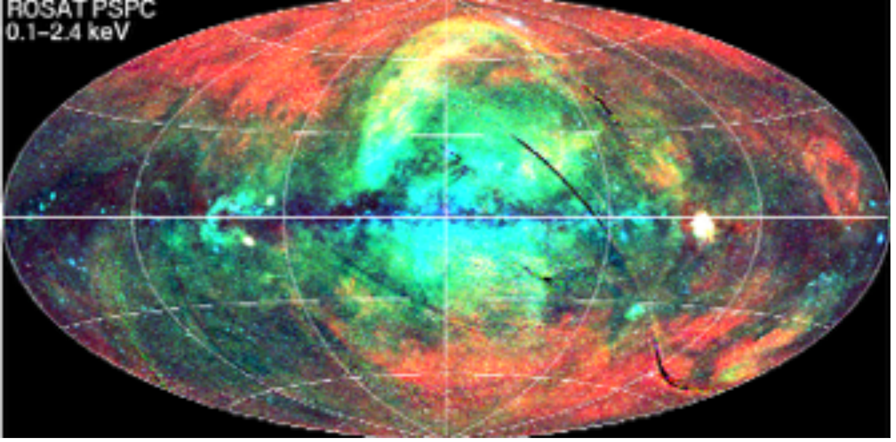
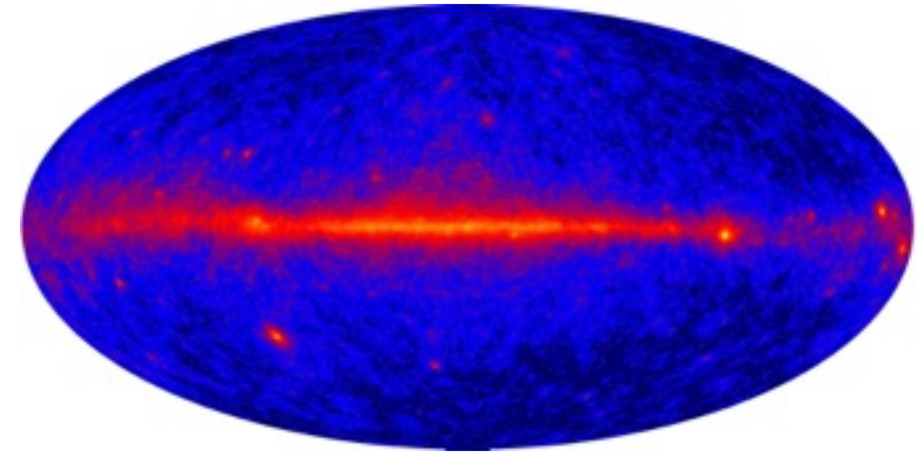




A Compact Coded-mask Imaging Camera with a CdTe Double-sided Strip Detector

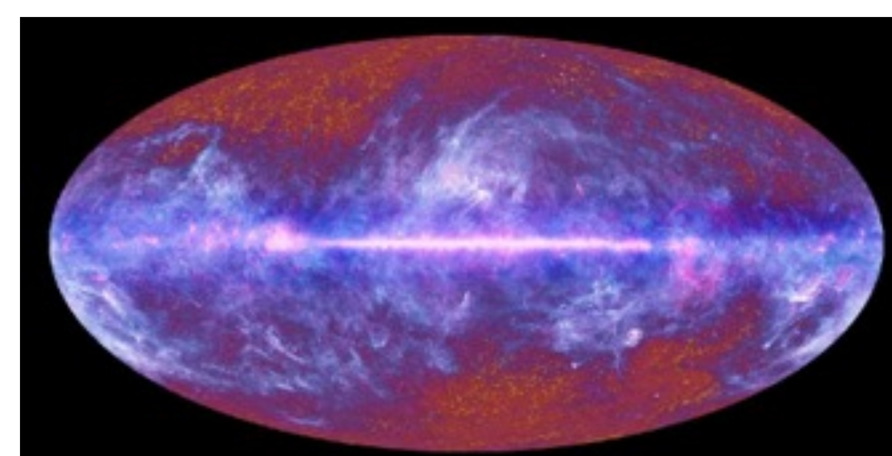
Yuusuke Uchida[1][2]

Atsushi Togo[1][2], Shin Watanabe[1][2], Shin'ichiro Takeda[1], Goro Sato[3], Hirokazu Odaka[1], Taro Fukuyama[1][2], Koichi Hagino[1][2], Tamotsu Sato[1][2],Tadayuki Takahashi[1][2]

ISAS/JAXA[1]

Department of Physics, The University of Tokyo[2]

Waseda University[3]

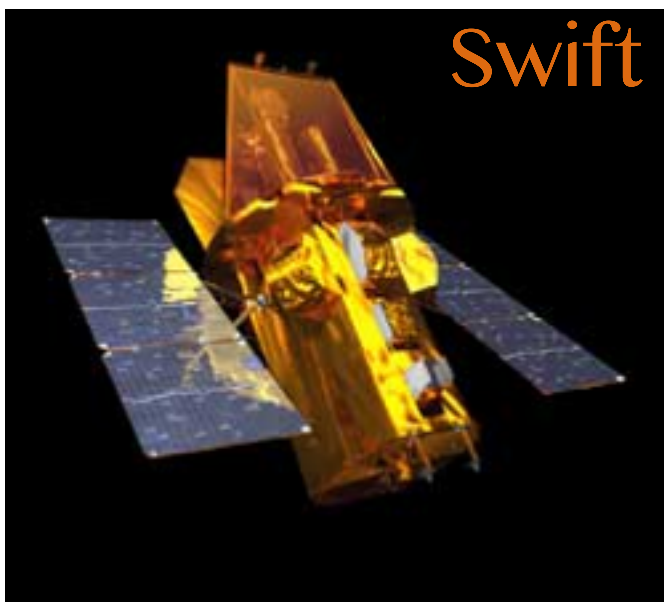


Wide FOV Gamma-ray Camara for Space

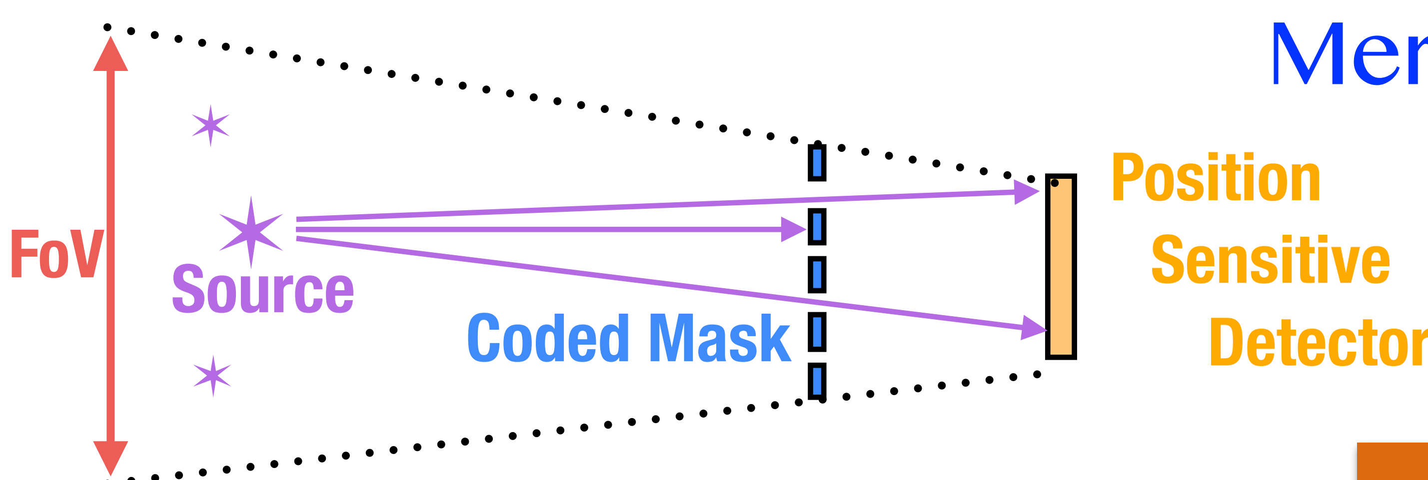
Astronomical objects are often "highly" variable in X-ray and Gamma-ray.

In order to monitor these sources and to study their nature,

An All Sky Monitor is important.



1) With a wide FOV coded-mask, Swift and Integral have provided spectral and temporal information of MANY hard X-ray sources.
2) Identification of these Hard X-ray Sources contributes greatly to our understanding of radiation mechanism of these sources.



Merits of the coded mask

- Wide Field of View (FoV)
- Good angular resolution (~10 arcmin)

Suitable for all sky monitor

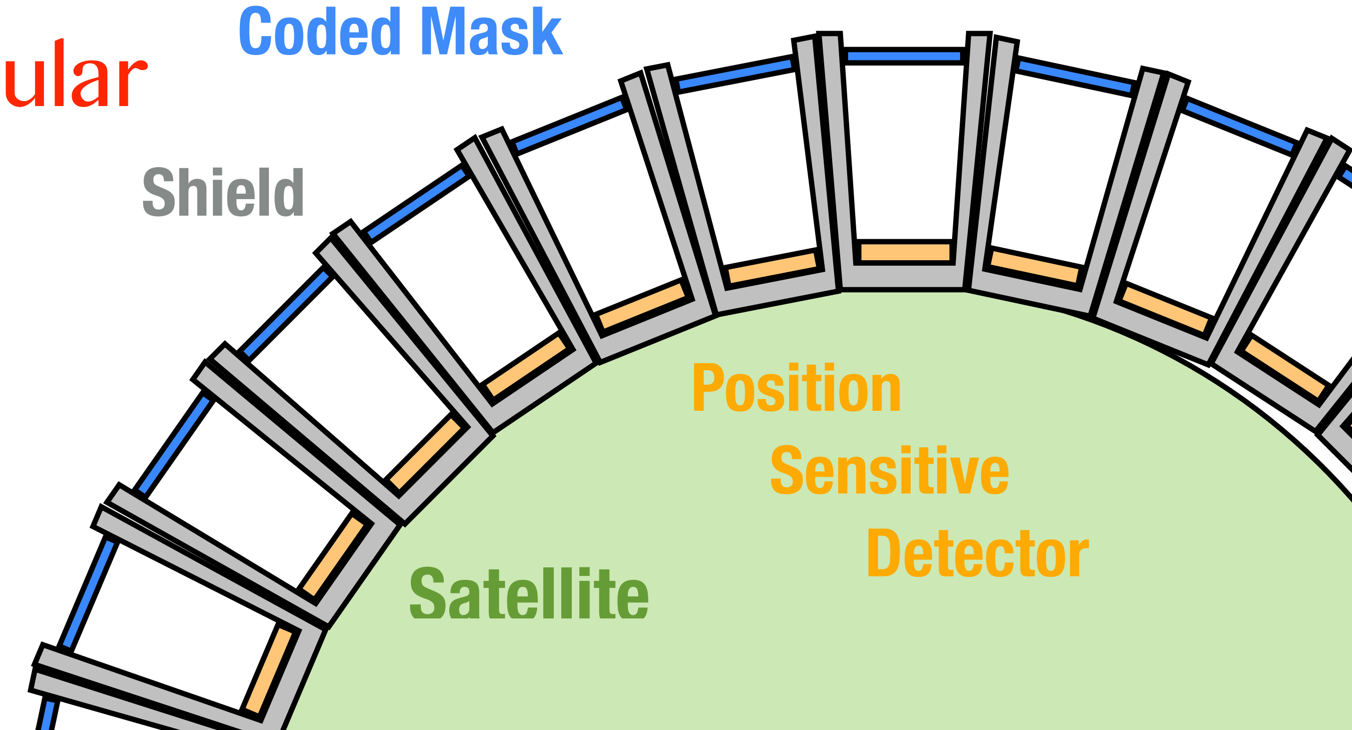
Wide FOV Gamma-ray Camara for Space

Our approach :

Small size coded mask module

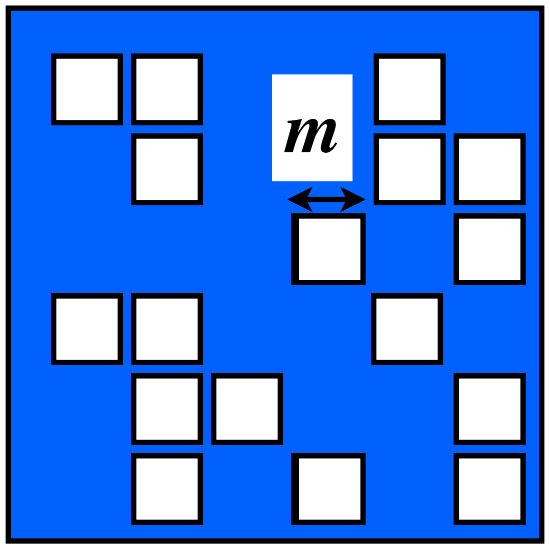
- Multiple modules : Sensitivity and FoV scalable
- Background rejection with anti coincidence shields
- Small satellite
- Low cost
- Variety of use

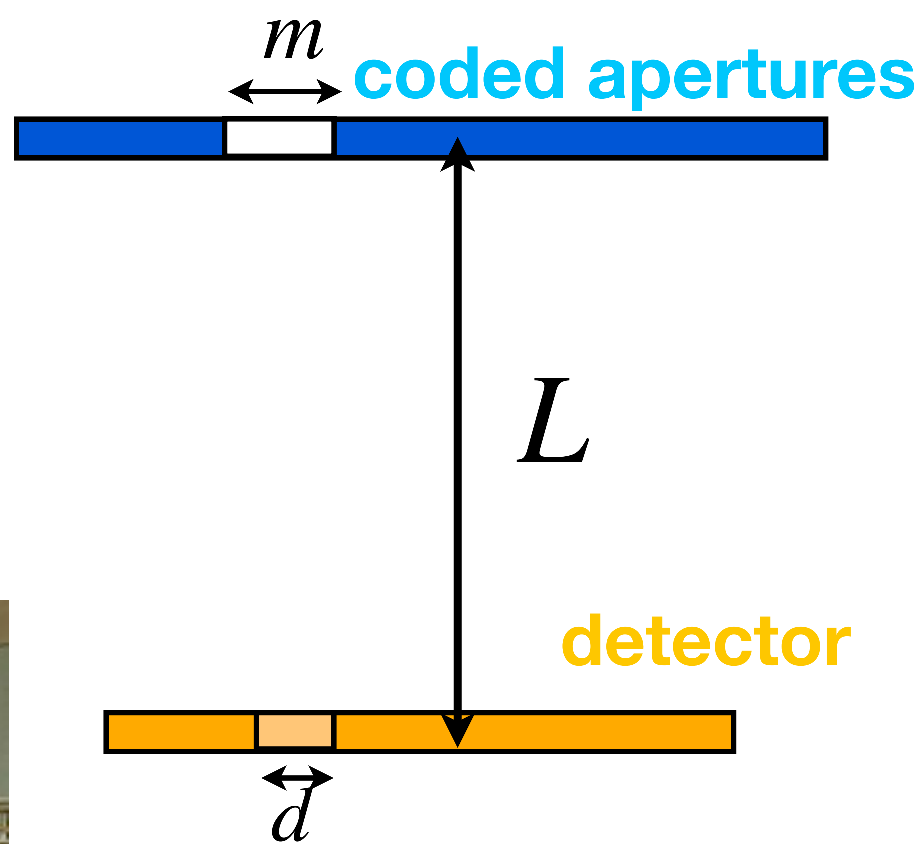
Difficulty : Keeping required angular resolution (~10 arcmin), when downsizing the imaging system.



How to make the imager smaller

Factors for angular resolution :





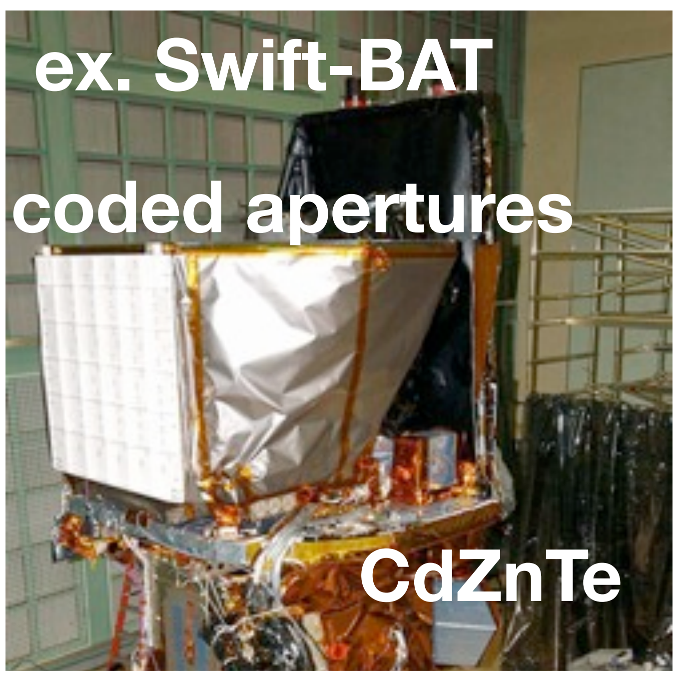
m : **mask pitches (hole size)**

d : **detector pitches**

L : **mask to detector distance**

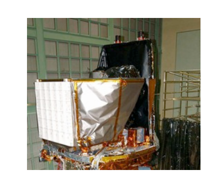
θ : **Angular resolution**

$$\theta \sim \frac{\sqrt{d^2 + m^2}}{L} \quad {}^{*}m > d$$



m: 5 mm × 5 mm × 1 mm *d: 4 mm × 4 mm × 2 mm*	=>	*L: ~ 1000 mm*

$\theta \approx$ 10 arc min



*m: *00 μm × *00 μm × *00 μm* *d: 250 μm × 250 μm × 750 μm*	=>	*L: ~ 100 mm*

Key : **fine pitches detector and coded apertures** ⇒ **make smaller**

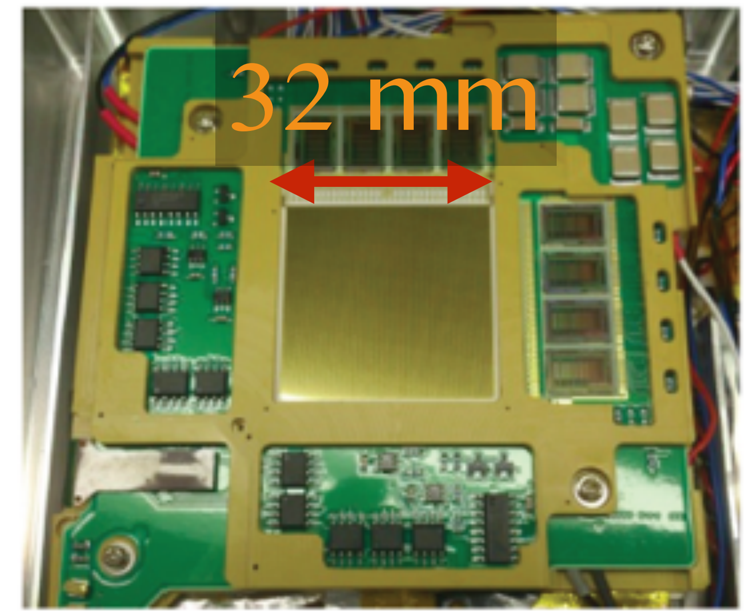
CdTe Double-side Strip Detector

KEY TECHNOLOGY Developed by ISAS/JAXA (ex. Watanabe et al. (2009))

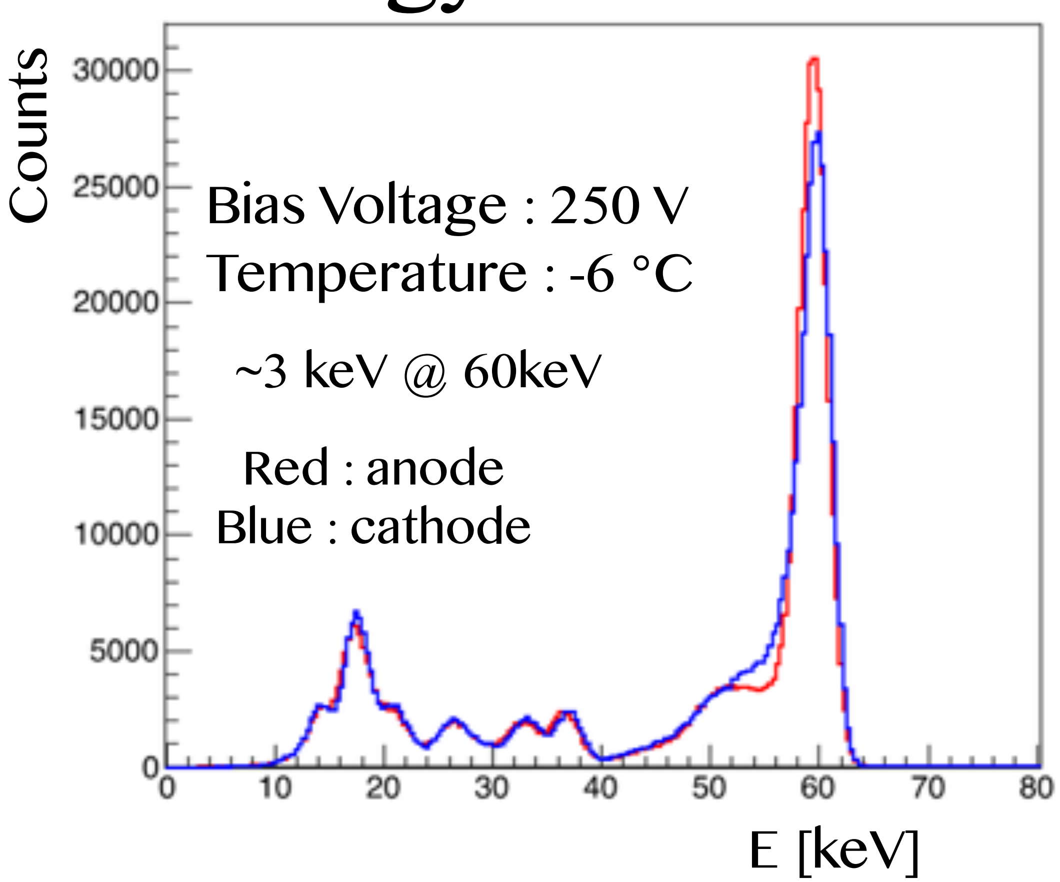
CdTe Double-side Strip Detector (CdTe DSD)

- Strip pitch : 250 μm
- Number of strips : 128 x 128 ch (16384 pixel)
- Detector size : 32 x 32 mm^2
- thickness : 750 μm

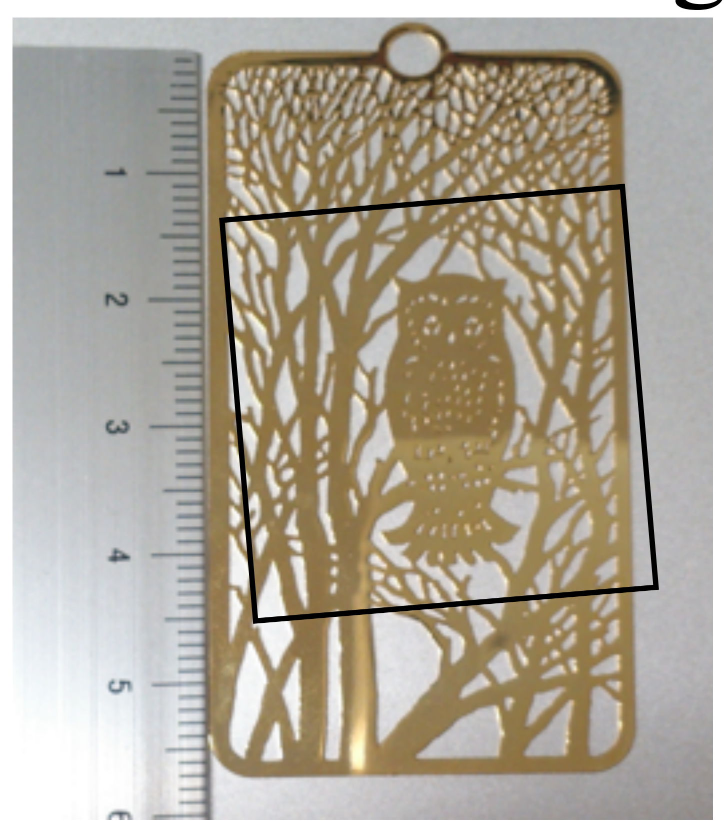
Based on CdTe "Schottky" Diode (Takahashi et al. 1998)

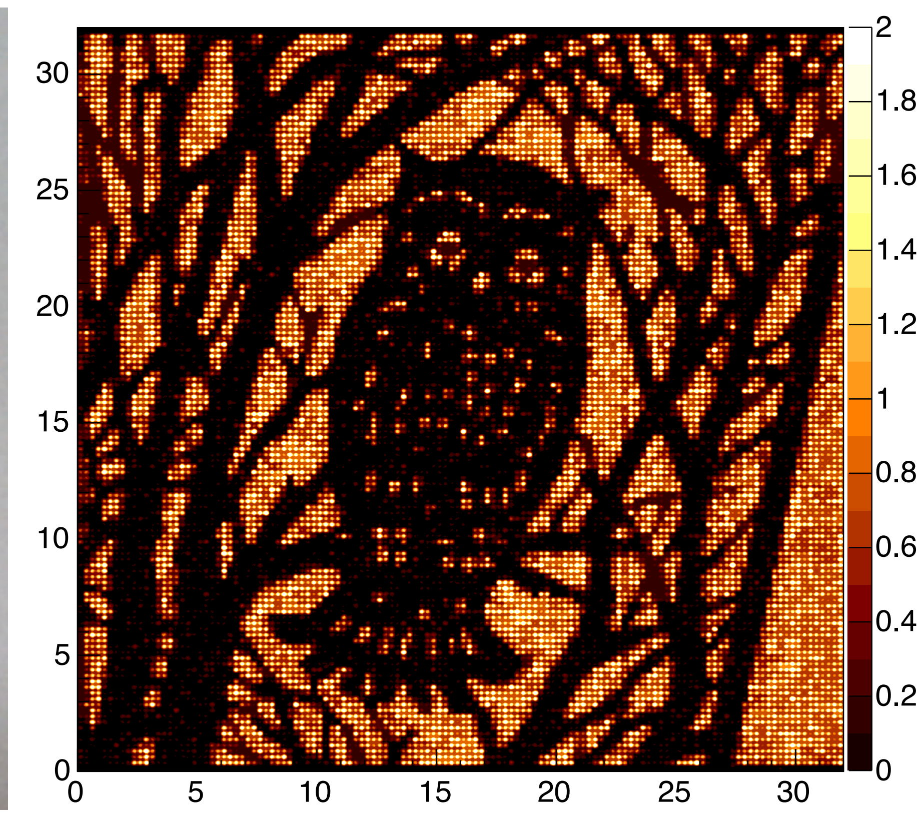


Energy Resolution



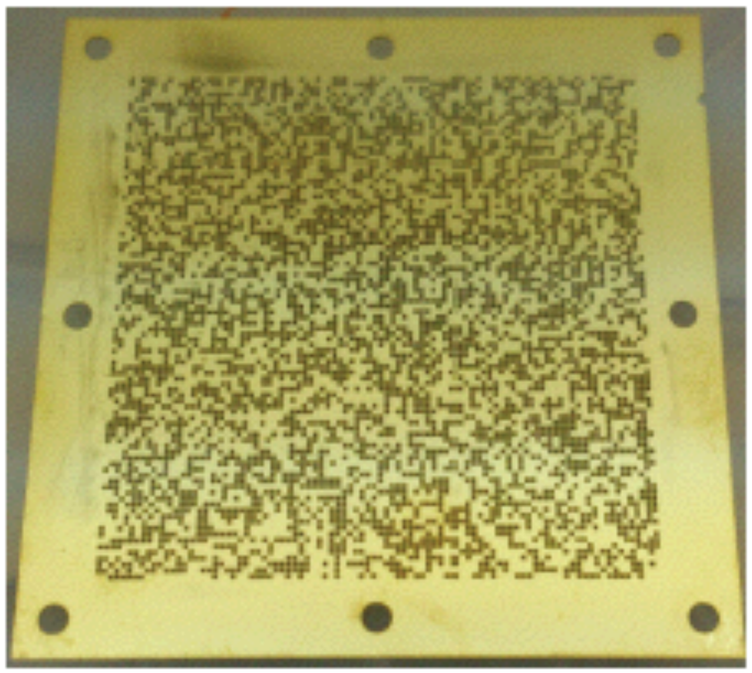
Imaging Capability





Compact Coded Mask Detector

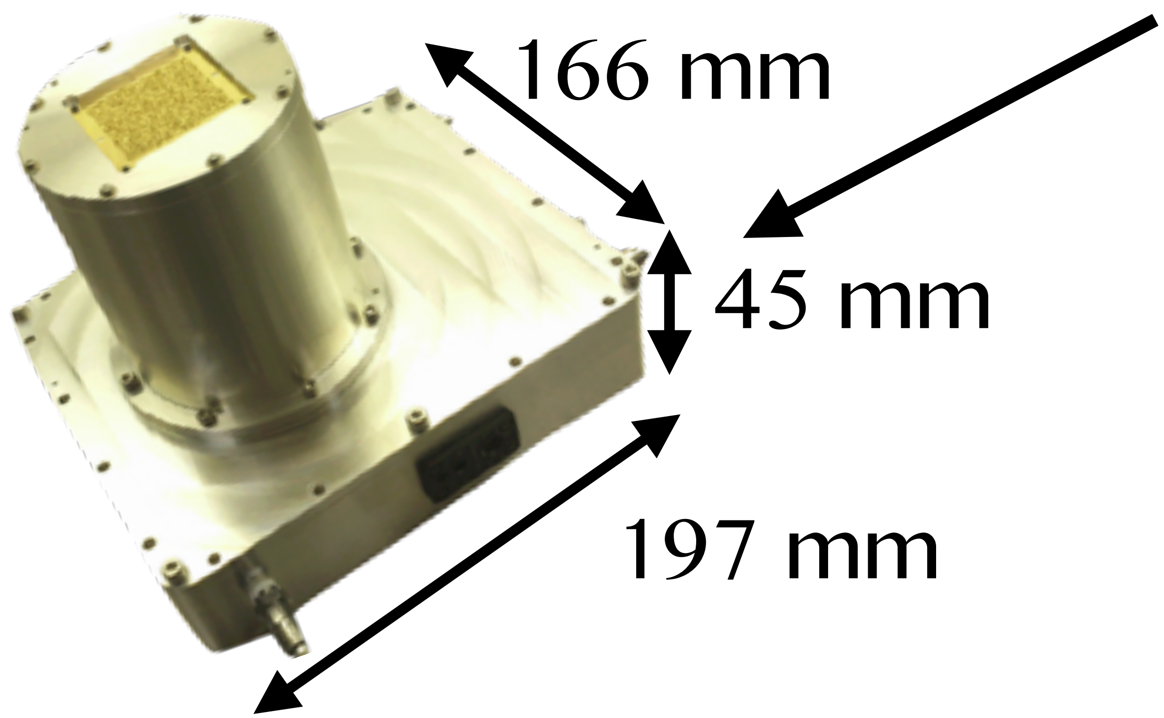
KEY TECHNOLOGY : Micro Coded Mask



a newly developed fine aperture coded mask

- Coded aperture : 350 μm
- Mask size : 36.75 x 36.75 mm^2
- Mask thickness : ~ 400 μm
- 8 stacks of Ni (50 μm) plated Au (2-3 μm)
- transparency
  : 0 % ~30 keV, 50 % @60 keV, 75%@120 keV
- Random Mask, mask open fraction 0.5
- Extracted from the pattern used in Swift/BAT

mask to detector : 120 mm



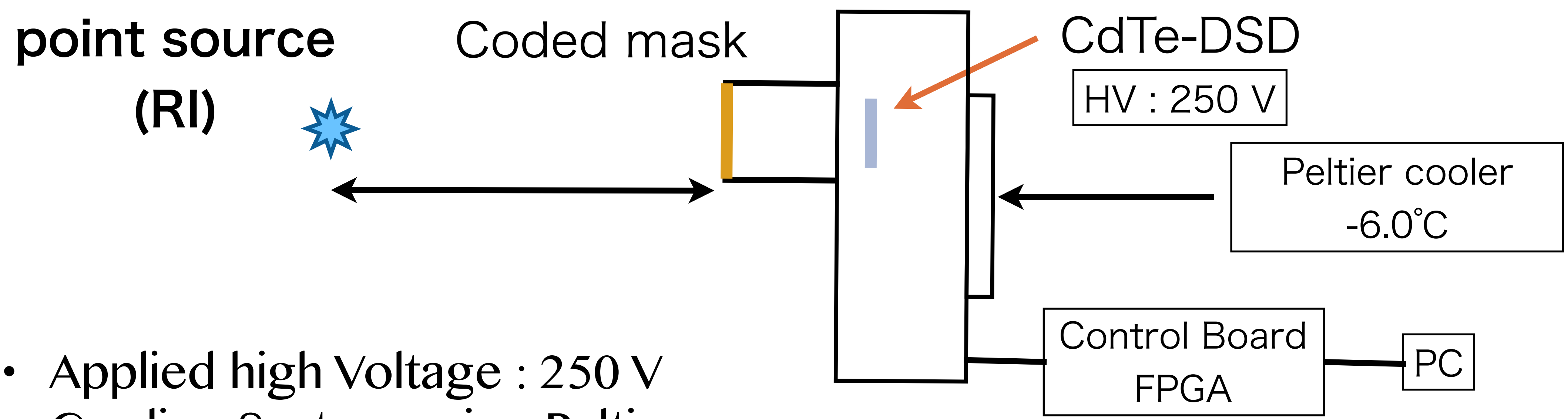
CdTe-DSD and readout electronics in this box.

Expected Performance

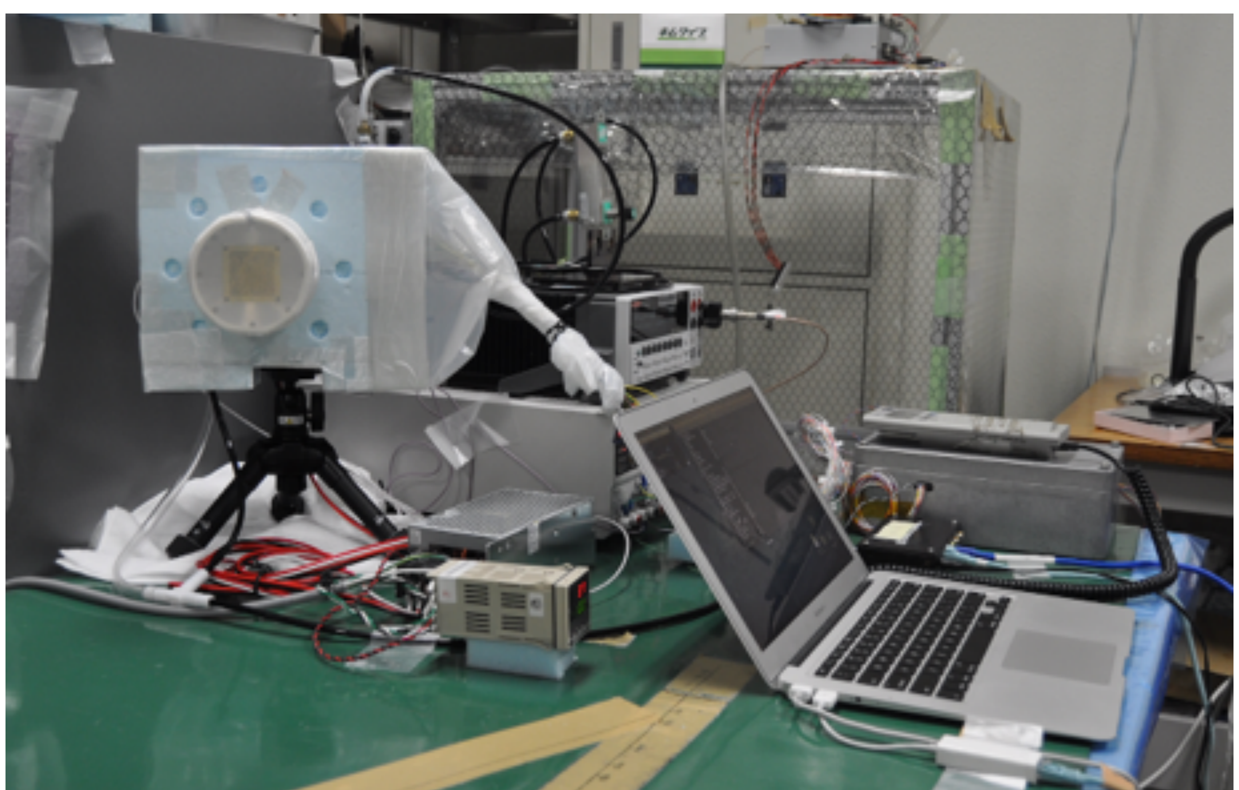
Angular resolution : ~13 arcmin

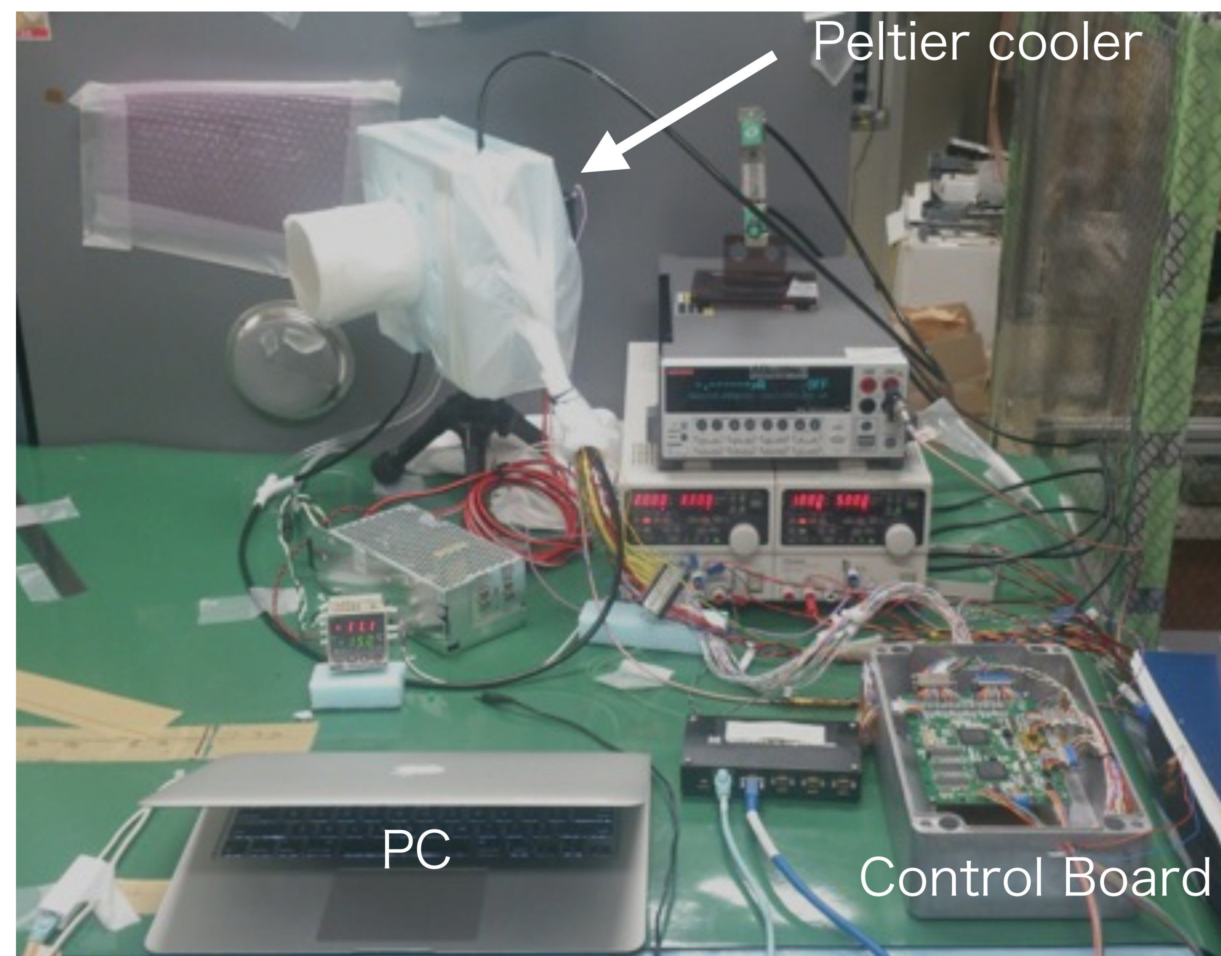
Field of View : ~ 30 x 30 deg^2

Experimental Setup

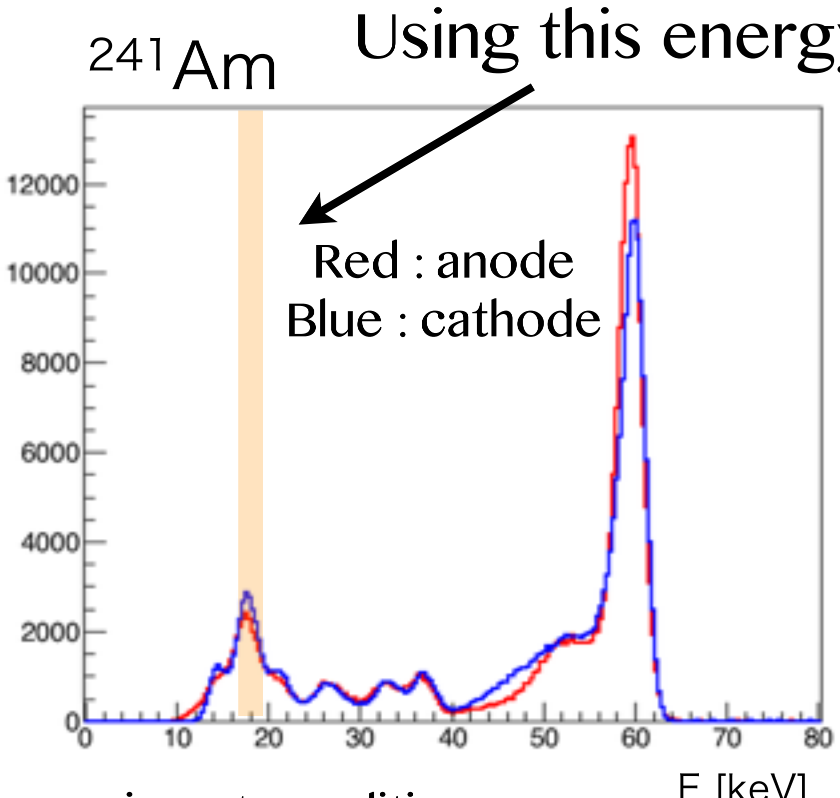


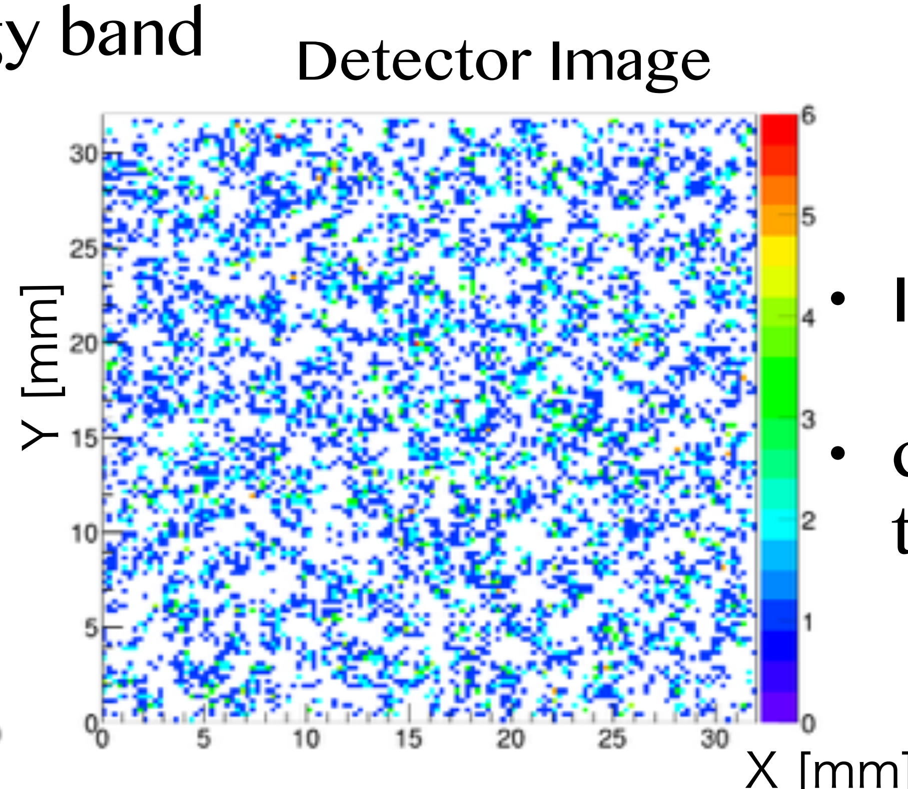
- Applied high Voltage : 250 V
- Cooling System using Peltier
- Image deconvolution method : Balanced Correlation Method





Performance Evaluation



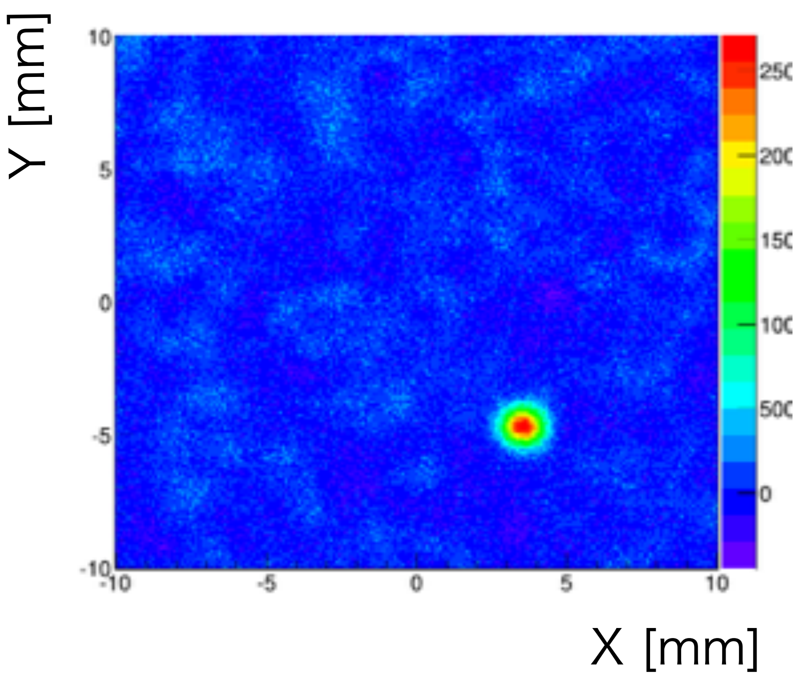


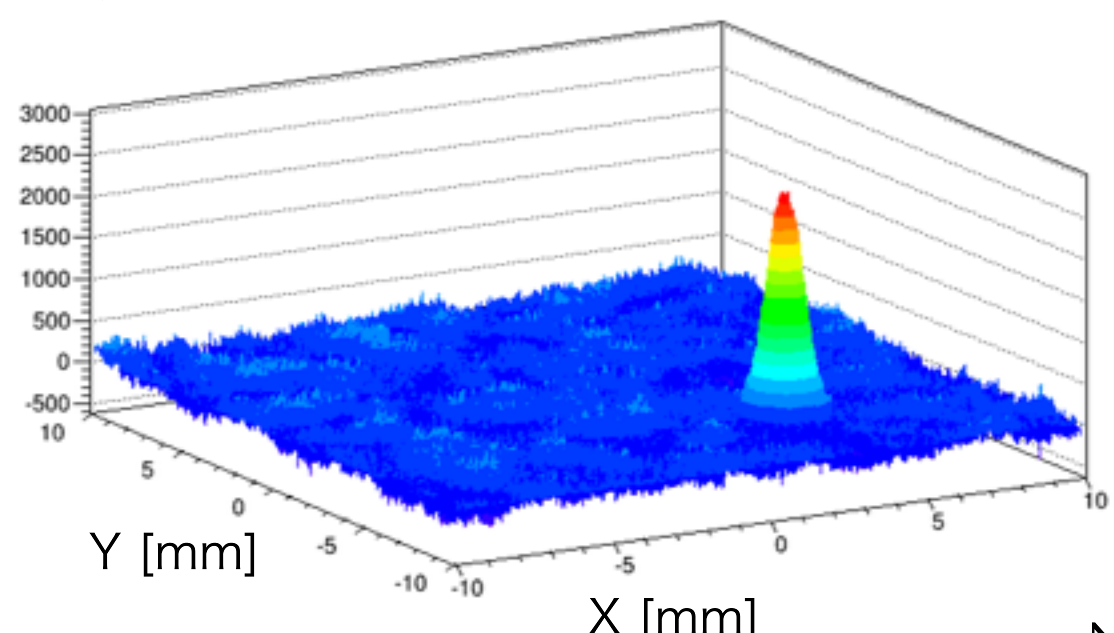
- Image reconstruction :16 - 20 keV
- distance between a mask to the source is 180 mm

<experiment condition>
Bias Voltage : 250 V
Temperature : –6 °C

Image reconstruction

☑ the source is located at correct position
☑ angular resolution is ~13 arcmin. (FWHM of the gaussian distribution)





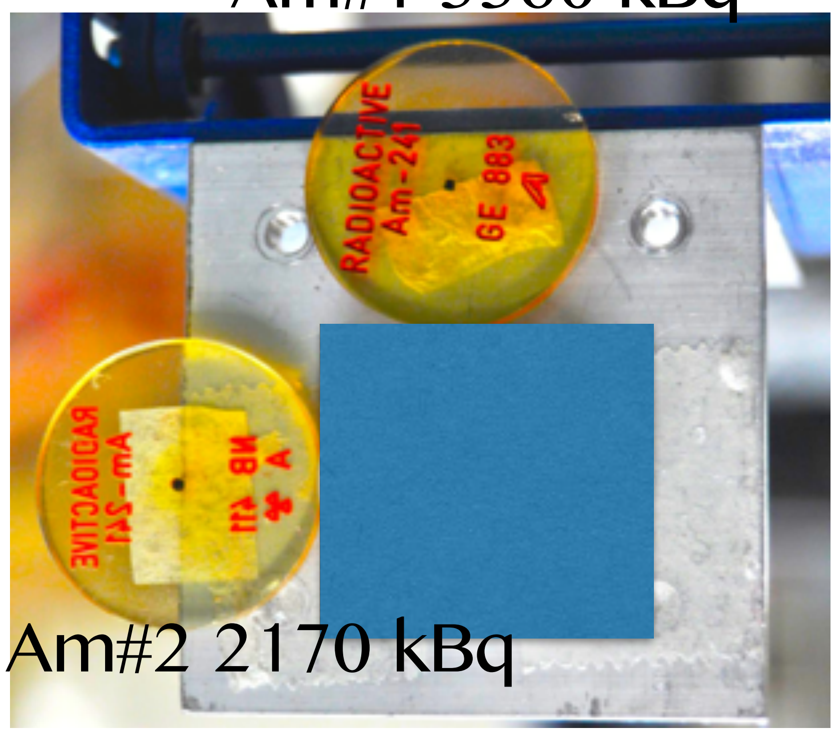
As Expected !

Linearity in sky image

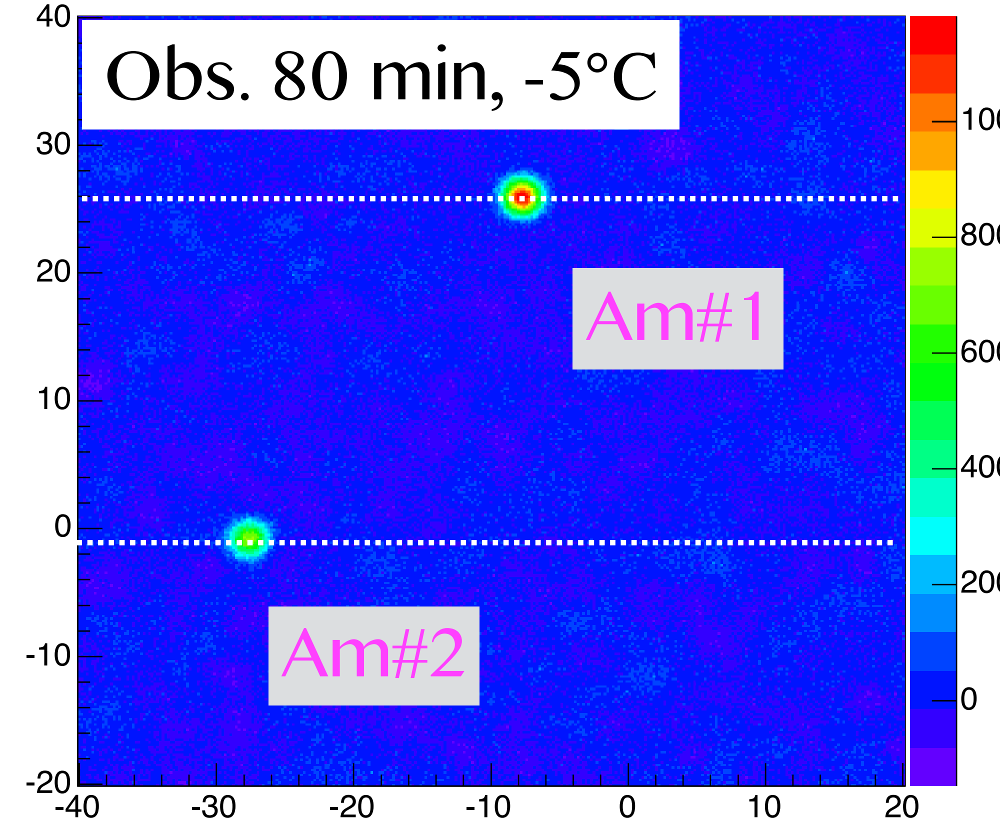
Factors for degrading image linearity :

- Non-unifomity of focal detector
- Polarization effect of CdTe

Am#1 3360 kBq

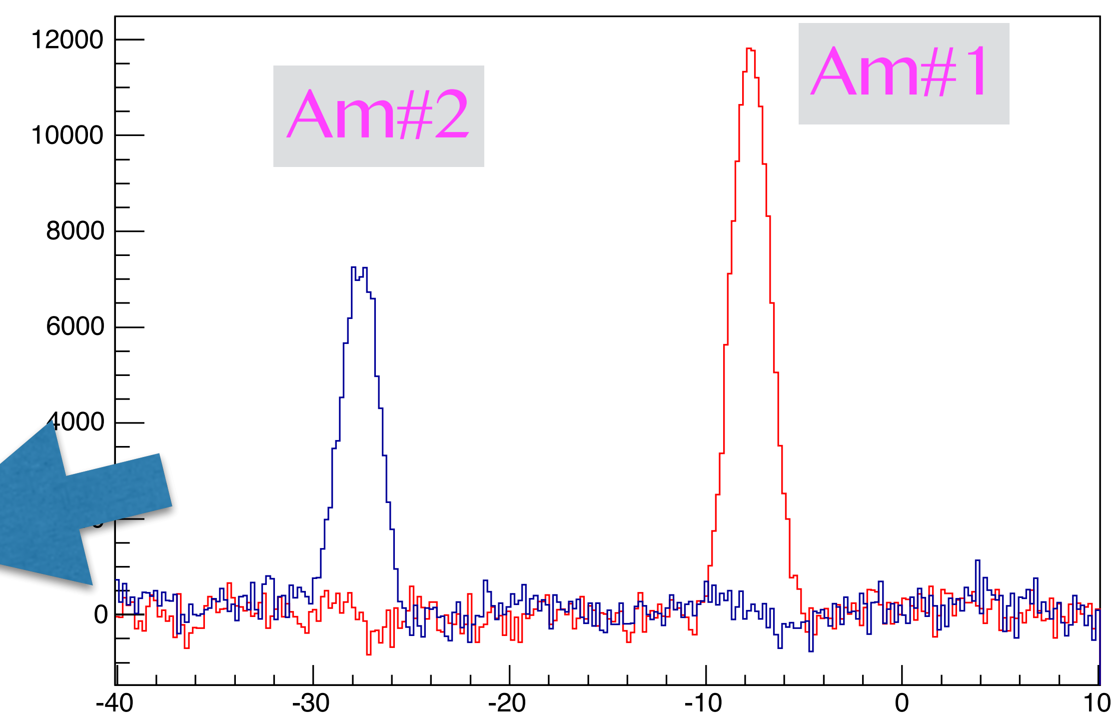


Am#2 2170 kBq



$$\frac{\text{Am\#1 Intensity (3360 kBq)}}{\text{Am\#2 Intensity (2170 kBq)}} = 1.55 \pm 0.1$$

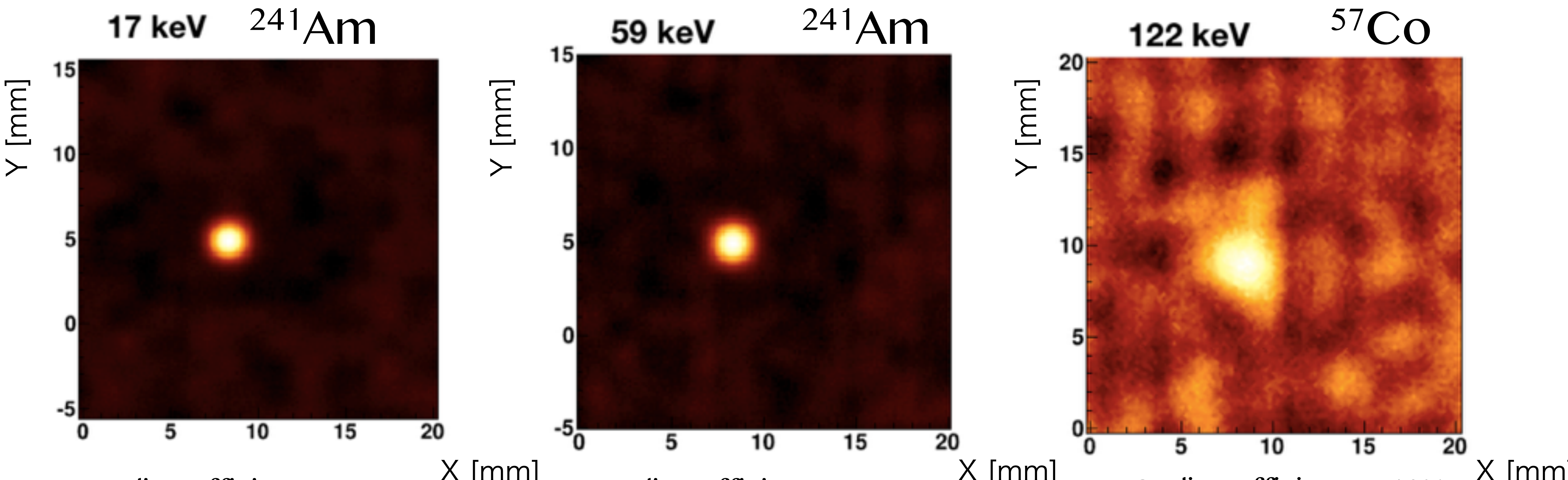
$$\frac{\text{Am\#1 Counts}}{\text{Am\#2 Counts}} = 1.64$$



Result is well consistent with the expected value.

Imaging capability in hard X-ray

Experimental results with ^{241}Am (17, 59 keV) and ^{57}Co (122 keV)



Coding efficiency ~100% | Coding efficiency ~40% | Coding efficiency ~10%

Imaging up to ~ 120 keV is achieved.

In high energy region, the coded mask becomes transparency.

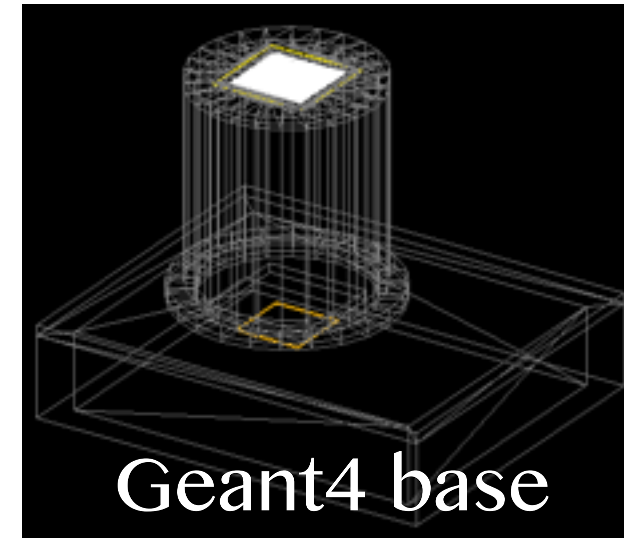
Although a thick mask can expand energy band,
it makes the field of view narrow.

Tradeoff studies and optimization are underway.

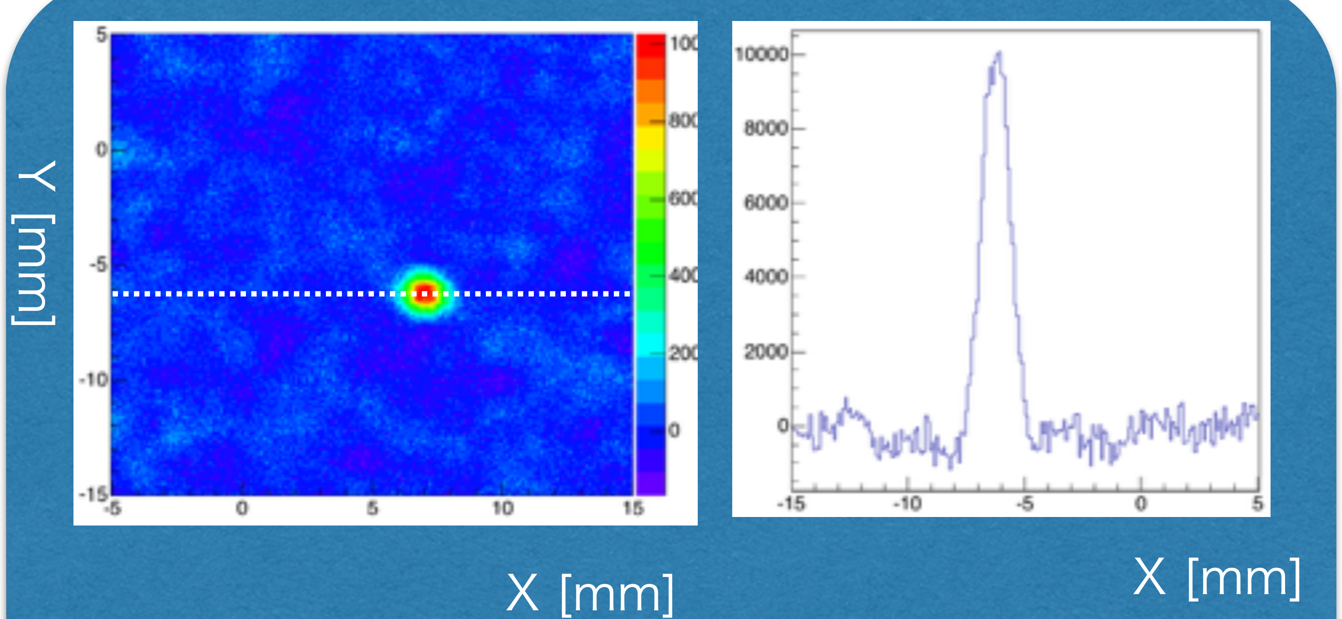
Development of MC simulator

Studies for astrophysical use

- Optimization of mask and detector configuration
- Orbital background and shield
- Arrangement of multiple modules
- Reduction of systematic error …. etc

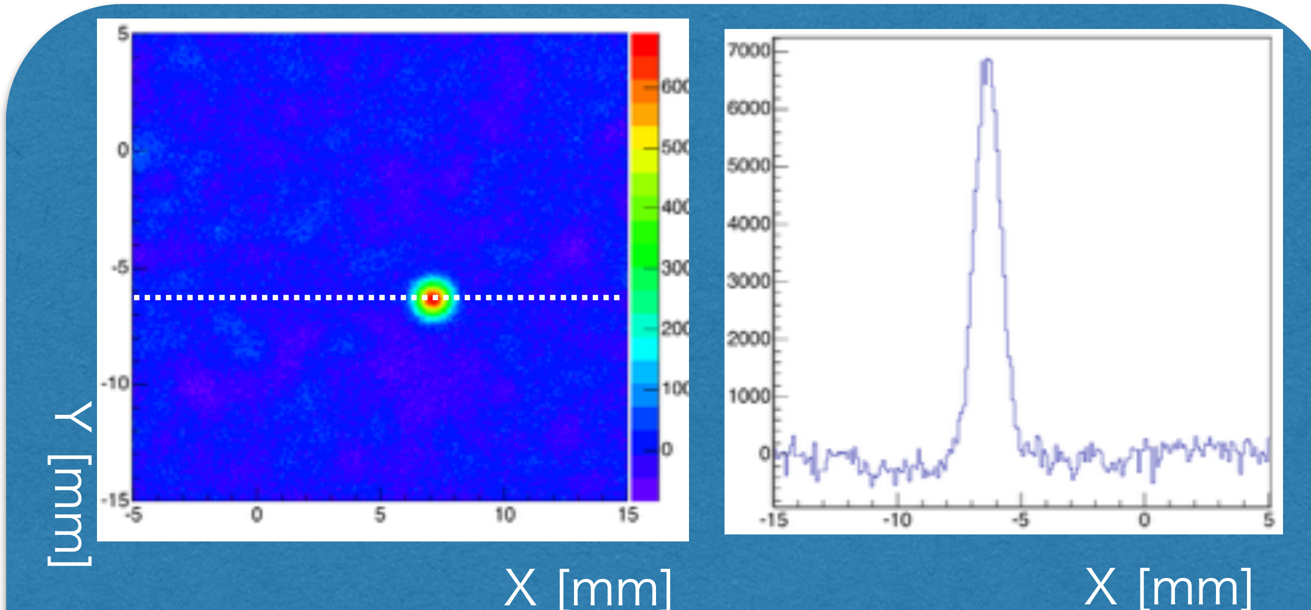


17 keV (Simulation)



FWHM 13.1 arcmin

^{241}Am, 17 keV (Experiment)



FWHM 12.9 arcmin

Next work

➡ **Design optimized for astrophysical use**

Summary

We have developed a new "Compact" imager for hard X-rays (10 - 100 keV) based on newly developed

1. Large area (~ 10 cm^2) and high resolution (~ a few hundred μm) CdTe Imagers —— CdTe Double Sided Detector

2. Fine pitch coded masks

The performance of the first prototype is very promising to realize an instrument to be onboard a future mission.

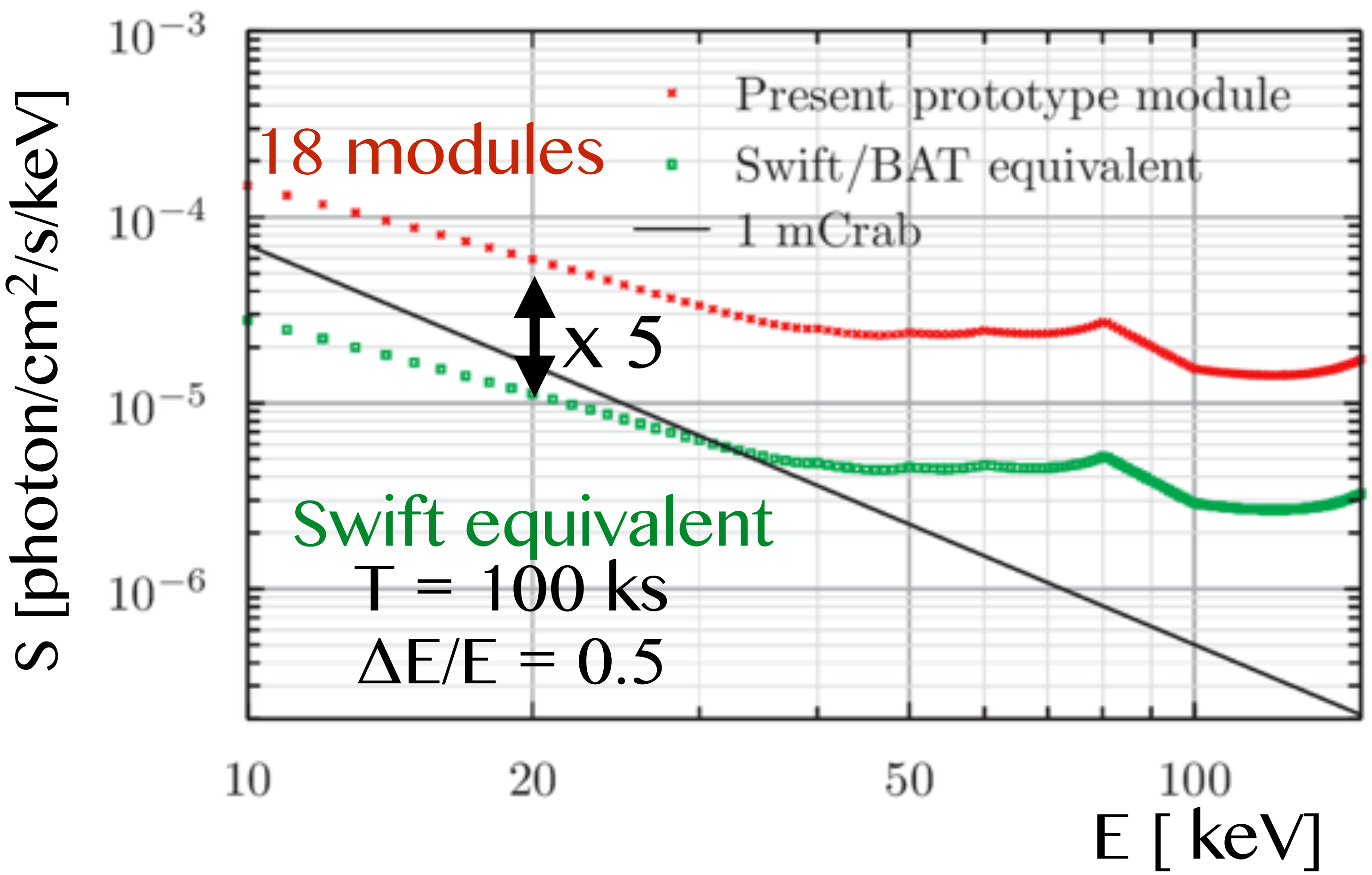
Angular resolution : ~ 10 - 15 arcmin
Energy range : 5 - 150 keV
Reasonable Sensitivity and All sky coverage
by using multiple units
with Narrow FOV + Shield

Thank you !!

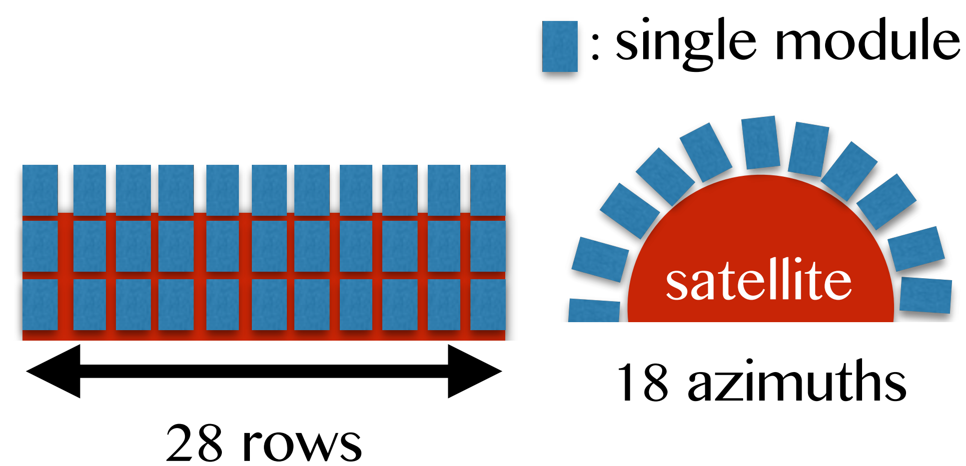
Simple Sensitivity Calculation for a future mission

	Swift/BAT	Our prototype	Figure of Merit = FoV x Area
FoV [deg	4600	256	With 18 units, can cover the same FoV
Detector Area [cm	5200	10.24	With 18x28 units, can achieve the same area

Sensitivity with fixed FoV = 4600 deg^2



Study case 18 x 28 units (Swift equivalent)



difference : ~ 5 times