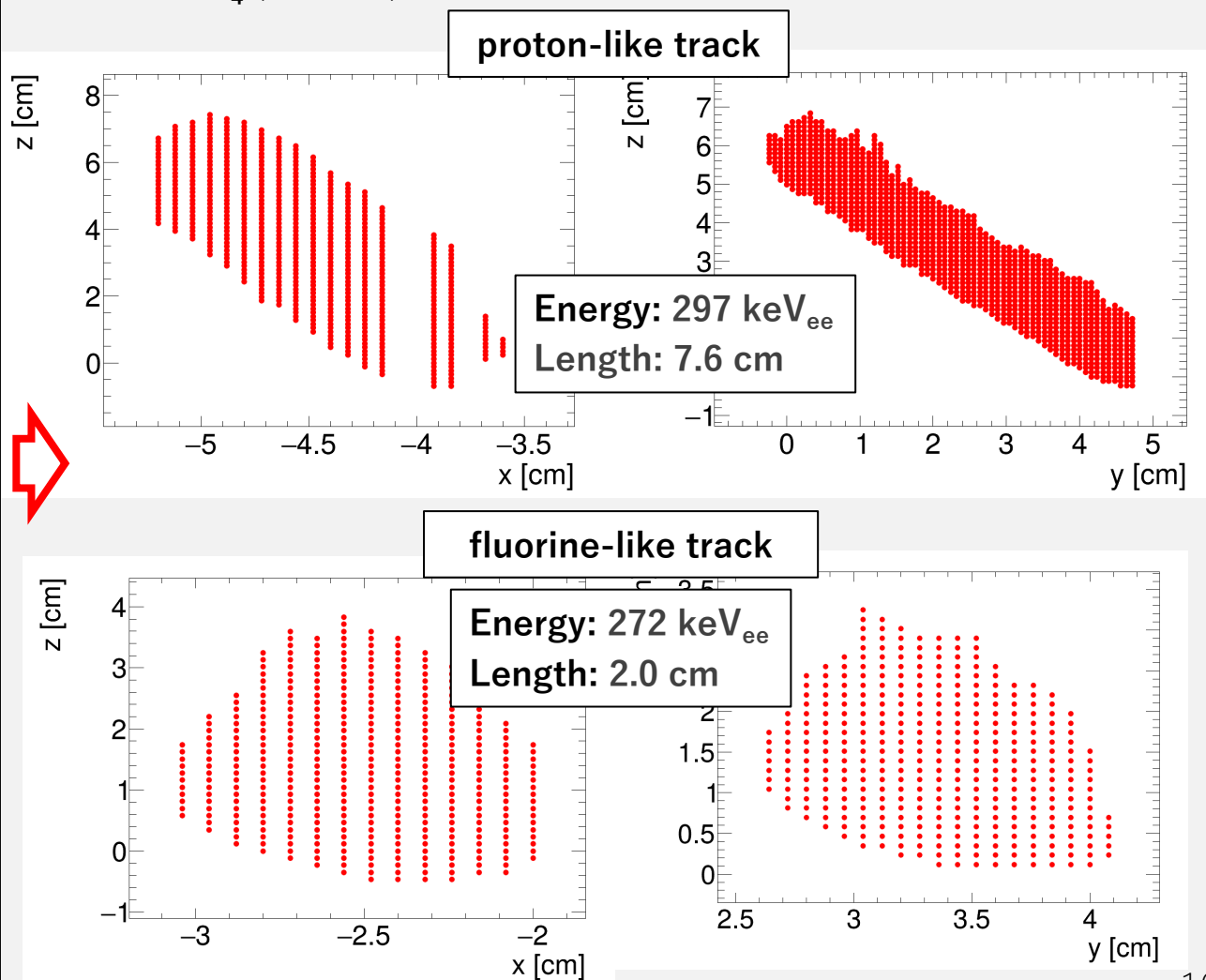
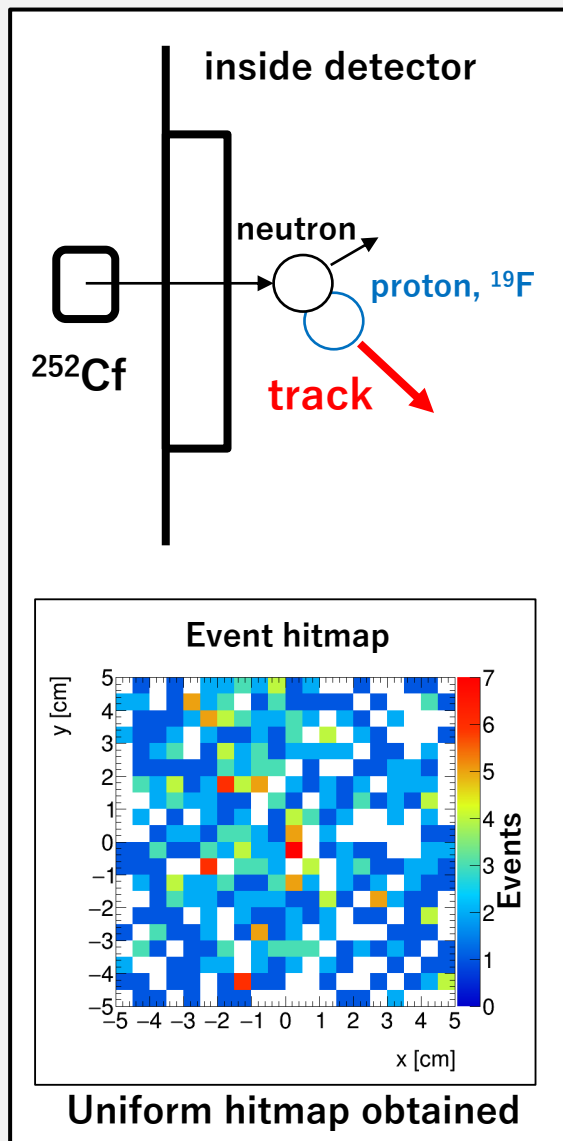
- Signals are read out from 128 channels in each readout board.
- An energy is calculated by integrating ADC waveforms over all channels.
- A track is reconstructed with the time-over-threshold (ToT) information for each channel.
- All electronics are arranged so as not to interfere with the neighboring module slot.

Event displays



First reconstructed tracks obtained using C/N-1.0 with NEWAGE module.

- Reconstructed tracks were obtained using a ^{252}Cf neutron source.
- Gas: CF_4 (0.1 atm)

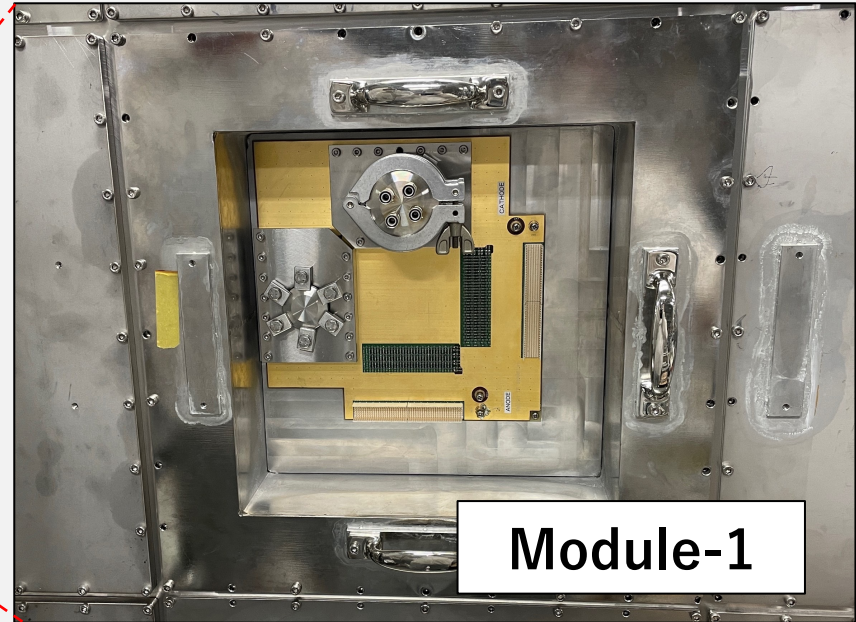
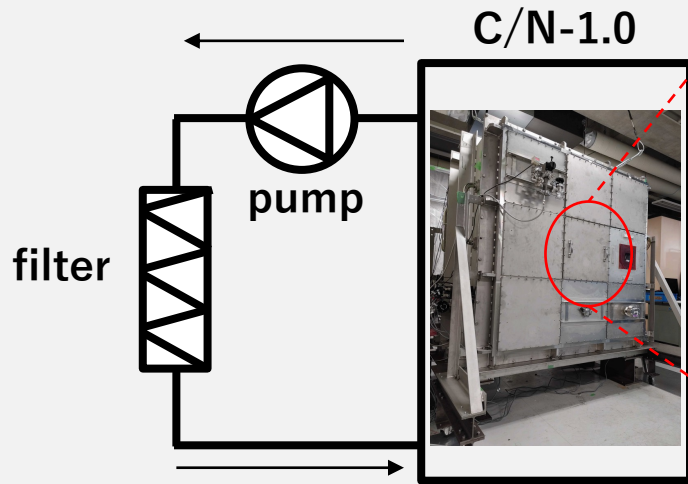


C/N-1.0 operation test

Measurement setup

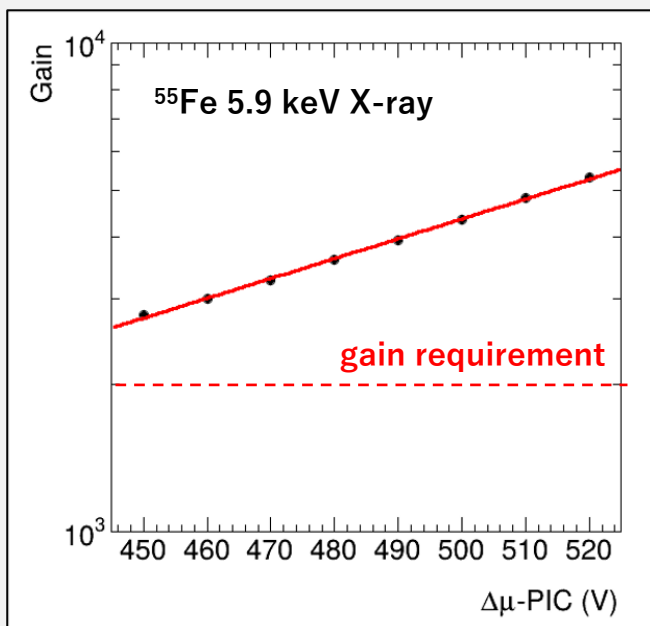
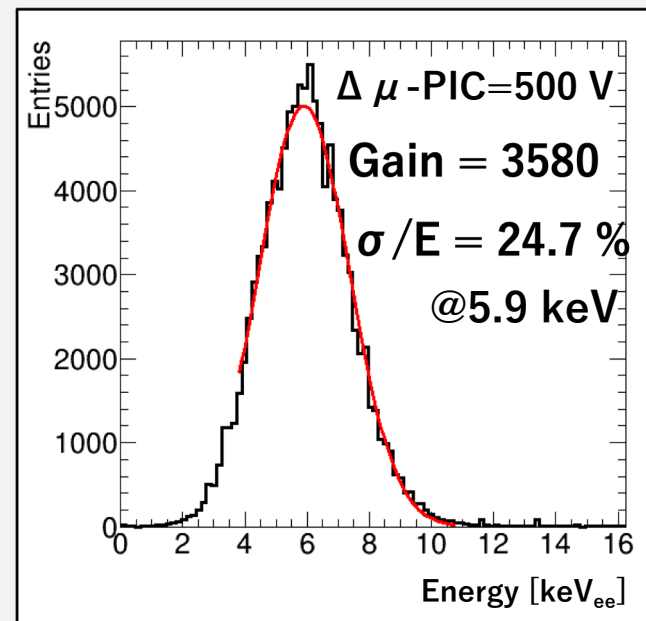
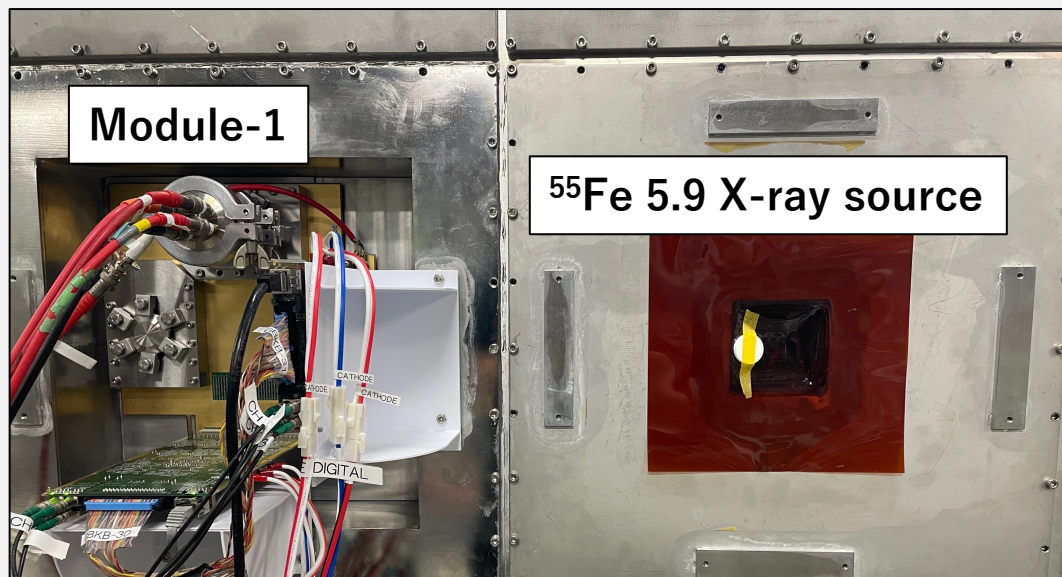
- Gas: CF_4 gas (0.1 atm)
- A circulation system with a filter for adsorbing impurities (a radioactive isotope and water) has already been built.

Schematic of circulation system



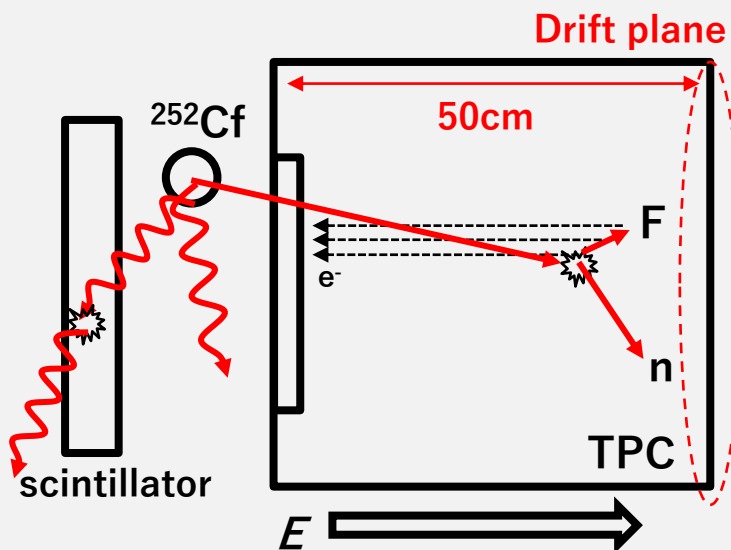
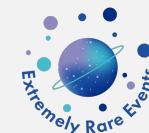
- Module-1 was installed in the center slot.
- Three operation tests were conducted.
 - ✓ Gas gain and energy resolution measurement (energy calibration)
 - ✓ Electron drift velocity measurement
 - ✓ Angular resolution measurement

Energy calibration



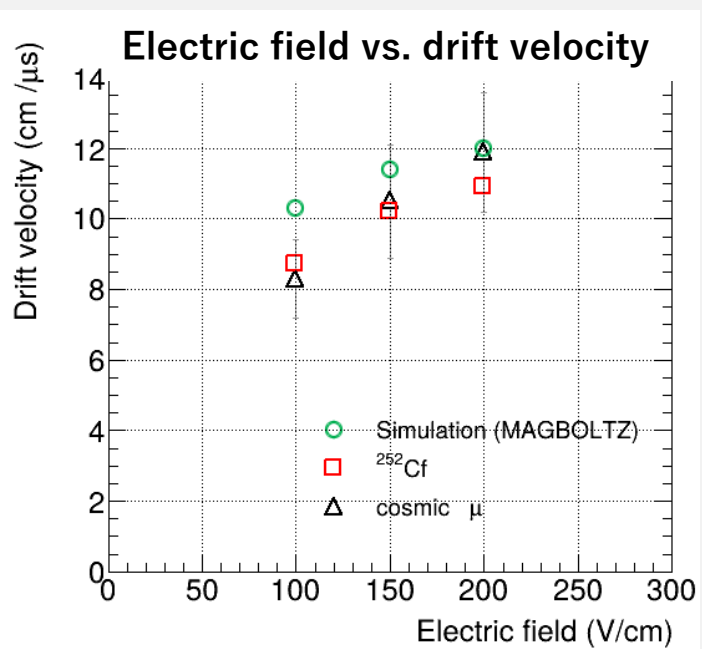
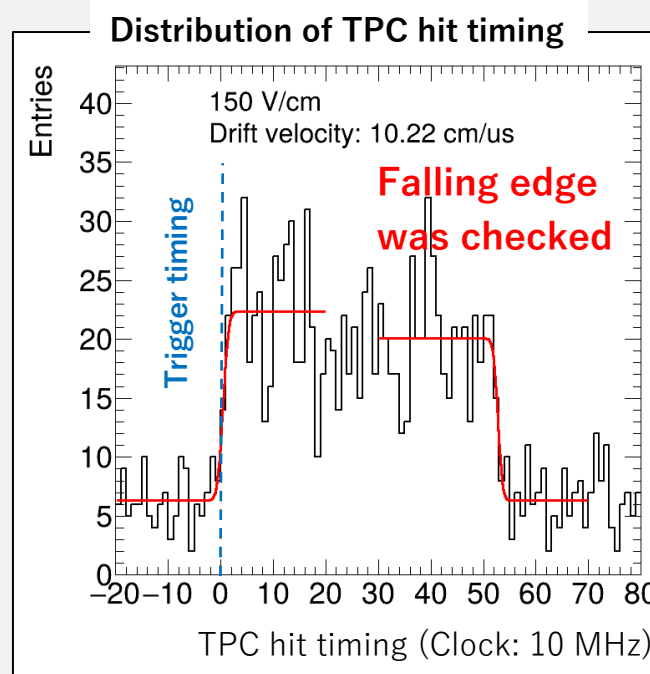
- An ^{55}Fe 5.9 keV X-ray source was used for energy calibration.
- An energy resolution comparable to or better than that of NEWAGE was measured.
- We confirmed that the required gas gain was achieved at an applied voltage with no discharge.

Drift velocity measurement



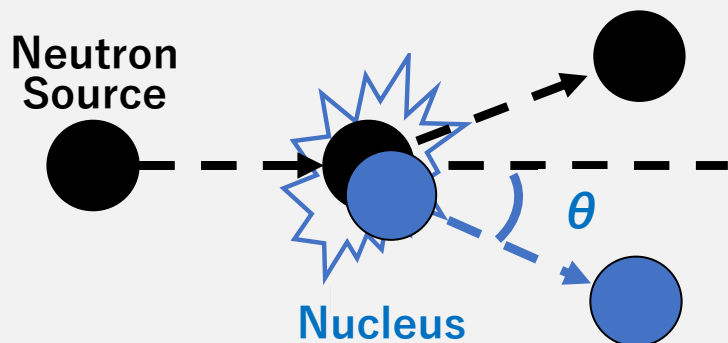
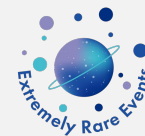
Measurement method

- Gamma rays and neutrons from a ^{252}Cf source were used.
- Events were triggered by a scintillator.
- The drift velocity was calculated from the time difference between the scintillator signal and the TPC signal.

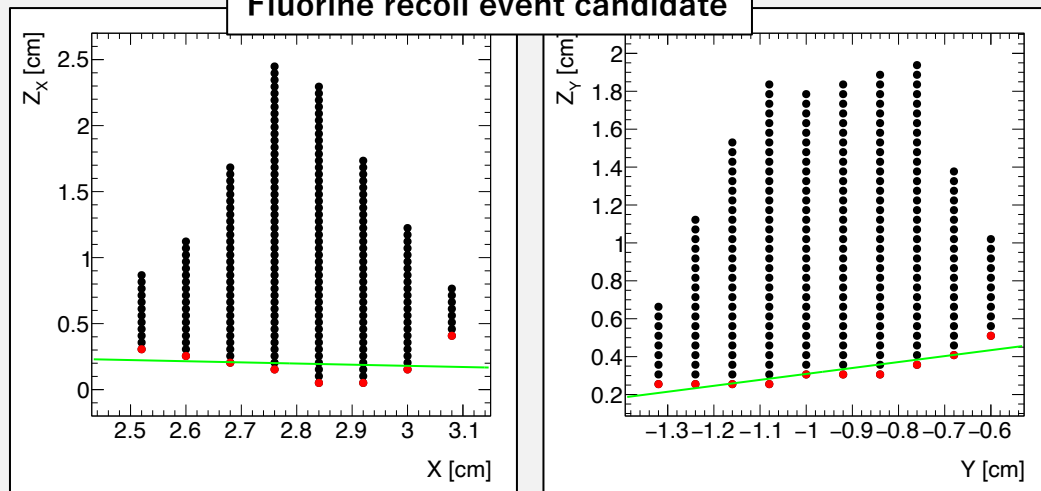


- Since a falling edge was observed, we confirmed that nuclear recoils nearby the drift plane are successfully detected.
 - The measured drift velocity as a function of the electric field strength is consistent with the simulation.
- **The electric field is properly formed.**

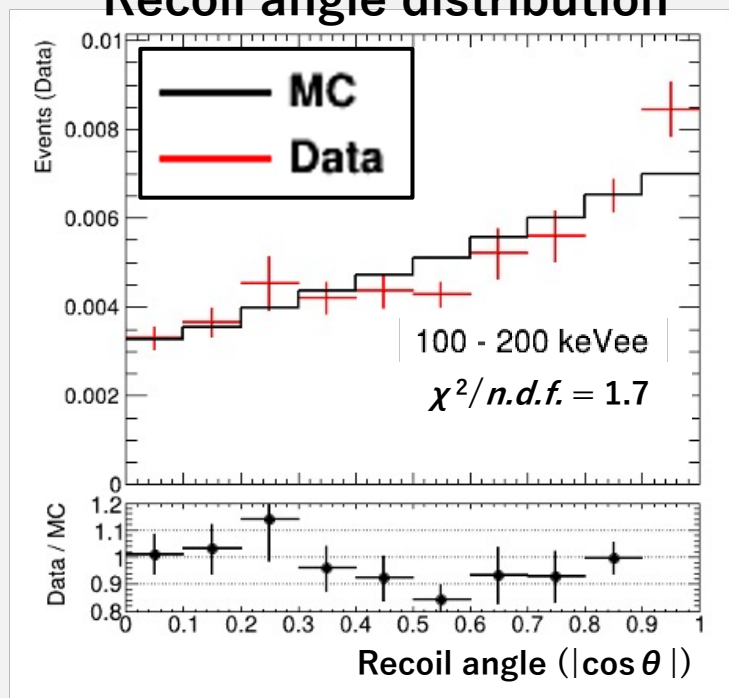
Angular resolution



Fluorine recoil event candidate



Recoil angle distribution



- The angular resolution was evaluated using a ^{252}Cf neutron source.
- The tracks were fitted with a linear function for each ToT rising point, and the expected angular distribution was obtained from Monte Carlo simulations.

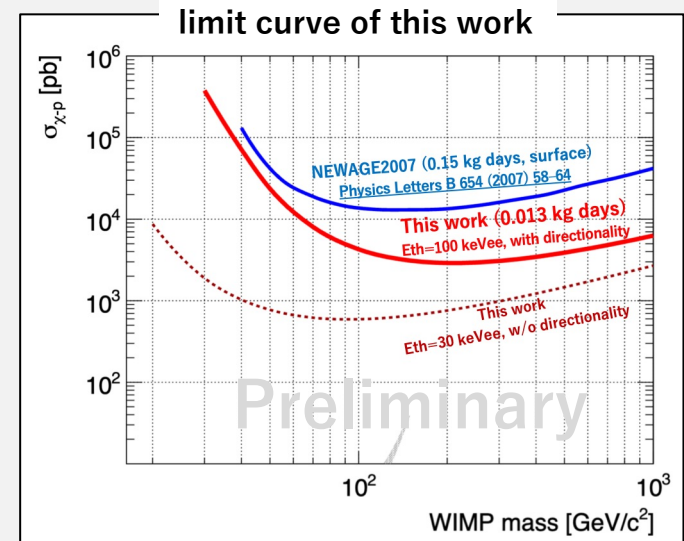
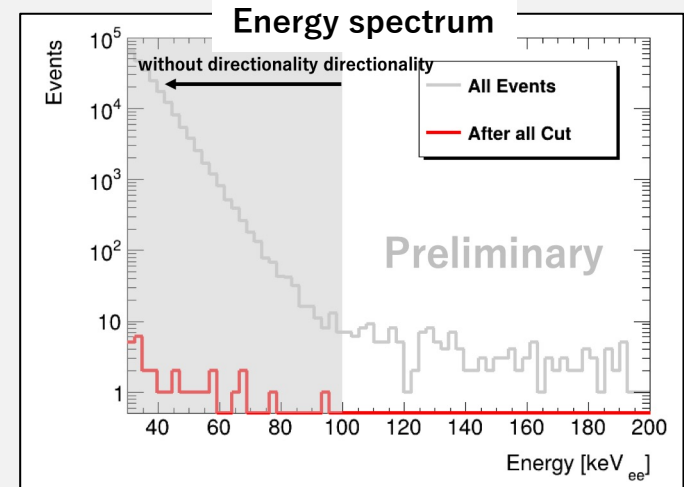
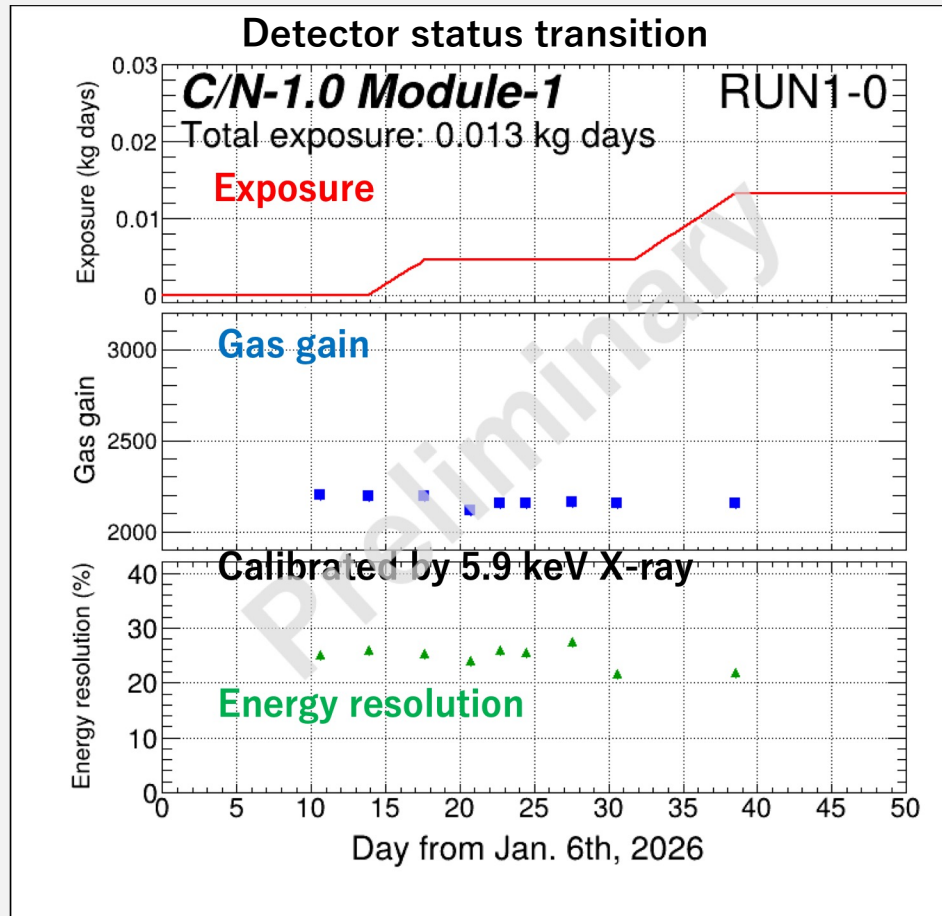


$$\sigma_{\text{reso}} = 48.5^{+2.8}_{-5.6}^{\circ} \text{ (stat.)} \quad (100 \text{ keV}_{\text{ee}} < E < 200 \text{ keV}_{\text{ee}})$$

$$\text{(NEWAGE: } \sigma_{\text{reso}} = 44.5^{+2.5}_{-3.1}^{\circ} \text{ (stat.))}$$

- **Angular information was obtained successfully.**
($> 100 \text{ keV}_{\text{ee}}$)

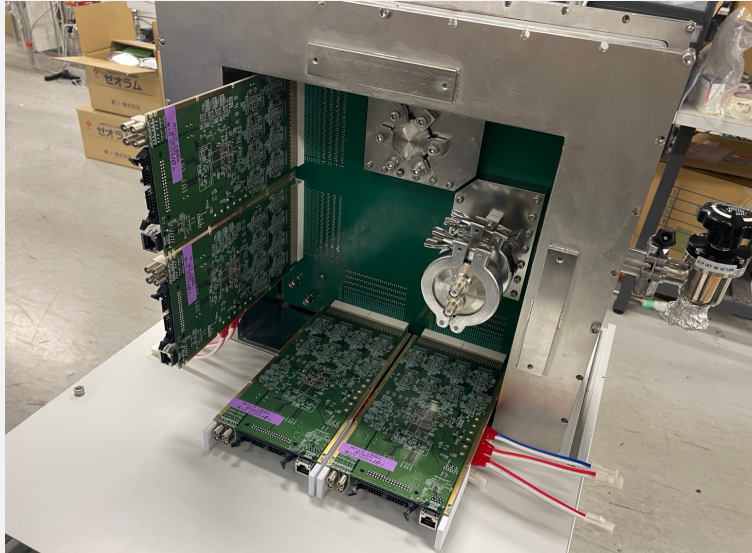
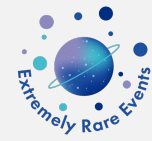
Demonstration for the long-term measurement



- Stable data acquisition for over 50 days was confirmed.
 - ✓ CF₄ 0.1 atm
 - ✓ 0.013 kg days exposure
- We obtained comparable limit to the NEWAGE surface run.
- The results with Module-1 demonstrate that C/N-1.0 is ready.

Prospects

Module-2

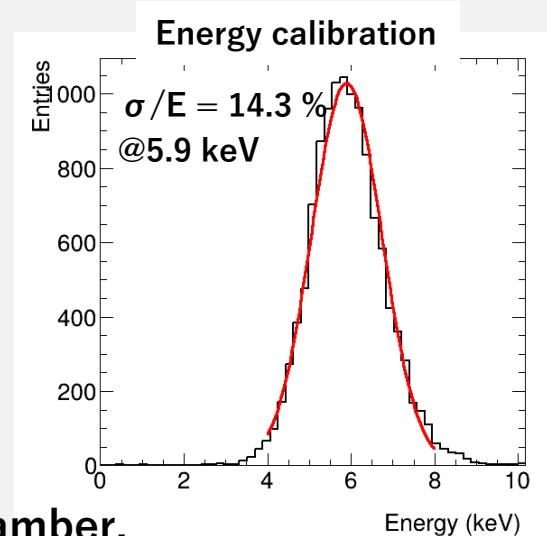
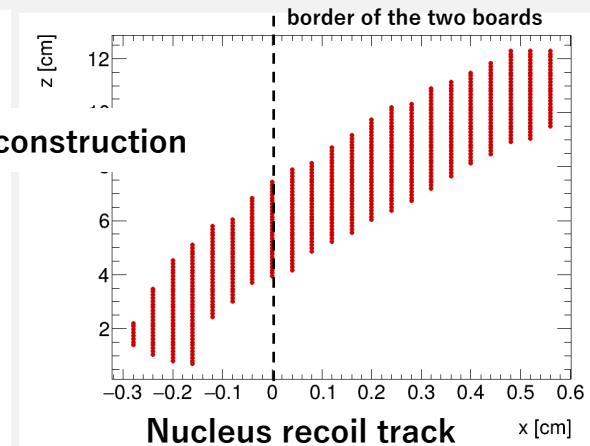
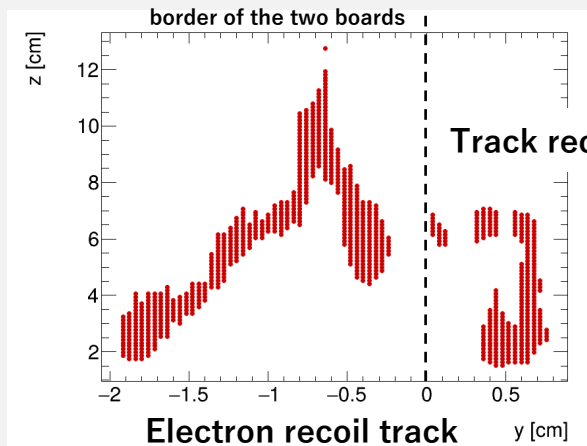


Features

	Module-1	Module-2
detection area	10×10 cm ²	10×10 cm ²
readout pitch	800 μm	400 μm
energy threshold with directionality	100 keV _{ee}	50 keV _{ee}

- Module-2 has 400 μm readout pitch.
- This detector aims to search for WIMPs above 50 keV_{ee}.
- Detector structure is same as Module-1 (μ-PIC + GEM).

➤ Track reconstruction and energy calibration have already been performed.



→ Detector performance is being evaluated with a test chamber.

C/N-1.0 roadmap



2026

2027

2030

...

The test operation has been completed, and the background study is ongoing.

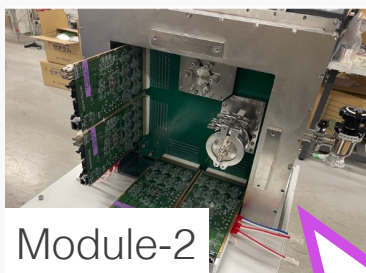
Large detection area and 400 μm readout pitch



2026~
detector commissioning
with a modular detector
at Kobe Univ.

underground
experiment
(commissioning)

**1 m³ exposure
underground
experiment (18 modules)**

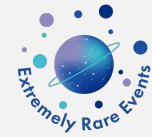


2026~
move to Kamioka lab.

Upgrade modules for
400 μm readout pitch

Start of the WIMP search
Installation of additional modules

Conclusion



- **NEWAGE is a direction-sensitive WIMP search experiment.**
 - ✓ A large volume detector is needed for greater sensitivity.

- **1m³ scale chamber "C/N-1.0" was tested with the Module-1 detector.**
 - ✓ ~ 50 days of operation was demonstrated.
 - ✓ C/N-1.0 can be used for WIMP searches with directionality.

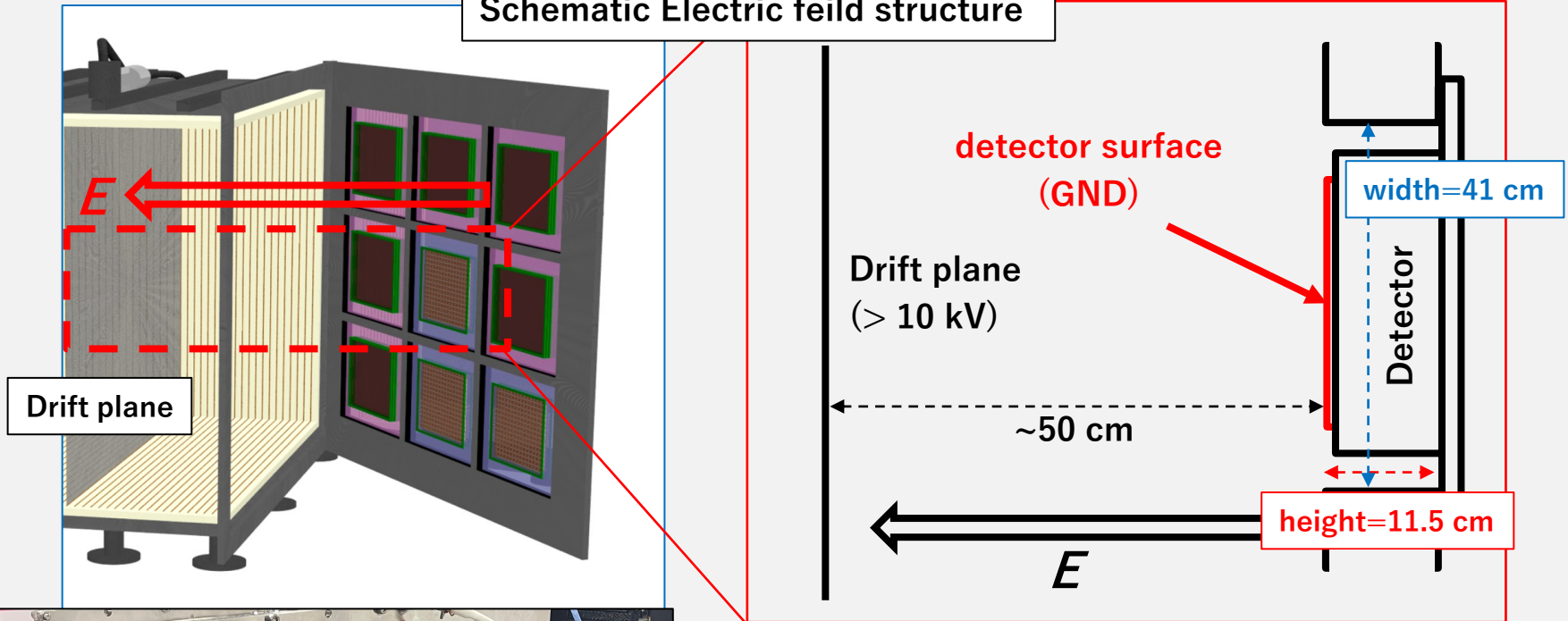
- **Prospects**
 - ✓ Development of new module detectors with greater position resolution.

Commissioning is ongoing toward starting the WIMP search.

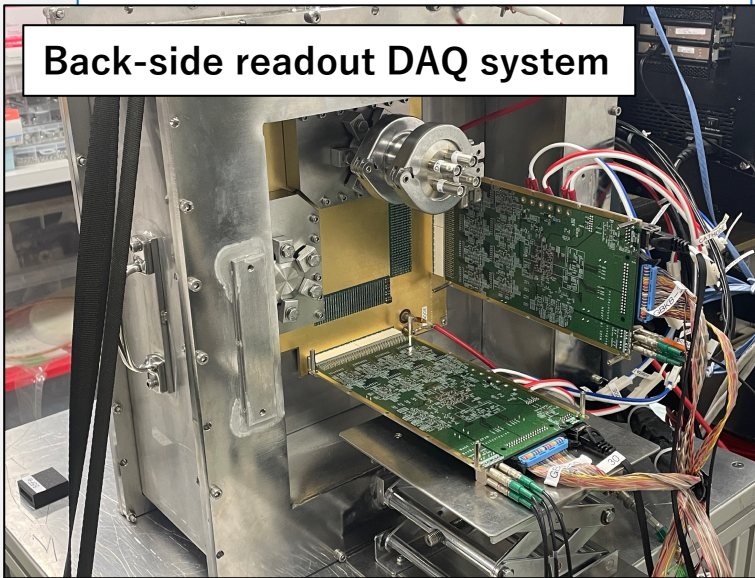
Back up

Detector structure

Schematic Electric field structure



Back-side readout DAQ system



Structure constraints

- The module width is less than 41 cm, and the detection plane is placed at a height of 11.5 cm.
- The detector surface is set as the GND plane.
- The detector DAQ is installed on the back side to avoid interference with other modules.

International collaboration (w/ Sheffield Gr.)

- C/N-1.0 has successfully hosted a detector from the University of Sheffield.
- Track information was successfully obtained.
- The details are available in the following [arXiv paper](#) and [A.McLean's talk](#).

arXiv:2602.12658v1 [physics.ins-det] 13 Feb 2026

PREPARED FOR SUBMISSION TO JINST

High Negative Ion Gain MMThGEM-Micromegas Detector for Directional Dark Matter Searches

A.G. McLean,^{a,b,c,d,1} S. Higashino,^e R.R. Marcelo Gregorio,^{b,d} K. Miuchi,^e and N.J.C. Spooner^d

^a*School of Physics, Chemistry and Earth Sciences, Adelaide University, Adelaide City Campus, Adelaide, SA 5005, Australia*

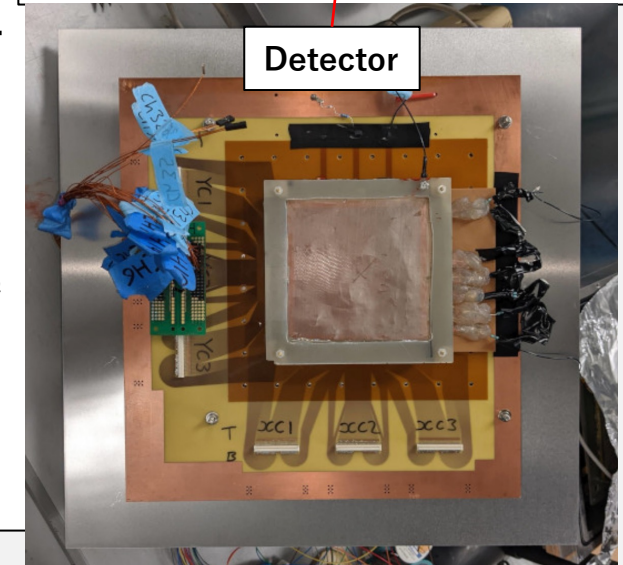
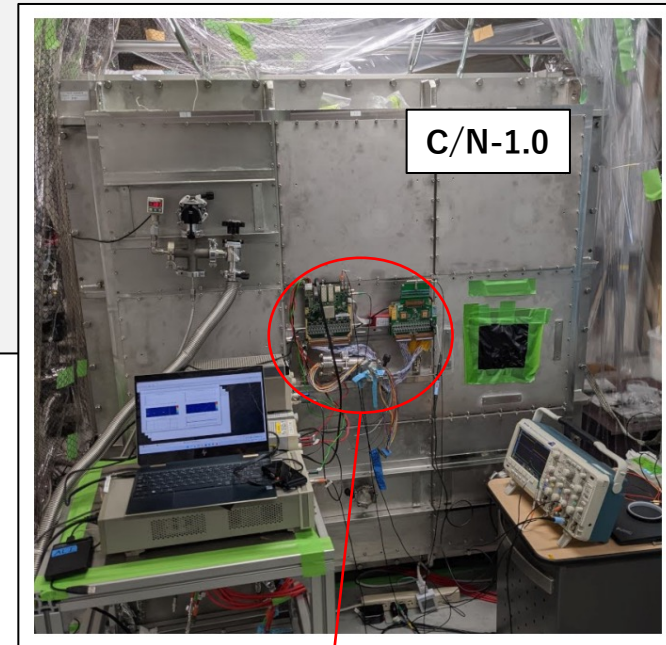
^b*Department of Nuclear Physics and Accelerator Applications, Australian National University, Garran Road, ACT 2601, Canberra, Australia*

^c*ARC Centre of Excellence for Dark Matter Particle Physics, Australia*

^d*Department of Physics and Astronomy, University of Sheffield, South Yorkshire, S3 7RH, United Kingdom*

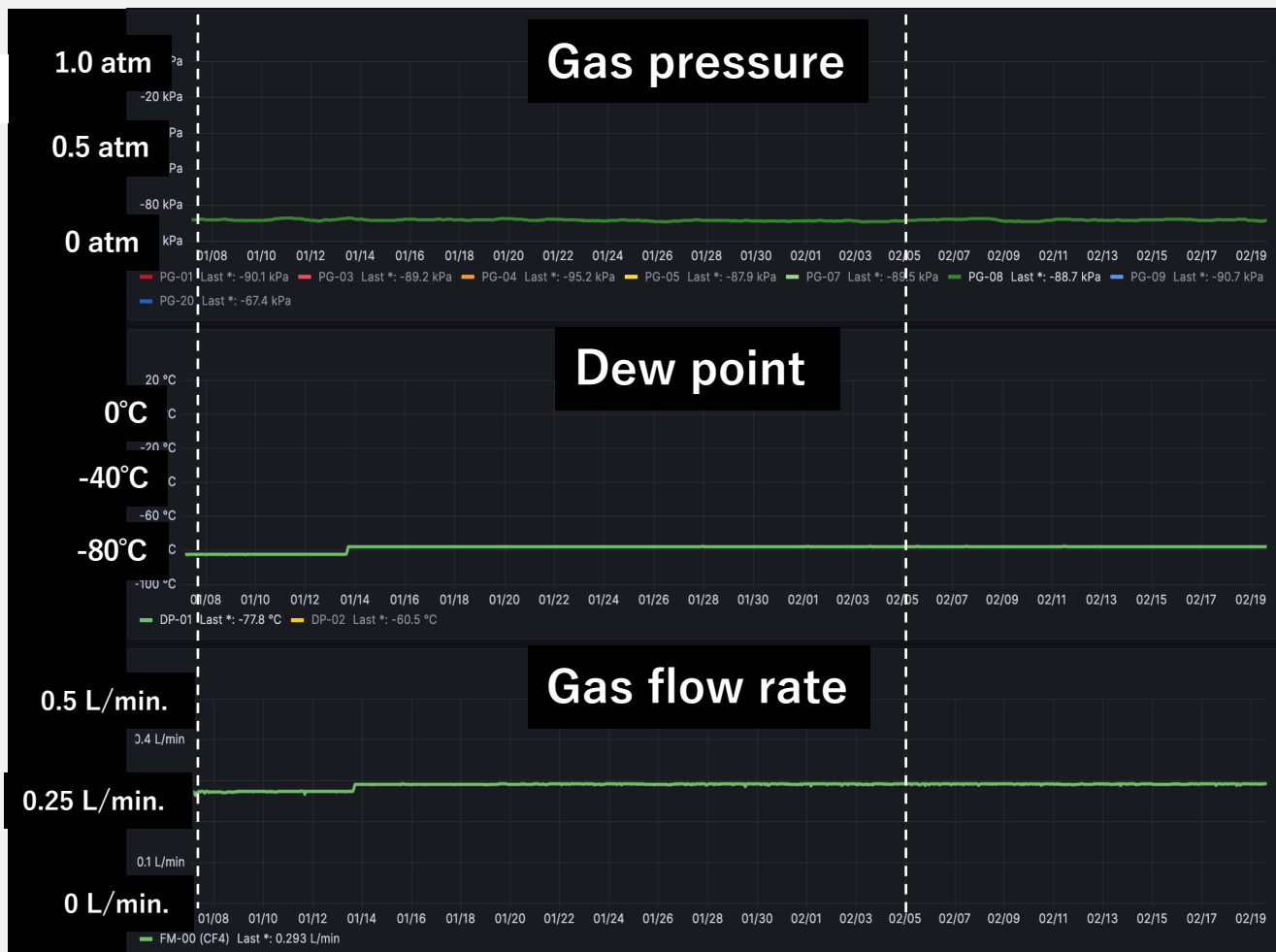
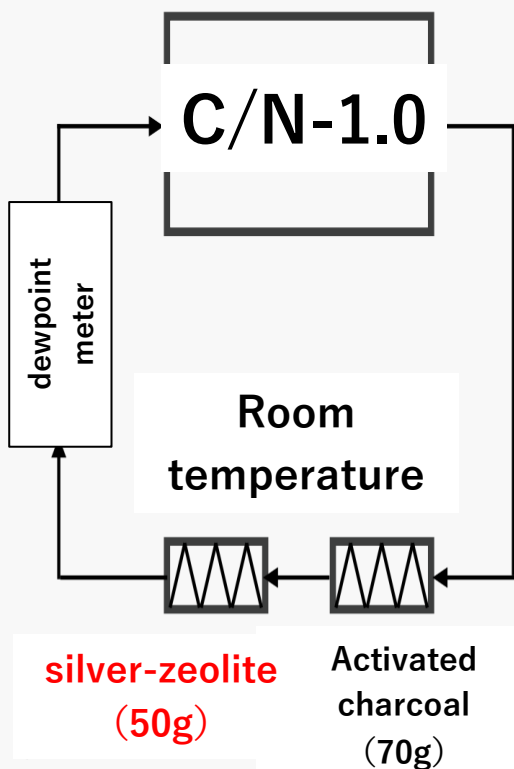
^e*Department of Physics, Kobe University, Rokkodaicho, Nada Hyogo 657-8501, Japan*

E-mail: alasdair.mclean@adelaide.edu.au



Gas Circulation System Status

Simplified Circulation system

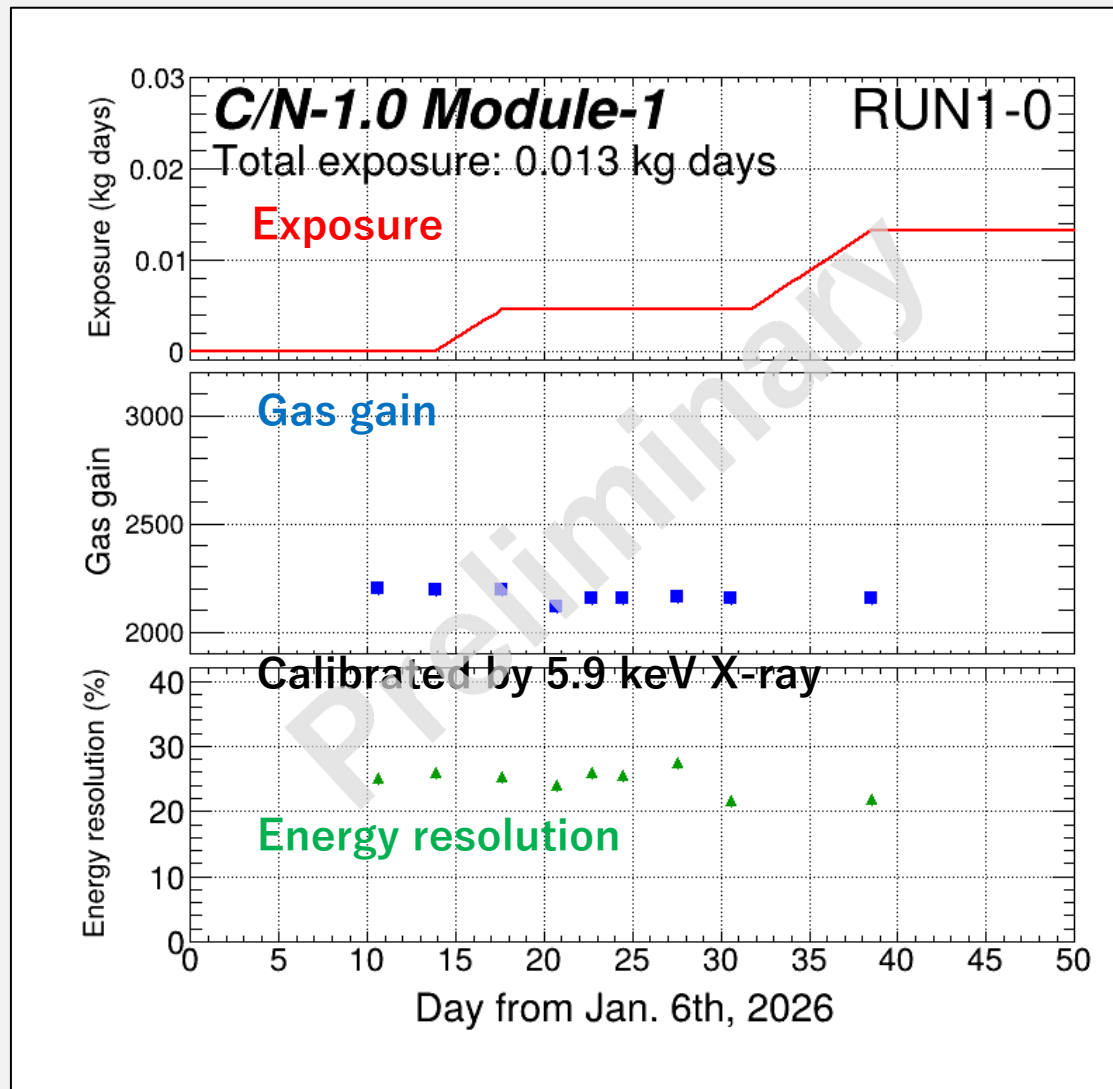
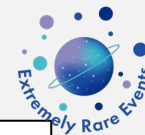


Jan. 6th, 2026
(gas was installed)

Feb. 6th, 2026

- Stably operated for more than 50 days after gas filling.

Detector status

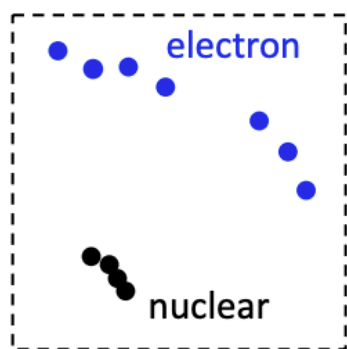


- CF_4 0.1atm
- 0.013 kg days exposure
- Periodical calibrations were performed using ^{55}Fe 5.9 keV X-rays and the gain fluctuation was approximately $\pm 2\%$.

Event selection: Cut line determination

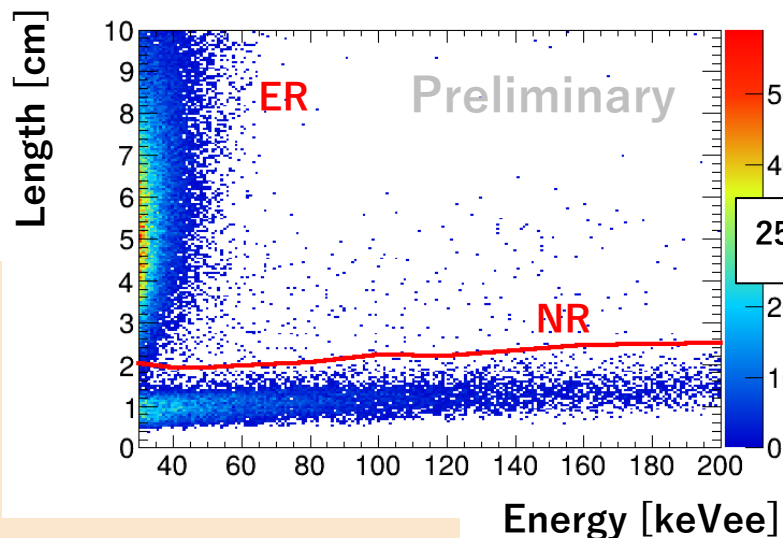
- Two types of event selection were mainly applied to reject environmental gamma rays.
- The cut line was determined using neutron and gamma irradiation from a ^{252}Cf source.

1. Energy-Length cut



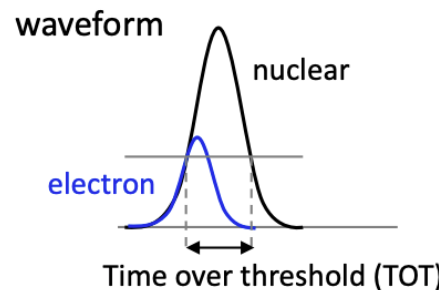
Track length of
electron is **long**

Track length of
nuclear is **short**



- Red line: $+3\sigma$ from NR median

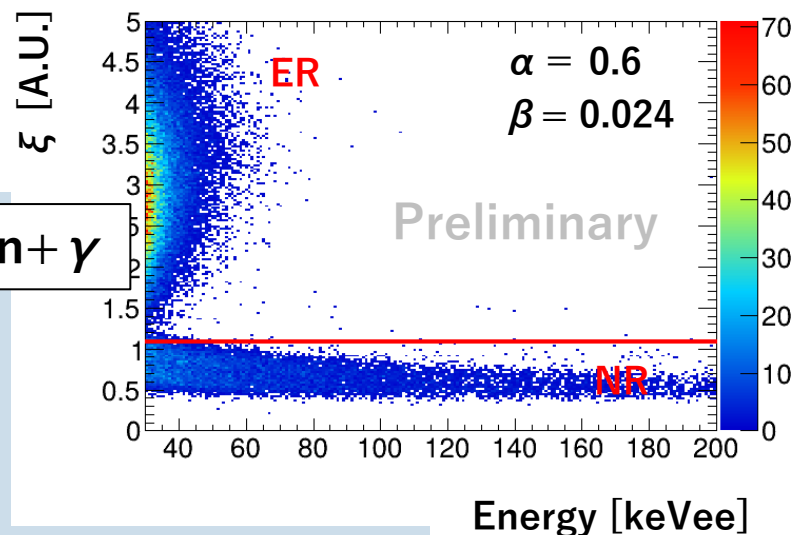
2. Energy-ToT cut



Electron has
small dE/dx

Nuclear has
large dE/dx

Define: $\xi \equiv \Sigma \text{ToT} * \beta / \text{Energy}^\alpha$ (empirical)

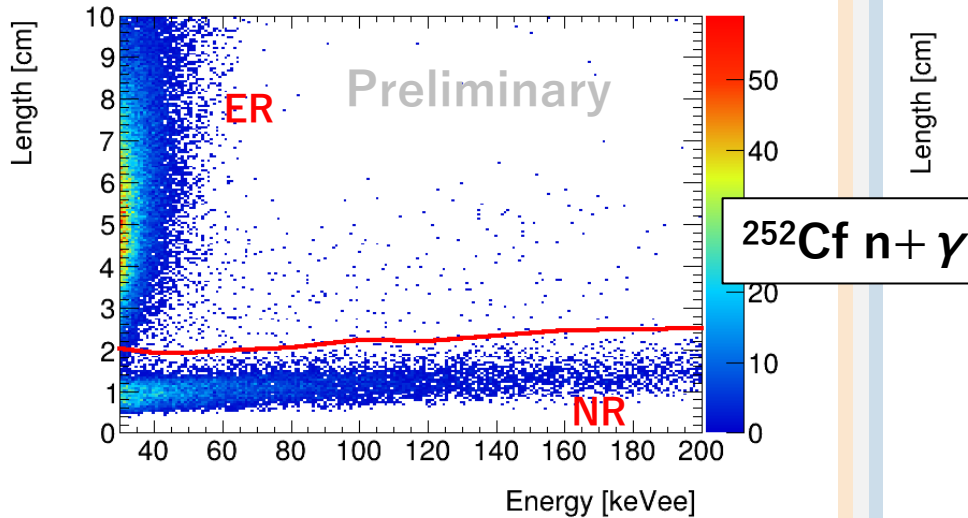


- Red line: constant parameter

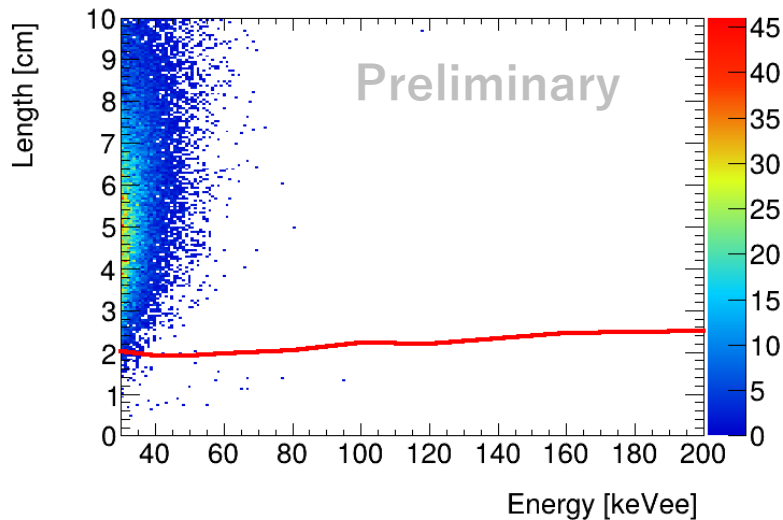
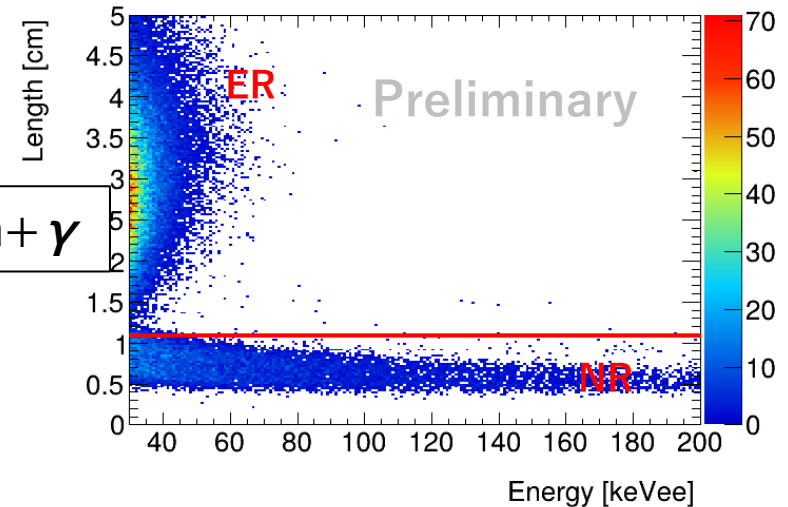
Event selection: Applied to BG data

- Results after applying the cuts to the background data.

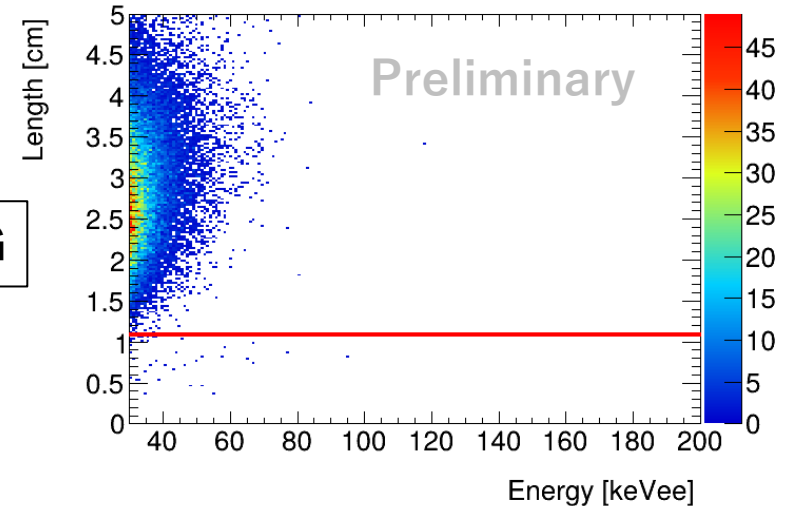
1. Energy-Length cut



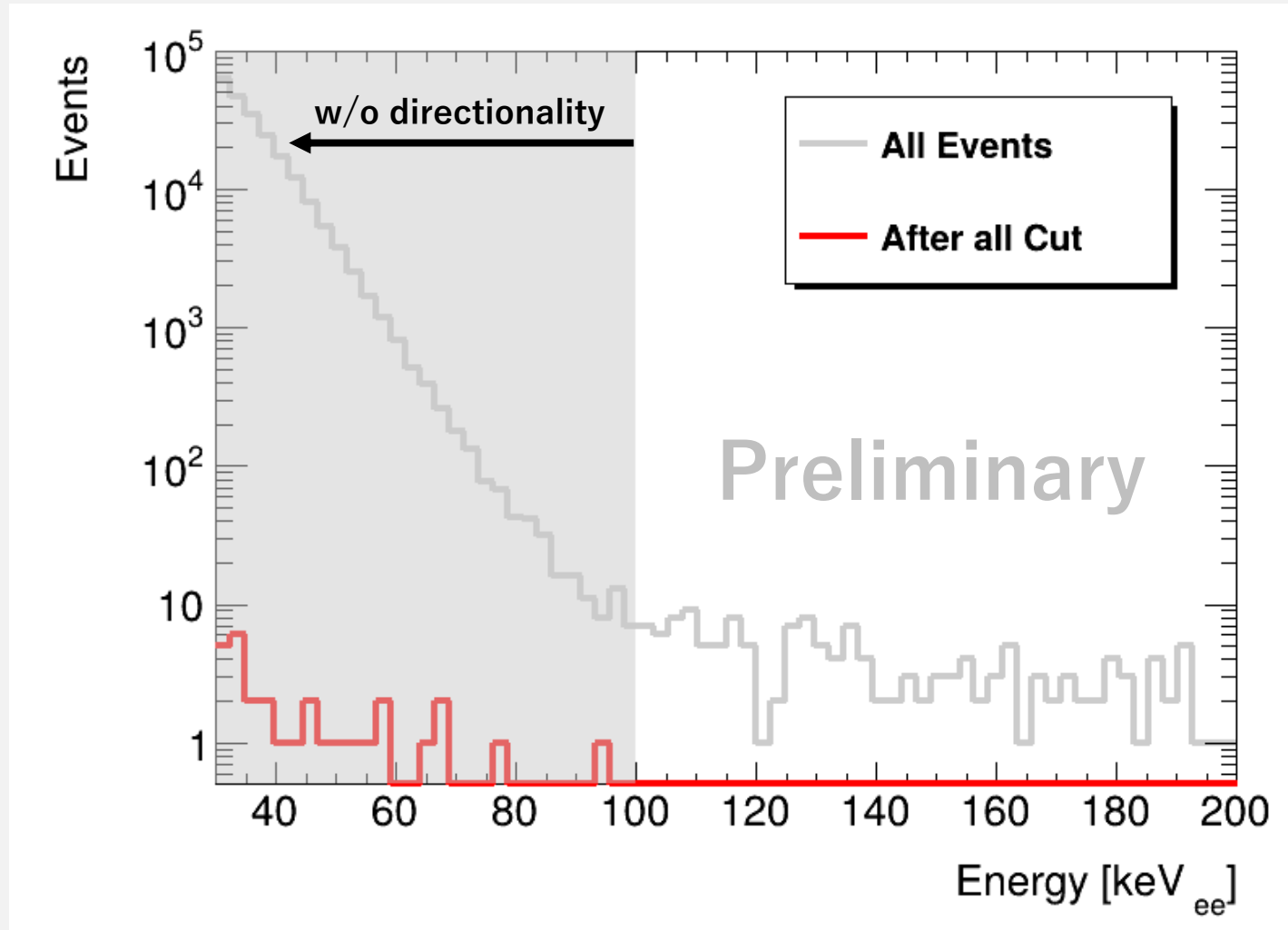
2. Energy-ToT cut



BG



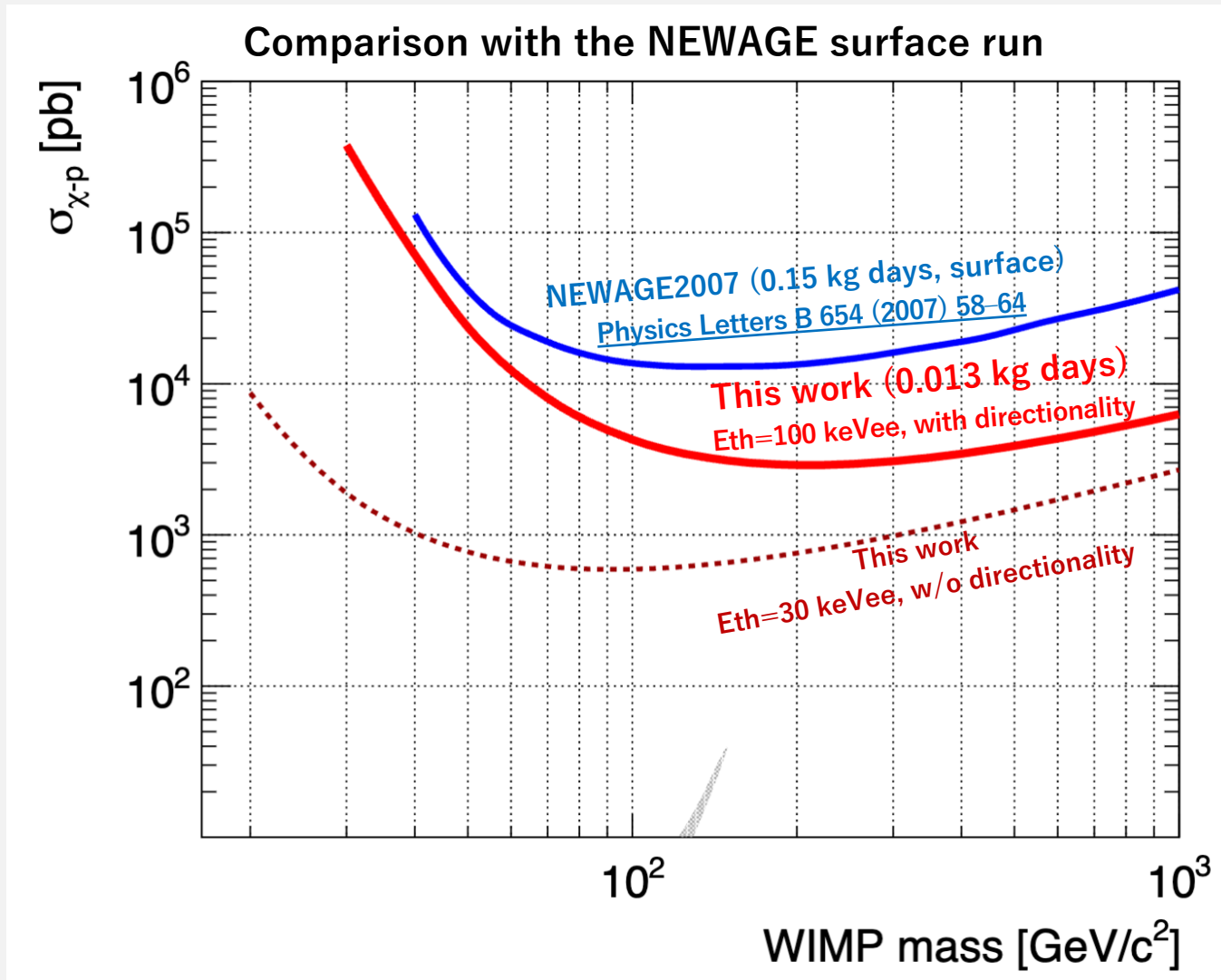
Energy spectrum



- No events remained in the 100–200 keV_{ee} range after event selection.

Results for BG run

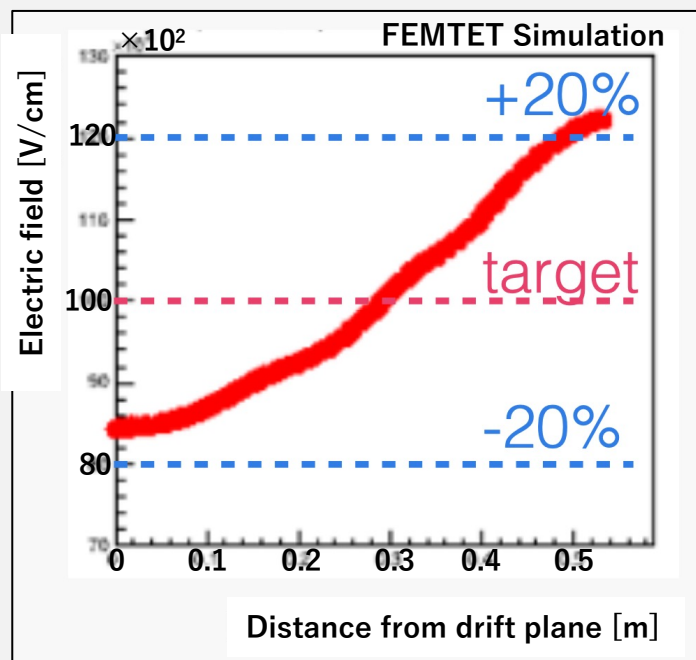
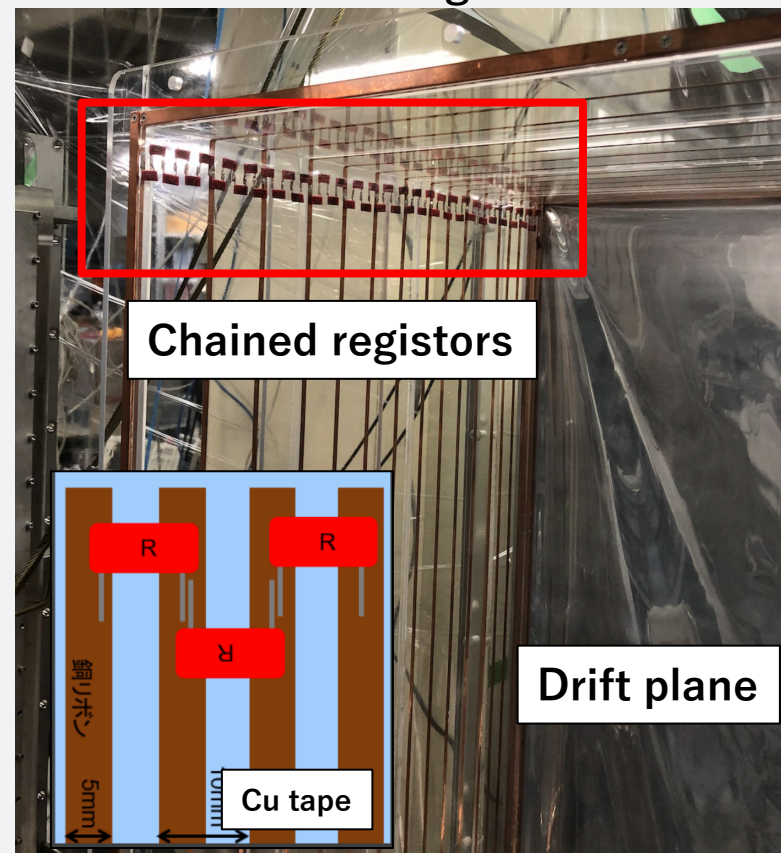
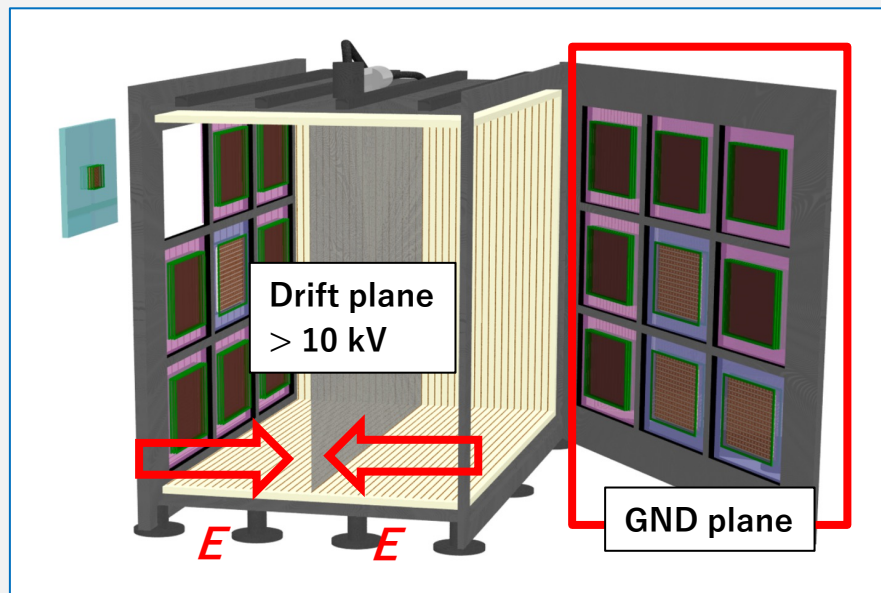
- Result of the surface BG run using C/N-1.0 (100 keVee energy threshold)



- Comparable results with NEWAGE surface one.
- The results with Module-1 demonstrate that C/N-1.0 is a practical and usable chamber.

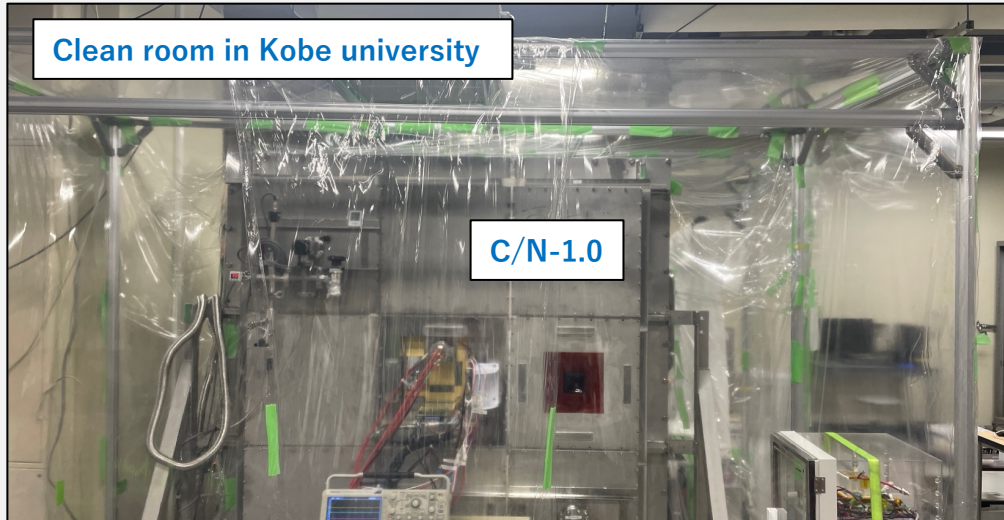
C/N-1.0 structures

Field cage

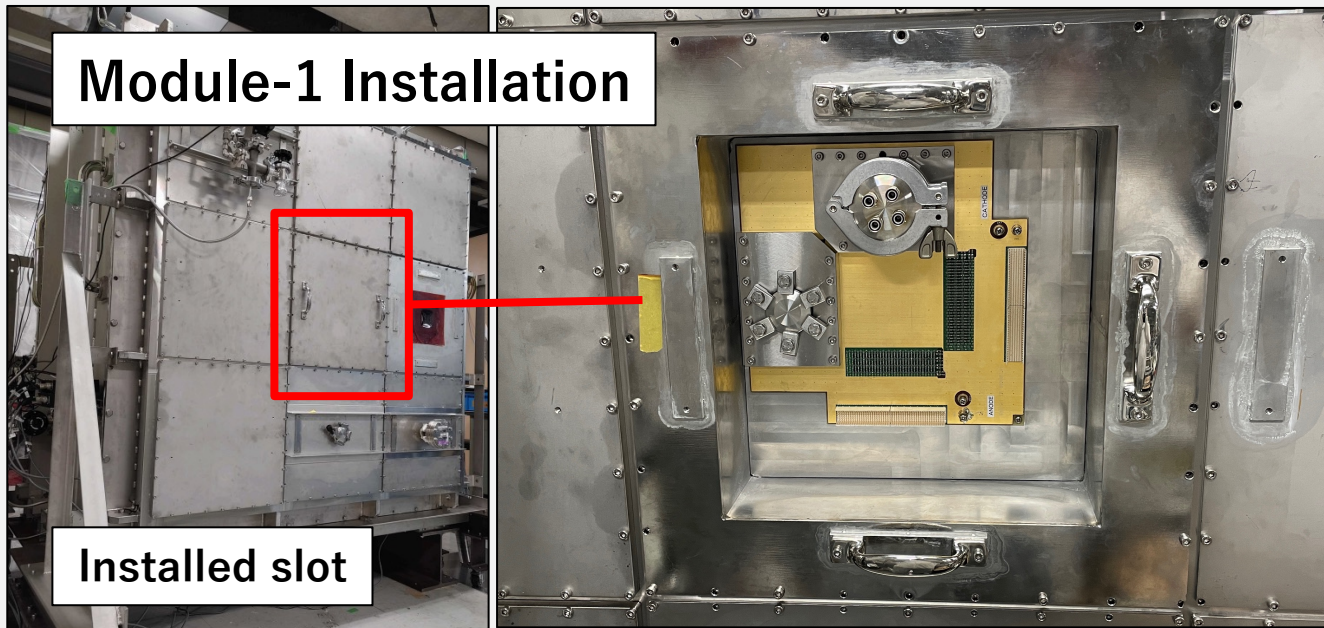


- The drift electric field is formed using a chained resistors.
- The detector is designed such that the readout plane serves as the ground (GND) plane.
- Simulation studies indicate that the drift-velocity uniformity is approximately within $\pm 20\%$.

Module-1 installation



- Module-1 has been installed in the clean room at Kobe University.
- The center slot was selected to minimize background from chamber components.

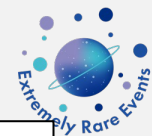


Module-1
installation had
been completed !!

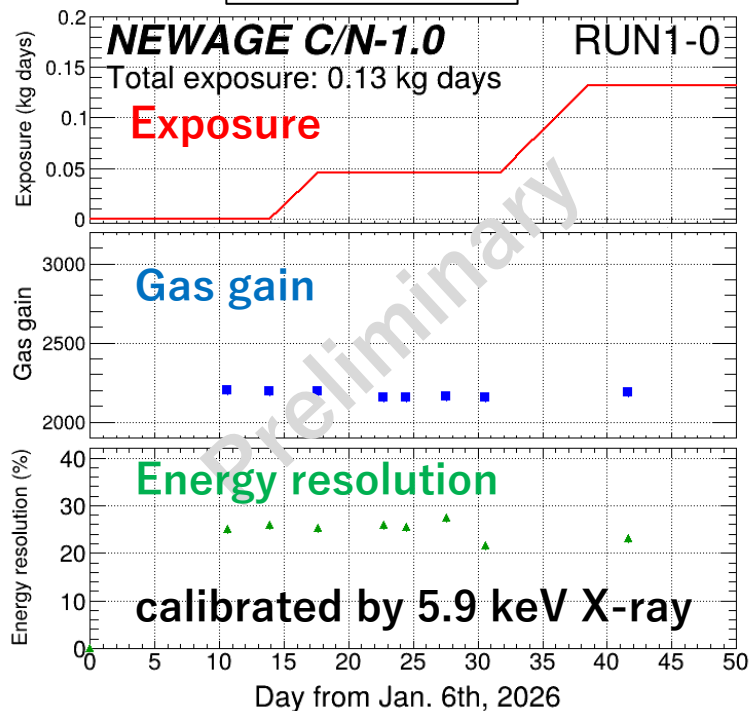


Next:
Testing for
track acquisition

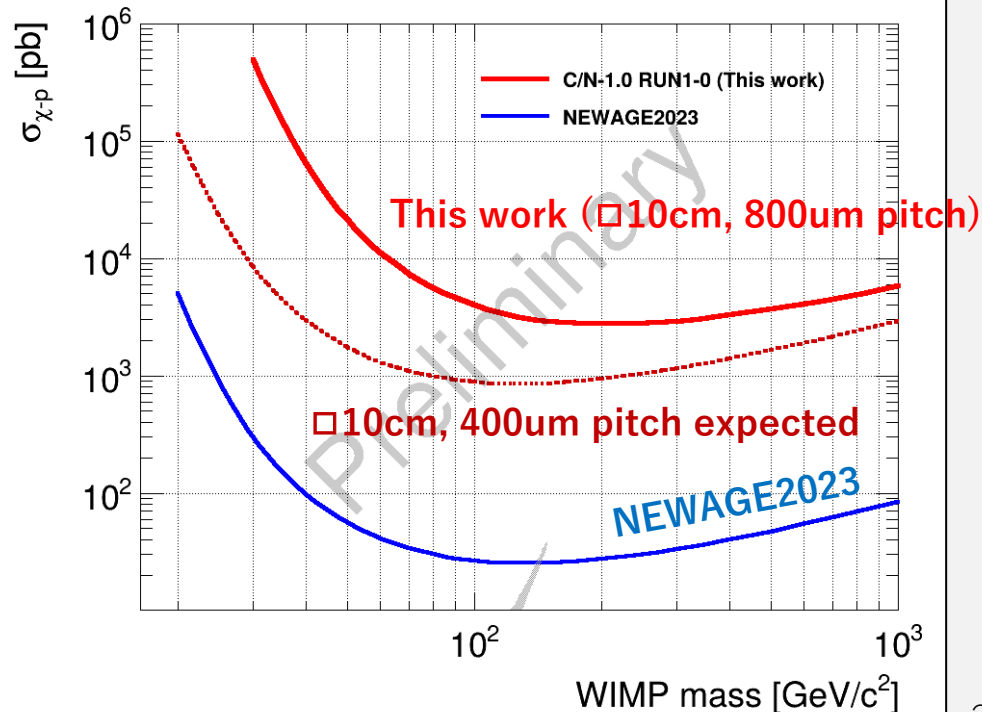
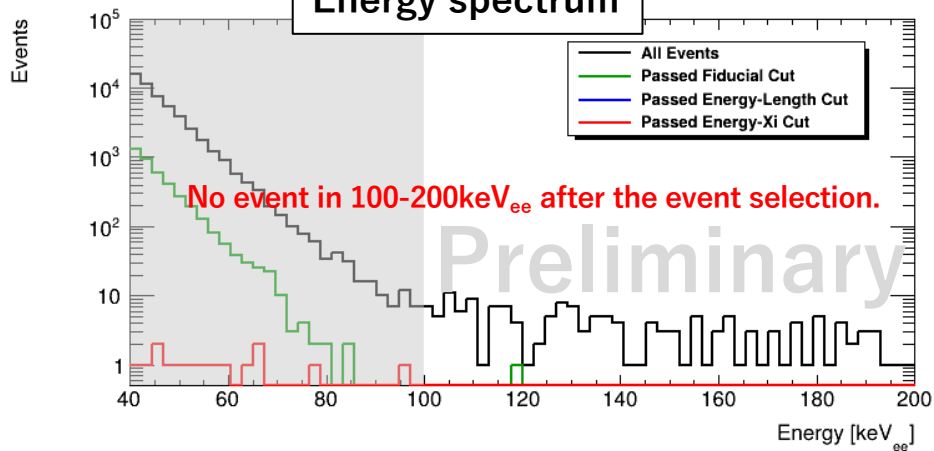
Surface WIMP search result



Run summary



Energy spectrum



- WIMP search result using C/N-1.0 with Module-1
 - 100 keV_{ee} energy threshold.
 - Gas gain and energy resolution was sufficiently stable.
 - Total exposure: 0.13 kg days.
- ~ 3000 pb (90 % C.L) at 200 GeV WIMP mass.

International collaboration (w/ Sheffield Gr.)

CYGNUS-10 Scale Kobe “BENTO” Vessel

A. McLean's slides in IDM2024

arXivの情報のみ載せる
実績のみ

Their detector

The “BENTO” vessel at Kobe University

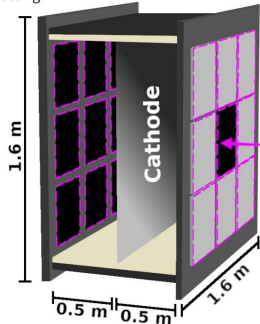
Large CYGNUS-10 scale vessel - 50 cm drift length

Modular design which can support up to 18 readout detector planes

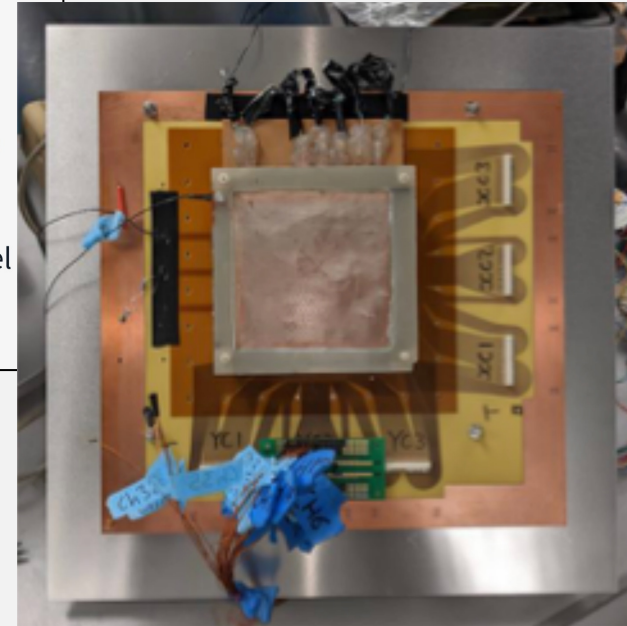
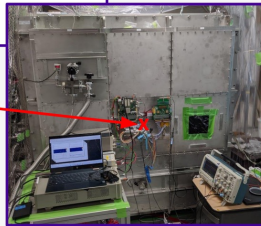
MMThGEM-Micromegas was transferred to the central panel on the BENTO vessel

Detector mounting conveniently fits test vessel dimensions

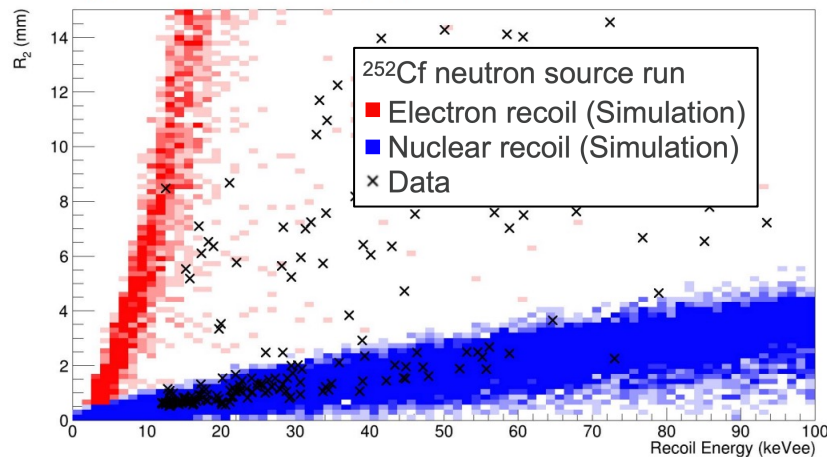
Kentaro and Satoshi welcome your detector modules for testing!



^{252}Cf source positioned externally 10 cm behind micromegas plane



With trigger threshold = 200 mV (LG), the effective recoil threshold ~ 12 keVee

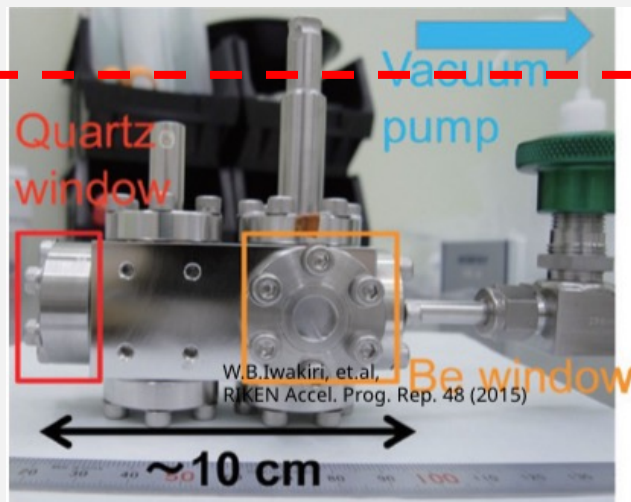


23

Successfully reconstructed nuclear recoil using C/N-1.0 !!

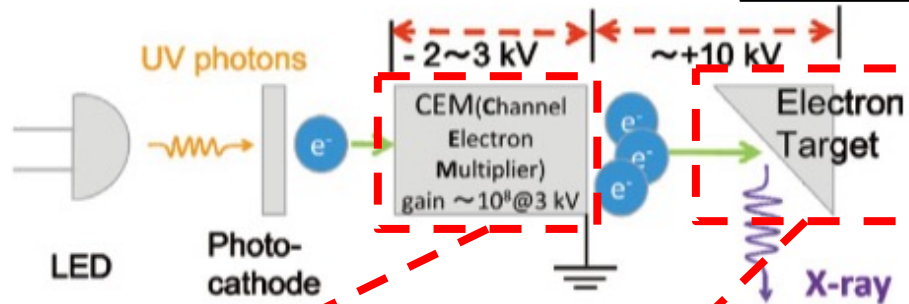
➤ in SF_6 gas (40 Torr)

MXS-30k



W.B.Iwakiri, et.al,
RIKEN Accel. Prog. Rep. 48 (2015)

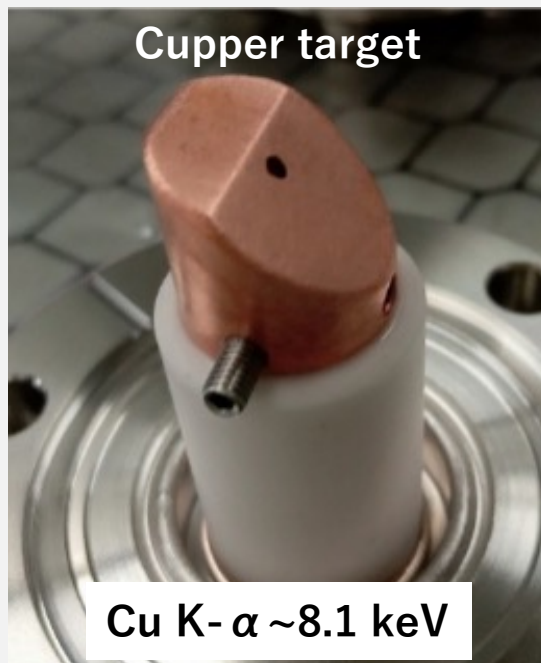
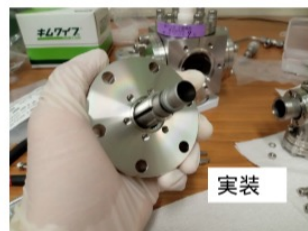
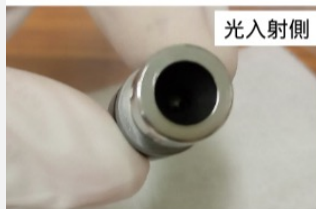
Internal structure



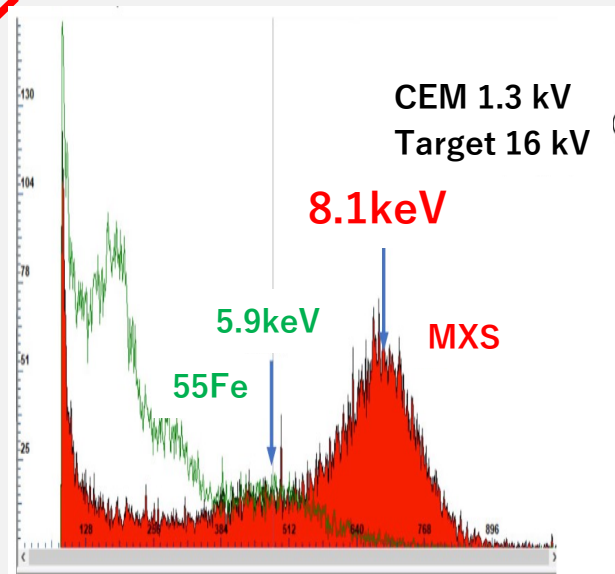
W.B.Iwakiri, et.al,
RIKEN Accel. Prog. Rep. 48 (2015)

reference:
Kentaro's talk in
MPGD workshop 2025
at Iwate Univ.

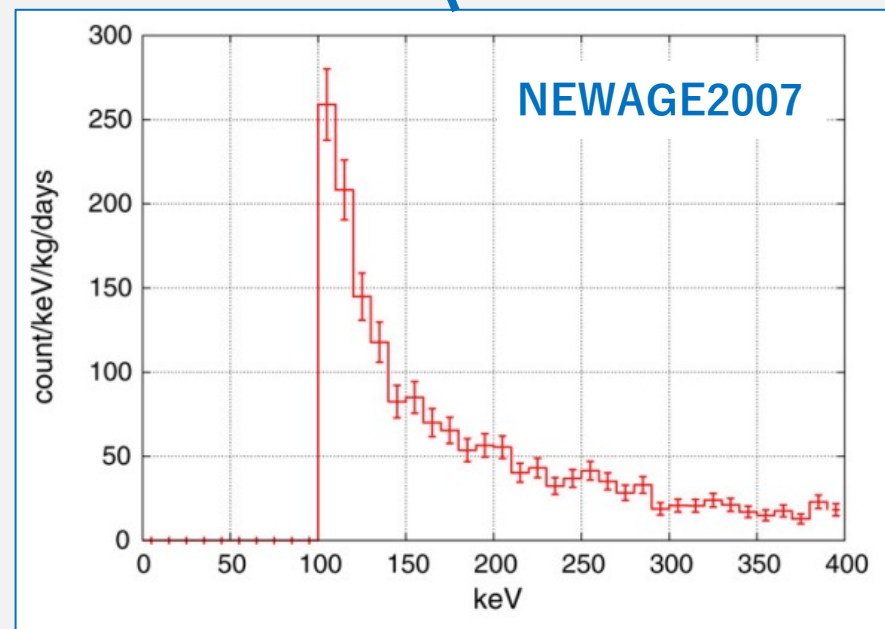
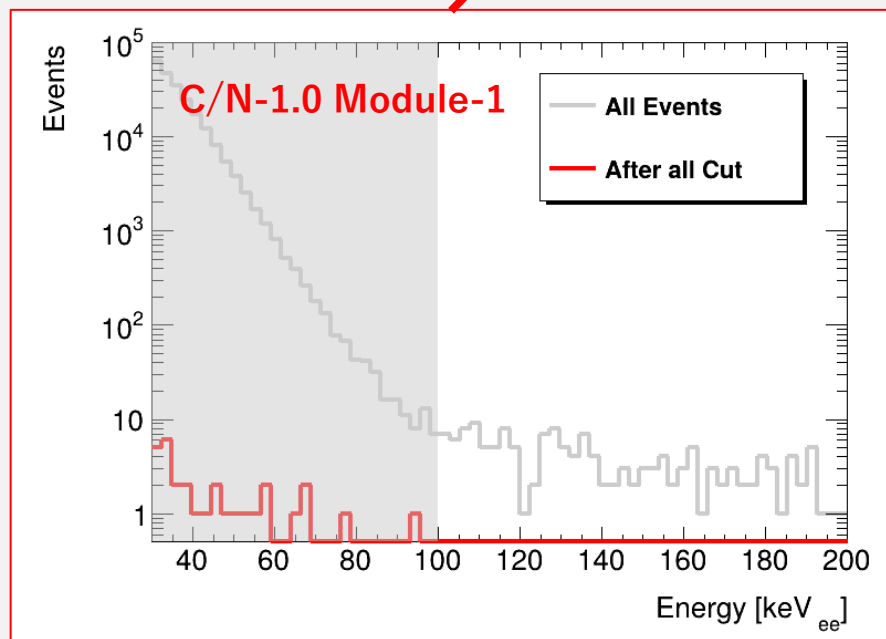
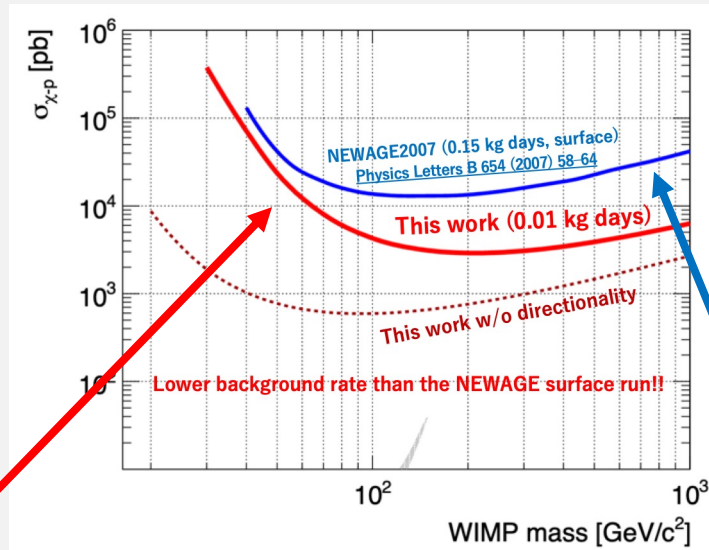
- CEM (channel electron multiplier)
 - オリジナルを踏襲
 - MgO 塗布済みの便利なものが入手可能
 - PHOTONIS 社 MAGNUM5900 COA EDR



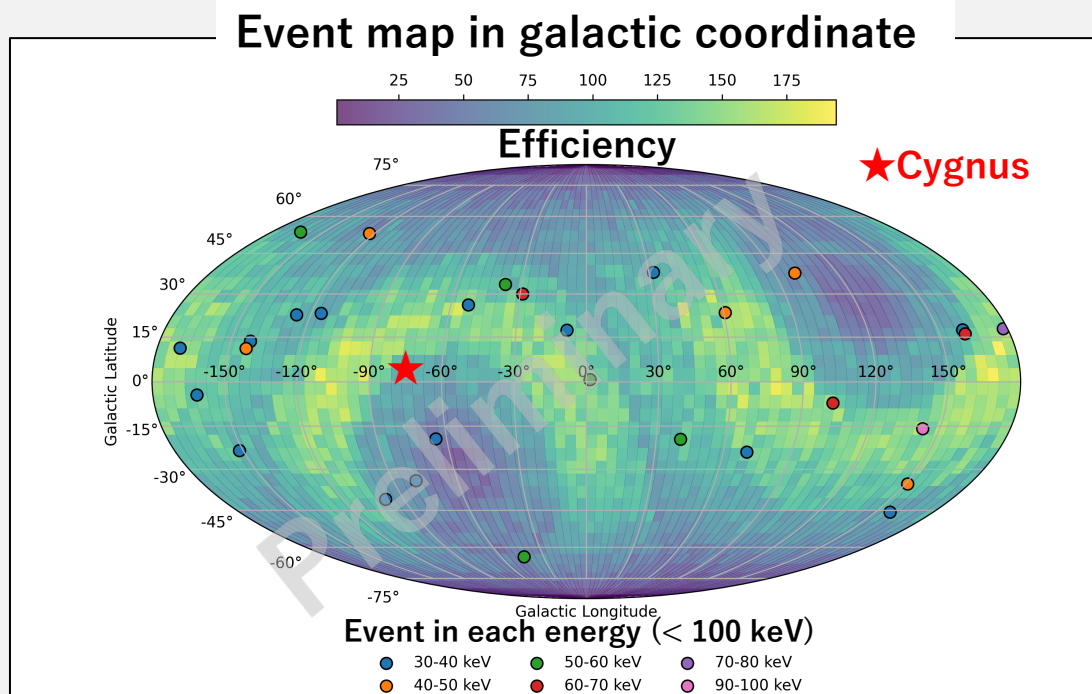
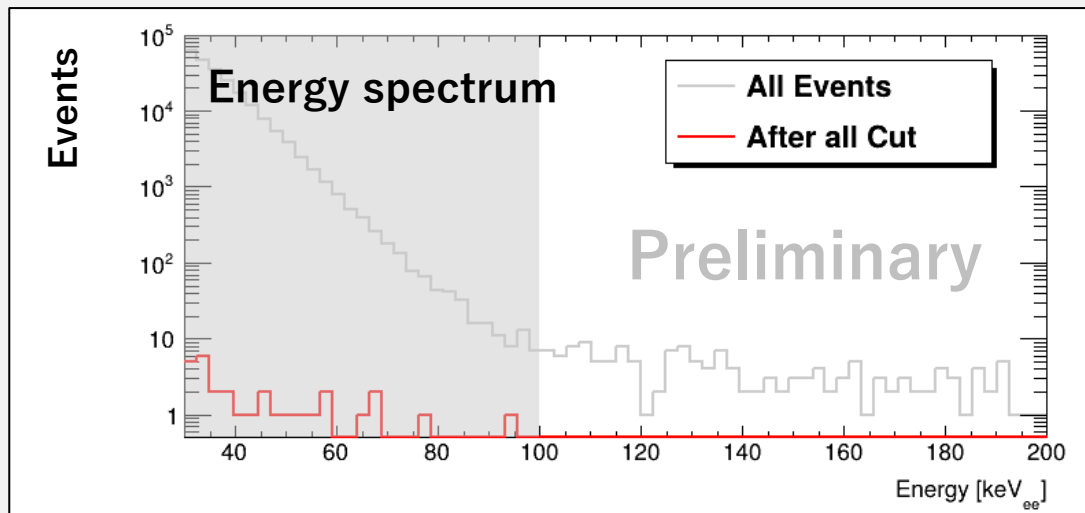
Cu K- α ~8.1 keV



Surface run comparison



Analysis result



Radon Decay Chain



Drift velocity calibration (cosmic μ)

- Measured drift velocity using cosmic μ .
 - Events were triggered by plastic scintillator

