



N-45-05

# Development of a surface alpha ray detector based on $\mu$ -TPC with low background

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# **Topics**

**1. Introduction**

**2. Surface alpha ray detector**

**3. Calibration and performance check**

**4. Inspection for a sample**

**5. Background study**

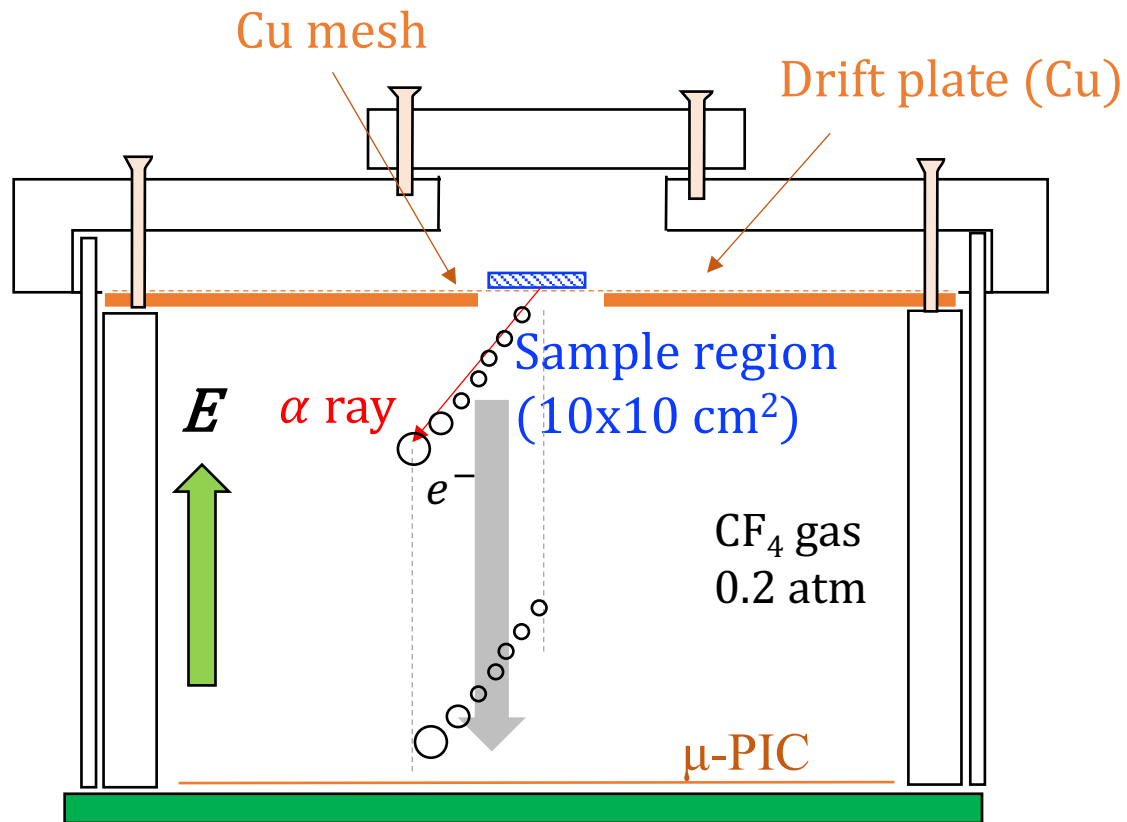
**6. Prospection**

**7. Conclusion**

# 1. Introduction

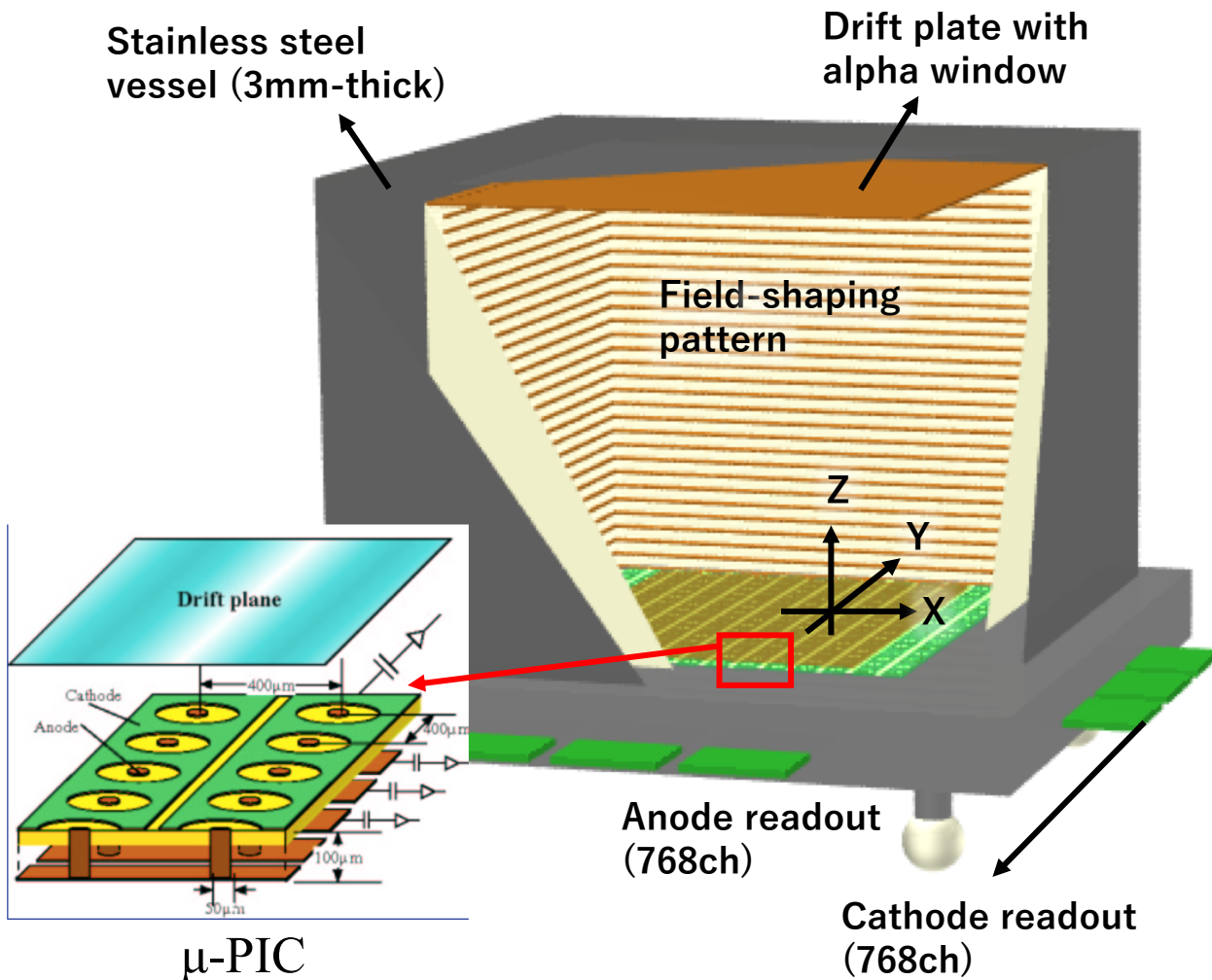
- As known, Dark Matter (DM) composes  $\sim 27\%$  in the universe. DM (WIMP as the candidate) direct search pioneers approach using a detector with **massive** and **low background**.
- DAMA observed the annual modulation in  $8.2\sigma$  as DM contribution, however other group (XENON100, LUX, ...) have not reproduced this signal.
- On the other hands, a direction sensitive DM search has been focused because of WIMP-wind. A recent sensitivity is also limited by radioactive impurities in the detector material.
- A pure material should be selected to design the detector for DM search, and therefore **the low background level radiation detector** is required.

## 2. Surface alpha ray detector Detector Mechanism



- A Measurement of radioactive impurities ( $^{238}\text{U}$ ,  $^{232}\text{Th}$ ) by detecting alpha ray emitted from the sample surface.
- Drift plate has an alpha-ray window.
- Sample is set on the window and supported by Cu mesh.
- Alpha ray 3D tracks are measured based on Time Projection Chamber.
- The hit time in  $\mu$ -PIC is converted to drift length.

## 2. Surface alpha ray detector Construction design



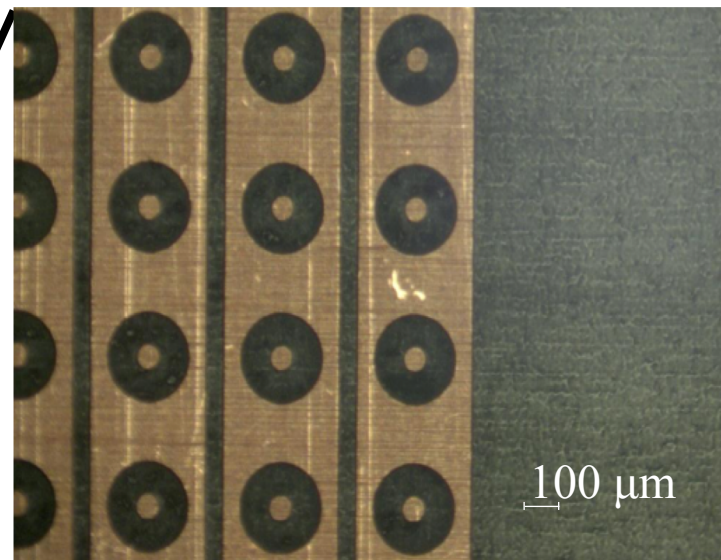
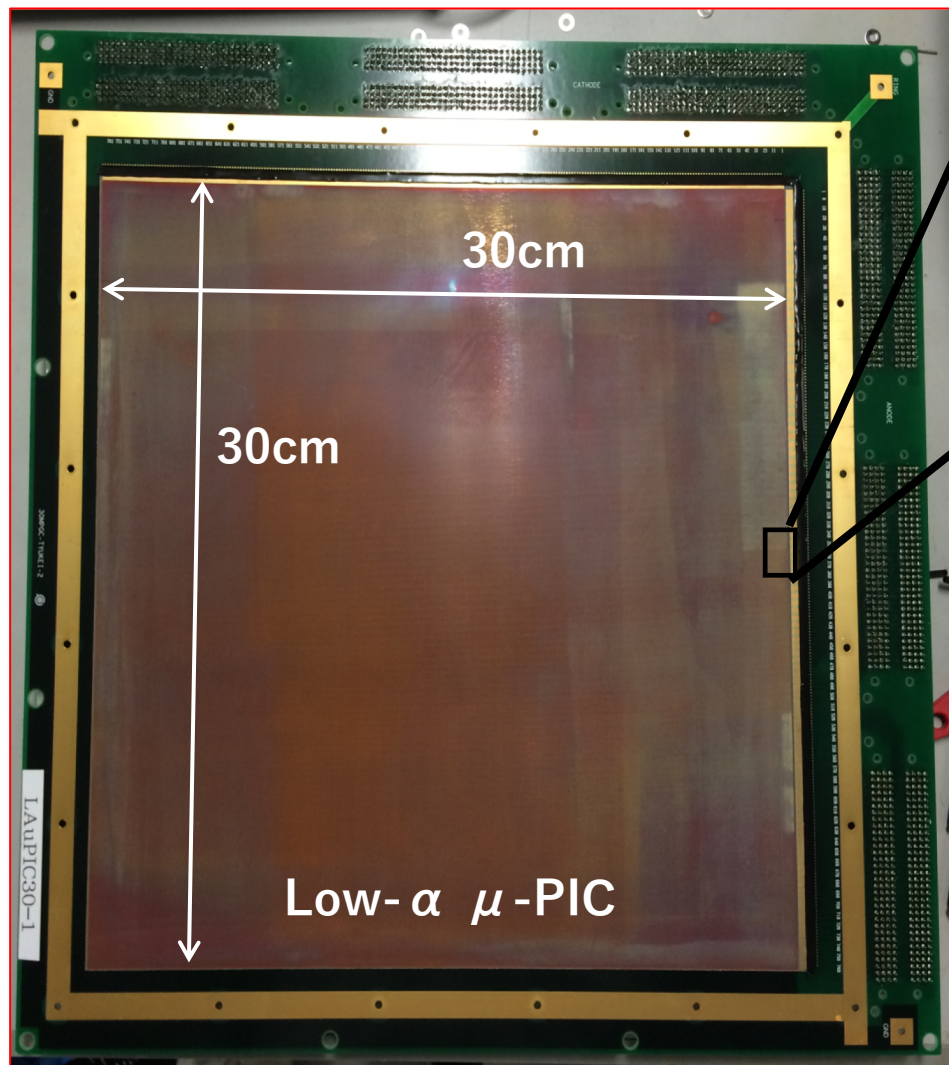
Gaseous detector (NEWAGE-0.3a)  
Based on TPC using  $\mu$ -PIC with a strip gap of 400  $\mu\text{m}$   
Lower pressure Gas:  $\text{CF}_4$  0.2 atm.

**Advantage:**

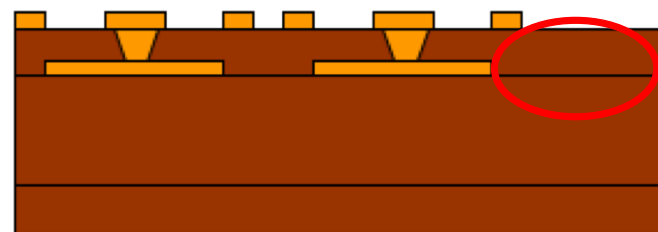
- (1) A position sensitivity.
- (2) An ability to take a sample and BG event at a same time.

Goal: BG rate  $10^{-4}$  alpha  $\text{cm}^{-2}$   $\text{hr}^{-1}$   
( $^{238}\text{U}$ ,  $^{232}\text{Th}$  ppb level for a thin film)

## 2. Surface alpha ray detector Installed Low- $\alpha$ $\mu$ -PIC



### New material

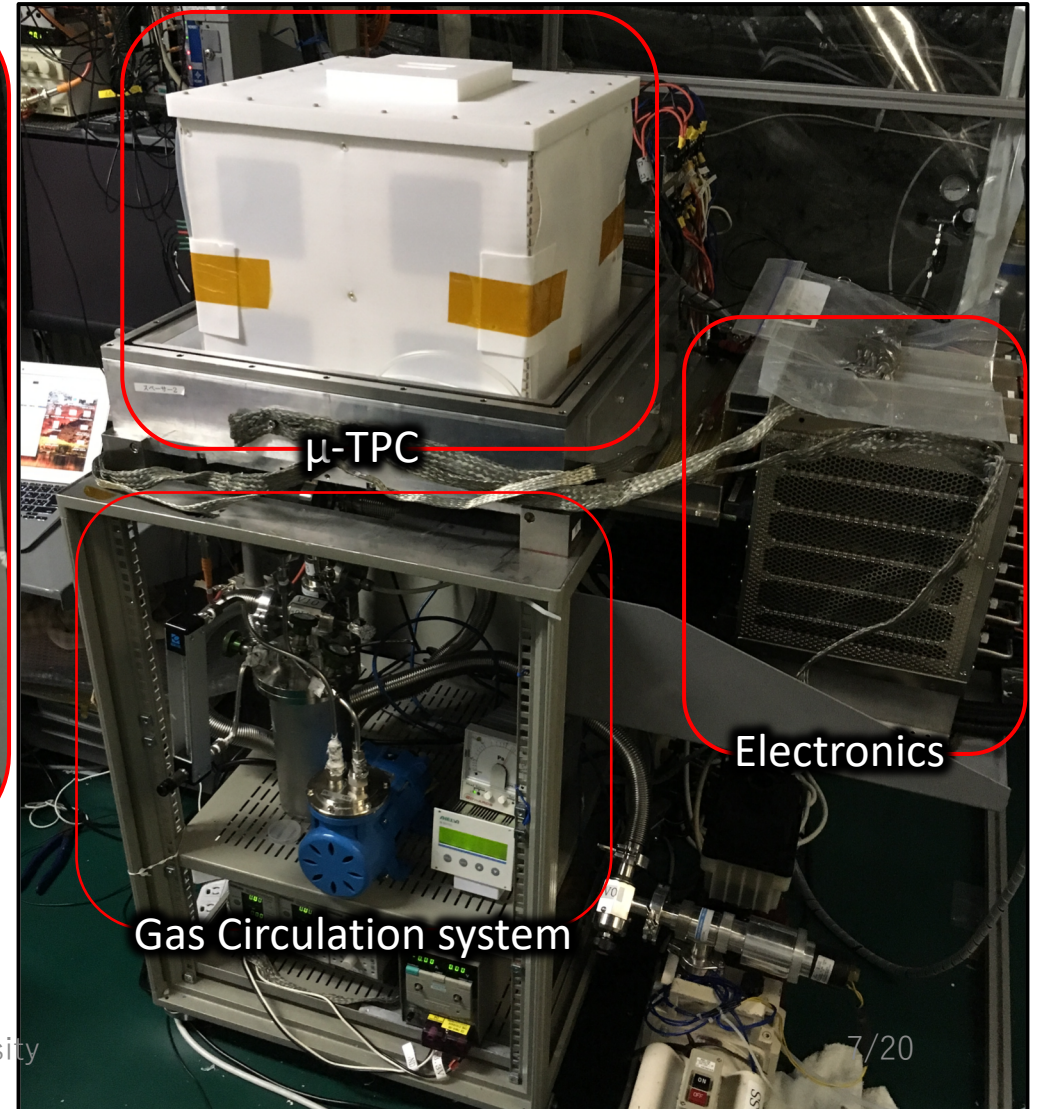
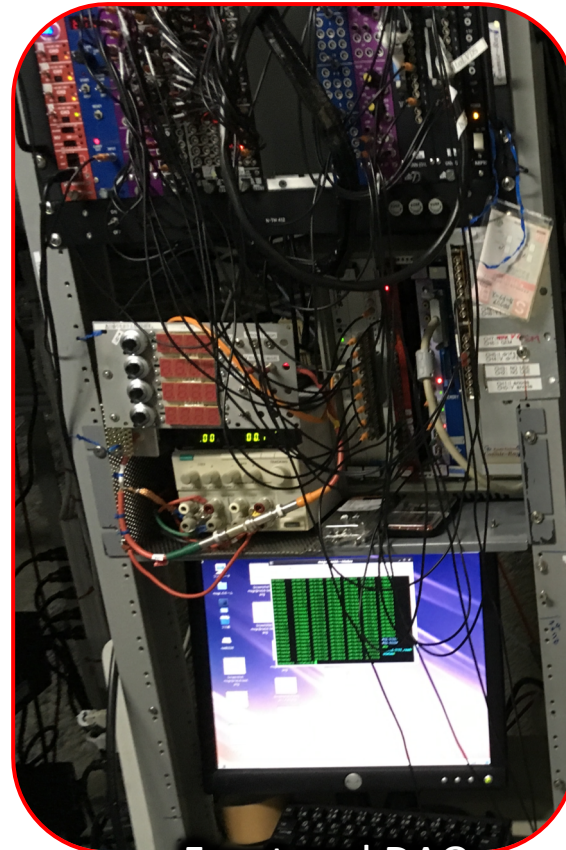


PI + epoxy

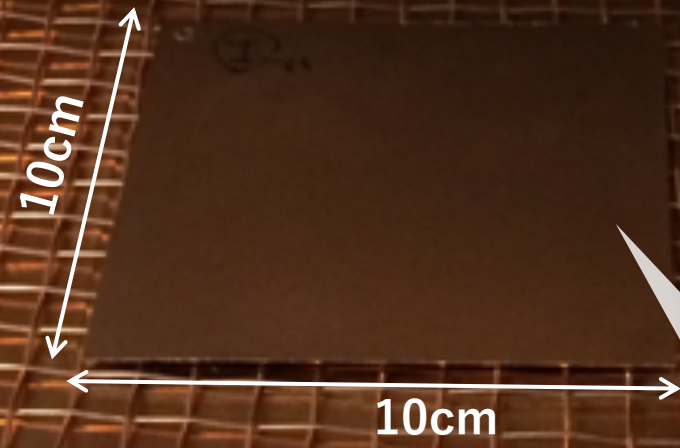
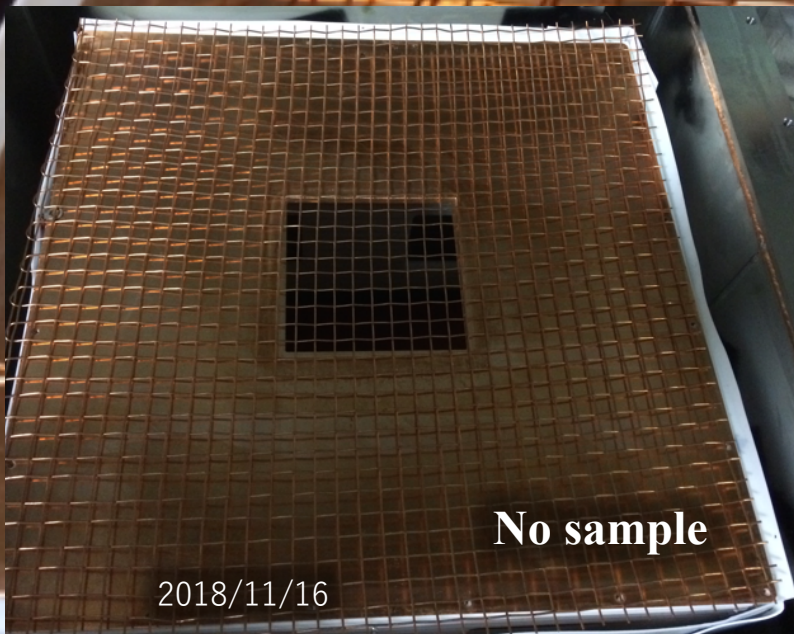
Sample	$^{238}\text{U}$ [ppm]	$^{232}\text{Th}$ [ppm]	備考
PI100 $\mu\text{m}$	0.39 $\pm$ 0.01	1.81 $\pm$ 0.04	Conventional $\mu$ -PIC material
PI+epoxy	<b>&lt; 2.98<math>\times 10^{-3}</math></b> <b>(90%CL)</b>	<b>&lt; 6.77<math>\times 10^{-3}</math></b> <b>(90%CL)</b>	New material

## 2. Surface alpha ray detector

### Detector building in Kamioka underground



### 3. Calibration and Performance check Setup



Po-210 accumulated on copper surface

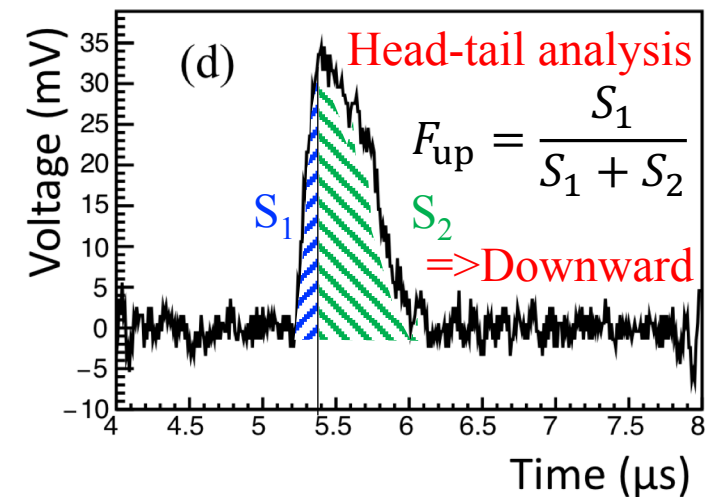
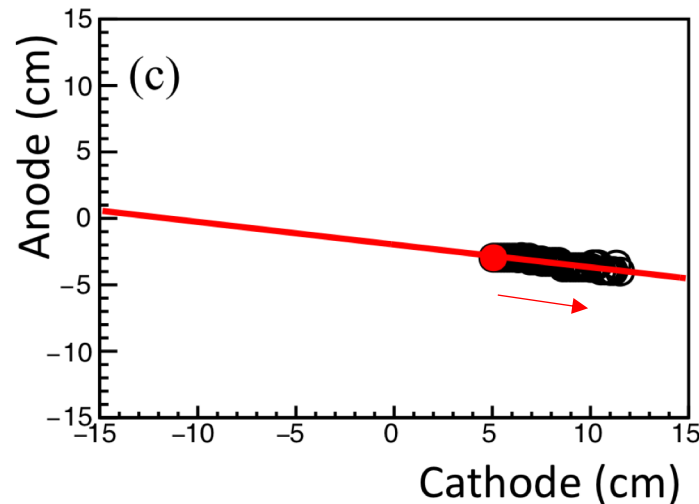
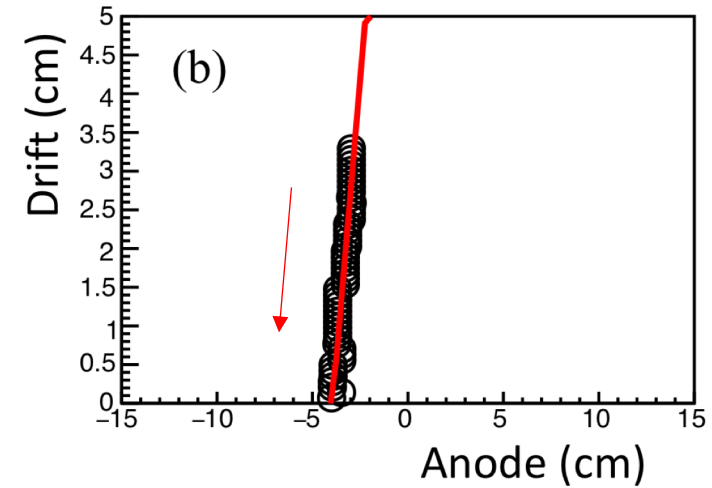
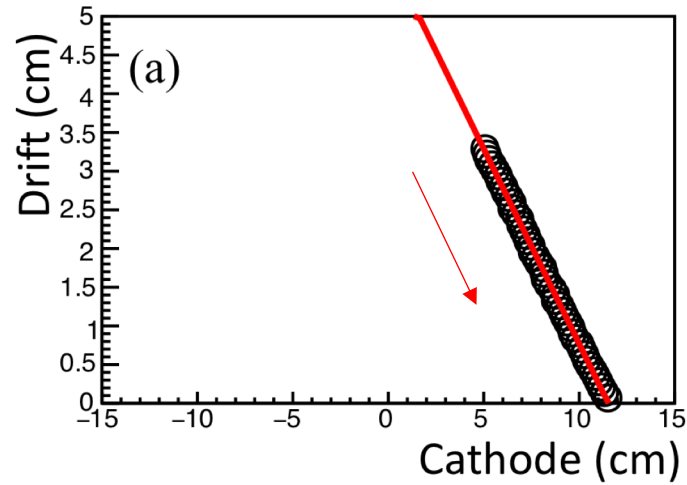
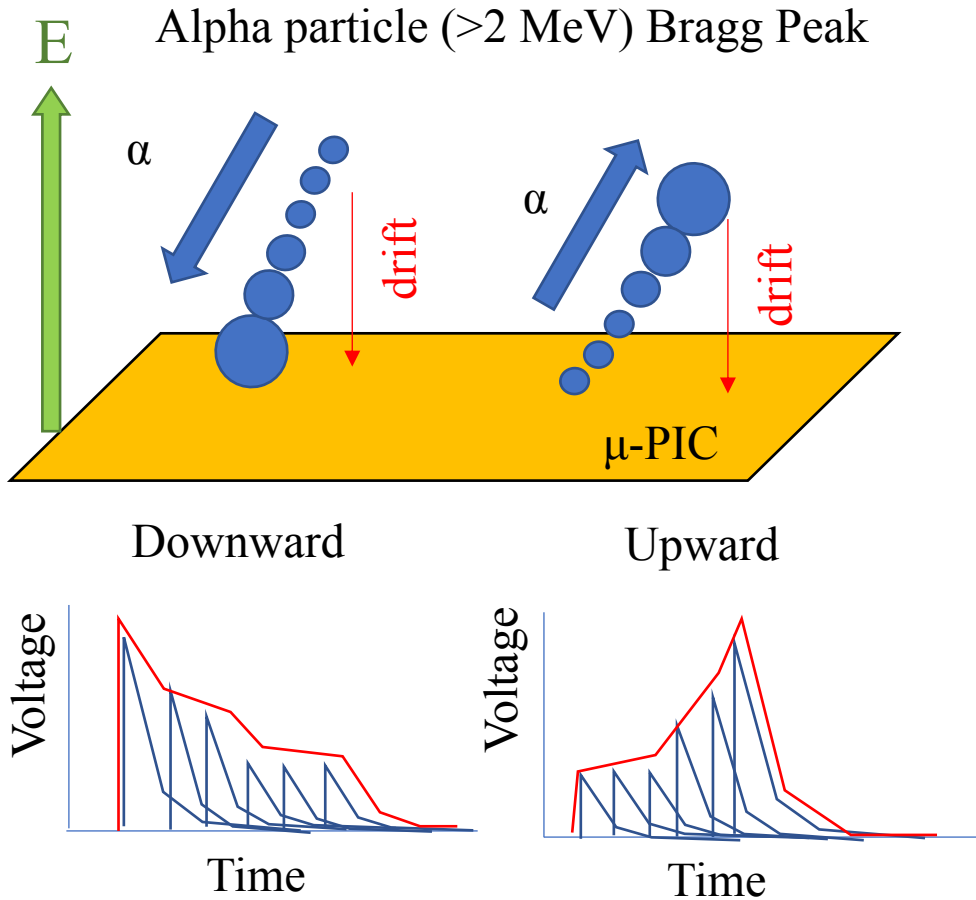
- size: 10x10x0.1 cm<sup>3</sup>
- 5.3 MeV alpha emit from <sup>210</sup>Po
- 1.43 ± 0.01 alpha/sec for 4.8-5.8 MeV

NIM A 884 (2018) 157.



# 3. Calibration and Performance check

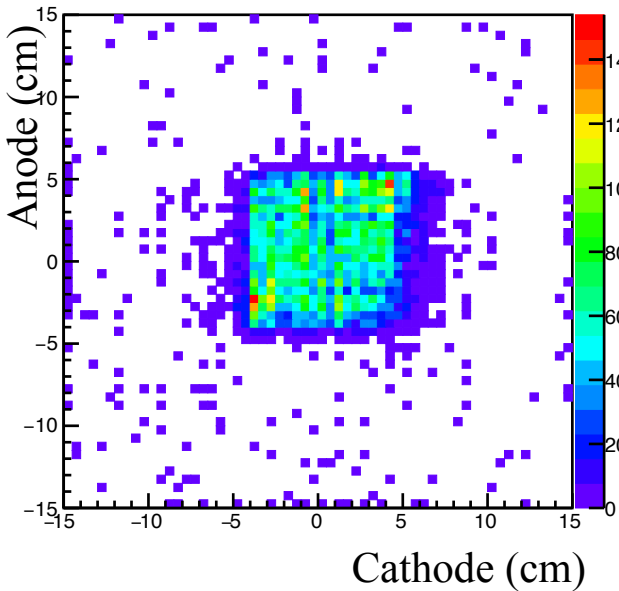
## Alpha event reconstruction



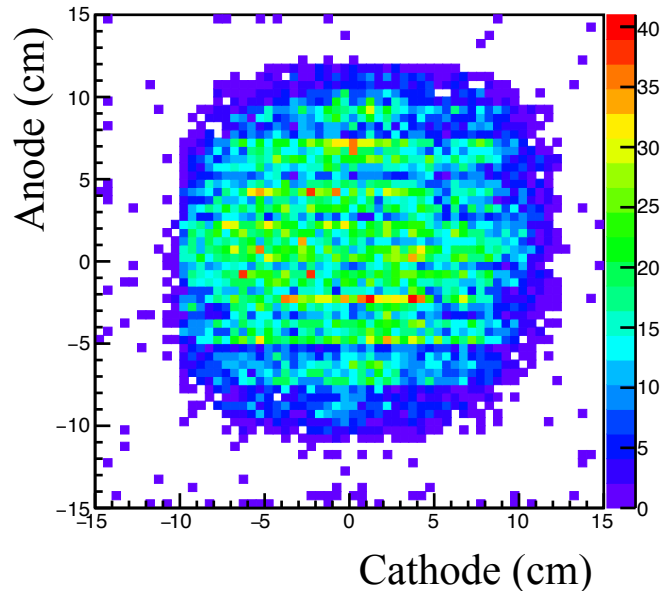
# 3. Calibration and Performance check

## Alpha energy and Imaging map

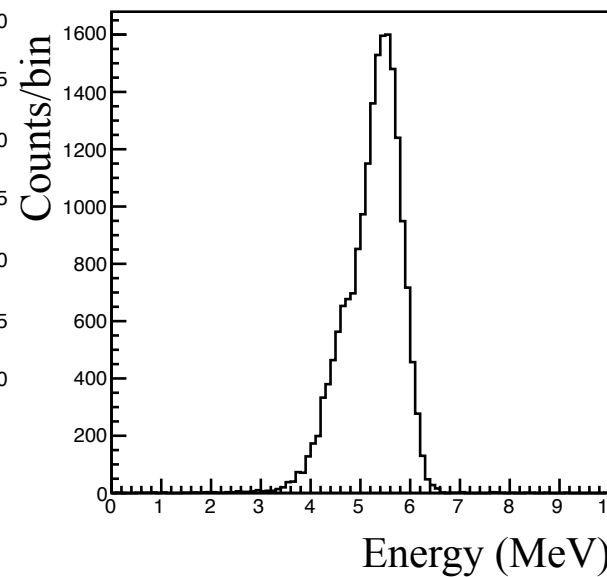
Alpha emit point



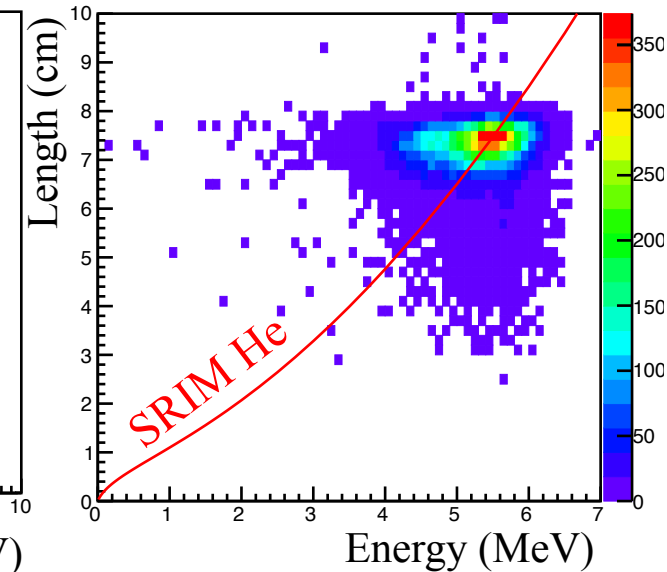
Alpha stop point



Energy spectrum



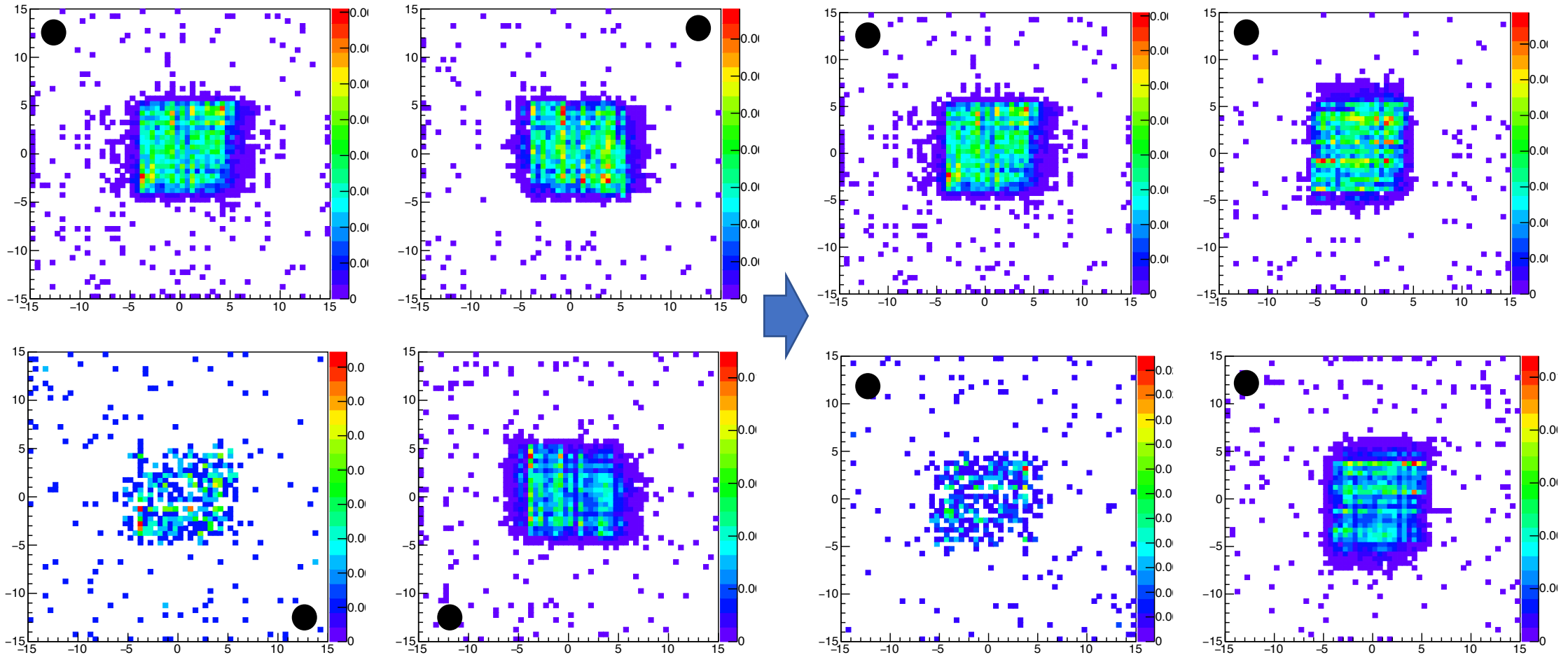
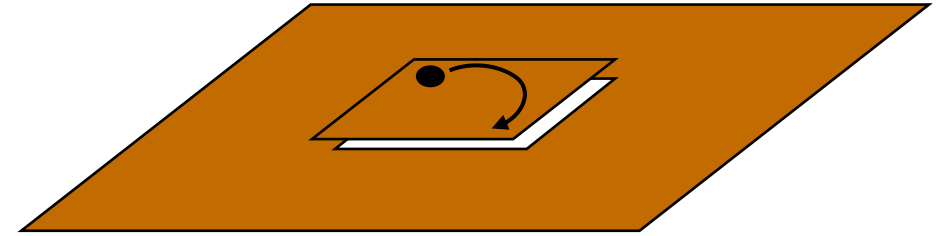
Energy vs. Length



Energy resolution: 19.6% FWHM for 5.3 MeV.  
It is reasonable in comparison with a recent NEWAGE detector resolution ( $\sim 10\% \sigma$ ) for radon alpha.

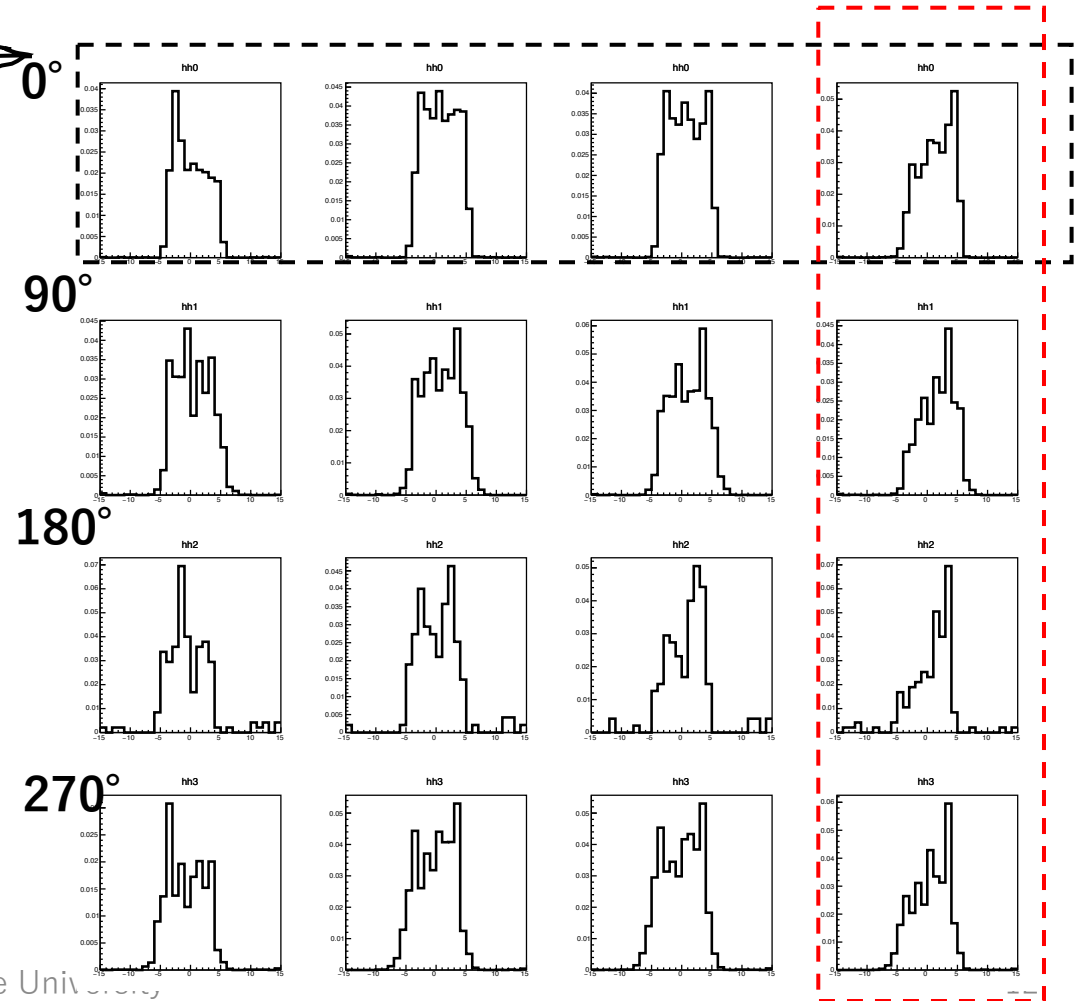
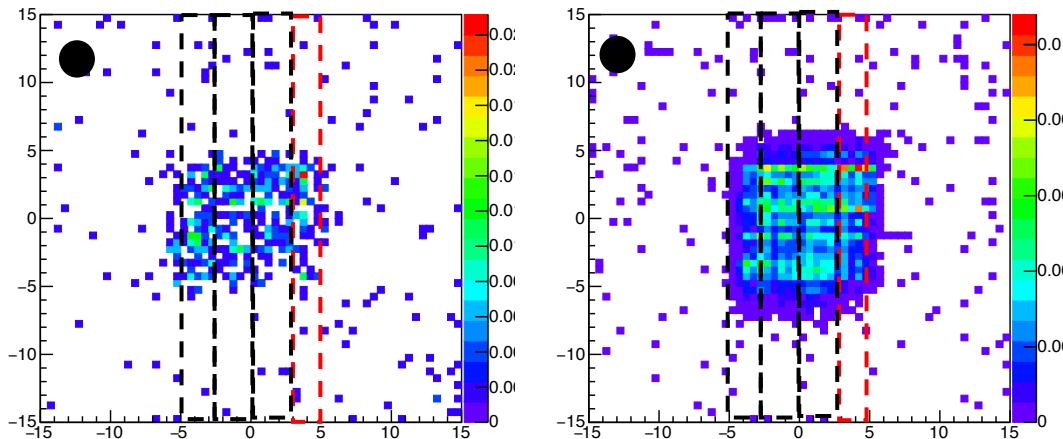
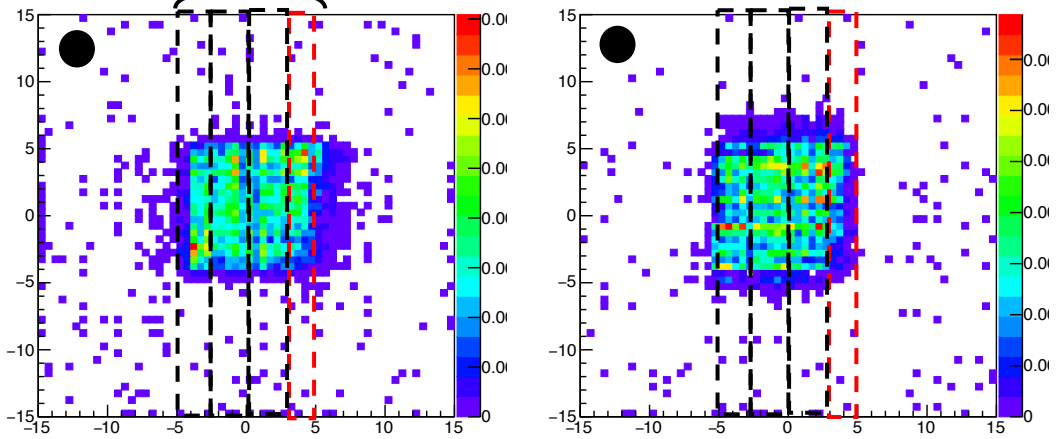
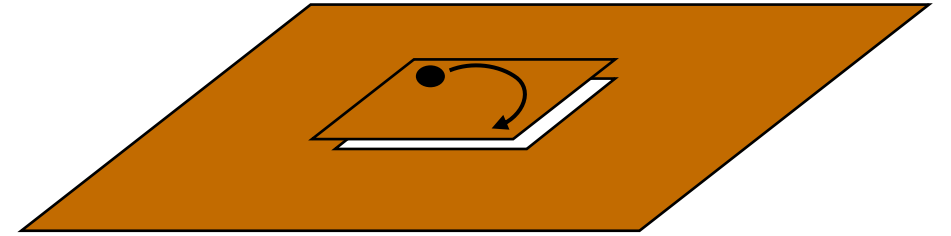
# 3. Calibration and Performance check

## Alpha energy and Imaging map

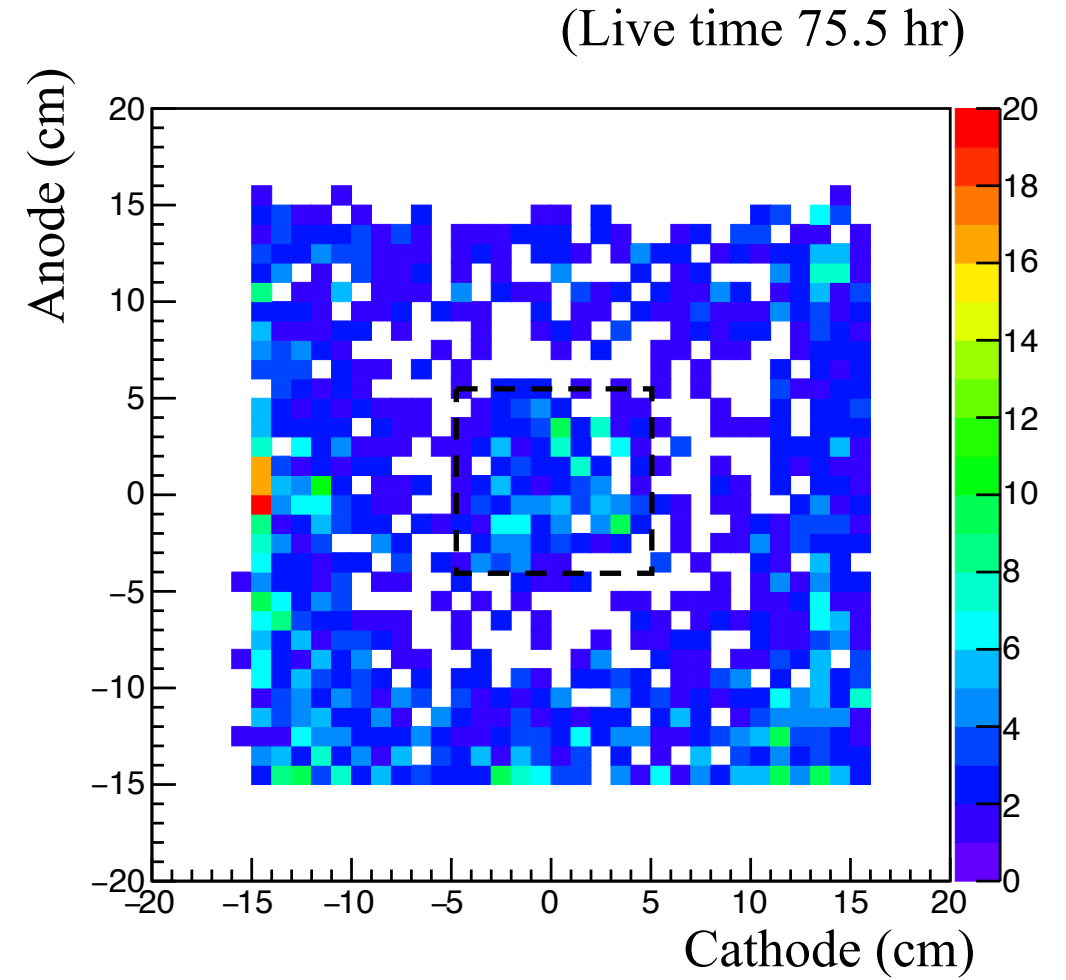
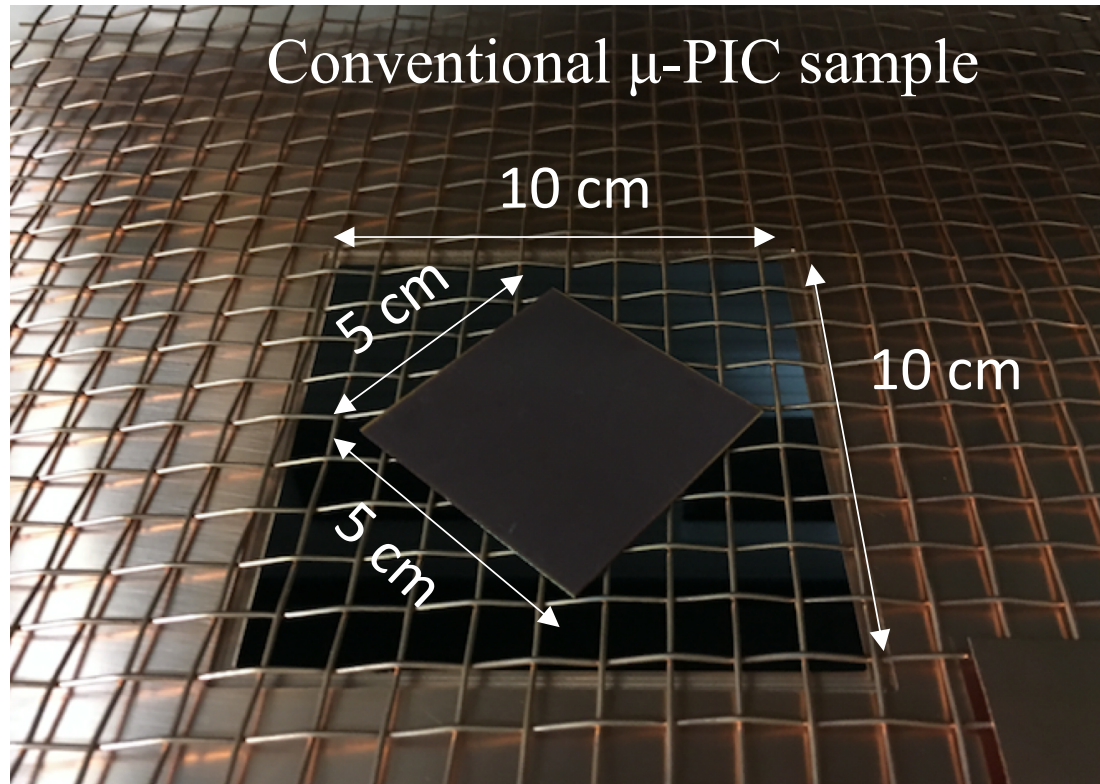


# 3. Calibration and Performance check

## Alpha energy and Imaging map

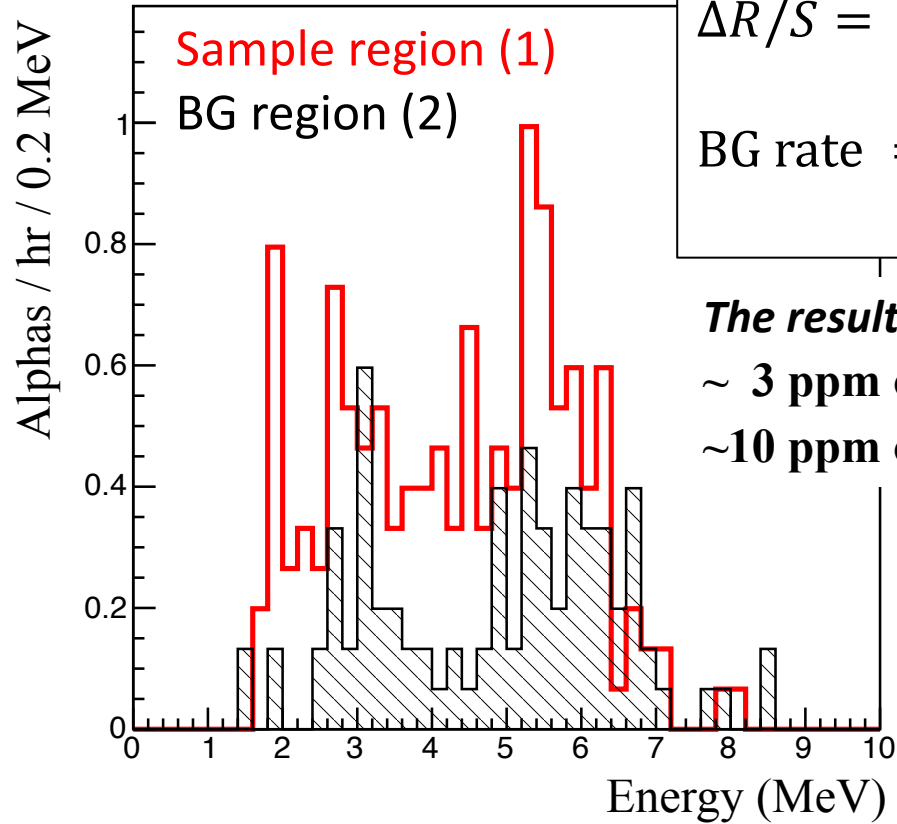
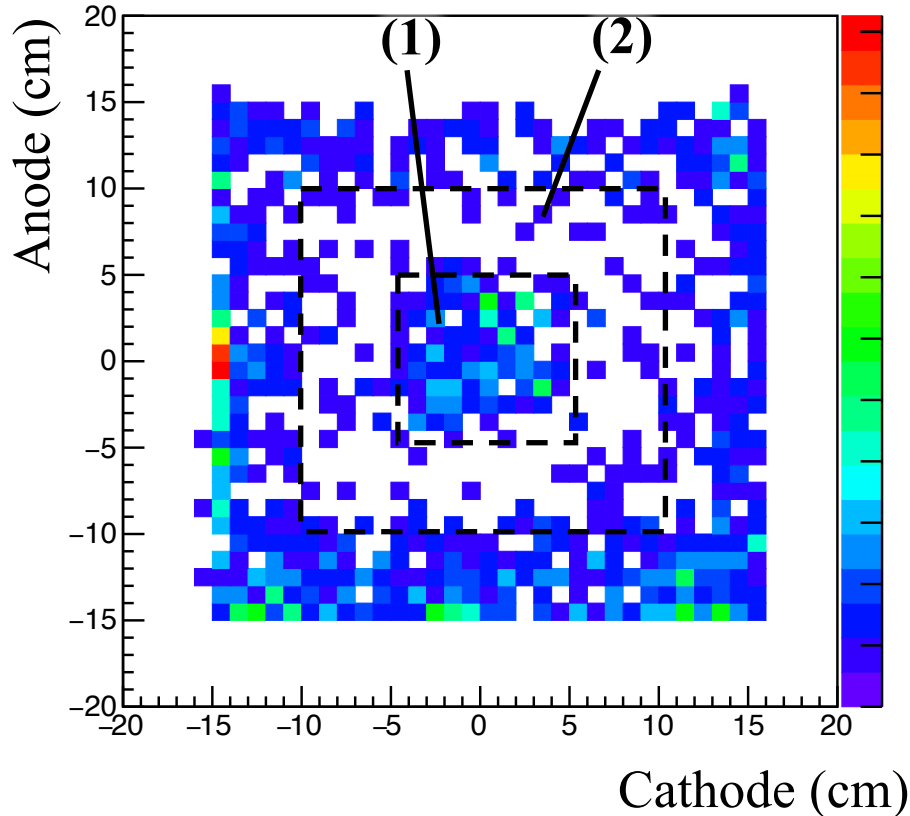


# 4. Inspection for a sample Setup



# 4. Inspection for a sample Result

Rejected upward alpha (Live time 75.5 hr)



$$R_{\mu\text{PIC}} = 2.50 (71) \text{ Alphas/hr}$$

$$R_{BG} = 1.23 (50) \text{ Alphas/hr}$$

$$\Delta R = R_{\mu\text{PIC}} - R_{BG}/3$$

$$\Delta R/S = 0.084 (41)$$

Alphas/cm<sup>2</sup>/hr

$$\text{BG rate} = 0.0041 (17)$$

Alphas/cm<sup>2</sup>/hr

*The result presents to*

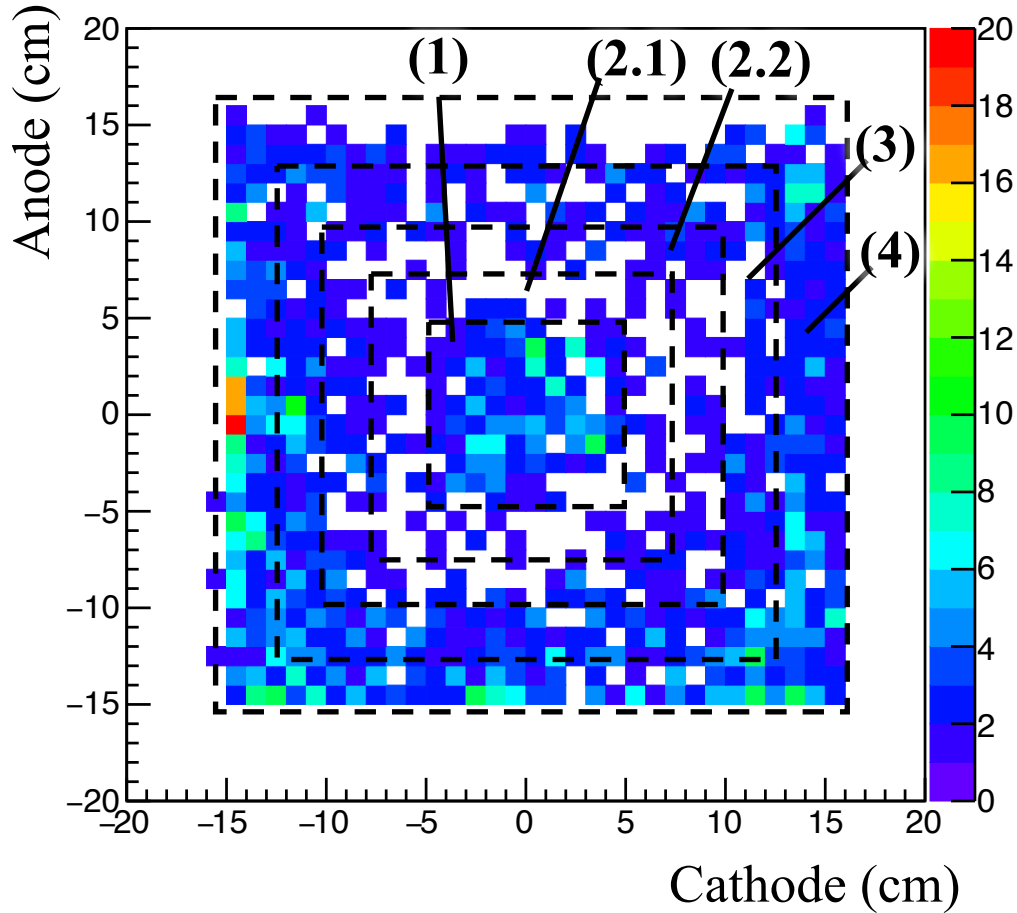
*~ 3 ppm of <sup>238</sup>U equivalent in the  $\mu$ -PIC,*

*~10 ppm of <sup>232</sup>Th equivalent in the  $\mu$ -PIC*

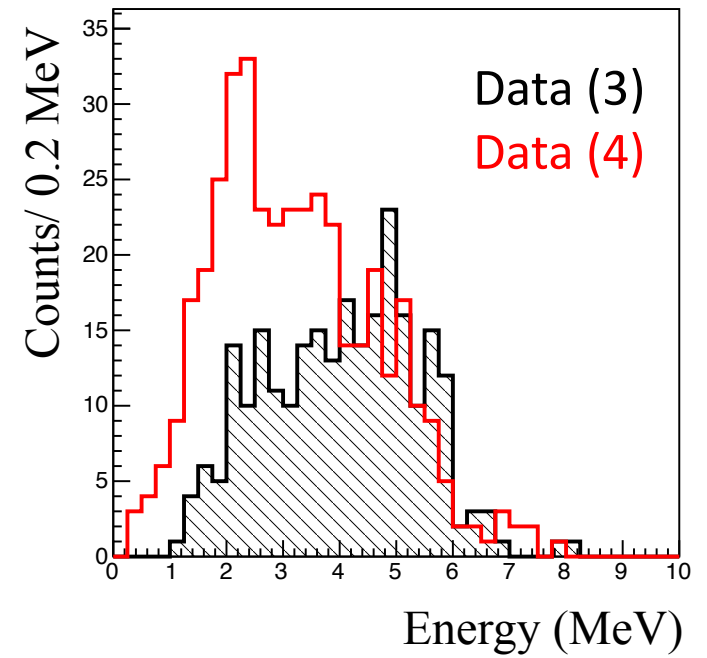
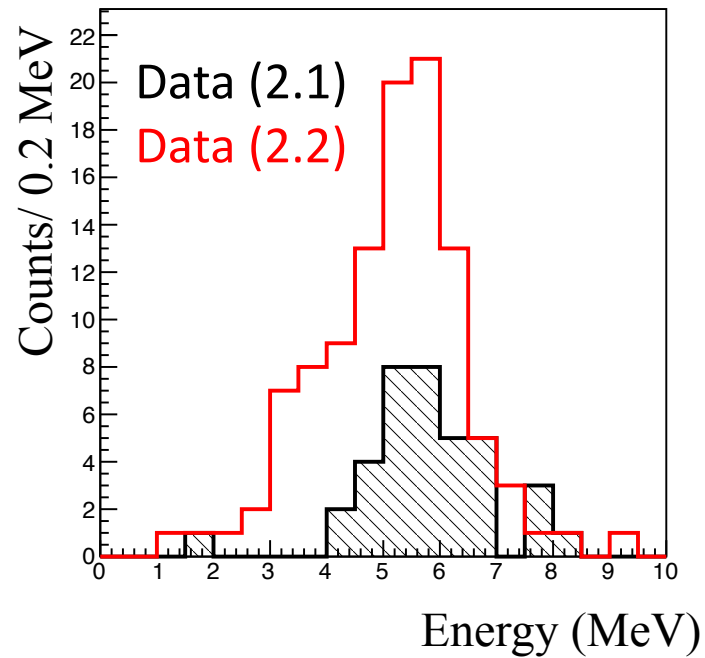
***The ability to take a sample and BG in a same time was established.***

# 5. Background study

(Live time 75.5 hr)

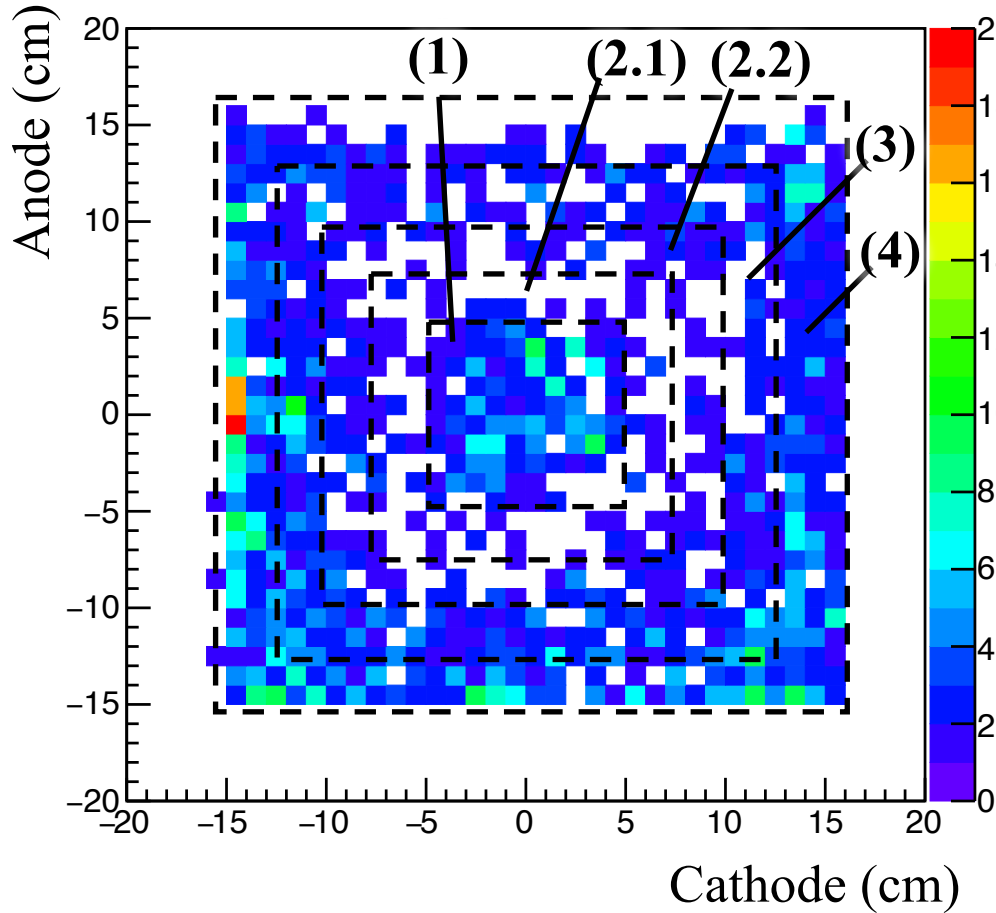


The energy spectra in background region (2.1), (2.2), (3), and (4). The (3) and (4) spectra are tend to distribute continuous.

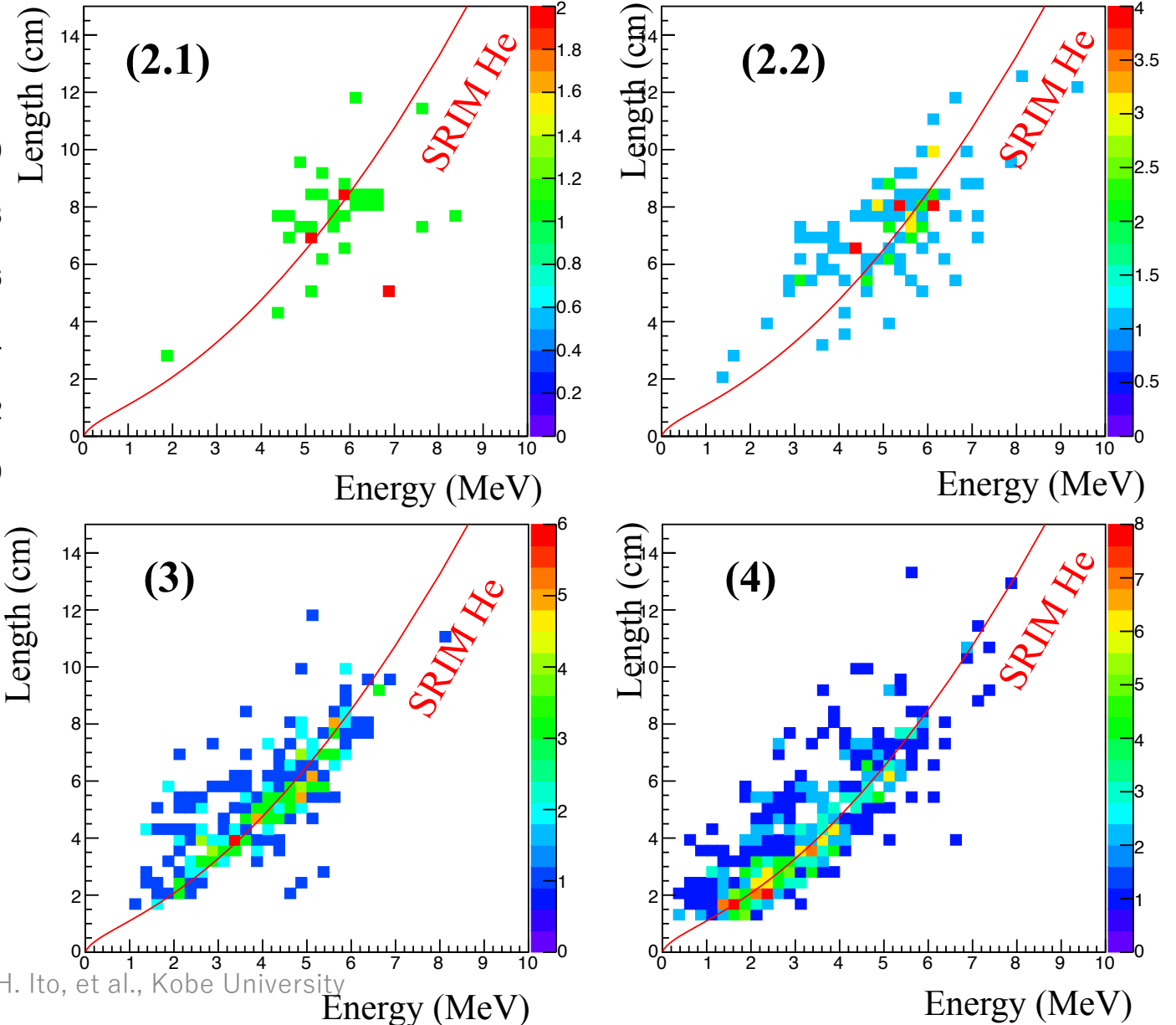


# 5. Background study

(Live time 75.5 hr)



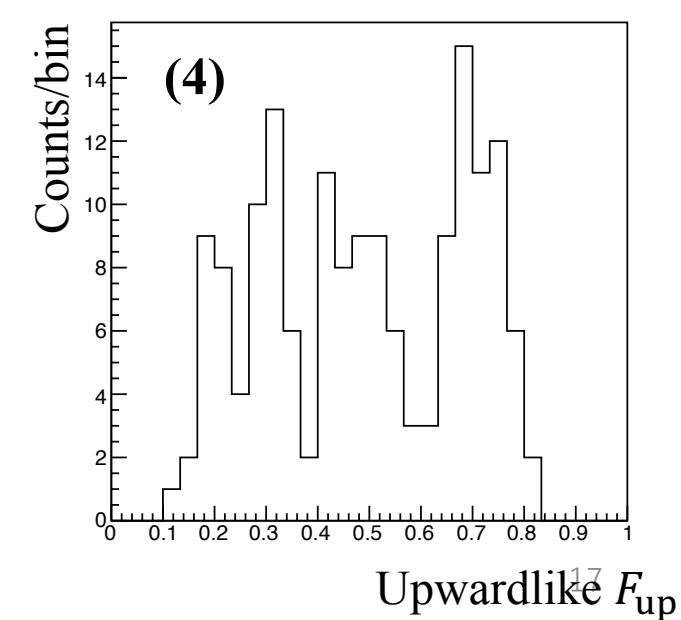
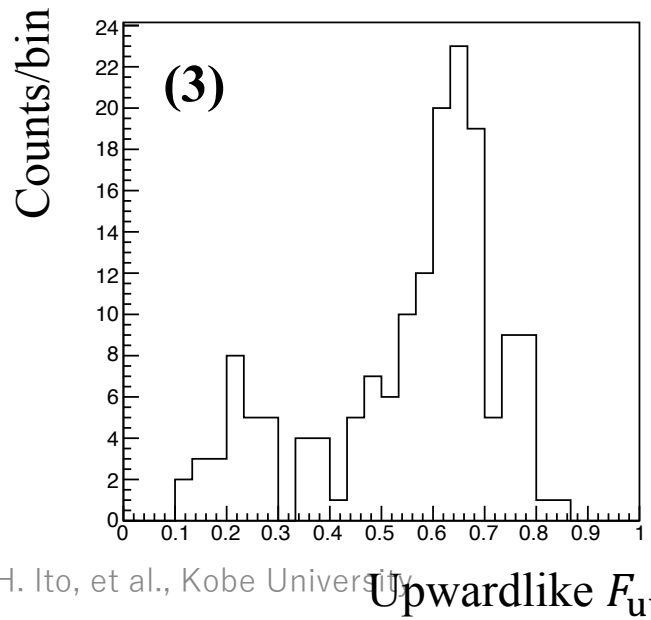
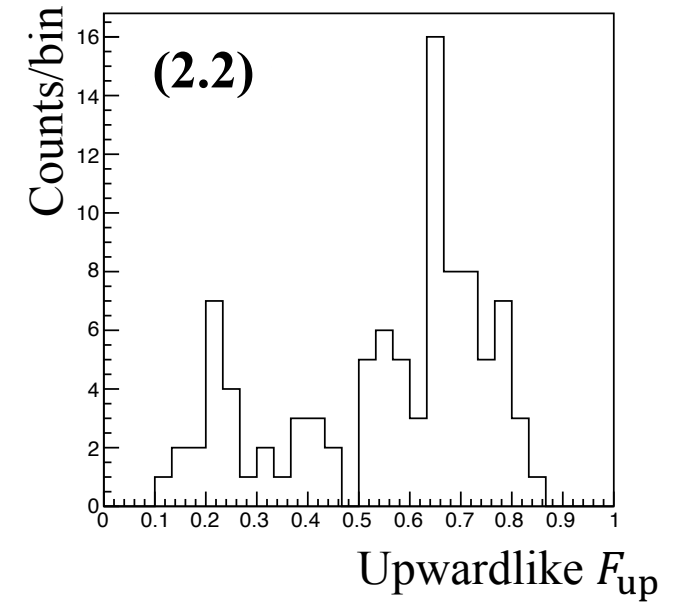
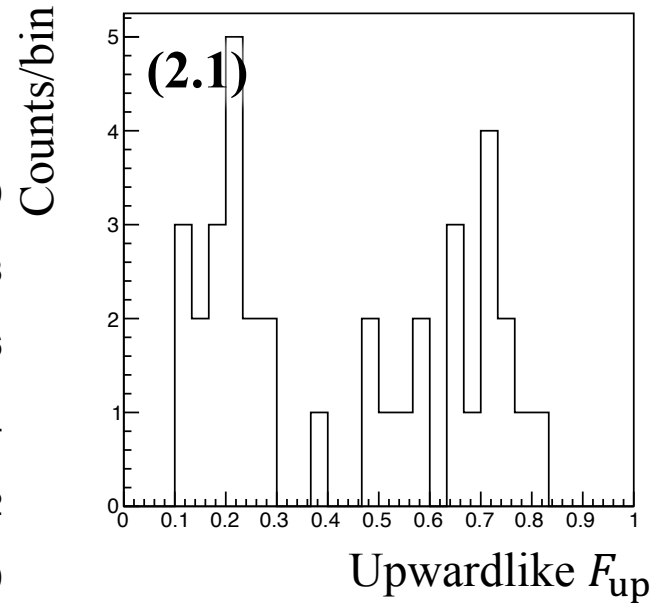
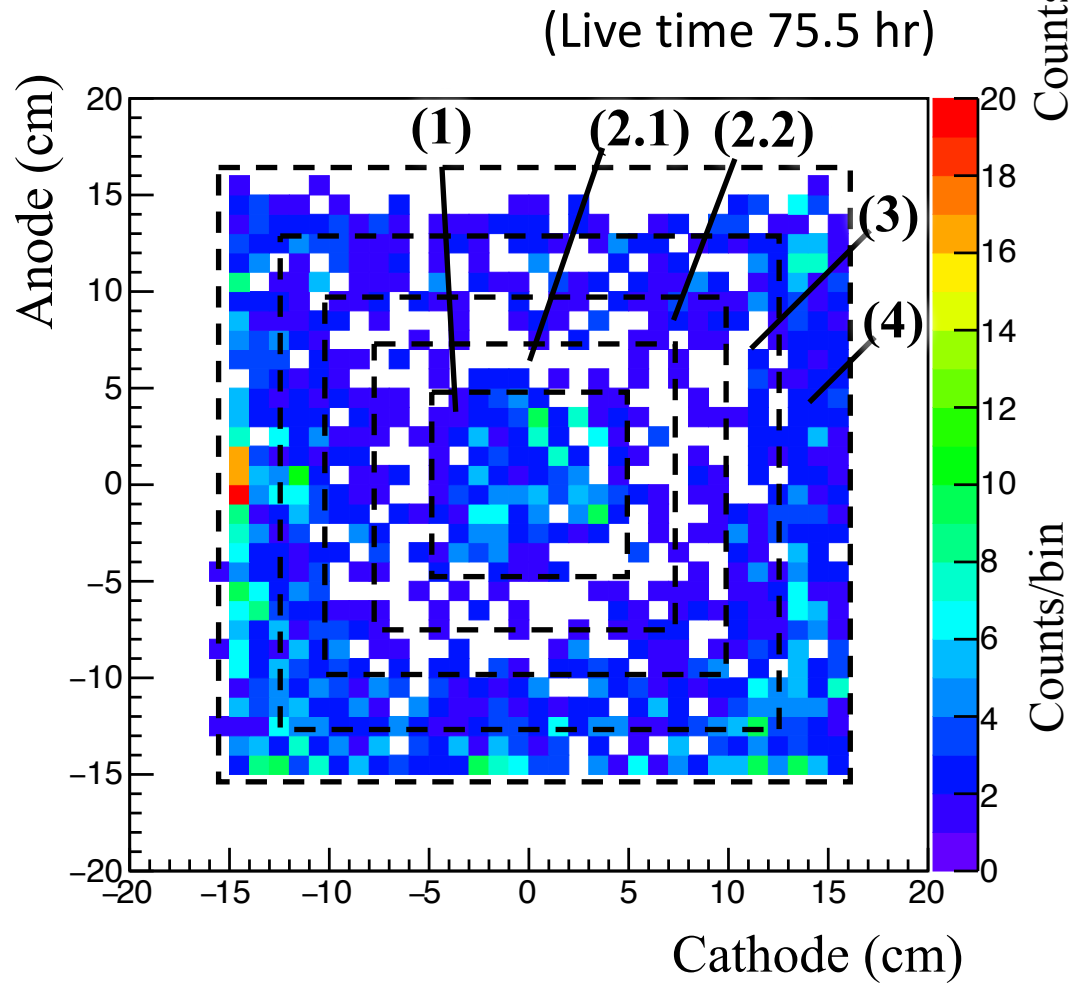
Candidates of BG are almost alpha ray from a relation between the track length and energy.



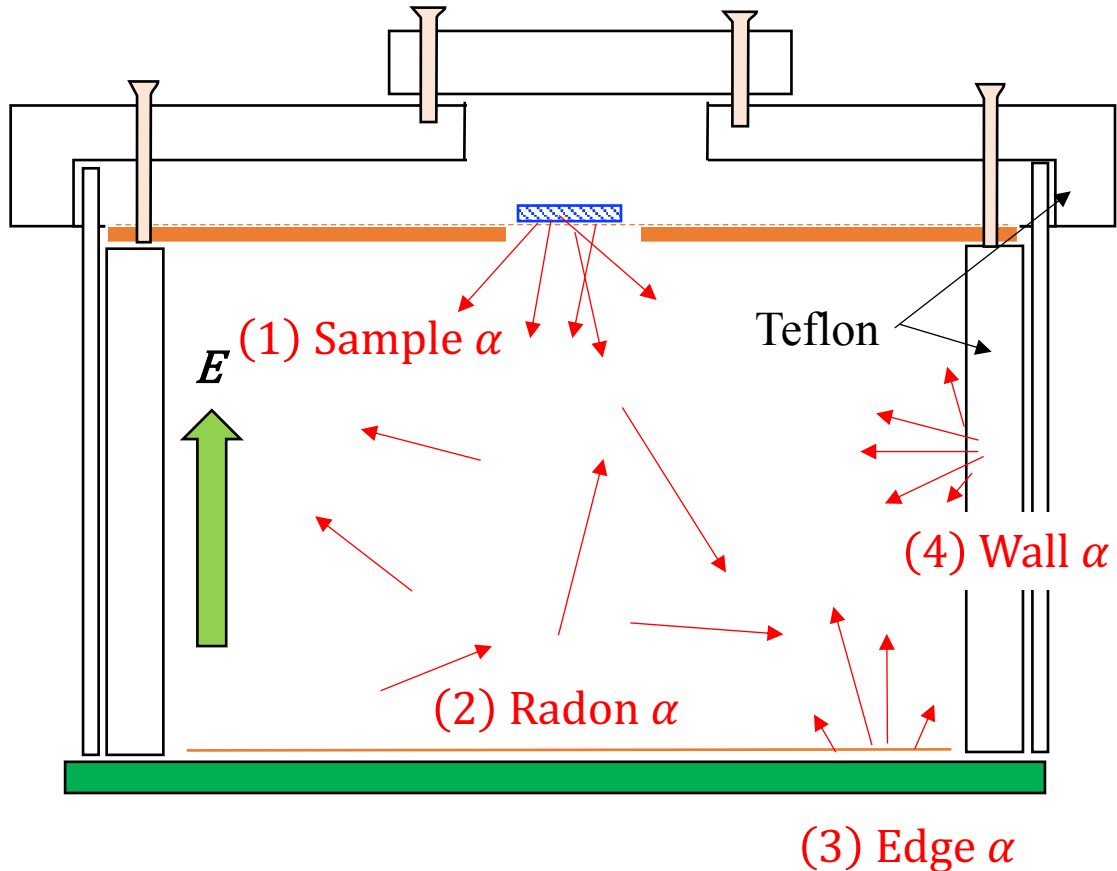


# 5. Background study

There is two peaks in head-tail analysis if the direction is isotropic such as radon alpha. (E > 3MeV)



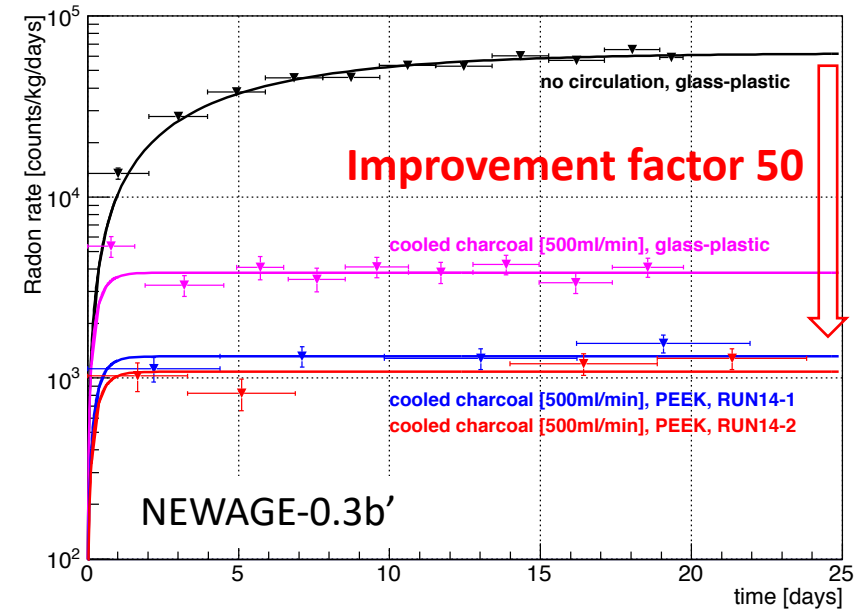
# 5. Background study



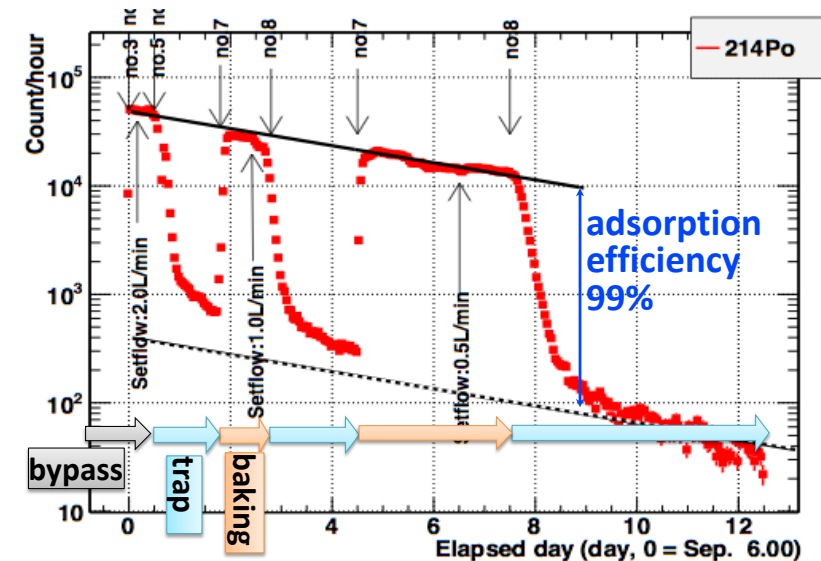
1. Sample alpha direction is a downward. We want to observed it.
2. Radon alpha direction is isotropic. The peak is 5-7 MeV. The radon is distributed on all region. **Since the downward radon alpha cannot be identified in offline analysis, it is the main background.**
3. Edge alpha direction was upward and the energy was continuous. The alpha can be emitted from an edge of  $\mu$ -PIC or electric connectors. It can be rejected by the head-tail analysis and fiducial cut.
4. Wall alpha direction was isotropic and the energy was continuous. The alpha can be rejected by the fiducial cut.

# 6. Prospection

- Radon alpha is dominated as the main Background with  $\sim 4 \times 10^{-3}$  alphas /  $\text{cm}^2$  / hr.
- We have a prospection **to improve factor 50** for achievement less than  $10^{-4}$  alphas /  $\text{cm}^2$  / hr using cooled charcoal.
- We made sure the radon suppression with factor 50 in the current NEWAGE detector.
- A recent study is achieved the radon suppression of 99% using the cooled charcoal.



K. Nakmura, Doctor Thesis 2015.



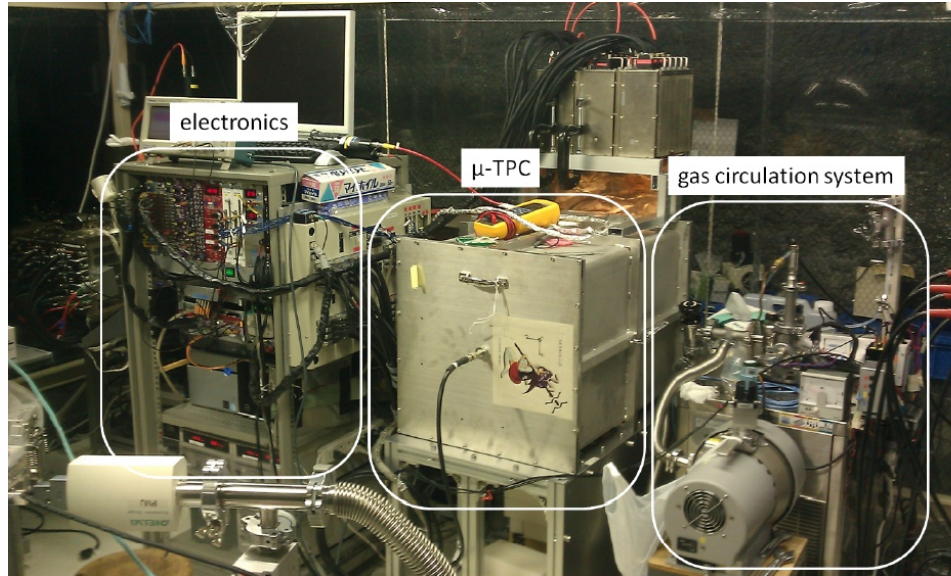
RADIOISOTOPES, 59, 29-36 (2010)

## 7. Conclusion

- We have been developing a surface alpha ray detector with  $\mu$ -PIC in low background to select purified material for dark matter direct search.
- The energy resolution was evaluated to be  $\sim 20\%$  FWHM for 5.3 MeV.
- It was demonstrated:
  - A position sensitivity,
  - An ability to take a Sample & BG at a same time.
- BG rate was achieved to  $\sim 4 \times 10^{-3}$  Alpha/cm<sup>2</sup>/hr (radon alpha is mainly).

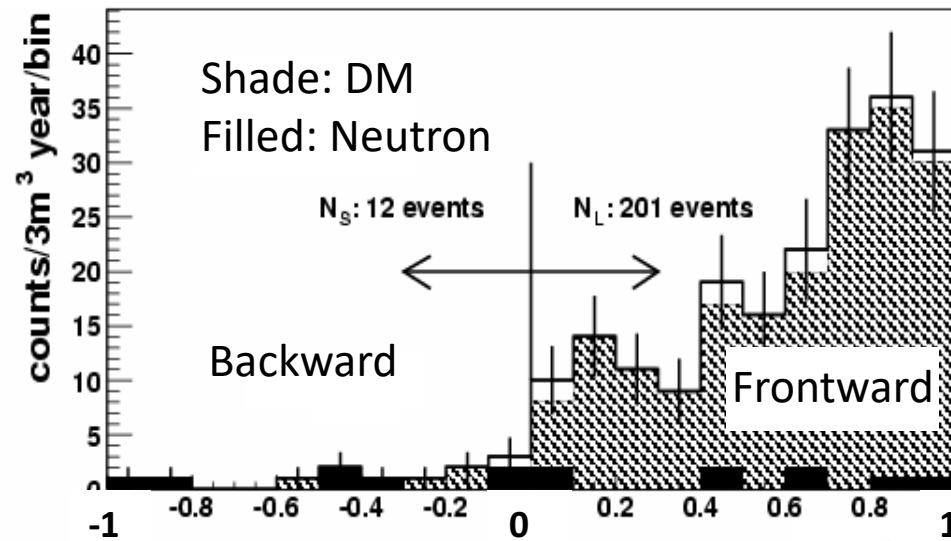
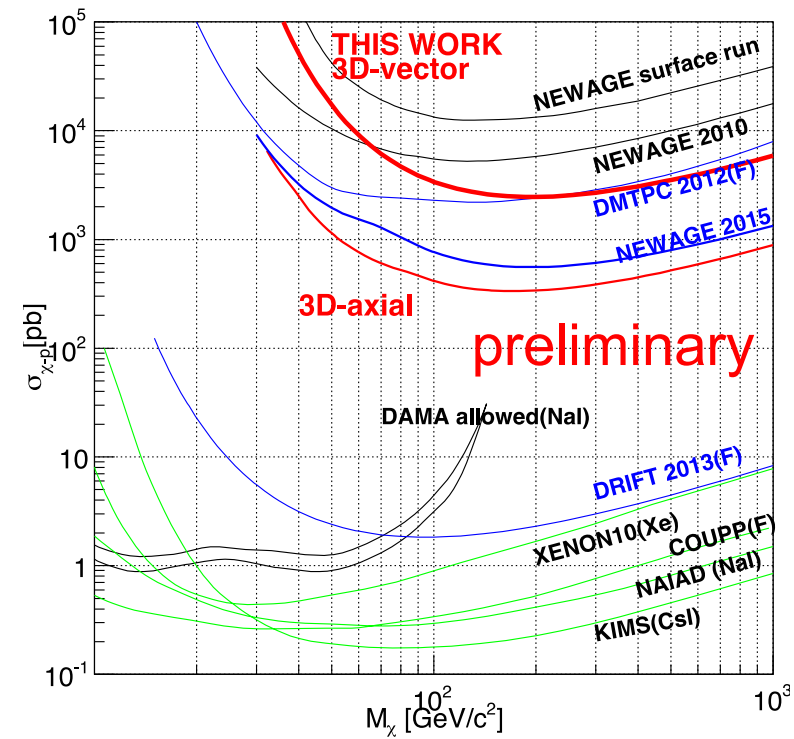
# Backup

# NEWAGE (NEw generation WIMP search with an Advanced Gaseous tracker Experiment)



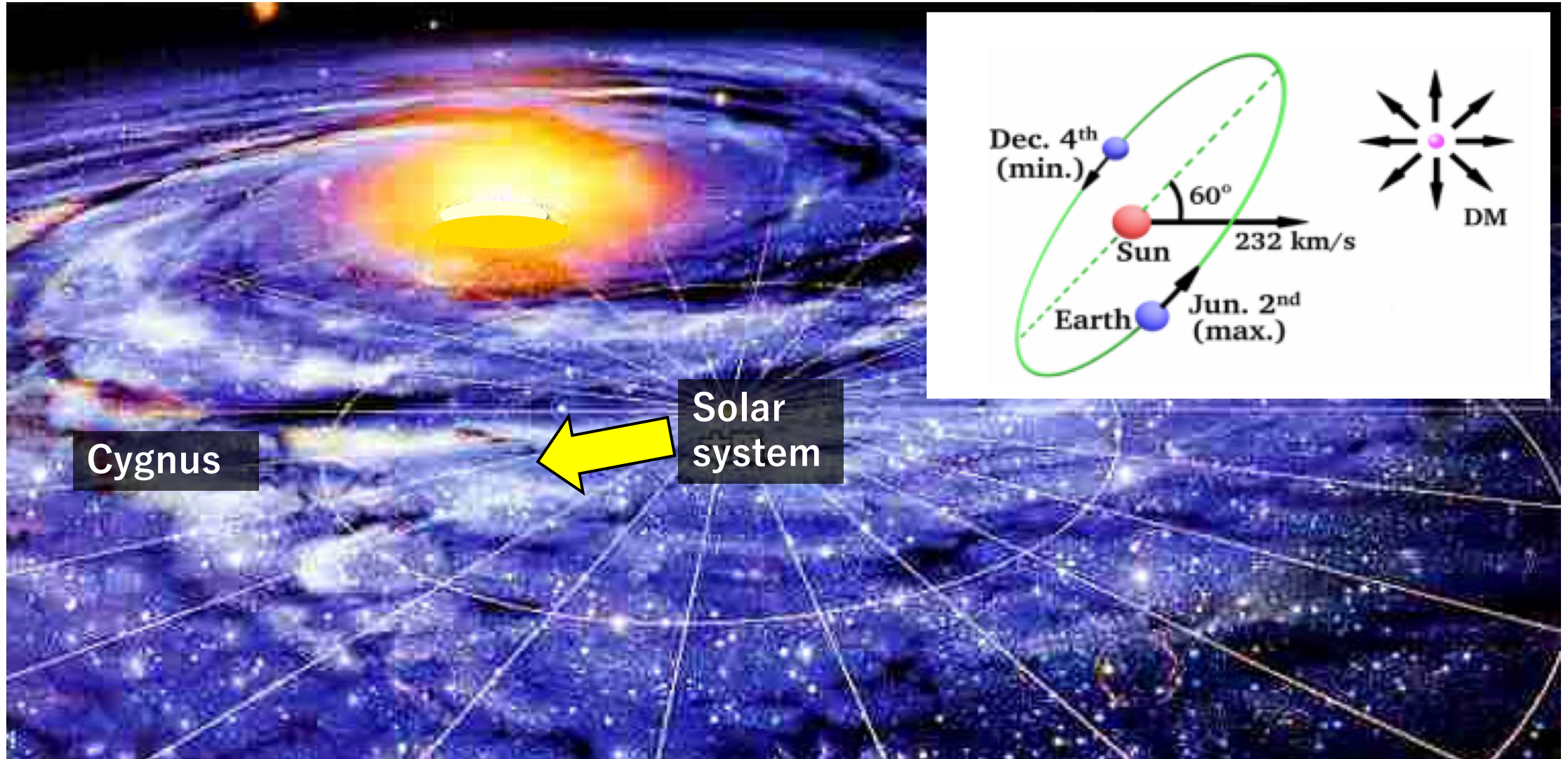
- period : 2013/7/20~8/11, 10/19~11/12
- live time : 434.85 days
- fiducial volume : 28×24×41 cm<sup>3</sup>
- mass : 10.36 g
- exposure : 4.51 kg · days

SD 90% C.L. upper limits and allowed region



R. Yakabe, Doctor thesis 2018

# WIMP-Wind



# Gas circulation system

