Development of Silicon-based X-ray Transient Monitor onto a Microsat

Kanazawa University

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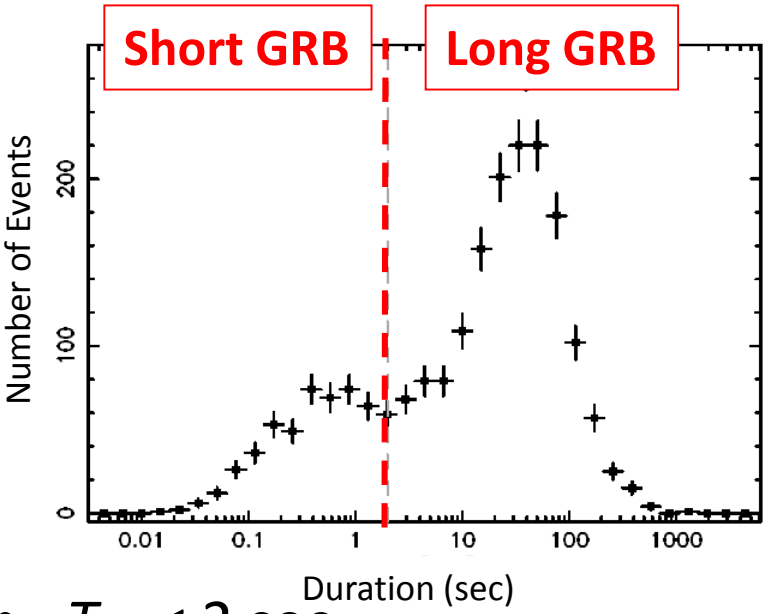
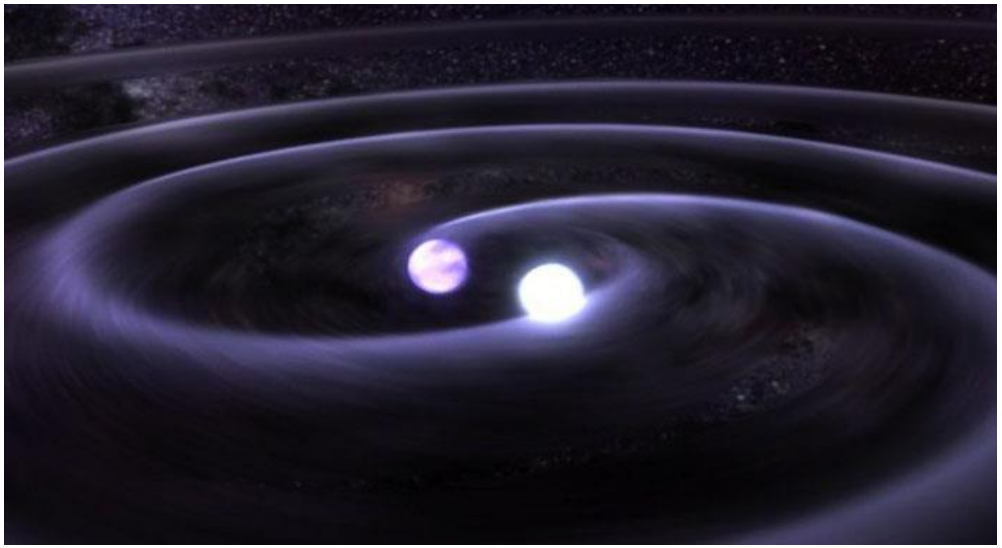
Short gamma-ray bursts





credit NASA

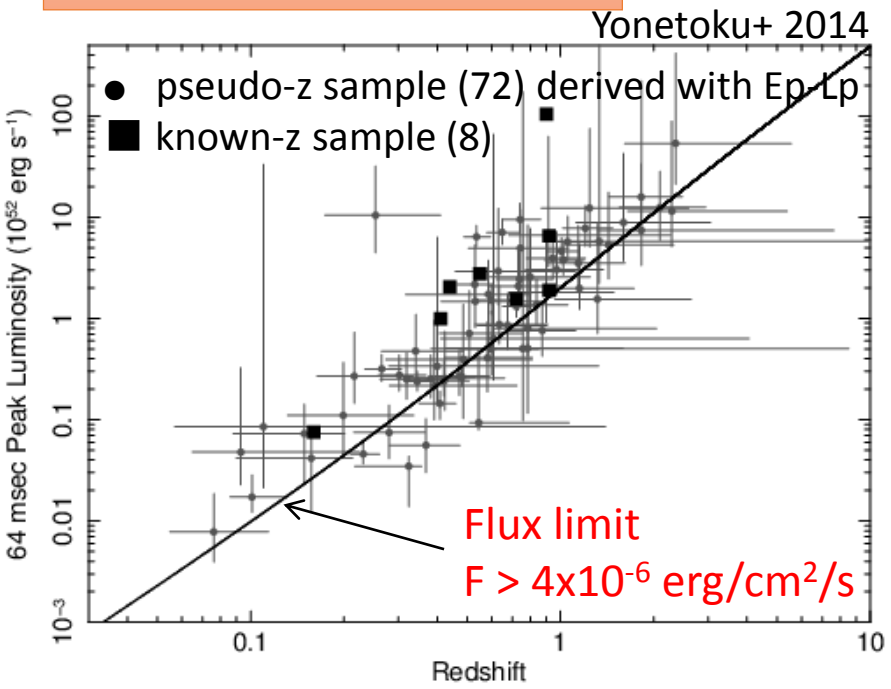
- T_{90} < 2 sec
- Associated with the coalescence of
  a binary system of compact objects(?)

What would be the keys to understanding of the progenitor?

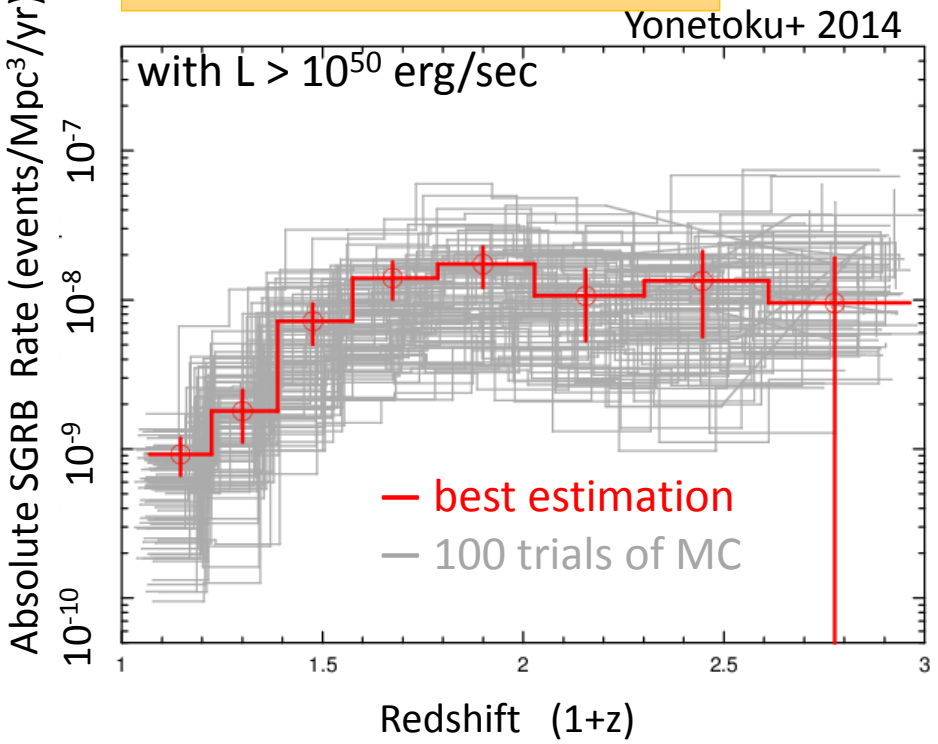
- gravitational-wave transients coincident with Short GRBs
  - GW? → KAGRA, advanced LIGO, & advanced VIRGO (2018-)
  - GRB? Swift/BAT(Hard X-ray band), Fermi/GBM (wide band, wide FoV, but moderate localization), and …
    soft X-ray imager with wide FoV for a microsatellite platform

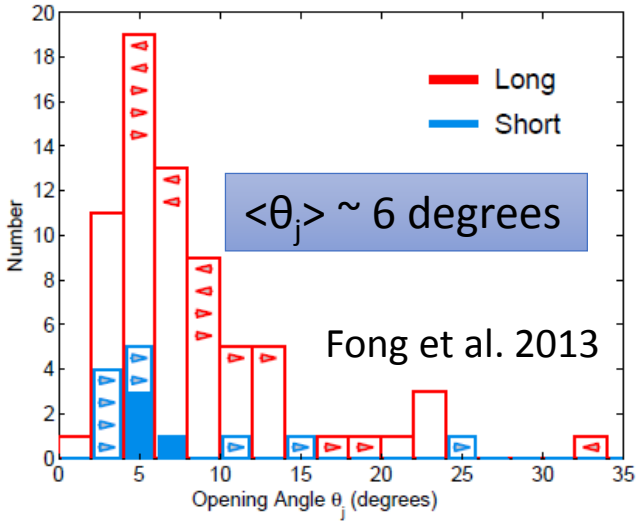
Event rate of SGRBs

Redshift Distribution



SGRB Formation Rate





Local Rate including geometrical factor

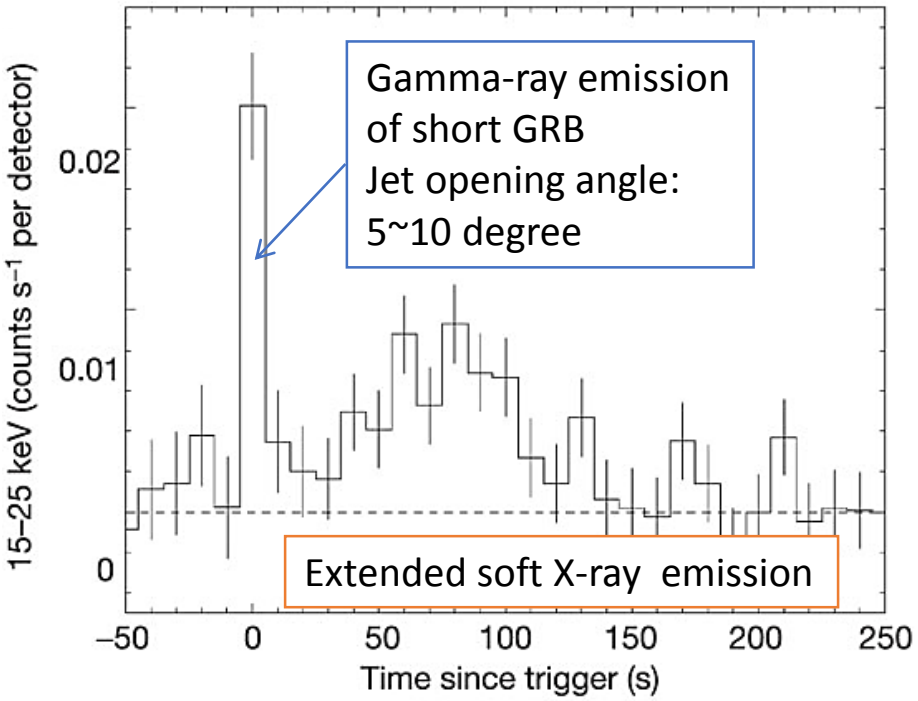
> 1.15 x 10^{-7} events/Mpc^3/yr (Lower Limit)

> 3.8 event/year in $(200Mpc)^3$ (Lower Limit)

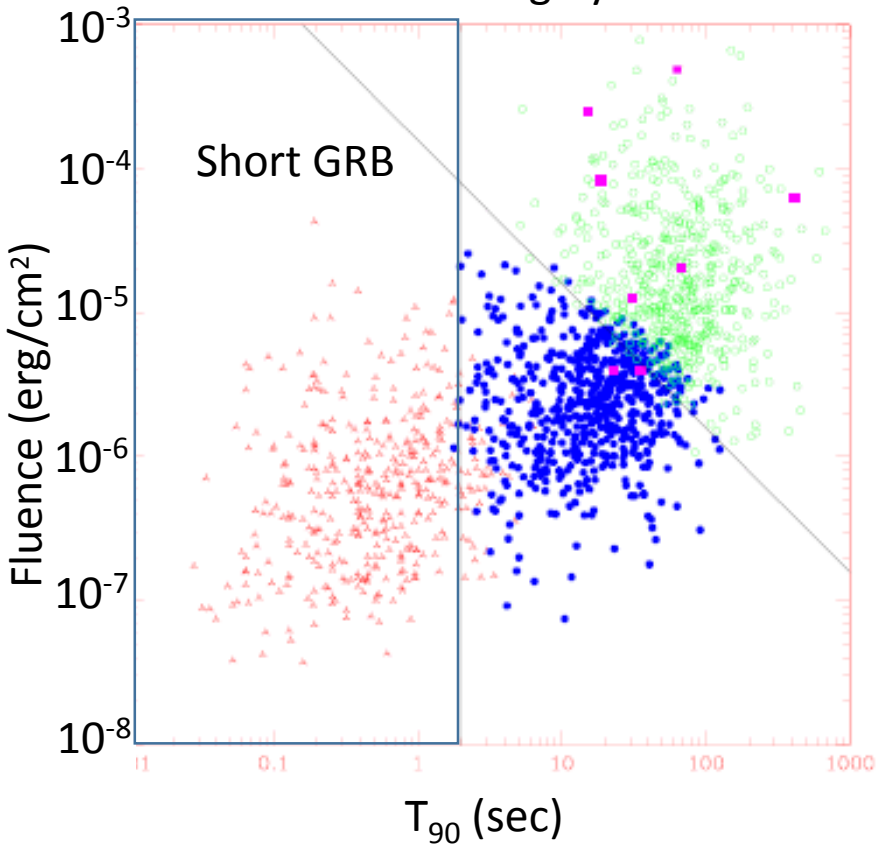
expected to detect GW

~ 10 events/year in $(200\ Mpc)^3$

Requirements for Detector



Bagoly et al. 2003

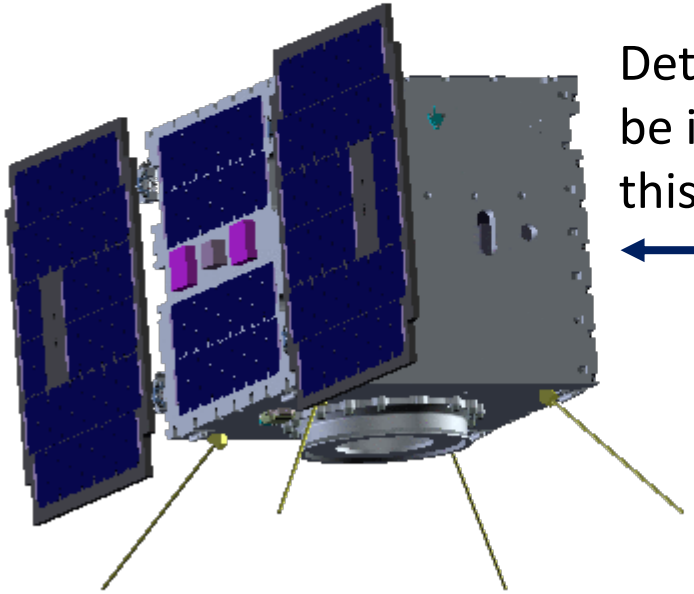


Extended Emission ($\propto E^{-2}$, 1~10 keV):
Expected photon flux : 10^{-6} erg/cm^2 ~ 300 photon/cm^2

Extended emission of nearby SGRBs is enough bright.
We can observe them by small instruments with 100 cm^2.

Micro-satellite proposed from Kanazawa Univ. (Kanazawa-SAT^3)

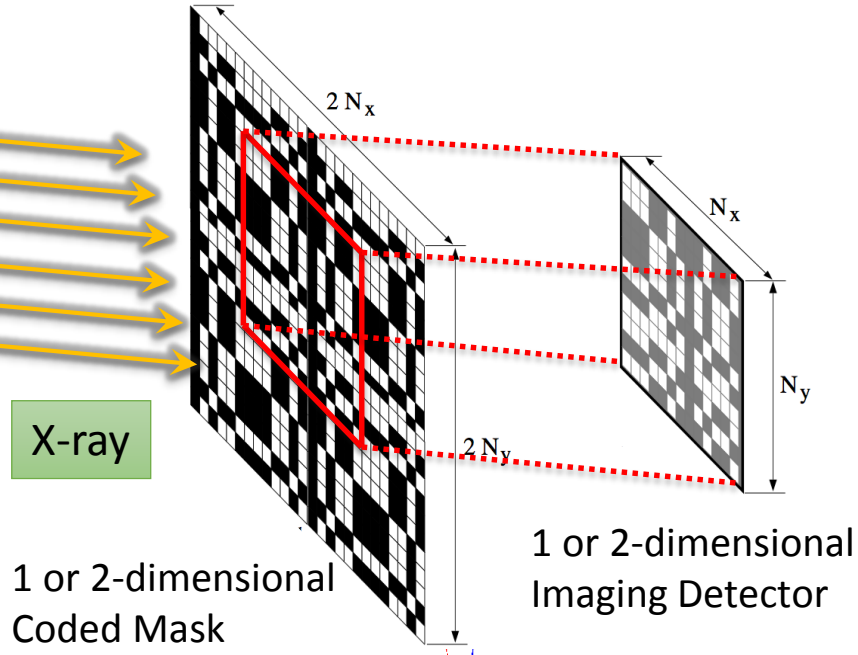
	Kanazawa-SAT^3
Orbit	LEO
Size	50 × 50 × 50 cm^3
Weight	< 50 kg
Electric Power	8 W for payload
Telemetry & Command	S-band (downlink) UHF (uplink)

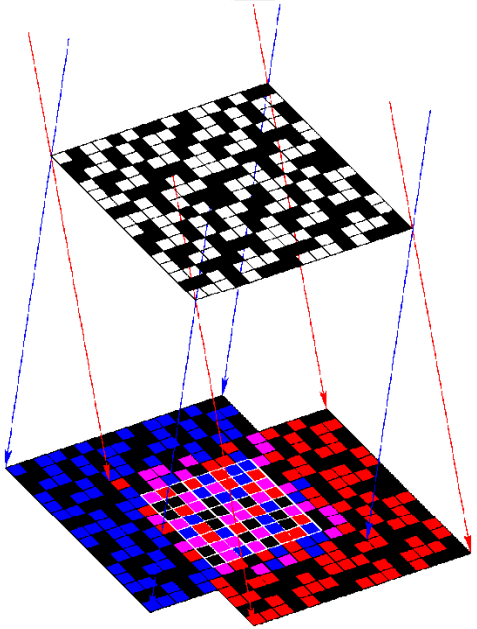


Detector will be installed on this side!

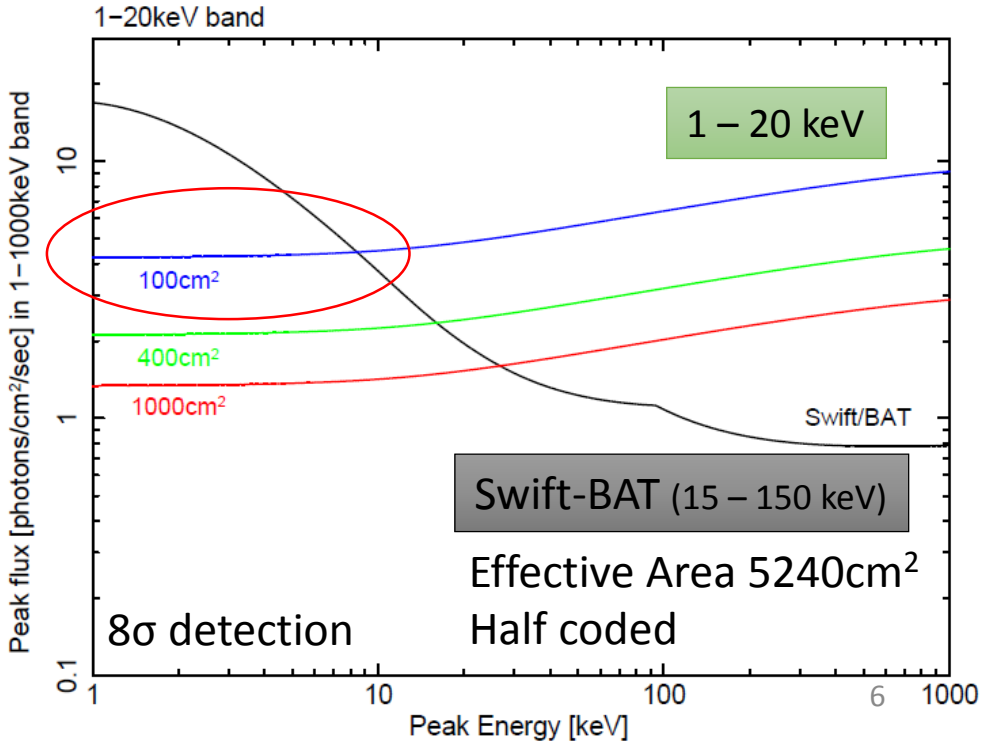
We plan to launch Kanazawa-SAT^3 in 2018-2019!

X-ray Imaging Detector

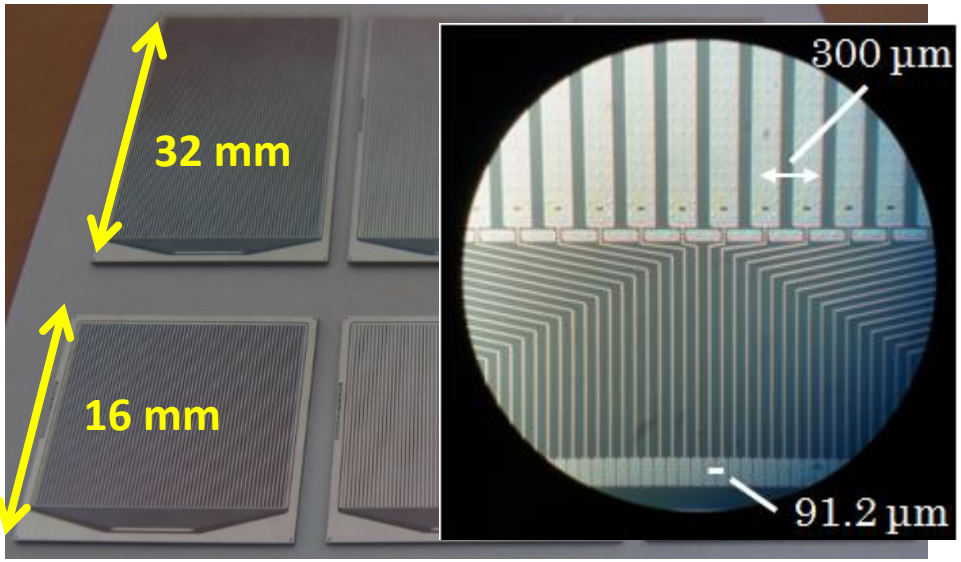




	X-ray Imaging Detector
Detector	Si single side strip (X and Y)
Energy	1 - 20 keV
Size	0.3mm pitch coded mask 6.4 cm × 7.68 cm × 2
Effective Area	100 cm2 @ ~1 keV (Half Coded)
Spatial Resolution	~15 arcmin (geometrical)
Field of View	~ 1 str
Weight	5 - 10 kg
Power Consumption	~ 8 W



Silicon Strip Detector(SSD)



Si strip sensor (Hamamatsu Photonics)

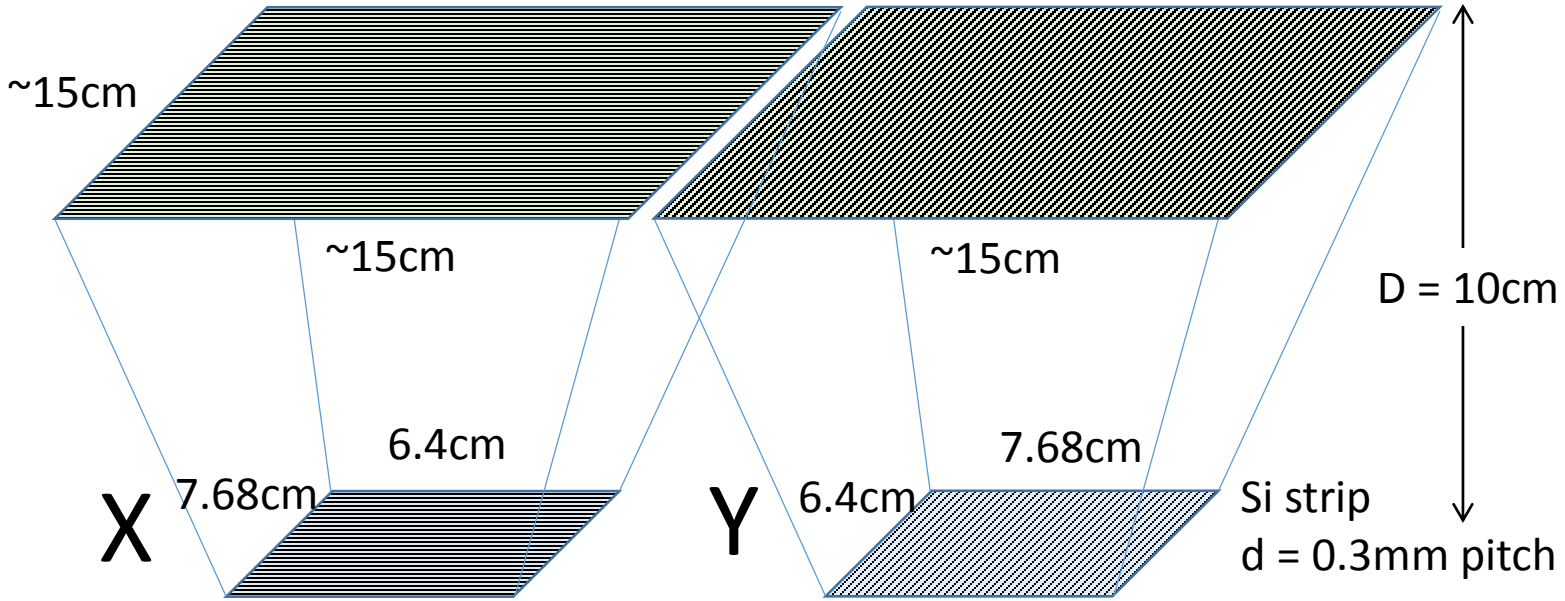
- 64 strips (0.3mm pitch)
- 0.5mm thickness (1~20 keV)
- Fan-out structure to connect ASIC
- Capacitance 5 ~ 10 pF each strip

Angular resolution

$\theta = \tan^{-1}(d/D) =$ 10 arcmin

for d = 0.3mm, D = 10cm

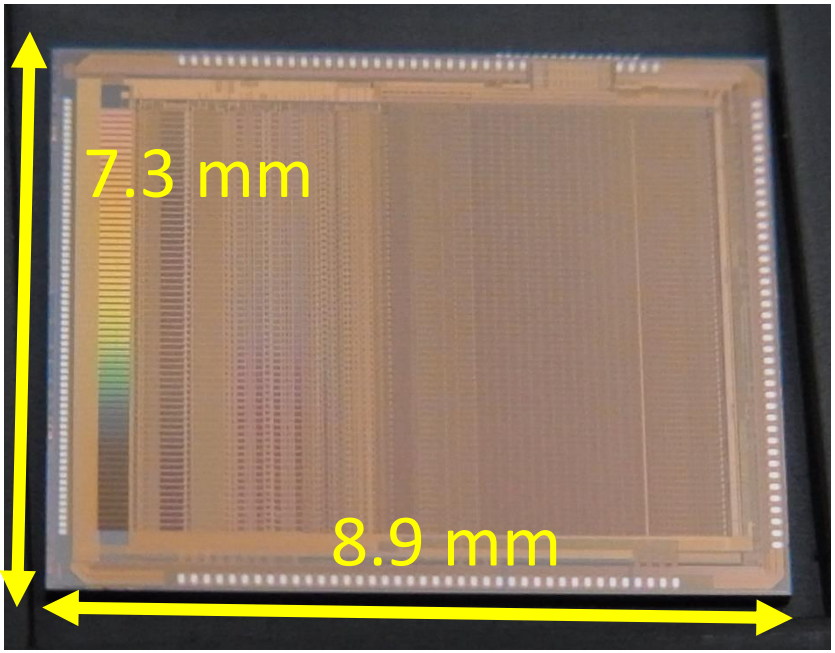
1-dimensional random mask

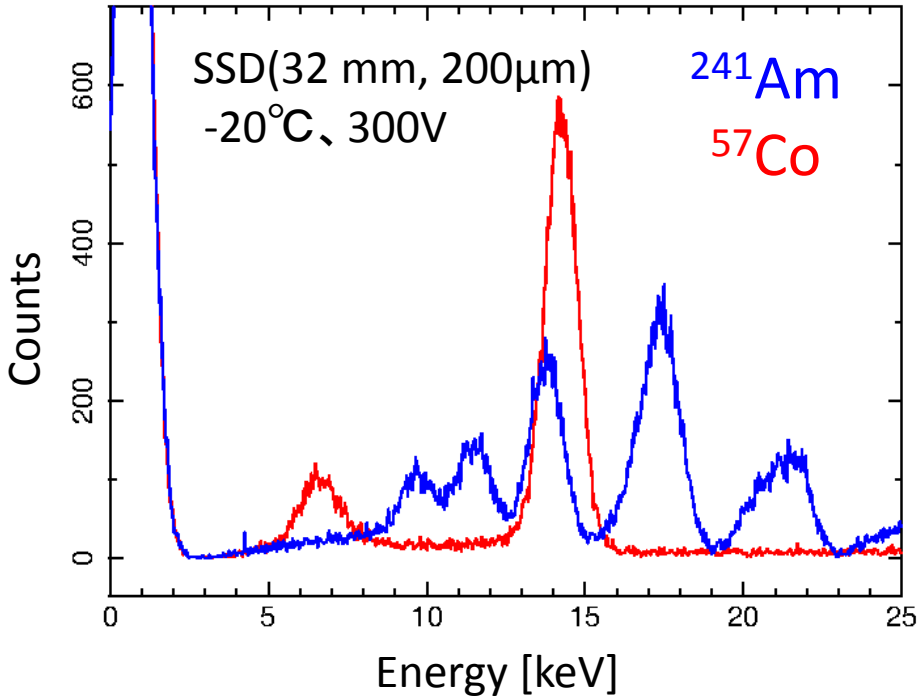


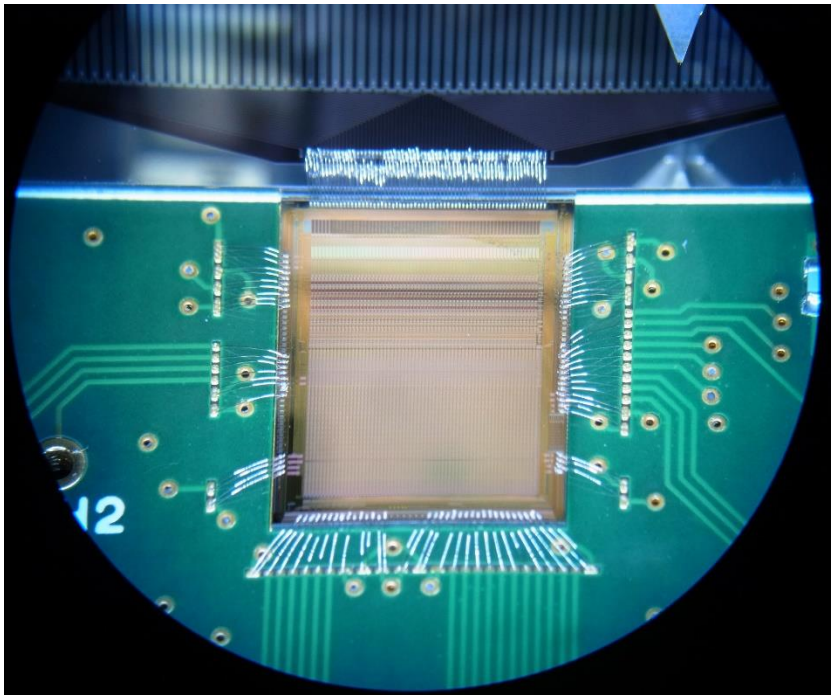
Front-end ASIC "ALEX"

- 64-channel analog inputs
- very high gain of ~ 750 mV/fC
- 10-bit Wilkinson-type ADCs
- Power consumption of ~ 120 mW

with the cooperation of
Prof. Ikeda, Harayama-san (ISAS/JAXA)
and Arimoto-san (Tokyo Tech.)







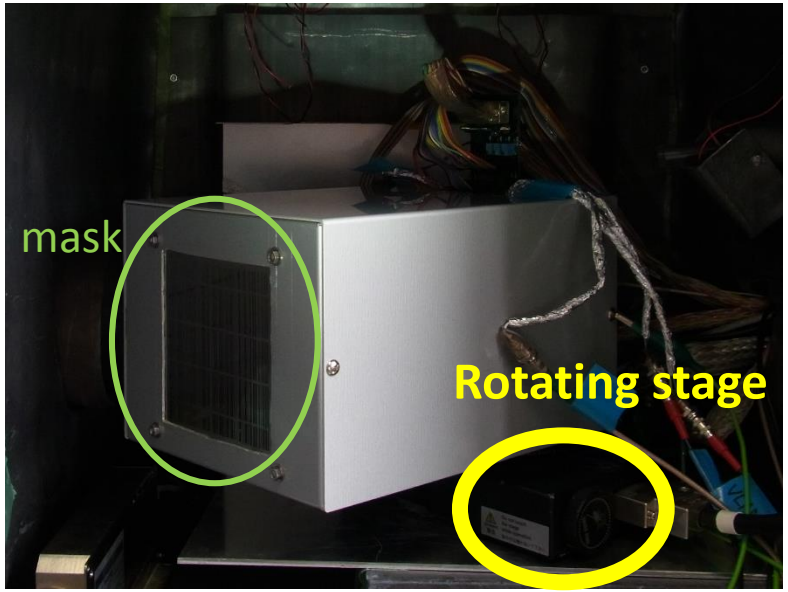
Imaging Exam. - Setup

Beamline at lab. of Kanazawa Univ.

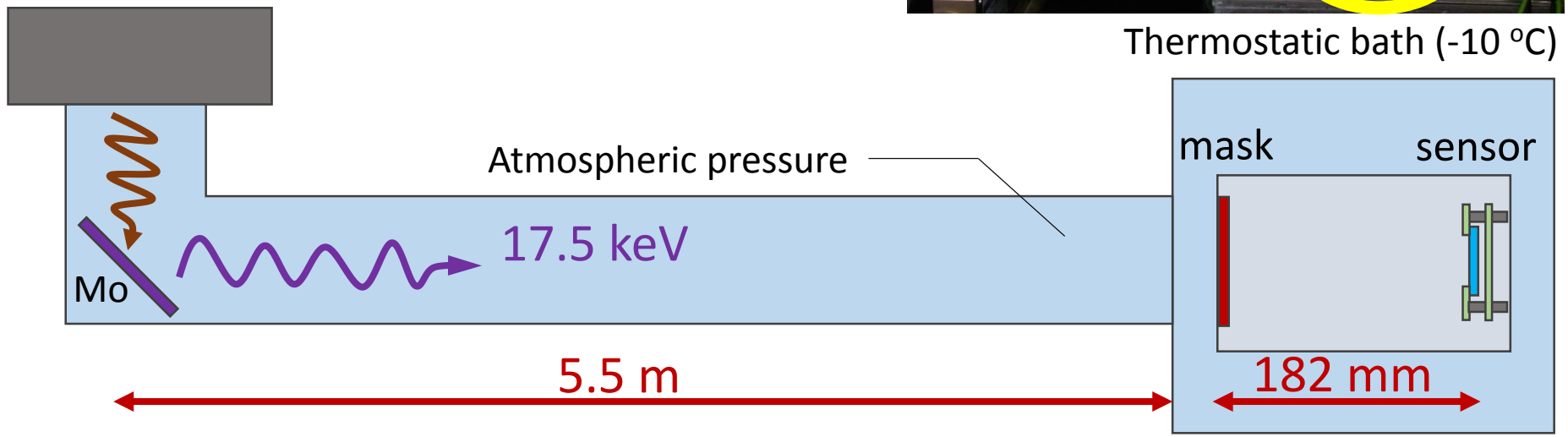
- Mono-energy of 17.5 keV produced from molybdenum
- Source divergence ~ 20 arcmin.

Detector

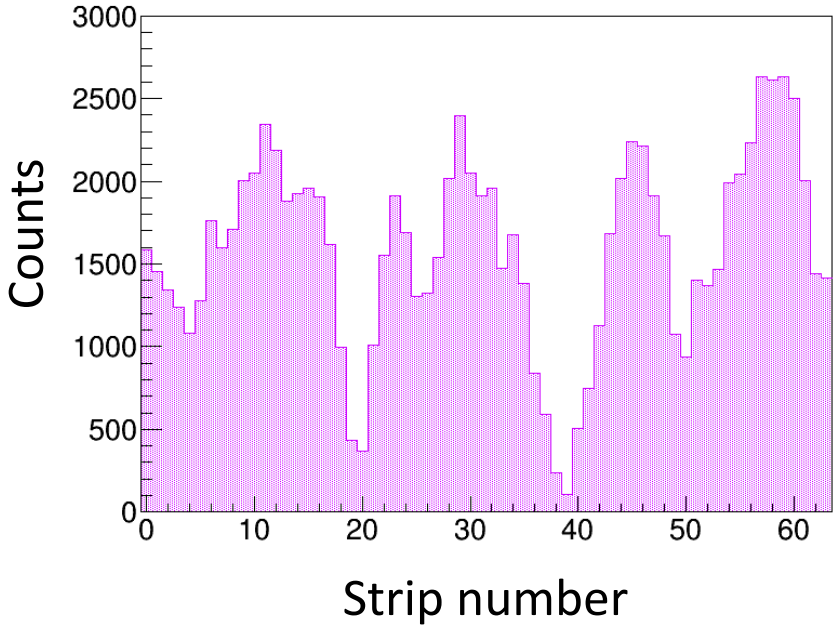
- 64-strip silicon detector
- tungsten mask with a thickness of 50 μm
- Geometrical angular resolution of 5.7 arcmin.



Thermostatic bath (-10 °C)

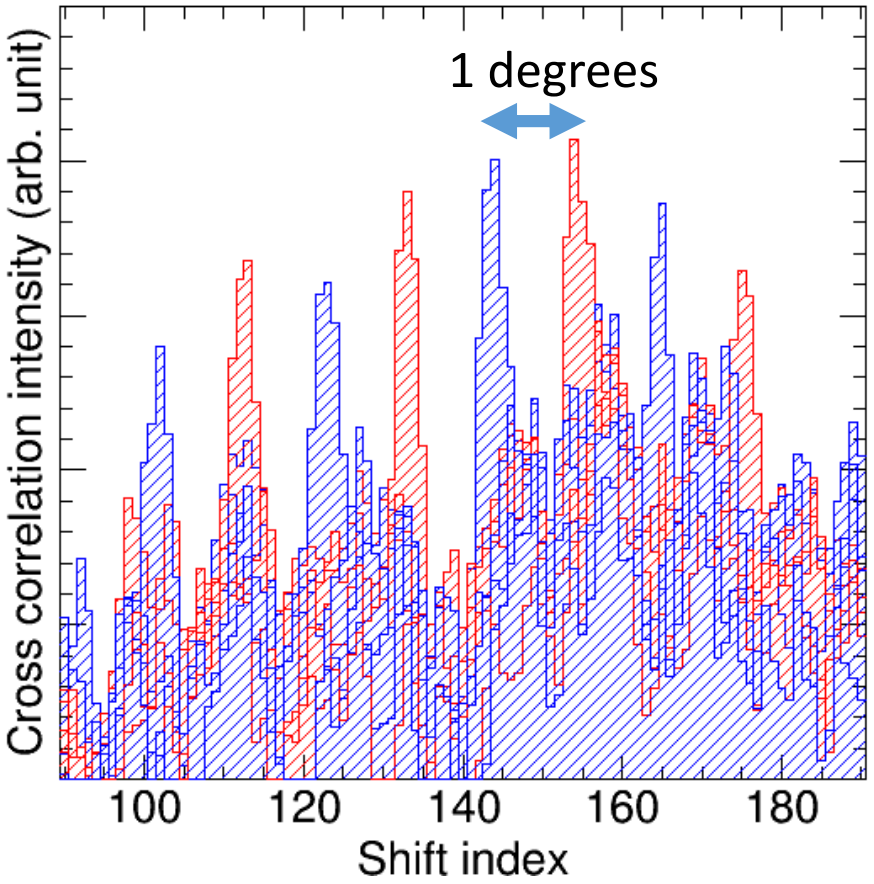


Imaging Exam. - Results



The pattern of the count distribution shifts following the rotating angle.

8 incident angles
with an interval of 1 degrees.



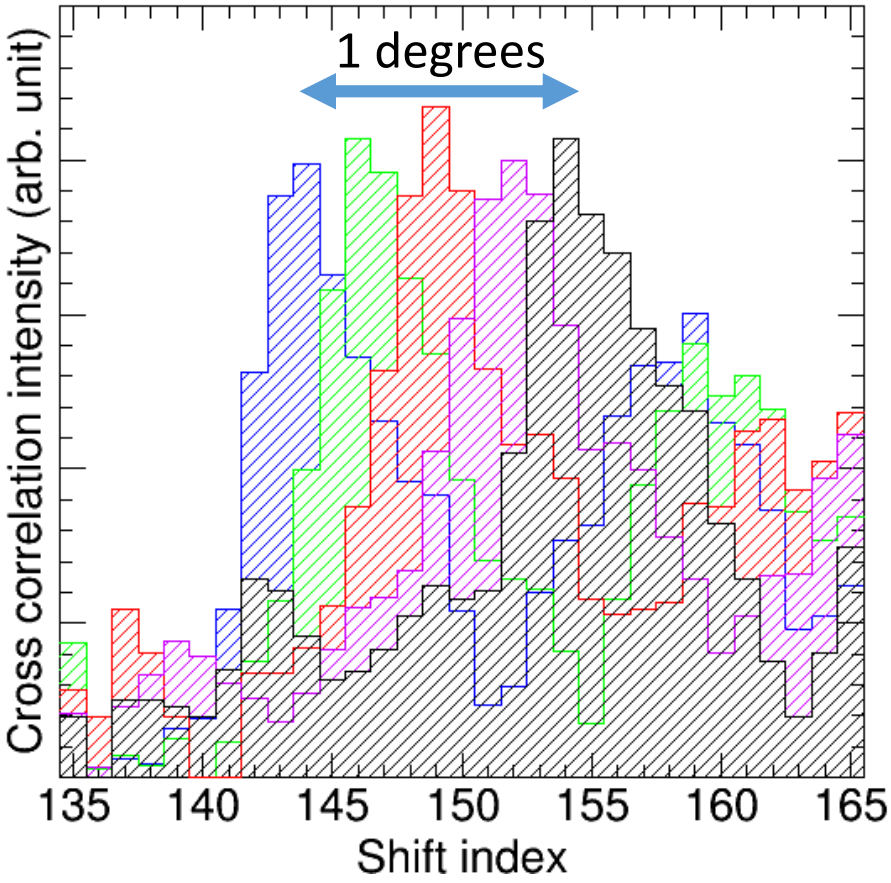
Cross correlation between
hit and mask patterns

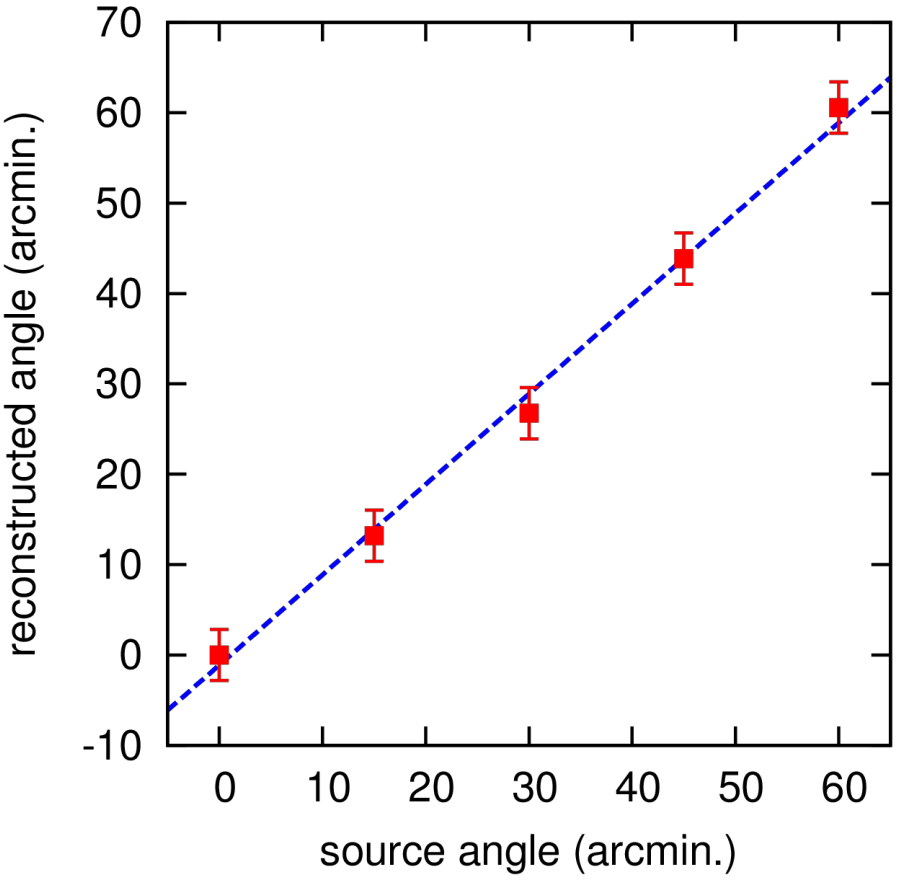
$$C_j = \sum_i d_i \cdot m_{i+j}$$

Shift index — hit pattern — mask pattern

Imaging Exam. - Results

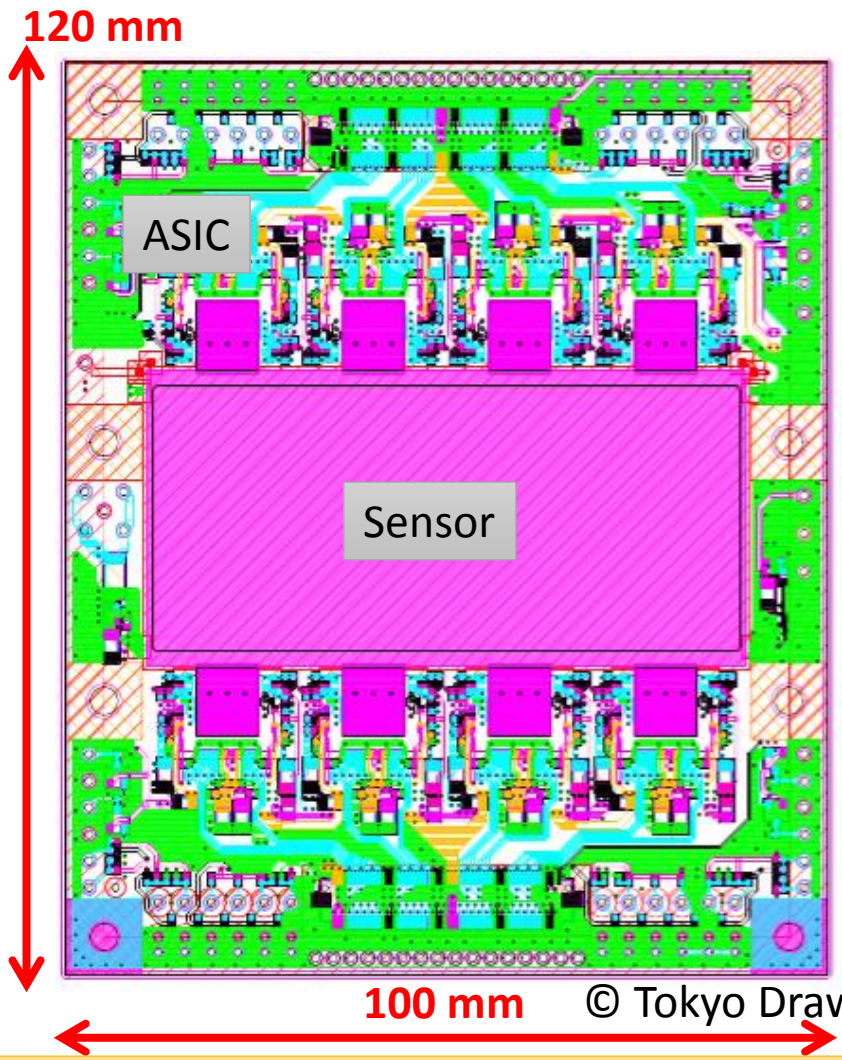
5 incident angles
with an interval of 15 arcminutes.

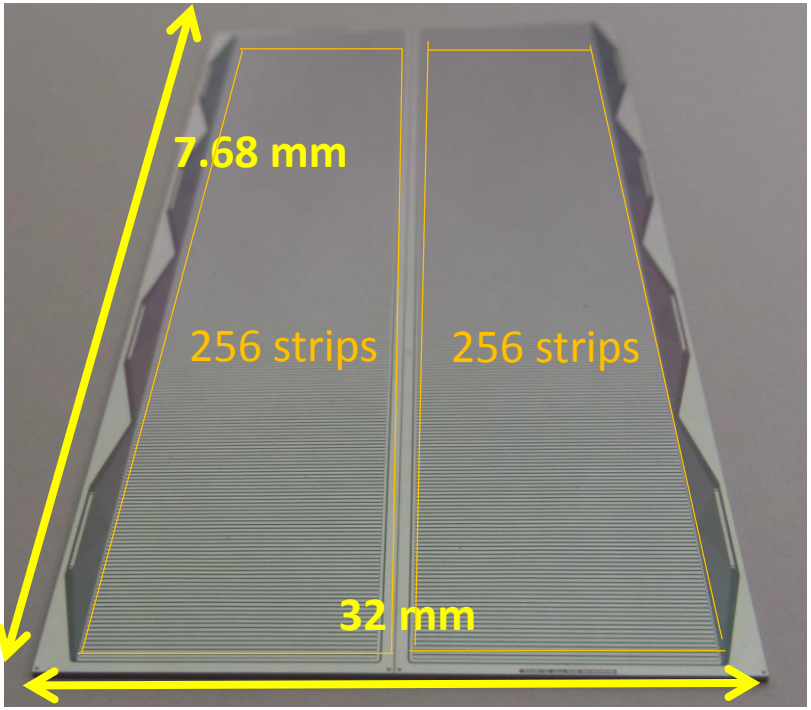


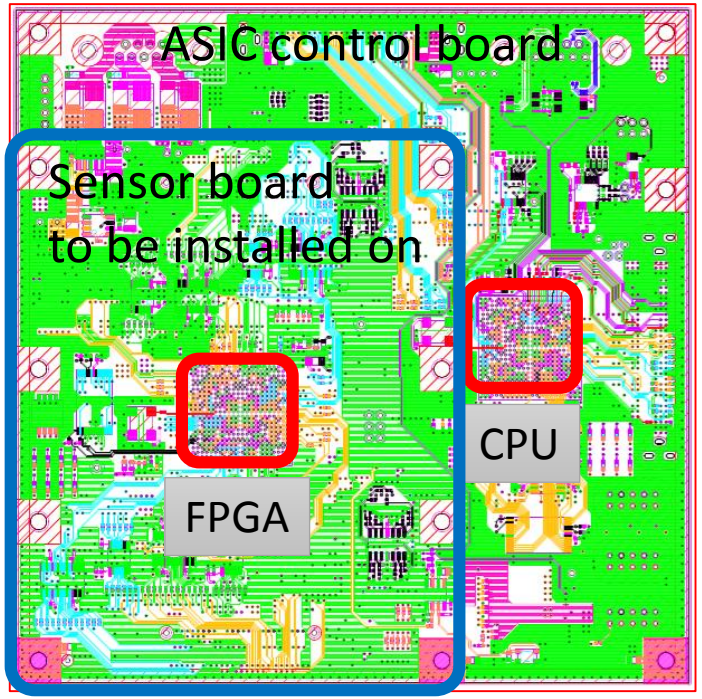


Confirmed the position determination accuracy is consistent with the one determined by the geometric factor of 5.7 arcminutes.

Prototype Model







Sensor with (256 + 256) strips and 8 ASICs
to be installed. ASICs are controlled in parallel.

Summary

- To detect short GRBs associated with gravitational waves, we are developing a coded X-ray imaging detector consisting with a silicon strip sensor and a tungsten mask.
- We have developed an ASIC for readout of low energy X-rays and confirmed that the detector can measure X-rays from 2 keV to 20 keV.
- We performed the imaging test with a miniature camera system and confirmed the position determination accuracy is consistent with the one determined by the geometrical factor of 5.7 arcminutes.
- The prototype model for the Kanazawa-SAT^3 is in development, which has a half geometrical area of the flight model, and these technology can be applied to the future HiZ-GUNDAM mission.