Evaluation of Low BG detectors for underground experiments

Kobe Univ. Ryota NAMAI
on behalf of the NEWAGE Collaboration

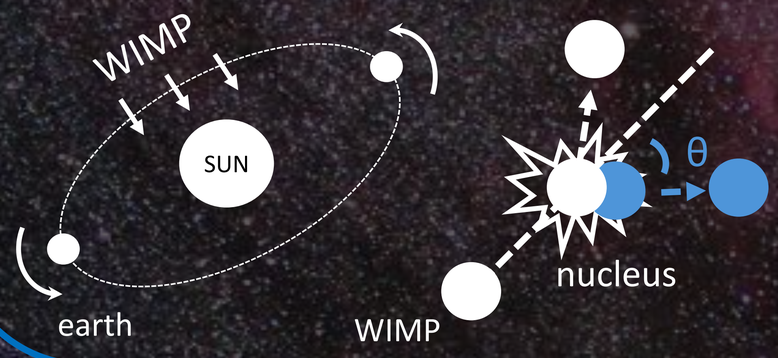
UGAP 2024 Workshop
2024, 4th-6th, March

1. Introduction

WIMP(Weakly Interacting Massive Particle)

- Candidate particles of dark matter.
- The predicted mass is about tens of GeV to hundreds of GeV
- Anisotropy is expected in coming direction of WIMP.

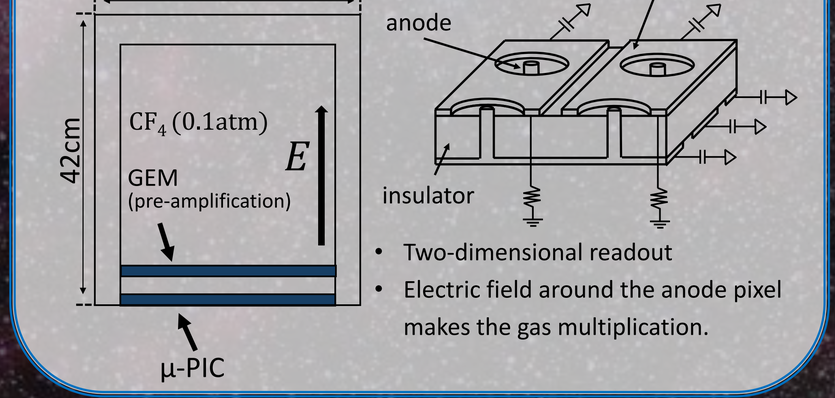
→ Make anisotropy of nuclear recoil



NEWAGE

- Direction-sensitive WIMPs search experiment.
- Using gaseous TPC.

Detector



- Two-dimensional readout
- Electric field around the anode pixel makes the gas multiplication.

Motivation

- The expected rate is very low.

→ To be **Low background** is important.

PTEP (2023) 103F01

- Had developed Low alpha(LA)μ-PIC (2017).

→ Reduced the RI (alpha rays) originating from the surface of the detector.

⇩ NEXT

- Also want to reduce radon originating from inside the detector.

→ **Developed a Low BG (LBG) μ-PIC.**

2. Production

Requirements

- Radon emanuation rate : 1/10 less than LAμ-PIC.
- Size : 768×768 pixels ($400\mu m$ pitch).
- Gain : > 1000 in CF_4 (0.1atm).
- Gain uniformity : $< 20\%$ RMS.

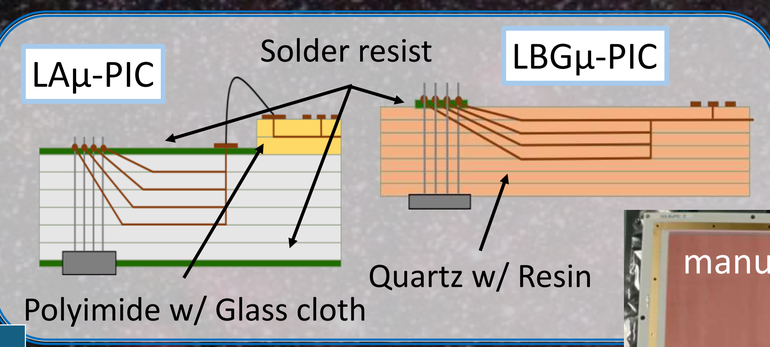
Modifications

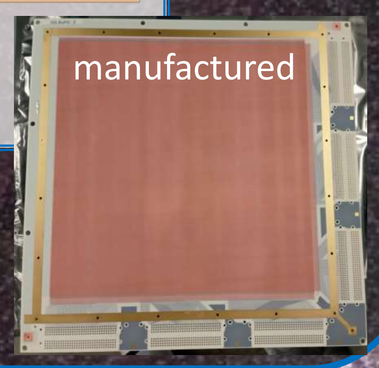
- Reduced solder resist area to 1/15.
- Thinner than LAμ-PIC.
- **Changed core material**

  Before : Polyimide w/ Glass cloth

  After : **Quartz with Resin** (Shin-Etsu Chemical. Co, Ltd.)

Core material	^{238}U upper [ppm]	^{238}U middle [ppm]	^{232}Th [ppm]
Polyimide w/ Glass cloth	$(7.8 \pm 0.1) \times 10^{-1}$	$(7.6 \pm 0.1) \times 10^{-1}$	3.42 ± 0.03
Quartz w/ Resin	$(5.6 \pm 1.0) \times 10^{-3}$	$(5.1 \pm 1.0) \times 10^{-3}$	$(1.2 \pm 0.4) \times 10^{-2}$





Material Screening

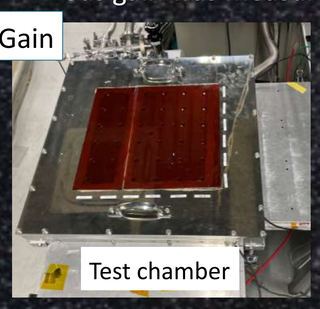
- RI material content reduced to about 1/100.

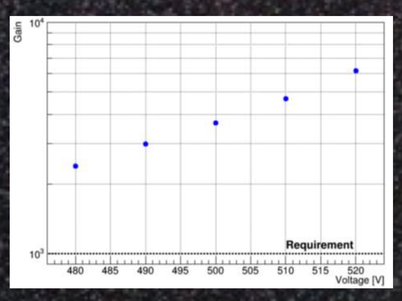
→ Less radon emanation is expected.

3. Measurement

Gas gain

- Gas gain was measured with a test chamber.

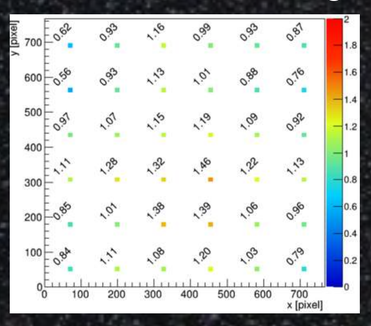


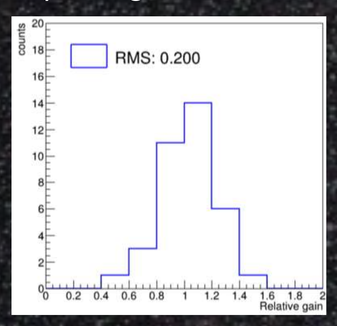


- Satisfied the requirement with anode > 480V

Gain uniformity

- The gain was measured at 6 x 6 points
- Be calculated relative gains by average





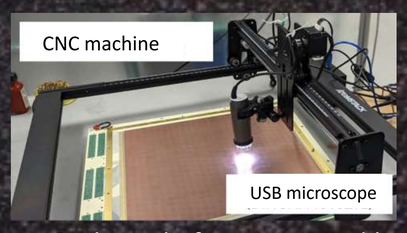
Relative gain distribution

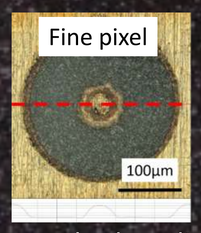
- RMS 20.0% : satisfied the requirement

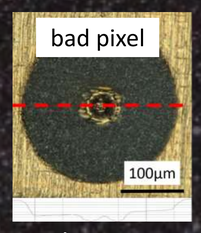
Visual Inspection

- It is not realistic to measure the gain of each pixel.

→ Developed the system to estimate the gains from images.

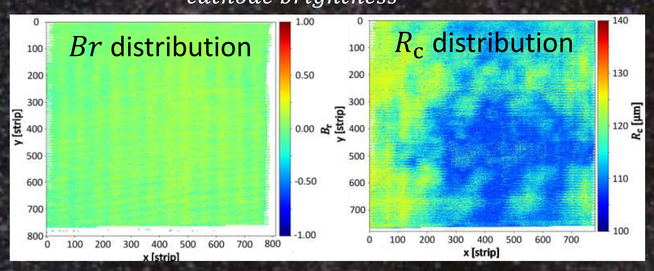






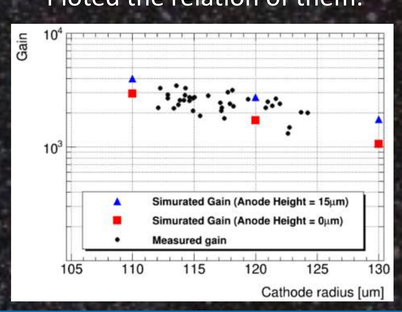
- Bad anode formation and large cathode radius reduce gas amplification.
- Measured anode brightness(Br), cathode radius(R_C)

$$Br = \frac{anode\ brightness - cathode\ brightness}{cathode\ brightness}$$



- Br uniformity is better than R_c.
- It was speculated that there was a relationship between R_c and gain distribution.

→ Ploted the relation of them.



- The red and blue point is simulated value with Garfield++.

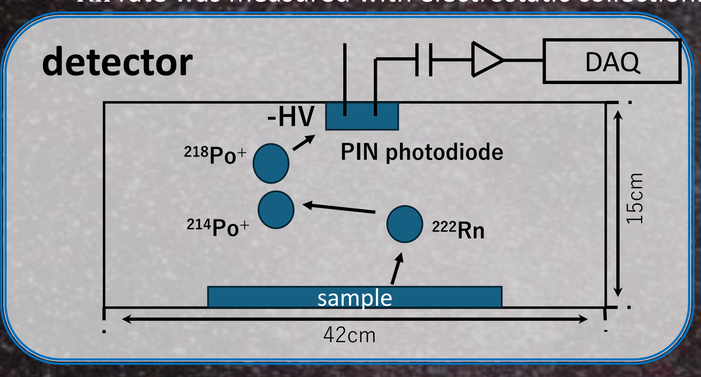
→ The contribution of R_c to the gain is larger than Br's one.

- Measured gain is correlated to R_c.

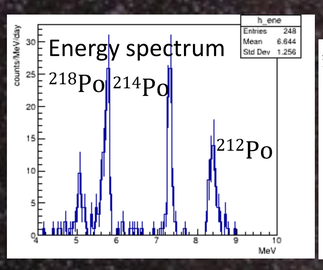
→ Gain uniformity can be corrected using R_c.

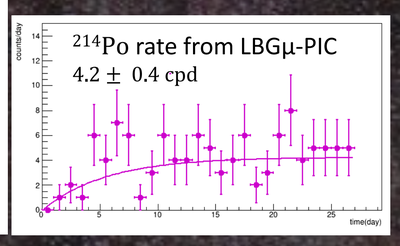
Background

- ^{222}Rn rate was measured with electrostatic collection.



- Measured ^{214}Po rate.





- Calculate radon rate from ^{214}Po rate.

Radon emanation rate

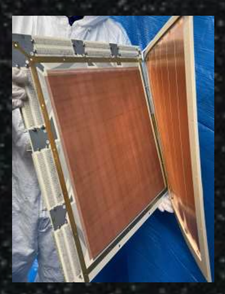
sample	Rn rate [mBq/m^3]
LAμ-PIC	85.2 ± 17.4
LBGμ-PIC	< 1.0 (90% C. L.)

- Achieved less than 1/60 of LAμ-PIC

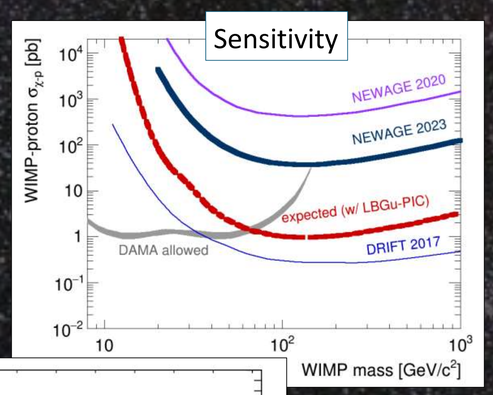
→ Paper is preparation

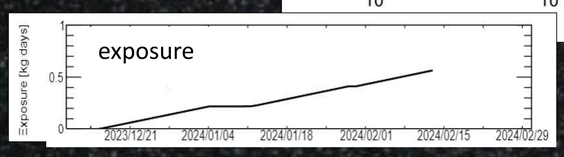
4. Prospects

- Installed in Kamioka underground experiment
- Started measurement from 2023/12/15
- Details of measurement will be presented by Satoshi H.



Installation





5. Conclusion

- The LBG μ-PIC was developed with a low amount of radon emanation.
- Gain uniformity is 20.0% RMS.
- Gas gain satisfies the requirement with anode voltage > 480V.
- Compared to the current LAμ-PIC, the radon emanation is now 1/60 or less.
- Installed to underground experiment and started WIMP search.