

IDM2026

NEWAGE :

low background underground experiment
for direction-sensitive dark matter search

Satoshi Higashino

on behave of NEWAGE collaboration

1 / 6 / 2026

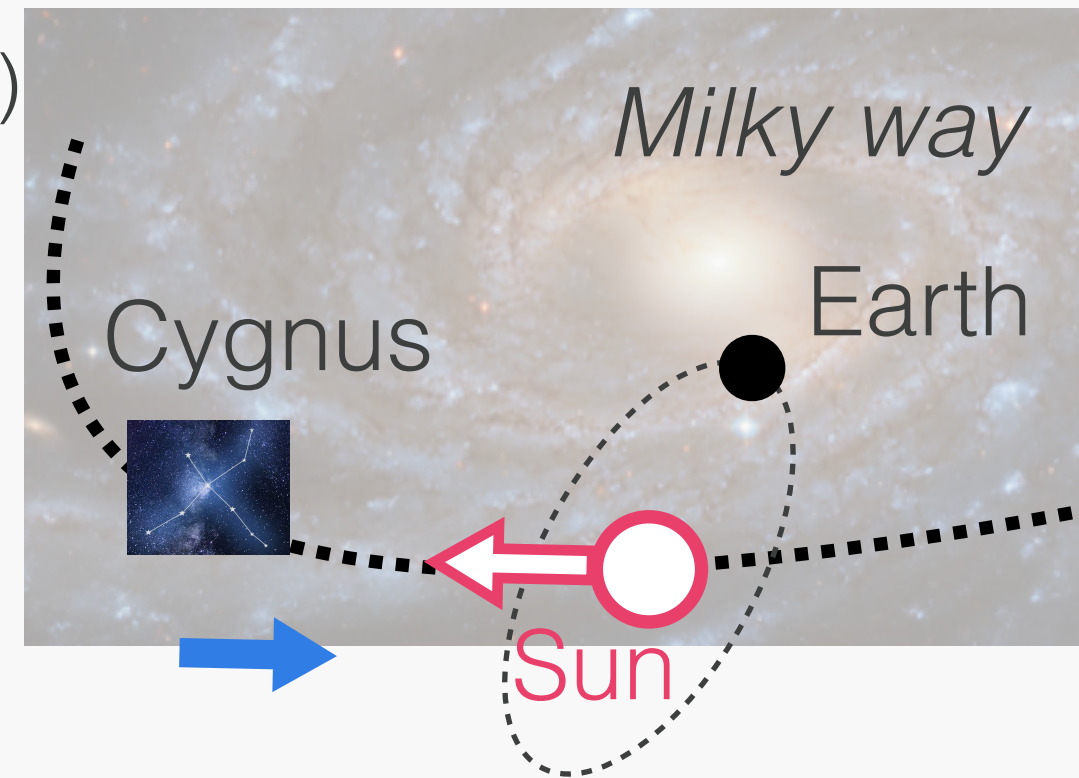
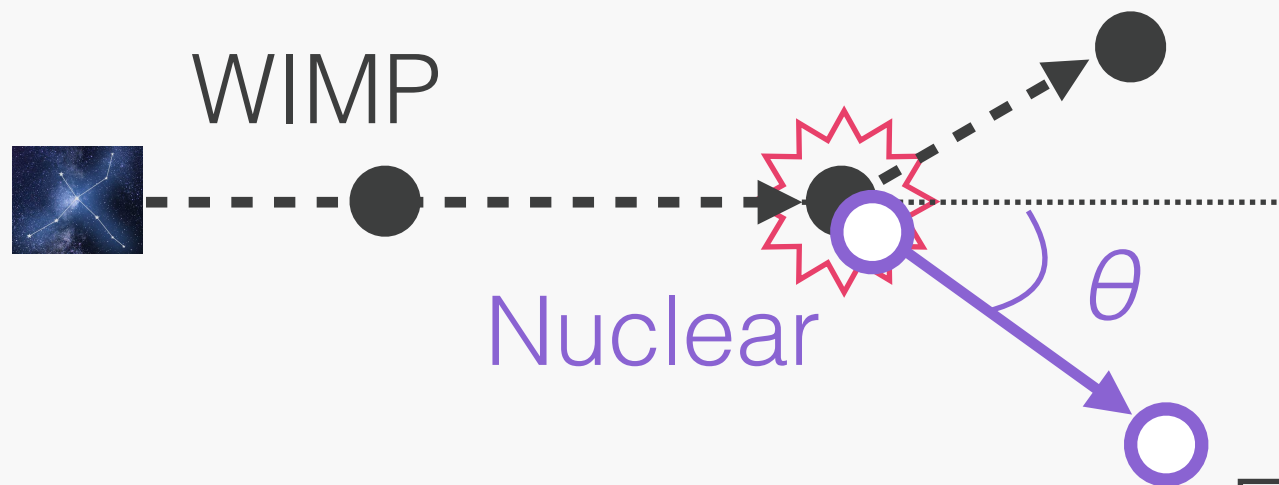


Introduction

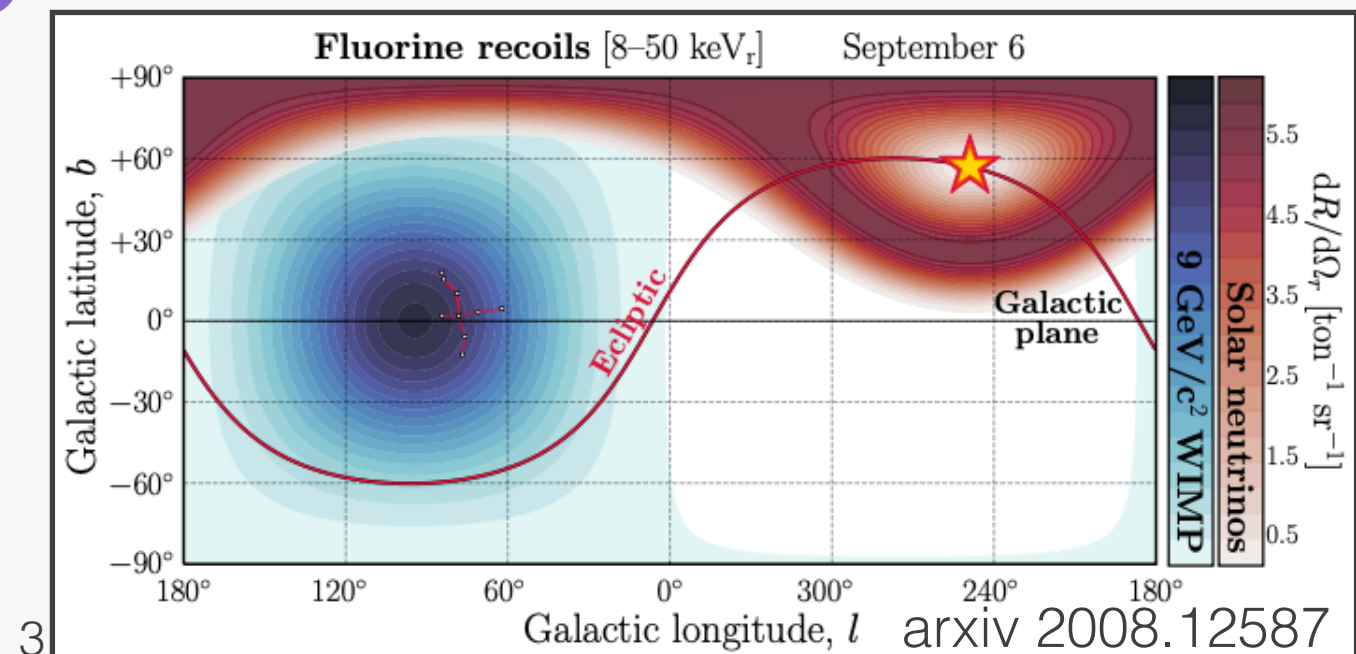
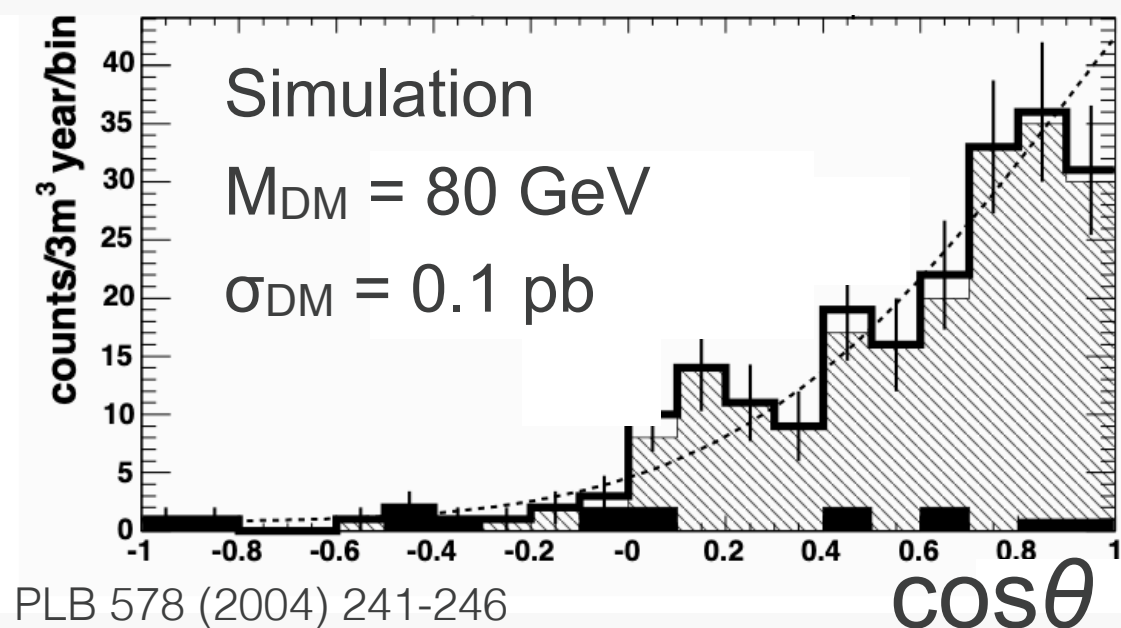
Direction-sensitive DM searches

- Detect scattering angle of nuclear recoils (NR) from the “Cygnus direction”

- leads a strong signature of WIMP
- allows to explore beyond the neutrino-fog

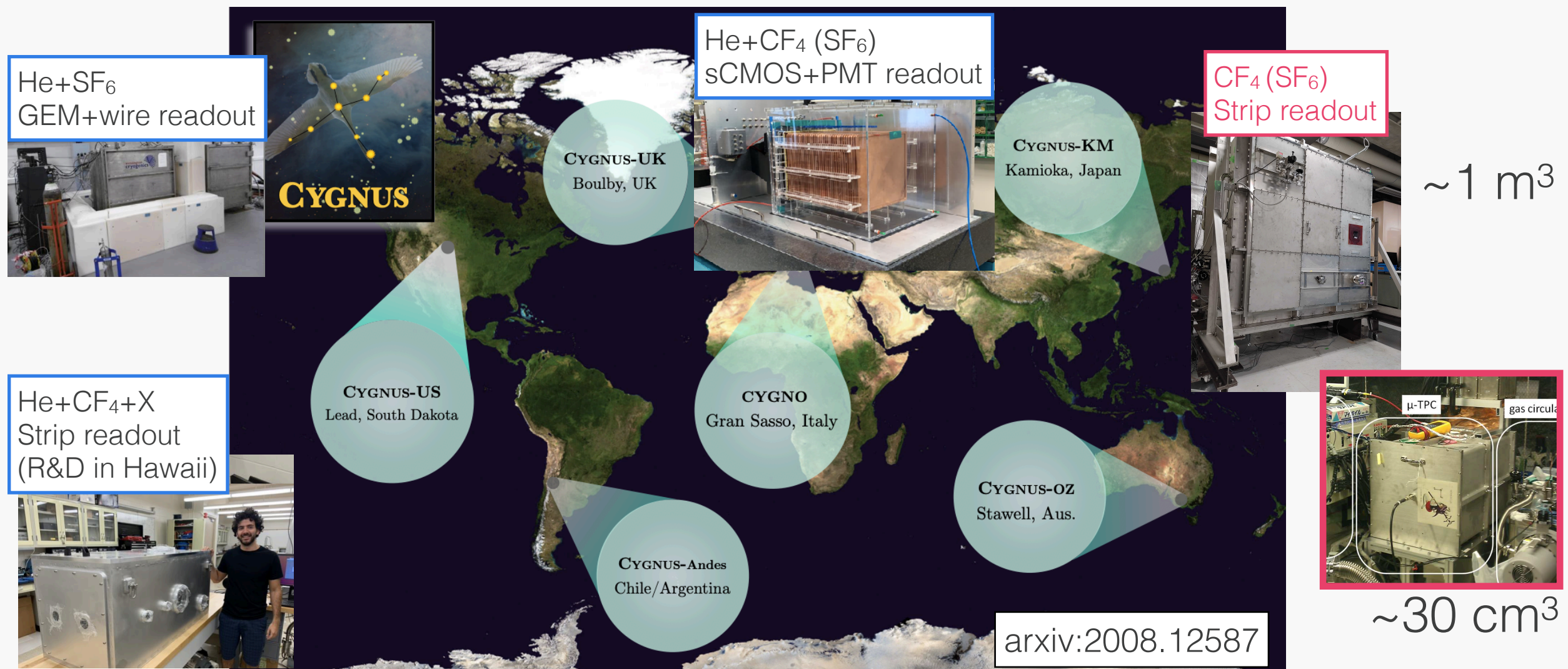


WIMP wind from Cygnus!



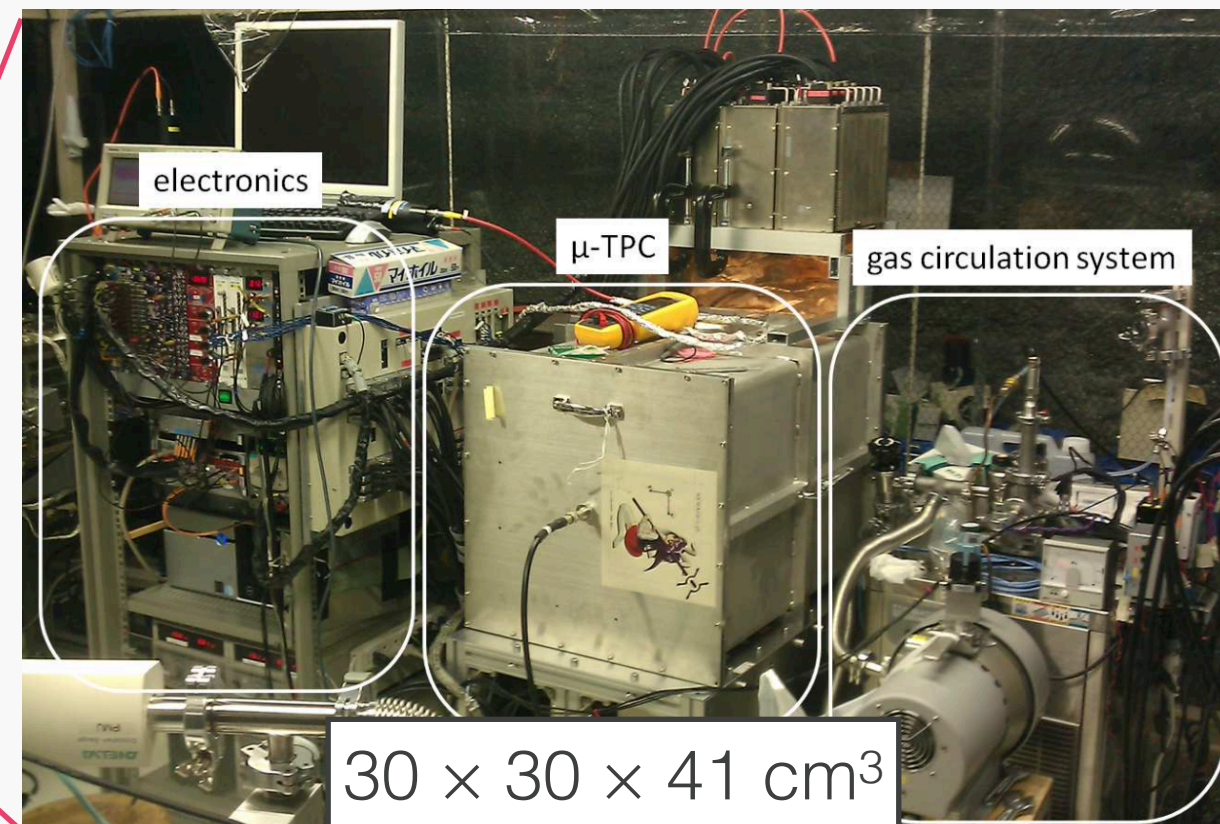
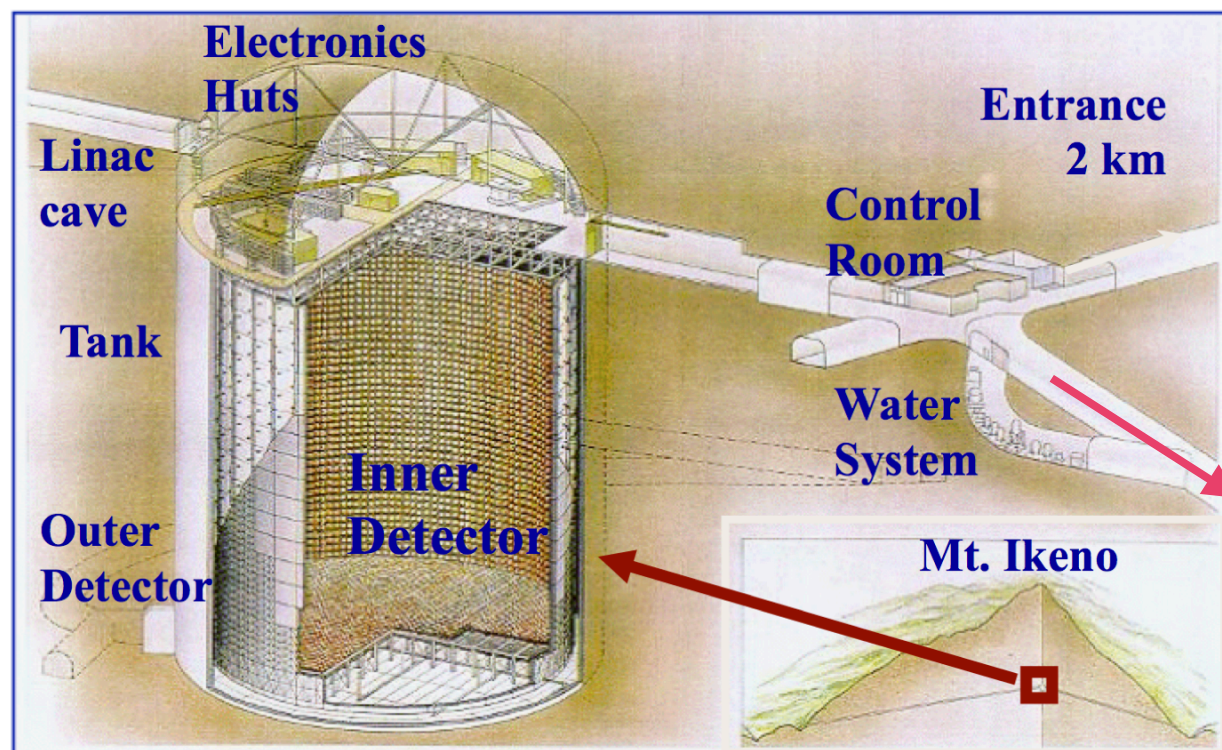
Direction-sensitive search methods

- **Particle tracking** is necessary to measure scattering angle from Cygnus direction
 - Need to measure < 10 keV nuclear recoil (**VERY short track!**)
- To achieve < 10 keV nuclear recoil track reconstruction, ...
 - use of **low pressure gas** to extend trajectory is one of the solutions
 - ▶ **CYGNUS**: world-wide consortium with low pressure gas + low BG toward DM, neutrino physics

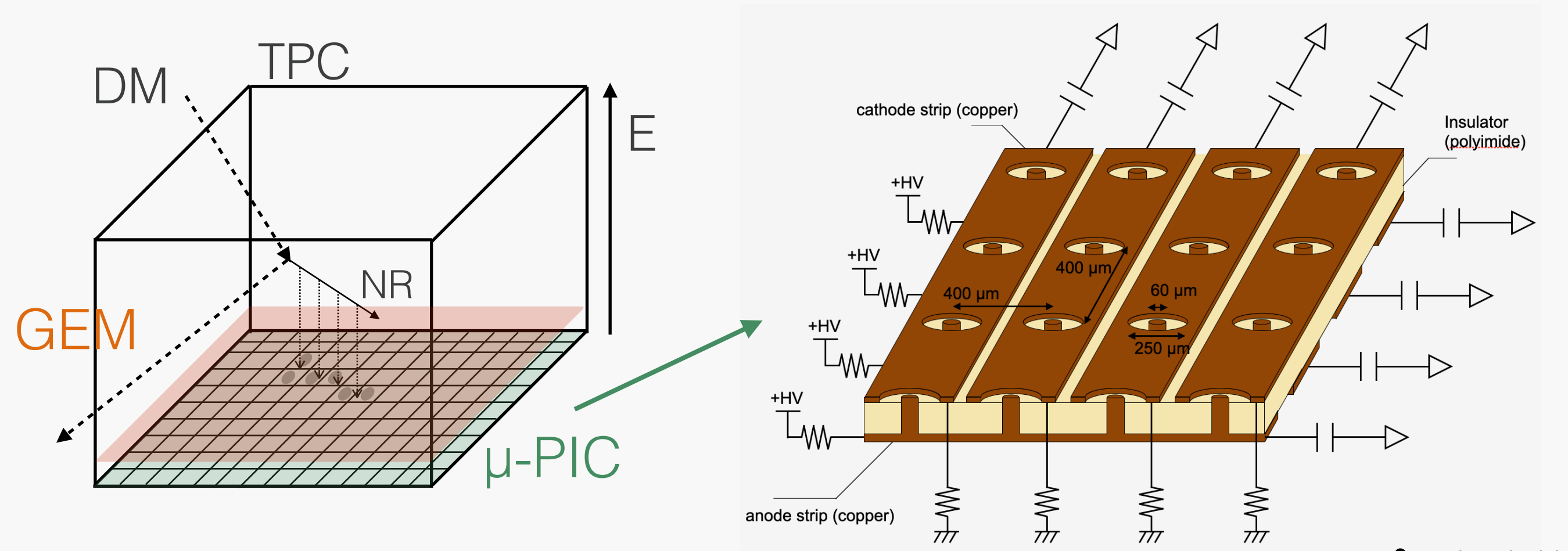


NEWAGE

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



NEWAGE: 3D track reconstruction

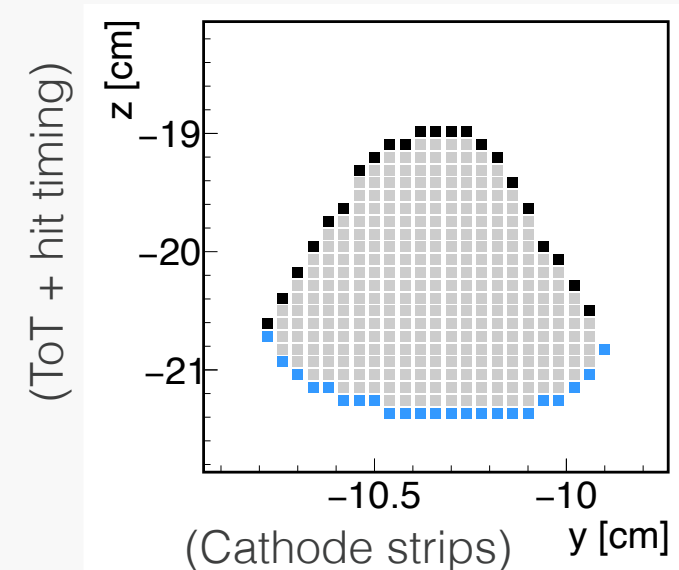
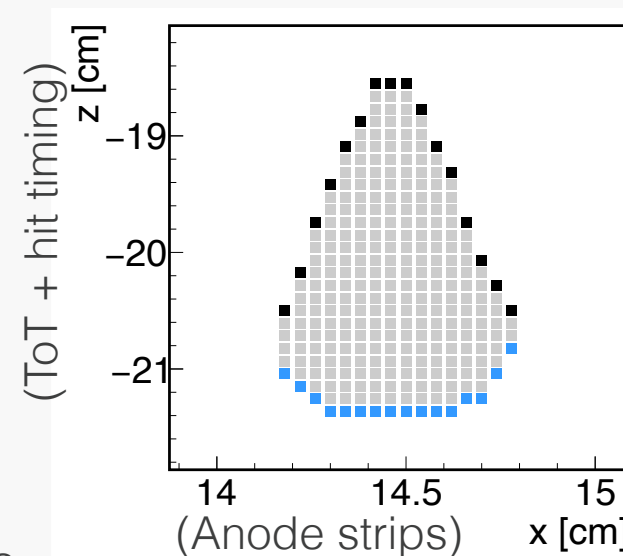
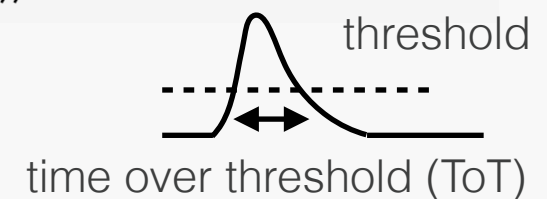


- GEM: Gas amplification
- μ -PIC:
 - 400 μm pitch 2D strip readout
 - Gas amplification

2D position + drift time

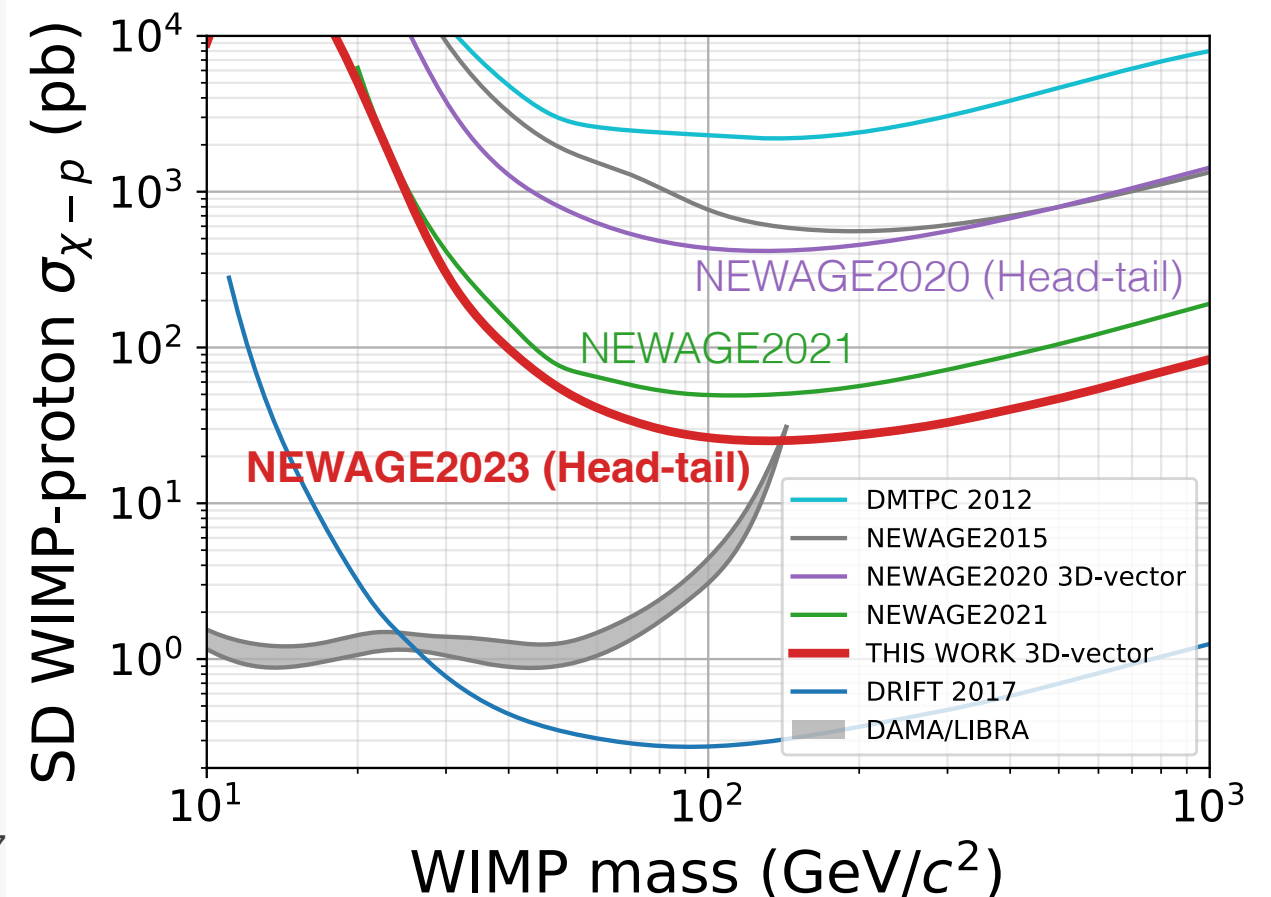
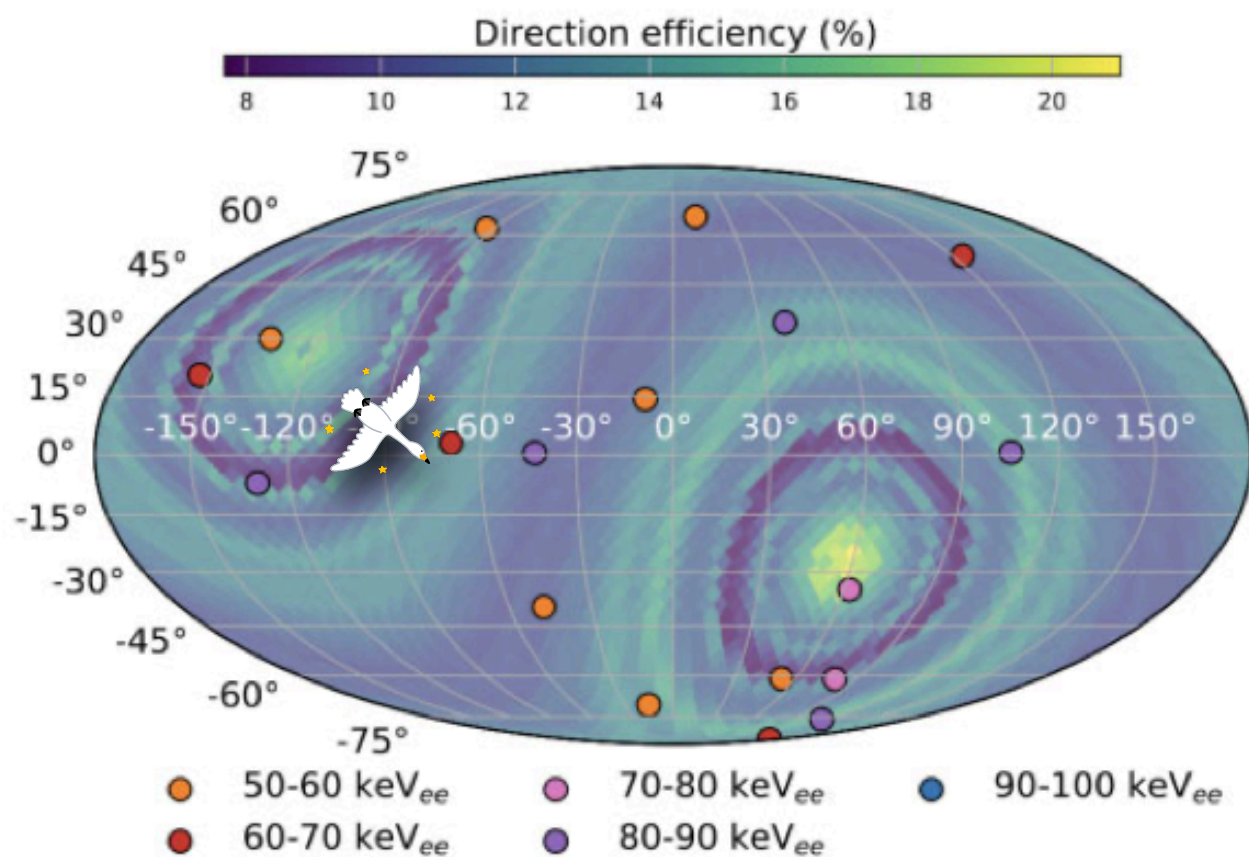
→ WIMP search with 3D track

NR event display



NEWAGE2023

- Null-consistent result in energy and directional distributions
 - ➔ Electron recoil rejection analysis updated and exposure increased
 - ➔ Limit is approaching DAMA/LIBRA allowed region
 - ➔ Head-tail recognition successfully implemented
- Future work: **BG rejection** and **large target volume**



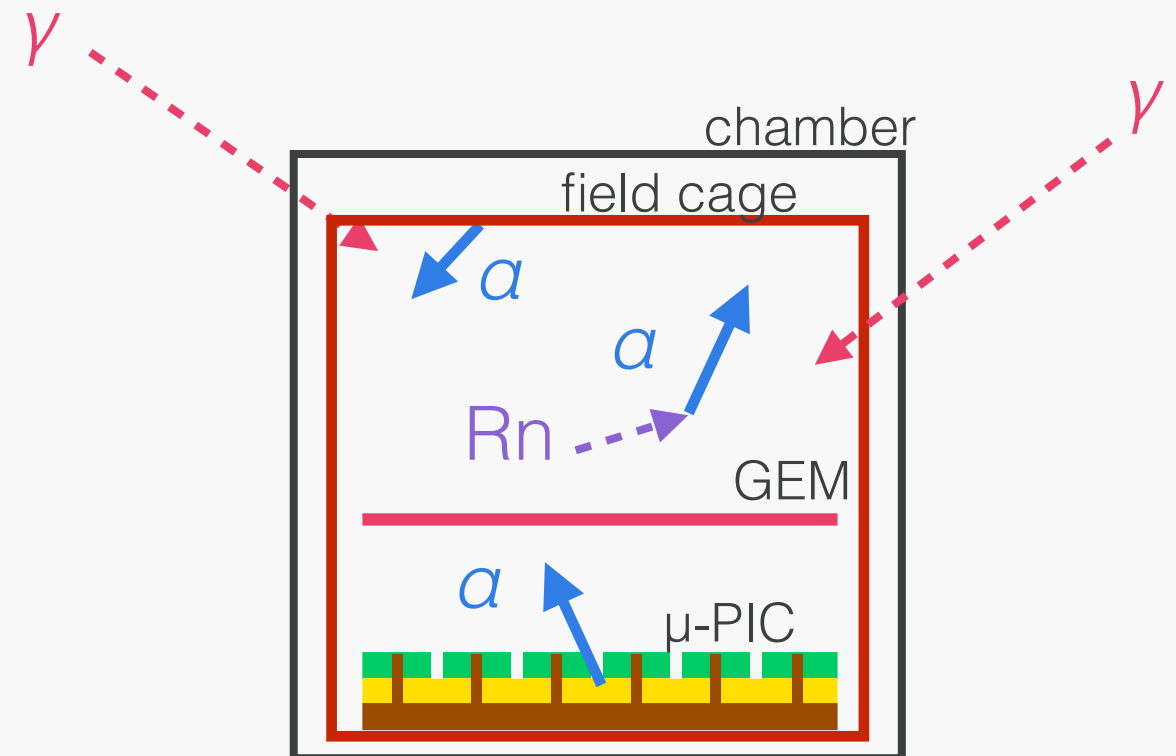
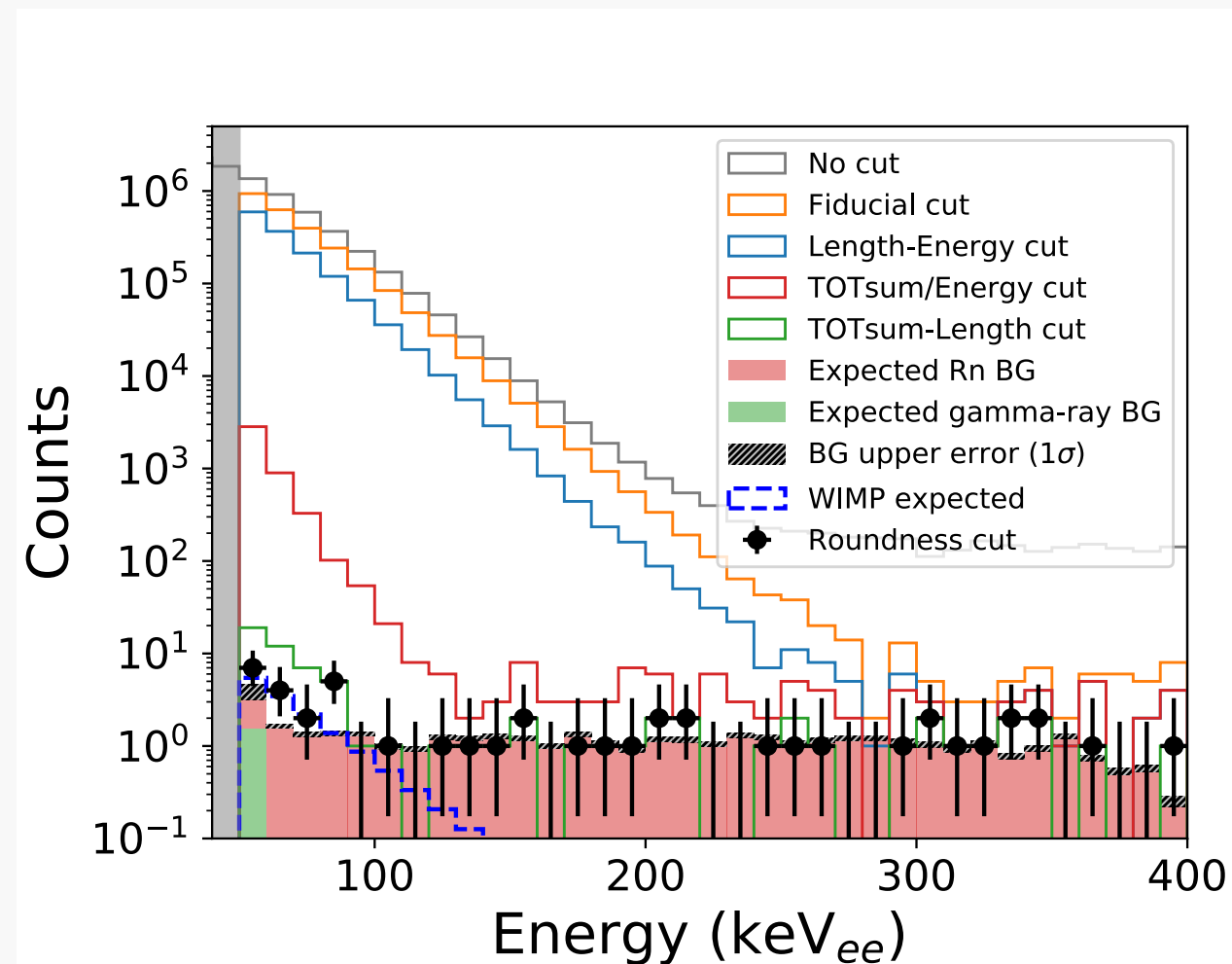
Strategy of BG rejection

- External BG

➔ Ambient gamma (and neutron): shielding

- Internal BG

➔ Radon emanation: “clean” detector development and gas purification



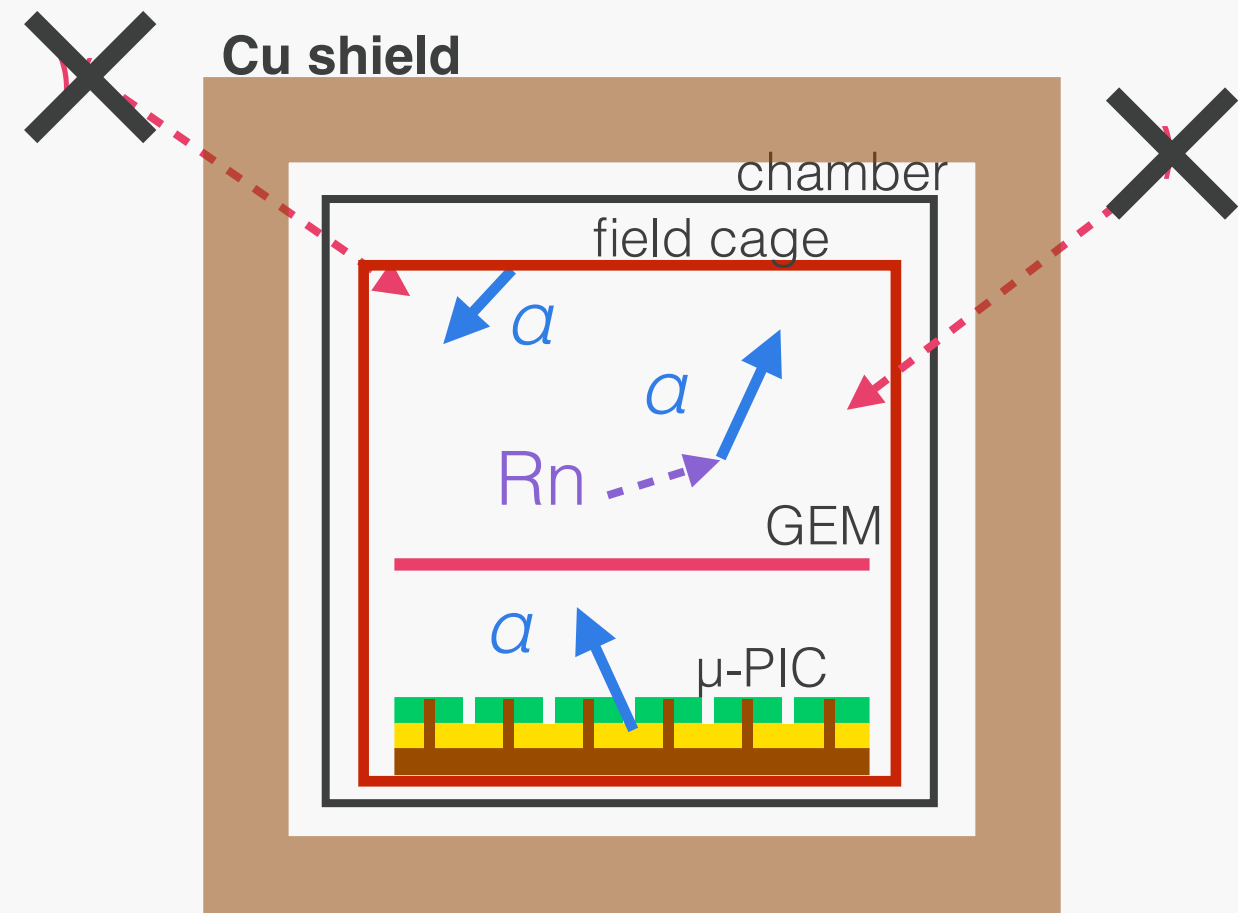
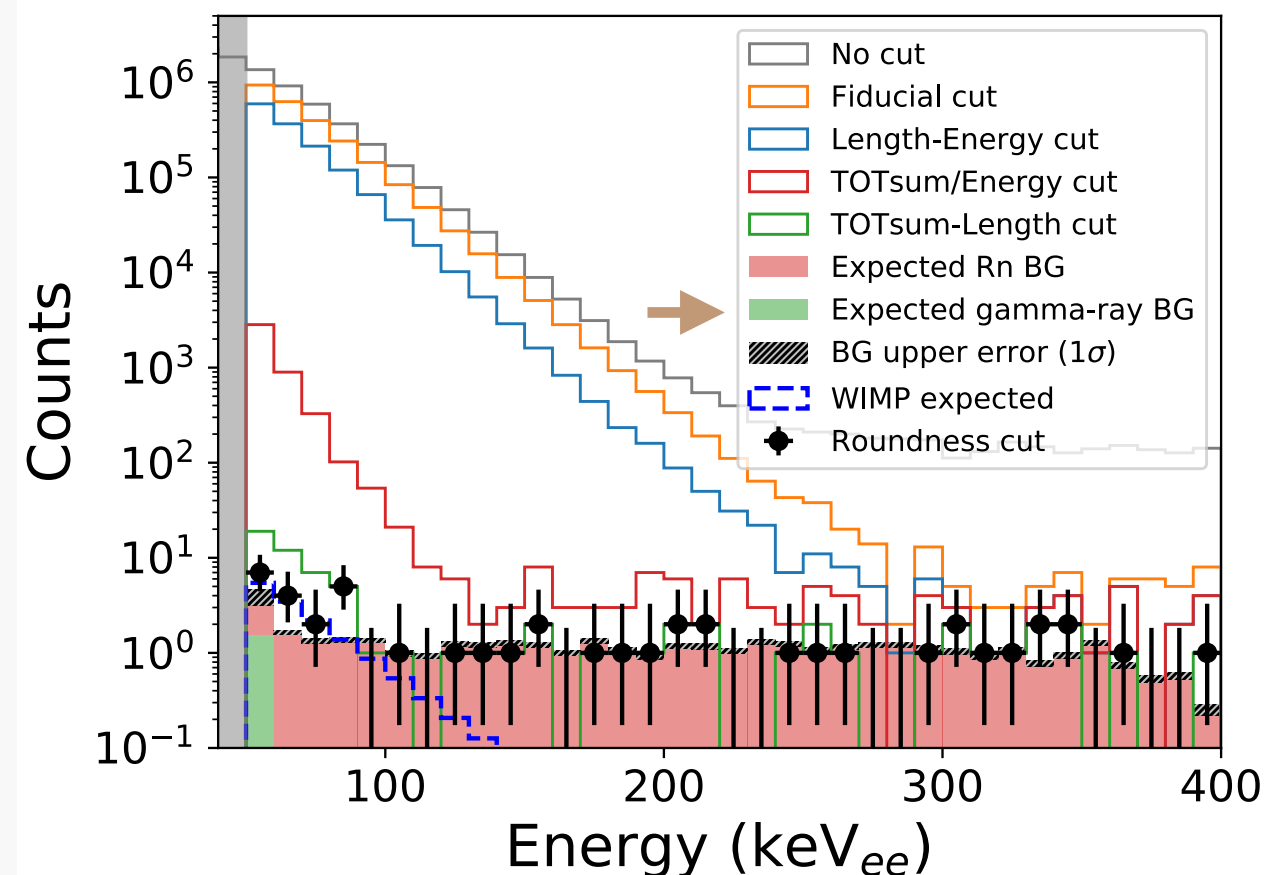
Strategy of BG rejection

- External BG

→ Ambient gamma (and neutron): shielding

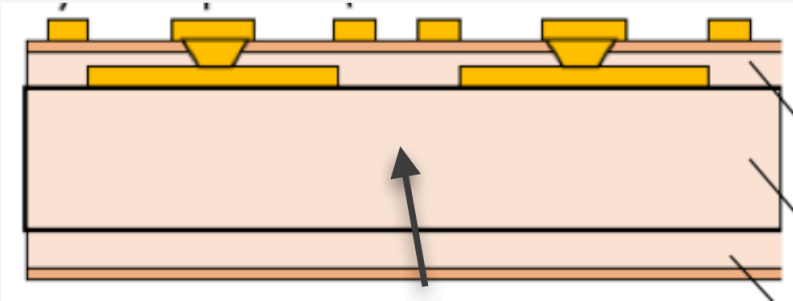
- Internal BG

→ Radon emanation: “clean” detector development and gas purification



Strategy of BG rejection

Low-BG μ -PIC (ver0: 2020, ver1: 2023)



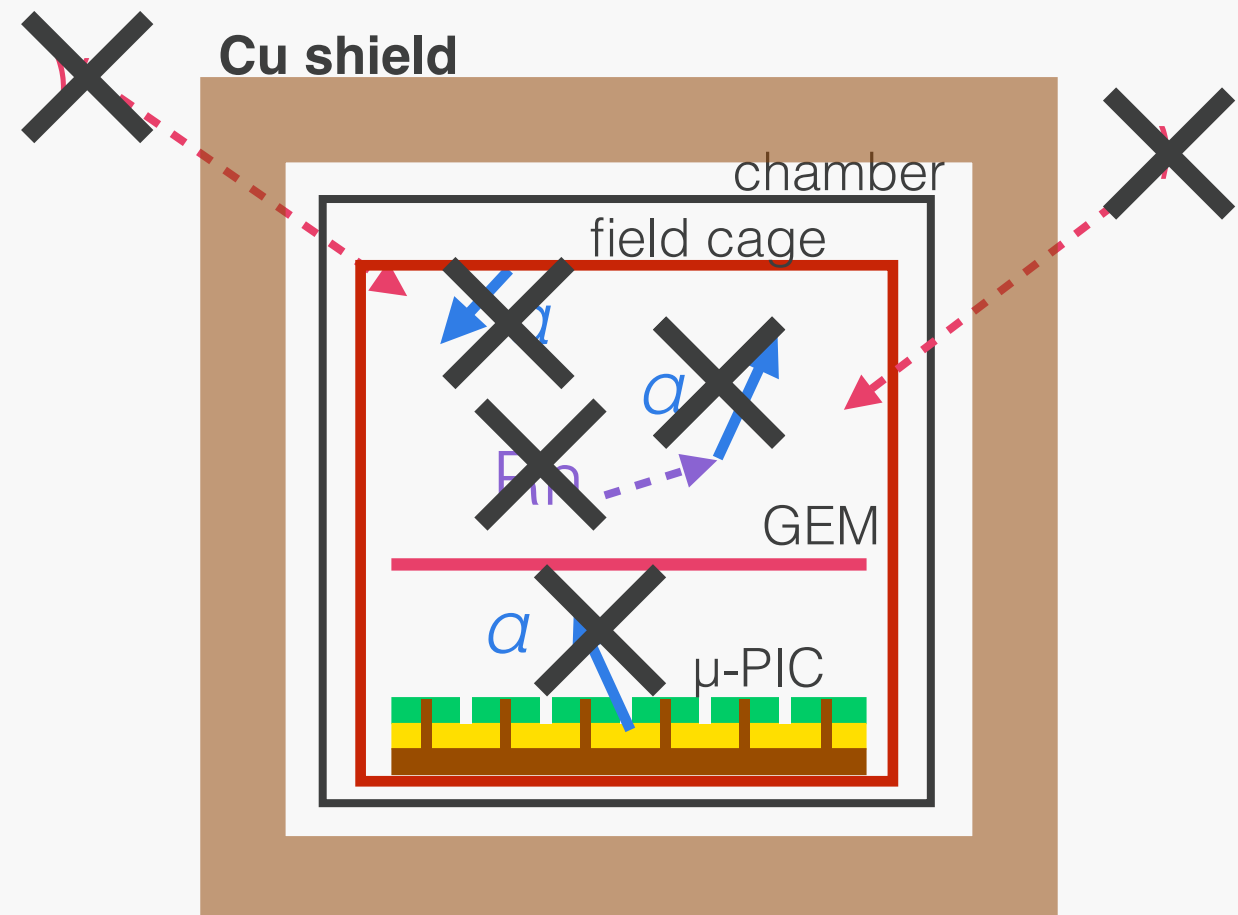
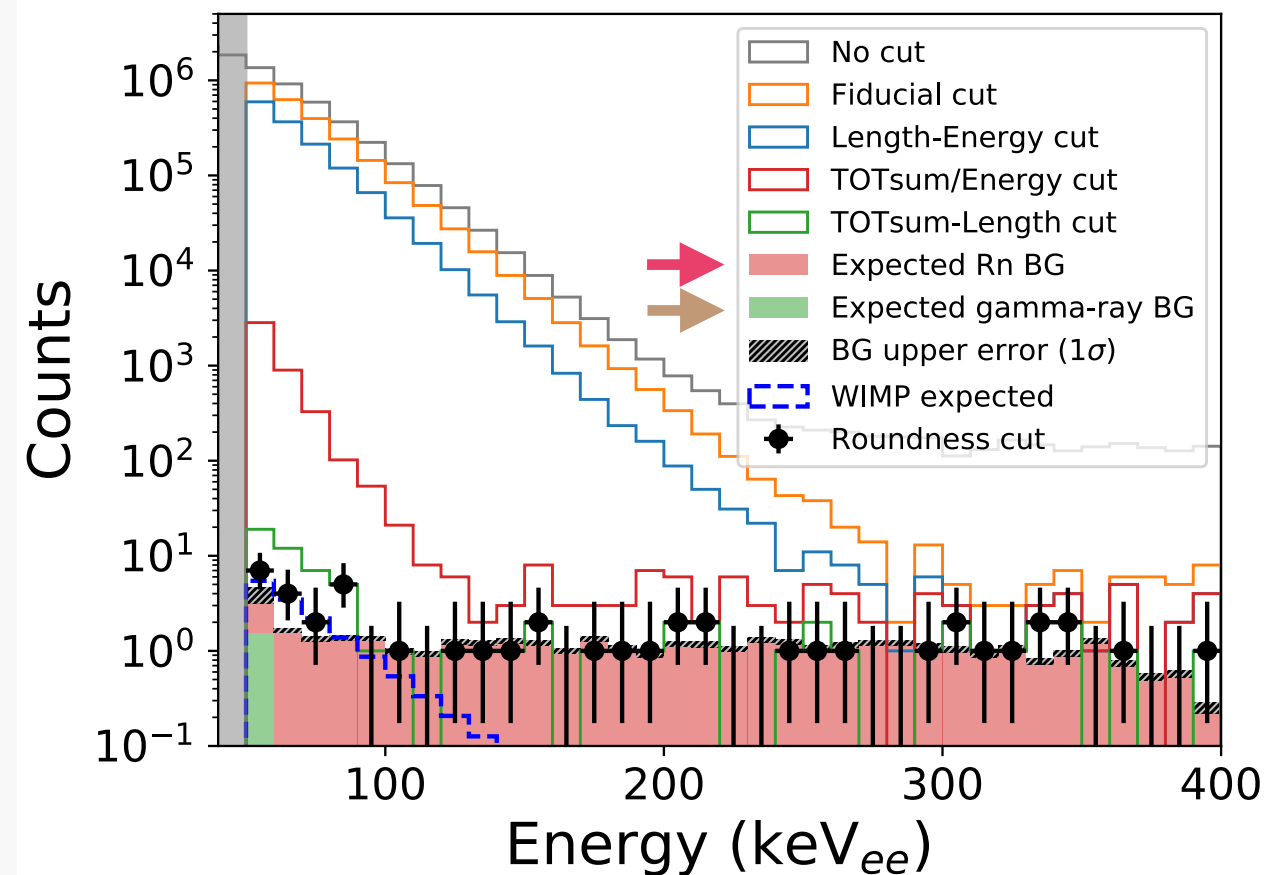
Quartz + Resin

- External

→ Ambient (shielding): shielding

- Internal

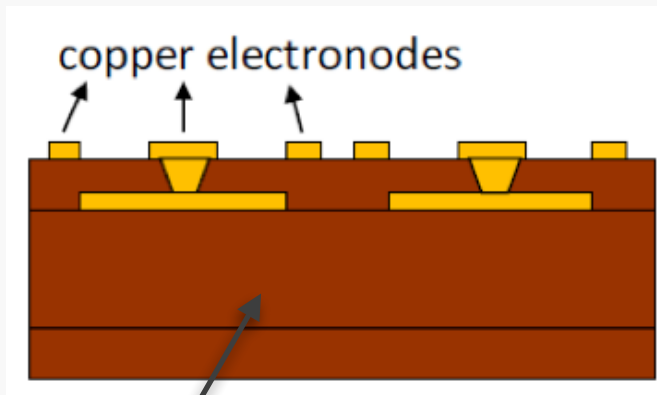
→ Radon emanation: clean detector development and gas purification



Radon BG reduction & Underground experiment

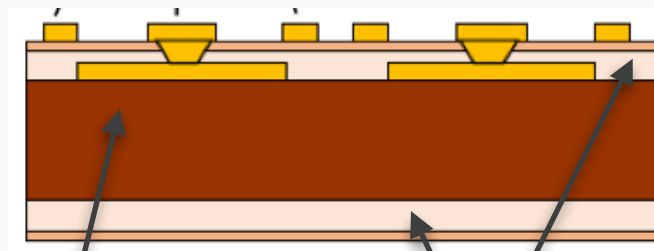
Clean detector development

Original design



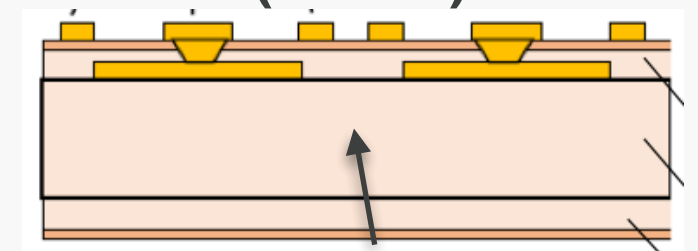
Polyimide
w/ glass cloth
(Rn contaminated)

Low **surface** alpha version
(LAPIC: 2017-)

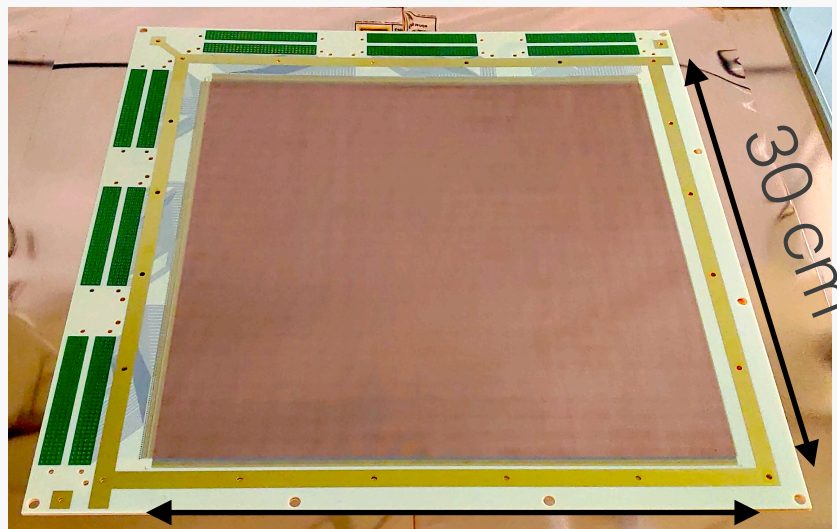


Polyimide
w/ glass cloth

Low-BG μ -PIC
ver.0: 2020-,
ver.1 (stable): 2023-



Quartz + Resin



30 cm

LBG μ -PIC
(DNP Inc.)

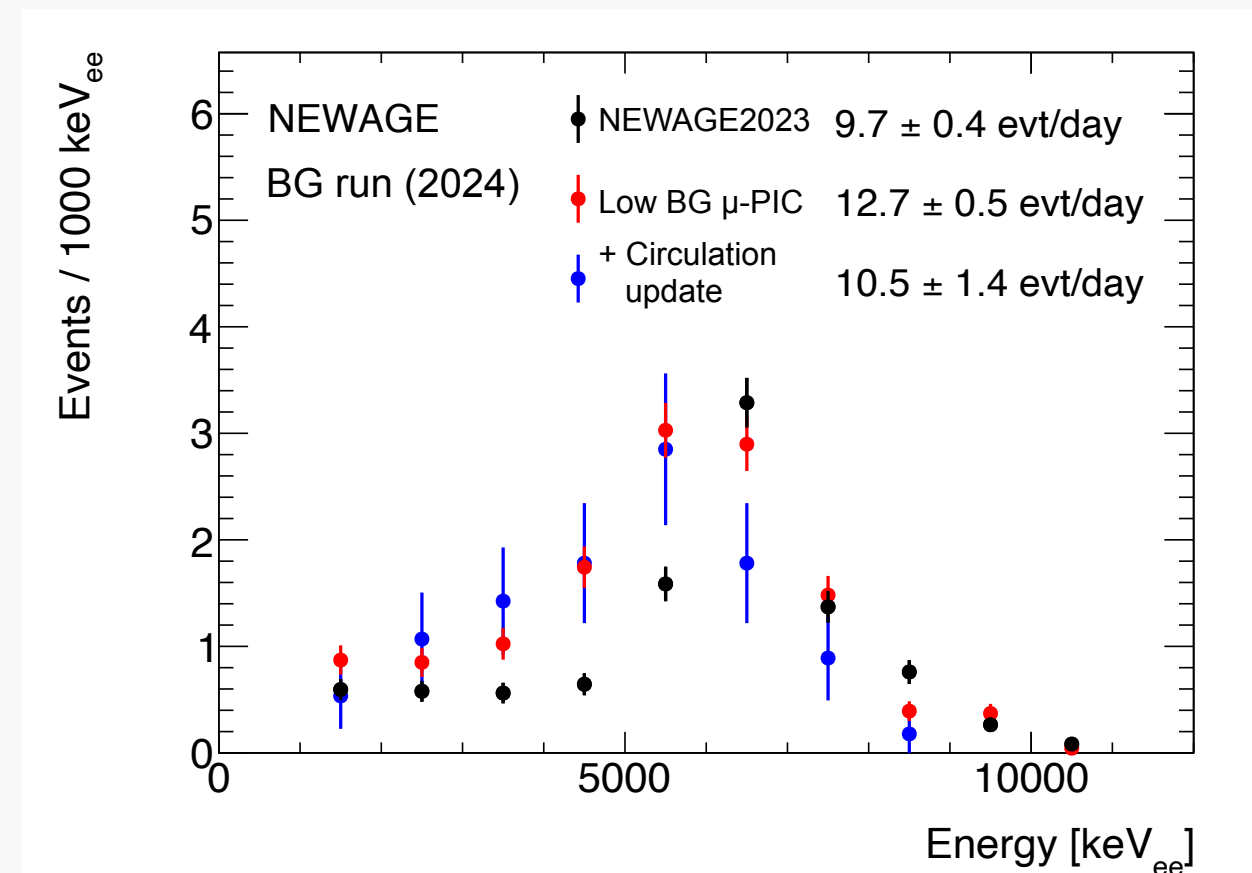
Radon emanation measurement:

LAPIC: **2.3 ± 0.5** [mBq / μ -PIC]

LBG μ -PIC: **<0.17** [mBq / μ -PIC]

(90% C.L.)

10

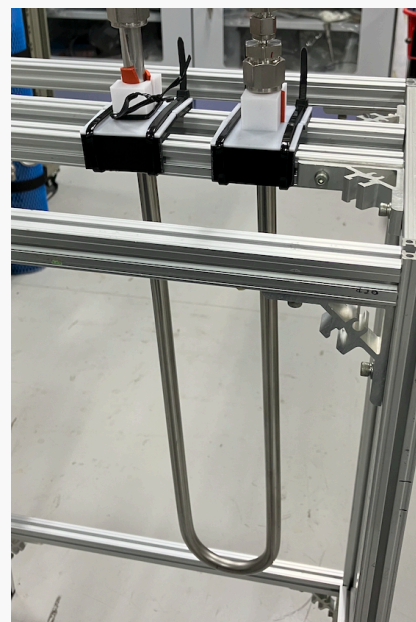
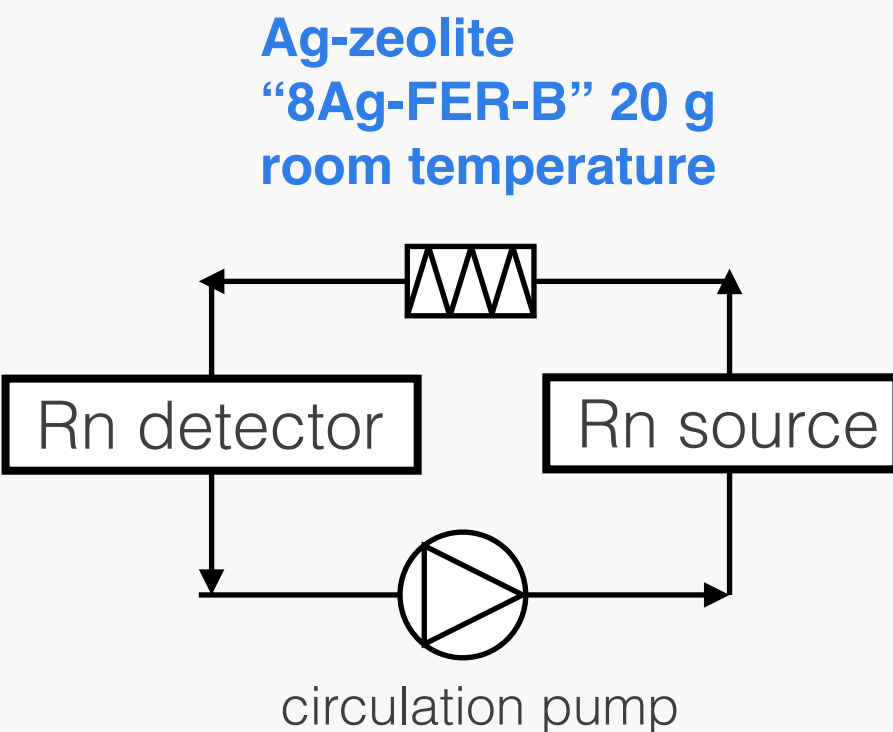


Not changed!?

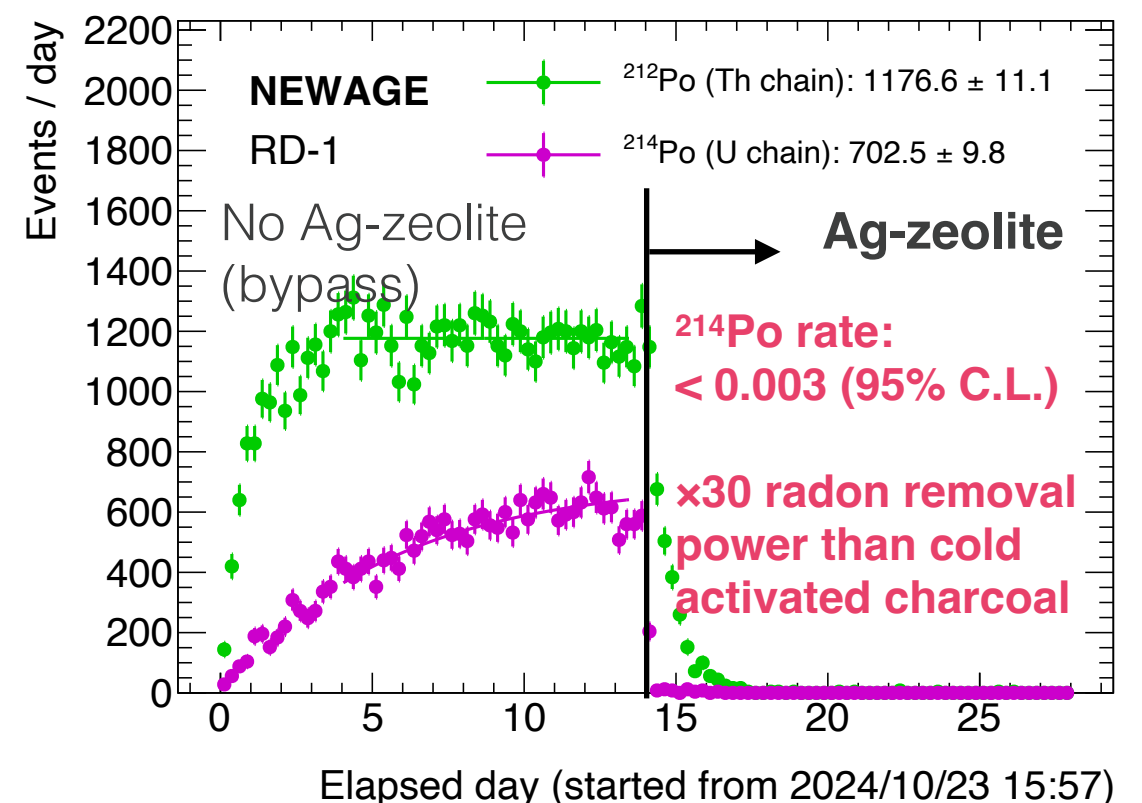
reported at IDM2024

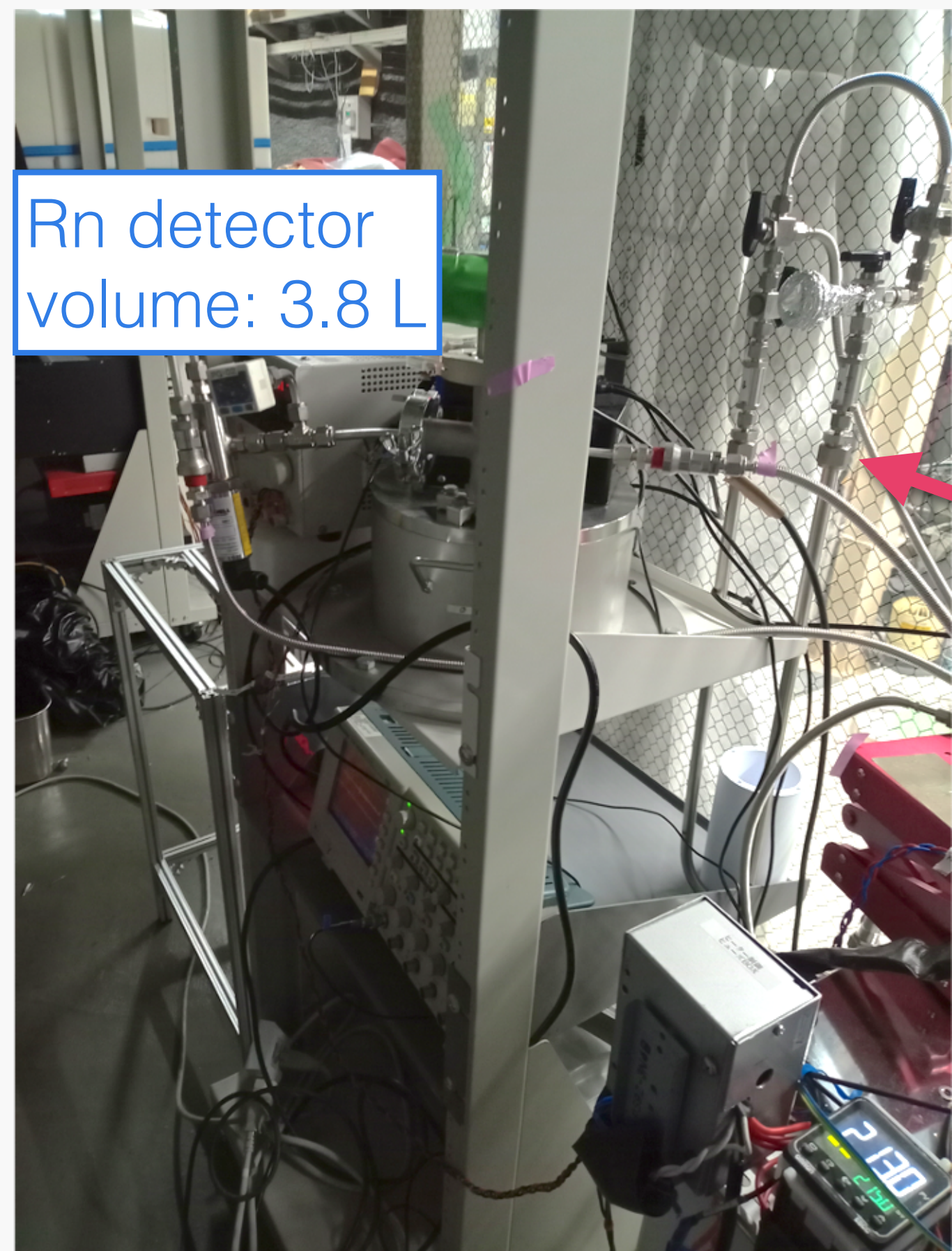
Ag-zeolite for Rn filtering

- “Clean” gas purification filter developments are discussed for a long time
 - ➔ especially for Rn reduction (JINST (2021) 16 P06024, JINST (2024) 19 P02004)
- SK/HK group reported a radon removal performance of silver-ion exchanged zeolite (“Ag-zeolite”)
 - ➔ PTEP 2025 (2025) 1, 013H01
 - Powerful radon removal performance even at room temperature
- NEWAGE group also tested to introduce an Ag-zeolite filter with low-pressure pure CF_4 gas



Ag-zeolite is filled in
1/2" stainless pipe

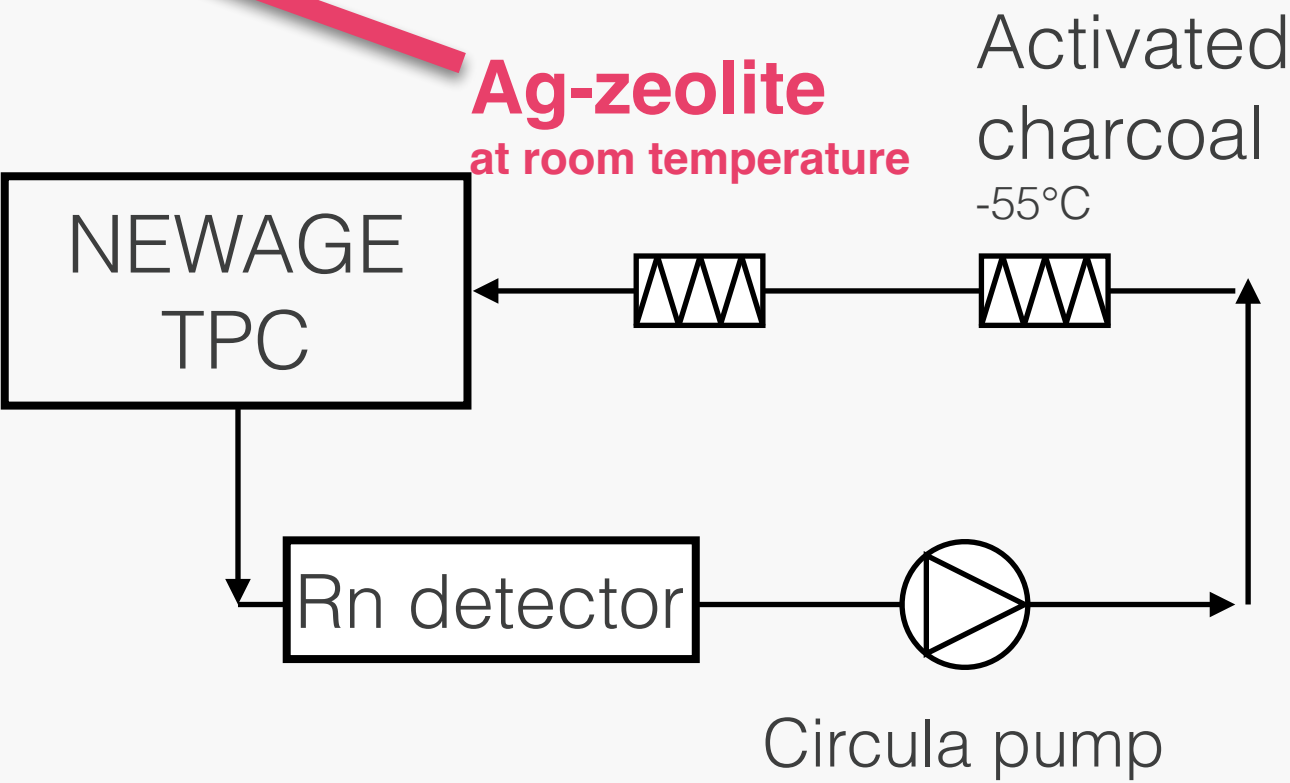




Rn detector
volume: 3.8 L

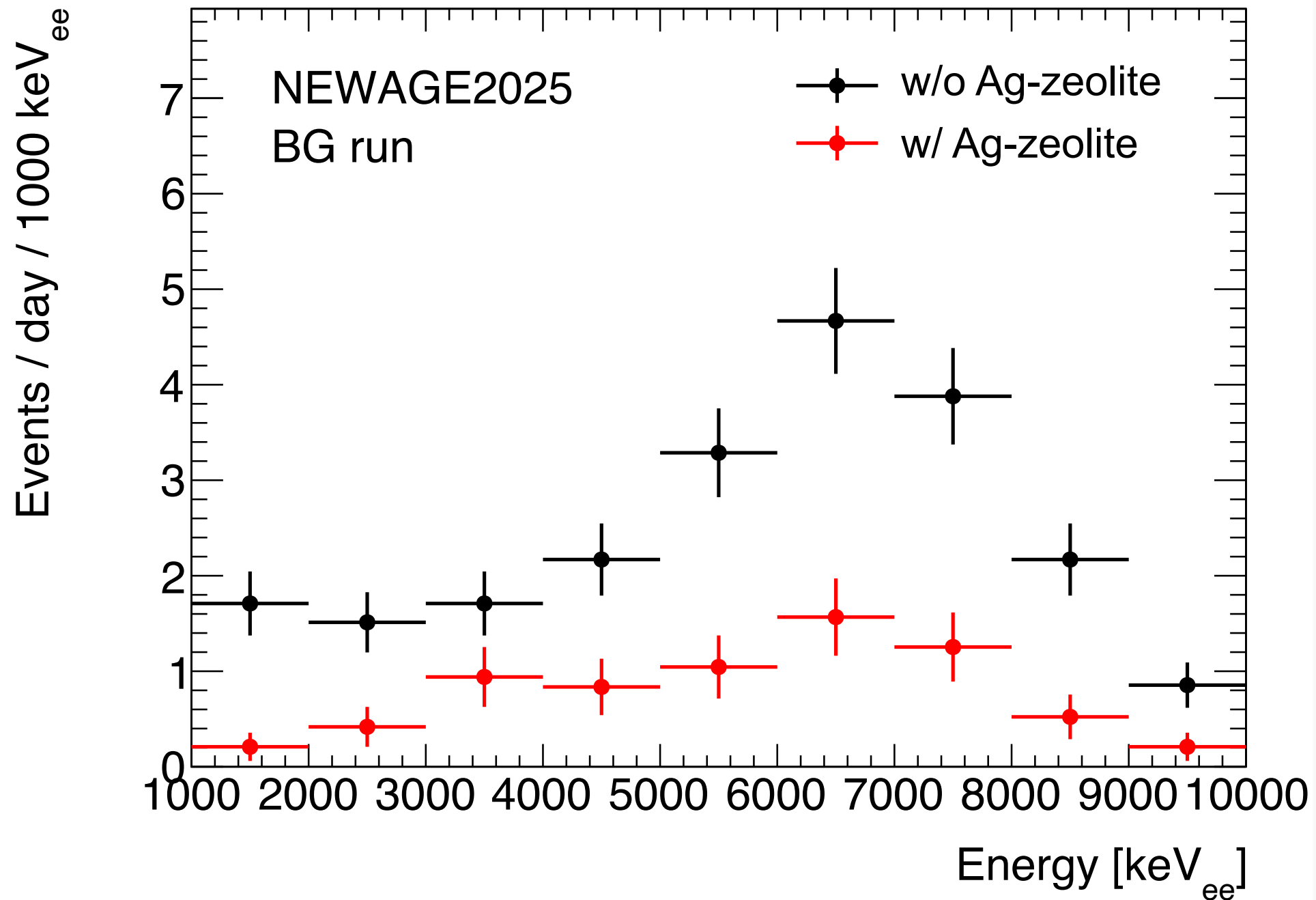
Ag-zeolite filter installed on July 2025

A part of NEWAGE circulation system
(in the Kamioka mine)



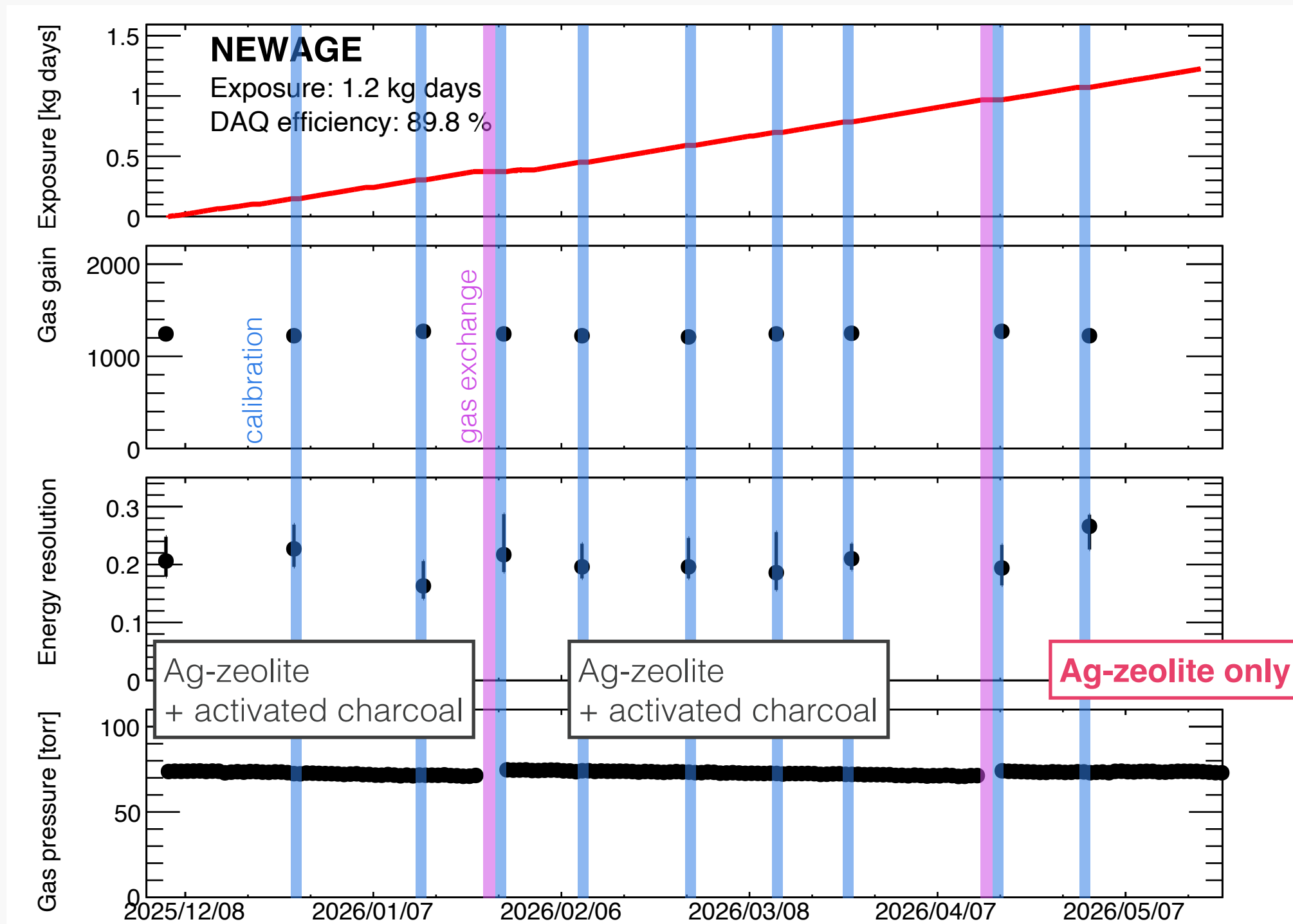
Ag-zeolite performance

- **Radon rate successfully reduced by 1/3**



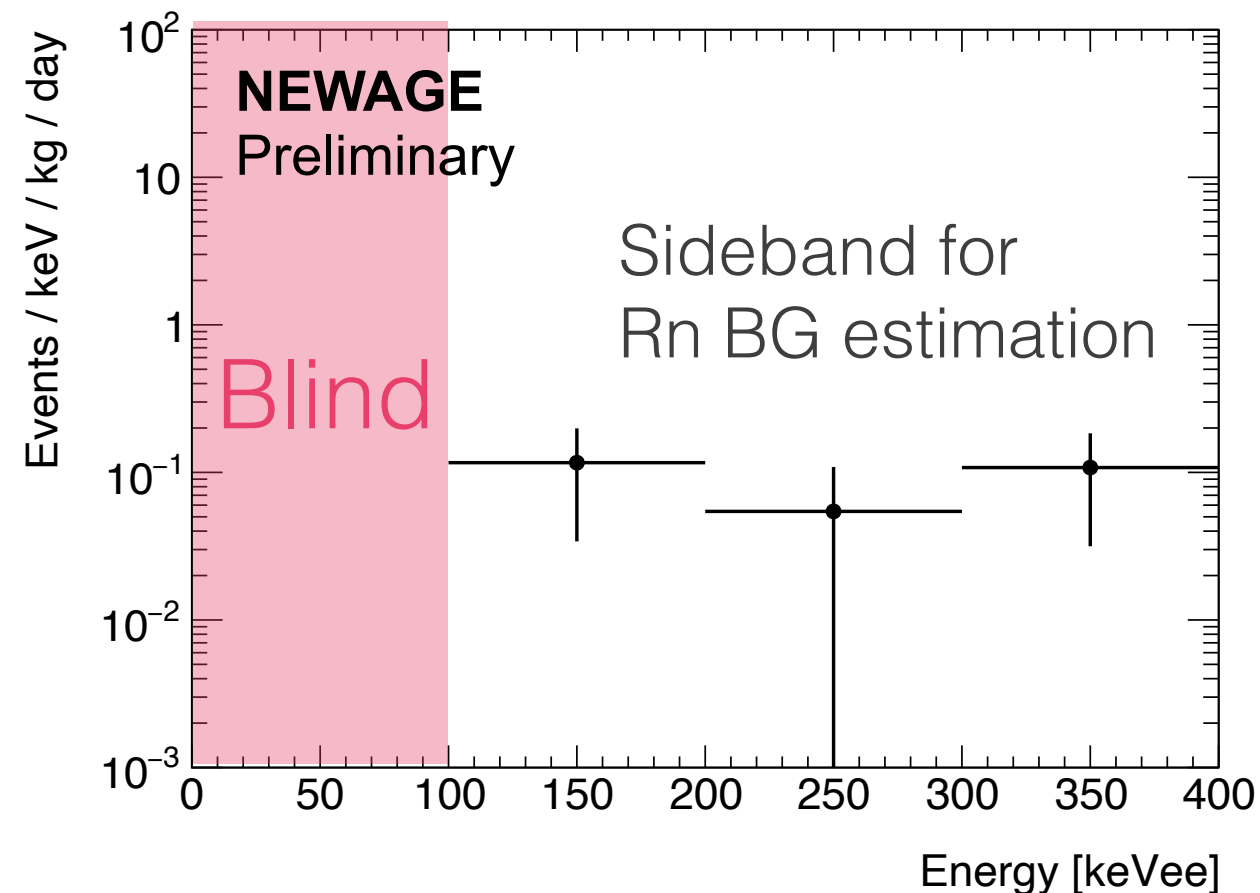
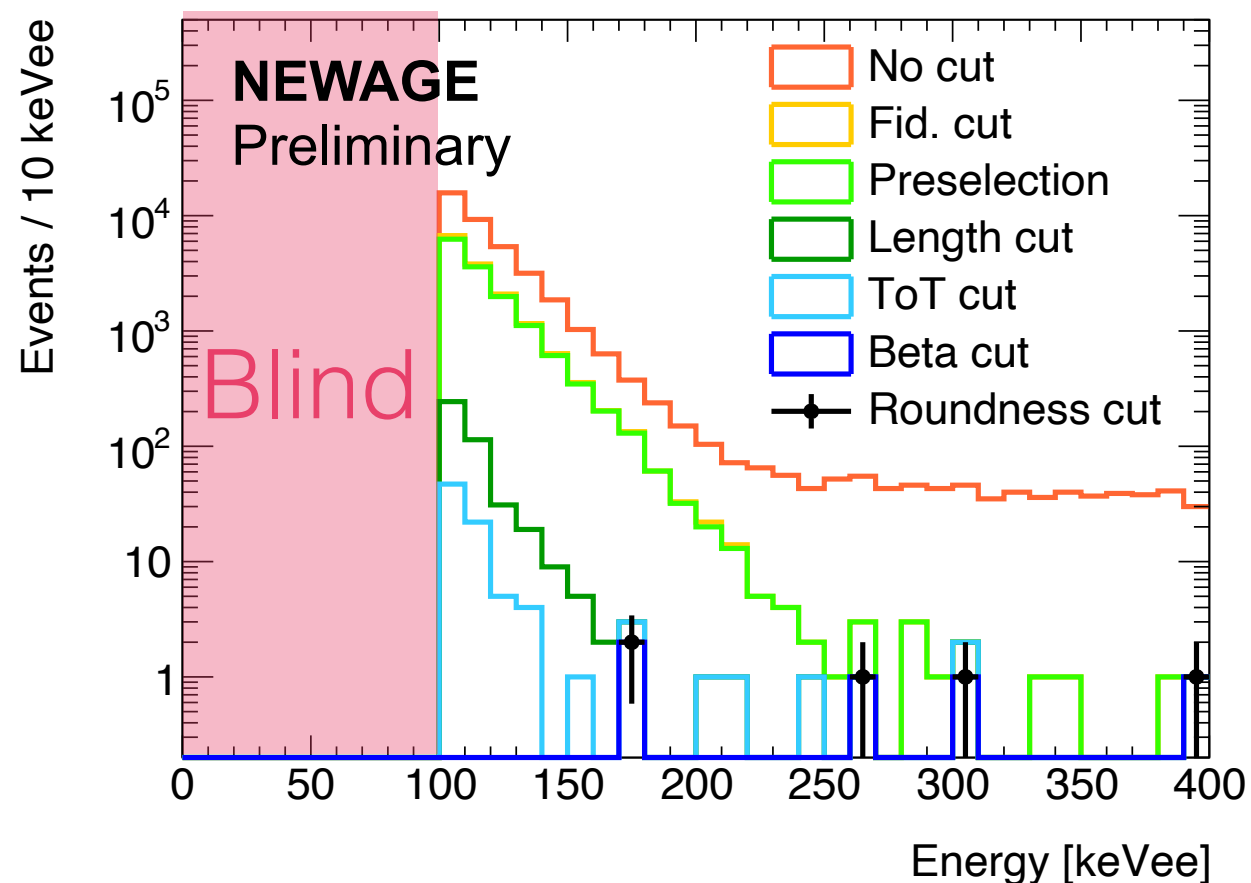
“NEWAGE 2025-2026”

- Measurement has started from Dec. 4 2025 after commissioning
 - ➔ ~ 1/3 exposure obtained comparing with the NEWAGE2023 analysis



Energy spectrum

- NEWAGE standard event selection applied (detail skipped) to estimate Rn BG
 - ➔ BG rejection performed by each selection
 - ➔ < 100 keVee region and directionality still blinded (analysis ongoing)
- Event rate considering detection and selection efficiencies keeps low
 - ➔ **Also 1/3 reduction after Ag-zeolite installation in the sideband (Rn BG-rich)**
 - **Consistent with ~ 6 MeV peak event reduction!**
- But remaining BG still limits the sensitivity → need to investigate the BG source more and more

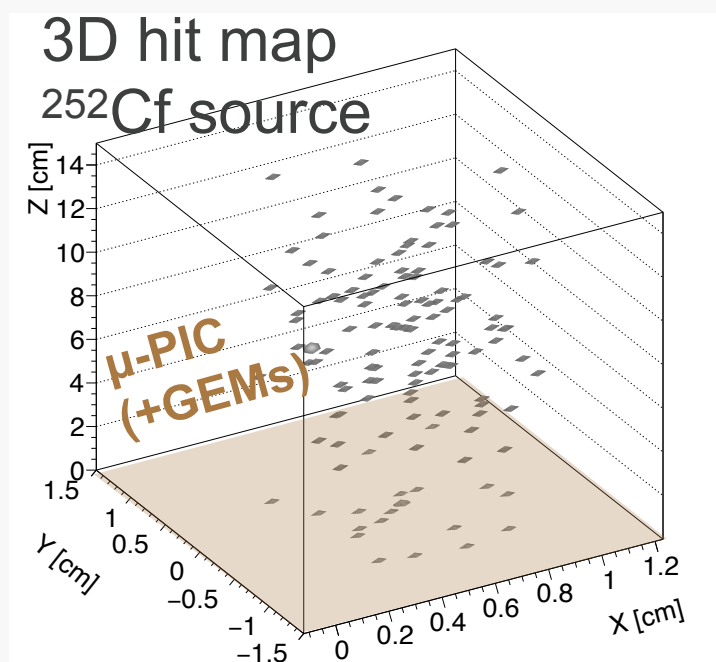
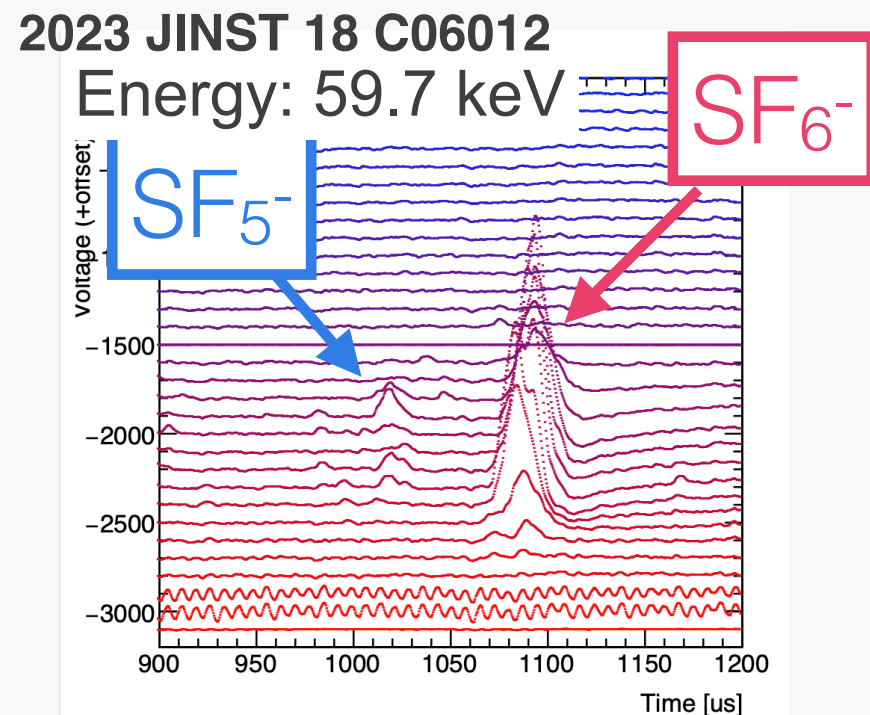
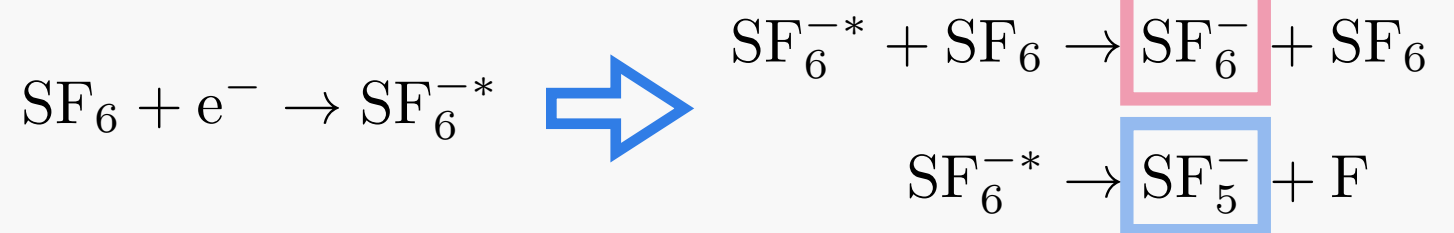
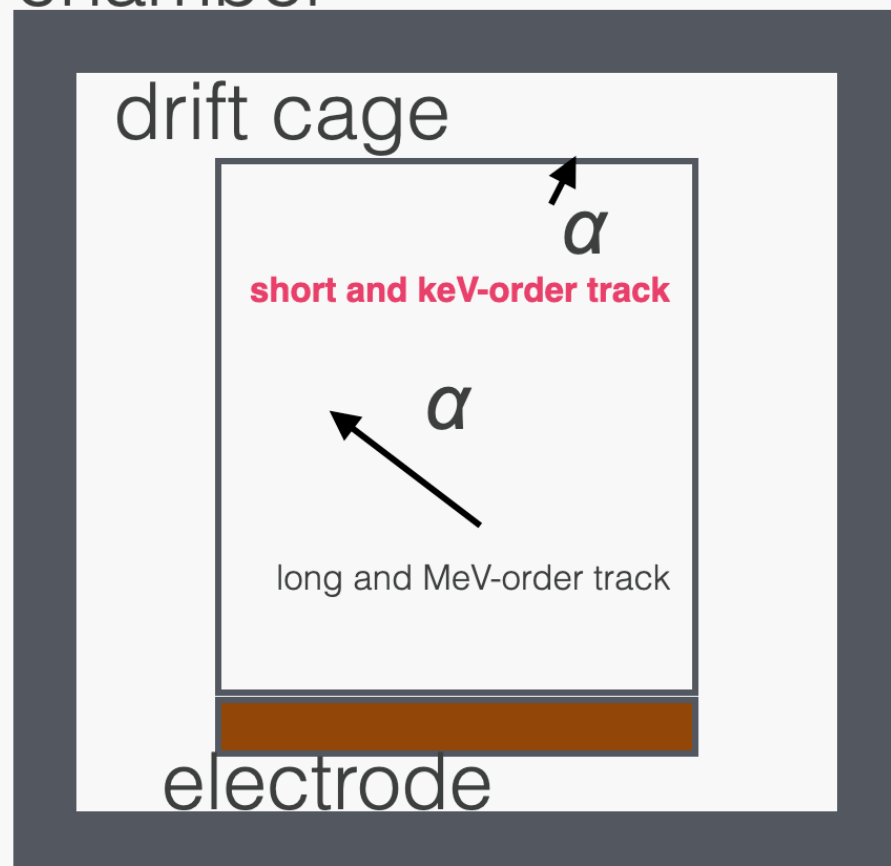


Future works and related activities

Further BG rejection

- Rn BG still remains and it limits the sensitivity
 - ➔ Alpha-rays stopped by a wall make short and keV-order track (mis-identified as NR)
 - keep finding the main Rn emanation source
 - development of Rn BG rejection method analytically
- “Negative-ion gas” such as SF₆ may allow absolute 3D position reconstruction

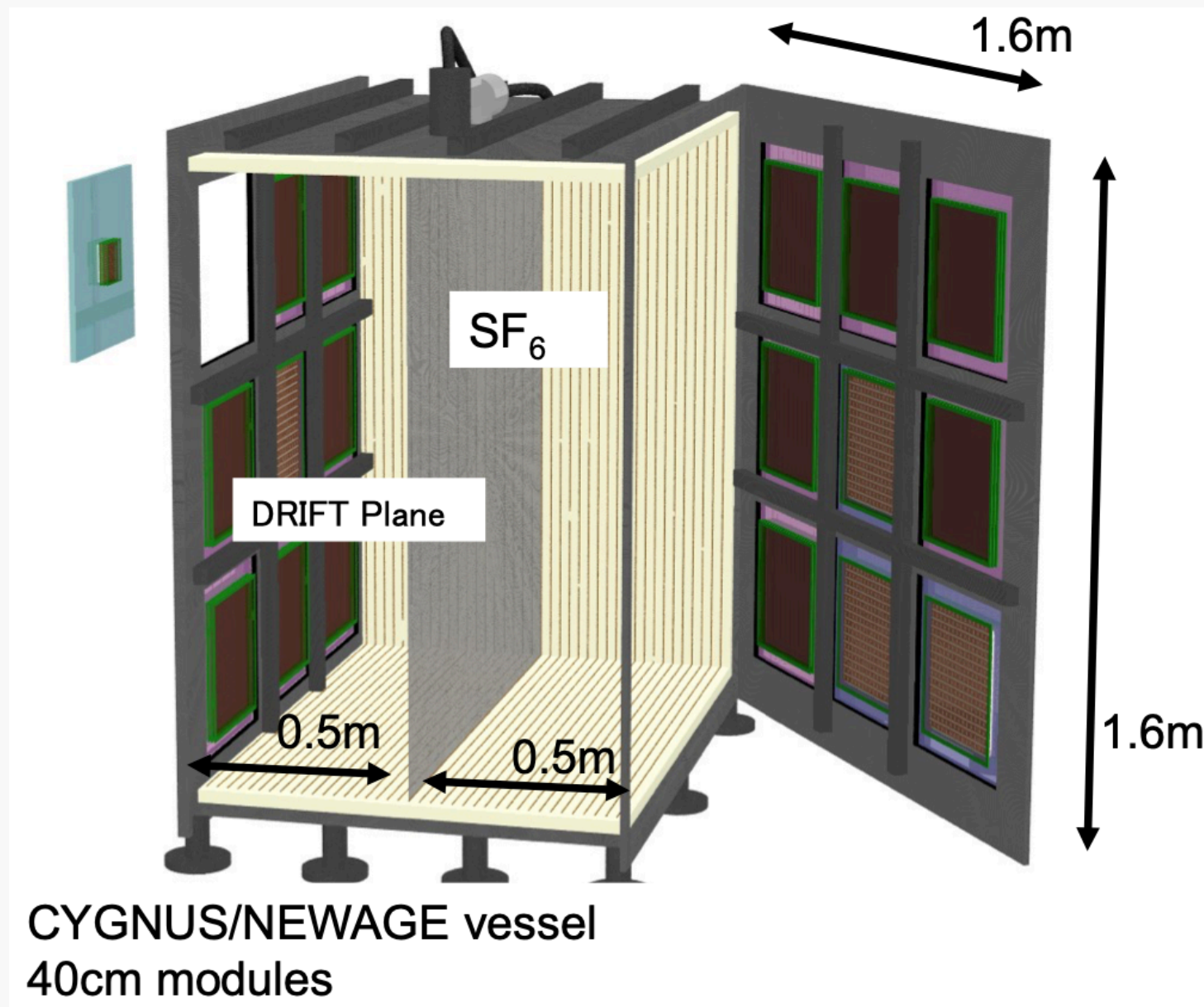
chamber



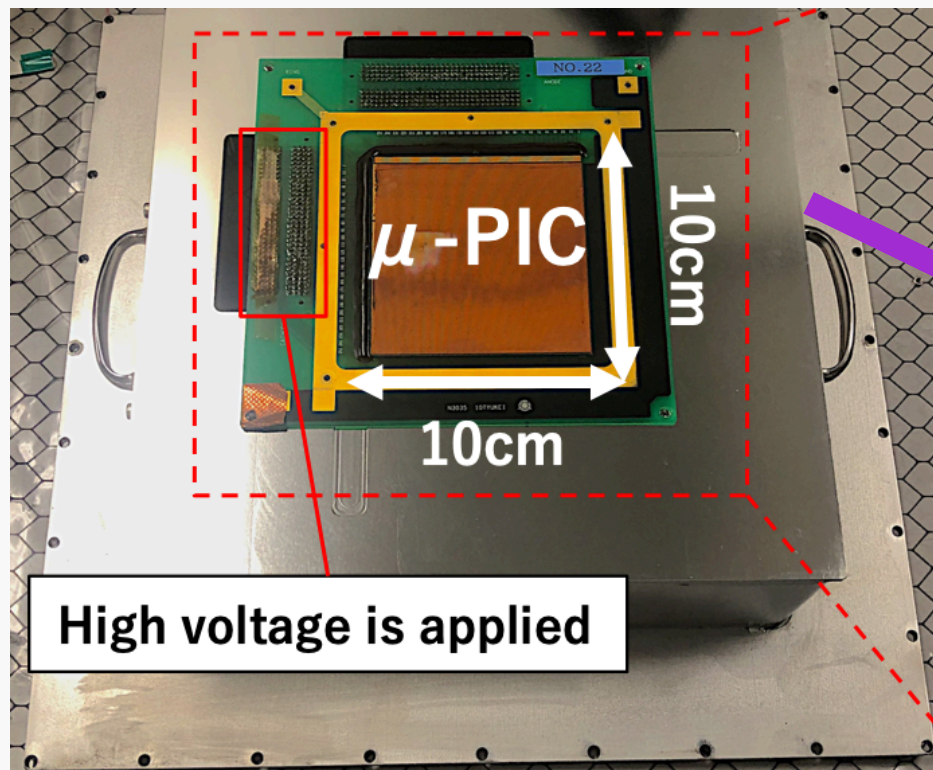
Large volume gaseous TPC: C/N-1.0

- Modulated chamber ($\sim 1 \text{ m}^3$) : 18 module windows are available
 - ➔ Enables to install the conventional NEWAGE detector ($30 \times 30 \text{ cm}^2$ fiducial area)
 - ➔ We can accept detectors from any other groups: your “clean” detectors are candidates!

Ryota will present the status of C/N-1.0 commissioning!

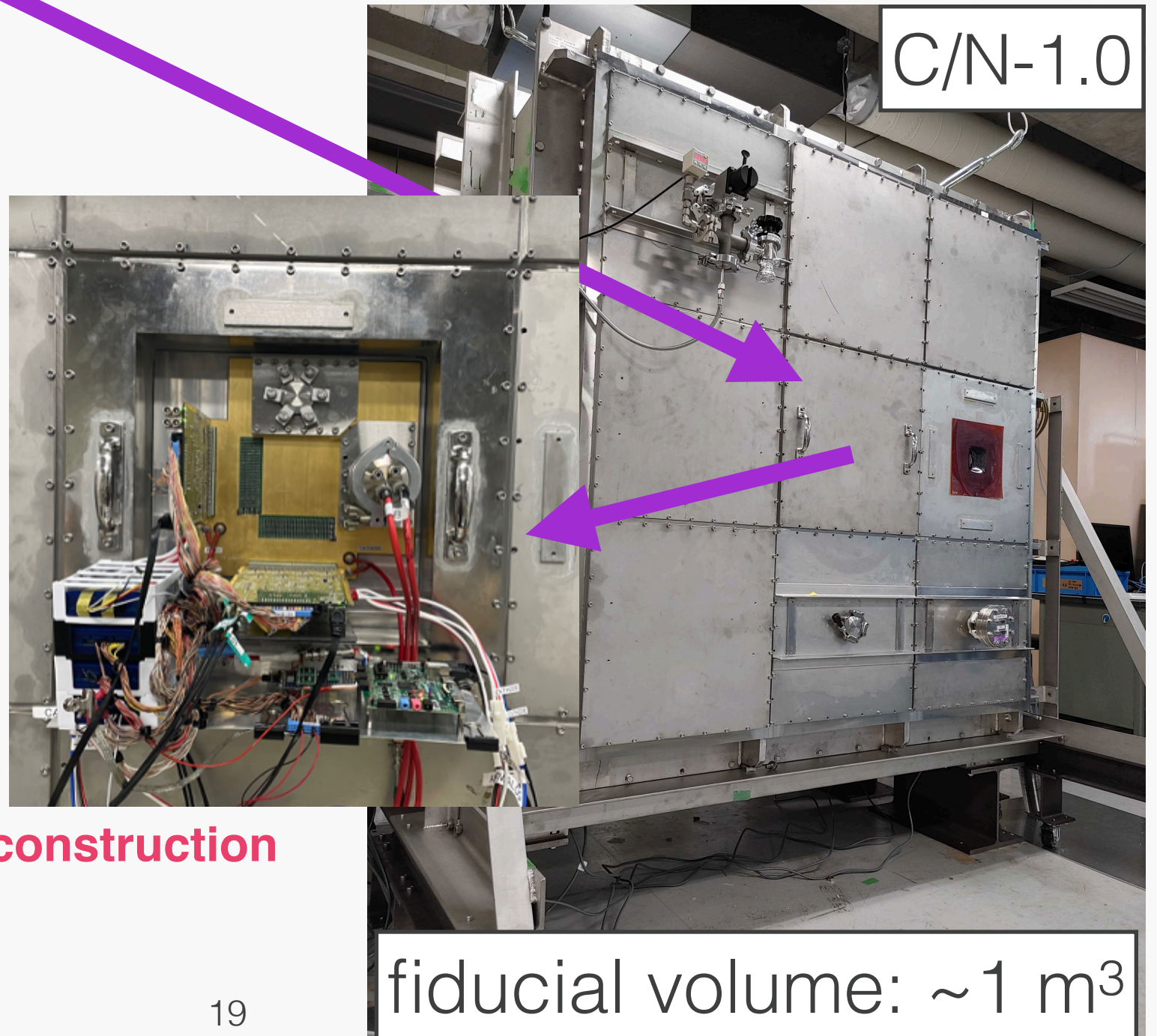


Initial position-sensitive module demonstration

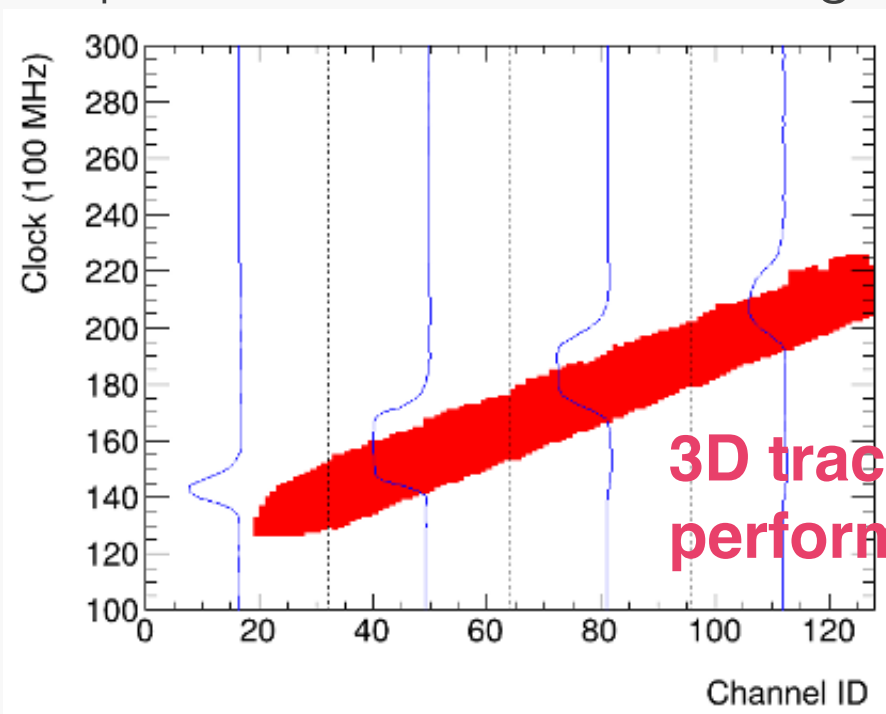


- The same detector system as NEWAGE's one
 - ➔ small size detector for the first trial

C/N-1.0

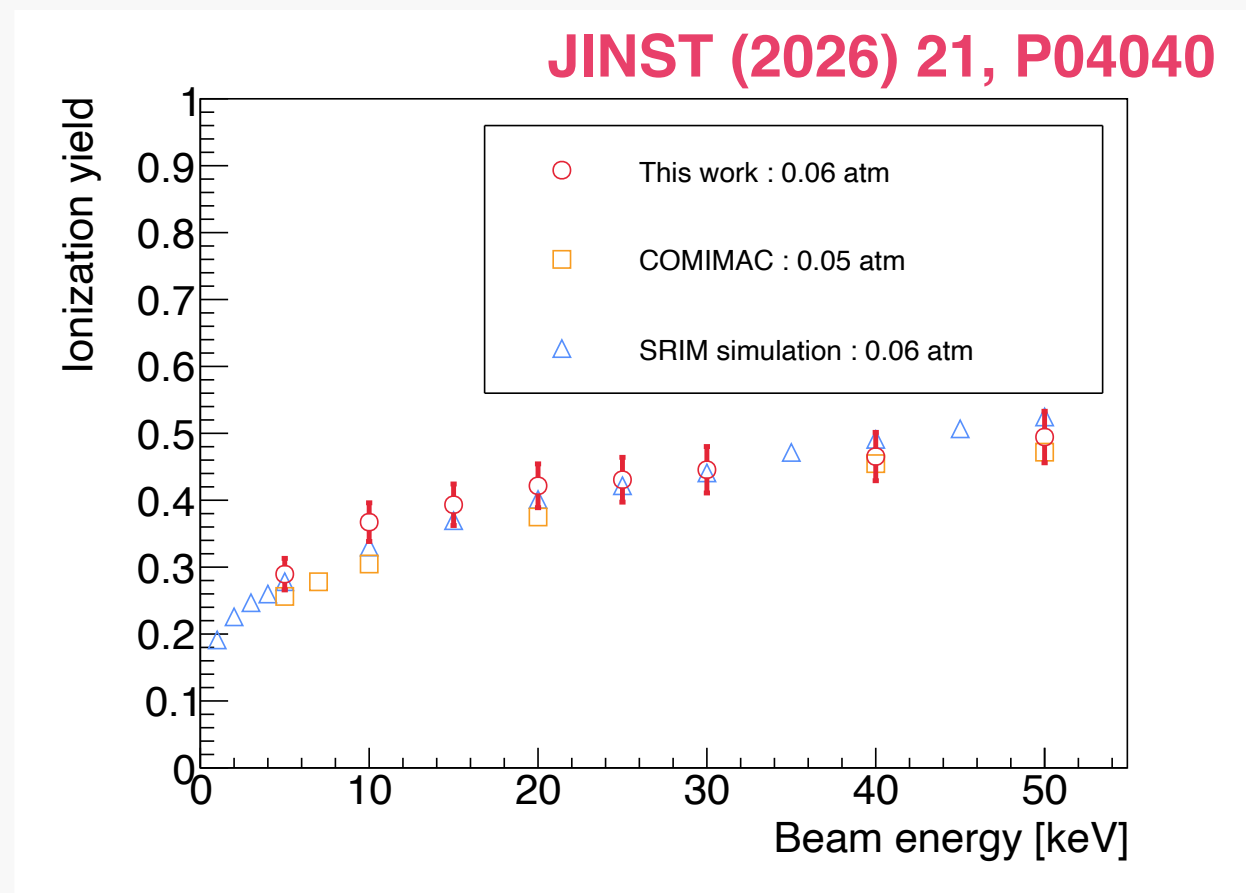
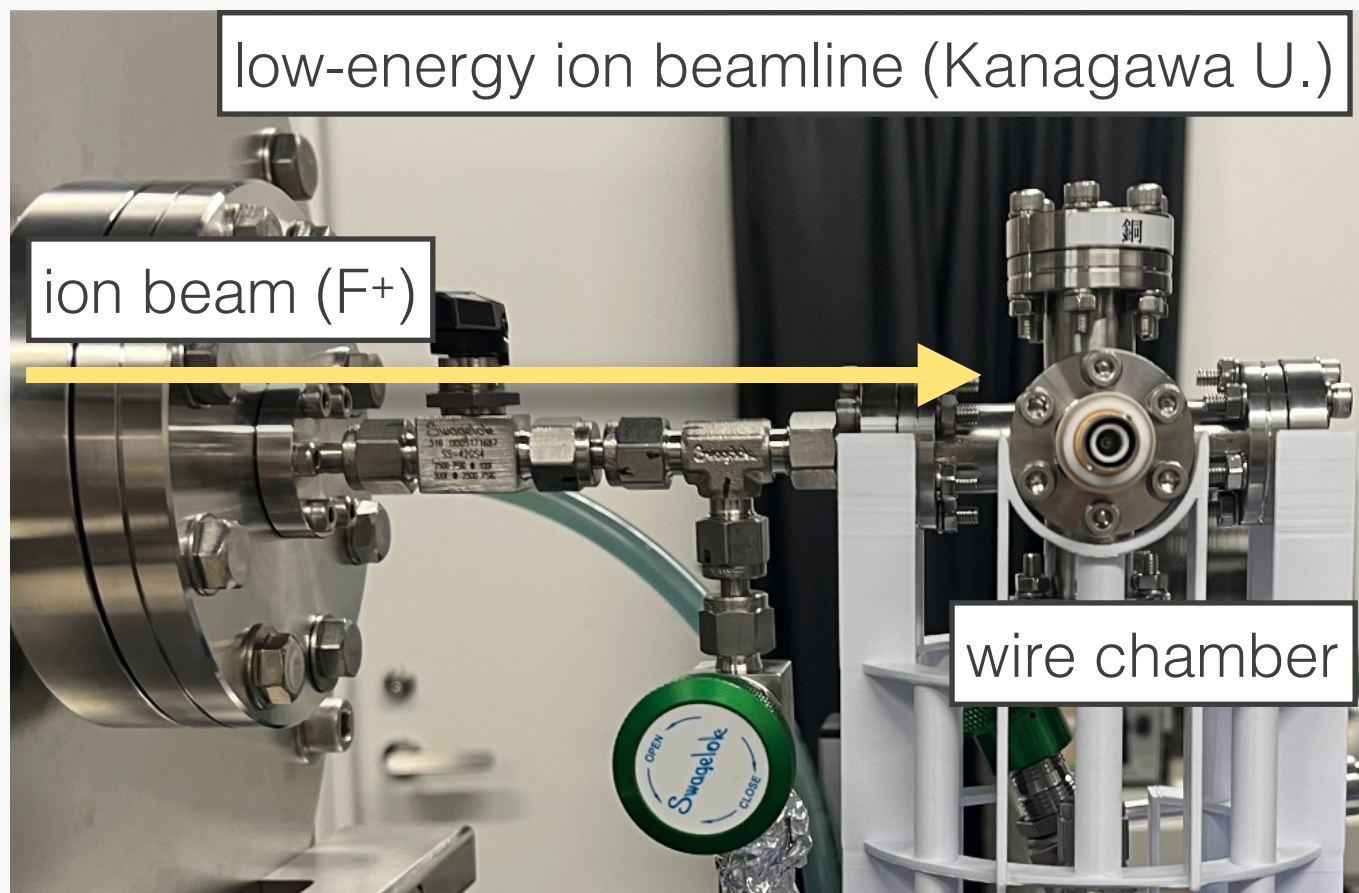


- Compact DAQ system to prevent interference to neighbors

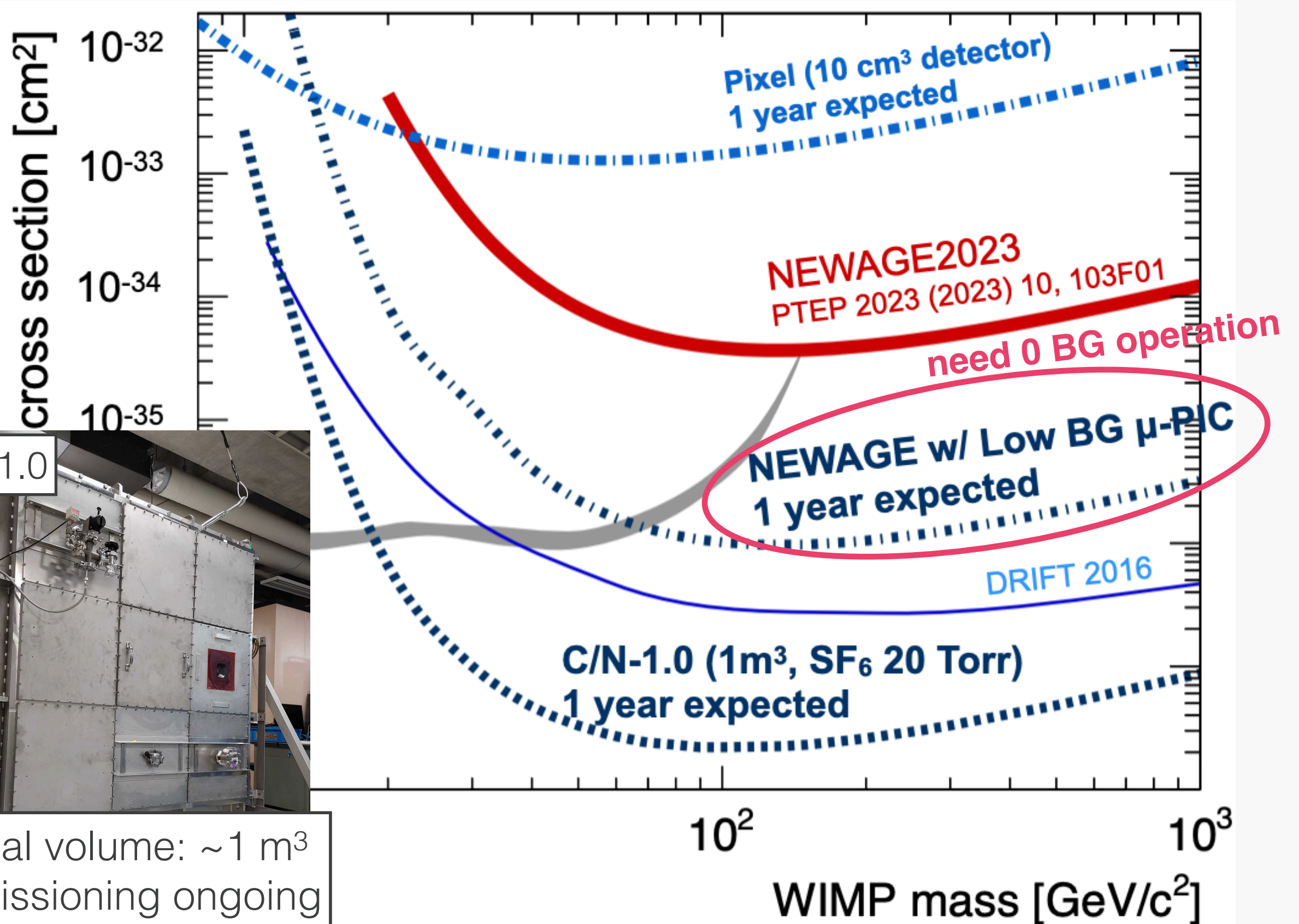


Ionization quenching factor measurement

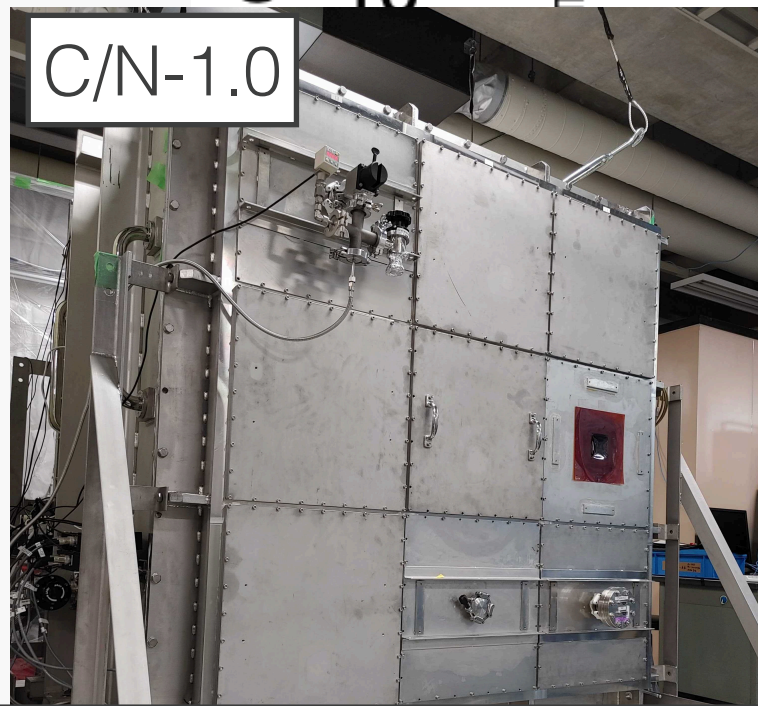
- Precise energy measurement is important as well as the directionality
 - Low-energy ion beam test was performed at 5-200 kV acceleration facility at Kanagawa U.
- 5 - 50 keV fluorine ions were injected to single-wire proportional chamber
 - filled with 0.06 atm CF_4 gas (assuming low-pressure NEWAGE operation)
- Result is consistent with COMIMAC and SRIM
 - Good demonstration of low-energy ion injection into gas detector in Japan!



Prospects



C/N-1.0



fiducial volume: ~ 1 m³
commissioning ongoing
@Kobe U.

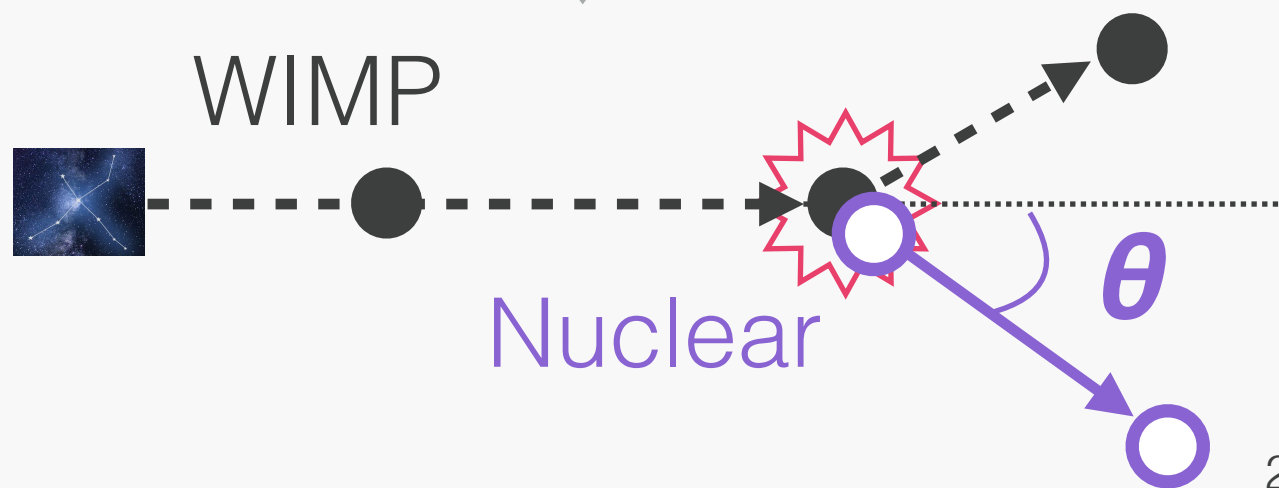
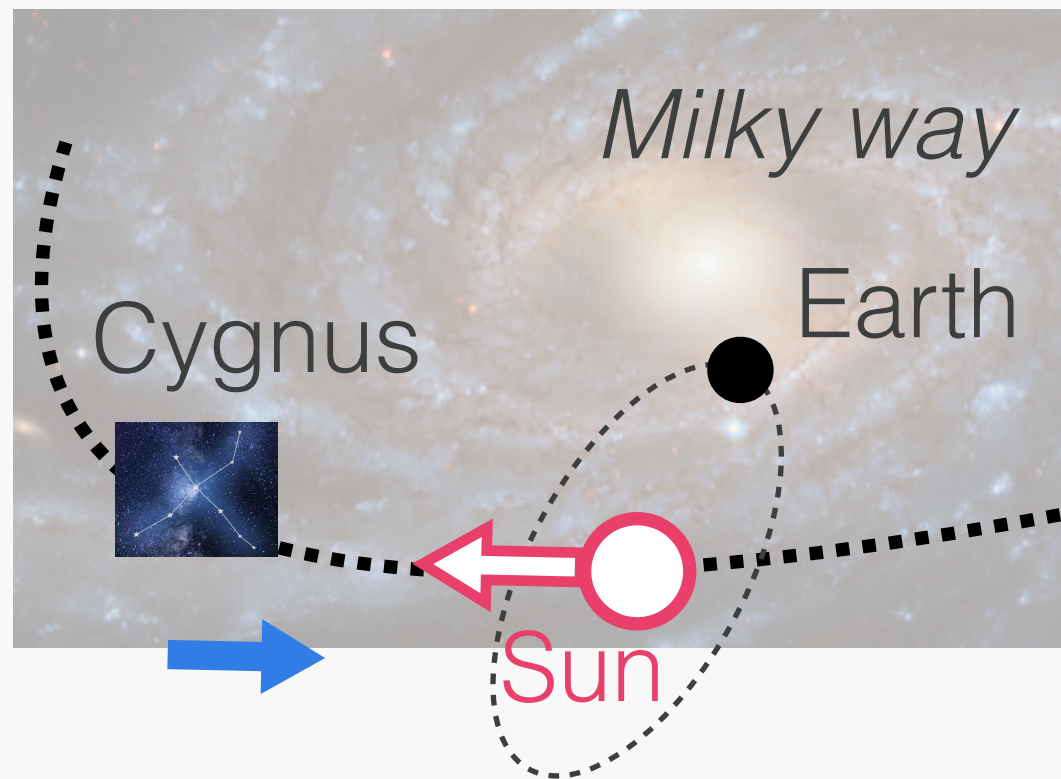
Summary

- NEWAGE is a direction-sensitive direct DM search experiment
 - ➔ Upper limit reached to the DAMA region
- Background reduction campaign is ongoing
 - ➔ Ag-zeolite successfully works as Rn filtering and reduced BG to $\sim 1/3$
 - ➔ Underground experiment stably ongoing
 - ➔ Further BG rejection studies are also in progress
- 1 m³ scale modular gaseous TPC commissioning started with a position-sensitive module
 - ➔ 3D track reconstruction performed → surface experiment ongoing!

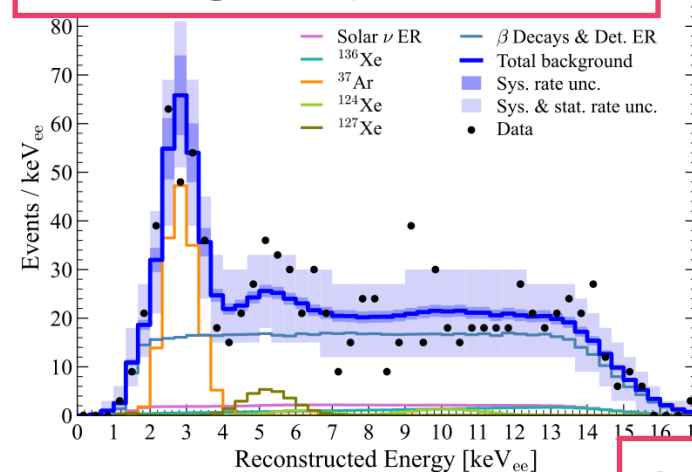
Backup

Direct dark matter (WIMP) searches

- Direct search = SM particle recoil detection
 - ➔ Its kinematics depends on the motion of the Earth, the sun, and the Milky Way Galaxy

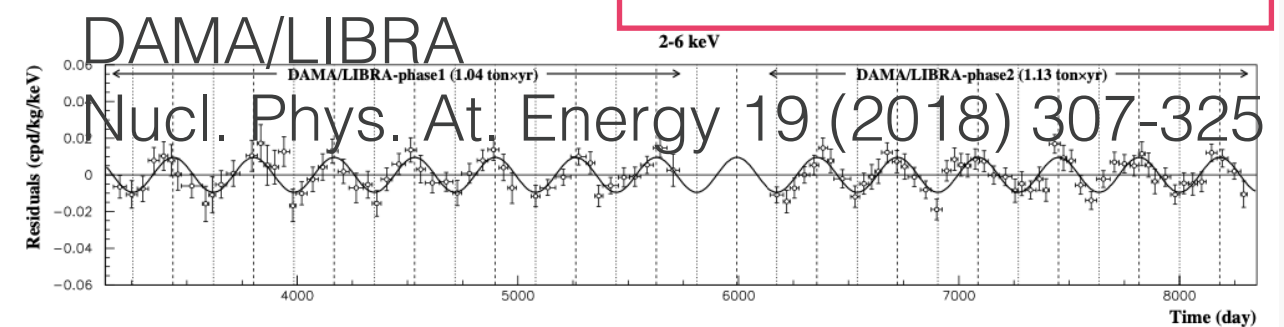


Energy spectrum



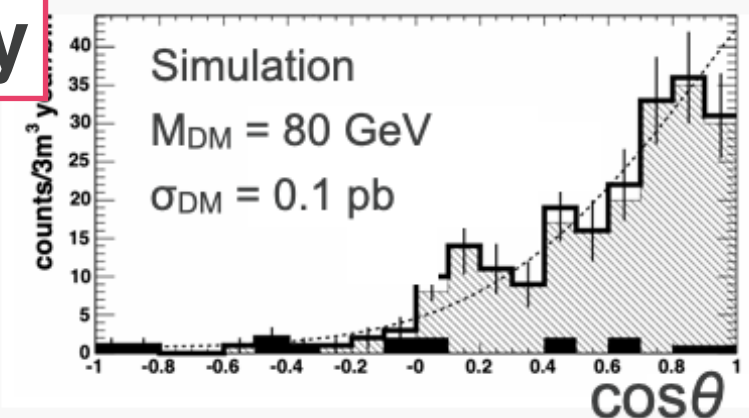
LZ: arXiv:2207.03764

Annual modulation



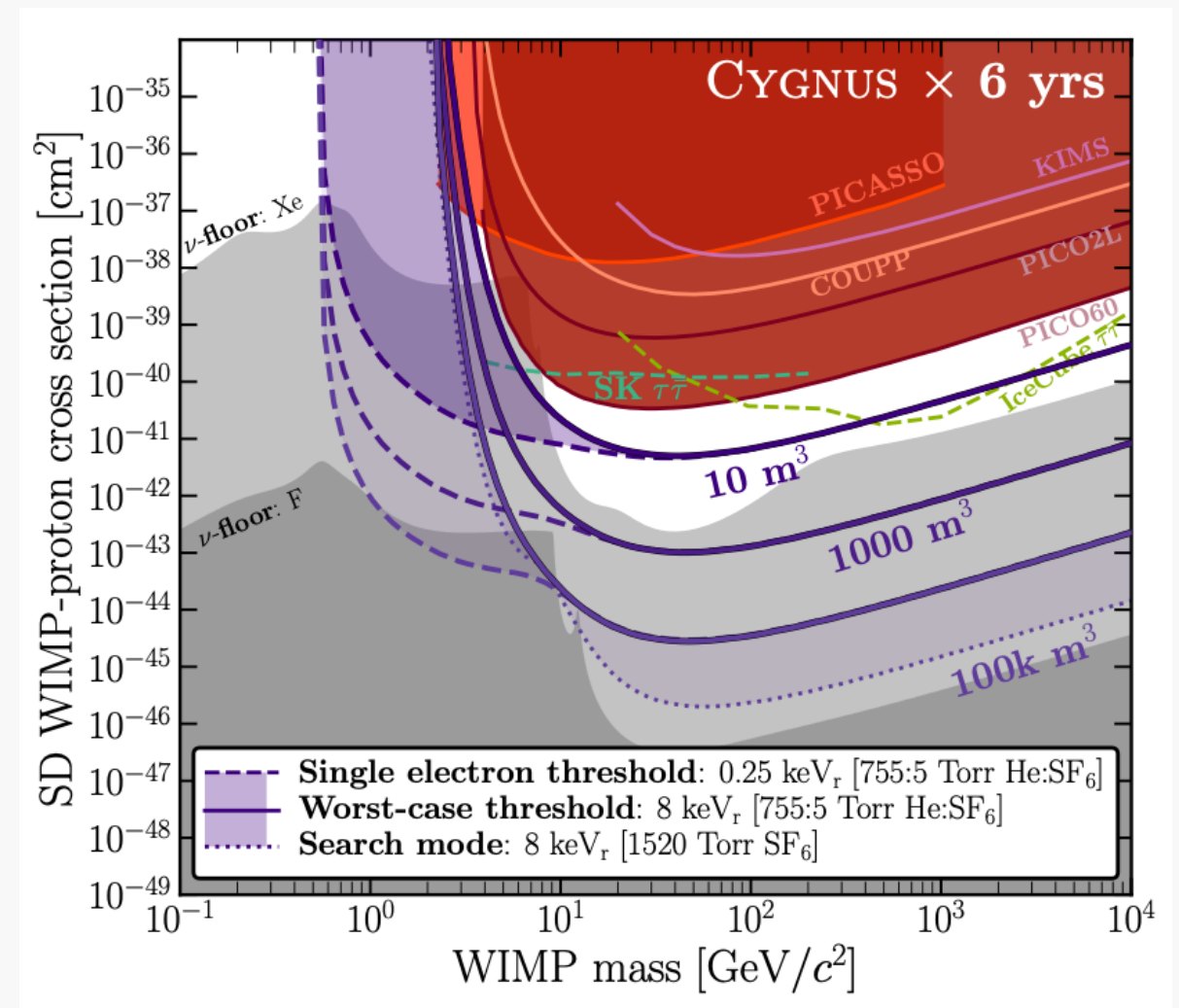
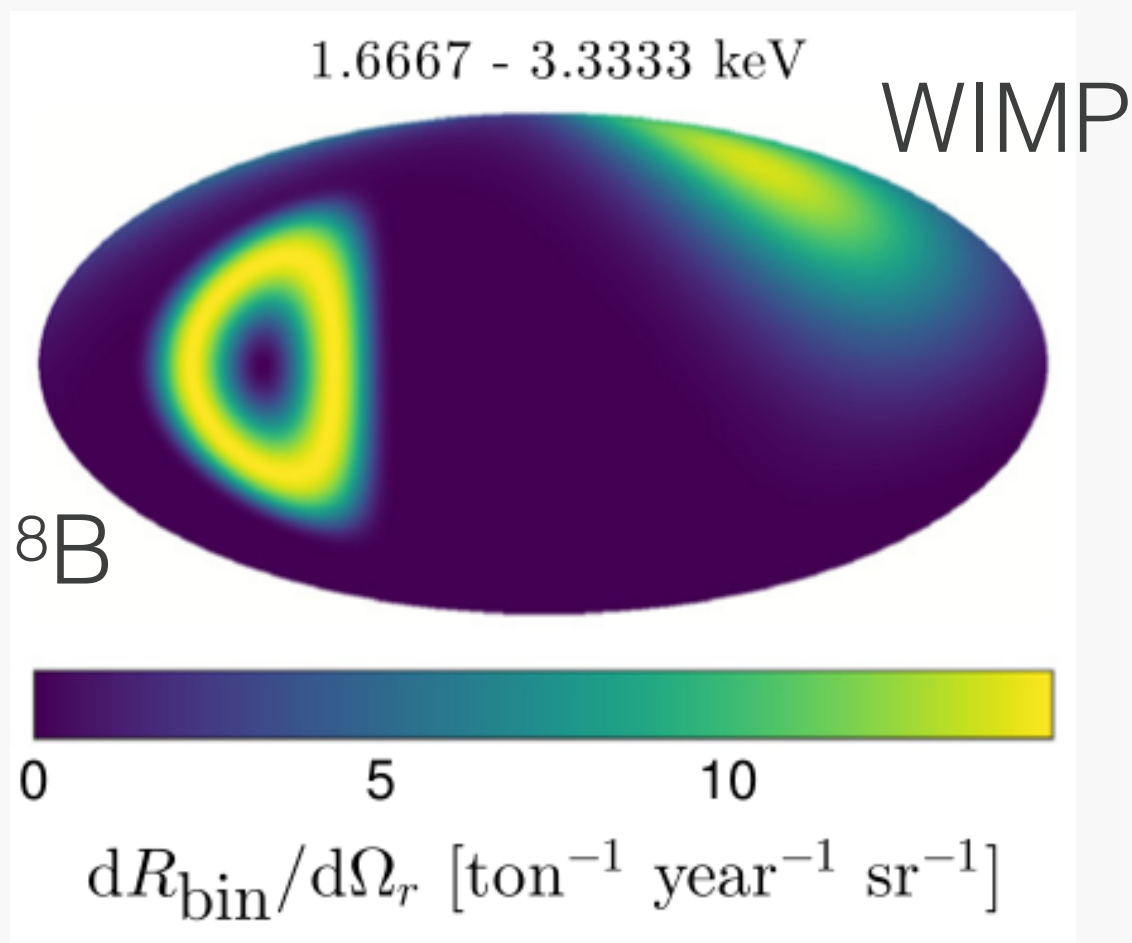
Directionality

PLB 578 (2004)
241-246



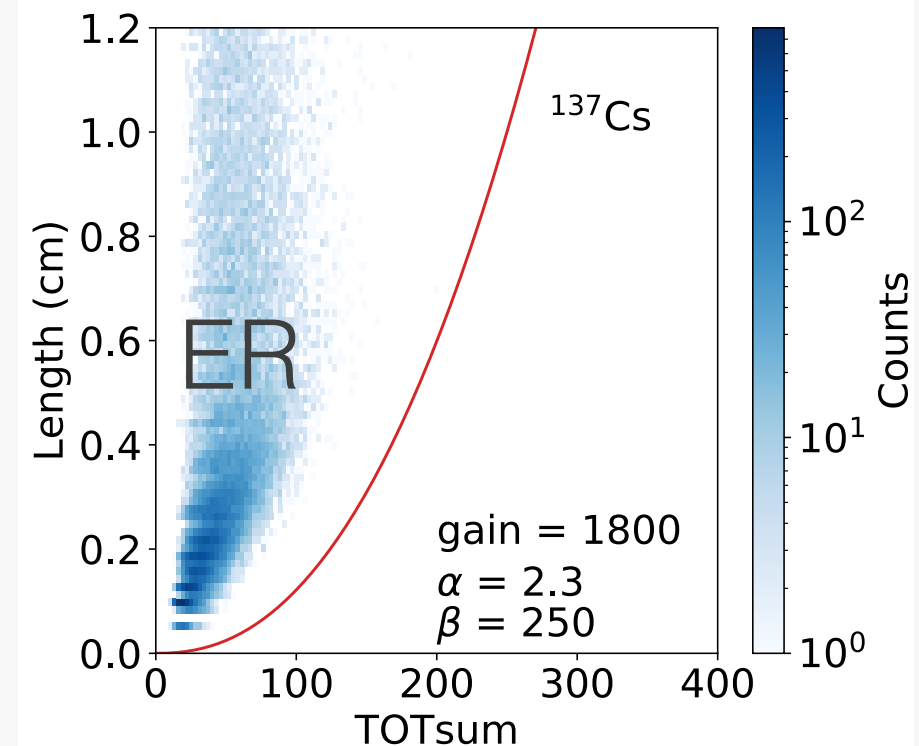
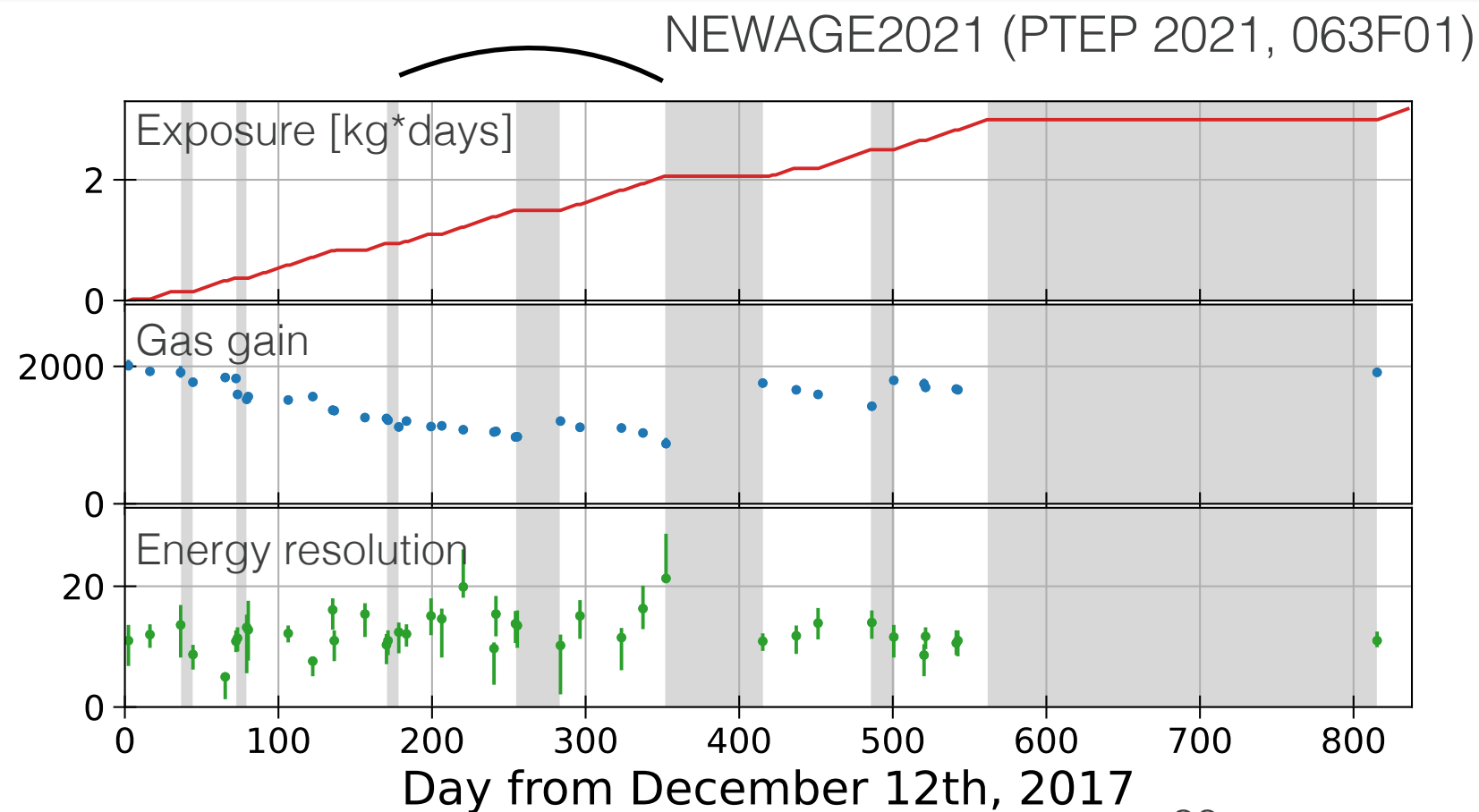
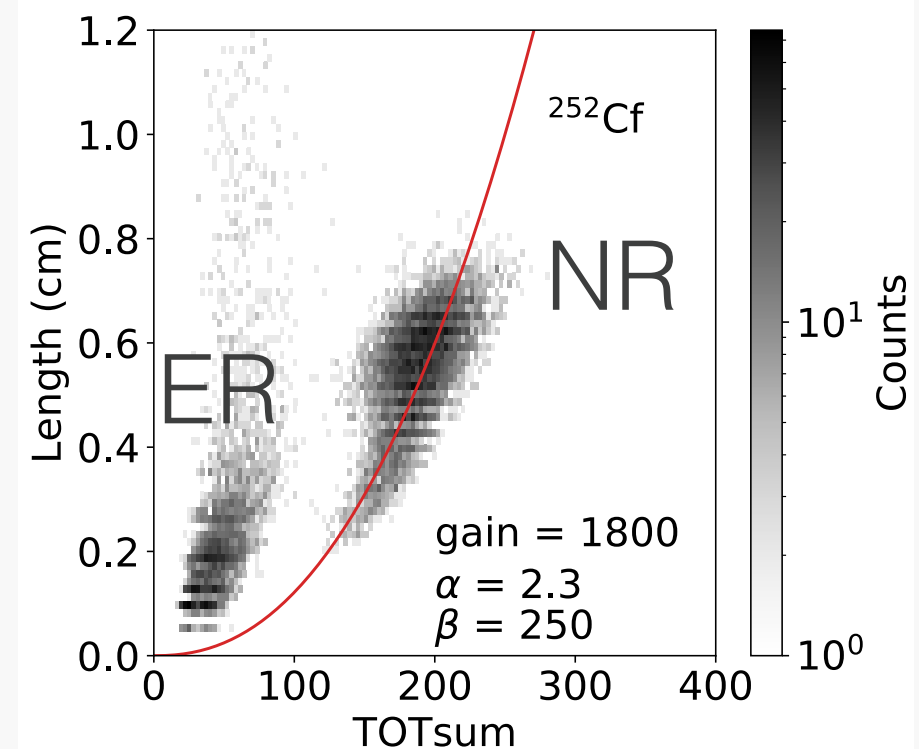
Benefits

- Strong signature of WIMP (CDM)
- Kinematics of DM (isotropic or non-isotropic?)
- ^8B ν rejection allows to explore “neutrino floor”
 - Neutrino-nucleus coherent scattering will be irreducible BG without directionality



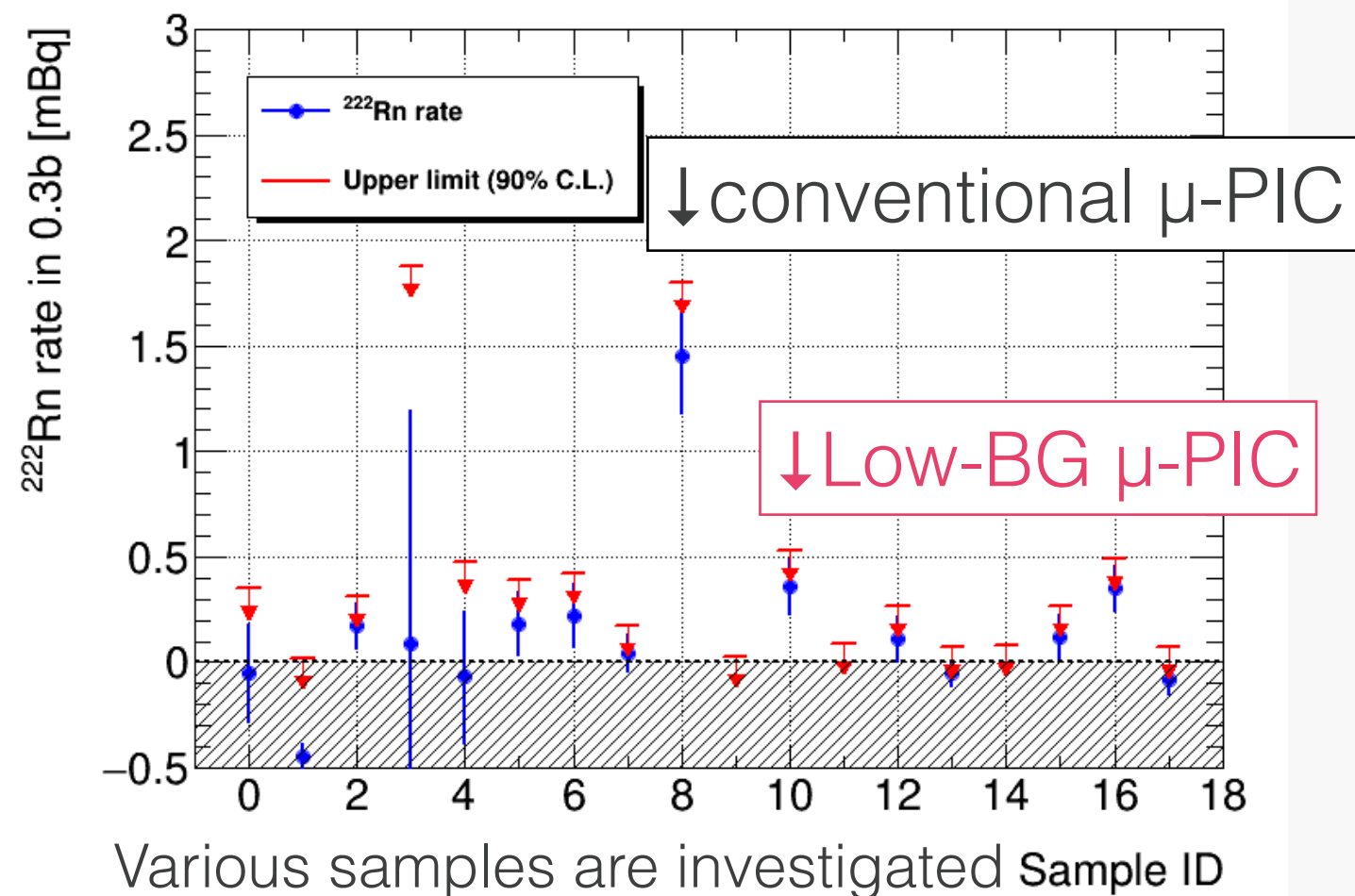
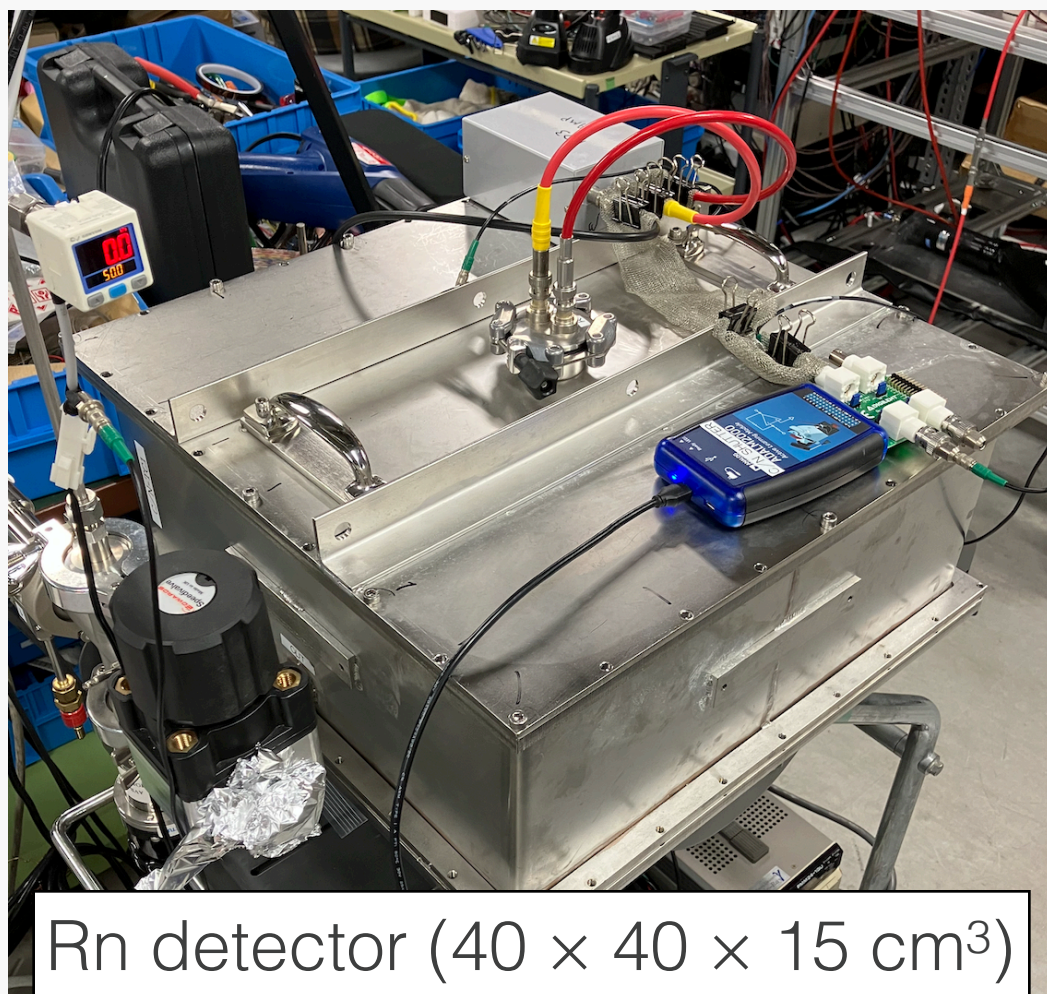
Underground measurement

- Increase statistics: 108 days $\rightarrow$ 318 days ($\times 3$)
PTEP 2021, 063F01 (NEWAGE2021)
 - $\rightarrow$ Use higher gain operation run
 - $\rightarrow$ Electron recoil (ER) by gamma rays should be removed
- Additional selection applied with multi-variate analysis
 - $\rightarrow$ correlation between track length, ToT and energy



What is the source of Rn BG?

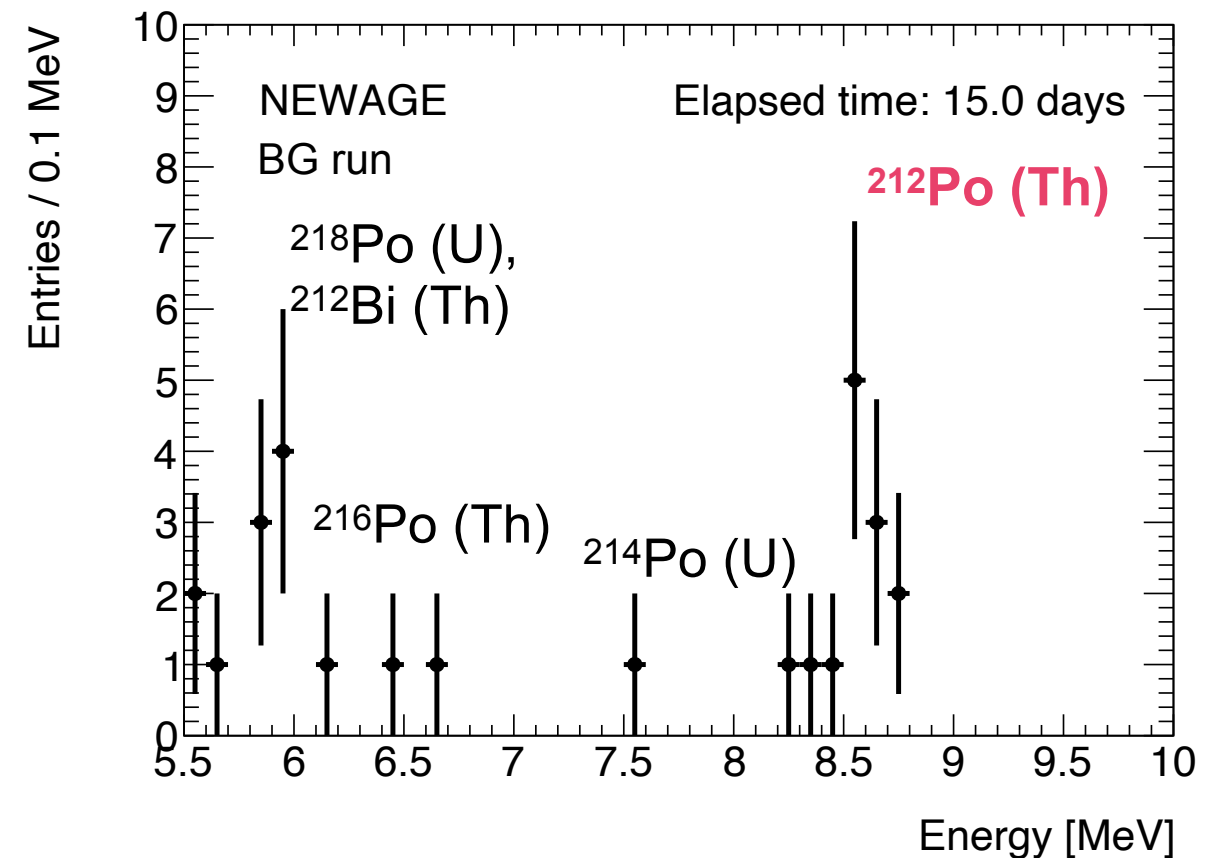
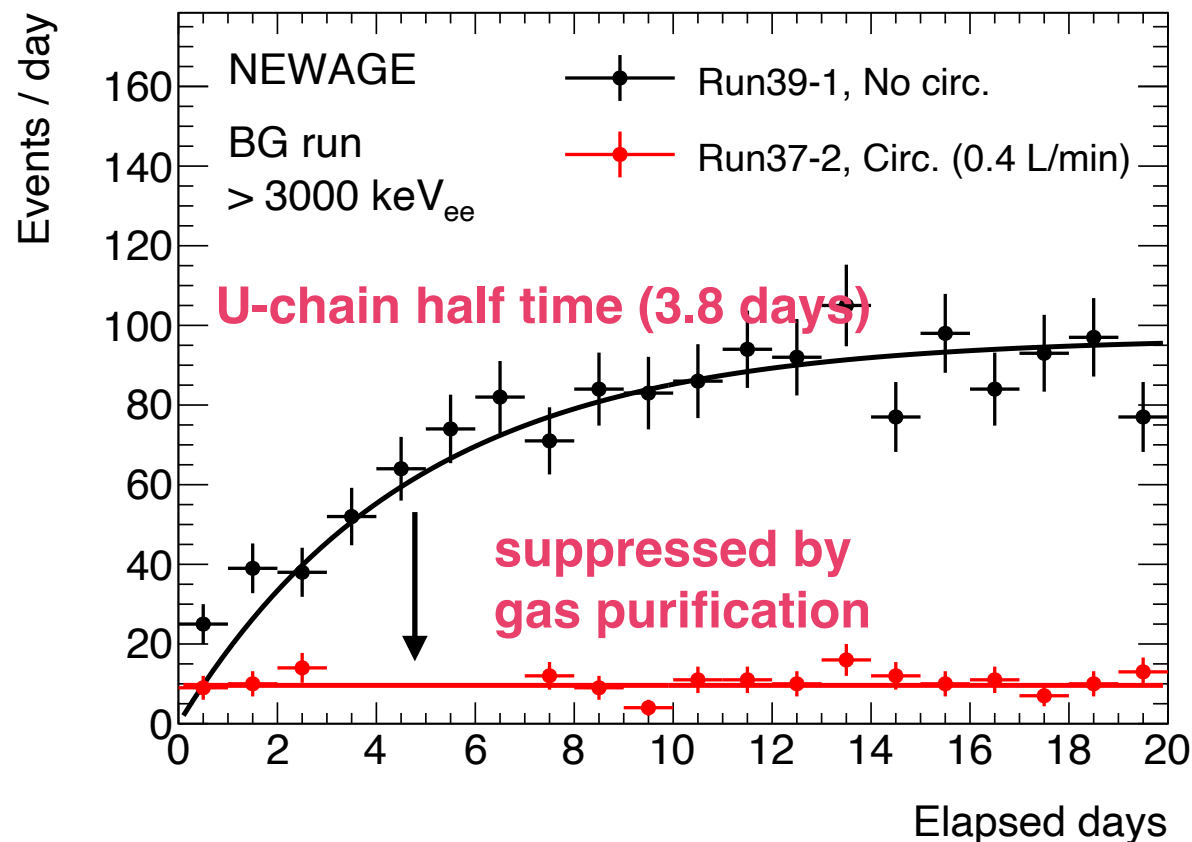
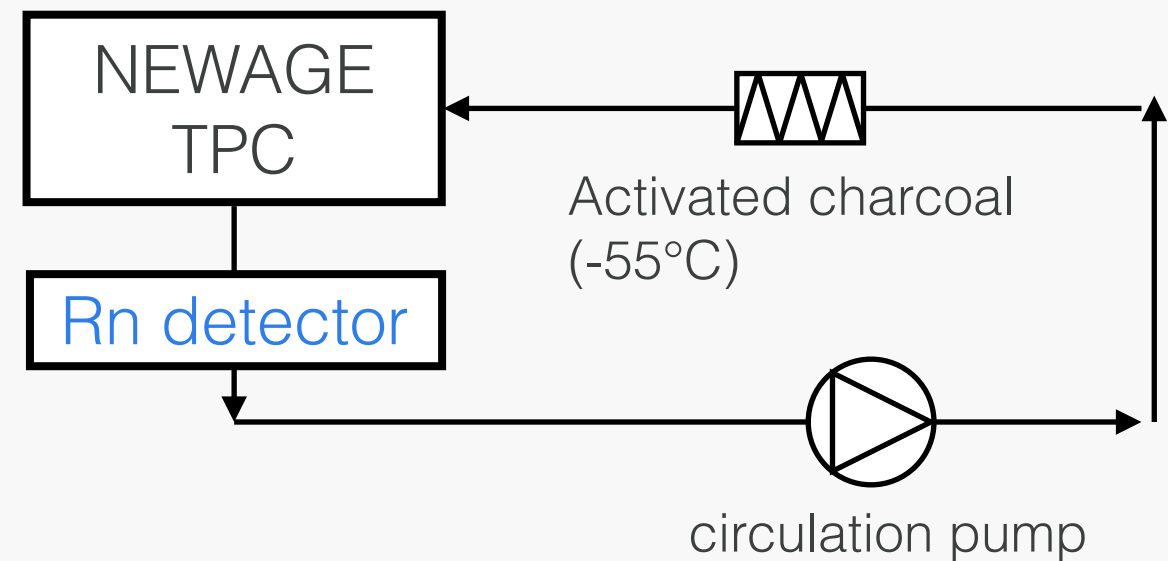
- Rn emanation rate for various TPC components was measured with electrostatic collection Rn detector
 - ➔ e.g. μ -PIC, intermediation PCB, field cage (PEEK), O-ring, HV feedthrough, ...
- No component can explain the amount of Rn BG in the NEWAGE detector



U / Th decay chain?

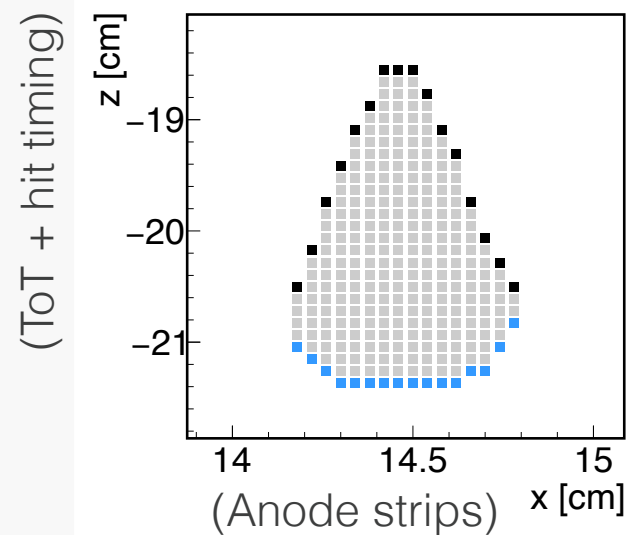
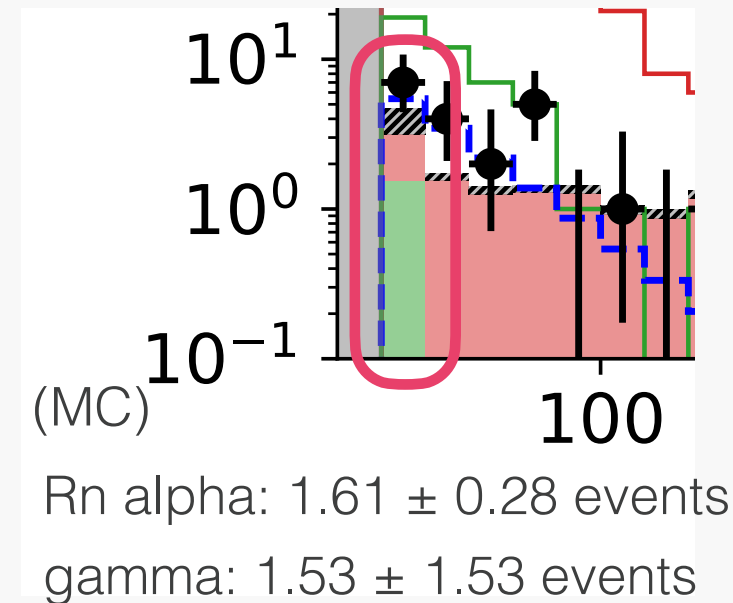
- Two independent tests were taken place
 - ➔ Circulation ON / OFF
 - ➔ Rn detector installation in the circulation system
- **Th-chain (^{220}Rn : 55.6 sec, ^{212}Pb : 10.6 h) is the dominant Rn source**
 - ➔ and these two results are consistent

NEWAGE circulation system (simplified)



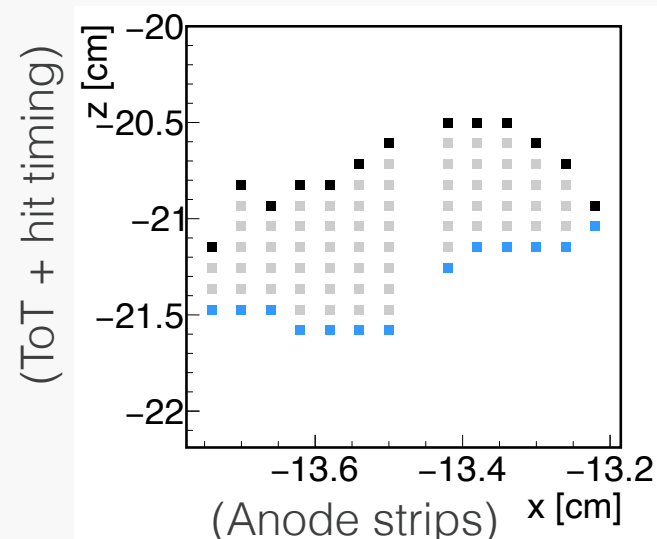
Review of ambient gamma-induced electron recoil

- The lowest energy bin is the most sensitive
 - ➔ Ambient gamma flux had been measured by CsI
 - ➔ Expected events were simulated but 100% unc. assigned
 - Detector response was not completely understood



Nuclear recoil-like event
in ^{252}Cf source run

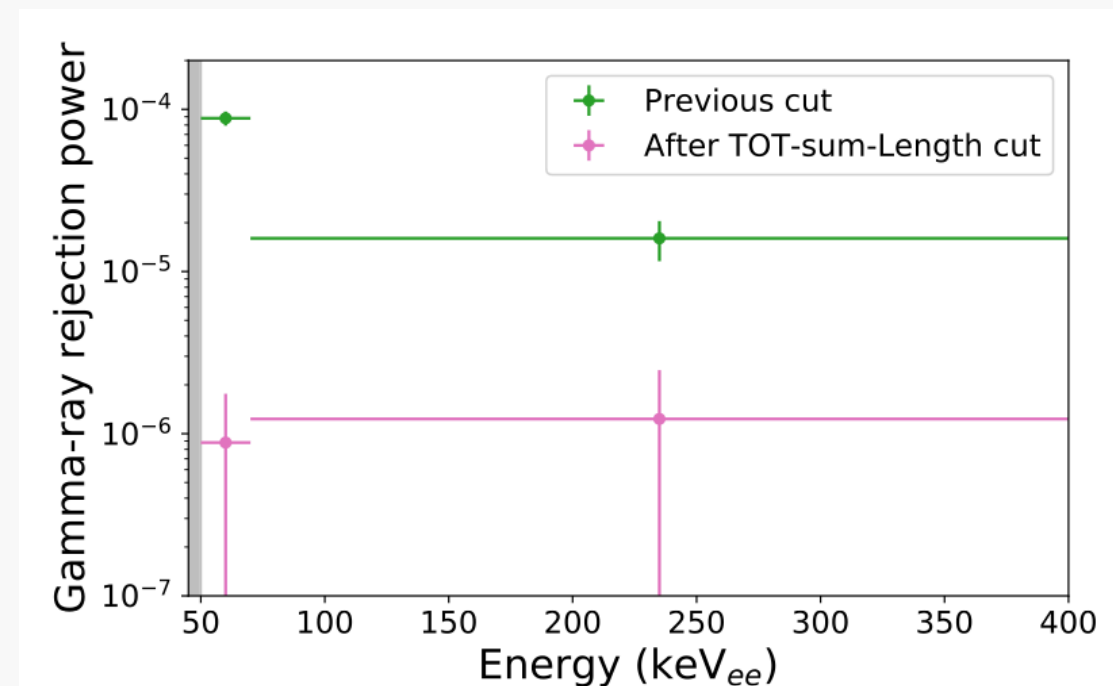
$$E = 160 \text{ keV}_{ee}$$



Electron recoil-like event
in ^{137}Cs run

$$E = 72 \text{ keV}_{ee}$$

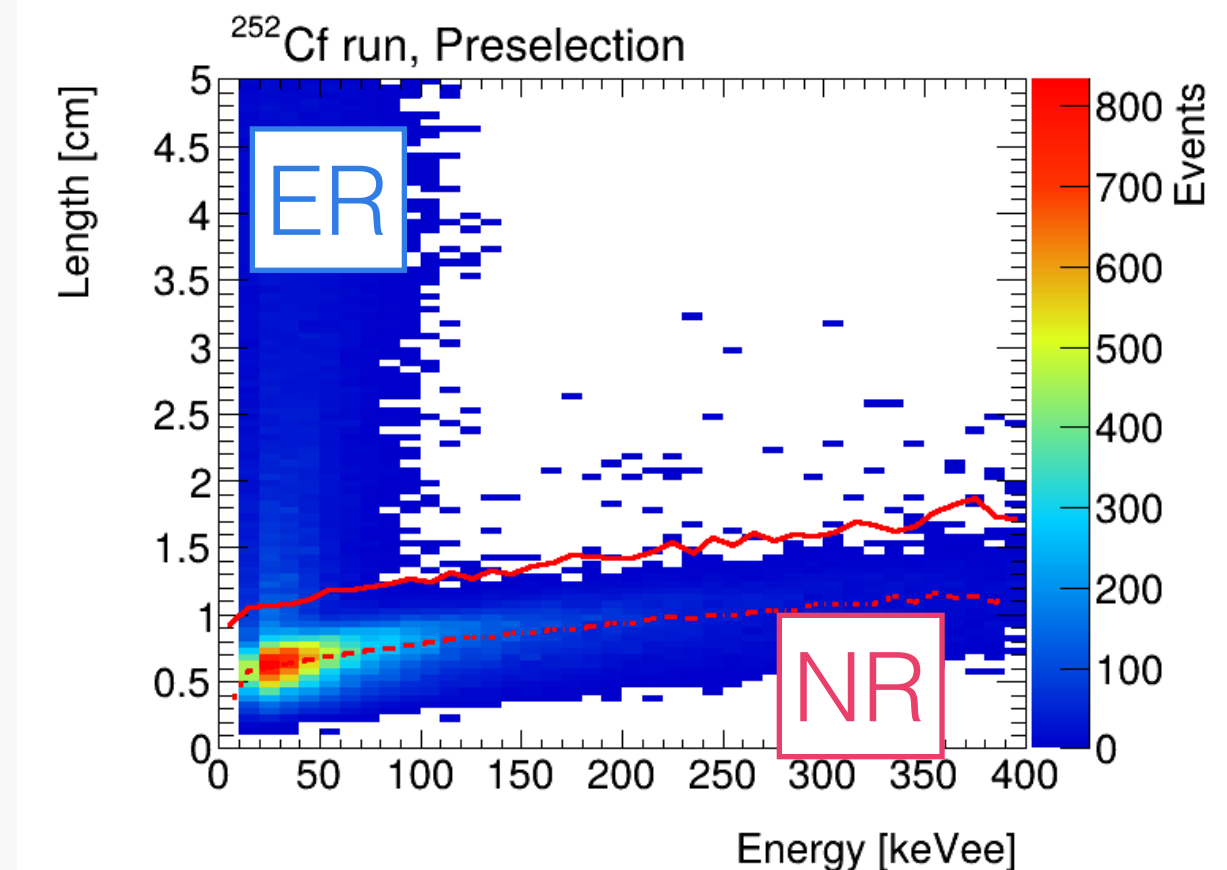
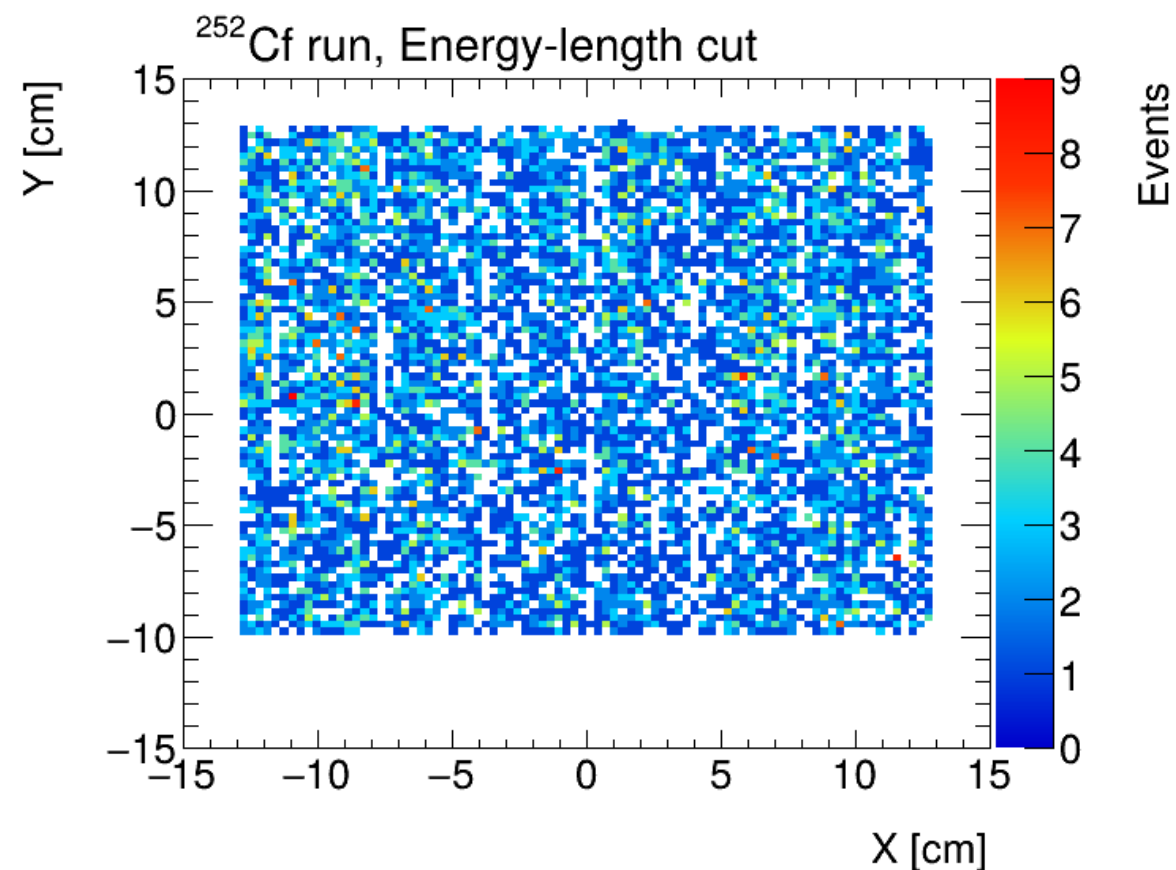
(this event was dropped
by our event selection)



Rejection power: $\sim 10^{-6}$
but need to reduce the ambient
gamma flux into our chamber itself

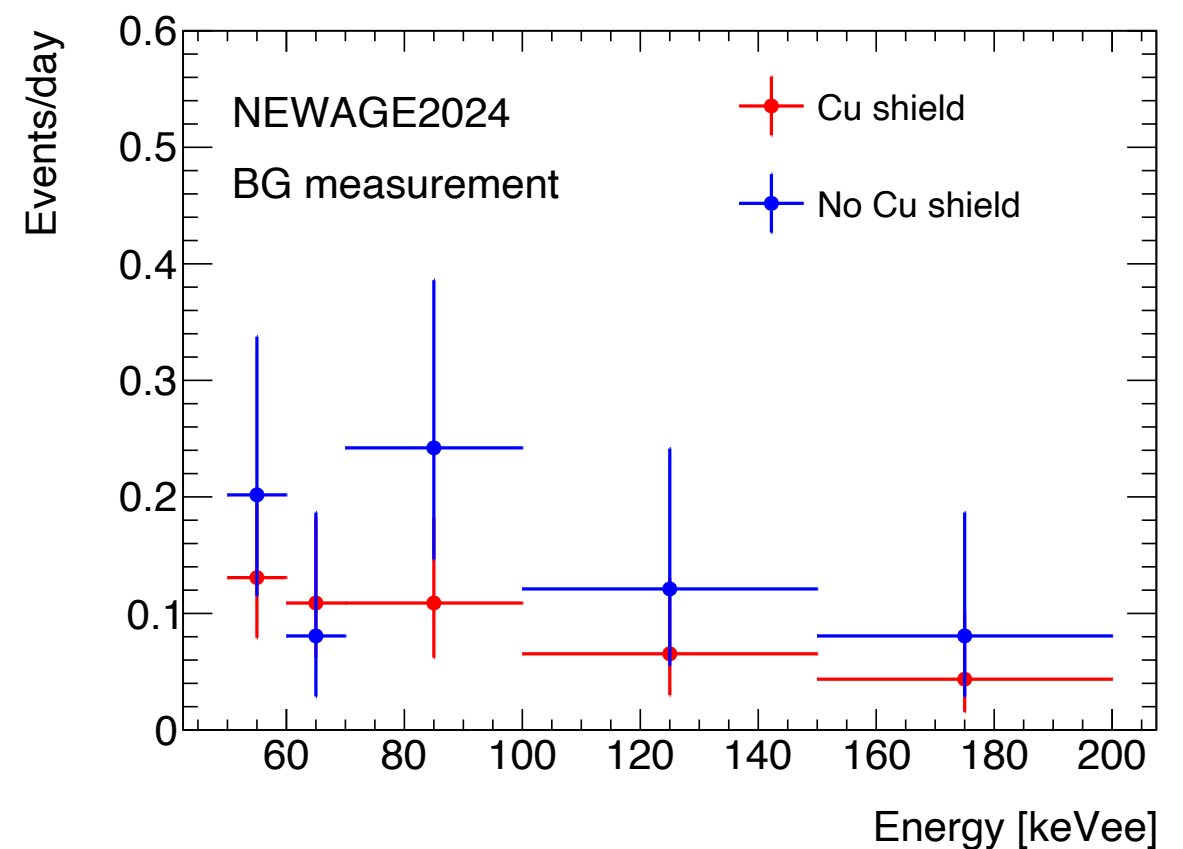
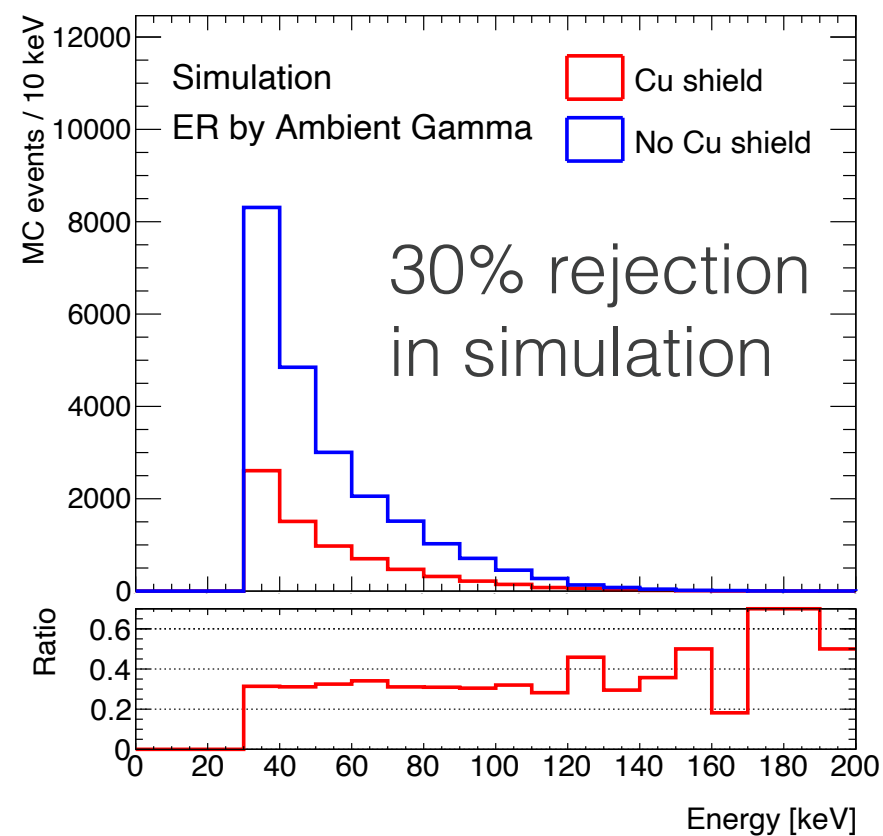
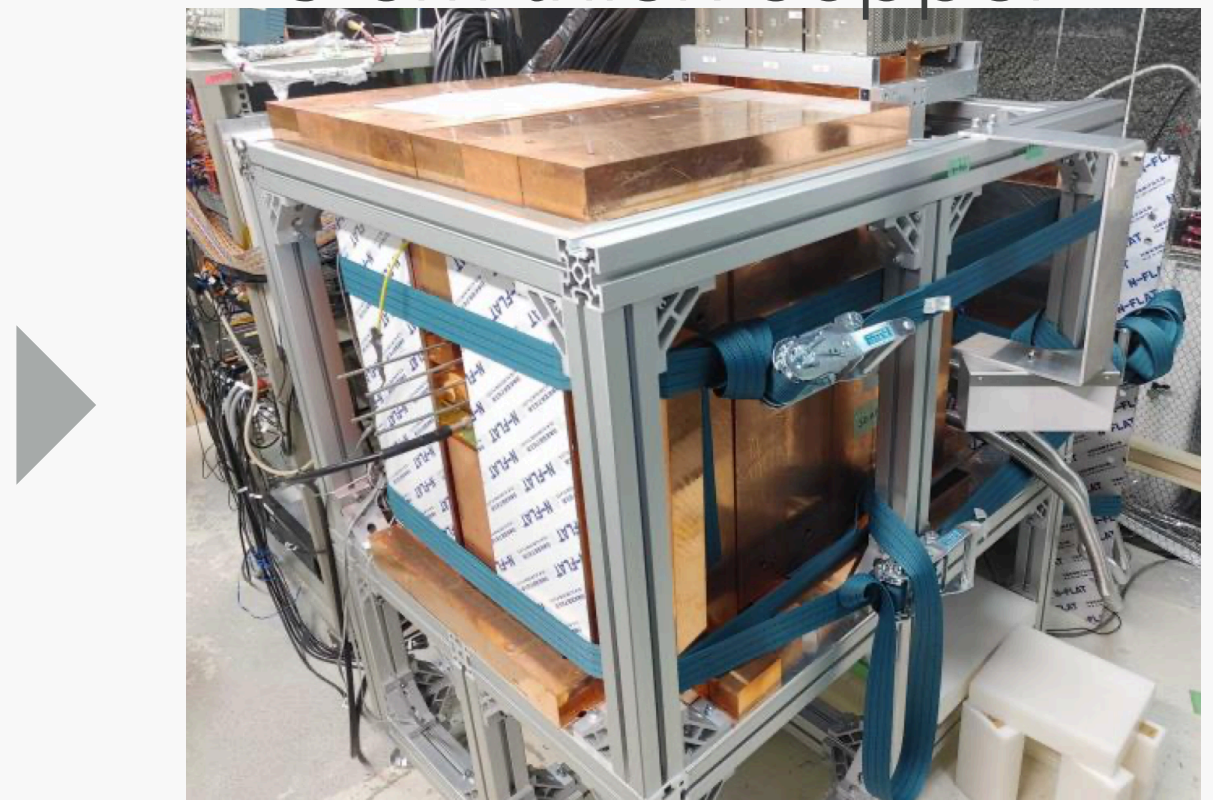
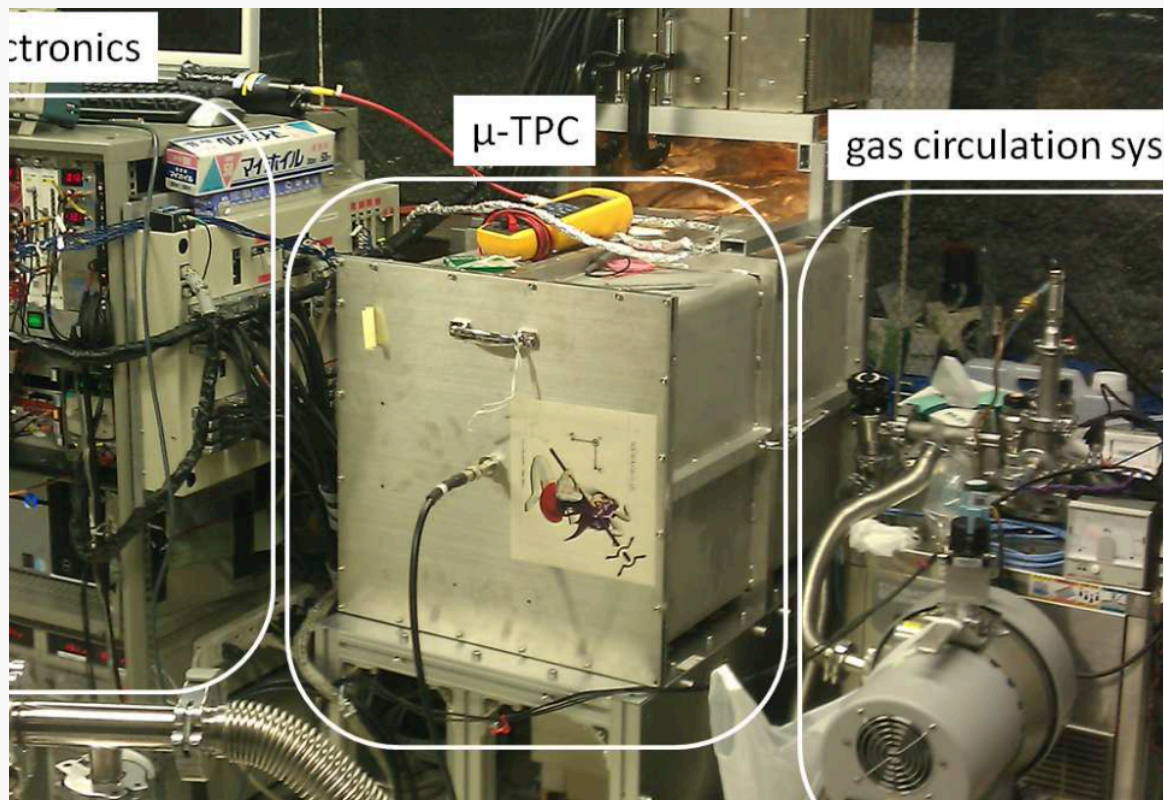
Neutron irradiation test (^{252}Cf source)

- Performance demonstration using ^{252}Cf source
 - ➔ Neutron irradiation from the top of the drift plane direction
 - ➔ Uniform distribution for detector plane was obtained
 - ➔ NR-ER separation successfully working by track information



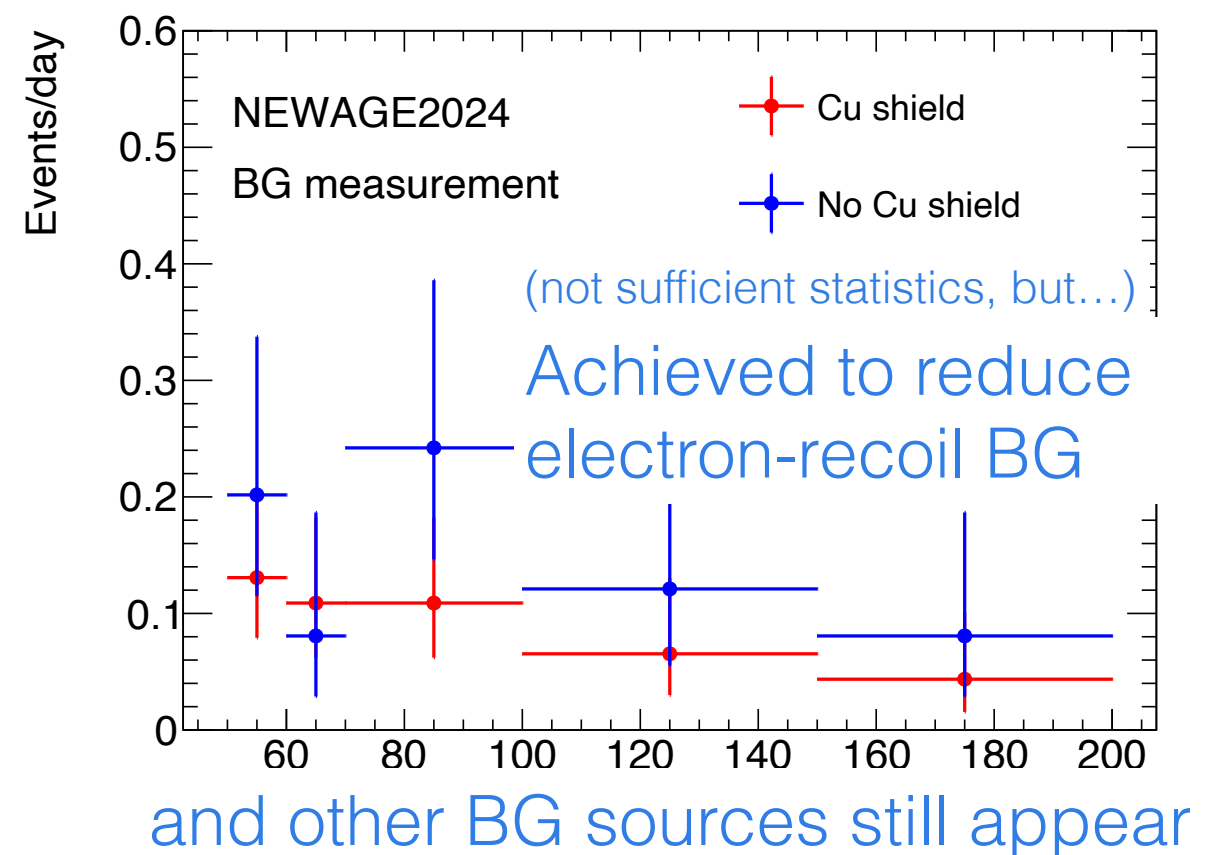
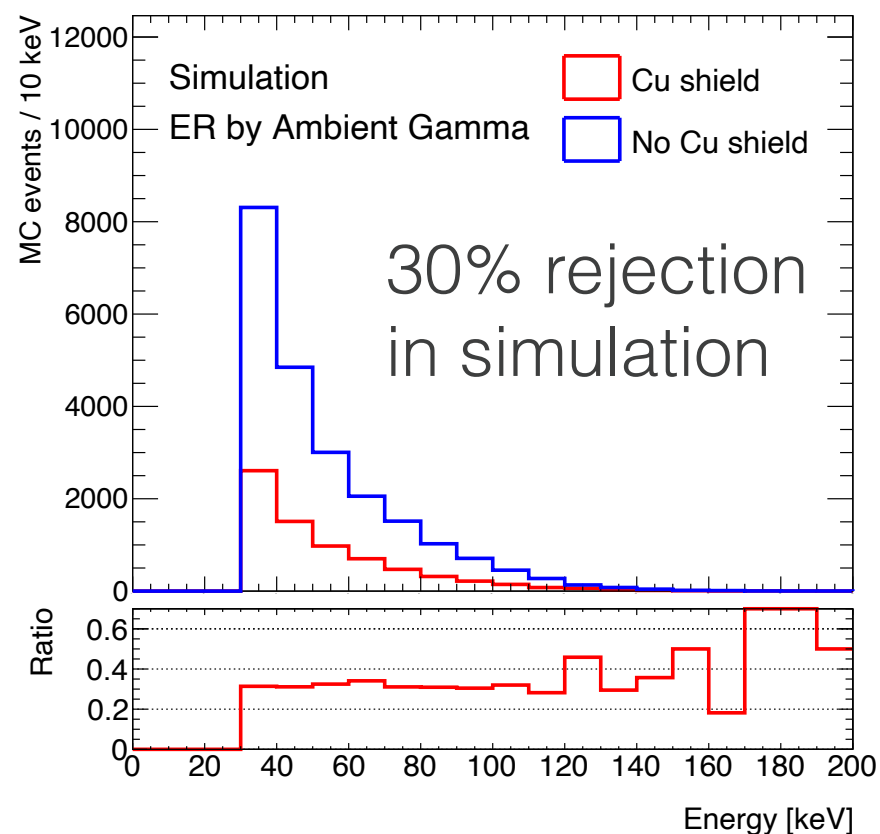
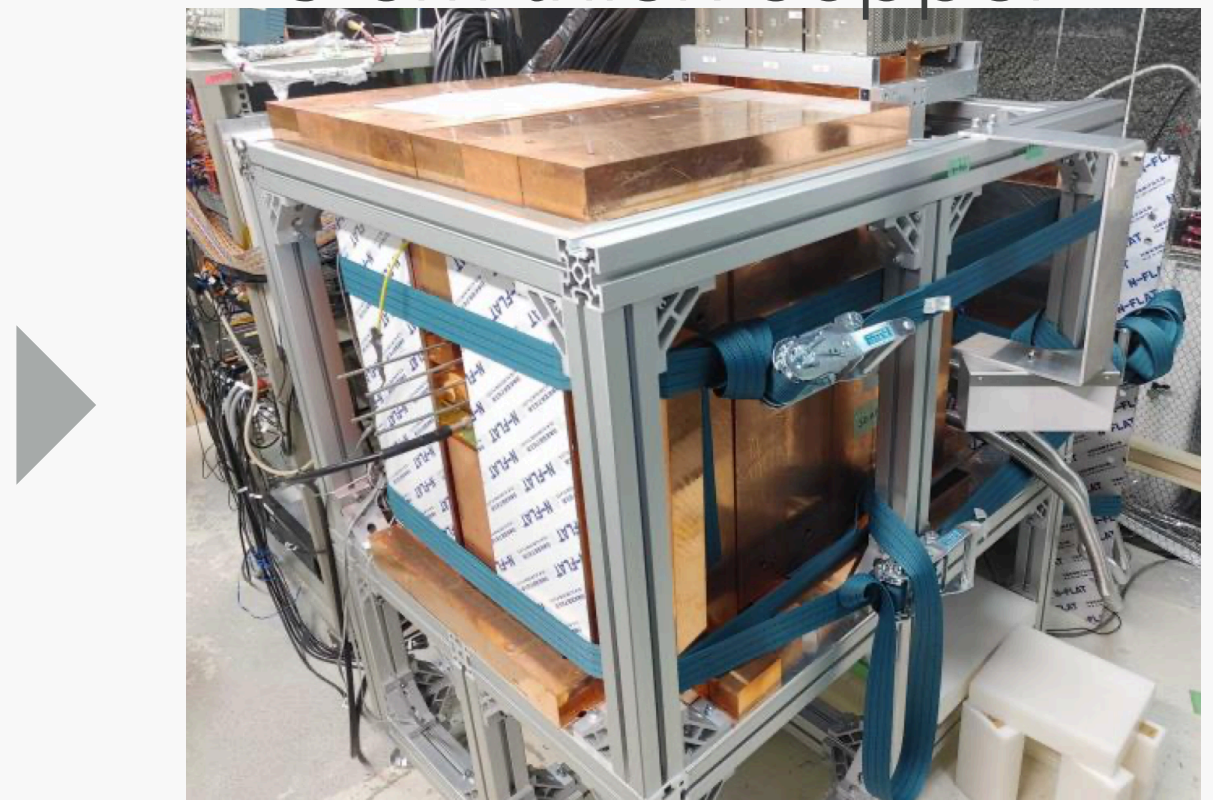
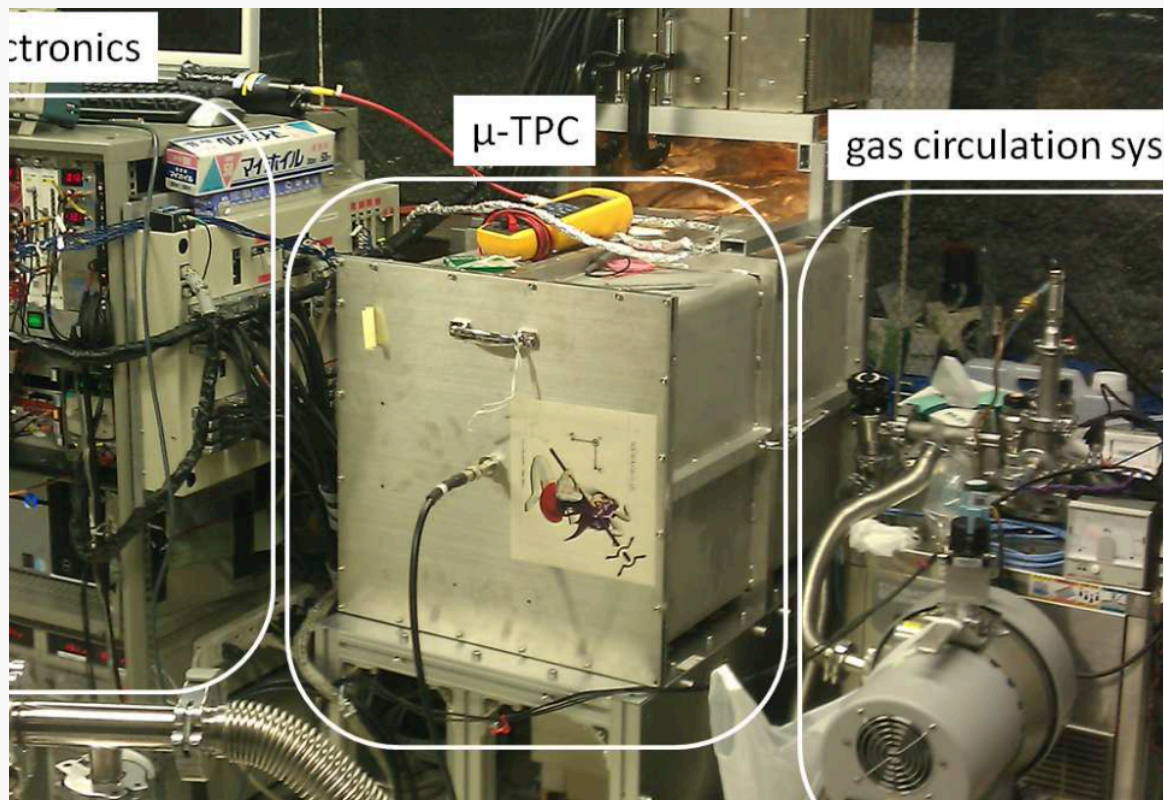
Copper shield

5 cm thick copper



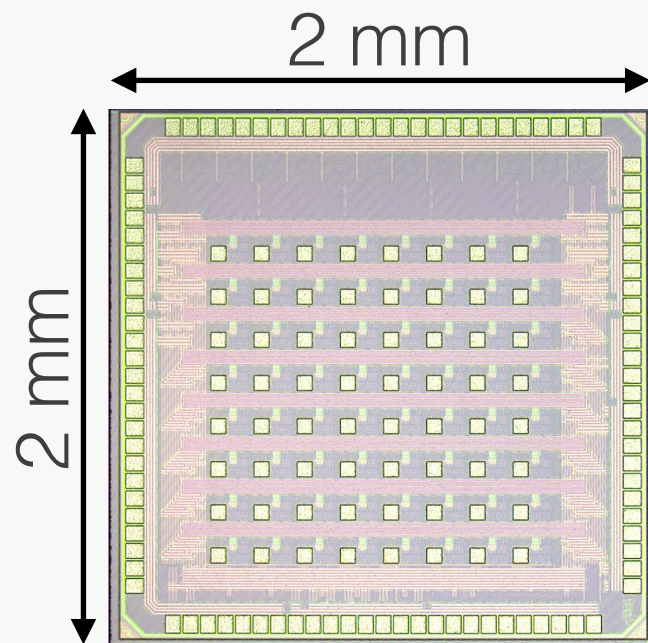
Copper shield

5 cm thick copper

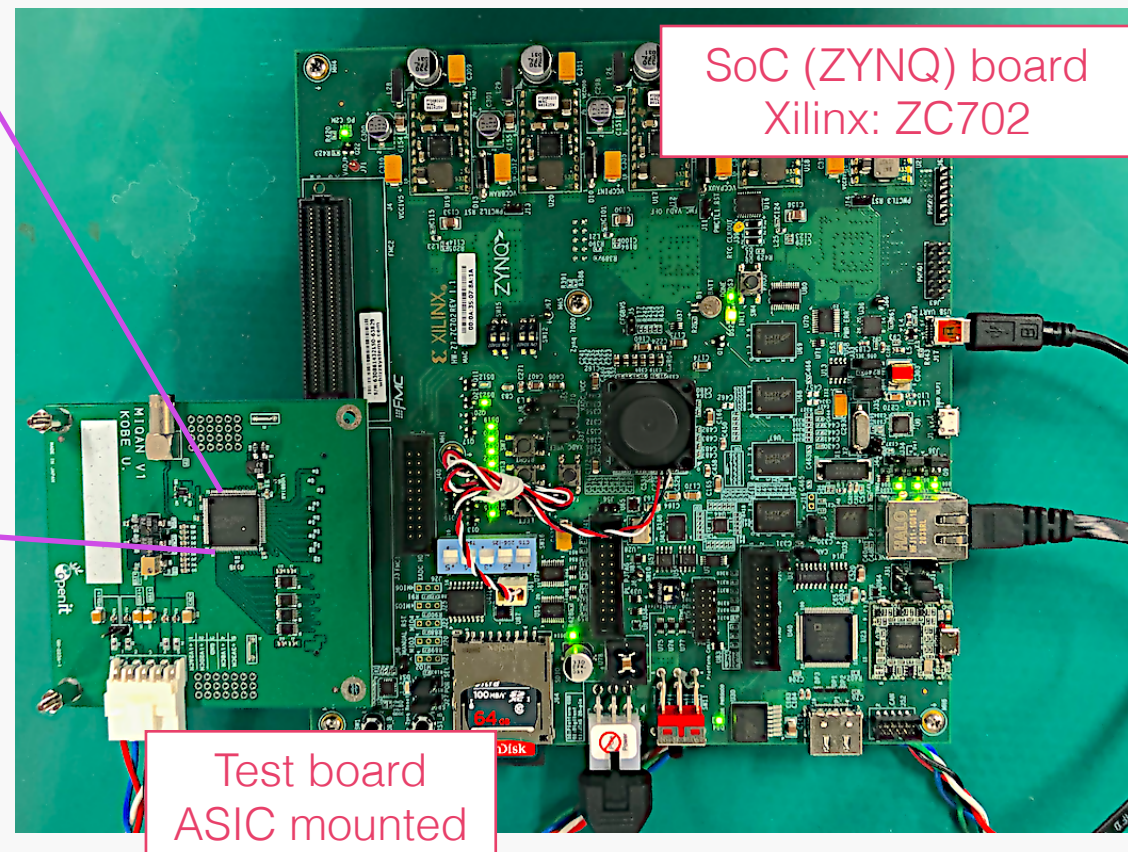


Strategy of short tracks detection

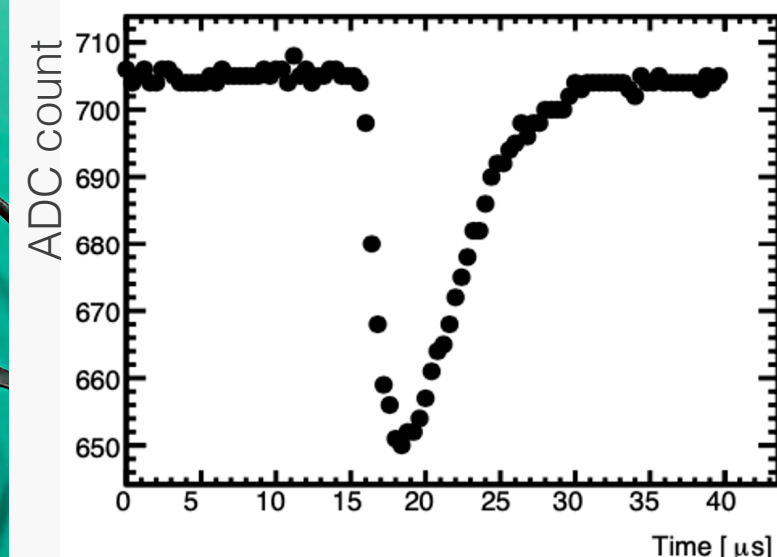
- Equal to low energy nuclear recoil detection
- Energy threshold is limited due to electrode's strip pitch ($400\text{ }\mu\text{m}$)
 - ➔ Started to develop fine granularity “pixel” readout detector
 - ➔ 64 ch ASIC developed and testing its performance



readout ASIC
($155\text{ }\mu\text{m}$)² pixel pad
connecting to electrodes
by bump bonding



Test pulse waveform
for a particular ch.



Analog circuit + ADC
successfully working!