Status of Large Direction-sensitive Gaseous TPC: C/N-1.0

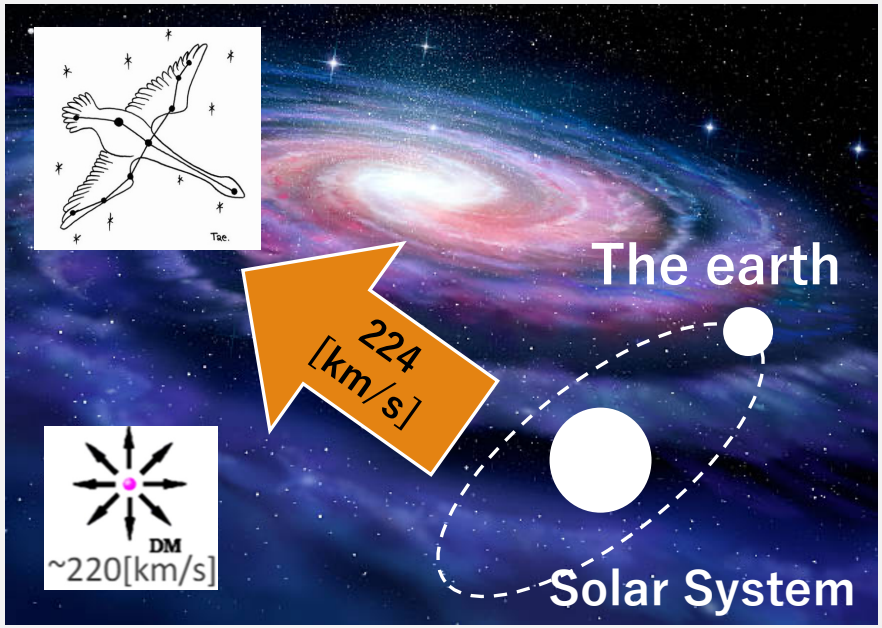
Ryota Namai (Kobe University)

CYGNUS2026

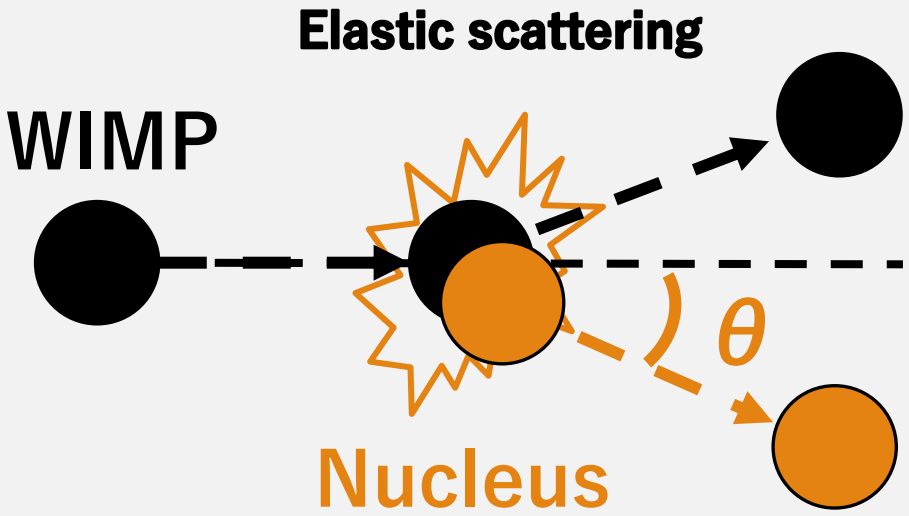
Feb 23rd, 2026 Kobe, Japan

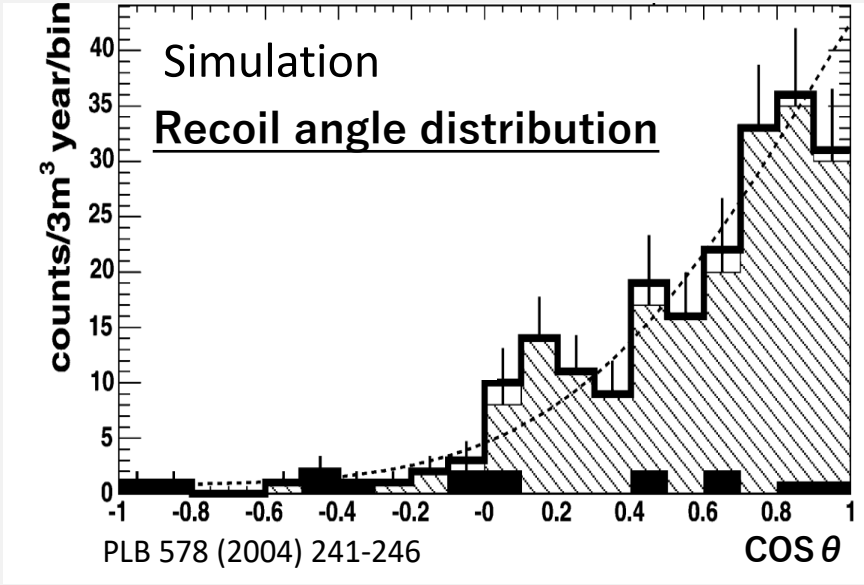
Introduction

Directional WIMP Direct Search



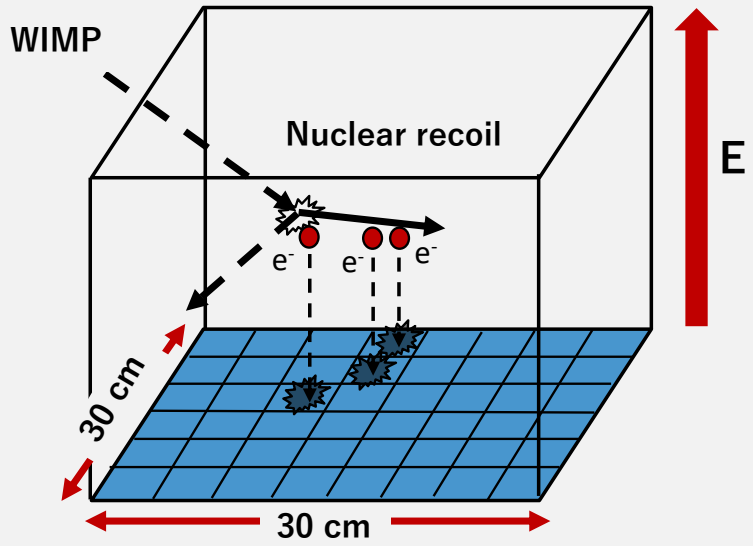
- DM is assumed to be WIMP in this talk.
- Although numerous experiments around the world are searching for WIMP, no experiment report the observation.
- Direction-sensitive dark matter searches provide access to the kinematic information of dark matter.





The NEWAGE experiment

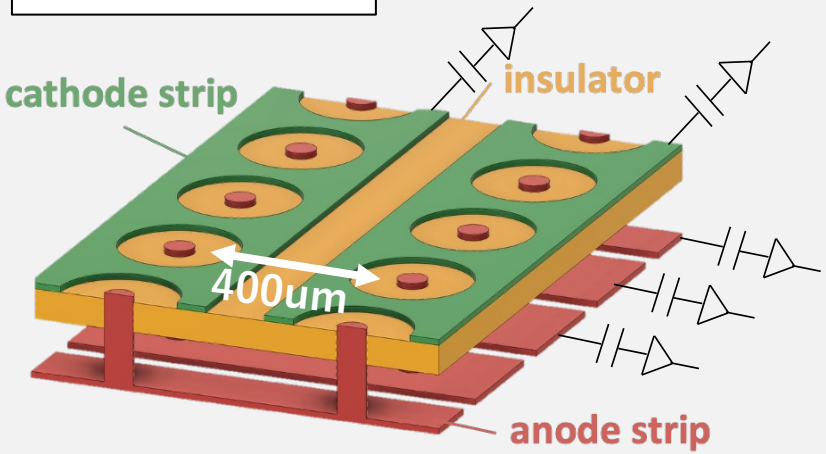
Gaseous Time Projection Chamber (TPC)



Detection principle

- Track is reconstructed with gaseous Time Projection Chamber (TPC)
  - Observe WIMP-nucleus elastic scattering.
  - Recoil nucleus ionizes atoms in the gas.
  - Ionized electrons are drifted in the electric field toward the μ-PIC detector.

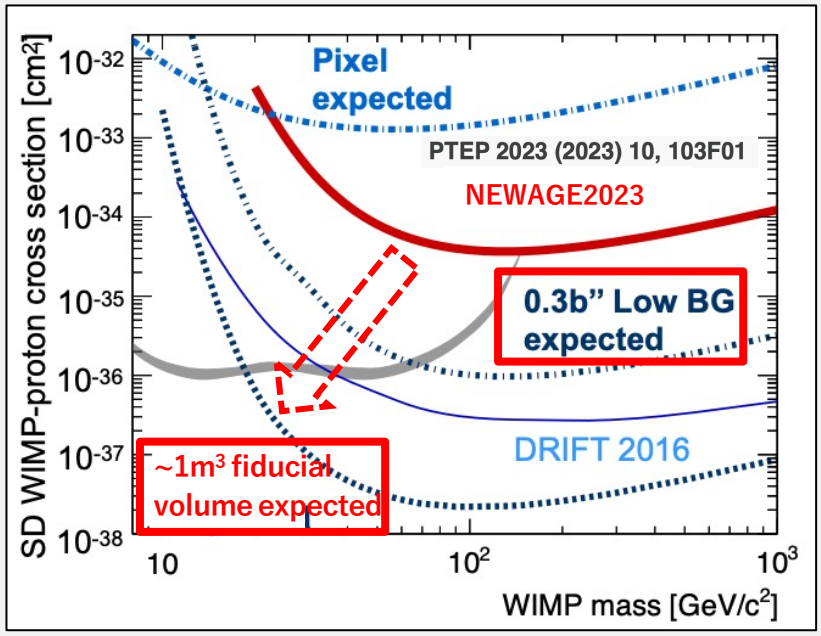
μ-PIC detector

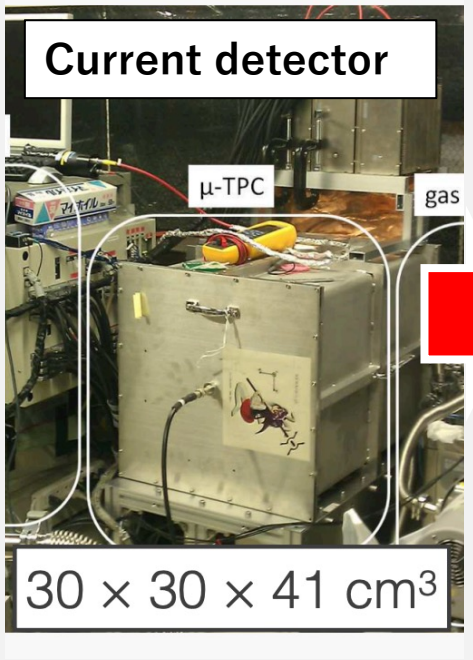


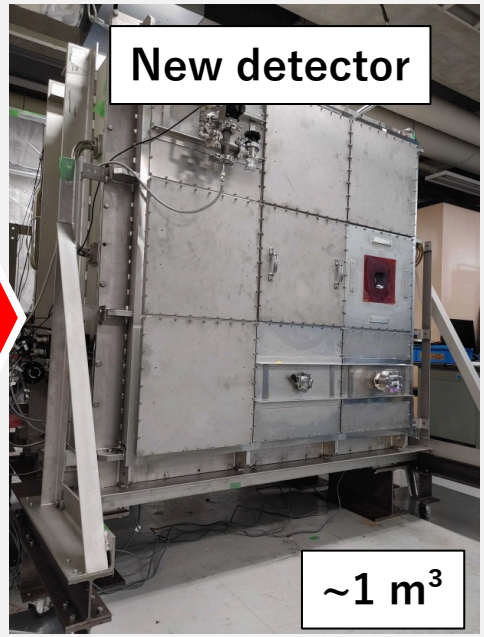
μ-PIC features

- Anode and cathode strips are aligned orthogonally with 400 μm 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.

Detector Enlargement for NEWAGE







- **NEWAGE has world leading sensitivity in direction-sensitive WIMP searches.**

Future plan

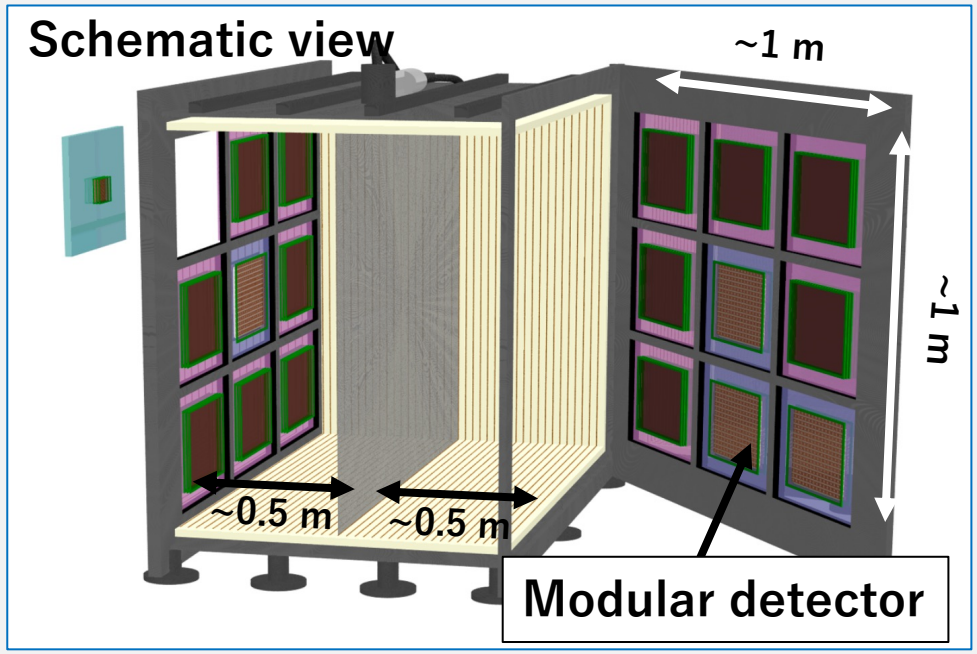
Satoshi's previous talk

- **Background rejection 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) is being developed at Kobe University.



Features of C/N-1.0

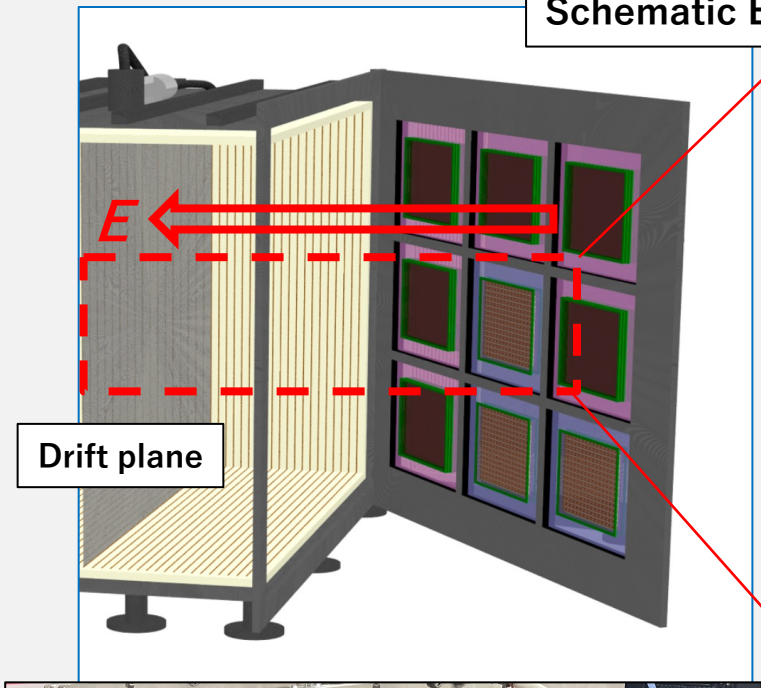
- Approximately 30 times larger than the NEWAGE fiducial volume.
- 18 module slots

Two modules are currently under development:

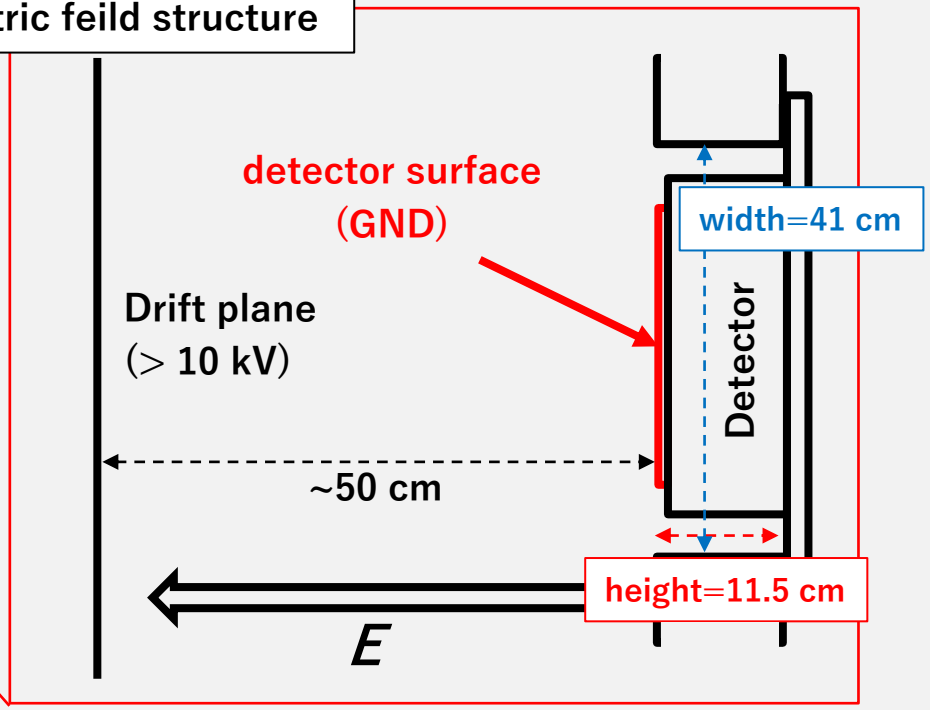
- Module-0: $(30\ \mathrm{cm})^2$ (without directionality)
- Module-1: $(10\ \mathrm{cm})^2$ (with directionality)

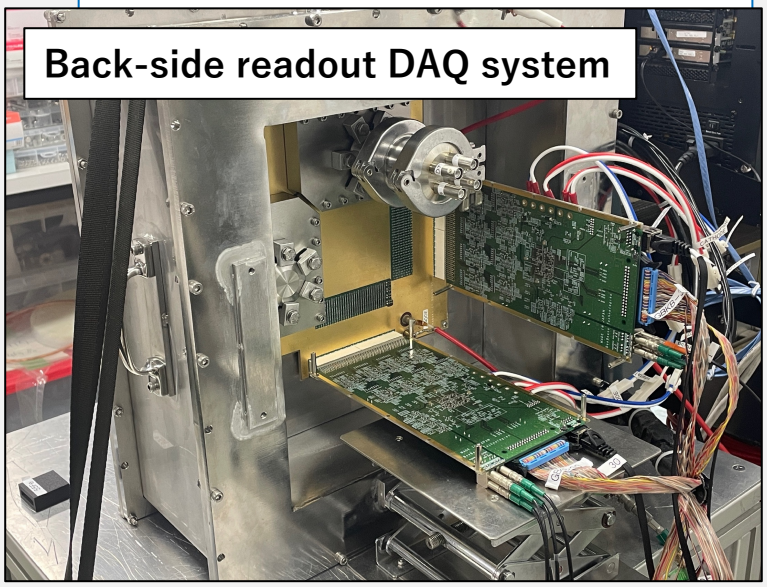
Kentaro's postor

Detector structure



Schematic Electric feild structure



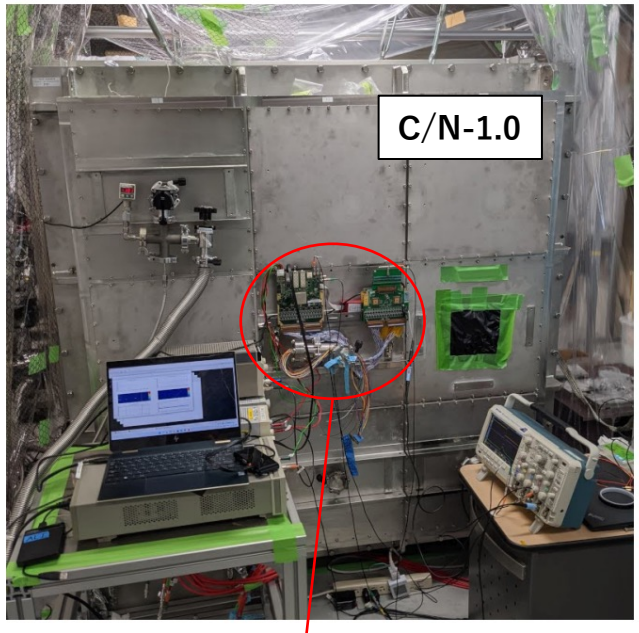


Structure constraints

- 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

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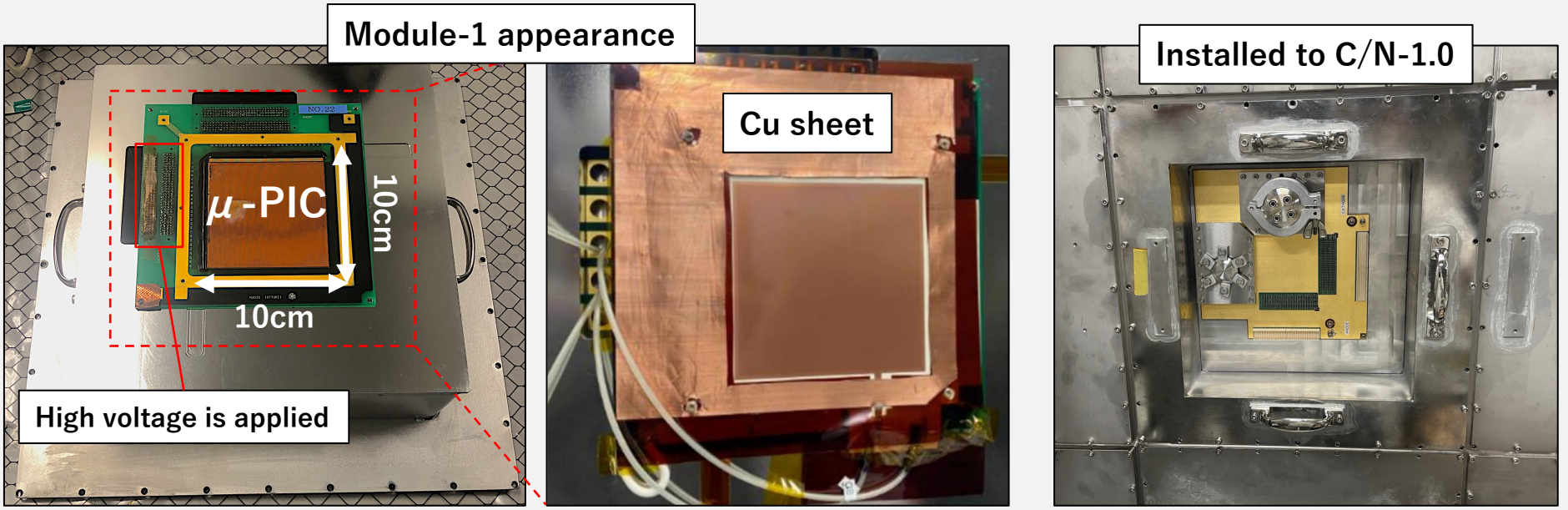
Module-1



- The high-voltage area is covered with a copper sheet connected to ground so that it is not exposed.

Features

	Module-1	NEWAGE
detection area	10×10 cm^2	30×30 cm^2
strip pitch	800 μm	400 μm
energy threshold w/ directionality	100 keVee	50 keVee

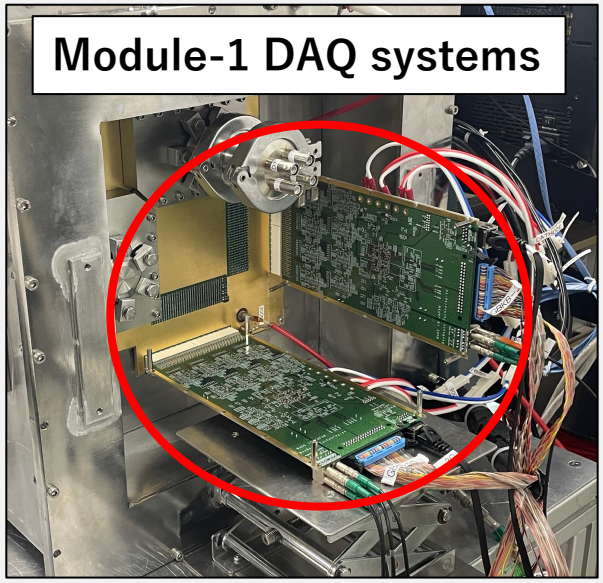
- Because of the limited number of channels of the prototype readout board, we used a 10 cm × 10 cm detector with an 800 μm channel pitch.
  → The purpose is to demonstrate C/N-1.0.

- The detector enables analysis with directionality above 100 keVee.

C/N-1.0 operation test

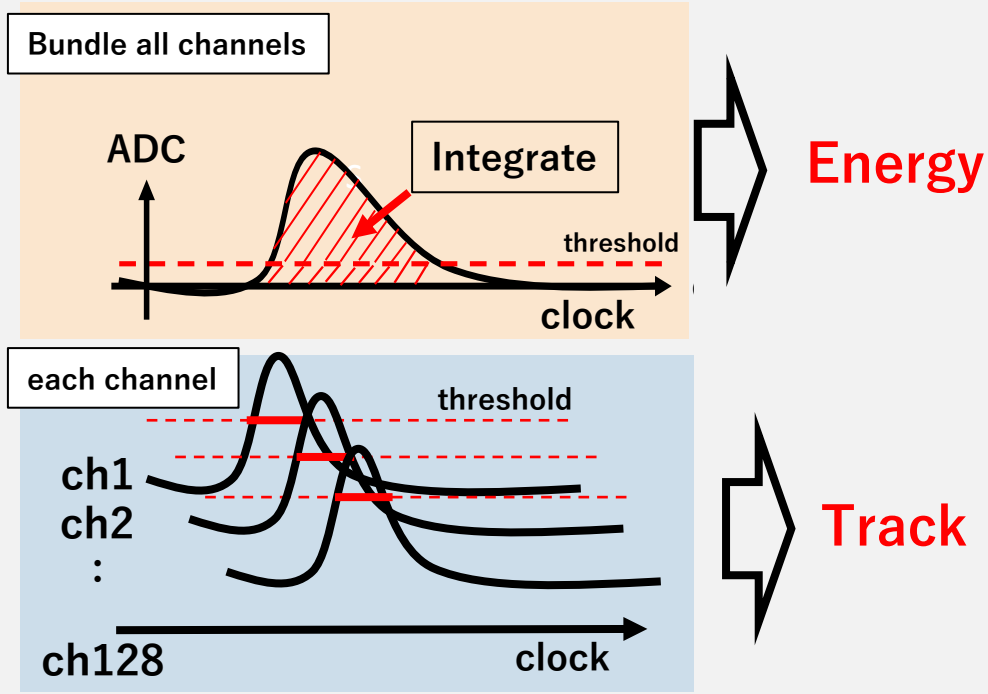
Data acquisition

Data Acquisition Flow



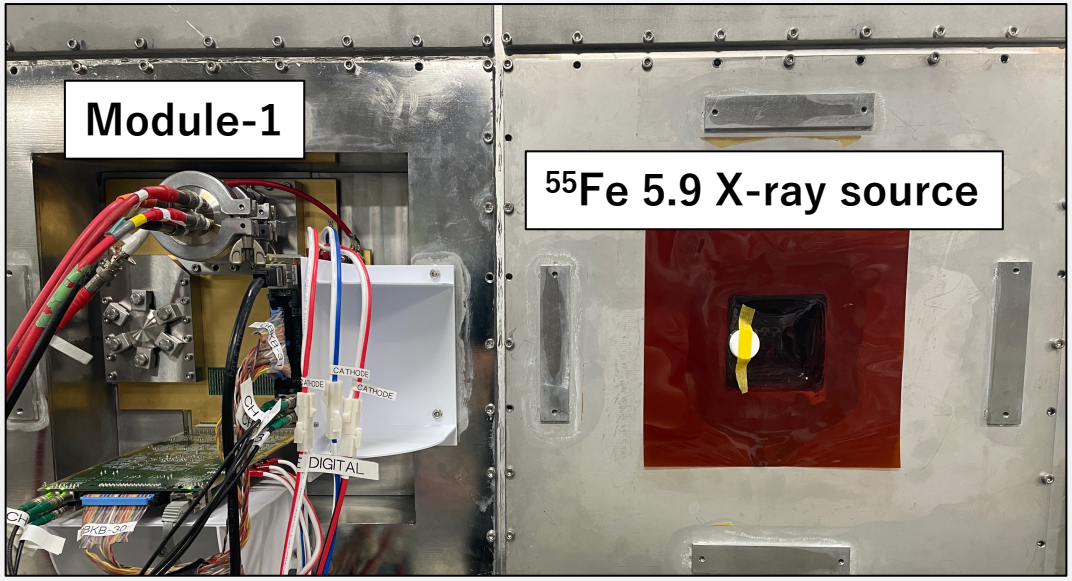
128 ch

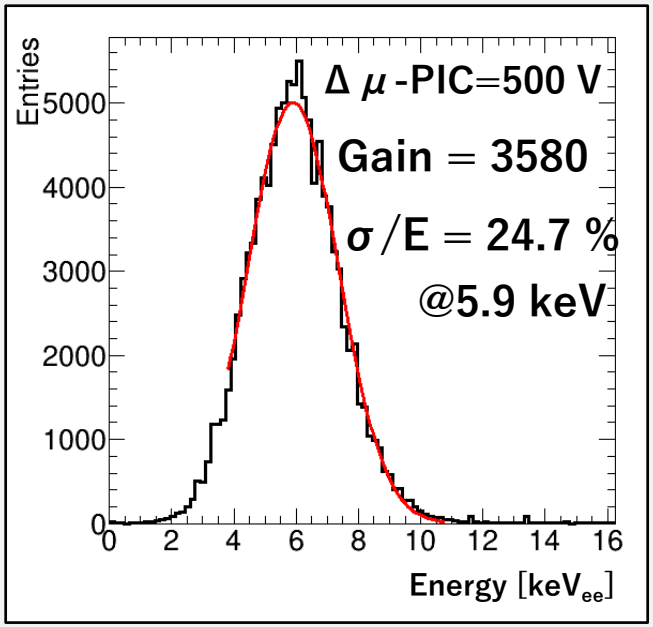
Readout

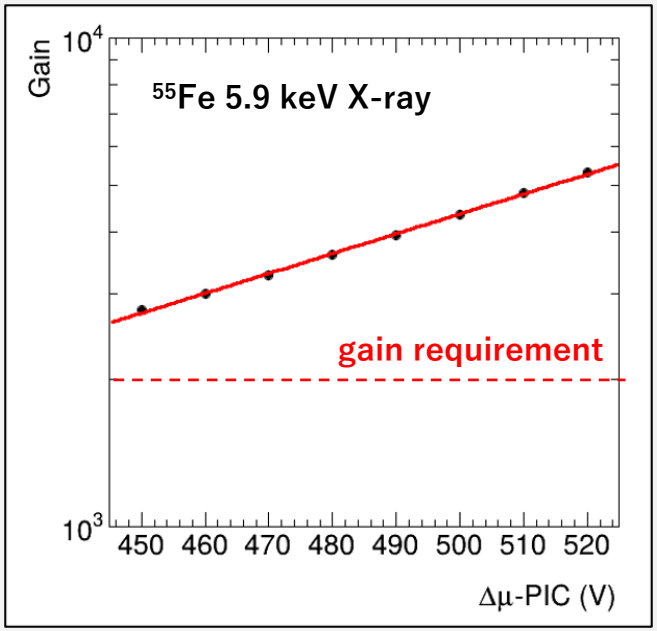


- Signals are readout from 128 channels with an 800 μm pitch.
- The energy is calculated from the integrated ADC waveforms over all channels.
- The track is reconstructed from the time-over-threshold (ToT) information from each channels.

Energy calibration

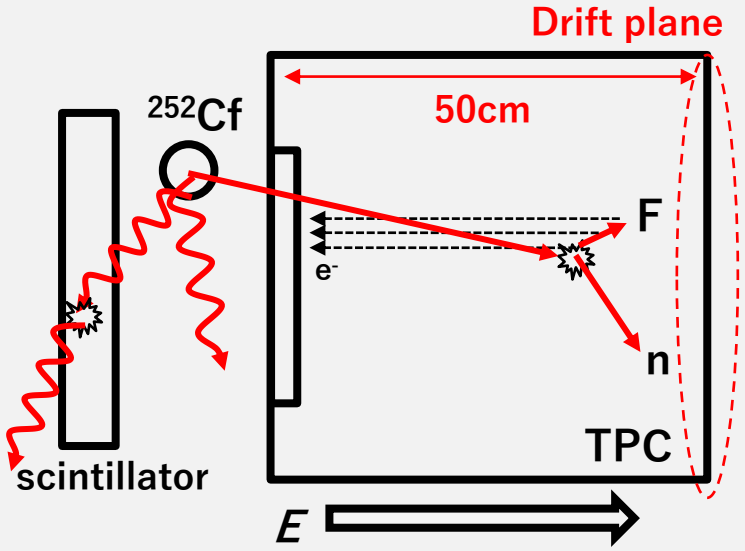






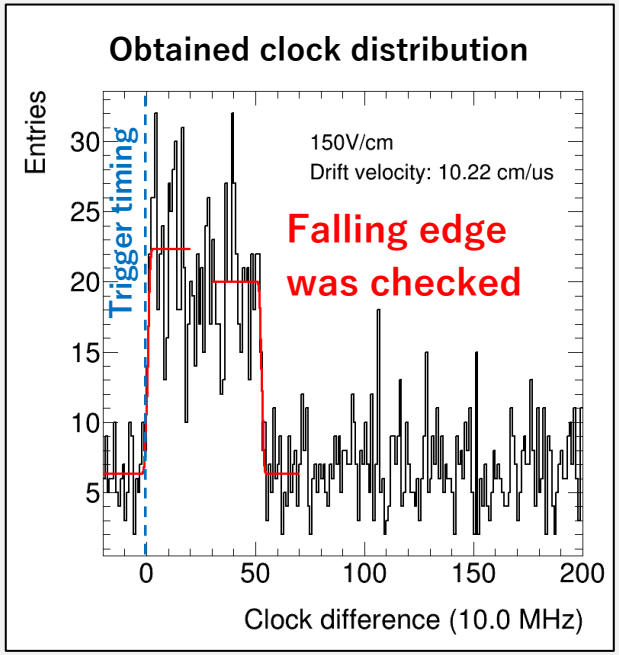
- An ^{55}Fe 5.9 keV X-ray source was used for energy calibration.
- We confirmed that the required gas gain was achieved at an applied voltage with no discharge.
- It is expected that an energy resolution comparable to or better than that of NEWAGE

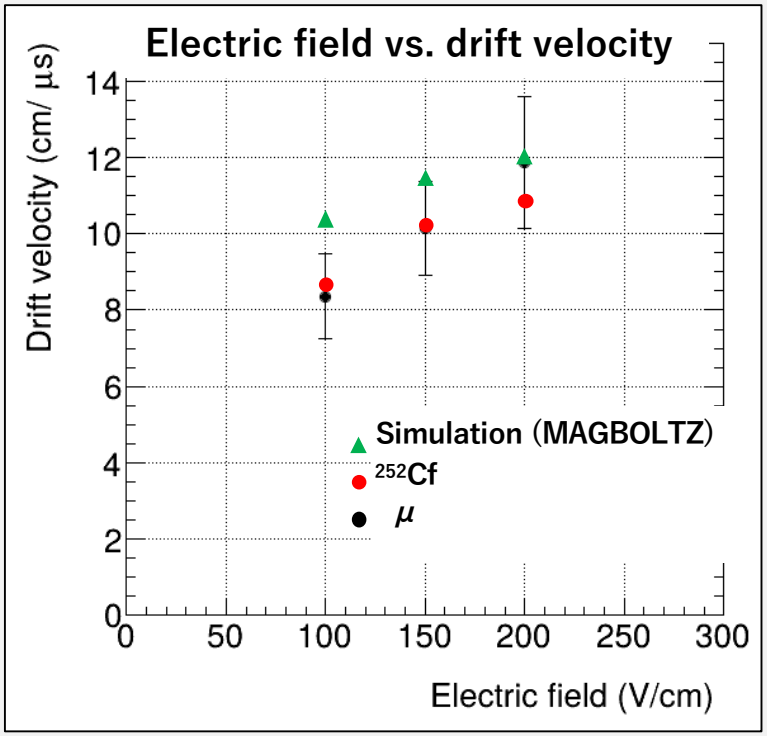
Drift velocity measurement



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.

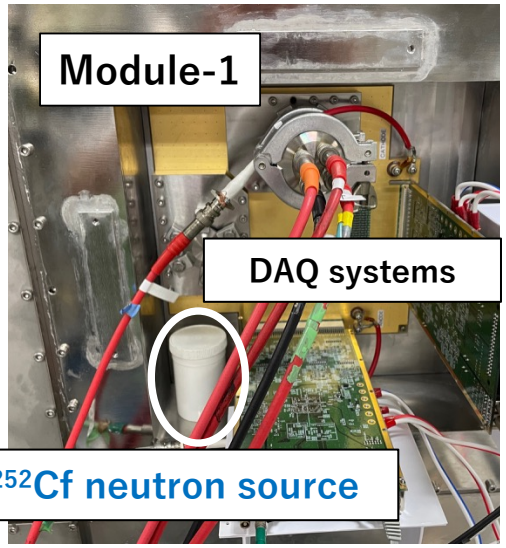


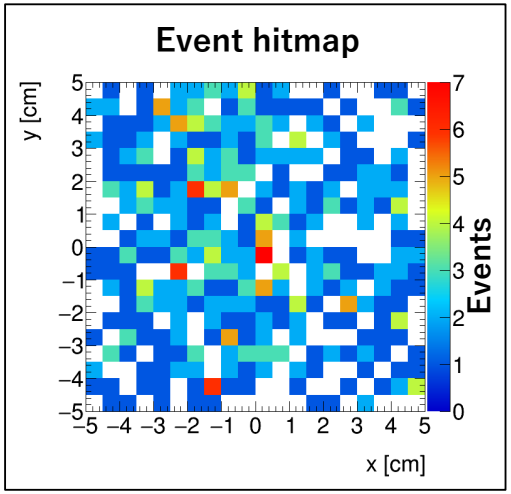


The drift velocity as a function of the electric field strength shows a trend consistent with the simulation.
→ the electric field is properly formed.

Track reconstruction

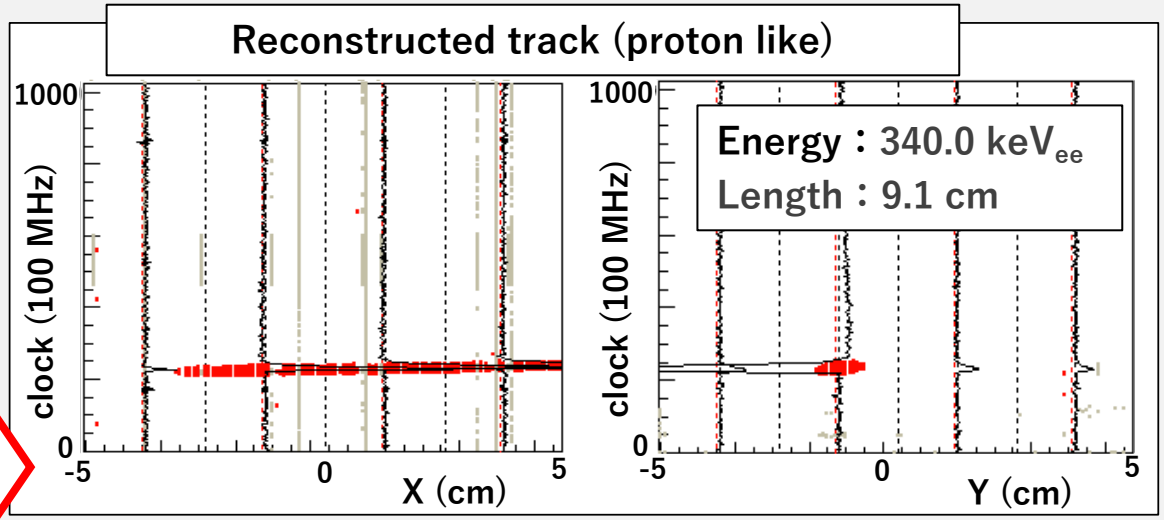
First track reconstruction with NEWAGE Modules in C/N-1.0

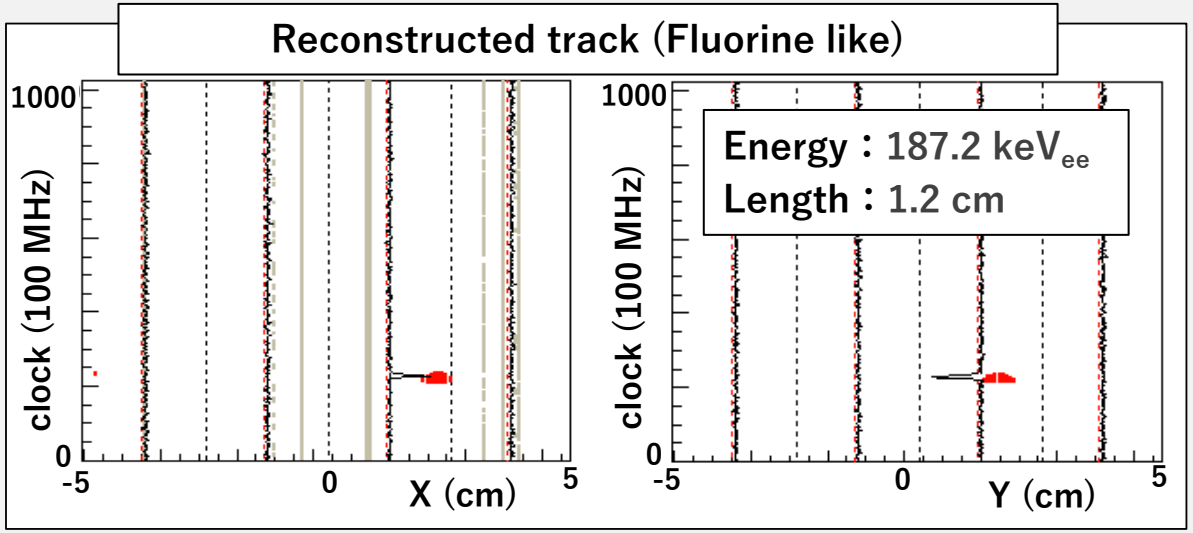




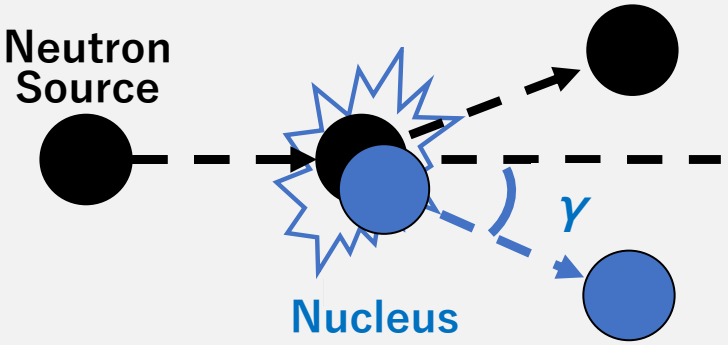
Obtaioned uniform hitmap

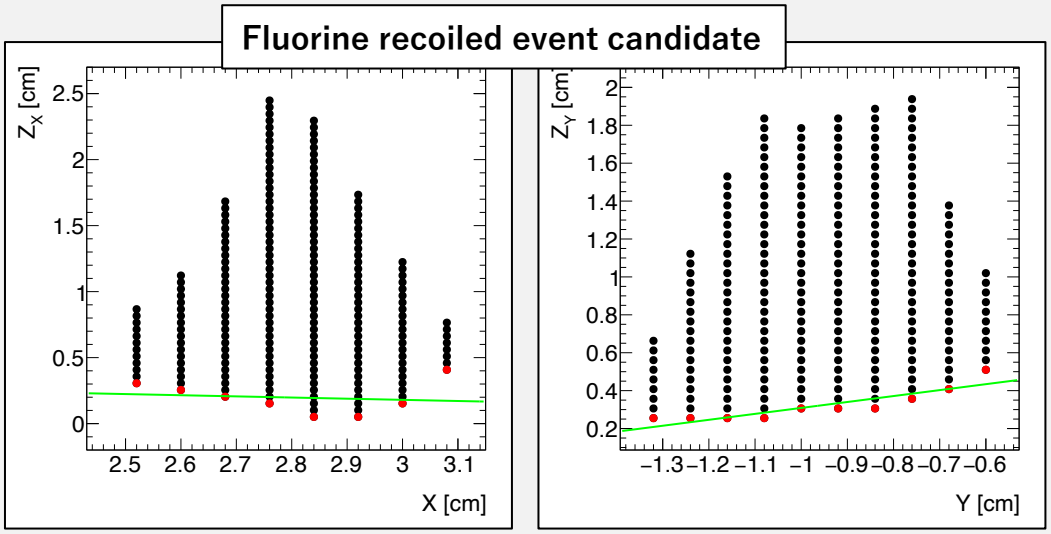
- Gas: CF_4 (0.1 atm)
- Reconstructed tracks were obtained using a ^{252}Cf neutron source.



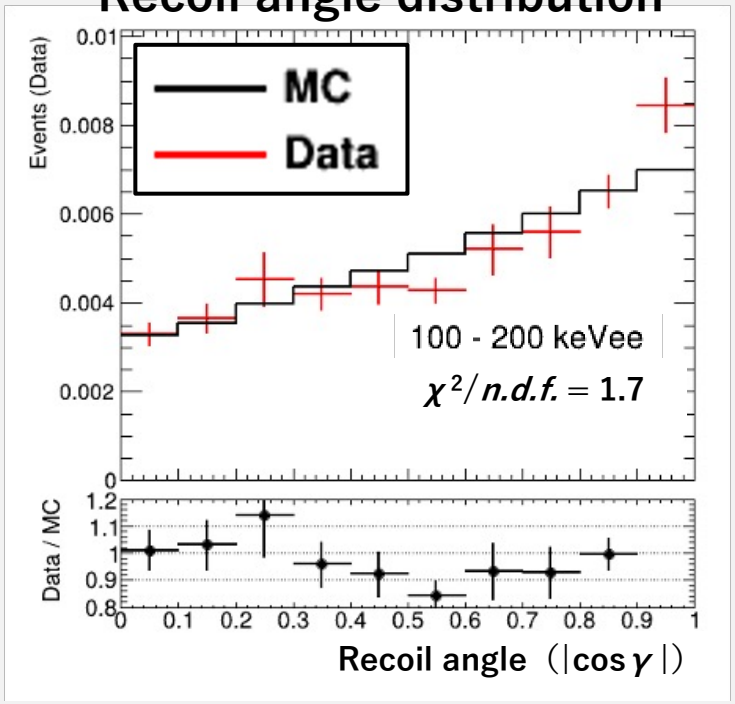


Angular resolution





Recoil angle distribution



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

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

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

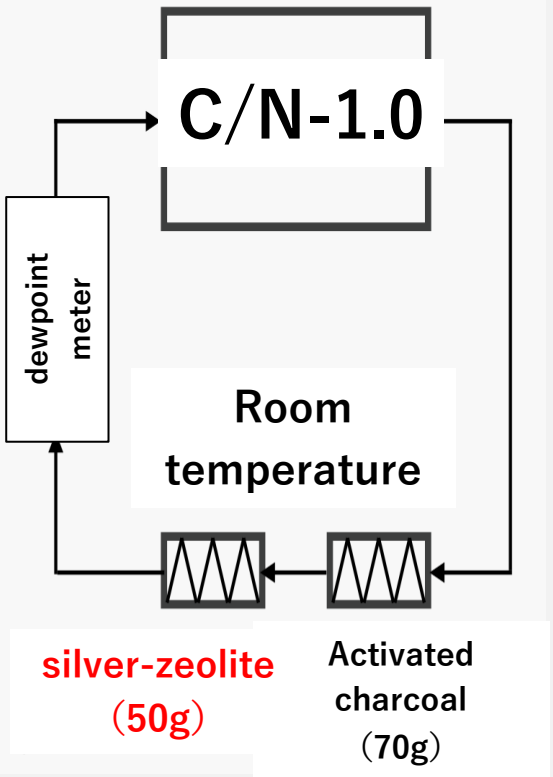
- **Angular infomation was obtained successfully.** (> 100 keV)

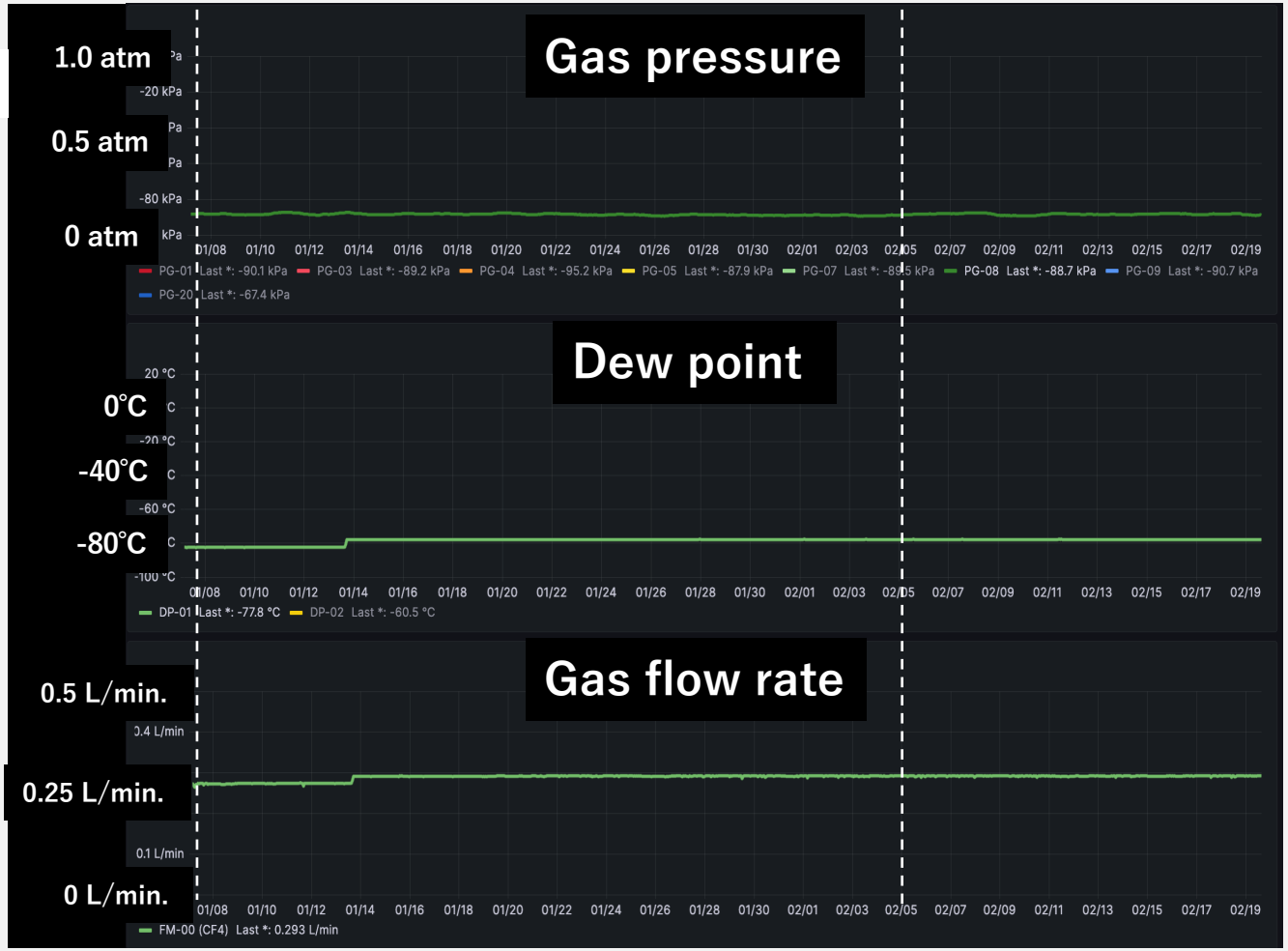
Surface commissioning: background run

C/N-1.0 demonstration using the Module-1 detector

Gas Circulation System Status

Simplified Circulation system



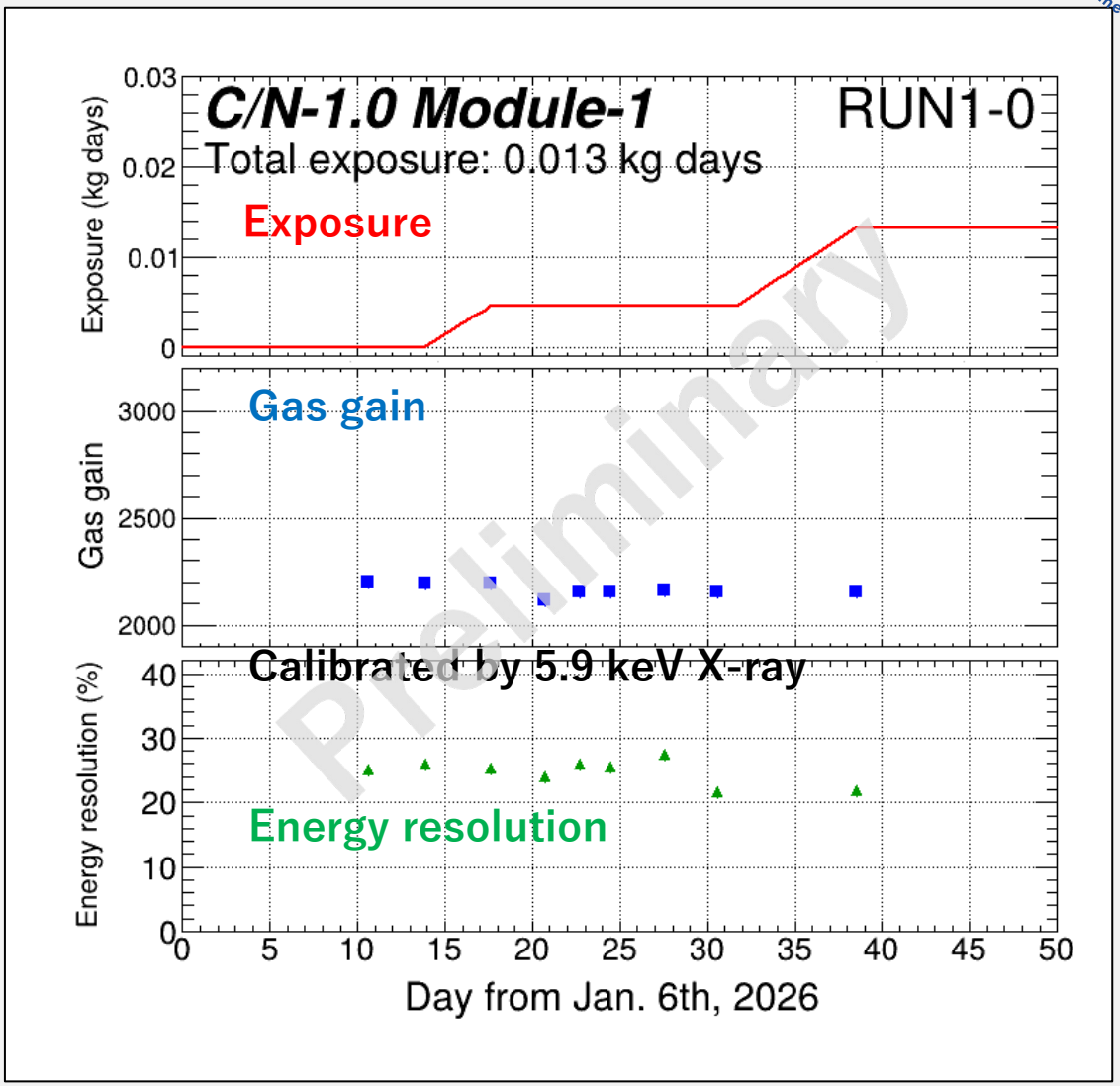


Jan. 6th, 2026
(gas was installed)

Feb. 6th, 2026

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

Detector status

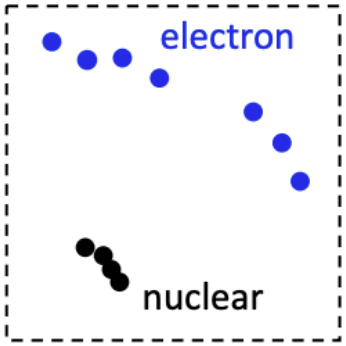


- CF_4 0.1atm
- 0.013 kg days exposure
- Periodical calibrations were performed using ^{55}Fe 5.9 keV X-rays and the gain fluctuation was approximately ±2%.

Event selection: Cut line determination

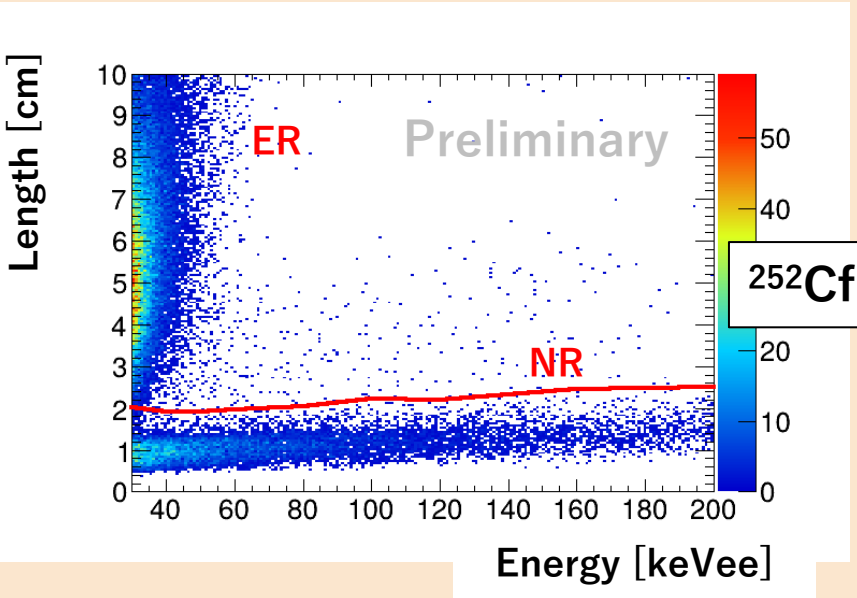
- Two types of event selection were mainly applied to reject environmental gamma rays.
- The cut line was determined using neutron and gamma irradiation from a ^{252}Cf source.

1. Energy-Length cut



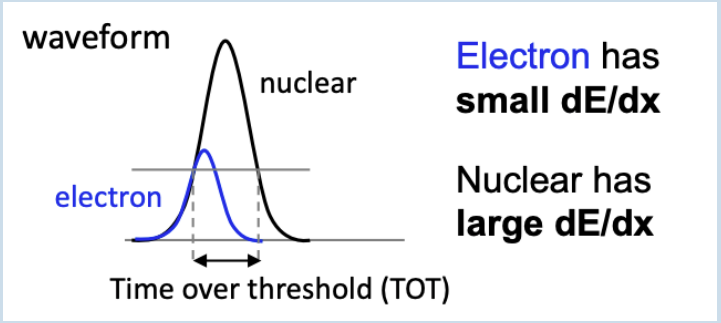
Track length of electron is **long**

Track length of nuclear is **short**

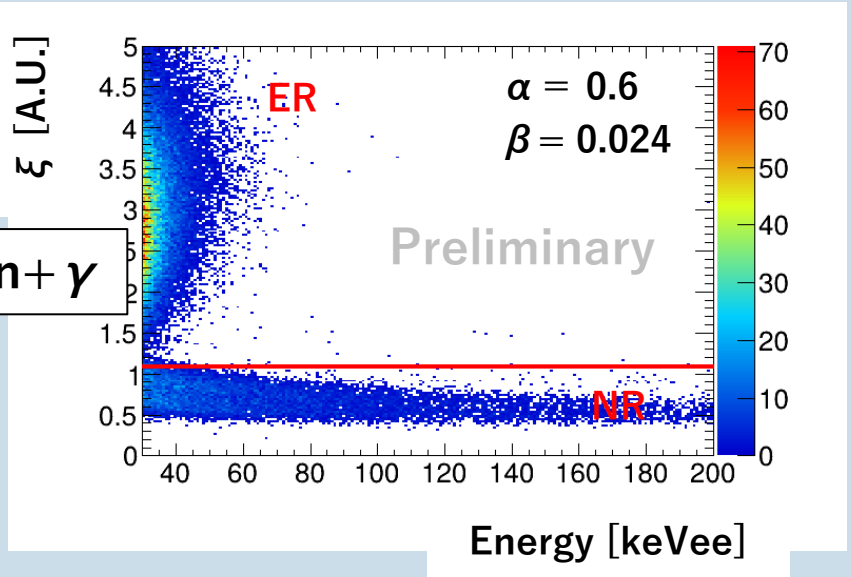


- Red line: $+3\sigma$ from NR median

2. Energy-ToT cut



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

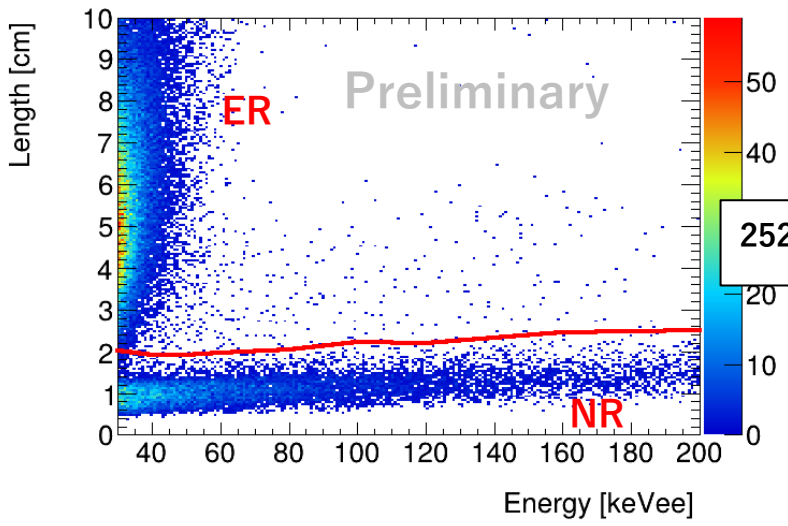


- Red line: constant parameter

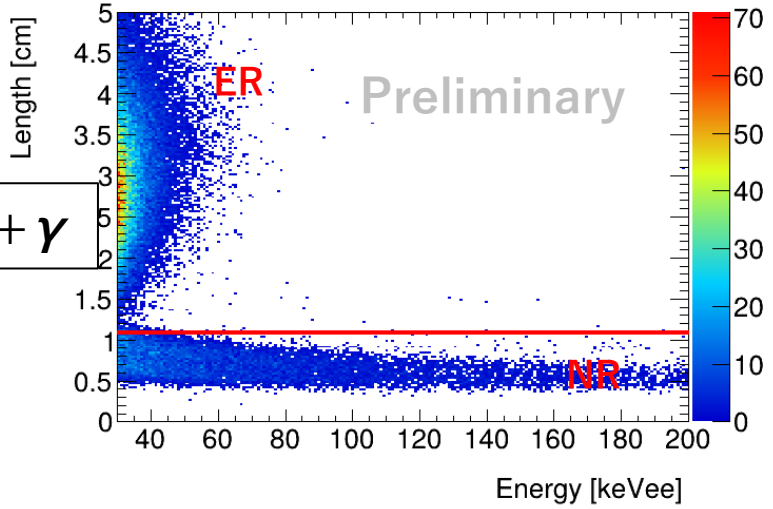
Event selection: Applied to BG data

- **Results after applying the cuts to the background data.**

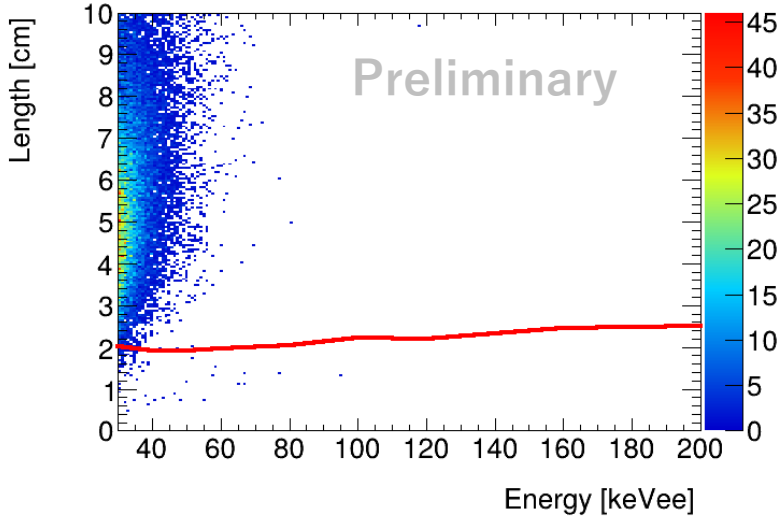
1. Energy-Length cut



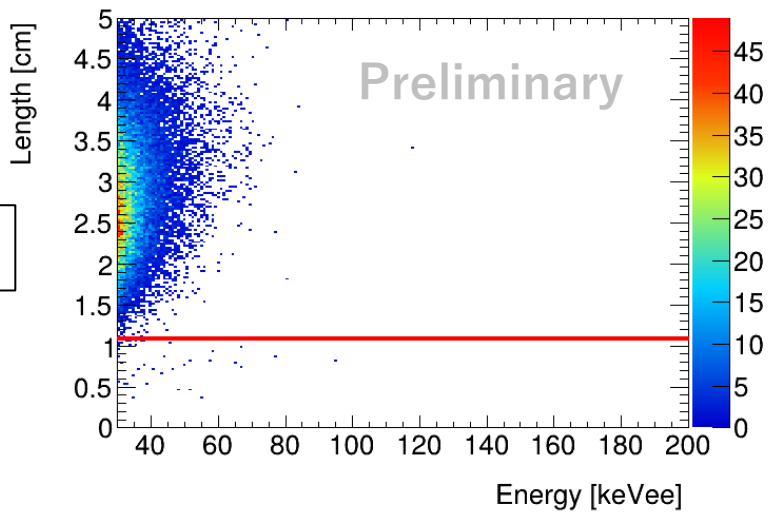
2. Energy-ToT cut



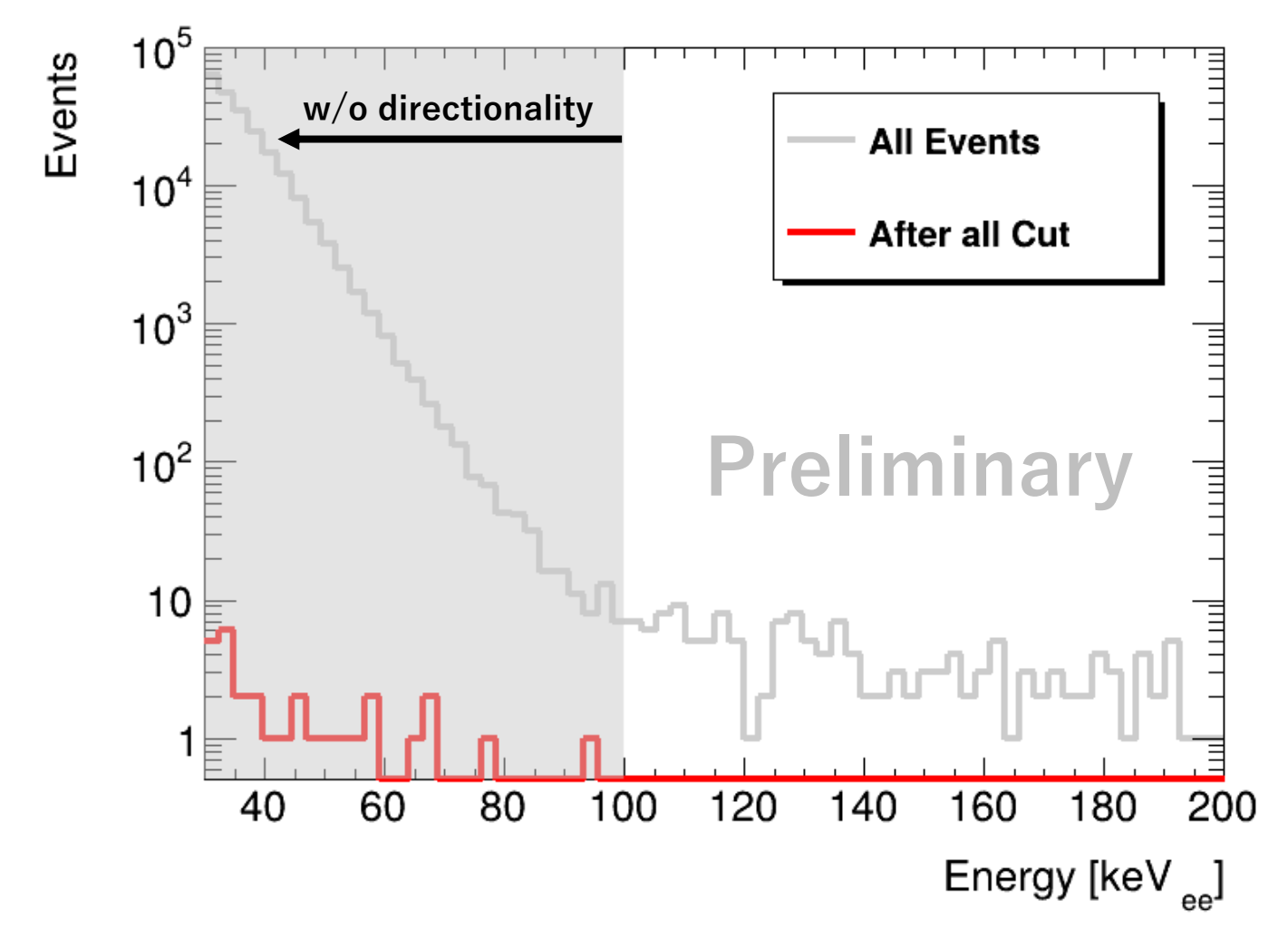
^{252}Cf n+γ



BG



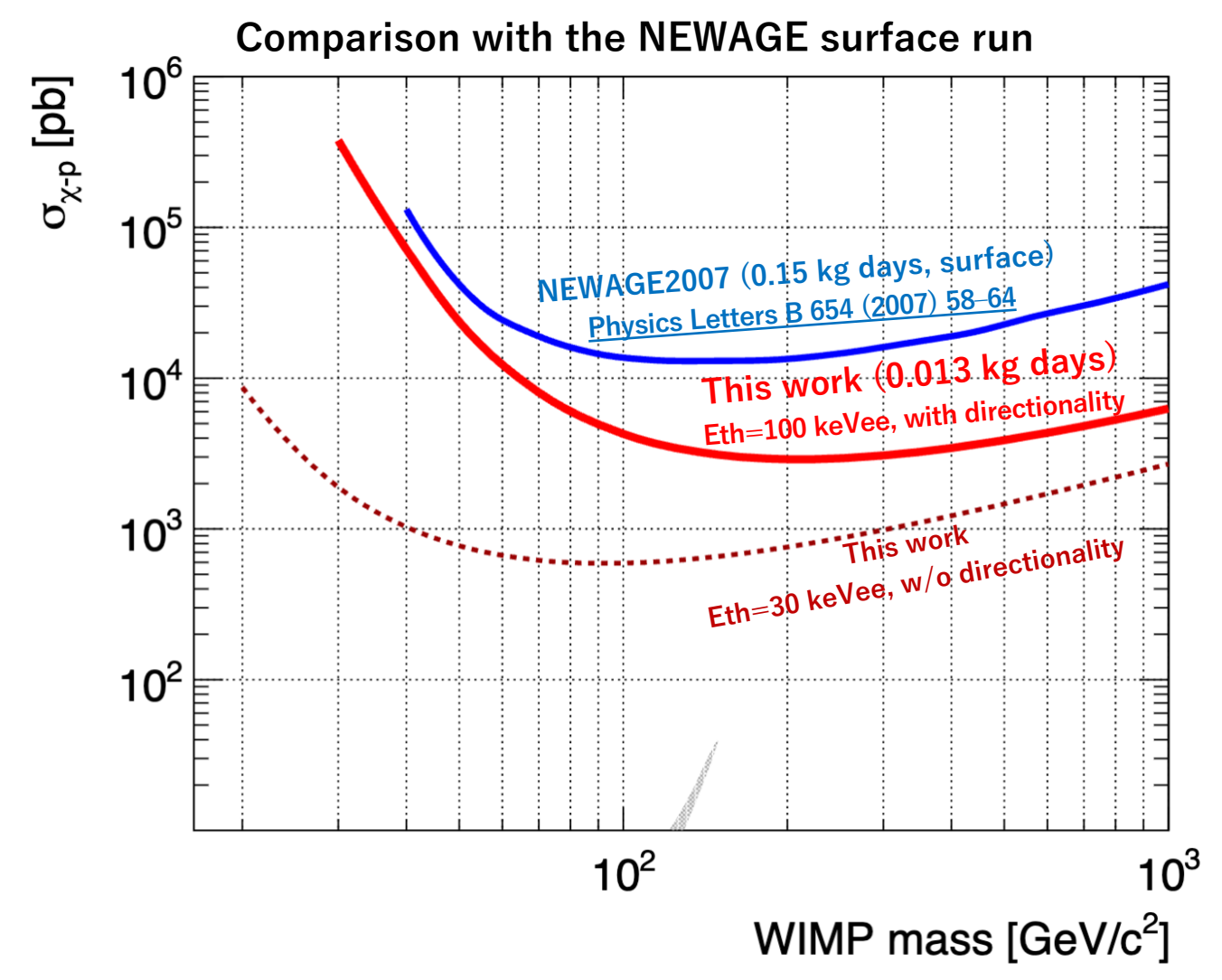
Energy spectrum



- **No events remained in the 100–200 keVee range after event selection.**

Results for BG run

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

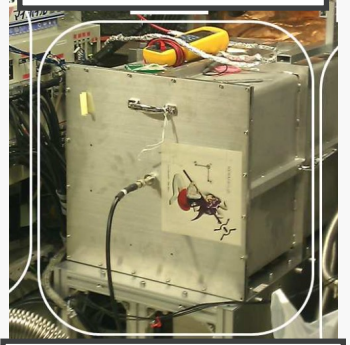


- Comparable results with NEWAGE surface one.
- The results with Module-1 demonstrate that C/N-1.0 is a practical and usable chamber.

C/N-1.0 roadmap

2025 2026 2027 2028 …

NEWAGE 0.3b''



30 × 30 × 41 cm^3

underground experiment (~100 live days)

continue experiment with CF_4 or SF_6 gas

Dec. 2023
Low BG μ-PIC installed

Pixel detector (small scale detector)

Low BG μ-PIC installation to C/N-1.0

C/N-1.0

1 m^3

2025~
detector commissioning with modular detector at Kobe Univ.

underground experiment (commissioning)

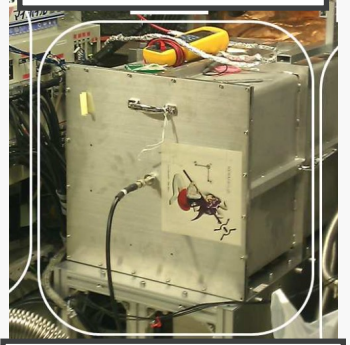
1 m^3 exposure underground experiment (18 modules)

2026~
move to Kamioka

C/N-1.0 roadmap

2025 2026 2027 2028 …

NEWAGE 0.3b''



30 × 30 × 41 cm³

underground experiment (~100 live days)

continue experiment with CF_4 or SF_6 gas

Dec. 2023
Low BG μ-PIC installed

feedback Low BG technologies to C/N-1.0 toward underground experiment

r (small scale detector)

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

μ-PIC
on to C/N-1.0

Large detection area and 400μm readout pitch

C/N-1.0

1 m³

2025~
detector commissioning with modular detector at Kobe Univ.

underground experiment (commissioning)

1 m³ exposure underground experiment (18 modules)

2026~
move to Kamioka

C/N-1.0 roadmap

2025 2026 2027 2028 …

NEWAGE 0.3b''

30 × 30 × 41 cm³

underground experiment (~100 live days)

continue experiment with CF_4 or SF_6 gas

Dec. 2023
Low BG μ-PIC installed

feedback Low BG technologies to C/N-1.0 toward underground experiment

r
(small scale detector)

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

μ-PIC
on to C/N-1.0

Large detection area and 400μm readout pitch

Start of the WIMP search
Installation of additional modules

C/N-1.0

1 m³

2025~
detector commissioning with modular detector at Kobe Univ.

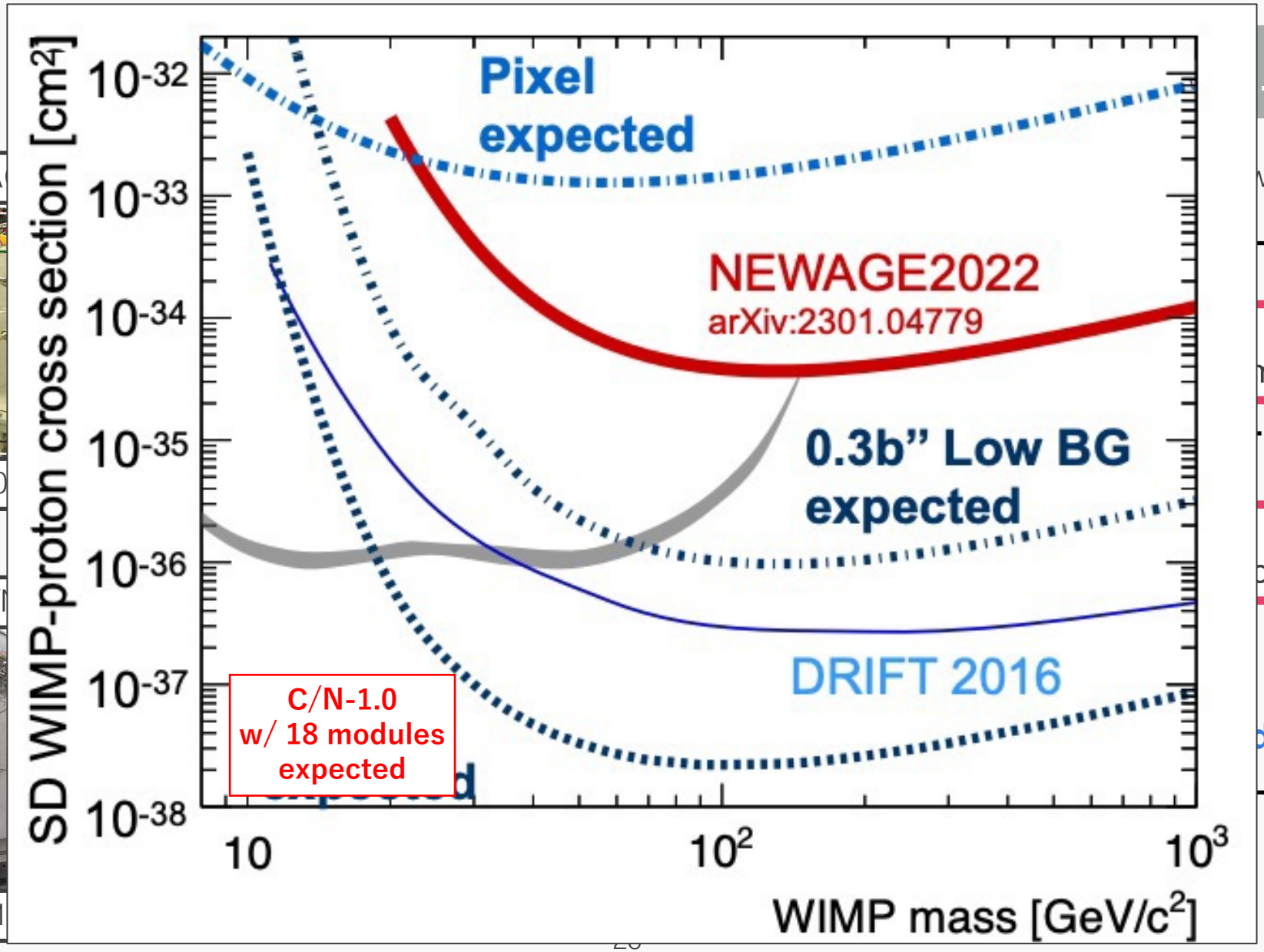
underground experiment (commissioning)

m³ exposure underground experiment (18 modules)

2026~
move to Kamioka

explore "DAMA/LIBRA region" with the full-size C/N-1.0

Expected limits



Conclusion

- **NEWAGE is a Direction-sensitive WIMP search experiment.**
  - ✓ **Large volume detector is needed for more sensitity.**

- **1m^3 scale chamber "C/N-1.0" test with Module-1 detector.**
  - ✓ **$>$ 50 days operation was demonstrated.**
  - ✓ **C/N-1.0 can be used for WIMP searches with directionality.**

- **Prospect**
  - ✓ **Development of new module detectors.**
  - ✓ **Evaluation of the background.**

Commisioning is ongoing toward starting the WIMP search

Conclusion

- NEWAGE is Direction-sensitive WIMP search experiment.
  - ✓ Large volume detector is needed for more sensitity.

- 1m^3 scale chamber "C/N-1.0" is demonstrated with Module-1 detector.
  - ✓ [illegible]
  - ✓ [illegible] ionality.

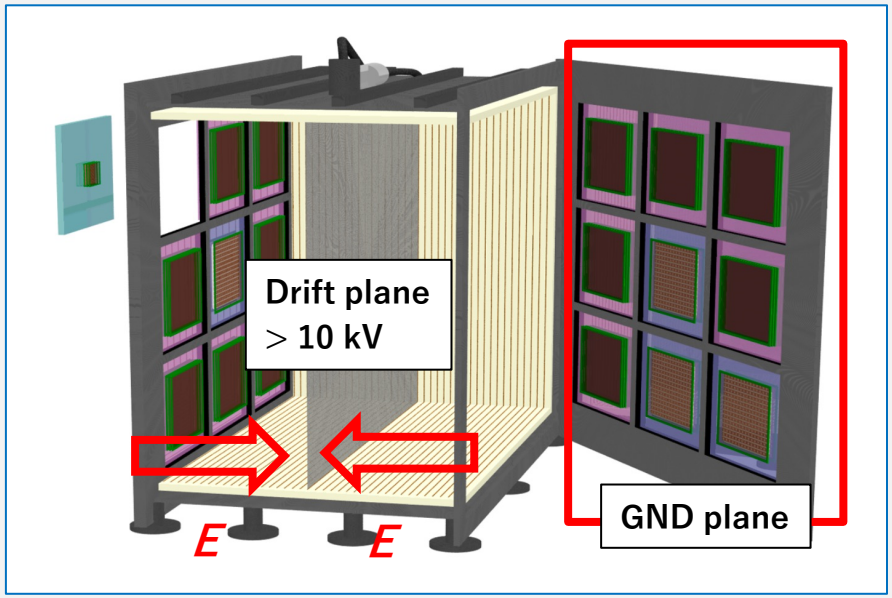
The C/N-1.0 is prepared.
Welcome detectors installed for.

- Pro[illegible]
  - ✓ [illegible]
  - ✓ Evaluation of background events.

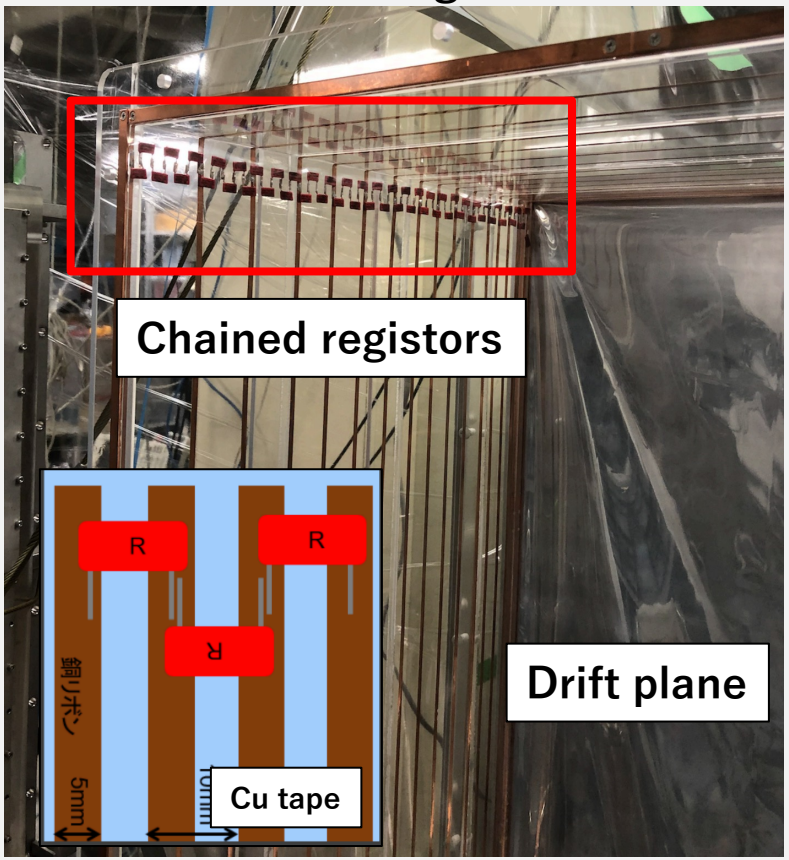
<u>Commisioning is ongoing toward starting WIMP search</u>

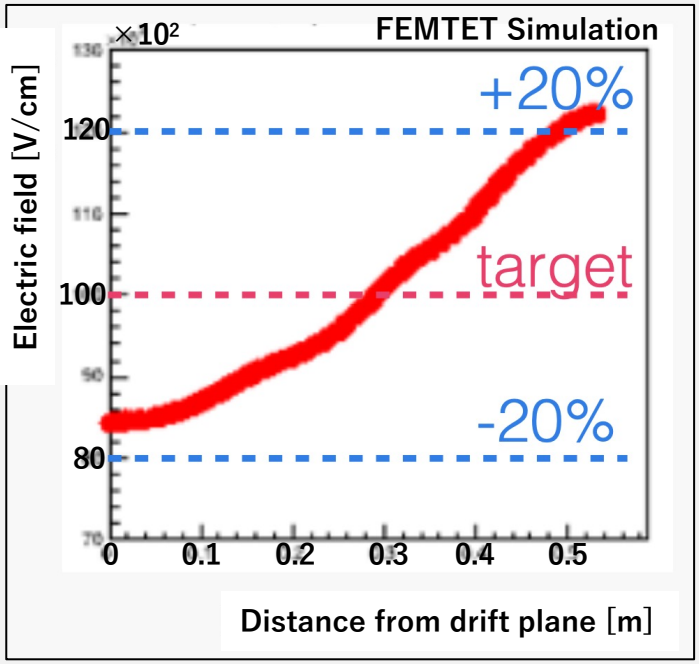
Back up

C/N-1.0 structures



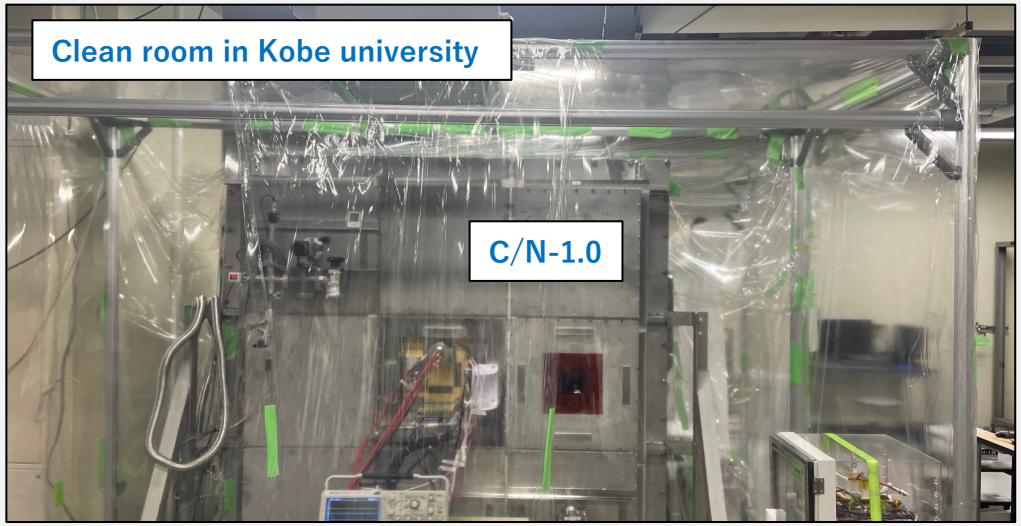
Field cage



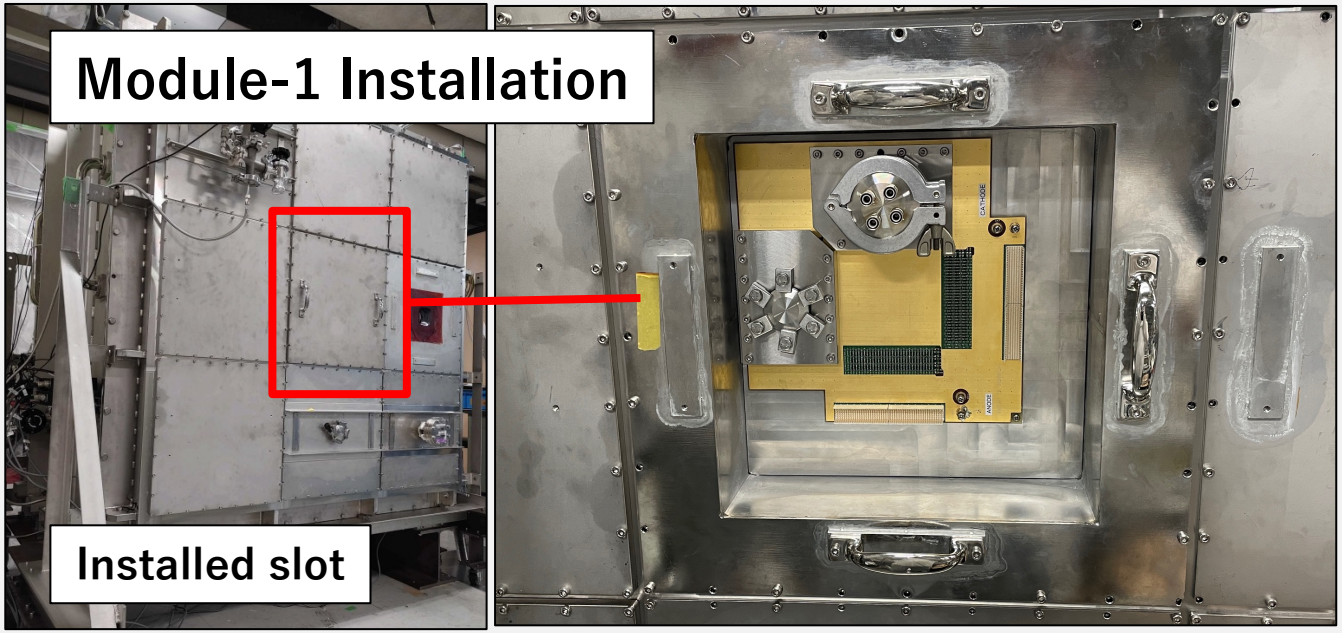


- The drift electric field is formed using a chained resistors.
- The detector is designed such that the readout plane serves as the ground (GND) plane.
- Simulation studies indicate that the drift-velocity uniformity is approximately within ±20%.

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.

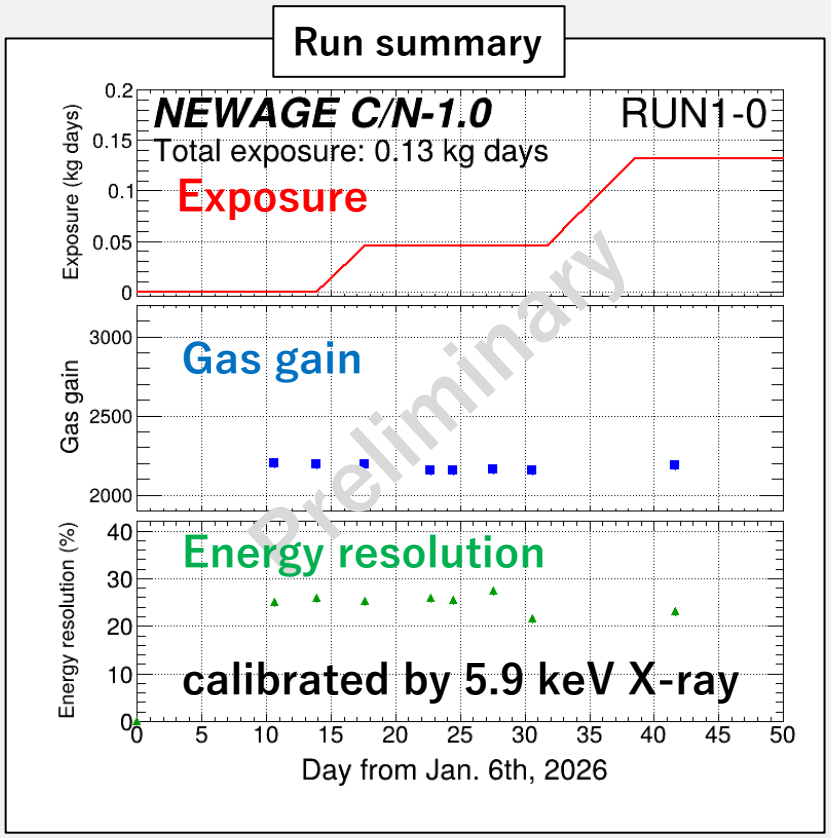


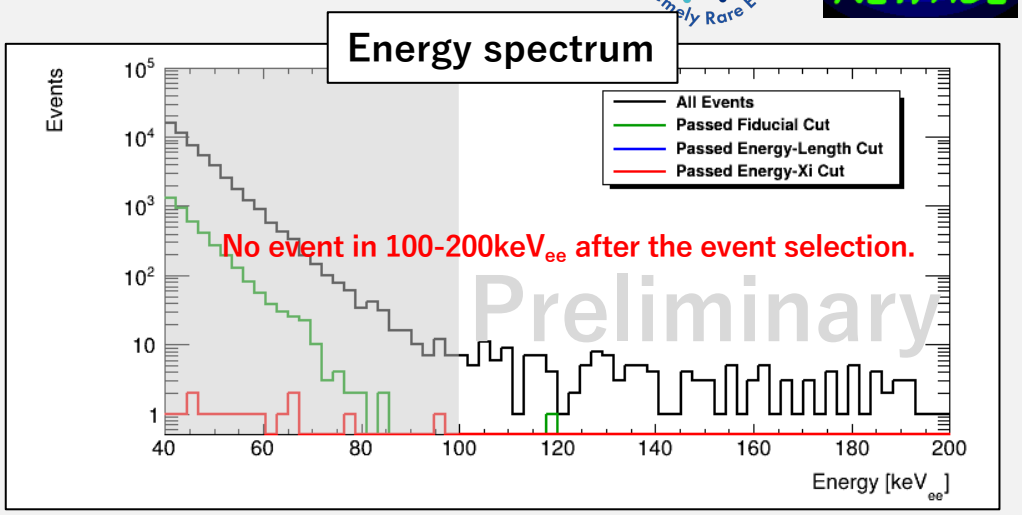
Module-1 installation had been completed !!

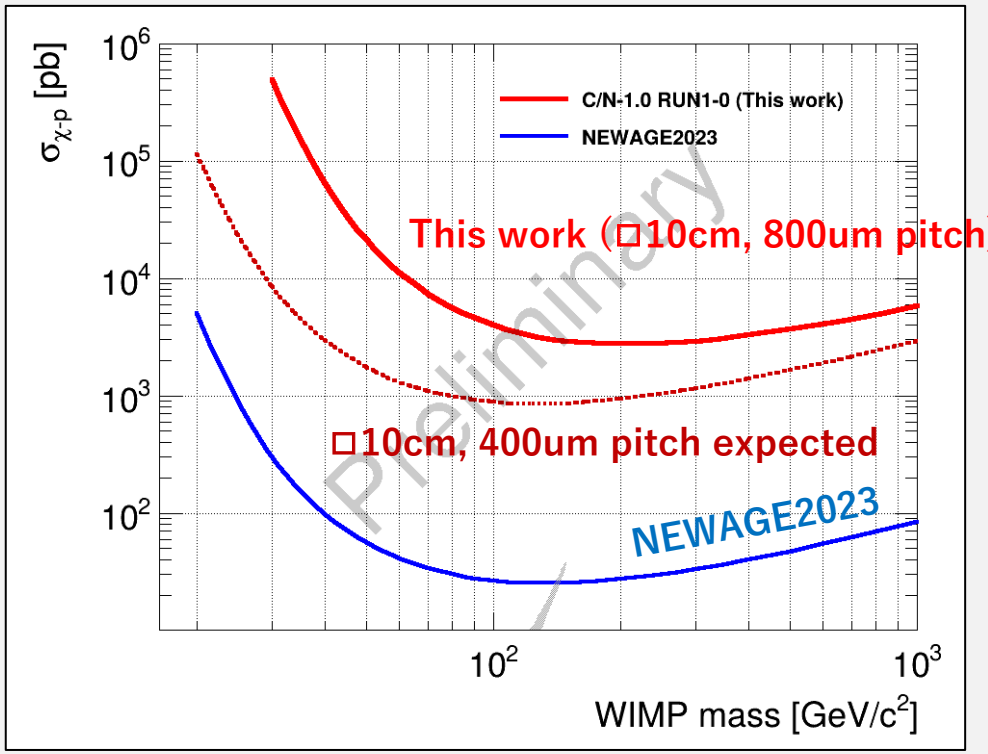
⇩

Next: Testing for track aquisition

Surface WIMP search result





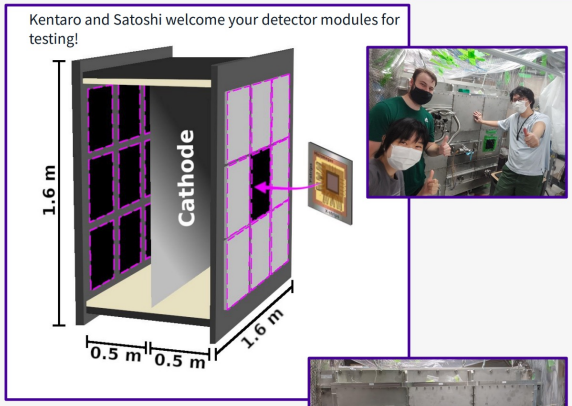


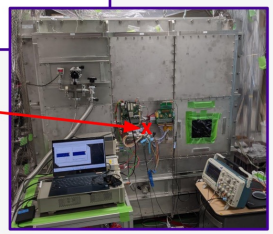
- WIMP search result using C/N-1.0 with Module-1
  - 100 keV$_{ee}$ energy threshold.
  - Gas gain and energy resolution was sufficiently stable.
  - Total exposure: 0.13 kg days.
- ~3000 pb (90 % C.L) at 200 GeV WIMP mass.

International collaboration (w/ Sheffield Gr.)

CYGNUS-10 Scale Kobe "BENTO" Vessel

A. McLean's slides in IDM2024





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

The "BENTO" vessel at Kobe University

Large CYGNUS-10 scale vessel - 50 cm drift length

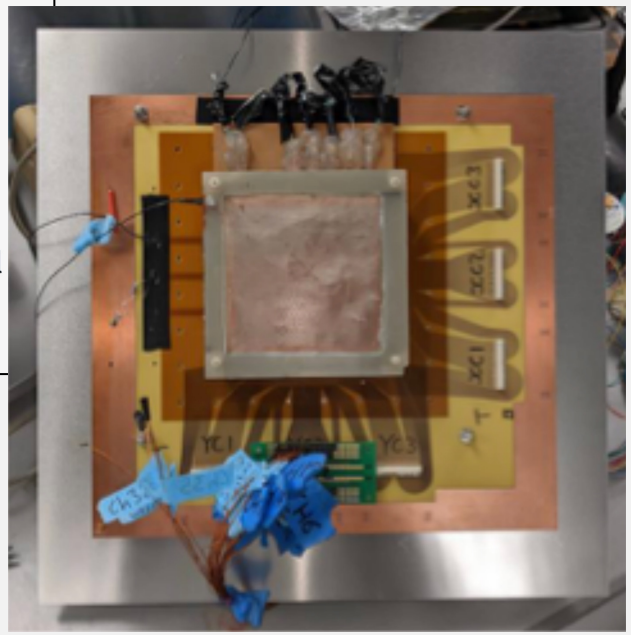
Modular design which can support up to 18 readout detector planes

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

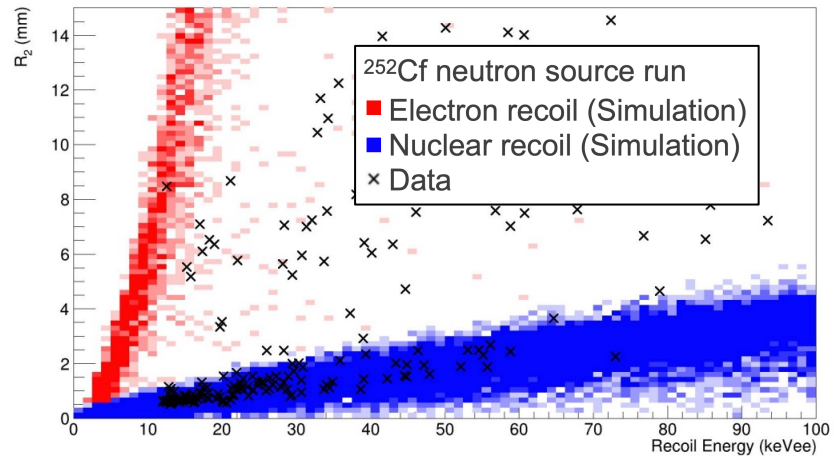
Detector mounting conveniently fits test vessel dimensions

arXivの情報のみ載せる実績のみ

Their detector



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



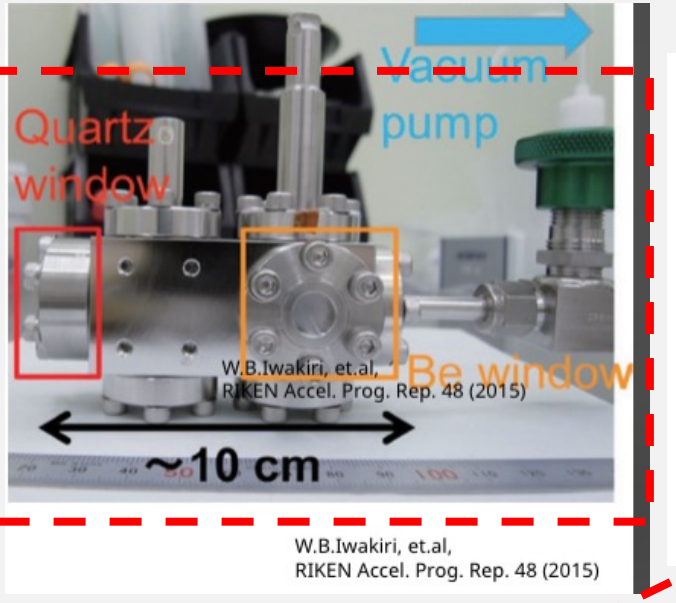
23

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

- in SF_6 gas (40 Torr)

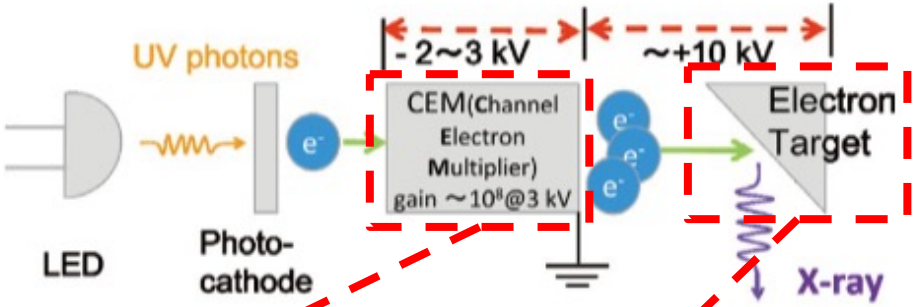
MXS-30k

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



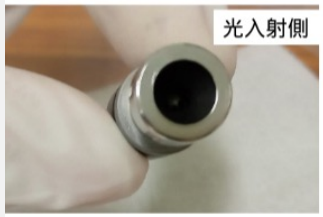
W.B.Iwakiri, et.al,
RIKEN Accel. Prog. Rep. 48 (2015)

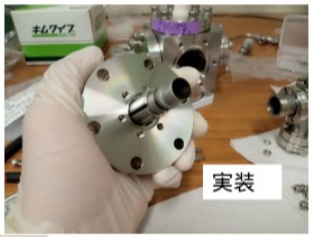
Internal structure

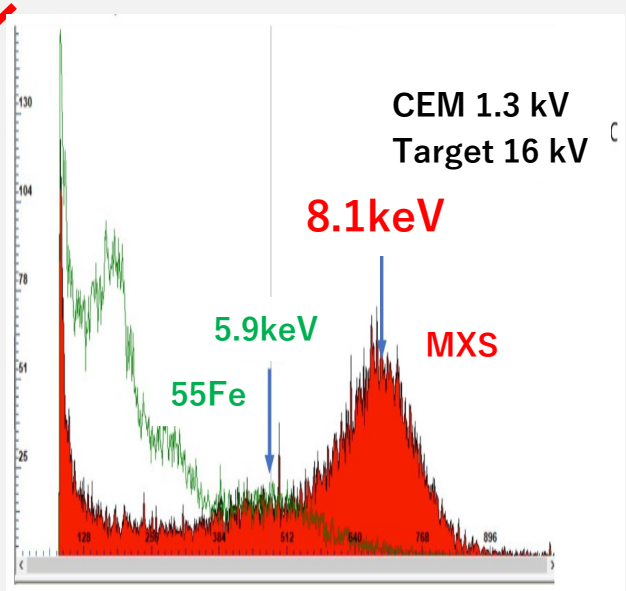


W.B.Iwakiri, et.al,
RIKEN Accel. Prog. Rep. 48 (2015)

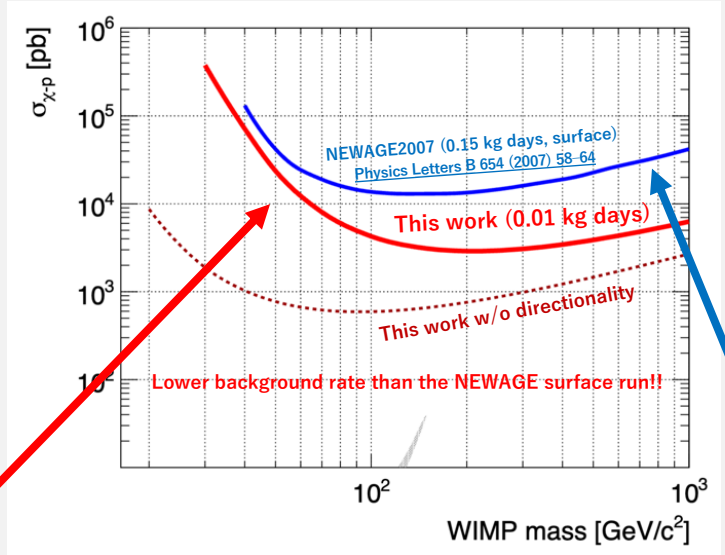
- CEM （ channel electron multiplier ）
  - オリジナルを踏襲
  - MgO 塗布済みの便利なものが入手可能
  - PHOTONIS 社　MAGNUM5900 COA EDR

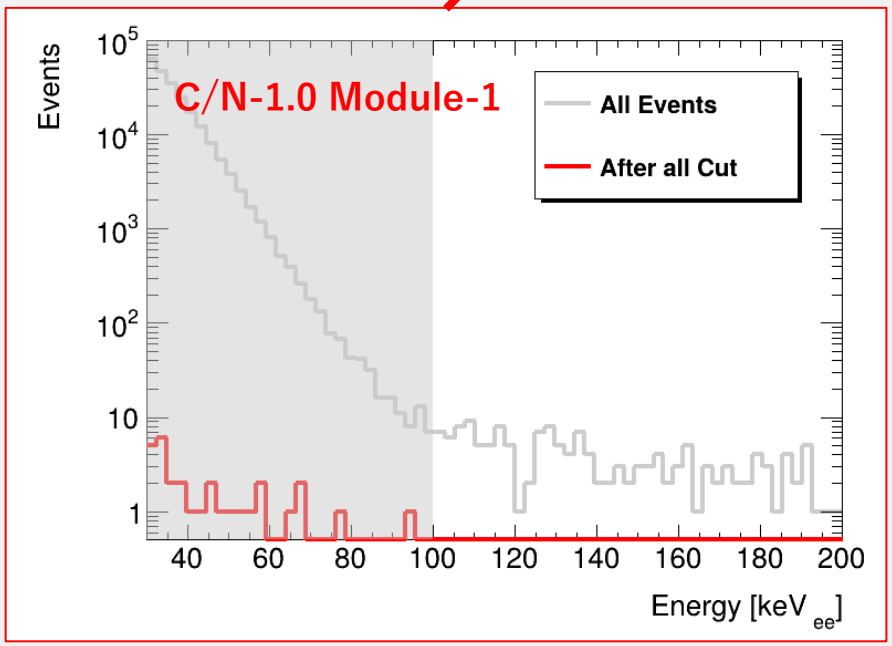


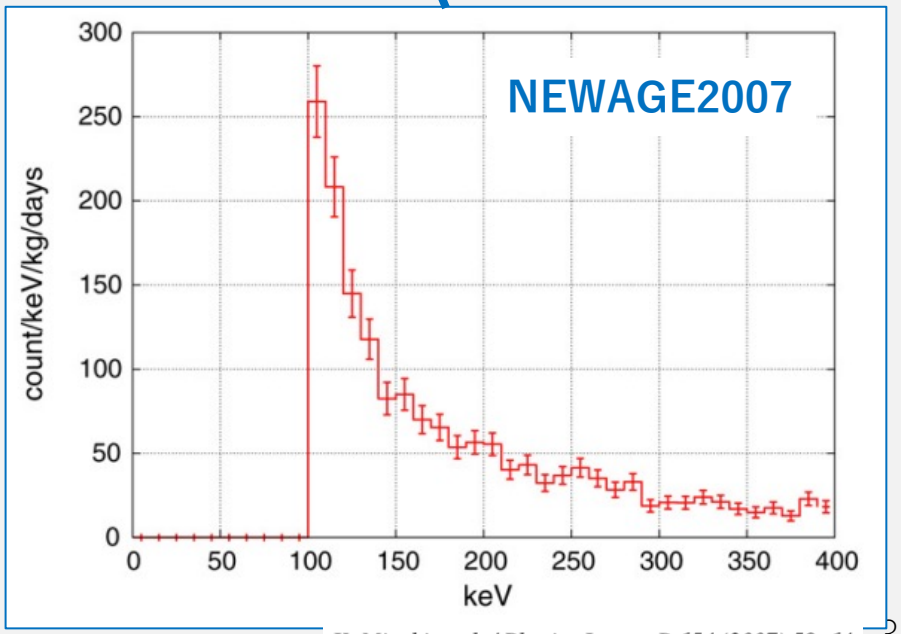




Surface run comparison

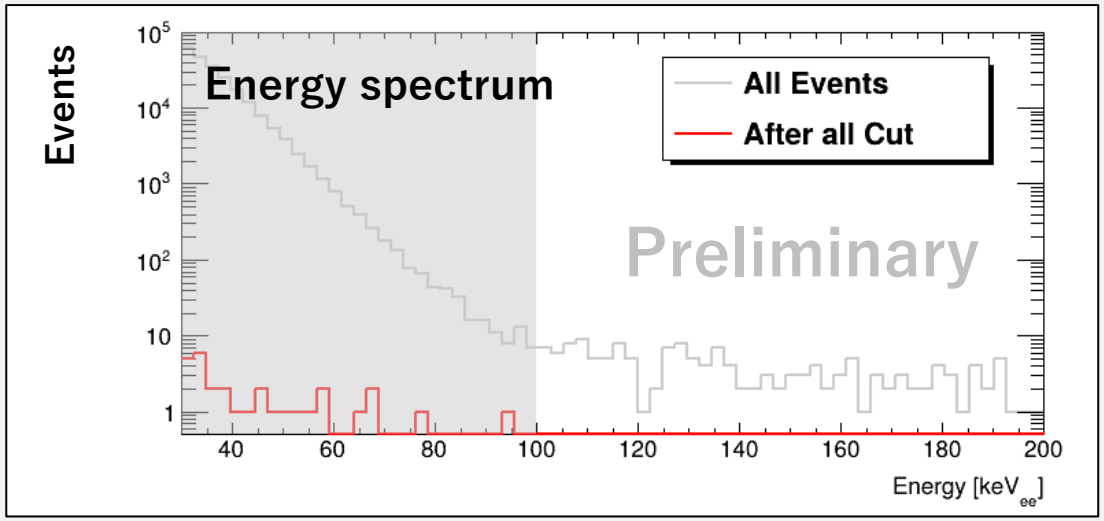


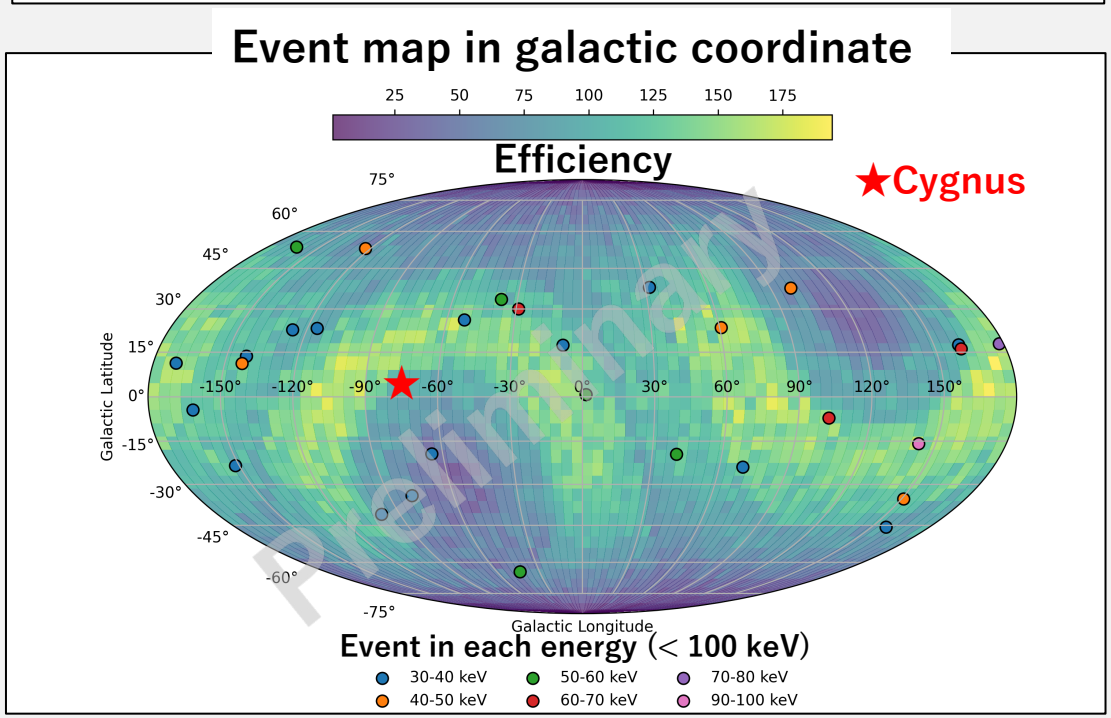




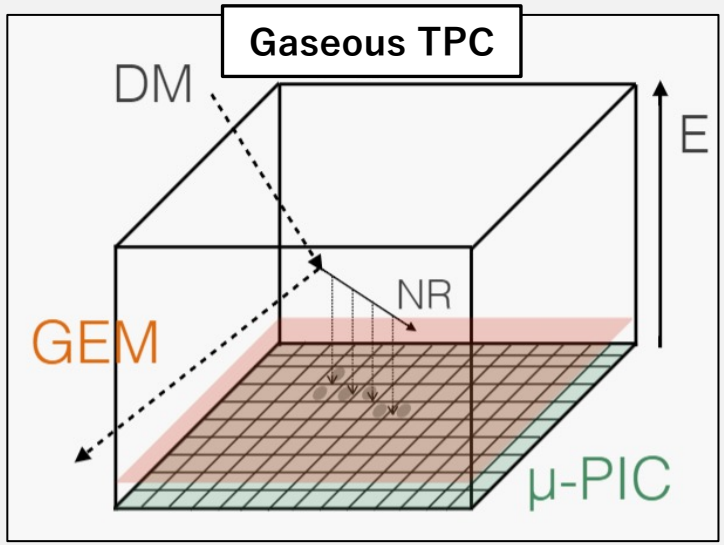
K. Miuchi et al. / Physics Letters B 654 (2007) 58–64

Analysis result





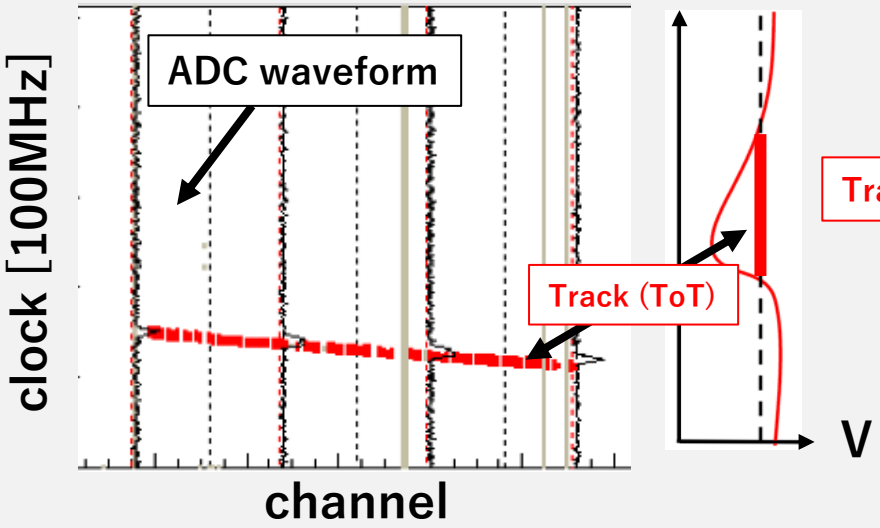
Data acquisition



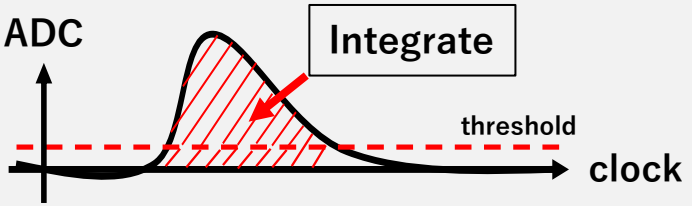
Readout data Readout

- Energy is calculated by integrating ADC waveform (4 channels)
- Track is reconstructed from Time over threshold (ToT) distribution (128 channels)

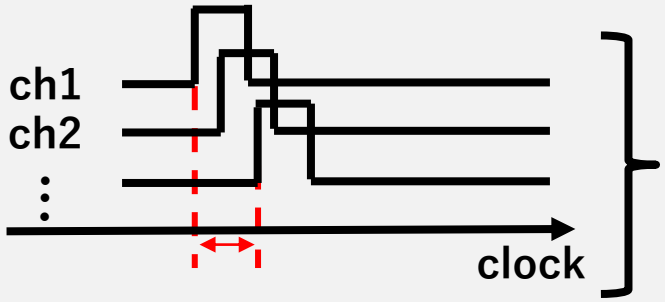
visualized readout data



Energy

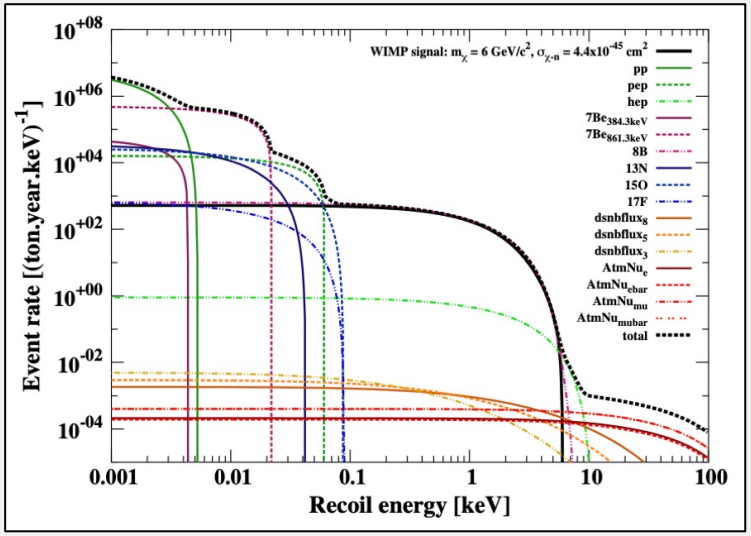


Track

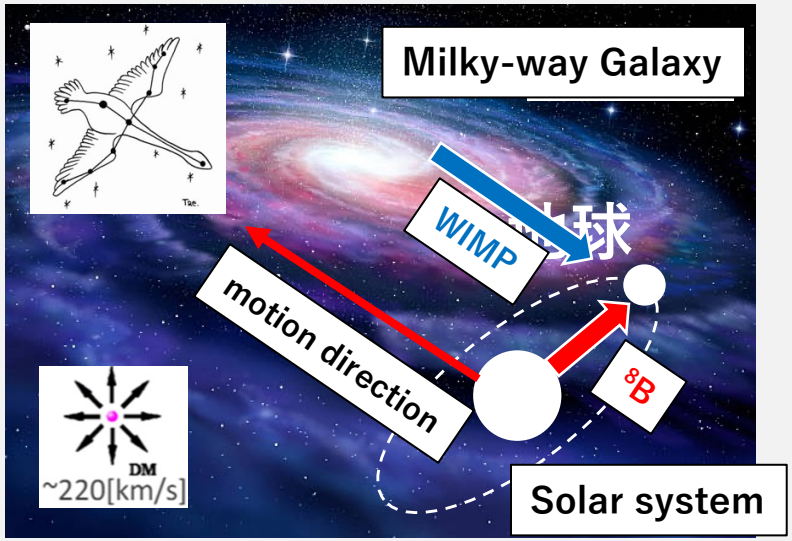


ニュートリノフォグ

- 大質量検出器によるXe原子核を用いたν(^{8}B)-原子核弾性散乱（CEνNS）観測の兆候
  - 以降はCEνNSを考慮しながらの探索が必須



- WIMPと^{8}Bの反跳エネルギースペクトルは類似
- 到来方向による分離が期待される。
  - 1m^3>規模の検出器の大型化　が必要
  - 検出器の低閾値化
- νFogを超えた方向感度を持つDM探索のための大型化技術の確立が求められる



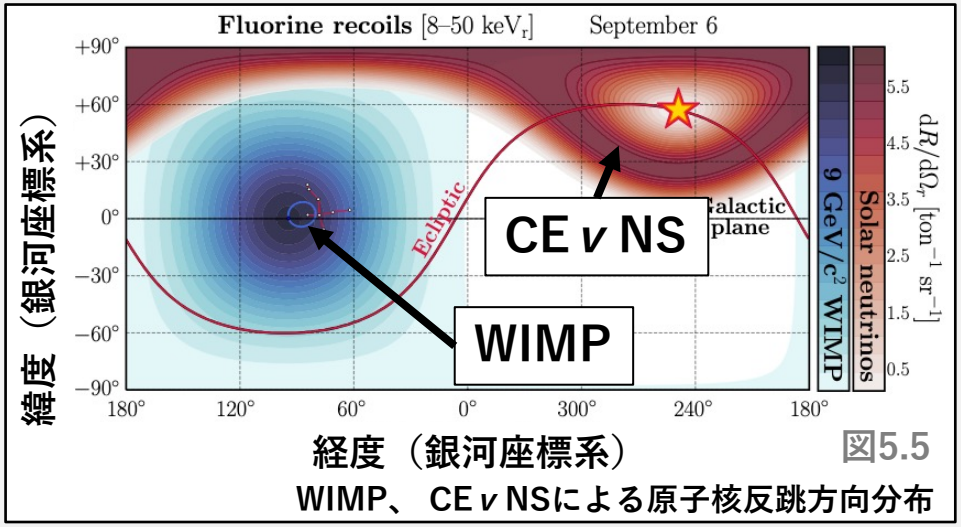
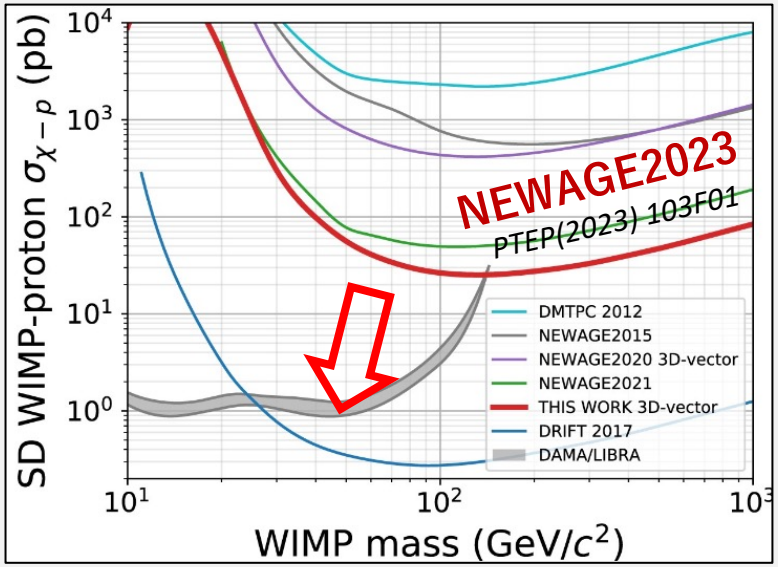


図5.5
WIMP、 CEνNSによる原子核反跳方向分布

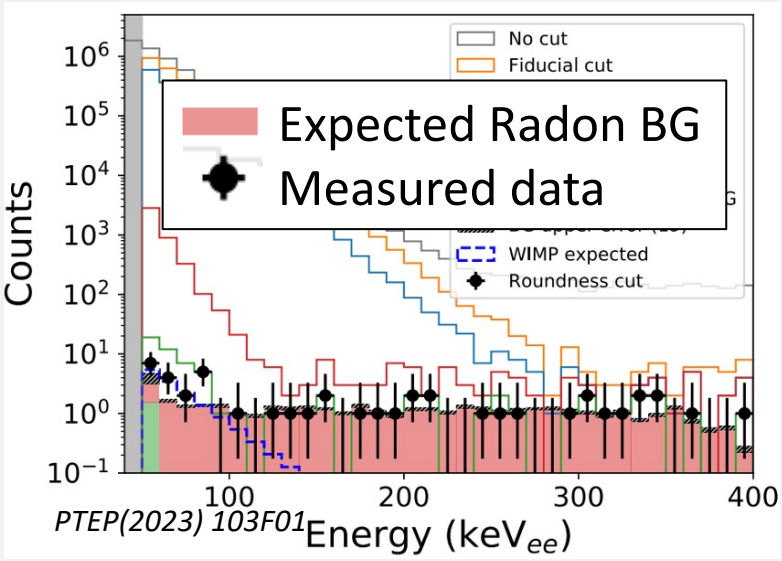
Vahsen, S. E., O'Hare, C. A. J., Lynch, W. A. et a

NEWAGE実験の取り組み



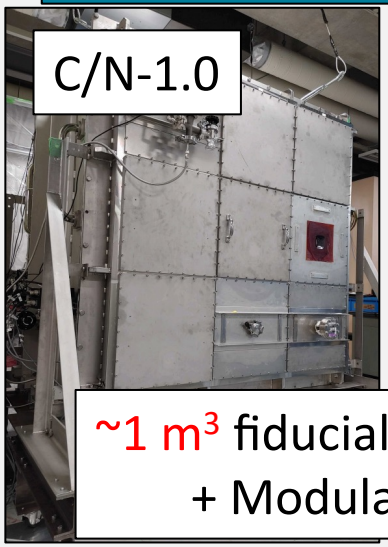
- World record in WIMP search with directional analysis.
- Two approaches to improve sensitivity.

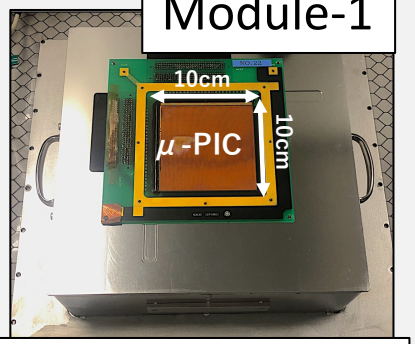
Background (BG) reduction



本報告のメイントピック

Chamber enlargement

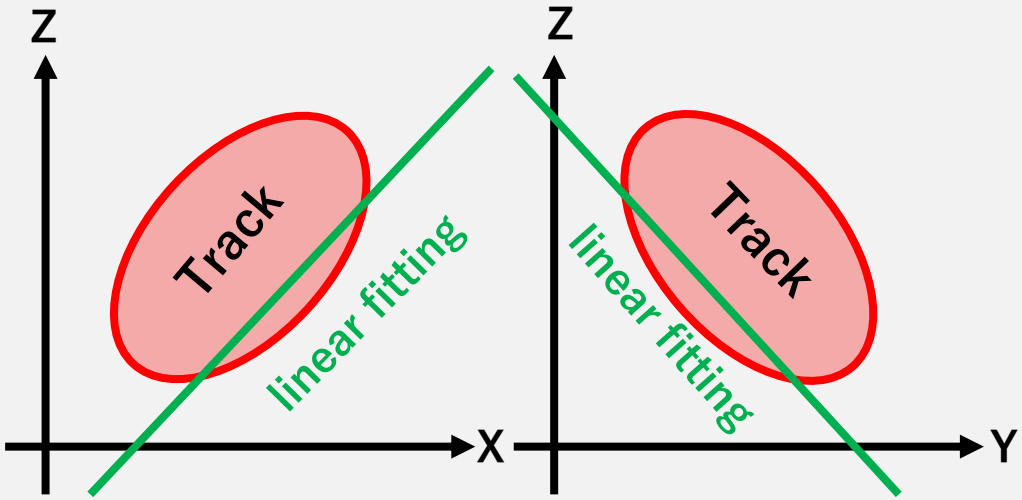




~1 m^3 fiducial volume chamber
+ Modular detector

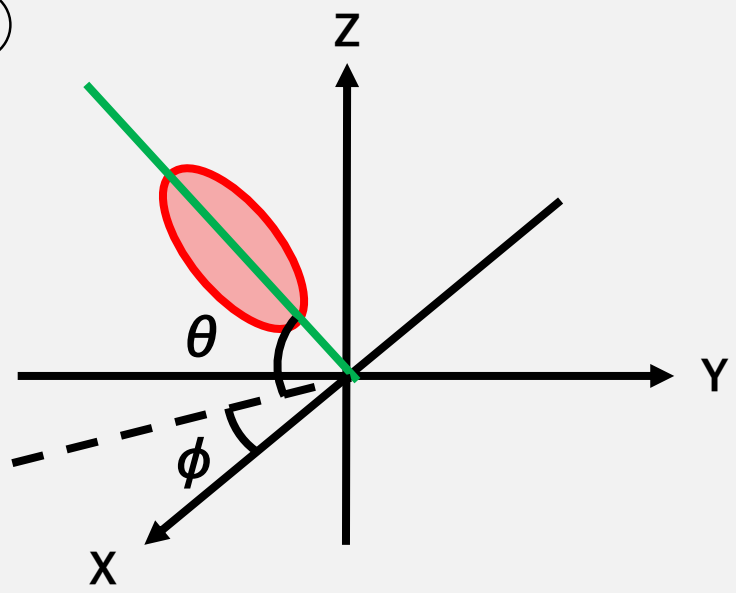
角度計算方法

①



- F原子核反跳を事象選別
- X-Z、Y-ZのToTを線形fitting

②

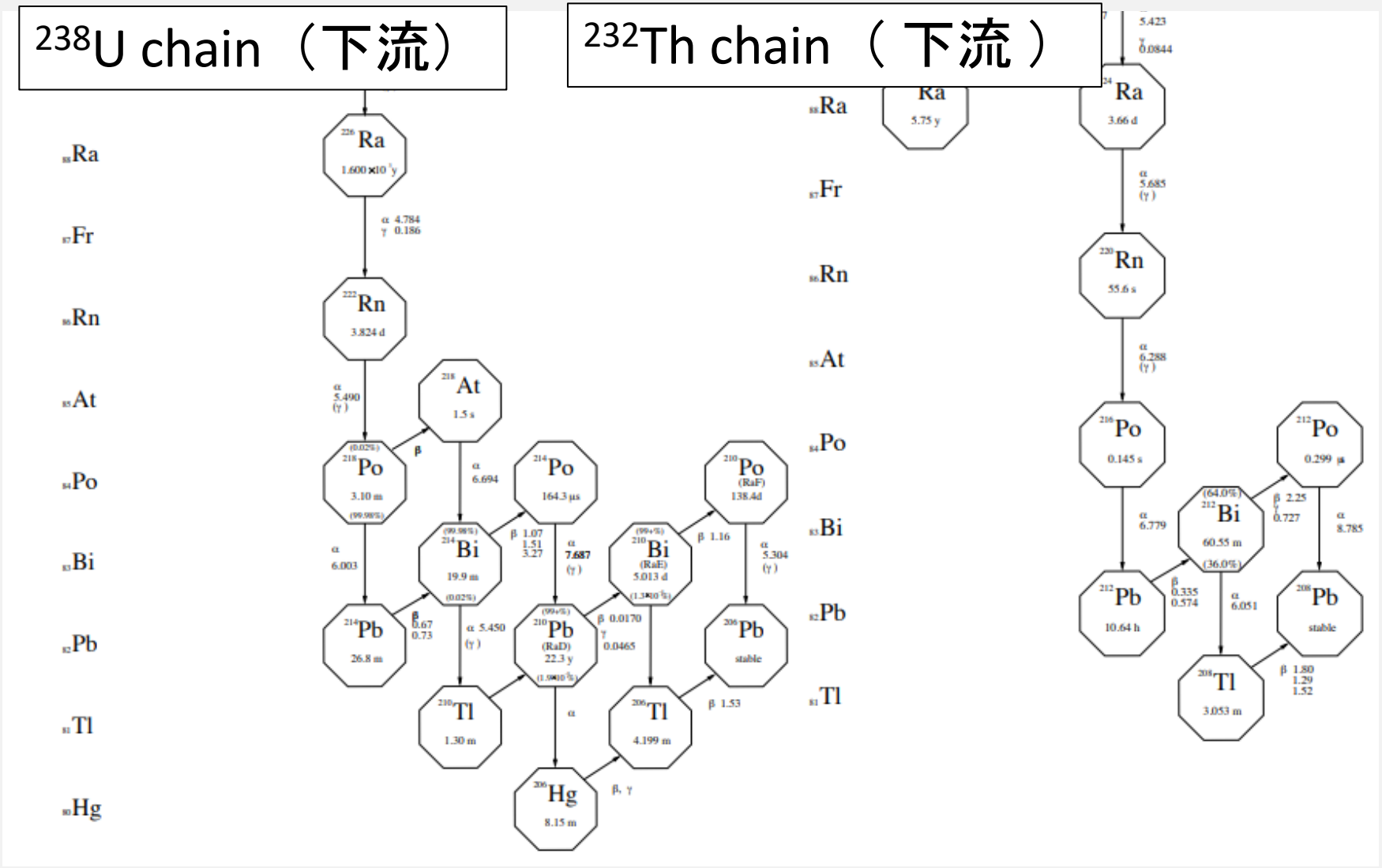


- X-Z、Y-Zの傾きから球面座標系における仰角、方位角を計算
- X-Z、Y-Zの傾きから球面座標系における仰角θ、方位角ϕを計算
- 線源照射方向に対する反跳方向γを計算

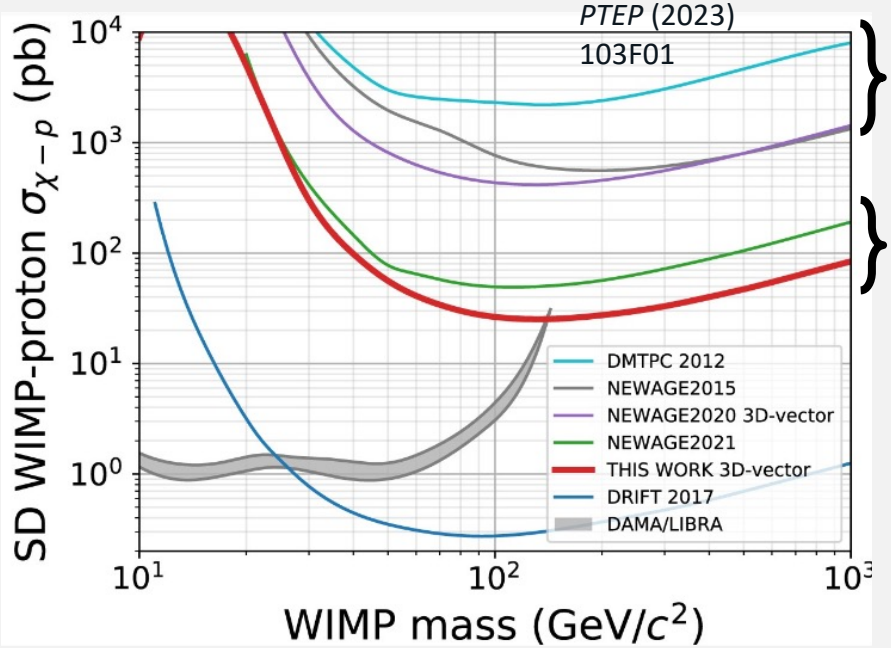
Radon Decay Chain

^{238}U chain （下流）

^{232}Th chain （下流）



μ-PIC開発の歴史と低バックグラウンド化の経緯



μ-PIC
NEWAGE2015 & 2020

Low α(LA)μ-PIC
NEWAGE2020 & 2023

低バックグラウンド化による感度の向上を行ってきた。

- Low α(LA)μ-PIC: 検出器表面からのαを抑制

→検出感度向上（PTEP (2023) 103F01）

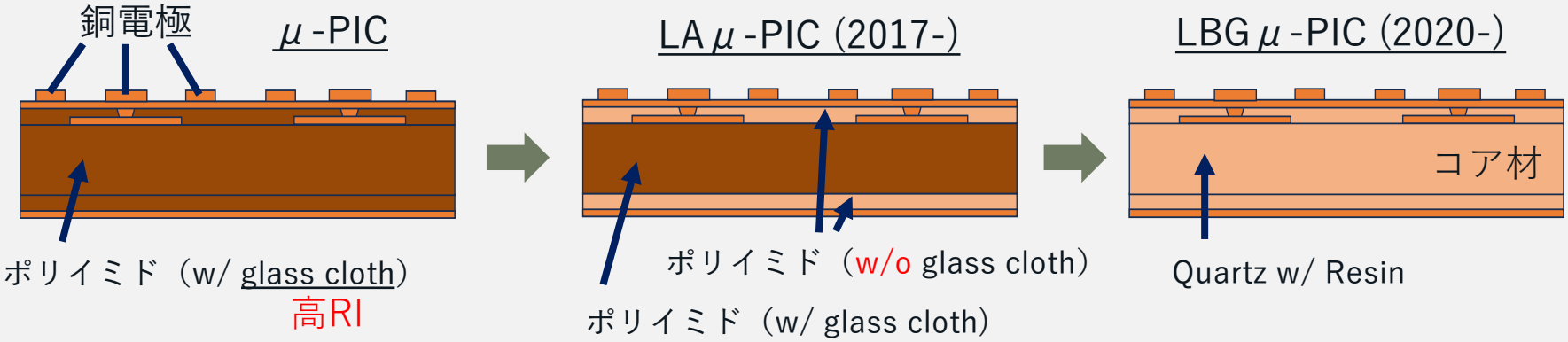
- 一方でラドンBGが顕在化

→コア材をより低RIなものにしたLow BG (LBG) μ-PIC を製作

- ラドンレート要求値: LA μ-PICの<1/10

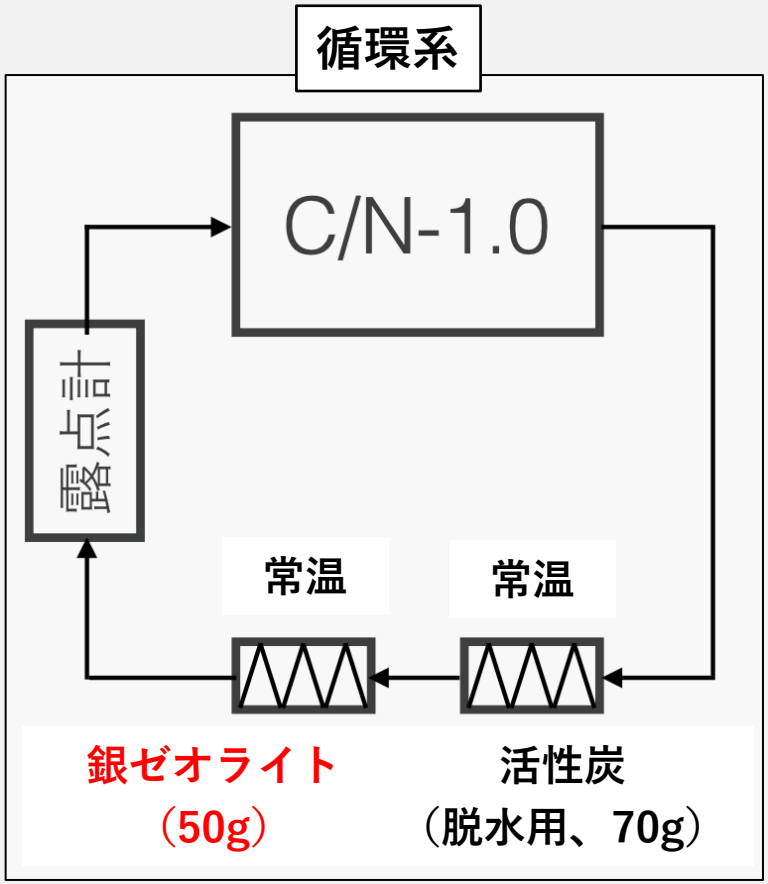
研究目的：LBG μ-PICの性能評価

μ-PICの改良

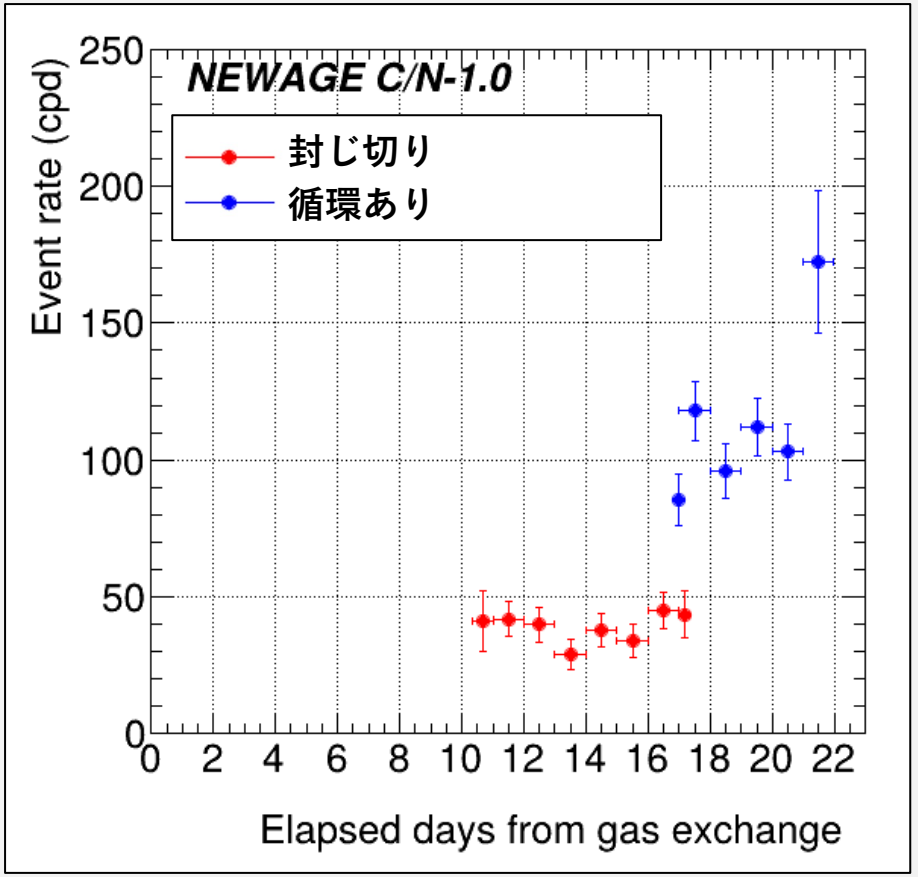


背景事象の抑制

- 検出器の部材のU、Th系列の放射性同位体崩壊に伴うα線が重大なBG源の一つとして存在。
- 銀ゼオライトの科学吸着による抑制の試み。
  - 現行NEWAGEで実証済み。



循環の有無での事象数（>200 keV）

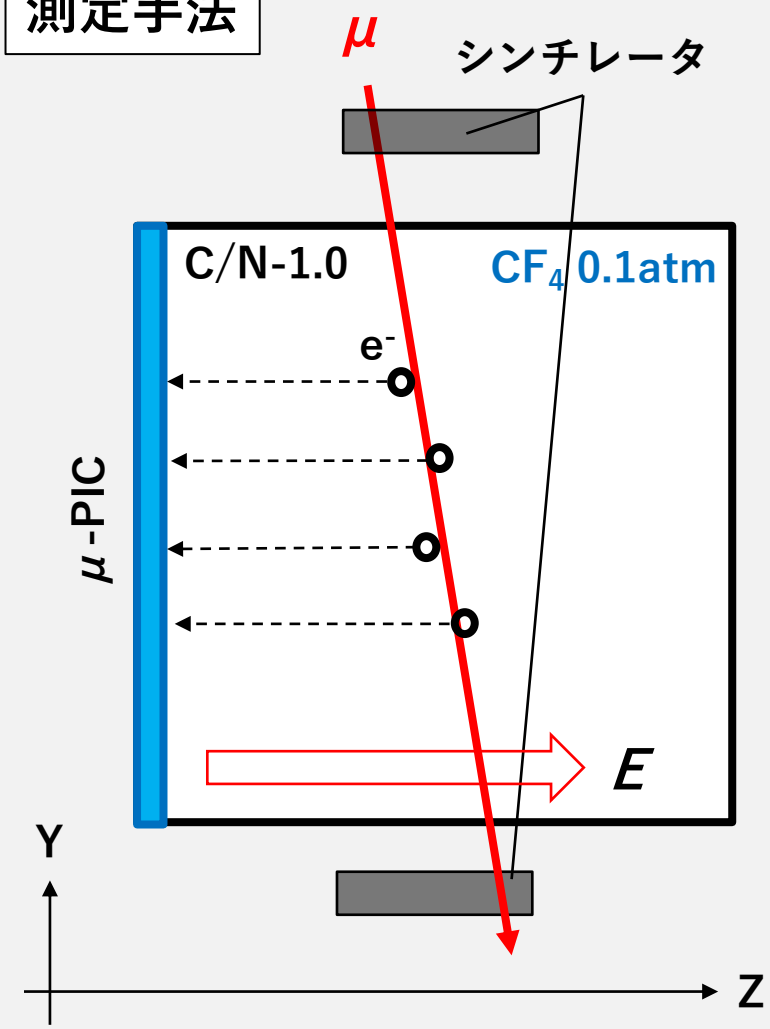


- 200keV以上の事象に対して1/2.7の事象数削減を確認。

ドリフト速度較正（cosmic μ）

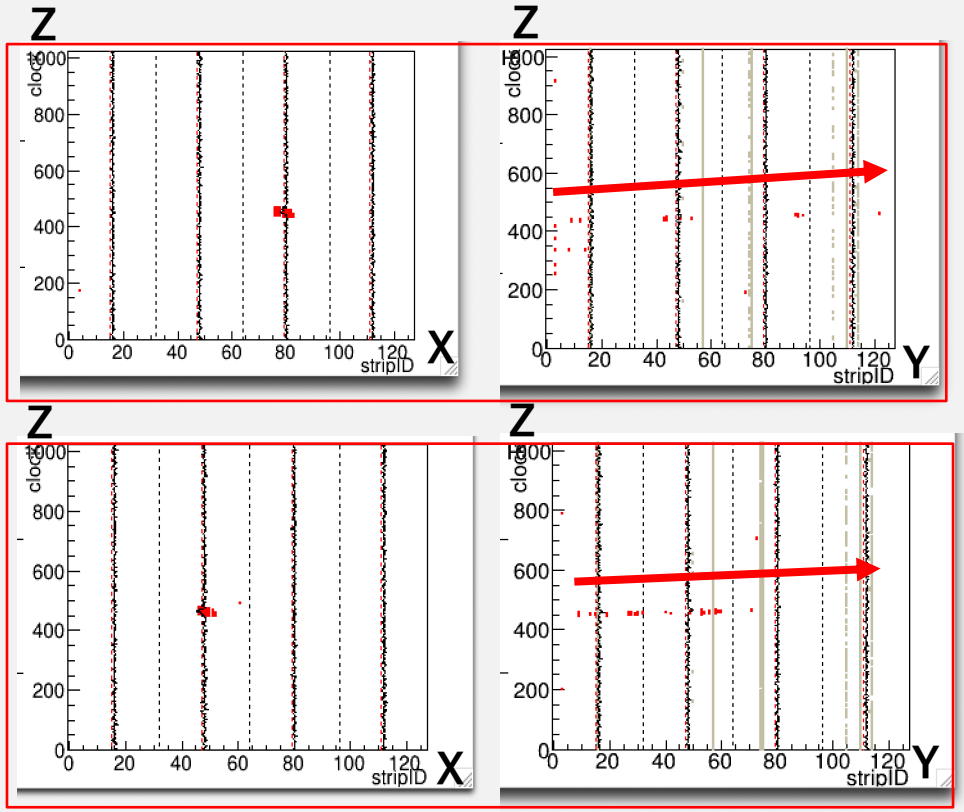
- 宇宙線μを使用した手法によってドリフト速度を確認

測定手法



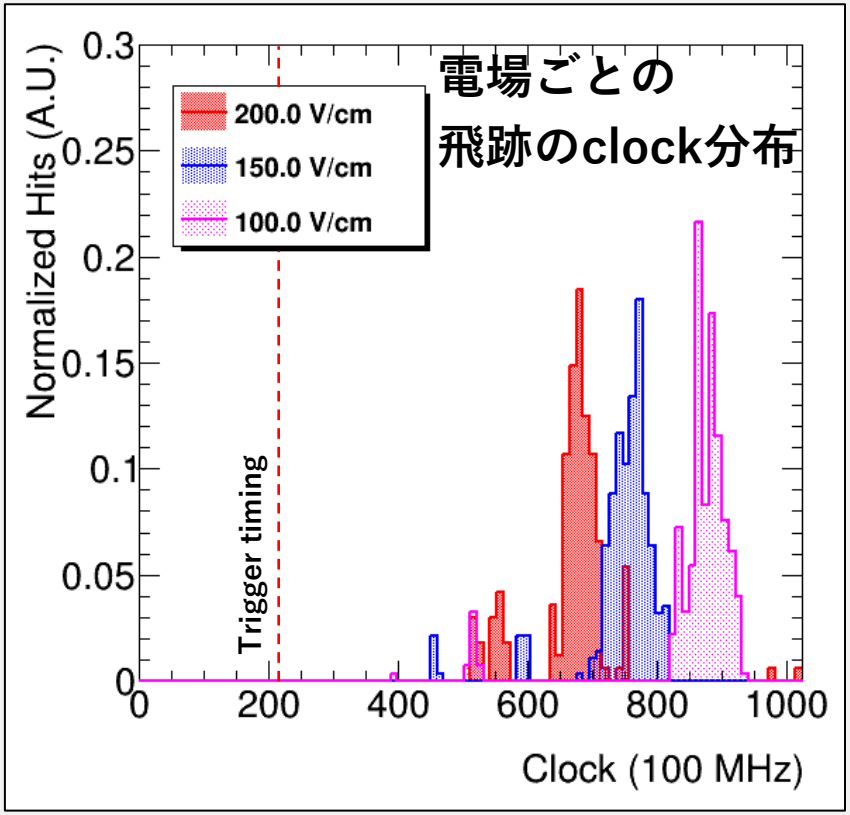
- 検出を挟んでシンチレータを配置
- 同時計測時にでトリガを発行

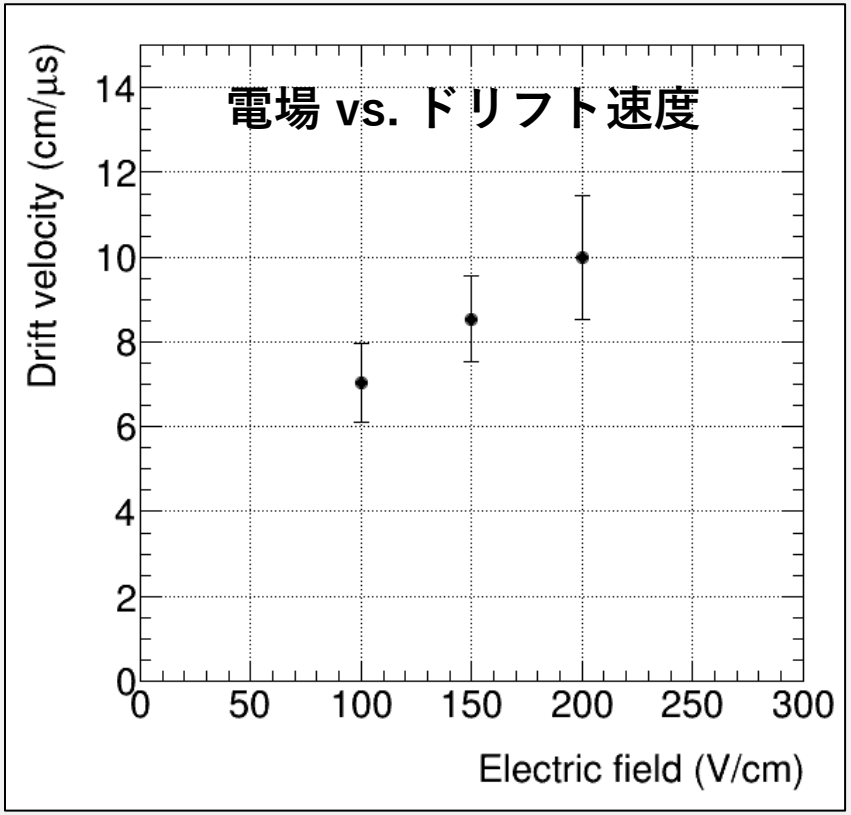
取得された飛跡の例



ドリフト速度較正 （cosmic μ）

- 異なる電場強度でドリフト速度測定を実施



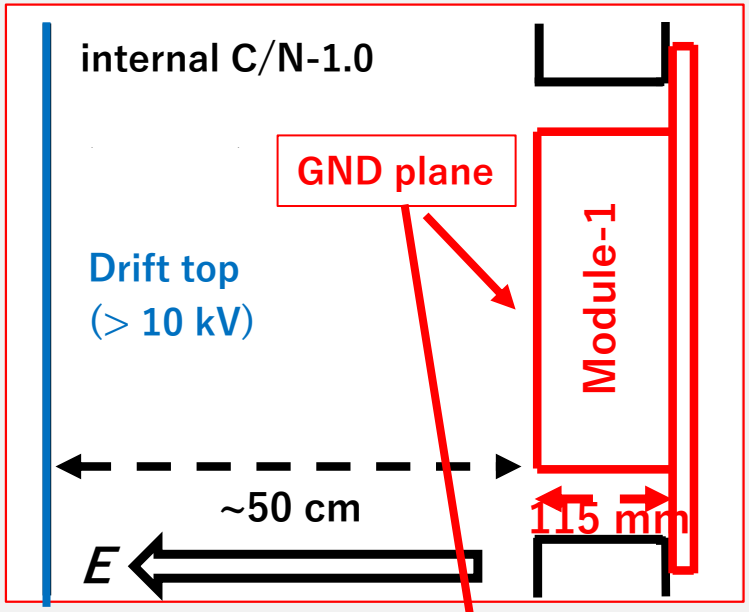


- ドリフト速度の測定が可能であることを確認

エネルギーと合わせて。。

⇒ C/N-1.0で飛跡の再構成が可能であることを確認

Module-1 (our detector)

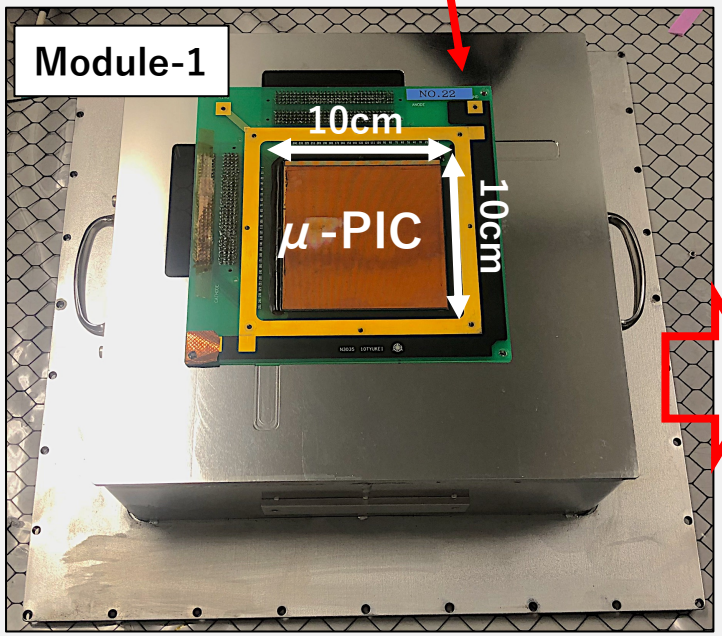


Structure constraint

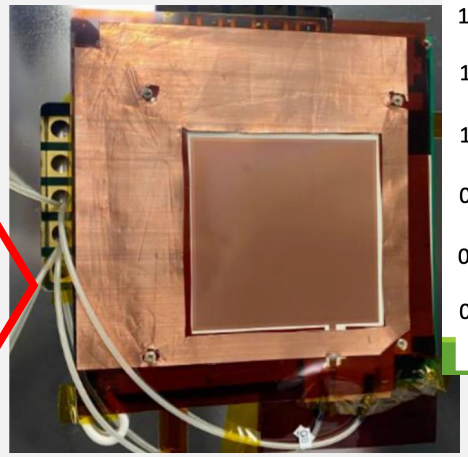
- A ground plane is constructed at a position elevated by 10 cm toward the drift plane.

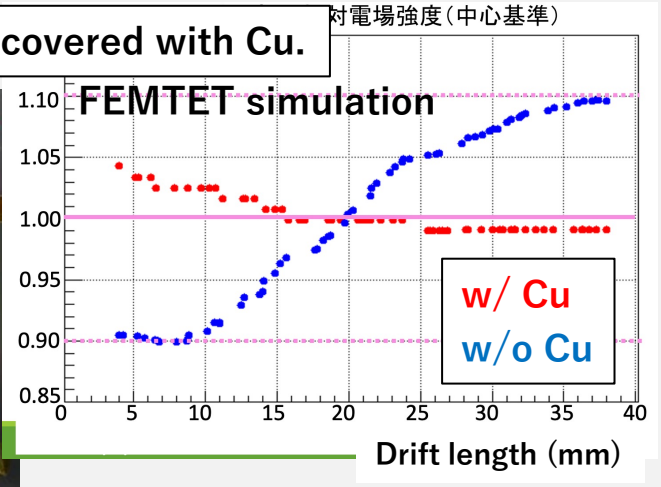
Features

	Module-1	NEWAGE
detection area	10×10 cm^2	30×30 cm^2
strip pitch	800 μm	400 μm
energy threshold w/ directionality	100 keVee	50 keVee



detector is covered with Cu.





For demonstration of C/N-1.0 operation.