

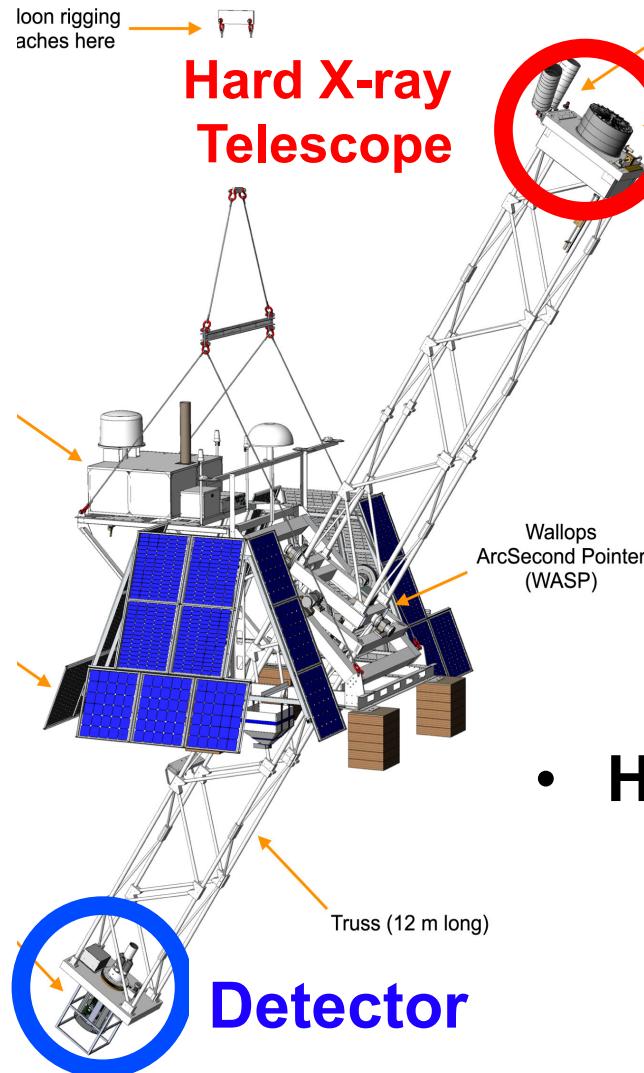
Quantum Beam Imaging Conference

Performance Changes After the First Flight of XL-Calibur

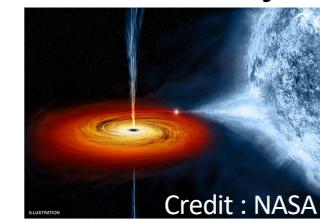
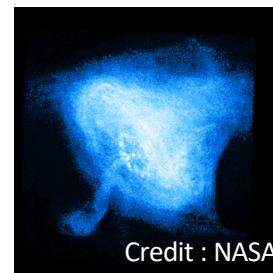
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XL-Calibur mission

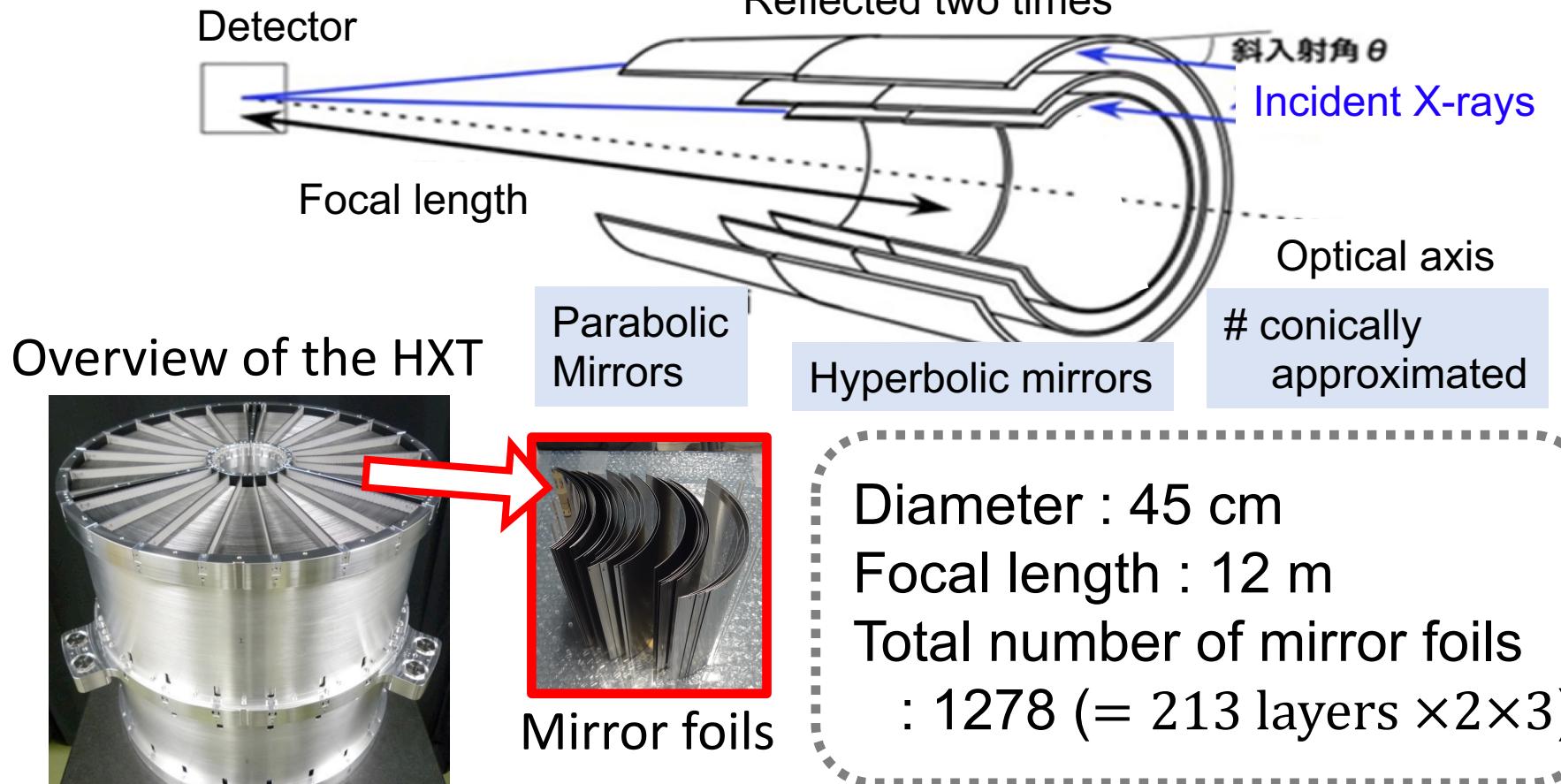


- **XL-Calibur : Balloon-borne mission**
 - Measures **polarization of hard X-rays** (in the range of 15 – 80 keV)
 - Collaborating between Japan, the USA, Sweden
- **Observation target**
 - Crab (pulsar)
 - Cygnus X-1 (High-mass X-ray binary)
- **High-sensitivity polarimetric observation**
 - **Detector** High signal-to-noise ratio
 - **Hard X-ray Telescope**
High light-gathering power
 - ✓ **Developed by the Japanese group**



Hard X-ray Telescope (HXT)

- The same type of the HXT of Hitomi satellite
- Originally developed for the FFAST mission
- **Wolter-I optics**

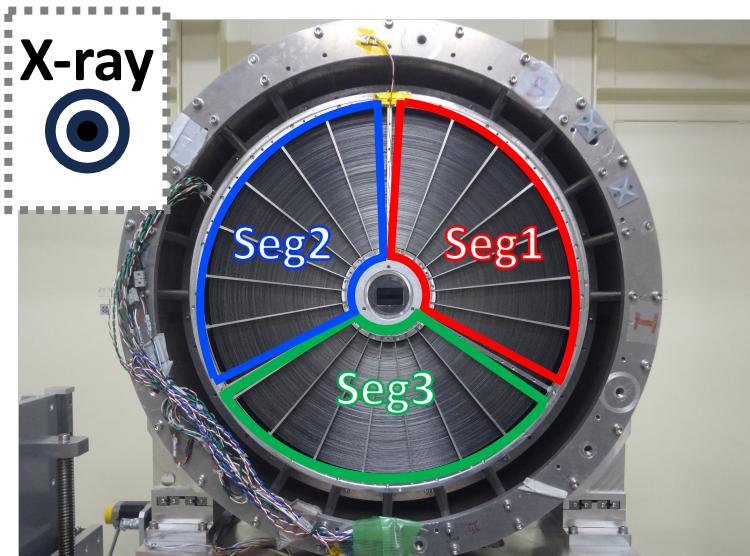


Hard X-ray Telescope (HXT)



- **Multilayer super mirror**

- Utilizing both total reflection and Bragg reflection
- This mirror effectively reflect hard X-rays



- **Divided into 3 segments**

- Along the circumferential direction
- **Seg1, Seg2, Seg3**



Segment arrangement during the flight
Taken during a ground test.

Development history of HXT

~ 2020	Completed optical adjustments
June 2021	Measured the performance of the HXT @SPring-8 (Hyogo, Japan)
June 12 th ~ 18 th 2022	Conducted the first flight (Arctic) Released XL-Calibur in Sweden
August 2022	Recovered the HXT in Canada
January and April 2023	Measured the performance of the HXT again @SPring-8

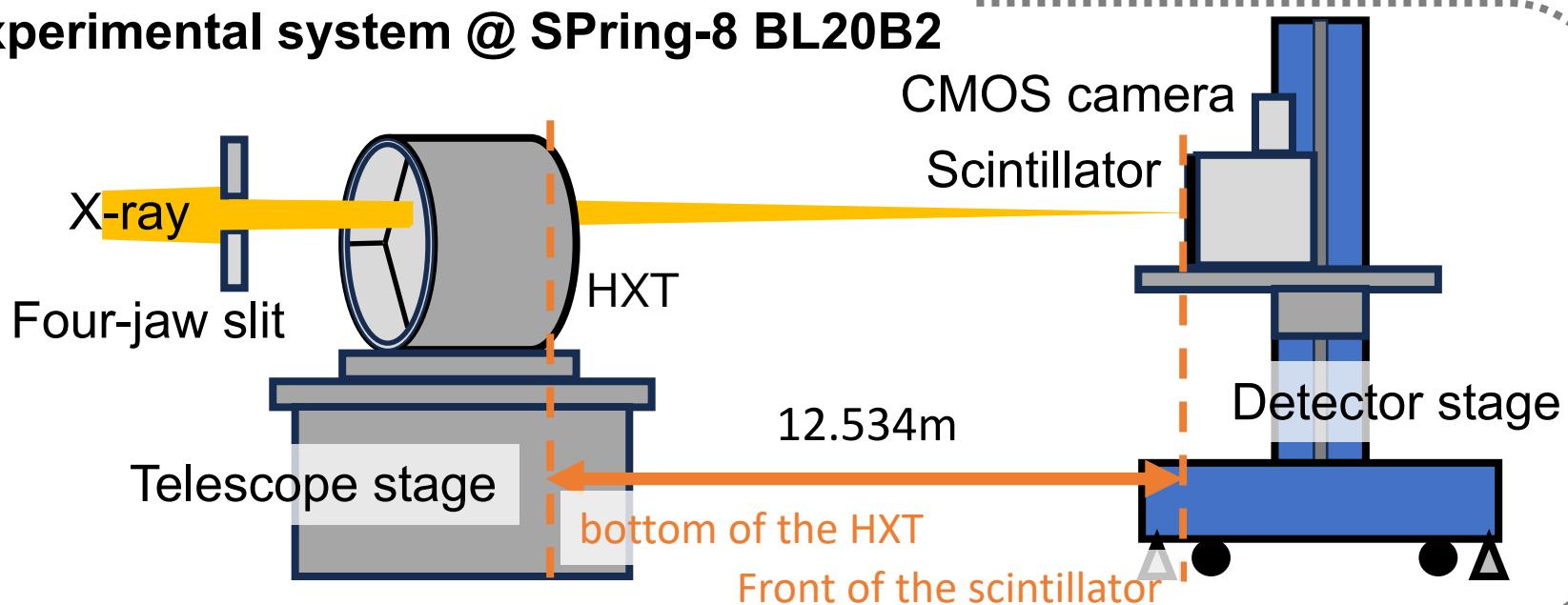
Did the performance of the HXT change after the flight?

The scene just
before release



Performance measurement

Experimental system @ SPring-8 BL20B2



There was no change in the system before and after the flight

Measurement
of **optical axis**



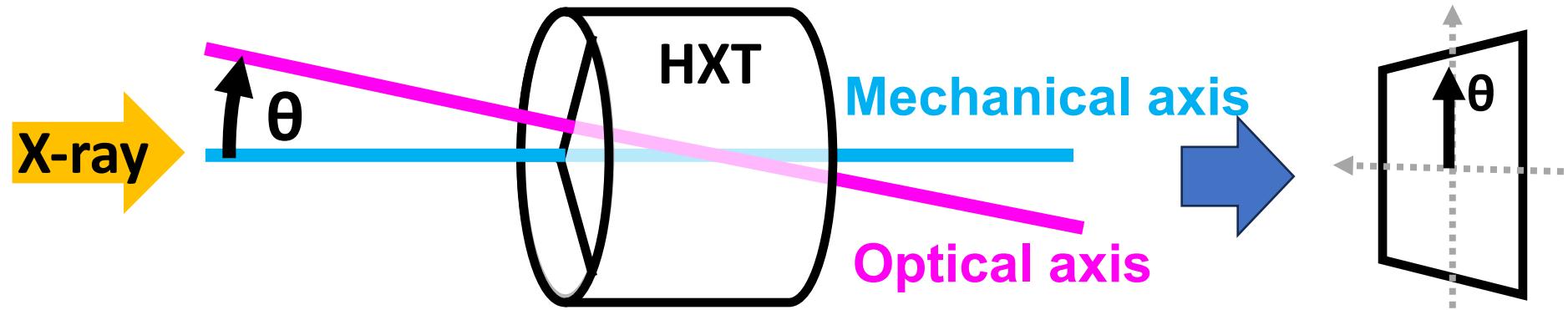
To determine the direction
for **efficient light reflection**

Measurement
of **HXT performance**



**Reflected image, Effective area,
and HPD (Half power diameter)**
were measured

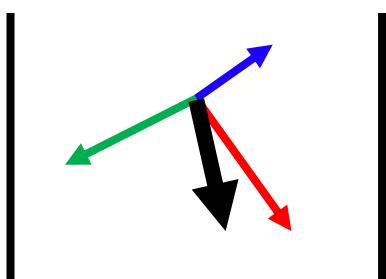
How to describe optical axis



Describe the direction of **the optical axis**
with respect to **the mechanical axis**
when viewed from the upstream

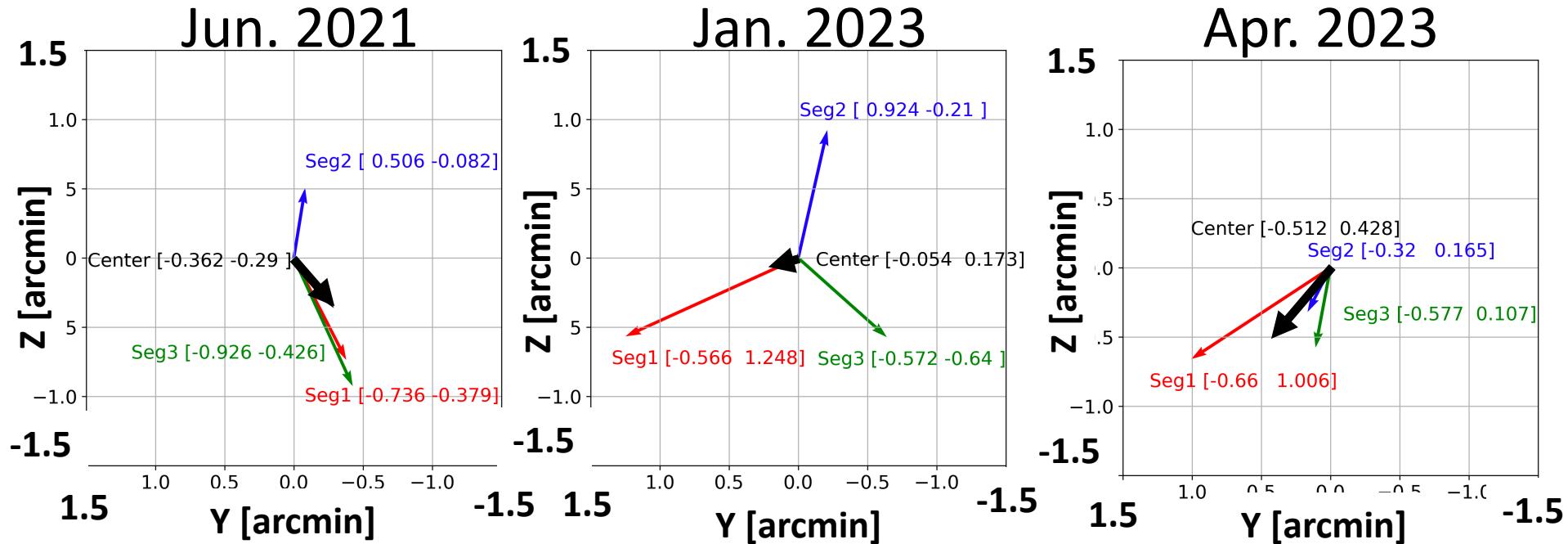
Represent as
a vector

Schematic diagram



- Colored arrow represents the optical axis of each segment (**Seg1**, **Seg2**, **Seg3**).
- Black arrow corresponds to the axis for the entire HXT.

Change in optical axes



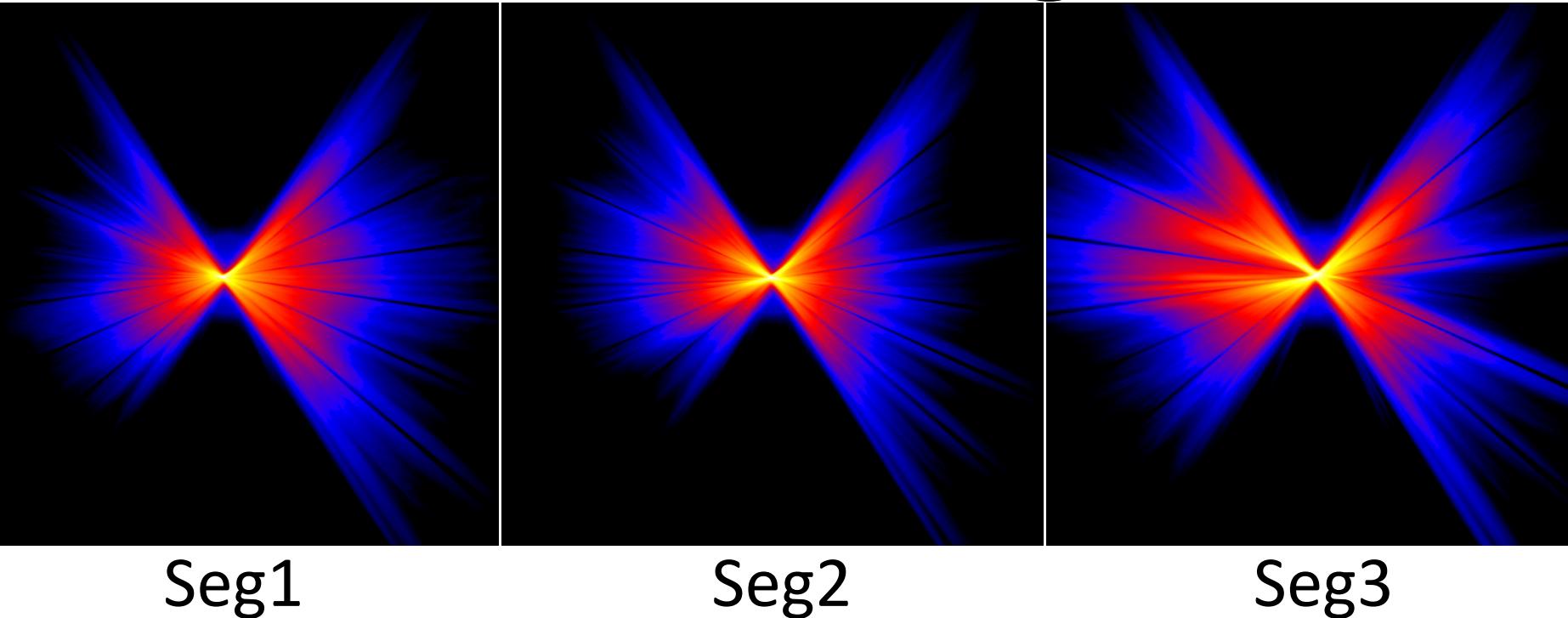
- There is no significant change in the optical axis for the entire HXT.

The difference should be understood to represent systematic errors.

Changes in reflected images

Reflected image of each segment for X-ray energy of 20 keV

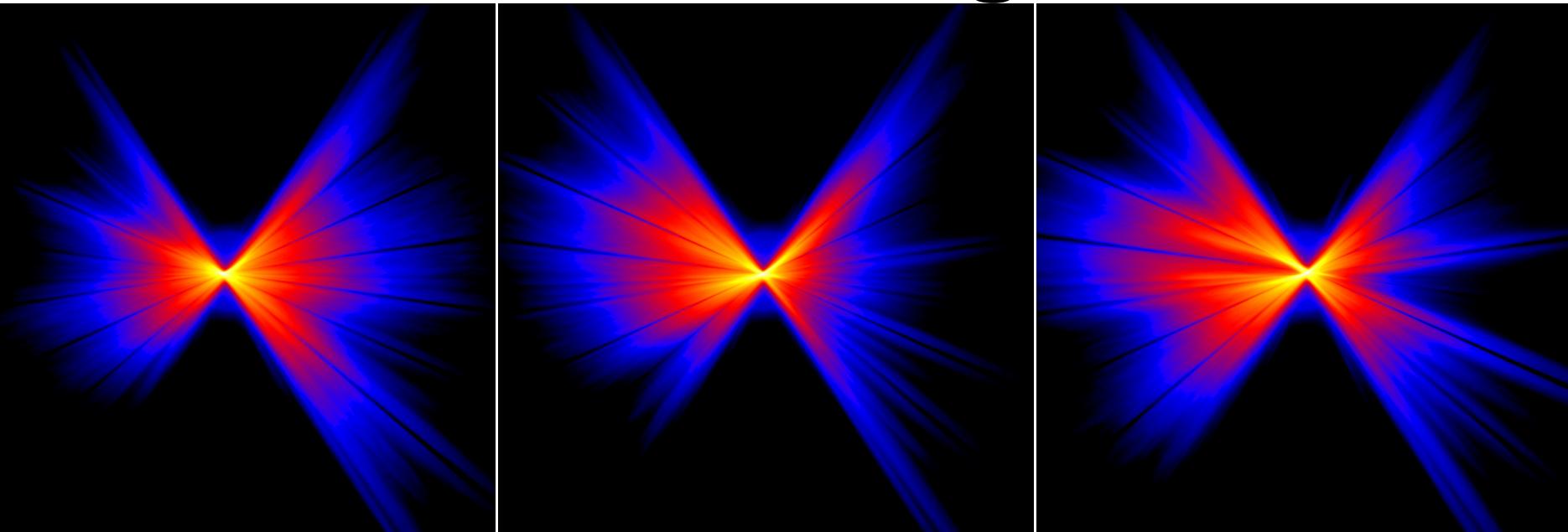
Before the flight



Changes in reflected images

Reflected image of each segment for X-ray energy of 20 keV

After the flight



Seg1

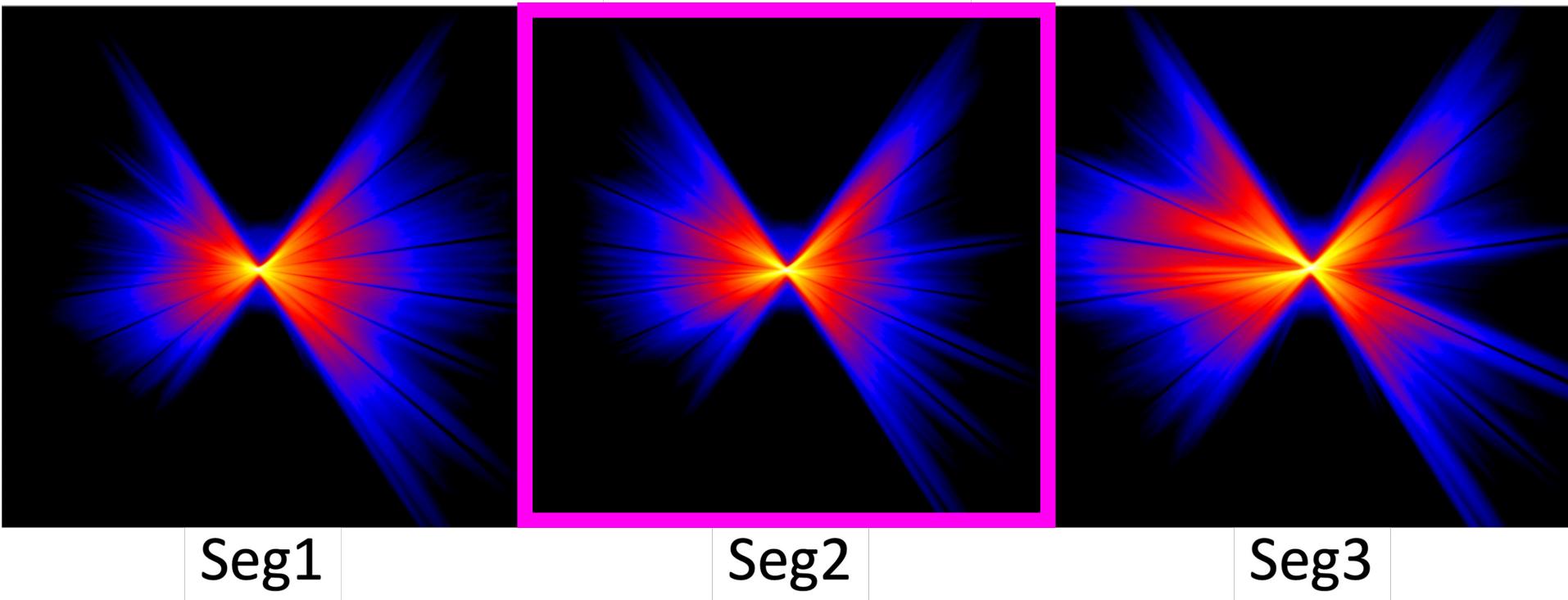
Seg2

Seg3

Changes in reflected images

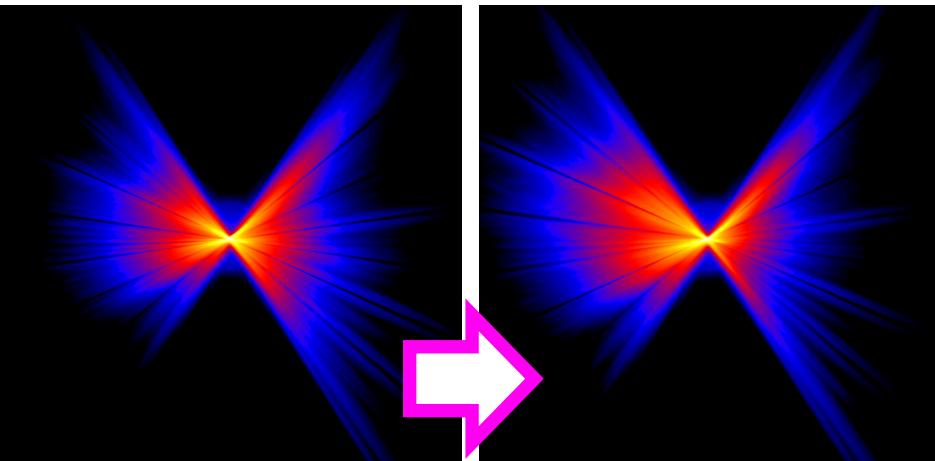
Reflected image of each segment for X-ray energy of 20 keV

Before



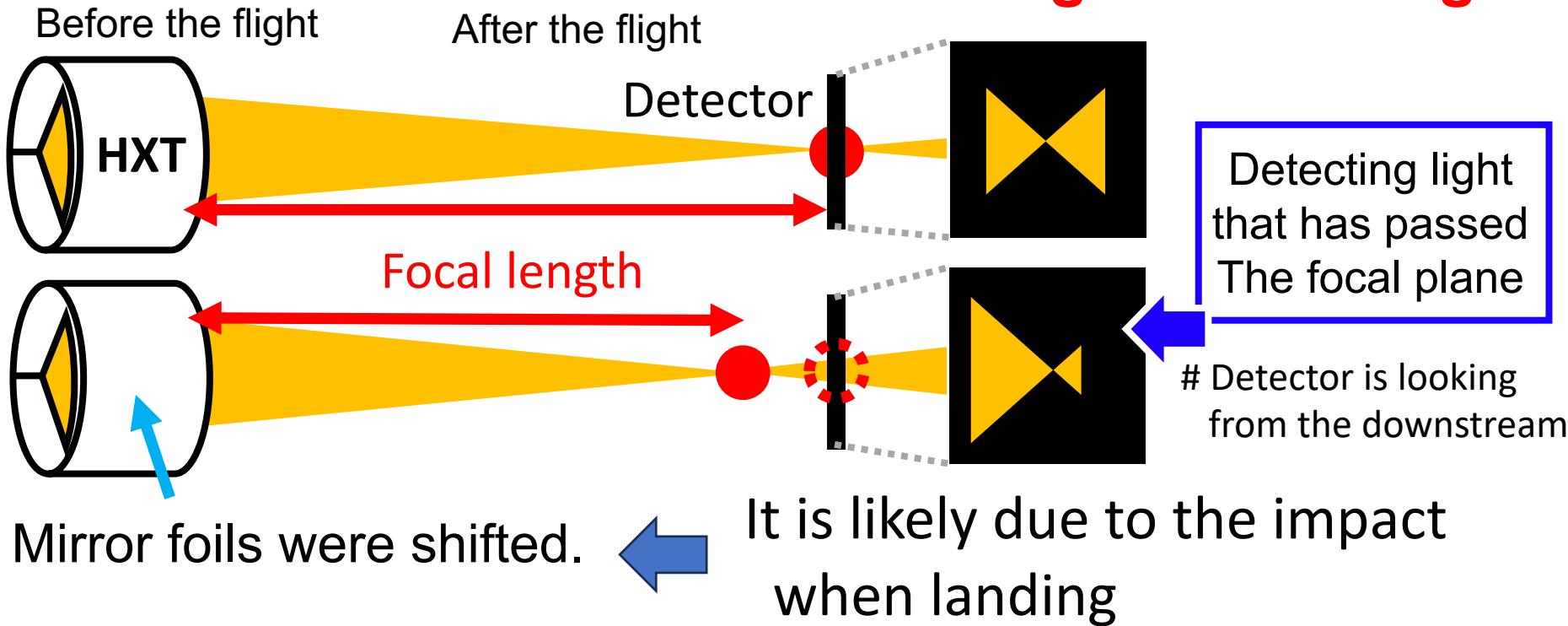
Focus on the changes in the image of Seg2

Change in the image of Seg2

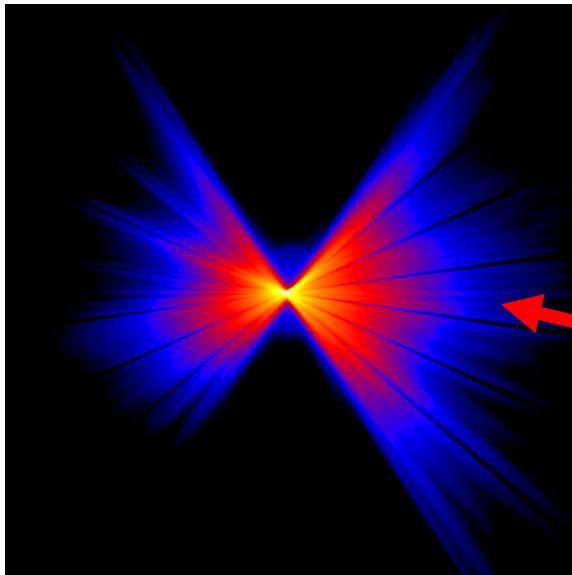


Before : Symmetric
After : Shifted to the left

This indicates
focal length has changed



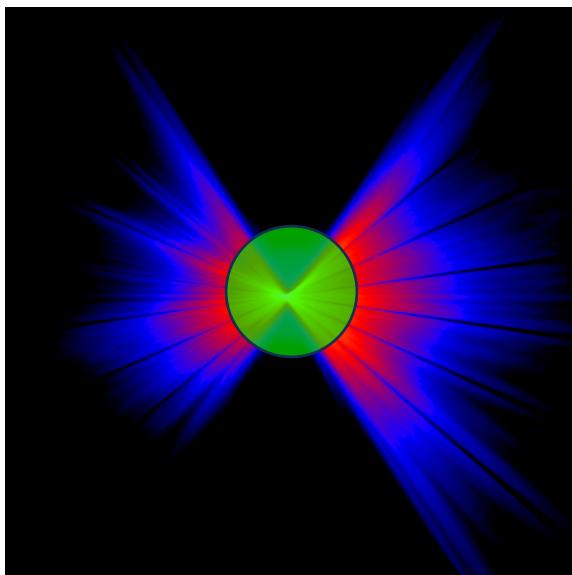
Performance of the Telescope



Effective area

Light-gathering power of the telescope

$$\frac{\text{Total amount of reflected light intensity}}{\text{X-ray beam intensity } [\text{cm}^{-2}]}$$

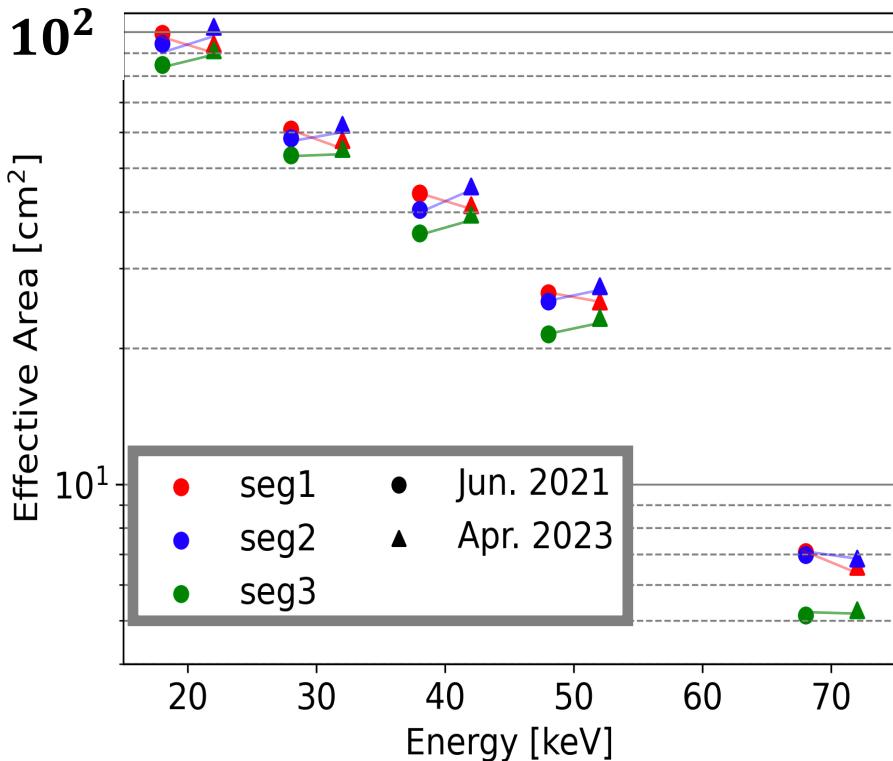


HPD (Half power diameter)

Angular resolution of the telescope

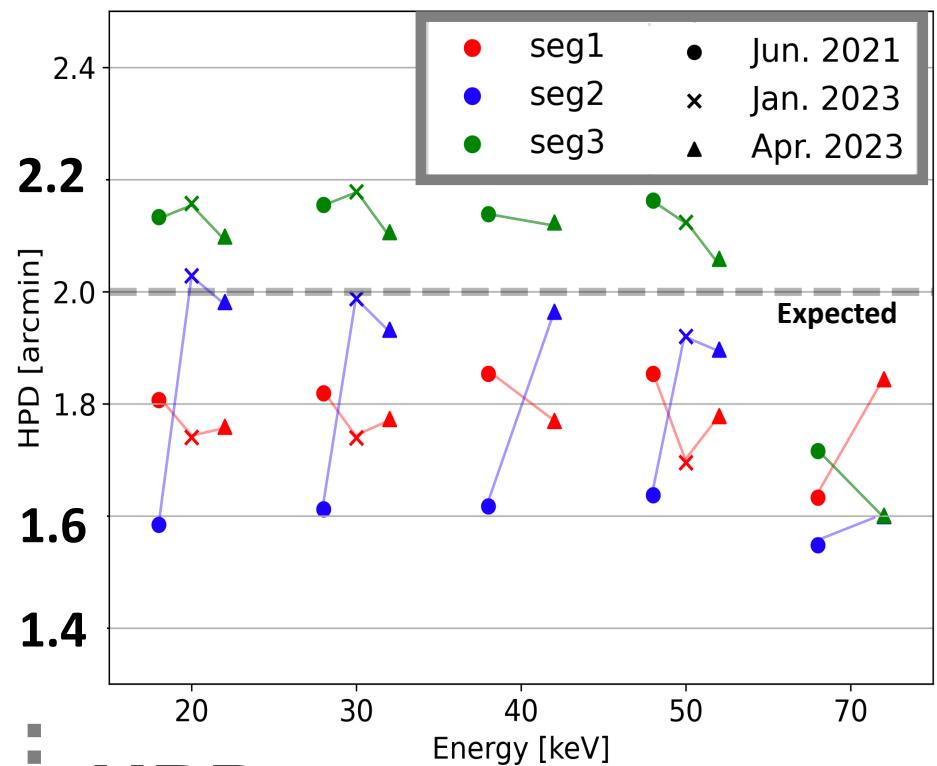
Diameter of the circle that contains half amount of reflected light

Changes in Effective area and HPD



Effective area

- No significant change



HPD

- Increased in Seg2
... plus $0.3' \sim 0.4'$
- Increased in
Seg1 (70 keV)

Summary and Future plan

- Measured and Compared the HXT performance before and after the flight.
 - The HPD has increased in **Seg1** (70 keV).
 - **Seg2**'s HPD has increased and the focal length has become shorter
 - The reflected image of **Seg3** has changed
- It was found that there was no significant change in performance of the HXT.
 - We plan to prepare for the 2nd flight in May 2024

Performance measurement

2nd flight @Sweden

