

SMILE-2+ :  
The 2018 balloon campaign in Australia  
of MeV gamma-ray telescope

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photo : Just before Launching @ Alice Springs, Australia, April 7th 2018

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- Introduction of SMILE-2+ experiment
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# Balloon Experiment : SMILE-2+

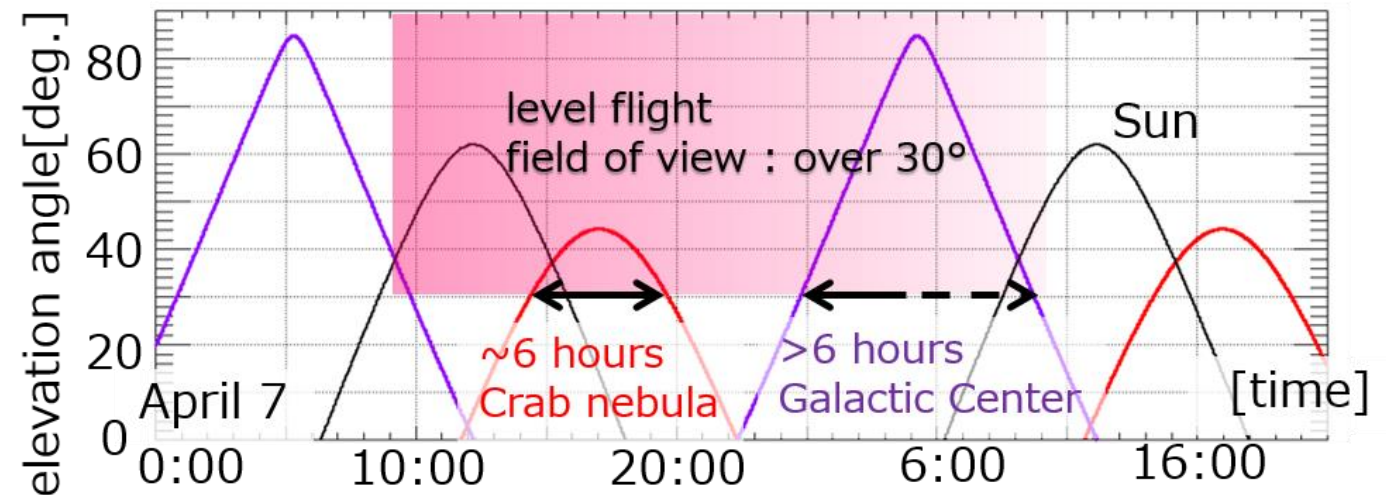
**Aim** : certificate imaging spectroscopy of ETCC using celestial objects

**Targets** :  $e^\pm$  annihilation line from the galactic center region

Crab nebula

**Requirements of detections with the significance of  $\sim 5\sigma$**  :

- Altitude :  $\sim 39$  km (atmospheric depth  $\sim 3.5$  g/cm<sup>2</sup>)
- Half Power Radius (HPR) :  $\sim 10$  degrees
- Effective area : a few cm<sup>2</sup>
- Energy Range : 0.3 – 1.5 MeV
- galactic center region :  $>6$  hours
- Crab nebula :  $\sim 6$  hours



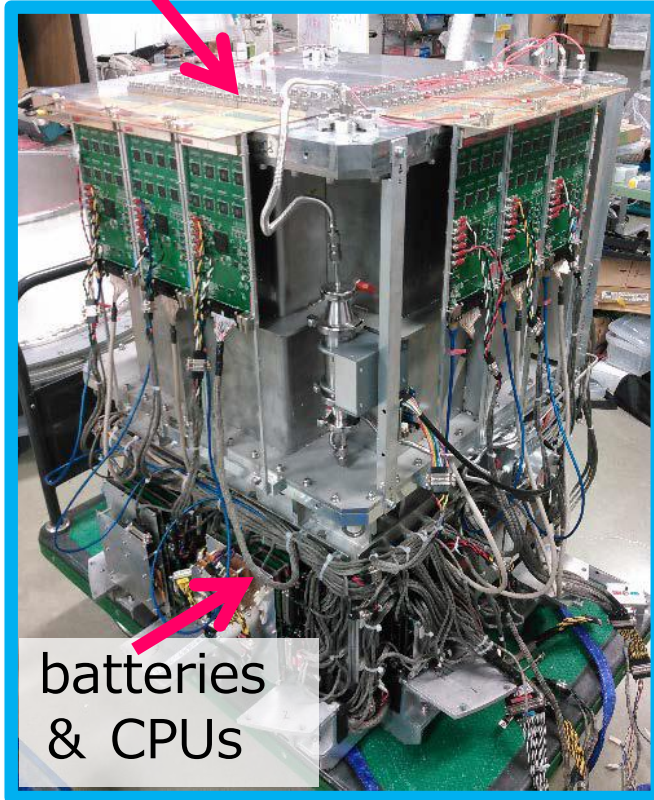
# SMILE-2+ gondola

Detector (ETCC)

Geomagnetic Sensor

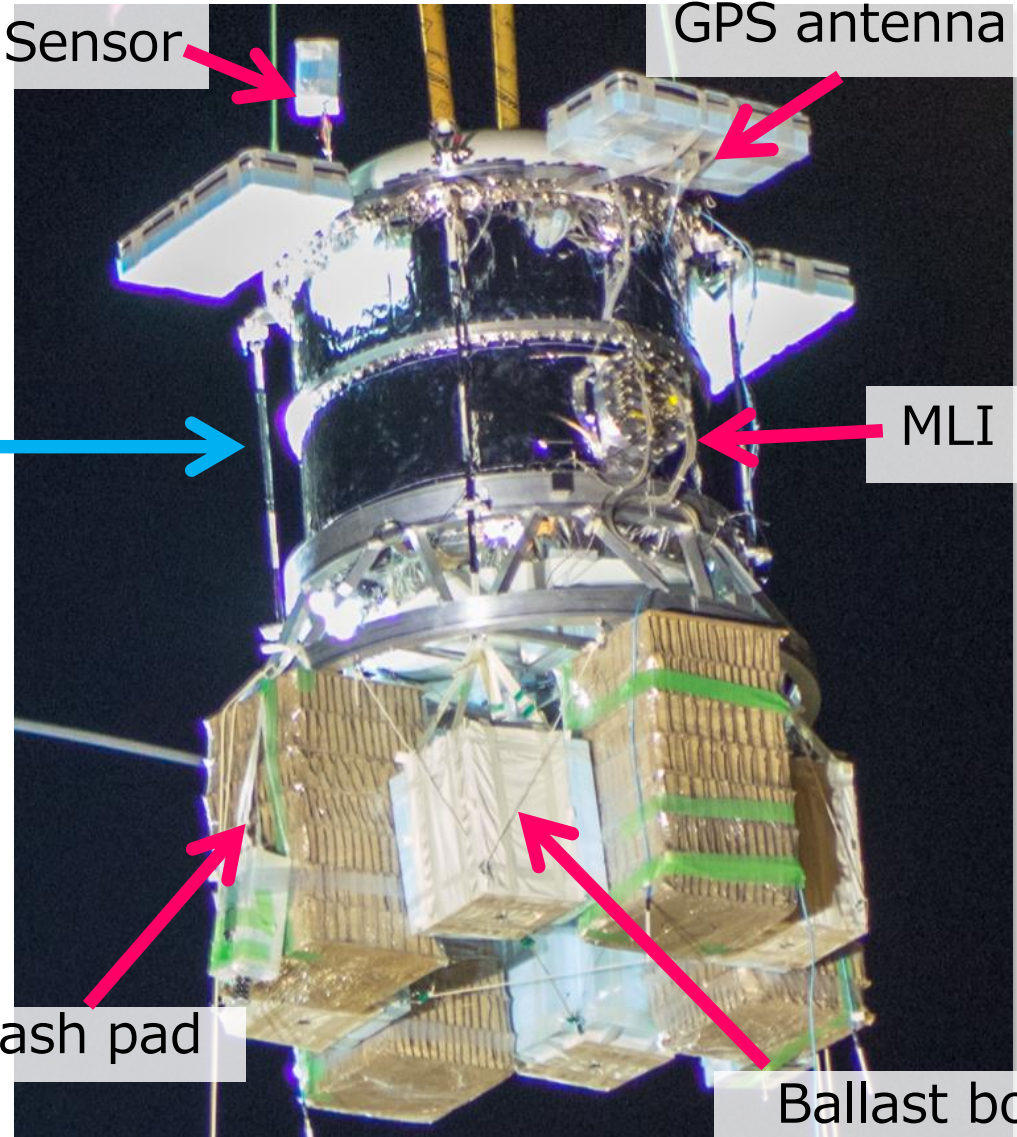
GPS antenna

~1 m



batteries  
& CPUs

Weight 511 kg  
Power 214 W  
No posture control  
Position sensor  $\sim 1^\circ$



~2 m



# Flight Overview of April 7 - 9

## April 7 (local time)

- 2:47-3:09 power on sequence
- 3:09 start of data acquisition
- 6:24 launching
- 8:44 start of level flight

## April 8

- 10:45 end of data acquisition
- 10:45-10:53 power off sequence
- 11:07 cut off
- 11:40 landing

## April 9

recovering

We appreciate balloon managing by JAXA.



level flight ~26 hours

- crab nebula ~6 hours
- galactic center >8hours

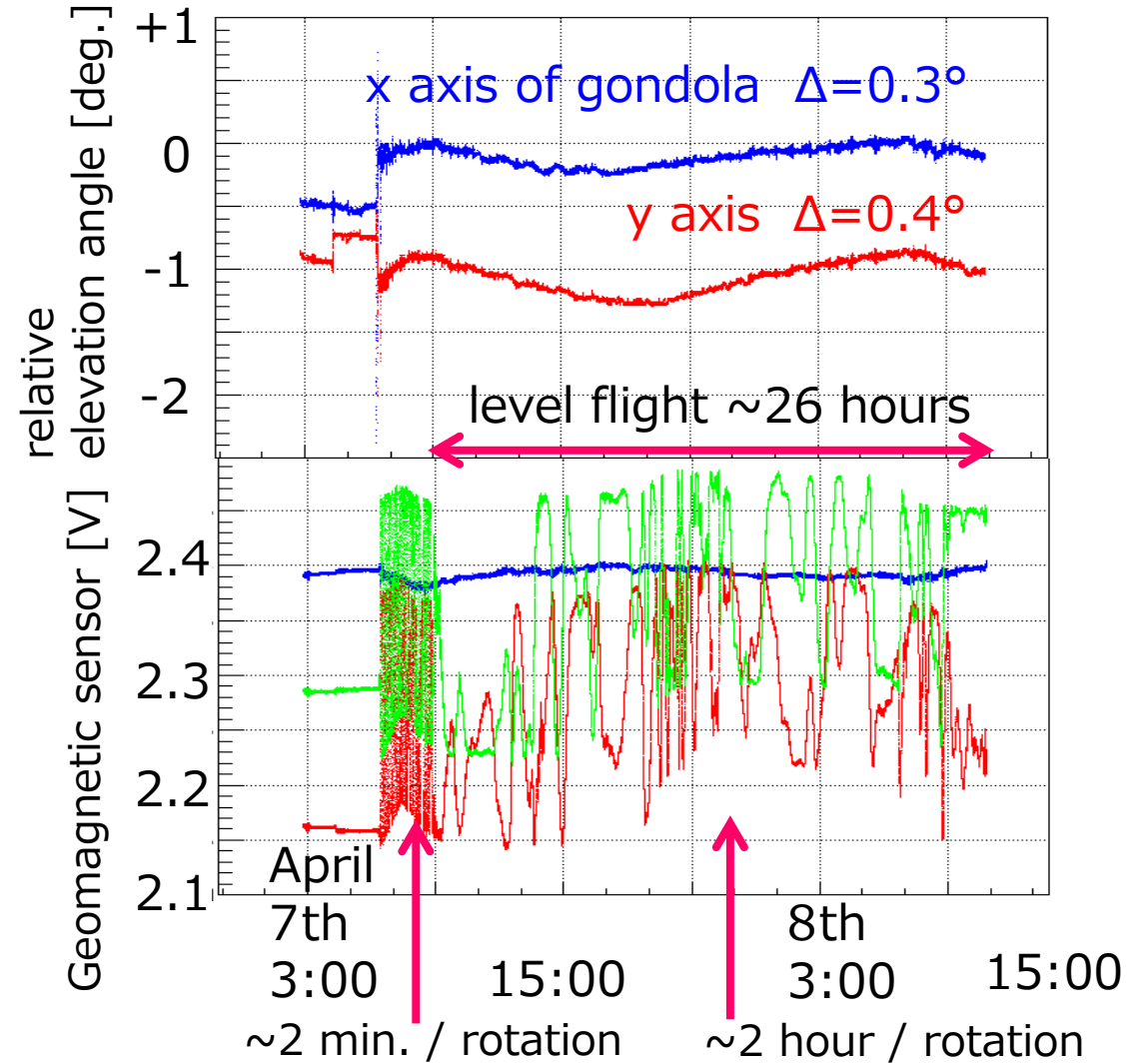
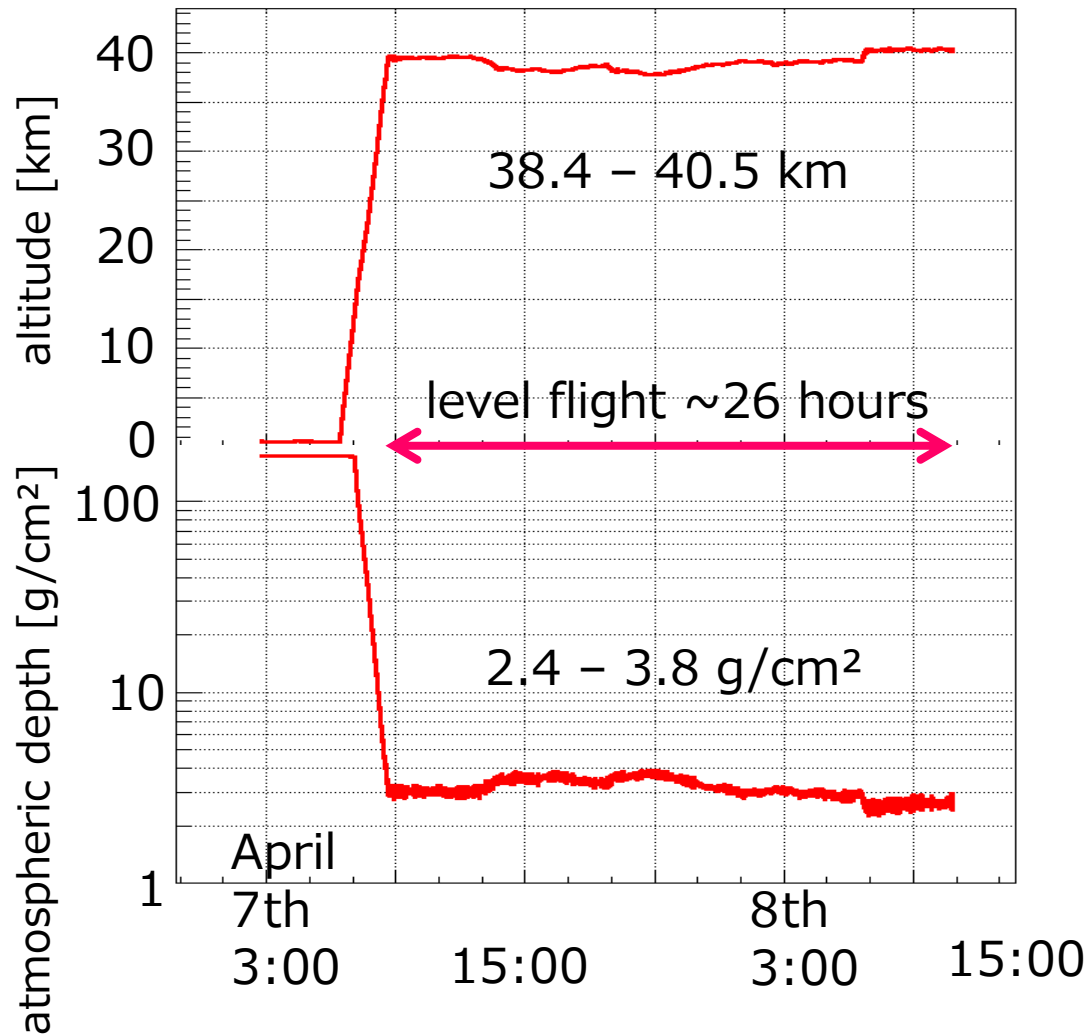
~150 m

$5 \times 10^5 \text{ m}^3$

JAXA ← gondola

We could observe two targets as planned, and recover the gondola safely and perfectly.

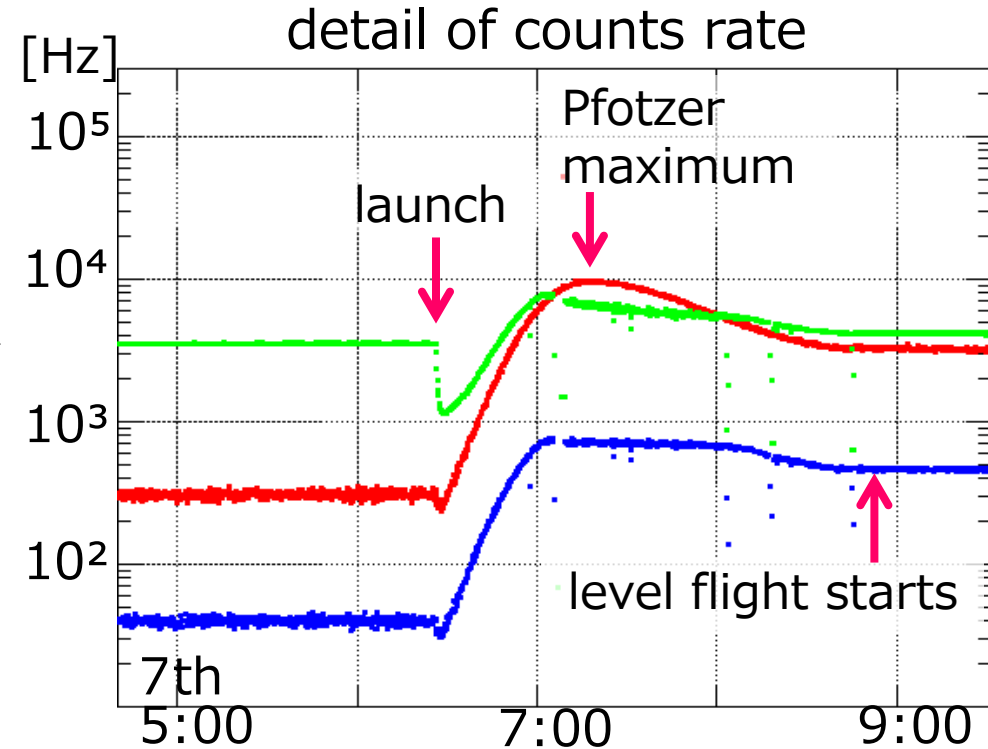
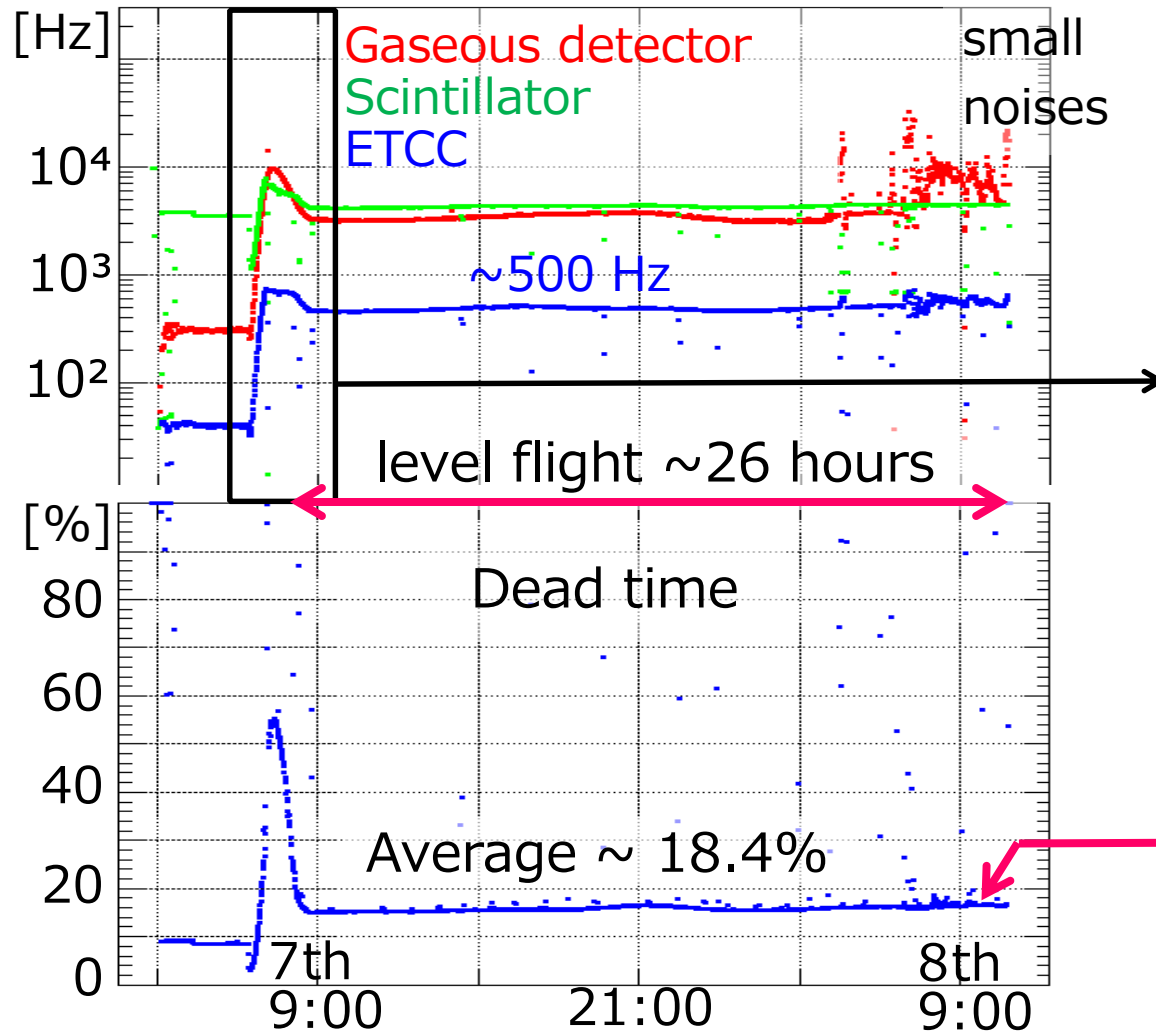
# Atmospheric Depth and Direction



The balloon flight satisfied the requirements of atmospheric depth.  
We succeeded in monitoring the direction of the gondola.

# Count Rate of Instruments

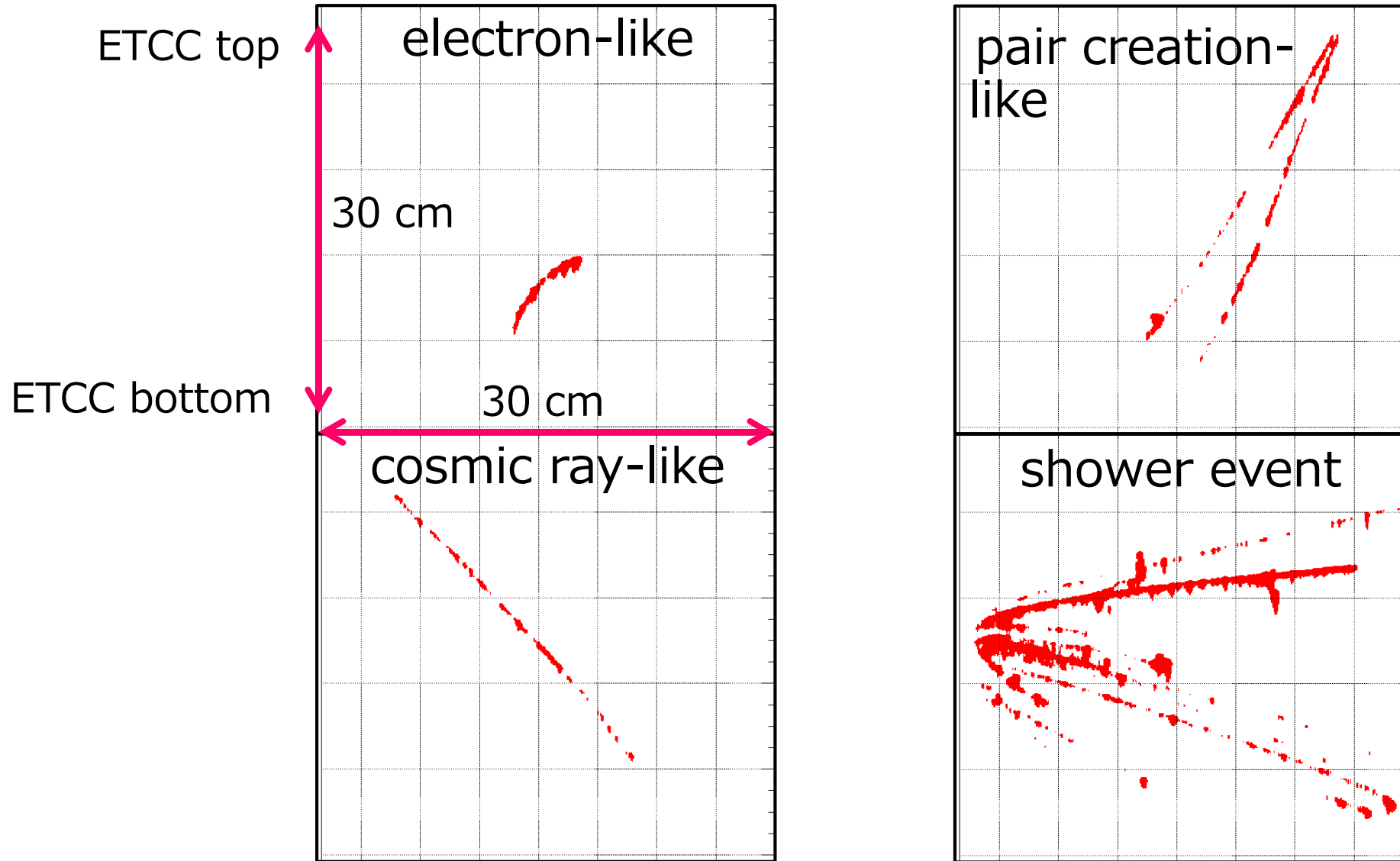
The ETCC trigger rate as preflight expectation was  $\sim 500$  Hz in level flight.



Small noises did not degrade data acquisition so far. No problem.

Our detector was stable at the balloon altitude as planned.

# Track of Charged Particle



Our gas detector succeeded in getting charged particles.



# Method of Flight Data Analysis

Two type of event analysis

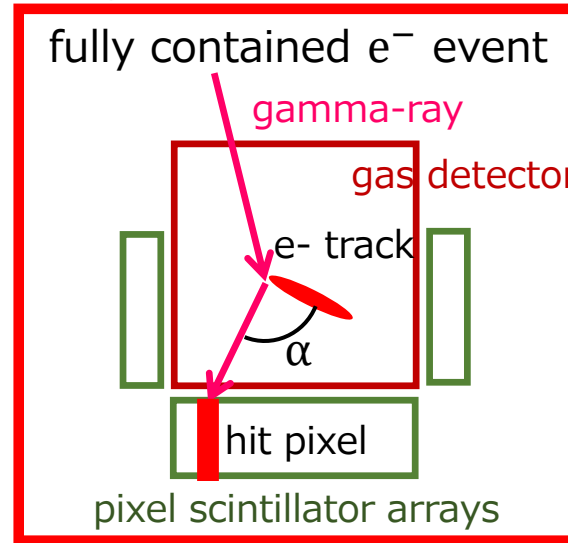
Here we present

only fully contained  $e^-$  event.

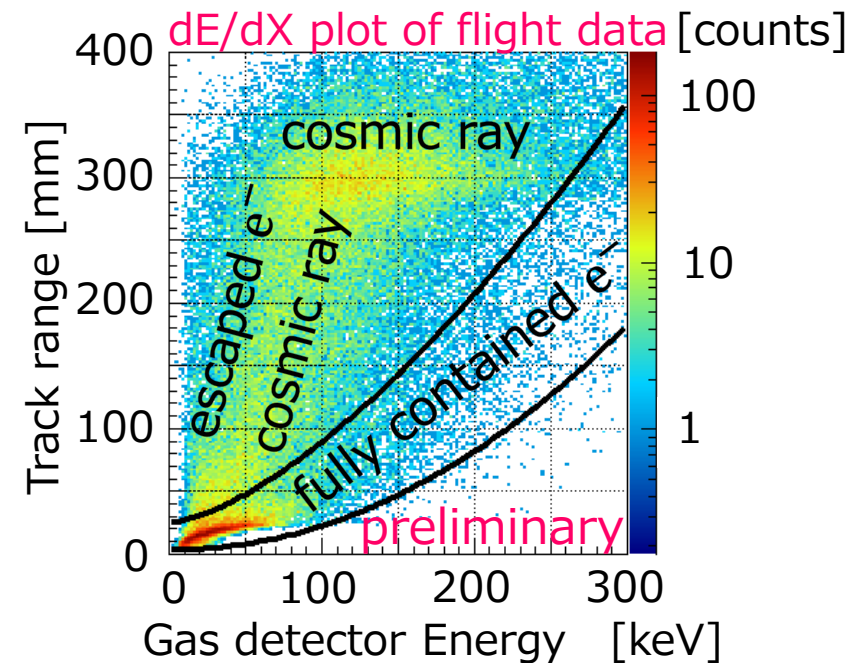
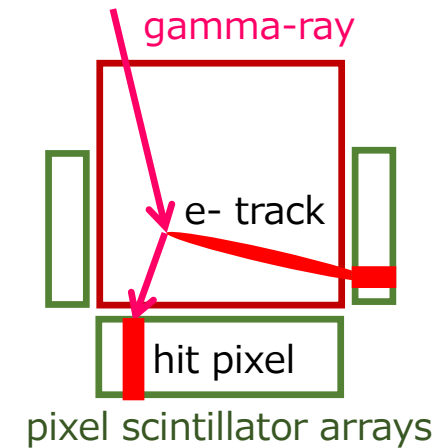
Event selection

1. single scintillator hit
2. fully contained electron selection
3. certification of Compton kinematics using  $\alpha$  angle selection

- Only simple selection
- No gamma-ray veto

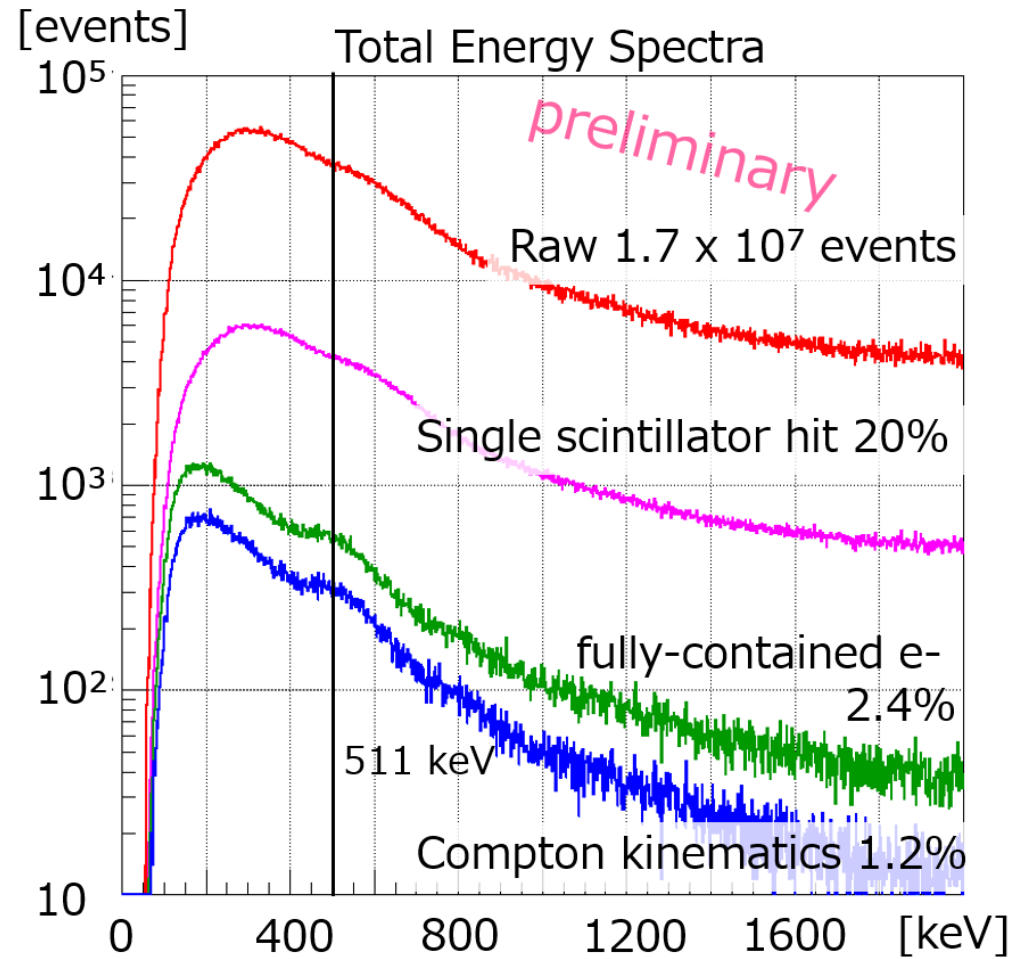


escaped  $e^-$  event

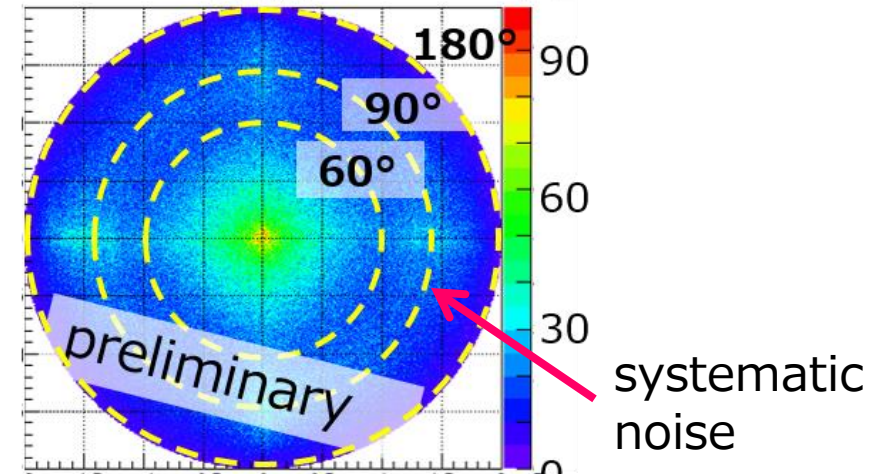


# Quick Check of Level Flight

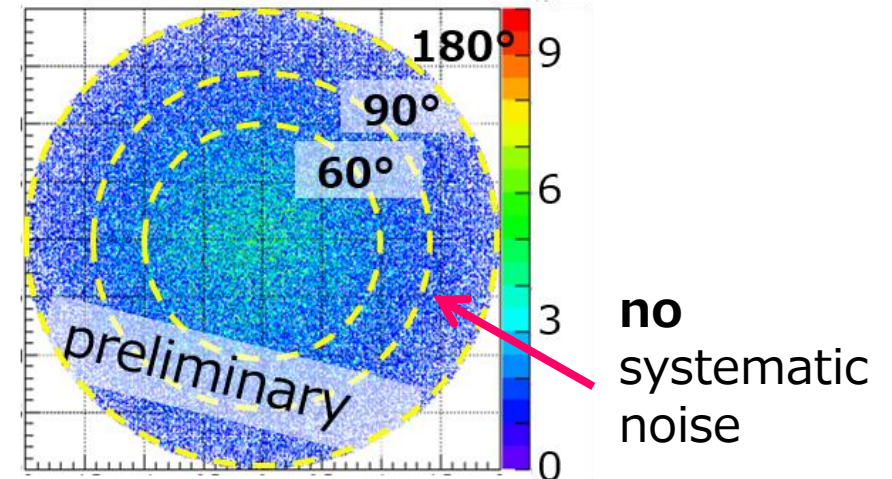
- Level flight :  $\sim 19$  hours before small noises of gas detector
- Live time :  $5.7 \times 10^4$  sec



All sky map from detector  
Raw [events]



after selection [events]



Our simple event selection succeeded in noise reduction.

# Compare with First Balloon Experiment

SMILE-I is the first balloon experiment using a small ETCC.

	SMILE-2+ fully-contained electron event	SMILE-I Takada <i>et al.</i> , 2011, ApJ
Ratio of gamma-ray events to all events	~1.2%	~1%
All gamma-ray rate[Hz]	~3.6	~0.06
Downward gamma-ray rate[Hz] zenith angle 0° - 60°	~1.7	~0.03

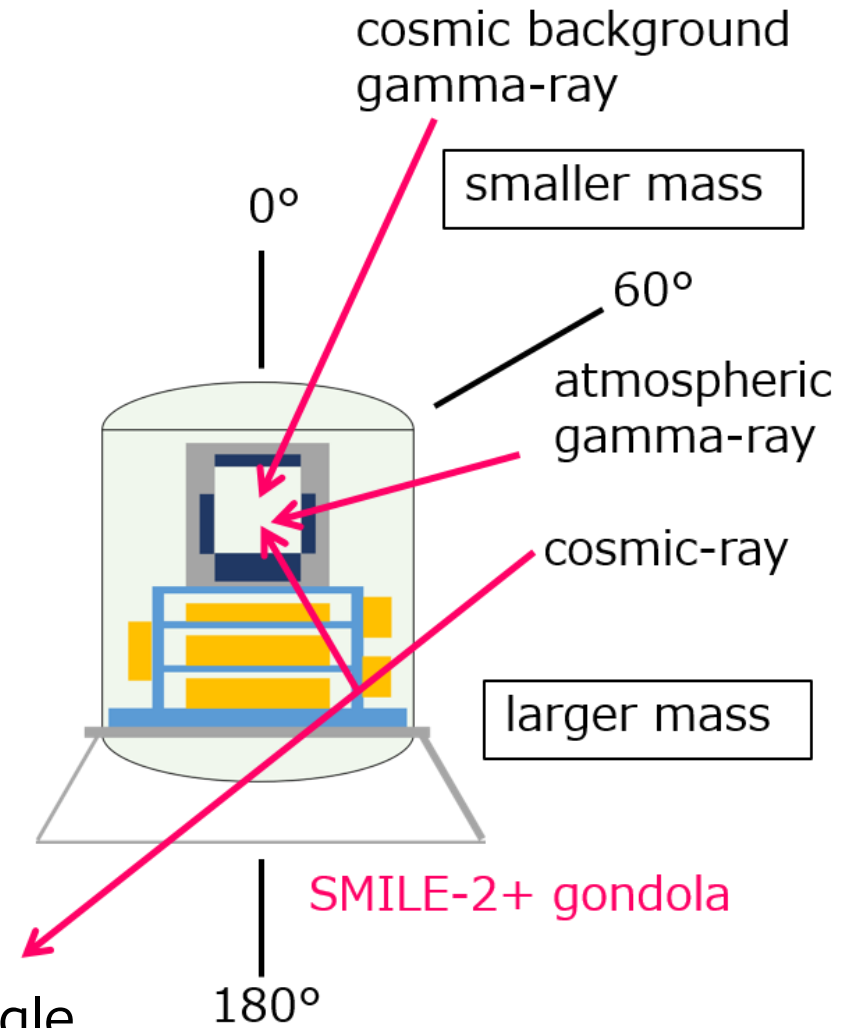
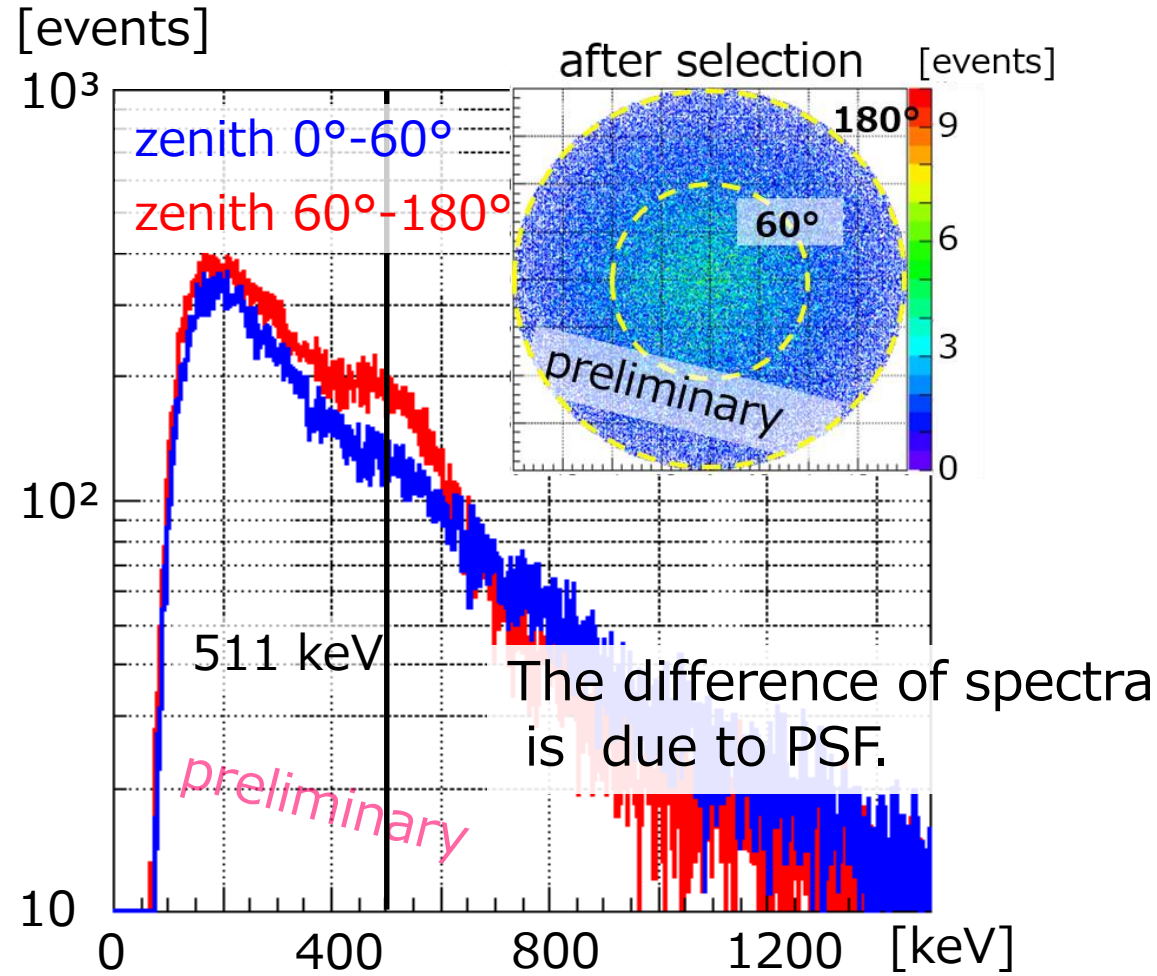
Effective area of SMILE-I :  $\sim 0.01 \text{ cm}^2$  ( $\sim 1/100$  of SMILE-2+)

SMILE-2+ quick checks seems consistent with SMILE-I results.

From this simple analysis, the performance of our detector looks as we planned.



# Zenith Angle Dependence of Energy Spectra



$e^\pm$  annihilation line is stronger at larger zenith angle, because of larger mass of the atmosphere and the instruments. Image enables us separate to the origin of 511 keV gamma-ray roughly.

# Summary

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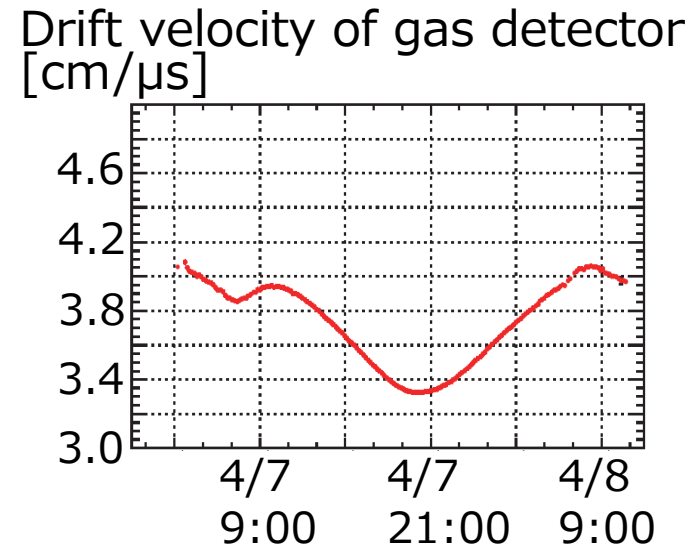
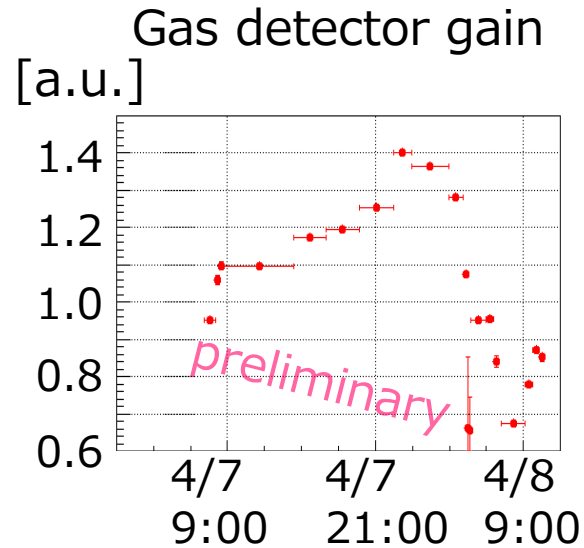
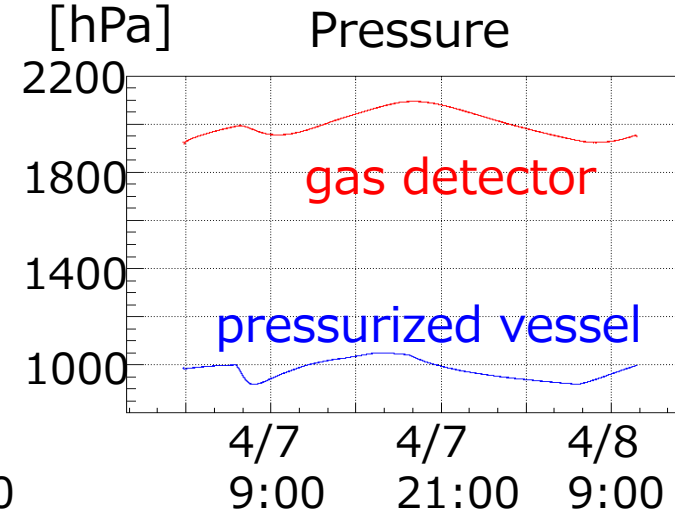
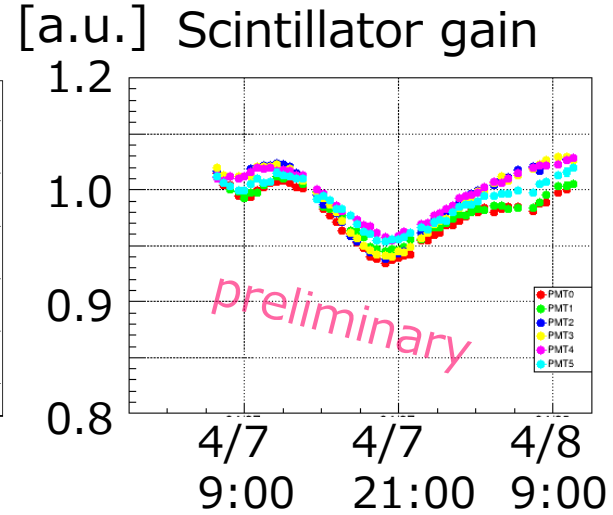
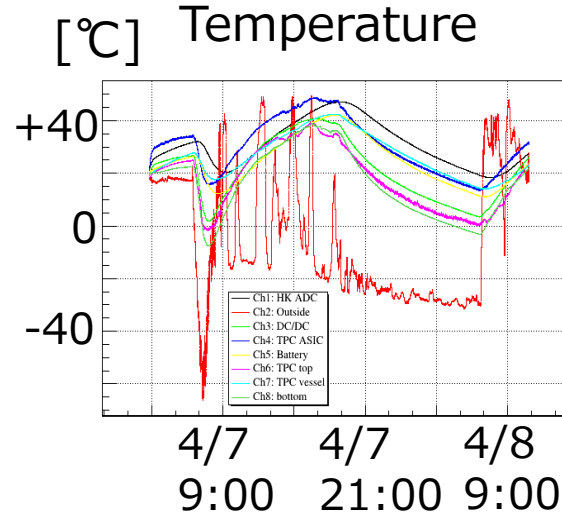
- The aim of SMILE-2+ is to certificate imaging spectroscopy of ETCC using celestial objects.
- The balloon flight lasted 29 hours, and the level flight continued during 26 hours at altitude 38.4-40.5 km.
- Observation times of  $e^\pm$  annihilation line from the galactic center region and the Crab nebula were >8 hours and 6 hours, respectively.
- Our detector was stable at the balloon altitude.
- The quick checks of SMILE-2+ seems consistent with the first balloon experiment, SMILE-I.
- Soon, we will show the results of observations of the  $e^\pm$  annihilation line from the galactic center and the Crab nebula.

Thank you.





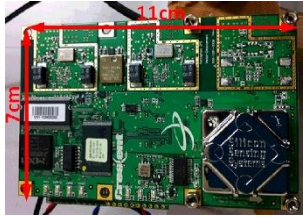
# Detector Status



# House-keeping Sensors

Sensors for location, direction, and atmospheric depth :

GPS compass



antenna



location :  $< 2.5$  m(RMS)  
azimuth angle :  $< 0.15^\circ$ (95%CL)

Geomagnetic aspect sensor



X 3  
x, y, z axis

accuracy :  $\pm 1.5^\circ$

Inclinometer



X 2  
East - West  
North - South

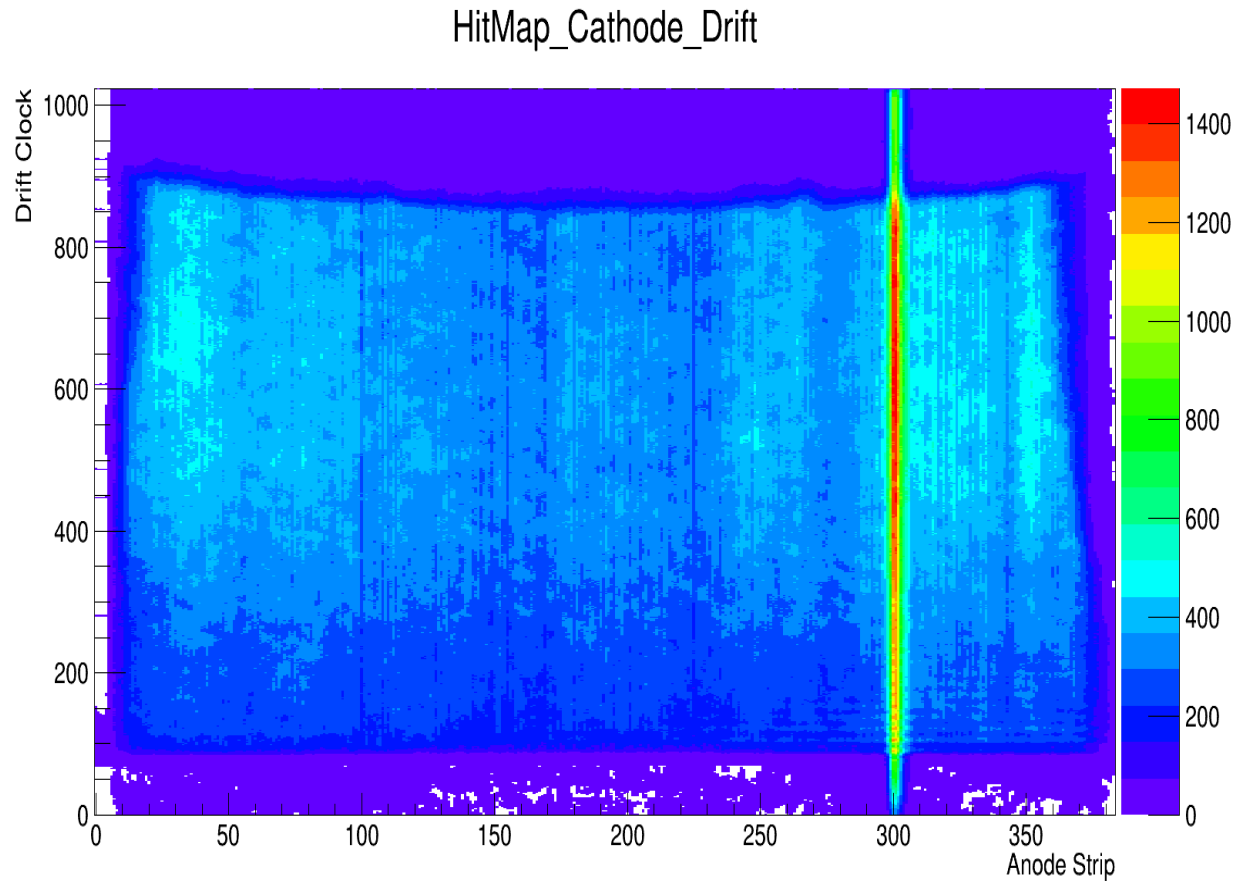
elevation angle :  $< 0.002^\circ$ (RMS)

outer pressure gauge



range : 0 - 130 hPa  
accuracy :  $\pm 0.2$  hPa

# Gas Detector Small Noise

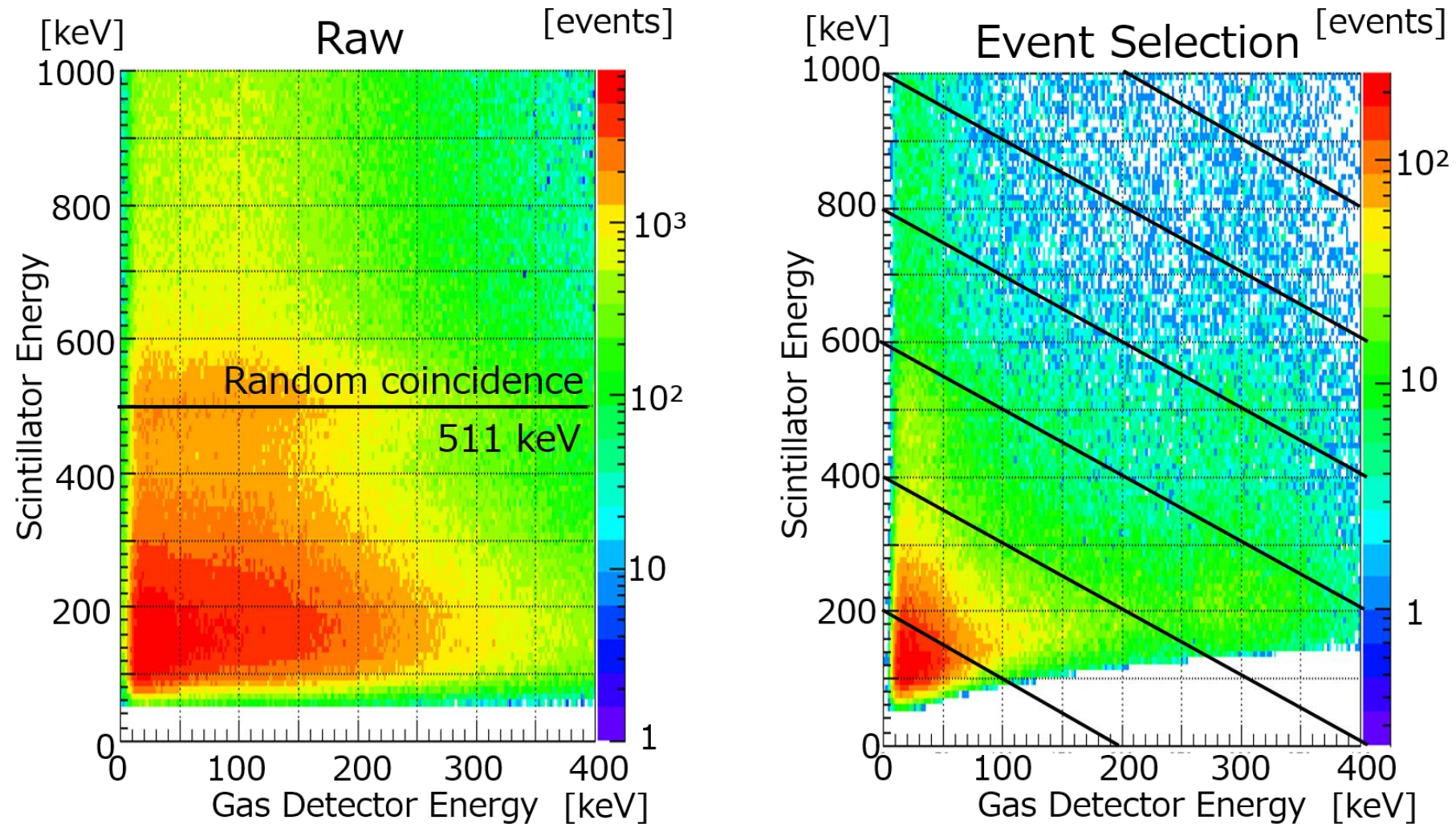


noises of  
gaseous detector

several strip  
( $\sim 1$  cm)



# Scintillator Energy vs Gas Detector Energy



Our event selection succeeded  
in excluding random coincidence events.