Using ISAS X-ray beamline
Measurement of Effective area of Lobster Eye Optics

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HiZ-GUNDAM Launch aim 2030s

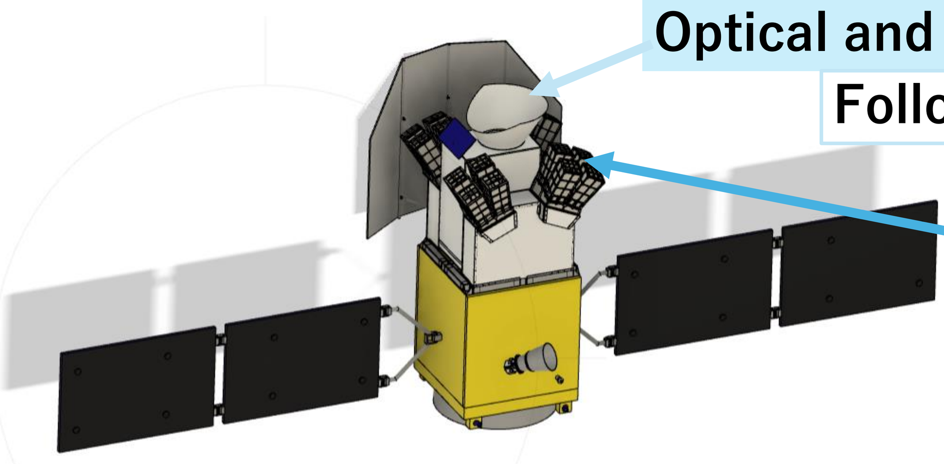
High-z Gamma-ray bursts for Unraveling the Dark Ages Mission

Early Space Exploration

- The properties of the early universe are different from those of the modern universe, and direct observation of the early universe is necessary to elucidate star formation and ionization states.
- The light luminosity of galaxies in the early universe are extremely dim, making it difficult to measure the physical condition.

Gamma-Ray Bursts

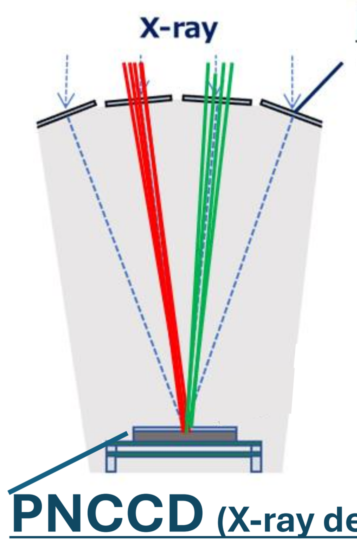
- GRB releases $10^{52\sim54}$erg energy in a few seconds
- Known as one of the brightest explosion in the universe



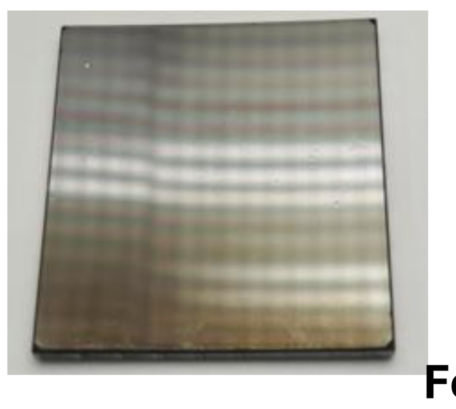
Optical and Near-Infrared Telescopes
Follow-up observation of detected GRBs

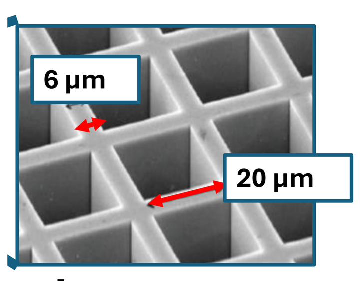
Wide Field X-ray Monitor
Detect and localize GRBs
- Energy band 0.4-4 keV
- Positioning accuracy < 3 arcmin

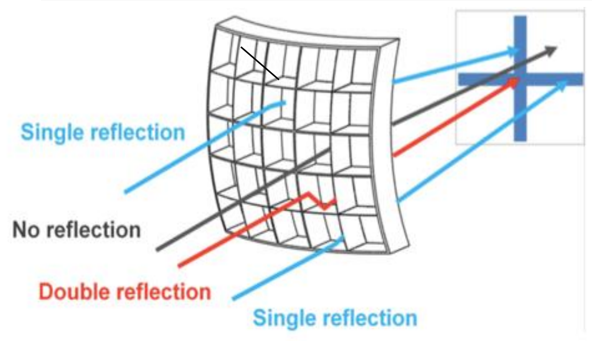
Structure of Wide Field X-ray Monitor



Lobster Eye Optics (LEO)

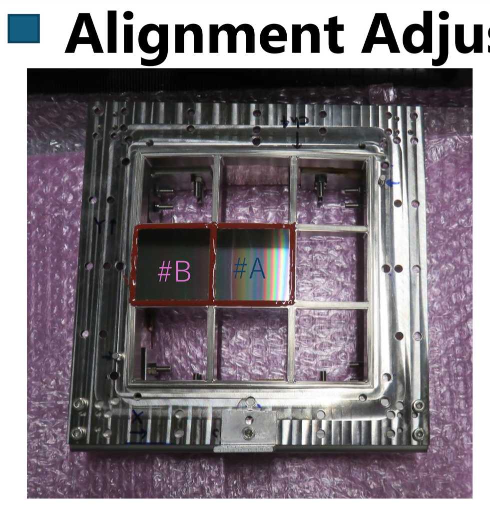


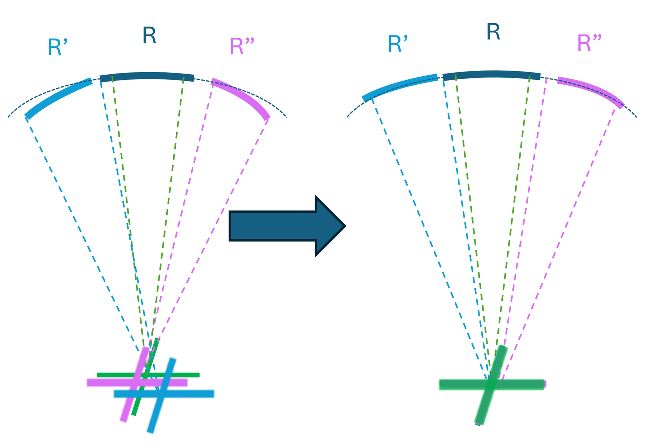




Feature
- Focus soft X-ray($10^{2\sim3}$eV)
- Background is removed by concentrating light
- Placed on a spherical surface to ensure a wide field of view

Alignment Adjustment





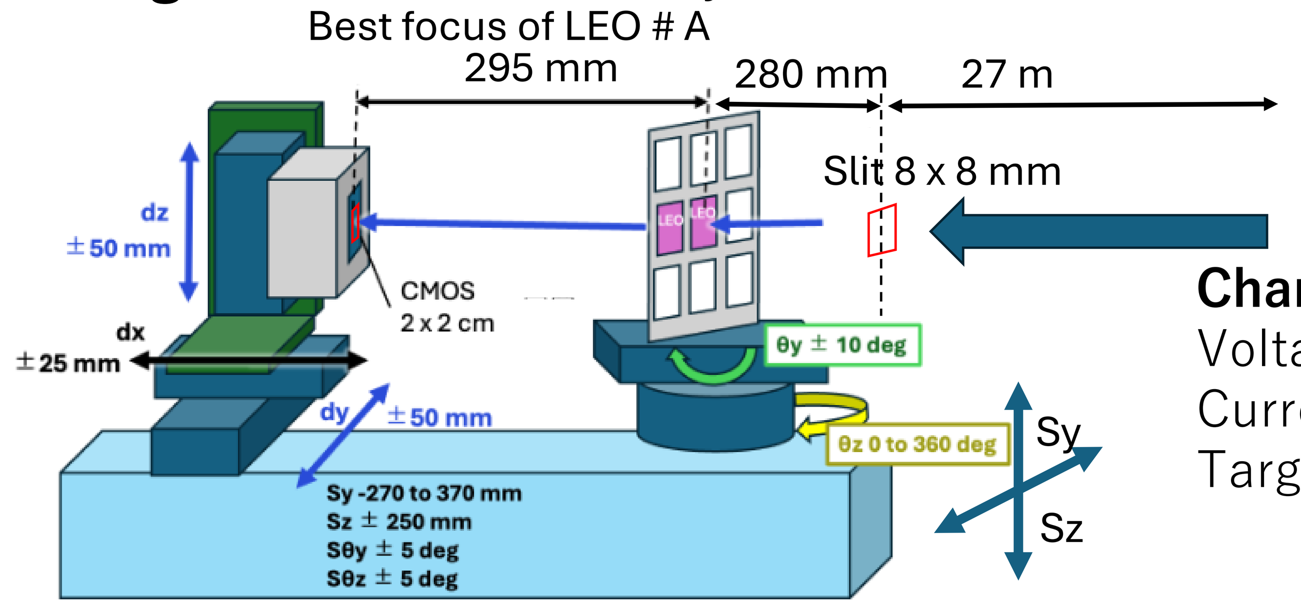
Adjust the focusing position of the LEOs by tuning the angle of the LEOs.

Fixed using silicon glue (WACKER RTV-S 691 A/B)

Objective

Parallel X-rays of the ISAS 30m beamline are used to investigate the angular dependence of the effective area of the aligned LEOs used in *HiZ-GUNDAM.*

Configuration ISAS X-ray beam line



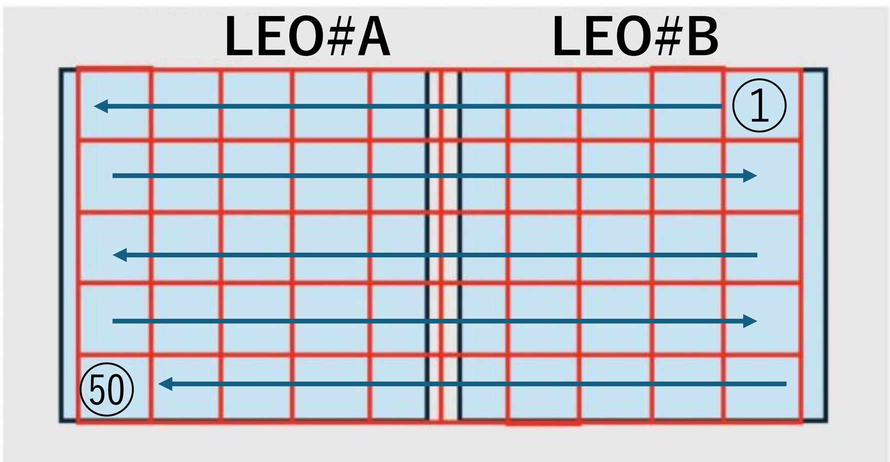
Characteristic X-ray
Voltage 5 kV
Current 10 mA
Target Al 1.5 keV

Grid scan

Combine images taken while moving the frame to cover the measured area.

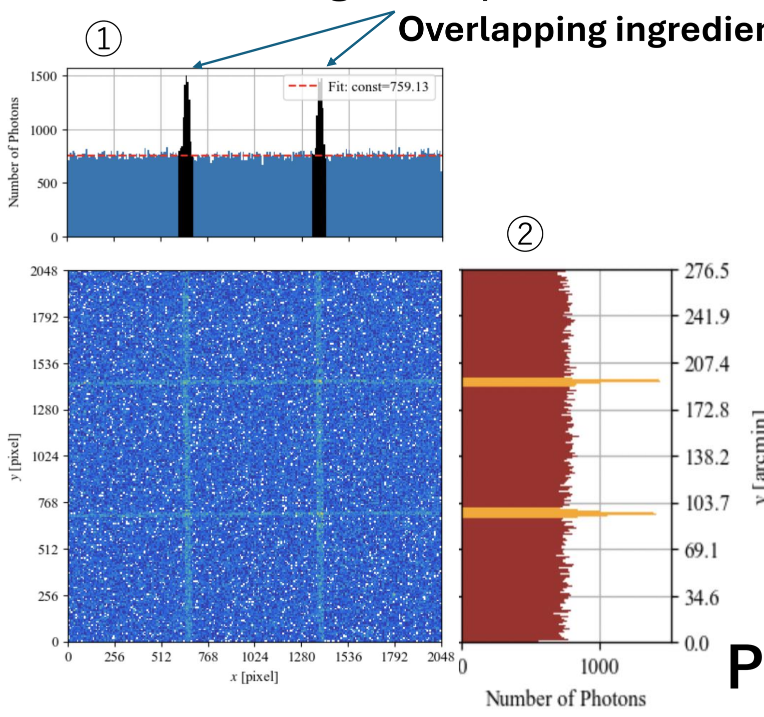
Exposure time	20 ms
Frame	1000

x 50 grids



X-ray Beam flux

Move the stage to a place where there is no LEO and irradiate the X-rays on the grid



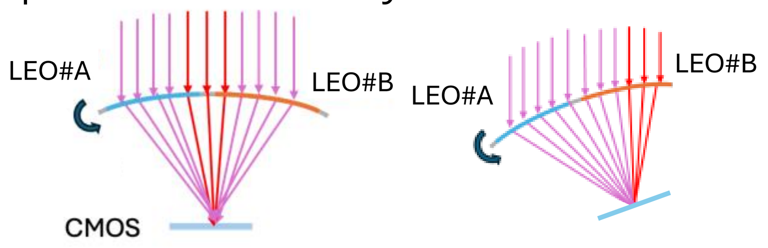
① X-axis projection to remove overlapping components and take a average count
②Subtract the overlapping components of the y-axis projection from the one obtained in ①
③Divide by the area used for counting

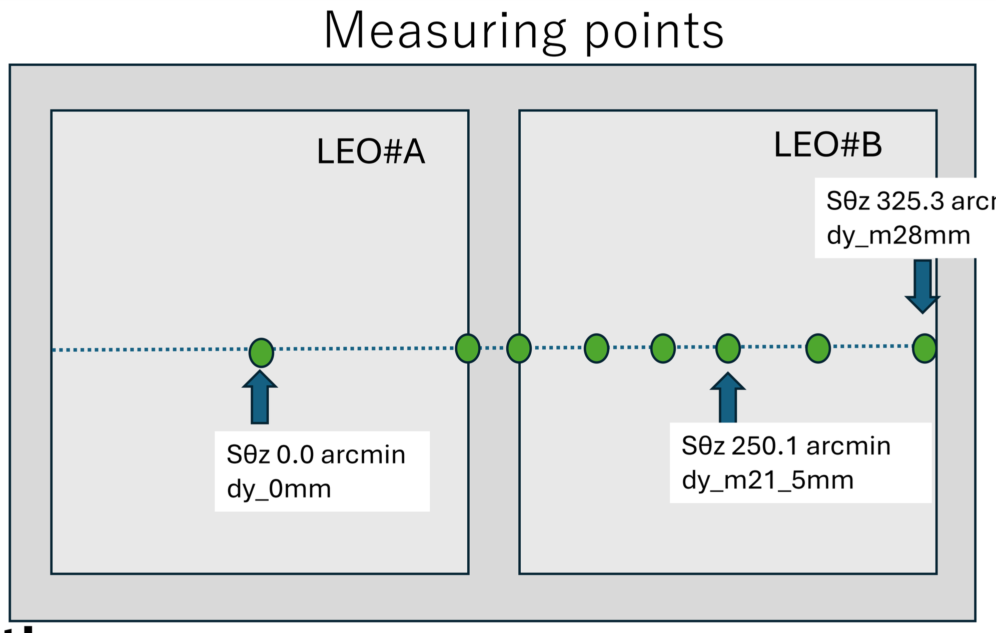
Total exposure time =20 ms x 1000 frames x 9 grids = 180 s
Photon counts = 162152 ±419 counts
Counting area = 4.37 cm^2

Photon flux = 1855.3 ± 4.8 counts/ cm^2/s

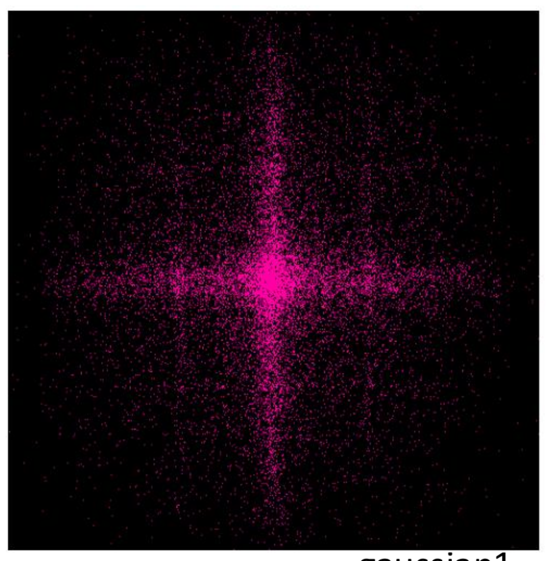
Effective area

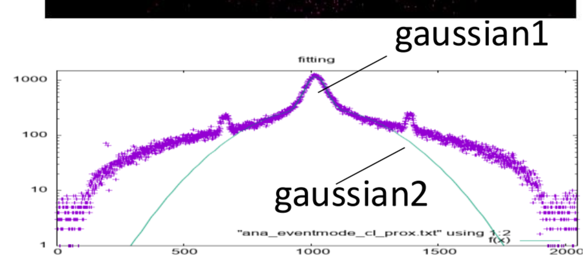
While keeping the image focused in the center of the CMOS, change the incidence position of X-ray





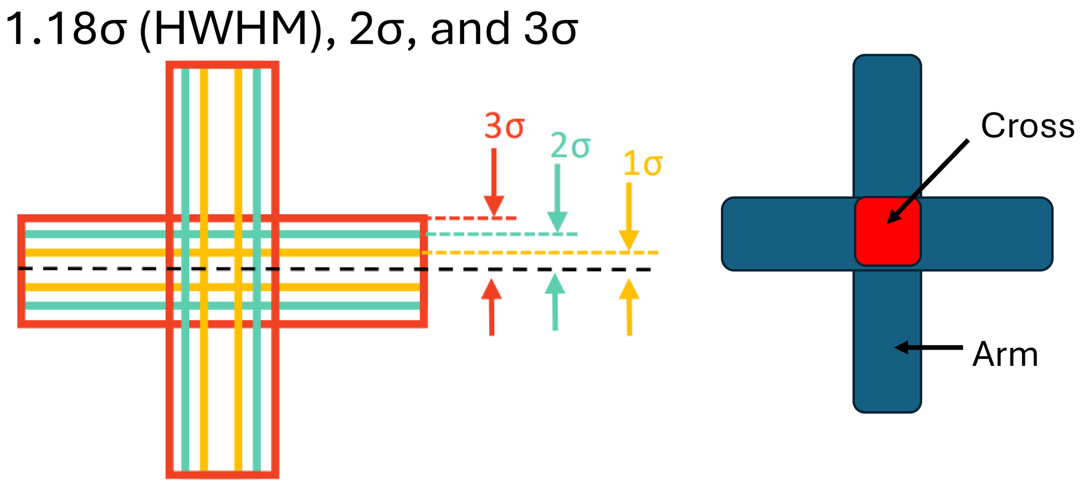
How to evaluate the effective area





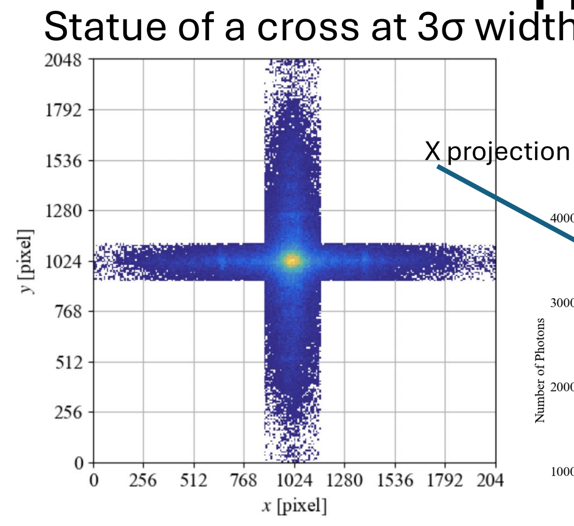
①Perform a double Gaussian fit on the projection and find the standard deviation σ of central Gaussian

② Count the photons in the region of the arm and center when the width of one of the crosses is 1σ, 1.18σ (HWHM), 2σ, and 3σ

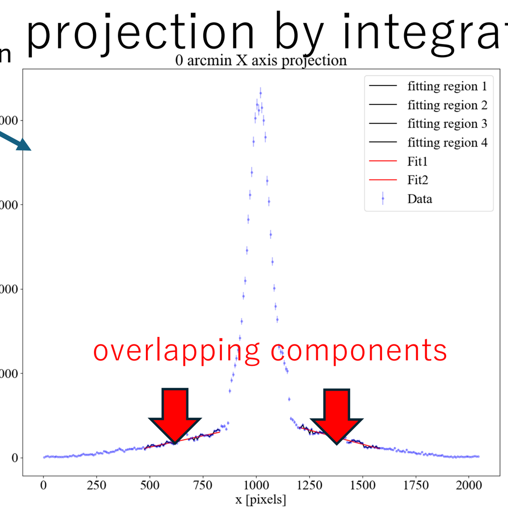


Get rid of overlapping components

Statue of a cross at 3σ width



Finding the overlapping components from the fitted projection by integrating

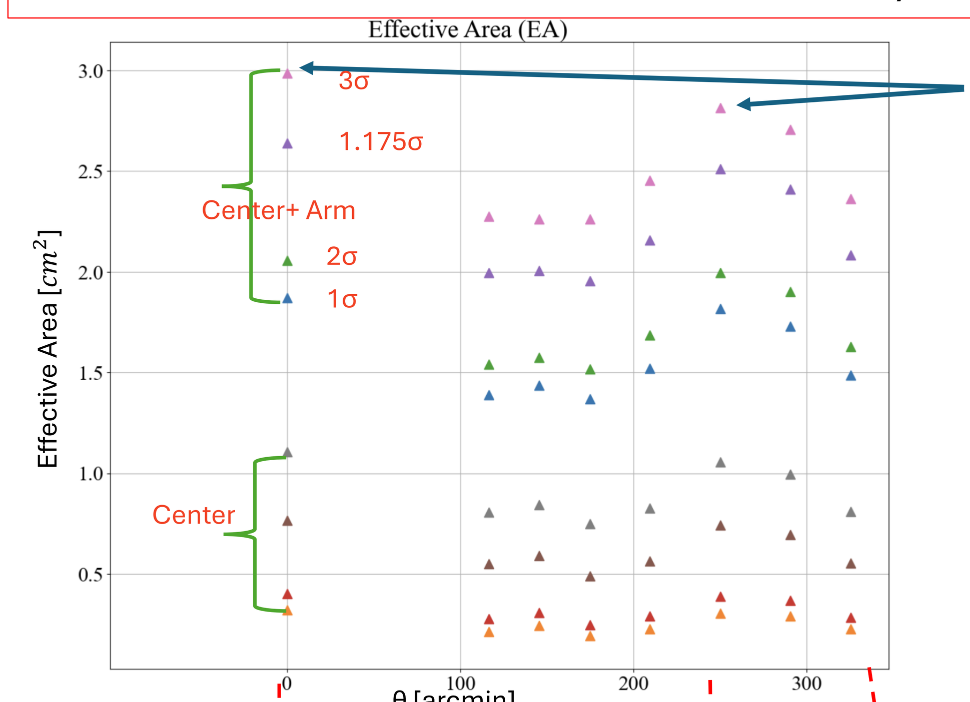


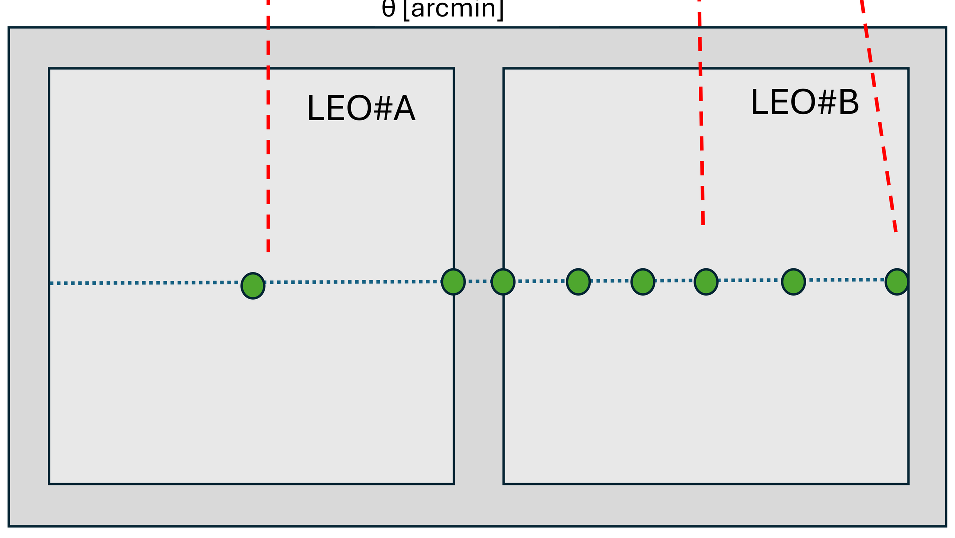
Overlapping component is 1.9% of total photon

Use the value that excludes 1.9% of the photons counted

Result

Effective area = Photon counts /Photon flux

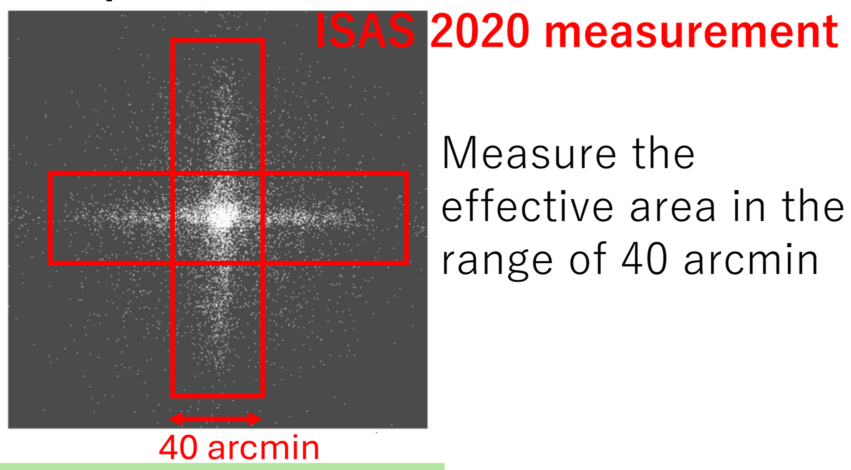




Large effective area at the center of LEOs

Range	LEO#A Center + Arm of effective area
3 σ	2.987 ± 0.008 cm²
2 σ	2.642 ± 0.008 cm²
1.18 σ	2.060 ± 0.008 cm²
1 σ	1.867 ± 0.008 cm²

Comparison with Past Measurements



Measure the effective area in the range of 40 arcmin

Range	Effective area @1.5 keV (2024ISAS) [cm²]	Effective area@1.5keV (2020ISAS)[cm²]
Center + Arm Width=40 arcmin	3.214±0.012	3.49
Center 40 x 40 arcmin	1.434±0.007	1.37

Center + Arm matched with a margin of error of 8.59% and center with a margin of error of 4.46%

Discussion

The effective area is the largest at the center of LEO and smaller at the boundary between LEO#A and LEO#B because it is blocked by the frame and it is difficult to focus light.

Conclusion

- Since the image of the cross was cut off at the end of the sensor, it was necessary to expand the measurement area next time
- Results from Einstein Probe and previous HiZ effective area simulations Comparison with the results of this measurement

Reference

X-ray performance and simulation study of lobster eye optics (Li 2020)