

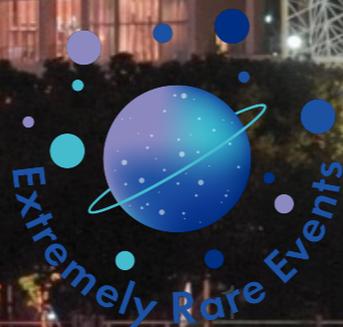
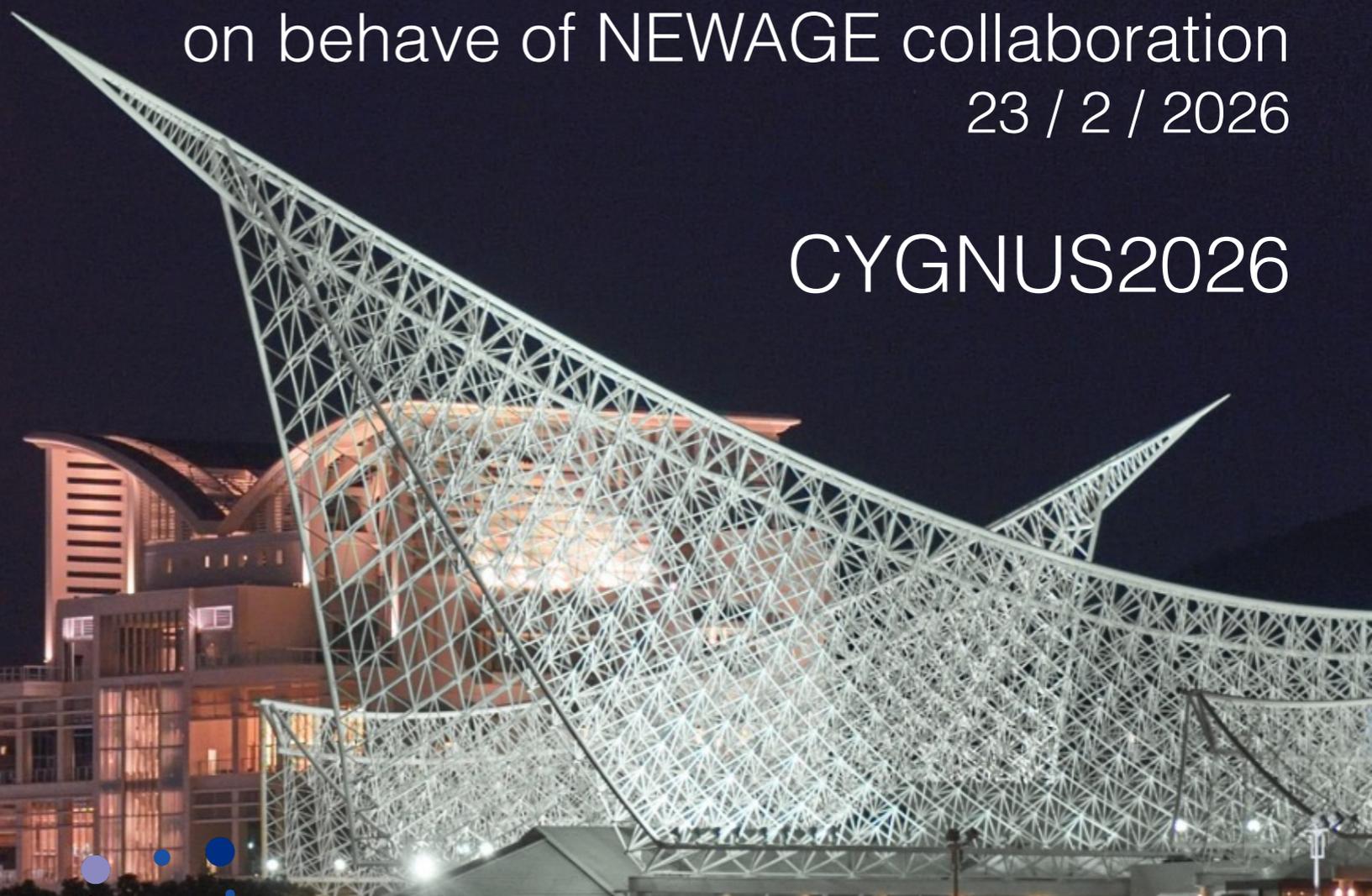
# NEWAGE

Satoshi Higashino

on behave of NEWAGE collaboration

23 / 2 / 2026

CYGNUS2026



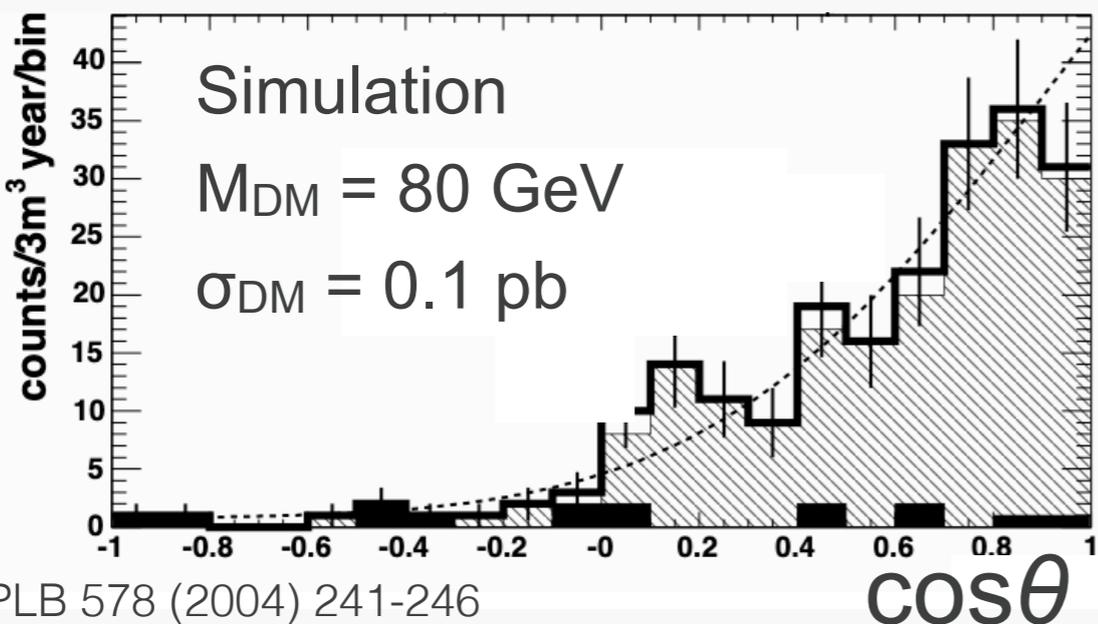
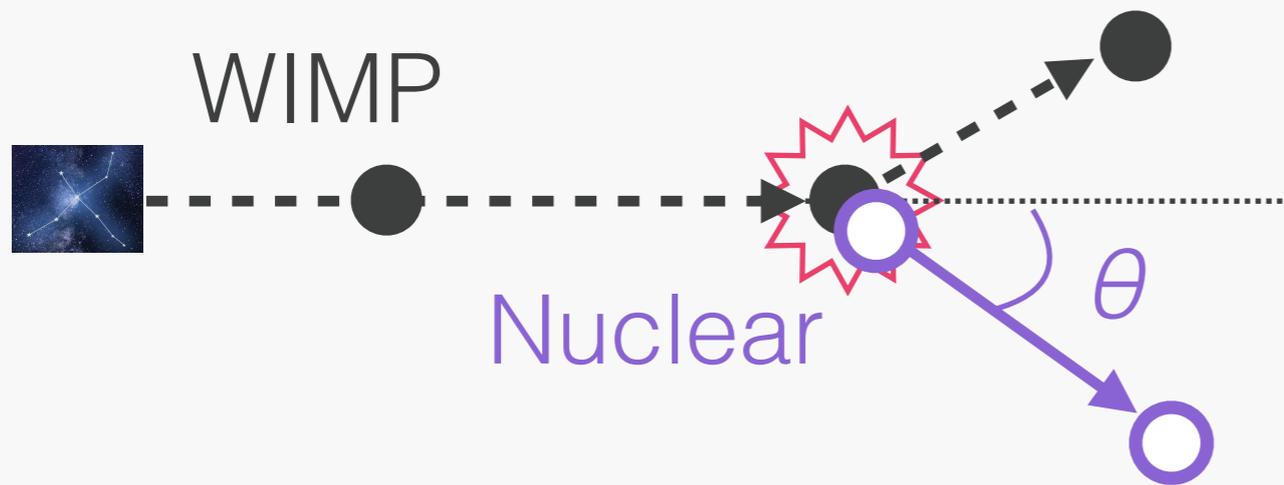


# Introduction

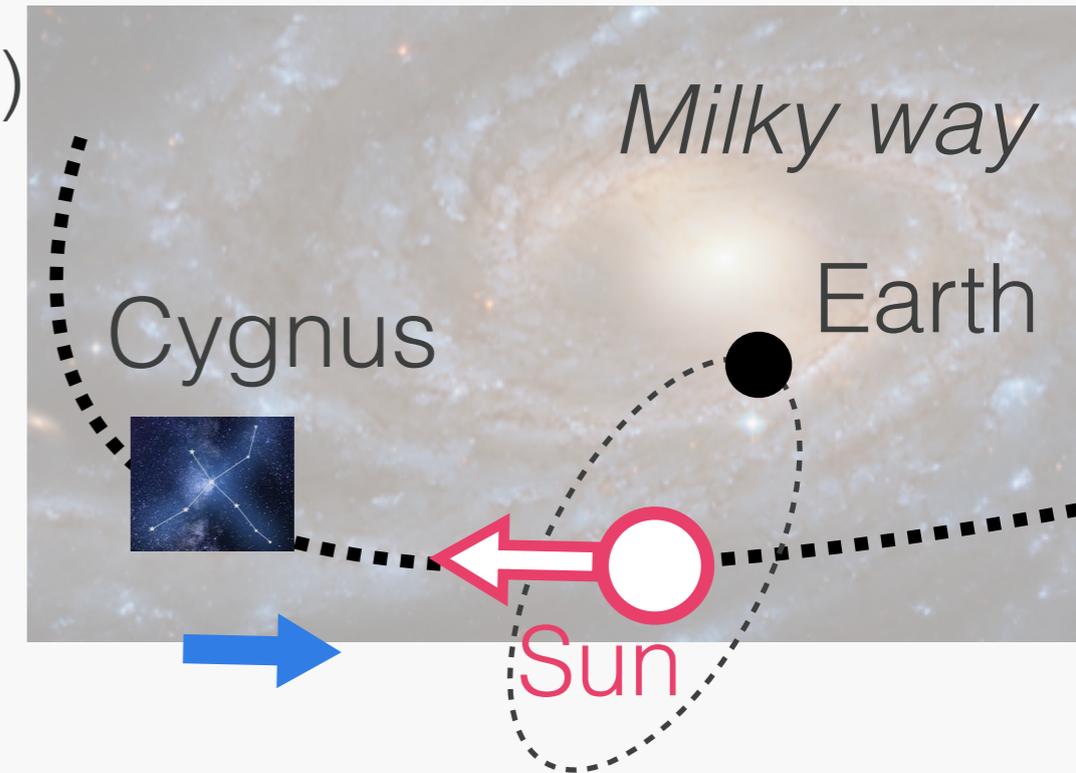
# Direction-sensitive DM searches

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

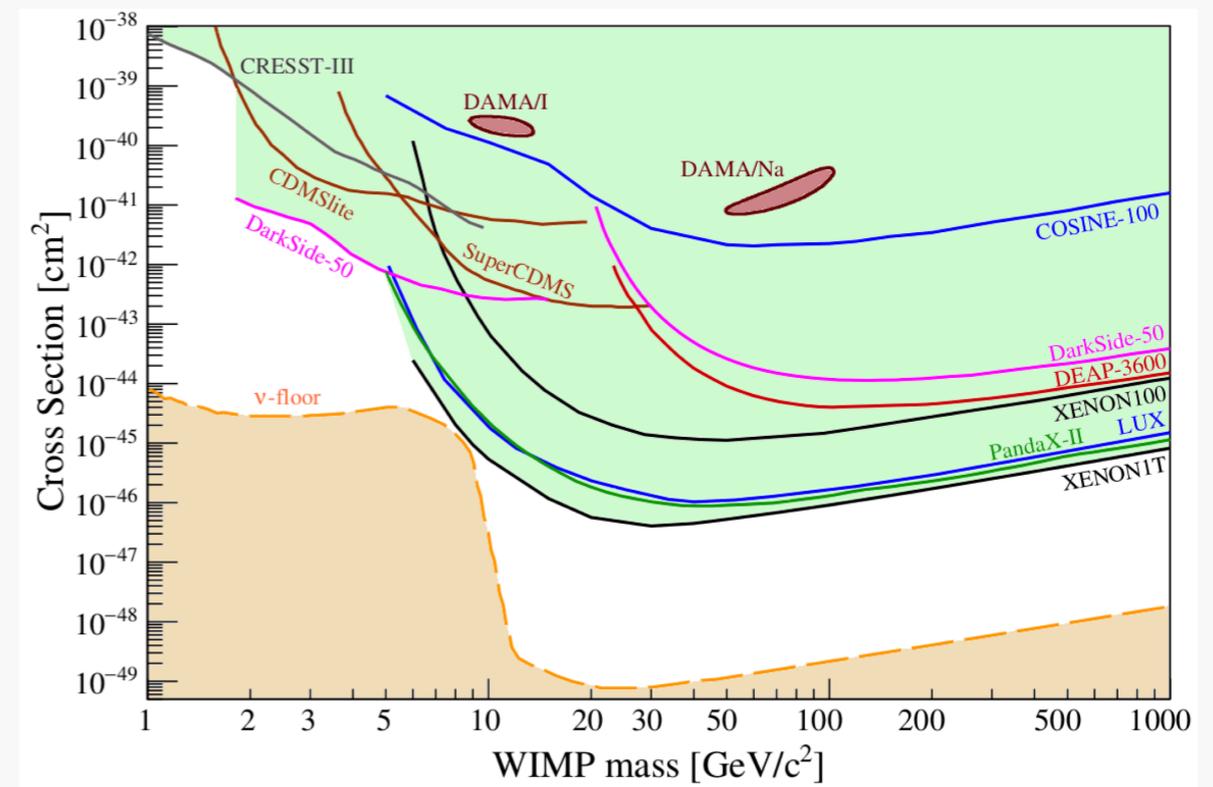
- leads a strong signature of WIMP
- allows to explore beyond the neutrino-fog



PLB 578 (2004) 241-246



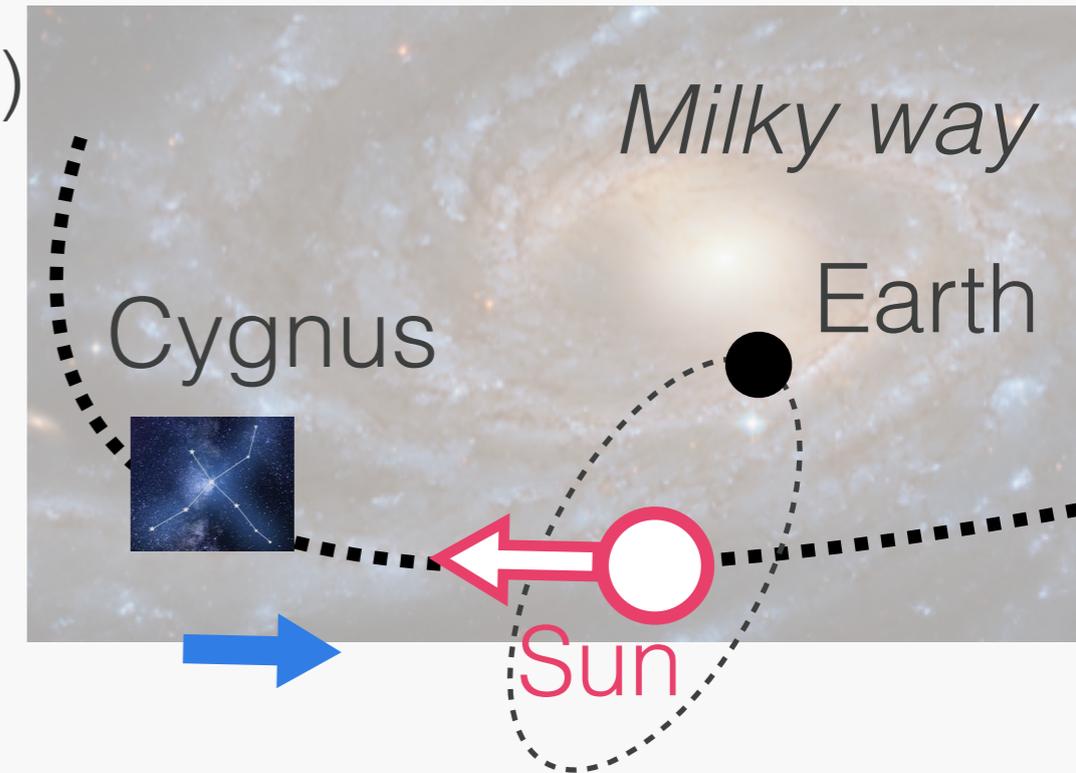
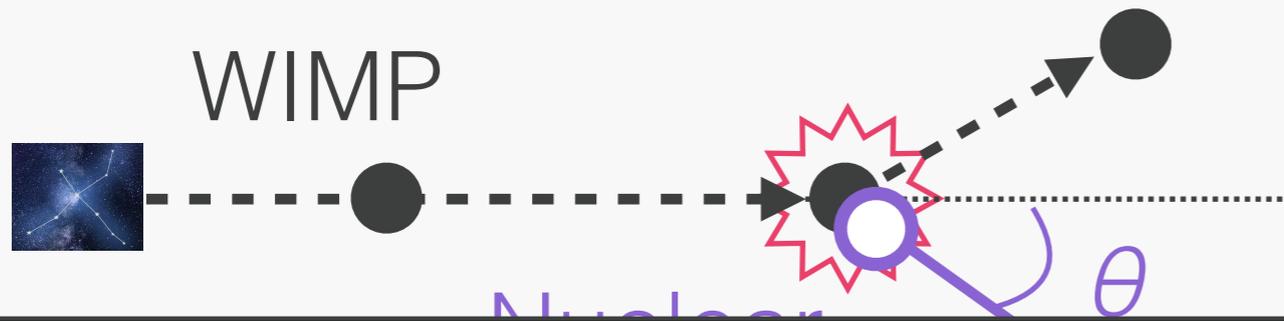
WIMP wind from Cygnus!



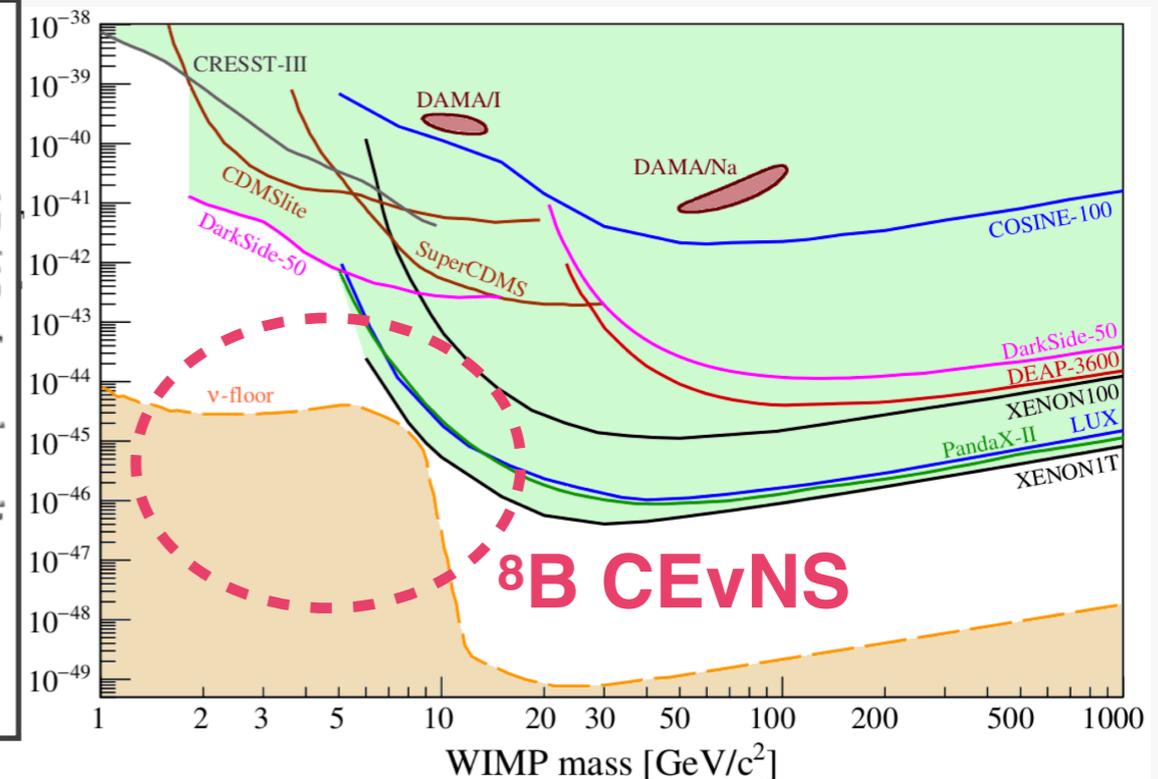
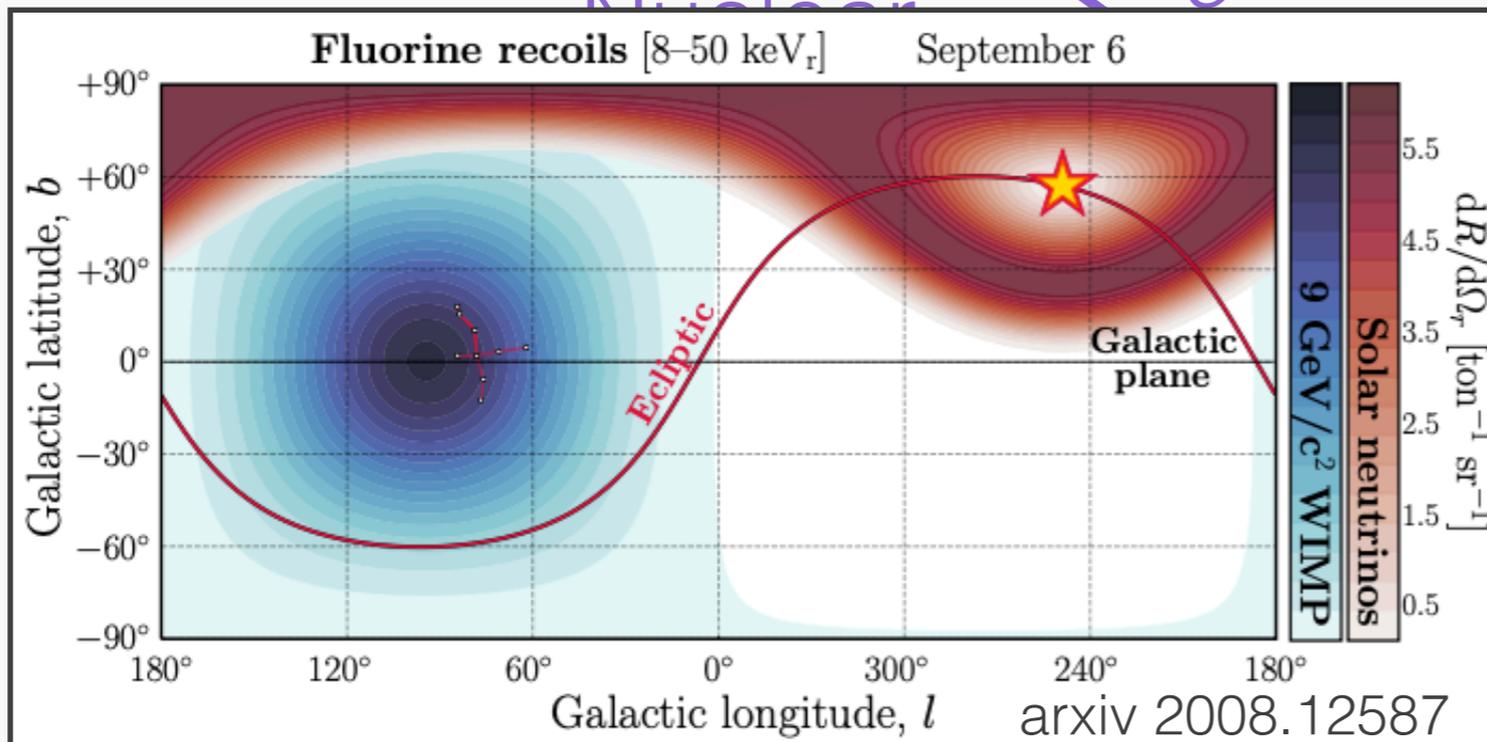
# Direction-sensitive DM searches

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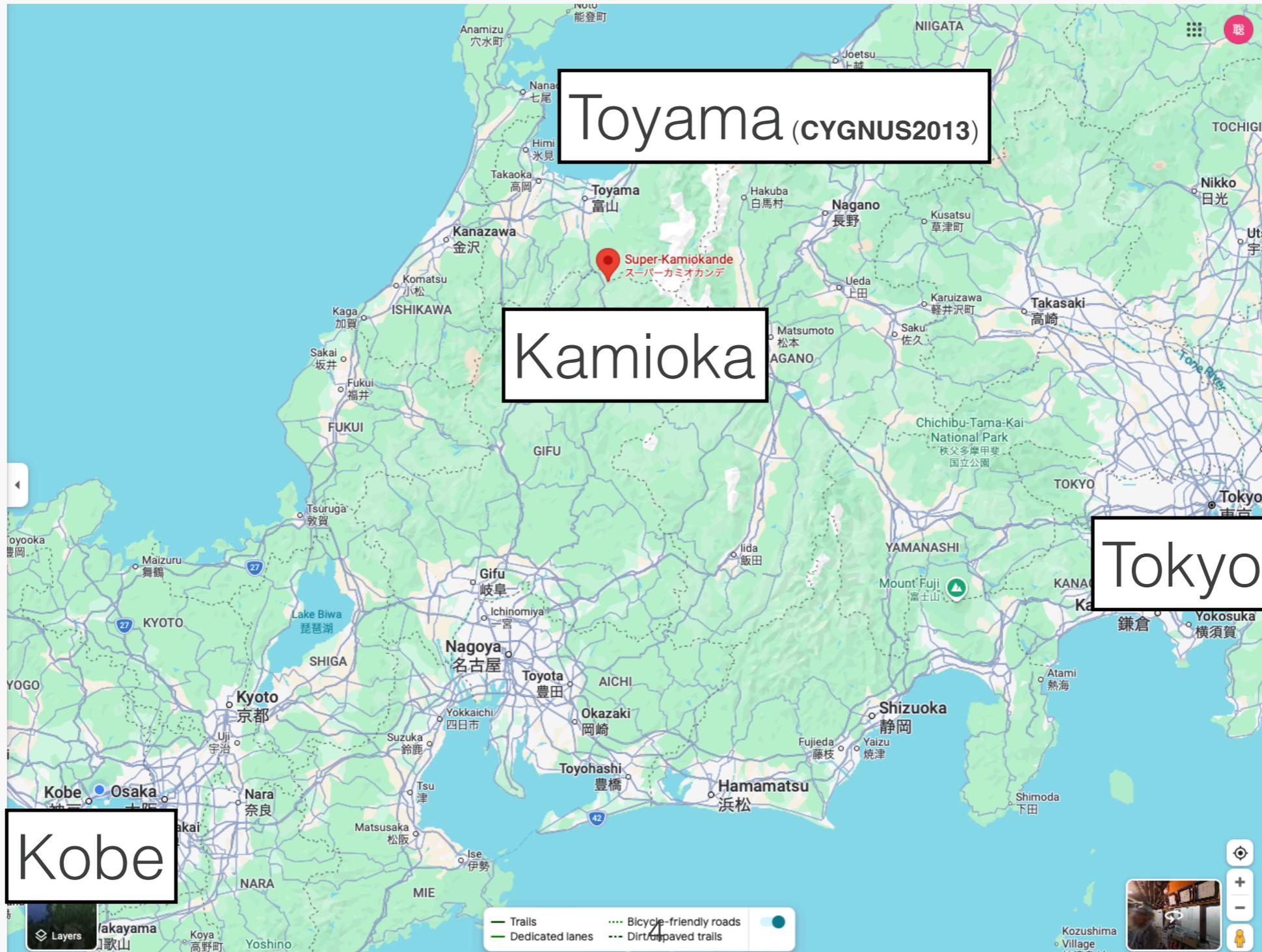


WIMP wind from Cygnus!



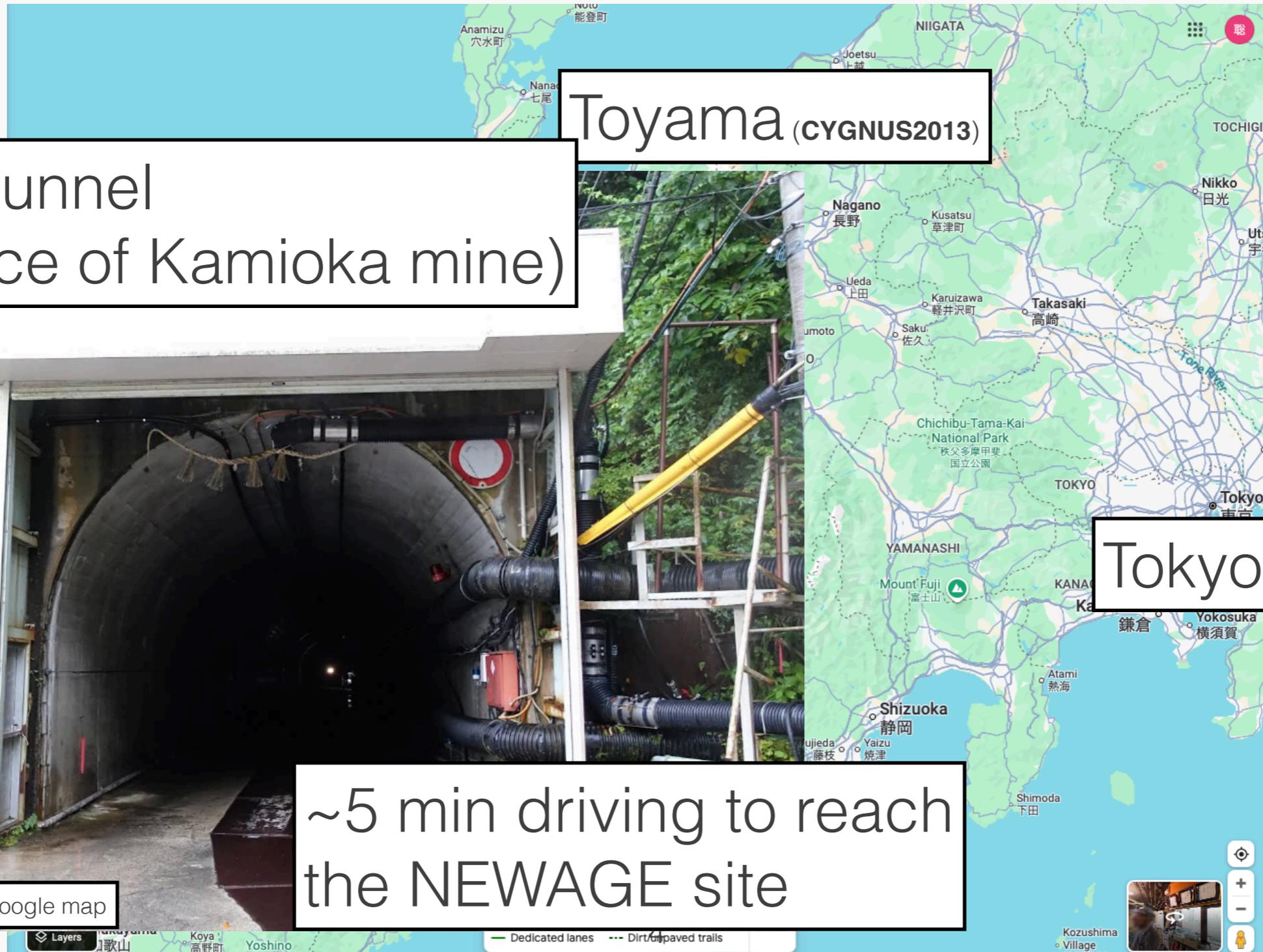
# NEWAGE

- 1,000 m underground experiment in the Kamioka mine
  - ➔ ~5h by train from Kobe



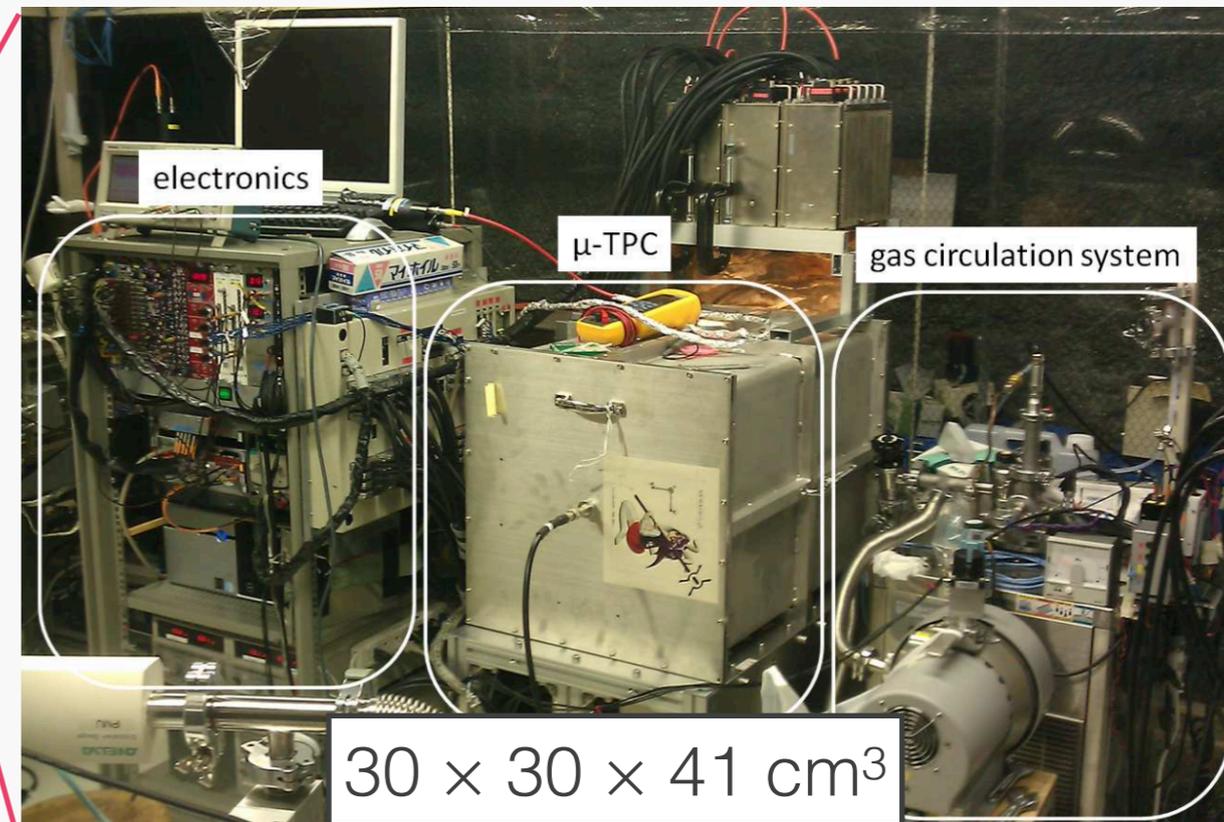
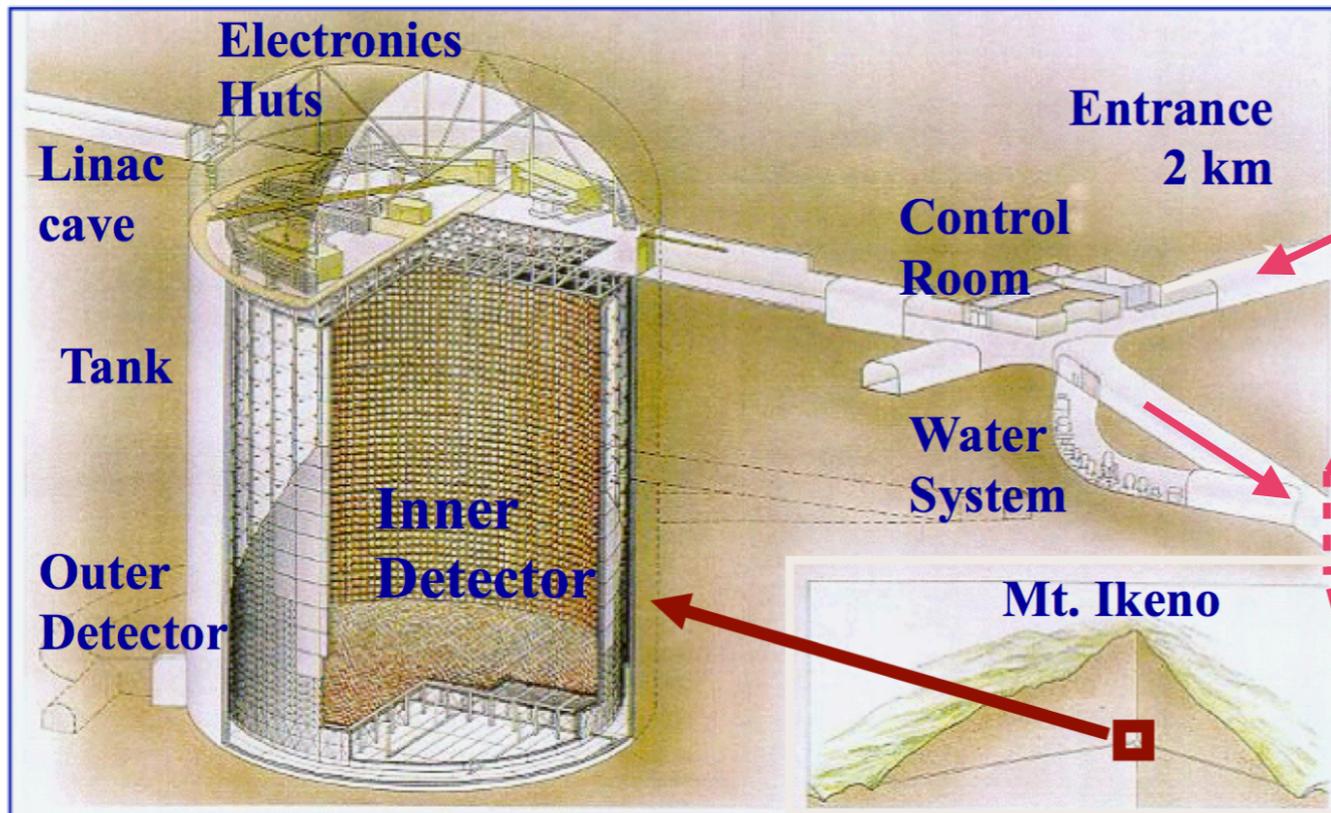
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# NEWAGE

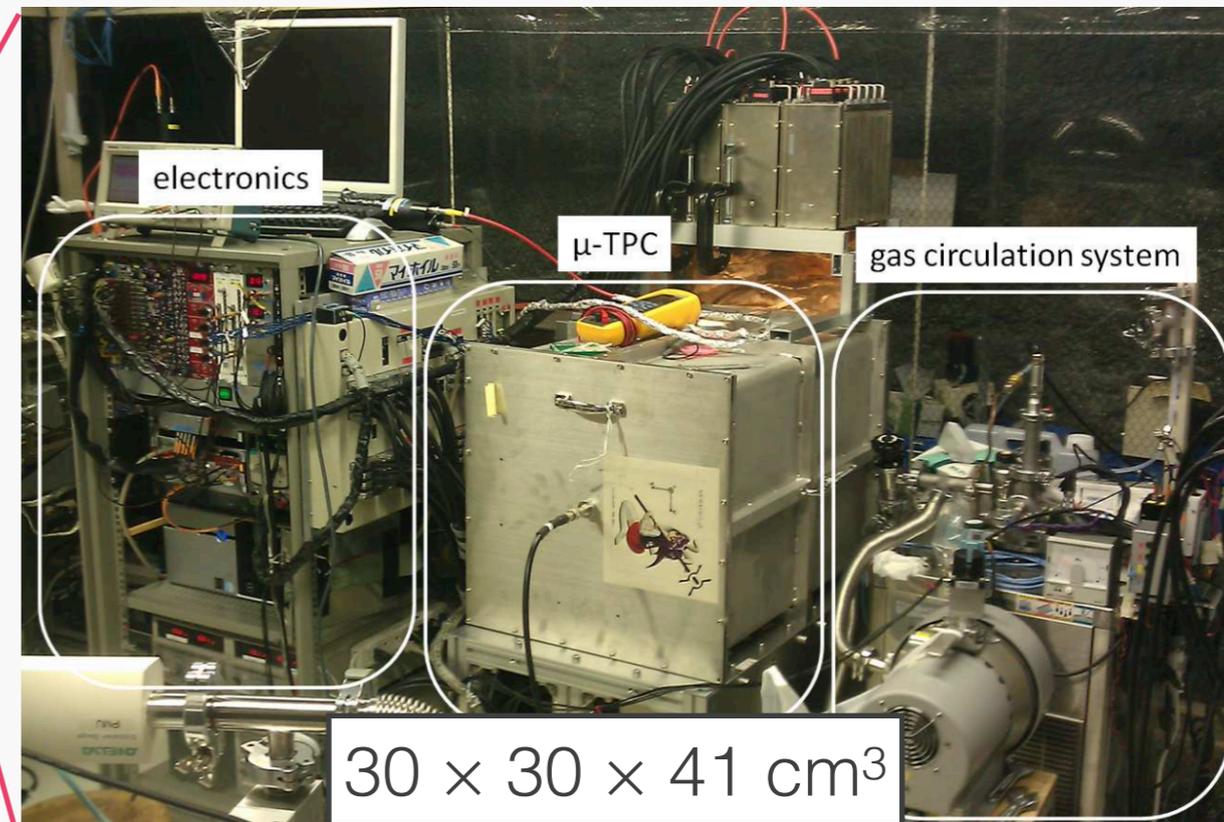
- Low pressure gaseous TPC
  - ➔  $30 \times 30 \times 41 \text{ cm}^3$  volume
  - ➔ filled with  $\text{CF}_4$  gas (0.1 atm)



# NEWAGE

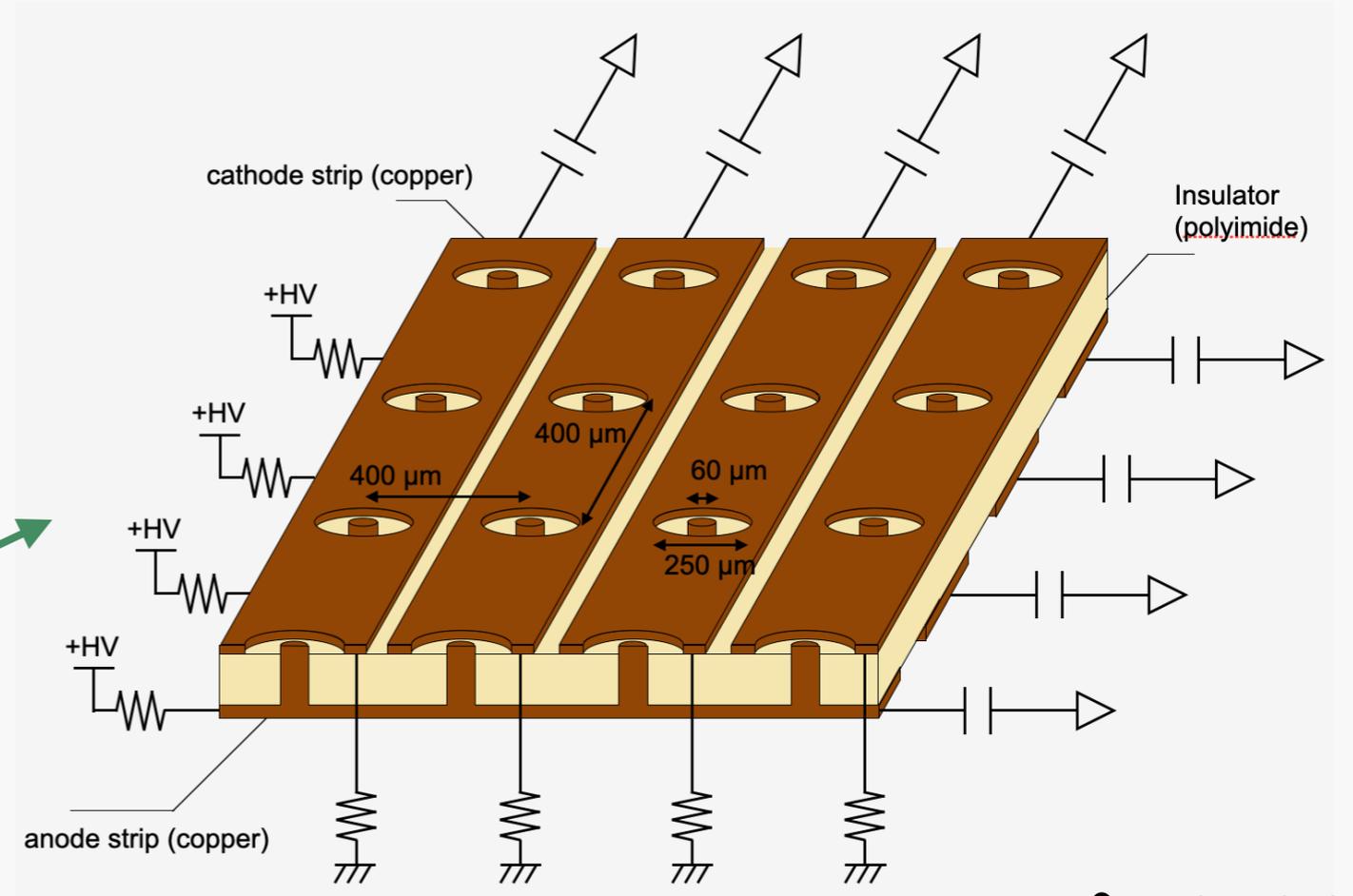
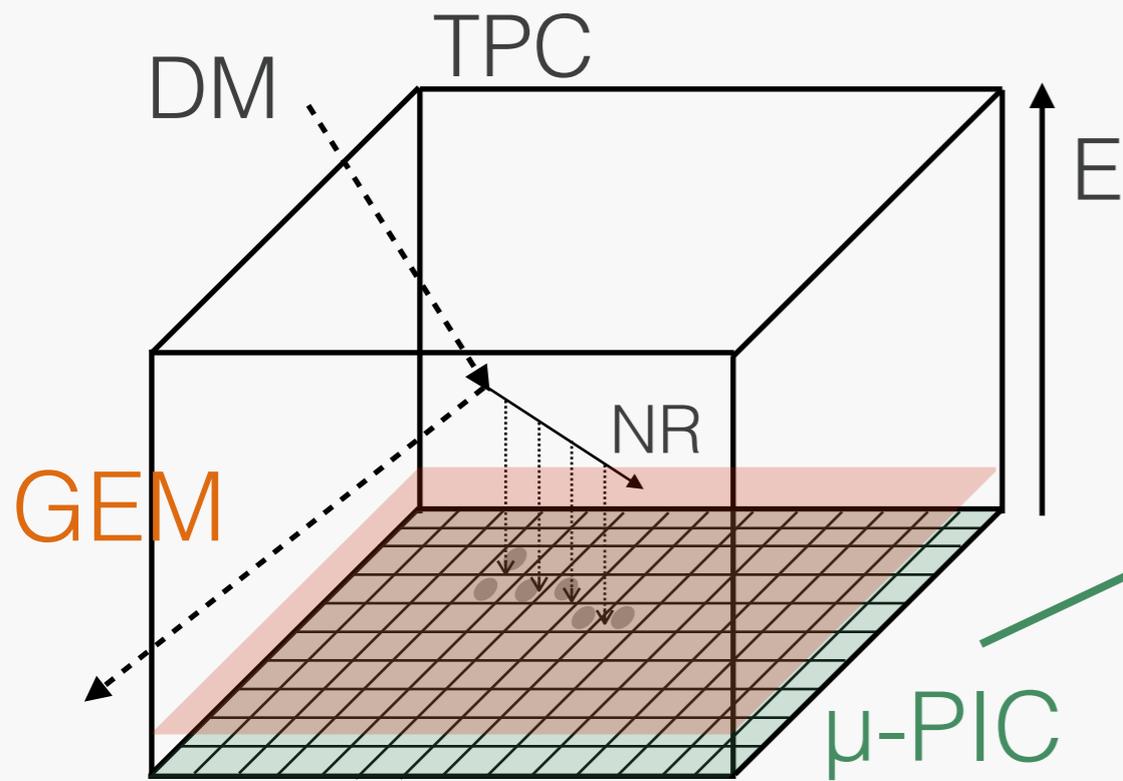
- Low pressure gaseous TPC
  - ➔  $30 \times 30 \times 41 \text{ cm}^3$  volume
  - ➔ filled with  $\text{CF}_4$  gas (0.1 atm)

2020~  
Copper shield installed



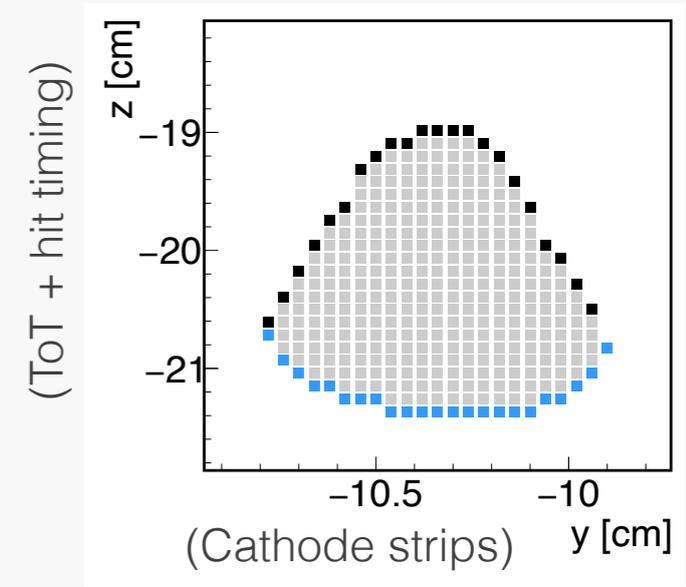
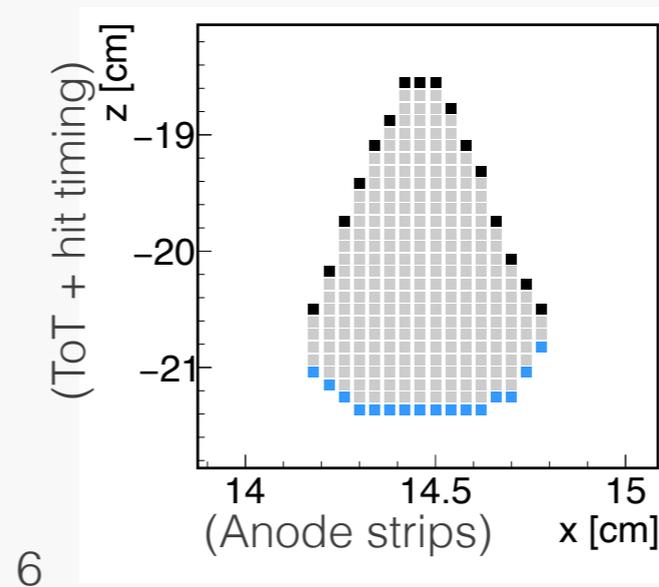
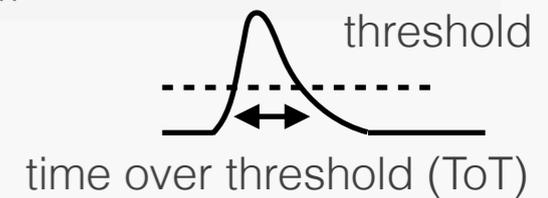
$30 \times 30 \times 41 \text{ cm}^3$

# NEWAGE: 3D track reconstruction



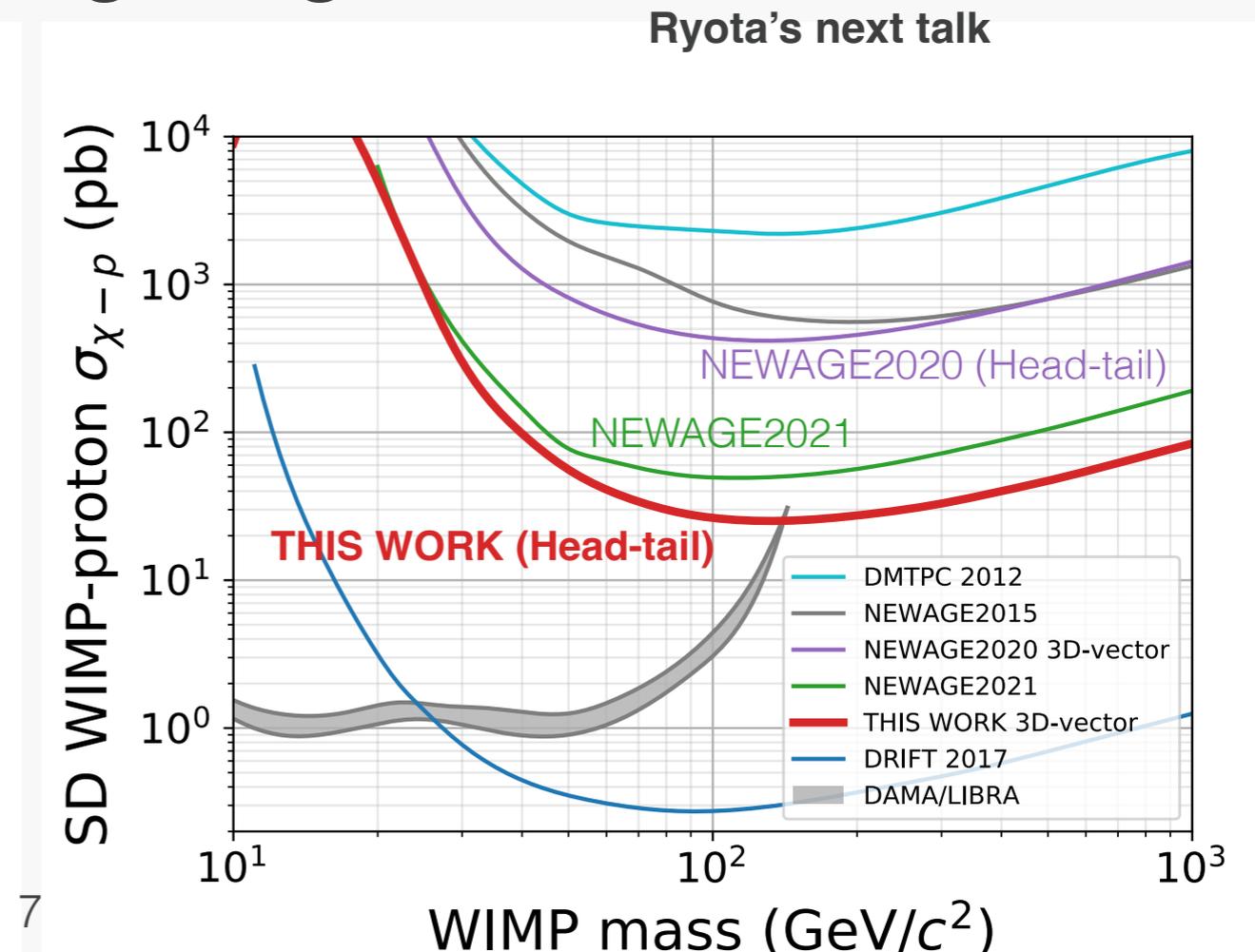
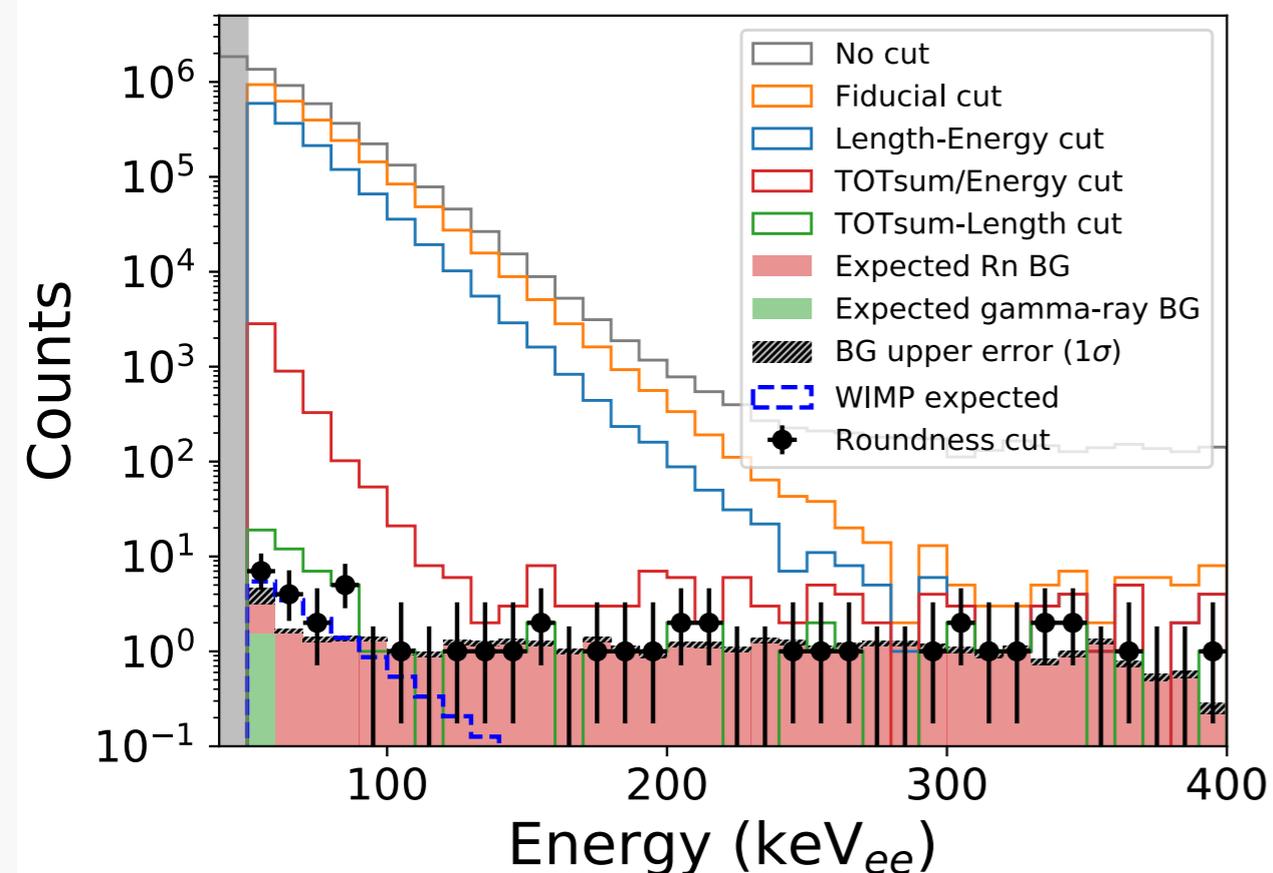
- GEM: Gas amplification
- $\mu$ -PIC:
  - 400  $\mu$ m pitch 2D strip readout
  - Gas amplification
  - 2D position + drift time
  - WIMP search with 3D track

NR event display



# Latest result

- 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**



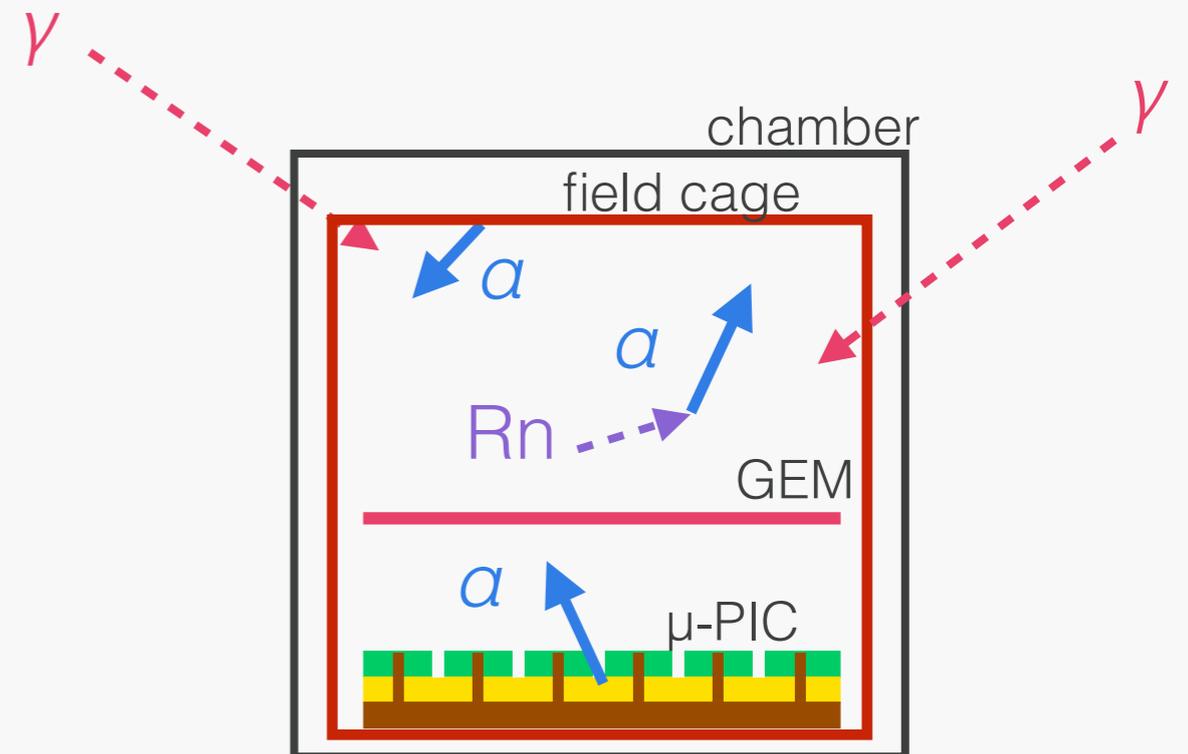
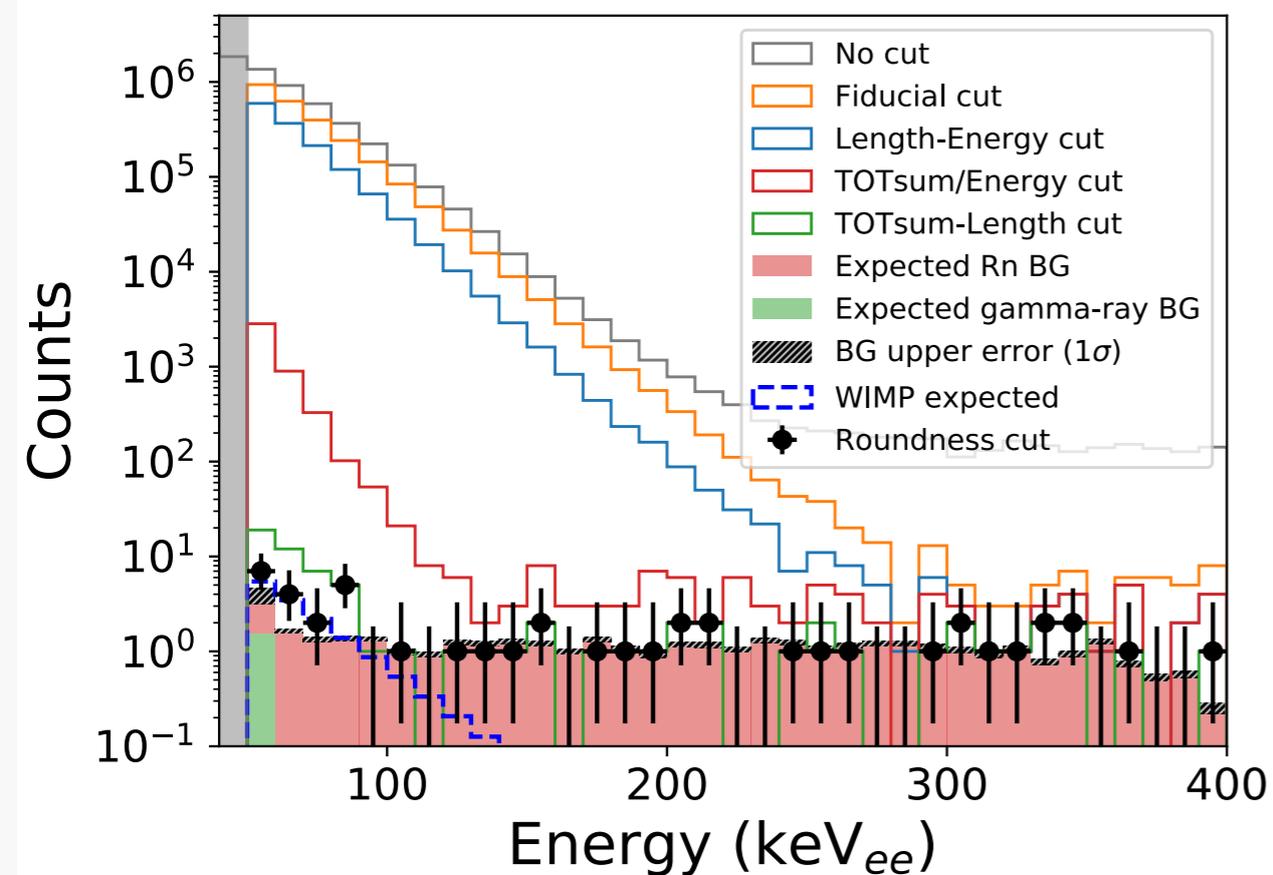
# Strategy of BG rejection

- External BG

- ➔ Ambient gamma (and neutron): shielding

- Internal BG

- ➔ Radon emanation: “clean” detector development



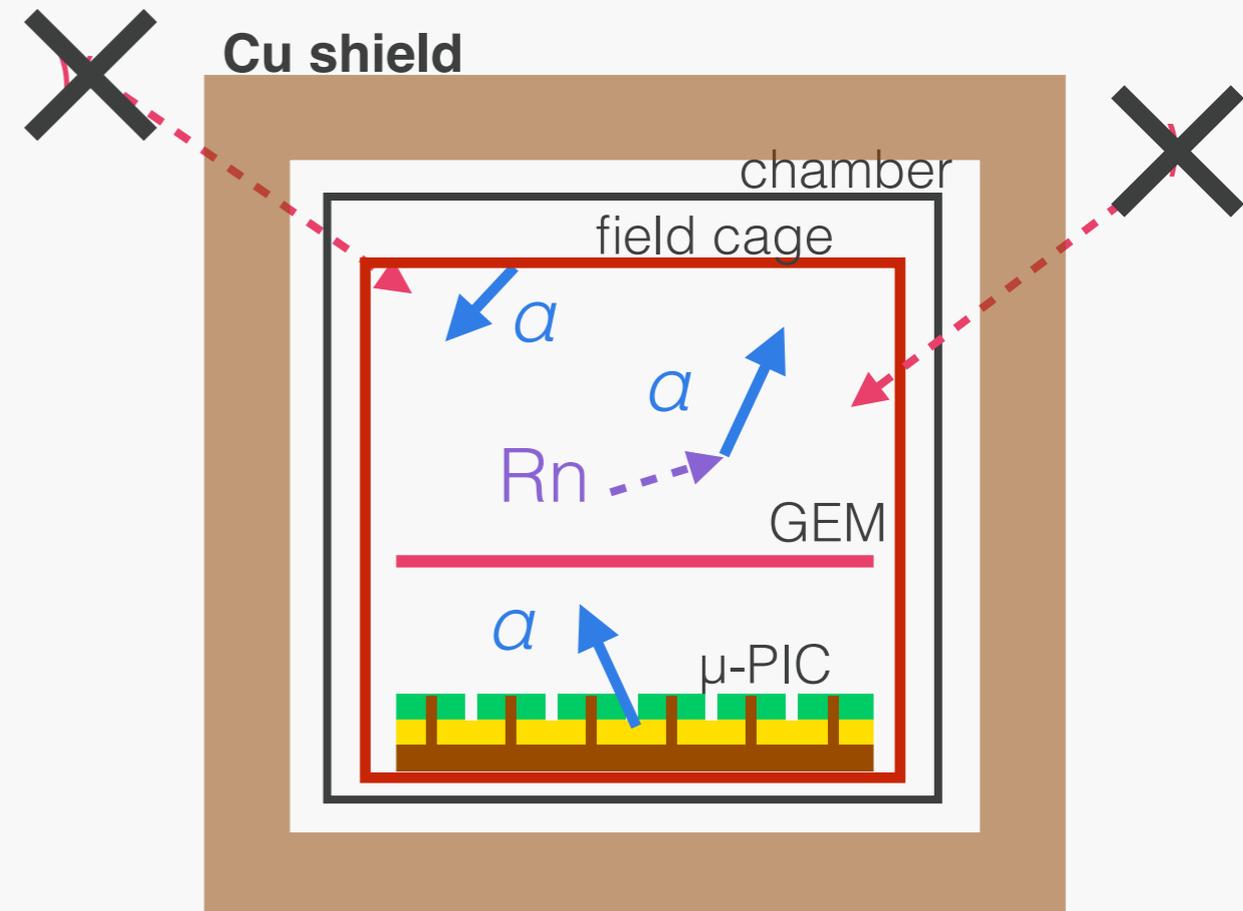
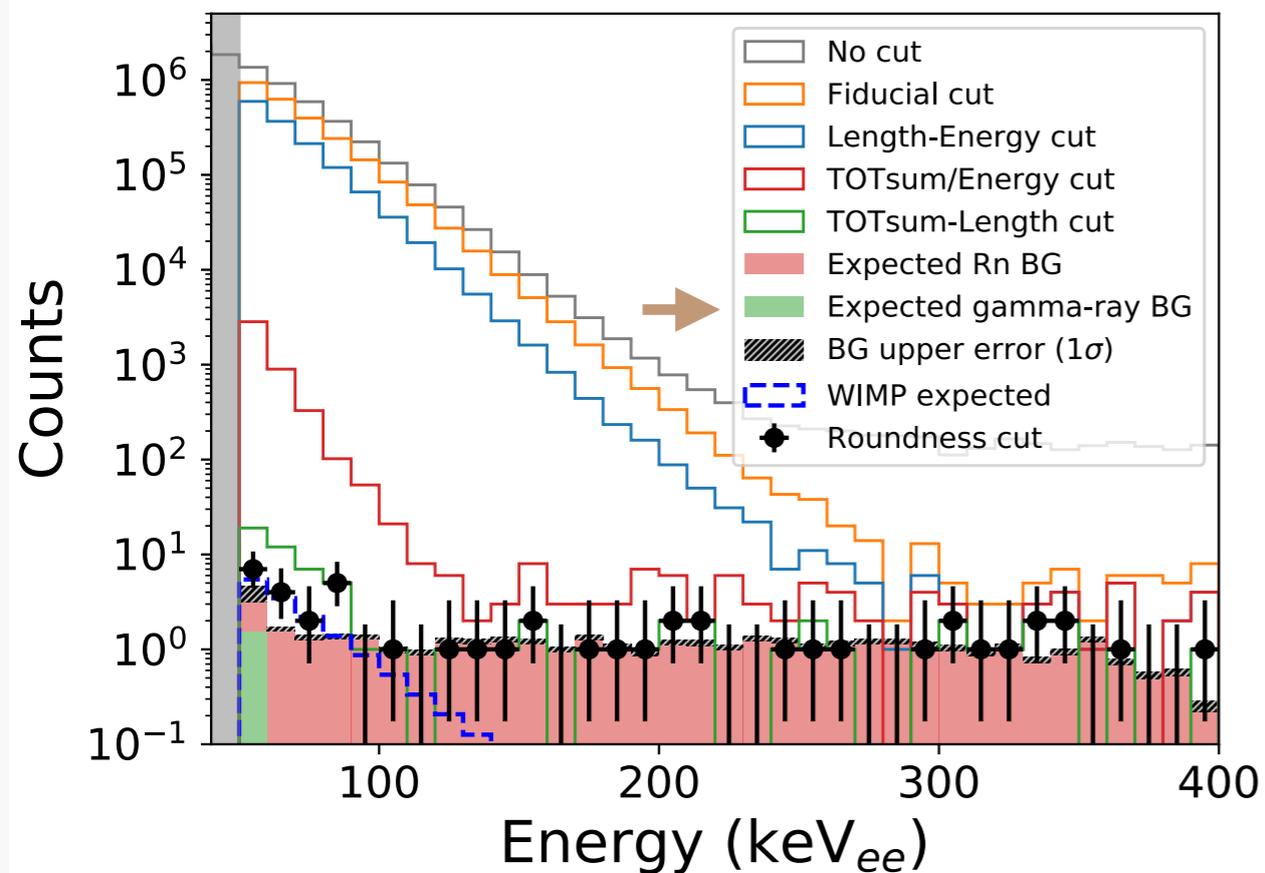
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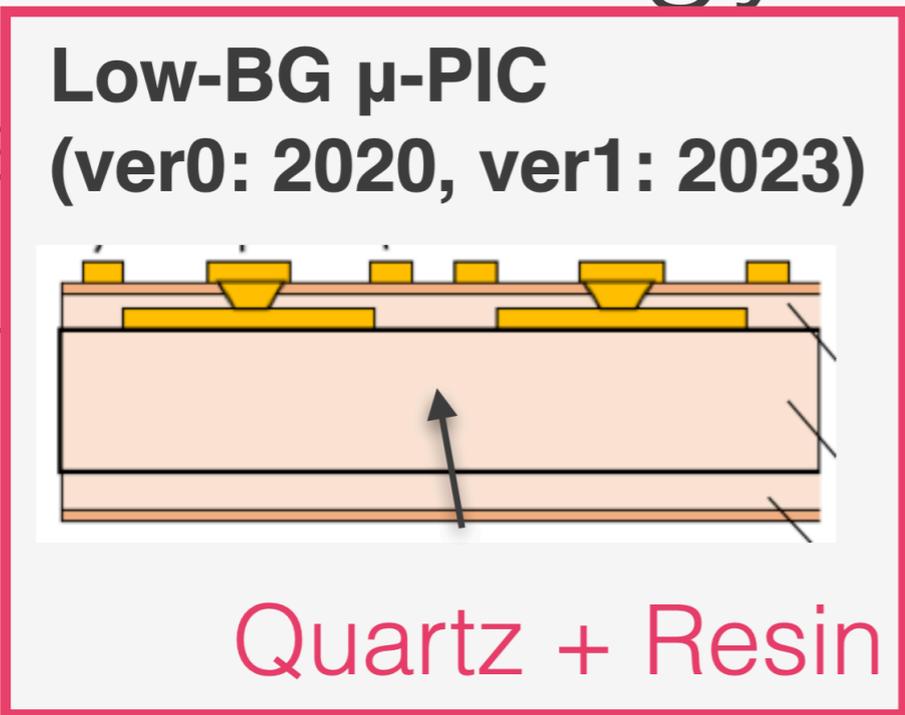
- Internal BG

- ➔ Radon emanation: “clean” detector development



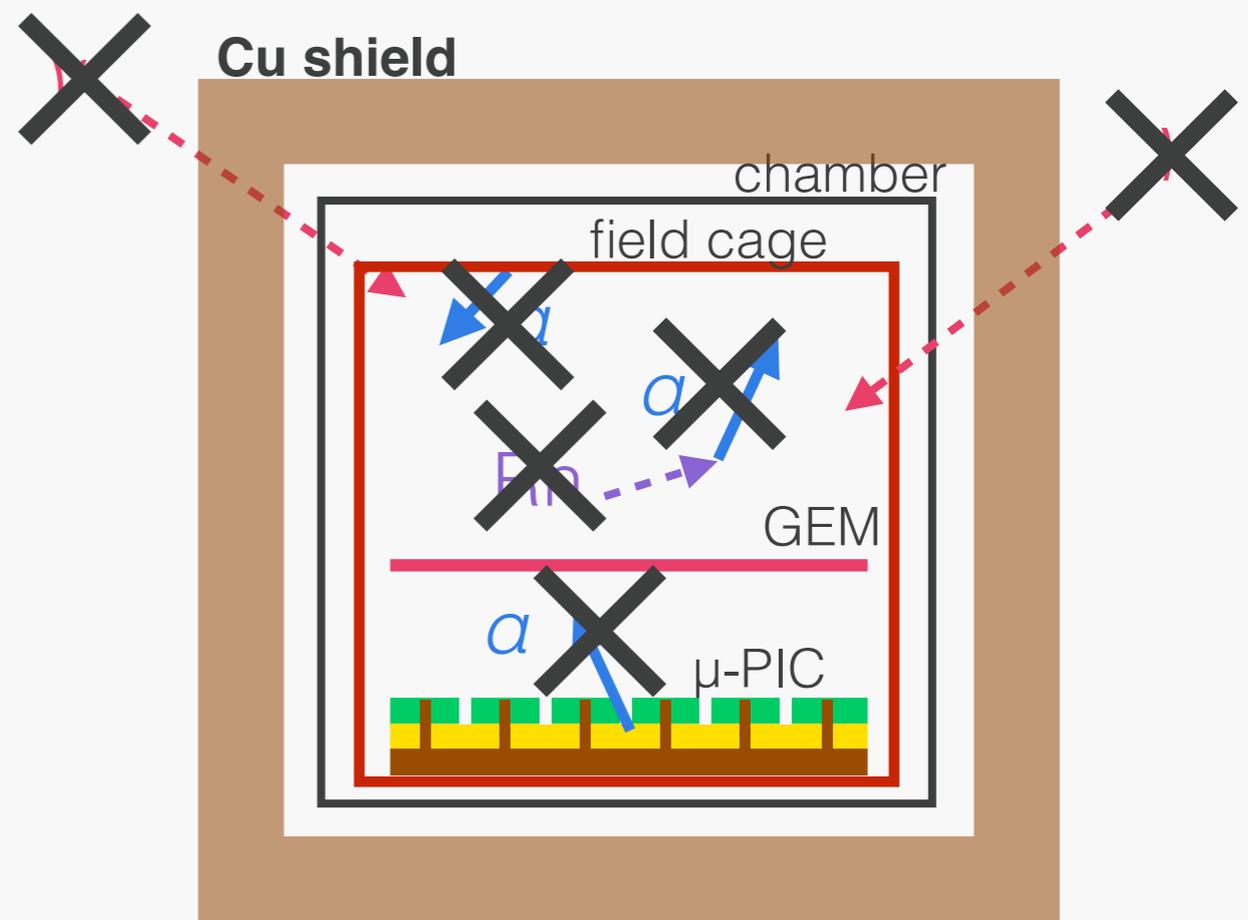
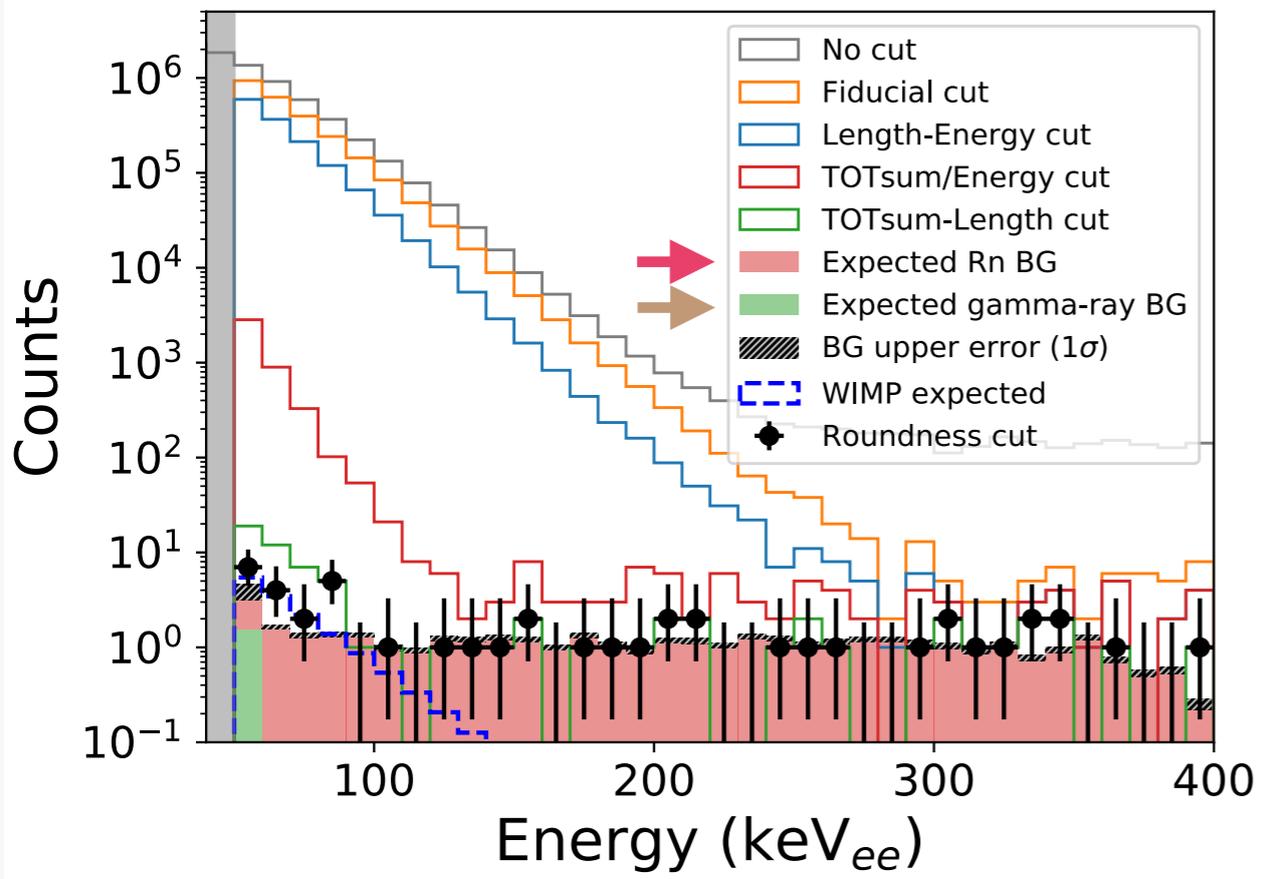
# Strategy of BG rejection

- External
- Internal



(neutron): s

→ Radon emanation: "clean" detector development

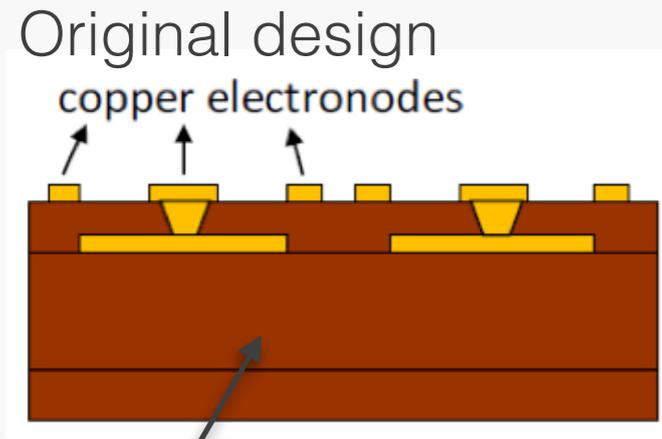




OF KOBE · PO

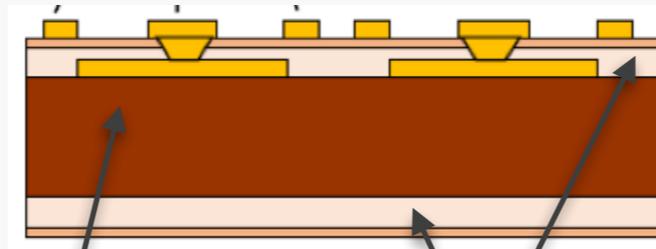
# Radon BG

# Development of “clean” detector



Original design  
copper electrodes  
Polyimide  
w/ glass cloth  
(Rn contaminated)

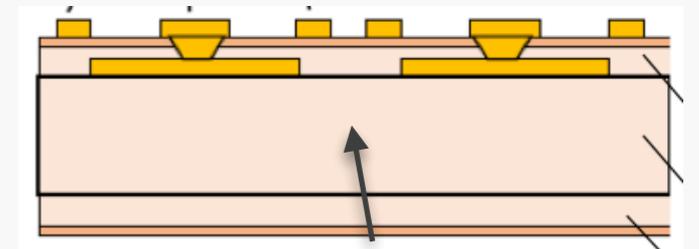
Low **surface** alpha version  
(LA $\mu$ -PIC: 2017-)



Polyimide  
w/ glass cloth

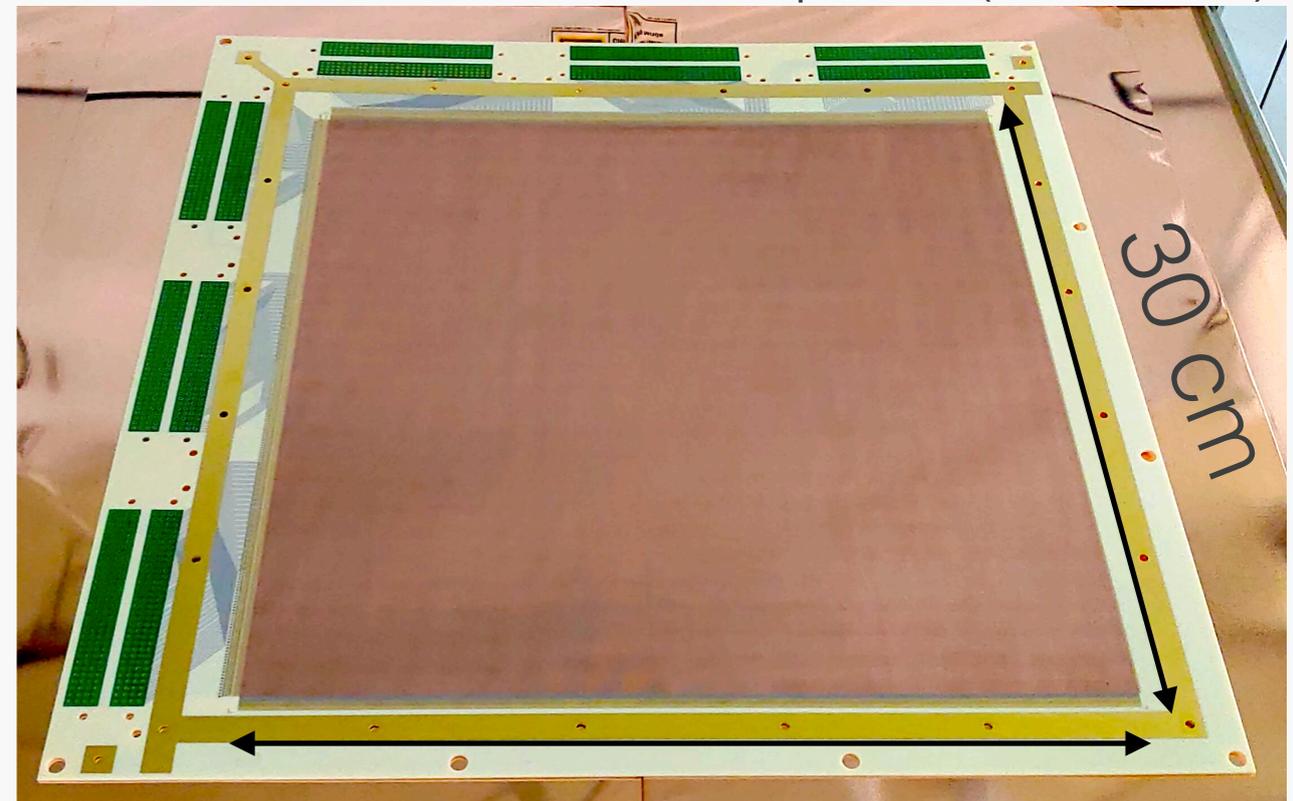
Polyimide  
w/o glass cloth

Low-BG  $\mu$ -PIC  
(2020-)



Quartz + Resin

LBG $\mu$ -PIC (DNP Inc.)



30 cm

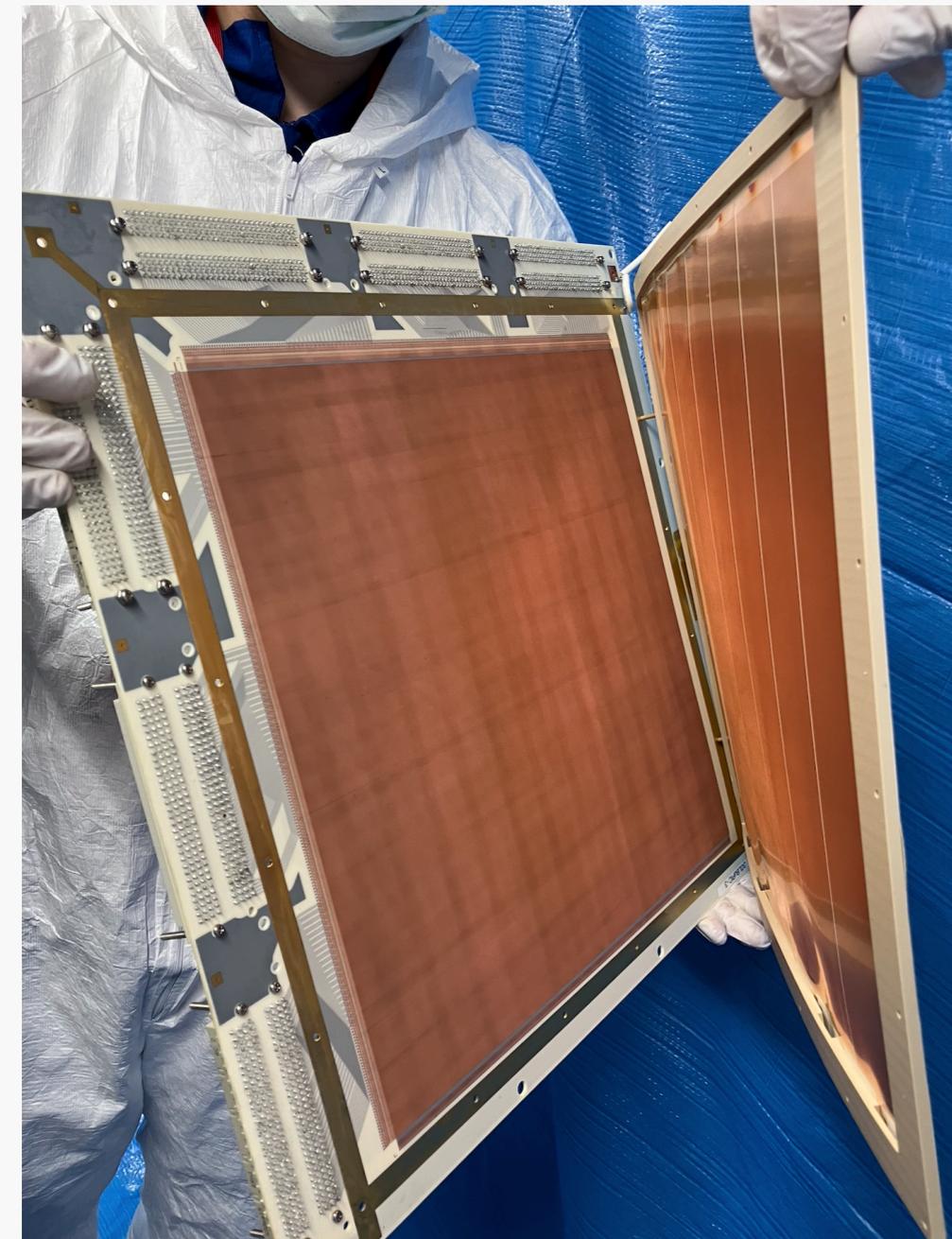
Radon emanation measurement:  
LA $\mu$ -PIC: **2.3 ± 0.5** [mBq /  $\mu$ -PIC]



LBG $\mu$ -PIC: **<0.17** [mBq /  $\mu$ -PIC]  
(90% C.L.)

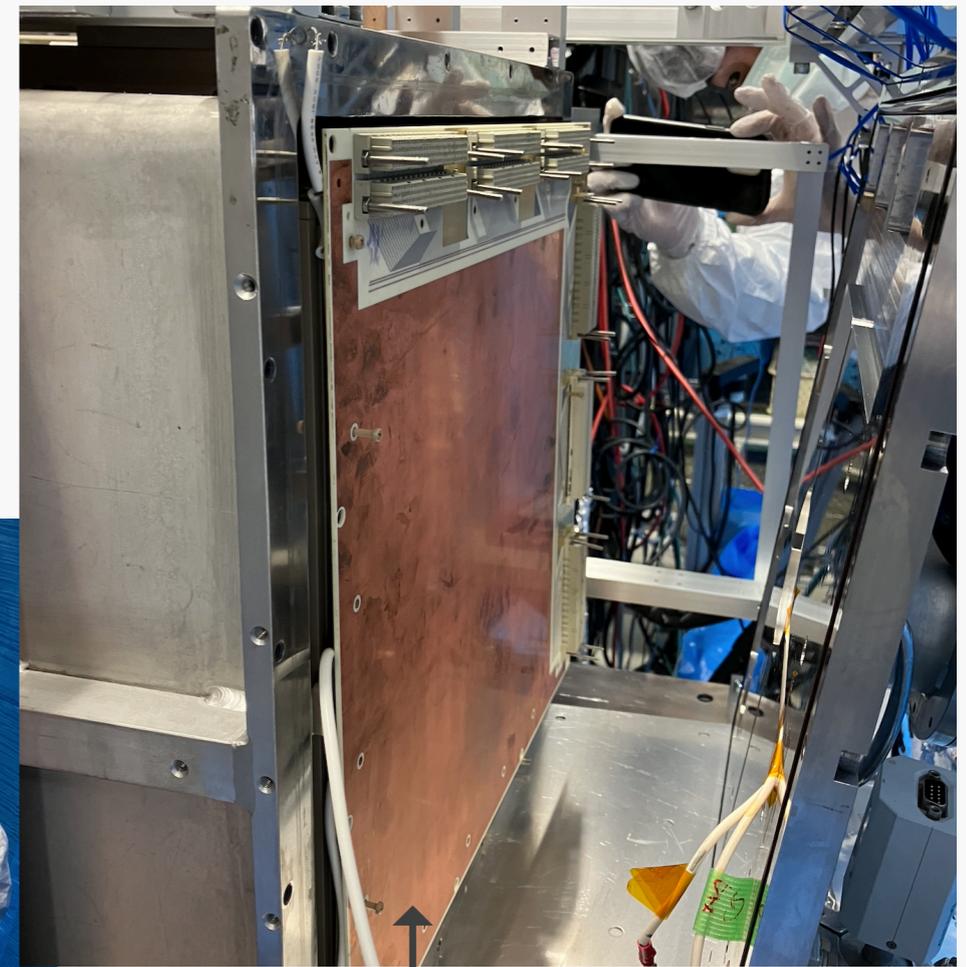
**NIM A 1072 (2025) 17014**

# Detector installation (Dec. 2023)



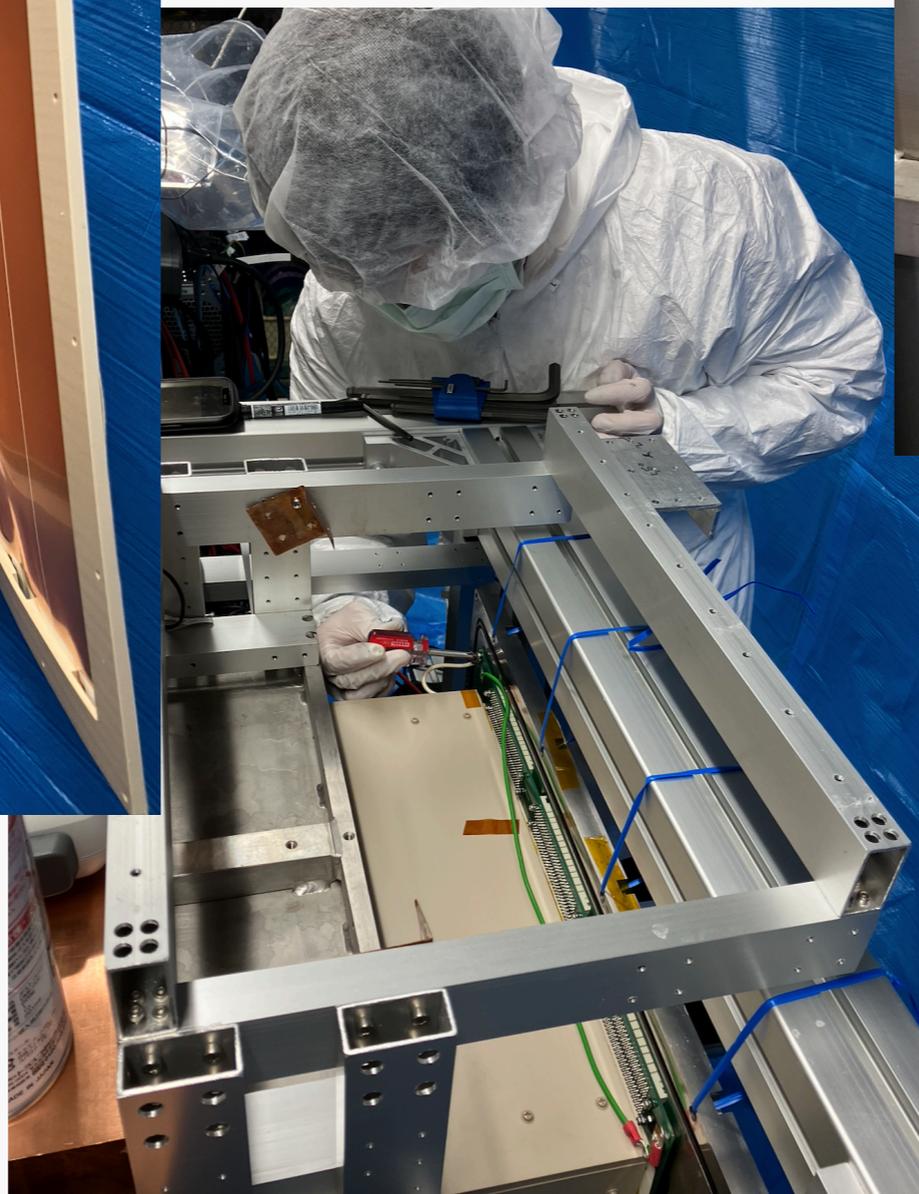
← GEM

↓ Ryota



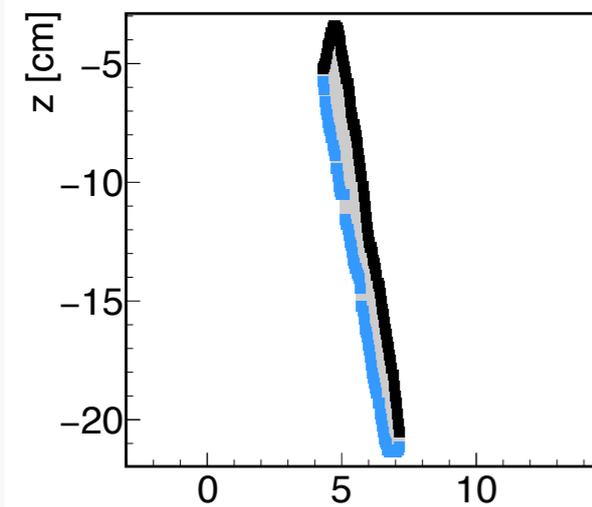
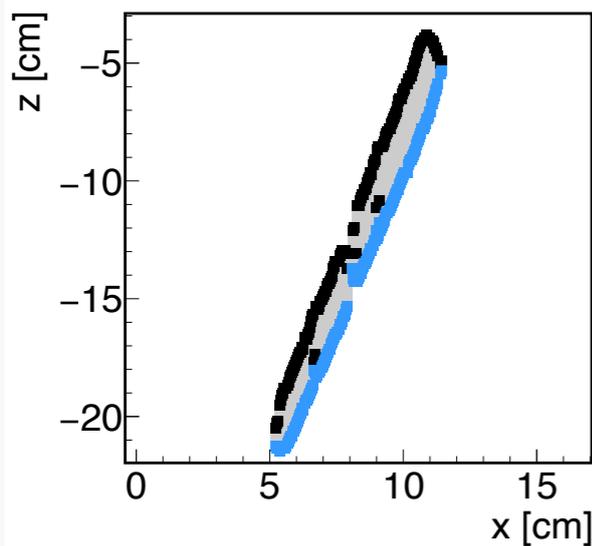
μ-PIC backplane

μ-PIC ↑



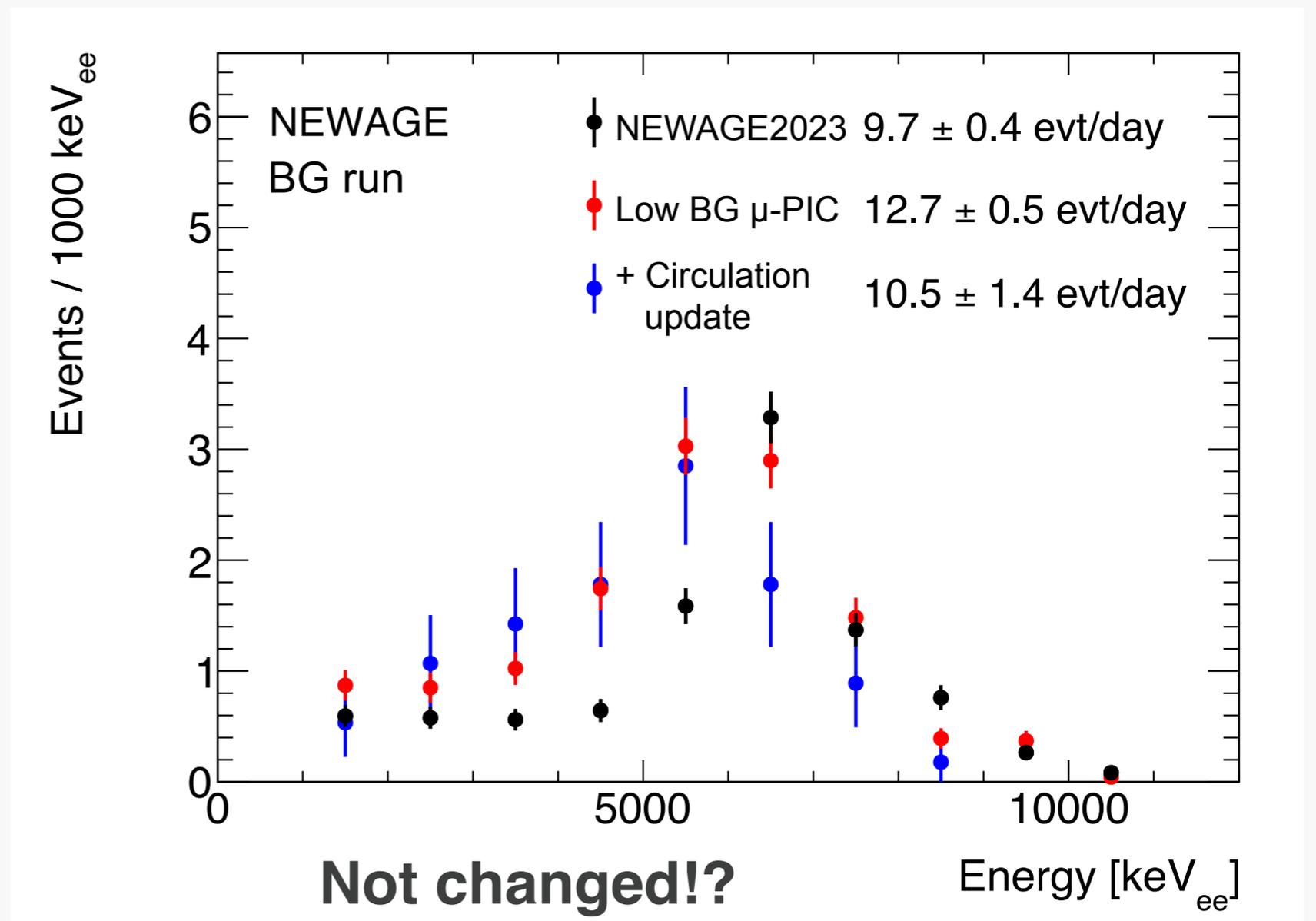
# Radon measurement

- Alpha from radon progenies can be identified by its energy and track length
  - ➔ 6 MeV alpha will have a track length of  $\sim 17$  cm (calculated by SRIM)
  - ➔ Events with  $> 4$  MeV are counted as alpha rays from radon and its progenies



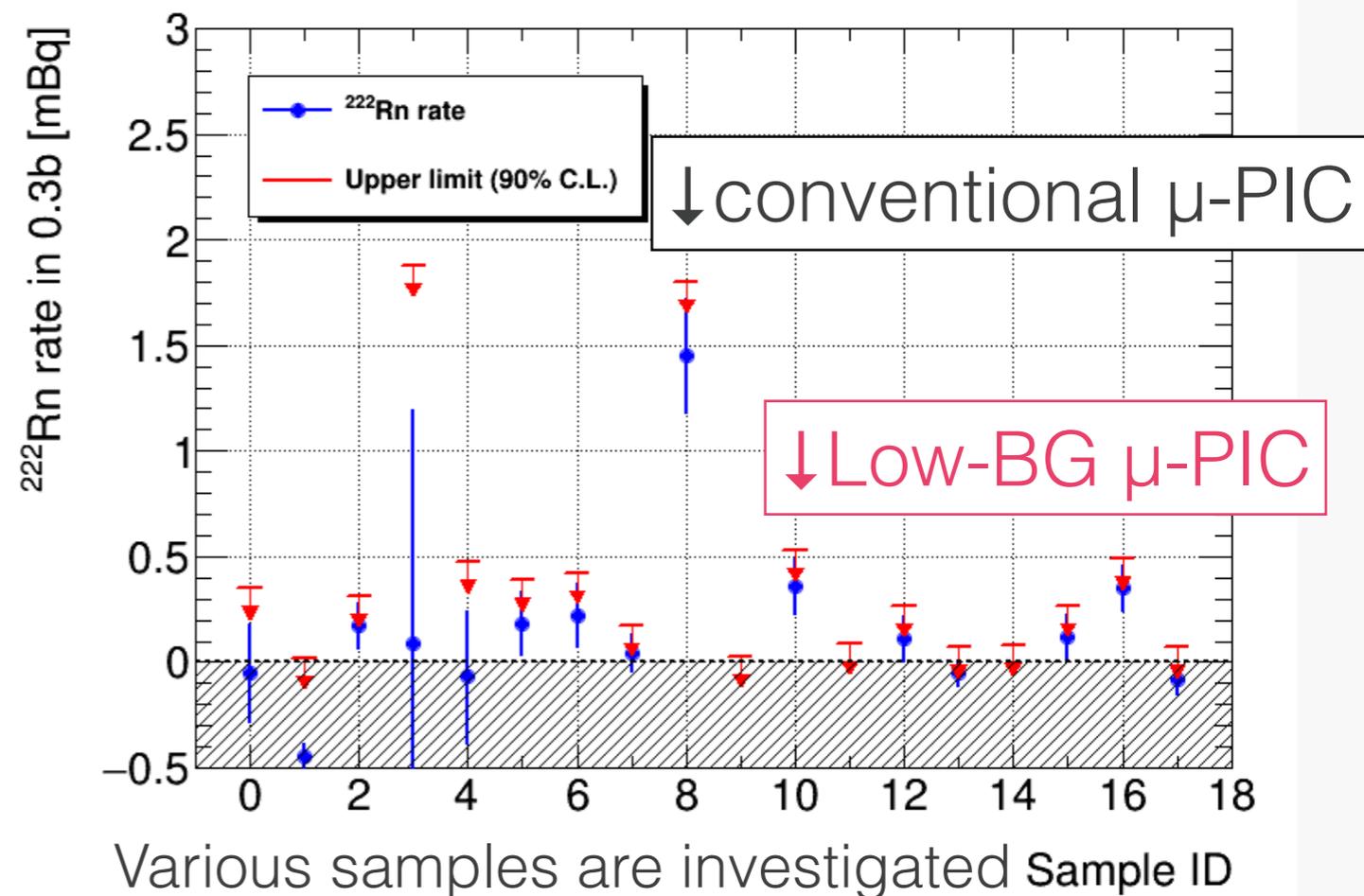
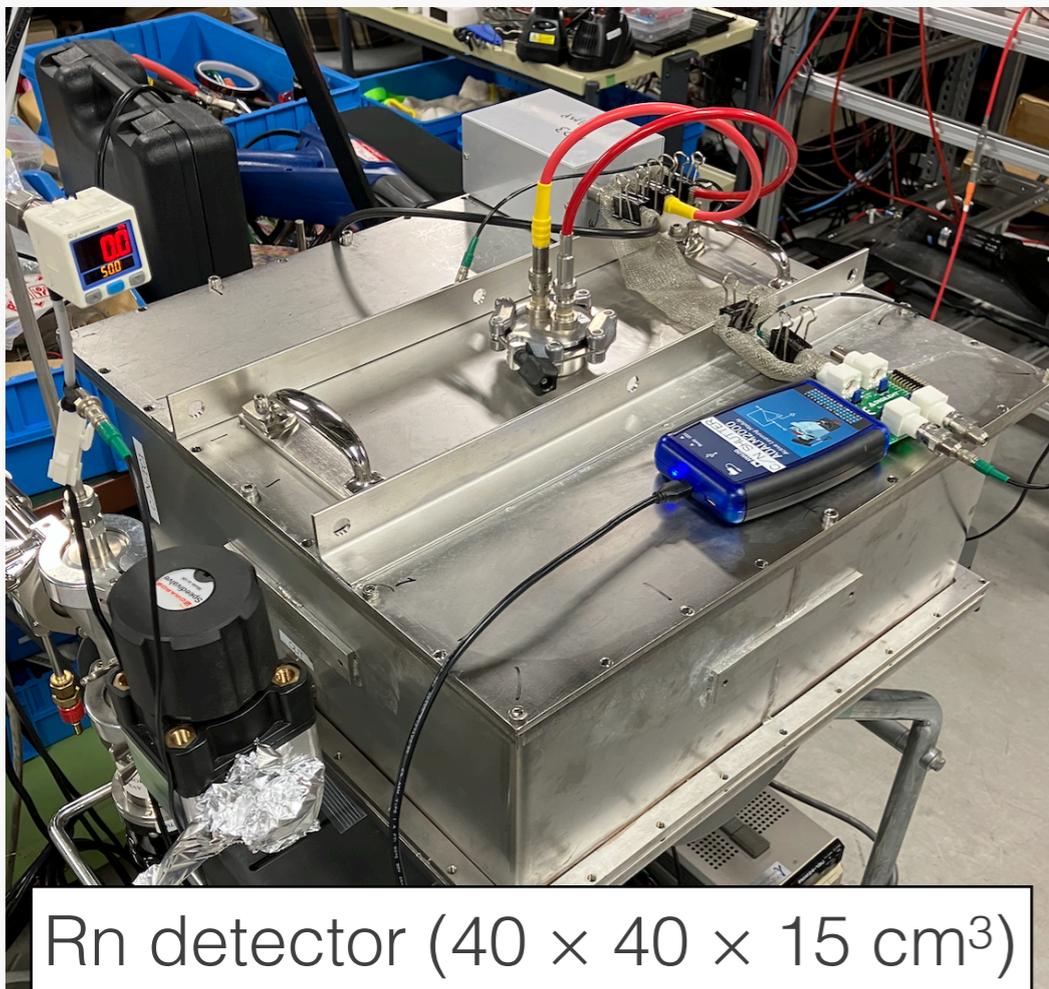
Typical alpha-like event

Energy =  $6.4 \text{ MeV}_{ee}$



# What is the source of Rn BG?

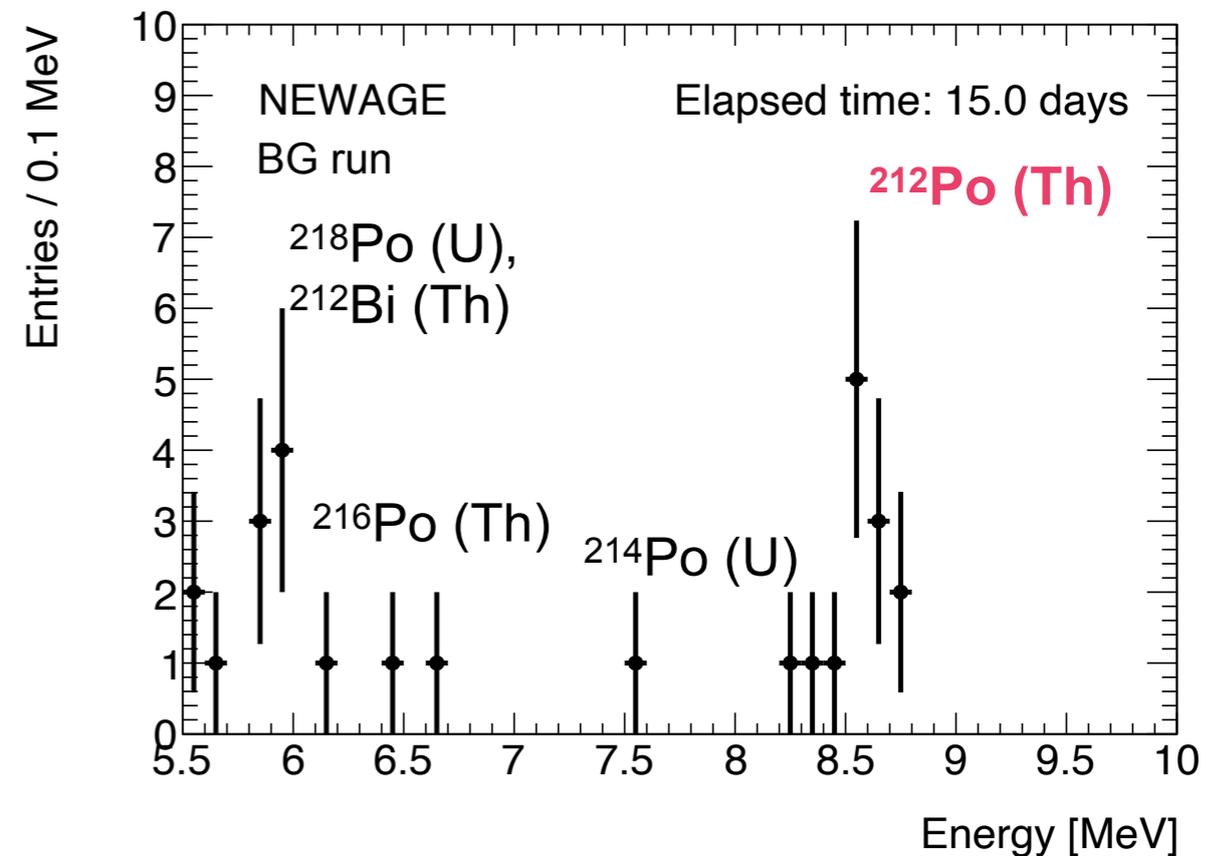
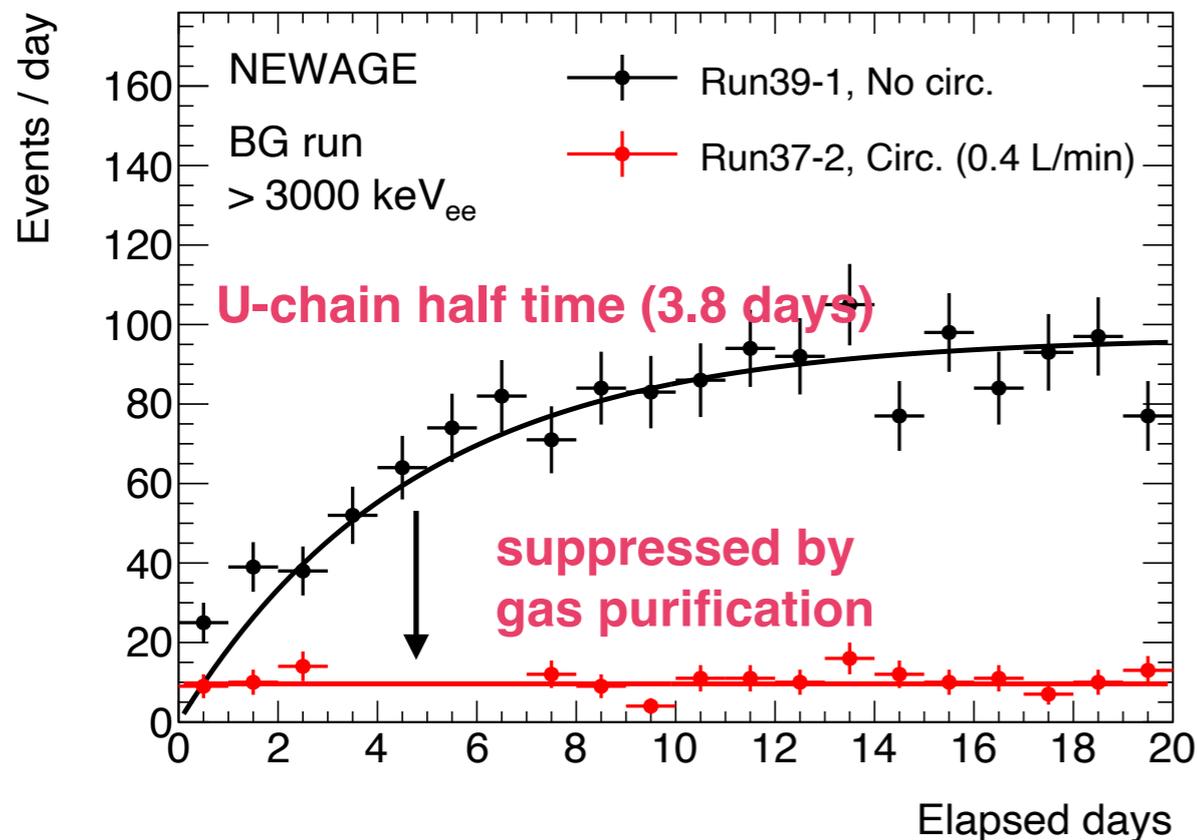
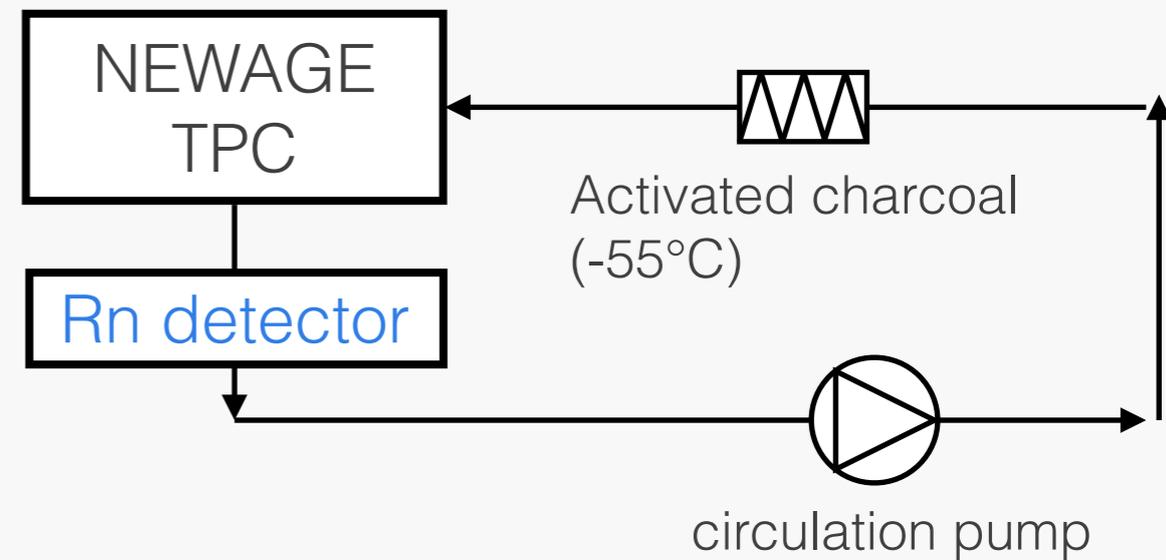
- Rn emanation rate for various TPC components was measured with electrostatic collection Rn detector
  - e.g.  $\mu$ -PIC, intermediation PCB, field cage (PEEK), O-ring, HV feedthrough, ...
- No component can explain the amount of Rn BG in the NEWAGE detector



# U / Th decay chain?

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

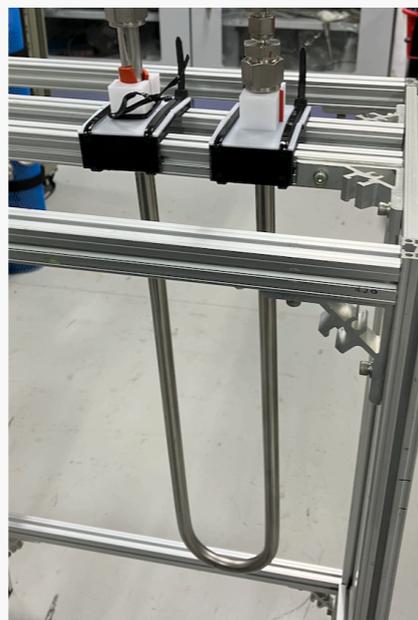
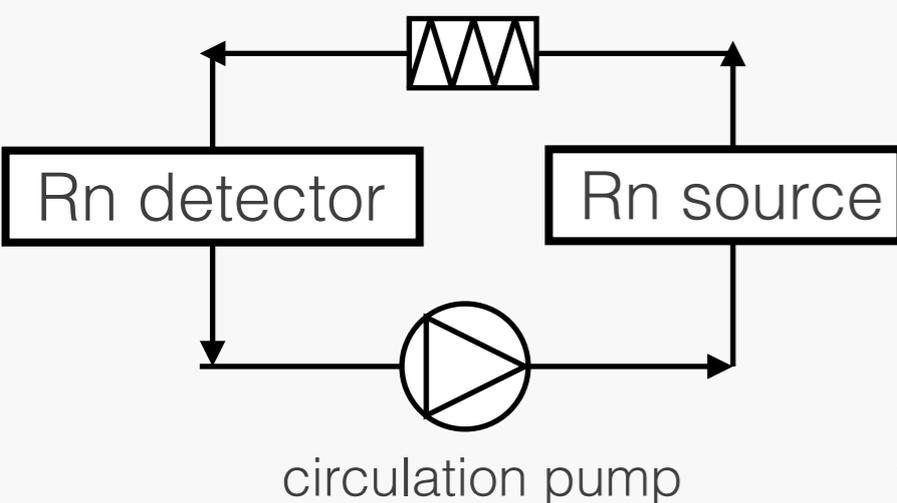
NEWAGE circulation system (simplified)



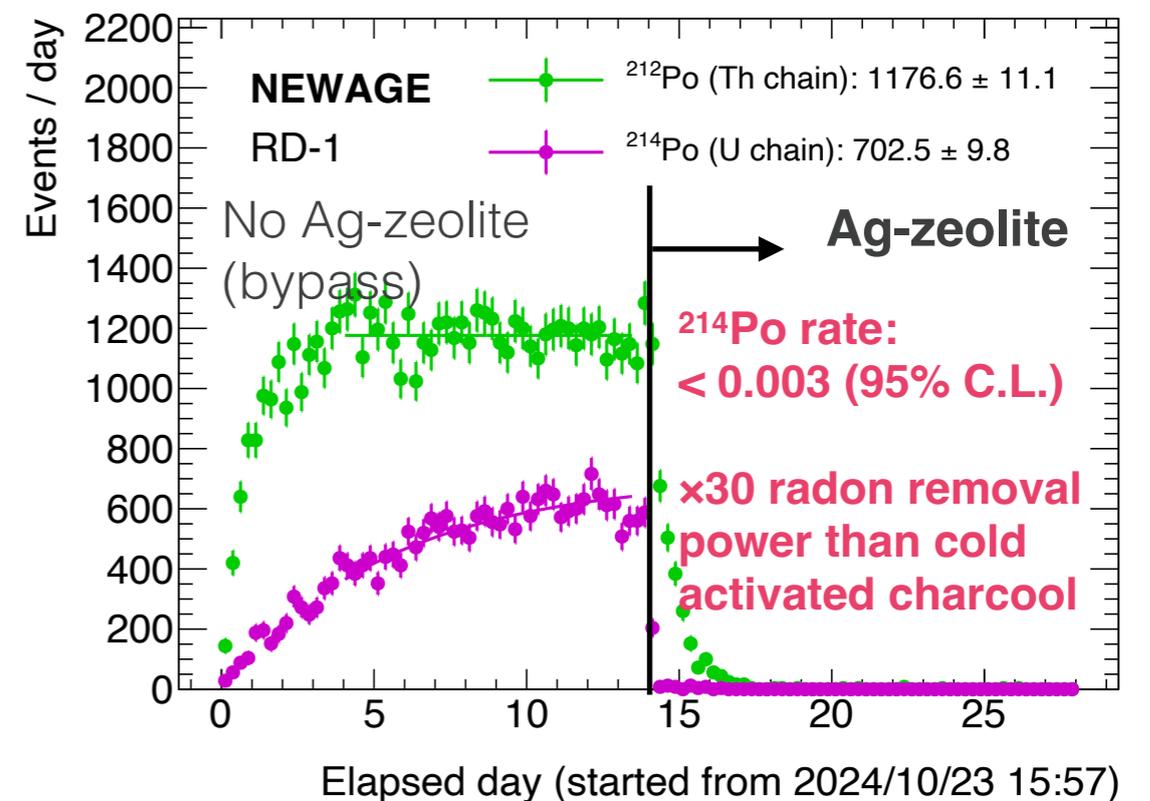
# Ag-zeolite for Rn filtering

- We discuss about “clean” gas purification filter 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
    - **Prof. Yasuo Takeuchi will give us a beneficial summary of the radon removal study tomorrow morning!**
- NEWAGE group also tested to introduce an Ag-zeolite filter with low-pressure pure CF<sub>4</sub> gas

Ag-zeolite  
“8Ag-FER-B” 20 g  
room temperature



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



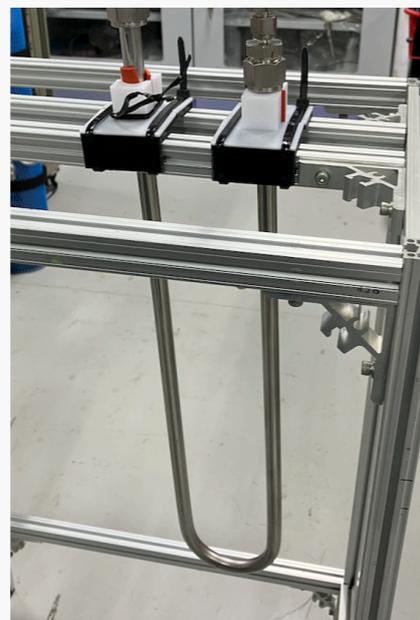
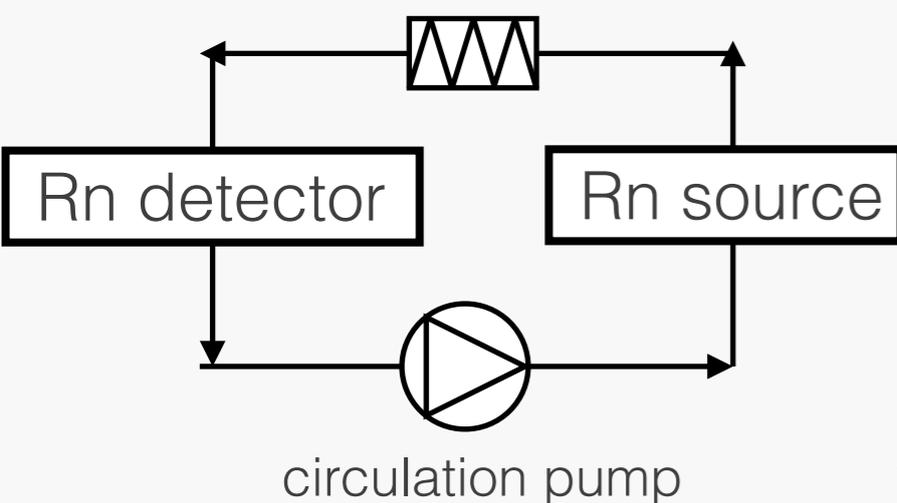
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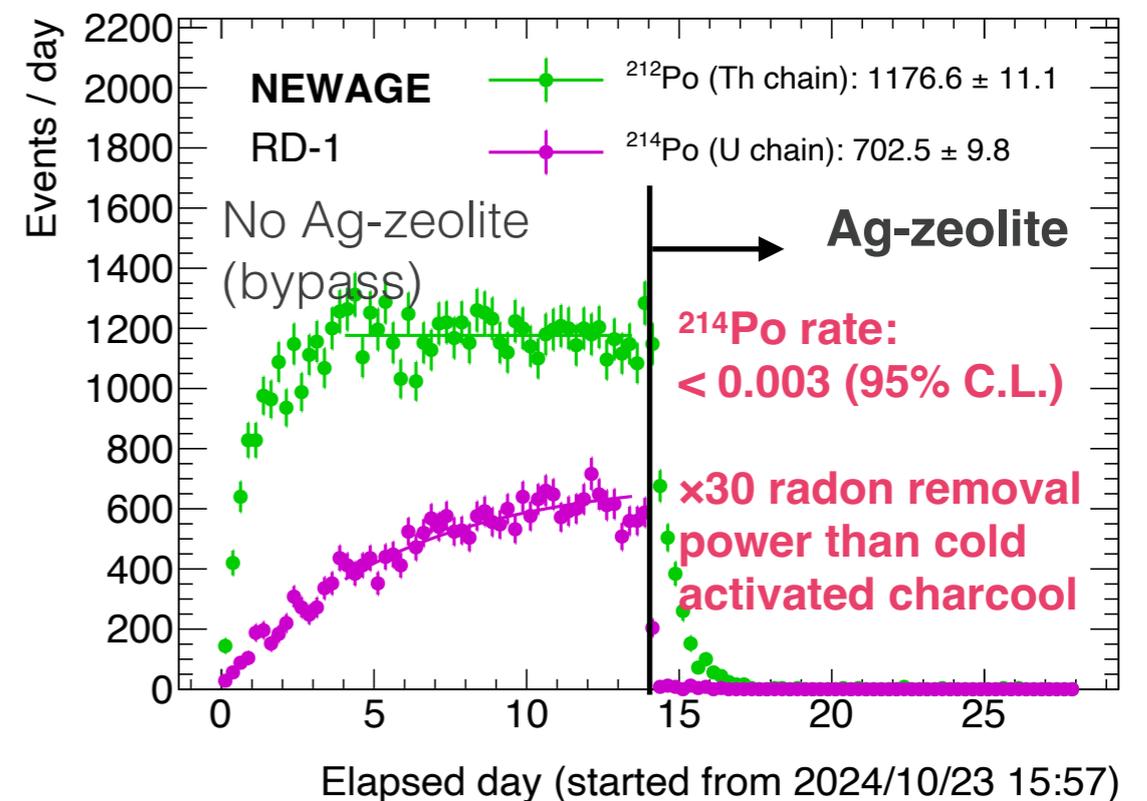
And very effectively remove Th-chain radon!  
Installed Ag-zeolite filter in NEWAGE system on July 2025

- NEWAGE group also tested to introduce an Ag-zeolite filter with low-pressure pure CF<sub>4</sub> gas

Ag-zeolite  
“8Ag-FER-B” 20 g  
room temperature

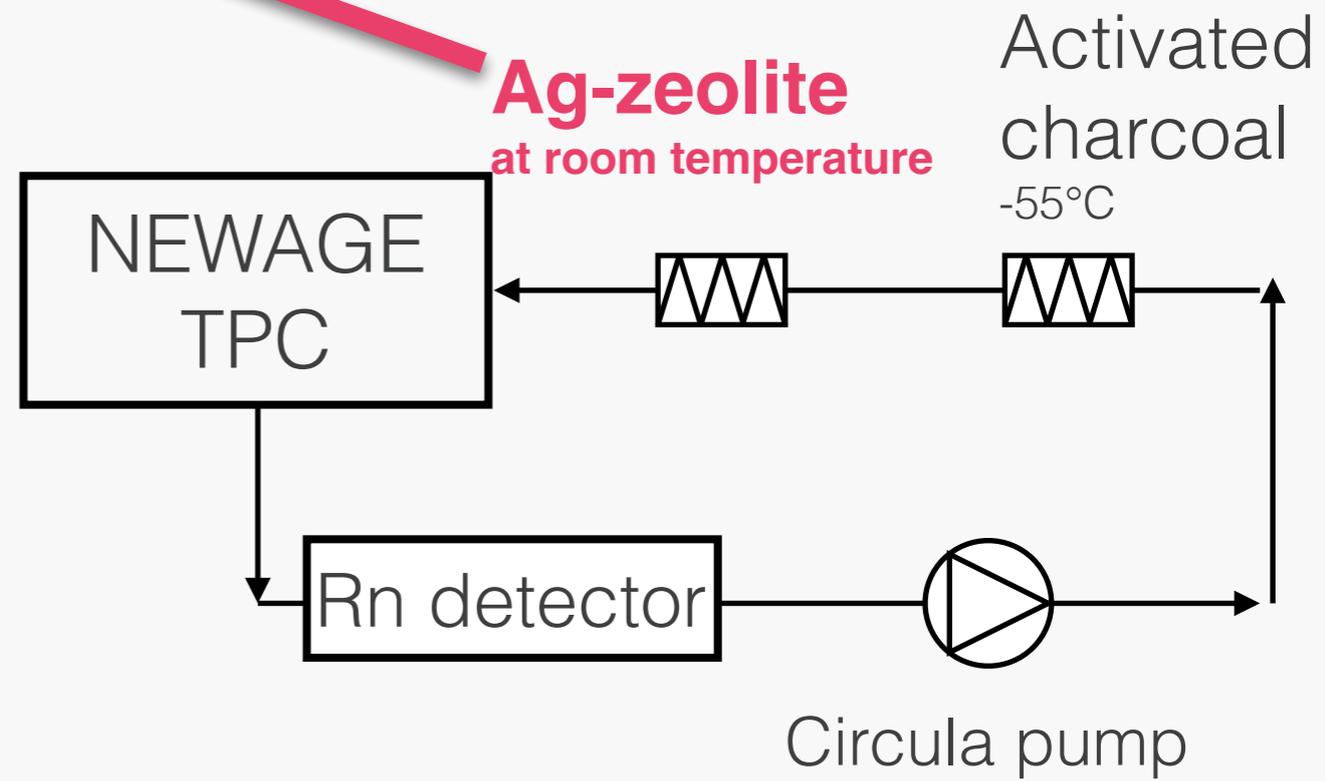


Ag-zeolite is filled in 1/2" stainless pipe



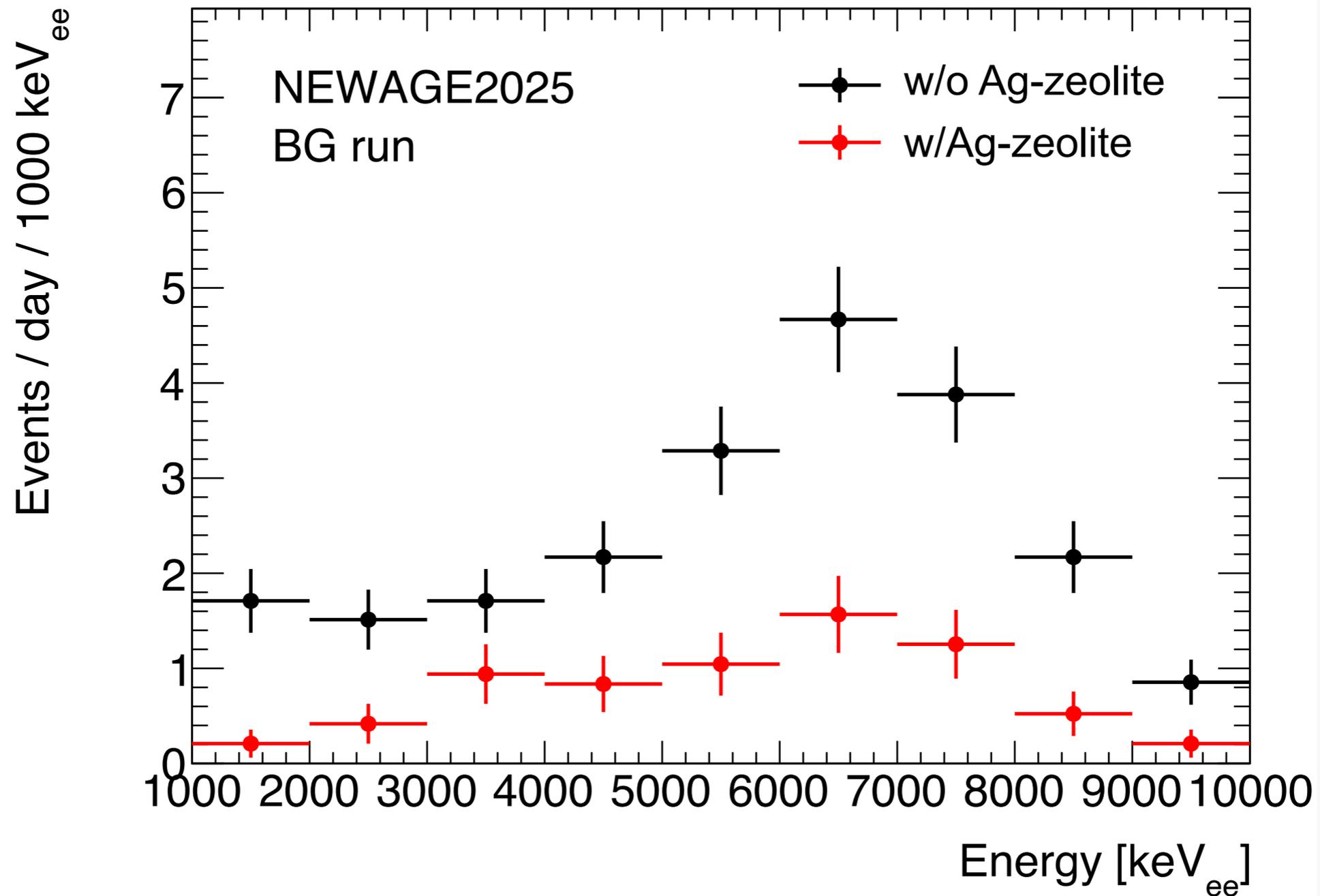
A part of NEWAGE circulation system  
(in the Kamioka mine)

Rn detector  
volume: 3.8 L



# Ag-zeolite performance

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

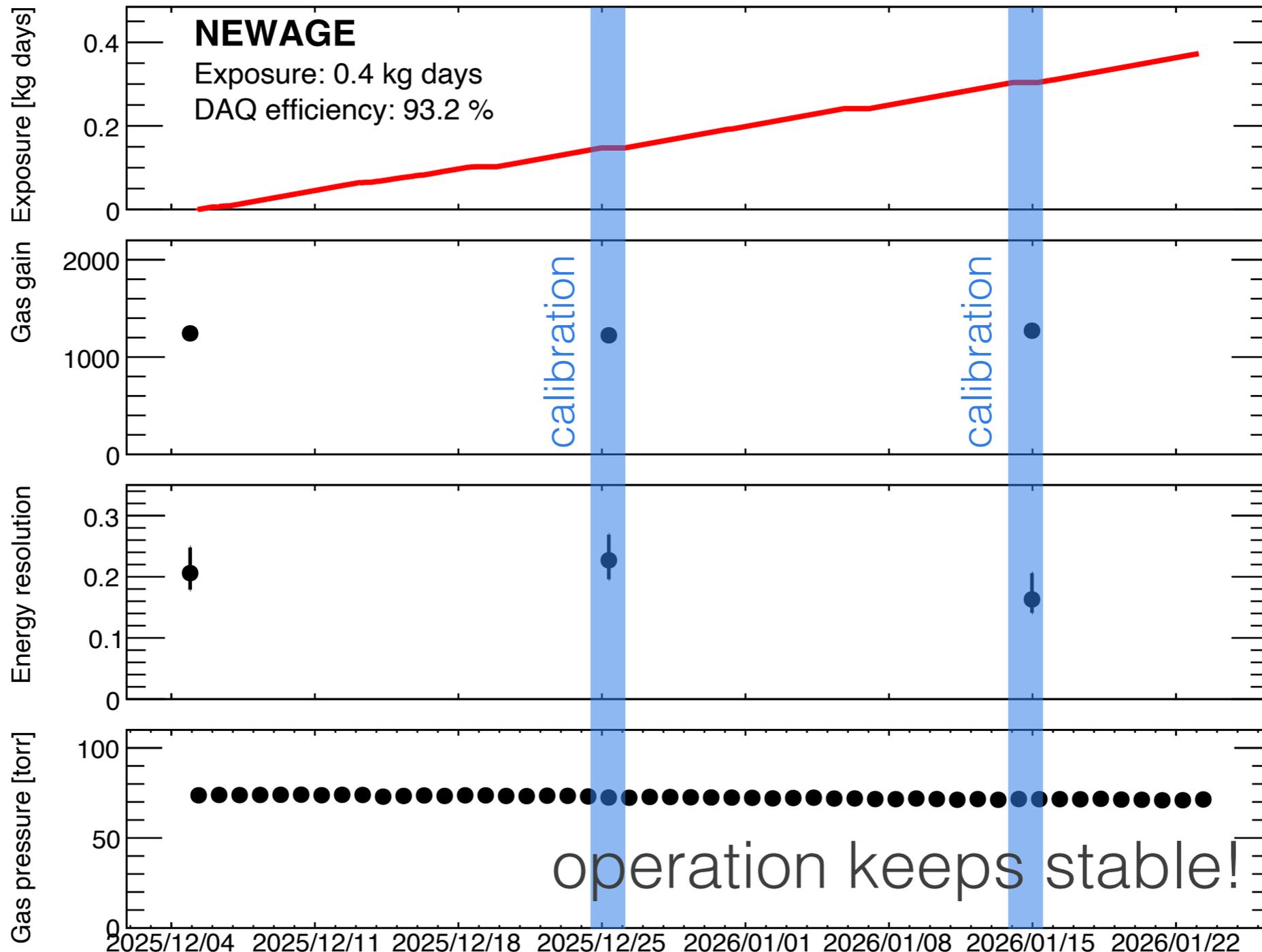


The background features a night-time photograph of Kobe, Japan. On the left is the illuminated orange tower of the Kobe Portland Cement Company, with 'OF KOBE-PO' visible at its top. To the right is the white, lattice-like roof of the Kobe University Sports Center. The city lights and buildings are visible in the background.

# Underground experiment

# NEWAGE2025

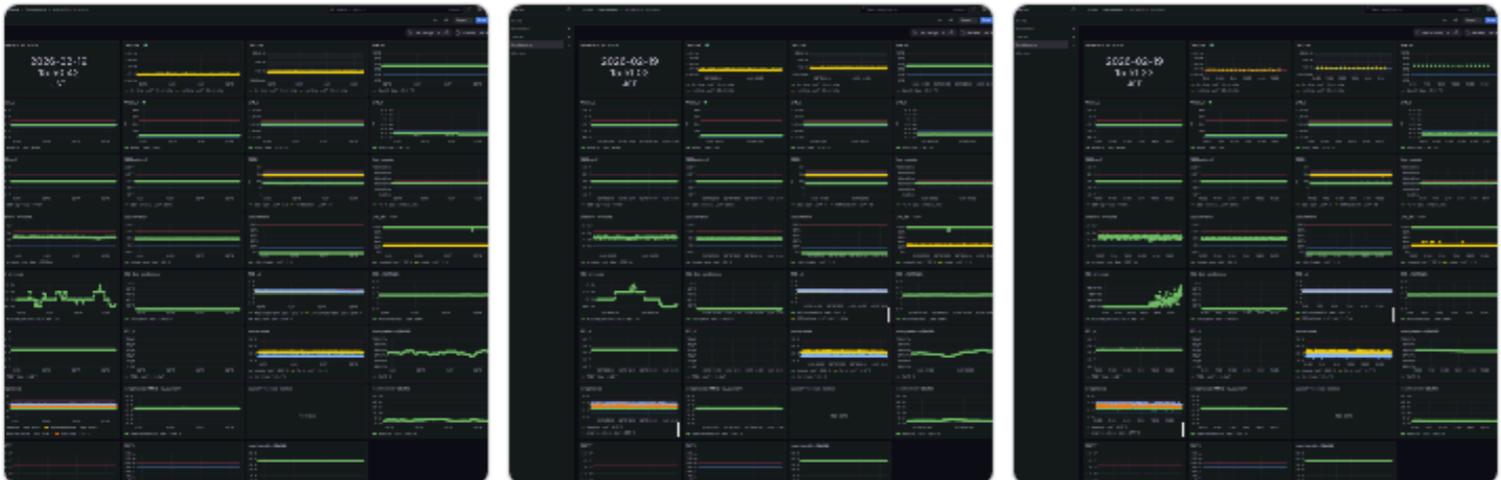
- Measurement has started from Dec. 4 2025 after commissioning
  - ➔ only 1/8 exposure obtained comparing with the NEWAGE2023 analysis



NEWAGE SM na2 APP 3:51 PM  
NEWAGE 0.3b status 😊

<http://10.240.101.210:3000/d/3tq-AbFnk/newage-0-3b-status?orgId=1&from=now-7d&to=now>  
<http://10.240.101.210:3000/d/3tq-AbFnk/newage-0-3b-status?orgId=1&from=now-2d&to=now>  
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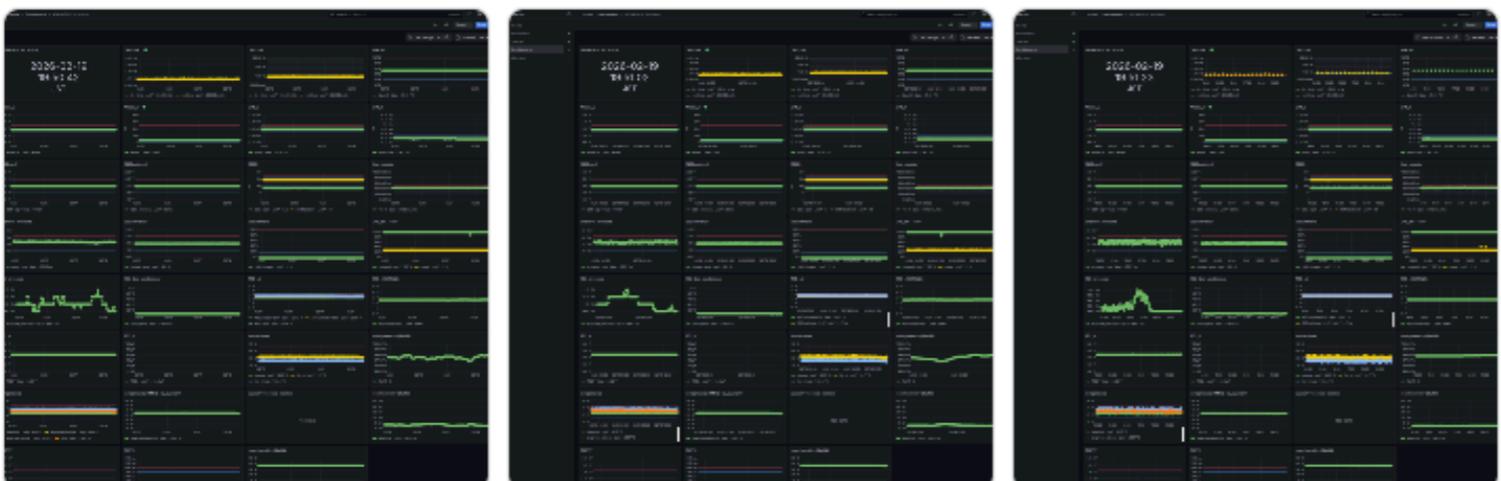
3 files | Download all



NEWAGE SM na2 APP 7:51 PM  
NEWAGE 0.3b status 😊

<http://10.240.101.210:3000/d/3tq-AbFnk/newage-0-3b-status?orgId=1&from=now-7d&to=now>  
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3 files | Download all

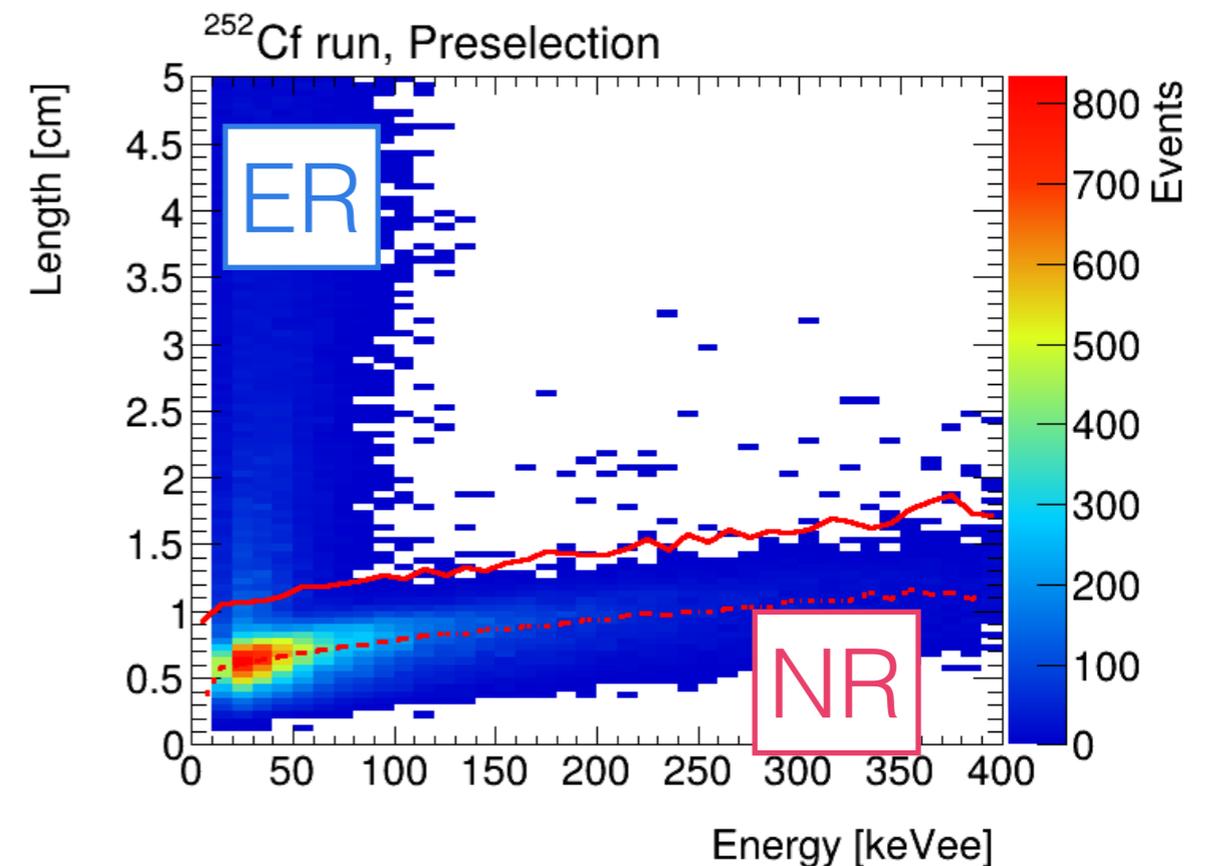
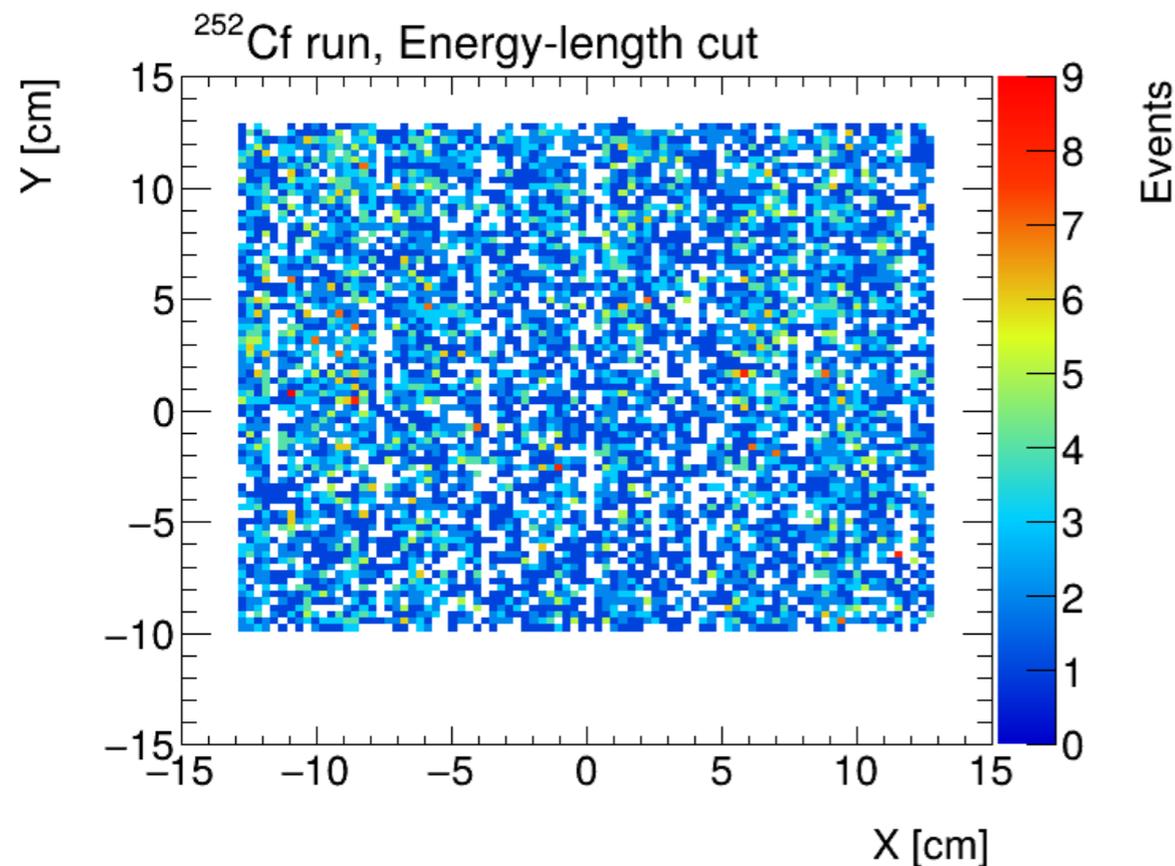


Detector status is monitored from Kobe University with Grafana + slack automatic posting

**Measurement is ongoing now!**

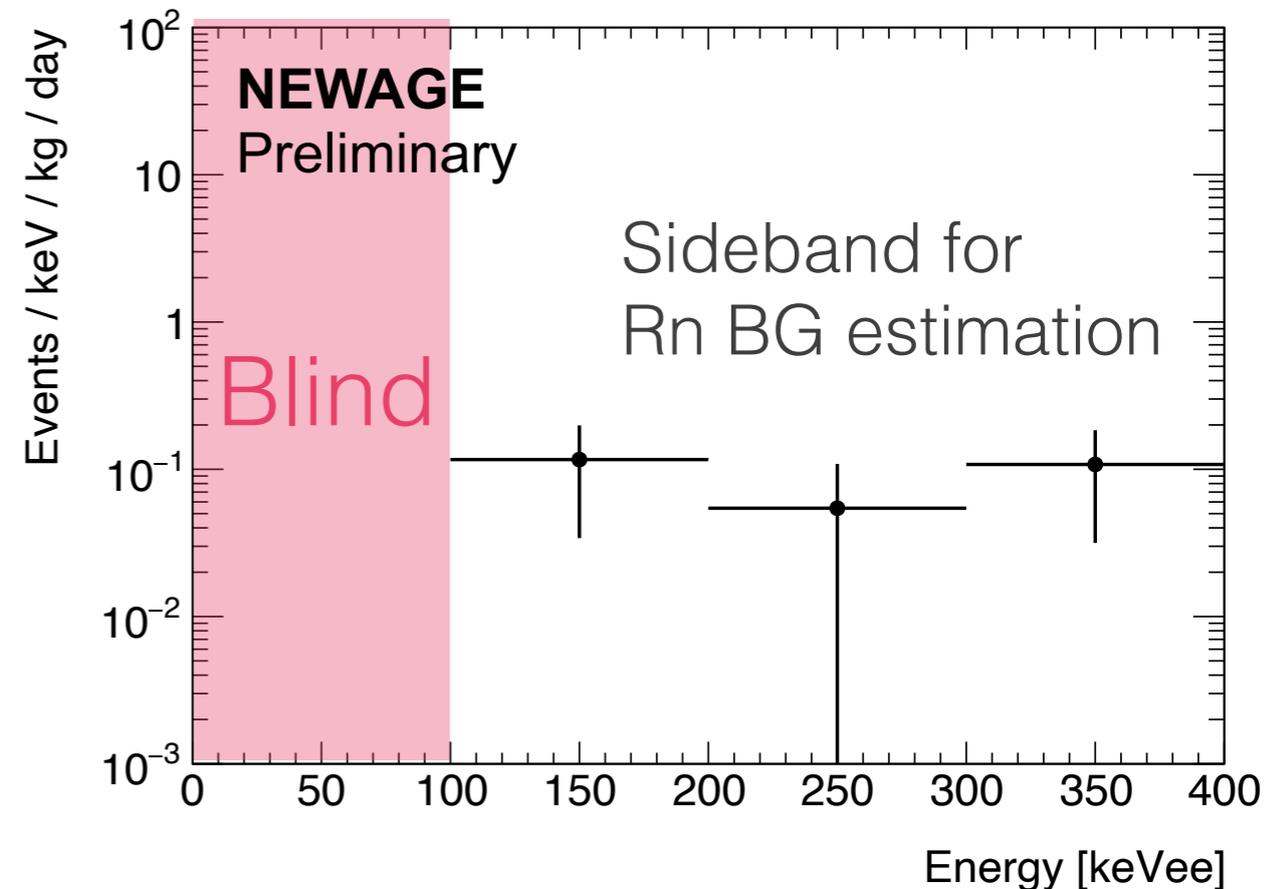
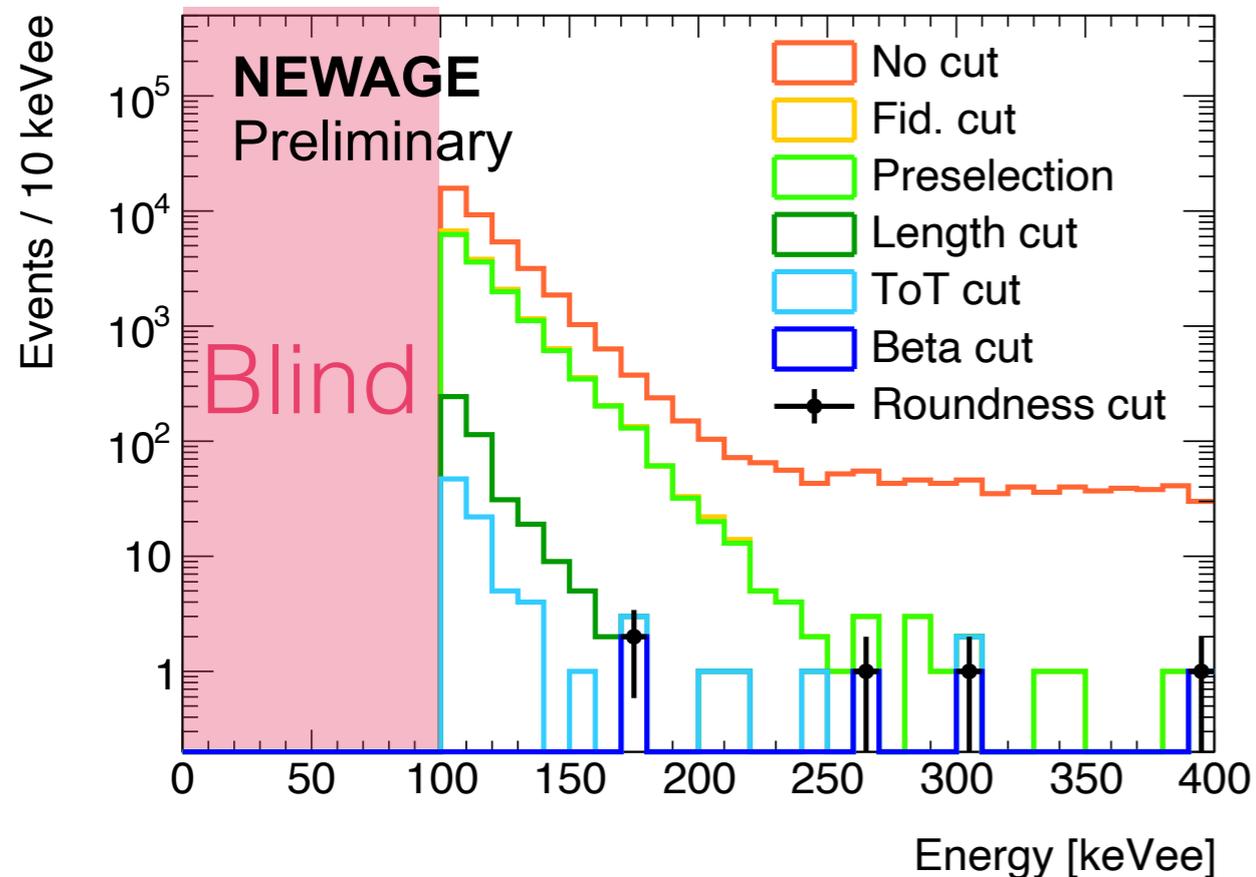
# Neutron irradiation test ( $^{252}\text{Cf}$ source)

- Performance demonstration using  $^{252}\text{Cf}$  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



# Energy spectrum

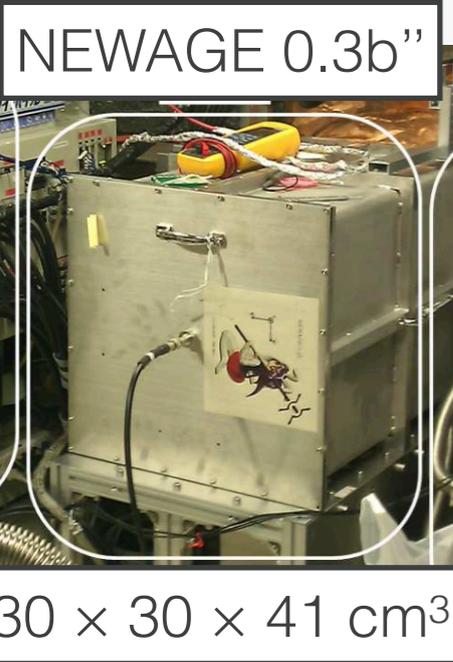
- NEWAGE standard event selection applied (detail skipped)
  - BG rejection performed by each selection
  - <100 keVee region and its directionality still blinded (analysis ongoing)
- Event rate considering detection and selection efficiencies keeps low
  - **Also 1/3 reduction after Ag-zeolite installation 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 plans and recent activities

# NEWAGE roadmap



**underground experiment (~100 live days)**

continue experiment with CF<sub>4</sub> or SF<sub>6</sub> gas

Dec. 2023  
Low BG  $\mu$ -PIC installed

Low BG  $\mu$ -PIC installation to C/N-1.0

Pixel detector (small scale detector)



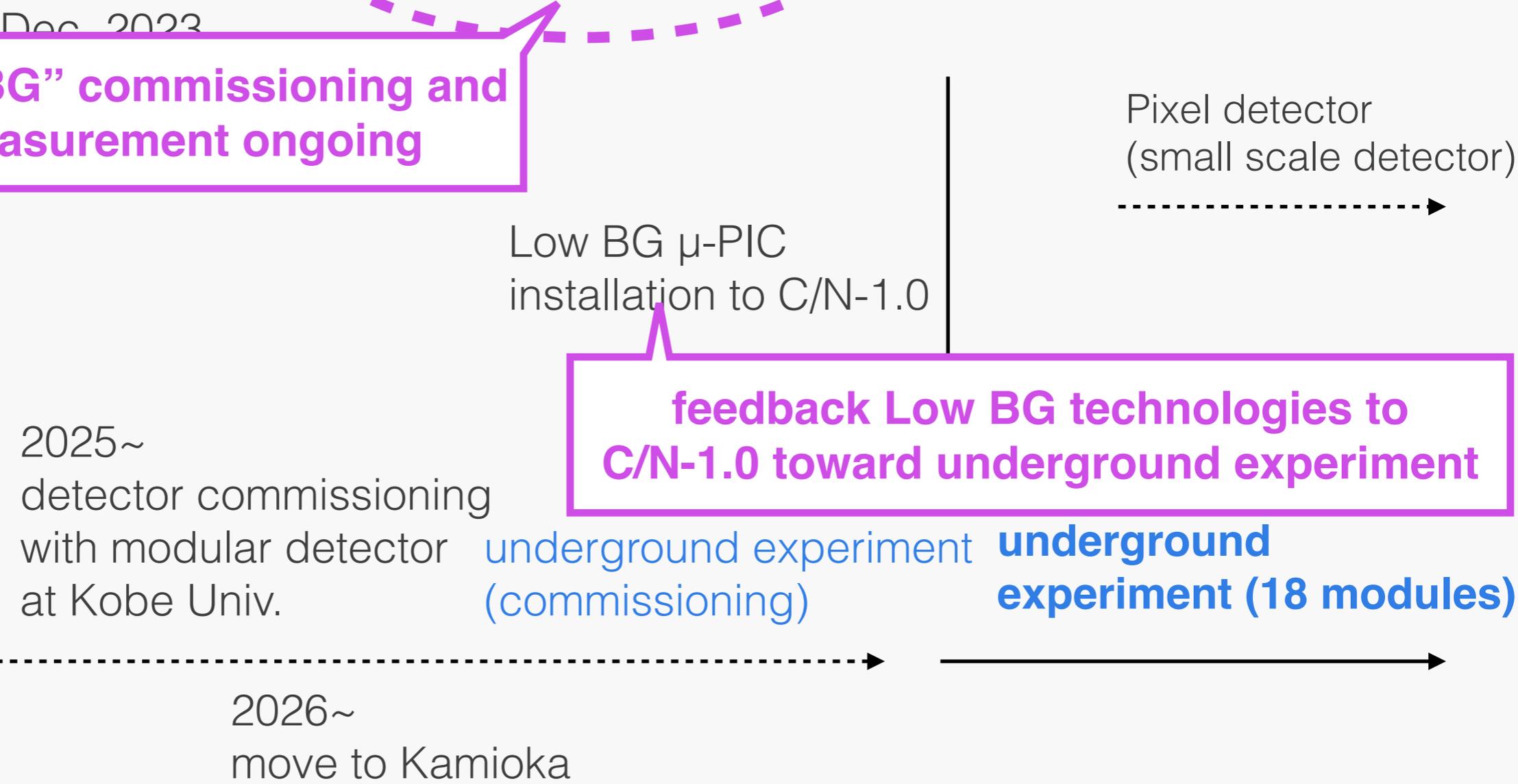
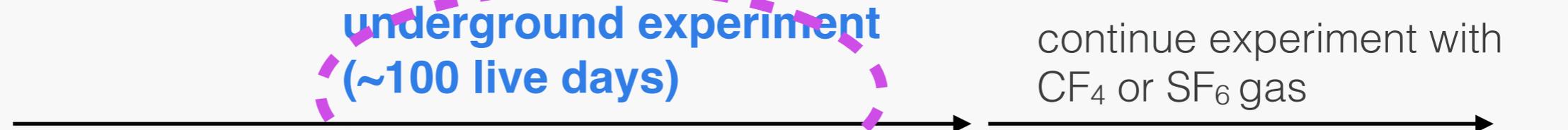
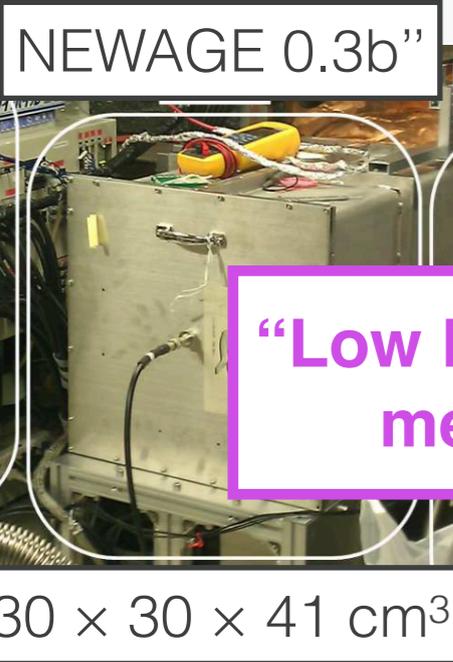
2025~  
detector commissioning with modular detector at Kobe Univ.

**underground experiment (commissioning)**

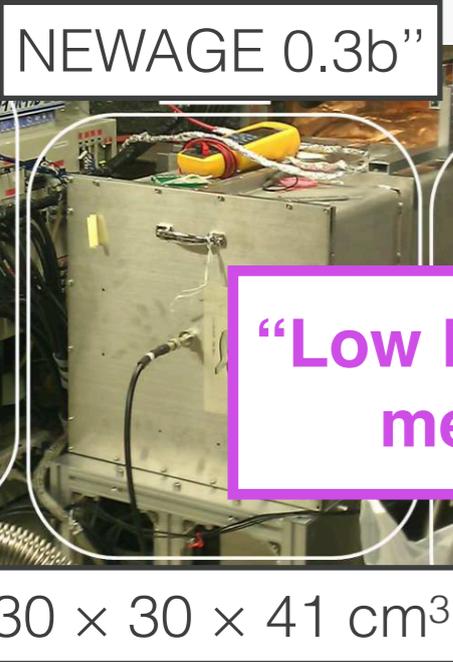
**1 m<sup>3</sup> exposure underground experiment (18 modules)**

2026~  
move to Kamioka

# NEWAGE roadmap



# NEWAGE roadmap



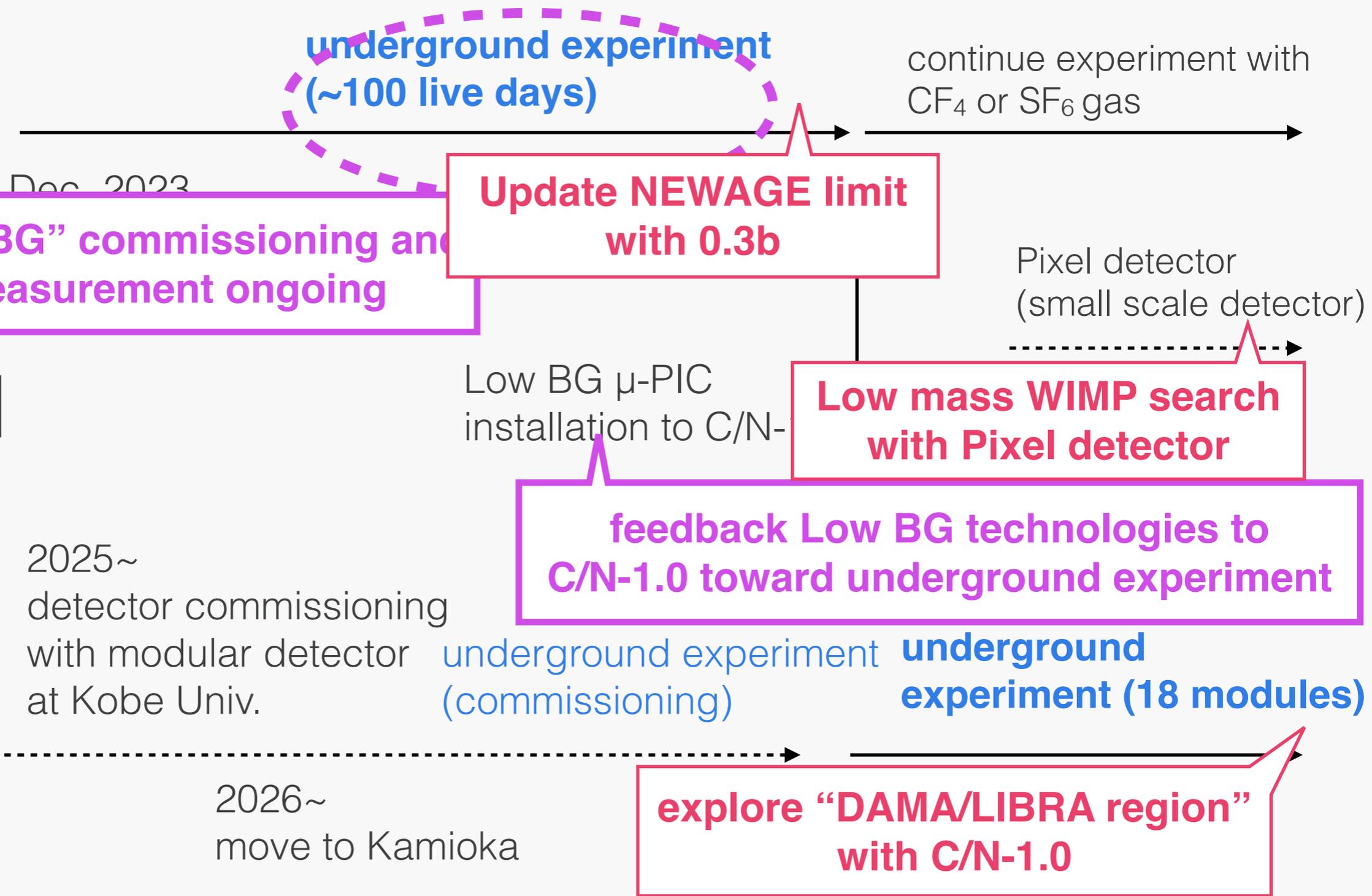
NEWAGE 0.3b

30 × 30 × 41 cm<sup>3</sup>

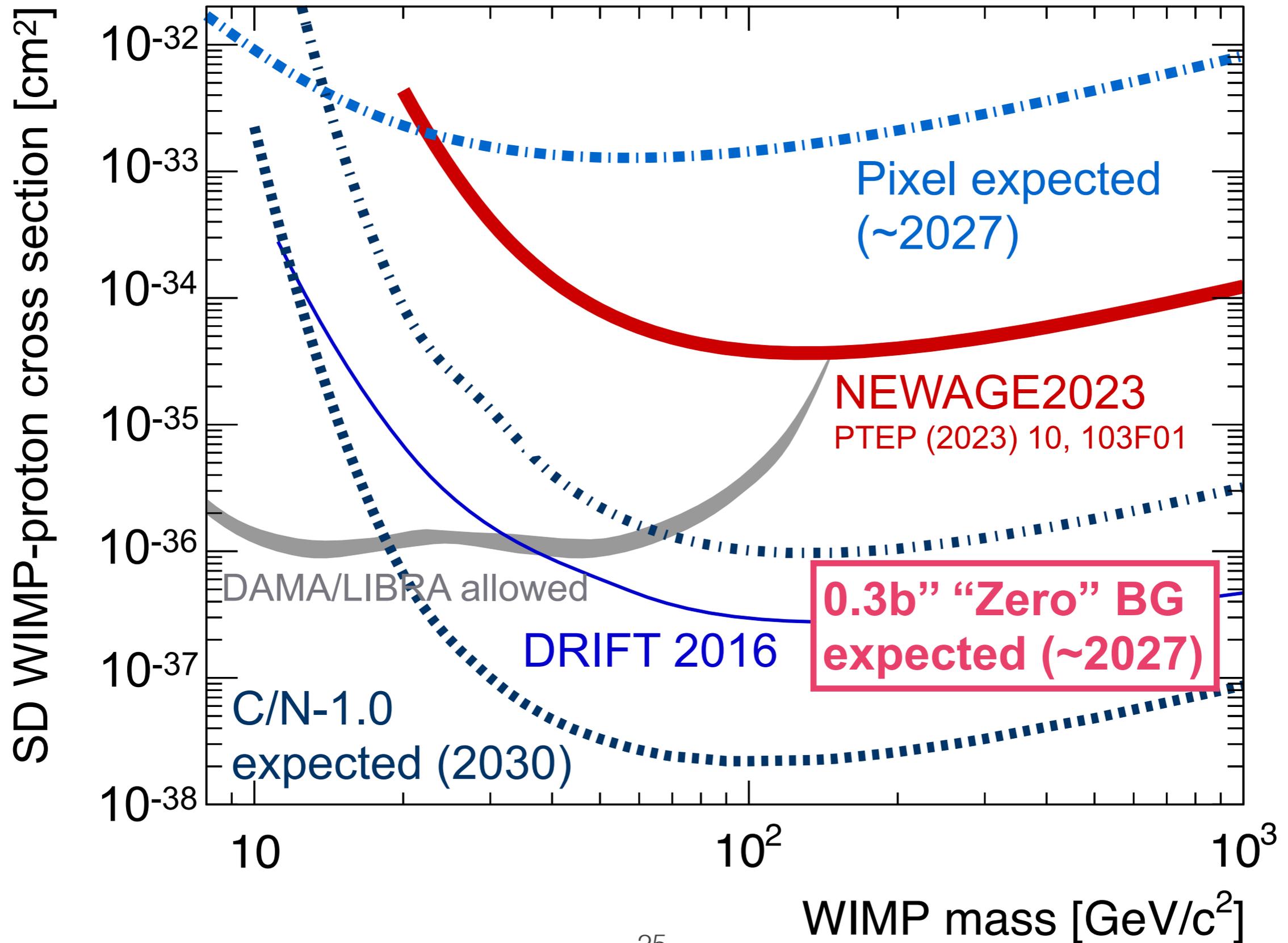


C/N-1.0

1 m<sup>3</sup>



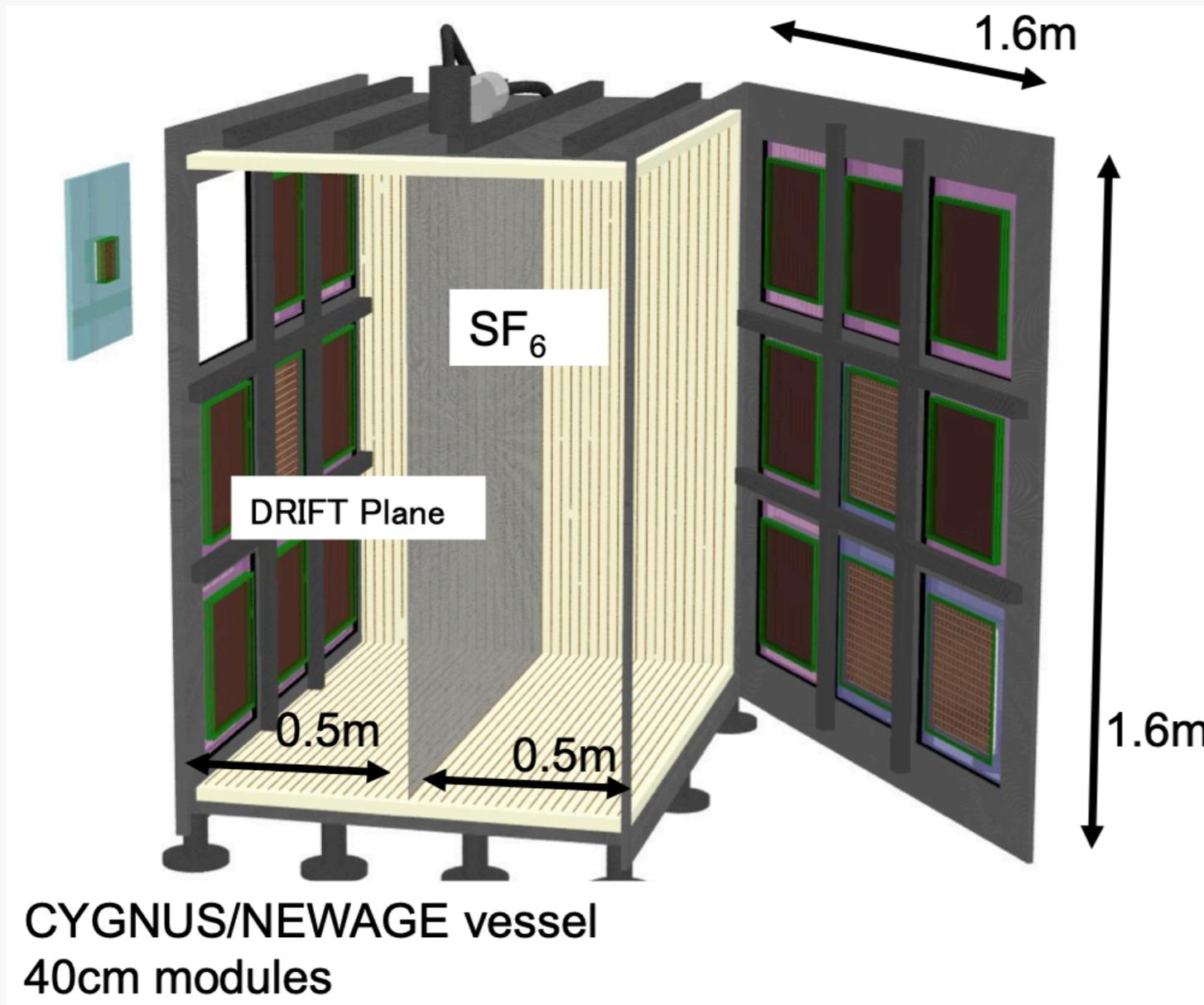
# Expected limits



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

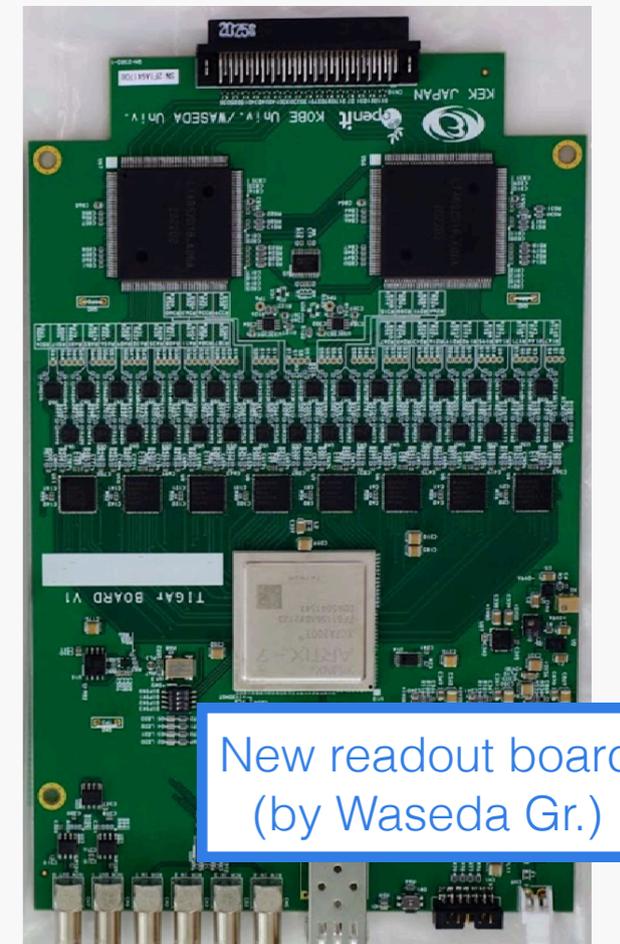
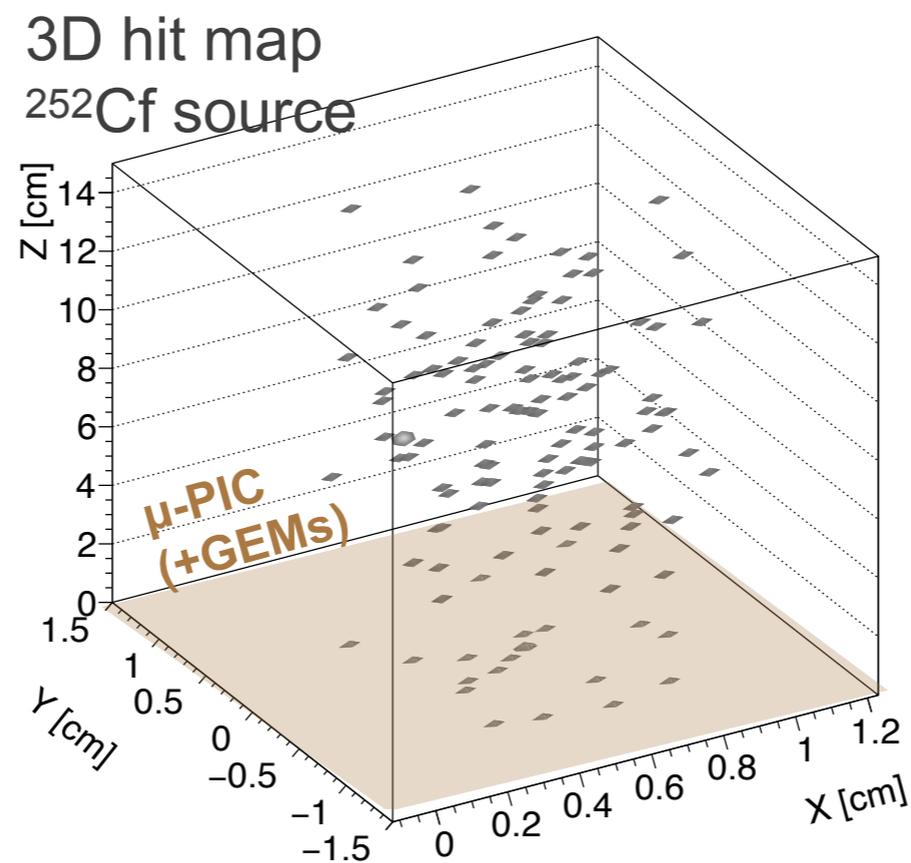
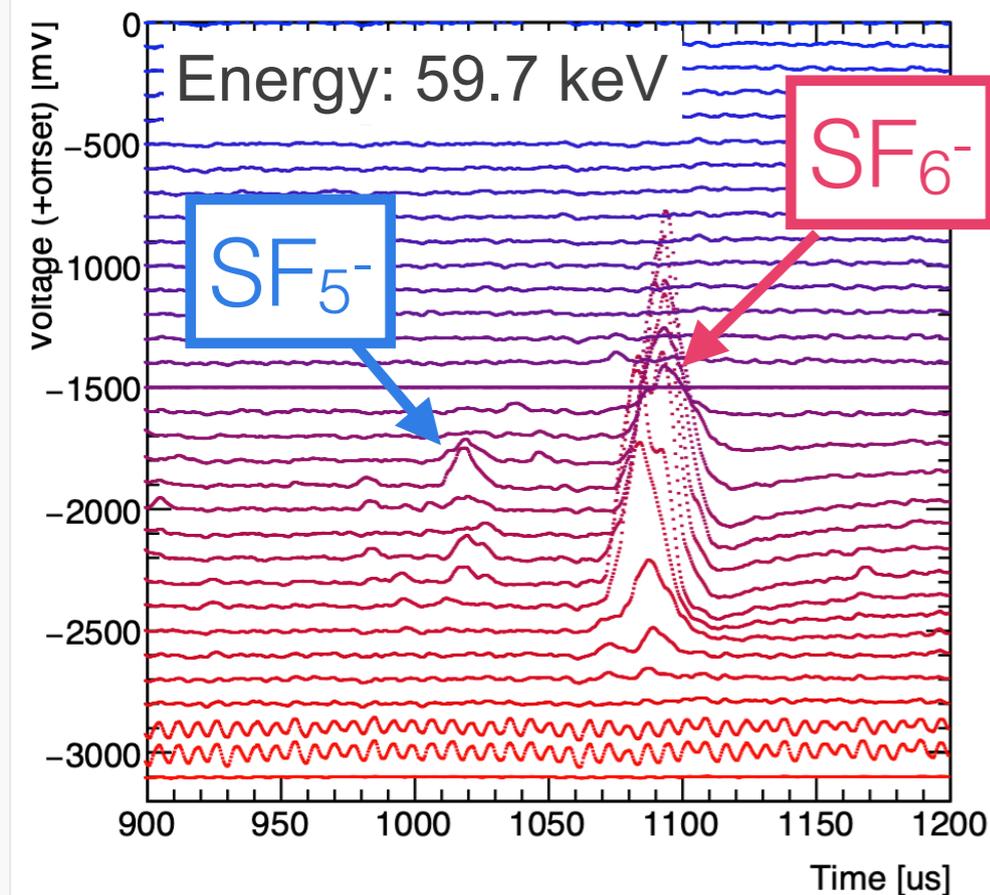
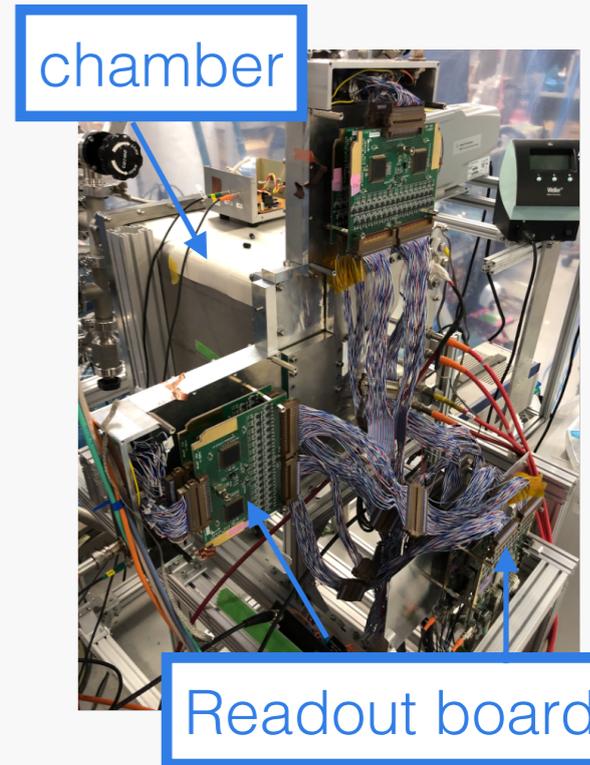
- Modulated chamber ( $\sim 1 \text{ m}^3$ ) : 18 module windows are available
  - Enables to install the conventional NEWAGE detector ( $30 \times 30 \text{ cm}^2$  fiducial area)
  - We can accept detectors from any other groups: your “clean” detectors are candidates!

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



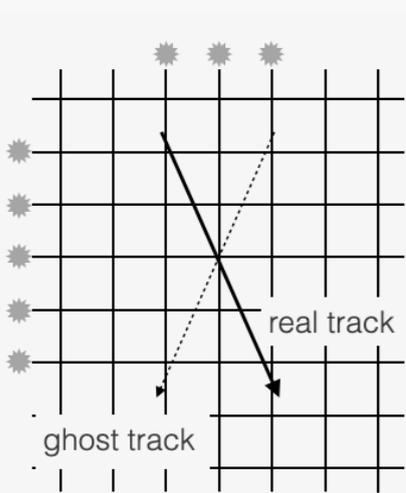
# SF<sub>6</sub>

- Tested using small detector with prototype electronics
- 2-peak signals are detected with a <sup>252</sup>Cf source
  - SF<sub>5</sub><sup>-</sup> peak detection efficiency is 70%
  - succeeded in reconstructing 3D position
- New readout board is developed by Waseda Gr.
  - Mass production is preparing to allow O(1000) ch readout

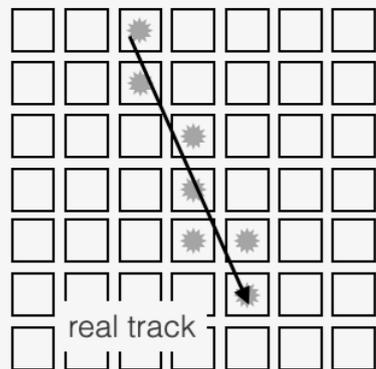


# Pixelization

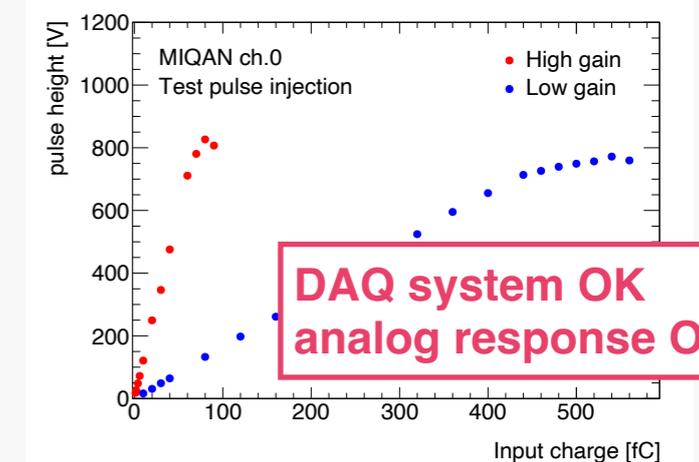
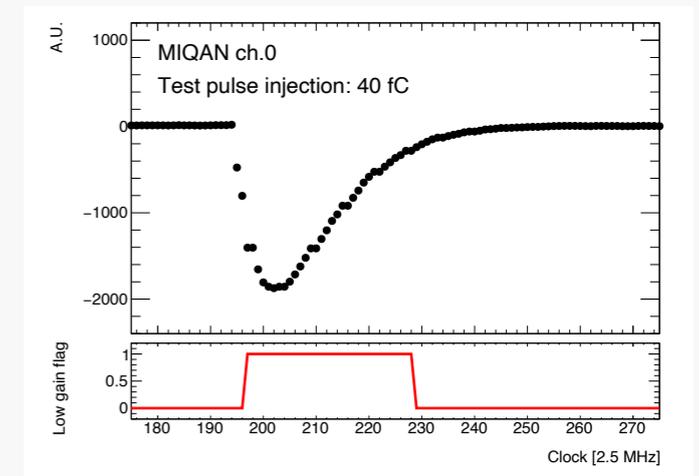
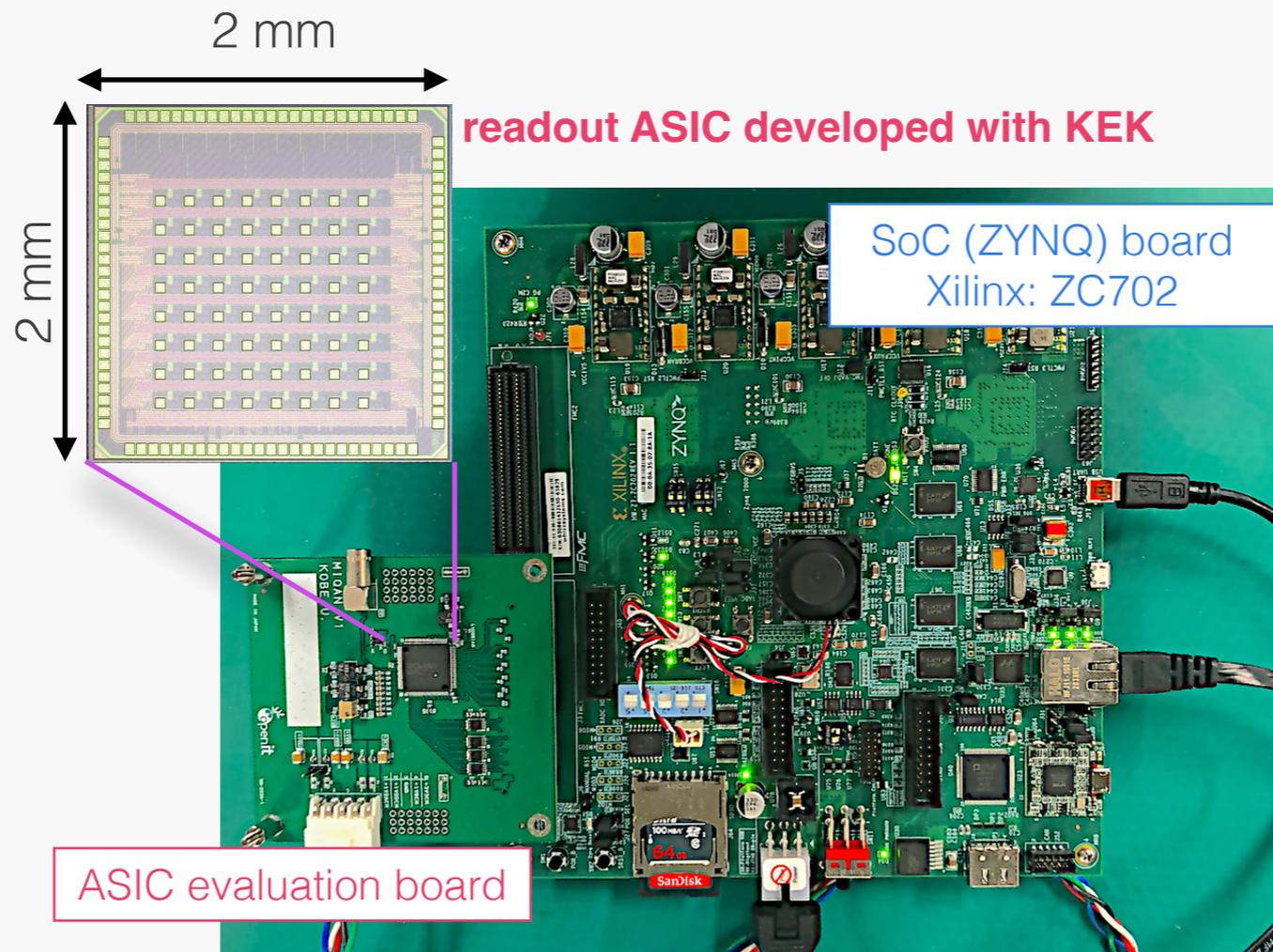
- Equal to low energy nuclear recoil detection
- Energy threshold is limited due to electrode's strip pitch (400  $\mu\text{m}$ )
  - ➔ Started to develop fine granularity "pixel" readout detector
    - ▶ to reduce "ghost track" reconstruction
  - ➔ Dedicated readout electronics (prototype) was prepared



Strip readout

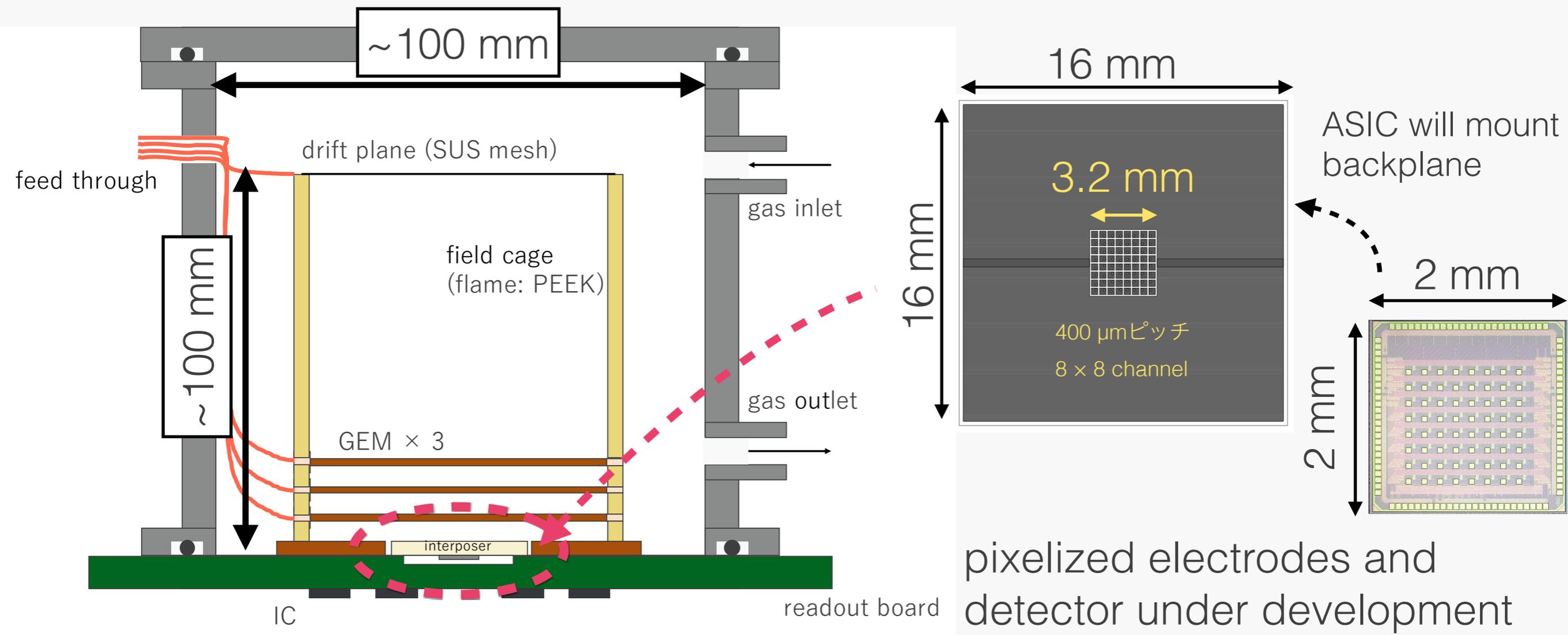


Pixel readout



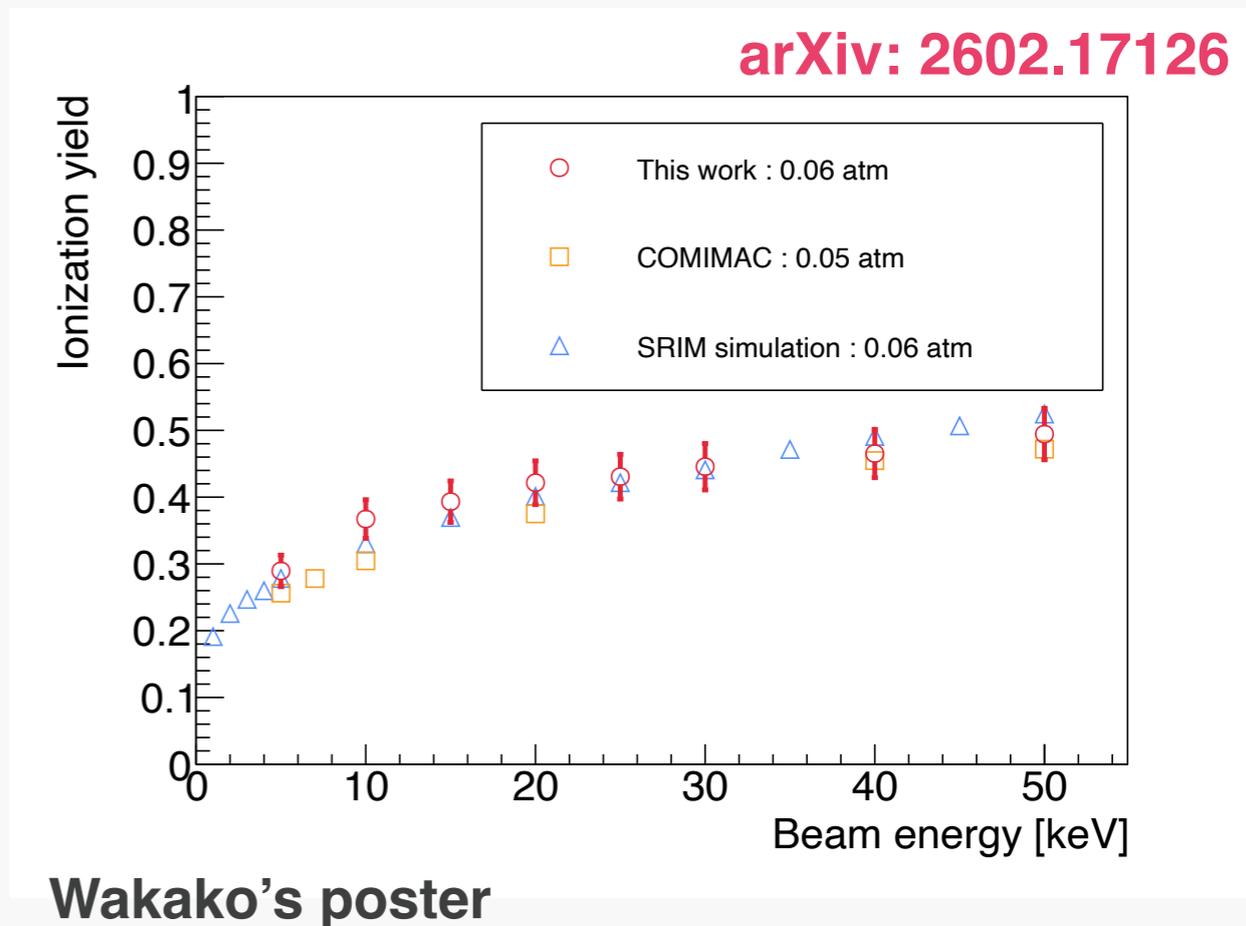
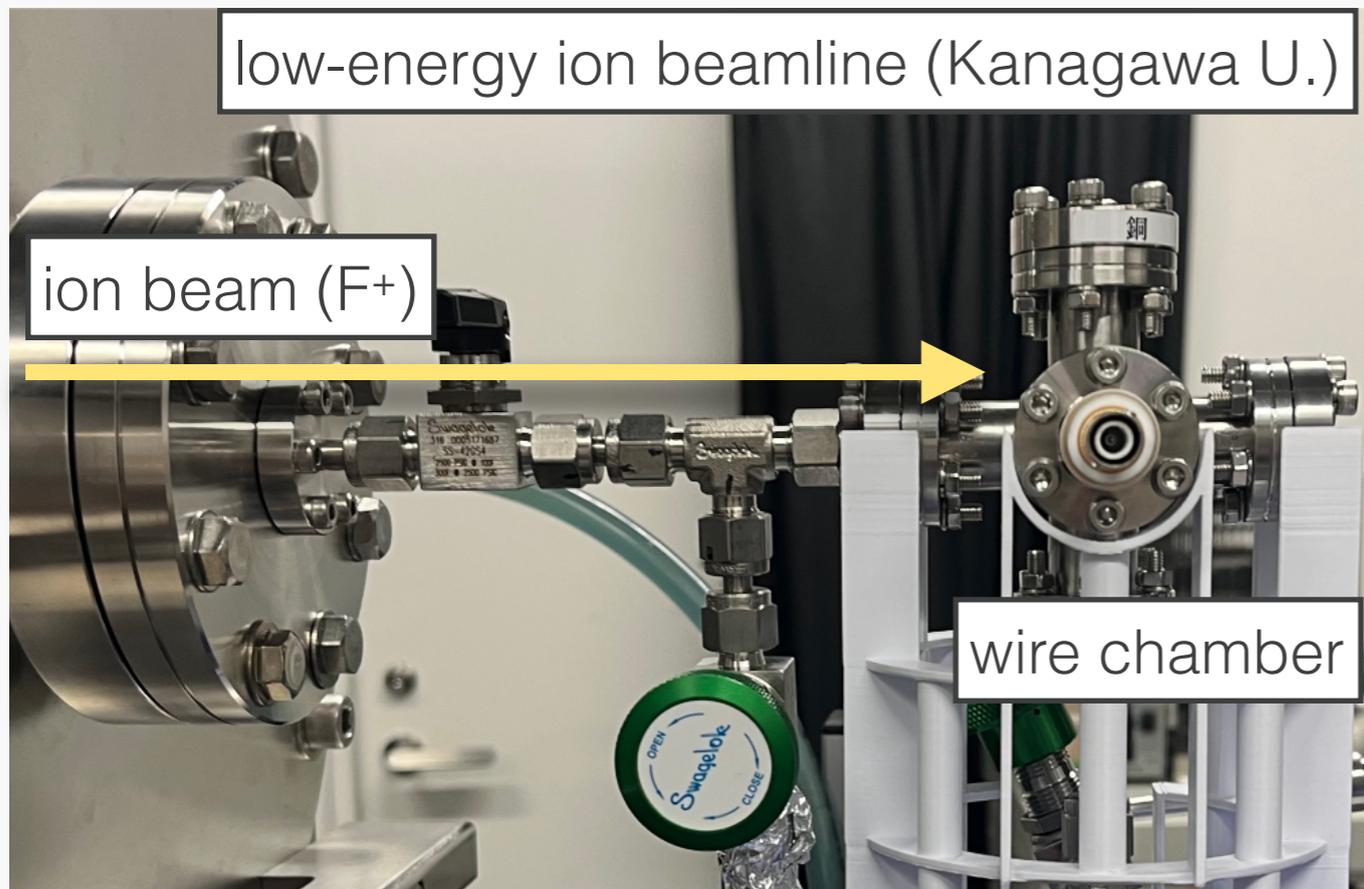
# Prototype pixel detector

- Started to develop a small size detector
  - ➔ for demonstration of pixel readout at the first stage
  - ➔ Pixel pitch keeps 400  $\mu\text{m}$  (due to difficulties of fine pitch electrode production)
- Assuming to use low pressure pure  $\text{SF}_6$  gas to enable additional  $\text{SF}_6$  studies



# Ionization quenching factor measurement

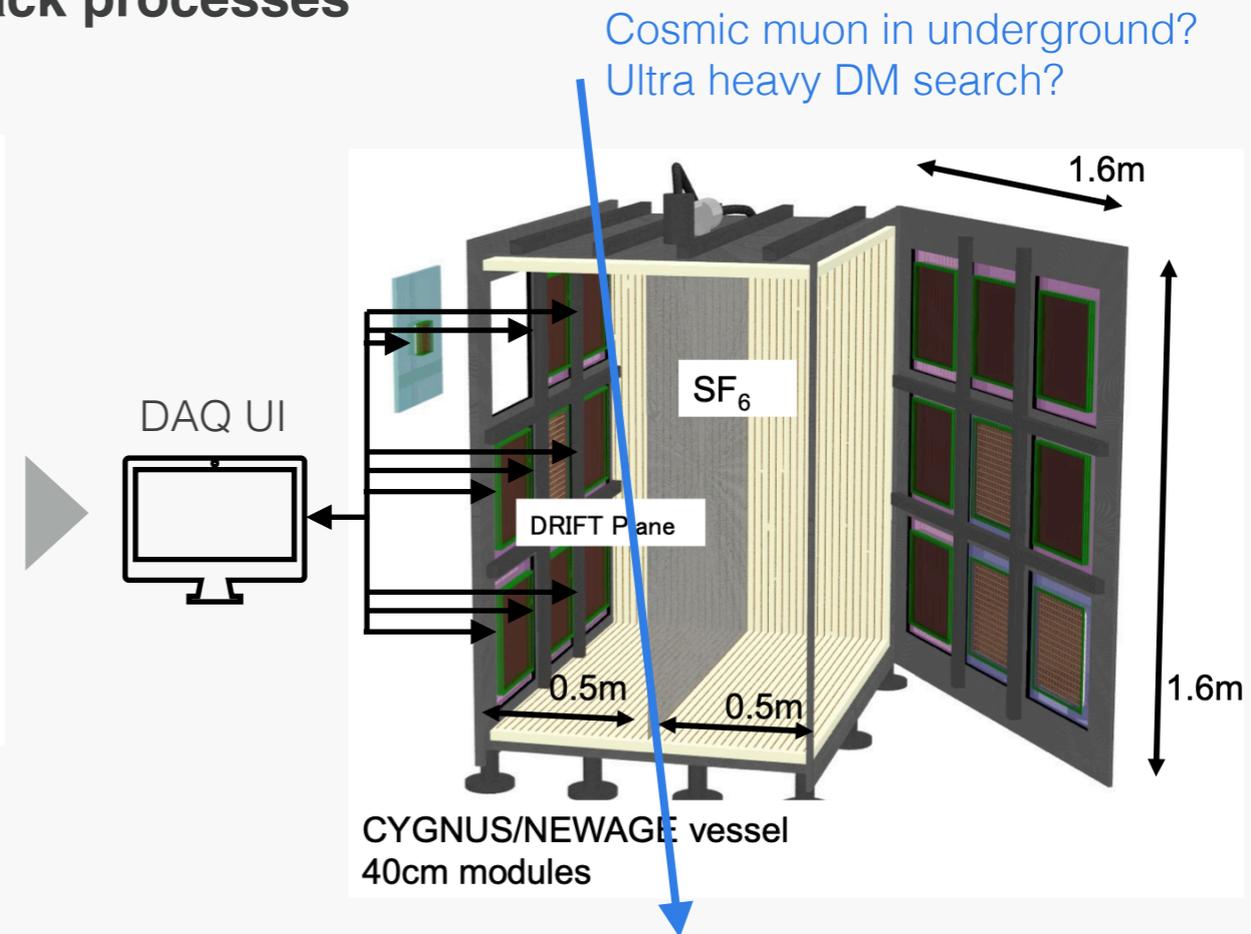
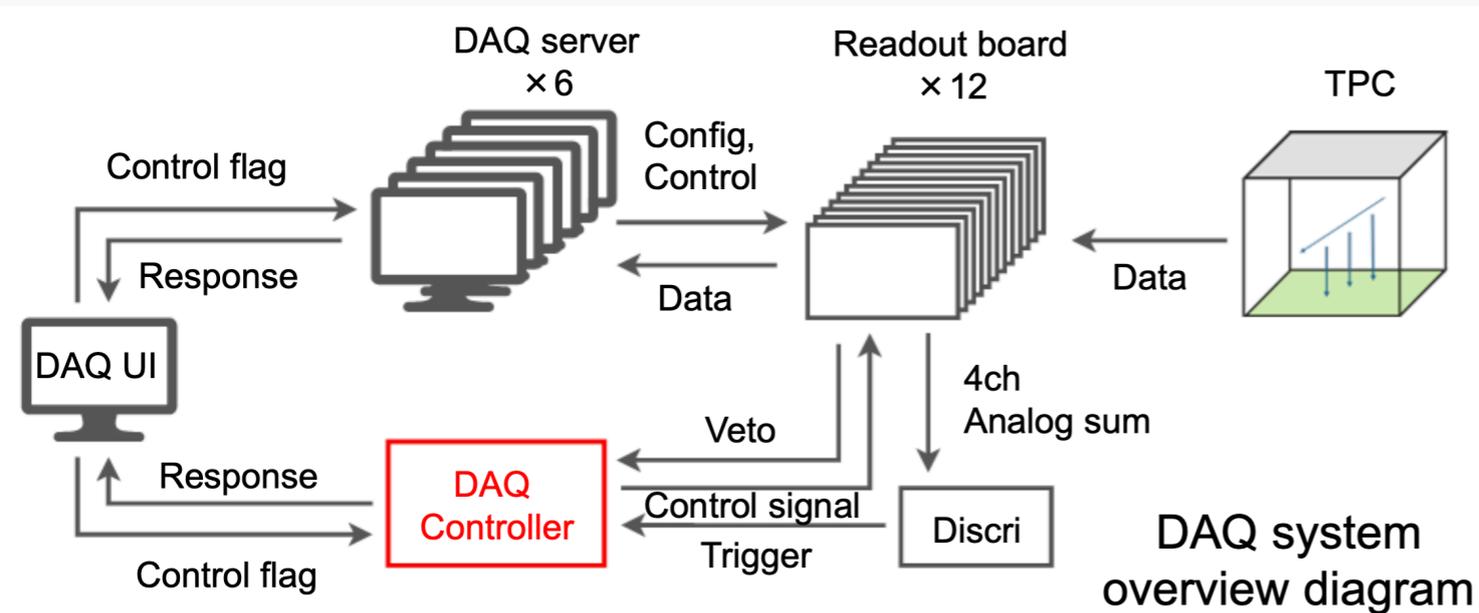
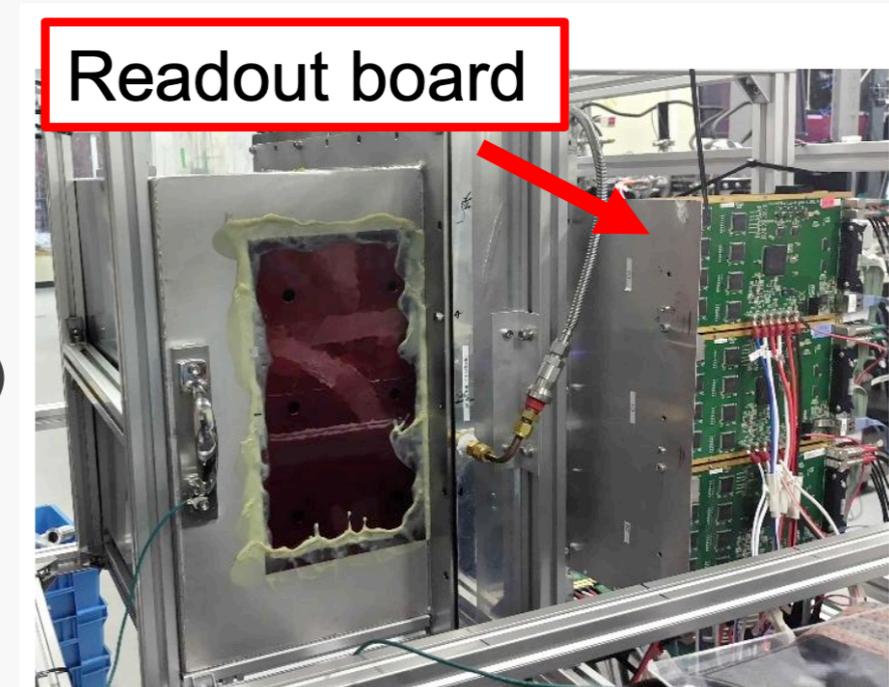
- Precise energy measurement is important as well as the directionality
  - Low-energy ion beam test was performed at 5-200 kV acceleration facility at Kanagawa U.
- 5 - 50 keV fluorine ions were injected to single-wire proportional chamber
  - filled with 0.06 atm  $\text{CF}_4$  gas (assuming low-pressure NEWAGE operation)
- Result is consistent with COMIMAC and SRIM
  - Good demonstration of low-energy ion injection into gas detector in Japan!



# Integrated DAQ system

- NEWAGE is using old DAQ system
  - ➔ need to replace electronics
- New system was developed for a Migdal search experiment
  - ➔ Enable to use it in NEWAGE as well
- Multi-DAQ servers are integrated in this system
  - ➔ DAQ for any detector can be integrated with this technology
  - ➔ **capable of reconstructing long tracks or back-to-back processes**

(Keishi's talk)



Shiori's poster

(focusing on the DAQ development for the Migdal search)

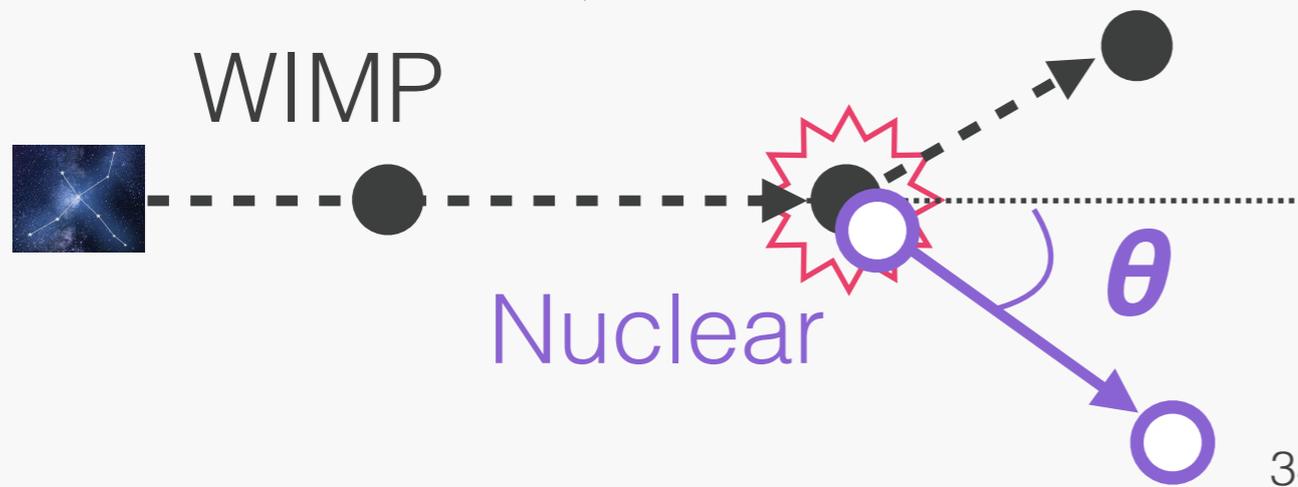
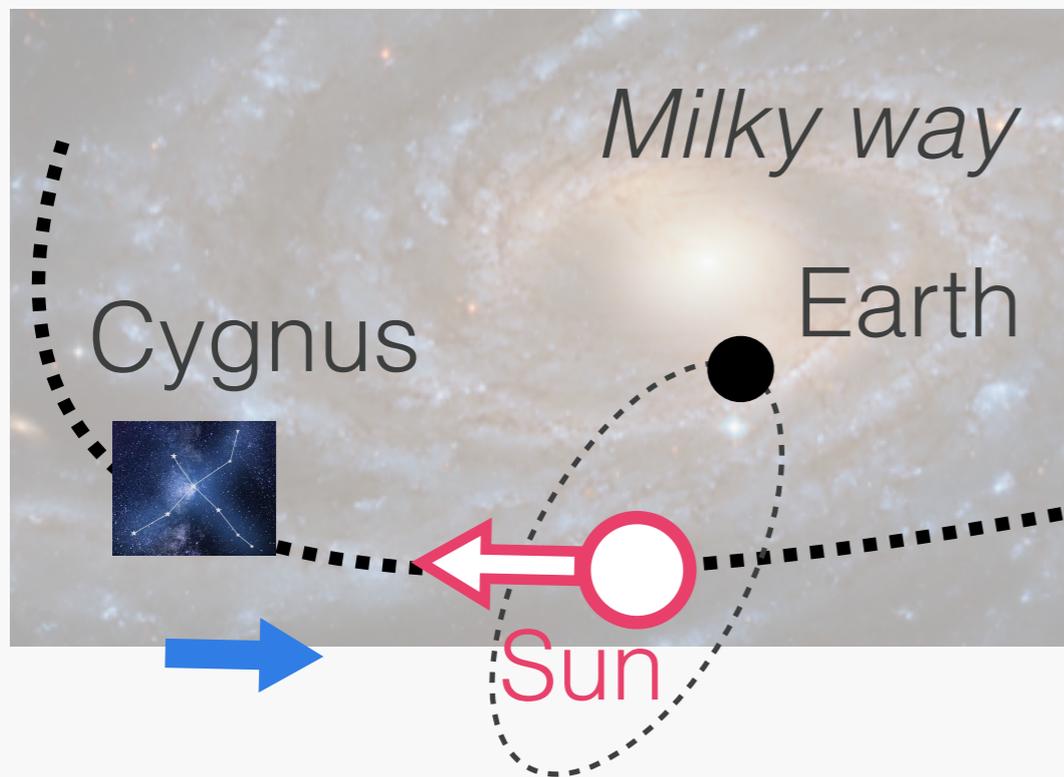
# Conclusion

- NEWAGE is conducting underground experiment in Kamioka observatory
  - ➔ focusing on the BG reduction studies
- Ag-zeolite filter was installed for radon capture
  - ➔ Radon BG was successfully reduced to be 1/3
  - ➔ Studies for additional reduction is ongoing
- Future upgrade plans are in progress
  - ➔ Large  $\mu$ -TPC, Pixel, SF<sub>6</sub>, IQF, DAQ, ... studies ongoing in parallel

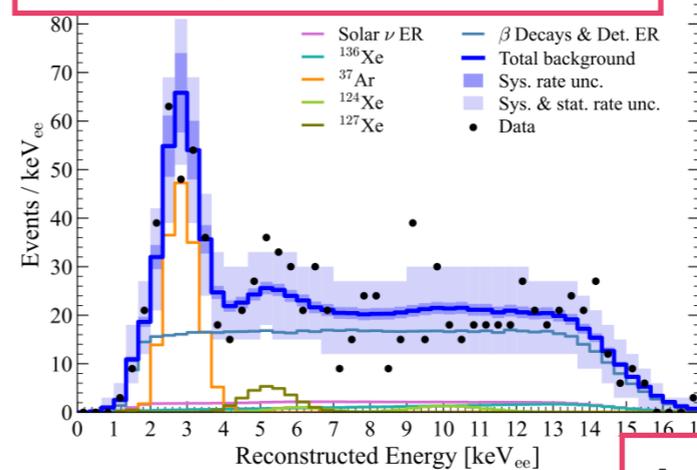
# Backup

# 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

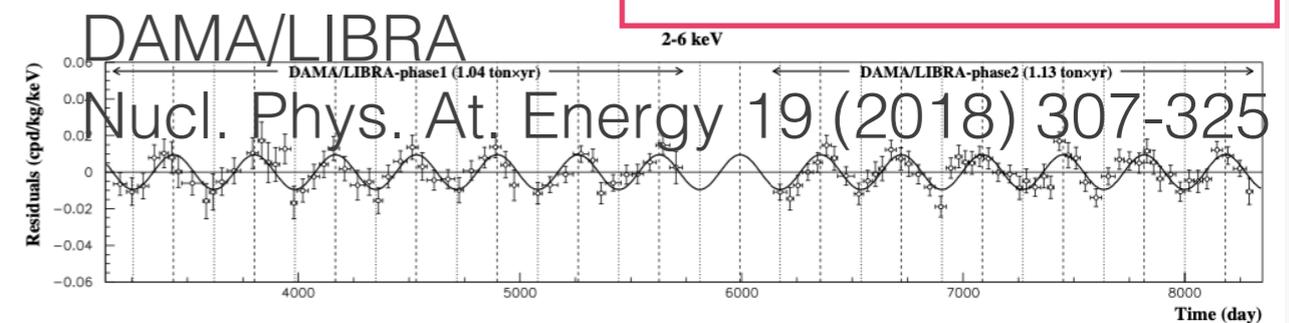


## Energy spectrum



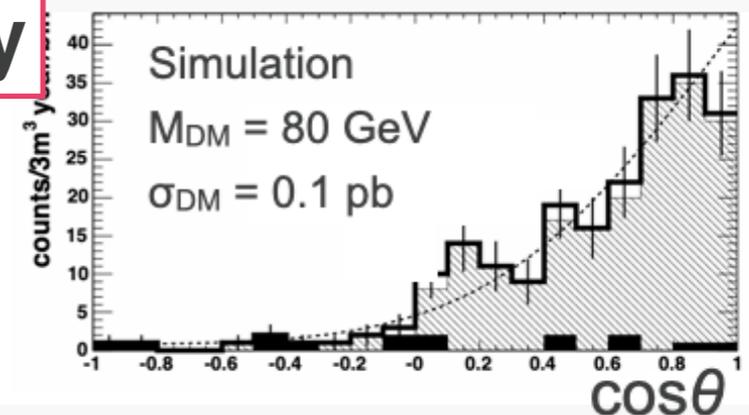
LZ: arXiv:2207.03764

## Annual modulation



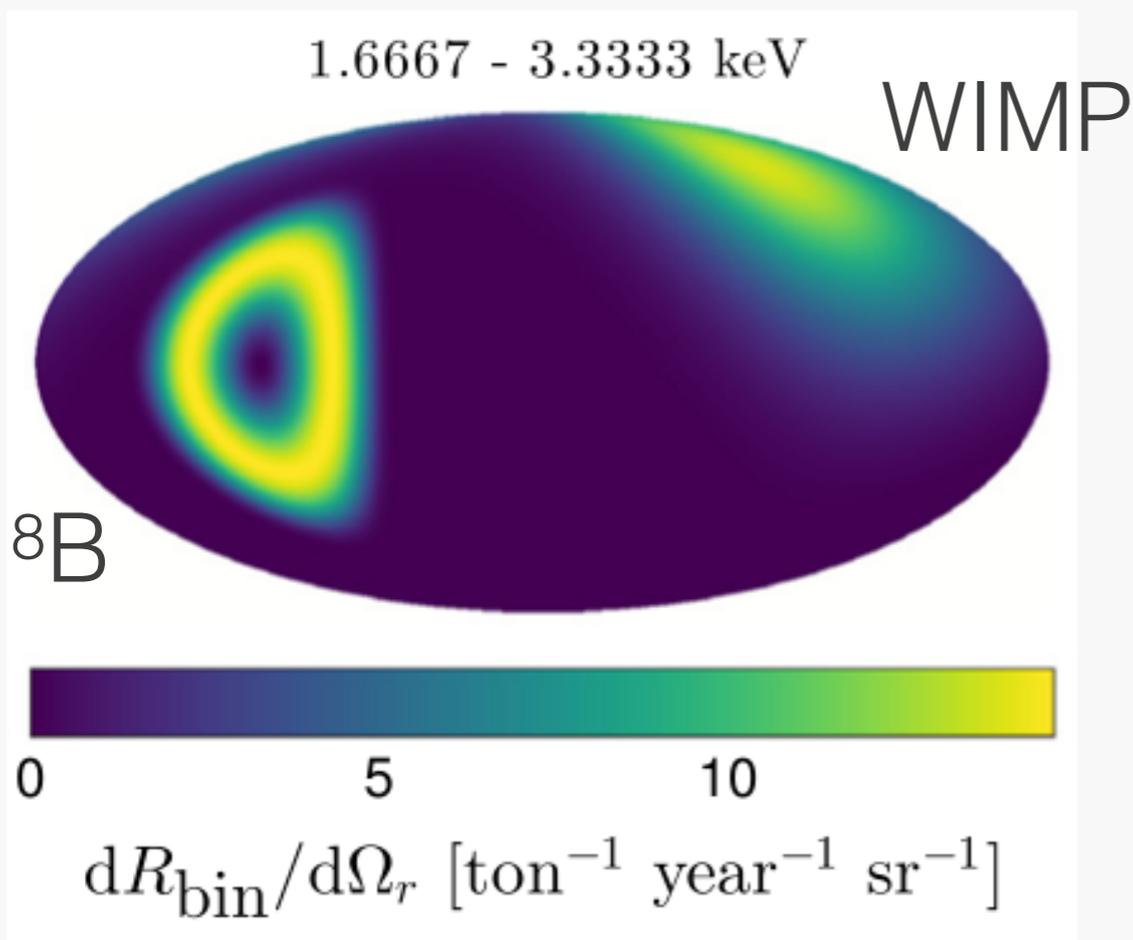
## Directionality

PLB 578 (2004)  
241-246

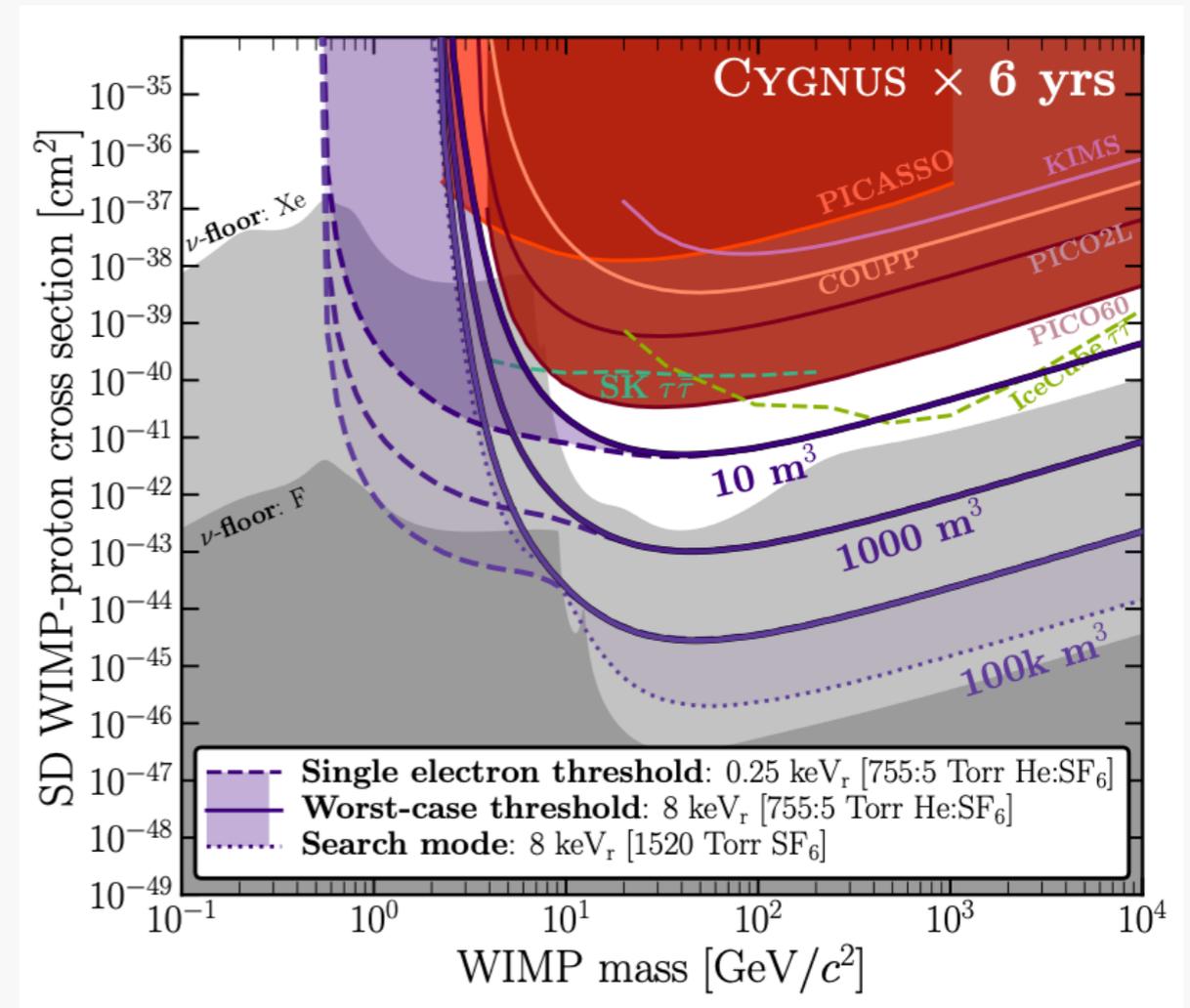


# Benefits

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



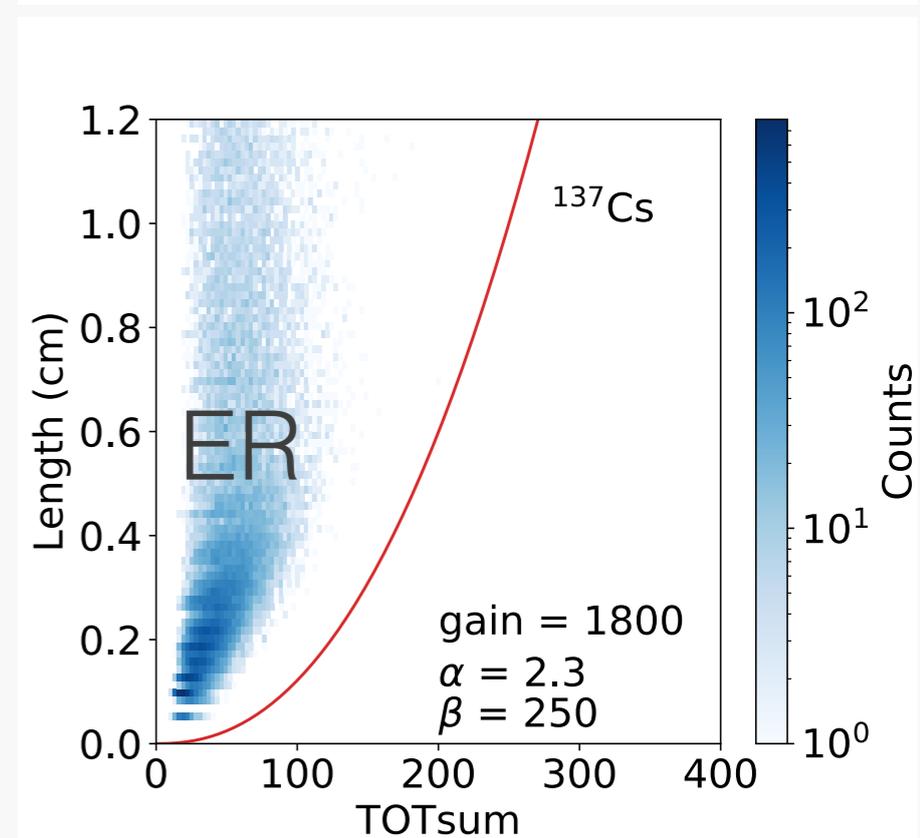
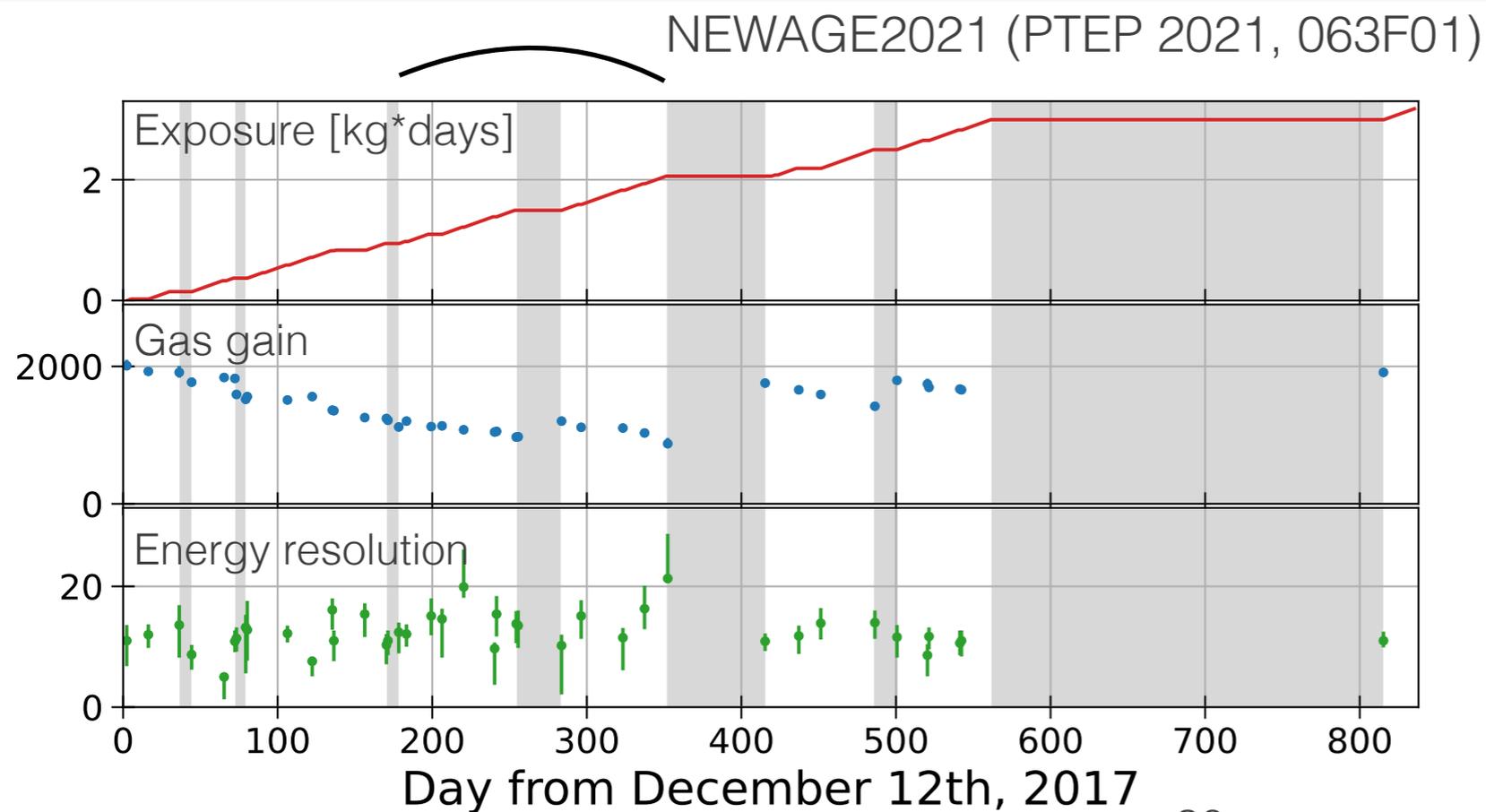
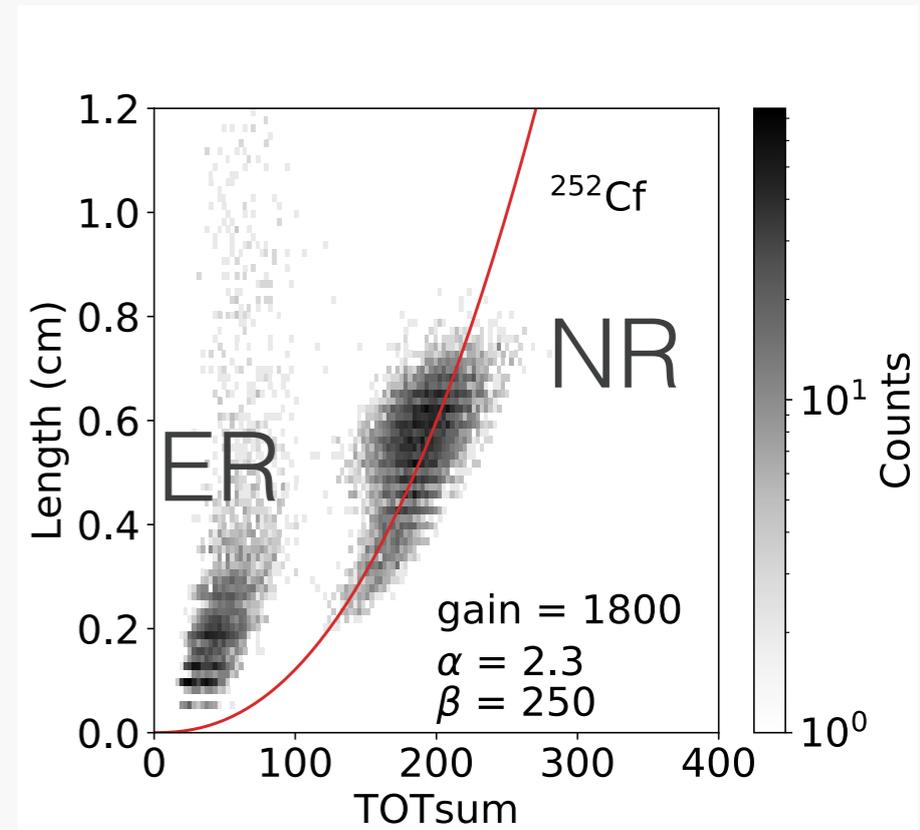
Physics Reports 627 (2016) 1-49



CYGNUS expected (arXiv:2008.12587)

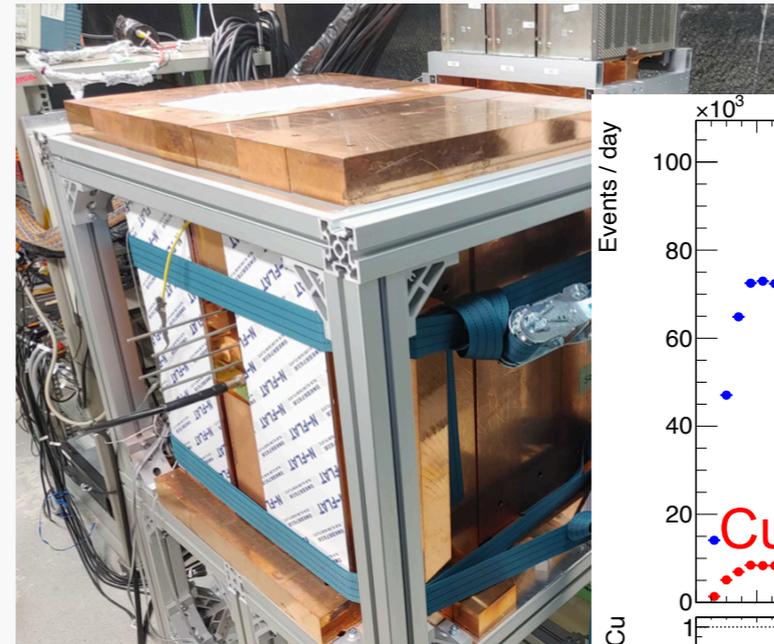
# Underground measurement

- 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

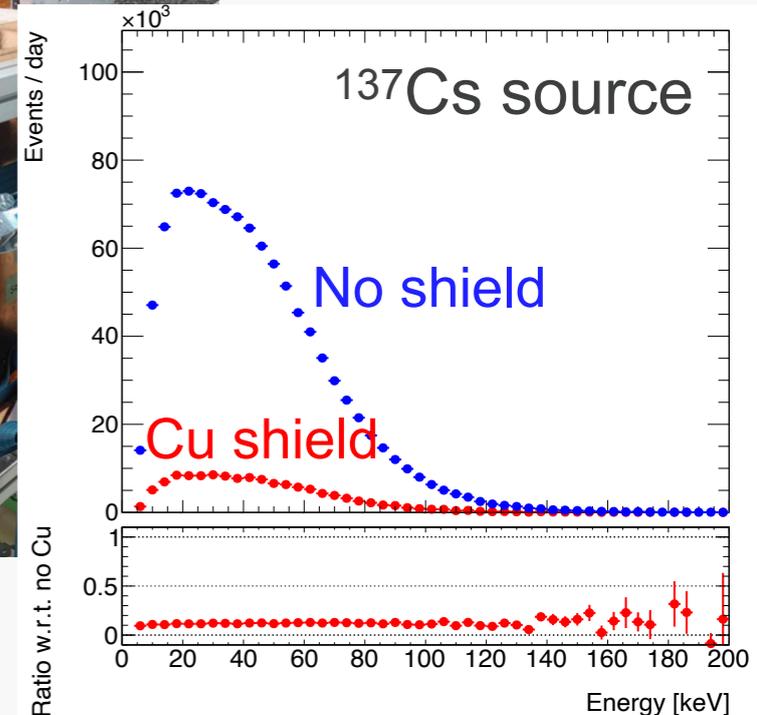


# Backgrounds

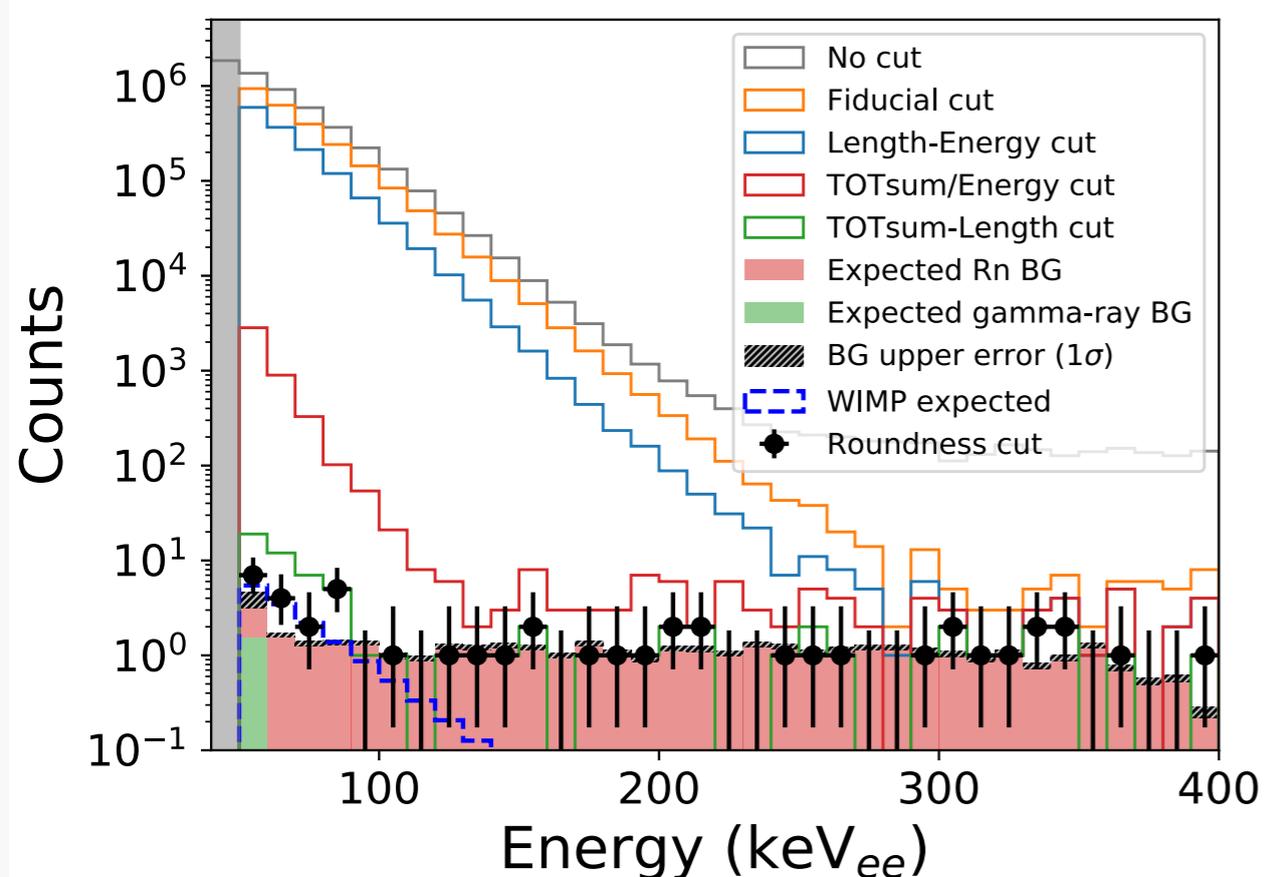
- Ambient gamma (external source)
  - ➔ Cu shield installed
  - ➔ Measurement ongoing
- Alpha from Rn progenies (internal source)
  - ➔ Emanation from the detector
  - ➔ “Clean” detector developed



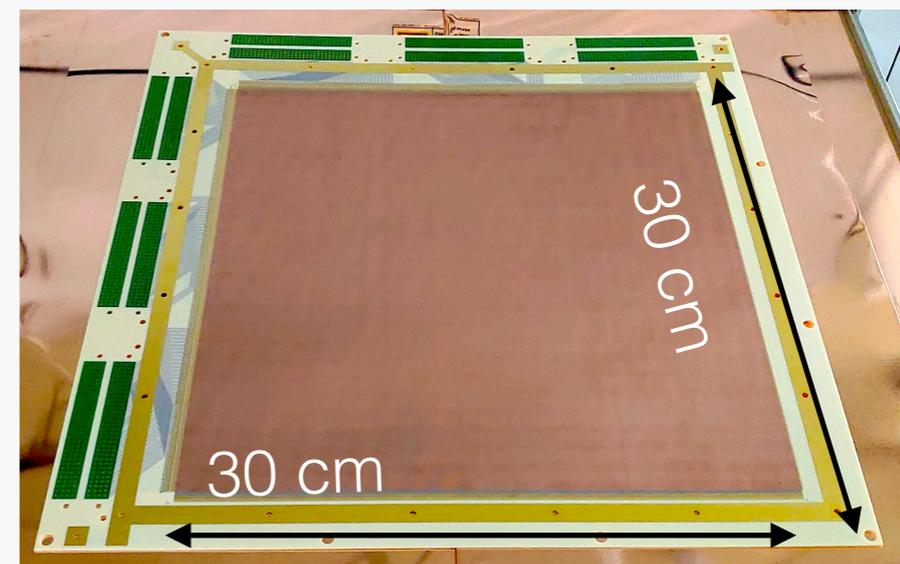
Cu shield



~90% rejection  
( $^{137}\text{Cs}$  source)



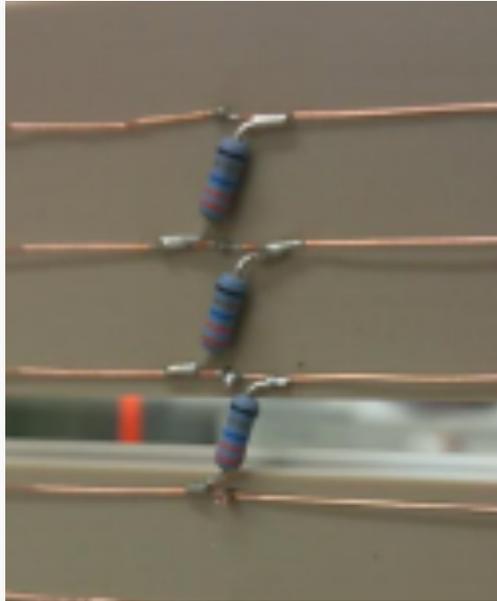
Low-BG  $\mu$ -PIC (DNP Inc.)



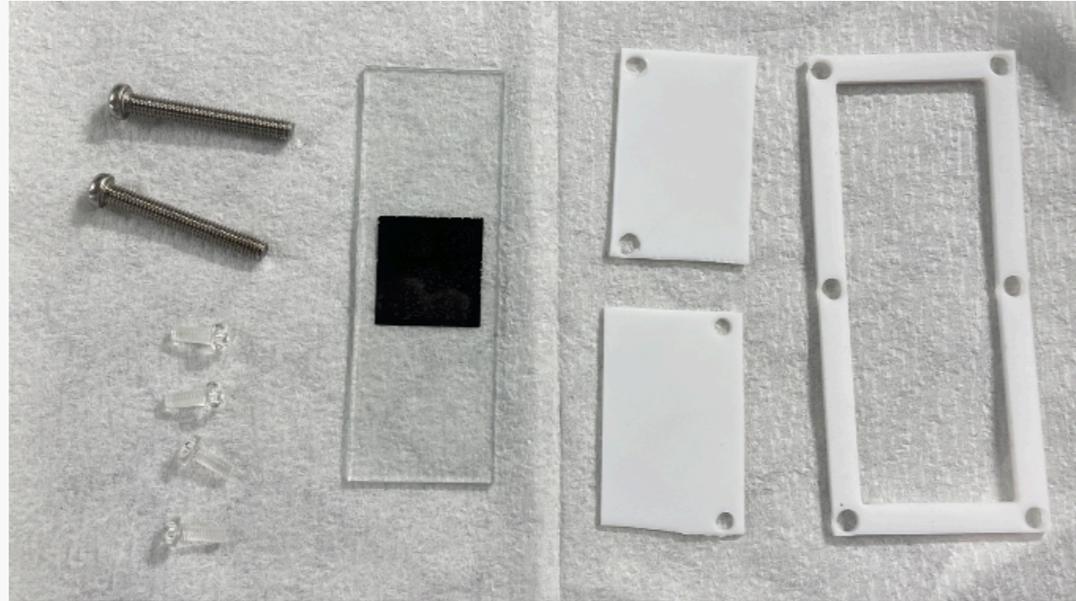
Rn emanation:  
< **1/10** from the previous version!

# What is “Dirty” materials?

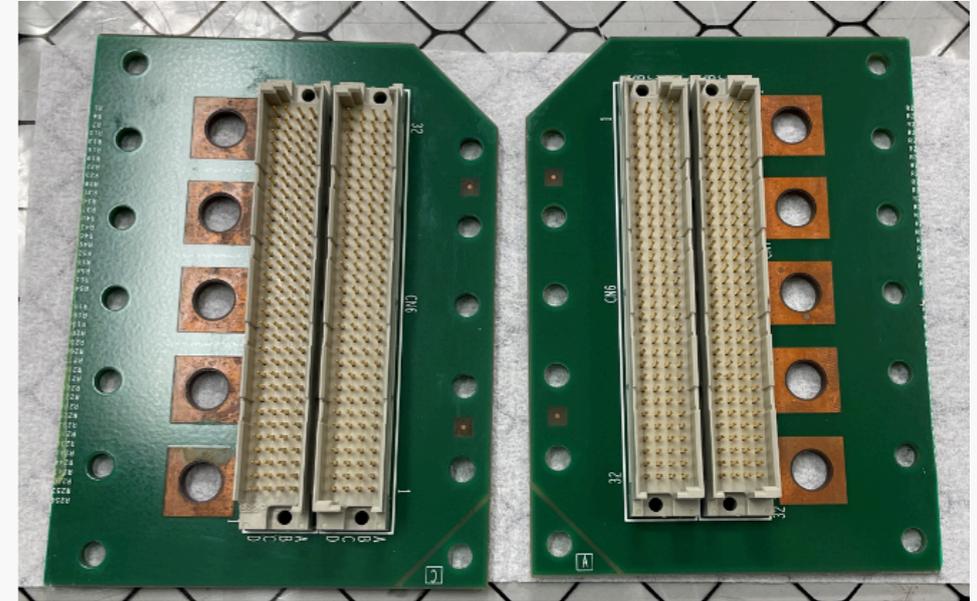
- One by one suspicious material check started using our radon detector
  - ➔ but no BG source materials are found...



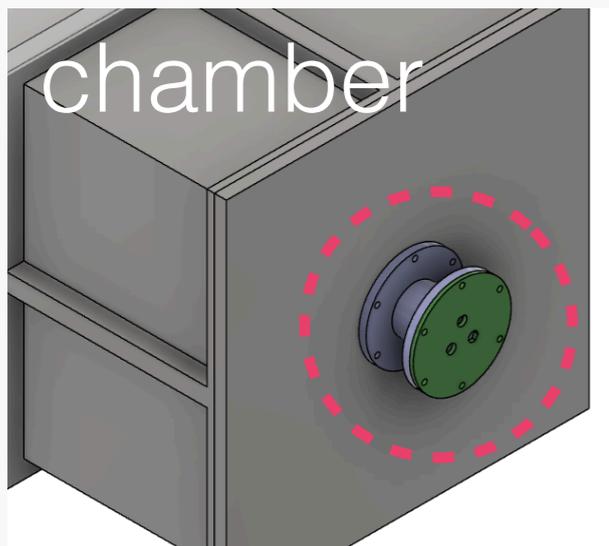
resistor for  
TPC field cage



$^{10}\text{B}$  plate for energy calibration,  
and its support material



Feed through board for  $\mu$ -PIC



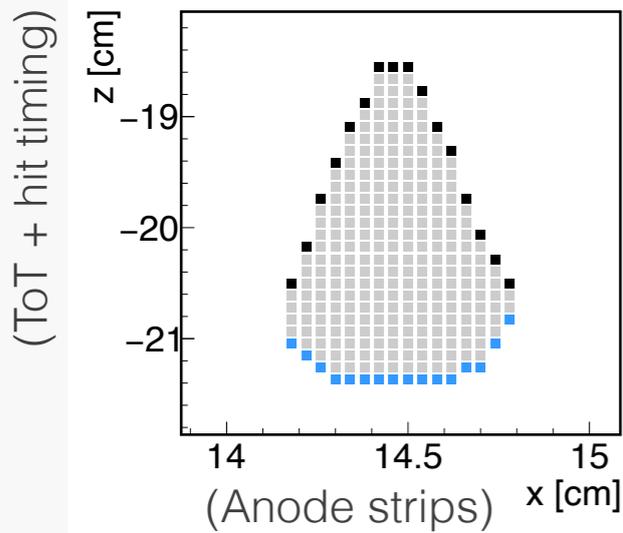
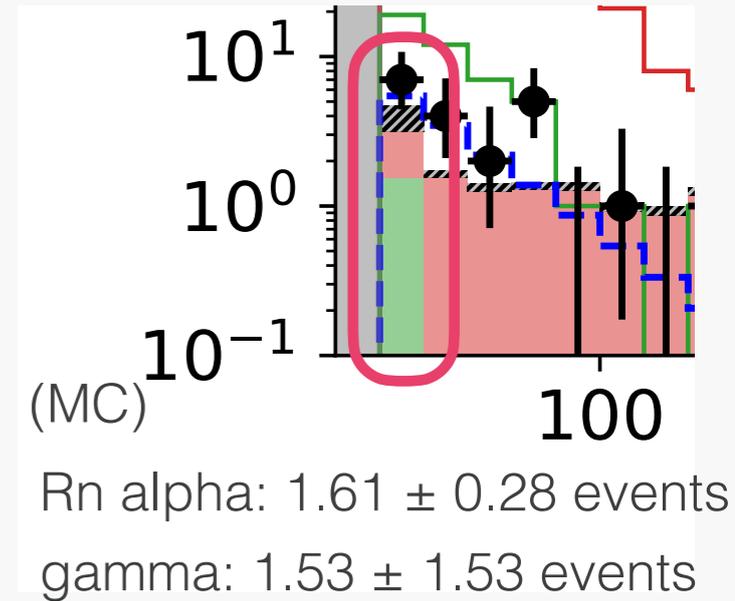
Next plan is to change feed through flange and its cylinder:  
inner surface may not be polished.  
(but radon BG level is not certain...)

New feed through system is ready, planning to exchange it  
during this summer

and investigation of  
other possibilities ongoing

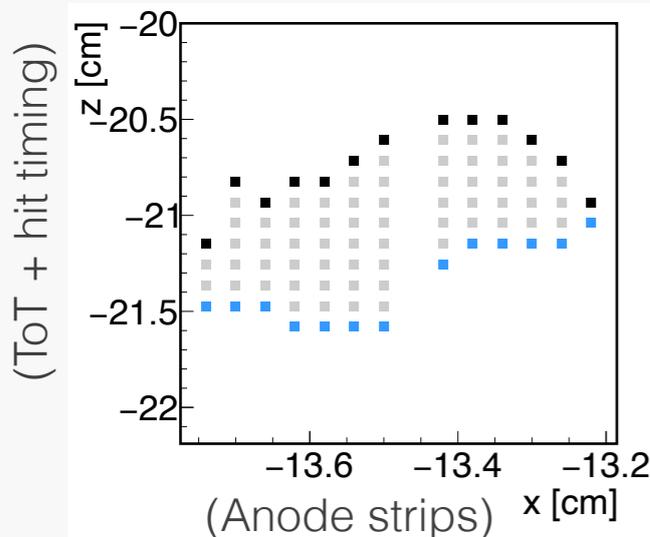
# Review of ambient gamma-induced electron recoil

- 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  $^{252}\text{Cf}$  source run

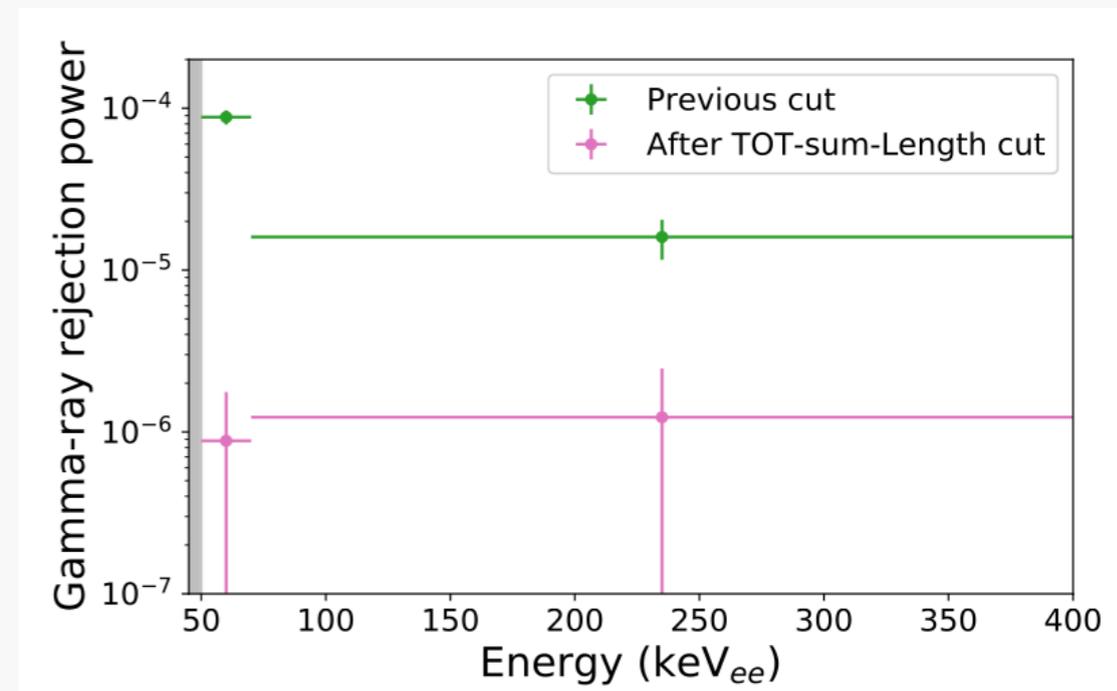
$$E = 160 \text{ keV}_{ee}$$



Electron recoil-like event  
in  $^{137}\text{Cs}$  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

# Copper shield

5 cm thick copper

