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NEWAGE: Status of underground direction-sensitive dark matter search with low-background gaseous TPC

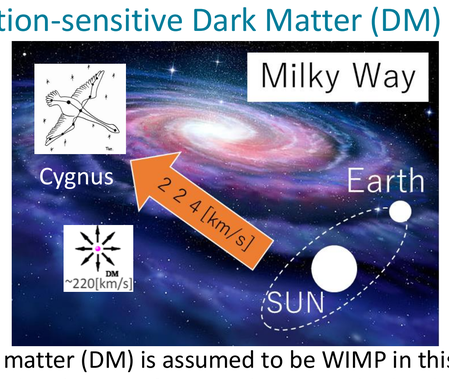
Ryota Namai

Kobe Univ.

on behalf of NEWAGE group

Introduction

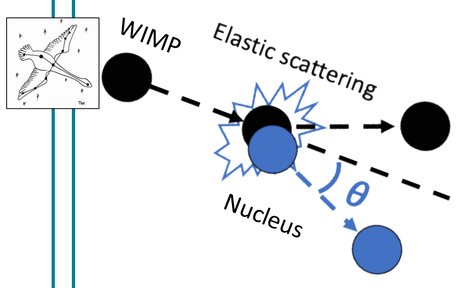
Direction-sensitive Dark Matter (DM) searches

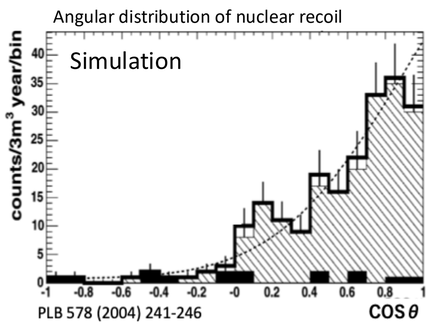


- Dark matter (DM) is assumed to be WIMP in this poster.
- If the distribution of WIMP obeys Standard Halo Model (SHM), the arrival direction of WIMP is biased toward the solar system moving (Cygnus).

→ Measurement of WIMP arrival direction is expected to provide strong SHM evidence.

How to detect the arrival direction?

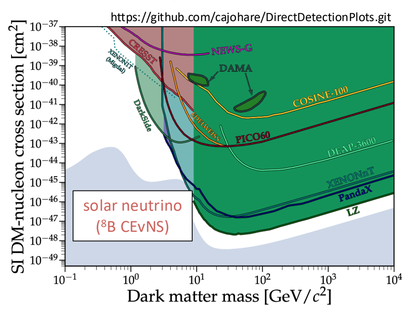


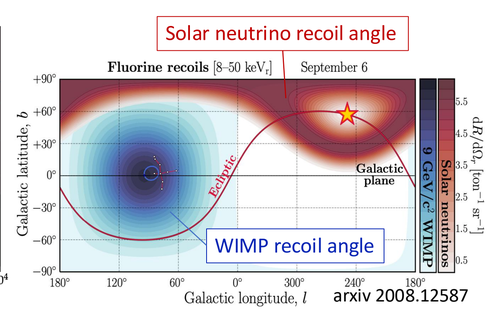


- Measuring the scattering angle of nucleus recoiled by the WIMP.
- The recoil angle is expected to be biased in the opposite direction of Cygnus.
- Nucleus track provides the recoil angle information.

→ Evidence of WIMPs is obtained from nucleus tracks.

Explore beyond the neutrino floor





- PandaX-4T and XENONnT reported the expectation of coherent elastic neutrino-nuclear scattering (CEvNS) event by solar (^{8}B) neutrinos in 2024.
- It is expected that the WIMP and ^{8}B signals can be identified using directional sensitivity.

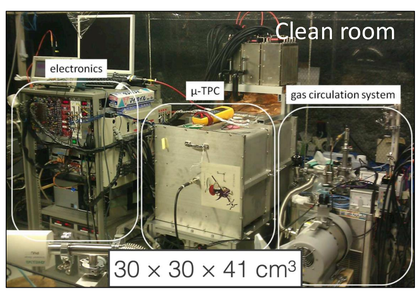
→ It is expected to be able to explore beyond the "neutrino fog".

NEWAGE

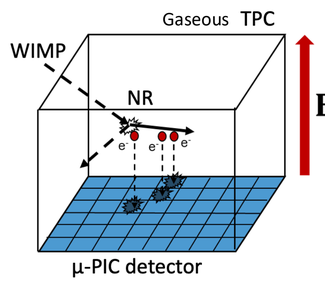
NEWAGE experiment

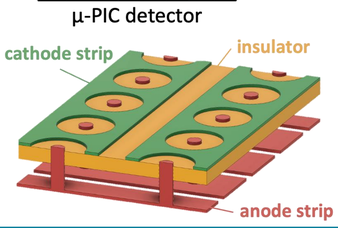
- Low background environment to search for rare events.

→ 1,000 m underground at the Kamioka mine.



3D track reconstruction





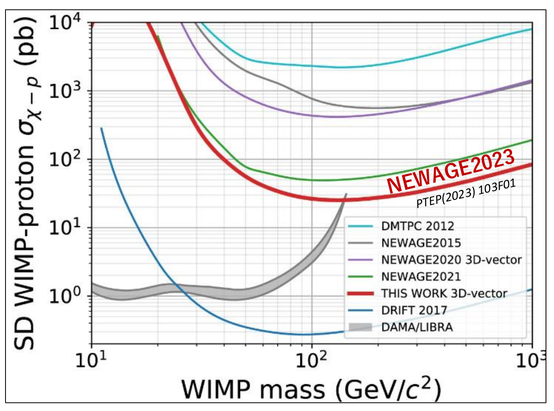
Time projection chamber (TPC)

- Filled with CF_4 0.1 atm.
- If nucleus is recoiled by WIMP, it will ionize the gas atoms.
- Ionized electrons will drift in electric field.
- 3D reconstruction of NR tracks by detecting ionized electrons.

μ-PIC (micro pixel chamber)

- Read out the drifted electrons.
- Reconstruct 3D track with 2D strip readout and event timing.
- Gas amplification.

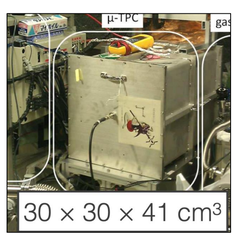
NEWAGE latest result and efforts

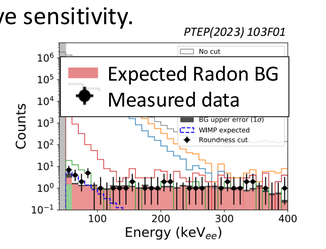


- World record in WIMP search with directional analysis.

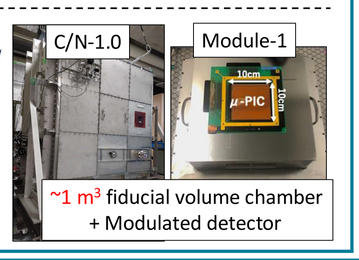
- Two approaches to improve sensitivity.

Background (BG) reduction

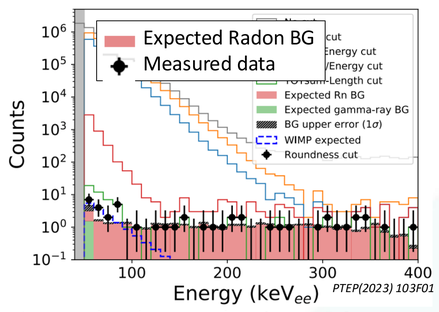




Chamber enlargement

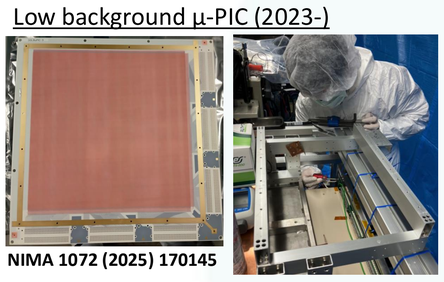


BG reduction



- Internal radon are dominant BG sources.
- It is essential to reduce the radon emanation rate in order to enhance sensitivity.

Low background μ-PIC (2023-)

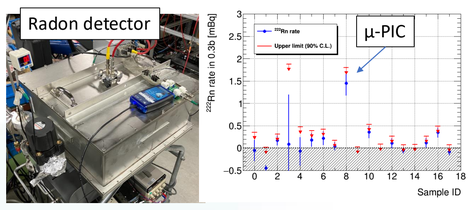


NIMA 1072 (2025) 170145

Material screening result using a radon detector

Sample	Radon emanation rate [mBq/chamber]
conventional μ-PIC	2.3 ± 0.5
Low BG μ-PIC	< 0.04 (90 % C.L.)

Material screening



- Screening chamber components → μ-PIC is the dominant radon source.

Installation of Ag-zeolite filter

- Installed Ag-zeolite filter to reduce radon in gas.

PTEP(2025)013H01

Sample	Radon adsorption coefficient [m³ kg⁻¹]
activated charcoal (-60 ℃)	379
Ag-zeolite	6506 ± 81

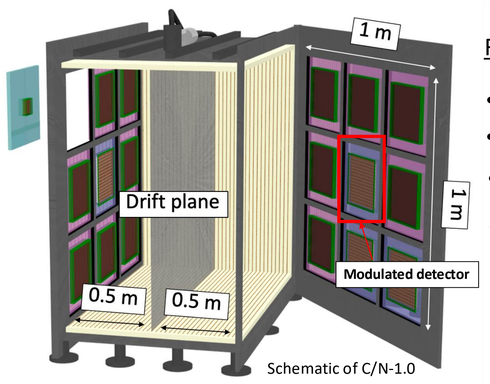
- The radon event rate was compared before and after the installation of Ag-zeolite in the NEWAGE circulation system.

Filter	Radon and its progenies event rate [event/day]
activated charcoal (-60℃)	13.8 ± 0.9
activated charcoal + Ag-zeolite	5.3 ± 0.7

- The radon rate was reduced by a factor of 2.6.

C/N-1.0

CYGNUS-KM/NEWAGE (C/N) -1.0

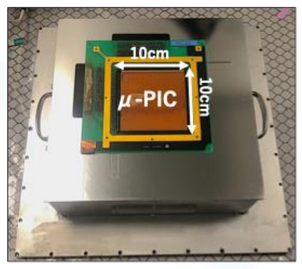


Schematic of C/N-1.0

Features

- ~1 m³ fiducial volume
- Modulated detectors
- CF_4 gas, 0.1 atm
- New readout DAQ system implemented in order not to conflict with neighboring modules

Modulated detector "Module-1"



Features

- Structure: GEM + μ-PIC

→ Same as the current NEWAGE detector structure.

- GEM (Gas Electron Multiplier)
  - Preamplifier

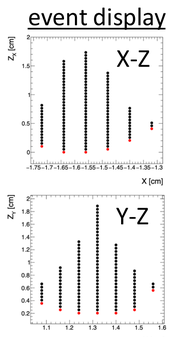
- 10 × 10 cm² detection area.
- 3D track reconstruction.

Evaluation of the modulated detector with a test chamber.

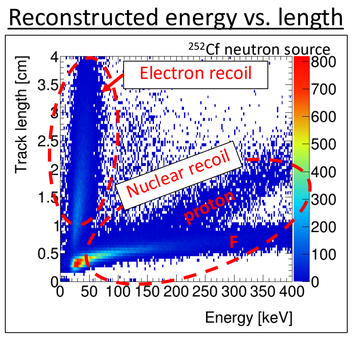
Track reconstruction

- To select nuclear recoil events, tracks are reconstructed and parameters are extracted.

event display



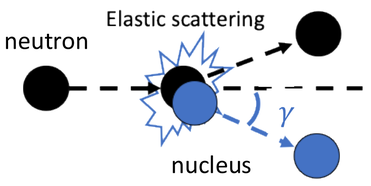
Reconstructed energy vs. length



Nuclear recoil event and electron one are separated clearly.

Angular resolution evaluation

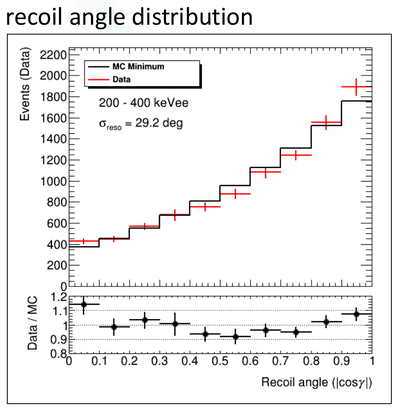
- Using neutrons from ^{252}Cf source



- Range of $200 < E < 400$ keV
- $\sigma_{\mathrm{reso}} = 29.2^{+1.8}_{-0.6}$ ° (stat.)

→ Equivalent to the NEWAGE result.

recoil angle distribution

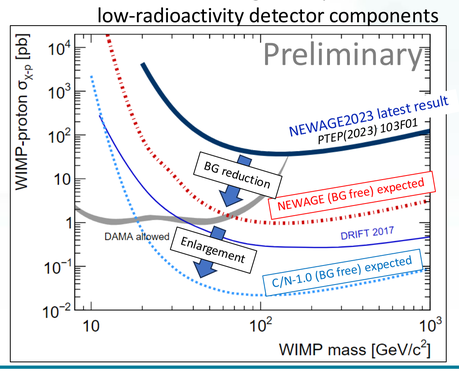


- Module-1 was installed in C/N-1.0.
- Surface commissioning in progress for operations.

Prospective

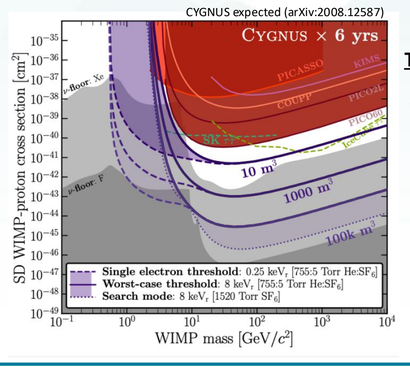
BG reduction

- Aiming for background-free measurement over 1 year.
  - Considering increasing the amount of Ag-zeolite.
  - Material screening and replacement with low-radioactivity detector components



Chamber enlargement

- Starting underground DM search with C/N-1.0
- After completing surface commissioning, scheduled for underground installation at Kamioka in spring 2026.



Towards the search for neutrino fog

- 10 m³ detector will reach the neutrino fog

(10 C/N-1.0 detectors)

- C/N-1.0 operation is an important step

Conclusions

- NEWAGE is a direction-sensitive WIMP search experiment.
  - Search and identify the WIMP properties using recoil direction.
  - The installation of the Ag-zeolite filter resulted in a reduction of radon-induced events.
  - Enlargement of the detector is underway to improve the detection sensitivity.
- Developing a 1 m³ size detector, "C/N-1.0".
  - Evaluated the performance of modulated detector "Module-1" to be installed in C/N-1.0.

  → Operation test with test chamber completed and the module already installed in C/N-1.0.
  - Surface commissioning of C/N-1.0 is ongoing